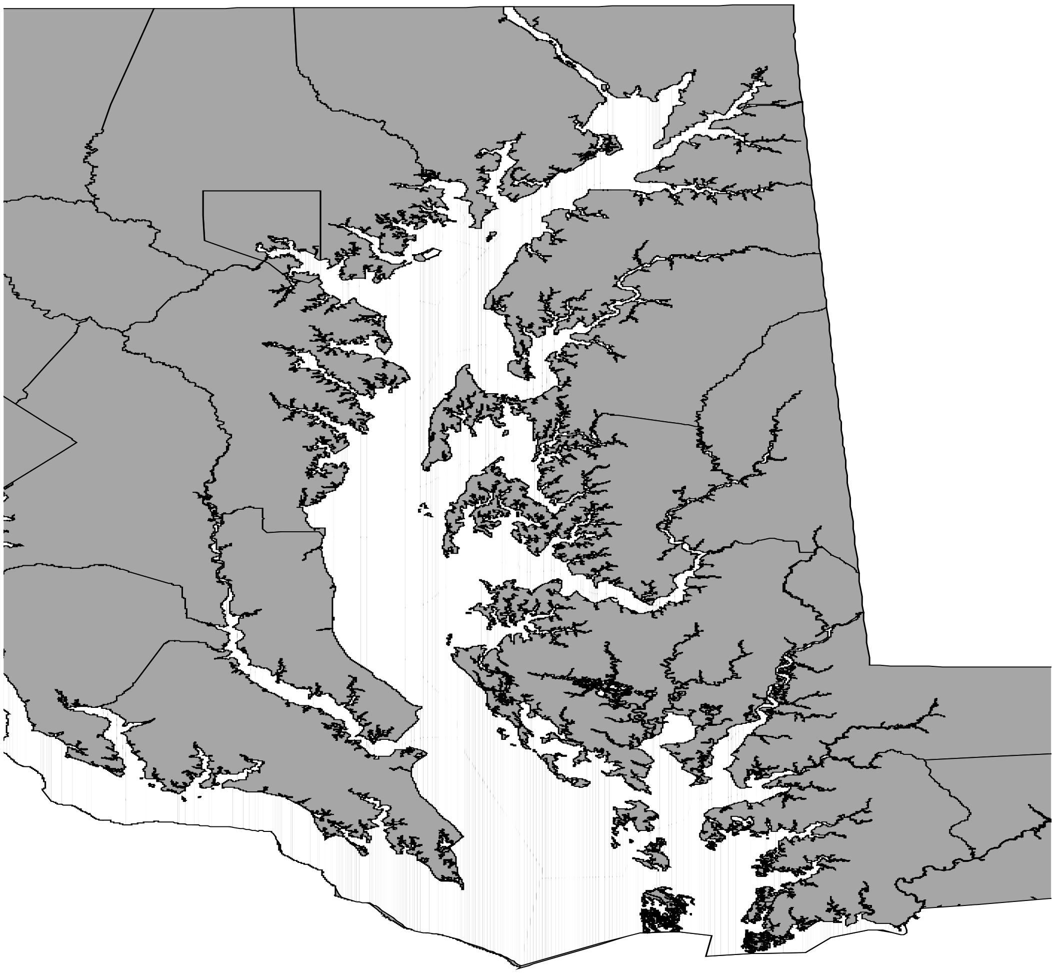

Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-14
2018 - 2019

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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

STATE: Maryland

PROJECT NO.: F-61-R-14

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PROGRESS: ANNUAL X

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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 2018 indicated that white perch relative abundance increased relative to 2017 and remained at high levels. The 2018 relative abundance value was the third highest in the 18 year time series. The 2011, 2014 and 2015 white perch year-classes were particularly strong. Age 1 white perch (2017 year-class) relative abundance was the fifth highest in the time series. Yellow perch relative abundance declined relative to 2017 and was more similar to levels seen during 2012 – 2014. The 2011, 2014 and 2015 yellow perch year-classes were strong. Recruitment in 2018 (age 1 yellow perch) was weak. Channel catfish relative abundance also declined and was below the time-series average, but increased slightly from 2017. Recruitment in 2017 (age 1 channel catfish) was weak.

Results from the Choptank River Fyke Net Survey in 2018 indicated that white perch relative abundance was stable compared to 2017. The 2018 relative abundance was generally higher than the period of 2011 – 2014. Similar to the upper Bay trawl, the 2011, 2014, and 2015 year-classes were strong. Yellow perch relative abundance was low in 2018, but somewhat higher than 2017 when catches were impacted by the extra-ordinarily warm February and March time period. Strong year-classes included 2011 and 2015 while the 2012, 2013 and 2016 year-classes were particularly weak. Channel catfish relative abundance increased relative to 2017 but was below the time-series average (19 year time series). White catfish relative abundance was above the time series average, but declined slightly from 2017. However, overlapping 95% confidence intervals suggest that the population was stable above average levels.

Channel catfish population dynamics were modeled with a Surplus Production model for the upper Chesapeake Bay. Population dynamics of channel catfish in the Choptank River were modelled with a Catch Survey Analysis. In the upper Chesapeake Bay, total population size exhibited a strong increasing trend since 2015 and biomass estimates were the highest of the time series (1980 – 2017). Estimated fishing mortality (F) was relatively low. Current results suggested that the stock was not overfished and that over fishing was not occurring. The Choptank River assessment indicated that that total population abundance declined after reaching a peak in 2011 (time series = 1989 – 2017), but total population abundance remained above the time series median. Pre-recruit abundance, the ultimate driver of exploitable biomass, was particularly low in 2017. During the decline, fishing mortality estimates were low and below suggested targets. This suggests that something other than fishing caused the decline. Most likely reasons were sustained reproductive failure or competition from invasive blue catfish.

Channel catfish population dynamics were inferred from fishery dependent trends in the lower Chesapeake Bay. Nanticoke River channel catfish relative abundance declined in 2017, but remained above the 75th percentile. Pocomoke River channel catfish relative abundance was between the 50th and 75th percentile, but the available time series was far shorter than other river systems. Patuxent River channel catfish relative abundance declined rapidly from 2014 to 2017 and was below median levels. The decline was concurrent with increasing blue catfish commercial landings. Potomac River channel catfish relative abundance from a fishery independent gill net survey indicated extremely low population levels. Commercial channel catfish landings were below 100,000 pounds in 2016 and 2017 compared to more than 400,000 pounds in 1987. Blue catfish landings increased to greater than 2,000,000 pounds in 2017.

U.S. Atlantic coastwide 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. American shad were angled from the Susquehanna River below Conowingo dam from 26 April through 1 June 2018, and 160 were successfully scale-aged. The 2013 (age 5) year-class was the most abundant for both male and female American shad in 2018. Estimates of abundance for American shad in the lower Susquehanna River decreased slightly in 2018, and remain well below time-series peak values observed in the early 2000's. Relative abundance of American shad in the Potomac River has significantly increased over the time series (1996-2018), and remained above average in 2018. American shad relative abundance in the Nanticoke River was not calculated; the sampling site required for this calculation was not visited by a commercial waterman partner in 2018. Relative abundance from 1988-2017 was highly variable and showed no significant trend over the time series. In 2018, the juvenile American shad abundance index increased in all systems surveyed, including the Upper Chesapeake Bay, Nanticoke River, and Potomac River. The Potomac River American shad juvenile abundance index continues to be the highest index in Maryland's portion of Chesapeake Bay.

Previously, hickory shad age structure has remained relatively consistent, with a wide range of ages and a high percentage of older fish. However, the past seven years (2012-2018) have seen no hickory shad over age seven. This suggests the age structure of hickory shad has become truncated in recent years.

Biologists sampled alewife and blueback herring from commercial pound and fyke nets in the Nanticoke River from 5 March through 30 April 2018. River herring CPUE in the Nanticoke River has declined over the time series (1989-2018) 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 2013-2018 to assess the river herring spawning stock in the upper Chesapeake Bay. The gill net was fished at four randomly chosen sites once a week from 15 March to 16 May 2018. Relative abundance of alewife increased in the North East River in 2018 while blueback herring relative abundance decreased. The 2014 year-class (age 4) was most abundant for the spawning stock of alewife, while the 2015 year-class (age 3) was most abundant for blueback herring. Juvenile abundance indices indicate that alewife and blueback herring recruitment increased in all systems surveyed in 2018, including the Upper Chesapeake Bay and Nanticoke 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. Harvest has fluctuated at a very low level from 2007 through 2017, with an estimated 9,170 weakfish harvested in 2017. The 2017 Maryland Chesapeake Bay commercial weakfish harvest of 219 pounds was well below the 1981 – 2017 Maryland Chesapeake Bay average of 42,501 pounds per year. The 2018 mean length for weakfish from the onboard pound net survey was 265 mm TL, the sixth lowest value of the time series. Three weakfish ranging from 274 to 281 mm TL was captured in the Choptank River gill net survey in 2018.

Summer flounder mean length from the pound net survey was 250 mm TL in 2018, which was the second lowest value in the time series. No summer flounder were measured during fish house sampling in 2018. Only four summer flounder were captured in the Choptank River gill net survey in 2018. The NMFS 2016 coast wide stock assessment update concluded that summer flounder stocks were not overfished, but overfishing was occurring.

Mean length of bluefish from the onboard pound net survey in 2018 was 291 mm TL, and was the sixth lowest value in the time-series. The length distribution indicated a shift back to smaller bluefish in 2016 through 2018. Only two bluefish were sampled from seafood dealer sampling measuring 297 and 368 mm TL, and weighing 249 and 440 grams. Eleven bluefish were captured in the Choptank River gill net survey in 2018. Bluefish have been encountered in low numbers all six years of the survey (3 – 24 fish per year). Reported Maryland bluefish commercial and charter boat harvest and inland recreational estimates in 2017 were all well below their time series means. The 2015 coast wide stock assessment update indicated the stock was not overfished and overfishing was not occurring.

The mean length of Atlantic croaker examined from the onboard pound net survey in 2018 was 271 mm TL, and was the seventh lowest value of the 26 year time series. Atlantic croaker sampled from seafood dealers had a mean total length and weight of 293 mm and 408 grams. 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 2018 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 only eight fish being captured in 2018. Maryland 2017 Atlantic croaker Chesapeake Bay commercial harvest, inland waters recreational harvest estimate and charter boat harvest values all declined from 2016, and all three were well below their long term means. The Atlantic croaker juvenile index had decreased steadily from 2012 to 2015. The juvenile index value increase to near the time series mean in 2017, but declined again in 2018.

The 2018 spot mean length of 180 mm TL was the third lowest value of the time-series, and the length frequency truncated in 2108. Spot aged from the onboard pound net survey were predominately age zero, with no age two fish encountered. Spot catch in the Choptank River gill net survey was highest in 2014, moderate in 2013 and 2017, and low in 2015, 2016 and 2018. Chesapeake Bay commercial spot harvest increased in 2017, but remained below the time series mean. The inland waters recreational harvest estimate in 2017 increased and was above 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 30 year time-series. The 2017 and 2018 index values increased, but were still below the time series mean.

Mean length for Atlantic menhaden sampled from the onboard pound net survey in 2018 was 231 mm FL, the sixth lowest value of the 15 year time-series. The 2017 and 2018 length frequency distributions were dominated by the 190, 210 and 230 millimeter size groups, and were less evenly distributed than in 2016. 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 (2016) to 2,257 fish (2018). Mean lengths for all meshes combined displayed little inter-annual variation, with the exception of 2017; which was slightly skewed to smaller fish. 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 2017 season ranged in age from 2 to 13 years old. Two year old (2015 year-class), three year old (2014 year-class), five year old (2012 year-class) and six year old (2011 year-class) striped bass dominated biological samples taken from pound nets and made up 83% of the sample. Check station sampling determined that the commercial summer/fall fishery harvest was comprised of three to twelve year-old striped bass from the 2004 through 2014 year-classes.

The December 2017 - February 2018 commercial drift gill net harvest consisted primarily of age 6, 7, and 8 year-old striped bass from the 2012, 2011 and 2010 year-classes that composed 85% of the total harvest. The contribution of fish older than age 9 was 8% for the gill net fishery. The youngest fish observed in the 2017-2018 sampled harvest were age 3 from the 2015 year-class. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 3 to 13 years old (2015 to 2005 year-classes).

Striped bass harvested during the 2017-2018 Atlantic coast commercial fishing season ranged from age 4 (2014 year-class) to age 20 (1998 year-class) with seventeen different year-classes represented in the sampled harvest. The most common age represented in the catch-at-age estimate was age 7, of the 2011 year-class, which represented 22% of the sampled harvest. Age 13 (2005 year-class) fish were also a significant contributor to the sample population at 17%. Striped bass sampled at Atlantic coast check stations during the 2017 – 2018 season had a mean length of 919 mm TL and mean weight of 9.3 kg.

The spring 2018 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 22 years old. Male striped bass ranged in age from 2 to 14 years old and females ranged in age from 5 to 22. Age 15 females from the above average 2003 year-class were most commonly observed, followed by age 7 females from the dominant 2011 year-class. The contribution of age 8+ females to the total female CPUE was 63%. The contribution of females age 8 and older to the spawning stock has been at or above 80% since 1996, with the exception of 2011, 2013, 2016, 2017 and 2018. The time-series average is 71%. The large numbers of females from the 2011 year-class entering the spawning stock and being encountered during the survey has likely contributed to the lower values in recent years.

The striped bass young-of-year index, a measure of striped bass spawning success in Chesapeake Bay, was 14.8 in 2018. The 2018 index was above the 65-year average of 11.8. MD DNR biologists have conducted the Young-of-Year Survey annually since 1954 to track the reproductive success of striped bass and help predict future population abundance. The largest spawning area, the Upper Bay, was also the most productive area surveyed in Maryland in 2018. Strong reproduction in five of the past eight years is an encouraging sign for the coastal population and for future fishing opportunities. During the 2018 survey, biologists collected over 36,000 fish of 55 different species, including 1,951 young-of-year striped bass. Results also showed that white perch and American shad also experienced above-average spawning success in the spring.

During the 2018 spring recreational trophy season, biologists intercepted 41 charter fishing trips and examined 118 striped bass. The average total length of striped bass sampled from the spring trophy fishery was 1037 mm total length. The average weight was 11.7 kg. Striped bass sampled from the spring trophy fishery ranged in age from 7 to 19 years old. The 2003 year-class (age 15) was the most frequently observed cohort, constituting 20% of the sampled harvest. In 2018, private boats caught an average of 0.7 fish per trip, while charter boats caught 4.4 fish per trip. The private boat catch per hour (CPH) was 0.1 fish per hour while charter boats had a CPH of 0.8 fish per hour.

Maryland Department of Natural Resources biologists continued to tag and release striped bass in spring 2018 in support of the US FWS coordinated interstate, coastal population study. A total of 2,427 striped bass were sampled and 1,080 striped bass were tagged and released with US FWS internal anchor tags March 30 through May 16, 2018 in Maryland. Of this sample, 369 were tagged in the Potomac River and 711 were tagged in the upper Chesapeake Bay area during the spring spawning stock assessment survey. A total of 667 striped bass were tagged from January 24 through February 15, 2018 during the US FWS cooperative offshore tagging cruise.

APPROVAL

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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 Normandeau Associates, Inc. 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. We would also like to thank Captain Rick Younger and crew of the *R/V Kerhin*, and Captain Michael Simonsen and crew of the *R/V Chesapeake*, for their assistance during the winter trawl survey.

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 Robert A. Boarman, on the Potomac River and B. Owen Clark, III on the Upper Chesapeake Bay.

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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 2018 through February 2018.

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. 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 2018, 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 20 February through 13 April (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 17 February 2018 in the Patapsco River area (Figure 3) and the Gunpowder River (Figure 4); the Gunpowder River on 22 February; the Bush River on 28 February 2018 (Figure 5). 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 5 March 2018 to 30 April 2018. 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 6). 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. Cooperating commercial fishermen only set fyke nets during 2018. All previous data were collected from fyke nets and pound nets.

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 (white perch) 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 and 2018 in 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 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 2017) 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 1+ abundance in the winter trawl survey. Any yellow perch < 130 mm, white perch < 110 mm, and channel catfish < 135 mm were assumed 1+. 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
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PROJECT NO. 1
JOB NO. 1

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

2019 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 62 of the 138 proposed tows. The reduced number of tows completed was due in part to the federal shutdown which delayed the start of sampling by three weeks. The survey utilizes a vessel leased from NOAA which had to remain in port until the federal government was reopened. In addition, portions of the upper Bay was iced over from Worton Point north making it impossible to sample. Sites on the Chester River were not sampled as we prioritized sites by historical catches to maximize sampling at historical sites. The trawl survey began January 25, 2019 and concluded on February 11, 2019. The survey collected 16,996 white perch, yielding 2,106 length measurements and 176 age samples (otoliths). Yellow perch numbered 925 with 804 length measurements and 76 age samples (otoliths). The catfish complex yielded 1,743 channel catfish (833 measurements), 32 white catfish (31 measurements) and 28 blue catfish (27 measurements).

Three sampling days were allocated to characterize the commercial yellow perch fishery. However, 4,524 yellow perch were measured and 164 fish were sacrificed for age determination. Areas sampled included the Gunpowder River (February 26 and 28, 2019) and the Bush River (February 23, 2019).

The Choptank River fyke net survey started February 22, 2019 and ended April 10, 2019. A total of 12,265 white perch were collected, yielding 2,915 length measurements and 155 age samples. Yellow perch numbered 1,352 (1,351 measurements and 132 ages); channel catfish numbered 661 (645 measurements) and white catfish numbered 576 (576 length measurements).

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. The data are currently being entered into a database and will be analyzed when available.

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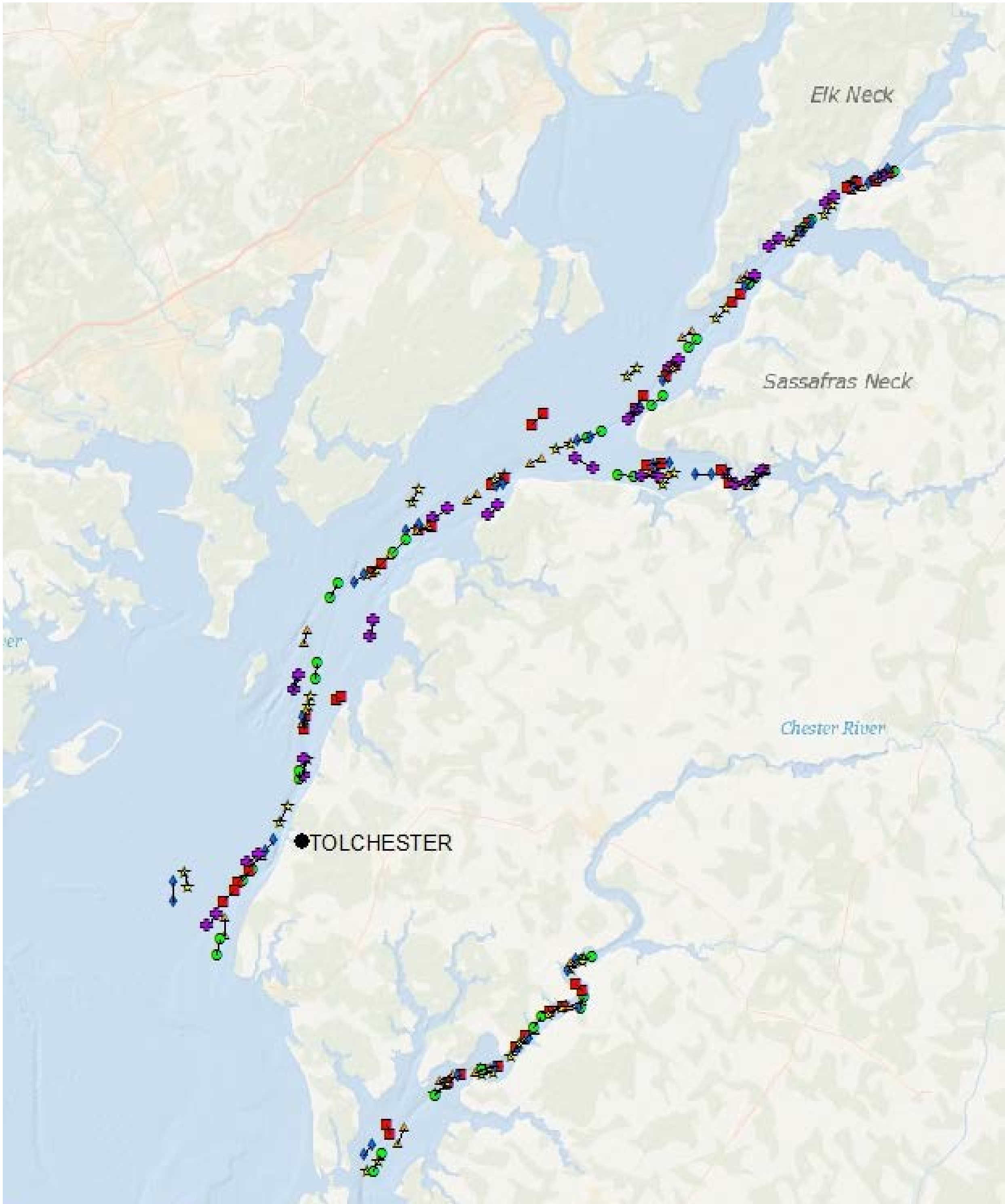

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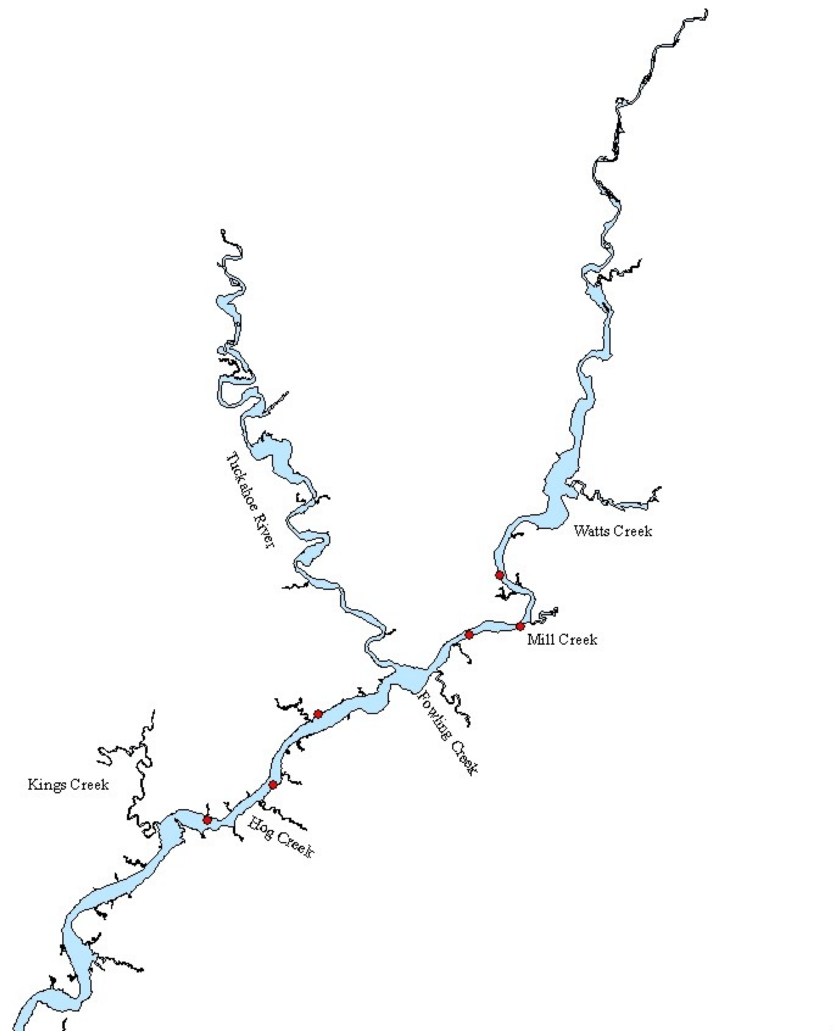

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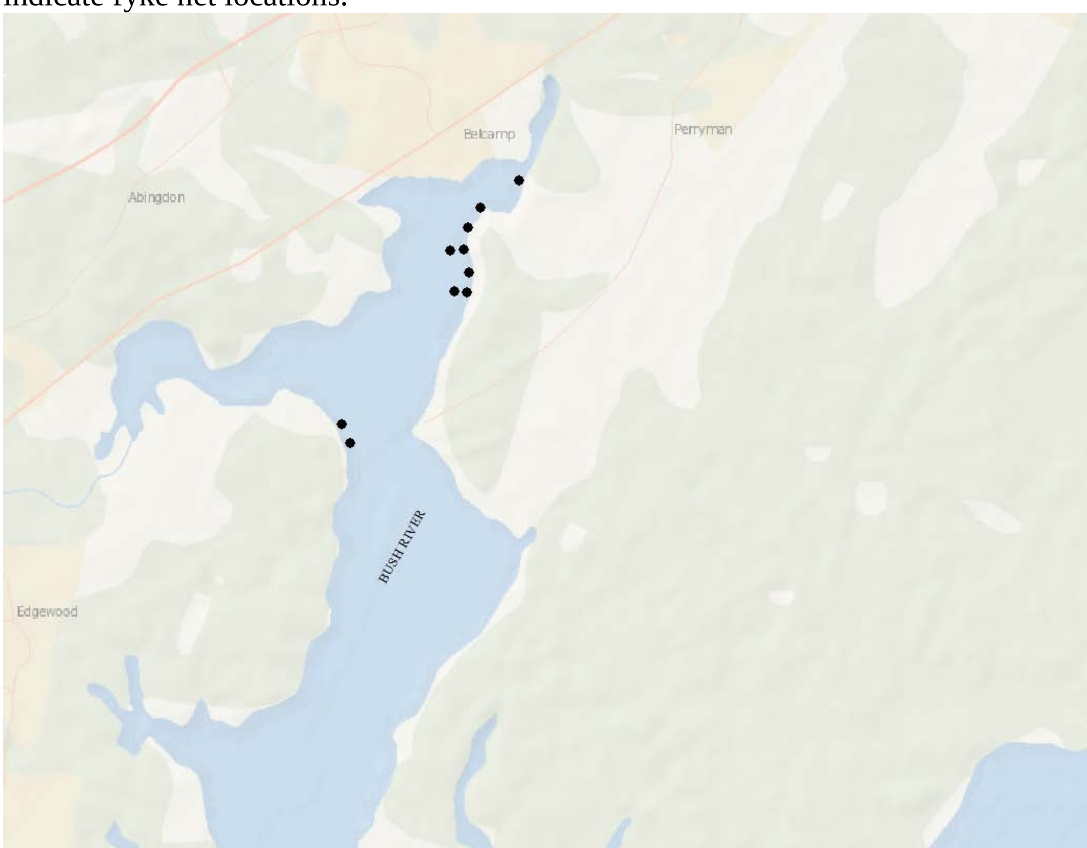

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Table 1. White perch catch-at-age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2018.

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

Table 2. White perch catch-at-age matrix from Choptank River fyke net survey, 2000 – 2018.

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

Table 3. White perch catch-at-age matrix from Nanticoke River fyke and pound net survey, 2000 – 2018. 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

Table 4. Yellow perch catch at age from upper Chesapeake Bay winter trawl survey, 2000 – 2018.

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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2018.

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

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2018.

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

Table 7. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2018. 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

Figure 7. White perch length-frequency from 2018 upper Chesapeake Bay winter trawl survey.

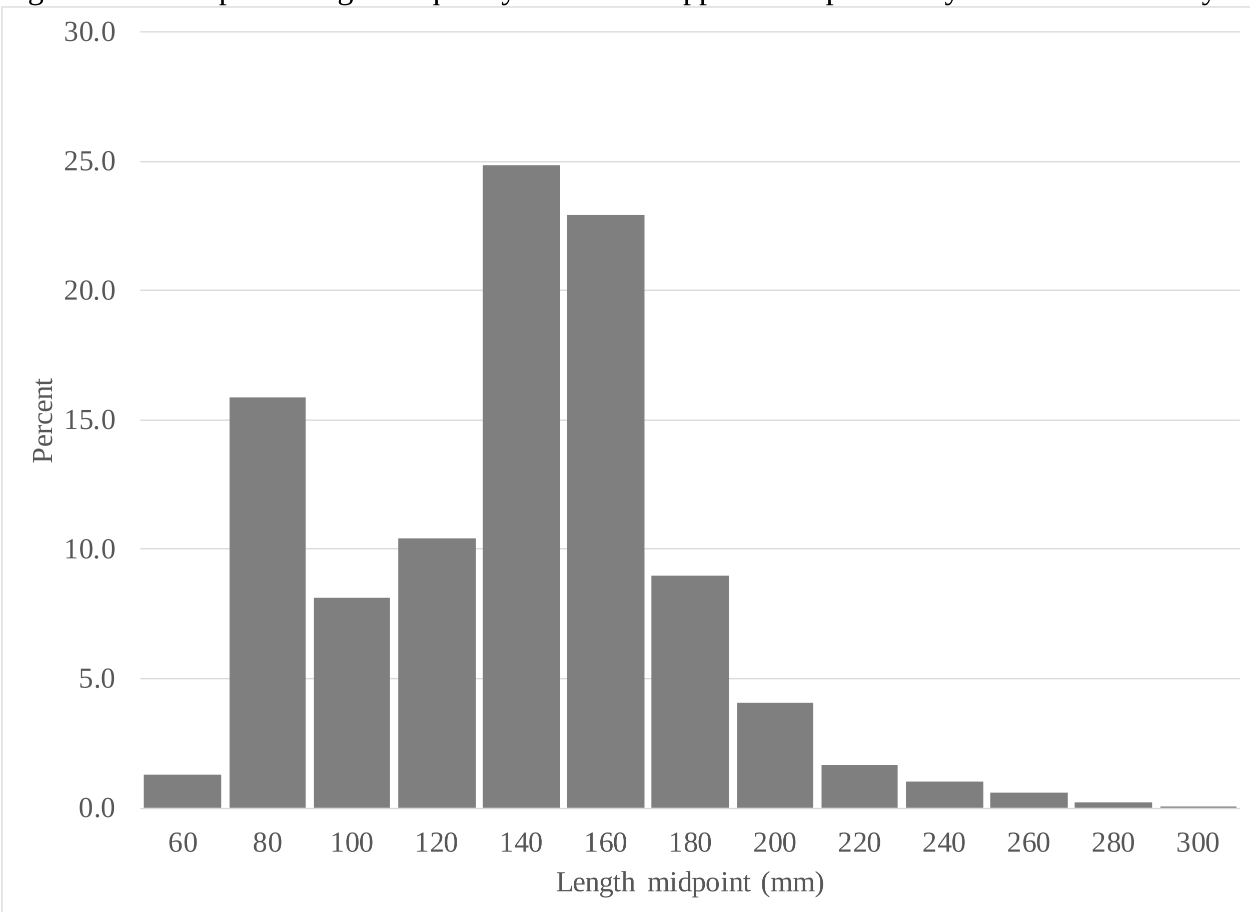


Table 8. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2018. Minimum length cut-offs in parentheses.

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

Figure 8. White perch length-frequency from 2018 Choptank River fyke net survey.

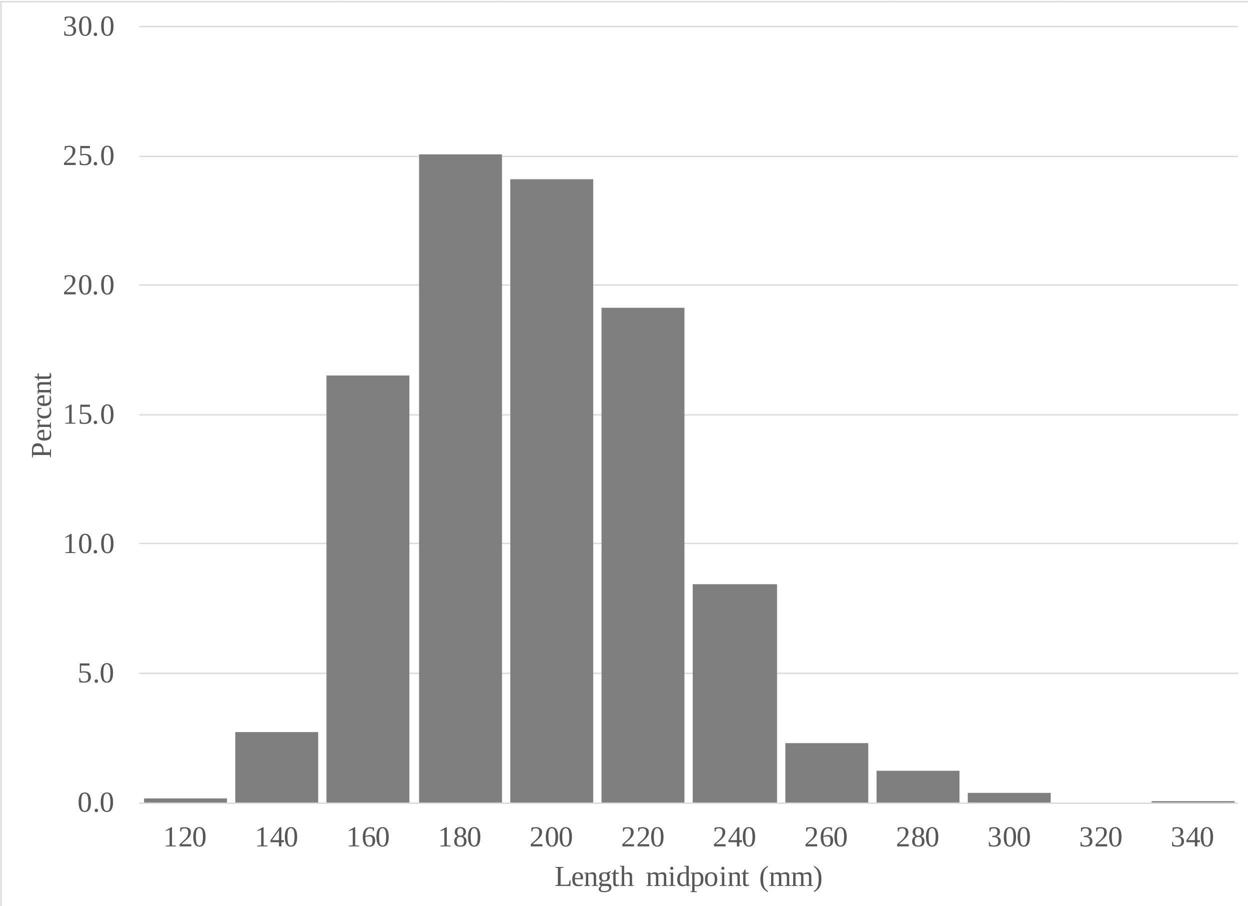


Table 9. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2018. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

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

Figure 9. White perch length-frequency from 2018 Nanticoke River fyke and pound net survey.

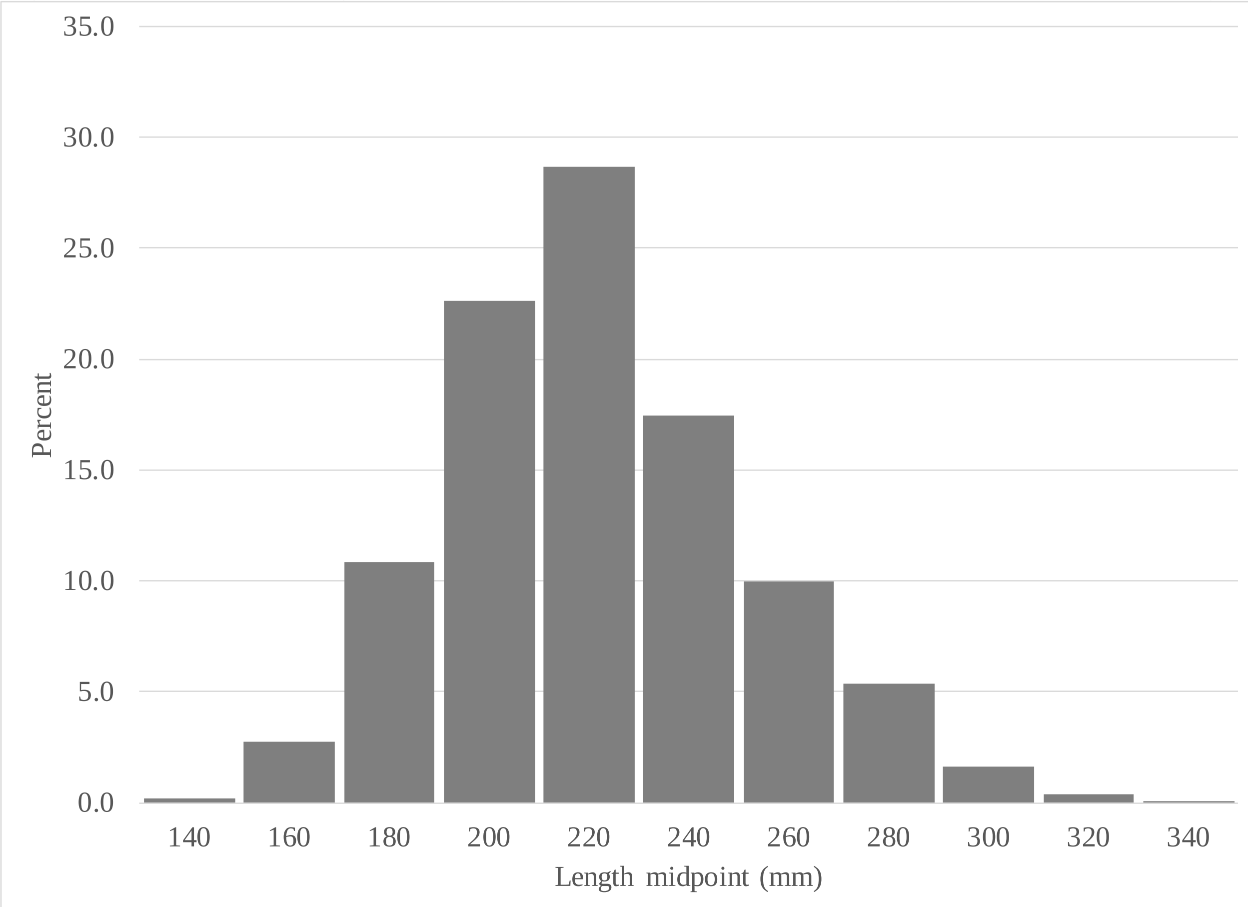


Table 10. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2018. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length-frequency from the 2018 upper Chesapeake Bay winter trawl survey.

