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

July 2018 - June 2019

F-50-R-27

Final Report

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UNITED STATES
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Final Performance Progress Report
Investigation of Maryland's Coastal Bays and Atlantic Ocean Finfish Stocks
July 1, 2018 through June 30, 2019

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Accomplishments July 1, 2018 - June 30, 2019

Completed July - October 2018

- Collected 20 trawl samples at 20 fixed locations on Maryland’s coastal bays, monthly
- Completed data entry and cleanup from prior month's sampling
- Accompanied commercial trawlers to gather biological information on adult finfishes in July, August, and October
- Edited the F-50-R-26 report through September

Completed September 2018

- Conducted beach seine sampling at 19 fixed locations on Maryland’s coastal bays
- Conducted the Submerged Aquatic Vegetation Habitat Survey beach seines at 21 sites in Sinepuxent Bay
- Completed the F-50-R-26 report
- Processed data request for the Atlantic States Marine Fisheries Commission Cobia Technical Committee

Completed October - November 2018

- Completed data entry/cleanup from September beach seine sampling
- Completed QA/QC for all data collected during the field sampling season
- Collected opercula from 89 tautog, 45 pelvic spines and 14 otolith (age structures) as well as the length, sex and weight for those fish
- Processed data requests for the University of Texas Marine Science Institute and The Nature Conservancy

Completed December 2018 - March 2019

- Accompanied commercial trawler to gather biological information on adult finfishes in December
- Conducted data analyses of the 2018 surveys
- Drafted the F-50-R-27 annual report
- Prepared for the 2019 field sampling season (Trawl and Beach Seine surveys)
- Determined sampling needs for the next Submerged Aquatic Vegetation Habitat Survey
- Cleaned and aged tautog opercula
- Updated recreational and forage finfish indices for trend analysis
- Collected 106 tautog opercula, 35 pelvic spines and 21 otolith samples from a charter boat for age structures, length, sex and weight
- Drafted metadata for shark logs
- Proofed 2007 - 2012 electronic shark logs
- Entered data from 2013 - 2017 shark logs and associated vessel logs from 2018
- Processed additional data request for the University of Texas Marine Science Institute
- Processed new data request for The Nature Conservancy and the Atlantic States Marine Fisheries Commission Weakfish Technical Committee

Completed April - June 2019

- Collected 20 trawl samples at 20 fixed locations on Maryland’s coastal bays, monthly
- Completed data entry and cleanup from prior months sampling

- Created database for shark logs
- Edited the F-50-R-27 report
- Processed data request for the University of Maryland Eastern Shore Marine Science Graduate Program

Completed June 2019

- Completed one trip onboard a trawler to gather biological information on adult finfishes
- Conducted beach seine sampling at 19 fixed locations on Maryland’s coastal bays
- Collected 20 trawl samples at 20 fixed locations on Maryland’s coastal bays

Preface

Analyses of the Trawl and Beach Seine surveys data revealed seasonal and temporal biases in the data collection (1972 - 1988) which significantly affected the overall time series dataset (1972 - present). These biases resulted from prioritization of resources by the department coupled with limited staff availability and lack of funding prior to 1989. Beginning in 1989, this survey was performed following a standardized sampling protocol, eliminating the biases of previous years. This report highlights trends resulting from data collected during the standardized (1989 - present) time period. No historical data (1972 - 1988) were included in these analyses.

Modifications to the sampling protocol were implemented in 2006. Changes included:
- collecting bottom water quality, latitude and longitude;
- developing a field identification guide of fishes and invertebrates;
- developing a voucher collection and annual staff review;
- estimating the percent opening of the beach seine;
- identifying bryozoans, macroalgae, and sponges as well as estimating the percent of the total volume collected per sample;
- identifying the bottom type at beach seine sites;
- labeling estimates of counts and volume;
- measuring the first 20 individuals of all fishes;
- measuring the total volume of comb jellies;
- using an anemometer and depth finder; and
- using a standardized datasheet.

Beginning in 2010, field data sheets were reviewed by the data collector as well as another on board biologist after the sample workup was completed to reduce errors. The verification process includes checking for appropriate common names, values, completeness, confusing information and legibility.

Beginning in 2008, all data from the Beach Seine, Drop Net and Trawl surveys were incorporated into a centralized database. Beginning in 2009, all data imported into the database were verified using the original field sheets or related transcribed copies from that time. Data verification for 1972 - 1988 was completed in 2017.

The Submerged Aquatic Vegetation Habitat Survey was added in 2012. After the 2012 pilot year, the east and west Sinepuxent Bay zones were combined into one. Further refinements were made to the sampling approach in 2014 by circling the beach seine for greater catchability of demersal fish.

Executive Summary

The investigation was developed to characterize juvenile and adult fishes and their abundances in Maryland's coastal bays and Atlantic Ocean, facilitate management decisions and protect finfish habitats. This investigation is comprised of four surveys: Beach Seine, Submerged Aquatic Vegetation Habitat and Trawl surveys in the bays behind Fenwick and Assateague Islands plus an Offshore Trawl Survey to characterize nearshore ocean adult finfishes. These 30 years of continuous 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, verification of submerged aquatic vegetation and academic research.

The investigation uses the previously mentioned four surveys and fisheries dependent information to meet the following four objectives:

1. Characterize the stocks and estimate relative abundance of juvenile and adult marine and estuarine species in the Maryland's coastal bays and near-shore Atlantic Ocean.
2. Delineate and monitor areas of high value as spawning, nursery and/or forage locations for finfish in order to protect against habitat loss or degradation.
3. Provide technical assistance by participating on inter- and intra-government committees and writing Atlantic States Marine Fisheries Commission compliance reports. Develop indices of age and length, relative abundance and other needed information necessary to assist in the management of regional and coastal fish stocks.
4. To enhance the knowledge of sharks that are of interest to recreational anglers.

In 2018, 42,558 fish were caught in the trawl and beach seine surveys (8,881 fish trawl and 33,677 fish beach seining)**.** Collected fishes represented 73 species which is within the normal representation range in a year. Four important recreational and forage species had below average trawl indices in 2018 including: Atlantic croaker, black sea bass, spot and summer flounder. American eel, Atlantic croaker, black sea bass, spot and weakfish had below average beach seine indices. Atlantic silversides and silver perch were the only species to have above average trawl index and summer flounder was the only species to have an above average beach seine index. In 2016, 2017 and 2018 summer flounder were frequently encountered in the April and May trawl samples but as the summer progressed they became more abundant in shallow water where they were captured in the Beach Seine Survey.

Richness is defined as the number of different species per embayment. For the 2018 Trawl Survey, Chincoteague Bay had the highest fish richness (39 species) whereas Newport Bay had the lowest (17 species). The Trawl Survey time series (1989 - 2018) results showed that Chincoteague Bay had the highest richness (90 species) and Newport Bay had the least (67 species).

Chincoteague Bay also has the highest richness for fishes (38 species) in the 2018 Beach Seine Survey whereas Ayers Creek has the lowest (nine species). The Beach Seine Survey time series (1989 - 2018) results showed that Assawoman Bay had the highest fish richness (87 species) and Ayers Creek (44 species) had the lowest.

Diversity is defined by the Shannon index results, which is a measurement of fish species richness and the proportion of those species in the sample population. In the 2018 Trawl Survey, Sinepuxent Bay (H = 1.91) was the most diverse and the St. Martin River (H = 1.23) was the least among the six trawled embayments. Diversity results from the trawl time series (1989 - 2018) indicated that Sinepuxent Bay (H = 1.69) was the most diverse whereas the St. Martin River (H = 1.33) was the least.

The 2018 Beach Seine Survey results indicated that the St. Martin River (H = 2.48) had the highest diversity whereas Assawoman Bay (H = 0.40) was the least. The Shannon index for the Beach Seine Survey time series (1989 - 2018) results showed that Chincoteague Bay (H = 1.63) was the most diverse whereas the Ayers Creek (H = 1.21) was the least.

Macroalgae bycatch is ephemeral with annual variation. It is quantified in these surveys for its positive and negative effects as habitat. Seventeen genera were collected by trawl and beach seine within the coastal bays in 2018. Results showed that *Agardhiella* were the most abundant macroalga (64.4 percent trawl and 77.7 percent beach seine) throughout the coastal bays in 2018.

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 fish. Preliminary 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 occurs during the day when the effects of low dissolved oxygen may not be evident. Dissolved oxygen levels have been improving since 1989 and salinity has increased. Temperatures, while increasing over the time of the surveys, were within the acceptable range for coastal fish.

The overall catch per unit effort of fishes in the Submerged Aquatic Vegetation Habitat Survey, especially tautog, demonstrates the importance of submerged aquatic vegetation as critical habitat in Sinepuxent Bay. The survey also confirms that with continued study and monitoring of this habitat, stock assessments and species specific habitat criteria can be refined.

A total of 211 tautog were examined during ten charter trips. Tautog ageing results showed 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 28 and the mean age was 6.8 years.

The Offshore Trawl Survey began in 1993 to obtain biological information on adult fishes in the nearshore Atlantic waters. Offshore sampling provides access to species and adult length groups not frequently captured in the Trawl and Beach Seine surveys that are conducted in Maryland's coastal bays. Twenty-nine species were collected from five trips in 2018. Fishes of recreational interested encountered from these trawls include summer flounder, clearnose skate, spiny dogfish, southern kingfish, Atlantic croaker and scup. A total of 315 summer flounder were measured from those offshore trawls. Thirty-five percent (110 fish) of the measured summer flounder were at or above the recreational minimum size limit (432 millimeters; 17 inches) and 92 percent (290 fish) were above 356 millimeters (14 inches), which is the length of female maturity.

Dependent shark records from a charterboat captain were reviewed to answer biological questions and their potential to meet F-50-R objectives to enhance the knowledge of sharks that are of interest to recreational anglers. Initial review covering 2007 – 2017 revealed that trips targeting offshore sharks such as blue sharks, shortfin mako and thresher sharks occurred in May and June. Most of the nearshore charter trips occurred within 20 nautical miles of shore. Those data indicated that dusky, sandbar and spinner sharks were most frequently caught in July and August. These data document a range extension for blacknose sharks (*Carcharhinus acronotus*) which have a northernmost range of North Carolina in literature. Of note, there were three great white sharks and zero bull sharks caught in that 11 year time period.

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Chapter 1: Trawl and Beach Seine Surveys

Introduction

The Coastal Bays Fisheries Investigation was developed to characterize fishes and their abundances in Maryland's coastal bays, facilitate management decisions and protect finfish habitats. The department has conducted the investigations 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 - 2018.

Over 140 adult and juvenile species of fishes, 26 molluscs and 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. delineate and monitor areas of high value as spawning, nursery and/or forage locations (habitat) for finfish in order to protect against habitat loss or degradation.

Methods

Study Area

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. Important tidal tributaries include: St. Martin River, Turville Creek, Herring Creek and Trappe Creek. 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 only 453 km^2 (175 mi^2). The bathymetry of the coastal bays is characterized by a few deep holes, narrow channels and shallow sand bars.

The Ocean City and Chincoteague inlets provide oceanic influences to these bays. Ocean City Inlet is formed at the boundaries of south Fenwick Island and north Assateague Island and is located at the convergence of Isle of Wight Bay and Sinepuxent Bay. Chincoteague Inlet located in Virginia is approximately 56 km (34 mi) south of the Ocean City Inlet.

Ocean City on Fenwick Island is a heavily developed area and the center of a $16 billion tourism industry catering to approximately 8 million visitors annually (Greater Ocean City Chamber of Commerce 2016). The western shore of the northern bays is dominated by residential development and a small amount of farmland. Areas south of Ocean City are less developed with more *Spartina* marshes and include three parks on the eastern barrier island: Assateague Island National Seashore, Assateague State Park and Chincoteague National Wildlife Refuge. These properties have beach front, campgrounds, dunes, marshes, off road vehicle access and small buildings. The western shore of the southern bays is made up of farmland, a state wildlife management area, and a small amount of residential development.

Data Collection

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 at 20 fixed sites throughout Maryland's coastal bays on a monthly basis from April through October (Table 1, Figures 1 - 3). With the exception of June and September, samples were taken beginning the third week of the month. Sampling began the second week in June and September in order 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 of 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. Shore beach seine sampling was conducted at 19 fixed sites beginning in the second weeks of June and September (Table 2, Figures 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.

Water Quality and Physical Characteristics

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: speed (kts), tide state, water clarity (Secchi disk; centimeters (cm)), water depth (ft), weather conditions and wind direction. 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 and 30 cm (1 ft) from the bottom, at each trawl site. 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. Difficulties determining tide resulted from inlet influences in Ocean City and Chincoteague, lack of appropriate tide stations for some sites and 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 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 (Table 3). Sex and maturity categories included: immature female, male, mature female (sook) and mature female with eggs. A subsample of the first 50 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 the 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 and biological significance as forage for adult gamefish and indicators of water quality.

The Geometric Mean (GM) was calculated to develop species specific annual trawl and beach seine indices of relative abundance (1989 - 2018). That method was adopted by 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 - 2018) and used as a point estimate for comparison to the annual (2018) estimate of relative abundance.

Fish diversity was calculated by the Shannon index (H). Shannon's index accounts for both abundance and evenness of the species present. 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 4. 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 2018. 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, turbidity) per bay (six systems) was derived from using the surface and bottom values. The DO averages were reviewed to see if the system overall fell below 5 mg/L (critical level of hypoxia in some systems).

Results and Discussion

Overview

Finfish were the most abundant taxa captured in the survey. Specifically, they accounted for 42,558 fish caught trawling (8,881) and beach seining (33,677 fish) in 2018 (Table 4**).** The total number of species and individual fish caught was similar to the last 10 years (Table 5). Collected fishes represented 73 species which is within the normal representation range in a year.

Atlantic silversides and silver perch had above average trawl indices (Table 6). Summer flounder had above average beach seine indices in 2018. Atlantic croaker, black sea bass, spot and summer flounder had below average trawl indices and American eel, Atlantic croaker, black sea bass, spot and weakfish had below average beach seine indices in 2018.

Crustaceans were the second most abundant taxa captured in this survey. Specifically, they accounted for 11,519 specimens caught trawling (8,231 crustaceans) and beach seining (3,288 crustaceans) in 2018 (Table 7). Sixteen crustaceans were identified, which is similar to the numbers found between 1989 and 2017. Crustaceans were dominated by blue crabs, grass shrimp and sand shrimp.

The third most abundant taxa captured in the survey were molluscs. Specifically, they accounted for 762 specimens caught trawling (622 molluscs) and beach seining (140 molluscs; Table 8). Molluscs were represented by 16 different species which is similar to the numbers of molluscs found between 1989 and 2017. The solitary glassy bubble snail was the most abundant in 2018.

Nineteen other types of animals were captured trawling and beach seining including: bryozoans, ctenophores, horseshoe crabs, northern diamondback terrapins, sponges and tunicates (Table 9).

Plants (SAV and macroalgae) were also captured in the trawls and beach seines (Table 10). Two species of SAV and 15 macroalgae genus were encountered in 2018. Red macroalgae were most abundant for both gears.

American eel (*Anguilla rostrata*)

Results

American eels were captured in 11 of 140 trawls (7.9%) and in two of 38 beach seines (5.3%). A total of 79 American eels were collected in trawl (76 fish) and beach seine (three fish) samples (Table 4). American eel ranked 18 out of 73 species in overall finfish abundance. The trawl and beach seine CPUEs were 4.3 fish/ha and < 0.1 fish/haul, respectively.

The 2018 the trawl relative abundance index was equal to the grand mean and the beach seine relative abundance index was below the grand mean (Figures 4 and 5). Since 1989, the trawl (three years) and beach seine (four years) indices rarely varied from the grand means.

The mean length of American eels increased from 64 mm in April to 75 mm in July in the Trawl Survey (Table 11). Two were collected trawling in September and they averaged 305 mm. In the Beach Seine Survey, there were three eels caught in September and the mean length was 262 mm (Table 12).

Discussion

American eels are important as forage for a variety of fishes and as bait for recreational anglers. Both trawl and beach seine gears catch a limited number of American eels but have value in assessing the abundance because the estimates vary little from year to year. Since American eels spawn in the Sargasso Sea, environmental conditions and ocean currents may be a factor influencing relative abundance (Murdy *et al.* 1997).

American eels were most frequently caught close to land in protected bays or creeks. Many of them were caught in Turville Creek where the department also conducts an annual elver survey further up the creek from the T006 sampling site. The abundance of elvers at this site was attributed to a moderately sized freshwater source close to the ocean inlet. The elvers were probably drawn to this area in search of freshwater in which to grow to adulthood. The distribution of preferred beach seine sites was likely due to their habitat preference for near shore, shallow weedy areas. The increase in mean length from April through July in the Trawl Survey is most likely due to collection of different year classes.

Atlantic croaker (*Micropogonias undulatus*)

Results

Atlantic croakers were captured in 17 of 140 trawls (12.1%) and in one of 38 beach seines (2.6%). A total of 82 juvenile Atlantic croakers were collected in trawl (81 fish) and beach seine (one fish) samples (Table 4). Atlantic croakers ranked 16 out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 4.6 fish/ha and < 0.1 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were both below the grand means (Figures 6 and 7). Since 1989, the trawl index frequently (16 years) varied from the grand mean and the beach seine index often (14 years) varied from the grand mean.

There was one fish caught in the Trawl Survey in August and it measured 228 mm. There were two fish measured in September (mean length 30 mm) and 47 fish measured in October (mean length 45 mm; Table 11). In the Beach Seine Survey, there was one fish caught and measured in September and it measured 32 mm (Table 12).

Discussion

In the history of the surveys, juvenile Atlantic croakers were more frequently caught in deeper water with the trawl and less often in beach seines. Therefore, the trawl index represents a more accurate picture of changes in relative abundance when compared to the beach seine index. Since 2007, trawl and beach seine indices have been average or below average and were consistently lower than in the 1990s. Data from this survey was supplied to the ASMFC for the southern coastal traffic light assessment in 2018. The decline in southern coastal abundance is also reflected in the traffic light assessment. Abundance can be influenced by environmental conditions and ocean currents (Murdy *et al.* 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 *et al.* 1997).

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 like the stronger currents found in Sinepuxent Bay. Juvenile Atlantic croakers seem to prefer the sheltered coves and creeks and share a similar pattern of distribution to spot and summer flounder. Atlantic croakers are a known prey item for summer flounder and may explain the co-occurrence of these species (Latour *et al.* 2008).

According to Murdy and Musick (2013), Atlantic croakers spawn in the continental shelf waters, peaking from August through October. That fact is supported by the Atlantic croakers length data collected from juveniles that immigrated into the coastal bays in the fall. The greatest number and the smallest juvenile Atlantic croakers were caught in September and October. Typically very small juvenile Atlantic croakers were caught in the fall and larger fish mid-summer. The few lengths we were able to sample this year support this observation. As expected for fall spawners, larger fish were caught in mid-summer.

Atlantic menhaden (*Brevoortia tyrannus*)

Results

Atlantic menhaden were captured in 22 of 140 trawls (15.7%) and in 20 of 38 beach seines (52.6%). Atlantic menhaden ranked first out of 73 species in overall finfish abundance. A total of 27,835 juvenile Atlantic menhaden were collected in trawl (89 fish) and beach seine (27,746 fish) samples (Table 4). The trawl and beach seine CPUE was 5.1 fish/ha and 730.1 fish/haul, respectively.

The 2018 trawl and the beach seine indices were equal to the grand means (Figures 8 and 9). Since 1989, the trawl index often (14 years) varied from the grand mean and the beach seine index occasionally (seven years) varied from the grand mean.

The mean length of Atlantic menhaden caught by trawl increased from a mean of 40 mm in May to a mean of 120 mm in October (Table 11). The Beach Seine Survey had similar results with an increase from a mean length of 59 mm in June to a mean length of 115 mm in September (Table 12).

Discussion
Atlantic menhaden were caught more often in near shore locations in the Beach Seine Survey; therefore, the beach seine index represents a more accurate picture of changes in relative abundance. In past years' good beach seine sites displayed a geographically wide dispersion that indicated a preference for shallow water 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 the Environment 2001). Those trawl sites are likely to have high chlorophyll concentrations; a desirable characteristic for a filter feeder (Wazniak *et al.* 2004). The increase in mean length in both the Trawl and Beach Seine surveys reflects growth of the cohort throughout the summer season.

Atlantic silverside (*Menidia menidia*)

Results
Atlantic silversides were captured in 20 of 140 (14.3%) trawls and in 35 of 38 beach seines (92.1%). A total of 1,710 Atlantic silversides were collected in trawl (311 fish) and beach seine (1,399 fish) samples (Table 4). Atlantic silversides ranked fourth out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 17.7 fish/ha and 36.8 fish/haul, respectively.

The 2018 trawl relative abundance index was above the grand mean and the beach seine relative abundance index was equal to the grand mean (Figures 10 and 11). Since 1989, the trawl index frequently (16 years) varied from the grand mean and beach seine index rarely (five years) varied from the grand mean.

The mean length of Atlantic silversides increased from 49 mm in June to 84 mm in October (Table 11). The Beach Seine Survey indicated a slight increase in mean length from 72 mm in June to 75 mm in September.

Discussion
Although the trawl index was above average in 2018, Atlantic silversides were more frequently caught in the Beach Seine Survey, which indicates a preference for shallow water habitat. Significant 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. Productive beach seine sites for collecting Atlantic

silversides were located in the shallow areas of all bays. Similar characteristics found at these sites were the proximity to land and/or inlets. Atlantic silversides are known to be a preferred forage species for larger gamefish and have been found occurring with spot, summer flounder and winter flounder at multiple sites in this survey. The size increase of Atlantic silversides between May and October is due to growth during the summer.

Bay anchovy (*Anchoa hepsetus*)

Results

Bay anchovies were captured in 86 of 140 trawls (61.4%) and in 20 of 38 beach seines (52.6%). A total of 6,419 bay anchovies were collected in trawl (5,413 fish) and beach seine (1,006 fish) samples (Table 4). Bay anchovies ranked second out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 308.3 fish/ha and 26.5 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were both equal to the grand means (Figures 12 and 13). Since 1989, the trawl (nine years) and beach seine (eight years) indices occasionally varied from the grand means.

The mean length of bay anchovies in the Trawl Survey was higher in the spring with the exception of April (mean length in April 55 mm, May 74 mm and June 78 mm) than in the summer and fall (mean length in July 53 mm, August 53 mm, September 58 mm and October 57 mm (Table 11). Larger bay anchovies were collected in June (mean 72 mm) than in September (52 mm) in the Beach Seine Survey (Table 12).

Discussion

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 do not fluctuate 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 known to be a preferred forage species for larger game fish and have been found occurring with spot and summer flounder at multiple sites in this survey. Females spawn multiple times from May to September and peak spawning occurs in July. The relatively constant size throughout the year reflects the extended recruitment through the summer. The length distribution by month was consistent between 2018 and 2019.

Black sea bass (*Centropristis striata*)

Results

Black sea bass were collected in 18 of 140 trawls (12.9%) and one of 38 beach seines (2.6%). A total of 26 juvenile black sea bass were collected in trawl (25 fish) and beach seine (one fish) samples (Table 4). Black sea bass were ranked 32 out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 1.4 fish/ha and < 0.1 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were both below the grand means for the second year in a row (Figures 14 and 15). Since 1989, the trawl index frequently (18 years) varied from the grand mean and beach seine index occasionally (eight years) varied from the grand mean.

The mean length of black sea bass increased from 60 mm in April to 179 mm in October in the Trawl Survey (Table 11). In the Beach Seine Survey, the length of the one fish caught in September was 119 mm (Table 12).

Discussion

The Trawl Survey catches more black sea bass; therefore, it was the better gear for inclusion in the 2018 ASMFC stock assessment. That gear is also used by other state's independent surveys that are also included in the stock assessment. Indices of relative abundance for both gears were included in the annual ASMFC compliance report. The Trawl and Beach Seine surveys have both had below average indices for the past two years.

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 2017). Some of the preferred sample sites had a hard shell bottom that provided the needed habitat structure desired by black sea bass (Murdy *et al.* 1997).

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 one. Occasionally smaller young of the year juveniles recruit in the fall but they did not in 2018.

Bluefish (*Pomatomus saltatrix*)

Results

Bluefish were collected in three of 140 trawls (2.1%) and in twelve of 38 beach seines (31.6%). A total of 27 juvenile bluefish were collected in trawl (three fish) and beach seine (24 fish) samples (Table 4). Bluefish ranked 29 out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 0.2 fish/ha and 0.6 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were both equal to the grand mean (Figures 16 and 17). Since 1989, the trawl (seven years) and beach seine (eight years) indices occasionally varied from the grand means.

The length of bluefish caught by the Trawl Survey increased from 106 mm in July to 250 mm in October (Table 11). In the Beach Seine Survey, the mean length increased from 76 mm in June to 159 mm in September (Table 12).

Discussion
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. Data from the Beach Seine Survey were used in the 2019 bluefish stock assessment and were included in the annual ASMFC compliance report. 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. Productive trawl and beach seine sites for collecting bluefish were located in Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay and St. Martin River. All productive sites were located north of the Ocean City Inlet with the exception of site S010 in Sinepuxent Bay. Bluefish may be drawn to the abundance of forage and the higher flushing rates of the areas close to the inlet. Increases in size as the year progressed in both surveys reflect the growth of the young of the year individuals through the summer.

Pinfish (*Lagodon rhomboides*)

Results
Pinfish were captured in six of 140 trawls (4.3%) and in 14 of 38 beach seines (36.8%). A total of 207 pinfish were collected in trawl (15 fish) and beach seine (192 fish) samples (Table 4). Pinfish ranked ninth out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 0.9 fish/ha and 5.0 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were both equal to the grand means (Figures 18 and 19). Since 1989, the trawl (19 years) and beach seine (16 years) indices frequently varied from the grand mean.

Pinfish mean length increased from 71 mm in July to 124 mm in September in the Trawl Survey (Table 11). Mean length increased from 59 mm in June to 137 mm in September in the Beach Seine Survey (Table 12).

Discussion
Pinfish 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. Pinfish abundance has improved since 1989. This may be tied to an increase in temperature over the time period. Pinfish are classified as a forage fish. Mean size increases though the year for both the Trawl and Beach Seine surveys was a result of growth.

Sheepshead (*Archosargus probatocephalus*)

Results
Sheepshead were collected in one of 140 trawls (0.7%) and three of 38 beach seines (7.8%). A total of eight juvenile sheepshead were collected in trawl (one fish) and beach seine (seven fish) samples (Table 4). Sheepshead ranked 42 out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 0.1 fish/ha and 0.2 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were equal to the grand means (Figures 20 and 21). Since 1989, the trawl (23 years) and beach seine (18 years) indices frequently varied from the grand means.

There was one fish caught by trawl and it measured 120 mm (Table 11). There were seven fish caught by beach seine in September and they ranged from 51 mm to 127 mm with a mean length of 71 mm (Table 12).

Discussion
Since 1997, there has been an increasing trend in sheepshead abundance which is of interest to recreational anglers. Anglers have caught adult sheepshead from the inlet. There were no sheepshead caught by trawl or beach seine before 1997, and they have become more consistently caught since 2011. Sheepshead were caught more frequently in shallow water (beach seine); therefore, the beach seine index represents a more accurate picture of changes in relative abundance when compared to the trawl index. Since sheepshead spawn offshore, environmental conditions including global weather patterns and ocean currents may be a factor influencing relative abundance as well as an increase in offshore artificial reefs, structure necessary for adult sheepshead habitat (Murdy and Musick 2013). Productive beach seine sites for collecting young of the year sheepshead were locations with or near SAV or rip rap. SAV is important juvenile habitat (Murdy and Musick 2013).

Silver perch (*Bairdiella chrysoura*)

Results
Silver perch were collected in 59 of 140 trawls (42.1%) and 17 of 38 beach seines (44.7%). A total of 2,749 silver perch were collected in trawl (1,380 fish) and beach seine (1,369 fish) samples (Table 4). Silver perch ranked third out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 78.6 fish/ha and 36 fish/haul, respectively.

The 2018 trawl relative abundance index was above the grand mean and the beach seine relative abundance index was equal to the grand mean (Figures 22 and 23). Since 1989, the trawl index frequently (16 years) varied from the grand mean and beach seine index rarely (two years) varied from the grand mean.

The mean size of silver perch increased from 82 mm in June to 114 mm in October in the trawl (Table 11). The mean size of silver perch increased from 59 mm in June to 102 mm in September in beach seine (Table 12).

Discussion
Silver perch are an important forage species and 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 (beach seine) and open water (trawl) locations; therefore, both indices represent an accurate picture of changes in relative abundance. Recent trawl indices indicate the species is doing well with three years of above average indices in the past seven. 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 *et al.* 1997, Murdy and Musick 2013). The size of silver perch by month in the Trawl and Beach Seine surveys reflects growth of individuals throughout the summer. Both the trawl and beach seine data indicated growth in size as the summer progressed.

Spot (*Leiostomus xanthurus*)

Results

Spot were collected in 52 of 140 trawls (37.1%) and 28 of 38 beach seines (73.7%). A total of 581 spot were collected in trawl (240 fish) and beach seine samples (341 fish; Table 4). Spot ranked fifth out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 13.7 fish/ha and 9.0 fish/haul, respectively.

The 2018 trawl and beach seine relative abundance indices were both below the grand means (Figures 24 and 25). Since 1989, the trawl (26 years) and beach seine (20 years) indices frequently varied from the grand means.

The mean length of spot increased from 26 mm in April to 174 mm in October in the Trawl Survey (Table 11). In the Beach Seine Survey, the mean length increased from 86 mm in June to 168 mm in October (Table 12).

Discussion

Spot are important to recreational anglers as a target species and for bait. They are also forage for many finfishes. Juvenile spot were widely dispersed in the samples collected throughout the coastal bays. This indicated that most of the Maryland coastal bays were favorable nursery habitat for spot. Both indices represent an accurate picture of changes in relative abundance. Data from the Trawl and Beach Seine surveys were included in the annual ASMFC compliance report. Data from this survey was supplied to the ASMFC for the southern coastal traffic light assessment in 2018. Since 2012, both trawl and beach seine spot indices have been predominantly below average, indicating the species is doing poorly. This observation is confirmed by the traffic light southern coastal assessment. Since spot spawn offshore, environmental conditions including global weather patterns and ocean currents may be a factor influencing relative abundance (Murdy *et al.* 1997). An increase in mean length through the summer reflects recruitment of young of the year in the spring and growth into the fall.

Summer flounder (*Paralichthys dentatus*)

Results

Summer flounder were collected in 73 of 140 trawls (52.1%) and 28 of 38 beach seines (73.68%). A total of 558 summer flounder collected in trawl (315 fish) and beach seine (243 fish) samples (Table 4). Summer flounder ranked sixth out of 73 species in overall finfish abundance. The trawl and beach seine CPUE was 17.9 fish/ha and 6.4 fish/haul, respectively.

The 2018 trawl relative abundance index was below the grand mean and the beach seine relative abundance index was above the grand mean (Figures 26 and 27). Since 1989, the trawl index frequently (20 years) varied from the grand mean and the beach seine index often (13 years) varied from the grand mean.

The mean length of summer flounder caught by trawl increased from 17 mm in April to 123 mm in October (Table 11). In the Beach Seine Survey, the mean length increased from 88 mm in June to 163 mm in September (Table 12).

Discussion
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. In recent years, the number of summer flounder caught in beach seines increased while the number caught in trawls has been below the grand mean. Data from the Trawl Survey were used in the 2018 joint ASMFC and Mid Atlantic Fishery Management Council summer flounder benchmark stock assessment. Indices from both surveys were included in the annual ASMFC compliance report.

Productive summer flounder trawl and beach seine sample sites were located in all bays. This indicated that most of the habitat of the Maryland coastal bays was 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. In both the trawl and beach seine surveys mean length increased thought the year reflecting growth of juvenile fish.

Weakfish (*Cynoscion regalis*)

Results
Weakfish were collected in 34 of 140 trawls (24.3%) and zero of 38 beach seines. A total of 362 juvenile weakfish were collected in trawl samples (362 fish; Table 4). Weakfish ranked seventh out of 73 species in overall finfish abundance. The trawl CPUE was 20.6 fish/ha.

The 2018 trawl relative abundance index was equal to the grand mean and beach seine relative abundance indices was below the grand mean (Figures 28 and 29). Since 1989, the trawl index often (14 years) varied from the grand mean and the beach seine index often (11 years) varied from the grand mean. Weakfish mean length increased from 64 mm in July to 138 mm in October (Table 11).

Discussion
Weakfish were caught more frequently in open water; therefore, the trawl index represents a more accurate picture of changes in relative abundance when compared to the beach seine index. The trawl index was included in the annual ASMFC compliance report. Data from the Trawl Survey were used in the 2015 ASMFC weakfish stock assessment. Weakfish were considered depleted but not overfished. The decline appears to be due to natural mortality (Northeast Fisheries Science Center 2009). 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.

Productive trawl sample sites for weakfish were located in all bays indicating a broad distribution in the coastal bays. They show a particular affinity to trawl sites in Assawoman Bay and the St. Martin River. Young of the year recruitment was most evident from July through October which follows the peak spawning period of May through June (Murdy and Musick 2013). The increase in mean length from July to October reflects growth of the young of the year weakfish.

Richness and Diversity

Results

Richness is the number of different fishes sampled. Diversity is defined by the Shannon index results, which is a measurement richness and the proportion of those species in the sample population. Chincoteague Bay was the embayment with the highest richness for fishes in the trawl time series (1989 - 2018) and in 2018 (Tables 13 and 14). This embayment had a total of 90 fishes collected and identified throughout the time series, an average of 36 species per year and 39 species in 2018 (Tables 13 and 14). Newport Bay had the lowest richness in the time series, 67 total fishes and an average of 21.4 species per year and also had the lowest richness in 2018 with 17 fishes (Table 14). The Shannon index for the trawl time series (1989 - 2018) indicated that Sinepuxent Bay (H = 1.69) was the most diverse whereas the St. Martin River (H = 1.33) was the least (Table 13). For 2018, the Shannon index results indicated that Sinepuxent Bay (H = 1.91) was the most diverse whereas St. Martin River (H = 1.23) was the least (Table 14).

The Beach Seine Survey time series (1989 - 2018) results indicated that Assawoman Bay and Isle of Wight Bay were tied for the richest (87 fishes) and Chincoteague Bay had the highest average richness (30.8 fishes). Ayers Creek had least richness in the time series (44 fishes) and the lowest average richness (14.5; Table 15). For 2018, Chincoteague Bay was the richest (38 species) embayment and Ayers Creek (nine) was the least (Table 16). The Shannon index time series (1989 - 2018) results indicated that Chincoteague Bay (H = 1.63) was the most diverse whereas the Ayers Creek (H = 1.21) was the least (Table 15). The 2018 results indicated that St. Martin River (H = 2.48) had the highest diversity whereas Isle of Wight Bay (H = 0.26) was the least diverse (Table 16).

Discussion

For trawl sampling, overall richness and diversity were not that different between the embayments. Chincoteague Bay dominated richness for the time series and for 2018, but this may be an artifact of several habitat types and a larger sample size in this bay. The opposite occurred in Newport Bay, low richness may be because of low samples size and less diverse habitat. Results for 2018 were consistent with the time series trends; there was little difference in richness between bays.

The Beach Seine Survey had a low salinity site on Ayers Creek which is an upper tributary of Newport Bay. The salinity was often below 3 ppt and can have a very different species composition than the rest which may influence the results. The Ayers Creek beach seine site was not considered an embayment and was included in the table to show abundance levels upstream of Newport Bay. Ayers Creek in 2018 can be characterized by low richness and diversity. The salinity was highly variable in the time series and that covariate affected species diversity. Ayers Creek has shown high levels of Atlantic menhaden and golden shiner (*Notemigonus crysoleucas*) on a regular basis throughout the time series. Infrequent abundance of spot and striped bass has also been recorded.

Mean beach seine survey diversity is uniform between bays for the time series, but there were some standouts in 2018. The St. Martins River and Sinepuxent Bay had greater diversity in 2018 while the Isle of Wight Bay had particularly low diversity.

For beach seine sampling, again there is little variance in richness and diversity by embayment. Assawoman and Isle of Wight bays join Chincoteague Bay with higher richness and diversity and are close to the inlets and as such get a greater variety of species. Newport Bay is an isolated bay with only two beach seine sites which would explain the lower values for this bay.

Richness and diversity are important components of a healthy estuary and should be monitored for indicators of depleted habitat. There was not a linear relationship between the richness and diversity in the coastal bays. Results showed that the coastal bays richness was relatively high while diversity was generally low; a value of three is considered good and four is excellent. A strong year class can reduce the diversity value by minimizing the effect of other fish contributions to the sample population. Therefore, 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.

The embayment sample size clearly has an influence on the richness and diversity for the time series and the terminal year of the survey. Co-variant differences among habitat for each site such as salinity, substrate, forage and protection could also serve as comparison criteria rather than or in addition to embayment.

Macroalgae

This time series spans 13 years from 2006 to 2018. To date, 20 genera and 65,548 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. *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.

Fourteen genera were collected by trawl within the coastal bays in 2018, which was below the average (14.62 genera) in the time series. The 2018 Shannon index of diversity among genera by trawl (H = 1.01) was below the time series average (H = 1.24). Results showed that *Agardhiella* were the most abundant macroalgae (64.4%) in 2018. The only other genera that contributed more than 5% to the sample population were *Ulva* (16.7%) and *Chaetomorpha* (11.6%; Table 10). The 2018 trawl CPUE (195.5 L/ha) was equal to the grand mean. Since 2006, the trawl CPUE rarely varied from the grand mean (Figure 30).

