Wes Moore
Governor

Josh Kurtz
Secretary

Investigation of Maryland's Coastal Bays and Atlantic Ocean Finfish Stocks

F-50-R-32

July 2023 - June 2024
Final Report

Prepared by:
Steve Doctor
Gary Tyler
Craig Weedon
Angel Willey

Fishing and Boating Services
580 Taylor Ave.
Annapolis, MD 21401
dnr.maryland.gov
Toll free in Maryland: 877-620-8305
Out of state call: 410-260-8305
TTY Users call via the MD Relay

8/2024 DNR

UNITED STATES
DEPARTMENT OF INTERIOR
Fish & Wildlife Service
Division of Federal Assistance
Region 5

Final Performance Progress Report
Investigation of Maryland's Coastal Bays and Atlantic Ocean Finfish Stocks
July 1, 2023 through June 30, 2024

Grantee: Maryland Department of Natural Resources – Fishing and Boating Services

Grant No.: F21AF03480

Segment No.: F-50-R-32

Title: MD F-50-R-32 Investigation of Maryland Coastal Bays and Atlantic Ocean Finfish Stock

Period Covered: July 1, 2023 - June 30, 2024

Prepared by: Angel Willey ______________________________
Angel Willey, Principal Investigator, Manager, Coastal Fisheries Program

Approved by: ______________________________
Carrie Kennedy, Division Director, Fishing and Boating Services

Approved by: ______________________________
Michael Luisi, Branch Director, Fishing and Boating Services

Date Submitted: August 28, 2024

Statutory Funding Authority:

Sport Fish Restoration ` CFDA #15.605	X
State Wildlife Grants (SWG) Cooperative Management Act **CFDA #15.634**	______

Table of Contents

List of Tables and Figures

Accomplishments July 1, 2023 - June 30, 2024

July - August 2023
- Collected 20 trawl samples at 20 fixed sites, monthly.
- Completed data entry and quality control from prior month's sampling.
- Edited the F-50-R-31 report.
- Wrote the Atlantic States Marine Fisheries Commission (ASMFC) Coastal Sharks Compliance report.

September - November 2023
- Collected 20 trawl samples at 20 fixed sites (monthly).
- Collected 19 beach seine samples at 19 fixed sites (September).
- Collected 18 Submerged Aquatic Vegetation Habitat Survey samples in Sinepuxent Bay (September).
- Finalized the F-50-R-31 report.
- Completed data entry and quality control from prior month's sampling.

December 2023 - March 2024
- Completed quality control for the entire dataset.
- Conducted data analyses of the surveys.
- Drafted the F-50-R-32 annual report.
- Collected 44 tautog opercula for ageing.
- Prepped and aged 210 tautog for the 2023 fishing year.

April - June 2024
- Prepared for the 2024 field sampling season (Trawl and Beach Seine surveys).
- Collected 20 trawl samples at 20 fixed sites (monthly).
- Collected 19 beach seine samples at 19 fixed sites (June).
- Completed data entry and quality control from prior months sampling.
- Edited the F-50-R-31 report.
- Wrote the Atlantic States Marine Fisheries Commission's black sea bass, scup, summer flounder, and tautog compliance reports.
- Collected 190 tautog opercula for ageing.

Year Round, as needed.
- Technical assistance benefiting finfishes of material value for recreation as per Sport Fish Restoration guidelines.
- Responded to data requests from the Atlantic States Marine Fisheries Commission technical committees, the Mid-Atlantic Fishery Management Council monitoring committees, the National Oceanic and Atmospheric Administration, and researchers.

Preface

With the receipt of Sport Fish Restoration funds in 1989, the Trawl and Beach Seine surveys were performed following standardized protocols, eliminating the biases of previous years (1972 - 1988). This report highlights trends resulting from data collected during the standardized period (1989 - present).

The Submerged Aquatic Vegetation Habitat Survey was added in 2012. Refinements were made to the sampling approach to improve catchability of demersal fish. The survey protocol was standardized in 2015.

Although the Sport Fish Restoration reporting period covers July 2023 through June 2024, the terminal year of data used in this report is 2023, because a full sampling season is needed for data analyses.

Acknowledgements

Staff would like to recognize the contributions of some dedicated researchers that have shared cold mornings and hot, muddy days on the coastal bays.

Alexis Park (MD DNR), Carrie Hoover (MD DNR), Charles Benfer (Auburn), Katie Eaton (Auburn), Michella Salvitti (University of Maryland Eastern Shore), Carly Toulan (Maryland Coastal Bays Program), Liz Wist (Maryland Coastal Bays Program), Sarah Cvach (MD DNR), Sloan Willey (Student), and Billy Weiland (Maryland Coastal Bays Program).

Executive Summary

The investigation was developed to characterize fishes and their abundances in Maryland's coastal bays and the Atlantic Ocean, protect finfish habitats, contribute to stock assessments, facilitate management decisions, and provide technical assistance on committees and projects. This investigation was comprised of Trawl, Beach Seine, and the Submerged Aquatic Vegetation Habitat surveys in the bays, behind Fenwick and Assateague Islands. Over 34 years of continuous standardized data support management decisions including compliance with the Atlantic States Marine Fisheries Commission and stock assessments. Data were also provided to state, federal, and university partners for education, essential fish habitat designations, and academic research.

The investigation uses the previously mentioned surveys to meet the following objectives:

1. characterize stocks and estimate relative abundance of fishes in Maryland's coastal bays and near-shore Atlantic Ocean;
2. delineate and monitor spawning, nursery and/or forage locations for finfish; and
3. provide technical assistance by participating on committees, writing Atlantic States Marine Fisheries Commission compliance reports, and contributing to environmental and permit reviews to help ensure potential impacts to fish and wildlife are avoided, minimized and/or compensated/mitigated.

In 2023 Finfish were the most abundant taxa captured in the survey. Specifically, they accounted for 30,467 fish caught in the Trawl and Beach Seine surveys in 2023 (8,664 fish trawling and 21,803 fish beach seining). The total number of individuals collected by trawl and beach seine, as well as the total number of individuals for both gears combined were within the normal range in the time series. Collected fishes represented 66 species for both gears combined, which was within the lowest quartile of values in the time series.

Pinfish had an above average trawl index while American eel, Atlantic croaker, Atlantic silverside, bay anchovy, bluefish, and summer flounder had below average trawl indices. Atlantic menhaden, spot, and summer flounder had above average beach seine indices while American eel, bay anchovy, bluefish, sheepshead, silver perch, and weakfish had below average indices. Since 2014, summer flounder had an average or below average trawl index and an average or above average beach seine index which may indicate a preference change to shallow habitat.

Richness is the number of different fishes sampled. High richness is an indicator that the overall habitat can support many species during their lifecycles. Embayment richness results differed by gear which was expected due to the different habitats sampled by each. Chincoteague Bay had the highest richness (90 fishes) in the trawl time series (1989 - 2023) whereas Newport Bay had the lowest (70 fishes). The Beach Seine Survey time series (1989 - 2023) results indicated that Assawoman Bay, Isle of Wight Bay, and Chincoteague Bay had the richest fish populations (89, 88, and 86 fishes respectively), and Newport Bay was lowest (74).

The Shannon Index of Diversity measures the proportion of fishes in the sample population. More evenly distributed species produces a greater H value. These values change from year to year and are generally low due to large year classes of baitfish such as menhaden, Atlantic silverside and bay anchovy. In 2023, the trawl survey consisted of 41.5% spot and 31.25% bay anchovy while the beach seine survey consisted of 71.5% Atlantic menhaden and 10% Atlantic silverside.

Macroalgae bycatch is ephemeral with annual variation. It is quantified in these surveys for its positive and negative effects as habitat. The 2023 trawl and beach seine CPUE for macroalgae were below to the time series grand means CPUE (43.7 L/ha and 21.9 L/haul, respectively). Fourteen genera were collected by trawl and beach seine in 2023. *Polysiphonia* remained the most abundant genus for the trawl while *Agardhiella* was most abundant for the beach seine.

The water quality at most sample sites was consistent with fish habitat requirements. Dissolved oxygen was rarely found below critical levels and the salinity range supports coastal fishes. Analysis of dissolved oxygen and fish catches from the surveys indicated that the coastal bays rarely experienced low enough dissolved oxygen to negatively impact abundances. However, the investigations sampling occurred during the day when the effects of low dissolved oxygen may not have been evident. Dissolved oxygen levels have been improving since 1989 and salinity has varied. Temperatures, while increasing over the time of the surveys, were within the acceptable range for coastal fishes.

The Submerged Aquatic Vegetation Habitat Survey has operated with a standardized protocol since 2015. The overall catch per unit effort of fishes in the submerged aquatic vegetation, especially tautog (*Tautoga onitis*) and black sea bass (*Centropristis striata*) demonstrates its importance as critical habitat in Sinepuxent Bay. The survey also confirms that with continued monitoring of fishes in this habitat, stock assessment and species-specific habitat criteria can be refined.

Tautogs (210 fish) were obtained for ageing from charter and party boats, private anglers, and the commercial bycatch fishery. Ageing results had a wide range of year classes ranging from two to 19 years old. The 2023 female and male mean and median age was six years. The age range for fishery recruit size (406 mm/16 in) ranged from four to nine years old for both sexes. The charter fleet remained concerned about overfishing the trophy size tautog and continued to promote the catch and release of large fish, especially females.

Technical expertise and field observations obtained from the previously mentioned surveys were provided for research and management. With the passage of the Atlantic States Coastal Cooperative Management Act and the Magnuson-Stevens Fishery Conservation and Management Act, entities such as the Atlantic States Marine Fisheries Commission, Mid-Atlantic Fishery Management Council, and the National Marine Fisheries Service require stock assessment and habitat information. Technical expertise and data were contributed for 12 species.

Chapter 1 Trawl and Beach Seine Surveys

Introduction

The investigation was developed to characterize fishes and their abundances in Maryland's coastal bays and the Atlantic Ocean. The Department has conducted the Trawl and Beach Seine surveys in Maryland's coastal bays since 1972, sampling with a standardized protocol since 1989. These gears target juvenile finfish although bycatch of crustaceans, macroalgae, molluscs, and sponges were common. This report includes data from 1989 - 2023.

Over 140 adult and juvenile species of fishes, 26 molluscs, 20 macroalgae genera, and two Submerged Aquatic Vegetation (SAV) species have been collected since 1972. These surveys contribute to the investigation's objectives in the following manner:

1. data are used to characterize the stocks and estimate relative abundance of juvenile marine and estuarine species in the coastal bays and near-shore Atlantic Ocean;
2. collects other information necessary to assist in the management of regional and coastal fish stocks; and
3. delineates and monitors areas of high value, such as spawning, nursery, and/or forage locations (habitat) for finfish.

Methods

Data Collection

The coastal bays are separated from the Atlantic Ocean to the east by Fenwick Island and Assateague Island. From north to south, Maryland's coastal bays are comprised of Assawoman, Isle of Wight, Sinepuxent, Newport, and Chincoteague bays. Covering approximately 363 square kilometers (km^2; 140 square miles (mi^2)), these bays and associated tributaries average only 0.9 meters (m; 3 feet (ft)) in depth and are influenced by a watershed of 453 km^2 (175 mi^2). The Ocean City and Chincoteague inlets provide oceanic influences on these bays. The Chincoteague Inlet, located in Virginia, is approximately 56 km (34 mi) south of the Ocean City Inlet. Fenwick Island is heavily developed whereas Assateague Island is home to Assateague State Park and Assateague Island National Seashore. The western shore from Sinepuxent Bay north is urban whereas Chincoteague Bay is rural, and the area in between is moderately developed.

A 25 ft C-hawk vessel with a 250 horsepower Yamaha engine was used for transportation to the sample sites and gear deployment. A Global Positioning System (GPS) was used for navigation, marking latitude and longitude coordinates in degrees and decimal minutes for each sample, and monitoring speed.

Gears

Trawl

Trawl sampling was conducted monthly at 20 fixed sites throughout the coastal bays from April through October (Table 1.1, Figure 1.1, Figure 1.2, and Figure 1.3). Except for June and September, samples were taken beginning the third week of the month. Sampling began the second week in June and September to allow enough time to incorporate beach seine collections.

The boat operator considered wind and tide (speed and direction) when determining trawl direction. A standard 4.9 m (16 ft) semi-balloon trawl net was used in areas with a depth greater than 1.1 m (3.5 ft). Each trawl was a standard six-minute (0.1 hour) tow at a speed of approximately 2.5 to 2.8 knots (kts). Speed was monitored during tows using the GPS. Waypoints marking the sample start (gear fully deployed) and stop (point of gear retrieval) locations were taken using the GPS to document location of the sample. Time was tracked using a stopwatch, which was started at full gear deployment.

Beach Seine

Beach seines were used to sample the shallow regions of the coastal bays frequented by juvenile fishes. Beach seine sampling was conducted at 19 fixed sites beginning in the second weeks of June and September (Table 1.2, Figure 1.1, Figure 1.2, and Figure 1.3).

A 30.5 m X 1.8 m X 6.4 millimeter (mm) mesh (100 ft X 6 ft X 0.25 inch (in) mesh) bag seine was used at 18 fixed sites in depths less than 1.1 m (3.5 ft) along the shoreline. Some sites necessitated varying this routine to fit the available area and depth. A 15.24 m (50 ft) version of the previously described net was used at site S019 due to its restricted sampling area. Coordinates were taken at the start and stop points as well as an estimated percentage of net open.

For each sampling method, chemical and physical data were documented at each location. Chemical parameters included Dissolved Oxygen (DO; milligrams/Liter (mg/L)), salinity (parts per thousand (ppt)), water temperature (Celsius (C)), and pH (Potential of Hydrogen). Physical parameters included tide state, water clarity (Secchi disk; centimeters (cm)), water depth (ft), weather conditions, wind direction, and wind speed (kts). Data were recorded on a standardized project data sheet printed on Rite in the Rain All Weather paper.

Dissolved oxygen, salinity, water temperature, and pH were taken with a Yellow Springs Instrument Pro Quatro at two depths, 30 cm (1 ft) below the surface (all gears) and 30 cm (1 ft) from the bottom (trawl). The Pro Quatro cable was marked in one-foot intervals. Chemical data were taken 30 cm below the surface for each beach seine site and at trawl site T019 due to the shallow depth (< 1.1 m). The Pro Quatro was calibrated at the beginning of each sampling round.

Water turbidity was measured with a Secchi disk. Secchi readings were taken on the shaded side of the boat without wearing sunglasses. The Secchi disk was lowered into the water until it could not be seen. It was then raised until the black and white pattern could just be seen. The biologist marked the position on the string with their fingers and measured the length of the string to the end of the disk.

Both beginning and ending depths for each trawl were read on a depth finder and recorded. At beach seine sites, depth was estimated by the biologists pulling the seine. Wind speed measurements were acquired using a handheld anemometer with digital readout. Measurements were taken facing into the wind. Tidal states were from the GPS tide feature.

Sample Processing

Fishes and invertebrates were identified, counted, and measured for Total Length (TL) using a wooden mm measuring board with a 90-degree right angle (Table 1.3). A meter stick was used for species over 500 mm. At each site, a subsample of the first 20 fish (when applicable) of each species were measured and the remainder counted. An exception to this was made for black drum, black sea bass, and summer flounder where encounters of more than 20 fish were measured to improve assessment data. On occasion, invertebrate species counts were estimated when counts were impractical.

Blue crabs were measured for carapace width, sex was determined, and female maturity stage identified. Sex and maturity categories included immature female, male, mature female (sook) and mature female with eggs. A subsample of the first 20 blue crabs at each site was measured and the rest were counted. Sex and maturity status of the rest of the blue crabs were not recorded.

Bryozoans, ctenophores, jellyfishes, macroalgae, sponges and SAV were measured volumetrically (L) using calibrated containers with small holes in the bottom to drain excess water. Small quantities (generally ≤ 10 specimens) of invertebrates were occasionally counted or visually estimated. Bryozoans, macroalgae, and sponges were combined for one volume measurement and a biologist estimated the percentage of each species in the sample. Unknown species were placed in Ziploc bags on ice or kept in a bucket of water and taken to the office for identification.

Data Analysis

Statistical analyses were conducted on species that historically were most abundant in the trawl and beach seine catch data. Additional species were added to the analyses dependent on their recreational importance, biological significance as forage, or indicators of water quality.

The Geometric Mean (GM) was calculated to develop species-specific annual trawl and beach seine indices of relative abundance (1989 - 2023). That method was adopted by the Atlantic States Marine Fisheries Commission (ASMFC) Striped Bass Technical Committee as the preferred index of relative abundance to model stock status. The mean was calculated using catch per area covered for trawl and catch per haul for beach seine. The geometric mean was calculated from the $\log_e(x + 1)$ transformation of the catch data and presented with 95% confidence intervals (Ricker, 1975). The geometric mean and confidence intervals were calculated as the antilog [$\log_e$-mean(x + 1)] and antilog [$\log_e$-mean(x + 1) ± standard error * (t value: $\alpha = 0.05$, n - 1)], respectively. A geometric grand mean was calculated for the time series (1989 - 2023) and used as a point estimate for comparison to the annual (2023) estimate of relative abundance.

Fish diversity was calculated by the Shannon index (H), which accounts for both abundance and evenness of the species present (Shannon, 1948). The proportion of species relative to the total number of species (pi) is calculated and then multiplied by the natural logarithm of this proportion (lnpi). The resulting product is summed across species and multiplied by -1. Typical values were generally between 1.5 and 3.5 in most ecological studies and the index is rarely greater than four. The Shannon index increases as both the richness and the evenness of the community increase.

Statistical analyses were conducted on all macroalgae from 2006 to 2023. The trawl measure of abundance, Catch Per Unit Effort (CPUE), was mean liters per hectare; the beach seine was mean liters per haul. Annual CPUE was compared to the time series grand mean. Macroalgae diversity was calculated by the Shannon index.

The Generalized Linear Model (GLM), and post hoc Duncan's Multiple Range Test (DMRT) were used to evaluate trawl survey annual and monthly mean parameter values for DO, salinity, temperature, and turbidity. For both surveys, the DO was reviewed at the set level to monitor if readings fell below 5 mg/L, a value considered necessary for life for some organisms, and 2 mg/L for hypoxic conditions (Chesapeake Bay Program, 2021).

Results and Discussion

Overview

Finfish were the most abundant taxa captured in the survey. Specifically, they accounted for 30,467 fish caught in the trawl and beach Seine surveys in 2023 (8,664 fish trawling and 21,803 fish beach seining; Table 1.4). The total number of individuals collected by trawl and beach seine, as well as the total number of individuals for both gears combined were within the normal range in the time series (Table 1.5). Collected fishes represented 66 species for both gears combined, which was within the lowest quartile of values in the time series.

Pinfish had an above average trawl index while American eel, Atlantic croaker, Atlantic silverside, bay anchovy, bluefish, and summer flounder had below average trawl indices. Atlantic menhaden, spot, and summer flounder had above average beach seine indices while American eel, bay anchovy, bluefish, sheepshead, silver perch, and weakfish had below average indices (Table 1.6). Since 2014, summer flounder had an average or below average trawl index and an average or above average beach seine index which may indicate a preference change to shallow habitat.

Seasonal arrival and peak abundance of fishes in the coastal bays has been steady and predictable based on the known spawning behavior (Table 1.7, Table 1.8). June reflects peak arrival and abundance of juveniles whereas September revealed diversity and richness. The surveys captured crucial signals of abundance.

Crustaceans were the second most abundant taxa captured in this survey. Specifically, they accounted for 5,549 specimens caught trawling (2,648 crustaceans) and beach seining (2,901 crustaceans) in 2023 (Table 1.9). Seventeen crustacean species were identified, and the three most abundant species were grass shrimp, blue crabs, and lady crab, all of which were excellent forage to support recreational finfish species.

The third most abundant category was other species. Fifteen other species were captured including sea squirt, sea nettle, comb jellies, horseshoe crabs, diamondback terrapins, sponges, and bryozoans (Table 1.10). Sea squirts were the most abundant by count (1,257) but red beard sponge was the greatest by volume (158.7 L).

The fourth most abundant taxa captured in the survey were molluscs. Specifically, they accounted for 665 specimens caught trawling (659 molluscs) and beach seining (6 molluscs;

Table 1.11). Molluscs were represented by 10 different species and the most abundant species were blue mussels, Atlantic brief squid, and solitary glass bubble snails.

Seventeen plant species were captured trawling and beach seining (Table 1.12). Two species of SAV and 15 macroalgae genera were encountered. SAV accounted for 171.2 L in the trawl and 53.2 L in the beach seine. Macroalgae accounted for 768.6 L in the trawl and 789.9 L in the beach seine.

American eel (*Anguilla rostrata*)

American eels, a forage and bait species of interest to recreational anglers, were not captured in trawls or beach seines in 2023 (Figure 1.4, Figure 1.5). This was the first time in the series that American eels were not captured. American eels spawn in the Sargasso Sea; therefore, environmental conditions and ocean currents may be a factor influencing relative abundance (Murdy, Birdsong, & Musick, 1997). The harvesting of both elvers and adult eels may affect population size.

American eels were previously caught close to land in shallow protected bays or creeks with macroalgae. Many of them were caught in Turville Creek (T006), a site known to have an abundance of macroalgae, where the Department also annually conducts an elver survey further up the creek. The abundance of elvers at this site was attributed to the moderately sized freshwater source close to the ocean inlet where elvers grow to adulthood. It was normal for both adults and juveniles to be captured in these surveys.

Atlantic croaker (*Micropogonias undulatus*)

Atlantic croakers, a species of interest to anglers, were captured in 17 of 140 trawls (12.1%) and in one of 38 beach seines (2.6%). A total of 161 juvenile Atlantic croakers were collected in trawl (159 fish) and beach seine (2 fish) samples (Table 1.4). Atlantic croakers ranked 9 out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 9.1 fish/ha and <0.1 fish/haul, respectively.

The 2023 trawl relative abundance index was below the grand mean and the beach seine relative abundance index was equal to the grand mean (Figure 1.6, Figure 1.7). Since 1989, the trawl index often (23 years) and the beach seine index sometimes (14 years) varied significantly from the grand means. In the history of the surveys, juvenile Atlantic croakers were more frequently caught in deeper water with the trawl; therefore, the trawl index represents a more accurate picture of changes in relative abundance. Abundance can be influenced by environmental conditions and ocean currents (Murdy, Birdsong, & Musick, 1997). Very cold winters negatively influence abundance by impacting overwintering young of the year and pushing spawning activity further south on the Atlantic coast in colder years (Murdy, Birdsong, & Musick, 1997). According to Murdy and Musick (2013), Atlantic croakers spawn in the continental shelf waters, peaking from August through October, and are transported by ocean currents to the coastal bays.

Productive trawl sites for collecting Atlantic croakers were in the relatively protected areas of Assawoman Bay, the St. Martin River, and Newport Bay. Most of those Atlantic croakers were very small and probably did not prefer the stronger currents found in Sinepuxent Bay. Juvenile Atlantic croakers share a similar pattern of distribution to spot and summer flounder. Atlantic croakers are a known prey item for summer flounder, which may explain the co-occurrence of these species (Latour, Gartland, Bonzek, & Johnson, 2008).

Atlantic croakers were caught April through September in the Trawl Survey. The monthly mean length ranged from 41 mm to 171 mm and increased monthly from April through August. In July there were a few young of the year individuals sampled indicating ingress of the next year class (Table 1.13). The Beach Seine Survey mean length in September was 210 mm (Table 1.14).

Atlantic menhaden (*Brevoortia tyrannus*)

Atlantic menhaden, a forage species, were captured in 18 of 140 trawls (12.1%) and in 24 of 38 beach seines (63.2%). Atlantic menhaden ranked first out of 66 species in overall finfish abundance. A total of 17,185 juvenile Atlantic menhaden were collected in trawl (633 fish) and beach seine (16,552 fish) samples (Table 1.4). The trawl and beach seine CPUE was 36 fish/ha and 435.6 fish/haul, respectively.

The 2023 trawl relative abundance index was equal to the grand mean and the beach seine index was above the grand mean (Figure 1.8, Figure 1.9). Since 1989, the trawl index sometimes (16 years) and the beach seine index sometimes (9 years) varied significantly from the grand means. Atlantic menhaden were caught more often in nearshore locations in the Beach Seine Survey; therefore, that index represents a more accurate picture of changes in relative abundance. Good beach seine sites were widely dispersed in shallow shoreline edge habitat with either muddy or sandy bottoms. Productive trawl sites for collecting Atlantic menhaden were in the protected headwaters of Turville Creek (T006) and the St. Martin River (T005) which have some of the preferred traits seen in the best beach seine sites: shallow depth and muddy bottom. Turville Creek is known to have high nutrient levels and may attract the prey sources of Atlantic menhaden (Maryland Department of Environment, 2001). Those trawl sites likely had high chlorophyll concentrations; a desirable characteristic for a filter feeder (Wazniak, et al., 2004).

The monthly mean length of Atlantic menhaden caught trawling increased from 36 mm in May to 96 mm in September, with a slight decrease in mean length to 72 mm in October (Table 1.13). The Beach Seine Survey had similar results with an increase from a mean length of 51 mm in June to a mean length of 93 mm in September (Table 1.14). The increase in mean length in both the Trawl and Beach Seine surveys reflects growth of the young of the year cohort throughout the summer season.

Atlantic silverside (*Menidia menidia*)

Atlantic silversides, a forage species, were captured in three of 140 trawls (2.1%) and in 31 of 38 beach seines (81.6%). A total of 1,842 Atlantic silversides were collected in trawl (6 fish) and beach seine 1,836 fish) samples (Table 1.4). Atlantic silversides ranked forth out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 0.3 fish/ha and 48.3 fish/haul, respectively.

The 2023 trawl relative abundance index was below the grand mean and beach seine relative abundance index was equal to the grand mean (Figure 1.10, Figure 1.11). Since 1989, the trawl index often (17 years) and beach seine index rarely (7 years) varied significantly from the grand mean. Atlantic silversides were more frequently caught in the beach seine survey, which indicates a preference for shallow water habitat. Similar characteristics found at these sites were the proximity to land and or inlets. Atlantic silversides are forage for gamefish and were frequently found occurring with spot, summer flounder, and winter flounder at multiple sites in this survey.

The Trawl Survey mean length ranged from 54 mm to 95 mm in June, August, and October (Table 1.13). The Beach Seine Survey mean lengths were 84 mm in June and 74 mm in September (Table 1.14). The monthly variability of the mean lengths is likely related to spawning during the monthly lunar spawning cycle, March through July (Murdy & Musick, 2013).

Bay anchovy (*Anchoa hepsetus*)

Bay anchovies, a forage species, were captured in 61 of 140 trawls (41.3%) and in 15 of 38 beach seines (38.5%). A total of 2,910 bay anchovies were collected in trawl (2,708 fish) and beach seine (202 fish) samples (Table 1.4). Bay anchovies ranked third out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 154.2 fish/ha and 5.3 fish/haul, respectively.

The 2023 trawl and beach seine relative abundance indices were both below the grand means (Figure 1.12, Figure 1.13). Since 1989, the trawl index often (18 years) and beach seine index sometimes (9 years) varied significantly from the grand means. Both bay anchovy indices represent an accurate picture of changes in relative abundance. Annual fluctuations in relative abundance may reflect a combination of environmental conditions (DO, nutrient levels, salinity, and water temperature) and ecological changes including shifts in species composition and habitat type. Bay anchovies were caught in both nearshore and open water locations indicating a wide distribution. Productive trawl and beach seine sites for collecting bay anchovies were in the northern bays for trawl and in the southern bays for beach seine. Bay anchovies are preferred forage for larger fishes and have been found occurring with spot and summer flounder at multiple sites in these surveys.

The monthly mean lengths of bay anchovies in the Trawl Survey ranged between 40 mm to 66 mm (Table 1.13). The mean monthly lengths from the Beach Seine Survey were 68 mm in June and 41 mm in September (Table 1.14). Spawning appears to occur multiple times from May to September. The presence of both smaller and larger individuals throughout the year reflects the extended recruitment through the summer.

Black sea bass (*Centropristis striata*)

Black sea bass, a species of interest to recreational anglers, were collected in 33 of 140 trawls (23.6%) and 10 of 38 beach seines (26.3%). A total of 138 juvenile black sea bass were collected in trawl (86 fish) and beach seine (52 fish) samples (Table 1.4). Black sea bass ranked 10 out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 4.9 fish/ha and 1.4 fish/haul, respectively.

In 2023, the trawl and beach seine relative abundance indices were both equal to the grand means (Figure 1.14, Figure 1.15). Since 1989, the trawl index often (17 years) and beach seine index sometimes (9 years) varied significantly from the grand means. The Trawl Survey usually catches more black sea bass; therefore, it was the better gear for inclusion in the 2023 ASMFC stock assessment.

Juvenile black sea bass were more abundant at sites nearest to inlets. Measured water quality parameters did not show a correlation with abundance of black sea bass so other factors such as proximity to the inlets and availability of physical structure in the bays are likely the reasons for differences in abundance between sites (Peters & Chigbu, 2017). Some of the preferred sample sites had a hard shell bottom that provided the needed habitat structure desired by black sea bass (Murdy, Birdsong, & Musick, 1997).

The monthly Trawl Survey mean length of black sea bass increased from 73 mm in April to 149 mm in October (Table 1.13). There was ingress of some smaller young of the year individuals in September. The Beach Seine Survey mean length increased from 81 mm in June to 106 mm in September (Table 1.14). Black sea bass increased in mean length through the sampling season reflecting growth, though the summer. The coastal bays are a nursery for young of the year black sea bass through age-1.

Pinfish (*Lagodon rhomboides*)

Pinfish, a species considered forage for adult gamefish, were collected in 12 of 140 trawls (8.6) and 17 of 38 seines (44.7%), A total of 261 pinfish were collected in trawl (29 fish) and beach seine (232 fish; Table 1.4). Pinfish ranked 8 out of 66 species in overall fish abundance. The trawl CPUE was 1.6 fish/ha and the beach seine CPUE was 6.1 fish/haul.

The 2023 trawl relative abundance index was above the grand mean while the beach seine relative abundance index was equal to the grand mean (Figure 1.16, Figure 1.17). Since 1989, the trawl index frequently (28 years) varied from the grand mean and beach seine index often (20 years) varied significantly from the grand mean. Pinfish were collected more frequently in shallow water; therefore, the beach seine index represents a more accurate picture of changes in relative abundance when compared to the trawl index. Pinfish are considered a warmer water species in the Mid-Atlantic. The SAV Habitat Survey indicates that SAV is important juvenile habitat.

Pinfish mean length increased from a mean length of 48 mm in May to 156 mm in October in the trawl survey (Table 1.13). Pinfish caught in the beach seine survey increased in mean length 63 mm in June to 128 mm in September (Table 1.14). Young of the year recruit to the coastal bays in May through July and grow as the summer progresses.

Sheepshead (*Archosargus probatocephalus*)

Sheepshead, a species of interest to recreational anglers, were collected in one of 140 trawls (0.7%) and zero of 38 beach seines (0%). A total of one juvenile sheepshead was collected in trawl (Table 1.4). Sheepshead ranked 63 out of 66 species in overall finfish abundance. The trawl CPUE was 0.1 fish/ ha.

The 2023 trawl relative abundance index was equal to the grand mean and the beach seine relative abundance indices was below the grand mean (Figure 1.18, Figure 1.19). Since 1989, the trawl (24 years) and beach seine (19 years) indices often varied significantly from the grand means. Sheepshead were caught more frequently in shallow water; therefore, the beach seine index represents a more accurate picture of changes in relative abundance when compared to the trawl index. Sheepshead were absent in both surveys from 1989 to 1997. Sheepshead spawn offshore; therefore, environmental conditions such as weather patterns and ocean currents may be a factor influencing relative abundance. Offshore artificial reefs, structure necessary for adult sheepshead habitat, may also influence abundance (Murdy & Musick, 2013). Young of the year sheepshead were caught at locations with or near SAV or riprap. SAV is important juvenile habitat (Murdy & Musick, 2013).