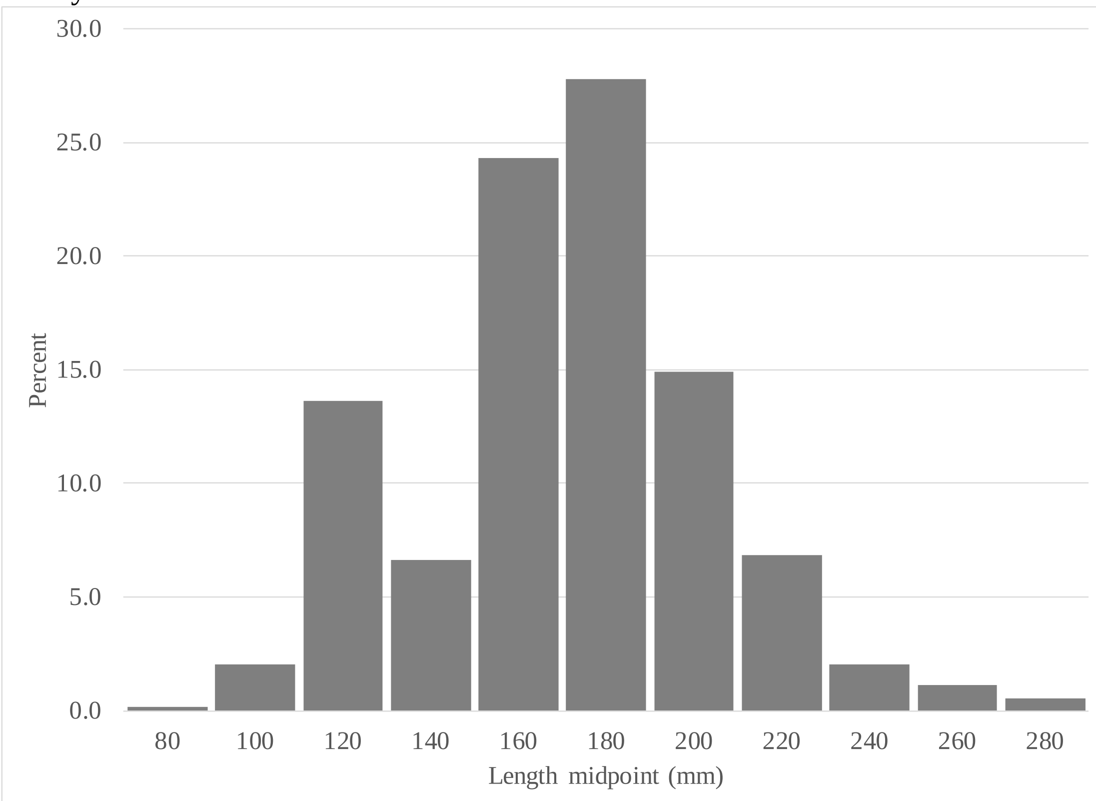


Table 11. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2018. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length-frequency from the 2018 Choptank River fyke net survey.

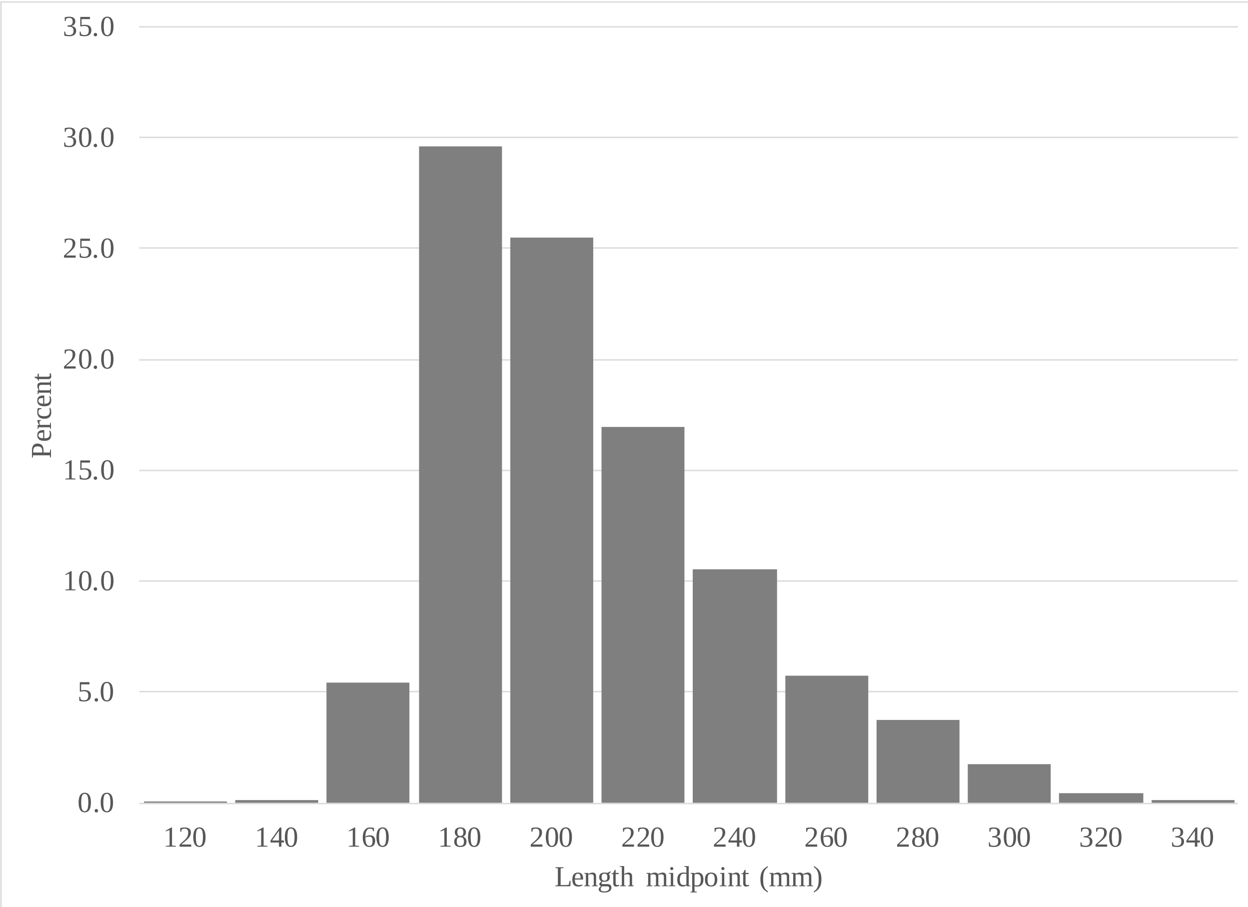


Table 12. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2018. Minimum length cut-offs in parentheses.

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

Figure 12. Yellow perch length frequency from the 2018 upper Chesapeake commercial fyke net survey.

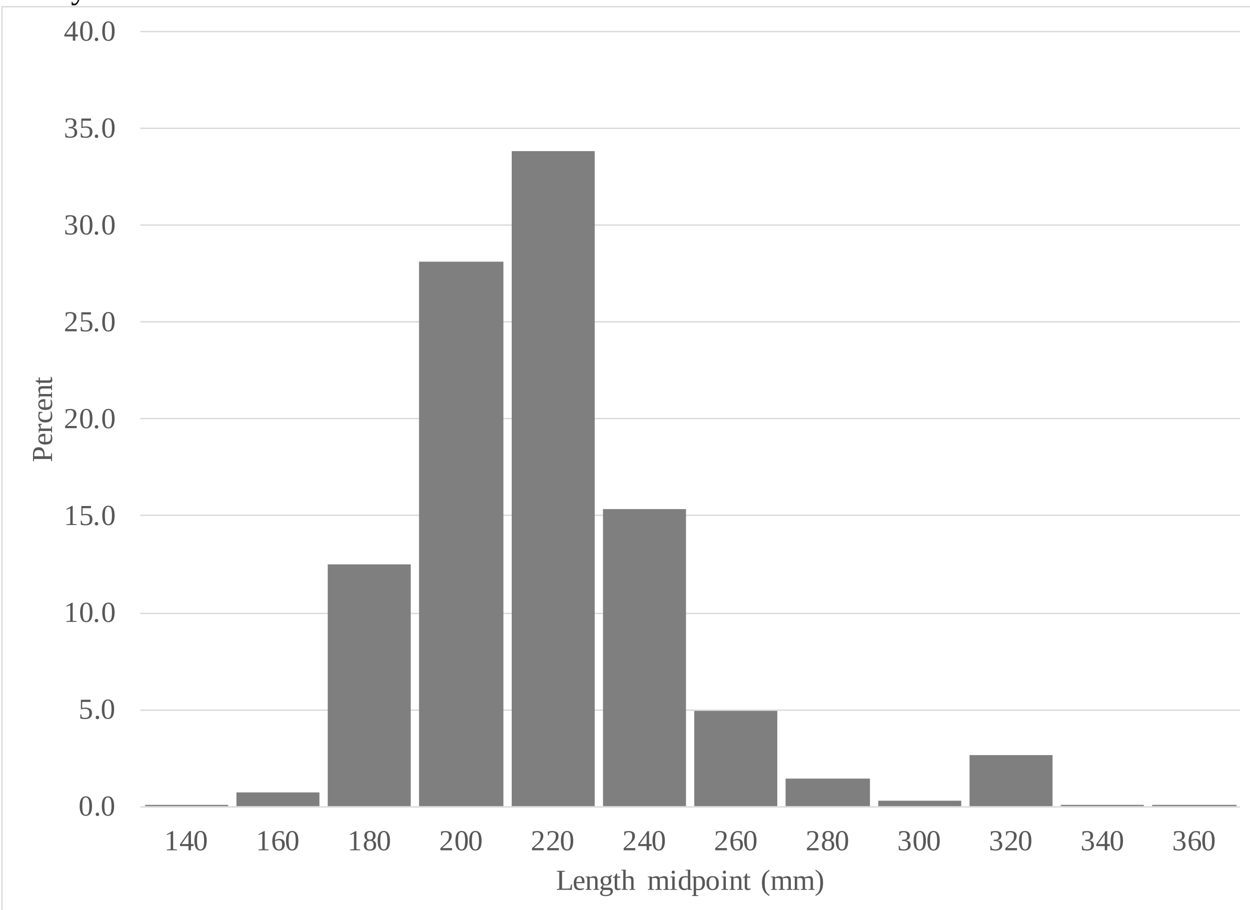


Table 13. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2018. Minimum length cut-offs in parentheses.

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

Figure 13. Length frequency of channel catfish from the 2018 upper Chesapeake Bay winter trawl survey.

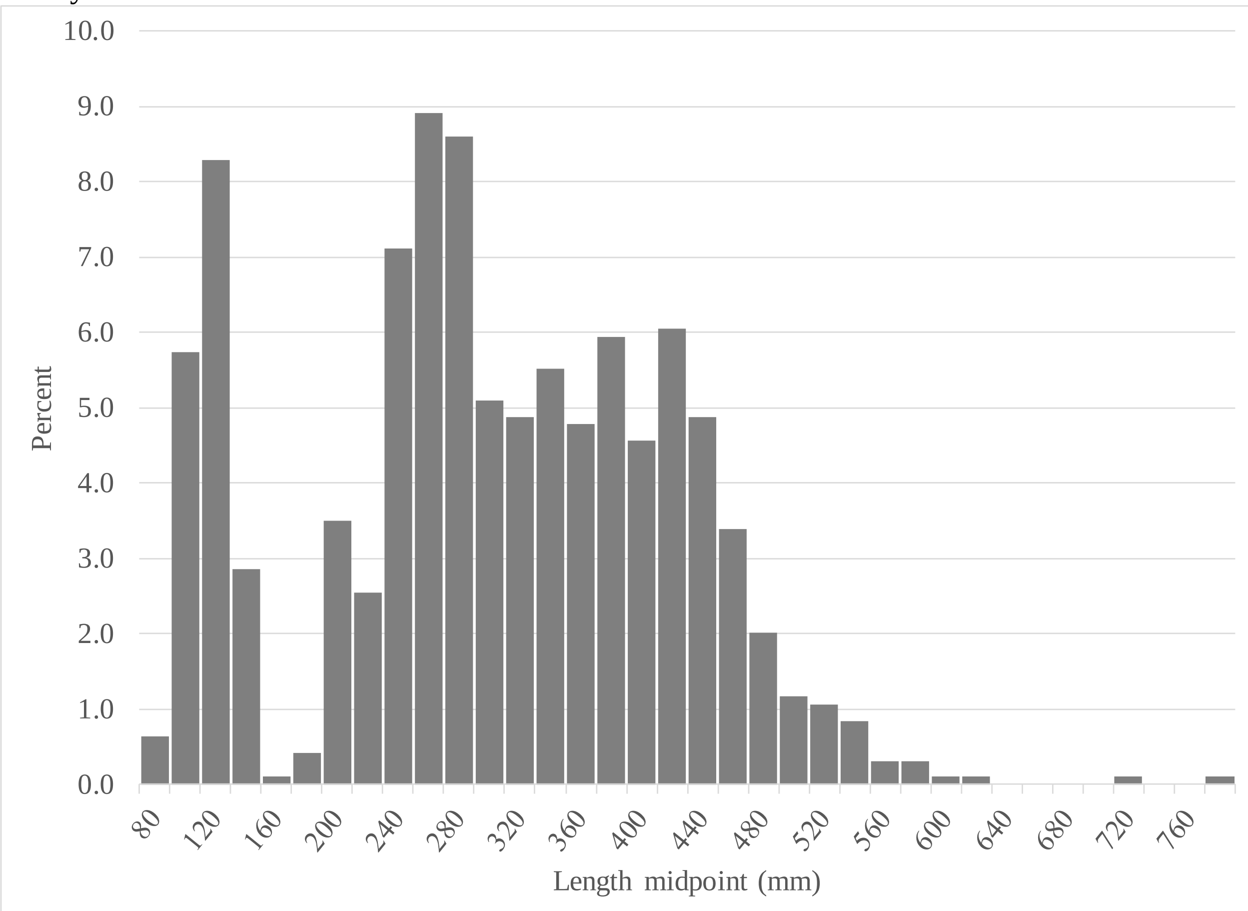


Table 14. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2018. Minimum length cut-offs in parentheses.

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

Figure 14. Channel catfish length frequency from the 2018 Choptank River fyke net survey.

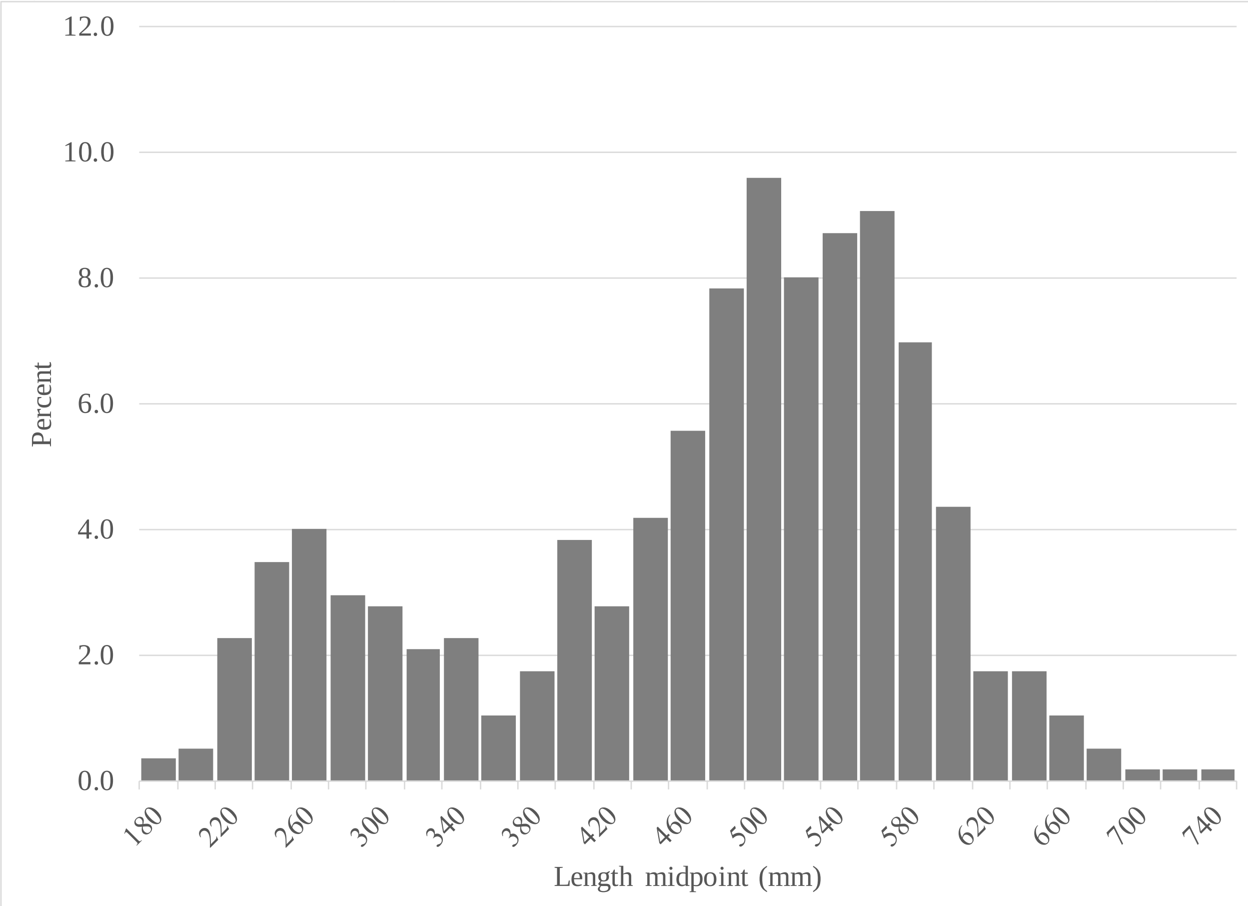


Table 15. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2018. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 15. Channel catfish length frequency from the 2018 Nanticoke River fyke and pound net survey.

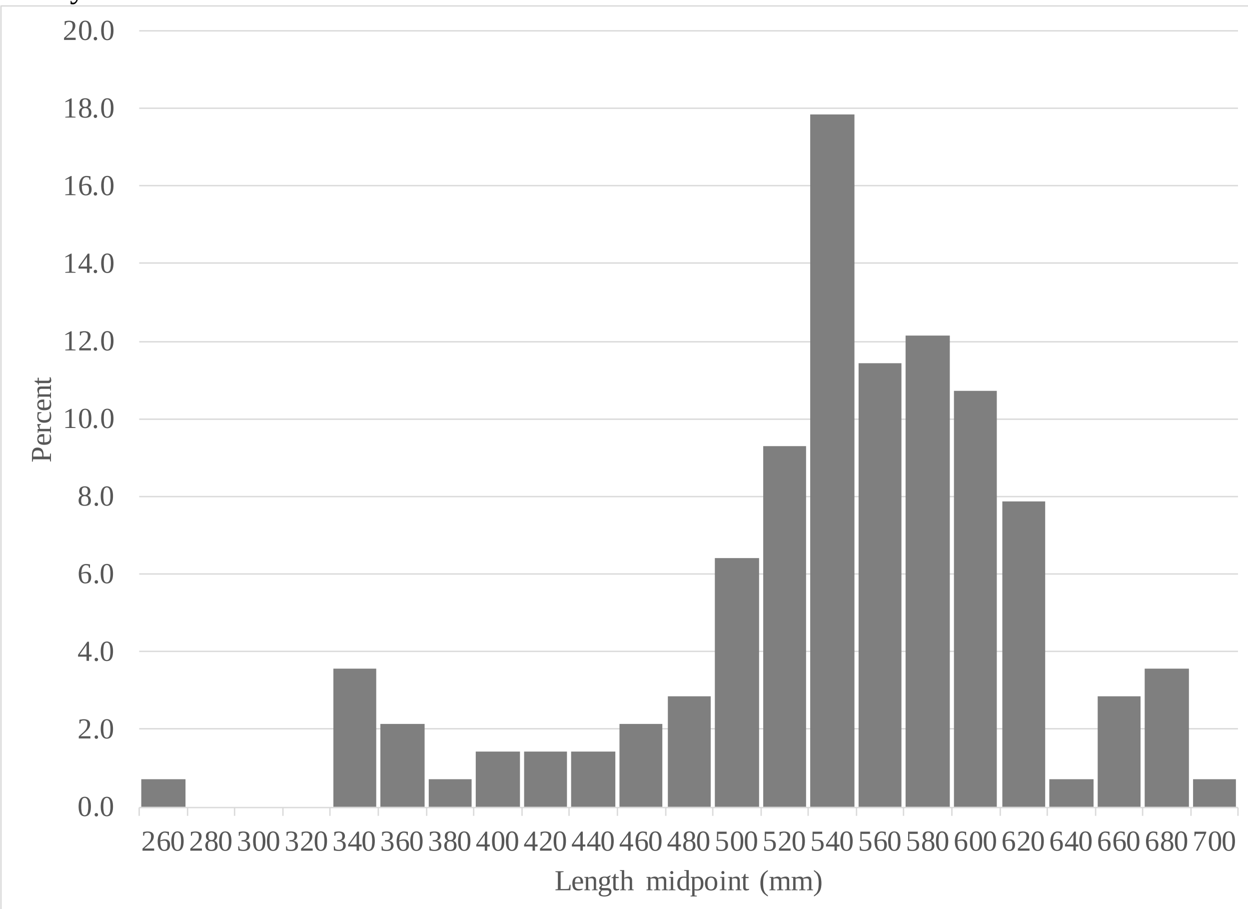


Table 16. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2018. Minimum length cut-offs in parentheses.

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

Figure 16. White catfish length frequency from the 2018 upper Chesapeake Bay winter trawl survey.

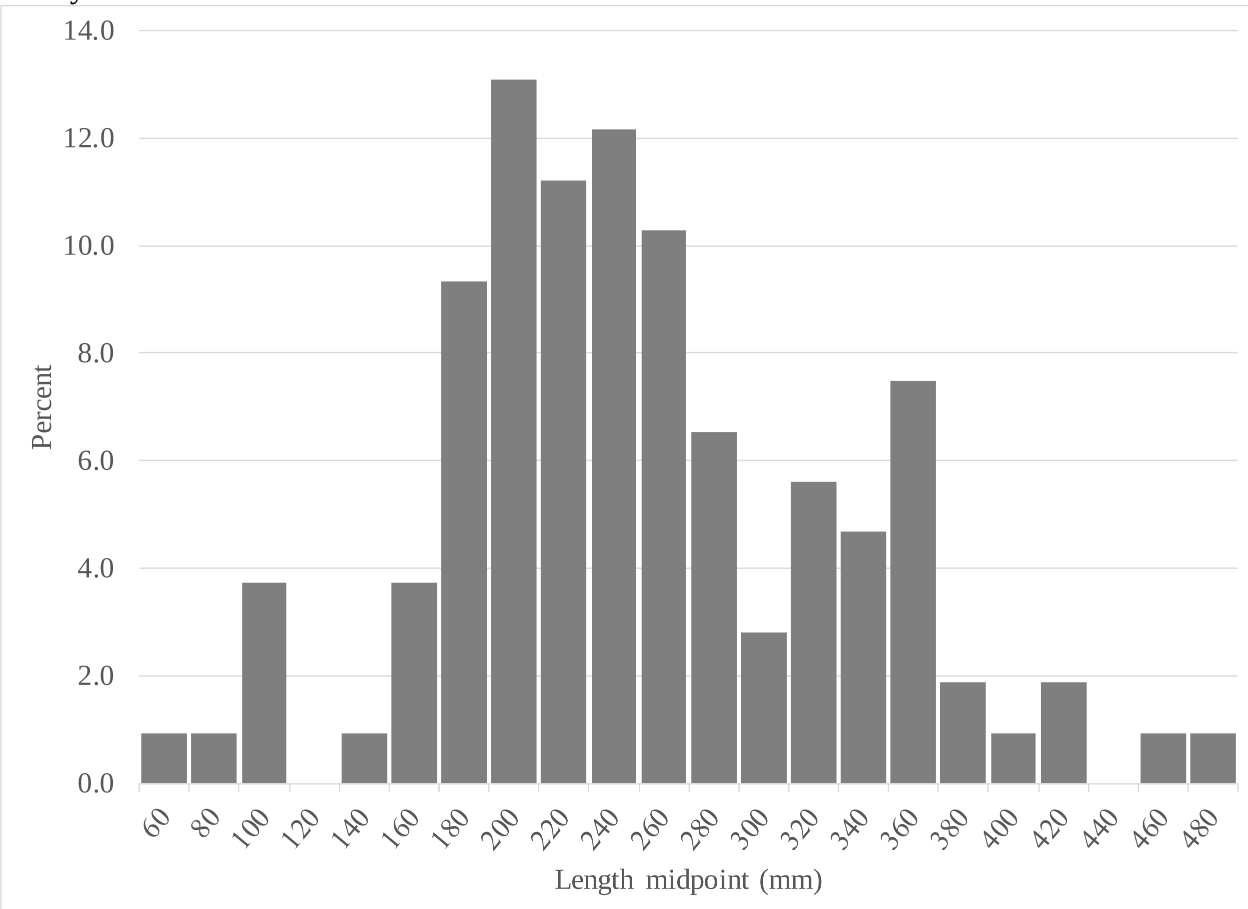


Table 17. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2018. Minimum length cut-offs in parentheses.

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

Figure 17. White catfish length frequency from the 2018 Choptank River fyke net survey.

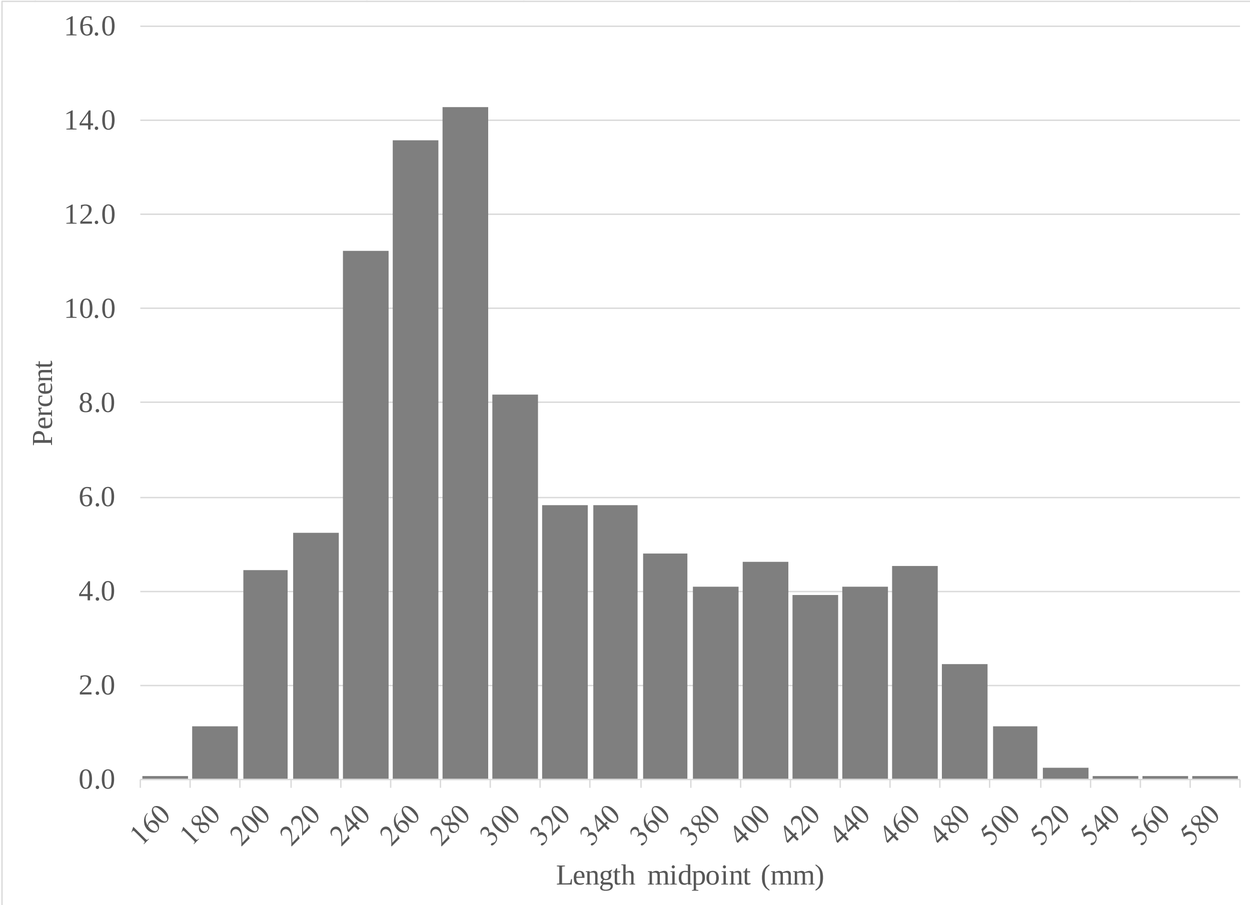


Table 18. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2018. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2018 Nanticoke River fyke and pound net survey.

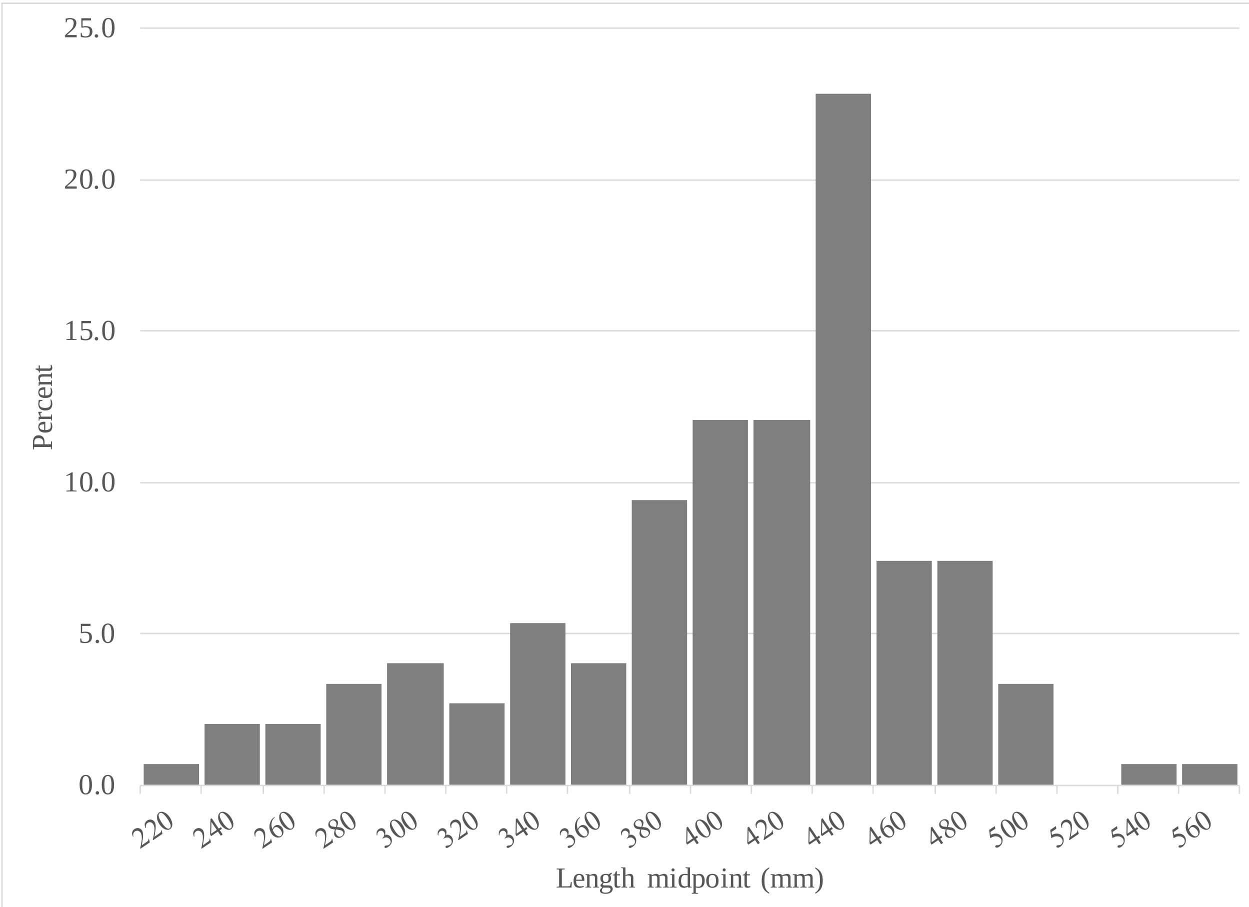


Table 19. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	Allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2010	F	4.0×10^{-6}	3.26	302	0.22	-0.42
	M	4.2×10^{-6}	3.23	209	0.60	0.09
	Combined	2.6×10^{-6}	3.33	302	0.17	-1.29
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
2000 – 2018	F	5.3×10^{-6}	3.20	288	0.26	-0.48
	M	4.7×10^{-6}	3.21	227	0.37	-0.36
	Combined	3.4×10^{-6}	3.28	275	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
2010	F	1.7×10^{-6}	3.41	345	0.16	-1.03
	M	3.4×10^{-5}	2.85	278	0.23	-0.25
	Combined	2.7×10^{-6}	3.32	313	0.19	-0.50
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
2000 - 2018	F	6.2×10^{-4}	2.35	316	0.21	-0.83
	M	1.7×10^{-5}	2.98	272	0.26	-0.38
	Combined	2.3×10^{-4}	2.52	299	0.23	-0.47

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
2010	F	1.3×10^{-5}	2.97		NSF	
	M	4.7×10^{-6}	3.16		NSF	
	Combined	9.9×10^{-6}	3.02		NSF	
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
2000 – 2018	F	1.7×10^{-5}	2.94	298	0.39	-0.37
	M	5.5×10^{-6}	3.14	271	0.25	-1.52
	Combined	8.8×10^{-6}	3.06	267	0.41	-0.56

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
2010	F	1.62 X 10^{-4}	2.57	292	0.51	0.29
	M	1.92 X 10^{-6}	3.34	254	0.49	-0.21
	Combined	3.40 X 10^{-5}	2.84	274	0.49	-0.09
2011	F	3.1 X 10^{-7}	4.10		NSF	
	M	9.4 X 10^{-7}	3.47	242	0.97	0.20
	Combined	9.1 X 10^{-8}	3.90	245	0.23	0.25
2012	F	1.4 X 10^{-6}	3.39	294	0.44	-0.06
	M	7.8 X 10^{-6}	3.06	258	0.46	-0.57
	Combined	7.7 X 10^{-7}	3.50	273	0.50	-0.27
2013	F	2.5 X 10^{-6}	3.31	**393**	**0.15**	**-2.02**
	M	1.5 X 10^{-5}	2.95	264	0.31	-0.39
	Combined	1.2 X 10^{-6}	3.44	294	0.29	-0.82
2014	F	9.0 X 10^{-6}	3.08	**410**	**0.10**	**-4.50**
	M	9.1 X 10^{-6}	3.05	250	0.45	-0.33
	Combined	4.8 X 10^{-6}	3.18	270	0.45	-0.25
2015	F	1.1 X 10^{-7}	3.89	**473**	**0.40**	**-12.80**
	M	1.7 X 10^{-5}	2.96	**246**	**1.52**	**0.33**
	Combined	7.5 X 10^{-7}	3.54	**248**	**1.45**	**0.31**
2016	F	1.4 X 10^{-6}	3.41	273	0.75	0.67
	M	1.4 x 10^{-6}	3.40	247	0.61	-0.04
	Combined	9.2 x 10^{-7}	3.48	263	0.59	0.04
2017	F	2.6 X 10^{-6}	3.28	298	0.56	0.63
	M	3.3 X 10^{-6}	3.23	253	0.46	-0.16
	Combined	1.1 X 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
1998 – 2018	F	4.2 X 10^{-6}	3.21	299	0.37	-0.37
	M	3.4 X 10^{-6}	3.23	242	0.52	-0.23
	Combined	2.0 X 10^{-6}	3.34	266	0.50	-0.16

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

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Choptank[1]	0.12	0.21	0.38	0.68	0.33	0.35	0.27	0.54	0.26	0.51
Nanticoke	0.30	0.21	0.27	0.20	0.29	0.41	NA	0.49	0.41	0.43
Upper Bay[1]	0.15	0.25	0.54	0.93	0.46	0.52	0.42	0.37	NA	NA

[1]Estimated F from stock assessment for 2009 – 2016 (Piavis and Webb 2018). 2017 and 2018 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.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Choptank	NR	NR	MIN	0.05	0.01	0.41	NR	0.32	MIN	MIN
Upper Bay[1]	0.23	0.27	0.32	0.31	0.20	0.15	0.20	0.49	0.32	0.11

[1]Fully recruited F from annual update of Piavis and Webb (2017).

Figure 19. Baywide young-of-year relative abundance index for white perch, 1962 – 2018, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

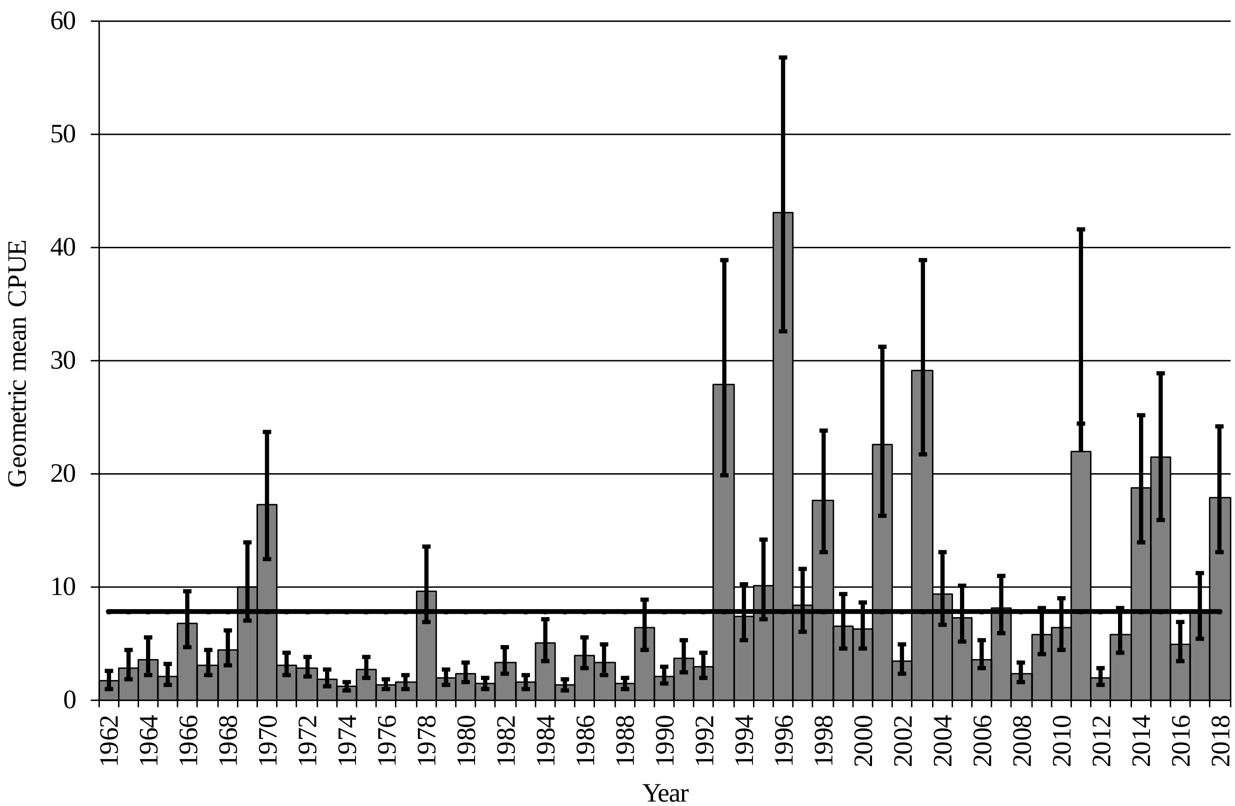


Figure 20. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Error bars=95% CI.

