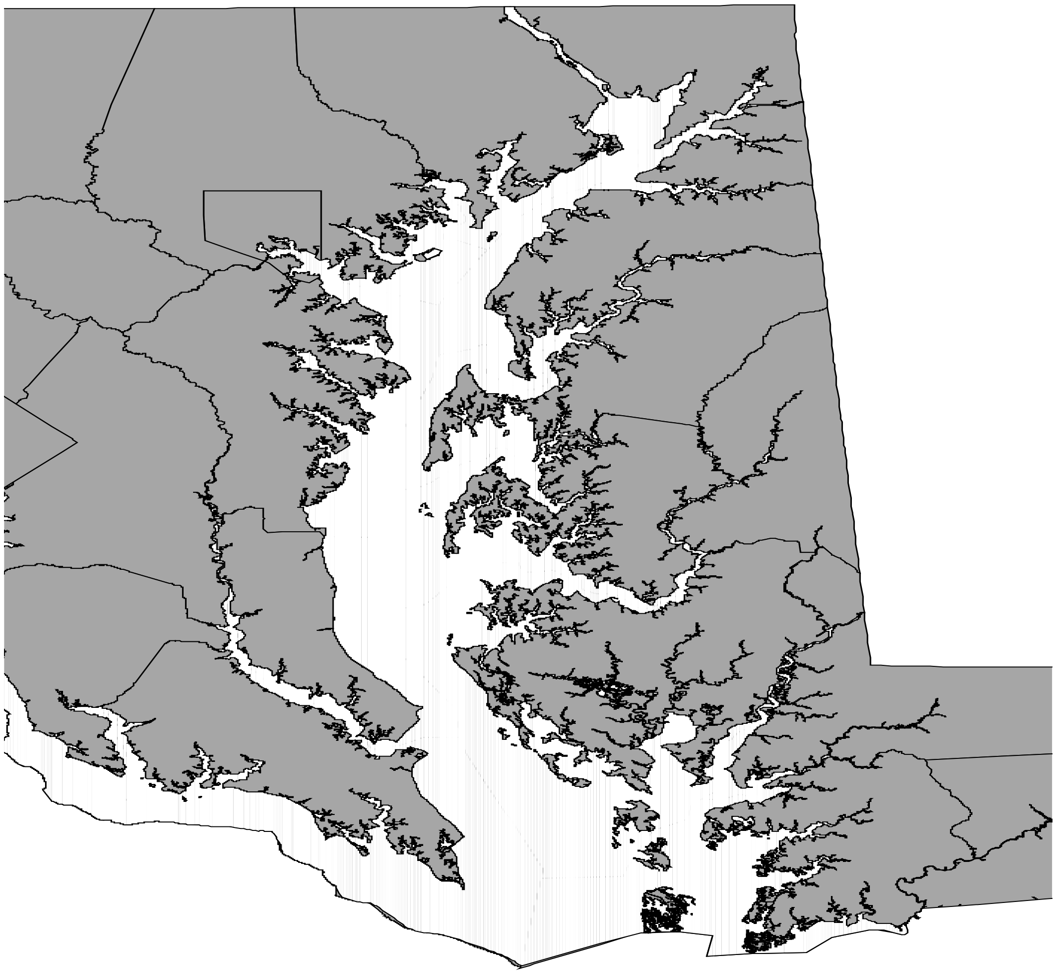

Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-15
2019 - 2020

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Chesapeake Bay Finfish Investigations

July 1, 2019 to June 30, 2020

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02/2019 DNR

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
PERFORMANCE REPORT

STATE: Maryland

PROJECT NO.: F-61-R-15

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: July 1, 2019 through June 30, 2020

Executive Summary

The primary objective of the Chesapeake Bay Finfish Investigations Survey was to monitor and biologically characterize resident and migratory finfish species in the Maryland portion of the Chesapeake Bay. This Survey provides information regarding relative abundance, age and size structure, recruitment, growth, mortality, and migration patterns of finfish populations in Maryland's Chesapeake Bay. The data generated are utilized in both intrastate and interstate management processes and provides reference points for future fisheries management considerations.

Annual winter trawl efforts in upper Chesapeake Bay during 2019 indicated that white perch relative abundance declined relative to 2018. The 2014, 2015, 2017 and 2018 year-classes were above average. Yellow perch relative abundance increased relative to 2018. The 2014, 2015 and 2018 year-classes were above average. Channel catfish relative abundance continued a three-year increase, but relative abundance remained below average. Age 1 channel catfish relative abundance was at the time series average in 2019 (2018 year-class).

White perch relative abundance in the Choptank River Fyke Net Survey in 2019 was at a time series low (2000 – 2019). Similar to the upper Bay trawl, the 2011, 2014, and 2015 year-classes were strong. Yellow perch relative abundance was very low in 2019. Channel catfish relative

abundance continued a three-year increase in relative abundance and was nearing the time-series average. White catfish continued a three-year decline in relative abundance and was below the time series average.

Yellow perch population dynamics were modeled with an Integrated Analysis model for the upper Chesapeake Bay stock. In the upper Chesapeake Bay, total population size declined from 2016 through 2018. The population estimate increased in 2019 and was above the time series average. Biomass declined 2017 – 2019 as the large 2011-year class aged out of the population. Recruitment was above average in four of the last eight years, but the four below average year-classes were extremely poor, adding nearly nothing to the population. Estimated fishing mortality (F) was below average in 2018 and 2019. There was a zero percent probability that F exceeded the target in 2019, indicating overfishing had not occurred. The Choptank River yellow perch population growth and decline was estimated from a fishery independent fyke net survey. The population expanded relatively quickly and for a sustained period from 1998 – 2010. The most recent period investigated, 2010 – 2019, failed to produce a statistically significant decline, but by extension, the analysis suggests that the population has been stable at best.

U.S. Atlantic coast wide Alosine stocks are near historic lows. Predation, bycatch, turbine mortality and limited access to prime spawning habitat continue to impact Alosine populations in Maryland's portion of Chesapeake Bay and its tributaries. A record low of 53 adult American shad were angled from the Susquehanna River below Conowingo Dam from 15 April through 30 May 2019, and 44 were successfully scale-aged. The 2014 (age 5) year-class was the most abundant for both male and female American shad in 2019. Estimates of absolute abundance of adult American shad in the lower Susquehanna River increased slightly in 2019. However, low recapture rates of tagged fish and retrospective bias in the surplus production model are likely masking the true population signal. The relative abundance index generated by the hook-and-line survey is a more reliable indicator of year to year changes in population size, and was the lowest on record in 2019. Conversely, relative abundance of American shad in the Potomac River significantly increased over the time series (1996-2019), and reached the highest value on record in 2019. Relative abundance of American shad in the Nanticoke River increased in 2019, but was highly variable and showed no significant trend over the time series. The 2019 juvenile American shad abundance index declined in the Upper Chesapeake Bay and Nanticoke River. Juvenile abundance in the Potomac River increased to the third highest value on record and continues to be the highest index in Maryland's portion of the Chesapeake basin.

The age composition of hickory shad sampled from brood stock collection efforts in the Susquehanna River expanded in 2019, with age 8+ fish being observed for the first time since 2011. Still, the proportion of fish of age 7 or greater remains low relative to the early years of brood stock collection (2004-2010). Hickory shad are infrequently encountered by other surveys, so biological information from other Maryland rivers is rarely available.

Biologists sampled alewife and blueback herring from commercial pound and fyke nets in the Nanticoke River from 1 March through 26 April 2019. Relative abundance of both species in the Nanticoke River has declined over the time series (1989-2019) and continues to be very low. Mean length continues to decline for blueback herring in this river. A multi-panel experimental anchored sinking gill net was deployed in the North East River from 2013-2019 to assess the river herring spawning stock in the upper Chesapeake Bay. The gill net was fished at four randomly chosen sites once weekly from 14 March to 14 May 2019. Relative abundance of both herring species in the North East River increased in 2019, especially for blueback herring, but no significant trends were observed over the time series. The 2015 year-class (age 4) was the most abundant for males and females of both species. Juvenile abundance indices for alewife declined slightly in the Upper Chesapeake Bay and Nanticoke River in 2019. The blueback herring juvenile abundance index remained stable in the Nanticoke River and increased substantially in the Upper Chesapeake Bay; this was unsurprising given the dramatic increase in spawning stock documented in the North East River.

Weakfish have experienced a sharp decline in abundance coast-wide. Recreational harvest estimates for inland waters by the NMFS for Maryland waters declined from 741,758 fish in 2000 to 763 in 2006, and have fluctuated at a very low level from 2007 through 2018. The NMFS estimated no weakfish were harvested in 2018. The 2018 Maryland Chesapeake Bay commercial weakfish harvest of two pounds was the lowest of the 1981 – 2018 time series, which averaged 41,383 pounds per year. The 2019 mean length for weakfish from the onboard pound net survey was 252 mm TL, the second lowest value of the time series. Four weakfish ranging from 270 to 327 mm TL were captured in the Choptank River gill net survey in 2019.

Summer flounder mean length from the pound net survey was 272 mm TL in 2019, which was the fifth lowest value in the time series. No summer flounder were measured during fish house sampling in 2018 or the Choptank River gill net survey in 2019. The NMFS 2019 coast wide stock assessment concluded that summer flounder stocks were not overfished, and overfishing was occurring, but recruitment has been generally low and fishing mortality is just below the threshold value.

Mean length of bluefish from the onboard pound net survey in 2019 was 345 mm TL, and was the highest value in the time-series. The length distribution indicated a shift back to larger bluefish in 2019 following distributions that were skewed toward smaller fish from 2016 through 2018. Only four bluefish were sampled from seafood dealer sampling in 2019, ranging from 377 to 487 mm TL in length and 495 to 1,080 grams in weight. Three bluefish were captured in the Choptank River gill net survey in 2019. Bluefish have been encountered in low numbers all seven years of the survey (3 – 24 fish per year). Reported Maryland bluefish commercial and charter boat harvest and inland recreational estimates in 2018 were all well below their time series means. The 2019 coast wide stock assessment update indicated the stock was overfished, but overfishing was not occurring.

The mean length of Atlantic croaker examined from the onboard pound net survey in 2019 was 212 mm TL, and was the lowest value of the 27 year time series. No Atlantic croaker were sampled from seafood dealers in 2019. Atlantic croaker age structure from pound net samples was truncated to age six, with a more even distribution than previous years. Length and age sample sizes were low in 2019 due to decreased availability. Atlantic croaker catches from the Choptank River gill net survey declined steadily the first three years of the survey; 476 fish in 2013, 269 fish in 2014 and 21 fish in 2015. The gill net catch remained low since with 43 fish being captured in 2019. Maryland 2018 Atlantic croaker Chesapeake Bay commercial harvest, inland waters recreational harvest estimate and charter boat harvest values were all well below their long term means. The Atlantic croaker juvenile index increased to the fourth highest value of the time series in 2019.

The 2019 spot mean length of 189 mm TL was the median value of the time-series, but the length frequency distribution remained truncated. Spot aged from the onboard pound net survey were almost evenly split between age zero and age one, with no age two fish encountered. Spot catch in the Choptank River gill net survey was highest in 2014, moderate in 2013, 2017 and 2019, and low in 2015, 2016 and 2018. Chesapeake Bay commercial spot harvest decreased in 2018, remaining below the time series mean. The inland waters recreational harvest estimate in 2018 decreased and was below the time-series mean. The spot juvenile index values in 2014, 2015 and 2016 were the 4th, 1st and 7th lowest values, respectively, in the 31 year time-series. The values increased from 2017 to 2019, but remain just below the time series mean.

Mean length for Atlantic menhaden sampled from the onboard pound net survey in 2019 was 215 mm FL, the second lowest value of the 16 year time-series. The 2019 length frequency distribution was bimodal and heavily skewed toward smaller fish. Atlantic Menhaden was the most common species captured by the Choptank River gill net survey in all years, with annual catches ranging from 1,171 fish to 2,257 fish, and 2,045 fish captured in 2019. Mean lengths for all meshes combined displayed little inter-annual variation, with 2017 and 2019 values being slightly lower. Length frequency distributions from the Choptank River gill net survey indicated the gear selects slightly larger menhaden than the pound net survey, and age samples from both surveys indicate the Choptank River gill net survey selects slightly older ages.

Resident/pre-migratory striped bass sampled from pound nets in the Chesapeake Bay during the summer – fall 2018 season ranged in age from one to fourteen years old. Age 3 striped bass from the above average 2015 year-class contributed 35% of the sample. Age 7 fish from the above average 2011 year-class contributed 16% in 2018 while striped bass age 6 and older comprised 25% of the sample. Striped bass sampled from pound nets ranged from 255 to 882 mm TL , with a mean length of 485 mm TL in 2018. Check station sampling determined that the commercial summer/fall fishery harvest was comprised of three to twelve year-old striped bass from the 2006 through 2015 year-classes. Striped bass over 700 mm TL were harvested throughout the season and contributed 9% to the overall harvest.

The December 2018 - February 2019 commercial drift gill net harvest consisted primarily of age 6,7, and 8 year-old striped bass from the 2013, 2012 and 2011 year-classes that composed 76% of the total harvest. The contribution of fish older than age 9 (7%) was similar to the 2017-2018 harvest (8%). The youngest fish observed in the 2018-2019 sampled harvest were age 4 from the 2015 year-class. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 4 to 13 years old (2015 to 2006 year-classes).

Striped bass harvested during the 2018-2019 Atlantic coast commercial fishing season ranged from age 5 (2014 year-class) to age 16 (2001 year-class). Thirteen different year-classes were represented in the sampled harvest. The most common age represented in the catch-at-age estimate was age 8 striped bass from the 2011 year-class, which represented 20% of the sampled harvest. Age 12 (2007 year-class) fish were also a significant contributor to the sample population at 18%. Striped bass sampled at Atlantic coast check stations during the 2018 – 2019 season had a mean length of 920 mm TL and mean weight of 9.5 kg.

The spring 2019 spawning stock survey indicated that there were 18 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 19 years old. Male striped bass ranged in age from 2 to 16 years old and females ranged in age from 6 to 19. Age 16 females from the above average 2003 year-class were most commonly observed, followed by age 8 females from the dominant 2011 year-class. The contribution of age 8+ females to the total female CPUE increased in 2019 to 87%, the highest value since 2010. This increase is likely driven by the addition of the 2011 year-class (age 8 in 2019) females to the spawning stock. The contribution of females age 8 and older to the spawning stock was at or above 80% for most years during the period of 1996-2015, but was below the time-series average (72%) for 2016 - 2018.

The striped bass young-of-year index, a measure of striped bass spawning success in Maryland's Chesapeake Bay, was 3.4 in 2019, below the 66-year average of 11.6. The index represents the average number of recently hatched striped bass captured in each sample. Although the cause of poor spawning success in 2019 was unclear, large variation in annual reproductive success is normal for striped bass populations. Typically, several years of average reproduction are interspersed with high and low years. Weather, river flows, and availability of food for newly hatched fish are all important factors. During this year's survey, biologists collected over 51,000 fish of 54 different species, including 445 young-of-year striped bass. Results showed that white perch and yellow perch also experienced below-average reproduction. In contrast, the abundance of some important forage species like silversides, spot, and menhaden increased in Maryland waters.

During the 2019 spring recreational trophy season, biologists intercepted 11 charter trips and examined 25 striped bass. The average total length of striped bass sampled from the spring trophy fishery was 990 mm total length. The average weight was 11.0 kg. Striped bass sampled from the spring trophy fishery ranged in age from 8 to 19 years old. In 2019, there were five year-classes representing greater than 10% of the sample: Age 9 – 2010 year-class (18.3%), Age 10 – 2009 year-class (22.7%), Age 12 - 2007 year-class (21.8%), Age 14 - 2005 year-class (10.1%) and Age 16 – 2003 year-class (10.1%). In 2019, private boats caught an average of 0.6 fish per trip, similar to 2015 while charter boats caught 3.8 fish per trip. The private boat catch per hour (CPH) was 0.1 fish per hour while charter boats had a CPH of 0.6 fish per hour.

Maryland Department of Natural Resources staff continued to tag and release striped bass in spring 2019 in support of the US FWS coordinated interstate, coastal population study. A total of 2,146 striped bass were sampled and a total of 1,104 striped bass were tagged and released with US FWS internal anchor tags between April 2and May 20, 2019 in Maryland. Of this sample, 306 were tagged in the Potomac River and 798 were tagged in the upper Chesapeake Bay area during the spring spawning stock assessment survey. A total of 89 striped bass were tagged during the US FWS cooperative offshore tagging cruise in 2019.

APPROVAL

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Maryland Department of Natural Resources

ACKNOWLEDGEMENTS

The Maryland Department of Natural Resources (MD DNR) would like to thank the Maryland Watermen's Association commercial captains and their crews who allowed us to sample their commercial harvest. We also wish to thank RMC Environmental Services personnel for their aid in acquiring tag returns and catch data from the fish lifts at Conowingo Dam. Appreciation is also extended to MD DNR Hatchery personnel, Brian Richardson and staff for otolith analysis of juvenile and adult American shad and to Connie Lewis, Fisheries Statistics, for providing commercial landings.

Striped bass were sampled for portions of this study from commercial pound nets owned and operated by Maryland Watermen's Association commercial captains and their crews and from numerous commercial striped bass check stations. Striped bass were collected from the Atlantic Ocean trawl and gill net fisheries by Gary Tyler and Steve Doctor. Experimental drift gill nets were operated by B. Owen Clark, III on the Upper Chesapeake Bay and Robert A. Boarman, on the Potomac River.

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CONTENTS

SURVEY TITLE: CHESAPEAKE BAY FINFISH INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 1
JOB NO. 1

POPULATION VITAL RATES OF RESIDENT FINFISH IN SELECTED TIDAL AREAS OF MARYLAND'S CHESAPEAKE BAY

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The primary objective of Job 1 was to provide data and analysis from routine monitoring of the following resident species: white perch (*Morone americana*), yellow perch (*Perca flavescens*), channel catfish (*Ictalurus punctatus*) and white catfish (*Ameiurus catus*) from selected tributaries in the Maryland portion of Chesapeake Bay. In order to update finfish population assessments and management plans, data on population vital rates should be current and clearly defined. Population vital rates include growth, mortality, and recruitment. Efficiency is often lacking when updating or initiating assessments because data are rarely compiled and synopsized in one convenient source. Data collected in an antecedent survey (MULTIFISH, F-54-R) have proved invaluable in compiling technical reports and providing the basis for sound management recommendations for these species. This job will enhance this efficiency by detailing current results of routine monitoring.

METHODS

I. Field Operations

Upper Chesapeake Bay Winter Trawl

The upper Chesapeake Bay winter bottom trawl survey is designed to collect fishery-independent data for the assessment of population trends of white perch, yellow perch, channel catfish and white catfish. Upper Chesapeake Bay was divided into five sampling areas; Sassafras River (SAS; 3 sites), Elk River (EB; 4 sites), upper Chesapeake Bay (UB; 6 sites), middle Chesapeake Bay (MB; 4 sites), and Chester River (CSR; 6 sites). The 23 sampling stations were approximately 2.6 km (1.5 miles) in length and variable in width (Figure 1). Each sampling station was divided into east/west or north/south halves by drawing a line parallel to the shipping channel. Sampling depth was divided into two strata; shallow water (< 6 m) and deep water (>6 m). Each site visit was then randomized for depth strata and the north/south or east/west directional components.

The winter trawl survey employed a 7.6 m wide bottom trawl consisting of 7.6 cm stretch-mesh body, 1.9 cm stretch-mesh in the cod end and a 1.3 cm stretch-mesh liner. Following the 10-minute tow at approximately 2.5 knots, the trawl was retrieved into the boat by winch and the catch emptied into either a culling board or large tub if catches were large. A minimum of 50 fish per species were sexed and measured. Non-random samples of yellow perch and white perch were sacrificed for otolith extraction and subsequent age determination. All species caught were identified and counted. If catches were prohibitively large to process, total numbers were extrapolated from volumetric counts. Volumetric subsamples were taken from the top of the tub, the middle of the tub, and the bottom of the tub. Six sampling rounds were scheduled from early January 2019 through February 2019.

Trawl sites have been consistent throughout the survey, but Chester River sites were added in 2011 and weather and operational issues caused incomplete sampling in some years. The 2003 survey was hampered by ice conditions such that only one of six rounds was completed. Retirement of the captain of the R/V Laidly during 2004 led to no rounds being completed. Only 1-½ rounds of the scheduled six rounds were completed in 2005 because of catastrophic engine failure. Ice-cover prevented the final two rounds of the 2007 survey and one round of the 2009 from being completed. Ice conditions also affected the 2010 and 2011 sample years where only 56 and 66 of the scheduled 108 trawls were completed, respectively. In 2013, ice-cover prevented the sampling of several Upper Bay sites allowing the completion of 86 of the scheduled 108 hauls. In 2014 and 2015, ice-cover once again prevented the sampling of several Upper Bay sites allowing the completion of 60 of the scheduled 108 hauls in 2014 and 107 of the

144 hauls in 2015. During 2017 and 2018, 137 and 129 of the scheduled 138 trawls were completed, respectively. The 2019 sampling season was hindered by the federal government budgetary shut down because the vessel utilized is a federal vessel. Sixty-three of the 138 trawl samples were completed. Various assessments utilized these data, and generally 2003 – 2005 were the only years where data accuracy was likely compromised due to small sample sizes.

Choptank River Fishery Independent Sampling

In 2019, six experimental fyke nets were set in the Choptank River to sample the four target species. Nets were set at river kilometers 63.6, 65.4, 66.6, 72.5, 74.4 and 78.1 and were fished two to three times per week from 22 February 2019 through 10 April 2019 (Figure 2). These nets contained a 64 mm stretch-mesh body and 76 mm stretch-mesh in the wings (7.6 m long) and leads (30.5 m long). Nets were set perpendicular to the shore with the wings at 45° angles.

Net hoops were brought aboard first to ensure that all fish were retained. Fish were then removed and placed into a tub and identified. All yellow perch and a subsample of up to 30 fish of each target species were sexed and measured. All non-target species were counted and released. Otoliths from a subsample of white perch and yellow perch were removed for age determination.

Upper Chesapeake Bay Fishery Dependent Sampling

Commercial fyke net catches were sampled for yellow perch on 26 and 28 February 2019 in the Gunpowder River (Figure 3) and on 23 February 2019 in the Bush River (Figure 4). All yellow perch were measured and sexed (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River Fishery Dependent Sampling

Resident species were sampled from pound nets and fyke nets set by commercial fishermen on the Nanticoke River from 1 March 2019 to 26 April 2019. This segment of the survey was completed in coordination with Project 2, Job 1 of this grant. Nets were set from Barren Creek (35.7 rkm) downstream to Monday's Gut (30.4 rkm; Figure 5). Net sites and dates fished were at the discretion of the commercial fishermen. Thirty randomly selected white perch from the fyke nets were sexed and measured and a subsample was processed for age determination (otoliths). A bushel of unculled, mixed catfish species was randomly selected, identified as channel catfish or white catfish and total lengths measured.

II. Data compilation

Population Age Structures

Population age structures were determined for yellow perch and white perch from the Choptank River, upper Chesapeake Bay trawl survey and yellow perch from the upper Bay commercial fyke net fishery. Population age structures were also determined for Nanticoke River white perch. Age-at-length keys for yellow perch and white perch (separated by sex) from the Choptank River fyke net survey, upper Bay commercial fyke net survey (yellow perch only), trawl survey and the Nanticoke River (white perch only) were constructed by determining the proportion-at-age per 20-mm length group. The proportion-at age for each length interval was multiplied by the total number-at-length from the entire sample for yellow perch from the upper Bay fyke net survey, the Nanticoke River white perch data and yellow perch from the Choptank River fyke net survey. The same was done for white perch from the trawl survey and the Choptank River fyke net survey, but the age-at-length key was applied to each individual haul/net lift and summed over the total sample. For the upper Bay trawl survey, the yellow perch age-length key was constructed in 10 mm increments and the age-at-length key was applied to individual hauls.

Length-frequency

Relative stock density (RSD) was used to describe length structures for white perch, yellow perch, channel catfish and white catfish. Gablehouse (1984) advocated incremental

RSD's to characterize fish length distributions. This method groups fish into five broad length categories: stock, quality, preferred, memorable and trophy. The minimum length of each category is based on all-tackle world records such that the minimum stock length is 20 - 26% of the world record length (WRL), minimum quality length is 36 - 41% of the WRL, minimum preferred length is 45 - 55% of the WRL, minimum memorable length is 59 - 64% of the WRL and minimum trophy length is 74 - 80% of the WRL. Minimum lengths were assigned from either the cut-offs listed by Gablehouse et al (1984) or were derived from world record lengths as recorded by the International Game Fish Association. Current length-frequency histograms were produced for all target species encountered.

Growth

Growth in length and weight was determined for yellow perch (the Choptank River and upper Chesapeake Bay) and white perch (Choptank and Nanticoke rivers). Growth in length over time and weight in relation to length were described with standard fishery equations. The allometric growth equation (weight (g) = α*length (mmTL)$^{\beta}$) described weight change as a function of length, and the vonBertalanffy growth equation (Length=$L_{\infty}(1-e^{-K(t-t_0)})$) described change in length with respect to age. Both equations were fit for white perch and yellow perch males, females, and sexes combined with SAS nonlinear procedures. Growth data for target species encountered in the trawl survey were not compiled due to the size selectivity of the gear. Length curve parameters have been compromised by a lack of younger fish in the collections due to size selectivity of the gear. This usually manifests in low t_0 and K values in the vonBertalanffy solutions. In order to mitigate these biases, we included average sizes of young of year target species collected in either the EJFS seine survey or upper Bay trawl survey within each target system, by month.

Mortality

White perch instantaneous fishing mortality (F) estimates were determined in Piavis and Webb (2018) for the Choptank River and upper Chesapeake Bay through 2016. Estimated F for 2017 through 2019 in the Choptank River and upper Bay, along with the entire Nanticoke River time series were determined from length converted catch curves (Pauly 1984; Huynh et al 2018). This method uses vonBertalanffy parameters L_∞ and K to form a relative age of each length interval. Appropriate annual estimates of the growth parameters by system were utilized. The regression slope of $\log_e$ abundance over a range of relative ages was the estimate of Z and F was Z-M.

Choptank River yellow perch mortality was estimated with a catch curve analysis of $\log_e$ transformed catches of ages 4 – oldest age captured. The slope of the line was –Z and M was assumed to be 0.25. Instantaneous fishing mortality (F) was Z-M. The wildly unequal recruitment and annual changes in catchability proved difficult to overcome in estimating the Choptank River mortality. Instantaneous mortality rates for yellow perch from the upper Bay were calculated with a statistical catch-at-age model (Piavis and Webb 2020) which is updated annually to produce a total allowable catch for the fishery.

Recruitment

Recruitment data were provided from age 1 relative abundance in the winter trawl survey and young-of-year relative abundance from the Estuarine Juvenile Finfish Survey (EJFS; see Project 2, Job2, Task 3 of this report). Cohort splitting was used to determine age 1 abundance in the winter trawl survey. Any yellow perch < 130 mm, white perch < 110 mm, and channel catfish < 135 mm were assumed to be one-year old fish. Since white catfish abundance was not well represented in the upper Bay trawl catches, data were not compiled for this species.

Previous yellow perch assessments indicated a suite of selected head-of-bay sites from the EJFS provided a good index of juvenile abundance. Therefore, only the Howell Pt., Sassafras River Natural Resources Management Area, Handy's Creek, Elk Neck Park, Parlor Pt., and Welch Pt. permanent sites were used to determine the yellow perch juvenile relative abundance index. The index is reported as an average $\log_e$ (catch+1) index. White perch juvenile relative abundance was the geometric mean (GM) abundance from all baywide permanent sites. Sites and methodology are reported in Project 2 Job 3 Task 3 of this report.

<u>Relative Abundance</u>

Relative abundance of catfish species from the Choptank River fyke net survey was determined as the average of the ratio of individual net catch per effort (N/soak time in days). For white perch and yellow perch, relative abundance at age was determined from the catch-at-age matrices. Fyke net effort for yellow perch from the Choptank River fyke net survey was defined as the amount of effort needed to collect 95% of each year's catch. This is necessary to ameliorate the effects of effort expended to catch white perch after the main yellow perch spawning run. The CPUE at age matrix included all yellow perch encountered. Prior to 1993, all sampling began 1 March, but the start date has varied since 1993 (usually beginning mid-February). In order to standardize data for time-trend analysis, CPUE from 1 March to the 95% catch end time was utilized. An exception was made for 2017 because of the extraordinarily warm winter. When nets were first fished on 23 February 2017, a large proportion of the female yellow perch were spent. Therefore, the 2017 index included February's catch and effort.

Relative abundance was also determined for target species from the winter trawl survey. Numbers at age (for yellow perch and white perch) per tow were divided by distance towed, standardized to 1 statue mile. The index was the average catch-at-age per 1 statute mile. For channel catfish, relative abundance was average catch per statute mile, *i.e.*, channel catfish were not aged. The results from the Chester River sites were incorporated into the tables and figures for white perch and channel catfish. A cursory examination of CPUE's from the traditional Bay sites and the Chester River showed that these CPUE's were very similar. However, catches of yellow perch were very low, and it appeared that the sites selected in Chester River are not informative for yellow perch abundance. Yellow perch CPUE is still reported as relative abundance from the original 18 sites.

RESULTS

Data are summarized either in tables or figures organized by data type (age structure, length structure, etc.), species, and survey. Data summaries are provided in these locations:

Population Age Structures

White perch	Tables 1-3
Yellow perch	Tables 3-6

Population Length Structures

White perch	Tables 7-9 and Figures 6-8
Yellow perch	Tables 10-12 and Figures 9-11
Channel catfish	Tables 13-15 and Figures 12-14
White catfish	Tables 16-18 and Figures 15-17

Growth

White perch	Tables 19-20
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Mortality

White perch	Table 23
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Recruitment

White perch	Figures 18-19
Yellow perch	Figures 20-21
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Relative Abundance

White perch	Tables 25-26
Yellow perch	Tables 27-28 and Figure 23
Channel catfish	Figures 24-25
White catfish	Figure 27

PROJECT NO. 1
JOB NO. 1

POPULATION VITAL RATES OF RESIDENT FINFISH IN SELECTED TIDAL AREAS OF MARYLAND'S CHESAPEAKE BAY

2020 PRELIMINARY RESULTS – WORK IN PROGRESS

Project 1 Job 1 is designed to be a clearing house for data collected in the winter/spring for resident species including yellow perch, white perch, channel catfish and white catfish. The project completed the winter trawl survey (upper Chesapeake Bay), commercial yellow perch fishery monitoring, which is essential for the full population analysis, and the Choptank River fishery independent fyke net survey.

The winter trawl completed 134 of the 138 proposed tows. The trawl survey began January 6, 2020 and concluded on February 20, 2020. The survey collected 51,820 white perch, yielding 4,419 length measurements and 117 age samples (otoliths). Yellow perch numbered 881 with 573 length measurements and 81 age samples (otoliths). The catfish complex yielded 6,549 channel catfish (1,409 measurements), 901 white catfish (475 measurements) and 2,647 blue catfish (686 measurements).

Three sampling days were allocated to characterize the commercial yellow perch fishery. However, 3,961 yellow perch were measured and 191 fish were sacrificed for age determination. Areas sampled included the Gunpowder River (March 1 and 10, 2020) and the Bush River (March 6, 2020).

The Choptank River fyke net survey started February 22, 2020 and ended March 17, 2020. The end date was at least three weeks earlier than anticipated due to a work at home order prompted by the coronavirus outbreak. A substantial portion of the white perch run was likely missed. A total of 6,430 white perch were collected, yielding 1,338 length measurements and 187 age samples. Yellow perch numbered 1,995 (1,995 measurements and 166 ages); channel catfish numbered 367 (367 measurements) and white catfish numbered 378 (349 length measurements). Invasive blue catfish were also encountered (13 total, 13 length).

In addition to these surveys, Job 1 tabulates data from the Nanticoke River Alosid survey from white perch, channel and white catfish collections. The invasive blue catfish are also encountered frequently, and although blue catfish are not a species of interest in this grant, length data are collected. However, this survey was impacted by the coronavirus stay at home order and data from 2020 will not be forthcoming.

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Figure 1. Upper Chesapeake Bay winter trawl survey locations, January 2019 – February 2019. Different symbols indicate each of 4 different sampling rounds.

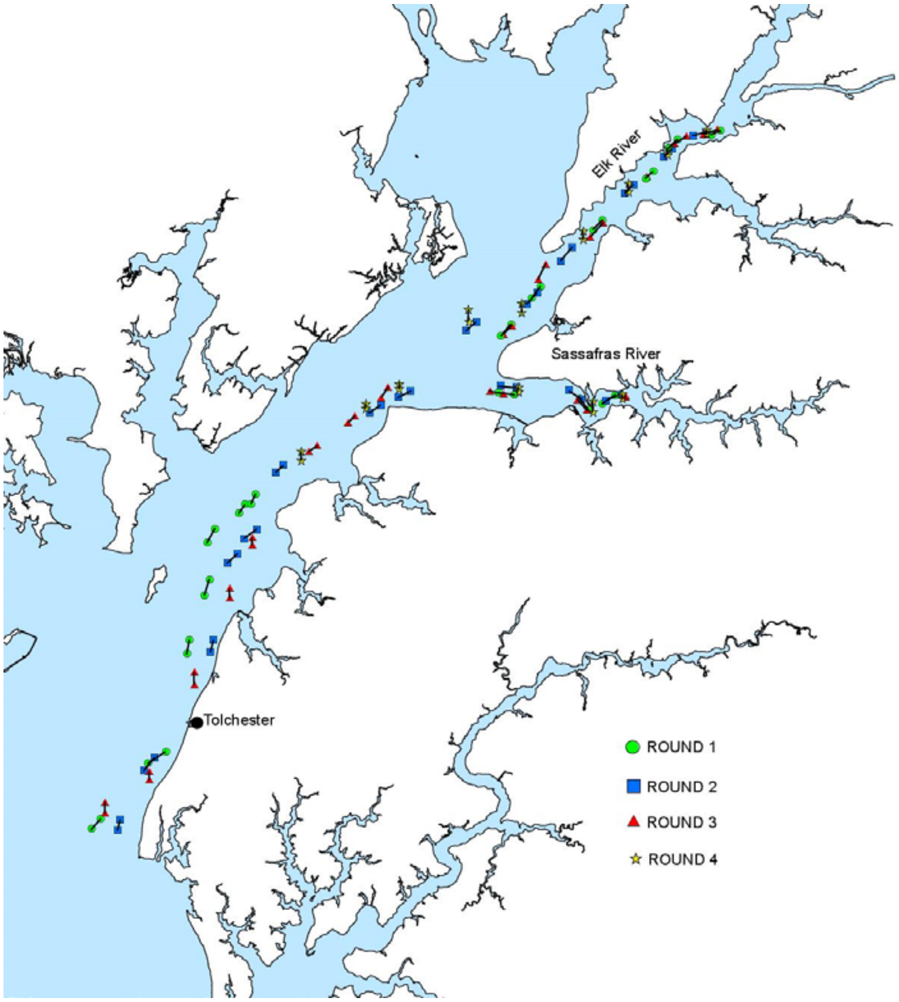


Figure 2. Choptank River fyke net locations, 2019. Circles indicate sites.

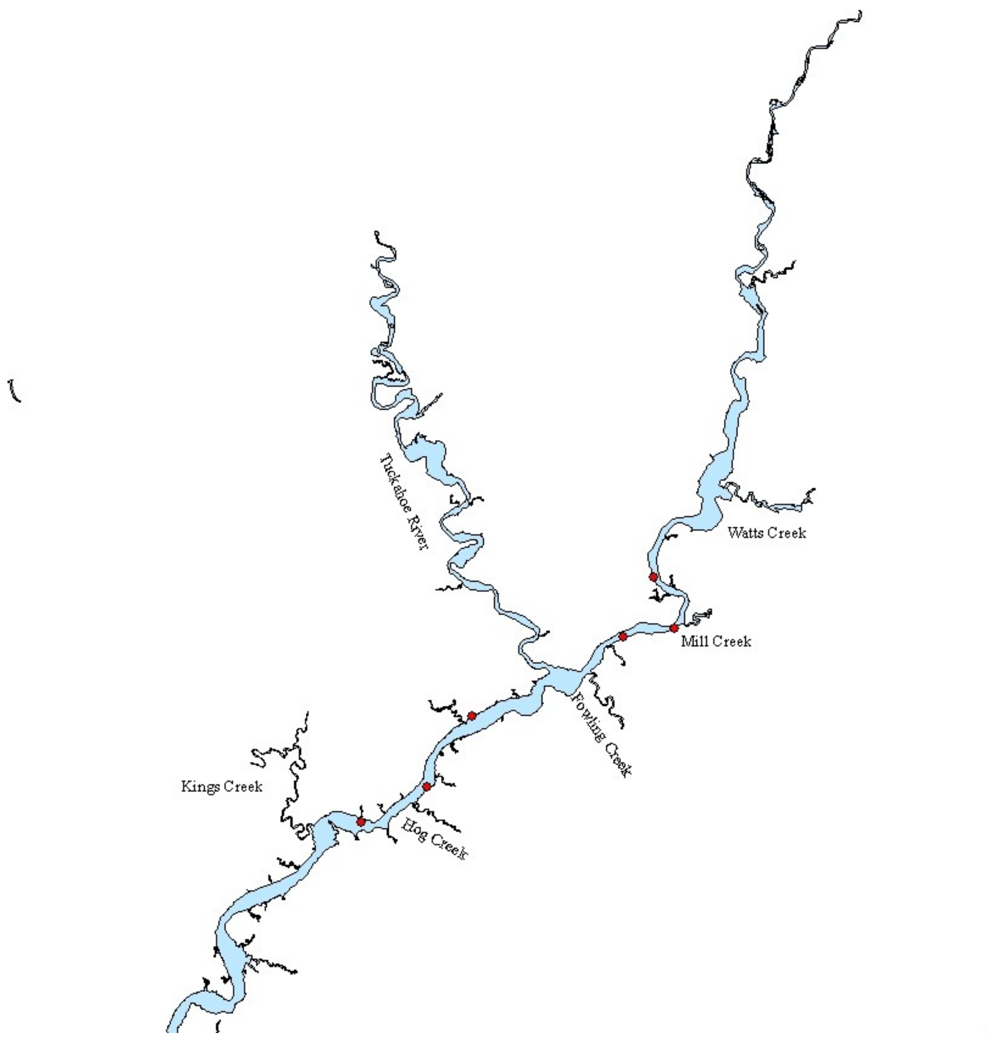


Figure 3. Commercial yellow perch fyke net sites sampled during 2019 in Gunpowder River. Circles indicate sites.

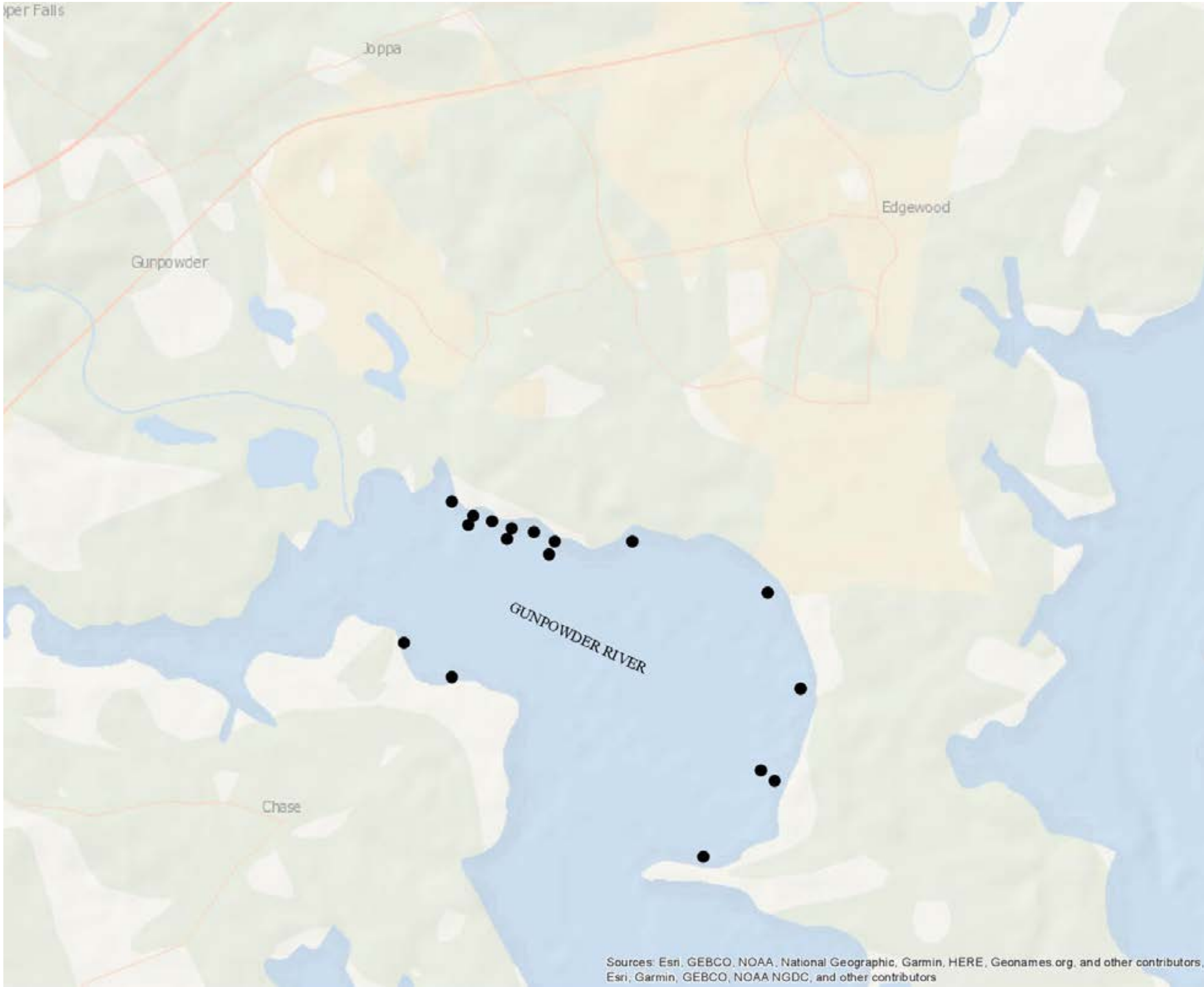


Figure 4. Commercial yellow perch fyke net sites sampled during 2019 in Bush River. Circles indicate fyke net locations.

Figure 5. Commercial fyke net and pound net sites sampled during 2019 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

Table 1. White perch catch-at-age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2019.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
2000	1,321	9,382	4,256	2,751	1,034	616	845	93	88	55
2001	2,796	5,375	8,628	1,658	2,519	547	1,321	1,402	324	199
2002	17,571	150	3,670	1,516	2,359	1,006	1,947	1,067	277	638
2003	1,655	3,123	573	263	365	419	1,479	33		197
2004	NOT SAMPLED									
2005	973	1,684	460	846	216	77	25	242	28	12
2006	9,597	3,172	7,589	2,283	1,680	469	285	281	65	130
2007	2,521	1,699	1,229	2,408	1,387	335	381	30	26	133
2008	16,173	2,715	6,995	5,269	1,654	571	229	252	93	93
2009	5,838	16,227	686	2,969	5,588	4,716	113	1,628	344	67
2010	4,943	2,679	4,591	159	3,205	1,184	1,963	154	252	388
2011	2,569	3,044	2,164	2,916	710	1,614	884	896	50	153
2012	10,231	3,532	1,713	840	873	938	1,695	756	1,016	304
2013	6,748	7,475	938	2,073	1,888	9,127	1,112	1,343	316	837
2014	2,604	1,587	14,973	2,492	1,661	804	1,664	605	346	604
2015	20,752	13,909	16,529	30,783	6,733	3,506	3,670	4,446	2,513	2,648
2016	32,999	22,876	22,391	11,261	11,165	4,312	1,718	451	1,153	2,398
2017	3,795	40,101	16,261	4,525	1,634	10,664	731	1,491	589	1,758
2018	11,209	7,223	37,094	23,942	1,205	3,402	6,969	917	749	92
2019	5,241	2,366	1,484	3,717	1,938	366	537	875	344	124

Table 2. White perch catch-at-age matrix from Choptank River fyke net survey, 2000 – 2019.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
2000	0	1	1,573	9,923	9,671	1,709	6,212	576	404	0
2001	0	2,177	4,947	14,849	11,090	8,135	1,305	3,399	474	0
2002	0	650	2,390	8,708	5,007	5,626	1,065	1,883	818	30
2003	0	572	9,594	8,773	8,684	364	7,217	1,881	835	834
2004	0	98	9,118	3,083	3,531	4,310	325	2,401	863	559
2005	0	801	3,759	12,029	7,543	4,687	1,682	397	2,531	116
2006	0	402	16,863	816	8,175	4,051	440	515	305	4,013
2007	0	258	1,931	25,125	2,719	11,741	4,194	1,655	1,834	1,452
2008	0	95	5,643	4,387	13,435	1,153	4,592	2,610	478	1,048
2009	0	369	149	5,220	1,427	9,501	1,150	1,793	1,021	650
2010	0	246	4,691	730	12,145	4,258	13,037	1,617	2,170	1,155
2011	0	21	247	5,313	844	5,080	3,115	3,824	553	1,027
2012	0	25	1,190	595	2,412	1,053	1,394	572	1,075	289
2013	0	2,794	2,706	4,060	562	1,639	378	2,649	728	1,767
2014	0	403	12,670	1,122	868	1,213	1,715	1,119	2,264	1,676
2015	0	0	0	22,945	1,654	3,706	1,666	571	293	1,432
2016	0	1,981	1,438	5	11,544	1,182	640	169	130	175
2017	0	3,805	5,788	915	0	11,524	483	37	0	234
2018	0	146	14,560	4,539	284	530	8,629	159	195	35
2019	0	90	323	5,801	3,274	178	382	2,057	40	33

Table 3. White perch catch-at-age matrix from Nanticoke River fyke and pound net survey, 2000 – 2019. 2007 -- 2009 include Marshyhope River data.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
2000	0	42	593	6,074	6,471	2,813	1,942	365	81	0
2001	0	0	681	796	3,262	1,822	689	785	94	38
2002	0	5	1,469	1,927	504	2,124	1,132	632	244	135
2003	0	97	318	2,559	1,567	446	994	652	180	175
2004	0	6,930	3,892	12,215	3,259	1,835	1,297	1,361	443	886
2005	0	826	1,302	5,847	3,903	5,288	2,400	1,237	1,497	2,582
2006	0	0	5,759	3,280	5,298	3,488	3,590	1,287	861	799
2007	0	497	1,948	12,876	727	6,236	2,260	2,716	977	1,573
2008	0	33	902	1,188	2,780	824	1,457	665	593	496
2009	0	70	1,351	4,135	2,117	6,216	1,188	1,651	889	1,470
2010	0	101	273	155	414	315	1,113	88	143	166
2011	0	933	1,625	7,817	1,167	4,433	1,750	5,133	1.050	3,034
2012	4	134	387	176	539	214	330	57	276	85
2013	5	418	1,342	1,587	270	615	433	671	207	723
2014	0	0	1,511	1,444	1,191	372	601	154	464	531
2015	NOT SAMPLED									
2016	10	630	2,627	140	12,472	2,982	1,410	128	266	693
2017	0	386	3,033	2,490	0	6,305	1,054	795	24	361
2018	0	25	481	1,483	483	114	1,104	128	41	13
2019	0	177	260	2,763	3,460	1,223	259	1,165	60	189

Table 4. Yellow perch catch at age from upper Chesapeake Bay winter trawl survey, 2000 – 2019.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
2000	44	77	13	85	3	15	4	0	0	5
2001	669	43	78	12	44	3	0	3	0	0
2002	1,170	847	83	178	14	86	0	8	4	0
2003	343	985	3,050	327	437	28	175	0	14	0
2004	NOT SAMPLED									
2005	446	320	0	70	9	0	0	0	0	0
2006	1,580	1,738	738	0	146	18	0	15	0	0
2007	167	150	385	112	71	26	2	0	0	0
2008	1,053	256	572	504	131	0	0	0	0	0
2009	215	1,051	54	117	105	23	1	0	0	0
2010	862	101	260	18	28	11	6	0	2	0
2011	51	185	29	118	0	15	6	0	0	0
2012	1,138	464	156	6	9	5	0	45	0	0
2013	135	262	77	32	1	1	1	0	1	0
2014	97	0	495	217	24	0	2	3	3	0
2015	1,144	48	0	692	74	19	0	0	0	0
2016	1,876	1,387	264	15	179	23	10	0	0	0
2017	244	1,364	443	0	0	64	5	0	0	0
2018	171	72	532	154	0	0	4	0	0	0
2019	766	31	20	94	13	0	0	0	0	0

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2019.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
1988	0	9	268	9	2	21	19	1	1	5
1989	0	0	80	234	81	41	8	2	2	0
1990	0	22	179	82	273	53	10	8	5	1
1991	0	7	41	53	18	44	9	2	2	0
1992	0	1	8	14	15	7	6	0	0	0
1993	0	3	75	150	98	109	37	7	4	0
1994	0	42	158	25	81	87	78	64	5	18
1995	0	79	258	23	68	67	42	37	5	21
1996	0	857	343	267	35	81	47	27	43	9
1997	0	14	641	99	86	0	19	24	8	0
1998	0	142	77	583	26	31	0	8	3	17
1999	0	306	8,514	86	3,148	32	9	8	0	6
2000	0	329	92	1,378	27	140	0	7	0	0
2001	0	878	1,986	102	1,139	19	72	2	0	0
2002	0	334	1,336	1,169	38	430	104	51	3	0
2003	0	369	440	922	333	34	226	35	32	2
2004	0	60	504	177	120	103	0	61	0	7
2005	0	1,667	137	416	134	55	140	23	52	15
2006	0	173	1,858	176	395	64	66	42	0	7
2007	0	1,512	737	1,560	33	182	109	28	10	12
2008	0	39	1,303	130	326	13	49	20	0	0
2009	0	0	866	2,119	140	127	23	3	0	6
2010	0	48	104	1,045	2,410	52	162	0	9	0
2011	0	193	0	40	721	882	53	109	0	0
2012	50	255	1,088	20	0	259	578	5	12	0
2013	0	178	159	469	13	17	64	114	0	4
2014	0	0	1,626	937	419	5	0	2	39	9
2015	0	186	24	2,635	426	117	4	2	13	3
2016	0	397	137	62	3,908	542	362	43	3	21
2017	0	147	375	139	5	962	213	105	0	18
2018	0	33	2,033	571	62	29	630	101	55	0
2019	0	33	101	907	168	7	4	113	3	14

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2019.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
1999	0	0	1,621	33	337	408	28	0	2	0
2000	0	35	138	2937	129	369	211	0	0	0
2001	0	0	83	90	432	17	9	17	0	0
2002	0	52	117	528	56	1,000	14	39	53	0
2003	0	27	565	78	361	45	418	6	15	25
2004	0	4	473	499	62	50	3	43	2	2
2005	0	18	27	1,320	414	73	37	0	26	5
2006	0	32	476	9	848	245	0	1	10	0
2007	0	2	290	1,400	23	548	168	3	0	14
2008	0	70	3,855	3,782	4,820	75	789	149	14	2
2009	0	87	128	663	490	648	5	80	35	0
2010	0	3	356	125	274	281	260	0	23	0
2011	0	41	56	703	152	355	183	102	0	0
2012	0	19	462	38	548	14	244	99	54	35
2013	0	83	469	1,143	110	392	43	45	8	14
2014	0	2	846	553	212	45	85	10	35	21
2015	0	25	33	1,356	685	277	0	16	32	32
2016	0	387	45	29	1,792	528	416	0	0	33
2017	0	136	2,282	0	0	1,080	234	194	0	0
2018	0	0	2,123	1,422	6	0	83	8	0	0
2019	0	0	68	2,010	2,235	2	10	192	2	0

Table 7. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2019. Minimum length cut-offs in parentheses.

Year	Stock (125 mm)	Quality (200 mm)	Preferred (255 mm)	Memorable (305 mm)	Trophy (380 mm)
2000	76.9	22.1	0.9	0.1	0.0
2001	89.8	9.9	0.3	0.0	0.0
2002	87.1	12.0	0.8	0.0	0.0
2003	83.6	14.3	1.2	0.5	0.0
2004	NOT SAMPLED				
2005	83.9	16.1	0.0	0.0	0.0
2006	88.4	10.8	0.1	<0.1	0.0
2007	92.3	7.0	0.7	0.0	0.0
2008	91.2	8.2	0.6	0.0	0.0
2009	92.0	7.3	0.6	0.0	0.0
2010	89.6	9.7	0.7	0.0	0.0
2011	87.2	11.6	1.2	0.0	0.0
2012	86.4	12.7	0.9	0.0	<0.1
2013	88.3	11.1	0.6	0.0	0.0
2014	92.8	6.7	0.4	0.1	0.0
2015	93.5	6.2	0.3	0.0	0.0
2016	89.7	9.9	0.3	0.1	0.0
2017	93.0	6.6	0.4	0.0	0.0
2018	92.5	6.6	0.9	0.0	0.0
2019	90.7	9.2	0.1	0.0	0.0

Figure 6. White perch length-frequency from 2019 upper Chesapeake Bay winter trawl survey.

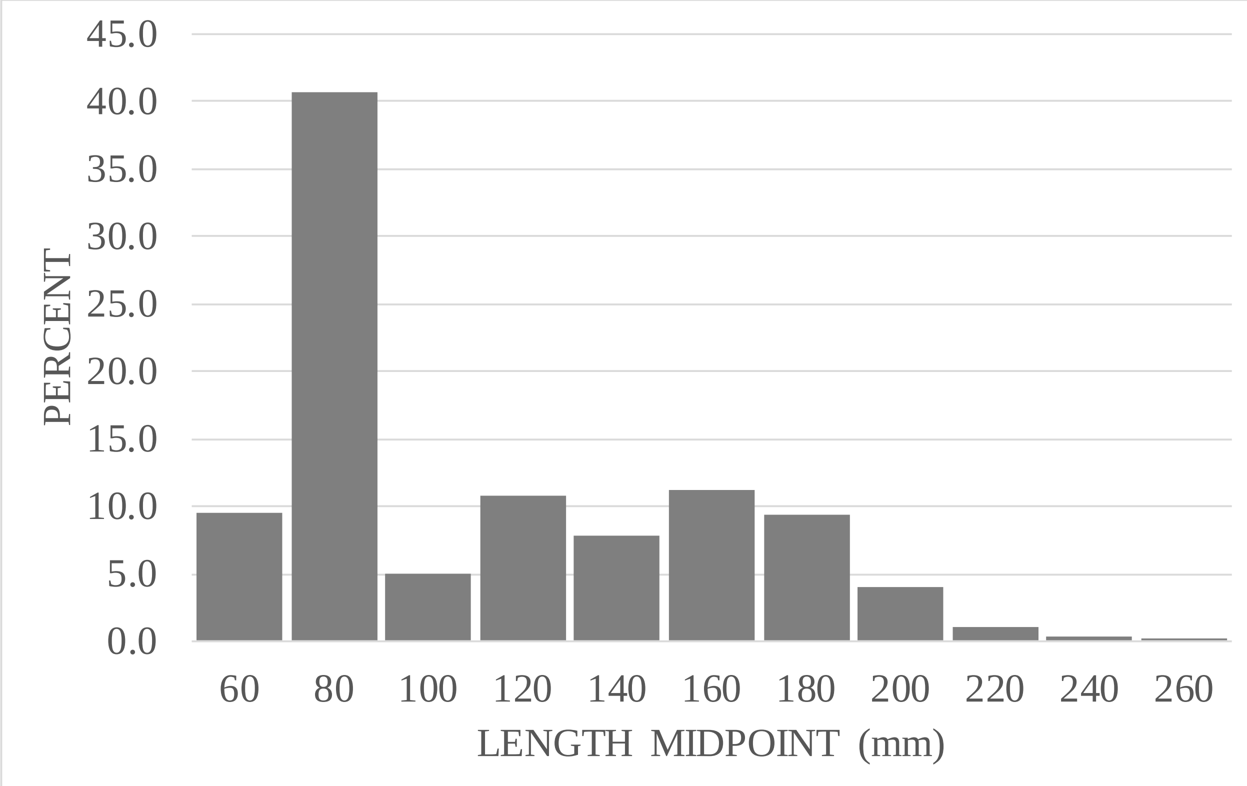


Table 8. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2019. Minimum length cut-offs in parentheses.

Year	Stock (125 mm)	Quality (200 mm)	Preferred (255 mm)	Memorable (305 mm)	Trophy (380 mm)
1993	72.5	25.0	2.4	0.1	0.0
1994	76.8	21.3	1.8	0.1	0.0
1995	84.3	14.9	0.8	0.0	0.0
1996	86.4	13.1	0.5	0.0	0.0
1997	80.0	19.1	0.8	0.1	0.0
1998	71.9	26.2	1.8	<0.1	0.0
1999	80.2	18.7	1.1	<0.1	0.0
2000	72.0	25.9	2.1	0.0	0.0
2001	84.6	14.4	1.0	0.0	0.0
2002	71.6	26.6	1.7	0.1	0.0
2003	76.4	22.2	1.3	0.1	0.0
2004	75.6	23.6	1.0	0.1	0.0
2005	78.5	19.9	1.5	0.1	0.0
2006	70.5	26.7	2.7	<0.1	0.0
2007	76.5	21.7	1.7	0.0	0.0
2008	73.8	24.9	1.2	<0.1	0.0
2009	73.0	25.5	1.4	0.1	0.0
2010	62.3	35.0	2.7	<0.1	0.0
2011	63.0	33.5	3.2	0.3	0.0
2012	51.9	42.9	4.9	0.2	0.0
2013	59.1	36.5	4.1	0.3	0.0
2014	76.0	21.7	2.1	0.2	0.0
2015	80.3	18.4	1.3	0.0	0.0
2016	48.0	46.5	5.2	0.3	0.0
2017	55.5	38.6	5.7	0.2	0.0
2018	56.0	40.9	3.0	0.4	0.0
2019	56.9	40.1	2.8	0.2	0.0

Figure 7. White perch length-frequency from 2019 Choptank River fyke net survey.

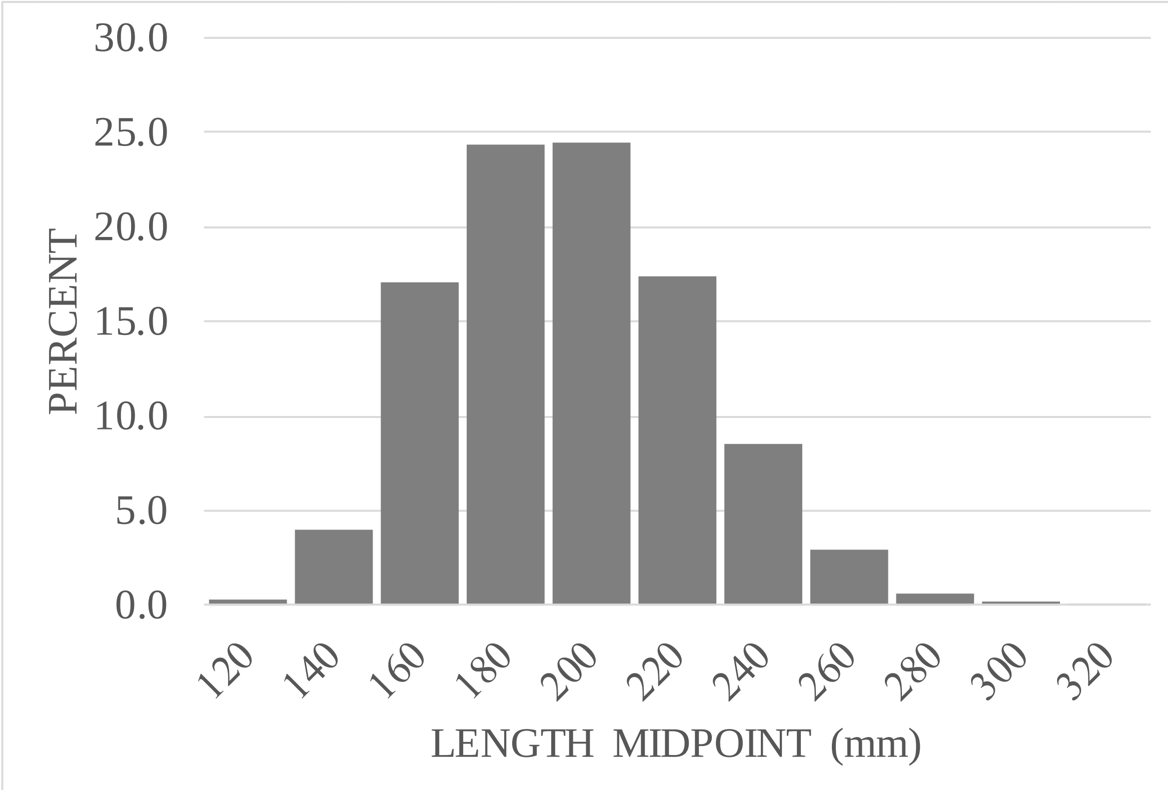


Table 9. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2019. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

Year	**Stock** (125 mm)	**Quality** (200 mm)	**Preferred** (255 mm)	**Memorable** (305 mm)	**Trophy** (380 mm)
1995	56.3	35.4	5.2	3.0	0.0
1996	37.8	54.2	7.3	0.7	0.0
1997	37.5	58.4	4.0	<0.1	0.0
1998	30.4	63.1	6.4	<0.1	0.0
1999	37.2	57.7	5.0	<0.1	0.0
2000	31.3	58.9	9.7	<0.1	0.0
2001	26.2	60.7	12.5	0.6	0.0
2002	32.4	52.9	14.3	0.4	0.0
2003	26.4	60.6	11.9	1.1	0.0
2004	23.0	61.0	14.0	2.0	0.0
2005	25.3	52.8	19.3	2.6	0.0
2006	26.1	56.7	16.3	<0.1	0.0
2007	36.3	52.4	10.0	1.4	0.0
2008	36.2	50.9	12.2	0.7	0.0
2009	33.6	53.2	12.2	1.0	0.0
2010	22.0	53.6	23.1	1.1	0.2
2011	25.1	53.0	19.1	2.7	0.0
2012	30.4	47.7	19.9	2.0	0.0
2013	23.6	49.8	23.2	3.4	0.0
2014	30.7	54.7	13.1	1.5	0.0
2015	NOT SAMPLED				
2016	22.4	60.8	15.7	1.2	0.0
2017	17.4	65.0	16.0	1.6	0.0
2018	44.3	40.6	14.8	0.3	0.0
2019	23.9	63.6	11.9	0.6	0.0

Figure 8. White perch length-frequency from 2019 Nanticoke River fyke and pound net survey.

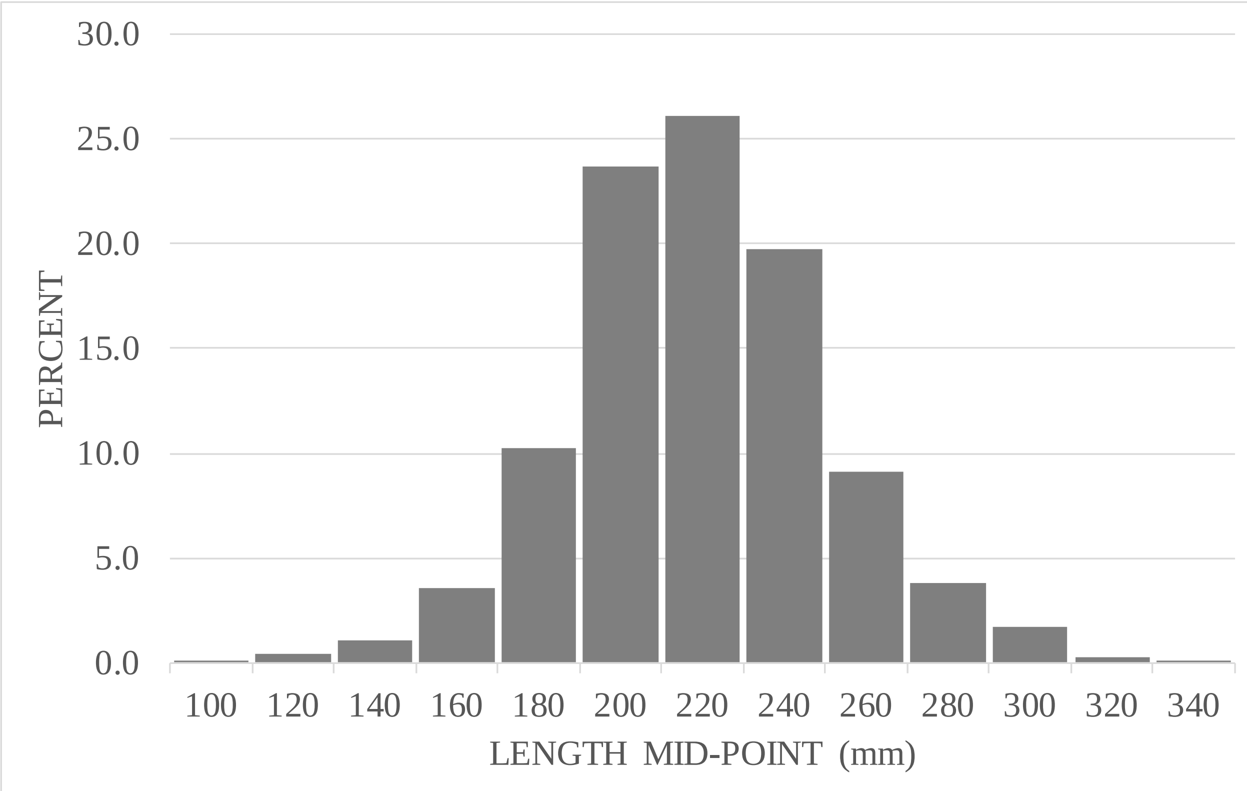


Table 10. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2019. Minimum length cut-offs in parentheses.

Year	**Stock** (140 mm)	**Quality** (216 mm)	**Preferred** (255 mm)	**Memorable** (318 mm)	**Trophy** (405 mm)
2000	84.2	14.3	1.5	0.0	0.0
2001	90.6	7.9	1.4	0.0	0.0
2002	87.8	10.7	1.5	0.0	0.0
2003	87.5	9.9	1.9	0.0	0.0
2004	NOT SAMPLED				
2005	98.6	1.4	0.0	0.0	0.0
2006	97.7	1.7	0.5	0.0	0.0
2007	98.7	0.4	0.8	0.0	0.0
2008	94.2	4.6	1.2	0.0	0.0
2009	93.4	4.6	2.0	0.0	0.0
2010	80.7	16.7	2.6	0.0	0.0
2011	83.7	12.8	3.5	0.0	0.0
2012	92.6	5.9	1.5	0.0	0.0
2013	96.4	3.2	0.4	0.0	0.0
2014	94.9	4.3	0.8	0.0	0.0
2015	83.5	15.2	1.3	0.0	0.0
2016	89.3	7.9	2.6	0.2	0.0
2017	96.2	2.8	1.0	0.0	0.0
2018	89.1	9.7	1.1	0.0	0.0
2019	85.6	12.9	1.5	0.0	0.0

Figure 9. Yellow perch length-frequency from the 2019 upper Chesapeake Bay winter trawl survey.

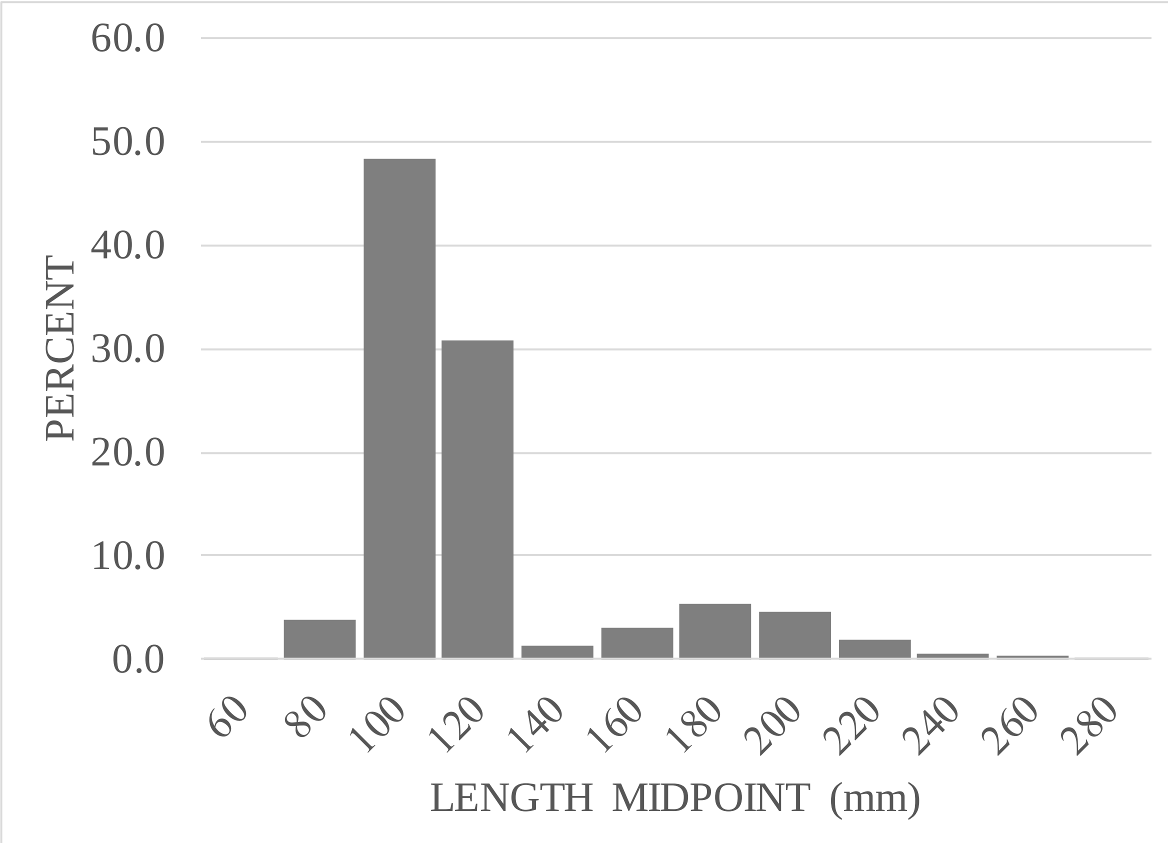


Table 11. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2019. Minimum length cut-offs in parentheses.

Year	Stock (140 mm)	Quality (216 mm)	Preferred (255 mm)	Memorable (318 mm)	Trophy (405 mm)
1989	66.7	24.4	8.2	0.7	0.0
1990	64.8	27.3	7.8	0.0	0.0
1991	58.7	23.4	18.0	0.0	0.0
1992	45.3	26.4	24.5	3.8	0.0
1993	34.6	31.7	30.3	3.3	0.0
1994	23.4	33.6	36.6	6.4	0.0
1995	45.5	28.1	23.1	3.3	0.0
1996	74.1	18.2	7.2	0.5	0.0
1997	57.5	29.3	12.9	0.3	0.0
1998	10.5	72.9	16	0.6	0.0
1999	86.0	12.4	2.4	<0.1	0.0
2000	71.6	19.0	9.1	0.2	0.0
2001	83.6	13.0	3.3	<0.1	0.0
2002	59.8	33.1	6.9	0.2	0.0
2003	67.0	27.4	5.4	0.2	0.0
2004	54.2	34.6	10.7	0.4	0.0
2005	75.1	17.2	7.4	0.2	0.0
2006	53.5	32.1	13.8	0.6	0.0
2007	74.9	15.0	9.9	0.2	0.0
2008	76.4	16.1	7.3	0.2	0.0
2009	77.3	17.4	5.1	<0.1	0.0
2010	64.3	25.6	10.0	0.1	0.0
2011	50.1	32.6	16.9	0.3	0.0
2012	51.5	30.8	16.7	1.0	0.0
2013	48.5	29.2	21.6	0.7	0.0
2014	79.9	13.9	6.0	0.2	0.0
2015	64.3	24.7	10.8	0.2	0.0
2016	49.5	30.4	19.8	0.4	0.0
2017	45.4	29.9	23.8	0.8	0.0
2018	65.4	24.6	9.6	0.3	0.0
2019	51.4	31.1	17.2	0.3	0.0

Figure 10. Yellow perch length-frequency from the 2019 Choptank River fyke net survey.

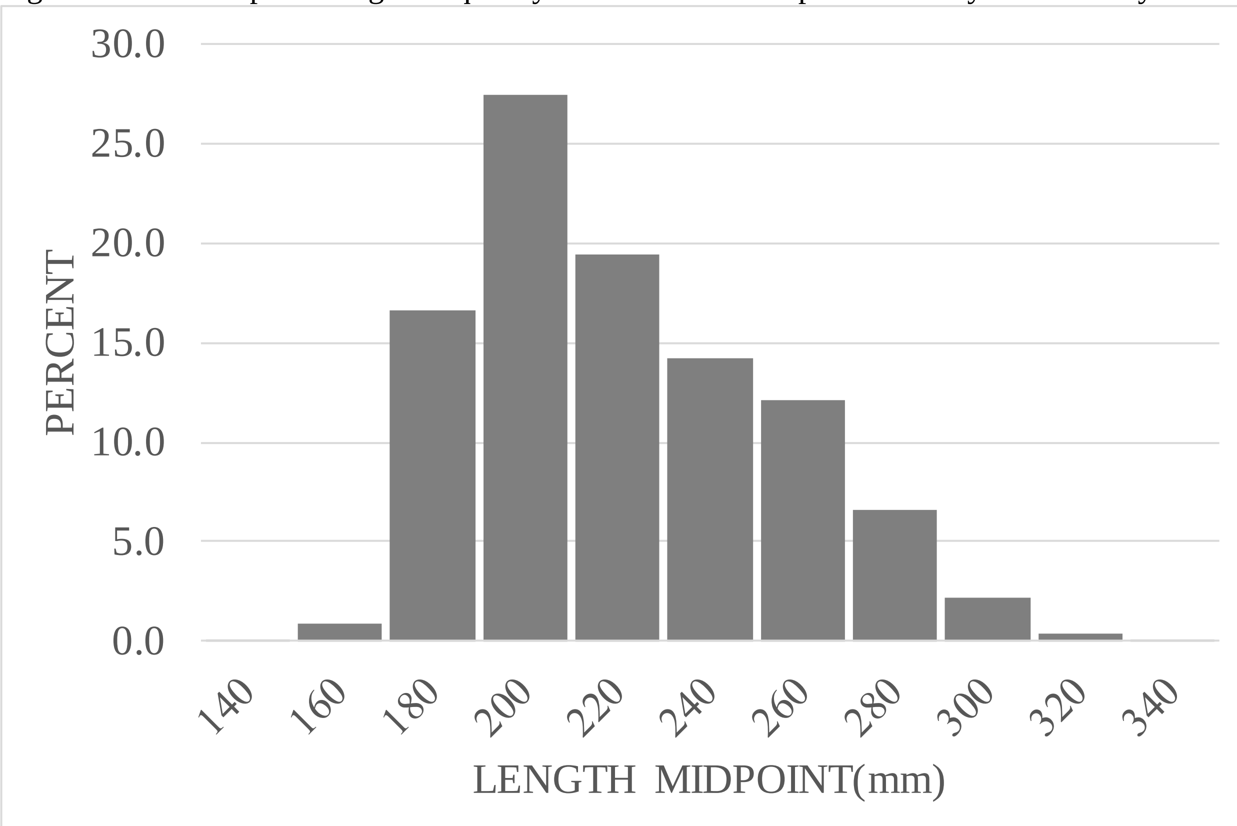


Table 12. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2019. Minimum length cut-offs in parentheses.

Year	**Stock** (140 mm)	**Quality** (216 mm)	**Preferred** (255 mm)	**Memorable** (318 mm)	**Trophy** (405 mm)
1988	71.8	25.3	3.1	0.0	0.0
1990	6.7	71.7	21	0.1	0.0
1998	24.2	51.0	24.7	<0.1	0.0
1999	40.2	52.3	7.3	0.2	0.0
2000	55.1	37.2	7.6	<0.1	0.0
2001	27.1	48.8	24.0	0.0	0.0
2002	17.8	63.1	18.9	0.2	0.0
2003	19.5	54.6	24.6	1.3	0.0
2004	9.6	66.3	23.8	0.3	0.0
2005	45.2	42.2	12.1	0.5	0.0
2006	35.0	52.8	12.0	0.2	0.0
2007	40.1	47.9	11.5	0.5	0.0
2008	31.6	55.3	13.0	0.1	0.0
2009	30.6	47.6	21.4	0.4	0.0
2010	20.9	60.3	18.2	0.6	0.0
2011	27.0	50.2	22.4	0.4	0.0
2012	22.1	54.5	22.6	0.7	0.0
2013	18.5	69.2	10.6	1.8	0.0
2014	50.6	44.2	5.0	0.2	0.0
2015	42.8	48.1	9.0	0.1	0.0
2016	35.1	44.0	20.8	0.1	0.0
2017	45.0	45.0	9.9	0.1	0.0
2018	52.3	42.6	4.8	0.3	0.0
2019	52.0	38.9	9.0	0.1	0.0

Figure 11. Yellow perch length frequency from the 2019 upper Chesapeake commercial fyke net survey.

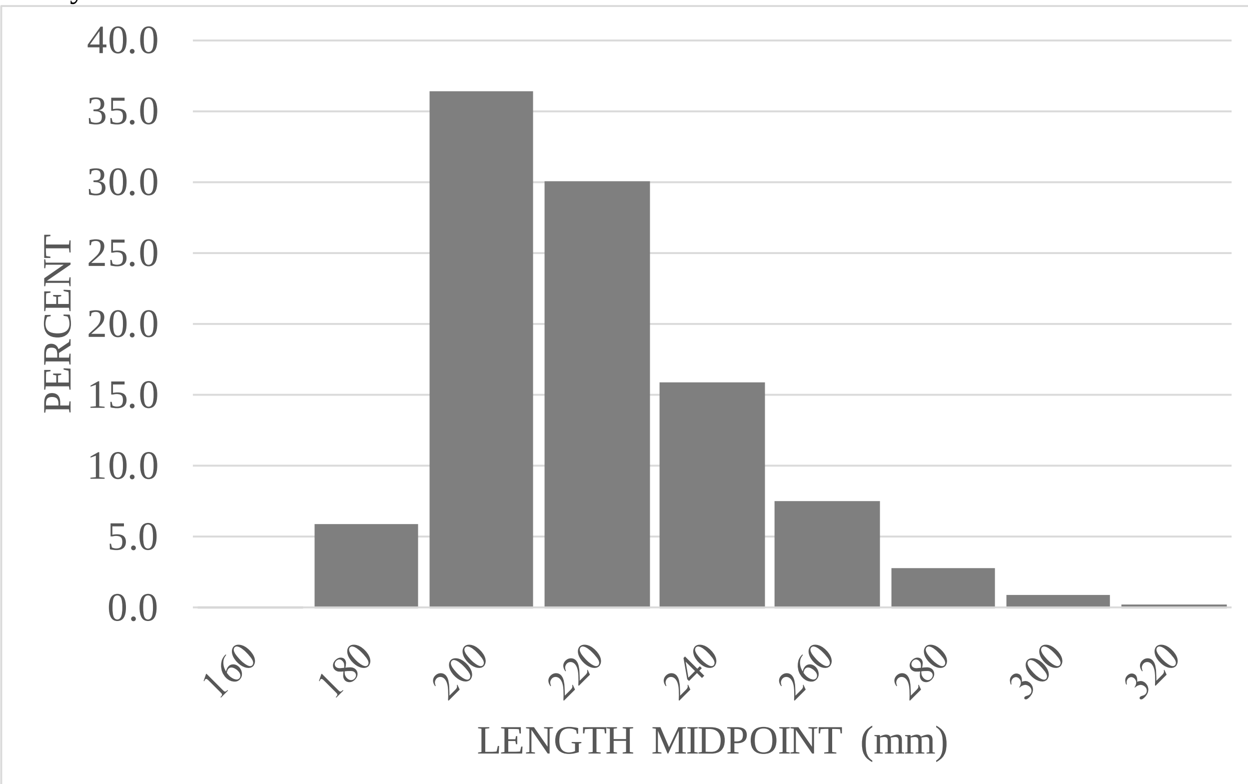


Table 13. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2019. Minimum length cut-offs in parentheses.

Year	**Stock** (255 mm)	**Quality** (460 mm)	**Preferred** (510 mm)	**Memorable** (710 mm)	**Trophy** (890 mm)
2000	88.5	4.5	6.4	0.6	0.0
2001	92.7	2.5	4.7	0.0	0.0
2002	89.4	7.3	3.2	0.0	0.0
2003	89.5	5.3	5.3	0.0	0.0
2004	NOT SAMPLED				
2005	73.8	10.0	16.2	0.0	0.0
2006	96.4	2.0	1.6	0.0	0.0
2007	95.6	2.2	2.2	0.0	0.0
2008	91.4	3.7	4.9	0.0	0.0
2009	94.1	2.1	3.8	0.0	0.0
2010	84.6	9.2	5.8	0.4	0.0
2011	76.3	14.0	9.7	0.0	0.0
2012	88.5	5.9	5.1	0.4	0.0
2013	88.2	2.4	9.5	0.0	0.0
2014	82.1	9.8	7.4	0.7	0.0
2015	93.8	2.0	3.8	0.4	0.0
2016	93.7	3.8	22.4	0.0	0.0
2017	92.1	3.5	3.8	0.6	0.0
2018	89.0	6.3	4.4	0.3	0.0
2019	85.6	12.9	1.5	0.0	0.0

Figure 12. Length frequency of channel catfish from the 2019 upper Chesapeake Bay winter trawl survey.

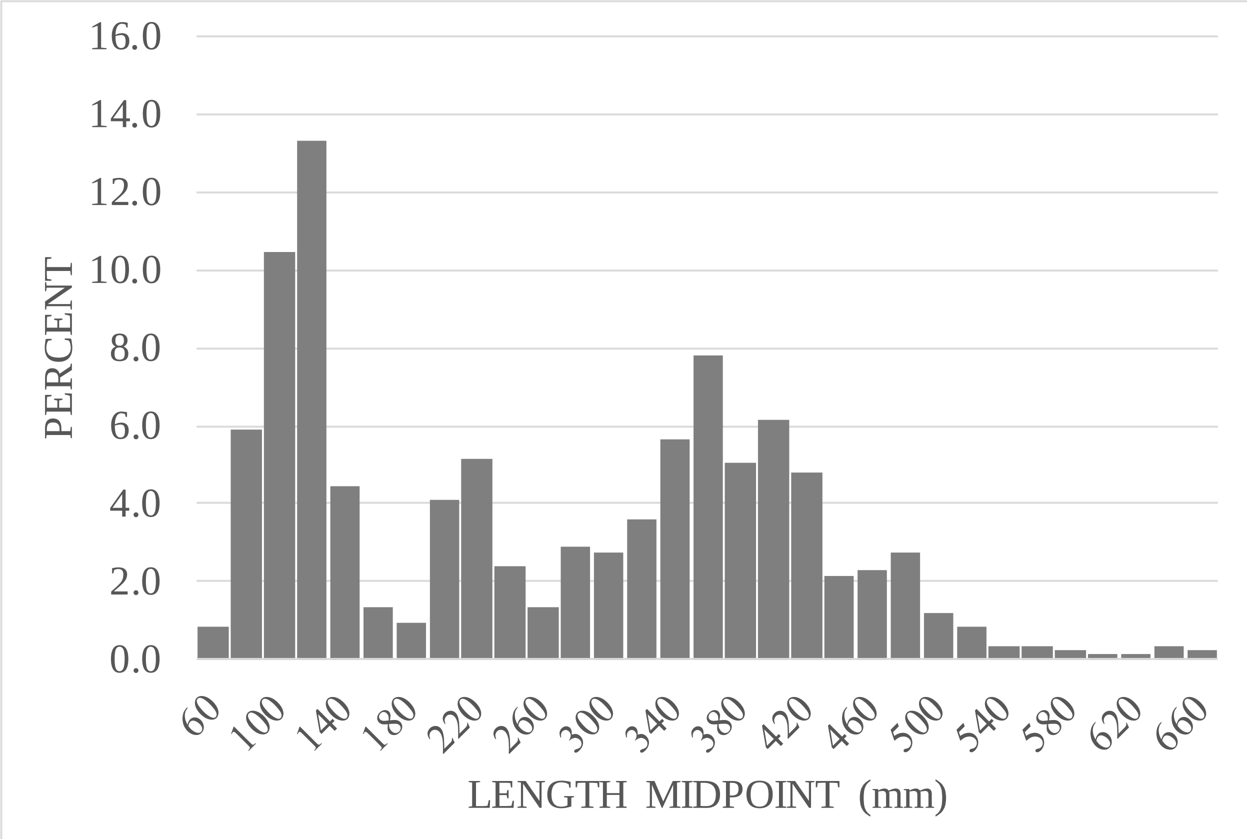


Table 14. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2019. Minimum length cut-offs in parentheses.

Year	**Stock** (255 mm)	**Quality** (460 mm)	**Preferred** (510 mm)	**Memorable** (710 mm)	**Trophy** (890 mm)
1993	53.4	24.0	22.6	0.0	0.0
1994	61.9	15.8	22.2	0.0	0.0
1995	21.0	20.4	58.6	0.0	0.0
1996	40.8	14.1	35.6	0.0	0.0
1997	19.8	16.4	63.8	0.0	0.0
1998	33.3	9.2	57.5	0.0	0.0
1999	31.3	10.6	58.1	0.0	0.0
2000	63.7	8.4	27.9	0.0	0.0
2001	53.2	6.7	40.1	0.0	0.0
2002	19.8	14.3	65.9	0.0	0.0
2003	84.2	5.8	9.9	0.0	0.0
2004	58.8	10.0	31.2	0.0	0.0
2005	79.2	9.3	11.5	0.0	0.0
2006	72.3	12.6	15.1	0.0	0.0
2007	84.9	7.1	8.0	0.0	0.0
2008	79.6	8.1	12.3	0.0	0.0
2009	74.3	8.2	27.0	0.0	0.0
2010	69.0	12.0	18.9	0.0	0.0
2011	73.4	13.4	13.2	0.0	0.0
2012	14.1	7.0	78.5	0.2	0.1
2013	33.3	11.6	54.9	0.2	0.0
2014	50.8	17.2	32.0	0.0	0.0
2015	73.6	12.9	13.5	0.0	0.0
2016	36.4	13.9	49.7	0.0	0.0
2017	37.5	14.4	48.1	0.0	0.0
2018	31.1	22.0	46.5	0.4	0.0
2019	23.1	10.0	66.7	0.2	0.0

Figure 13. Channel catfish length frequency from the 2019 Choptank River fyke net survey.

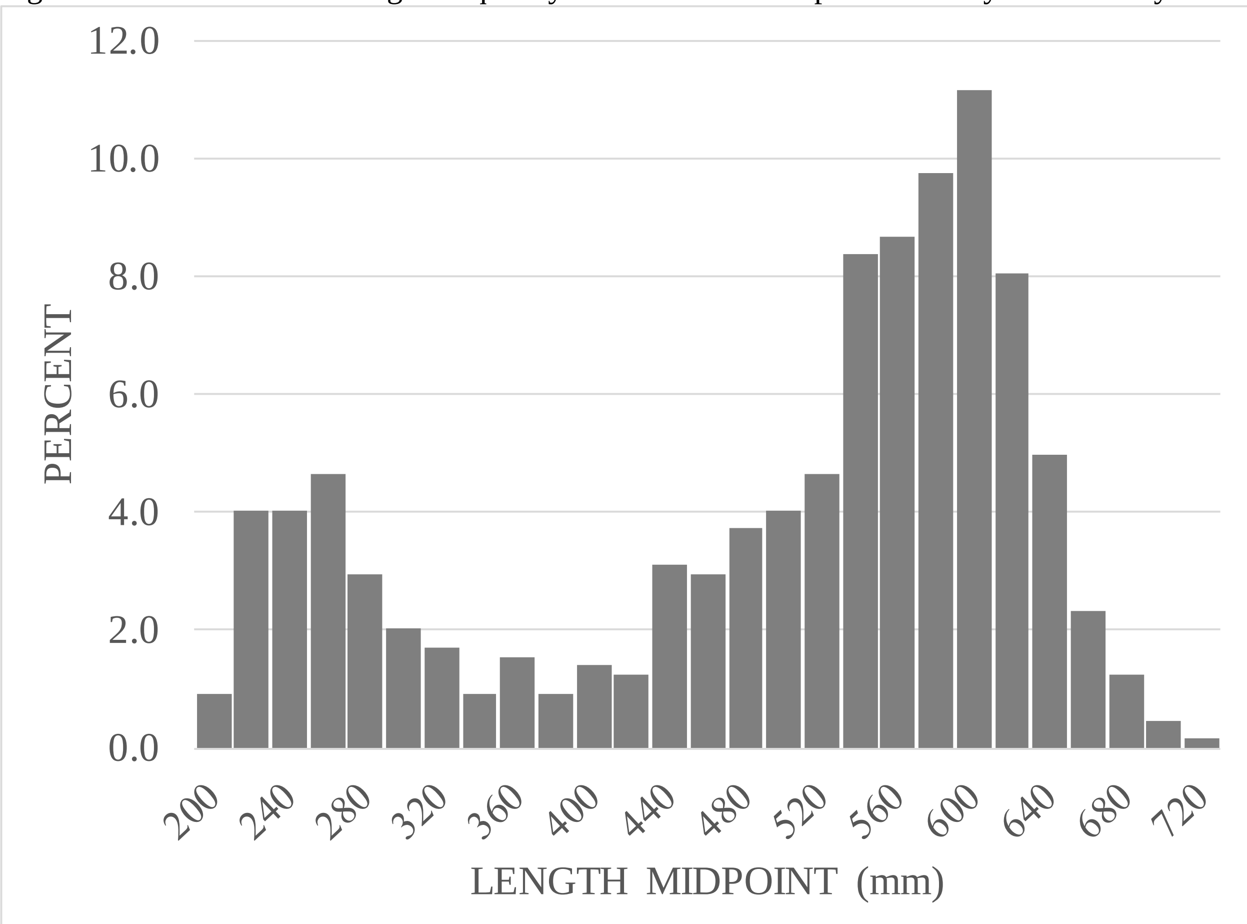


Table 15. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2019. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

Year	**Stock** (255 mm)	**Quality** (460 mm)	**Preferred** (510 mm)	**Memorable** (710 mm)	**Trophy** (890 mm)
1995	72.3	19.4	8.2	0.0	0.0
1996	65.8	23.8	10.4	0.0	0.0
1997	62.2	27.5	10.2	0.0	0.0
1998	60.3	27.7	12.0	0.0	0.0
1999	80.6	14.6	4.7	0.0	0.0
2000	70.9	22.1	7.1	0.0	0.0
2001	70.2	22.9	6.9	0.0	0.0
2002	56.4	31.1	12.5	0.0	0.0
2003	52.3	29.2	18.4	0.0	0.0
2004	60.8	27.8	11.5	0.0	0.0
2005	48.8	30.6	20.6	0.0	0.0
2006	63.7	23.0	13.3	0.0	0.0
2007	67.4	22.8	9.8	0.0	0.0
2008	69.4	17.8	12.6	0.3	0.0
2009	66.5	18.4	15.1	0.0	0.0
2010	45.0	23.3	30.0	1.7	0.0
2011	74.1	13.0	13.0	0.0	0.0
2012	22.5	30.2	47.3	0.0	0.0
2013	32.5	27.3	49.2	0.0	0.0
2014	10.0	17.0	73.0	0.0	0.0
2015	NOT SAMPLED				
2016	15.2	13.3	70.5	0.9	0.0
2017	15.5	15.0	68.9	0.5	0.0
2018	11.3	10.6	77.3	0.7	0.0
2019	23.6	1.8	58.1	0.4	0.0

Figure 14. Channel catfish length frequency from the 2019 Nanticoke River fyke and pound net survey.

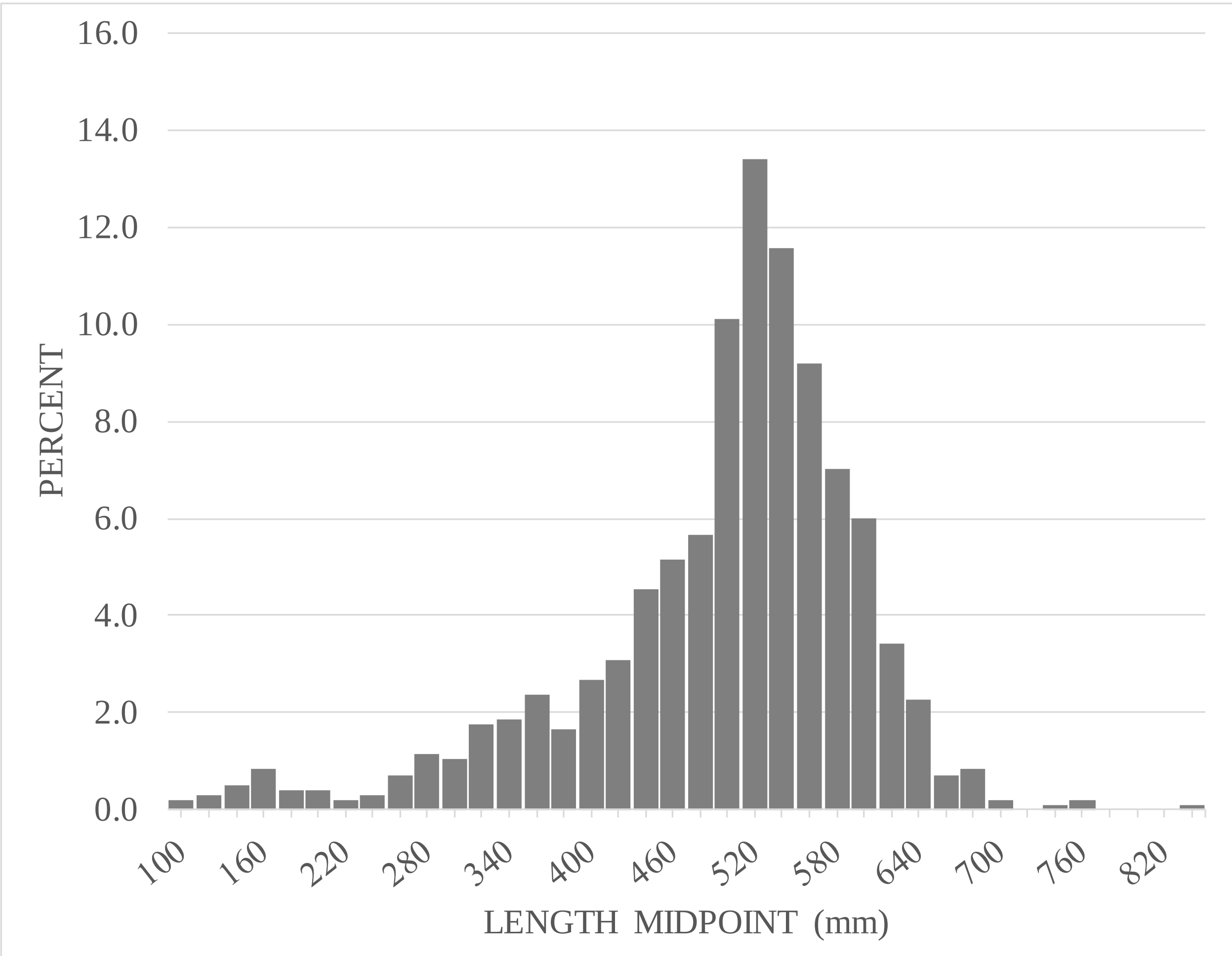


Table 16. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2019. Minimum length cut-offs in parentheses.

Year	**Stock** (165 mm)	**Quality** (255 mm)	**Preferred** (350 mm)	**Memorable** (405 mm)	**Trophy** (508 mm)
2000	NONE COLLECTED				
2001	41.9	54.8	3.2	0.0	0.0
2002	57.1	42.9	0.0	0.0	0.0
2003	85.0	15.0	0.0	0.0	0.0
2004	NOT SAMPLED				
2005	96.6	3.4	0.0	0.0	0.0
2006	90.0	10.0	0.0	0.0	0.0
2007	85.7	14.3	0.0	0.0	0.0
2008	85.7	14.3	0.0	0.0	0.0
2009	83.0	17.0	0.0	0.0	0.0
2010	87.0	10.9	2.2	0.0	0.0
2011	81.9	17.3	0.8	0.0	0.0
2012	70.2	26.9	3.0	0.0	0.0
2013	70.5	28.2	0.7	0.7	0.0
2014	77.1	20.0	2.9	0.0	0.0
2015	69.6	26.4	2.0	2.0	0.0
2016	59.1	34.1	3.8	3.0	0.0
2017	68.4	27.9	3.0	0.7	0.0
2018	53.1	31.6	11.2	4.1	0.0
2019	37.5	50.0	0.0	12.5	0.0

Figure 15. White catfish length frequency from the 2018 upper Chesapeake Bay winter trawl survey.

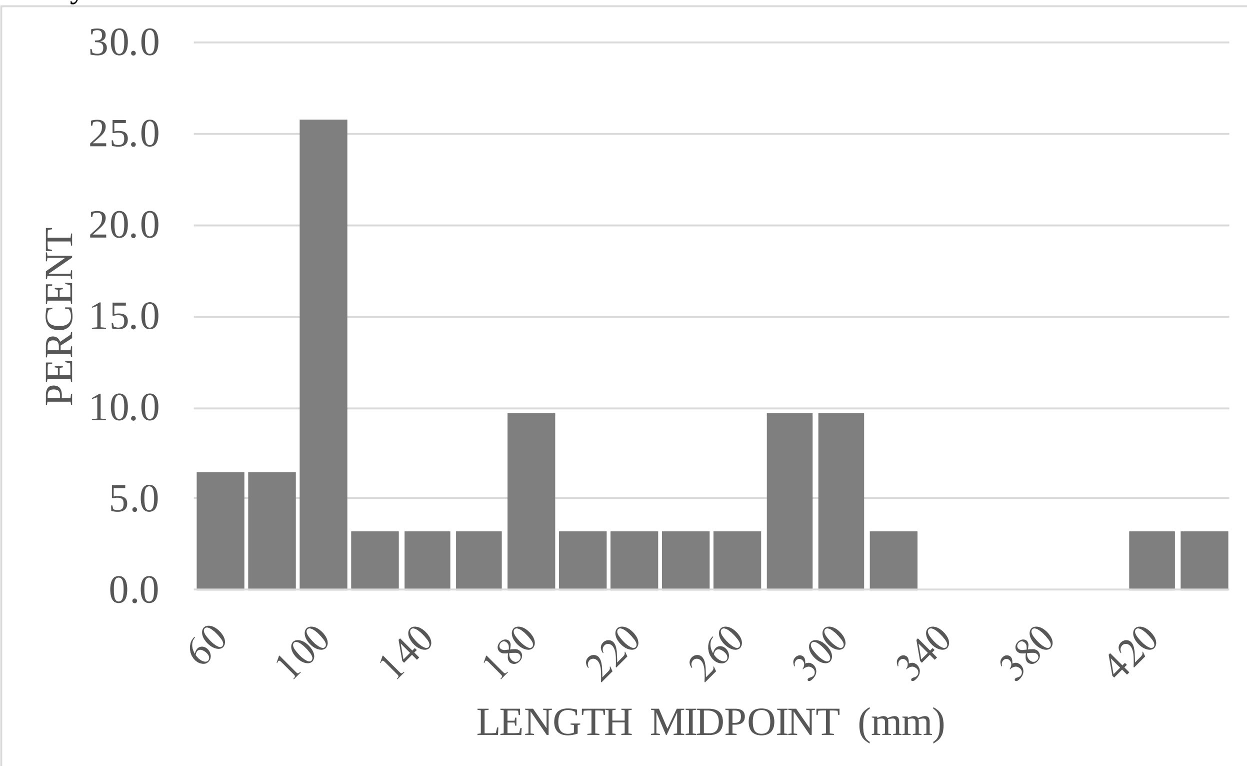


Table 17. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2019. Minimum length cut-offs in parentheses.

Year	Stock (165 mm)	Quality (255 mm)	Preferred (350 mm)	Memorable (405 mm)	Trophy (508 mm)
1993	45.6	19.4	4.9	27.2	2.9
1994	42.2	28.9	10.2	18.8	0.0
1995	19.3	47.8	8.9	23.1	0.9
1996	45.6	22.1	6.1	24.4	1.5
1997	29.7	48.5	6.9	12.9	2.0
1998	42.6	44.1	2.9	10.3	0.5
1999	44.8	38.6	5.9	10.8	0.0
2000	50.6	29.2	7.6	12.4	0.3
2001	44.8	29.5	4.8	20.0	1.0
2002	7.8	38.9	15.4	35.5	2.4
2003	25.2	35.8	11.9	26.5	0.4
2004	15.2	54.8	20.9	9.5	0.0
2005	37.4	41.0	15.5	6.0	0.0
2006	29.1	45.4	13.3	12.0	0.2
2007	49.6	39.1	7.5	3.8	0.0
2008	26.1	44.4	13.8	15.5	0.3
2009	25.3	48.6	9.9	15.8	0.5
2010	19.6	52.5	11.3	16.2	0.4
2011	23.5	33.5	9.7	33.1	0.2
2012	12.5	50.6	13.3	22.9	0.8
2013	4.7	34.9	17.8	41.5	1.1
2014	11.0	35.9	15.3	35.6	2.2
2015	3.1	46.0	5.3	17.7	0.9
2016	23.5	32.2	14.8	28.2	1.2
2017	21.2	34.1	17.2	27.3	0.3
2018	25.3	44.3	12.3	17.6	0.5
2019	19.3	50.3	8.5	19.4	2.4

Figure 16. White catfish length frequency from the 2019 Choptank River fyke net survey.

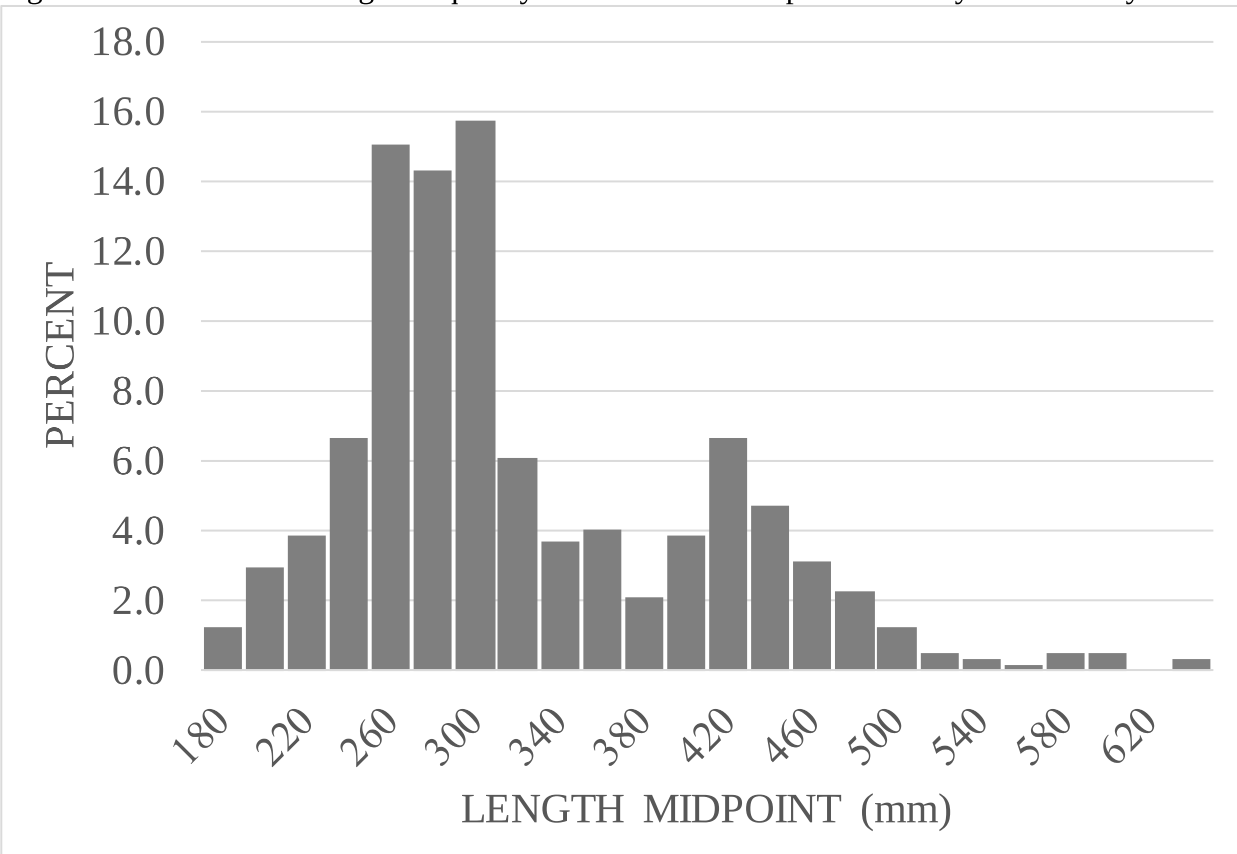


Table 18. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2019. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

Year	**Stock** (165 mm)	**Quality** (255 mm)	**Preferred** (350 mm)	**Memorable** (405 mm)	**Trophy** (508 mm)
1995	35.7	32.8	14.3	16.6	0.6
1996	42.4	36.9	10.5	9.6	0.6
1997	42.1	37.4	10.9	8.2	1.4
1998	27.9	48.2	17.4	6.0	0.0
1999	41.0	34.5	14.4	10.1	0.0
2000	39.9	42.1	12.0	6.0	0.0
2001	46.2	28.2	16.0	9.0	0.6
2002	37.0	34.6	15.2	12.8	0.5
2003	17.6	32.4	23.5	25.0	1.5
2004	13.2	45.3	34.9	6.6	0.0
2005	47.0	30.3	13.6	9.1	0.0
2006	70.0	21.1	4.3	4.6	0.0
2007	40.0	37.3	14.7	8.0	0.0
2008	62.5	24.1	8.5	4.6	0.3
2009	55.8	21.8	10.5	10.5	1.4
2010	21.4	25.0	14.3	28.6	10.7
2011	43.7	43.7	5.7	5.7	6.9
2012	11.9	25.8	29.6	30.5	2.2
2013	25.4	23.9	16.4	29.4	5.0
2014	10.5	29.7	19.2	38.0	2.6
2015	NOT SAMPLED				
2016	39.2	17.7	17.9	24.3	1.0
2017	10.6	28.4	29.4	31.3	0.3
2018	3.4	16.8	20.8	57.0	0.5
2019	14.0	40.3	21.7	22.9	1.1

Figure 17. White catfish length frequency from the 2019 Nanticoke River fyke and pound net survey.

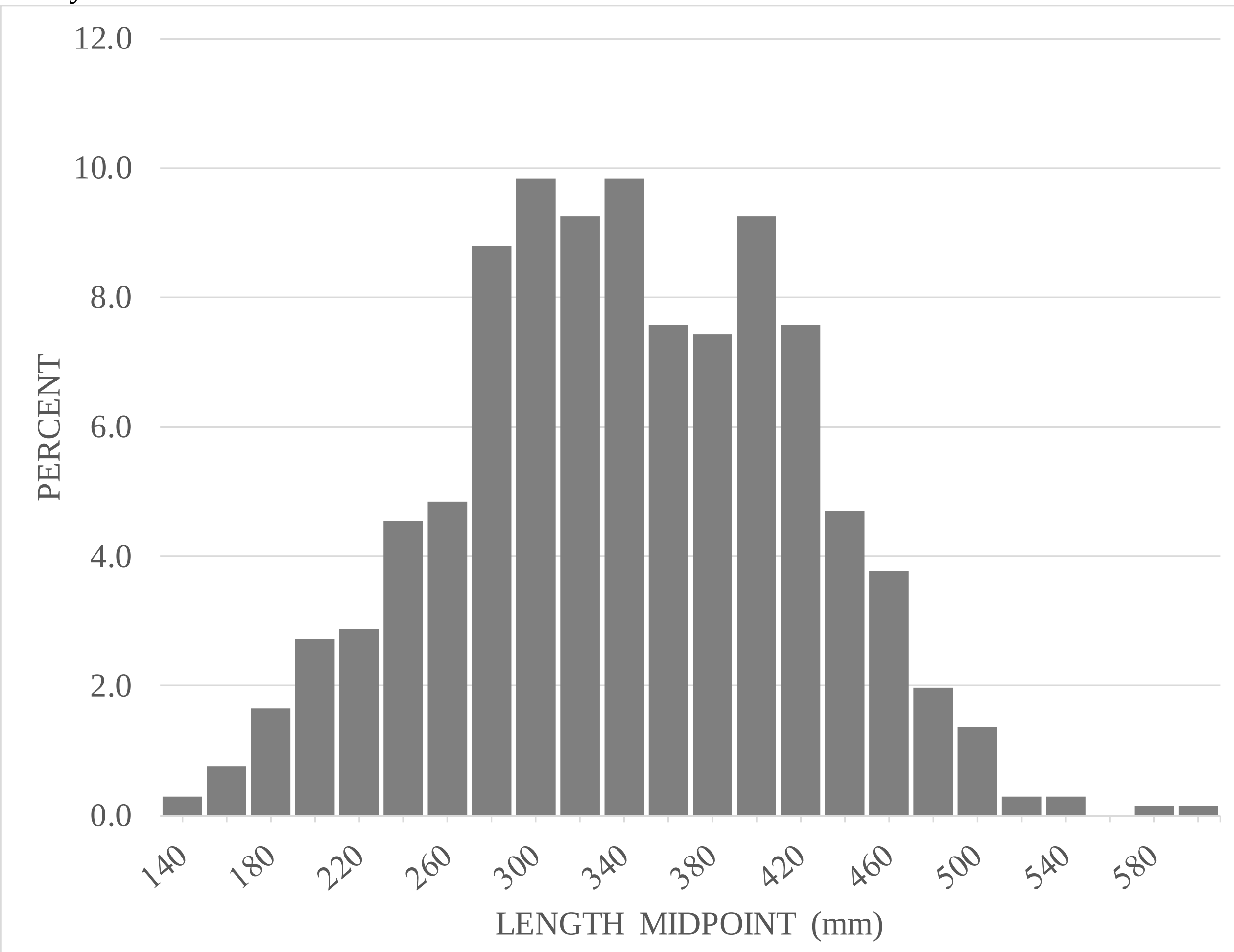


Table 19. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	Allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2011	F	2.3×10^{-6}	3.35	324	0.18	-0.93
	M	2.4×10^{-6}	3.34	223	0.35	-0.43
	Combined	2.0×10^{-6}	3.38	326	0.15	-1.49
2012	F	6.9×10^{-6}	3.17	273	0.34	-0.02
	M	4.5×10^{-6}	3.23	229	0.36	-0.16
	Combined	3.1×10^{-6}	3.31	259	0.34	0.00
2013	F	8.9×10^{-6}	3.10	273	0.34	-0.39
	M	4.4×10^{-6}	3.21	228	0.42	-0.43
	Combined	3.8×10^{-6}	3.25	259	0.31	-0.82
2014	F	5.9×10^{-6}	3.18	278	0.33	-0.18
	M	1.2×10^{-6}	3.46	226	0.42	-0.16
	Combined	2.9×10^{-6}	3.30	259	0.35	-0.13
2015	F	2.3×10^{-6}	2.92	278	0.27	-0.57
	M	3.2×10^{-6}	3.23	228	0.29	-0.68
	Combined	1.3×10^{-5}	3.03	267	0.26	-0.78
2016	F	3.4×10^{-6}	3.29	334	0.19	-0.95
	M	7.9×10^{-7}	3.56	215	0.60	0.01
	Combined	3.2×10^{-6}	3.30	340	0.15	-1.80
2017	F	5.2×10^{-6}	3.21	338	0.16	-1.58
	M	2.4×10^{-6}	3.34	219	0.74	-0.16
	Combined	3.0×10^{-6}	3.31	310	0.15	-2.77
2018	F	1.6×10^{-5}	3.00	256	0.51	0.01
	M	1.5×10^{-6}	3.21	211	0.80	0.16
	Combined	7.8×10^{-6}	3.28	249	0.48	-0.11
2019	F	1.4×10^{-5}	3.02	284	0.26	-0.46
	M	1.7×10^{-4}	2.54	234	0.36	-0.25
	Combined	1.1×10^{-5}	3.06	280	0.24	-0.71
2000 – 2019	F	5.3×10^{-6}	3.20	288	0.26	-0.48
	M	5.5×10^{-6}	3.18	227	0.37	-0.36
	Combined	3.4×10^{-6}	3.28	276	0.25	-0.71

Table 20. White perch growth parameters from Nanticoke River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size

Sample Year	Sex	(allometry) alpha	beta	(von Bertalanffy) L-inf	K	t_0
2011	F	1.6×10^{-6}	3.42	313	0.25	0.12
	M	7.8×10^{-6}	3.13	271	0.23	-0.38
	Combined	1.5×10^{-6}	3.43	297	0.23	-0.25
2012	F	4.5×10^{-6}	3.25		NSF	
	M	1.0×10^{-5}	3.08	306	0.18	-0.79
	Combined	2.9×10^{-6}	3.32	329	0.16	-1.04
2013	F	7.7×10^{-6}	3.14	307	0.28	-0.16
	M	1.7×10^{-5}	2.99	276	0.27	-0.35
	Combined	6.2×10^{-6}	3.18	295	.27	-0.29
2014	F	1.5×10^{-5}	2.60	311	0.25	-0.29
	M	6.5×10^{-5}	2.73	269	0.33	-0.09
	Combined	5.4×10^{-5}	2.77	295	0.27	-0.25
2015	F	NA	NA		NA	
	M	NA	NA		NA	
	Combined	NA	NA		NA	
2016	F	9.2×10^{-5}	2.70	302	0.33	0.25
	M	1.1×10^{-5}	3.07	288	0.27	-0.21
	Combined	2.9×10^{-5}	2.90	296	0.30	0.05
2017	F	5.2×10^{-6}	3.21	323	0.26	-0.25
	M	4.7×10^{-6}	3.21	308	0.21	-0.52
	Combined	3.1×10^{-6}	3.29	318	0.23	-0.49
2018	F	NSF		287	0.30	0.06
	M	1.4×10^{-5}	3.02	262	0.33	-0.13
	Combined	NSF		311	0.23	-0.56
2019	F	7.2×10^{-6}	3.14	284	0.38	-0.06
	M	2.2×10^{-5}	2.98	234	0.59	0.08
	Combined	7.0×10^{-6}	3.14	475	0.75	0.49
2000 - 2019	F	6.2×10^{-6}	3.18	298	0.28	-0.16
	M	7.0×10^{-6}	3.14	274	0.26	-0.33
	Combined	5.8×10^{-6}	3.18	251	0.42	-0.03

Table 21. Yellow perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size. **Bold indicates unreliable estimates.**

Sample Year	Sex	allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2011	F	1.2×10^{-6}	3.02	276	0.58	0.03
	M	4.7×10^{-6}	3.17	232	0.57	-0.11
	Combined	3.2×10^{-6}	3.25	245	0.74	0.12
2012	F	7.0×10^{-6}	3.08	374	0.18	-1.97
	M	1.5×10^{-6}	3.37	**258**	**0.29**	**-2.37**
	Combined	6.7×10^{-6}	3.09	292	0.34	-1.07
2013	F	9.2×10^{-6}	3.02	294	0.53	-0.02
	M	1.7×10^{-5}	2.92	**322**	**0.10**	**-6.10**
	Combined	1.5×10^{-5}	2.94	267	0.53	-0.23
2014	F	1.5×10^{-5}	2.94	308	0.39	0.12
	M	9.7×10^{-6}	3.03	276	0.30	-0.71
	Combined	1.5×10^{-5}	2.94	282	0.42	0.05
2015	F	1.7×10^{-5}	2.94	337	0.27	-0.41
	M	2.1×10^{-6}	3.32	234	0.52	-0.22
	Combined	9.6×10^{-6}	3.04	334	0.22	-0.98
2016	F	3.3×10^{-7}	3.66	300	0.34	-1.18
	M	3.6×10^{-6}	3.21	290	0.22	-1.85
	Combined	4.0×10^{-7}	3.62	269	0.45	-0.36
2017	F	2.1×10^{-4}	2.52	321	0.20	-1.90
	M	3.9×10^{-5}	2.79	282	0.18	-2.74
	Combined	3.8×10^{-5}	2.82	286	0.24	-1.59
2018	F	4.7×10^{-5}	2.75	318	0.35	-0.09
	M	4.0×10^{-6}	3.19	254	0.65	1.22
	Combined	2.1×10^{-5}	2.89	265	0.60	0.67
2019	F	2.6×10^{-5}	2.86	338	0.18	-2.82
	M	6.9×10^{-7}	3.52	267	0.34	-0.75
	Combined	9.5×10^{-6}	3.04	291	0.28	-1.43
2000 –2019	F	1.7×10^{-5}	2.94	298	0.38	-0.41
	M	4.4×10^{-6}	3.18	270	0.26	-1.47
	Combined	8.9×10^{-6}	3.05	268	0.41	-0.60

Table 22. Yellow perch growth parameters from upper Chesapeake Bay fyke nets for males, females, and sexes combined. NA=data not available NSF=no solution found. **Bold indicates unreliable estimates.**

Sample Year	Sex	allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2011	F	3.1×10^{-7}	4.10		NSF	
	M	9.4×10^{-7}	3.47	242	0.97	0.20
	Combined	9.1×10^{-8}	3.90	245	0.23	0.25
2012	F	1.4×10^{-6}	3.39	294	0.44	-0.06
	M	7.8×10^{-6}	3.06	258	0.46	-0.57
	Combined	7.7×10^{-7}	3.50	273	0.50	-0.27
2013	F	2.5×10^{-6}	3.31	**393**	**0.15**	**-2.02**
	M	1.5×10^{-5}	2.95	264	0.31	-0.39
	Combined	1.2×10^{-6}	3.44	294	0.29	-0.82
2014	F	9.0×10^{-6}	3.08	**410**	**0.10**	**-4.50**
	M	9.1×10^{-6}	3.05	250	0.45	-0.33
	Combined	4.8×10^{-6}	3.18	270	0.45	-0.25
2015	F	1.1×10^{-7}	3.89	**473**	**0.40**	**-12.80**
	M	1.7×10^{-5}	2.96	**246**	**1.52**	**0.33**
	Combined	7.5×10^{-7}	3.54	**248**	**1.45**	**0.31**
2016	F	1.4×10^{-6}	3.41	273	0.75	0.67
	M	$1.4 \text{ x } 10^{-6}$	3.40	247	0.61	-0.04
	Combined	$9.2 \text{ x } 10^{-7}$	3.48	263	0.59	0.04
2017	F	2.6×10^{-6}	3.28	298	0.56	0.63
	M	3.3×10^{-6}	3.23	253	0.46	-0.16
	Combined	1.1×10^{-6}	3.45	270	0.55	0.19
2018	F	2.5 X 10-6	3.31	347	0.28	-0.35
	M	1.4 X 10-6	3.40	238	0.47	-0.33
	Combined	1.3 X 10-6	3.42	349	0.23	-0.69
2019	F	1.2×10^{-6}	3.45	314	0.37	-0.27
	M	6.6×10^{-7}	3.54	242	0.55	-0.19
	Combined	5.7×10^{-7}	3.57	273	0.47	-.019
1998 – 2019	F	4.0×10^{-6}	3.22	300	0.37	-0.36
	M	3.1×10^{-6}	3.24	242	0.52	-0.23
	Combined	1.9×10^{-6}	3.35	266	0.50	-0.15

Table 23. Estimated instantaneous fishing mortality rates (F) for white perch. NR= not reliable; NA=not available; MIN= minimal, at or near M estimate.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Choptank[1]	0.21	0.38	0.68	0.33	0.35	0.27	0.54	0.26	0.51	0.47
Nanticoke	0.21	0.27	0.20	0.29	0.41	NA	0.49	0.41	0.43	0.47
Upper Bay[1]	0.25	0.54	0.93	0.46	0.52	0.42	0.37	NA	NA	NA

[1]Estimated F from stock assessment for 2009 – 2016 (Piavis and Webb 2018). 2017 -- 2019 estimated from length converted catch curves.

Table 24. Estimated instantaneous fishing mortality rates (F) for yellow perch. NR= not reliable; MIN=minimal, at or near M estimate.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Choptank	NR	MIN	0.05	0.01	0.41	NR	0.32	MIN	MIN	0.38
Upper Bay[1]	0.28	0.34	0.32	0.21	0.15	0.20	0.46	0.31	0.11	0.21

[1]Fully recruited F from annual update of Piavis and Webb (2020).

Figure 18. Baywide young-of-year relative abundance index for white perch, 1962 – 2019, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

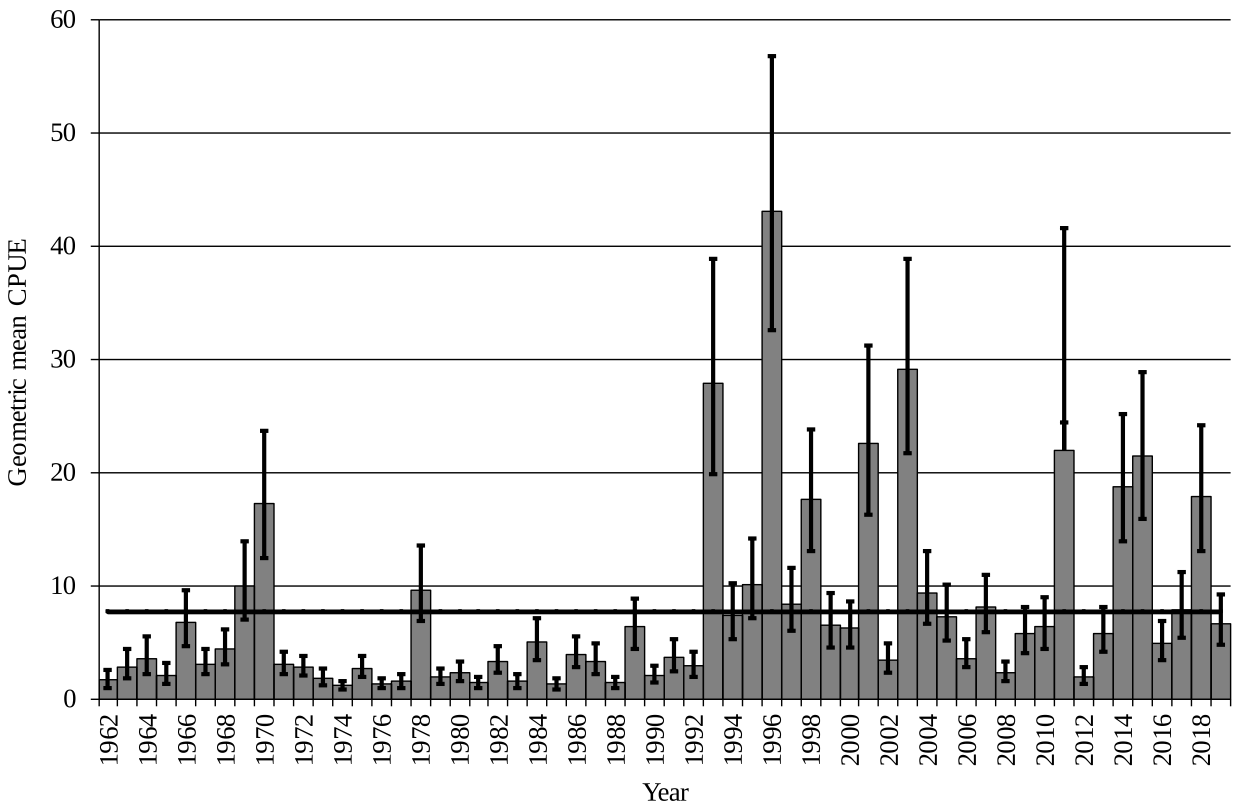


Figure 19. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Error bars=95% CI.

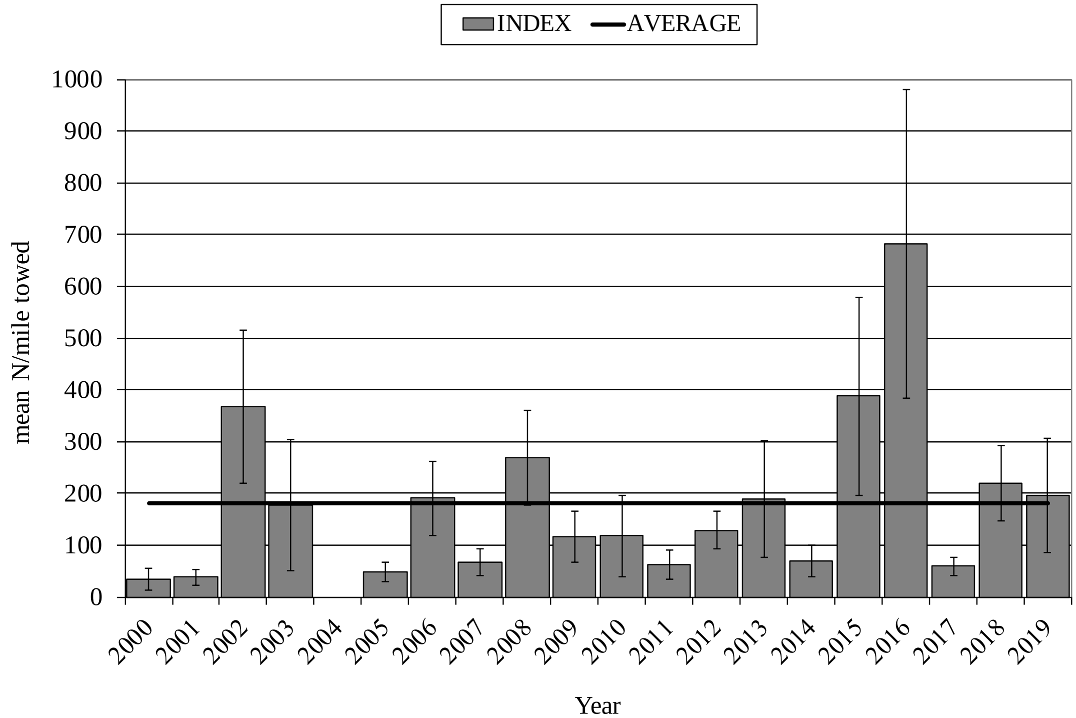


Figure 20. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2019, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

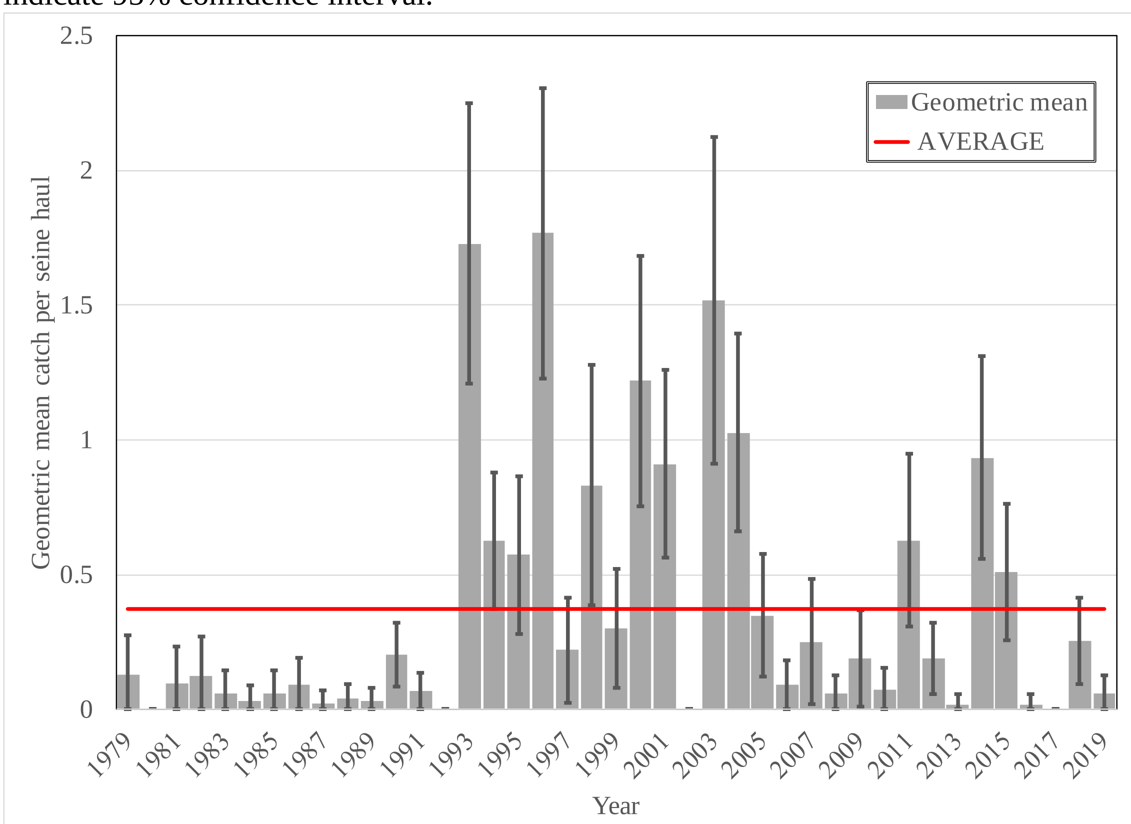


Figure 21. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Error bars=95% CI.

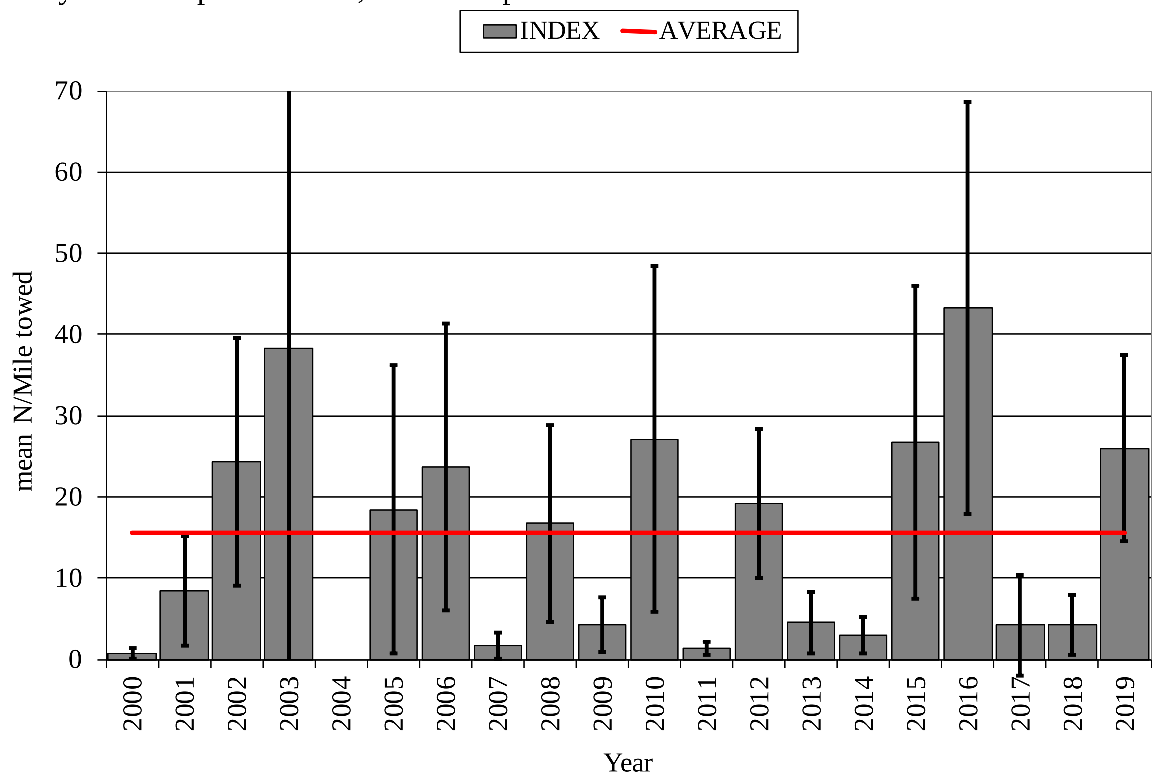


Figure 22. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

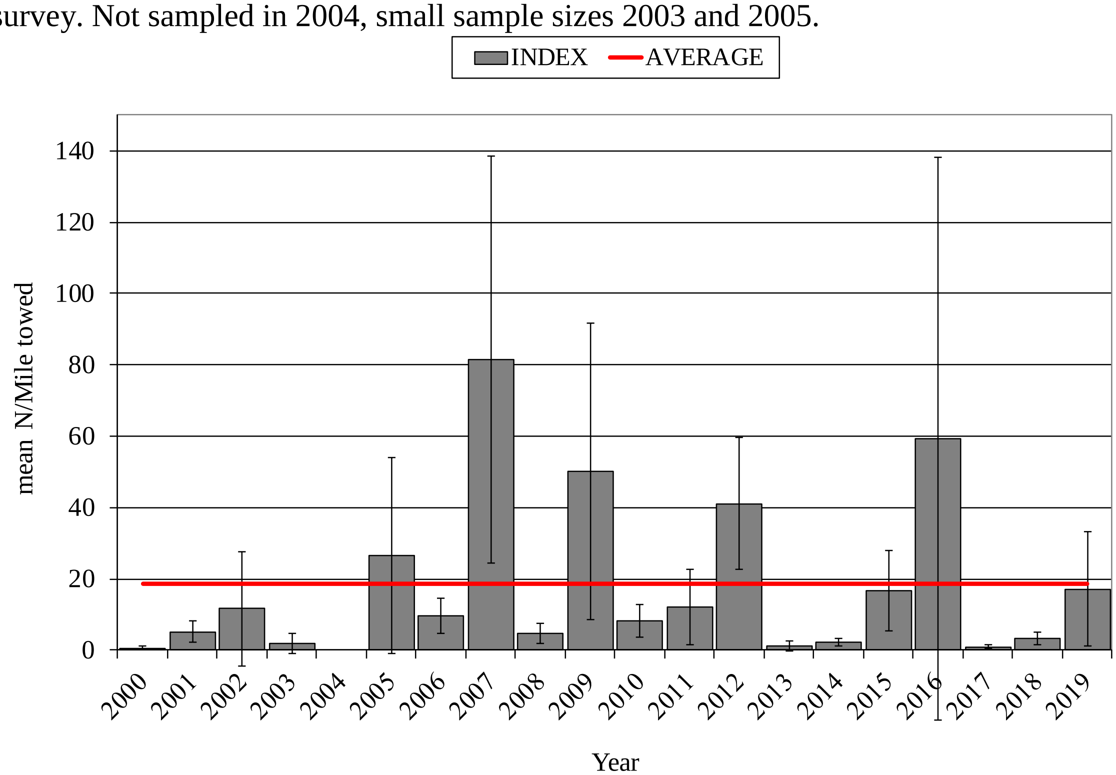


Table 25. White perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2019. Chester River sites included starting 2011.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	No. Tows
2000	34.9	227.3	102.2	65.9	24.8	15.0	20.7	2.4	2.3	1.6	497.0	79
2001	38.1	78.9	123.2	23.5	37.4	7.9	19.4	20.6	4.7	2.9	356.6	115
2002	367.4	2.9	71.1	28.8	44.5	19.0	36.8	20.5	5.3	12.3	608.6	110
2003	177.3	343.6	71.5	33.7	45.8	55.9	180.7	4.4	0.0	26.6	939.5	20
2004	NOT SAMPLED											
2005	46.1	78.1	22.7	41.1	10.5	3.7	1.2	11.7	1.4	0.6	217.0	43
2006	190.6	63.2	153.2	47.2	35.7	10.2	6.3	6.1	1.5	2.7	516.6	108
2007	67.0	44.3	31.8	61.6	34.9	8.4	9.2	0.8	0.6	3.0	261.7	71
2008	268.7	44.7	113.3	84.5	25.7	8.8	3.5	3.8	1.4	1.4	555.9	108
2009	117.3	486.9	13.7	59.4	112.1	95.2	2.3	33.4	7.2	1.4	928.9	90
2010	177.9	130.4	163.4	5.6	96.7	41.7	68.9	5.8	9.5	13.9	714.0	56
2011	61.8	73.2	52.0	69.8	16.9	38.5	21.1	21.5	1.2	4.0	360.0	78
2012	128.9	44.5	21.1	10.3	10.7	11.6	20.9	9.4	12.5	3.7	273.7	143
2013	188.8	237.4	29.8	66.5	61.8	288.6	37.2	44.8	10.8	27.7	993.3	116
2014	69.8	43.1	411.1	67.4	44.2	21.1	41.4	13.2	7.4	9.1	727.9	72
2015	388.5	264.8	312.9	572.4	125.0	63.9	67.2	80.3	45.0	47.6	1,967.7	108
2016	682.1	457.0	451.7	222.8	236.1	86.4	34.2	9.2	23.2	35.4	2,238.0	112
2017	59.6	614.4	246.2	69.1	24.8	164.5	11.4	23.3	9.6	27.3	1,250.0	137
2018	220.6	139.7	711.8	461.2	23.5	65.8	137.5	18.4	15.2	2.0	1,795.8	129
2019	196.1	79.0	47.5	117.7	60.2	11.4	16.7	27.1	11.1	3.8	570.7	62

Table 26. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2019.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	Total effort
2000	0.0	0.0	5.1	32.0	31.2	5.5	20.0	1.9	1.3	0.0	97.0	310
2001	0.0	7.0	16.0	47.9	35.8	26.2	4.2	11.0	1.5	0.0	149.6	310
2002	0.0	2.1	7.8	28.5	16.4	18.4	3.5	6.2	2.7	0.1	85.5	306
2003	0.0	2.2	36.8	33.6	33.3	1.4	27.7	7.2	3.2	3.2	148.5	261
2004	0.0	0.4	36.3	12.3	14.1	17.2	1.3	9.6	3.4	2.2	96.8	251
2005	0.0	3.4	16.0	51.2	32.1	19.9	7.2	1.7	10.8	0.5	142.7	235
2006	0.0	1.7	71.5	3.5	34.6	17.2	1.9	2.2	1.3	17.0	150.8	236
2007	0.0	1.3	9.5	123.8	13.4	57.8	20.7	8.2	9.0	7.2	250.8	203
2008	0.0	0.4	22.8	17.7	54.2	4.6	18.5	10.5	1.9	4.2	134.8	248
2009	0.0	1.8	0.7	24.9	6.8	45.2	5.5	8.5	4.9	3.1	101.3	210
2010	0.0	1.7	32.6	5.1	84.3	29.6	90.5	11.2	15.1	8.0	195.5	223
2011	0.0	0.1	1.0	22.0	3.5	21.0	12.9	15.8	2.3	4.2	82.7	242
2012	0.0	0.1	5.4	2.7	11.0	4.8	6.4	2.6	4.6	1.4	62.0	220
2013	0.0	9.3	9.0	13.6	1.9	5.5	1.3	8.9	2.4	5.9	57.8	299
2014	0.0	1.5	46.4	4.1	3.2	4.4	6.3	4.1	8.3	6.1	84.4	273
2015	0.0	0.0	0.0	107.7	7.8	17.4	7.8	2.7	1.4	6.7	151.5	213
2016	0.0	6.5	4.7	<0.1	38.1	3.9	2.1	0.6	0.4	0.6	56.9	303
2017	0.0	17.8	27.2	4.3	0.0	54.1	2.3	0.2	0.0	1.1	101.5	213
2018	0.0	0.5	47.6	14.8	0.9	1.7	28.2	0.5	0.6	<0.1	99.4	306
2019	0.0	0.3	1.1	20.6	11.6	0.6	1.4	7.3	0.2	0.1	43.2	282

Table 27. Yellow perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2019.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	No. Trawls
2000	1.0	1.5	0.2	1.6	0.1	0.3	0.1	0.0	0.0	0.1	4.8	79
2001	9.6	0.6	1.0	0.2	0.6	<0.1	0.0	<0.1	0.0	0.0	12.0	115
2002	24.8	17.2	1.7	3.6	0.3	1.8	0.0	0.2	0.1	0.0	49.7	110
2003	38.3	135.7	422.1	46.3	61.6	4.0	24.8	0.0	2.0	0.0	735.0	20
2004	NOT SAMPLED											
2005	19.1	13.4	<0.1	3.1	0.4	<0.1	<0.1	0.0	<0.1	0.0	36.0	43
2006	21.7	36.5	15.8	0.0	3.3	0.4	0.0	0.4	0.0	0.0	78.1	108
2007	3.6	3.3	8.4	2.4	1.5	0.6	0.1	<0.1	0.0	0.0	19.9	71
2008	17.0	4.1	9.1	8.0	2.1	0.0	0.0	0.0	0.0	0.0	40.2	108
2009	4.4	21.2	1.1	2.4	2.1	0.5	<0.1	0.0	0.0	0.0	31.7	90
2010	27.1	3.3	8.5	0.6	0.9	0.4	0.2	0.0	0.1	0.0	41.1	56
2011	1.4	4.6	0.7	2.9	0.0	0.4	0.1	0.0	0.0	0.0	10.1	66
2012	18.8	6.8	2.2	0.1	0.1	0.1	0.0	0.7	0.0	0.0	29.0	107
2013	4.5	9.6	2.8	1.2	<0.1	<0.1	<0.1	0.0	<0.1	0.0	18.2	86
2014	0.4	0.0	15.5	6.8	0.8	0.0	0.1	0.1	0.1	0.0	23.7	60
2015	26.7	1.1	0.0	16.1	1.8	0.4	0.0	0.0	0.0	0.0	46.1	86
2016	30.6	44.8	6.1	0.3	4.3	0.6	0.2	0.0	0.0	0.0	87.0	83
2017	4.2	24.8	8.2	0.0	0.0	1.2	0.1	0.0	0.0	0.0	38.4	101
2018	4.2	1.7	12.6	3.6	0.0	0.0	0.1	0.0	0.0	0.0	22.2	99
2019	26.0	1.0	0.7	3.2	0.5	0.0	0.0	0.0	0.0	0.0	31.4	63

Table 28. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2019.