Seven genera were sampled within the coastal bays by beach seine in 2018. The Shannon index of diversity among genera (H = 0.69) was below the time series average (H = 1.12). Results showed that *Agardhiella* were most abundant (77.7%). The only other genera that contributed more than 5% to the sample population was *Ulva* (17.1%; Table 10). The 2018 beach seine CPUE (26.1 L/haul) was equal to the grand mean. Since 2006, the beach seine CPUE rarely varied from the grand mean (Figure 31).

Over the trawl time series, mean CPUE was higher in the embayments north of Ocean City Inlet. However, these areas had lower average Shannon index values than areas south of the inlet (Figure 32). The beach seine time series showed a similar trend in CPUE while the Shannon index was variable among those areas littoral zone (Figure 33).

Assawoman Bay: This embayment has been dominated by *Rhodophyta* since sampling began in 2006. Six different genera were collected by trawl in 2018, which was below the average (7.7 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment (H = 0.54) was below the time series average (H = 0.89). Results showed that *Agardhiella* (78.3%) was most abundant. *Ulva* (21.6%) was the only other genera that contributed more than 5% to the sample population. The 2018 CPUE (759.7 L/ha) was equal to the grand mean (Figure 34). Since 2006, the trawl CPUE rarely varied from the grand mean.

Three different genera were collected by beach seine in 2018, which was below the average (6.3 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment (H = 0.11) was below the time series average (H = 0.76). Results showed that *Agardhiella* (97.7%) was most abundant. The beach seine CPUE (46.3 L/haul) was equal to the grand mean (Figure 35). Since 2006, the beach seine CPUE rarely varied from the grand mean.

Isle of Wight Bay: This embayment has been dominated by *Rhodophyta* since sampling began in 2006. Five different genera were collected by trawl in 2018, which was above the average (seven genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment (H = 0.73) was below the time series average (H = 0.74). *Agardhiella* was most abundant (75.3%). The only other genera that contributed more than 5% to the sample population were *Enteromorpha* (13.4%) and *Ulva* (11.3%; Table 10). The trawl CPUE (313.9 L/ha) was equal to the grand mean (Figure 36). Since 2006, the trawl CPUE rarely varied from the grand mean.

Five different genera were collected by beach seine in 2018, which was below the average (6.8 genera) for this embayment in the time series. The 2018 Shannon index of diversity among genera within this embayment (H = 0.76) was below the time series average (H = 1.05). *Agardhiella* (49.7%) was the most abundant; *Ulva* (48.8%) was the only other genera that contributed more than 5% of the sample population. The 2018 beach seine CPUE (34.9 L/haul) was equal to the grand mean (Figure 37). Since 2006, the beach seine CPUE rarely varied from the grand mean.

St. Martin River: This river has been dominated by *Rhodophyta* since sampling began in 2006, except in 2013, when *Chlorophyta* were dominant in the deeper water sampled by the trawl. Three different genera of macroalgae were collected by trawl in 2018, which was above the time series average (5.5 genera). The 2018 Shannon index of diversity among genera (H = 0.4) was below the times series average (H = 0.78). *Agardhiella* (87.7%) was most abundant; *Ulva* (11.7%) was the only other genera that contributed more than 5% of the sample population. Trawl CPUE (123.5 L/ha) in 2018 was equal to the grand mean (Figure 38). Since 2006, the trawl CPUE rarely varied from the grand mean.

Four different genera were collected by beach seine in 2018, which was below the average (3.46 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment in 2018 (H = 0.46) was above the time series average (H = 0.44). *Agardhiella* (83.8%) was most abundant. Ulva (15.9%) was the only other genera that contributed more than 5% of the sample population. The 2018 beach seine CPUE (119.4 L/haul) was equal to the grand mean (Figure 39). Since 2006, the beach seine CPUE rarely varied from the grand mean.

Sinepuxent Bay: This embayment has been dominated by *Rhodophyta* in nine of the 11 years since sampling began in 2006. *Chlorophyta* were dominant in 2008, 2009 and 2018. Nine different genera of macroalgae were collected by trawl in 2018, which was below the average (9.8 genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment in 2018 (H = 0.83) was below the average (H = 1.3). *Ulva* (70.5%) and *Agardhiella* (24.1%) were the only genera that contributed more than 5% of the sample population. Trawl CPUE (20.2 L/ha) in 2018 was equal to the grand mean (Figure 40). Since 2006, the trawl CPUE rarely varied from the grand mean.

Three different genera were collected by beach seine in 2018, which was below the average (six genera) for this embayment in the time series. The Shannon index of diversity among genera within this embayment in 2018 (H = 0.31) was below the average (H = 0.52). *Agardhiella* (90.9%) was most abundant. *Ulva* (8.9%) was the only other genera that contributed more than 5% of the sample population. The 2018 beach seine CPUE (24.9 L/haul) was equal to the grand mean (Figure 41). Since 2006, the beach seine CPUE rarely varied from the grand mean.

Newport Bay: This embayment has been dominated by *Rhodophyta* in eight of the 11 years since sampling began in 2006. *Chlorophyta* were dominant in 2008 - 2010 and 2018. Eight different genera were collected by trawl in 2018, which was above the average (6.8 genera) for this embayment in the time series. The 2018 Shannon index of diversity among genera (H = 1.03) within this embayment was equal to the time series average (H = 1.03). *Ulva* (53.4%) and *Agardhiella* (37.3%) were the only genera that contributed more than 5% of the sample population. Trawl CPUE (14.8 L/ha) was below to the grand mean (Figure 42). Since 2006, the trawl CPUE rarely varied from the grand mean.

Two different genera were collected by beach seine in 2018, which was below the average (four genera) for this embayment in the time series. The Shannon index of diversity among genera (H = 0.22) was below the time series average (H = 0.37). *Agardhiella* (94.4%) and Ulva (5.6%) were most abundant. The 2018 beach seine CPUE (2.33 L/haul) was below to the grand mean (Figure 43). Since 2006, the beach seine CPUE occasionally varied from the grand mean.

Chincoteague Bay: This embayment has undergone shifts in dominance from *Rhodophyta* in 2006 - 2007, *Phaeophyta* in 2008, *Chlorophyta* in 2009 - 2010, *Rhodophyta* in 2011 - 2014, *Chlorophyta* in 2015, *Rhodophyta* in 2016 - 2017 and *Chlorophyta* in 2018. Ten different genera were collected by trawl in 2018, which was above the times series average (11.4 genera). The 2018 Shannon index of diversity among genera (H = 0.96) was below the average (H = 1.52) within this embayment for the time series. *Chaetomorpha* (69.7%) was most abundant; *Agardhiella* (14.8%) and *Polysiphonia* (10.3%) were the only genera that contributed more than 5% of the sample population. The CPUE (83.1 L/ha) was equal to the grand mean (Figure 44). Since 2006, the trawl CPUE rarely varied from the grand mean.

Six different genera were collected by beach seine in 2018, which was above the average (seven genera) for this embayment in the time series. The Shannon index of diversity among genera (H = 1.13) was below the time series average (H = 0.95). *Polysiphonia* (57.6%) was most abundant, *Chaetomorpha* (20.1%) and *Agardhiella* (17.6%) were the only other genera that contributed more than 5% of the sample population. The 2018 beach seine CPUE (4.57 L/haul) was below the grand mean (Figure 45). Since 2006, the beach seine CPUE occasionally varied from the grand mean.

Discussion

Macroalgae in Maryland's coastal bays were investigated consistently over 13 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* may not be accurate because the Trawl and Beach Seine surveys did not sample macroalgae habitat such as bulkheads, jetties and rocks where macroalgae have been observed. However, those data show that *Rhodophyta* and *Chlorophyta* were present at high levels in the embayments closest to high human density population.

The embayments north of the Ocean City Inlet showed 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 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.

Chincoteague Bay was the most diverse embayment for macroalgae which can have both positive and negative impacts. 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 founder 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 *et al*. 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 *et al.* 2018).

Water Quality and Physical Characteristics

Temperature

Analysis of the 2018 Trawl Survey water quality data beginning in April showed increasing average water temperatures for Assawoman, Newport, and Chincoteague bays through August. Isle of Wight and Sinepuxent bays along with the St. Martin River all had surface water temperatures that peaked in July (Figure 46). The highest surface temperature (31.2 C) was recorded at site T006 in July 2018 in Turville Creek. The lowest surface temperature (8.7 C) for all bays was recorded in April at site T008 in Sinepuxent Bay, the closest site to the Ocean City Inlet.

The average temperature in 2018 from all trawl samples was 22.5 C, which was similar to 2017 (22.6 C). The St. Martin River (23.4 C), Chincoteague (23.3 C) and Isle of Wight bays (23.1 C) were the warmest bodies of water for average temperatures. Sinepuxent Bay was the coolest bay with an average of 20.4 C. A significant increase in mean surface water temperature was observed from 1989 to 2018 ($r(29) = 0.59$, $p = 0.0007$; Figure 47).

The Beach Seine Survey had two rounds of sampling in June and September; therefore, related water quality information does not show the gradual progression of measurements (temperature, salinity, DO and turbidity) possible from graphically representing data. There was an 8.6 C difference between the highest recorded temperature (28.0 C at site S006) and lowest temperature (19.4 C at site S007) during the month of June (Figure 48). In September, the temperature difference between the highest recorded temperature (28.3 C at site S017) and lowest temperature (24.0 C at site S010) was 4.3 C. The most abrupt decreases in temperature measured between June and September at sites in the St. Martin River (3.8 C) and Sinepuxent Bay (2.4 C).

Dissolved Oxygen

As expected, trawl DO levels generally decreased as water temperatures increased (Figure 49). The surface DO level only dipped once to below 5 mg/L and that occurred in September with 4.83 mg/L at site T012 (4.83 mg/L). The mean DO for all bays in 2018 from trawling was 7.3 mg/L. A significant increase in surface DO has been observed from 1998 to 2018 for all trawl sites grouped together ($r(19) = 0.82$, $p < 0.0001$).

The 2018 Beach Seine Survey mean DO was generally higher in June than September. The 2018 Beach Seine Survey DO was above 5 mg/L for all samples except two (Figure 50). One instance occurred in September at the site accessed from land, S019 Ayers Creek. The other occasion occurred at site S003, also in September.

Salinity

The 2018 Trawl Survey average salinity for all bays was 23 ppt which was lower than 2017 (24.8 ppt). Sinepuxent Bay had the highest average salinity at 26.2 ppt and the St. Martin River had the lowest (19.9 ppt). For the St. Martin River, Assawoman, Isle of Wight and Chincoteague bays the lowest levels of salinity were reached in June. Newport Bay exhibited its lowest salinity in May. Decreases in salinity were not as pronounced in Sinepuxent Bay (Figure 51).

For the 2018 Beach Seine Survey, salinity increased from June to September at all sites. Chincoteague Bay experienced the largest salinity increase in September, increasing by 5.4 ppt (Figure 52).

Turbidity

Monitoring of turbidity was initiated in 2006 and continued through 2018. Newport Bay was the most turbid water system (72.4 cm) in the 2018 Trawl Survey whereas Sinepuxent Bay was the least (107.7 cm). The bottom was visible seven times (5%) out of 140 total samples. Visibility decreased during the warmer months A significant increase in water clarity has been observed from 2006 to 2018 ($r(12) = 0.638$, $p = 0.019$; Figure 54).

The waters became more turbid in Assawoman, Isle of Wight and Sinepuxent bays from June to September for the 2018 Beach Seine Survey. Turbidity in the St. Martin River did not change during this period (Figure 55). The most turbid system was Assawoman Bay with an average Secchi of 44.7 cm. Isle of Wight Bay had the best visibility with an average of 67.4 cm. and Sinepuxent Bay in September.

Discussion

The surface temperatures around the earth made 2018 the fourth warmest year dating back to 1880. Only 2015, 2016 and 2017 were warmer (NASA 2019). Sustained increases in water temperature overtime will create habitat for southern fish species while reducing habitat for fishes that cannot tolerate or prefer cooler water.

Of the water quality parameters, DO concentrations can have the greatest immediate impact on fisheries resources. Dissolved oxygen typically decreases from April through the warmer months and then increases again in the fall as temperatures decrease. Some of the 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).

Hypoxia exists when DO levels can no longer support the majority of life; the DO level for this condition is usually set below 2 mg/L. For organisms in the Chesapeake Bay, 5 mg/L is usually accepted as necessary for life, but can vary based on the organism. For example, a DO of 6 mg/L is necessary for larvae and eggs of migratory fish, however, some animals such as crabs and bottom dwelling fish can tolerate DO levels as low as 3 mg/L (Chesapeake Bay Program 2007).

Preliminary analysis of DO and fish catches from the surveys indicated that the coastal bays rarely experience low enough DO's to negatively impact fish abundances. DO peaks during the day and can actually supersaturate from photosynthesis and bottoms out at night when respiration occurs. Our sampling occurs during the day when low DO events 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 over-ridden by high respiration and hypoxia would result.

Di Liberto (2018) reported that the rains in Maryland were so heavy that, statewide, the May - July period was the wettest in state history (124 years), with July becoming the second wettest July on record. These rainfalls contributed to abnormal decreases in salinity seen in Newport Bay during May and Chincoteague Bay was in June. Sinepuxent Bay remained normal as it received the most ocean influence of all the embayments. Salinity recovered from the extremes (< 15 ppt) in July when sampling occurred.

Differences in DO, salinity, temperature and turbidity were influenced by the residence times of these systems. Donkers and Zimmerman (1982) define residence time as "the time it takes for any water parcel of the sample to leave the lagoon through its outlet to the sea." Residence times in the coastal bays increases with distance from an inlet and flow: Assawoman Bay 37 - 52 days; Isle of Wight Bay 5 - 6 days; Sinepuxent Bay 9 - 10 days; Newport Bay 47 - 92 days; and Chincoteague Bay 83 - 97 days (Maryland Department of Environment 2014).

Brown tides, precipitation and wind can create turbidity. Turbidity generally increases in the coastal bays as the water becomes warmer and this pattern was observed for 2018. The 2004 National Park Service precipitation study indicated that turbidity was not influenced by precipitation to the same extent as chlorophyll *a* for the same period (Dennison et al. 2009). Although mean surface temperature has risen since 2006, there was an inverse relationship between predicted and observed water clarity. Water clarity has increased with temperature since 2006. This situation needs a closer analysis beyond annual mean comparison.

Carter *et al*. (1994) studied Potomac River water quality and weather data from 1980 to 1989 and reported that SAV coverage decreased when Secchi depths fell below 65 cm. Analysis of trawl Secchi values demonstrated a significant increase in water clarity ranging from an annual mean of 71.4 cm in 2006 to 86.4 cm for 2018.

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Table 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 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 3. Measurement types for fishes and invertebrates captured during 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 4. List of fishes collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 38.

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	CPUE (T) #/Hect.	CPUE (S) #/Haul
Atlantic menhaden	*Brevoortia tyrannus*	27,835	89	27,746	5.1	730.1
Bay anchovy	*Anchoa mitchilli*	6,419	5,413	1,006	308.3	26.5
Silver perch	*Bairdiella chrysoura*	2,749	1,380	1,369	78.6	36.0
Atlantic silverside	*Menidia menidia*	1,710	311	1,399	17.7	36.8
Spot	*Leiostomus xanthurus*	581	240	341	13.7	9.0
Summer flounder	*Paralichthys dentatus*	558	315	243	17.9	6.4
Weakfish	*Cynoscion regalis*	362	362		20.6	
Striped killifish	*Fundulus majalis*	265		265		7.0
Pinfish	*Lagodon rhomboides*	207	15	192	0.9	5.0
Striped anchovy	*Anchoa hepsetus*	181	108	73	6.2	1.9
Inland silverside	*Menidia beryllina*	129	15	114	0.9	3.0
Winter flounder	*Pseudopleuronectes americanus*	117	11	106	0.6	2.8
Oyster toadfish	*Opsanus tau*	107	74	33	4.2	0.9
Northern pipefish	*Syngnathus fuscus*	100	61	39	3.5	1.0
Spotfin mojarra	*Eucinostomus argenteus*	87	10	77	0.6	2.0
Atlantic croaker	*Micropogonias undulatus*	82	81	1	4.6	<0.1
Rainwater killifish	*Lucania parva*	81	2	79	0.1	2.1
American eel	*Anguilla rostrata*	79	76	3	4.3	<0.1
Black drum	*Pogonias cromis*	78	18	60	1.0	1.6
Golden shiner	*Notemigonus crysoleucas*	71		71		1.9
Hogchoker	*Trinectes maculatus*	69	59	10	3.4	0.3
Mummichog	*Fundulus heteroclitus*	69	12	57	0.7	1.5
Northern puffer	*Sphoeroides maculatus*	61	43	18	2.4	0.5
Atlantic needlefish	*Strongylura marina*	50		50		1.3
Striped blenny	*Chasmodes bosquianus*	49	5	44	0.3	1.1
Spotted seatrout	*Cynoscion nebulosus*	39		39		1.0
Striped bass	*Morone saxatilis*	32	1	31	0.1	0.8
Naked goby	*Gobiosoma bosc*	31	26	5	1.5	0.1
Bluefish	*Pomatomus saltatrix*	27	3	24	0.2	0.6
Dusky pipefish	*Syngnathus floridae*	27	7	20	0.4	0.5
Smallmouth flounder	*Etropus microstomus*	27	17	10	1.0	0.3
Black sea bass	*Centropristis striata*	26	25	1	1.4	<0.1
Blackcheek tonguefish	*Symphurus plagiusa*	25		25		0.7
Rough silverside	*Membras martinica*	20		20		0.5
White mullet	*Mugil curema*	20		20		0.5
Spotted hake	*Urophycis regia*	18	18		1.0	
Southern kingfish	*Menticirrhus americanus*	16	10	6	0.6	0.2

Table 4. List of fishes collected in Maryland's Coastal Bays Trawl (T) and Beach Seine (S) surveys from April through October, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 38.

Common Name	Scientific Name	Total Number Collected	Number Collected (T)	Number Collected (S)	CPUE (T) #/Hect.	CPUE (S) #/Haul
Northern kingfish	*Menticirrhus saxatilis*	14	11	3	0.6	<0.1
Striped burrfish	*Chilomycterus schoepfii*	12	9	3	0.5	<0.1
Pumpkinseed	*Lepomis gibbosus*	10		10		0.3
Bluegill	*Lepomis macrochirus*	9		9		0.2
Sheepshead	*Archosargus probatocephalus*	8	1	7	0.1	0.2
Sheepshead minnow	*Cyprinodon variegatus*	8	1	7	0.1	0.2
Green goby	*Microgobius thalassinus*	6	5	1	0.3	<0.1
Inshore lizardfish	*Synodus foetens*	6	4	2	0.2	<0.1
Lined seahorse	*Hippocampus erectus*	6	5	1	0.3	<0.1
Mosquitofish	*Gambusia affinis*	6		6		0.2
Northern searobin	*Prionotus carolinus*	6	6		0.3	
Pigfish	*Orthopristis chrysoptera*	6	3	3	0.2	<0.1
Southern stingray	*Dasyatis americana*	6	1	5	0.1	0.1
Atlantic spadefish	*Chaetodipterus faber*	5	3	2	0.2	<0.1
Skilletfish	*Gobiesox strumosus*	5		5		0.1
Florida pompano	*Trachinotus carolinus*	4	3	1	0.2	<0.1
Lookdown	*Selene vomer*	4	3	1	0.2	<0.1
Bluespotted cornetfish	*Fistularia tabacaria*	3	3		0.2	
Gray snapper	*Lutjanus griseus*	3	1	2	0.1	<0.1
Halfbeak	*Hyporhamphus unifasciatus*	3		3		<0.1
Ladyfish	*Elops saurus*	3		3		<0.1
Atlantic moonfish	*Selene setapinnis*	2	2		0.1	
Cownose ray	*Rhinoptera bonasus*	2		2		<0.1
Spanish mackerel	*Scomberomorus maculatus*	2	2		0.1	
Striped cusk-eel	*Ophidion marginatum*	2	2		0.1	
Striped searobin	*Prionotus evolans*	2	2		0.1	
Windowpane	*Scophthalmus aquosus*	2	2		0.1	
Alewife	*Alosa pseudoharengus*	1		1		<0.1
Atlantic herring	*Clupea harengus harengus*	1	1		0.1	
Bandtail puffer	*Sphoeroides spengleri*	1		1		<0.1
Blue runner	*Caranx crysos*	1	1		0.1	
Butterfish	*Peprilus triacanthus*	1	1		0.1	
Conger eel	*Conger oceanicus*	1		1		<0.1
Harvestfish	*Peprilus paru*	1		1		<0.1
Planehead filefish	*Stephanolepis hispidus*	1	1		0.1	
Smooth puffer	*Lagocephalus laevigatus*	1	1		0.1	

Table 4. List of fishes collected in Maryland's Coastal Bays Trawl (T) and Beach Seine (S) surveys from April through October, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 38.

	Total Number Collected	Number Collected (T)	Number Collected (S)
Total Finfish	**42,558**	**8,881**	**33,677**

Table 5. Number of species and individual fish caught by year and gear in the Trawl and Beach Seine surveys from 2007 - 2018.

	Number of Species			Number of fish		
Year	Trawl	Beach Seine	Combined	Trawl	Beach Seine	Combined
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

Table 6. Summary of the 2018 Trawl and Beach Seine surveys species abundance defined as above, below or equal to the grand mean.

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

Table 7. List of crustaceans collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 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*	7,768	5,674	2,094			323.1	55.1
Grass shrimp	*Palaemonetes sp.*	1,562	337	354	286	585	35.5	24.7
Sand shrimp	*Crangon septemspinosa*	928	548	10	370		52.3	0.3
Brown shrimp	*Farfantepenaeus aztecus*	450	320	130			18.2	3.4
Say mud crab	*Dyspanopeus sayi*	351	339	12			19.3	0.3
Long-armed hermit crab	*Pagurus longicarpus*	243	182	61			10.4	1.6
White shrimp	*Litopenaeus setiferus*	141	110	31			6.3	0.8
Lady crab	*Ovalipes ocellatus*	37	28	9			1.6	0.2
Atlantic rock crab	*Cancer irroratus*	13	13				0.7	
Mantis shrimp	*Squilla empusa*	11	11				0.6	
Portly spider crab	*Libinia emarginata*	4	4				0.2	
Atlantic mud crab	*Panopeus herbstii*	3	3				0.2	
Bigclaw snapping shrimp	*Alpheus heterochaelis*	3	3				0.2	
Mud crab	*Panopeus sp.*	2	1	1			0.1	<0.1
Snapping shrimps	*Alpheidae*	2	1	1			0.1	<0.1
Longnose spider crab	*Libinia dubia*	1	1				0.1	
	Total Crustaceans	**11,519**	**7,575**	**2,703**	**656**	**585**		

Table 8. List of molluscs collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 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
Solitary glassy bubble snail	*Haminoea solitaria*	518	18		500						29.5			
Mudsnails	*Nassarius sp.*	149	10	139							0.6	3.6		
Atlantic brief squid	*Lolliguncula brevis*	48	48								2.7			
Eastern mudsnail	*Nassarius obsoletus*	9	9								0.5			
Atlantic oyster drill	*Urosalpinx cinerea*	7	6	1							0.3	<0.1		
Convex slippersnail	*Crepidula convexa*	6	6								0.3			
Baltic macoma	*Macoma balthica*	5	5								0.3			
Thick-lip drill	*Eupleura caudata*	5	5								0.3			
Northern quahog	*Mercenaria mercenaria*	3	3								0.2			
Purplish tagelus	*Tagelus divisus*	3	3								0.2			
Stout tagelus	*Tagelus plebeius*	3	3								0.2			
Lemon drop	*Doriopsilla pharpa*	2	2								0.1			
Atlantic jackknife	*Ensis directus*	1	1								0.1			
Common Atlantic slippersnail	*Crepidula fornicata*	1	1								0.1			
Elongate macoma	*Macoma tenta*	1	1								0.1			
Green jackknife	*Solen viridis*	1	1								0.1			
	Total Molluscs	**762**	**122**	**140**	**500**									

Table 9. List of other species collected in Maryland's coastal bays Trawl (T) and Beach Seine (S) surveys from April through October, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 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*	2,713	33		2,680			1.5			154.5			<0.1
Sea nettle	*Chrysaora quinquecirrha*	580	144	2	432	2	26.1	7.5	5.0	1.0	32.8	0.1	1.8	0.2
Comb jellies	*Ctenophora*	355	171	8	176		279.3	25.2	128.7	21.0	19.8	0.2	23.2	1.2
Hairy sea cucumber	*Sclerodactyla briareus*	90	79	11							4.5	0.3		
Beroe comb jelly	*Beroe ovata*	52	33	19							1.9	0.5		
Horseshoe crab	*Limulus polyphemus*	51	44	7							2.5	0.2		
Northern diamondback terrapin	*Malaclemys terrapin terrapin*	16	8	8							0.5	0.2		
Sand dollar	*Echinarachnius parma*	9	9								0.5			
Common sea cucumber	*Cucumaria pulcherrima*	6	5	1							0.3	<0.1		
Moon jelly	*Aurelia aurita*	4	4								0.2			
Sea cucumbers	*Cucumariidae*	2	2								0.1			
Sea pork	*Aplidium sp.*	1	1				7.4				0.1		0.4	
Sea gooseberry	*Pleurobrachia pileus*	1	1								0.1			
Bryozoans	*Ectoprocta*	1	1				143.0	0.6			0.1		8.2	<0.1
Goldstar tunicate	*Botryllus schlosseri*						12.5	6.8					0.7	0.2
Rubbery bryozoan	*Alcyonidium sp.*						80.7	9.0					4.6	0.2
Halichondria sponge	*Halichondria sp.*						229.4	39.9					13.1	1.1
Red beard sponge	*Microciona prolifera*						168.3	10.6					9.6	0.3
Sulphur sponge	*Cliona celata*						5.5						0.3	
	Total Other	**3,881**	**535**	**56**	**3,288**	**2.0**	**952.2**	**101.1**	**133.7**	**22.0**				

Table 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, 2018. Species are listed by order of total abundance. Total trawl sites = 140, total seine sites = 38.

Common Name	Genus	Specific Volume (L) (T)	Specific Volume (L) (S)	Estimated Volume (L) (T)	Estimated Volume (L) (S)
SAV					
Eel grass	*Zostera*	50.7	85.1		0.3
Widgeongrass	*Ruppia*	2.1	0.9		0.3
	Total SAV	**52.8**	**86.0**		**0.5**
Macroalgae					
Brown					
Common southern kelp	*Laminaria*	2.6			
Sour weeds	*Desmarestia*	0.5			
Brown bubble algae	*Colpomenia*	0.2			
Rockweed	*Fucus*	0.1			
		3.4			
Green					
Sea lettuce	*Ulva*	590.5	161.0		
Green hair algae	*Chaetomorpha*	409.6	11.0		
Hollow green weed	*Enteromorpha*	75.4			
Green fleece	*Codium*	8.6	0.2		
Green tufted seaweed	*Cladophora*	1.2			
		1,085.3	**172.2**		
Red					
Agardh's red weed	*Agardhiella*	2,279.8	729.5	0.3	
Tubed weeds	*Polysiphonia*	60.7	35.0		
Banded weeds	*Ceramium*	2.3			
Graceful red weed	*Gracilaria*	0	1.6		
Barrel weed	*Champia*	0			
		2,342.8	**766.2**	**0.3**	
Yellow-Green					
Water felt	*Vaucheria*		0.8		
			0.8		
Others					
Slurry	*Unknown decaying*	108.9			
		108.9			
	Total Macroalgae	**3,540.4**	**939.1**	**0.3**	

Table 11. Length by month for selected fishes from the Trawl Survey in 2018.

	Month	Number counted	Number measured	Min length (mm)	Max length (mm)	Mean Length (mm)	SD
American eel (*Anguilla rostrata*)	Apr	6	6	40	112	63.8	24.9
	May	48	31	50	170	62.9	20.5
	Jun	16	16	60	85	71.3	6.7
	Jul	4	4	68	90	75.3	10
	Aug						
	Sep	2	2	220	390	305	120.2
	Oct						
Atlantic croaker (*Micropogonias undulatus*)	Apr						
	May						
	Jun						
	Jul						
	Aug	1	1	228	228	228	
	Sep	29	29	15	57	30.3	10.2
	Oct	51	47	20	112	45.3	22.3
Atlantic menhaden (*Brevoortia tyrannus*)	Apr						
	May	14	14	36	48	40.1	3.6
	Jun	11	11	42	86	55.2	11.3
	Jul	7	7	73	94	80.4	7.1
	Aug	44	44	80	117	97.8	10.4
	Sep	11	11	90	129	115.6	10.9
	Oct	2	2	109	130	119.5	14.8
Atlantic silverside (*Menidia menidia*)	Apr						
	May						
	Jun	110	59	20	72	49	11.4
	Jul	159	83	35	85	63.8	10.8
	Aug	26	20	60	87	74.3	7.5
	Sep	10	10	53	88	68.9	10.6
	Oct	6	6	66	93	83.8	9.5
Bay anchovy (*Anchoa mitchilli*)	Apr	15	15	34	73	54.7	14
	May	252	111	55	95	74.1	7.6
	Jun	119	75	59	99	77.7	7.2
	Jul	1,164	308	10	95	52.8	21
	Aug	1,619	301	24	110	52.6	17.6
	Sep	710	239	18	134	57.5	18.3
	Oct	1,534	162	21	97	57.2	15.9

Table 11. cont. Length by month for selected fishes from the Trawl Survey in 2018.

	Month	Number counted	Number measured	Min length (mm)	Max length (mm)	Mean Length (mm)	SD
Black sea bass (*Centropristis striata*)	Apr	2	2	37	82	59.5	31.8
	May	2	2	95	100	97.5	3.5
	Jun	2	2	135	150	142.5	10.6
	Jul	6	6	135	150	141.3	6.5
	Aug	4	4	153	187	171.5	15.1
	Sep	8	8	75	200	170.1	40
	Oct	1	1	179	179	179	
Bluefish (*Pomatomus saltatrix*)	Apr						
	May						
	Jun						
	Jul	1	1	106	106	106	
	Sep	1	1	170	170	170	
	Oct	1	1	250	250	250	
Pinfish (*Lagodon rhomboides*)	Apr						
	May						
	Jun						
	Jul	10	10	35	103	70.8	24.3
	Aug	3	3	119	149	138.3	16.8
	Sep	2	2	120	127	123.5	5
	Oct						
Sheepshead (*Archosargus probatocephalus*)	Apr						
	May						
	Jun						
	Jul						
	Sep						
	Oct	1	1	120	120	120	
Silver perch (*Bairdiella chrysoura*)	Apr						
	May						
	Jun	3	3	70	88	82	10.4
	Jul	203	97	17	95	53	19.9
	Aug	742	190	50	150	85.8	15.5
	Sep	332	171	55	193	95.6	18.4
	Oct	100	91	69	160	114.1	15.3
Spot (*Leiostomus xanthurus*)	Apr	2	2	24	27	25.5	2.1
	May	1	1	88	88	88	
	Jun	11	11	35	120	79.6	33.7
	Jul	53	51	68	155	105.5	20.6
	Aug	75	75	60	190	145.3	25.2
	Sep	89	87	57	190	164	20.4
	Oct	9	9	136	192	173.7	16.2

Table 11 cont. Length by month for selected fishes from the Trawl Survey in 2018.

	Month	Number counted	Number measured	Min length (mm)	Max length (mm)	Mean Length (mm)	SD
Summer flounder (*Paralichthys dentatus*)	Apr	1	1	17	17	17	
	May	53	53	31	232	65	27.4
	Jun	56	56	60	372	99.8	45.8
	Jul	48	48	80	200	113.2	26.8
	Aug	40	40	78	240	120	35
	Sep	93	92	80	485	126.8	49.4
	Oct	24	24	82	230	123	29.9
Weakfish (*Cynoscion regalis*)	Apr						
	May						
	Jun						
	Jul	241	150	28	111	63.7	18.1
	Aug	94	89	45	161	101	20
	Sep	23	23	51	152	107.6	26.4
	Oct	4	4	115	152	138	17.1

Table 12. Length by month for selected fishes from the Beach Seine Survey in 2018. Weakfish (*Cynoscion regalis*) were not present in the survey and were not included.

	Month	Number counted	Number measured	Min length (mm)	Max length (mm)	Mean Length (mm)	SD
American eel	Jun						
(*Anguilla rostrata*)	Sep	3	3	230	300	262	35.4
Atlantic croaker	Jun	1	1	1	32	32	
(*Micropogonias undulatus*)	Sep						
Atlantic menhaden	Jun	24,662	212	33	360	59.3	31.2
(*Brevoortia tyrannus*)	Sep	1,444	101	85	290	114.8	20
Atlantic silverside	Jun	487	235	22	135	71.5	26.8
(*Menidia menidia*)	Sep	912	254	33	100	74.9	10.6
Bay anchovy	Jun	181	103	26	88	71.6	12.3
(*Anchoa mitchilli*)	Sep	825	152	22	80	52.2	9.8
Black sea bass	Jun	1	1	119	119	119	
(*Centropristis striata*)	Sep						
Bluefish	Jun	16	16	53	104	75.6	14.1
(*Pomatomus saltatrix*)	Sep	8	8	100	220	159.4	45.8
Pinfish	Jun	135	74	30	97	58.5	14.1
(*Lagodon rhomboides*)	Sep	57	57	53	180	136.7	26.6
Sheepshead	Jun						
(*A. probatocephalus*)	Sep	7	7	51	127	70.6	27.1
Silver perch	Jun	13	13	28	82	59	16
(*Bairdiella chrysoura*)	Sep	1,352	181	54	190	102.3	23.8
Spot	Jun	216	138	20	147	86.1	25.5
(*Leiostomus xanthurus*)	Sep	122	124	51	235	168.7	28.6
Summer flounder	Jun	200	162	47	340	88.4	29.2
(*Paralichthys dentatus*)	Sep	43	43	80	390	162.9	49.3

Table 13. Finfish richness and diversity by system for the 1989 - 2018 Trawl Survey. 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. Sample size: Assawoman Bay (n = 630); St. Martin River (n = 420); Isle of Wight Bay (n = 420); Sinepuxent Bay (n = 630); Newport Bay (n = 420); Chincoteague Bay (n = 1,680).

Embayment	Richness	Mean Richness	Mean Diversity
Assawoman Bay	79	28.2	1.41
St. Martin River	75	23.6	1.33
Isle of Wight Bay	85	31	1.62
Sinepuxent Bay	74	25.3	1.69
Newport Bay	67	21.4	1.45
Chincoteague Bay	90	36	1.50

Table 14. Finfish richness and diversity by system for the 2018 Trawl Survey. 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. Sample size: Assawoman Bay (n = 21); St. Martin River (n = 14); Isle of Wight Bay (n = 14); Sinepuxent Bay (n = 21); Newport Bay (n = 14); Chincoteague Bay (n = 56).

Embayment	Richness	Diversity
Assawoman Bay	30	1.52
St. Martin River	26	1.23
Isle of Wight Bay	33	1.25
Sinepuxent Bay	28	1.91
Newport Bay	17	1.26
Chincoteague Bay	39	1.70

Table 15. Finfish richness and diversity by system for the 1989 - 2018 Beach Seine Survey. 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. Sample size: Assawoman Bay (n = 180); St. Martin River (n = 60); Isle of Wight Bay (n = 180); Sinepuxent Bay (n = 180); Newport Bay (n = 120); Chincoteague Bay (n = 360); Ayers Creek (n = 60).

Embayment	Richness	Mean Richness	Mean Diversity
Assawoman Bay	87	30.5	1.58
St. Martin River	71	20.6	1.35
Isle of Wight Bay	87	29.3	1.56
Sinepuxent Bay	76	25	1.38
Newport Bay	68	19.7	1.60
Chincoteague Bay	78	30.8	1.63
Ayers Creek	44	14.5	1.21

Table 16. Finfish richness and diversity by system for the 2018 Beach Seine Survey. 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. Sample size: 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); Ayers Creek (n = 2).