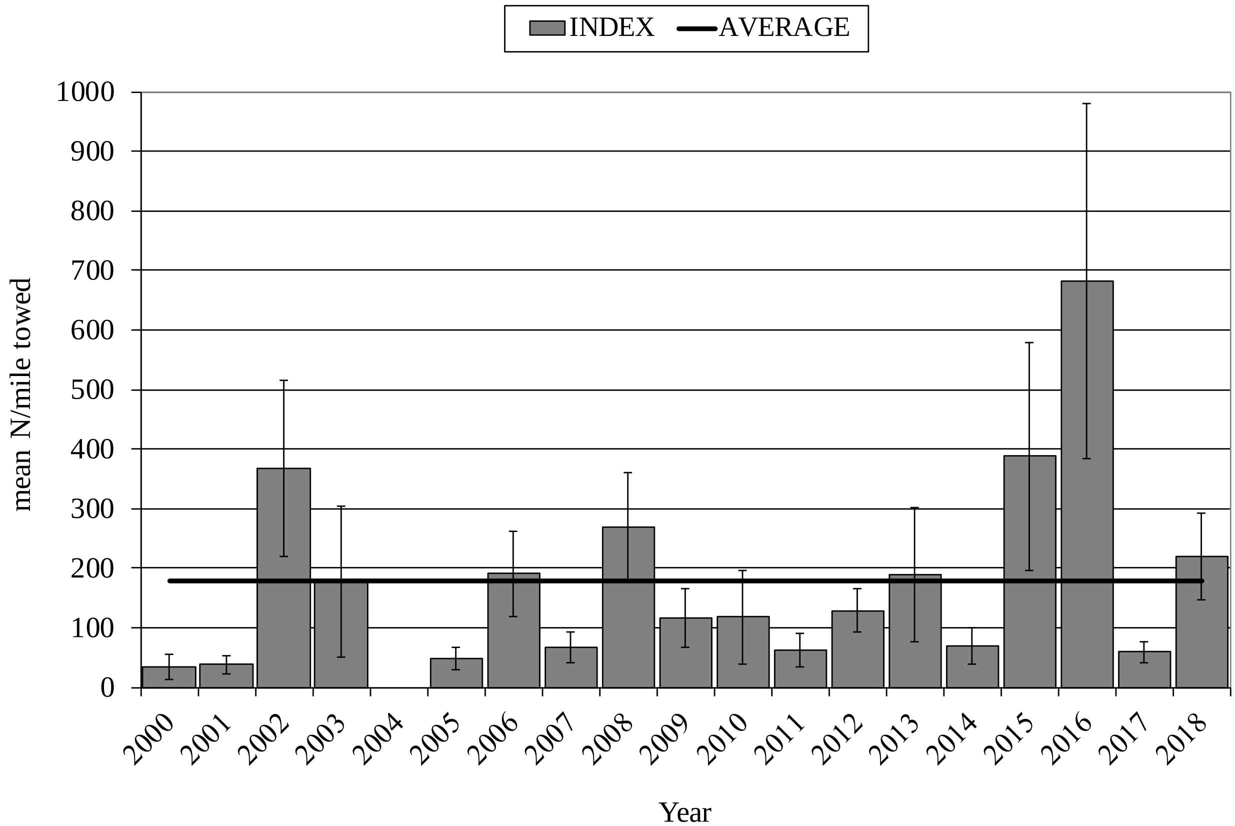


Figure 21. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2018, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

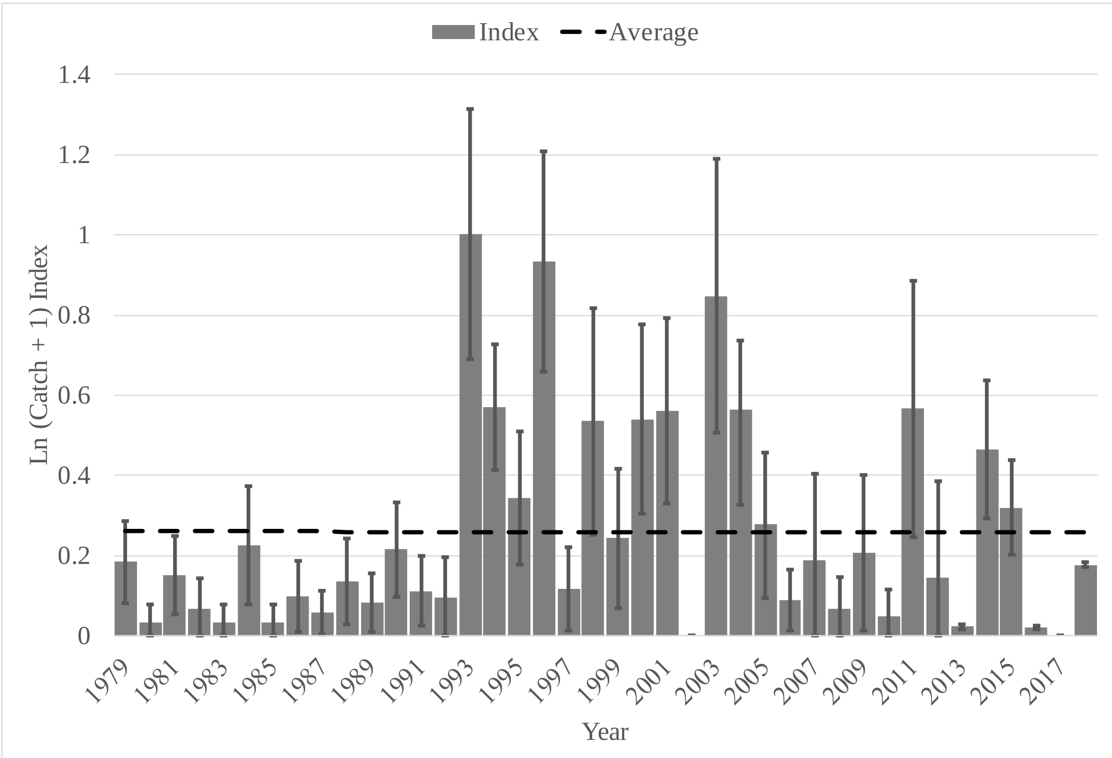


Figure 22. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Error bars=95% CI.

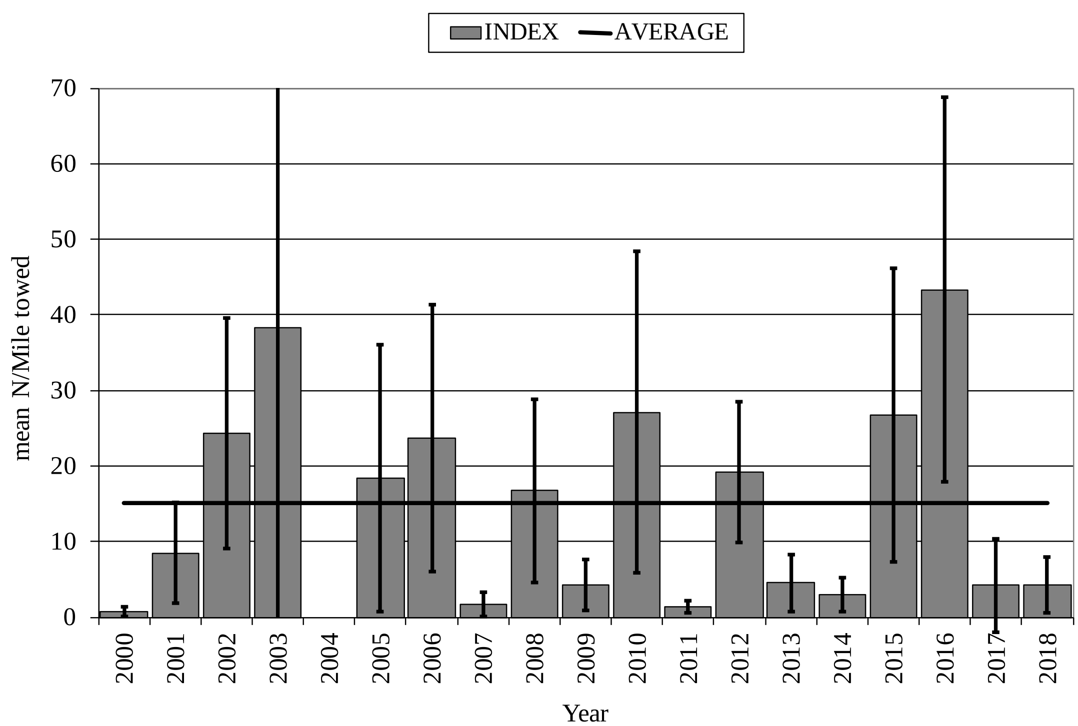


Figure 23. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

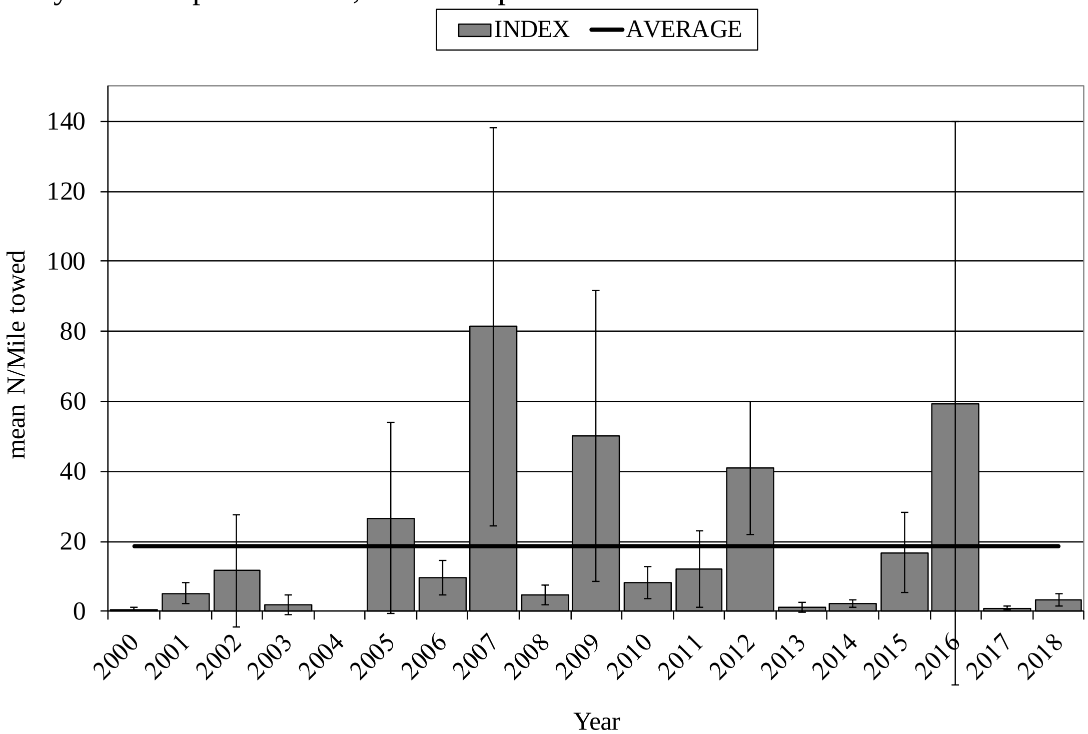


Table 25. White perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2018. Chester River sites included starting 2011.

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

Table 26. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2018.

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	21.7	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

Table 27. Yellow perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2018.

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

Table 28. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2018.

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

Figure 24. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2018. Effort standardized from 1 March – 95% total catch date. Trendline statistically significant at P<0.001.

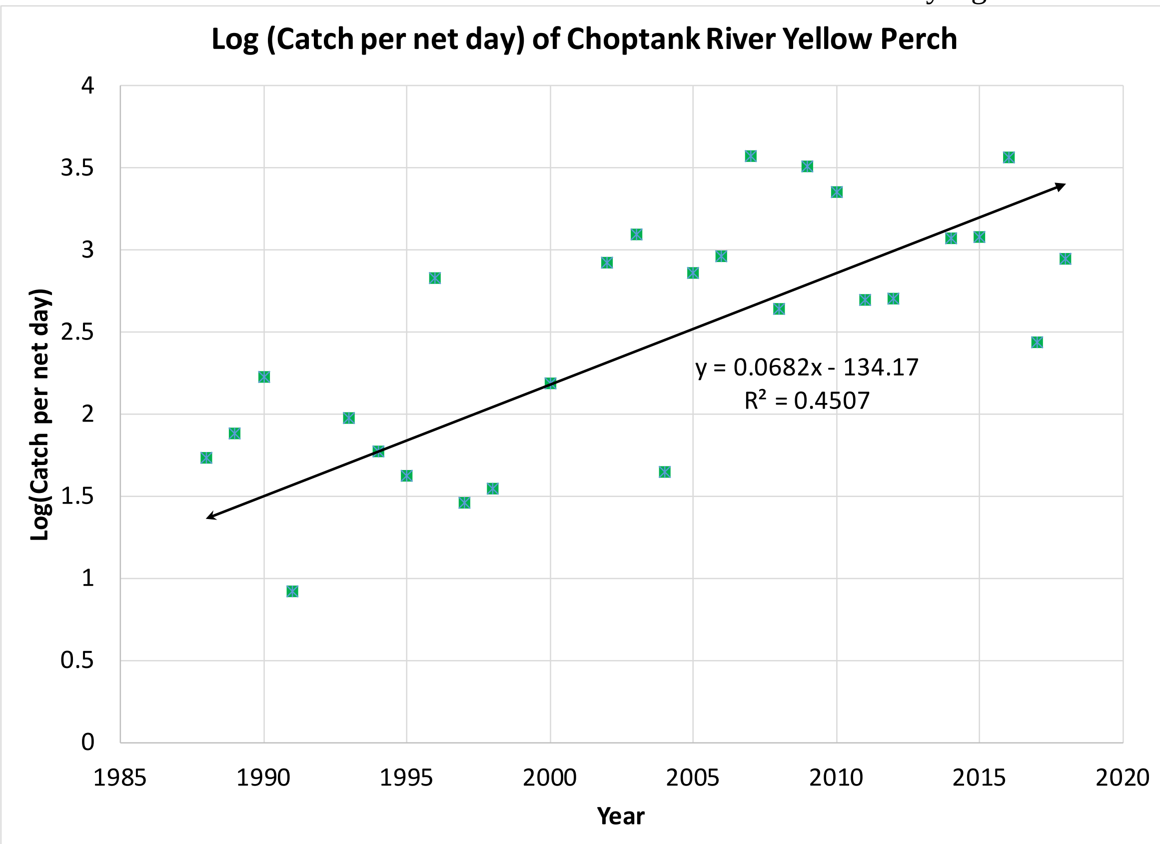


Figure 25. Channel catfish relative abundance (N/mile towed) from the upper Chesapeake Bay winter trawl survey, 2000-2018. Not surveyed in 2004, small sample sizes in 2003 and 2005.

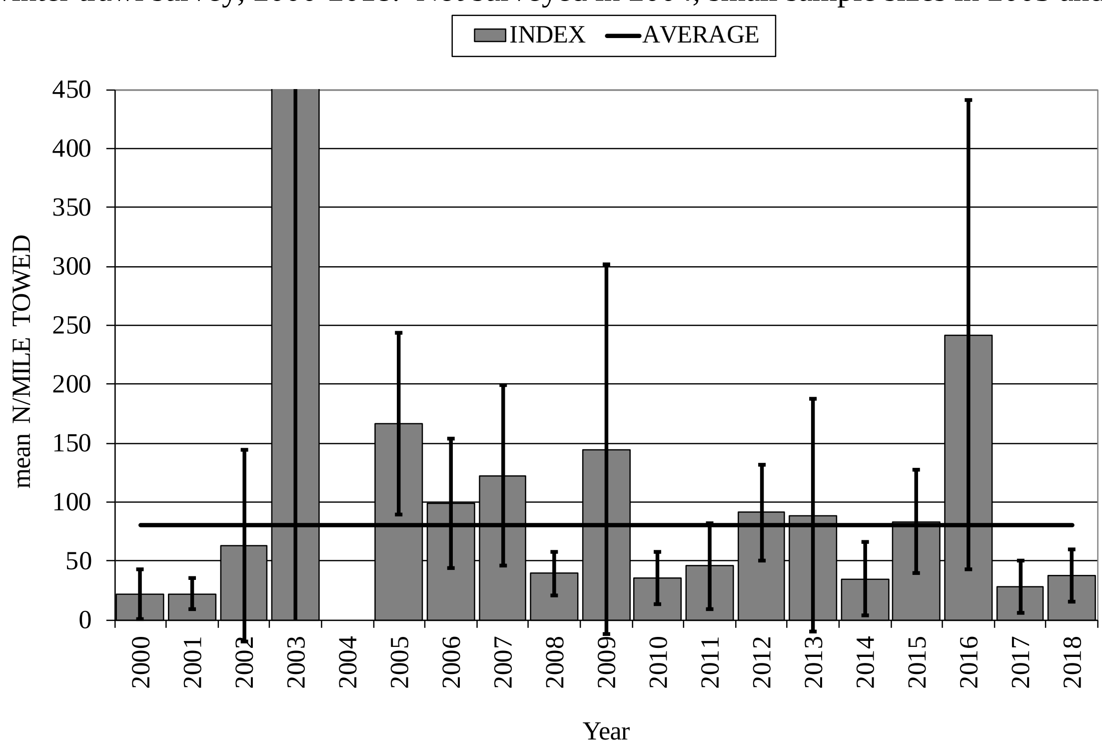


Figure 26. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2018. Horizontal line indicates time series average relative abundance.

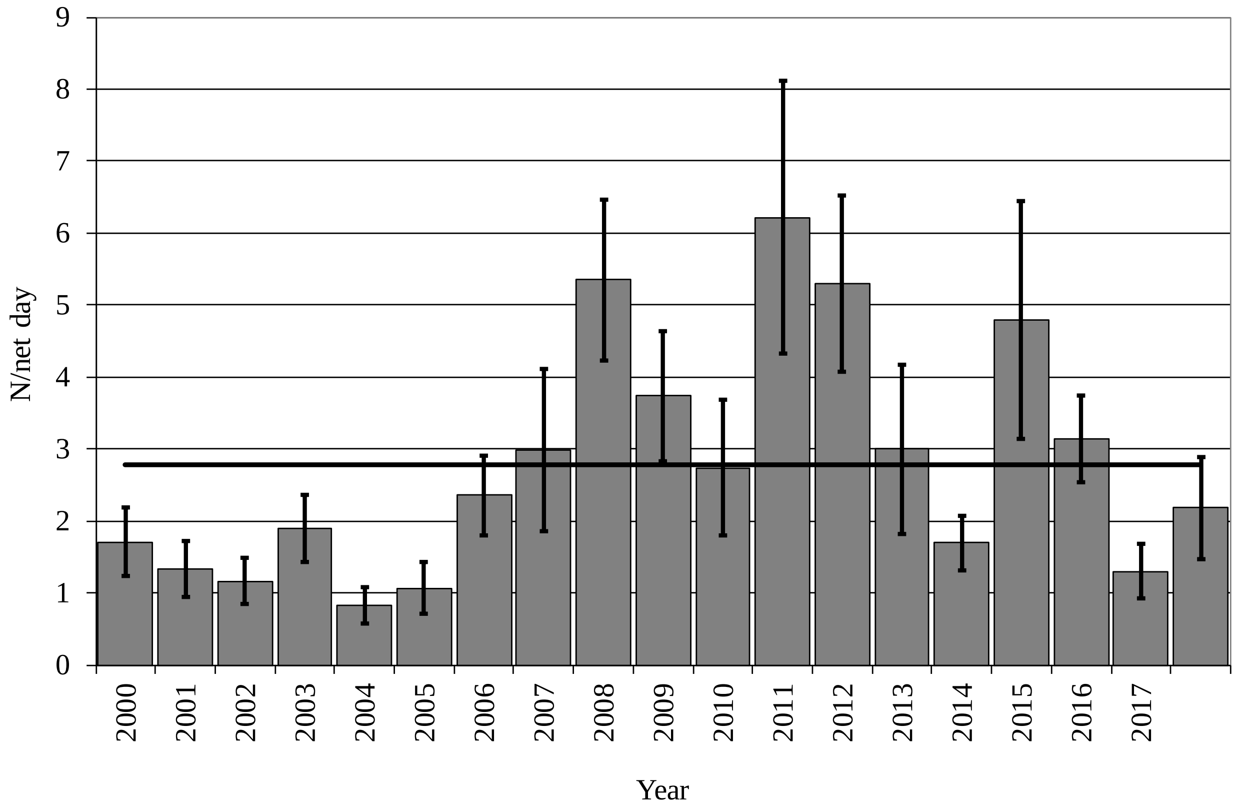
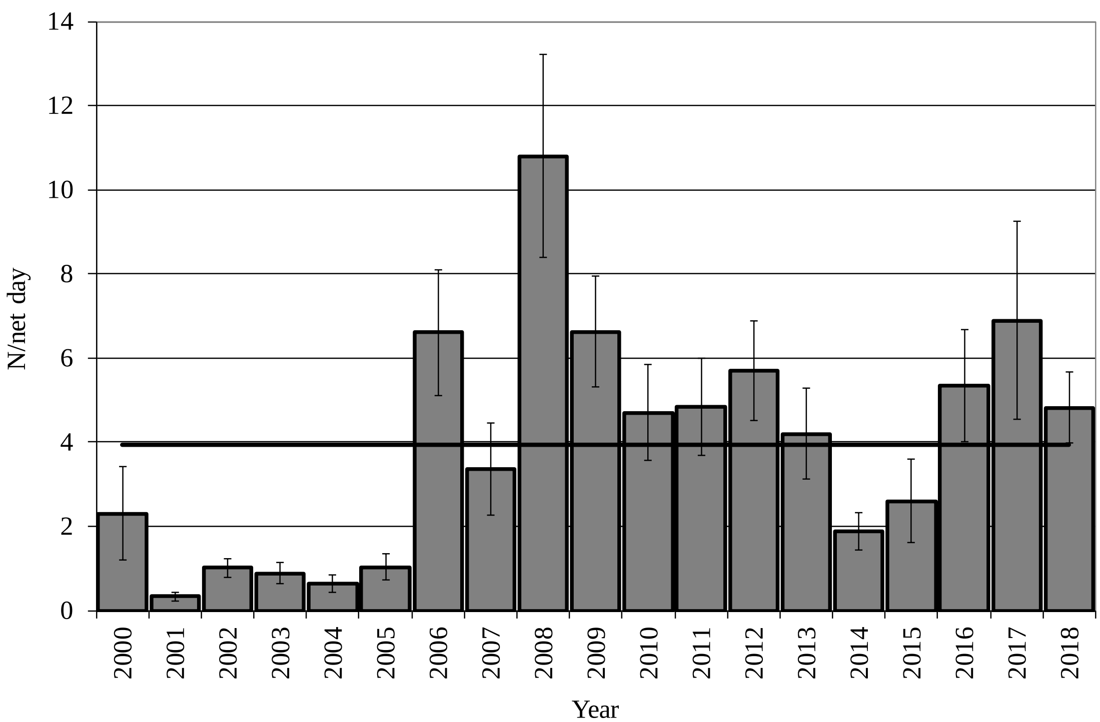


Figure 27. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2018. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF CHANNEL CATFISH IN SELECT TIDAL AREAS OF MARYLAND

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The objective of Job 2 was to assess channel catfish (*Ictalurus punctatus*) stock size, describe trends in recruitment and relate current and historical mortality estimates to various biological reference points. Channel catfish were introduced into Maryland waters as early as the late 1800's. Since those introductions, channel catfish have become self-sustaining, expanded their range, and are considered a naturalized species (Sauls et al 1998).

Channel catfish inhabit fresh or brackish waters in Chesapeake Bay and its tributaries. Currently, recreational and commercial channel catfish fisheries are unregulated in tidal waters in Maryland (no minimum size limit, creel limit or seasonal closures). The Potomac River Fisheries Commission (PRFC) manages channel catfish in the Potomac River mainstem. The minimum size limit in the Potomac River is 203 mm (8 inches; TL) for commercial and recreational fisheries with no closed season or catch limits.

Channel catfish are important to recreational and commercial fishers throughout Maryland's portion of Chesapeake Bay. The Marine Recreational Information Program (MRIP) produces estimates of recreational catch with fair precision (National Oceanic and Atmospheric Administration, personal communication, December 18, 2018). Estimated channel catfish recreational harvest (MRIP) averaged 1,003,632 pounds during

1982 – 2017; for the five year period, 2013 – 2017, average recreational catfish harvest was 1,869,778 pounds (86% above the long term average). In 2017, channel catfish was the third largest recreational harvest in Maryland (by weight), trailing only striped bass (*Morone saxatilis*) and white perch (*M. americana*).

In addition to MRIP estimates, recreational harvest estimates are available from geographically and temporally limited surveys. A Maryland Department of Natural Resources (MD DNR) creel survey conducted during the spring of 1985 in the lower Susquehanna River estimated that recreational fishers harvested 25,894 channel catfish (Weinrich et al. 1986). The estimated Susquehanna recreational harvest in 1985 was four times higher than any other year of the survey (1980 – 1984). Commercial harvest in the Susquehanna River and upper Chesapeake Bay region mimicked the increased recreational harvest over that same period.

Maryland's baywide commercial channel catfish harvest peaked in 2014 at 2.43 million pounds, slightly above the previous peak in 1996 (2.41 million pounds). Channel catfish commercial landings (by weight) trailed only Atlantic menhaden (*Brevoortia tyrannus*) and gizzard shad (*Dorosoma cepedianum*) in 2017. Areas above the Chesapeake Bay bridges accounted for 71% of the total Maryland commercial harvest in 2017.

Channel catfish populations were last assessed in 2015 (Piavis and Webb 2016). This Job is an update of the 2015 assessment. The 2015 assessment described population dynamics in two systems, the Head-of-Bay (HOB; areas north of the Preston Lane Memorial Bridges), and the Choptank River with fish population models. Indices of relative abundance (fishery dependent and fishery independent, when available) were utilized to illustrate trends in population abundance in areas other than HOB and the Choptank River.

METHODS

Bay-wide Landings

Maryland commercial fishery landings were available from the 1920's, but fishers were only required to report catch as general catfish landings (mixed species, predominately bullheads (*Ameiurus spp.*), channel catfish, and white catfish (*A. catus*)) until 1996. Beginning in 1996, commercial fishers were required to report catfish landings as general, channel catfish, or white catfish. Beginning in 2012, the general catfish category was omitted and commercial harvesters recorded catch to species, including blue catfish (*I. furcatus*) and flathead catfish (*Pylodictis olivaris*). The amount of channel catfish reported in the general category for the years 1996 – 2011 was calculated by determining the proportion of channel catfish in the combined white and channel catfish landings. This proportion was then multiplied by the amount of general catfish landed. The estimated annual landings of channel catfish in the general category were then added to the declared channel catfish landings for an estimated total commercial removal. To determine commercial channel catfish landing prior to 1996, the general catfish landings were multiplied by the average proportion of channel catfish of the total declared catfish landings by species for the years 1996 – 2011. Bullheads were considered an insignificant portion of landings prior to 1996.

Recreational landings, as estimated by the MRIP, were fairly precise, but several years contained estimates where the proportional standard error (PSE) was > 40%. A regression of estimated recreational harvests with PSE's < 0.40 versus commercial landings was highly significant (R^2 =0.88 P<0.001). Therefore, estimated harvest from years with PSE < 40% were compared to commercial landings to determine the average proportion of recreational landings to commercial landings. The average proportion was then applied to annual commercial harvest of years when PSE's of the recreational estimate exceeded 40%.

Head-of-Bay Surplus Production Model

Surplus production models fit biomass estimates to the equation

$$B_{t+1} = B_t + rB_t(1 - B_t/K) - C_t \qquad [1]$$

where r is the intrinsic rate of increase, K is carrying capacity and C_t is total removals in year t.

The model took the form of the Haddon (2001) implementation where a series of biomass estimates were generated to maximize a log-likelihood function by solving for r, K, and initial biomass (B_0). An estimated index was derived from the equation

$$I = q[(B_{t+1} + B_t)/2]e^{\mathrm{E}} \qquad [2]$$

where I is the estimated index, q is catchability and e^{ε} is the lognormal residual error. This form simplified the solution by not having to solve for a catchability parameter for each index. Average catchability for each index was $e^{(1/n)\,\Sigma\,\ln(I_t\,/\,B)_t}$. The log function to be maximized was simply the sum of all log-likelihoods multiplied by a weighting factor.

The log-likelihood function for an individual index is

$$LL = -n/2[\ln(2\pi) + 2\ln(\sigma) + 1] \qquad [3]$$

where $\sigma = \sqrt{\sum (\ln I_t - \ln I_{t,\exp})^2 \sqrt{\;} / n}$, and n is the number of data points in the series. This assessment utilized an equal weighting scheme.

All runs were performed in an Excel spreadsheet using the Solver algorithm to estimate biomass and solve for the 3 unknown parameters (B_0, r, K). Reference points and fishing mortality were estimated from standard relationships (Prager 1994; Haddon 2001):

Maximum Sustainable Yield = $rK/4$

$B_{msy} = K/2$

$F_{msy} = r/2$

Instantaneous fishing mortality $(F) = -\ln[1 - C_t / (B_t + B_{t+1}) / 2]$.

Model Inputs

There were five indices of relative abundance available for modeling purposes. There were three fishery dependent indices [commercial catch per unit effort (CPUE) from the fyke net, pound net and fish pot fisheries] and two fishery independent indices [Striped Bass Spawning Stock Survey (SBSSS)**,** Project 2, Job 3, Task 2; and the upper Bay winter trawl survey, Project 1 Job 1]. Positively correlated indices were identified, and a final run was completed using the commercial fyke net CPUE index, the commercial fish pot index, the commercial pound net index, the fishery independent drift gill net survey and the bottom trawl survey.

The fishery dependent indices were derived from MD DNR Fisheries Service commercial landings database. Effort data for these gear types were available from 1980 – 1984, 1990, and 1992 – 2017. An index of effort was constructed to standardize landings because commercial catch reporting was completed monthly and not on a per trip basis. The index was nominal fishing effort, or simply the total number of nets declared by fishers in any month. Only fishers that reported catfish harvest > 500 pounds were used for relative abundance estimates. This eliminated fishers that were not targeting channel catfish. The final annual index was total pounds harvested divided by total nominal effort.

Fishery independent data from the experimental SBSSS in HOB were compiled and included in the surplus production model (Figure 1). Since the model is a weight-based model, indices based on numbers were transformed to weight-based indices. Channel catfish weight per gill net set was estimated by determining average channel catfish length per mesh size per gill net set and applying a length-weight formula from the Susquehanna Flats area of HOB (Fewlass 1980):

$$\log_{10}(W) = 3.09684 \times \log_{10}(L) - 2.1622$$

where W is weight (g) and L is total length (cm). The average weight per gill net set and mesh size was then multiplied by the total number captured per mesh size and net set. The final index was the geometric mean weight per net set standardized to 100-m^2 gill net hours.

The fishery independent HOB winter trawl survey provided channel catfish relative abundance for HOB (Figure 2). Species count data from this survey (2000-2002; 2006 - 2017) were transformed to biomass per mile towed with the same allometric equation utilized in the drift gill net index formulation. The index was geometric mean channel catfish biomass per mile for channel catfish greater than 355 mm. Observation of commercial fishing practices suggested that fish < 355 mm are not marketable.

Total removals by the commercial and recreational fisheries were estimated on a regional basis. Removals from HOB were easily obtained from the commercial landings data base because fishermen are required to submit landings by system. Catfish reporting in HOB was identical to the Bay-wide process detailed above. Recreational landings from HOB were estimated from the raw dataset supplied by MRIP. A SAS program from MRIP was modified to ascertain landings from all counties in the HOB region. Four years had very high PSE estimates. Those years were adjusted by applying the average proportion of recreational channel catfish landings to commercial channel catfish to the commercial landings in those four years.

Uncertainty

Bootstrapping, or resampling residuals and adding them to the natural logarithm of the expected indices, and re-exponentiating the values was used to quantify model uncertainty (n = 5,000 trials). Mean, median, standard deviation and coefficient of variation were calculated for all fitted parameters and each estimate of annual biomass and F. Confidence intervals (80% CI) were determined from cumulative percent distributions of the bootstrapped parameter estimates.

Choptank River Catch Survey Analysis

Model Description

Catch Survey Analysis (CSA) is a two stage population assessment model that requires relatively modest input data (Collie and Sissenwine 1983). Most assessments that utilize CSA are length based so the time and cost burdens of aging fishery dependent and independent samples are negated. Data requirements are indices of pre-recruit and post-recruit abundance, total removals from the population, assumed natural mortality (M) and a scalar relating pre-recruit selectivity to post-recruit selectivity.

The CSA relates pre-recruit relative abundance to post-recruit relative abundance in numbers in the following year, such that:

$$R_{t+1} = (R_t + P_t)\, e^{-M_t} - C_t\, e^{-M_t (1-T_t)} \qquad [4]$$

where R_t is the post-recruit abundance at the start of year t, P_t is the pre-recruit abundance at the start of year t, M is instantaneous natural mortality, C_t is harvest in year t (in numbers), and T is the fraction of time between the survey and the harvest.

The model assumes survey catch r and p for post-recruits and pre-recruits, respectively, relate to absolute abundance by a survey catchability (q) such that:

$$r_t = R_t\, q \qquad [5]$$

and,

$$p_t = P_t\, q\, \Phi \qquad [6]$$

where Φ is a scalar relating the pre-recruit selectivity to post-recruit selectivity,

$$\Phi = s_p/s_r \qquad [7]$$

and s_p and s_r are pre-recruit and post-recruit selectivity coefficients from the fishery independent survey, respectively. Note that the absolute selectivity values are not required, rather the relative value is utilized in the model.

Substituting [5] and [6] into equation [4] yields

$$r_{t+1} = (r_t + p_t / \Phi)\, e^{-M} - q\, C_t\, e^{-Mt (1 - T t)} \qquad [8]$$

This assessment reparameterized the model (Mensil 2003). Instead of solving for expected survey indices, this model searches and solves for actual pre-recruit abundance

(P) and the first year's post-recruit abundance (R_1). Subsequent post-recruit abundance is determined from equation [4].

Expected pre- and post-recruit indices were derived from the geometric mean catchability (q_{avg}) where

$$q_{avg} = e^{(1/n) * \sum (\log_e (n_t / N_t)} \qquad [9]$$

It follows that the expected pre-recruit and post-recruit indices were

$$p_{exp,\,t} = P_t/(q_{\,avg} * \Phi) \qquad [10]$$

$$r_{exp,\,t} = R_t/q_{\,avg} \qquad [11].$$

The objective function then becomes the minimization of the sums of squared errors between the observed and expected pre- and post-recruit indices:

$$SSQ = W_p * \sum (\log_e (p_{obs,\,t}) - (\log_e (p_{exp,\,t}))^2 + W_r * \sum (\log_e (r_{obs,\,t}) - (\log_e (r_{exp,\,t}))^2 \; [12]$$

where W_p and W_r are weighting factors for pre-recruit and post-recruit indices, respectively.

Fishing mortality (F) is not analytically estimated within the model. Rather, harvest rate (*h*) is estimated from total removals (C) and abundance estimates (P and R). Harvest rate *h* was estimated as

$$h_{\,t} = C_t /((P_{\,t} + R_{\,t}) * e^{-Mt*Tt}) \qquad [13]$$

Total instantaneous fishing mortality (F) can then be determined from

$$F_{\,t} = -\log_e (1-h_t). \quad [14]$$

The model was compiled in a Microsoft Excel spreadsheet and the Solver routine was used to fit the model.

Inputs

The CSA model requires an estimate of M, Φ (a scalar relating pre-recruit selectivity to post recruit selectivity), survey indices of pre-recruit (p_t) and post-recruit (r_t) abundance, and total removals (C_t). Indices of abundance were determined from the Choptank River fyke net survey (see Project 1 Job 1; Figure 3 this Job). Pre-recruits were those channel catfish less than 405 mm TL and greater than 305 mm TL. Post-recruit channel catfish were those fish greater than 404 mm TL. Natural mortality was set at a constant M = 0.2 for both analyses. The scalar Φ was 1.0 for both assessments based on length frequency diagrams of catches the Choptank River fyke net survey. Time of removals (T) was set at mid-year (0.5).

Harvest estimates were determined for the commercial and recreational fisheries. Numbers of commercially harvested channel catfish were determined by dividing pounds harvested (by gear type) by estimated average weight of legal channel catfish. Average legal weight was determined from our fyke net catches. The same allometric equation used for the HOB analysis was used to transform average length to average weight.

Recreational channel catfish harvest for the Choptank River was estimated from total inland harvest estimates from the MRIP (National Marine Fisheries Service, personal communication, September 2018). The proportion of recreational to commercial landings was determined by dividing total recreational inland landings by bay-wide commercial landings. That proportion was applied to Choptank River commercial landings to estimate recreational landings in this system. Negligible release losses were assumed for all fisheries.

Uncertainty

The model was bootstrapped 5,000 times by resampling residuals and adding them to the natural logarithm of the expected index values, then re-exponentiating the values. Mean, median, coefficient of variation (CV) and bias were calculated for *q* and each estimate of P_t and R_t, exclusive of the terminal year for the pre-recruit value. Confidence intervals (80%) were determined from cumulative percent distributions of the bootstrapped parameter estimates.

Other Areas

Previous attempts to fit population models to other areas have failed, largely due to lack of fishery independent surveys (Piavis and Webb 2013). Qualitative methods to describe population trends in the Nanticoke, Pocomoke, Patuxent, and Potomac rivers were employed.

