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

F-50-R-30

July 2021 - June 2022
Final Report

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Investigation of Maryland's Coastal Bays and Atlantic Ocean Finfish Stocks
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Accomplishments July 1, 2021 - June 30, 2022

July - August 2021
- 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-29 report
- Wrote the Atlantic States Marine Fisheries Commission (ASMFC) Coastal Sharks Compliance report
- Collected two tautog opercula for ageing

September - October 2021
- Collected 20 trawl samples at 20 fixed sites (monthly)
- Collected 19 beach seine samples at 19 fixed sites (September)
- Collected 16 Submerged Aquatic Vegetation Habitat Survey samples in Sinepuxent Bay (September)
- Finalized the F-50-R-29 report
- Completed data entry and quality control from prior month's sampling
- Collected two tautog opercula for ageing

November 2021
- Completed quality control for the entire dataset
- Collected 60 tautog opercula for ageing

December 2021 - March 2022
- Conducted data analyses of the 2021 surveys
- Drafted the F-50-R-29 annual report
- Collected 23 tautog opercula for ageing
- Prepped and aged 201 tautog for the 2021 fishing year
- Finfish abundance indices for black sea bass, bluefish and summer flounder were provided to the National Marine Fisheries Service Science Center for stock assessment updates
- Black drum indices were provided for consideration of an Atlantic States Marine Fisheries Commission (ASMFC) benchmark stock assessment

April - June 2022
- Prepared for the 2022 field sampling season (Trawl and Beach Seine surveys)
- Determined sampling needs for the next Submerged Aquatic Vegetation Habitat Survey
- 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-30 report
- Wrote the Atlantic States Marine Fisheries Commission’s black sea bass, scup, summer flounder, and tautog compliance reports
- Atlantic croaker indices were provided for consideration in the ASMFC traffic light assessment
- Collected 112 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, 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 2021 through June 2022, the terminal year of data used in this report is 2021, because a full sampling season is needed for data analyses.

Executive Summary

The investigation was developed to characterize juvenile and adult fishes and their abundances in Maryland's coastal bays and the Atlantic Ocean, facilitate management decisions, and protect finfish habitats. This investigation was comprised of three surveys: Beach Seine, Submerged Aquatic Vegetation Habitat, and Trawl surveys in the bays, behind Fenwick and Assateague Islands. Over 30 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 inter- and intra-government committees and writing Atlantic States Marine Fisheries Commission compliance reports. Develop indices and other needed information necessary to assist in the management of regional and coastal fish stocks.

In 2021, 14,851 fish were caught in the Trawl and Beach Seine surveys (4,549 fish trawling and 10,302 fish beach seining). Collected fishes represented 70 species, which is within the normal representation range in a year. Atlantic croaker, bay anchovy, bluefish, spot, summer flounder, and weakfish had below average trawl indices. Sheepshead and summer flounder had above average beach seine indices while American eel, bay anchovy, bluefish, silver perch, spot, and weakfish had below average indices.

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 (89 fishes) in the trawl time series (1989 - 2021) whereas Newport Bay had the lowest (69 fishes). The Beach Seine Survey time series (1989 - 2021) results indicated that Assawoman Bay and Isle of Wight Bay had the richest fish populations (88 and 87 fishes respectively) and Newport Bay was lowest (70).

Diversity is a measurement of richness and the proportion of species in the sample population. The 2021 trawl and beach seine surveys were dominated by bay anchovy (54.3% trawl) and Atlantic menhaden (60.1% beach seine), which reduced diversity for some embayments. Shannon index results for the trawl time series (1989 - 2021) indicated that Sinepuxent Bay was most diverse whereas the St. Martin River was the least. Shannon index results for the beach seine time series (1989 - 2021) indicated that Chincoteague Bay was most diverse whereas the St. Martin River and Sinepuxent Bay were the least.

Macroalgae bycatch is ephemeral with annual variation. It is quantified in these surveys for its positive and negative effects as habitat. The 2021 trawl CPUE (57.1 L/ha) was below the grand mean and the beach seine CPUE (33.5 L/haul) was equal to the grand mean. Thirteen genera

were collected by trawl and beach seine within the coastal bays in 2021. *Agardhiella* remained the most abundant genus for both gears.

The water quality tested at the majority of 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 have not 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*), 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 (201 fish) were obtained for ageing from charter and party boats, and private anglers. Ageing results had a wide range of year classes and large fish caught by hook and line in the Atlantic Ocean off Ocean City, Maryland. The maximum age was 20 and the mean age was 6.8 years.

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

These surveys were developed to characterize fishes and their abundances in Maryland's coastal bays, facilitate management decisions, and protect finfish habitats. 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 finfish although bycatch of crustaceans, macroalgae, molluscs, and sponges were common. This report includes data from 1989 - 2021.

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 investigations 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 needed 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, in order to protect against habitat loss or degradation.

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 to 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 225 horsepower Evinrude Etec 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 took into account 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 percent 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)), and water temperature (Celsius (C)). 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, and water temperature were taken with a Yellow Springs Instrument Pro2030 at two depths, 30 cm (1 ft) below the surface (all gears) and 30 cm (1 ft) from the bottom (trawl). The Pro2030 cord was marked in one foot intervals. Chemical data were only taken 30 cm below the surface for each beach seine site due to the shallow depth (< 1.1 m). The Pro2030 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 the user 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 or occasionally estimated by checking the published tide tables for the sampled areas. Occasional difficulties determining tide may have resulted from inlet influences in Ocean City and Chincoteague, lack of appropriate tide stations for some sites, or wind driven tidal influences.

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. 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 - 2021). 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 - 2020) and used as a point estimate for comparison to the annual (2021) 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 2021. 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.

To evaluate water quality at trawl sites, the mean for each parameter (DO, salinity, temperature, and turbidity) per bay was derived from using the surface and bottom values. For both gears, the DO averages were reviewed to see if the system 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 14,851 fish caught trawling (4,549) and beach seining (10,302 fish) in 2021 (Table 1.4). Collected fishes represented 70 species, which is within the normal range in a year for the past 15 years (Table 1.5). The total catch and the trawl catch in number of individuals collected was the lowest in the time series, while the beach seine catch was the fourth lowest in the time series. Atlantic croaker, bay anchovy, bluefish, spot, summer flounder, and weakfish had below average trawl indices. Sheepshead and summer flounder had above average beach seine indices while American eel, bay anchovy, bluefish, silver perch, spot, and weakfish were below average (Table 1.6). 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.

Crustaceans were the second most abundant taxa captured in this survey. Specifically, they accounted for 5,837 specimens caught trawling (2,591 crustaceans) and beach seining (3,216 crustaceans) in 2021 (Table 1.7). Fourteen crustaceans were identified and the three most abundant species of crustaceans were blue crabs, grass shrimp, and white shrimp all of which were excellent forage to support recreational finfish species.

The third most abundant taxa captured in the survey were molluscs. Specifically, they accounted for 985 specimens caught trawling (256 molluscs) and beach seining (729 molluscs; Table 1.8). Molluscs were represented by 19 different species and the most abundant species were blue mussels, sponge slugs, and Atlantic brief squid.

Sixteen other animals were also captured including bryozoans, ctenophores, horseshoe crabs, northern diamondback terrapins, sponges, and tunicates (Table 1.9). Sea squirts were the most abundant by count (1,883) but comb jellies were the highest by volume (469 L).

Fifteen plants were captured trawling and beach seining (Table 1.10). Two species of SAV and 13 macroalgae genera were encountered. Beach seine site S019 had stonewort, *Nitella sp*., present, which is not regularly collected at that site.

American eel (*Anguilla rostrata*)

American eels, a forage and bait species of interest to recreational anglers, were captured in seven of 140 trawls (5%) and in one of 38 beach seines (2.6%). Seventeen American eels were collected in trawl (16 fish) and beach seine (1 fish) samples (Table 1.4). American eel ranked 29 out of 70 species in overall finfish abundance. The trawl and beach seine CPUEs were 0.9 fish/ha and <0.1 fish/haul, respectively.

The 2021 trawl relative abundance index was equal to the grand mean and the beach seine relative abundance index was below the grand mean (Figure 1.4, Figure 1.5). Since 1989, the trawl (4 years) and beach seine (6 years) indices rarely varied significantly from the grand means. American eels spawn in the Sargasso Sea; therefore, environmental conditions and ocean currents may be a factor influencing relative abundance (Murdy, Birdsong, & Musick, 1997).

American eels were most frequently 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, which is supported by the two length classes of eels present in the samples.

The 16 American eels caught by the Trawl Survey measured 50 mm to 270 mm. The minimum size increased from April through July reflecting growth of the young of the year (Table 1.11). In the Beach Seine Survey, one American eel was caught in June measuring 45 mm (Table 1.12). It is 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 five of 38 beach seines (13.2%). A total of 150 juvenile Atlantic croakers were collected in trawl (142 fish) and beach seine (8 fish) samples (Table 1.4). Atlantic croakers ranked 10 out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 8.1 fish/ha and 0.2 fish/haul, respectively.

The 2021 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 (19 years) and the beach seine index occasionally (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.

Good trawl sites for collecting Atlantic croakers were located 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 August in the Trawl Survey. The monthly mean size ranged from 30 mm to 249 mm and increased from April through August except in July, when some age-1 plus individuals were caught in addition to the young of the year individuals (Table 1.11). The Beach Seine Survey mean length was 64 mm in June and one measuring 280 mm was caught in September (Table 1.12).

Atlantic menhaden (*Brevoortia tyrannus*)

Atlantic menhaden, a forage species, were captured in 22 of 140 trawls (16.7%) and in 21 of 38 beach seines (55.3%). Atlantic menhaden ranked first out of 70 species in overall finfish abundance. A total of 6,540 juvenile Atlantic menhaden were collected in trawl (344 fish) and beach seine (6,196 fish) samples (Table 1.4). The trawl and beach seine CPUE was 19.6 fish/ha and 163 fish/haul, respectively.

Both the 2021 trawl and beach seine relative abundance indices were equal to the grand means (

Figure 1.8,

Figure 1.9). Since 1989, the trawl index often (17 years) and the beach seine index occasionally (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 located 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 by the Trawl Survey increased from a mean of 41 mm in May to a mean of 90 mm in October, with the exception of August when several larger specimens were caught (Table 1.11). The Beach Seine Survey had similar results with an increase from a mean length of 44 mm in June to a mean length of 85 mm in September with the most individuals caught in June (Table 1.12). 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 eight of 140 trawls (5.7%) and in 34 of 38 beach seines (89.5%). A total of 1,756 Atlantic silversides were collected in trawl (21 fish) and beach seine (1,735 fish) samples (Table 1.4). Atlantic silversides ranked third out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 1.2 fish/ha and 45.6 fish/haul, respectively.

The 2021 trawl and beach seine relative abundance indices were both equal to the grand means (Figure 1.10,

Figure 1.11). Since 1989, the trawl index often (17 years) and beach seine index rarely (6 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.

Atlantic silverside were caught in the Trawl Survey in May (2 fish) and June (18 fish) and ranged in size from 31 mm to 126 mm (Table 1.11). The Beach Seine Survey mean lengths were 85 mm in June and 77 mm in September (Table 1.12). The monthly variability of the mean lengths is likely related to the monthly lunar spawning cycle, March through July (Murdy & Musick, 2013).

Bay anchovy (*Anchoa hepsetus*)

Bay anchovies, a forage species, were captured in 71 of 140 trawls (50.1%) and in 20 of 38 beach seines (52.6%). A total of 2,950 bay anchovies were collected in trawl (2,468 fish) and beach seine (482 fish) samples (Table 1.4). Bay anchovies ranked second out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 140.6 fish/ha and 12.7 fish/haul, respectively.

The 2021 trawl and beach seine relative abundance indices were both below the grand means (Figure 1.12,

Figure 1.13). Since 1989, the trawl (13 years) and beach seine (9 years) indices occasionally 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 anchovy indices have not fluctuated much from year to year but stay close to the mean reflecting stable and protracted recruitment each year. 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 located 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 49 mm to 64 mm (Table 1.11). The mean monthly lengths from the Beach Seine Survey were 69 mm in June and 45 mm in September (Table 1.12). Spawning appears to occur multiple times from May to September and peaked in July. 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 29 of 140 trawls (20.7%) and 10 of 38 beach seines (26.3%). A total of 74 juvenile black sea bass were collected in trawl (49 fish) and beach seine (25 fish) samples (Table 1.4). Black sea bass ranked 15 out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 2.8 fish/ha and 0.7 fish/haul, respectively.

In 2021, both the trawl and beach seine relative abundance indices were equal to the grand means (
Figure 1.14,
Figure 1.15). Since 1989, the trawl index often (20 years) and beach seine index rarely (8 years) varied significantly from the grand means. The Trawl Survey catches more black sea bass; therefore, it was the better gear for inclusion in the 2018 ASMFC stock assessment.

Juvenile black sea bass were more abundant at sites nearest to inlets than in the mid bays. Abiotic factors measured 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 101 mm in June to 164 mm in September (Table 1.11). The Beach Seine Survey mean length increased from 84 mm in June to 101 mm in September (Table 1.12). Black sea bass increased in length throughout the sampling season reflecting growth. The coastal bays are a nursery for young of the year black sea bass through age-1.

Bluefish *(Pomatomus saltatrix)*

Bluefish, a species of interest to recreational anglers, were collected in zero of 140 trawls (0%) and in two of 38 beach seines (5.3%). Eight juvenile bluefish were collected in beach seine samples (Table 1.4). Bluefish ranked 39 out of 70 species in overall finfish abundance. The beach seine CPUE was 0.2 fish/haul.

The 2021 trawl and beach seine relative abundance indices were both below the grand means (Figure 1.16, Figure 1.17). Since 1989, the trawl (8 years) index rarely varied from the grand mean and the beach seine (11 years) index occasionally varied significantly from the grand means. Bluefish were caught more frequently in near shore locations; therefore, the beach seine index represents a more accurate picture of changes in relative abundance when compared to the trawl index. 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. The Beach Seine Survey catches more bluefish; therefore, it was the better indicator of species abundance. Bluefish indices are consistent with the stock assessment.

Historically productive trawl and beach seine sites for collecting bluefish were located in Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, and the St. Martin River. These sites were located north of the Ocean City Inlet with the exception of site S010 in Sinepuxent Bay. Bluefish may have been drawn to the abundance of forage and the higher flushing rates of the areas close to the inlet.

Eight bluefish were caught in the September Beach Seine Survey. The mean length was 112 mm (Table 1.12).

Sheepshead (*Archosargus probatocephalus*)

Sheepshead, a species of interest to recreational anglers, were collected in one of 140 trawls (0.7%) and nine of 38 beach seines (23.7%). A total of 61 juvenile sheepshead were collected in trawl (two fish) beach seine (59 fish; Table 1.4). Sheepshead ranked 17 out of 70 species in overall finfish abundance. The trawl CPUE was 0.1 fish/ haul and the beach seine CPUE was 1.6 fish/haul.

The 2021 trawl relative abundance index was equal to the grand mean while the beach seine was above 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. Presence has been consistent since 2011. 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).

There were two sheepshead caught in the trawl in September and they measured 115 mm and 135 mm. Sheepshead caught in the beach seine were all caught in September and ranged in total length from 13 mm to 185 mm with a mean of 79 mm (Table 1.12).

Silver perch (*Bairdiella chrysoura*)

Silver perch, a forage species, were collected in 37 of 140 trawls (26.4%) and 10 of 38 beach seines (26.3%). A total of 628 silver perch were collected in trawl (527 fish) and beach seine (101 fish) samples (Table 1.4). Silver perch ranked fifth out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 30 fish/ha and 2.6 fish/haul, respectively.

The 2021 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 (3 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).

In the Trawl Survey, the monthly mean size ranged from 44 mm in July to 139.7 in June, with the most individuals caught in July (Table 1.11). Silver perch mean length increased from July through October with young of the year cohort growth. In the Beach Seine Survey, one silver perch was caught in June and the length was 156 mm. Seventy-five silver perch were caught in September and the mean length was 88 mm. (Table 1.12).

Spot (*Leiostomus xanthurus*)

Spot are important forage, to recreational anglers for bait, and as a target species. Spot were collected in 56 of 140 trawls (32.1%) and 29 of 38 beach seines (76.3%). A total of 718 spot were collected in trawl (281 fish) and beach seine samples (437 fish; Table 1.4). Spot ranked fourth out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 16 fish/ha and 11.5 fish/haul, respectively.

The 2021 trawl and beach seine relative abundance indices were both below the grand means (Figure 1.22, Figure 1.23). Since 1989, the trawl index frequently (26 years) varied significantly from the grand mean and the beach seine (23 years) index often varied significantly from the grand mean. Spot spawn offshore; therefore, environmental conditions including global weather patterns, ocean currents and the North Atlantic Oscillator 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 72 mm in May to 152 mm in October (Table 1.11). In the Beach Seine Survey, the mean length increased from 104 mm in June to 161 mm in September (Table 1.12). The increase in mean length reflects growth of the cohort throughout the summer season.

Summer flounder (*Paralichthys dentatus*)

Summer flounder, a species of interest to recreational anglers, were collected in 28 of 140 trawls (20%) and 30 of 38 beach seines (79%). A total of 303 summer flounder were collected in trawl (81 fish) and beach seine (222 fish) samples (Table 1.4). Summer flounder ranked sixth out of 70 species in overall finfish abundance. The trawl and beach seine CPUE was 4.6 fish/ha and 5.8 fish/haul, respectively.

The 2021 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 often (23 years) varied significantly from the grand mean and the beach seine index occasionally (15 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. More recently, the number of summer flounder caught in beach seines increased while the number caught in trawls has decreased.

Productive summer flounder trawl and beach seine sites were located 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, 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 ranged from 34 to 271 mm with the most individuals caught in May (Table 1.11). In the Beach Seine Survey, the mean length increased from 78 mm in June to 128 mm in September (Table 1.12). 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 19 of 140 trawls (13.6%) and zero of 38 beach seines. A total of 206 juvenile weakfish were collected in trawl samples (Table 1.4). Weakfish ranked eighth out of 70 species in overall finfish abundance. The trawl CPUE was 11.7 fish/ha.

The 2021 trawl and beach seine relative abundance indices were both below the grand means (Figure 1.26, Figure 1.27). Since 1989, the trawl (16 years) and beach seine indices (13 years) occasionally varied significantly from the grand means. Weakfish were caught more frequently 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 located 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 32 mm in July to 151 mm in October with most individuals caught in July and August (Table 1.11). Young of the year recruitment was most evident from July through October, 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 2021 Trawl Survey, Isle of Wight (26 species) held the most species of fishes and Newport Bay (14 fishes) was the least diverse (Table 1.13). The Shannon index results indicated that Isle of Wight Bay (H = 2.1) was the most diverse whereas Chincoteague Bay (H = 1.0) was the least diverse.

Over time, Chincoteague Bay had the highest richness (89 fishes) and annual mean richness (34.8 fishes) in the trawl 1989 - 2021 time series (Table 1.14). Newport Bay had the lowest richness (69 fishes) and mean richness (21 fishes) in the time series. The Shannon index results for the trawl time series indicated that Sinepuxent Bay (H = 1.7) was the most diverse whereas the St. Martin River (H = 1.3) was the least diverse.

In the 2021 Beach Seine Survey, Chincoteague Bay (38 species) held the most species of fishes and the Newport Bay (21 fishes) was the least diverse (Table 1.15). The Shannon index results indicated that Assawoman Bay (H = 2.3) was most diverse whereas Chincoteague Bay (H = 0.8) was the least diverse.

The Beach Seine Survey time series (1989 - 2021) results indicated that Assawoman Bay had the richest fish populations (88 fishes) while Chincoteague Bay had the highest mean richness (33.6 fishes; Table 1.16). Newport Bay had the lowest richness (70 fishes) and annual mean richness (20 fishes) in the time series. Beach Seine Survey diversity results throughout the time series indicated that Chincoteague Bay (H = 1.7) was most diverse over the other embayments.

Ayers Creek is not an embayment and its habitat is not similar to the previously mentioned embayments sampled by beach seine. Those data were included in the tables to show the results of Newport Bay's headwaters, which were lower in richness and diversity than the embayments, yet show a remarkable number of fish species (44 fishes) in the time series (Table 1.16). Ayers Creek has had high abundance of Atlantic menhaden and golden shiners on a regular basis, whereas spot were infrequently encountered.

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 because the analysis favors species richness proportions at equal levels in the sample population. High diversity will allow for resilience to climate change. Diversity alone should not be used as a single indicator for healthy fish abundance because strong inner annual year classes are required to sustain species populations that are subject to high fishing or natural mortality.

Macroalgae

The macroalgae time series spans 16 years from 2006 - 2021. To date, 20 genera and 69,839 L of macroalgae were collected in Maryland's coastal bays by the trawl and beach seine. Since this time series began, Rhodophyta (red macroalgae) have been the dominant macroalgae in both gears (Table 1.17). Chlorophyta (green macroalgae) was the second most abundant macroalgae in the time series. Phaeophyta (brown macroalgae) and Xanthophyta (yellow - green macroalgae) were also represented in the survey collections.

Twelve genera were collected by trawl within the coastal bays in 2021, which was below the average (14.5 genera) in the time series (Table 1.10). The 2021 Shannon index of diversity among genera by trawl (H = 1.3) was equal the time series average (H = 1.3). Results indicated that *Agardhiella* were the most abundant macroalgae (54.5%) in 2021. The other genera that contributed more than 5% to the sample population were *Polysiphonia* (21.8 %), *Chaetomorpha*

(10.6%), and *Ulva* (9.1%). The 2021 trawl CPUE (57.1 L/ha) was below the grand mean. Since 2006, the trawl CPUE occasionally varied significantly from the grand mean (Figure 1.28).

Nine genera were sampled within the coastal bays by beach seine in 2021 (Table 1.10). The Shannon index of diversity among genera (H = 0.8) was below the time series average (H = 1.1). Results indicated that *Agardhiella* were most abundant (74.5%). The only other genera that contributed more than 5% to the sample population were *Polysiphonia* (7.7%) and *Ulva* (6.7%). The 2021 beach seine CPUE (33.5 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE occasionally varied significantly from the grand mean (Figure 1.29).

Macroalgae in Maryland's coastal bays were investigated consistently over 16 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 show that Rhodophyta and Chlorophyta were present at high levels in the embayments closest to high human density population. The terminal year (2021) and preceding two years had a dramatic decrease in overall abundance of macroalgae compared to the peak abundance in 2008 and 2016. *Agardhiella* remained the most abundant genus at low levels compared to the time series.

In previous years, the embayments north of the Ocean City Inlet had single species dominance of *Agardhiella* and subsequently had the highest CPUE when compared to the southern embayments. 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, specifically sea lettuce abundance was variable, yet appeared able to compete with the Rhodophytes when suitable conditions presented themselves.

Assawoman Bay

This embayment has been dominated by Rhodophyta since sampling began in 2006 (Table 1.17). Seven different genera were collected by trawl in 2021, which was below the average (7.4 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment (H = 0.8) was equal the time series average (H = 0.8). *Agardhiella* (69.8%) was most abundant genus. *Ulva* (25.4%) was the only other genus that contributed more than 5% to the sample population. The 2021 CPUE (47.1 L/ha) was below the grand mean. Since 2006, the trawl CPUE frequently varied significantly from the grand mean (Figure 1.30).

Five different genera were collected by beach seine in 2021, which was below the average (6.1 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment (H = 0.5) was above the time series average (H = 0.7). *Agardhiella* (85.6%) was most abundant, followed by *Ulva* (11%). The beach seine CPUE (107.6 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE frequently varied significantly from the grand mean (Figure 1.31).

Isle of Wight Bay
This embayment has been dominated by Rhodophyta since sampling began in 2006 (Table 1.17). Six different genera were collected by trawl in 2021, which was below the average (6.6 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment (H = 0.3) was below the time series average (H = 0.7). *Agardhiella* was most abundant (95%). The trawl CPUE (165.2 L/ha) was below the grand mean. Since 2006, the trawl CPUE occasionally varied significantly from the grand mean (Figure 1.32).

Five different genera were collected by beach seine in 2021, which was below the average (6.6 genera) for this embayment in the time series. The 2021 Shannon index of diversity among genera within this embayment (H = 0.5) was below the time series average (H = 1). *Agardhiella* (85.2%) was the most abundant, followed by Ulva (13.4%). The 2021 beach seine CPUE (7 L/haul) was below the grand mean. Since 2006, the beach seine CPUE occasionally varied significantly from the grand mean (Figure 1.33).

St. Martin River
This river has been dominated by Rhodophyta since sampling began in 2006, except in 2013, and 2021 when *Chlorophyta* were dominant in the deeper water sampled by the trawl (Table 1.17). Five different genera of macroalgae were collected by trawl in 2021, which was below the time series average (5.2 genera). The 2021 Shannon index of diversity among genera (H = 0.9) was above the time series average (H = 0.8). *Ulva* (56.6%) was most abundant; *Agardhiella* (37.7%) and *Enteromorpha* (5.6%) were the only other genera that contributed more than 5% of the sample population. Trawl CPUE (14.3 L/ha) in 2021 was equal to the grand mean. Since 2006, the trawl CPUE occasionally varied significantly from the grand mean (Figure 1.34).

Six different genera were collected by beach seine in 2021, which was above the average (3.5 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment in 2021 (H = 0.3) was below the time series average (H = 0.4). *Agardhiella* (94.4%) was most abundant and the only genera that contributed more than 5% of the sample population. The 2021 beach seine CPUE (13.5 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE occasionally varied significantly from the grand mean (Figure 1.35).

Sinepuxent Bay
This embayment has been dominated by Rhodophyta in 13 of the 16 years since sampling began in 2006 (Table 1.17). Ten different genera of macroalgae were collected by trawl in 2021, which was above the average (9.7 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment in 2021 (H = 1.2) was below the average (H = 1.3). *Agardhiella* (43.3%) was most abundant; *Ulva* (36.2%) and *Polysiphonia* (15.8%) were the only genera that contributed more than 5% of the sample population. Trawl CPUE (23.9 L/ha) in 2021 was equal the grand mean. Since 2006, the trawl CPUE occasionally varied significantly from the grand mean (Figure 1.36).

Seven different genera were collected by beach seine in 2021, which was above the average (6 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment in 2021 (H = 0.5) was below the average (H = 0.6). *Agardhiella* (88.6%) was most abundant. *Polysiphonia* (7.1%) was the only other genera that contributed more than

5% of the sample population. The 2021 beach seine CPUE (34.1 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE occasionally varied significantly from the grand mean (Figure 1.37).

Newport Bay
This embayment has been dominated by Rhodophyta in 13 of the 16 years since sampling began in 2006 (Table 1.17). Eight different genera were collected by trawl in 2021, which was above the average (6.5 genera) for this embayment in the time series. The 2021 Shannon index of diversity among genera (H = 0.9) within this embayment was below the time series average (H = 1.1). *Polysiphonia* (67.6%) was most abundant. *Agardhiella* (20.1%) and *Ulva* (8.6%) were the only other genera that contributed more than 5% of the sample population. Trawl CPUE (60 L/ha) was equal to the grand mean. Since 2006, the trawl CPUE frequently varied significantly from the grand mean (Figure 1.38).

Three genera were collected by beach seine in 2021, which was below the average (3.1 genera) for this embayment in the time series. The Shannon index of diversity among genera (H = 0.7) was above the time series average (H = 0.4). *Agardhiella* (57.4%) was most abundant. *Polysiphonia* (42.6%) was the only other genera that contributed more than 5% of the sample population. The 2021 beach seine CPUE (13.8 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE occasionally varied significantly from the grand mean (Figure 1.39).

Chincoteague Bay
This embayment has undergone periodic shifts in macroalgae dominance (Table 1.17). Ten different genera were collected by trawl in 2021, which was below the times series average (11.4 genera). The 2021 Shannon index of diversity among genera (H = 1.4) was below the average (H = 1.5) within this embayment for the time series. *Polysiphonia* (33.6%) was most abundant; *Agardhiella* (31.8%) and *Chaetomorpha* (26.7%) were the only other genera that contributed more than 5% of the sample population. The CPUE (56.3 L/ha) was below the grand mean. Since 2006, the trawl CPUE occasionally varied significantly from the grand mean (Figure 1.40).

Ten different genera were collected by beach seine in 2021, which was above the average (6.9 genera) for this embayment in the time series. The Shannon index of diversity among genera (H = 0.8) was below the time series average (H = 0.9). *Polysiphonia* (65.8%) was most abundant. *Agardhiella* (31.1%) was the only other genera that contributed more than 5% of the sample population. The 2021 beach seine CPUE (19.4 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE frequently varied significantly from the grand mean (Figure 1.41).

Overall, macroalgae richness was moderate and diversity was low across the embayments. Chincoteague Bay was the richest and most diverse embayment in both surveys, a condition that reacts to changes in the environment. The high abundance of *Codium* in 2020 was not present in 2021. This concerning invasive species competes with eelgrass or widgeon grass, can accumulate in dense patches preventing movement of fishes, and smothers shellfish beds. It has been reported that *Codium* and other macroalgae epiphytes consisting of diatoms, zooplankton, larval species of shellfish, and sponges live on the surface (Oktay, 2008).

Macroalgae may benefit the coastal bays in nutrient cycling and by providing cover, food, and habitat for crustaceans, fishes, and other organisms. Timmons (1995) found summer flounder from the south shores of Rehoboth Bay and Indian River have a preference for sand but have been captured near large aggregations of *Agardhiella tenera* only when large numbers of grass shrimp (*Palaemonetes vulgaris*) were present. This survey has also captured large numbers of summer flounder in association with *Agardhiella tenera* and *Ulva*. Underwater visualization is needed to confirm those interactions because the catch was bundled together in the codend when the tow was complete. Dense macroalgae canopies covering SAV were observed in Chincoteague and Sinepuxent bays, which can indirectly inhibit the productivity of seagrasses through changes in the biogeochemical environment (Hauxwell, Cebrian, Furlong, & Valiela, 2001). Shifts in the dominance of macroalgae over seagrasses in estuaries have been primarily attributed to nutrient overloading and light limitation. In estuaries where *Ulva* and *Zostera* co-exist and compete, climate change and eutrophication driven increases in carbon dioxide are likely to be important in promoting the dominance of *Ulva* over *Zostera* (Young, Peterson, & Gobler, 2018).

Water Quality

Water Temperature

The mean seasonal trawl temperatures varied by as much as 3.0 C among the bays. For all bays, mean surface temperature peaked in July as expected (Figure 1.42). Water temperature was coolest in April within all bays except Newport Bay. Newport Bay had a slightly higher temperature in April than October. The average trawl temperature for all bays in 2021 was 22.6 C, which was lower than the average temperature in 2020 (24.0 C; Figure 1.43). Regression analysis of the annual April through October 1989 to 2021 mean surface water temperature indicated a significant increase in temperature over the time series ($r(33) = 0.60$, $p = 0.0003$; Figure 1.43).

During the June Beach Seine Survey, there was an 8.2 C difference between the highest (29 C at site S006) and lowest temperatures (20.8 C at site S009; Figure 1.44). In September, the temperature difference between the highest (27.1 C at site S012) and lowest temperature (23.8 C at site S008) was 3.3 C. When comparing June and September results, the St. Martin River and Sinepuxent Bay experienced the most abrupt temperature changes (3.2 C St. Martin River and 1.2 C Sinepuxent Bay).

The average mean temperature has increased since 1989, which has supported the abundance and species composition expansion of fishes and invertebrates into Maryland waters. These surveys have documented an increased abundance of species traditionally considered southern, such as Atlantic spadefish, pinfish, sheepshead, and penaeid shrimp. Warmer temperatures have supported range expansions into our sampling area and warrants monitoring of changes in species composition.

Dissolved Oxygen

As expected, the trawl DO generally decreased as water temperatures increased (Figure 1.45). The mean trawl DO for all bays in 2021 was 6.6 mg/L. Surface DO measured below 5 mg/L eight times in 2021 and those events were scattered from June through September. For organisms in the Chesapeake Bay, 5 mg/L is accepted as necessary for life, but that value can vary based on the organism (Chesapeake Bay Program, 2021). For example, a DO of up to 6 mg/L is necessary for larvae and eggs of spawning migratory fish, however, some bottom dwelling fishes can tolerate DO levels as low as 3 mg/L (Chesapeake Bay Program, 2021). Regression analysis of the annual April through October 1998 to 2021 mean DO results indicated a significantly increasing DO since 1998 ($r(24) = 0.68$, $p = 0.0003$; Figure 1.46).

The 2021 Beach Seine Survey mean DO was higher in September than June, and was equal or above 5 mg/L for 30 out 38 samples (Figure 1.47). Despite DO being below 5 mg/L eight times with the lowest DO occurring at S019 (2.9 mg/L) in September, catches were within normal expectations. Hypoxic conditions (below 2 mg/L) were not observed in the 2021 survey; however, it has occurred six times since 1998. Five of those occurrences were at S019 and once was at T006. Low DO concentrations give rise to the concern that hypoxia is occurring in the Maryland coastal bays during the summer months although at this point it is infrequent and long term consequences have not been apparent (i.e. fish kills).