YEAR	AGE										Sum	Total
	1	2	3	4	5	6	7	8	9	10+	CPE	effort
1988	0.0	0.2	4.5	0.2	0.0	0.4	0.3	0.0	0.0	0.1	5.7	59
1989	0.0	0.0	1.2	3.4	1.2	0.6	0.1	0.0	0.0	0.0	6.6	68
1990	0.0	0.3	2.6	1.2	4.0	0.8	0.1	0.1	0.1	0.0	9.3	68
1991	0.0	0.1	0.6	0.8	0.3	0.6	0.1	0.0	0.0	0.0	2.5	70
1992	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.5	113
1993	0.0	0.0	0.6	1.3	0.8	0.9	0.3	0.1	0.0	0.0	4.0	120
1994	0.0	0.4	1.4	0.2	0.7	0.8	0.7	0.6	0.0	0.2	4.9	114
1995	0.0	0.7	2.1	0.2	0.6	0.6	0.3	0.3	0.0	0.2	5.0	121
1996	0.0	6.1	2.5	1.9	0.3	0.6	0.3	0.2	0.3	0.1	12.2	140
1997	0.0	0.1	4.2	0.6	0.6	0.0	0.1	0.2	0.1	0.0	5.8	153
1998	0.0	0.9	0.5	3.8	0.2	0.2	0.0	0.1	0.0	0.1	5.8	154
1999	0.0	1.7	47.8	0.5	17.7	0.2	0.1	0.0	0.0	0.0	68.0	178
2000	0.0	2.0	0.6	8.4	0.2	0.9	0.0	0.0	0.0	0.0	12.0	164
2001	0.0	5.3	11.9	0.6	6.8	0.1	0.4	0.0	0.0	0.0	25.1	167
2002	0.0	1.9	7.5	6.6	0.2	2.4	0.6	0.3	0.0	0.0	19.5	178
2003	0.0	3.1	3.6	7.6	2.8	0.3	1.9	0.3	0.3	0.0	19.8	121
2004	0.0	0.4	3.2	1.1	0.8	0.7	0.0	0.4	0.0	0.0	6.6	156
2005	0.0	9.0	0.7	2.2	0.7	0.3	0.8	0.1	0.3	0.1	14.2	186
2006	0.0	1.1	11.8	1.1	2.5	0.4	0.4	0.3	0.0	0.0	17.6	158
2007	0.0	10.8	5.3	11.1	0.2	1.3	0.8	0.2	0.1	0.1	29.9	140
2008	0.0	0.2	7.8	0.8	2.0	0.1	0.3	0.1	0.0	0.0	11.3	166
2009	0.0	0.0	6.1	14.8	1.0	0.9	0.2	0.0	0.0	0.0	23.0	143
2010	0.0	0.4	0.8	7.9	18.3	0.4	1.2	0.0	0.1	0.0	26.3	144
2011	0.0	1.2	0.0	0.2	4.6	5.6	0.3	0.7	0.0	0.0	12.6	158
2012	0.4	2.3	9.8	0.2	0.0	2.3	5.2	<0.1	0.1	0.0	20.5	111
2013	0.0	0.7	0.6	1.9	<0.1	<0.1	0.3	0.5	0.0	<0.1	3.5	249
2014	0.0	0.0	8.6	4.9	2.2	<0.1	0.0	<0.1	0.2	<0.1	16.0	190
2015	0.0	1.4	0.2	17.2	2.9	1.3	<0.1	<0.1	<0.1	<0.1	23.2	147
2016	0.0	2.3	0.8	0.4	22.5	3.1	2.1	0.3	0.2	0.1	29.9	174
2017	0.0	0.9	2.3	0.8	<0.1	5.9	1.3	0.6	0.0	0.1	12.1	162
2018	0.0	0.2	9.9	2.8	0.3	0.1	3.1	0.5	0.3	0.0	17.1	204
2019	0.0	0.2	0.5	4.7	0.9	<0.1	<0.1	0.6	<0.1	0.1	7.0	195

Figure 23. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2019. Effort standardized from 1 March – 95% total catch date.

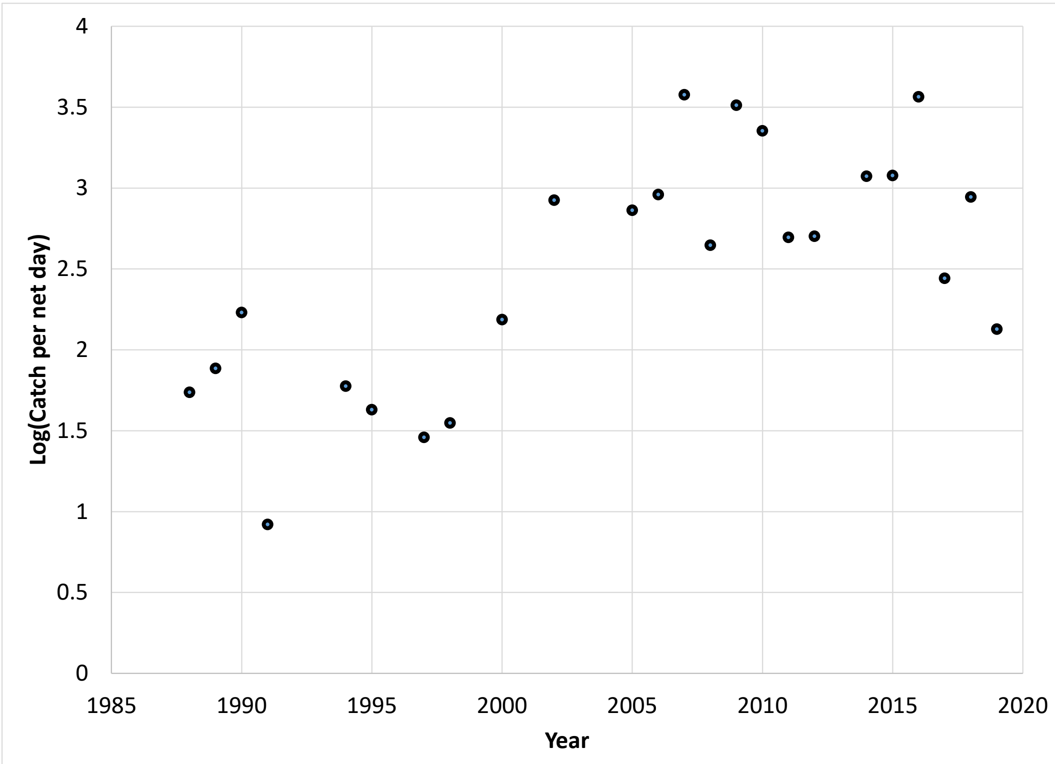


Figure 24. Channel catfish relative abundance (N/mile towed) from the upper Chesapeake Bay winter trawl survey, 2000-2019. Not surveyed in 2004, small sample sizes in 2003 and 2005.

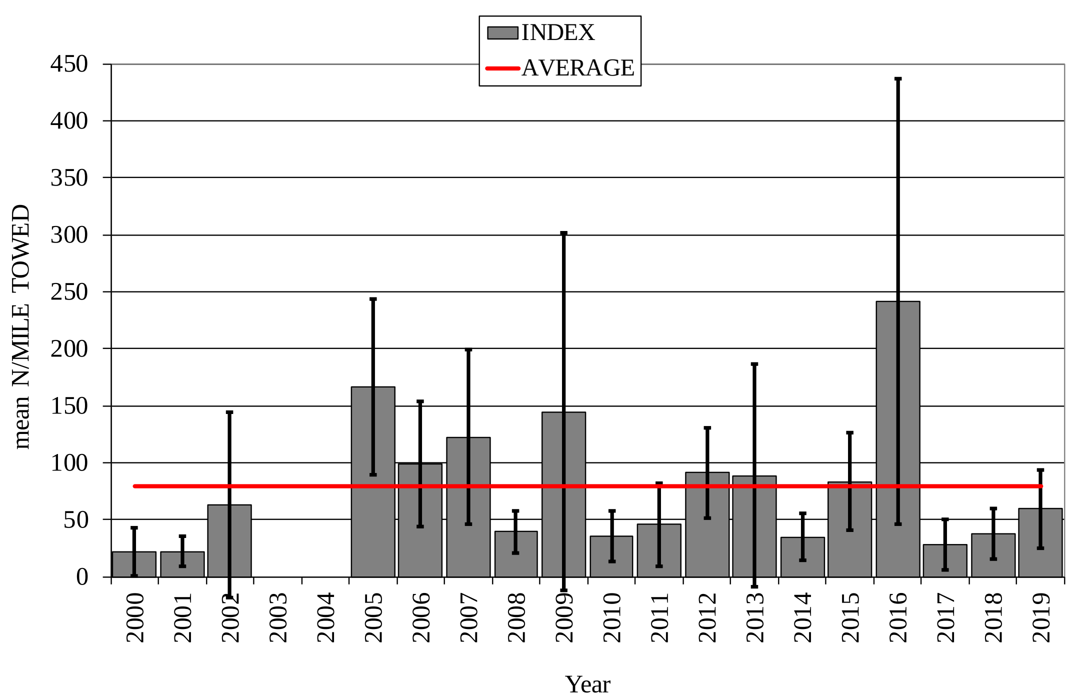


Figure 25. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2019. Horizontal line indicates time series average relative abundance.

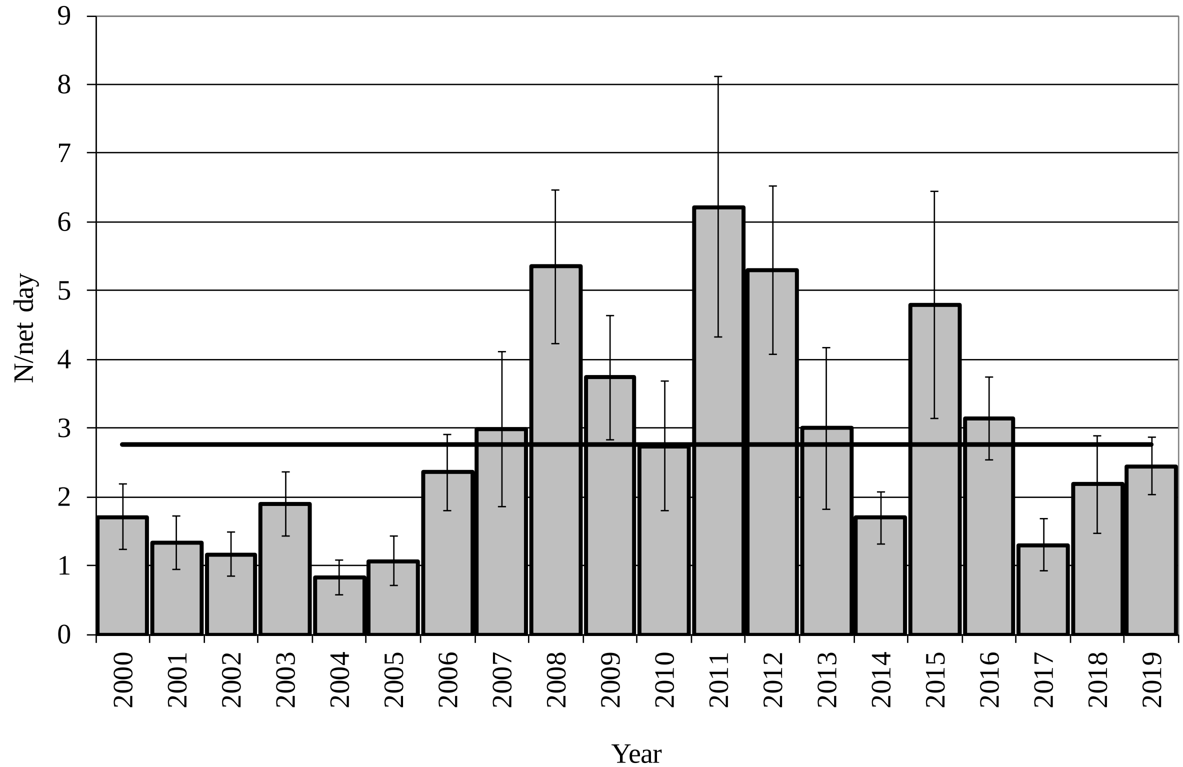
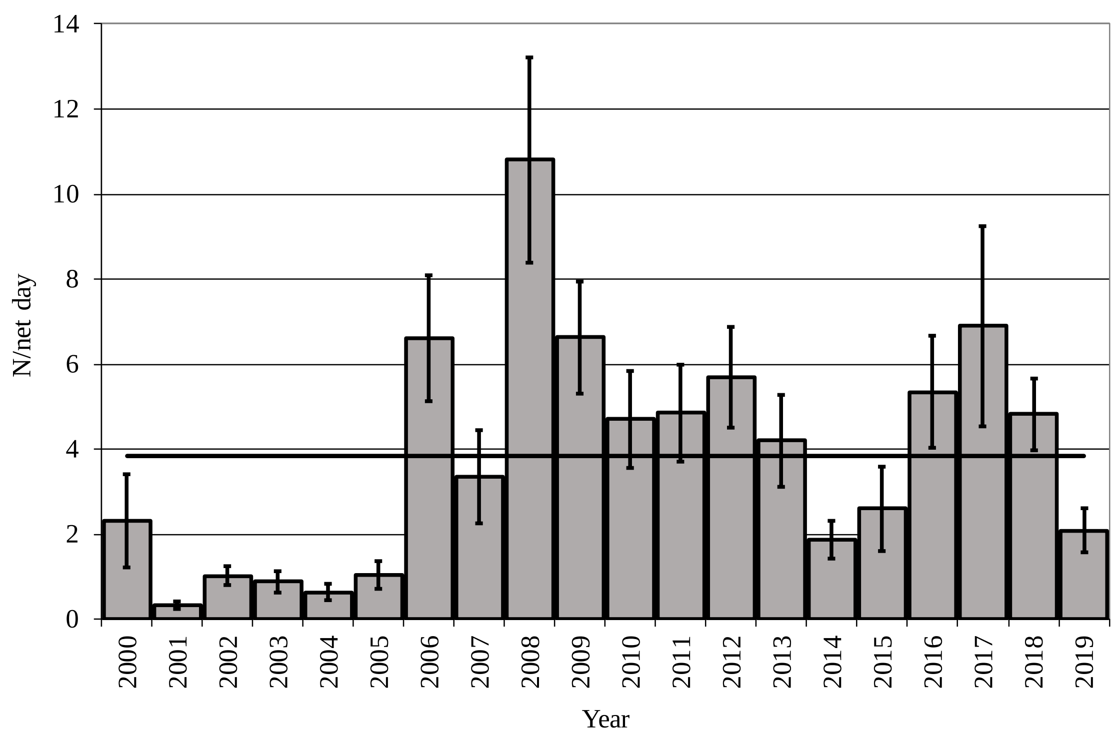


Figure 26. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2019. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF HEAD-OF-BAY YELLOW PERCH STOCKS IN MARYLAND

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

Yellow perch (*Perca flavescens)* are an important finfish resource in Maryland's tidewater region. The dense aggregation during the late February – March spawning period offers recreational anglers the earliest opportunity to fish. Yellow perch are similarly an important seasonal fishery for commercial fishers. The modest commercial fishery occurs during a slack season between striped bass (*Morone saxatilis)* and white perch *(M. americana)* gill netting and the white perch spawning run. Over the 10 year period 2010 -- 2019, annual commercial harvest in Maryland ranged from 12,075 kg in 2013 to 29,366 kg in 2019 and averaged 21,370 kg. Since 1929, landings averaged 43,437 kg annually. However, changes in regulations, population abundance, and commercial effort drastically influence landings history.

The commercial fishery is predominately a fyke net fishery located above the Preston Lane Memorial Bridges in the upper Chesapeake Bay region. Fyke net harvest accounted for 98% of the total yellow perch commercial harvest over the five year period 2015 – 2019. From 1988 – 1999, commercial fishers in the upper Bay had a closed season in February, and an 8 ½" minimum size limit (no maximum size limit). During 2000 – 2007, the commercial fishery had a closed season in February, and an 8½" – 11" slot limit in order to preserve larger spawning females and to enhance population age structure (Uphoff and Piavis 1999). Regulations changed for the 2008 fishing season due to a legislative mandate that caused a closure of the commercial yellow perch fishery from 1 January 2008 through 15 March 2008. The January – mid March closure encompassed a significant part of the commercial yellow perch season. Completion of a suitable stock assessment in late 2008 prompted the establishment of a total allowable catch (TAC) for the upper Bay commercial yellow perch fishery. Hard caps on the upper Chesapeake Bay commercial fishery were determined annually from 2009 – 2019 (Table 1).

The recreational fishery is generally a bank-based bait fishery in upstream reaches of spawning tributaries. Recreational participation can vary among years due to inclement weather patterns, availability of public access and yellow perch population levels (personal observation). Recreational fishers had a 5 fish daily creel limit and a 9" minimum size limit (msl) with no closed season, 1988 -- 2008. Middle western shore tributaries and the Nanticoke River on the eastern shore remained closed to recreational harvest. Recreational yellow perch fishery restrictions were eased in 2009, whereby all areas were opened to harvest under a 9" msl and a 10 fish daily creel limit. Recreational creel surveys were conducted during the 2008 and 2009 spawning runs (Wilberg and Humphrey 2008, 2009). Results from the creel surveys indicated that recreational harvest was minor. Another survey indicated that yellow perch harvest in the uppermost reach of the Susquehanna River in Maryland ranged from 4,500 – 6,000 yellow perch during the late 1950's and early 1960's (McCauley et al. 2007).

This report updated and refined the statistical catch-at-age model to estimate fishing mortality, abundance in both biomass and numbers, and recruitment of upper Bay yellow perch. The update included three more years of data (2017 -- 2019) and the model was refined by revisiting fishery independent indices, truncating the time series and modelling the commercial selectivity with a gamma distribution function instead of estimating each selectivity at age. A higher natural mortality rate was applied to the plus group to better reflect population decay after age 8. Due to the lack of trawl tuning indices early in the time series, the full model was run and bootstrapped and distributions of population size at age for 2005 were utilized to run population simulations from 2005 -- 2019. In addition, we updated the spawning stock biomass per recruit model (SSB/R) that was used to set biological reference points contained in the current Fisheries Management Plan (Piavis and Uphoff 1999; Yellow Perch Workgroup 2019). The $F_{0.1}$ reference point from a yield per recruit model (YPR) was also determined. We incorporated the fishery selectivity vector produced from the current assessment along with updated growth parameters into the new SSB/R model.

Data from an on-going fishery independent fyke net survey in the Choptank River were also analyzed. The Choptank River is located in the mid-Bay region on Maryland's eastern shore. The watershed encompasses 371,000 acres. The Choptank River has an active recreational-only yellow perch fishery (9" minimum size limit, 10 fish creel limit). The fyke net survey provided a time-series of relative abundance estimates spanning 32 years. This survey provides the only dataset of adult yellow perch relative abundance outside of the upper Chesapeake Bay.

METHODS

Upper Chesapeake Bay statistical catch-at-age model

Data

Fishery dependent data

The area assessed included the Chesapeake Bay north of the Preston Lane Memorial Bridges and all tributaries except the Chester River (Figure 1). Data supported a base model run covering 1998 – 2019. Commercial landings and effort were needed for the assessment. Commercial fishermen are obligated to submit monthly catch reports and effort (number of nets) by gear and area for each day fished (Lewis 2010). Effort was calculated as the number of fyke nets utilized by watermen that landed more than 100 pounds of yellow perch during the commercial season, multiplied by the number of days the gear were deployed.

No estimates of recreational harvest prior to 2008 were available from creel surveys specifically designed to estimate yellow perch harvest, but we assumed recreational harvest to be a minor component of the total removals. Directed creel surveys conducted in the upper Bay during 2008 and 2009 estimated that recreational harvest in the Bush River was only 242 yellow perch in 2008 and 234 in 2009, and 1,480 yellow perch in Northeast River in 2009 (Wilberg and Humphrey 2008, 2009). The Marine Recreational Information Program (MRIP) samples tidal-fresh areas, but in many years encounter rates are insufficient to produce informative recreational estimates. Estimates from MRIP coinciding with the assessment time frame provided relatively precise estimates for only seven of twenty-two years (Personal communication, National Marine Fisheries Service, Fisheries Statistics Division, 2020). Additionally, the accuracy of those more precise estimates is doubtful given that estimates included years where recreational harvest topped 63,500 kg.

Biological samples were taken from cooperating commercial fyke net fishermen, from 1998 – 2019. Not all regions were sampled in every year, but biologists generally visited at least two areas per year. These included the Middle River, Back River, Bush River, Gunpowder River, Sassafras River and Northeast River. Random samples were taken from pre-culled catches (Table 2). Yellow perch were measured (mm TL) and sex was determined by examining external gonadal exudation. A non-random subsample was procured for otolith extraction and subsequent age determination. Ages were determined by counting annular rings on otoliths submersed in glycerin under a dissecting microscope with direct light. Weights and lengths were also taken for these specimens. Ages were mostly determined by one experienced reader. Percent agreement and precision were recently determined between the two age readers with percent agreement at 97% and mean CV of 0.56% (see Appendix A in Piavis and Webb 2011). These values compared favorably with estimates of precision from a yellow perch population in Pennsylvania (Niewinski and Ferreri 1999) and a population in Lake Erie (Vandergoot et al. 2008).

We formulated a commercial catch-at-age (CAA) matrix for each sample year by sex, for ages 2 – 8+. Length and weight data were disaggregated by sex into 20 mm length intervals. Average weight, by sex, in each interval was multiplied by the number of yellow perch (by sex) in each interval to get a total interval weight. Sample weights of all intervals were summed to get total sample weight by sex. Total landings by sex were calculated by multiplying reported commercial landings by the proportion of sex-specific sample weights. Total number of harvested yellow perch was determined by multiplying the sex-specific landings estimates by the number of sex-specific yellow perch in the sample divided by the total sex-specific sample weight.   Total number harvested by sex and age-class was determined by formulating annual sex-specific age-length keys in 20 mm increments for legal sized fish only. The estimated total number harvested by sex was multiplied by the sex-specific proportion catch-at-age to get the number at age and sex harvested. Male and female CAA matrices were added together to arrive at a final annual CAA matrix. We substituted the lowest annual catch for an age-group if there was no representation of an age-class in any particular year (Table 3).

Fishery independent data

We also incorporated data from fishery-independent surveys into the model. The upper Bay winter trawl survey, initiated in December 1999, provided age-specific relative abundance data (Figure 2; see Project 1 Job1 for operational details). An annual age-length key (10 mm intervals) was created and applied to the length structure of each individual haul. The age-length key was not sex-specific because male yellow perch were not routinely ripe, making sex determination difficult. The age 1, age 2, and age 3+ trawl indexes were geometric mean catch per statute mile towed.

Another age 1 index was developed from the Estuarine Juvenile Finfish Survey (EJFS; Durrell 2019). The EJFS is a seine survey in several areas of the Chesapeake Bay. Previous yellow perch assessments indicated that a suite of selected upper Bay seine sites provided a reliable index of age 0 abundance. Therefore, only the Handy Pt., Hyland Pt., Oldfield Pt. Sassafras River Natural Resources Management Area, Parlor Pt., Fishing Battery Island and Plum Pt. sites were used to index abundance. The index was the age 0 geometric mean catch per seine haul, lagged one year (in reality, a six-month lag at worst). So, the 2004 survey indexed age 1 abundance in 2005, the 2005 survey indexed age 1 abundance in 2006, *et cetera*.

Population Model

The previous version of the yellow perch population model utilized a statistical catch at age model (Integrated Analysis from Haddon, 2001). Details of the original model (heretofore, base model) were detailed in Piavis and Webb (2017). The first version of the base model was adopted in 2009, and since then the model results were particularly stable. However, there were difficulties in estimating population size, recruitment and instantaneous fishing mortality (F) in years where the trawl index was unavailable (2003 -- 2005).

Our current approach included producing a final model run with truncated results, 2005 -- 2019. First, the base model was run and bootstrapped 10,000 times by resampling and randomizing model residuals, and adding them back to the fishery independent indices. This produced a distribution of N at age for the first year of a Monte Carlo simulation (heretofore final model run) encompassing the years 2005 -- 2019. The estimates of N at age for 2005 were $\log_e$ transformed to normalize the distributions. The final run model was run 20,000 times with fixed N at age for 2005. These values were randomly selected from the distribution of N at age based on the mean and standard deviation from the bootstrapped base model.

There were two differences in the base run and final run as compared to the 2017 assessment. First, the selectivity at age for the commercial fishery was modeled with a gamma distribution which decreased the number of parameters that needed to be estimated. Lastly, previous models assumed instantaneous natural mortality (M) as 0.25 for all age groups. This produced an unrealistic “pile-up” or accumulation of yellow perch in the final age group (8+ years old). Natural mortality was increased to M=0.60 for the 8+ age group. This value was chosen by simulating population decay so that abundance was very low (approximately 1% of age 7 yellow perch) by age 15. This was reasonable since the commercial fishery has a maximum size limit and natural mortality would be the major component of removals for the plus group.

The final model was run 20,000 times and median values were deemed the final estimates. Uncertainty was described as two standard deviations of the distribution of the estimates. Coefficients of variation and bias were estimated for all values of importance. The base model results and final model results were compared graphically for the truncated time-series.

Spawning stock biomass per recruit and biological reference points

We used a Thompson-Bell Spawning Stock Biomass per Recruit analysis (SSB/R) following the procedures of Gabriel et al. (1989) to determine the percentage of SSB/R of an unfished stock that current harvest was producing and at what level of fishing intensity various reference points would have been met. The method uses the fishery selectivity pattern to scale F and the number mature at age to define SSB/R more precisely. The Thompson-Bell modification determines the number (N_{ts}) and weight (W_{ts}) available at spawning as

$$N_{ts} = N_t \bullet e^{-((c \bullet p_t \bullet F) + d \bullet M)}$$

where $N_t = N_{t-1} \bullet e^{-((p_{t-1} \bullet F) + M)}$

and $W_{ts} = fr_{ts} \bullet N_{ts} \bullet W_t$

where c is the fraction of F before spawning, p is the fraction vulnerable to harvest at age (selectivity), d is the fraction of M that occurs before spawning, fr_{ts} is the fraction mature at age t, and W_t is the mean weight at age (Table 4). We used an arbitrary initial cohort of 100,000 at age 0. The assessment was run for 12 age-classes. Female yellow perch growth rate was modeled with vonBertalanffy growth parameters (L_∞ = 300 mm K = 0.37 t_0 = -0.36) and an allometric length-weight relationship (α = 4.0 X 10^{-6} β = 3.22) from upper Bay yellow perch during 1998 -- 2019 (see Project 1 Job1). The fishery selectivity vector for a fishery with an 8 1/2" to 11" slot limit was taken from the current assessment. This models the SSB/R for a predominantly commercial fishery. For a predominantly recreational fishery (9" minimum size limit) selectivity was the same as an earlier assessment (Piavis and Uphoff 1999).

The Thompson-Bell SSB/R analysis was constructed as a Microsoft Excel spreadsheet. An initial run with F = 0 determined the unfished (virgin) spawning stock biomass. We selected $F_{35\%}$ and $F_{25\%}$ as target and limit reference points, consistent with the current Yellow Perch Fisheries Management Plan (Yellow Perch Workgroup 2019). These reference points are the level of F that produce the reproductive output of stock sizes that are 35% and 25% of virgin stock size, respectively.

The biomass corresponding to the various reference points were identified, and the Goal Seek option within a Microsoft Excel spreadsheet was used to determine what instantaneous fishing mortality rates produced $F_{25\%}$, and $F_{35\%}$. The model was also run with F values of 0 to 1.2 in increments of 0.1 to produce SSB/R curves.

The Thompson-Bell yield per recruit model was used to determine $F_{0.1}$ reference point. The yield per recruit model stated that

$$N_t = N_{t-1} \bullet e^{-(p_{t-1} \bullet F + M)}$$

and yield $(Y_t) = W_t \bullet ((p_t \bullet F)/(p_t \bullet F = M)) \bullet (1 - e^{-(p_t \bullet F + M)}) \bullet N_t$

The fishery specific selectivity-at-age vectors (p_t) were the same as the SSB/R model. Yield was determined for F's ranging from 0 - 1.2 in increments of 0.1, except the yield at F=0.01 was determined in order to find the slope of the line at the origin in order to assess $F_{0.1}$.

Choptank River relative abundance analysis

Relative abundance data were derived from fyke net sampling in the Choptank River (Project 1 Job 1). Data from 1988 were taken from a previous survey (Casey et al 1988). Catch per unit effort (CPUE) was determined as the number of yellow perch caught per net day. Over the years, the starting date of this survey has varied. In order to standardize the dataset as accurately as possible, a 1 March start date was used. The Choptank River survey is a multi-species survey, so fyke netting was generally extended well past the end of the yellow perch spawning run. An effort cut-off was determined for each year as the day when 95% of the total yellow perch catch from 1 March occurred.

Previous analyses were modeled with SAS PROC NLIN procedure utilizing catch per unit effort data since 1988 (Piavis and Webb 2017). The non-linear estimation is unlikely to accurately describe finer scale population trajectory over thirty plus years. For this assessment, the plotted catch per effort was fit with a polynomial trendline to identify upward or downward phases (splines) in relative abundance. Once these discrete time periods were identified, we ran a linear regression of each spline to ascertain the significance of the trend. Outliers were identified as standardized residuals greater than or equal to +/- 2.0 . Outliers were removed and the regression was rerun.

RESULTS

Upper Chesapeake Bay statistical catch-at-age model

The model fit the commercial selectivity to a dome-shaped pattern, as was expected given the adoption of the slot limit during 2000. Yellow perch were fully recruited at age 5 and s_{8+} was 0.51 (Figure 3). Catchability for the commercial fyke net fishery was estimated as 2.29×10^{-5}, catchability of the trawl survey was 7.5×10^{-6} and the selectivity at age for the trawl survey was 1.0 for age 1, 0.89 for age 2 and 0.22 for age 3+. Catchability of the seine survey was 7.9×10^{-5}.

Abundance estimates (all ages) ranged from 0.78 million in 2014 to 1.98 million in 2016. Estimates averaged 1.28 million yellow perch during 2005– 2019, and averaged 1.5 million yellow perch in the last five years of the assessment. The terminal year (2019) abundance was estimated at 1.35 million yellow perch. Precision, as described by two standard deviations of the simulation results, was within acceptable ranges. Two standard deviations of the estimates averaged +/- 25% (Figure 4). Biomass was at a time series low in 2012 (101,000 kg). The biomass estimate in the terminal year of the assessment was 161,000 kg, and the time series average was 148,000 kg (Figure 5). Maximum biomass was 189,000 kg in 2017. Analysis of the standard deviations of the simulations indicated that the values were precisely estimated.

Instantaneous fishing mortality (fully selected F) ranged from 0.23 – 0.46 during 2005 – 2019. Fishing mortality peaked in 2016 at 0.46. Fully recruited F was 0.21 in the terminal year and averaged 0.23 since 2005 (Figure 6). Estimates were fairly well estimated, with 2 standard deviations averaging 30% of the estimates.

Estimated recruitment (abundance of age 1 yellow perch) ranged from 21,800 yellow perch in 2014 (2013 year-class) to 987,000 yellow perch in 2015 (2014 year-class) and averaged 334,000 yellow perch, 2005 – 2020 (Figure 7). Yellow perch recruitment was poor in 2012, 2013, 2016 and 2017. Recently, above average recruitment was estimated for the 2011, 2014, 2015 and 2018 year-classes, respectively. Recruitment was estimated precisely, with 2 standard deviations averaging 20% of the estimates. The 2019 terminal year estimates of abundance at age illustrate the impact of uneven recruitment (Figure 8).

Coefficients of variation (CV) for estimates of N were below 15%, while CV's of instantaneous fishing mortality ranged from 12.7% to 18.3%. Biomass estimates had CV's that largely mimicked CV's of abundance (Table 5). Recruitment CV's ranged from 8.5% to 26.4% and averaged 11%. The high value was for 2005 and represents the selection from the simulation distribution and not the fit of the model. Exclusive of that data point, CV's ranged from 8.5% to 11.6%.

Parsimony of the final run was judged by comparing results with the base run. All estimates (N, F and R) of the final run tracked the base run results. Abundance estimates between the two models varied from 5.1% to 10.4% (Figure 9), and estimates of F varied from 4% to 15% (Figure 10). Recruitment estimates between the two models tracked very closely, with differences ranging from 0.2% to 10.0% (Figure 11).

Spawning stock biomass per recruit and biological reference points

Spawning stock biomass per recruit modeling produced percent maximum spawning potential (%MSP) at F curves for a fishery with an 8 ½" – 11" slot limit (commercial fishery; Figure 12) and a fishery with a 9" minimum size limit (recreational fishery; Figure 13). For the upper Bay, which is a predominately commercial fishery, the target reference point ($F_{35\%}$) was 0.49 and the limit reference point ($F_{25\%}$) was 0.75. Yield per recruit modeling produced $F_{0.1}$ reference point of 0.11 and F_{max} could not be determined. Fully selected F in 2019 (0.21) produced a %MSP of 59%. The distribution of F from the Monte Carlo simulations indicated that there was a 0% chance that F exceeded $F_{35\%}$ in the upper Chesapeake Bay during 2019 (Figure 14). For a predominately recreational fishery (9" minimum size limit), the target reference point ($F_{35\%}$) was 0.37 and the limit reference point ($F_{25\%}$) was 0.55. Yield per recruit modeling produced $F_{0.1}$ reference point of 0.37, and F_{max} was 0.87.

Choptank River relative abundance analysis

A third order polynomial trend line indicated a period of population increase from 1997 to 2010 and population decline from 2010 to 2019 (R^2=0.73; Figure 15). In addition to those splines, visual inspection indicated that there may be a statistically significant decline immediately prior to the population increase identified as beginning in 1997. Regression analysis of these three splines was informative. The first time period investigated was 1993 through 1998. After removal of outliers, a statistically significant declining slope was identified (R^2 =0.81 P=0.04; Figure 16). Instantaneous rate of decline (the slope of the line) was -0.09. Regression analysis of the upward spline (1997 – 2010) was highly statistically significant (R^2 =0.51 P=0.01; Figure 17). The instantaneous increase equaled 0.13. The third phase (2010 – 2019) was not statistically significant (R^2 =0.14 P=0.31; Figure 18).

DISCUSSION

The current assessment included some substantial modifications over the previous assessment (Piavis and Webb 2017). Model assumptions remained similar despite the modifications. Most important are the assumptions that there is no net immigration or emigration in the stock (unit stock assumption), that M is constant and accurately assigned and that catchability does not vary over time. Each of these assumptions were discussed in great detail previously (Piavis and Webb 2017).

The assumption of constant M is usually discussed in terms of annual variability, but in the current assessment, a higher M was assigned to the plus group (intra-annual variation). This was necessary because there was an unrealistic pile up effect of older yellow perch in the plus group. Since the commercial fishery operates with a maximum size limit, natural mortality (M) is the main factor in reducing abundance of the plus group. This change resulted in more realistic estimates of abundance, and since there is a greater contribution per older fish to total biomass, those estimates are also more likely appropriate. Going forward, annual fluctuations in M may become a confounding factor, as over the last several years invasive blue catfish (*Ictalurus furcatus*) and flathead catfish (*Pylodictis olivaris*) have colonized large portions of the assessment area. Any substantial increase in predation may cause error in model results.

Another modification was that the commercial fishery catchability was fit using a gamma distribution. Base runs were performed both with gamma distributions and estimating catchability at age directly. Each method provided identical results. The benefit of fitting catchability with the gamma distribution was that only two parameters were estimated as opposed to six.

The biggest modification was using a bootstrapped base model with data from 1998 – 2019 to obtain a probable distribution of abundance at age for 2005. This was necessary because the primary tuning indices were derived from the winter trawl survey which was intermittently performed during the period 2000 – 2005. The previous model runs were beset with problems due to this lack of tuning indices early in the time series. Estimates for years that did not have tuning indices were often near to being outside of the confidence intervals, and many bootstrap runs failed to fit reasonably. The current method incorporated the variability of the early estimates and provided much more stable model runs. The low bias estimates and coefficients of variation indicate that the final model was stable and results were reasonable.

The final assessment indicated that the upper Bay yellow perch population declined persistently, but gradually, from 2005 – 2011. Age 1 recruitment estimates were below average in five of those seven years. The 2007 and 2009 age 1 abundance estimates (2006 and 2008 year classes) were particularly weak. These sustained below average recruitment events were the primary cause of the total population decline, as F was well below the conservative target for most of the time period. The population increase in 2012 was due to the large recruitment event of the 2011 year class. The population failed to increase after 2012 because of the particularly weak year classes mentioned. Strong year classes in 2014 and 2015 enabled the population to expand to above average levels in four of the last five years. Currently, the fishery is operating on only two year classes.

Population expansion is unlikely, in spite of a strong 2018 year class because the 2012, 2013, 2016, and 2017 year classes were so weak. This demonstrates the boom and bust nature of yellow perch population dynamics (Piavis et al. 1993). Three of the last seven years of recruitment were very strong, but because four of the last seven years failed to produce a meaningful contribution to population abundance, abundance will likely decline. The decline will become more prominent as age four and five yellow are removed from the population due to fishing and natural mortality

The Choptank River yellow perch population growth and decline was estimated from a fishery independent fyke net survey. The population expanded relatively quickly and for a sustained period from 1998 – 2010. The most recent period investigated, 2010 – 2019 failed to produce a statistically significant decline, but by extension, the analysis suggests that the population has been stable at best. Inspection of age 3 relative abundance (see Table 28 in Project 1 Job 1) as an indication of recruitment to the adult population, suggests that the 2015 year class was strong and the 2014 year class was mediocre. Upper Bay and Choptank River yellow perch year class success generally mimic each other, but our data imply that the 2014 year class was considerably weaker in the Choptank River. As such, where the upper Bay population is dominated by two year classes in the exploitable population, the Choptank River is dominated by only one year class.

PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF WHITE PERCH IN SELECT REGIONS OF CHESAPEAKE BAY, MARYLAND

2020 PRELIMINARY RESULTS – WORK IN PROGRESS

Job 2 is designed to assess white perch, yellow perch and channel catfish on a rotating, triennial basis. The white perch assessment is currently in progress. The assessments will be unchanged from the 2017 assessment. The upper Chesapeake Bay and the Choptank River populations will be analyzed separately with a Catch Survey Analysis (CSA). The primary data set for the upper Bay assessment is derived from the winter trawl survey. The primary data set for the Choptank River assessment is the fishery independent fyke net survey. Each model will produce estimates of abundance of recruited and pre-recruited white perch and fishing mortality. Outputs can then be compared to presumptive biological reference points. The lower Chesapeake Bay populations will be analyzed by inspecting trends in relative abundance of fishery dependent statistics and the fishery independent Estuarine Juvenile Finfish Survey. Currently, all the data have been collected, entered and checked for accuracy.

LIST OF TABLES

LIST OF FIGURES

CITATIONS

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Table 1. Upper Chesapeake Bay commercial yellow perch total allowable catch (TAC, pounds), actual harvest, and adjusted TAC (adjusted based on previous years' quota overage).

YEAR	TAC	ADJUSTED TAC	HARVEST
2009	38,000		49,951
2010	44,900	39,949	49,629
2011	47,200	37,520	37,543
2012	38,973	38,950	36,975
2013	29,800	29,800	19,352
2014	27,200	27,200	19,305
2015	30,489	30,489	34,478
2016	46,098	42,109	56,501
2017	52,992	45,976	44,426
2018	59,662	59,662	53,502
2019	53,368	53,368	51,737

Table 2. Sample sizes for lengths and ages and the years used in forming the catch-at-age matrix for upper Chesapeake Bay yellow perch.

Year	Length sample size	Age sample size	
		Females	Males
1998	890	131	67
1999	1,453	231	42
2000	1,670	187	59
2001	4,45	79	19
2002	1,440	79	43
2003	1,078	69	35
2004	964	70	39
2005	973	56	45
2006	1,015	56	44
2007	1,386	53	34
2008	8,927	272	89
2009	1,321	69	42
2010	1,322	56	49
2011	1,031	58	59
2012	1,057	64	38
2013	1,127	80	48
2014	871	65	31
2015	1,379	35	27
2016	1,861	54	48
2017	2,033	43	43
2018	1,701	54	31
2019	2,051	56	40

Table 3. Catch-at age matrix for upper Chesapeake Bay yellow perch, 1998 –2019. Entries in bold were lowest value to substitute for 0 estimated catch.

Year	2	3	4	5	6	7	8+
1998	5,460	3,086	51,318	151,407	**127**	**1,437**	**414**
1999	0	224,304	7,503	65,241	79,448	6,984	794
2000	0	876	162,415	4,826	9,278	15,570	**414**
2001	0	27,708	11,273	169,957	3,936	4,546	7,441
2002	4,902	24,777	119,202	11,544	211,205	4,101	27,478
2003	231	45,646	1,400	34,692	4,621	37,693	3,612
2004	0	55,005	70,522	8,333	8,088	**1,437**	6,462
2005	0	377	99,246	24,017	3,068	1,437	4,127
2006	1,735	24,636	580	31,575	7,688	**1,437**	580
2007	0	5,604	54,280	1,564	20,722	6,972	1,173
2008	0	1,643	5,076	7,509	127	1,551	414
2009	1,596	1,746	34,940	27,300	29,895	1,681	3,194
2010	268	31,845	11,182	24,510	25,136	23,258	2,057
2011	874	2,498	37,262	11,092	15,746	13,532	7,413
2012	282	25,352	1,313	40,802	1,126	15,353	14,779
2013	659	8,741	25,652	3,250	7,555	1,757	1,889
2014	0	23,789	12,008	6,035	1,410	4,073	1,699
2015	412	412	49,496	14,831	11,300	**1,437**	4,708
2016	6,083	2,151	1,780	87,015	22,180	16,320	2,448
2017	0	63,772	**580**	**348**	38,891	6,505	7,039
2018	0	57,674	35,290	**348**	**127**	2,784	**414**
2019	0	**377**	55,054	69,398	**127**	**1,437**	10,487

Table 4. Input variables for Thompson-Bell spawning stock biomass per recruit and yield per recruit models. f_{rs} = proportion mature, c=proportion of fishing mortality before spawning, d=proportion of natural mortality before spawning, and M=instantaneous natural mortality.

Age	f_{rs}	selectivity pattern (p)		c	d	M
		Slot limit	9"msl			
1	0.00	0.00	0.00	0.95	0.15	0.25
2	0.35	0.01	0.18	0.95	0.15	0.25
3	0.80	0.28	0.50	0.95	0.15	0.25
4	1.00	0.70	0.80	0.95	0.15	0.25
5	1.00	1.00	1.00	0.95	0.15	0.25
6	1.00	1.00	1.00	0.95	0.15	0.25
7	1.00	1.00	1.00	0.95	0.15	0.25
8	1.00	0.50	1.00	0.95	0.15	0.25
9	1.00	0.30	1.00	0.95	0.15	0.25
10	1.00	0.10	1.00	0.95	0.15	0.25
11	1.00	0.05	1.00	0.95	0.15	0.25
12	1.00	0.05	1.00	0.95	0.15	0.25

Table 5. Coefficient of variation and bias of population abundance (N), instantaneous fishing mortality (F), age 1 recruitment (R) and biomass (B) for upper Chesapeake Bay yellow final model.

Parameter	C.V.	Bias[1]	Parameter	C.V.	Bias[1]
N 2005	14.7	-1.2	R 2005	26.4	-3.2
N 2006	13.8	-1.2	R 2006	8.6	-0.8
N 2007	13.8	-1.2	R 2007	8.5	-0.9
N 2008	12.4	-1.2	R 2008	8.7	-0.9
N 2009	12.3	-1.2	R 2009	9.5	-1.0
N 2010	12.0	-1.2	R 2010	9.7	-1.1
N 2011	12.3	-1.3	R 2011	9.9	-1.1
N 2012	11.0	-1.2	R 2012	9.3	-1.0
N 2013	11.2	-1.2	R 2013	9.7	-1.0
N 2014	11.4	-1.2	R 2014	10.7	-1.2
N 2015	11.7	-1.3	R 2015	11.6	-1.3
N 2016	11.8	-1.3	R 2016	11.4	-1.3
N 2017	12.5	-1.4	R 2017	11.0	-1.2
N 2018	13.2	-1.5	R 2018	10.3	-1.0
N 2019	12.4	-1.4	R 2019	10.2	-1.1
F 2005	16.4	-2.6	B 2005	15.6	-1.3
F 2006	15.4	-2.2	B 2006	15.3	-1.3
F 2007	15.4	-2.3	B 2007	14.9	-1.3
F 2008	14.0	-1.4	B 2008	15.3	-1.4
F 2009	12.7	-1.2	B 2009	13.9	-1.3
F 2010	13.3	-1.2	B 2010	14.1	-1.4
F 2011	13.8	-0.9	B 2011	14.4	-1.5
F 2012	14.7	-1.2	B 2012	14.5	-1.5
F 2013	15.0	-1.2	B 2013	12.7	-1.4
F 2014	14.5	-1.1	B 2014	12.2	-1.3
F 2015	13.3	-0.9	B 2015	12.4	-1.3
F 2016	15.4	-1.2	B 2016	12.6	-1.4
F 2017	18.3	-1.7	B 2017	13.3	-1.5
F 2018	17.3	-1.5	B 2018	13.9	-1.6
F 2019	16.1	-1.1	B 2019	14.2	-1.6

[1] Bias= 100(Median-Mean)/Median

Figure 1. Upper Chesapeake Bay study area. Solid lines indicate areas not included in the assessment.

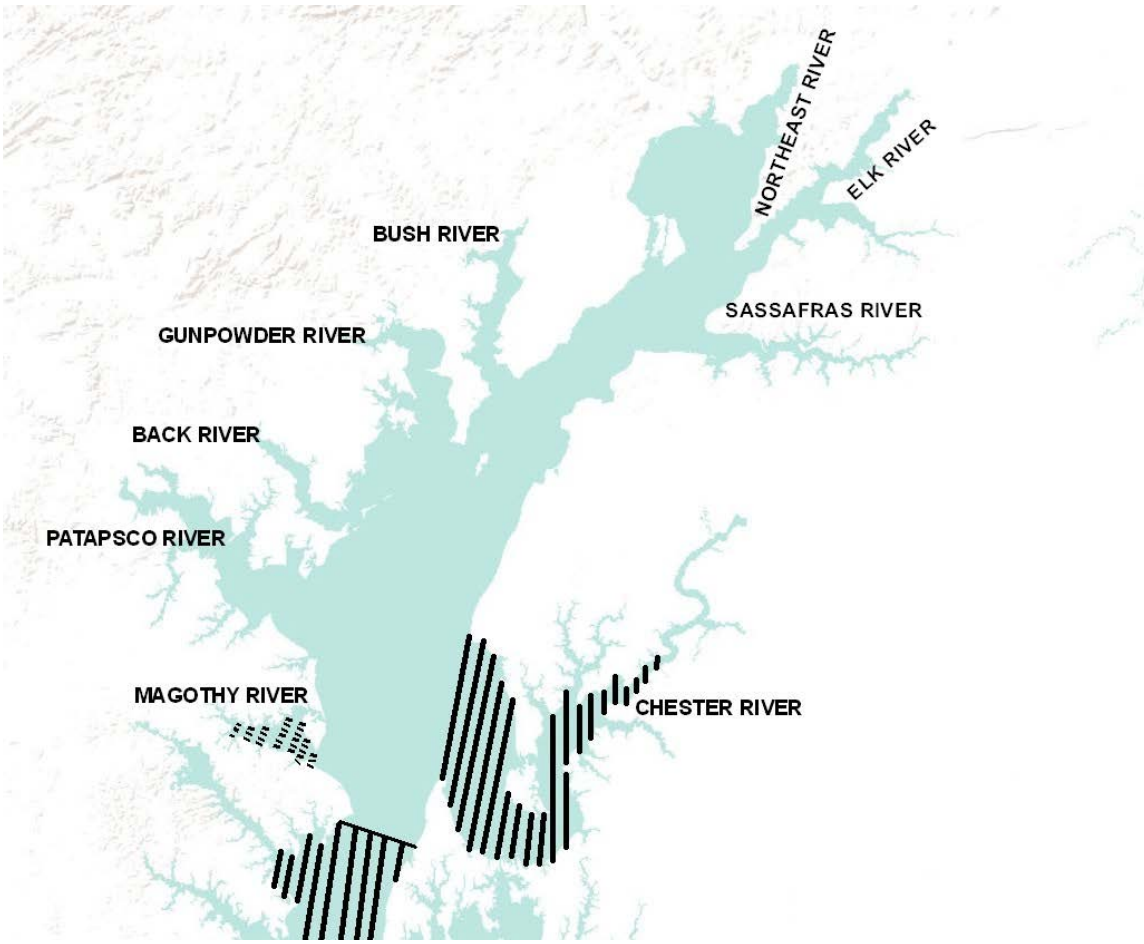


Figure 2. Upper Chesapeake Bay winter trawl survey locations for the 2019 sampling season.

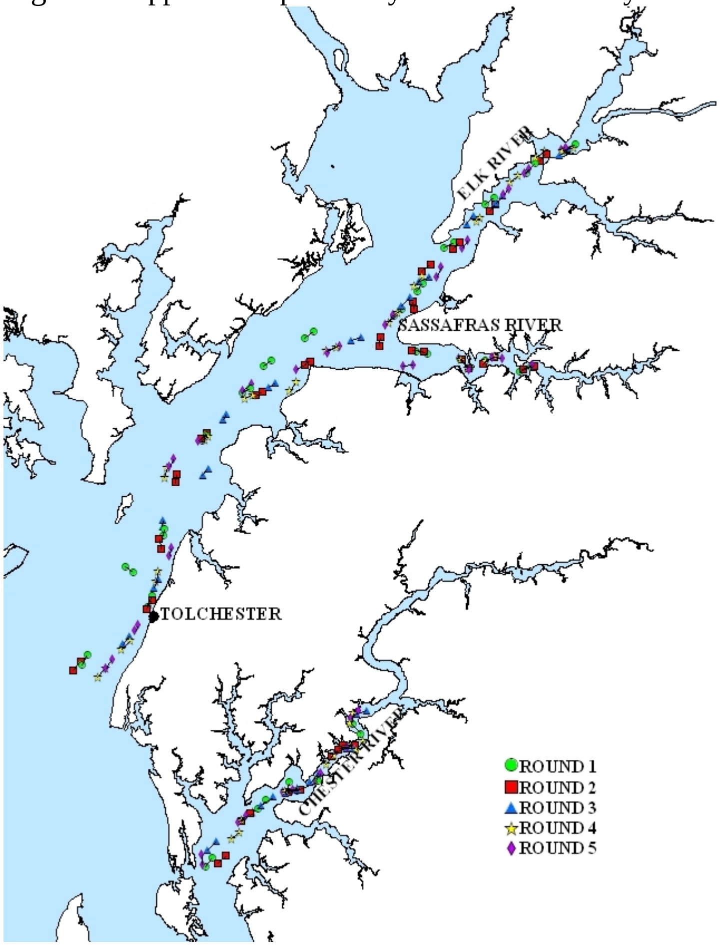


Figure 3. Yellow perch commercial fyke net selectivity curve from final model run.

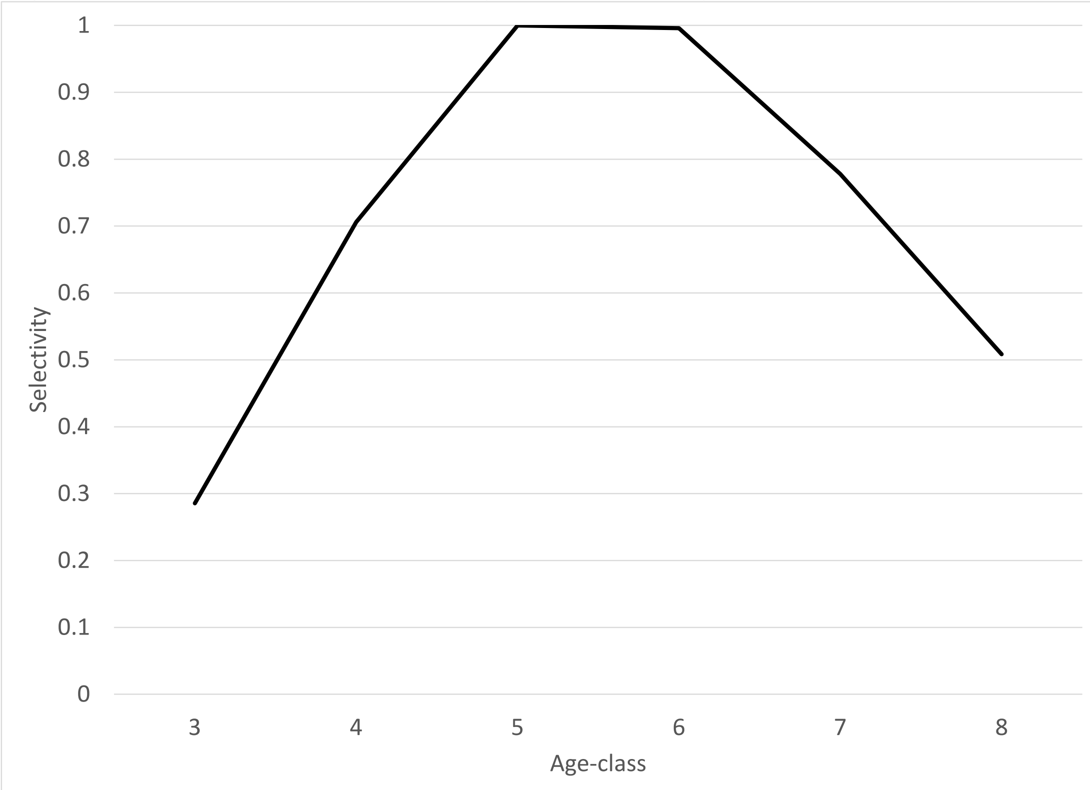


Figure 4. Upper Chesapeake Bay yellow perch abundance estimates (N, all ages), 2005 – 2019. Error bars are 2 standard deviations from simulations.

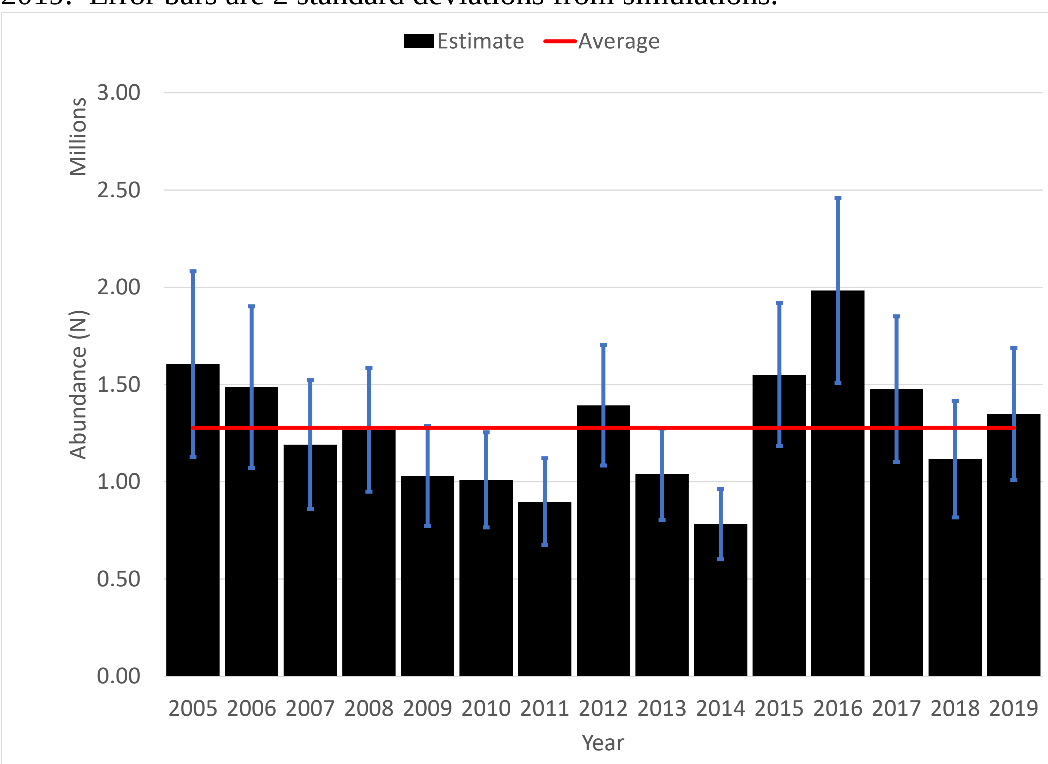


Figure 5. Upper Chesapeake Bay yellow perch biomass (kg, all ages) estimates, 2005 – 2019. Error bars are 2 standard deviations from simulations.

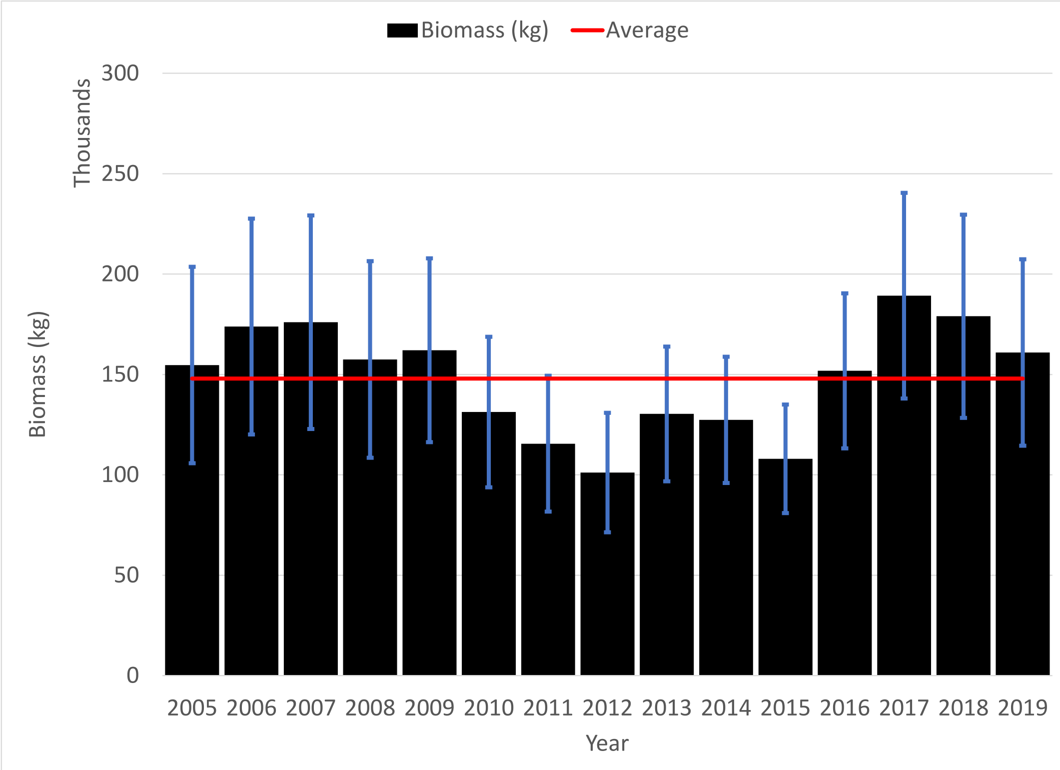


Figure 6. Upper Chesapeake Bay yellow perch fully recruited instantaneous fishing mortality (F) estimates, 2005 -- 2019. Error bars are 2 standard deviations from simulations.

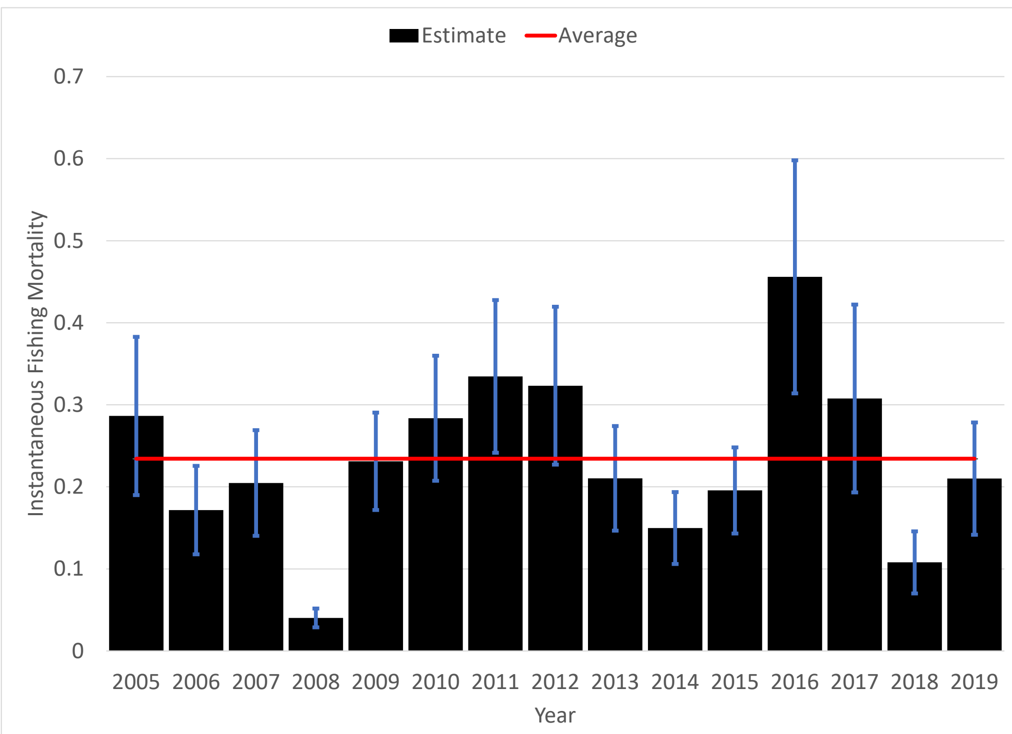


Figure 7. Upper Chesapeake Bay yellow perch recruitment (R, age 1) estimates, 1998 – 2019. Horizontal line indicates time series average. Error bars are 2 standard deviations from simulations.

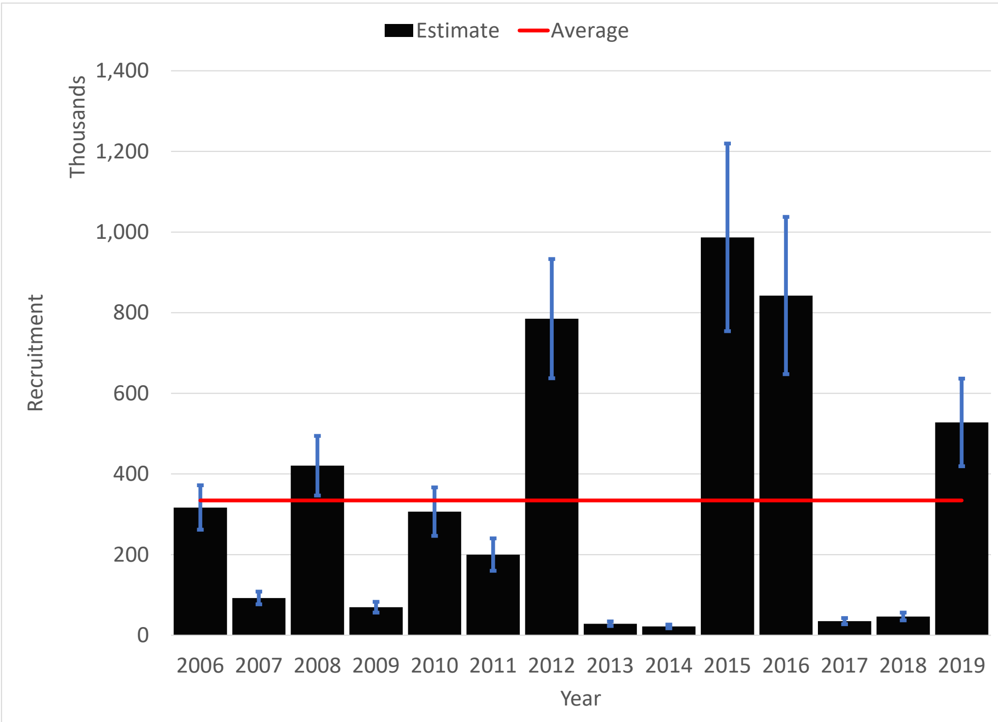


Figure 8. Abundance at age of upper Bay yellow perch in the terminal year of the assessment (2019). Error bars = +/- 2 standard deviations.

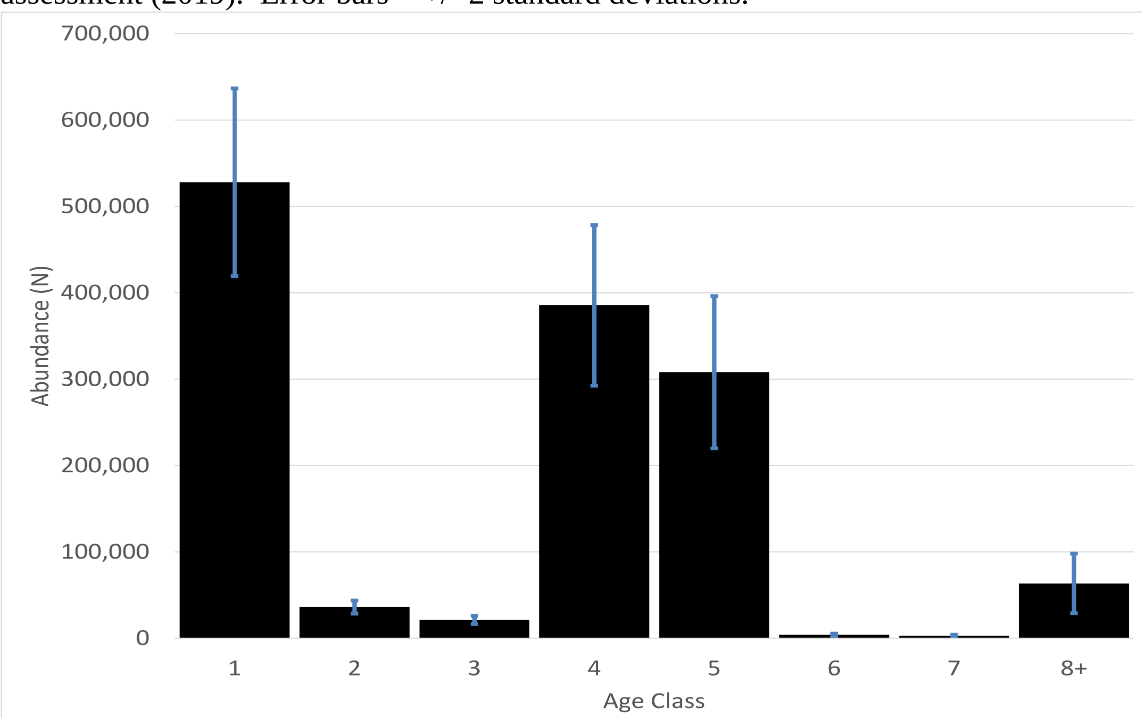


Figure 9. Comparison of base run and final run abundance estimates, 2005 – 2019.

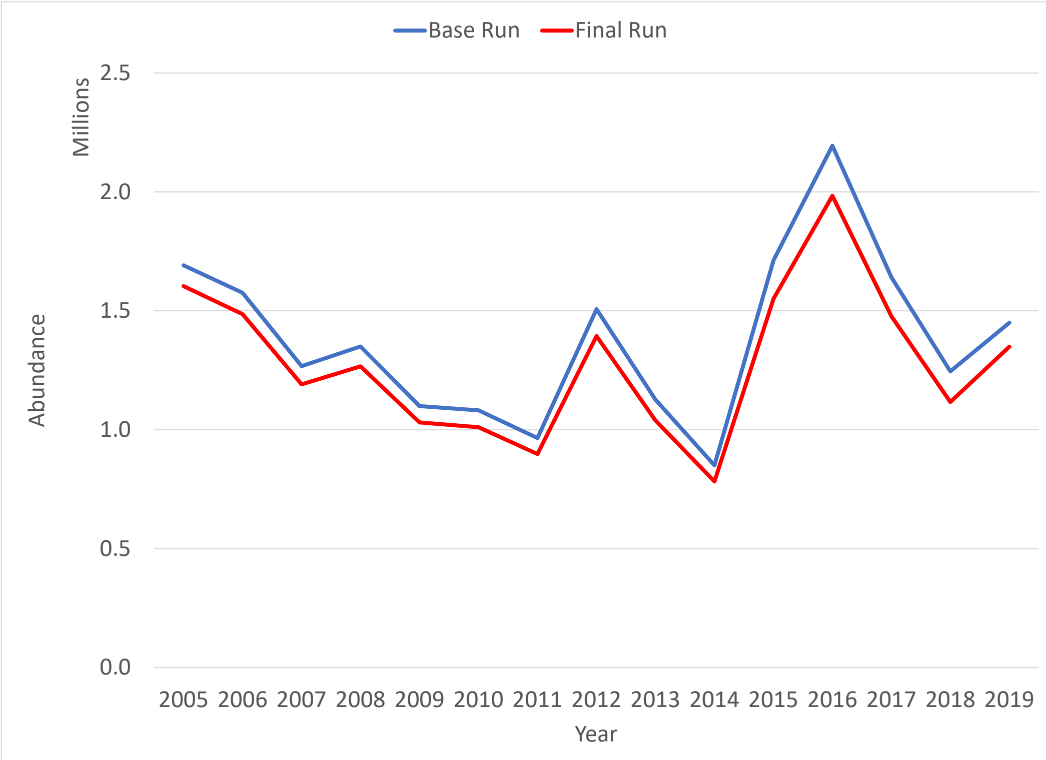


Figure 10. Comparison of base run and final run F estimates, 2005 – 2019.

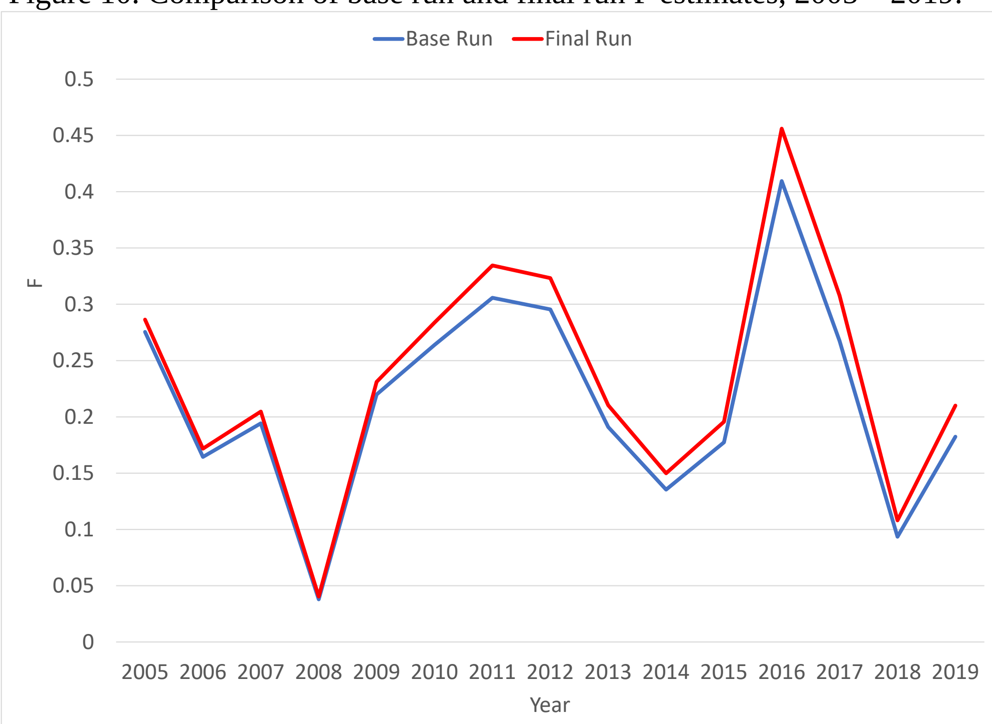


Figure 11. Comparison of base run and final run recruitment estimates, 2005 – 2019.

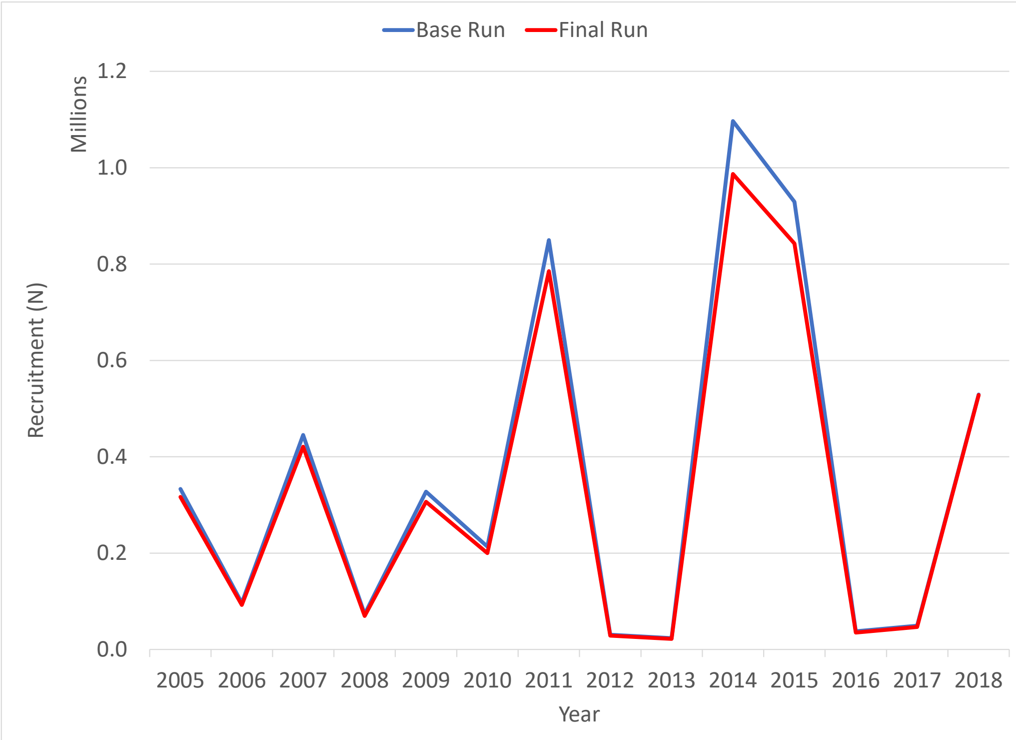


Figure 12. Percent maximum spawning potential (%MSP) versus F from Chesapeake Bay yellow perch spawning stock biomass/recruit model for 8 1/2" – 11" slot limit.

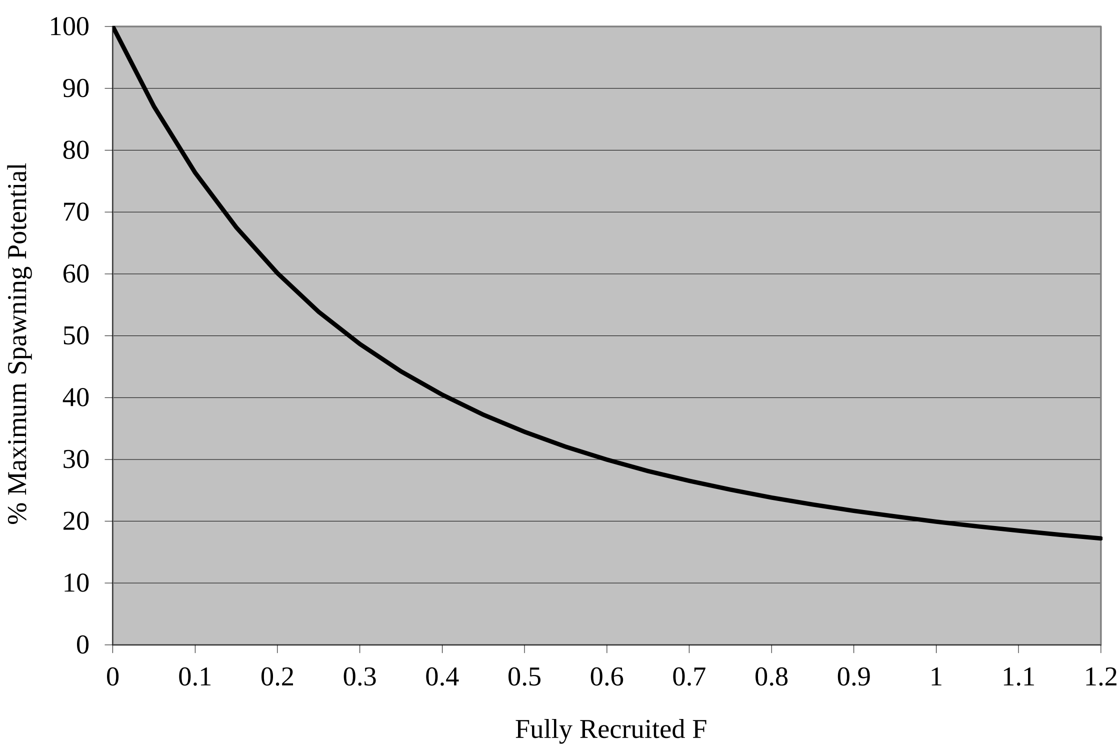


Figure 13. Percent maximum spawning potential (%MSP) versus F from Chesapeake Bay yellow perch spawning stock biomass/recruit model for 9” minimum size limit.

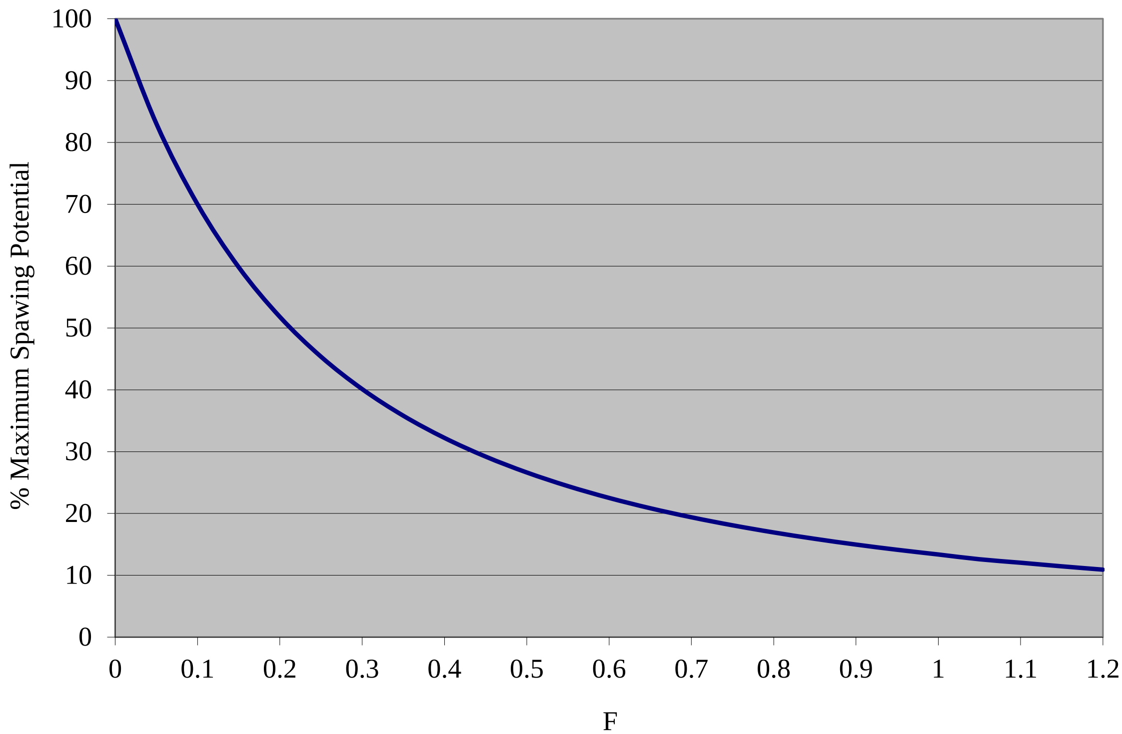


Figure 14. Probability distribution of instantaneous fishing mortality (F) estimates from upper Bay yellow perch simulations for 2019. Vertical dashed line is target F.

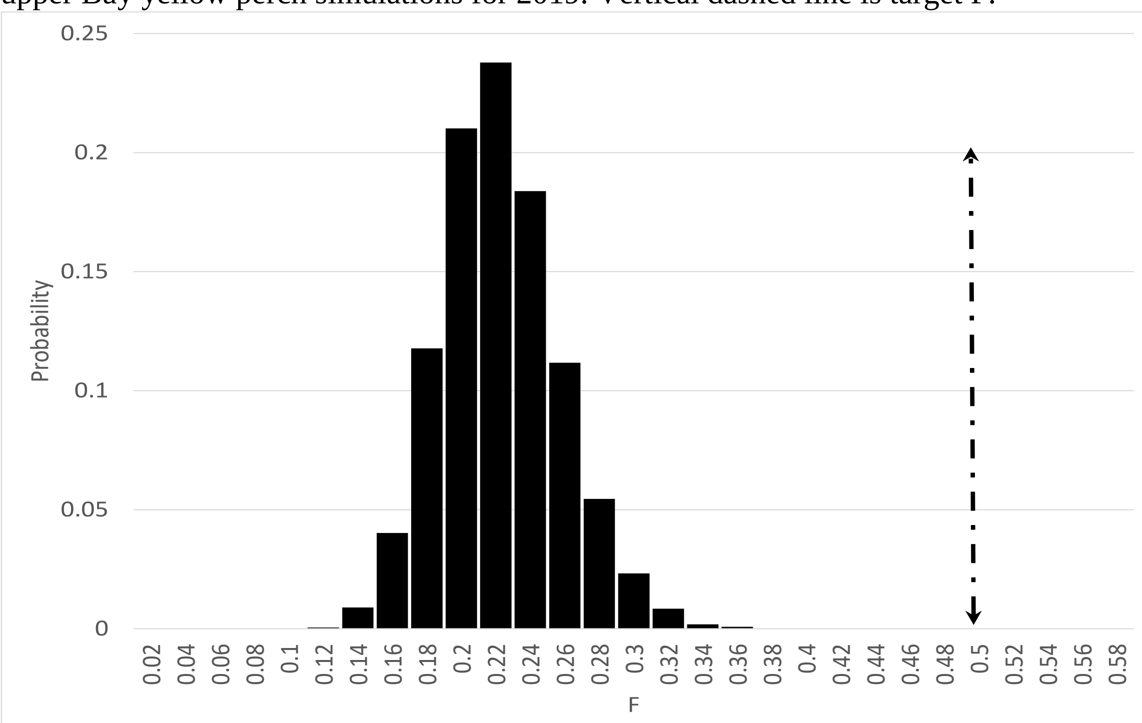


Figure 15. Yellow perch relative abundance [$\log_e$ (fish/net day)] from the Choptank River fishery independent fyke net survey, 1988 – 2019. Trendline fit is a third order polynomial.

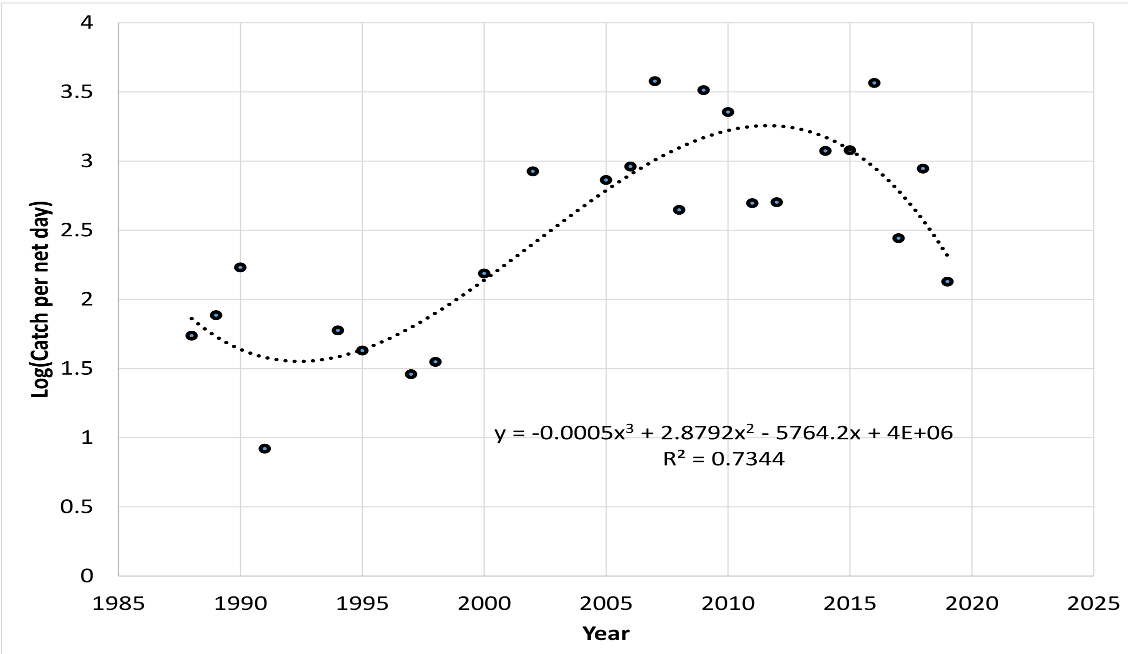


Figure 16. Linear regression of Choptank River yellow perch catch per unit effort, 1993 – 1998.

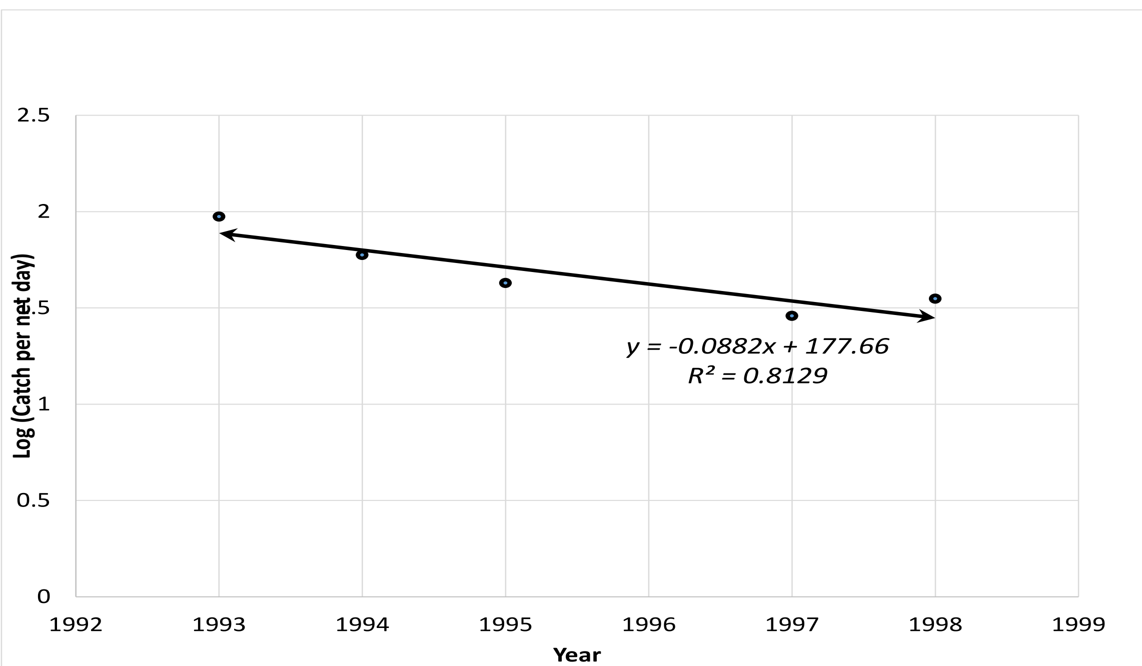


Figure 17. Linear regression of Choptank River yellow perch catch per unit effort, 1998 – 2010.

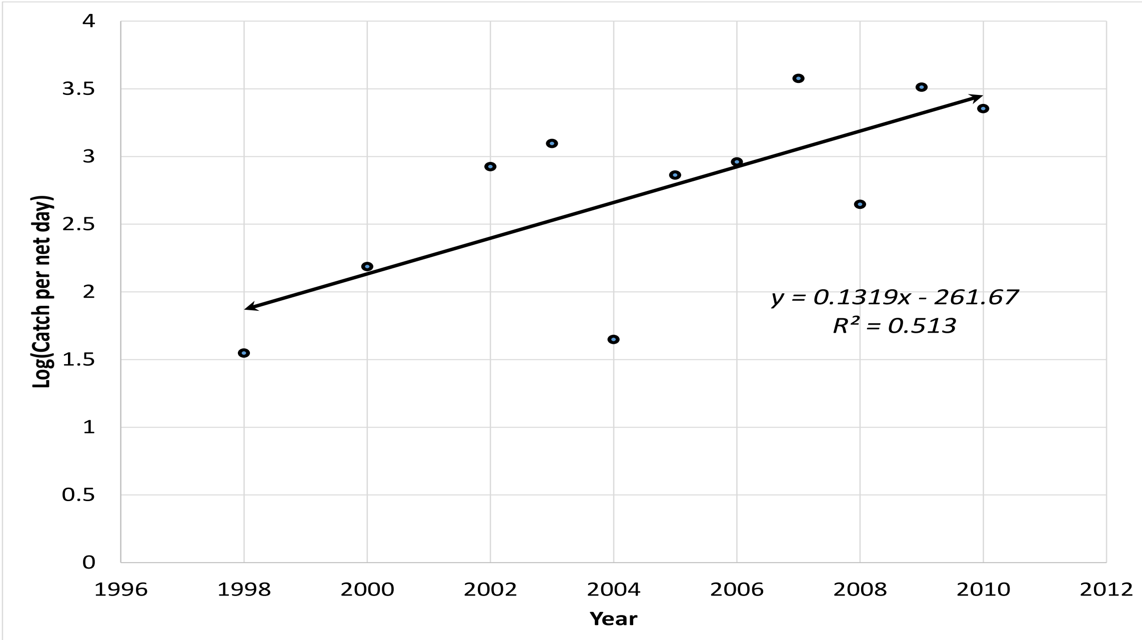
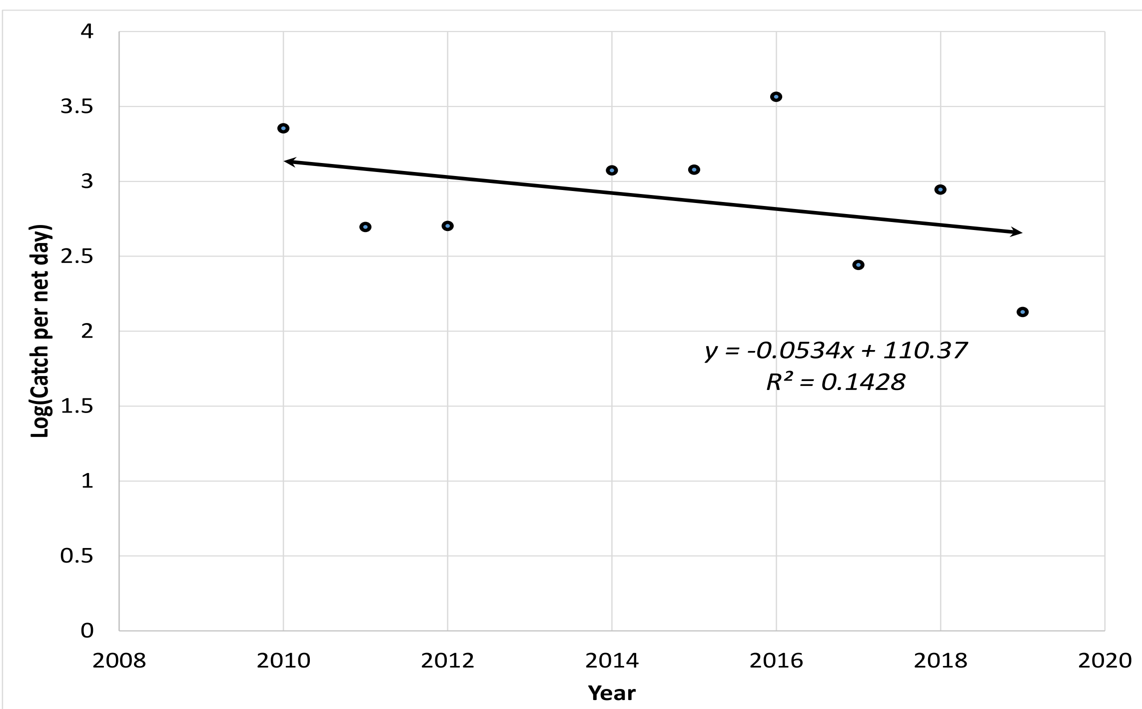


Figure 18. Linear regression of Choptank River yellow perch catch per unit effort, 2010 – 2019.



PROJECT NO. 2
JOB NO. 1

STOCK ASSESSMENT OF ADULT AND JUVENILE ALOSINE SPECIES IN THE CHESAPEAKE BAY AND SELECTED TRIBUTARIES

Prepared by
Robert J. Bourdon

INTRODUCTION

The primary objective of Project 2, Job 1 was to assess trends in the stock status of American shad, hickory shad and river herring (i.e., alewife and blueback herring) in Maryland's portion of the Chesapeake Bay and selected tributaries. Information regarding adult alosine species and their subsequent spawning success in Maryland tributaries was collected for this project by the Maryland Department of Natural Resources utilizing both fishery independent and dependent sampling gear. Biologists independently sampled adult American shad by hook and line fishing from the Susquehanna River below the Conowingo Dam to collect stock composition data and to estimate abundance. Stock composition and relative abundance of adult American shad in the Potomac River were assessed using fishery-independent gill nets (SBSSS; Project 2, Job 3, Task 2). Fishery dependent sampling was conducted on the Nanticoke River; biologists worked with commercial fishermen to collect stock composition data and to estimate relative abundance of adult American shad and river herring. Hickory shad stock composition was assessed in the Susquehanna River by the Maryland Department of Natural Resources Fish Health and Hatcheries Program. River herring were independently sampled using an experimental gill net in the North East River. Data collected by this project were used to prepare and update stock assessments and fishery management plans for the Atlantic States Marine Fisheries Commission (ASMFC), the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC), and the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team.

METHODS

Data Collection

Susquehanna River

Adult American shad were angled by Maryland Department of Natural Resources staff from the Conowingo Dam tailrace on the lower Susquehanna River two to four times per week from 15 April through 30 May 2019 (Figure 1). Two or three rods were fished simultaneously; each rod was rigged with two shad darts and lead weight was added when required to achieve proper depth. American shad were sexed (by expression of gonadal products), total length (TL) and fork length (FL) were measured to the nearest millimeter (mm), and scales were removed below the insertion of the dorsal fin for ageing and spawning history analysis. Fish in good physical condition, with the exception of spent or post-spawn fish, were tagged with Floy tags (color-coded to identify the year tagged) and released. A Maryland Department of Natural Resources hat was awarded for returned tags.

Normandeau Associates, Inc. was responsible for observing and/or collecting American shad at the Conowingo Dam fish lifts. American shad collected in the East Fish Lift (EFL) were deposited into a trough, directed past a 1.2 m x 3.0 m counting window, identified to species and counted by experienced technicians. American shad captured from the West Fish Lift (WFL) were counted and either used for experiments (e.g. hatchery brood stock, oxytetracycline [OTC] analysis, sacrificed for otolith extraction) or returned to the tailrace. For both lifts, tags were used to identify American shad captured in the Maryland Department of Natural Resources hook and line survey in the current and previous years.

A non-random roving creel survey provided both American and hickory shad catch and effort data from recreational anglers in the Conowingo Dam tailrace, concurrent with the Maryland Department of Natural Resources American shad hook and line survey. Stream bank anglers were interviewed about shad catch that day and hours spent fishing. A voluntary logbook survey also provided location, catch, and hours fished for American and hickory shad for each participating angler. Beginning in 2014, anglers could participate in the logbook survey by recording fishing trips through the Volunteer Angler Shad Survey on the Maryland Department of Natural Resources' website:

http://dnr.maryland.gov/Fisheries/Pages/survey/index.aspx

Due to the low number of hickory shad typically observed by this project, Maryland Department of Natural Resources' Fish Health and Hatcheries Program provided additional hickory shad data (2004-2019) from their brood stock collection. Hickory shad were collected in in the Susquehanna River near Lapidum, MD for hatchery brood stock and were sub-sampled for age, repeat spawning marks, sex, length (mm FL), and weight (g). In 2004 and 2005, fish were collected using hook and line fishing in both the Susquehanna River and its tributary, Deer Creek. More recently fish have been collected primarily by electrofishing, supplemented by hook and line fishing (2006-2019). Scale samples were taken from the first 20 fish per day for age determination.

Nanticoke River

Five commercial fyke nets and two pound nets were surveyed for American shad, hickory shad and river herring between 1 March and 26 April 2019 (Figure 2). Fish captured from these nets were sorted according to species and transferred to the survey boat for processing. All nets were generally sampled twice per week during the survey period. Fish were sexed (by expression of gonadal products), measured to the nearest mm (TL and FL), and scales were removed below the insertion of the dorsal fin for ageing and spawning history analysis. The first ten alewife and the first ten blueback herring encountered per sampling day were sacrificed to remove otoliths for ageing. Otoliths from dead adult American shad were removed for OTC analysis by Delaware Division of Fish and Wildlife (DE DFW).

Ichthyoplankton sampling was conducted on the Nanticoke River in cooperation with the Fish Habitat and Ecosystem Program (Federal Aid Grant F-63-R, Segment 2, Job 1, Section 3) on seven days between 5 April to 26 April 2019. The presence/absence of alosine eggs or larvae was noted (time and field conditions prevented species identification of alosine eggs or larvae). These samples were collected following historical methodology: the river was divided into eighteen one-mile cells and ten of these cells were randomly selected during each sampling day (Figure 3). The ichthyoplankton net was constructed of 500 μm mesh net with a 500 mm metal ring opening. The net was towed with the tide for two minutes at approximately two knots. At the conclusion of the tow, the contents were flushed down into a mason jar for presence/absence determination.

Potomac River

The Striped Bass Spawning Stock Survey (SBSSS; Project 2, Job 3, Task 2) provided American shad scales from the Potomac River to compare age structure and repeat spawning of fish in this river with fish sampled from the Susquehanna and Nanticoke rivers. American shad were captured in gill nets targeting striped bass that were fished from 2 April to 10 May 2019. All American shad were sexed and measured (TL and FL) to the nearest mm. A random subset of fish (10/sex/20mm length group) were scaled for age and spawning history analysis; scales were removed below the insertion of the dorsal fin.

North East River

A multi-panel experimental anchored sinking gill net was deployed in the North East River to assess the adult river herring spawning stock. The gill net was fished at four randomly chosen sites once per week for 10 weeks from 14 March to 14 May 2019. Sampling locations were randomly assigned from a grid superimposed on a map of the system (Figure 4). The grid consisted of 112 quadrats equaling 0.093 square kilometer per cell. Sampling sites were subsequently randomized for depth to determine if the net would be set in shallow or deep water within the quadrat. Four alternate sites were also randomly chosen and sampled in cases where the chosen site was inadequate. For example, if depth was below 1.8 m at a given site, the next available alternate site was selected.

Individual net panels were 30.5 m (100 feet) long and 1.8 m (6 feet) deep. The net had a 0.9 cm – 1.3 cm (3/8 – ½ inch) poly-foamcore float line and a 22.7 kg (50 pound) lead line. Nets were hung with 61 m (200 feet) of stretch netting for every 30.5 m of net. From 2013 – 2014, the panels were constructed of 0.33 mm diameter monofilament twine in 6.4 cm (2.5 inch), 7.0 cm (2.75 inch) and 7.6 cm (3 inch) mesh. Beginning in 2015, the 7.6 cm mesh panel was replaced with a 5.7 cm (2.25 inch) mesh panel, as there was evidence that the previous mesh size selections were not successful in capturing smaller sized blueback herring. The three panels were tied together to fish simultaneously and were soaked for 30 minutes before retrieval. Panel order was randomly chosen before the net was assembled at the start of the survey for each year. Two nets were assembled annually, and routine maintenance to mend holes in the net was conducted throughout the sampling season.

Following deployment of the net, water quality, depth and tidal stage were noted. All river herring were sexed and measured (TL and FL) to the nearest mm. Scales were removed from the first 20 alewife and the first 20 blueback herring encountered per panel for ageing and spawning history analysis. The first ten alewife and the first ten blueback herring encountered per sampling day were sacrificed to remove otoliths for ageing. A variety of other important sport fish were also measured to the nearest mm TL.

Ageing Protocol

Alosine scales collected from all rivers were aged following established protocols (Elzey et al., 2015) as recommended by Atlantic states' ageing experts (ASMFC 2013). A minimum of four scales per sample were cleaned, mounted between two glass slides and read for age and spawning history using a Micron 385 microfiche reader. The scale edge was counted as an annuli due to the assumption that each fish had completed a full year's growth at the time of capture. Ages were not assigned to regenerated scales or to scales that were difficult to read. Repeat spawning marks were counted on all alosine scales during ageing.

In 2019, age determination was done independently by three readers. If the age and spawning mark estimates did not fully match between at least two readers, the scale was jointly re-read as a group. If a consensus age or spawning mark could not be determined jointly, the sample was eliminated from further analysis. Hickory shad scales from the Susquehanna River were aged by the Maryland Department of Natural Resources Fish Health and Hatcheries Program.

During the 2018 ageing process, biologists noted that scales with faint or non-distinct annuli produced different age estimates when analyzed on different microfiche readers. Most notably, a Bell and Howell MT-609 microfiche frequently used in past seasons had the tendency to produce younger ages for such scales. Beginning in 2018, efforts were made for all scales to be read on comparable equipment to eliminate any potential bias towards younger ages.

Otoliths from subsamples of river herring (10/species/sampling day) were collected and archived for comparison of ageing structure results; otoliths will be processed as time allows.

Data Analysis

Ichthyoplankton

The percent of positive tows (i.e., those containing alosine eggs or larvae) was determined as the number of tows with eggs and/or larvae divided by the total number of tows. These data have been reported since 2005.

Sex, Age and Stock Composition

Male-female ratios were derived for American shad collected from the Susquehanna River below Conowingo Dam, from pound and fyke nets in the Nanticoke River, and from gill nets in the Potomac River. Hickory shad male-female ratios were derived from data provided by the Maryland Department of Natural Resources Fish Health and Hatcheries Program's brood stock collection on the Susquehanna River. Male-female ratios were also derived for alewife and blueback herring captured by experimental gill nets in the North East River and fyke and pound nets in the Nanticoke River.

Scales were collected as described above for the duration of the sampling season. When the total number of samples per species amounted to greater than 300 samples by river, approximately 300 random subsamples, proportional to catch by date, were processed for ageing and then applied to total catch using an age-length key derived from the subsampled ages.

The percentages of repeat spawners by species and system (sexes combined) were arcsine-transformed (in degrees) before looking for linear trends over time. For all statistics, significance was determined at $\alpha = 0.05$.

Otoliths collected from subsamples of American shad (Nanticoke and Susquehanna Rivers) were primarily used for hatchery vs. wild origin determination. All hatchery produced juvenile American shad stocked in Maryland, Delaware and the Susquehanna River basins have unique fluorescent OTC marks. Otolith examination by the Pennsylvania Fish and Boat Commission (PFBC) and the DE DFW indicated the percent of non-hatchery fish present from American shad collected in the WFL and, when available, Maryland's portion of the Nanticoke River, respectively.

Adult Relative Abundance

Using catch-per-unit-effort (CPUE) as a measure of relative abundance is a common practice in fisheries science. A geometric mean CPUE (GM CPUE) was calculated as the average LN (CPUE + 1) for each fishing/sampling day, transformed back to the original scale for most of the surveys analyzed by this project. A combined lift GM CPUE was calculated using the total number of adult fish lifted per hour of operation at the EFL and WFL at Conowingo Dam. Catch-per-angler-hour (CPAH) for American shad angled in the Susquehanna River and hickory shad angled in the region were calculated from the data collected by the logbook survey (paper logbook data and online angler reports were combined) and roving creel survey.

From 1988-1995, catches from all pound nets sampled on the Nanticoke River were factored into a measure of relative abundance (GM CPUE). Beginning in 1996, methods were revised to only include data from one pound net (Mill Creek) because it was consistently sampled over the time series; harvest from other pound nets was sporadic. Fyke nets were not included in the calculation because anecdotal evidence from the Nanticoke River suggested that they have a poor success rate in the capture of American shad relative to pound nets, rendering the efforts between the two methods uncomparable. Alewife and blueback herring GM CPUE was only calculated with fyke net data because pound nets were not consistently set in ideal habitat for river herring. Only trips following the first observed fish of each species per year were used in the GM CPUE calculation. No CPUE was calculated for hickory shad in the Nanticoke River due to the low number encountered by either gear type. In the Potomac River, the SBSSS calculated CPUE as the number of American shad caught per 836 square meters (1,000 square yards) of experimental drift gill net per hour fished. There was a slight decrease in the fishing effort by the SBSSS in the Potomac River beginning in 2015. The program reduced the length of three mesh panels (7.6 cm, 9.5 cm and 11.4 cm) from 45.7 m to 22.9 m in an attempt to catch fewer blue catfish.

The North East River gill net CPUE was estimated separately for alewife and blueback herring using catch from the 6.4 cm and 7.0 cm mesh panels, as these two panels were consistently sampled in all years. Alewife CPUE was calculated using summed catch and effort data from the first eight weeks of the survey, as the run typically tails off in early May. Conversely, the last six weeks of catch and effort data were summed to calculate the blueback herring CPUE since the run does not typically begin until early April. Catch was pooled across mesh sizes and a GM CPUE was reported as the number of fish caught per set of experimental gill net per hour fished. A second GM CPUE calculation was completed for both river herring species using all meshes currently being fished (5.7 cm, 6.4 cm and 7.0 cm). Since the 5.7 cm inch mesh was only added in 2015, the resulting CPUE time series was truncated to 2015-2019. Each gill net mesh size has a size selectivity bias, and this bias cannot be totally removed by utilizing multiple mesh size panels (Hamely 1975; Millar and Fryer 1999). Correction factors for each mesh size selectivity have not been estimated for river herring.

Catch-per-unit-effort is one of the most commonly used measures of relative abundance, but inter-annual fluctuations may be due to factors other than a change in abundance (e.g. temperature, flow, turbidity, etc.). Index standardization is a method that attempts to remove the influence that other factors may have on CPUE. Standardization is done by fitting statistical models to catch and effort data that incorporate the relationship of the covariates with catch (Maunder and Punt 2004). Due to the non-linear relationship of catch of American shad by hook and line in the Conowingo Dam tailrace, a generalized additive model (GAM) was used to standardize this index of abundance using relevant covariates. A GAM allows for smoothing functions as the link function between catch and covariates. The covariates explored for the model included: surface water temperature (°C), river flow in thousands of cubic feet per second (USGS Water Resources station 01578310 Susquehanna River at Conowingo, MD; USGS 2019) and day of the year. Variance Inflation Factors (VIFs) were used to assess collinearity of the covariates to determine which covariates to incorporate in the model (Zuur et al 2009). Several statistical distributions for the response variable were investigated and model selection was determined based on the model with dispersion closest to one, the highest deviance explained and the lowest Akaike Information Criterion (AIC). All models were run in RStudio (R Core Team 2015) utilizing the mgcv package (Wood 2011).

Population Estimates

Chapman's modification of the Petersen statistic was used to estimate abundance of American shad in the Conowingo Dam tailrace (Chapman 1951):

$$N = (C+1)(M+1)/(R+1)$$

where N is the relative population estimate, C is the number of fish examined for tags at the EFL after the annual tagging effort began, M is the number of fish tagged minus 3% tag loss, and R is the number of tagged fish recaptured at the EFL, excluding recapture of previous years' tags. Prior to 2001, C was the number of fish examined for tags at both the EFL and WFL, and R was the number of tagged fish recaptured at both lifts excluding recaps of previous years' tags. Protocol changed in 2001 where some American shad captured at the WFL were returned to the tailrace. Observations at the WFL were omitted to avoid double counting beginning in 2001. Calculation of 95% confidence limits (N^*) for the Petersen statistic were based on sampling error associated with recaptures in conjunction with Poisson distribution approximation (Ricker 1975):

$$N^* = (C+1)(M+1)/(R^t+1)$$

where

$$R^t = (R+1.92) \pm (1.96\sqrt{(R+1)})$$

Overestimation of abundance by the Petersen statistic (due to low recapture rates) necessitated the additional use of a biomass surplus production model (SPM; MacCall 2002, Weinrich et al. 2008):

$$N_t = N_{t-1} + [r\, N_{t-1}(1-(N_{t-1}/ K))] - C_{t-1}$$

where N_t is the population (numbers) in year t, N_{t-1} is the population (numbers) in the previous year, r is the intrinsic rate of population increase, K is the maximum population size, and C_{t-1} is losses associated with upstream and downstream fish passage and ocean bycatch in the previous year (equivalent to catch in SPM). Fish passage mortalities are calculated as 100% of adult American shad emigrating back through Holtwood Dam (N_{Holt}) and 25% for adult American shad emigrating back through the Conowingo Dam (N_{Cono}). Annual ocean bycatch estimates (L) are provided by the Northeast Fishery Science Center and are extrapolated from data generated by the Northeast Fisheries Observer Program. A bycatch coefficient (b) represents the estimated proportion of total American shad bycatch that is specific to the Susquehanna stock. Therefore losses in the previous year are calculated as:

$$C_{t-1} = N_{Holt} + 0.25 * (N_{Cono} - N_{Holt}) + b * L$$

Model parameters were estimated using the evolutionary procedure in the Solver application of Microsoft Excel. The model was fit to indices of relative abundance for American shad in Conowingo dam tailrace. Assumptions included: 1) accurate estimates of adult American shad turbine mortality, 2) the indices of relative abundance chosen for the fitting procedure were proportional to true abundance, 3) any losses from the stock were associated with mortality (no straying occurs), and 4) environmental influences were constant.

The SPM requires starting values for the initial population (B_0) in 1985, a carrying capacity estimate (K), an estimate of the intrinsic rate of growth (r) and a bycatch coefficient (b). For model development in 2019 the starting values were as follows: B_0 was set as 7,876, which was the Petersen statistic for 1985, K was set as 10,089,920 fish, which was ten times the highest Petersen estimate of the time series, r was set as 0.5, and b was set at 0.005. These starting values were adjusted by the model during the fitting procedure, which was constrained to search within r = 0.01 to 1.0, K = 1 million to 30 million fish, B_0 = 5,000 to 100,000 fish and b = 0.0 to 0.05. Additionally, the model was constrained to produce population estimates greater than the total number of American shad lifted or removed by the Conowingo Dam fish lifts. The model was run multiple times varying the indices of abundance. The run with the lowest sum of squares, lowest AICc, and reasonable parameter estimates was chosen.

Mortality

Chapman-Robson methodology (Chapman and Robson 1960) was used to estimate total instantaneous mortalities (Z) of adult American shad, hickory shad and river herring from all systems surveyed where age data were available. Age composition data were used in the analysis, where the first age-at-full recruitment was the age with the highest frequency and estimates were only made when data was available from three or more age-classes (including first fully-recruited age). Therefore Z was calculated as:

$$Z = -1 * ln (T / (N + T - 1))$$

where T is calculated as:

$$T = 0 * n_0 + 1 * n_1 + 2 * n_2 + \ldots A * n_A$$

where n_0 is the number of fish at the first fully recruited age, n_1 is the number of fish one year older than first fully recruited age, and this is carried out for all age groups greater than the first fully recruited age. The Chapman-Robson estimate is less biased than traditional catch curve methods (Dunn et al. 2002) and was recommended for use by peer reviewers of the most recent river herring benchmark stock assessment (ASMFC 2012).

Juvenile Abundance

The Maryland Department of Natural Resources Estuarine Juvenile Finfish Seine Survey (EJFS; Project 2, Job 3, Task 3) provided juvenile indices (geometric mean catch per haul) for alewife and blueback herring from fixed stations in the Nanticoke River and upper Chesapeake Bay, and for American shad in the Nanticoke and Potomac rivers, upper Chesapeake Bay and baywide. Hickory shad data are not reported by the EJFS due to historically infrequent encounters.

<u>RESULTS</u>

Ichthyoplankton

Ichthyoplankton tows were conducted on five days in 2019. Fertilized alosine eggs and/or larvae were present at 37.9% of tow stations in 2019 (Figure 5). Salinity at tow stations ranged from 0.0 to 2.1 ppt. An absence of observed eggs and/or larvae occurred from 2006-2008, and in 2012.

American Shad

Sex, Age and Stock Composition

The male-female ratio of adult American shad captured by hook and line from the Conowingo Dam tailrace in 2019 was 1:0.69. Of the 53 fish sampled by this gear, 44 were successfully scale-aged (Table 1). Males were present in age groups four through six and females were found in age groups four through eight. The 2014 year-class (age five) was the most abundant for males (46.2%) and the 2013 year-class (age six) was most abundant for females (38.9%; Table 2). Forty-two percent of males and 72% of females were repeat spawners (Figure 6). The arcsine-transformed proportion of these repeat spawners (sexes combined) significantly increased over the time series (1984-2019; $r^2 = 0.67$, $P < 0.001$; Figure 7). Analysis by PFBC of 283 American shad otoliths collected from the WFL at Conowingo Dam showed that 68% were wild fish and 32% were hatchery-produced fish in 2019; these percentages were similar to those from 2018 where 61% were wild fish and 39% were hatchery-produced fish.

The male-female ratio for adult American shad captured in the Nanticoke River was 1:0.71. Of the 41 American shad collected from Nanticoke River pound and fyke nets in 2019, 40 were successfully analyzed for age and repeat spawning marks. Both males and females were present in age groups four through seven (Table 1). The 2014 year-class (age five) was the most abundant for males (52.2%) and the 2013 year-class (age six) was most abundant for females (41.2%; Table 3). Forty-eight percent of males and 71% of females were repeat spawners. The arcsine-transformed proportion of Nanticoke River repeat spawning American shad (sexes combined) has significantly increased over the time series (1988-2019; $r^2 = 0.32$, $P < 0.001$; Figure 8). Analysis by DE DFW of American shad otoliths collected from the Nanticoke River were not completed for the 2019 samples.

In response to increasing catches on the Potomac River, scales were only taken from a subsample of American shad beginning in 2017. The goal was to collect scales from ten individuals per sex per 20 mm length group for each year of the survey. Of the 284 total shad observed by the survey in 2019, 119 were scaled and successfully analyzed for age and repeat spawning marks. An age-length key was applied to assign ages to the entire sampled population (Table 1). The male-female ratio for adult American shad captured in the Potomac River was 1:1.73. Males were present in age groups three through seven, and females were present in age groups four through nine (Table 1). The 2013 year-class (age six) was the dominant age group for both males (31.7%) and females (54.4%; Table 4). Forty percent of males and 79% of females were repeat spawners. The arcsine-transformed proportion of Potomac River repeat spawning American shad (sexes combined) showed no significant trend over the time series (2002-2019; $r^2 = 0.02$, $P = 0.55$; Figure 9).

Adult Relative Abundance

Hook and line sampling at the Conowingo Dam occurred for 12 days in 2019. A record low total of 53 adult American shad were encountered by the gear; all of these fish were captured by Maryland Department of Natural Resources staff from a boat. No shore sampling occurred in 2019. Peak catch by hook and line (14 fish) occurred on 28 May 2019 at a surface water temperature of 20°C. This was later than peak catch in many other years and considerably later than peak catch at the Conowingo EFL. Maryland Department of Natural Resources staff tagged 43 (90%) of the sampled fish. No American shad tag recaptures were reported by a recreational or commercial fishermen in 2019.

The Conowingo EFL operated for 46 days between 1 April and 31 May 2019. Of the 4,787 American shad that passed at the EFL, 73% (3,472 fish) passed between 1 May and 12 May 2019. Peak passage was on 3 May; 1,314 American shad were recorded on this date. Only one floy tagged American shad was counted at the EFL and was identified as being tagged in 2019 (Table 5).

The Conowingo WFL operated for 20 days between 1 May and 31 May 2019. The 390 captured American shad were retained for hatchery operations, sacrificed for otolith collection or returned alive to the tailrace. Peak capture from the WFL was on 1 May, when 132 American shad were collected. No tagged American shad were recaptured by the WFL in 2019 (Table 5).

The various model configurations explored for developing a GAM for the hook and line index and how each model performed are summarized in Table 6. Due to observed collinearity of day of the year with surface water temperature, day of the year was removed from the model. Since GAMs are highly sensitive to collinearity, a more stringent variance inflation factor (VIF) cutoff may be necessary. For example, Booth et al. (1994) suggest a cutoff of 1.5. This more stringent cutoff would lead to the removal of the flow variable, leaving only surface water temperature. For this reason, models that included temperature and flow, and models that just included temperature were explored.

Overall, models that included both temperature and flow explained more deviance, but only slightly more than models with just temperature, which indicated temperature had a greater effect on catch than flow (Table 6). Of the models that included both temperature and flow, results indicated that both models 2 and 3 were acceptable. Model 2 was slightly over-dispersed, while model 3 was slightly under-dispersed. Slight under-dispersal is generally preferable to being over-dispersed (Laura Lee, North Carolina Department of Environment and Natural Resources, pers. comm.), so model 3 was chosen as the best fit model.

The best fit model utilized temperature and flow as explanatory variables linked to catch using cubic spline regression, year as a factor level, with the natural logarithm of effort as an offset, and a negative binomial response distribution. This model showed no obvious signs of pattern in the residuals (Figure 10). The standardized annual hook and line CPUE exhibits substantial year to year variability and peaked in 1998 (Figure 11). Relative abundance has generally declined since that time and reached its lowest level in 2019.

The Conowingo Dam fish lifts provided another opportunity to measure American shad relative abundance. Both counts of fish lifted at the Conowingo Dam and the combined lift GM CPUE mirrored the hook and line index for years when both the East and West Fish lifts were operating (Figure 12). Like all measures of relative abundance, there are caveats to accepting these indices as indicative of true abundance. Lift efficiency and river flows affected run counts at Conowingo Dam, while the number and frequency of lifts affected GM CPUE. All three indices measured in this region of the Susquehanna River showed a broad general trend that abundance was low in the 1990s, increased to a peak in the early 2000s, and then declined to low levels of abundance (Figures 11 and 12).

Thirty-two interviews were conducted over six days during the creel survey at the Conowingo Dam Tailrace. Catch per angler hour increased marginally in 2019 relative to 2018 (Table 7), but had no significant trend over the time series (2001-2019; $r^2 = 0.15$, $P = 0.11$).

Two anglers returned paper logbooks in 2019. Additionally, six anglers participated online by recording their trips through Maryland Department of Natural Resources' Volunteer Angler Shad Survey. American shad CPAH calculated from shad logbook data combined with data from

Maryland Department of Natural Resources' Volunteer Angler Shad Survey increased marginally in 2019 relative to 2018 (Table 8). Online angler data was included in the CPAH calculation beginning in 2014. The logbook CPAH estimate of adult American shad relative abundance peaked in 2001, but exhibited no significant trend over the time series (2001-2019; $r^2 = 0.14$, $P = 0.11$; Table 8).

The Nanticoke River pound net GM CPUE was average in 2019, was highly variable, and showed no significant trend over the time series (1996-2019; $r^2 = 0.01$, $P = 0.61$, Figure 13). Only the indices from 1996-2019 were used in the trend analysis because prior to 1996, estimates were calculated using all pound net data, not just Mill Creek. The Potomac River gill net CPUE significantly increased over the time series (1996-2019; $r^2 = 0.52$, $P < 0.001$, Figure 14).

Population Estimates

The Petersen statistic estimated 102,813 American shad in the Conowingo Dam tailrace in 2019 with an upper confidence limit of 179,095 fish and a lower confidence limit of 30,728 fish (Figure 15). The SPM with the lowest sum of squares that best represented American shad in the Conowingo Dam tailrace utilized the CPUE from the hook and line survey. This run estimated a population of 57,606 American shad in the Conowingo Dam tailrace in 2019 and produced realistic estimates of the model parameters r, K and B_0 ($r = 0.247$, $K = 23{,}426{,}254$, $B_0 = 71{,}109$; Figure 16).

Despite differences between the Petersen estimate and SPM, the overall population trends derived from each population model were fairly similar (Figures 15 and 16). Specifically, the SPM showed an increasing population size from the beginning of the time series to a peak in 2000, followed by a rapid decline through 2007 (Figure 16). Petersen estimates followed a similar pattern if the high levels of uncertainty in 2004 and 2008 (due to low recapture rates) are considered

(Figure 15). The SPM exhibited retrospective bias in the terminal years of the time series, falsely suggesting a slight increase in population size since 2013. American shad abundance has likely been relatively stable at low levels in recent years, though some decline may still be occurring.

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate (Z) for American shad, sexes combined, in 2019 was 0.87; there was no significant trend in mortality estimates from the Conowingo Dam over the time series (1984-2019; r^2 = 0.00, P = 0.80, Figure 17). The total instantaneous mortality estimate for American shad, sexes combined, in the Nanticoke River in 2019 was 0.99; there was no significant trend in mortality estimates over the time series of the Nanticoke River survey (1989-2019; r^2 = 0.00, P = 0.75, Figure 18). The Potomac River total instantaneous mortality estimate (Z) for American shad, sexes combined, in 2019 was 1.35; mortality increased significantly over the time series (2002-2019; r^2 = 0.39, P = 0.006, Figure 19). Sex-specific mortality estimates for American shad were not calculated in 2019 due to either limited sample size or failure to exhibit two ages past the age of full recruitment, a requirement of the Chapman-Robson age-based method.

Juvenile Abundance

In 2019, juvenile American shad abundance indices provided by the EJFS demonstrated increased juvenile production in the Potomac River and minor declines in both the Nanticoke River and Upper Chesapeake Bay (Figures 20-23). Juvenile indices were not corrected for hatchery contribution.

Hickory Shad

Sex, Age and Stock Composition

Only eight hickory shad were captured in the Nanticoke River pound and fyke net survey in 2019; the hickory shad sample from this river is generally not large enough to draw meaningful conclusions about sex or age composition. In the Susquehanna River, 191 hickory shad were sampled by the broodstock collection survey in 2019. The male-female ratio was 1:1.29. Of the total fish captured by this survey, 98 were successfully aged. Males were present in age groups three through seven and females were present in age groups three through eight (Table 9). The 2015 year-class (age 4) was the most abundant year class for both males (42.5%) and females (46.6%, Table 10). In 2019, an age eight hickory shad was observed for the first time since 2011 (Table 10). The arcsine-transformed proportion of repeat spawners (sexes combined) decreased significantly over the time series (2004-2019; $r^2 = 0.41$, $P = 0.008$; Figure 24).

Relative Abundance

Hickory shad relative abundance, expressed as CPAH, from logbook and Volunteer Angler Survey data declined over the time series (1998-2019; $r^2 = 0.18$, $P = 0.05$; Figure 25). Hickory shad CPAH in 2019 was 3.66, which was a decrease from the 2018 value (5.40, Table 11). Given the small sample size of hickory shad captured on the Nanticoke River in most years, no measure of relative abundance was calculated.

Mortality

Total instantaneous hickory shad mortality, sexes combined, in the Susquehanna River was estimated as Z = 0.85, which was a decrease from 2018 (Z = 1.12). Mortality varied without trend over the time series (2004-2019; $r^2 = 0.34$, $P = 0.02$; Figure 26).

Alewife and Blueback Herring

Sex, Age and Stock Composition

The 2019 male-female ratio for Nanticoke River alewife was 1:1.58. Of the total 2,235 alewife observed by the survey, 316 were subsequently aged. Alewife were present from ages three to eight and the 2015 year-class (age four, sexes combined) was the most abundant, accounting for 45.2% of the total catch (Table 12). The 2019 male-female ratio for Nanticoke River blueback herring was 1:0.92. Of the 1,441 blueback herring sampled, 312 were subsequently aged. Blueback herring were present from ages three to seven and the 2015 year-class (age four, sexes combined) was the most abundant, accounting for 62.2% of the sample (Table 13). Blueback herring ages nine to eleven were not observed since 2000, which is evident in the decrease of the percent of blueback herring ages six and older observed in recent years (Table 13).

For the Nanticoke River, 55.3% of alewife and 30.2% of blueback herring were repeat spawners (sexes combined) in 2019. There was no trend in the arcsine-transformed proportion of alewife repeat spawners over the time series (1990-2019; $r^2 = 0.08$, $P = 0.13$; Figure 27). Blueback herring repeat spawning decreased over the same time period (1990-2019; $r^2 = 0.62$, $P < 0.001$; Figure 27).

Alewife mean length (FL mm) from the Nanticoke River varied without trend since the inception of this survey (1989-2019; $r^2 = 0.02$, $P = 0.46$; Figure 28), while blueback herring mean length (FL mm) significantly decreased across the time series (1989-2019; $r^2 = 0.48$, $P < 0.001$; Figure 28).

Since the inception of the North East River gill net survey, more female alewife were encountered by the gear than male alewife. The male-female ratio for alewife in 2019 was 1:1.34. Alewife of ages three to eight were present in 2019. The 2014 (age five) and 2015 (age four) year-classes were the dominant age groups in 2019, comprising 43.8% and 43.6% of the sample respectively (Table 14; Figure 29).

Female blueback herring catch far exceeded that of males in 2019; the male-female ratio for blueback herring was 1:3.38. Blueback herring were present from ages three to eight in 2019; this was the first year that age eight or greater blueback herring were observed by the survey. The 2015 (age four) year-class for blueback herring was the most abundant in 2019, comprising 64.6% of the sample (Table 15; Figure 30).

For the North East River in 2019, 55.4% of alewife and 47.0% of blueback herring were repeat spawners (sexes combined). No significant trend in the occurrence of repeat spawning alewife (2013-2019, $r^2 = 0.05$, $P = 0.64$; Figure 31) or blueback herring (2013-2019, $r^2 = 0.02$, $P = 0.77$; Figure 31) was observed over the time series.

Adult Relative Abundance

Data from five fyke nets on the Nanticoke River were used to calculate relative abundance of river herring in 2019. The GM CPUE for Nanticoke River alewife decreased over the time series (1990-2019; $r^2 = 0.23$, $P = 0.01$; Figure 32). The GM CPUE for blueback herring also decreased over the time series (1989-2019; $r^2 = 0.58$, $P < 0.001$; Figure 32).

The North East River gill net survey captured 503 alewife and 713 blueback herring; compared to 2018, alewife catch slightly increased while blueback herring catch increased substantially to the highest level observed by the survey. Total catch of blueback herring exceeded that of alewife catch in the North East River for the first time in 2019. Peak catch of alewife (124 fish) occurred on 4 April 2019 when the water temperature was 10.4°C (Figure 33). Peak catch of blueback herring (298 fish) occurred about a month later on 30 April 2019 when the water temperature was 16.7°C (Figure 33). The majority of alewife were caught in the 6.4 cm (2.5 inch) mesh in all years of the survey except for 2019 when 51.9% of all alewife were captured in the 7.0 cm (2.75 inch) mesh (Figure 34). Alewife ranged in size from 213-290 mm FL. Similar to most other years, the majority of blueback herring were caught in the 5.7 cm (2.25 inch) mesh in 2019 (Figure 35). Blueback herring ranged in size from 204-279 mm FL.

Traditionally, catch-per-unit-effort estimates for the North East River survey were made with pooled catches from the 6.4 cm and 7.0 cm meshes, as those meshes were fished since the inception of the survey. This method indicated an increase in both alewife and blueback herring CPUE compared to 2018. No significant linear trends were observed over the time series for either species (2013-2019; Alewife: $r^2 = 0.38$, $P = 0.14$; Blueback herring: $r^2 = 0.25$, $P = 0.25$; Figure 36). We also calculated CPUE with catch pooled for the 5.7 cm, 6.4 cm and 7.0 cm meshes, resulting in the truncation of the time series to 2015-2019. This method produced similar year to year changes in CPUE compared to the traditional method, and no significant trends were observed for alewife or blueback herring (2015-2019; Alewife: $r^2 = 0.13$, $P = 0.58$; Blueback herring: $r^2 = 0.19$, $P = 0.46$; Figure 37). Regardless of pooling method, the increase in blueback herring CPUE in 2019 was substantial and is a marked improvement after three consecutive years of decline. Discretion should be used when interpreting these results as they have not been corrected for selectivity bias of the mesh sizes. Total catch of other important sport fish are noted in Table 16.

Mortality

Total 2019 instantaneous mortality for Nanticoke River alewife (sexes combined) was estimated as Z = 0.83. Total instantaneous mortality for Nanticoke River blueback herring (sexes combined) was Z = 1.15. There was no significant trend in mortality estimates for either species over the time series (1989-2019; Alewife: $r^2 = 0.02$, $P = 0.45$, Figure 38; Blueback herring: $r^2 = 0.03$, $P = 0.34$, Figure 39).

The 2019 total instantaneous mortality estimates for alewife from the North East River was Z = 1.48, and the blueback herring estimate was Z = 1.11. There was no significant trend in mortality estimates for either species over the time series (2013-2019; Alewife: $r^2 = 0.06$, $P = 0.61$; Blueback herring: $r^2 = 0.02$, $P = 0.79$; Figure 40).

Juvenile Abundance

Data provided by the EJFS indicated that juvenile GM CPUE of alewife declined slightly in the Upper Chesapeake Bay and the Nanticoke River in 2019 (Figure 41). Blueback herring juvenile GM CPUE increased substantially in the Upper Chesapeake Bay and remained stable in the Nanticoke River (Figure 42).

DISCUSSION

American Shad

American shad are historically one of the most important exploited fish species in North America, but the stock has drastically declined due to the loss of habitat, overfishing, ocean bycatch, stream blockages, pollution, and exposure to invasive predators. American shad restoration in upper Chesapeake Bay began in the 1970s with the building of fish lifts and the stocking of juvenile American shad. Maryland closed the commercial and recreational American shad fisheries in 1980, and the ocean intercept fishery closed in 2005. While the American shad adult stock has shown some improvement in select river systems, the 2020 ASMFC stock assessment indicated that most stocks have not recovered and populations remain near historic lows (ASMFC 2020).

The population size of American shad in the lower Susquehanna basin was relatively stable over the past ten years (2009-2019; SPM estimate), although at a much lower level than the peak observed in 2000, and compared to historical abundance. This follows a period (2001-2007) when calculated indices of relative abundance generally decreased (including the hook and line CPUE, lift CPUE, logbook CPAH and creel CPAH).

The Petersen estimate and SPM results were both useful techniques for providing estimates of American shad abundance at Conowingo Dam. Both models indicate that the population is depleted and likely near historic lows. The apparent increase in population in recent years (2013-2019) according to the SPM is due to retrospective bias. In reality, the abundance of American shad in the Susquehanna River is stable or in slight decline. The SPM likely underestimates American shad abundance, while the Petersen statistic likely overestimates the population, especially in years of low recapture rates of tagged fish. Trends, rather than the actual numbers, produced by the models should be emphasized when assessing the American shad population at the Conowingo Dam tailrace. Recovery of this population is limited by the available spawning habitat below Conowingo Dam and stocking success. Relicensing of Conowingo Dam is anticipated in 2020. Stipulations of the settlement agreement between Exelon Generation Co LLC and the Maryland Department of the Environment should improve fish passage and contribute to rebuilding anadromous fish stocks in the Susquehanna River.

Calculated indices of abundance for the lower Susquehanna River exhibited varying trends in 2019. While the hook and line CPUE declined to the lowest level on record for the survey, both the recreational creel and logbook survey CPUE increased relative to 2018. The Conowingo lift CPUE (east and west fish lifts combined) decreased relative to 2018, and approached the time series minimum observed in 2014; total number of American shad captured by the lifts was the lowest on record. All indices remain well below peak CPUE observed in the late 1990's and early 2000's. The Nanticoke River CPUE (1988-2019) was slightly above average in 2019, but demonstrates no significant trend over the time series. The Potomac River CPUE (1996-2019) increased over time and reached the highest value on record in 2019, indicating substantial improvement in this river. However, high levels of total mortality (Z) have been documented in the Potomac in recent years; the 2020 benchmark stock assessment found that the terminal three-year (2015-2017) average Z for adult American shad exceeded the $Z_{40\%SBPR}$ reference point (ASMFC 2020).

Peak capture of American shad in the Conowingo Dam tailrace by hook and line occurred over three weeks later than peak passage at both the East and West Fish Lifts. However, peak capture by hook and line was only 14 fish in 2019, which is substantially lower than in other years. Due to high river flows, the dam consistently operated at full generation and was frequently under spill conditions, both of which may impede or eliminate hook and line fishing opportunities. Peak hook and line capture in 2019 coincided with a brief period of decreased river flow, which likely contributed to increased angling success. Surface water temperature during peak capture by hook and line (20°C) was slightly above the optimum migration temperature (17-19°C; Leggett and Whitney 1972) but still within commonly observed migration temperature values. Peak passage at the East Fish Lift (15.6°C) was below the optimum migration temperature range (Leggett and Whitney 1972). Additionally, water temperatures at peak capture both by hook and line and at the East Fish Lift were within the optimal temperature range for spawning (14-20°C; Stier and Crance 1985). Efficient and timely passage of American shad at Conowingo Dam is important to ensure migration and spawning occurs at the appropriate temperatures and in the appropriate habitats.

Ageing American shad using scales is common practice, as it the only non-lethal ageing structure for this fish. However, many researchers have called into question the accuracy of scale ageing (ASMFC 2020). Ageing other hard structures, such as otoliths, produces higher age agreement between readers compared to scales (Duffy et al. 2012), but ageing from otoliths sacrifices repeat spawning information. We will remain consistent with historical ageing methods until alternative ageing structures or techniques can be implemented in our lab.

The percent of repeat spawning American shad below the Conowingo Dam increased over time. The percent of repeat spawners was usually less than 10% in the Conowingo Dam tailrace throughout the 1980s (Weinrich et al. 1982). In contrast, 55% of aged American shad at the Conowingo Dam were repeat spawners in 2019, and, on average, 47% of aged fish were repeat spawners over the past five years. Similar estimates of repeat spawning were observed in recent years for American shad collected from Virginia rivers (Hilton et al., 2019), and from the Potomac River which is unimpeded by dam construction within the natural migration range of anadromous fishes. The average percent of repeat spawners from the Potomac River was 17% in the 1950s (Walburg and Sykes 1957), but was 65% in 2019 (Figure 9). Increased repeat spawning in these river systems may indicate increased survival of adult fish. This could be due to decreased bycatch in Atlantic Ocean fisheries, increased abundance leading to more fish reaching older ages, reductions in natural mortality, and/or reader bias. Additional river systems along the Atlantic coast that had increasing trends in repeat spawners included the Merrimack River (1999-2005; ASMFC 2007), the Nanticoke River (Figure 8) and the James Rivers (2000-2002; Olney et al., 2003).

Juvenile American shad indices have shown some positive signs in recent years. After many years of minimal juvenile production from the early 1980s through the mid 1990s, both the Potomac River and Upper Chesapeake Bay systems have had a number of years of successful spawns. Recent Potomac River and cumulative baywide juvenile abundance indices exceeded the values observed in the early years of the survey that dates back to 1959. The Nanticoke River has not shown as encouraging signs as the other surveyed systems and has remained at low levels of juvenile abundance since 1969.

Hickory Shad

Hickory shad stocks drastically declined due to habitat loss, overfishing, stream blockages and pollution. A statewide moratorium on the harvest of hickory shad in Maryland waters was implemented in 1981 and is still in effect today.

Adult hickory shad are difficult to capture due to their aversion to fishery independent (fish lifts) and dependent (pound and fyke net) gears. Very few hickory shad were historically observed using the EFL in the Susquehanna River. A notable exception was in 2011 when 20 hickory shad were counted at the EFL viewing window. Despite the traditionally low number of hickory shad observed passing the Conowingo Dam, Deer Creek (a tributary to the Susquehanna River downstream of Conowingo Dam) has the greatest densities of hickory shad in Maryland (Richardson et al. 2009). Nearly half (46%) of all hickory shad reported in statewide logbook and volunteer angler surveys were captured in Deer Creek or in the Susquehanna River near the mouth of Deer Creek.

Prior to 2012, hickory shad age structure was relatively consistent, with a wide range of ages and a high percentage of older fish. Age structure has truncated since that time, although a single age-eight fish was present in 2019; this was the first time a fish over the age of seven was observed since 2011. Richardson et. al (2004) found ninety percent of hickory shad from upper Chesapeake Bay had spawned by age four, and this stock generally consisted of few virgin fish. However, the percentage of repeat spawning fish captured has decreased significantly over the time series and reached its lowest value in 2019. Fewer older fish combined with a smaller proportion of repeat spawners may indicate poor year classes and/or an increase in mortality at older ages.

Estimates of Z are primarily attributed to M because only a catch and release fishery exists for hickory shad in Maryland. Hickory shad ocean bycatch is minimized compared to the other alosines because both mature adults and immature sub-adults migrate and overwinter closer to the coast (ASMFC 2009). This is confirmed by the fact that few hickory shad are observed portside as bycatch in the ocean small-mesh fisheries (Matthew Cieri, Maine Dep. Marine Res., pers. comm.).

Adult hickory shad may spawn up to six weeks before American shad (late March to late April versus late April to early June), and juvenile hickory shad reach a larger size earlier in the summer. Because of their larger size, ability to avoid gear, and preference for deeper water, sampling for juvenile hickory shad from mid-summer through fall is generally unsuccessful (Richardson et al. 2009). These juveniles also exhibit the same negative phototaxis as the adults, migrating to deeper, darker water away from the shallow beaches sampled by haul seines.

Alewife and Blueback Herring

Alewife and blueback herring numbers declined drastically for the same reasons discussed for American shad and hickory shad. The most recent stock assessment, released in 2017, showed the coastwide meta-complex of river herring stocks on the US Atlantic coast was depleted to near historic lows, and declines in mean length of at least one age were observed in most rivers examined (ASMFC 2017). This assessment corresponded with the low indices of abundance for both species observed in the Nanticoke River by this project through 2019. Crecco and Gibson (1990) found alewife in the Nanticoke River to be fully exploited and severely depleted prior to the start of Maryland Department of Natural Resources fishery-dependent sampling in this river.

Both alewife and blueback herring relative abundance increased in the North East River in 2019 relative to 2018, but no significant trends were detected over time (2013-2019). However, the substantial increase in blueback herring relative abundance in 2019 followed three consecutive years of decline, and exceeded that of alewife for the first time. The significance of these fluctuations in the North East River is unclear given that the survey is temporally limited. The shorter time series may be reflecting near-term variability rather than broad scale population gains or losses.

Amendment 2 of the ASMFC Interstate Fishery Management Plan for American Shad and River Herring required states to develop and implement a sustainable fishery plan for jurisdictions wishing to maintain an open commercial or recreational fishery. Due to the decline in and persistently low levels of river herring in Maryland, a moratorium on the possession of river herring went into effect on 26 December 2011. The moratorium on river herring eliminated any directed in-river mortality experienced by these species, and there are a number of efforts underway to reduce incidental catch of river herring in ocean fisheries as well. Beginning in 2014, the Mid-Atlantic and New England Fisheries Management Councils placed incidental catch caps for river herring and American shad on the Atlantic herring and mackerel fleets (Federal Register 2014a, 2014b). As of 12 March 2019, due to high amounts of bycatch of river herring and American shad by trawl fisheries early in the season, regulations outlined by the aforementioned catch caps were enforced to limit further bycatch in the Southern New England/Mid-Atlantic management region (Federal Register 2019). The expectation is that these efforts to reduce bycatch mortality on river herring will lead to increased spawning stock, with a corresponding increase in repeat spawning and production of juvenile river herring. The ASMFC 2017 stock assessment update did not indicate a change to the stock status for Maryland's river herring populations.

However, given that it has only been a few years since these bycatch measures were enacted, any resulting changes may take more time to become apparent.