Landings

Channel catfish landings were determined from MD DNR commercial landings database for the Nanticoke, Pocomoke and Patuxent rivers. Adjustments due to changes in the species reporting requirements were identical to the bay-wide landings discussed above. The Potomac River Fisheries Commission (PRFC) provided commercial landings from the Potomac River (Potomac River Fisheries Commission, personal communication, April 7, 2019). Catfish landings were identified to species from 2003 – 2014. From 1985 – 2002, catfish were coded as mixed (white catfish and channel catfish) and bullhead species. Channel catfish landings for the period 1985 – 2002 were estimated as mixed catfish landings × proportion of channel catfish of total catfish landings during the nearest 5 year period, 2003 – 2007 (0.85). From 1964 – 1984, catfish landings were reported as mixed bullhead and catfish species. Channel catfish landings for the period 1964 – 1984 were estimated as catfish landings × proportion of channel catfish of total landings during the period 1985 – 2002. Maryland's portion of the Potomac River catfish landings (PRFC data) were added to MD DNR's landings from the Potomac River tributaries to get a total Potomac River landings history.

Fishery Dependent Relative Abundance Indices

Area specific relative abundance indices were determined from the fishery dependent commercial landings database. The indices were computed in the same manner as detailed in the Model Inputs section above for the HOB surplus production model. Gear specific indices were constructed for the fyke net, pound net and fish pot fisheries. In some cases a combined fyke net and fish pot index was utilized.

Fishery Independent Relative Abundance Indices

A gill net survey designed to estimate spawning stock biomass of striped bass in Potomac River (SBSSS) was utilized to describe population trends (Figure 1). This survey is analogous to the drift gill net survey in HOB that was included in the HOB surplus production model. Data encompassed the time period 1984 – 2017.

RESULTS

Landings

Baywide commercial landings generally varied between 400,000 pounds and 700,000 pounds from 1929 through the mid-1970's (Figure 4). Landings increased rapidly from 1976 through 1996 to 2.4 million pounds. Since 1996, landings decreased to a recent low in 2007, and then increased to over 2.4 million pounds in 2012 and 2014.

Since 2014, baywide commercial landings decreased linearly to 1.6 million pounds in 2017. Baywide recreational landings estimates varied greatly over the period 1983 – 2017 (Figure 5). A time series low was estimated in 1988, but recreational landings trended upward through 1996 which corresponded with the rise in commercial landings. Recreational landings during the period 1997 – 2006 were notably low, but a general rebound occurred during 2007 – 2015. In 2017, an estimated 330,000 pounds of channel catfish were harvested recreationally in Maryland.

Head-of-Bay Surplus Production Model

Total estimated fishery removals from HOB, by weight, exhibited a bimodal pattern during the assessment time-period. The first landings cycle (commercial and recreational combined) showed a gradual increase from about 0.5 million pounds in 1981 to 2.4 million pounds in 1996 (Figure 6). The next trough bottomed in 2005 at 0.4 million pounds. The latest up-cycle was more rapid than the first, peaking at 2.1 million pounds in 2015 before declining to 1.4 million pounds in 2017.

The model included five biomass-based relative abundance indices. Three fishery dependent indices were generated from landings data which included a fyke net index, a fish pot index and a pound net index (1980 – 1984, 1990, 1991 – 2017). In addition, two fishery independent indices (the gill net survey, 1985 – 2017; and the winter trawl survey, 2000 – 2017) were included in the model. The fyke net index exhibited a bimodal pattern with one peak in 1990 and a broader peak covering the years 2006 – 2009 (Figure 7). The fish pot index showed a very gradual increase from 1981 – 2003, and a rapid increase from 2005 to a time-series high in 2011. The index then declined through 2017 (Figure 8). The pound net index largely mimicked the other fishery dependent indices.

Relative abundance estimates peaked in the mid 1990's, bottomed around 2007, and rose again to a second peak in 2016 (Figure 9). The fishery independent gill net survey indicated relatively high index values during 1985 – 1987, a time period where no fyke net index was available. The gill net index corroborated the higher fyke net index during the latter portion of the time series (Figure 10). The winter trawl survey was more temporally limited than the other four indices. The trawl index indicated periods of higher biomass during 2008 – 2011 and 2014 – 2016 than in the early 2000's (Figure 11), similar to the pound net and drift gill net indices.

The model fit the data well. Estimated parameters r, K, and B_0 were 0.32, 17.4 million pounds, and 4.0 million pounds, respectively. Biomass increased from 4.0 million pounds in 1980 to 8.8 million pounds in 1990. Channel catfish biomass then trended lower to 6.5 million pounds in 2000, but increased to 10.9 million pounds in 2009 and 2010. The period 2009 – 2017 had biomass estimates ranging from 9.3 million pounds to 12.0 million pounds. The final year biomass estimate (2017) was 12.0 million pounds (Figure 12). Instantaneous fishing mortality (F) peaked during 1995 – 1999, but then fell to low levels during 2004 – 2014. Instantaneous fishing mortality in the final year of the assessment (2017) was estimated to be 0.12 (Figure 12). Over the course of the assessment, F averaged 0.16. Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ K or 8.7 million pounds. F_{msy} was estimated as ½ r or 0.16. Maximum sustainable yield was estimated $rK/4$, or 1.4 million pounds.

Previous studies have indicated that the absolute values for biomass and fishing mortality from surplus production models may not be precise, but the ratios of $B:B_{msy}$ and $F:F_{msy}$ are particularly robust (Prager 1994). Ratios of $B:B_{msy}$ and $F:F_{msy}$ indicated a period of increasing biomass and moderate F between 1983 and the mid 1990's. Fishing mortality then rose to unsustainable levels for eight years during 1994 − 2001, that is, the $F{:}F_{msy}$ ratio was greater than 1.0 (Figure 13). After 2001, the $F{:}F_{msy}$ ratio declined and the $B{:}B_{msy}$ ratio increased. The $B{:}B_{msy}$ and $F{:}F_{msy}$ ratios in the final year of the assessment were 1.38 and 0.76, respectively. Based on these point estimates, the HOB channel catfish stock is not overfished and overfishing is not occurring.

Bootstrapping provided estimates of uncertainty for this model (Table 1). The intrinsic rate of increase (r) was estimated with good precision (CV=27%). Estimates of K and B_0 were less precisely estimated with CV's equal to 39% and 34%, respectively. Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than r and K in model outputs and subsequent management advice. Coefficients of variation of annual biomass estimates ranged from 22 − 35%. In contrast, the ratio $B{:}B_{msy}$ was very precisely estimated in all years (CV range = 17% − 25%). Confidence intervals for biomass ratios were produced from the bootstrap analysis of uncertainty. These confidence intervals were somewhat broader than expected (Figure 14). In the final year of the assessment (2017), there was only an 8% chance that channel catfish were overfished (*i.e.*, a stock is overfished when $B{:}B_{msy} < 1.0$).

Coefficients of variation of annual fishing mortality estimates ranged from 18% − 32%. However, the maximum occurred in the first year because of the highly variable B_0 estimate. In contrast, the ratio $F{:}F_{msy}$ was precisely estimated in all years (CV range = 15% − 25%). Comparisons of the confidence intervals demonstrated the increased precision of the F ratio estimates (Figure 15). In the final year of the assessment (2017), there was a 4% chance that overfishing was occurring (*i.e.*, overfishing is occurring when $F{:}F_{msy} > 1.0$).

Choptank River Catch-Survey Analysis (CSA)

Total channel catfish removals from the Choptank River, in numbers, were estimated for the assessment time period 1993 – 2017. Commercial and recreational harvest was generally low during 1993 – 2004, ranging from 11,000 – 48,000 fish, except for the nearly 100,000 fish estimated for 1999. Harvest increased substantially after 2004, and peaked in 2011 at 168,000 fish. Annual removals during 2005 – 2017 averaged 117,000 channel catfish (Figure 16).

The model included two indices from a MD DNR Fisheries Service fishery independent fyke net survey. One index was a pre-recruit relative abundance index and the other was a post-recruit relative abundance index. The pre-recruit index remained in a low range relative to the entire time series, from 1995 – 2005. The pre-recruit index increased after 2006, more than doubling the previous high relative abundance value (Figure 17). The post-recruit index had a similar pattern, but the higher relative abundance of the recruited fish did not begin until 2008. Since 2008, relative abundance values were greater than the time series average in seven of the eleven years (Figure 18).

The CSA model fit the population data very well. Catchability of the survey (q) was estimated as 3.2×10^{-6}. Pre-recruit population abundance generally tracked the increase in the survey's relative abundance values, with relatively low pre-recruit abundance during 1995 – 2004, followed by relatively high pre-recruit abundance through 2011 (Figure 19). Since 2011, pre-recruit abundance trended lower except for

2015. Post-recruit channel catfish abundance varied between 200,000 and 400,000 channel catfish from 1993 – 2007 (Figure 20). After 2007, recruited channel catfish abundance accelerated quite swiftly with the recruited population increasing from an estimated 246,000 fish in 2008 to 766,000 fish in 2012. Total population abundance (pre-recruit and post-recruit combined) varied between 269,000 – 498,000 channel catfish during 1993 – 2006. Total abundance rose to 1.1 million channel catfish by 2011 and declined to 645,000 by 2017. Over the time-series, total population averaged 563,000 channel catfish. The final two years of the assessment indicated a decline in total population numbers, but abundance was still greater than the time-series average (Figure 21).

Instantaneous fishing mortality (F) was generally low, varying between 0.04 and 0.15 for most of the assessment period (Figure 22). Average F for the entire time series was 0.16 and F in the final year of the assessment was 0.17. No F-based, biomass-based or abundance-based biological reference points have been adopted for Chesapeake Bay area channel catfish stocks. Therefore, no conclusions may be definitively drawn regarding overfishing or overfished status for Choptank River channel catfish stocks.

Bootstrapping provided estimates of uncertainty for this model (5,000 trials; Table 2). Survey catchability (q) was precisely estimated (CV=2%). Coefficients of variation for pre-recruit abundance estimates ranged from 17.5% – 21.5%. Coefficients of variation for post-recruit abundance were more variable than the pre-recruit abundances. Coefficients of variation ranged from 11.3% – 29.7%. However, the largest CV was encountered in the initial year (1993) estimate. Exclusive of that year, CV ranged from 11.3% -- 21.2%. Confidence intervals (80%) were produced for pre-recruit abundance (Figure 19), post-recruit abundance (Figure 20), total abundance (Figure 21) and F (Figure 22).

Other Areas

Nanticoke River channel catfish data included commercial fishery landings and a fishery dependent relative abundance index. Commercial landings from 1987 – 2011 were variable ranging form just under 20,000 pounds to 145,000 pounds (Figure 23). Since 2011, landings increased to a time-series high in 2014 of more than 180,000 pounds before declining through 2017 to nearly 60,000 pounds. Commercial fishery CPUE's generated from the fish pot fishery were quite variable and exhibited no discernable trend other than a notable increase in relative abundance from 2010 through 2014 (Figure 24). Relative abundance was at or above the 75th percentile during the last six years (2012 – 2017).

Prior to the 2015 assessment, Pocomoke River channel catfish had not been investigated due to low or no commercial landings, and therefore, perceived lower availability to recreational fishermen (Piavis and Webb 2016). This is demonstrated by the fact that prior to 2003 commercial landings were intermittent, at best. From 2003 – 2010, landings were less than 30,000 pounds annually. Landings increased dramatically in 2011 to over 150,000 pounds (Figure 25). Landings reverted back to lower harvest levels in 2016 and 2017. A fishery dependent relative abundance index was derived from the combined fyke net and fish pot fisheries. This approach was necessary because of the intermittent characteristics of the commercial fishery. The relative abundance index mirrored the commercial landings, indicating that there was no tremendous increase in effort to cause the almost 100 X increase in landings during 2011 -- 2014. Despite the overall landings collapse in 2015 – 2017, relative abundance measures remained above the median in 2015 and 2017 (Figure 26).

Patuxent River channel catfish data included commercial fishery landings and a fishery dependent relative abundance. Patuxent River channel catfish landings were generally stable around median landings, 1999 -- 2008 (Figure 27). Landings decreased to very low levels since 2014. During that time period, blue catfish landings increased to nearly 100,000 pounds which far exceeded channel catfish landings. Both the fyke net and fish pot fisheries were examined for a suitable relative abundance index. As with the Pocomoke fisheries, we combined the fyke net and pot fisheries. Relative abundance values were at or above the 75th percentile during 1998 – 2008 (Figure 28). Relative abundance declined rapidly in 2015 and has remained very low. In contrast, blue catfish relative abundance increased during 2013 – 2016 with the blue catfish relative abundance far exceeding that of channel catfish. All 2017 Patuxent River blue catfish harvest was from trotlines (recently legalized in Maryland tidal waters) so relative abundance values were not comparable.

Potomac River channel catfish landings, as report to the Potomac River Fishery Commission (PRFC), had to be adjusted for differences in reporting requirements similar to landings from the MD DNR commercial database. Estimated combined Maryland and PRFC landings of channel catfish from Potomac River and tributaries indicated a protracted decline in landings from 1987 through 2017. Landings have been below 150,000 pounds since 2003 (Figure 29). No fishery dependent relative abundance indices could be calculated. After 2003, catches became sparse and/or intermittent for various gears. The fishery independent Potomac River drift gill net survey indicated that the biomass index was below the 75th percentile since 2006 and was at or below median relative abundance in 8 of the last 10 years (Figure 30). Blue catfish in the gill net survey first appeared in 1995. Blue catfish relative abundance increased greatly as channel catfish relative abundance declined.

DISCUSSION

Channel catfish provide valuable recreational and commercial fisheries while occupying an important ecological niche among brackish-tidal fresh ecosystems in Maryland's portion of the Chesapeake Bay. Recreational and commercial fishermen, combined, harvested an estimated 1.9 million pounds of channel catfish in tidal waters of Maryland in 2017. The primary objective of this Job was to describe trends in channel catfish abundance throughout the Bay region. Model runs proved informative for HOB and Choptank River channel catfish populations. Using commercial landings as a proxy of channel catfish availability to recreational anglers, the assessment areas accounted for 91% of the total channel catfish population in Maryland's tidal waters (HOB = 72%; Choptank River = 19%). The qualitatively assessed areas accounted for another 7% of the total channel catfish availability. In contrast to previous years, HOB and Choptank River accounted for 59% of the total in 2014 and the other four areas accounted for 28% of total 2014 landings (Piavis and Webb 2016).

The HOB surplus production model fit well and the general population trends were similar to previous assessments (Piavis and Webb 2013; Piavis and Webb 2016). However, record or near record high relative abundance values for the winter trawl and pound net indices (2016), fyke net index (2015) and gill net index (2014) caused the model to re-evaluate estimated model parameters and management benchmarks (Table 3). Carrying capacity (*K*) increased from 8.7 million pounds in the 2011 assessment to 17.4 million pounds in the current assessment. This increase was due to the higher relative abundance estimates since 2014, and directly affected MSY and MSY-derived estimates. Intrinsic rate of increase (*r*) declined as *K* increased. Estimated MSY remained relatively stable since MSY= ¼ *rK*. Regardless, the utilization of B-ratios and F-ratios rather than the point estimates of B and F maintained the relativity of the estimates to the respective management benchmarks. Estimates of *K* in future runs would likely decrease or at least remain stable should relative abundance values decrease in the next few years; the model estimates would also be expected to be derived much more precisely. Conversely, should relative abundance increase, estimation of *K* would likely become more difficult.

Maximum sustainable yield (MSY) was estimated as 1.4 million pounds. Total estimated removals marginally exceeded MSY in only two years during the first expansion/plateau phase of channel catfish abundance (1980 – 1994), and during those two years biomass was at or above B_{msy} (B_{msy} = the population biomass that can sustain harvest at MSY). Conversely, total estimated removals exceeded MSY in all but two years when the population contracted (1995 – 2002) and channel catfish production was not sufficient to buffer the increased harvest as biomass fell below B_{msy}. During the second expansion phase, 2003 – 2011, removals only exceeded MSY in 2010 and 2011, and were substantially below MSY, 2003 – 2009. Recently, harvest (commercial and recreational) was above MSY in 2014 – 2016, but biomass was considerably greater than

B_{msy}, 2008 – 2017. The population biomass during 2017 was 38% higher than B_{msy}, and therefore, not overfished. Bootstrap analysis indicated only an 8% chance that the stock is overfished. However, the bootstrap analysis contained model runs that should be considered failed fits. More than 10% of the runs indicated that biomass never exceeded B_{msy} during the assessment time period. The lower confidence interval bound for the $B{:}B_{msy}$ ratio (Figure 14) were all below 1.0 during 1980 -- 2016, but without a more robust *a priori* reason for excluding those runs, all bootstraps were included in the uncertainty analysis. This decision makes the 8% chance of being overfished a very conservative estimate.

Inspection of the trajectories of F generally moved opposite that of biomass. A discussion of the F trends is largely redundant with the above discussion of harvests in excess of MSY. The model results demonstrated the resilience of the population to F rates greater than F_{msy}, but when the $F{:}F_{msy}$ ratio exceeded one and the $B{:}B_{msy}$ ratio was less than one (overfishing was occurring while the stock was overfished) the population declined by almost one-third (1996 – 2003) and recreational and commercial harvest harvests declined to very low levels. Recreational and commercial catch remained low for years. For instance, in 2005, recreational harvest was only 4% of the previous high and commercial harvest was only 20% of the previous high. Once the F:Fmsy ratio returned to acceptable levels after 2003, overfished status ended by 2006 and the population rebounded and increased an estimated 80% by 2017. The F:Fmsy ratio in 2017 was 0.76 (overfishing was not occurring) and bootstrap analysis indicated that there was only a 4% chance that overfishing was occurring.

The winter trawl survey (Project 1 Job 1) was utilized as an index of adult biomass in the HOB model run, but sub-adults are also encountered. Relative abundance of age 1 channel catfish indicated above average year-class formation in 2006, 2008, 2011, 2014 and 2015 (see Project 1 Job 1, Figure 23). The 2006 and 2008 year-classes are likely responsible for the increased production since 2014. Given expected growth rates, the 2011, 2014 and 2015 year-classes should sustain population expansion for future years if the commercial and recreational fisheries harvests remain at or below MSY.

The Choptank River channel catfish assessment utilized a CSA model fit to our long term experimental fyke net survey (Project 1 Job 1). Population trajectories indicated an expanding population through 2011 which closely tracked our experimental fyke net indices. Pre-recruit indices began a decline in 2010 which broke the uptrend seen during 2004 – 2009. The previous assessment (Piavis and Webb 2016) indicated that this was the first demonstrable cycle during the time-series, providing a much needed contrast for the model to fit. Magnusson and Hilborn (2007) investigated what population trajectories and models provided informative fishery management advice. Although the authors did not investigate CSA type models, results indicated that fishery population models that performed the best did so when there were sustained contrasting periods of population abundance. The contrast provided by the most recent decline in pre-recruit indices greatly increased the precision of the model. The population declined after 2011, but a large increase in pre-recruits in 2015 and muted fishing removals sustained the number of recruits such that the total population remained above median levels. Since 2015 pre-recruit abundance returned to lower levels.

No biological reference points have been formally established to determine overfished or overfishing status. However, the moderate time series of F rates and population responses, combined with previous assessments can allow for a broad evaluation of the fishery and the channel catfish population. Age data collected in the mid 1990's from Choptank River channel catfish were analyzed and a critical F threshold was determined as F=0.6 (Uphoff et al. 2007). This value is similar to channel catfish threshold F's simulated for the upper Mississippi River channel catfish population where a threshold F reference point was F=0.54 (Slipke et al. 2002). Our model estimated the time-series highest F's in 1999, 2005 and 2006 at F levels between 0.35 and 0.40, below both the Mississippi River and the Choptank River proposed threshold F's. In spite of the higher F's in 1999, 2005 and 2006 population expansion continued. This indicates that the recent population contraction while F's remained low (below F=0.23) likely was not due to overfishing, but rather decreased production. The decreased production may be from poor spawning success or an increase in natural mortality (M). Alternatively, the F estimates may be biased low if the estimate of removals was misspecified. Overfishing was not occurring during the final year of the assessment since estimates of F rates were below the putative thresholds suggested for Choptank River stocks and Mississippi River stocks. In addition, the 2017 total abundance was 45% above the time series median and within 20% of the 75^{th} percentile. Using these levels as proxy biological reference points for overfished status, the Choptank River channel catfish stock is likely not overfished.

Channel catfish relative abundance trends in the Nanticoke, Pocomoke, Patuxent, and Potomac rivers were quite different among the four systems. The two lower eastern shore rivers (the Nanticoke and Pocomoke rivers) declined from higher relative abundance levels in 2014 but remained above suggested management benchmarks. The Potomac River channel catfish population has been below historical levels for quite some time, while the Patuxent River population appears to have contracted considerably since the previous assessment (Piavis and Webb 2016).

Fishery dependent data from the Nanticoke River appear fairly robust in both scope (relative abundance data since 1980) and breadth (annual landings of 60,000 pounds or greater throughout much of the time series). Landings declined from a time-series high in 2014 to lower levels during 2015 – 2017. Relative abundance also declined over this time period, but remained above the 75th percentile. This indicated that the channel catfish population declined from very high levels but remained above the conservative proxy for overfished status. Given the magnitude of the relative abundance decline this channel catfish stock may be at an inflection point where further declines could be rapid if sub-adult production is low in the future.

Pocomoke River channel catfish landings were especially low until 2011 when landings increased 800%. Landings remained high through 2015 and declined to extremely low levels in 2016 and 2017. Relative abundance values in the terminal year (2017) remained between median levels and the 75th percentile. The landings history and relative abundance measures may indicate that a new fishery based on market demands and increased availability began over the last decade and waned as quickly as it waxed.

Patuxent River channel catfish population levels, determined from fishery dependent relative abundance measurements, were at or above median levels for most the 1998 – 2014 time period. Since 2014, relative abundance declined rapidly to time series lows in 2017. These declines coincided with increased blue catfish landings and relative abundance. Declines in channel catfish landings while blue catfish increased could be caused by commercial fishermen shifting to target blue catfish directly. Relative abundance values would be impacted if directed channel catfish effort was below meaningful levels. This is a particular problem when using fishery dependent relative abundance to index population levels. Recently, trotlines were included as an authorized commercial fishing gear in tidal waters of Maryland. Significant channel catfish commercial effort may have shifted to trot-lining which targets blue catfish. In 2017, trotlines accounted for 91% of Patuxent River blue catfish commercial harvest, whereas fish pots (traditional catfish gear) landed almost 10,000 pounds of blue catfish in 2016, and none in 2017. This obvious shift in commercial catfish effort makes the interpretation of fishery dependent data difficult.

Potomac River channel catfish landings declined to relatively low levels after 2002. Relative abundance from an experimental gill net survey similarly declined, but abundance did rebound to safe levels, 2009 – 2012. Since 2012, relative abundance has only been one-half of median levels suggesting dire population contraction. The channel catfish landings decline preceded the large increase in blue catfish landings, but in 2017 blue catfish landings exceeded channel catfish landings by a factor of 30. Blue catfish relative abundance peaked in 2015 and 2016 before declining somewhat in 2017. Blue catfish colonization may be acting to preclude channel catfish stock growth through interspecific competition, both directly through predation and indirectly by out-competing channel catfish for prey or critical habitat.

Blue catfish have emerged as a potential threat to channel catfish populations in Maryland's Chesapeake Bay region. The omnivore has dominated large Chesapeake Bay tributaries in Virginia, and are firmly established in the Potomac and Patuxent rivers. Colonization is also in an advanced state in the Nanticoke River. The ability of blue catfish to overwhelm an ecosystem was documented in Virginia rivers where blue catfish comprised 75% of fish biomass from an electrofishing survey (Schloesser et al. 2011). Similarly, tagging studies in the James River (VA) estimated 1.6 million blue catfish, 240 mm – 460 mm, in a 12 km reach of river (Fabrizio et al. 2018). Prior to blue catfish and flathead catfish introductions to the Cape Fear (NC) River system in 1966, channel catfish accounted for approximately 25% of the ictalurid fish community, but by the late 1990's blue catfish accounted for 85% of the ictalurid community with channel catfish accounting for less than 10% (Moser and Roberts 1999). Beyond these surveys in Atlantic slope rivers, channel catfish and blue catfish co-exist in fishable numbers. Mississippi River drainage systems including the Mississippi River, the Missouri River, impounded sections of the Tennessee River and the Osage River contain sympatric populations of channel and blue catfish (Pugh and Schramm 1999, Timmons 1999, Gale et al. 1999, Graham and DeiSanti 1999).

Blue catfish may compete with channel catfish for available resources or more directly through predation. Stomach analyses of blue catfish in the Chesapeake Bay region and other east coast regions indicated some degree of direct predation on channel catfish. Most analyses explored the impact of blue catfish on depleted fishes such as *Alosa* spp., economically important species like blue crab (*Callinectes sapidus*) or ecologically important forage species. However, channel catfish were the second most prevalent finfish food item in blue catfish stomachs in five Maryland Chesapeake Bay tributaries (Aguilar et al. 2017). The five systems surveyed were all within areas assessed in this report including two systems in HOB, a tributary to the Nanticoke River, the Potomac River and the Patuxent River. In the Potomac River, catfish species were also prevalent in blue catfish stomachs, but given low channel catfish population levels it is more likely that unidentified catfish species were blue catfish (M. Groves personal communication, presentation to the Invasive Catfish Symposium Nov 6, 2017 https://www.chesapeakebay.net/what/event/catfish_symposium). A diet analysis in Lake Oconee, GA found that channel catfish were a seasonally important component of blue catfish diets (Jennings et al. 2018). Channel catfish were the second highest finfish on a relative importance scale during the spring. Even infrequent predation on channel catfish could substantially raise natural mortality if blue catfish densities approach those seen in Virginia tributaries as Schmitt et al. (2018) posited for species such as blue crab and alosids.

Indirect competition between channel catfish and blue catfish is likely harder to prove. There are no recent channel catfish feeding studies in Chesapeake Bay, but gizzard shad, Atlantic menhaden and white perch were large components of blue catfish finfish diets in Chesapeake Bay tributaries (Aguilar et al. 2017; Schmitt et al. 2018) and likely overlap with channel catfish diets. Benthic invertebrates, including *Gammarus* spp. and Dipterans, comprised a portion of blue catfish diets (Schmitt et al. 2018; Schloesser et al. 2011). Benthic invertebrates and *Gammarus* spp. were also important to channel catfish, particularly young channel catfish, in Maryland's portion of the Susquehanna River (Fewlass 1980; Weisberg and Janicki 1985). These dietary overlaps are a potential competitive bottleneck for both channel catfish and blue catfish.

PROJECT NO. 1
JOB NO. 2

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

2019 PRELIMINARY RESULTS – WORK IN PROGRESS

Job 2 is designed to assess white perch, yellow perch and channel catfish on a rotating, triennial basis. The yellow perch assessment is currently in progress. The upper Chesapeake Bay assessment utilized a statistical catch at age model, tuned with relative abundance at age from the winter trawl survey and the Estuarine Juvenile Finfish Survey (EJFS) young-of-year yellow perch index. Changes to this year's model included modelling harvest selectivity at age with a gamma distribution, improving the EJFS index by incorporating more sites and exploring Monte Carlo simulation runs. The base model (1998 – 2019) was run and bootstrapped 20,000 times in order to get a distribution of abundance at age from the 2005 population. These distributions were utilized in Monte Carlo simulations to model yellow perch population abundance from 2005 – 2019. This truncated model was investigated because the trawl survey tuning indices were not available on a consistent basis until 2006. The Choptank River yellow perch population will be assessed by analyzing relative abundance indices from the Choptank River fyke net survey (1989 – 2019). These data have been entered, but not yet analyzed. Preliminary plots of relative abundance indicated that the yellow perch population was stable at lower levels.

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Table 1. Uncertainty parameters for Head-of-Bay channel catfish surplus production model.

Parameter/Year		Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
r		0.322	0.330	0.323	0.088	-0.3	26.8
K		17,386,872	19,729,943	17,736,692	7,758,580	-2.0	39.3
B_0		4,009,584	4,258,405	3,985,560	1,453,404	0.6	34.1
B_{1981}		4,416,086	4,681,807	4,389,066	1,539,247	0.6	32.9
B_{1982}		4,990,831	5,276,903	4,977,691	1,637,200	0.3	31.0
B_{1983}		5,584,854	5,894,096	5,579,126	1,739,113	0.1	29.5
B_{1984}		6,075,268	6,407,434	6,079,945	1,830,755	-0.1	28.6
B_{1985}		6,649,229	7,000,774	6,658,075	1,901,799	-0.1	27.2
B_{1986}		6,986,876	7,351,309	7,006,976	1,950,830	-0.3	26.5
B_{1987}		7,440,789	7,812,226	7,459,025	1,990,138	-0.2	25.5
B_{1988}		8,095,008	8,466,100	8,106,253	2,021,269	-0.1	23.9
B_{1989}		8,826,613	9,188,090	8,824,776	2,045,019	0.0	22.3
B_{1990}		8,802,691	9,146,932	8,765,526	2,067,811	0.4	22.6
B_{1991}		8,745,881	9,080,555	8,692,324	2,094,649	0.6	23.1
B_{1992}		9,059,250	9,389,928	8,991,807	2,122,503	0.8	22.6
B_{1993}		9,168,891	9,496,024	9,089,036	2,151,159	0.9	22.7
B_{1994}		9,721,793	10,049,527	9,637,421	2,181,385	0.9	21.7
B_{1995}		9,296,314	9,625,034	9,220,349	2,218,739	0.8	23.1
B_{1996}		8,763,403	9,104,478	8,690,799	2,252,238	0.8	24.7
B_{1997}		7,770,077	8,129,557	7,718,312	2,281,873	0.7	28.1
B_{1998}		7,568,004	7,948,656	7,524,158	2,315,339	0.6	29.1
B_{1999}		7,042,519	7,443,404	7,007,121	2,349,242	0.5	31.6
B_{2000}		6,486,203	6,906,225	6,453,555	2,393,461	0.5	34.7
B_{2001}		6,745,248	7,182,157	6,713,202	2,454,558	0.5	34.2
B_{2002}		6,668,715	7,119,171	6,637,852	2,509,180	0.5	35.2
B_{2003}		7,069,878	7,530,453	7,044,728	2,571,146	0.4	34.1
B_{2004}		7,349,112	7,814,151	7,333,670	2,624,361	0.2	33.6
B_{2005}		7,816,247	8,280,190	7,801,967	2,674,535	0.2	32.3
B_{2006}		8,787,042	9,243,041	8,765,256	2,716,309	0.2	29.4
B_{2007}		9,330,724	9,768,585	9,283,308	2,740,643	0.5	28.1
B_{2008}		10,243,768	10,662,376	10,176,371	2,763,940	0.7	25.9
B_{2009}		10,489,293	10,887,867	10,409,884	2,790,045	0.8	25.6
B_{2010}		10,941,878	11,333,962	10,849,824	2,824,273	0.8	24.9
B_{2011}		10,860,788	11,257,824	10,741,083	2,869,644	1.1	25.5
B_{2012}		10,255,672	10,673,088	10,154,147	2,917,392	1.0	27.3
B_{2013}		9,561,279	10,009,452	9,470,894	2,958,484	1.0	29.6
B_{2014}		9,630,587	10,112,090	9,571,339	2,997,013	0.6	29.6
B_{2015}		9,322,240	9,838,633	9,270,110	3,035,961	0.6	30.9
B_{2016}		10,712,979	11,264,914	10,688,532	3,076,818	0.2	27.3
B_{2017}		12,035,585	12,624,919	12,028,824	3,131,017	0.1	24.8

Table 1. (Continued)

Parameter/Year	Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
F_{1980}	0.158	0.165	0.159	0.053	-0.6	32.4
F_{1981}	0.116	0.120	0.117	0.036	-0.6	29.7
F_{1982}	0.117	0.120	0.117	0.032	-0.3	27.2
F_{1983}	0.140	0.142	0.140	0.036	-0.1	25.3
F_{1984}	0.122	0.123	0.122	0.029	0.1	23.7
F_{1985}	0.160	0.161	0.160	0.036	0.1	22.7
F_{1986}	0.136	0.136	0.136	0.030	0.3	21.8
F_{1987}	0.101	0.101	0.101	0.021	0.3	20.6
F_{1988}	0.085	0.085	0.085	0.016	0.1	19.1
F_{1989}	0.176	0.175	0.176	0.033	0.0	18.7
F_{1990}	0.181	0.181	0.181	0.034	-0.5	19.0
F_{1991}	0.132	0.133	0.133	0.025	-0.7	18.9
F_{1992}	0.153	0.154	0.154	0.029	-0.8	18.7
F_{1993}	0.096	0.096	0.097	0.018	-0.9	18.3
F_{1994}	0.205	0.206	0.207	0.038	-1.0	18.6
F_{1995}	0.232	0.234	0.234	0.047	-0.9	20.2
F_{1996}	0.319	0.324	0.322	0.074	-1.0	22.8
F_{1997}	0.228	0.233	0.230	0.058	-0.7	24.8
F_{1998}	0.289	0.296	0.291	0.078	-0.7	26.5
F_{1999}	0.315	0.325	0.317	0.095	-0.6	29.2
F_{2000}	0.176	0.182	0.177	0.054	-0.6	29.8
F_{2001}	0.233	0.241	0.235	0.073	-0.5	30.3
F_{2002}	0.149	0.153	0.149	0.046	-0.5	30.1
F_{2003}	0.164	0.169	0.165	0.050	-0.4	29.7
F_{2004}	0.130	0.134	0.131	0.039	-0.2	29.0
F_{2005}	0.054	0.055	0.054	0.015	-0.2	27.1
F_{2006}	0.102	0.104	0.103	0.026	-0.3	25.4
F_{2007}	0.053	0.053	0.053	0.013	-0.5	23.7
F_{2008}	0.114	0.116	0.115	0.026	-0.7	22.5
F_{2009}	0.088	0.090	0.089	0.020	-0.8	22.0
F_{2010}	0.135	0.138	0.137	0.030	-0.9	21.9
F_{2011}	0.194	0.198	0.197	0.046	-1.2	23.2
F_{2012}	0.223	0.229	0.225	0.059	-1.1	25.6
F_{2013}	0.148	0.152	0.149	0.041	-1.0	26.7
F_{2014}	0.193	0.199	0.194	0.055	-0.7	27.5
F_{2015}	0.251	0.260	0.253	0.077	-0.6	29.8
F_{2016}	0.151	0.154	0.152	0.038	-0.2	24.5
F_{2017}	0.122	0.123	0.122	0.027	-0.1	21.9

Table 1. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
$(B/B_{MSY})_{1980}$	0.461	0.444	0.445	0.078	3.5	17.6
$(B/B_{MSY})_{1981}$	0.508	0.492	0.493	0.092	3.1	18.8
$(B/B_{MSY})_{1982}$	0.574	0.559	0.561	0.112	2.3	20.1
$(B/B_{MSY})_{1983}$	0.642	0.630	0.631	0.136	1.8	21.6
$(B/B_{MSY})_{1984}$	0.699	0.689	0.689	0.158	1.5	23.0
$(B/B_{MSY})_{1985}$	0.765	0.757	0.756	0.182	1.2	24.0
$(B/B_{MSY})_{1986}$	0.804	0.798	0.795	0.198	1.0	24.8
$(B/B_{MSY})_{1987}$	0.856	0.851	0.849	0.214	0.8	25.2
$(B/B_{MSY})_{1988}$	0.931	0.925	0.924	0.233	0.7	25.2
$(B/B_{MSY})_{1989}$	1.015	1.006	1.008	0.249	0.7	24.8
$(B/B_{MSY})_{1990}$	1.013	0.999	1.008	0.238	0.5	23.9
$(B/B_{MSY})_{1991}$	1.006	0.989	1.003	0.230	0.3	23.2
$(B/B_{MSY})_{1992}$	1.042	1.023	1.041	0.233	0.1	22.8
$(B/B_{MSY})_{1993}$	1.055	1.033	1.056	0.229	-0.1	22.2
$(B/B_{MSY})_{1994}$	1.118	1.093	1.119	0.237	-0.1	21.7
$(B/B_{MSY})_{1995}$	1.069	1.042	1.073	0.215	-0.3	20.6
$(B/B_{MSY})_{1996}$	1.008	0.981	1.012	0.195	-0.3	19.9
$(B/B_{MSY})_{1997}$	0.894	0.869	0.894	0.171	-0.1	19.6
$(B/B_{MSY})_{1998}$	0.871	0.849	0.870	0.170	0.1	20.0
$(B/B_{MSY})_{1999}$	0.810	0.792	0.806	0.164	0.5	20.7
$(B/B_{MSY})_{2000}$	0.746	0.731	0.736	0.162	1.3	22.2
$(B/B_{MSY})_{2001}$	0.776	0.763	0.767	0.175	1.1	23.0
$(B/B_{MSY})_{2002}$	0.767	0.756	0.759	0.183	1.1	24.2
$(B/B_{MSY})_{2003}$	0.813	0.803	0.807	0.198	0.8	24.7
$(B/B_{MSY})_{2004}$	0.845	0.836	0.841	0.211	0.5	25.2
$(B/B_{MSY})_{2005}$	0.899	0.889	0.898	0.225	0.2	25.3
$(B/B_{MSY})_{2006}$	1.011	0.998	1.013	0.247	-0.2	24.8
$(B/B_{MSY})_{2007}$	1.073	1.056	1.078	0.255	-0.4	24.1
$(B/B_{MSY})_{2008}$	1.178	1.155	1.186	0.268	-0.7	23.2
$(B/B_{MSY})_{2009}$	1.207	1.177	1.215	0.258	-0.7	21.9
$(B/B_{MSY})_{2010}$	1.259	1.223	1.269	0.254	-0.8	20.8
$(B/B_{MSY})_{2011}$	1.249	1.210	1.258	0.236	-0.7	19.5
$(B/B_{MSY})_{2012}$	1.180	1.139	1.186	0.209	-0.6	18.4
$(B/B_{MSY})_{2013}$	1.100	1.061	1.101	0.188	-0.1	17.8
$(B/BMSY)_{2014}$	1.108	1.071	1.110	0.187	-0.2	17.4
$(B/BMSY)_{2015}$	1.072	1.038	1.073	0.178	-0.1	17.2
$(B/BMSY)_{2016}$	1.232	1.198	1.243	0.203	-0.9	16.9
$(B/B_{MSY})_{2017}$	1.384	1.348	1.399	0.224	-1.0	16.6

Table 1. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
$(F/F_{MSY})_{1980}$	0.982	0.998	0.999	0.154	-1.7	15.4
$(F/F_{MSY})_{1981}$	0.723	0.733	0.733	0.117	-1.3	16.0
$(F/F_{MSY})_{1982}$	0.727	0.734	0.733	0.124	-0.8	16.9
$(F/F_{MSY})_{1983}$	0.870	0.878	0.875	0.158	-0.6	18.0
$(F/F_{MSY})_{1984}$	0.758	0.765	0.761	0.147	-0.4	19.2
$(F/F_{MSY})_{1985}$	0.995	1.004	0.999	0.203	-0.4	20.3
$(F/F_{MSY})_{1986}$	0.848	0.856	0.848	0.180	0.0	21.1
$(F/F_{MSY})_{1987}$	0.628	0.635	0.627	0.137	0.2	21.6
$(F/F_{MSY})_{1988}$	0.529	0.535	0.526	0.117	0.4	21.8
$(F/F_{MSY})_{1989}$	1.092	1.107	1.086	0.241	0.6	21.8
$(F/F_{MSY})_{1990}$	1.123	1.140	1.115	0.242	0.7	21.2
$(F/F_{MSY})_{1991}$	0.823	0.836	0.816	0.173	0.9	20.7
$(F/F_{MSY})_{1992}$	0.952	0.967	0.944	0.197	0.9	20.3
$(F/F_{MSY})_{1993}$	0.598	0.607	0.592	0.120	1.0	19.8
$(F/F_{MSY})_{1994}$	1.276	1.295	1.263	0.248	1.1	19.1
$(F/F_{MSY})_{1995}$	1.442	1.463	1.429	0.263	0.9	18.0
$(F/F_{MSY})_{1996}$	1.981	2.009	1.973	0.348	0.4	17.3
$(F/F_{MSY})_{1997}$	1.418	1.437	1.421	0.248	-0.2	17.2
$(F/F_{MSY})_{1998}$	1.798	1.823	1.807	0.327	-0.5	18.0
$(F/F_{MSY})_{1999}$	1.960	1.994	1.980	0.386	-1.0	19.4
$(F/F_{MSY})_{2000}$	1.097	1.117	1.105	0.230	-0.7	20.6
$(F/F_{MSY})_{2001}$	1.452	1.483	1.460	0.328	-0.6	22.1
$(F/F_{MSY})_{2002}$	0.924	0.945	0.927	0.220	-0.2	23.3
$(F/F_{MSY})_{2003}$	1.020	1.046	1.020	0.256	0.1	24.4
$(F/F_{MSY})_{2004}$	0.810	0.831	0.807	0.210	0.4	25.3
$(F/F_{MSY})_{2005}$	0.338	0.346	0.335	0.087	0.8	25.2
$(F/F_{MSY})_{2006}$	0.636	0.652	0.629	0.164	1.2	25.1
$(F/F_{MSY})_{2007}$	0.327	0.335	0.323	0.081	1.3	24.3
$(F/F_{MSY})_{2008}$	0.712	0.730	0.701	0.171	1.5	23.4
$(F/F_{MSY})_{2009}$	0.549	0.562	0.540	0.123	1.6	21.9
$(F/F_{MSY})_{2010}$	0.842	0.861	0.829	0.177	1.6	20.6
$(F/F_{MSY})_{2011}$	1.207	1.233	1.191	0.236	1.4	19.1
$(F/F_{MSY})_{2012}$	1.385	1.413	1.372	0.256	0.9	18.1
$(F/F_{MSY})_{2013}$	0.920	0.936	0.913	0.164	0.7	17.6
$(F/FMSY)_{2014}$	1.200	1.219	1.191	0.213	0.8	17.5
$(F/FMSY)_{2015}$	1.562	1.587	1.555	0.286	0.5	18.1
$(F/FMSY)_{2016}$	0.942	0.947	0.924	0.153	1.9	16.1
$(F/F_{MSY})_{2017}$	0.759	0.759	0.744	0.112	2.1	14.8

[1] Bias defined as 100*(est-med)/med

Table 2. Uncertainty parameters for Choptank River channel catfish catch survey analysis model.