Embayment	Richness	Diversity
Assawoman Bay	30	0.40
St. Martin River	26	2.48
Isle of Wight Bay	28	0.26
Sinepuxent Bay	25	2.14
Newport Bay	28	1.65
Chincoteague Bay	38	1.74
Ayers Creek	9	0.45

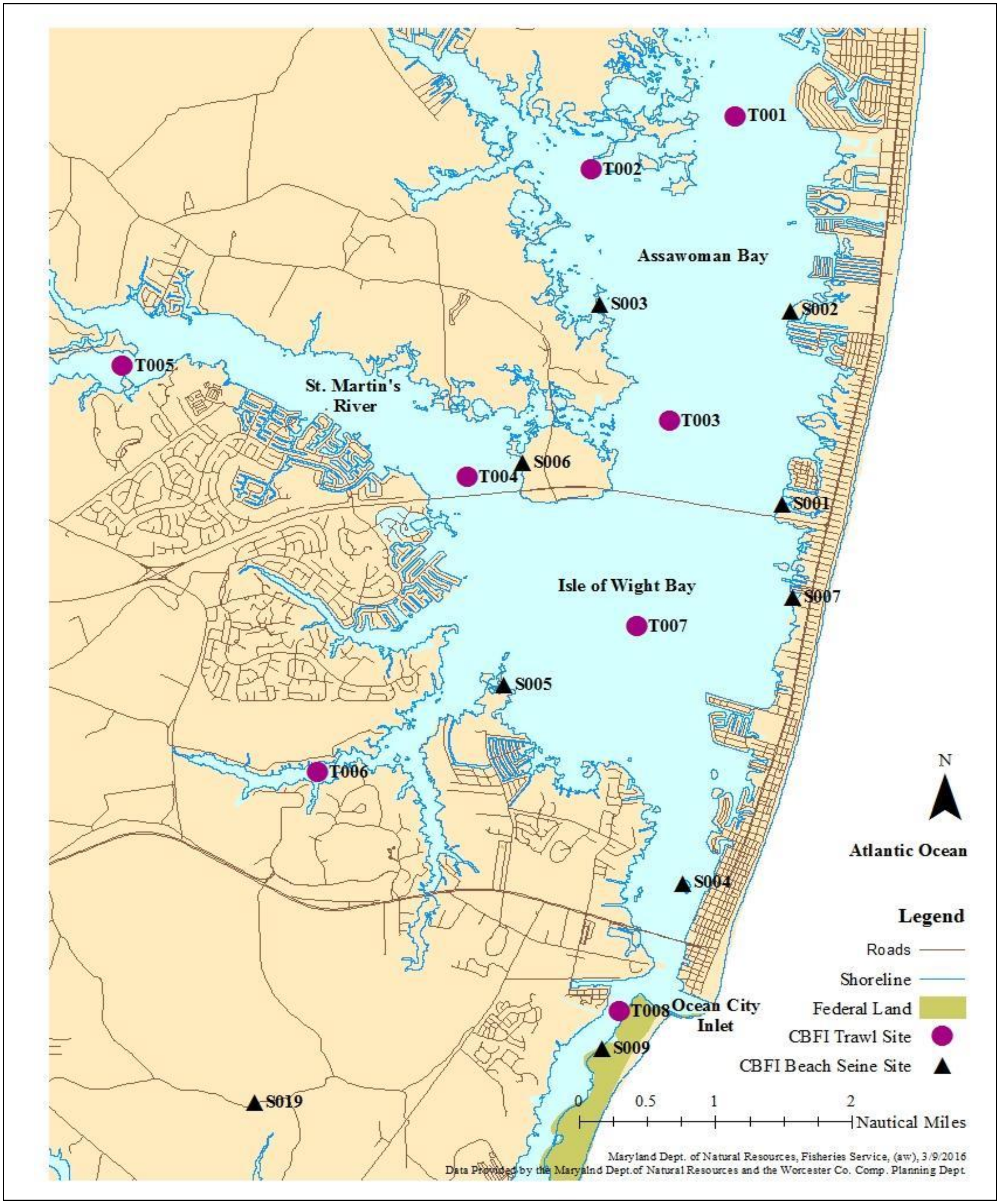

Figure 1. Trawl and Beach Seine surveys 2018 sampling locations in the Assawoman and Isle of Wight bays, Maryland.

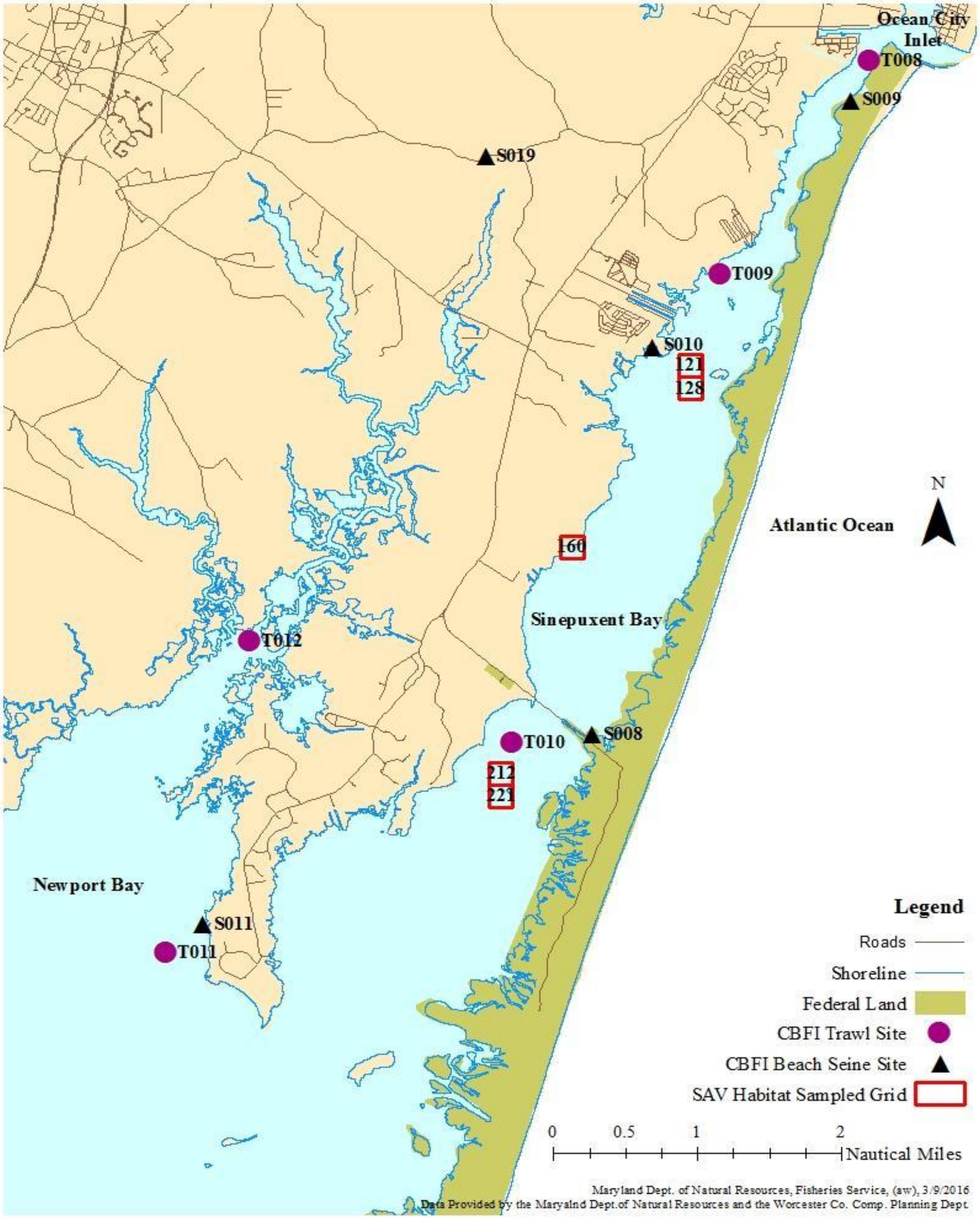

Figure 2. Trawl and Beach Seine surveys 2018 sampling locations in Sinepuxent and Newport bays, Maryland.

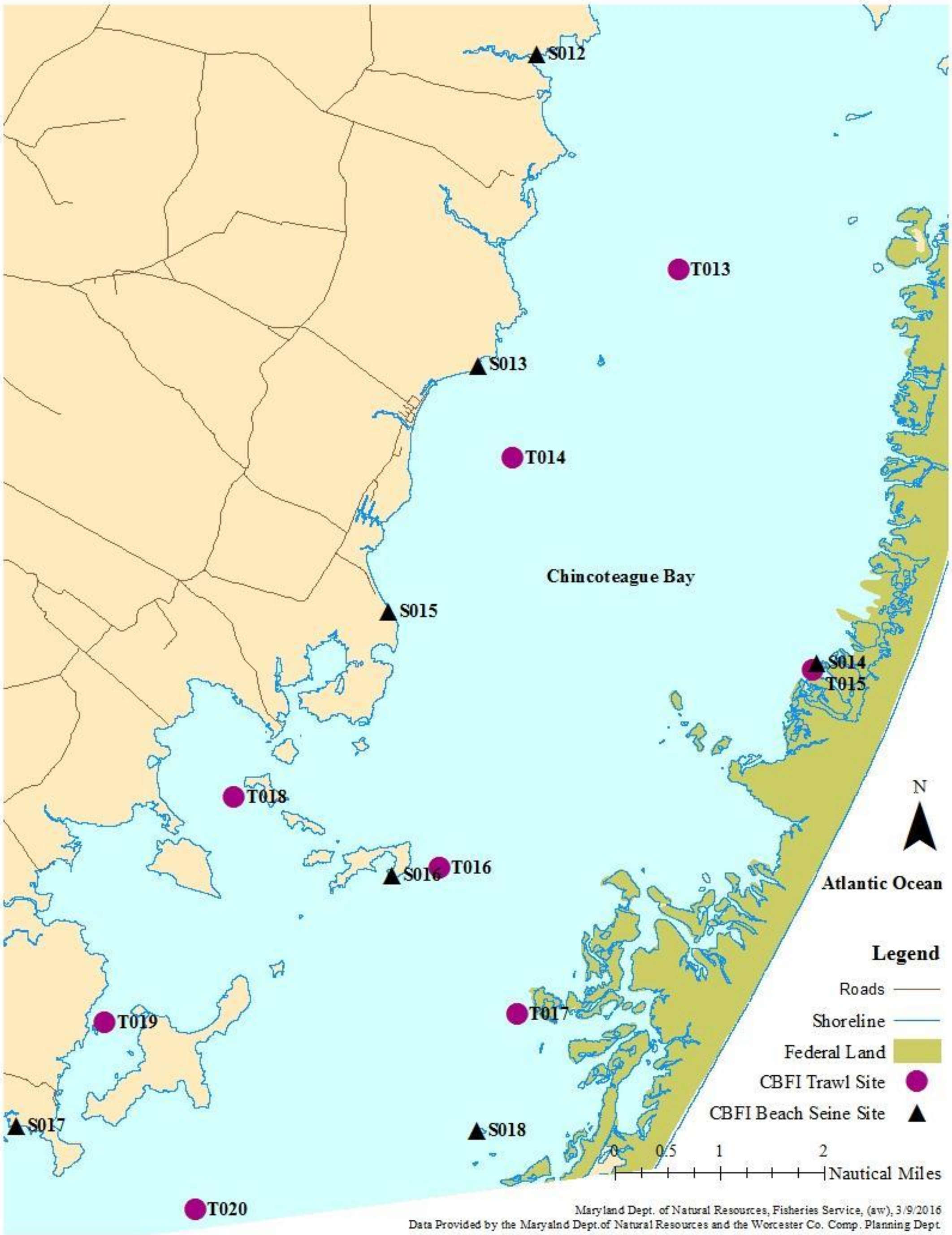

Figure 3. Trawl and Beach Seine surveys 2018 sampling locations in Chincoteague Bay, Maryland.

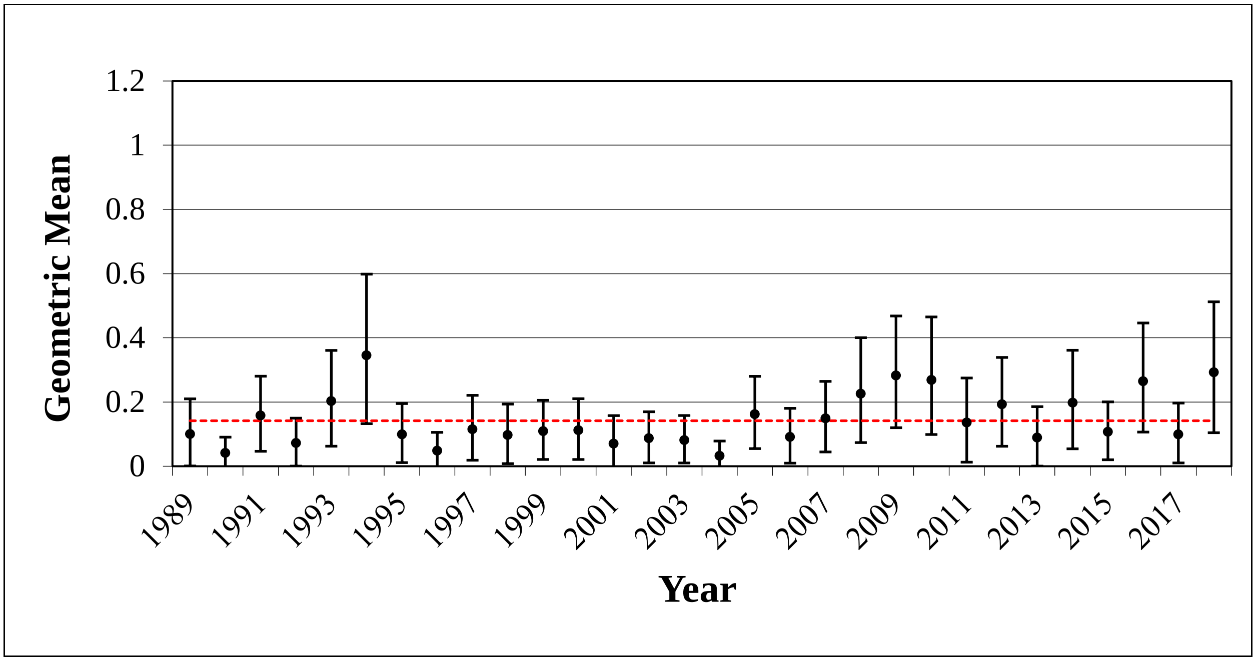

Figure 4. American eel (*Anguilla rostrata)* trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

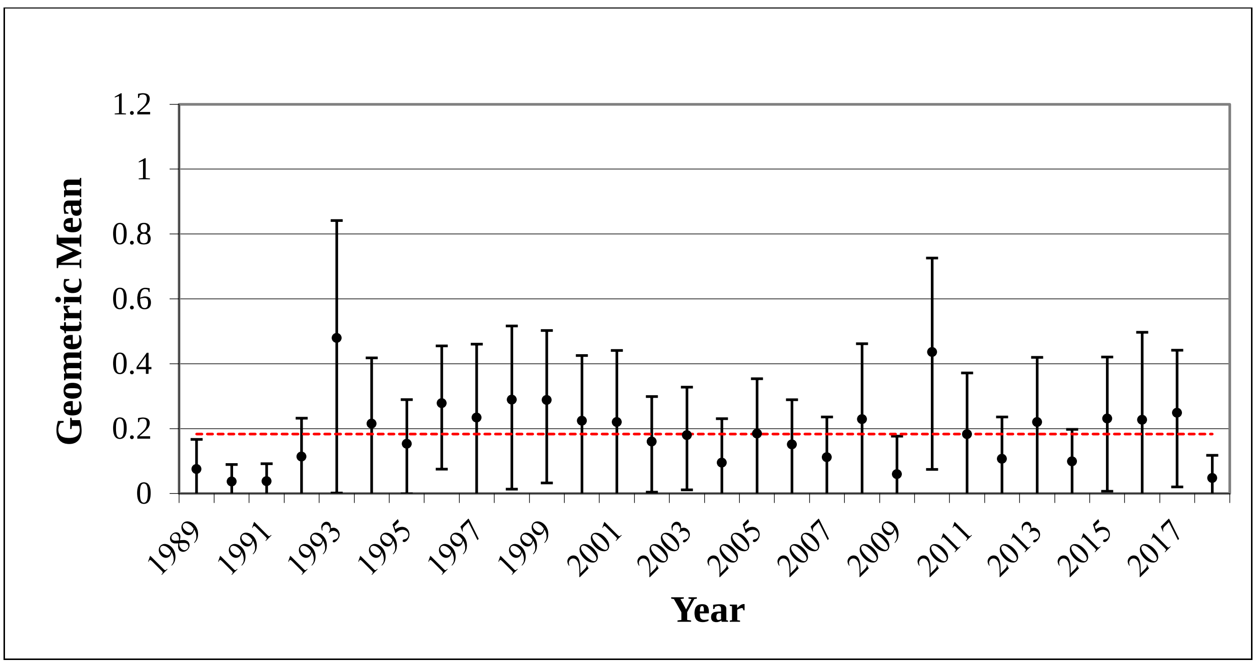

Figure 5. American Eel (*Anguilla rostrata*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

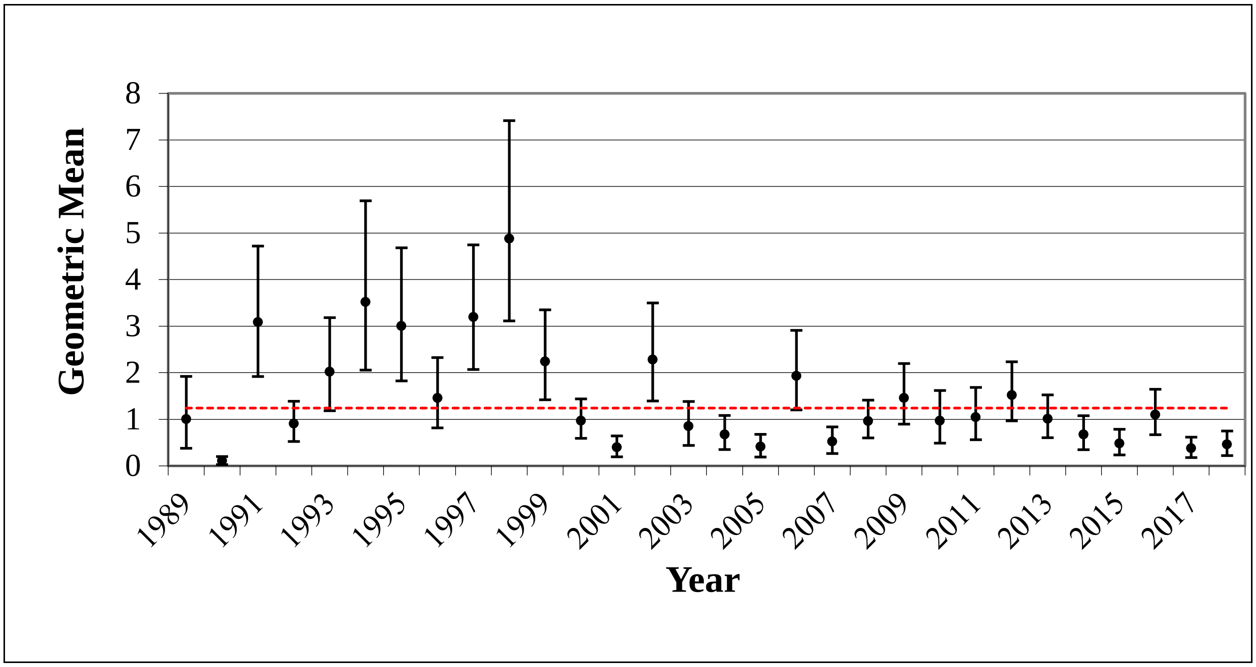

Figure 6. Atlantic croaker (*Micropogonias undulatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

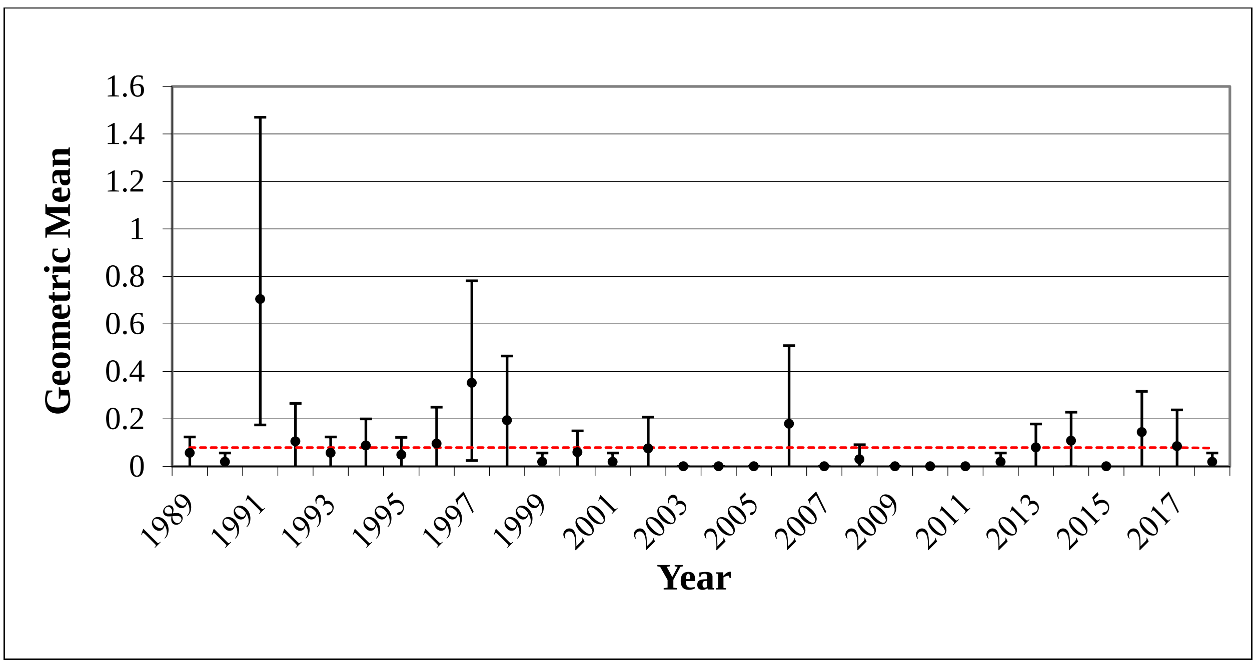

Figure 7. Atlantic croaker (*Micropogonias undulatus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

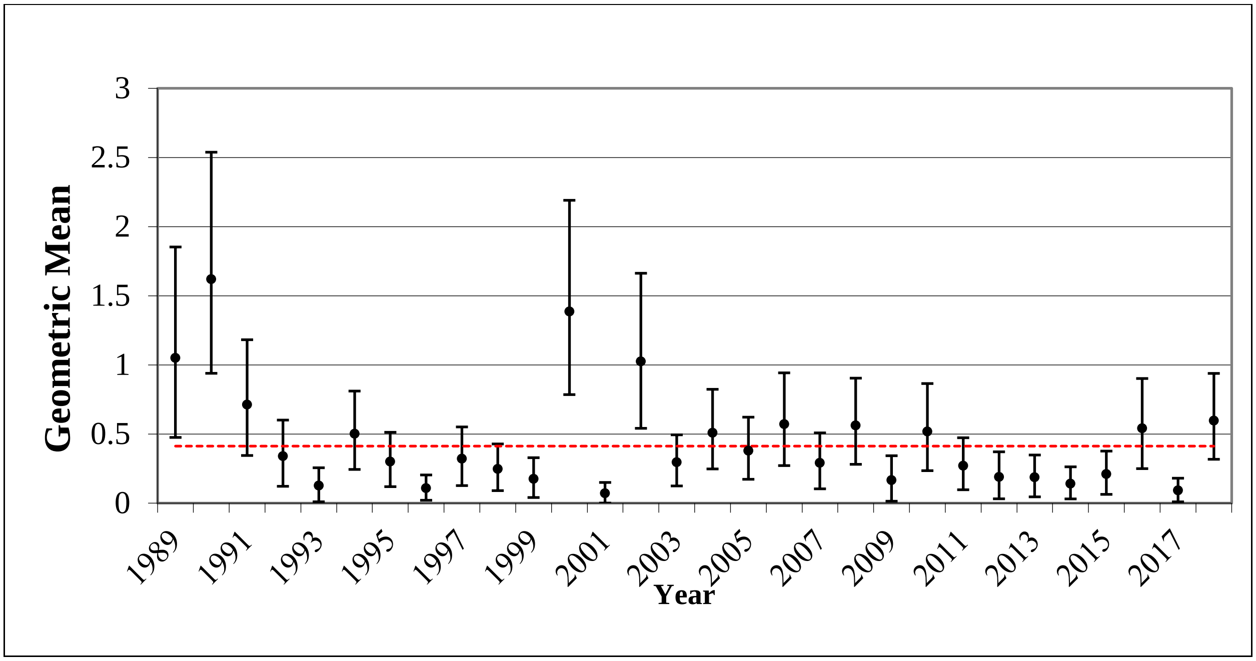

Figure 8. Atlantic menhaden (*Brevoortia tyrannus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

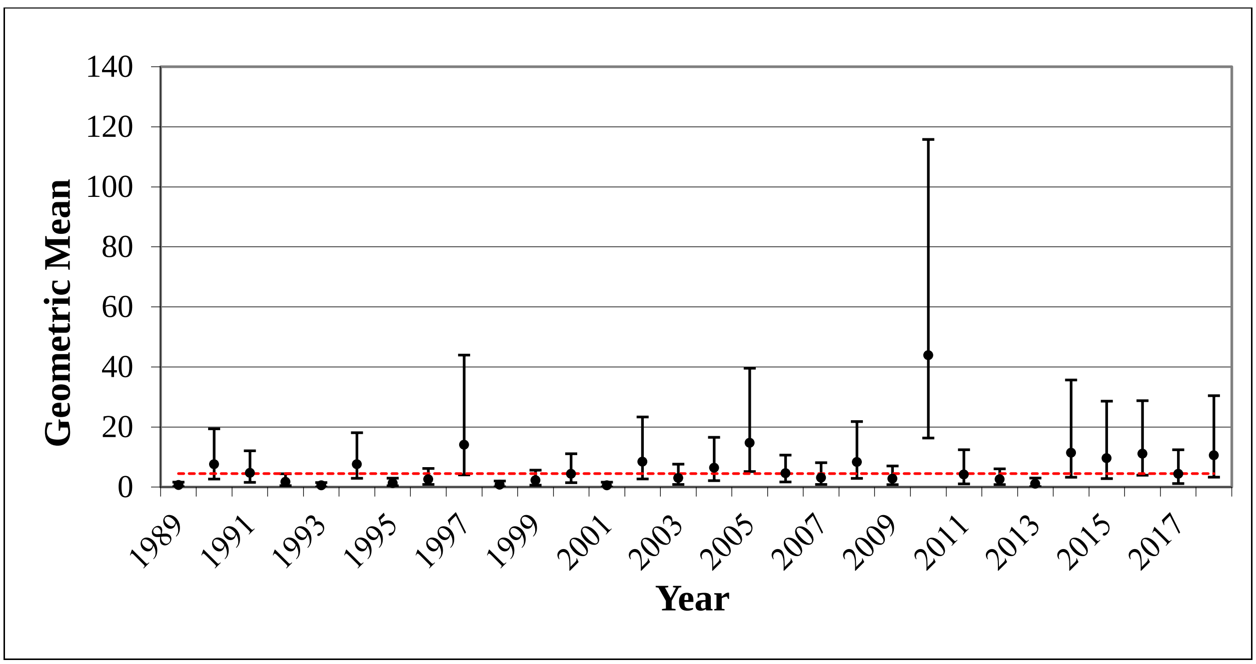

Figure 9. Atlantic menhaden (*Brevoortia tyrannus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

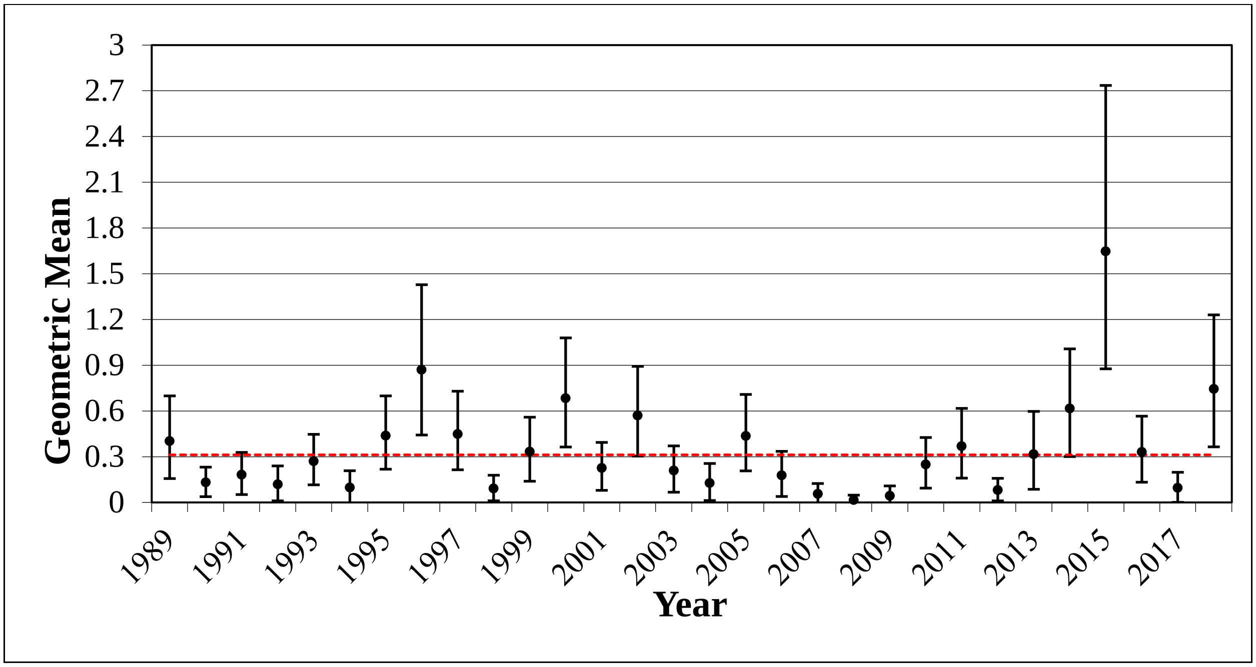

Figure 10. Atlantic silverside (*Menidia menidia*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

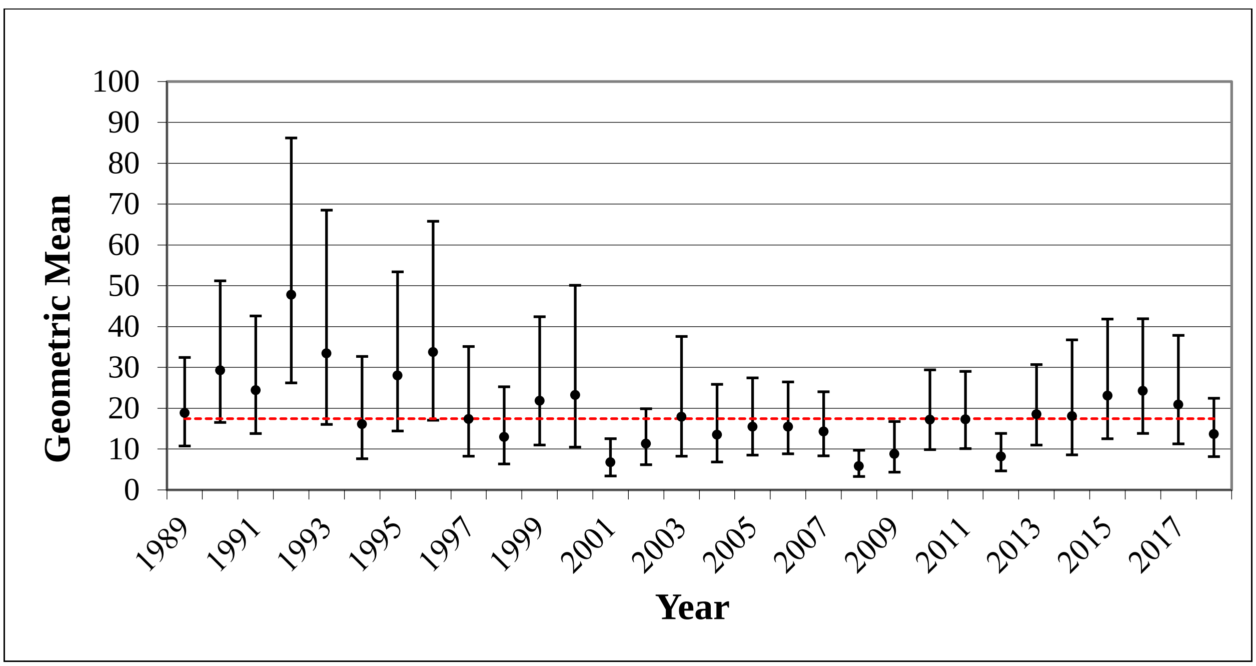

Figure 11. Atlantic silverside (*Menidia menidia*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

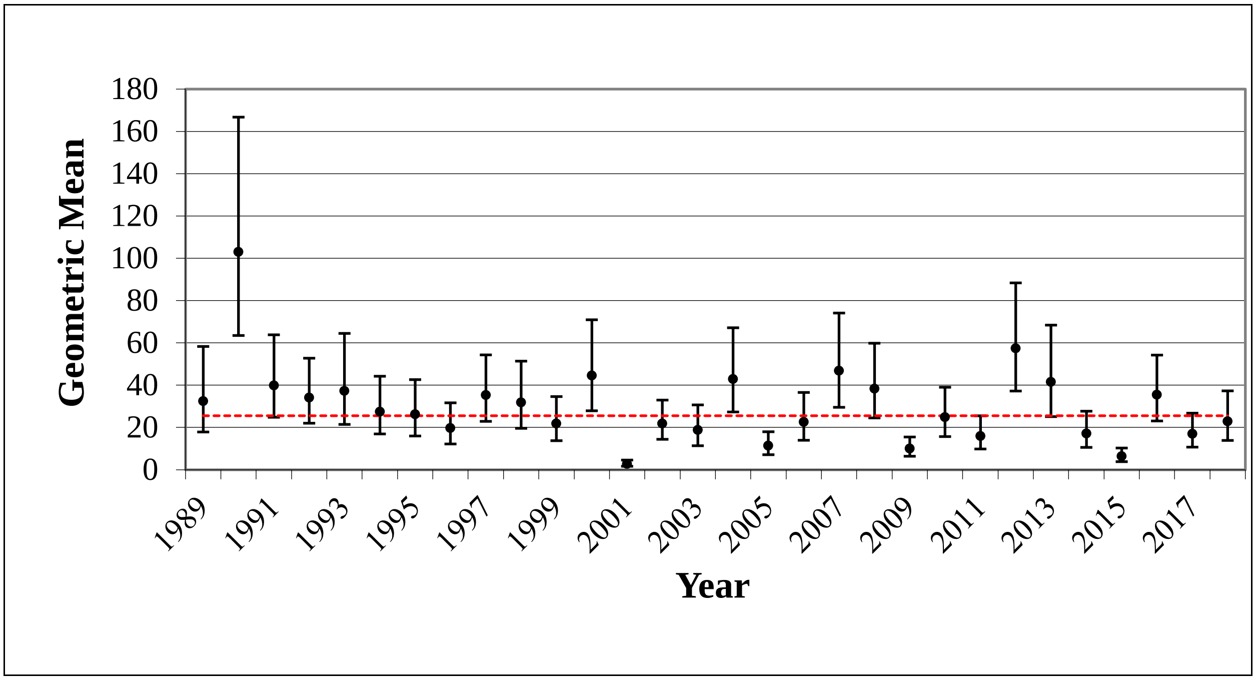

Figure 12. Bay anchovy (*Anchoa mitchilli*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

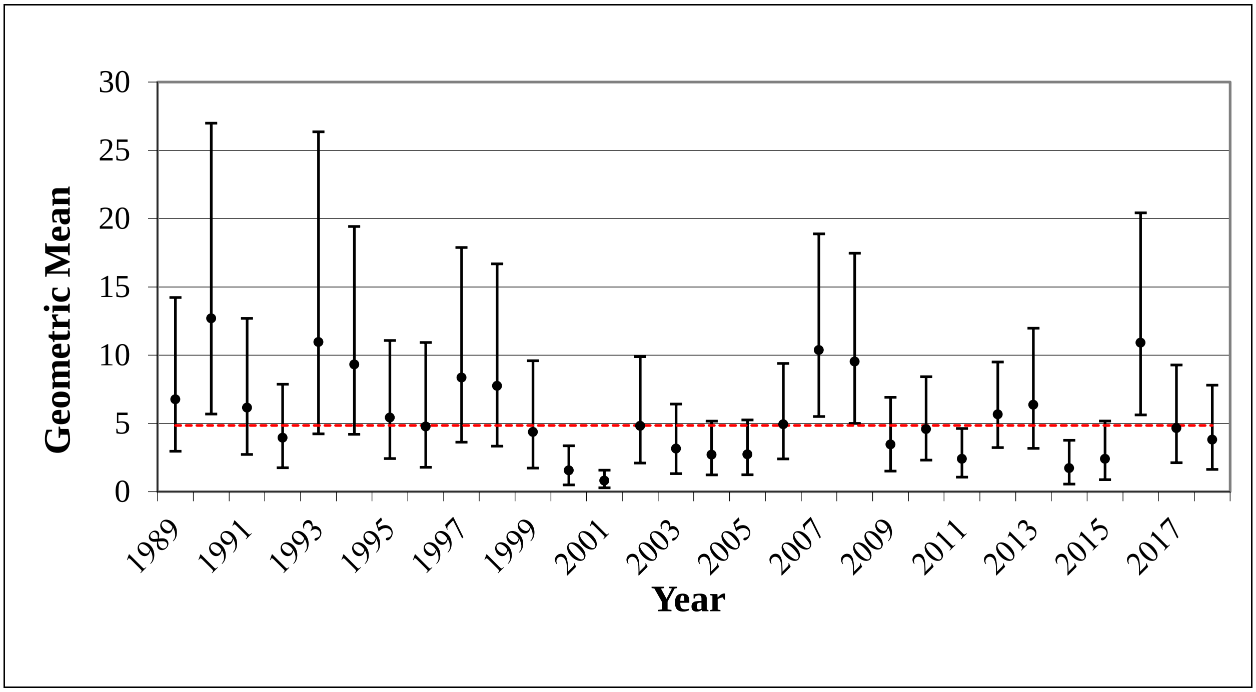

Figure 13. Bay anchovy (*Anchoa mitchilli*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