Dissolved oxygen peaks during the day and can actually supersaturate from photosynthesis and bottoms out at night when respiration occurs. Sampling occurs during the day when low DO impacts on fish catches may not be evident. Shen *et al*. (2008) investigated hypoxia in a Virginia tributary to the Chesapeake Bay, utilizing a DO-algae model to examine DO fluctuations beginning in July and ending in the fall. Experiments with the model demonstrated that macroalgae influenced the net ecosystem metabolism because of its respiration and growth rates. Nutrient input due to human activity would encourage blooms of macroalgae, which would yield high DO levels during the day. During nighttime hours, DO levels were overridden by high respiration leading to hypoxic conditions.

Salinity

The 2021 Trawl Survey bay wide average salinity (27.4 ppt) was higher than 2020 (25.9 ppt). Newport Bay salinity was the lowest (23.7) over the 2021 sampling period (Figure 1.48). Salinity in most of the embayments tended to rise as the season progressed. The Newport Bay average was influenced by the salinity taken at site, T012, which was located in Trappe Creek, far from the inlets with multiple creeks draining into that area. Sinepuxent Bay, which is located nearby the inlet, had the highest average seasonal salinity (29.5 ppt). Regression analysis of the annual April through October 1989 to 2021 mean salinity results indicated no significant trend in salinity ($r(33) = 0.02$, $p = 0.924$; Figure 1.49).

The Beach Seine Survey bay wide salinities varied between June and September. The lowest salinities were within Chincoteague Bay in June (23.4 ppt) and Newport Bay in September (27.1). The highest salinities were within Sinepuxent Bay in both June (30.0) and September (29.0 ppt; Figure 1.50).

Turbidity

The 2021 Trawl Survey bay wide mean turbidity was 101 cm. The St. Martin River was the most turbid embayment (mean = 63.8 cm) whereas Chincoteague Bay was the least (mean = 120.4 cm; Figure 1.51). The bottom was visible 14 times (10%) out of 140 samples. Visibility decreased during the warmer months.

Regression analysis of the annual April through October 1989 to 2021 mean turbidity results indicated no significant trend in turbidity since 2006 ($r(16) = 0.52$, $p = 0.0407$; Figure 1.52). The bay wide mean turbidity value over the time series from 2006 to 2021 was 87.4 cm. This was below the 2021 mean (101 cm). Site T020, located on the Maryland - Virginia state line, was the clearest (133.1 cm) in the time series.

The waters became less turbid in Sinepuxent, Newport, and Chincoteague bays from June to September in the 2021 Beach Seine Survey (Figure 1.53). Turbidity increased in the other three bays. Newport Bay had the worst annual visibility (53.9 cm) and Chincoteague Bay had the best mean annual visibility (66.2 cm).

Although Kemp *et al*. (2004) found that 150 cm was a sufficient depth to allow enough light for SAV growth, most of the trawl and beach seine sites do not have SAV. Few trawl sites are suitable for SAV and are limited by depth (>5 ft), located near channels or high flow areas. Unlike trawl sites, beach seine sites are less than <5 ft deep but are mostly devoid of SAV except for a few sites on the eastern side of Chincoteague Bay. SAV may be limited at those sites by not only turbidity, but also warm summer water temperatures, bottom substrate, and macroalgae.

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 race track	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, north east 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, north east 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 north west 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	South east 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	Wing span
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 2021. Species are listed by order of total abundance (T n = 140, S n = 38).

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	CPUE (T) #/ha	CPUE (S) #/haul
Atlantic menhaden	*Brevoortia tyrannus*	6,540	344	6,196	19.6	163.0
Bay anchovy	*Anchoa mitchilli*	2,950	2,468	482	140.6	12.7
Atlantic silverside	*Menidia menidia*	1,756	21	1,735	1.2	45.6
Spot	*Leiostomus xanthurus*	718	281	437	16.0	11.5
Silver perch	*Bairdiella chrysoura*	628	527	101	30.0	2.6
Summer flounder	*Paralichthys dentatus*	303	81	222	4.6	5.8
Striped anchovy	*Anchoa hepsetus*	221	170	51	9.7	1.3
Weakfish	*Cynoscion regalis*	206	206		11.7	
Striped killifish	*Fundulus majalis*	192		192		5.0
Atlantic croaker	*Micropogonias undulatus*	150	142	8	8.1	0.2
Blackcheek tonguefish	*Symphurus plagiusa*	130	13	117	0.7	3.1
Hogchoker	*Trinectes maculatus*	83	72	11	4.1	0.3
Inshore lizardfish	*Synodus foetens*	80	35	45	2.0	1.2
Winter flounder	*Pseudopleuronectes americanus*	76	13	63	0.7	1.6
Black sea bass	*Centropristis striata*	74	49	25	2.8	0.7
White mullet	*Mugil curema*	71		71		1.9
Sheepshead	*Archosargus probatocephalus*	61	2	59	0.1	1.6
Mummichog	*Fundulus heteroclitus*	58	4	54	0.2	1.4
Pigfish	*Orthopristis chrysoptera*	53	2	51	0.1	1.3
Atlantic needlefish	*Strongylura marina*	52		52		1.4
Pinfish	*Lagodon rhomboides*	49	1	48	0.1	1.3
Lookdown	*Selene vomer*	32	23	9	1.3	0.2
Oyster toadfish	*Opsanus tau*	30	7	23	0.4	0.6
Striped mullet	*Mugil cephalus*	27		27		0.7
Black drum	*Pogonias cromis*	24	2	22	0.1	0.6
Northern pipefish	*Syngnathus fuscus*	24	3	21	0.2	0.6
Dusky pipefish	*Syngnathus floridae*	19	2	17	0.1	0.4
Harvestfish	*Peprilus paru*	19	1	18	0.1	0.5
American eel	*Anguilla rostrata*	17	16	1	0.9	<0.1
Golden shiner	*Notemigonus crysoleucas*	17		17		0.4
Halfbeak	*Hyporhamphus unifasciatus*	16		16		0.4
Naked goby	*Gobiosoma bosc*	16	9	7	0.5	0.2
Northern sennet	*Sphyraena borealis*	14	13	1	0.7	<0.1
Northern puffer	*Sphoeroides maculatus*	13	2	11	0.1	0.3
Spotfin mojarra	*Eucinostomus argenteus*	11	3	8	0.2	0.2
Tautog	*Tautoga onitis*	10	1	9	0.1	0.2
Blue runner	*Caranx crysos*	9	3	6	0.2	0.2

Table 1.4. List of fishes collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2021. Species are listed by order of total abundance (T n = 140, S n = 38).

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	CPUE (T) #/ha	CPUE (S) #/haul
Striped blenny	*Chasmodes bosquianus*	9		9		0.2
Bluefish	*Pomatomus saltatrix*	8		8		0.2
Spotted hake	*Urophycis regia*	8	8		0.5	
Southern stingray	*Dasyatis americana*	7		7		0.2
Spotted seatrout	*Cynoscion nebulosus*	7	4	3	0.2	<0.1
Gizzard shad	*Dorosoma cepedianum*	6		6		0.2
Alewife	*Alosa pseudoharengus*	5		5		0.1
Bluespotted cornetfish	*Fistularia tabacaria*	4	1	3	0.1	<0.1
Rainwater killifish	*Lucania parva*	4	1	3	0.1	<0.1
Feather blenny	*Hypsoblennius hentz*	3		3		<0.1
Lined seahorse	*Hippocampus erectus*	3	3		0.2	
Smallmouth flounder	*Etropus microstomus*	3	1	2	0.1	<0.1
Southern kingfish	*Menticirrhus americanus*	3	2	1	0.1	<0.1
Striped bass	*Morone saxatilis*	3		3		<0.1
Striped burrfish	*Chilomycterus schoepfii*	3	1	2	0.1	<0.1
Striped searobin	*Prionotus evolans*	3	1	2	0.1	<0.1
Butterfish	*Peprilus triacanthus*	2	2		0.1	
Green goby	*Microgobius thalassinus*	2		2		<0.1
Northern searobin	*Prionotus carolinus*	2	1	1	0.1	<0.1
Northern stargazer	*Astroscopus guttatus*	2	1	1	0.1	<0.1
Scup	*Stenotomus chrysops*	2	2		0.1	
Spanish mackerel	*Scomberomorus maculatus*	2	2		0.1	
Atlantic cutlassfish	*Trichiurus lepturus*	1	1		0.1	
Blueback herring	*Alosa aestivalis*	1		1		<0.1
Bluegill	*Lepomis macrochirus*	1		1		<0.1
Cobia	*Rachycentron canadum*	1		1		<0.1
Conger eel	*Conger oceanicus*	1		1		<0.1
Largemouth bass	*Micropterus salmoides*	1		1		<0.1
Orange filefish	*Aluterus schoepfii*	1	1		0.1	
Planehead filefish	*Stephanolepis hispida*	1	1		0.1	
Pumpkinseed	*Lepomis gibbosus*	1		1		<0.1
Smooth butterfly ray	*Gymnura micrura*	1		1		<0.1
Spotfin butterflyfish	*Chaetodon ocellatus*	1		1		<0.1
	Total Finfish	**14,851**	**4,549**	**10,302**		

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

Table 1.6. Summary of the 2021 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*	Equal	Below
Atlantic croaker	*Micropogonias undulatus*	Below	Equal
Atlantic menhaden	*Brevoortia tyrannus*	Equal	Equal
Atlantic silverside	*Menidia menidia*	Equal	Equal
Bay anchovy	*Anchoa mitchilli*	Below	Below
Black sea bass	*Centropristis striata*	Equal	Equal
Bluefish	*Pomatomus saltatrix*	Below	Below
Sheepshead	*Archosargus probatocephalus*	Equal	Above
Silver perch	*Bairdiella chrysoura*	Equal	Below
Spot	*Leiostomus xanthurus*	Below	Below
Summer flounder	*Paralichthys dentatus*	Below	Above
Weakfish	*Cynoscion regalis*	Below	Below

Table 1.7. List of crustaceans collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2021. Species are listed by order of total abundance (T n = 140, S n = 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
Blue crab	*Callinectes sapidus*	3,170	1,407	1,763			80.1	46.4
Grass shrimp	*Palaemonetes sp.*	1,191	76	45	85	985	9.2	27.1
White shrimp	*Litopenaeus setiferus*	533	497	36			28.3	0.9
Lady crab	*Ovalipes ocellatus*	188	76	112			4.3	2.9
Sand shrimp	*Crangon septemspinosa*	176	86	3	50	37	7.7	1.1
Brown shrimp	*Farfantepenaeus aztecus*	173	141	32			8.0	0.8
Long-armed hermit crab	*Pagurus longicarpus*	138	45	93			2.6	2.4
Say mud crab	*Dyspanopeus sayi*	129	113	16			6.4	0.4
Arrow Shrimp	*Tozeuma carolinense*	92		92				2.4
Mantis shrimp	*Squilla empusa*	37	37				2.1	
Atlantic rock crab	*Cancer irroratus*	3	3				0.2	
Portly spider crab	*Libinia emarginata*	3	3				0.2	
Bigclaw snapping shrimp	*Alpheus heterochaelis*	2	2				0.1	
Lesser blue crab	*Callinectes similis*	2		2				<0.1
	Total Crustaceans	**5,837**	**2,486**	**2,194**	**135**	**1,022**		

Table 1.8. List of molluscs collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2021. Species are listed by order of total abundance (T n = 140, S n = 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*	600				600						15.8		
Sponge slug	*Doris verrucosa*	165	69	96							3.9	2.5		
Atlantic brief squid	*Lolliguncula brevis*	152	147	5							8.4	0.1		
Eastern mudsnail	*Nassarius obsoletus*	17	3	14							0.2	0.4		
Solitary glassy bubble snail	*Haminoea solitaria*	17	2		15						1.0			
Bruised nassa	*Nassarius vibex*	10	3	7							0.2	0.2		
Atlantic oyster drill	*Urosalpinx cinerea*	8	7	1							0.4	<0.1		
Common Atlantic slippersnail	*Crepidula fornicata*	2	2								0.1			
Eastern oyster	*Crassostrea virginica*	2		2								<0.1		
Northern quahog	*Mercenaria mercenaria*	2		2								<0.1		
Stout tagelus	*Tagelus plebeius*	2	2								0.1			
Cayenne keyhole limpet	*Diodora cayenensis*	1	1								0.1			
Dwarf surfclam	*Mulinia lateralis*	1		1								<0.1		
Green jackknife	*Solen viridis*	1	1								0.1			
Lemon drop	*Doriopsilla pharpa*	1	1								0.1			
Purplish tagelus	*Tagelus divisus*	1	1								0.1			
Ribbed mussel	*Geukensia demissa*	1		1								<0.1		
Striped nudibranch	*Cratena pilata*	1	1								0.1			
Threeline mudsnail	*Nassarius trivittatus*	1	1								0.1			
	Total Molluscs	**985**	**241**	**129**	**15**	**600**								

Table 1.9. List of other species collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October 2021. Species are listed by order of total abundance (T n = 140, S n = 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*	1,883	77	1	1,805		21.1			2.0	107.2	<0.1	1.2	<0.1
Sea nettle	*Chrysaora quinquecirrha*	838	286	2	550		1.5				47.6	<0.1	<0.1	
Comb jellies	*Ctenophora*	358	235	7	116	0	418.4	50.5		0.5	20.0	0.2	23.8	1.3
Moon jelly	*Aurelia aurita*	68	63	5							3.6	0.1		
Horseshoe crab	*Limulus polyphemus*	46	15	31							0.9	0.8		
Hairy sea cucumber	*Sclerodactyla briareus*	37	27	10							1.5	0.3		
Northern diamondback terrapin	*Malaclemys terrapin terrapin*	8	3	5							0.2	0.1		
Sea gooseberry	*Pleurobrachia pileus*	6	6								0.3			
Hydromedusae	*Hydrozoa*	1	1								0.1			
Goldstar tunicate	*Botryllus schlosseri*						3.7	0.1					0.2	
Sea pork	*Aplidium sp.*						5.8	0.1					0.3	
Bryozoans	*Ectoprocta*						33.3	9.2					1.9	0.2
Rubbery bryozoan	*Alcyonidium sp.*						1.6	4.0					<0.1	0.1
Halichondria sponge	*Halichondria sp.*						37.2	7.4					2.1	0.2
Red beard sponge	*Microciona prolifera*						72.5	8.5					4.1	0.2
Sulphur sponge	*Cliona celata*						30.8						1.8	
	Total Other	**3,245**	**713**	**61**	**2,471**	**0.3**	**625.8**	**79.8**		**2.5**				

Table 1.10. 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 2021. Species are listed by order of total abundance (T n = 140, S n = 38).

Common Name	Genus	Specific Volume (L) (T)	Specific Volume (L) (S)
SAV			
Eelgrass	*Zostera*	5.9	3.9
Widgeon grass	*Ruppia*	0.4	5.0
	Total SAV	6.3	8.9
Macroalgae			
Brown			
Common southern kelp	*Laminaria*	0.5	
	Total Brown	0.5	
Green			
Green hair algae	*Chaetomorpha*	106.4	4.1
Sea lettuce	*Ulva*	90.8	81.7
Green Fleece	*Codium*	13.8	7.7
Hollow green weed	*Enteromorpha*	9.5	3.4
Green tufted seaweed	*Cladophora*	8.5	
Smooth stonewort	*Nitella*		0.5
	Total Green	228.9	97.4
Red			
Agardh's red weed	*Agardhiella*	546.3	899
Tubed weeds	*Polysiphonia*	218.4	190.9
Barrel weed	*Champia*	2.6	0.03
Graceful red weed	*Gracilaria*	2.1	
Banded weeds	*Ceramium*	1.3	0.1
	Total Red	770.7	1090.3
Yellow-Green			
Water felt	*Vaucheria*	2.6	19.1
	Total Yellow-Green	2.6	19.1
	Total Macroalgae	1,002.7	1,206.53

Table 1.11. Length by month for selected fishes from the 2021 Trawl Survey.

	Month	Number Counted	Number Measured	Min Length (mm)	Max Length (mm)	Mean Length (mm)	SD
American eel (*Anguilla rostrata*)	April	8	8	50	170	67.3	41.6
	May	3	3	51	62	58	6.1
	June	1	1	255	255	255	
	July	4	4	60	270	147.5	93.9
Atlantic croaker (*Micropogonias undulatus*)	April	2	2	30	40	35	7.1
	May	62	40	40	108	68	11.8
	Jun	55	46	75	204	121	16.6
	Jul	20	20	140	249	182.5	30.1
	Aug	3	3	89	192	152.7	55.6
Atlantic menhaden (*Brevoortia tyrannus*)	May	16	16	33	49	41.1	5.4
	Jun	298	82	30	90	47.3	11.5
	Jul	10	10	50	84	62.7	8.9
	Aug	4	4	79	122	94	19.1
	Sep	11	10	69	107	89.7	11.4
	Oct	5	5	85	95	90.4	4.1
Atlantic silverside (*Menidia menidia*)	May	2	2	31	126	78.5	67.2
	Jun	18	18	32	98	58.8	17.4
Bay anchovy (*Anchoa mitchilli*)	April	8	8	51	79	58.9	8.8
	May	43	42	35	80	60	7.3
	Jun	213	152	29	89	63.9	
	Jul	431	235	20	93	52.5	20.4
	Aug	1,409	141	22	92	53.1	17
	Sep	320	91	36	95	54.4	16.2
	Oct	44	44	19	77	49.7	15
Black sea bass (*Centropristis striata*)	Jun	13	13	61	127	100.7	19.3
	Jul	23	22	20	146	115.6	26.1
	Aug	7	7	39	160	133.9	42.2
	Sep	6	6	138	188	163.7	20.9
Sheepshead (*Archosargus probatocephalus)*	Sep	2	2	115	135	125	14.1
Silver perch (*Bairdiella chrysoura*)	Jun	3	3	130	150	139.7	10
	Jul	293	132	19	167	44.4	25.8
	Aug	102	71	55	162	84.4	16.1
	Sep	118	84	72	125	97.9	10.7
	Oct	11	11	91	126	106.5	11.8
Spot (*Leiostomus xanthurus*)	May	9	8	67	76	72.4	3
	Jun	124	67	25	190	91.6	42.1
	Jul	65	57	54	206	99.5	27.9
	Aug	60	44	71	180	125.7	18
	Sep	21	21	125	199	141	15.7
	Oct	3	3	145	160	152	7.5

	Month	Number Counted	Number Measured	Min Length (mm)	Max Length (mm)	Mean Length (mm)	SD
Summer flounder (*Paralichthys dentatus*)	April	2	2	37	160	98.5	87
	May	28	27	34	172	64.6	26.9
	Jun	16	16	41	241	82.3	46.5
	Jul	15	15	80	271	127.2	56.9
	Aug	16	16	80	261	111.8	53.8
	Sep	4	4	88	110	96.5	10.6
Weakfish (*Cynoscion regalis*)	Jul	77	68	32	79	47.4	10.5
	Aug	105	66	45	130	96.5	15.1
	Sep	20	20	86	129	104	11.1
	Oct	4	4	121	151	133	12.8

Table 1.12. Length by month for selected fishes from the 2021 Beach Seine Survey.

	Month	Number Counted	Number Measured	Min Length (mm)	Max Length (mm)	Mean Length (mm)	SD
American eel (*Anguilla rostrata*)	Jun	1	1	45	45	45	
Atlantic croaker (*Micropogonias undulatus*)	Jun	7	7	27	157	64.3	58.7
	Sep	1	1	280	280	280	
Atlantic menhaden (*Brevoortia tyrannus*)	Jun	5,916	203	30	88	43.9	7.9
	Sep	1,097	38	62	132	85.4	17.5
Atlantic silverside (*Menidia menidia*)	Jun	638	226	20	131	85.4	17.5
	Sep	1,097	192	17	111	77.4	10.8
Bay anchovy (*Anchoa mitchilli*)	Jun	457	109	35	92	68.7	10.6
	Sep	25	25	22	87	45.2	20.3
Black sea bass (*Centropristis striata*)	Jun	14	14	52	109	84	14.5
	Sep	11	11	35	183	101	47.7
Bluefish (*Pomatomus saltatrix*)	Sep	8	8	102	130	111.8	22.3
Sheepshead (*Archosargus probatocephalus*)	Sep	59	57	13	185	78.8	22.6
Silver perch (*Bairdiella chrysoura*)	Jun	1	1	156	156	156	
	Sep	100	75	43	123	88.3	17.7
Spot (*Leiostomus xanthurus*)	Jun	350	181	30	215	103.8	49.9
	Sep	87	86	70	223	160.5	27.9
Summer flounder (*Paralichthys dentatus*)	Jun	171	152	45	287	78.3	33.5
	Sep	51	51	78	490	128.4	60.1

Table 1.13. Finfish richness and diversity by system for the 2021 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	24	1.4
St. Martin River	23	1.5
Isle of Wight Bay	26	2.1
Sinepuxent Bay	17	1.6
Newport Bay	14	1.7
Chincoteague Bay	19	1.0

Table 1.14. Finfish richness and diversity by system for the 1989 - 2021 Trawl Survey Assawoman Bay (n = 693), St. Martin River (n = 462), Isle of Wight Bay (n = 462), Sinepuxent Bay (n = 693), Newport Bay (n = 462), and Chincoteague Bay (n = 1,848)).

Embayment	Richness	Mean Richness	Mean Diversity
Assawoman Bay	81	28	1.4
St. Martin River	75	23.4	1.3
Isle of Wight Bay	85	30.3	1.6
Sinepuxent Bay	74	24.9	1.7
Newport Bay	69	21	1.4
Chincoteague Bay	89	34.8	1.5

Table 1.15. Finfish richness and diversity by system for the 2021 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	36	2.3
St. Martin River	27	2.2
Isle of Wight Bay	28	1.7
Sinepuxent Bay	34	1.7
Newport Bay	21	1.4
Chincoteague Bay	38	0.8
Ayers Creek	10	0.5

Table 1.16. Finfish richness and diversity by system for the 1989 - 2021 Beach Seine Survey: Assawoman Bay (n = 198), St. Martin River (n = 66), Isle of Wight Bay (n = 198), Sinepuxent Bay (n = 198), Newport Bay (n = 132), Chincoteague Bay (n = 396), and Ayers Creek (n = 66).

Embayment	Richness	Mean Richness	Mean Diversity
Assawoman Bay	88	30.6	1.6
St. Martin River	71	20.8	1.4
Isle of Wight Bay	87	29.5	1.6
Sinepuxent Bay	80	28	1.4
Newport Bay	70	20	1.6
Chincoteague Bay	85	33.6	1.7
Ayers Creek	44	14.1	1.2

Table 1.17. Macroalgae dominance in the Maryland Coastal Bays as sampled by the Trawl and Beach Seine surveys 2006 - 2021.

	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

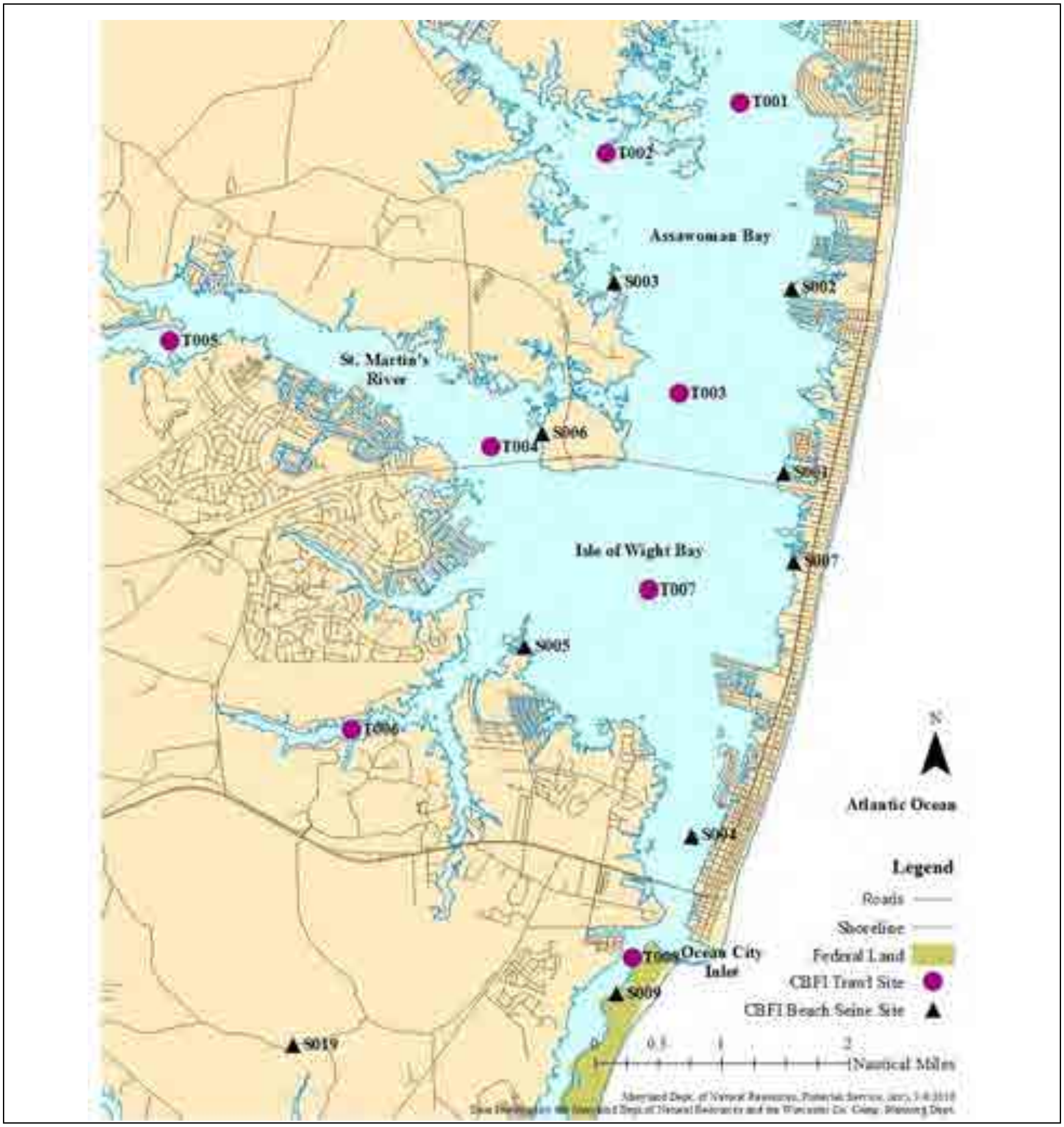

Figure 1.1. Trawl and Beach Seine surveys sampling locations in the Assawoman and Isle of Wight bays, Maryland.

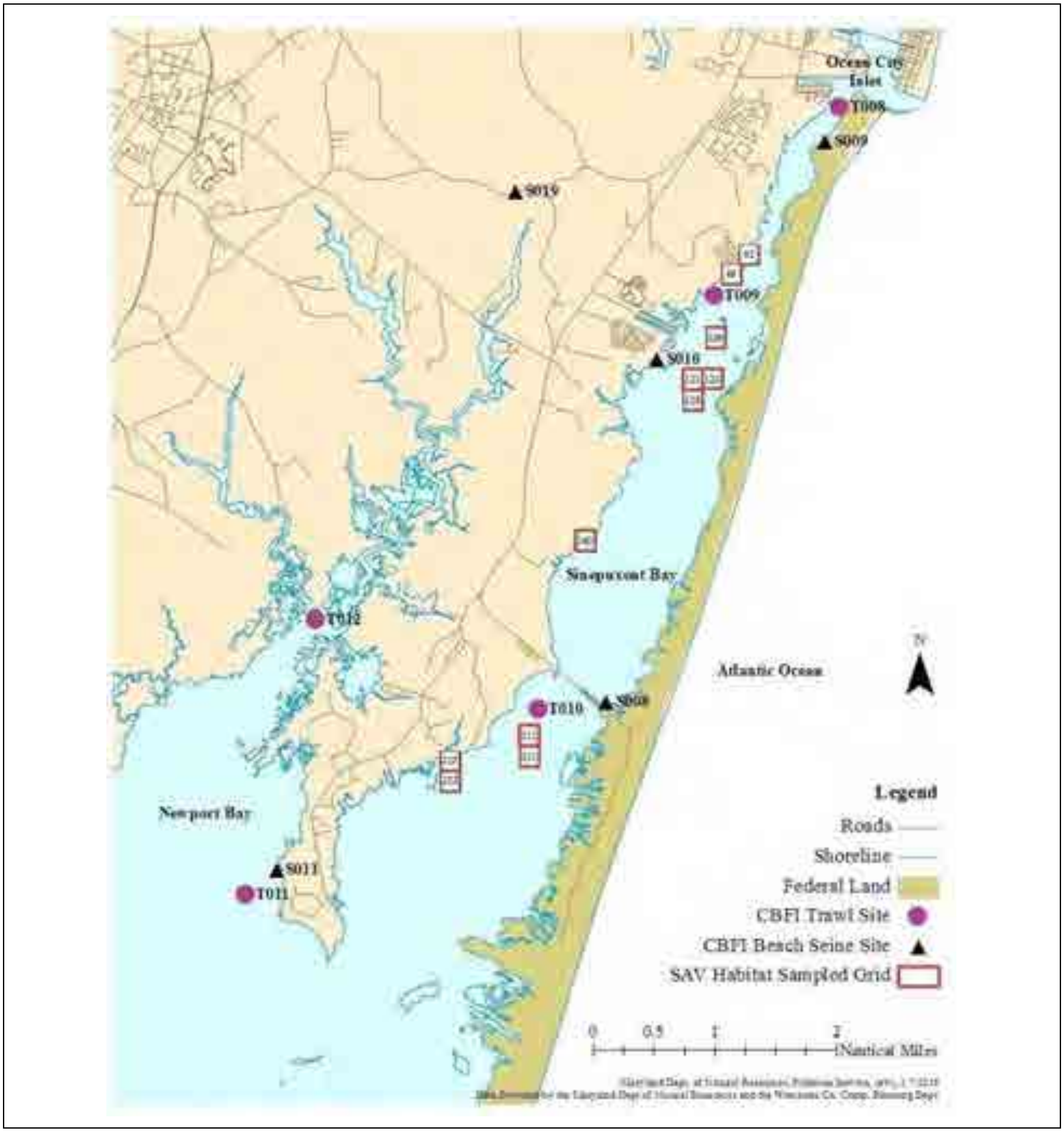

Figure 1.2. Trawl and Beach Seine surveys sampling locations in Sinepuxent and Newport bays, Maryland.

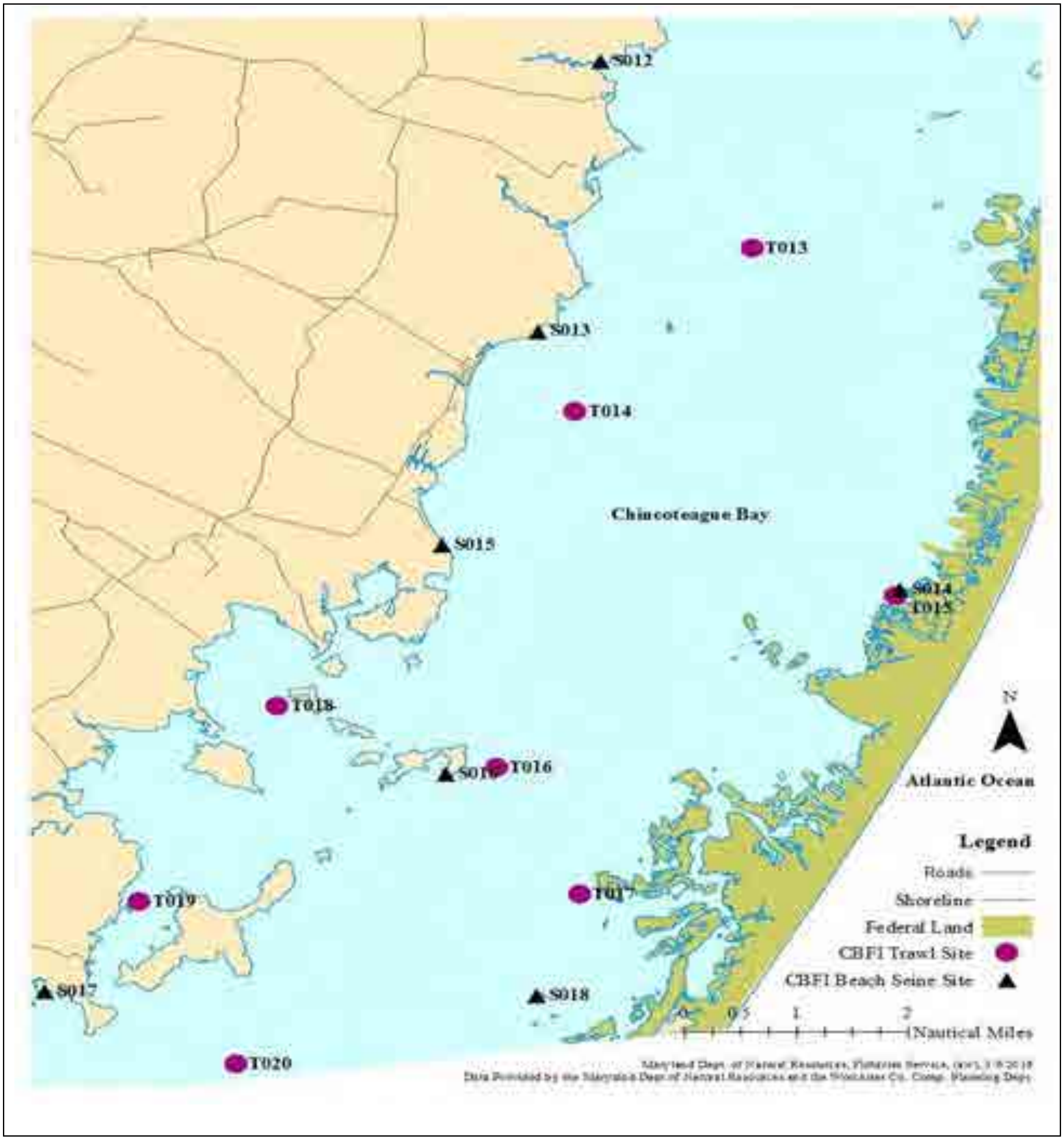

Figure 1.3. Trawl and Beach Seine surveys sampling locations in Chincoteague Bay, Maryland.