Estimate/Parameter	Estimate	Mean	Median	CV	Bias[1]
q	3.17E-06	3.16E-06	3.15E-06	2.0	0.7
Recruit N 1993	206,057	206,131	195,518	29.7	5.4
Recruit N 1994	233,660	236,407	228,936	21.2	2.1
Recruit N 1995	390,627	393,050	388,810	13.1	0.5
Recruit N 1996	347,624	350,697	347,265	12.2	0.1
Recruit N 1997	314,893	318,397	315,745	11.4	-0.3
Recruit N 1998	254,992	258,340	256,104	11.5	-0.4
Recruit N 1999	201,232	204,670	202,744	12.1	-0.7
Recruit N 2000	189,789	192,934	190,684	15.3	-0.5
Recruit N 2001	228,914	232,392	229,732	12.8	-0.4
Recruit N 2002	228,576	232,637	230,637	11.4	-0.9
Recruit N 2003	195,991	200,125	198,397	11.3	-1.2
Recruit N 2004	238,327	243,057	240,457	12.9	-0.9
Recruit N 2005	202,816	207,717	205,390	13.0	-1.3
Recruit N 2006	234,453	239,529	234,829	17.4	-0.2
Recruit N 2007	246,081	253,813	248,536	18.6	-1.0
Recruit N 2008	429,956	438,689	431,248	16.5	-0.3
Recruit N 2009	568,238	576,998	569,118	15.5	-0.2
Recruit N 2010	644,937	655,091	646,319	14.3	-0.2
Recruit N 2011	610,952	622,727	617,767	14.0	-1.1
Recruit N 2012	765,753	774,834	767,461	12.8	-0.2
Recruit N 2013	577,312	586,664	580,142	14.1	-0.5
Recruit N 2014	480,551	491,008	485,255	14.6	-1.0
Recruit N 2015	418,082	429,379	424,307	14.9	-1.5
Recruit N 2016	734,624	750,955	740,425	14.0	-0.8
Recruit N 2017	610,849	626,427	618,432	13.9	-1.2
Recruit N 2018	445,498	459,272	452,902	15.6	-1.6
Pre-Recruit N 1993	101,278	104,559	102,851	19.8	-1.5
Pre-Recruit N 1994	264,629	264,842	258,067	20.7	2.5
Pre-Recruit N 1995	54,153	55,484	55,239	17.7	-2.0
Pre-Recruit N 1996	73,280	74,486	73,465	19.2	-0.3
Pre-Recruit N 1997	19,422	20,008	19,947	17.5	-2.6
Pre-Recruit N 1998	34,929	35,781	35,598	18.4	-1.9
Pre-Recruit N 1999	140,134	140,536	137,157	20.9	2.2
Pre-Recruit N 2000	109,159	110,262	107,773	20.7	1.3
Pre-Recruit N 2001	62,148	63,630	62,487	18.9	-0.5
Pre-Recruit N 2002	40,620	41,609	41,189	18.2	-1.4
Pre-Recruit N 2003	147,605	149,248	144,807	21.5	1.9
Pre-Recruit N 2004	49,595	50,851	50,345	18.3	-1.5
Pre-Recruit N 2005	210,915	212,214	206,487	21.3	2.1
Pre-Recruit N 2006	192,680	197,048	191,447	21.5	0.6
Pre-Recruit N 2007	358,184	361,118	351,284	21.1	2.0
Pre-Recruit N 2008	426,382	428,348	418,306	21.0	1.9
Pre-Recruit N 2009	389,563	393,206	384,335	20.5	1.4
Pre-Recruit N 2010	284,830	289,057	284,496	19.7	0.1
Pre-Recruit N 2011	510,518	509,834	497,382	20.1	2.6
Pre-Recruit N 2012	87,298	89,639	89,208	18.1	-2.1
Pre-Recruit N 2013	153,998	157,418	155,833	19.1	-1.2
Pre-Recruit N 2014	155,570	158,912	156,276	19.6	-0.5
Pre-Recruit N 2015	545,035	553,686	536,600	21.5	1.6
Pre-Recruit N 2016	79,198	81,894	81,469	18.4	-2.8
Pre-Recruit N 2017	33,743	34,989	34,908	17.5	-3.3

[1] Bias defined as 100*(est-med)/med

Table 3. Head of Bay surplus production model parameters and management benchmarks from 2011, 2014 and 2017 assessments. MSYand B in million pounds.

	Assessment Year		
Parameter	2017	2014	2011
r	0.32	0.58	0.68
K	17.4	10.7	8.7
MSY	1.4	1.6	1.5
B_{2014}	9.6	6.8	N/A
B_{2011}	10.9	8.2	6.8
F_{2014}	0.19	0.28	N/A
F_{2011}	0.19	0.26	0.29
$B:BMSY_{2014}$	1.11	1.28	N/A
$B:BMSY_{2011}$	1.25	1.55	1.55
$F:FMSY_{2014}$	1.2	0.97	N/A
$F:FMSY_{2011}$	1.2	0.92	0.86

Figure 1. Head-of-Bay and Potomac River fishery independent drift gill net sampling locations, 1985 -- 2017.

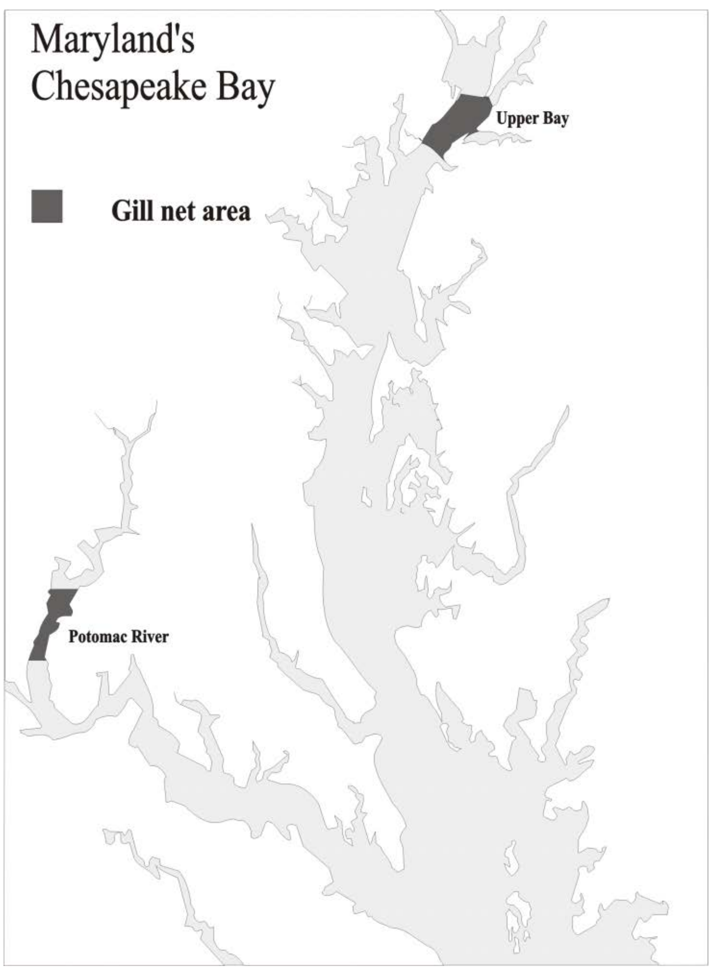


Figure 2.   Head-of-Bay winter trawl sites, 1999 -- 2017 (triangles=main bay sites, squares=Elk River sites, circles=Sassafras River sites).

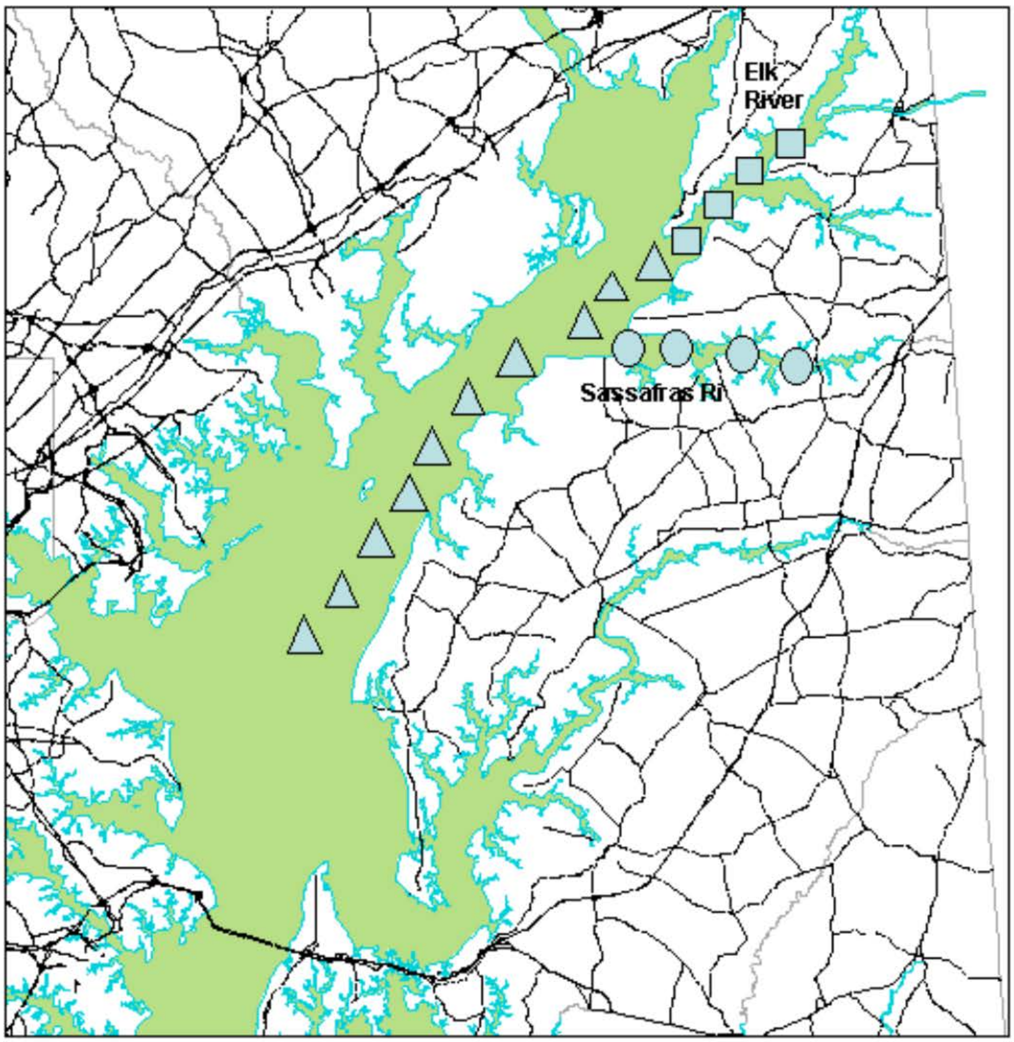


Figure 3. Choptank River fyke net locations, 2017. Circles indicate sites.

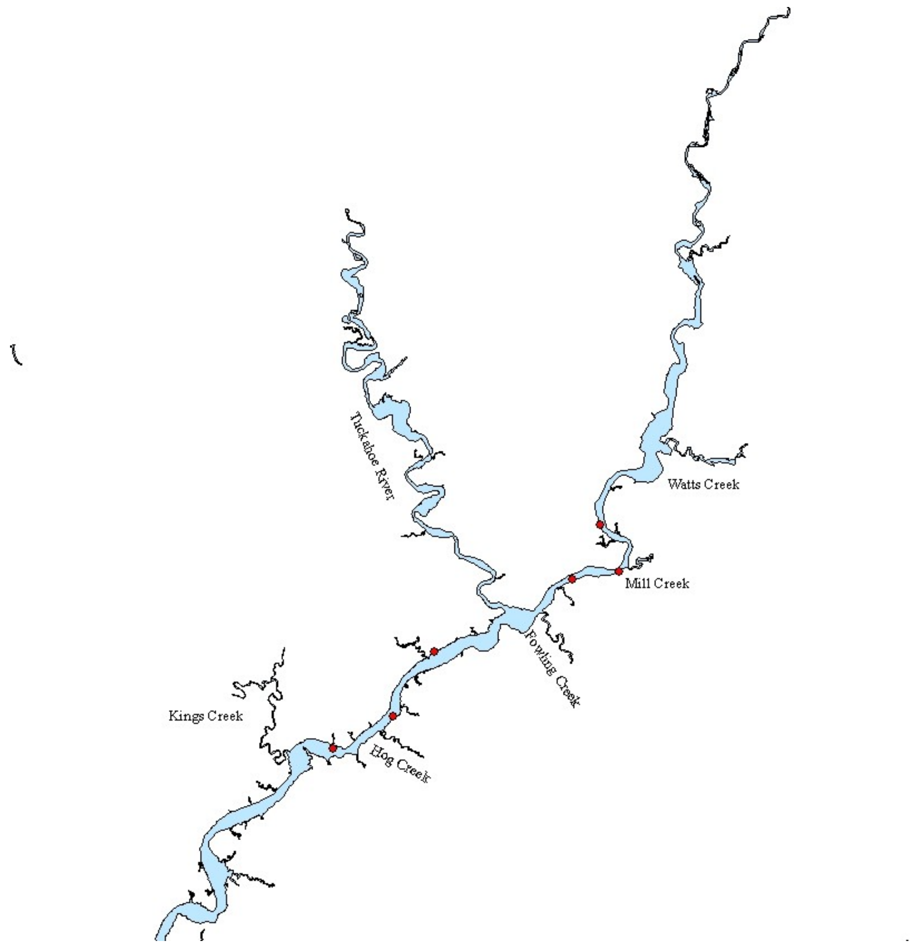


Figure 4. Adjusted Maryland commercial channel catfish landings, 1929 – 2017.

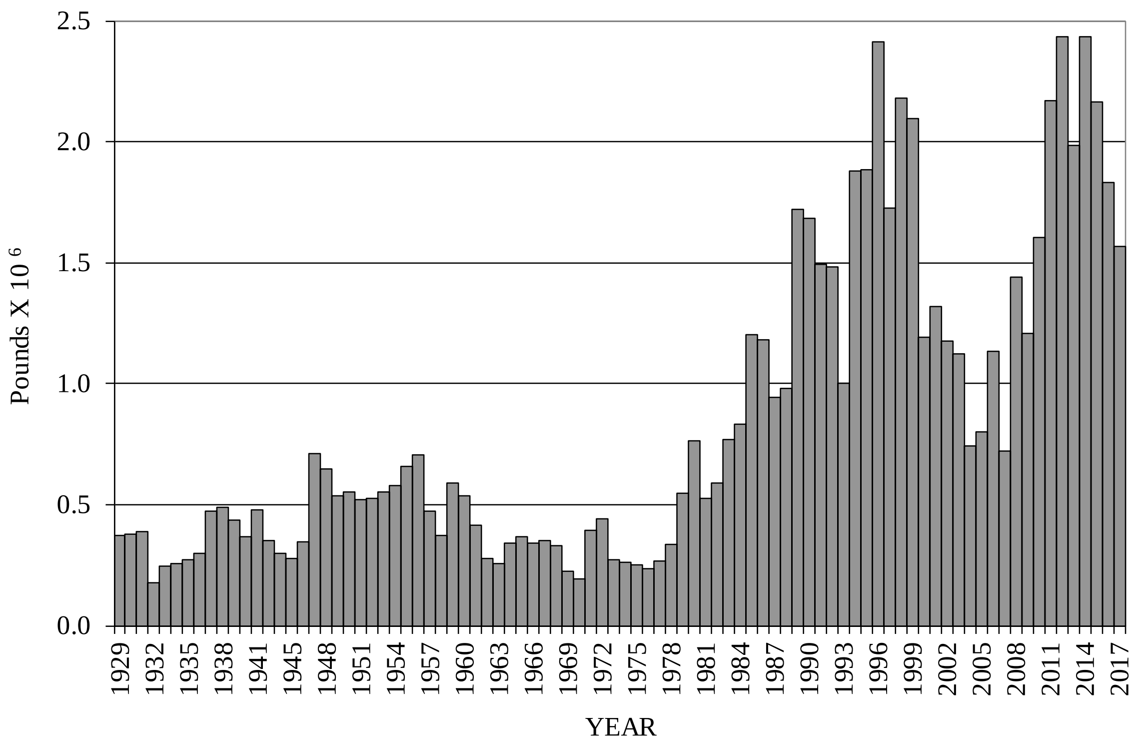


Figure 5. Estimated channel catfish landings from the recreational fishery, 1983 – 2014. Error bars = 1 standard error.

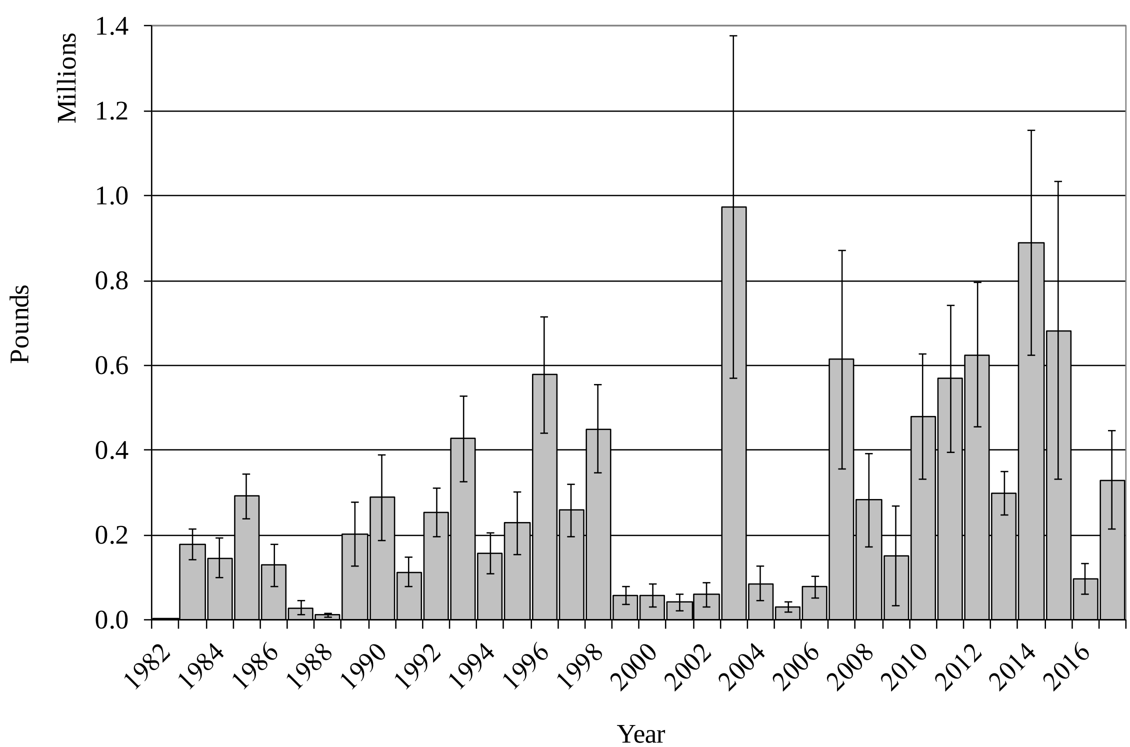


Figure 6. Head-of Bay channel catfish removals from commercial and recreational fisheries, 1980 – 2017.

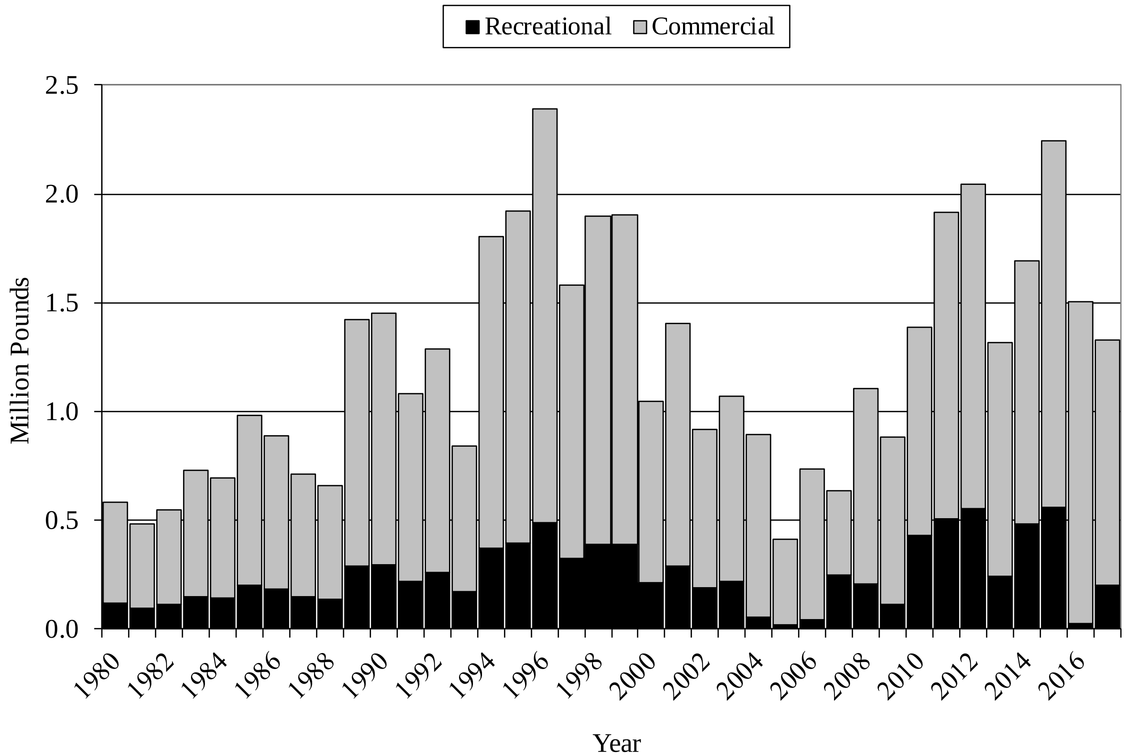


Figure 7. Observed and expected HOB commercial fyke net index, 1980 – 2017.

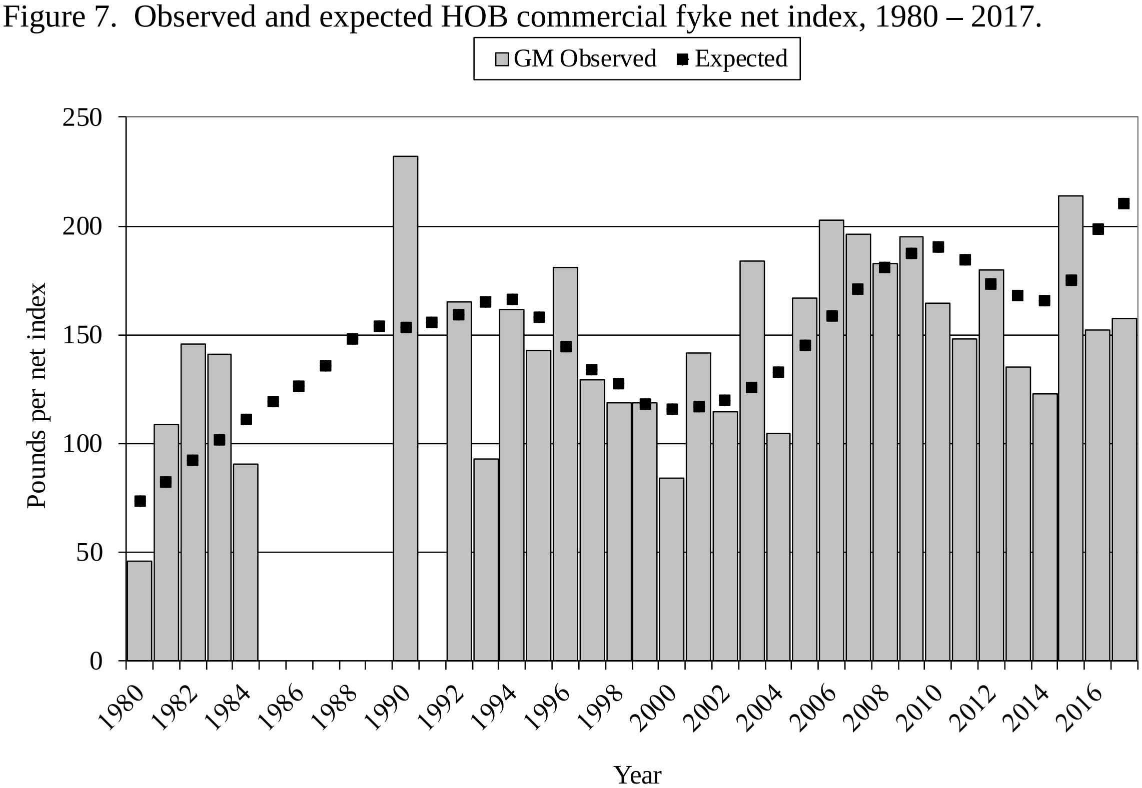


Figure 8. Observed and expected HOB commercial fish pot net index, 1980 – 2017.

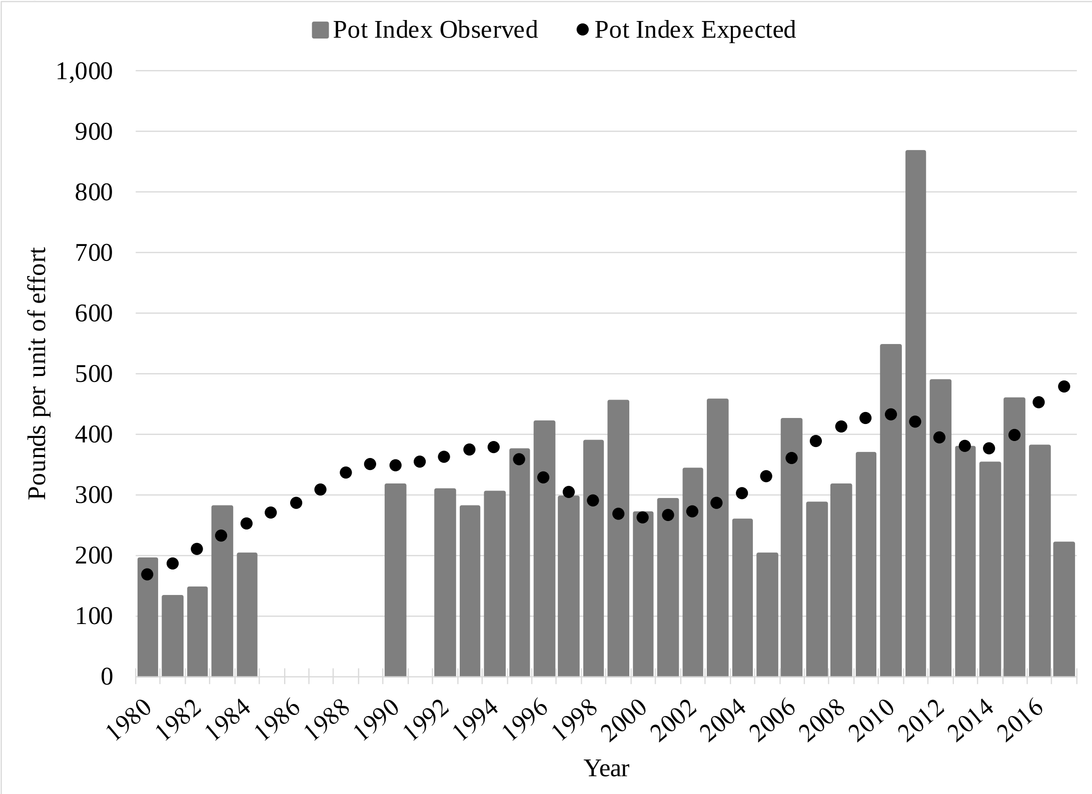


Figure 9. Observed and expected HOB commercial pound net index, 1980 – 2017.

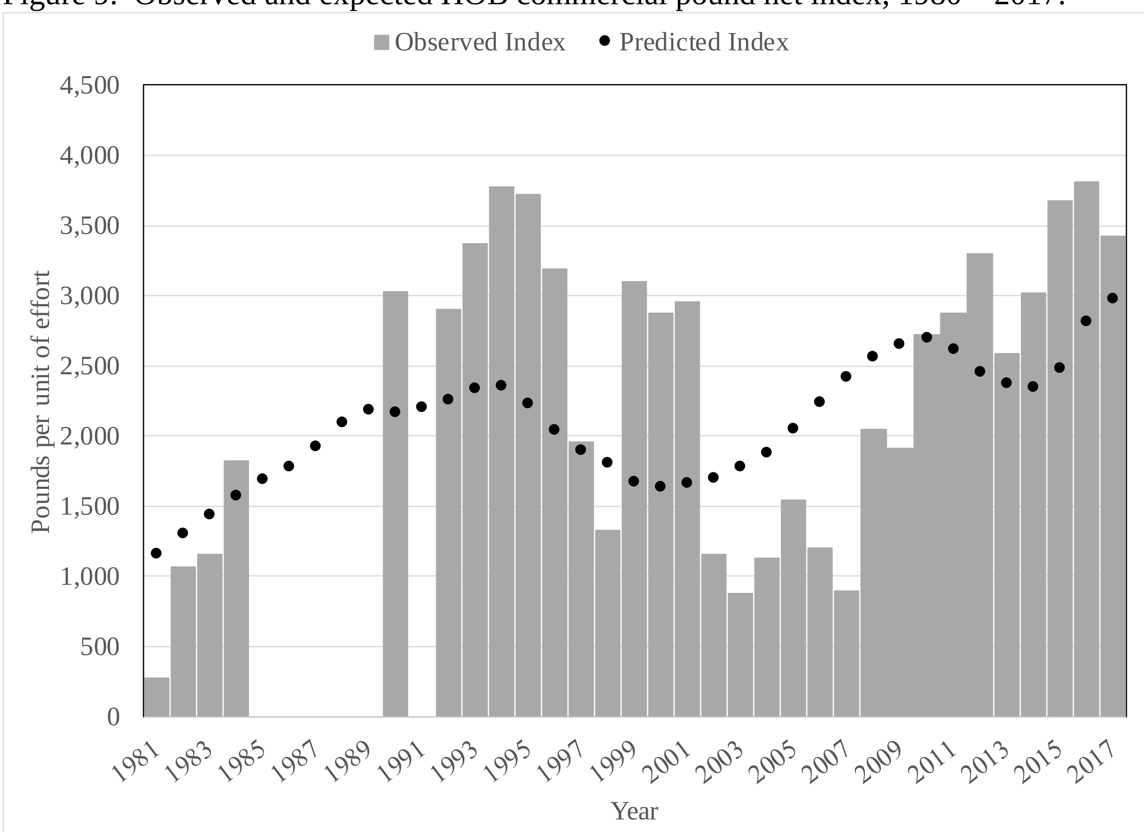


Figure 10. Observed and expected biomass index from HOB gill net survey, 1985 – 2017.

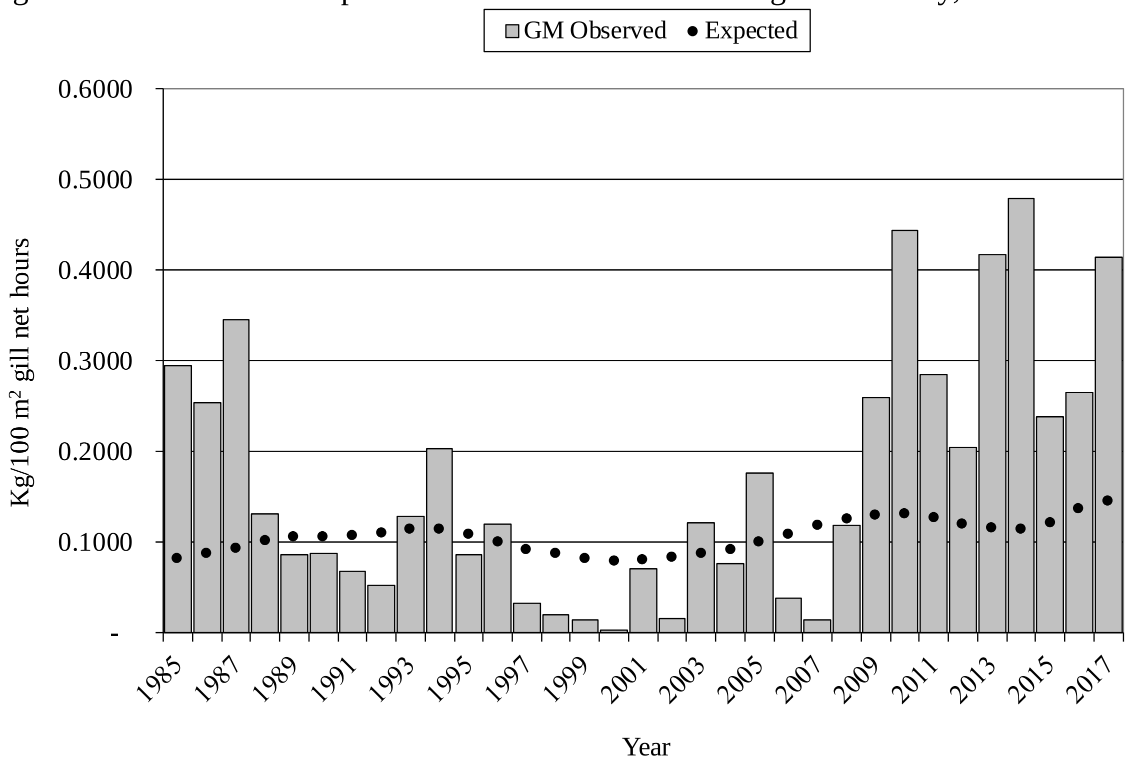


Figure 11. Observed and expected channel catfish biomass index from upper Bay winter trawl survey, 2000 – 2002 and 2006 – 2017.

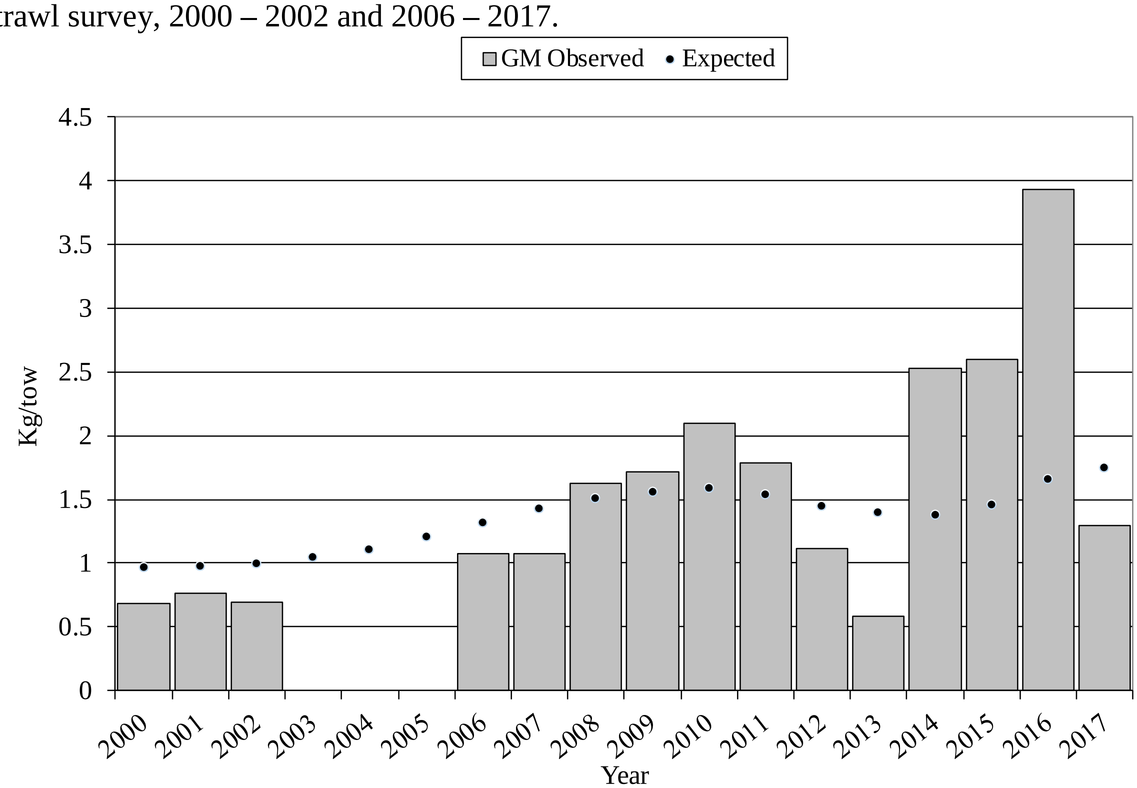


Figure 12. Biomass and fishing mortality estimates from Head-of-Bay channel catfish surplus production model.