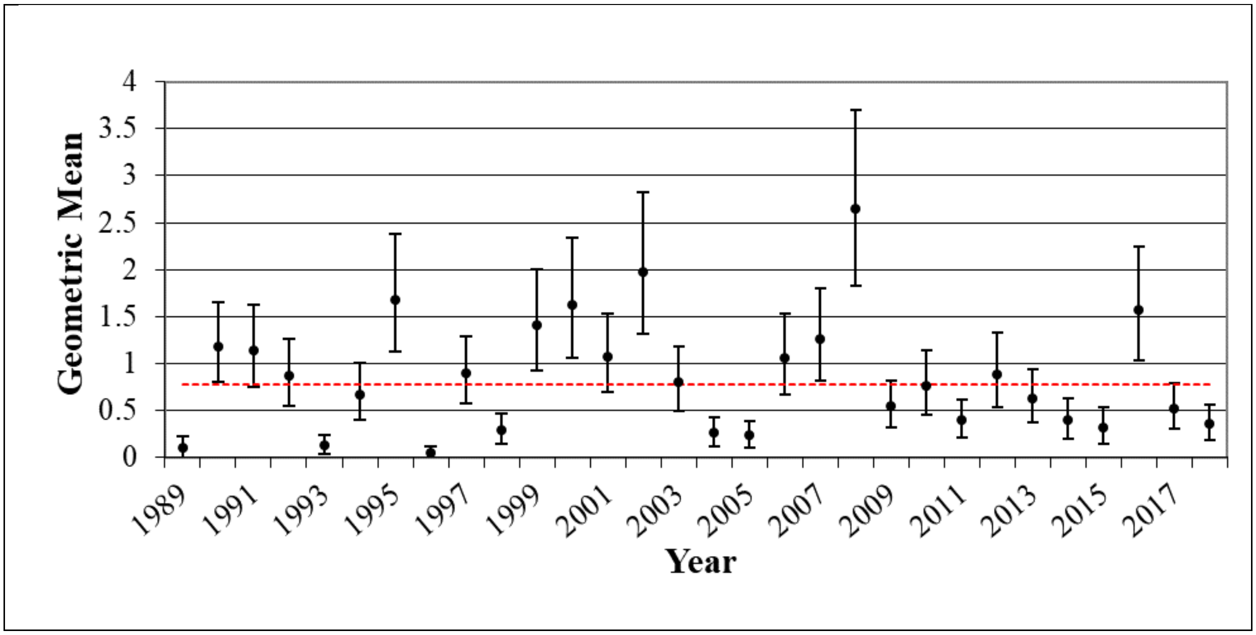

Figure 14. Black sea bass (*Centropristis striata*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

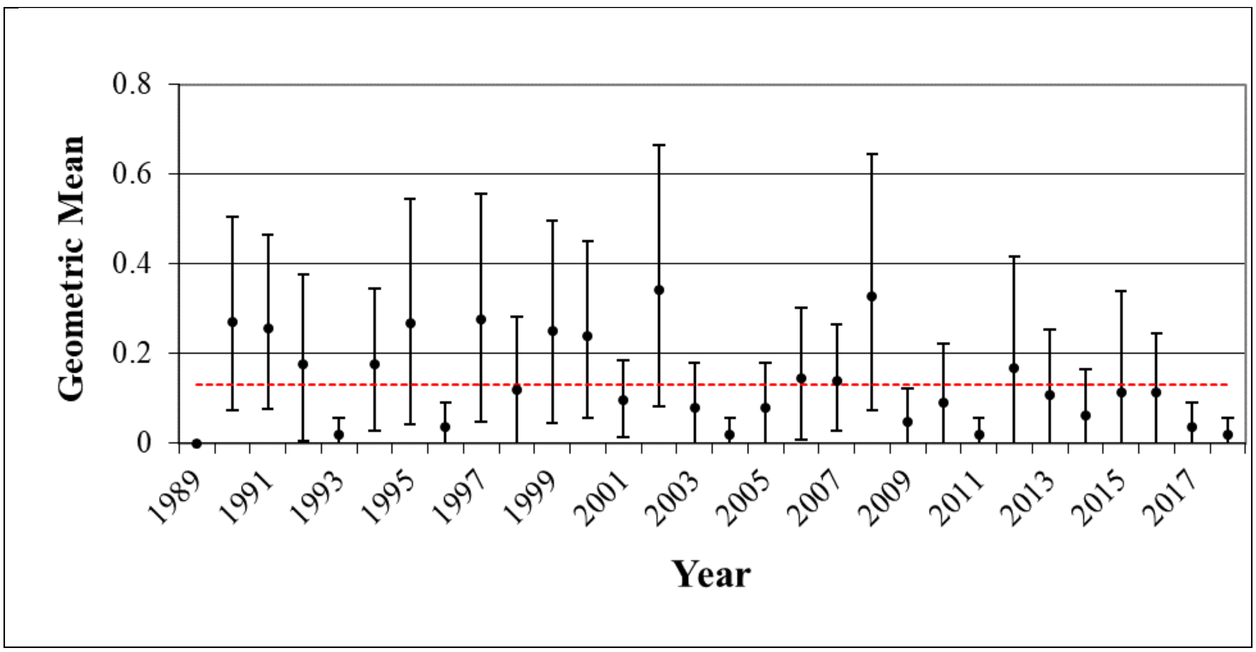

Figure 15. Black sea bass (*Centropristis striata*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

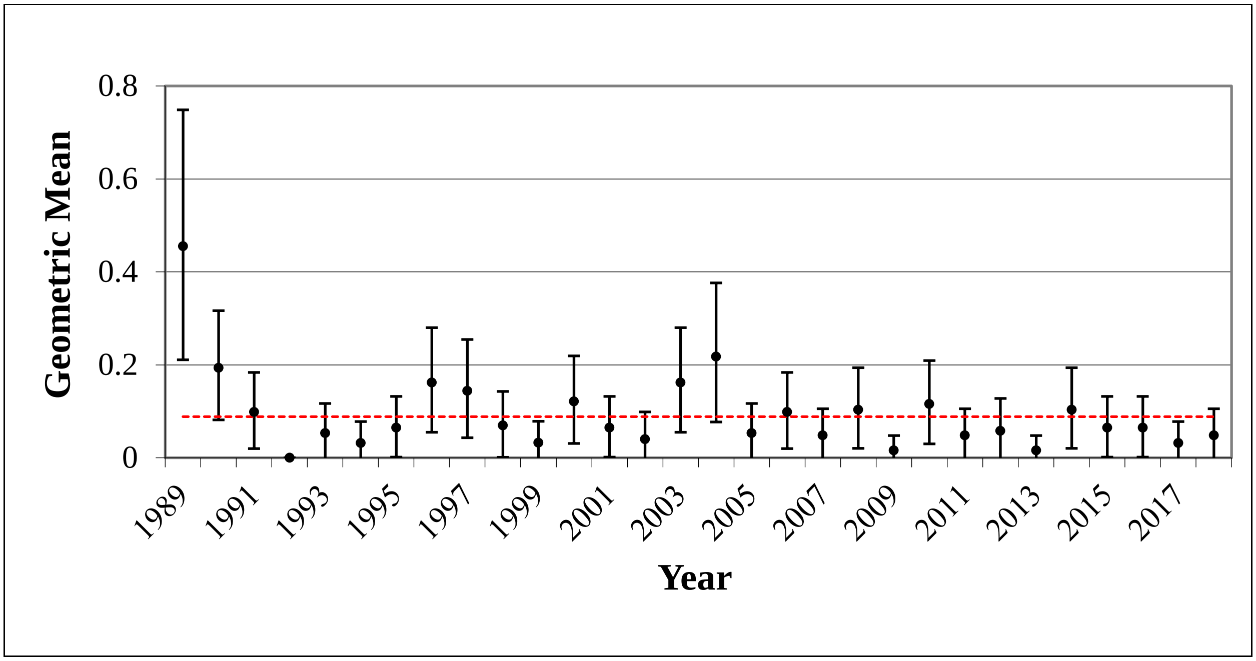

Figure 16. Bluefish (*Pomatomus saltatrix*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

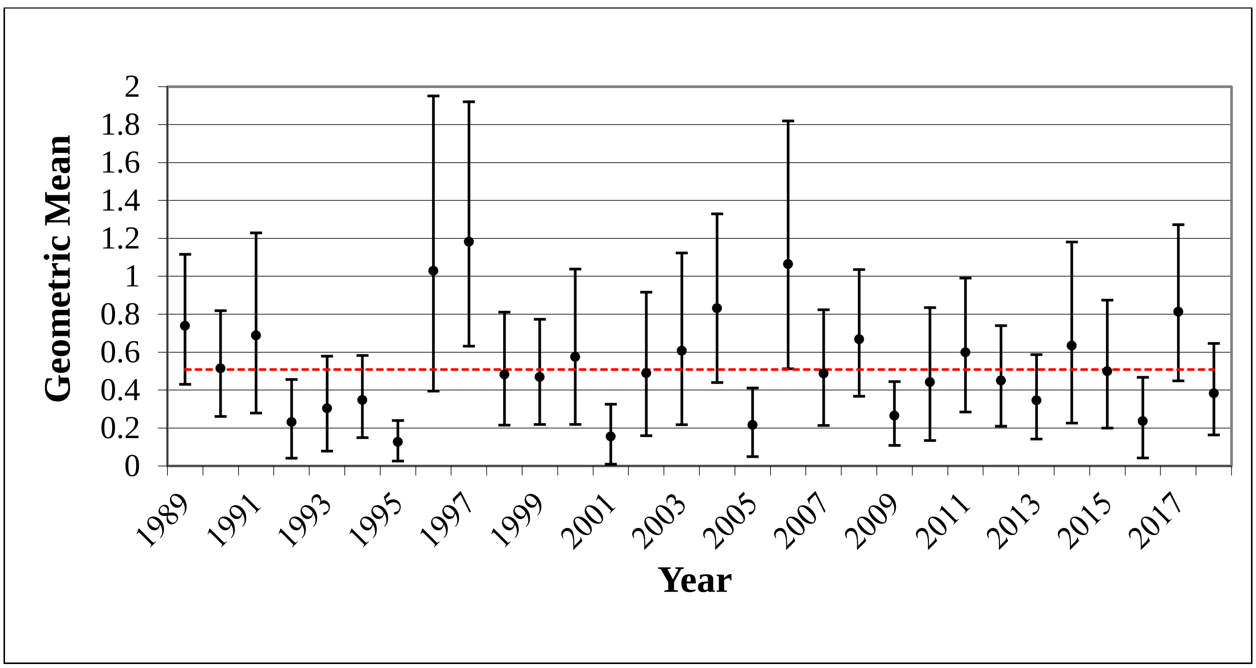

Figure 17. Bluefish (*Pomatomus saltatrix*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

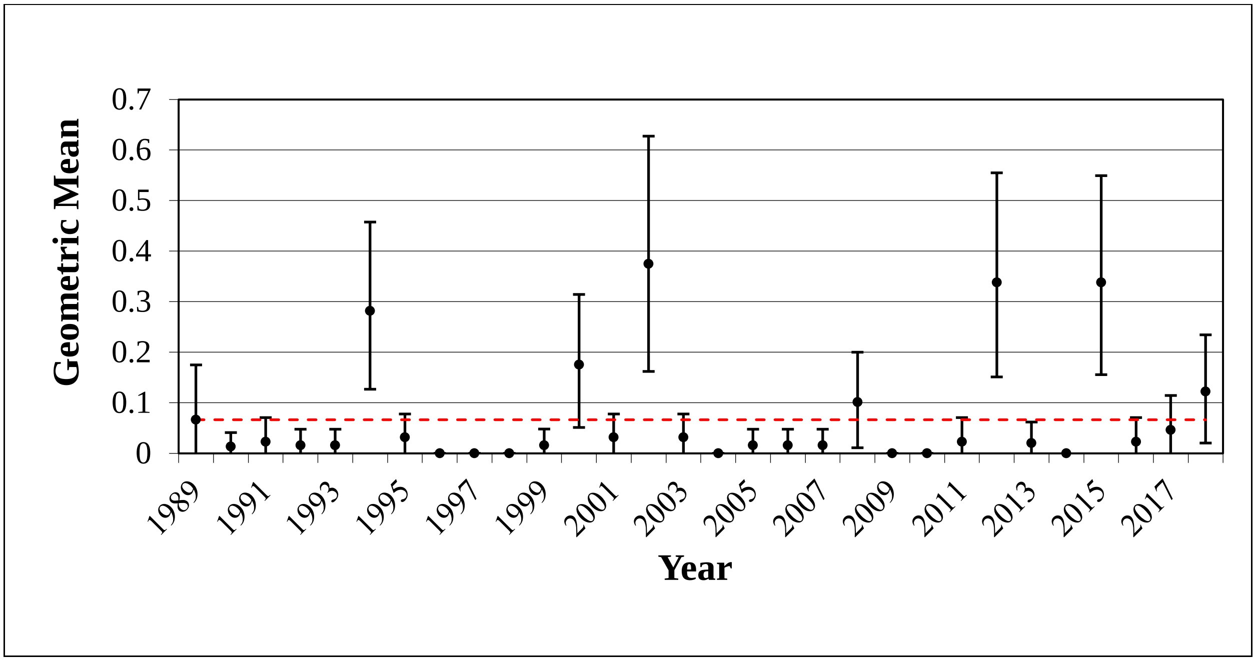

Figure 18. Pinfish (*Lagodon rhomboides)* trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

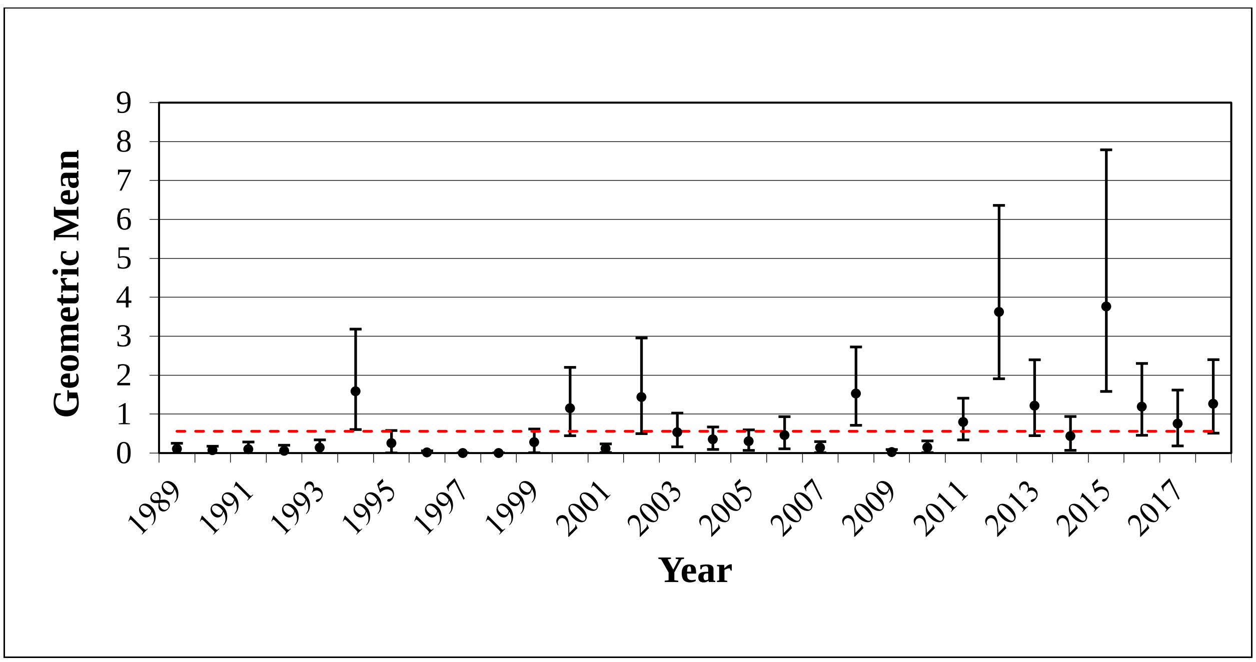

Figure 19. Pinfish (*Lagodon rhomboides)* beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

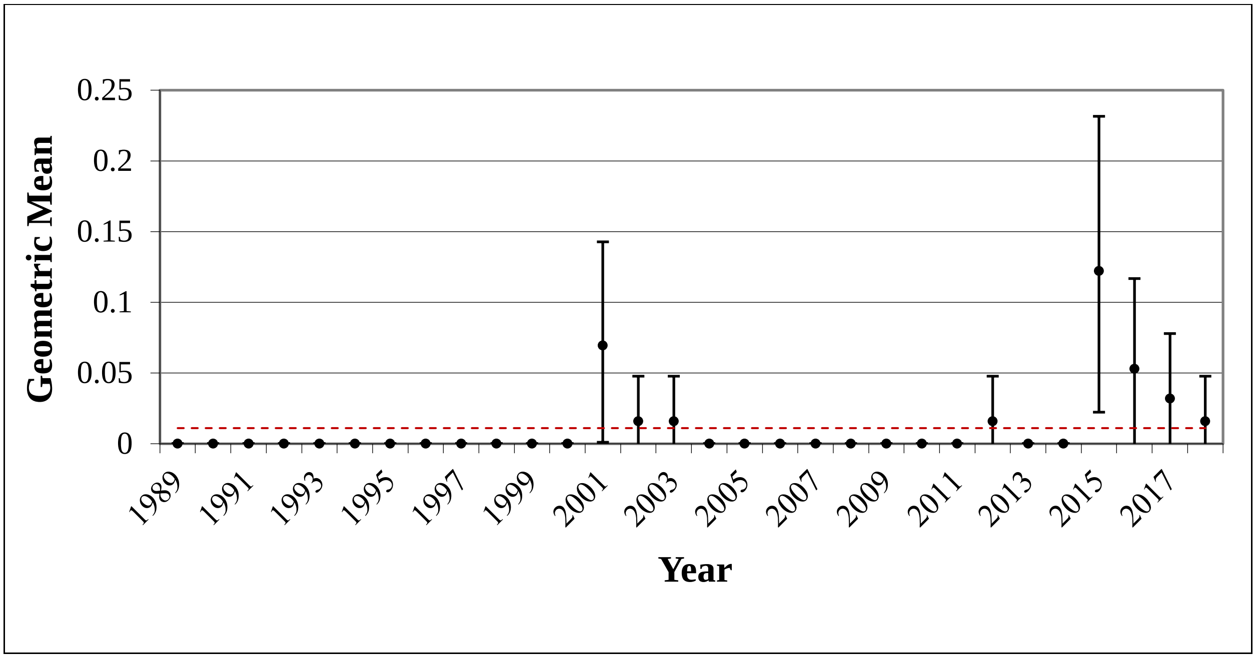

Figure 20. Sheepshead (*Archosargus probatocephalus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

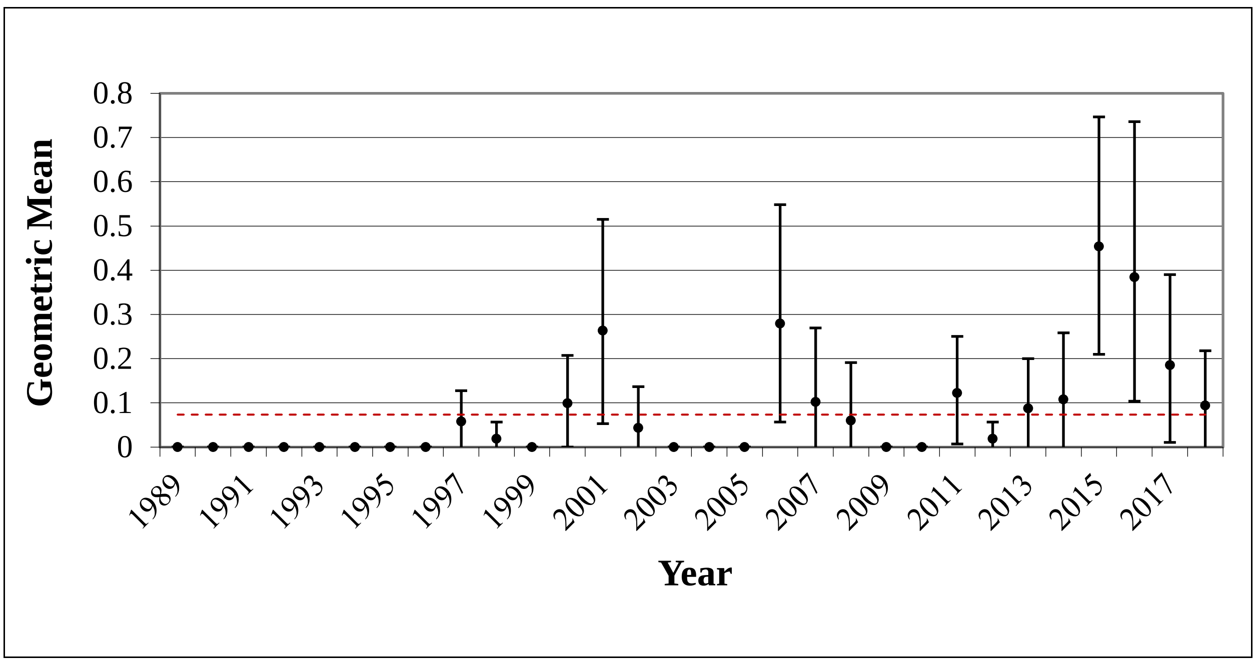

Figure 21. Sheepshead (*Archosargus probatocephalus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

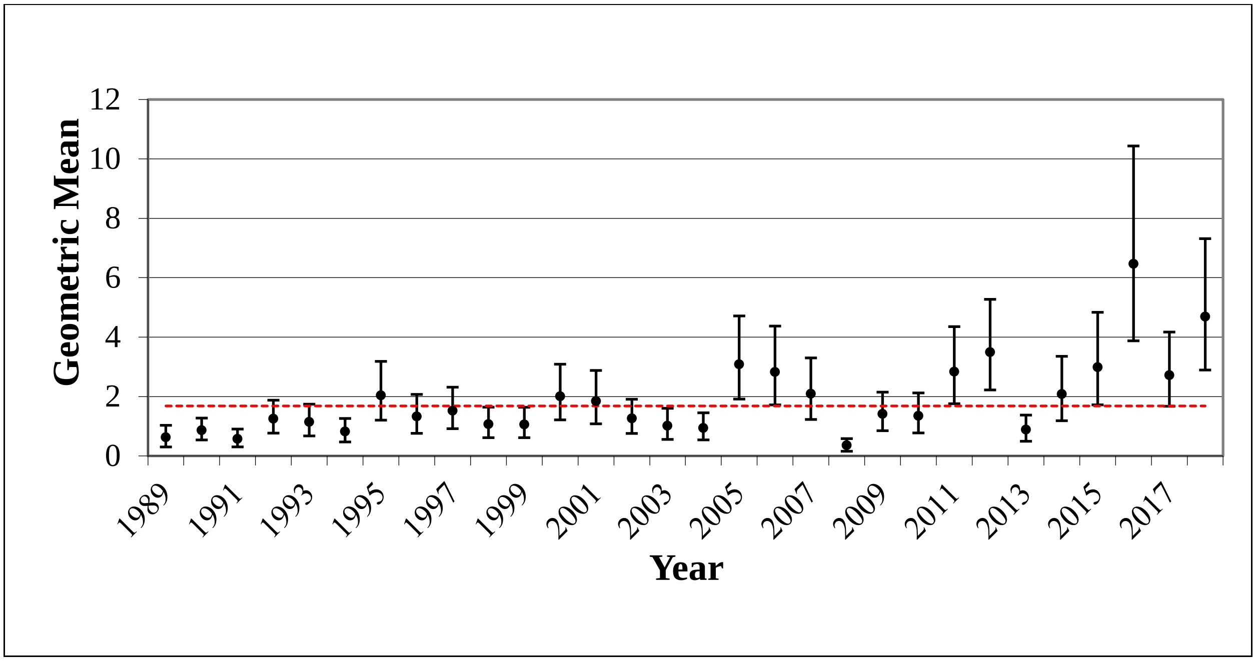

Figure 22. Silver perch (*Bairdiella chrysoura*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

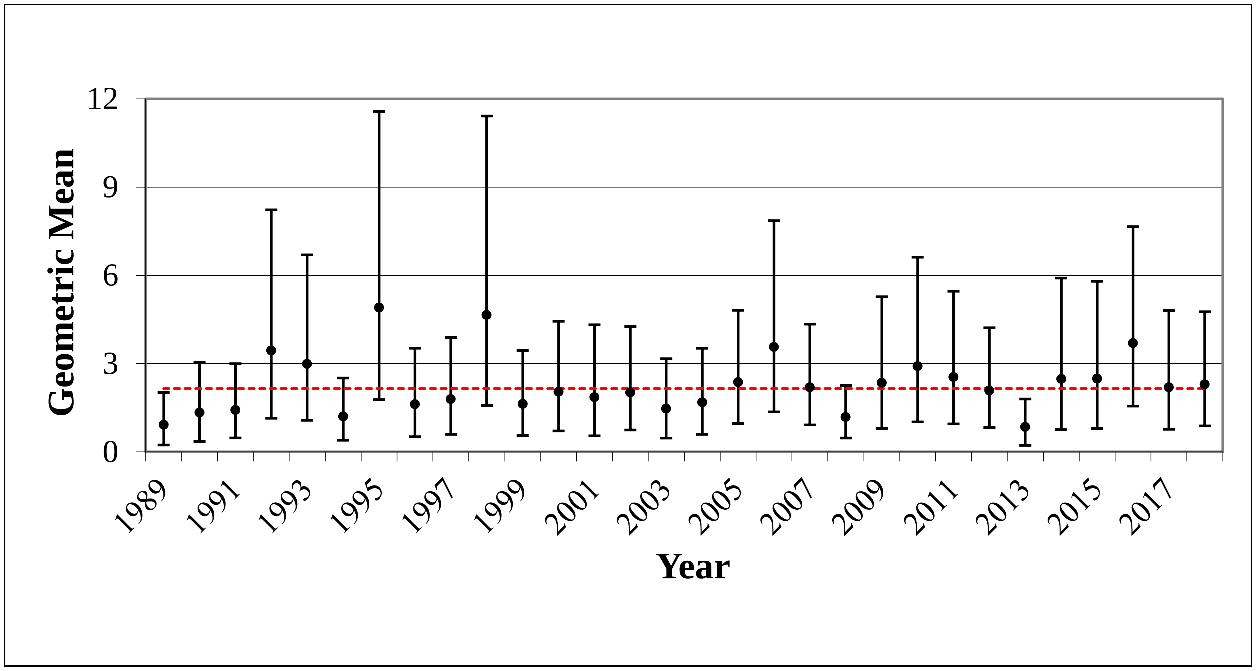

Figure 23. Silver perch (*Bairdiella chrysoura*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

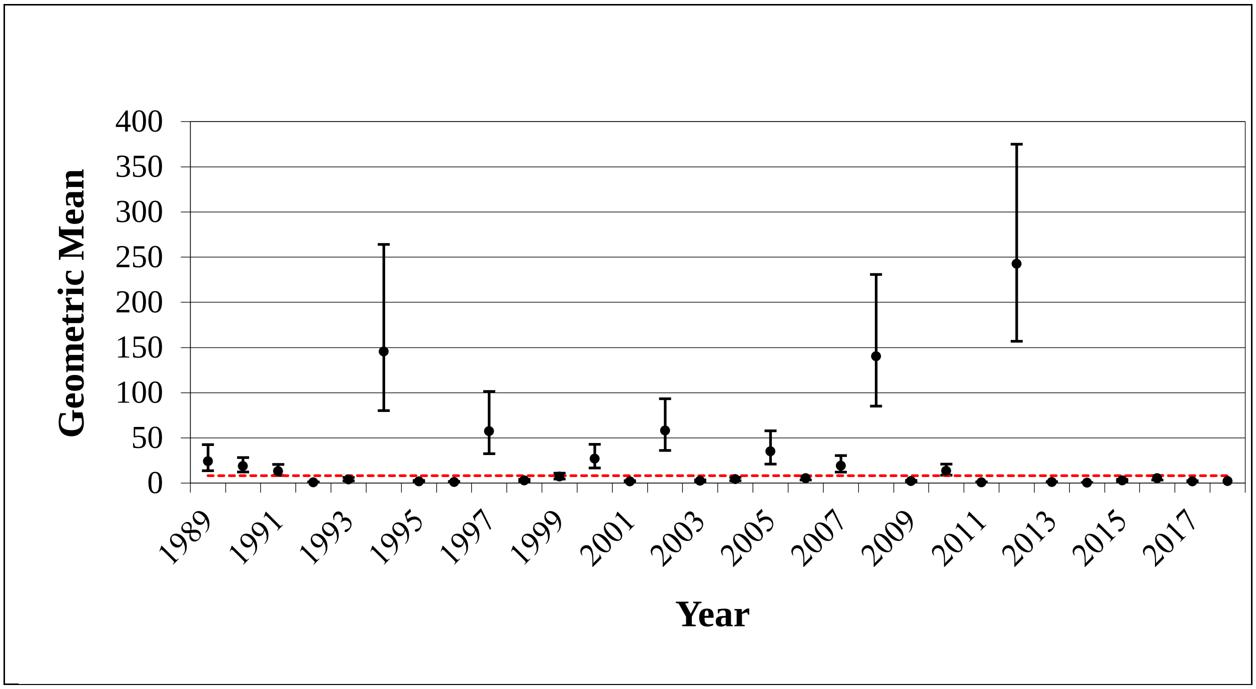

Figure 24. Spot (*Leiostomus xanthurus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

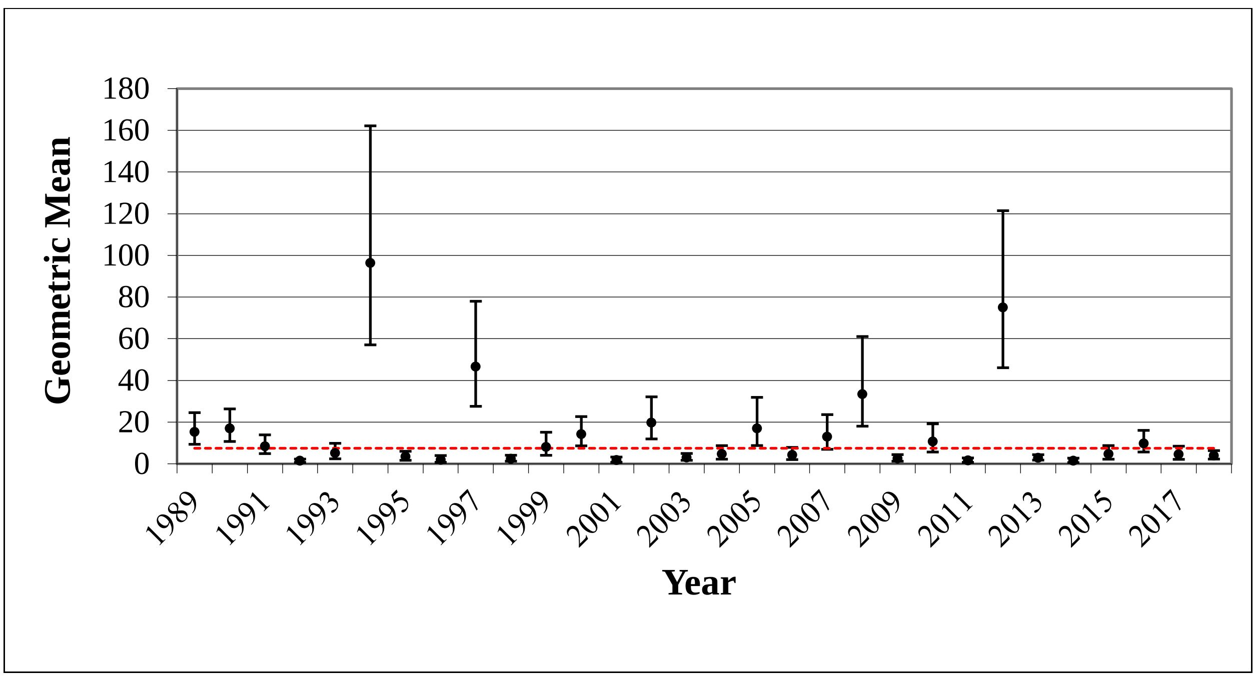

Figure 25. Spot (*Leiostomus xanthurus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

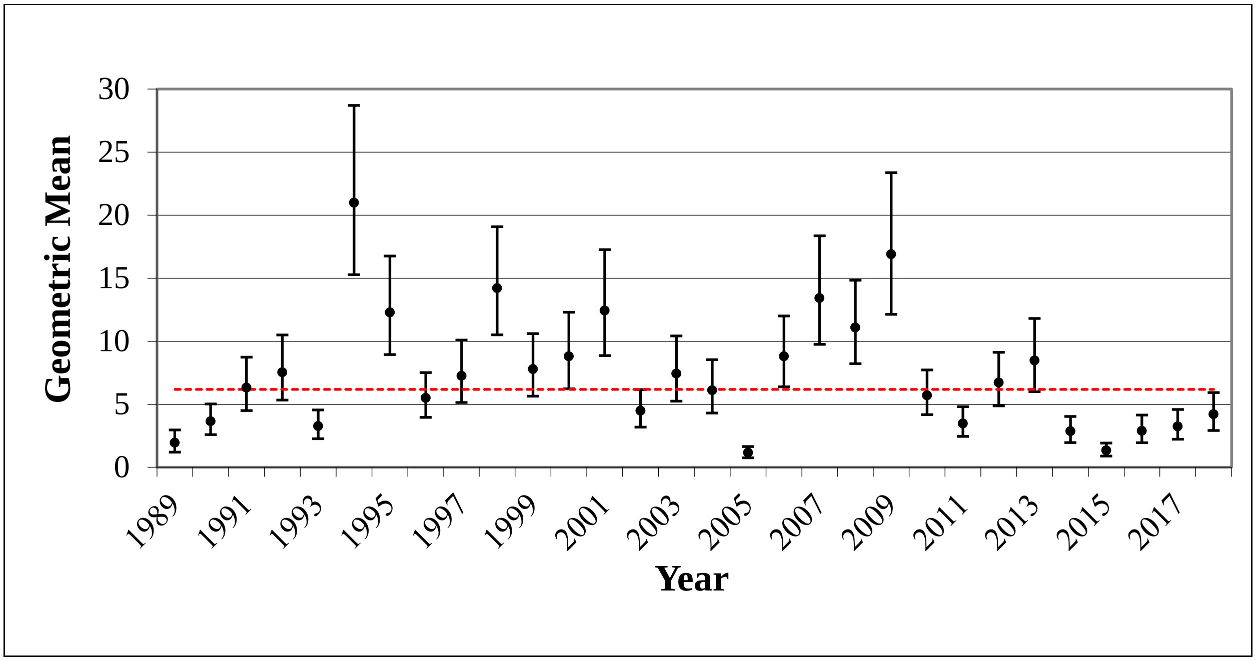

Figure 26. Summer flounder (*Paralichthys dentatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

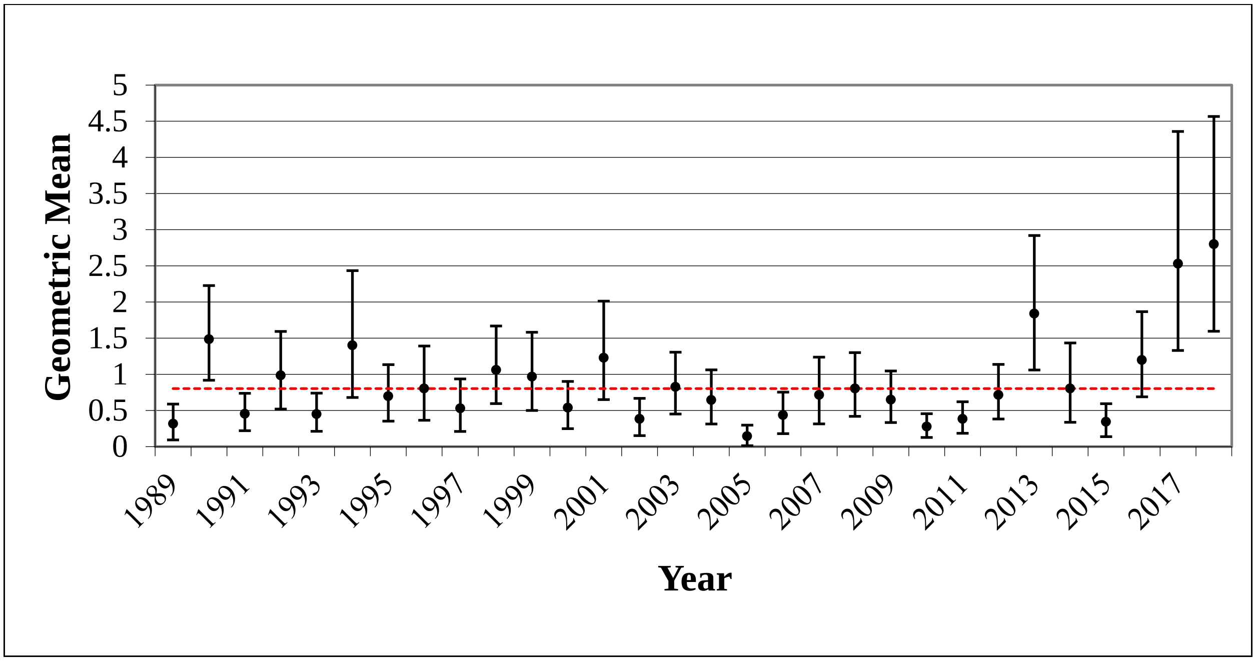

Figure 27. Summer flounder (*Paralichthys dentatus*) beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

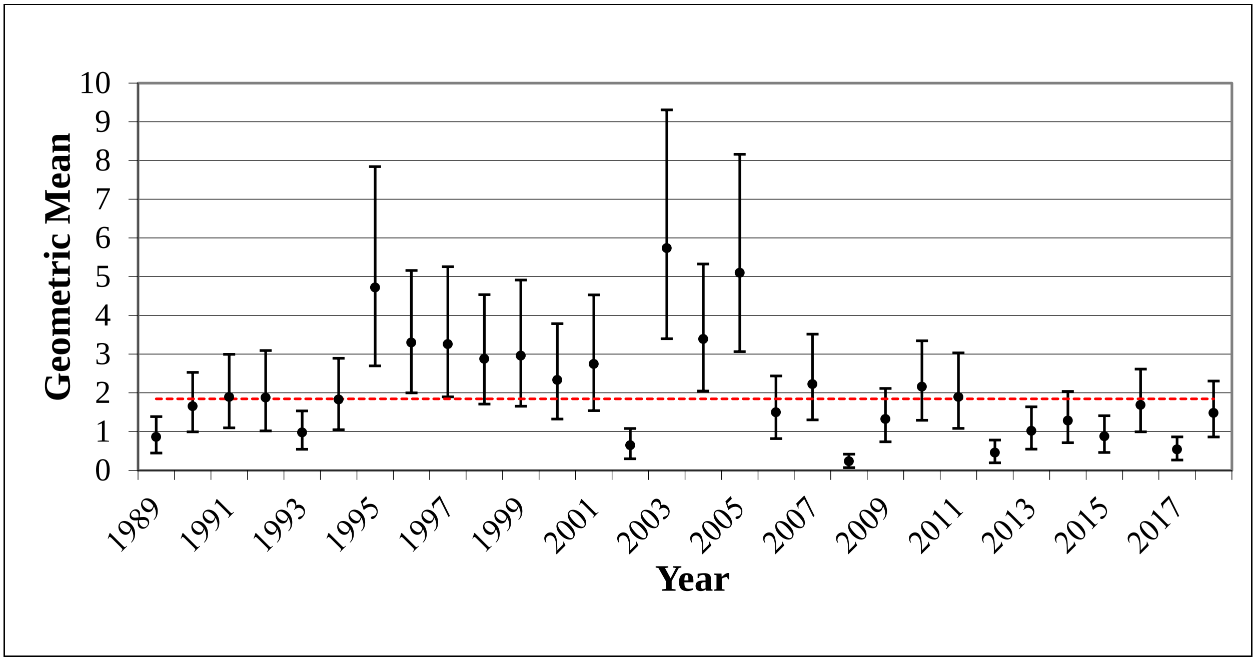

Figure 28. Weakfish (*Cynoscion regalis)* trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 140/year).