Silver perch (*Bairdiella chrysoura*)

Silver perch, a forage species, were collected in 40 of 140 trawls (28.6%) and 14 of 38 beach seines (36.8%). A total of 775 silver perch were collected in trawl (624 fish) and beach seine (151 fish) samples (Table 1.4). Silver perch ranked fifth out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 35.5 fish/ha and 4.0 fish/haul, respectively.

The 2023 trawl relative abundance index was equal to the grand mean and the beach seine relative abundance index was below the grand mean (Figure 1.20, Figure 1.21). Since 1989, the trawl index often (18 years) varied significantly from the grand mean and the beach seine index rarely (5 years) varied from the grand mean.

Silver perch were widely dispersed in samples collected throughout the coastal bays. This indicates that most of the habitat of the Maryland coastal bays is favorable for this species. They were caught in both near shore and open water locations; therefore, both indices represent an accurate picture of changes in relative abundance. Since silver perch spawn offshore and juveniles utilize SAV, environmental conditions including global weather patterns and ocean currents may be a factor influencing relative abundance (Murdy, Birdsong, & Musick, 1997) (Murdy & Musick, 2013).

Silver perch were collected by trawl from May through October and the mean size varied from 45 mm to 144 mm. The mean length was the smallest in July and greatest in the early and later months reflecting recruitment in mid-summer (Table 1.13). In the Beach Seine Survey, the mean length was 141 mm in June and 84 mm in September (

Table 1.14).

Spot (*Leiostomus xanthurus*)

Spot are important as forage for larger fish and to recreational anglers for bait and as a target species. Spot were collected in 82 of 140 trawls (58.6%) and 37 of 38 beach seines (97.4%). A total of 5,431 spot were collected in trawl (3,599 fish) and beach seine samples (1,832 fish; Table 1.4). Spot ranked second out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 205.0 fish/ha and 48.2 fish/haul, respectively.

The 2023 trawl relative abundance index was equal to the grand mean and beach seine relative abundance index was above the grand mean (Figure 1.22, Figure 1.23). Since 1989, both the trawl (27 years) and the beach seine (25 years) indices frequently varied significantly from the grand mean. Spot spawn offshore; therefore, environmental conditions including global weather patterns, ocean currents and the North Atlantic Oscillation may be a factor influencing relative abundance (Murdy, Birdsong, & Musick, 1997). Both indices indicated that the Maryland coastal bays are suitable nursery habitat for spot and represent an accurate picture of changes in relative abundance.

The Trawl Survey monthly mean length of spot increased from 40 mm in May to 137 mm in October (Table 1.13). In the Beach Seine Survey, the mean length increased from 99 mm in June to 145 mm in September (

Table 1.14). The increase in mean length reflects growth of the young of the year cohort throughout the summer season.

Summer flounder *(Paralichthys dentatus)*

Summer flounder, a species of interest to recreational anglers, were collected in 49 of 140 trawls (35.0%) and 29 of 38 beach seines (76.3%). A total of 430 summer flounder were collected in trawl (170 fish) and beach seine (260 fish) samples (Table 1.4). Summer flounder ranked sixth out of 66 species in overall finfish abundance. The trawl and beach seine CPUE was 9.7 fish/ha and 6.8 fish/haul, respectively.

The 2023 trawl relative abundance index was below the grand mean while the beach seine index was above the grand mean (Figure 1.24, Figure 1.25). Since 1989, the trawl index frequently (25 years) varied significantly from the grand mean and the beach seine index often (17 years) varied from the grand mean. In the past, summer flounder were caught more frequently in open water trawls; therefore, the trawl index represented a more accurate picture of changes in relative abundance when compared to the beach seine index. Since 2014, summer flounder have had an average or below average trawl index and an average or above average beach seine index which may indicate a preference change to shallow habitat (Figure 1.26).

Productive summer flounder trawl and beach seine sites were in all bays. This indicated that most of the Maryland coastal bays were favorable nursery habitat. Summer flounder are pelagic spawners and changes in relative abundance may reflect a combination of environmental conditions (DO, nutrient levels, salinity, pH, and water temperature) and ecological changes including shifts in forage species composition and habitat type. Those variables may have affected spawning and juvenile success.

The monthly mean length of summer flounder caught by the Trawl Survey increased from 50 mm in April to 130 mm in September with the most individuals caught in July (Table 1.13). In the Beach Seine Survey, the mean length increased from 67 mm in June to 116 mm in September (

Table 1.14). The increase in mean length reflects growth of the young of the year cohort throughout the summer season.

Weakfish (*Cynoscion regalis*)

Weakfish, a species of interest to recreational anglers, were collected in 25 of 140 trawls (17.9%) and zero of 38 beach seines. A total of 295 juvenile weakfish were collected in trawl samples (Table 1.4). Weakfish ranked seventh out of 66 species in overall finfish abundance. The trawl CPUE was 16.8 fish/ha.

The 2023 trawl relative abundance index was equal to the grand mean (Figure 1.27). Since 1989, the trawl (18 years) often varied significantly from the grand mean. Weakfish were only caught in open water; therefore, the trawl index represents a more accurate picture of changes in relative abundance. Changes in relative abundance may reflect a combination of environmental conditions (DO, nutrient levels, salinity, and water temperature) and ecological changes including shifts in species composition and habitat type. Historical productive trawl sample sites for weakfish were in all coastal bays, indicating a broad distribution, with a particular affinity towards Assawoman Bay and the St. Martin River.

Weakfish mean length increased from 57 mm in July to 127 mm in October with most individuals caught in July (Table 1.13). Young of the year recruitment was most evident in July, which follows the peak spawning period of May through June (Murdy & Musick, 2013).

Richness and Diversity

Richness is the number of different fishes sampled. Diversity is defined by the Shannon index results, which is a measurement of richness and the proportion of those species in the sample population. In the 2023 Trawl Survey, Chincoteague Bay (24 fishes) held the most species of fishes and Newport Bay (15 fishes) was the least diverse (Table 1.15). The Shannon index results indicated that Sinepuxent Bay (H = 2.5) was the most diverse whereas Newport Bay (H = 1.0) was the least diverse.

Over time, Chincoteague Bay had the highest richness (90 fishes) and annual mean richness (34 fishes) in the trawl 1989 - 2023 time series (Table 1.16). Newport Bay had the lowest richness (70 fishes) and mean richness (21 fishes) in the time series. The Shannon index results for the trawl time series indicated that Sinepuxent Bay (H = 2.0) was the most diverse whereas the St. Martin River and Assawoman Bay (H = 1.6) were the least diverse.

In the 2023 Beach Seine Survey, Chincoteague Bay (39 species) held the most species of fishes, and the St. Martin River (15 fishes) had the least species of fish (Table 1.17). The Shannon index results indicated that Isle of Wight (H = 2.0) was most diverse whereas St. Martin River (H = 0.4) was the least diverse.

The Beach Seine Survey time series (1989 - 2023) results indicated that Assawoman Bay had the richest fish populations (89 fishes) while Chincoteague Bay had the highest mean richness (34 fishes; Table 1.18). St. Martin River had the lowest richness (71 fishes) and tied with Newport Bay for the lowest annual mean richness (21 fishes) in the time series. Beach Seine Survey diversity results throughout the time series indicated that Chincoteague Bay (H = 1.9) was most diverse.

The Ayers Creek site is located at the intersection of tidal/non-tidal water, connected via a large pipe grouped separately. In 2023, there were 10 species of fish and low diversity (H = 0.1). However, in the time series, this site's richness (44 fishes; H = 1.3) was a result of shifting habitat based on rainfall and tidal influences (Table 1.18). Atlantic menhaden (63%), spot (16.4%), and golden shiner (9.7%) were the largest contributors to the catch over time. Other fishes included alewife, black crappie, brown bullhead, sunfishes, weakfish, and spotted seatrout.

Richness and diversity are important components of a healthy estuary and can provide fish communities resilience to changes in the environment. There was not a linear relationship between the richness and diversity in the coastal bays. Results indicated that the coastal bays' richness was relatively high while diversity was generally low. A strong year class can reduce the diversity value by minimizing the effect of other fish contributions to the sample population. The diversity analysis favored species richness proportions at equal levels in the sample population. While richness or diversity alone should not be used as a single indicator for sustainable fish abundance, as strong inner annual year classes are required to sustain species populations subject to high fishing pressure or natural mortality, increased diversity should allow for resilience to climate change.

Macroalgae

To date, 21 genera and 76,250 L of macroalgae were collected in Maryland's coastal bays using the trawl and beach seine from 2006 - 2023. Rhodophyta (red macroalgae) have been the dominant macroalgae in both gears (Table 1.19). Chlorophyta (green macroalgae), Phaeophyta (brown macroalgae), and Xanthophyta (yellow - green macroalgae) were also represented in the survey collections.

Fourteen genera and 768.6 L were collected by trawl within the coastal bays in 2023 (Table 1.12). The 2023 Shannon index of diversity among genera by trawl (H = 1.1) was below the time series average (H = 1.2). Results indicated that *Polysiphonia* were the most abundant macroalgae (52%) in 2023. The other genera that contributed more than 5% to the sample population were *Agardhiella* (38%). The 2023 trawl CPUE (43.7 L/ha) was below the grand mean (Figure 1.28). Since 2006, the trawl CPUE occasionally varied significantly from the grand mean.

Twelve genera and 789.9 L were collected by beach seine in 2023 (Table 1.12). The Shannon index of diversity among genera (H = 0.6) was below the time series average (H = 1.1). Results indicated that *Agardhiella* were most abundant (79%). The only other genera that contributed more than 5% to the sample population were *Polysiphonia* (18.7%). The 2023 beach seine CPUE (21.9 L/haul) was below the grand mean (Figure 1.29). Since 2006, the beach seine CPUE occasionally varied significantly from the grand mean.

Macroalgae in Maryland's coastal bays were investigated consistently over 18 years. The results of this investigation show distribution and abundance of macroalgae encountered by each gear. These data are highly variable, and the survey designs were not developed to perform a population assessment for macroalgae. Abundances of Chlorophyta, Phaeophyta, Rhodophyta, and Xanthophyta are representative of our samples. The Trawl and Beach Seine surveys did not sample macroalgae habitat such as bulkheads, jetties, and rocks where macroalgae have been observed. However, the survey data shows that Rhodophyta and Chlorophyta were present at high levels in the bays closest to high human density population. The terminal year (2023) showed decreases in abundance compared to the previous year.

The bays north of the Ocean City Inlet had single species dominance of *Agardhiella* and the highest CPUE when compared to the southern bays. This stronghold of abundance must be driven by the environmental conditions that favor this genus such as water clarity, nutrient levels, salinity, and water temperature; however, these effects on macroalgae production are not clear. Chlorophyta abundance, specifically sea lettuce, was variable yet appeared able to compete with the Rhodophytes when suitable conditions presented themselves. *Polysiphonia* abundance and distribution has increased to complete *Agardhiella.*

Water Quality

These surveys collected surface water temperature and salinity since 1989. Dissolved oxygen and turbidity were added in 1998. Bottom water quality taken from annual mean depth of 6.5 feet was included at trawl sites in 2006, and pH was added in 2022 to monitor for changes in acidification that could impact fishes (Tomasetti & Gobler, 2020). There is increasing evidence that many ecologically and/or economically important shellfish and finfish that experience decreased survival and/or growth when exposed to hypoxia are further impaired by concurrent acidification. The tidal flushing, wave action and shallow depths allowed and provided for productive water habitat. The mean difference between surface and bottom temperature (0.25 C), dissolved oxygen (0.3mg/L), and salinity (-0.3) showed no broad dead zones or layering by temperature or salinity from April to October. The analysis below is based on the trawl surface water quality parameters because they provide the longest timeseries of information.

Temperature

Surface water temperature GLM results comparing annual means across the time series indicated significant interannual variability ($F_{34,4858} = 4.70$, $p < 0.01$). The DMRT results showed six temperature groups, with the year 2020 the hottest (24.04 C) and 1992 the coolest (19.48 C). The linear regression analysis of annual mean temperature by year showed a weak-medium relationship ($R^2 = 0.36$) of increasing temperature over time in the last thirty five years (Figure 1.30). Interannual variation was most prominent during October ($F_{33,680} = 33.29$, $p < 0.01$; Figure 1.31), and the October linear regression results were not predictive ($R^2 = 0.03$) of increasing water temperature over time (1989 - 2023).

Dissolved Oxygen

Dissolved oxygen has been measured since 1998 and annual means have been above 6 mg/L since 2005. The linear regression analysis showed a weak-medium relationship ($R^2 = 0.29$) of improvement over time (Figure 1.32). During the warmest month of the survey, the July annual mean average (mg/L) was 5.9 and has ranged from 4.6 to 7.3 since 1998. The July linear regression analysis showed a weak-medium relationship ($R^2 = 0.21$) of improvement over time. (Figure 1.33).

Salinity

Salinity GLM results comparing annual means across the time series indicated significant interannual variability ($F_{34,4822} = 44.8$, $p < 0.01$) and being within the normal limits for Mid-Atlantic saltwater fishes. The DMRT results showed five salinity groups, ranging from 22 to 30 ppt. The linear regression analysis of showed no predictive relationship ($R^2 = 0.02$; Figure 1.34).

Turbidity
Water clarity has been measured since 2006. GLM results comparing annual means across the time series indicated significant interannual variability ($F_{20,2617} = 6.66$, $p < 0.01$). The DMRT results showed four distinct turbidity groups, with the most recent years in the best group. The linear regression analysis showed a weak-medium relationship ($R^2 = 0.35$) of improvement over time (Figure 1.35). Deeper sunlight penetration was a benefit to SAV habitat.

pH

This was the second year (2023) of monitoring pH in these surveys, and the median pH was 7.9 with no difference at depth in the water column.

Table 1.1. Trawl Survey site descriptions.

Site Number	Bay	Site Description	Longitude	Latitude
T001	Assawoman Bay	On a line from Corn Hammock to Fenwick Ditch	38 26.243	75 04.747
T002	Assawoman Bay	Grey's Creek (mid creek)	38 25.859	75 06.108
T003	Assawoman Bay	Assawoman Bay (mid bay)	38 23.919	75 05.429
T004	Isle of Wight Bay	St. Martin River, mouth	38 23.527	75 07.327
T005	Isle of Wight Bay	St. Martin River, in lower Shingle Landing Prong	38 24.425	75 10.514
T006	Isle of Wight Bay	Turville Creek, below the racetrack	38 21.291	75 08.781
T007	Isle of Wight Bay	Middle of Isle of Wight Bay, north of the shoals in bay (False Channel)	38 22.357	75 05.776
T008	Sinepuxent Bay	Day marker 2, south for 6 minutes (north end of Sinepuxent Bay)	38 19.418	75 06.018
T009	Sinepuxent Bay	Day marker 14, south for 6 minutes (Sinepuxent Bay north of Snug Harbor)	38 17.852	75 07.310
T010	Sinepuxent Bay	Day marker 20, south for 6 minutes (0.5 miles south of the Assateague Island Bridge)	38 14.506	75 09.301
T011	Chincoteague Bay	Newport Bay, across mouth	38 13.024	75 12.396
T012	Chincoteague Bay	Newport Bay, opposite Gibbs Pond to Buddy Pond, in marsh cut	38 15.281	75 11.603
T013	Chincoteague Bay	Between day marker 37 and 39	38 10.213	75 13.989
T014	Chincoteague Bay	1 mile off village of Public Landing	38 08.447	75 16.043
T015	Chincoteague Bay	Inlet Slough in Assateague Island (also known as Jim's Gut)	38 06.370	75 12.454
T016	Chincoteague Bay	300 yards off east end of Great Bay Marsh, west of day marker (also known as, south of day marker 20)	38 04.545	75 17.025
T017	Chincoteague Bay	Striking Marsh, south end about 200 yards	38 03.140	75 16.116
T018	Chincoteague Bay	Boxiron (Brockatonorton) Bay (mid-bay)	38 05.257	75 19.494
T019	Chincoteague Bay	Parker Bay, north end	38 03.125	75 21.110
T020	Chincoteague Bay	Parallel to and just north of the Maryland/Virginia state line, at channel	38 01.328	75 20.057

Table 1.2. Beach Seine Survey site descriptions.

Site Number	Bay	Site Description	Latitude	Longitude
S001	Assawoman Bay	Cove behind Ocean City Sewage Treatment Plant, 62nd street	38 23.273	75 04.380
S002	Assawoman Bay	Bayside of marsh at Devil's Island, 95th street	38 24.749	75 04.264
S003	Assawoman Bay	Small cove, east side, small sand beach; sand spit, bayside of Goose Pond	38 24.824	75 06.044
S004	Isle of Wight Bay	North side of Dredge Spoil Island across east channel from 4th street, northeast corner of the Ocean City Flats	38 20.388	75 05.390
S005	Isle of Wight Bay	Beach on sand spit north of Cape Isle of Wight (also known as, in cove on marsh spit, east and south of mouth of Turville Creek	38 21.928	75 07.017
S006	Isle of Wight Bay	Beach on west side of Isle of Wight, St. Martin River (also known as Marshy Cove, west side of Isle of Wight, north of route 90 Bridge)	38 23.627	75 06.797
S007	Isle of Wight Bay	Beach, 50th street (next to Seacrets)	38 22.557	75 04.301
S008	Sinepuxent Bay	Sandy beach, northeast side, Assateague Island Bridge at National Seashore	38 14.554	75 08.581
S009	Sinepuxent Bay	Sand beach 0.5 miles south of Inlet on Assateague Island	38 19.132	75 06.174
S010	Sinepuxent Bay	Grays Cove, in small cove on north side of Assateague Pointe development's fishing pier	38 17.367	75 07.977
S011	Chincoteague Bay	Cove, 800 yards northwest of Island Point	38 13.227	75 12.054
S012	Chincoteague Bay	Beach north of Handy's Hammock (also known as, north side, mouth of Waterworks Creek)	38 12.579	75 14.921
S013	Chincoteague Bay	Cove at the mouth of Scarboro Creek	38 09.340	75 16.426
S014	Chincoteague Bay	North of the entrance to Inlet Slew	38 06.432	75 12.404
S015	Chincoteague Bay	Narrow sand beach, south of Figgs Landing	38 07.000	75 17.578
S016	Chincoteague Bay	Cove, east end, Great Bay Marsh (also known as Big Bay Marsh)	38 04.482	75 17.597
S017	Chincoteague Bay	Beach, south of Riley Cove in Purnell Bay	38 02.162	75 22.190
S018	Chincoteague Bay	Cedar Island, south side, off Assateague Island	38 02.038	75 16.619
S019	Chincoteague Bay	Land site - Ayers Creek at Sinepuxent Road	38 18.774	75 09.414

Table 1.3. Measurement types for fishes and invertebrates captured in the Trawl and Beach Seine surveys.

Species	Measurement Type
Crabs	Carapace width
Finfishes (most species)	Total length
Horseshoe Crabs	Prosomal width
Rays	Wingspan
Sharks	Total length
Shrimp	Rostrum to telson
Squid	Mantle length
Turtles	Carapace length
Whelks	Tip of spire to anterior tip of the body whorl

Table 1.4. List of fishes collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2023. Species are listed by order of total abundance (T = 140, S = 38).

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	CPUE (T) #/ha	CPUE (S) #/haul
Atlantic menhaden	*Brevoortia tyrannus*	17,185	633	16,552	36.0	435.6
Spot	*Leiostomus xanthurus*	5,431	3,599	1,832	205.0	48.2
Bay anchovy	*Anchoa mitchilli*	2,910	2,708	202	154.2	5.3
Atlantic silverside	*Menidia menidia*	1,842	6	1,836	0.3	48.3
Silver perch	*Bairdiella chrysoura*	775	624	151	35.5	4.0
Summer flounder	*Paralichthys dentatus*	430	170	260	9.7	6.8
Weakfish	*Cynoscion regalis*	295	295		16.8	
Pinfish	*Lagodon rhomboides*	261	29	232	1.6	6.1
Atlantic croaker	*Micropogonias undulatus*	161	159	2	9.1	<0.1
Black sea bass	*Centropristis striata*	138	86	52	4.9	1.4
Striped anchovy	*Anchoa hepsetus*	134	64	70	3.6	1.8
Pigfish	*Orthopristis chrysoptera*	118	32	86	1.8	2.3
Black drum	*Pogonias cromis*	82	51	31	2.9	0.8
Inshore lizardfish	*Synodus foetens*	79	33	46	1.9	1.2
White mullet	*Mugil curema*	67		67		1.8
Atlantic needlefish	*Strongylura marina*	49		49		1.3
Northern puffer	*Sphoeroides maculatus*	40	16	24	0.9	0.6
Northern pipefish	*Syngnathus fuscus*	38	15	23	0.9	0.6
Blackcheek tonguefish	*Symphurus plagiusa*	34	9	25	0.5	0.7
Dusky pipefish	*Syngnathus floridae*	34	15	19	0.9	0.5
Striped killifish	*Fundulus majalis*	31		31		0.8
Oyster toadfish	*Opsanus tau*	28	7	21	0.4	0.6
Smallmouth flounder	*Etropus microstomus*	28	15	13	0.9	0.3
Striped mullet	*Mugil cephalus*	27	1	26	0.1	0.7
Hogchoker	*Trinectes maculatus*	21	14	7	0.8	0.2
Lined seahorse	*Hippocampus erectus*	19	7	12	0.4	0.3
Northern searobin	*Prionotus carolinus*	19	18	1	1.0	<0.1
Halfbeak	*Hyporhamphus unifasciatus*	16		16		0.4
Naked goby	*Gobiosoma bosc*	15	8	7	0.5	0.2
Spotfin mojarra	*Eucinostomus argenteus*	15	3	12	0.2	0.3
Southern stingray	*Dasyatis americana*	13	1	12	0.1	0.3
Blue runner	*Caranx crysos*	11	4	7	0.2	0.2
Winter flounder	*Pseudopleuronectes americanus*	11		11		0.3
Tautog	*Tautoga onitis*	10	7	3	0.4	<0.1
Bluefish	*Pomatomus saltatrix*	8		8		0.2
Mummichog	*Fundulus heteroclitus*	8	1	7	0.1	0.2
Striped searobin	*Prionotus evolans*	8	4	4	0.2	0.1

Table 1.4. List of fishes collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2023. Species are listed by order of total abundance (T = 140, S = 38).

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	CPUE (T) #/ha	CPUE (S) #/haul
Florida pompano	*Trachinotus carolinus*	7		7		0.2
Lookdown	*Selene vomer*	7	6	1	0.3	<0.1
Southern kingfish	*Menticirrhus americanus*	7	5	2	0.3	<0.1
Striped blenny	*Chasmodes bosquianus*	5		5		0.1
Atlantic stingray	*Dasyatis sabina*	4		4		0.1
Orange filefish	*Aluterus schoepfii*	4	4		0.2	
Spotted seatrout	*Cynoscion nebulosus*	4		4		0.1
Striped burrfish	*Chilomycterus schoepfii*	4	1	3	0.1	<0.1
Feather blenny	*Hypsoblennius hentz*	3		3		<0.1
Golden shiner	*Notemigonus crysoleucas*	3		3		<0.1
Atlantic cutlassfish	*Trichiurus lepturus*	2	2		0.1	
Bluespotted cornetfish	*Fistularia tabacaria*	2		2		<0.1
Butterfish	*Peprilus triacanthus*	2	2		0.1	
Green goby	*Microgobius thalassinus*	2		2		<0.1
Mosquitofish	*Gambusia affinis*	2		2		<0.1
Northern kingfish	*Menticirrhus saxatilis*	2		2		<0.1
Southern Flounder	*Paralichthys lethostigma*	2	1	1	0.1	<0.1
Spanish mackerel	*Scomberomorus maculatus*	2	1	1	0.1	<0.1
Windowpane	*Scophthalmus aquosus*	2	2		0.1	
Atlantic spadefish	*Chaetodipterus faber*	1		1		<0.1
Clearnose skate	*Raja eglanteria*	1	1		0.1	
Gag	*Mycteroperca microlepis*	1	1		0.1	
Gizzard shad	*Dorosoma cepedianum*	1		1		<0.1
Greenside darter	*Etheostoma blennioides*	1	1		0.1	
Planehead filefish	*Stephanolepis hispida*	1		1		<0.1
Sheepshead	*Archosargus probatocephalus*	1	1		0.1	
Spotted hake	*Urophycis regia*	1	1		0.1	
Striped bass	*Morone saxatilis*	1		1		<0.1
Striped cusk-eel	*Ophidion marginatum*	1	1		0.1	
Total Finfish		30,467	8,664	21,803		

Table 1.5. Number of species and individual fish caught by year and gear in the Trawl and Beach Seine surveys (T = 140, S = 38).

	Number of Species			Number of Fish		
Year	Trawl	Beach Seine	Combined	Trawl	Beach Seine	Combined
1989	48	59	74	20,954	7,704	28,658
1990	55	52	70	28,080	21,362	49,442
1991	51	70	82	11,460	14,798	26,258
1992	49	60	70	8,188	21,426	29,614
1993	55	66	78	25,156	24,776	49,932
1994	55	56	72	48,087	29,386	77,473
1995	57	56	75	12,295	14,062	26,357
1996	49	51	67	10,258	17,083	27,341
1997	49	58	69	25,588	33,324	58,912
1998	52	59	71	11,684	13,729	25,413
1999	56	64	80	13,828	24,571	38,399
2000	60	61	81	19,167	22,664	41,831
2001	53	63	75	9,242	6,702	15,944
2002	69	57	81	16,766	32,716	49,482
2003	51	44	62	11,676	13,227	24,903
2004	48	51	66	9,231	19,473	28,704
2005	49	56	73	13,771	21,069	34,840
2006	51	60	79	10,053	10,380	20,433
2007	58	61	79	12,937	12,373	25,310
2008	56	59	79	26,942	19,122	46,065
2009	56	59	78	5,385	13,775	19,160
2010	49	59	74	10,887	34,552	45,439
2011	56	50	70	8,232	20,666	28,898
2012	52	57	71	36,002	11,289	47,291
2013	50	60	76	14,213	7,640	21,853
2014	46	58	68	7,586	52,093	60,329
2015	59	59	74	8,568	33,139	41,777
2016	44	63	71	9,480	18,187	27,667
2017	44	54	65	5,628	23,082	28,710
2018	55	59	73	8,881	33,677	42,558
2019	51	55	68	30,985	22,800	53,785
2020	46	63	74	5,654	17,912	23,566
2021	48	61	70	4,549	10,302	14,851
2022	42	55	66	9,723	45,598	55,321
2023	46	55	66	8,664	21,803	30,467

Table 1.6. Summary of the 2023 Trawl and Beach Seine surveys; species abundance is defined as above, below, or equal to the grand mean.

Common Name	Scientific Name	Trawl	Beach Seine
American eel	*Anguilla rostrata*	Below	Below
Atlantic croaker	*Micropogonias undulatus*	Below	Equal
Atlantic menhaden	*Brevoortia tyrannus*	Equal	Above
Atlantic silverside	*Menidia menidia*	Below	Equal
Bay anchovy	*Anchoa mitchilli*	Below	Below
Black sea bass	*Centropristis striata*	Equal	Equal
Bluefish	*Pomatomus saltatrix*	Below	Below
Pinfish	*Lagodon rhomboides*	Above	Equal
Sheepshead	*Archosargus probatocephalus*	Equal	Below
Silver perch	*Bairdiella chrysoura*	Equal	Below
Spot	*Leiostomus xanthurus*	Equal	Above
Summer flounder	*Paralichthys dentatus*	Below	Above
Weakfish	*Cynoscion regalis*	Equal	Below

Table 1.7. Proportion of catch by month in the Trawl Survey time series (1989 - 2023). Green highlight indicates months of high abundance.

	Apr	May	Jun	Jul	Aug	Sep	Oct
American eel (*Anguilla rostrata*)	25.8	25.4	22.9	13.6	8.8	2.5	0.9
Atlantic croaker (*Micropogonias undulatus*)	3.6	6.8	12.2	13.4	5.7	14.0	44.3
Atlantic menhaden (*Brevoortia tyrannus*)	1.0	30.0	47.2	9.9	5.5	2.6	3.7
Atlantic silverside (*Menidia menidia*)	6.3	1.7	34.9	32.0	5.1	15.0	5.0
Bay anchovy (*Anchoa mitchilli*)	4.8	5.6	9.1	18.6	32.4	17.6	11.7
Black sea bass (*Centropristis striata*)	1.9	10.4	20.3	24.6	19.8	16.5	6.5
Pinfish (*Lagodon rhomboides*)	0.0	9.5	17.8	23.7	24.1	19.7	5.3
Sheepshead (*Archosargus probatocephalus*)	2.9	0.0	0.0	8.6	8.6	20.0	60.0
Silver perch (*Bairdiella chrysoura*)	0.0	0.3	0.8	19.4	42.7	29.8	6.9
Spot (*Leiostomus xanthurus*)	0.8	15.9	32.9	20.7	15.0	10.4	4.3
Summer flounder (*Paralichthys dentatus*)	2.7	18.4	32.0	20.8	13.6	8.5	4.1
Weakfish (*Cynoscion regalis*)	0.0	0.0	0.2	60.9	30.6	7.0	1.2

Table 1.8. Proportion of catch by month in the Beach Seine Survey the time series (1989 - 2023). Green highlight indicates months of high abundance.

	June	September
American eel (*Anguilla rostrata*)	71.5	28.5
Atlantic croaker (*Micropogonias undulatus*)	81.6	18.4
Atlantic menhaden (*Brevoortia tyrannus*)	74.6	25.4
Atlantic silverside (*Menidia menidia*)	18.1	81.9
Bay anchovy (*Anchoa mitchilli*)	37.2	62.8
Black sea bass (*Centropristis striata*)	77.1	22.9
Pinfish (*Lagodon rhomboides*)	89.2	10.8
Sheepshead (*Archosargus probatocephalus*)	6.0	94.0
Silver perch (*Bairdiella chrysoura*)	1.5	98.5
Spot (*Leiostomus xanthurus*)	78.7	21.3
Summer flounder (*Paralichthys dentatus*)	77.5	22.5
Weakfish (*Cynoscion regalis*)	2.0	98.0

Table 1.9. List of crustaceans collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2023. Species are listed by order of total abundance (T = 140, S = 38).

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	Estimated Count (T)	Estimated Count (S)	CPUE (T) #/Hect.	CPUE (S) #Haul
Grass shrimp	*Palaemonetes sp.*	1,940	29	51	405	1,455	24.7	39.6
Blue crab	*Callinectes sapidus*	1,735	948	787			54.0	20.7
Lady crab	*Ovalipes ocellatus*	429	242	187			13.8	4.9
Long-armed hermit crab	*Pagurus longicarpus*	336	151	185			8.6	4.9
Say mud crab	*Dyspanopeus sayi*	290	274	16			15.6	0.4
Brown shrimp	*Farfantepenaeus aztecus*	261	206	55			11.7	1.4
Sand shrimp	*Crangon septemspinosa*	195	78	6	91	20	9.6	0.7
White shrimp	*Litopenaeus setiferus*	130	108	22			6.2	0.6
Arrow Shrimp	*Tozeuma carolinense*	104	4			100	0.2	2.6
Mantis shrimp	*Squilla empusa*	95	91	4			5.2	0.1
Lesser blue crab	*Callinectes similis*	16	4	12			0.2	0.3
Portly spider crab	*Libinia emarginata*	11	11				0.6	
Atlantic mud crab	*Panopeus herbstii*	2	2				0.1	
Bigclaw snapping shrimp	*Alpheus heterochaelis*	2	2				0.1	
Flatclaw hermit	*Pagurus pollicaris*	2	1	1			0.1	<0.1
Atlantic rock crab	*Cancer irroratus*	1	1				0.1	
Atlantic marsh fiddler	*Uca pugnax*							
	Total Crustaceans	**5,549**	**2,152**	**1,326**	**496**	**1,575**		

Table 1.10. List of other species collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2023. Species are listed by order of total abundance (T = 140, S = 38).