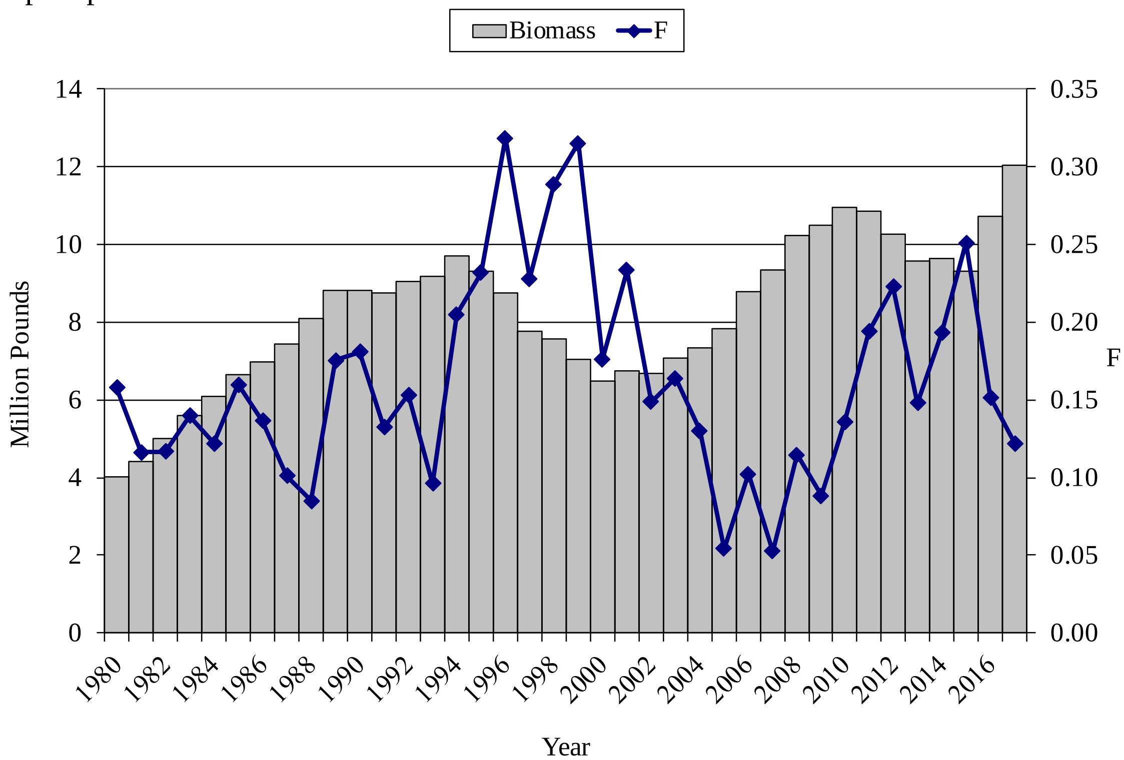


Figure 13. Biomass and fishing mortality ratios from Head-of-Bay channel catfish surplus production model.

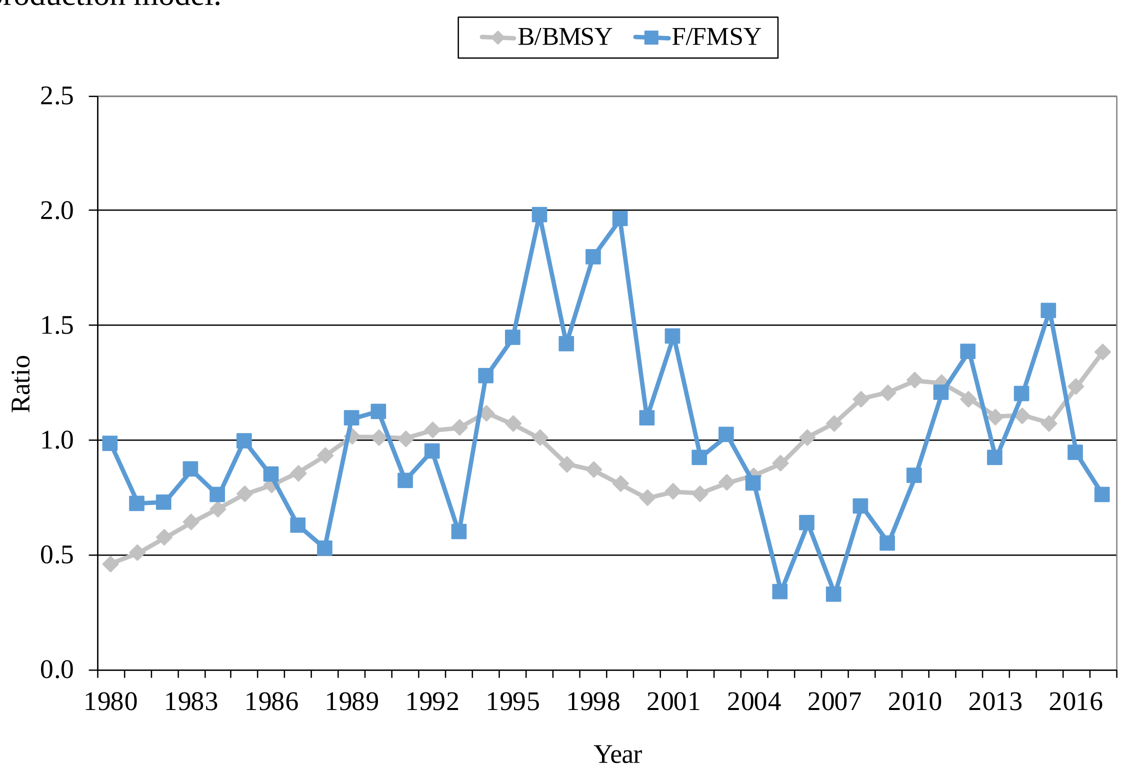


Figure 14. Biomass ratio and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

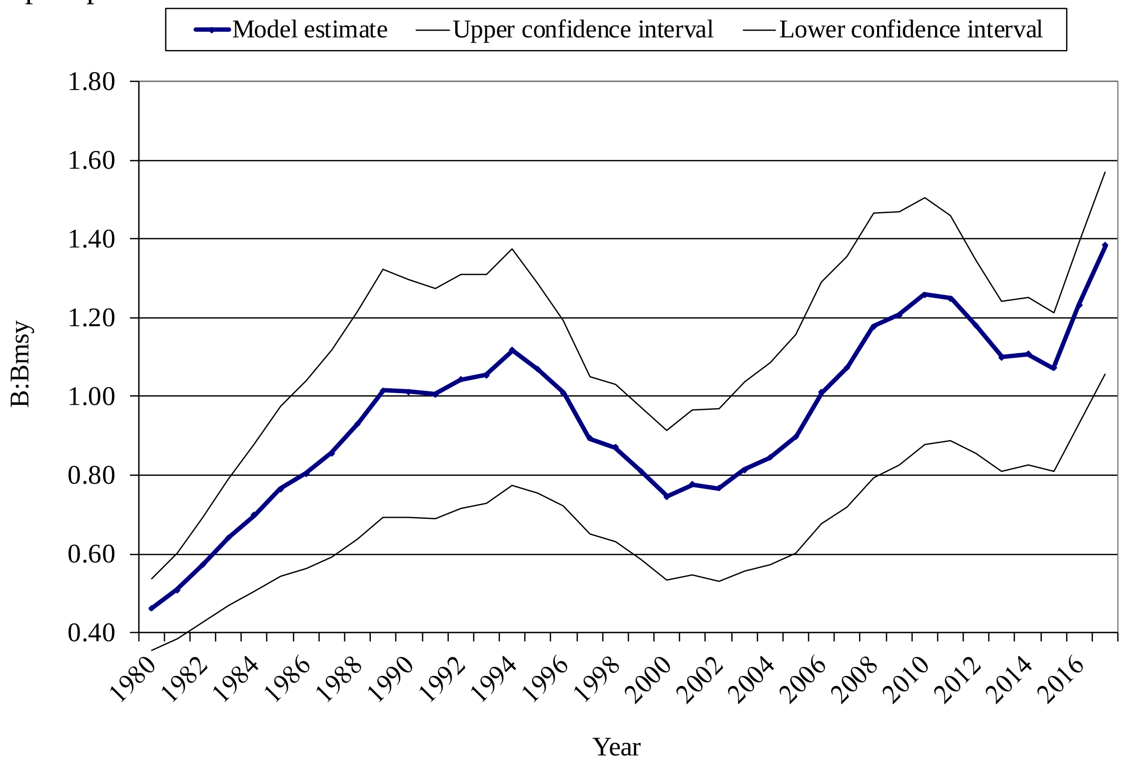


Figure 15. Fishing mortality ratio and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

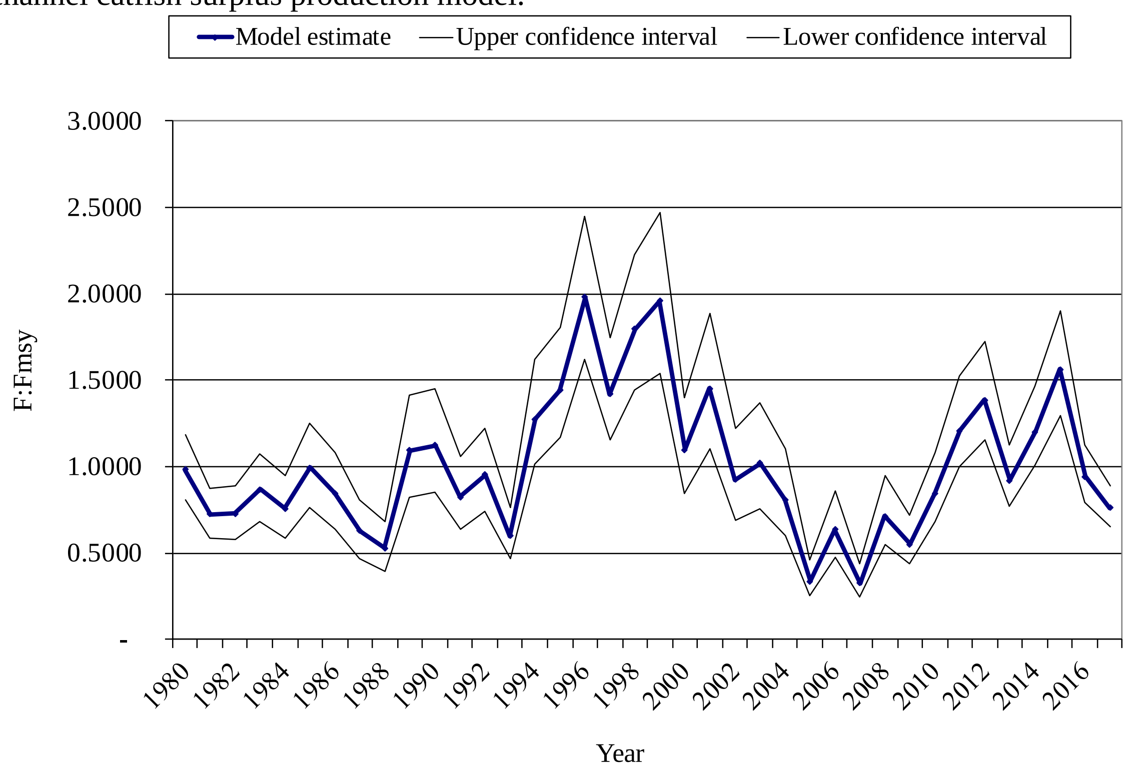


Figure 16. Choptank River channel catfish removals from commercial and recreational fisheries, 1993 – 2017.

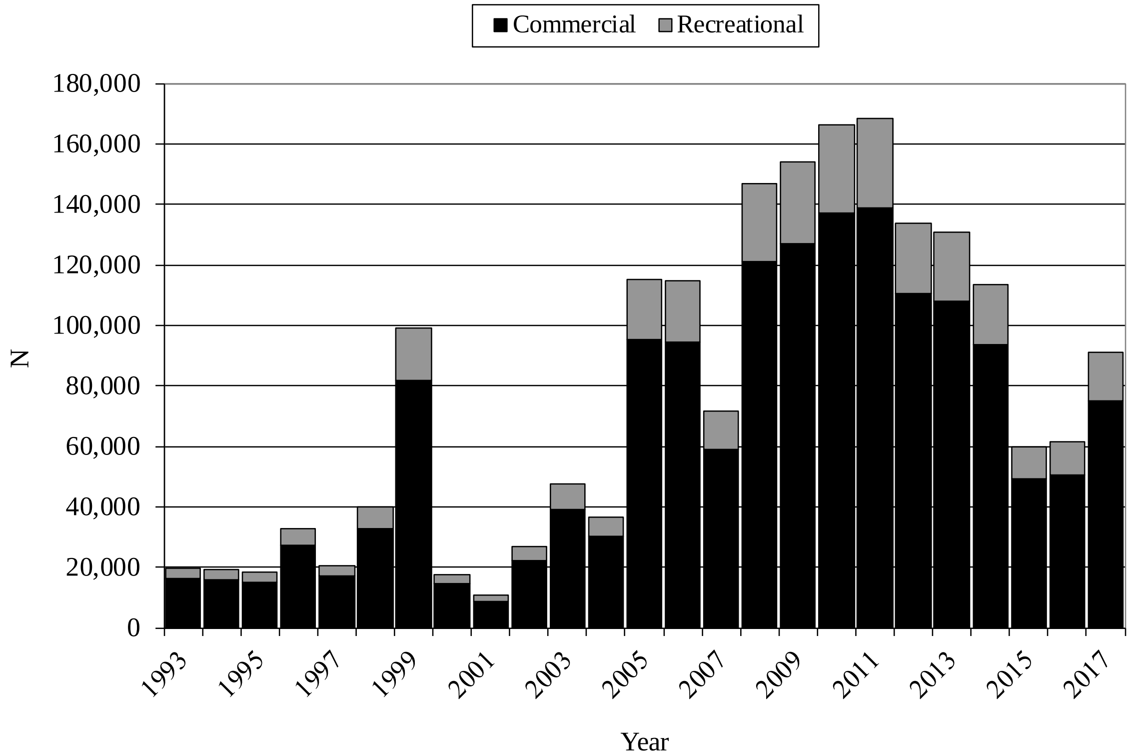


Figure 17. Observed and expected pre-recruit channel catfish index from Choptank River catch survey analysis.

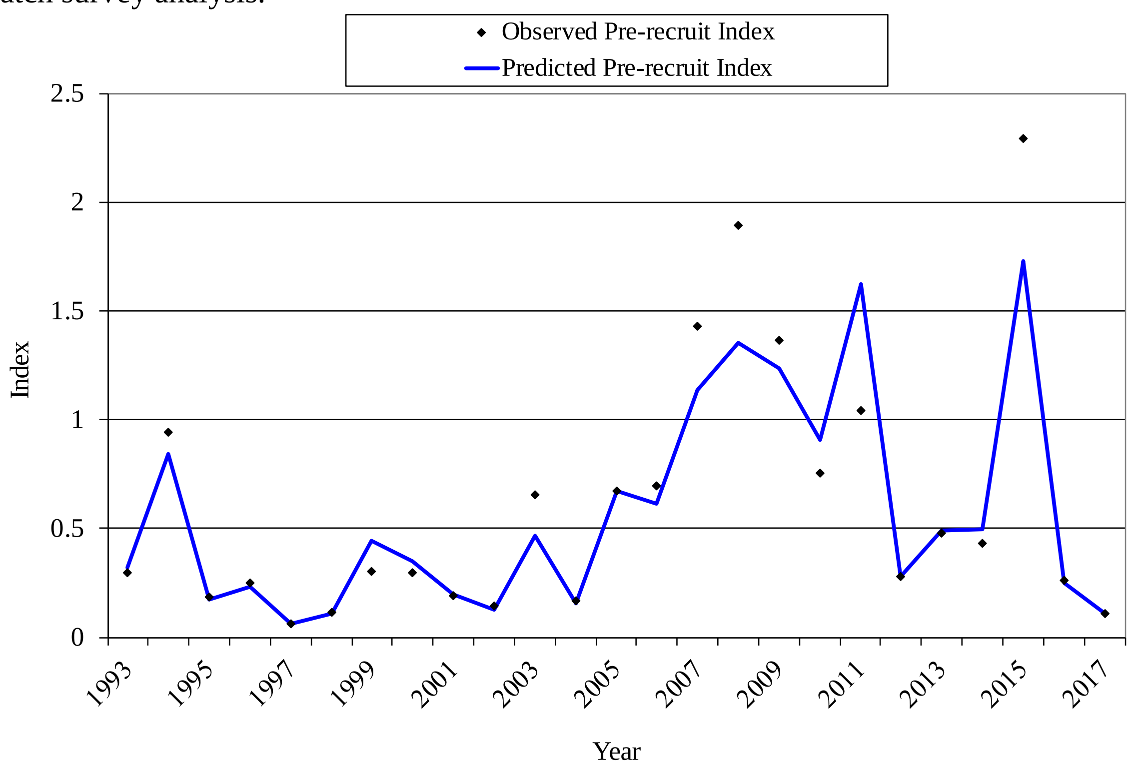


Figure 18. Observed and expected post-recruit channel catfish index from Choptank River catch survey analysis.

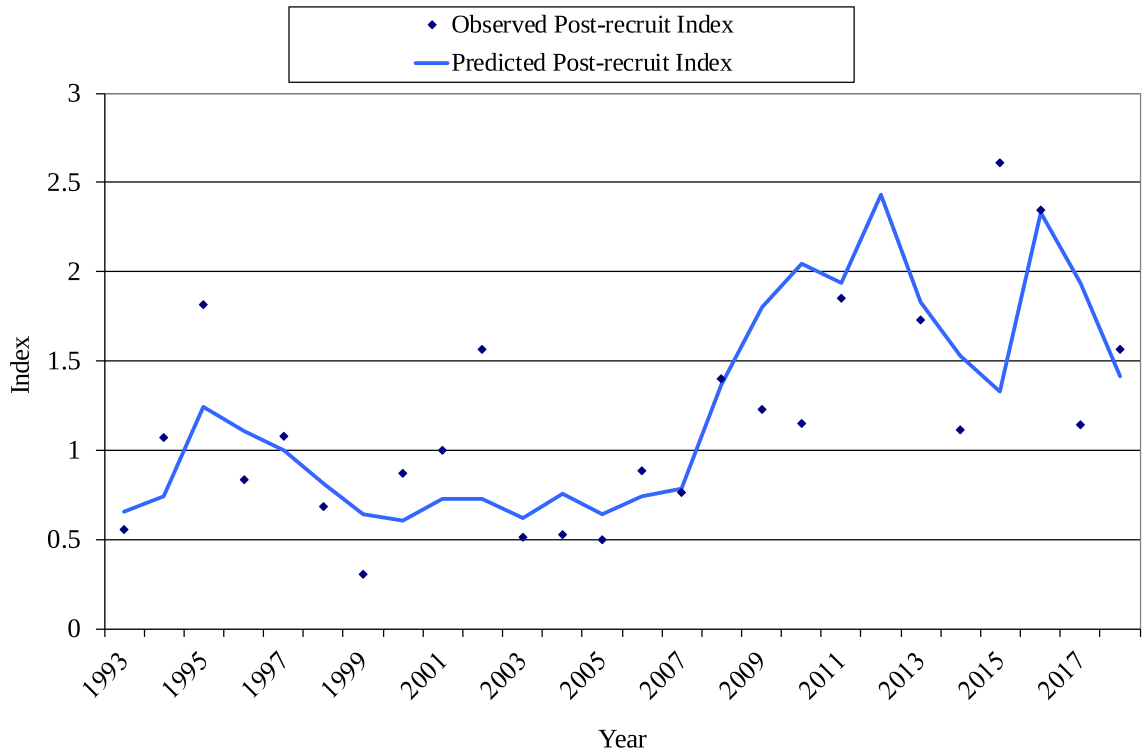


Figure 19. Choptank River channel catfish pre-recruit abundance with 80% confidence intervals from catch survey analysis.

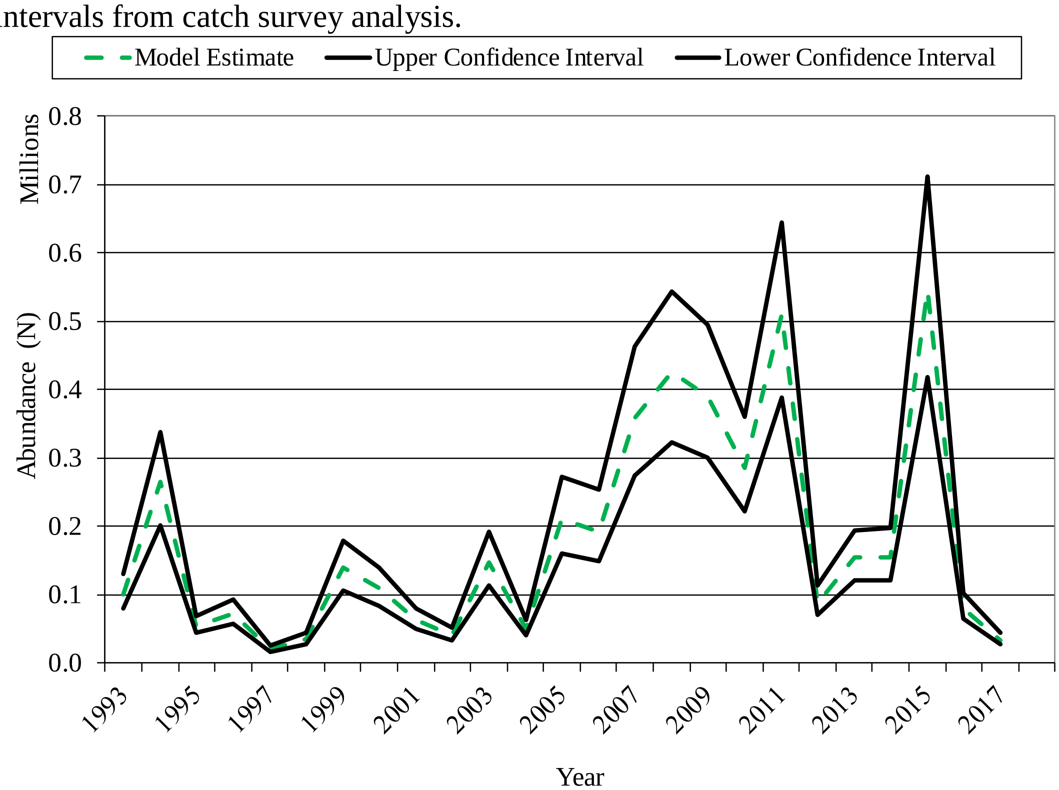


Figure 20. Choptank River channel catfish post-recruit abundance with 80% confidence intervals from catch survey analysis.

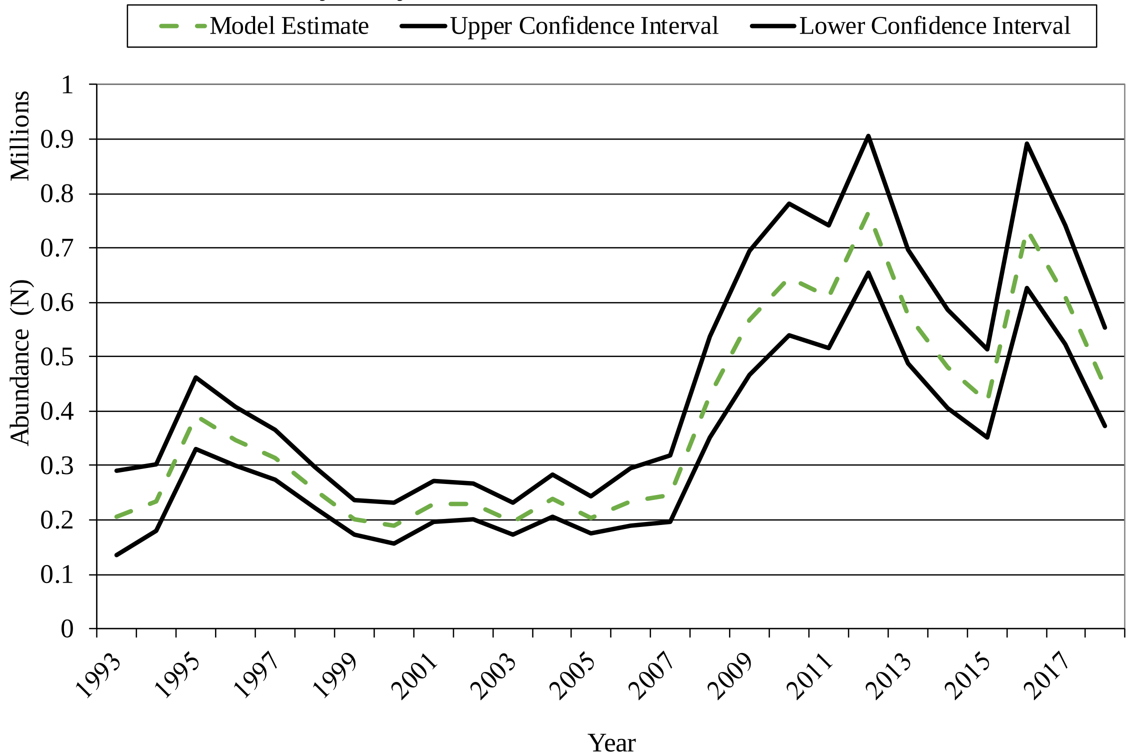


Figure 21. Total channel catfish population abundance estimates and 80% confidence intervals from Choptank River catch survey analysis.

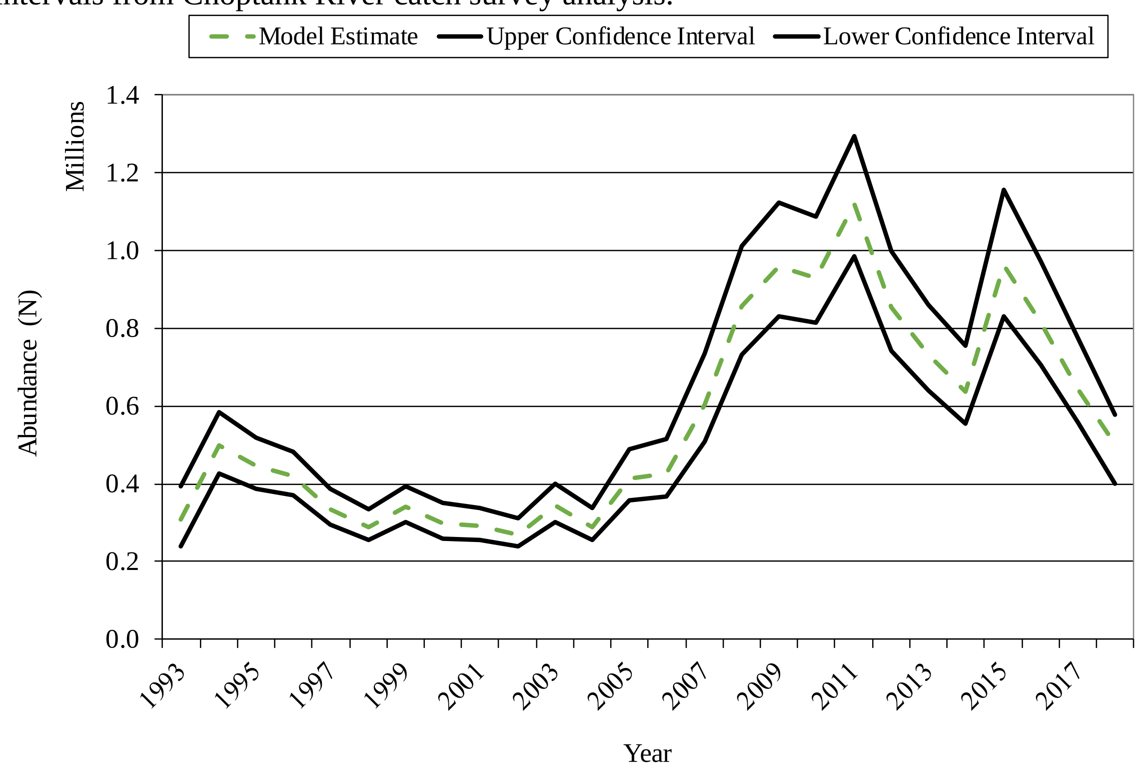


Figure 22. Estimated fishing mortality and 80% confidence intervals for Choptank River channel catfish from catch survey analysis.

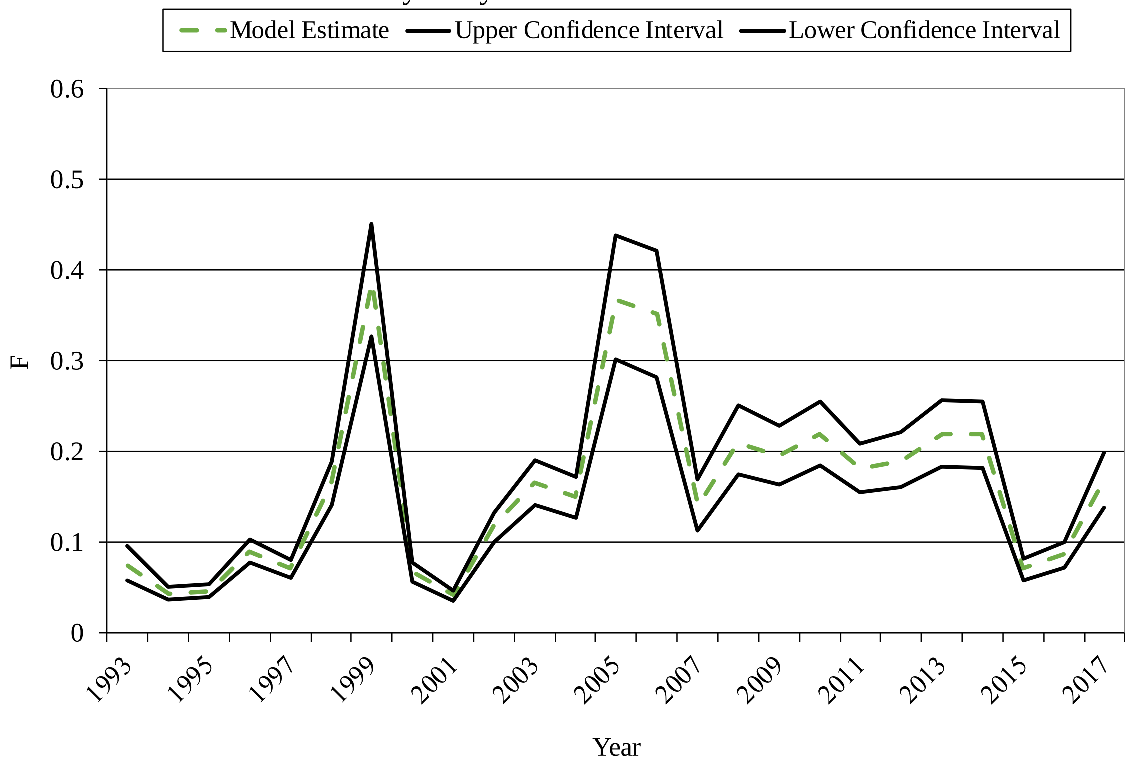


Figure 23. Nanticoke River channel catfish commercial landings, 1987 – 2017.

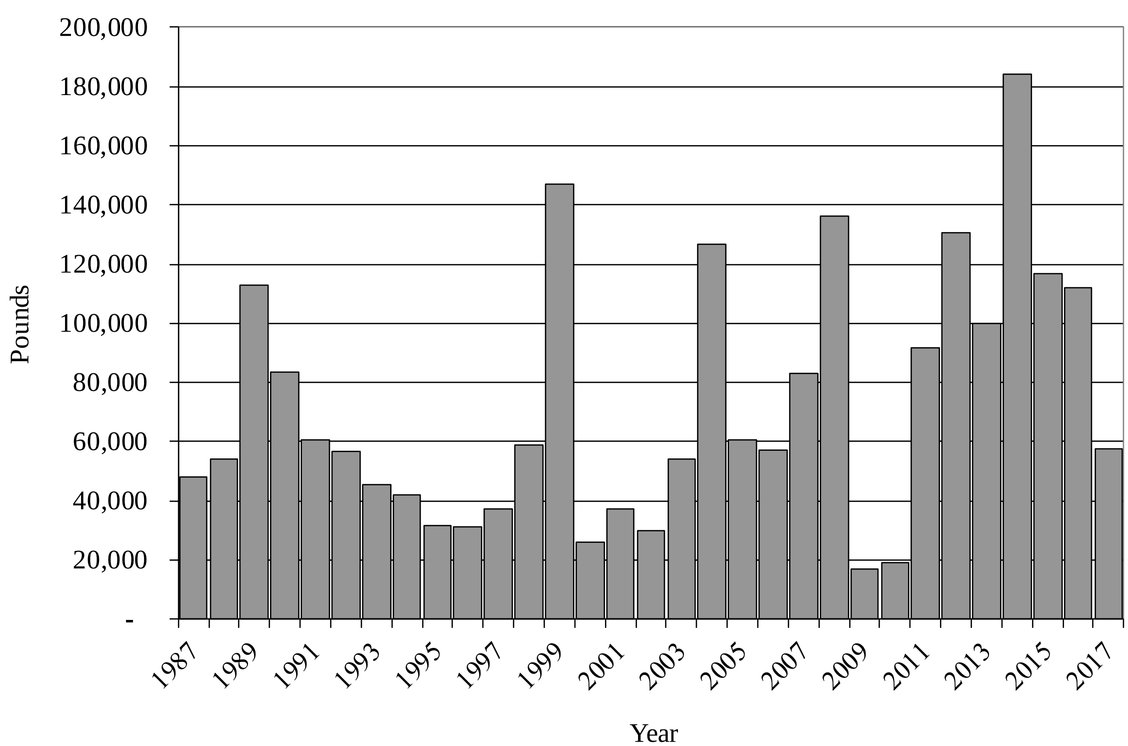


Figure 24. Nanticoke River commercial fish pot channel catfish relative abundance and 75th percentile, 1980 – 2017.

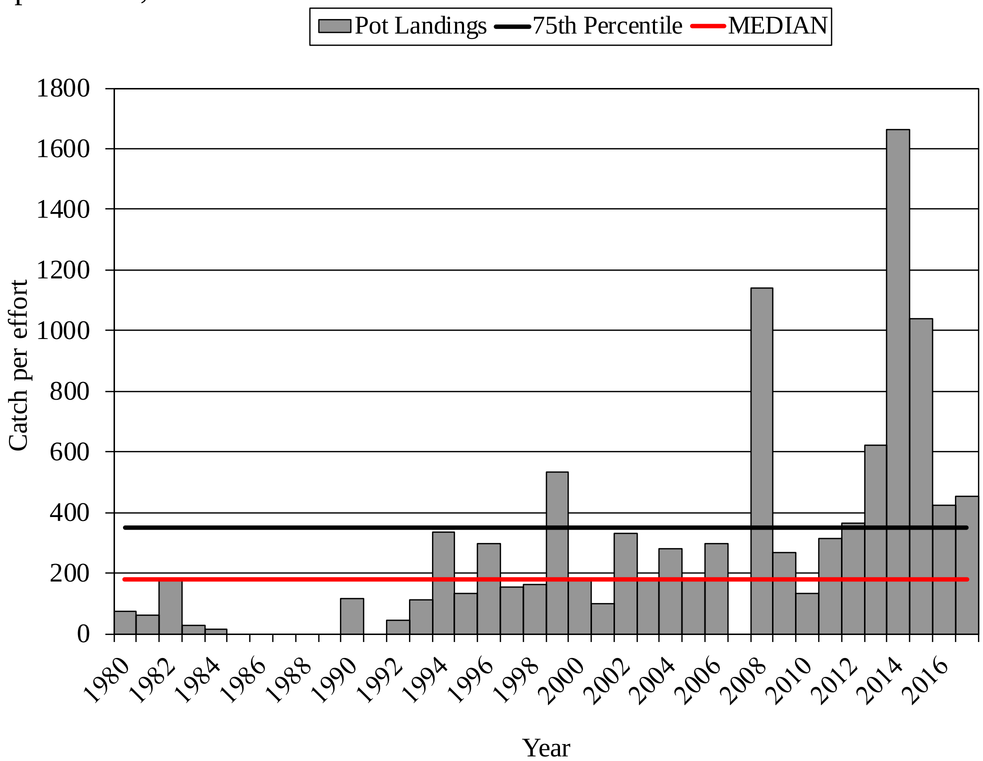


Figure 25. Pocomoke River channel catfish commercial landings, 2003 – 2017.