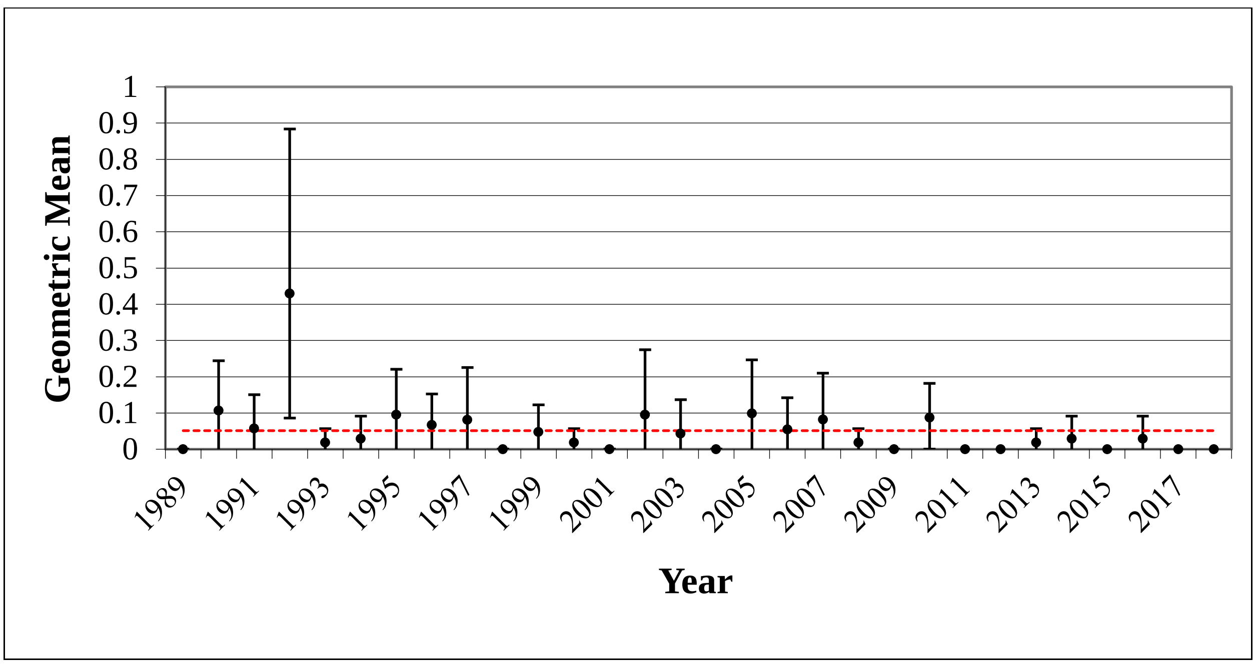

Figure 29. Weakfish (*Cynoscion regalis)* beach seine index of relative abundance (geometric mean) with 95% confidence intervals (1989 - 2018). Dotted line represents the 1989 - 2018 time series grand mean (n = 38/year).

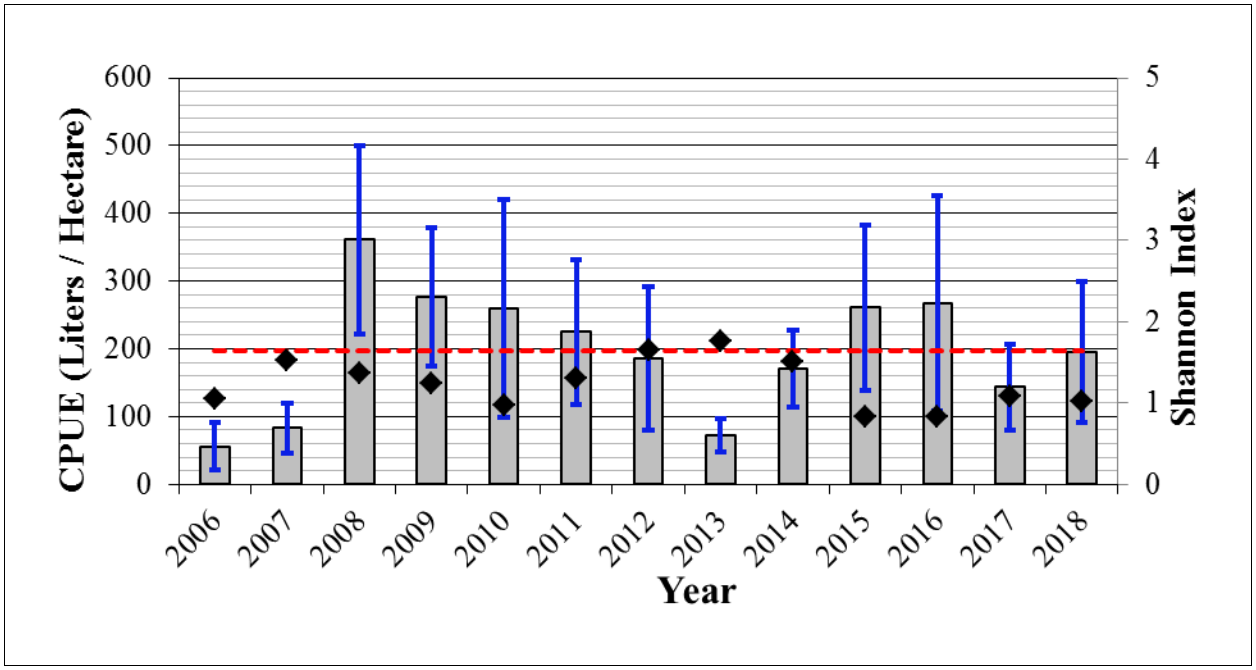

Figure 30. Coastal bays trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 140/year). Black diamond represents the Shannon index of diversity.

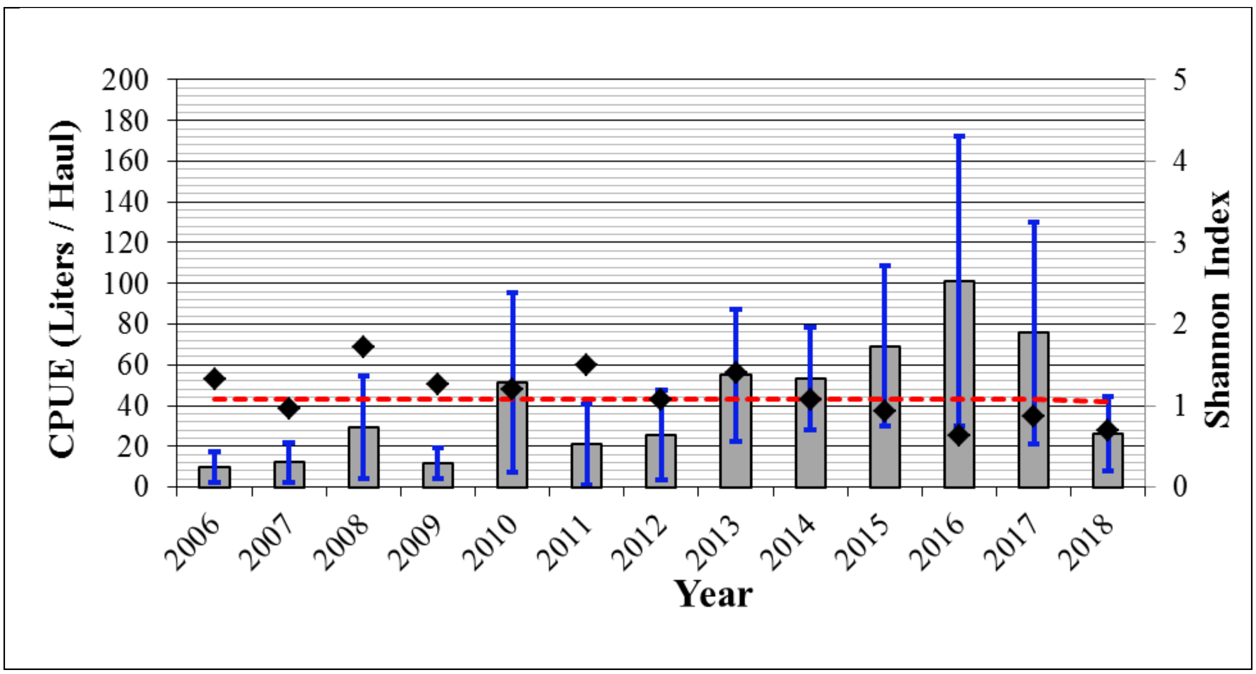

Figure 31**.** Coastal bays beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 36/year). Black diamond represents the Shannon index of diversity.

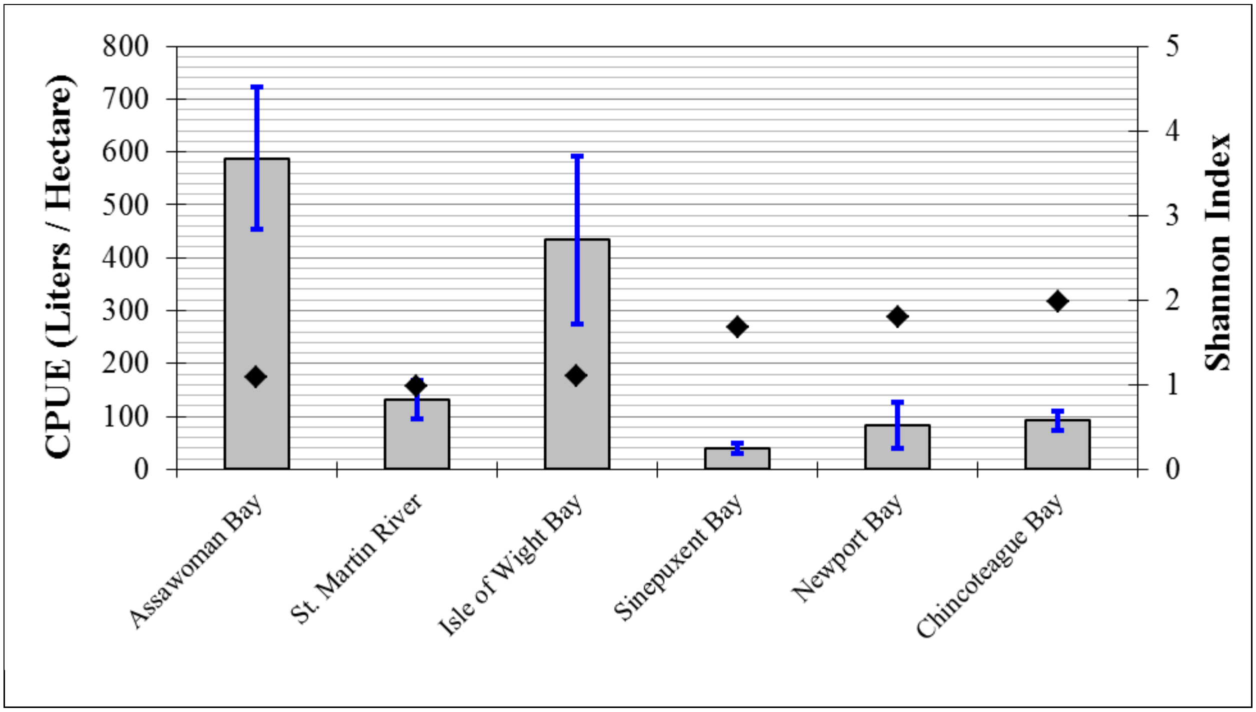

Figure 32. Coastal bays trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Black diamond represents the 2006 - 2018 time series Shannon index of diversity.

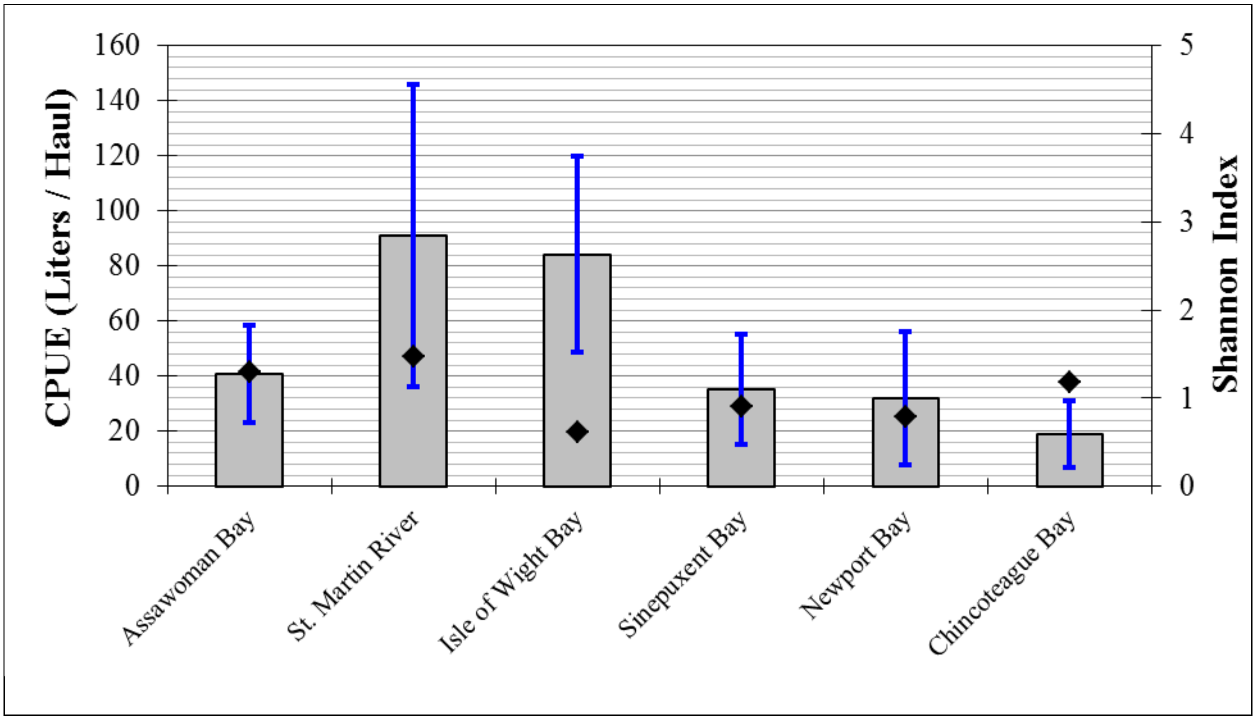

Figure 33. Beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2017). Black diamond represents the 2006 - 2017 time series Shannon index of diversity.

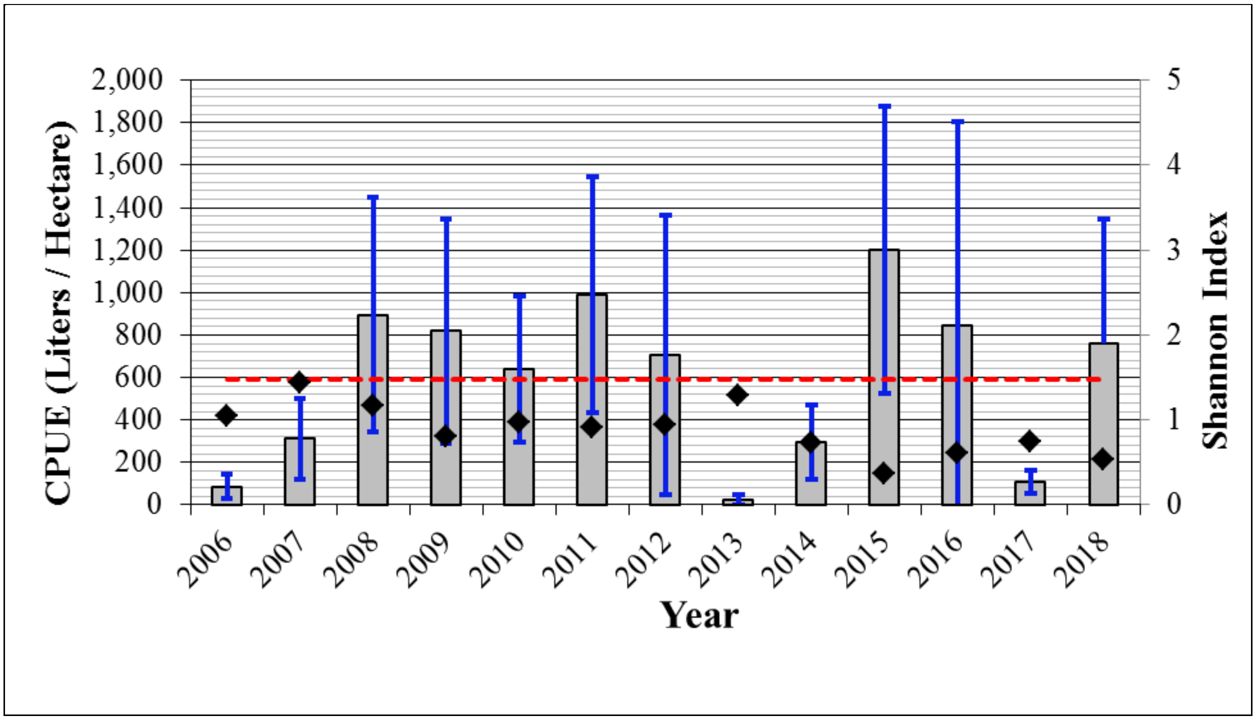

Figure 34. Assawoman Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 21/year). Black diamond represents the Shannon index of diversity.

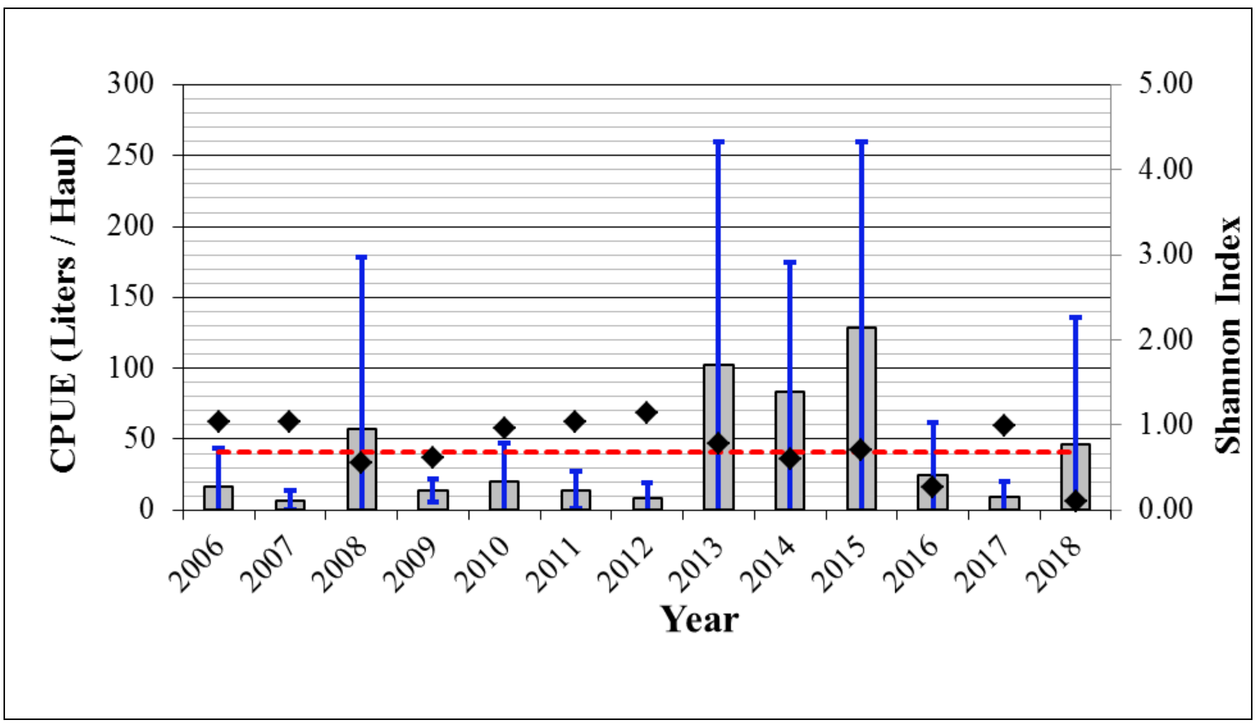

Figure 35. Assawoman Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2018). Dotted line represents the 2006 - 2018 time series CPUE grand mean, (n = 6/year). Black diamond represents the Shannon index.

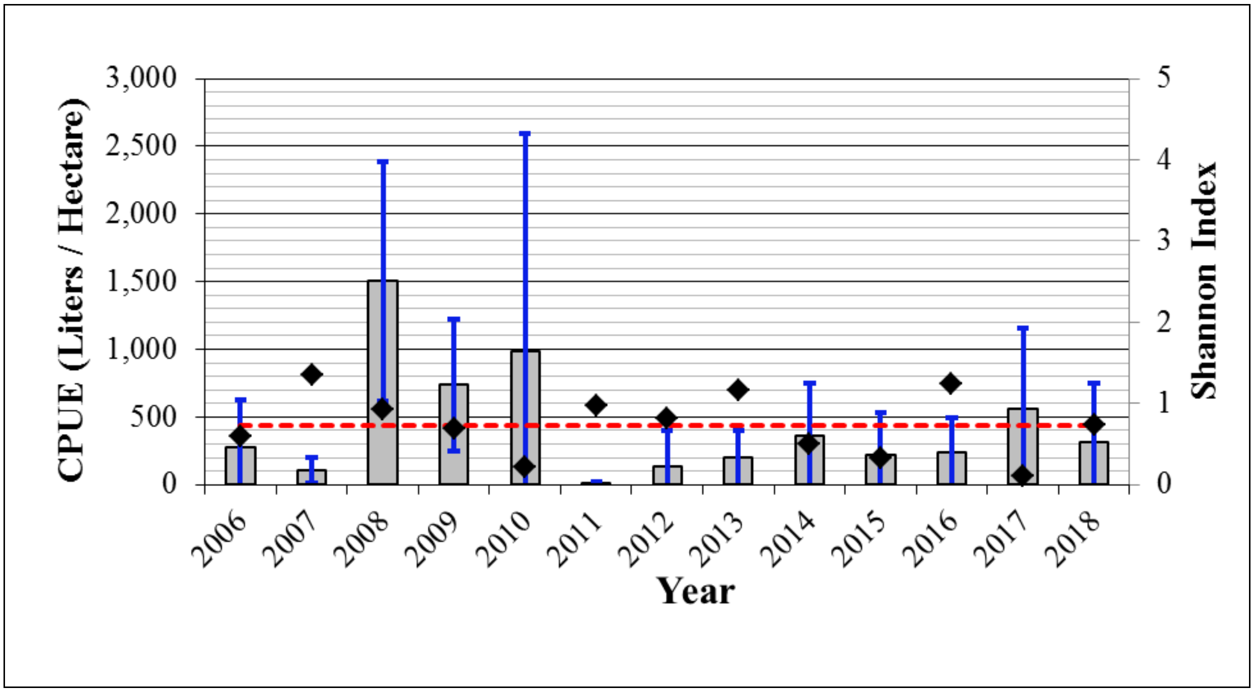

Figure 36. Isle of Wight Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 14/year). Black diamond represents the Shannon index of diversity.

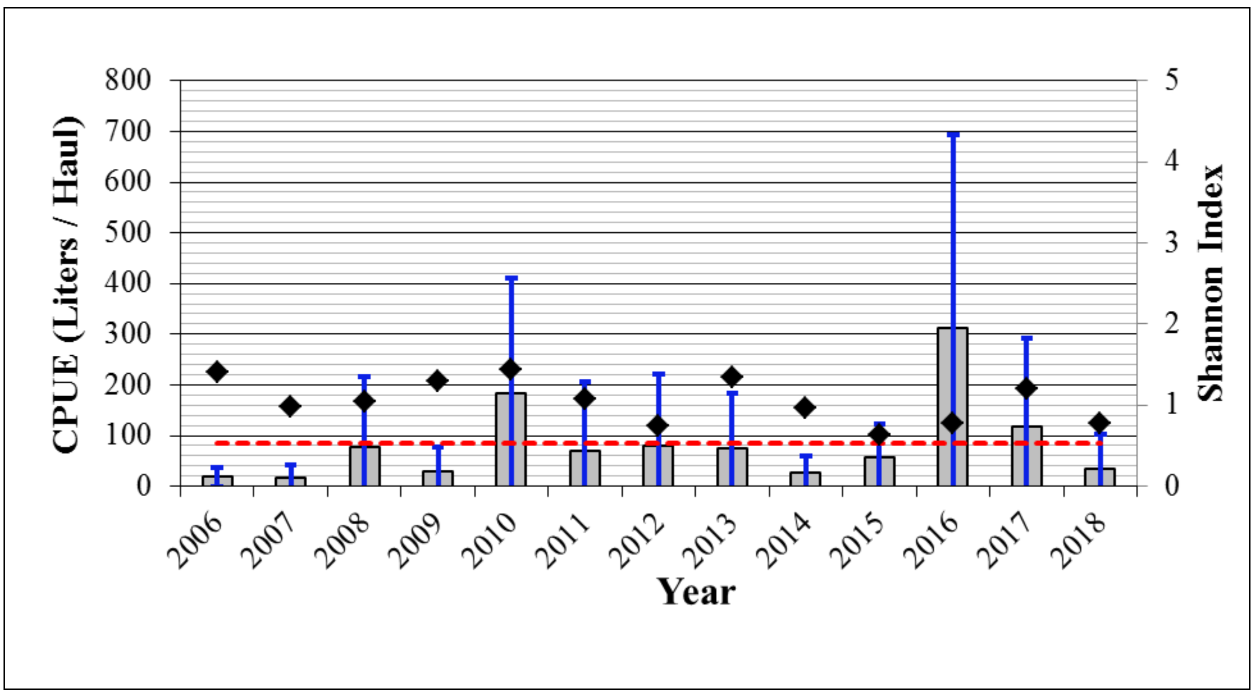

Figure 37. Isle of Wight Bay beach seine index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 4/year). Black diamond represents the Shannon index.

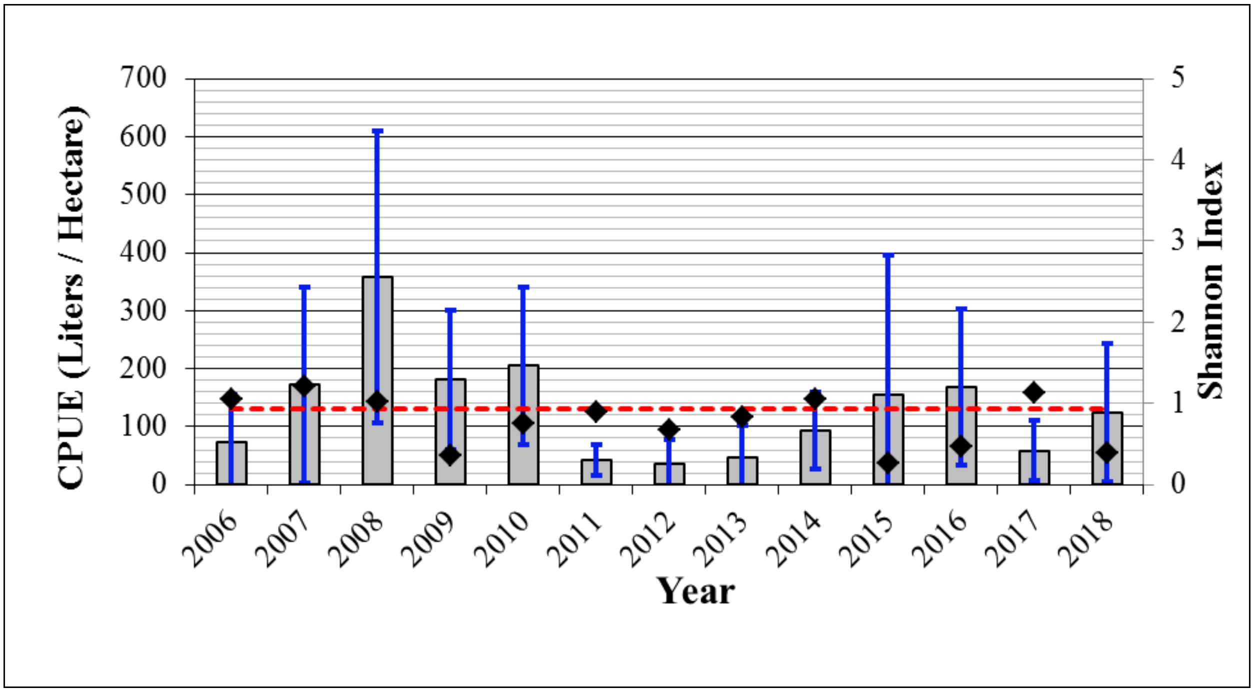

Figure 38. St. Martin River trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 14/year). Black diamond represents the Shannon index of diversity.

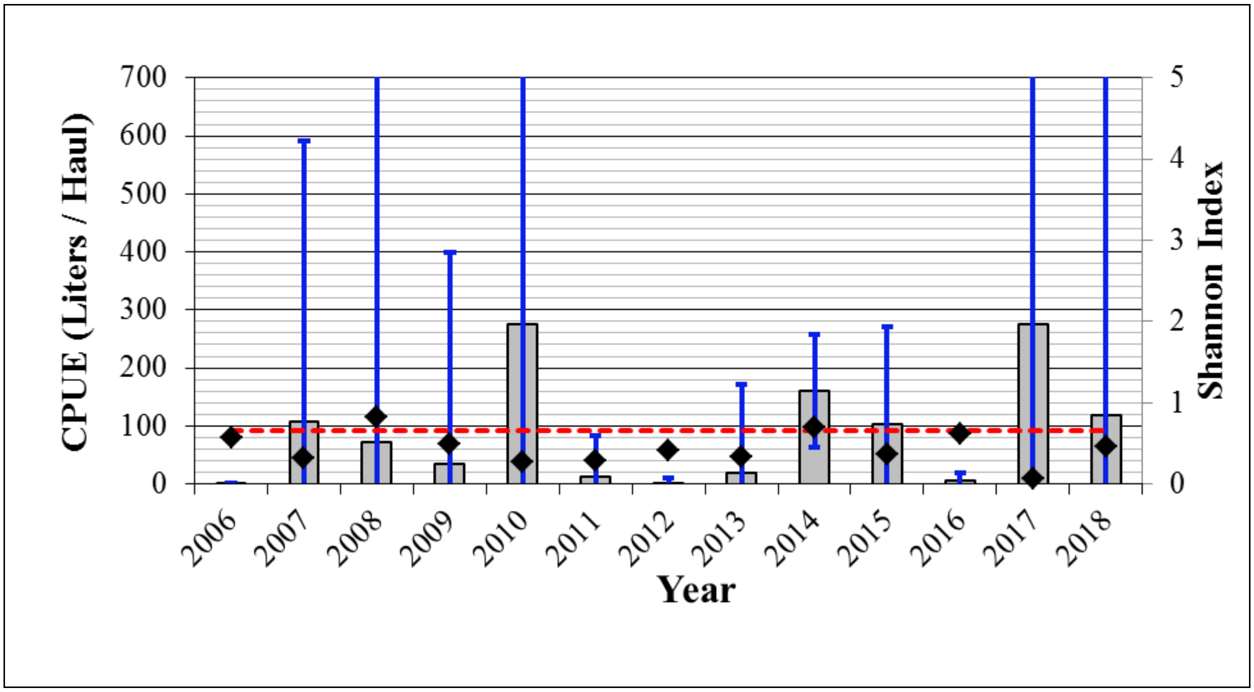

Figure 39. St. Martin River beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 2/year). Black diamond represents the Shannon index of diversity.

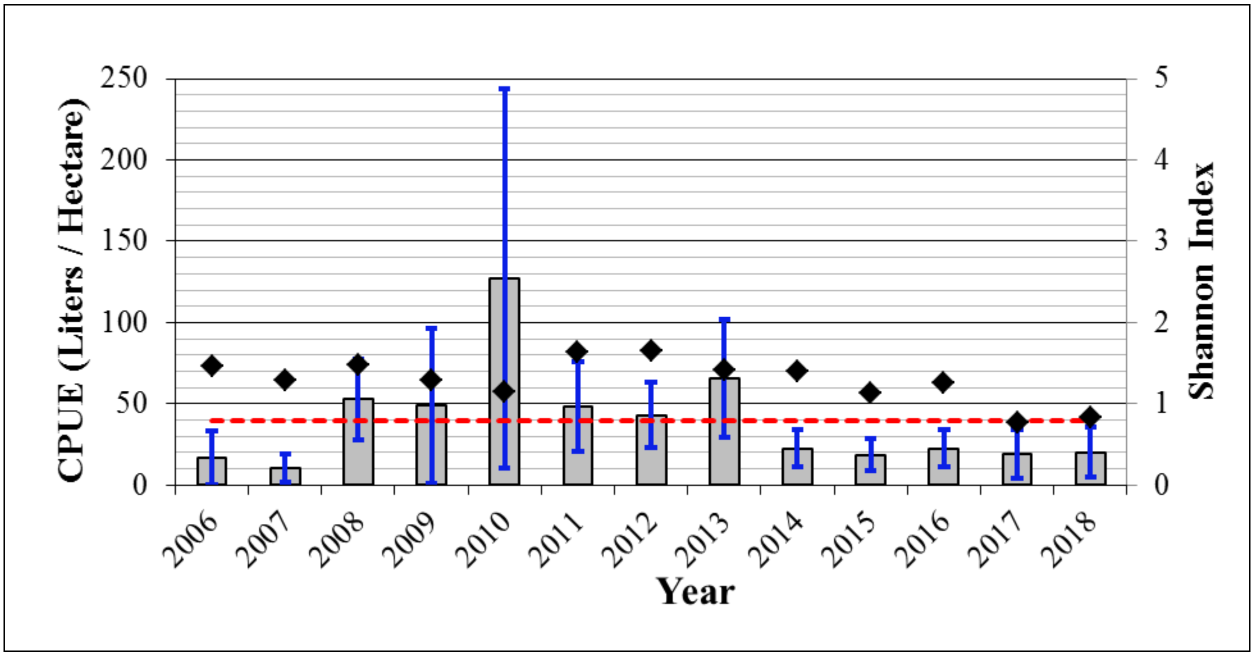

Figure 40. Sinepuxent Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 21/year). Black diamond represents the Shannon index of diversity.

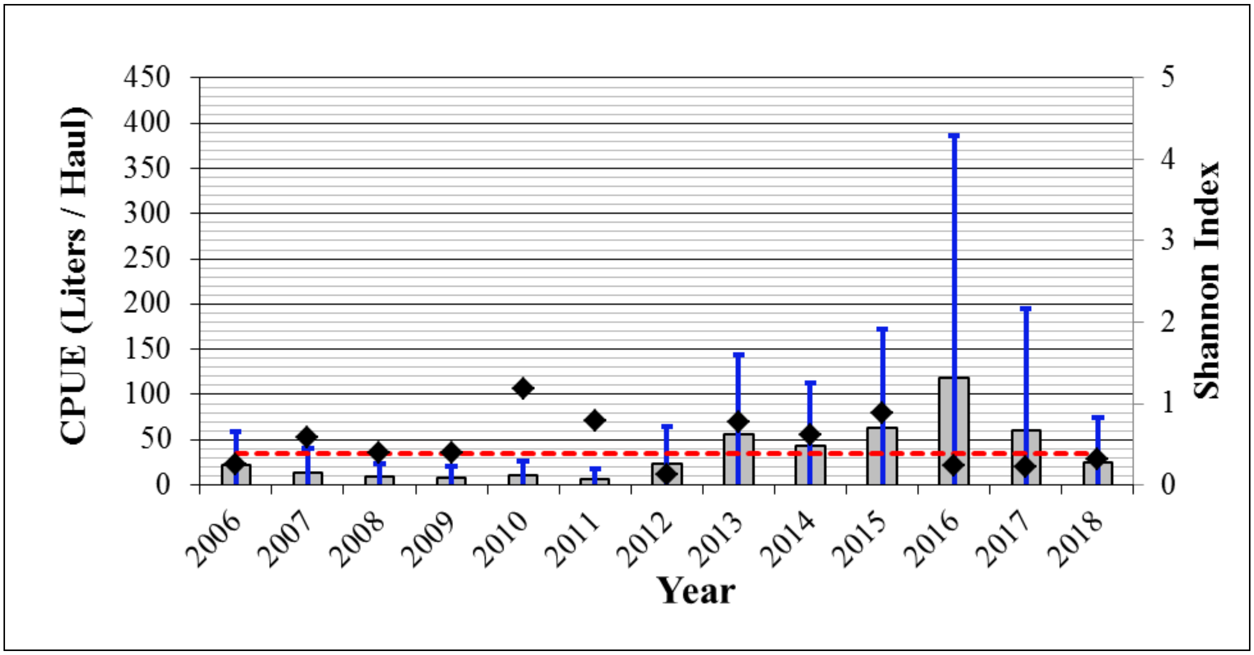

Figure 41. Sinepuxent Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 6/year). Black diamond represents the Shannon index of diversity.