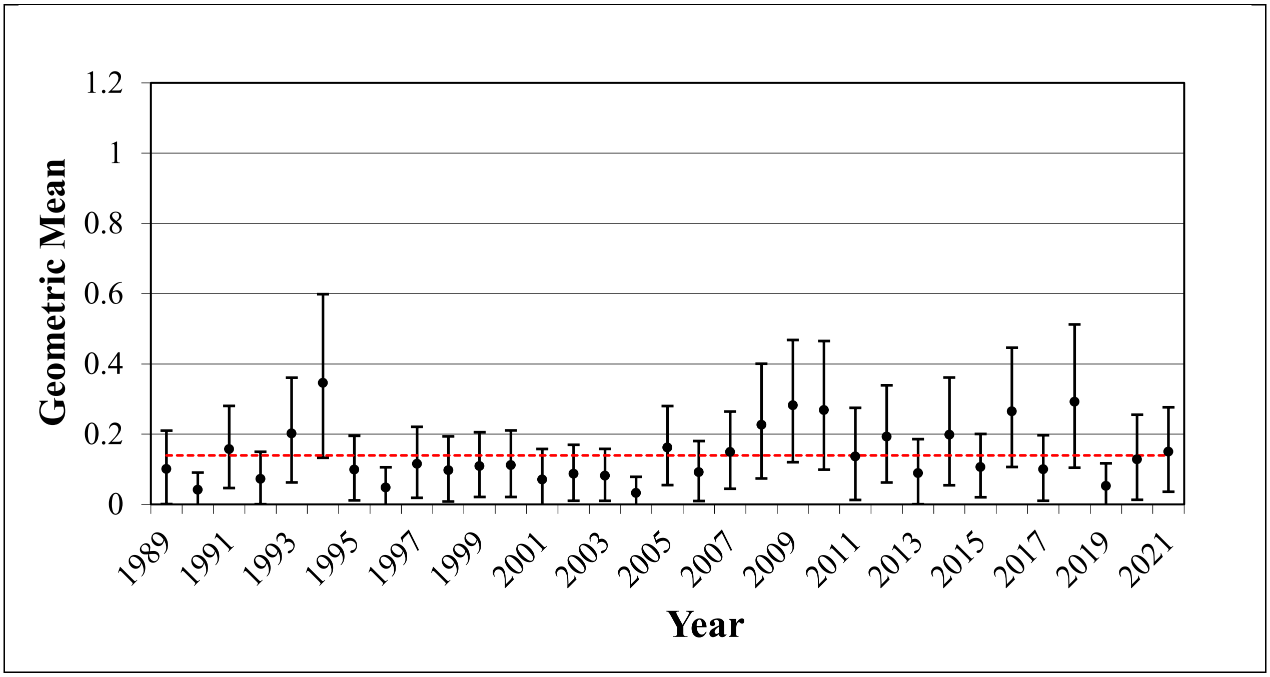

Figure 1.4. American eel (*Anguilla rostrata*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120).

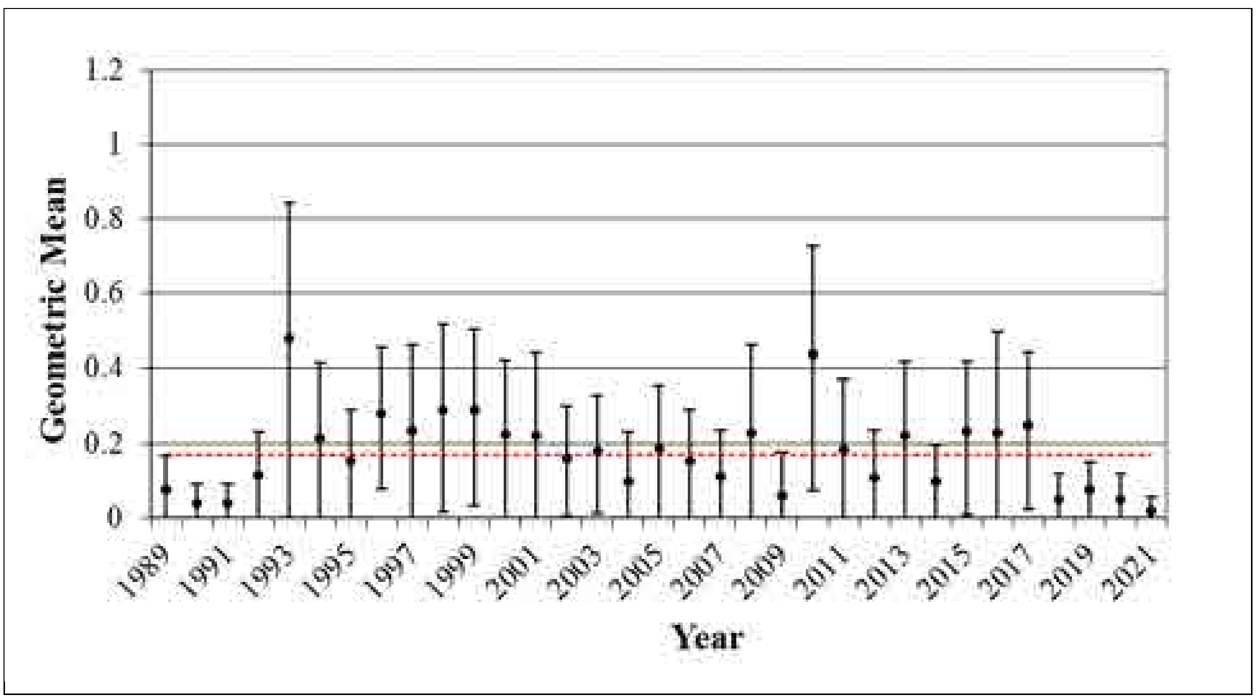

Figure 1.5. American eel (*Anguilla rostrata*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

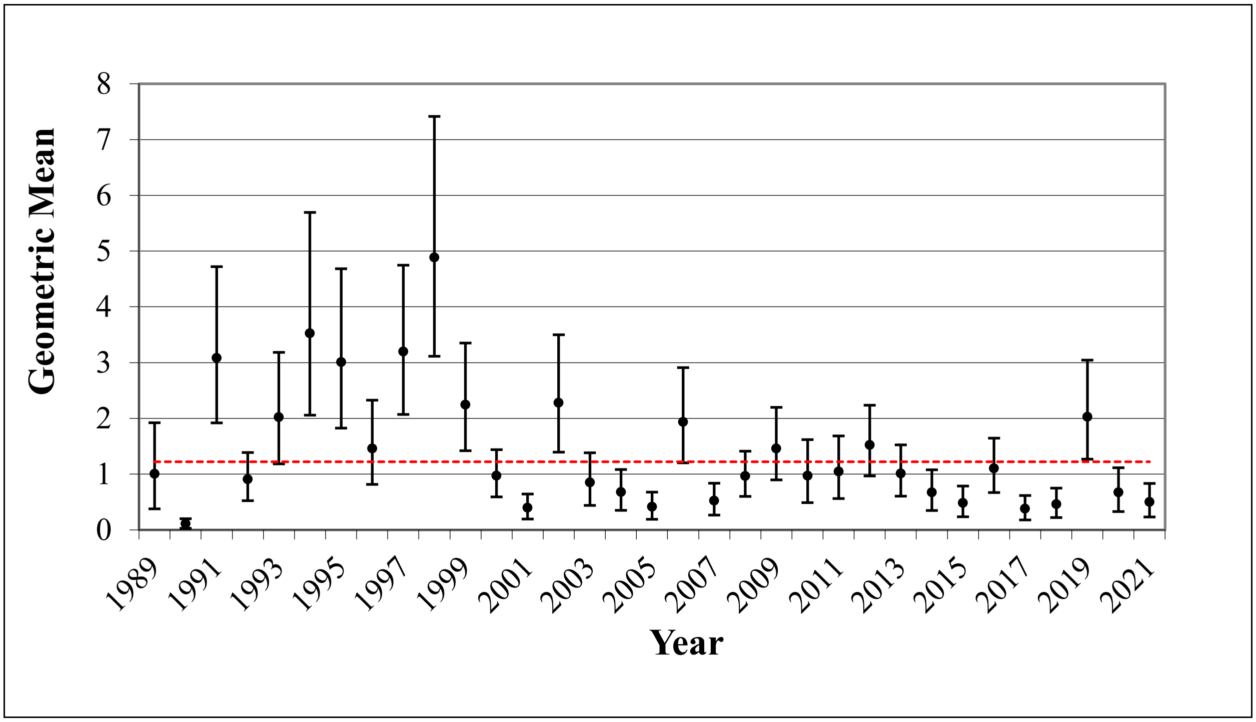

Figure 1.6. Atlantic croaker (*Micropogonias undulatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120).

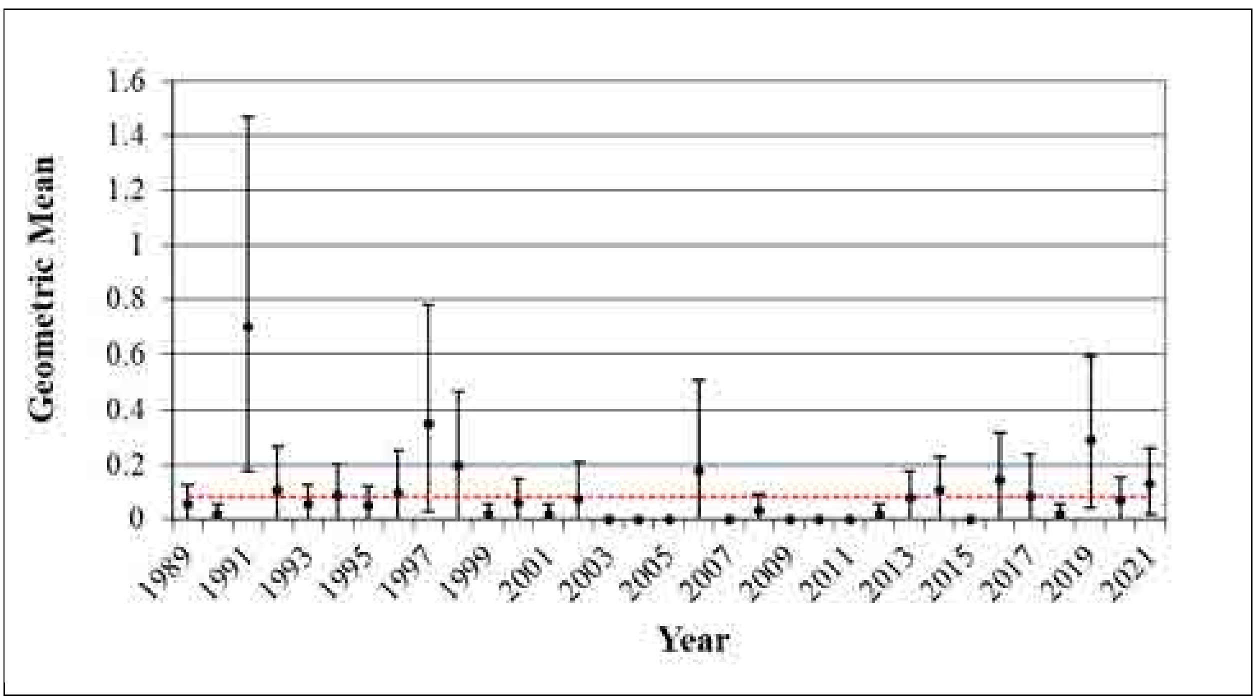

Figure 1.7. Atlantic croaker (*Micropogonias undulatus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

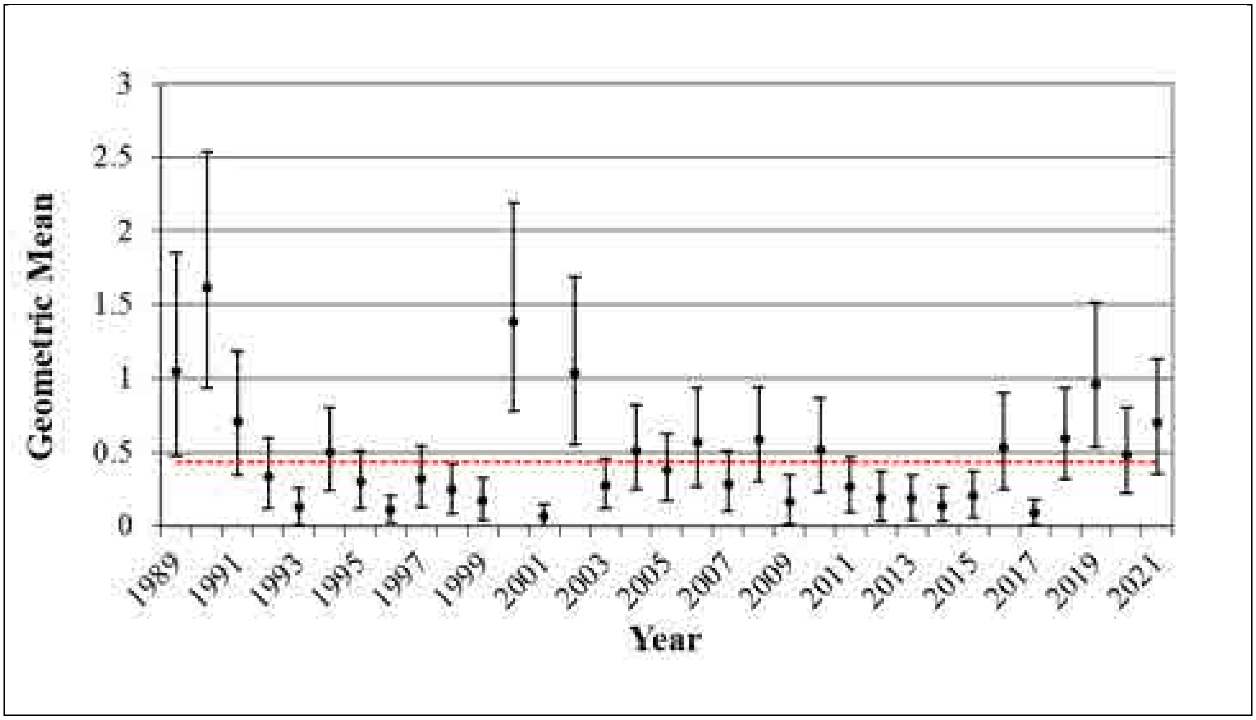

Figure 1.8. Atlantic menhaden (*Brevoortia tyrannus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989 – 2019, 2021}$ = 140/year, n_{2020} = 120).

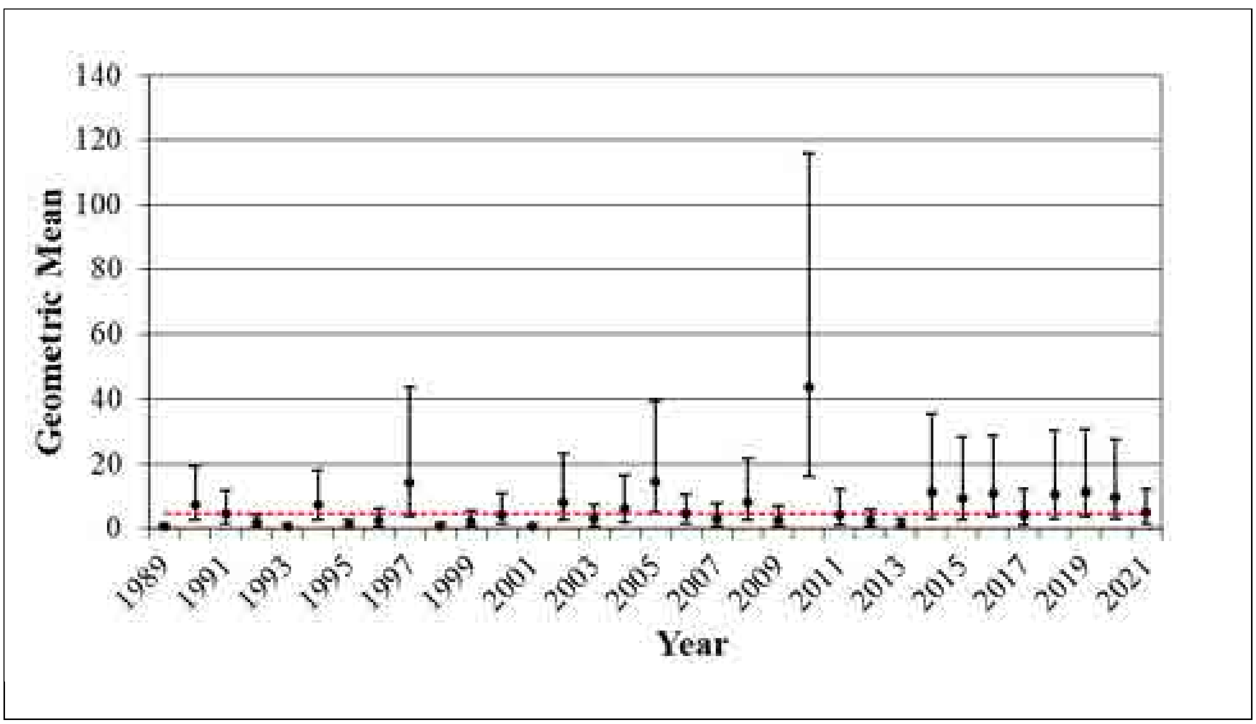

Figure 1.9. Atlantic menhaden (*Brevoortia tyrannus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

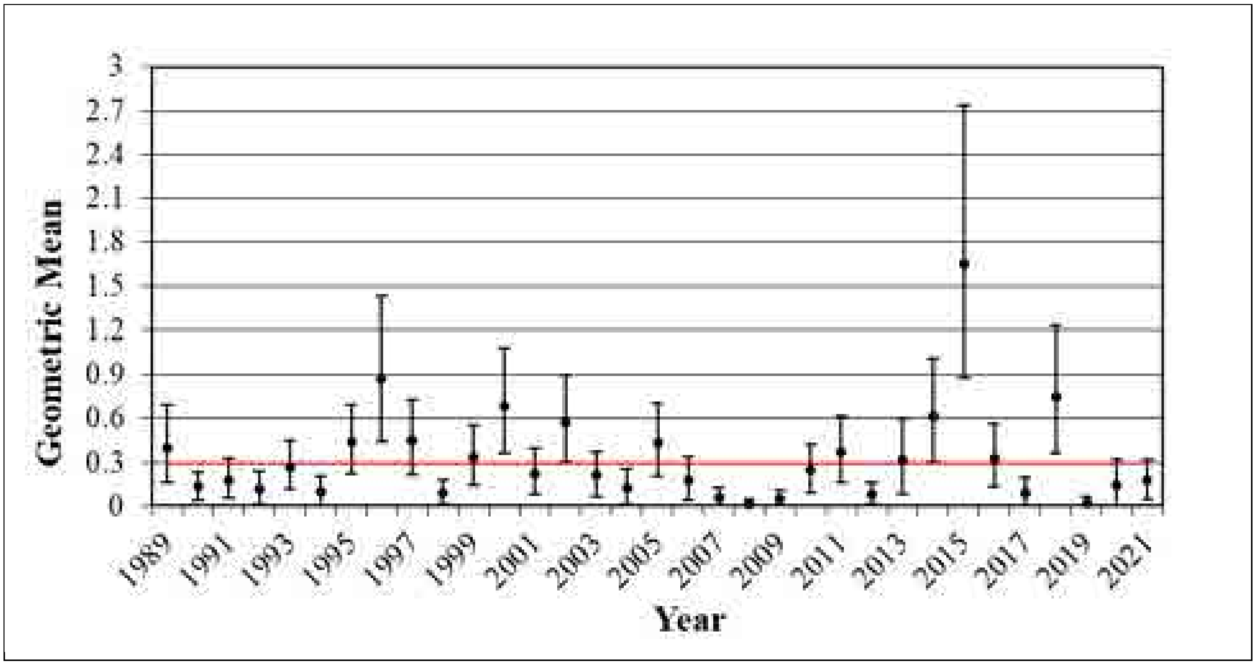

Figure 1.10. Atlantic silverside (*Menidia menidia*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120).

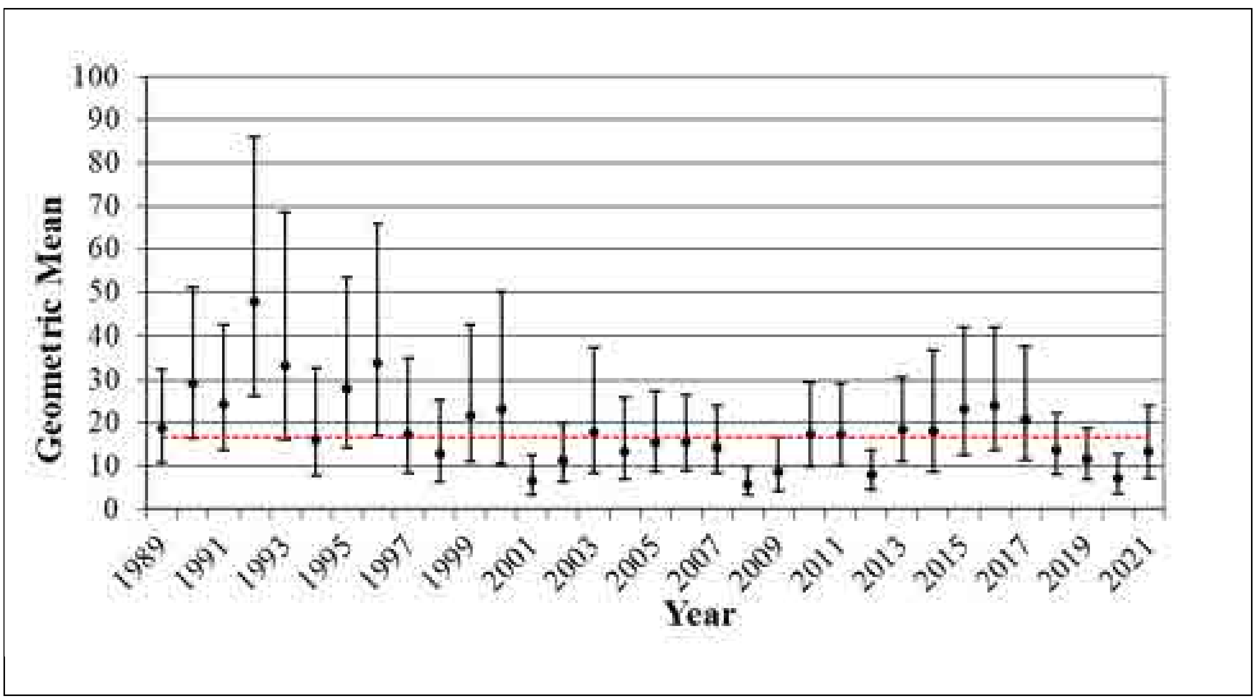

Figure 1.11. Atlantic silverside (*Menidia menidia*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

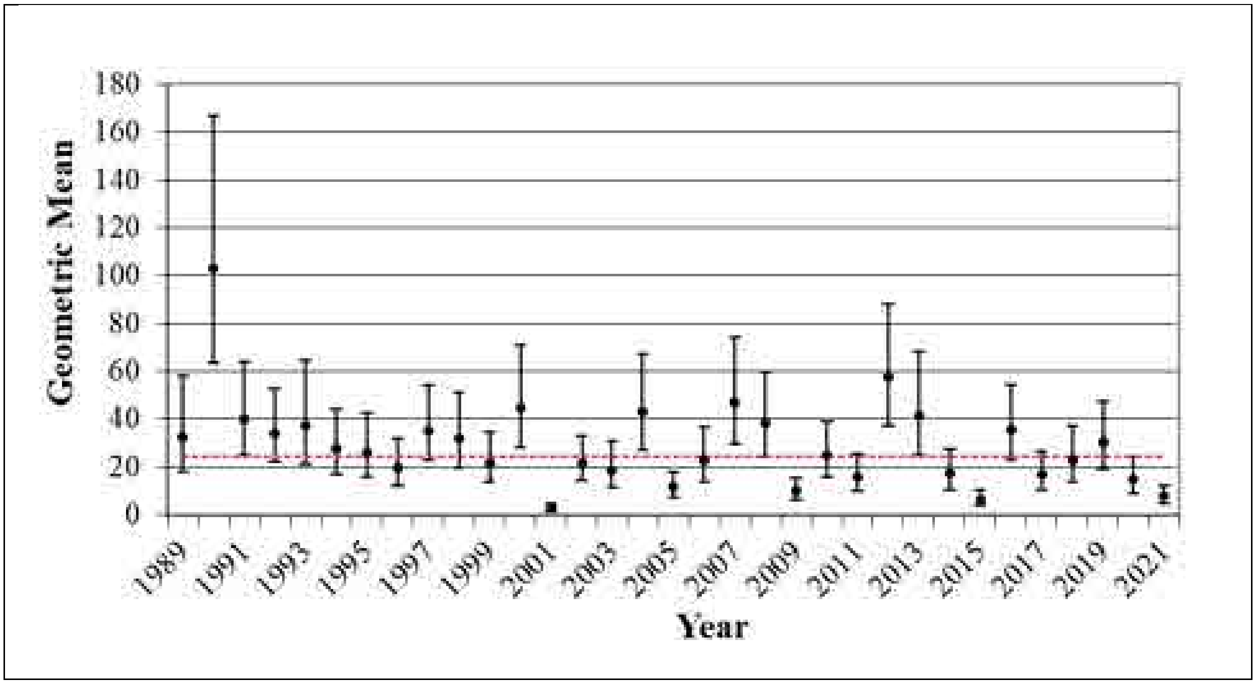

Figure 1.12. Bay anchovy (*Anchoa mitchilli*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120).

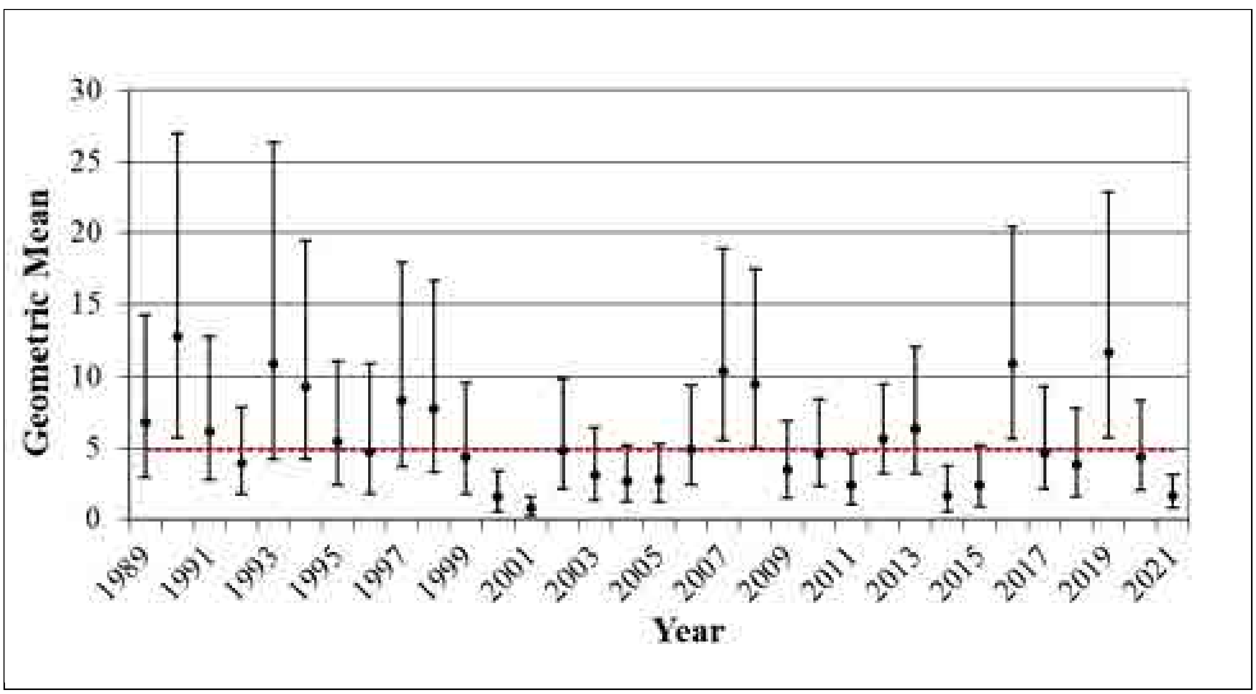

Figure 1.13. Bay anchovy (*Anchoa mitchilli*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

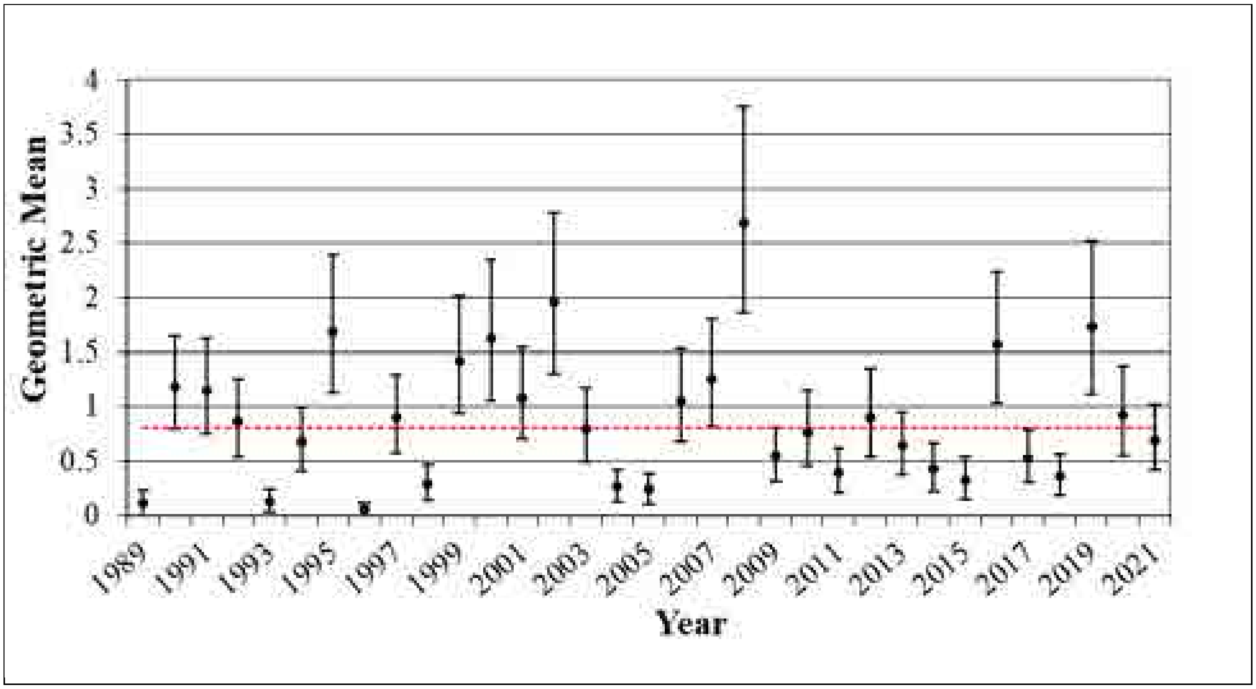

Figure 1.14. Black sea bass (*Centropristis striata*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019,\ 2021}$ = 140/year, n_{2020} = 120).