Common Name	Scientific Name	Total Number Collected	No. Collect (T)	No. Collect (S)	Est. Cnt. (T)	Est. Cnt. (S)	Spec. Vol (L) (T)	Spec. Vol (L) (S)	Est. Vol (L) (T)	Est. Vol (L) (S)	CPUE (T) #/Hect.	CPUE (S) #/Haul	CPUE (T) #/Hect. Vol.	CPUE (S) #/Haul Vol.
Sea squirt	*Molgula manhattensis*	1,257	12		945	300	124.3				54.5	7.9	7.1	
Sea nettle	*Chrysaora quinquecirrha*	328	216		112		2.0				18.7		0.1	
Comb jellies	*Ctenophora*	232	93	7	132		46.5	3.3	1.3		12.8	0.2	2.7	<0.1
Moon jelly	*Aurelia aurita*	155	152	3			2.0		2.0		8.7	<0.1	0.2	
Beroe comb jelly	*Beroe ovata*	82	79	3							4.5	<0.1		
Hairy sea cucumber	*Sclerodactyla briareus*	69	63	6							3.6	0.2		
Horseshoe crab	*Limulus polyphemus*	67	49	18							2.8	0.5		
Northern diamondback terrapin	*Malaclemys terrapin terrapin*	11	9	2							0.5	<0.1		
Lions mane	*Cyanea capillata*	2	1	1							0.1	<0.1		
Sea pork	*Aplidium sp.*						16.1	3.2					0.9	<0.1
Bryozoans	*Ectoprocta*						73.8	11.9					4.2	0.3
Rubbery bryozoan	*Alcyonidium sp.*						10.8	0.9					0.6	<0.1
Halichondria sponge	*Halichondria sp.*						83.6	7.5					4.8	0.2
Red beard sponge	*Microciona prolifera*						158.7	0.6					9.0	<0.1
Sulphur sponge	*Cliona celata*						55.4						3.1	
	Total Other	**2,203**	**674**	**40**	**1,189**	**300.0**	**573.3**	**27.3**	**3.3**					

Table 1.11. List of molluscs collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2023. Species are listed by order of total abundance (T = 140, S = 38).

Common Name	Scientific Name	Total Number Collected	No. Collect (T)	No. Collect (S)	Est. Cnt. (T)	Est. Cnt. (S)	Spec. Vol (L) (T)	Spec. Vol (L) (S)	Est. Vol (L) (T)	Est. Vol (L) (S)	CPUE (T) #/Hect.	CPUE (S) #Haul	CPUE Vol (T) #/Hect	CPUE Vol (S) #/Haul
Blue mussel	*Mytilus edulis*	305			305						17.4			
Atlantic brief squid	*Lolliguncula brevis*	153	153								8.7			
Solitary glassy bubble snail	*Haminoea solitaria*	101	26		75						5.8			
Slippershells	*Crepidula sp.*	46	1		45						2.6			
Bruised nassa	*Nassarius vibex*	34	32	2							1.8	<0.1		
Sponge slug	*Doris verrucosa*	13	13								0.7			
Atlantic oyster drill	*Urosalpinx cinerea*	5	5								0.3			
Eastern mudsnail	*Nassarius obsoletus*	5	1	4							0.1	0.1		
Bay scallop	*Argopecten irradians*	2	2								0.1			
Cayenne keyhole limpet	*Diodora cayenensis*	1	1								0.1			
	Total Molluscs	**665**	**234**	**6**	**425**									

Table 1.12. List of Submerged Aquatic Vegetation (SAV) and macroalgae collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2023. Species are listed by order of total abundance (T= 140, S = 38).

Common Name	Genus	Specific Volume (L) (T)	Specific Volume (L) (S)
<u>SAV</u>			
Eelgrass	*Zostera*	167.3	40.2
Widgeon grass	*Ruppia*	3.9	13.0
	Total SAV	**171.2**	**53.2**
<u>Macroalgae</u>			
Brown			
Common southern kelp	*Laminaria*	0.3	0.1
Sour weeds	*Desmarestia*	0.2	
		0.5	**0.1**
Green			
Sea lettuce	*Ulva*	23.8	5.9
Green fleece	*Codium*	8.8	2.6
Hollow green weed	*Enteromorpha*	4.0	1.6
Green hair algae	*Chaetomorpha*	2.2	0.7
Green sea fern	*Bryopsis*	1.4	
Green tufted seaweed	*Cladophora*	0.1	
		40.4	**10.8**
Red			
Tubed weeds	*Polysiphonia*	399.9	147.8
Agardh's red weed	*Agardhiella*	291.9	625.5
Barrel weed	*Champia*	16.2	0.9
Banded weeds	*Ceramium*	12.5	3.1
Hairy basket weed	*Spyridia*	0.1	0.1
Graceful red weed	*Gracilaria*		0.6
		720.6	**777.9**
Yellow-Green			
Water felt	*Vaucheria*	7.1	1.1
		7.1	**1.1**
	Total Macroalgae	**768.6**	**789.9**

Table 1.13. Length by month for selected fishes from the 2023 Trawl Survey.

	Month	Number Counted	Number Measured	Min Length (mm)	Max Length (mm)	Mean Length (mm)	SD
Atlantic croaker (*Micropogonias undulatus*)	April	93	21	22	55	41	9.9
	May	31	23	36	104	80.9	13.1
	June	20	20	76	148	110.9	16.7
	July	10	10	27	172	124	47.7
	Aug	4	4	102	215	171.9	50.2
	Sep	1	0				
Atlantic menhaden (*Brevoortia tyrannus*)	May	116	29	31	46	36.2	3.2
	June	472	34	32	95	41.1	14.4
	July	12	12	52	95	73	12.9
	Aug	17	17	62	92	71.5	9.2
	Sep	8	8	74	104	93.3	10.0
	Oct	8	7	64	79	71.6	4.9
Atlantic silverside (*Menidia menidia*)	June	3	3	63	85	71	12.2
	Aug	2	2	53	55	54	1.4
	Oct	1	1	95	95	95	
Bay anchovy (*Anchoa mitchilli*)	April	35	21	42	63	50.9	5.4
	May	41	41	32	75	59.7	8.7
	June	35	34	53	110	66.7	10.6
	July	981	241	12	135	40.2	17.1
	Aug	999	179	21	98	45.4	17.4
	Sep	573	70	22	100	51.0	17.7
	Oct	44	43	22	72	46.6	11.3
Black sea bass (*Centropristis striata*)	April	1	1	73	73	73	
	May	4	4	83	95	89.8	5.1
	June	6	6	71	106	90.5	16.6
	July	35	35	87	145	124.6	12.8
	Aug	25	25	110	165	135.2	14.0
	Sep	14	14	45	170	108.1	40.6
	Oct	1	1	149	149	149	
Pinfish (*Lagodon rhomboides*)	May	1	1	48	48	48	
	June	5	5	28	61	50.4	13
	July	5	5	29	113	91.4	35.5
	Aug	15	15	20	137	73.6	41.1
	Sep	2	2	125	133	129	5.7
	Oct	1	1	156	156	156	
Sheepshead (*Archosargus probatocephalus*)	April	1	1	107	107	107	

Table 1.13. Length by month for selected fishes from the 2023 Trawl Survey.

	Month	Number Counted	Number Measured	Min Length (mm)	Max Length (mm)	Mean Length (mm)	SD
Silver perch (*Bairdiella chrysoura*)	May	2	2	142	147	144.5	3.5
	June	1	1	140	140	140	
	July	250	89	15	206	45.1	29.2
	Aug	214	109	40	175	73.2	17.6
	Sep	138	92	45	131	89.7	17.3
	Oct	19	19	94	133	108.8	11.2
Spot (*Leiostomus xanthurus*)	April	23	20	28	52	40.6	8.9
	May	1604	117	22	180	74.1	20.2
	June	912	182	35	132	93.3	13.9
	July	629	211	61	200	122.4	16.9
	Aug	218	133	38	170	133.1	15.1
	Sep	202	87	102	186	137	12.7
	Oct	11	11	123	152	137.6	8.3
Summer flounder (*Paralichthys dentatus*)	April	1	1	50	50	50	
	May	35	35	40	311	69.6	46
	June	15	15	52	109	73.9	18.1
	July	67	67	45	200	81.6	21.6
	Aug	29	29	63	300	89.9	42.2
	Sep	18	18	67	347	130.4	82.7
	Oct	5	5	83	131	108.6	20.3
Weakfish (*Cynoscion regalis*)	July	205	145	26	125	57.3	17.8
	Aug	65	62	55	180	97.6	20.8
	Sep	19	19	85	141	114.4	14.8
	Oct	2	2	113	141	127	19.8

Table 1.14. Length by month for selected fishes from the 2023 Beach Seine Survey.

	Month	Number Counted	Number Measured	Min Length (mm)	Max Length (mm)	Mean Length (mm)	SD
Atlantic croaker	Jun						
(*Micropogonias undulatus*)	Sep	2	2	190	231	210.5	29.0
Atlantic menhaden	Jun	12,114	219	34	220	51.2	21.5
(*Brevoortia tyrannus*)	Sep	4,438	134	18	285	93.4	34.3
Atlantic silverside	Jun	500	230	19	132	84.2	27.4
(*Menidia menidia*)	Sep	1,336	232	45	112	74.0	12.4
Bay anchovy	Jun	142	95	43	120	68.4	11.1
(*Anchoa mitchilli*)	Sep	60	42	14	95	41.0	17.8
Black sea bass	Jun	49	49	58	112	81.3	13.2
(*Centropristis striata*)	Sep	3	3	75	140	106.7	32.5
Pinfish	Jun	199	75	37	101	63.8	10.8
(*Lagodon rhomboides*)	Sep	33	33	42	165	128.5	30.0
Silver perch	Jun	4	4	135	152	141.8	7.2
(*Bairdiella chrysoura*)	Sep	147	98	13	165	84.3	20.0
Spot	Jun	1,575	329	30	207	99.1	35.4
(*Leiostomus xanthurus*)	Sep	257	185	59	246	145.5	23.1
Summer flounder	Jun	164	164	32	290	67	26.0
(*Paralichthys dentatus*)	Sep	96	96	70	283	116.8	46.7

Table 1.15. Finfish richness and diversity by system for the 2023 Trawl Survey (Assawoman Bay (n = 21), St. Martin River (n = 14), Isle of Wight Bay (n = 14), Sinepuxent Bay (n = 21), Newport Bay (n = 14), and Chincoteague Bay (n = 56)).

Embayment	Richness	Diversity
Assawoman Bay	22	1.5
St. Martin River	23	1.3
Isle of Wight Bay	22	1.6
Sinepuxent Bay	22	2.5
Newport Bay	15	1.0
Chincoteague Bay	24	1.1

Table 1.16. Finfish richness and diversity by system for the 1989 - 2023 Trawl Survey Assawoman Bay (n = 735), St. Martin River (n = 490), Isle of Wight Bay (n = 490), Sinepuxent Bay (n = 735), Newport Bay (n = 490), and Chincoteague Bay (n = 1,960)).

Embayment	Richness	Mean Richness	Mean Diversity
Assawoman Bay	82	28	1.6
St. Martin River	79	23	1.6
Isle of Wight Bay	85	30	1.8
Sinepuxent Bay	76	25	2.0
Newport Bay	70	21	1.7
Chincoteague Bay	90	34	1.7

Table 1.17. Finfish richness and diversity by system for the 2023 Beach Seine Survey (Assawoman Bay (n = 6), St. Martin River (n = 2), Isle of Wight Bay (n = 6), Sinepuxent Bay (n = 6), Newport Bay (n = 4), Chincoteague Bay (n = 12), and Ayers Creek (n = 2)).

Embayment	Richness	Diversity
Assawoman Bay	30	1.4
St. Martin River	15	0.4
Isle of Wight Bay	29	2.0
Sinepuxent Bay	31	1.0
Newport Bay	29	1.8
Chincoteague Bay	39	0.8
Ayers Creek	10	0.1

Table 1.18. Finfish richness and diversity by system for the 1989 - 2023 Beach Seine Survey: Assawoman Bay (n = 210), St. Martin River (n = 70), Isle of Wight Bay (n = 210), Sinepuxent Bay (n = 210), Newport Bay (n = 148), Chincoteague Bay (n = 420), and Ayers Creek (n = 70).

Embayment	Richness	Mean Richness	Mean Diversity
Assawoman Bay	89	31	1.8
St. Martin River	71	21	1.4
Isle of Wight Bay	88	29	1.8
Sinepuxent Bay	81	28	1.5
Newport Bay	74	21	1.8
Chincoteague Bay	86	34	1.9
Ayers Creek	44	14	1.3

Table 1.19. Macroalgae dominance in the Maryland Coastal Bays as sampled by the Trawl and Beach Seine surveys 2006 - 2023.

	Assawoman Bay	Isle of Wight Bay	St. Martin River	Sinepuxent Bay	Newport Bay	Chincoteague Bay
2006	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2007	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2008	Rhodophyta	Rhodophyta	Rhodophyta	Chlorophyta	Chlorophyta	Phaeophyta
2009	Rhodophyta	Rhodophyta	Rhodophyta	Chlorophyta	Chlorophyta	Chlorophyta
2010	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Chlorophyta	Chlorophyta
2011	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2012	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2013	Rhodophyta	Rhodophyta	Chlorophyta	Rhodophyta	Rhodophyta	Rhodophyta
2014	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2015	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Chlorophyta
2016	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2017	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2018	Rhodophyta	Rhodophyta	Rhodophyta	Chlorophyta	Rhodophyta	Chlorophyta
2019	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2020	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Chlorophyta
2021	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2022	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta
2023	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta	Rhodophyta

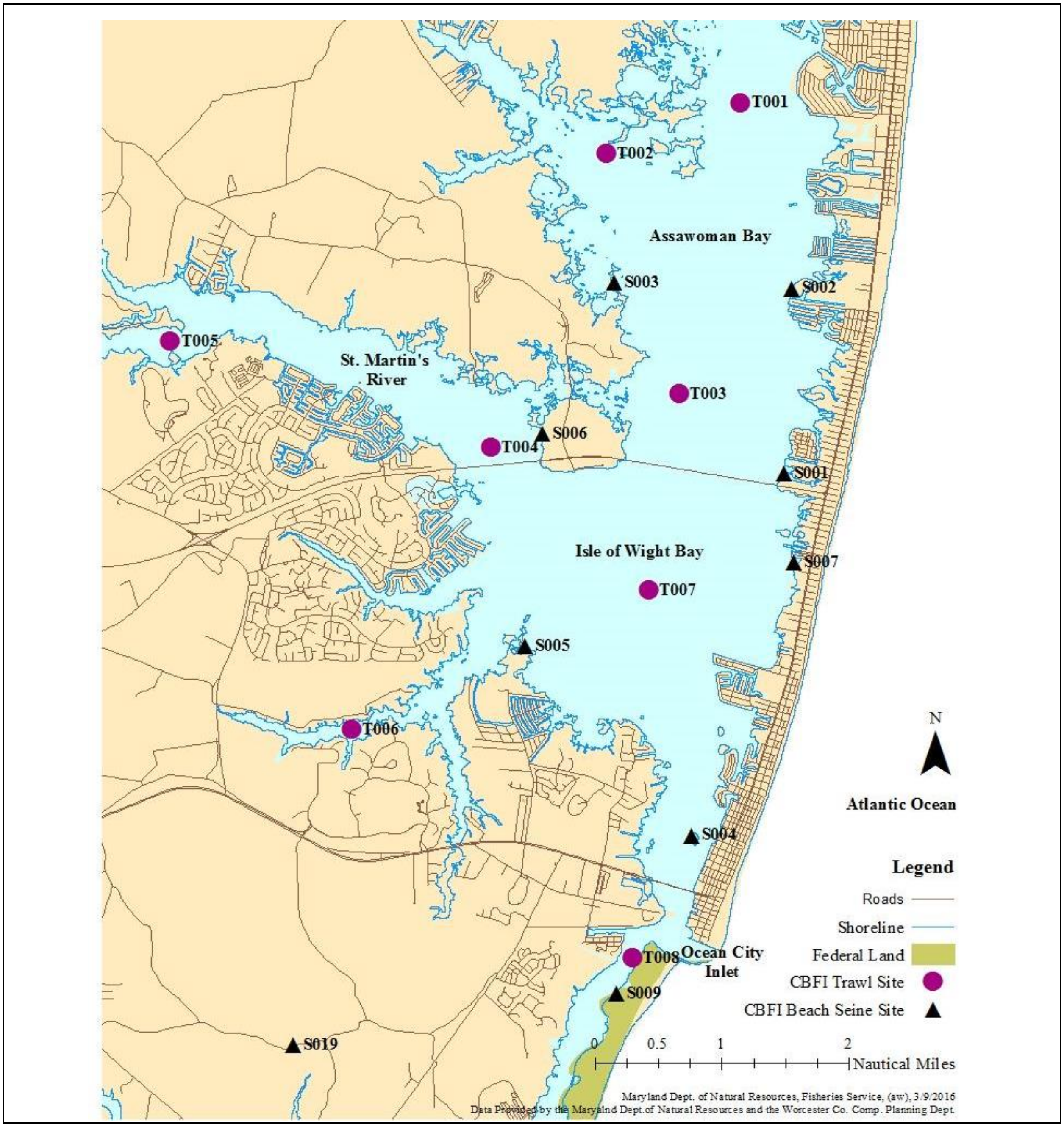

Figure 1.1. Trawl and Beach Seine surveys sampling locations in the Assawoman and Isle of Wight bays, Maryland.

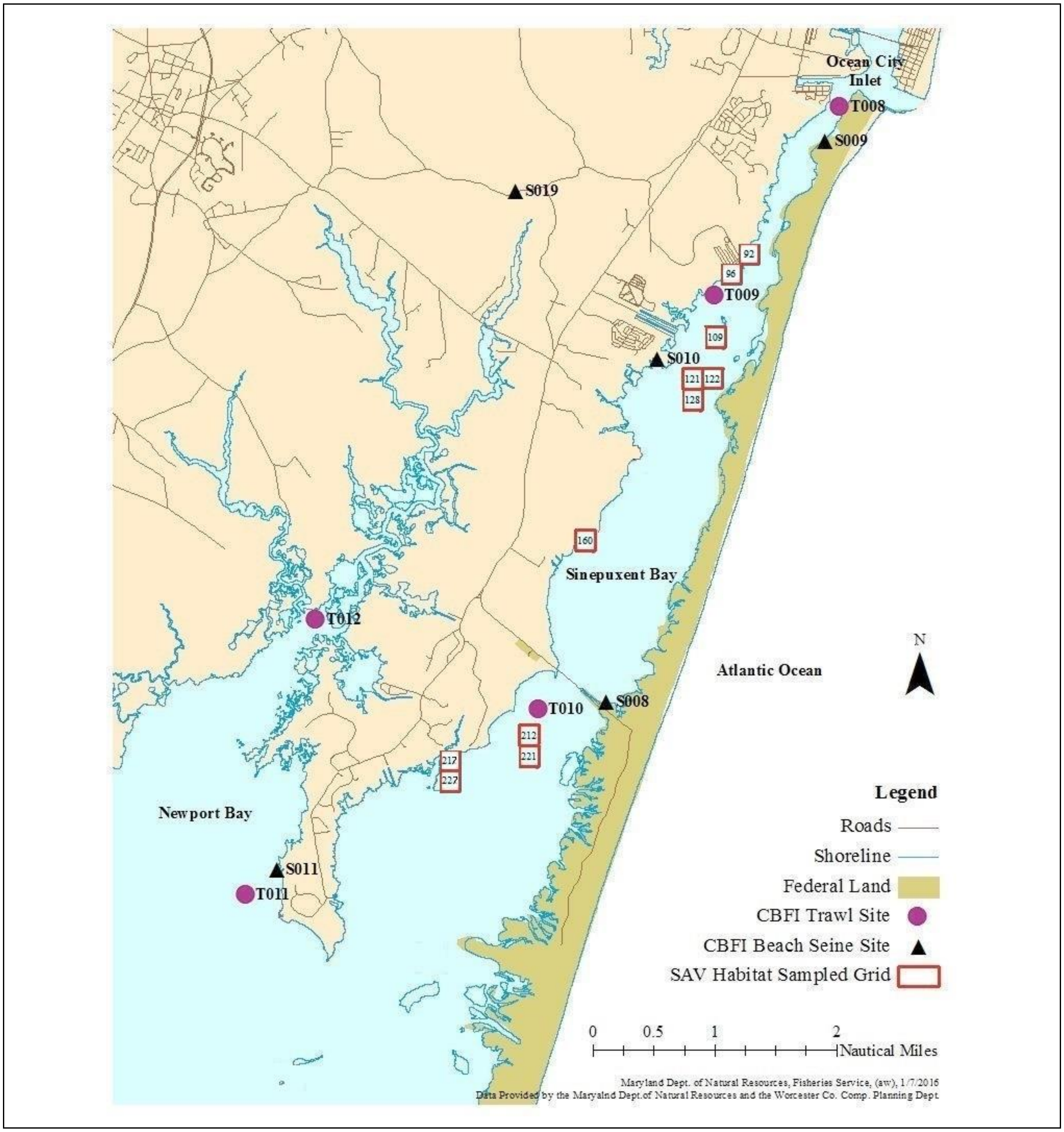

Figure 1.2. Trawl and Beach Seine surveys sampling locations in Sinepuxent and Newport bays, Maryland

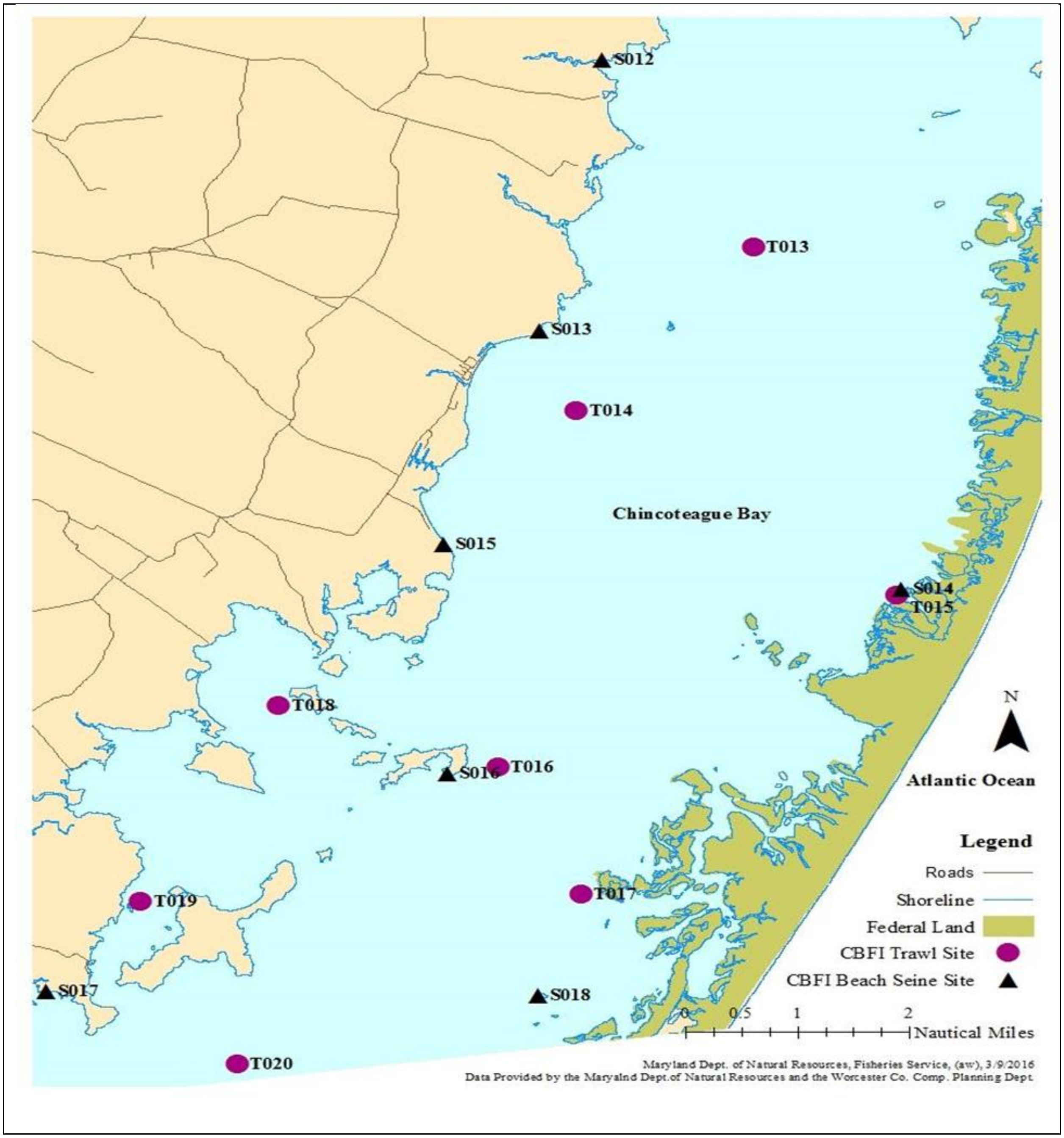

Figure 1.3. Trawl and Beach Seine surveys sampling locations in Chincoteague Bay, Maryland.

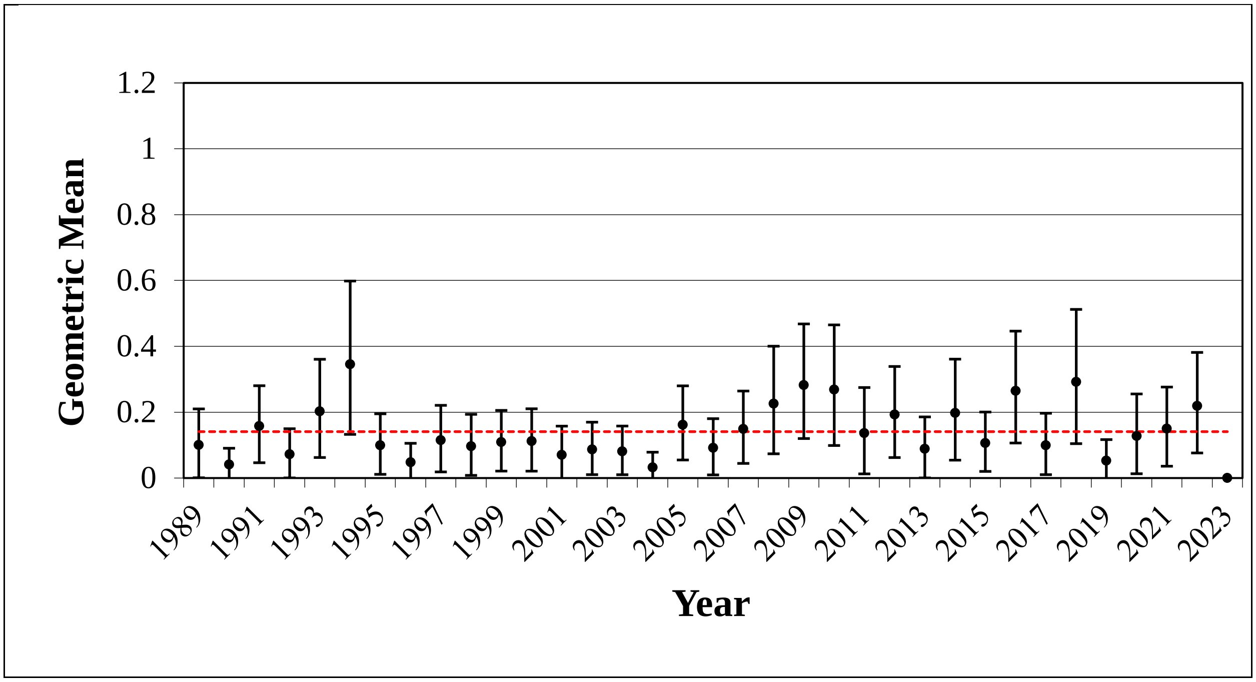

Figure 1.4. American eel (*Anguilla rostrata*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989 - 2019, 2021 - 2023}$ = 140/year, n_{2020} = 120).

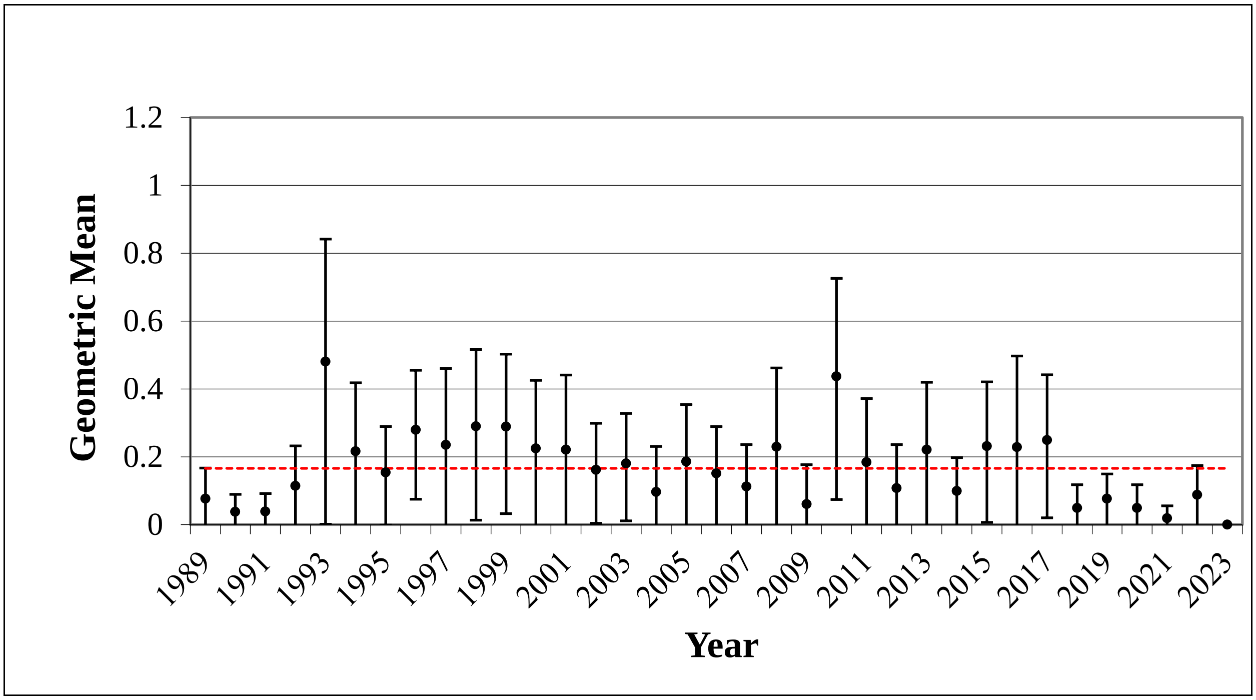

Figure 1.5. American eel (*Anguilla rostrata*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

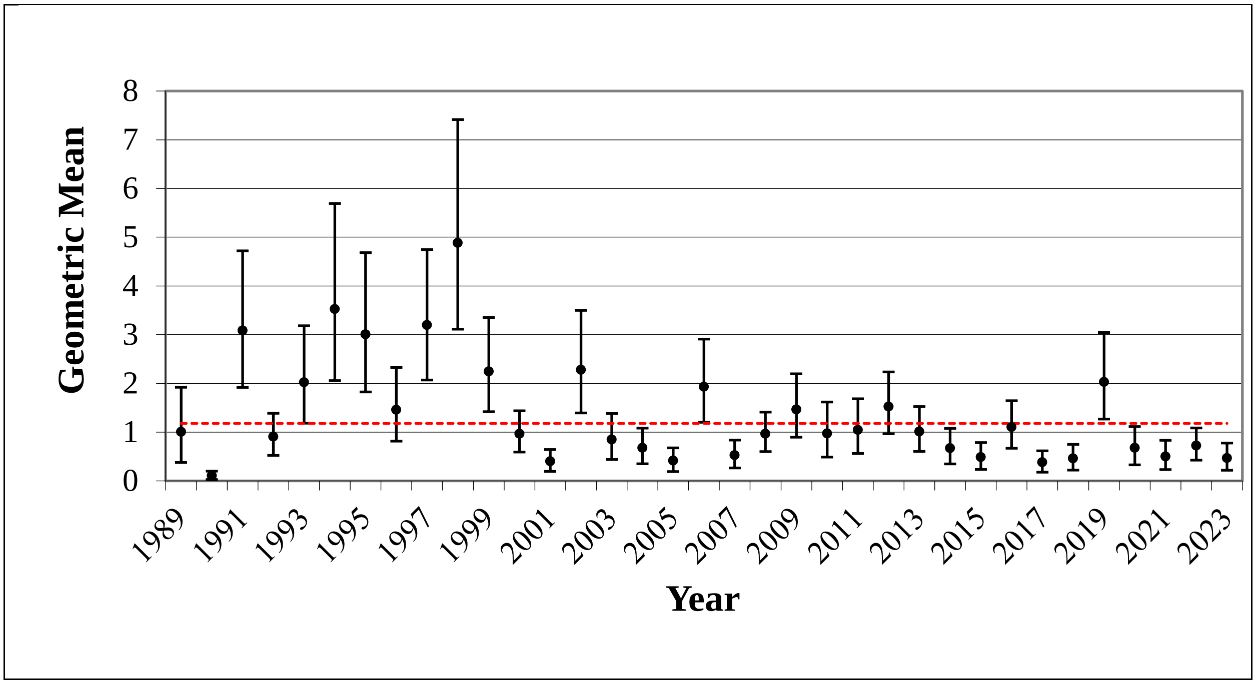

Figure 1.6. Atlantic croaker (*Micropogonias undulatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989 - 2019, 2021 - 2023}$ = 140/year, n_{2020} = 120).