Mortality estimates in recent years for alewife and blueback herring in the North East and Nanticoke Rivers were generally high. In 2019, the mortality estimate for alewife was higher in the North East River than the Nanticoke River, while blueback mortality estimates were similar for both rivers. The 2012 river herring stock assessment attributed high mortality of river herring to a combination of factors including fishing (in-river directed and ocean bycatch), inadequate access to habitats, impaired water quality, excessive predation, and climate change (ASMFC 2012). Genetic studies suggest a greater proportion of Mid-Atlantic blueback herring are caught as incidental catch in the southern New England Atlantic herring fishery (78% of samples; Hasselman et al. 2015), which could contribute to the high mortality for North East River and Nanticoke River blueback herring estimated by this project. However, the fishing effort in the Atlantic Herring fishery has declined substantially in recent years due to reduced quota. This quota reduction, combined with the aforementioned catch caps, has substantially reduced at sea mortality of river herring. Invasive catfish in the Chesapeake Bay region also pose a threat to these species, as alosines are known prey items for flathead catfish and blue catfish (Moran et al. 2016) that are spreading throughout the region. Results from Schmitt et al. (2017) demonstrated that flathead catfish of all sizes were highly piscivorous and displayed an affinity for the consumption of blueback herring and American shad. Blue catfish, while certainly a predator of alosines, tended to be more opportunistic and displayed fewer conclusive selectivity patterns.

Population age structure for the North East River and the Nanticoke River is similar to that of other river herring populations in the region (Hilton et al. 2015), but should be interpreted with caution. Results from the ASMFC River Herring Ageing Workshop found that precision between states and even within ageing labs was low and highly variable (ASMFC 2013). The workshop also revealed otolith ages to be younger than scale ages for younger fish and otolith ages to be older than scales ages for older fish. More research is required with known age fish to validate ageing methods for these species, as was recommended by the 2012 River Herring Stock Assessment.

PROJECT NO. 2
JOB NO. 1

STOCK ASSESSMENT OF ADULT AND JUVENILE ALOSINE SPECIES IN THE CHESAPEAKE BAY AND SELECTED TRIBUTARIES

2020 PRELIMINARY RESULTS - WORK IN PROGRESS

Data collection for Job 1 Project 2 in 2020 was severely impacted by state mandated work restrictions in response to the COVID-19 pandemic. Most notably, no field sampling activities were conducted on the Nanticoke or Susquehanna Rivers in 2020; very limited sampling was conducted in the North East River prior to the COVID-19 shutdown. Analyses of the available data, described below, are currently in progress.

River herring were independently sampled using an experimental gill net deployed in the North East River on only one day in 2020. In a typical year, the river is surveyed once a week for ten weeks from mid-March to mid-May. Biologists encountered 83 adult alewife on 11 March 2020 and collected 75 scale samples for ageing and spawning history analysis. Male and female alewife ranged in size from 210 - 261 mm FL and 234 - 274 mm FL respectively. Blueback herring arrive in the river later than alewife and thus were not observed in 2020.

Sampling activities of the Striped Bass Spawning Stock Survey (SBSSS; Project 2, Job 3, Task 2) were not impacted to the extent of other surveys. The SBSSS provided American shad scales from the Potomac River to determine the age structure and occurrence of repeat spawning. A total of 141 American shad were observed from 14 April 2020 to 16 May 2020; scale samples were taken from 103 of these fish. Male and female American shad ranged in size from 348 - 474 mm FL and 366 - 512 mm FL respectively.

Collection of juvenile American shad and river herring by the Estuarine Juvenile Finfish Survey (EJFS) was conducted as usual in 2020. Twenty-two fixed stations were surveyed from Maryland's portion of the Chesapeake Bay and tributaries during July, August, and September 2020.

Limited recreational catch and release fishing information is available for American and hickory shad from volunteer angler surveys. However, participation is traditionally low and the state of Maryland prohibited recreational fishing throughout much of the spring season.

The complete analyses of the data collected in 2020 to assess trends in adult and juvenile alosine species will appear in the next F-61 Chesapeake Bay Finfish Investigations report.

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Table 1. Number of adult American shad and repeat spawners by sex and age sampled from the Conowingo Dam tailrace (hook and line), Nanticoke River (gears combined), and Potomac River (gill net) in 2019.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
4	7	0	4	0	11	0
5	12	6	3	2	15	8
6	7	5	7	7	14	12
7	0	0	3	3	3	3
8	0	0	1	1	1	1
Totals	26	11	18	13	44	24
Percent Repeats	42.3%		72.2%		54.5%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
4	6	0	1	0	7	0
5	12	7	6	2	18	9
6	4	3	7	7	11	10
7	1	1	3	3	4	4
Totals	23	11	17	12	40	23
Percent Repeats	47.8%		70.6%		57.5%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	7	0	0	0	7	0
4	28	0	7	0	35	0
5	28	15	23	10	51	25
6	33	19	98	80	131	99
7	8	8	48	48	56	56
8	0	0	3	3	3	3
9	0	0	1	1	1	1
Totals	104	42	180	142	284	184
Percent Repeats	40.4%		79.1%		64.9%	

Table 2. Proportion at age of American shad, sexes combined, angled from the Conowingo Dam tailrace, 1982-2019. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages.

Year	N	Age							
		2	3	4	5	6	7	8	9
1982	73	0.00	0.25	0.63	0.12	0.00	0.00	0.00	0.00
1983	9	0.00	0.00	0.11	0.89	0.00	0.00	0.00	0.00
1984	124	0.00	0.24	0.36	0.26	0.11	0.02	0.00	0.00
1985	174	0.00	0.13	0.48	0.28	0.10	0.01	0.00	0.00
1986	425	0.00	0.24	0.53	0.22	0.01	0.00	0.00	0.00
1987	386	0.00	0.17	0.49	0.33	0.01	0.00	0.00	0.00
1988	252	0.01	0.25	0.49	0.21	0.03	0.00	0.00	0.00
1989	269	0.00	0.17	0.43	0.32	0.07	0.00	0.00	0.00
1990	305	0.00	0.05	0.45	0.39	0.09	0.01	0.00	0.00
1991	347	0.00	0.02	0.19	0.49	0.27	0.02	0.00	0.00
1992	371	0.00	0.05	0.16	0.48	0.22	0.08	0.00	0.00
1993	233	0.00	0.03	0.36	0.36	0.21	0.04	0.00	0.00
1994	435	0.00	0.03	0.33	0.50	0.12	0.02	0.00	0.00
1995*	620	0.00	0.02	0.25	0.52	0.19	0.01	0.00	0.00
1996*	446	0.00	0.06	0.34	0.36	0.22	0.02	0.00	0.00
1997*	606	0.00	0.10	0.42	0.33	0.12	0.02	0.00	0.00
1998	308	0.00	0.03	0.44	0.38	0.11	0.02	0.00	0.00
1999*	821	0.00	0.09	0.44	0.39	0.07	0.00	0.00	0.00
2000*	737	0.00	0.01	0.52	0.41	0.05	0.01	0.00	0.00
2001*	969	0.00	0.04	0.27	0.48	0.20	0.02	0.00	0.00
2002*	800	0.00	0.02	0.20	0.37	0.29	0.12	0.01	0.00
2003	781	0.00	0.02	0.29	0.38	0.22	0.08	0.00	0.01
2004	386	0.00	0.02	0.21	0.52	0.22	0.03	0.00	0.00
2005	385	0.00	0.02	0.26	0.31	0.32	0.09	0.01	0.00
2006	338	0.00	0.05	0.46	0.35	0.07	0.04	0.02	0.00
2007	449	0.00	0.04	0.36	0.38	0.20	0.01	0.01	0.00
2008	161	0.00	0.04	0.48	0.36	0.11	0.01	0.00	0.01
2009	622	0.00	0.03	0.59	0.30	0.08	0.01	0.00	0.00
2010	437	0.00	0.03	0.43	0.43	0.10	0.01	0.00	0.00
2011	172	0.00	0.00	0.19	0.52	0.27	0.02	0.00	0.00
2012	177	0.00	0.03	0.18	0.34	0.32	0.13	0.01	0.00
2013	297	0.00	0.00	0.05	0.30	0.33	0.24	0.06	0.02
2014	428	0.00	0.01	0.13	0.43	0.35	0.08	0.00	0.00
2015	279	0.00	0.08	0.29	0.45	0.15	0.03	0.00	0.00
2016	366	0.00	0.01	0.15	0.59	0.23	0.02	0.00	0.00
2017	264	0.00	0.05	0.33	0.52	0.10	0.00	0.00	0.00
2018	160	0.00	0.03	0.14	0.52	0.28	0.03	0.01	0.00
2019	44	0.00	0.00	0.25	0.34	0.32	0.07	0.02	0.00

Table 3. Proportion at age of American shad, sexes combined, captured in the Nanticoke River, 1989-2019. The survey was not completed in 2015 due to the unavailability of a commercial waterman partner.

Year	N	Age									
		1	2	3	4	5	6	7	8	9	10
1989	335	0.00	0.00	0.13	0.54	0.23	0.05	0.02	0.02	0.00	0.00
1990	291	0.00	0.00	0.02	0.28	0.53	0.12	0.04	0.01	0.00	0.00
1991	372	0.00	0.00	0.06	0.26	0.42	0.19	0.06	0.01	0.00	0.00
1992	135	0.00	0.01	0.03	0.16	0.32	0.31	0.17	0.00	0.00	0.00
1993	199	0.00	0.01	0.01	0.14	0.39	0.22	0.15	0.07	0.02	0.01
1994	146	0.00	0.01	0.17	0.39	0.31	0.09	0.03	0.01	0.00	0.00
1995	126	0.00	0.01	0.07	0.33	0.39	0.19	0.02	0.00	0.00	0.00
1996	112	0.00	0.00	0.08	0.34	0.33	0.16	0.09	0.00	0.00	0.00
1997	84	0.00	0.00	0.08	0.44	0.30	0.11	0.06	0.01	0.00	0.00
1998	65	0.00	0.00	0.05	0.34	0.42	0.15	0.05	0.00	0.00	0.00
1999	23	0.00	0.00	0.04	0.26	0.52	0.13	0.04	0.00	0.00	0.00
2000	185	0.00	0.00	0.04	0.43	0.38	0.14	0.01	0.02	0.00	0.00
2001	102	0.00	0.00	0.12	0.26	0.34	0.25	0.03	0.00	0.00	0.00
2002	138	0.00	0.00	0.08	0.30	0.24	0.30	0.08	0.01	0.00	0.00
2003	126	0.00	0.00	0.02	0.25	0.39	0.26	0.08	0.01	0.00	0.00
2004	56	0.00	0.00	0.05	0.27	0.48	0.14	0.05	0.00	0.00	0.00
2005	40	0.00	0.00	0.05	0.25	0.30	0.23	0.10	0.05	0.03	0.00
2006	8	0.00	0.00	0.25	0.00	0.63	0.00	0.00	0.13	0.00	0.00
2007	65	0.00	0.00	0.12	0.43	0.32	0.05	0.03	0.03	0.02	0.00
2008	40	0.00	0.00	0.25	0.45	0.20	0.08	0.00	0.00	0.03	0.00
2009	80	0.00	0.00	0.09	0.45	0.39	0.05	0.03	0.00	0.00	0.00
2010	33	0.00	0.00	0.06	0.24	0.45	0.24	0.00	0.00	0.00	0.00
2011	62	0.00	0.00	0.10	0.47	0.34	0.08	0.02	0.00	0.00	0.00
2012	174	0.02	0.00	0.03	0.24	0.41	0.26	0.04	0.00	0.00	0.00
2013	31	0.00	0.00	0.00	0.00	0.16	0.52	0.16	0.13	0.03	0.00
2014	69	0.00	0.00	0.00	0.13	0.28	0.43	0.13	0.01	0.01	0.00
2015	-	-	-	-	-	-	-	-	-	-	-
2016	50	0.00	0.00	0.02	0.14	0.38	0.24	0.18	0.04	0.00	0.00
2017	36	0.00	0.00	0.08	0.36	0.36	0.19	0.00	0.00	0.00	0.00
2018	5	0.00	0.00	0.00	0.20	0.80	0.00	0.00	0.00	0.00	0.00
2019	40	0.00	0.00	0.00	0.18	0.45	0.28	0.10	0.00	0.00	0.00

Table 4. Proportion at age of American shad, sexes combined, captured in the Potomac River, 2002-2019. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages.

Year	N	Age							
		3	4	5	6	7	8	9	10
2002	48	0.02	0.19	0.17	0.40	0.21	0.02	0.00	0.00
2003	141	0.01	0.22	0.31	0.26	0.11	0.08	0.01	0.00
2004	97	0.00	0.21	0.36	0.33	0.05	0.05	0.00	0.00
2005	97	0.01	0.34	0.28	0.25	0.09	0.01	0.01	0.01
2006	52	0.02	0.25	0.27	0.31	0.08	0.04	0.04	0.00
2007	200	0.07	0.57	0.27	0.08	0.01	0.01	0.01	0.00
2008	176	0.06	0.45	0.36	0.09	0.03	0.01	0.00	0.00
2009	31	0.00	0.16	0.19	0.39	0.16	0.06	0.00	0.03
2010	75	0.07	0.48	0.27	0.09	0.04	0.03	0.03	0.00
2011	56	0.13	0.18	0.36	0.27	0.07	0.00	0.00	0.00
2012	67	0.00	0.06	0.40	0.31	0.18	0.04	0.00	0.00
2013	105	0.00	0.01	0.10	0.50	0.30	0.09	0.00	0.01
2014	105	0.00	0.00	0.16	0.58	0.23	0.03	0.00	0.00
2015	120	0.03	0.08	0.46	0.35	0.08	0.00	0.00	0.00
2016	140	0.00	0.14	0.54	0.25	0.06	0.01	0.00	0.00
2017*	140	0.01	0.14	0.50	0.34	0.01	0.00	0.00	0.00
2018*	182	0.00	0.02	0.23	0.59	0.13	0.04	0.00	0.00
2019*	284	0.02	0.13	0.19	0.45	0.20	0.01	0.00	0.00

Table 5. Number of recaptured American shad in 2019 at the Conowingo Dam East and West Fish Lifts.

East Lift			West Lift		
Tag Color	Year Tagged	Number Recaptured	Tag Color	Year Tagged	Number Recaptured
Green	2019	1	Green	2019	0

Table 6. The six generalized additive model (GAM) configurations and performance statistics explored for standardizing the hook and line catch per unit effort index (1987-2019).

Model Number	Cofactor(s)	Response Variable Distribution	N	Effective Degrees of Freedom	Deviance Explained	Dispersion	AIC
1	Temp + Flow	Poisson	481	47.63	45.50%	10.19	7095.13
2	Temp + Flow	Tweedie	481	38.74	40.80%	3.08	4026.96
3	Temp + Flow	Negative Binomial	481	38.80	39.60%	0.92	4058.02
4	Temp	Poisson	481	40.01	42.60%	10.47	7325.11
5	Temp	Tweedie	481	36.16	38.00%	3.09	4041.08
6	Temp	Negative Binomial	481	36.19	36.90%	0.91	4075.52

Table 7. Catch, effort and catch-per-angler-hour (CPAH) of American shad from the recreational creel survey in the Susquehanna River below Conowingo Dam, 2001-2019. Due to sampling limitations, no data were available for 2011.

Year	Number of Interviews	Hours Fished for American Shad	American Shad Catch (numbers)	American Shad CPAH
2001	87	199.4	991	4.97
2002	52	85.3	291	3.41
2003	64	146.7	818	5.58
2004	95	189.3	233	1.23
2005	26	51.8	62	1.20
2006	70	210.8	305	1.45
2007	30	107.5	128	1.19
2008	16	32.5	24	0.74
2009	39	85.0	120	1.41
2010	31	50.5	112	2.22
2012	45	188.8	145	0.77
2013	52	168.8	105	0.62
2014	79	227.5	321	1.41
2015	57	153.4	272	1.77
2016	125	309.0	606	1.96
2017	73	190.5	483	2.54
2018	61	120.9	152	1.26
2019	32	62.1	163	2.62

Table 8. Catch, effort and catch-per-angler-hour (CPAH) from spring logbooks for American shad, 2001-2019. Since 2014, data from Maryland's Volunteer Angler Shad Survey has been combined with logbook data.

Year	Number of Participants	Total Reported Angler Hours	American Shad Catch (numbers)	Catch Per Angler Hour
2001	12	347.5	1,735	4.99
2002	12	508.5	1,801	3.54
2003	13	621.0	1,222	1.97
2004	17	442.0	1,036	2.34
2005	18	406.5	533	1.31
2006	19	740.0	769	1.04
2007	17	558.0	873	1.56
2008	22	790.0	1,269	1.61
2009	15	543.8	967	1.78
2010	16	490.0	981	2.00
2011	9	201.8	413	2.05
2012	5	180.5	493	2.73
2013	6	219.3	313	1.43
2014	15	225.0	467	2.08
2015	10	171.0	364	2.13
2016	9	304.0	687	2.26
2017	10	155.0	288	1.86
2018	7	191.5	242	1.26
2019	8	101.0	218	2.16

Table 9. Number of adult hickory shad and repeat spawners by sex and age sampled from the brood stock collection survey in the Susquehanna River in 2019.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	10	0	4	0	14	0
4	17	1	27	0	44	1
5	8	4	16	2	24	6
6	4	3	7	4	11	7
7	1	1	3	3	4	4
8	0	0	1	1	1	1
Totals	40	9	58	10	98	19
Percent Repeats	22.5%		17.2%		19.4%	

Table 10. Proportion at age of hickory shad, sexes combined, sampled by the brood stock collection survey in the Susquehanna River and Deer Creek (a lower Susquehanna tributary), 2004-2019.

Year	**N**	**Age**							
		2	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2004	80	0.00	0.08	0.24	0.28	0.19	0.19	0.04	0.00
2005	80	0.00	0.06	0.18	0.29	0.34	0.11	0.01	0.01
2006	178	0.01	0.09	0.32	0.30	0.20	0.07	0.02	0.00
2007	139	0.00	0.07	0.24	0.34	0.21	0.12	0.02	0.01
2008	149	0.00	0.09	0.30	0.34	0.20	0.05	0.02	0.00
2009	118	0.00	0.08	0.17	0.45	0.20	0.10	0.01	0.00
2010	240	0.00	0.13	0.38	0.31	0.11	0.07	0.00	0.00
2011	216	0.00	0.30	0.30	0.27	0.09	0.03	0.01	0.00
2012	200	0.00	0.27	0.40	0.25	0.08	0.02	0.00	0.00
2013	193	0.00	0.21	0.46	0.24	0.08	0.01	0.00	0.00
2014	100	0.00	0.11	0.37	0.40	0.12	0.00	0.00	0.00
2015	113	0.01	0.30	0.43	0.20	0.05	0.00	0.00	0.00
2016	120	0.00	0.21	0.31	0.36	0.12	0.01	0.00	0.00
2017	59	0.00	0.17	0.31	0.37	0.14	0.02	0.00	0.00
2018	40	0.00	0.15	0.53	0.25	0.08	0.00	0.00	0.00
2019	98	0.00	0.14	0.45	0.25	0.11	0.04	0.01	0.00

Table 11. Catch, effort and catch-per-angler-hour (CPAH) from logbooks for hickory shad, 1998-2019. Since 2014, data from Maryland's Volunteer Angler Shad Survey has been combined with logbook data.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad	Catch Per Angler Hour
1998	19	600	4,980	8.30
1999	15	817	5,115	6.26
2000	14	655	3,171	4.84
2001	12	578	2674	4.63
2002	12	572	2451	4.28
2003	13	635	3143	4.95
2004	17	750	3233	4.31
2005	18	560	2098	3.75
2006	19	811	4928	6.08
2007	17	590	3396	5.76
2008	22	1,001	5520	5.51
2009	15	585	2022	3.45
2010	16	625	1981	3.17
2011	9	241	1802	7.47
2012	5	218	867	3.99
2013	6	254	1692	6.67
2014	15	267	1204	4.51
2015	10	244	538	2.20
2016	9	369	1384	3.76
2017	10	234	657	2.81
2018	7	327	1763	5.40
2019	14	166	608	3.66

Table 12. Percent catch-at-age for adult alewife, sexes combined, sampled from the Nanticoke River from 1989-2019. The survey was not completed in 2015 due to the unavailability of a commercial waterman partner. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages.

		Age							
Year	**N**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1989	435	0.00	0.05	0.37	0.38	0.16	0.04	0.00	0.00
1990	749	0.00	0.09	0.23	0.38	0.22	0.05	0.03	0.00
1991	850	0.00	0.03	0.48	0.26	0.15	0.06	0.01	0.01
1992	778	0.00	0.05	0.28	0.49	0.12	0.05	0.01	0.00
1993	637	0.00	0.03	0.24	0.38	0.28	0.06	0.02	0.00
1994	642	0.00	0.06	0.25	0.40	0.22	0.07	0.00	0.00
1995*	728	0.00	0.06	0.42	0.30	0.15	0.08	0.00	0.00
1996*	548	0.00	0.21	0.37	0.27	0.09	0.04	0.01	0.00
1997	256	0.00	0.09	0.47	0.31	0.09	0.01	0.02	0.00
1998	271	0.00	0.04	0.45	0.34	0.14	0.03	0.00	0.00
1999	317	0.00	0.09	0.21	0.40	0.27	0.02	0.00	0.00
2000	228	0.00	0.07	0.59	0.21	0.11	0.03	0.00	0.00
2001	239	0.00	0.07	0.36	0.43	0.11	0.03	0.00	0.00
2002	282	0.00	0.01	0.21	0.35	0.35	0.07	0.01	0.00
2003	168	0.00	0.04	0.19	0.35	0.35	0.07	0.00	0.00
2004	203	0.00	0.06	0.31	0.31	0.21	0.09	0.03	0.00
2005	169	0.00	0.04	0.40	0.25	0.19	0.11	0.02	0.00
2006	170	0.00	0.04	0.18	0.49	0.23	0.04	0.02	0.00
2007	218	0.00	0.07	0.40	0.27	0.19	0.06	0.01	0.00
2008	183	0.00	0.04	0.27	0.45	0.15	0.08	0.01	0.01
2009	216	0.00	0.04	0.38	0.35	0.18	0.05	0.00	0.00
2010	69	0.00	0.03	0.28	0.33	0.30	0.06	0.00	0.00
2011	182	0.00	0.04	0.36	0.28	0.25	0.05	0.01	0.00
2012*	527	0.00	0.13	0.31	0.33	0.18	0.05	0.00	0.00
2013	128	0.00	0.06	0.24	0.38	0.22	0.09	0.01	0.00
2014*	564	0.00	0.02	0.32	0.51	0.13	0.02	0.01	0.00
2015	-	-	-	-	-	-	-	-	-
2016*	1,058	0.00	0.02	0.16	0.55	0.26	0.01	0.00	0.00
2017*	586	0.00	0.21	0.31	0.34	0.13	0.01	0.00	0.00
2018	172	0.00	0.17	0.47	0.22	0.11	0.03	0.00	0.00
2019*	959	0.00	0.03	0.45	0.35	0.12	0.04	0.01	0.00

Table 13. Percent catch-at-age for adult blueback herring, sexes combined, sampled from the Nanticoke River from 1989-2019. The survey was not completed in 2015 due to the unavailability of a commercial waterman partner. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages.

		Age									
Year	**N**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1989	701	0.00	0.02	0.32	0.35	0.22	0.07	0.02	0.00	0.00	0.00
1990	732	0.00	0.02	0.15	0.29	0.25	0.20	0.06	0.02	0.01	0.00
1991	719	0.00	0.02	0.24	0.21	0.29	0.15	0.06	0.02	0.00	0.00
1992	258	0.00	0.03	0.21	0.24	0.23	0.17	0.09	0.02	0.00	0.00
1993	509	0.00	0.01	0.13	0.32	0.28	0.16	0.06	0.02	0.00	0.00
1994	452	0.00	0.06	0.29	0.38	0.19	0.06	0.01	0.00	0.00	0.00
1995	65	0.00	0.08	0.35	0.25	0.20	0.08	0.05	0.00	0.00	0.00
1996	223	0.00	0.03	0.38	0.42	0.13	0.01	0.02	0.00	0.00	0.00
1997	347	0.00	0.04	0.15	0.30	0.43	0.07	0.01	0.00	0.00	0.00
1998	232	0.00	0.03	0.26	0.27	0.27	0.16	0.01	0.00	0.00	0.00
1999	123	0.00	0.07	0.19	0.46	0.23	0.07	0.00	0.00	0.00	0.00
2000	198	0.00	0.06	0.51	0.25	0.11	0.06	0.01	0.00	0.00	0.01
2001	105	0.00	0.08	0.45	0.35	0.10	0.02	0.00	0.00	0.00	0.00
2002	146	0.00	0.06	0.35	0.44	0.14	0.01	0.00	0.00	0.00	0.00
2003	128	0.00	0.02	0.30	0.41	0.21	0.04	0.01	0.00	0.00	0.00
2004	132	0.00	0.12	0.37	0.33	0.09	0.08	0.01	0.00	0.00	0.00
2005	18	0.00	0.22	0.50	0.17	0.11	0.00	0.00	0.00	0.00	0.00
2006	68	0.00	0.03	0.28	0.54	0.13	0.01	0.00	0.00	0.00	0.00
2007	74	0.00	0.26	0.41	0.24	0.07	0.03	0.00	0.00	0.00	0.00
2008	82	0.00	0.10	0.51	0.30	0.04	0.04	0.01	0.00	0.00	0.00
2009	66	0.00	0.21	0.56	0.20	0.02	0.02	0.00	0.00	0.00	0.00
2010	26	0.00	0.08	0.58	0.23	0.12	0.00	0.00	0.00	0.00	0.00
2011	122	0.00	0.07	0.55	0.27	0.10	0.01	0.00	0.00	0.00	0.00
2012	136	0.01	0.15	0.38	0.37	0.08	0.02	0.00	0.00	0.00	0.00
2013	82	0.00	0.06	0.40	0.29	0.18	0.02	0.04	0.00	0.00	0.00
2014*	455	0.00	0.14	0.46	0.33	0.07	0.01	0.00	0.00	0.00	0.00
2015	-	-	-	-	-	-	-	-	-	-	-
2016	147	0.00	0.10	0.37	0.39	0.12	0.02	0.00	0.00	0.00	0.00
2017	76	0.00	0.13	0.39	0.30	0.16	0.01	0.00	0.00	0.00	0.00
2018	77	0.00	0.30	0.35	0.29	0.05	0.01	0.00	0.00	0.00	0.00
2019*	487	0.00	0.07	0.62	0.21	0.08	0.02	0.00	0.00	0.00	0.00

Table 14. Percent catch-at-age for adult alewife, sexes combined, sampled from the North East River from 2013-2019. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages.

Year	N	Age					
		3	4	5	6	7	8
2013	175	0.02	0.12	0.29	0.37	0.19	0.02
2014	547	0.37	0.34	0.18	0.06	0.04	0.01
2015*	688	0.08	0.72	0.17	0.02	0.00	0.00
2016*	454	0.07	0.13	0.58	0.19	0.02	0.00
2017*	413	0.43	0.28	0.17	0.11	0.02	0.00
2018*	470	0.09	0.71	0.12	0.06	0.02	0.00
2019*	498	0.01	0.44	0.44	0.07	0.04	0.00

Table 15. Percent catch-at-age for adult blueback herring, sexes combined, sampled from the North East River from 2013-2019. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages.

Year	N	Age					
		3	4	5	6	7	8
2013	33	0.09	0.52	0.24	0.09	0.06	0.00
2014	155	0.19	0.41	0.36	0.03	0.01	0.00
2015*	507	0.12	0.73	0.11	0.04	0.00	0.00
2016	192	0.11	0.25	0.47	0.15	0.02	0.00
2017	184	0.49	0.15	0.26	0.09	0.01	0.00
2018	130	0.58	0.27	0.06	0.07	0.02	0.00
2019*	709	0.03	0.65	0.23	0.05	0.05	0.01

Table 16. Counts of species (other than alewife and blueback) captured in the North East River gill net survey from 2013-2019.

SPECIES	2013	2014	2015	2016	2017	2018	2019
AMERICAN SHAD		2					
ATLANTIC MENHADEN	145	145	476	908	145	141	19
BLUE CATFISH			1	1			
BLUEGILL				1			1
BROWN BULLHEAD	66	132	78	123	15	25	46
CARP	2	1	2				
CHANNEL CATFISH	17	45	50	7	6	19	18
GIZZARD SHAD	2,617	850	104	568	112	13	54
GOLDEN SHINER			1		4	2	2
GOLDFISH	2		2	1			2
HICKORY SHAD	19	25	5	15	5	2	10
LARGEMOUTH BASS	1		1	1		1	
PUMPKINSEED	1	1	2	4	1		
QUILLBACK			2				
REDEAR SUNFISH					1		
STRIPED BASS	39	39	42	50	42	15	13
WALLEYE		1					1
WHITE CATFISH	1	1		1	1		2
WHITE PERCH	287	227	1,273	813	257	320	268
WHITE SUCKER	3	1	1	1	2		1
YELLOW PERCH			6	2	1	1	1

Figure 1. Conowingo Dam Tailrace (Susquehanna River) hook and line sampling location for American shad in 2019.

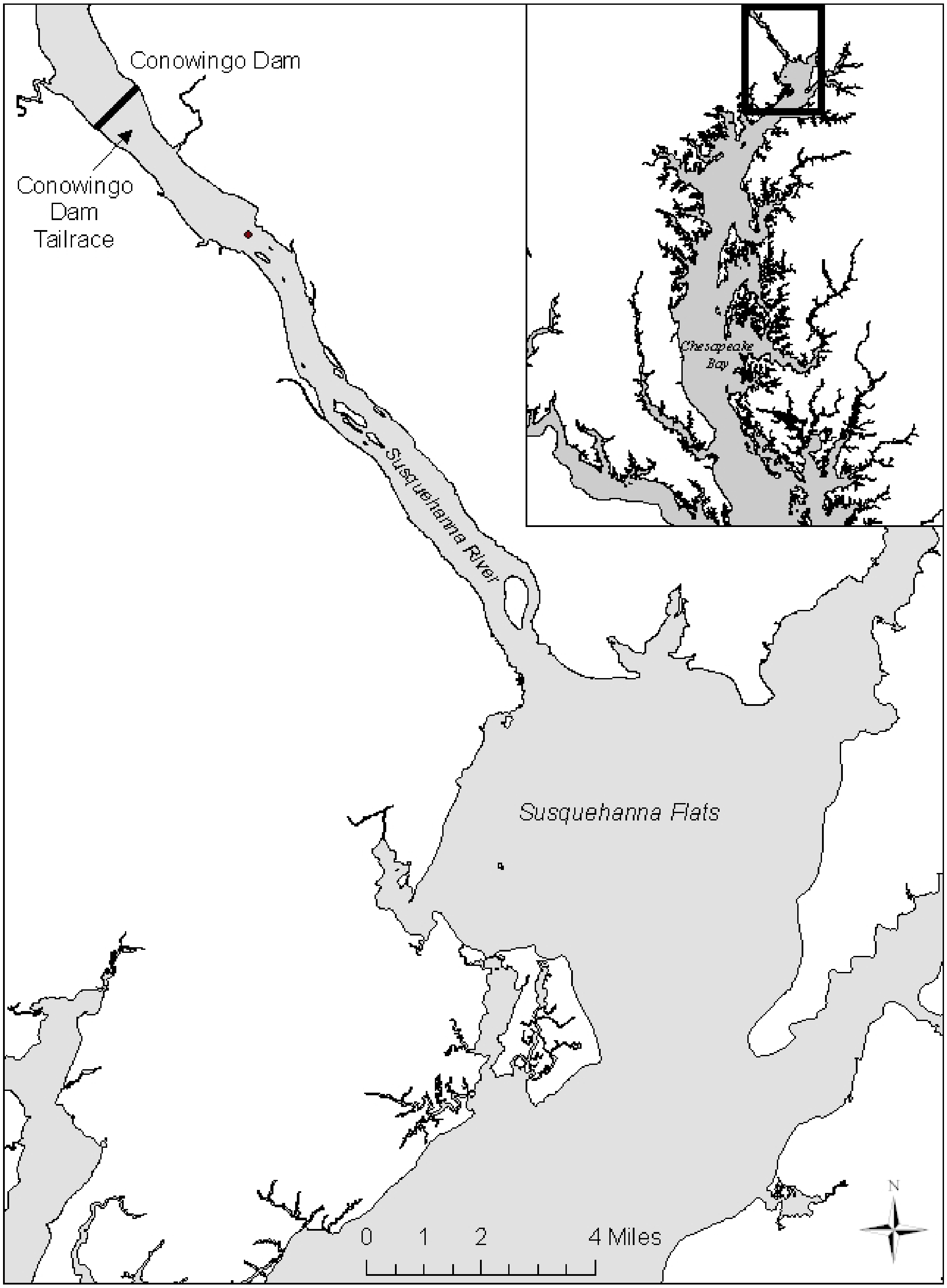


Figure 2. Nanticoke River fyke net sites for adult alosine sampling in 2019.

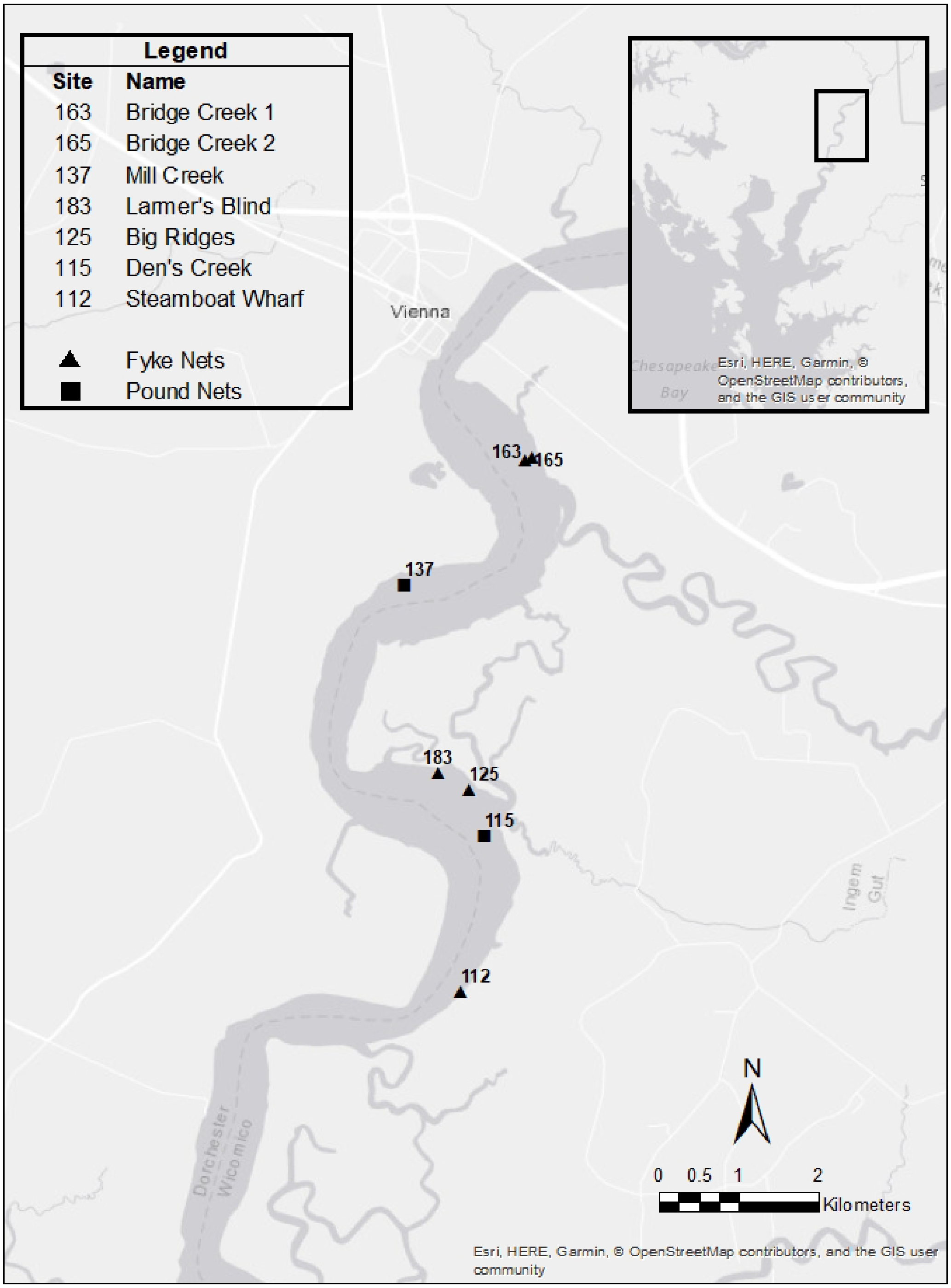


Figure 3. Nanticoke River sites for alosine ichthyoplankton sampling in 2019.

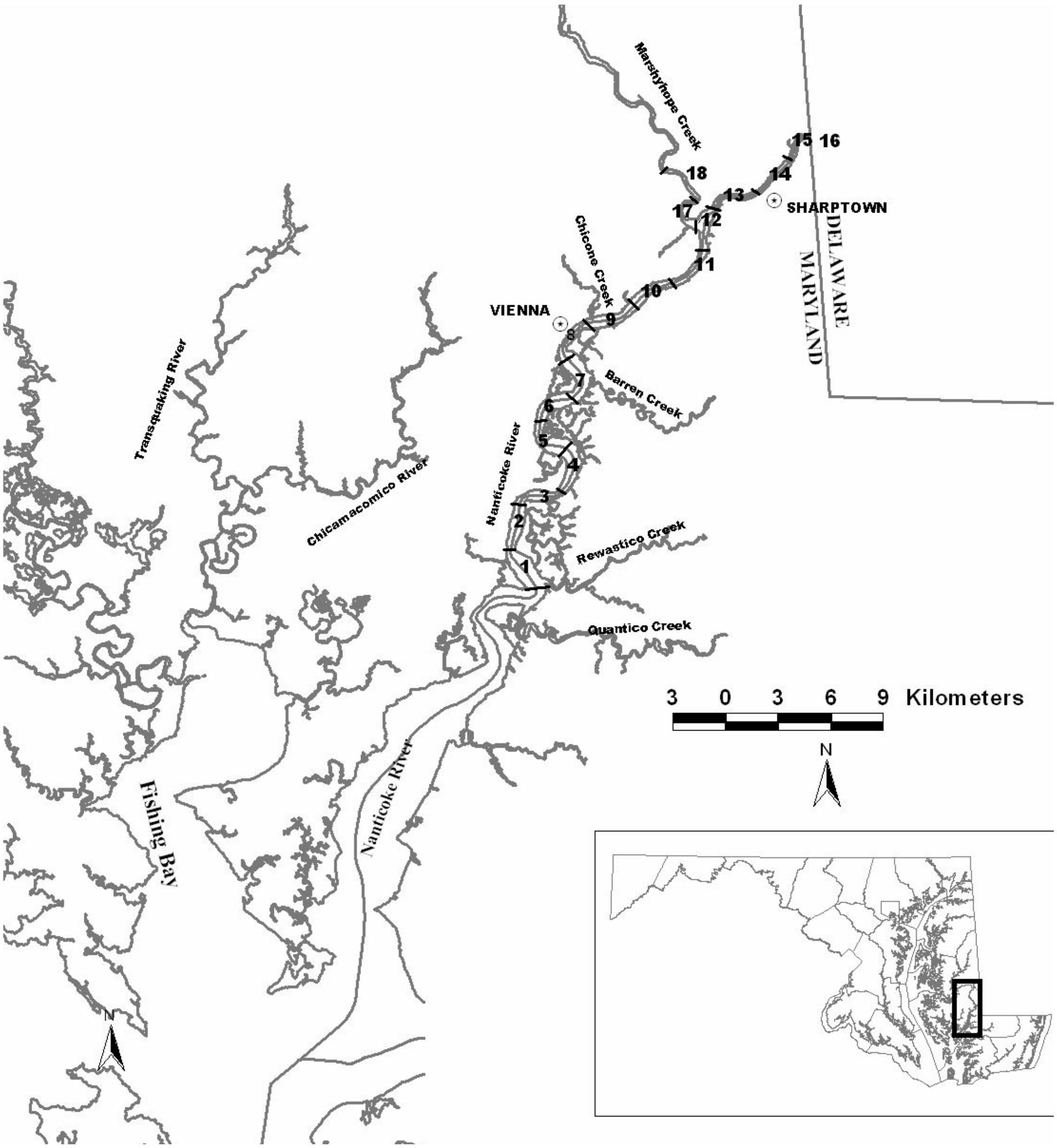


Figure 4. Grid of 305 m x 305 m quadrats overlaid on a map of the North East River from which sites were randomly chosen for the North East River sinking gill net survey, 2013-2019.

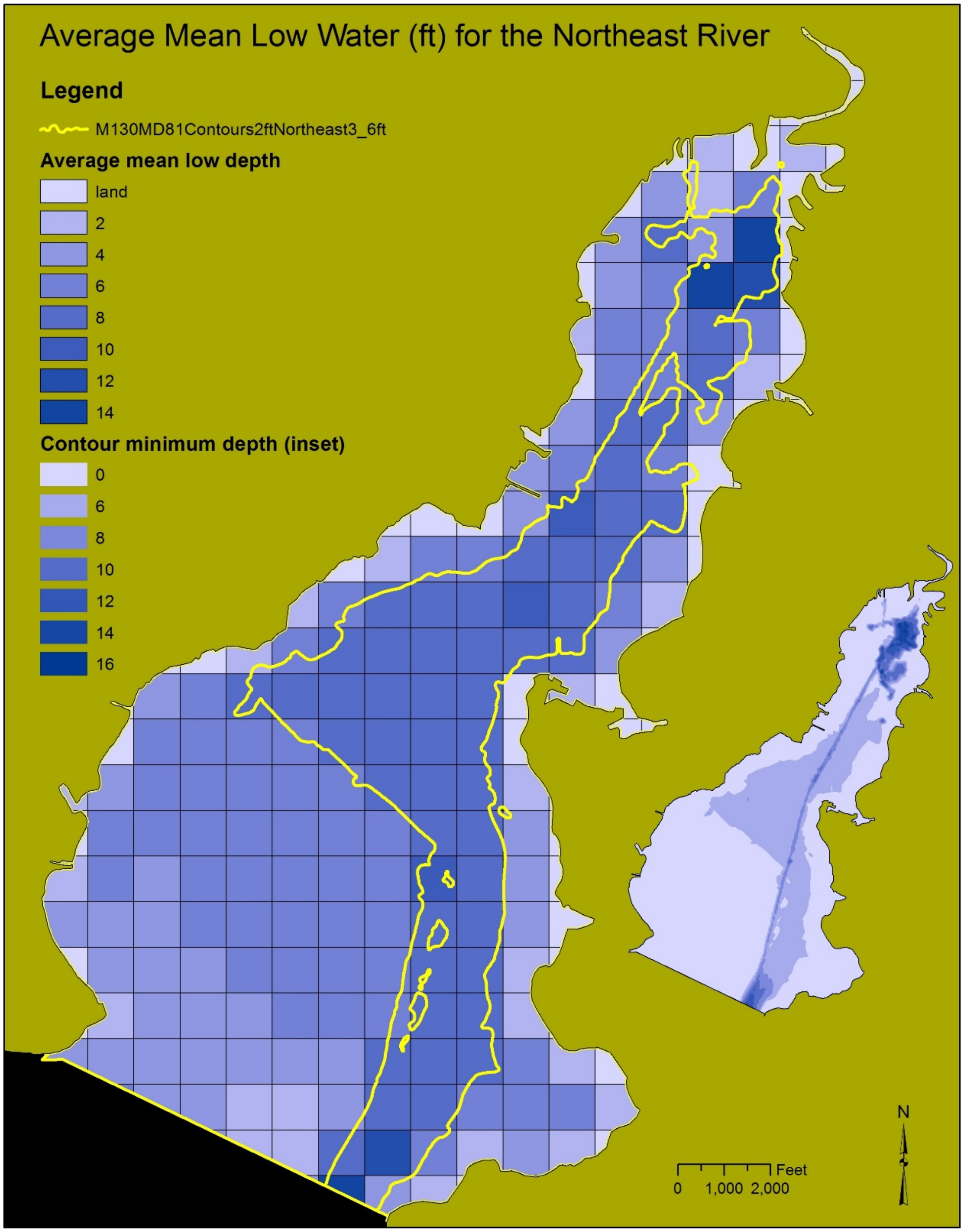


Figure 5. Percentage of sites with clupeid eggs or larvae in the Nanticoke River, 2005-2019.

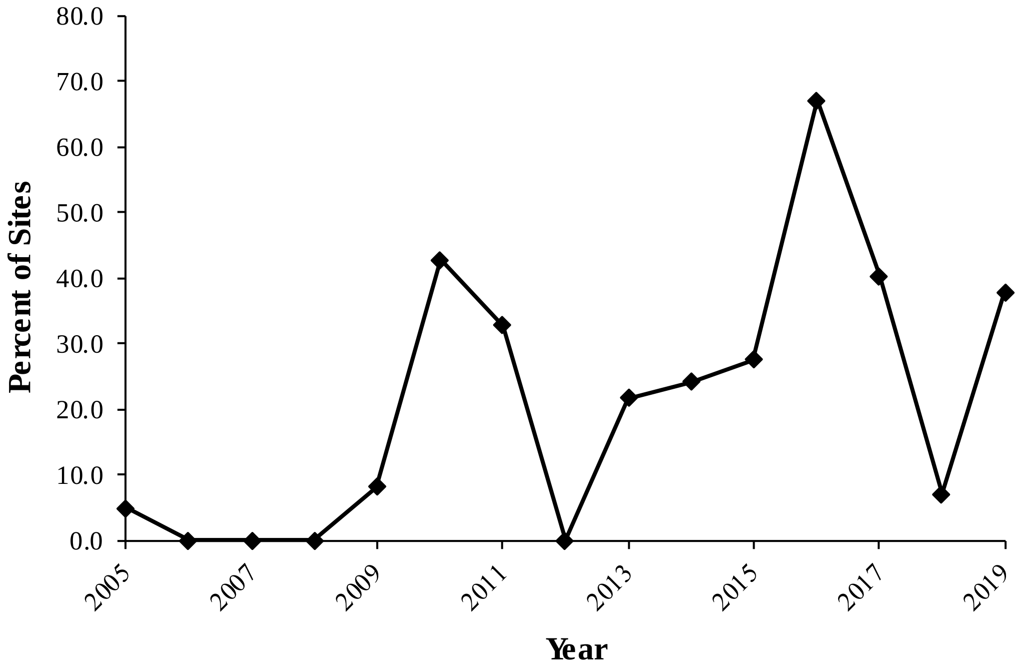


Figure 6. Percent of American shad repeat spawners by sex collected in the Conowingo Dam tailrace, 1982-2019.

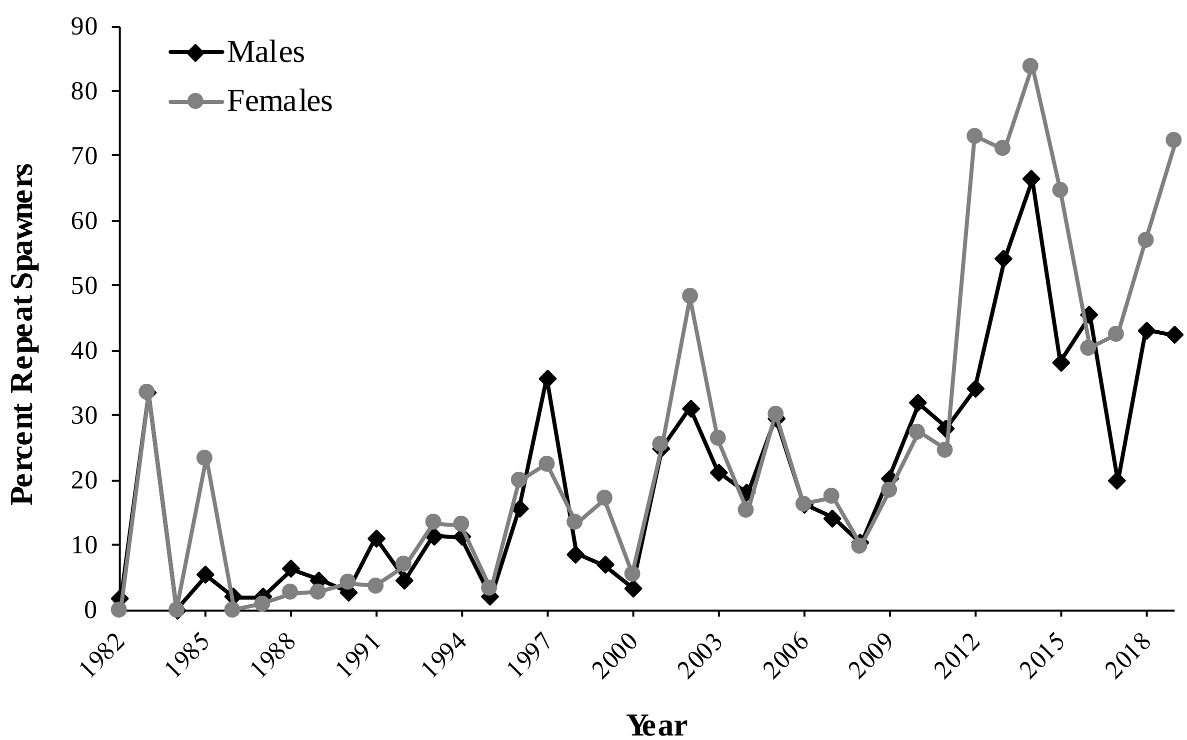


Figure 7. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2019.

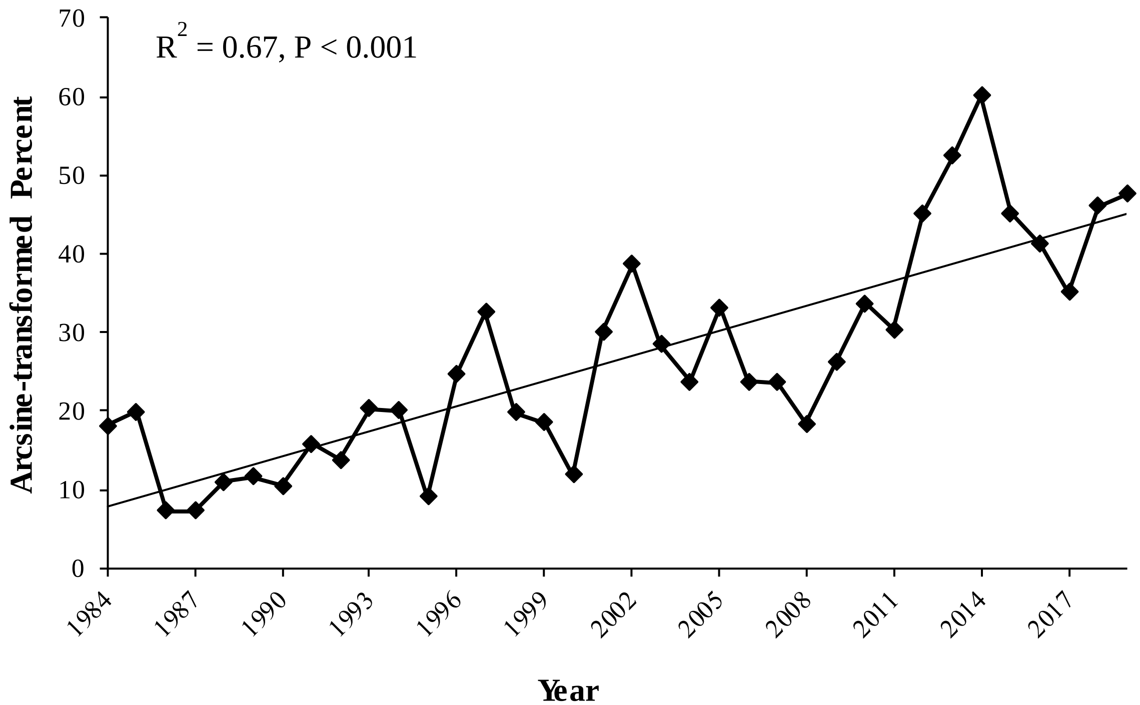


Figure 8. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River, 1988-2019.

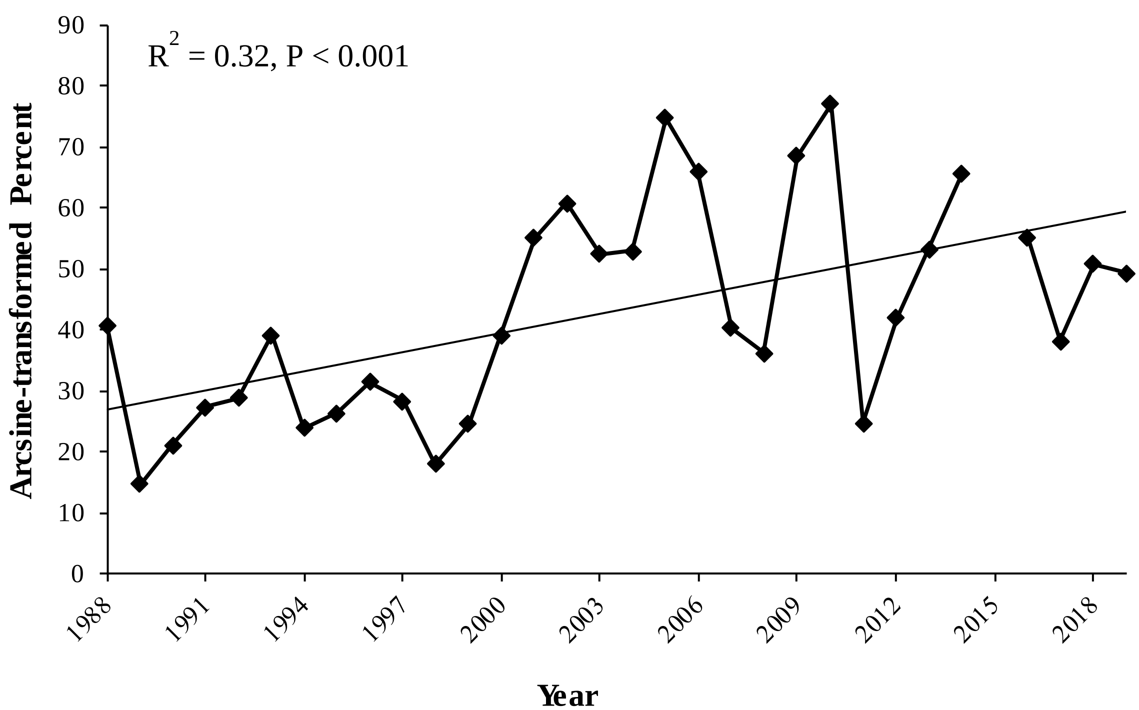


Figure 9. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River, 2002-2019.

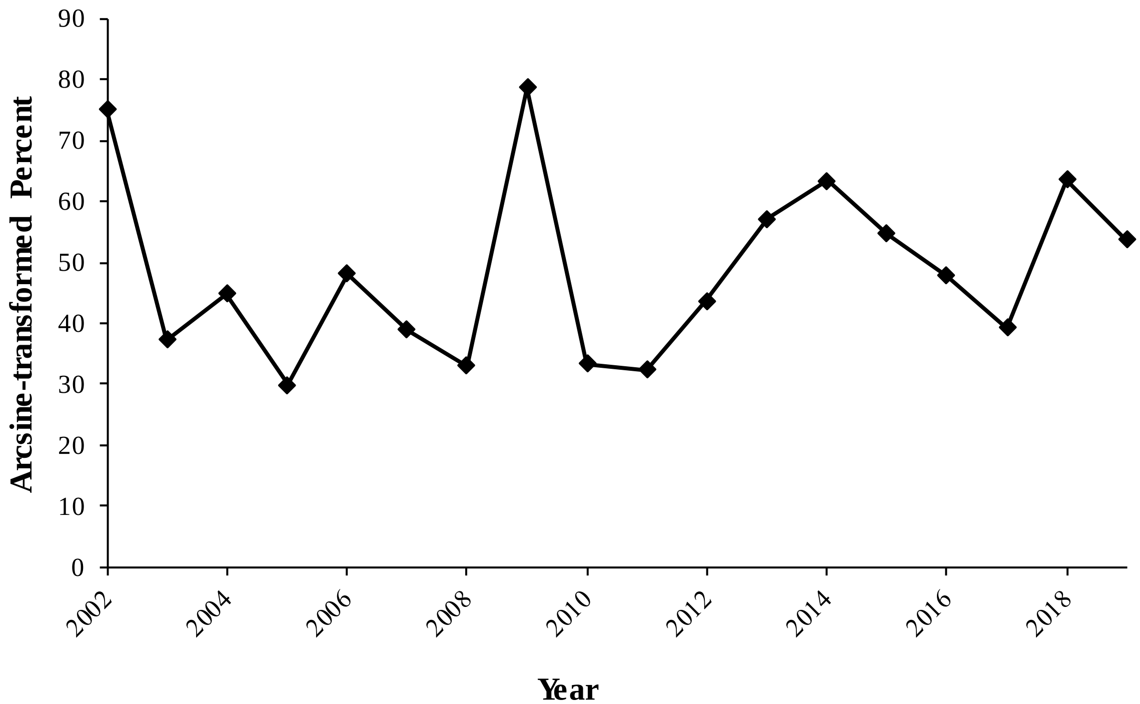


Figure 10. Pearson residuals from the best fit generalized additive model (GAM) in 2019 used to standardize the Susquehanna River hook and line catch per unit effort (CPUE) index.

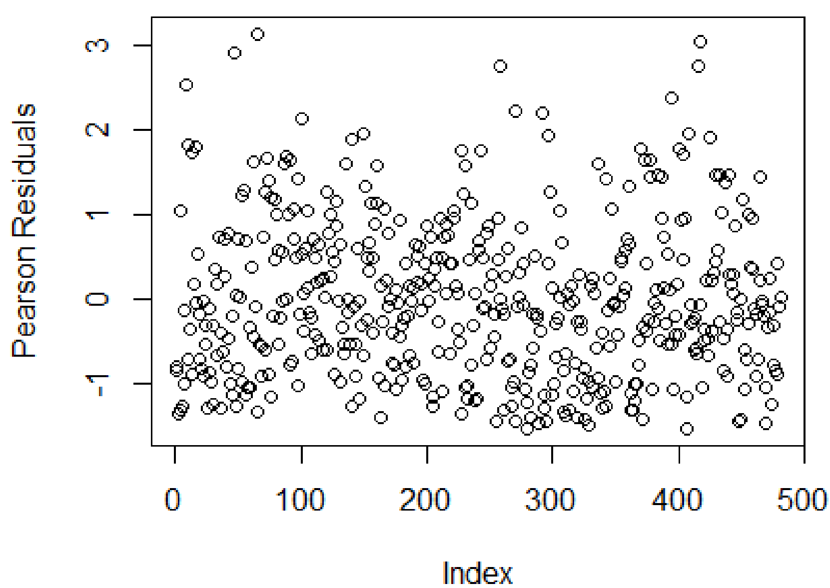


Figure 11. American shad standardized CPUE with 95% confidence intervals estimated by a generalized additive model for the Conowingo Dam tailrace hook and line sampling, 1987-2019.

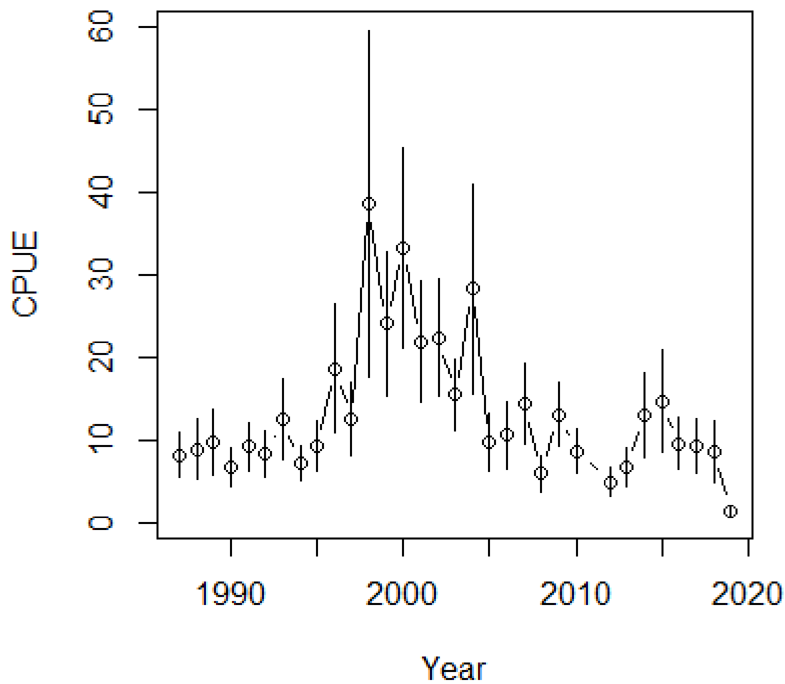


Figure 12. American shad geometric mean CPUE (fish per lift hour) and the total number of American shad lifted at the East and West Fish Lifts at the Conowingo Dam, 1991-2019.

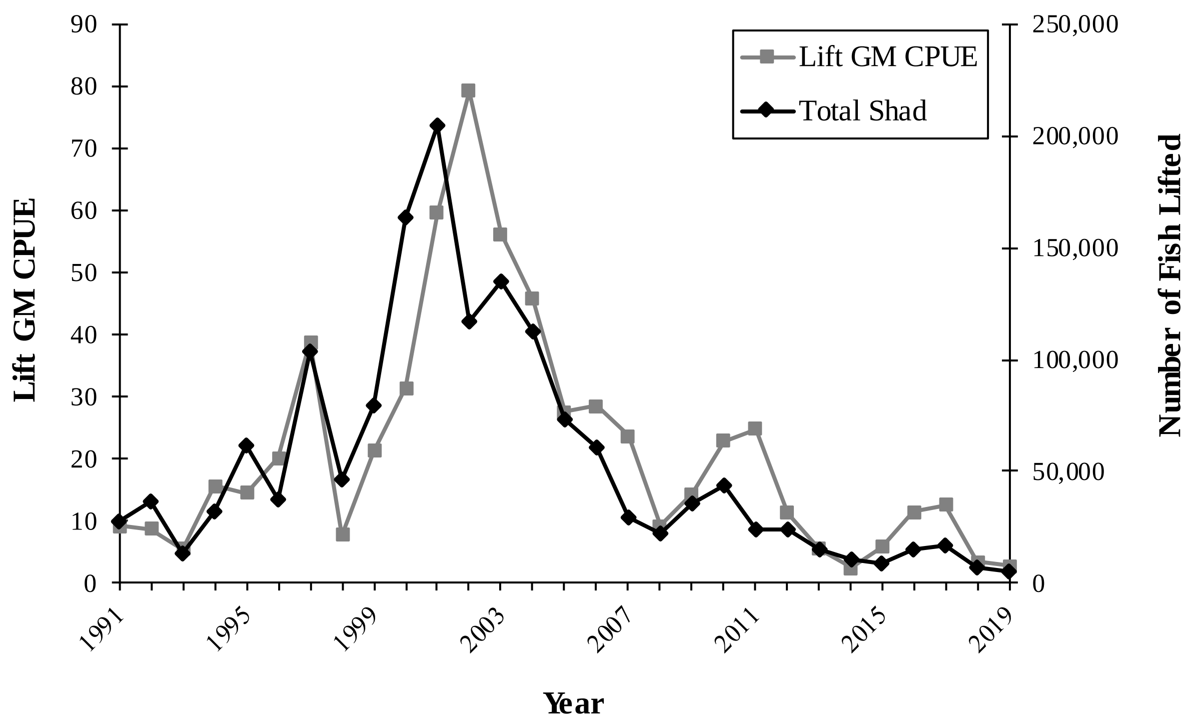


Figure 13. American shad geometric mean CPUE (fish per net day) from the Mill Creek pound net in the Nanticoke River, 1988-2019. No pound nets were fished in 2004, 2015, and 2018.

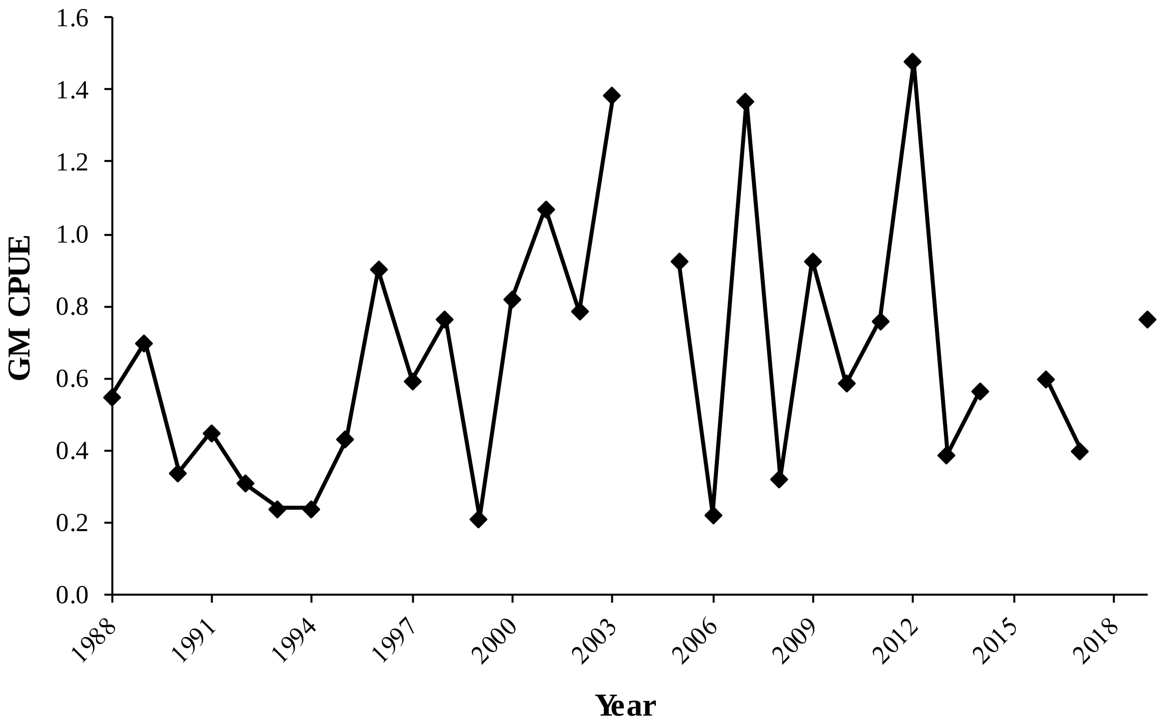


Figure 14. American shad mean CPUE (fish per 914 square meters of experimental drift gill net per hour fished) from the Potomac River, 1996-2019.

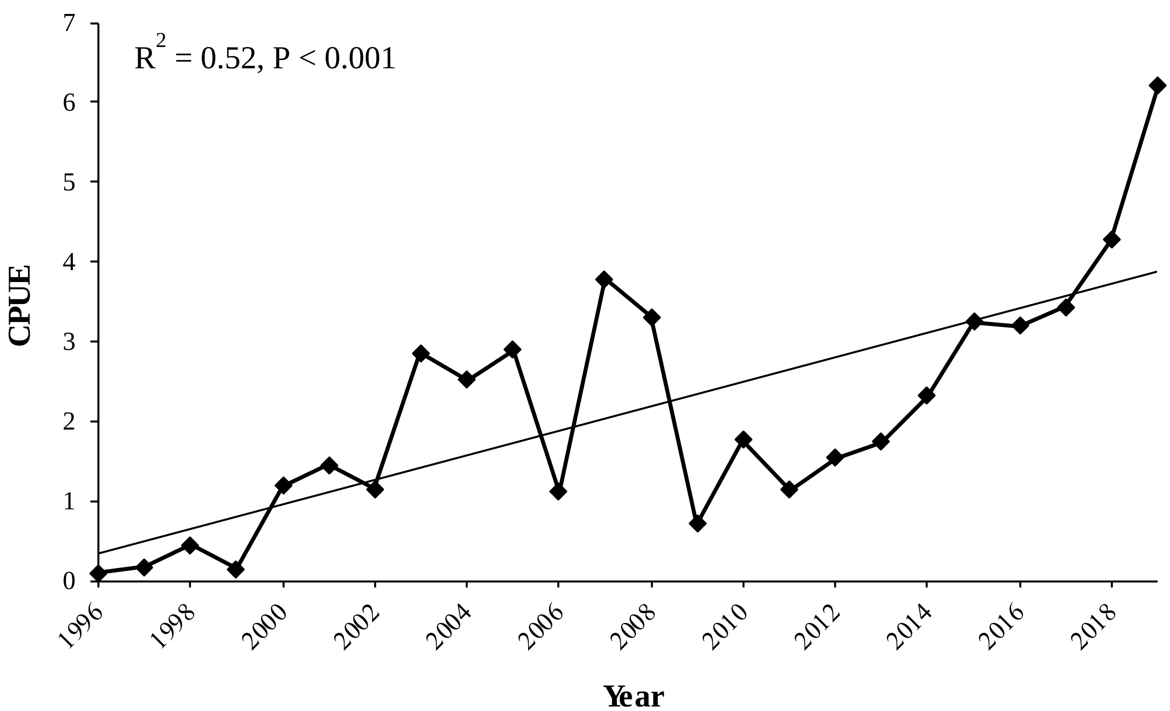


Figure 15. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic with 95% confidence limits, 1986-2019.

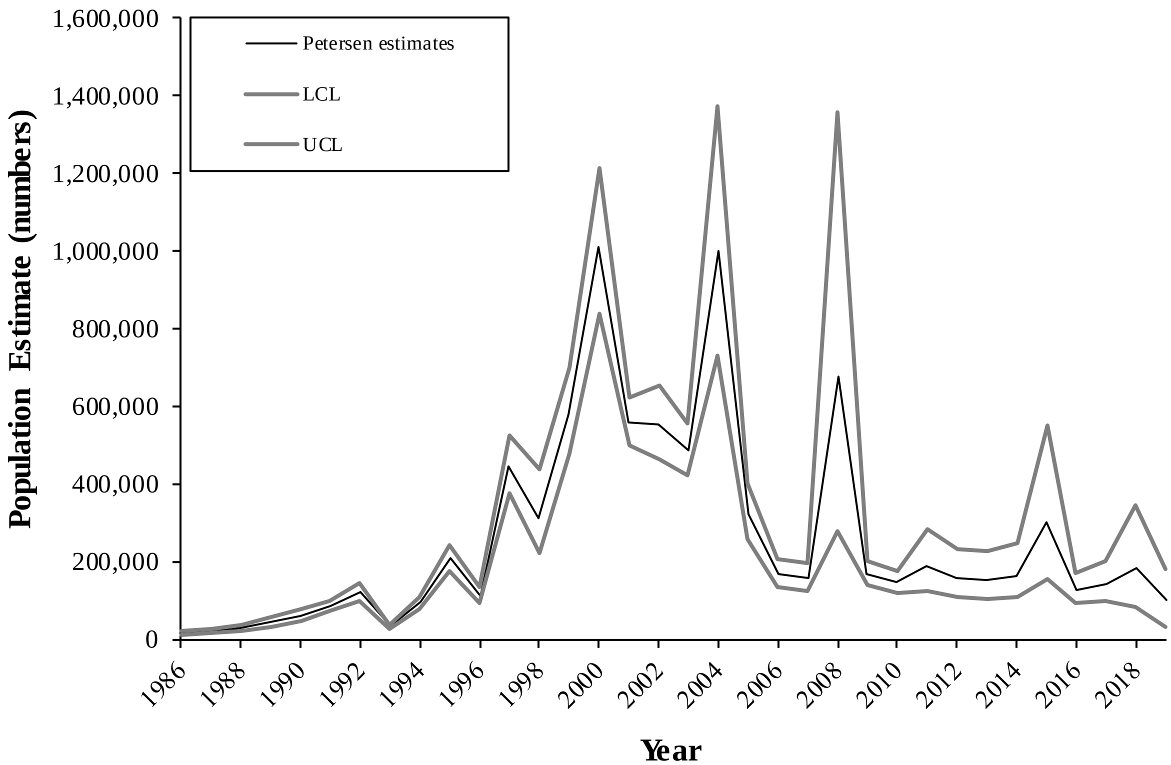


Figure 16. Conowingo Dam tailrace adult American shad abundance estimates from the surplus production model (SPM), 1986-2019.

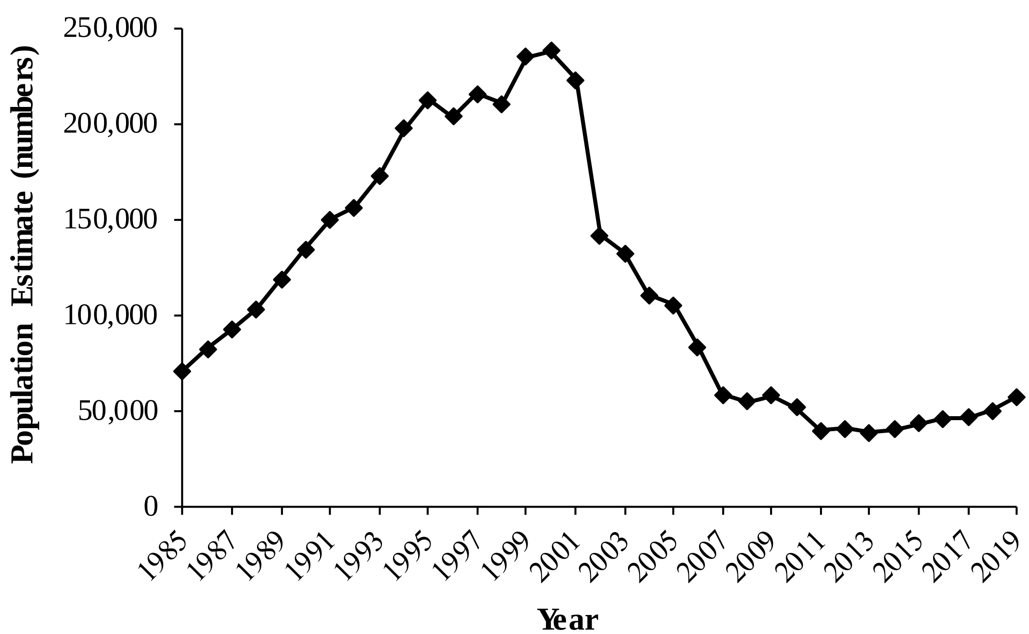


Figure 17. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for American shad, sexes combined, captured in the Conowingo dam tailrace (1984-2019). The $Z_{40\%\ SBPR}$ reference point was determined in the 2020 ASMFC benchmark stock assessment for American shad and is specific to the southern iteroparous region.

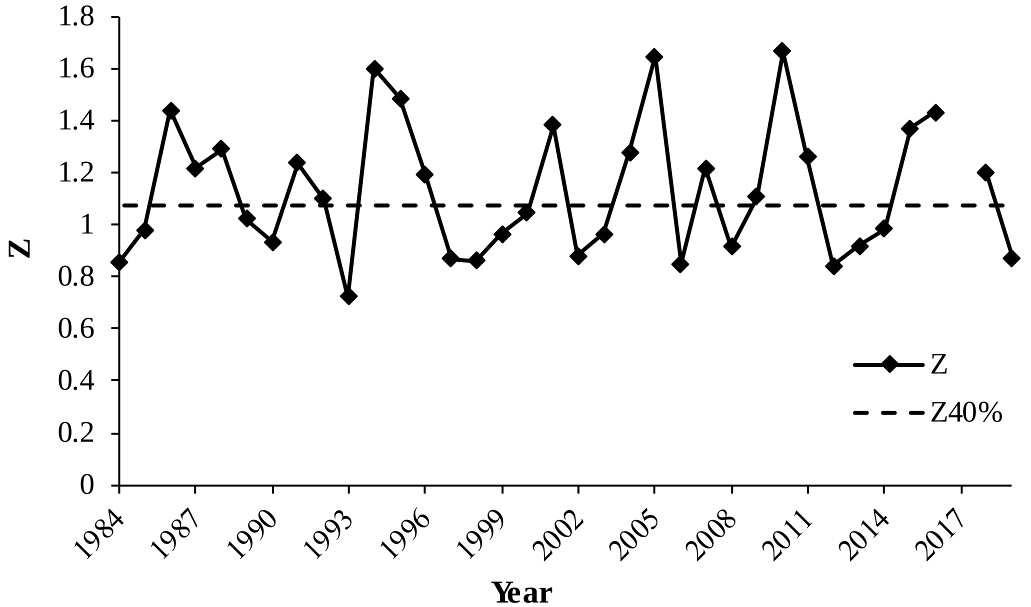


Figure 18. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for American shad, sexes combined, captured in the Nanticoke River (1989-2019). The $Z_{40\%\ SBPR}$ reference point was determined in the 2020 ASMFC benchmark stock assessment for American shad and is specific to the southern iteroparous region.

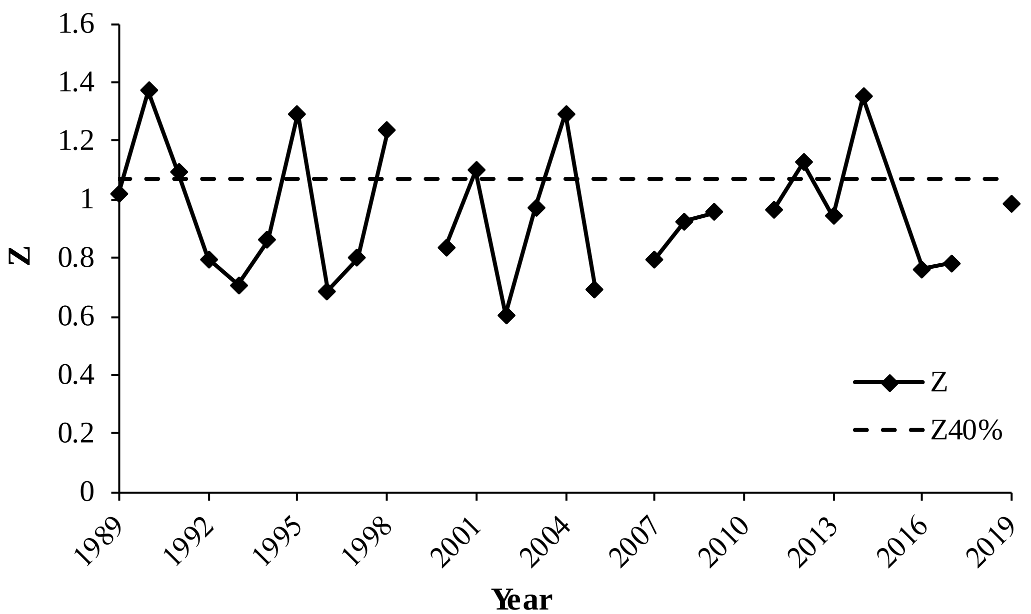


Figure 19. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for American shad, sexes combined, captured in the Potomac River (2002-2019). The $Z_{40\%\ SBPR}$ reference point was determined in the 2020 ASMFC benchmark stock assessment for American shad and is specific to the southern iteroparous region.

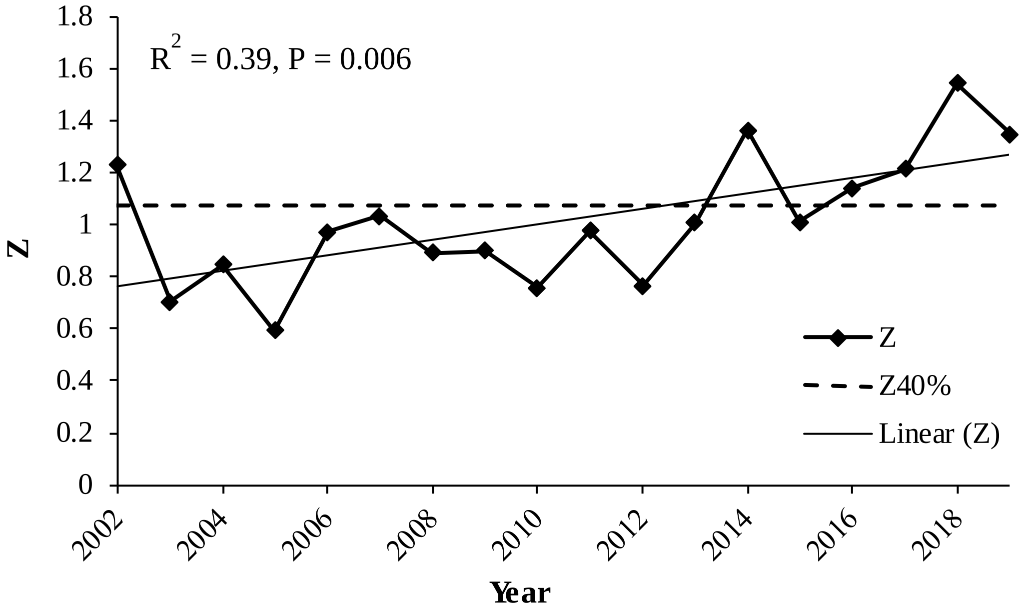


Figure 20. Baywide juvenile American shad geometric mean CPUE (catch per haul), 1959-2019.

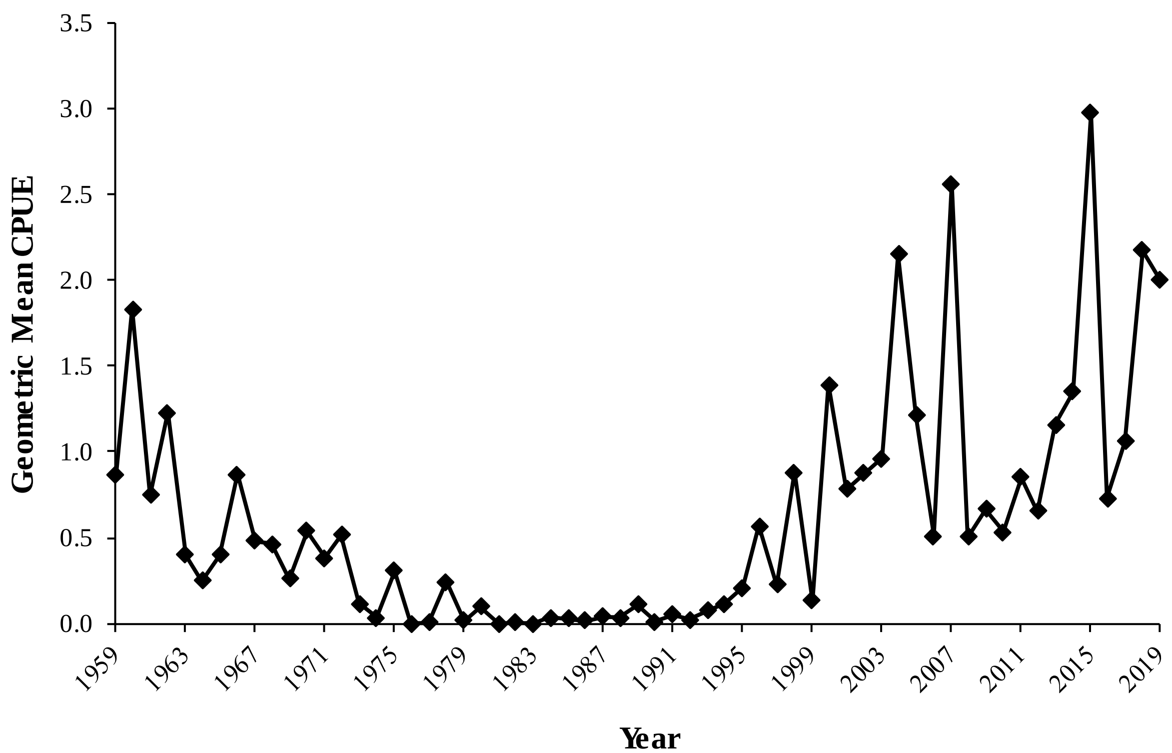


Figure 21. Upper Chesapeake Bay juvenile American shad geometric mean CPUE (catch per haul), 1959-2019.

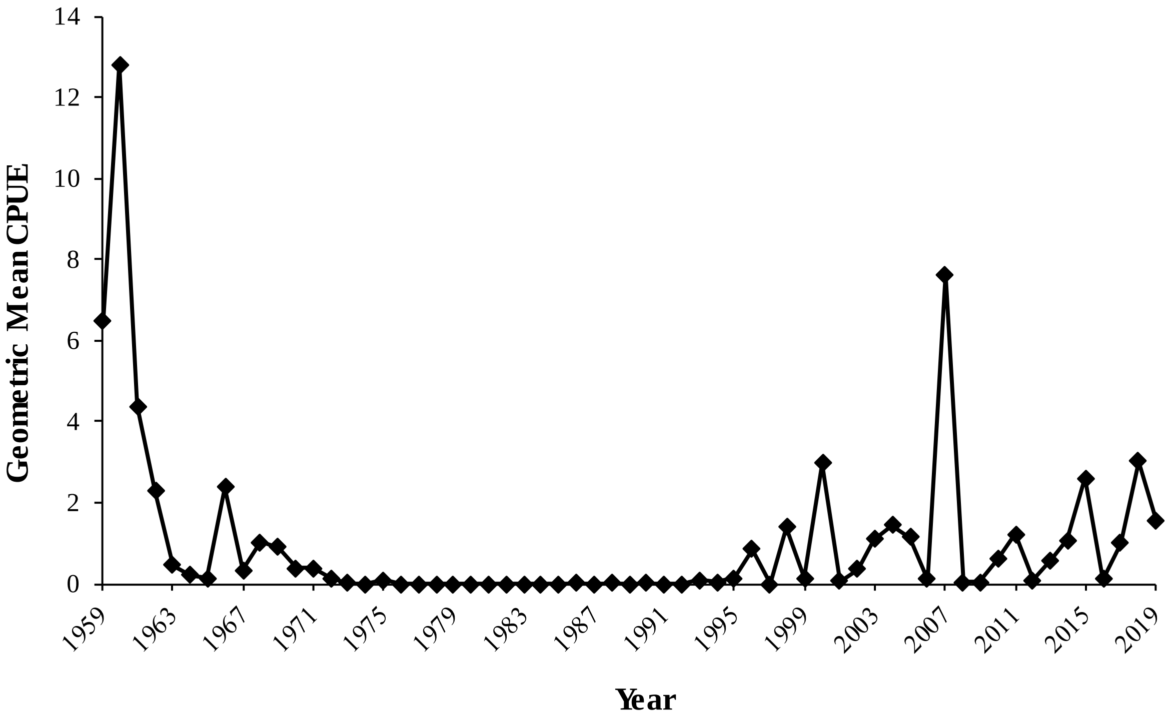


Figure 22. Potomac River juvenile American shad geometric mean CPUE (catch per haul), 1959-2019.

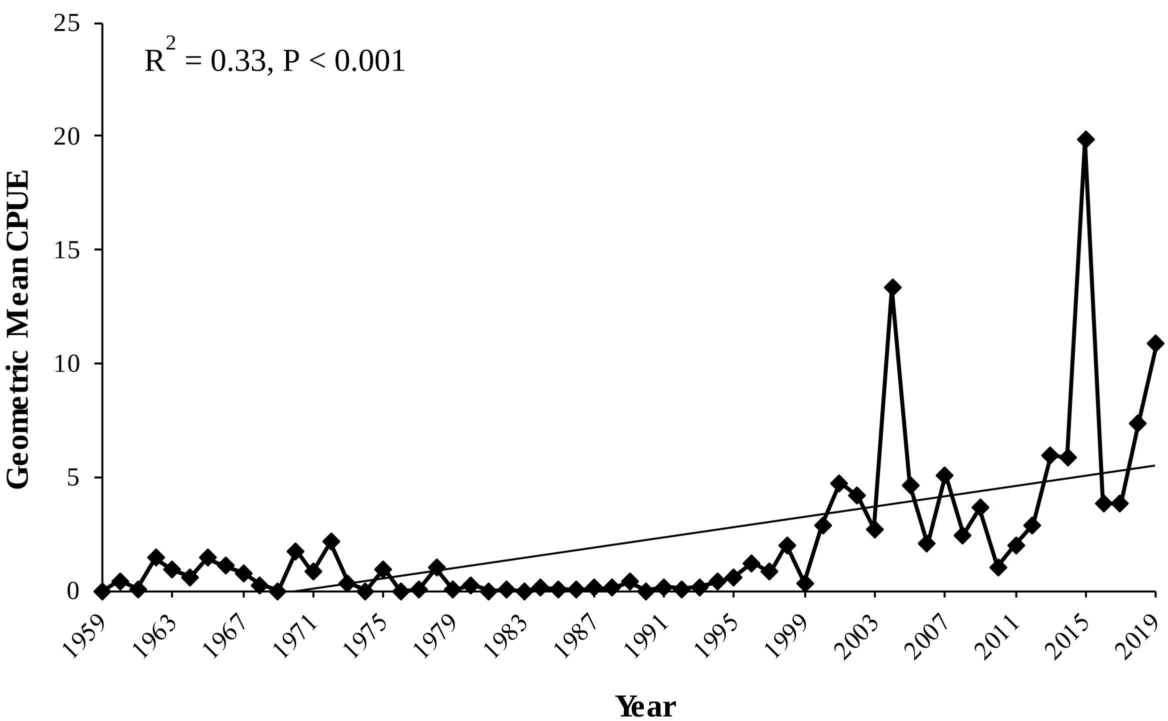


Figure 23. Nanticoke River juvenile American shad geometric mean CPUE (catch per haul), 1959-2019.

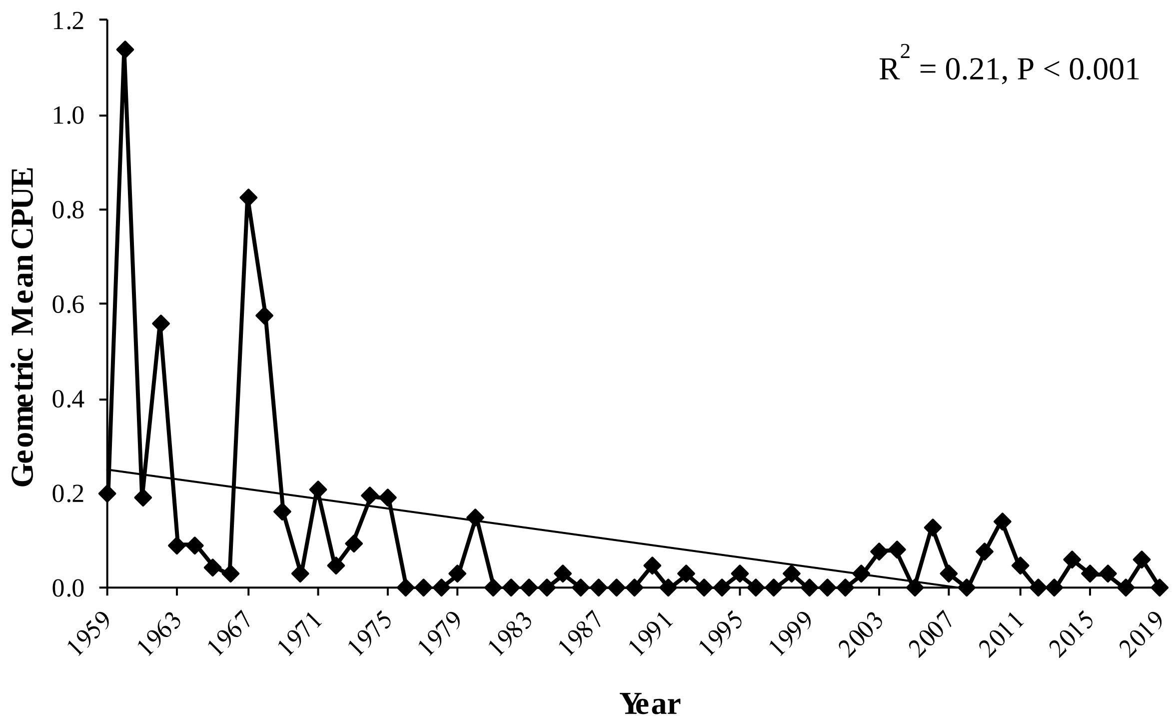


Figure 24. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from the Susquehanna River and Deer Creek (a lower Susquehanna River tributary), 2004-2019.

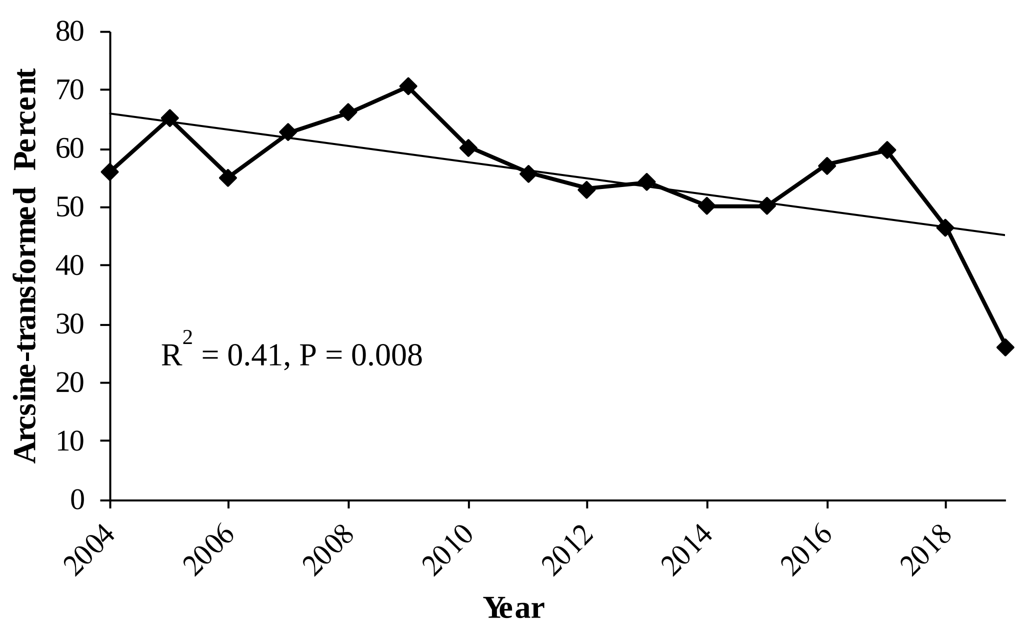


Figure 25. Statewide catch-per-angler-hour (CPAH) of hickory shad from paper logbook and online volunteer angler surveys, 1998-2019.

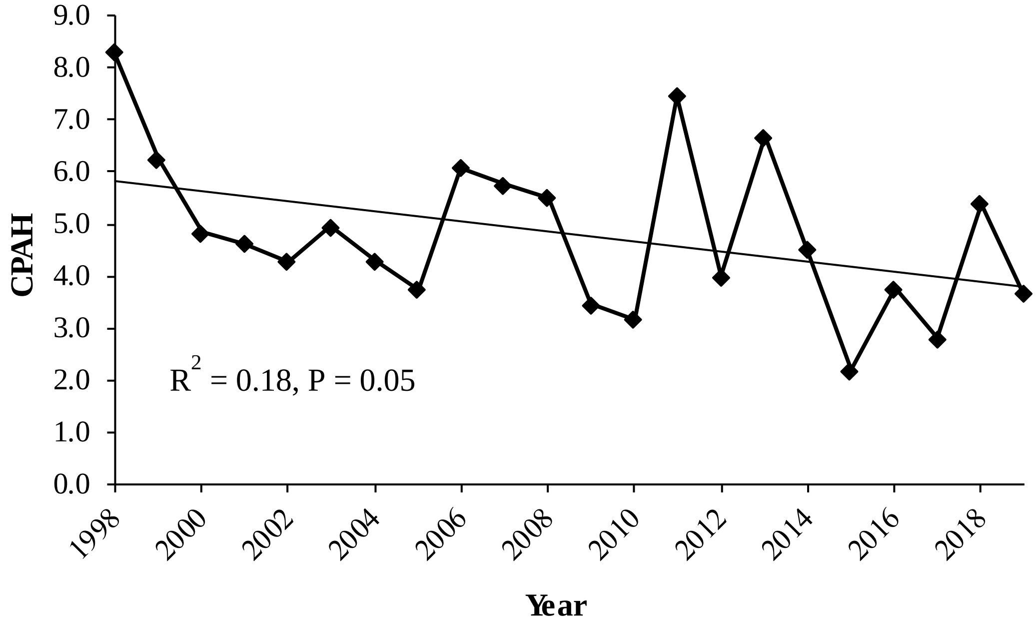


Figure 26. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for hickory shad, sexes combined, captured in the Susquehanna River (2004-2019).

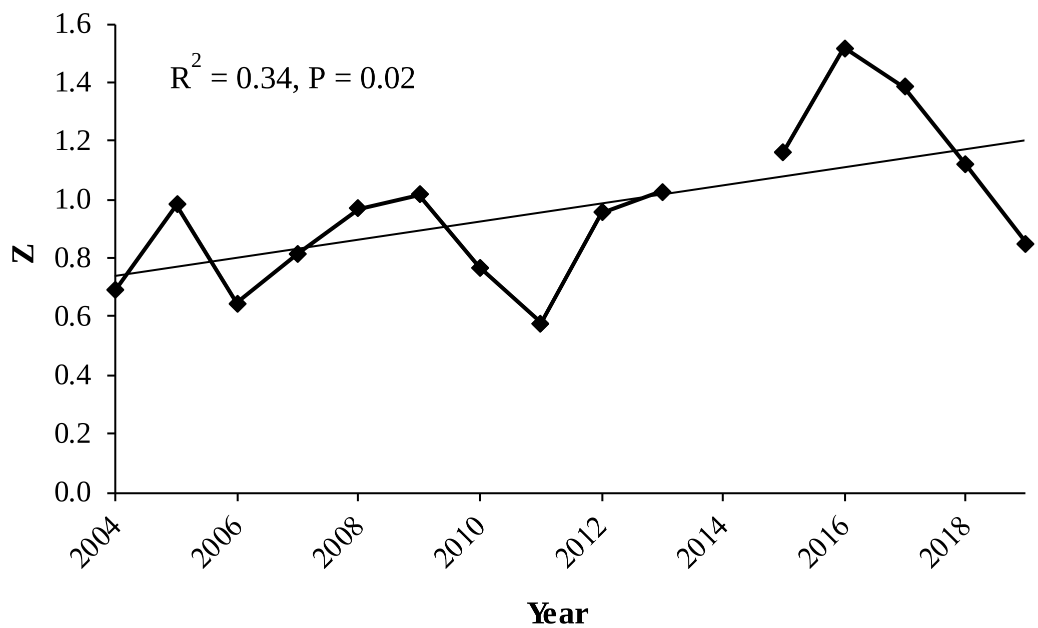


Figure 27. Arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1990-2019.

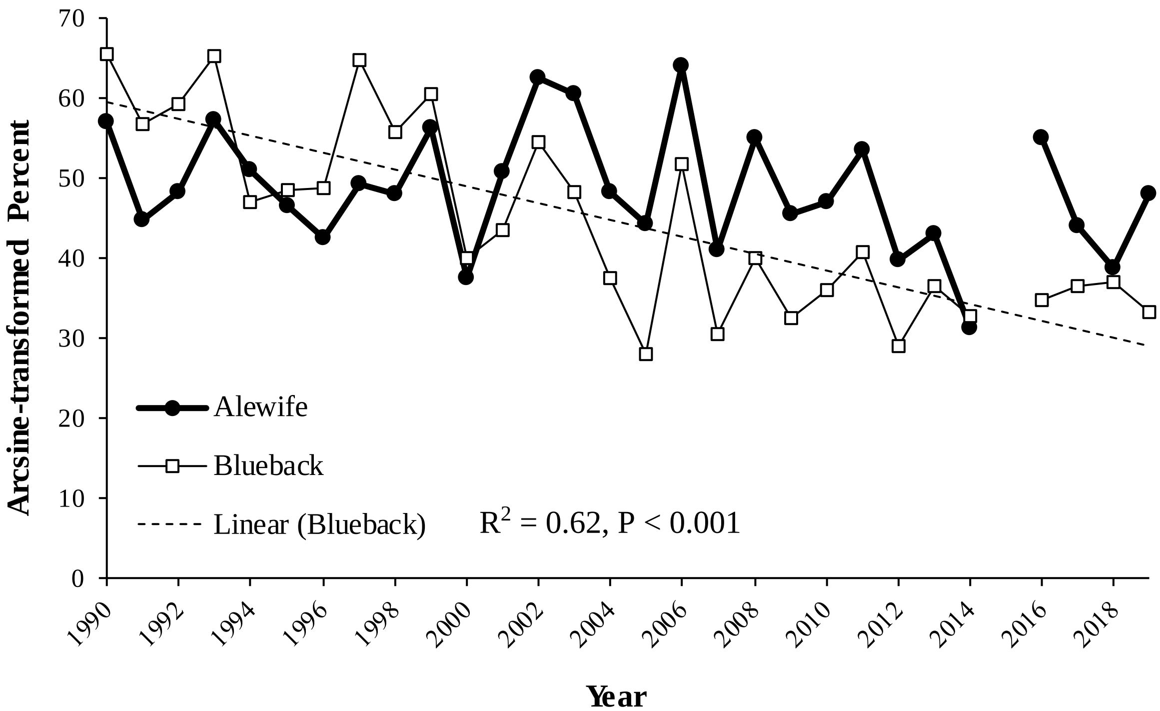


Figure 28. Mean fork length (mm) of adult alewife and blueback herring from the Nanticoke River, 1989-2019.

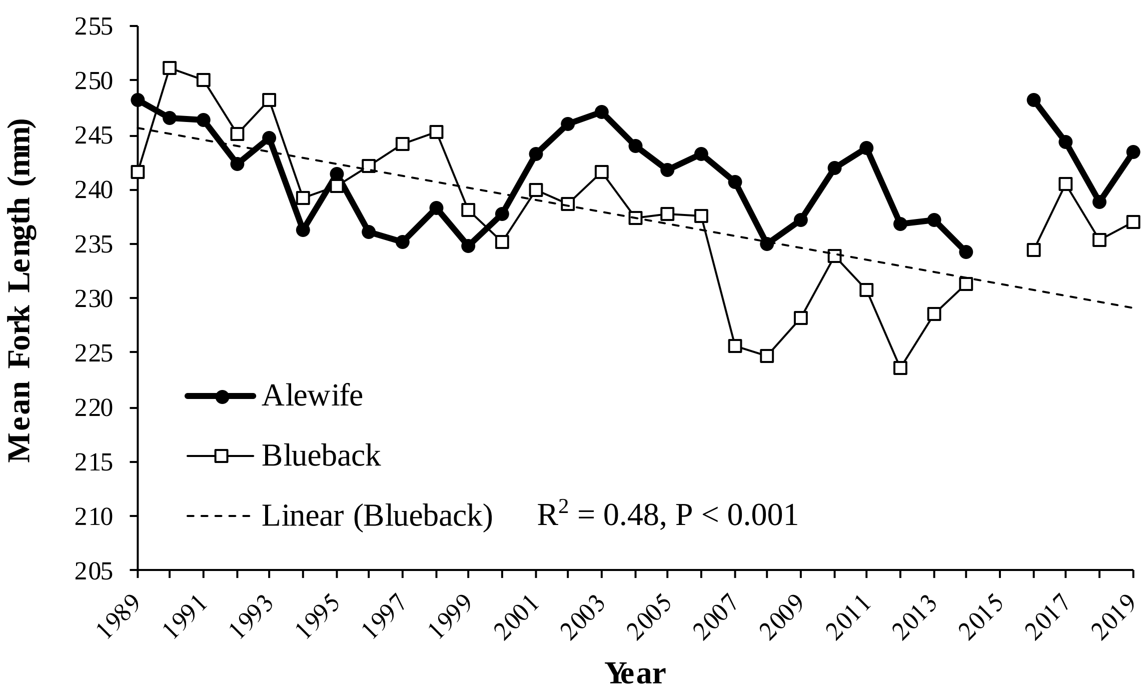


Figure 29. Percent catch-at-age by year of alewife from the North East River, 2013-2019.

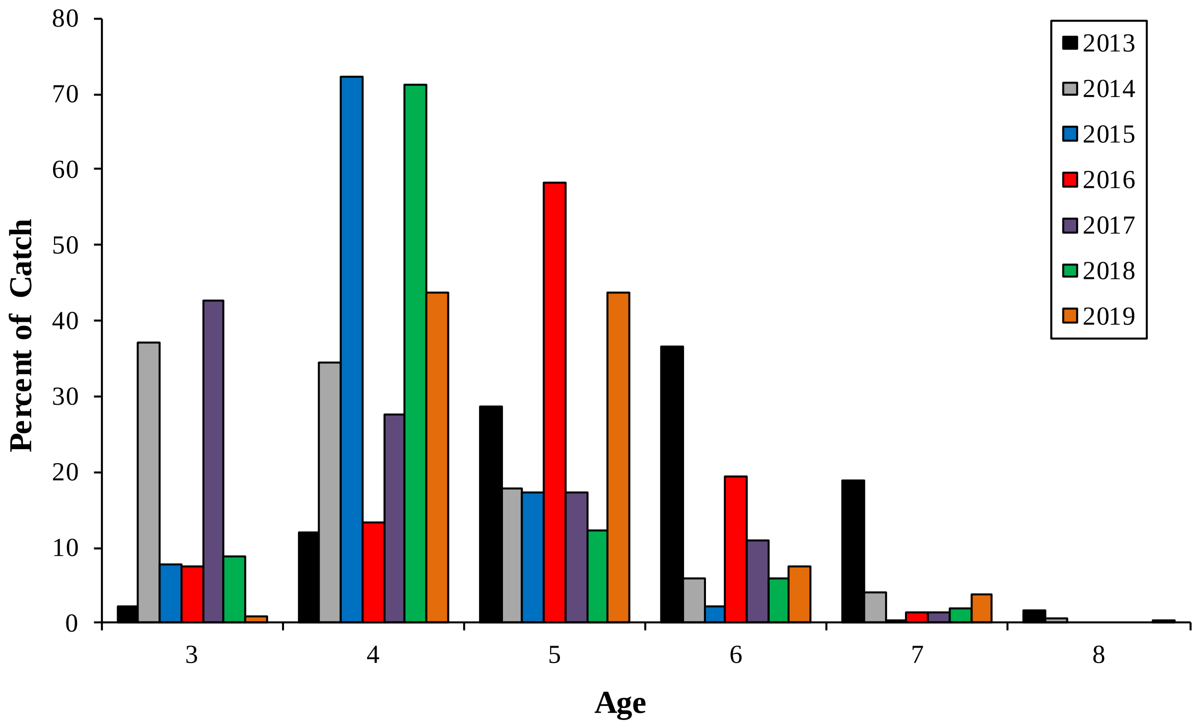


Figure 30. Percent catch-at-age by year of blueback herring from the North East River, 2013-2019.

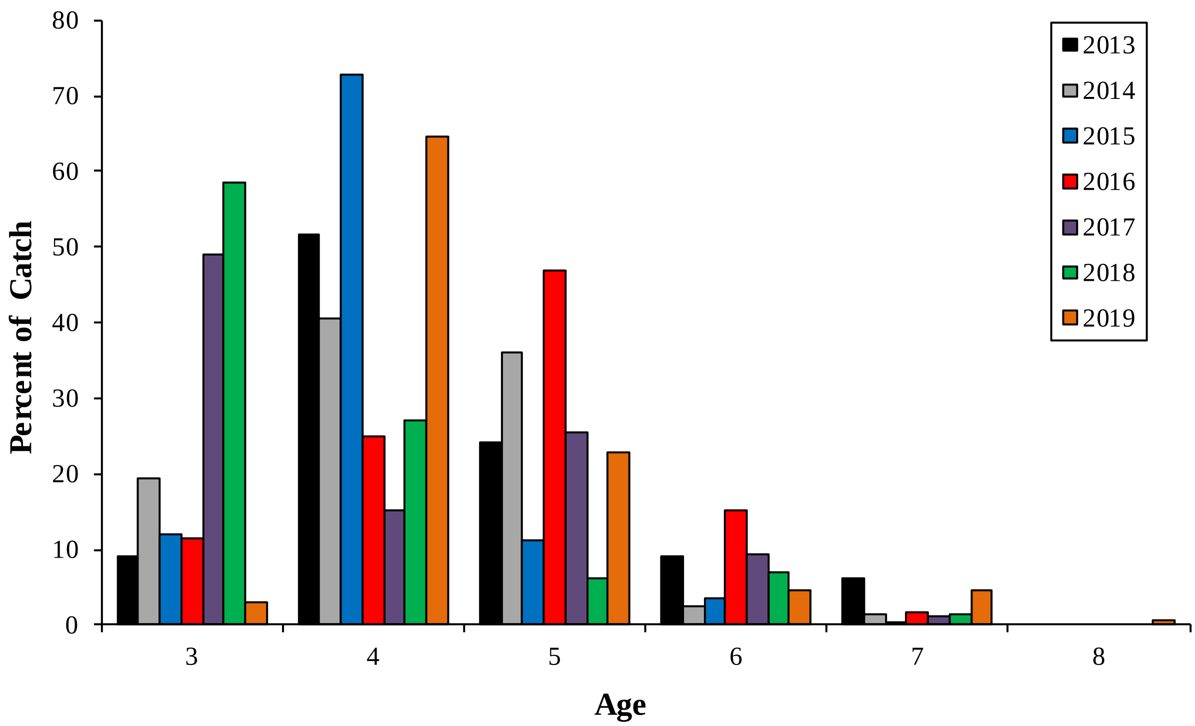


Figure 31. Arcsine-transformed percentages of repeat spawning alewife and blueback herring (sexes combined) collected from the North East River, 2013-2019.

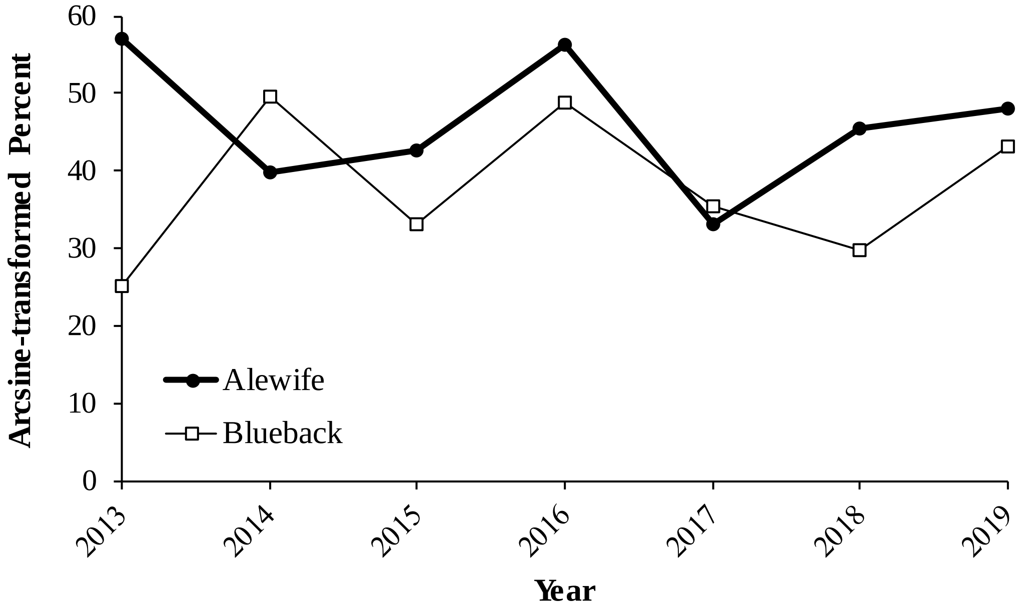


Figure 32. Geometric mean CPUE (catch per net day) of adult alewife and blueback herring from Nanticoke River fyke nets, 1989-2019. No fyke nets were fished in 2012 and 2015.

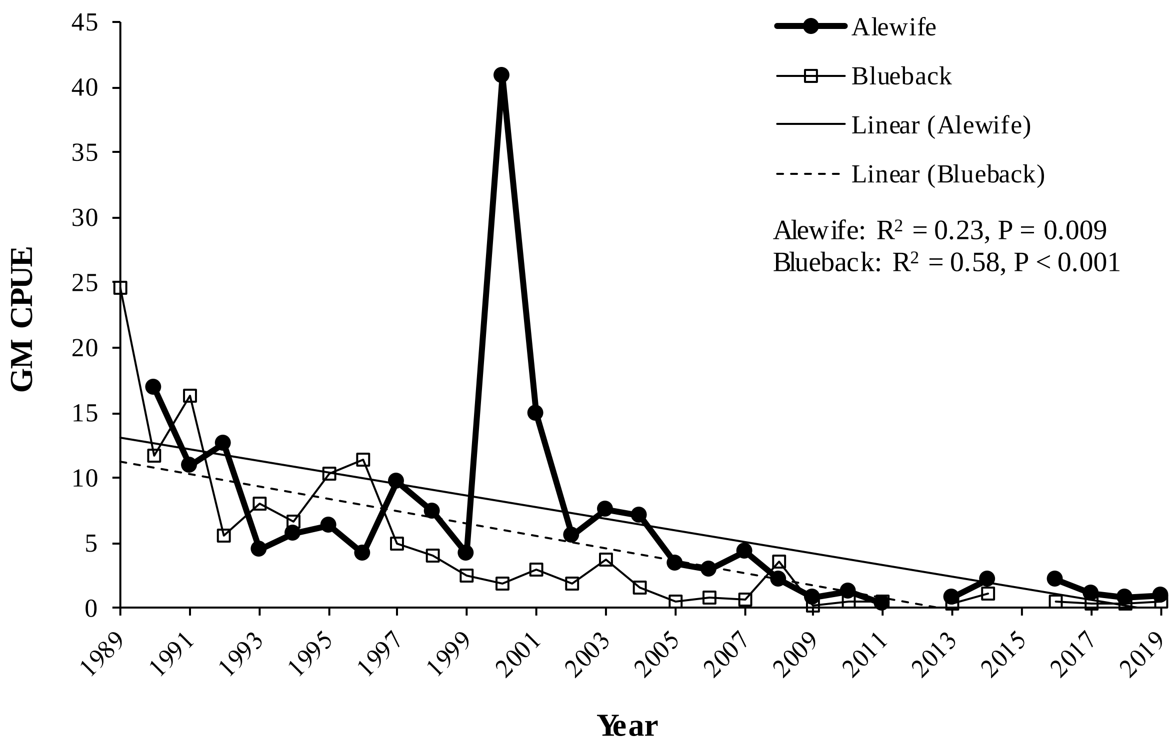


Figure 33. North East River catch per day of alewife and blueback herring, plotted with surface water temperature for 2019.

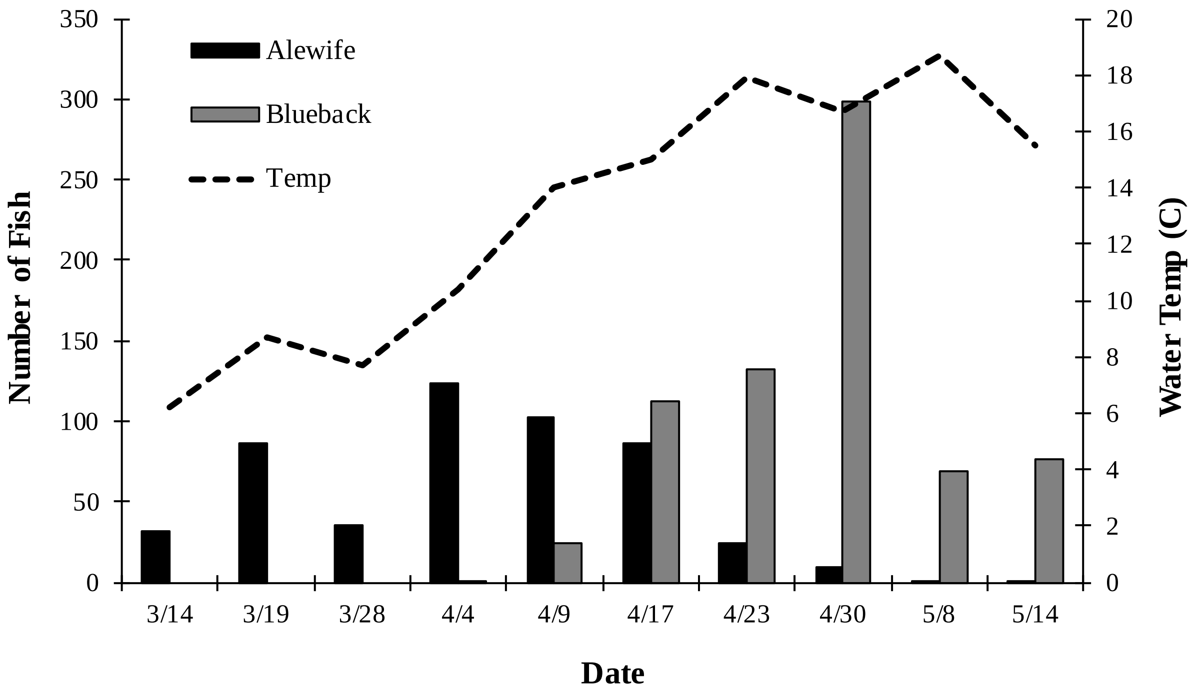


Figure 34. Percent of total catch by mesh size of alewife from the North East River, 2013-2019.

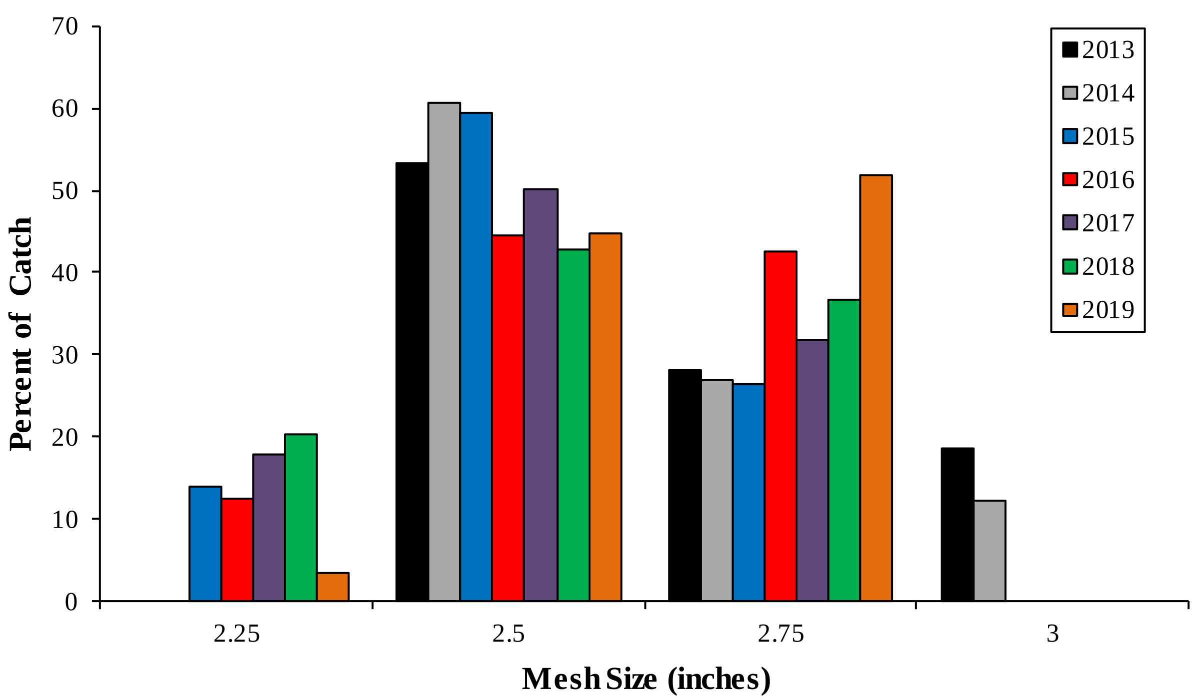


Figure 35. Percent of total catch by mesh size of blueback herring from the North East River, 2013-2019.

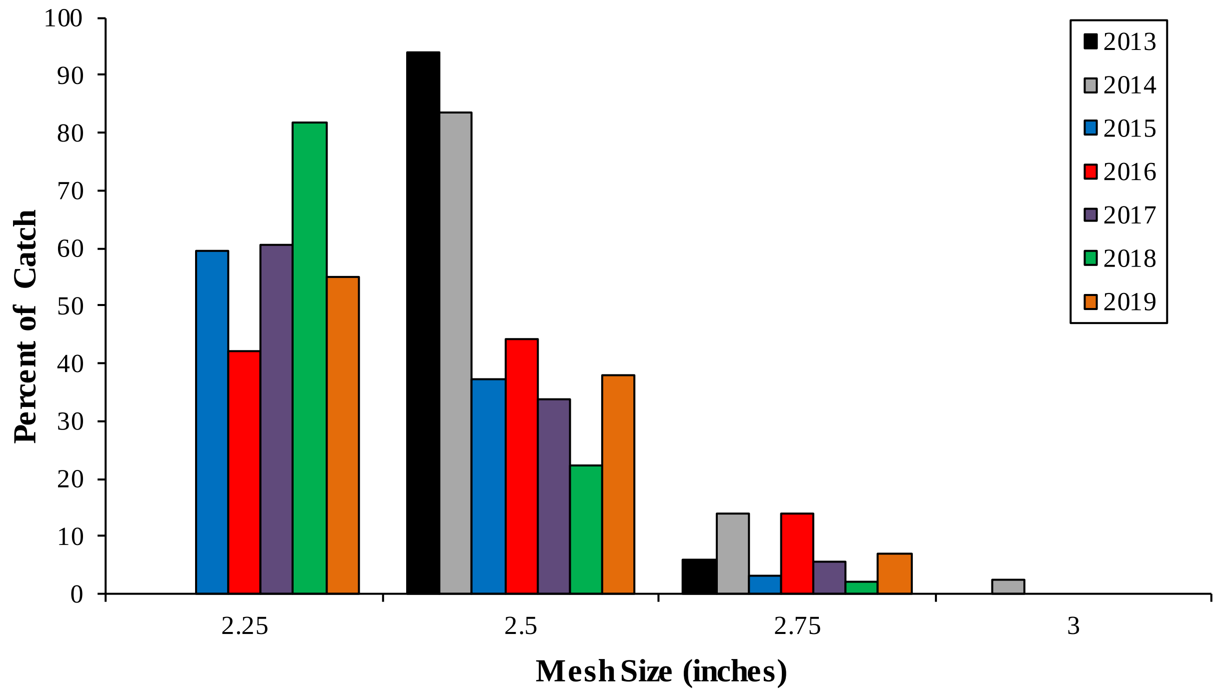


Figure 36. Alewife and blueback herring CPUE (number of fish caught per set of experimental gill net per hour fished) from the North East River gill net survey, 2013-2019. Catch was pooled across the 2.5” and 2.75” mesh panels for all years.

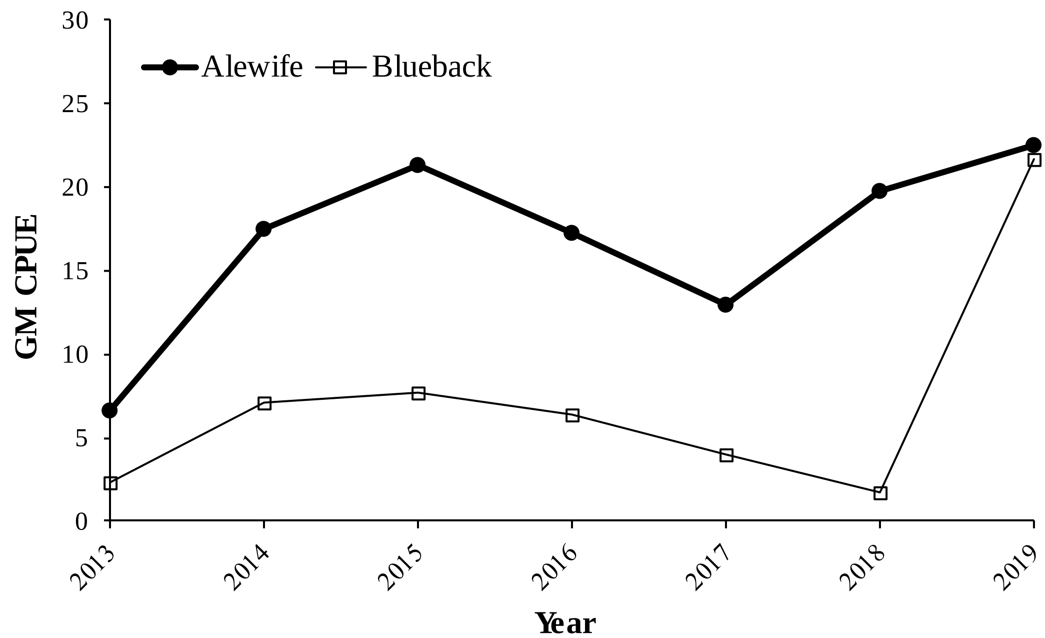


Figure 37. Alewife and blueback herring CPUE (number of fish caught per set of experimental gill net per hour fished) from the North East River gill net survey, 2015-2019. Catch was pooled across the 2.25”, 2.5”, and 2.75” mesh panels for all years.

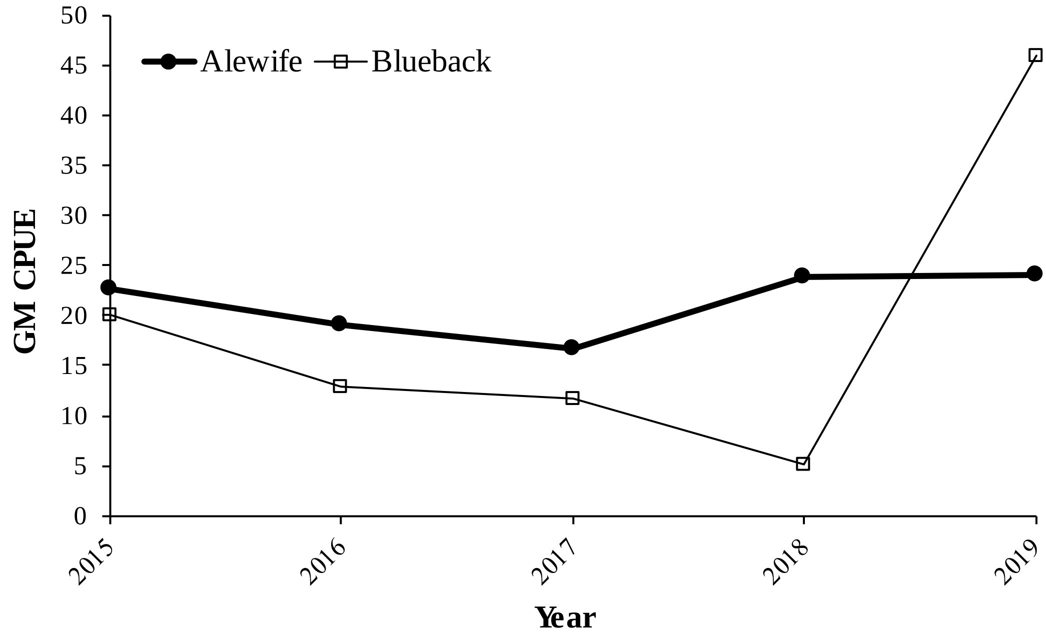


Figure 38. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for alewife, sexes combined, captured in the Nanticoke River (1989-2019). $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks were determined by the 2017 ASMFC river herring stock assessment update and are specific to the Nanticoke River.

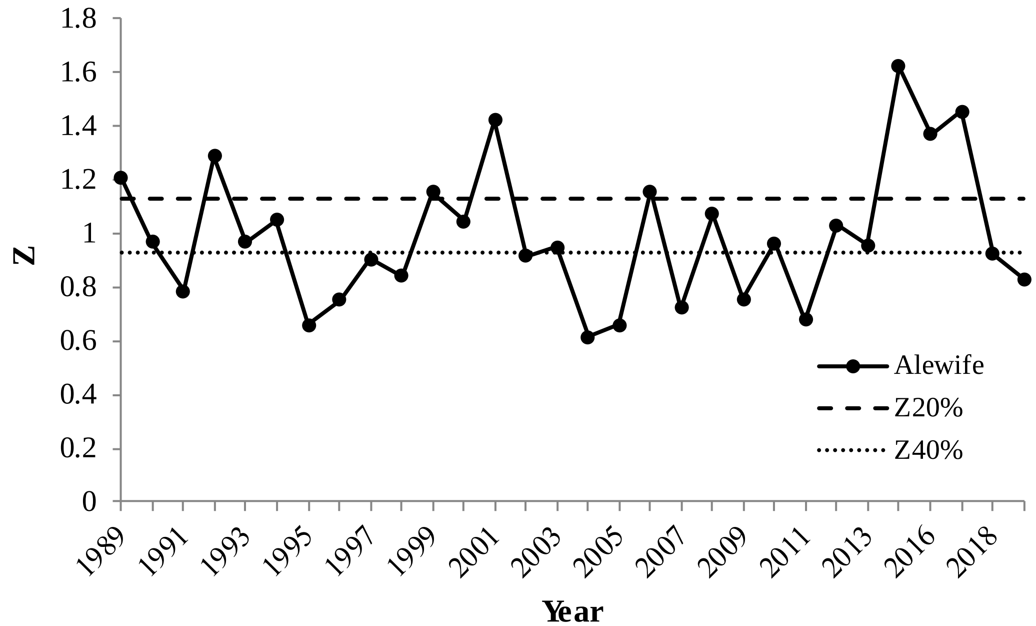


Figure 39. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for blueback herring, sexes combined, captured in the Nanticoke River (1989-2019). $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks were determined by the 2017 ASMFC river herring stock assessment update and are specific to the Nanticoke River.

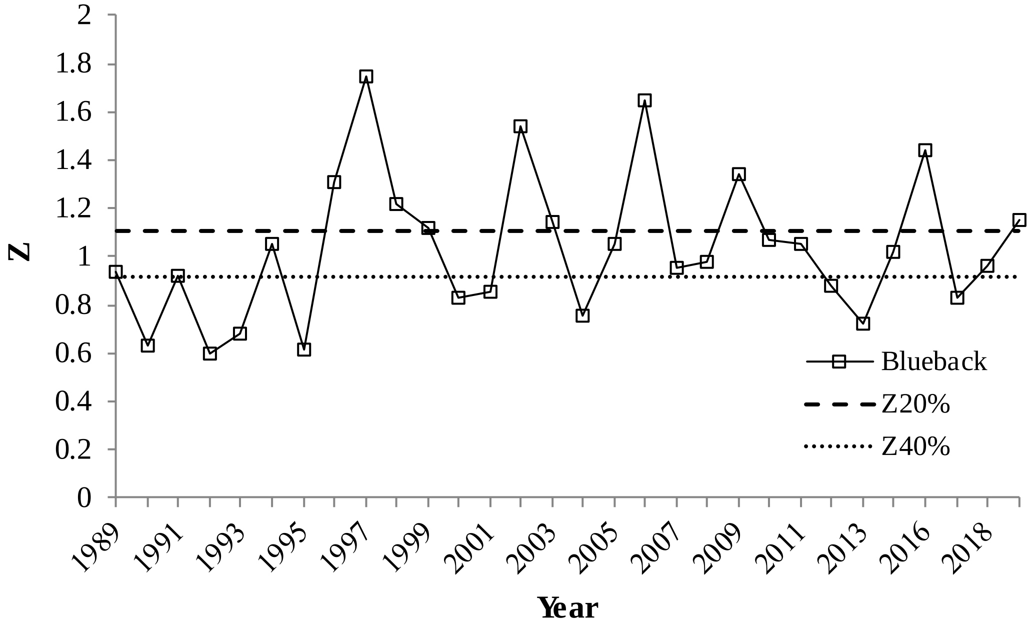


Figure 40. Age-based Chapman-Robson total instantaneous mortality (Z) estimates for alewife and blueback herring, sexes combined, captured in the North East River (2013-2019).

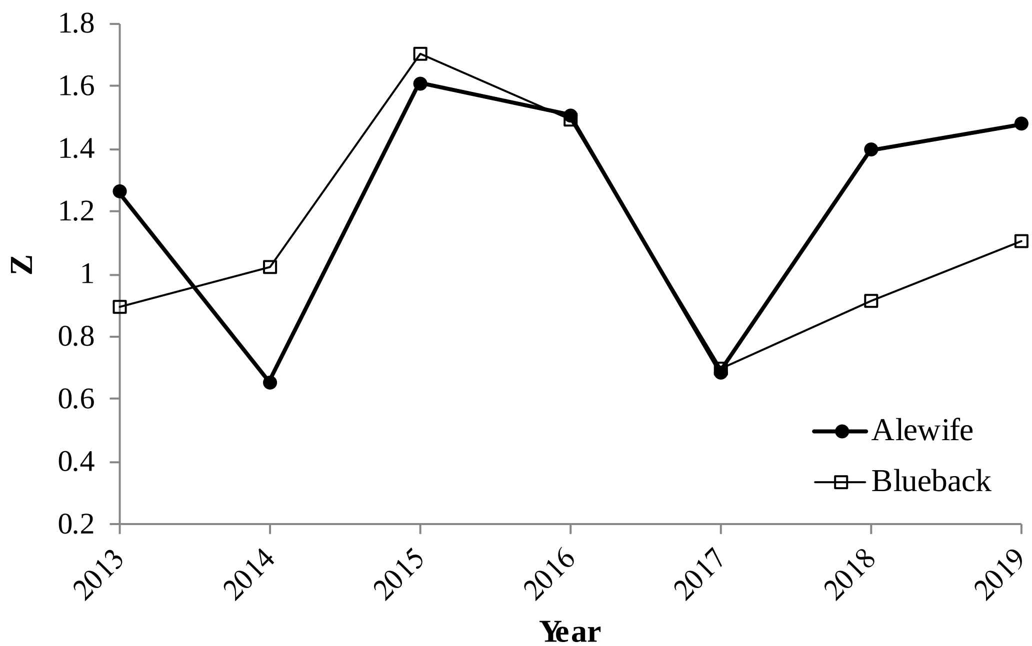


Figure 41. Upper Bay juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2019.

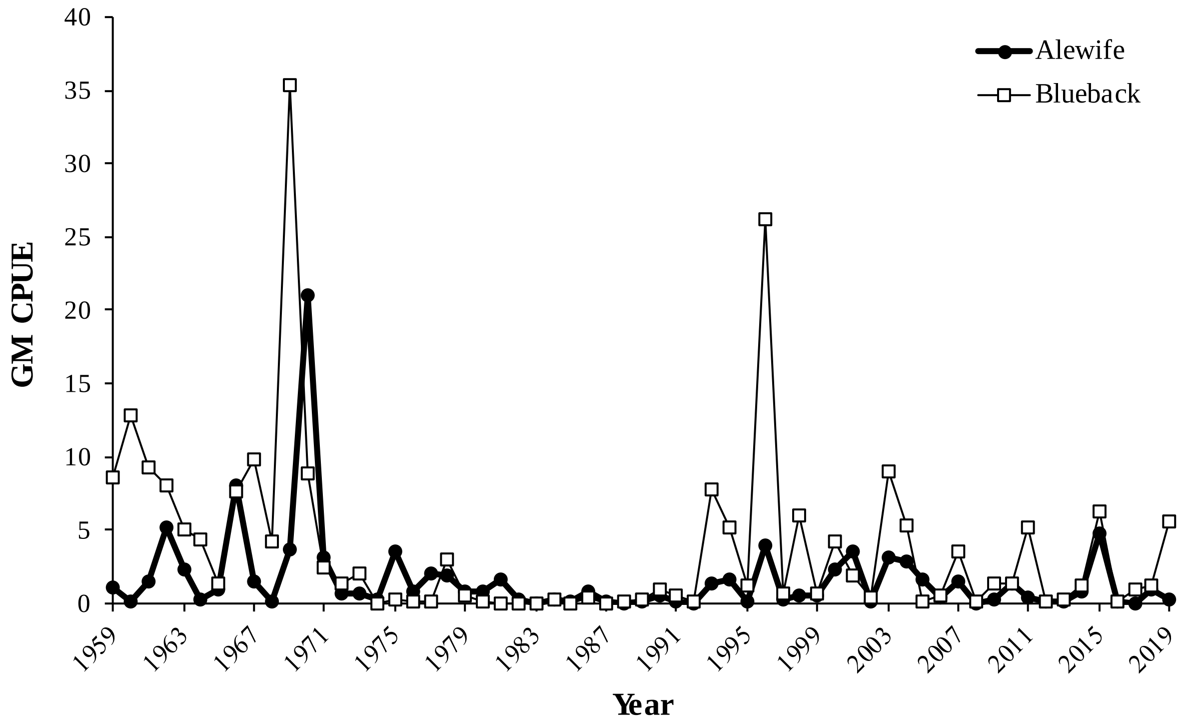
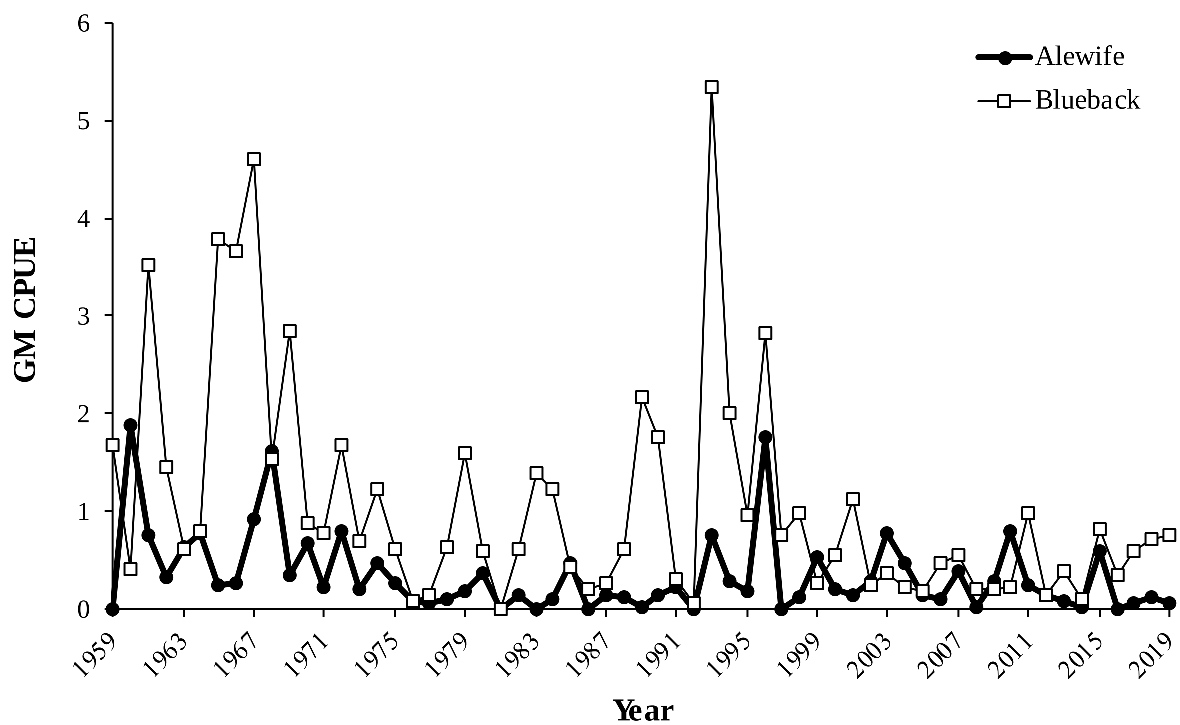


Figure 42. Nanticoke River juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2019.



PROJECT NO. 2
JOB NO. 2

STOCK ASSESSMENT OF SELECTED RECREATIONALLY IMPORTANT ADULT MIGRATORY FINFISH IN MARYLAND'S CHESAPEAKE BAY

Prepared by Harry W. Rickabaugh Jr. and Katherine M. Messer

INTRODUCTION

The primary objective of Project Two Job Two was to characterize recreationally important migratory finfish stocks in Maryland's Chesapeake Bay by age, length, weight, growth and sex. Atlantic croaker (*Micropogonias undulates*), bluefish (*Pomatomus saltatrix*), spot (*Leiostomus xanthurus*), summer flounder (*Paralichthys dentatus*) and weakfish (*Cynoscion regalis*) are very important sportfish in Maryland's Chesapeake Bay. Black drum (*Pogonias cromis*), Red drum (*Sciaenops ocellatus*), Spanish mackerel (*Scomberomorus maculates*) and spotted seatrout (*Cynoscion nebulosus*) are less popular in Maryland because of lower abundance, but are targeted by anglers when available (Chesapeake Bay Program 1993). Atlantic menhaden (*Brevoortia tyrannus*) are a key component to the Bay's food chain as forage for predatory sportfish (Hartman and Brandt 1995, Overton et al 2000).

The Maryland Department of Natural Resources (Department) has conducted summer pound net sampling since 1993, and began a fishery independent gill net survey in the Choptank River in 2013. The data collected from these efforts provide information for the preparation and updating of stock assessments and fishery management plans by the Department, the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC). This information is also utilized by the

Department in managing the state's valuable migratory finfish resources through the regulatory/statutory process.