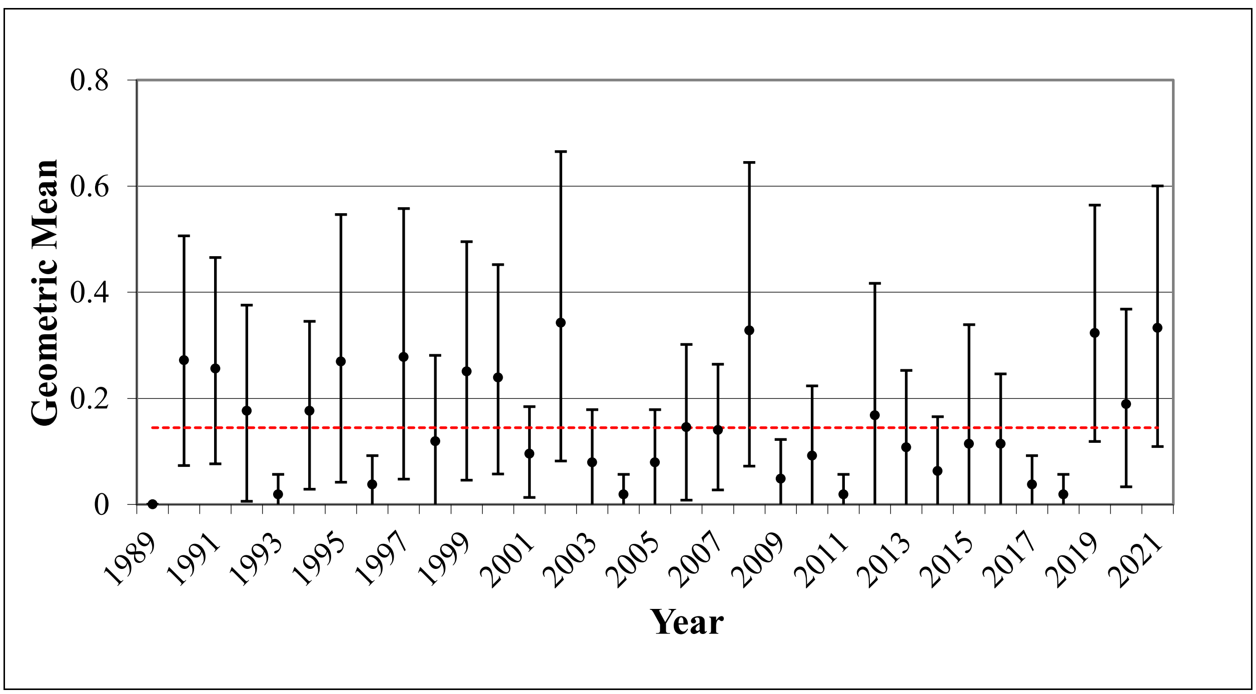

Figure 1.15. Black sea bass (*Centropristis striata*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

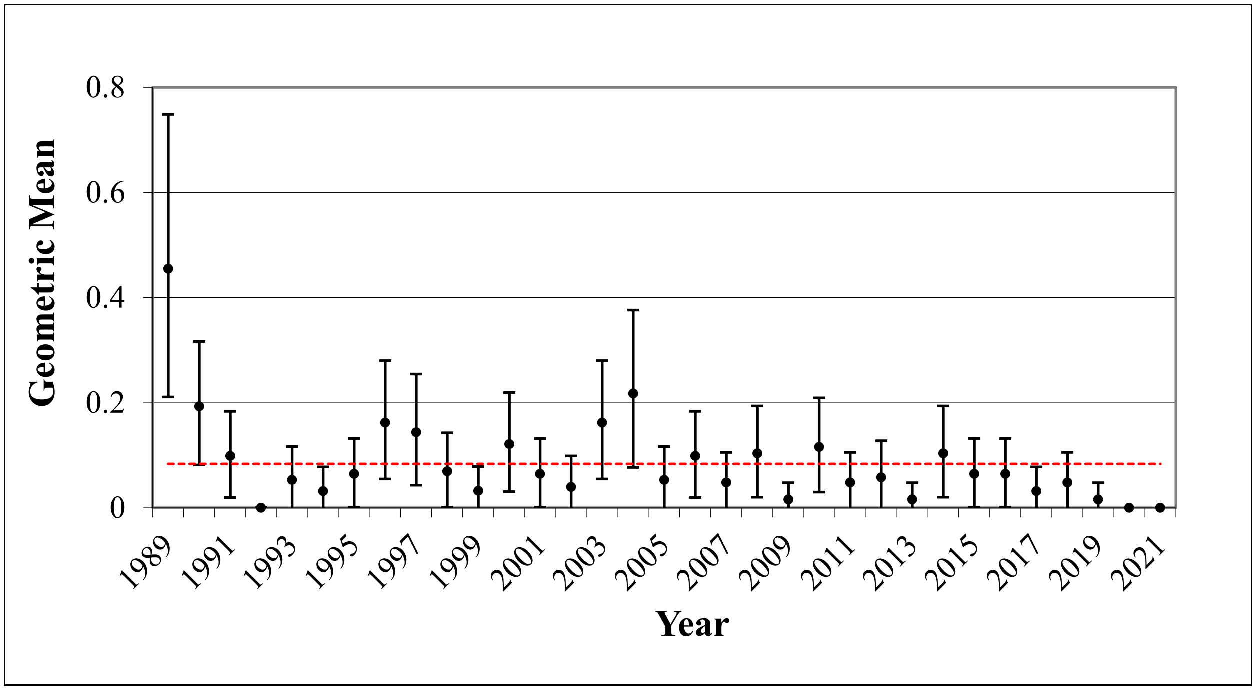

Figure 1.16. Bluefish (*Pomatomus saltatrix*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019,\,2021}$ = 140/year, n_{2020} = 120).

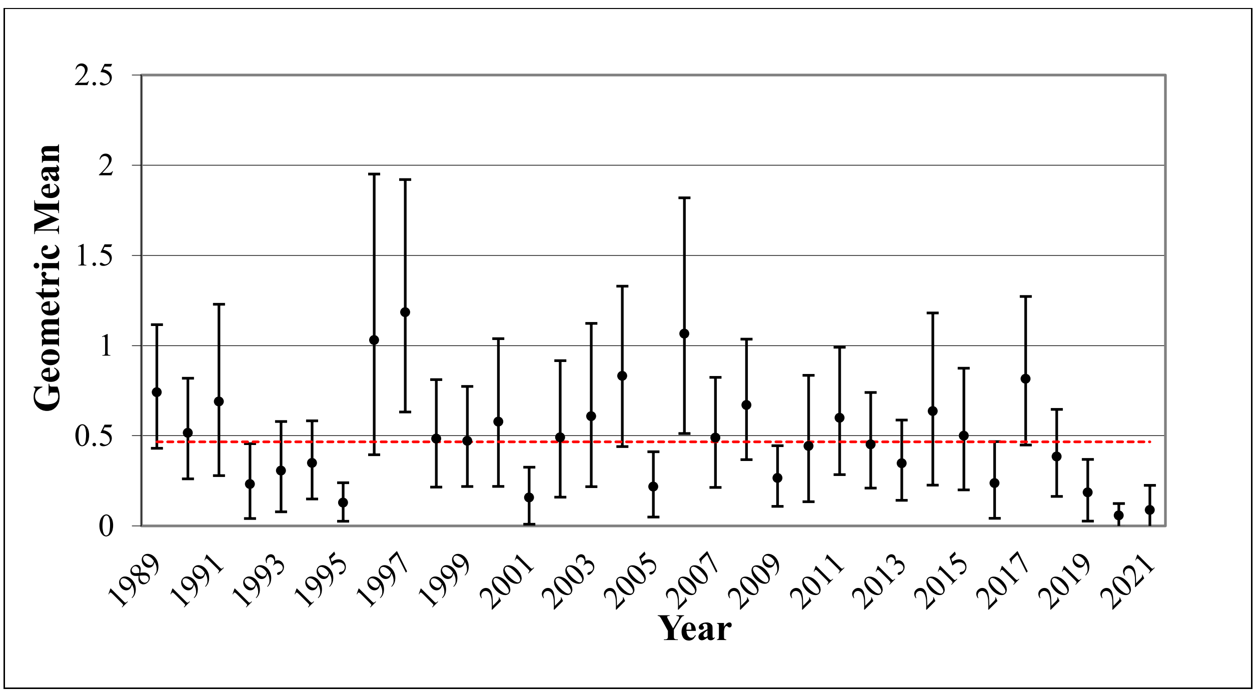

Figure 1.17. Bluefish (*Pomatomus saltatrix*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

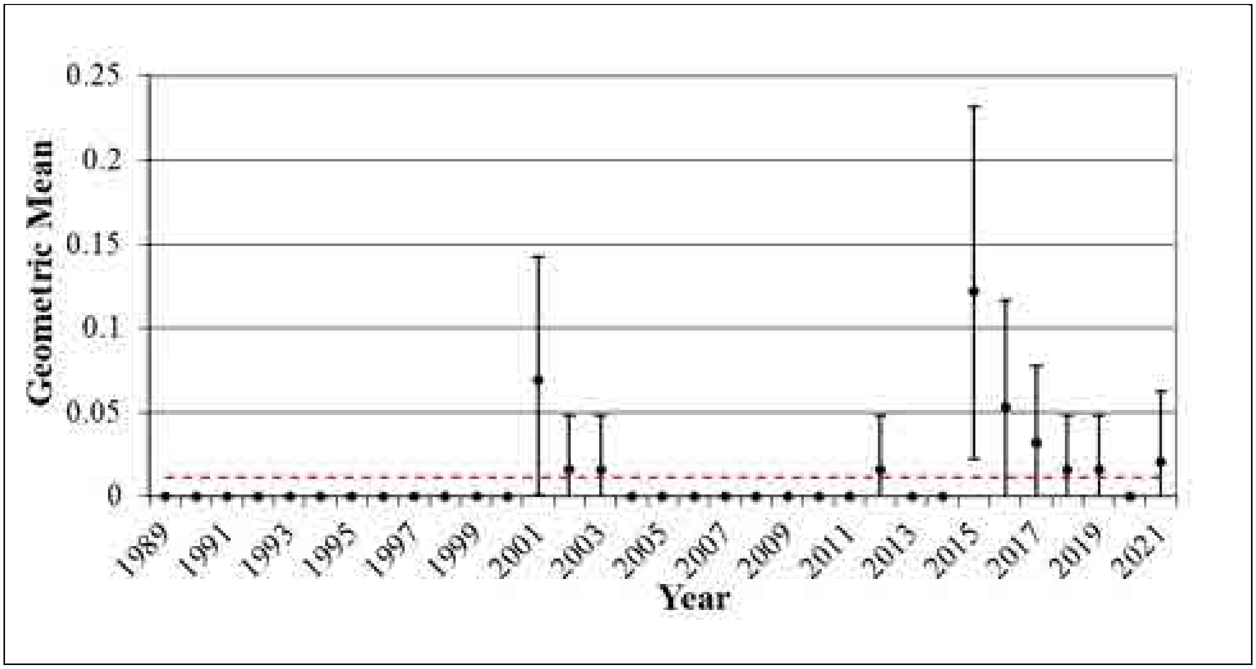

Figure 1.18. Sheepshead (*Archosargus probatocephalus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019,\ 2021}$ = 140/year, n_{2020} = 120).

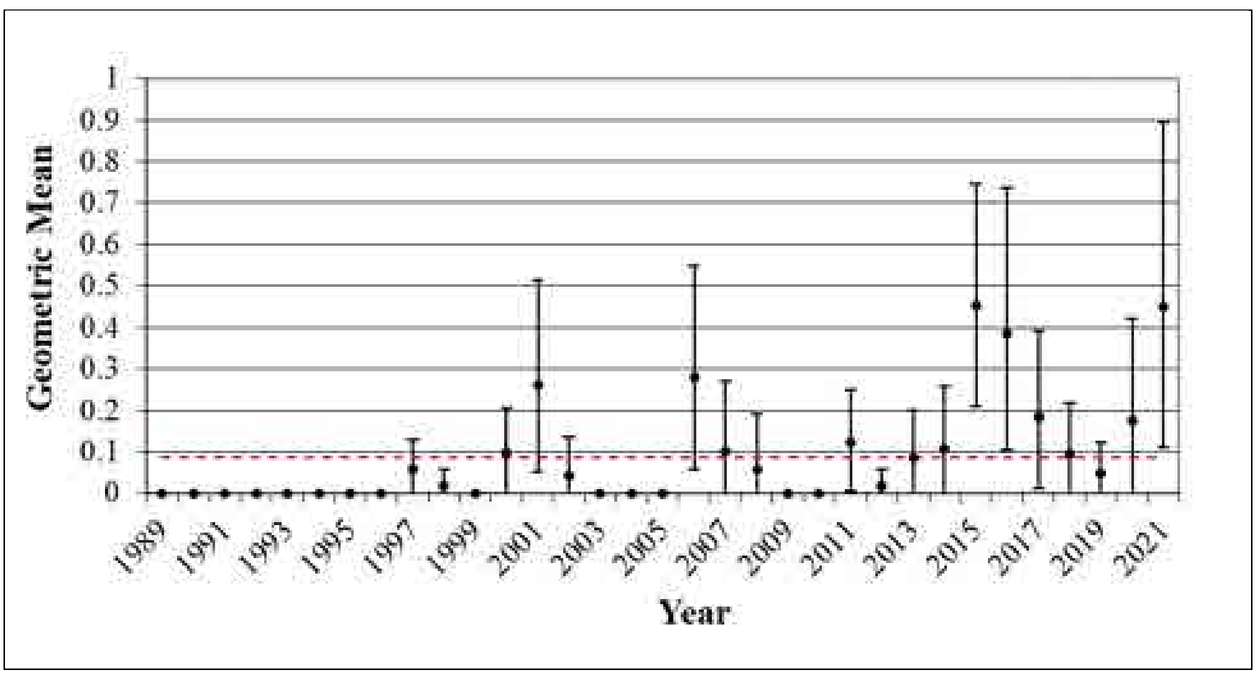

Figure 1.19. Sheepshead (*Archosargus probatocephalus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

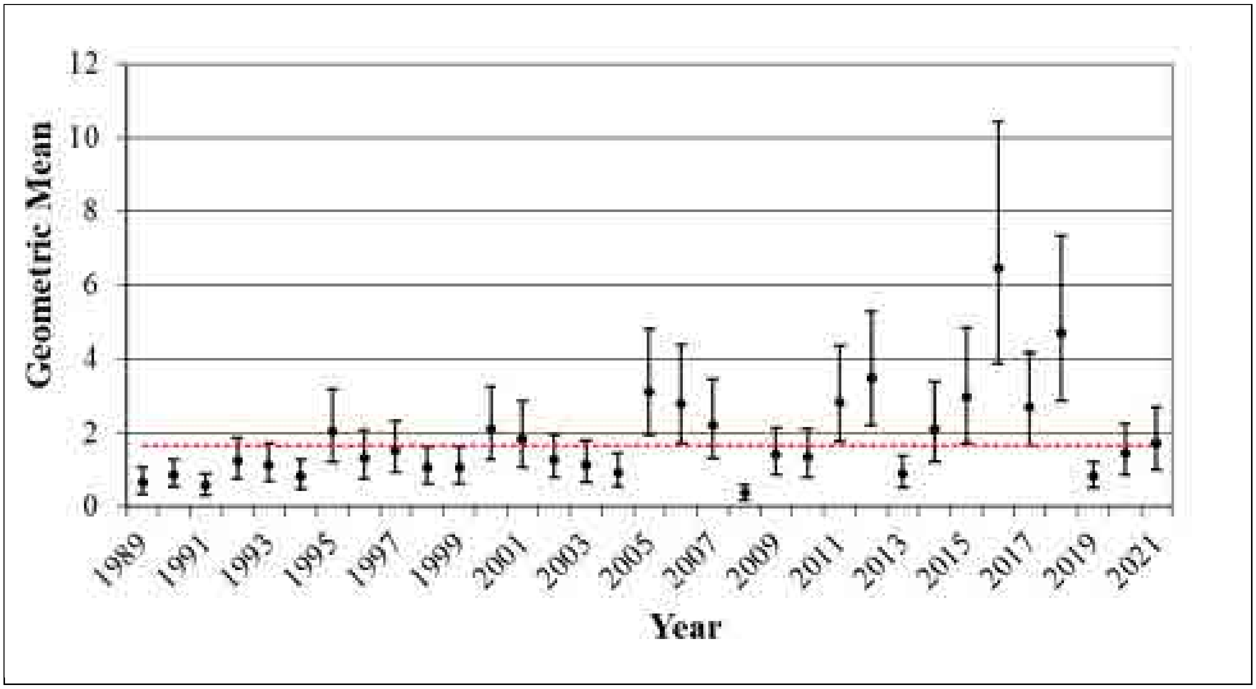

Figure 1.20. Silver perch (*Bairdiella chrysoura*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120).

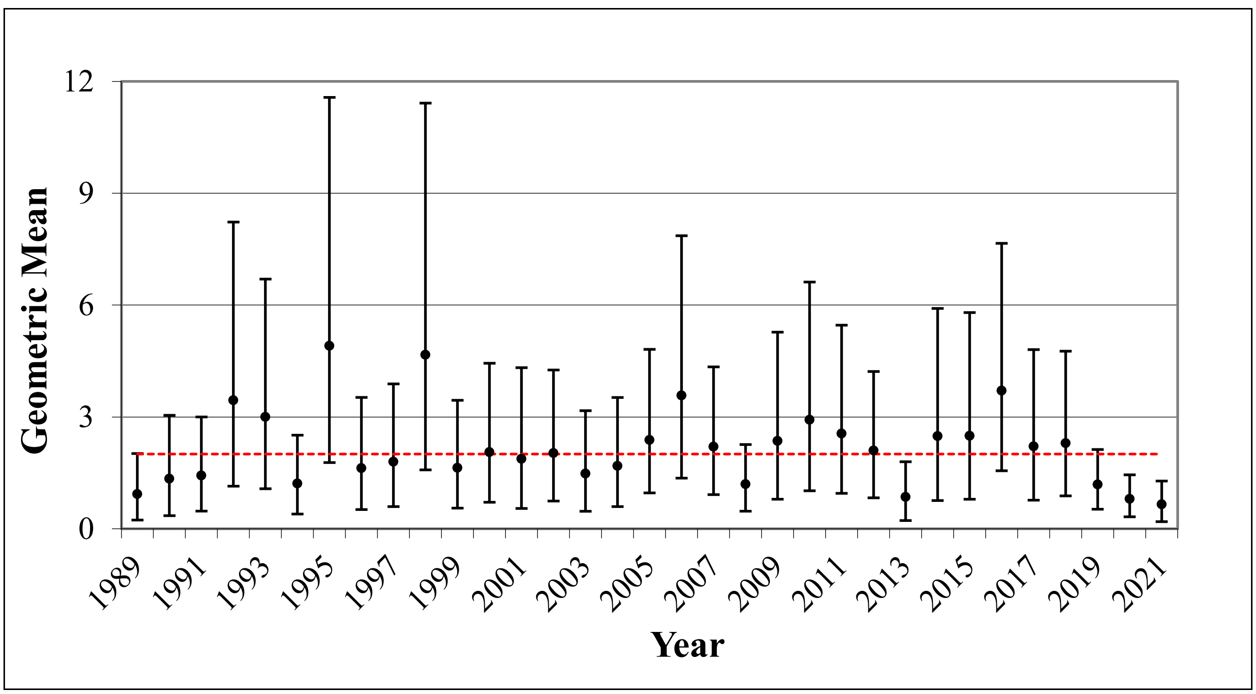

Figure 1.21. Silver perch (*Bairdiella chrysoura*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

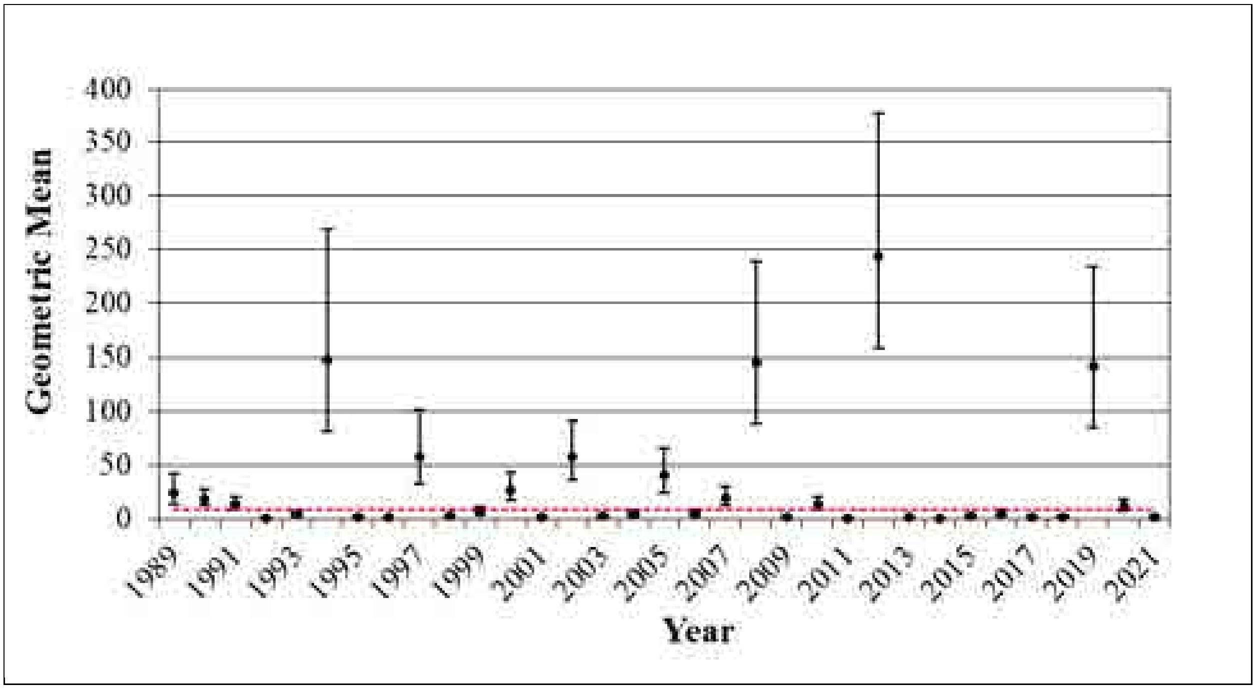

Figure 1.22. Spot (*Leiostomus xanthurus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019,\,2021}$ = 140/year, n_{2020} = 120).

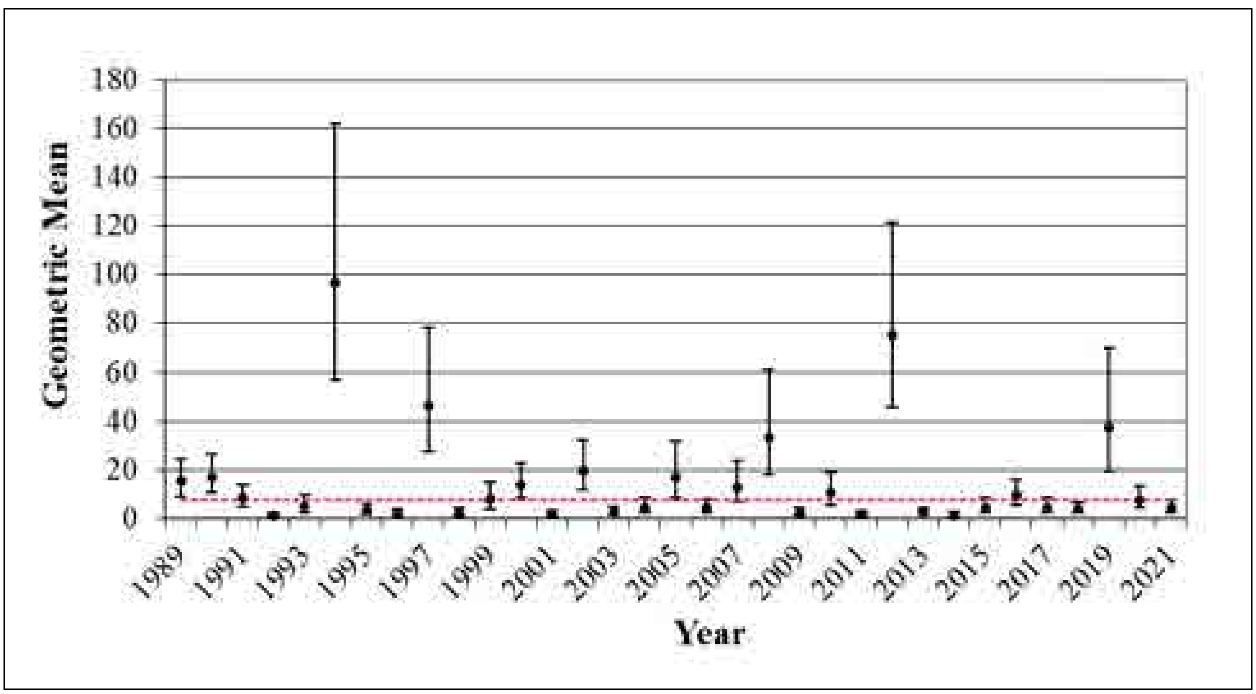

Figure 1.23. Spot (*Leiostomus xanthurus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

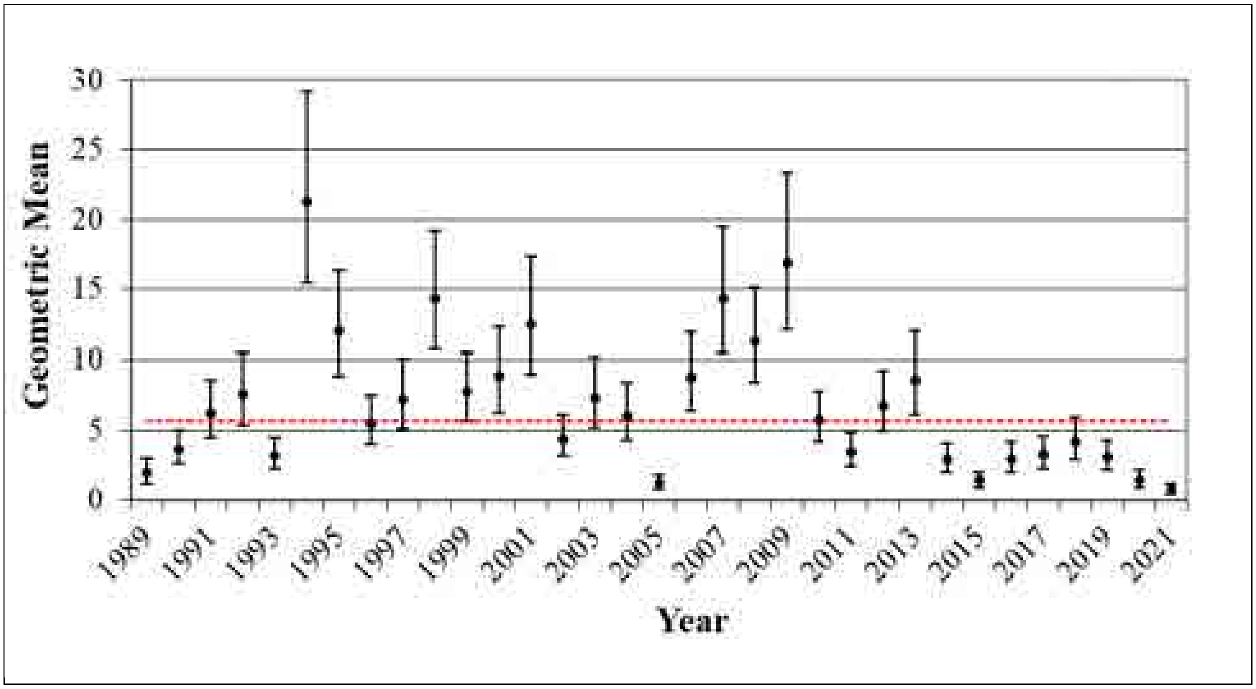

Figure 1.24. Summer flounder (*Paralichthys dentatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120).

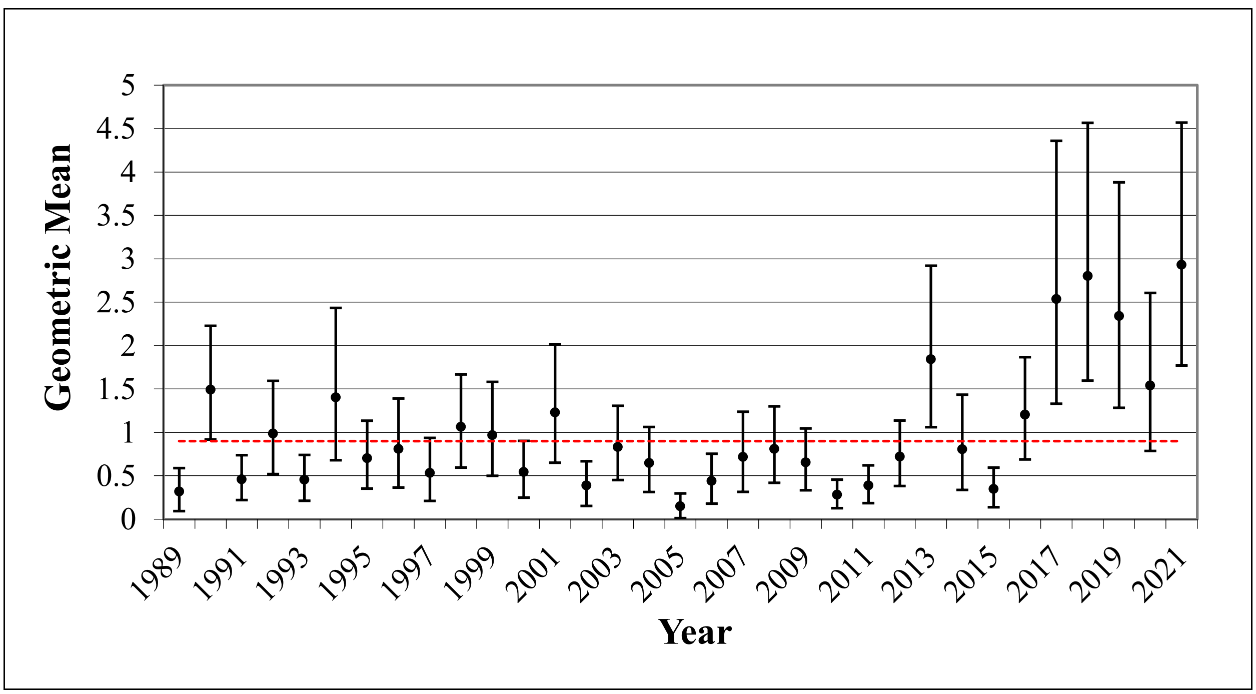

Figure 1.25. Summer flounder (*Paralichthys dentatus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

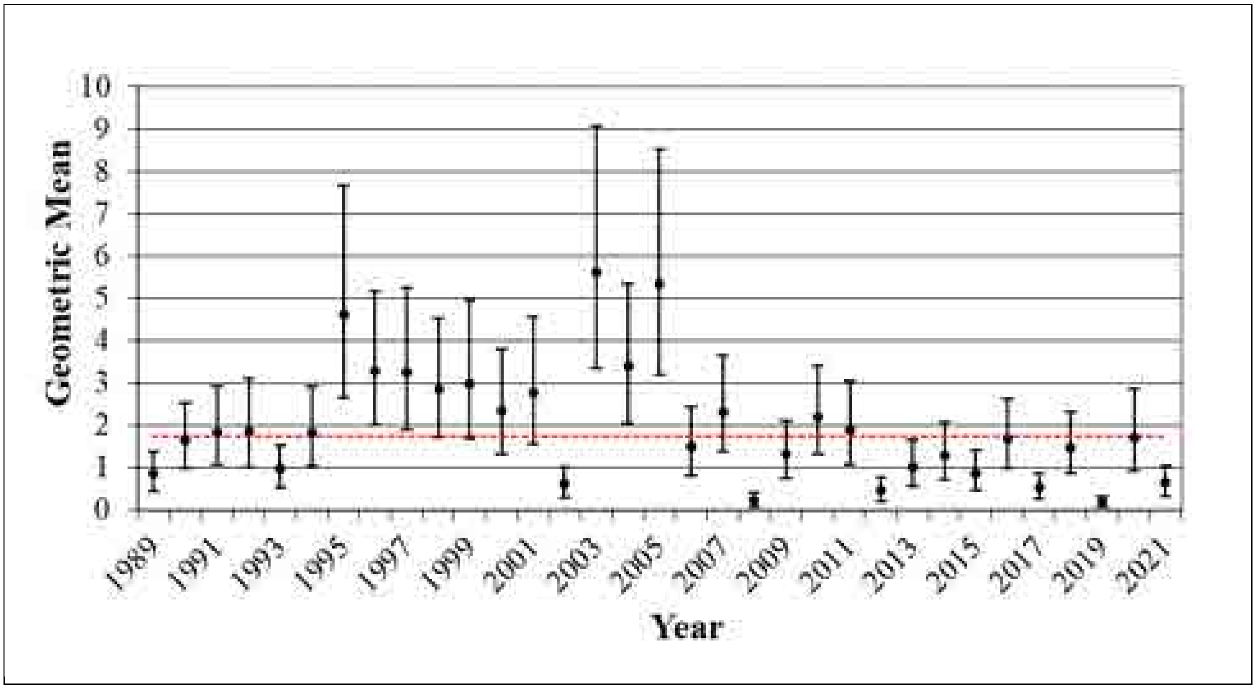

Figure 1.26. Weakfish (*Cynoscion regalis)* trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean ($n_{1989-2019,\,2021}$ = 140/year, n_{2020} = 120).