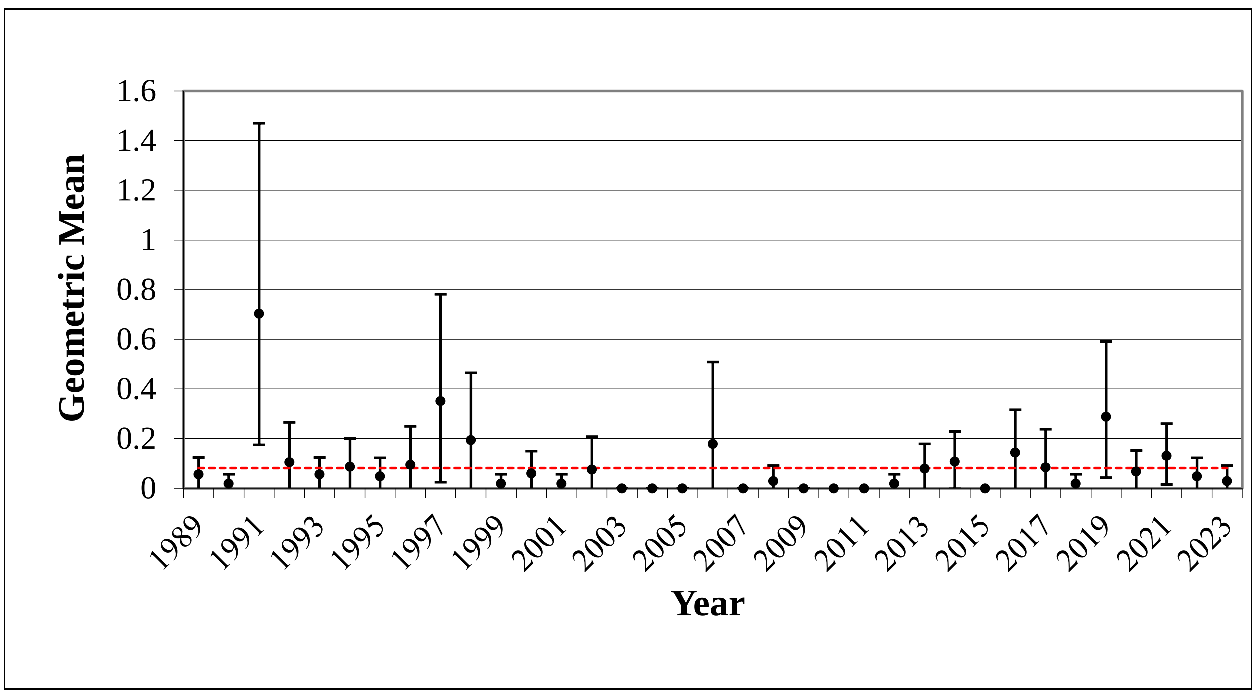

Figure 1.7. Atlantic croaker (*Micropogonias undulatus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

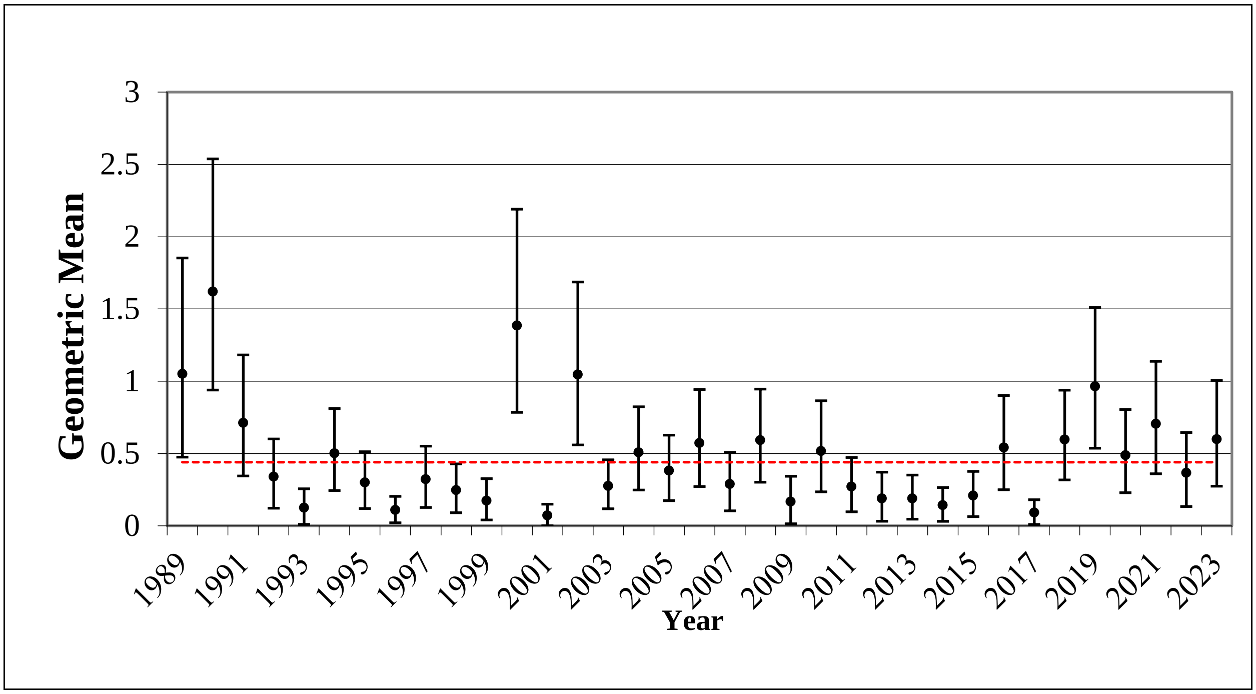

Figure 1.8. Atlantic menhaden (*Brevoortia tyrannus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989 - 2019, 2021 - 2023}$ = 140/year, n_{2020} = 120).

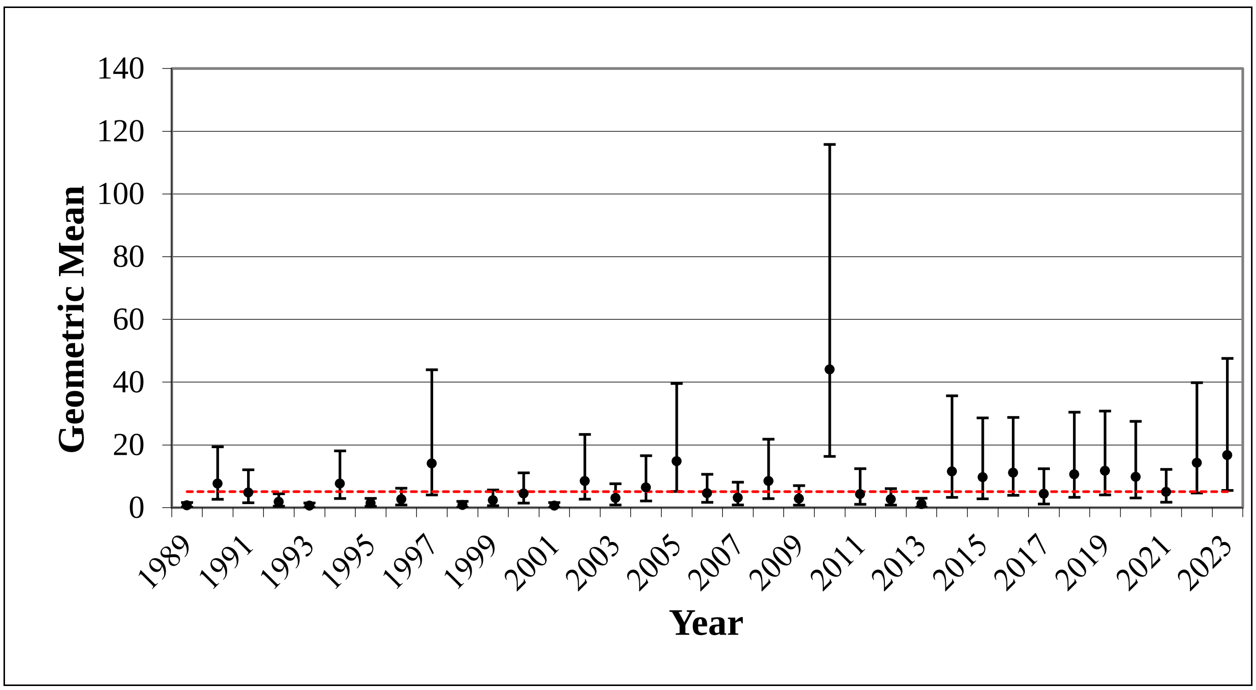

Figure 1.9. Atlantic menhaden (*Brevoortia tyrannus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

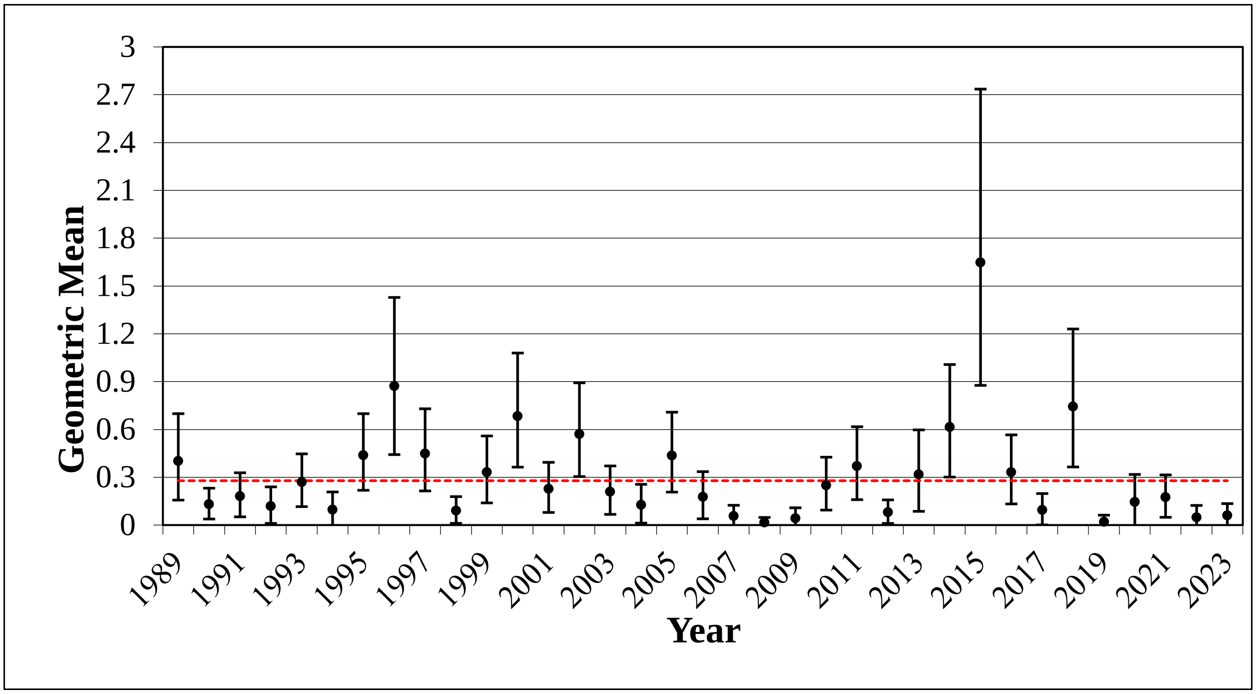

Figure 1.10. Atlantic silverside (*Menidia menidia*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989 - 2019, 2021 - 2023}$ = 140/year, n_{2020} = 120).

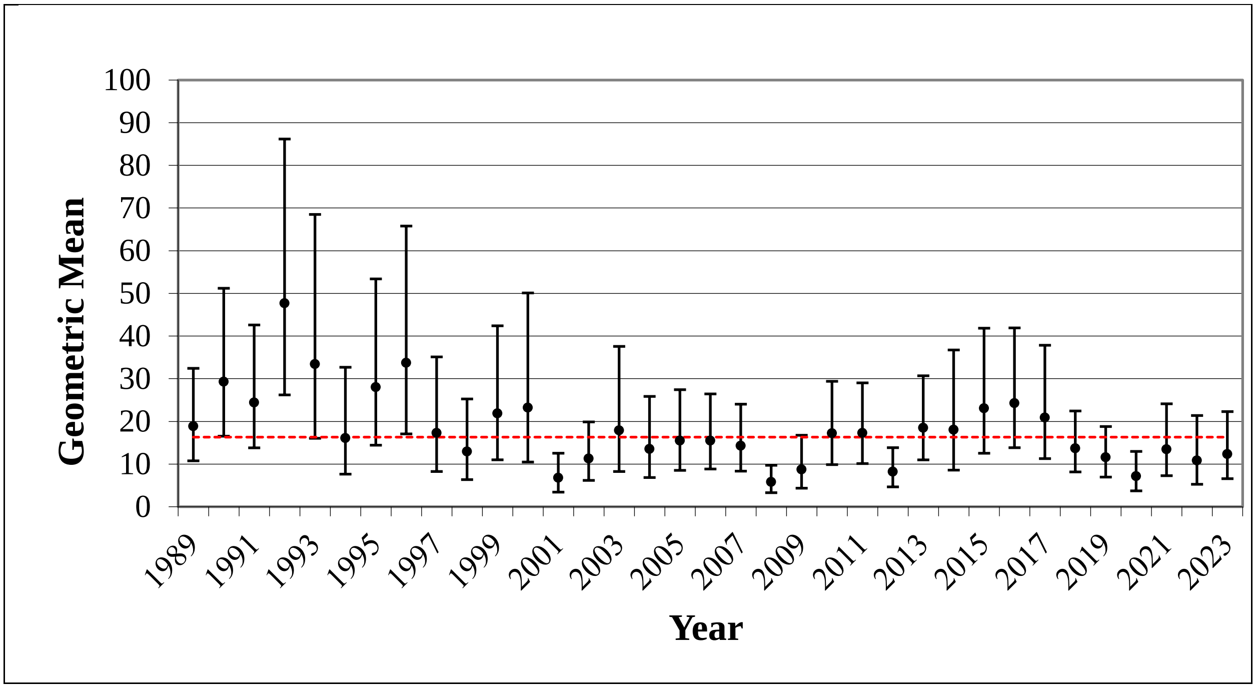

Figure 1.11. Atlantic silverside (*Menidia menidia*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

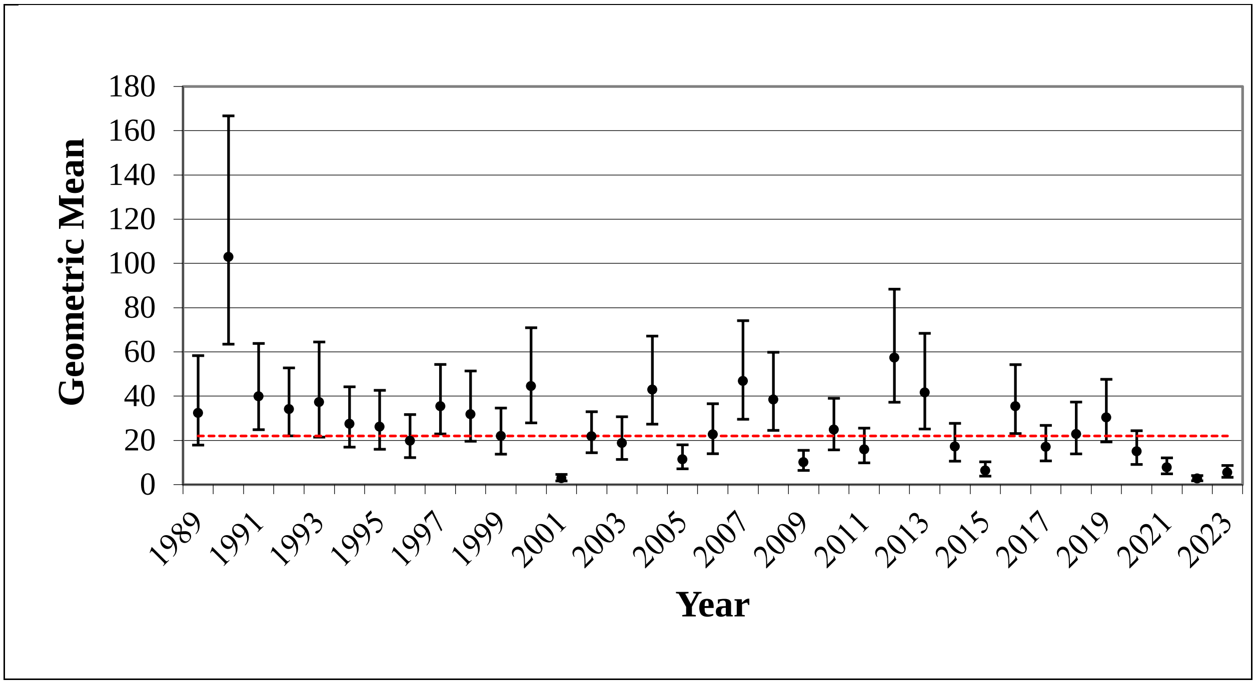

Figure 1.12. Bay anchovy (*Anchoa mitchilli*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\text{ - }2019,\ 2021\text{ - }2023}$ = 140/year, n_{2020} = 120).

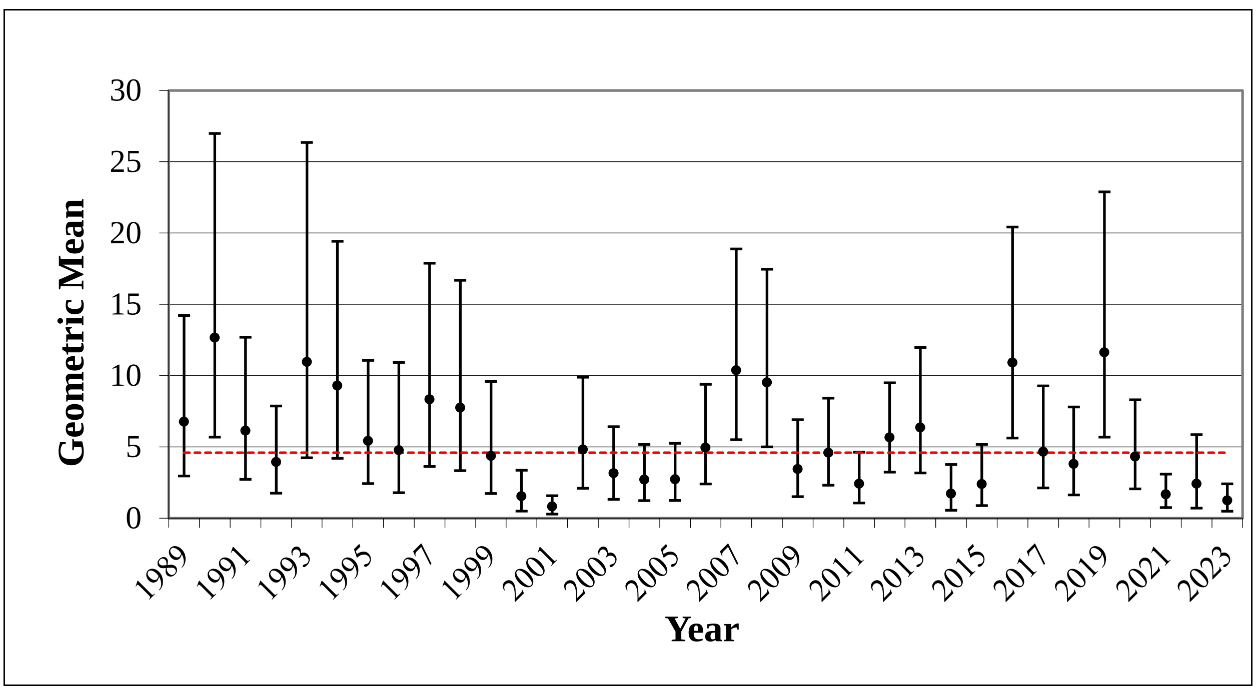

Figure 1.13. Bay anchovy (*Anchoa mitchilli*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

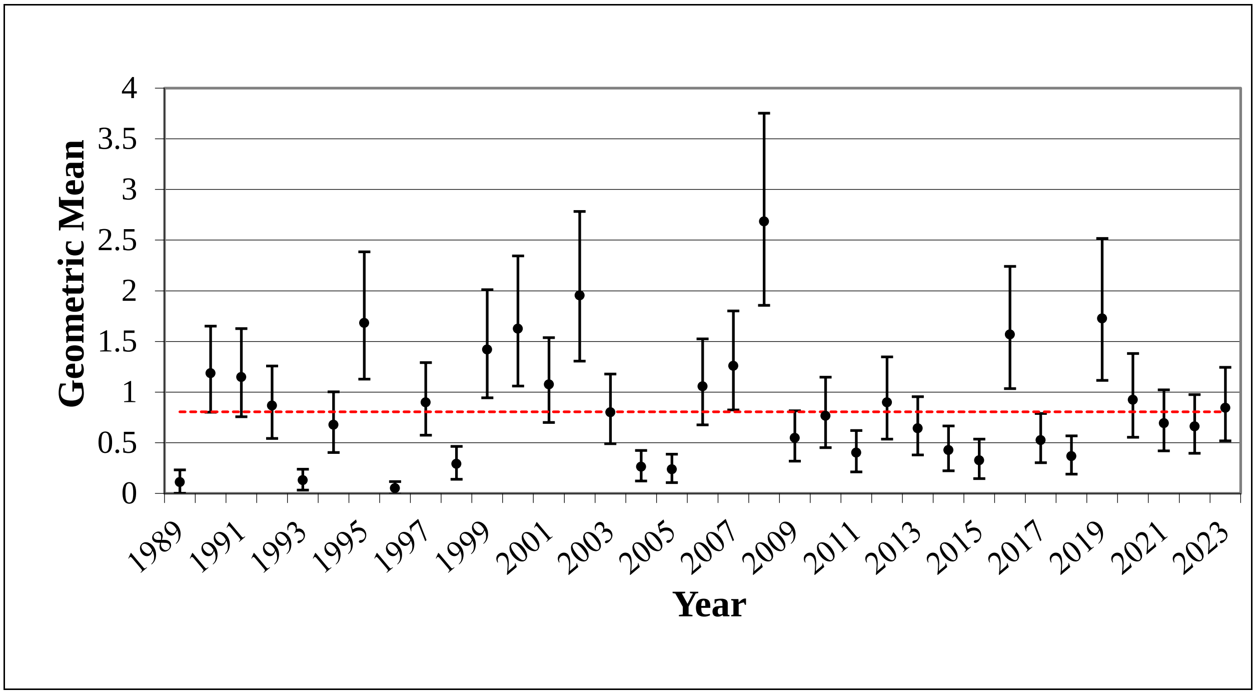

Figure 1.14. Black sea bass (*Centropristis striata*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\text{ - }2019,\ 2021\text{ - }2023}$ = 140/year, n_{2020} = 120).

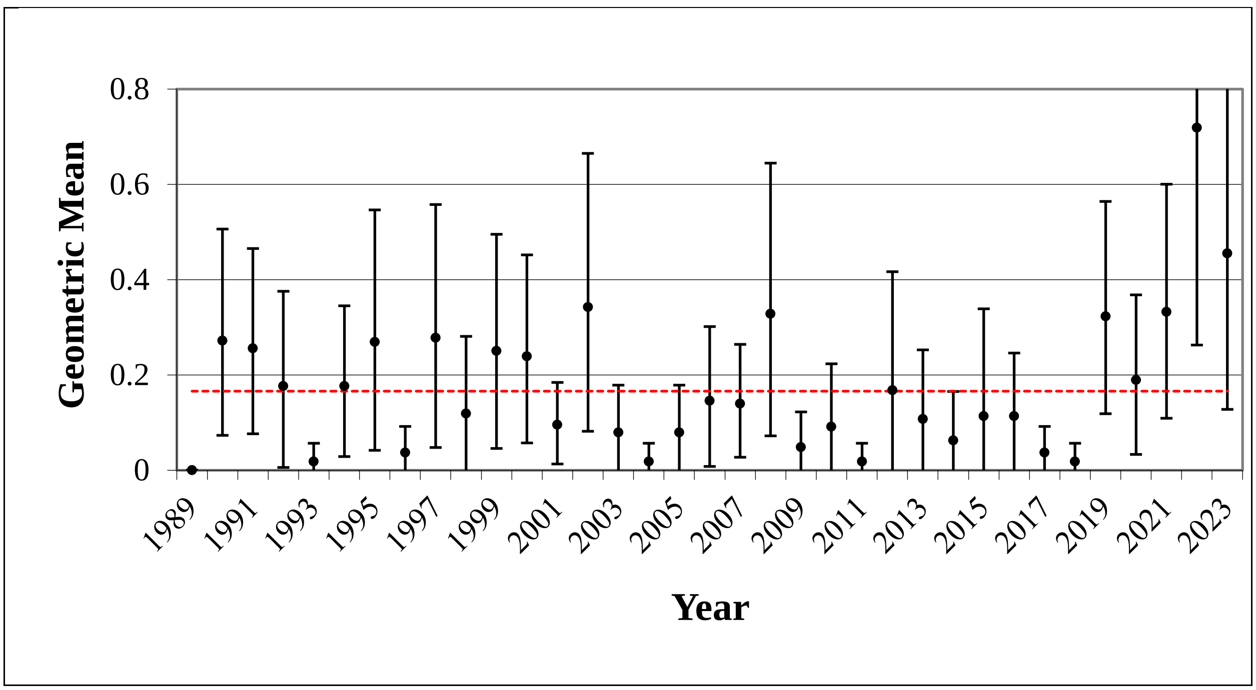

Figure 1.15. Black sea bass (*Centropristis striata*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

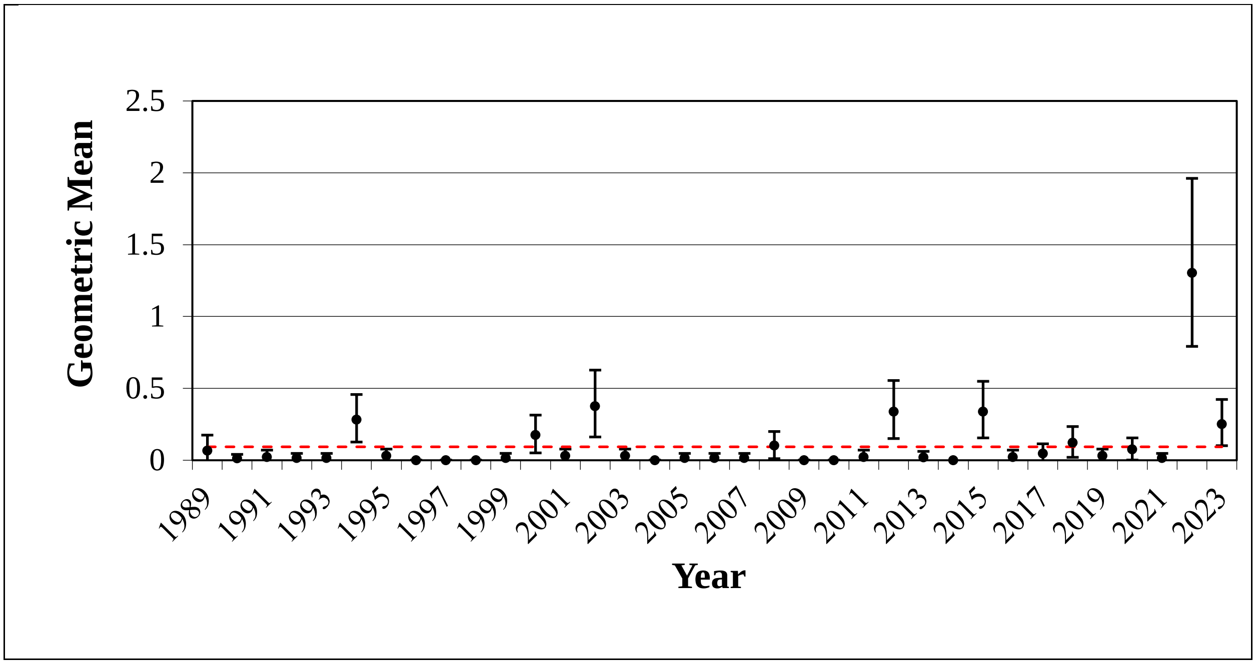

Figure 1.16. Pinfish (*Lagodon rhomboides*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\ -\ 2019,\ 2021\ -\ 2023}$ = 140/year, n_{2020} = 120).