METHODS

Data Collection

The onboard pound net survey relies on the cooperation of pound net fishermen. Pound nets from the lower Chesapeake Bay and Potomac River were monitored throughout the 27 years of this survey (1993-2019). In 2019, commercial pound nets were sampled inside the mouth of the Potomac River and in Chesapeake Bay north of the Potomac River to Barren Island (Figure 1). Each site was sampled once every two weeks, weather and fisherman's schedule permitting. Data from pound nets were also included from Job 3 from the lower Chester River and Herring Bay in 2019 (Figure 1). Staff collected length data and Atlantic menhaden scale samples when target species of Job 2 were encountered and staff could sample them without impacting the completion of Job 3 sampling. Net soak time and the manner in which the pound nets were fished were consistent with the fisherman's day-to-day operations. There were no cooperating commercial fisherman on the lower eastern side of Chesapeake Bay in 2017, 2018, and the beginning of 2019 so fish dealer sampling was conducted on Upper Hooper Island.

During onboard sampling, all targeted species were measured from each net when possible. When it was not practical to measure all fish, a random sample of each species was measured and the remaining individuals enumerated if possible. All measurements were to the nearest millimeter total length (TL) except for Spanish mackerel which were measured to the nearest millimeter fork length (FL). Fifty randomly selected Atlantic menhaden were measured to the nearest millimeter FL each day, when available, and scale samples were taken from 10 to 25 of the measured fish. Water temperature (°C), salinity (parts per thousand), GPS coordinates (NAD 83), date and hours fished were also recorded at each net. Hours fished was not entered in the database if the net was not emptied on the day of sampling or the previous day fished.

During seafood dealer sampling, all specimens of the target species were measured to the nearest millimeter and weighed to the nearest gram when possible. Subsamples of 50 pound boxes of fish were sampled if sampling all individual fish was not practical. Date of capture, gear type and the location of nets were also recorded when available.

A subsample of fish was retained and brought back to the lab for processing from the onboard sampling effort. Otoliths were taken and individual weights (g), TL (mm) and sex were determined from subsampled Atlantic croaker, spot and weakfish. Prior to 2011, Atlantic croaker and weakfish otoliths were processed and aged by the South Carolina Department of Natural Resources. Otoliths from 2011 to 2019 were processed and aged by project biologists. All spot otoliths were processed and aged by the project biologists. For all three species, the left otolith from each specimen was mounted to a glass slide for sectioning. If the left otolith was damaged or missing the right otolith was substituted. Otoliths were mounted to a glass slide using Crystalbond® 509 and sectioned with a Buehler IsoMet® low speed saw using two blades separated by a 0.4 mm spacer. Allied High Tech Products Inc. impregnated diamond metal bonded, high concentration cutting blades, measuring 102 millimeters in diameter and 0.31 millimeters thick (model number 60-20070) were used. The 0.4 millimeter sections were then mounted on microscope slides and viewed under a microscope at five to six power to determine the number of annuli. All age structures were read by two readers. If readers did not agree, both readers reviewed the structures together, and if agreement still could not be reached the sample was not assigned an age. In 2013 two readers made initial age evaluations, but due to logistical limitations only one reader reexamined structures in which annuli counts differed. Atlantic menhaden scales were aged by two Department biologists using the same procedure outlined above. A minimum of four scales per sample were cleaned, mounted between two glass slides and read for age using an Anacomp Inc. Micron 385 microfiche reader. In 2015, the ASMFC conducted an Atlantic menhaden aging workshop. It was determined that Department biologist were sometimes over aging Atlantic menhaden by counting accessory rings on some scales (ASMFC 2015). This discrepancy was corrected for fish aged in 2015 and thereafter, therefore Atlantic menhaden ages prior to 2015 may be biased high.

A fishery independent gill net survey targeting adult Atlantic croaker, Atlantic menhaden, bluefish and spot was conducted in the lower Choptank River beginning in 2013 to provide an index of relative abundance and collect biological information for these species. The survey was conducted once a week in June, July and August in the main stem of the river (52 sets per year) from an imaginary line crossing from Howell Point to Jenkins Creek downstream to the river mouth (Figure 2). Logistical issues led to changes in sampling dates or missed sets in 2013, 2015, 2016 and 2017 (Table 1). The survey uses a simple random design in which the river has been divided into a block grid, with each block being a 457.2 meters square (Figure 3). An experimental gill net constructed of four 30.5 meter by 1.8 meter net panels with stretch mesh sizes of 6.4 centimeter (2.5 inches), 7.6 centimeter (3.0 inches), 8.9 centimeter (3.5 inches) and 10.2 centimeter (4.0 inches) was anchored within the randomly selected grid. The order of the mesh sizes was randomly selected prior to net construction, and each panel iwas separated by an approximately 1.2 meter gap. Nets were rigged to sink using 5/8 inch float core line and 65 pound lead core line, and mesh constructed of number eight monofilament netting, except for the 6.4 centimeter mesh which was constructed of number four monofilament. New nets were ordered prior to the 2020 fishing season, and 65 pound lead core line was not available, therefore 75 pound lead core line was substituted. Four sampling blocks were sampled each day beginning approximately 30 minutes prior to sunrise. A GPS unit was used to navigate to the center of the grid. Each net site was designated as either shallow or deep using an alternating pattern set randomly at the beginning of the sampling season. Sampling blocks with appreciable depth change were set toward the shallow or deep side of the block perpendicular to the channel according to the shallow or deep designation. Any site with no appreciable depth change was set in the center of the sampling block perpendicular to the channel. Sets were not made in less than 1.5 meters or more than 12.2 meters to avoid net inefficiency at shallow sites or potential areas of hypoxia at deeper sites. Nets soaked for one hour prior to retrieval.

Immediately following deployment of each set, salinity (parts per thousand), secchi disk reading (meters), tidal stage, time, weather, wind direction and wind speed (knots) were recorded. All fish were enumerated by species and mesh size in which they were captured. All Atlantic croaker, bluefish, spot, striped bass, summer founder, weakfish and white perch were measured to the nearest millimeter TL. The first five Atlantic menhaden from each site and net panel were measured to the nearest millimeter FL, with scales being taken from the first five fish for each mesh panel each day (not each site).

Juvenile indices were calculated for Atlantic croaker, spot and weakfish from Department Blue Crab Trawl Survey data. This survey utilizes a 4.9 meter semi-balloon otter trawl with a body and cod end of 25-millimeter-stretch-mesh and a 13-millimeter-stretch-mesh cod end liner towed for six minutes at 4.0-4.8 kilometers/hour. The systems sampled included the Chester River, the Choptank River, Eastern Bay, the Patuxent River (six fixed sampling stations each), Tangier Sound (five fixed stations) and Pocomoke Sound (eight fixed stations). Each station was sampled once a month from May through October. Juvenile Atlantic croaker, spot and weakfish collected by this survey have been enumerated, and entered into a computer database since 1989 (Davis et al.1995).

Analytical Procedures

Commercial and recreational harvests for the target species were examined utilizing Maryland's mandatory commercial reporting system and the Marine Recreational Information Program (MRIP; National Marine Fisheries Service, personal communication), respectively. MRIP data was downloaded in January 2020. Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2018. Only commercial harvest from Maryland's portion of Chesapeake Bay is included in this report. MRIP estimates of recreational harvest are for Maryland inland waters only. This includes both Maryland's portion of Chesapeake Bay and coastal bays, but not the Atlantic Ocean. Chesapeake Bay waters are not separable in the MRIP online data query.

Beginning in 1993, Maryland has required charter boat captains to submit log books indicating the number of trips, number of anglers and number of fish harvested and released by species. Trips in which a species was targeted but not caught could not be distinguished from the log books since no indication of target species is given. Therefore, no CPUE was derived. All Maryland charter boat data in this report were from Chesapeake Bay. Since the 2019 charter log book data had not been finalized, only data through 2018 were analyzed.

Instantaneous total mortality rates (Z) for weakfish and Atlantic croaker were calculated using the Ssentongo and Larkin (1973) length based method,

$$Z = \{K/(y_{bar} - y_c)\}$$

where lengths are converted: $y = -\log_e (1-L/L_\infty)$, and $y_c = -\log_e (1-L_c/L_\infty)$, L = total length, L_c = length of first recruitment to the fisheries, K = growth coefficient and L_∞ = length that an average fish would achieve if it continued to grow. Von Bertalanffy parameters (K and L_∞) for weakfish for all years were estimated from otolith ages collected during the 1999 Chesapeake Bay pound net survey (Jarzynski *et al* 2000). The 1999 survey growth data had to be utilized because of severe age truncation in the weakfish population in subsequent years. Parameters for weakfish were L_∞ = 840 millimeter TL and K= 0.38. L_c was 305 millimeter TL. Von Bertalanffy parameters for Atlantic croaker mortality estimates were derived from pooled ages (otoliths; n = 3,473) determined from 2003-2019 Chesapeake Bay pound net survey data, and June through September 2003-2019 measurements of age zero Atlantic croaker (n=463) from the MD DNR Blue Crab Trawl Survey's Tangier Sound samples (Chris Walstrum MD DNR personnel communication 2019). Trawl data were included to provide age zero fish that had not recruited to the pound net gear, and represented samples taken from the same time period and region as the pound net samples. Parameters for Atlantic croaker estimates from 2003-2019 were L_∞ =

380 millimeters TL and K= 0.38, while L_c for Atlantic croaker was 229 millimeters TL. L_∞ has continued to decrease as additional years of data have been added, leading to more lengths in earlier years being above L_∞. Growth parameters used in the 2016 ASMFC stock assessment (ASMFC 2017a), using coast-wide data and combined sexes, were L_∞ = 459 millimeters TL and K= 0.16. Total mortality estimates were generated using both sets of growth parameters for comparison purposes.

Annual length frequency distributions were constructed when sample size was sufficient for Atlantic croaker, Atlantic menhaden, bluefish, spot, summer flounder, and weakfish utilizing 20 millimeter length groups for both the onboard pound net and Choptank River gill net surveys. Length-at-age keys were constructed for Atlantic croaker, Atlantic menhaden and weakfish using age samples through 2019. Age and length data were assigned to 20 millimeter groups for each species and then the length-at-age key was applied to the length frequency by year to determine the proportion at age for Atlantic croaker in 2000 and 2002 through 2019, weakfish from 2003 through 2019 and Atlantic menhaden from 2005 through 2019. Age and length data for spot were assigned to 10 millimeter TL groups and the length-at-age key was applied to the length frequency to determine the proportion at age by year for 2007 through 2019. It was necessary to supplement Maryland spot ages with Virginia Marine Recourses Commission (VMRC) spot age data for a small number of fish greater than 270 millimeters in the 2007, 2011 and 2012 samples.

Geometric mean catch per set of gill nets per hour was calculated for Atlantic croaker, Atlantic menhaden and spot from the Choptank River gill net survey. A set was all four mesh panels combined by site. Since zero hauls are common, all catch data was catch+1 to avoid taking the natural logarithm of zero.

Chesapeake Bay juvenile indices were calculated as the geometric mean (GM) catch per tow. All catch data were catch+1 to avoid taking the logarithm of zero tows. Since juvenile weakfish have been consistently caught only in Tangier and Pocomoke sounds, only these areas were utilized in this analysis to minimize zeros that may represent unsuitable habitat rather than relative abundance. Similarly the Atlantic croaker index was limited to Tangier Sound, Pocomoke Sound and the Patuxent River. All sites and areas were used for the spot index. Indices and 95% confidence intervals were derived using SAS® software (SAS 2010). Maps displaying sampling sites were created using ArcGIS version ArcMap 10.3 software for both the Choptank River gill net and onboard pound net surveys.

RESULTS and DISCUSSION

The onboard pound net survey sampled the Potomac River and Chesapeake Bay from June 4, 2019 through September 20, 2019 (Table 2). All of the target species and seventeen non-target species were encountered in 2019 (Table 3). Two seafood dealer sampling trips were made at two different dealers in June, four of the target species were encountered. Seafood dealer sampling did not continue beyond June, as an additional commercial fishermen was added to the pound net survey. The Choptank River fishery independent gill net survey was conducted once per week from June 7, 2019 to August 28, 2019. Seven of the target species and eleven non-target species were captured in 2019 (Table 4).

Weakfish

Sixty-three weakfish were sampled in the 2019 pound net survey, an increase from 2018, but still well below the 27 year average of 292 fish per year. Weakfish mean length in 2019 was 252 millimeters TL, the second lowest value of the time series (Table 5). The 2019 weakfish length frequency distribution was skewed toward smaller fish, with 67% of the catch being under 270 millimeters TL (Figure 4). Males and females each accounted for 29% and 71%, respectively, of the 63 weakfish in which sex was determined. Mean length and weight were slightly greater in females than males, with females averaging 253 millimeters TL and 162 grams and males averaging 248 millimeters TL and 153 grams. No weakfish were encountered during seafood dealer sampling.

Chesapeake Bay weakfish length-frequencies were truncated during 1993 – 1998, while those for 1999 and 2000 contained considerably more weakfish greater than 380 millimeters TL. However, this trend reversed from 2001 to 2019, with far fewer large weakfish being encountered. Only one of the 63 weakfish sampled in the 2019 pound net survey was above the commercial size limit of 305 millimeters TL (12 inches) and the recreational size limit of 331 millimeters TL (13 inches).

Four weakfish were captured and measured in the Choptank River gill net survey in 2019, with lengths ranging from 270 to 327 millimeters TL. Weakfish catch was very low throughout the survey ranging from zero to four fish per year (Table 4). Ten of the eleven weakfish captured by the survey were in the 6.4 centimeter mesh, and one was captured in the 7.6 centimeter mesh. Traditionally, weakfish have been a common catch by anglers in late summer and early fall in the lower Choptank River. The slightly later arrival of weakfish to the sampling area and the current depleted condition of the coast wide stock are likely causes of weakfish being rarely encountered by the survey.

The 2018 Maryland Chesapeake Bay commercial weakfish harvest of two pounds was the lowest on record (Figure 5). The 1981 – 2018 Maryland Chesapeake Bay average commercial harvest was 41,383 pounds per year. Harvest was higher in the 1980s averaging 121,732 pounds per year, declined in the 1990s averaging 32,779 pounds per year, and was much lower the past ten years averaging 302 pounds per year. Estimated Maryland recreational harvested from inland waters during 2018 was zero fish (Figure 5). The time series mean harvest for Maryland inland waters from 1981-2018 was 283,862 fish. According to the MRIP estimates, Maryland anglers released 3,183 (PSE = 83.9) weakfish from inland waters in 2018, the lowest value of the 1981-2018 time series, and well below the time series mean estimate of 291,224 fish per year. Estimated recreational harvest decreased steadily from 741,758 fish in 2000 to 763 in 2006, and fluctuated at a very low level from 2007 through 2018. Both the recreational harvest estimates and the reported commercial landings since 2010 may have been affected by a regulation change that took place in April 2010. The new regulation reduced the bag limit from three fish to one fish per recreational angler per day, and the commercial harvest was limited to a bycatch only fishery, with daily catch limits of 50 pounds in the Chesapeake Bay and 100 pounds in the Atlantic Ocean. Very few commercial trips landed weakfish at these limits since the inception, making it likely that low abundance, and not current regulations, was primarily responsible for the low total harvest. The reported harvest from Maryland charter boat captains ranged from 51 to 75,011 weakfish from 1993 to 2018 (Figure 6), with a sharp decline occurring in 2003, and the lowest value occurring in 2018. Reported charter boat harvest slowly increased from 2014 to 2017, reaching 2,152 fish prior to the sharp decline in 2018.

The weakfish juvenile GM was stable from 2013 to 2015, with values just below the time series mean, but declined in 2016 and remained low through 2018 (Figure 7). The 2019 index value increased to 2.11 fish per tow, similar to the 2013 to 2015 values. Weakfish juvenile abundance generally increased from 1989 to 1996, and remained at a relatively high level through 2001, but generally decreased from 2003 to 2008 with moderate to low values since. The relatively low abundance of juvenile weakfish since 2003 is similar to that of the early 1990's, but harvest continues to be exceptionally low, unlike the higher harvest in the early 1990's.

Weakfish otoliths were collected from 63 fish in 2019. Eighty-nine percent of sampled weakfish were age one, 11% were age two, and no age three plus fish were sampled (Table 6). Age samples from 2003 – 2005 were comprised of 45% or more age two plus weakfish, and then dramatically shifted to primarily age one fish from 2006-2011, with zero to 30% age two plus fish and no age three fish from 2008 to 2011. Age structure expanded to include three year old weakfish in 2012 and 2013, with 46% and 65% of sampled fish being age two plus, respectively, indicating a slight shift back toward older weakfish. The 2014 age sample size was too small to make valid comparisons (six fish). No age three plus fish were sampled in 2015 – 2017 or 2019, and only one in 2018, but low sample size since 2005 could have led to missed age classes.

Mortality estimates for 2006 through 2012 and 2014 through 2019 could not be calculated because of extremely low sample size, while instantaneous total mortality estimates calculated for 2004, 2005 and 2013 were Z=1.29, Z = 1.44 and Z = 1.55, respectively (Table 8), indicating total mortality has remained high. Maryland's length-based estimates in the mid-2000s were similar to the coastal assessment of Z = 1.4 for cohorts since 1995 (Kahn et al. 2005), and the estimates from the 2016 ASMFC stock assessment, which estimated Z values of 1.98, 1.90, and 1.45 in 2004, 2005 and 2013, respectively (ASMFC 2016).

The most recent weakfish benchmark Stock Assessment Workshop, completed by ASMFC in 2016, utilized a Bayesian model with time-varying M and spatial heterogeneity (ASMFC 2016), and was updated in 2019 with data through 2017, including the recalibrated MRIP time series (ASMFC 2019). The assessment update indicated weakfish biomass was very low; F was moderate in 2017 and M was high but stable to slightly decreasing from 2014 to 2017. The stock was classified as depleted and total mortality was just above the threshold in 2017, indicating it is too high to allow for recovery. The stock assessment confirmed that the low commercial and recreational weakfish harvest in Maryland and low abundance in the sampling surveys, was directly related to a very low coast wide stock abundance.

Summer Flounder

Summer flounder pound net survey mean lengths varied widely from 2004-2019. Mean total lengths have ranged from the time series high of 374 millimeters TL in 2005 and 2010 to the time series low of 191 millimeters TL in 2017 (n = 394, Table 5). The mean length increased to 272 mm TL in 2019 (n = 125, Table 5), but was still the fifth lowest value of the 27 year survey time series. The length frequency distributions from the onboard sampling from 2004-2012 were either bimodal with peaks at the 130 to 150 millimeter TL intervals and between 310 to 430 millimeter TL intervals, or more normal in distribution with a singular peak between the 310 to 430 millimeter TL length groups. Generally, the bimodal distribution occurs when an abundant year class recruits to the fishing gear (at around 130 millimeters TL). The 2013 and 2014 length frequency distributions were heavily skewed toward smaller fish, with 66% and 58% below 290 millimeter TL in length, respectively. The 2015 distribution shifted to larger fish, but reverted back to smaller fish in 2016. The 2017 - 2019 length distributions were bimodal, with both peaks shifting to slightly larger fish each year (Figure 8). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches to the 2019 recreational size limit of 420 millimeter TL indicated one percent of the 168 sampled flounder were of legal size in 2019, compared to 3% in 2018, 2% in 2017, none in 2016, 9% in 2015, 4% in 2014 and 10% in 2013. No summer flounder were encountered during seafood dealer sampling or the Choptank River gill net survey in 2019.

The 2018 Maryland Chesapeake Bay commercial summer flounder harvest totaled 2,617 pounds, similar to 2017 (2,859 pounds), and the third lowest value of the 1981 – 2018 time series (Figure 9). Maryland Chesapeake Bay landings decreased from 2005 - 2016, before increasing slightly in 2016, well below the annual mean harvest of 25,405 pounds. In recent years the commercial flounder fishery has been managed by quota, with varying regulations and season closures to ensure the quota was not exceeded. The recreational inland harvest estimate of 18,071 fish (PSE = 31.7) caught in 2018 was a decrease from the 2017 estimate, and was the third lowest value of the time series (Figure 9). The 2018 MRIP recreational inland waters release estimate of 558,590 fish (PSE = 42.7) decreased compared to 2017 (771,763 fish, PSE = 29.6). The recreational inland fishery has primarily been from the Maryland coastal bays in recent years. Regulations have been more restrictive in the past 10 years than earlier in the time series.

Reported Chesapeake Bay summer flounder charter boat harvest has generally declined throughout the 1990 – 2018 time series, with the highest number landed in 1993 (10,445 fish) and the lowest in 2018 (7 fish) (Figure 10). Magnitude of harvest generally decreased in discrete time blocks, with 1993-2000 averaging 5,072 fish per year, 2001-2009 averaging 944 fish per year and 2010-2018 averaging 209 fish per year, with annual catch varying within these time blocks.

A coast wide stock assessment using the Age Structured Assessment Program (ASAP) was conducted in 2019, with a terminal year of 2017 (NEFSC 2019). The NMFS assessment concluded that summer flounder stocks were not overfished, and overfishing was not occurring. However, spawning stock biomass has been declining, fishing mortality has been just below the threshold, and recruitment has generally been below average in recent years. The stock assessment review panel warned fishing reductions may be necessary if these condition persist, particularly if recruitment remains low.

Bluefish

Bluefish sampled from the onboard pound net survey averaged 345 millimeters TL during 2019, the highest value of the 27 year time series (Table 5). The pound net survey length frequency distributions have been bimodal most years (Figure 11). The 2005-2007 and 2012-2015 pound net sampling indicated a larger grade of bluefish were available in those years, although small bluefish still dominated the population, with primary peaks in the 230-270 millimeter TL groups. This trend reversed in 2008–2011 and 2016-2018 when larger bluefish became scarce. The 2019 length distribution was the first with the primary peak of the bimodal distribution occurring for larger fish (350 millimeter TL group), indicating a slightly better grade of bluefish were availed in 2019 than in most recent years. Variable migration patterns into Chesapeake Bay may be responsible for these differences. Crecco (1996) reviewed bluefish angler catches and suggested that the bulk of the stock was displaced offshore. Lack of forage and inter-specific competition with striped bass were possible reasons for this displacement.

Only four bluefish were sampled from seafood dealer sampling in 2019 with lengths and weights ranging from 377 to 487 millimeters TL and 495 to 1,080 grams. Three of the four fish were larger than the mean length of 405 millimeters TL from the 2017 seafood dealer sampling (n = 172; Figure 12).

Bluefish have been captured in low numbers during all seven years of the Choptank River gill net survey, with three being captured in 2019 (Table 4). Bluefish lengths for all panels and years combined ranged from 218 to 500 millimeters TL (n=58), with the one measurement from 2019 being 330 millimeters. Sample size was too small to make meaningful comparisons to length by net mesh size. Bluefish were most often captured in the 6.4 centimeter mesh for all years combined, with the 7.6 centimeter mesh panel accounting for the second highest catch (Figure 13).

Maryland’s Chesapeake Bay commercial bluefish harvest in 2018 was 7,286 pounds, the second lowest value in the 1981-2018 time series, and below the average of 106,594 pounds per year (Figure 14). Chesapeake Bay commercial landings were higher in the 1980s averaging 321,402 pounds per year, but have been variable since and only averaging 41,607 pounds from 1990 to 2018. Recreational inland harvest estimates for bluefish were high through most of the 1980’s, but have fluctuated at a lower level since 1991 (Figure 14). The 2018 harvest estimate of 178,955 fish (PSE = 39.1) increased slightly compared to 2017, but was still the third lowest estimate of the 1981-2018 time series. Estimated inland recreational releases were 253,869 fish (PSE = 26.3) in 2018, well below the time series mean of 775,417 fish (Figure 14). Reported bluefish harvest from Chesapeake Bay charter boat logs ranged from 7,316 – 133,499 fish per year from 1993 to 2018, with the 2018 harvest being the lowest of the 26 year time series (Figure 15).

A stock assessment of Atlantic coast bluefish utilized a forward projecting catch at age model including data through 2014 (NEFSC 2015). An operational assessment was conducted by the North East Fisheries Science Center in 2019, using the same model structure, with data through 2018 and the recalibrated MRIP estimates of recreational harvest. The assessment indicated over fishing was not occurring in the terminal year, but overfishing occurred during most previous years, and the stock was overfished (ASMFC personal communication, report was not available at the time of writing). These findings required enacting coast wide regulation changes in 2020 to reduce harvest and rebuild the stock.

Atlantic Croaker

Atlantic croaker mean length from the onboard pound net survey decreased in 2019 to 212 millimeters TL, and was the lowest value of the 27 year time series (Table 5). Only 202 Atlantic croaker were encountered in the survey in 2019, the lowest number sampled and well below the 1,503 annual average. The onboard pound net length frequency distribution for 2019 was heavily skewed toward smaller fish, with 74% of all sampled fish being below 230 millimeter TL, and only seven percent of the sample over 250 millimeters TL (Figure 16).

Mean lengths and weights by sex for Atlantic croaker sampled from the onboard pound net survey in 2019 were 224 millimeters TL and 152 grams for females (n = 87) and 218 millimeters TL and 140 grams for males (n = 48). Pound net samples were 64% female and 36% male. Samples in which sex determination and weight were taken were not randomly selected; therefore, sex specific data may be biased. No Atlantic croaker were sampled from seafood dealers in 2019.

Atlantic croaker geometric mean catch per hour from the Choptank River gill net survey declined through the first three years of the survey, and remained low in recent years (Figure 17), with a maximum total catch of 476 fish in 2013, and a minimum value of eight fish in 2018. The 6.4 centimeter mesh net caught the highest proportion of Atlantic croaker in all years except 2015, with proportion of catch declining as mesh size increased (Figure 18). In 2015 the 7.6 centimeter mesh accounted for the highest proportion of catch, but sample size was very low. Length frequency shifted to longer fish as mesh sized increased (Figure 19), indicating the size selective nature of gill nets. This emphasizes the need to utilize multi-panel gill nets. Year to year length frequency comparisons were not made do to the low sample sizes in 2015 through 2019. Anecdotal reports from commercial and recreational fishermen indicated Atlantic croaker catches were unusually low from the Choptank River and northward since 2015, but catches were somewhat higher in Tangier Sound and the Potomac River. The decreased catches, coupled with declining landings, suggest decreased availability in the mid to upper bay in recent years.

The 2018 Maryland Atlantic croaker Chesapeake Bay commercial harvest of 43,102 pounds was similar to the 2017 value of 40,599 pounds, well below the 1981 to 2018 mean of 372,151 pounds per year, but was a slight increase following four consecutive years of 45% or greater declines in annual harvest (Figure 20). The 2018 recreational inland harvest estimate was 305,469 fish (PSE = 28.6) a 28% decrease from 2017, and well below the 1981-2018 average of 1,211,263 fish. The 2018 recreational release estimate of 203,013 (PSE = 21.9) fish was over 13 times lower than the 2017 value (Figure 20), and well below the 1981-2018 average of 2,322,316 fish per year. Reported Atlantic croaker harvest from charter boats ranged from 607 – 418,313 fish per year during the 26 year time period (Figure 21), with the low value occurring in 2018, and nine consecutive years of declining charter boat harvest.

Since 1989, the Atlantic croaker juvenile index varied without trend with the highest values occurring in the late 1990s. This index increased to the fourth highest value of the 31 year time series in 2008, but fell sharply in 2009 and remained low through 2011, before spiking again in 2012 (Figure 22). The GM steadily decreased the following three years to the 2nd lowest value of the time series in 2015 (0.21 fish per tow). The index value has varied since, with the 2019 value (4.9 fish per tow) increasing to the third highest value of the time series. Atlantic croaker recruitment has been linked to environmental factors including winter temperature in nursery areas (Lankford and Targett 2001, Hare and Able 2007); prevailing winds, currents and hurricanes during spawning; and larval ingress (Montane and Austin 2005, Norcross and Austin 1986). Because of these strong environmental influences, high spawning stock biomass may not result in good recruitment, and a high degree of variability can be expected.

Ages derived from Atlantic croaker otoliths from the onboard pound net survey in 2019 ranged from zero to seven (n=83; Table 9). The number of Atlantic croaker sampled for length in 2019 (n=203) was applied to an age-length key for 2019 (Table 9). This application indicated age zero accounted for 80% of sampled fish and ages one through three accounted for 17% of sampled fish (Table 9). Age structure in 2019 was heavily skewed to younger fish, with very few older individuals encountered. Sample size for both aged and measured fish was much lower than in previous years and may not have accurately represented the true age distribution. Atlantic croaker typically recruit to the fishery at age two, with full recruitment occurring at age three or four. Age zero fish are retained near the end of the season, but are not of marketable size. The contribution of strong year classes (1998, 2002, 2006, 2008 and 2012) to the catch can be seen in Table 9. The high percentage of age zero fish in age samples corroborates the indication of a stronger 2019 year class suggested by the juvenile index.

Instantaneous total mortality estimates in 2019 using Maryland growth parameters and ASMFC stock assessment growth parameters were $Z = 1.82$ and $Z = 1.25$, respectively (Table 8). Both sets of estimates indicate the same trend, with Maryland only growth parameters indicating a larger range of values (Figure 23). Total mortality estimates were relatively stable at a low level from 1999 through 2009. Estimates of Z increased rapidly during 2010 -- 2014 and were more variable. Total mortality generally increased through 2017, declined slightly in 2018, and increased to the time series high in 2019. Recruitment has generally been poor in recent years, leading to increased mortality rates on recent year classes, and fewer fish reaching older ages and larger lengths.

In 2017, the ASMFC Atlantic Croaker Technical Committee completed a stock assessment using a statistical catch at age model using data through 2014 (ASMFC 2017a). The assessment was not endorsed for management use by an independent review panel primarily due to conflicting signals in trends from independent indices and fishery removals. The panel did agree, based on the information provided, that immediate management actions were not necessary. The panel also recommended the Traffic Light Analysis (TLA) continue to be used to trigger management action as needed. The ASMFC South Atlantic Board tasked the Atlantic Croaker Technical Committee to explore revisions to the TLA following the assessment. That work was completed in 2018, and the ASMFC voted to incorporate those changes at its February 2019 meeting. The new TLA will initially be updated with data through 2019 and evaluated in October of 2020.

Spot

The 2019 spot mean length from the onboard sampling of 198 millimeters TL increased compared to the 2018 value of 180 millimeters TL, and was the median value of the 27 year time series (Table 5). Eighty-five percent of spot encountered in the onboard pound net survey in 2019 were between 170 and 219 millimeters TL, indicating a truncated length frequency distribution (Figure 24). No jumbo spot (>254 millimeter TL) were present in the 2019 onboard sampling (total measured = 1,395). Abundance of jumbo spot in the survey has been low for the past several years (0-3% of sample, 2005-2019). This followed good catches in the early part of the decade (10% in 2003, 13% in 2004).

The length frequency distribution and mean length from seafood dealer sampling indicated larger spot were being harvested by the pound net fishery than observed during onboard sampling in previous years (Figure 25, Table 7). This would be expected as smaller spot are not generally marketable as food fish. In 2019 these metrics were similar from both surveys, another signal of a lack of larger spot, which led to harvest shifting to smaller individuals.

Spot catch per hour in the Choptank River gill net survey was highest in 2014, moderate in 2013, 2017 and 2019, and lowest in 2015, 2016 and 2018 (Figure 26). Total annual catch ranged from a low of 109 fish in 2016 to a high of 749 in 2014. The 6.4 centimeter mesh captured the majority of spot each year (Figure 27), accounting for over 92% of catch in 2013, 2014, 2016, 2018 and 2019, and accounted for 73% and 82% of the catch in 2015 and 2017 respectively. The 7.6 centimeter mesh accounted for the second highest proportion of spot captured in all years. Only one to four spot were captured in the 8.9 centimeter mesh in 2013, 2015, and 2017, and no spot were captured in the 10.2 centimeter mesh through the seven year time series. Annual length frequency distributions have been variable throughout the survey, with similar distributions in 2013 and 2014 centered on the 200 and 210 millimeter length groups. Bimodal distributions were apparent in 2015 and 2017, and singular peak distributions were centered on the 190 millimeters TL group in 2016, 2018 and 2019 (Figure 28). These shifts are likely driven by year class strength, which has been generally poor in recent years. Large shifts in length distribution are not uncommon in short lived species with variable recruitment, such as spot.

Commercial harvest from Maryland's portion of Chesapeake Bay remained stable in 2013 and 2014 at 257,881 and 254,443 pounds, respectively (Figure 29), but declined to 62,251 pounds in 2015, and to 17,760 pounds in 2016, the fourth lowest value of the 38 year time series. Harvest increased in 2017 to 97,075 pounds, but declined again in 2018 to 41,453 pounds, below the long term mean of 127,982 pounds per year. Maryland recreational inland harvest estimates from the MRIP indicated that spot catches since 1981 have been highly variable (Figure 29). Recreational harvest ranged from 927,140 fish in 1996 to 6,295,175 fish in 1987, while the number released fluctuated from 374,925 in 1996 to 4,320,616 in 1991. The 2018 recreational inland waters harvest estimate of 1,172,994 fish (PSE = 26.6) was below the time series mean of 2,637,237 fish. The release estimate of 928,677 fish (PSE = 46.2) was also below the time series mean of 2,047,524 fish (Figure 29). Reported spot charter boat logbook harvest from 1993 to 2018 ranged from 74,763 to 847,311 fish per year (Figure 30). The 2018 reported harvest was the lowest on record, and well below the time series mean of 443,183 fish.

Spot juvenile trawl index values from 1989-2019 were quite variable (Figure 31). The 2010 GM value of 104.5 spot per tow was the highest value of the time series, the 2011 value declined to the second lowest of the 31 year time series, and the 2012 value increased to nearly the time series mean. The index values declined from 2012 to the time series low in 2015 (0.29 fish per tow). The index values were somewhat higher for 2016 through 2018, and increased to 11.8 in 2019 slightly below the time series mean.

In 2019, 52% of spot sampled from the onboard pound net survey were age one, 48% were age zero, and no age two plus fish were encountered (192 ages and 1,395 lengths; Table 10). Age two plus spot were also absent in 2016 and 2018, and were rare in 2017. Age one spot dominated the pound net catch from 2007 to 2011, accounting for 75% to 99% of sampled fish. During this same time period, age zero and age two fish were present every year, with age zero accounting for 0.4% to 24.3% of sampled spot and age two accounting for 0.2% to 3.3%.

In a relatively short-lived species such as spot, age and length structure will be greatly influenced by recruitment events. The shift in length frequency, general decrease in mean size and reduction in percent jumbo spot observed from 2005 through 2019 could be indicative of growth overfishing. Reduced recreational harvest and reduced proportion of age one spot in 2016 are likely due to the very poor 2015 year class, and the continued low abundance of age two fish, and lack of age three plus fish, is likely due to below average year classes since 2012. Based on the juvenile index, 2018 year class was similar to the 2017 year class and higher than the 2014 through 2016 year classes, but was still below average, the 2019 year class was a marked increase and may lead to greater availability of age one spot in 2020.

In 2017, the ASMFC Spot Stock Assessment Committee completed a stock assessment using a catch survey analysis model, utilizing data through 2014 (ASMFC 2017b). The assessment was not endorsed for use by an independent review panel primarily due to conflicting signals in trends from independent indices and fishery removals. The panel did agree, based on the information provided, that immediate management actions were not necessary. The panel also recommended the Traffic Light Analysis (TLA) continue to be used to trigger management action as needed. The ASMFC South Atlantic Board tasked the Spot Plan Review Team to explore revisions to the TLA following the assessment. That work was completed in 2018, and the ASMFC voted to incorporate those changes at its February 2019 meeting. The new TLA will initially be updated with data through 2019 and evaluated in October of 2020.

Red Drum

Red drum have been encountered sporadically through the 27 years of the onboard pound net survey, with none being measured in nine years and 458 being measured in 2012 (Table 5). Six red drum were measured in 2019 averaging 528 millimeters TL and ranging from 395 to 1,025 millimeters TL. Recreational anglers in Maryland are allowed one red drum between 18 and 27 inches TL, one of the encountered red drum fell within the slot limit. No red drum were encountered during fish dealer sampling in 2019.

Maryland Chesapeake Bay commercial fishermen reported harvesting no red drum in 2018, compared to the 2013 spike of 2,923 pounds, and the 1981 to 2017 mean of 497 pounds per year (Figure 32). The high 2013 landings value was likely due to a large year class growing into the 18 – 25 inch slot limit. The current slot limit and a five fish daily harvest limit were put into place in 2003. Prior to 2003 a fish limit was in place with an 18 inch minim size limit and only one fish over 27 inches.

MRIP estimated zero recreational harvest in 2018 for Maryland inland waters, and estimated releases were 4,127 (PSE = 101.4) red drum (Figure 32). Recreational harvest estimates have been extremely variable with zero harvest estimates for 28 of the 38 years, and very high PSE values. Recreational release estimates in 2012 indicated juvenile red drum were plentiful throughout much of Maryland's portion of Chesapeake Bay and its tributaries, and that most of these fish were sub-legal, but catches returned to lower levels beginning in 2013.

Maryland charter boat captains reported harvesting red drum from the Chesapeake Bay in every year from 1993-2017, except for 1996. Harvest was low for all years, ranging from zero to a high of 269 fish in 2012, with ten red drum being harvested in 2018 (Figure 33). The low reported annual harvest indicated red drum were available in Maryland's portion of Chesapeake Bay, but confirms the species limited availability to recreational anglers, as also indicated by the annual MRIP estimates. Maryland is near the northern limit of the red drum range, and catches of legal size fish should increase if the stock expands in response to the current Atlantic coast stock recovery plan (ASMFC 2002).

Black Drum

Black drum are only occasionally encountered during the onboard pound net sampling, with four being sampled in 2019 (Table 5). Lengths throughout the time series have ranged from 220 to 1,330 millimeters TL. Commercial harvest of black drum was banned for Maryland's portion of Chesapeake Bay in 1999, but 117 pounds were reported in 2017 (Figure 34), none were reported in 2018. Recreational inland water harvest and release estimates from 1981 to 2018 have been variable, with harvest ranging from zero (20 years) to 11,374 fish in 1983 (Figure 34). In 2018, MRIP estimated 1,262 black drum were harvested (PSE = 81.7) and 19,557 were released (PSE = 55.3). The harvest estimates are tenuous since the MRIP survey is unlikely to accurately represent a small short lived seasonal fishery, such as the black drum fishery in Maryland, as evidenced by the high PSE values of the estimates. Charter boat logs indicated black drum were harvested in Maryland's portion of Chesapeake Bay in all years of the 1993-2018 time series, with a mean catch of 331 fish per year (range = 2 – 894; Figure 35). The lowest value of the time series was reported in 2018.

Spanish Mackerel

Spanish mackerel have been measured for FL, TL or both each year of the onboard pound net sampling. Since 2001, however, the majority of samples have been FL only to be consistent with data collected by other state and federal agencies. During this time period FL from the onboard sampling has ranged from 123 – 682 millimeters. The survey encountered 1,337 Spanish mackerel in 2019 with a mean length of 374 millimeters FL. The 2019 sample size was unusually large, with the number of mackerel measured having been low for most years (Table 5). The largest samples prior to 2019 occurred from 2005-

2007 and in 2013. Ten Spanish mackerel were sampled during fish house sampling in 2019, with a mean length of 433 millimeters FL. Seven Spanish mackerel were encountered in the Choptank River gill net survey in 2019, only the third year any were encountered. Two were captured in the 6.4 centimeter mesh, three in the 7.6 centimeter mesh and two in the 8.9 centimeter mesh.

The 2018 commercial harvest of Spanish mackerel in Maryland's portion of Chesapeake Bay was 2,920 pounds (Figure 36), and was below the 1981 to 2018 mean of 4,664 pounds per year. Reported commercial harvests of zero pounds were common in the early 1980s, but landings have become more stable since 1988 with a peak of 23,266 pounds in 2000.

Recreational inland waters harvest estimates were variable from 1981 – 2018, with 11 years of zero harvest and a peak of 44,430 fish in 2009 (Figure 36). The 2018 estimated recreational Spanish mackerel harvest of 18,682 fish (PSE = 42.5) was above the time series mean of 9,925 fish. Most years have high PSE values, so these estimates are considered tenuous. Spanish mackerel charter boat harvest from 1993 to 2018 ranged from 53 – 10,638 fish per year, with a harvest of 1,328 fish in 2018 (Figure 37). It would appear that Spanish mackerel are providing a small but somewhat consistent opportunity for recreational anglers in Maryland's portion of Chesapeake Bay.

Spotted Seatrout

Spotted seatrout are rarely encountered during sampling, with annual observations ranging from zero (12 years) to 23 fish during the onboard pound net survey. Thirteen spotted seatrout were encountered during the onboard pound net survey with a mean TL of 391 millimeters (Table 5). Six spotted seatrout were captured in the gill net survey in

2019, the first year any were captured in the survey. Individuals were captured in all mesh size except the 10.2 centimeter mesh, and had a mean length of 351 millimeters TL. No spotted seatrout were encountered during fish house sampling in 2019. Commercial harvest of spotted seatrout in Maryland's portion of Chesapeake Bay averaged 2,562 pounds from 1981-2018, however, 11 of 12 years had zero harvest from 1981-1992 (Figure 38). Reported 2018 commercial harvest was one pound. Recreational harvest estimates for inland waters indicated a modest but variable fishery during the mid-1980s through the mid-1990s. Estimated harvest averaged 45,272 fish per year from 1986 to 1999, but was lower from 2000 to 2018, including seven years of zero harvest, and averaged 8,407 fish per year. MRIP estimated no spotted seatrout were captured in Maryland inland waters in 2018. The high PSE values indicate the MRIP survey does not provide reliable estimates for this species in Maryland.

Reported spotted seatrout harvest from 2018 charter boat logs was two fish. Reported harvest ranged from 2 – 20,003 fish per year and averaged 2,762 fish per year for the 24 year time series (Figure 39). No harvest was reported in 1993 and 1994, but it is not clear if spotted seatrout were not reported at that time or none were captured. Therefore, these years were not included in the time series. The recreational spotted seatrout fishery in Chesapeake Bay is prosecuted by a small group of anglers that are likely under-represented in the MRIP estimation design. This is supported by the 2007 and 2008 reported charter harvest values that approximated the time series mean coinciding with zero value estimates by MRIP.

Atlantic Menhaden

Mean length for Atlantic menhaden sampled onboard commercial pound nets in 2019 was 215 millimeters FL (n = 868), the second lowest value of the 16 year time series (Table 5). Atlantic menhaden length frequencies from onboard sampling have varied annually (Figure 40). The 2016 onboard pound net sampling distribution was more evenly distributed than previous years, but the 2017 and 2018 distributions were dominated by the 190, 210 and 230 millimeter size groups. The 2019 distribution was bimodal and heavily skewed toward smaller fish with 61% of sampled menhaden in the 170 or 190 millimeter length groups.

Fifty-one Atlantic menhaden were sampled from seafood dealers in 2019, with a mean length of 237 millimeters and a mean weight of 224 grams (Table 7). The length frequency distribution was more evenly divide among length groups than the onboard sampling specimens, but the 170 millimeter length group still accounted for the highest proportion of fish (Figure 41). Sample size was much smaller form the fish house survey, and is likely not representative of the overall menhaden harvest.

Atlantic menhaden was the most common species captured by the Choptank River gill net survey, with annual catches ranging from 1,171 fish (2016) to 2,257 fish (2018; Table 4). The 2019 catch was 2,045 fish the third highest of the seven year survey. The geometric mean catch per hour of Atlantic menhaden from the gill net survey was steady from 2013 to 2015, slightly lower in 2016 and 2017, increased to the time series high in 2018, and decreased in 2109, but was still the second highest value of the time series (Figure 42). The 7.6 centimeter mesh and the 6.4 centimeter mesh accounted for over 70% of the catch, annually (Figure 43). The 7.6 centimeter mesh caught the highest proportion of Atlantic menhaden from 2013 through 2015 and in 2019, and the 6.4 centimeter mesh the highest from 2016 through 2018. Length frequency distributions from the Choptank River gill net survey indicated the gear selected slightly larger Atlantic menhaden than the pound net survey (Figure 44), with the 230 and 250 millimeter length groups combined accounting for over 60% of the catch annually from 2013-2018. The 2019 length frequency was the first year with a bimodal distribution, the primary peak still occurred at the 250 millimeter FL group, but a lesser peak occurred at the 190 millimeter FL group. Mean lengths for all meshes combined displayed little inter-annual variation, with values between 254 and 257 millimeters FL for five of the years and a value of 243 millimeters FL in 2017 and 2019 (Table 11).

Atlantic menhaden scale samples were taken from 277 fish from the onboard pound net survey in 2019, but ages could only be assigned to 271 fish (Table 12). After applying the annual length frequencies (867 lengths in 2019) to the corresponding age length keys, 65% of sampled fish were age one, 11% were age two, 12% were age three and ages four through six were also present. Corrections in Maryland's assigning of annuli following the 2015 ASMFC Atlantic menhaden aging workshop likely reduced the age estimates of some fish from 2015 to 2019 compared to the method used in previous years. One hundred fifteen scale samples were taken and aged from the Choptank River gill net survey in 2019. Age three accounted for 34% of sampled fish, age two accounted for 24%, age one accounted 22%, age four accounted for 15% and age five accounted for 5% of sampled Atlantic menhaden (Table 13). Commercial pound nets and the Choptank River gill net survey selected slightly different ages. The gill net survey had fewer age one fish in all years, and a higher proportion of age three plus fish in all years. Both surveys had their highest proportion of age one fish in 2019, indicating the lower mean lengths and shifts to smaller fish in the length frequency distributions is due to an increase in the number of age one fish encountered.

Average annual Atlantic menhaden commercial harvest in Maryland's portion of Chesapeake Bay was 6.7 million pounds from 1981 to 1989, 3.2 million pounds from 1990 to 2004 and 7.9 million pounds from 2005 to 2016 (Figure 45). Harvest fell to 2.8 million pounds in 2017, the first year landings were below 5 million pounds since 2003, and remained low in 2018 at 2,785,393 pounds. A coast wide quota was established by ASMFC during the 2013 fishing year (ASMFC 2012), with individual states getting a percentage of the total allowable catch based on historical landings. Prior to 2013, the Atlantic menhaden fishery in Maryland had no restrictions, aside from general commercial fishing license requirements and regulations, including a prohibition on purse seining. The 2017 and 2018 seasons were the only ones in which Maryland did not reach its quota.

A benchmark ASMFC Atlantic menhaden stock assessment was conducted in 2019 using the Beaufort Assessment Model which is a forward-projecting statistical catch-at-age model (SEDAR 2020a). A suite of Ecological Reference Point (ERP) models were also developed to try and account for Atlantic menhaden as a prey species. (SEDAR 2020b). The single species model concluded overfishing was not occurring and the stock was not overfished, and was not in danger of exceeding either single species reference point in the near future. An exploratory ERP model was presented to the ASMFC Atlantic Menhaden Board that also indicated the same stock status, but current fecundity and fishing mortality values were closer to the target values than the single species reference points, indicating there is little room to expand the fishery. The Board requested other ERP projections to help them select appropriate reference point values in the future.

PROJECT NO. 2
JOB NO. 2

STOCK ASSESSMENT OF SELECTED RECREATIONALLY IMPORTANT ADULT MIGRATORY FINFISH IN MARYLAND'S CHESAPEAKE BAY

2020 PRELIMINARY RESULTS – WORK IN PROGRESS

Onboard pound net survey sampling, through the 2020 portion of the reporting period, was conducted on June 1, June 15, June 22 and June 30, 2020, with one to three nets sampled each day. During these trips the survey took length measurements from 16 American Shad, two Atlantic croaker, 275 Atlantic menhaden, 23 black drum, 99 bluefish, one cobia, four hickory shad, nine northern kingfish, six summer flounder, 21 Spanish mackerel, 594 spot, 39 spotted seatrout, 317 striped bass, one weakfish and one white catfish. Subsamples for aging were collected from one Atlantic croaker, 105 Atlantic menhaden, 64 spot and one weakfish. Sampling continued into the next reporting period.

Two cooperating fishermen were contracted for the 2020 sampling season, one in lower Eastern Shore area, and one at the mouth of the Potomac River. Seafood dealer sampling was not conducted in the first half of the 2020 sampling season, since regional coverage improved compared to 2018 and early 2019, and to minimize potential staff and seafood industry personnel exposure to the SARS-COV-2 virus, through increased person to person interactions.

The Choptank River gill net survey was conducted on four days for a total of 16 sites form June 5, 2020 to June 23, 2020 during the second half of the reporting period. The survey caught one Atlantic croaker, 305 Atlantic menhaden, 41 gizzard shad, 157 spot, eight striped bass and 19 white perch. Sampling continued into the next reporting period.

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Table 1. Total numbers of sets per month by year for the Choptank River gill net survey, 2013 - 2019.

Year	June	July	August	September	Total Sets
2013	8	16	16	8	48
2014	16	20	16		52
2015	16	16	16		48
2016	12	14	16	4	46
2017	16	16	19		51
2018	16	20	16		52
2019	16	20	16		52

Table 2. Areas sampled, number of sampling trips, mean surface water temperature and mean surface salinity by month for the onboard pound net survey in 2019.

Area	Month	Number of Samples	Mean Water Temp. C	Mean Salinity (ppt)
Point Lookout	June	3	24.8	8.3
Point Lookout	July	2	27.6	9.0
Chester River	July	1	28.1	5.1
West Bay	July	2	28.4	9.9
East Bay	July	1	28.2	9.8
Point Lookout	August	4	26.4	12.1
West Bay	August	3	28.7	11.8
East Bay	August	3	28.3	12.0
Chester River	August	1	28.2	7.9
Point Lookout	September	2	25.1	13.5
West Bay	September	4	25.2	14.3
East Bay	September	3	24.3	14.5
Point Lookout	October	1	20.5	15.6
Chester River	October	1	16.0	11.8
Chester River	November	1	8.6	8.6
Herring Bay	November	1	9.6	10.0

Table 3. List of non-target species observed during the 2019 onboard pound net survey.

Common Name	Scientific Name
Amberjack	*Spp. Seriola*
Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic spadefish	*Chaetodipterus faber*
Channel catfish	*Ictalurus punctatus*
Cobia	*Rachycentron canadum*
Cownose ray	*Rhinoptera bonasus*
Crevalle jack	*Caranx hippos*
Florida pompano	*Trachinotus carolinus*
Gizzard shad	*Dorosoma cepedianum*
Harvestfish	*Peprilus alepidotus*
Lookdown	*Selene vomer*
Northern searobin	*Prionotus carolinus*
Silver perch	*Bairdiella chrysoura*
Southern stingray	*Dasyatis americana*
Striped bass	*Morone saxatilis*
Striped burrfish	*Chilomycterus schoepfi*
Striped mullet	*Mugil cephalus*

Table 4. Total catch by species in numbers from the Choptank River gill net survey, 2013 – 2019.

Common Name	2013	2014	2015	2016	2017	2018	2019
Atlantic Croaker	476	269	21	32	53	8	43
Atlantic Menhaden	1,584	2,247	1,782	1,171	1,292	2,257	2,045
Black Drum	0	0	0	1	0	0	0
Blue Catfish	0	0	0	0	0	0	2
Blue Crab	34	44	165	127	107	107	103
Bluefish	11	22	7	3	3	11	3
Butterfish	0	2	2	0	0	1	0
Channel Catfish	0	0	0	0	0	1	3
Cownose Ray	0	1	0	0	0	2	0
Gizzard Shad	180	231	188	36	28	12	42
Harvestfish	0	0	0	2	2	13	2
Hickory Shad	0	0	0	0	1	3	0
Hogchoker	3	39	6	6	14	5	14
Horseshoe Crab	0	0	0	0	0	3	1
Northern Kingfish	1	9	0	1	1	0	0
Oyster Toadfish	0	0	0	0	0	0	1
Spanish Mackerel	0	0	0	1	0	6	7
Spot	272	749	222	109	298	154	389
Spotted Seatrout	0	0	0	0	0	0	6
Striped Bass	16	33	14	50	79	103	48
Summer Flounder	2	0	0	2	5	4	0
Weakfish	0	0	1	3	1	3	4
White Catfish	0	0	0	0	0	0	3
White Perch	18	41	55	64	67	8	32
Total Catch	2,597	3,687	2,463	1,608	1,951	2,701	2,748

Table 5. Mean length (millimeter TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993-2019.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Weakfish																											
mean length	276	291	306	293	297	337	334	361	334	325	324	273	278	290	275	276	262	253	236	284	304	332	293	256	257	265	252
std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42	52	22	24	24	48	33	65	31	31	35	29	26
n	435	642	565	1,431	755	1,234	851	333	76	196	129	326	304	62	61	42	23	47	26	93	67	6	23	64	27	16	63
Summer flounder																											
mean length	347	309	297	335	295	339	325	347	358	324	353	327	374	286	341	347	368	374	359	338	268	268	336	273	191	250	272
std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66	72	64	84	67	130	89	73	61	77	86	69	74
n	209	845	1,669	930	818	1,301	1,285	1,565	854	486	759	577	499	1,274	1,056	982	277	197	213	161	194	101	43	41	394	125	168
Bluefish																											
mean length	312	316	323	307	330	343	306	303	307	293	320	251	325	311	318	260	265	297	245	298	297	319	327	289	299	291	345
std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70	41	43	60	48	77	59	62	79	48	53	59	50
n	45	621	912	619	339	378	288	398	406	592	223	581	841	1,422	1,509	2,676	1,181	493	290	877	1,000	443	392	132	111	72	756
Atlantic croaker																											
mean length	233	259	286	294	301	310	296	302	317	279	287	311	317	304	307	298	320	295	281	274	276	249	265	254	258	271	212
std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54	62	50	34	31	42	36	31	22	23	50	24	30
n	471	1,081	974	2,190	1,450	1,057	1,399	2,209	733	771	3,352	1,653	2,398	1,295	2,963	1,532	91	1,970	1,764	1,842	2,320	1,438	942	2,239	2,037	214	202
Spot																											
mean length	184	207	206	235	190	230	213	230	239	184	216	208	197	191	208	198	185	201	193	179	196	194	194	175	200	180	198
std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23	21	21	22	18	24	20	20	18	19	25	18	22
n	309	451	158	275	924	60	572	510	126	681	1,354	882	2,818	2,195	519	1,195	33	51	582	1,508	1,302	420	127	135	1,063	1,149	1,396
Spotted Seatrout																											
mean length		448	452			541	460								414	464	262		361	436	456	499	487	625	464		391
std. dev.		86	42				134								43	72	22		142	112	29	70			51		70
n		4	6			1	2								3	10	23		4	8	5	4	1	1	3		13
Black Drum																											
mean length		1,106	741	353		1,074				435	475	780	1,130	1,031	1,144	875	1,147	1,061	978	997	882	1,080	993	952		610	564
std. dev.		175	454	20		182				190	20	212		228	95	238	84	345	188		236	150	171	429		350	383
n		2	3	2		12				7	4	44	1	8	9	5	13	3	3	1	4	14	4	4		3	4

Table 5. Continued.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Red Drum																											
mean length						302	332	648		316	506	647	353	366	658	361			678	318	469	954		340	549	1,191	528
std. dev.							71			44		468		21	40	57			18	71	39			10	105	162	247
n						1	16	1		177	1	2	1	16	2	21			2	458	16	1		3	19	4	6
Spanish Mackerel (Total Length)																											
mean length	261	391	487	481	520	418	468	455													508		343	404			
std. dev.	114	55	38	55		45	82	66													37			53			
n	3	78	39	27	1	4	45	35													124		1	10			
Spanish Mackerel (Fork Length)																											
mean length			418	401	437	379		386	406	422	405	391	422	439	436	407	418			393	428	536	437	345	446	427	374
std. dev.			34	62				34	34	81	63	95	33	35	51	59	53			74	36		41	16	54	144	54
n			44	27	1	1		49	19	20	11	8	373	445	158	18	7			107	331	1	3	10	9	9	1,337
Menhaden (Fork Length)																											
mean length												262	282	238	243	246	245	232	213	243	251	223	219	208	217	231	215
std. dev.												28	36	42	41	29	40	36	39	25	31	38	28	42	24	24	41
n												213	1,052	826	854	826	366	836	773	755	762	775	864	732	723	668	868

Table 6. Percentage of weakfish by age and year, number of age samples and number of length samples by year, using pound net length and age data 2003-2019.

Year	Age 1	Age 2	Age 3	Age 4	# of Ages	# of Lengths
2003	8.8	72.6	15.7	2.9	48	129
2004	55.9	39.2	4.9		59	326
2005	39.8	55.2	4.8	0.3	109	304
2006	70.1	22.2	7.6	0.1	62	62
2007	67.8	24.2	7.9	0.1	61	61
2008	85.7	7.1	7.1		41	42
2009	77.3	22.7			22	22
2010	100.0				45	47
2011	80.8	15.4			26	27
2012	54.2	42.3	3.5		71	93
2013	34.7	51.9	13.4		52	67
2014	33.3	16.7	50.0		6	6
2015	47.0	53.0			19	23
2016	85.9	14.2			63	64
2017	77.8	22.2			27	27
2018	73.4	18.8	7.8		15	16
2019	88.71	11.29			63	63

Table 7. Mean length (millimeter TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay seafood dealer sampling in 2017- 2019.

	2017	2018	2019
Summer flounder			
mean length	392		
std. dev.	28		
n	17	0	0
Bluefish			
mean length	405	333	453
std. dev.	71	50	51
n	172	2	4
Atlantic croaker			
mean length	262	293	
std. dev.	26	18	
n	761	121	0
Spot			
mean length	213	210	204
std. dev.	19	13	6
n	425	53	123
Spotted Seatrout			
mean length	381		
std. dev.	52		
n	7	0	0
Red Drum			
mean length	598		
std. dev.	45		
n	2	0	0
Weakfish			
mean length		334	
std. dev.		11	
n	0	2	0
Spanish Mackerel (Fork Length)			
mean length	455	421	433
std. dev.	59	49	80
n	35	37	10
Menhaden (Fork Length)			
mean length	218		237
std. dev.	27		43
n	285	0	51

Table 8. Atlantic croaker and weakfish instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999–2019.

		Growh parameters From MD only	Growh parameters From ASMFC SA
Year	Weakfish	Atlantic Croaker	Atlantic Croaker
1999	0.74	0.28	0.34
2000	0.4	0.31	0.36
2001	0.62	0.24	0.28
2002	0.58	0.25	0.27
2003	0.73	0.33	0.40
2004	1.29	0.26	0.32
2005	1.44	0.22	0.27
2006	*	0.19	0.24
2007	*	0.22	0.31
2008	*	0.22	0.29
2009	*	0.37	0.38
2010	*	0.25	0.47
2011	*	0.67	0.55
2012	*	0.66	0.89
2013	1.55	0.72	0.83
2014	*	1.41	1.02
2015	*	1.24	0.87
2016	*	1.61	1.11
2017	*	1.41	1.00
2018	*	0.81	0.60
2019	*	1.82	1.25

* Insufficient sample size to calculate 2006 – 2012, 2014 - 2019 weakfish estimates.

Table 9. Percentage of Atlantic croaker by age and year, number of age samples and number of length samples by year, using pound net length and age data, 1999-2019.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	# Aged	# Measured
1999		34.0	22.5	3.3	9.4	4.2	16.0	6.0	4.2	0.4					180	1,399
2000		10.1	42.5	25.1	1.0	1.4	4.9	7.4	5.3	2.2					145	2,209
2001	No Data															
2002	18.4	4.0	10.1	8.9	29.4	24.0	1.0		3.0	0.5	0.6				66	771
2003		15.2	38.6	1.3	12.2	26.6	3.8	0.1	0.2	0.1	0.7	0.3	1.0		129	3,352
2004		0.6	54.9	5.0	5.4	6.9	23.3	3.1	0.0	0.2		0.6			161	1,653
2005		10.1	4.8	51.5	7.6	1.5	7.3	11.4	5.6		0.1	0.1			190	2,398
2006	16.7	6.3	18.1	4.8	36.8	2.3	3.2	5.0	5.2	1.8				0.1	253	1,295
2007		11.2	14.4	30.0	8.8	27.0	1.3	1.1	1.6	3.3	1.0	0.3			275	2,963
2008	5.5	7.2	28.3	14.0	19.0	4.5	17.6	1.0	0.4	0.5	1.7	0.3			288	1,532
2009		30.9	8.5	37.4	11.1	7.8	1.8	2.2	0.3						222	1,381
2010		1.2	25.7	8.7	36.5	15.8	9.4	0.9	1.3	0.3		0.3			267	2,516
2011		0.8	17.4	48.2	11.3	16.6	3.6	1.7	0.3	0.1					245	1,886
2012	10.2	0.9	22.5	21.8	34.1	6.5	2.8	0.9	0.3						255	1,842
2013		13.5	2.3	24.7	22.2	27.9	4.1	4.9	0.1		0.2				247	2,320
2014		6.23	67.78	1.39	14.97	6.55	2.25	0.58	0.12	0.12					193	1,436
2015			7.04	81.67	0.74	6.77	1.18	2.61							126	942
2016	2.76	1.62	5.44	20.37	63.91	1.50	4.31	0.06	0.04						175	2,239
2017	1.02	9.28	5.54	17.81	19.51	46.48	0.36								230	2,064
2018	5.14	18.03	18.48	8.42	14.29	18.19	17.45								83	214
2019	79.56	13.05	2.96	1.48	0.49	1.48	0.49	0.49							134	203

Table 10. Percentage of spot by age and year, number of age samples and number of length samples by year, using pound net length and age data, 2007-2019.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Ages	Lengths
2007	21.3	75.0	3.3		0.4	98	519
2008	20.8	78.6	0.6			206	1,201
2009	7.7	90.7	1.6			232	614
2010	5.9	90.1	4.0			91	300
2011	0.4	99.4	0.2			173	582
2012	39.5	59.8	0.7			230	1,408
2013	3.6	96.4				167	1,285
2014	5.0	88.5	6.5			161	420
2015	9.1	88.4	2.6			78	127
2016	53.1	46.9				111	137
2017	19.1	80.5	0.3			228	1063
2018	62.2	37.8				185	1149
2019	48.12	51.88				192	1395

Table 11. Atlantic menhaden mean length (millimeter FL), standard deviation, and sample size from the Choptank River gill net survey, 2013- 2019.

Year	Mean Length	Std. Dev.	n
2013	254	27	278
2014	256	24	459
2015	258	24	420
2016	254	24	308
2017	243	22	362
2018	257	23	573
2019	243	34	473

Table 12. Atlantic menhaden percentage at age, number of age samples and number of length samples by year using, pound net length and age data, 2005-2019.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	# Aged	# Measured
2005		2.74	25.86	42.61	25.64	3.15			345	1,061
2006		40.44	28.27	18.36	9.70	2.62	0.60		289	826
2007		22.64	37.44	24.70	10.72	3.95	0.55		379	854
2008		16.60	44.55	29.36	7.27	1.94	0.28		385	826
2009	0.40	16.79	24.92	38.04	17.15	2.72			258	512
2010		42.98	30.61	14.93	8.26	2.50	0.60		388	836
2011		38.03	31.41	19.88	9.12	1.57			392	773
2012		14.51	56.74	21.45	4.26	1.80	0.77	0.48	355	755
2013		23.89	27.73	24.33	15.98	6.49	1.35	0.23	315	762
2014		33.00	36.20	18.70	10.00	2.20			229	775
2015		34.28	54.42	8.08	2.51	0.71			245	882
2016		42.75	30.02	19.27	7.23	0.72			241	732
2017		42.60	44.12	8.81	3.71	0.75			295	1058
2018		45.28	29.72	15.41	6.20	3.05	0.35		187	668
2019		64.93	10.86	12.13	8.38	3.48	0.22		271	867

Table 13. Atlantic menhaden percentage at age, number of age samples and number of length samples by year using the Choptank River gill net length and age data, 2015-2019.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	# Aged	# Measured
2015		2.04	49.94	34.28	12.65	1.08			157	420
2016		12.26	29.29	44.74	11.68	2.02			140	308
2017		7.05	53.27	29.18	8.83	1.67			163	362
2018		5.91	30.37	35.89	22.72	5.11			131	558
2019		21.84	23.91	33.90	15.00	5.36			115	473

Figure 1. Onboard pound net survey and fish house sampling site locations for 2019.

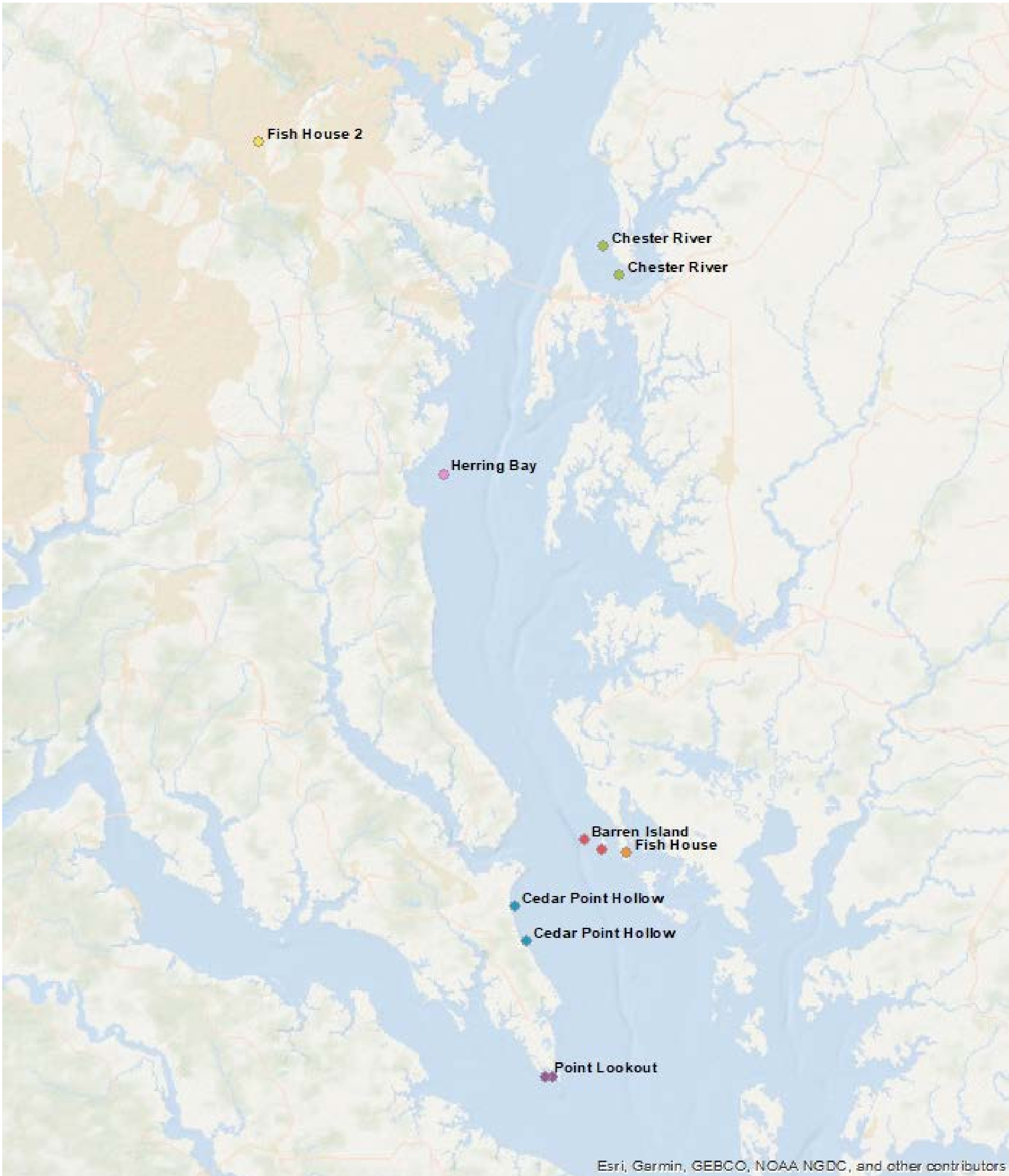


Figure 2. The Choptank River gill net survey sampling site locations for 2019.

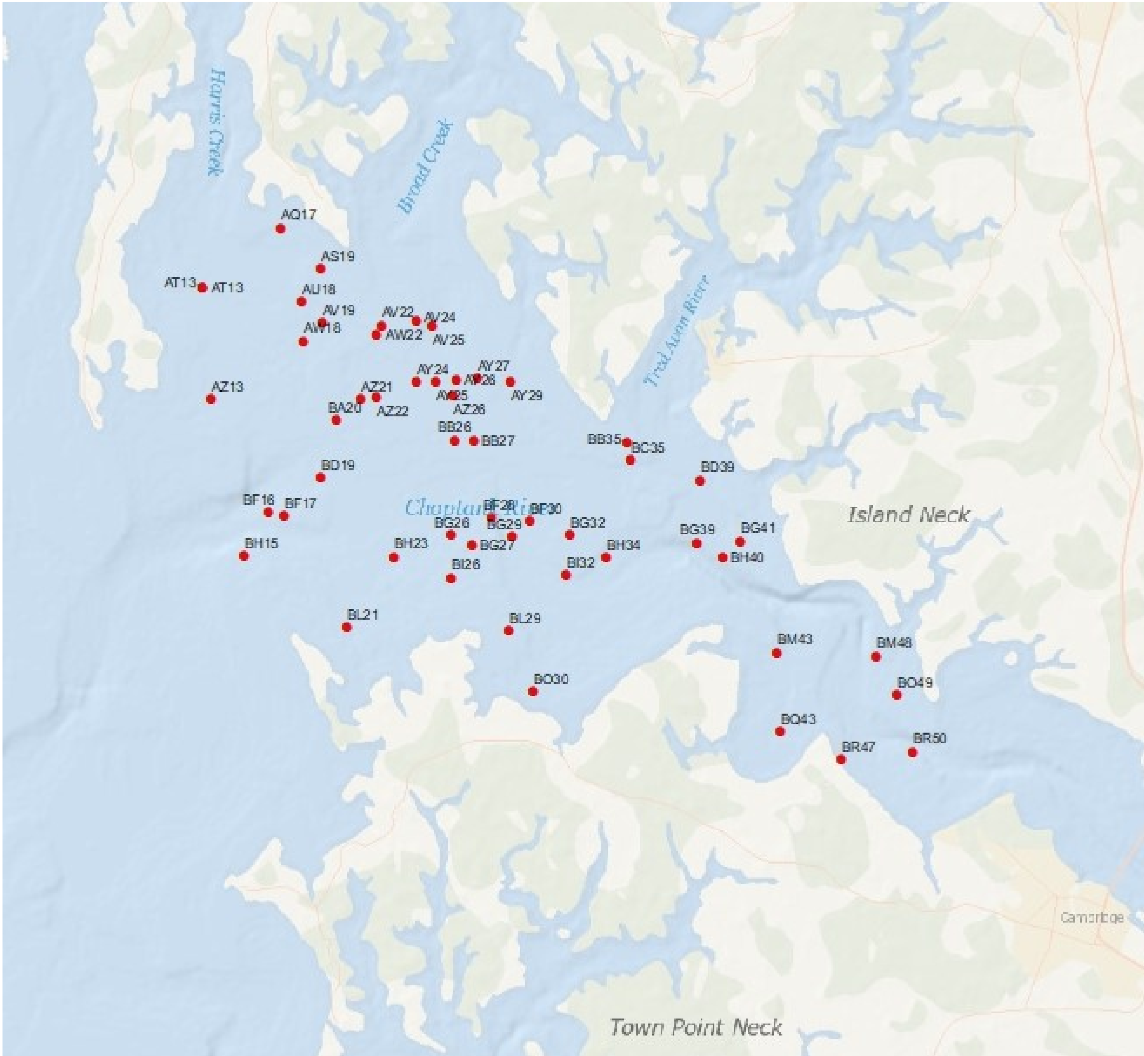


Figure 3. The Choptank River gill net survey sampling grid and grid names used in all years of the survey.

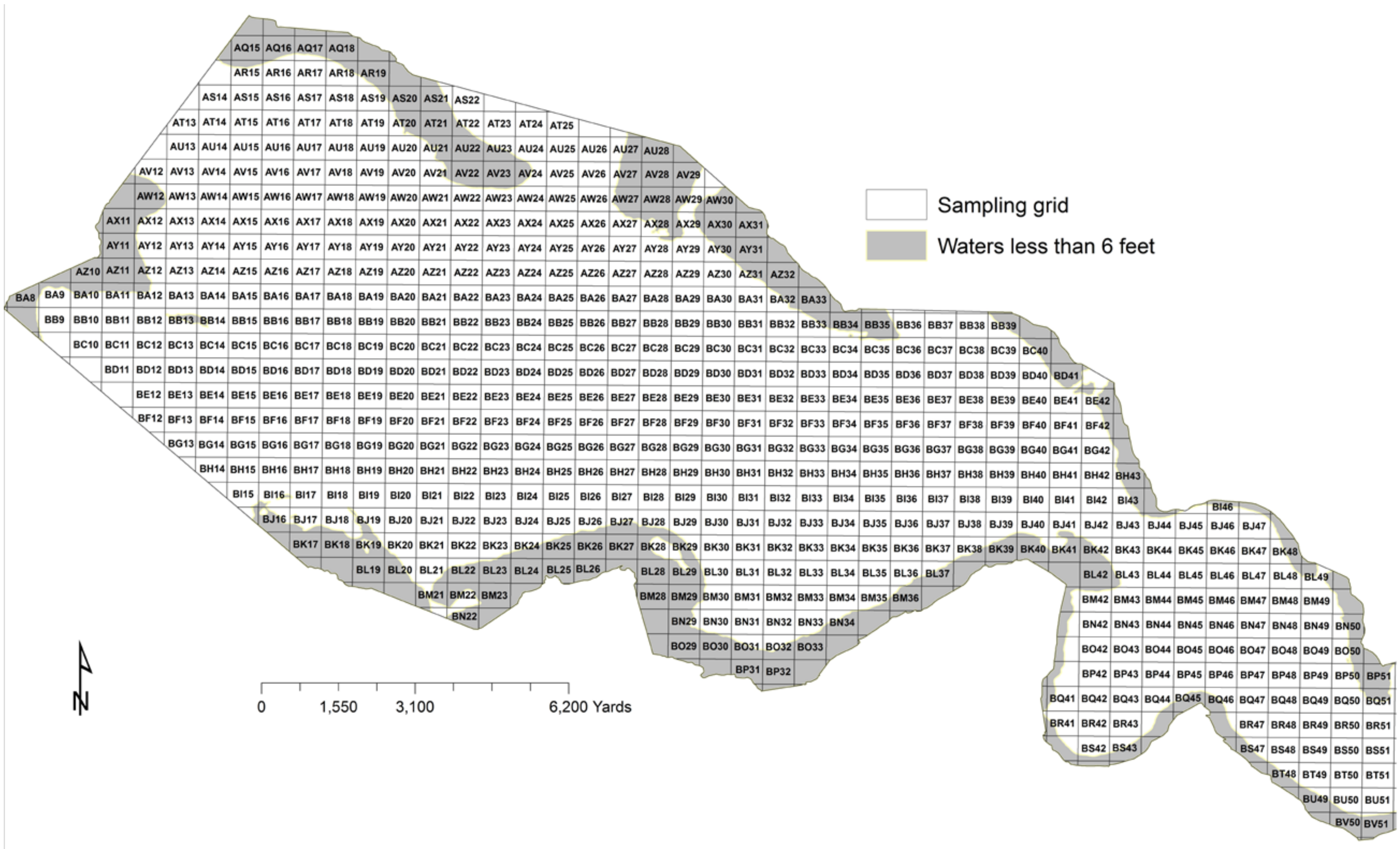


Figure 4. Weakfish length frequency distributions from onboard pound net sampling, 2010-2019. Note: 2011 210 millimeter length group was truncated to preserve scale, actual value is 50% and 2018 270 millimeter length group was truncated to preserve scale, actual value is 44%.

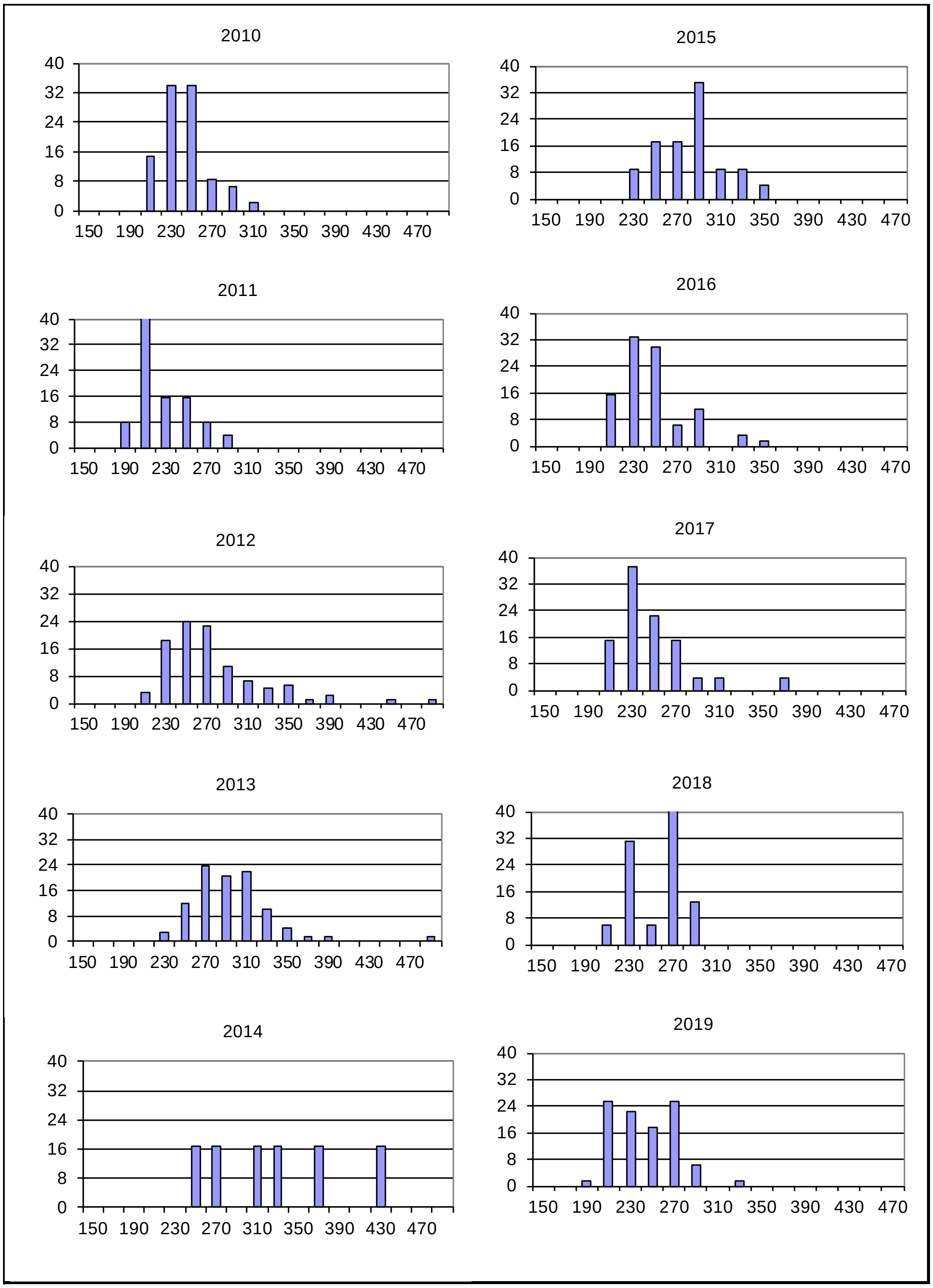


Figure 5. Maryland's commercial landings of weakfish in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational weakfish harvest and release estimates in numbers from 1981-2018.

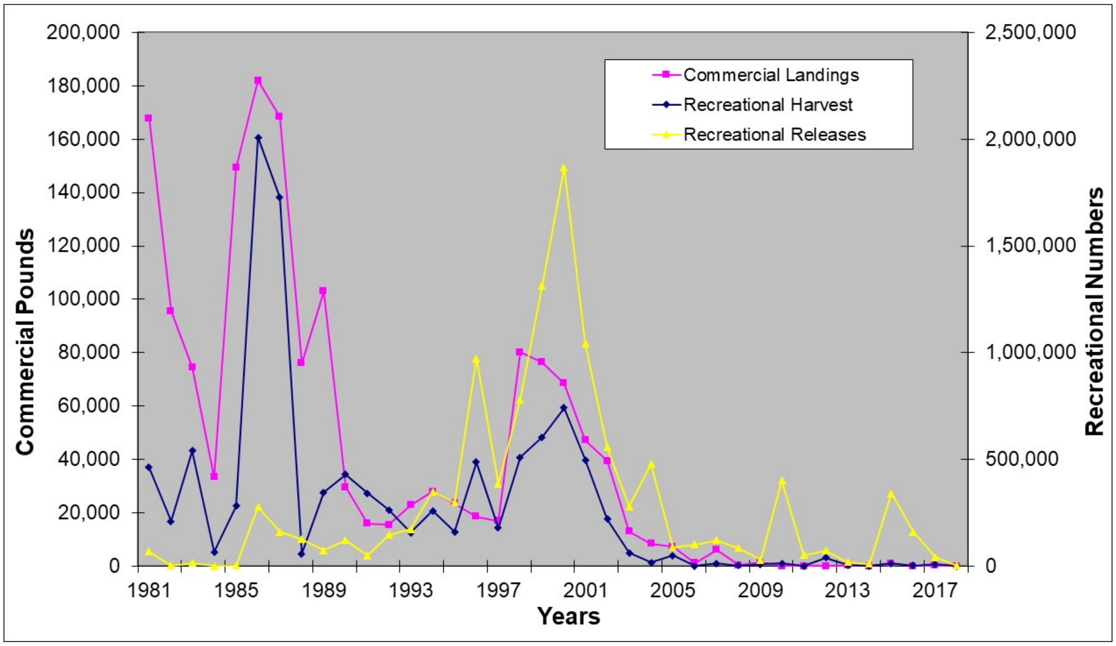


Figure 6. Maryland charter boat log book weakfish harvest in numbers and the number of anglers participating in trips catching weakfish, 1993-2018.

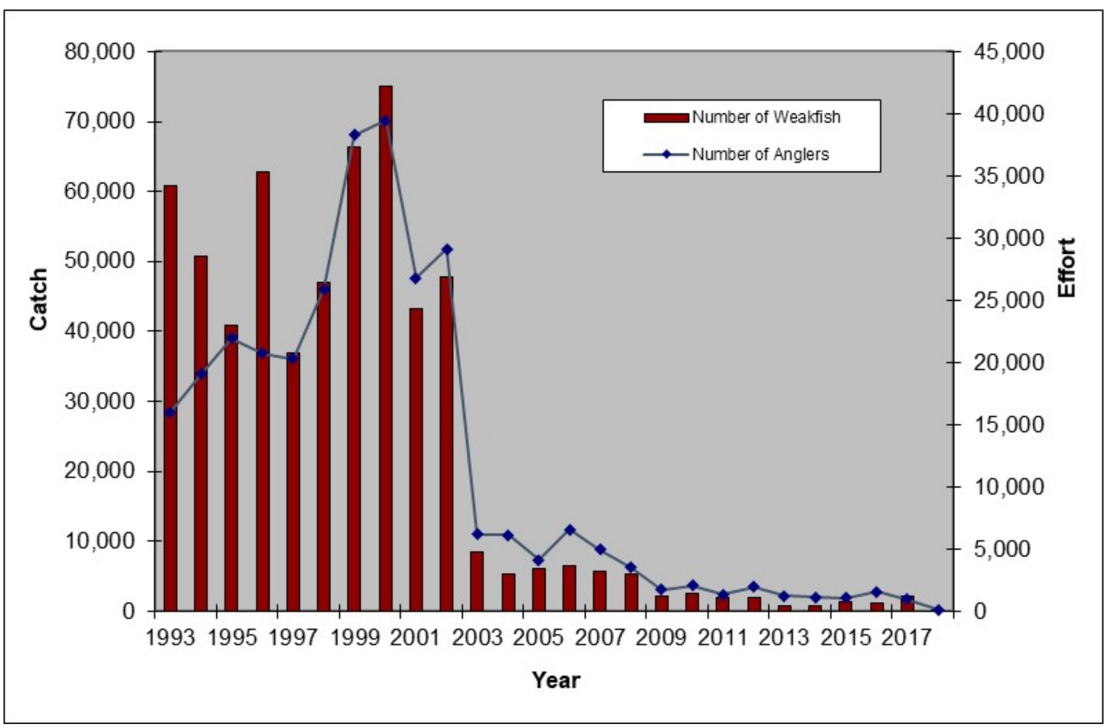


Figure 7. Maryland juvenile weakfish geometric mean catch per trawl, 95% confidence intervals and time series mean for Maryland's lower Chesapeake Bay, 1989-2019.

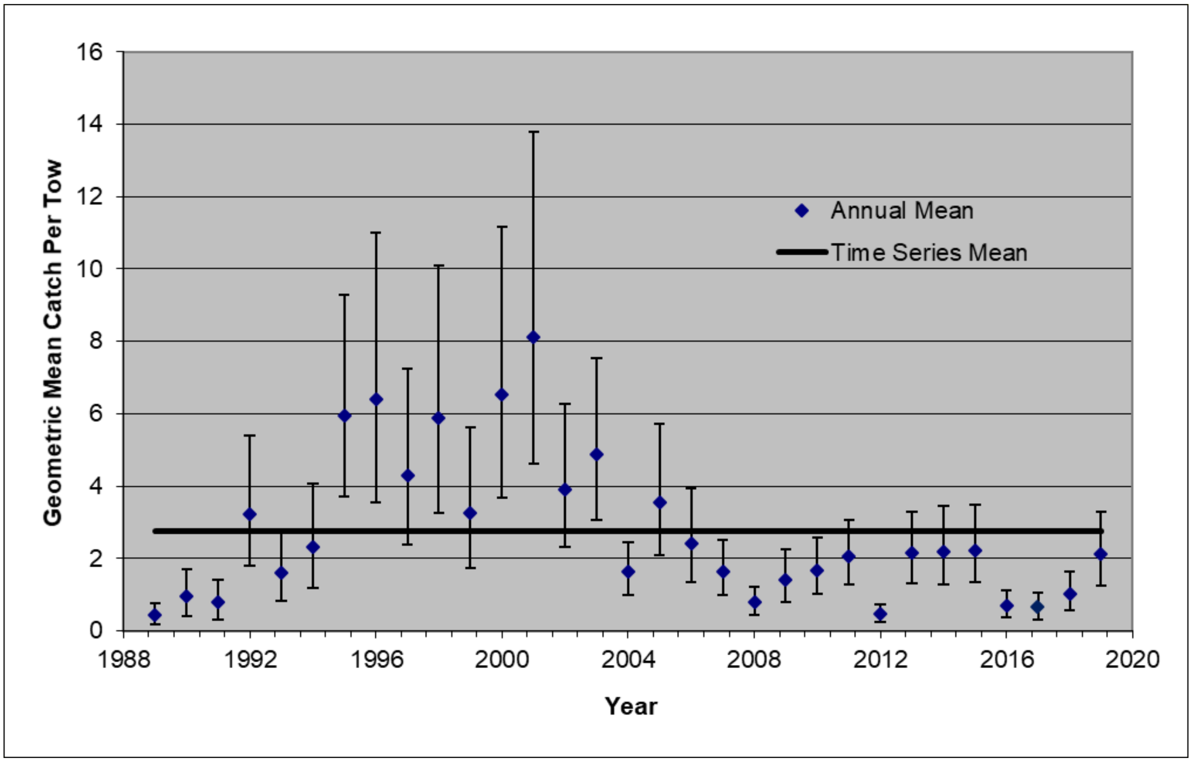


Figure 8. Summer flounder length frequency distributions from onboard pound net sampling, 2010-2019.

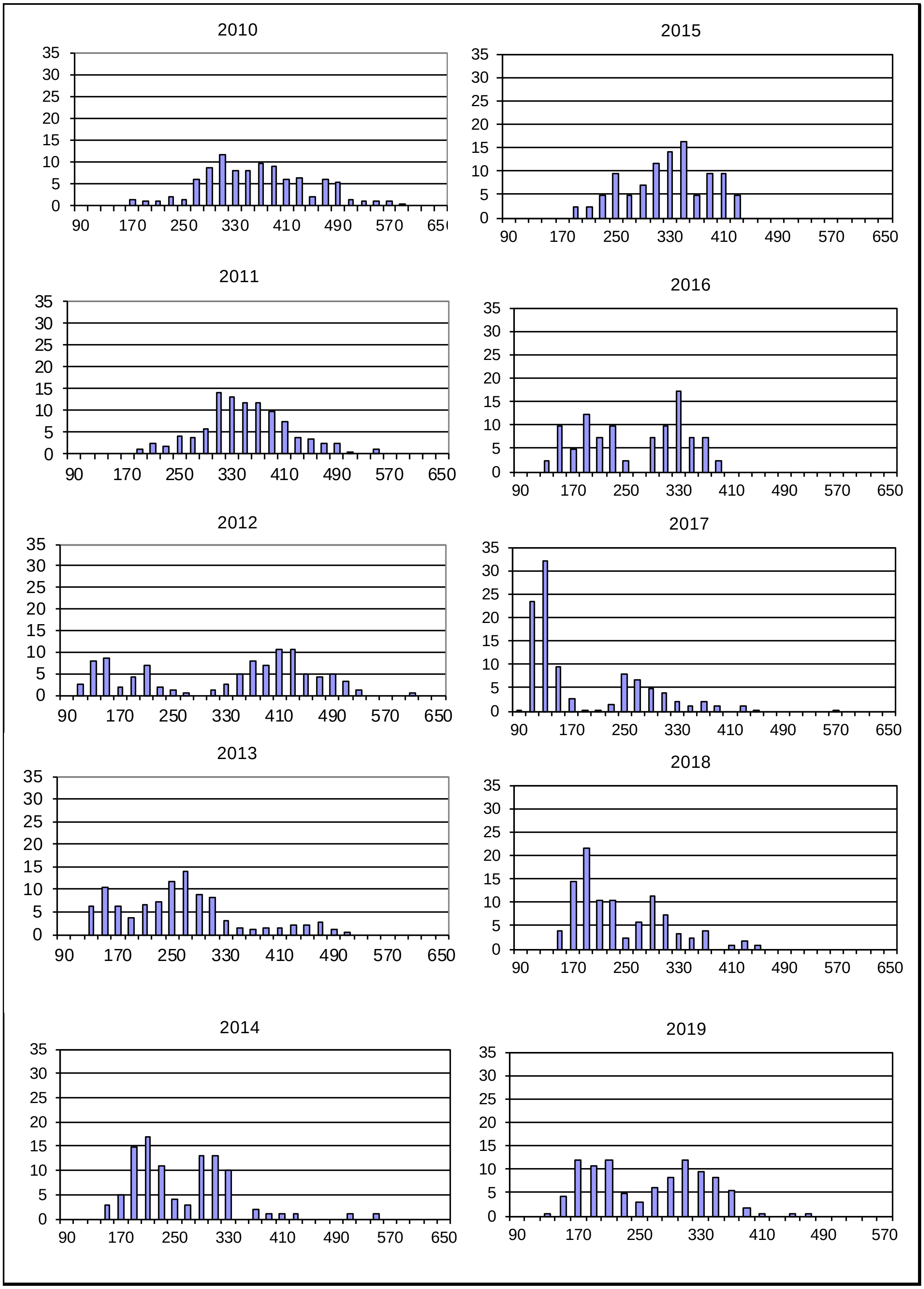


Figure 9. Maryland's commercial landings of summer flounder in pounds from the Chesapeake Bay and the MRIP Maryland summer flounder inland recreational harvest and release estimates in numbers from 1981-2018.

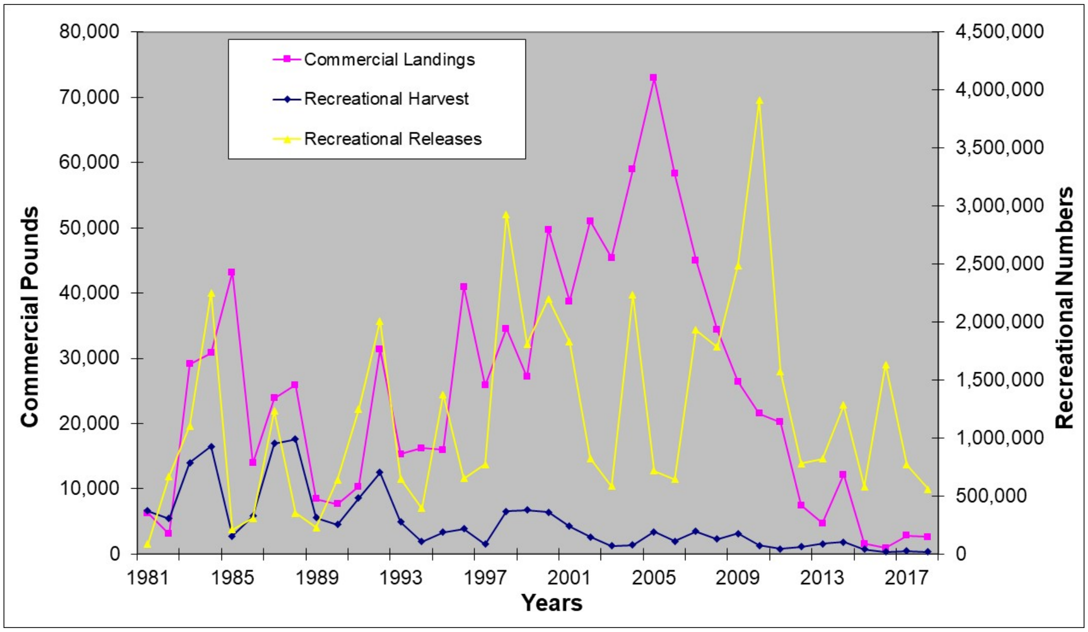


Figure 10. Maryland charter boat log book summer flounder harvest in numbers and the number of anglers participating in trips catching summer flounder, 1993-2018.

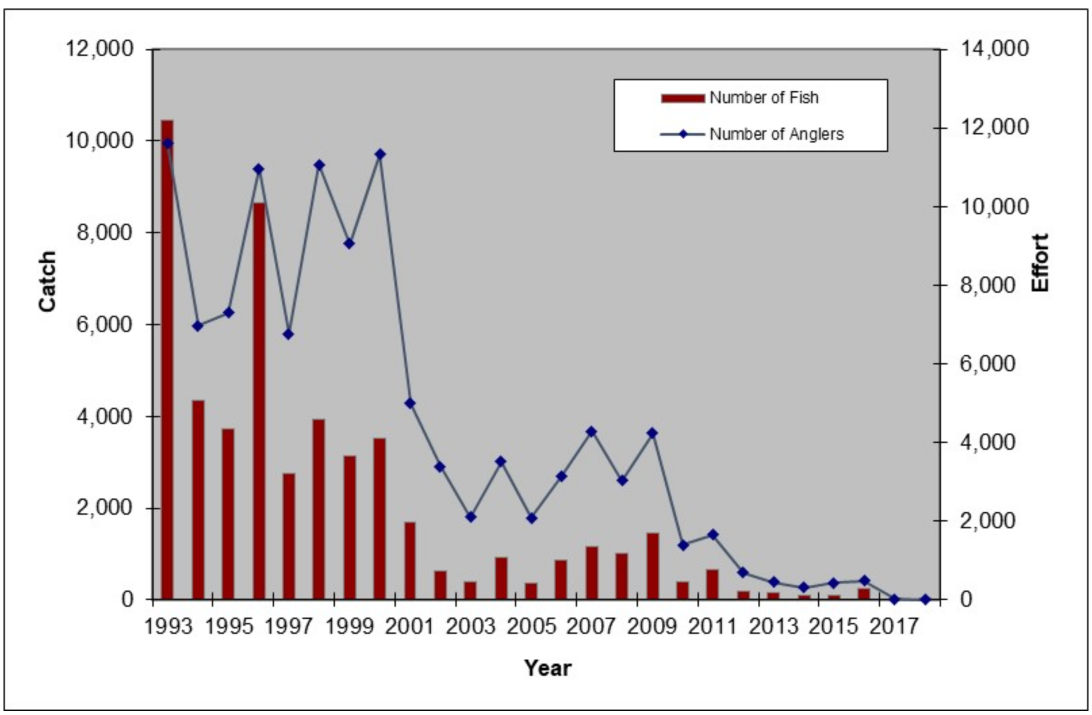


Figure 11. Bluefish length frequency distributions from onboard pound net sampling, 2010-2019.

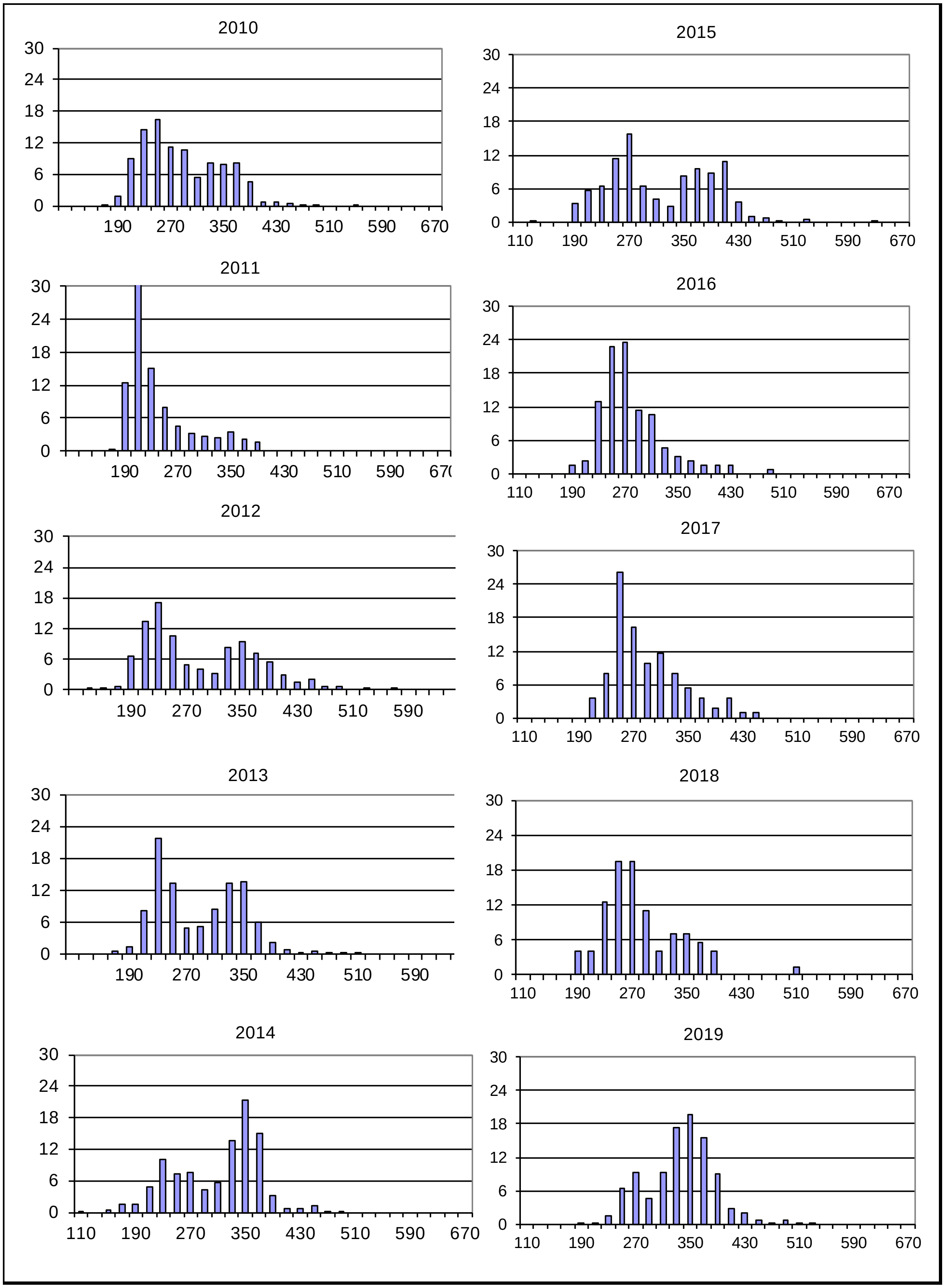


Figure 12. Bluefish length frequency distributions from seafood dealer sampling in 2017- 2019.

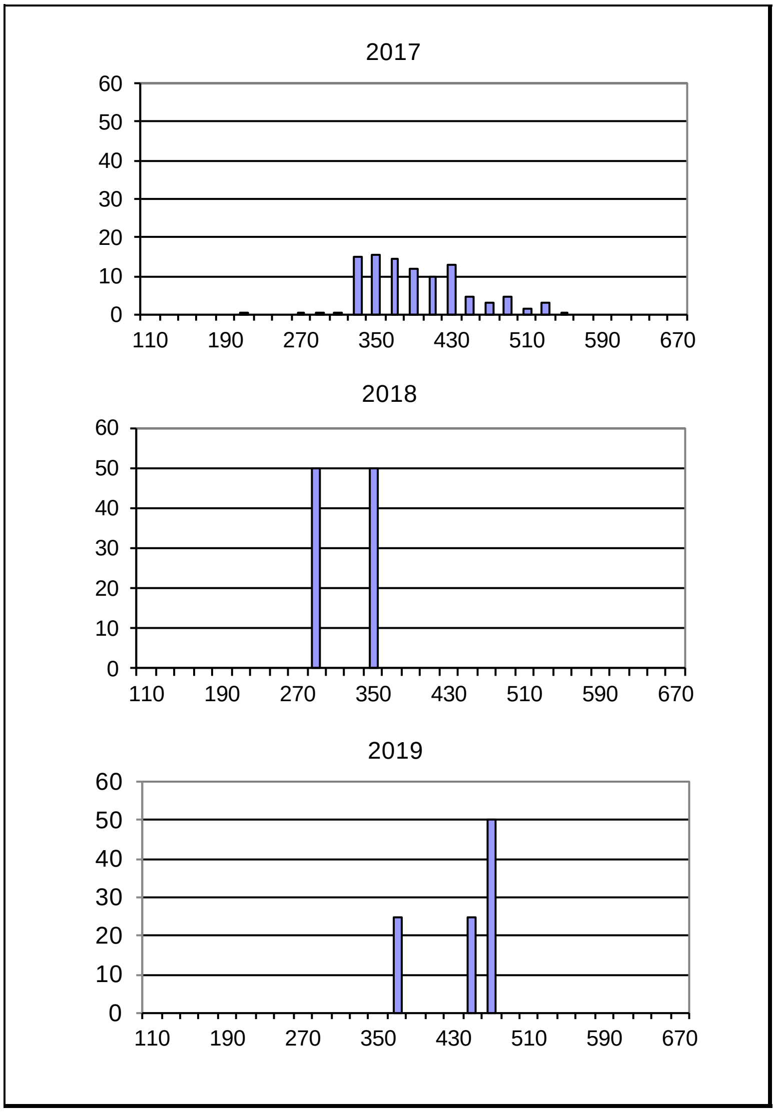


Figure 13. Proportion of bluefish catch by mesh size, all years combined, for the Choptank River gill net survey, 2013-2019.

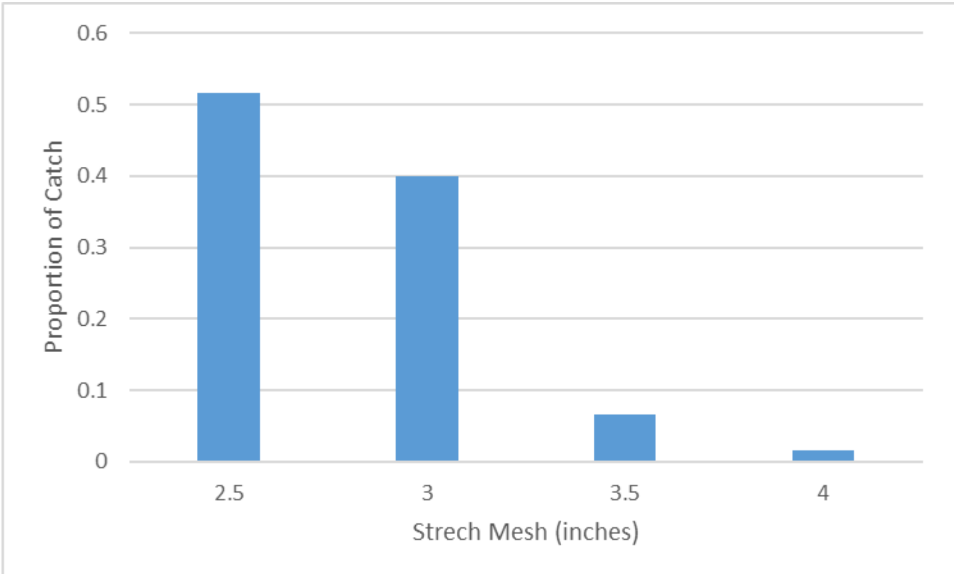


Figure 14. Maryland's commercial landings of bluefish in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational bluefish harvest and release estimates in numbers from 1981-2018.

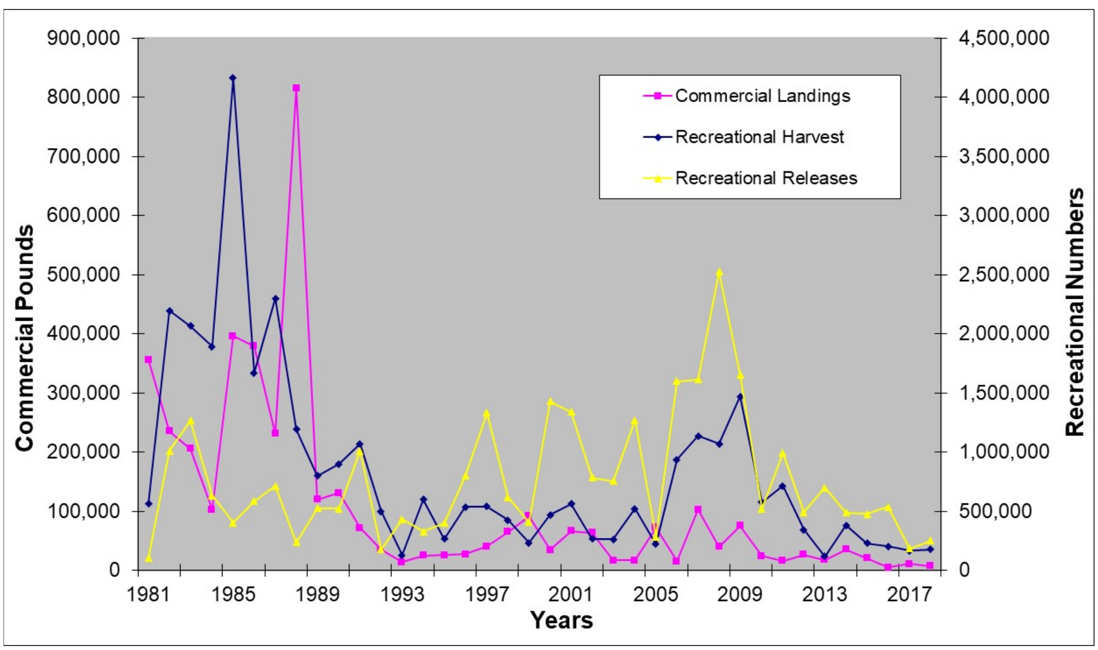


Figure 15. Maryland charter boat log book bluefish harvest in numbers and the number of anglers participating in trips catching bluefish, 1993-2018.

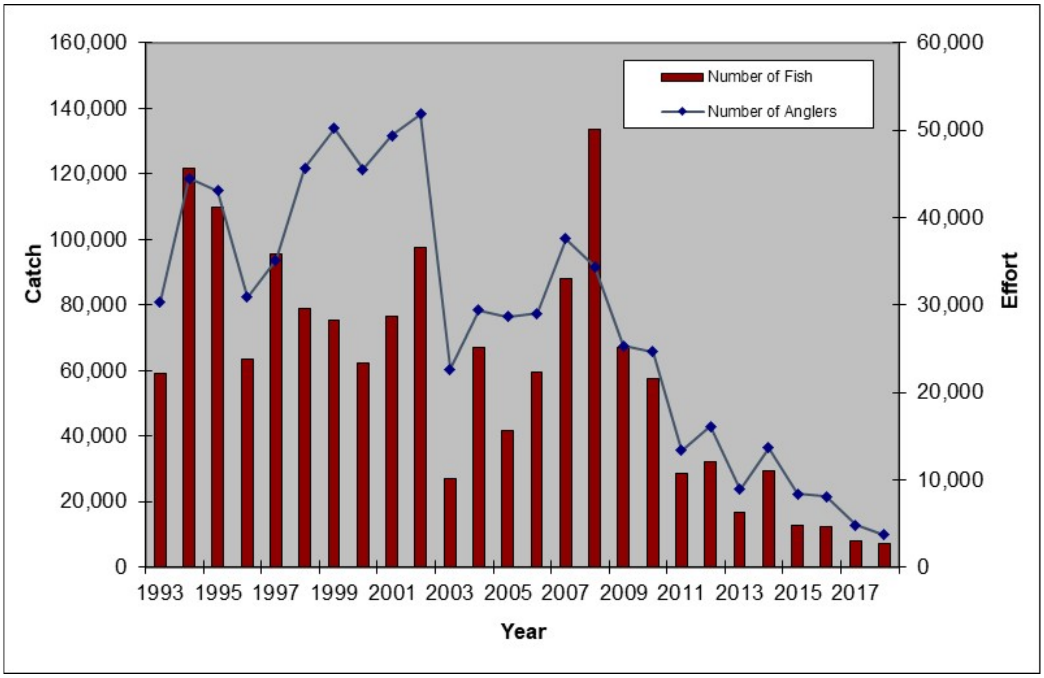


Figure 16. Atlantic croaker length frequency distributions from onboard pound net sampling, 2010-2019.

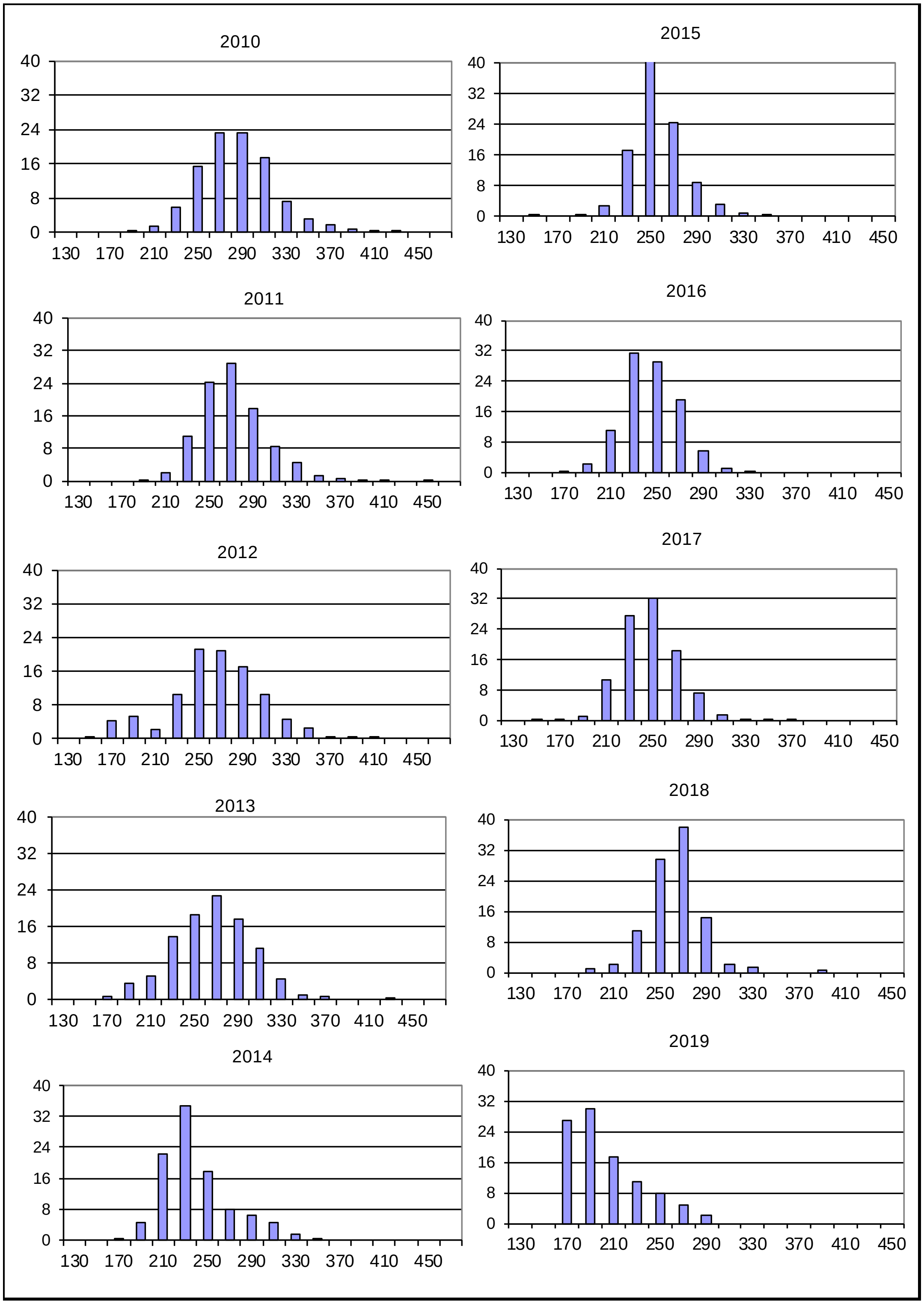


Figure 17. Geometric mean catch per hour of Atlantic croaker for the Choptank River gill net survey, 2013-2019.

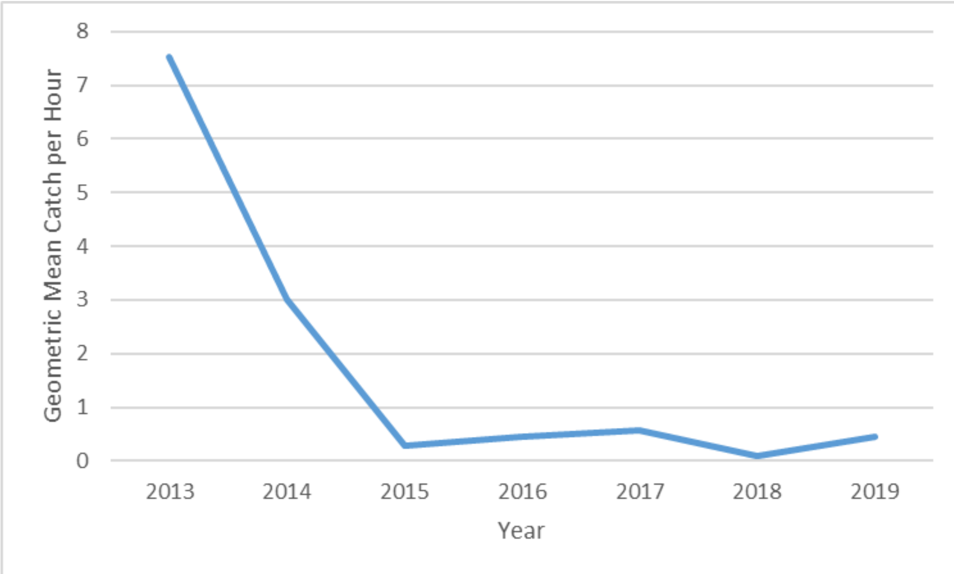


Figure 18. Proportion of Atlantic croaker catch by mesh size and year for the Choptank River gill net survey, 2013-2019.

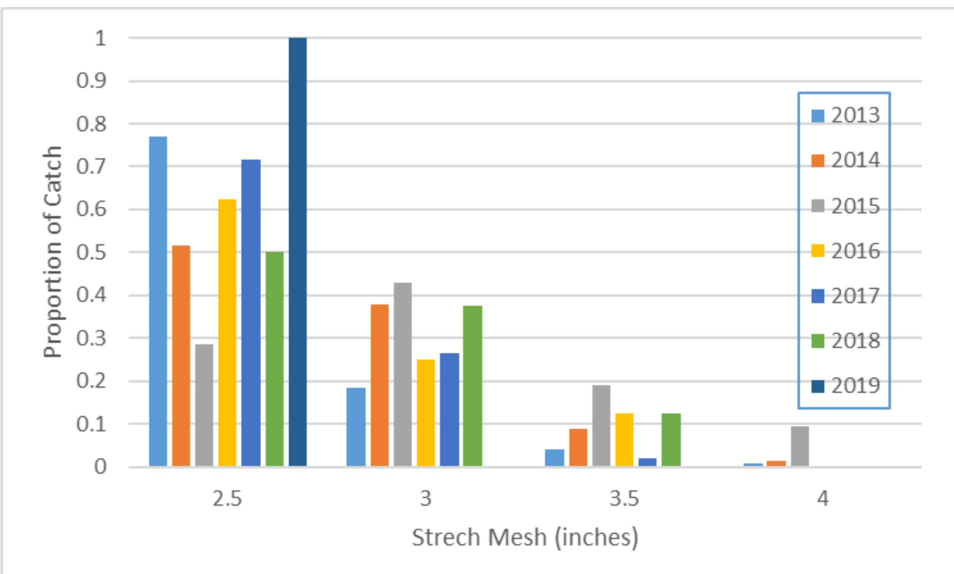


Figure 19. Atlantic croaker length frequency distribution from the Choptank River gill net survey by stretched mesh size in inches, 2013-2019 combined.

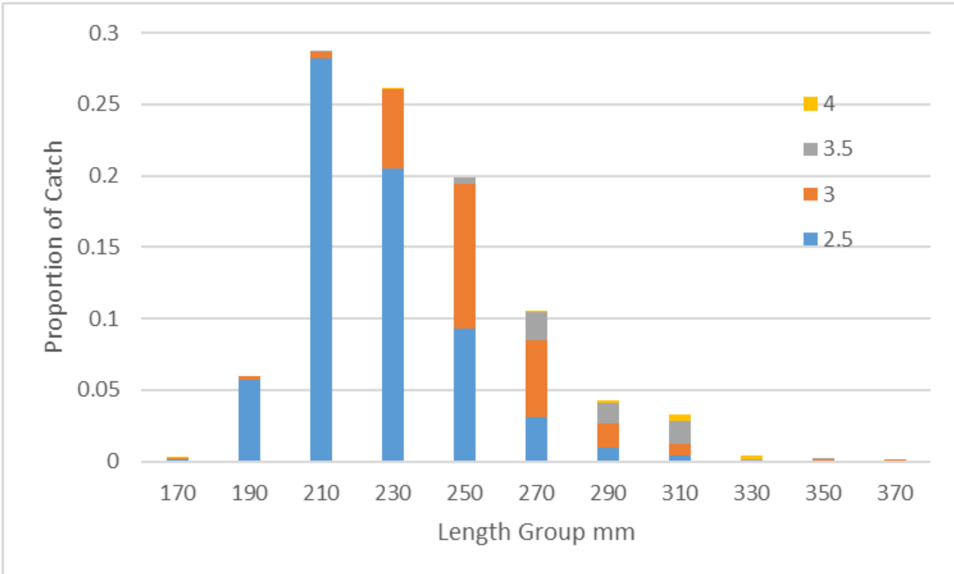


Figure 20. Maryland's commercial landings of Atlantic croaker in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational Atlantic croaker harvest and release estimates in numbers from 1981-2018.

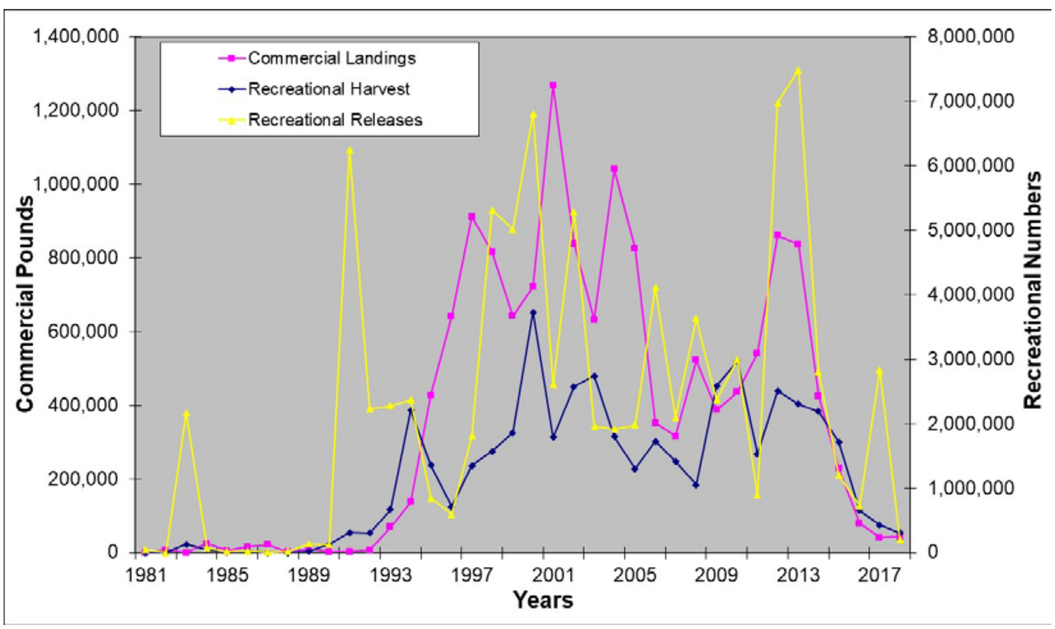


Figure 21. Maryland charter boat log book Atlantic croaker harvest in numbers and the number of anglers participating in trips catching Atlantic croaker, 1993-2018.

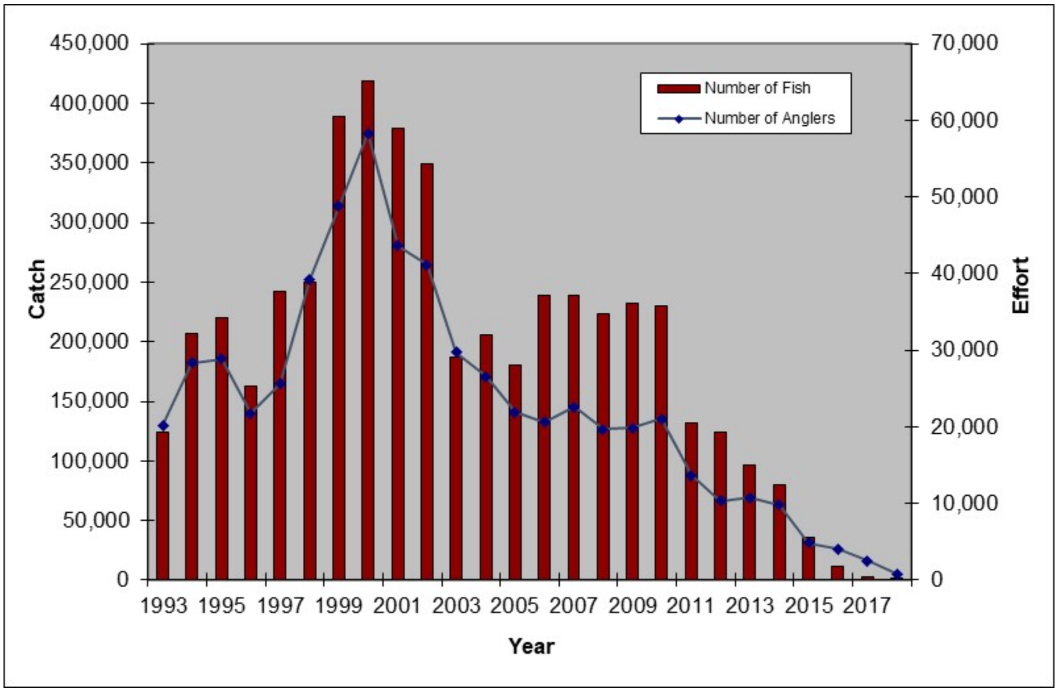


Figure 22. Maryland juvenile Atlantic croaker geometric mean catch per trawl, 95% confidence intervals and time series mean for Maryland's lower Chesapeake Bay, 1989-2019. 1998 data point was omitted for scale (GM 1998 = 30.05 - 9.02, +12.72).

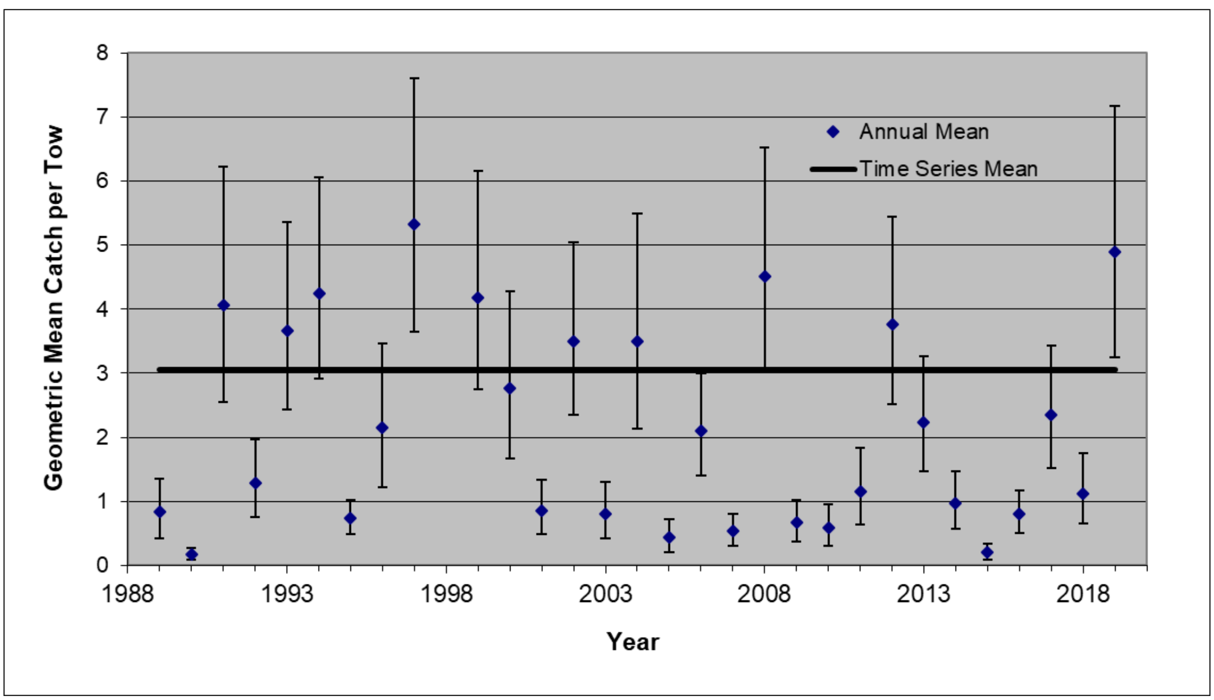


Figure 23. Atlantic croaker total mortality estimates using Maryland age data to derive growth parameters and using the growth parameters from the ASMFC 2017 stock assessment, 1999 - 2019.

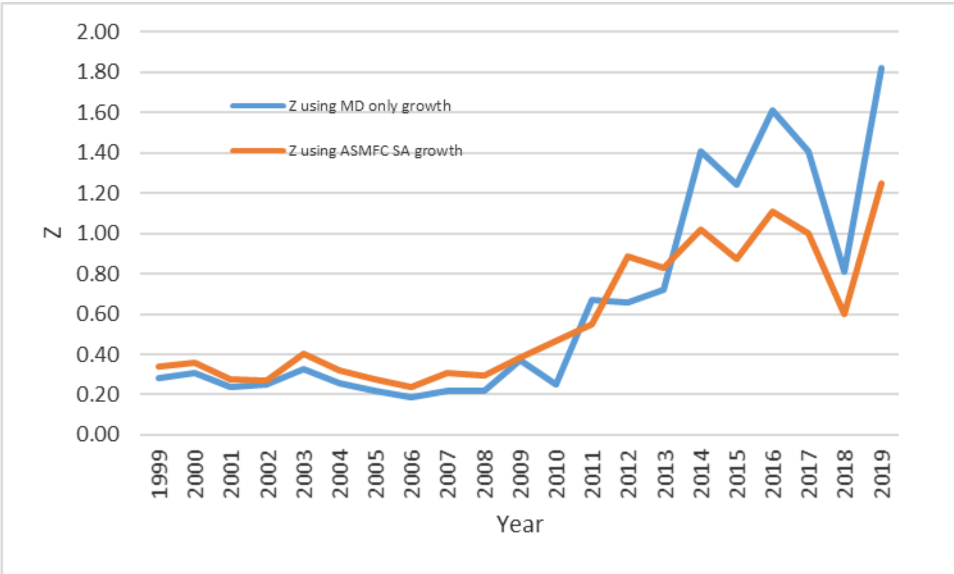


Figure 24. Spot length frequency distributions from onboard pound net sampling, 2010-2019.

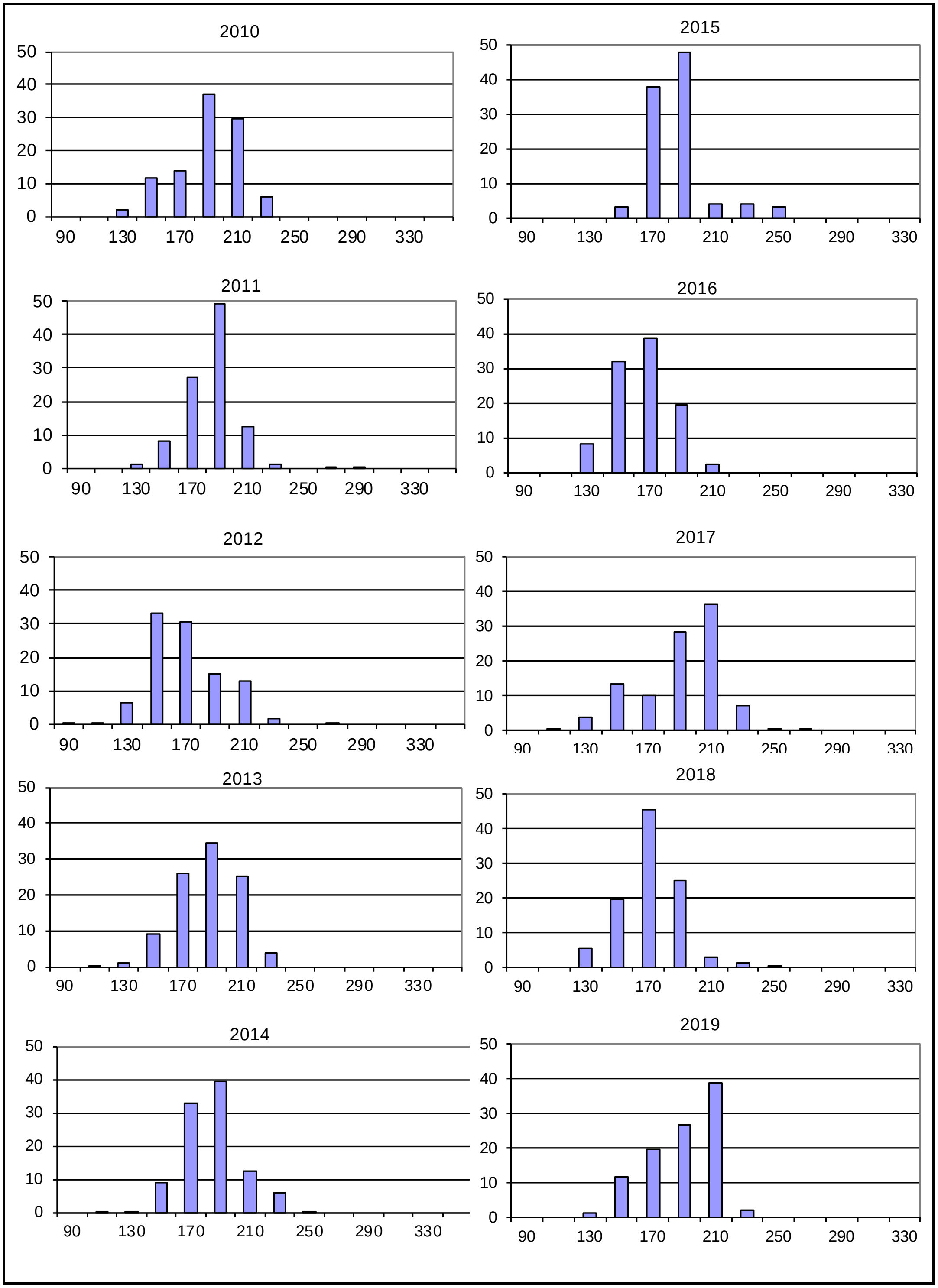


Figure 25. Spot length frequency distributions from seafood dealer sampling in 2017-2019.

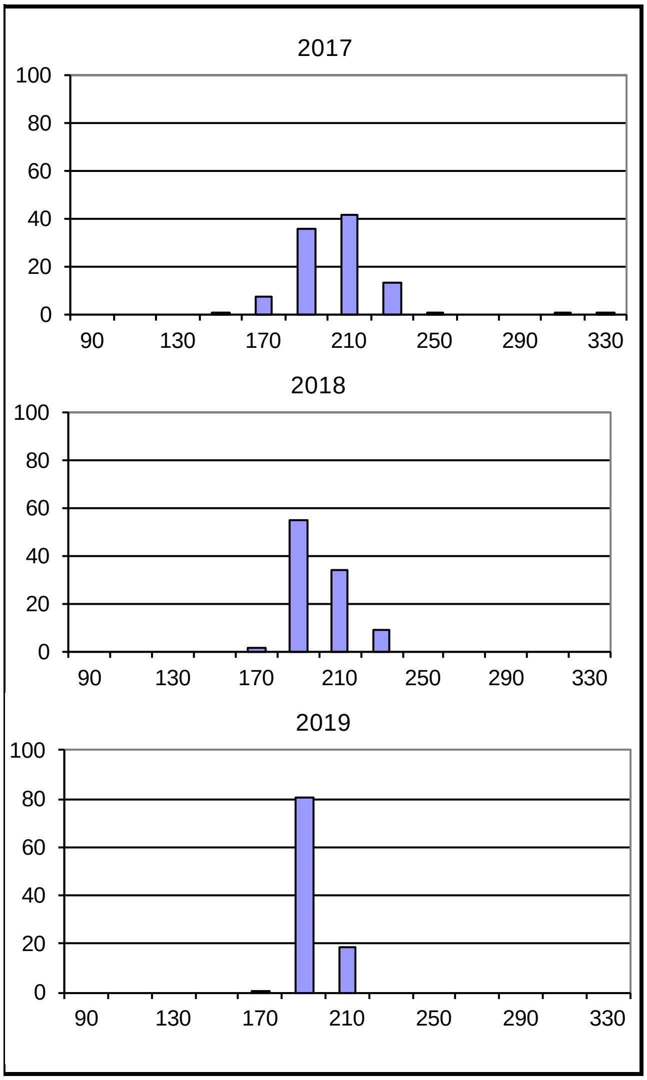


Figure 26. Geometric mean catch per hour of spot for the Choptank River gill net survey, 2013-2019.

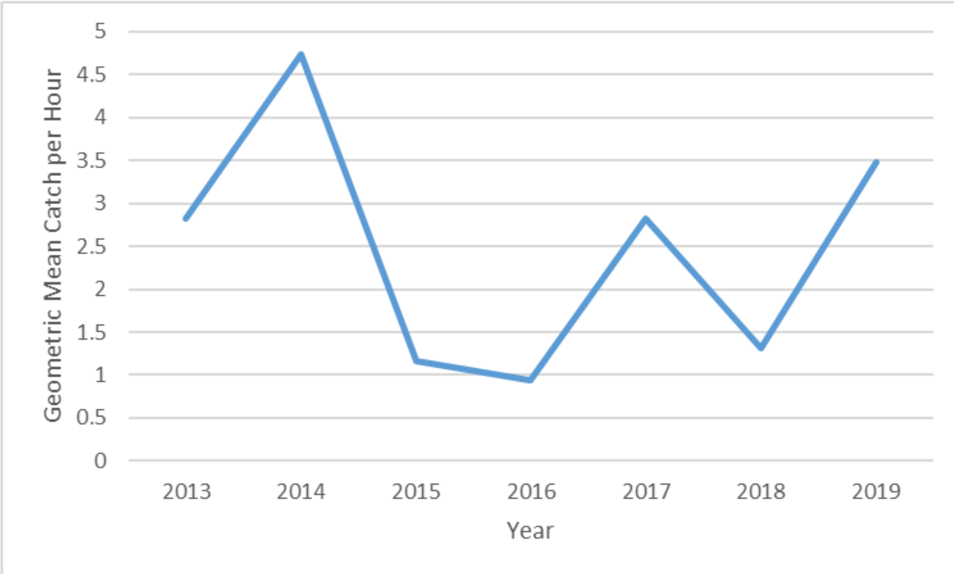


Figure 27. Proportion of spot captured in the Choptank River gill net survey by mesh size and year, 2013-2019.

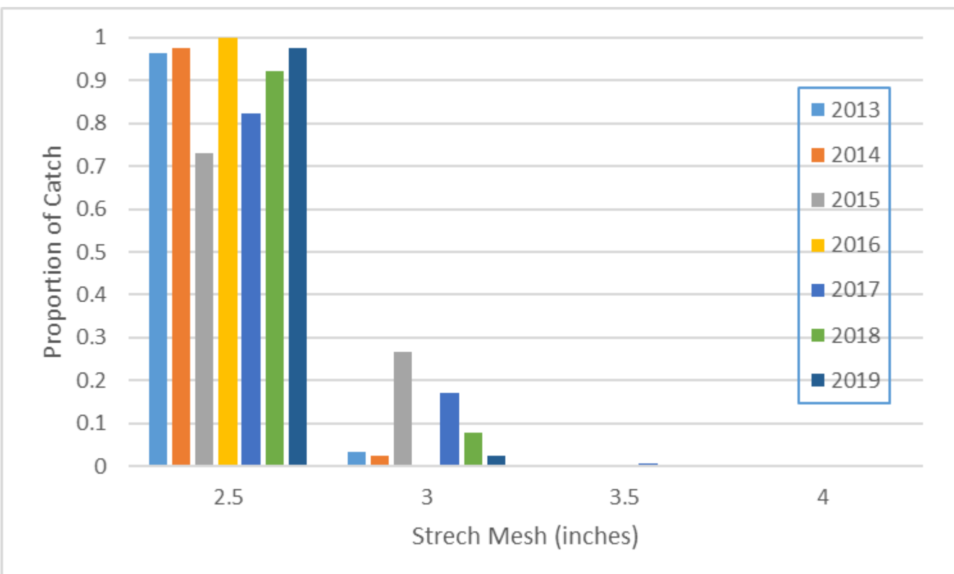


Figure 28. Spot length frequency distributions from the Choptank River gill net survey for 2013-2019.

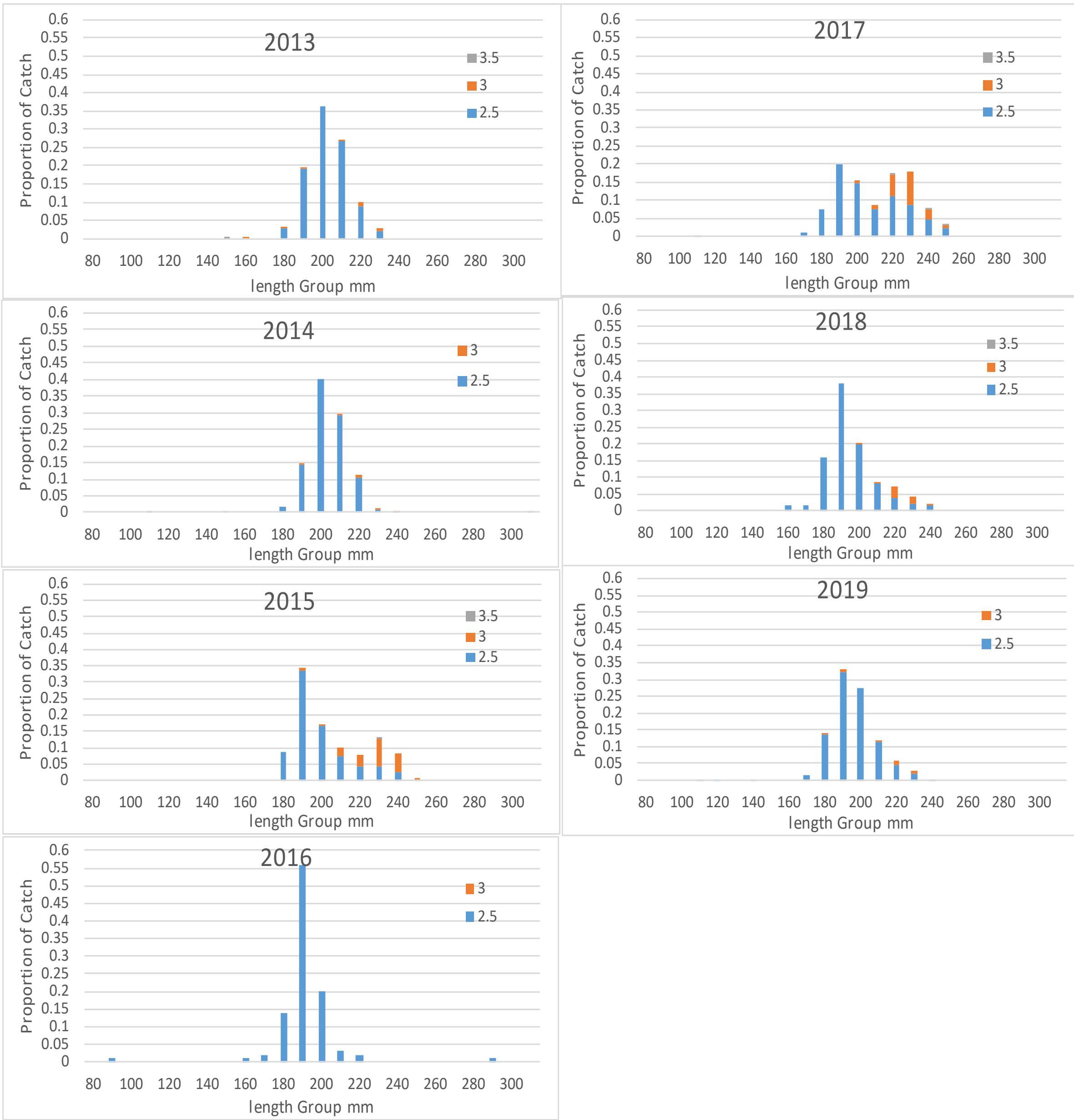


Figure 29. Maryland's commercial landings of spot in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational spot harvest and release estimates in numbers from 1981-2018.