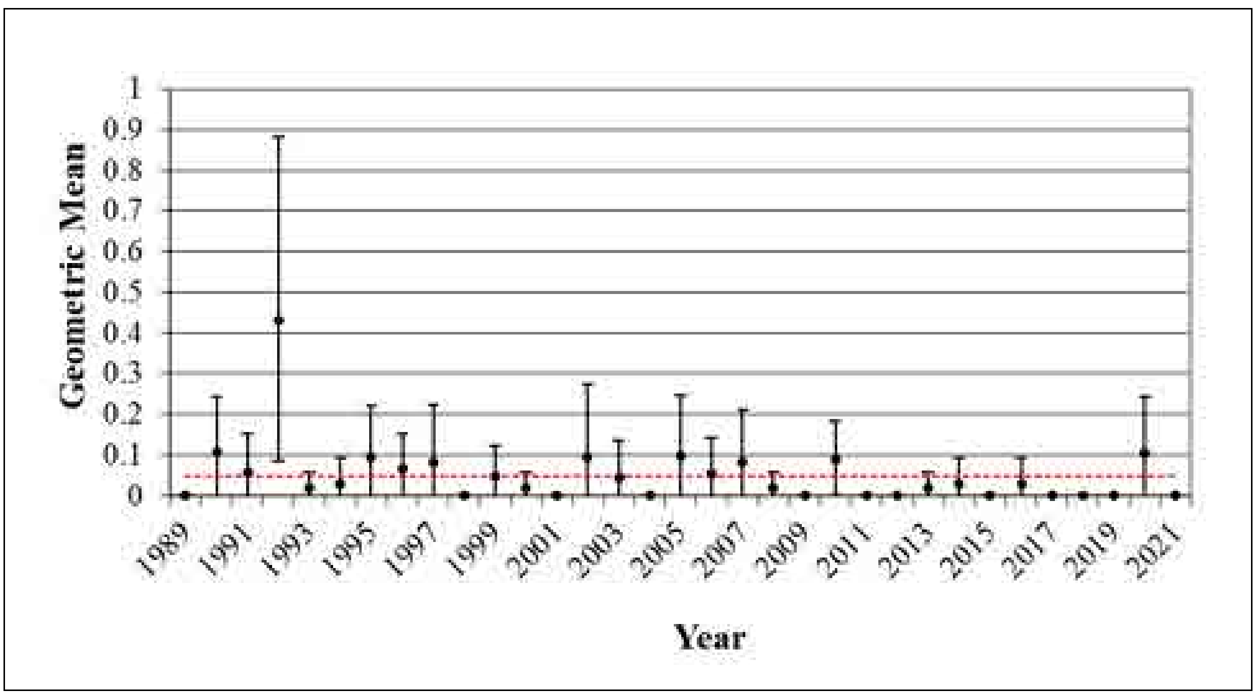

Figure 1.27. Weakfish (*Cynoscion regalis)* beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2021). Dotted line represents the 1989 - 2021 time series grand mean (n = 38/year).

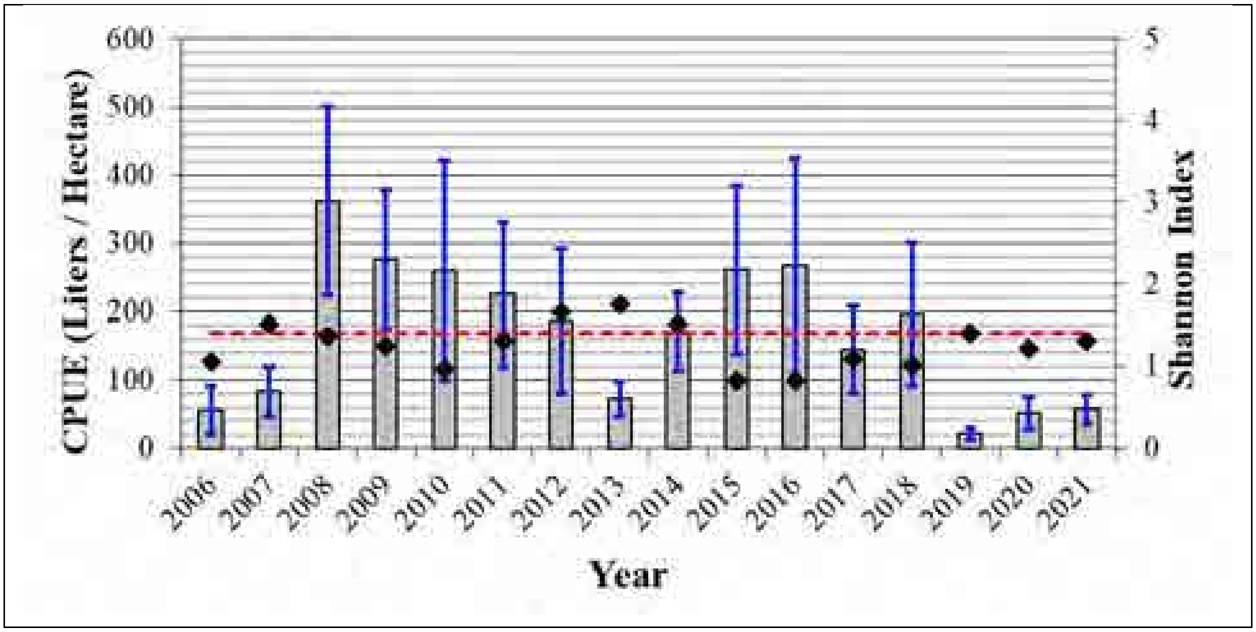

Figure 1.28. Coastal bays trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean ($n_{1989-2019, 2021}$ = 140/year, n_{2020} = 120). Black diamond represents the Shannon index of diversity.

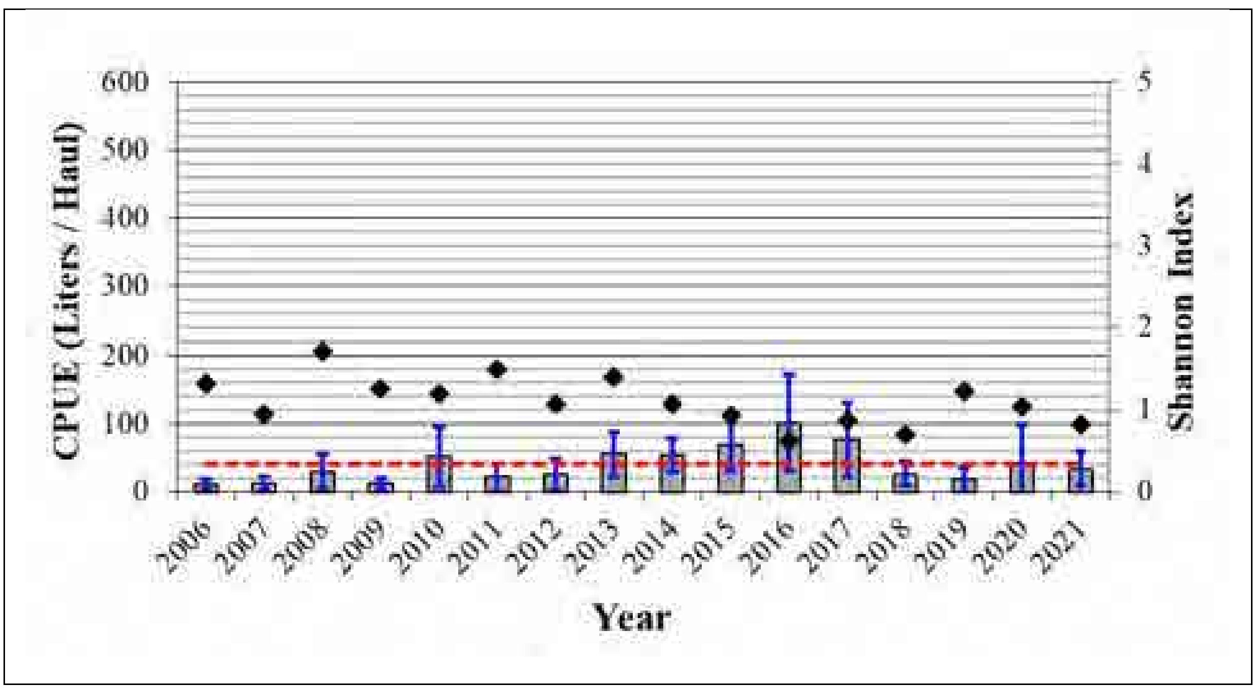

Figure 1.29. Coastal bays beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 36/year). Black diamond represents the Shannon index of diversity

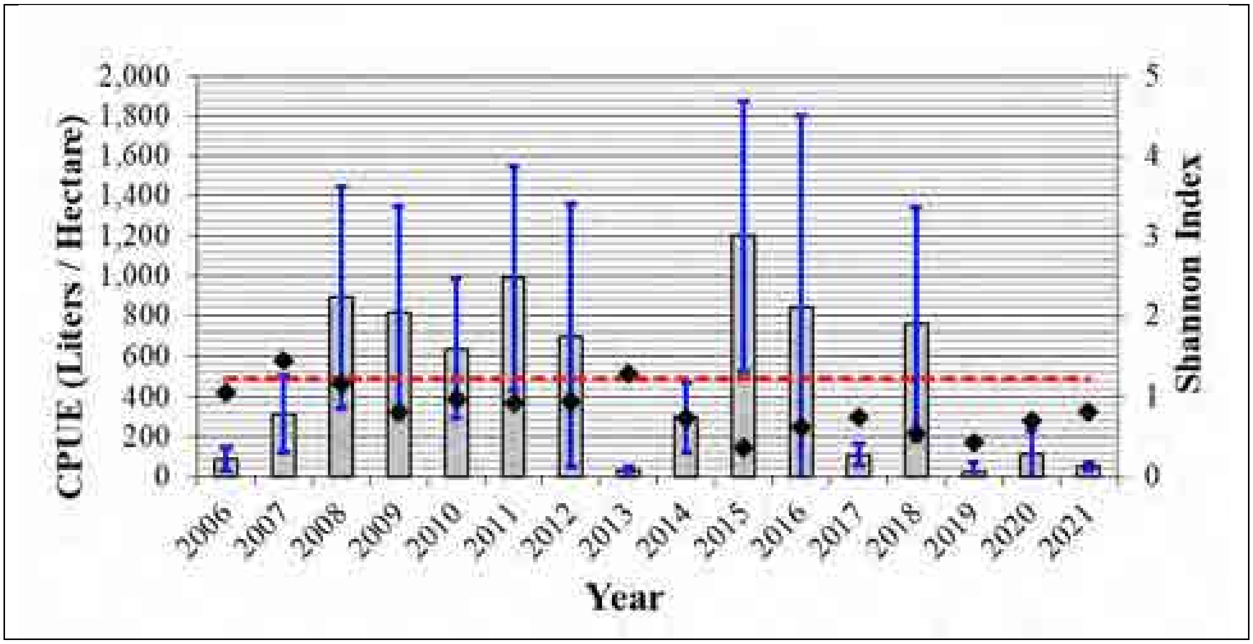

Figure 1.30. Assawoman Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 21/year). Black diamond represents the Shannon index of diversity.

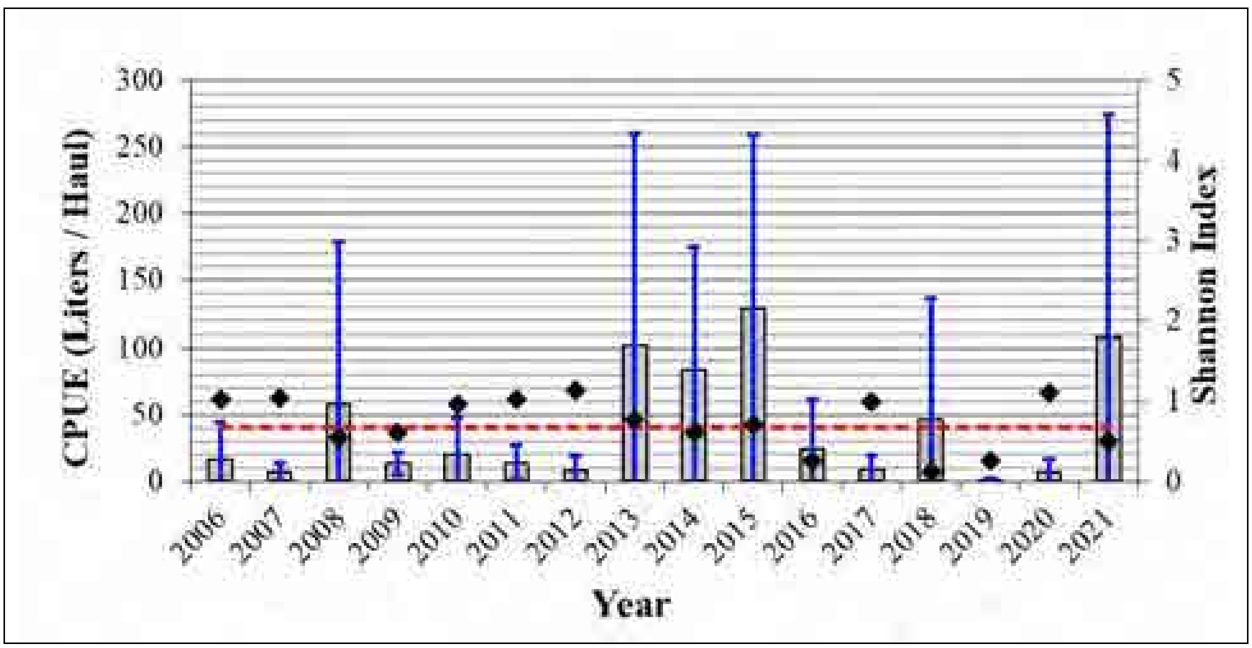

Figure 1.31. Assawoman Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2021). Dotted line represents the 2006 - 2021 time series CPUE grand mean (n = 6/year). Black diamond represents the Shannon index.

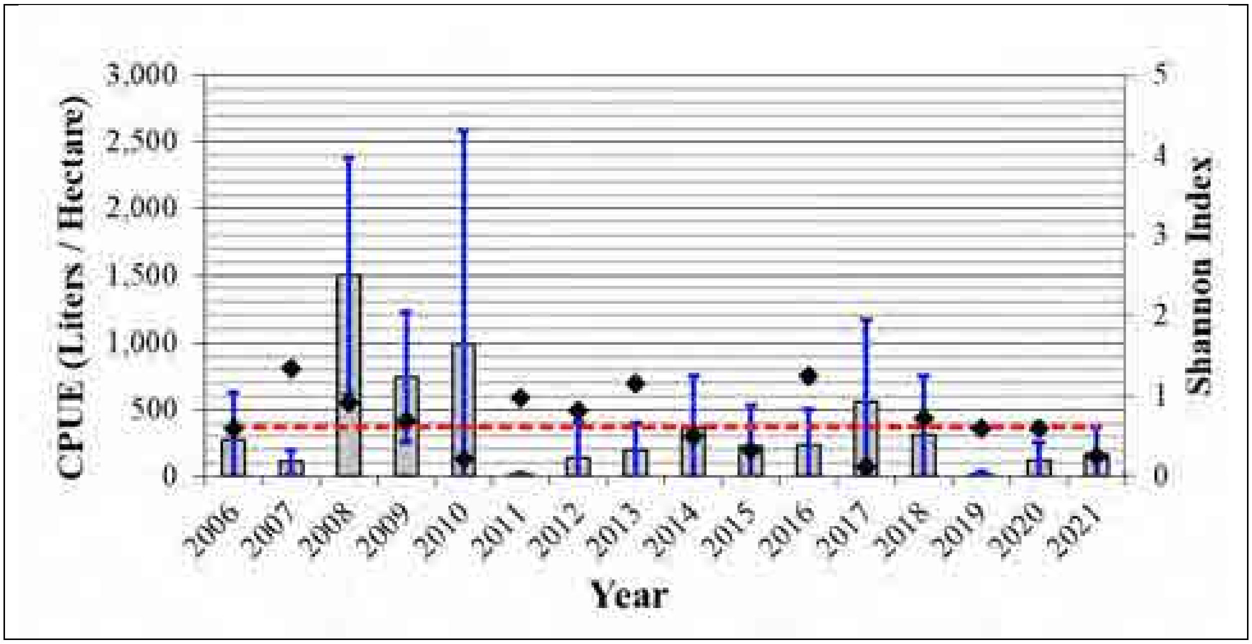

Figure 1.32. Isle of Wight Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 14/year). Black diamond represents the Shannon index of diversity.

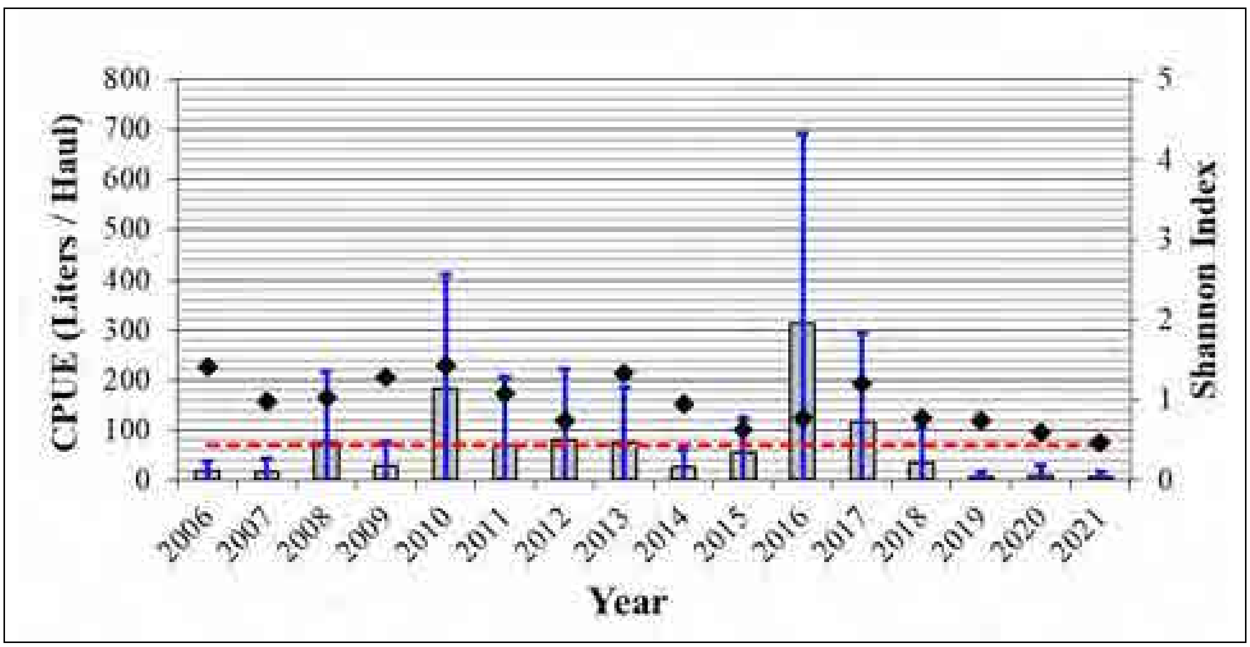

Figure 1.33. Isle of Wight Bay beach seine index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 4/year). Black diamond represents the Shannon index.

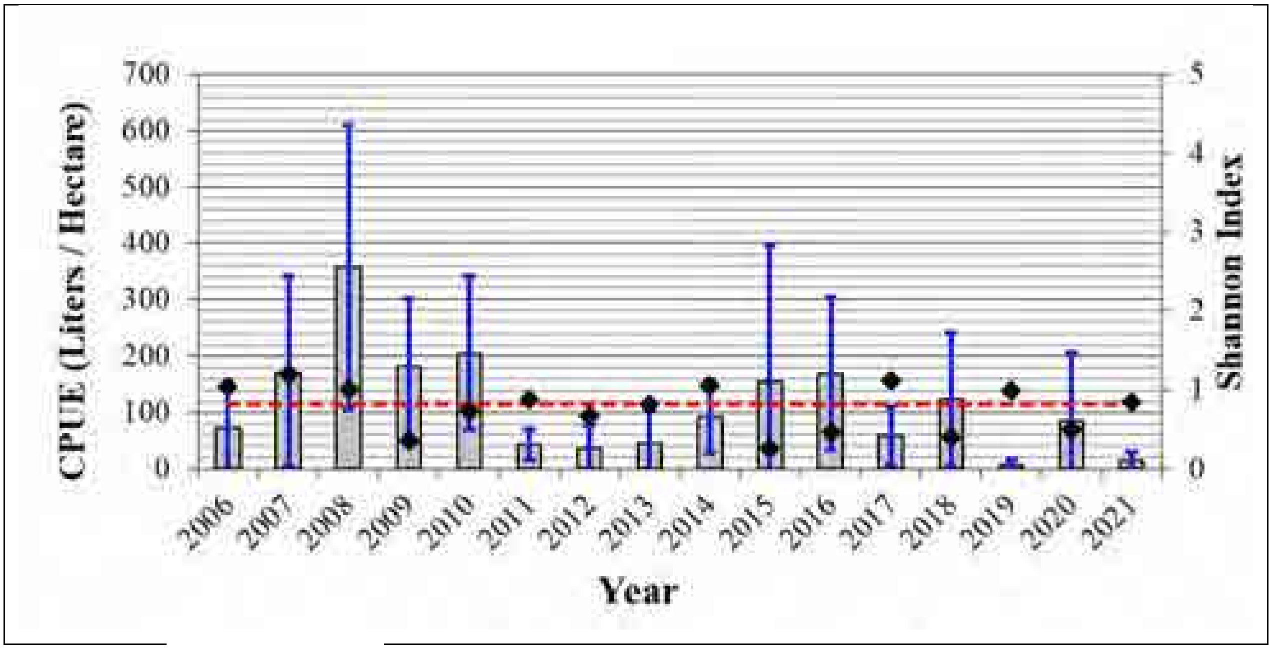

Figure 1.34. St. Martin River trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 14/year). Black diamond represents the Shannon index of diversity.

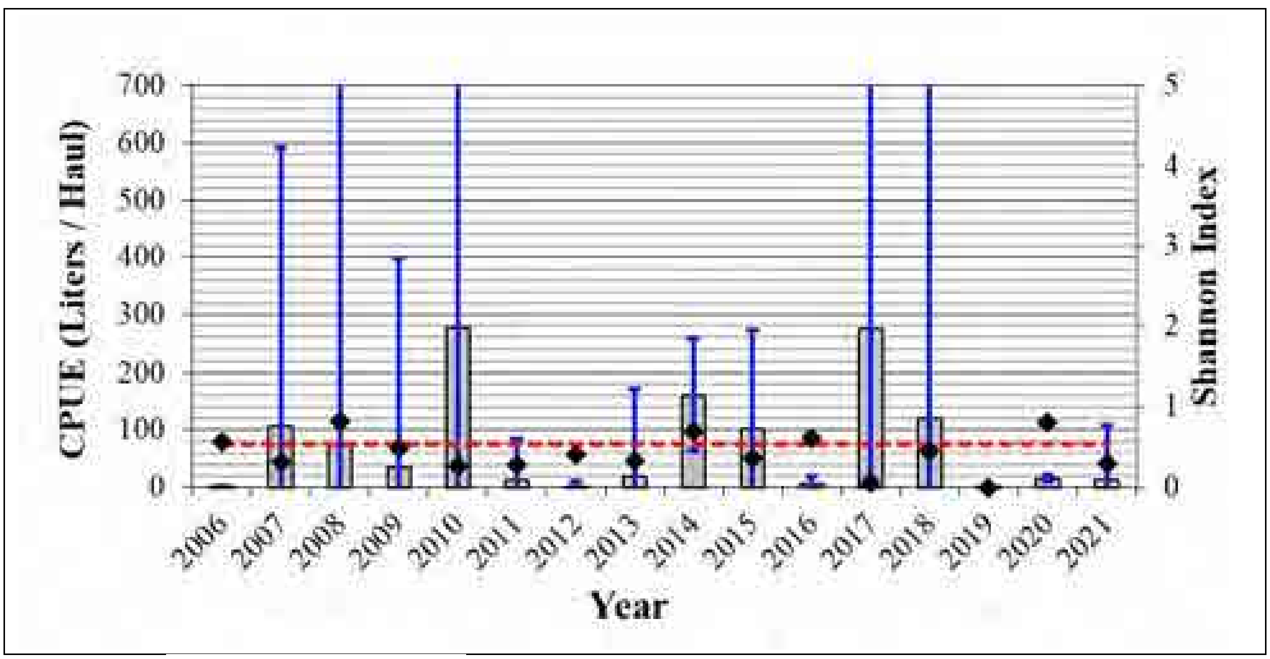

Figure 1.35. St. Martin River beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 2/year). Black diamond represents the Shannon index of diversity.

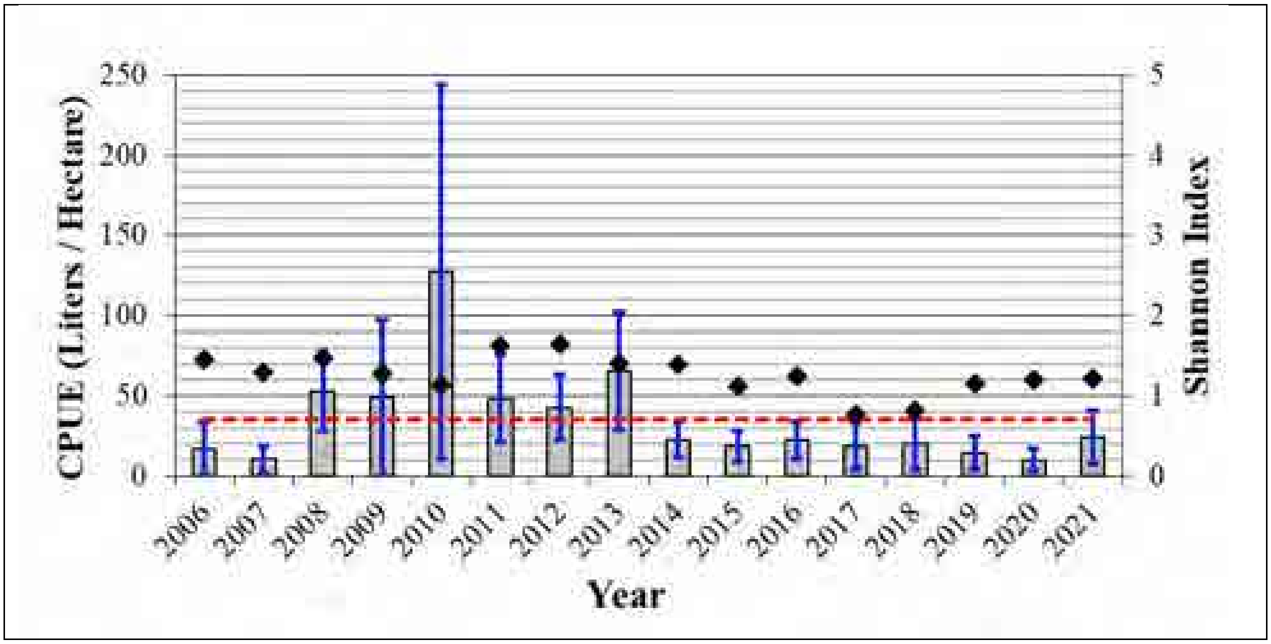

Figure 1.36. Sinepuxent Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 21/year). Black diamond represents the Shannon index of diversity.

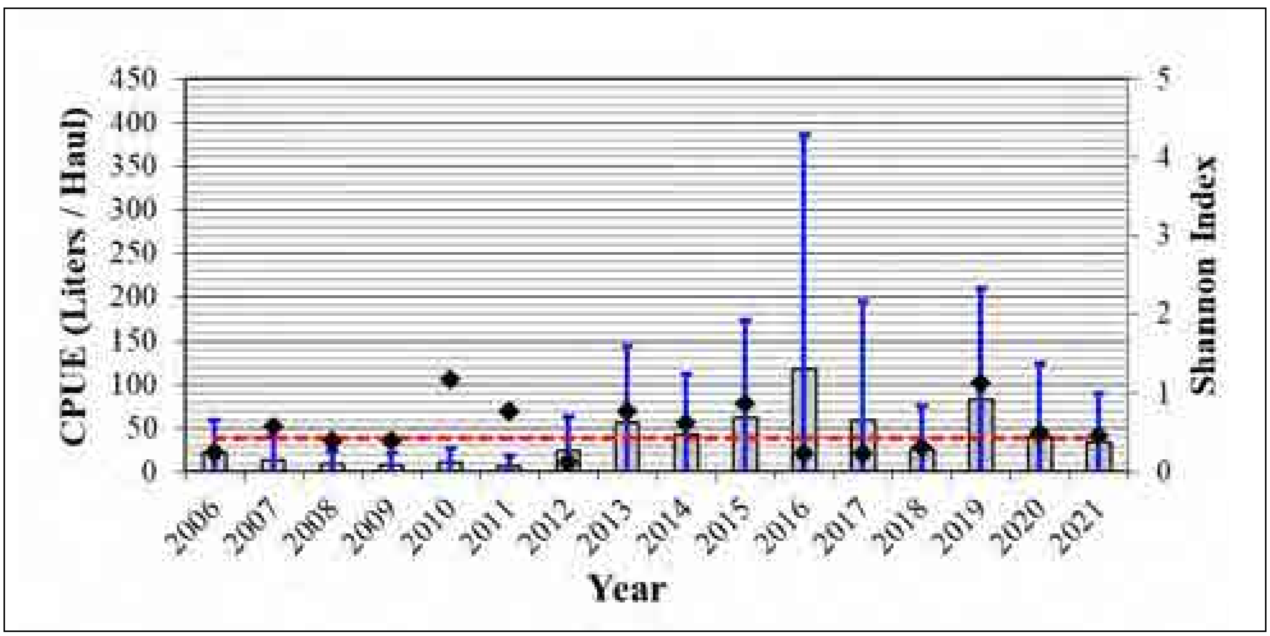

Figure 1.37. Sinepuxent Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 6/year). Black diamond represents the Shannon index of diversity.

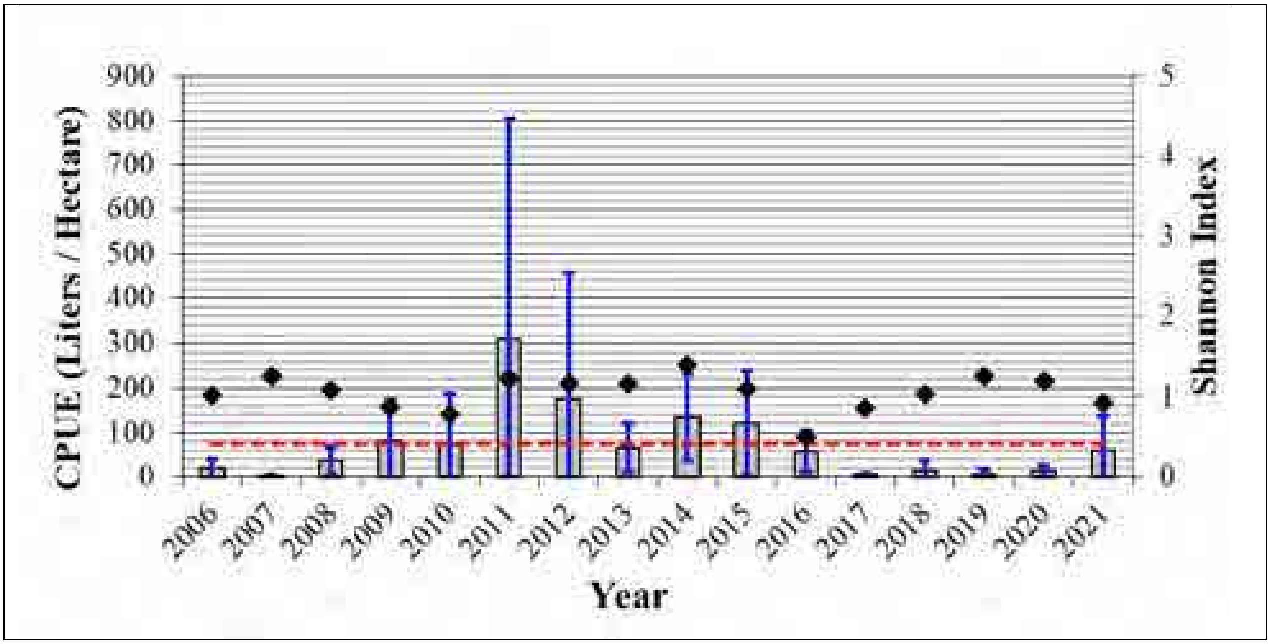

Figure 1.38. Newport Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 14/year). Black diamond represents the Shannon index of diversity.