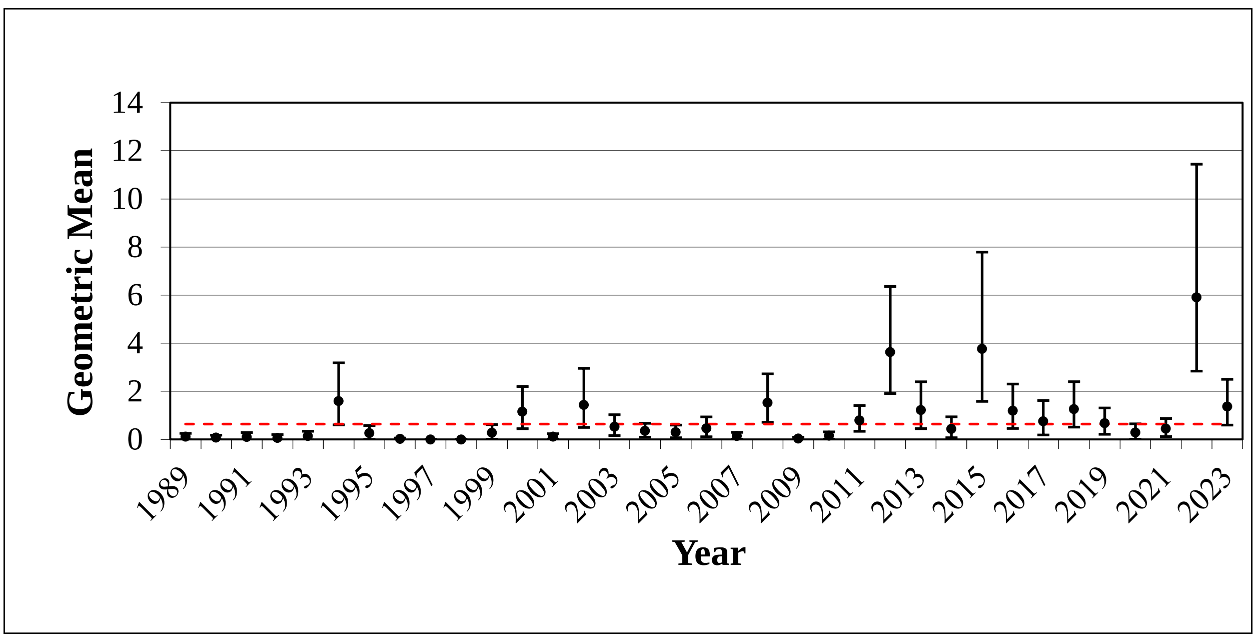

Figure 1.17. Pinfish (*Lagodon rhomboides*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

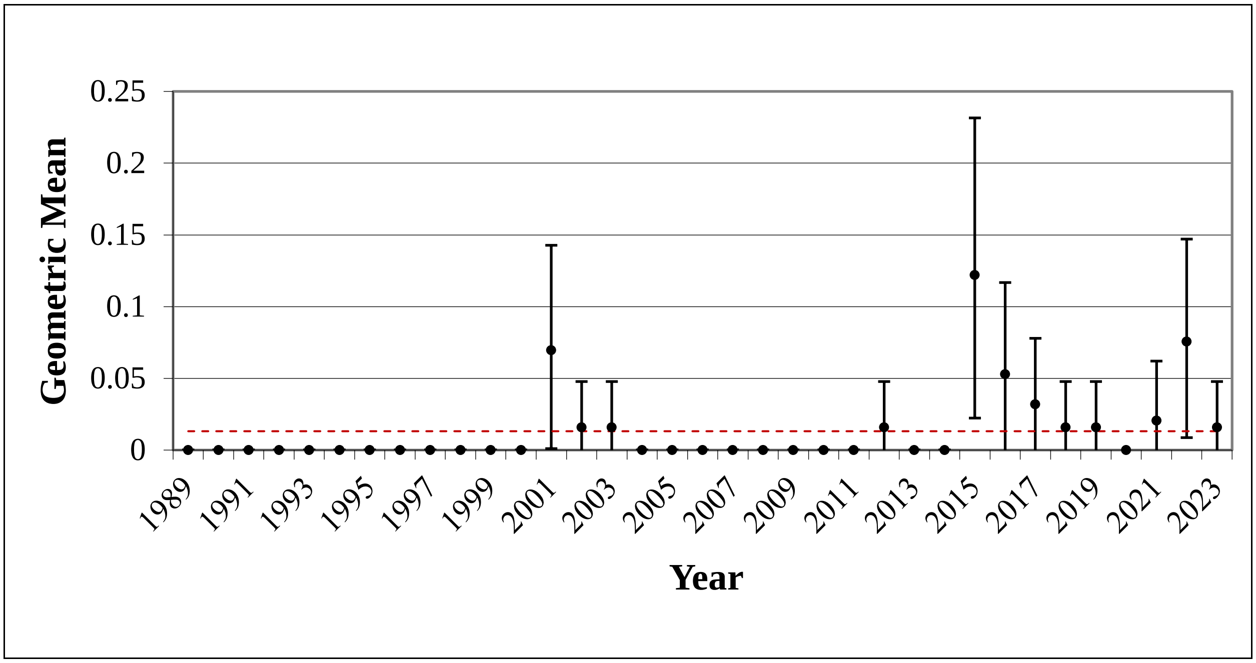

Figure 1.18. Sheepshead (*Archosargus probatocephalus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\text{ - }2019,\ 2021\text{ - }2023}$ = 140/year, n_{2020} = 120).

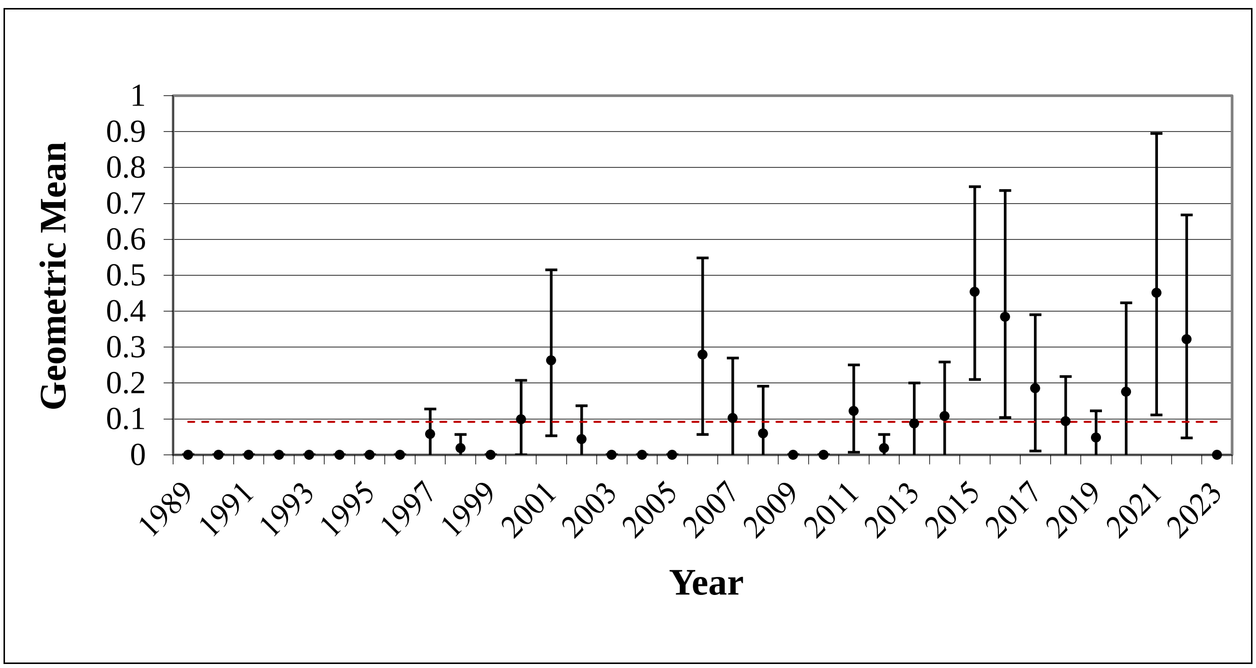

Figure 1.19. Sheepshead (*Archosargus probatocephalus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 – 2023 time series grand mean (n = 38/year).

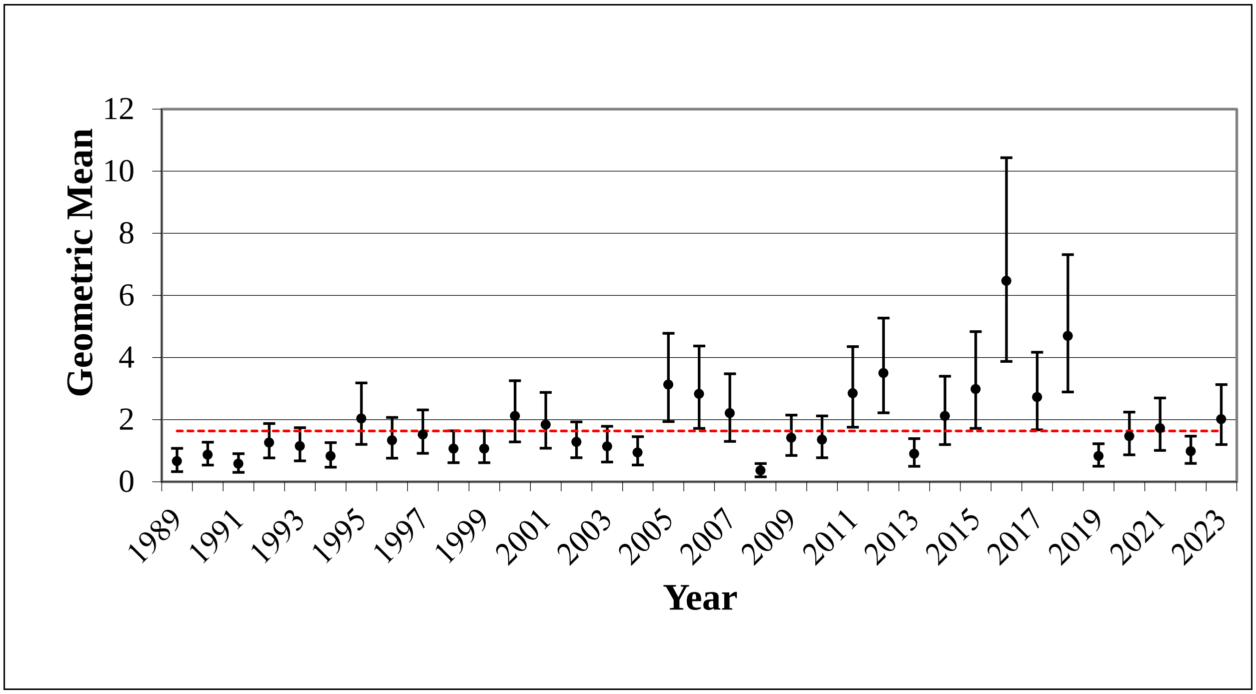

Figure 1.20. Silver perch (*Bairdiella chrysoura*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\text{ - }2019,\ 2021\text{ - }2023}$ = 140/year, n_{2020} = 120).

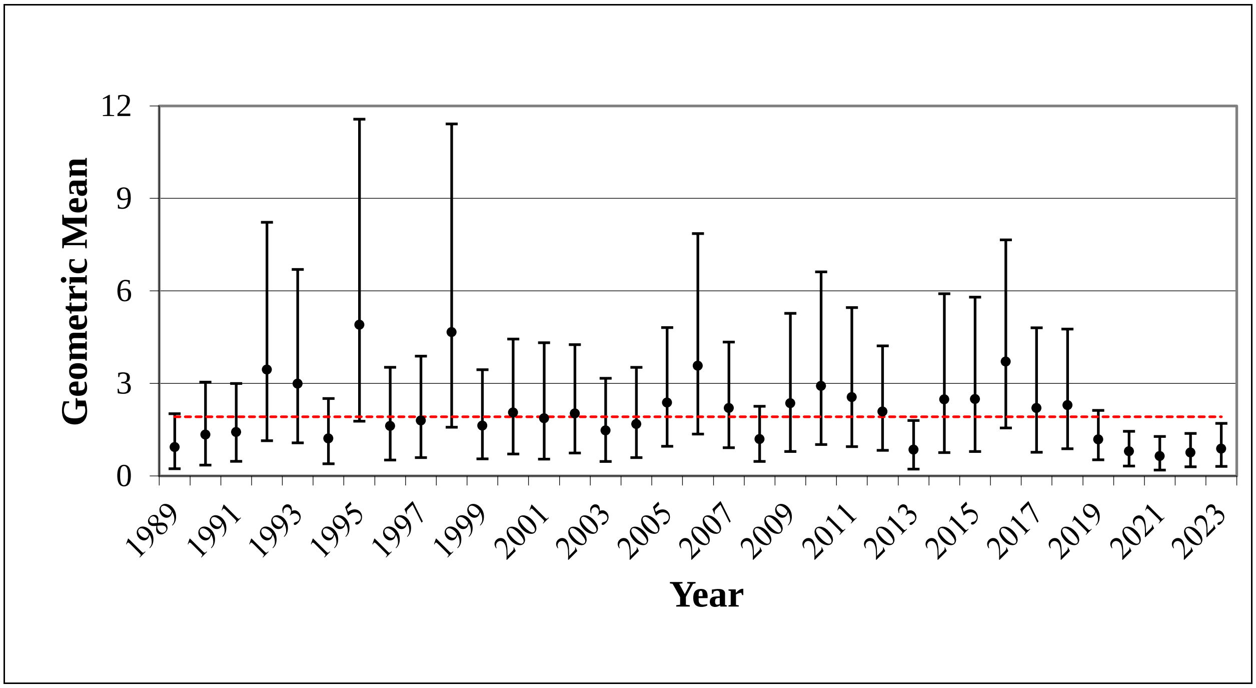

Figure 1.21. Silver perch (*Bairdiella chrysoura*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

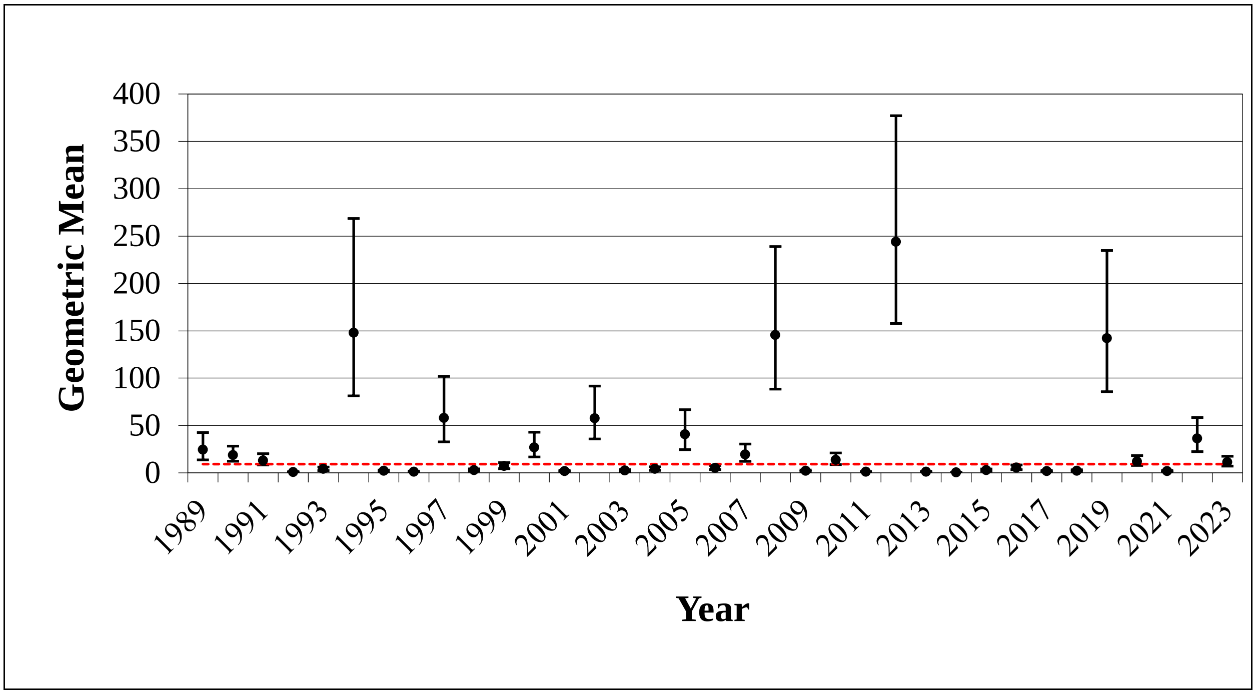

Figure 1.22. Spot (*Leiostomus xanthurus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\text{ - }2019,\ 2021\text{ - }2023}$ = 140/year, n_{2020} = 120).

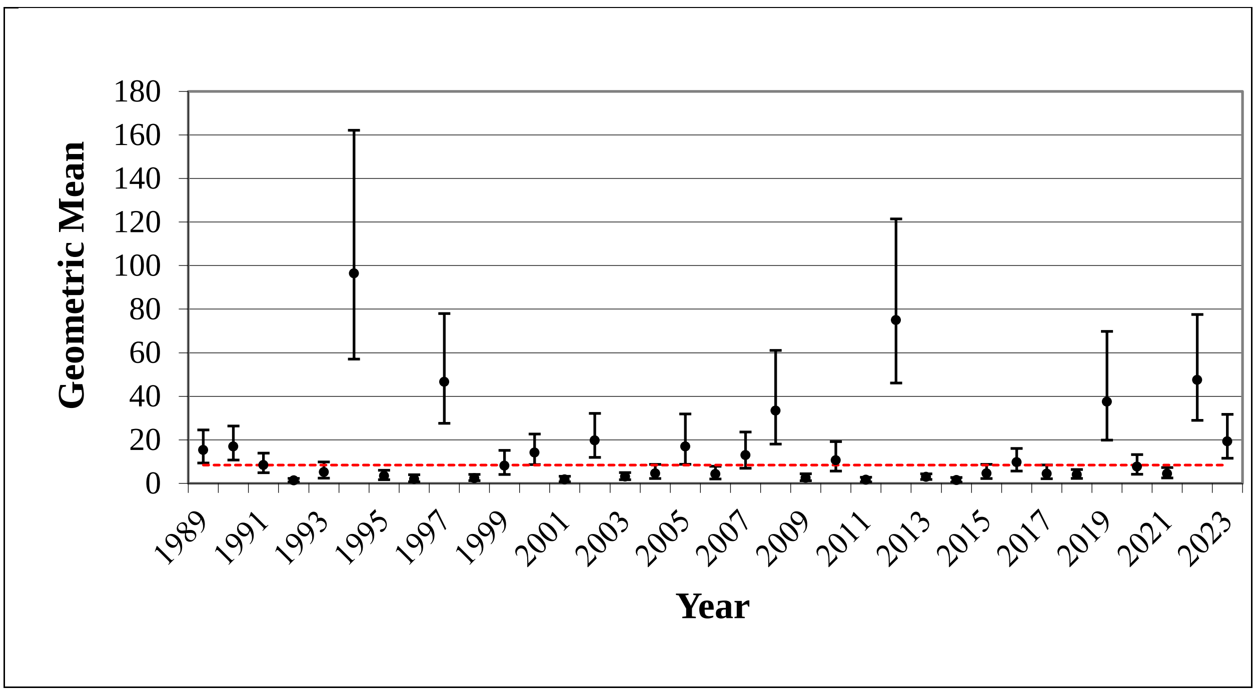

Figure 1.23. Spot (*Leiostomus xanthurus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

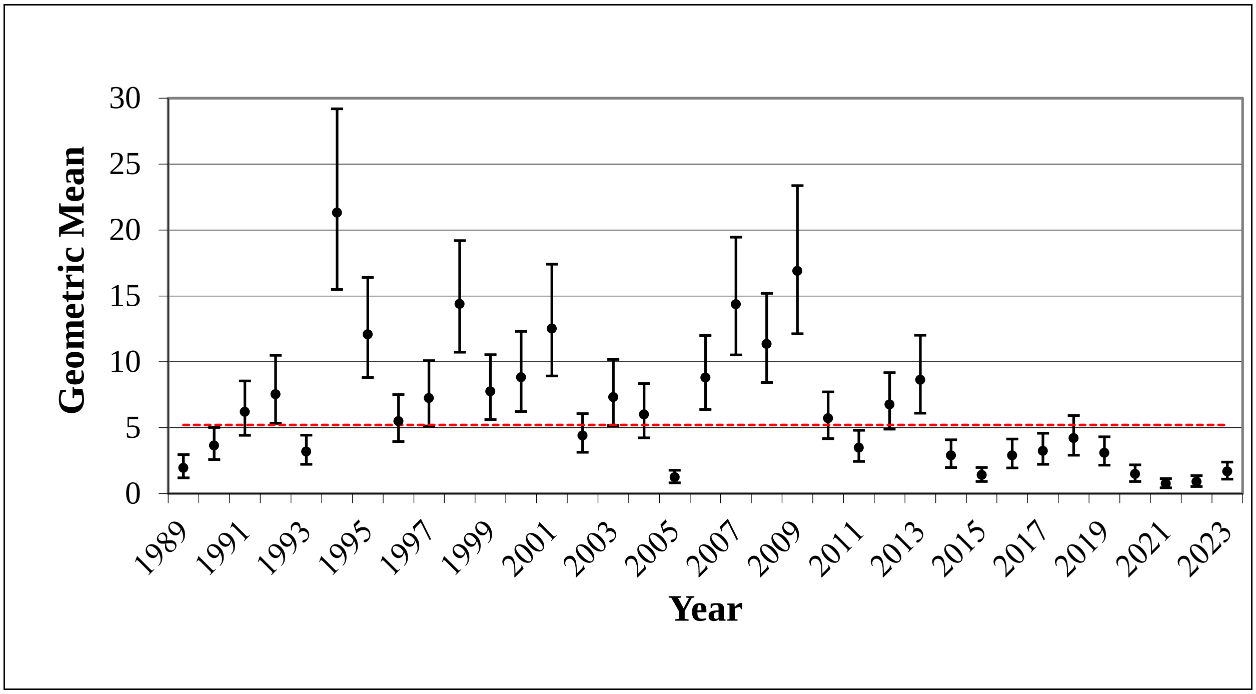

Figure 1.24. Summer flounder (*Paralichthys dentatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989\text{ - }2019,\ 2021\text{ - }2023}$ = 140/year, n_{2020} = 120).

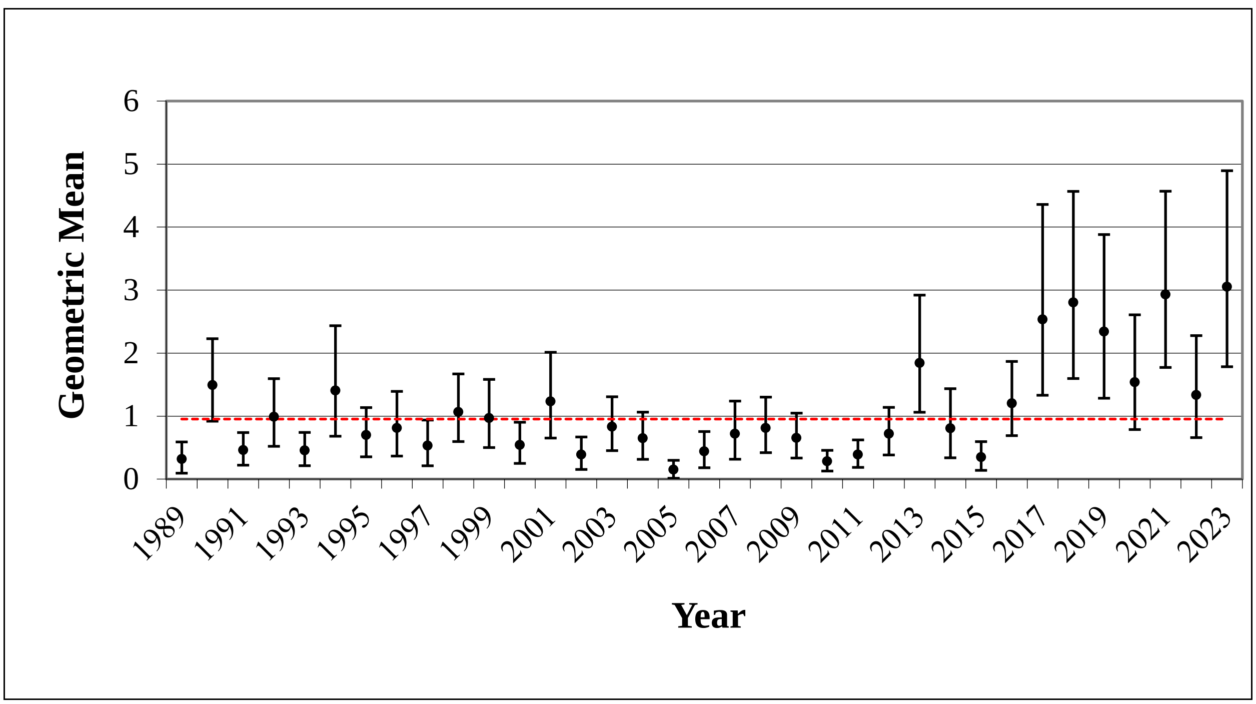

Figure 1.25. Summer flounder (*Paralichthys dentatus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean (n = 38/year).

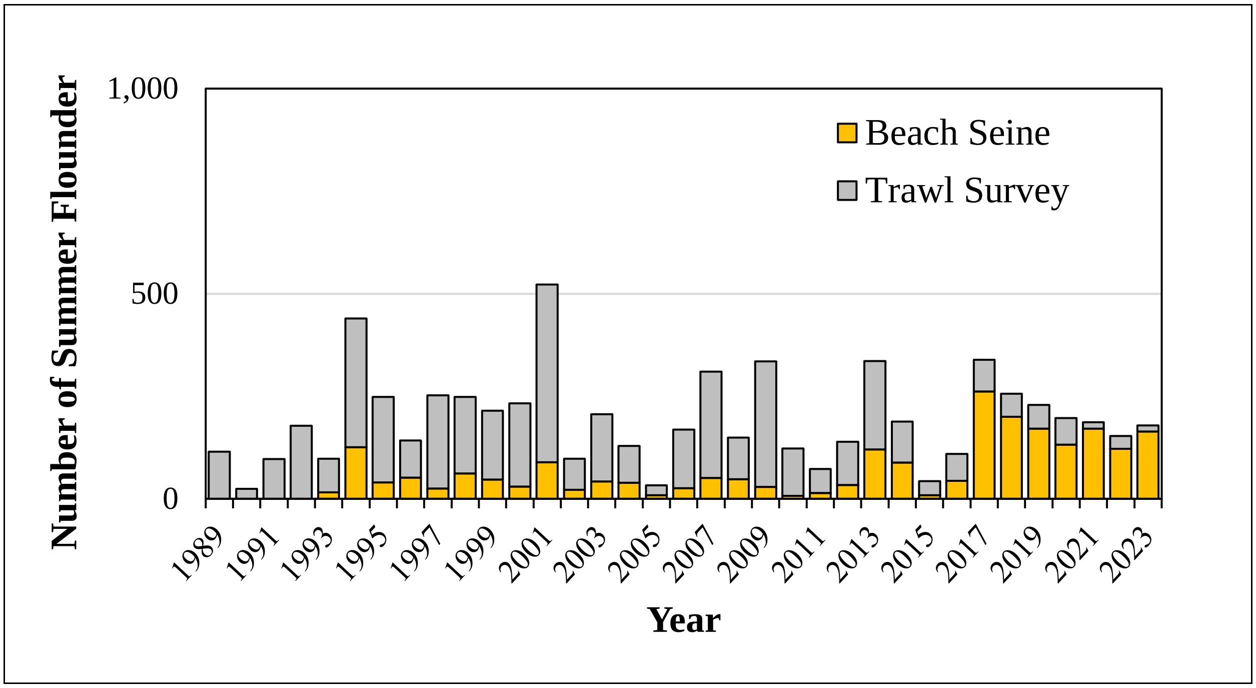

Figure 1.26. Summer flounder (*Paralichthys dentatus*) relative abundance shift toward shallow water in June.

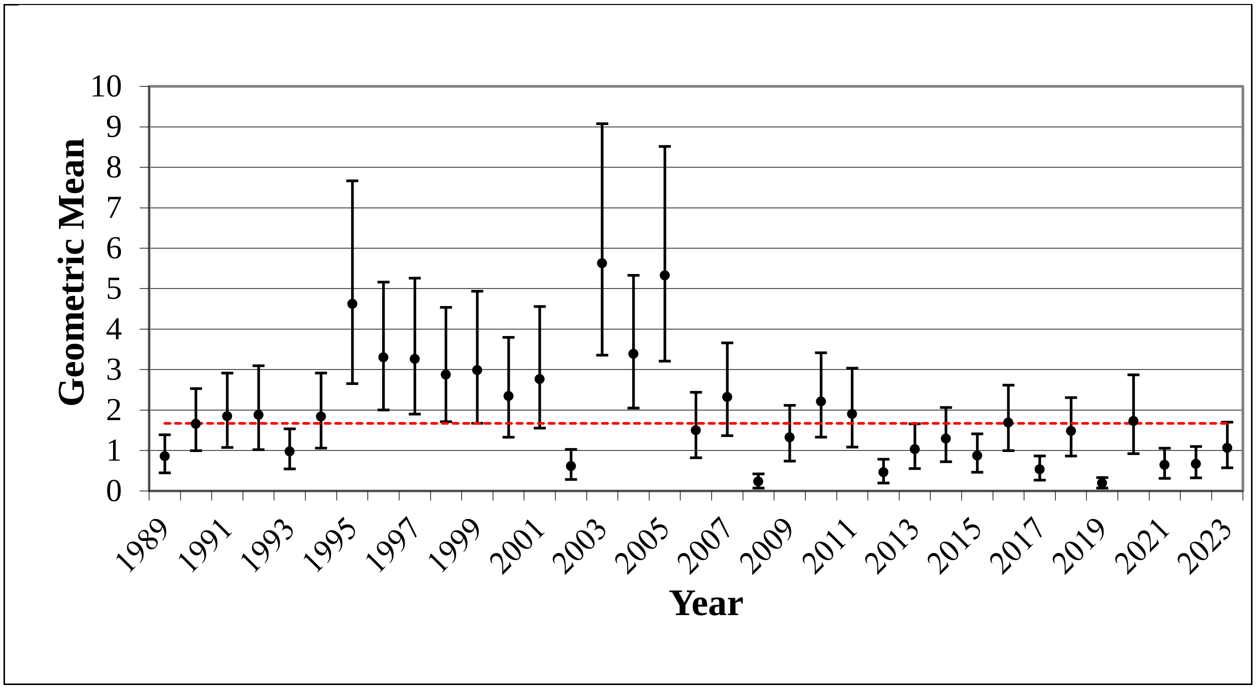

Figure 1.27. Weakfish (*Cynoscion regalis)* trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2023). Dotted line represents the 1989 - 2023 time series grand mean ($n_{1989 - 2019, 2021 - 2023}$ = 140/year, n_{2020} = 120).

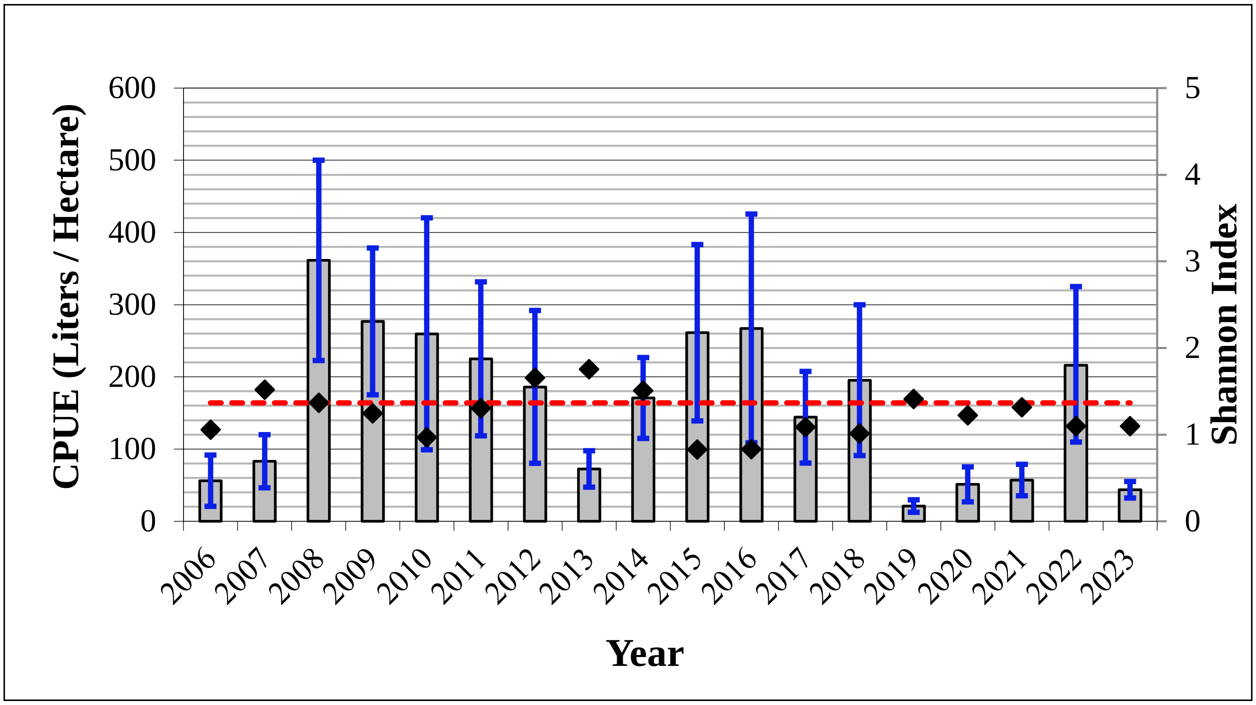

Figure 1.28. Coastal bays trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2023). Red line represents the 2006 - 2023 time series CPUE grand mean ($n_{1989 - 2019, 2021 - 2022}$ = 140/year, n_{2020} = 120). Black diamond represents the Shannon index of diversity.