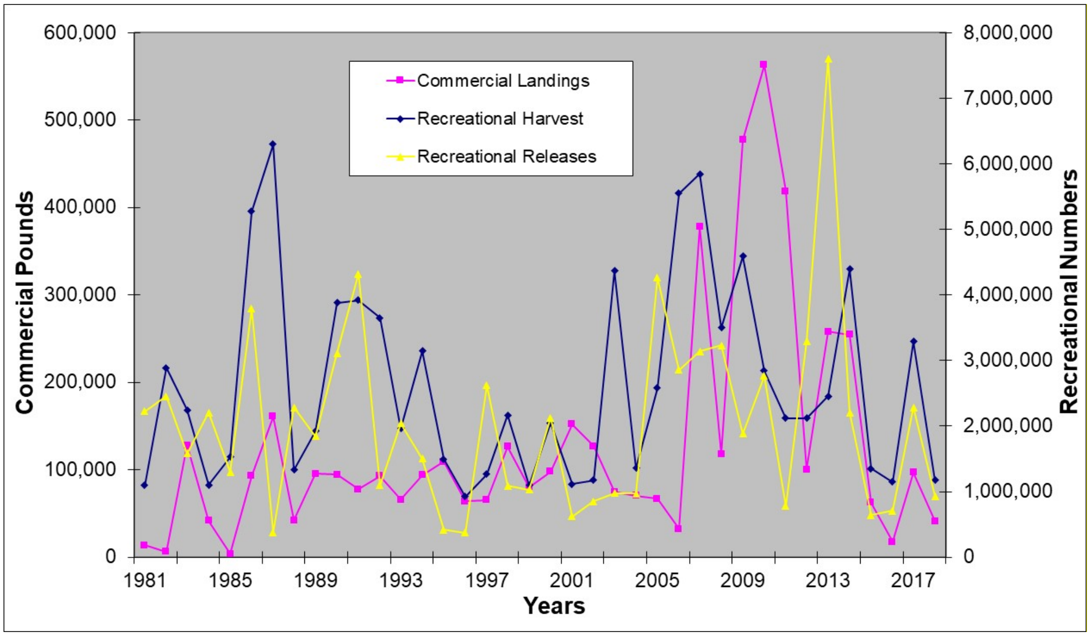


Figure 30. Maryland charter boat log book spot harvest in numbers and the number of anglers participating in trips catching spot, 1993-2018.

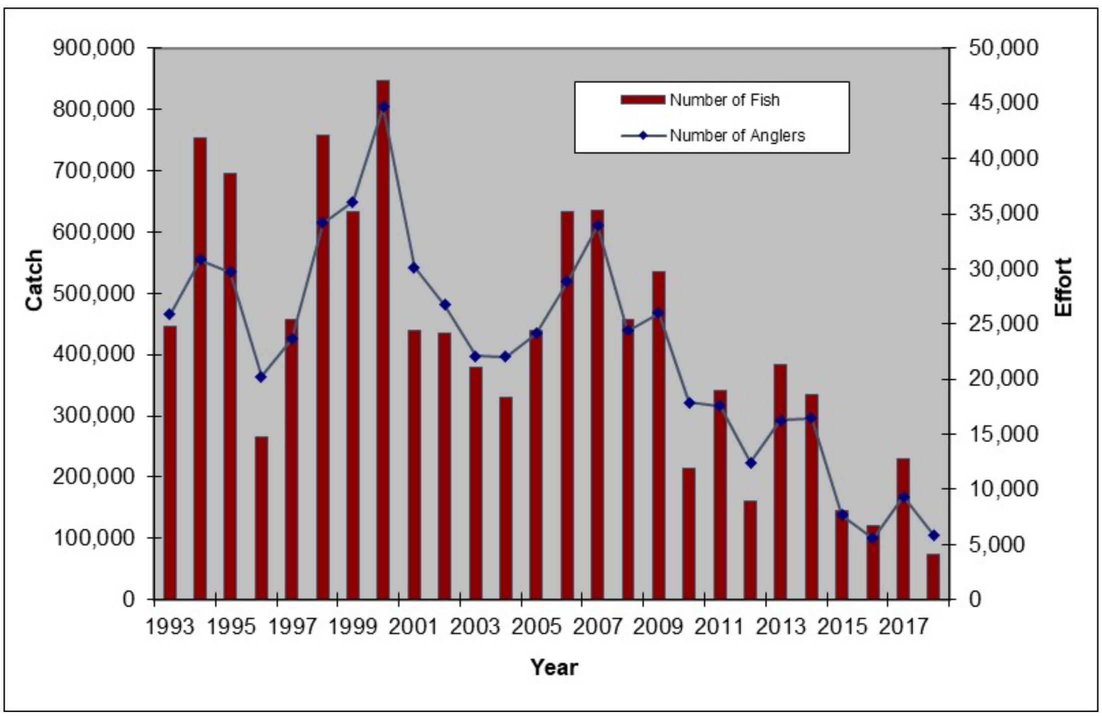


Figure 31. Maryland juvenile spot geometric mean catch per trawl, 95% confidence intervals and time series mean for Maryland's lower Chesapeake Bay, 1989-2019.

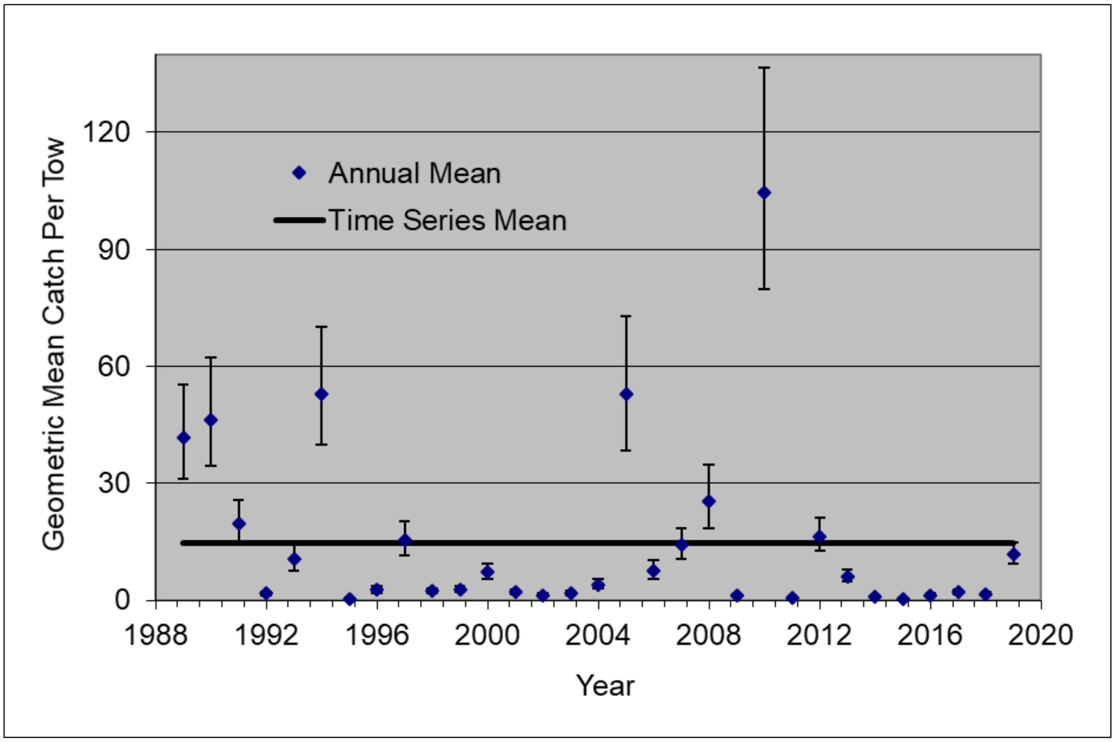


Figure 32. Maryland's commercial landings of red drum in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational red drum harvest and release estimates in numbers from 1981-2018.

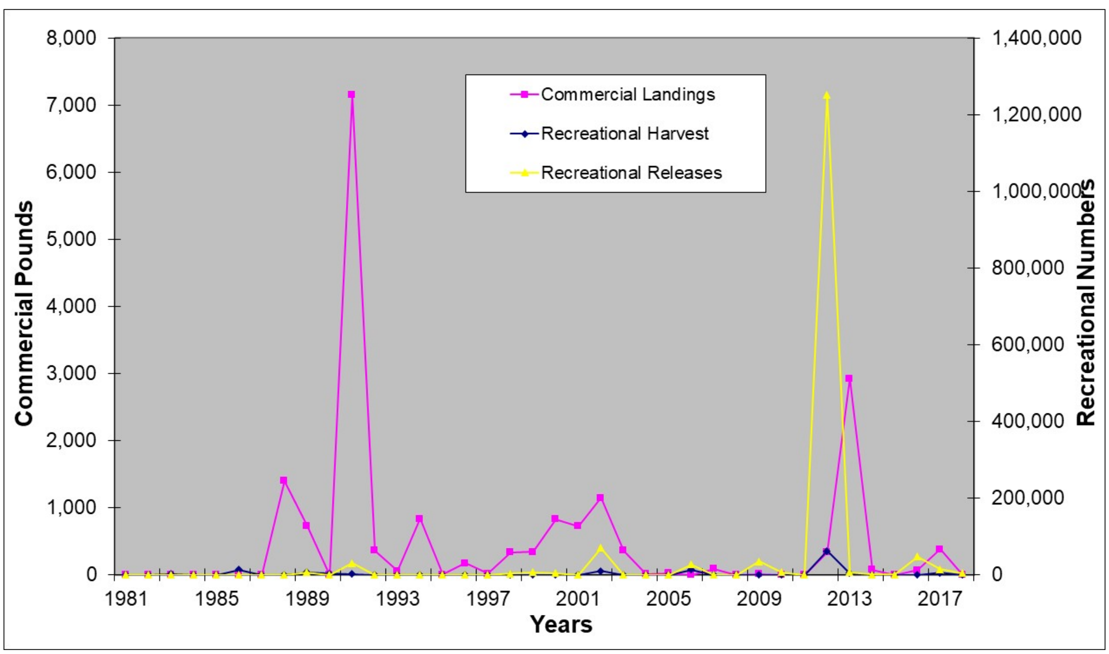


Figure 33. Maryland charter boat log book red drum harvest in numbers and the number of anglers participating in trips catching red drum, 1993-2018.

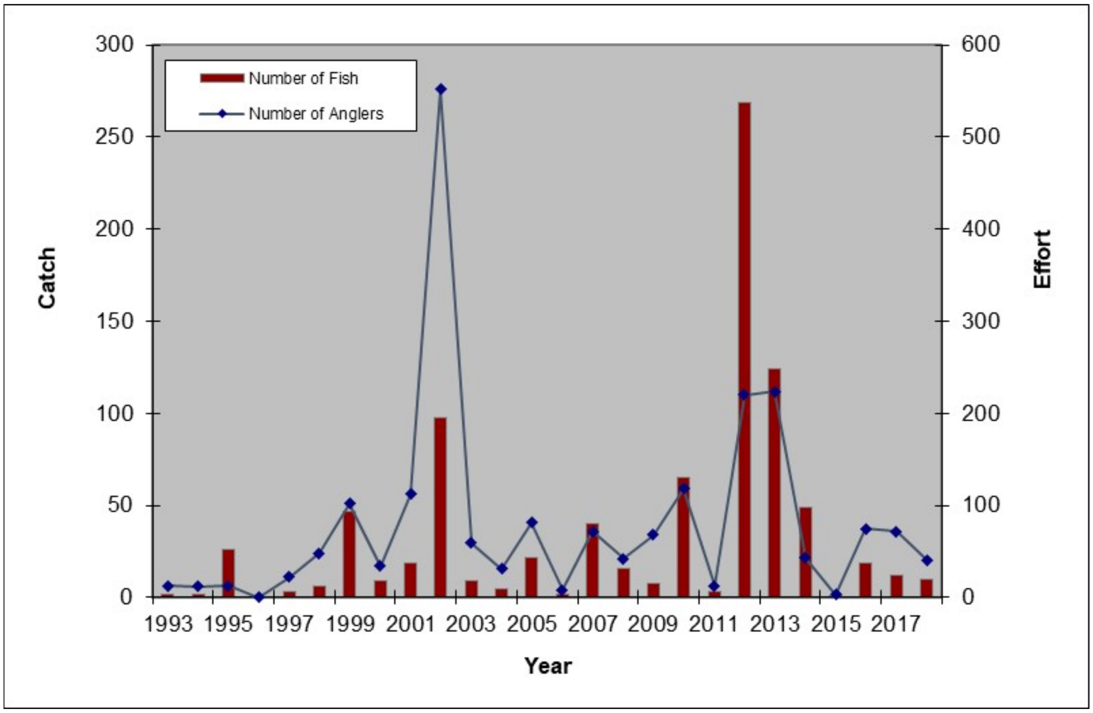


Figure 34. Maryland's commercial landings of black drum in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational black drum harvest and release estimates in numbers from 1981-2018.

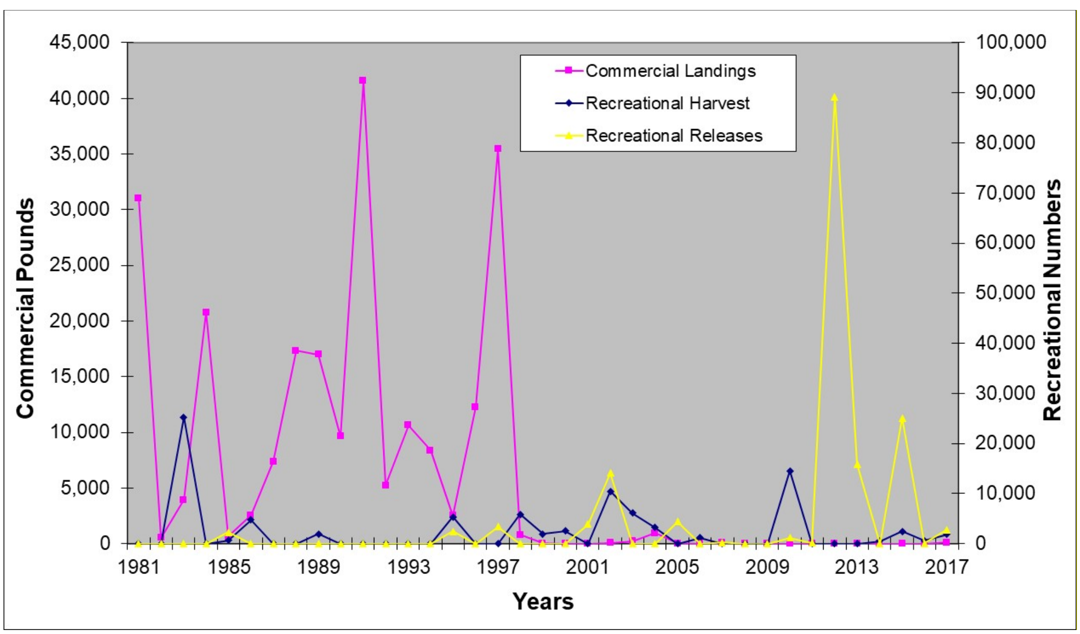


Figure 35. Maryland charter boat log book black drum harvest in numbers and the number of anglers participating in trips catching black drum, 1993-2018.

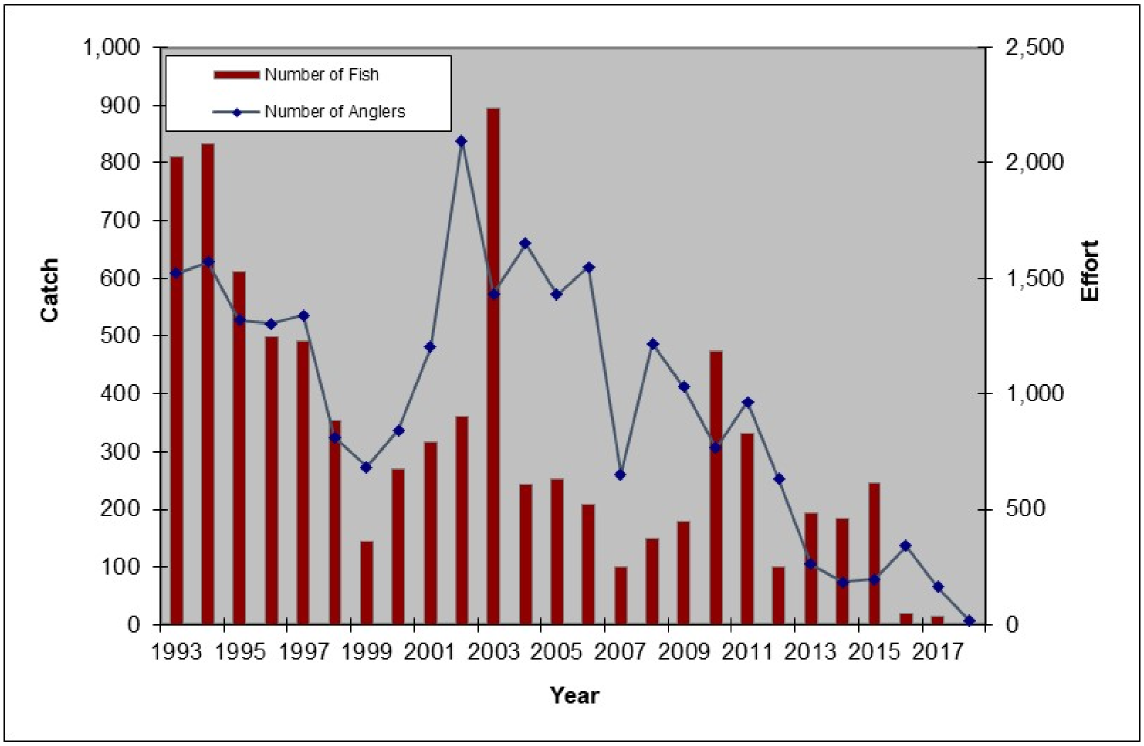


Figure 36. Maryland's commercial landings of Spanish mackerel in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational Spanish mackerel harvest and release estimates in numbers from 1981-2018.

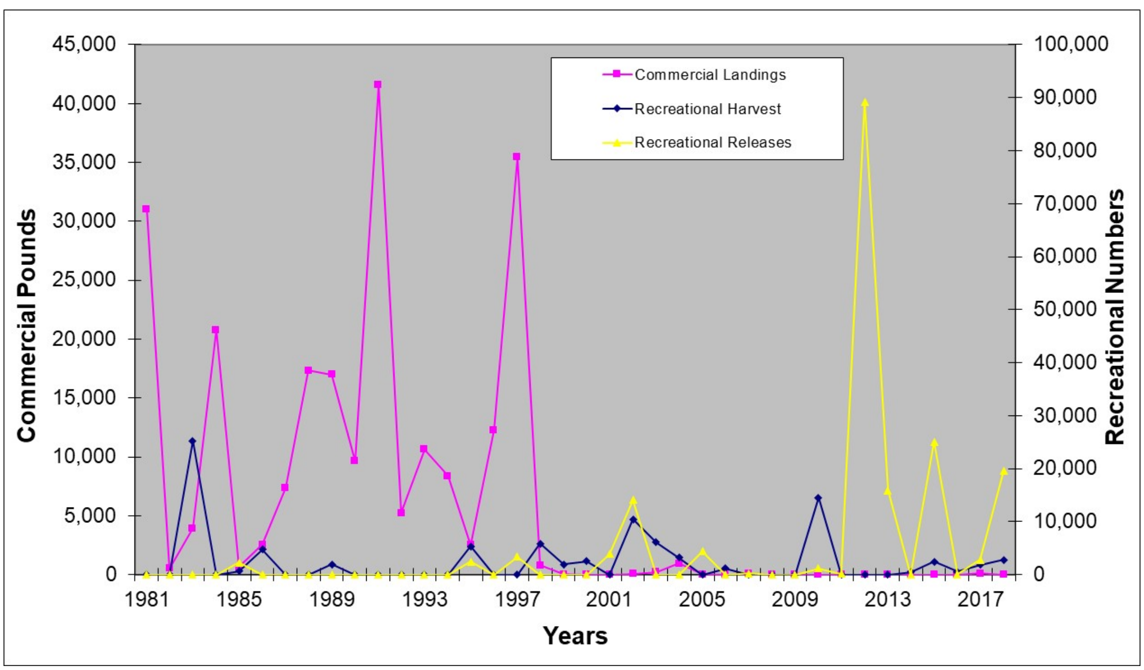


Figure 37. Maryland charter boat log book Spanish mackerel harvest in numbers and the number of anglers participating in trips catching Spanish mackerel, 1993-2018.

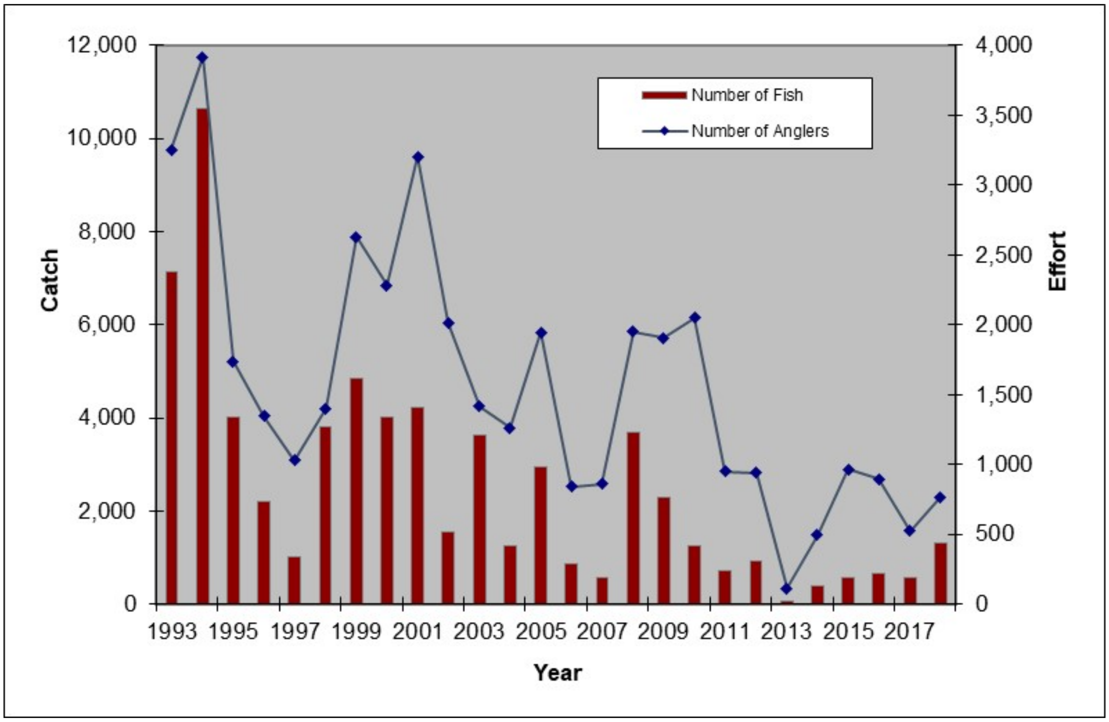


Figure 38. Maryland's commercial landings of spotted seatrout in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational spotted seatrout harvest and release estimates in numbers from 1981-2018.

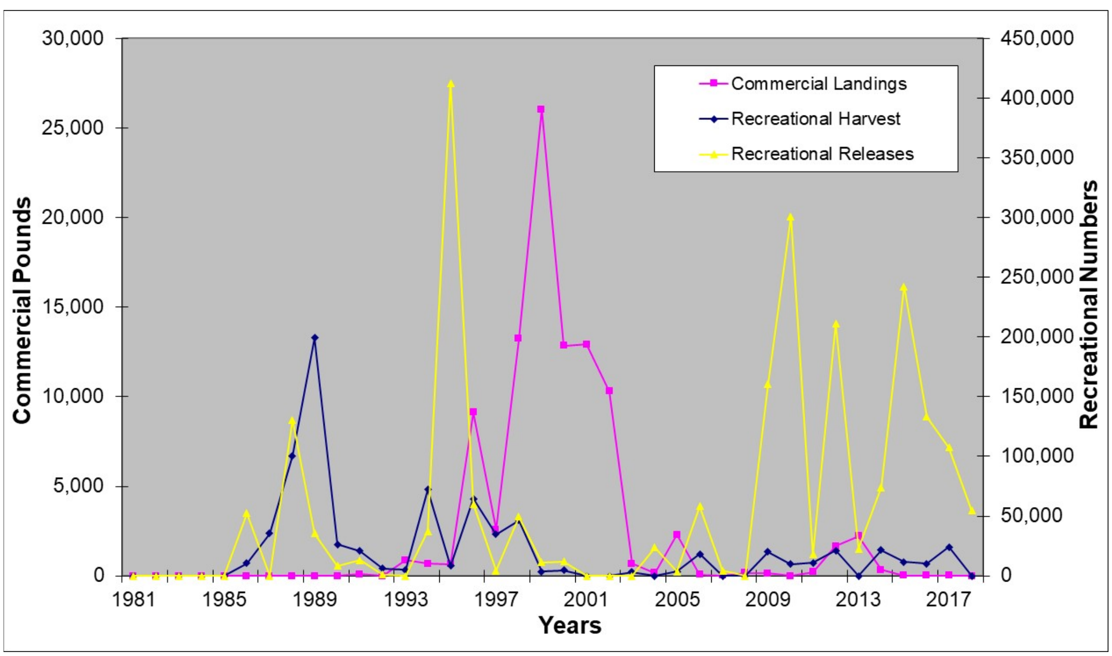


Figure 39. Maryland charter boat log book spotted seatrout harvest in numbers and the number of anglers participating in trips catching spotted seatrout, 1993-2018.

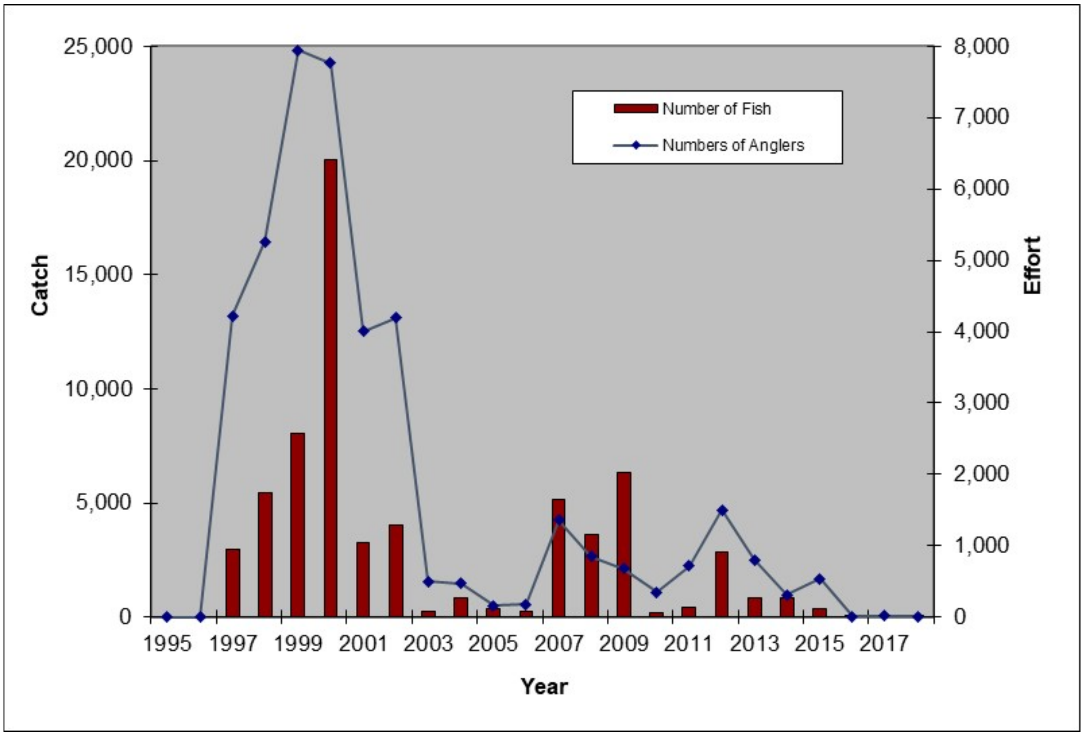


Figure 40. Atlantic menhaden length frequency distributions from onboard pound net sampling, 2010-2019, in 2012 the 230 FL value is 40 percent.

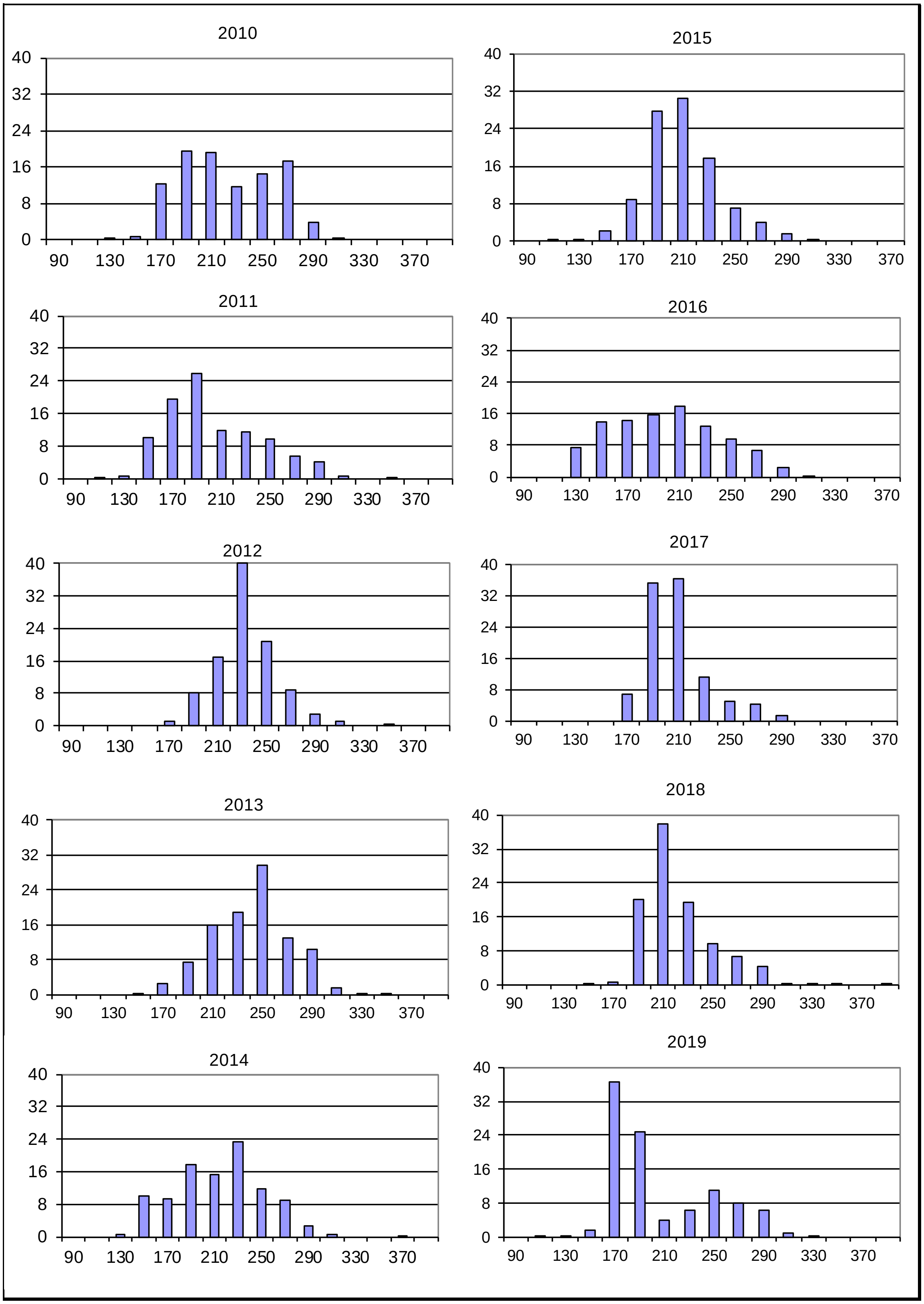


Figure 41. Atlantic menhaden length frequency distributions from seafood dealer sampling in 2019.

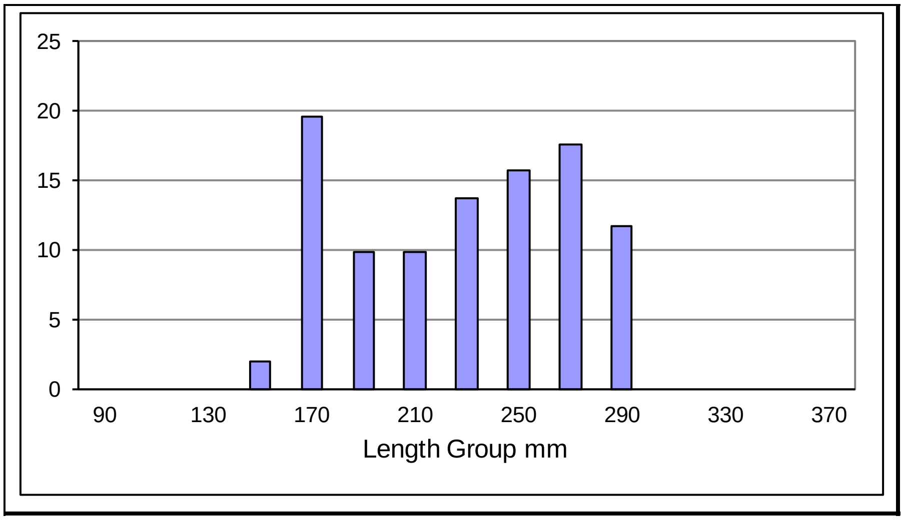


Figure 42. Geometric mean catch per hour of Atlantic menhaden for the Choptank River gill net survey, 2013-2019.

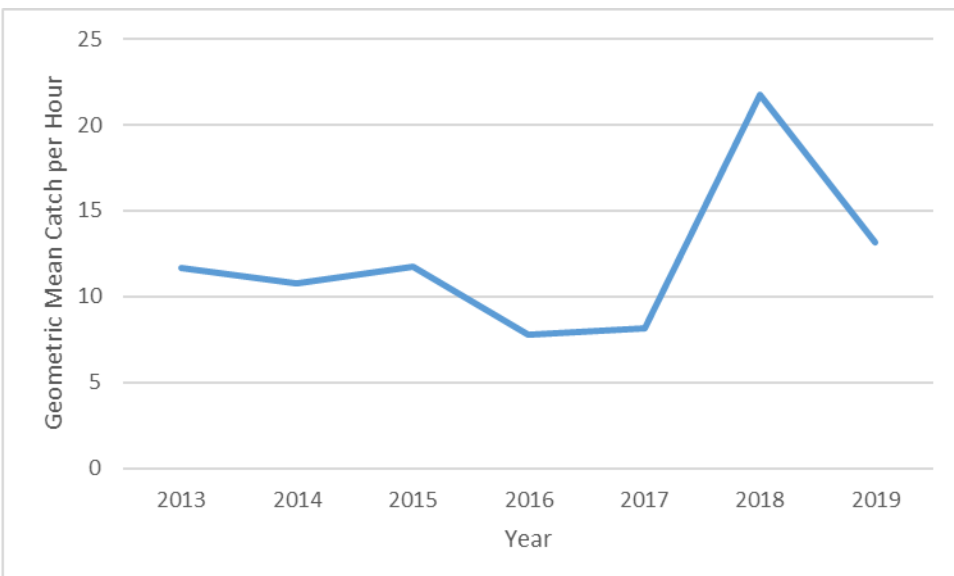


Figure 43. Atlantic menhaden proportion of catch by panel and year from the Choptank River gill net survey, 2013-2019.

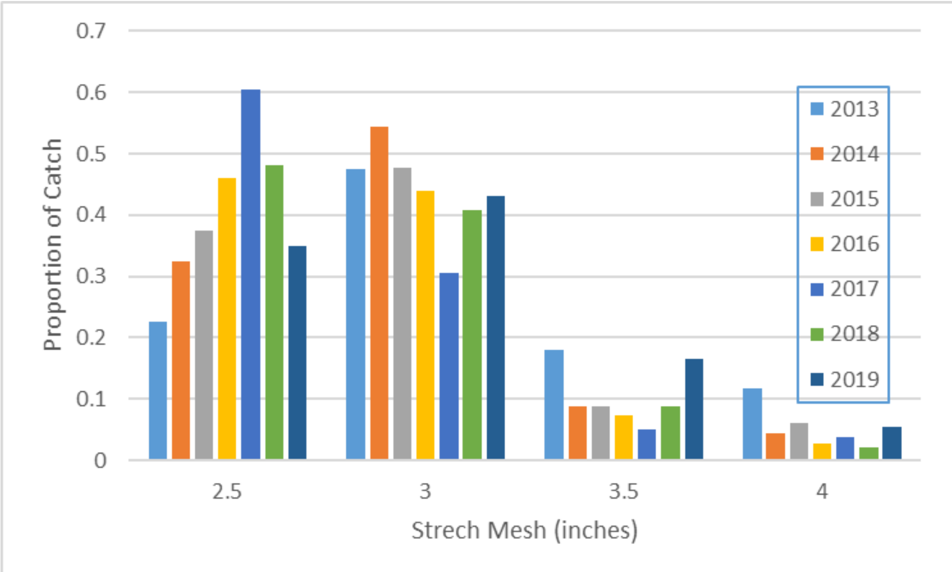


Figure 44. Atlantic menhaden length frequency distributions from the Choptank River gill net survey by year, 2013-2019.

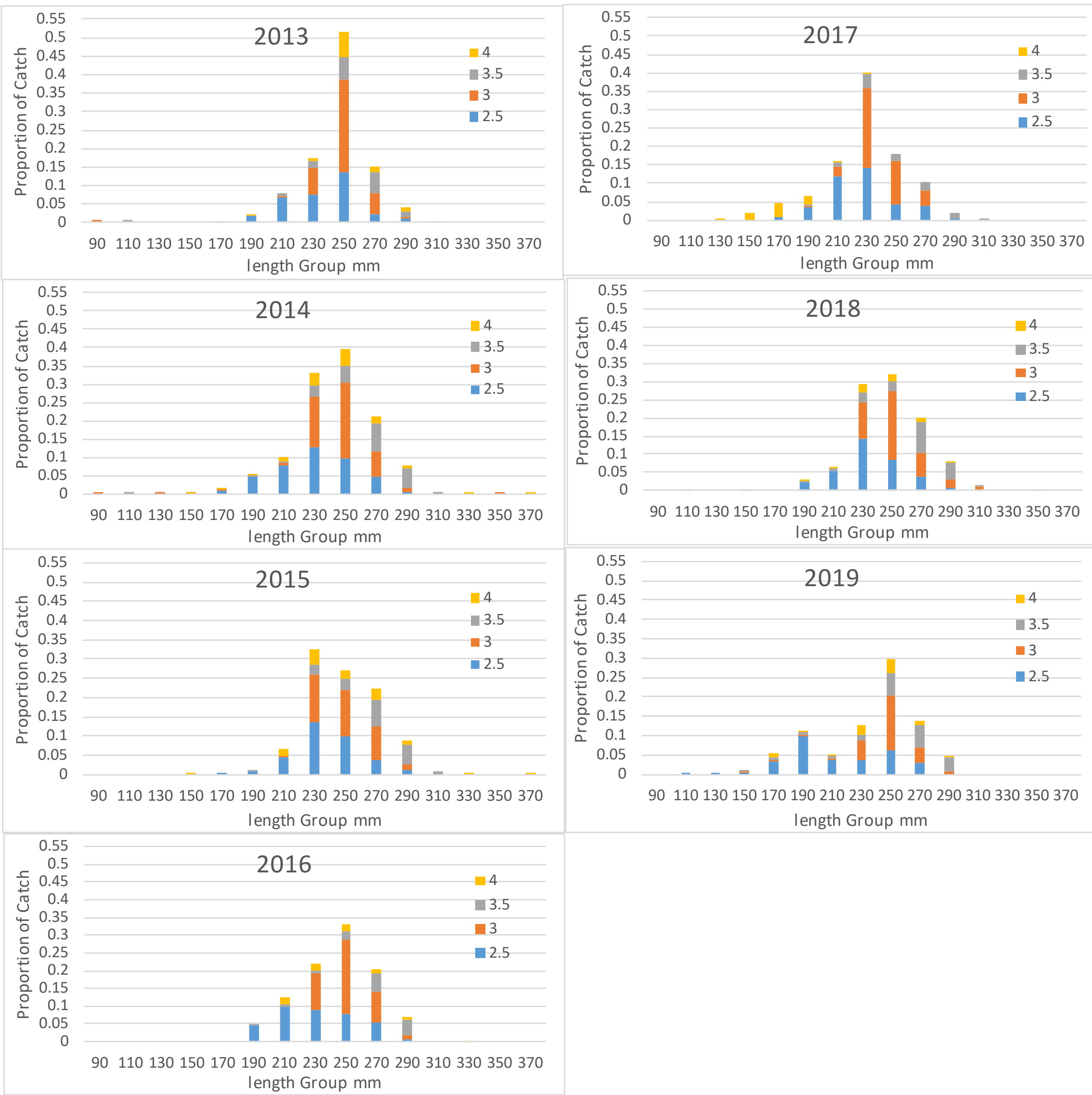
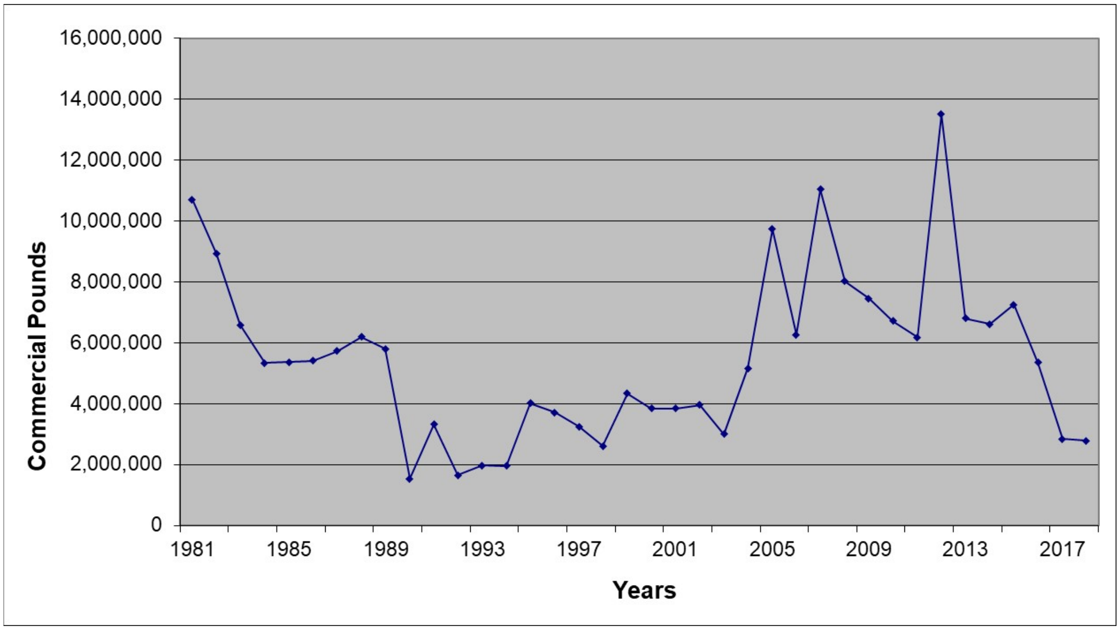


Figure 45. Maryland's Chesapeake Bay commercial landings for Atlantic menhaden from 1981-2018.



PROJECT NO. 2
JOB NO 3.
TASK NO. 1A

SUMMER – FALL STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

Prepared by Jeffrey Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1A was to finalize the characterization of the size and age structures of the 2018 Maryland striped bass *Morone saxatilis* commercial summer/fall fishery and provide preliminary results, as available, for the 2019 summer/fall season. Completed results for the 2019 summer/fall sample season will be reported in the F61-R-16 Chesapeake Bay Finfish Investigations report. The 2018 commercial summer/fall fishery operated on a combination of common pool and individual transferable quota (ITQ) systems (see Project 2, Job 3, Task 5A). The 2018 ITQ commercial summer/fall fishery was open from 1 June through 31 December for pound net gear and 1 June through 30 November for hook and line gear. The 2018 common pool fishery was open two days each month from June to November. These fisheries targeted resident/pre-migratory striped bass. Harvested fish were sampled at commercial check stations and additional fish were sampled by visiting pound nets throughout the season.

In addition to characterizing the size and age structures of the commercial catch, data from this survey were used to monitor temporal trends in size-at-age of the harvest. These data also provided the foundation for the construction of the Maryland catch-at-age matrix utilized by the Atlantic States Marine Fisheries Commission (ASMFC) in coastal striped bass stock assessment. Length and age distributions constructed from the 2018 commercial summer/fall fishery were used to characterize the length and age structure of the summer/fall 2018 Chesapeake Bay commercial harvest and the majority of the summer/fall recreational harvest.

METHODS

Commercial pound net monitoring

Before sampling was implemented at check stations in 2000, fish were sampled only from pound nets. Between 1993 and 1999, pound net monitoring and accompanying tagging studies were restricted to legal-sized striped bass (≥ 457 mm or 18 inches TL). In 2000, full-net sampling was initiated at pound nets in an effort to quantify the size and age structure of striped bass catch. Commercial pound net monitoring had been conducted in tandem with a mark-recapture study designed to estimate the total instantaneous fishing mortality rate (F) on resident Chesapeake Bay striped bass (Hornick et al. 2005). In 2005, the tagging study was eliminated but striped bass were still sampled monthly from pound nets to continue the characterization of the resident stock.

From 1993-1999, it was assumed that the size and age structures of striped bass sampled at pound nets were representative of the size and age structures of striped bass landed by the commercial pound net fishery. This assumption was questioned because commercial fishermen sometimes removed fish over 650 mm TL from nets prior to Fishing and Boating Services (FABS) staff examination, or during the culling process. These larger striped bass are highly marketable, so fishermen prefer to sell them rather than let them be tagged and released. In 2000, potential biases in the tagging study length distributions were ascertained by adding a check station component to the commercial pound net monitoring (MD DNR 2002). This allowed for the direct comparison of the length distribution of striped bass sampled from pound nets to the length distribution of harvested striped bass sampled at check stations.

Pound net sampling occurred two to seven times per month from June through November 2018 (Table 1). The pound nets sampled were not randomly selected, but were chosen according to watermen's schedules and the best chance of obtaining fish. During 2018, striped bass were sampled from pound nets in the upper and lower Bay. Whenever possible, all striped bass in a pound net were measured in order to characterize by-catch. A full net sample was not possible when pound nets contained too many fish to be transferred to holding tanks on FABS boats. If a full net could not be sampled, a random sub-sample was taken.

At each net sampled, striped bass were measured for total length (mm TL), and the presence and category of external anomalies were noted. Scales were removed from two fish per 10 mm length group per month, up to 700 mm TL, and from all fish greater than 700 mm TL. Other data recorded included latitude and longitude, date the net was last fished, depth, surface salinity, surface water temperature, air temperature, Secchi depth (m), and whether the net was fully or partially sampled.

Commercial summer/fall check station monitoring

All striped bass harvested in Maryland's commercial striped bass fisheries are required to pass through a MD DNR approved check station (see Project 2, Job 3, Task 5A). Check stations across Maryland were sampled for summer/fall harvested fish each month from June through November 2018 (Figure 1). The change to an ITQ system resulted in the use of one type of commercial tag for all gears and prevented differentiation between pound net and hook and line harvested striped bass because the seasons are concurrent. Therefore, the combined fishery will be referred to as the summer/fall fishery for sampling purposes. An overall sample size target was established based on the combined hook and line and pound net targets from previous years. This resulted in a sample target of 500 fish per month for the season. Original target sample sizes were based on methods and age-length keys (ALKs) derived from the 1997 and 1998 MD DNR pound net tagging studies. Check stations were chosen by monitoring their activity and selecting from those landing 8% or more of the monthly harvest in the previous year. Stations that reported higher harvests were sampled more frequently. This method generally distributed the sampling effort so that sample sizes were proportional to landings.

Scale samples were removed from two fish per 10 mm length group per visit from fish less than 700 mm TL (maximum three samples per length group per month) and from all fish greater than 700 mm TL. A subsample of five fish per 10 mm length group per trip was used if a high number of large fish 700 to 800 mm TL were encountered. All scales from fish >800 mm TL were taken.

Analytical Procedures

Scale ages from the pound net and check station surveys were combined and applied to all fish lengths sampled. Striped bass sampled from pound nets and from commercial hook and line check stations do not significantly differ in length at age (Fegley 2001). Striped bass harvested by each gear exhibited statistically indistinguishable ($P>0.05$, $F=0.8532$) and nearly identical age-length relationships; therefore ages derived from one fishery could be applied to the other. This is not surprising since both fisheries are concurrent within Maryland, and minimum and maximum size regulations are identical.

Age composition of the summer/fall fishery was estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). In the first stage, total length and scale samples were taken based on 10 mm length groups, which were assumed to be a random sample of the commercial harvest. In stage two, a fixed sub-sample of scales were randomly chosen to be aged based on 20 mm length groups. Scales from check stations and pound net monitoring were combined to create the ALK. Approximately twice as many scale samples as ages per length group were selected to be read based on the variance of ages per length group (Barker et al. 2004). Target sample sizes were: length group<300 mm=3 scales per length group; 300-400 mm=4 scales per length group; 400-700 mm=5 scales per length group; >700 mm=10 scales per length group. In some cases, the actual number of scales aged was limited by the number of samples available per length group.

Year-class was determined by reading acetate impressions of the scales placed in microfiche readers, and age was calculated by subtracting year-class from collection year. The resulting ages were used to construct an ALK. The catch-at-age for the fishery was calculated by applying the ALK to the summer/fall fishery sampled length frequency and expanding the resulting age distribution to the landings for the summer/fall fishery.

To determine recruitment into the summer/fall fishery, the age structure of the harvest over time was examined. The age structure of the harvest for the 2018 summer/fall fishery was also compared to previous years. An ANOVA with a Duncan's multiple range test (SAS 2006) was performed to compare lengths and weights of striped bass harvested between months in 2018.

Mean length- and weight-at-age of striped bass landed in the summer/fall fishery were derived by applying ages to all sampled fish, and then weighting the means on the length distribution at each age. Mean length- and weight-at-age were calculated by year-class for the aged sub-sample of fish. Mean length-at-age and weight-at-age were also estimated for each year-class using an expansion method. Expanded means were calculated with an age-length key and a probability table which applied ages from the sub-sample of aged fish to all sampled fish. Due to non-normality, age-specific length distributions based on the aged sub-sample are often biased compared to the age-specific length distribution based on the entire length sample (Bettoli and Miranda 2001). Finally, length frequencies from the pound net monitoring and check station samples were examined.

RESULTS and DISCUSSION

Commercial pound net monitoring

During the 2018 striped bass pound net study, a total of 4,868 striped bass were sampled from six pound nets in the upper Bay and three pound nets in the lower Bay. The nine nets were sampled a total of 27 times during the study (Table 1).

Striped bass sampled from pound nets ranged from 255-882 mm TL, with a mean length of 485 mm TL (Figure 2). In 2018, 62% of striped bass collected from full net samples were less than the commercial minimum legal size of 18 inches (457 mm) TL and 46% of fish from partially sampled nets were sub-legal.

Mean total length of the aged sub sample are presented in Table 2. Striped bass sampled from pound nets ranged from 1 to 14 years of age when the combined age length key was applied to the entire sample (Table 3, Figure 2). Age 3 fish from the above average 2015 year-class contributed 35% of the sample. Age 7 fish from the above average 2011 year-class contributed 16% in 2018, which was similar to the contribution in the previous year (17%). Striped bass age 6 and older comprised 25% of the sample, which was higher than their contribution in the previous year (21%; Figure 3).

Commercial summer/fall check station monitoring

A total of 2,086 striped bass were sampled at summer/fall check stations in 2018. The mean length of sampled striped bass was 575 mm TL. Length frequencies of legal sized striped bass (n=2,378) sampled at pound nets were similar to length distributions from the check stations (Figure

4). Striped bass sampled from the summer/fall fishery ranged from 443 to 926 mm TL and from 3 to 12 years of age (Figure 5). Less than 1% of the sampled harvest was sub-legal (<457 mm TL). Mean lengths-at-age and weights-at-age of the aged sub sample for the 2018 summer/fall fishery are shown in Tables 4 and 5.

Striped bass in the 450-550 mm length groups accounted for 52% of the summer/fall harvest (Figure 5). Larger fish from the above average 2011 year-class have influenced the number of larger fish in the harvest. Striped bass over 700 mm TL were harvested throughout the season (Figure 6) and contributed 9% to the overall harvest. Historically, these fish have not been available in large numbers during the summer (MD DNR 2002).

The 2018 summer/fall reported harvest accounted for 56%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2018 with 798,885 pounds landed (see Project 2, Job 3, Task 5A). Landings reported by the MD DNR commercial reporting section were 122,894 pounds for hook and line gear and 675,991 pounds for pound net gear. The combined length frequency and ages of the sampled fish were applied to the total summer/fall fishery harvest. The estimated 2018 catch-at-age in pounds and numbers of fish for the summer/fall fishery is presented in Table 6. A fourteen year old fish (2004 year-class) was encountered in pound net monitoring, but was not encountered in the check station subsample so no weight was available for a fish of this age. By weight, the majority (89%) of the harvest was composed of four to seven year-old striped bass. Striped bass from the above average 2011 (age 7) year class contributed 30% to the harvest and were the highest contribution to the fishery. Striped bass from the 2014 year class (age 4) contributed the second highest percentage to the harvest (26%). Striped bass age 8 and older contributed 5% to the overall harvest in 2018, which was similar to 2017 (7%).

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 52% of the 2018 summer/fall harvest (Figure 5). A similar percentage of fish >630 mm TL were harvested in 2018 (28%) compared to 2017 (34%). In 2018, 115 fish from pound net monitoring and 84 fish from check station sampling were aged. Younger fish (age 4 to 7) were abundant, accounting for the majority of the harvest (Figure 7). Length frequencies of legal-sized fish sampled from pound nets and all fish from check stations were almost identical, except for a small increase in frequency around 630-670 mm (Figure 4). Mean lengths-at-age have remained nearly the same since 2000 (Figure 8).

A Duncan's multiple range test (SAS 2006) was performed on lengths and weights of striped bass harvested between months (α=0.05). Striped bass were significantly larger (TL= 626 mm and WT=2.51 kg) in June and smaller in August (TL=523 mm and WT=1.24 kg, respectively). Lengths and weights were similar in July and October (TL=601 mm, 596 mm, and WT=2.19 kg, 2.18 kg), respectively. Duncan's groups are presented in Tables 7 and 8.

PROJECT NO. 2
JOB NO 3.
TASK NO. 1A

SUMMER – FALL STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

2019 PRELIMINARY RESULTS – WORK IN PROGRESS

Commercial pound net monitoring

During the 2019 striped bass pound net study, a total of 7,167 striped bass were sampled and 561 scale samples were collected for ageing from two pound nets in the upper Bay one pound net in the middle Bay and six pound nets in the lower Bay. The nine nets were sampled a total of 29 times during the study.

Striped bass sampled from pound nets ranged from 184-953 mm TL, with a mean length of 469 mm TL. A complete breakdown of catch by length and age for the 2019 summer/fall season will be available in the F61-R-16 Chesapeake Bay Finfish Investigations report.

Commercial summer/fall check station monitoring

A total of 1,897 striped bass were sampled and 324 scale samples were collected for ageing at summer/fall check stations in 2019. The mean length of sampled striped bass was 534 mm TL. Striped bass sampled from the summer/fall fishery ranged from 446 to 880 mm TL. Less than 1% of the sampled harvest was sub-legal (<457 mm TL). Mean lengths-at-age and weights-at-age will be available in the next F-61 Chesapeake Bay Finfish Investigations report.

CITATIONS

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Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2018 Maryland Chesapeake Bay commercial pound net monitoring survey.

Month	Area	Number of Nets Sampled	Mean Water Temp (°C)	Mean Salinity (ppt)	Number of Fish Sampled
June	Upper	2	22.9	5.0	527
	Middle	-	-	-	-
	Lower	3	24.4	10.1	59
July	Upper	2	26.5	6.8	874
	Middle	-	-	-	-
	Lower	4	26.0	10.4	70
August	Upper	4	26.5	1.0	838
	Middle	-	-	-	-
	Lower	3	27.4	8.2	109
September	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	4	27.6	8.6	725
October	Upper	1	23.3	4.7	314
	Middle	-	-	-	-
	Lower	1	17.1	9.3	508
November	Upper	2	6.9	0.1	504
	Middle	-	-	-	-
	Lower	1	7.8	6.4	340

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2018.

Year-class	Age	n	Mean Length (mm TL)	Lower CL	Upper CL
2017	1	5	300	280	321
2016	2	8	333	319	346
2015	3	20	408	390	426
2014	4	16	467	429	504
2013	5	4	518	471	565
2012	6	10	672	599	746
2011	7	31	727	701	753
2010	8	5	751	651	851
2009	9	4	824	796	852
2008	10	3	838	765	912
2007	11	8	836	811	862
2006	12	0	-	-	-
2005	13	0	-	-	-
2004	14	1	871	*	*

*Due to low sample size, lower and upper CL values are not included.

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, June through November 2018. Sum of columns may not equal due to rounding.

Year-class	Age	Pound Net Monitoring	
		Number Sampled at Age (n)	Percent of Total
2017	1	48	1.0
2016	2	330	6.8
2015	3	1,694	34.8
2014	4	1,190	24.5
2013	5	367	7.5
2012	6	333	6.8
2011	7	784	16.1
2010	8	102	2.1
2009	9	7	0.1
2008	10	4	0.1
2007	11	9	0.2
2006	12	0	0
2005	13	0	0
2004	14	1	<0.1
Total		**4,868**	**100.0**

Table 4. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) sampled from the commercial summer/fall check stations in Maryland's Chesapeake Bay, June through November 2018.

Year-class	Age	n	Mean Length (mm TL)	Lower CL	Upper CL
2015	3	2	539	*	*
2014	4	11	509	483	535
2013	5	8	573	521	624
2012	6	8	641	568	715
2011	7	36	698	669	726
2010	8	6	722	664	780
2009	9	4	834	760	907
2008	10	3	854	754	953
2007	11	5	848	787	909
2006	12	1	815	*	*

*Due to low sample size, lower and upper CL values are not included.

Table 5. Mean weight-at-age (kg) of legal-size striped bass (≥457 mm TL/18 in TL) sampled from the commercial summer/fall check stations in Maryland's Chesapeake Bay, June through November 2018.

Year-class	Age	n	Mean Weight (kg)	Lower CL	Upper CL
2015	3	2	1.53	*	*
2014	4	11	1.23	1.07	1.40
2013	5	8	1.75	1.14	2.36
2012	6	8	2.47	1.59	3.36
2011	7	36	3.34	2.91	3.77
2010	8	6	3.54	2.70	4.38
2009	9	4	5.30	3.74	6.86
2008	10	3	6.39	5.38	7.41
2007	11	5	6.02	4.78	7.25
2006	12	1	5.97	*	*

*Due to low sample size, lower and upper CL values are not included.

Table 6. Estimated catch-at-age of striped bass landed by the Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2018.

Year-class	Age	Summer/Fall Total Catch at Age			
		Landings in Pounds of Fish	**Percent of Total**	**Landings in Numbers of Fish**	**Percent of Total**
2015	3	51,707	6.5	15,329	8.1
2014	4	210,975	26.4	77,802	41.3
2013	5	144,127	18.0	37,357	19.8
2012	6	114,405	14.3	21,010	11.1
2011	7	240,917	30.2	32,718	17.4
2010	8	27,858	3.5	3,570	1.9
2009	9	2,844	0.4	243	0.1
2008	10	1,561	0.2	111	0.1
2007	11	4,108	0.5	310	0.2
2006	12	383	0.0	29	<0.1
Total*		**798,885**	**100.0**	**188,479**	**100.0**

* Sum of columns may not equal totals due to rounding.

Table 7. Duncan's multiple range test for mean length by month for the Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2018. Months with the same Duncan grouping letter are not significantly different (α=0.05) in mean length.

Duncan Grouping	Month	Mean Length (mm)	Number of Fish Sampled
A	June	626	445
B	July	601	233
B	October	596	356
C	September	560	480
D	November	525	153
D	August	523	419

Table 8. Duncan's multiple range test for mean weight by month for the Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2018. Months with the same Duncan grouping letter are not significantly different (α=0.05) in mean weight.

Duncan Grouping	**Month**	**Mean Weight (kg)**	**Number of Fish Sampled**
A	June	2.51	445
B	October	2.19	356
B	July	2.18	233
C	September	1.61	479
D	November	1.45	153
E	August	1.24	419

Figure 1. Locations of Chesapeake Bay commercial summer/fall check stations and pound nets sampled from June through November 2018.

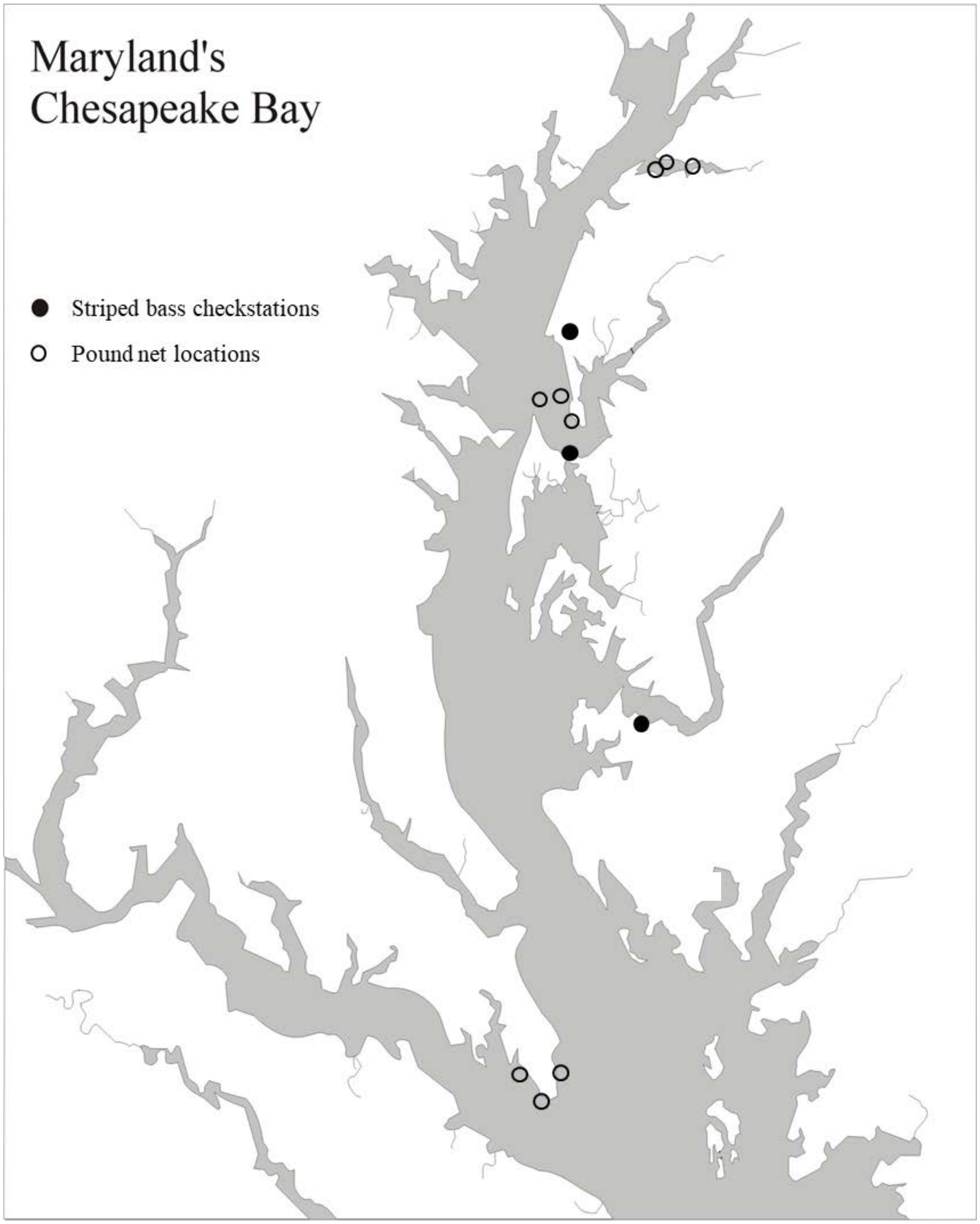


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, June through November 2018.

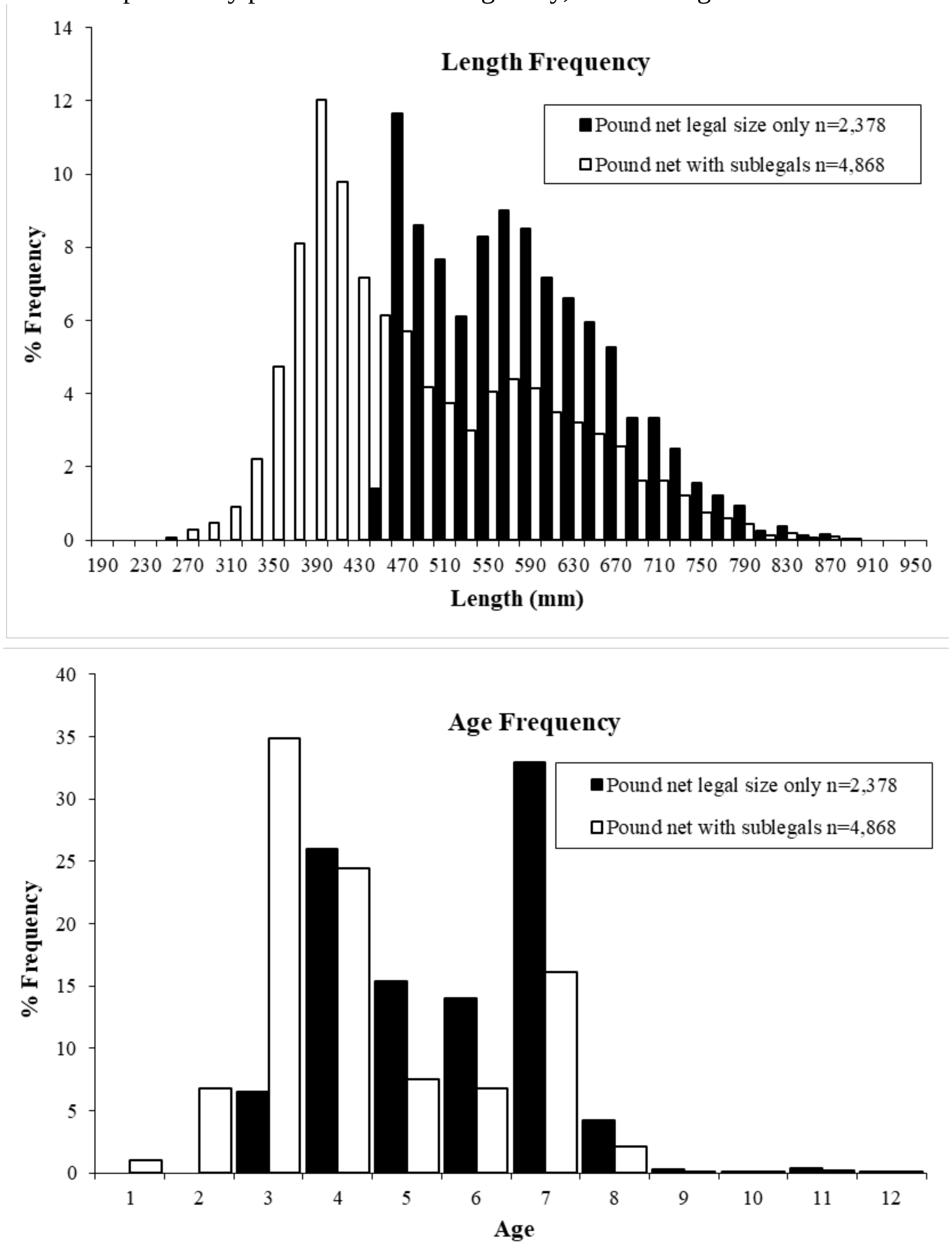


Figure 3. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2018. *Note partial net sampling for legal sized fish was conducted from 1996 to 1999. Full net samples started in 2000.

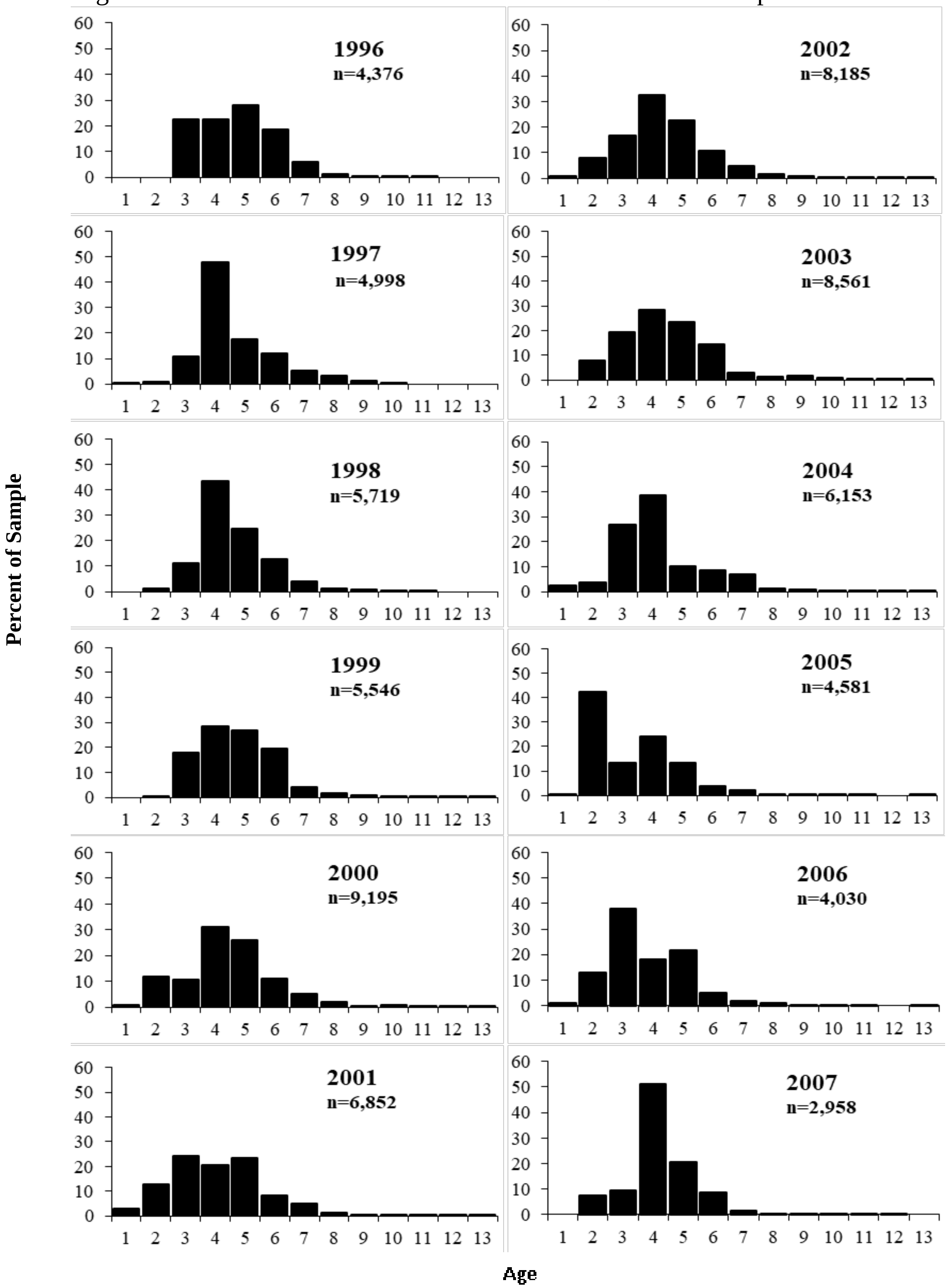


Figure 3. Continued.

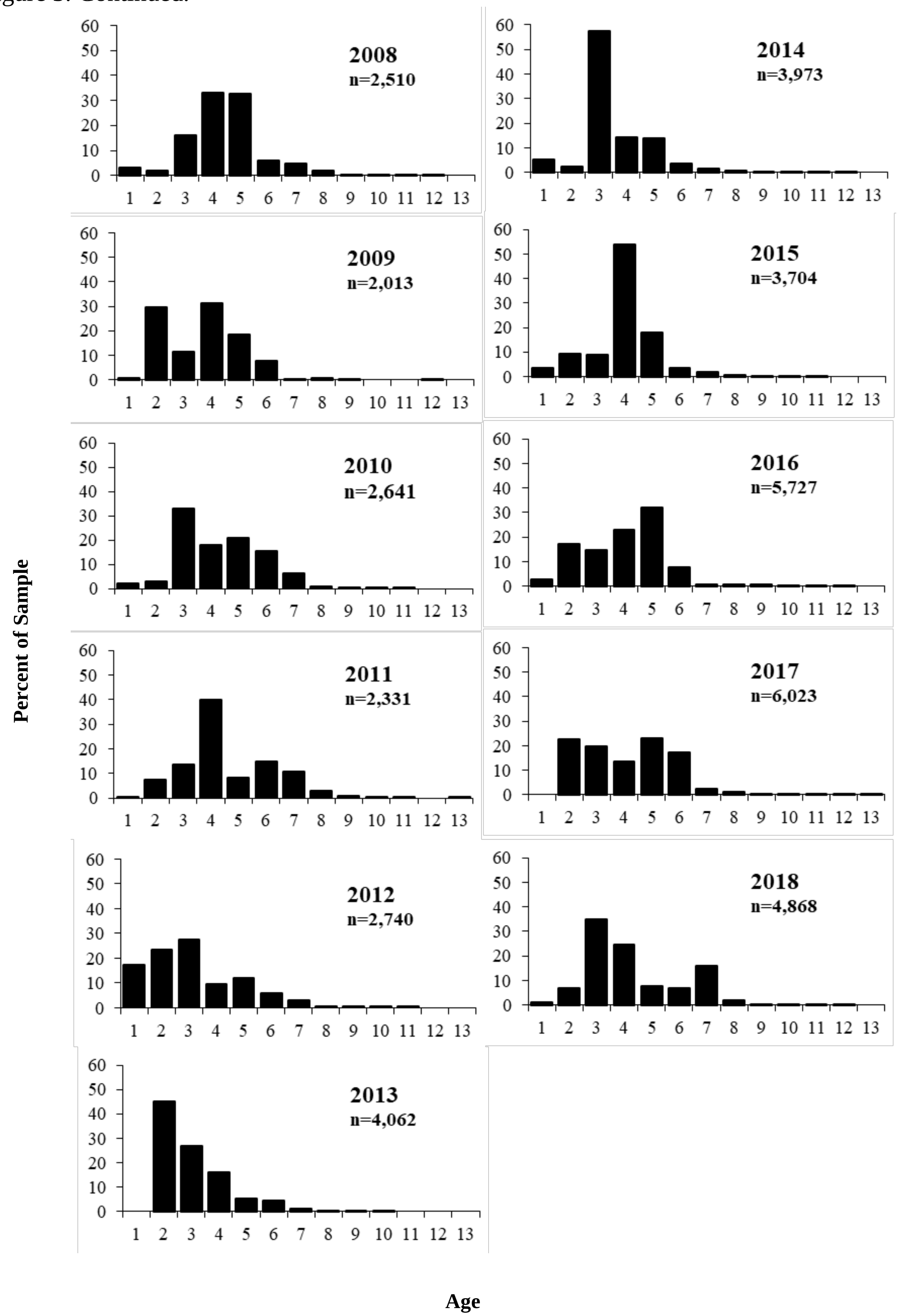


Figure 4. Length frequency of striped bass sampled during the 2018 pound net monitoring and the summer/fall check station surveys. All fish were sampled from June through November 2018. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

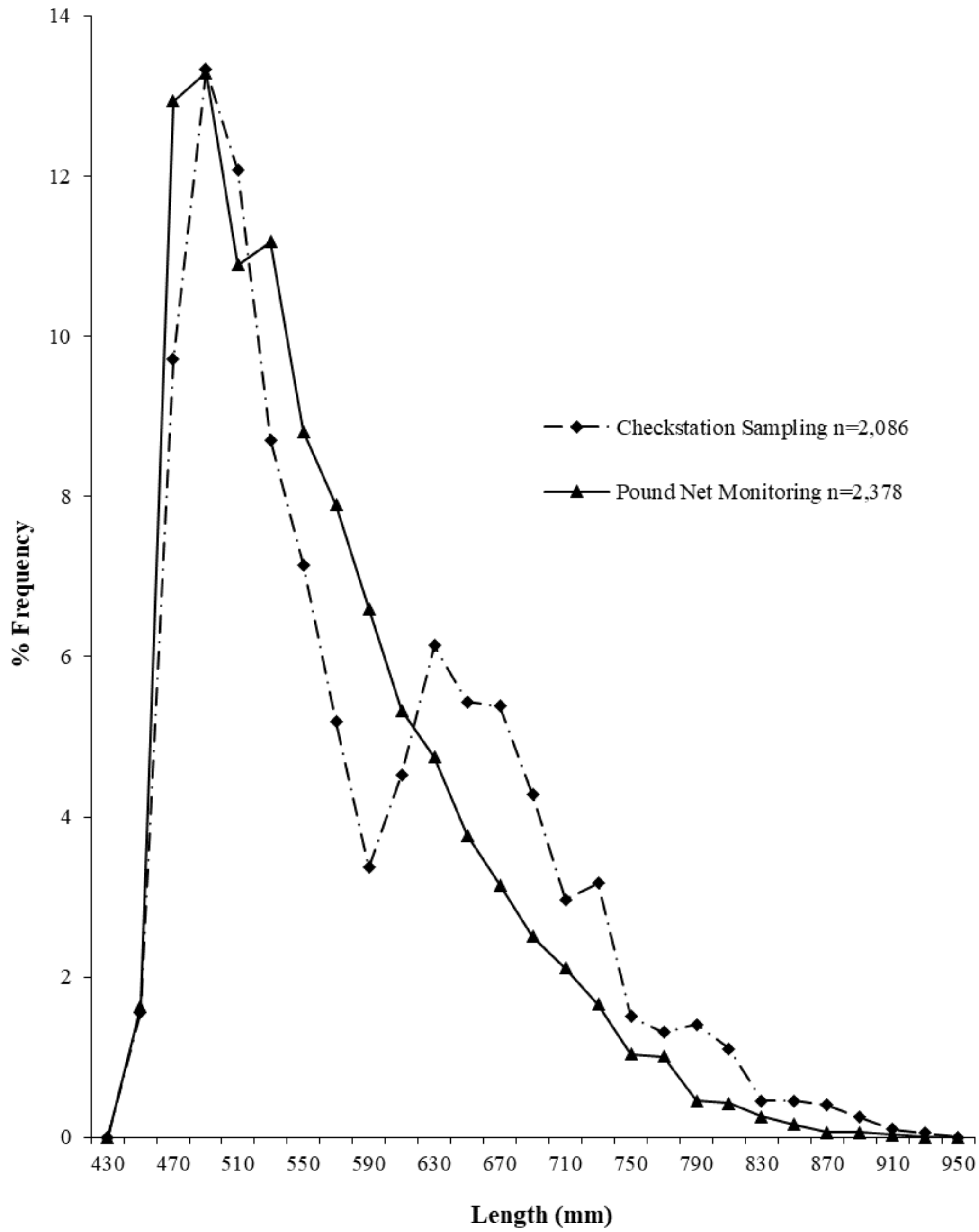


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, June through November 2018.

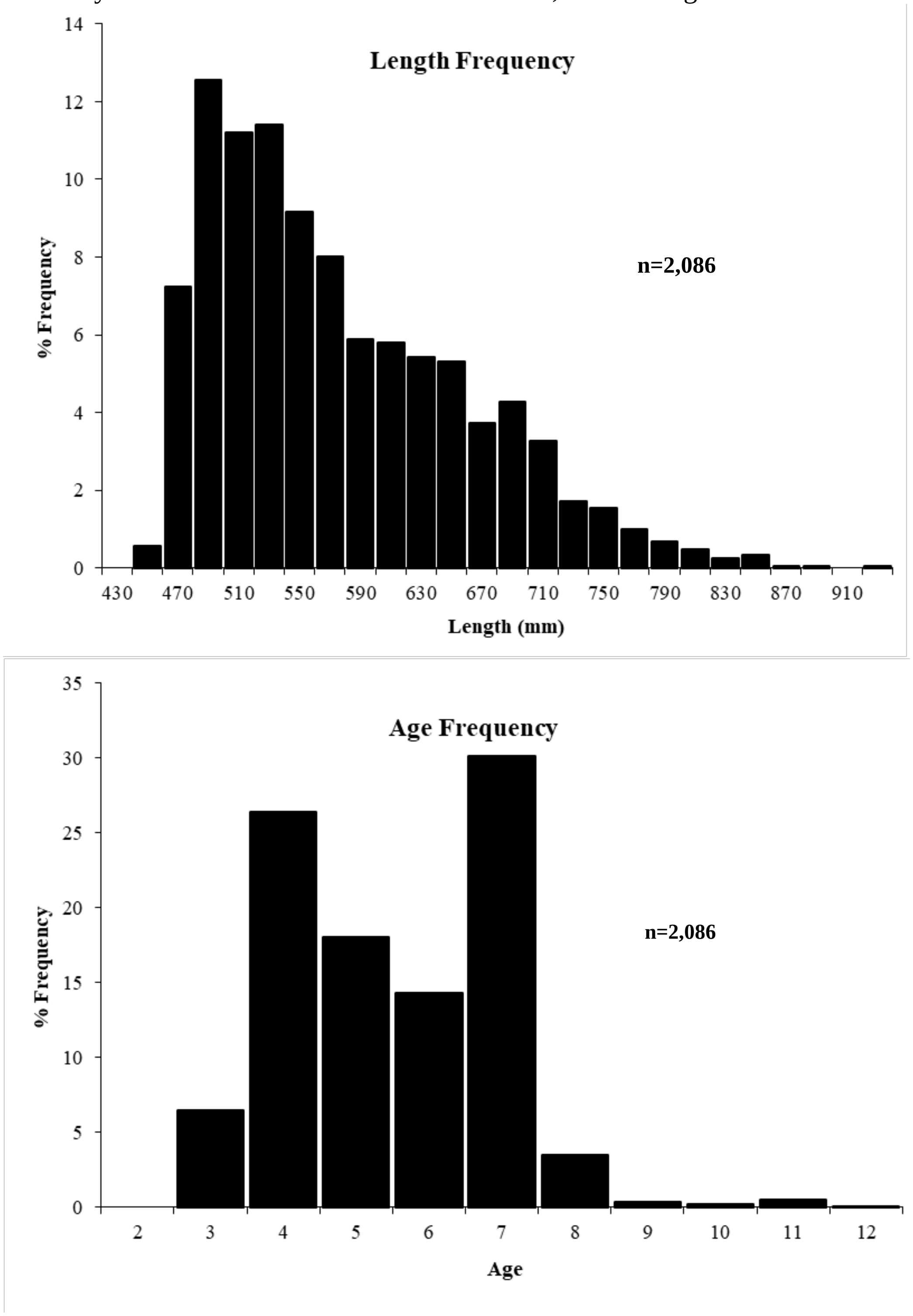


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, June through November 2018.

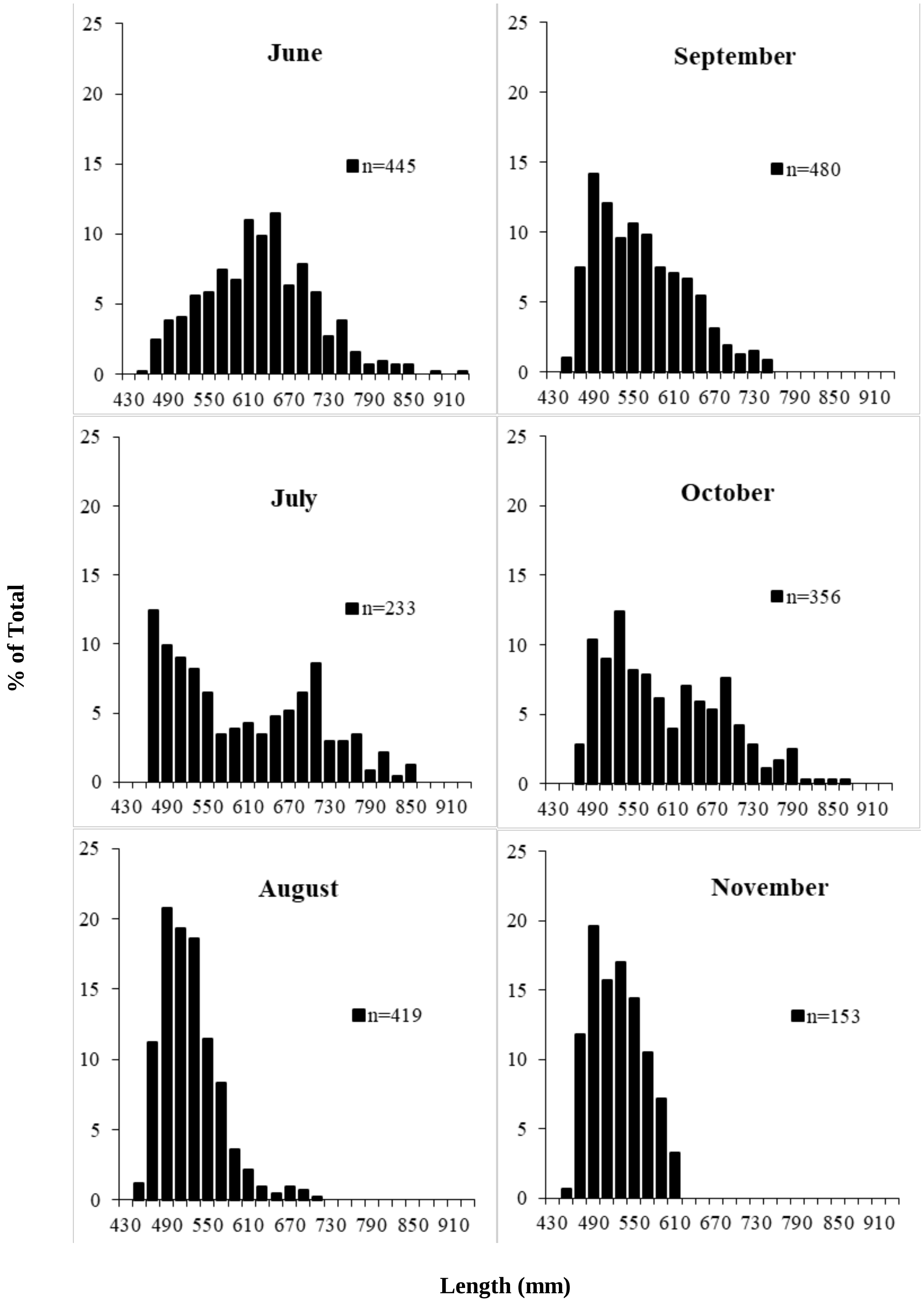


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, 1999 through 2018. Note-pound net check station sampling began in 2000 and gears are combined beginning in 2014.

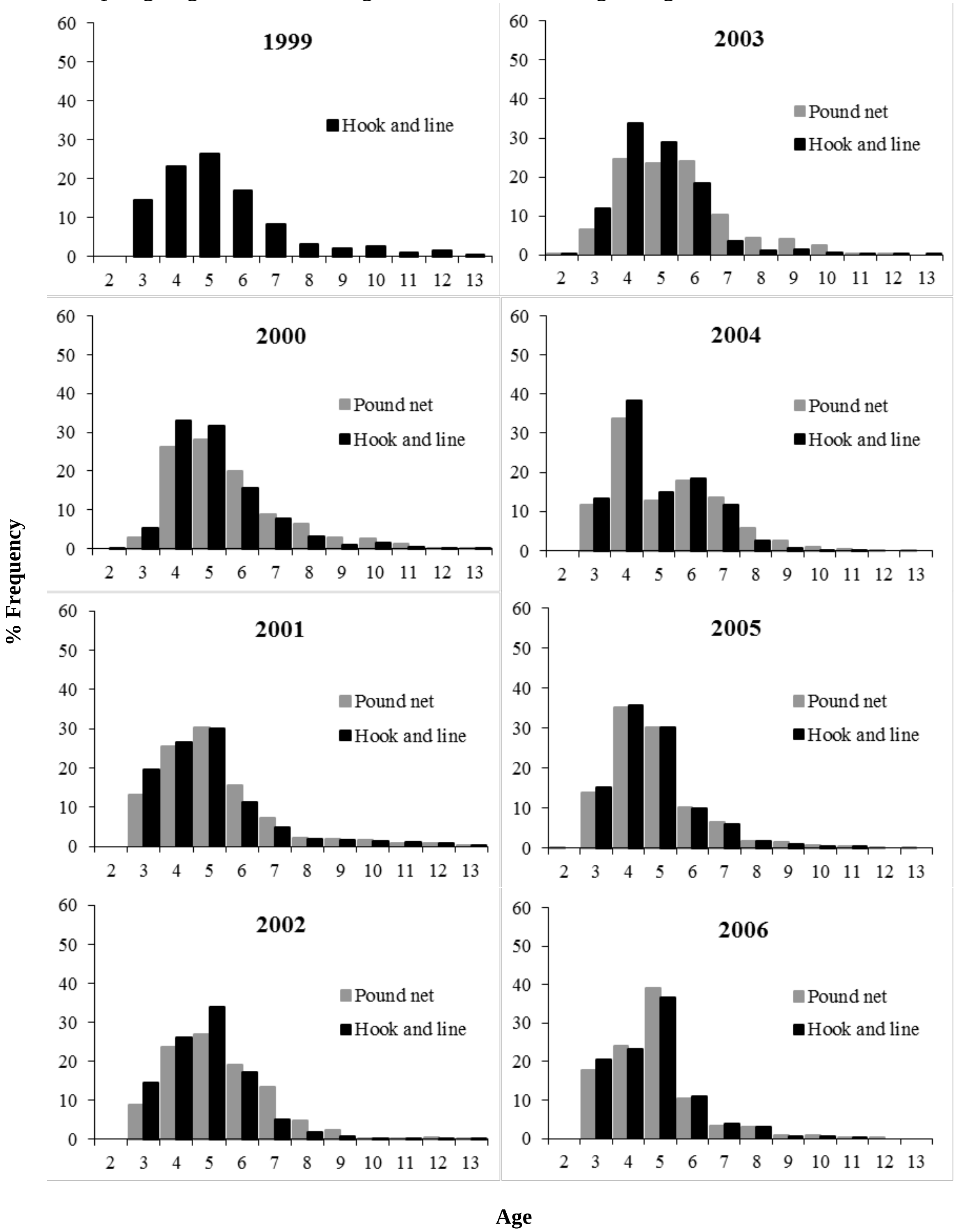


Figure 7. Continued.

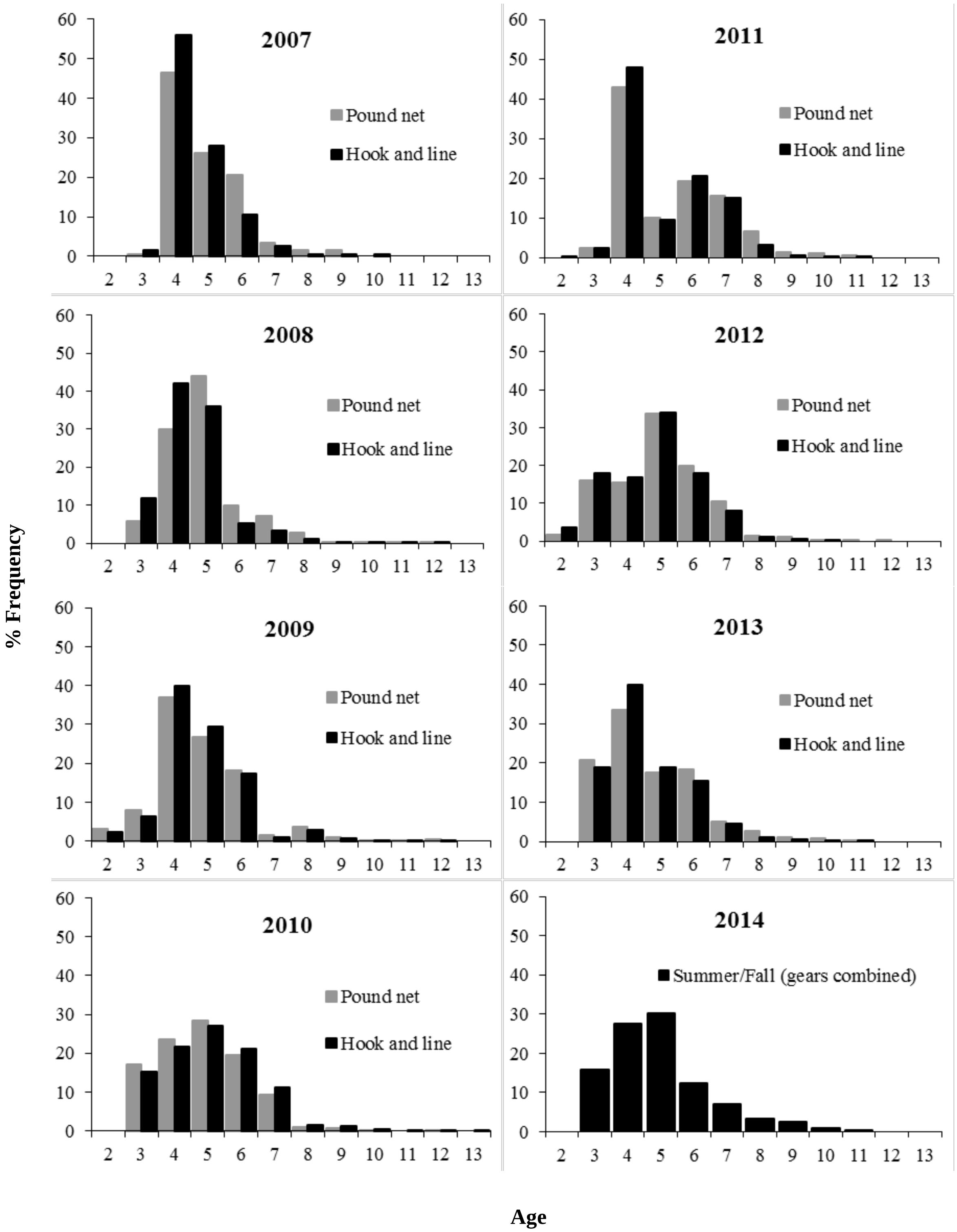


Figure 7. Continued

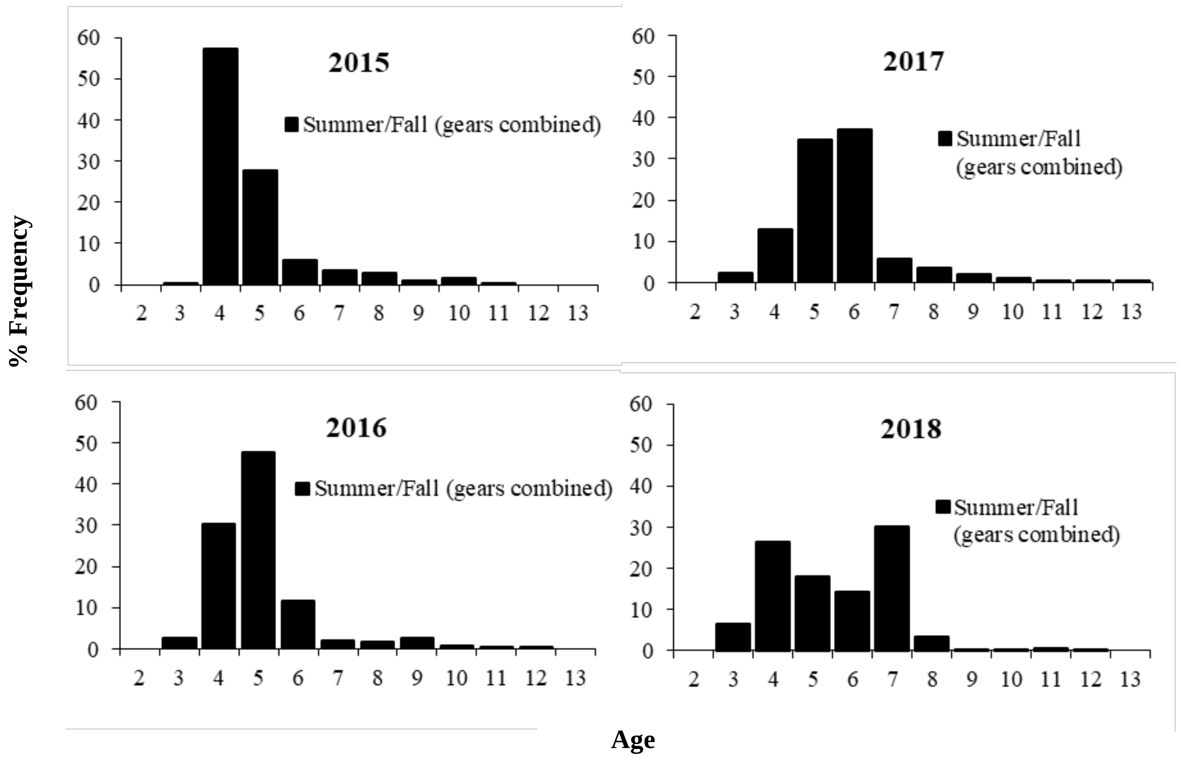
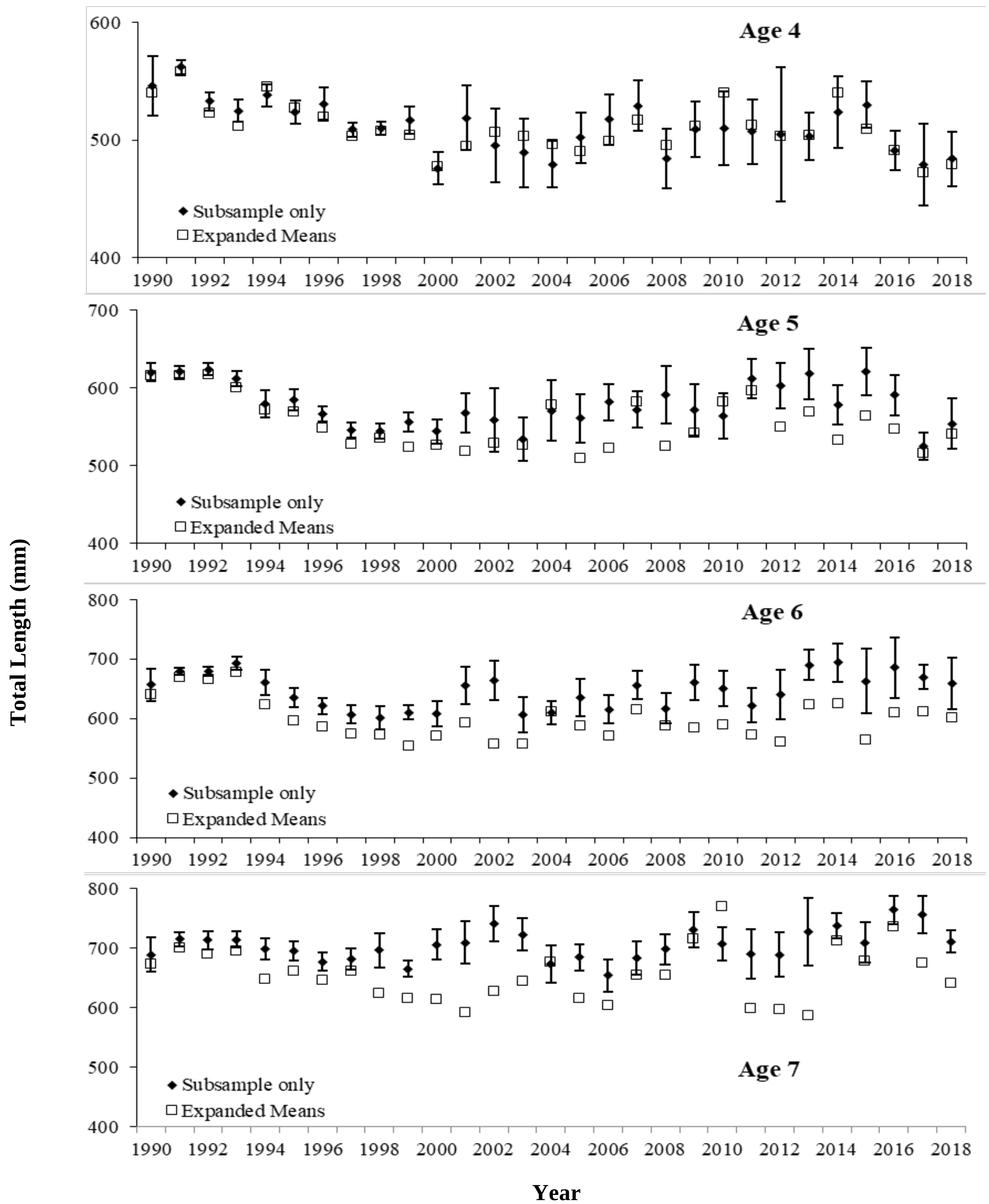


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for age 4, 5, 6, and 7 striped bass sampled from Maryland Chesapeake Bay pound nets and commercial summer/fall check stations, 1990 through 2018. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating means. The 95% confidence intervals are shown around points in the sub-sample data series. Note different scales.



PROJECT NO. 2
JOB NO. 3
TASK NO. 1B

WINTER STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

Prepared by Jeffrey Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1B was finalize the characterization of the size and age structure of striped bass (*Morone saxatilis*) sampled from the December 1, 2018 – February 28, 2019 commercial drift gill net fishery and provide preliminary results, as available, for the 2019-2020 winter season. Completed results for the 2019-2020 winter sample season will be reported in the F61-R-16 Chesapeake Bay Finfish Investigations report. This fishery targets resident/pre-migratory Chesapeake Bay striped bass and accounts for 40-50% of the annual Maryland Chesapeake Bay commercial harvest.

In addition to characterizing the size and age structure of this component of the commercial harvest, these data were used to monitor temporal trends in length and weight-at-age of resident/pre-migratory striped bass. These data were also used as part of the Maryland catch-at-age matrix utilized in the Atlantic States Marine Fisheries Commission's (ASMFC) coastal striped bass stock assessment.

Maryland's Chesapeake Bay commercial fisheries have been using an individual transferable quota (ITQ) system since 2014 (see Project 2, Job 3, Task 5A). Watermen were assigned an individual quota for the year that they could harvest during any open season. For each month of the ITQ drift gill net fishery, fish could be harvested Monday through Friday during the entire month. A small number of watermen elected to stay in a common pool fishery, in which they shared a monthly quota, with daily harvest limits, similar to the old system. The common pool fishery was open for three days in December, five days in January and two days in February.

METHODS

Data collection procedures

All striped bass harvested in Maryland's commercial striped bass fishery are required to pass through a Maryland Department of Natural Resources (MD DNR) approved check station. Striped bass check stations were sampled for the winter stock assessment according to a stratified random sampling design. Strata were defined as either high-use, medium-use, or low-use check stations based on landings from the previous year. Individual check stations that processed 8% or greater of the monthly catch were designated as high-use stations, stations that processed between 3% and 7.9% of the catch were designated as medium-use, and any stations that processed less than 3% of the catch were designated as low-use. High-use and medium-use stations were sampled at a 3 to 1 ratio; three high-use stations were sampled for every visit to a medium-use station with a sample intensity of one visit per week for the duration of the fishery, or multiple times per week when quota was caught quickly. Low-use sites were not sampled. Days and stations were randomly selected each month, although the results of the random draw were frequently modified because of weather, check station hours, and other logistical constraints.

Monthly sample targets were 1,000 fish in December and 1,250 fish in both January and February, for a total target sample size of 3,500 fish. Sampling at this level provides an accurate representation of both the length and age distributions of the harvest (Fegley et al. 2000). Estimated number of fish caught was calculated by using mean weight of fish sampled by month. At each check station a random sample of striped bass was measured (mm TL) and weighed (kg). For fish less than 700 mm TL, scales were taken randomly from two fish per 10 mm length group per visit. For fish between 700 mm TL and 799 mm TL, scales were taken randomly from three fish per 10 mm length group per visit and scales were taken from all fish greater than or equal to 800 mm TL.

Analytical procedures

Age composition of the sample was estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). In the first stage, length and scale samples were taken. These were assumed to be a random sample of the commercial harvest. In stage two, a fixed subsample of scales was randomly chosen to be aged. Approximately twice as many scales as ages per 20 mm length group were selected to be read based on the range of ages per length group (Barker et al. 2004). Target sample sizes of scales to be read were five scales per length groups 400-700 mm and 10 scales per length groups >700 mm. In some cases, the actual number of scales aged was limited by the number of samples available per length group.

Ages were assigned to scales by viewing acetate impressions in a microfiche reader. The resulting age-length key was applied to the sample length-frequency to generate a sample age distribution. Finally, the age distribution of the total 2018-2019 winter gill net harvest was estimated by applying the sample age distribution to the total reported landings. Because the winter gill net season straddles two calendar years, ages were calculated by subtracting year-class (assigned by scale readers) from the year in which the fishery ended. For example, for the December 2018 – February 2019 gill net season, the year used for age calculations was 2019.

Mean lengths- and weights-at-age were calculated by year-class for the aged subsample of fish. Mean length-at-age and weight-at-age were also estimated for each year-class using an expansion method (Hoover 2008). Age-specific length distributions based on the aged subsample are often different than the age-specific length distribution based on the entire length sample. Bettoli and Miranda (2001) suggest that the subsample means-at-age are often biased. Expanded means were calculated with an age-length key and a probability table that applied ages from the subsample of aged fish to all sampled fish. The two calculation methods would result in equal means only if the length distributions for each age-class were normal, which rarely occurs with these data.

To examine recruitment into the winter drift gill net fishery and the age-class structure of the harvest over time, the expanded age structure of the 2018-2019 harvest was compared to that of previous years beginning with the 1993-1994 gill net season. Trends in growth were examined by plotting actual mean length-at-age and mean weight-at-age of aged subsamples, with confidence intervals, by year, for individual age-classes. Expanded mean lengths-at-age and weights-at-age were also plotted on the same time-series graph for comparison.

RESULTS and DISCUSSION

A total of 3,526 striped bass was sampled and 152 striped bass were aged from the harvest between December 2018 - February 2019. The northern-most check station sampled in this survey was located in Millington, MD on the eastern shore, while the southern-most station was located in Crisfield (Figure 1). Check stations were visited by biologists six times in December, seven times in January, and six times in February.

Commercial drift gill nets have been limited to mesh sizes no less than 5 and no greater than 7 inches since the fishery reopened after the 1985-1990 moratorium. As a result, the range in ages of the commercial striped bass drift gill net landings has not fluctuated greatly since the inception of

MD DNR check station monitoring during the 1993-1994 gill net season (Figure 2). In most years, the majority of fish landed were between 4 and 8 years old. However, the contribution of individual ages to the overall landings has varied annually based on year-class strength.

Commercial landings are reported to MD DNR through multiple electronic and written reporting systems (Project No. 2, Job No. 3, Task No. 5A). The number of fish landed for the 2018-2019 season was estimated by dividing reported monthly harvest weight by the mean monthly weight of check station samples. Total reported landings were 676,989 pounds and the estimated number of fish was 104,435 (Table 1). According to the catch-at-age analysis, the 2018-2019 commercial drift gill net harvest consisted primarily of age 8 striped bass from the 2011 year-class (40%; Table 2). The 2013 and 2012 year-classes (ages 6 and 7) composed an additional 36% of the total harvest. The contribution of fish older than age 9 (7%) was similar to the 2017-2018 harvest (8%). The youngest fish observed in the 2018-2019 sampled harvest were age 4 from the 2015 year class (5%).

Mean lengths and weights-at-age of the aged subsample and the estimated means from the expansion technique are presented in Tables 3 and 4. Expanded mean lengths and weights-at-age were generally similar to previous years. Striped bass were recruited into the winter gill net fishery beginning at age 4 (2015 year-class), with an expanded mean length and weight of 504 mm TL and 1.6 kg, respectively. The 2011 year-class (age 8) was most commonly observed in the sampled landings and had an expanded mean length and weight of 663 mm TL and 3.6 kg, respectively. The expanded mean length and weight of the oldest fish in the aged subsample (age 13, 2006 year-class) were 847 mm TL and 8.1 kg, respectively.

The length frequency of the check station samples is presented in Figure 3. The length frequency distribution was dominated by fish in the 510-710 mm length groups. A total of 4 sub-legal fish <457 mm TL (18 inches) were observed in 2018-2019 sampling.

Time-series of subsampled and expanded mean lengths and weights for the period 1994-2019 are shown in Figures 4 and 5 for fish ages 4 through 9, which generally make up 95% or more of the harvest. In recent years, mean length-at-age and weight-at-age for ages 6 to 8 have become less variable as the ITQ system has encouraged the harvest of larger, more profitable fish and sample sizes of these larger fish have increased. Mean length-at-age and weight-at-age for ages 4, 5 and 9 striped bass are more variable, likely due to smaller sample sizes or greater range of lengths and weights for each age group.

PROJECT NO. 2
JOB NO. 3
TASK NO. 1B

2019-2020 WINTER STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

2019-2020 SEASON PRELIMINARY RESULTS

A total of 3,559 striped bass were sampled and 506 scale samples were collected from the harvest between December 2019 - February 2020. The northern-most check station sampled in this survey was located in Millington, MD on the eastern shore, while the southern-most station was located near Crisfield. Check stations were visited by biologists five times in December, five times in January, and four times in February.

Commercial gill nets have been limited to mesh sizes no less than 5 and no greater than 7 inches since the fishery reopened after the 1985-1990 moratorium. As a result, the range in ages of the commercial striped bass drift gill net landings has not fluctuated greatly since the inception of MD DNR check station monitoring during the 1993-1994 gill net season. In most years, the majority of fish landed were between 4 and 8 years old. However, the contribution of individual ages to the overall landings has varied annually based on year-class strength. Data analysis is ongoing and complete results for the 2019-2020 winter season of harvest-, length-, and weight-at-age will be provided in the F61-R-16 Chesapeake Bay Finfish Investigations report.

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Quinn, T.J., R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press. 542pp.

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Table 1. Reported pounds harvested, check station average weights, and estimated fish harvested by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2018 - February 2019.

Month	Harvest (lbs)	Check station average wt. (lb)	Estimated # harvested
December 2018	183,848	6.62	27,763
January 2019	317,032	6.42	49,351
February 2019	176,109	6.45	27,321
Total*	**676,989**		**104,435**

* Sum of columns may not equal totals due to rounding.

Table 2. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2018 - February 2019.

Year-class	Age	Catch	Percentage of the catch
2015	4	5,277	5
2014	5	12,292	12
2013	6	16,942	16
2012	7	21,161	20
2011	8	41,353	40
2010	9	6,696	6
2009	10	646	1
2007	12	39	<1
2006	13	30	<1
Total*		**104,435**	**100**

* Sum of columns may not equal totals due to rounding.

Table 3. Mean total lengths (mm TL) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2018 - February 2019.

Year-class	Age	n fish aged	Mean TL (mm) of subsample	Estimated # at-age in sample	Expanded mean TL(mm)
2015	4	10	482	178	504
2014	5	15	499	415	516
2013	6	14	560	572	560
2012	7	26	685	714	630
2011	8	63	716	1,396	663
2010	9	17	761	226	645
2009	10	5	813	22	756
2007	12	1	802	1	806
2006	13	1	847	1	847
Total*		**152**		**3,526**	

* Sum of columns may not equal totals due to rounding.

Table 4. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2018 - February 2019.

Year-class	Age	n fish aged	Mean WT (kg) of subsample	Estimated # at-age in sample	Expanded mean weight (kg)
2015	4	10	1.35	178	1.60
2014	5	15	1.57	415	1.71
2013	6	14	2.25	572	2.20
2012	7	26	3.85	714	3.13
2011	8	63	4.54	1,396	3.60
2010	9	17	5.42	226	3.38
2009	10	5	7.11	22	5.29
2007	12	1	7.12	1	6.18
2006	13	1	8.00	1	8.10
Total*		**152**		**3,526**	

* Sum of columns may not equal totals due to rounding.

Figure 1. Registered Maryland Chesapeake Bay check stations sampled for commercial drift gill net harvested striped bass, December 2018 - February 2019.

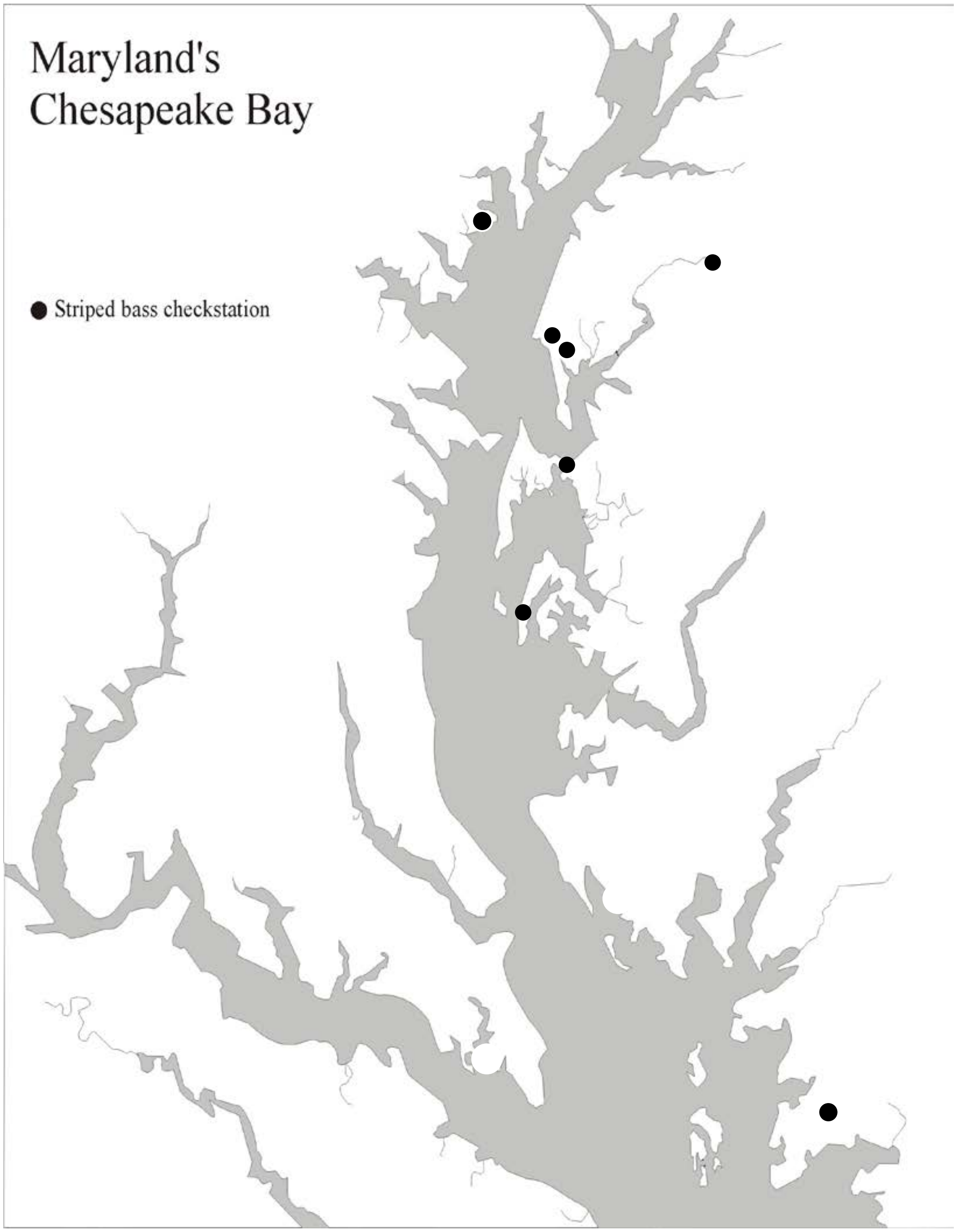
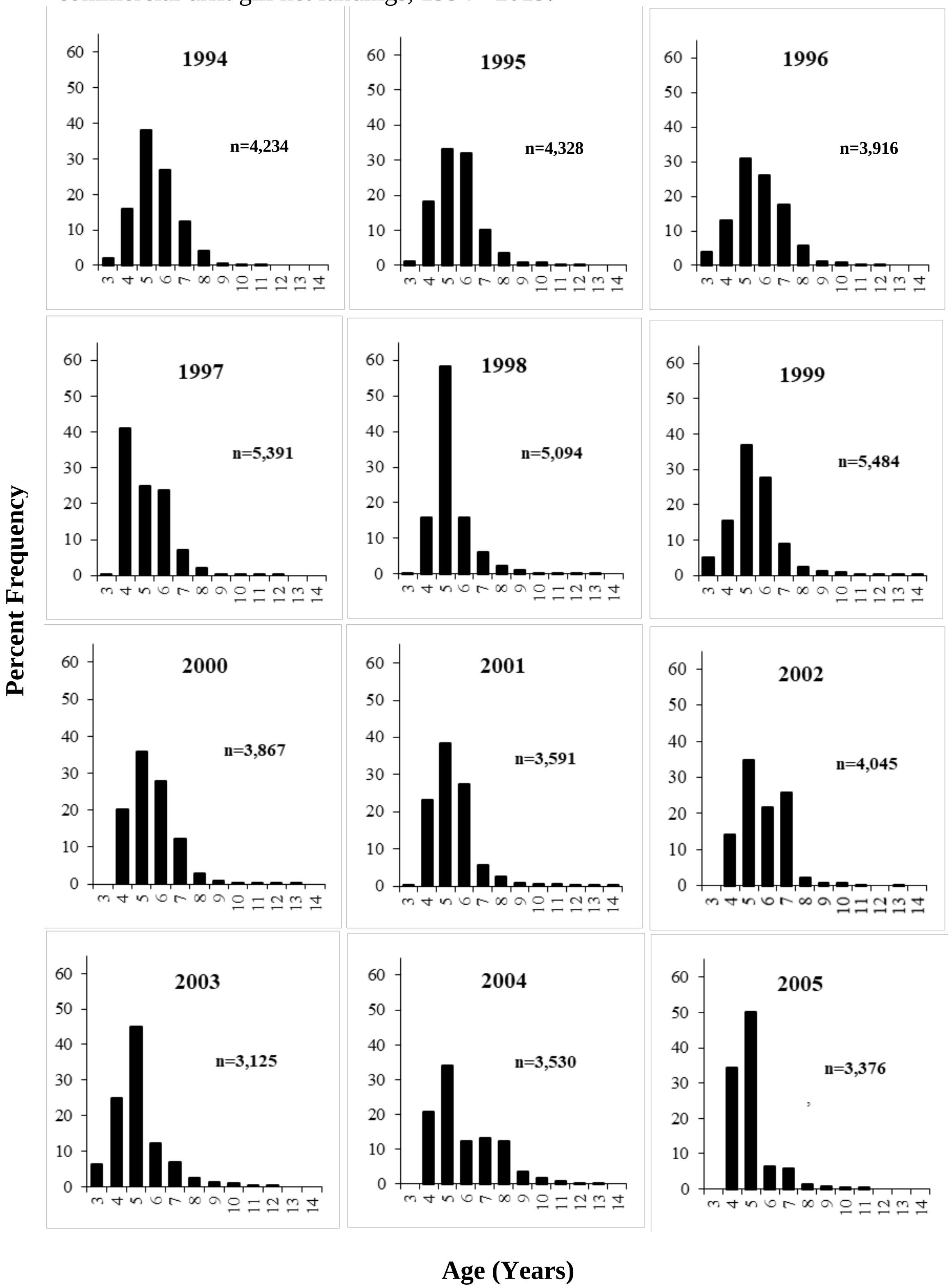


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994 - 2019.



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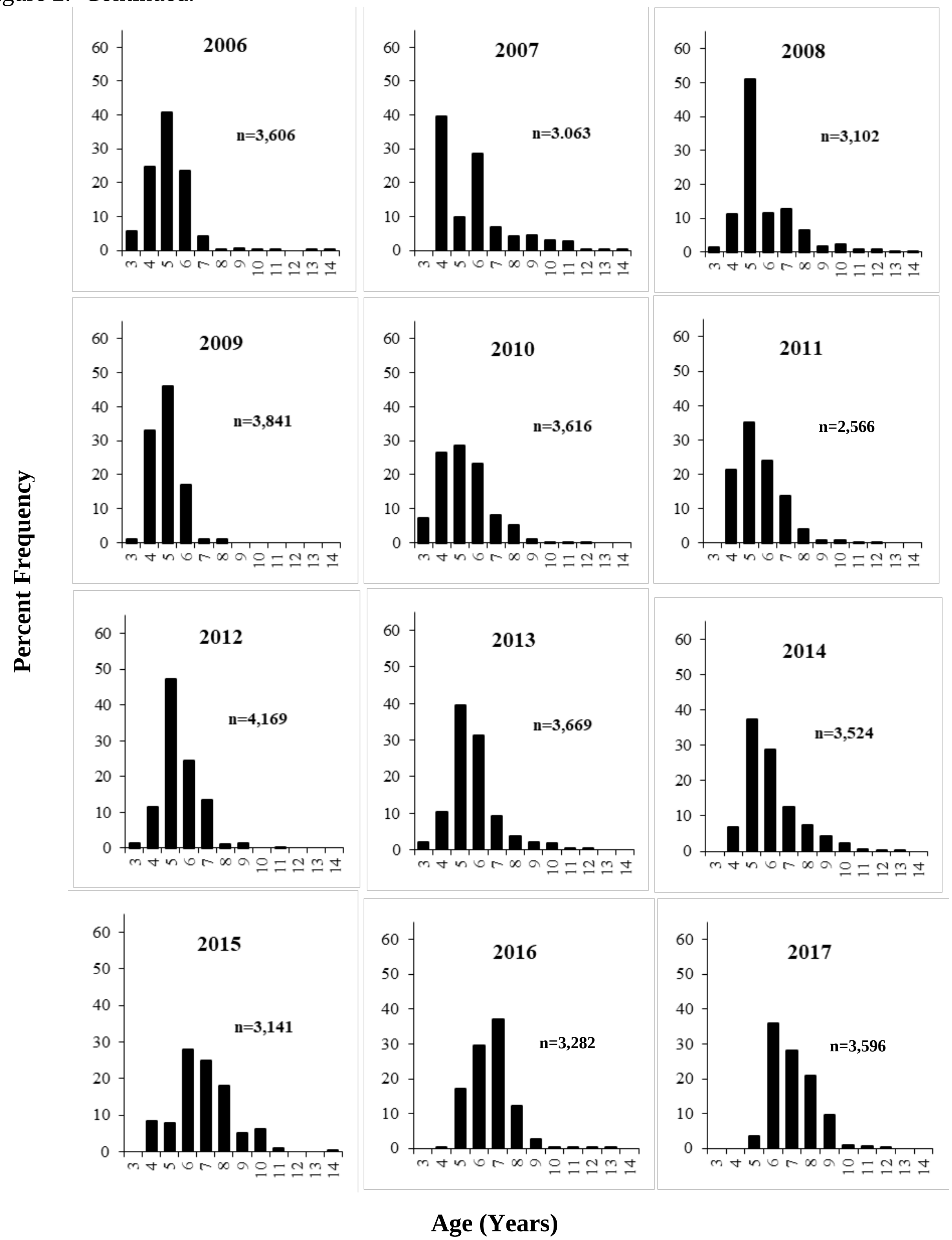

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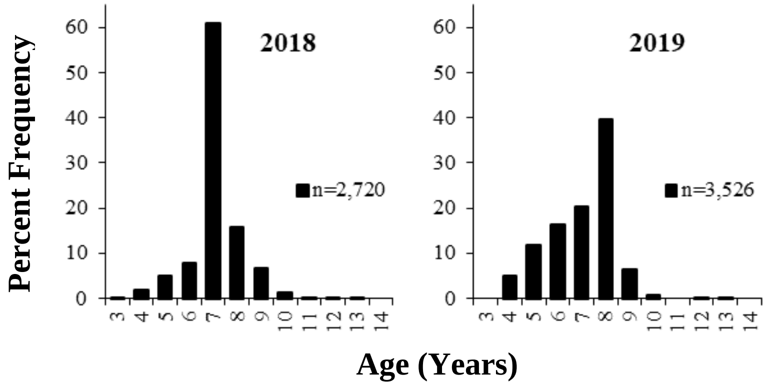


Figure 3. Length frequency distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2018 - February 2019.

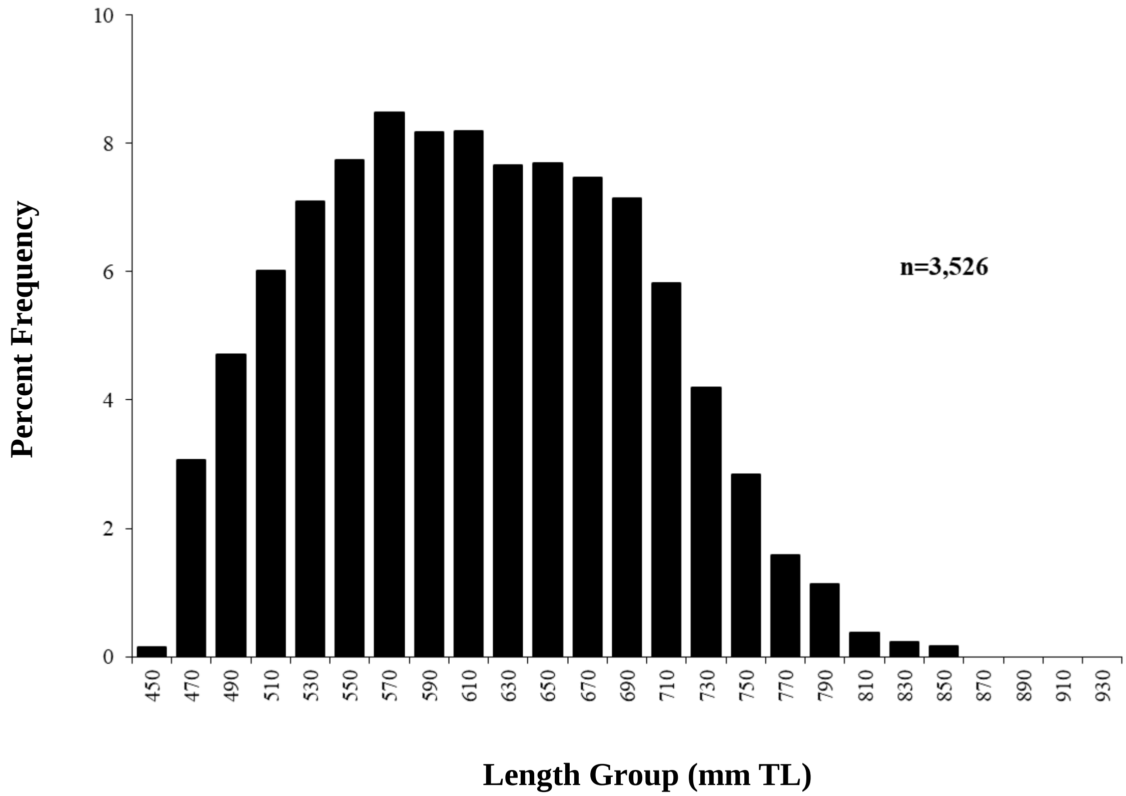
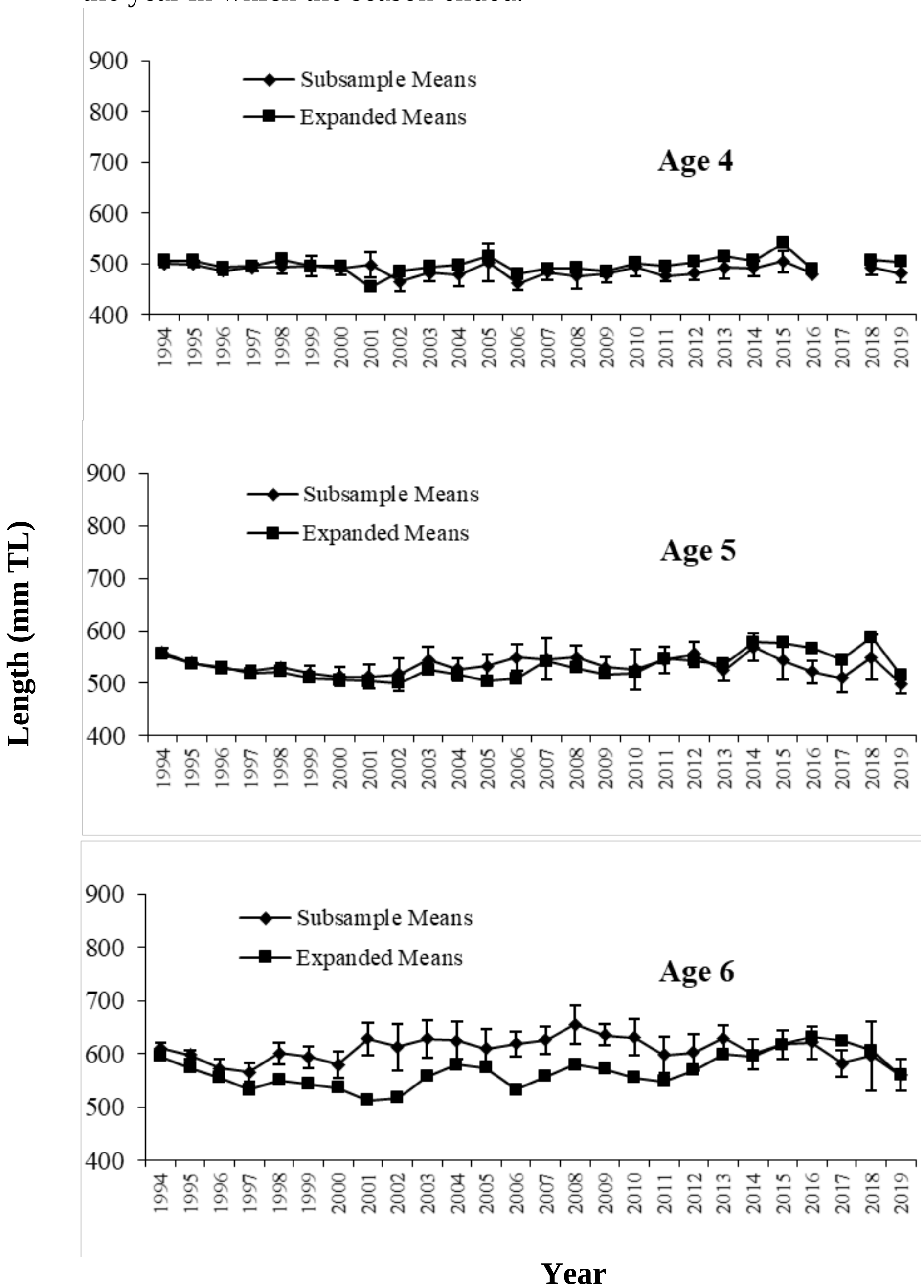


Figure 4. Mean total lengths (mm TL) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994 - 2019 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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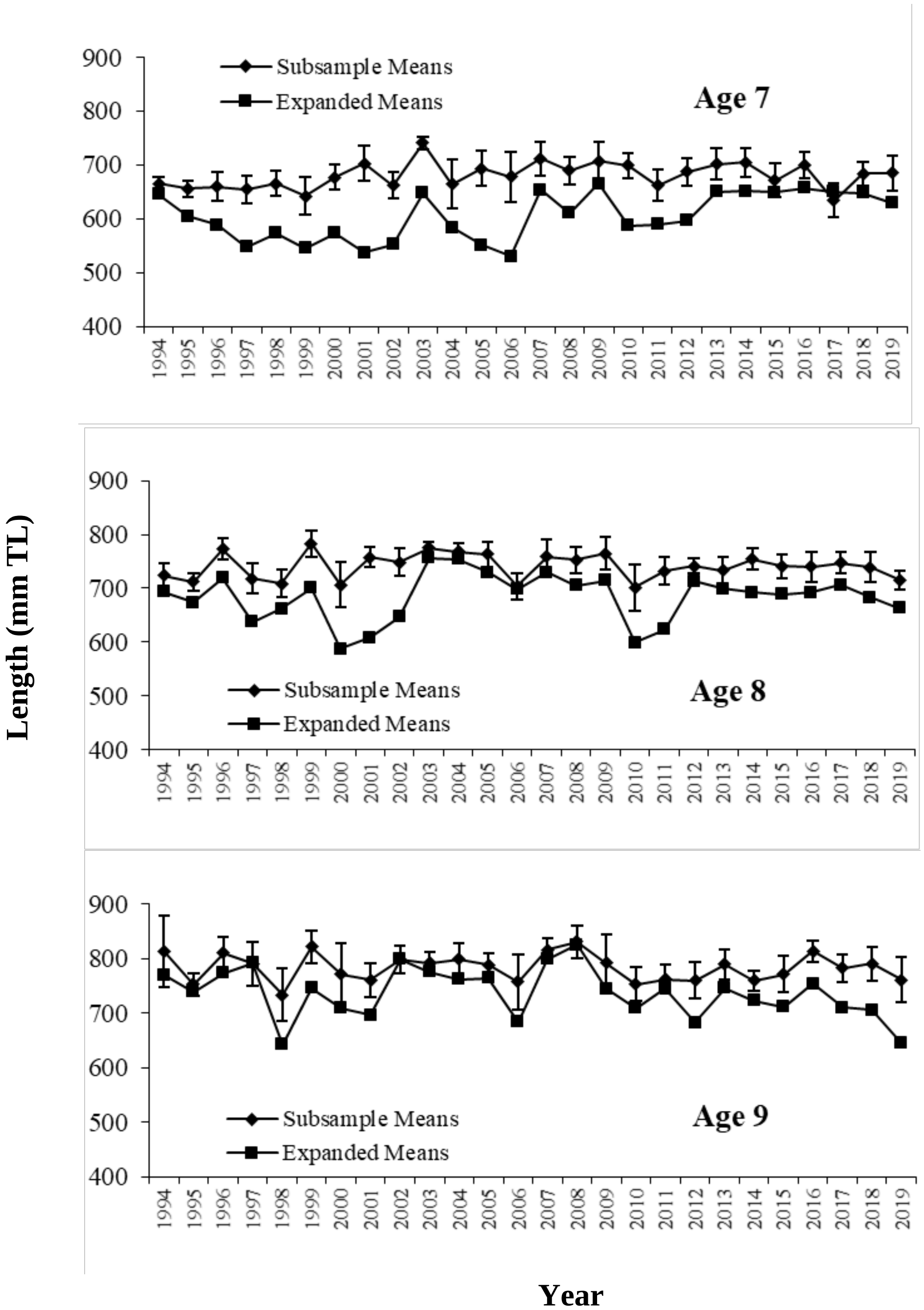
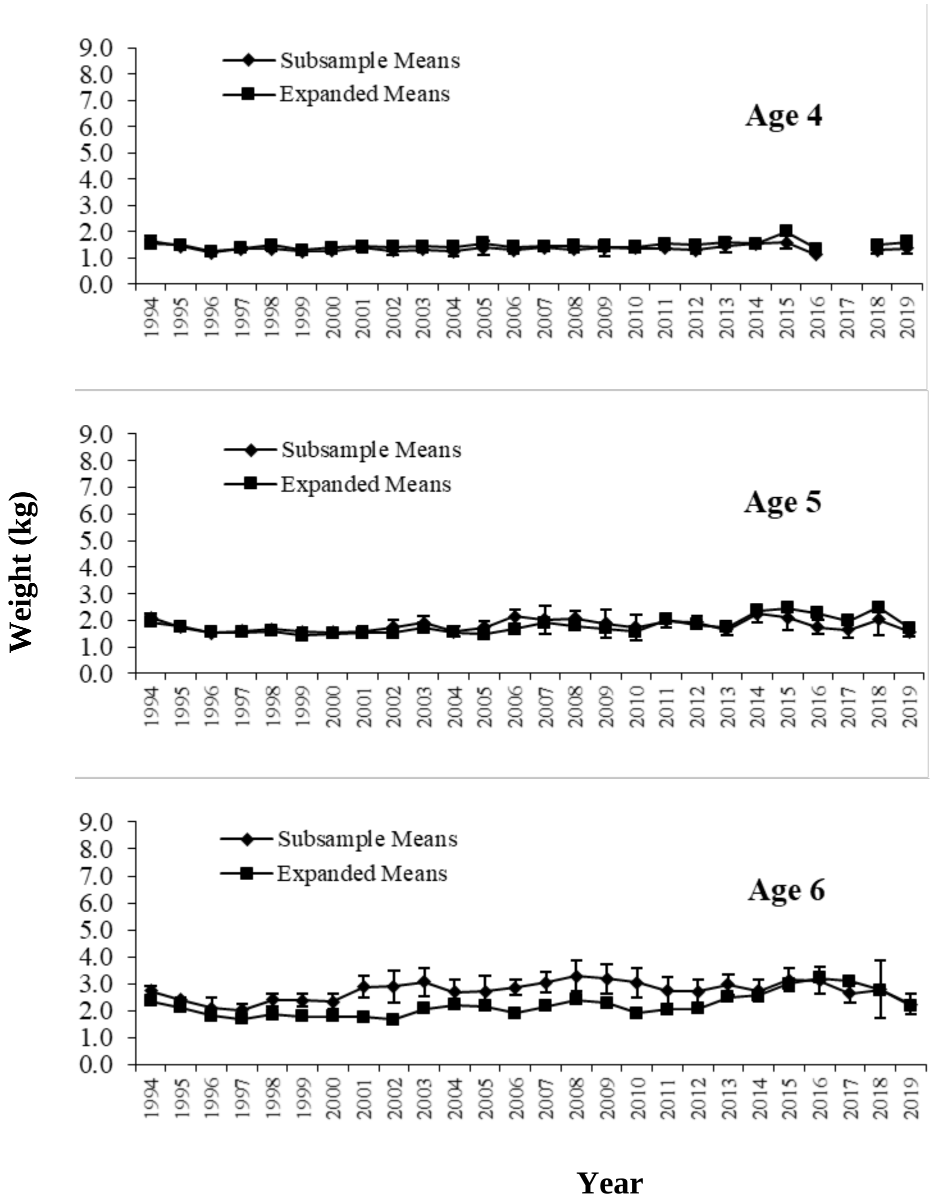


Figure 5. Mean weights (kg) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994 - 2019 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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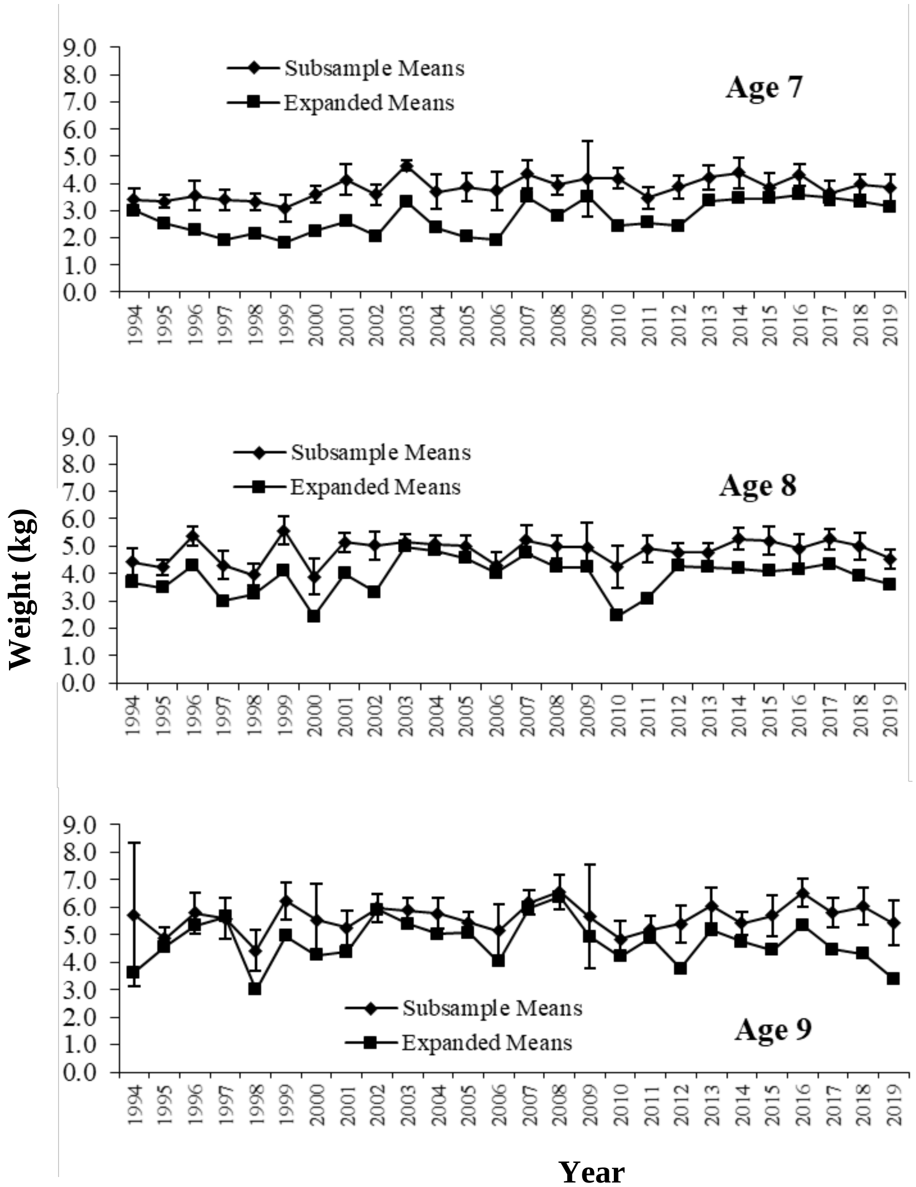

PROJECT NO. 2
JOB NO. 3
TASK NO. 1C

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Jeffrey Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1C was to finalize the characterization of the size and age structure of commercially harvested striped bass from Maryland’s Atlantic coast during the 2018-2019 season and provide preliminary results, as available, for the 2019-2020 season. Completed results for the 2019-2020 sample season will be reported in the F61-R-16 Chesapeake Bay Finfish Investigations report. Trawls and gill nets were permitted during the Atlantic season within state waters (to 3 miles offshore). The 2019 season opened October 1, 2018 and ended May 31, 2019. The 2019 Atlantic striped bass season continued to be managed with a reduced annual quota under Addendum IV to Amendment 6 of the Atlantic Striped Bass Interstate Fishery Management Plan (Giuliano et al. 2014). Although this report covers the October 2018 – May 2019 fishing season, the quota is managed by calendar year. This fishery was managed with a 24 inch total length (TL) minimum size limit and an annual quota of 90,727 pounds. Maryland’s Atlantic coast fishery is not as large as the Chesapeake Bay commercial fishery and its annual quota composes only 6% of Maryland’s ocean and bay quotas combined. Monitoring of the coastal fishery began for the 2007 fishing season (November 1, 2006 – April 29, 2007) to improve Maryland's catch-at-age and weight-at-age estimates used in the annual compliance report to the Atlantic States Marine Fisheries Commission, as well as the coast-wide stock assessment.