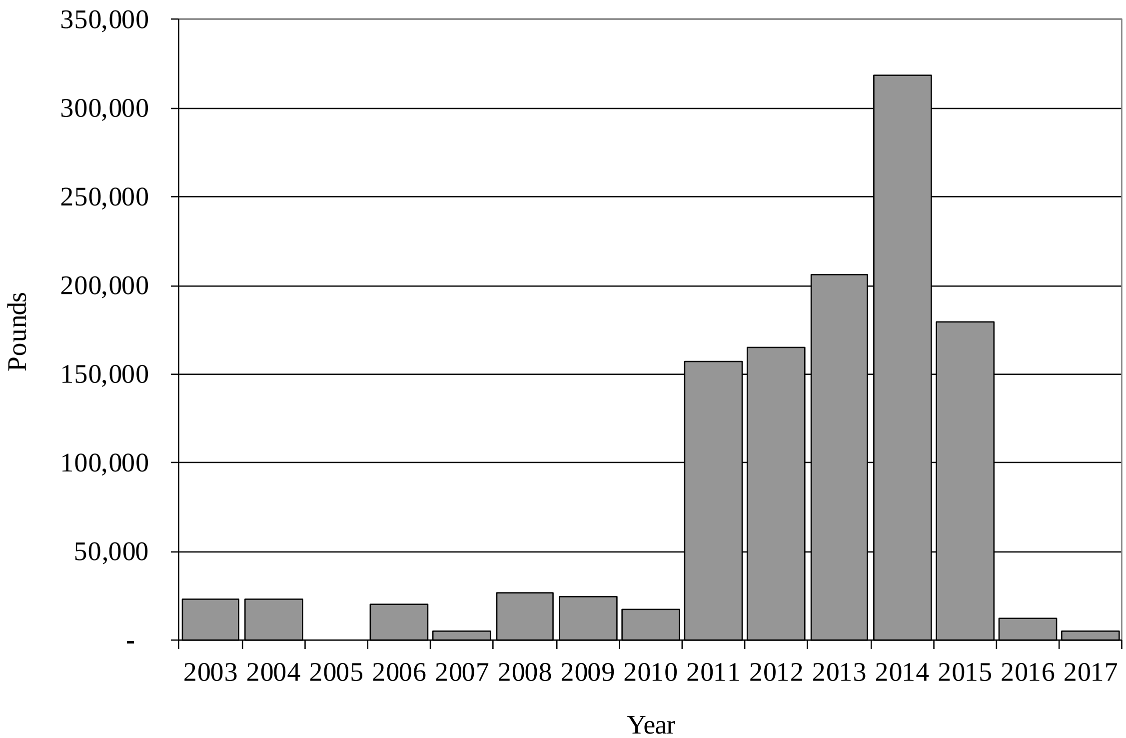


Figure 26. Pocomoke River commercial fish pot and fyke net channel catfish relative abundance and 75th percentile, 2003 – 2017.

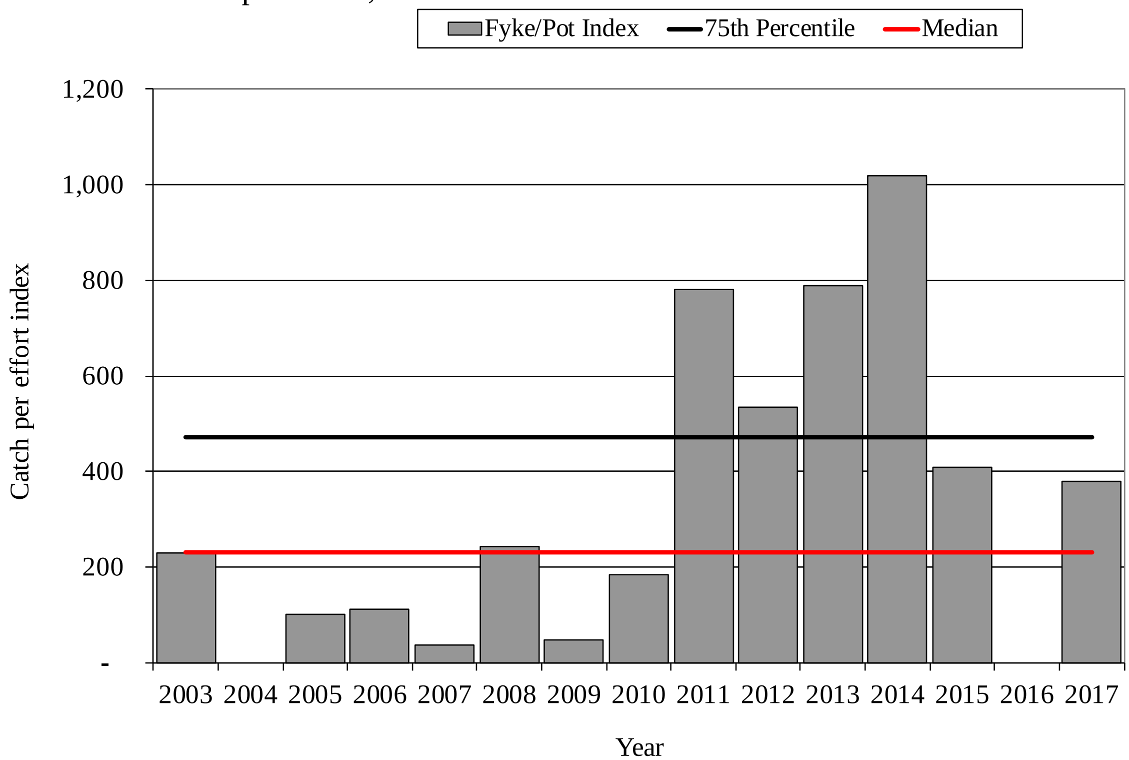


Figure 27. Patuxent River channel catfish and blue catfish commercial landings, 1987 – 2017.

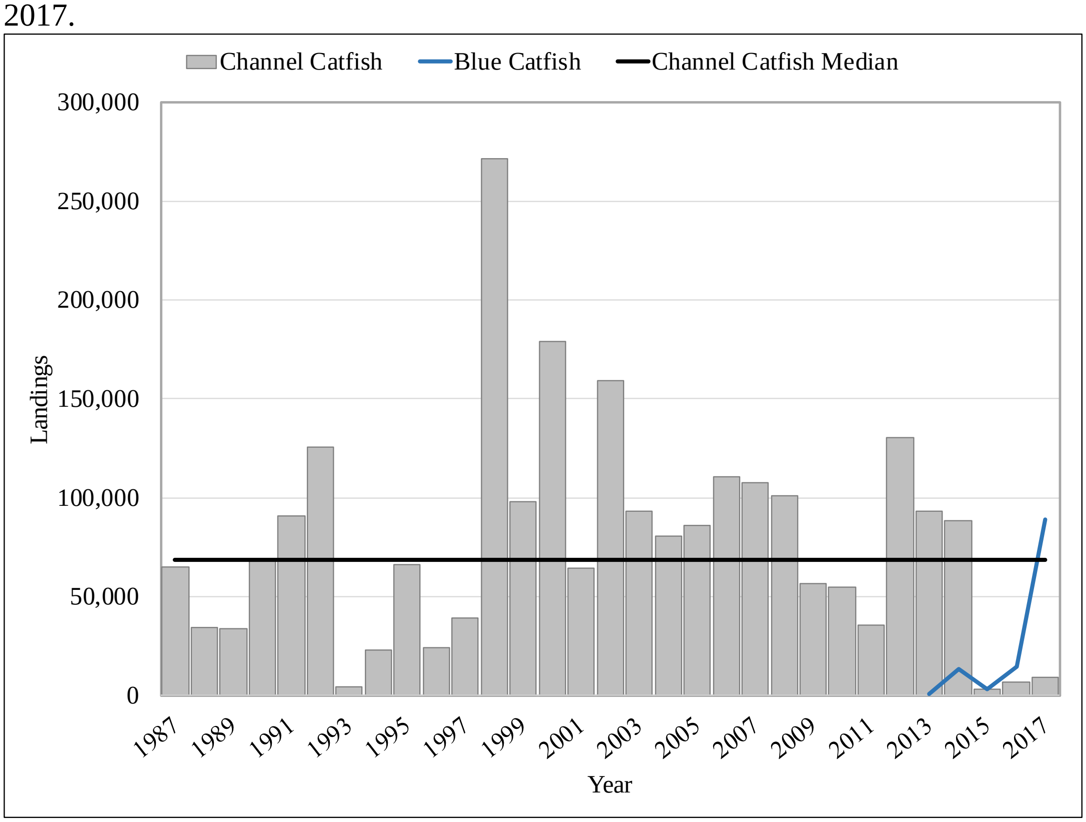


Figure 28. Patuxent River commercial fish pot/fyke net channel catfish and blue catfish relative abundance, 1990 – 2017.

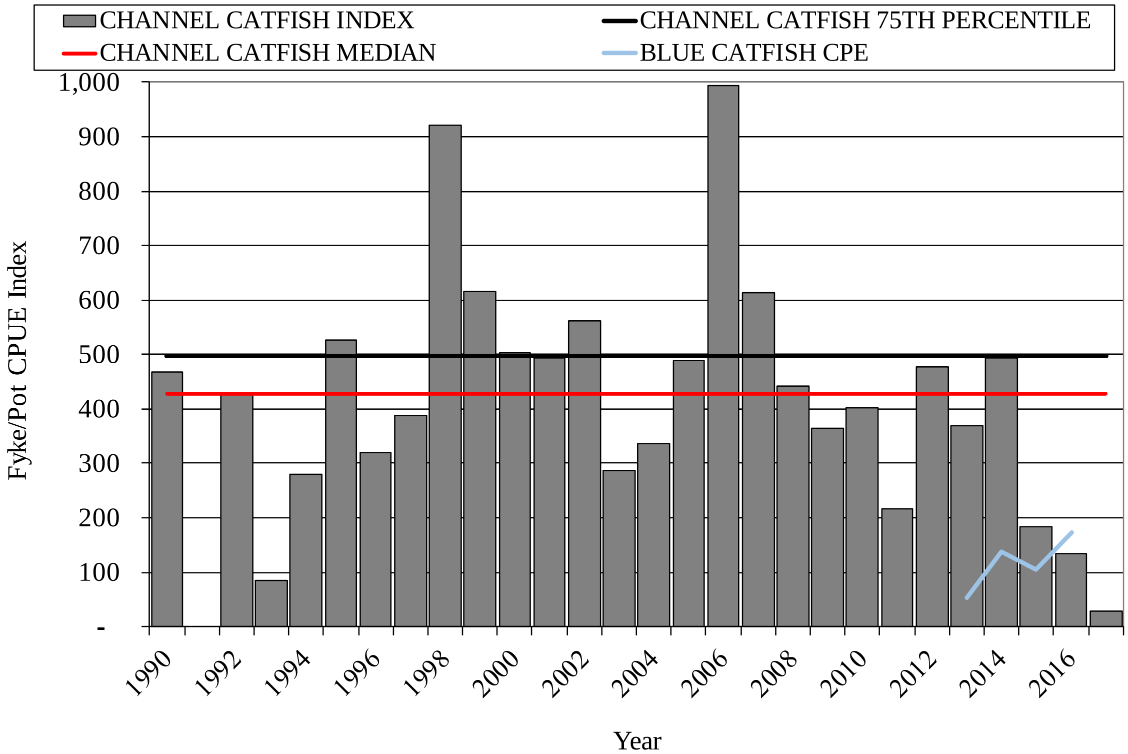


Figure 29. Potomac River channel catfish commercial landings, 1987 – 2017. Data from Potomac River Fishery Commission and MD DNR.

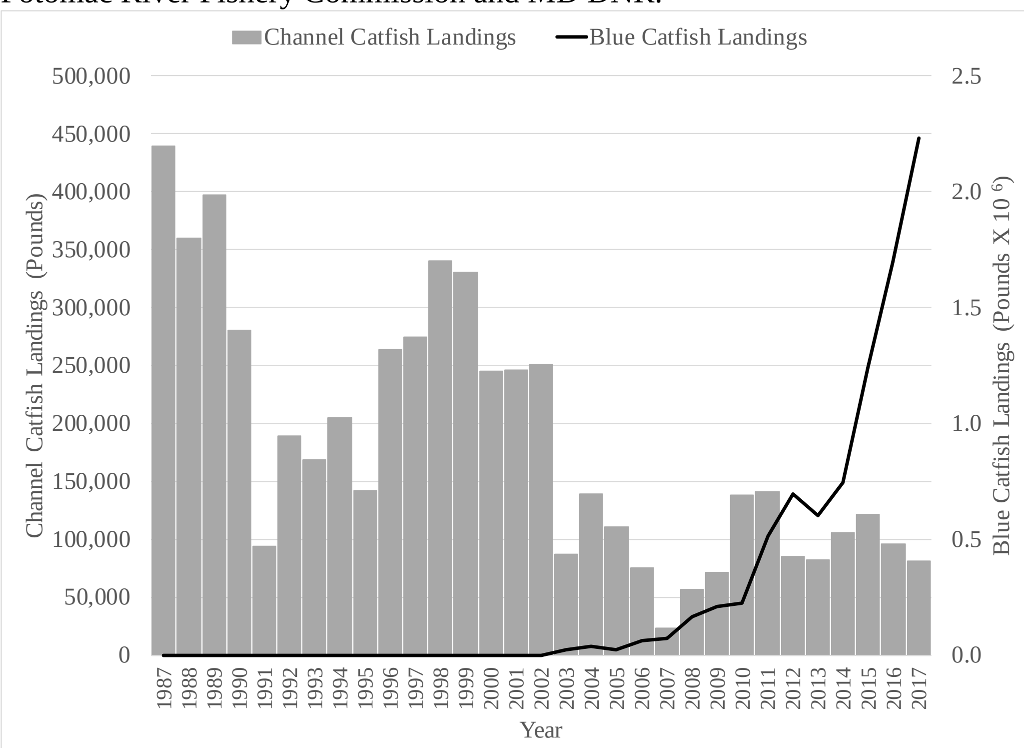
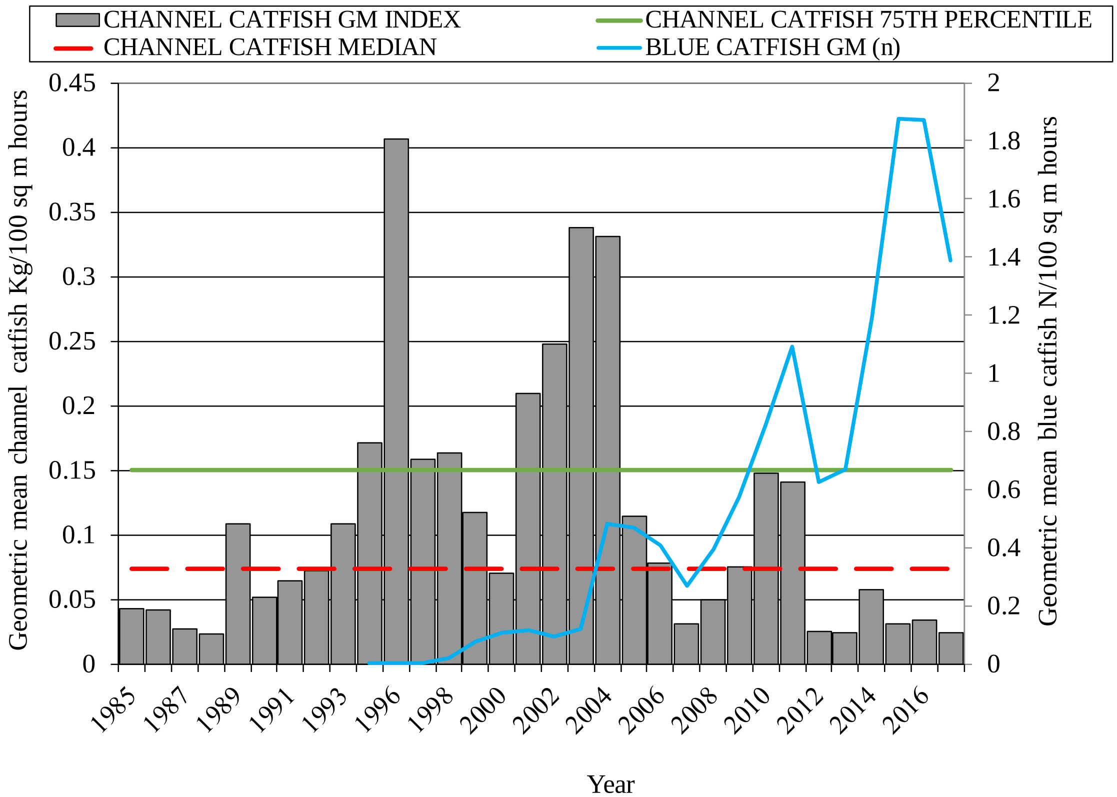


Figure 30. Channel catfish biomass index and blue catfish N index from Potomac River gill net survey, 1985-2017.



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 and Anthony A. Jarzynski

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. Similar data was collected for adult American shad in the Potomac River utilizing 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, hickory 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 26 April through 1 June 2018 (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 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

American shad catch that day and hours spent fishing. A voluntary logbook survey also provided location, catch, and hours fished for American shad in the lower Susquehanna River for each participating angler. The same information was collected for hickory shad in various locations throughout the Chesapeake Bay region. 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 (2004-2018) 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 (2006-2018). Scale samples were taken from the first 20 fish per day for age determination.

Nanticoke River

Eight commercial fyke nets were surveyed for American shad, hickory shad and river herring between 5 March and 30 April 2018 (Figure 2). No pound nets were set in 2018. Fish captured from these nets were sorted according to species and transferred to the survey boat for processing. All nets were sampled one to two days 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 five days between 2 April to 30 April 2018. 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 2018. All American shad were sexed, measured (TL and FL) to the nearest mm, and scales were removed below the insertion of the dorsal fin for ageing and spawning history analysis.

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 15 March to 16 May 2018. Sampling locations were randomly assigned from a grid superimposed on a map of the system (Figure 4). The grid consisted of 112 quadrats equaling 0.06 square kilometer per cell. Sampling sites were subsequently randomized for depth to determine if the net would be set in shallow or deeper 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 the current mesh size selection was 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.

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 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, random subsamples of 300, proportional to catch by date, were processed for ageing and then applied to total catch using an age-length key.

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. Otoliths were archived for future reference and comparative studies.

Age determination from scales was attempted for all American shad and blueback herring samples (all rivers) and for alewife captured in the Nanticoke River. Age determination from scales was attempted for 300 randomly chosen samples for alewife from the North East River. In 2018, age determination was done independently by three readers including one experienced reader and two inexperienced readers. The scale was jointly re-read by all three readers if both inexperienced readers' age or spawning history determination did not match that of the experienced reader. 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 this year, efforts were made for all scales to be read on comparable equipment to eliminate any potential bias towards younger 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 $\alpha = 0.05$.

All hatchery produced juvenile American shad stocked in Maryland, Delaware and the Susquehanna basin 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 commonly used 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 lifting 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. However, in 2018, for the first time since 2015 and only the second time since 1988, the Mill Creek pound net was not set. Therefore, relative abundance of American shad was not calculated in 2018 for the Nanticoke River.

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 914 square meters 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. Beginning in 2018, 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 2015-2018. 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 a 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 2018) 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 estimated bycatch mortality 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}). The estimated bycatch mortality is derived from ocean fisheries landings (*L*) known to encounter American shad as incidental catch (i.e. the Atlantic herring and mackerel fisheries). A bycatch coefficient (*b*) is estimated to fit the model to these fisheries' landings. 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 a non-equilibrium approach that follows an observation-error fitting method (i.e., assumes that all errors occur in the relationship between true stock size and the index used to measure it). The model is fit to indices of abundance for American shad in the Conowingo dam tailrace. Assumptions include accurate adult American shad turbine mortality estimation and that the bycatch of American shad in the ocean fisheries is proportional to the directed fishery landings.

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 2015 the starting values were as follows: B_0 was set as 7,876, which was the Petersen statistic for 1985, *K* was set as 3,040,551 fish, which was three times the highest Petersen estimate of the time series, *r* was set as 0.50, and *b* was set at 0.032. These starting values were adjusted by the model during the fitting procedure using Evolver 4.0 for Windows that utilizes a genetic algorithm for optimization. The fitting procedure was constrained to search within *r* = 0.01 to 1.0, *K* = 100,000 to 30 million fish, B_0 = 5,682 (the lower confidence limit of the 1985 Petersen statistic) to 1 million fish and *b* = 0.001 to 1.0. The final estimates for each of these parameters in 2015 were then used as the starting values for model development in 2018 (B_0 = 54,176, *K* = 1,005,502, *r* = 0.57, and *b* = 0.51). The model was run multiple times varying the indices of abundance and the landings data from which bycatch mortality was derived. The run with the lowest sum of squares and best parameter estimates was chosen.

Mortality

Chapman-Robson methodology (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 was 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.

RESULTS

Ichthyoplankton

Ichthyoplankton tows were conducted on five days in 2018. Fertilized alosine eggs and/or larvae were present at 7.1% of tow stations in 2018 (Figure 5). Salinity at tow stations ranged from 0.1 to 1.9 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 was 1:1.79. Of the 177 fish sampled by this gear, 160 were successfully scale-aged (Table 1). Males were present in age groups three through seven and females were found in age groups four through eight. The 2013 year-class (age five) was the most abundant for males (53.5%) and females (51.0%; Table 1). Forty-three percent of males and 57% of females were repeat spawners. The percentages of repeat spawners increased in 2018 after three consecutive years of decreases (Figure 6). The arcsine-transformed proportion of these repeat spawners (sexes combined) significantly increased over the time series (1984-2018; $r^2 = 0.65$, $P < 0.001$; Figure 7). Analysis by PFBC of 321 American shad otoliths collected from the WFL at Conowingo Dam showed that 61% were wild fish and 39% were hatchery-produced fish in 2018; these percentages were similar to those from 2017 where 58% were wild fish and 42% were hatchery-produced fish.

The male-female ratio for adult American shad captured in the Nanticoke River was 1:1.5. Only five American shad were collected from Nanticoke fyke nets in 2018; all were successfully analyzed for age and repeat spawning marks (Table 1). Males were present in age groups four and five (2014 and 2013 year-classes; Table 1), while females were only present in age group five (2013 year-class; Table 1). Fifty percent of males and 67% 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, (1988-2018; $r^2 = 0.33$, $P < 0.001$; Figure 8). Analysis by DE DFW of American shad otoliths collected from the Nanticoke River were not completed for the 2018 samples.

The male-female ratio for adult American shad captured in the Potomac River was 1:1.82. All 96 American shad collected were successfully aged (Table 1). Males were present in age groups four through seven, and females were present in age groups five through eight (Table 1). The 2013 year-class (age five) was the dominant age group for both males (61.8%) and females (58.1%; Table 1). Eighty-two 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 (2002-2018; $r^2 = 0.016$, $P = 0.62$; Figure 9).

Adult Relative Abundance

Sampling at the Conowingo Dam occurred for 10 days in 2018. A total of 177 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 2018. Peak catch by hook and line (43 fish) occurred on 7 May 2018 at a surface water temperature of 16°C. Maryland Department of Natural Resources staff tagged 159 (90%) of the sampled fish. One American shad tag recapture was reported by a recreational angler in 2018; it was recaptured approximately four miles downstream of the Conowingo Dam, and was originally tagged in 2017.

The Conowingo EFL operated for 48 days between 2 April and 3 June 2018. Of the 6,992 American shad that passed at the EFL, 87% (6,113 fish) passed between 2 May and 14 May 2018. Peak passage was on 4 May; 1,061 American shad were recorded on this date. Five of the American shad counted at the EFL counting windows were identified as being tagged in 2018 (Table 2).

The Conowingo WFL operated for 15 days between 27 April and 31 May 2018. The 465 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 5 May, when 118 American shad were collected. Two tagged American shad were recaptured by the WFL, and both were tagged in 2018 (Table 2).

The various model configurations explored for developing a GAM for the hook and line index and how each model performed are summarized in Table 3. 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 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 3). The model results also 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 was variable from 2007-2018, and remained below the high indices observed from 1998-2002 (Figure 11).

The Conowingo Dam fish lifts provide 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 declined to low levels of abundance (Figures 11 and 12).

Sixty-five interviews were conducted over six days during the creel survey at the Conowingo Dam Tailrace. Catch per angler hour decreased in 2018 after four consecutive years of increases (Table 4), and has no significant trend over the time series (2001-2018; $r^2 = 0.19$, $P = 0.08$).

Two anglers returned paper logbooks in 2018. Additionally, five 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 declined in 2018 to the second lowest value since the inception of the survey (Table 5). Online angler data was included in the CPAH calculation beginning in 2014. The logbook CPAH estimate of adult American shad relative abundance decreased significantly over the time series (2000-2018; $r^2 = 0.24$, $P = 0.04$; Table 5).

No adult relative abundance calculations were completed for the Nanticoke River; the Mill Creek pound net that had been consistently sampled across most of the time series, and was favored for GM CPUE determination, was not fished in 2018 (Figure 13). The Potomac River gill net CPUE significantly increased over the time series (1996-2018; $r^2 = 0.46$, $P < 0.001$, Figure 14).

Population Estimates

The Petersen statistic estimated 180,601 American shad in the Conowingo Dam tailrace in 2018 with an upper confidence limit of 347,421 fish and a lower confidence limit of 85,182 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, the lift index and used the Atlantic herring and mackerel combined landings to estimate bycatch losses. This run estimated a population of 67,705 American shad in the Conowingo Dam tailrace in 2018 and produced realistic estimates of the model parameters *r*, *K* and B_0 (*r* = 0.56, *K* = 1,029,489, B_0 = 54,143; Figure 16). The 2018 SPM estimate was just below the lower confidence interval of the Petersen estimate for 2018.

Despite differences in yearly estimates, 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 2001, 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), and both models show a slight decline since 2009.

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate for male American shad increased from 2017 to Z = 1.42. Female American shad total instantaneous mortality was Z = 1.11; there was no female mortality estimate in 2017 due to insufficient numbers of year classes required for calculation. This was only the second year that the Chapman-Robson method was utilized, so no analysis for trends was completed. A total instantaneous mortality estimate for American shad captured in the Nanticoke River was not calculated due to small sample size (n = 5).

Juvenile Abundance

In 2018 the juvenile American shad abundance index provided by the EJFS exhibited a slight increase in the Nanticoke River and moderate increases in upper Chesapeake Bay and the Potomac River (Figures 17-20). Juvenile indices were not corrected for hatchery contribution.

Hickory Shad

Sex, Age and Stock Composition

No hickory shad were captured in the Nanticoke River pound and fyke net survey in 2018. In the Susquehanna River, 271 hickory shad were sampled by the broodstock collection survey. The male-female ratio was 1:0.70. Of the total fish captured by this survey, 40 were successfully aged. Males and females were present in age groups three through six (Table 6). The 2014 year-class (age 4) was the most abundant year class for both males (54.2%) and females (50.0%, Table 6). Since 2012, no hickory shad of ages greater than seven were observed (Table 7). The arcsine-transformed proportion of repeat spawners (sexes combined) decreased significantly over the time series (2004-2018; $r^2 = 0.30$, $P = 0.03$; Figure 21).

Relative Abundance

Shad logbook and Volunteer Angler Shad Survey data indicated that hickory shad CPAH declined over the time series (1998-2018; $r^2 = 0.22$, $P = 0.03$). Hickory shad CPAH in 2018 was 5.40, which was an increase from the 2017 value (2.80, Table 8). No hickory shad were captured on the Nanticoke River in 2018, so no measure of relative abundance was completed.

Mortality

Total instantaneous hickory shad mortality in the Susquehanna River was estimated as Z = 1.12, which was a decrease from 2017 (Z = 1.76). Due to the change in methodology for estimating mortality beginning in 2017, these values cannot be compared to previously reported estimates.

Alewife and Blueback Herring

Sex, Age and Stock Composition

The 2018 male-female ratio for Nanticoke River alewife was 1:1.44. Of the 228 alewives sampled, 172 were subsequently aged. Alewife were present from ages three to seven and the 2014 year-class (age four, sexes combined) was the most abundant, accounting for 46.5% of the total catch (Table 9). The 2018 male-female ratio for Nanticoke River blueback herring was 1:0.79. Of the 105 blueback herring sampled, 77 were subsequently aged. Blueback herring were present from ages three to seven and the 2014 year-class (age four, sexes combined) was the most abundant, accounting for 35.1% of the sample (Table 10). 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 10).

For the Nanticoke River, 39.0% of alewife and 36.4% of blueback herring were repeat spawners (sexes combined). There was no trend in the arcsine-transformed proportion of alewife repeat spawners over the time series (1990-2018; $r^2 = 0.09$, $P = 0.12$). Blueback herring repeat spawning decreased over the same time period (1990-2018; $r^2 = 0.61$, $P < 0.001$; Figure 22).

Alewife mean length (FL mm) from the Nanticoke River varied without trend since the inception of this survey (1989-2018; $r^2 = 0.03$, $P = 0.34$), while blueback herring mean length (FL mm) significantly decreased across the time series (1989 – 2018; $r^2 = 0.53$, $P < 0.001$; Figure 23).

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 2018 was 1:1.14. Alewife of ages three to seven were present in 2018. The 2014 year-class was the most abundant in 2018 (age four), comprising 71.1% of the sample (Figure 24).

The male-female ratio for blueback herring in 2018 was 1:1.73. Blueback herring were present from ages three to seven from 2013 through 2018. The 2015 year-class for blueback herring was the most abundant in 2018 (age 3) comprising 58.5% of the sample in 2018 (Figure 25). For the North East River in 2018, 51.0% of alewife and 24.6% of blueback herring were repeat spawners (sexes combined).

Adult Relative Abundance

Data from eight fyke nets on the Nanticoke River were used to calculate relative abundance of river herring in 2018. The GM CPUE for Nanticoke River alewife decreased over the time series (1990-2018; $r^2 = 0.22$, $P = 0.01$; Figure 26). The coefficient of determination from this analysis indicated the data only has a marginal fit to the predicted linear model. The GM CPUE for blueback herring also decreased over the time series (1989-2018; $r^2 = 0.59$, $P < 0.001$; Figure 26).

The North East River gill net survey captured 470 alewife and 139 blueback herring; the numbers represent a moderate increase and decrease, respectively, when compared to the catch in 2017. Peak catch of alewife (120 fish) occurred on 3 April 2018 when the water temperature was 9.2°C (Figure 27). Peak catch of blueback herring (85 fish) occurred about a month later on 8 May 2018 when the water temperature was 19.2°C (Figure 27). The majority of alewife were caught in the 6.4 cm mesh in all years (Figure 28). Alewife ranged in size from 195-281 mm FL. The majority of the blueback herring was caught in the 5.7 cm mesh in 2018 (Figure 29). Blueback herring ranged in size from 202-264 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 alewife CPUE and a decrease in blueback herring CPUE, compared to 2017. No significant linear trends were observed over the time series for either species (2013-2018; Alewife: $r^2 = 0.23$, $P = 0.33$; Blueback herring: $r^2 = 0.08$, $P = 0.58$; Figure 30). Beginning in 2018, we also calculated CPUE with catches pooled for the 5.7 cm, 6.4 cm and 7.0 cm meshes, resulting in the truncation of the time series to 2015-2018. This method produced similar year to year changes in CPUE compared to the traditional method, and no significant trends were observed for alewife (2015-2018; $r^2 < 0.00$, $P = 0.97$; Figure 31). However, a significant decreasing trend was observed for blueback herring using the new estimation method (2015-2018; $r^2 < 0.95$, $P = 0.03$; Figure 31). Discretion should be used when interpreting these results, regardless of pooling method, as they have not been corrected for selectivity bias of the mesh sizes. Total catch of other important sport fish are noted in Table 11.

Mortality

Total instantaneous mortality for Nanticoke River alewife (sexes combined) was estimated as Z = 0.92. Total instantaneous mortality for Nanticoke River blueback herring (sexes combined) was Z = 0.96. The 2018 total instantaneous mortality estimates for alewife from the North East River was Z = 1.40, and the blueback herring estimate was Z = 0.92.

Juvenile Abundance

Data provided by the EJFS indicated that juvenile GM CPUE of both alewife and blueback herring increased in all systems surveyed in 2018, including upper Bay and the Nanticoke River (Figures 32-33).

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, and pollution. 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. The American shad adult stock has shown some improvement since the inception of restoration efforts, although the 2007 ASMFC stock assessment indicated that stocks were still declining in most river systems along the east coast (ASMFC 2007). A new benchmark stock assessment of American shad, due to be completed in 2020, will provide updates to coastwide population trends.

The population size of American shad in the lower Susquehanna basin was relatively stable over the past nine years (2009-2018; SPM estimate), although at a much lower level than the peak observed in 2000 and 2001, 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 show the population relatively stable at low levels (2007-2018), although both models indicated a slight decline in the population in recent years (2009-2018). The SPM likely underestimated American shad abundance, while the Petersen statistic likely overestimated 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 likely limited by the available spawning habitat below Conowingo Dam and stocking success.

All calculated indices of abundance for the lower Susquehanna River, including the hook and line CPUE, Conowingo lift CPUE, and creel and logbook CPAH, declined in 2018.
The Potomac River CPUE (1996-2018) increased over time, indicating some improvement in this river, while Susquehanna River American shad continue to be significantly impacted.

Peak capture of American shad in the Conowingo Dam tailrace by hook and line occurred three days after peak passage of American shad at the East Fish Lift and two days after peak capture at the West Fish Lift. Surface water temperature during peak capture by hook and line (16°C) was slightly below 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 (18°C) was within 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 well 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 2007). 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, 52% of aged American shad at the Conowingo Dam were repeat spawners in 2018, and, on average, 51% 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., 2015), 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 80% in 2018, representing the third highest percent occurrence of repeat spawners in the time series (Figure 9). Increased repeat spawning in these river systems may indicate increased survival of adult fish. This could be due to decreased harvest 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, most systems have had a number of years of successful spawns. Recent Potomac River and baywide juvenile abundance indices exceeded the values observed in the early years of the survey that dates back to 1959. The upper Bay juvenile index increased this year to the third highest value in the time series. The Nanticoke River, while exhibiting a marginal increase in juvenile abundance in 2018, has not shown as encouraging signs of successful juvenile production as the other surveyed systems.

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). Catch rates exceeded four fish per hour for all years except 2009, 2010, 2015 and 2017 according to shad logbook data collected from anglers (1998-2017).

Previously, hickory shad age structure was relatively consistent, with a wide range of ages and a high percentage of older fish, although the past seven years (2012-2018) have seen no hickory shad over the age of seven. This suggests the age structure of hickory shad has truncated in recent years. 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. Additionally, the percentage of repeat spawning fish captured has decreased significantly over the time series and reached its lowest value in 2018. Fewer older fish combined with a smaller proportion of repeat spawners may indicate poor year classes and/or an increase in natural 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 2018. 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. However, alewife relative abundance in the North East River increased over the course of the survey. Blueback herring relative abundance in the North East River increased from 2013-2015, but decreased since. The significance of these fluctuations 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 14 March 2018, due to high amounts of bycatch of American shad and river herring by mid-water 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 (NOAA 2018). The expectation is that these efforts to reduce by-catch mortality on river herring will lead to increased spawning stock, with a corresponding increase in repeat spawning and production of juvenile river herring. While it has only been a few years since these measures were enacted, the ASMFC 2017 stock assessment update did not indicate a change to the stock status for Maryland's river herring populations.

Mortality estimates in recent years for alewife and blueback herring in the North East and Nanticoke rivers were high. In 2018, 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. 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 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

2019 PRELIMINARY RESULTS - WORK IN PROGRESS

Analysis of the data collected in 2019 for Job 1 project 2 to assess trends in adult and juvenile alosine species in the Chesapeake Bay and selected tributaries is currently in progress. Data were collected by several surveys of American and hickory shad, and river herring (i.e. alewife and blueback) in the Susquehanna, Nanticoke, Potomac and North East rivers.

Adult American shad were angled by staff from the lower Susquehanna River one to three times per week from 15 April through 30 May 2019. Biologists encountered 53 adult American shad and collected 44 scale samples for ageing and spawning history analysis. Forty-three fish were marked with floy tags to formulate mark-recapture population estimates. Male American shad ranged in size from 326 - 449 mm FL, and female American shad ranged in size from 362 - 510 mm FL. Catch was markedly lower this year relative to previous years, likely due to consistently high flows which can limit angling success.

In 2019, biologists worked with commercial fishermen in the Nanticoke River to collect stock composition data and to estimate relative abundance of adult American and hickory shad, and river herring from 1 March through 26 April 2019. Data from this survey are still being entered into the database at this time. Biologists also completed ichthyoplankton tows during the month of April in the Nanticoke 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 in the Susquehanna and Nanticoke Rivers. A record total of 284 American shad were encountered by this survey in 2019.

River herring were independently sampled using an experimental gill net deployed in the North East River at four randomly chosen sites once a week from 14 March to 14 May 2019. The gill net was set 40 times and encountered 503 alewife and a survey record 713 blueback herring. A total of 300 alewife scale samples and 300 blueback herring scale samples are being processed for ageing.

The complete analyses of the data collected in 2019 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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Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	4	0	0	0	4	0
4	12	3	11	2	23	5
5	31	16	52	29	83	45
6	9	5	35	24	44	29
7	2	1	3	2	5	3
8	0	0	1	1	1	1
Totals	58	25	102	58	160	83
Percent Repeats	43.1%		56.9%		51.9%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
4	1	0	0	0	1	0
5	1	1	3	2	4	3
Totals	2	1	3	2	5	3
Percent Repeats	50.0%		66.7%		60.0%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
4	4	1	0	0	4	1
5	8	8	12	5	20	13
6	21	18	36	30	57	48
7	1	1	10	10	11	11
8	0	0	4	4	4	4
Totals	34	28	62	49	96	77
Percent Repeats	82.4%		%		80.2%	

Table 2. Number of recaptured American shad in 2018 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
Blue	2018	5	Blue	2018	2
Yellow	2017	1	Yellow	2017	0

Table 3. The six generalized additive model (GAM) configurations and performance statistics explored for standardizing the hook and line catch per unit effort index.

Model Number	Cofactor(s)	Response Variable Distribution	N	Effective Degrees of Freedom	Deviance Explained	Dispersion	AIC
1	Temp + Flow	Poisson	469	47.04	42.60%	10.40	7044.33
2	Temp + Flow	Tweedie	469	37.62	38.50%	3.47	3979.12
3	Temp + Flow	Negative Binomial	469	37.52	33.70%	0.92	4015.90
4	Temp	Poisson	469	38.99	39.50%	10.70	7280.21
5	Temp	Tweedie	469	35.14	36.30%	3.50	3992.23
6	Temp	Negative Binomial	469	35.16	31.10%	0.90	4031.57

Table 4. Catch, effort and catch-per-angler-hour (CPAH) from the recreational creel survey in the Susquehanna River below Conowingo Dam, 2001-2018. 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	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49
2006	78	227.3	305	1.34
2007	30	107.5	128	1.19
2008	16	32.5	24	0.74
2009	40	85.0	120	1.41
2010	36	64.0	114	1.78
2012	58	189.0	146	0.77
2013	63	161.8	107	0.66
2014	81	227.0	312	1.37
2015	64	158.9	263	1.65
2016	164	308.5	612	1.98
2017	94	185.0	483	2.61
2018	65	110.1	145	1.32

Table 5. Catch, effort and catch-per-angler-hour (CPAH) from spring logbooks for American shad, 2001-2018. 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	574.0	1,735	3.02
2002	12	516.0	1,801	3.49
2003	13	614.0	1,221	1.99
2004	17	430.5	1,033	2.40
2005	18	403.5	531	1.32
2006	19	736.5	768	1.04
2007	17	547.5	868	1.59
2008	22	750.3	1,268	1.69
2009	15	536.8	964	1.80
2010	16	488.3	865	1.77
2011	9	166.3	46	0.28
2012	5	168.5	344	2.04
2013	6	226.3	263	1.16
2014	15	232.0	467	2.01
2015	10	169.5	346	2.04
2016	9	254.0	487	1.92
2017	10	157.0	227	1.45
2018	7	249.5	242	0.97

Table 6. Number of adult hickory shad and repeat spawners by sex and age sampled from the brood stock collection survey in the Susquehanna River in 2018.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	5	0	1	0	6	0
4	13	7	8	2	21	9
5	5	5	5	4	10	9
6	1	1	2	2	3	3
Totals	24	13	16	8	40	21
Percent Repeats	54.2%		50.0%		52.5%	

Table 7. Percent of hickory shad by age and number sampled from the brood stock collection survey in the Susquehanna River and Deer Creek (a lower Susquehanna tributary), by year, 2004-2018.