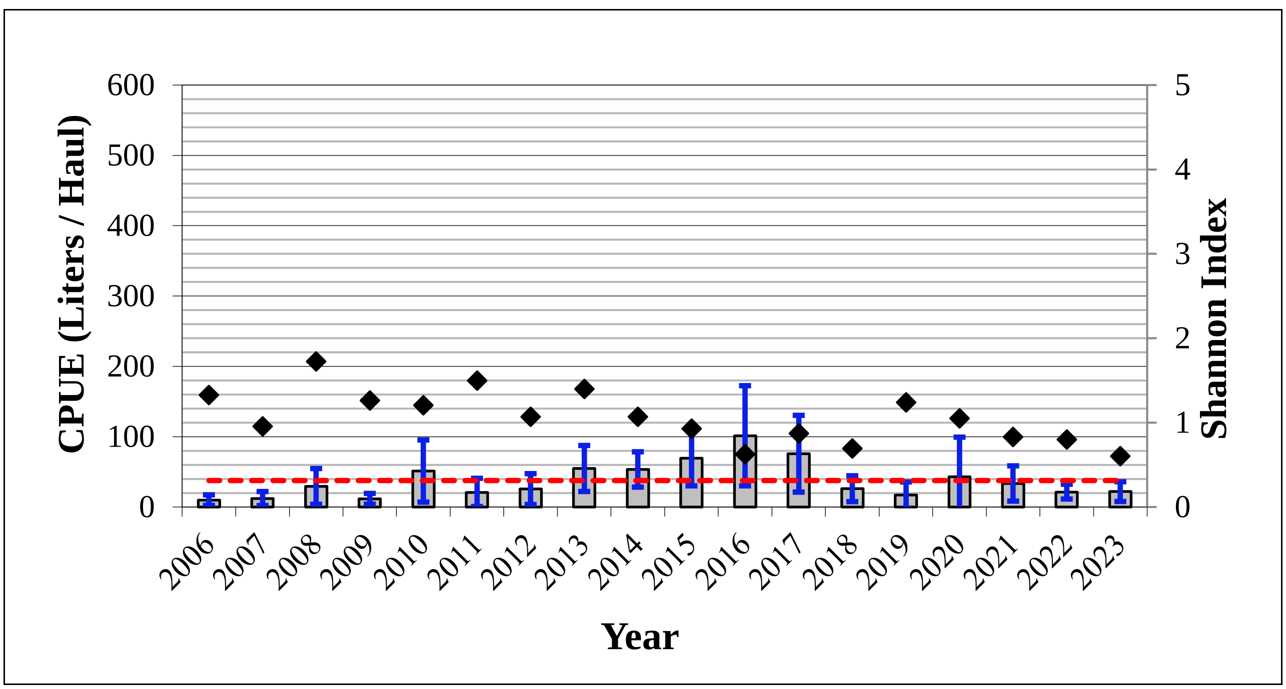

Figure 1.29. Coastal bays beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2023). Red line represents the 2006 - 2023 time series CPUE grand mean (n = 36/year). Black diamond represents the Shannon index of diversity

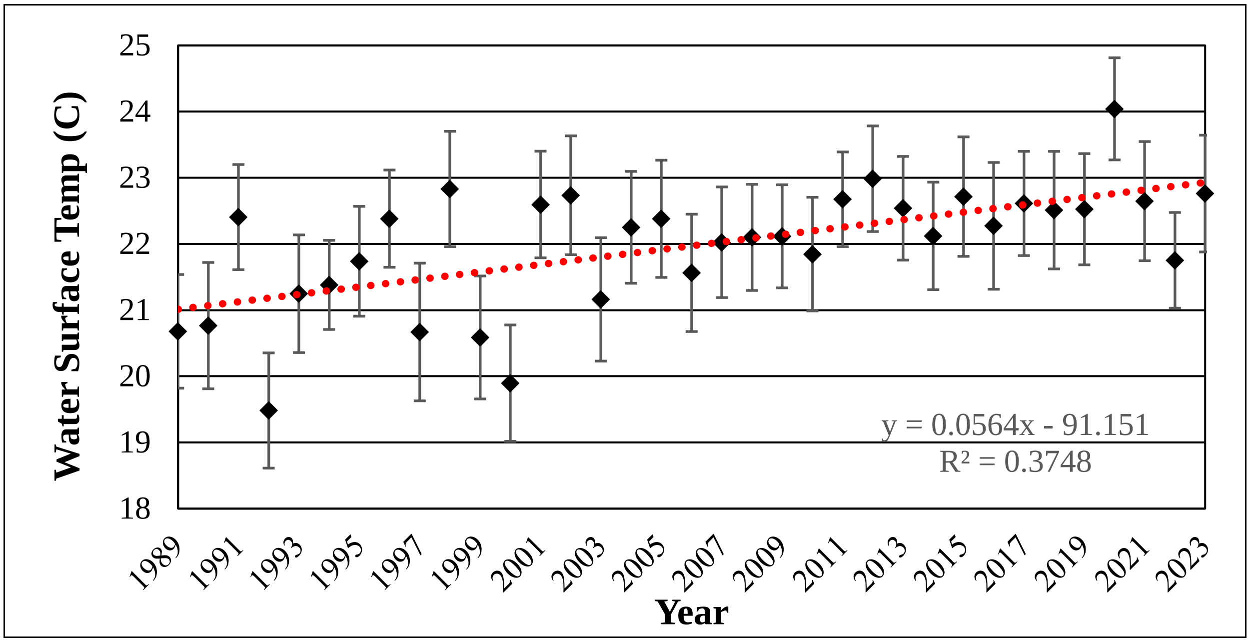

Figure 1.30. Distribution of annual mean surface water temp (C) with 95% confidence intervals from the Trawl Survey (1989 - 2023).

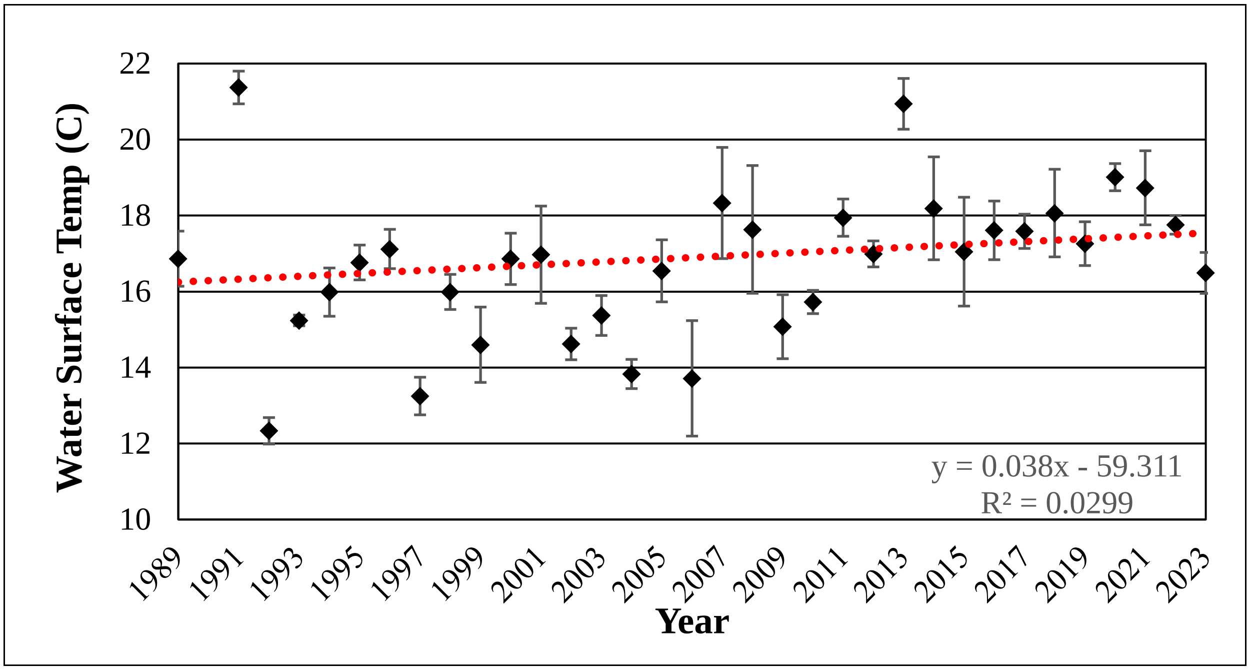

Figure 1.31. Distribution of October mean surface water temp (C) with 95% confidence intervals from the Trawl Survey (1993 - 2023).

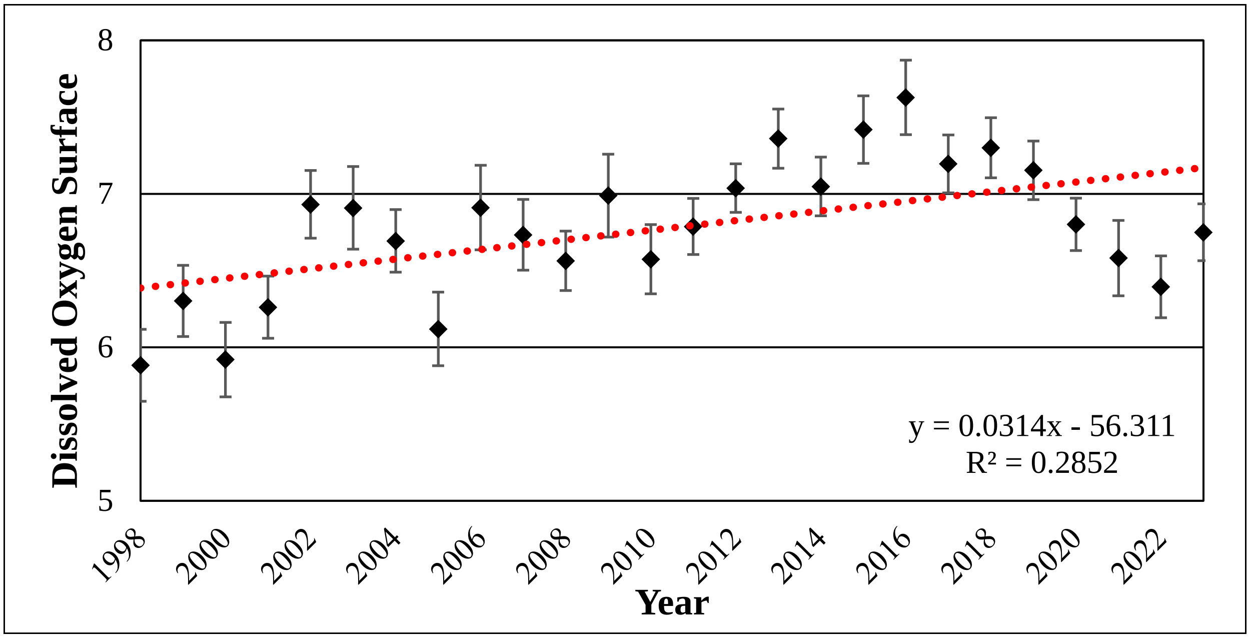

Figure 1.32. Distribution of annual mean surface dissolved oxygen (mg/L) with 95% confidence intervals from the Trawl Survey (1998 - 2023).

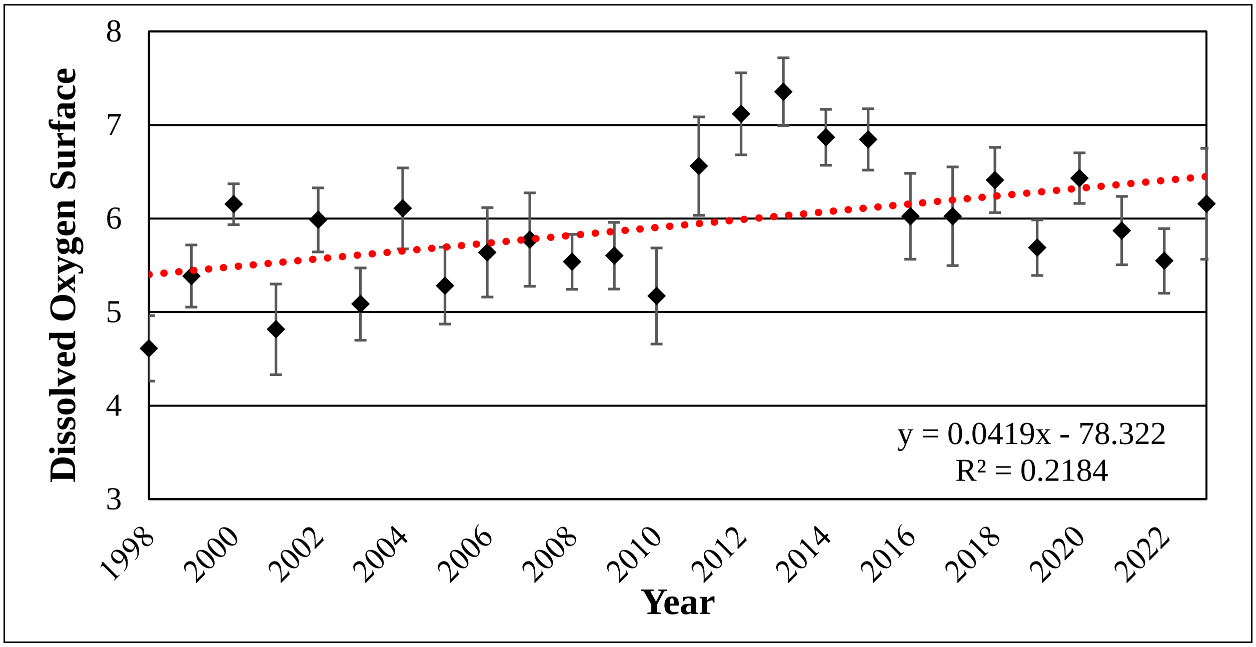

Figure 1.33. Distribution of July mean surface dissolved oxygen (mg/L) with 95% confidence intervals from the Trawl Survey (1998 - 2023).

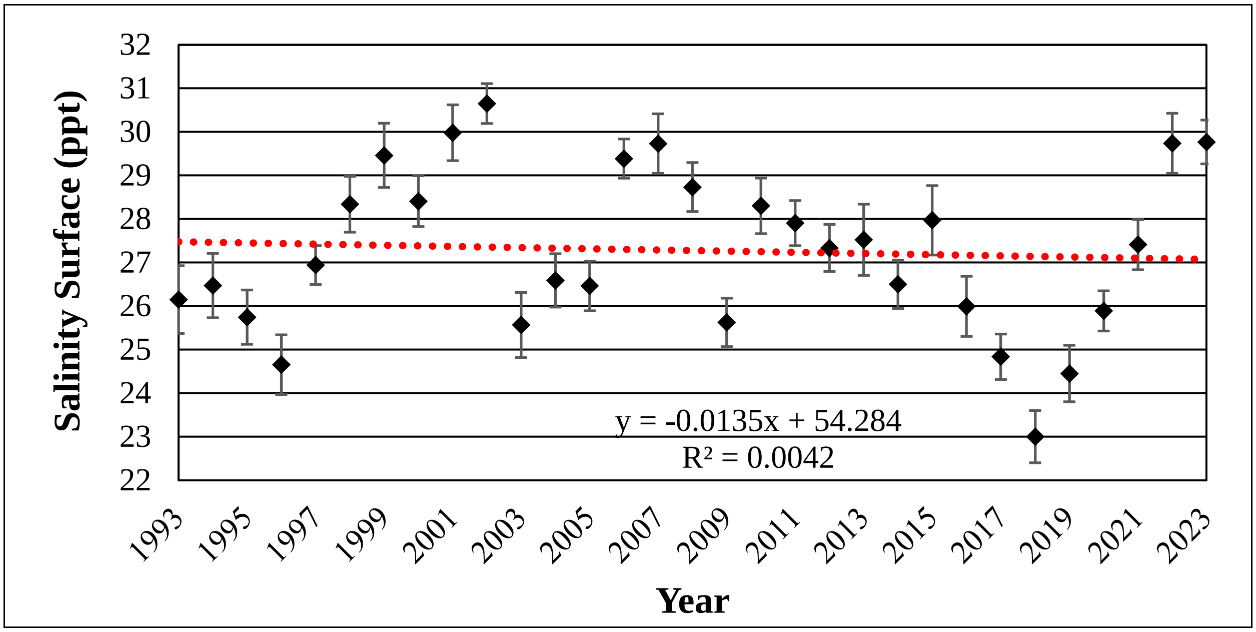

Figure 1.34. Distribution of annual mean surface salinity with 95% confidence intervals from the Trawl Survey (1993 - 2023).

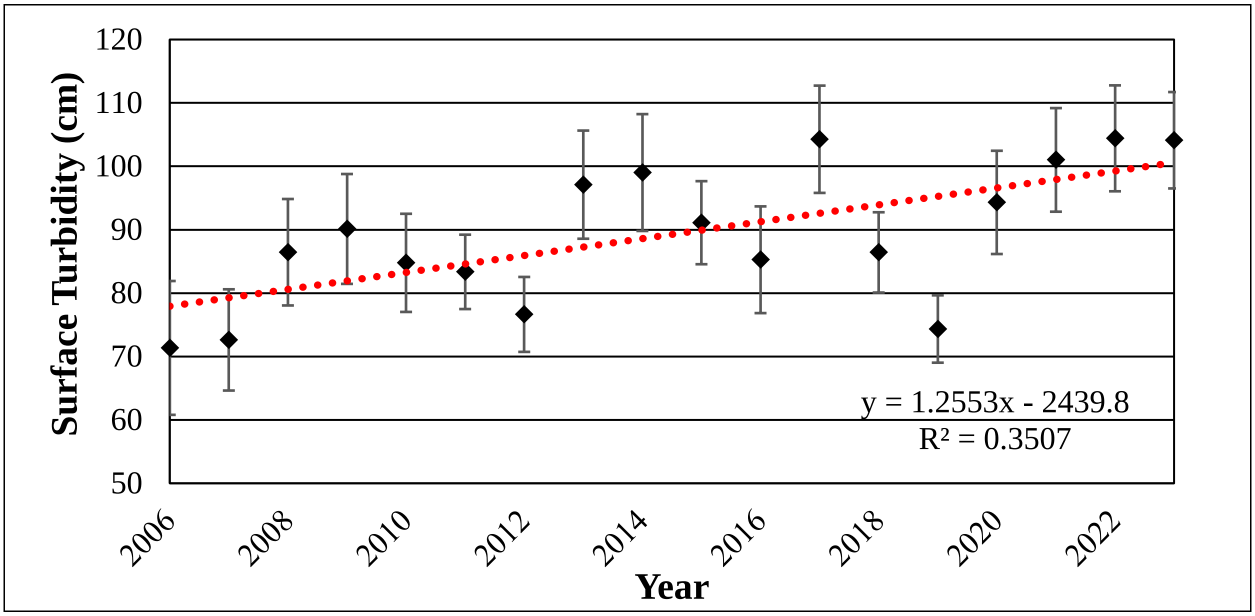

Figure 1.35. Distribution of annual mean turbidity (cm) with 95% confidence intervals from the Trawl Survey (2006 - 2023).

Chapter 2 Submerged Aquatic Vegetation Habitat Survey

Introduction

Two species of Submerged Aquatic Vegetation (SAV) are found in Maryland's coastal bays: eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). SAV beds were once found throughout the coastal bays, but the majority were located along the Assateague Island shoreline. SAV species provide a wide variety of functions essential to the ecological health of the bays; foremost among them is as prime nursery habitat. The young of many species depend upon the grass beds for protection and feeding at some point in their life cycle (Coastal Bays Sensitive Areas Technical Task Force, 2004). With SAV playing such a significant role in the life cycle of many fishes and its susceptibility to anthropogenic perturbations, the characterization of fisheries resources within these areas is important (Connolly & Hindell, 2006). As a result, the Department began sampling the SAV beds in 2012 with standardization in 2015. This survey was designed to meet the following two objectives:

1. characterize SAV habitat usage by fish assemblages in Maryland's coastal bays; and
2. incorporate the results to guide management decisions.

Methods

Sinepuxent Bay was selected in 2015 because it had the most readily available SAV beds in proximity with our established Trawl and Beach Seine surveys sites discussed in Chapter 1 (Table 2.1, Figure 2.1). Site verification was conducted in 2015 to confirm SAV presence because it has been declining since the geographic information systems maps were created for this survey back in 2012. That map used a 305 m X 305 m grid overlay of areas where SAV beds had been present for at least five years prior to the implementation of this survey and was based on data from the Virginia Institute of Marine Sciences SAV survey (2021). Potential sites were selected from an annual reconnaissance to ensure SAV was present, and the beach seine could be deployed properly.

All sampling was conducted in the water and onboard a 25 ft C-hawk center console boat with a 250 horsepower Yamaha engine during daylight in September. Latitude and longitude coordinates were used to navigate to sample grid locations. Visual and physical determination of the SAV percent coverage was estimated in quartiles and confirmed throughout the beach seine haul by two staff. The GPS was also used to obtain coordinates at the start and stop points of each beach seine haul.

The SAV beach seine with a zippered bag measured 15.24 m X 1.8 m X 6.4 mm mesh (50 ft X 6 ft X 0.25 in mesh). Staff estimated the percentage of net open, and a rangefinder was used to quantify the 35-meter seine hauls. Staff ensured that the lead line remained on the bottom until the catch was enclosed in the bag. The catch was taken to the boat for processing. Water quality and physical characteristic data were collected using the same method and parameters described in Chapter 1. Samples were processed using the same methods described in Chapter 1.

Data Analysis

The Generalized Linear Model (GLM) procedure, and post hoc Duncan's Multiple Range Test (DMRT) were used to measure and compare relative abundance and size variation among different SAV coverage. The maximum alpha value of 0.05 was used for all tests. Fish diversity was calculated using the Shannon index. An annual index of relative abundance was developed using the geometric mean and confidence intervals calculated as the antilog [log_e-mean (x + 1)] and antilog [log_e-mean (x + 1) ± standard error * (t value: $\alpha = 0.05$, n - 1)], respectively. A geometric grand mean was calculated for the time series (2015 - 2023) and used as a point estimate for comparison to the annual (2023) estimate of relative abundance. Catch per unit of effort (CPUE) was calculated as a catch/beach seine haul and could be further normalized for survey comparisons of abundance in fish per hectare with some caution based on access and catchability for the larger gears. Area swept for this survey was estimated as 0.04004919 ha/seine haul. The Beach Seine Survey was estimated as 0.0906704 ha/seine haul, and the Trawl Survey was 0.125415 ha/trawl.

Results and Discussion

Sample Size and Distribution

These results were based on all samples collected in Sinepuxent Bay in early September from 2015 - 2023 (Table 2.1, Figure 2.1). In 2023, sixteen stratified samples were collected in SAV coverage greater than 25% within four of the survey's sampling grids. The sample size was uneven because widgeon grass beds were difficult to locate, and effort was placed towards finding SAV beds with 26 - 50% coverage and above (Table 2.2). Targeting SAV beds with at least 25% SAV coverage allows resources to be focused on the habitat that needed sampling and was not covered by other surveys.

Abundance by Habitat Category

The survey's 2023 sampling collected 29 fishes and 1,943 fish (Table 2.3). The most abundant species were silver perch, pigfish, striped anchovy, tautog, and black sea bass. Conger eel, northern sennet, and smooth puffer were present in 2023 for the first time in the survey. The most abundant crustaceans were blue crabs and grass shrimp (Table 2.4).

Over the time series, a total of 53 fishes and 19,575 fish were collected (Table 2.3). In 2023, Atlantic silverside relative abundance (6.6 fish/haul) was well below the time series mean (53.9 fish/haul). Silver perch (75.7 fish/haul) rebounded above the time series mean (49.7 fish/haul). Black sea bass (6.4 fish/haul), tautog (7.8 fish/haul), and pinfish (1.8 fish/haul) were also above the time series means (Table 2.3).

CPUE comparisons among surveys using area swept was not straight forward due to gear bias (e.g. gear size, crew, catchability). The presence and absence of fishes among survey's during September from 2015 - 2023 clearly showed more tautog, black sea bass, and sheepshead in SAV habitat. An area swept comparison could have doubled or tripled the magnitude of the SAV catch based on area swept calculations (Table 2.5).

GLM results comparing fishes' relative abundance among the SAV coverage quadrats showed significant results for Pinfish ($F_{3,148} = 3.13$, $p < 0.05$). The GLM results also showed insignificant F-values for black sea bass, pigfish, sheepshead, tautog, blue crab and grass shrimp.

The Duncan's Multiple Range Test results showed higher relative abundance in medium -high or high coverage SAV for pinfish, sheepshead and tautog (Table 2.6).

In preparation for the next regional tautog benchmark stock assessment, indices of relative abundance using geometric means, 95% confidence intervals and a calculated grand mean were development for tautog and other species such as Atlantic silverside, black sea bass, pinfish, pigfish, sheepshead, silver perch, and blue crab (Figure 2.2 – 2.9).

Fishes with abundance above the time series grand mean in 2023 were pigfish and silver perch. Black sea bass, pinfish and tautog were equal to the grand mean, while Atlantic silverside, sheepshead, and blue crab abundance was below the grand mean. The overall increase in juvenile tautog abundance may be a direct result of modifying recreational fishing and protecting peak spawning periods back in 2018. These results show that SAV Habitat is essential to sustain juvenile tautog populations in Maryland.

Fish Species Richness and Diversity by Habitat Category

Fish richness (number of species) was generally high (53 fishes total, 27 average per year) throughout the time series. Eelgrass was more available in the survey than widgeon grass (Table 2.7). The denser coverage SAV held more fishes, but medium coverage SAV was more diverse (H = 2.2) (Table 2.8). The large abundance of Atlantic silverside and silver perch reduced the diversity index results as the analysis favors species richness proportions at equal levels in the sample population and penalized the large cohort effect with lower H values.

Fish Length Composition by SAV Coverage

Relationships of total length and SAV coverage were investigated for significant interactions. Black sea bass, sheepshead, silver perch, and tautog were selected for GLM and DMRT analysis (Table 2.9). Results indicated significant differences in length for silver perch ($F_{3,2971} = 39.6$ $p < 0.01$) and tautog ($F_{3,899} = 20.9$, $p < 0.01$). Silver perch were larger in low coverage SAV beds while tautog were the largest in medium-high and high SAV and smaller in the sparser coverage categories. While larger tautogs were caught in medium-high SAV coverage, they were all young of year (age-0). Denser SAV coverage may be more suitable habitat for growth and protection as size - selective predation influences natural mortality (Meekan & Fortier, 1996) (Searcy & Sponaugle, 2001) (Bergenius, Meekan, Robertson, & McCormick, 2002) (Grorud-Colvert & Sponaugle, 2006) (Searcy, Eggleston, & Hare, 2007).

Water Quality

These data were taken annually in September in depths less than four feet. The tidal flushing, wave action and shallow depths allowed and provided for productive water habitat throughout the survey. Water temperature, salinity, DO, turbidity, and pH results showed significant interannual variation and were within acceptable limits for Mid-Atlantic fishes and forage crustaceans (2015-2023).

The water temperature GLM results comparing annual means across the time series indicated significant interannual variability ($F_{8,148} = 67.11$, $p < 0.05$). The linear regression results were not predictive (R^2=0.0) of increasing water temperature over time (2015 - 2023) (Figure 2.10).

Salinity GLM results comparing annual means across the time series indicated significant interannual variability ($F_{8,148} = 502.1$, $p < 0.05$). The linear regression analysis showed no predictive relationship (R^2=0.11) (Figure 2.11)

The dissolved oxygen times series annual mean was 6.47 mg/L with limited stratification at depth. The linear regression analysis showed a weak relationship (R^2=0.12) and a slight negative slope of improvement over time (Figure 2.12). In 2018, high water temperatures coincided with the lowest levels of dissolved oxygen in the survey.

Water clarity GLM results comparing annual means across the time series indicated significant interannual variability ($F_{8,148} = 10.36$, $p < 0.05$). The DMRT results showed four distinct turbidity groups, with the most recent years in the best groups. The linear regression analysis showed a weak-medium relationship (R^2=0.35) of improvement over time (Figure 2.13). Deeper sunlight penetration was a benefit to SAV habitat.

This was the second year (2023) of monitoring pH in these surveys, and the median pH was 7.9 with no difference at depth in the water column

Table 2.1. Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey site descriptions.

Grid Number	Site Description	Latitude	Longitude	Number of Samples
092	Between Eagles Nest and OC Airport; W side of channel	38 18.263	75 06.987	2
095	SAV beds vicinity Castaways, West of Tiki Bar	38 17.980	75 07.311	9
096	SAV beds vicinity Castaways Jackspot Waterfront Tiki bar	38 18.019	75 07.177	26
109	East of Snug Harbor Road, middle of Sinepuxent Bay, South of small island	38 17.622	75 07.376	4
120	East of Gray's Cove and south of Frontier Town	38 17.130	75 07.724	3
121	East of Snug Harbor, west of small island	38 17.221	75 07.651	25
122	East of Snug Harbor, west of small island; pulled towards the south	38 17.167	75 07.523	6
126	Northeast of Day Marker #13	38 17.114	75 07.734	5
127	Southeast of Devils Island, near channel edge on east side of marsh	38 17.075	75 07.793	4
128	South of duck blind, east of green marker	38 17.061	75 07.659	22
160	700 meters northeast of Potfin Road along the shoreline	38 15.900	75 08.761	21
212	South of Verrazano Bridge, west of Sandy Point Island; on channel edge	38 14.295	75 09.404	9
217	Northwest shoreline along Rum Point	38 14.116	75 10.160	3
221	Southwest of small island, south of Verrazano Bridge	38 14.147	75 09.402	9
227	Southwest shoreline along Rum Point	38 13,953	75 10.217	1

Table 2.2. Submerged Aquatic Vegetation Habitat Survey sample size by percent coverage and dominate SAV species (2015 - 2023).

	Percent SAV Coverage				Total by Characteristic	Grand Total
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%		
Eelgrass (*Zostera marina*)	14	22	37	49	122	149
Widgeon grass (*Ruppia maritima*)	8	8	7	4	27	

Table 2.3. List of fishes collected from the Submerged Aquatic Vegetation Habitat Survey (2015 – 2023). Catch per unit of effort (CPUE) was calculated as fish/haul.

Specimen Name	2015 - 2023 (n = 149)			2023 (n = 16)		
	Count	x̄ CPUE	x̄ length	Count	CPUE	x̄ length
Atlantic silverside (*Menidia menidia*)	8,025	53.9	83	106	6.6	91
Silver perch (*Bairdiella chrysoura*)	7,404	49.7	76	1,211	75.7	76
Tautog (*Tautoga onitis*)	902	6.1	77	124	7.8	84
Sheepshead (*Archosargus probatocephalus*)	460	3.1	70	1	0.1	70
Striped anchovy (*Anchoa hepsetus*)	447	3.0	78	128	8.0	76
Black sea bass (*Centropristis striata*)	412	2.8	80	103	6.4	90
Pigfish (*Orthopristis chrysoptera*)	306	2.1	78	141	8.8	74
Halfbeak (*Hyporhamphus unifasciatus*)	258	1.7	147	20	1.3	141
Pinfish (*Lagodon rhomboides*)	213	1.4	121	28	1.8	113
Dusky pipefish (*Syngnathus floridae*)	194	1.3	156	19	1.2	159
Northern pipefish (*Syngnathus fuscus*)	145	1.0	176	9	0.6	137
Spotfin mojarra (*Eucinostomus argenteus*)	139	0.9	79	3	0.2	71
Striped blenny (*Chasmodes bosquianus*)	108	0.7	63			
Oyster toadfish (*Opsanus tau*)	101	0.7	71	2	0.1	115
Spot (*Leiostomus xanthurus*)	75	0.5	128	1	0.1	136
Bay anchovy (*Anchoa mitchilli*)	72	0.5	67			
Northern puffer (*Sphoeroides maculatus*)	37	0.2	121	9	0.6	94
Bluespotted cornetfish (*Fistularia tabacaria*)	31	0.2	329	2	0.1	284
Summer flounder (*Paralichthys dentatus*)	29	0.2	185	2	0.1	348
Striped burrfish (*Chilomycterus schoepfii*)	27	0.2	169	1	0.1	105
Gray snapper (*Lutjanus griseus*)	24	0.2	72			
Spotfin butterflyfish (*Chaetodon ocellatus*)	20	0.1	56	4	0.3	39
Lined seahorse (*Hippocampus erectus*)	16	0.1	115	10	0.6	119
Atlantic needlefish (*Strongylura marina*)	13	0.1	276	2	0.1	151
Atlantic menhaden (*Brevoortia tyrannus*)	11	0.1	112			
White mullet (*Mugil curema*)	10	0.1	171			
Rainwater killifish (*Lucania parva*)	9	0.1	38			

Table 2.3 continued. List of fishes collected from the Submerged Aquatic Vegetation Habitat Survey (2015 – 2023). Catch per unit of effort (CPUE) was calculated as fish/haul.