METHODS

Data collection procedures

All striped bass commercially harvested in Maryland are required to pass through a Maryland Department of Natural Resources (MD DNR) approved check station. Check stations are typically cooperating fish dealers who report daily landings to MD DNR. A review of 2005 – 2016 check station activity indicated that 86% of striped bass harvested along Maryland's Atlantic coast passed through two check stations in Ocean City, Maryland. Consequently, sampling occurred between these two check stations as fish came in during the season. Catches were typically intermittent and MD DNR personnel sampled when fish were available. A monthly sample target of 150 fish was established. Fish were measured (mm TL) and weighed (kg) and scales were randomly taken from five fish per 10 mm length group per day for age determination.

Analytical procedures

Age composition of the Atlantic fisheries was estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). In the first stage, total length and scale samples were taken, which were assumed to be a random sample of the commercial harvest. In stage two, a fixed sub-sample of scales were randomly chosen to be aged.

Year-class was determined by reading acetate or acrylic impressions of the scales that were projected in microfiche readers. Because the Atlantic coast fishery spans two calendar years, age was calculated by subtracting the assigned year-class from the year in which the fishery ended. In the October 2018 – May 2019 Atlantic fishery, the year used for age calculations was 2019. These ages were then used to construct the age-length key (ALK). The age distribution of the Atlantic coast harvest was estimated by applying the sample age distribution to the total landings as reported from the check stations.

An expansion method was applied to an aged sub-sample to estimate mean lengths- and weights-at-age. Bettoli and Miranda (2001) suggested that age-specific length distributions based on an aged sub-sample are often different than the age-specific length distribution based on the entire length sample. The two calculation methods (sub-sample means and expanded means) would result in equal means only if the length distributions for each age-class were normal, which rarely occurs in these data. Therefore, expanded means were calculated with an ALK and a probability table that applied ages from the sub-sample of aged fish to all sampled fish.

RESULTS and DISCUSSION

Check stations reported 3,157 fish landed during the 2018 – 2019 Atlantic coast season (Table 1) (Savannah Lewis, Data Management and Quota Monitoring Program, Personal Communication). This was similar to the previous two years and among the lowest number of striped bass reported at Atlantic check stations in the time series (Figure 1). Sampling at coastal check stations was conducted on sixteen days between November 2018 and May 2019. A total of 187 fish were weighed and measured. Fish ages were determined directly from 154 scale samples. Commercial fishermen have a limited area to harvest striped bass (~62 square miles) within Maryland waters. During the 2019 Atlantic striped bass fishing season, fish were frequently observed by commercial fisherman in the Exclusive Economic Zone, where harvest is prohibited (Gary Tyler, Coastal Fisheries Program, Personal Communication). Consequently, fish were harvested intermittently and were difficult to intercept at the check stations.

The catch-at-age estimate determined that thirteen year-classes were represented in the sampled harvest, ranging from age 5 (2014 year-class) to age 18 (2001 year-class) (Table 1; Figure 2). The most frequent age represented in the catch-at-age estimate was age 8, the 2011 year-class, which represented 20% of the sampled harvest (Table 1). Striped bass recruit into the Atlantic coast fishery as young as age 4, but due to the 24 inch minimum size limit, few fish younger than age 5 are harvested. Age 12 (2007 year-class) fish were also significant contributors to the sample population at 18% (Table 1; Figure 2).

Striped bass sampled at Atlantic coast check stations during the 2018 – 2019 season had a mean length of 920 mm TL and mean weight of 9.5 kg. The sample length distribution was bimodal and ranged from 617 to 1192 mm TL (Figure 3). The weight of fish sampled ranged from 2.3 to 18.6 kg. Age 8 striped bass (2011 year-class), the most abundant age group sampled, had a mean length of 777 mm TL and mean weight of 5.5 kg (Tables 2 and 3, Figures 4 and 5). Expanded mean lengths and mean weights were very similar to those determined from subsamples only (Figures 4 and 5).

PROJECT NO. 2
JOB NO. 3
TASK NO. 1C

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

2019-2020 SEASON PRELIMINARY RESULTS – WORK IN PROGRESS

In most years, the majority of fish landed were between 7 and 11 years old. However, the contribution of individual ages to the overall landings has varied annually based on year-class strength. Data analysis for the 2019-2020 season is ongoing and complete results of harvest-, length-, and weight-at-age will be provided in the F61-R-16 Chesapeake Bay Finfish Investigations report.

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Table 1. Estimated harvest-at-age of striped bass (numbers of fish) landed by the Maryland Atlantic coast commercial fishery, October 2018 – May 2019.

Year-Class	**Age**	**Number of Fish**	**Percent**
2014	5	132	4.2
2013	6	222	7.0
2012	7	34	1.1
2011	8	633	20.1
2010	9	181	5.7
2009	10	285	9.0
2008	11	248	7.9
2007	12	557	17.6
2006	13	118	3.7
2005	14	341	10.8
2004	15	150	4.8
2003	16	221	7.0
2002	17	0	0.0
2001	18	34	1.1
Total*		3,157	100

*Sum of columns may not equal totals due to rounding.

Table 2. Mean total lengths (mm) by year-class of striped bass sampled from Atlantic coast fishery, October 2018 – May 2019. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

Year-Class	**Age**	**n Fish Aged**	**Mean TL (mm)**	**LCL**	**UCL**
2014	5	5	638	624	652
2013	6	10	667	646	689
2012	7	2	788	*	*
2011	8	30	777	737	818
2010	9	11	889	822	957
2009	10	14	969	937	1001
2008	11	12	982	947	1017
2007	12	25	993	973	1013
2006	13	7	1025	950	1101
2005	14	15	1039	996	1081
2004	15	8	1074	1023	1125
2003	16	12	1104	1076	1133
2002	17	0			
2001	18	2	1123	*	*
Total		**153**			

*Values omitted due to high variability from small sample size.

Table 3. Mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, October 2018 – May 2019. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

Year-Class	Age	n Fish Aged	Mean Weight (kg)	LCL	UCL
2014	5	5	2.7	2.5	2.9
2013	6	10	3.0	2.7	3.3
2012	7	2	4.9	*	*
2011	8	30	5.5	4.5	6.5
2010	9	11	8.3	6.6	10.0
2009	10	14	10.2	9.1	11.3
2008	11	12	10.6	9.4	11.9
2007	12	25	12.0	11.3	12.7
2006	13	7	12.2	8.9	15.4
2005	14	15	12.5	11.6	13.3
2004	15	8	14.1	11.5	16.7
2003	16	12	14.2	12.8	15.6
2002	17	0			
2001	18	2	13.5	*	*
Total		**153**			

*Values omitted due to high variability from small sample size.

Figure 1. Reported number of Atlantic striped bass landed per season at Maryland Atlantic check stations.

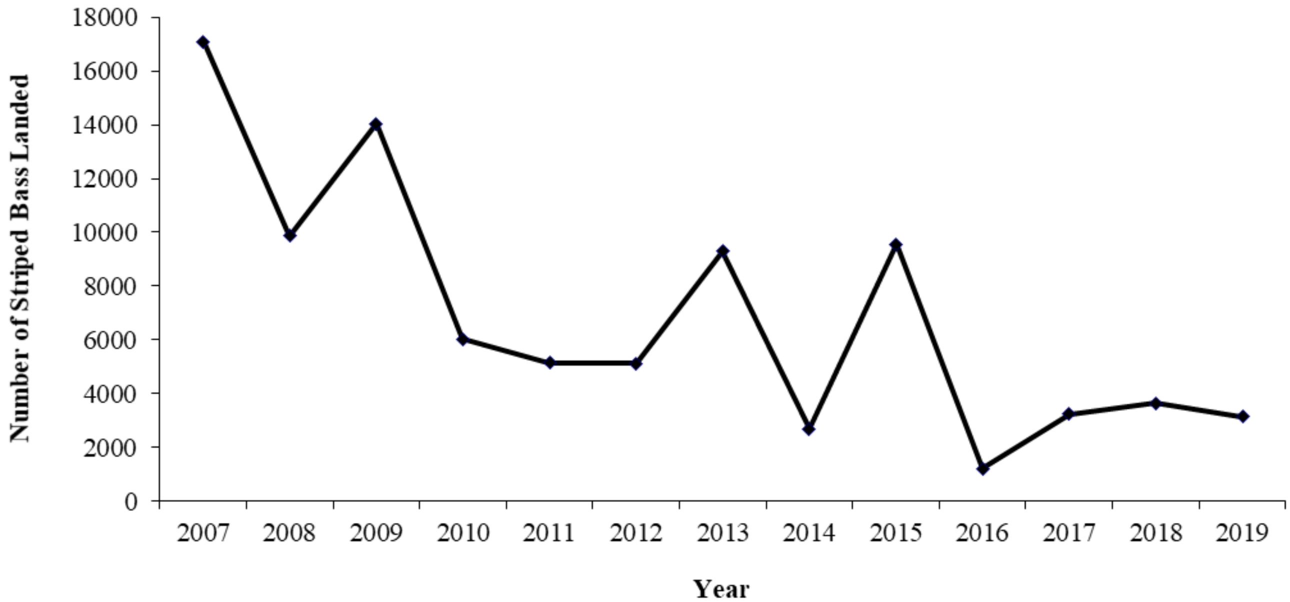
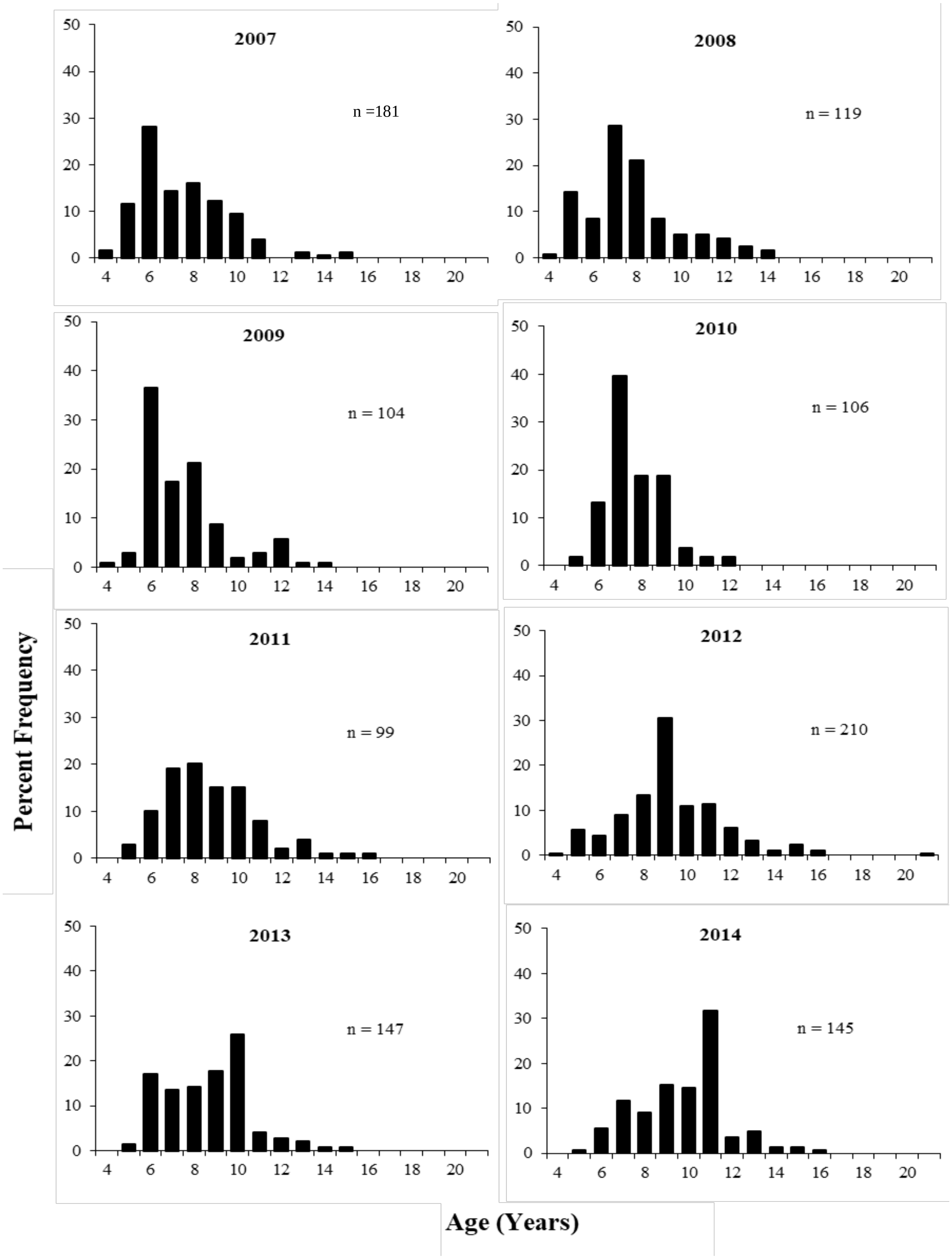


Figure 2. Age distribution of striped bass sampled from the Atlantic coast fishery, 2007 – 2019 seasons.



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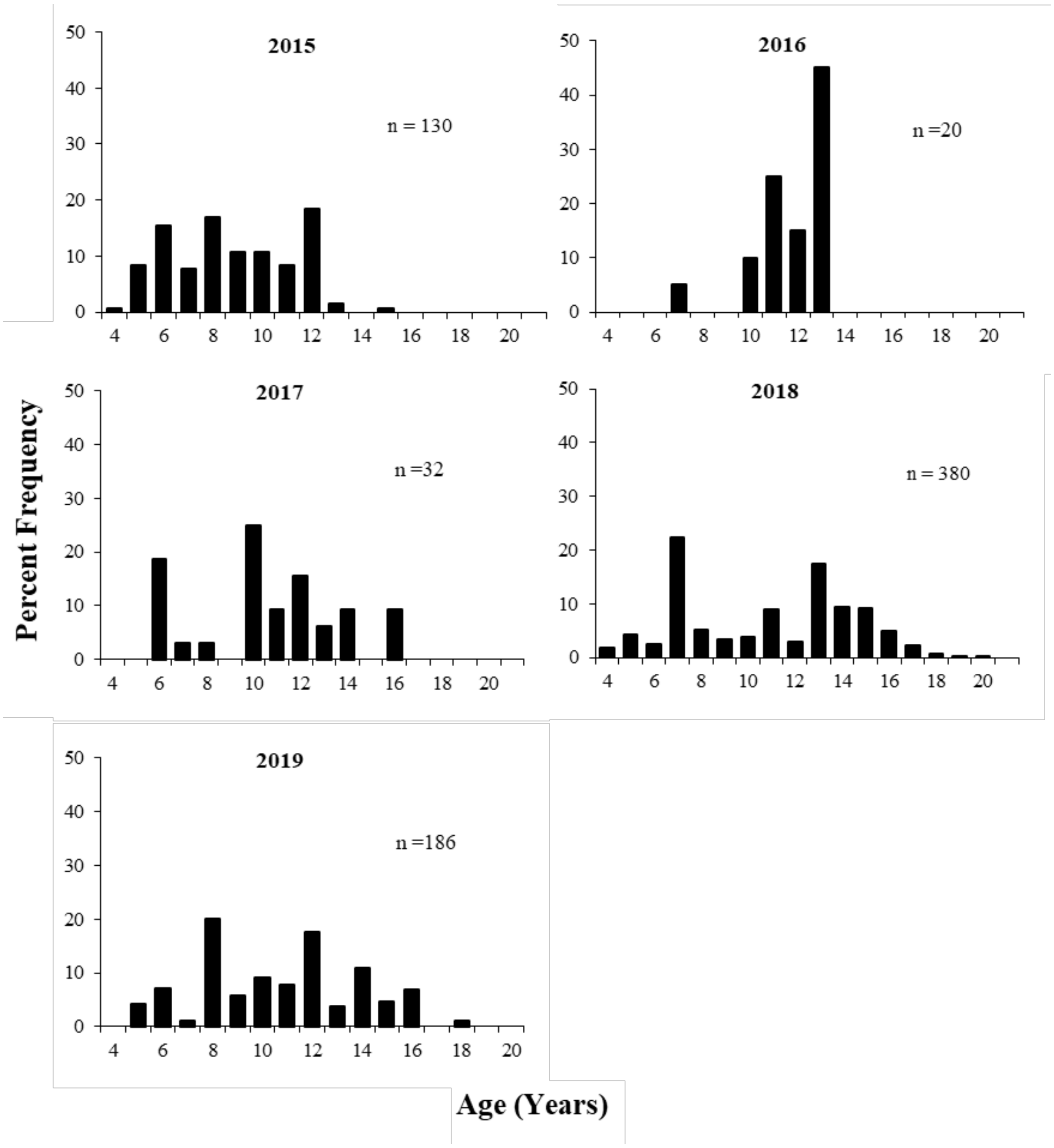
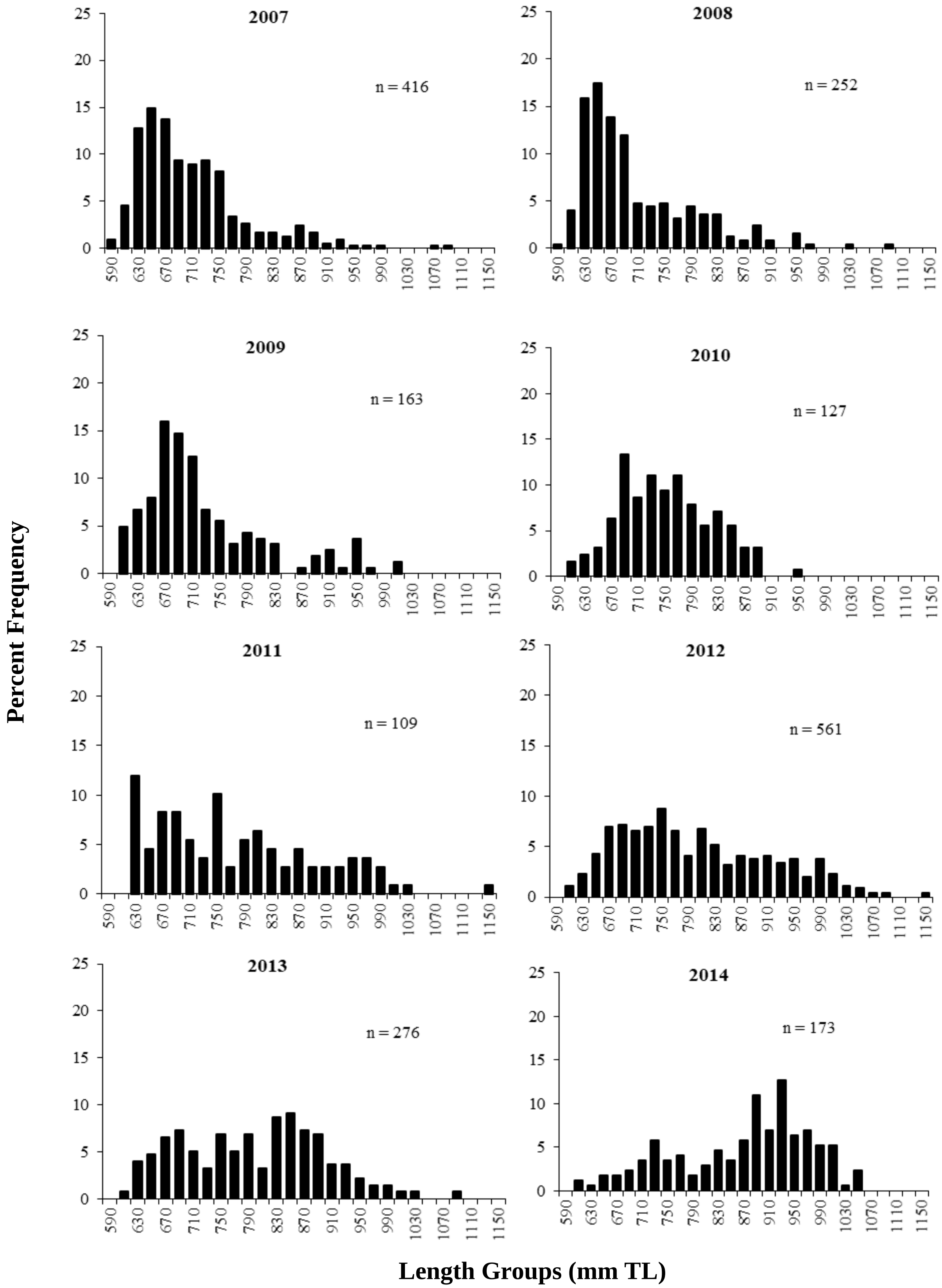


Figure 3. Length distribution of striped bass sampled from the Atlantic coast fishery, 2007 – 2019 seasons. *Note different x and y-axis scale for 2015 – 2019.



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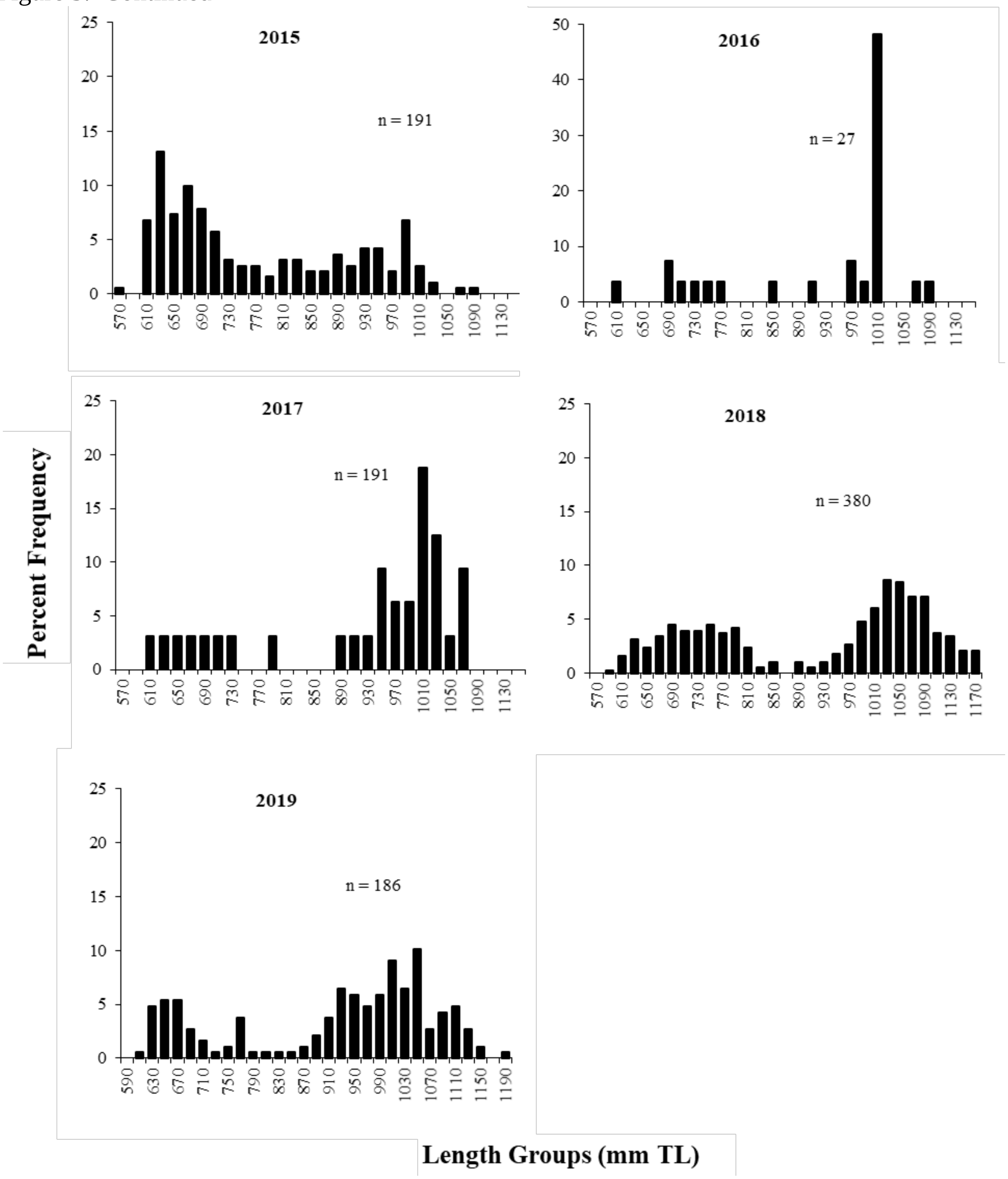
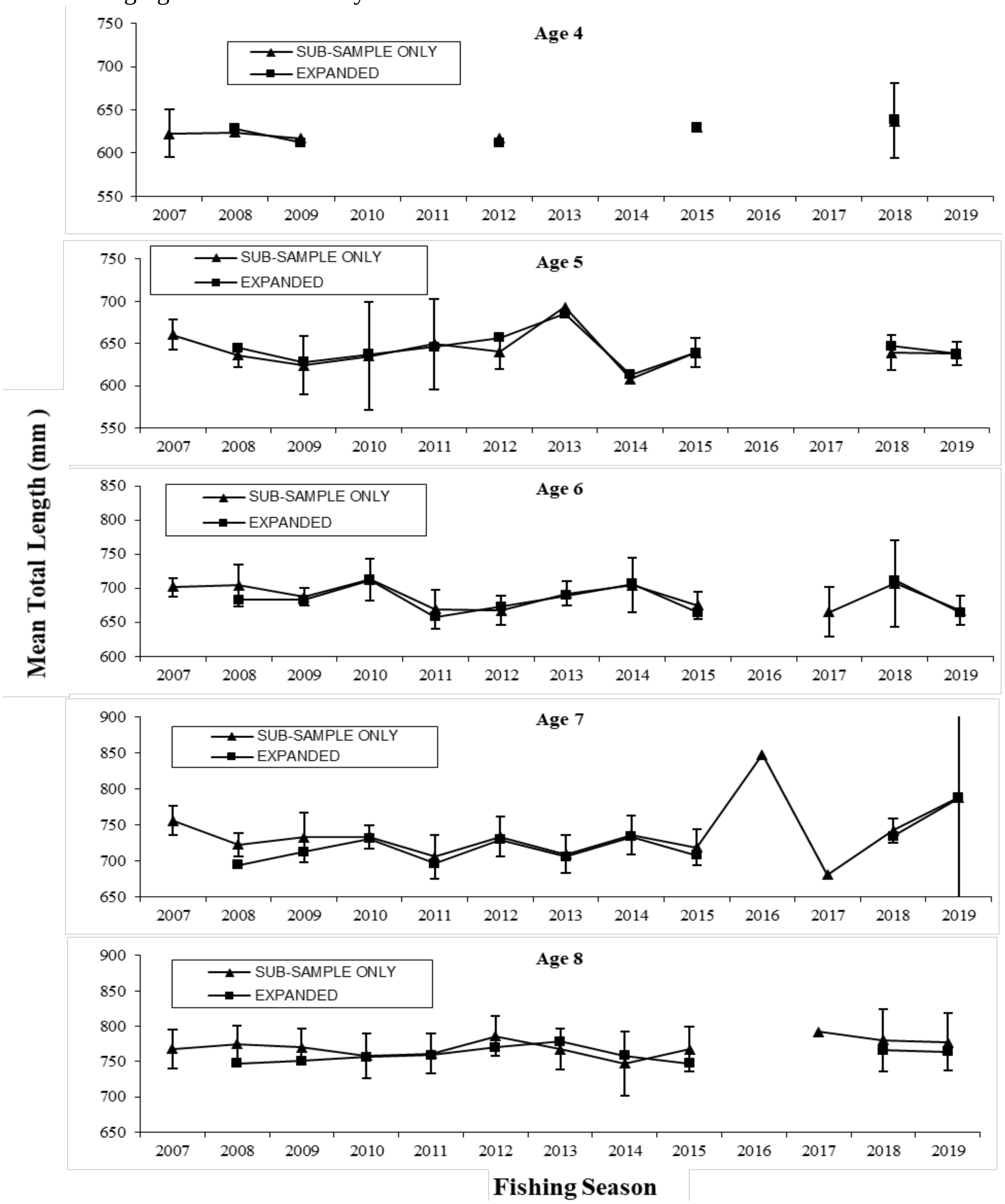


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2007 – 2019 (95% confidence intervals included when permitted by sample size). Expanded means (estimated from entire sample) are also shown, but were not calculated in 2016 and 2017 as all samples were chosen for aging. *Note different y-axis scales.



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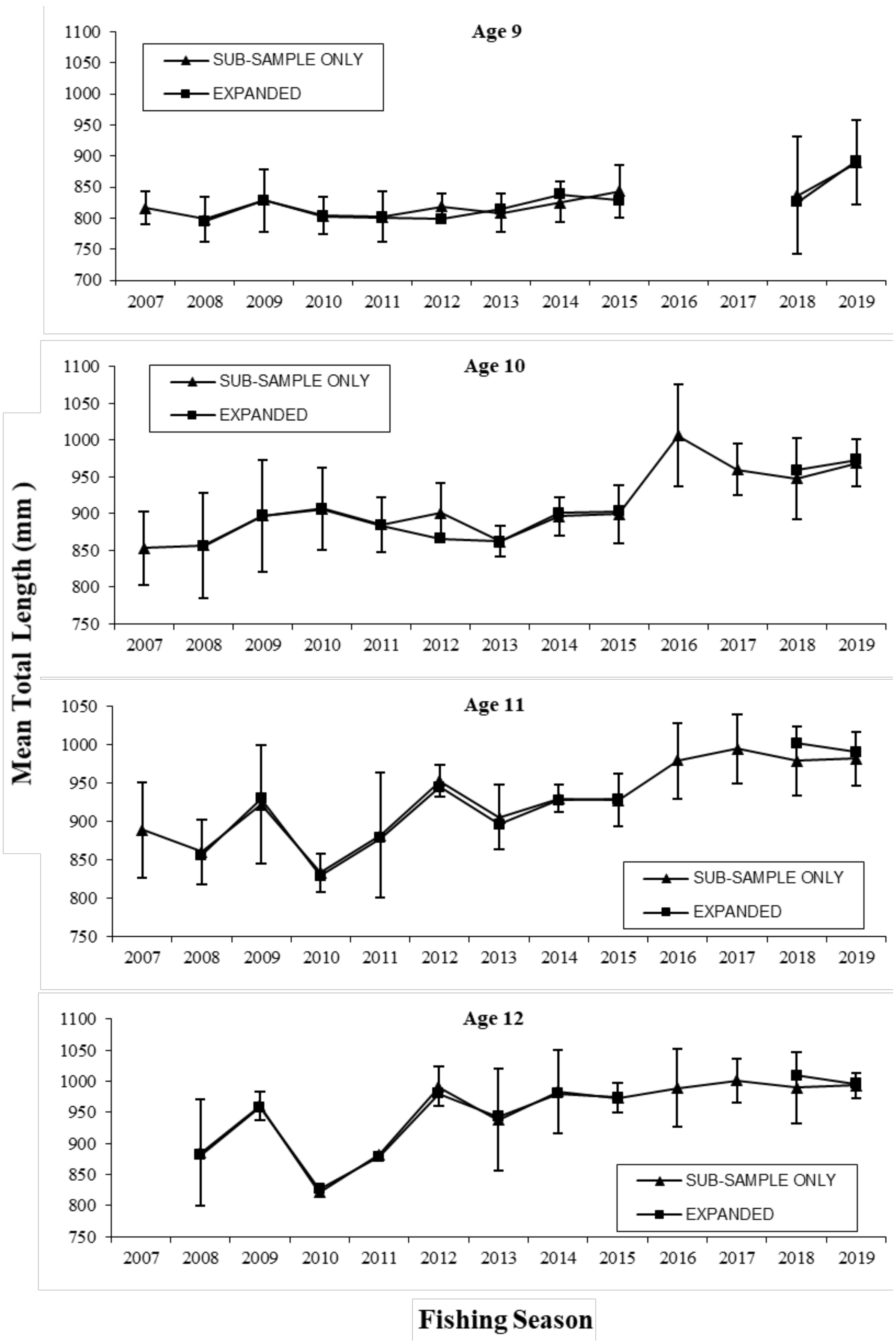
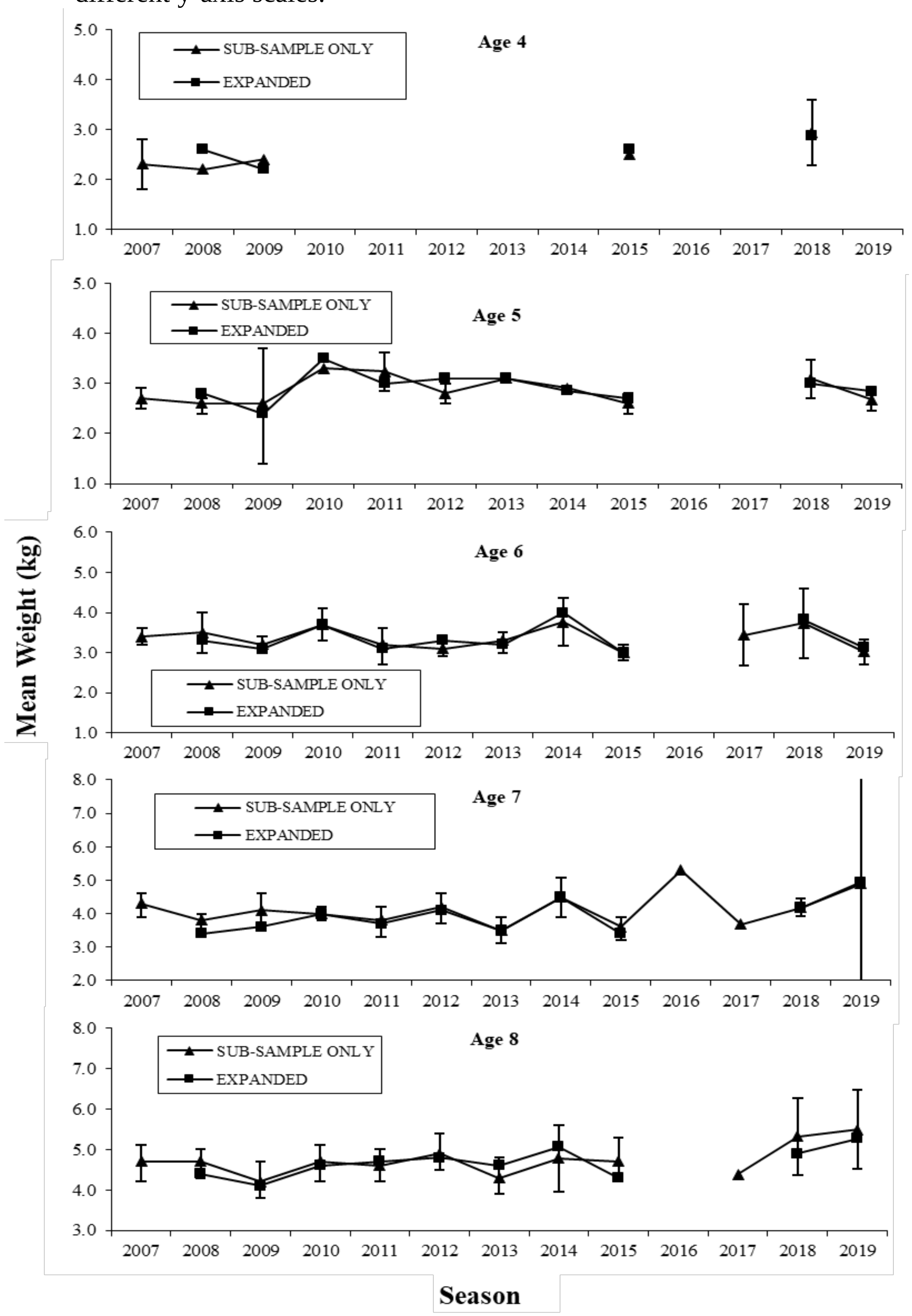


Figure 5. Mean weight (kg) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2007 – 2019 (95% confidence intervals included when permitted by sample size). Expanded means (estimated from entire sample) are also shown, but were not calculated in 2016 and 2017 as all samples were chosen for aging. *Note different y-axis scales.



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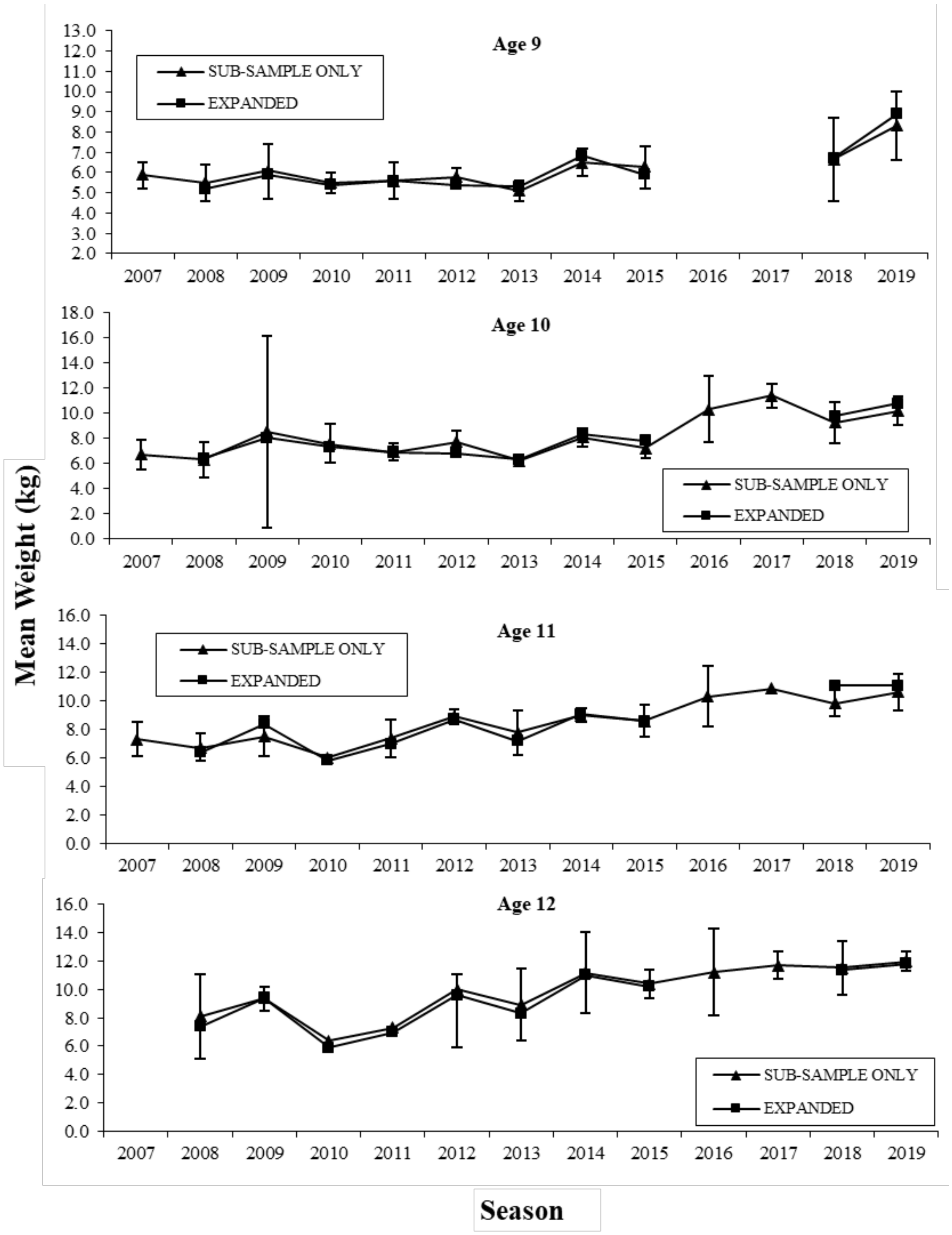

PROJECT NO. 2
JOB NO. 3
TASK NO. 2

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Beth A. Versak

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 2 were to finalize estimates of relative abundance-at-age for striped bass in Chesapeake Bay during the 2019 spring spawning season and to provide preliminary results for characterizing the 2020 spawning population. Completed abundance estimates and additional results for the 2020 spawning season will be reported in the next F-61-R-16 Chesapeake Bay Finfish Investigations report. Since 1985, the Maryland Department of Natural Resources (MD DNR) has employed multi-panel experimental drift gill nets to monitor the Chesapeake Bay component of the Atlantic coast striped bass population. Because Chesapeake Bay spawners can contribute up to 90% of the Atlantic coastal stock in some years (Richards and Rago 1999), indices derived from this effort are important in the coastal stock assessment process. Indices produced from this study are currently used to guide management decisions concerning recreational and commercial striped bass fisheries from North Carolina to Maine.

A secondary objective of Task 2 was to characterize the striped bass spawning population within the Chesapeake Bay. Length distribution, age structure, average length-at-age, and percentage of striped bass older than age 8 present on the spawning grounds were examined. In addition, an Index of Spawning Potential (ISP) for female striped bass, an age-independent measure of female spawning biomass within the Chesapeake Bay, was calculated.

METHODS

Data Collection Procedures

Multi-panel experimental drift gill nets were deployed in the Potomac River and in the Upper Chesapeake Bay in 2019 (Figure 1). Gill nets were fished 6 days per week, weather permitting, in April and May. In the Potomac River, sampling was conducted from April 2 to May 10 for a total of 30 sample days. In the Upper Bay, sampling was conducted from April 4 to May 20 for a total of 38 sample days.

Individual net panels were approximately 150 feet long, and ranged from 8.0 to 11.5 feet deep depending on mesh size. The panels were constructed of multifilament nylon webbing in 3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0 and 10.0-inch stretch-mesh, with gaps of 5 to 10 feet between each panel. In the Upper Bay, all 10 panels were tied together, end to end, to fish the entire suite of meshes simultaneously. In the Potomac River, because of the design of the fishing boat, the gang of panels was split in half, with two suites of panels (5 meshes tied together) fished simultaneously end to end. Additionally on the Potomac River, to avoid the small mesh panels being destroyed by large catches of blue catfish, the 3.0, 3.75 and 4.5 inch panels were cut in half to approximately 75 feet each. In both systems, all 10 panels were fished twice daily unless weather or tide prohibited a second set. Overall soak times for each panel ranged from 10 to 160 minutes.

Sampling locations were assigned using a stratified random design. The Potomac River and Upper Bay spawning areas were each considered a stratum. One randomly chosen site per day was fished in each spawning area. Sites were chosen from a grid superimposed on a map of each system. The Potomac River grid consisted of 40, 0.5-square-mile quadrats, while the Upper Bay grid consisted of 31, 1-square-mile quadrats. GPS equipment, buoys, and landmarks were used to locate the appropriate quadrat in the field. Once in the designated quadrat, air and surface water temperatures, surface salinity, and water clarity (Secchi depth) were measured.

All striped bass captured in the nets were measured for total length (mm TL), sexed by expression of gonadal products, and released. Scales were taken from 2-3 randomly chosen male striped bass per 10 mm length group up to 700 mm TL, per week, for a maximum of 10 scale samples per length group over the entire season. Scales were taken from all males over 700 mm TL and from all females regardless of total length. Scales were removed from the left side of the fish, above the lateral line, and between the two dorsal fins. Additionally, if time and fish condition permitted, U. S. Fish and Wildlife Service internal anchor tags were applied (Project No. 2, Job No. 3, Task 4).

Analytical Procedures

Development of age-length keys

Sex-specific age-length keys (ALKs) were used to develop catch-per-unit-effort (CPUE) estimates. The scale allocation procedure, in use since 2003, designated two sex-specific groups of scales pooled from both the spring gill net sampling and the spring striped bass recreational season creel survey (Project No. 2, Job No. 3, Task 5B; Barker et al., 2003).

Development of selectivity-corrected CPUEs and variance estimates

CPUEs for individual mesh sizes and length groups were calculated for each spawning area. CPUE was standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. Mesh-specific CPUEs were calculated by summing the catch in each length group across days and meshes, and dividing the result by the total effort for each mesh. This ratio of sums approach was assumed to provide the most accurate characterization of the spawning population, which exhibits a high degree of emigration and immigration from the sampling area during the two-month sampling interval. The dynamic state of the spawning population precludes obtaining an instantaneous, representative sample on a given day, whereas a sum of the catches absorbs short-term variability and provides a cumulative snapshot of spawning stock density. In addition, it was necessary to compile catches across the duration of the survey in each length group so that sample sizes were large enough to characterize gill net selectivity.

Sex-specific models have been used since 2000 to develop selectivity coefficients for female and male fish sampled from the Potomac River and Upper Bay. Model building and hypothesis testing determined that unique physical selectivity characteristics were evident by sex, but not by area (Waller 2000, unpublished data). Therefore, sex-specific selectivity coefficients for each mesh and length group were estimated by fitting a skew-normal model to spring data from 1990 to 2000 (Helser et al., 1998).

Sex-specific selectivity coefficients were used to correct the mesh-specific length group CPUE estimates. The selectivity-corrected CPUEs were then averaged across meshes and weighted by the capture efficiency of the mesh, resulting in a vector of selectivity-corrected length group CPUEs for each spawning area and sex.

Sex-specific ALKs were applied to the appropriate vectors of selectivity-corrected length group CPUEs to attain estimates of selectivity-corrected year-class CPUEs. Sex- and area-specific, selectivity-corrected, year-class CPUEs were calculated using the skew-normal selectivity model. These area- and sex-specific estimates of relative abundance were summed to develop estimates of relative abundance for Maryland's Chesapeake Bay. Before pooling over spawning areas, weights corresponding to the fraction of total spawning habitat encompassed by each spawning area were assigned. The Choptank River has not been sampled since 1996, therefore, values for 1997 to the present were weighted using only the Upper Bay (0.615) and the

Potomac River (0.385; Hollis 1967). In order to incorporate Bay-wide indices into the coastal assessment model, 15 age-specific indices were developed, one for each age from age 1 through age 15-plus.

Confidence limits for the individual sex- and area-specific CPUEs are presented. In addition, confidence limits for the pooled age-specific CPUE estimates are produced according to the methods presented in Cochran (1977), utilizing estimation of variance for values developed from stratified random sampling. Details of this procedure can be found in Barker and Sharov (2004).

Finally, additional spawning stock analyses for Chesapeake Bay striped bass were performed, including:

- Development of daily water temperature and catch patterns to examine relationships;
- Examination of the spawning stock length-at-age (LAA) structure among areas and over time, and calculation of confidence intervals for sex- and area-specific length-at-age (α=0.05);
- Examination of trends in the age composition of the Bay spawning stock and the percentage of the female spawning stock older than age 8, and calculation of the total stock older than age 8;
- Development of an index of spawning potential (ISP) for each system by converting the selectivity-corrected length group CPUE of female striped bass over 500 mm TL to biomass utilizing the regression equation (Rugolo and Markham 1996):

$$\ln weight_{kg} = 2.91 * \ln length_{cm} - 11.08 \qquad \text{(Equation 1)}$$

This equation was re-evaluated using length and weight data from female striped bass sampled during the 2009-2013 spring recreational seasons (Project No. 2, Job No. 3, Task No. 5B, this report). The resulting equation was almost identical and therefore no changes were made in the calculation of ISP.

RESULTS AND DISCUSSION

CPUEs and variance

A total of 408 scales were aged to create the sex-specific ALKs (Table 1). Annual CPUE calculations produced four vectors of selectivity-corrected sex- and age-specific CPUE values. The un-weighted time-series data are presented by area in Tables 2-7.

With one exception, the 2019 un-weighted CPUEs decreased relative to the previous year. For the second year in a row, female catches were unusually low on the Potomac. The 2019 un-weighted CPUE for Potomac females (5) was the second lowest value in the time-series, well below the average of 26 (Table 2). It is unclear why the female catches on the Potomac have been so low, as the Upper Bay females are not showing the same trend. The un-weighted CPUE for Potomac males (278) was also down, below the time-series average of 429 (Table 3).

The Upper Bay female CPUE (44) was the only increase observed, and was similar to the time-series average of 43. It ranked 17th in the 35 years of the survey (Table 4). As a result of using a combined ALK, CPUE values were calculated for age 4 and 5 females in the Upper Bay, although they were not actually captured in the survey. The un-weighted CPUE for Upper Bay males (445) was slightly lower than 2018, and just below the average of 456 (Table 5).

As in 2018, the abundant 2011 year-class (age 8 fish) held the highest age-class CPUE values for female fish in both systems. Age 4 and 5 males from the 2015 and 2014 year-class were very abundant in both systems. The Choptank River has not been sampled since 1996, but the results are included here for the historical record (Tables 6 and 7).

Area- and sex-specific, weighted CPUE values were pooled for use in the annual coastwide striped bass stock assessment. These indices are presented in a time-series for ages one through 15+ (Table 8). The 2019 selectivity-corrected, total, weighted CPUE (409) ranked 26th in the 35 year survey, below the time-series average of 493.

Confidence limits were calculated for the pooled and weighted CPUEs (Tables 9 and 10). Confidence limits could not be calculated for the 15+ age group in years when these values are the sum of multiple age-class CPUEs. Coefficients of Variation (CV) of the 2019 age-specific CPUEs were all below 0.10, with the exception of the age 14 group, indicating a small variance in CPUE. Historically, 83% of the CV values were less than 0.10 and 91% were less than 0.25 (Table 11). CV values greater than 1.0 were limited to older age-classes sampled during and immediately following the moratorium. The increased variability was likely attributed to small sample sizes associated with those older age-classes when the population size was low.

Tables 12 and 13 present CPUEs by year-class, un-weighted and weighted by spawning area, respectively. In most cases, the percentages by age, sex, and area were similar for the un-weighted and weighted CPUEs. Unless otherwise noted, all CPUEs and percentages discussed here are the weighted values.

Like last year, the above-average 2015 year-class was the most prevalent cohort in the spawning stock this year, composing 40% of the total CPUE, followed by the 2014 year-class at 19%. Upper Bay fish made up 73% of the total CPUE. Males were most frequently encountered, composing 93% of the total CPUE. This was due to the large contribution of the 2015 and 2014 year-class males.

The 2015 year-class made the largest contribution to the male CPUE in the Potomac River at 43%, followed by the 2014 year-class at 20%. In the Upper Bay, the 2015 year-class contributed 42% to the male CPUE and the 2014 year-class contributed 20%. Older males were not frequently encountered. In the Potomac, 66% of the male CPUE was made up of fish ages 4 and younger, while in the Upper Bay, that number was 58%.

Historically the female contribution has been less than 10% to each system’s CPUE. The female contribution to the Upper Bay CPUE was 9%, and 2% to the Potomac CPUE. Female

CPUEs were distributed across many year-classes in the Upper Bay, with 8 year-old female fish from the 2011 year-class contributing the most to its female CPUE (22%). This is similar to previous dominant year-class contributions of 8 year-old females, as they recruited to the spawning stock. In 2011, the 2003 females contributed 20% to the total female CPUE, and in 2004, the 1996 females also contributed 20%. Females from the age 15+ group, comprised mainly of 16 year old fish from the 2003 year-class contributed 18% in the Upper Bay. Female CPUEs in the Potomac were very low, with the 15+ age group contributing 47% to the total female CPUE.

Temperature and catch patterns

Daily surface water temperature on the Potomac River was 10°C at the start of the survey, and increased steadily through the month of April to 19°C. Water temperature was 20°C when the survey ended on May 10. Female CPUEs were very low through the entire survey (Figure 2). The majority of females were encountered during the first half of April, as water temperature rose. The largest peaks in male CPUE were observed during the second week of April, as water temperatures approached the 14°C mark necessary to initiate spawning (Fay et al., 1983).

Upper Bay surface water temperatures remained fairly stable throughout the survey. The survey began at 10°C, increased quickly to 14°C during the first two weeks of April, then slowly increased to a high of 18°C in mid-May. Water temperatures dropped to 15°C during the third week of May before rebounding. Females were encountered during the entire survey, with peak catches on April 17 and 18 and May 2 (Figure 3). The first peak in male CPUE was on April 13, as the water hit 14°C. The largest peak in male CPUE occurred on April 24, as the water warmed quickly to 17°C.

Length composition of the stock

In 2019, a total of 2,146 striped bass was measured. On the Potomac River, 448 male and 10 female striped bass were measured; 1,596 males and 90 females were measured from the Upper Bay (Figure 4). Each system measured one fish of unknown sex. The mean length of female striped bass (969 ± 38 mm TL) was significantly larger than the mean length of male striped bass (467 ± 4 mm TL, $P < 0.0001$), consistent with the known biology of the species. Mean lengths are presented with 2 standard errors.

The mean length of male striped bass collected from the Potomac River (469 ± 9 mm TL) was statistically similar to that sampled in the Upper Bay (466 ± 5 mm TL, $P < 0.584$). Male striped bass on the Potomac ranged from 291 to 1087 mm TL. Small males between 390 and 450 mm TL composed 51% of the Potomac River male catch in 2019, representing fish primarily from the above average 2015 year-class (Figure 4). The influence of these young fish was evident in the skewed uncorrected and selectivity-corrected CPUE peaks in Figure 5.

Male striped bass on the Upper Bay ranged from 221 to 1044 mm TL. Similar to Potomac males, the peak in the length frequency between 390-450 mm TL (53% of catch; Figure 4) likely represents younger males from the 2015 year-class. Male CPUE in the Upper Bay showed a similar distribution to the Potomac, representing the 2016 through 2011 year-classes (Figure 5).

Female striped bass sampled from the Potomac River (1088 ± 57 mm TL) in 2019 were significantly longer than those in the Upper Bay (956 ± 41 mm TL; $P=0.0011$). Sample size on the Potomac was small (n=10) and the Upper Bay length distribution was distributed across a wide range of length groups. Female striped bass on the Potomac ranged from 858 to 1206 mm TL, while females sampled in the Upper Bay ranged from 506 to 1322 mm TL (Figure 4). The peaks in both systems between 1050 and 1130 mm TL likely represent the 2005 through 2003 year-classes. Females from the 2011 year-class are distributed over a wide range from 690 to 850 mm TL (Figure 4).

Female CPUE in the Potomac River was generally low and sporadic due to a small sample size (Figure 6). In the Upper Bay, female CPUEs covered a wide range of length groups (Figure 6). The largest peak in selectivity-corrected CPUE at 890 mm resulted from two fish caught in small mesh net, with a low selectivity for their size group. The peak in the uncorrected CPUE at 1090 mm TL represented the above-average 2005 year-class. Application of the selectivity model to the data corrected the catch upward in cases where few fish were captured in meshes that had a low selectivity for their size.

Length at age (LAA)

Based on previous investigations which indicated no influence of area on mean LAA, samples from the Potomac River, Upper Bay and the spring recreational creel sampling (Project 2, Job 3, Task 5B) were again combined in 2019 to produce separate male and female ALKs (Warner et al., 2006; Warner et al., 2008; Giuliano and Versak 2012).

Age- and sex-specific LAA statistics are presented in Tables 14 and 15. Small sample sizes at age in both systems precluded testing for differences in LAA relationships in some cases. When year-classes are below average in abundance, or at extremes in age, sample sizes are sometimes too small to analyze statistically. This is the case particularly for female striped bass, as they are encountered much less frequently on the spawning grounds. In 2019, Potomac River female sample sizes were small, and only four ages had a large enough sample to compare. A one-way analysis of variance (ANOVA) was performed, where possible, to determine differences in mean LAA by sex, between areas (Upper Bay and Potomac). Few differences between sample areas were detected in LAA for either sex in 2019 ($\alpha > 0.05$). All female lengths-at-age were similar between the two areas. Age 3 male fish were significantly longer on the

Potomac River (367 mm TL) than the Upper Bay (323 mm TL, P=0.0004). Age 9 males were significantly shorter on the Potomac River (630 mm TL) than the Upper Bay (787 mm TL, P=0.0315).

Mean lengths-at-age were compared between years for each sex, areas combined (ANOVA, α=0.05). Male and female LAAs have been relatively stable since the mid-1990s (Figures 7 and 8). Mean lengths of males were similar in 2018 and 2019 for all ages except age 5 (P=0.0345), age 6 (P<0.0213) and age 13 (P=0.0351). In these three cases, males in 2019 were significantly longer than the same aged fish were in 2018. Mean lengths of females were similar in 2018 and 2019 for all ages except age 11 (P=0.0199), age 13 (P=0.0157) and age 16 (P=0.0488). Age 11 females in 2019 (856 mm TL) were significantly shorter than age 11 fish in 2018 (1013 mm TL). Ages 13 and 16 were significantly longer in 2019 than those ages in 2018.

Age composition of the stock

Eighteen age-classes, ranging from 2 to 19 were encountered (Tables 14 and 15). Of the 242 male fish aged from the survey (Table 1), ages 8 and 4 (2011 and 2015 year-classes) were the most commonly encountered. On the Potomac River, the males encountered ranged from age 2 through 16, while on the Upper Bay, males ages 2 through 14 were captured. Females ranged in age from 8 to 18 on the Potomac River, and 6 to 19 on the Upper Bay. Of the 100 aged female scales (Table 1), age 16 females from the above average 2003 year-class were most commonly observed, followed by age 8 females from the dominant 2011 year-class.

The abundance of 2 to 5 year-old striped bass in the Maryland Chesapeake Bay spawning stock has been variable since 1985, with clear peaks of abundance corresponding to strong year-classes (Figure 9). Relative to 2018, six of the fourteen age-specific CPUEs decreased in 2019. The contribution of the 15+ age group has been strong for the past ten years, driven by older females (Figure 9).

The contribution of age 8+ females to the total female CPUE increased in 2019 to 87%, the highest value since 2010 (Figure 10). This increase is likely driven by the addition of the 2011 year-class (age 8 in 2019) females to the spawning stock. The contribution of females age 8 and older to the spawning stock was at or above 80% for most years during the period of 1996-2015, but was below the time-series average (72%) for 2016 - 2018.

The percentage of the overall sample (males and females combined) age 8 and older has been variable since 1997 (Figure 11). The 2019 value of 17% was an increase from last year, and approximately equal to the time-series average of 16%. The percentage of age 8+ fish is heavily influenced by strong year-classes and shows cyclical variations (Figure 9). The lower values in recent years of age 8+ fish were due to the high number of young fish (from the 2015, 2014, and 2013 year-classes) encountered on the spawning grounds.

The Chesapeake Bay estimates of female ISP, expressed as biomass, have been calculated for the two largest spawning areas in Maryland's portion of the Bay. Maryland's estimates are more variable than the female spawning stock biomass (SSB) estimates produced in the coastwide stock assessment. Coastal estimates have shown a slow decline over the past decade (ASMFC 2019). Maryland's Chesapeake Bay estimates showed an increase from 2011 to 2015, before declining in recent years. The MD DNR estimates of ISP generated from the Upper Bay have been variable, but were very high for the period of 2012 to 2015. The 2019 ISP value of 371 was well below the high values of that previous period, but slightly above the time-series average of 353 (Table 16, Figure 12). The 2019 Potomac River female ISP of 58 was the lowest value since 1986.

PROJECT NO. 2
JOB NO. 3
TASK NO. 2

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

2020 PRELIMINARY RESULTS

Data collected during the 2020 spring spawning season are currently being analyzed. The survey start was delayed slightly due to COVID-19. In the Potomac River in 2020, sampling was conducted from April 14 to May 16 for a total of 25 sample days. In the Upper Bay, sampling was conducted from April 14 to May 22 for a total of 32 sample days.

Scale samples are currently being processed and aged, therefore no CPUE estimates are available at this time. A total of 906 scales were collected for use in creating the sex-specific ALKs. In the Potomac River, a total of 392 striped bass were sampled: 350 males and 42 females. Of those 392 fish, 222 (57%) were tagged with U. S. Fish and Wildlife Service internal anchor tags. In the Upper Bay, at total of 1,598 striped bass were captured: 1,531 males and 67 females. Of the 1,598 fish encountered, 642 (40%) were tagged.

Male striped bass on the Potomac ranged from 272 to 1030 mm TL, with a mean of 469 mm TL. Male striped bass on the Upper Bay ranged from 251 to 1118 mm TL, with a mean of 481 mmd TL. Female striped bass sampled from the Potomac ranged from 609 to 1246 mm TL, with a mean of 1062 mm TL. Upper Bay female striped bass ranged from 468 to 1157 mm TL, and had a mean of 937 mm TL.

The final, complete analyses of the spring 2020 spawning stock survey data will appear in the next F-61-R-16 Chesapeake Bay Finfish Investigations report.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL).

	MALES				FEMALES			
Length group (mm)	Upper Bay	Potomac River	Creel	Male Total	Upper Bay	Potomac River	Creel	Female Total
230	1	0	0	**1**	0	0	0	**0**
250	0	0	0	**0**	0	0	0	**0**
270	1	0	0	**1**	0	0	0	**0**
290	1	3	0	**4**	0	0	0	**0**
310	7	1	0	**8**	0	0	0	**0**
330	4	4	0	**8**	0	0	0	**0**
350	4	5	0	**9**	0	0	0	**0**
370	4	4	0	**8**	0	0	0	**0**
390	4	6	0	**10**	0	0	0	**0**
410	4	1	0	**5**	0	0	0	**0**
430	5	4	0	**9**	0	0	0	**0**
450	3	4	0	**7**	0	0	0	**0**
470	4	5	0	**9**	0	0	3	**3**
490	4	3	0	**7**	0	0	3	**3**
510	4	6	0	**10**	1	0	1	**2**
530	4	2	0	**6**	1	0	7	**8**
550	4	4	0	**8**	1	0	6	**7**
570	7	5	0	**12**	1	0	4	**5**
590	7	2	0	**9**	0	0	3	**3**
610	6	6	0	**12**	1	0	0	**1**
630	5	3	0	**8**	2	0	1	**3**
650	7	2	0	**9**	1	0	2	**3**
670	8	3	0	**11**	1	0	1	**2**
690	7	2	0	**9**	3	0	1	**4**
710	9	2	6	**17**	3	0	2	**5**
730	8	2	3	**13**	3	0	0	**3**
750	5	2	0	**7**	1	0	2	**3**
770	6	2	1	**9**	4	0	0	**4**
790	5	0	2	**7**	0	0	2	**2**
810	7	0	0	**7**	2	0	1	**3**
830	1	0	1	**2**	2	0	1	**3**
850	4	0	0	**4**	0	1	0	**1**
870	0	0	1	**1**	2	0	0	**2**
890	0	1	2	**3**	2	0	0	**2**
910	1	0	0	**1**	1	0	1	**2**
930	1	0	0	**1**	2	0	1	**3**
950	0	0	0	**0**	1	0	1	**2**
970	0	0	0	**0**	4	0	0	**4**
990	1	0	0	**1**	3	0	1	**4**
1010	1	0	0	**1**	2	0	1	**3**
1030	1	1	0	**2**	4	0	0	**4**
1050	1	0	0	**1**	5	0	1	**6**
1070	0	0	0	**0**	7	1	0	**8**
1090	0	1	0	**1**	10	2	0	**12**
1110	0	0	0	**0**	4	3	1	**8**
1130	0	0	0	**0**	3	2	1	**6**
1150	0	0	0	**0**	4	0	2	**6**
1170	0	0	0	**0**	2	0	0	**2**
1190	0	0	0	**0**	3	0	0	**3**
1210	0	0	0	**0**	2	1	0	**3**
1230	0	0	0	**0**	0	0	0	**0**
1250	0	0	0	**0**	1	0	0	**1**
1270	0	0	0	**0**	0	0	0	**0**
1290	0	0	0	**0**	0	0	0	**0**
1310	0	0	0	**0**	0	0	0	**0**
1330	0	0	0	**0**	1	0	0	**1**
Total	**156**	**86**	**16**	**258**	**90**	**10**	**50**	**150**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2019 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Potomac River was not sampled in 1994.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	0.0	0.0	0.0	0.1	0.5	0.2	0.0	0.2	0.1	0.1	0.0	0.5	0.0	0.6	**2**
1986	0.0	0.0	1.0	7.3	0.7	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**10**
1987	0.0	0.0	0.0	2.9	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	**10**
1988	0.0	0.0	0.0	1.7	2.4	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	**10**
1989	0.0	0.0	0.0	0.0	6.9	4.7	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**16**
1990	0.0	0.0	0.0	0.0	1.6	3.7	3.5	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	**11**
1991	0.0	0.0	0.0	0.0	0.6	0.6	1.5	2.0	6.6	0.3	1.8	0.0	0.0	0.0	0.6	**14**
1992	0.0	0.0	0.0	2.6	6.4	6.7	8.7	11.4	8.2	8.7	0.0	0.0	0.0	0.0	0.0	**53**
1993	0.0	0.0	0.0	1.0	8.2	7.7	9.4	15.2	14.3	8.6	4.3	0.0	0.0	0.0	0.0	**69**
1994																
1995	0.0	0.0	0.0	0.0	0.0	3.1	4.6	4.8	4.6	6.6	5.5	5.0	0.7	0.0	0.0	**35**
1996	0.0	0.0	0.0	0.0	0.8	0.2	3.9	7.1	6.8	8.8	5.4	8.1	3.3	0.0	0.0	**45**
1997	0.0	0.0	0.0	3.1	0.5	4.0	3.0	5.3	9.2	10.2	4.2	4.8	1.4	1.5	0.0	**47**
1998	0.0	0.0	0.0	0.0	0.0	0.8	0.3	1.0	3.2	2.7	4.4	4.6	1.6	0.7	0.0	**19**
1999	0.0	0.0	0.0	0.0	0.0	2.1	3.7	4.2	4.8	2.0	6.4	2.6	0.6	0.0	0.3	**27**
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	1.4	2.4	7.8	1.2	1.4	5.1	0.0	**27**
2001	0.0	0.0	0.0	1.0	0.0	0.0	2.9	4.6	7.2	4.0	4.3	3.0	5.2	0.0	0.0	**32**
2002	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.1	12.3	5.9	5.5	2.7	6.0	1.8	2.2	**40**
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.8	3.5	2.8	1.6	0.3	1.5	0.0	**12**
2004	0.0	0.0	0.0	0.0	0.0	1.6	2.8	13.5	6.3	8.6	11.6	6.6	3.5	4.8	1.3	**61**
2005	0.0	0.0	0.0	0.0	1.9	0.0	1.6	0.6	2.7	2.5	4.6	4.1	1.7	0.8	2.3	**23**
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	6.3	9.2	4.1	5.1	9.6	2.3	6.5	**44**
2007	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.9	1.4	3.2	7.5	4.5	1.4	3.8	3.2	**26**
2008	0.0	0.0	0.0	0.4	0.4	0.0	0.9	0.1	0.4	1.8	2.4	4.9	1.2	1.2	1.4	**15**
2009	0.0	0.0	0.3	0.0	0.5	0.5	0.3	2.6	4.3	1.9	2.3	1.9	4.6	1.2	1.4	**22**
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	2.3	0.7	1.5	2.2	5.9	4.1	**19**
2011	0.0	0.0	0.1	0.8	0.4	0.0	0.0	0.9	0.4	2.0	1.1	1.1	1.1	0.4	2.6	**11**
2012	0.0	0.0	0.0	1.0	1.4	4.7	2.6	1.1	1.6	1.0	1.6	1.8	0.8	1.0	3.1	**22**
2013	0.0	0.0	0.0	0.0	0.2	1.5	0.7	2.0	0.7	3.3	2.0	1.5	1.1	0.8	3.9	**18**
2014	0.0	0.0	0.0	0.0	0.2	0.3	1.8	1.3	2.8	4.1	7.3	0.5	2.5	0.5	3.2	**25**
2015	0.0	0.0	0.0	0.0	0.0	0.4	0.9	1.3	0.6	2.3	4.0	9.7	1.9	4.5	3.1	**29**
2016	0.0	0.0	0.0	0.0	5.2	2.3	1.5	0.4	0.8	0.6	1.8	1.9	3.1	0.6	2.8	**21**
2017	0.0	0.0	0.0	0.3	0.3	7.1	3.8	2.8	0.8	6.9	3.6	5.7	4.7	3.4	4.9	**44**
2018	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.4	0.9	0.1	0.9	0.1	0.7	0.6	1.9	**8**
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.3	0.0	0.0	0.1	1.2	2.1	**5**
Average																**26**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2019 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Potomac River was not sampled in 1994.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	285.3	517.6	80.6	10.5	0.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**896**
1986	0.0	241.5	375.9	531.2	8.2	8.2	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1166**
1987	0.0	144.5	283.5	174.6	220.8	3.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	**829**
1988	0.0	18.2	107.4	63.8	75.9	81.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**347**
1989	0.0	51.9	240.9	134.5	39.1	55.2	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**543**
1990	0.0	114.2	351.8	172.8	73.8	28.3	33.8	26.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	**803**
1991	0.0	19.9	91.2	96.6	49.7	37.8	28.7	22.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0	**352**
1992	0.3	36.3	202.4	148.9	97.6	73.0	39.1	19.0	6.1	0.8	8.4	0.0	0.0	0.0	0.0	**632**
1993	0.0	30.4	141.7	133.9	101.4	83.7	62.6	43.6	21.9	1.8	0.0	0.0	0.0	0.0	0.0	**621**
1994																
1995	0.0	9.1	143.9	61.1	18.7	20.4	25.3	32.2	11.3	10.7	0.1	0.0	0.8	0.0	0.0	**334**
1996	0.0	0.0	230.6	172.9	24.8	26.8	17.7	22.7	19.3	3.6	0.6	0.8	0.0	0.0	0.0	**520**
1997	0.0	49.5	54.3	112.9	95.7	12.2	5.7	10.8	17.2	13.6	2.2	2.6	0.0	0.0	0.0	**377**
1998	0.0	72.9	200.7	29.8	128.9	49.8	16.9	11.7	4.3	9.0	8.6	5.0	2.9	0.5	0.0	**541**
1999	0.0	9.9	316.9	151.2	103.6	65.4	19.1	10.3	6.9	3.8	4.4	3.1	1.9	0.0	0.0	**696**
2000	0.0	1.9	42.2	136.8	48.5	18.1	14.8	9.8	5.5	0.0	0.1	3.7	0.1	0.4	0.9	**283**
2001	0.0	10.6	36.1	43.5	33.8	12.6	8.9	7.8	4.8	1.7	2.2	4.0	0.8	0.6	0.0	**167**
2002	0.0	27.2	75.4	48.7	52.4	23.0	20.9	7.9	2.3	3.4	2.2	1.6	2.0	0.0	0.6	**268**
2003	0.0	12.6	79.0	39.6	24.5	31.6	22.5	10.0	7.0	9.5	3.2	3.7	5.8	0.2	0.2	**249**
2004	0.0	10.5	148.8	90.4	25.9	17.6	19.5	17.2	8.4	8.1	11.5	1.8	1.1	1.6	1.6	**364**
2005	0.0	10.9	11.0	14.9	16.3	4.7	4.5	3.6	4.1	3.1	1.9	1.2	0.0	0.0	0.0	**76**
2006	0.0	8.3	127.1	20.7	33.5	14.5	6.3	6.9	8.2	9.1	7.4	4.7	0.6	0.4	0.0	**248**
2007	0.0	10.4	16.6	37.1	5.3	5.6	4.3	2.1	2.6	2.8	5.4	1.0	0.8	2.0	0.1	**96**
2008	0.0	6.1	35.8	20.1	12.0	1.7	1.8	2.3	1.1	1.2	1.3	2.5	0.4	0.0	0.2	**86**
2009	0.0	35.2	35.9	116.5	23.1	56.9	9.1	10.5	10.5	2.8	3.8	2.6	3.7	0.6	0.6	**312**
2010	0.0	3.2	104.9	58.0	49.2	29.7	23.9	1.7	6.8	3.6	0.9	1.2	1.3	0.6	0.4	**285**
2011	0.0	27.6	95.7	164.4	51.2	54.4	29.6	24.7	6.2	5.2	6.1	4.1	4.9	2.1	5.3	**481**
2012	0.0	19.0	44.4	15.1	13.9	6.4	6.0	4.8	4.1	1.4	2.1	1.3	0.6	4.1	0.0	**123**
2013	0.0	6.7	19.9	50.9	23.7	17.6	8.6	5.0	1.5	1.9	0.2	0.1	0.0	0.0	0.0	**136**
2014	0.0	1.0	196.1	40.1	55.2	18.2	19.8	3.7	9.1	4.5	6.9	0.8	1.8	0.0	0.0	**357**
2015	0.0	33.4	12.9	613.7	49.8	50.2	15.5	12.1	9.4	5.5	3.0	2.1	0.9	1.6	4.0	**814**
2016	0.0	71.0	66.5	11.9	79.8	11.1	6.7	1.6	1.4	1.2	2.6	1.1	0.6	0.0	0.2	**256**
2017	0.0	59.4	116.3	32.9	70.8	141.7	20.9	15.9	11.7	9.8	7.4	20.2	0.8	1.7	0.4	**510**
2018	0.0	1.8	261.2	148.3	23.5	18.8	51.9	6.2	2.3	0.3	0.4	2.2	2.2	8.1	0.0	**527**
2019	0.0	28.8	35.1	118.1	54.5	6.2	12.5	13.1	1.0	0.6	0.0	5.2	1.0	0.8	0.8	**278**
Average																**429**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985-2019 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	0.0	0.8	0.0	0.3	0.1	0.5	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.3	**2**
1986	0.0	0.0	0.3	24.3	0.0	0.0	0.5	0.5	3.8	0.0	0.0	0.0	0.0	0.0	0.3	**30**
1987	0.0	0.0	0.0	3.1	26.8	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	8.8	8.5	**50**
1988	0.0	0.0	4.2	8.8	6.5	31.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**52**
1989	0.0	0.0	1.2	1.8	6.2	3.9	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**22**
1990	0.0	0.0	0.0	0.3	0.0	0.3	1.8	5.3	0.0	0.0	0.0	0.9	0.6	0.0	0.0	**9**
1991	0.0	0.0	0.0	0.5	3.2	0.5	2.3	3.1	2.2	0.0	1.2	0.0	0.0	0.0	1.2	**14**
1992	0.0	0.0	0.2	4.4	3.5	5.6	4.4	4.9	4.3	4.2	0.3	0.0	0.5	1.1	0.4	**34**
1993	0.0	0.0	0.0	3.0	5.1	2.0	4.0	4.8	4.0	3.9	2.0	1.3	2.3	2.1	0.0	**35**
1994	0.0	0.0	0.0	0.4	0.8	3.0	1.3	2.9	1.5	2.9	1.1	0.0	0.0	0.0	0.0	**14**
1995	0.0	0.0	0.0	0.0	1.7	20.2	19.5	7.7	11.2	5.2	5.7	2.0	7.0	0.0	0.0	**80**
1996	0.0	0.0	0.0	0.0	0.0	1.3	11.2	10.2	6.4	5.4	7.0	1.8	0.0	0.0	0.0	**43**
1997	0.0	0.0	0.0	0.0	0.0	0.0	1.9	10.9	17.9	1.6	0.0	0.7	0.5	0.0	0.0	**33**
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.0	2.6	5.2	1.3	1.3	0.0	0.0	0.5	**17**
1999	0.0	0.0	0.0	0.0	0.0	2.8	0.0	1.7	6.7	3.2	0.7	0.9	0.0	3.5	0.0	**19**
2000	0.0	0.0	0.0	0.0	0.0	2.2	3.3	1.0	3.0	5.9	2.5	5.7	0.1	0.3	0.0	**24**
2001	0.0	0.0	0.0	0.0	0.5	2.1	4.6	13.5	5.6	5.8	7.5	5.0	1.4	1.5	0.3	**48**
2002	0.0	0.0	0.0	0.0	0.0	6.9	1.1	3.1	9.0	2.6	2.3	2.0	1.6	0.8	0.0	**29**
2003	0.0	0.0	0.0	0.0	0.0	1.7	7.0	8.5	8.9	16.8	12.1	4.3	3.9	2.6	0.0	**66**
2004	0.0	0.0	0.0	0.0	0.0	0.3	2.2	7.9	11.0	7.2	9.4	3.0	1.5	0.5	3.0	**46**
2005	0.0	0.0	0.0	0.0	0.0	0.2	1.4	3.3	7.9	9.0	10.2	9.5	3.4	1.2	4.8	**51**
2006	0.0	0.0	0.0	0.0	2.8	4.2	3.1	0.3	4.3	6.2	3.2	5.4	7.4	1.8	5.9	**45**
2007	0.0	0.0	0.0	0.0	0.0	0.5	3.4	2.8	4.3	5.5	11.4	5.0	1.3	3.8	7.1	**45**
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.8	2.6	4.2	3.6	7.8	2.1	0.8	1.7	**25**
2009	0.0	0.0	0.0	0.0	3.2	3.8	0.2	2.9	8.5	2.8	6.6	4.8	10.5	3.8	5.1	**52**
2010	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.3	2.2	2.7	1.4	2.0	2.1	6.6	6.3	**27**
2011	0.0	0.0	0.0	4.9	2.0	1.2	1.3	6.4	1.3	2.5	1.2	1.0	2.1	1.2	2.2	**27**
2012	0.0	0.0	0.0	0.0	1.5	6.8	6.2	6.4	15.4	5.8	8.8	9.3	4.5	3.8	19.2	**87**
2013	0.0	0.0	0.3	2.4	1.8	15.2	5.2	10.8	8.1	16.7	4.5	9.0	3.9	5.3	13.0	**96**
2014	0.0	0.0	0.0	0.0	1.3	6.6	14.7	5.3	12.7	11.5	18.6	1.5	11.6	3.0	17.4	**104**
2015	0.0	0.0	0.0	3.7	2.3	4.5	8.0	7.3	3.1	10.6	10.7	14.1	3.0	8.9	11.1	**87**
2016	0.0	0.0	0.0	0.1	12.5	3.9	3.3	2.1	3.5	1.5	4.9	4.8	7.9	1.2	6.2	**52**
2017	0.0	0.0	0.0	2.4	2.6	12.6	3.0	1.8	1.4	5.9	3.6	6.7	5.1	3.6	4.3	**53**
2018	0.0	0.0	0.0	1.1	1.9	1.2	9.9	2.1	1.6	1.2	1.4	0.6	3.2	2.5	9.8	**37**
2019	0.0	0.0	0.0	1.3	0.6	0.6	3.5	9.4	6.2	5.5	0.5	2.3	0.5	5.1	8.0	**44**
Average																**43**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985-2019 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	47.5	148.8	1.9	0.0	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**199**
1986	0.0	219.0	192.3	450.8	0.4	3.4	2.2	3.8	1.3	0.0	0.0	0.0	0.0	0.0	1.2	**874**
1987	0.0	131.7	231.0	68.1	138.8	0.0	2.1	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**576**
1988	0.0	52.1	38.0	61.6	37.8	36.8	0.6	0.0	0.0	7.2	0.0	0.0	0.0	0.0	0.0	**234**
1989	0.0	8.1	102.3	17.4	21.1	26.9	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**192**
1990	0.0	56.7	28.4	92.8	20.1	24.9	22.9	16.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**263**
1991	0.0	84.1	254.9	36.8	40.9	11.3	16.0	9.5	4.3	0.1	0.0	0.0	0.0	0.0	0.0	**458**
1992	0.0	22.5	193.9	150.1	19.4	52.9	27.7	19.1	7.5	0.5	0.0	0.0	0.0	0.0	0.0	**494**
1993	0.0	30.6	126.2	149.1	63.0	16.3	27.3	9.9	7.5	0.5	0.0	0.0	0.0	0.0	0.0	**430**
1994	0.0	25.4	54.5	96.3	101.8	43.2	14.5	26.8	6.4	2.1	0.3	0.0	0.0	0.0	0.0	**371**
1995	0.0	79.0	108.4	75.8	89.8	52.9	30.0	11.6	12.4	3.7	7.2	0.9	0.0	0.0	0.0	**471**
1996	0.0	6.2	433.5	57.6	23.3	86.2	59.2	34.1	29.0	11.8	12.0	0.0	0.6	0.0	0.0	**753**
1997	0.0	28.9	38.8	155.5	15.4	23.9	23.5	15.0	8.9	2.0	12.1	0.0	0.7	0.0	0.0	**325**
1998	0.0	13.0	106.6	34.6	162.0	20.9	10.0	17.1	20.9	11.9	5.4	8.7	0.0	0.0	0.0	**411**
1999	0.0	7.7	81.8	33.6	30.4	14.6	4.8	0.6	4.7	1.6	0.4	0.2	0.3	0.0	0.0	**181**
2000	0.0	22.2	64.6	83.6	47.7	80.4	28.0	10.6	6.1	6.2	3.9	3.3	1.4	0.4	0.3	**359**
2001	0.0	1.4	40.9	70.2	64.9	27.6	35.3	33.0	5.8	10.4	3.5	0.4	0.5	0.0	0.4	**294**
2002	0.0	120.7	19.1	34.1	106.7	48.2	42.2	43.7	20.1	5.2	2.4	1.1	1.9	0.0	0.0	**445**
2003	0.0	17.7	131.9	62.1	42.2	89.8	62.9	29.7	29.1	22.3	8.1	4.0	2.4	0.4	0.4	**503**
2004	0.0	40.3	221.1	140.5	52.7	44.0	56.0	49.7	28.7	20.0	13.7	2.6	2.5	1.4	0.0	**673**
2005	0.0	100.6	161.8	110.2	145.9	36.3	36.8	29.4	32.5	20.7	14.2	5.7	0.3	0.0	0.0	**694**
2006	0.0	7.0	339.9	52.2	53.6	34.3	16.9	15.5	16.6	17.3	11.0	6.3	1.3	1.0	0.0	**573**
2007	0.0	6.3	26.2	100.4	20.9	20.8	15.7	7.3	7.8	7.1	6.5	4.5	2.2	1.4	0.2	**227**
2008	0.0	1.5	117.5	163.5	175.0	26.4	35.2	28.8	14.8	13.5	10.4	10.3	18.7	3.8	3.2	**623**
2009	0.0	43.2	45.7	175.9	66.0	185.1	28.3	25.7	32.9	8.8	15.4	12.1	22.3	2.9	1.5	**666**
2010	0.0	10.2	177.8	45.6	74.8	63.6	72.1	8.4	14.8	10.1	4.1	4.7	5.4	5.4	22.5	**520**
2011	0.0	20.1	59.2	92.8	39.5	57.9	42.0	50.7	10.9	7.9	7.0	8.5	0.7	4.2	8.3	**410**
2012	0.0	12.8	56.8	27.7	27.5	15.3	26.0	26.7	21.8	4.8	15.8	10.8	1.7	4.0	0.7	**252**
2013	0.0	53.7	81.2	138.5	56.9	56.6	33.9	31.9	24.9	25.7	3.6	9.2	3.5	1.1	5.4	**526**
2014	0.0	13.2	331.5	60.6	59.3	20.6	25.3	7.5	12.6	7.8	13.2	1.5	2.7	0.4	6.7	**563**
2015	0.0	10.1	3.8	357.4	41.9	45.8	21.3	18.7	16.3	21.5	16.6	11.8	5.9	3.8	3.5	**578**
2016	0.0	63.9	45.7	22.7	200.3	26.7	17.0	4.6	5.1	6.1	7.5	6.2	4.9	0.3	8.0	**419**
2017	0.0	66.7	116.0	31.1	74.6	117.2	17.5	15.3	9.4	8.0	8.5	16.7	3.3	1.2	2.1	**488**
2018	0.0	1.8	145.1	133.7	32.7	30.2	89.7	9.7	11.1	3.1	4.8	1.0	4.5	11.3	0.0	**479**
2019	0.0	28.5	42.2	188.8	89.0	13.8	24.6	23.5	7.5	5.4	1.6	2.4	5.9	6.9	5.3	**445**
Average																**456**

Table 6. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Choptank River during the 1985-1996 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Choptank River was not sampled in 1995, and has not been sampled since 1996.

	AGE														
YEAR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**
1985	0	0.0	0.0	0.0	2.2	0.8	2.9	0.8	1.0	0.4	0.0	0.6	1.3	0.5	1.0	**12**
1986	0	0.0	0.0	12.8	1.9	1.0	1.6	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	**18**
1987	0	0.0	0.0	6.8	20.7	3.3	0.6	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.5	**38**
1988	0	0.0	0.0	9.2	10.8	16.4	3.2	0.0	1.0	1.0	0.0	0.0	0.0	0.7	0.4	**43**
1989	0	0.0	0.0	17.0	31.8	22.7	39.1	3.0	0.5	0.6	0.0	0.0	0.5	0.0	0.0	**115**
1990	0	0.0	0.0	0.0	15.7	24.2	15.9	40.7	3.1	3.0	0.0	0.0	4.7	2.5	4.4	**114**
1991	0	0.0	0.0	1.3	0.8	22.9	23.1	15.5	32.9	4.8	3.4	0.0	14.1	14.1	5.1	**138**
1992	0	0.0	1.0	0.0	1.4	9.9	28.1	18.7	19.0	15.6	0.0	0.0	16.3	3.4	0.0	**113**
1993	0	0.0	0.0	3.0	0.0	5.4	15.2	30.1	23.5	19.0	8.2	1.6	2.8	5.6	2.8	**117**
1994	0	0.0	0.0	0.0	7.5	7.1	8.8	7.7	31.3	6.1	4.0	0.0	0.0	0.0	0.0	**73**
1995																
1996	0	0.0	0.0	0.0	6.9	26.4	38.3	37.0	36.5	37.5	21.6	8.7	1.1	0.0	0.0	**214**
Average																**90**

Table 7. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Choptank River during the 1985-1996 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Choptank River was not sampled in 1995, and has not been sampled since 1996.

	AGE														
YEAR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**
1985	0.0	162.2	594.7	23.9	7.3	4.8	10.0	0.0	3.5	0.0	0.0	0.0	0.5	0.0	0	**807**
1986	0.0	290.2	172.6	393.9	12.0	6.1	1.6	1.2	0.0	0.0	0.0	0.0	0.6	0.0	0	**878**
1987	0.0	223.3	262.0	79.0	156.4	9.6	0.7	1.2	0.4	0.0	0.0	0.0	0.7	0.0	0	**733**
1988	0.0	27.0	223.3	114.6	53.5	111.5	4.7	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0	**536**
1989	0.0	228.5	58.1	466.1	278.6	191.9	173.9	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0	**1399**
1990	0.0	59.5	280.4	36.3	198.1	165.8	75.9	116.9	5.0	0.0	2.3	0.0	4.3	0.0	0	**944**
1991	0.0	410.4	174.9	112.2	62.1	115.6	79.8	55.5	18.2	0.6	0.0	0.0	0.0	0.0	0	**1029**
1992	0.0	16.2	733.0	135.2	168.4	141.9	136.4	81.2	23.6	10.1	0.0	0.0	0.0	11.3	0	**1457**
1993	0.0	291.3	128.8	1156.4	193.5	158.8	161.5	147.3	45.9	11.3	3.5	0.0	0.0	0.0	0	**2298**
1994	0.0	112.8	463.3	99.5	835.2	270.9	139.4	188.5	54.9	9.2	7.6	8.3	0.9	0.0	0	**2191**
1995																
1996	0.0	7.8	682.2	106.0	280.6	171.5	334.1	91.1	85.6	11.8	23.1	0.0	0.0	0.0	0	**1794**
Average																**1279**

Table 8. Mean values of the annual, pooled, weighted, age-specific CPUEs (1985–2019) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

	Age															
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Sum**
1985	0.0	140.5	305.5	31.9	4.8	1.3	2.2	0.0	0.4	0.1	0.0	0.4	0.3	0.0	0.7	**488**
1986	0.0	230.2	261.1	497.6	4.0	5.3	2.0	2.9	2.8	0.0	0.0	0.0	0.0	0.0	0.9	**1007**
1987	0.0	142.2	258.0	115.1	176.1	17.9	2.2	2.6	0.2	0.0	0.0	0.0	0.0	0.3	0.3	**715**
1988	0.0	40.8	77.6	71.3	57.0	74.6	1.3	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.3	**327**
1989	0.0	33.1	154.7	80.5	45.5	48.8	32.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	**396**
1990	0.0	78.1	158.1	120.4	48.3	34.3	32.0	29.8	0.9	0.1	0.1	0.5	0.7	0.1	0.2	**504**
1991	0.0	73.4	191.9	62.2	47.1	26.7	26.0	19.2	10.6	0.4	1.5	0.0	0.6	0.6	1.1	**461**
1992	0.1	27.4	221.1	153.5	58.6	69.9	42.9	29.1	13.7	7.0	3.3	0.0	0.9	1.2	0.2	**629**
1993	0.0	41.0	132.0	187.2	88.2	51.0	51.9	37.1	22.6	7.4	3.1	0.8	1.4	1.4	0.1	**625**
1994	0.0	26.8	103.5	98.0	117.9	59.5	34.0	42.9	17.6	8.6	3.1	1.3	0.3	0.0	0.0	**513**
1995	0.0	50.0	117.2	68.4	60.9	51.6	40.0	25.0	19.7	11.6	9.6	3.5	4.6	0.0	0.0	**462**
1996	0.0	4.0	368.3	102.2	34.7	69.5	64.4	42.3	35.4	16.7	15.2	4.7	1.6	0.0	0.0	**759**
1997	0.0	36.8	44.8	140.3	46.5	20.9	18.9	22.1	26.6	11.4	9.9	3.3	1.2	0.6	0.0	**383**
1998	0.0	36.1	142.8	32.7	149.3	32.3	13.2	18.5	17.3	15.0	9.1	9.9	1.7	0.4	0.3	**479**
1999	0.0	8.6	172.4	78.9	58.6	36.7	11.7	7.0	11.5	5.2	4.8	2.8	1.1	2.1	0.1	**402**
2000	0.0	14.4	55.9	104.1	48.0	57.7	25.0	13.8	8.3	8.3	7.0	7.4	1.5	2.5	0.5	**354**
2001	0.0	4.9	39.1	60.3	53.2	23.1	29.1	33.3	11.6	12.1	9.3	6.1	3.5	1.2	0.4	**287**
2002	0.0	84.6	40.8	39.7	85.8	42.7	35.0	33.1	23.5	8.4	5.8	3.6	5.2	1.2	0.4	**410**
2003	0.0	15.7	111.5	53.4	35.4	68.4	51.6	27.6	26.7	29.1	14.7	7.2	6.1	2.5	0.3	**450**
2004	0.0	28.8	193.2	121.2	42.4	34.6	44.4	47.3	30.1	23.1	23.1	6.7	4.2	3.7	2.7	**605**
2005	0.0	66.0	103.6	73.5	96.6	24.3	25.9	21.7	27.5	20.4	17.5	11.3	3.0	1.0	3.8	**496**
2006	0.0	7.5	257.9	40.1	47.6	29.2	14.8	12.7	18.4	21.6	13.1	11.0	9.3	2.7	6.1	**492**
2007	0.0	7.9	22.5	76.0	14.9	15.3	13.5	7.4	9.0	10.0	16.0	8.0	3.0	5.4	5.3	**214**
2008	0.0	3.3	86.0	108.4	112.3	16.9	23.0	19.7	11.3	12.0	10.1	14.0	13.4	3.3	3.6	**437**
2009	0.0	40.1	42.1	153.0	51.6	138.2	21.1	22.7	31.2	9.0	15.8	12.1	23.4	4.8	4.8	**570**
2010	0.0	7.5	149.7	50.4	65.0	50.5	54.9	6.7	13.9	10.2	4.0	5.1	5.9	9.9	19.4	**453**
2011	0.0	23.0	73.3	123.7	45.4	57.3	38.0	44.9	10.1	9.1	7.9	7.8	4.0	4.3	9.6	**458**
2012	0.0	15.2	52.0	23.2	23.7	17.8	23.1	22.6	25.0	7.4	16.5	13.6	4.4	6.7	13.5	**265**
2013	0.0	35.6	57.8	106.2	45.3	51.5	27.6	28.9	21.1	28.0	5.8	11.8	5.0	4.3	12.8	**442**
2014	0.0	8.5	279.3	52.7	58.6	23.9	32.9	9.8	20.1	15.2	25.0	2.3	10.5	2.3	16.0	**557**
2015	0.0	19.1	7.3	458.5	46.4	50.4	24.3	21.2	15.8	22.7	19.5	20.5	6.6	10.2	11.7	**734**
2016	0.0	66.6	53.7	18.6	163.6	24.0	15.6	4.9	6.2	5.4	9.3	7.9	9.3	1.1	9.9	**396**
2017	0.0	63.9	116.1	33.5	74.9	137.2	22.2	17.8	11.5	15.0	11.7	24.3	7.3	4.9	5.9	**546**
2018	0.0	1.8	189.9	140.0	30.3	26.5	81.9	9.8	9.0	2.9	4.3	1.9	5.9	11.8	6.8	**523**
2019	0.0	28.6	39.5	162.4	76.1	11.3	22.1	25.5	8.8	7.1	1.3	4.9	4.4	8.1	9.3	**409**
Average																**493**

Table 9. Lower confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2019) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0.0	127.3	277.1	28.8	4.2	1.0	0.9	*0.0*	*0.0*	*0.0*	0.0	*0.0*	*0.0*	*0.0*	*
1986	0.0	214.2	245.6	464.6	3.6	4.8	1.7	2.7	1.8	0.0	0.0	0.0	0.0	*0.0*	*
1987	0.0	130.4	245.1	110.6	167.8	12.1	*0.0*	2.3	*0.0*	0.0	0.0	0.0	0.0	0.1	*
1988	0.0	36.2	69.3	65.8	53.8	68.0	0.1	*0.0*	*0.0*	0.7	0.0	0.0	0.0	*0.0*	*
1989	0.0	24.7	148.0	66.1	35.5	41.5	24.8	*0.0*	0.0	*0.0*	0.0	0.0	*0.0*	0.0	*
1990	0.0	65.6	148.3	116.3	42.3	28.9	29.4	23.9	0.4	*0.0*	*0.0*	0.0	*0.0*	*0.0*	*
1991	0.0	57.0	182.6	58.6	44.8	22.6	22.4	16.5	5.4	*0.0*	0.6	0.0	*0.0*	*0.0*	*0.0*
1992	0.1	23.0	206.8	145.6	54.6	65.7	38.7	26.1	11.0	4.1	2.3	0.0	*0.0*	*0.0*	*
1993	0.0	30.5	125.3	159.4	83.6	47.7	47.1	31.7	18.1	3.8	1.7	*0.0*	0.0	*0.0*	*
1994	0.0	21.7	89.3	94.5	96.8	52.9	31.3	38.7	12.5	7.5	2.3	1.0	0.3	0.0	*
1995	0.0	45.8	114.5	66.4	59.3	49.6	38.5	24.1	18.7	11.0	9.2	3.2	1.9	0.0	*
1996	0.0	*0.0*	347.2	98.2	26.3	65.2	57.3	37.9	30.4	10.3	10.3	3.1	1.1	0.0	0.0
1997	0.0	35.9	43.5	136.8	44.9	20.3	18.2	20.5	21.9	10.7	6.3	3.0	1.1	0.5	0.0
1998	0.0	35.7	138.9	31.4	144.5	31.6	11.3	17.7	16.7	14.3	8.7	8.8	1.2	0.3	0.2
1999	0.0	6.9	168.6	76.5	56.8	35.5	11.4	6.6	10.3	4.6	4.4	2.5	1.1	0.5	0.1
2000	0.0	13.5	53.7	101.8	46.7	55.8	23.4	13.2	7.9	7.6	6.5	5.5	1.4	1.2	0.5
2001	0.0	4.4	37.6	58.6	51.7	22.1	28.2	32.1	11.0	11.5	8.7	5.3	3.0	0.8	0.4
2002	0.0	75.7	39.3	38.8	83.3	40.4	33.9	32.2	22.0	7.4	5.4	3.3	3.7	0.3	*
2003	0.0	14.4	107.5	51.8	34.2	65.8	49.3	26.7	25.5	26.7	13.2	6.3	5.1	1.5	0.3
2004	0.0	22.8	188.7	118.3	41.1	33.3	43.3	45.5	28.0	22.3	21.8	6.1	3.8	3.2	*
2005	0.0	62.8	98.9	71.0	92.8	23.3	24.9	21.0	26.4	19.2	16.4	10.2	2.6	0.9	*
2006	0.0	6.4	242.1	38.4	45.6	27.6	14.2	12.3	17.2	20.0	12.1	9.8	7.2	2.2	*
2007	0.0	6.9	21.4	74.0	14.5	14.9	12.5	6.2	8.0	9.3	13.2	7.0	2.8	3.9	*
2008	0.0	2.8	82.1	104.0	106.8	16.2	22.0	18.7	10.7	11.3	9.3	12.6	6.8	2.9	*
2009	0.0	38.5	40.6	148.4	49.8	133.1	20.5	21.9	29.3	8.5	15.0	10.8	20.6	4.3	*
2010	0.0	7.0	144.8	49.2	63.3	49.0	53.1	6.2	13.3	9.7	3.8	4.8	5.6	8.8	*
2011	0.0	22.0	71.1	120.2	43.8	55.2	37.1	43.1	9.8	8.8	7.6	5.5	3.5	3.8	*
2012	0.0	14.2	50.2	22.4	22.8	16.7	22.0	20.7	23.2	6.9	15.6	9.2	3.8	5.5	*
2013	0.0	30.4	55.2	103.0	43.6	48.8	26.3	25.7	20.2	26.1	5.4	10.8	4.5	3.7	*
2014	0.0	7.9	271.5	50.6	56.6	21.5	30.0	8.5	18.4	13.7	22.9	2.1	9.0	1.8	*
2015	0.0	18.0	7.0	448.3	44.6	48.9	23.3	20.5	15.3	21.4	18.3	19.0	5.6	7.1	*
2016	0.0	63.0	52.6	18.1	159.3	23.1	14.7	4.6	5.8	5.2	8.7	7.3	8.4	0.9	*
2017	0.0	58.7	113.1	32.4	72.7	133.5	21.4	17.1	11.0	13.8	10.7	22.5	6.5	4.5	*
2018	0.0	1.7	182.5	135.2	29.2	25.4	78.8	9.4	8.2	2.6	4.1	1.7	5.3	7.5	*
2019	0.0	25.3	38.1	158.5	74.0	10.8	20.8	24.3	7.5	6.0	1.3	4.4	4.0	5.9	*

* Notes: Shadings note negative values that have been changed to zero. Confidence intervals could not be calculated for age 15+ when more than one age class was present in the group.

Table 10. Upper confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2019) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

	Age													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0.0	153.6	334.0	35.1	5.4	1.6	3.4	0.2	2.6	0.2	0.1	0.8	0.6	0.1	*
1986	0.0	246.2	276.6	530.6	4.5	5.8	2.4	3.2	3.8	0.0	0.0	0.0	0.0	0.1	*
1987	0.0	154.0	270.9	119.6	184.5	23.7	5.4	2.8	2.3	0.0	0.0	0.0	0.0	0.5	*
1988	0.0	45.3	86.0	76.8	60.2	81.1	2.5	1.0	1.1	8.0	0.0	0.0	0.0	0.1	*
1989	0.0	41.6	161.4	95.0	55.5	56.0	41.0	0.6	0.1	0.2	0.0	0.0	0.1	0.0	*
1990	0.0	90.5	168.0	124.5	54.3	39.6	34.7	35.7	1.3	0.5	0.3	1.0	5.3	1.7	*
1991	0.0	89.8	201.2	65.8	49.4	30.8	29.6	21.8	15.8	1.2	2.3	0.0	6.3	5.4	2.9
1992	0.3	31.8	235.4	161.4	62.7	74.1	47.1	32.0	16.3	10.0	4.2	0.0	7.3	8.9	*
1993	0.0	51.4	138.7	215.1	92.9	54.2	56.7	42.5	27.1	11.0	4.5	1.7	2.8	7.6	*
1994	0.0	32.0	117.8	101.5	138.9	66.1	36.7	47.0	22.7	9.6	3.8	1.5	0.3	0.0	*
1995	0.0	54.2	120.0	70.3	62.5	53.5	41.5	25.9	20.6	12.1	10.1	3.8	7.2	0.0	*
1996	0.0	10.8	389.5	106.1	43.2	73.9	71.5	46.6	40.4	23.2	20.1	6.3	2.2	0.0	0.0
1997	0.0	37.8	46.1	143.9	48.2	21.6	19.7	23.8	31.2	12.1	13.6	3.6	1.3	0.6	0.0
1998	0.0	36.4	146.7	34.1	154.0	33.0	15.1	19.4	17.9	15.7	9.5	11.0	2.2	0.5	0.4
1999	0.0	10.3	176.2	81.3	60.4	37.9	12.1	7.4	12.7	5.7	5.3	3.1	1.2	3.8	0.2
2000	0.0	15.2	58.2	106.4	49.2	59.7	26.5	14.4	8.6	9.0	7.4	9.3	1.6	3.8	0.6
2001	0.0	5.4	40.5	61.9	54.6	24.2	30.0	34.5	12.1	12.8	9.8	6.8	4.0	1.6	0.5
2002	0.0	93.6	42.3	40.7	88.3	45.0	36.2	33.9	25.0	9.3	6.2	3.9	6.7	2.1	*
2003	0.0	17.1	115.5	55.1	36.6	71.0	54.0	28.5	28.0	31.4	16.2	8.1	7.2	3.5	0.4
2004	0.0	34.9	197.7	124.0	43.7	35.9	45.4	49.0	32.2	24.0	24.3	7.3	4.7	4.2	*
2005	0.0	69.2	108.4	76.0	100.5	25.2	26.8	22.5	28.5	21.5	18.5	12.5	3.3	1.2	*
2006	0.0	8.6	273.7	41.7	49.5	30.9	15.4	13.1	19.6	23.1	14.2	12.2	11.3	3.2	*
2007	0.0	8.9	23.6	78.1	15.3	15.7	14.4	8.5	10.1	10.8	18.8	8.9	3.3	7.0	*
2008	0.0	3.7	90.0	112.8	117.9	17.6	24.0	20.7	11.8	12.7	10.8	15.4	20.0	3.6	*
2009	0.0	41.7	43.6	157.6	53.5	143.3	21.8	23.4	33.1	9.4	16.7	13.5	26.2	5.3	*
2010	0.0	8.0	154.6	51.6	66.6	52.0	56.7	7.2	14.5	10.7	4.1	5.4	6.2	11.1	*
2011	0.0	24.0	75.6	127.3	46.9	59.4	39.0	46.8	10.3	9.5	8.1	10.2	4.6	4.8	*
2012	0.0	16.2	53.8	24.0	24.6	19.0	24.1	24.6	26.9	7.9	17.5	17.9	4.9	8.0	*
2013	0.0	40.8	60.4	109.4	47.1	54.2	28.9	32.1	21.9	30.0	6.2	12.8	5.5	4.8	*
2014	0.0	9.1	287.0	54.7	60.6	26.2	35.8	11.0	21.9	16.6	27.1	2.6	11.9	2.8	*
2015	0.0	20.1	7.7	468.8	48.1	51.9	25.2	21.8	16.2	24.0	20.7	22.0	7.5	13.3	*
2016	0.0	70.2	54.8	19.1	168.0	24.8	16.4	5.1	6.5	5.5	9.8	8.5	10.2	1.4	*
2017	0.0	69.1	119.1	34.5	77.0	140.8	23.0	18.4	11.9	16.2	12.7	26.1	8.0	5.3	*
2018	0.0	1.9	197.2	144.9	31.5	27.6	85.0	10.1	9.8	3.1	4.6	2.1	6.4	16.2	*
2019	0.0	31.9	40.8	166.3	78.1	11.8	23.3	26.7	10.2	8.1	1.4	5.4	4.7	10.3	*

* Note: Confidence intervals could not be calculated for age 15+ when more than one age class was present in the group.

Table 11. Coefficients of Variation of the annual, pooled, weighted, age-specific CPUEs (1985–2019) for the Maryland Chesapeake Bay striped bass spawning stock.

	Age													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0	0.05	0.05	0.05	0.06	0.11	0.28	2.16	2.50	1.04	0.29	0.58	0.64	2.14	*
1986	0	0.03	0.03	0.03	0.06	0.05	0.09	0.05	0.18	0	0	0	0.28	2.62	*
1987	0	0.04	0.03	0.02	0.02	0.16	0.76	0.05	4.32	0	0	0	0.34	0.36	*
1988	0	0.06	0.05	0.04	0.03	0.04	0.45	0.00	13.03	0.42	0	0	0	1.10	*
1989	0	0.13	0.02	0.09	0.11	0.07	0.12	1.17	0.29	2.92	0	0	1.31	0	*
1990	0	0.08	0.03	0.02	0.06	0.08	0.04	0.10	0.28	1.51	1.07	0.49	3.18	7.85	*
1991	0	0.11	0.02	0.03	0.02	0.08	0.07	0.07	0.25	0.96	0.29	0	5.10	4.29	0.82
1992	0.79	0.08	0.03	0.03	0.03	0.03	0.05	0.05	0.10	0.21	0.14	0	3.38	3.16	*
1993	0	0.13	0.03	0.07	0.03	0.03	0.05	0.07	0.10	0.24	0.23	0.54	0.49	2.19	*
1994	0	0.10	0.07	0.02	0.09	0.06	0.04	0.05	0.15	0.06	0.13	0.11	0.06	0	*
1995	0	0.04	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.29	0	*
1996	0	0.87	0.03	0.02	0.12	0.03	0.06	0.05	0.07	0.19	0.16	0.17	0.16	0	0
1997	0	0.01	0.01	0.01	0.02	0.02	0.02	0.04	0.09	0.03	0.18	0.05	0.05	0.07	0
1998	0	0.00	0.01	0.02	0.02	0.01	0.07	0.02	0.02	0.02	0.02	0.05	0.15	0.11	0.21
1999	0	0.10	0.01	0.01	0.02	0.02	0.02	0.03	0.05	0.06	0.05	0.06	0.02	0	0.19
2000	0	0.03	0.02	0.01	0.01	0.02	0.03	0.02	0.02	0.04	0.03	0.13	0.03	0.26	0.02
2001	0	0.05	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.06	0.07	0.18	0.03
2002	0	0.05	0.02	0.01	0.01	0.03	0.02	0.01	0.03	0.06	0.03	0.04	0.14	0.37	*
2003	0	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.06	0.09	0.20	0.04
2004	0	0.10	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.02	0.03	0.04	0.06	0.07	*
2005	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.05	0.06	0.07	*
2006	0	0.07	0.03	0.02	0.02	0.03	0.02	0.02	0.03	0.04	0.04	0.06	0.11	0.09	*
2007	0	0.06	0.02	0.01	0.01	0.01	0.03	0.08	0.06	0.04	0.09	0.06	0.04	0.14	*
2008	0	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.05	0.25	0.05	*
2009	0	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.06	0.06	0.05	*
2010	0	0.03	0.02	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.03	0.03	0.06	*
2011	0	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.15	0.07	0.06	*
2012	0	0.03	0.02	0.02	0.02	0.03	0.02	0.04	0.04	0.03	0.03	0.16	0.07	0.10	*
2013	0	0.07	0.02	0.01	0.02	0.03	0.02	0.06	0.02	0.03	0.04	0.04	0.05	0.06	*
2014	0	0.03	0.01	0.02	0.02	0.05	0.04	0.06	0.04	0.05	0.04	0.04	0.07	0.10	*
2015	0	0.03	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.07	0.15	*
2016	0	0.03	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.05	0.11	*
2017	0	0.04	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.04	0.04	0.04	0.05	0.04	*
2018	0	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.03	0.04	0.05	0.18	*
2019	0	0.06	0.02	0.01	0.01	0.02	0.03	0.02	0.07	0.07	0.02	0.05	0.04	0.13	*

* Note: CV values >1.00 are noted by shading. CVs could not be calculated for age 15+ when more than one age class was present in the group.

Table 12. Un-weighted striped bass catch per unit effort (CPUE) by year-class, April through May 2019. Values are presented by sex, area, and percent of total. CPUE is number of fish per hour in 1000 yards of experimental drift net.

Year-class	Age	Pooled Unweighted CPUE	% of Total	Females		Males	
				Potomac	Upper Bay	Potomac	Upper Bay
2018	1	0.0	0.0	0.0	0.0	0.0	0.0
2017	2	57.2	7.4	0.0	0.0	28.8	28.5
2016	3	77.3	10.0	0.0	0.0	35.1	42.2
2015	4	308.2	40.0	0.0	1.3	118.1	188.8
2014	5	144.1	18.7	0.0	0.6	54.5	89.0
2013	6	20.6	2.7	0.0	0.6	6.2	13.8
2012	7	40.6	5.3	0.0	3.5	12.5	24.6
2011	8	46.6	6.0	0.6	9.4	13.1	23.5
2010	9	14.8	1.9	0.2	6.2	1.0	7.5
2009	10	11.8	1.5	0.3	5.5	0.6	5.4
2008	11	2.1	0.3	0.0	0.5	0.0	1.6
2007	12	9.9	1.3	0.0	2.3	5.2	2.4
2006	13	7.5	1.0	0.1	0.5	1.0	5.9
2005	14	13.9	1.8	1.2	5.1	0.8	6.9
≤2004	15+	16.2	2.1	2.1	8.0	0.8	5.3
Total		771.1		4.5	43.6	277.6	445.4
% of Total				0.6	5.7	36.0	57.8
% of Sex				9.4	90.6	38.4	61.6
% of System				1.6	8.9	98.4	91.1

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, April through May 2019. Values are presented as percent of total, sex-specific, and area-specific CPUE. CPUE is number of fish per hour in 1000 yards of experimental drift net.

Year-class	Age	Pooled Weighted CPUE	% of Total	Females		Males	
				Potomac	Upper Bay	Potomac	Upper Bay
2018	1	0.0	0.0	0.0	0.0	0.0	0.0
2017	2	28.6	7.0	0.0	0.0	11.1	17.5
2016	3	39.5	9.6	0.0	0.0	13.5	25.9
2015	4	162.4	39.7	0.0	0.8	45.5	116.0
2014	5	76.1	18.6	0.0	0.4	21.0	54.7
2013	6	11.3	2.8	0.0	0.4	2.4	8.5
2012	7	22.1	5.4	0.0	2.1	4.8	15.1
2011	8	25.5	6.2	0.2	5.8	5.0	14.4
2010	9	8.8	2.2	0.1	3.8	0.4	4.6
2009	10	7.1	1.7	0.1	3.4	0.2	3.3
2008	11	1.3	0.3	0.0	0.3	0.0	1.0
2007	12	4.9	1.2	0.0	1.4	2.0	1.5
2006	13	4.4	1.1	0.1	0.3	0.4	3.7
2005	14	8.1	2.0	0.4	3.1	0.3	4.3
≤2004	15+	9.3	2.3	0.8	4.9	0.3	3.3
Total		409.2		1.7	26.8	107.0	273.7
% of Total				0.4	6.5	26.1	66.9
% of Sex				6.1	93.9	28.1	71.9
% of System				1.6	8.9	98.4	91.1

* Spawning area weights used: Potomac (0.385); Upper Bay (0.615).

Table 14. Mean length-at-age (mm TL) statistics for male striped bass collected in the Potomac River and the Upper Bay, and areas combined, April through May 2019.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2017	2	POTOMAC	7	313	296	330	18	7
		UPPER	7	302	260	344	45	17
		COMBINED	14	308	288	327	33	9
2016	3	POTOMAC	10	367	351	383	23	7
		UPPER	7	323	309	336	15	5
		COMBINED	17	349	334	364	30	7
2015	4	POTOMAC	24	457	434	480	55	11
		UPPER	25	421	392	450	71	14
		COMBINED	49	439	420	457	66	9
2014	5	POTOMAC	14	515	479	551	63	17
		UPPER	18	495	466	525	60	14
		COMBINED	32	504	482	526	61	11
2013	6	POTOMAC	6	598	559	636	37	15
		UPPER	8	612	568	656	53	19
		COMBINED	14	606	579	632	45	12
2012	7	POTOMAC	10	663	622	704	58	18
		UPPER	22	622	594	649	62	13
		COMBINED	32	635	612	657	63	11
2011	8	POTOMAC	11	689	649	729	60	18
		UPPER	40	698	678	718	62	10
		COMBINED	51	696	679	713	61	9
2010	9	POTOMAC	1	630	-	-	-	-
		UPPER	11	787	747	828	60	18
		COMBINED	12	774	728	820	73	21
2009	10	POTOMAC	0	-	-	-	-	-
		UPPER	6	769	677	860	87	36
		COMBINED	6	769	677	860	87	36
2008	11	POTOMAC	0	-	-	-	-	-
		UPPER	3	823	755	892	28	16
		COMBINED	3	823	755	892	28	16
2007	12	POTOMAC	1	886	-	-	-	-
		UPPER	5	819	784	854	28	13
		COMBINED	6	830	791	869	37	15
2006	13	POTOMAC	1	1087	-	-	-	-
		UPPER	2	1014	633	1395	42	30
		COMBINED	3	1038	910	1167	52	30
2005	14	POTOMAC	0	-	-	-	-	-
		UPPER	2	1021	874	1167	16	12
		COMBINED	2	1021	874	1167	16	12
2003	16	POTOMAC	1	1032	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	1032	-	-	-	-

Table 15. Mean length-at-age (mm TL) statistics for female striped bass collected in the Potomac River and the Upper Bay, and areas combined, April through May 2019.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
		POTOMAC	0	-	-	-	-	-
2013	6	UPPER	2	597	*	*	*	*
		COMBINED	2	597	*	*	*	*
		POTOMAC	0	-	-	-	-	-
2012	7	UPPER	7	640	566	713	79	30
		COMBINED	7	640	566	713	79	30
		POTOMAC	1	858	-	-	-	-
2011	8	UPPER	15	761	706	817	100	26
		COMBINED	16	767	714	820	99	25
		POTOMAC	1	1062	-	-	-	-
2010	9	UPPER	6	866	738	994	122	50
		COMBINED	7	894	770	1018	134	51
		POTOMAC	0	-	-	-	-	-
2009	10	UPPER	8	908	787	1029	145	51
		COMBINED	8	908	787	1029	145	51
		POTOMAC	0	-	-	-	-	-
2008	11	UPPER	2	856	*	*	*	*
		COMBINED	2	856	*	*	*	*
		POTOMAC	0	-	-	-	-	-
2007	12	UPPER	8	1003	953	1053	60	21
		COMBINED	8	1003	953	1053	60	21
		POTOMAC	3	1096	1060	1132	15	8
2006	13	UPPER	0	-	-	-	-	-
		COMBINED	3	1096	1060	1132	15	8
		POTOMAC	2	1119	916	1322	23	16
2005	14	UPPER	13	1084	1041	1128	72	20
		COMBINED	15	1089	1051	1126	68	17
		POTOMAC	0	-	-	-	-	-
2004	15	UPPER	5	1060	1020	1101	33	15
		COMBINED	5	1060	1020	1101	33	15
		POTOMAC	0	-	-	-	-	-
2003	16	UPPER	19	1126	1104	1148	46	11
		COMBINED	19	1126	1104	1148	46	11
		POTOMAC	1	1130	-	-	-	-
2002	17	UPPER	1	1137	-	-	-	-
		COMBINED	2	1134	1089	1178	5	4
		POTOMAC	2	1154	493	1815	74	52
2001	18	UPPER	1	1217	-	-	-	-
		COMBINED	3	1175	1017	1333	63	37
		POTOMAC	0	-	-	-	-	-
2000	19	UPPER	3	1203	946	1460	103	60
		COMBINED	3	1203	946	1460	103	60

* Values omitted for being biologically unreasonable due to small sample sizes.

Table 16. Index of spawning potential by year, for female striped bass ≥ 500 mm TL sampled from spawning areas of the Chesapeake Bay during March, April and May since 1985. The index is selectivity-corrected CPUE converted to biomass (kg) using parameters from a length-weight regression.

Year	Upper Bay	Potomac River
1985	65	26
1986	152	46
1987	400	89
1988	250	64
1989	120	81
1990	98	63
1991	109	139
1992	275	379
1993	279	421
1994	87	Not Sampled
1995	548	294
1996	348	392
1997	240	362
1998	156	227
1999	168	281
2000	193	325
2001	479	272
2002	276	399
2003	563	118
2004	376	530
2005	470	196
2006	406	458
2007	419	263
2008	229	163
2009	483	190
2010	280	213
2011	168	105
2012	799	150
2013	770	172
2014	876	222
2015	765	309
2016	414	165
2017	411	387
2018	323	73
2019	371	58
Average	**353**	**224**

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, spring 2019.

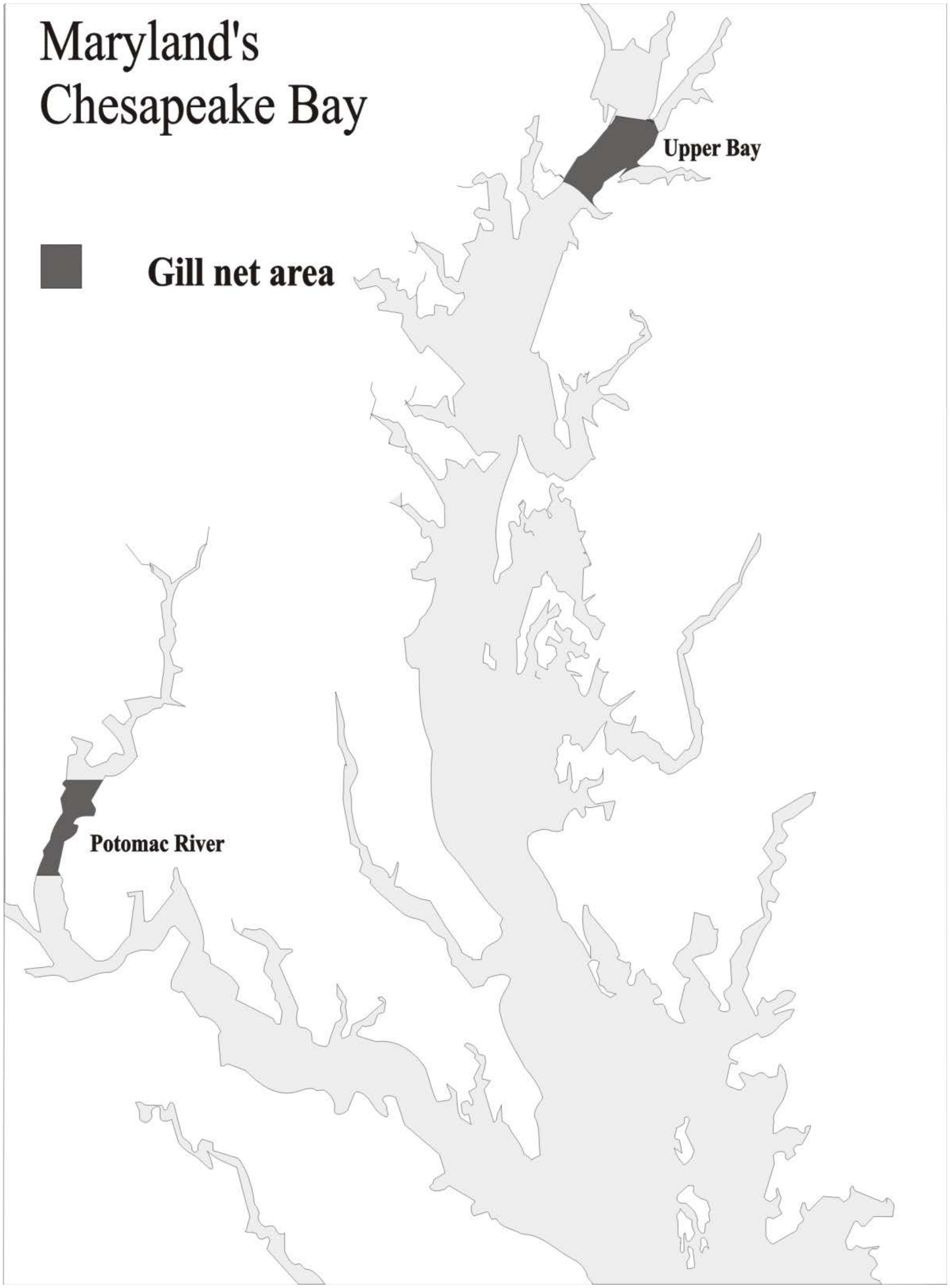
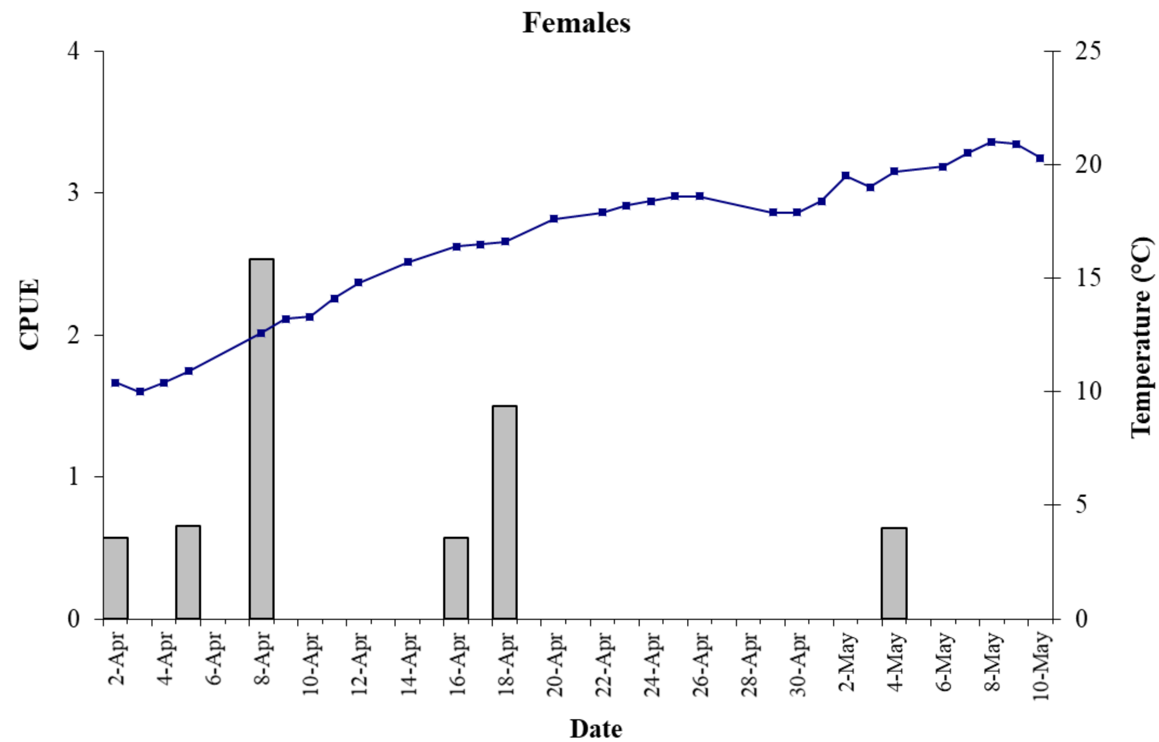


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water temperature in the spawning reach of the Potomac River, April through May 2019. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.



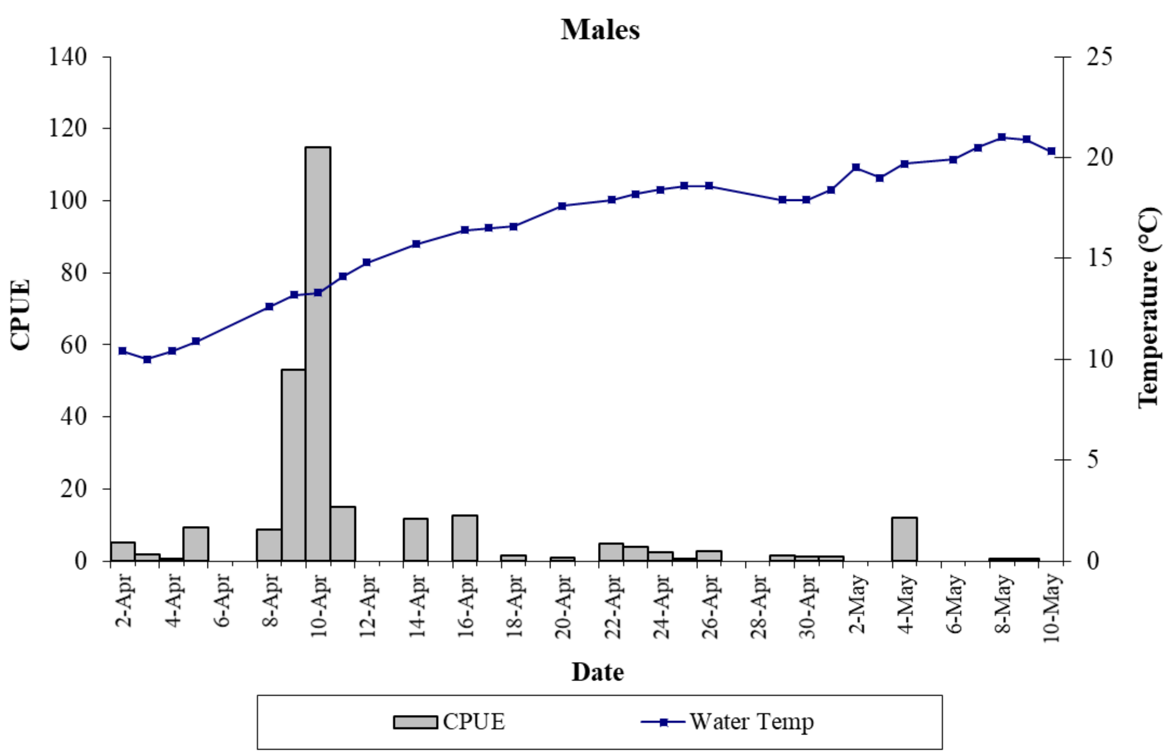
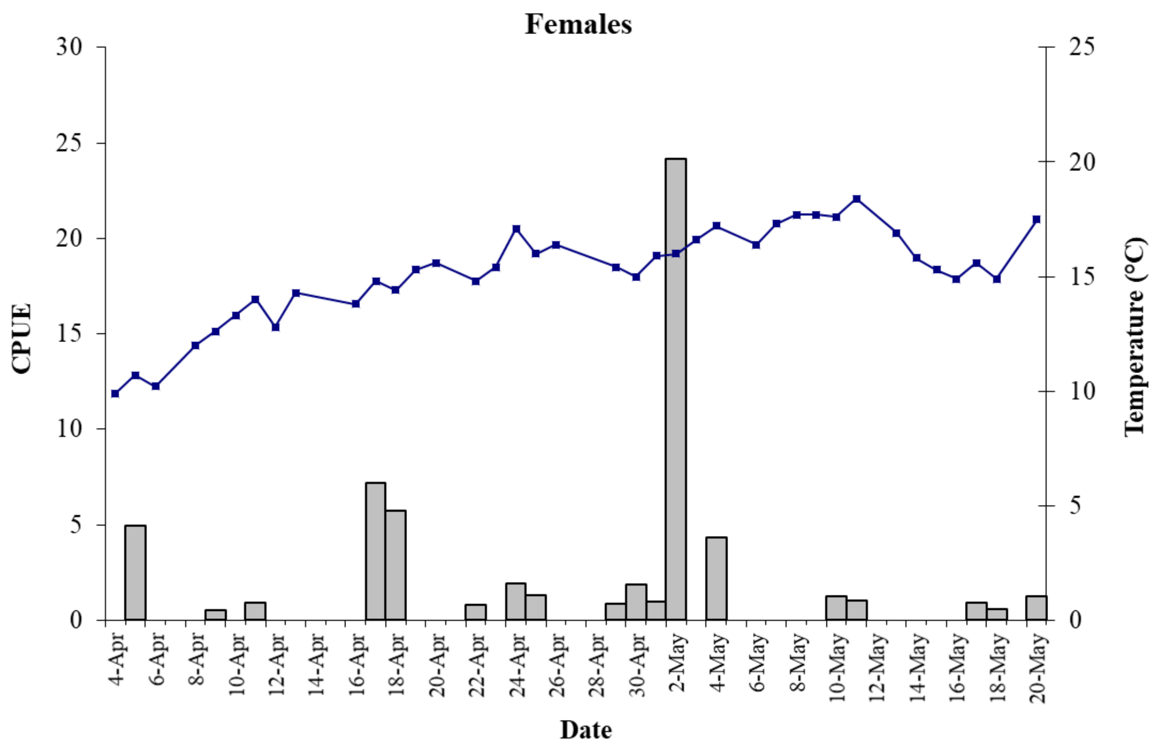


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water temperature in the spawning reach of the Upper Chesapeake Bay, April through May 2019. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.



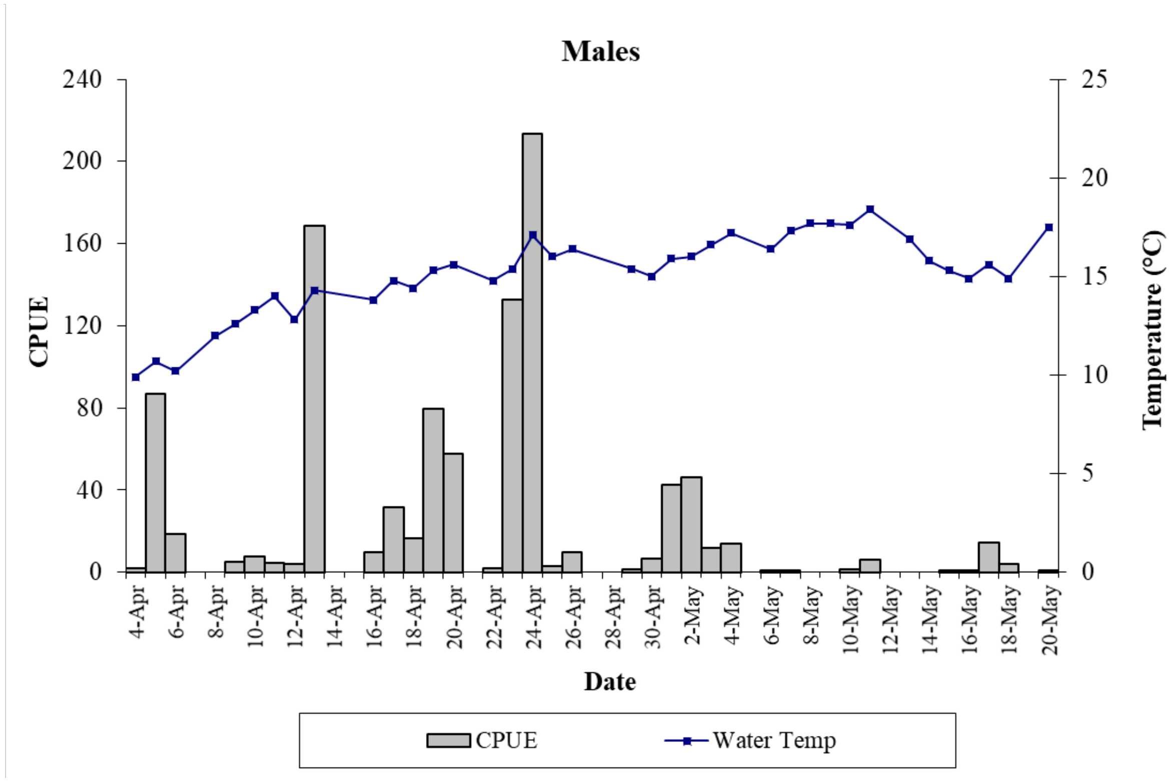
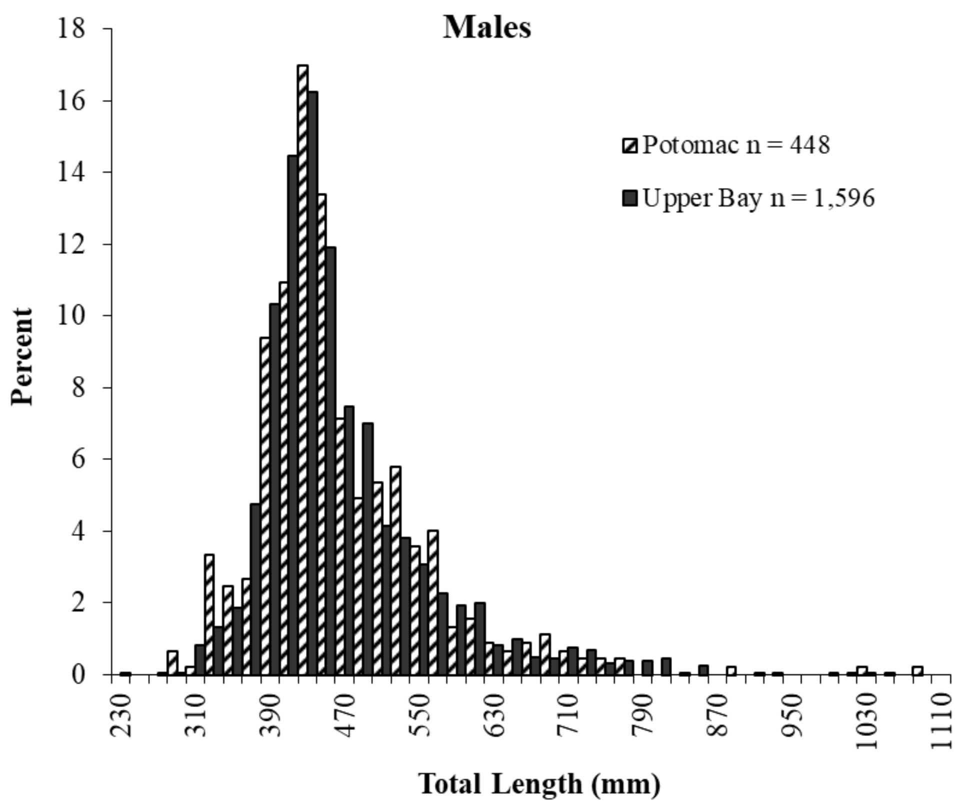


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, April through May 2019. Note different scales.