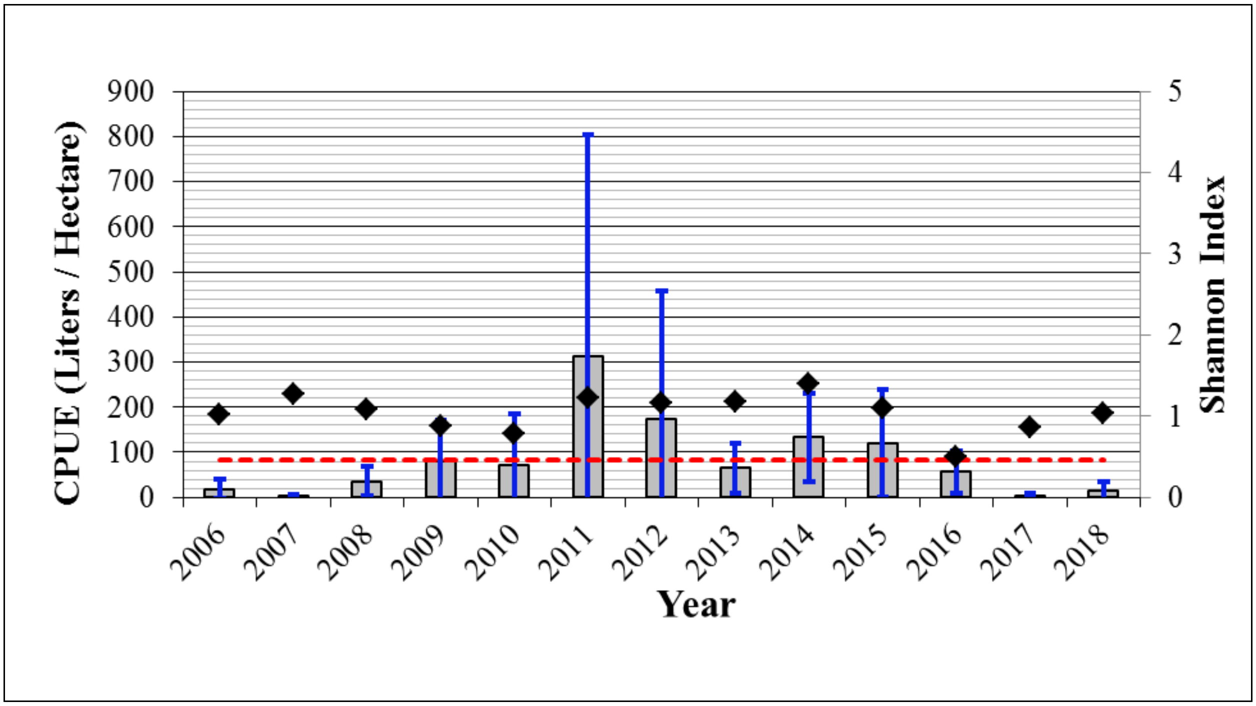

Figure 42. Newport Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 14/year). Black diamond represents the Shannon index of diversity.

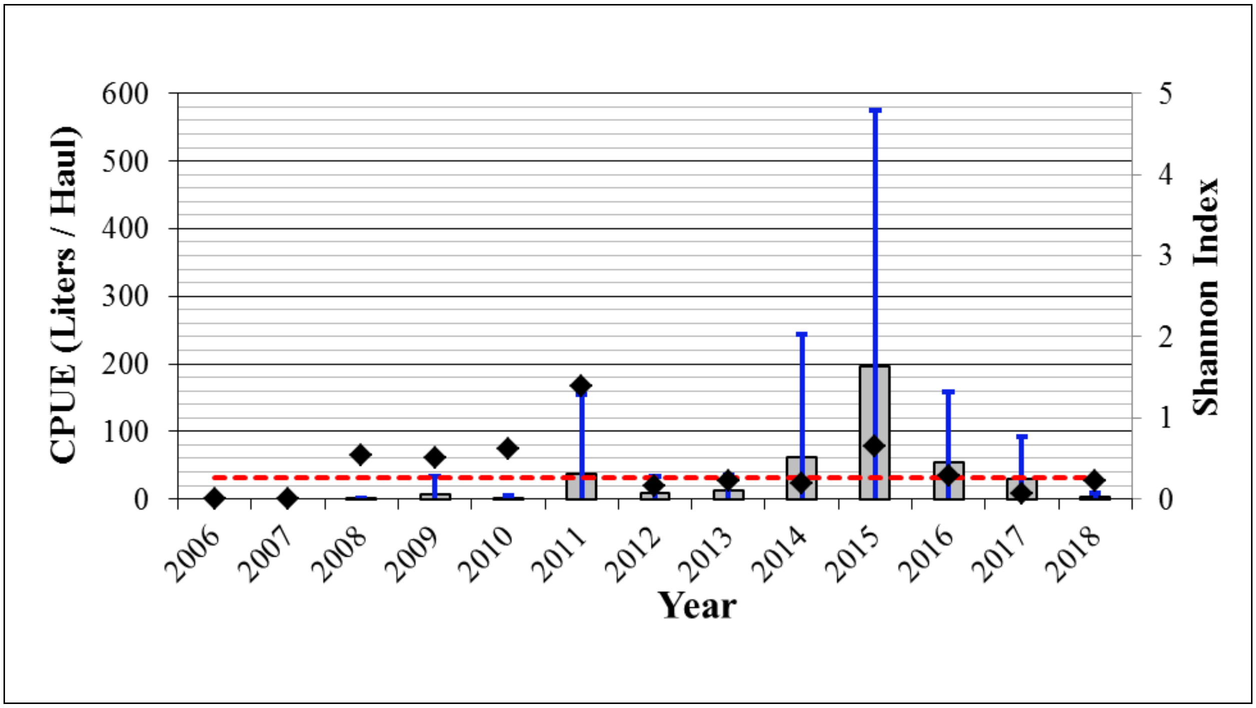

Figure 43. Newport Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 4/year). Black diamond represents the Shannon index of diversity.

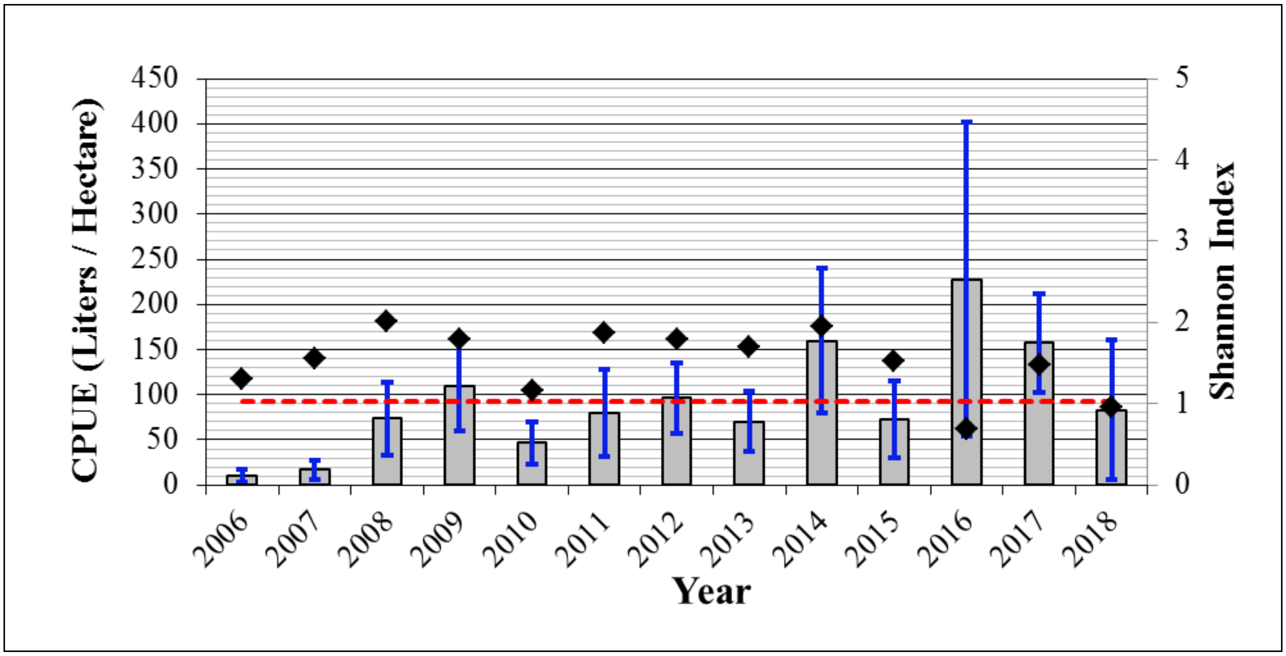

Figure 44. Chincoteague Bay trawl index of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006 - 2018). Dotted line represents the 2006 - 2018 time series CPUE grand mean, (n = 56/year). Black diamond represents the Shannon index of diversity.

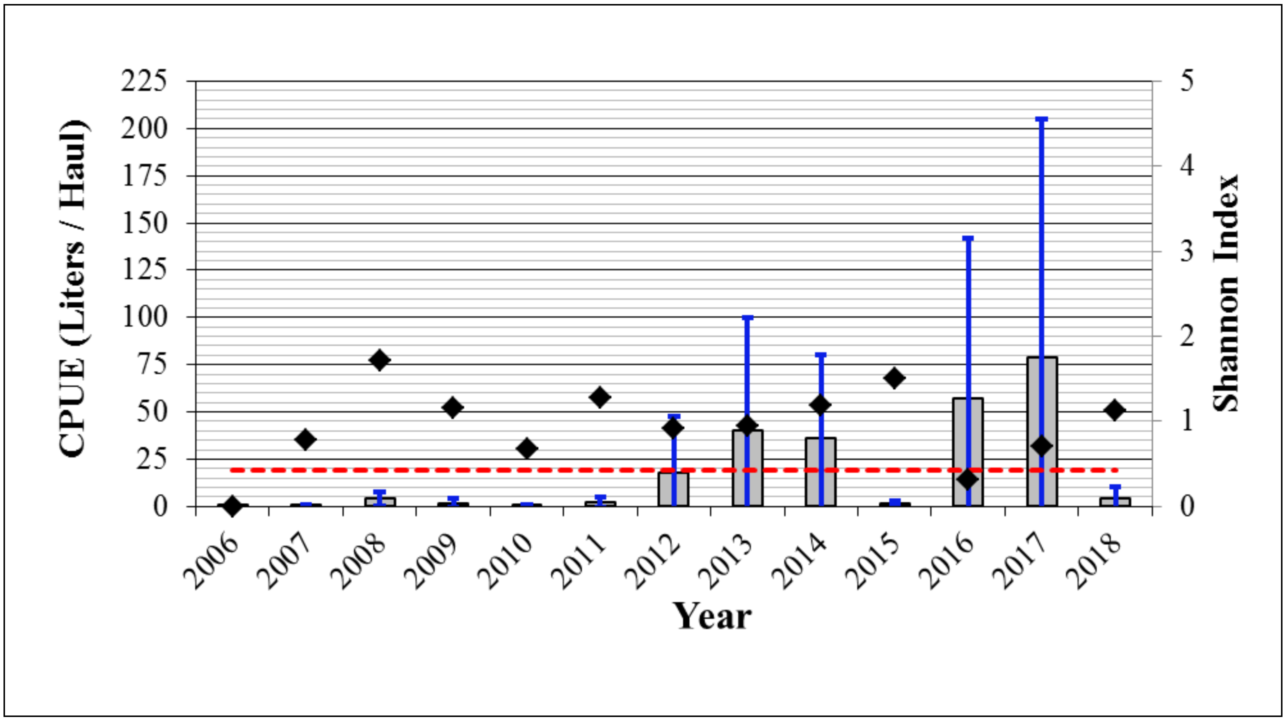

Figure 45. Chincoteague Bay beach seine index of macroalgae relative abundance (CPUE; L/haul) with 95% confidence intervals (2006 - 2018). Red line represents the 2006 - 2018 time series CPUE grand mean, (n = 12/year). Black diamond represents the Shannon index of diversity.

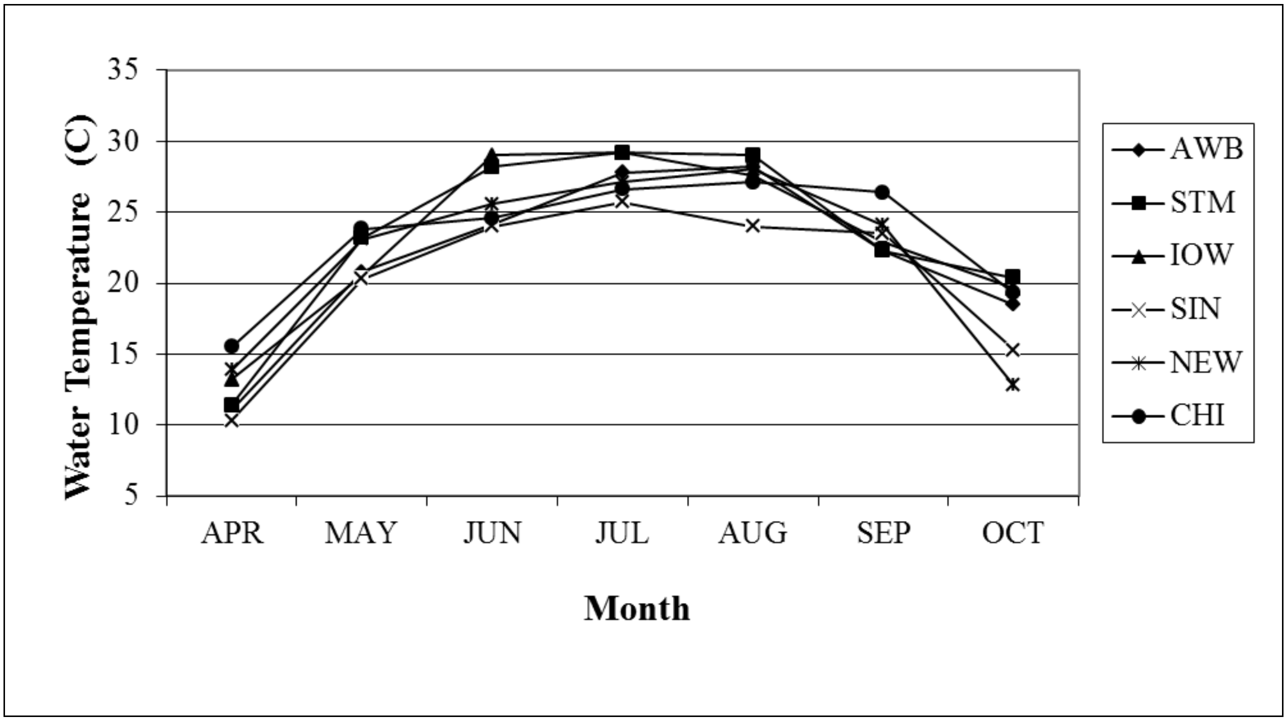

Figure 46. Trawl Survey mean water temperature (Celsius) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

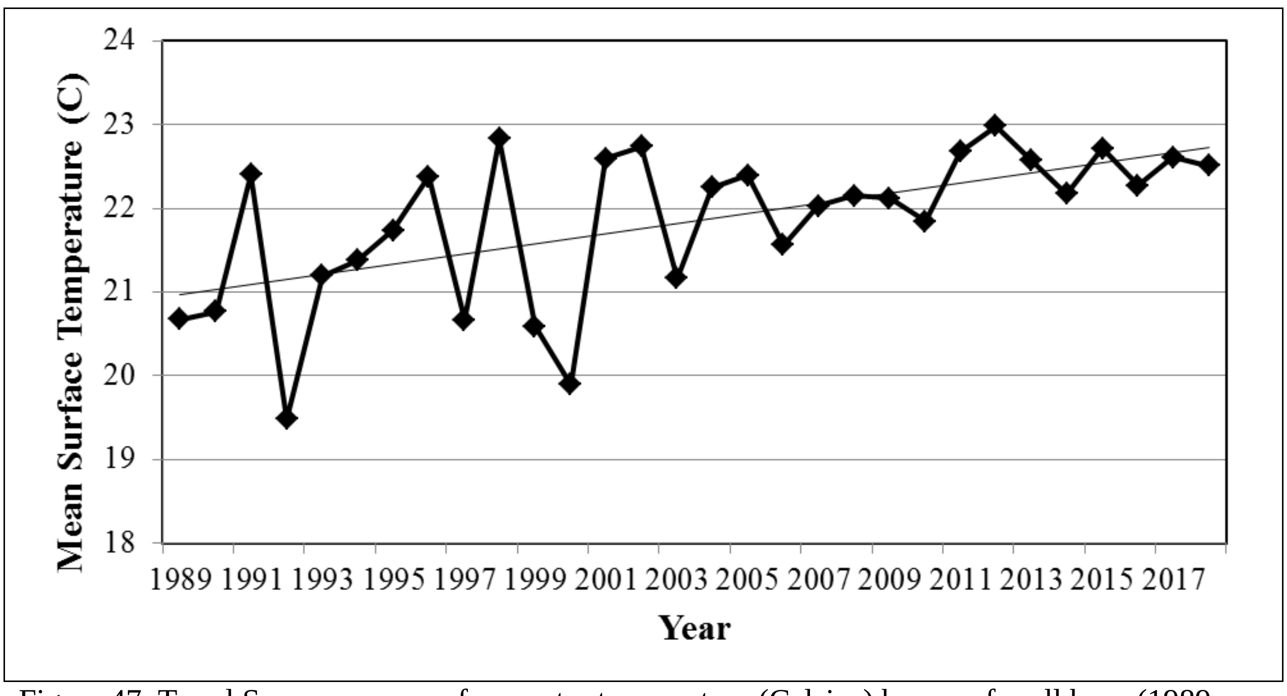

Figure 47. Trawl Survey mean surface water temperature (Celsius) by year for all bays (1989 - 2018).

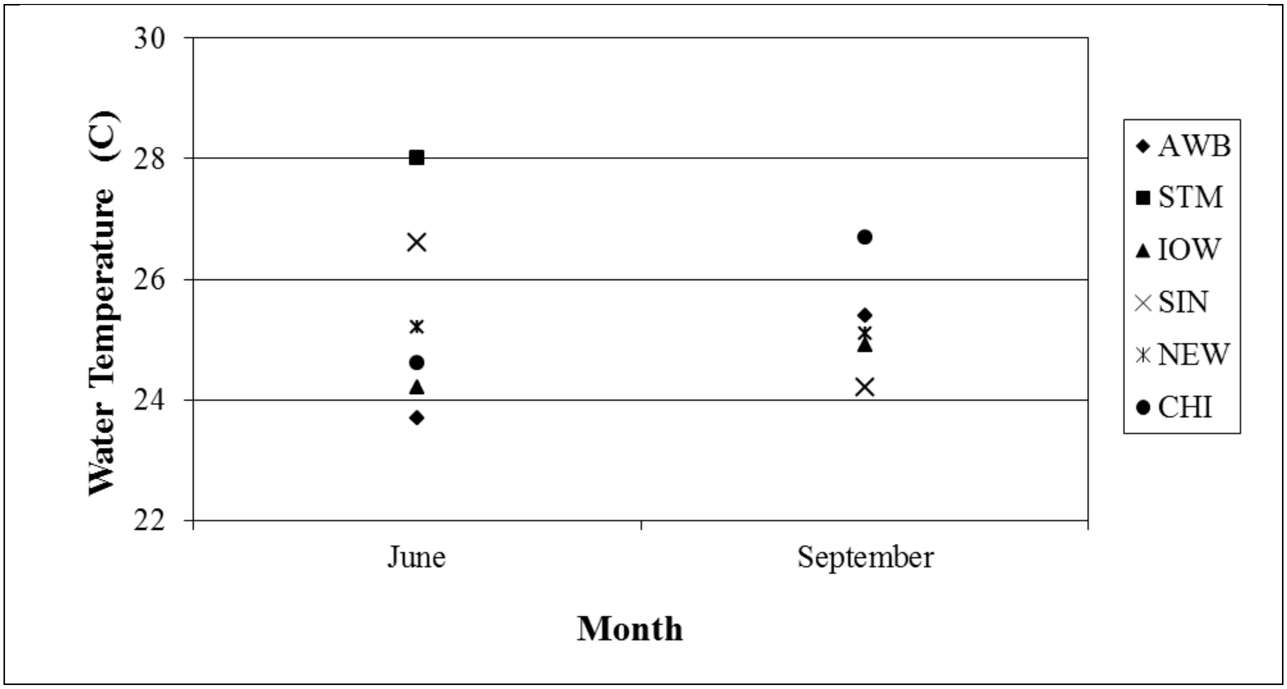

Figure 48. Beach Seine Survey mean water temperature (Celsius) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

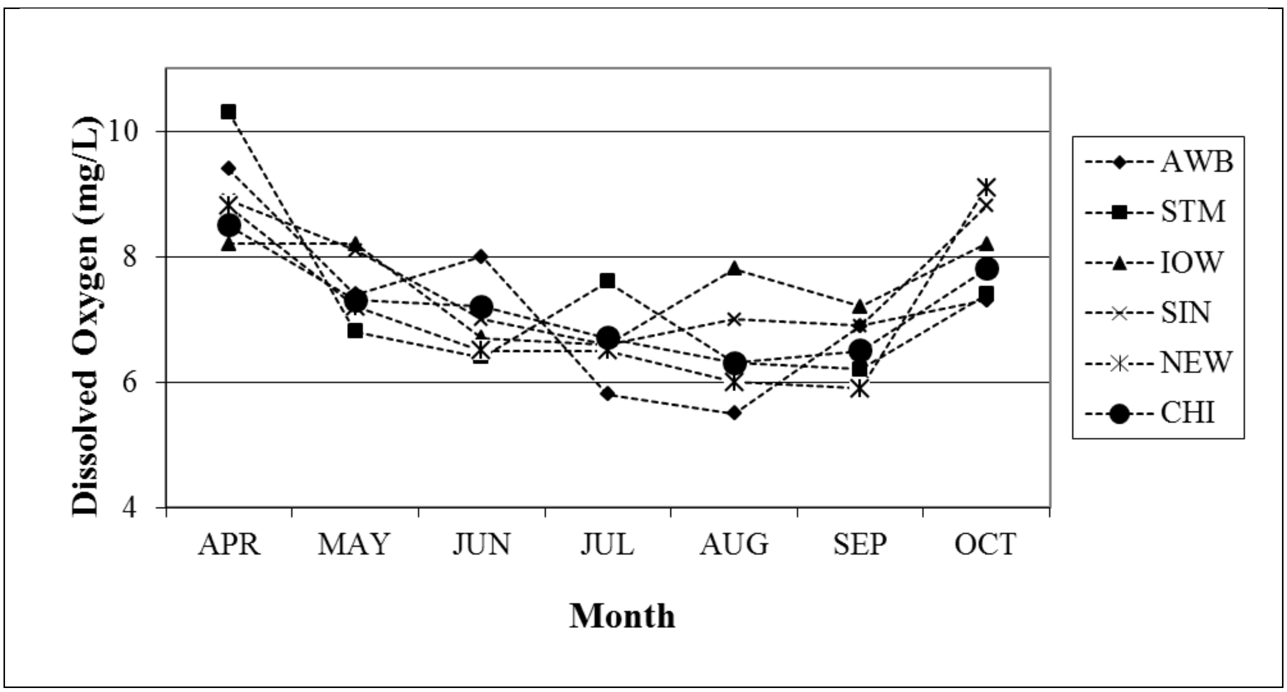

Figure 49. Trawl Survey mean dissolved oxygen (mg/L) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

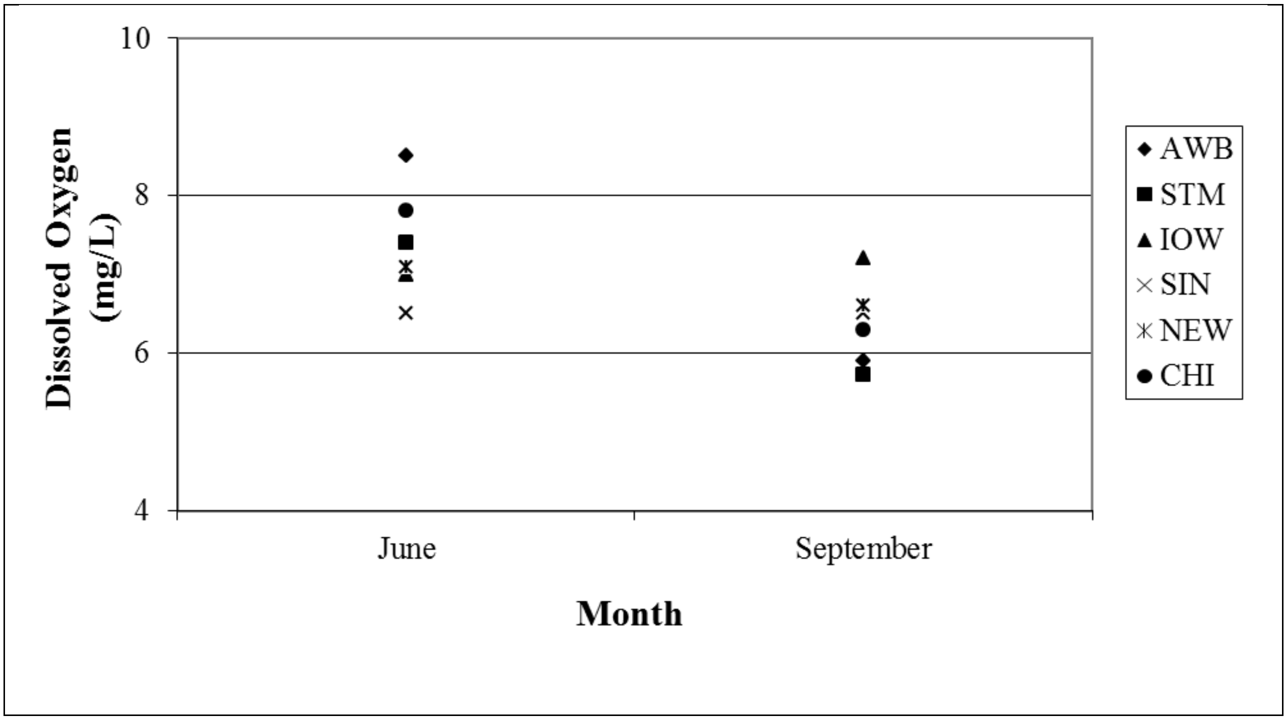

Figure 50. Beach Seine Survey mean dissolved oxygen (mg/L) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

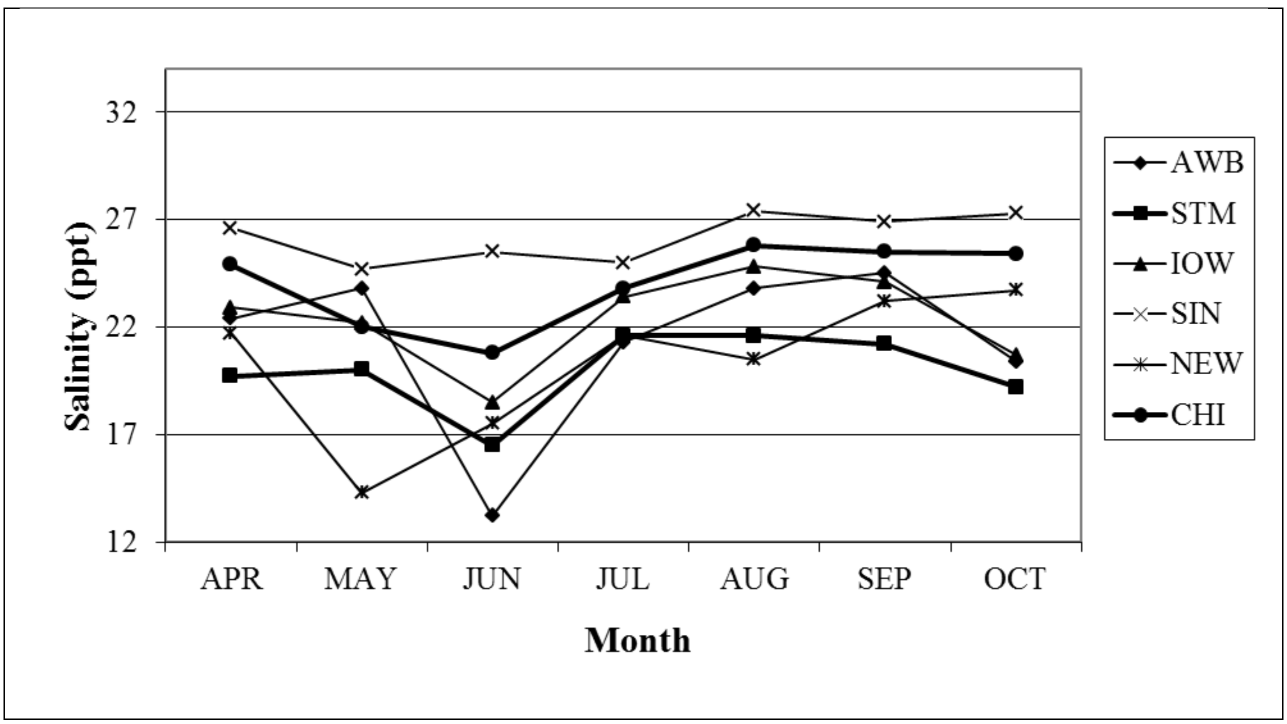

Figure 51. Trawl Survey mean salinity (parts per thousand) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

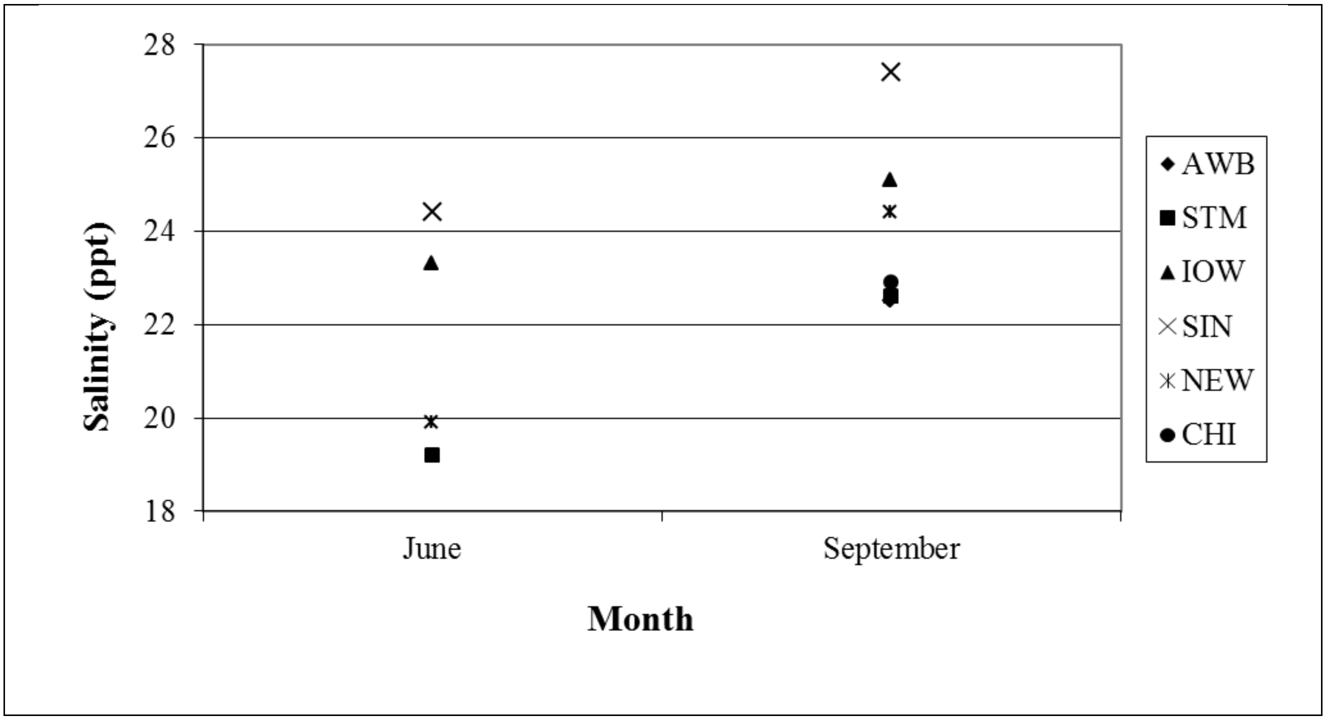

Figure 52. Beach Seine Survey mean salinity (parts per thousand) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

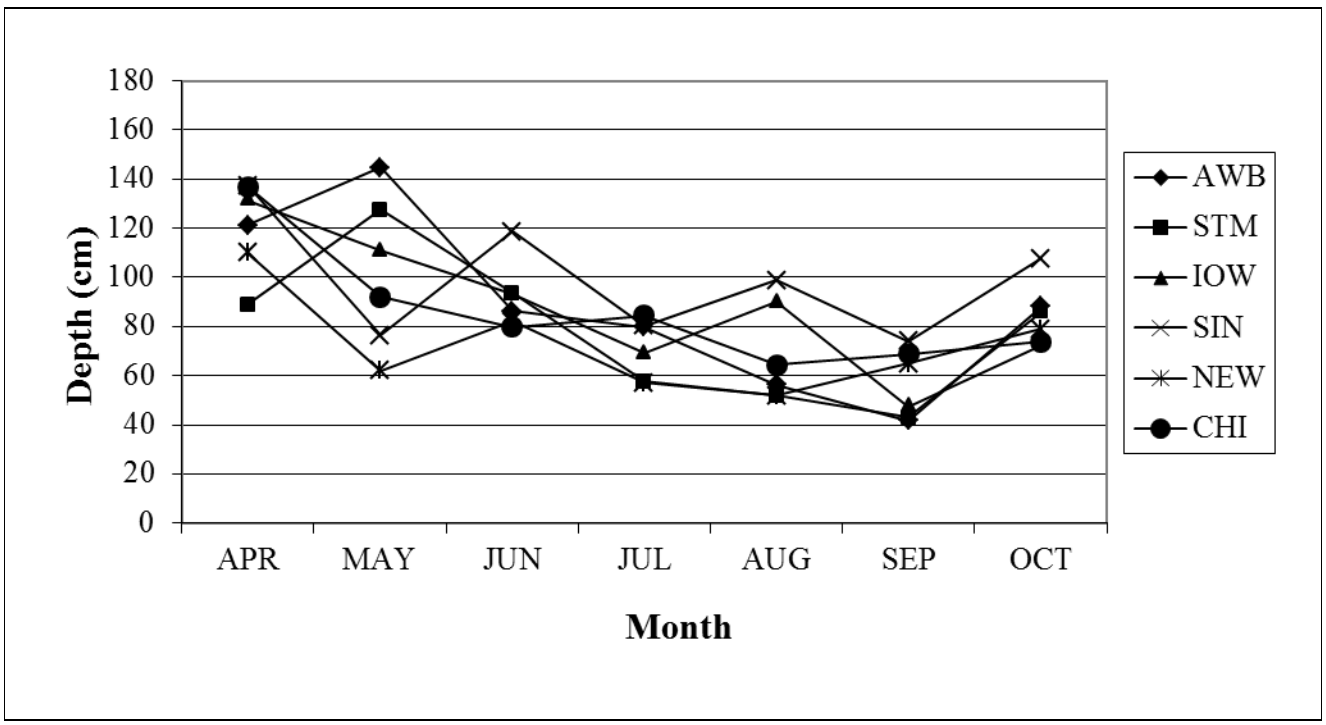

Figure 53. Trawl Survey mean turbidity (centimeters) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

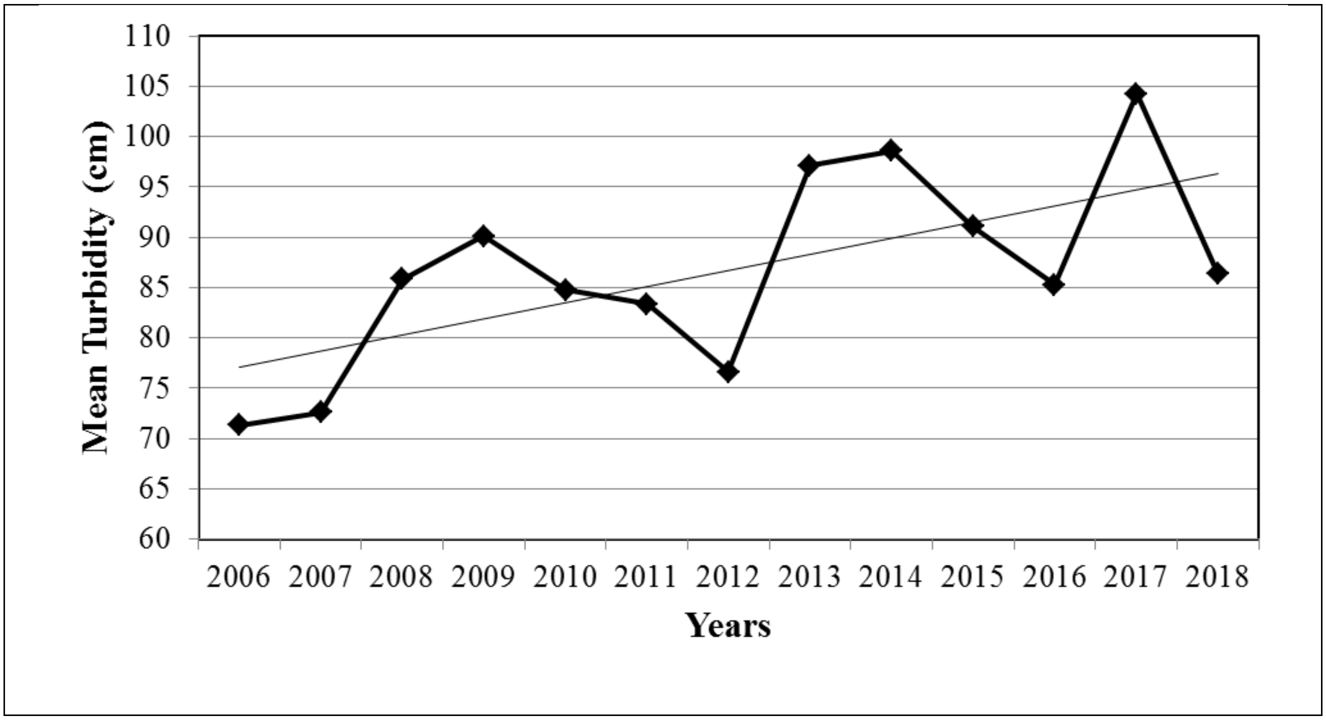

Figure 54. Trawl Survey mean turbidity (centimeters) by year for all bays (2018).