Specimen Name	2015 - 2023 (n = 149)			2023 (n = 16)		
	Count	x̄ CPUE	x̄ length	Count	CPUE	x̄ length
Feather blenny (*Hypsoblennius hentz*)	8	0.1	69			
American eel (*Anguilla rostrata*)	7	0.0	291	3	0.2	254
Bluefish (*Pomatomus saltatrix*)	6	0.0	120			
Lookdown (*Selene vomer*)	6	0.0	84	5	0.3	85
Naked goby (*Gobiosoma bosc*)	6	0.0	36			
Spotted seatrout (*Cynoscion nebulosus*)	6	0.0	116			
Inshore lizardfish (*Synodus foetens*)	5	0.0	138	1	0.1	24
Southern kingfish (*Menticirrhus americanus*)	5	0.0	103			
Blackcheek tonguefish (*Symphurus plagiusa*)	4	0.0	88			
Northern kingfish (*Menticirrhus saxatilis*)	4	0.0	121			
Striped mullet (*Mugil cephalus*)	4	0.0	197			
Atlantic croaker (*Micropogonias undulatus*)	3	0.0	57	1	0.1	57
Black drum (*Pogonias cromis*)	3	0.0	133			
Gag (*Mycteroperca microlepis*)	3	0.0	149	2	0.1	140
Atlantic spadefish (*Chaetodipterus faber*)	2	0.0	83			
Conger eel (*Conger oceanicus*)	2	0.0	220	2	0.1	220
Northern sennet (*Sphyraena borealis*)	2	0.0	95	2	0.1	95
Southern stingray (*Dasyatis americana*)	2	0.0	420			
Striped bass (*Morone saxatilis*)	2	0.0	482			
Cobia (*Rachycentron canadum*)	1	0.0	147			
Harvestfish (*Peprilus paru*)	1	0.0	30			
Skilletfish (*Gobiesox strumosus*)	1	0.0	46			
Smallmouth flounder (*Etropus microstomus*)	1	0.0	60			
Smooth puffer (*Lagocephalus laevigatus*)	1	0.0	78	1	0.1	78
Spanish mackerel (*Scomberomorus maculatus*)	1	0.0	170			
Striped killifish (*Fundulus majalis*)	1	0.0	107			

Table 2.4. List of forage crustaceans collected from the Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey (2015 - 2023). Catch per unit of effort (CPUE) was calculated as fish/haul.

Specimen Name	2015 – 2023 (n =149)			2023 (n = 16)		
	Count	x̄ CPUE	x̄ length	Count	CPUE	x̄ length
Blue crab (*Callinectes sapidus*)	4,627	31.1	58	85	5.3	87
Grass shrimp (*Palaemonetes sp.*)	2,574	17.3		122	7.6	
Brown shrimp (*Farfantepenaeus aztecus*)	772	5.2	81	7	0.4	89

Table 2.5. September species abundance survey comparisons in Maryland's coastal bays (2015 - 2023). Catch per unit of effort (CPUE) was calculated as fish per beach seine or fish per trawl.

Specimen Name	SAV Habitat Survey September n = 149		Beach Seine Survey September n = 171		Trawl Survey September n = 180	
	Count	x̄ CPUE	Count	x̄ CPUE	Count	x̄ CPUE
Atlantic silverside (*Menidia menidia*)	8,025	53.9	15,124	88.4	21	0.1
Silver perch (*Bairdiella chrysoura*)	7,404	49.7	5,519	32.3	2,109	11.7
Tautog (*Tautoga onitis*)	902	6.1	20	0.1	4	
Sheepshead (*Archosargus probatocephalus*)	460	3.1	216	1.3	6	0
Black sea bass (*Centropristis striata*)	412	2.8	34	0.2	110	0.6
Pigfish (*Orthopristis chrysoptera*)	306	2.1	301	1.8	61	0.3
Halfbeak (*Hyporhamphus unifasciatus*)	258	1.7	134	0.8		
Pinfish (*Lagodon rhomboides*)	213	1.4	329	1.9	51	0.3
Spot (*Leiostomus xanthurus*)	75	0.5	2,542	14.9	3,462	19.2
Northern puffer (*Sphoeroides maculatus*)	37	0.2	100	0.6	42	0.2
Summer flounder (*Paralichthys dentatus*)	29	0.2	324	1.9	172	1.0
Gray snapper (*Lutjanus griseus*)	24	0.2	13	0.1		
Atlantic menhaden (*Brevoortia tyrannus*)	11	0.1	32,609	190.7	103	0.6
Striped bass (*Morone saxatilis*)	2		84	0.5	1	
Blue crab (*Callinectes sapidus*)	4,627	31.1	4,086	23.9	2,625	14.6
Grass shrimp (*Palaemonetes sp.*)	2,574	17.3	118	0.7	47	0.3
Brown shrimp (*Farfantepenaeus aztecus*)	772	5.2	487	2.8	844	4.7

Table 2.6. Submerged Aquatic Vegetation Habitat Survey (2015 – 2023) Generalized Linear Model and Duncan's multiple range test for relative abundance by quartile SAV coverage (results greater than 0.05 were not significant (n.s.)).

Specimen Name	Percent SAV Coverage Low < 25%	 Medium 26 - 50%	 Medium - High 51 - 75%	 High 76 - 100%
Black sea bass (*Centropristis striata*)	($F_{3,148}$ = 1.2, p = n.s.)			
	$\bar{x}$ = 0.7	$\bar{x}$ = 3.1	$\bar{x}$ = 4.0	$\bar{x}$ = 2.4
	A	A	A	A
Pigfish (*Orthopristis chrysoptera*)	($F_{3,148}$ = 1.93, p = n.s.)			
	$\bar{x}$ = 0.3	$\bar{x}$ = 2.7	$\bar{x}$ = 2.7	$\bar{x}$ = 1.8
	A/ B	A	A	A / B
Pinfish (*Lagodon rhomboides*)	($F_{3,148}$ = 3.13, $p < 0.05$)			
	$\bar{x}$ = 1.3	$\bar{x}$ = 1.0	$\bar{x}$ = 0.8	$\bar{x}$ = 2.3
	A / B	A / B	B	A
Sheepshead (*Archosargus probatocephalus*)	($F_{3,148}$ = 1.75, p = n.s.)			
	$\bar{x}$ = 1.0	$\bar{x}$ = 1.8	$\bar{x}$ = 5.0	$\bar{x}$ = 3.1
	B	A / B	A	A
Silver perch (*Bairdiella chrysoura*)	($F_{3,148}$ = 1.08, p = n.s.)			
	$\bar{x}$ = 15.6	$\bar{x}$ = 54.3	$\bar{x}$ = 58.6	$\bar{x}$ = 53.9
	A	A	A	A
Tautog (*Tautoga onitis*)	($F_{3,148}$ = 2.63, p = n.s.)			
	$\bar{x}$ = 3	$\bar{x}$ = 3.4	$\bar{x}$ = 6.3	$\bar{x}$ = 8.7
	B	B	A / B	A
Blue crab (*Callinectes sapidus*)	($F_{3,148}$ = 0.95, p = n.s.)			
	$\bar{x}$ = 19.5	$\bar{x}$ = 34.1	$\bar{x}$ = 30.3	$\bar{x}$ = 34.8
	A	A	A	A
Grass shrimp (*Palaemonetes sp.*)	($F_{3,148}$ = 1.98, p = n.s.)			
	$\bar{x}$ = 2.7	$\bar{x}$ = 18.1	$\bar{x}$ = 23.7	$\bar{x}$ = 17.4
	B	A / B	A	A / B

Table 2.7. Submerged Aquatic Vegetation Habitat Survey (2015 - 2023) richness of fishes by habitat category.

	Percent SAV Coverage			
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%
Combined (All SAV)	32	38	43	39
Eelgrass (*Zostera marina*)	24	31	36	37
Widgeon grass (*Ruppia maritima*)	27	26	28	15

Table 2.8. Submerged Aquatic Vegetation Habitat Survey (2015 - 2023) Shannon – Index Diversity H values of fishes by habitat category.

	Percent SAV Coverage			
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%
Combined (All SAV)	1.5	1.7	1.6	1.5
Eelgrass (*Zostera marina*)	1.5	2.2	1.7	1.5
Widgeon grass (*Ruppia maritima*)	1.4	1.1	1.2	1.0

Table 2.9. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2023) Generalized Linear Model and Duncan's multiple range test for mean length and percent SAV coverage (results greater than 0.05 were not significant (n.s.)).

	Percent SAV Coverage			
Specimen Name	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%
Black sea bass (*Centropristis striata*)	($F_{3,403}$ = 2.44, p = n.s.)			
	$\bar{x}$ = 86.2	$\bar{x}$ = 74.0	$\bar{x}$ = 79.4	$\bar{x}$ = 83.0
	A	B	A / B	A / B
Sheepshead (*Archosargus probatocephalus*)	($F_{3,449}$ = 0.08, p = n.s.)			
	$\bar{x}$ = 69.9	$\bar{x}$ = 69.9	$\bar{x}$ = 70.0	$\bar{x}$ = 70.0
	A	A	A	A
Silver perch (*Bairdiella chrysoura*)	($F_{3,2971}$ = 39.6 $p < 0.01$)			
	$\bar{x}$ = 85.5	$\bar{x}$ = 76.2	$\bar{x}$ = 76.9	$\bar{x}$ = 72.7
	A	B	B	C
Tautog (*Tautoga onitis*)	($F_{3,899}$ = 20.9, $p < 0.01$)			
	$\bar{x}$ = 63.7	$\bar{x}$ = 71.6	$\bar{x}$ = 80.6	$\bar{x}$ = 77.8
	C	B	A	A
Blue crab (*Callinectes sapidus*)	($F_{2,997}$ = 0.06, p = n.s.)			
	$\bar{x}$ = 58.0	$\bar{x}$ = 57.7	$\bar{x}$ = 57.3	$\bar{x}$ = 57.9
	A	A	A	A

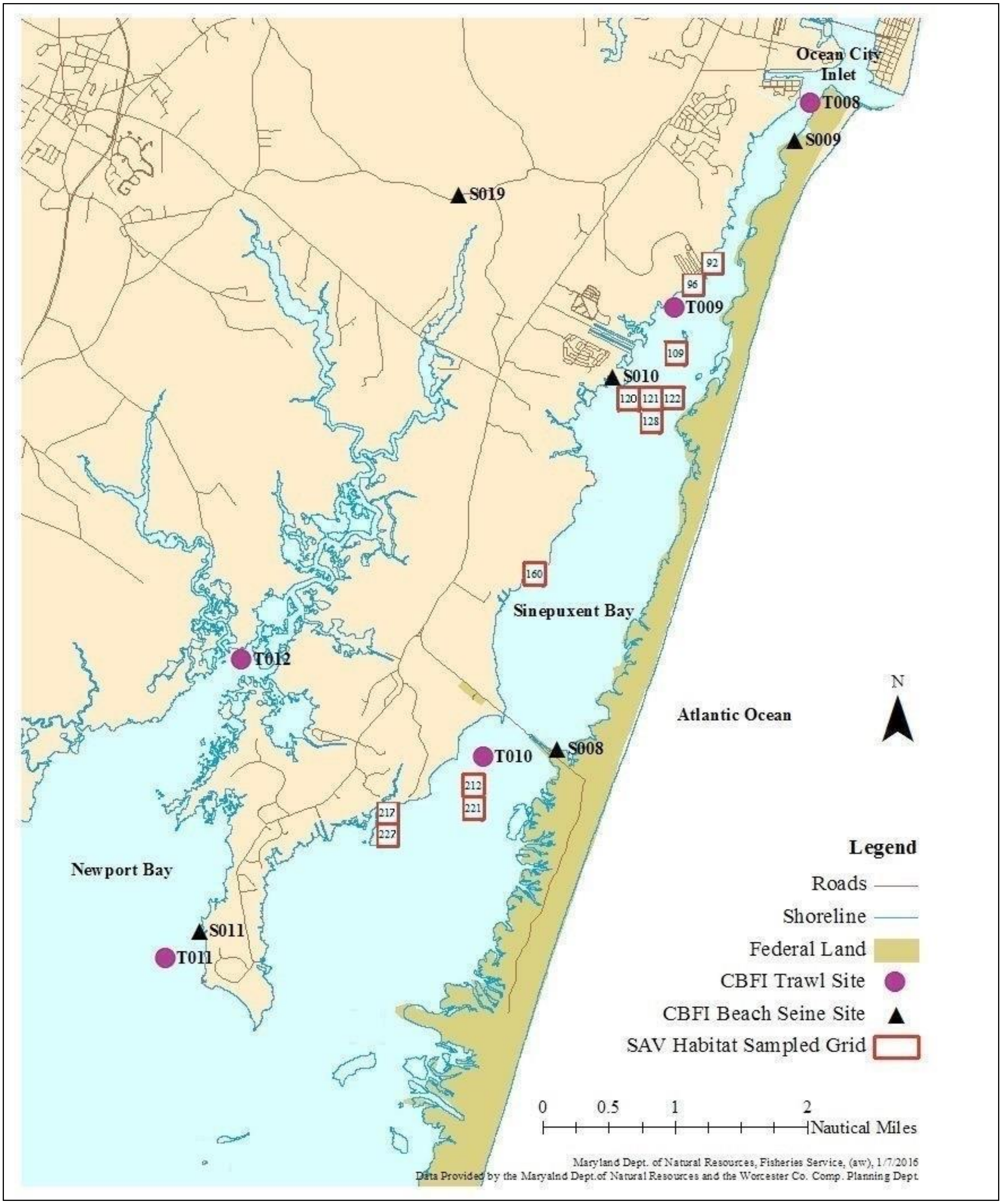

Figure 2.1. Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey and Trawl and Beach Seine surveys sample site locations (2015 - 2023).

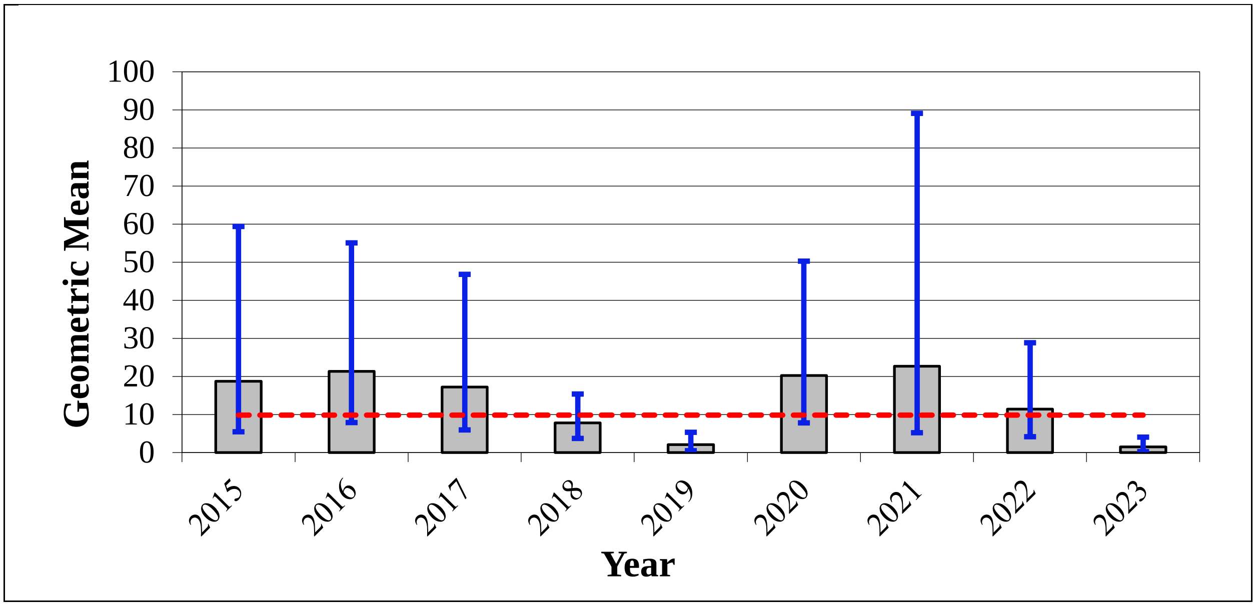

Figure 2.2. Atlantic silverside SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year).

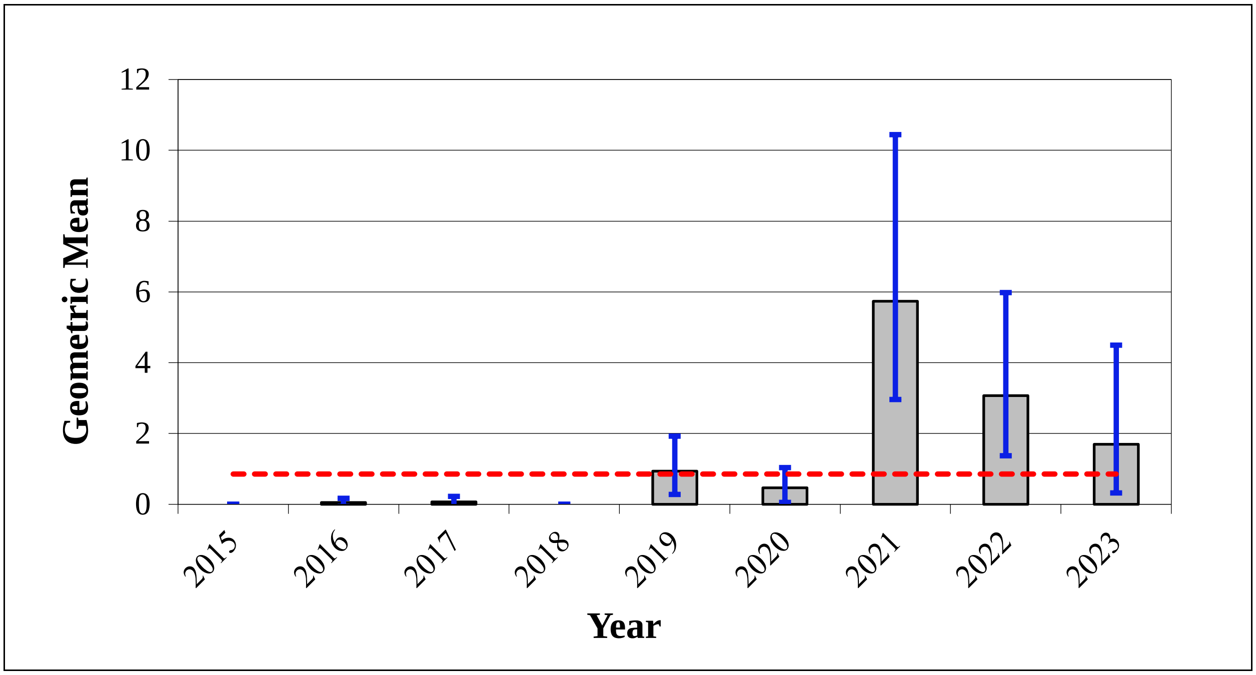

Figure 2.3. Black sea bass SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year).

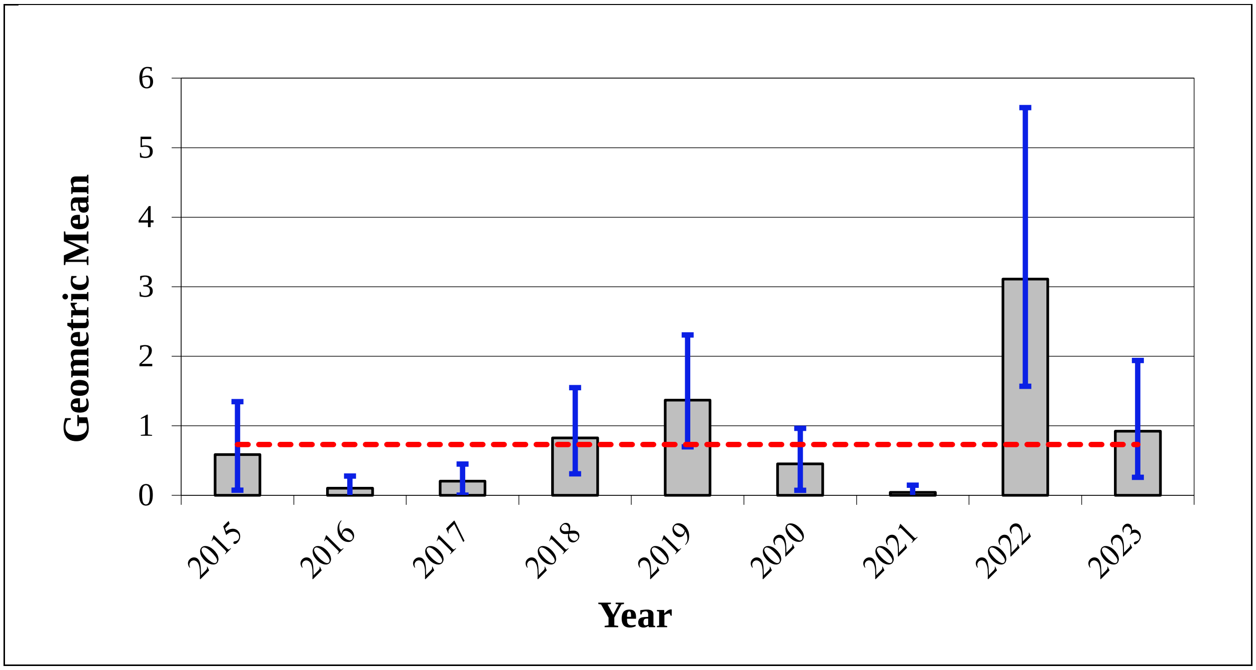

Figure 2.4. Pinfish SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year).

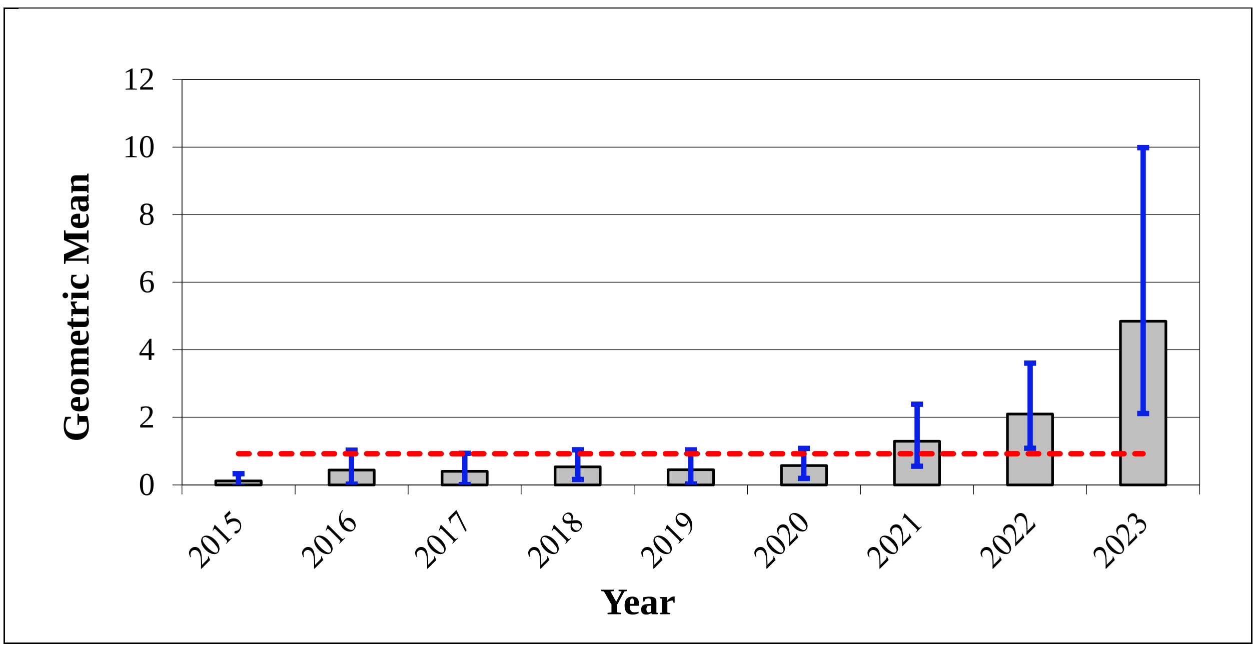

Figure 2.5. Pigfish SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year).

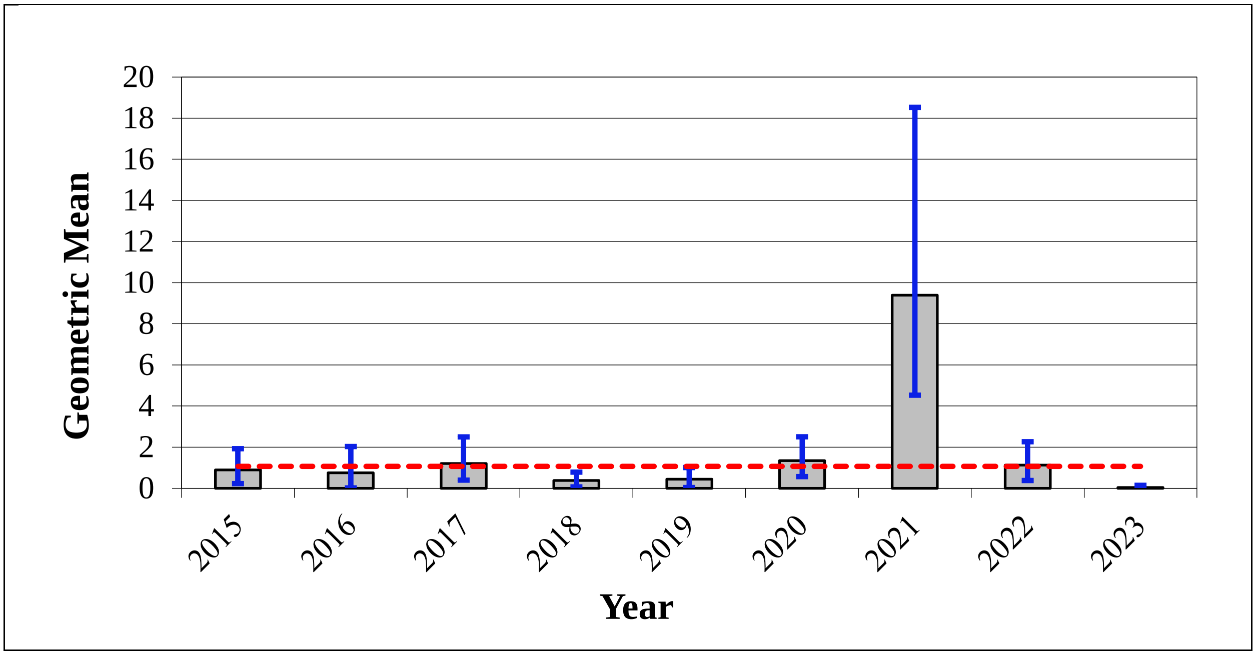

Figure 2.6. Sheepshead SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year).

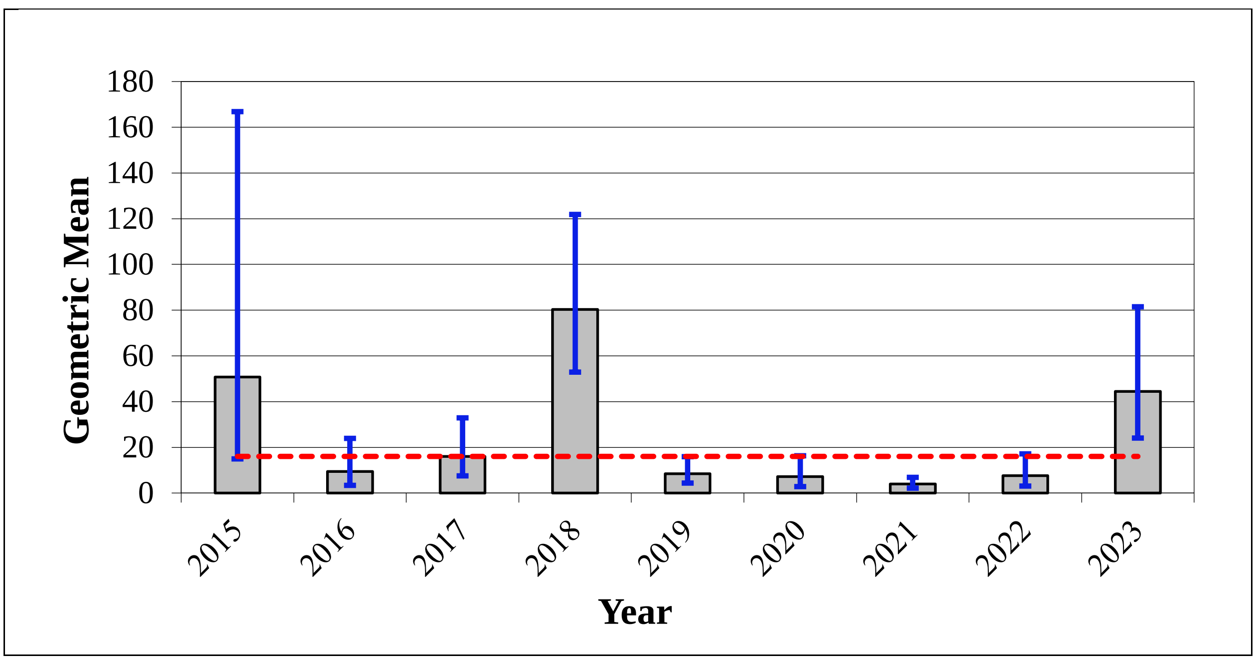

Figure 2.7. Silver perch SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year.

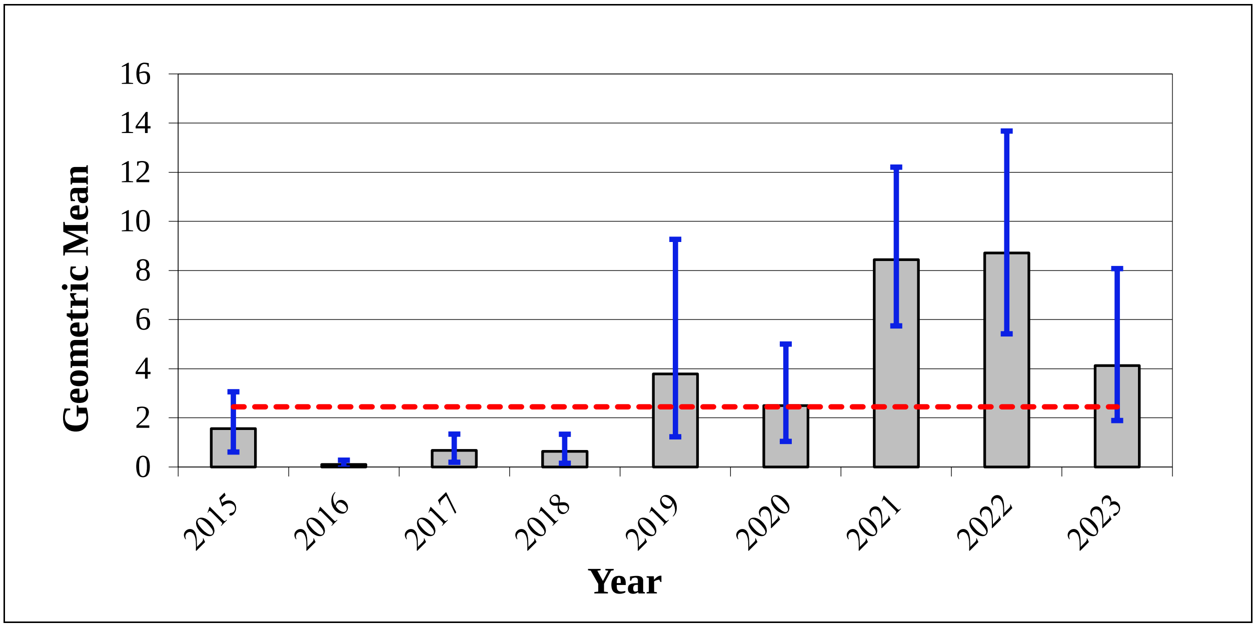

Figure 2.8. Tautog SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year).