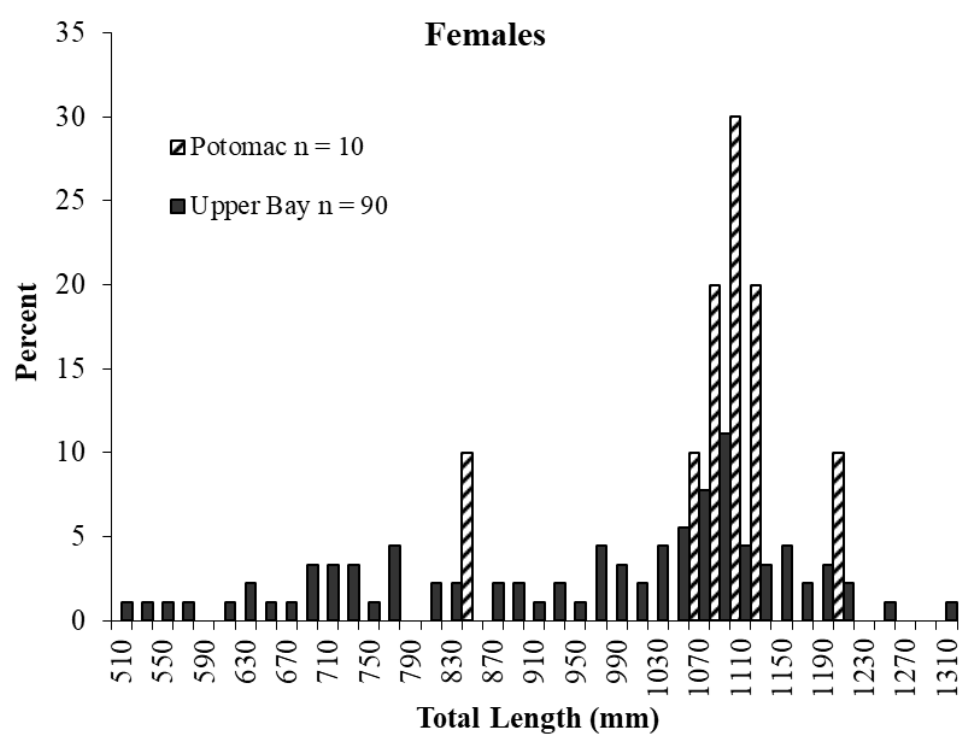
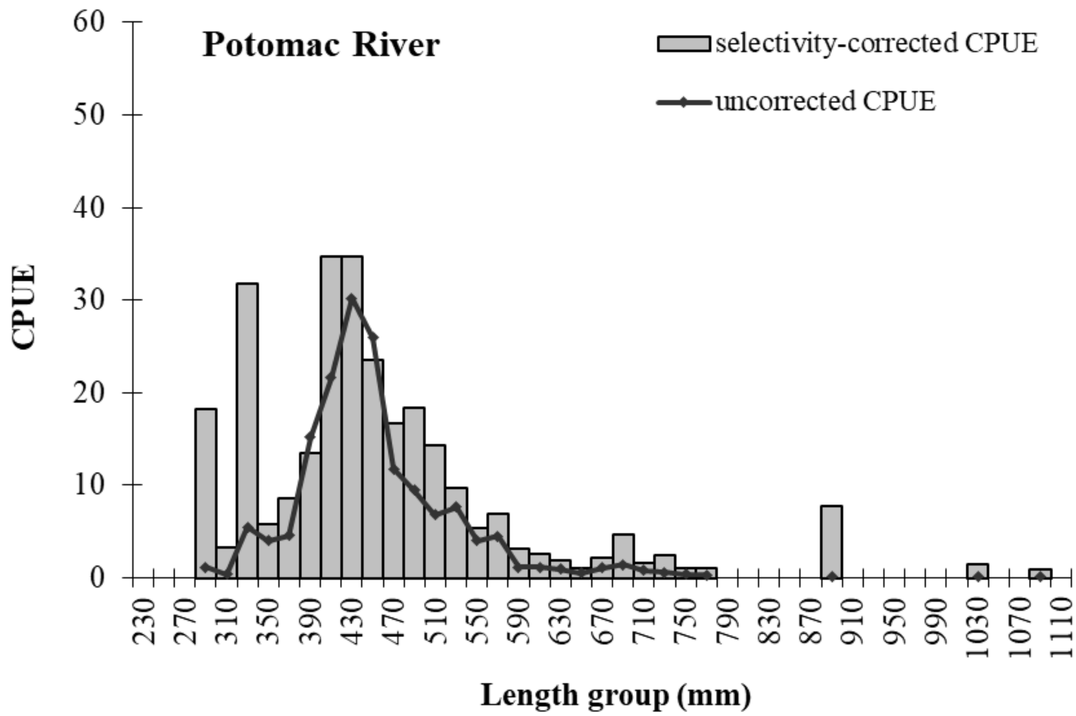


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2019. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



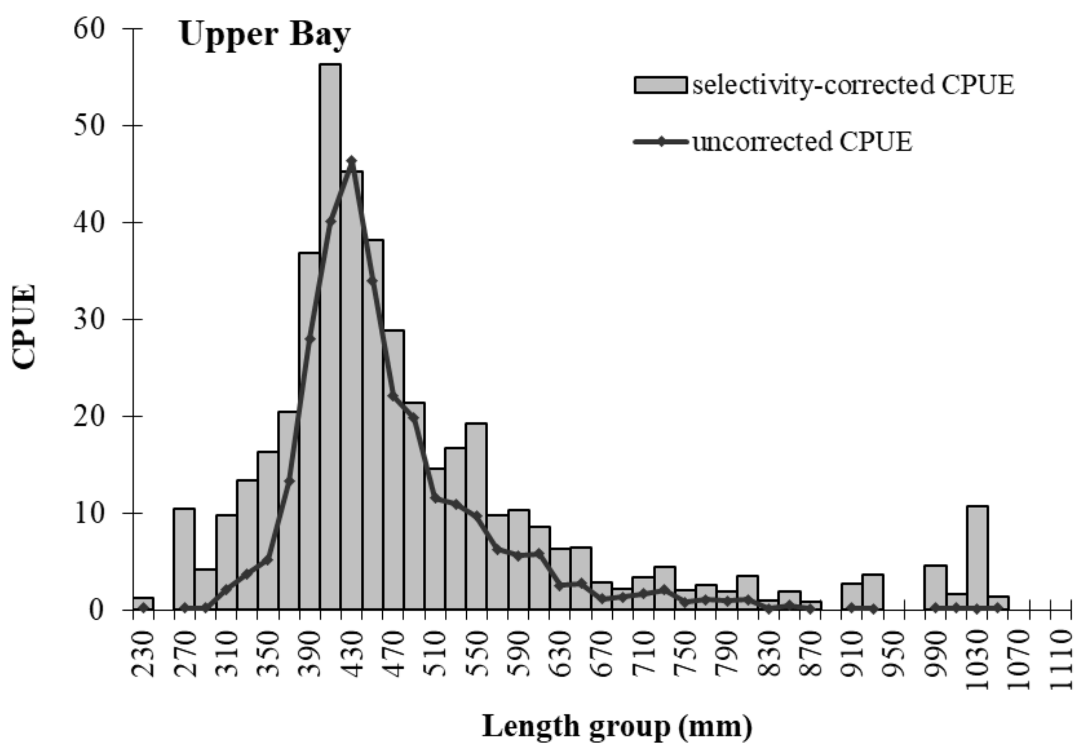
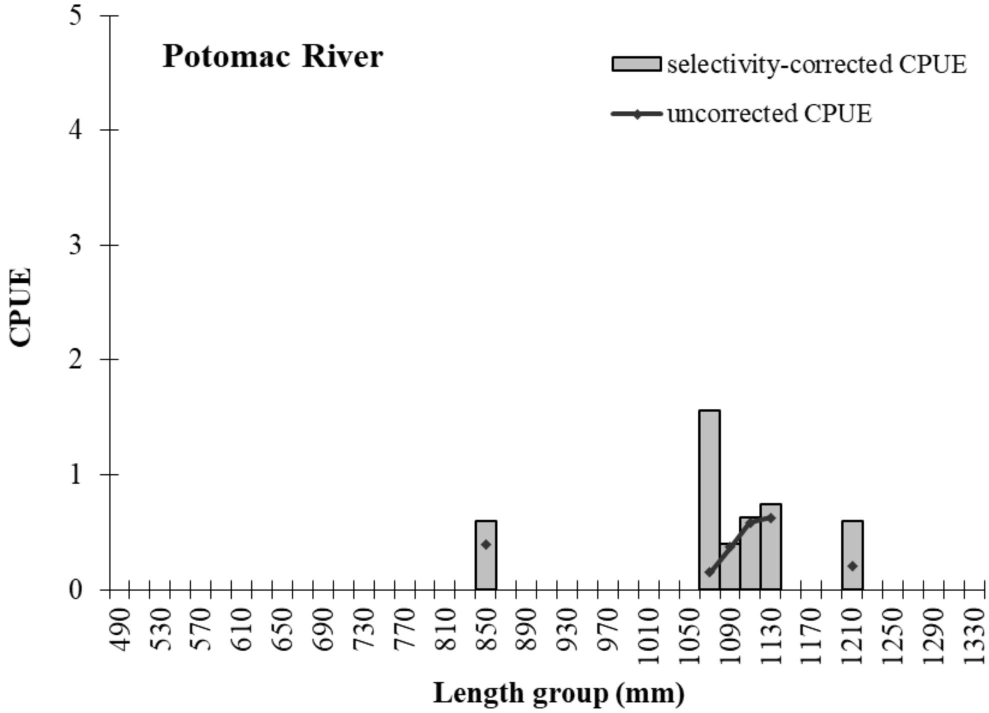


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2019. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



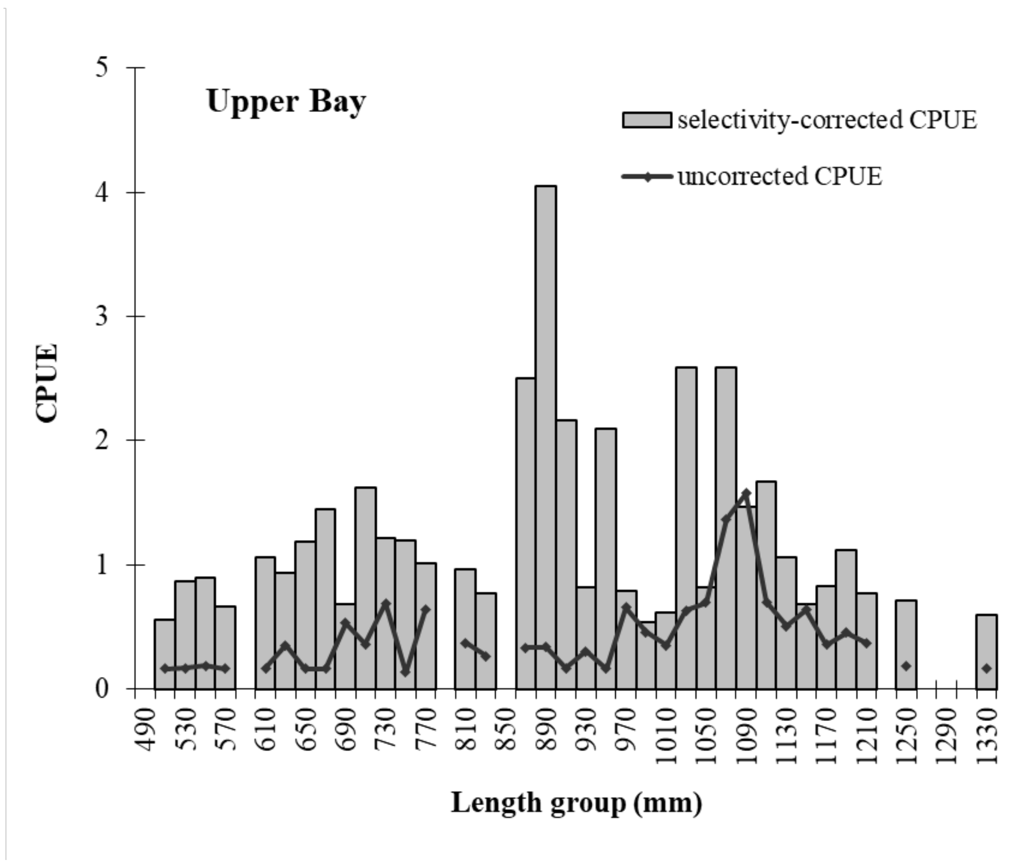


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during March through May, 1985-2019. Error bars are ± 2 standard errors (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

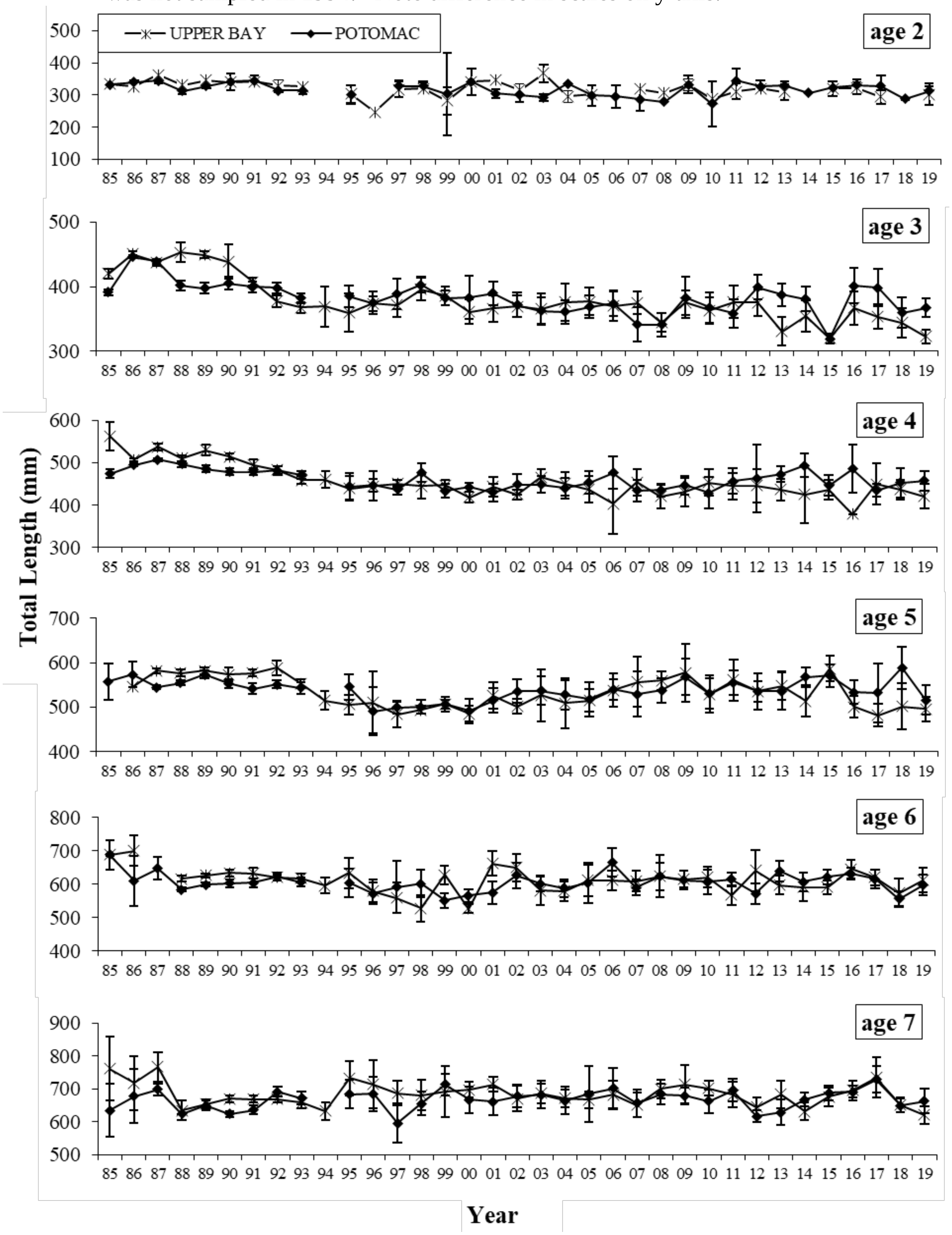


Figure 7. Continued.

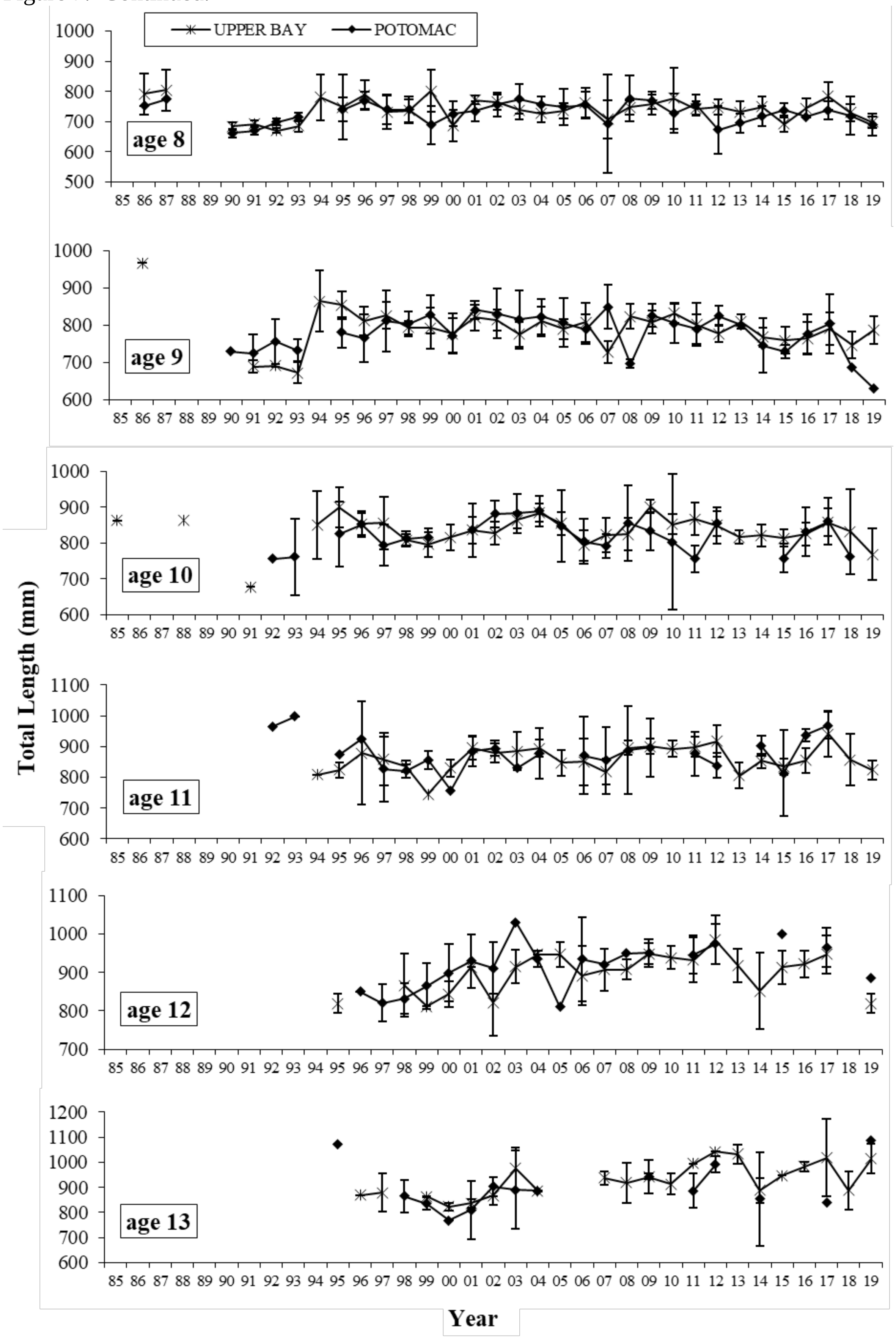


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during March through May, 1985–2019. Error bars are ± 2 standard errors (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

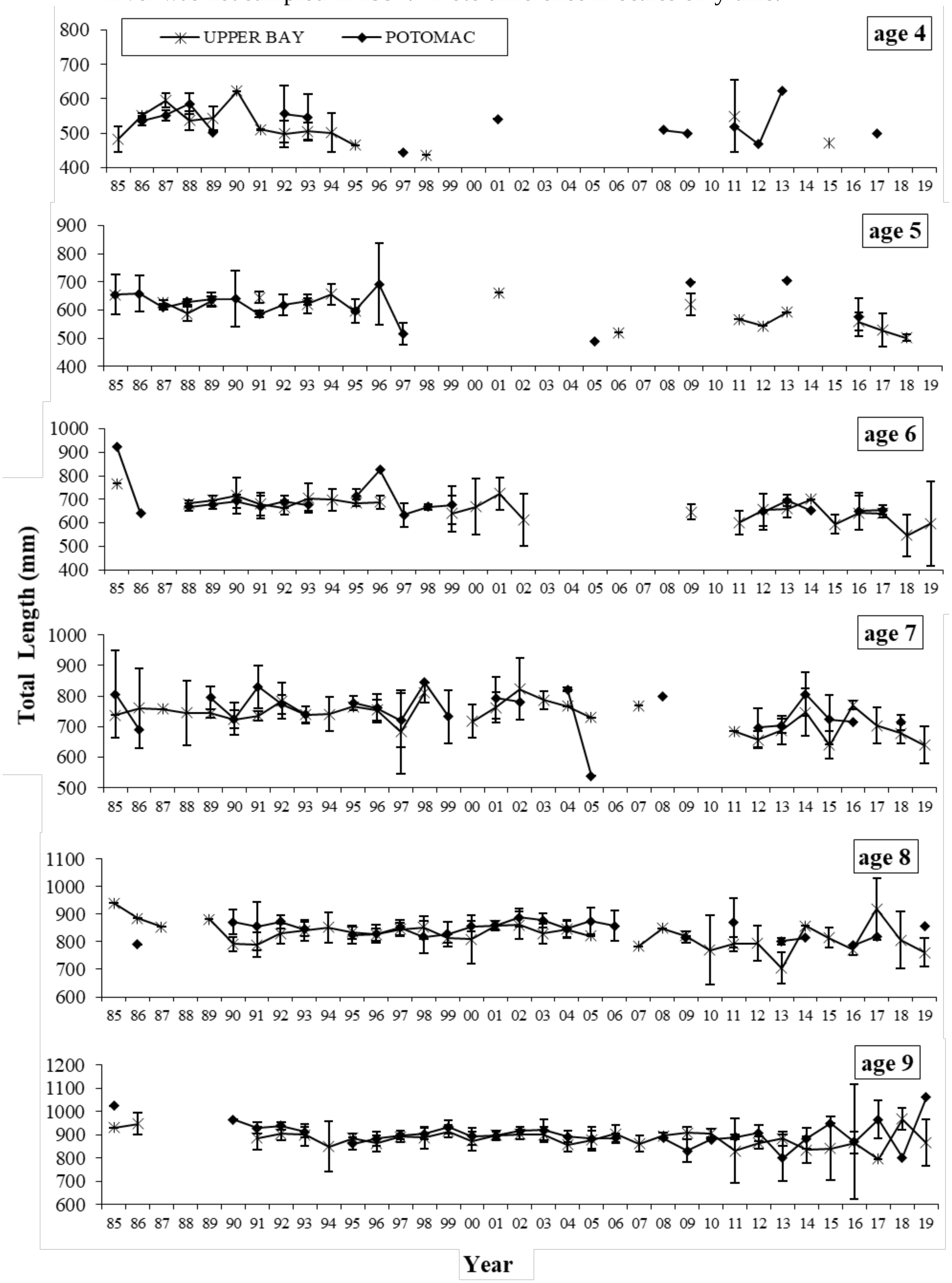


Figure 8. Continued.

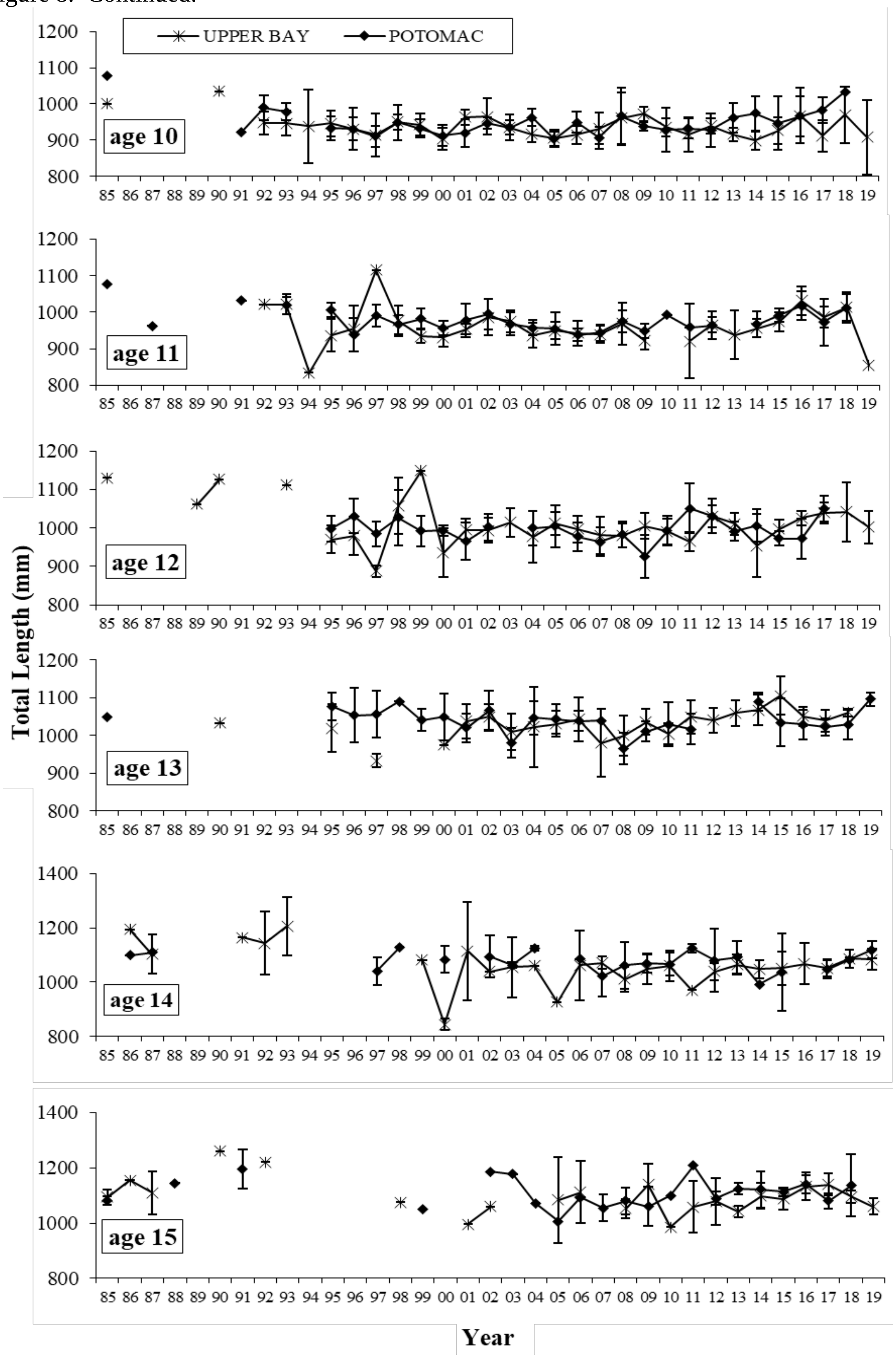


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15+. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

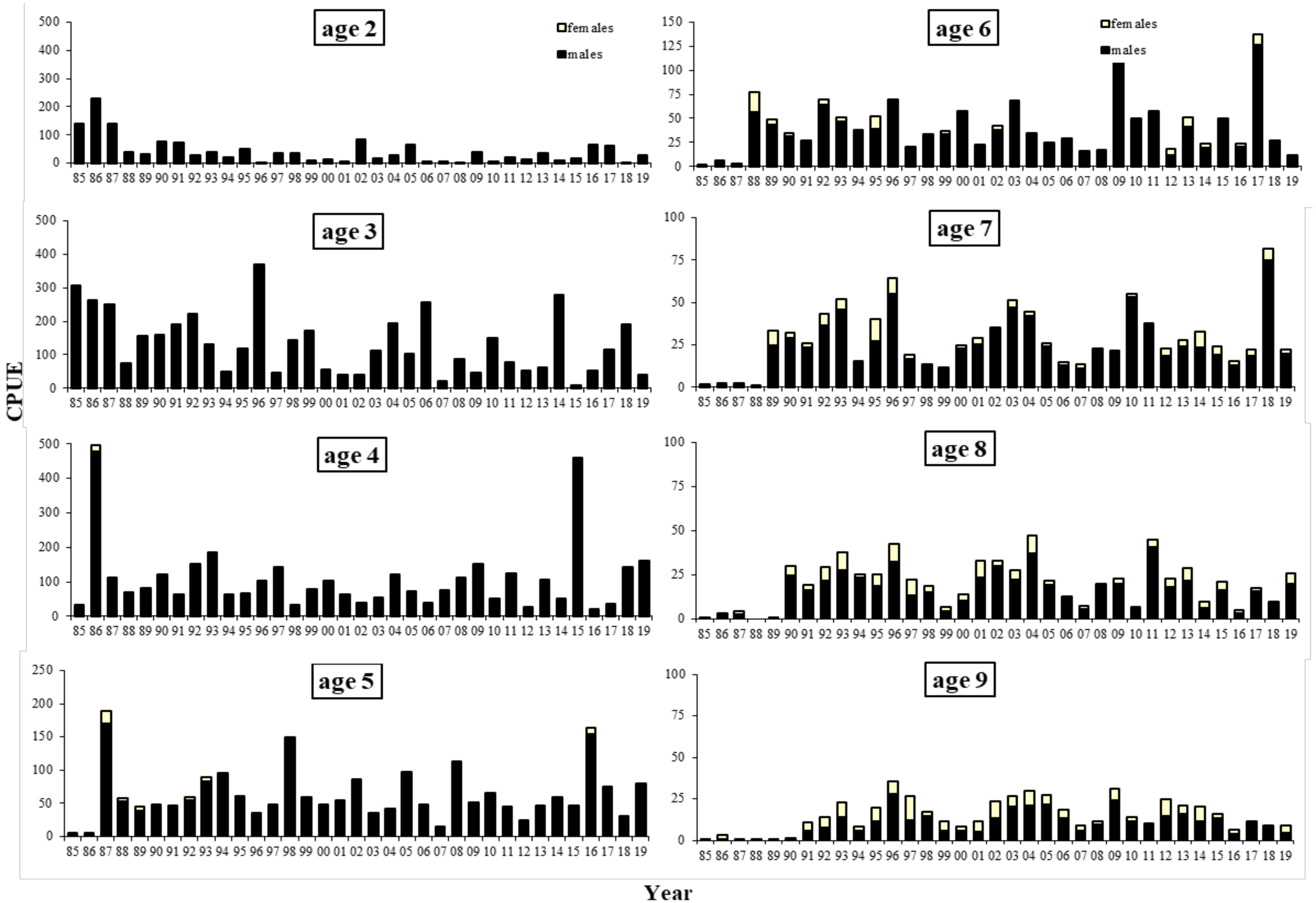


Figure 9. Continued.

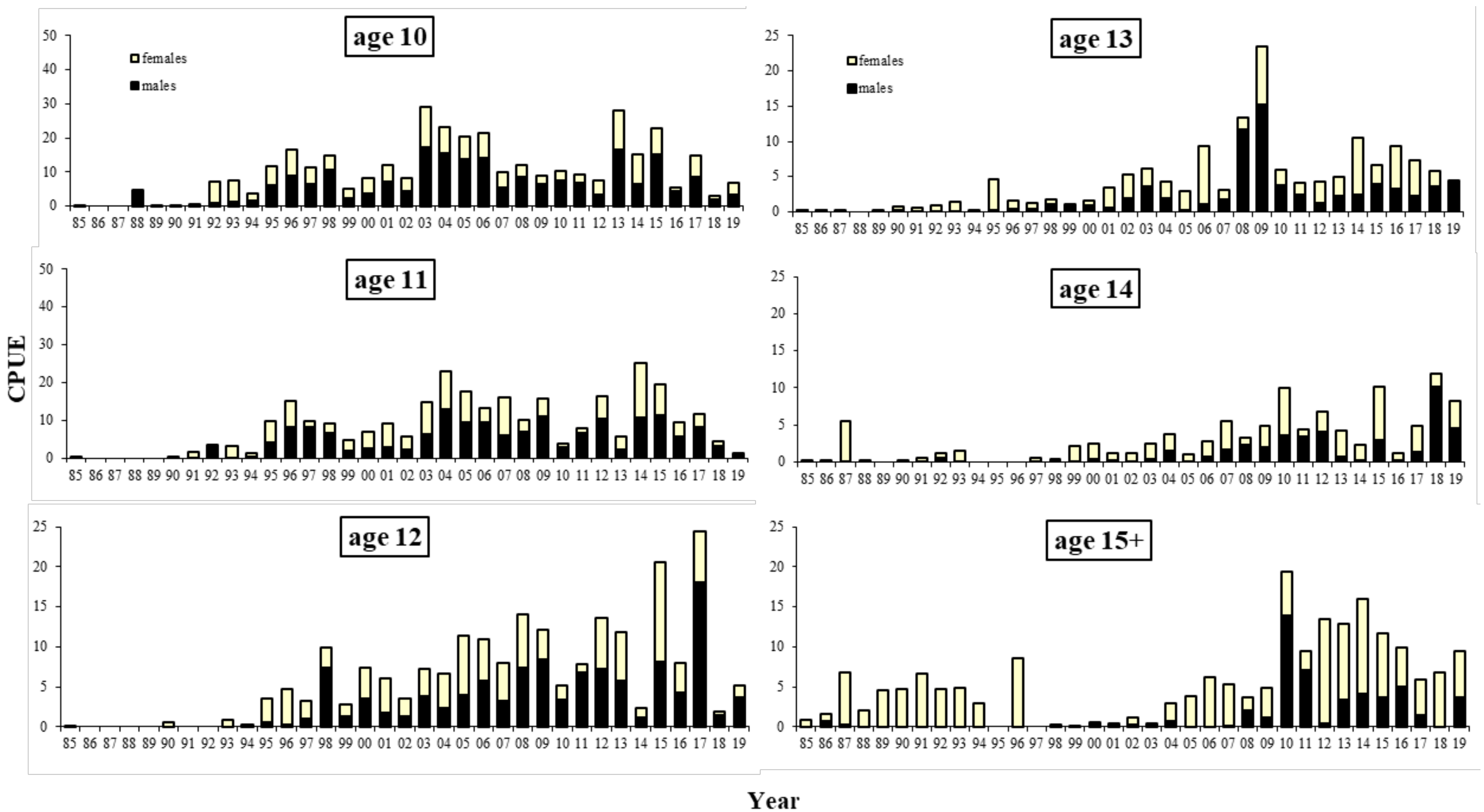
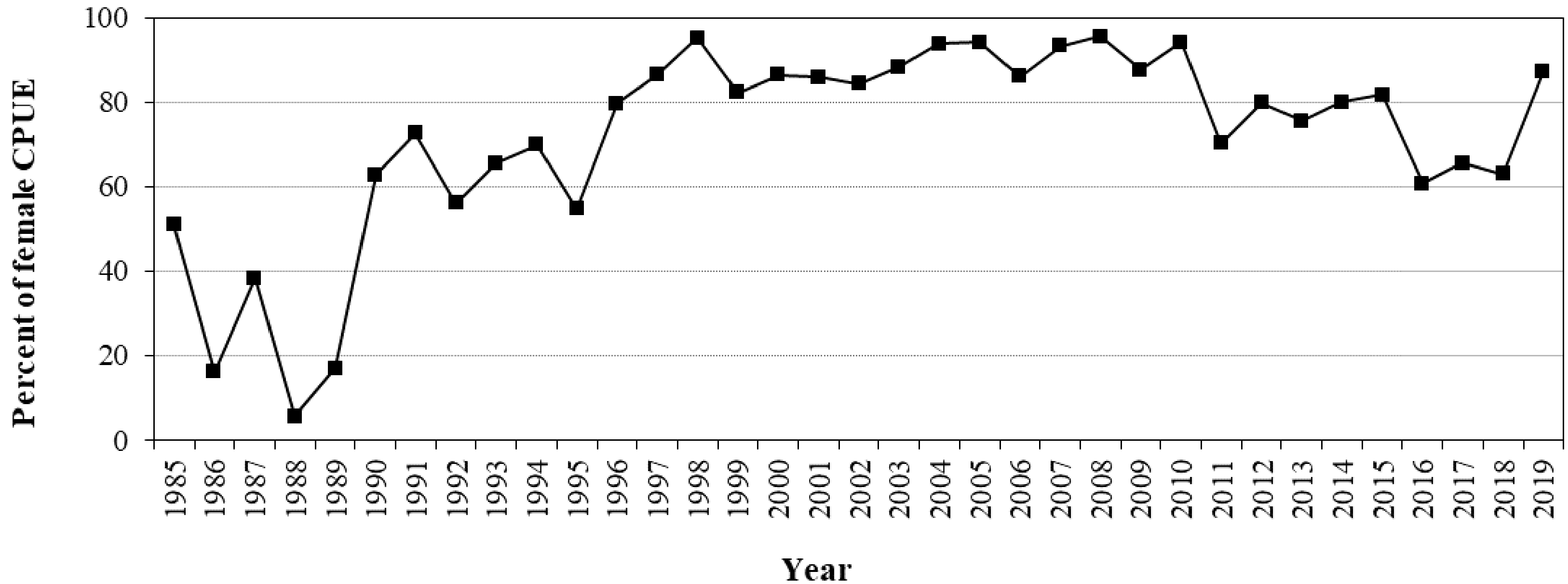
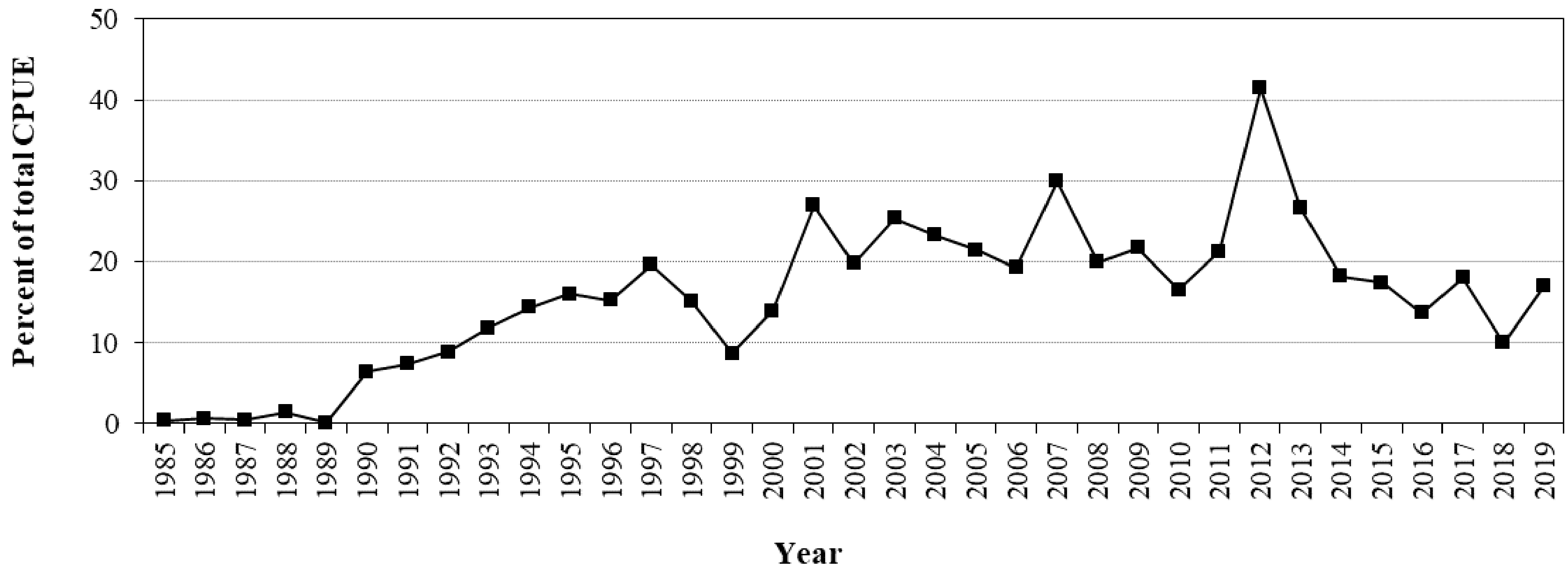


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, March through May, 1985-2019 (Choptank River to 1996). Effort is standardized as 1000 square yards of net per hour. Area-specific indices were weighted based on the relative size of the spawning areas* before area-specific indices were pooled.



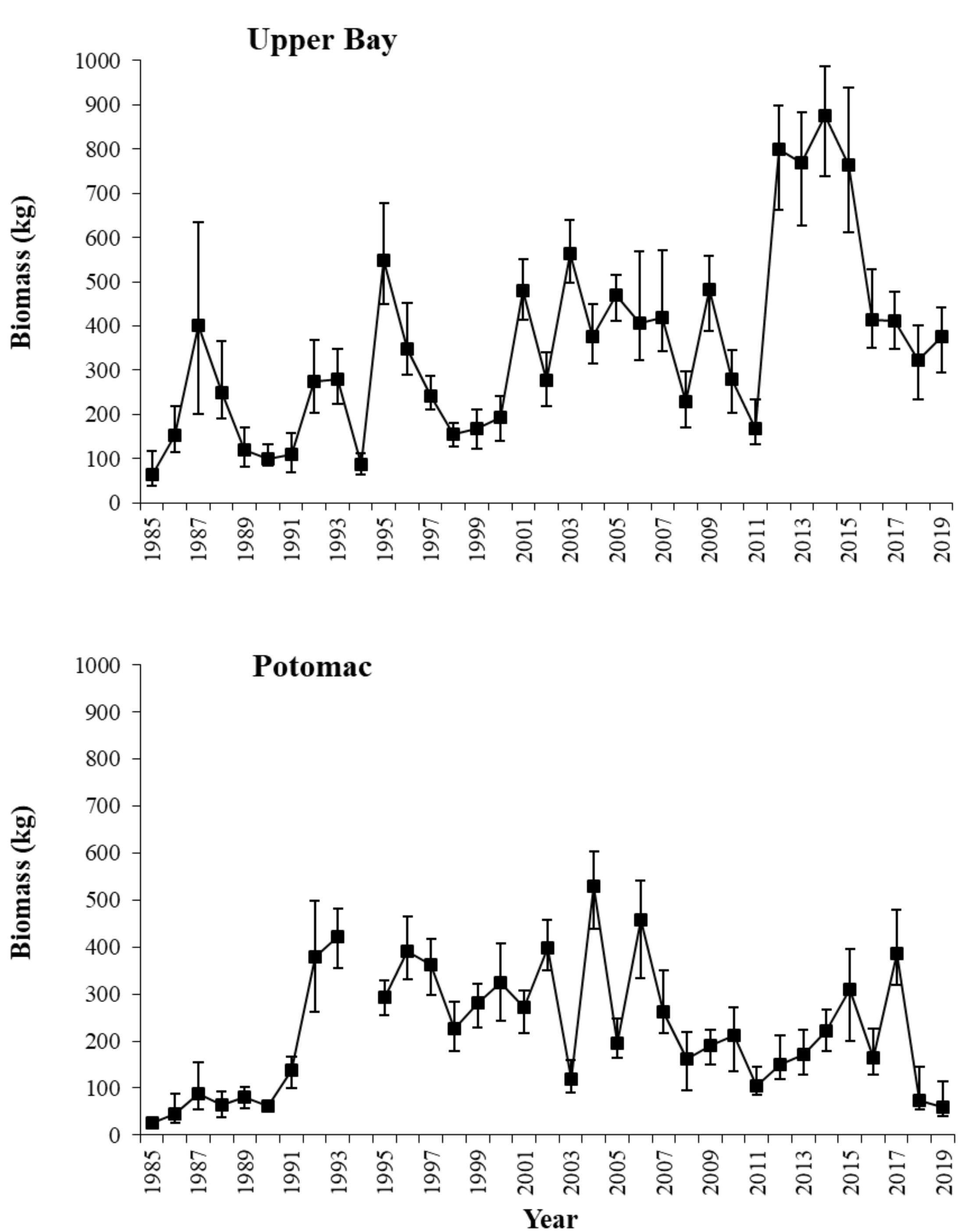
* Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385. (Hollis 1967).

Figure 11. Percentage (selectivity-corrected CPUE) of male and female striped bass age 8 and over sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, March through May, 1985-2019 (Choptank River to 1996). Effort is standardized as 1000 square yards of net per hour. Area-specific indices were weighted based on the relative size of the spawning areas* before area-specific indices were pooled.



* Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385. (Hollis 1967).

Figure 12. Index of spawning potential, expressed as biomass (kg), of female striped bass greater than or equal to 500 mm TL collected from experimental drift gill nets fished in two spawning areas of the Maryland Chesapeake Bay during March through May, 1985-2019. The index is corrected for gear selectivity, and bootstrap 95% confidence intervals are shown around each point.



PROJECT NO. 2
JOB NO. 3
TASK NO. 3

MARYLAND JUVENILE STRIPED BASS SURVEY

Prepared by Eric Q. Durell

INTRODUCTION

The primary objective of Project 2, Job 3, Task 3, was to document annual year-class success for young-of-the-year (YOY) striped bass (Morone saxatilis) in Chesapeake Bay. Annual indices of relative abundance provide an early indicator of future adult stock recruitment (Schaefer 1972; Goodyear 1985) and document annual variation and long-term trends in abundance and distribution.

METHODS

Sample Area and Intensity

Juvenile indices were derived from sampling at 22 fixed stations within Maryland's portion of the Chesapeake Bay (Table 1, Figure 1). Sample sites were divided among four of the major spawning and nursery areas; seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank rivers. Sites have been sampled continuously since 1954, with changes in some site locations when physical conditions or access restrictions dictate.

Changes to two auxiliary sampling sites were necessary in 2019. The Patuxent River auxiliary site at Peterson Point (#90) was lost to construction of riprap shoreline protection. A replacement site was established approximately 2 miles upstream at Grammers Cove (#170). The auxiliary site on the Susquehanna Flats at Tyding's Estate (#144) could not be sampled due to thick submerged aquatic vegetation and matted algae. Since no suitable replacements are available the

Tyding's Estate site will be revisited in the future.

From 1954 to 1961, Maryland's juvenile survey included inconsistent stations and rounds. Sample sizes ranged from 34 to 46. Indices derived for this period include only stations which are consistent with subsequent years. In 1962, stations were standardized and a second sample round was added for a total of 88 samples. A third sample round, added in 1966, increased sample size to 132.

Sites were sampled monthly, with rounds (sampling excursions) occurring during July (Round I), August (Round II), and September (Round III). Replicate seine hauls, a minimum of thirty minutes apart, were taken at each site in each sample round. This protocol produced a total of 132 samples from which Bay-wide means were calculated.

Auxiliary stations have been sampled on an inconsistent basis and were not included in survey indices. These data enhance geographical coverage in rivers with permanent stations or provide information from areas not otherwise surveyed. They are also useful for replacement of permanent stations when necessary. Replicate hauls at auxiliary stations were discontinued in 1992 to conserve time and allow increased geographical coverage of spawning areas. Auxiliary stations were sampled at the Head of Bay (Susquehanna Flats and one downstream station), and the Patuxent River (Table 1, Figure 1).

Sample Protocol

A 30.5-m x 1.24-m bagless beach seine of untreated 6.4-mm bar mesh was set by hand. One end was held on shore while the other was fully stretched perpendicular from the beach and swept with the current. Field trials have shown that 492 m^2 is a realistic estimate of the area swept by the seine under ideal field conditions. When depths of 1.2 m or greater were encountered, the offshore end was deployed along this depth contour. An estimate of distance from the beach to this depth was recorded.

Striped bass and selected other species were separated into 0 and 1+ age groupings. Ages were assigned from length-frequencies and verified through scale examination. Age 0 fish were measured (mm total length) from a random sample of up to 30 individuals per site and round. All other finfish were identified to species and counted.

Additional data were collected at each site and sample round. These included: time of first haul, maximum distance from shore, weather, maximum depth, surface water temperature (^oC), tide stage, surface salinity (ppt), primary and secondary bottom substrates, and submerged aquatic vegetation within the sample area (ranked by quartiles). Dissolved oxygen (DO), pH, and turbidity (Secchi disk) were added in 1997. All data since 1957 were entered and archived in Statistical Analysis System (SAS) databases (SAS 1990).

Estimators

The most commonly referenced striped bass 'juvenile index' is the arithmetic mean (AM). The AM has been used to predict harvest in New York waters (Schaefer 1972). Goodyear (1985) validated this index as a predictor of harvest in the Chesapeake Bay. The AM is an unbiased estimator of the mean regardless of the underlying frequency distribution (McConnaughey and Conquest 1992). The AM, however, is sensitive to high sample values (Sokol and Rolhf 1981). Additionally, detection of significant differences between annual arithmetic means is often not possible due to high variances (Heimbuch et al. 1983; Wilson and Wiesburg 1991).

The geometric mean (GM) was adopted by the Atlantic States Marine Fisheries Commission (ASMFC) Striped Bass Technical Committee in 1992 as the preferred index of relative abundance to model stock status. The GM is calculated from the $\log_e(x+1)$ transformation, where x is an individual seine haul catch. One is added to all catches in order to transform zero catches, because the log of 0 is undefined (Ricker 1975). Since the $\log_e$-transformation stabilizes the variance of catches (Richards 1992) the GM estimate is more precise than the AM and is not as sensitive to a single large sample value. It is almost always lower than the AM (Ricker 1975). The GM is presented with 95% confidence intervals (CIs) which are calculated as antilog ($\log_e(x+1)$ mean $\pm$ 2 standard errors), and provide a visual depiction of sample variability.

A third estimator, the proportion of positive hauls (PPHL), is the ratio of hauls containing juvenile striped bass to total hauls. Because the PPHL is based on the binomial distribution, it is very robust to bias and sampling error and greatly reduces variances (Green 1979). Its use as supplementary information is appropriate since seine estimates are often neither normally nor log-normally distributed (Richards 1992).

Comparison of these three indices is one method of assessing their accuracy. Similar trends among indices create more certainty that indices reflect actual changes in juvenile abundance. Greatly diverging trends may identify error in one or more of the indices.

Bay-wide annual indices are compared to the target period average (TPA). The TPA is the average of indices from 1959 through 1972. These years have been suggested as a period of stable biomass and general stock health (ASMFC 1989) and "an appropriate stock rebuilding target" (Gibson 1993). The TPA provides a fixed reference representing an average index produced by a healthy population. A fixed reference is an advantage over a time-series average that is revised annually and may be significantly biased by long-term trends in annual indices.

Differences among annual means were tested with an analysis of variance (GLM; SAS 1990) on the $\log_e(x+1)$ transformed data. Means were considered significant at the α=0.05 level. Duncan's multiple range test was used to differentiate means.

RESULTS

Bay-wide Means

A total of 445 YOY striped bass was collected at permanent stations in 2019, with individual samples yielding between 0 and 24 fish. The AM (3.4) and GM (1.95) were both below their respective time-series averages and TPAs (Tables 2 and 3, Figures 2 and 3). The PPHL was 0.75, indicating that 75% of samples produced juvenile striped bass. The PPHL was similar to the time-series average of 0.71 (Table 4, Figure 4).

A one-way analysis of variance (ANOVA) performed on the $\log_e$-transformed catch values indicated significant differences among annual means (ANOVA: $P<0.0001$) (SAS 1990). Duncan's multiple range test ($\alpha=0.05$) found that the 2019 $\log_e$-mean was significantly greater than just six years of the time-series.

System Means

Head of Bay - In 42 samples, 163 juveniles were collected at the Head of Bay sites for an AM of 3.9, less than the time-series average (11.8) and the TPA (17.3) (Table 2, Figure 5). The GM of 2.33 was less than the time-series average (5.80) and the TPA (7.27) (Table 3, Figure 6). Differences in annual $\log_e$-means were significant (ANOVA: $P<0.0001$). Duncan's multiple range test ($p=0.05$) found the 2019 Head of Bay $\log_e$-mean greater than just five year-classes of the time-series.

Potomac River - A total of 105 juveniles was collected in 42 samples on the Potomac River. The AM of 2.5 was lower than both the time-series average (8.1) and TPA (9.2) (Table 2, Figure 5). The GM of 1.27 was also below the time-series average (3.55) and TPA (3.93) (Table 3, Figure 7). Analysis of variance of $\log_e$-means indicated significant differences among years (ANOVA: $P<0.0001$). Duncan's multiple range test ($\alpha=0.05$) ranked the 2019 Potomac River year-class significantly larger than just one year (1969) of the time-series.

Choptank River - A total of 75 juveniles was collected in 24 Choptank River samples. The AM of 3.1 was below the time-series average of 20.7 and the TPA (10.8) (Table 2, Figure 5). The GM of 1.97 was less than its time-series average (7.96) and TPA (5.00) (Table 3, Figure 8). Differences among years were significant (ANOVA: $P<0.0001$). Duncan's multiple range test ($\alpha=0.05$) found the 2019 Choptank River year-class significantly larger than just two years of the time-series, and significantly smaller than 20 years of the time-series.

Nanticoke River - A total of 102 juveniles was collected in 24 samples on the Nanticoke River. The AM of 4.3 was below the time-series average (8.9) and the TPA (8.6) (Table 2, Figure 5). The GM of 2.72 was below its time-series average (4.07) and TPA (3.12) (Table 3, Figure 9). Striped bass recruitment in the Nanticoke River exhibited significant differences among years (ANOVA: $P<0.0001$). Duncan's multiple range test ($\alpha=0.05$) found the 2019 index significantly greater than just six years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 66 juveniles were caught in 12 samples, resulting in an AM of 5.5, and a GM of 3.97. The AM was below the time-series average, but the GM was above its time-series average (Table 5).

On the **Patuxent River**, 30 YOY striped bass were caught in 18 samples. The AM of 1.7 and GM of 1.05 were both less than their respective time-averages (Table 5).

DISCUSSION

Striped bass recruitment in Maryland's portion of Chesapeake Bay was poor in 2019. Duncan's multiple range test ($\alpha=0.05$) found the 2019 year-class significantly larger than only the six worst year-classes in the history of the survey. The GM ranked in the 33rd percentile of the time-series. Although low in abundance, YOY striped bass were distributed widely, as indicated by the above-average PPHL.

Recruitment in individual systems is often variable, but was consistently poor in 2019. Based on the percentile ranking of each system's GM, the Nanticoke performed best of all areas surveyed, with a GM ranked in the 55th percentile. The Head of Bay, Choptank, and Nanticoke GMs all ranked in the lower third of their respective time-series.

RELATIONSHIP OF AGE 0 TO AGE 1 INDICES

INTRODUCTION

Indices of age 1 (yearling) striped bass (Table 6) developed from the Maryland juvenile striped bass surveys were tested for relationship to YOY indices by year-class. Previous analysis yielded a significant relationship with age 0 indices explaining 73% (r^2=0.73, P$\leq$ 0.001) of the variability in age 1 indices one year later (MD DNR 1994). The strength of this relationship led to the incorporation of the age 1 index into coastal stock assessment models by the ASMFC Striped Bass Technical Committee. The utility of age 1 indices as a potential fishery independent verification of the YOY index also makes this relationship of interest.

METHODS

Age 1 indices were developed from the Maryland beach seine data (Table 6). Size ranges were used to determine catch of age 1 fish from records prior to 1991. Since 1991, striped bass have been separated into 0, 1 and 2+ age groups in the recorded data. Age groups were assigned by length-frequencies and later confirmed through direct examination of scales. Annual indices were computed as arithmetic means of log transformed catch values [$\log_e$ (x+1)], where x is an individual seine haul catch. Regression analysis was used to test the relationship between age 0 and subsequent age 1 mean catch per haul.

RESULTS AND DISCUSSION

The relationship of age 0 to subsequent age 1 relative abundance was significant and explained 58% of the variability ($r^2 = 0.58$, $p \leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was: $C_1 = (0.178)(C_0) - 0.0624$, where C_1 is the age 1 index and C_0 is the age 0 index. While still significant, the model has lost predictive power since 1994 when $r^2 = 0.73$. The addition of quadratic and cubic terms yielded even poorer fits.

This year's actual index of age 1 striped bass (0.23) was lower than the predicted index of 0.31. The small, negative residual indicates that survival during the first winter of the 2018 year-class was slightly less than expected. Examination of residuals (Figure 11) shows that this regression equation can be often be used to predict subsequent yearling striped bass abundance with reasonable certainty in the case of average sized year-classes such as that of 2018. Lower than expected abundance of age 1 striped bass may be an indication of density-dependent processes operating at high levels of abundance, such as cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

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LIST OF TABLES

LIST OF FIGURES

Table 1. Maryland juvenile striped bass survey sample sites.

Site Number	River or Creek	Area or Nearest Landmark
		HEAD OF CHESAPEAKE BAY SYSTEM
* 168	Susquehanna Flats	North side Fishing Battery Light Island
* 130	Susquehanna Flats	North side of Plum Point
* 144	Susquehanna Flats	Tyding's Estate, west shore of flats
* 59	Northeast River	Carpenter Point, K.O.A. Campground beach
3	Northeast River	Elk Neck State Park beach
31	Elk River	Oldfield Point
5	Elk River	Hyland Point Light
115	Bohemia River	Parlor Point
160	Sassafras River	Sassafras N.R.M.A., opposite Ordinary Point
10	Sassafras River	Howell Point, 500 yards east of point
164	Worton Creek	Handy Point, 0.3 miles west of Green Point Wharf
* 88	Chesapeake Bay	Beach at Tolchester Yacht Club
		POTOMAC RIVER SYSTEM
139	Potomac River	Hallowing Point, VA
50	Potomac River	Indian Head, old boat basin
51	Potomac River	Liverpool Point, south side of pier
52	Potomac River	Blossom Point, mouth of Nanjemoy Creek
163	Potomac River	Aqualand Marina
55	Wicomico River	Rock Point
56	Potomac River	St. George Island, south end of bridge

* Indicates auxiliary seining site

Table 1. Continued.

Site Number	River or Creek	Area or Nearest Landmark
	CHOPTANK RIVER SYSTEM	
2	Tuckahoe Creek	Northeast side near mouth
148	Choptank River	North side of Jamaica Point
161	Choptank River	Dickinson Bay, 0.5 miles from Howell Point
29	Choptank River	Castle Haven, northeast side
	NANTICOKE RIVER SYSTEM	
36	Nanticoke River	Sharptown, pulpwood pier
166	Nanticoke River	Opposite Red Channel Marker #26
38	Nanticoke River	Opposite Chapter Point, above light #15
39	Nanticoke River	Tyaskin Beach
	PATUXENT RIVER SYSTEM	
* 85	Patuxent River	Selby Landing
* 86	Patuxent River	Nottingham, Windsor Farm
* 91	Patuxent River	Milltown Landing
* 92	Patuxent River	Eagle Harbor
* 106	Patuxent River	Sheridan Point
* 170	Patuxent River	Grammers Cove

* Indicates auxiliary seining site

Table 2. Maryland juvenile striped bass survey arithmetic mean (AM) catch per haul at permanent sites.

Year	Head of Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1954	0.9	5.2	1.2	25.1	5.2
1955	4.4	5.7	12.5	5.9	5.5
1956	33.9	6.2	9.8	8.2	15.2
1957	5.4	2.5	2.1	1.3	2.9
1958	28.2	8.4	19.5	22.5	19.3
1959	1.9	1.6	0.1	1.8	1.4
1960	9.3	4.3	9.0	4.7	7.1
1961	22.1	25.8	6.0	1.5	17.0
1962	11.4	19.7	6.1	6.6	12.2
1963	6.1	1.1	5.4	4.1	4.0
1964	31.0	29.1	10.6	13.3	23.5
1965	2.2	3.4	9.5	21.6	7.4
1966	32.3	10.5	13.6	3.3	16.7
1967	17.4	1.9	5.3	4.1	7.8
1968	13.1	0.7	6.3	9.0	7.2
1969	26.6	0.2	4.8	6.2	10.5
1970	33.1	20.1	57.2	17.1	30.4
1971	23.7	8.5	6.3	2.0	11.8
1972	12.1	1.9	11.0	25.0	11.0
1973	24.5	2.1	1.3	1.1	8.9
1974	19.9	1.5	15.3	3.9	10.1
1975	7.6	7.8	4.7	5.2	6.7
1976	9.9	3.2	2.4	1.7	4.9
1977	12.1	1.9	1.2	1.0	4.8
1978	12.5	7.9	6.0	4.8	8.5
1979	8.3	2.2	2.8	0.9	4.0
1980	2.3	2.2	1.0	1.8	2.0
1981	0.3	1.4	1.3	2.4	1.2
1982	5.5	10.0	13.0	6.2	8.4
1983	1.2	2.0	0.9	1.0	1.4
1984	6.1	4.7	2.8	1.5	4.2
1985	0.3	5.6	3.7	2.1	2.9
1986	1.6	9.9	0.5	2.2	4.1
1987	1.3	6.4	12.1	2.5	4.8
1988	7.3	0.4	0.7	0.4	2.7
1989	19.4	2.2	97.8	2.9	25.2
1990	3.8	0.6	3.1	0.9	2.1
1991	3.9	2.5	12.2	1.1	4.4

Table 2. Continued.

Year	Head of Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1992	1.3	22.1	4.3	4.3	9.0
1993	23.0	36.4	105.5	9.3	39.8
1994	23.4	3.9	19.3	21.5	16.1
1995	4.4	8.7	17.7	10.4	9.3
1996	25.0	48.5	154.4	43.7	59.4
1997	8.3	10.6	7.3	3.5	8.0
1998	8.3	10.8	32.6	3.8	12.7
1999	3.1	15.7	48.2	18.7	18.1
2000	13.3	7.8	21.2	17.6	13.8
2001	13.4	7.8	201.9	40.1	50.8
2002	3.1	7.0	0.7	7.8	4.7
2003	28.4	23.6	41.8	8.7	25.8
2004	7.8	4.0	22.8	19.5	11.4
2005	13.2	10.3	55.2	1.5	17.8
2006	1.5	6.7	5.8	3.2	4.3
2007	20.2	4.9	14.3	15.4	13.4
2008	5.9	3.3	0.5	1.0	3.2
2009	6.8	7.8	11.3	6.5	7.9
2010	7.3	5.7	3.3	4.6	5.6
2011	10.3	12.8	125.7	24.3	34.6
2012	0.7	1.7	0.1	0.6	0.9
2013	4.9	7.0	4.8	6.1	5.8
2014	15.2	2.3	12.5	17.3	11.0
2015	9.9	11.3	43.0	53.0	24.2
2016	2.0	3.7	1.1	0.9	2.2
2017	26.5	8.5	6.8	4.4	13.2
2018	24.2	5.5	20.3	8.9	14.8
2019	3.9	2.5	3.1	4.3	3.4
Average	11.8	8.1	20.7	8.9	11.6
TPA*	17.3	9.2	10.8	8.6	12.0

* TPA (target period average) is the average from 1959 through 1972.

Table 3. Maryland juvenile striped bass survey geometric mean (GM) catch per haul at permanent sites.

Year	Head of Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1955	1.49	3.78	2.36	2.26	2.26
1956	6.88	4.50	6.22	5.29	5.29
1957	1.92	1.78	1.16	1.40	1.40
1958	22.07	3.93	11.01	11.12	11.12
1959	0.95	0.61	0.09	0.59	0.59
1960	3.18	2.44	4.31	3.01	3.01
1961	7.46	12.82	5.40	6.61	6.61
1962	3.73	6.70	3.14	4.25	4.25
1963	3.01	0.54	2.01	1.61	1.61
1964	15.41	9.15	4.92	9.04	9.04
1965	0.76	0.92	2.18	1.56	1.56
1966	15.89	4.95	5.52	6.24	6.24
1967	3.92	1.03	2.80	2.28	2.28
1968	6.13	0.39	3.85	2.69	2.69
1969	12.21	0.12	2.55	2.81	2.81
1970	13.71	10.97	25.41	12.48	12.48
1971	10.45	3.48	2.51	4.02	4.02
1972	4.95	0.96	5.36	3.26	3.26
1973	11.92	1.10	0.43	2.33	2.33
1974	6.79	0.66	3.55	2.62	2.62
1975	2.34	3.56	2.71	2.81	2.81
1976	2.70	1.46	0.89	1.58	1.58
1977	4.99	0.78	0.81	1.61	1.61
1978	6.51	3.33	2.65	3.75	3.75
1979	4.56	1.15	1.12	1.73	1.73
1980	1.43	1.04	0.58	1.01	1.01
1981	0.17	0.68	0.84	0.59	0.59
1982	2.98	3.50	5.68	3.54	3.54
1983	0.61	0.62	0.64	0.61	0.61
1984	2.23	1.42	2.13	0.81	1.64
1985	0.19	1.45	1.78	0.94	0.91
1986	0.90	3.09	0.32	1.24	1.34
1987	0.16	3.01	3.06	1.36	1.46
1988	2.25	0.22	0.40	0.28	0.73
1989	8.54	1.15	28.10	1.94	4.87
1990	2.20	0.38	1.34	0.56	1.03
1991	1.99	0.84	4.42	0.52	1.52

Table 3. Continued.

Year	Head of Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1992	0.87	6.00	2.07	1.72	2.34
1993	15.00	15.96	27.87	4.56	13.97
1994	12.88	2.01	7.71	9.06	6.40
1995	2.85	4.47	9.96	3.76	4.41
1996	15.00	13.60	33.29	19.13	17.61
1997	6.15	3.67	3.95	1.74	3.91
1998	4.32	4.42	21.10	2.74	5.50
1999	1.91	5.84	20.01	5.52	5.34
2000	8.84	3.52	12.53	10.86	7.42
2001	7.15	5.01	86.71	20.31	12.57
2002	1.35	3.95	0.38	4.89	2.20
2003	11.89	12.81	20.56	3.25	10.83
2004	4.17	2.36	9.52	9.65	4.85
2005	8.48	7.92	16.81	1.07	6.91
2006	0.95	2.42	2.81	1.65	1.78
2007	8.21	2.20	7.87	5.41	5.12
2008	2.33	1.40	0.34	0.73	1.26
2009	2.85	3.75	6.61	4.18	3.92
2010	2.90	2.17	2.23	2.96	2.54
2011	5.79	7.18	26.14	12.99	9.57
2012	0.44	0.95	0.08	0.37	0.49
2013	3.29	3.13	3.53	4.14	3.42
2014	8.02	1.07	6.28	5.10	4.06
2015	7.20	6.07	21.69	25.71	10.67
2016	1.14	2.36	0.64	0.68	1.25
2017	18.52	3.82	3.40	2.23	5.88
2018	14.48	2.97	8.85	5.78	6.96
2019	2.33	1.27	1.97	2.72	1.95
Average	5.80	3.55	7.96	4.07	4.30
TPA*	7.27	3.93	5.00	3.12	4.32

* TPA (target period average) is the average from 1959 through 1972.

Table 4. Maryland Chesapeake Bay arithmetic mean (AM) and log mean with coefficients of variation (CV), proportion of positive hauls (PPHL) with 95% confidence intervals (CI), and number of seine hauls (n) for juvenile striped bass.

Year	**AM**	**CV (%) of AM**	**Log Mean**	**CV (%) of Log Mean**	**PPHL**	**Low CI**	**High CI**	**n**
1957	2.9	205.5	0.87	100.72	0.66	0.52	0.80	44
1958	19.3	94.2	2.50	48.56	0.89	0.79	0.99	36
1959	1.4	198.3	0.47	171.23	0.30	0.14	0.45	34
1960	7.1	149.2	1.39	86.32	0.72	0.58	0.87	36
1961	17.0	183.3	2.03	61.04	0.96	0.90	1.02	46
1962	12.2	160.8	1.66	82.85	0.75	0.66	0.84	88
1963	4.0	182.6	0.96	111.85	0.56	0.45	0.66	88
1964	23.5	162.3	2.31	60.35	0.90	0.83	0.96	88
1965	7.4	247.7	0.94	140.06	0.47	0.36	0.57	88
1966	16.7	184.8	1.98	67.16	0.86	0.80	0.92	132
1967	7.8	263.9	1.19	100.40	0.69	0.61	0.77	132
1968	7.2	175.3	1.31	94.10	0.65	0.57	0.73	132
1969	10.5	224.0	1.34	104.40	0.62	0.54	0.70	132
1970	30.4	157.5	2.60	52.73	0.95	0.91	0.99	132
1971	11.8	187.0	1.61	80.43	0.81	0.74	0.88	132
1972	11.0	250.8	1.45	91.54	0.72	0.64	0.80	132
1973	8.9	229.2	1.20	110.90	0.61	0.53	0.70	132
1974	10.1	261.9	1.29	102.42	0.65	0.57	0.74	132
1975	6.7	152.2	1.34	86.76	0.73	0.66	0.81	132
1976	4.9	279.4	0.95	113.88	0.60	0.51	0.68	132
1977	4.8	236.4	1.96	113.00	0.62	0.54	0.70	132
1978	8.5	145.6	1.56	77.24	0.77	0.69	0.84	132
1979	4.0	182.1	1.00	100.24	0.66	0.58	0.74	132
1980	2.0	174.8	0.70	114.68	0.54	0.45	0.62	132
1981	1.2	228.2	0.46	150.34	0.39	0.30	0.47	132
1982	8.4	160.1	1.51	79.73	0.76	0.68	0.83	132
1983	1.4	268.0	0.48	152.37	0.38	0.30	0.46	132
1984	4.2	228.2	0.97	106.58	0.65	0.57	0.73	132
1985	2.9	253.0	0.65	152.02	0.42	0.33	0.50	132
1986	4.1	272.2	0.85	121.40	0.55	0.47	0.64	132
1987	4.8	262.1	0.90	124.54	0.51	0.42	0.59	132
1988	2.7	313.8	0.55	170.46	0.37	0.29	0.45	132
1989	25.2	309.1	1.77	90.18	0.75	0.68	0.82	132
1990	2.1	174.8	0.71	120.74	0.49	0.41	0.58	132
1991	4.4	203.8	0.93	120.27	0.52	0.43	0.60	132

Table 4. Continued.

Year	AM	CV (%) of AM	Log Mean	CV (%) of Log Mean	PPHL	Low CI	High CI	n
1992	9.0	267.0	1.20	105.19	0.67	0.59	0.75	132
1993	39.8	279.1	2.71	49.53	0.96	0.93	0.99	132
1994	16.1	150.4	2.00	66.96	0.84	0.78	0.90	132
1995	9.3	153.3	1.69	66.42	0.86	0.80	0.92	132
1996	59.4	369.2	2.92	45.50	0.99	0.96	1.00	132
1997	8.0	135.6	1.59	70.98	0.80	0.74	0.87	132
1998	12.7	164.8	1.87	65.72	0.86	0.78	0.92	132
1999	18.1	208.4	1.85	77.45	0.80	0.75	0.88	132
2000	13.8	120.8	2.13	53.69	0.91	0.86	0.96	132
2001	50.8	308.9	2.61	57.22	0.92	0.88	0.97	132
2002	4.7	141.3	1.16	91.89	0.67	0.59	0.75	132
2003	25.8	136.9	2.47	55.42	0.92	0.88	0.97	132
2004	11.4	177.8	1.77	67.01	0.87	0.81	0.93	132
2005	17.8	237.3	2.07	59.12	0.90	0.86	0.95	132
2006	4.3	178.6	1.02	103.67	0.59	0.51	0.67	132
2007	13.4	177.3	1.81	71.92	0.83	0.76	0.89	132
2008	3.2	213.1	0.81	119.32	0.54	0.45	0.62	132
2009	7.9	154.3	1.59	66.66	0.86	0.80	0.92	132
2010	5.6	175.0	1.26	82.49	0.77	0.69	0.84	132
2011	34.6	580.4	2.36	51.94	0.93	0.89	0.97	132
2012	0.9	197.5	0.40	152.53	0.35	0.27	0.43	132
2013	5.8	115.7	1.49	63.93	0.84	0.78	0.90	132
2014	11.0	179.7	1.62	80.21	0.77	0.69	0.84	132
2015	24.2	179.2	2.46	49.21	0.98	0.96	1.00	132
2016	2.2	140.0	0.81	99.38	0.61	0.52	0.69	132
2017	13.2	136.6	1.93	65.98	0.83	0.77	0.90	132
2018	14.8	137.7	2.07	58.19	0.91	0.86	0.96	132
2019	3.4	134.0	1.08	79.95	0.75	0.68	0.82	132
Average	11.8	204.9	1.46	91.05	0.71	0.64	0.79	
TPA*	12.0	194.8	1.52	93.18	0.71	0.62	0.80	

* TPA (target period average) is the average from 1959 through 1972.

Table 5. Maryland juvenile striped bass survey arithmetic (AM) and geometric (GM) mean catch per haul and number of seine hauls per year (n) for auxiliary sample sites.

	Patuxent River			Head of Bay		
Year	AM	GM	n	AM	GM	n
1983	0.1	0.04	18	0.6	0.33	12
1984	0.6	0.39	18	0.9	0.43	12
1985	3.2	1.95	18	1.0	0.24	12
1986	2.4	1.17	18	0.9	0.54	12
1987	2.9	0.94	17	0.3	0.26	9
1988	0.6	0.40	17	1.6	1.07	21
1989	1.4	0.92	18	10.4	1.91	21
1990	0.3	0.17	18	5.0	2.24	21
1991	0.9	0.53	18	2.2	0.98	20
1992	9.5	1.85	18	0.5	0.26	20
1993	104.3	47.18	18	28.0	11.11	21
1994	4.1	2.82	18	6.3	2.31	21
1995	7.3	3.46	18	3.0	1.15	21
1996	420.4	58.11	18	12.4	4.69	20
1997	7.3	2.72	18	2.7	2.18	20
1998	13.2	7.58	18	3.0	1.51	16
1999	7.3	5.39	18	3.6	2.13	13
2000	9.7	5.03	18	8.6	5.68	15
2001	17.3	10.01	18	19.5	6.62	15
2002	1.2	0.69	18	1.0	0.42	15
2003	61.1	22.17	18	16.1	11.79	16
2004	2.1	1.29	18	7.7	4.40	15
2005	8.9	3.91	18	5.5	4.35	15
2006	1.0	0.66	18	0.7	0.31	15
2007	15.2	6.07	18	5.3	2.72	15
2008	0.3	0.24	18	3.5	2.02	15
2009	3.0	1.87	18	2.1	1.14	15

Table 5. Continued.

	Patuxent River			Head of Bay		
Year	**AM**	**GM**	**n**	**AM**	**GM**	**n**
2010	3.3	2.49	18	3.7	1.45	15
2011	42.5	13.41	18	12.3	5.75	21
2012	0.1	0.04	18	1.9	0.71	21
2013	6.0	2.63	18	4.9	2.82	15
2014	5.1	2.70	18	5.3	4.34	15
2015	11.5	4.15	18	6.3	4.15	15
2016	1.4	0.83	18	1.5	0.90	15
2017	7.9	2.08	18	12.4	6.62	14
2018	6.9	2.65	18	12.6	7.37	12
2019	1.7	1.05	18	5.5	3.97	12
Average	21.4	5.93		5.9	3.00	
Median	4.1	2.08		3.7	2.13	

Table 6. Log mean catch per haul of age 0 and age 1 striped bass by year-class.

Year-class	**Age 0**	**Age 1**
1957	0.87	0.08
1958	2.50	0.45
1959	0.47	0.07
1960	1.39	0.14
1961	2.03	0.39
1962	1.66	0.19
1963	0.96	0.07
1964	2.31	0.29
1965	0.94	0.19
1966	1.98	0.14
1967	1.19	0.20
1968	1.31	0.19
1969	1.34	0.10
1970	2.60	0.74
1971	1.61	0.37
1972	1.45	0.35
1973	1.20	0.21
1974	1.29	0.20
1975	1.32	0.12
1976	0.95	0.05
1977	0.96	0.16
1978	1.56	0.26
1979	1.00	0.16
1980	0.70	0.02
1981	0.46	0.02
1982	1.51	0.28
1983	0.48	0.00
1984	0.97	0.14
1985	0.65	0.03
1986	0.85	0.05
1987	0.90	0.06
1988	0.55	0.14
1989	1.77	0.28
1990	0.71	0.17
1991	0.93	0.11
1992	1.20	0.18
1993	2.71	0.56

Table 6. Continued.

Year-class	Age 0	Age 1
1994	2.00	0.12
1995	1.69	0.07
1996	2.92	0.23
1997	1.59	0.16
1998	1.87	0.31
1999	1.85	0.23
2000	2.13	0.28
2001	2.61	0.58
2002	1.16	0.07
2003	2.47	0.55
2004	1.77	0.25
2005	2.07	0.25
2006	1.02	0.07
2007	1.81	0.27
2008	0.81	0.11
2009	1.59	0.16
2010	1.26	0.02
2011	2.36	0.30
2012	0.40	0.05
2013	1.49	0.11
2014	1.62	0.20
2015	2.46	0.35
2016	0.81	0.13
2017	1.93	0.09
2018	2.07	0.23
2019	1.08	N/A

Figure 1. Maryland Chesapeake Bay juvenile striped bass survey site locations.

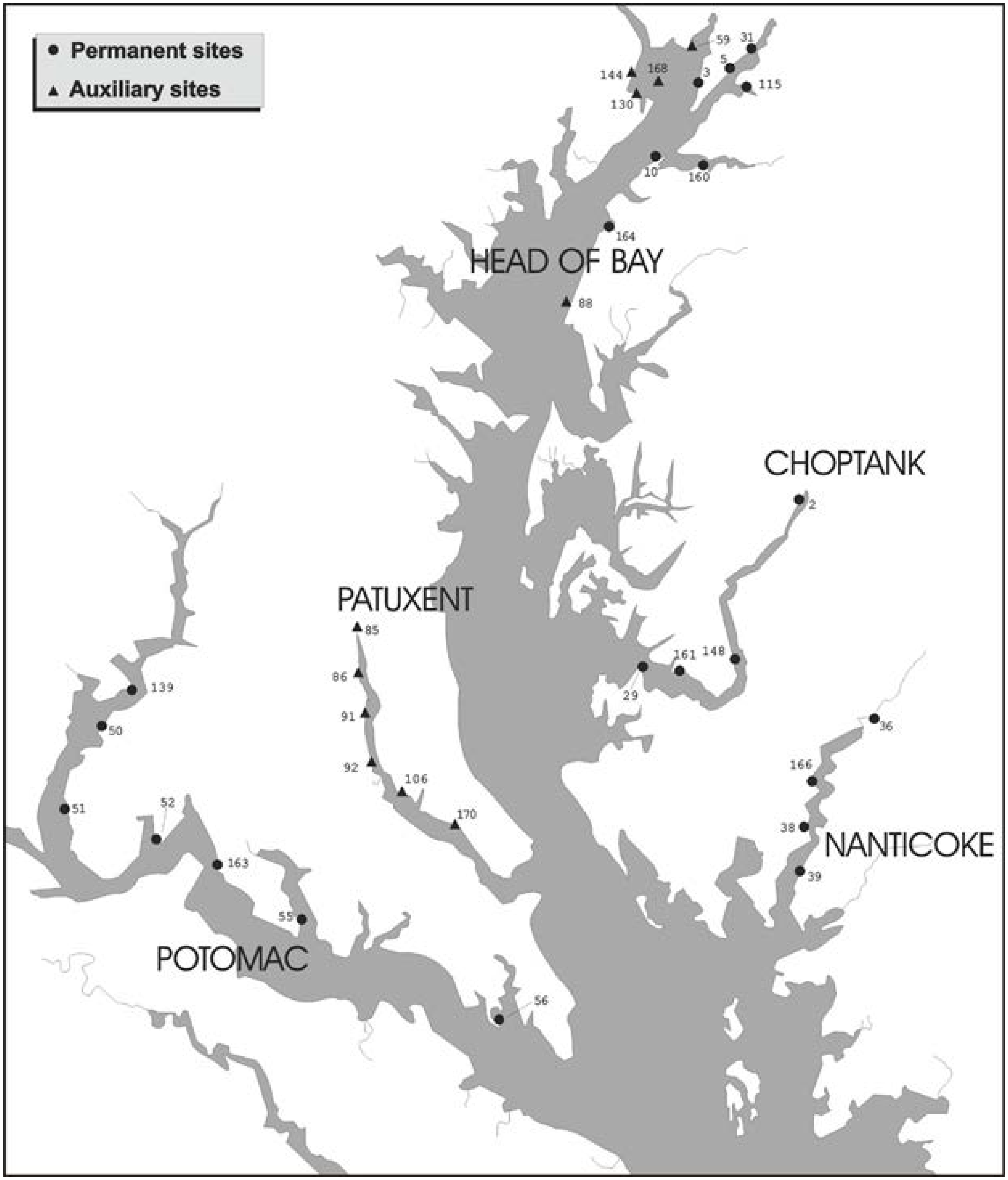


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

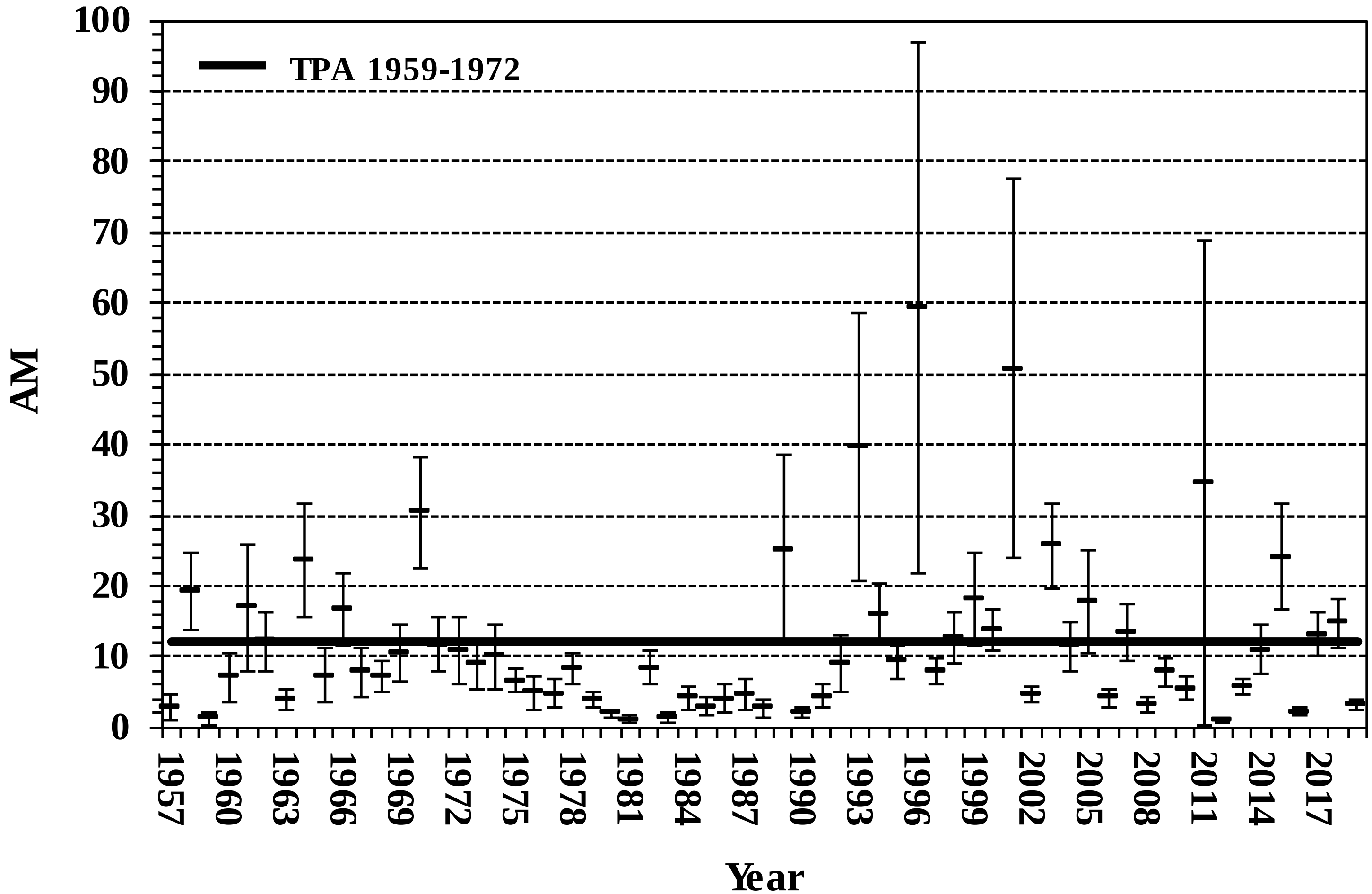


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

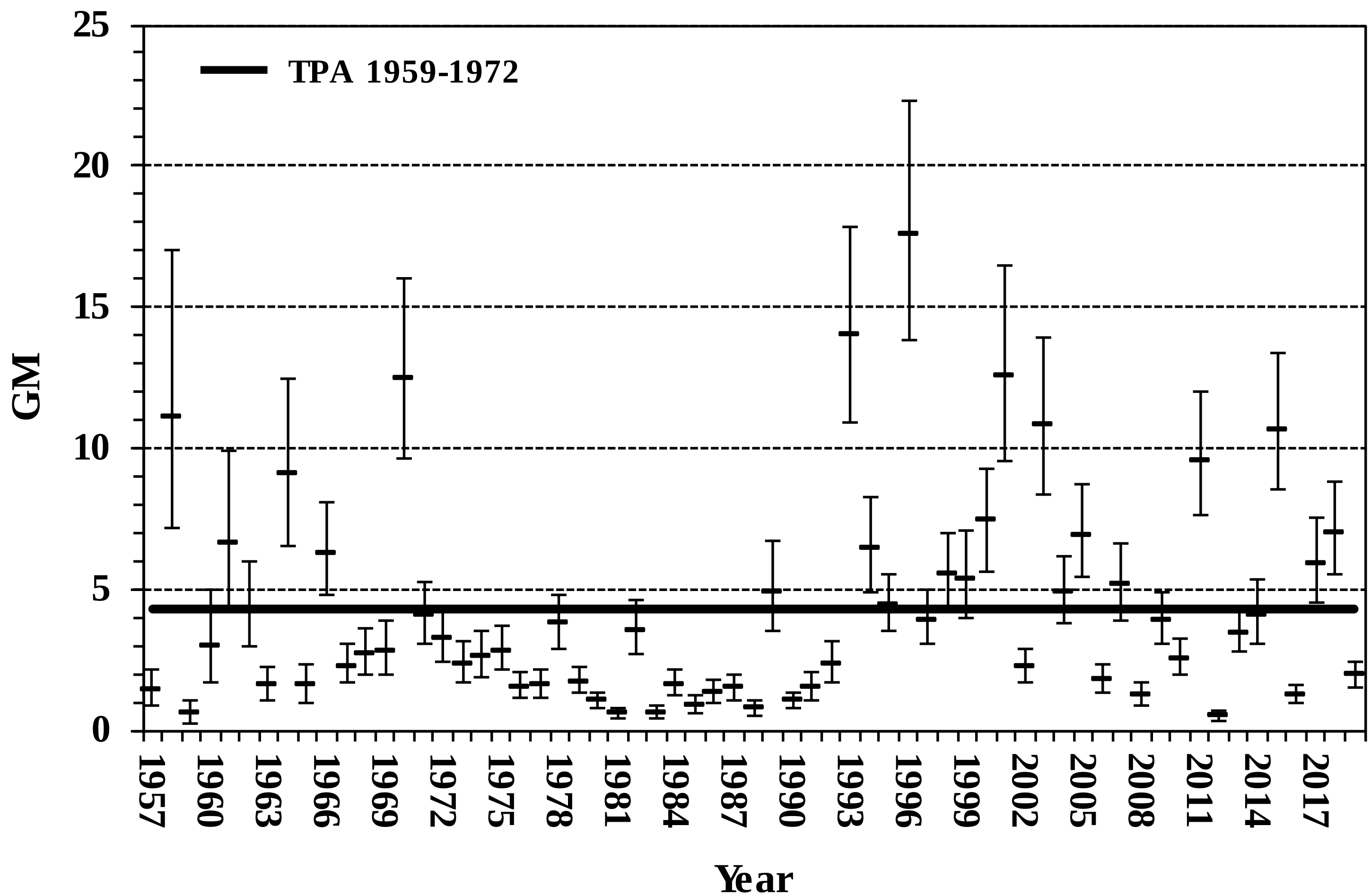


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

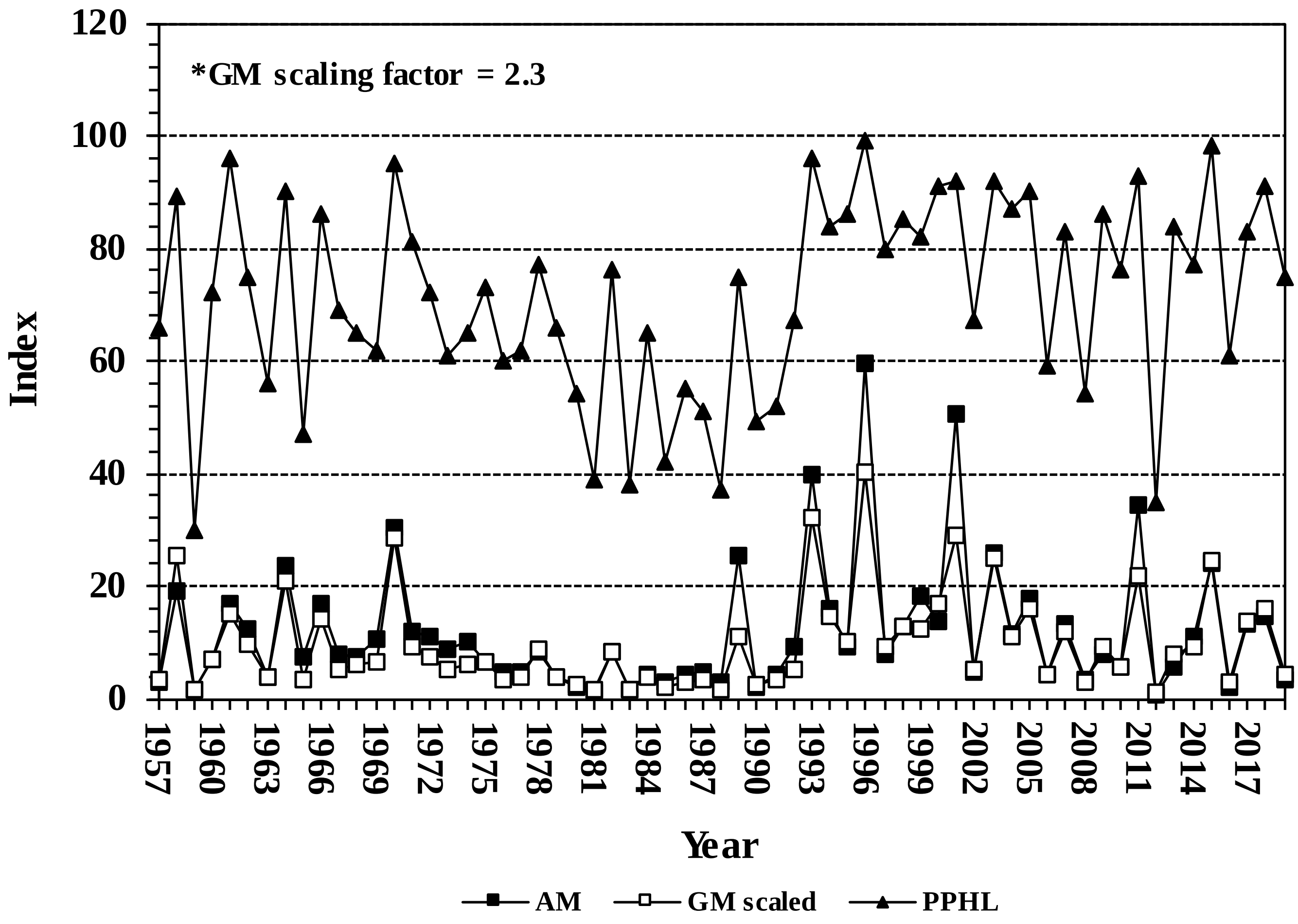


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

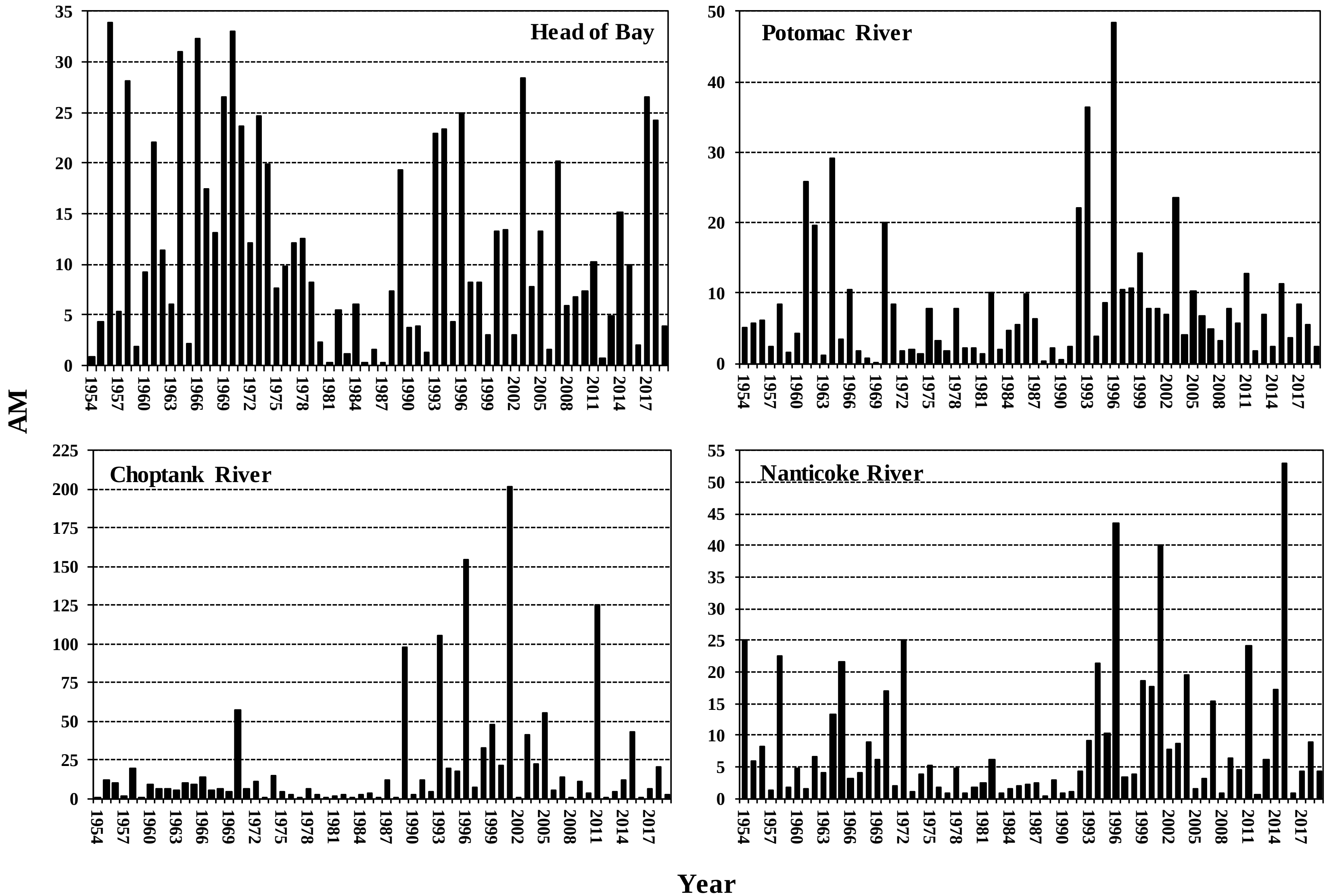


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

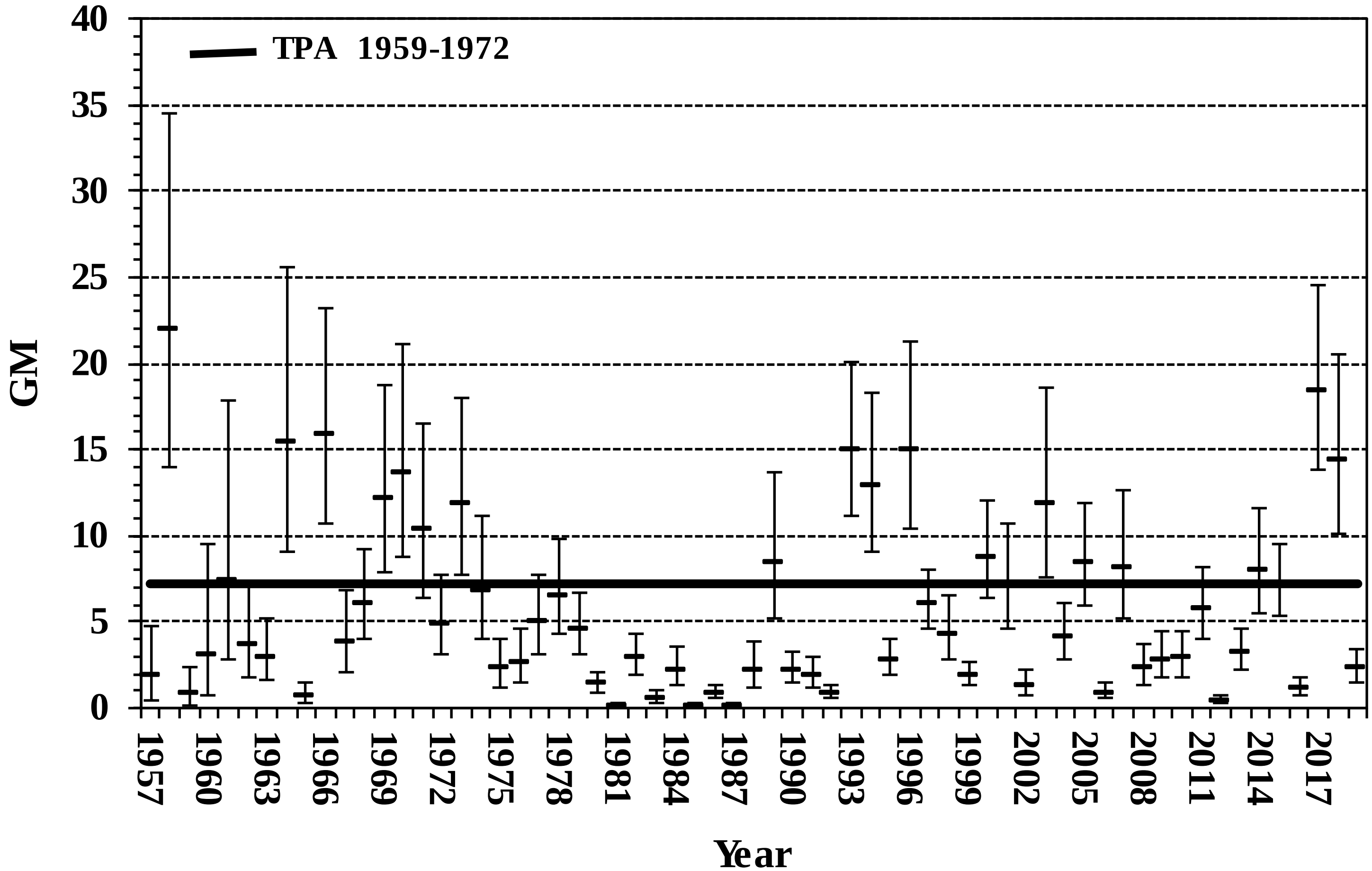


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

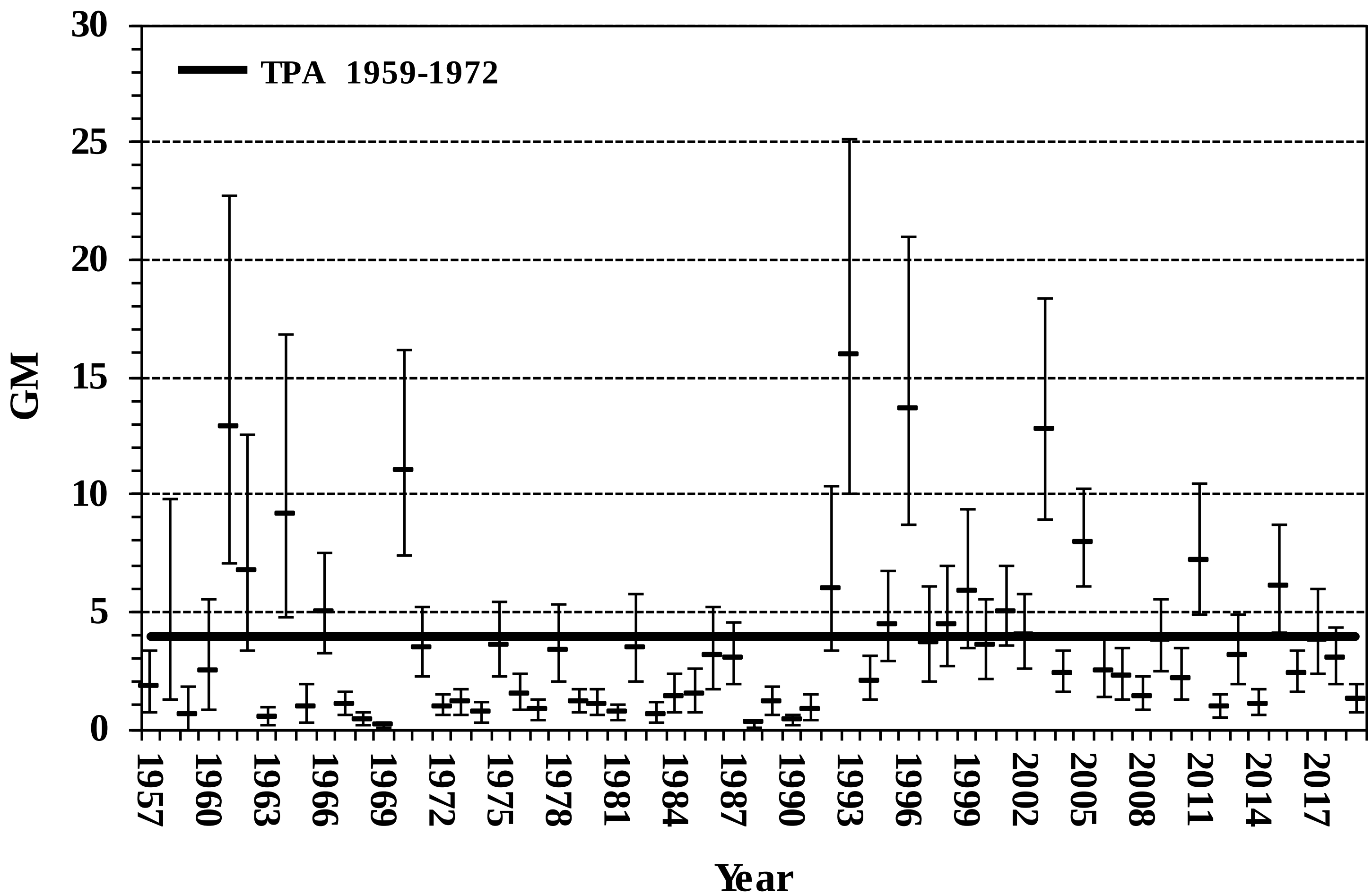


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

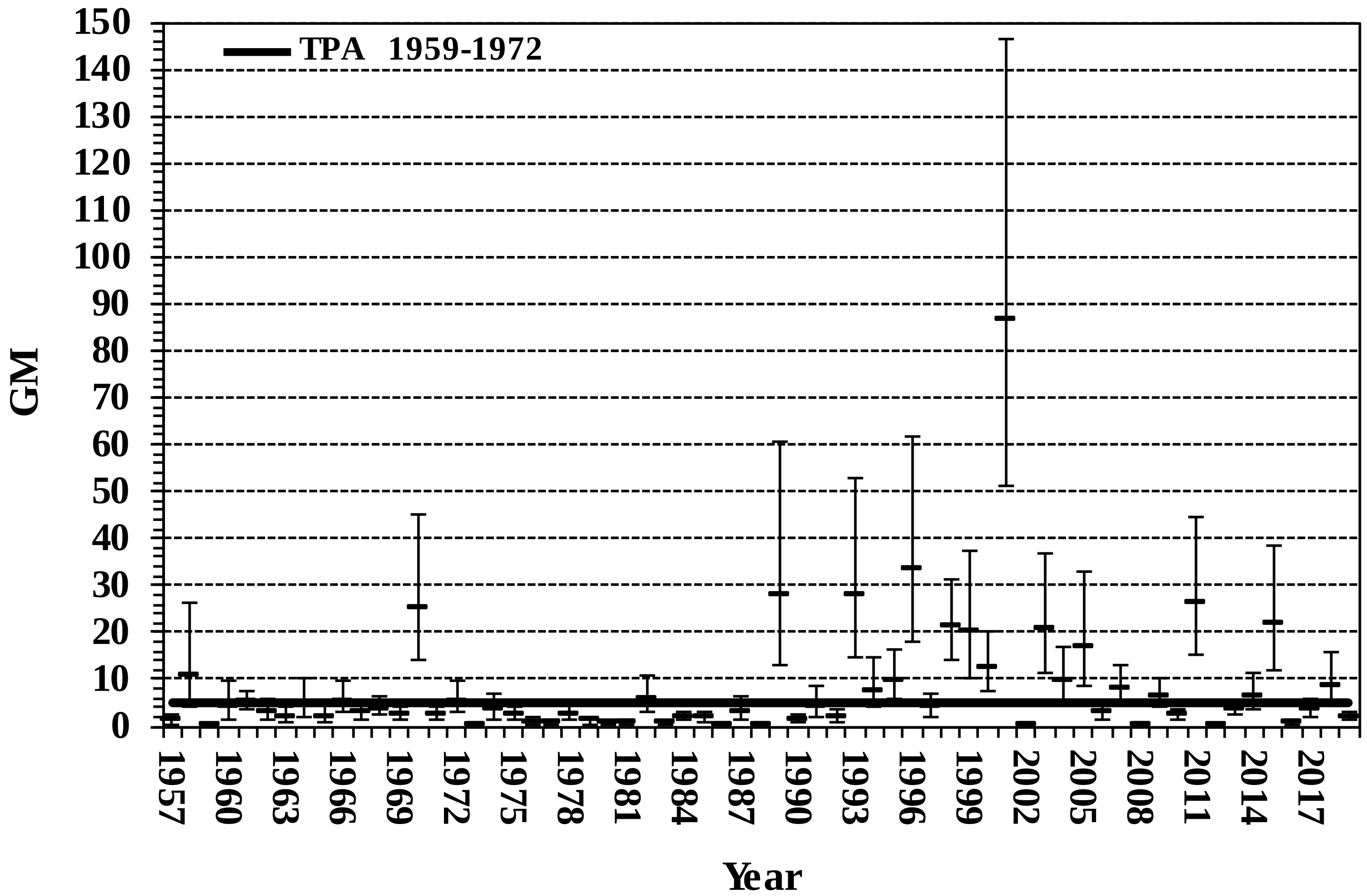
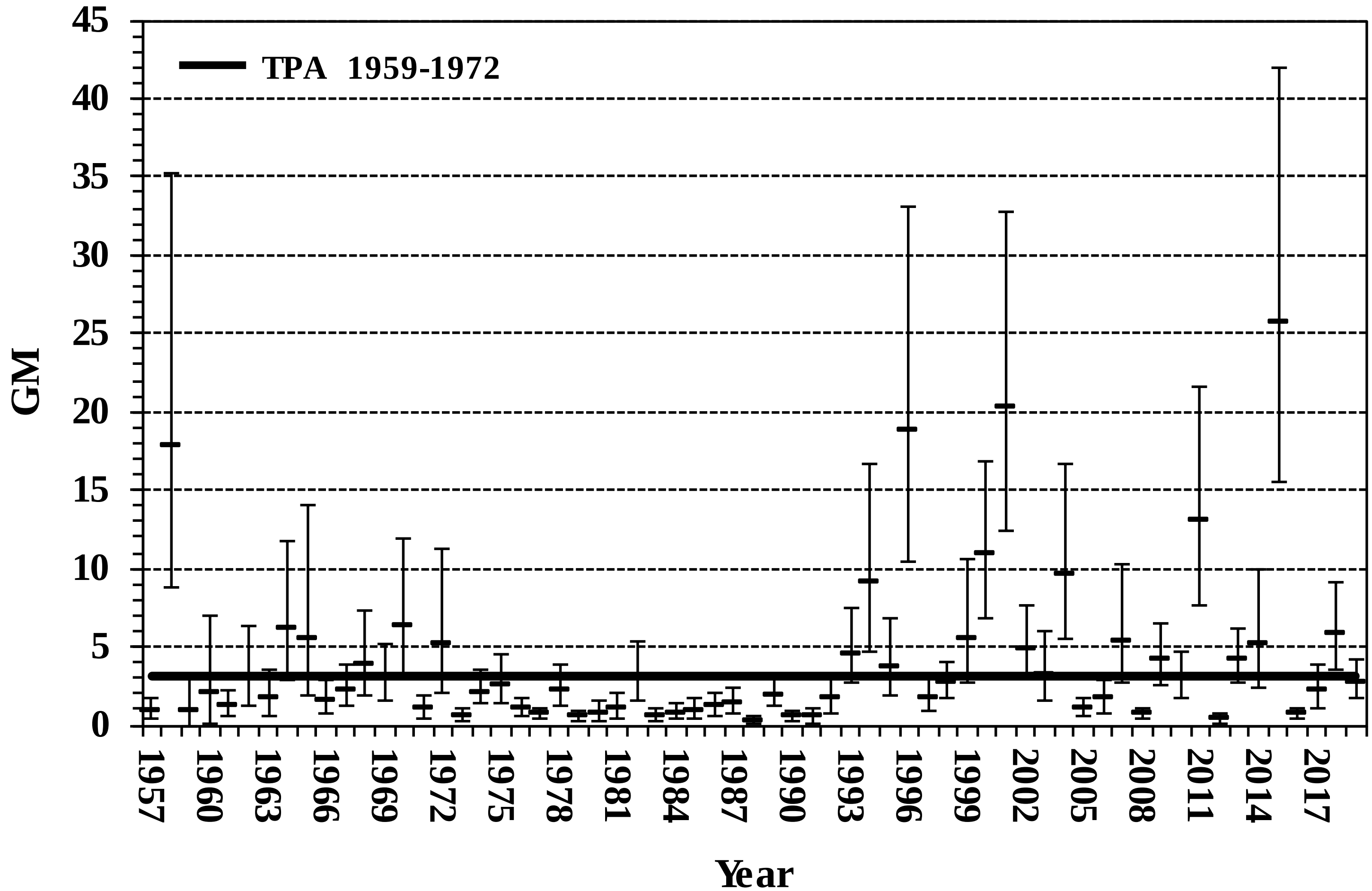


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).



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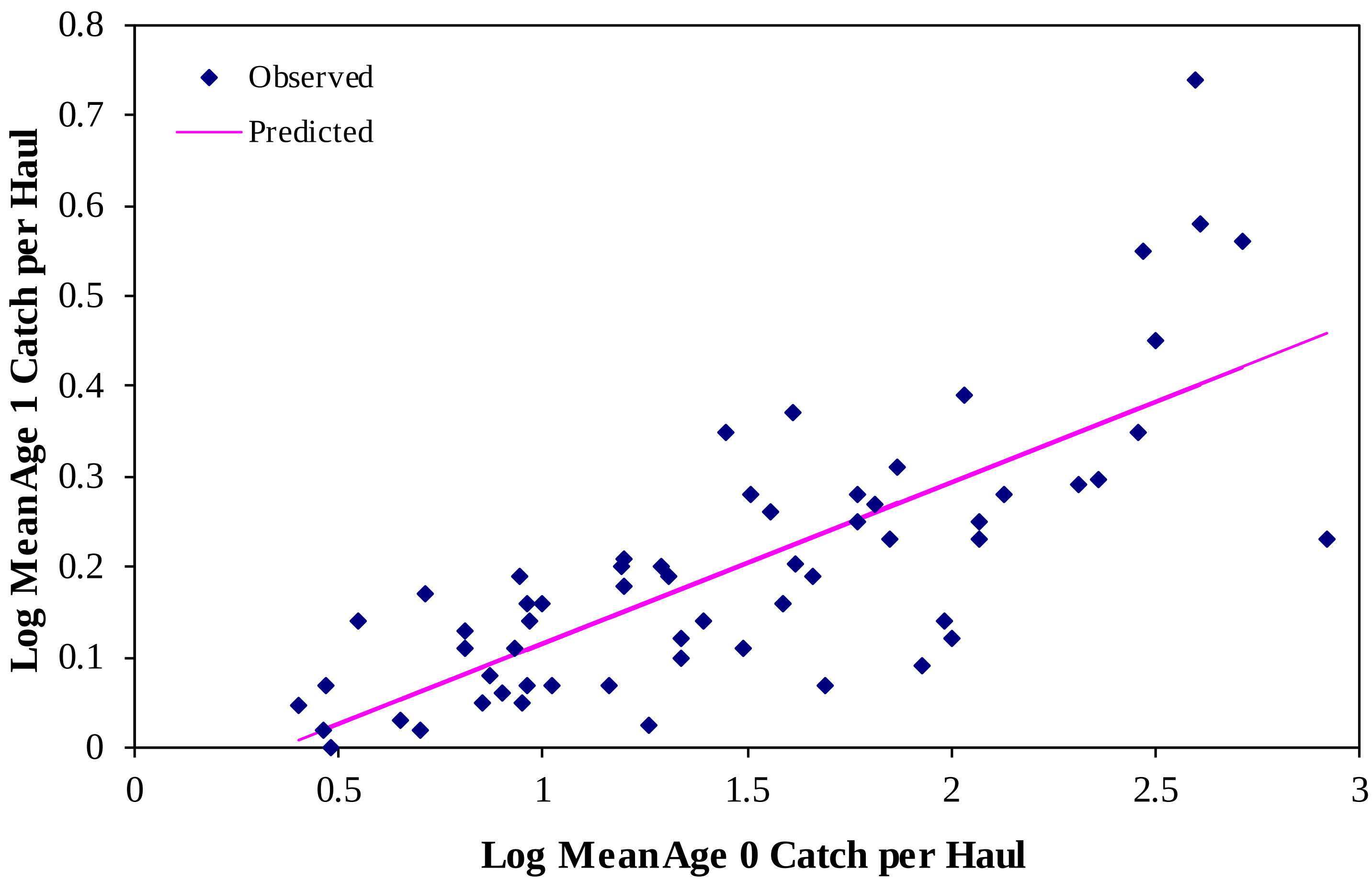
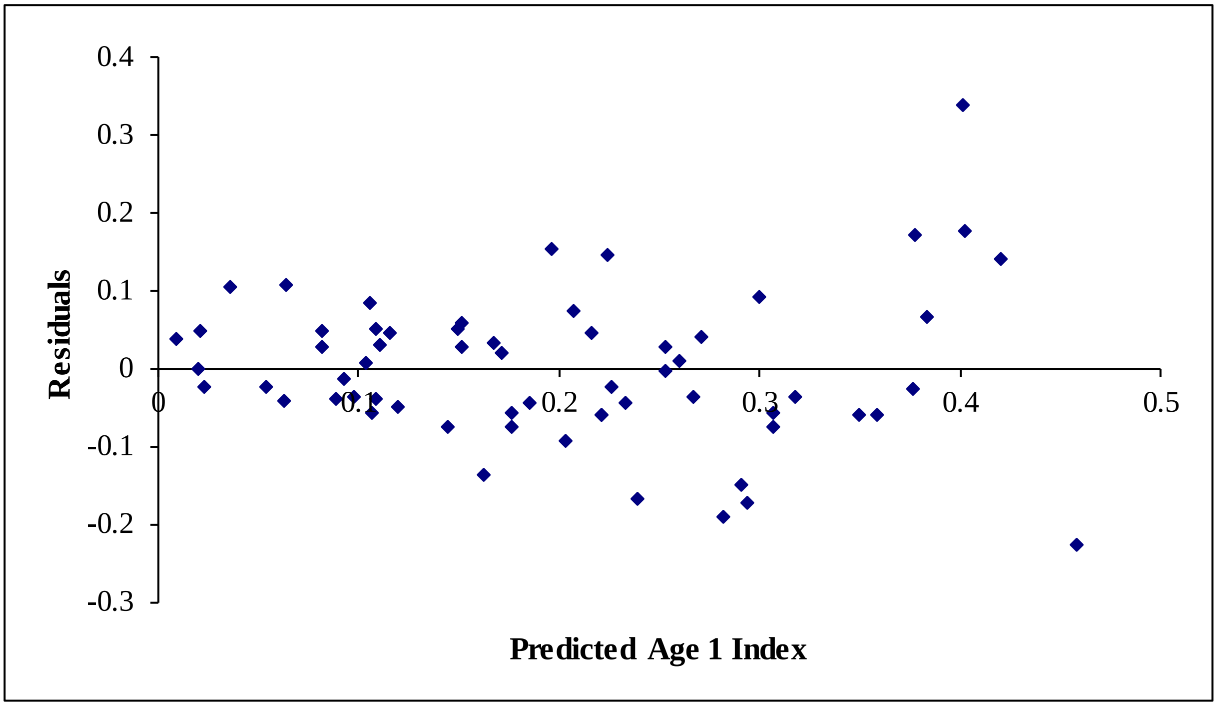
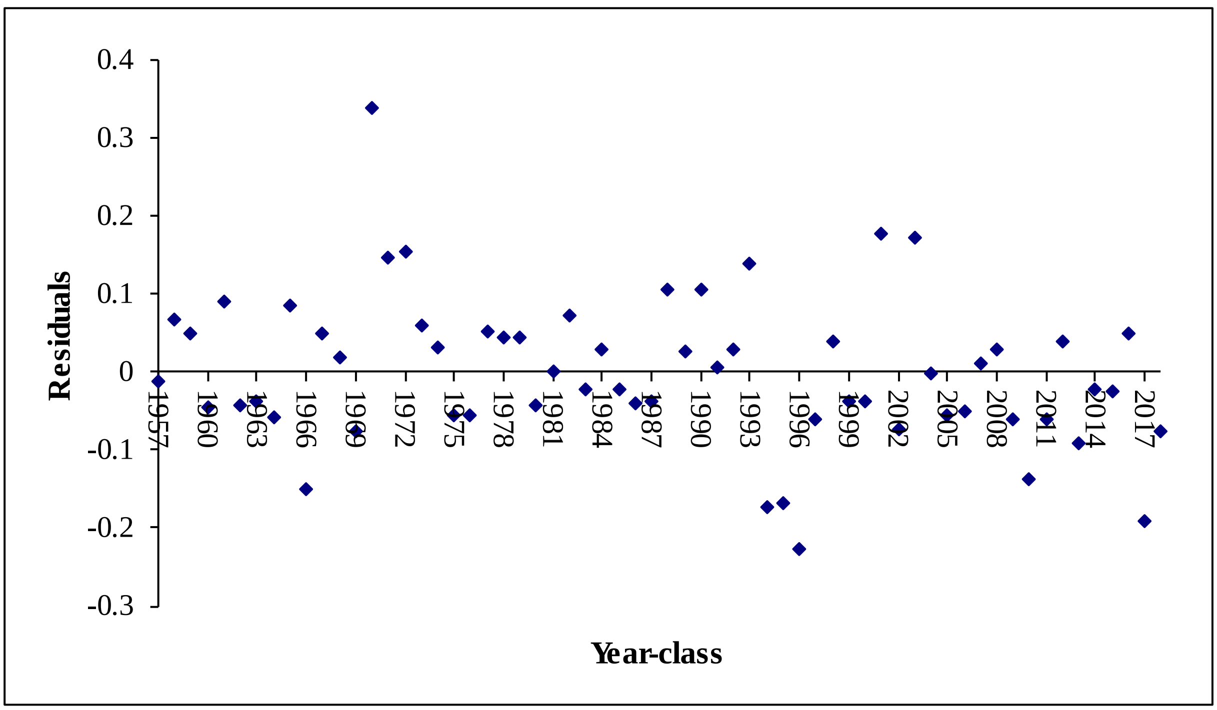


Figure 11. Residuals of age 1 and age 0 striped bass regression.





PROJECT NO. 2
JOB NO. 3
TASK NO. 4

STRIPED BASS TAGGING

Prepared by Beth A. Versak

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 4 were to finalize the characterization of striped bass tagging activities in Maryland's portion of the Chesapeake Bay in 2019 and to provide preliminary results for the 2020 tagging programs. Completed results for the 2020 tagging activities will be reported in the F-61-R-16 Chesapeake Bay Finfish Investigations report. The Maryland Department of Natural Resources (MD DNR) has been a key partner in the offshore cooperative winter tagging cruise and continues to maintain the long-term data set for the cruise. For these reasons, the offshore tagging activities were also summarized and included in this report.

MD DNR and partnering agencies tagged striped bass as part of the United States Fish and Wildlife Service's (USFWS) Cooperative Coastwide Striped Bass Tagging Program. Fish were tagged from the Chesapeake Bay resident/pre-migratory and spawning stocks, and from the Atlantic coastal stock. Subsequently, tag numbers and associated fish attribute data were forwarded to the USFWS, with the captor providing recovery information directly to the USFWS. These data are used to evaluate stock dynamics (mortality rates, survival rates, growth rates, etc.) of Chesapeake Bay resident and Atlantic coast striped bass stocks.

METHODS

Sampling procedures

From the beginning of April through mid-May 2019, a fishery-independent spawning stock study was conducted in which tags were applied to fish captured with experimental multi-panel drift gill nets in the upper Chesapeake Bay and the Potomac River (see Project 2, Job 3, Task 2) (Figure 1). Fish sampled during this study were measured for total length to the nearest millimeter (mm TL) and examined for sex, reproductive stage and external anomalies. Internal anchor tags were applied to healthy fish, regardless of size, and scale samples were collected from a sub-sample for age determination. Scales were taken from two to three male fish per week per 10-mm length group up to 700 mm TL, for a total of 10 scale samples per length group over the course of the survey. Scale samples were taken from all males over 700 mm TL, all female fish and all recaptures of previously tagged fish.

In 2019, the offshore tagging cruise was conducted using hook and line, onboard a contracted sportfishing vessel departing from Virginia Beach, VA. The goal was to tag as many coastal migratory striped bass as possible while they were wintering in the Atlantic Ocean off the mouth of Chesapeake Bay. Participants in the sampling effort included USFWS, North Carolina Division of Marine Fisheries (NC DMF), Atlantic States Marine Fisheries Commission (ASMFC), MD DNR, U. S. Coast Guard, North Carolina Wildlife Resources Commission, North Carolina Department of Environmental Quality, North Carolina State University, Virginia Marine Resources Commission, Virginia Institute of Marine Science, Mid-Atlantic Fisheries Management Council and Delaware State University.

Sampling was conducted during 13 fishing trips, between January 16 and February 14, 2019.

Six lines with custom-made tandem parachute rigs were trolled at 2 to 3 knots, in depths of 30 to 101 feet (9 to 31 m).

Captured fish were placed in holding tanks equipped with an ambient water flow-through system for observation prior to tagging. Vigorous, healthy fish were measured for total length to the nearest millimeter (mm TL) and tagged. Scales were taken from the first five striped bass per 10-mm TL group from 400-800 mm TL, and from all striped bass less than 400 mm TL and greater than 800 mm TL.

Tagging procedures

For all surveys, internal anchor tags, supplied by the USFWS, were inserted through an incision made in the left side of the fish, slightly behind and below the tip of the pectoral fin. This small, shallow incision was made with a #12 curved scalpel after removing a few scales from the tag area. The incision was angled anteriorly through the musculature, encouraging the incision to fold together and the tag streamer to lie back along the fish's side. The tag anchor was then pushed through the remaining muscle tissue and peritoneum into the body cavity and checked for retention.

Analytical Procedures

Survival, fishing mortality and natural mortality rates from fish tagged during the spring in Maryland were estimated based on historic release and recovery data. The instantaneous rates – catch and release (IRCR) model is the primary model utilized and employs an age-independent form of the IRCR model developed by Jiang et al. (2007) to estimate survival, fishing mortality and natural mortality. The candidate models run in the IRCR model are formulated based on historical regulatory changes in striped bass management. Additional details on the methodologies can be found in the latest peer reviewed stock assessment report (Northeast Fisheries Science Center 2019), however it does not contain 2019 data.

Estimates for Maryland's spawning stock are broken into two size groups: $\geq$457 mm TL (18 inches) and $\geq$711 mm TL (28 inches). The recovery year began on the first day of spring tagging in the time series (March 28) and continued until March 27 of the following year. Survival and mortality estimates for fish tagged in spring 2019 will not be completed until after March 27, 2020.

Tag release and return data from spring male fish, ≥457 mm TL and <711 mm TL (18 – 28 inches TL), are used to develop annual estimates of fishing mortality for the Chesapeake Bay pre-migratory stock. Male fish less than 28 inches are generally accepted to compose the majority of the Chesapeake Bay resident stock, while larger fish are predominantly coastal migrants. Release and recapture data from Maryland and Virginia (provided by Virginia Institute of Marine Science) were combined to produce a Baywide fishing mortality estimate. Similar to the coastwide methods, the IRCR model was utilized to calculate the Chesapeake Bay estimates. Further details on the methodologies and results can be found in the latest stock assessment report (Northeast Fisheries Science Center 2019).

Estimates of survival, fishing mortality and recovery rates for the cooperative offshore tagging data are calculated using the same methods as Maryland's spring tagging data and will be conducted by the USFWS.

For each study, t-tests were used to test for significant differences between the mean lengths of striped bass that were tagged and all striped bass measured for total length (SAS 1990). This was done to determine if the tagged fish were representative of the entire sample. Lengths were considered different at $P \leq 0.05$. Additionally a Kolmogorov-Smirnov test (KS-test) was used to test for differences between length distributions. Distributions were considered different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Spring tagging

The spring sampling component monitored the size and sex characteristics of striped bass spawning in the Potomac River and the upper Chesapeake Bay. Sampling occurred between April 2 and May 20, 2019. A total of 2,146 striped bass were sampled and 1,104 (51%) were tagged as part of this long-term survey (Table 1).

On many occasions, large samples were caught in a short period of time which required fish to spend a considerable amount of time submerged in the gill net or in the boat, thereby increasing the potential for mortality. In these cases, biologists measured all fish but were only able to tag a sub-sample. Typically, these large concentrations of fish were of a smaller size and captured in small mesh panels. Larger fish were encountered less frequently, and therefore a higher proportion was tagged. This resulted in a significantly greater mean length of tagged fish than the mean length of all fish sampled. Mean total length of striped bass tagged during spring 2019 (527 mm TL) was significantly greater (t-value = -5.87, $P<0.0001$) than that of the sampled population (490 mm TL) (Figure 2). This was also evident in the significant difference of the two length frequencies ($D=0.111$, $P<0.0001$).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2019 data) will be used to estimate an instantaneous fishing mortality rate on resident fish for the 2019-2020 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Estimates of survival and fishing mortality for the 2019 Chesapeake Bay spawning stock, as well as the resident stock, will be presented in a future report of the ASMFC Striped Bass Tagging Subcommittee.

Cooperative offshore tagging activities

The primary objective of the offshore tagging trips was to apply tags to as many striped bass as possible. Striped bass were difficult to locate in 2019. The majority of fish sampled in recent years were encountered in federal waters off the mouth of Chesapeake Bay.

In 2019, 91 striped bass were encountered and 89 (98%) were tagged (Table 2). The mean lengths of all fish sampled (1033 mm TL) and of those tagged (1034 mm TL) were not statistically different (t-value = -0.07, P=0.943, Figure 3). The mean total length of striped bass tagged in 2019 (1034 mm TL) was not significantly different than the length of fish tagged from the 2018 hook and line trips (1046 mm TL, t-value = 1.05, P=0.295). Length distributions between the two years were also similar (D=0.104, P=0.366). Estimates of survival and mortality based on fish tagged in the 2019 offshore study will be presented in a future report of the ASMFC Striped Bass Tagging Subcommittee.

PROJECT NO. 2
JOB NO. 3
TASK NO. 4

STRIPED BASS TAGGING

2020 PRELIMINARY RESULTS

Spring tagging

Due to COVID-19, the 2020 survey was delayed slightly, and sampling occurred between April 14 and May 22, 2020. A total of 1,990 striped bass were sampled and 864 (43%) were tagged as part of this long-term survey. Mean total length of striped bass tagged during spring 2020 (549 mm TL) was significantly greater (t-value = -5.61, $P<0.0001$) than that of the sampled population (506 mm TL). Estimates of survival and fishing mortality for the 2020 Chesapeake Bay spawning stock, as well as the resident stock, will be presented in a future report of the ASMFC Striped Bass Tagging Subcommittee.

Cooperative offshore tagging activities

In 2020, hook and line sampling was conducted onboard a contracted sportfishing vessel departing from Virginia Beach, VA. Sampling was conducted during 13 fishing trips, between January 23 and February 18, 2020.

While fishing with hook and line, 202 striped bass were encountered and 199 (99%) were tagged. The mean lengths of all fish sampled and of those tagged were the same at 1048 mm TL. Estimates of survival and fishing mortality based on fish tagged in the 2020 North Carolina study will be presented in a future report of the ASMFC Striped Bass Tagging Subcommittee.

The final, complete analyses of the 2020 striped bass tagging activities will appear in the F-61-R-16 Chesapeake Bay Finfish Investigations report.

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Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, April - May 2019.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	4/2/19 - 5/10/19	459	306	612001 – 612306
Upper Chesapeake Bay	4/4/19 - 5/20/19	1,687 [b]	798	602990 – 603500 606870 – 607000 611501 – 611660
Spring spawning survey totals:		2,146	1,104	

[a] Not all tags in reported sequences were applied; some were lost, destroyed, or applied out of order.
[b] Total sampled includes two USFWS recaptures and one American Littoral Society recapture.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2019 cooperative offshore tagging trips.

System	Gear	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences
Nearshore Atlantic Ocean (Near MD, VA, NC coasts)	Hook & Line	1/16/19 – 2/14/19	91	89	607668 – 607674 607701 – 607782

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2019.

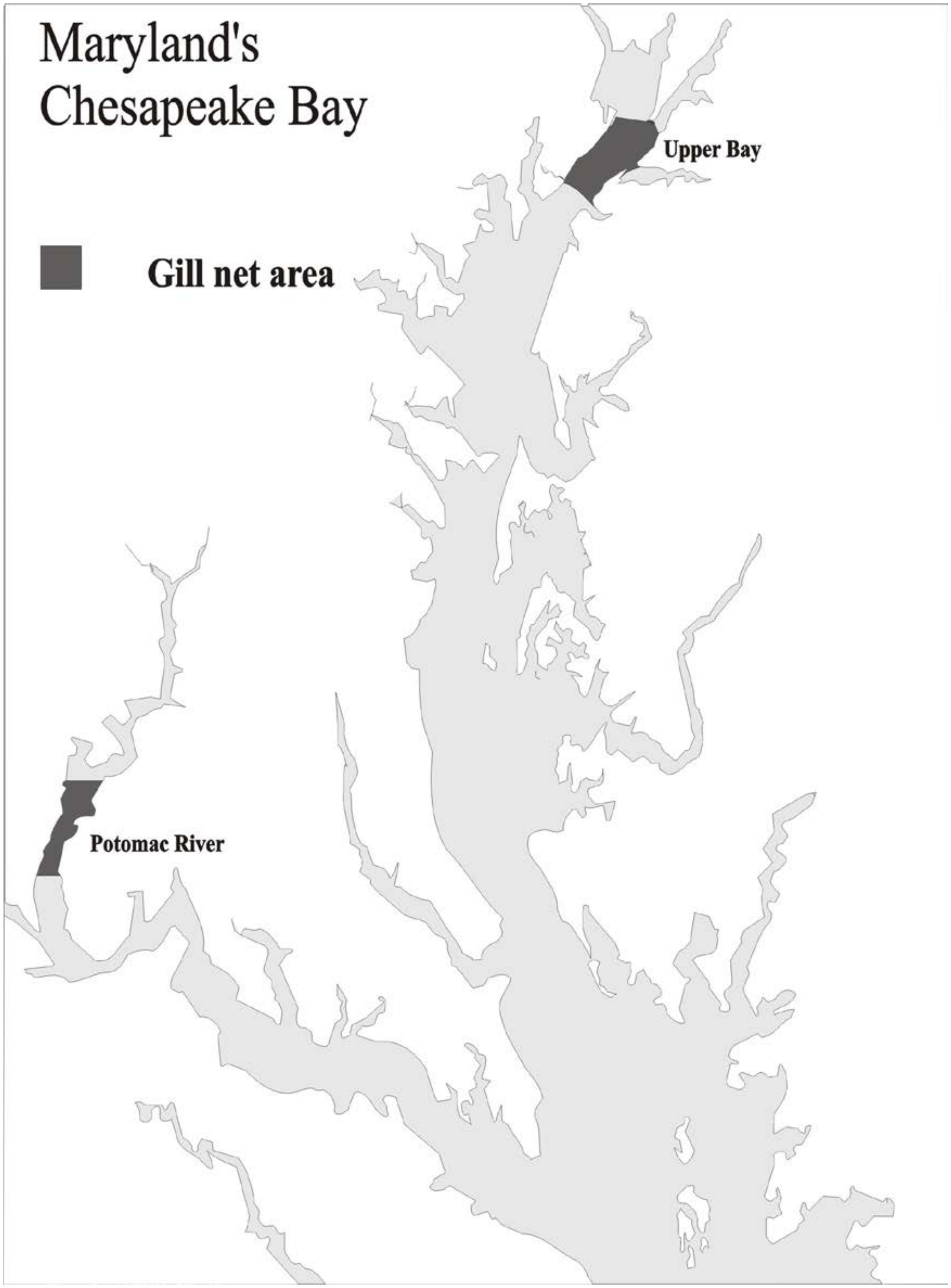


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay, April - May 2019.

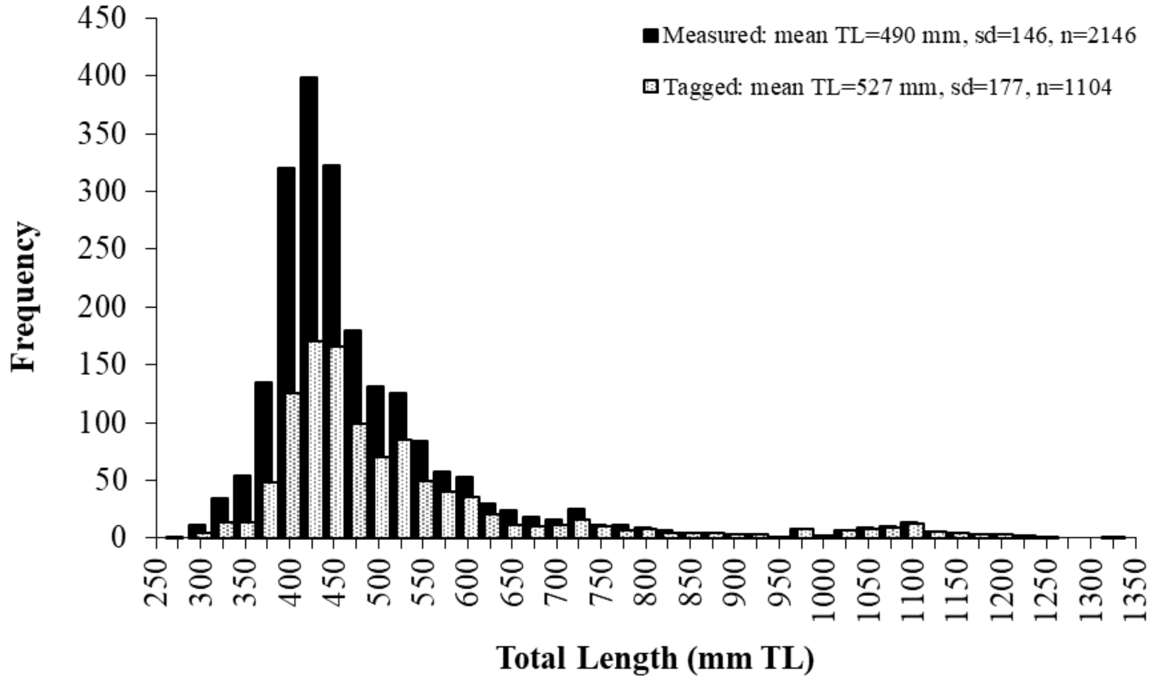
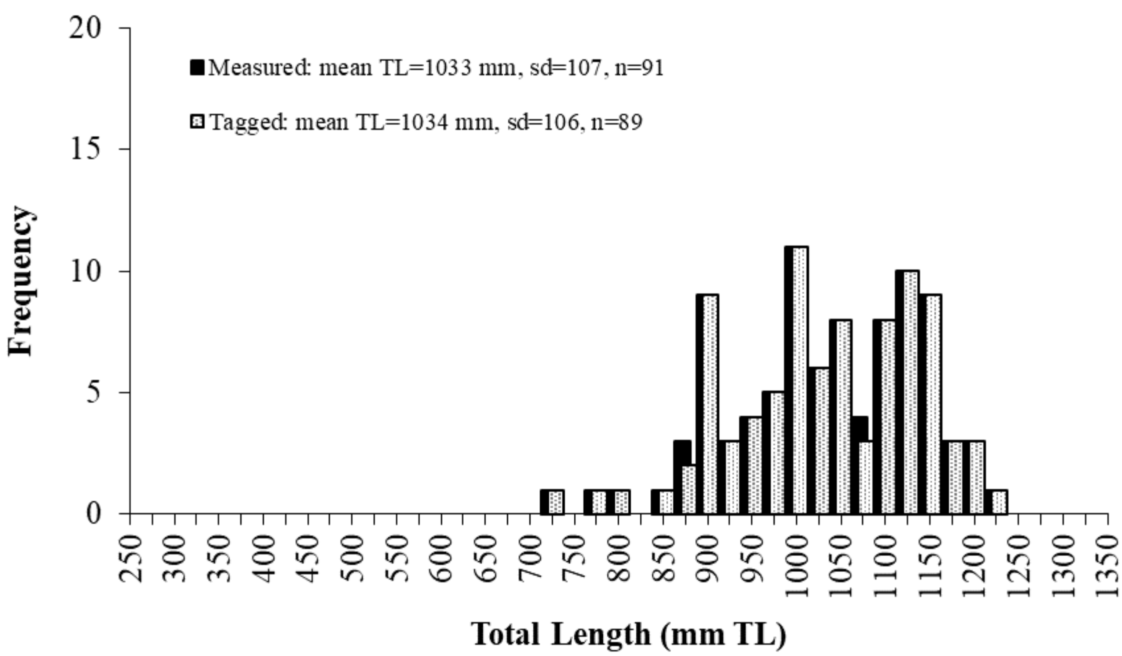


Figure 3. Length frequencies of striped bass measured and tagged during the cooperative offshore tagging trips, January – February 2019.



PROJECT NO. 2
JOB NO. 3
TASK NO. 5A

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Eric Q. Durell

INTRODUCTION

The objectives of Project 2, Job 3, Task 5A were to: present a final accounting of the commercial striped bass harvest in 2018; describe the harvest monitoring conducted by the Maryland Department of Natural Resources (MD DNR); and present preliminary information regarding Maryland's 2019 commercial fishery monitoring. A final accounting of the 2019 commercial fishery and monitoring activities will be presented in the F-61-R-16 Chesapeake Bay Finfish Investigations report.

Maryland completed its twenty-eighth year of commercial fishing under the quota system since the striped bass fishing moratorium was lifted in 1990. The official 2018 commercial quota for Maryland's Chesapeake Bay and tributaries was 1,471,888 pounds, identical to 2017. Historically, the commercial fishery received 42.5% of the state's total annual Chesapeake Bay striped bass quota, but the current quota was formulated under Addendum IV to Amendment 6 of the Atlantic Striped Bass Interstate Fisheries Management Plan, which prescribed a 20.5% reduction in quota (Atlantic States Marine Fisheries Commission, 2014). The Chesapeake Bay commercial fishery was subject to an 18 – 36 inch total length (TL) slot limit. There was a separate quota of 90,727 pounds for the Atlantic fishery, also mandated by Addendum IV through a conservation equivalency plan. The Atlantic fishery was subject to a 24 inch (TL) minimum size and limited to the state's jurisdictional coastal waters. Detailed fishery regulations are presented in Table 1. The commercial quota system is based on a calendar year.

Beginning in 2014, Maryland's Chesapeake Bay commercial striped bass fisheries were changed to an individual transferable quota (ITQ) management system. Fishermen were given the option of remaining in the previous derby-style fishery, now called the Common Pool. The

2018 commercial fishery operated on a combination of a Common Pool and the ITQ system, with 97% of the quota in the ITQ system. ITQ participants were assigned a share of the commercial quota based partly on their harvest history, and could fish any open season and legal gear. A portion of the commercial quota was reserved for commercial fishermen who opted to remain in the old, derby-style management system. The total Common Pool quota was 48,176 pounds and was determined by combining individual allocations from participants. Individuals in the Common Pool system were only allowed to fish on certain days during the season, and had a maximum allowable catch per day and week. Common Pool gear was limited to hook-and-line (summer/fall) and gill net (winter). All pound net and haul seine harvest was under the ITQ system.

Each fishery was managed with specific seasons that could be modified by MD DNR as necessary. The 2018 ITQ commercial summer/fall fishery opened on June 1 and closed on December 31. Hook-and-line gear was permitted Monday – Thursday; haul seines were permitted Monday – Friday; and pound nets were permitted Monday – Saturday. The Chesapeake Bay 2018 ITQ drift gill net season was split, with the first segment from January 1 through February 28, 2018 and the second segment from December 3 through December 31, 2018, Monday – Friday. The Common Pool fishery was open by public notice as follows: 3 days in January; 4 days in February; 2 days each June – Nov; 3 days in December. The Atlantic coast fishery permitted two gear types, drift gill net and trawl, and the season occurred in two segments: January 1 through May 31, 2018 and October 1 through December 31, 2018, Monday – Friday.

Commercial harvest data for striped bass can be used as a general measure of stock size (Schaefer 1972, Goodyear 1985). Catch per unit effort (CPUE) data have traditionally been used more widely outside of the Chesapeake Bay as an indicator of stock abundance (Ricker 1975, Cowx 1991). Catch and effort data provide useful information regarding the various components of a fishery and group patterns of use for the fisheries resource. Catch data collected from check station reports and effort data from monthly fishing reports (MFR) from striped bass fishermen were analyzed with the primary objective of presenting a post-moratoria summary of baseline data on commercial catch and CPUE.

METHODS

All commercially harvested striped bass were required to be tagged by fishermen prior to landing with colored, serial numbered, tamper-evident tags inserted in the mouth of the fish and out through the operculum. These tags could verify the harvester and fishery type, and easily identify legally harvested fish to the public and law enforcement. Each harvest day and prior to sale, all tagged striped bass were required to pass through a MD DNR approved commercial fishery check station. Fish dealers distributed throughout the state volunteered to act as check stations (Figure 1). Check station employees, acting as representatives of MD DNR, were responsible for counting, weighing and verifying that all fish were tagged. Check stations also recorded harvest data on the individual fisherman's striped bass permit. Harvest data were reported to MD DNR by gear or fishery type through multiple of the following systems: 1) Weekly written log reports from designated check stations; 2) daily reporting from the Atlantic Coastal Cooperative Statistics Program's (ACCSP) Standard Atlantic Fisheries Information System (SAFIS); 3) the Fishing Activity and Catch Tracking System (FACTS); 4) daily phone reports from check stations (only required during common pool fishery); 5) monthly fishing reports (MFRs) from those fishermen opting not to use daily electronic reporting methods. These reports allowed MD DNR to monitor progress towards quotas (Figures 2 and 3). Fishermen were then required to return their striped bass permits and unused tags to MD DNR at the end of the season.

The following information was compiled from each commercial fisherman's harvest reports: Day of Month, NOAA Fishing Area, Gear Code, Quantity of Gear, Duration Fished, Number of Sets, Trip Length (hours), Number of Crew, and Pounds (by species). CPUE estimates for each gear type were derived by dividing total pounds landed by each gear by the number of reported trips from the MFRs.