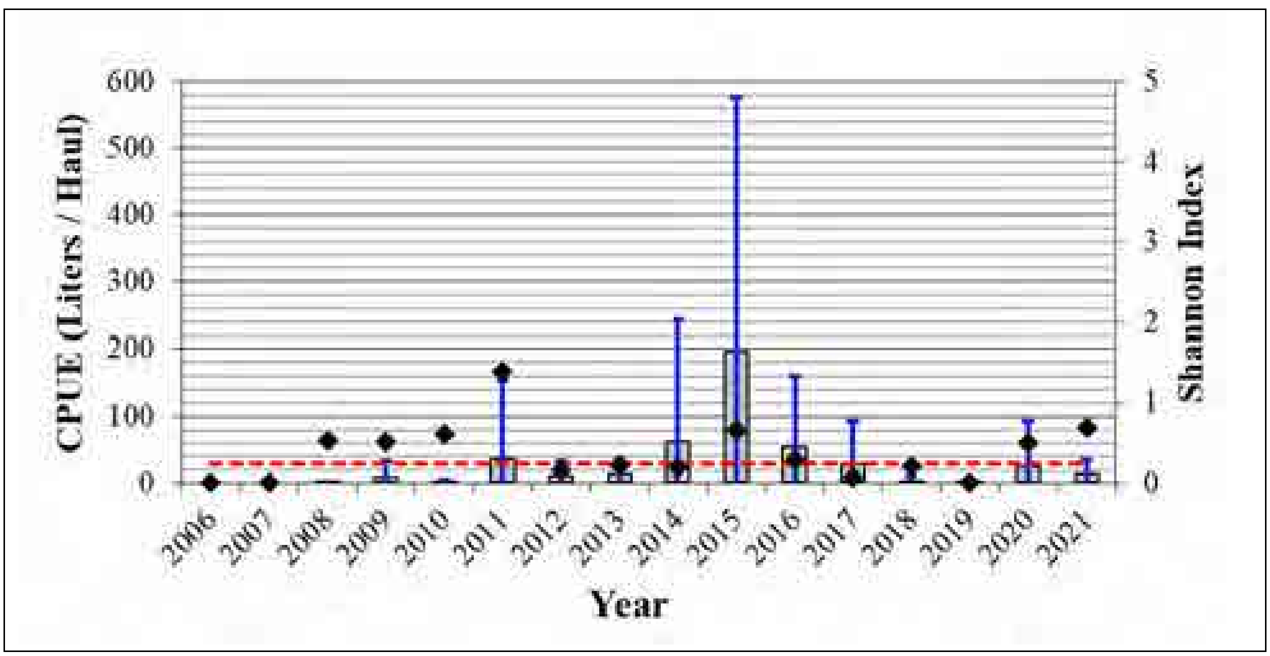

Figure 1.39. Newport Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 4/year). Black diamond represents the Shannon index of diversity.

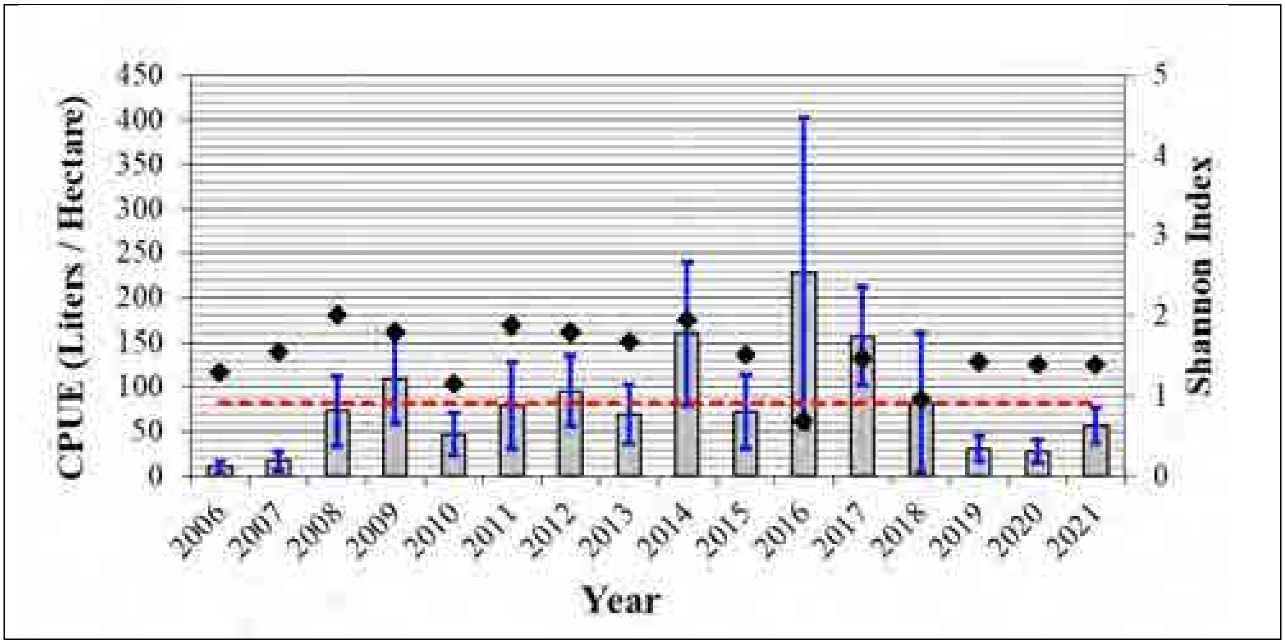

Figure 1.40. Chincoteague Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2021). Dotted line represents the 2006 - 2021 time series CPUE grand mean (n = 56/year). Black diamond represents the Shannon index of diversity.

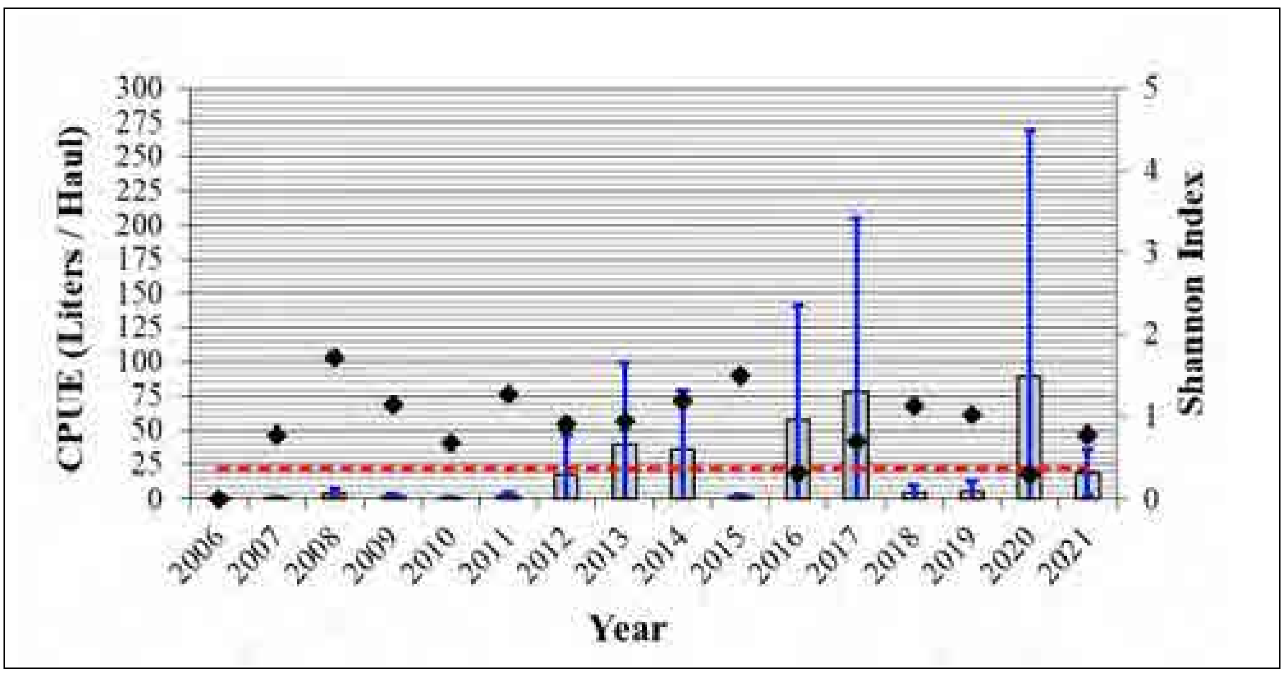

Figure 1.41. Chincoteague Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2021). Red line represents the 2006 - 2021 time series CPUE grand mean (n = 12/year). Black diamond represents the Shannon index of diversity.

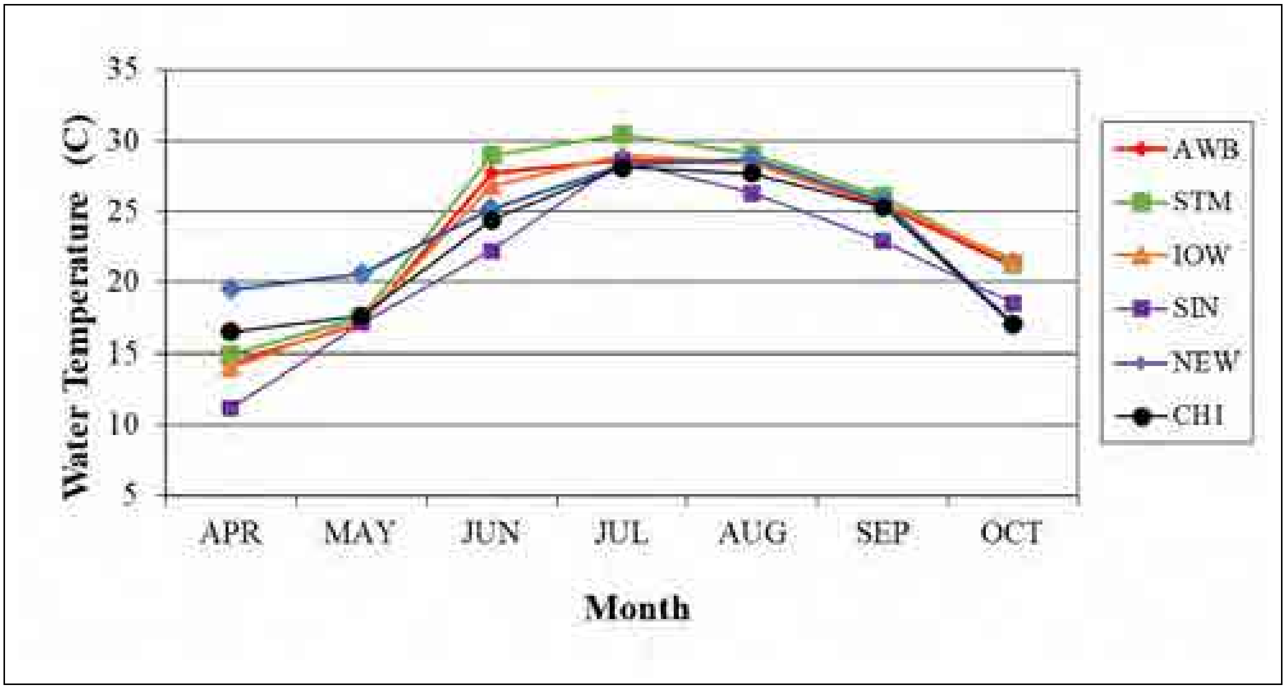

Figure 1.42. Trawl Survey (2021) mean water temperature (C) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI).

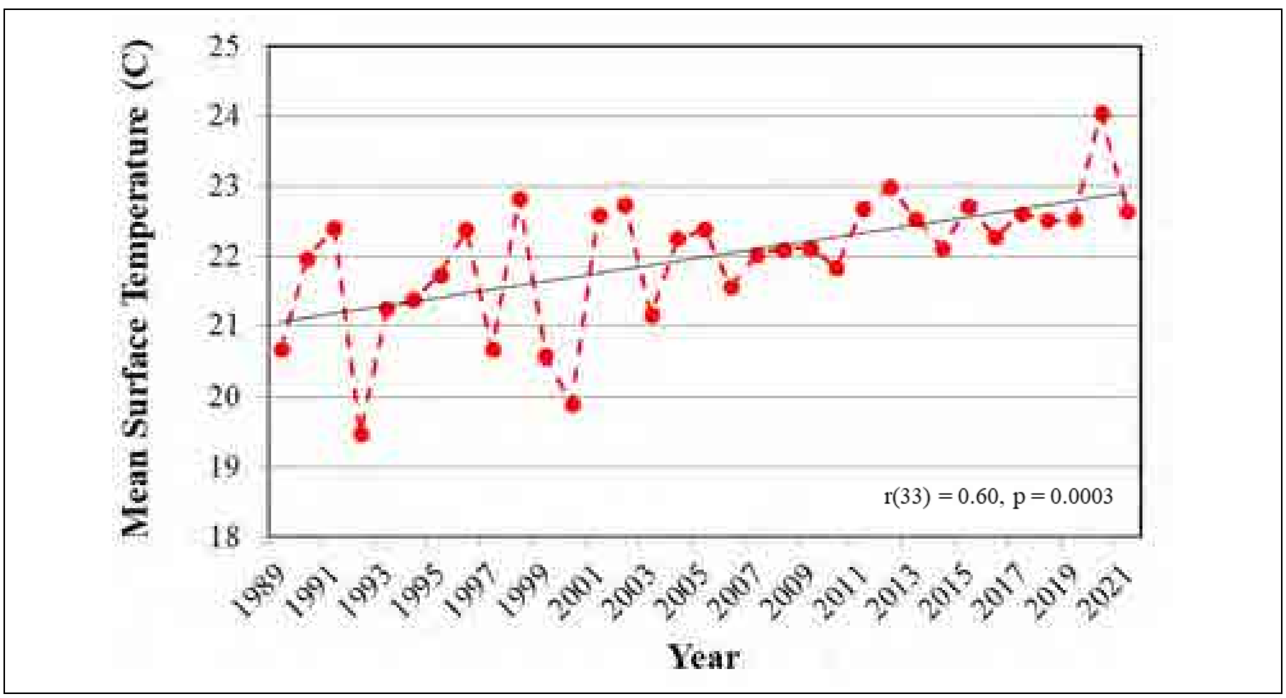

Figure 1.43. Evaluation of the mean annual Trawl Survey surface water temperature (C).

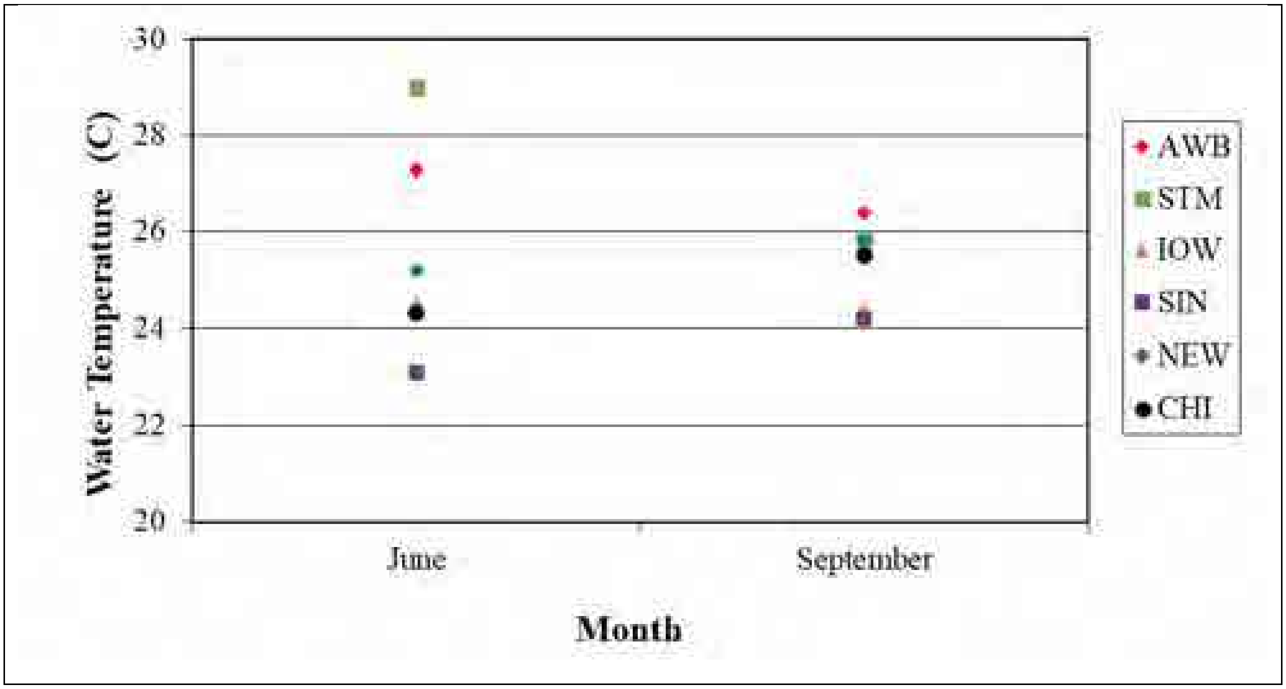

Figure 1.44. Beach Seine Survey (2021) mean water temperature (C) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI).

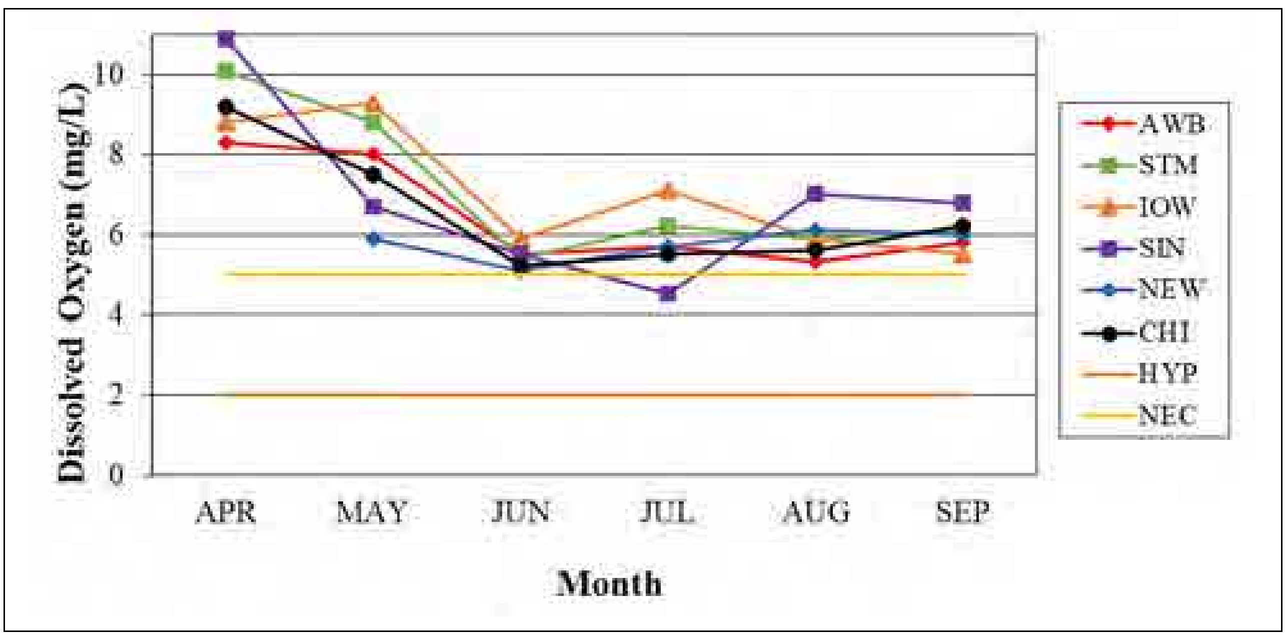

Figure 1.45. Trawl Survey (2021) mean Dissolved Oxygen (DO; mg/L) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI). A DO value of 5 mg/L was considered necessary for life (NEC). Hypoxic conditions (HYP) occur when DO drops to 2 mg/L or less.

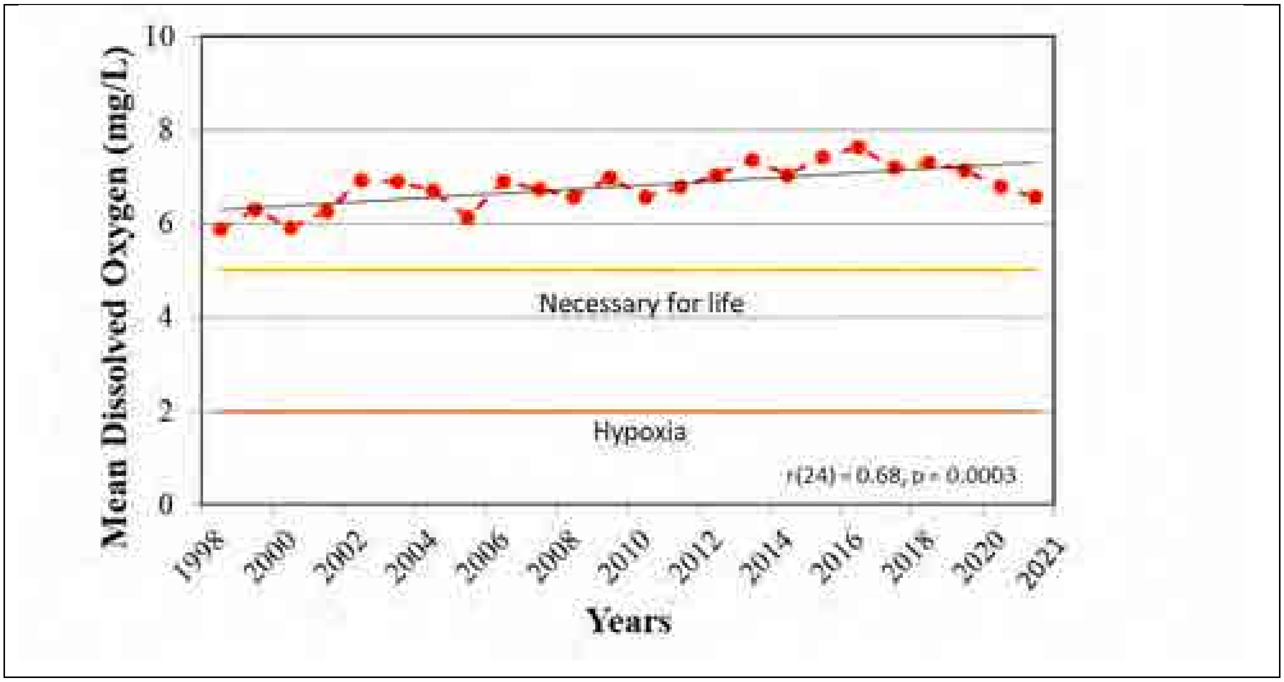

Figure 1.46. Trawl Survey annual mean Dissolved Oxygen (DO; mg/L) by year. A DO value of 5 mg/L was considered necessary for life. Hypoxic conditions occur when DO drops below 2 mg/L.

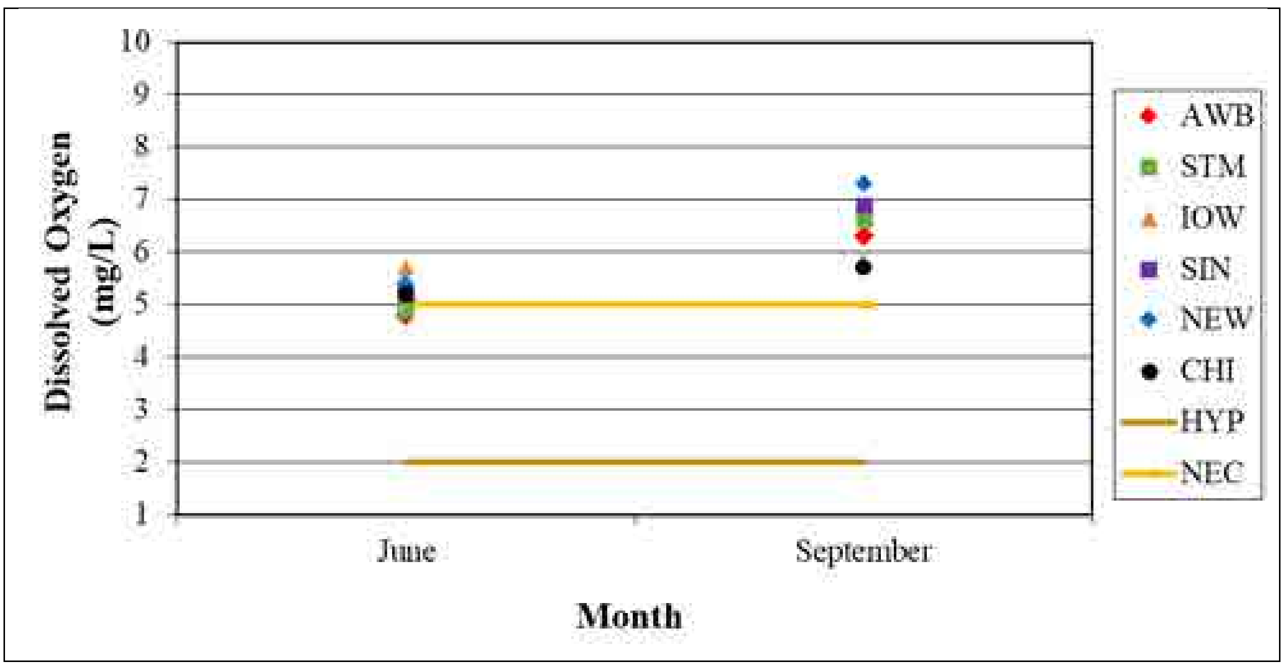

Figure 1.47. Beach Seine Survey (2021) mean Dissolved Oxygen (DO; mg/L) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI). A DO value of 5 mg/L was considered necessary for life (NEC). Hypoxic conditions (HYP) occur when DO drops below 2 mg/L.

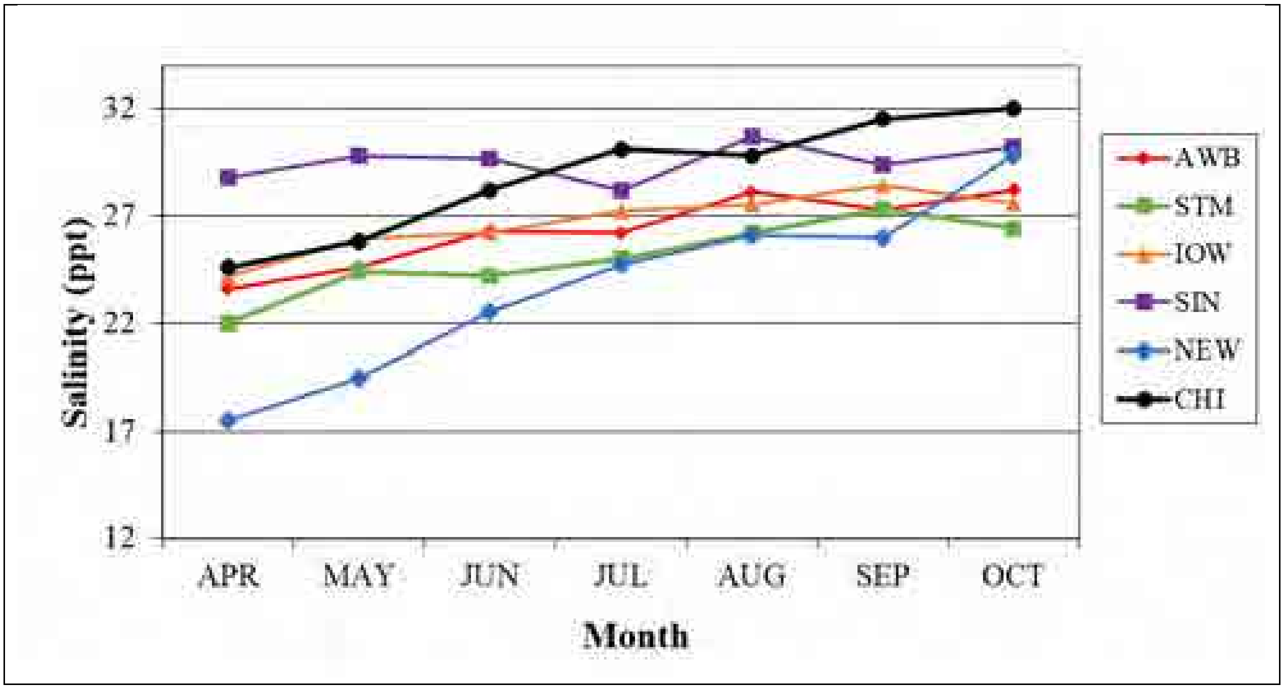

Figure 1.48. Trawl Survey (2021) mean salinity (ppt) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI).

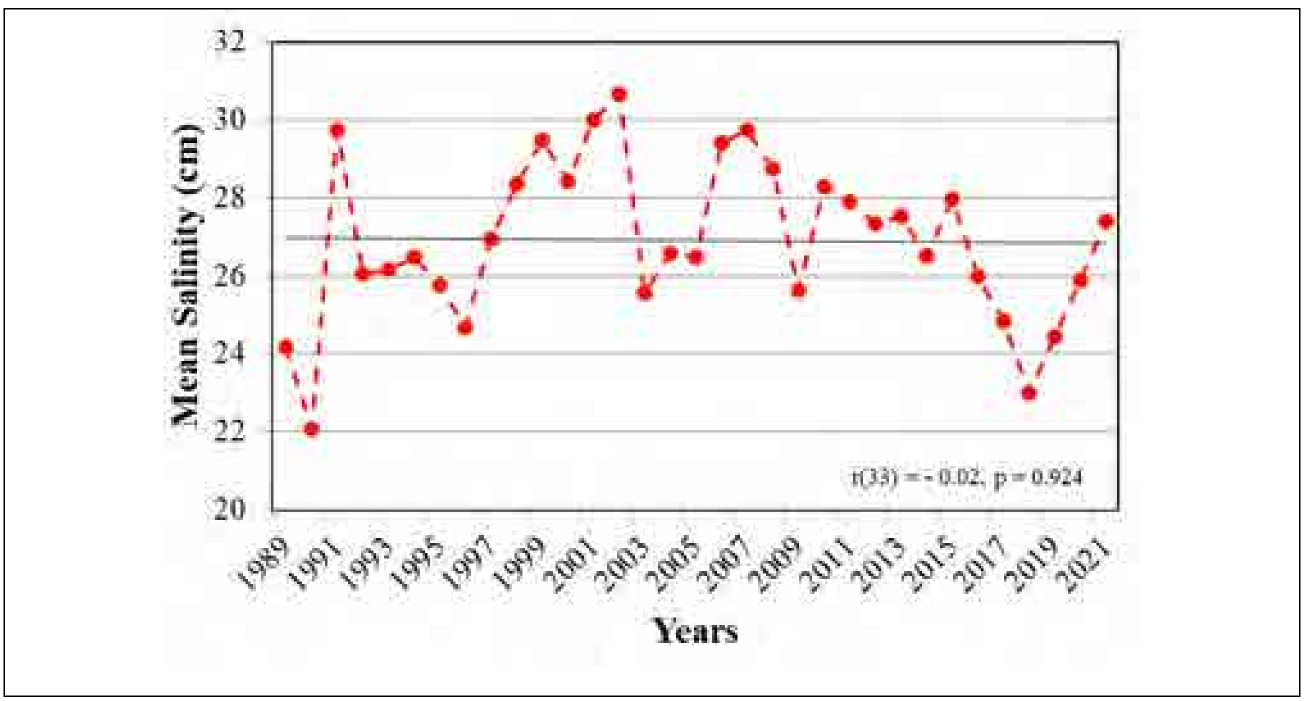

Figure 1.49. Evaluation of the mean Trawl Survey salinity (ppt).

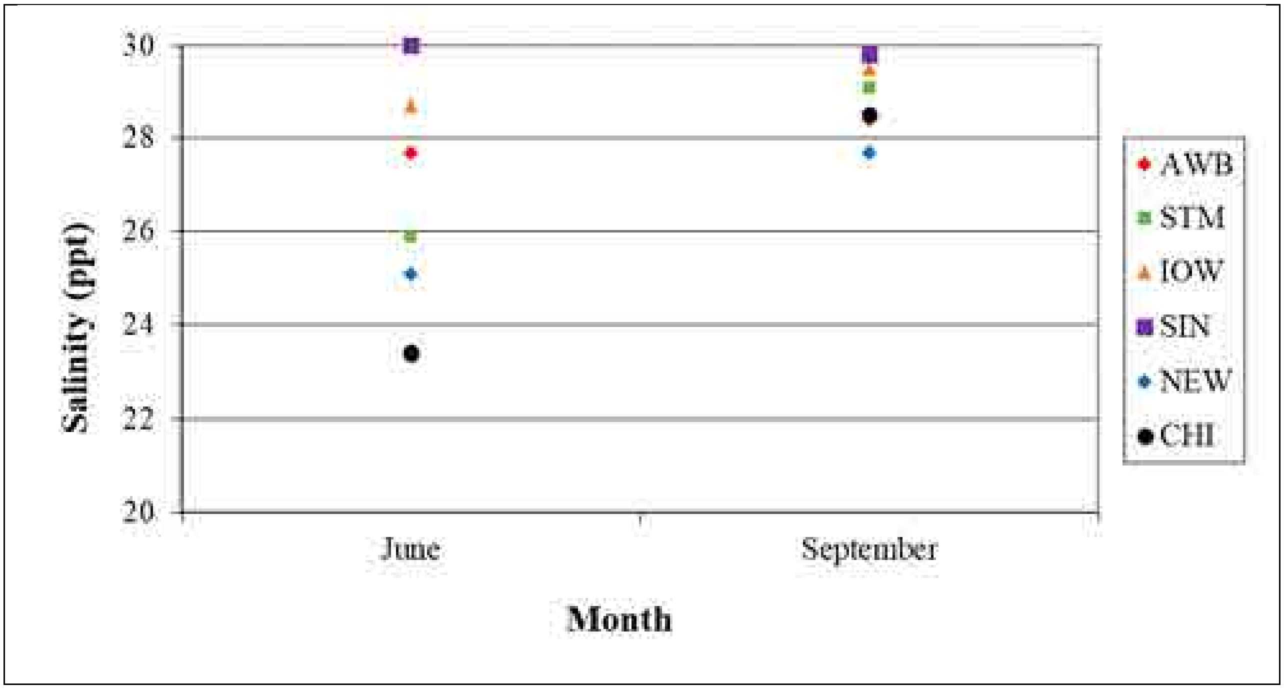

Figure 1.50. Beach Seine Survey(2021) mean salinity (ppt) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI).