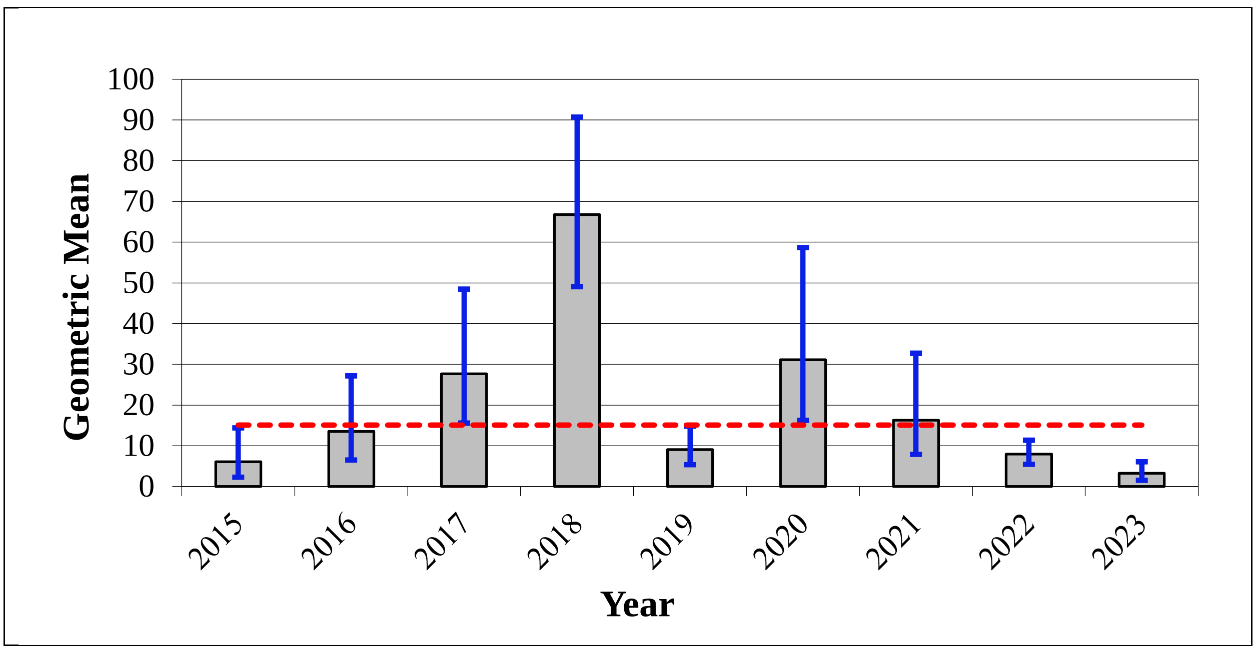

Figure 2.9. Blue crab SAV Habitat Survey beach seine index of relative abundance (geometric mean) with 95% confidence intervals (2015 - 2023). Dotted line represents the 2015 - 2023 time series grand mean (n = 149, average 16/year.

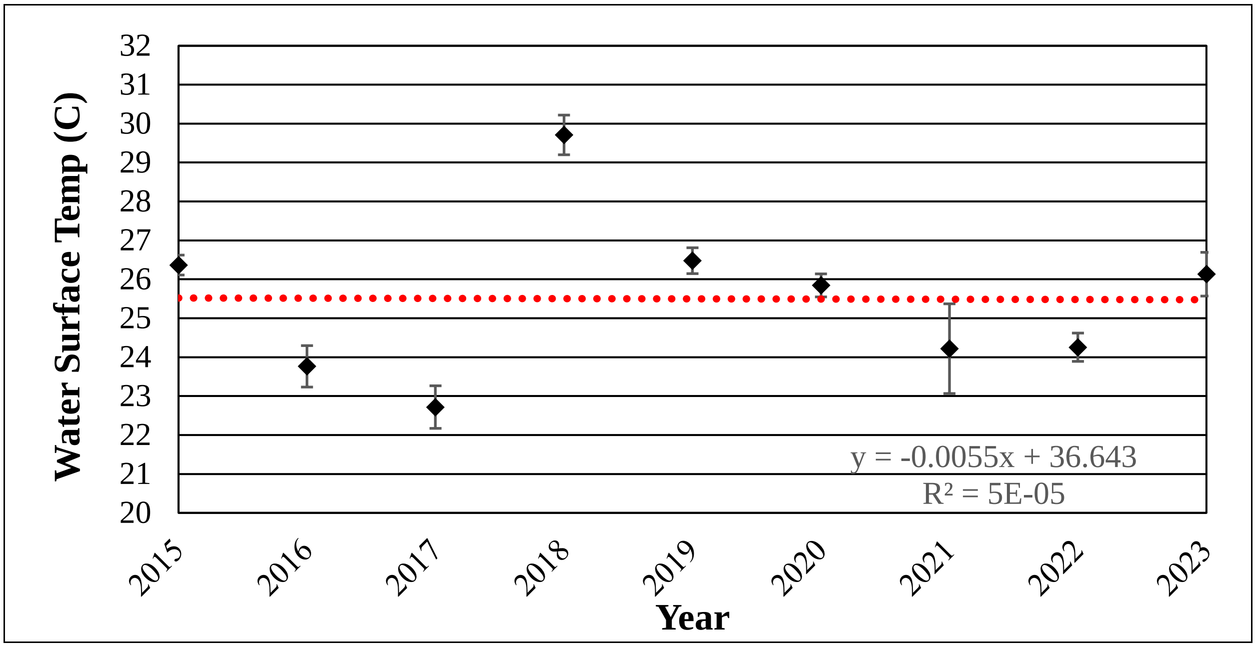

Figure 2.10. Distribution of surface water temperature from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2023).

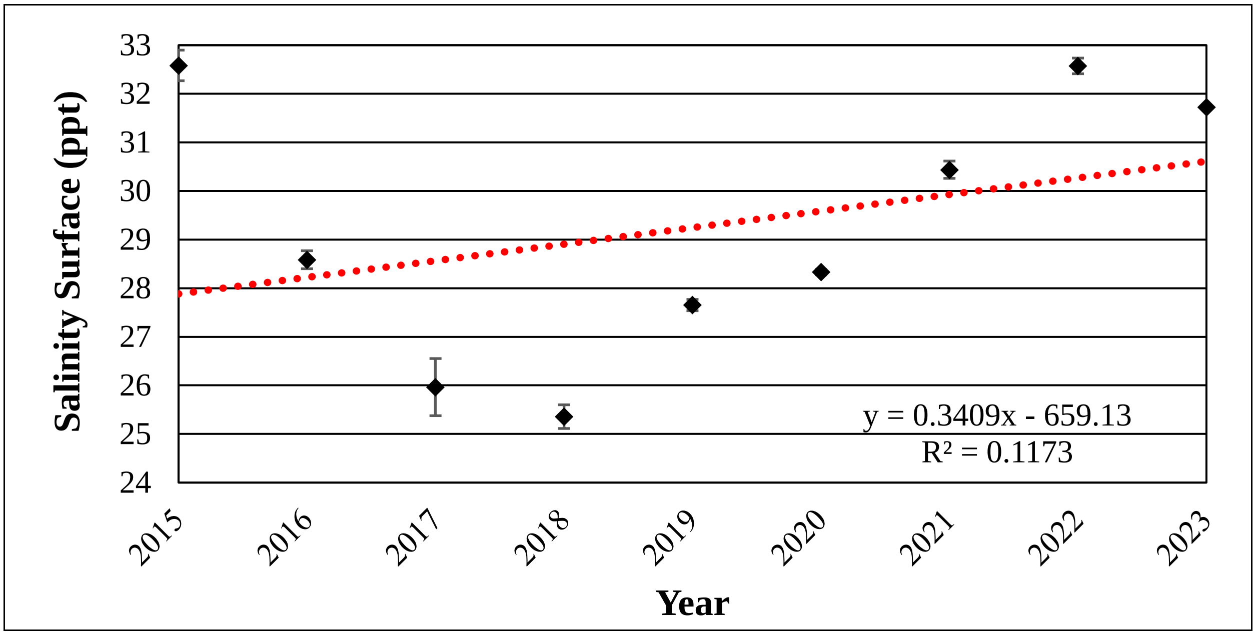

Figure 2.11. Distribution of surface salinity from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2023).

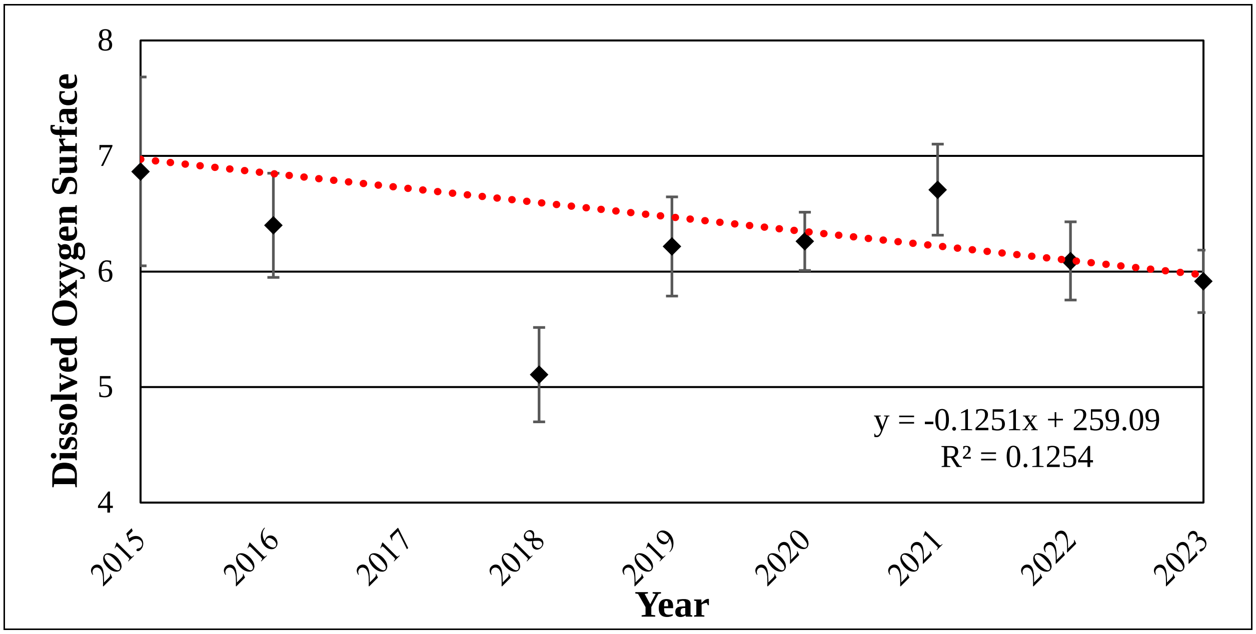

Figure 2.12. Distribution of surface dissolved Oxygen from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2023).

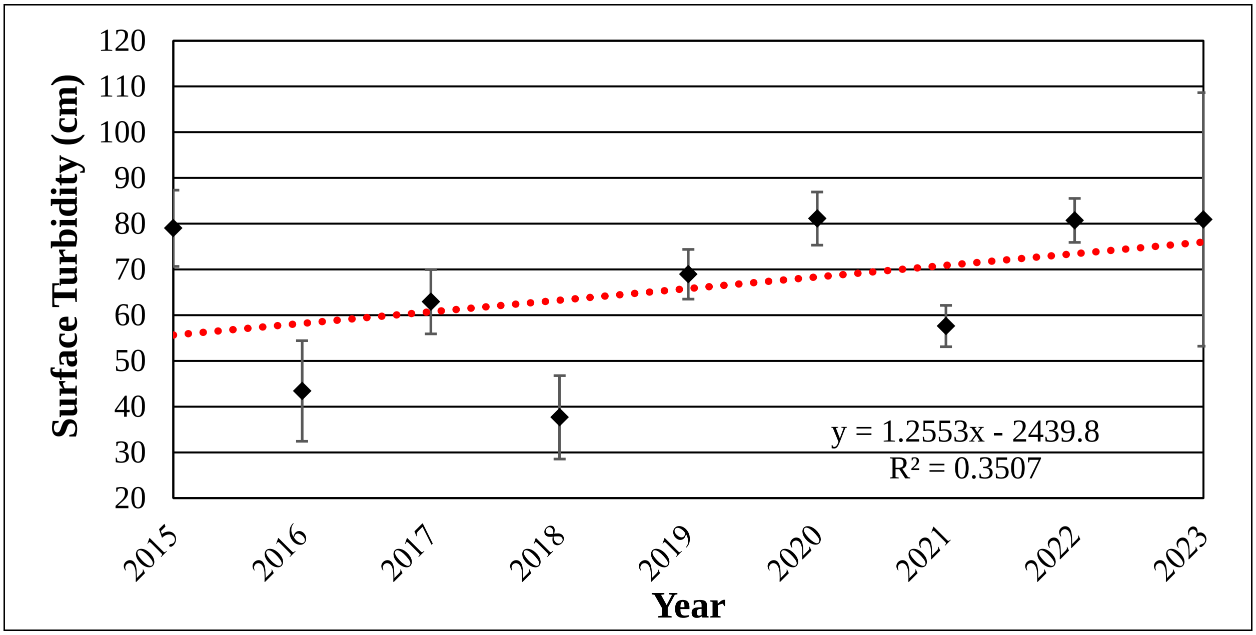

Figure 2.13. Distribution of turbidity from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2023).

Chapter 3 Fisheries Dependent Tautog (*Tautoga onitis*) Data Collection (2016 - 2023)

Tautog biological collections in 2023 were obtained from eight dockside trips (62%) and one at sea charter trip (38%). Length, sex, and opercula were collected from 211 tautog. Those samples represented the range of fish lengths commonly caught in the recreational fishery in Maryland. Age data was determined on 200 tautog and were combined with the historical state data. Those will be submitted to the Atlantic States Marine Fisheries Commission Tautog Stock Assessment Subcommittee for the Delmarva Regional Age Length Key.

The 2023 aged sample lengths ranged from 242 mm to 762 mm, the mean length was 418 mm, and median length was 420 mm for both sexes combined. Female fish aged comprised 64.5% (n = 129) and the mean length was smaller (411 mm) than the male mean length (431 mm; 35.5%; n = 71). Tautog were placed into one inch length bins, and the 431.8 mm/17 inch had the highest proportion (23.5%; Table 3.1). Tautog ages ranged from two to 19 years, the mean age was 6.5 years, and the median age was six years. Age six tautog comprised 21% of the samples and was the largest age bin (Table 3.2). The 2023 female and male mean and median age was six years. The age range for the recruit size tautog (406 mm/16 in) ranged from four to nine years old for both sexes.

The combined sex age frequency results from 2018 - 2023 (n = 1,221) included both legal and sublegal fish. These results indicated that five-year old tautog were most frequently caught by recreational anglers over that time series (Figure 3.1). The von Bertalanffy growth curve was fitted to the 2018 - 2023 length-age data (n = 1,221) using three parameter estimates (m = 3): asymptotic length in centimeters (Linf ∞), growth rate (K), and age at zero size (t0). The growth curve estimate results were similar to previous estimates (Linf, 70.98; k, 0.11 and t0, -2.13; Figure 3.2).

Overall, the Maryland recreational tautog population has a broad range of year classes. The large variance for length at age for the tautog under age ten should continue to be monitored. The charter fleet remained concerned about overfishing the trophy size tautog and continued to promote the catch and release of large fish, especially females.

Table 3.1. Tautog proportion at length of samples collected from Ocean City, Maryland (2023; n = 200). Red cells indicate undersized fish (> 406.4 mm/16 in).

Length (mm)	254	279.4	304.8	330.2	355.6	381	406.4	431.8	457.2	482.6	508	533.4	558.8	584.2	609.6	*Over*	762
Length (in)	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		30
Percent	3.5	5	5	4	3.5	2	23	23.5	10	8.5	5.5	2.5	1.5	1	1		0.5

Table 3.2. Tautog proportion at age of samples collected from Ocean City, Maryland (2023; n = 200).

Age	2	3	4	5	6	7	8	9	10	11	12	13	14	*Over*	19
Percent	0.5	7	11	14	21	17.5	13	9	3	1.5	0.5	0.5	1		0.5

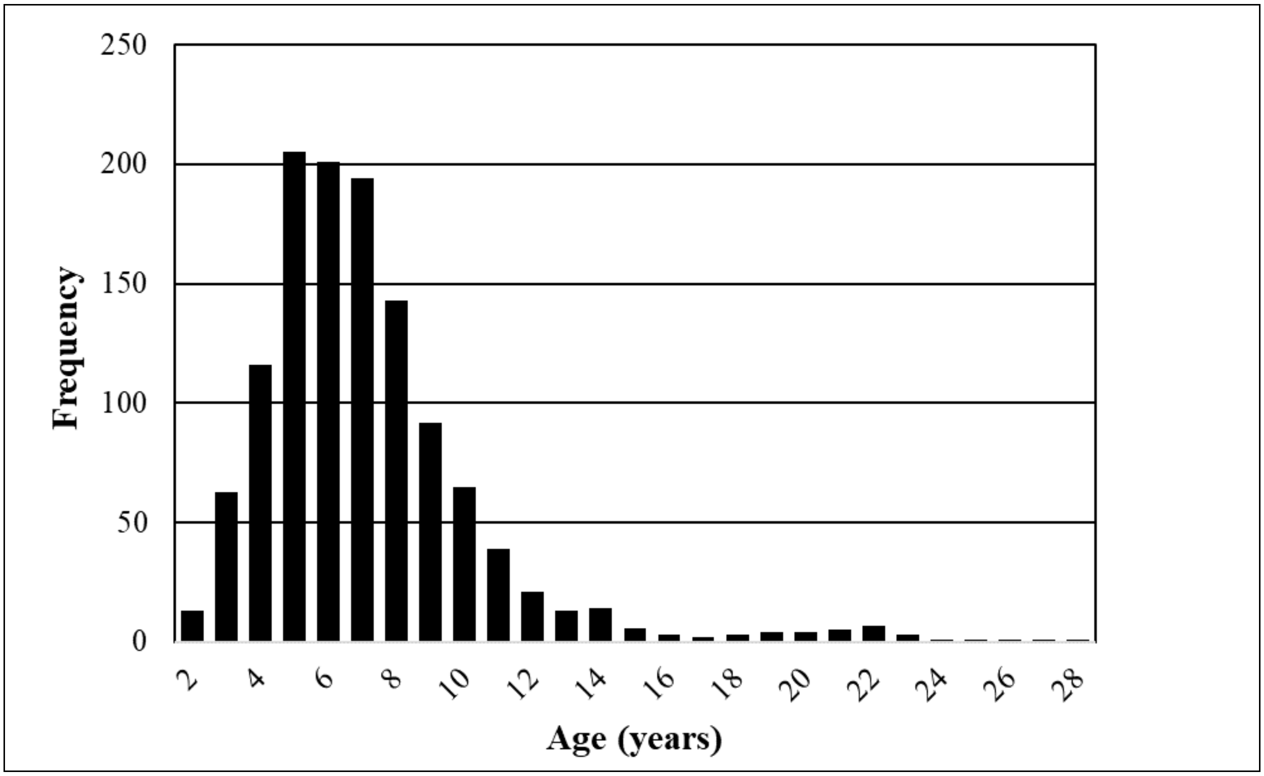

Figure 3.1. Tautog age frequency representing fish commonly caught in the recreational fishery in Ocean City, Maryland, (2018 - 2023; n = 1,221).

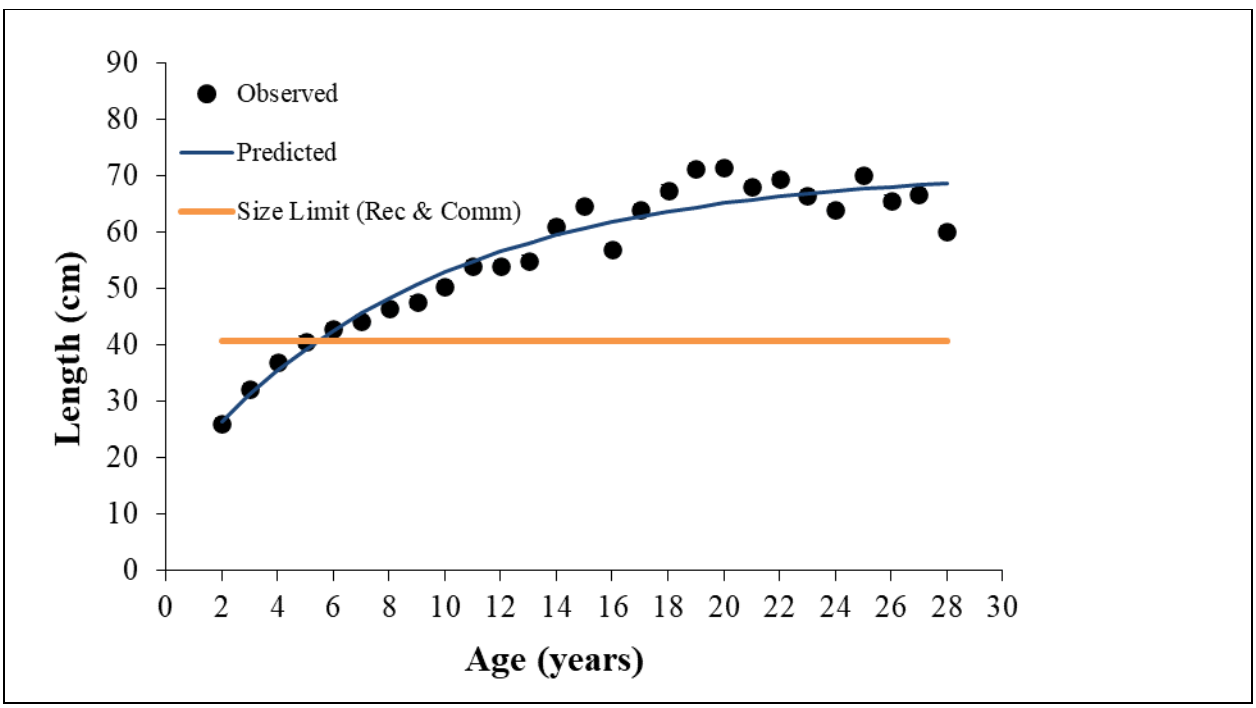

Figure 3.2. Tautog length-at-age and von Bertalanffy growth curve results with 95% confidence intervals, Ocean City, Maryland (2018 - 2023; n = 1,221).

Chapter 4 Technical Assistance

One of the grant objectives was to contribute technical expertise and field observations from surveys to various research and management forums regarding finfish species found in the Maryland coastal bays and near shore Atlantic waters. With the passage of the Atlantic Coastal Fisheries Cooperative Management Act, various entities such as the Atlantic States Marine Fisheries Commission (ASMFC), Mid-Atlantic Fishery Management Council (MAFMC) and the National Marine Fisheries Service (NMFS) require stock assessment information to assess management measures.

Direct participation by Survey personnel as representatives to these various management entities provided effective representation of Maryland interests through the development, implementation, and refinement of management options for Maryland as well as coastal fisheries management plans. In addition, survey information was used to formulate management plans and provided evidence of compliance with state and federal fisheries management plans. A summary of the participation and contributions are presented in Table 4.1.

Table 4.1. Summary of technical assistance for July 1, 2023 – June 30, 2024.

Data Requested	Committee Participation F-50 Support	Data included in the ASMFC Compliance Report	ASMFC Compliance Report F-50 Support	Data Provided During 2022/2023 Assessment/Update	Data Provided to Researchers
Atlantic croaker		Trawl		Trawl	
Atlantic menhaden		Trawl/Beach Seine		Trawl	
Black drum		Beach Seine		Beach Seine	
Black sea bass	ASMFC/MAFMC	Trawl/Beach Seine	Yes	Trawl	Trawl/Beach Seine
Bluefish		Beach Seine		Trawl/Beach Seine	
Coastal sharks	ASMFC		Yes		
Cobia					Trawl/Beach Seine/SAV Habitat
Cownose ray					Trawl/Beach Seine
Gray triggerfish					Trawl/Beach Seine
Pinfish					Trawl/Beach Seine
Horseshoe Crab		Trawl		Trawl	
Multispecies					Trawl/Beach Seine
Red drum				Beach Seine	

Scup	ASMFC/MAFMC		Yes		
Spot		Trawl/Beach Seine			
Sheepshead					Trawl
Shrimp (brown/white)					Trawl
Spotted seatrout		Beach Seine			Trawl
Summer flounder	ASMFC/MAFMC	Trawl/Beach Seine	Yes	Trawl	
Tautog	ASMFC	Trawl/Beach Seine/SAV Habitat/Dependent Collection	Yes	Trawl/Beach Seine/SAV Habitat Survey/Dependent Collection	
Weakfish		Trawl			
Water Quality					Trawl
Other Technical Committee Expertise					
ASMFC, Northeast Area Monitoring and Assessment Program					
DNR, Chesapeake and Coastal Services, Climate Fellowship					
National Estuary Program, Maryland Coastal Bays Program Science and Technical Advisory Committee					
National Oceanic and Atmospheric Administration Highly Migratory Species Advisory Panel					

References

Bergenius, M. A., Meekan, M. E., Robertson, D. R., & McCormick, M. I. (2002). Larval growth predicts the recruitment success of a coral reef fish. *Oecologia, 131*, 521-525.

Chambers, R. C., Candelmo, A. C., Habeck, E. A., Poach, M. E., Wieczorek, D., Cooper, K. R., . . . Phelan, B. A. (2014). Effects of elevated CO2 in the early life stages of summer flounder, Paralichthys dentatus, and potential consequences of ocean acidification. *Biogeosciences, 11*, 1613–1626. doi:https://doi.org/10.5194/bg-11-1613-2014

Chesapeake Bay Program. (2021, February 8). *Dissolved Oxygen*. Retrieved February 9, 2021, from Chesapeake Bay Program: https://www.chesapeakebay.net/discover/ecosystem/dissolved_oxygen

Coastal Bays Sensitive Areas Technical Task Force. (2004). *Maryland coastal bays aquatic sensitive initiative.* Coastal Zone Management Division. Annapolis: Maryland Department of Natural Resources.

Connolly, R. M., & Hindell, J. S. (2006). Review of nekton patterns and ecological processes in seagrass landscapes. *Estuarine, Coastal and Shelf Science, 68*, 433-444.

Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean acidification: the other CO220 problem. *Annual Review of Marine Science*, 169-192.

Dorf, B. A., & Powell, J. C. (1997). Distribution, abundance and habitat characteristics of juvenile tautog (tautoga onitis, Family Labridae) in Narragansett Bay, Rhode Island, 1988-1992. *Estuaries, 20*, 589-600.

Grorud-Colvert, K., & Sponaugle, S. (2006). Influence of condition on behavior and survival potential of a newly settled coral reef fish. *Marine Ecology Progress Series, 327*, 278-388.

Hauxwell, J., Cebrian, J., Furlong, C., & Valiela, I. (2001). Macroalgal canopies contribute to eelgrass (Zostera marina) decline in temperate estuarine ecosystems. *Ecology, 82*(4), 1007 - 1022.

Kemp, W. M., Batuik, R., Bartleson, R., Bergstrom, P., Carter, V., Gallegos, G., . . . Wilcox, D. (2004). Habitat requirements for submerged aquatic vegetation in Chesapeake Bay: Water quality, light regime, and physical-chemical factors. *Estuaries, 27*, 363–377.

Latour, R. J., Gartland, J., Bonzek, C. F., & Johnson, R. (2008). The Trophic Dynamics of Summer Flounder (Paralichthys Dentatus) In Chesapeake Bay. *Fishery Bulletin, 106*(1), 47-57. Retrieved February 8, 2021, from https://scholarworks.wm.edu/cgi/viewcontent.cgi?article=1559&context=vimsarticles

Maryland Department of Environment. (2001). *Total maximum daily loads of Nitrogen and Phosphorus for five tidal tributaries in the northern coastal bays system, Worcester County.* Baltimore: Maryland Department of Environment.

Meekan, M. G., & Fortier, L. (1996). Selection for fast growth during the larval life of Atlantic cod Gadus morhua on the Scotian Shelf. *Marine Ecology Progress Series, 137*, 25-37.

Murdy, E. O., & Musick, J. A. (2013). *Field guide to the fishes of the Chesapeake Bay.* Baltimore, Maryland: The Johns Hopkins University Press.

Murdy, E., Birdsong, R. S., & Musick, J. A. (1997). *Fishes of Chesapeake Bay* (Illustrated ed.). Washington, D.C.: Smithsonian Institution Press.

National Estuary Program. (2006). *Volunteer Estuary Monitoring: A Methods Manual.* Office of Wetlands, Oceans, and Watersheds. Environmental Protection Agency. Retrieved January 2023, from https://www.epa.gov/nep/volunteer-estuary-monitoring-methods-manual.

Oktay, D. S. (2008, September). *Yesterday's Island Today's Nantucket*. Retrieved July 12, 2021, from https://yesterdaysisland.com/2008/features/19a.php

Peters, R., & Chigbu, P. (2017). Spatial and temporal patterns of abundance of juvenile black sea bass (Centropristis striata) in Maryland coastal bays. *Fishery Bulletin, 115*(4), 504-516. doi:10.7755/FB.115.4.7

Pipkin, W. (2021, December 6). *Warm temperatures move more shrimp into Chesapeake waters*. Retrieved February 15, 2022, from Bay Journal: https://www.bayjournal.com

Ricker, W. E. (1975). *Computation and interpretation of biological statistics of fish populations.* Department of the Environment Fisheries and Marine Service. Ottawa: Bulletin of the Fisheries Research Board of Canada.

Ringwood, A. H., & Keppler, C. J. (2002). Water quality variation and clam growth: Is pH really a non-issue in estuaries? *Estuaries*, 901–907. Retrieved January 2023

Scott C. Doney, V. J. (2009, March 1). *Ocean Acidification: The Other CO2 Problem.* Retrieved from Reviews In Advance: http://oceans.mit.edu/wp-content/uploads/doney_ann_rev_proof.pdf

Searcy, S. P., & Sponaugle, S. (2001). Selective mortality during the larval juvenile transition in two coral reef fishes. *Ecology, 64*, 2452-2470.

Searcy, S. P., Eggleston, D. B., & Hare, J. A. (2007). Is growth a reliable indicator of habitat quality and essential fish habitat for a juvenile estuarine fish? *Canadian Journal of Fisheries and Aquatic Sciences, 64*, 681-691.

Shannon, C. E. (1948, October). A mathematical theory of communication. *The Bell System Technical Journal, 27*, 379-423, 623-656. Retrieved February 8, 2021, from http://people.math.harvard.edu/~ctm/home/text/others/shannon/entropy/entropy.pdf

Shen, J., Wang, T., Herman, J., Mason, P., & Arnold, G. (2008). Hypoxia in a coastal embayment of the Chesapeake Bay: a model diagnostic study of oxygen dynamics. *Estuaries and Coasts, 31*, 652-663. doi:10.1007/s12237-008-9066-3

Timmons, M. (1995). *Relationships between macroalgae and juvenile fishes in the inland bays of Delaware.* Newark: University of Delaware.

Tomasetti, S. J., & Gobler, C. (2020). Dissolved oxygen and pH criteria leave fisheries at risk. *Science, 368*, 372-373.

Virginia Institute of Marine Science. (2021). *SAV Monitoring & Restoration*. Retrieved February 8, 2021, from Virginia Institute of Marine Science: https://www.vims.edu/research/units/programs/sav/access/maps/index.php

Wazniak, C., Goshorn, D., Hall, M., Blazer, D., Jesien, R., Wilson, D., . . . Sturgis, B. (2004). *State of the Maryland coastal bays.* University of Maryland Center for Environmental Science: Integration and Application Network, Maryland Department of Natural Resources: Maryland Coastal Bays Program.

Young, C. S., Peterson, B. J., & Gobler, C. J. (2018). The bloom - forming macroalgae, Ulva, outcompetes the seagrass, Zostera marina, under high CO2 conditions. *Estuaries and Coasts, 41*, 2340 – 2355. Retrieved from https://doi.org/10.1007/s12237-018-0437-0