The striped bass harvest weights presented in this report were supplied by the Data Management and Quota Monitoring Program of MD DNR Fishing and Boating Services. Prior to 2001, the pounds landed were determined using the MFRs. Due to delays in submission of the MFRs and the time necessary to enter the data, there would often appear to be discrepancies between the MFRs, check station activity reports, and daily check station reports. Since 2001, in order to avoid these issues and obtain more timely data, the pounds landed have come from the weekly check station activity reports, online SAFIS and FACTS reports, and daily check station telephone reports regarding the Common Pool fishery. However, all four data sources are generally corroborative and the change in data source reported here was considered to have no appreciable effect on the results and conclusions.

The average weight of fish harvested was calculated using two methods. The first was by dividing the total weight of landings by the number of fish reported in the weekly check station activity reports. The second method involved direct sampling of striped bass at check stations by MD DNR biologists to characterize the harvest of commercial fisheries by measuring and weighing a sub-sample of fish (Project 2, Job 3, Tasks 1A, 1B, and 1C, in this report). The change to the ITQ system prevented biologists from discerning what gear types were used to harvest striped bass sampled at check stations. Therefore, striped bass measured and weighed by biologists at check stations were combined into seasons (Summer/Fall, Winter, Atlantic). However, based on permitted gear types and harvest trends during those seasons, biologists could eliminate certain gear types within seasons and locations.

The number of fishing trips in which striped bass were landed was determined from the MFRs (Table 2). The reported harvest was divided by the number of trips to calculate an estimate of CPUE, expressed as pounds harvested per trip.

RESULTS AND DISCUSSION

On the Chesapeake Bay and its tributaries, 1,424,303 pounds of striped bass were harvested in 2018 (Table 2). This harvest was 47,585 pounds, or 3%, under the 1,471,888 pound quota. The reported number of fish landed was 293,643 (Table 2). The pound net fishery landed 47% of the total landings by weight, followed by the drift gill net fishery at 44% and the hook-and-line fishery with 9% of the total Bay landings. No striped bass were harvested with haul seines.

Maryland's Atlantic coast landings were reported at 3,493 striped bass, weighing 79,836 pounds (Table 2). The gill net fishery made up nearly 100% of the Atlantic harvest, by weight, with only 350 pounds harvested by the trawl fishery.

Comparisons of Average Weight

The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 4.85 pounds when calculated from the check station activity reports and 5.99 pounds when measured by biologists (Table 3). Mean weights by specific gear type or season ranged from 3.94 to 6.62 pounds from check station activity reports, and 4.14 to 7.22 pounds when measured by biologists. By both methods of estimation, the largest striped bass landed in the Chesapeake Bay were taken by the winter drift gill net fishery. The smallest fish harvested in the Bay were taken by pound nets, according to check station activity reports.

Striped bass were also sampled at Atlantic coast check stations to characterize coastal harvest (Project 2, Job 3, Task 1C, this report). Striped bass sampled from the Atlantic coast fisheries (combined gears) by MD DNR biologists averaged 15.11 pounds (Table 3). The average weight calculated from the check station activity reports (22.86 pounds) was over 50% greater. Average weights calculated from check station reports indicate that fish harvested by gill net were heavier than those harvested by trawl. This could not be corroborated by biological sampling because harvest gear was not always discernible.

Commercial Harvest Trends

Commercial striped bass quotas and harvests have been relatively consistent in the Chesapeake Bay since the late-1990s (Figure 4). Gill nets have historically been responsible for most of the Bay striped bass harvest. In 2018, however, pound nets accounted for more harvest than gill nets for the first time since 2001. The hook-and-line fishery generally harvests the least of the three major Chesapeake Bay gears, and in 2018 was the lowest observed since 1996 (Table 4, Figure 5).

Similar to the Chesapeake Bay fisheries, the Atlantic harvest increased in the early 1990s after the moratorium was lifted, but has been highly variable since 2000 (Figure 4). The drift gill net fishery accounted for the majority of the Atlantic harvest in 2018, consistent with the previous two years (Table 4, Figure 5).

Commercial CPUE Trends

In Chesapeake Bay, pound nets were the most efficient striped bass harvest gear again in 2018, followed by drift gill nets and hook-and-line. Pound net CPUE (540) exceeded drift gill net CPUE (448) for the second consecutive year (Table 5). The hook-and-line fishery CPUE (188) decreased slightly relative to last year but has varied without trend for the last decade. All gear-specific CPUEs were above their respective time-series averages (Figure 6).

On the Atlantic coast, drift gill net was by far the most efficient harvest gear with a CPUE of 598 pounds per trip. The CPUE for trawlers (44) was the lowest of the time-series (Table 5, Figure 6). Since the Atlantic season was expanded to include May and October in 2016, large catches of striped bass have occurred by gill net in May (Figure 3). These large catches are responsible for record high Atlantic gill net CPUE for the second consecutive year (Table 5, Figure 6).

PROJECT NO. 2
JOB NO. 3
TASK NO. 5A

COMMERCIAL FISHERY HARVEST MONITORING

2019 PRELIMINARY REPORT - WORK IN PROGRESS

Maryland's 2019 commercial striped bass quota for Chesapeake Bay remained unchanged at 1,471,888 pounds. A portion of that total (40,566 pounds) was designated for Common Pool participants and the rest was available to the ITQ fishery.

The 2019 ITQ commercial summer/fall fishery opened on June 1 and closed on December 31. Hook-and-line gear was permitted Monday – Thursday; haul seines were permitted Monday – Friday; and pound nets were permitted Monday – Saturday. The Chesapeake Bay 2019 ITQ drift gill net season was split, with the first segment from January 1 through February 28, and the second segment from December 3 through December 31. The Common Pool fishery was open by public notice for 5 days in January, 2 days in Feb, and 2 days each June – September. Chesapeake Bay fisheries were subject to an 18-36 inch (TL) slot limit.

Maryland's 2019 Atlantic coast quota was unchanged at 90,727 pounds. The Atlantic fishery permitted two gear types, drift gill net and trawl, and the season occurred in two segments: January 1 through May 31, and October 1 through December 31. The Atlantic fishery was subject to a 24 inch (TL) minimum size limit.

Mandatory harvest reporting methods remained unchanged. MD DNR biologists continued fisheries-dependent surveys of the harvest. Landings were not finalized at the time of this writing but will be reported in the F-61-R-16 Chesapeake Bay Finfish Investigations report.

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Table 1. Striped bass commercial regulations by gear type for the 2018 calendar year.

Area	Gear Type	Annual Quota	Number of Participants	Trip Limit	Minimum Size	Reporting Requirement
Bay and Tributaries	Pound Net	No gear-specific quotas for ITQ	199	No trip limits for ITQ	18-36 in TL slot	Monthly Harvest Report
	Haul Seine	No gear-specific quotas for ITQ	0	No trip limits for ITQ	18-36 in TL slot	Monthly Harvest Report
	Hook-and-Line	Included in Common Pool 48,176; No ITQ Quota	149	Common Pool – 250 lbs/license/week, 500 lbs/vessel/day; No trip limits for ITQ	18-36 in TL slot	Monthly Harvest Report
	Gill Net	Included in Common Pool 48,176; No ITQ Quota	278	Common Pool – 300 lbs/license/week, 1,200lbs/vessel/day; No trip limits for ITQ	18-36 in TL slot	Monthly Harvest Report
Total Bay Quota		**1,471,888**				
Atlantic Coast	Trawl and Gill Net	90,727	33	No trip limits for ITQ	24 in TL min	Monthly Harvest Report
Total Maryland Quota		**1,562,615**				

Table 2. Summary of striped bass commercial harvest statistics by gear type for the 2018 calendar year.

Area	Gear Type	Pounds[1]	Number of Fish[1]	Trips[2]
Chesapeake Bay[3]	Haul Seine	0	0	0
	Pound Net	675,991	171,382	1,251
	Hook-and-Line	122,894	27,749	653
	Gill Net	625,418	94,512	1,395
	Chesapeake Total	**1,424,303**	**293,643**	**3,299**
Atlantic Coast	Trawl	350	40	8
	Gill Net	79,486	3,453	133
	Atlantic Total	**79,836**	**3,493**	**141**
Maryland Totals		**1,504,139**	**297,136**	**3,440**

1. Data from check station activity reports.

2. Trips were defined as days fished when striped bass catch was reported on MFRs.

3. Includes all Maryland Chesapeake Bay and tributaries, except main stem Potomac River.

Table 3. Striped bass average weight (lbs) by gear type for the 2018 calendar year. Average weights calculated by MD DNR biologists include 95% confidence intervals.

Area	Gear Type	Average Weight from Check Station Logs (pounds)[1]	Average Weight from Biological Sampling (pounds)[2]	Sample Size from Biological Sampling[2]
Chesapeake Bay[3]	Haul Seine	N/A	N/A	N/A
	Pound Net	3.94	4.14 (4.05-4.23)	2,085
	Hook-and-Line	4.43		
	Gill Net	6.62	7.22 (7.13-7.30)	3,163
	Chesapeake Total Harvest	**4.85**	**5.99 (5.92-6.07)**	**5,248**
Atlantic Coast	Trawl	8.75	15.11 (13.99-16.23)	248
	Gill Net	23.02		
	Atlantic Total Harvest	**22.86**	**15.11 (13.99-16.23)**	**248**

1. Data from check station activity reports, pounds divided by the number of fish reported.

2. Data from check station sampling by MD DNR biologists, all months combined.

3. Includes all Maryland Chesapeake Bay and tributaries, except main stem Potomac River.

Table 4. Pounds of striped bass harvested by commercial gear type, 1990 to 2018.

Year	Hook-and-Line	Pound Net	Drift Gill Net	Atlantic Gill Net	Atlantic Trawl
1990	700	1,533	130,947	83	4,843
1991	2,307	37,062	331,911	1,426	14,202
1992	7,919	157,627	609,197	422	17,348
1993	8,188	181,215	647,063	127	3,938
1994	51,948	227,502	831,823	3,085	15,066
1995	29,135	290,284	869,585	10,464	71,587
1996	54,038	336,887	1,186,447	23,894	38,688
1997	367,287	467,217	1,216,686	28,764	55,792
1998	536,809	613,122	721,987	36,404	51,824
1999	790,262	667,842	1,087,123	24,590	51,955
2000	747,256	462,086	1,001,304	40,806	66,968
2001	398,695	647,990	586,892	20,660	71,156
2002	359,344	470,828	901,407	21,086	68,300
2003	372,551	602,748	744,790	24,256	73,893
2004	355,629	507,140	921,317	27,697	87,756
2005	283,803	513,519	1,211,365	12,897	33,974
2006	514,019	672,614	929,540	45,710	45,383
2007	643,598	528,683	1,068,304	38,619	74,172
2008	432,139	559,087	1,216,581	37,117	80,888
2009	650,207	566,898	1,050,188	32,937	94,390
2010	519,117	650,628	934,742	28,467	16,335
2011	441,422	646,978	865,537	18,595	2,806
2012	424,408	565,079	861,135	25,935	51,609
2013	382,783	530,601	747,798	26,240	67,292
2014	218,987	664,508	922,203	22,515	98,408
2015	160,750	614,478	661,639	14,621	20,005
2016	154,238	611,075	660,148	19,197	478
2017	196,538	612,556	630,666	79,276	1,181
2018	122,894	675,991	625,418	79,486	350

Table 5. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2018.

Year	Hook-and-Line	Pound Net	Drift Gill Net	Atlantic Gill Net	Atlantic Trawl
1990	25	81	76	21	161
1991	77	96	84	65	254
1992	70	130	114	84	271
1993	52	207	125	25	188
1994	108	248	139	129	284
1995	71	220	156	75	994
1996	85	210	188	151	407
1997	145	252	228	215	465
1998	164	273	218	217	381
1999	151	273	293	167	416
2000	160	225	276	281	485
2001	154	231	202	356	416
2002	178	208	252	248	382
2003	205	266	292	240	582
2004	170	162	285	148	636
2005	168	200	324	143	336
2006	251	360	340	315	873
2007	201	322	359	327	1,325
2008	205	303	298	383	1,108
2009	206	351	324	326	1,348
2010	193	391	448	235	511
2011	224	390	397	155	187
2012	179	321	374	157	832
2013	205	359	411	190	1,602
2014	165	367	503	221	1,295
2015	176	359	537	287	1,819
2016	162	433	465	231	68
2017	200	477	425	562	118
2018	188	540	448	598	44
Average	156	285	296	226	613
5 year avg	178	435	476	380	669

Figure 1. Map of the 2018 Maryland authorized commercial striped bass check stations.

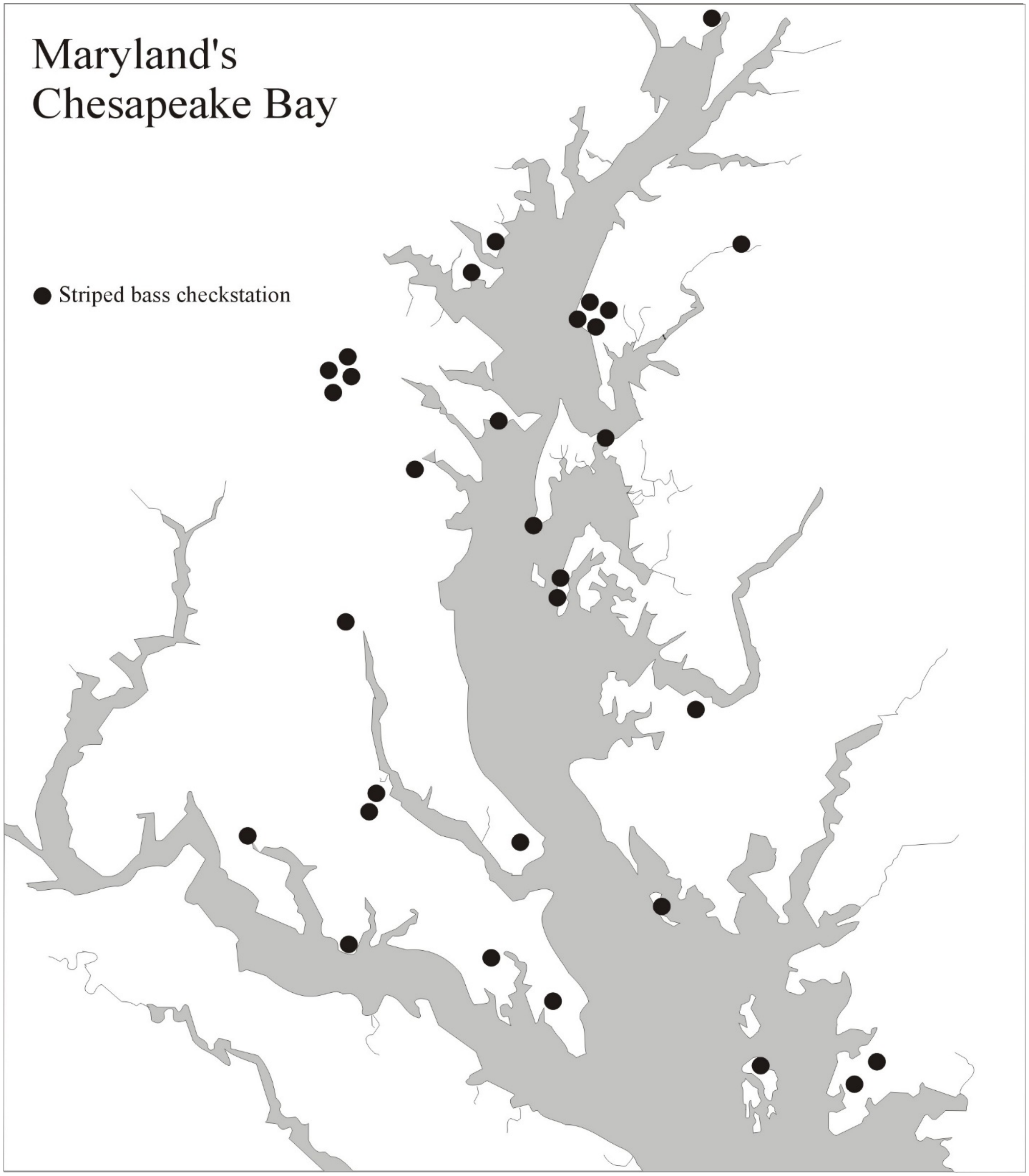
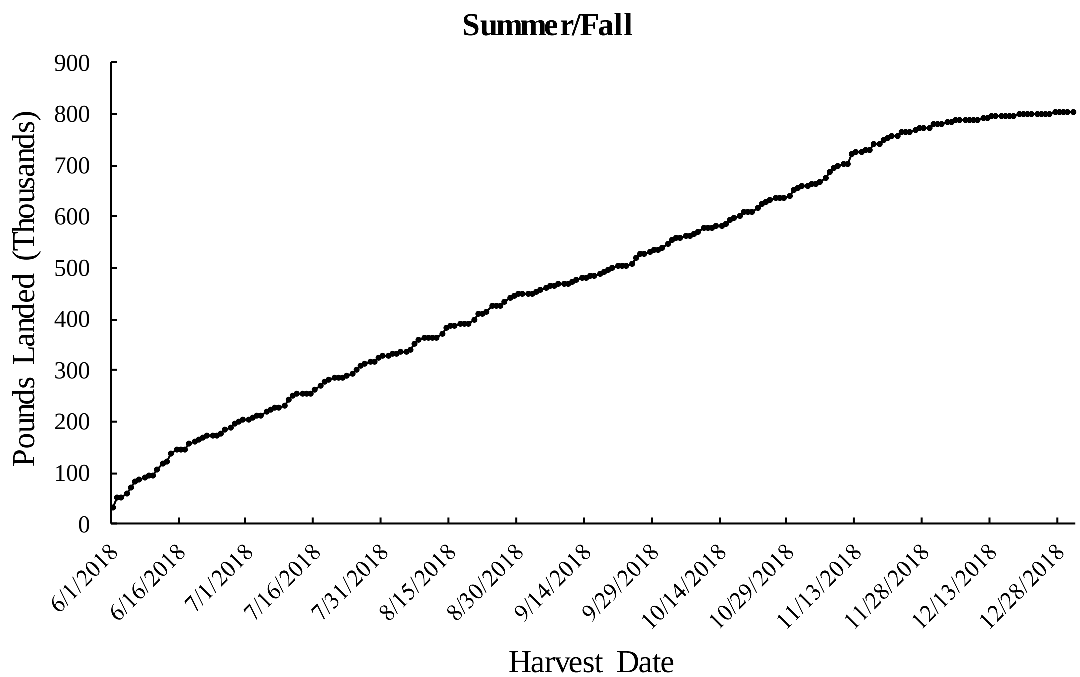


Figure 2. Maryland's Chesapeake Bay summer/fall (pound net and hook-and-line) and winter (gill net) fisheries cumulative striped bass landings from check station reports for calendar year 2018. Note different scales.



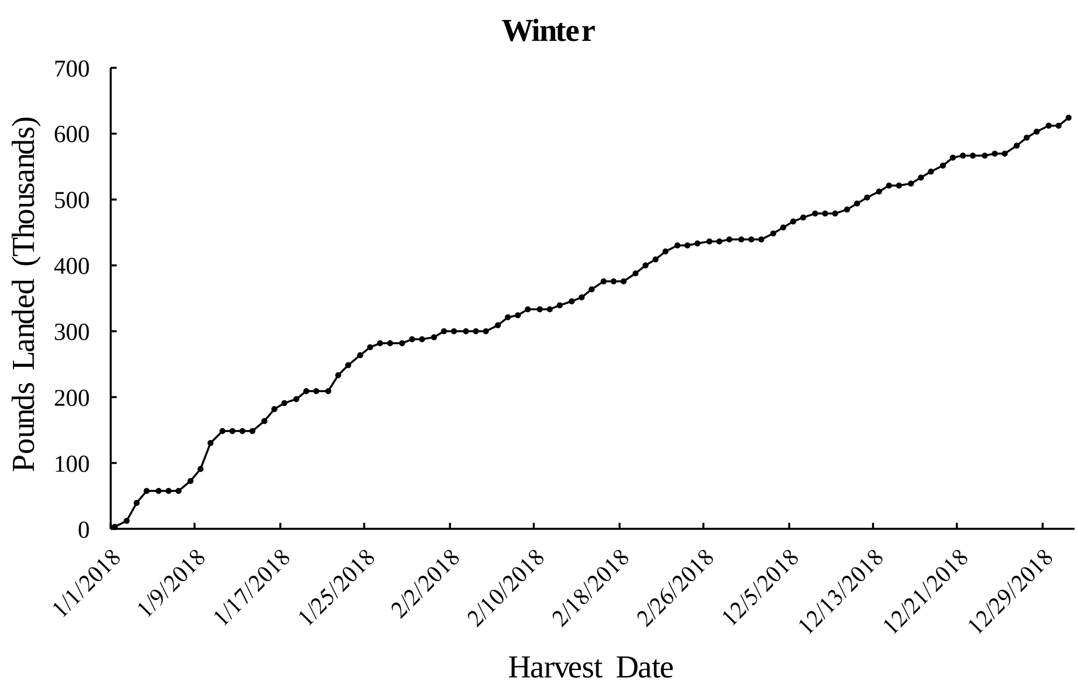


Figure 3. Maryland's Atlantic trawl and gill net fisheries (combined) cumulative striped bass landings from check station reports, January-May and October-December 2018.

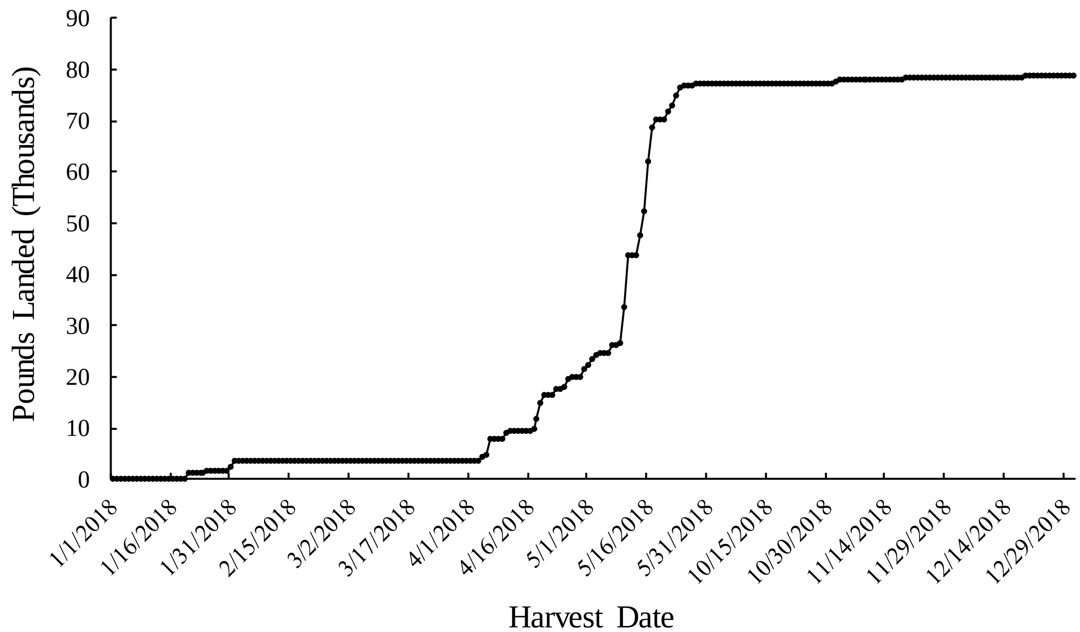
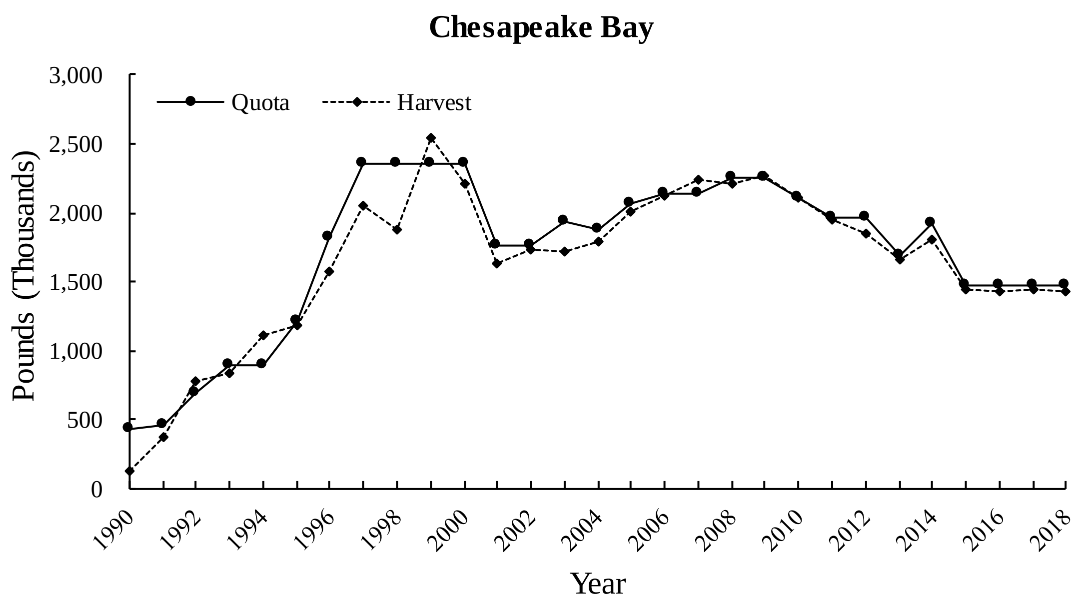


Figure 4. Maryland's Chesapeake Bay and Atlantic Ocean quotas (pounds) and harvests (pounds) for all gears, 1990-2018. Note different scales.



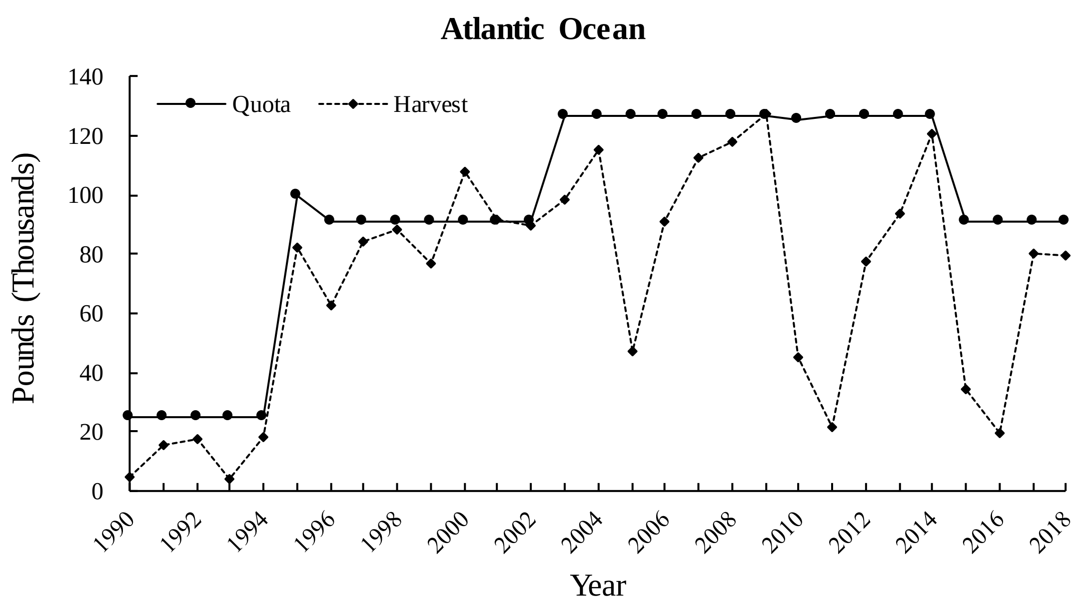
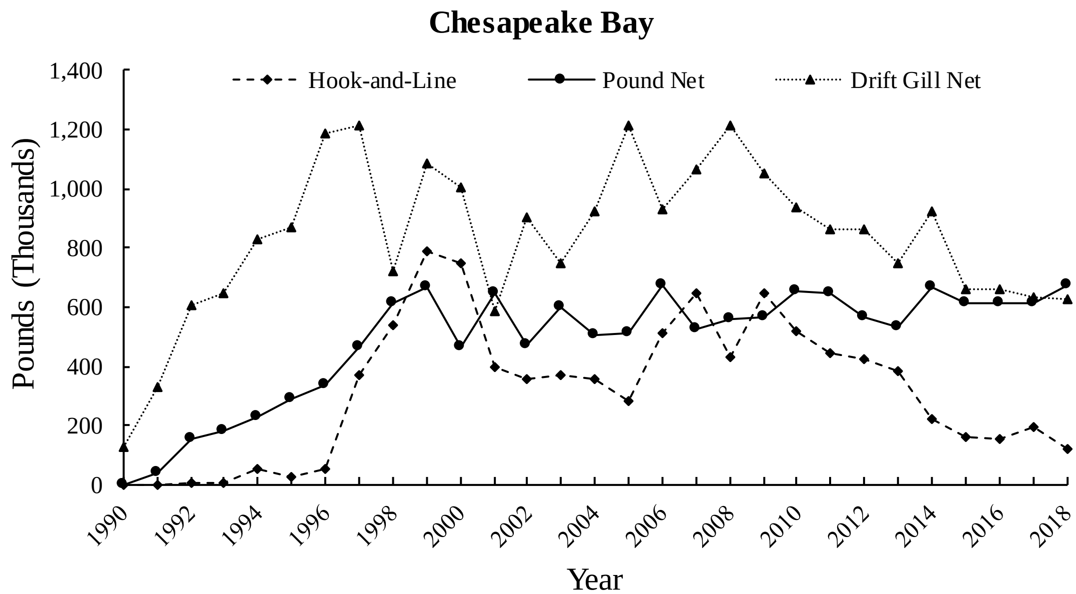


Figure 5. Maryland's Chesapeake Bay and Atlantic Ocean striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2018. Note different scales.



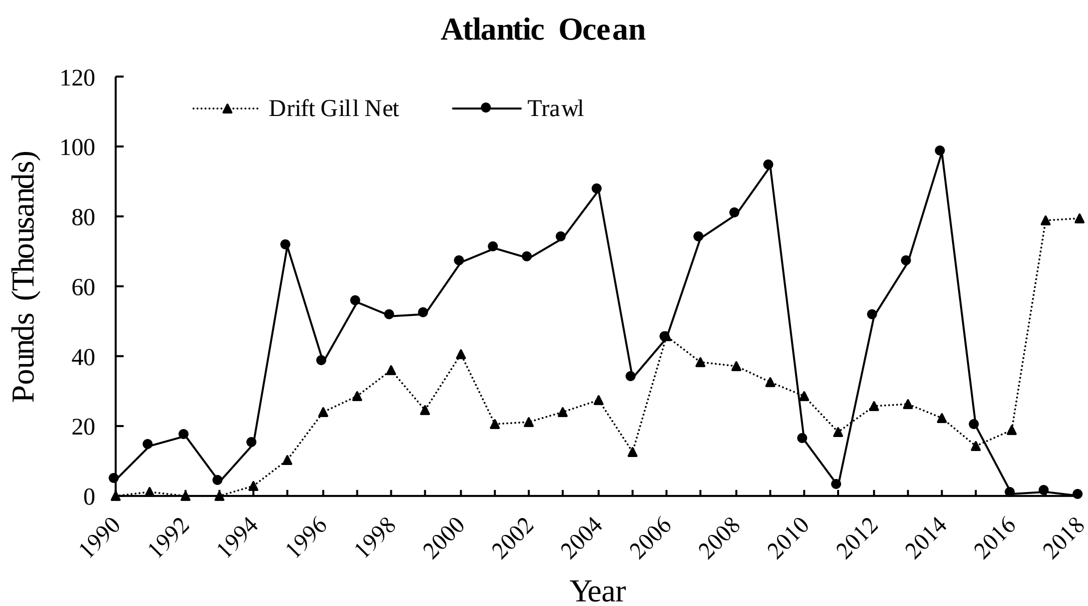
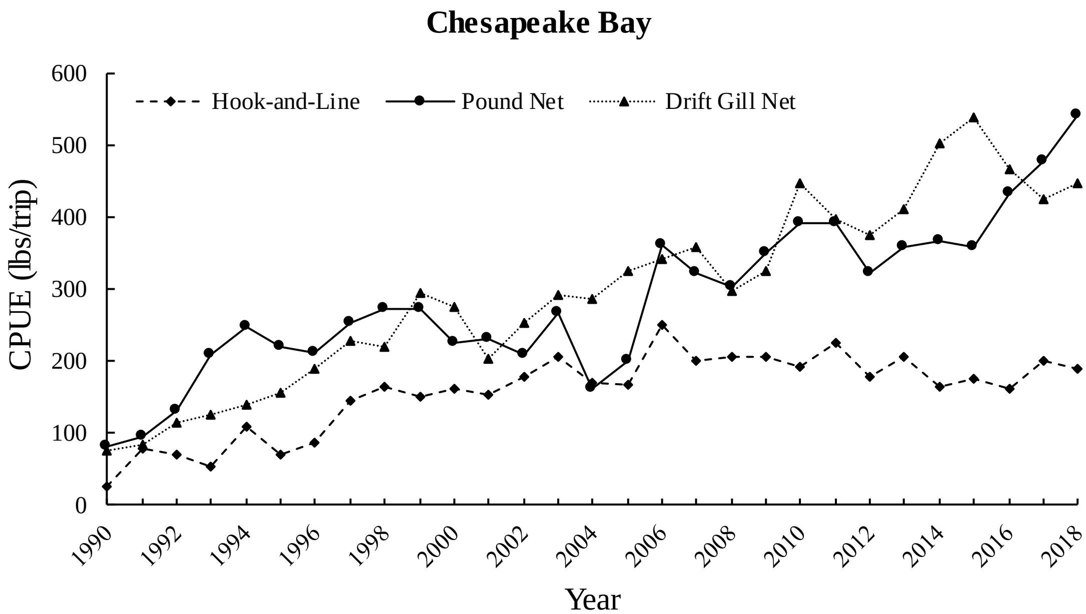
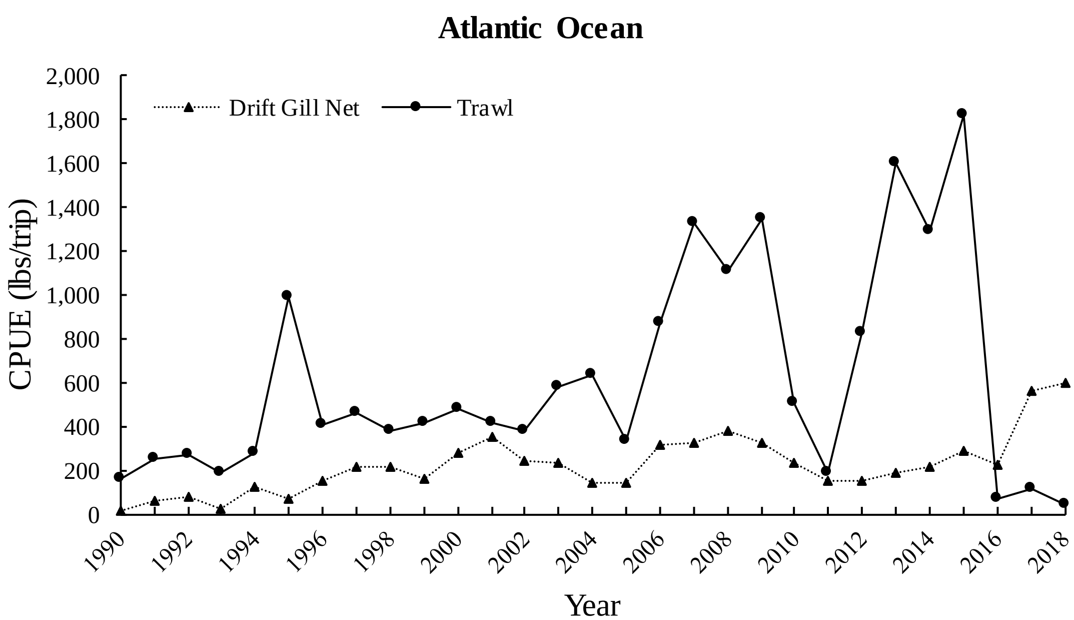


Figure 6. Maryland's Chesapeake Bay and Atlantic Ocean striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990-2018. Trips were defined as days on which striped bass were landed. Note different scales.





PROJECT NO. 2
JOB NO. 3
TASK NO. 5B

CHARACTERIZATION OF THE STRIPED BASS SPRING RECREATIONAL SEASON AND SPAWNING STOCK IN MARYLAND

Prepared by Simon C. Brown

INTRODUCTION

The primary objective of Project 2, Job 3, Task 5B was to finalize the characterization of the size, age and sex composition of striped bass (*Morone saxatilis*) sampled from the 2019 spring recreational season, which began on Saturday, April 20 and continued through May 15. The secondary objective was to estimate recreational harvest rates and catch per unit effort during the spring recreational season. Preliminary results as available for the 2020 spring recreational season are reported and complete results for the 2020 spring recreational season will be reported in the F61-R-16 Chesapeake Bay Finfish Investigations report.

A portion of the Atlantic migratory striped bass stock returns to Chesapeake Bay annually in the spring to spawn in the various tributaries (Pearson 1938; Merriman 1941; Tresselt 1952; Raney 1952; Raney 1957; Chapoton and Sykes 1961; Dovel 1971; Dovel and Edmunds 1971; Kernehan et al. 1981). Mansueti and Hollis (1963) reported that the spawning season runs from April through June. After spawning, migratory striped bass leave the tributaries and exit the bay to their summer feeding grounds in the Atlantic Ocean. Water temperatures can significantly influence the harvest of migratory striped bass in any one year, with coastal migrants remaining in Chesapeake Bay longer during cool springs (Jones and Sharov 2003). In some years, ripe, pre-spawn females have been captured as late as the end of June and early July (Pearson 1938; Raney

1952; Vladykov and Wallace 1952), although this has not been observed in recent years. Increasing water temperatures tend to trigger migrations out of the bay and northward along the Atlantic coast (Merriman 1941; Raney 1952; Vladykov and Wallace 1952).

Estimates indicate that in the mid-1970s, over 90% of the coastal striped bass harvested from southern Maine to Cape Hatteras were fish spawned in Chesapeake Bay (Berggren and Lieberman 1978; Setzler et al. 1980; Fay et al. 1983). Consequently, spawning success and young-of-year survival in the Chesapeake Bay and its tributaries have a significant effect on subsequent striped bass stock size and catch from North Carolina to Maine (Raney 1952; Mansueti 1961; Alperin 1966; Schaefer 1972; Austin and Custer 1977; Fay et al. 1983).

Maryland's post-moratorium spring striped bass season targets coastal migrant fish in the main stem of Chesapeake Bay. The first spring season opened in 1991 with a 16-day season, 36-inch minimum size, and a one fish per season creel limit (Speir et al. 1999). Spring season regulations have become progressively more liberal since 1991 as stock abundance increased (Table 1).

In response to the results of the 2013 benchmark assessment indicating a steady decline in the spawning stock biomass, the ASMFC Management Board approved Addendum IV to Amendment 6 in October 2014. The Addendum established new fishing mortality reference points (F target and threshold). In order to reduce F to a level at or below the new target, the coastal states and the Chesapeake Bay states/jurisdictions were required to implement a 25% harvest reduction of coastal migrant fish from 2013 levels. The 2019 spring season was 25 days long (April 20 – May 15), with a one fish (≥35 inches) per person, per day, creel limit. Fishing was permitted in Chesapeake Bay from Brewerton Channel to the Maryland – Virginia line, excluding all bays and tributaries (Figure 1). The final estimates of the 2019 Maryland and Virginia spring harvest of coastal migrant striped bass in Chesapeake Bay are reported annually to ASMFC.

The Maryland Department of Natural Resources (MD DNR) Striped Bass Program initiated a dockside creel survey for the spring fishery in 2002. The main objectives are:

1. Develop a time-series of catch per unit effort (CPUE) of the spring trophy fishery,
2. Determine the sex ratio and spawning condition of harvested fish,
3. Characterize length and weight of harvested fish,
4. Characterize the age-distribution of harvested fish, and
5. Collect scales and otoliths to supplement MD DNR age-length keys and for an ongoing ageing validation study of older fish.

METHODS

A dockside creel survey was conducted at least two days per week at high-use charter boat marinas (Table 2) with effort focused on collecting biological data on the catch. Because of the half-day structure of some charter trips, charter boats returned in two waves. Return times depended on how fast customers reached the creel daily limit. Sites were not chosen by a true random draw. Biologists arrived at a chosen site between 9:00 and 10:00 AM to intercept the first wave of returning boats. If it became apparent that fishing activity from that site was minimal (i.e. most charter boats were tied up at the dock), biologists moved to the nearest site in search of higher fishing activity.

Biologists alternated between four major charter fishing ports in 2019: Kentmorr Marina, Chesapeake Beach/Rod & Reel, Deale/Happy Harbor, and Solomons Island/Harbor Marina (Table 2). Preference was given to high-use sites to ensure the target of 60 fish per week would be sampled. Geographic coverage was spread out as much as possible between the middle and lower Bay. Biological data were collected from charter boat harvest. Interviews with anglers from charter boats were eliminated in 2008. Charter boat fishing activity is adequately characterized through the mandated charter logbook system. Charter boat mates, however, were asked how long lines were in the water so that CPUE could be calculated.

A separate creel survey was previously conducted at public boat ramps to specifically target private boat and shore anglers, but was concluded in 2017. The National Oceanic and Atmospheric Administration's Marine Recreational Information Program (MRIP) performs similar angler interviews of private boat and shore anglers (https://www.fisheries.noaa.gov/topic/recreational-fishing-data). For continuity, MRIP data were used to estimate spring trophy season CPUEs from 2002-2019, and is presented alongside private boat creel survey data for 2002-2017. To calculate CPUEs, MRIP data for waves 2 (March/April) and 3 (April/May) were downloaded and filtered for private boat and shore angler trips targeting striped bass, that were intercepted in Maryland during the spring trophy season, and where fishing occurred in the main-stem of the Bay. The list of MRIP variable and value combinations used to filter the MRIP data for the striped bass spring trophy season and to calculate CPUEs is contained in Tables 3A and 3B.

Biological Data Collection

Biologists approached mates of charter boats and requested permission to collect data from the catch (Table 4). Total length (mm TL) and weight (kg) were measured. Mean annual lengths and weights were calculated along with bootstrapped 95% confidence intervals. Mean lengths and weights between years were analyzed using an analysis of variance (ANOVA, α=0.05). Because female striped bass grow larger than males (Bigelow and Schroeder 1953) a one-way ANOVA was performed separately on males and females. When significant differences were detected among years, a Duncan's multiple range test (α=0.05) was then performed to examine pairwise differences across all years. Additional data on the lengths of striped bass captured and released during the spring season were obtained through the Volunteer Angler Survey which was initiated in 2006 by MD DNR.

The season sampling target for collecting scales was 12 scale samples per 10 mm length group up to 1000 mm TL, for each sex. Scales were collected from every fish greater than 1000 mm TL. A portion of these scale samples was used to supplement scales collected during the spring spawning stock gill net survey (Project No. 2, Job No. 3, Task No. 2) for the construction of a combined spring age-length key. The age structure of fish sampled by the creel survey was estimated using the sex and survey combined spring age-length key.

The season sampling target for otoliths was 2 fish per 10 mm length group greater than or equal to 800 mm TL, for each sex. Otoliths were extracted by using a hacksaw to make a vertical cut from the top of the head above the margin of the pre-operculum down to a level above the eye socket. A second cut was made horizontally from the front of the head above the eye until it intersected the first cut, exposing the brain. The brain was removed carefully to expose the sagittal otoliths, which lie below and behind the brain. Otoliths were removed with tweezers and stored dry in labeled plastic vials for later processing.

Spawning condition was determined based on descriptions of gonad maturity presented by Snyder (1983). Spawning condition was coded as pre-spawn, post-spawn or unknown, and sex was coded as male, female or unknown. “Unknown” for sex or spawning condition refers to fish that were not examined internally, or were not identified with certainty. Ovaries that were swollen and either orange colored (early phase) or green colored (late phase) indicated a pre-spawn female. Shrunken ovaries of a darker coloration indicated post-spawn females. Pre- and post-spawn males were more difficult to distinguish. To verify sex and spawning condition of males, pressure was applied to the abdomen to judge the amount of milt expelled, and an incision was made in the abdomen for internal inspection. Those fish yielding large amounts of milt were determined to be pre-spawn. Male fish with flaccid abdomens or that produced only small amounts of milt were considered post-spawn.

Calculation of Harvest and Catch Rates

A striped bass spring trophy season dataset derived from the MRIP database for private boat and shore anglers was used to estimate Harvest Per Trip (HPT), Harvest Per Angler (HPA), Catch Per Trip (CPT), and Catch Per Hour (CPH). Harvest and release numbers of incidental species other than striped bass were transformed to zero, in order to retain all catch level data for trips where striped bass was the primary target. HPA was calculated by dividing the number of striped bass harvested on a trip by the number of anglers in the fishing party. CPT was defined as number of striped bass harvested, plus number of striped bass released, for each trip. CPH was calculated by dividing the total catch of striped bass by the number of hours fished for each trip. MRIP variables used for these calculations are defined in Table 4B.

HPT, HPA and CPT were also calculated from charter boat logbook data. CPH was calculated using the charter boat log data and the average duration of charter boat trips from mate interview data. Charter boat captains are required to submit data to MD DNR indicating the days and areas fished, number of anglers fishing, and numbers of striped bass caught and released. In place of a paper logbook, captains can also submit their data electronically to MD DNR through the Standard Atlantic Fisheries Information System (SAFIS), coordinated by the Atlantic Coastal Cooperative Statistics Program (ACCSP). In cases where a captain combined data from multiple trips into one log entry, those data were excluded, so only single trip entries were analyzed. Approximately 20% of the charter data has been excluded each year using this criterion.

The analysis of charter boat catch rates used a subset of data to include only fishing that occurred in areas specified in the MD DNR regulations during the spring season (Figure 1). Data from the fisheries in the Susquehanna Flats area (NOAA codes 013 and 089) were therefore excluded from this analysis.

RESULTS AND DISCUSSION

The numbers of MRIP trip and angler interviews intercepted in Maryland, which targeted striped bass in the Chesapeake Bay during the spring trophy season are presented in Table 5A. In 2019, there were 166 angler interviews contained in the MRIP dataset comprised of anglers intercepted from 69 private boat trips and 11 shore trips (Table 5A).

In 2019, there were a total of 404 recorded logbook trips during the spring trophy season, with 14% excluded as multiple trips resulting in the analysis of 347 single trips. This is approximately only a quarter (23%) of the amount of trips logging non-zero striped bass catch as compared with previous years.

The number of charter boats intercepted and number of striped bass examined each year are presented in Table 5B. In 2019, a total of 25 fish were examined from 11 charter trips intercepted with nonzero striped bass harvest (Table 5B). Despite consistent sampling effort, the number of striped bass intercepted at charter marinas in 2019 was very low as compared with previous years. Observations made during the trophy season suggest that low salinity due to anomalous precipitation and freshwater input in the preceding fall/winter season may have shifted the distribution of striped bass to the lower bay during the spring trophy season. Numbers of blue catfish which prefer a lower salinity were encountered in the harvest of striped bass charter boat trips conducted in the mid-Bay.

BIOLOGICAL DATA

Length and Weight

Length distribution

In the 2019 spring striped bass season, fish lengths measured from the harvest ranged from 876 mm TL to 1152 mm TL with a mean of 990 mm TL (n=25, Table 6A, Figure 2). The average size of harvested striped bass has increased since 2016 when regulatory changes increased the minimum size limit to 35 inches (Table 1). In 2019, the mean length estimate was less than the three previous years, but was above the long-term mean and is the fourth largest in the time series. However, the mean size estimate in 2019 lacks precision due to a low sample size and has 95% confidence intervals overlapping with the previous four years (Table 6A).

Mean length

The mean length of females (1014 mm TL) was greater than the mean length of males (895 mm TL), which is typical of the biology of the species (Bigelow and Schroeder 1953). Male striped bass mean length in 2019 was lower than the previous three years and was similar to the long-term average. Statistical comparisons were not conducted due to the low samples size of males (n=5). Female striped bass length in 2019 was 8% larger than the long-term average (Table 6A, Figure 3). ANOVA indicated significant differences in mean length among years for females ($p<0.0001$). Duncan's multiple range test for females ($\alpha=0.05$) found that the mean length in 2019 was not significantly different than the previous three years (2016, 2017, 2018) but was significantly different than all years before 2016 (Table 6A, Figure 3).

The mean daily lengths of female striped bass harvested in 2019 showed no apparent trend, however daily sample size was not adequate ($n<5$) to characterize mean size on 4 of 7 sample dates

(Figure 4). Mean daily length data for 2002 and 2011 have shown larger females were caught earlier in the season (Goshorn et al.1992, Barker et al. 2003).

The Striped Bass Program receives supplemental length data from anglers who submit information through the online Volunteer Angler Survey. Data collected during the spring season through the Volunteer Angler Survey includes lengths of striped bass that were caught and released in addition to lengths of striped bass that were harvested. In 2019, anglers reported lengths for 31 striped bass caught during the trophy season and released. The mean reported length of fish caught and released was 560 mm TL.

Mean weight

Not all fish measured were weighed due to filleting occurring on boats prior to fish being intercepted on shore. Fish weights sampled during the 2019 spring striped bass season ranged from 7.3 kg to 16.1 kg. The mean weight in 2019 was 11.0 kg and 95% confidence intervals indicate it is similar to the mean weight in 2016, 2017, and 2018 (Table 6B, Figure 5).

The mean weight of females (12.0 kg) was greater than the mean weight of males (7.9 kg), consistent with data from previous years. Females tend to grow larger than males, and most striped bass over 13.6 kg (30.0 lb) are females (Bigelow and Schroeder 1953). Low sample size (n=13) precludes the statistical comparison of weight among years. However, qualitatively the mean weight and associated 95% confidence intervals of females and males in 2019 encompass the mean weights of females and males since 2016 (Figure 5).

Age Structure

The number of scales aged from the creel survey has varied between years. In 2019, 66 scale samples from the creel survey were aged, which includes supplementary scale samples obtained through June 15. The age distribution estimated from the combined age-length key applied to lengths of striped bass sampled from the 2019 spring recreational harvest ranged from 8 to 19 years old (Figure 6). Striped bass between eight and twelve years old have typically contributed the most to the spring recreational harvest with each age comprising an average 10% to 20% (Figure 6). However, the above average 2003 and 2005 year-classes have continued to contribute greater than 10% to the spring recreational harvest beyond age 12. In 2019, year-classes representing greater than 10% of the sample were: 2010 (18.3%, age 9), 2009 (22.7%, age 10), 2007 (21.8%, age 12), 2005 (10.1%, age 14) and 2003 (10.1%, age 16). The 2003 year-class appears to have peaked in the spring recreational harvest between ages 9 to 11 (2012-2014), and has tapered off since (Figure 6). Likewise, the above average 2011 year-class appears to have just begun to increase its contribution to the spring recreational harvest at age 8, increasing from 0.4% in 2018 to 7.3% in 2019.

Sex Ratio

There were no striped bass which received an unknown sex designation in 2019. As in past years, the 2019 spring season harvest was dominated by female striped bass with a female to male ratio of 4:1 (Table 7A). Although the sample size was low (n=25) the 2019 sex ratio estimate of 80% female is similar to the long-term averages (Table 7B). However, this is lower than the previous three years which were all above 90% (Table 7B).

Spawning Condition

Percent pre-spawn females

The need to understand spawning condition of the female portion of the catch helped initiate this study in 2002. Goshorn et al. (1992) studied the spawning condition of large female striped bass in the upper Chesapeake Bay spawning area during the 1982-1991 spawning seasons. Their results suggested that most large females spawn before mid-May in the upper Chesapeake

Bay spawning area, indicating a high potential to harvest gravid females in the spring fishery. From 2002 – 2019 the percentage of pre-spawn females in the spring season harvest has declined from a maximum of 63% in 2005 to a minimum of 6% in 2018 (Table 8). Only two pre-spawn females were observed in 2019, however due to the low over-all sample size of females (n=20) this was a larger percentage than in 2018. The onset of striped bass spawning is related to warming water temperatures on the spawning grounds in the spring, and alterations to the timing of spring warming from year-to-year could alter striped bass spawning phenology in warm versus cold years (Peer and Miller 2014). However, in recent years with prolonged cold spring seasons (2015 and 2018), the percent of pre-spawn females in the harvest still declined to all-time lows as compared with previous years, which is the opposite result of what would be expected if female spawning phenology is driven solely by spring water temperatures on the spawning grounds. Shifting demographics of the striped bass stock towards higher proportions of older and larger females could also be altering the average time of spawning since larger, older individuals may spawn earlier in the season than smaller, younger individuals (Cowan et al. 1993).

Daily spawning condition of females

The percentage of post-spawn females tends to be lower at the beginning of the season and then increase after the beginning of May (Figure 7). In 2019, only two of twenty female striped bass encountered were in pre-spawn condition (Figure 7). The dates of encounter were April 26th and May 8th.

CATCH RATES AND FISHING EFFORT

Harvest Per Trip Unit Effort

Charter boat activity can be accurately characterized from existing reporting methods, so no targeted interviews of charter boat anglers were conducted during the spring season in 2019. Creel survey interview data were previously used to obtain harvest rate estimates for private vessels, however this portion of the survey was ended in 2017. For continuity, MRIP interview data were used to calculate harvest rates for private boats for 2002-2019. Harvest per trip (HPT) was calculated from combined charter boat logbook and SAFIS data, and creel survey interviews, using only fish kept during each trip.

The mean HPT in 2019 according to charter boat data was 1.5 fish per trip (Table 9A) which was 65% below the long term mean charter boat HPT (4.3 fish per trip) and the lowest in the time series. The mean HPT from MRIP private boat interviews of 0.2 fish per trip was 67% below the long-term mean private boat HPT (0.6 fish per trip). The charter and private HPT have fallen since 2016 despite consistent minimum size limit regulations in the recreational fishery (Table 9A).

Mean harvest per angler, per trip (HPA) was calculated by dividing the total number of fish kept on a vessel by the number of people in the fishing party. Like HPT above, HPA was expected to be reduced from previous years due to regulations implemented to achieve harvest reduction. HPA from charter boat data in 2019 was 0.26 fish per person (Table 9B) which was a 63% reduction from the long-term mean (0.70 fish per trip). HPA for private anglers, calculated from MRIP interview data, was <0.1 fish per person for both 2018 and 2019 which is the lowest in the time series (Table 9B).

Catch Per Unit Effort

In every year, charter boats have caught (kept and released) more fish per trip and per hour than have private boats (Tables 10A and 10B). The higher charter boat catch rates are likely attributable to the greater level of experience of the charter boat captains. Also, charter captains are in constant communication amongst themselves, enabling them to better track daily movements and feeding patterns of migratory striped bass and consistently operate near larger aggregations of fish.

In 2019, private boats intercepted by MRIP caught an average of 0.6 fish per trip, which was 65% below the long-term average of 1.7 fish per trip (Table 10A). Charter boats caught 3.8 fish per trip, which was 37% below the long-term average (6.0 fish per trip, Table 10B). The private boat catch per hour (CPH) was 0.1 fish per hour while charter boats had a CPH of 0.6 fish per hour.

Angler Characterization

States of residence

In 2019, 166 MRIP angler interviews were conducted during the period April 20-May 15 (Table 5A). Similar to previous years a majority of anglers were from Maryland (86%). Anglers from neighboring Mid-Atlantic States comprised 11% of the total (Table 11).

PROJECT NO. 2
JOB NO. 3
TASK NO. 5B

CHARACTERIZATION OF THE STRIPED BASS SPRING RECREATIONAL SEASON AND SPAWNING STOCK IN MARYLAND

2020 PRELIMINARY RESULTS

Data collected during the 2020 spring recreational season (May 1-May 15) are currently being analyzed. In 2020, biological sampling of harvested striped bass from the charter boat fleet was conducted two or more days a week depending on the availability of fish from for a total of nine sample days. The final, complete analyses of the spring 2020 recreational survey data will be available in the F-61-R-16 Chesapeake Bay Finfish Investigations report.

During the 2020 spring recreational season, 30 striped bass from 8 intercepted charter boat trips were measured, weighed, and internally examined for spawning condition. Biological samples collected from examined fish for aging studies include 30 scale samples and 28 otoliths. Female striped bass (n=28) were a mean Total Length of 996 mm and mean weight of 10.40 kg. Internal examination revealed 93% of female striped bass harvested had recently spawned. Male striped bass (n=2) were a Total Length of 935 mm and 1003 mm. Scale samples are currently being processed and aged, therefore no age distribution of the 2020 spring recreational harvest is available at this time.

CITATIONS

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Table 1. History of changes made to MD DNR fishing regulations for Maryland striped bass spring trophy seasons, 1991-2019.

Year	Open Season	Min Size Limit (In.)	Bag Limit (# Fish)	Open Fishing Area
1991	5/11-5/27	36	1 per person, per season, with permit	Main stem Chesapeake Bay, Annapolis Bay Bridge-VA State line
1992	5/01-5/31			
1993	5/01-5/31		1 per person, per season	
1994	5/01-5/31	34	1 per person, per day, 3 per season	
1995	4/28-5/31	32	1 per person, per day, 5 per season	Main stem Chesapeake Bay, Brewerton Channel-VA State line
1996	4/26-5/31		1 per person, per day	
1997	4/25-5/31			
1998	4/24-5/31			
1999	4/23-5/31	28		
2000	4/25-5/31			
2001	4/20-5/31			
2002	4/20-5/15			
2003	4/19-5/15			
2004	4/17-5/15			
2005	4/16-5/15			
2006	4/15-5/15	33		
2007	4/21-5/15	28-35 or larger than 41		
2008	4/19-5/13	28		
2009	4/18-5/15			
2010	4/17-5/15			
2011	4/16-5/15			
2012	4/21-5/15			
2013	4/20-5/15			
2014	4/19-5/15			
2015	4/18-5/15	28-36 or larger than 40		
2016	**4/16-5/15**	35 inches or larger	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2017	**4/15-5/15**			
2018	**4/21-5/15**			
2019	**4/20-5/15**			

Table 2. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002 2019. Sites are listed in a clockwise direction around Maryland's section of the Chesapeake Bay.

Region	**Site Name**	**Site Number**
Eastern Shore-Upper Bay	Rock Hall	01
Eastern Shore-Middle Bay	Matapeake Boat Ramp	02
Eastern Shore-Middle Bay	Kent Island Marina/Hemingway's	15
Eastern Shore-Middle Bay	Kentmorr Marina	03
Eastern Shore-Middle Bay	Queen Anne Marina	04
Eastern Shore-Middle Bay	Knapps Narrows Marina	13
Eastern Shore-Middle Bay	Tilghman Is./Harrison' s	05
Western Shore-Lower Bay	Pt. Lookout State Park	16
Western Shore-Lower Bay	Solomons Island Boat Ramp	17
Western Shore-Lower Bay	Solomons Island/Harbor Marina	18
Western Shore-Lower Bay	Solomons Island/Beacon Marina	19
Western Shore-Lower Bay	Solomons Island/Bunky's Charter Boats	06
Western Shore-Lower Bay	Solomons /Calvert Marina	07
Western Shore-Middle Bay	Breezy Point Fishing Center and Ramp	08
Western Shore-Middle Bay	Chesapeake Beach/Rod & Reel	09
Western Shore-Middle Bay	Herrington Harbor South	14
Western Shore-Middle Bay	Deale/Happy Harbor	10
Western Shore-Middle Bay	South River	12
Western Shore-Upper Bay	Sandy Pt. State Park Boat Ramp and Beach	11

Table 3A. Variable and value combinations used to filter MRIP interview data for relevance to the spring trophy season.

Variable	**Definition**	**Value**
ST	Fips code for state of intercept	24 (Maryland)
DATE	Date	3rd Saturday in April – May 15th
AREA	Area of fishing	“F” (Chesapeake Estuary)
PRIM1_COMMON	Primary species targeted	“STRIPED BASS”
MODE_F	Fishing mode	1:5 (shore), 8 (private/rental boat)

Table 3B. MRIP variables used to calculate harvest and catch per unit effort rates

Variable	**Definition**
COMMON	Common name of fish species
ID_CODE	Angler interview identifier
PRT_CODE	Trip identifier
CLAIM_UNADJ	Unadjusted count of fish that were caught, landed whole, and available for identification to species and enumeration by the interviewer.
HARVEST_UNADJ	Unadjusted number of fish that were caught, not released live, but not available in whole form for examination, identification, or enumeration.
RELEASE_UNADJ	Unadjusted number of fish that were caught and released alive.
HRSF	Hours fished

Table 4. Biological data collected by the Maryland striped bass spring season creel survey, 2019.

Measurement or Test	**Units or Categories**
Total length (TL)	to nearest millimeter (mm)
Weight	kilograms (kg) to the nearest tenth
Sex	male, female, unknown
Spawning condition	pre-spawn, post-spawn, unknown

Table 5A. Annual number of selected trips intercepted by MRIP, by type, and number of anglers interviewed, through May 15th.

Year	Trips Intercepted	Private Boat	Shore	Number of Anglers
2002	40	39	1	85
2003	40	40	0	68
2004	102	100	2	177
2005	37	37	0	58
2006	21	21	0	31
2007	54	43	11	88
2008	28	18	10	33
2009	60	51	9	82
2010	30	24	6	42
2011	70	60	10	118
2012	25	25	0	38
2013	38	31	7	52
2014	66	59	7	91
2015	77	72	5	130
2016	90	78	12	149
2017	108	106	2	191
2018	181	170	11	380
2019	80	69	11	166

Table 5B. Number of intercepted trips, by type (fishing mode), anglers interviewed and fish examined by the Maryland striped bass spring season creel survey, through May 15.

Year	Charter Boat	Private Boat	Shore	Not Specified	Anglers Interviewed	Fish Examined
2002	140	45	0	2	458	503
2003	114	65	0	2	332	478
2004	88	42	1	7	178	462
2005	53	1	0	0	93	275
2006	101	28	10	0	344	464
2007	50	483	9	0	809	301
2008	34	265	6	0	329	200
2009	27	275	1	0	747	216
2010	45	193	0	0	601	263
2011	63	299	0	0	824	234
2012	37	172	0	0	447	130
2013	35	169	3	0	456	182
2014	48	209	1	0	580	211
2015	57	201	3	0	546	177
2016	58	221	0	0	585	197
2017	77	180	7	0	501	150
2018	41	--	--	--	--	118
2019	11	--	--	--	--	25

Table 6A. Mean lengths of striped bass (mm TL) with 95% confidence limits sampled by the Maryland striped bass spring season creel survey, through May 15.

Year	Mean TL (mm) All Fish	Mean TL (mm) Females	Mean TL (mm) Males
2002	**887** (879-894)	**895** (886-903)	**846** (828-864)
2003	**894** (885-903)	**899** (889-909)	**834** (813-864)
2004	**889** (881-897)	**896** (886-903)	**827** (810-845)
2005	**893** (885-902)	**898** (888-907)	**867** (852-883)
2006	**923** (917-930)	**929** (922-936)	**886** (875-897)
2007	**861** (852-871)	**869** (858-881)	**827** (806-848)
2008	**920** (910-931)	**933** (922-944)	**877** (853-900)
2009	**913** (902-925)	**930** (917-942)	**860** (836-883)
2010	**913** (902-924)	**932** (921-944)	**833** (812-855)
2011	**890** (880-901)	**906** (895-917)	**829** (808-851)
2012	**863** (849-876)	**885** (872-899)	**795** (771-818)
2013	**924** (914-934)	**934** (924-943)	**853** (824-883)
2014	**946** (937-956)	**952** (942-961)	**882** (850-915)
2015	**935** (921-949)	**952** (939-967)	**859** (832-888)
2016	**999** (992-1006)	**1002** (995-1010)	**951** (937-965)
2017	**1005** (994-1017)	**1011** (1000-1022)	**928** (892-972)
2018	**1037** (1024-1050)	**1044** (1031-1057)	**967** (943-993)
2019	**990** (956-1027)	**1014** (977-1051)	**895** (883-911)
Mean	**926** (905-951)	**938** (917-961)	**868** (848-889)

Table 6B. Mean weight of striped bass (kg) with 95% confidence limits sampled by the Maryland striped bass spring season creel survey, through May 15.

Year	Mean Weight (kg) All Fish	Mean Weight (kg) Females	Mean Weight (kg) Males
2002	**7.3** (7.1-7.5)	**7.4** (7.2-7.6)	**6.1** (5.7-6.4)
2003	**7.6** (7.3-7.9)	**7.7** (7.3-8.0)	**5.9** (5.2-6.6)
2004	**7.6** (7.4-7.8)	**7.8** (7.5-8.0)	**5.9** (5.5-6.4)
2005	**7.3** (7.1-7.6)	**7.5** (7.2-7.8)	**6.4** (6.0-6.7)
2006	**8.1** (7.9-8.4)	**8.3** (8.0-8.5)	**6.7** (6.4-7.1)
2007	**6.8** (6.4-7.1)	**7.1** (6.7-7.5)	**5.7** (5.2-6.1)
2008	**7.8** (7.5-8.1)	**8.2** (7.8-8.5)	**6.7** (6.1-7.2)
2009	**7.9** (7.6-8.2)	**8.3** (8.0-8.7)	**6.4** (5.8-6.9)
2010	**7.8** (7.5-8.1)	**8.3** (8.0-8.6)	**5.7** (5.2-6.1)
2011	**7.3** (7.0-7.6)	**7.7** (7.4-8.0)	**5.6** (5.1-6.1)
2012	**6.7** (6.4-7.1)	**7.2** (6.9-7.6)	**5.3** (4.7-5.8)
2013	**8.3** (8.0-8.6)	**8.6** (8.3-8.9)	**6.3** (5.7-7.0)
2014	**9.1** (8.8-9.4)	**9.3** (9.0-9.6)	**6.8** (6.1-7.5)
2015	**8.6** (8.2-9.0)	**9.1** (8.7-9.6)	**6.5** (5.8-7.1)
2016	**10.2** (10.0-10.4)	**10.3** (10.1-10.6)	**8.4** (7.6-9.2)
2017	**10.7** (10.3-11.1)	**10.8** (10.4-11.2)	**8.9** (7.7-10.5)
2018	**11.7** (11.1-12.3)	**12.0** (11.5-12.6)	**8.9** (8.1-9.7)
2019	**11.0** (9.3-12.7)	**12.0** (10.2-13.7)	**7.9** (7.3-9.0)
Mean	**8.4** (7.8-9.1)	**8.7** (8.1-9.5)	**6.7** (6.2-7.2)

Table 7A. Number of female (F), male (M), and unknown (U) sex striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

Year	F	M	U	Total (Include U)	Total (Exclude U)	F + U
2002	342	70	92	504	412	434
2003	404	37	39	480	441	443
2004	406	45	11	462	451	417
2005	233	39	3	275	272	236
2006	393	63	8	464	456	401
2007	242	49	10	301	291	252
2008	155	45	0	200	200	155
2009	166	48	2	216	214	168
2010	212	50	1	263	262	213
2011	186	48	0	234	234	186
2012	98	32	0	130	130	98
2013	160	22	0	182	182	160
2014	194	17	0	211	211	194
2015	143	33	1	177	176	144
2016	184	13	0	197	197	184
2017	137	12	1	150	149	137
2018	105	11	2	118	116	107
2019	20	5	0	25	25	25

Table 7B. Percent females, using three different calculation methods, sampled by the Maryland striped bass spring season creel survey, through May 15. Means are presented with 95% confidence intervals.

Year	**%F (Include U)**	**%F (Exclude U)**	**%F (Assume U were Female)**
2002	68	83	86
2003	84	92	92
2004	88	90	90
2005	85	86	86
2006	85	86	86
2007	80	83	84
2008	78	78	78
2009	77	78	78
2010	81	81	81
2011	79	79	79
2012	75	75	75
2013	88	88	88
2014	92	92	92
2015	81	81	81
2016	93	93	93
2017	91	92	92
2018	91	90	91
2019	80	80	80
Mean	**83**	**85**	**85**

Table 8. Spawning condition of the female portion of catch, sampled by the Maryland striped bass spring season creel survey, through May 15. Females of unknown spawning condition are excluded. Means are presented with 95% confidence intervals.

	Pre-spawn Females		Post-spawn Females	
Year	**n**	**%**	**n**	**%**
2002	150	45	181	55
2003	231	58	168	42
2004	222	55	180	45
2005	144	63	85	37
2006	162	41	231	59
2007	142	59	97	41
2008	47	30	108	70
2009	81	49	83	50
2010	62	29	150	71
2011	79	42	107	58
2012	29	30	69	70
2013	46	29	114	71
2014	53	27	141	73
2015	34	24	109	76
2016	23	13	157	87
2017	17	12	120	88
2018	6	6	99	94
2019	2	10	18	90
Mean	**--**	**34** (27-42)	**--**	**65** (57-73)

Table 9A. Mean harvest of striped bass per trip (HPT), with 95% confidence limits, calculated from Maryland charter boat logbook data, spring season creel survey interview data, and MRIP data, through May 15. SAFIS data were combined with the charter logbook data from 2011 through the present.

Year	Charter Trips	Charter Mean HPT	Private Creel Mean HPT	MRIP Mean HPT
2002	1,424	**4.7** (4.6-4.8)	**1.1** (0.6-1.4)	**0.3** (0.1-0.4)
2003	1,393	**5.7** (5.6-5.8)	**1.1** (0.7-1.4)	**1.0** (0.6-1.3)
2004	1,591	**5.4** (5.3-5.5)	**2.2** (1.7-2.8)	**0.7** (0.5-1.0)
2005	1,965	**5.5** (5.4-5.6)	--	**1.0** (0.8-1.3)
2006	1,934	**5.3** (5.2-5.4)	**1.4** (0.6-2.1)	**0.8** (0.4-1.3)
2007	1,607	**4.3** (4.2-4.4)	**0.7** (0.6-0.8)	**0.3** (0.1-0.6)
2008	1,755	**4.9** (4.8-5.1)	**0.6** (0.5-0.7)	**0.6** (0.2-1.1)
2009	1,849	**5.0** (4.9-5.1)	**0.9** (0.7-1.0)	**0.8** (0.5-1.1)
2010	1,986	**4.8** (4.7-4.9)	**1.1** (0.9-1.3)	**0.4** (0.1-0.8)
2011	1,849	**5.0** (4.9-5.1)	**0.9** (0.7-1.0)	**0.6** (0.4-0.9)
2012	1,546	**4.2** (4.0-4.4)	**0.5** (0.3-0.6)	**0.4** (0.2-0.7)
2013	1,822	**4.9** (4.8-5.1)	**0.9** (0.7-1.1)	**0.3** (0.2-0.5)
2014	1,481	**5.5** (5.3-5.6)	**0.9** (0.8-1.1)	**1.0** (0.7-1.4)
2015	1,392	**2.8** (2.7-3.0)	**0.2** (0.1-0.3)	**0.5** (0.3-0.8)
2016	1,380	**3.9** (2.8-4.1)	**0.5** (0.4-0.7)	**0.7** (0.5-0.9)
2017	995	**2.4** (2.3-2.5)	**0.2** (0.1-0.3)	**0.4** (0.3-0.6)
2018	713	**2.1** (1.9-2.2)	**--**	**0.1** (0.1-0.2)
2019	347	**1.5** (1.3-1.6)	**--**	**0.2** (0.1-0.3)
Mean	1,502	**4.3** (3.7-4.9)	**0.9** (0.7-1.1)	**0.6** (0.4-0.7)

Table 9B. Mean harvest of striped bass per angler, per trip (HPA), with 95% confidence limits, calculated from Maryland charter boat logbook data, spring season creel survey interview data, and MRIP data, through May 15. SAFIS data were combined with the charter logbook data from 2011 through the present.

Year	Charter Trips	Charter Mean HPA	Private Creel Mean HPA	MRIP Mean HPA
2002	1,424	**0.78** (0.76-0.79)	**0.4** (0.3-0.6)	**0.1** (<0.1-0.2)
2003	1,393	**0.93** (0.92-0.94)	**0.4** (0.3-0.5)	**0.6** (0.3-0.8)
2004	1,591	**0.88** (0.86-0.89)	**0.7** (0.5-0.8)	**0.4** (0.3-0.6)
2005	1,965	**0.88** (0.87-0.89)	**--**	**0.7** (0.5-0.8)
2006	1,934	**0.86** (0.87-0.85)	**0.5** (0.2-0.7)	**0.5** (0.2-0.9)
2007	1,607	**0.69** (0.68-0.71)	**0.3** (0.2-0.3)	**0.2** (0.1-0.3)
2008	1,755	**0.79** (0.78-0.81)	**0.2** (0.2-0.3)	**0.5** (0.1-0.9)
2009	1,849	**0.81** (0.80-0.82)	**0.3** (0.3-0.4)	**0.6** (0.4-0.8)
2010	1,986	**0.76** (0.75-0.77)	**0.4** (0.3-0.5)	**0.3** (0.1-0.6)
2011	1,849	**0.78** (0.77-0.80)	**0.3** (0.3-0.3)	**0.4** (0.2-0.5)
2012	1,546	**0.67** (0.64-0.71)	**0.2** (0.1-0.2)	**0.3** (0.1-0.5)
2013	1,822	**0.75** (0.74-0.77)	**0.3** (0.3-0.4)	**0.2** (0.1-0.4)
2014	1,481	**0.82** (0.81-0.84)	**0.3** (0.3-0.4)	**0.7** (0.5-1.0)
2015	1,392	**0.45** (0.43-0.47)	**0.1** (0.0-0.1)	**0.3** (0.2-0.5)
2016	1,380	**0.65** (0.63-0.67)	**0.2** (0.2-0.3)	**0.4** (0.3-0.5)
2017	995	**0.41** (0.39-0.42)	**0.1** (<0.1-0.1)	**0.2** (0.2-0.3)
2018	713	**0.35** (0.33-0.37)	**--**	**0.1** (<0.1-0.1)
2019	347	**0.26** (0.23-0.29)	**--**	**0.1** (<0.1-0.1)
Mean	1,502	**0.70** (0.60-0.78)	**0.3** (0.2-0.4)	**0.4** (0.3-0.5)

Table 10A. Private boat mean catch, effort, and catch per hour, with 95% confidence limits, from the Maryland striped bass spring season creel survey interview data and MRIP interview data, through May 15. Catch is defined as number of fish harvested plus number of fish released.

Year	Private Boat catch/trip	Private Boat hours/trip	Private Boat catch/hour	MRIP catch/trip	MRIP hours/trip	MRIP catch/hour
2002	**1.6** (0.9-2.4)	**4.9** (4.3-5.5)	**0.3** (0.2-0.5)	**0.9** (0.3-1.6)	**5.5** (4.9-6.2)	**0.1** (<0.1-0.2)
2003	**1.8** (0.9-2.8)	**5.4** (4.8-6.0)	**0.5** (0.2-0.7)	**1.9** (1.2-2.6)	**4.5** (4.0-5.1)	**0.4** (0.2-0.6)
2004	**3.5** (2.0-4.9)	**4.6** (3.8-5.3)	**1.0** (0.6-1.4)	**0.9** (0.6-1.2)	**5.1** (4.7-5.5)	**0.2** (0.1-0.2)
2005	**--**	**2.5**	**--**	**1.9** (1.2-2.7)	**3.8** (3.3-4.5)	**0.6** (0.4-0.8)
2006	**2.3** (1.1-3.5)	**4.9** (4.2-5.7)	**0.7** (0.3-1.1)	**2.2** (1.3-3.3)	**5.1** (4.1-6.2)	**0.4** (0.3-0.6)
2007	**1.6** (1.2-2.0)	**5.0** (4.9-5.1)	**0.3** (0.2-0.4)	**0.8** (0.5-1.2)	**4.9** (4.4-5.5)	**0.2** (0.1-0.3)
2008	**1.0** (0.7-1.3)	**4.5** (4.2-4.7)	**0.3** (0.2-0.4)	**1.1** (0.3-1.9)	**5.4** (4.2-6.6)	**0.2** (0.1-0.3)
2009	**1.6** (1.0-2.1)	**4.7** (4.5-4.8)	**0.4** (0.2-0.5)	**1.4** (0.8-2.3)	**4.8** (4.4-5.2)	**0.3** (0.2-0.6)
2010	**1.6** (1.2-2.0)	**4.7** (4.5-4.9)	**0.4** (0.3-0.5)	**3.5** (1.0-6.7)	**5.5** (4.9-6.1)	**0.8** (0.2-1.6)
2011	**1.2** (1.0-1.4)	**4.4** (4.2-4.6)	**0.3** (0.2-0.4)	**1.3** (0.6-2.4)	**4.0** (3.7-4.4)	**0.3** (0.2-0.5)
2012	**0.8** (0.5-1.1)	**4.8** (4.6-5.1)	**0.2** (0.1-0.3)	**2.7** (0.8-5.7)	**5.7** (4.8-6.5)	**0.5** (0.1-1.0)
2013	**1.3** (1.0-1.7)	**4.4** (4.2-4.7)	**0.3** (0.2-0.4)	**2.0** (0.7-3.5)	**4.3** (3.4-5.3)	**0.5** (0.2-0.8)
2014	**1.2** (1.0-1.4)	**4.7** (4.4-4.9)	**0.3** (0.2-0.4)	**2.3** (1.1-3.9)	**5.1** (4.5-5.7)	**0.6** (0.3-1.0)
2015	**0.7** (0.5-1.0)	**6.3** (4.7-9.5)	**0.2** (0.1-0.2)	**1.2** (0.7-1.8)	**5.2** (4.7-5.7)	**0.2** (0.1-0.4)
2016	**2.6** (1.5-4.0)	**5.1** (4.9-5.3)	**0.5** (0.3-0.8)	**3.0** (1.4-5.0)	**5.3** (4.8-5.8)	**0.7** (0.3-1.3)
2017	**0.7** (0.4-0.9)	**4.6** (4.4-4.8)	**0.2** (0.1-0.2)	**1.4** (0.9-2.0)	**5.7** (5.3-6.1)	**0.3** (0.2-0.6)
2018	**--**	**--**	**--**	**0.7** (0.4-1.0)	**5.7** (5.3-6.0)	**0.1** (0.1-0.2)
2019	**--**	**--**	**--**	**0.6** (0.3-0.9)	**5.5** (5.1-6.0)	**0.1** (0.1-0.2)
Mean	**1.6** (1.2-2.0)	**4.7** (4.3-5.0)	**0.4** (0.3-0.5)	**1.7** (1.3-2.0)	**5.1** (4.8-5.3)	**0.4** (0.3-0.5)

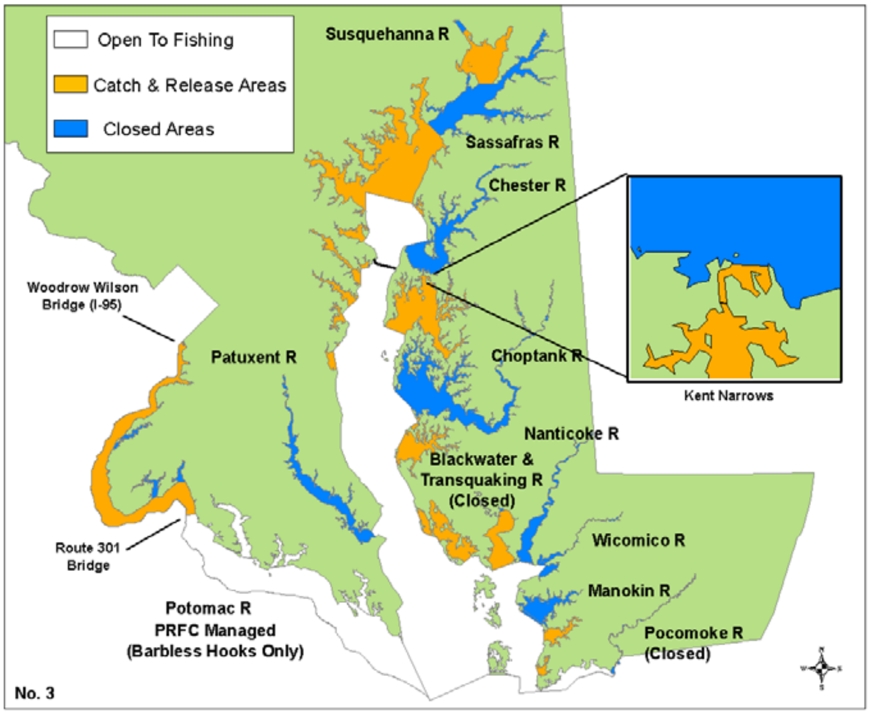
Table 10B. Charter boat mean catch, effort, and catch per hour, with 95% confidence limits, calculated from charter boat logbook data, through May 15. Catch is defined as number of fish harvested plus number of fish released. Mean hours per trip are from creel survey interview data until 2009 where the mean hours per trip are from mate interviews. SAFIS data were combined with the charter logbook data from 2011 through the present.

Year	n	Mean catch/trip	Mean hours/trip (From interview data)	Mean catch/hour
2002	1,487	**5.5** (5.4-5.7)	**5.5** (5.3-5.7)	**1.0** (0.9-1.1)
2003	1,420	**7.3** (7.0-7.6)	**4.0** (3.7-4.4)	**1.8** (1.7-1.9)
2004	1,629	**7.4** (7.0-7.7)	**4.0** (3.6-4.4)	**1.8** (1.7-1.9)
2005	1,994	**6.9** (6.6-7.1)	**3.1** (2.6-3.5)	**2.2** (2.1-2.3)
2006	1,990	**8.0** (7.7-8.2)	**3.6** (3.2-3.9)	**2.2** (2.1-2.3)
2007	1,793	**8.1** (7.8-8.4)	**4.6** (4.1-5.0)	**1.8** (1.7-1.8)
2008	1,755	**6.4** (6.2-6.6)	--	--
2009	1,849	**6.0** (5.9-6.2)	**3.4** (2.9-4.0)	**1.8** (1.7-1.8)
2010	1,986	**5.7** (5.5-5.8)	**4.4** (4.0-4.9)	**1.3** (1.2-1.3)
2011	1,849	**5.8** (5.6-6.0)	**4.2** (3.5-4.9)	**1.4** (1.3-1.4)
2012	1,546	**5.0** (4.8-5.2)	**5.5** (4.9-6.1)	**0.9** (0.9-1.0)
2013	1,822	**5.4** (5.3-5.6)	**5.2** (4.7-5.7)	**1.0** (1.0-1.1)
2014	1,481	**5.9** (5.7-6.1)	**4.8** (4.3-5.2)	**1.2** (1.2-1.3)
2015	1,392	**6.0** (5.7-6.4)	**6.3** (6.0-6.7)	**1.0** (0.9-1.0)
2016	1,380	**5.2** (4.9-5.5)	**5.7** (5.6-5.9)	**0.9** (0.9-1.0)
2017	995	**4.5** (3.9-5.1)	**6.3** (6.1-6.5)	**0.7** (0.6-0.8)
2018	713	**4.4** (3.9-5.1)	**5.8** (5.4-6.3)	**0.8** (0.7-0.9)
2019	347	**3.8** (3.3-4.3)	**5.9** (5.5-6.4)	**0.6** (0.6-0.7)
Mean	1,502	**6.0** (5.4-6.5)	**4.8** (4.4-5.3)	**1.3** (1.1-1.6)

Table 11. State of residence and number of anglers interviewed by the Maryland striped bass spring season creel survey, through May 15. MRIP data were used beginning in 2018.

Year	MD	VA	PA	DE	WV	NJ	Other
2002	353	48	27	6	0	2	15
2003	260	31	19	7	1	2	7
2004	107	30	17	3	0	6	11
2005	66	13	4	0	2	0	6
2006	227	56	22	9	6	3	10
2007	679	71	32	8	3	2	11
2008	266	29	16	1	2	4	4
2009	651	44	46	0	4	0	2
2010	482	42	18	3	4	0	52
2011	491	23	19	1	0	1	9
2012	381	26	23	2	4	3	8
2013	407	20	21	0	2	0	6
2014	484	39	30	5	10	2	4
2015	483	27	24	2	3	0	7
2016	474	49	25	2	5	0	10
2017	413	31	32	10	1	2	10
2018	279	16	55	14	2	2	4
2019	142	7	9	3	1	0	4

Figure 1. MD DNR maps showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 20-May 3, 2019 (top) and May 4-May 15, 2019 (bottom)



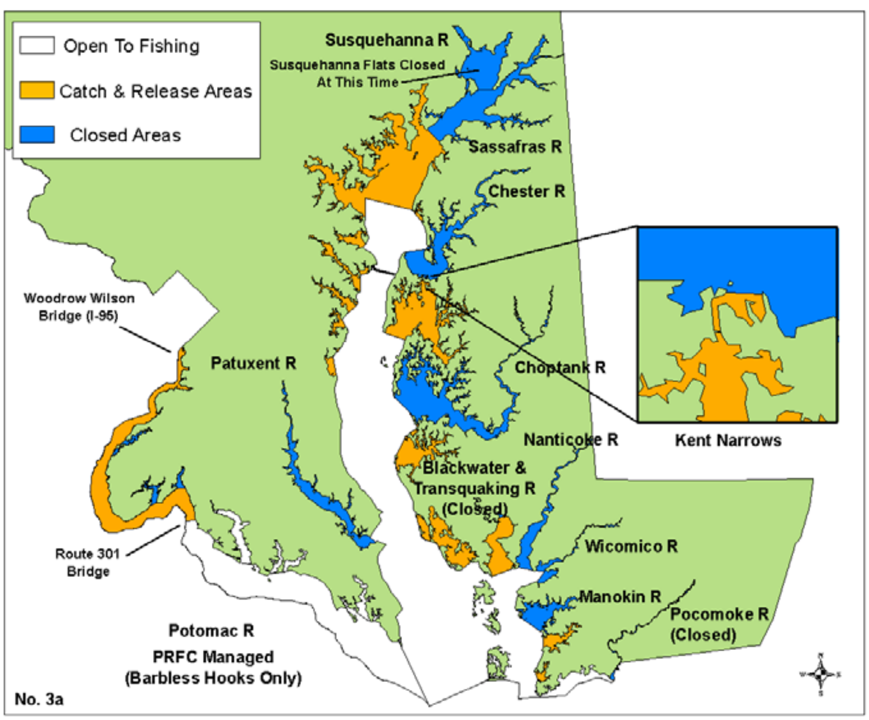


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

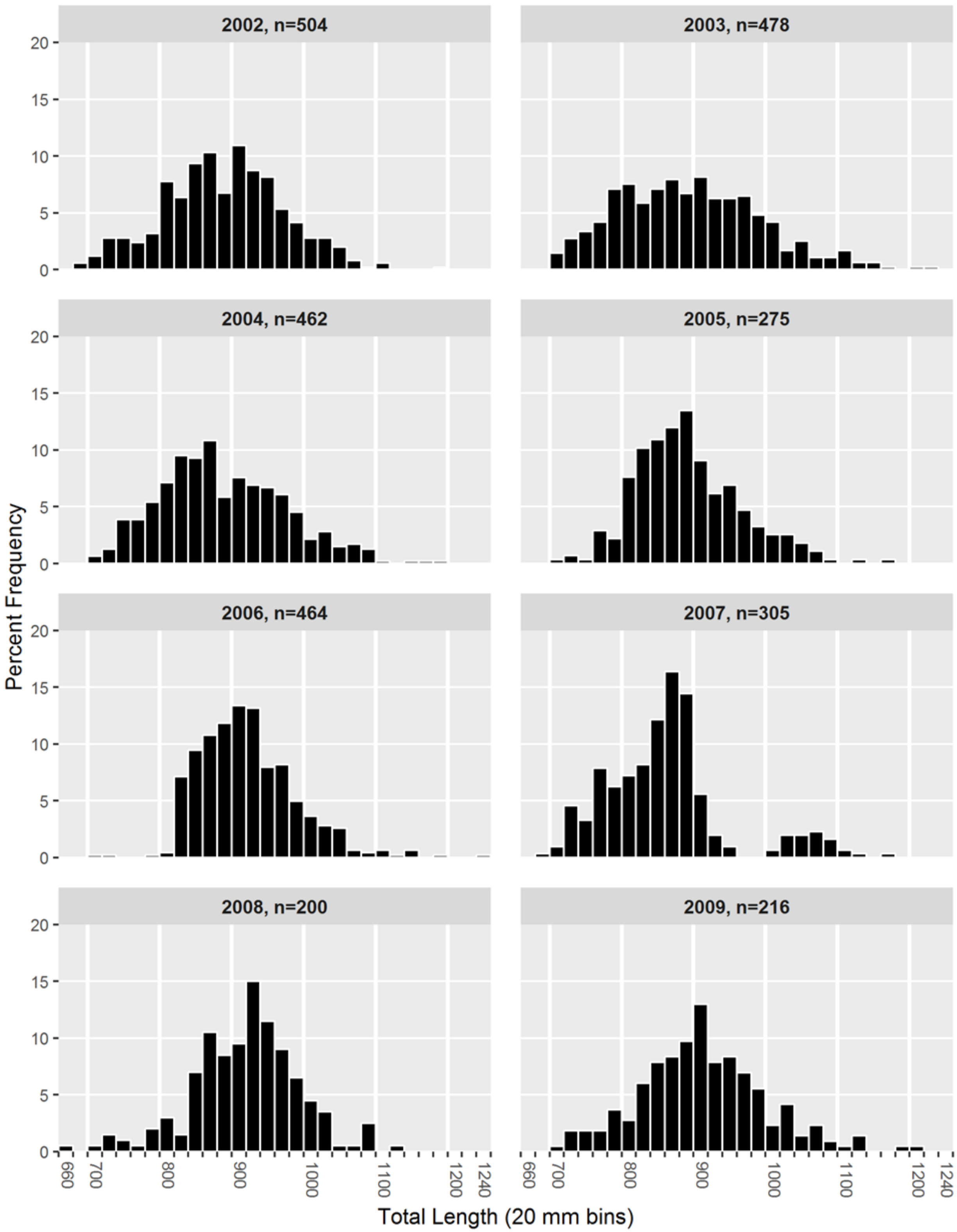


Figure 2. Continued.

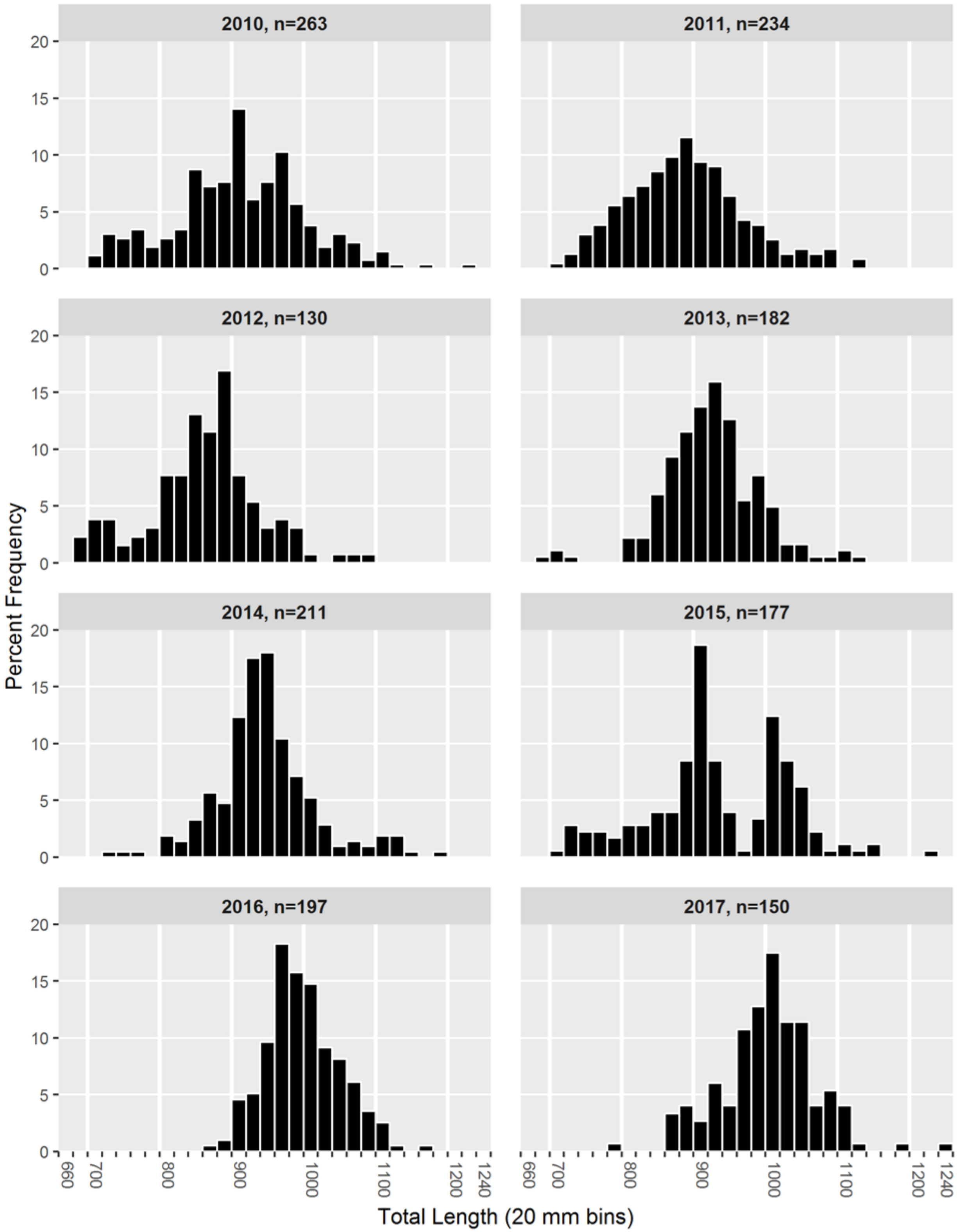


Figure 2. Continued.

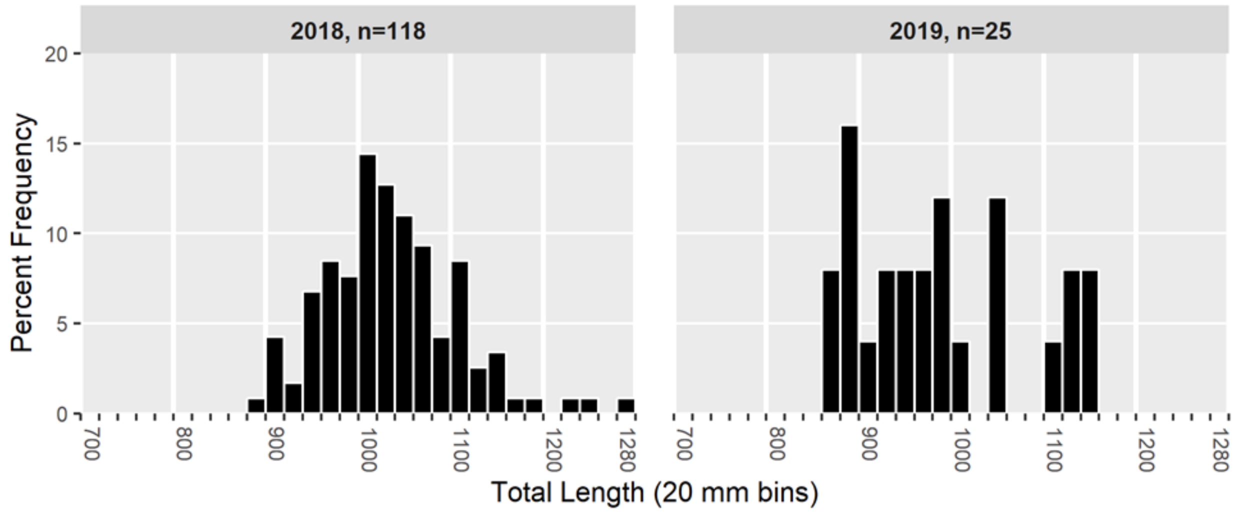


Figure 3. Mean length of female and male striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

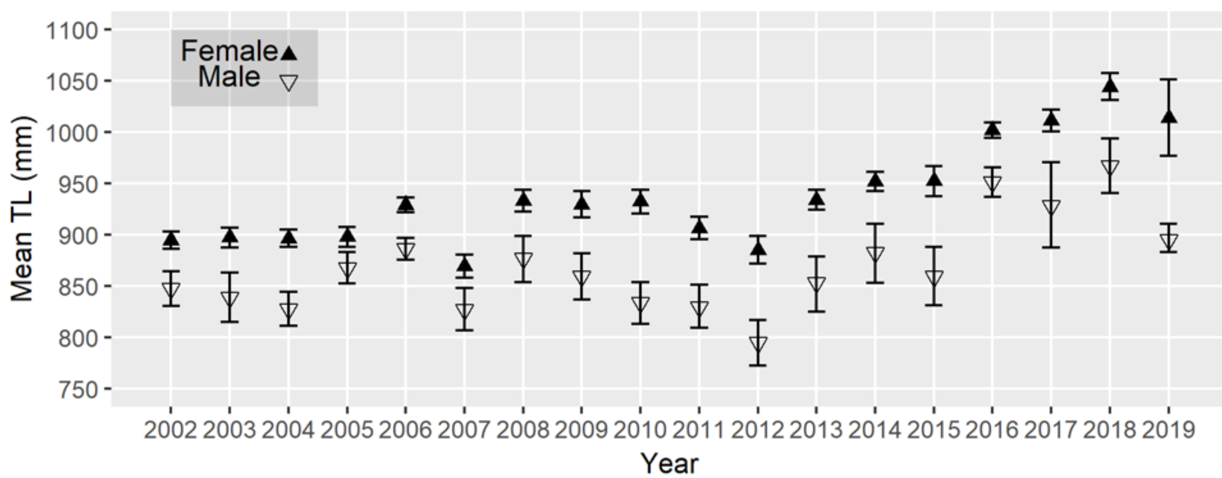


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

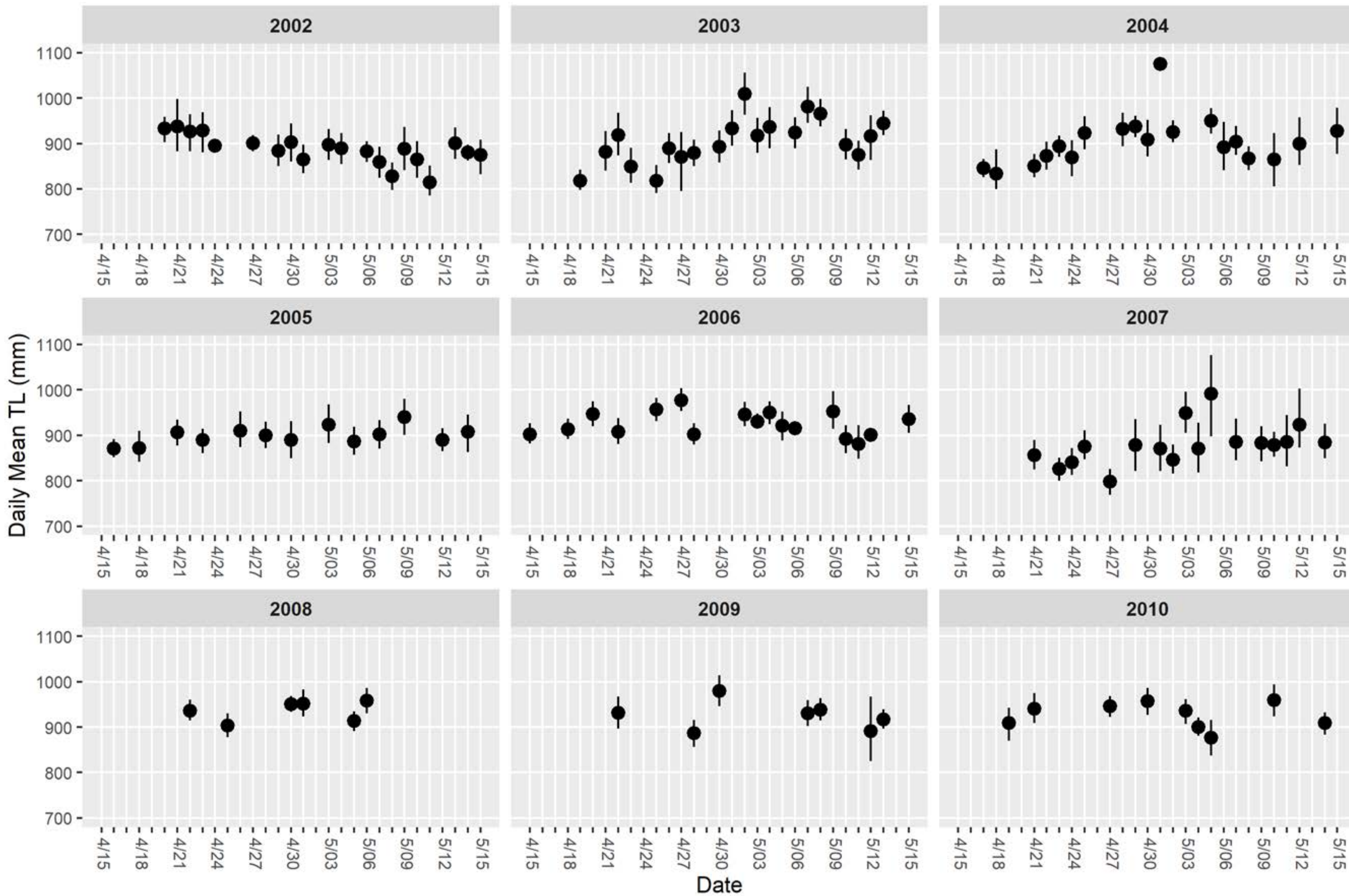


Figure 4. Continued.

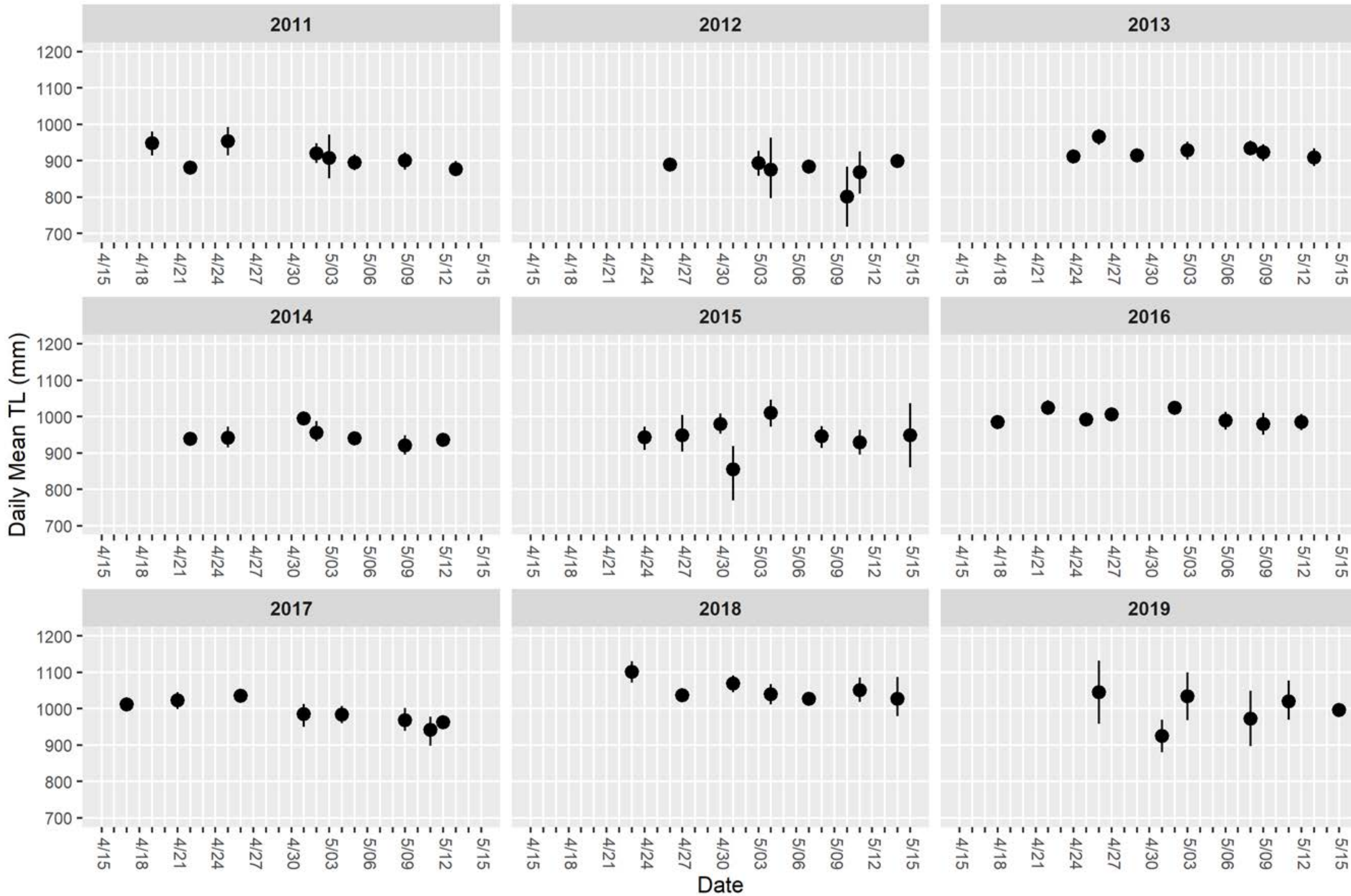


Figure 5. Mean weight of female and male striped bass (kg) with 95% confidence intervals sampled by the Maryland striped bass spring season creel survey, through May 15.

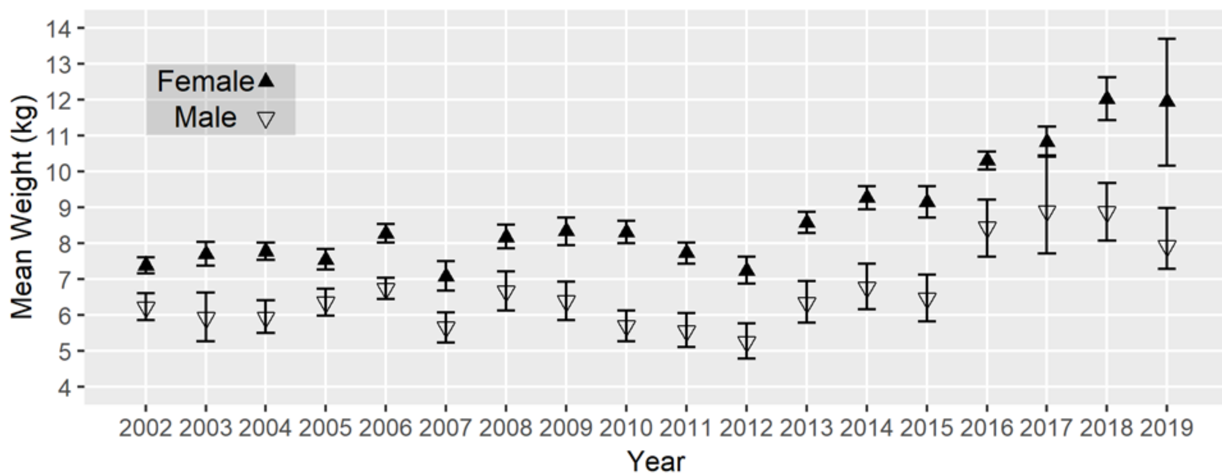


Figure 6. Estimated age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

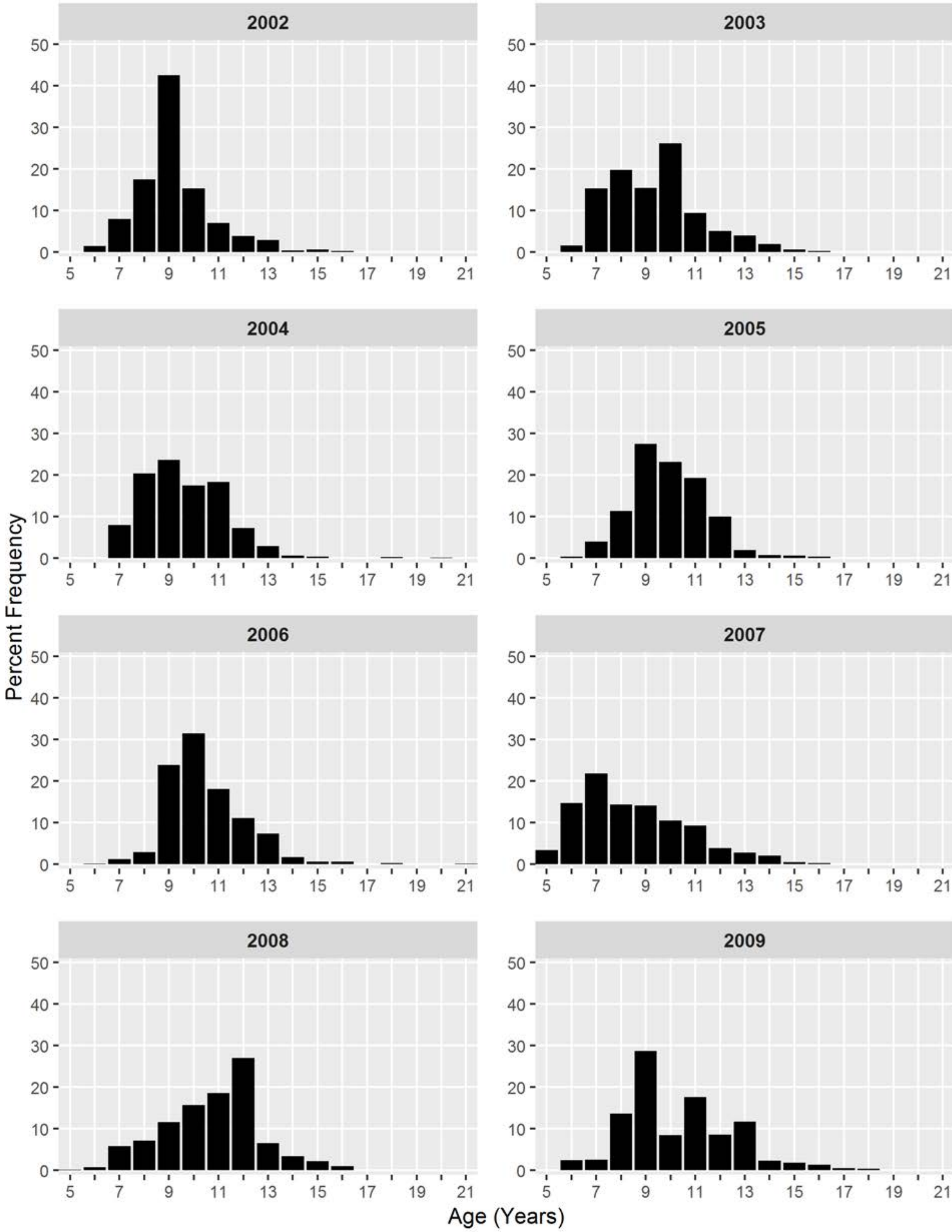


Figure 6. Continued.

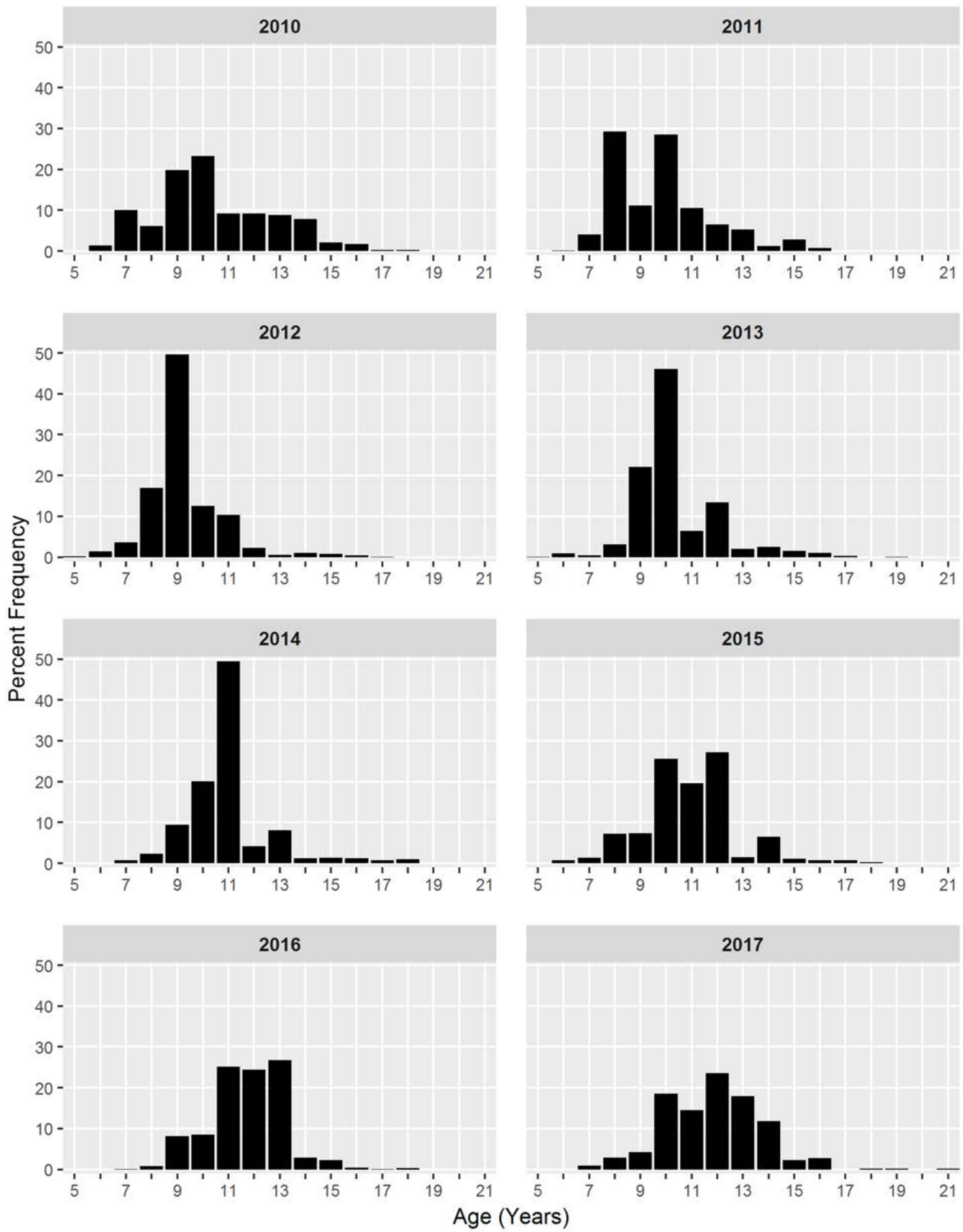


Figure 6. Continued.

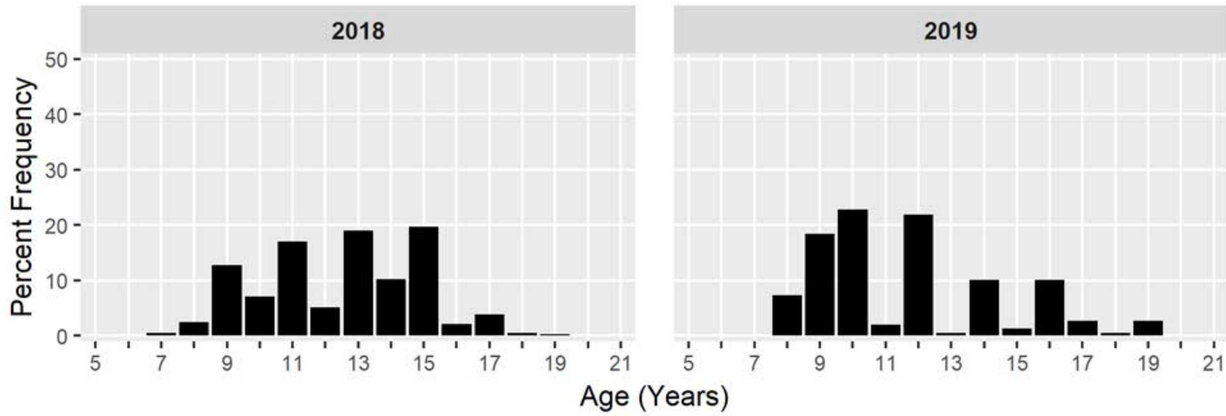


Figure 7. Daily percent of female striped bass in post-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

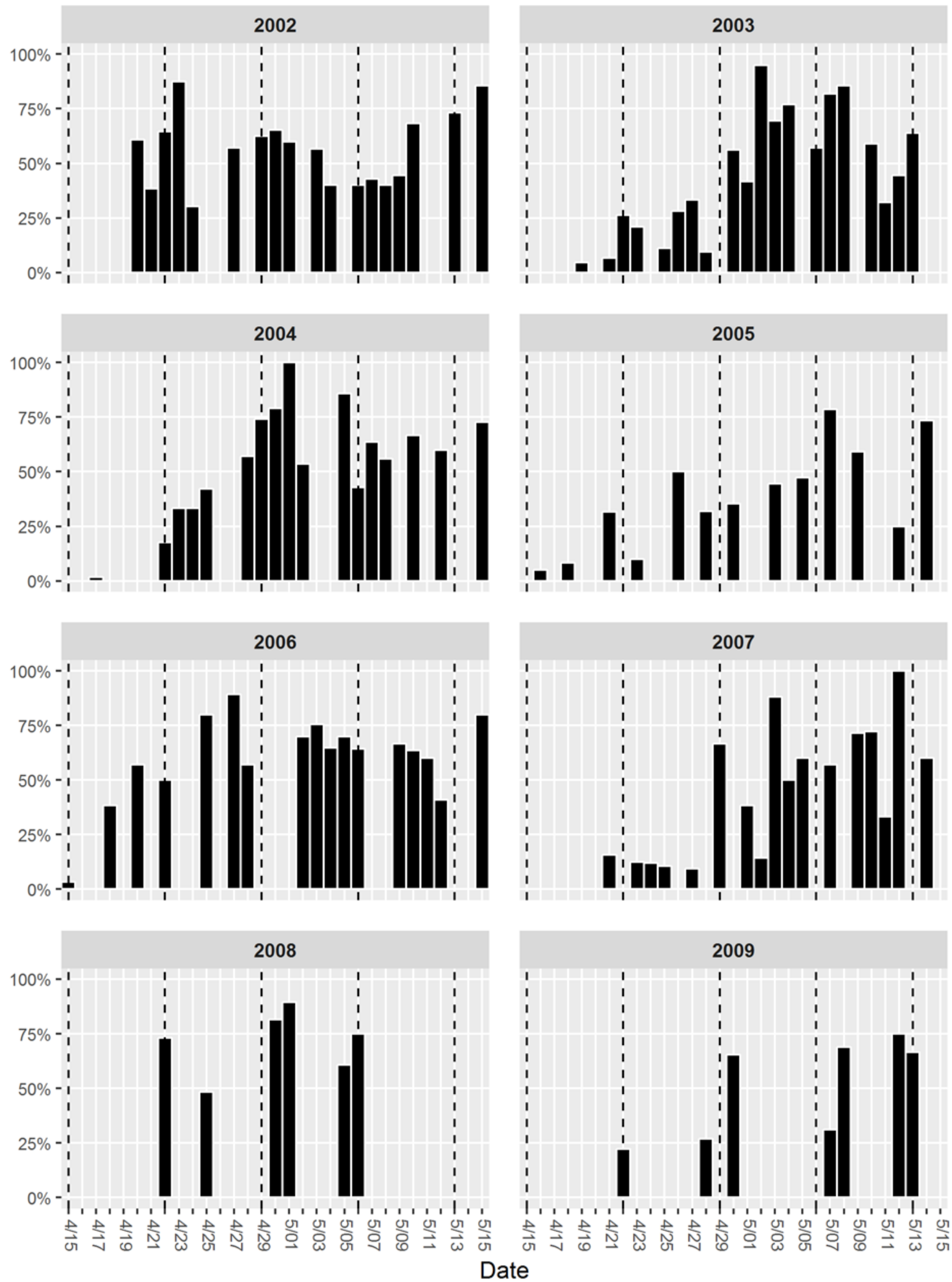


Figure 7. Continued.

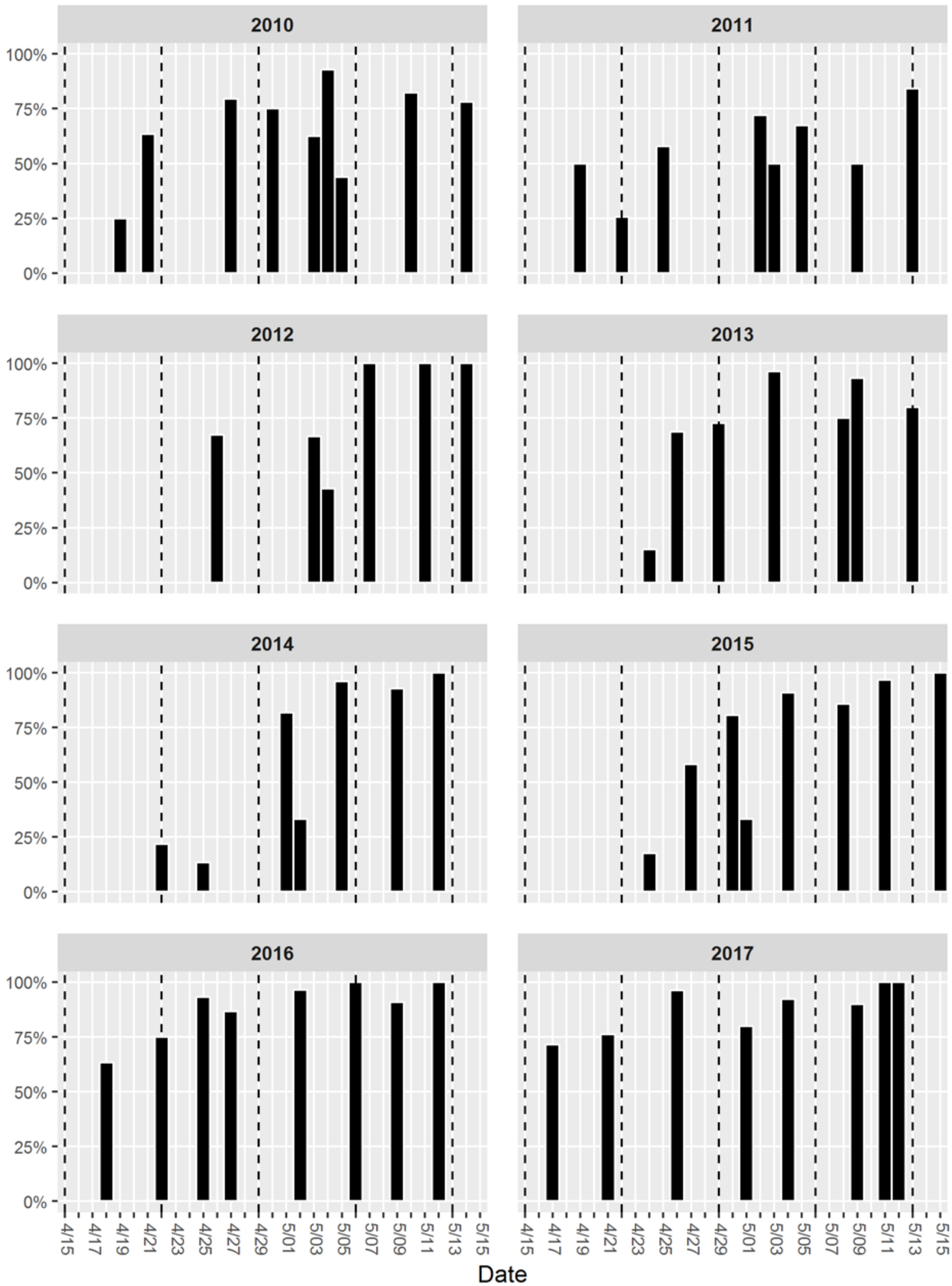
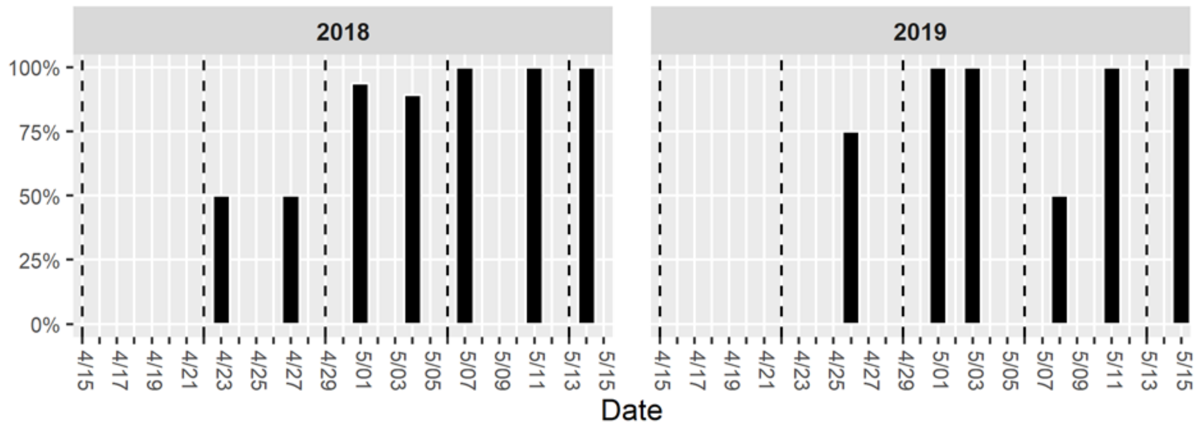


Figure 7. Continued.



PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDINATION

Prepared by Eric Q. Durell, Harry Rickabaugh, Robert J. Bourdon and Harry T. Hornick

The objective of Job 4 was to document and summarize participation of Survey personnel in various research and management forums regarding fifteen resident and migratory finfish species found in Maryland's Chesapeake Bay. With the passage of the Atlantic Coastal Fisheries Cooperative Management Act, various management entities such as the Atlantic States Marine Fisheries Commission (ASMFC), the Mid-Atlantic Migratory Fish Council (MAMFC), the Chesapeake Bay Living Resources Subcommittee (CBLRS), the Potomac River Fisheries Commission (PRFC), and the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC), require current stock assessment information in order to assess management measures. The Survey staff also participated in ASMFC, US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) fishery research and management forums.

Direct participation by Survey personnel as representatives to 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 thirteen finfish species as well as providing evidence of compliance with state and federal regulations. A summary of this participation and contributions is presented below.

Alosines:

Project staff attended SRAFRC meetings as Maryland representatives to discuss American shad and river herring stock status, restoration, and management in the Susquehanna River.

The ASMFC Technical Committee representative served as a member of the Plan Review Team, attended the American shad Technical Committee meetings and prepared the annual American Shad and River Herring Compliance Report for Maryland. The Technical Committee representative also presented results of American shad population modeling at the ASMFC benchmark stock assessment methods workshop. Alosine project staff prepared data, analyses, and a summary report for the American shad benchmark stock assessment.

Project staff served as a Maryland representative for the Atlantic Coast River Herring Collaborative Forum (formerly the River Herring Technical Expert Working Group), attending meetings.

Atlantic Croaker:

Project staff served on the Atlantic Croaker Technical Committee (TC), and prepared the ASMFC Annual Maryland Atlantic Croaker Compliance Report. The Technical Committee representative is also assigned to the Traffic Light Analysis (TLA) Subgroup of the TC and the Atlantic Croaker Pan Development team and assisted in the development Addendum III that included revisions to the TLA and developed coast wide regulation options to be enacted, should the TLA trip management action.

Atlantic Menhaden:

Project staff served on the ASMFC Plan Review Team, and prepared the Annual Maryland Atlantic Menhaden Compliance Report required by ASMFC.

Black Drum:

ASMFC Technical Committee representative prepared the Annual Black Drum Compliance Report for Maryland, and currently serves as Chair of the Technical Committee.

Bluefish:

The ASMFC Bluefish Technical Committee representative prepared the ASMFC Annual Bluefish Status Compliance Report for Maryland and provided Chesapeake Bay juvenile bluefish data to the Mid-Atlantic Fishery Management Council.

Red Drum:

Staff prepared the Maryland Red Drum Compliance Report required by ASMFC.

Spanish Mackerel:

Staff prepared the Maryland Spanish Mackerel Compliance Report required by ASMFC.

Spot:

Project staff served on the Spot Plan Review Team (PRT), and prepared the ASMFC Annual Maryland Spot Compliance Report. Staff member was also assigned to the Traffic Light Analysis (TLA) Subgroup of the PRT and the Spot Pan Development team and assisted in the development Addendum III that includes revisions to the TLA and developed coast wide regulation options to be enacted, should the TLA trip management action. Staff was also assigned to the newly created Spot Technical Committee, and serves as chair of that committee.

Spotted Seatrout:

Staff prepared the Maryland Spotted Seatrout Compliance Report required by ASMFC.

Striped Bass:

Project staff served on the ASMFC Striped Bass Tagging Sub Committee, the Interstate Tagging Committee, the ASMFC Bluefish Technical Committee, and as Maryland representatives to the Potomac River Fisheries Commission (PRFC) Finfish Advisory Board.

Project staff served as Maryland alternate representatives to the ASMFC Striped Bass Scientific and Statistical Committee, the Striped Bass Stock Assessment Subcommittee, and produced Maryland's Annual Striped Bass Compliance Report to the ASMFC.

Weakfish:

ASMFC Weakfish Technical Committee representative for Maryland participated in Weakfish Technical Committee conference calls, and prepared the ASMFC Annual Maryland Weakfish Compliance Report

PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDINATION

2020 PRELIMINARY RESULTS – WORK IN PROGRESS

A staff member was assigned to the newly created Spot Technical Committee (TC), and serves as chair of that committee. This staff member served on the Atlantic States Marine Fisheries Commission (ASMFC) Spot and Atlantic Croaker Plan Development Team in development of Addendum III to each species Fisheries Management Plan. This responsibility required participating in a conference call and continued email correspondence to draft and edit the documents in the reporting period. A staff member also served on the Atlantic Croaker Technical committee and Spot Plan Review Team, and as such attended one webinar to approve the draft addenda for ASMFC South Atlantic Board review. Staff also participated in one webinar of the ASMFC Weakfish Technical Committee to review sampling requirements required by the ASMFC Fisheries Management Plan for Weakfish. Staff participated in a conference call of the ASMFC red drum technical committee and stock assessment subcommittee and presented at the red drum simulation assessment data and methods workshop. A staff member participated in multiple shad and river herring technical committee conference calls to develop improvements to Amendments 2 and 3, to provide feedback on the 2020 benchmark stock assessment, and to develop management and monitoring changes in response to stock assessment results. Staff also participated in multiple conference calls of the Susquehanna River Anadromous Fish Restoration Cooperative Technical Committee to discuss fish passage issues, invasive species, and dam relicensing.

Staff completed and submitted ASMFC required compliance reports for alewife herring, American shad, Atlantic croaker, Atlantic menhaden, black drum, blueback herring, bluefish, red drum and striped bass. Staff reviewed state compliance reports to ASMFC fisheries management plans for alewife herring, American shad, blueback herring, Atlantic Menhaden and spot, and attended the corresponding conference calls, as members of the ASMFC plan review teams for those species.

Striped Bass Data Sharing and Web Page Development

To augment data sharing efforts, Striped Bass Program staff in 2002 developed a web page within the MD DNR web site presenting historical Juvenile Striped Bass Survey (Job 3) results. This effort has enabled the public to access Striped Bass Program data directly. In 2016, the Program's web presence was expanded to include individual pages for many surveys conducted by the Striped Bass Program. The new web pages added survey reports, species data, glossary, and information about the biologists. The new home page can be found at http://dnr.maryland.gov/fisheries/Pages/striped-bass/index.aspx.

Total page views to specific Striped Bass Program pages for the period January 2019 to December 2019 are provided in Table 1. The Juvenile Index survey page is still the most viewed page by visitors. A significant spike in page views occurred in late October coinciding with the issue of the striped bass juvenile index press release. Many large or complex data requests are still handled directly by Striped Bass Program staff. However, web page access to survey information has saved staff a considerable amount of time answering basic and redundant data requests.

Table 1. Visits to the Striped Bass Program's web pages (http://dnr.maryland.gov/fisheries/Pages/striped-bass/), January 2019 through December 2019.

Striped Bass Program Project Sites	Page Views
Juvenile Index (/juvenile-index.aspx)	1,793
Home Page (/index.aspx)	466
Volunteer Angler Survey (sb_survey.aspx)	514
Adult Spawning Stock Survey (/studies.aspx)	342
Recreational (/recreational.aspx)	229
Glossary (/glossary.aspx)	268
Commercial (/commercial.aspx)	294
Reports (/reports.aspx)	156
Biologists (/biologists.aspx)	66
Species (/species.aspx)	82
Total	4,235

Project staff also provided Maryland striped bass data and biological samples such as scale and finfish samples, to other state, federal, private and academic researchers. These included the National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), University of Maryland, University of Delaware, Virginia Institute of Marine Sciences, Georgetown University, and State management agencies. For the past contract year, (July 1, 2019 through June 30, 2020) the following specific requests for information have been accommodated:

-Atlantic States Marine Fisheries Commission (ASMFC).
Provision of striped bass juvenile index data; results from fishery dependent monitoring programs and age/length keys developed from results of fishery monitoring programs; updated striped bass fishery regulations; striped bass commercial fishery data, striped bass spawning stock CPUE data; current striped bass commercial fishery data. Staff also provided bluefish recruitment data to ASMFC.

-Mr. Alexander Aspinwall, VMRC. Provision of migrant striped bass harvest estimate and seasonal striped bass length frequencies and age-length keys from commercial and recreational fishery monitoring.

-Mr. Bob Murphy, Chesapeake Research Consortium Center for Ecological Sciences. Provision of raw data from Spring Spawning Stock Survey and Juvenile Seine Survey.

-Ms. Barbara Hutniczak, Organization for the Economic Cooperation and Development. Provision of recreational striped bass catch-at-age estimates and age-length-keys for Chesapeake bay.

-Ms. Lauren Rodriguez, University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory. Provision of Juvenile Seine Survey data.

- Maryland Charterboat Association (MCA). Provision of striped bass fishery regulations, striped bass recreational, and charter boat harvest data.

-Ms. Alexandra Fries, University of Maryland Center for Environmental Science. Provision of bay anchovy data from the Juvenile Seine Survey.

-Mr. Marty Gary, Potomac River Fisheries Commission (PRFC).
Provision of striped bass juvenile survey data, commercial harvest data and commercial regulation information.

-Mr. David Sikorski, CCA, Maryland. Provision of striped bass harvest estimates and striped bass juvenile survey data.

-The Striped Bass Program staff also provided biological information and related reports to nineteen (19) additional scientists, students and concerned stakeholders.

Atlantic Sturgeon, Shortnose Sturgeon and Sea Turtle Interaction Summary for Chesapeake Bay Finfish Investigations
Project No.: F-61-R-15

Prepared by Paul G. Piavis, Harry W. Rickabaugh, Eric Q. Durell, Robert J. Bourdon and Harry T. Hornick

Summary

The primary objective of the Chesapeake Bay Finfish Investigations Survey, F-61-R-15, was to monitor and biologically characterize resident and migratory finfish species in the Maryland portion of the Chesapeake Bay during the 2019 – 2020 sampling season. The F-61-R Survey provides a long-term series of annual reports that provide information regarding recruitment, relative abundance, age and size structure, growth, mortality, and migration patterns of finfish populations in Maryland's Chesapeake Bay. This intent of this particular report is to summarize any interactions of these biological surveys with endangered species such as Atlantic sturgeon, shortnose sturgeon, and sea turtles. During the 2019 – 2020 sampling season, there were no documented Atlantic sturgeon, shortnose sturgeon or sea turtle encounters.

CONTENTS:

PROJECT I: RESIDENT SPECIES STOCK ASSESSMENT

JOB 1: Population vital rates of resident finfish in selected tidal areas of Maryland's Chesapeake Bay.

JOB 2: Population assessment of white perch in select regions of Chesapeake Bay, Maryland.

PROJECT 2: INTERJURISDICTIONAL SPECIES STOCK ASSESSMENT

JOB 1: Alosa Species: Stock assessment of adult and juvenile anadromous *Alosa* species in the Chesapeake Bay and selected tributaries.

JOB 2: Migratory Species: Stock assessment of selected recreationally important adult migratory finfish in Maryland's Chesapeake Bay.

JOB 3: Striped Bass: Stock assessment of adult and juvenile striped bass in Maryland's Chesapeake Bay and selected tributaries.

Task 1: Summer-Fall stock assessment and commercial fishery monitoring.
Task 2: Characterization of striped bass spawning stocks in Maryland.
Task 3: Maryland juvenile striped bass survey.

<u>PROJECT I</u>: **RESIDENT SPECIES STOCK ASSESSMENT**

JOB 1: Population vital rates of resident finfish in selected tidal areas of Maryland's Chesapeake Bay.

JOB 2: Population assessment of white perch in select regions of Chesapeake Bay, Maryland.

<u>Introduction</u>

The objective of Project 1, Job 1 is to determine population vital rates (relative abundance, age, growth, mortality, and recruitment) of yellow perch, white perch, and catfish species in tidal regions of Chesapeake Bay. Job 2 is a rotational, triennial stock assessment of yellow perch (integrated analysis), white perch (catch survey analysis) or channel catfish (surplus production modeling). However, all data collections and surveys are performed under Job1.

Research Surveys:

1. Upper Chesapeake Bay Winter Trawl
2. Fishery Dependent Yellow Perch Fyke Net Survey
3. Fishery Independent Choptank River Fyke Net Survey

1. Upper Chesapeake Bay Winter Trawl Survey

<u>Atlantic Sturgeon Interactions</u>

No Atlantic sturgeon were sampled or observed in the Upper Chesapeake Bay Winter Trawl Survey during the Survey period of July 1, 2019 through June 30, 2020.

<u>Shortnose Sturgeon and Sea Turtle Interactions</u>

No shortnose sturgeon or sea turtles were sampled or observed in the Upper Chesapeake Bay Winter Trawl Survey during the Survey period of July 1, 2019 through June 30, 2020.

2. Fishery Dependent Yellow Perch Fyke Net Survey

Atlantic Sturgeon Interactions

This survey is performed with the cooperation of commercial fishermen and the objective is to collect commercial catch at age and length data of yellow perch. No data on other species are collected. However, no Atlantic sturgeon were sampled or observed in the Commercial Fyke Net Survey during the Survey period of July 1, 2019 through June 30, 2020.

Shortnose Sturgeon and Sea Turtle Interactions

This survey is performed with the cooperation of commercial fishermen and the objective is to collect commercial catch at age and length data of yellow perch. No data on other species are collected. However, no shortnose sturgeon or sea turtles were sampled or observed in the Commercial Fyke Net Survey during the Survey period of July 1, 2019 through June 30, 2020.

3. Fishery Independent Choptank River Fyke Net Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed in the Choptank River Fyke Net Survey during the Survey period of July 1, 2019 through June 30, 2020.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed in the Choptank River Fyke Net Survey during the Survey period of July 1, 2019 through June 30, 2020.

PROJECT 2: INTERJURISDICTIONAL SPECIES STOCK ASSESSMENT

JOB 1: Alosa Species: Stock assessment of adult and juvenile anadromous *Alosa* in the Chesapeake Bay and select tributaries.

Research Surveys:

1. Nanticoke River Pound/Fyke Net Survey
2. Nanticoke River Ichthyoplankton Survey

1. Nanticoke River Pound/Fyke Net Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during the Survey period of this project from July 1, 2019 through June 30, 2020.

Shornose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of this project from July 1, 2019 through June 30, 2020.

2. Nanticoke River Ichthyoplankton Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during the Survey period of July 1, 2019 through June 30, 2020.

Shornose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of July 1, 2019 through June 30, 2020.

PROJECT 2:

JOB 2: Migratory Species: Stock assessment of selected recreationally important adult migratory finfish in Maryland's Chesapeake Bay.

Research Survey:

1. **Summer Pound Net Survey**

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during the Survey period of July 1, 2019 through June 30, 2020.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles sampled or observed during the Survey period of July 1, 2019 through June 30, 2020.

Project 2, JOB 3: **Striped Bass: Stock assessment of adult and juvenile striped bass in Maryland's Chesapeake Bay and selected tributaries.**

Task 1: Summer-Fall stock assessment and commercial fishery monitoring.

Research Survey:

1. **Summer - Fall Pound Net Survey**

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during this Survey for the period of July 1, 2019 through June 30, 2020.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of July 1, 2019 through June 30, 2020.

Task 2: Characterization of striped bass spawning stocks in Maryland.

Research Survey:

1. Spring Striped Bass Experimental Drift Gill Net Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during this Survey for the period of July 1, 2019 through June 30, 2020.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of July 1, 2019 through June 30, 2020.

Project 2, Job 3,

Task 3: Maryland juvenile striped bass survey

Research Survey:

1. Juvenile Striped Bass Seine Survey

Atlantic Sturgeonn Interactions

No Atlantic sturgeon were sampled or observed during this Survey for the period of July 1, 2019 through June 30, 2020.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of July 1, 2019 through June 30, 2020.