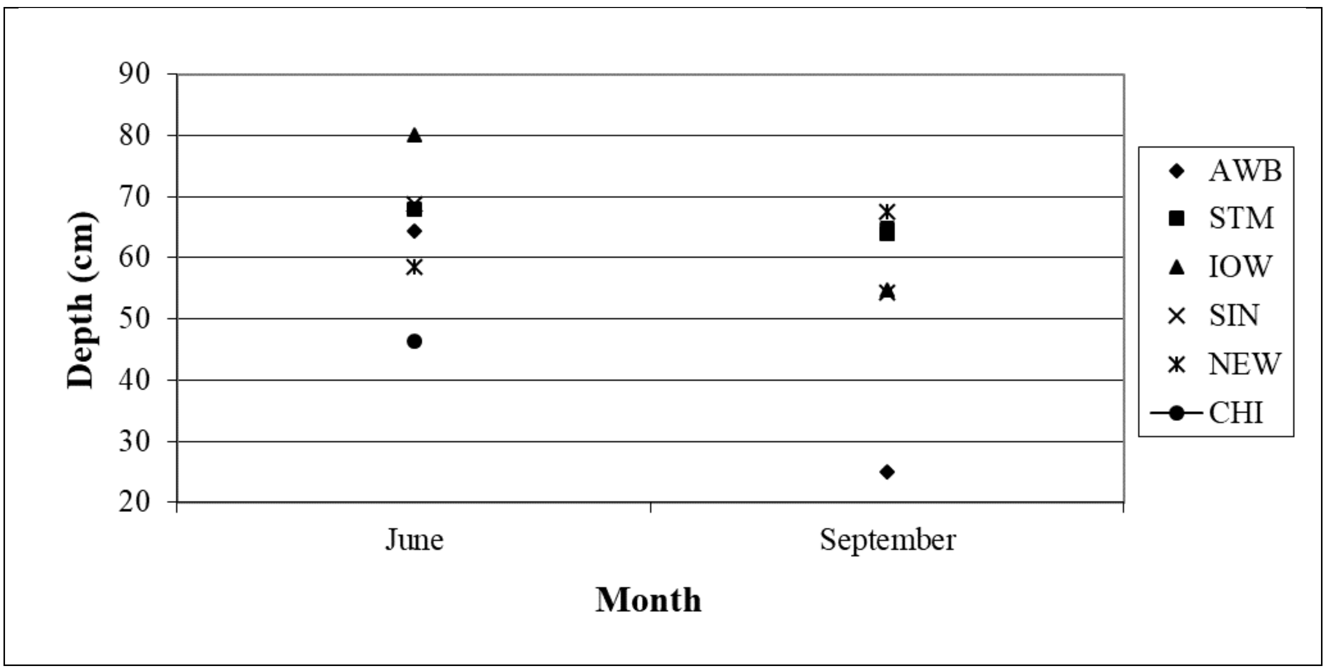

Figure 55. Beach Seine Survey mean turbidity (centimeters) by month (2018) in Assawoman Bay (AWB), St. Martin River (STM), Isle of Wight Bay (IOW), Sinepuxent Bay (SIN), Newport Bay (NEW) and Chincoteague Bay (CHI).

Chapter 2: Submerged Aquatic Vegetation Habitat Survey

Introduction

The department has been conducting the Trawl and Beach Seine surveys since 1972, with a standardized protocol since 1989. That survey was designed to characterize and quantify juvenile finfish abundance but those gears rarely sample sites in Submerged Aquatic Vegetation (SAV). Currently, there is limited information specific to Maryland's coastal bays submerged aquatic vegetation beds as critical or essential habitat for living resources.

There are two SAV species found in Maryland's coastal bays: eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). While SAV beds are found throughout the coastal bays, they are not distributed evenly. The majority of the eelgrass beds are located along the Assateague Island shoreline. Widgeon grass is also present but at lower abundance. 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 and Hindell 2006). As a result, the department expanded the project to include sampling the SAV beds in 2012. 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 of this study to better guide management decisions.

Methods

Sampling Period

All sampling was conducted during daylight on six days in September over a three year period: 2015 September 1; 2016 September 13, 15; 2017 September 7, 8 and 12 and 2018 September 4, 5 and 6.

Study Area

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 (Figure 1 and Table 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 (2015). Potential sites were selected from the reconnaissance if SAV was present and the site was not too deep to seine. The sites sampled in 2015 were revisited in 2016, 2017 and 2018. An additional grid was added in 2018.

Data Collection

A 25 ft C-hawk with a 225 horsepower Evinrude Etec engine was used as the sampling platform in September. Latitude and longitude coordinates (waypoints) 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 the seine haul.

A 15.24 m X 1.8 m X 6.4 mm mesh (50 ft X 6 ft X 0.25 in mesh) zippered bag seine was used. This gear was called the SAV beach seine. Staff estimated percent of net open and a range finder was used to quantify the 35 meter seine haul. Staff ensured that the lead line remained on the bottom until the catch was enclosed in the zipper 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. Only surface data were collected due to the shallow depth (less than 1.5 m). Data were recorded on a standardized project data sheet printed on Rite in the Rain All Weather paper.

Sample Processing

Samples were processed using the same methods described in Chapter 1 with the exception of increasing the number of fish measured in 2016 and 2017. Length targets were adjusted to improve statistical precision to evaluate habitat utilization by size. The 2016 target of 100 fish lengths per beach seine haul for silver perch (*Bairdiella chrysoura*) and Atlantic silversides (*Menidia menidia*) was reduced to 50 fish lengths per beach seine haul in 2017 and 2018 based on evaluation of the 2016 data.

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 the mean catch of fish per hectare. The alpha value of 0.05 was used for all tests. The Kruskal-Wallis H test, an unbalanced analysis of variance and post hoc Duncan's multiple range tests were used to measure and compare 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

Sample Size and Distribution

These results were based on 64 unbalanced random samples collected from 2015 to 2018 within six SAV grids (Table 1 and Figure 1). Each year the number of beach seine hauls increased (12, 14, 17 and 21 respectively). The samples were distributed between four categories of SAV coverage: 25% or less (13 samples), 26% - 50% (14 samples), 51% - 75% (15 samples) and 76% - 100% (22 samples). These samples were also categorized by substrate as either sand (25 samples) or mud (39 samples). Additionally, each sites dominant SAV species was identified; eelgrass was most abundant (42 samples) followed by widgeon grass (22 samples). Furthermore, sites were also investigated for habitat interaction such as SAV coverage, substrate and dominant SAV species (Table 2).

Fish Species Abundance by Habitat Category

A total of 40 species and 9,419 fish were collected during this four year investigation. The most abundant species were silver perch and Atlantic silversides (Table 3). Four crustacean species were captured in the survey with blue crabs, grass shrimp and brown shrimp being abundant (Table 4).

Results indicated that significant habitat effects or interaction on species abundance occurred for 11 fishes and three forage crustacean species within the sample population (Table 5). The results of the Kruskal-Wallis test (hereafter abbreviated as KWt) for percent SAV coverage showed significant differences in abundance for northern pipefish ($\chi2(3) = 15.30$, $p < 0.01$), silver perch ($\chi2(3) = 10.48$, $p < 0.05$), blue crab ($\chi2(3) = 10.07$, $p <0.05$) and grass shrimp ($\chi2(3) = 13.23$, $p < 0.01$). The abundance of the other species was not different among the coverage categories (Table 5).

Primary substrate KWt results showed significant differences in abundance for gray snapper ($\chi2(1) = 4.06$, $p < 0.05$), halfbeak ($\chi2(1) = 4.40$, $p < 0.05$), pigfish ($\chi2(1) = 3.99$, $p < 0.05$), pinfish ($\chi2(1) = 4.32$, $p < 0.05$), sheepshead ($\chi2(1) = 8.59$, $p < 0.01$), striped blenny ($\chi2(1) = 4.84$, $p < 0.05$) and brown shrimp ($\chi2(1) = 10.23$, $p = 0.01$). The abundance of the other species was not different between sand or mud within SAV beds (Table 5).

Dominant SAV KWt results showed significant differences in abundance for Atlantic silverside ($\chi2(1) = 12.01$, $p < 0.01$), bay anchovy ($\chi2(1) = 9.04$, $p < 0.01$), gray snapper ($\chi2(1) = 8.96$, $p < 0.01$), northern pipefish ($\chi2(1) = 6.61$, $p < 0.05$), sheepshead ($\chi2(1) = 5.44$, $p < 0.05$), tautog ($\chi2(1) = 6.36$, $p < 0.05$), blue crab ($\chi2(1) = 4.41$, $p < 0.05$), brown shrimp ($\chi2(1) = 7.78$, $p < 0.01$) and grass shrimp ($\chi2(1) = 5.38$, $p < 0.05$). The abundance of other species was not different between dominant eelgrass and widgeon grass (Table 5).

An unbalanced analysis of variance (hereafter abbreviated as ANOVA) and post hoc Duncan's Multiple Range Test (hereafter abbreviated as DMRT) were performed on those species which had significant results from the KWt analysis. The effects of SAV coverage on abundance for northern pipefish ($F_{3,64} = 3.64$, $p < 0.05$) were significant (Table 6). Silver perch results were not significant; however, an unbalanced two way analysis of variance resulted in a significant difference between low and medium-high coverage for silver perch ($t\ (_3) = 2.32$, $p < 0.05$). The post hoc DMRT analysis confirmed the difference.

Blue crab results were not significant (Table 6). An unbalanced two way analysis of variance showed significant differences between low and high coverage SAV ($t\ (_3) = 2.14$, $p < 0.05$). While this analysis showed a significant difference among those categories, the DMRT did not (Table 6). However, the effects of SAV coverage on abundance of grass shrimp ($F_{3,64} = 3.96$, $p < 0.05$) were significant. The DMRT results showed significant higher mean abundance of grass shrimp within medium-high coverage SAV.

An unbalanced ANOVA was performed on species with significant results from the KWt for primary substrate (Table 7). Gray snapper ($F_{1,64} = 7.48$, $p < 0.05$), pigfish ($F_{1,64} = 4.45$, $p < 0.05$), Pinfish ($F_{1,64} = 5.90$, $p < 0.05$), sheepshead ($F_{1,64} = 13.81$, $p < 0.05$), striped blenny, ($F_{1,64} = 4.37$, $p < 0.05$), and brown shrimp ($F_{1,64} = 6.16$, $p < 0.05$) showed a significant difference in mean abundance between sand versus mud substrate. The post hoc DMRT results showed significant higher mean abundance in sand versus mud for all these species. Halfbeak results were not significant for both the ANOVA and DMRT.

An unbalanced ANOVA was performed on species with significant results from the KWt for dominant SAV (Table 8). Atlantic silverside ($F_{1,64} = 5.83$, $p < 0.05$), bay anchovy ($F_{1,64} = 9.16$, $p < 0.05$), gray snapper ($F_{1,64} = 9.80$, $p < 0.05$), sheepshead, ($F_{1,64} = 4.03$, $p < 0.05$), tautog ($F_{1,64} = 4.79$, $p < 0.05$), brown shrimp, ($F_{1,64} = 7.14$, $p < 0.01$) and grass shrimp ($F_{1,64} = 8.73$, $p < 0.01$) showed a significant difference in mean abundance between dominant eelgrass versus widgeon grass beds. The post hoc DMRT results showed significant higher mean abundance in widgeon grass versus eelgrass, except for tautog. Northern pipefish and blue crab results were not significant for the ANOVA and DMRT.

Fish Species Richness and Diversity by Habitat Category

Fish richness (number of species) and diversity (evenness of those species) was investigated among habitat categories. Richness values were high across all SAV categories. The medium-high SAV coverage category (51 - 75%) with sand substrate and widgeon grass contained the most species (25 fish; Table 9). Diversity results showed that medium-high SAV coverage category (51 - 75%) with sand substrate and eelgrass was the most diverse ($H = 1.77$; Table 10).

Fish Length Composition by Habitat Category

Fish total length was investigated among SAV coverage, substrate and dominant SAV. Atlantic silverside, silver perch and tautog were selected based on sample size. Blue crab and brown shrimp were selected as a forage indicator as well. The unbalanced ANOVA showed differences in mean length by SAV coverage category for Atlantic silverside ($F_{3,1415} = 19.19$, $p < 0.01$), silver perch ($F_{3,1854} = 35.21$, $p < 0.01$), tautog $F_{3,79} = 7.19$, $p < 0.01$) and brown shrimp ($F_{3,424} = 8.8$, $p < 0.01$); blue crab results were not significant (Table 11). The post hoc DMRT results showed significant length differences among SAV categories for all species except blue crab (Table 11). Atlantic silverside and silver perch were smallest in high coverage SAV. Brown shrimp were smallest in medium coverage SAV and tautog varied without trend among the SAV categories (Table 11).

Results of the unbalanced ANOVA for mean length and primary substrate showed significant differences in length by substrate for Atlantic silverside ($F_{1,1415} = 10.21$, $p < 0.05$), tautog ($F_{1,79} = 4.5$, $p < 0.05$), blue crab ($F_{1,1869} = 3.92$, $p < 0.05$) and brown shrimp ($F_{1,424} = 10.97$, $p < 0.01$); silver perch results were not significant (Table 12). The post hoc DMRT results showed that tautog, blue crab and brown shrimp were smaller in SAV beds with mud substrate verses sand.

Results of the unbalanced ANOVA for mean length and dominant SAV showed that Atlantic silverside ($F_{1,1415} = 47.84$, $p < 0.01$), blue crab ($F_{1,1869} = 12$, $p < 0.01$) and brown shrimp ($F_{1,424} = 48.82$, $p < 0.01$) were different in size between eelgrass and widgeon grass (Table 13). Silver perch and tautog results were not significant. The post hoc DMRT results showed that Atlantic silverside were smaller in eelgrass dominated beds, while blue crab and brown shrimp were smaller in widgeon grass beds.

Water Quality

The surface water quality parameters were tested by an unbalanced ANOVA and post hoc DMRT. Mean water temperature ($F_{3,63} = 193.91$, $p < 0.0001$), salinity ($F_{3,63} = 301.58$, $p < 0.0001$), dissolved oxygen ($F_{3,63} = 39.83$, $p < 0.0001$) and turbidity ($F_{3,63} = 18.61$, $p < 0.0001$) all resulted in significant differences between and among survey years (2015 - 2018; Table 14). The post hoc DMRT results showed that 2018 had the highest water temperature ($\bar{x}$ = 29.7) very close to SAV temperature threshold of 30 C. Dissolved oxygen and water clarity was the lowest in the time series in 2018 (Table 14).

Discussion

The most striking result was the abundance of tautog and sheepshead compared to the lack thereof in the Trawl and Beach Seine surveys described in Chapter 1. Outputs from this survey were included in Maryland's 2018 Tautog (*Tautoga onitis*) Compliance Report to the Atlantic States Marine Fisheries Commission. This survey could be an important component to our regional stock assessment.

The abundance of sheepshead, tautog, pinfish, pigfish and gray snapper were relatively high in this survey indicating a preference to select SAV habitat for these species. The Beach Seine and Trawl surveys that sample non-SAV habitat resulted in lower abundance of these species.

The SAV coverage categories were not a significant selection criterion as were the secondary characteristics such as mud or sand and/or dominant eelgrass or widgeon grass within the beds. Gray snapper abundance jumped to 21.9 fish per hectare in SAV with sand substrate. Other fish (halfbeak, pigfish, pinfish, sheepshead and striped benny) also showed higher abundance in sand as did brown shrimp. The brown shrimp length ($\bar{x}$ = 83.1 mm) was not indicative of a prey species for these fish.

The interaction of eelgrass verses widgeon grass resulted in higher abundance of northern pipefish and tautog in eelgrass, whereas widgeon grass was preferred by Atlantic silverside, bay anchovy, gray snapper, sheepshead, blue crab, brown shrimp and grass shrimp. Richness results for fish was highest in widgeon grass (28 species), sand (28 species) and sand and widgeon grass (25 species). With the secondary interactions aside, SAV beds with medium-high coverage contained 32 fish species, which was the highest of any grouping. Diversity values were generally low and driven down by the large abundance of silver perch and Atlantic silverside. The highest diversity value (H = 1.77) was in medium-high coverage sand and eelgrass beds.

The most abundant fishes in this survey, silver perch and Atlantic silversides, had the smallest mean length in high SAV coverage. Previous growth history as well as size - selective predation mortality may also influence interpretation of juvenile growth rates (Meekan and Fortier 1996; Searcy and Sponaugle 2001; Bergenius *et al.* 2002; Grorud-Colvert and Sponaugle 2006; Searcy *et al.* 2007). Tautog mean length was smallest in the medium coverage SAV. These fish most likely are age 0 ($\bar{x}$ = 64.8 mm), while those in low and medium-high coverage were age 1 ($\bar{x}$ = 88.4 and 93.7 mm, respectively). Narraganset Bay tautog otolith - estimated mean growth rate is 0.5 mm per day (Dorf 1994). Those fish most likely grow a bit slower in the cooler temperatures of Rhode Island than Maryland.

The interannual variation of the coastal bays presented a challenge in the survey design and that is why the month of September was selected to normalize other interactions such as the distant to the inlet and basic water chemistry parameters. The surface water temperature, salinity and dissolved oxygen were significantly different from the previous three years. The mean temperature (29.7 C, 2018) was borderline close to the SAV threshold and seven degrees warmer than the previous year. Dissolved oxygen (5.1) and water clarity (37.7) were the lowest of the time series and most likely a result of the increased water temperature.

In conclusion, the survey produced valuable results with little effort compared to other work performed by the department. Sampling was increased each year in an attempt to balance the sites. Sampling effort should remain at the current level of 21 samples.

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List of Tables and Figures

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Table 1. Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey site descriptions (2015 – 2018).

Grid Number	Site Description	Latitude	Longitude	Number of Samples
109	East of Snug Harbor Road, Middle of Sinepuxent Bay, South of Small Island	38 17.622	75 07.376	4
121	East of Snug Harbor; West of Small Island	38 17.221	75 07.651	14
128	South of Duck Blind; East of Green Marker	38 17.061	75 07.659	9
160	700 meters northeast of Potfin Road along the shoreline	38 15.900	75 08.761	19
212	South of Verrazano Bridge; West of Sandy Point Island; on channel edge	38 14.295	75 09.404	9
221	Southwest of Small Island; South of Verrazano Bridge	38 14.147	75 09.402	9

Table 2. Submerged Aquatic Vegetation Habitat Survey sample size by habitat characteristics (2015 – 2018).

	Percent SAV					
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%	Total by Characteristic	Grand Total
Eelgrass (*Zostera marina*)	10	6	8	18	42	64
Widgeon grass (*Ruppia maritima*)	3	8	7	4	22	
Sand	6	8	4	7	25	64
Mud	7	6	11	15	28	
Sand - Eelgrass (*Z. marina*)	3	4	2	4	13	64
Mud - Eelgrass (*Z. marina*)	7	2	6	14	29	
Sand - Widgeon grass (R. *maritima*)	3	4	2	3	12	
Mud - Widgeon grass (R. *maritima*)	0	4	5	1	10	

Table 3. Fishes collected in Maryland's coastal bays Submerged Aquatic Vegetation Habitat Survey from Sinepuxent Bay in September by year (2015 – 2018). Catch per unit of effort (CPUE) was fish/hectare.

Specimen Name	2015 – 2018 (n = 64)				2018 (n = 21)			
	# of fish	CPUE	SE ±	x̄ length	# of fish	CPUE	SE ±	x̄ length
Silver perch (*Bairdiella chrysoura*)	5,251	2,048.7	411.7	73	2,564	3048.6	819.3	76
Atlantic silverside (*Menidia menidia*)	3,062	1,194.6	217.0	83	537	638.5	299.7	81
Halfbeak (*Hyporhamphus unifasciatus*)	237	92.5	25.9	148	9	10.7	4.4	146
Dusky pipefish (*Syngnathus floridae*)	106	41.4	10.3	159	13	15.5	7.4	143
Northern pipefish (*Syngnathus fuscus*)	106	41.4	7.7	159	27	32.1	11.2	189
Sheepshead (*Archosargus probatocephalus*)	102	39.8	8.8	75	14	16.7	7.0	69
Tautog (*Tautoga onitis*)	80	31.2	7.9	80	32	38.1	19.5	68
Oyster toadfish (*Opsanus tau*)	67	26.1	5.2	71	39	46.4	10.9	70
Striped blenny (*Chasmodes bosquianus*)	63	24.6	4.9	65	21	25.0	7.7	67
Pinfish (*Lagodon rhomboides*)	50	19.5	4.6	122	30	35.7	11.6	128
Pigfish (*Orthopristis chrysoptera*)	48	18.7	4.4	87	19	22.6	8.1	98
Spotfin mojarra (*Eucinostomus argenteus*)	35	13.7	4.1	80	19	22.6	8.6	86
Gray snapper (*Lutjanus griseus*)	25	9.8	3.8	73	7	8.3	6.3	61
Bay anchovy (*Anchoa mitchilli*)	23	9.0	3.5	65	2	2.4	2.4	78
Spot (*Leiostomus xanthurus*)	21	8.2	4.0	152	1	1.2	1.2	179
Striped burrfish (*Chilomycterus schoepfii*)	17	6.6	1.9	182	3	3.6	2.0	165
Northern puffer (*Sphoeroides maculatus*)	15	5.9	1.7	147	7	8.3	3.6	157
Rainwater killifish (*Lucania parva*)	14	5.5	2.9	38	2	2.4	2.4	32
Summer flounder (*Paralichthys dentatus*)	13	5.1	1.7	206	7	8.3	3.2	205
Spotfin butterflyfish (*Chaetodon ocellatus*)	11	4.3	1.9	64	7	8.3	4.7	47
Atlantic menhaden (*Brevoortia tyrannus*)	9	3.5	2.1	117	7	8.3	6.1	111
Striped anchovy (*Anchoa hepsetus*)	8	3.1	1.3	78	7	8.3	3.6	78
White mullet (*Mugil curema*)	8	3.1	1.2	174	4	4.8	2.8	174
Spotted seatrout (*Cynoscion nebulosus*)	6	2.3	1.1	116	2	2.4	1.6	112
Naked goby (*Gobiosoma bosc*)	5	2.0	1.6	39				

Table 3 continued. Fishes collected in Maryland's coastal bays Submerged Aquatic Vegetation Habitat Survey from Sinepuxent Bay in September by year (2015 – 2018). Catch Per Unit of Effort (CPUE) was fish/hectare.

Specimen Name	2015 – 2018 (n = 64)				2018 (n = 21)			
	# of fish	CPUE	SE ±	x̄ length	# of fish	CPUE	SE ±	x̄ length
Southern kingfish (*Menticirrhus americanus*)	5	2.0	1.3	103				
American eel (*Anguilla rostrata*)	4	1.6	0.9	318	2	2.4	1.6	186
Northern kingfish (*Menticirrhus saxatilis*)	4	1.6	1.1	121	4	4.8	3.3	121
Striped mullet (*Mugil cephalus*)	4	1.6	1.6	197				
Atlantic needlefish (*Strongylura marina*)	3	1.2	0.7	260	1	1.2	1.2	282
Black drum (*Pogonias cromis*)	3	1.2	0.9	133	2	2.4	2.4	124
Black sea bass (*Centropristis striata*)	3	1.2	0.9	142				
Atlantic croaker (*Micropogonias undulatus*)	2	0.8	0.5	57	1	1.2	1.2	73
Bluefish (*Pomatomus saltatrix*)	2	0.8	0.5	150	2	2.4	1.6	150
Bluespotted cornetfish (*Fistularia tabacaria*)	2	0.8	0.5	356				
Gag (*Mycteroperca microlepis*)	1	0.4	0.4	168	1	1.2	1.2	168
Lined seahorse (*Hippocampus erectus*)	1	0.4	0.4	130	1	1.2	1.2	130
Skilletfish (*Gobiesox strumosus*)	1	0.4	0.4	46	1	1.2	1.2	46
Southern stingray (*Dasyatis americana*)	1	0.4	0.4	230				
Striped killifish (*Fundulus majalis*)	1	0.4	0.4	107				

Table 4. Forage crustaceans collected in Maryland's coastal bays Submerged Aquatic Vegetation Habitat Survey from Sinepuxent Bay in September by year (2015 – 2018). Catch Per Unit of Effort (CPUE) was individual/hectare.

Specimen Name	2015 – 2018 (n = 64)				2018 (n = 21)			
	# of fish	CPUE	SE ±	x̄ length	# of fish	CPUE	SE ±	x̄ length
Blue crab (*Callinectes sapidus*)	2,897	1,130.3	143.2	56	1703	2024.9	265.7	65
Grass shrimp (*Palaemonetes sp.*)	1,321	515.4	109.9		358	425.7	181.7	
Brown shrimp (*Farfantepenaeus aztecus*)	686	267.6	84.5	79	296	352.0	81.2	76
Sand shrimp (*Crangon septemspinosa*)	2	0.8	0.8					

Table 5. Results of the Submerged Aquatic Vegetation Habitat Survey (2015 - 2018) Kruskal - Wallis test for percent SAV coverage, primary substrate and dominant SAV on fish abundance. Alpha of 0.05 was used as the cutoff for significance; results greater than 0.05 were not significant (n.s.).

Specimen Name	Percent SAV	Primary Substrate	Dominant SAV
Atlantic silverside (*Menidia menidia*)	n.s.	n.s.	($\chi 2(1) = 12.01$, $p < 0.01$)
Bay anchovy (*Anchoa mitchilli*)	n.s.	n.s.	($\chi 2(1) = 9.04$, $p < 0.01$)
Gray snapper (*Lutjanus griseus*)	n.s.	($\chi 2(1) = 4.06$, $p < 0.05$)	($\chi 2(1) = 8.96$, $p < 0.01$)
Halfbeak (*Hyporhamphus unifasciatus*)	n.s.	($\chi 2(1) = 4.40$, $p < 0.05$)	n.s.
Northern pipefish (*Syngnathus fuscus*)	($\chi 2(3) = 15.30$, $p < 0.01$)	n.s.	($\chi 2(1) = 6.61$, $p < 0.05$)
Pigfish (*Orthopristis chrysoptera*)	n.s.	($\chi 2(1) = 3.99$, $p < 0.05$)	n.s.
Pinfish (*Lagodon rhomboides*)	n.s.	($\chi 2(1) = 4.32$, $p < 0.05$)	n.s.
Sheepshead (*Archosargus probatocephalus*)	n.s.	($\chi 2(1) = 8.59$, $p < 0.01$)	($\chi 2(1) = 5.44$, $p < 0.05$)
Silver perch (*Bairdiella chrysoura*)	($\chi 2(3) = 10.48$, $p < 0.05$)	n.s.	n.s.
Striped blenny (*Chasmodes bosquianus*)	n.s.	($\chi 2(1) = 4.84$, $p < 0.05$)	n.s.
Tautog (*Tautoga onitis*)	n.s.	n.s.	($\chi 2(1) = 6.36$, $p < 0.05$)
Blue crab (*Callinectes sapidus*)	($\chi 2(3) =10.07$, $p < 0.05$)	n.s.	($\chi 2(1) = 4.41$, $p < 0.05$)
Brown shrimp (*Farfantepenaeus aztecus*)	n.s.	($\chi 2(1) = 10.23$, $p < 0.01$)	($\chi 2(1) = 7.78$, $p < 0.01$)
Grass shrimp (*Palaemonetes sp.)*	($\chi 2(3) =13.23$, $p < 0.01$)	n.s.	($\chi 2(1) = 5.38$, $p < 0.05$)

Table 6. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for CPUE and percent SAV coverage.

Specimen Name	Percent SAV			
	Low < 25%	Medium 26 - 50%	Medium-High 51 - 75%	High 76 - 100%
	($F_{3,64} = 3.64$, $p < 0.05$)			
Northern pipefish (*Syngnathus fuscus*)	$\bar{x} = 5.76$	$\bar{x} = 24.97$	$\bar{x} = 48.27$	$\bar{x} = 68.10$
	A	A / B	A / B	B
	($F_{3,64} = 1.70$, $p = 0.1774$)			
Silver perch (*Bairdiella chrysoura*)	$\bar{x} = 524$	$\bar{x} = 2,435$	$\bar{x} = 3,223$	$\bar{x} = 1,903$
	A	A / B	B	A / B
	($F_{3,64} = 1.79$, $p = 0.1580$)			
Blue crab (*Callinectes sapidus*)	$\bar{x} = 495.5$	$\bar{x} = 1348.3$	$\bar{x} = 1188.5$	$\bar{x} = 1326.8$
	A	A	A	A
	($F_{3,64} = 3.96$, $p < 0.05$)			
Grass shrimp (*Palaemonetes sp.*)	$\bar{x} = 48$	$\bar{x} = 410.2$	$\bar{x} = 1,092$	$\bar{x} = 465.3$
	A	A	B	A

Table 7. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for CPUE and primary substrate.

Specimen Name	Primary Substrate	
	Sand	Mud
	($F_{1,64} = 7.48$, $p < 0.05$)	
Gray snapper (*Lutjanus griseus*)	$\bar{x} = 21.9$	$\bar{x} = 1.9$
	A	B
	($F_{1,64} = 1.27$, $p = 0.2636$)	
Halfbeak (*Hyporhamphus unifasciatus*)	$\bar{x} = 128.8$	$\bar{x} = 69.1$
	A	A
	($F_{1,64} = 4.45$, $p < 0.05$)	
Pigfish (*Orthopristis chrysoptera*)	$\bar{x} = 29.9$	$\bar{x} = 11.5$
	A	B
	($F_{1,64} = 5.90$, $p < 0.05$)	
Pinfish (*Lagodon rhomboides*)	$\bar{x} = 32.9$	$\bar{x} = 10.8$
	A	B
	($F_{1,64} = 13.81$, $p < 0.05$)	
Sheepshead (*Archosargus probatocephalus*)	$\bar{x} = 76.9$	$\bar{x} = 16.0$
	A	B
	($F_{1,64} = 4.37$, $p < 0.05$)	
Striped blenny (*Chasmodes bosquianus*)	$\bar{x} = 36.9$	$\bar{x} = 16.6$
	A	B
	($F_{1,64} = 6.16$, $p < 0.05$)	
Brown shrimp (*Farfantepenaeus aztecus*)	$\bar{x} = 519.4$	$\bar{x} = 106.3$
	A	B

Table 8. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for CPUE and dominant SAV.

Specimen Name	Dominant SAV Species	
	Eelgrass	Widgeon Grass
	($F_{1,64}$ = 5.83, $p < 0.05$)	
Atlantic silverside (*Menidia menidia*)	$\bar{x}$ = 829.3	$\bar{x}$ = 1892.0
	A	B
	($F_{1,64}$ = 9.16, $p < 0.05$)	
Bay anchovy (*Anchoa mitchilli*)	$\bar{x}$ = 1.7	$\bar{x}$ = 22.6
	A	B
	($F_{1,64}$ = 9.80, $p < 0.05$)	
Gray snapper (*Lutjanus griseus*)	$\bar{x}$ = 1.7	$\bar{x}$ = 24.9
	A	B
	($F_{1,64}$ = 3.19, $p < 0.05$)	
Northern pipefish (*Syngnathus fuscus*)	$\bar{x}$ = 51.1	$\bar{x}$ = 22.7
	A	A
	($F_{1,64}$ = 4.03, $p < 0.05$)	
Sheepshead (*Archosargus probatocephalus*)	$\bar{x}$ = 27.3	$\bar{x}$ = 63.5
	A	B
	($F_{1,64}$ = 4.79, $p < 0.05$)	
Tautog (*Tautoga onitis*)	$\bar{x}$ =43.4	$\bar{x}$ =7.9
	A	B
	($F_{1,64}$ = 2.65, $p < 0.05$)	
Blue crab (*Callinectes sapidus*)	$\bar{x}$ = 963.7	$\bar{x}$ = 1448.2
	A	A
	($F_{1,64}$ =7.14 , $p < 0.01$)	
Brown shrimp (*Farfantepenaeus aztecus*)	$\bar{x}$ = 111.8	$\bar{x}$ = 565.2
	A	B
	($F_{1,64}$ = 8.73, $p < 0.01$)	
Grass shrimp (*Palaemonetes sp.*)	$\bar{x}$ = 293.7	$\bar{x}$ = 938.6
	A	B

Table 9. Submerged Aquatic Vegetation Habitat Survey Richness of fishes by habitat category.

	Percent SAV			
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%
Combined (All SAV and Substrate)	26	31	32	26
Eelgrass (*Zostera marina*)	21	22	19	22
Widgeon grass (*Ruppia maritima*)	14	26	28	17
Sand	20	28	28	19
Mud	18	15	22	21
Sand - Eelgrass (*Z. marina*)	13	18	12	14
Mud - Eelgrass (*Z. marina*)	18	11	17	20
Sand - Widgeon grass (*R. maritima*)	14	24	25	16
Mud - Widgeon grass (*R. maritima*)		9	18	8

Table 10. Submerged Aquatic Vegetation Habitat Survey Shannon - Index Diversity H values of fishes by habitat category.

	Percent SAV			
	Low < 25%	Medium 26 - 50%	Medium - High 51 - 75%	High 76 - 100%
Combined (All SAV and Substrate)	1.32	1.21	1.11	1.27
Eelgrass (*Zostera marina*)	1.47	1.35	0.78	1.30
Widgeon grass (*Ruppia maritima*)	0.56	1.11	1.21	1.15
Sand	1.10	1.19	1.35	1.12
Mud	1.25	1.15	0.85	1.40
Sand - Eelgrass (*Z. marina*)	1.48	1.30	1.77	1.07
Mud - Eelgrass (*Z. marina*)	1.25	1.21	0.62	1.40
Sand - Widgeon grass (*R. maritima*)	0.56	1.10	1.01	1.14
Mud - Widgeon grass (*R. maritima*)		0.97	1.26	1.08

Table 11. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for mean length and percent SAV coverage.

Specimen Name	Percent SAV Low < 25%	Medium 26 - 50%	Medium-High 51 - 75%	High 76 - 100%
Atlantic silverside (*Menidia menidia*)	($F_{3,1415}$ = 19.19, $p < 0.01$)			
	$\bar{x}$ = 84.4	$\bar{x}$ = 83.9	$\bar{x}$ = 83.1	$\bar{x}$ = 80.8
	A	A / B	B	C
Silver perch (*Bairdiella chrysoura*)	($F_{3,1854}$ = 35.21, $p < 0.01$)			
	$\bar{x}$ = 81.3	$\bar{x}$ = 75.2	$\bar{x}$ = 75.7	$\bar{x}$ = 68.7
	A	B	B	C
Tautog (*Tautoga onitis*)	($F_{3,79}$ = 7.15, $p < 0.01$)			
	$\bar{x}$ = 88.4	$\bar{x}$ = 64.8	$\bar{x}$ = 93.7	$\bar{x}$ = 74.1
	A / B	C	A	B / C
Blue crab (*Callinectes sapidus*)	($F_{3,1869}$ = 0.45, $p = 0.7185$)			
	$\bar{x}$ = 56.0	$\bar{x}$ = 55.7	$\bar{x}$ = 52.8	$\bar{x}$ = 57.2
	A	A	A	A
Brown shrimp (*Farfantepenaeus aztecus*)	($F_{3,424}$ = 8.8, $p < 0.01$)			
	$\bar{x}$ = 85.5	$\bar{x}$ = 72.6	$\bar{x}$ = 80.6	$\bar{x}$ = 82.3
	A	B	A	A

Table 12. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for mean length and primary substrate.

Specimen Name	Primary Substrate	
	Mud	Sand
Atlantic silverside (*Menidia menidia*)	($F_{1,1415} = 10.21$, $p < 0.05$)	
	$\bar{x} = 81.9$	$\bar{x} = 83.2$
	A	B
Silver perch (*Bairdiella chrysoura*)	($F_{1,854} = 0.55$, $p = 0.4584$)	
	$\bar{x} = 72.9$	$\bar{x} = 73.5$
	A	A
Tautog (*Tautoga onitis*)	($F_{1,79} = 4.5$, $p < 0.05$)	
	$\bar{x} = 83.2$	$\bar{x} = 72.6$
	A	B
Blue crab (*Callinectes sapidus*)	($F_{1,1869} = 3.92$, $p < 0.05$)	
	$\bar{x} = 57.4$	$\bar{x} = 54.1$
	A	B
Brown shrimp (*Farfantepenaeus aztecus*)	($F_{1,424} = 10.97$, $p < 0.01$)	
	$\bar{x} = 83.1$	$\bar{x} = 76.5$
	A	B

Table 13. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for mean length and dominant SAV.