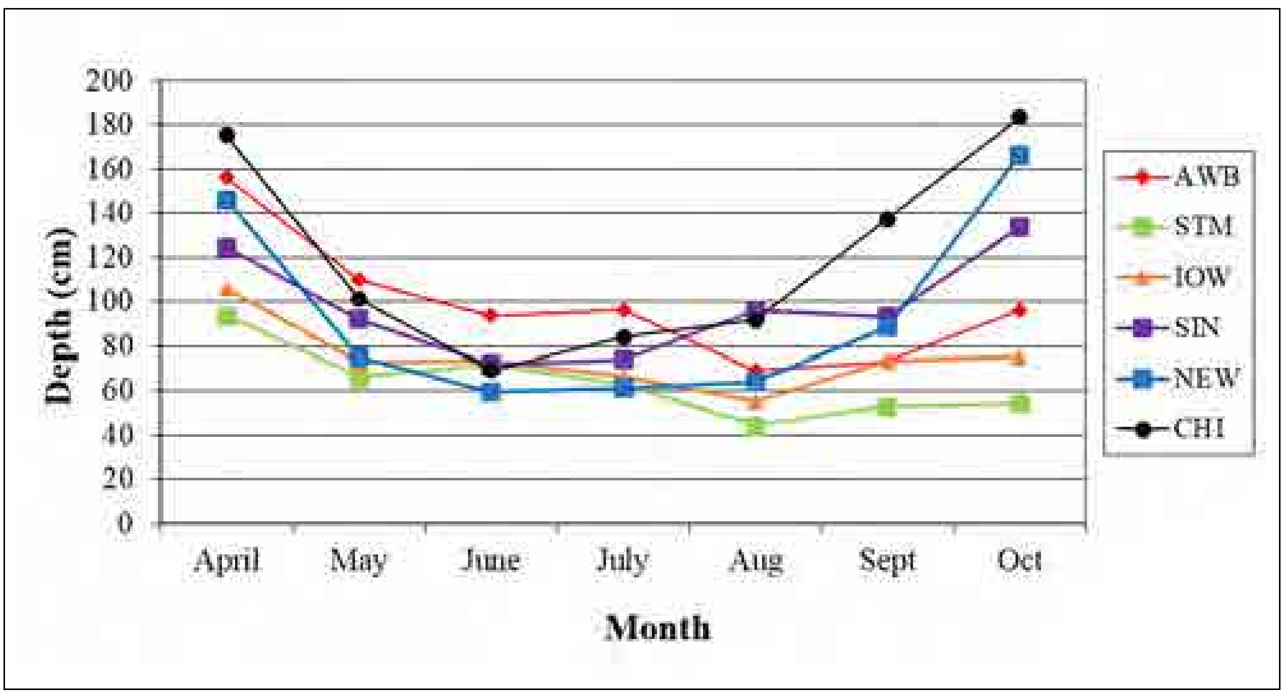

Figure 1.51. Trawl Survey (2021) mean turbidity (cm) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI).

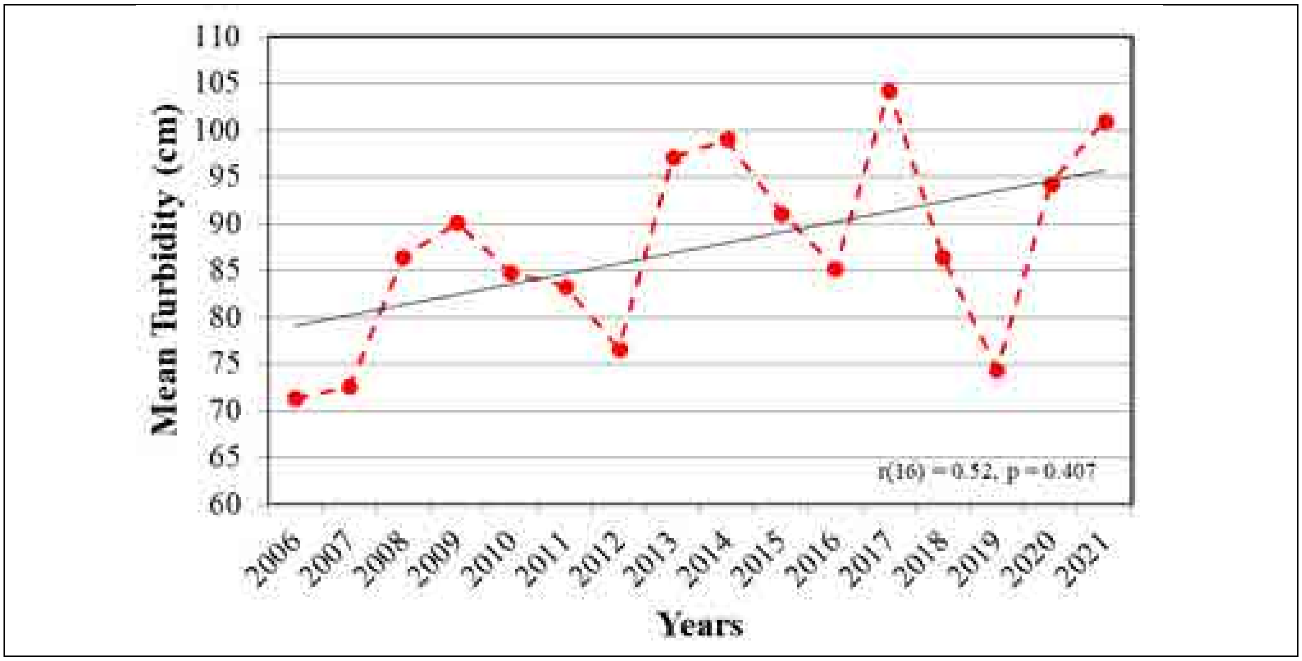

Figure 1.52. Evaluation of the mean annual Trawl Survey turbidity (cm).

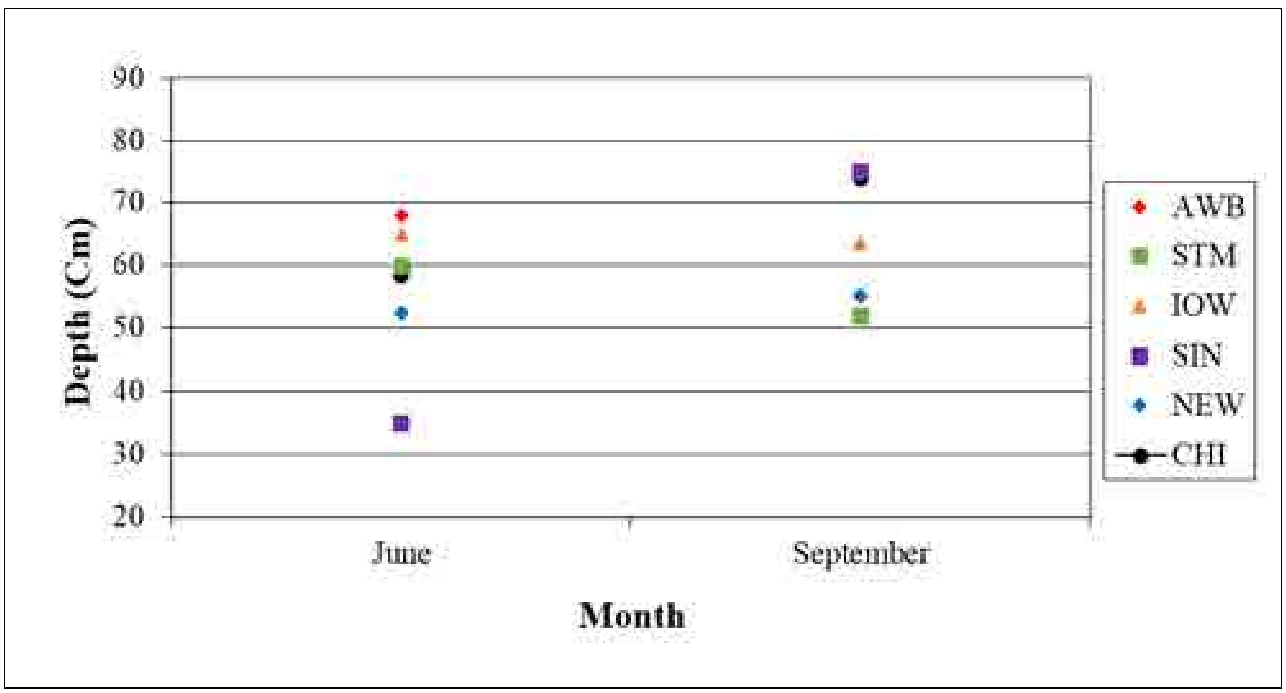

Figure 1.53. Beach Seine Survey (2021) mean turbidity (cm) by month in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW), and Chincoteague Bay (CHI).

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. Both 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

Data Collection

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 overlaying 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 from a 25 ft C-hawk during daylight in September over a seven year period from 2015 - 2021. Latitude and longitude coordinates in degrees and decimal minutes were used to navigate to sample locations. The global positioning system 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 percent 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.

Sample Processing

Samples were processed using the same methods described in Chapter 1 with the exception of increasing the length sample targets for specific fish of interest to improve statistical precision to evaluate habitat utilization by size. Previously (2020), the Atlantic silverside length target was reduced from 50 to 20 fish per beach seine haul.

Data Analysis

Comparisons of fish abundance were based on the SAV beach seine catch from each habitat type. Habitat types were characterized by SAV coverage quantified by the estimated percent of SAV in the sample area, bottom type substrate and the dominant SAV species in sample area. Catch per unit of effort was calculated as CPUE = catch/area swept (ha). Area swept for this survey was 0.04004919 ha/seine haul. The Beach Seine Survey was 0.0906704 ha/seine haul and the Trawl Survey was 0.125415 ha/trawl. The maximum alpha value of 0.05 was used for all tests. The Kruskal-Wallis H test, an unbalanced analysis of variance (ANOVA) and post hoc Duncan's Multiple Range Test (DMRT) were used to measure and compare CPUE, independent variable main effects and interactions relative to species abundance. Fish diversity was calculated using the Shannon index. Fish length compositions were compared among selected habitat types using analysis of variance and Duncan's multiple range test.

Results and Discussion

Sample Size and Distribution

These results were based on 115 unbalanced random samples collected from 2015 to 2021 within 12 SAV grids (Table 2.1, Figure 2.1). The number of beach seine hauls (samples) each year was 12, 14, 17, 21, 19, 16, and 16 respectively. Those samples were distributed between four categories of SAV coverage: 25% or less (22 samples), 26% - 50% (24 samples), 51% - 75% (34 samples), and 76% - 100% (35 samples). These samples were also categorized by primary substrate as either sand (53 samples) or mud (62 samples). Additionally, each sample's dominant SAV species was identified; eelgrass was most abundant (88 samples) followed by widgeon grass (27 samples). Furthermore, samples were categorized for habitat interaction such as SAV coverage, substrate, and dominant SAV species (Table 2.2).

Abundance by Habitat Category

The survey's 2021 sampling collected 27 fishes and 3,795 fish (Table 2.3). The most abundant species by count were Atlantic silversides, sheepshead, tautog, and black sea bass. Two new fishes caught in this survey were harvestfish and lookdown. The most abundant crustaceans by count were blue crabs, grass shrimp, and brown shrimp (Table 2.4). Over the complete time series, a total of 48 fishes and 15,519 fish were collected (Table 2.3). Silver perch relative abundance has declined since 2005 while black sea bass, tautog, and sheepshead abundance has increased (Table 2.3). CPUE results in this survey showed higher relative abundance for many popular species such as tautog, sheepshead, halfbeak, and black sea bass compared to those in Chapter 1. Blue crab, grass shrimp, and brown shrimp also showed the same results (Table 2.5).

Atlantic menhaden, spot, and summer flounder relative abundance was greater in non-SAV habitat as expected based on results from Chapter 1. Tautog relative abundance in 2021 was the second highest in this survey (Figure 2.2). This increase may be a direct result of modifying recreational regulations in 2018 to protect this species during the peak spawning periods. The tautog abundance results from the SAV Habitat Survey were compared to the surveys in Chapter 1 by ANOVA and post hoc DMRT. Those comparisons indicated significant ($F_{3,401} = 22.97$, $p < 0.01$) differences with relative abundance much higher in SAV than other coastal bays habitat such as sandy beaches, macroalgae assemblages, and deeper muddy bottom in the channels and river systems. The result show that SAV Habitat is essential to sustain juvenile tautog populations in Sinepuxent Bay. This survey's abundance indices will be considered for inclusion in the next stock assessment. Those data are a reliable indicator of Maryland tautog spawning success, whereas the Beach Seine and Trawl surveys are not appropriate for tautog management because they do not sample in SAV.

Fish relative abundance within SAV was further characterized by percent SAV coverage, primary substrate, and dominant SAV species. Overall, the results of the Kruskal-Wallis test (KWt) indicated significant differences of fish abundance for these habitat characteristics (9 fishes, 3 crustaceans; Table 2.6). The KWt identified potential selectivity preferences for SAV habitat characteristics with the assumption that higher species abundance in a particular defined characteristic demonstrated a preferred habitat. The KWt results with significant interactions were further investigated by ANOVA and post hoc DMRT to determine if the abundance levels differences.

SAV coverage results from the ANOVA identified two fishes, dusky pipefish, and northern pipefish, with significant differences in relative abundance. Moreover, the DMRT analysis also identified pigfish, sheepshead, and grass shrimp with significant difference in abundance by SAV coverage (Table 2.7). Dusky pipefish and pigfish preferred the densest SAV coverage while northern pipefish, sheepshead and grass shrimp abundance peaked in medium - high SAV coverage. Primary substrate ANOVA and DMRT showed a significant difference in abundance for sheepshead and brown shrimp towards sand substrate (Table 2.8). Dominant SAV species ANOVA results had higher abundance within eelgrass for dusky pipefish, northern pipefish, and striped burrfish while gray snapper and brown shrimp preferred widgeon grass. The post hoc DMRT results found significant differences in relative abundance for those species as well as pigfish, which preferred eelgrass. Tautog results were not significant; however, mean abundance was higher in eelgrass (Table 2.9).

While many of the species within the SAV did not indicate a significant preference for a particular SAV coverage, substrate, or SAV species, this could be due to the inability to isolate the specific characteristics during the analysis. When conducting a test on a particular characteristic, the secondary and tertiary interactions may have influenced the results. Overall, the SAV Habitat Survey had higher abundance within the survey and across the surveys for select fishes of recreational fishing interest (Table 2.3).

Fish Species Richness and Diversity by Habitat Category

Fish richness (number of species) was generally high (48 fishes total, 26.5 average per year) throughout the time series except in the multivariate categories that contained widgeon grass over mud (Table 2.10). This result may be bias of sample size as that specific habitat was uncommon throughout the time series (Table 2.2).

Diversity (evenness of those species) results indicated that medium and medium - high SAV coverage categories (26 - 50% and 51 - 75%) with sand substrate and eelgrass was the most diverse (H = 2.0; Table 2.11). The large abundance of Atlantic silverside and silver perch reduced the diversity index results because the analysis favors species richness proportions at equal levels in the sample population. High diversity will allow for resiliency to climate change.

Fish Length Composition by Habitat Category

Relationships of total length and habitat characteristics were investigated for significant interactions. Black sea bass, sheepshead, silver perch, and tautog were selected for ANOVA and DMRT analysis (Table 2.12). SAV coverage ANOVA and DMRT results indicated significant differences in length for silver perch and tautog. Silver perch were largest in low SAV coverage and smallest in high SAV coverage. Tautog were the largest in medium-high SAV and smaller in the other coverage categories. While larger tautogs were caught in medium-high SAV coverage, they were all young of year (age-0). The Narragansett Bay tautog estimated mean growth rate was 0.5 mm per day (Dorf & Powell, 1997). Medium-high 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).

Primary substrate ANOVA and post hoc DMRT results found significant differences in length for sheepshead, silver perch, and tautog (Table 2.13). Silver perch were larger in SAV beds within sand substrate whereas tautog were larger within muddy or soft bottom SAV beds.

Dominant SAV ANOVA and DMRT results showed significant differences in length for tautog (Table 2.14). This mean length difference may not be biologically significant, but may show that YOY tautog that survive longer select eelgrass habitat over widgeon grass.

Multivariate habitat selection by fish length may be due to food availability specific for the life stage of the fish, or shelter adequate for successful protection. The ANOVA and DMRT sensitivity may have found size differences not worthy of distinction for habitat selection. The SAV coverage category may be the driving factor regardless of substrate or SAV species in regards toward fish length or abundance.

Water Quality

While the water temperature, salinity, dissolved oxygen, and turbidity results were within acceptable limits for fishes and forage crustaceans throughout the survey time series, the ANOVA and DMRT results comparing annual water quality across the time series indicated significant interannual variability, especially in 2018 (Figures 2.3 - 2.6). This year showed high temperatures, lower salinity, lower dissolved oxygen, and higher turbidly. The mean water temperature in 2018 (29.7 C) was borderline close to the SAV threshold (30.0 C), but has decrease since then. The terminal year (2021) values improved, as did the tautog abundance (Figure 2.2.). Increases in water clarity is promising for SAV growth. The survey design performed well to dampen the effects of water quality variation within SAV habitat.

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
096	SAV beds vicinity Castaways Jackspot Waterfront Tiki bar	38 18.019	75 07.177	10
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	20
122	East of Snug Harbor, west of small island; pulled towards the south	38 17.167	75 07.523	2
128	South of duck blind, east of green marker	38 17.061	75 07.659	15
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 habitat characteristics (2015 - 2021).

	Percent SAV Coverage				Total by Characteristic	Grand Total
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%		
Eelgrass (*Zostera marina*)	14	16	27	31	88	115
Widgeon grass (*Ruppia maritima*)	8	8	7	4	27	
Sand	13	14	14	12	53	115
Mud	9	10	20	23	62	
Sand - Eelgrass (*Z. marina*)	6	10	12	9	37	115
Mud - Eelgrass (*Z. marina*)	8	6	15	22	51	
Sand - Widgeon grass (R. *maritima*)	7	4	2	3	16	
Mud - Widgeon grass (R. *maritima*)	1	4	5	1	11	

Table 2.3. List of fishes collected from the Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey (2015 - 2021). Catch per unit of effort (CPUE) was fish/hectare.

Specimen Name	2015 - 2021 (n = 115)			2021 (n = 16)		
	Count	x̄ CPUE	x̄ length	Count	CPUE	x̄ length
Atlantic silverside (*Menidia menidia*)	6,900	1,498.2	83	2,909	4,539.7	84
Silver perch (*Bairdiella chrysoura*)	5,885	1,277.8	75	93	145.1	89
Tautog (*Tautoga onitis*)	566	122.9	72	163	254.4	83
Sheepshead (*Archosargus probatocephalus*)	420	91.2	70	272	424.5	71
Halfbeak (*Hyporhamphus unifasciatus*)	225	48.9	149	19	29.7	141
Black sea bass (*Centropristis striata*)	186	40.4	77	138	215.4	72
Striped anchovy (*Anchoa hepsetus*)	165	35.8	75	66	103.0	78
Spotfin mojarra (*Eucinostomus argenteus*)	136	29.5	79			
Dusky pipefish (*Syngnathus floridae*)	134	29.1	155	16	25.0	140
Northern pipefish (*Syngnathus fuscus*)	127	27.6	177	9	14.0	105
Pigfish (*Orthopristis chrysoptera*)	108	23.4	88	31	48.4	81
Oyster toadfish (*Opsanus tau*)	98	21.3	69	8	12.5	71
Pinfish (*Lagodon rhomboides*)	98	21.3	122	1	1.6	162
Striped blenny (*Chasmodes bosquianus*)	98	21.3	62	30	46.8	59
Bay anchovy (*Anchoa mitchilli*)	71	15.4	67	12	18.7	72
Spot (*Leiostomus xanthurus*)	67	14.5	129			
Summer flounder (*Paralichthys dentatus*)	27	5.9	173	4	6.2	132
Northern puffer (*Sphoeroides maculatus*)	25	5.4	136	1	1.6	145
Gray snapper (*Lutjanus griseus*)	24	5.2	72	1	1.6	65
Striped burrfish (*Chilomycterus schoepfii*)	20	4.3	181			
Bluespotted cornetfish (*Fistularia tabacaria*)	19	4.1	346	11	17.2	356
Spotfin butterflyfish (*Chaetodon ocellatus*)	14	3.0	62	1	1.6	64
Atlantic menhaden (*Brevoortia tyrannus*)	11	2.4	112	1	1.6	95
Atlantic needlefish (*Strongylura marina*)	10	2.2	295	1	1.6	371
White mullet (*Mugil curema*)	10	2.2	171			

Table 2.3 continued. List of fishes collected from the Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey (2015 - 2021). Catch per unit of effort (CPUE) was fish/hectare.

Specimen Name	2015 - 2021 (n = 115)			2021 (n = 16)		
	Count	x̄ CPUE	x̄ length	Count	CPUE	x̄ length
Rainwater killifish (*Lucania parva*)	9	2.0	37			
Feather blenny (*Hypsoblennius hentz*)	7	1.5	70	2	3.1	63
Naked goby (*Gobiosoma bosc*)	6	1.3	36			
Spotted seatrout (*Cynoscion nebulosus*)	6	1.3	116			
Southern kingfish (*Menticirrhus americanus*)	5	1.1	103			
American eel (*Anguilla rostrata*)	4	0.9	318			
Blackcheek tonguefish (*Symphurus plagiusa*)	4	0.9	88	1	1.6	58
Lined seahorse (*Hippocampus erectus*)	4	0.9	122	3	4.7	119
Northern kingfish (*Menticirrhus saxatilis*)	4	0.9	121			
Striped mullet (*Mugil cephalus*)	4	0.9	197			
Bluefish (*Pomatomus saltatrix*)	4	0.9	120	1	1.6	82
Black drum (*Pogonias cromis*)	3	0.7	133			
Atlantic croaker (*Micropogonias undulatus*)	2	0.4	57			
Atlantic spadefish (*Chaetodipterus faber*)	2	0.4	83			
Inshore lizardfish (*Synodus foetens*)	2	0.4	164			
Southern stingray (*Dasyatis americana*)	2	0.4	420			
Cobia (*Rachycentron canadum*)	1	0.2	147			
Gag (*Mycteroperca microlepis*)	1	0.2	168			
Harvestfish (*Peprilus paru*)	1	0.2	30	1	1.6	30
Lookdown (*Selene vomer*)	1	0.2	82	1	1.6	82
Skilletfish (*Gobiesox strumosus*)	1	0.2	46			
Spanish mackerel (*Scomberomorus maculatus*)	1	0.2	170			
Striped killifish (*Fundulus majalis*)	1	0.2	107			

Table 2.4. List of forage crustaceans collected from the Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey (2015 - 2021). Catch per unit of effort (CPUE) was fish/hectare.

Specimen Name	2015 - 2021 (n =115)			2021 (n = 16)		
	Count	x̄ CPUE	x̄ length	Count	CPUE	x̄ length
Blue crab (*Callinectes sapidus*)	4,361	946.9	55	421	657.0	56
Grass shrimp (*Palaemonetes sp.*)	2,330	505.9		636	992.5	
Brown shrimp (*Farfantepenaeus aztecus*)	765	166.1	81	15	23.4	73

Table 2.5. September species abundance survey comparisons in Maryland's coastal bays (2015 - 2021). Catch per unit of effort (CPUE) was individual/hectare.

Specimen Name	SAV Habitat Survey n = 115		Beach Seine Survey All Bay Sites n = 133		Trawl Survey All Bay Sites n = 140	
	Count	x̄ CPUE	Count	x̄ CPUE	Count	x̄ CPUE
Silver perch (*Bairdiella chrysoura*)	5,885	1,227.8	5,293	452.2	1,915	109.1
Tautog (*Tautoga onitis*)	566	122.9	16	1.4		
Sheepshead (*Archosargus probatocephalus*)	420	91.2	173	14.8	5	0.3
Halfbeak (*Hyporhamphus unifasciatus*)	225	48.9	116	9.9		
Black sea bass (*Centropristis striata*)	186	40.4	28	2.4	93	5.3
Pigfish (*Orthopristis chrysoptera*)	108	23.4	110	9.4	20	1.1
Pinfish (*Lagodon rhomboides*)	98	21.3	225	19.2	13	0.7
Spot (*Leiostomus xanthurus*)	67	14.5	1,790	152.9	2,168	123.5
Summer flounder (*Paralichthys dentatus*)	27	5.9	218	18.6	151	8.6
Northern puffer (*Syngnathus maculatus*)	25	5.4	64	5.5	32	1.8
Gray snapper (*Lutjanus griseus*)	24	5.2	12	1.0		
Atlantic menhaden (*Brevoortia tyrannus*)	11	2.4	23,821	2035.1	92	5.2
Blue crab (*Callinectes sapidus*)	4,361	946.9	3,845	328.5	2,485	141.5
Grass shrimp (*Palaemonetes sp.*)	2,330	505.9	2,904	248.1	333	19.0
Brown shrimp (*Farfantepenaeus aztecus*)	765	166.1	425	36.3	753	42.9

Table 2.6. Results of the Submerged Aquatic Vegetation Habitat Survey's (2015 - 2021) Kruskal - Wallis test for percent SAV coverage, primary substrate, and dominant SAV on fish abundance (results greater than 0.05 were not significant (n.s.)).

Specimen Name	Percent SAV Coverage	Primary Substrate	Dominant SAV Species
Atlantic silverside (*Menidia menidia*)	n.s.	n.s.	n.s.
Black sea bass (*Centropristis striata*)	n.s.	($\chi 2(1) = 6.06$, $p < 0.05$)	n.s.
Dusky pipefish (*Syngnathus floridae*)	($\chi 2(3) = 12.34$, $p < 0.01$)	n.s.	($\chi 2(1) = 7.58$, $p < 0.01$)
Gray snapper (*Lutjanus griseus*)	n.s.	n.s.	($\chi 2(1) = 16.42$, $p < 0.01$)
Halfbeak (*Hyporhamphus unifasciatus*)	n.s.	n.s.	n.s.
Northern pipefish (*Syngnathus fuscus*)	($\chi 2(3) = 15.18$, $p < 0.01$)	($\chi 2(1) = 6.17$, $p < 0.05$)	($\chi 2(1) = 6.96$, $p < 0.01$)
Pigfish (*Orthopristis chrysoptera*)	($\chi 2(3) = 9.97$, $p < 0.05$)	n.s.	($\chi 2(1) = 4.28$, $p < 0.05$)
Pinfish (*Lagodon rhomboides*)	n.s	n.s.	n.s.
Sheepshead (*Archosargus probatocephalus*)	($\chi 2(3) = 8.33$, $p < 0.05$)	($\chi 2(1) = 4.35$, $p < 0.05$)	n.s.
Silver perch (*Bairdiella chrysoura*)	($\chi 2(3) = 12.87$ $p < 0.01$)	n.s.	n.s.
Striped burrfish (*Chilomycterus schoepfii*)	n.s.	n.s.	($\chi 2(1) = 5.22$, $p < 0.05$)
Tautog (*Tautoga onitis*)	($\chi 2(3) = 19.52$, $p < 0.01$)	n.s.	($\chi 2(1) = 18.25$, $p < 0.01$)
Blue crab (*Callinectes sapidus*)	($\chi 2(3) = 13.03$, $p < 0.01$)	n.s.	n.s.
Brown shrimp (*Farfantepenaeus aztecus*)	n.s.	($\chi 2(1) = 9.67$, $p < 0.01$)	($\chi 2(1) = 12.14$, $p < 0.01$)
Grass shrimp (*Palaemonetes sp.*)	($\chi 2(3) = 11.5$, $p < 0.01$)	n.s.	n.s.

Table 2.7. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) ANOVA and Duncan's multiple range test for CPUE and percent 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%
Dusky pipefish *(Syngnathus floridae*)	($F_{3,114} = 3.05$, $p < 0.05$)			
	x̄ = 7.9	x̄ = 14.6	x̄ = 34.5	x̄ = 47
	B	B	A/B	A
Northern pipefish (*Syngnathus fuscus*)	($F_{3,114} = 3.28$, $p < 0.05$)			
	x̄ = 4.5	x̄ = 25	x̄ = 42.1	x̄ = 29.4
	B	A / B	A	A / B
Pigfish (*Orthopristis chrysoptera*)	($F_{3,114} = 1.96$, p = n.s.)			
	x̄ = 7.9	x̄ = 20	x̄ = 28.1	x̄ = 33.8
	B	A / B	A / B	A
Sheepshead (*Archosargus probatocephalus*)	($F_{3,114} = 1.89$, p = n.s.)			
	x̄ = 23.8	x̄ = 50.6	x̄ = 152	x̄ = 100.6
	B	A / B	A	A / B
Silver perch (*Bairdiella chrysoura*)	($F_{3,114} = 1.07$, p = n.s.)			
	x̄ = 388.2	x̄ = 1,510.6	x̄ = 1,540	x̄ = 1,422.5
	A	A	A	A
Tautog (*Tautoga onitis*)	($F_{3,114} = 1.60$, p = n.s.)			
	x̄ = 74.9	x̄ = 59.3	x̄ = 133.66	x̄ = 186.2
	A	A	A	A
Blue crab (*Callinectes sapidus*)	($F_{3,114} = 2.53$, p = n.s.)			
	x̄ = 485.8	x̄ = 1,010.2	x̄ = 925.3	x̄ = 1,214.2
	A	A	A	A
Grass shrimp (*Palaemonetes sp.*)	($F_{3,114} = 2.65$, p = n.s.)			
	x̄ = 67	x̄ = 492.1	x̄ = 752.8	x̄ = 551.5
	B	A / B	A	A / B

Table 2.8. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) ANOVA and Duncan's multiple range test for CPUE and primary substrate.

Specimen Name	Primary Substrate	
	Sand	Mud
Black sea bass (*Centropristis striata*)	($F_{1,114} = 0.33$, p = n.s.)	
	$\bar{x} = 48.5$	$\bar{x} = 30.6$
	A	A
Sheepshead (*Archosargus probatocephalus*)	($F_{1,114} = 6.17$, $p < 0.05$)	
	$\bar{x} = 144.6$	$\bar{x} = 45.5$
	A	B
Brown shrimp (*Farfantepenaeus aztecus*)	($F_{1,114} = 4.12$, $p < 0.05$)	
	$\bar{x} = 270$	$\bar{x} = 77$
	A	B

Table 2.9. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) ANOVA and Duncan's multiple range test for CPUE and dominant SAV.

Specimen Name	Dominant SAV Species	
	Eelgrass	Widgeon Grass
Dusky pipefish (*Syngnathus floridae*)	($F_{1,114} = 4.57$, $p < 0.05$)	
	$\bar{x} = 35.2$	$\bar{x} = 9.25$
	A	B
Gray snapper (*Lutjanus griseus*)	($F_{1,114} = 18.3$, $p < 0.01$)	
	$\bar{x} = 0.56$	$\bar{x} = 20.3$
	B	A
Northern pipefish (*Syngnathus fuscus*)	($F_{1,114} = 5.33$, $p < 0.05$)	
	$\bar{x} = 32.9$	$\bar{x} = 10.2$
	A	B
Pigfish (*Orthopristis chrysoptera*)	($F_{1,114} = 1.53$, p = n.s.)	
	$\bar{x} = 26.2$	$\bar{x} = 14.8$
	A	B
Striped burrfish (*Chilomycterus schoepfii*)	($F_{1,114} = 4.39$, $p < 0.05$)	
	$\bar{x} = 5.7$	$\bar{x} = 0$
	A	B
Tautog (*Tautoga onitis*)	($F_{1,114} = 2.27$, p = n.s.)	
	$\bar{x} = 114.2$	$\bar{x} = 60.1$
	A	A
Brown shrimp (*Farfantepenaeus aztecus*)	($F_{1,114} = 14.1$, $p < 0.01$)	
	$\bar{x} = 71.5$	$\bar{x} = 474.4$
	B	A

Table 2.10. Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) Richness of fishes by habitat category.