Specimen Name	Dominant SAV Species	
	Eelgrass	Widgeon Grass
Atlantic silverside (*Menidia menidia*)	($F_{1,1415} = 47.84$, $p < 0.01$)	
	$\bar{x} = 81.1$	$\bar{x} = 83.8$
	A	B
Silver perch (*Bairdiella chrysoura*)	($F_{1,854} = 2.15$, $p = 0.1423$)	
	$\bar{x} = 74$	$\bar{x} = 72.8$
	A	A
Tautog (*Tautoga onitis*)	($F_{1,79} = 0.6$, $p = 0.4393$)	
	$\bar{x} = 80.7$	$\bar{x} = 74.4$
	A	A
Blue crab (*Callinectes sapidus*)	($F_{1,1869} = 12$, $p < 0.01$)	
	$\bar{x} = 58.5$	$\bar{x} = 52.7$
	A	B
Brown shrimp (*Farfantepenaeus aztecus*)	($F_{1,424} = 48.82$, $p < 0.01$)	
	$\bar{x} = 86.4$	$\bar{x} = 73.4$
	A	B

Table 14. Results of the Submerged Aquatic Vegetation Habitat Survey ANOVA and Duncan's multiple range test for mean surface water quality parameters (water temperature, salinity, dissolved oxygen and water turbidity) by sampling year.

Parameter	Sampling Year			
	2015	2016	2017	2018
	($F_{3,63}$ = 193.91, $p < 0.0001$)			
Temperature	$\bar{x}$ = 26.4	$\bar{x}$ = 23.8	$\bar{x}$ = 22.7	$\bar{x}$ = 29.7
	A	B	C	D
	($F_{3,63}$ = 301.58, $p < 0.0001$)			
Salinity	$\bar{x}$ = 32.6	$\bar{x}$ = 28.6	$\bar{x}$ = 26.0	$\bar{x}$ = 25.4
	A	B	C	D
	($F_{3,63}$ = 39.83, $p < 0.0001$)			
Dissolved oxygen	$\bar{x}$ = 6.9	$\bar{x}$ = 6.4	$\bar{x}$ = 8.7	$\bar{x}$ = 5.1
	A	A	B	C
	($F_{3,63}$ = 18.61, $p < 0.0001$)			
Turbidity (Secchi depth)	$\bar{x}$ = 79	$\bar{x}$ = 43.4	$\bar{x}$ = 62.9	$\bar{x}$ = 37.7
	A	B	C	B

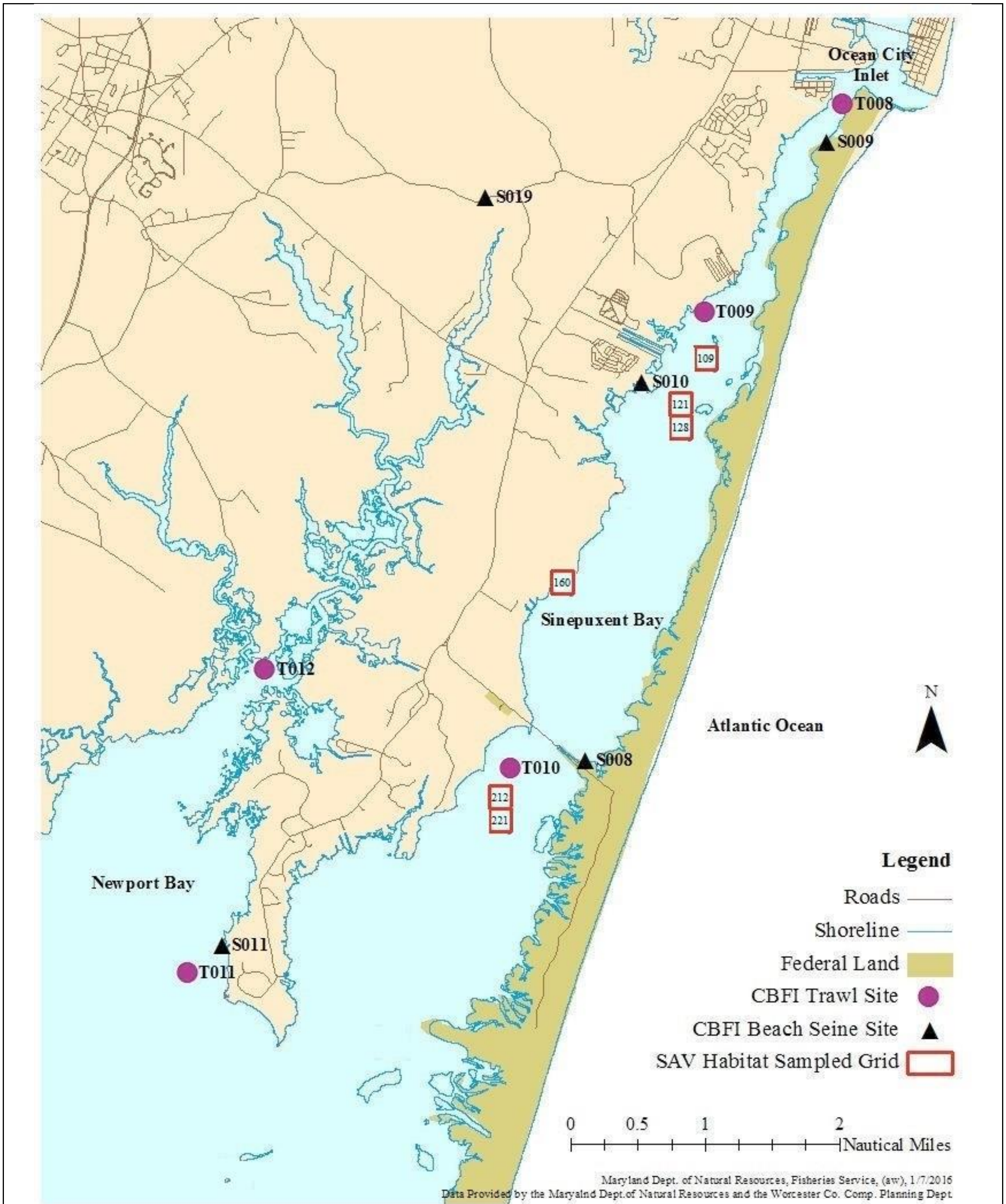

Figure 1. Sinepuxent Bay Submerged Aquatic Vegetation Habitat Survey and Trawl and Beach Seine surveys sample site locations (September 2015 - 2018).

Chapter 3: Fisheries Dependent Tautog Data Collection

Excerpt from the Maryland 2018 Compliance Report to the Atlantic States Marine Fisheries Commission (ASMFC)

The ASMFC mandated ageing structures were collected between the Ocean City charter and party boat fleet. A total of 211 tautog opercula were aged from ten different recreational trips during 2018: March (1 trip, n = 22), November (2 trips, n = 86) and December (7 trips, n = 103). Those samples represented the range of fish lengths commonly caught in the recreational fishery in Maryland. All fish were collected at sea, except for 39 fish that were collected at the dock. Weights were obtained on 192 aged fish. Seventy-nine paired opercula/pelvic spines were collected and sent to Massachusetts Division of Marine Fisheries for ageing and fifty-two paired opercula/otoliths were also collected. There were 31 samples with all three ageing structures collected (operculum, otolith, pelvic spine).

Fish length (n = 211) ranged from 241 mm to 780 mm, mean length was 417 mm (SE ± 7.81) and median length was 385 mm for both sexes combined. Females comprised 62.1% (n = 131) of the samples, mean length was 412 mm (SE ± 10.05) and the median length was 380 mm. Males comprised 37.5% (n = 79) of the samples, mean length was 427 mm (SE ± 12.35) and the median length was 390 mm (Figure 1). Unknown sex comprised 0.4% (n = 1) of the samples, its length was 241 mm.

Fish weight (n = 192) ranged from 310 g to 9,040 g, mean weight was 1,804.6 g (SE ± 127.56) and median weight was 1,005 g for both sexes combined. Females comprised 60.4% (n = 116) of the samples, mean weight was 1,810 g (SE ± 175.49) and the median weight was 975 g. Males comprised 39.1% (n = 75) of the samples, mean weight was 1,816 g (SE ± 181.89) and the median weight was 1,190 g (Figure 1). Unknown sex comprised 0.5% (n = 1) of the samples and weighed 310 g.

Fish age (n = 211) ranged from two to 28 years, mean age was 6.8 years (SE ± 0.33) and median age was five years for both sexes combined. Female mean age was 6.9 years (SE ± 0.42) and the median age was five years. Male mean age was 6.5 years (SE ± 0.57) and the median age was five years (Figure 1). The unknown sex sample was two years old.

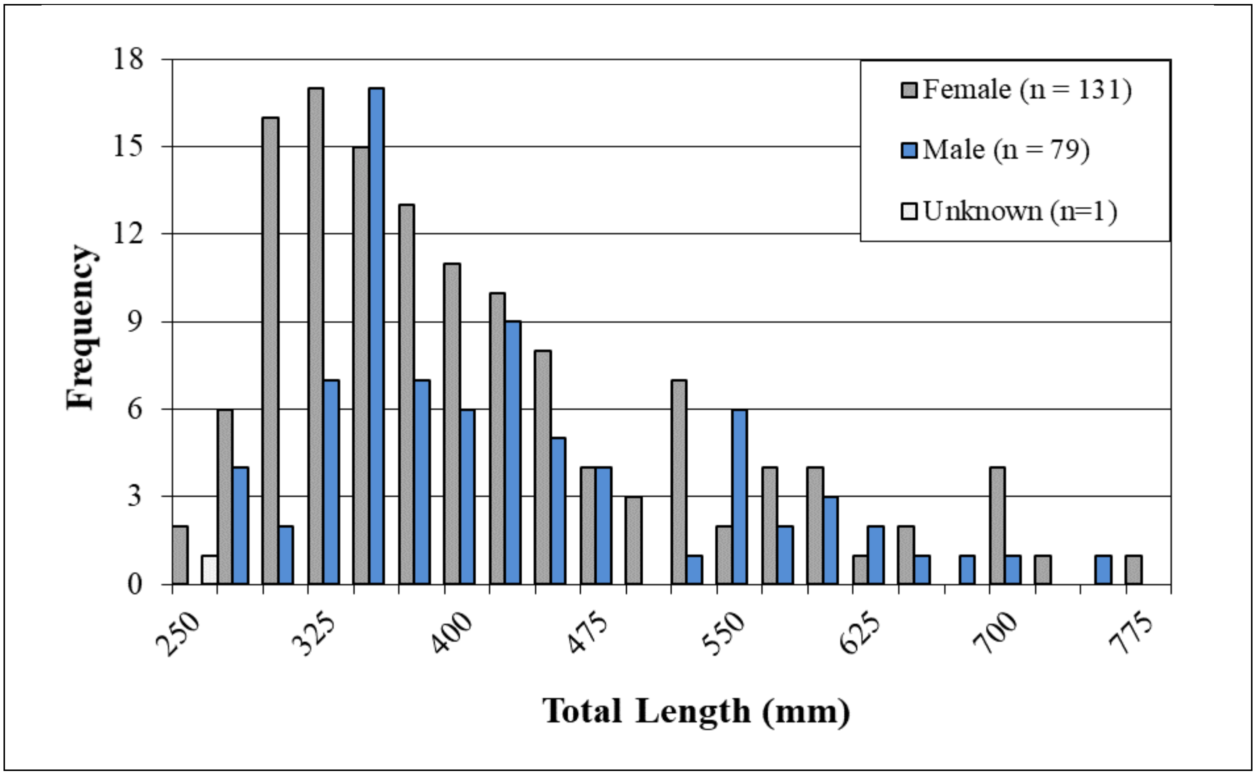

Figure 1. Length distribution of aged tautog by sex collected by hook and line from charter and party boats, Ocean City, Maryland (2018; n = 211).

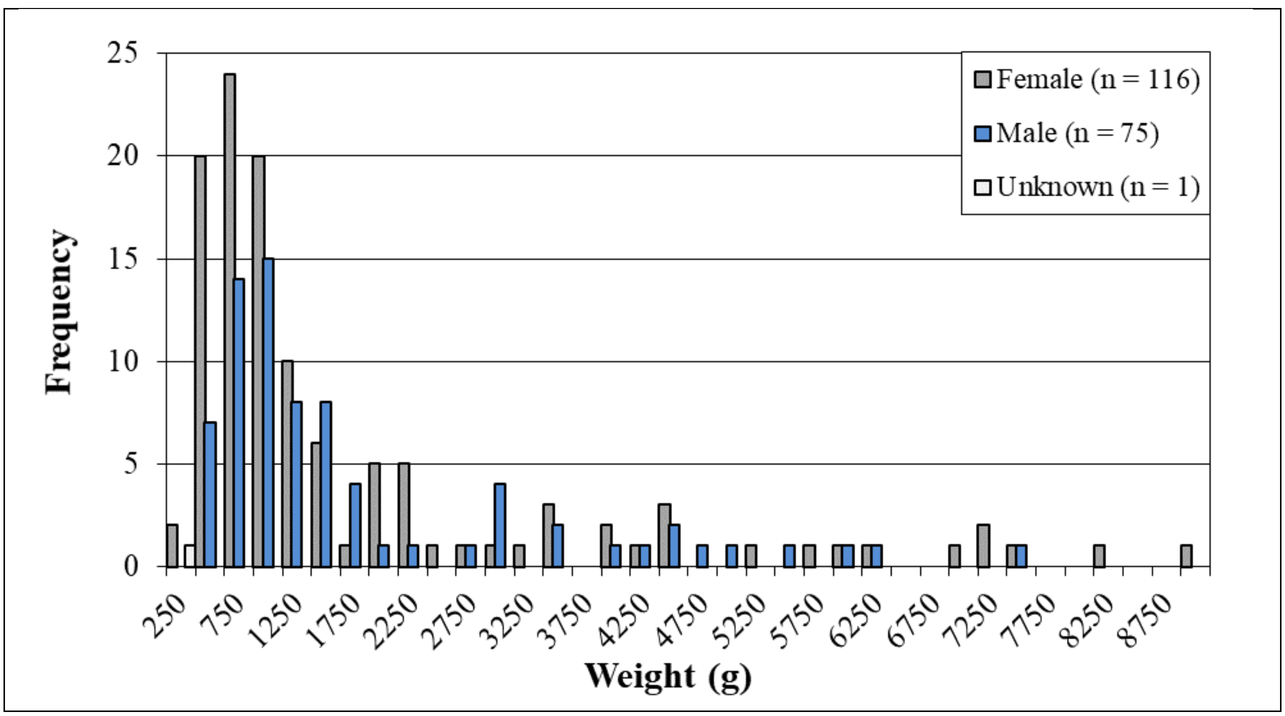

Figure 2. Weight distribution of aged tautog by sex collected by hook and line from charter and party boats, Ocean City, Maryland (2018; n = 192).

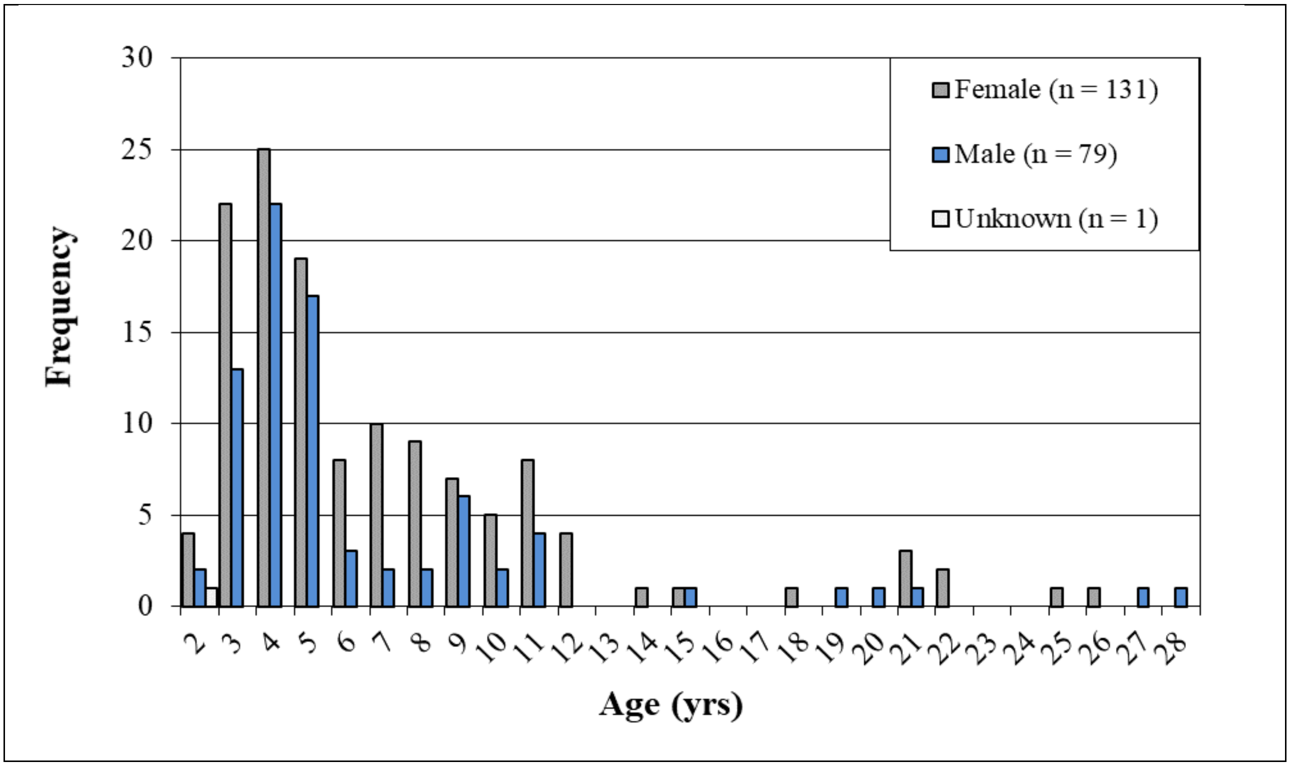

Figure 3. Age distribution of tautog by sex collected by hook and line from charter and party boats, Ocean City, Maryland (2018; n = 211).

Chapter 4: Offshore Trawl Survey

Introduction

The department has conducted the Offshore Trawl Survey since 1993 to obtain biological information on adult fishes in the nearshore Atlantic waters. Offshore sampling provides access to species and adult length groups not frequently captured in the Trawl and Beach Seine surveys conducted in Maryland's coastal bays. This survey contributes to three objectives by collecting data that can be used to:

1. characterize the stocks and estimate relative abundance of adult marine and estuarine species in the coastal bays and near-shore Atlantic Ocean;
2. develop annual indices of age and length, relative abundance and other information necessary to assist in the management of regional and coastal fish stocks; and
3. delineate and monitor areas of high value as spawning, nursery and/or forage locations for finfish in order to protect against habitat loss or degradation.

Methods

Time

Sampling trips (five) were conducted during 2018 on June 12, July 9, August 14, October 19 and December 12. Trawls usually occurred at night but the October trip was conducted during the day. The December trip occurred from early evening on December 12 and lasted until early morning December 13.

Gear and Location

Sampling was conducted on commercial trawlers using a standard summer flounder bottom trawl net (Table 1). Sites were determined by the fishing vessel captains on a trip by trip basis depending on the target species. All trawls were conducted one to three miles from shore, except for the December trip which was approximately 19 miles offshore.

Trawling

Start depth (ft), time, surface water temperature (C), weather and wind direction were recorded when the trawl net was 100 percent deployed. Wind speed (kts) was taken using an anemometer. End time and stop depth was recorded at haul back. Data were recorded on a standardized data sheet.

Sample Processing

A representative subsample of the catch was collected from each haul and placed into a 100 Liter (L) tub. The total catch of horseshoe crabs was counted and used to calculate the proportion each subsample represented to the total catch. Species of interest such as summer flounder were sorted from the main catch and all individuals of these species were measured. All fishes and invertebrates were measured as in Chapter 1 and all prohibited species were released. Staff biologists consulted Gosner (1978) and Robins and Ray (1986) for assistance with species identification.

Data Analysis

Statistical analyses were conducted on all species. Abundance estimates of selected species were extrapolated from the subsampling regime proportional catch calculations.

Results

Trawl time varied with time ranging between 18 and 125 minutes. Water temperature ranged from a high of 24.4 C in August to a low of 8.3 C in December. Depth over the course of the surveys ranged from 10.7 m to 31.7 m (Table 2).

Numbers of species collected ranged from seven to 17 per trip (Table 2). Fishes of recreational interest encountered from these trawls include summer flounder (*Paralichthys dentatus*), clearnose skate (*Raja eglanteria*), spiny dogfish (*Squalus acanthias*), southern kingfish (*Menticirrhus americanus*), Atlantic croaker (*Micropogonias undulatus*) and scup (*Stenotomus chrysops*) and spot (*Leiostomus xanthurus*; Table 3). Common invertebrates encountered were horseshoe crabs (*Limulus polyphemus*), portly spider crab (*Libinia emarginata*), channeled whelk (*Busycotypus canaliculatus*) and knobbed whelk (*Busycon carica*).

From all trips combined, 315 summer flounder were measured (Table 3). Lengths ranged in size from 225 mm (8.9 inches (in)) to 590 mm (23.2 in; Figure 1). The mean was 416.7 mm (16.4 in) and the mode was 412 mm (16.2 in). Thirty-five percent (110 fish) of the measured summer flounder were at or above the recreational minimum size limit (431.8 mm; 17 in) and 92% (290 fish) were above 355.6 mm (14 in length at female maturity; Table 4). The proportion of summer flounder less than 355.6 mm and 431.8 mm (17 in) was examined over time in order to identify potential recruitment pulses in the nearshore population. The results varied without trend over the 2013 - 2018 time series. The mean percent less than 431.8 mm (17 in) was 65.1%.

Discussion

This survey provides information on the seasonality and relative abundance of adult sportfishes and forage species in nearshore waters including summer flounder, spot and southern kingfish. The GPS data can be used to document fish abundances from nearshore shoals, slews and open areas. Data from this survey indicated that this is an important habitat area for southern kingfish, spot, summer flounder and elasmobranchs. It also documents presence of different finfish life stages (e.g. elasmobranchs and summer flounder) in these habitats. The majority of summer flounder measured in 2018 had reached the length of maturity which is 355.6 mm (14 in) for females and 304.8 mm (12 in) for males (Manooch 1984).

Southern kingfish are harvested by recreational fishermen. Adults of this demersal species prefer the sandy substrates of ocean beaches (Murdy and Musick 2013). Southern kingfish can also be found in muddy to sandy substrates which is the substrate often encountered in the trawls of this survey.

References

Gosner, K. L. 1978. Peterson Field Guide-Atlantic Seashore. Boston. Houghton Mifflin Company.

Manooch, C. S. 1984. Fisherman's Guide: Fishes of the Southeastern United States. North Carolina State Museum of Natural History. Raleigh, NC. 362 pp.

Murdy, E. and J.M. Musick. Field guide to fishes of the Chesapeake Bay. Baltimore, MD. The Johns Hopkins University Press; 2013.

Robins, R. C. and G. C. Ray. 1986. Peterson Field Guide: Atlantic Coast Fishes. Boston. Houghton Mifflin Company. 354 pp.

List of Tables and Figures

Table 1. Gear specifications for the subsampled commercial trawls off Ocean City, Maryland from June, July, August, October and December 2018.

Trip Date	Net Codend Mesh (cm)	Net Body Mesh (cm)	Head Rope Width (m)	Foot Rope Width (m)
June 12	14.0	15.2	33.5	39.6
July 9	14.0	15.2	21.9	29.0
August 14	14.0	14.0	24.4	30.5
October 1	14.0	14.0	24.4	30.5
December	14.0	14.0	12.2	18.3

Table 2. Commercial trawl subsample summary off Ocean City, Maryland from June, July, August, October and December 2018.

Trip Date	Sets	Depth Range (m)	Surface Temperature (C)	Species		
				Number Present	Number Counted	Number Measured
June 12	2	10.7 - 12.2	19.3 - 19.4	7	118	106
July 9	1	14.0 - 14.0	22.8	9	158	134
August 14	3	13.7 - 17.7	24.4	13	223	215
October 1	3	14.6 - 17.9	22.8	17	163	151
December 6	6	15.5 - 31.7	8.3	9	381	258

Table 3. List of species collected in subsampled commercial offshore trawls off Ocean City, Maryland from June, July, August, October and December 2018, n = 1,043. Species were grouped (finfish, crustaceans, molluscs and other) and listed by order of extrapolated total number, n = 10,025.

Common Name	Scientific Name	Total Number Counted	Total Number Extrapolated
Finfish Species			
Winter skate	*Leucoraja ocellata*	116	771
Summer flounder	*Paralichthys dentatus*	315	333
Clearnose skate	*Raja eglanteria*	48	207
Spiny dogfish	*Squalus acanthias*	27	184
Bullnose ray	*Myliobatis freminvillei*	10	123
Southern kingfish	*Menticirrhus americanus*	12	117
Atlantic croaker	*Micropogonias undulatus*	4	75
Windowpane flounder	*Scophthalmus aquosus*	10	56
Atlantic angel shark	*Squatina dumeril*	19	19
Cownose ray	*Rhinoptera bonasus*	5	5
Scup	*Stenotomus chrysops*	4	4
Monkfish	*Lophius americanus*	4	4
Spot	*Leiostomus xanthurus*	3	3
Striped burrfish	*Chilomycterus schoepfii*	3	3
Southern stingray	*Dasyatis americana*	2	2
Spiny butterfly ray	*Gymnura altavela*	2	2
Sandbar shark	*Carcharhinus plumbeus*	1	1
Hogchoker	*Trinectes maculatus*	1	1
	Total Finfish	586	1,910
Crustacean Species			
Lady crab	*Ovalipes ocellatus*	6	100
Blue crab	*Callinectes sapidus*	17	113
Portly spider crab	*Libinia emarginata*	10	162
Six-spined spider crab	*Libinia dubia*	3	45
Broad claw hermit crab	*Pagurus pollicaris*	4	45
Jonah crab	*Cancer borealis*	6	40
Atlantic rock crab	*Cancer irroratus*	1	1
Brown shrimp	*Farfantepenaeus aztecus*	1	1
	Total Crustaceans	45	507
Mollusc Species			
Knobbed whelk	*Busycon carica*	16	83
Channeled whelk	*Busycotypus canaliculatus*	4	276
	Total Molluscs	20	359
Other Species			
Horseshoe crab	*Limulus polyphemus*	392	7,249
	Total Other	392	7,249

Table 4. Percent of summer flounder (*Paralichthys dentatus*) bycatch below the female length at maturity and recreational minimum size from subsampled commercial offshore trawls off Ocean City, Maryland from 2014 - 2018.

Year	Number of Trawls	Percent Below 355.6 mm (14 in)	Percent Below 431.8 mm (17 in)	Catch Per Unit Effort #/Trawl
2014	12	23.0	66.7	10.5
2015	6	20.5	47.1	5.7
2016	14	17.4	66.3	6.1
2017	13	9.0	65.7	5.2
2018	15	7.9	65.1	21

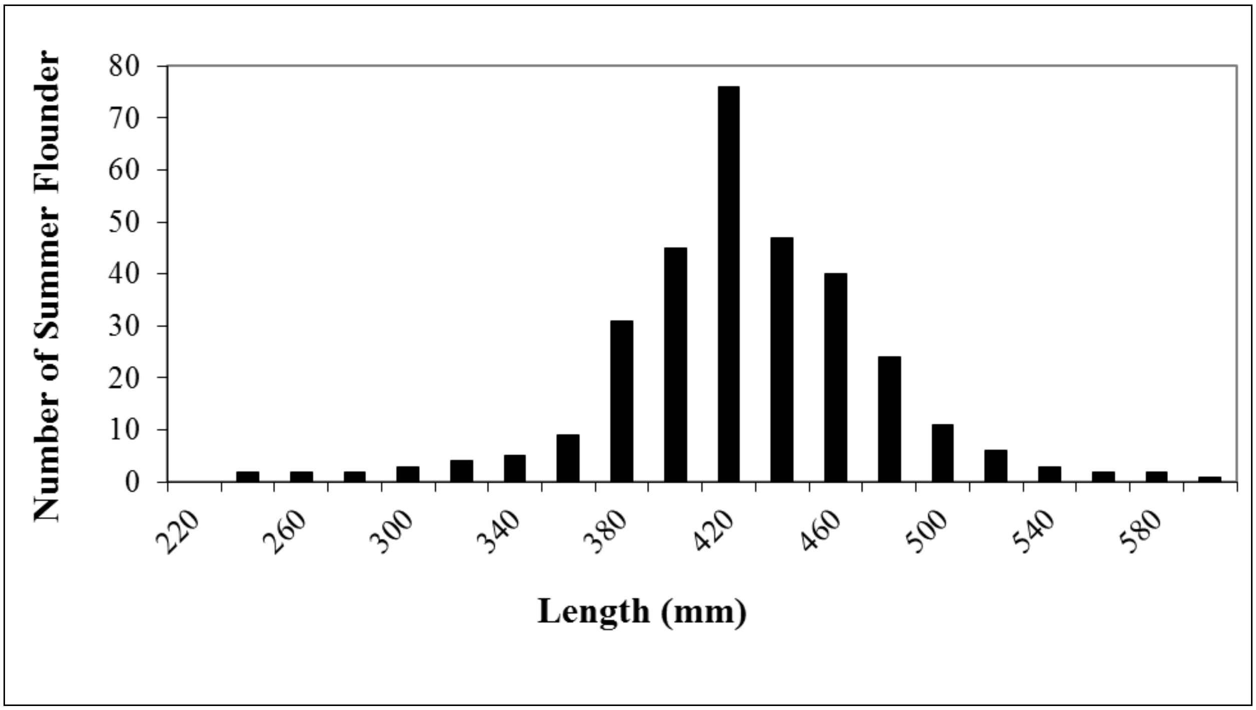

Figure 1. Summer flounder (*Paralichthys dentatus*) length (mm) frequency from commercial offshore trawls subsampled off Ocean City, Maryland from June, July, August, October and December 2018, n = 315. Data were derived from five trawl trips (15 trawls total) taken at different water depths.

Chapter 5: Technical Assistance

One of the 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 for eight finfish species as well as providing evidence of compliance with state and federal fisheries management plans. A summary of the participation and contributions is presented below.

Atlantic croaker

Project staff provided Atlantic croaker data utilized for stock assessment to the ASMFC.

Black sea bass

Project staff provided black sea bass data and expertise utilized for the ASMFC, MAFMC and NMFS stock assessment. Assigned staff participated on the ASMFC Technical Committee and prepared our state compliance report.

Bluefish

Project staff provided bluefish data utilized for stock assessment to the ASMFC, MAFMC and NMFS.

Coastal sharks

Assigned staff participated on the ASMFC Technical Committee and prepared our state compliance report. Shark data from the Offshore Trawl Survey was included in Maryland's ASMFC compliance report.

Spot

Project staff provided spot data utilized for stock assessment and traffic light assessment to the ASMFC.

Summer flounder

Project staff provided summer flounder data and expertise utilized for the ASMFC, MAFMC and NMFS stock assessment. Assigned staff participate on the ASMFC Technical Committee and prepared our state compliance report.

Tautog

Project staff provided tautog data and expertise utilized for the ASMFC stock assessment. Assigned staff participated on the ASMFC Technical Committee and prepared our state compliance report.

Weakfish

Project staff provided weakfish data utilized for stock assessment to the ASMFC.

Chapter 6: Dependent Shark Review

Introduction

This review will evaluate the ability of shark records from a charterboat captain to answer biological questions and their potential to meet F-50-R objectives to enhance the knowledge of sharks that are of interest to recreational anglers. Those data can characterize sharks in the recreational fishery off Maryland and may improve biological knowledge leading to better angler experiences.

Methods

Personal fishing records were obtained from a charterboat captain whom specializes in shark fishing out of Ocean City, Maryland. Recorded information included: species, total length, fork length, sex, estimated weight, date and location. All prohibited species were released as well as most others. Those records were received in paper and electronic formats. Electronic and some paper records were entered and proofed. Additional records will continue to be added and proofed. The database structure was constructed and the data will be imported during the next grant cycle. Metadata was drafted and will continue to be updated.

Results

Initial review of data covering 2007 – 2017 revealed that trips targeting offshore sharks such as blue sharks (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*) and thresher sharks (*Alopias vulpinus*) occurred in May and June. Most of the nearshore charter trips occurred within 20 nautical miles of shore. Those data indicated that dusky (*Carcharhinus obscurus*), sandbar (*Carcharhinus plumbeus*) and spinner sharks (*Carcharhinus brevipinna*) were most frequently caught in July and August (Tables 1 and 2). Of note, there were three great white sharks *Carcharodon carcharias*) and zero bull sharks (*Carcharhinus leucas*) caught in that 11 year time period.

Discussion

Initial exploration of these data indicate that useful biological information can be obtained that may improve recreational fishing opportunities. These charter records demonstrate that recreational anglers have access to a wide variety of sharks from Maryland waters. The two most commonly caught (and released) species from these charter trips were prohibited species. The third most common species, the spinner shark, was present but reports of catches from the recreational public were uncommon. These data could indicate that the average recreational angler has identification difficulties and may misidentify the spinner shark as a blacktip, sandbar or dusky shark.

These data show blue and shortfin mako sharks were caught primarily in May and June, however, this may be a function of the fishing location rather than availability. Anecdotal reports indicate blue sharks are offshore all summer, but effort occurs toward other species. Fishing in late spring is often hampered by unfavorable weather conditions which reduced effort and is reflected in the catch reports of pelagic shark species.

These data show a possible range extension for the blacknose shark. Schulze-Haugen *et al* (2003) documents the blacknose shark range as North Carolina to Brazil. The northward expansion could be a result of warmer water temperatures and/or changes in the Gulf Stream which could provide more fishing opportunities to anglers.

References

Schulze-Haugen, M., Corey, T. and N. Kohler, editors. Guide to Sharks, Tunas & Billfishes of the U.S. Atlantic & Gulf of Mexico. NOAA Fisheries, Rhode Island Sea Grant. Narragansett, RI. 2003.

List of Tables Page

Table 1. Annual shark catch frequency from an Ocean City, Maryland charter boat, 2007 - 2018.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Atlantic sharpnose shark (*Rhizoprionodon terraenovae*)	60	200	134	101	38	58	83	42	69	88	114	987
Bignose shark (*Carcharhinus altimus*)				1								1
Blacknose shark (*Carcharhinus acronotus*)				1		1			15	6		23
Blacktip shark (*Carcharhinus limbatus*)		3	2	10	6	9	12	1	16	17	2	78
Blue shark (*Prionace glauca*)		35	46	5	1	27	9	43	16	16	23	221
Common thresher shark (*Alopias vulpinus*)	2	3			2		1	2	2		1	13
Dogfish shark, smooth (*Mustelus canis*)		3		1			3	1	3		1	12
Dogfish shark, spiny (*Squalus acanthias*)		1					1		2			4
Dusky shark (*Carcharhinus obscurus*)	193	133	213	229	171	182	121	158	119	108	136	1,763
Great white shark (*Carcharodon carcharias*)					1		1	1				3
Hammerhead shark, scalloped (*Sphyrna lewini*)			2			8		3	3	2	3	21
Hammerhead shark, smooth (*Sphyrna zygaena*)	2	5	6	4	13	5	2	12	2	4	4	59
Sand tiger shark (*Carcharias taurus*)	4	1	18	10	2	5		8	6	3	27	84
Sandbar shark (*Carcharhinus plumbeus*)	62	150	132	169	151	90	150	117	60	102	201	1,384
Shortfin mako shark (*Isurus oxyrinchus*)		8	20	7	6	12	6	15	16	8	6	104
Spinner shark (*Carcharhinus brevipinna*)	8	63	133	149	19	150	52	86	273	223	191	1,347
Tiger shark (*Galeocerdo cuvier*)		6	7	6	1	4	6	4	1		1	36
Total	331	611	713	693	411	551	447	493	603	577	710	6,140

Table 2. Monthly shark catch frequency (2007 – 2017) from an Ocean City, Maryland charter boat.

	May	June	July	August	September	October	Total
Atlantic sharpnose shark (*Rhizoprionodon terraenovae*)		46	545	323	65	8	987
Bignose shark (*Carcharhinus altimus*)				1			1
Blacknose shark (*Carcharhinus acronotus*)			14	9			23
Blacktip shark (*Carcharhinus limbatus*)		15	36	26	1		78
Blue shark (*Prionace glauca*)	146	74			1		221
Common thresher shark (*Alopias vulpinus*)	4	1	3	1	2	2	13
Dogfish shark, smooth (*Mustelus canis*)	3		1	4	1	3	12
Dogfish shark, spiny (*Squalus acanthias*)	3			1			4
Dusky shark (*Carcharhinus obscurus*)		171	536	788	245	23	1,763
Great white shark (*Carcharodon carcharias*)		2	1				3
Hammerhead shark, scalloped (*Sphyrna lewini*)		5	11	4	1		21
Hammerhead shark, smooth (*Sphyrna zygaena*)		39	12	4	4		59
Sand tiger shark (*Carcharias taurus*)			27	26	17	14	84
Sandbar shark (*Carcharhinus plumbeus*)	31	173	214	466	431	69	1,384
Shortfin mako shark (*Isurus oxyrinchus*)	47	54			3		104
Spinner shark (*Carcharhinus brevipinna*)		176	615	446	106	4	1,347
Tiger shark (*Galeocerdo cuvier*)		28	8				36
Total	234	784	2,023	2,099	877	123	6,140