	Percent SAV Coverage			
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%
Combined (All SAV and Substrate)	31	38	39	32
Eelgrass (*Zostera marina*)	24	29	31	30
Widgeon grass (*Ruppia maritima*)	26	26	28	15
Sand	28	34	34	21
Mud	20	23	27	29
Sand - Eelgrass (*Z. marina*)	19	25	26	18
Mud - Eelgrass (*Z. marina*)	19	22	25	29
Sand - Widgeon grass (*R. maritima*)	25	24	24	12
Mud - Widgeon grass (*R. maritima*)	6	9	18	8

Table 2.11. Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) 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 and Substrate)	1.5	1.5	1.5	1.5
Eelgrass (*Zostera marina*)	1.5	2	1.5	1.4
Widgeon grass (*Ruppia maritima*)	1.4	1.1	1.2	1
Sand	1.4	1.5	1.7	1.4
Mud	1.5	1.4	1.3	1.4
Sand - Eelgrass (*Z. marina*)	1.3	2	2	1.5
Mud - Eelgrass (*Z. marina*)	1.4	1.6	1.2	1.4
Sand - Widgeon grass (*R. maritima*)	1.4	1.1	1	0.9
Mud - Widgeon grass (*R. maritima*)	1.5	1	1.3	1.1

Table 2.12. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) ANOVA and Duncan's multiple range test for mean length and percent 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*)	($F_{3,185}$ = 1.02, p = n.s.) $\bar{x}$ = 86.2 A	$\bar{x}$ = 72.2 A	$\bar{x}$ = 74.5 A	$\bar{x}$ = 77.2 A
Sheepshead (*Archosargus probatocephalus*)	($F_{3,409}$ = 0.14, p = n.s.) $\bar{x}$ = 69.8 A	$\bar{x}$ = 69.4 A	$\bar{x}$ = 70.4 A	$\bar{x}$ = 70.5 A
Silver perch (*Bairdiella chrysoura*)	($F_{3,2453}$ = 54.89 p < 0.01) $\bar{x}$ = 85.5 A	$\bar{x}$ = 76.3 B	$\bar{x}$ = 76.6 B	$\bar{x}$ = 70.5 C
Tautog (*Tautoga onitis*)	($F_{3,565}$ = 20.73, p < 0.01) $\bar{x}$ = 63.8 C	$\bar{x}$ = 63.6 C	$\bar{x}$ = 79.1 A	$\bar{x}$ = 71.6 B

Table 2.13. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) ANOVA and Duncan's multiple range test for mean length and primary substrate (results greater than 0.05 were not significant (n.s.)).

Specimen Name	Primary Substrate Mud	 Sand
Black sea bass (*Centropristis striata*)	($F_{1,185}$ = 0, p = n.s.) $\bar{x}$ = 76.7 A	$\bar{x}$ = 76.9 A
Sheepshead (*Archosargus probatocephalus*)	($F_{1,409}$ = 2.36, p = n.s.) $\bar{x}$ = 71.8 A	$\bar{x}$ = 69.7 A
Silver perch (*Bairdiella chrysoura*)	($F_{1,2453}$ = 25.7, p < 0.01) $\bar{x}$ = 73.2 B	$\bar{x}$ = 76.8 A
Tautog (*Tautoga onitis*)	($F_{1,565}$ = 22.71, p < 0.01) $\bar{x}$ = 76.7 A	$\bar{x}$ = 69.6 B

Table 2.14. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021) ANOVA and Duncan's multiple range test for mean length and dominant SAV (results greater than 0.05 were not significant (n.s.)).

Specimen Name	Dominant SAV Species	
	Eelgrass	Widgeon Grass
Black sea bass (*Centropristis striata*)	($F_{1,185} = 3.8$, p = n.s.)	
	$\bar{x} = 75.9$	$\bar{x} = 88.6$
	A	A
Sheepshead (*Archosargus probatocephalus*)	($F_{1,409} = 0.19$, p = n.s.)	
	$\bar{x} = 70.2$	$\bar{x} = 70.9$
	A	A
Silver perch (*Bairdiella chrysoura*)	($F_{1,2453} = 2.58$, p = n.s.)	
	$\bar{x} = 74.5$	$\bar{x} = 75.8$
	A	A
Tautog (*Tautoga onitis*)	($F_{1,565} = 27.29$, $p < 0.01$)	
	$\bar{x} = 73.7$	$\bar{x} = 61.8$
	A	B

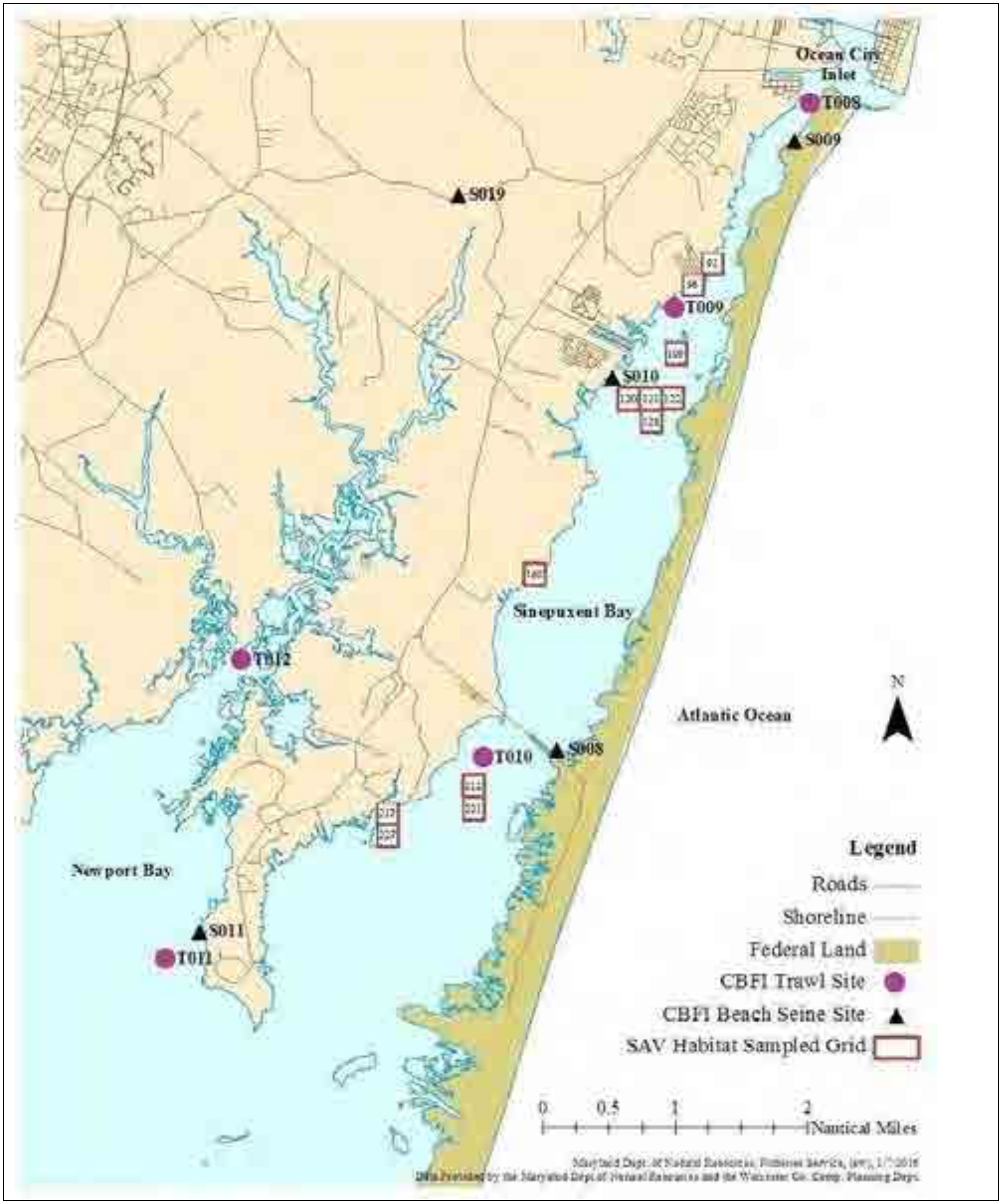

Figure 2.1. Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey and Trawl and Beach Seine surveys sample site locations (2015 - 2021).

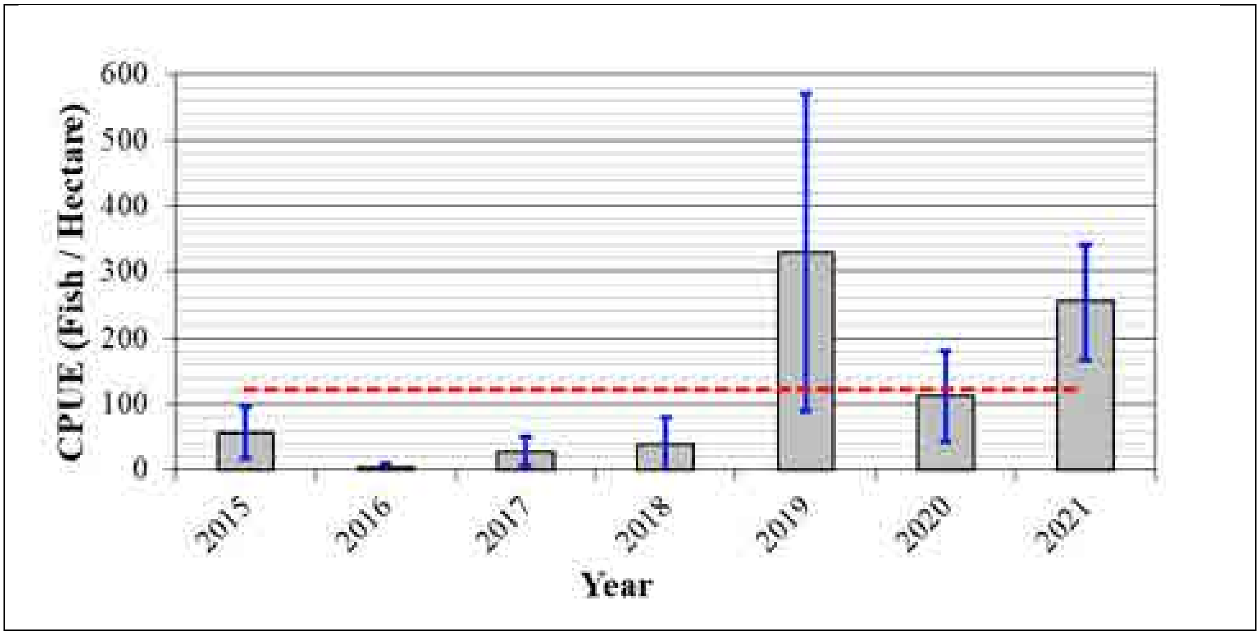

Figure 2.2. Tautog CPUE from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021). Dotted line represents the 2015 - 2021 time series grand mean (n = 115).

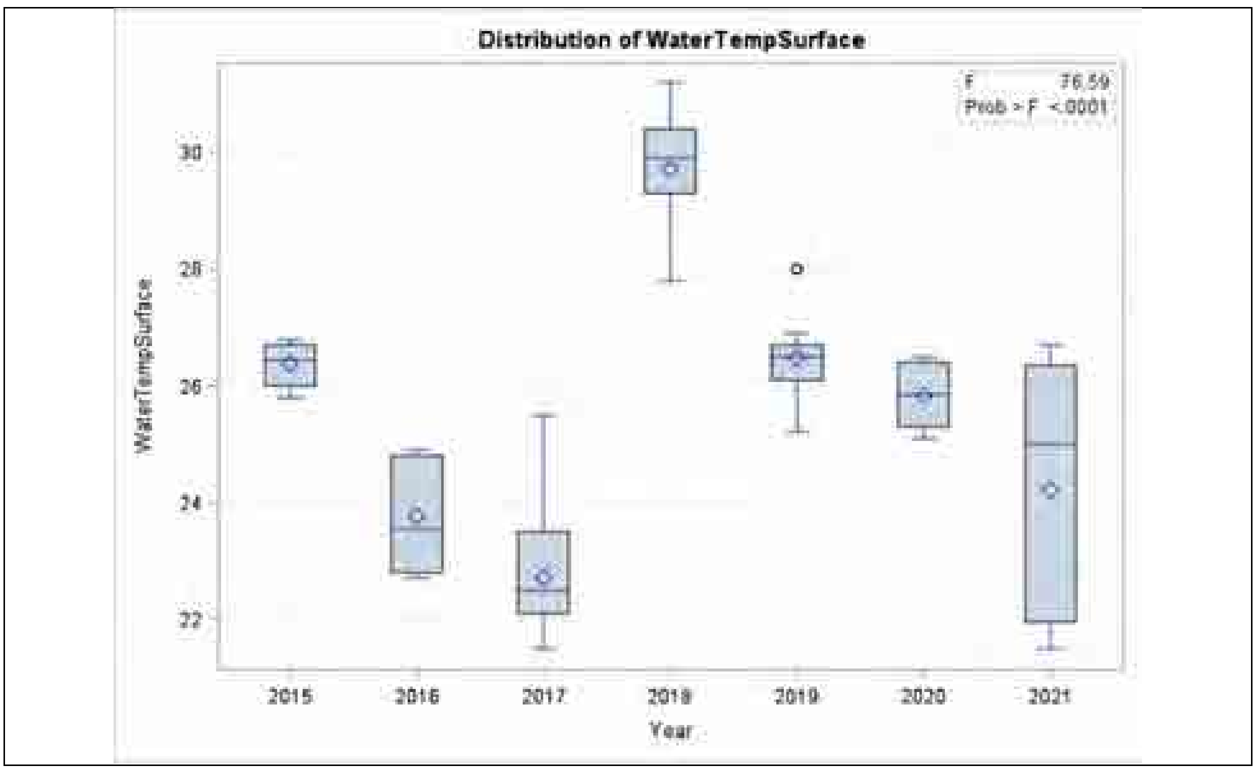

Figure 2.3. Distribution of surface water temperature from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021).

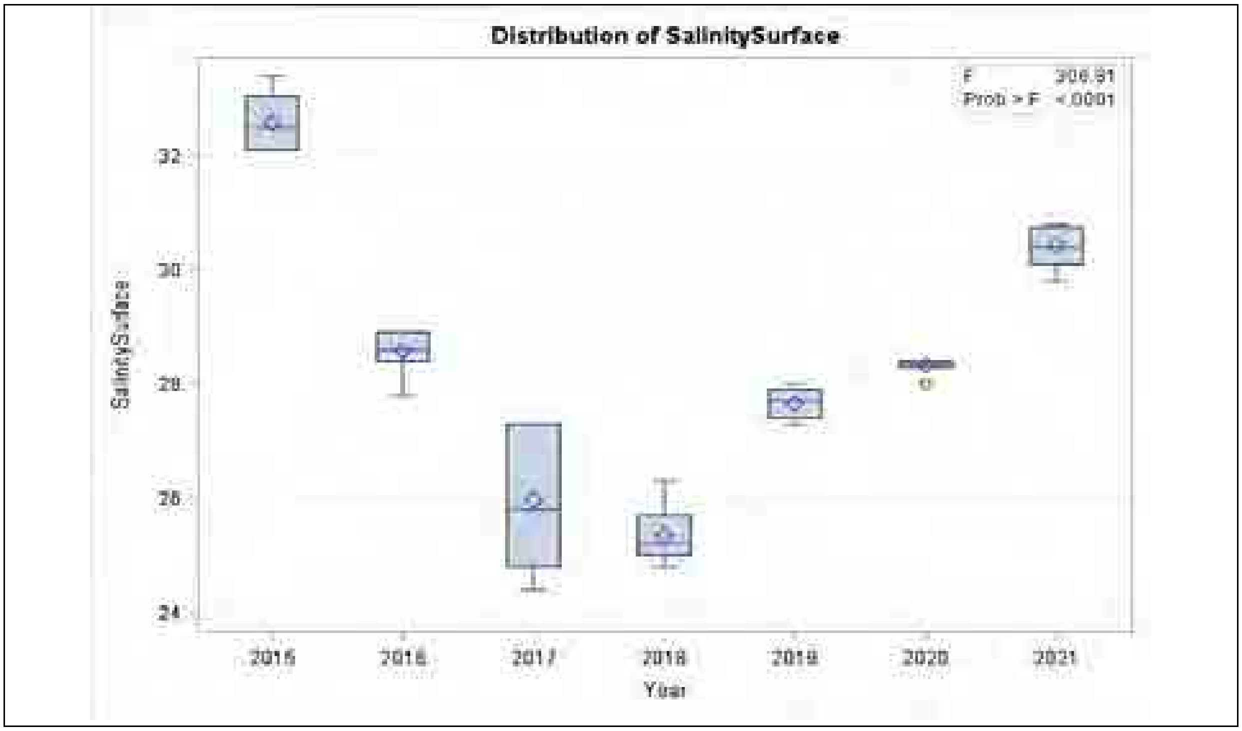

Figure 2.4. Distribution of surface salinity from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021).

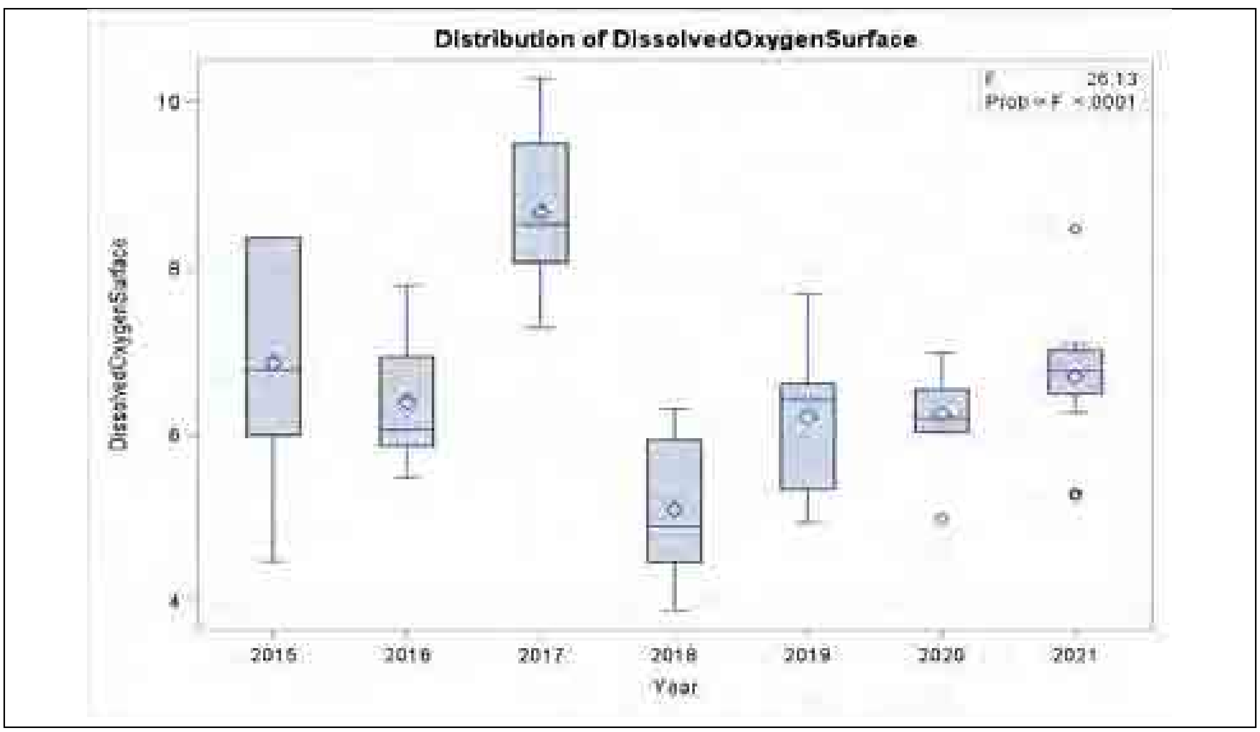

Figure 2.5. Distribution of surface dissolved Oxygen from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021).

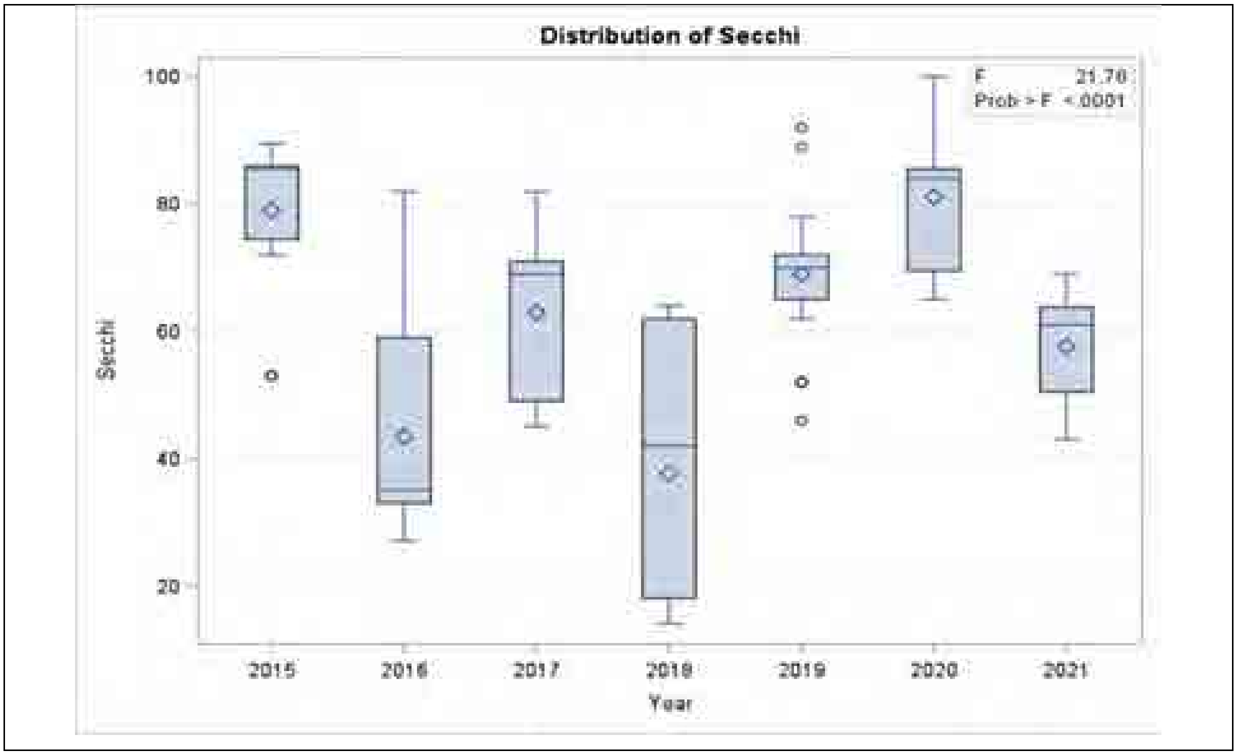

Figure 2.6. Distribution of turbidly from the Submerged Aquatic Vegetation Habitat Survey (2015 - 2021).

Chapter 3 Fisheries Dependent Tautog (*Tautoga onitis*) Data Collection (2016 - 2021)

Length, sex, and opercula were collected from 201 tautog from April to December 2021 among the Ocean City charter fleet rack project (76.5%), DNR observer of 100% collection on board a charter trip (21%), a private boat angler (1%) and by spearfishing (1.5%). Those samples represented the range of fish lengths commonly caught in the recreational fishery in Maryland in 2021. Age was determined on 196 tautog and were combined with the historical state data which will be submitted to the ASMFC Tautog Stock Assessment Subcommittee for the Delmarva Regional Age Length Key.

Aged fish total lengths ranged from 222 mm to 775 mm, mean length was 430 mm, and median length was 425 mm for both sexes combined. Females comprised 59% (n = 119) of the samples with a mean length of 414 mm and median length of 407 mm. Males comprised 41% (n = 82) of the samples with a mean length of 453 mm and median length of 440 mm. The 431.8 mm length bin had the highest proportion of catch (25.5%; Table 3.1).

Fish age ranged from two to 20 years, mean age was six years, and the median age was seven years. Age-seven tautog comprised 22.4% of the samples and was the largest age bin (Table 3.2). The mean and median age was six years for females and seven years for males. The combined sex age frequency results from 2016 - 2021 (n = 1,270) indicated that five-year old tautog were most frequently caught by recreational anglers (Figure 3.1).

The von Bertalanffy growth curve was fitted to the 2016 - 2021 length-age data (n = 1,270) using three parameter estimates (m = 3): asymptotic length in centimeters (Linf ∞), growth rate (K), and age at zero size (t0). Tautog length-at-age data and the von Bertalanffy growth curve estimate results were similar to the previous parameters in the stock assessment (Linf, 70.65; k, 0.11 and t0, -2.11; Figure 3.2). The 2015 Benchmark Stock Assessment growth curve analyses indicated a clear distinction between growth parameters for tautog in Southern (VA, MD, DE, NJ) and Northern (NY, RI, MA, CT) states. Southern states have higher $L\infty$ and lower K values than Northern states.

Overall, the Maryland recreational tautog fishery is preforming well, with a broad range of year classes and juvenile abundance. The charter fleet has moved towards voluntary catch and release of large fish, especially females.

Table 3.1. Tautog proportion at length of samples collected from Ocean City, Maryland (2021; n = 196). Green cells indicate legal fish (406.4 mm/16 in).

Length (mm)	228.6	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	635	*Over*	787.4
Length (in)	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		31
Percent	1.0	1.5	2.6	2.6	5.6	2.6	4.6	18.9	25.5	7.7	10.7	7.7	4.6	2.0	1.0	0.5	0.5		0.5

Table 3.2. Tautog proportion at age of samples collected from Ocean City, Maryland (2021; n = 196).

Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*Over*	20
Percent	1.5	2.6	9.7	15.3	19.9	22.4	10.7	7.1	3.1	1.5	2.6	1.0	1.0	1.0		0.5

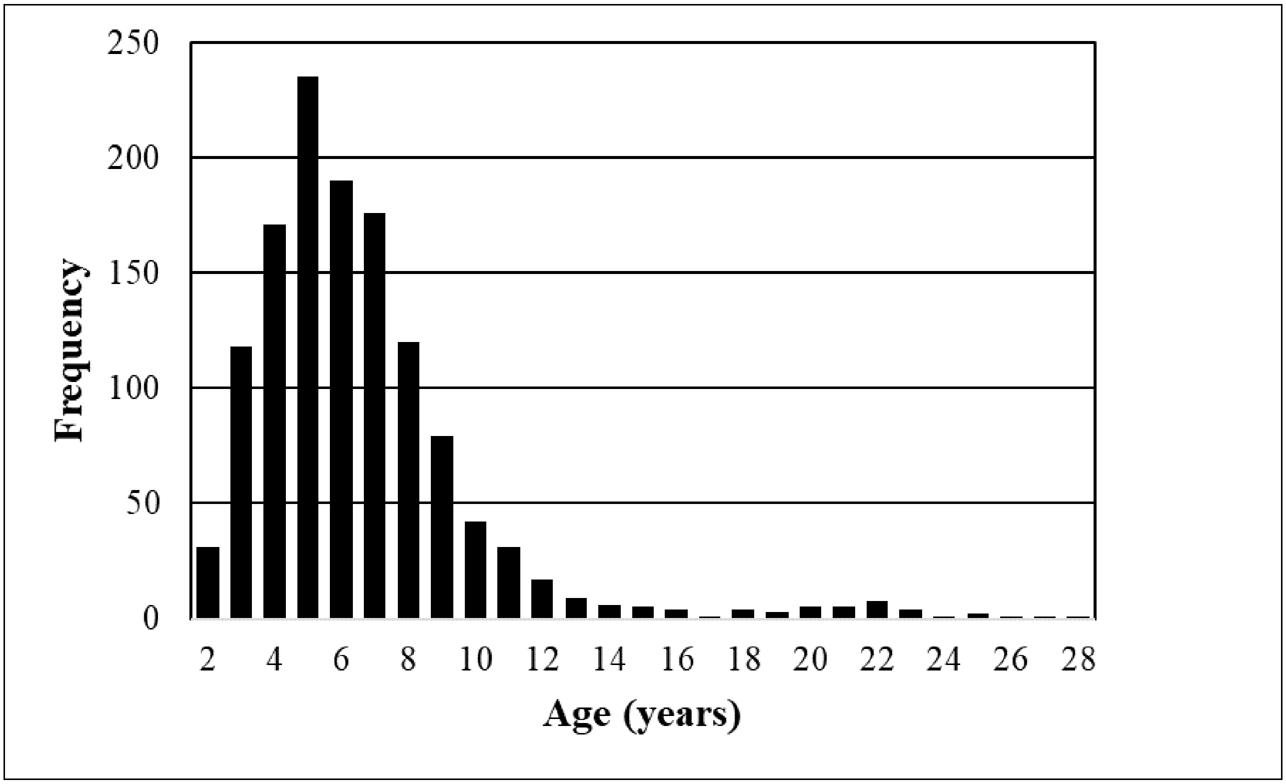

Figure 3.1. Tautog age frequency representing fish commonly caught in the recreational fishery in Ocean City, Maryland, (2016 - 2021; n = 1,270).

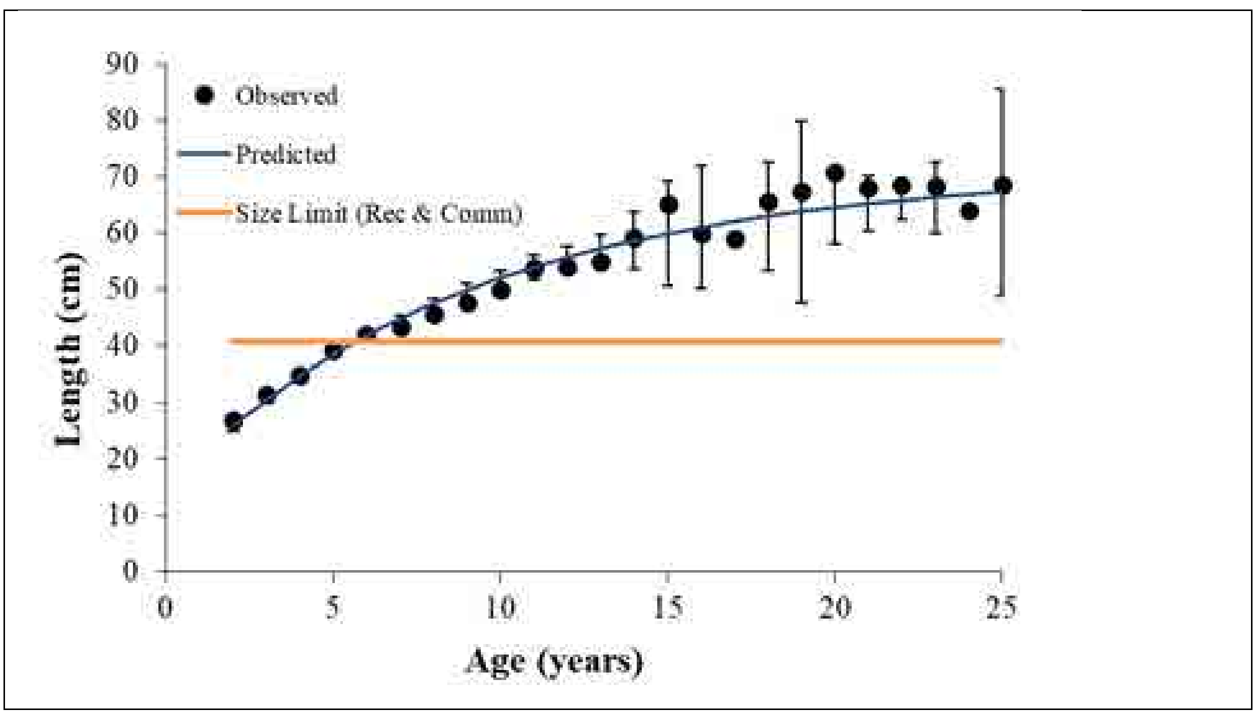

Figure 3.2. Tautog length-at-age and von Bertalanffy growth curve results with 95% confidence intervals, Ocean City, Maryland (2016 - 2021; n = 1,270).

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 in order 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.

Species	Technical Committee Participation	Data Provided for the ASMFC Compliance Report	F-50-R Staff Wrote the ASMFC Compliance Report	Data Provided During 2021/2022 Assessment/Update	2021/2022 Stock Assessment/Update Participation
Atlantic croaker		Trawl			
Black drum		Beach Seine		Beach Seine	
Black sea bass	ASMFC/MAFMC	Trawl/Beach Seine	Yes	Trawl	
Bluefish		Beach Seine		Trawl/Beach Seine	
Coastal sharks	No ASMFC meetings held		Yes		
Cobia		Beach Seine			
Red drum				Beach Seine	
Scup	ASMFC/MAFMC		Yes		
Spot		Trawl/Beach Seine			
Spotted seatrout		Beach Seine			
Summer flounder	ASMFC/MAFMC	Trawl/Beach Seine	Yes	Trawl	

Tautog	ASMFC	Trawl/Beach Seine/SAV Habitat Survey/Dependent Collection	Yes	Trawl/Beach Seine/SAV Habitat Survey/Dependent Collection	Yes
Weakfish		Trawl			
Other Technical Committee Expertise					
ASMFC, Northeast Area Monitoring and Assessment Program					
DNR, Chesapeake and Coastal Services, Climate Change Planning Committee					
National Estuary Program, Maryland Coastal Bays Program Science and Technical Advisory Committee National Oceanic and Atmospheric Administration Highly Migratory Species Advisory Panel					

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