Year	N	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
2004	80		7.5	23.8	27.5	18.8	18.8	3.8	
2005	80		6.3	17.5	28.8	33.8	11.3	1.3	1.3
2006	178	0.6	9.0	31.5	29.8	20.2	7.3	1.7	
2007	139		6.5	23.7	33.8	20.9	12.2	2.2	0.7
2008	149		9.4	29.5	33.6	20.1	5.4	2.0	
2009	118		7.6	16.9	44.9	19.5	10.2	0.8	
2010	240		12.5	37.9	31.3	11.3	6.7	0.4	
2011	216		30.1	30.1	27.3	8.8	2.8	0.9	
2012	200		26.5	39.5	24.5	7.5	2.0		
2013	193		21.2	45.6	23.8	8.3	1.0		
2014	100		11.0	37.0	40.0	12.0			
2015	113	0.9	30.1	43.4	20.4	5.3			
2016	120		20.8	30.8	35.8	11.7	0.8		
2017	59		16.9	30.5	37.3	13.6	1.7		
2018	40		15.0	52.5	25.0	7.5			

Table 8. Catch, effort and catch-per-angler-hour (CPAH) from logbooks for hickory shad, 2001-2018. 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
2001	12	578	2,674	4.63
2002	12	572	2,451	4.28
2003	13	635	3,143	4.95
2004	17	750	3,233	4.31
2005	18	560	2,098	3.75
2006	19	811	4,928	6.08
2007	17	590	3,396	5.76
2008	22	1,001	5,520	5.51
2009	15	584	2,021	3.46
2010	16	623	1,972	3.16
2011	9	242	1,799	7.42
2012	5	218	867	3.99
2013	6	254	1,688	6.65
2014	15	269	1,192	4.43
2015	10	243	513	2.11
2016	9	368	1,377	3.75
2017	10	234	656	2.80
2018	7	299	1,611	5.40

Table 9. Percent catch-at-age for adult alewife sampled from the Nanticoke River from 1989 - 2018. Age 6+ includes all catch age 6 – 11. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages to those fish based on size.

		Age				
Year	N	2	3	4	5	6+
1989	435	0	5	37	38	20
1990	749	0	9	23	38	31
1991	850	0	3	48	26	23
1992	778	0	5	28	49	18
1993	637	0	3	24	38	35
1994	642	0	6	25	40	29
1995*	728	0	6	42	30	23
1996*	548	0	21	37	27	14
1997	256	0	9	47	31	13
1998	271	0	4	45	34	17
1999	317	0	9	21	40	30
2000	228	0	7	59	21	13
2001	239	0	7	36	43	14
2002	282	0	1	21	35	43
2003	168	0	4	19	35	42
2004	203	0	6	31	31	33
2005	169	0	4	40	25	31
2006	170	0	4	18	49	29
2007	218	0	7	40	27	26
2008	183	0	4	27	45	24
2009	216	0	4	38	35	22
2010	69	0	3	28	33	36
2011	182	0	4	36	28	31
2012*	527	0	13	31	33	23
2013	128	0	6	24	38	32
2014*	564	0	2	32	51	15
2015	0	0	0	0	0	0
2016*	1,058	0	2	16	55	27
2017*	586	0	21	31	34	14
2018	172	0	17	47	22	15

Table 10. Percent catch-at-age for adult blueback herring sampled from the Nanticoke River from 1989 - 2018. Age 6+ includes all catch age 6 – 11. * indicates years where not all fish were aged and an age-length key was subsequently used to assign ages to those fish based on size.

Year	N	Age				
		2	3	4	5	6+
1989	701	0	2	32	35	31
1990	732	0	2	15	29	54
1991	719	0	2	24	21	52
1992	258	0	3	21	24	52
1993	509	0	1	13	32	53
1994	452	0	6	29	38	27
1995	65	0	8	35	25	32
1996	223	0	3	38	42	17
1997	347	0	4	15	30	52
1998	232	0	3	26	27	44
1999	123	0	7	19	46	29
2000	198	0	6	51	25	18
2001	105	0	8	45	35	12
2002	146	0	6	35	44	15
2003	128	0	2	30	41	26
2004	132	0	12	37	33	17
2005	18	0	22	50	17	11
2006	68	0	3	28	54	15
2007	74	0	26	41	24	9
2008	82	0	10	51	30	9
2009	66	0	21	56	20	3
2010	26	0	8	58	23	12
2011	122	0	7	55	27	11
2012	136	1	15	38	37	10
2013	82	0	6	40	29	24
2014*	455	0	14	46	33	8
2015	0	0	0	0	0	0
2016	147	0	10	37	39	14
2017	76	0	13	39	30	17
2018	77	0	30	35	29	6

Table 11. Counts of species (other than alewife and blueback) captured in the North East River gill net survey from 2013-2018.

SPECIES	2013	2014	2015	2016	2017	2018
AMERICAN SHAD		2				
ATLANTIC MENHADEN	145	145	476	908	145	141
BLUE CATFISH			1	1		
BLUEGILL				1		
BROWN BULLHEAD	66	132	78	123	15	25
CARP	2	1	2			
CHANNEL CATFISH	17	45	50	7	6	19
GIZZARD SHAD	2617	850	104	568	112	13
GOLDEN SHINER			1		4	2
GOLDFISH	2		2	1		
HICKORY SHAD	19	25	5	15	5	2
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
WALLEYE		1				
WHITE CATFISH	1	1		1	1	
WHITE PERCH	287	227	1273	813	257	320
WHITE SUCKER	3	1	1	1	2	
YELLOW PERCH			6	2	1	1

Figure 1. Conowingo Dam Tailrace (Susquehanna River) hook and line sampling location for American shad in 2018.

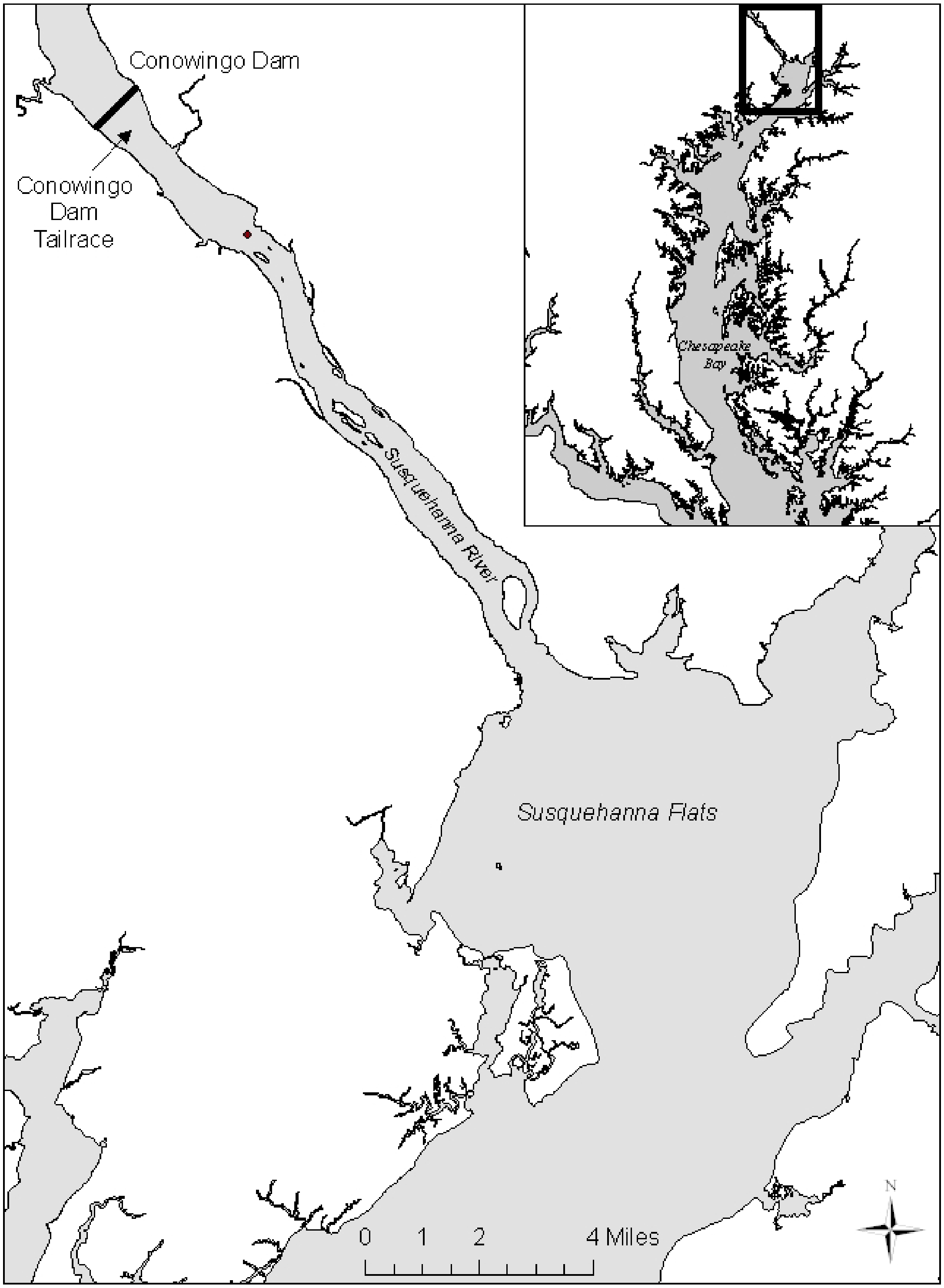


Figure 2. Nanticoke River fyke net sites for adult alosine sampling in 2018. No pound nets were fished in 2018.

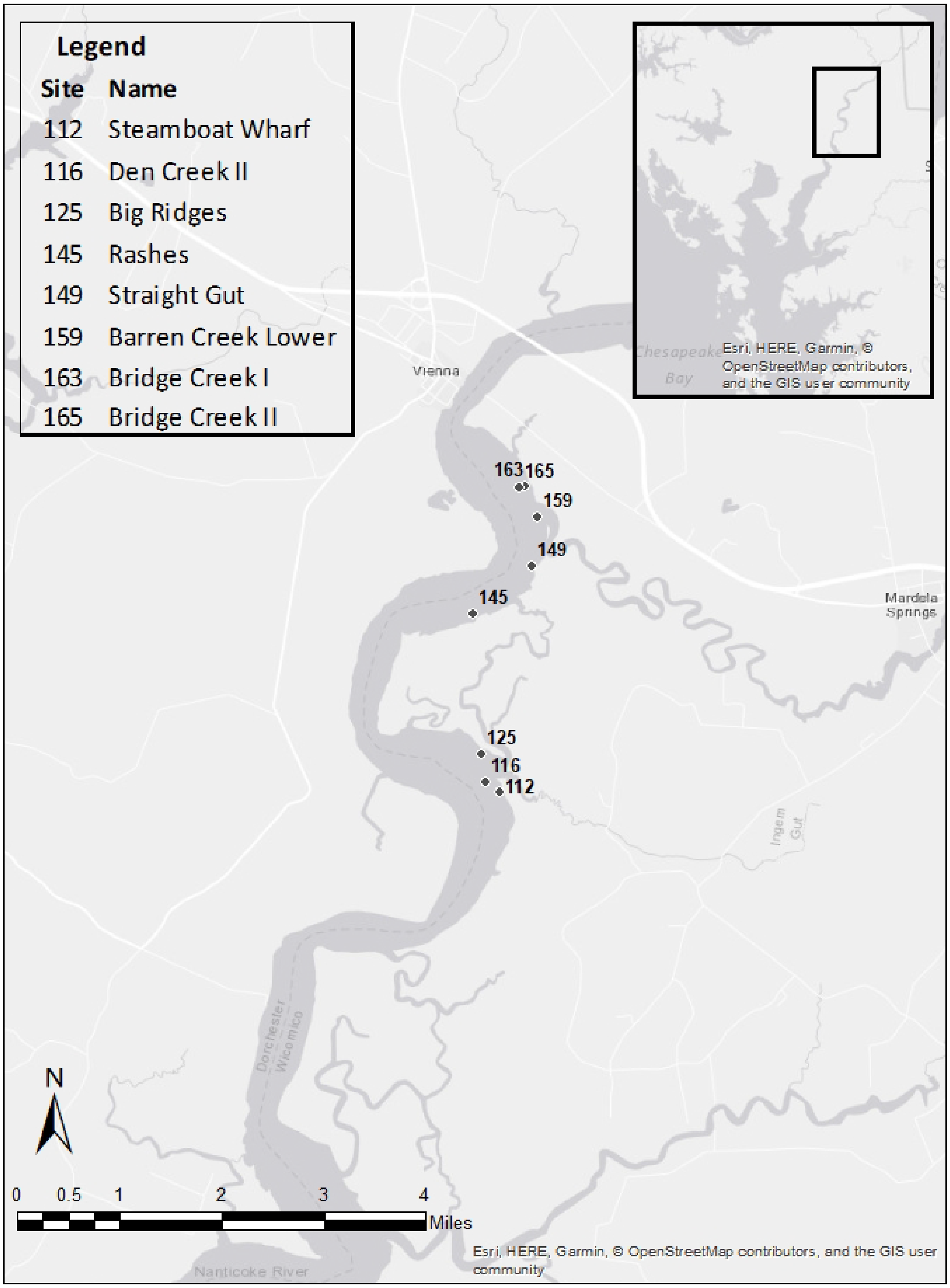


Figure 3. Nanticoke River sites for alosine ichthyoplankton sampling in 2018.

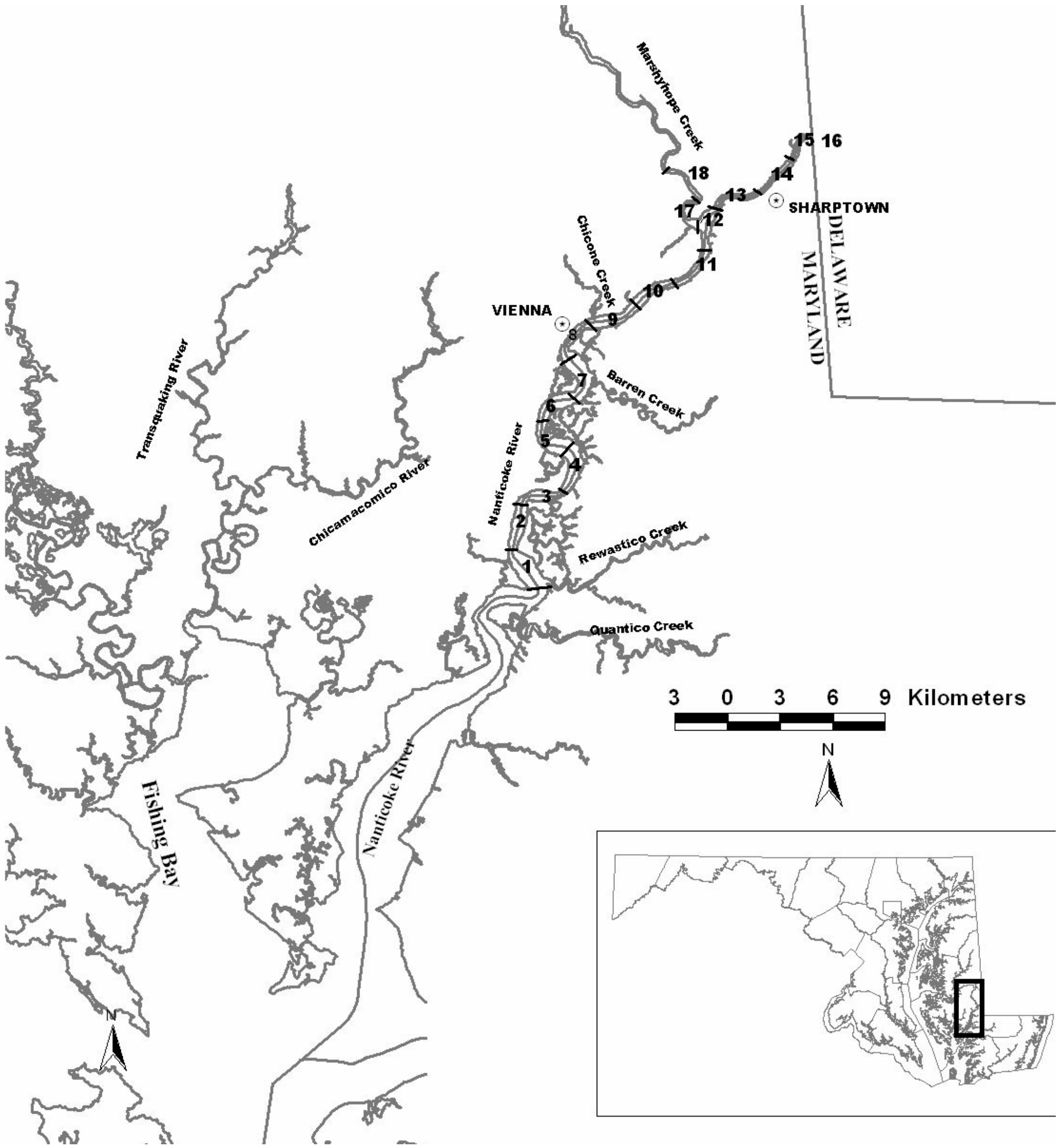


Figure 4. Grid of 914 m x 914 m quadrats overlaid on a map of the North East River from which sites were randomly chosen for the North East River sinking gill net survey, 2013-2018.

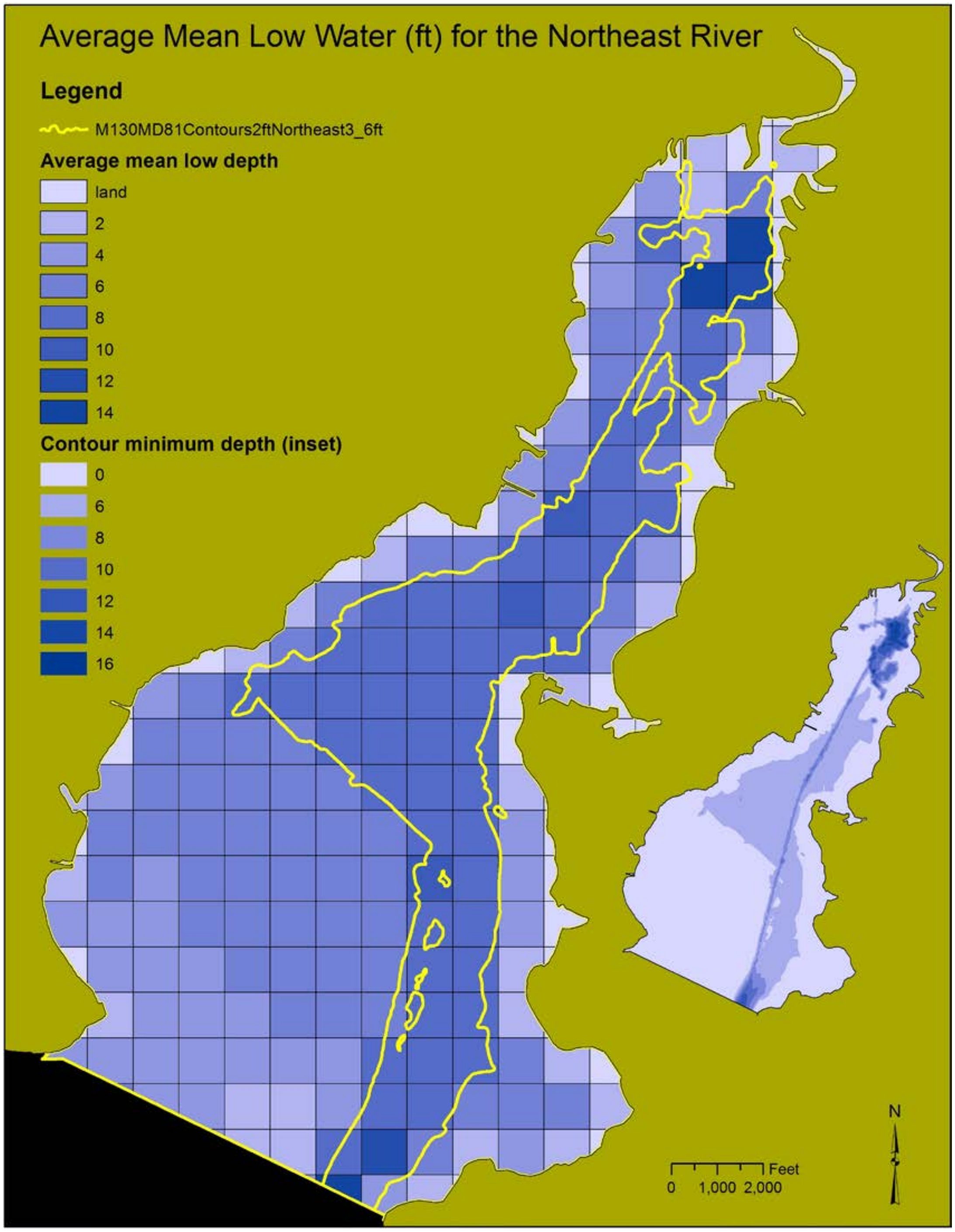


Figure 5. Percentage of sites with clupeid eggs or larvae in the Nanticoke River (2005-2018).

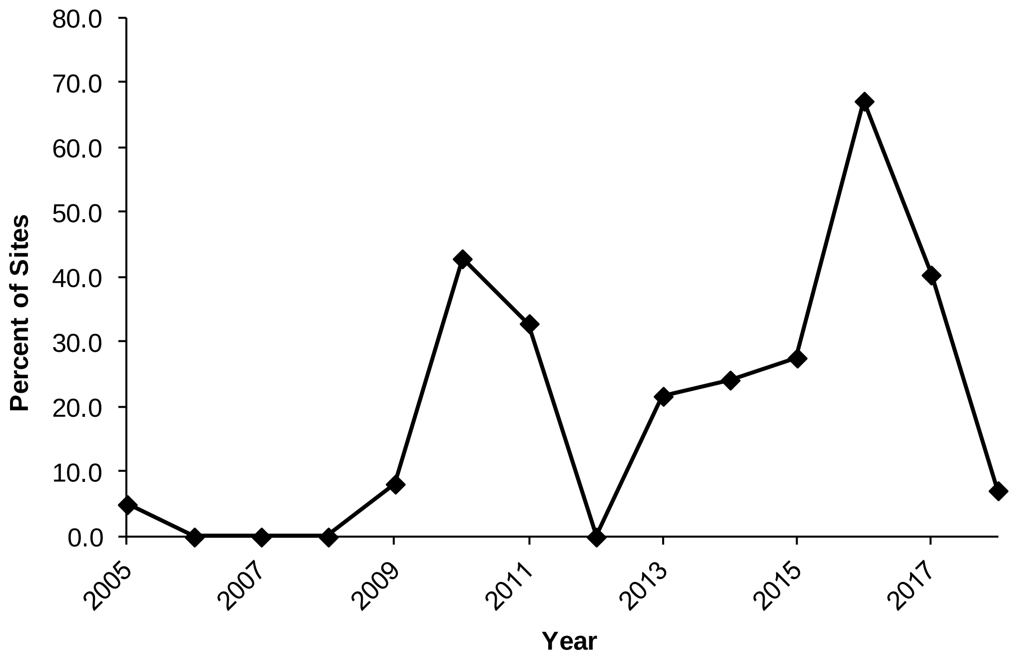


Figure 6. Percent of American shad repeat spawners by sex collected in the Conowingo Dam tailrace (1982-2018).

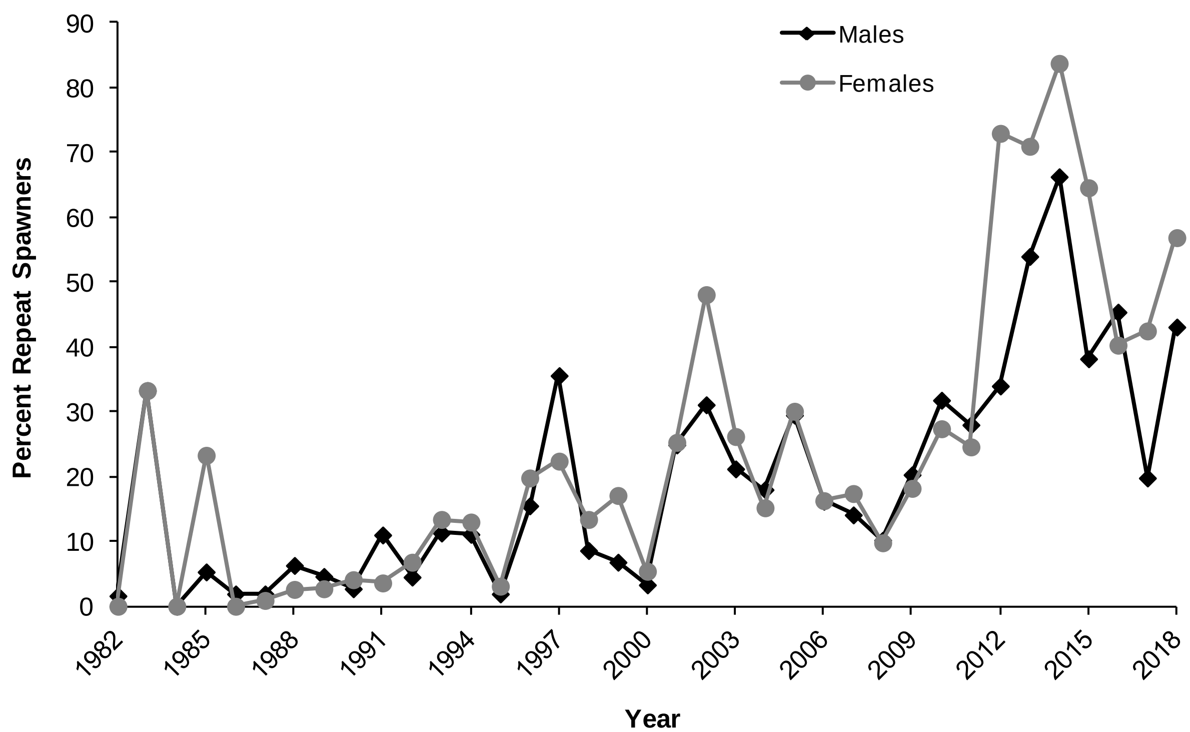


Figure 7. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2018.

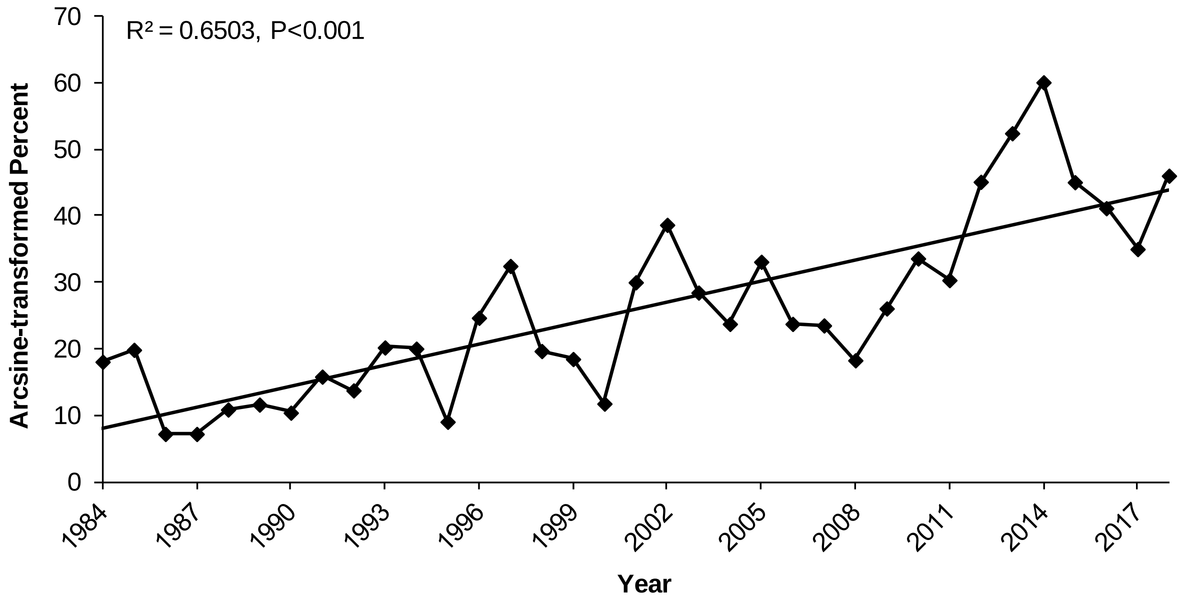


Figure 8. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River, 1988-2018.

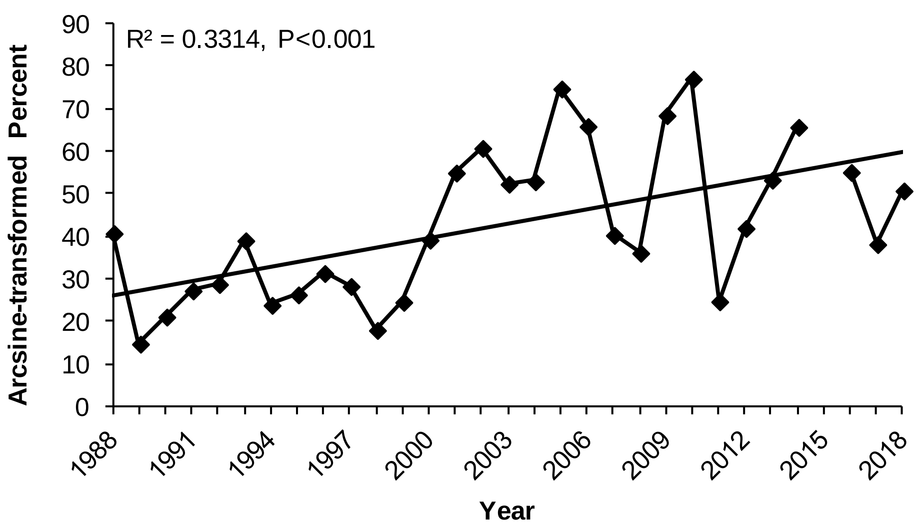


Figure 9. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River, 2002-2018.

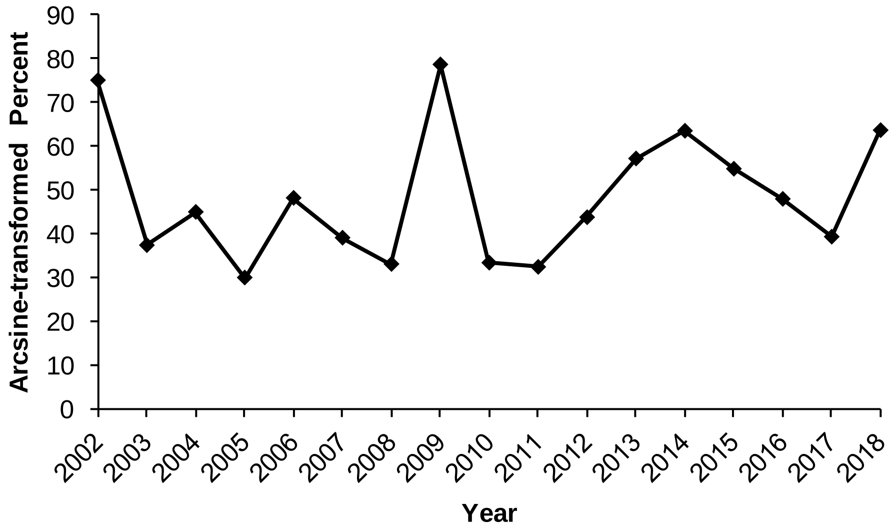


Figure 10. Pearson residuals from the best fit generalized additive model (GAM) in 2018 used to standardize the Susquehanna River hook and line catch per unit effort (CPUE) index.

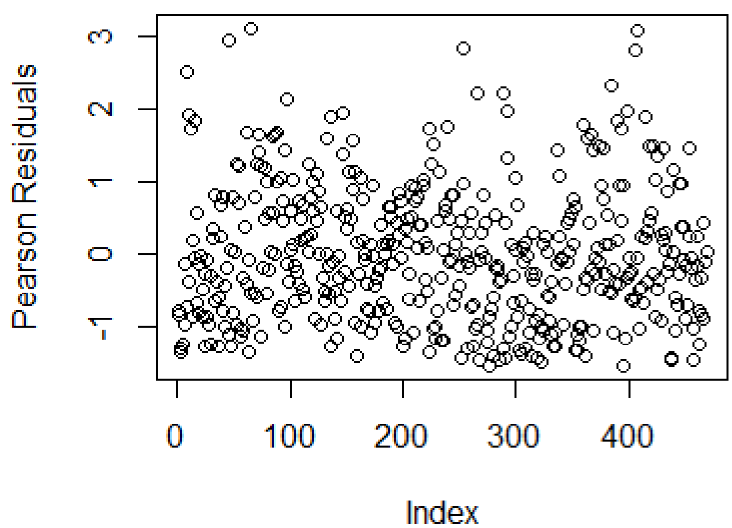


Figure 11. American shad standardized CPUE with 95% confidence intervals estimated by a generalized additive model for the Conowingo Dam tailrace hook and line sampling, 1987-2018.

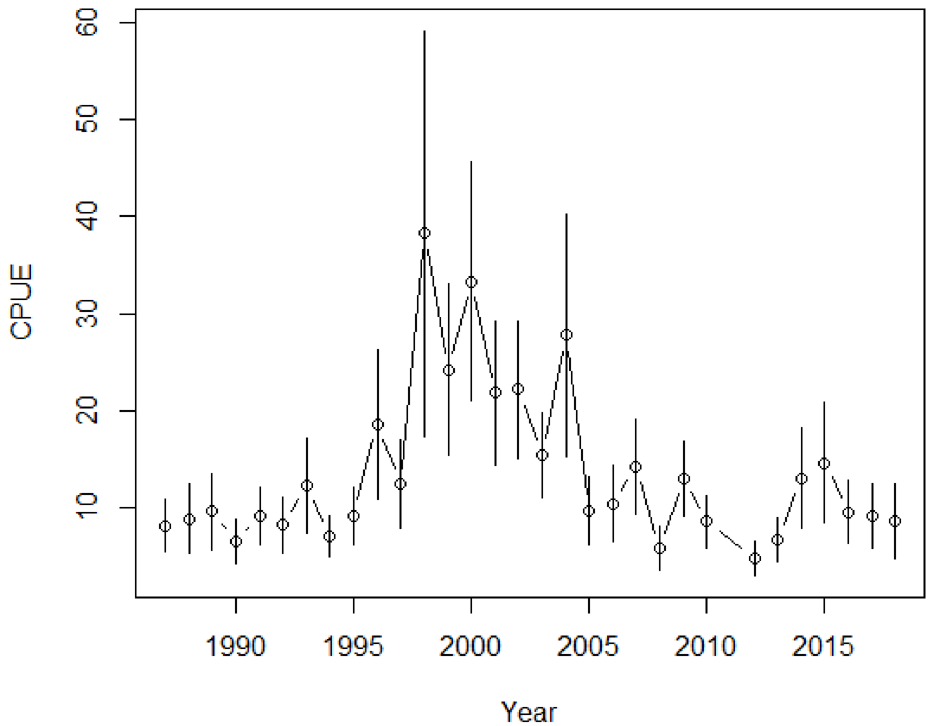


Figure 12. American shad geometric mean CPUE (fish per lift hour) and the total number of American shad lifted at the East and West Fish Lifts at the Conowingo Dam, 1991-2018.

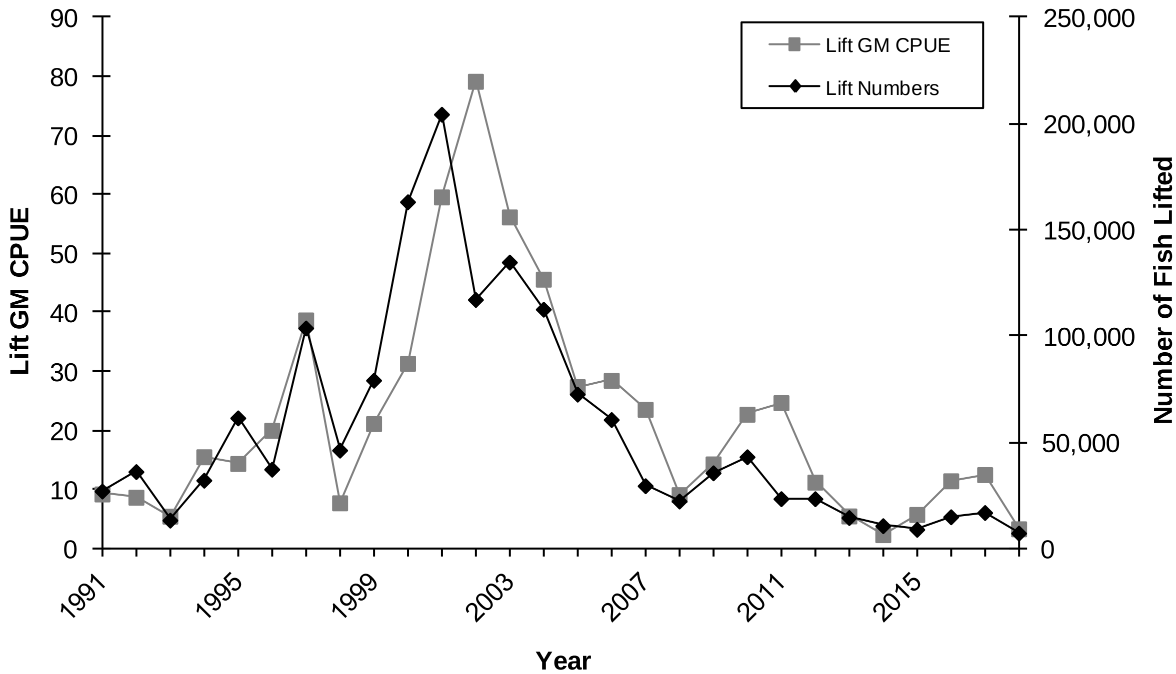


Figure 13. American shad geometric mean CPUE (fish per net day) from the Mill Creek pound net in the Nanticoke River, 1988-2017. No pound nets were fished in 2004, 2015, and 2018.

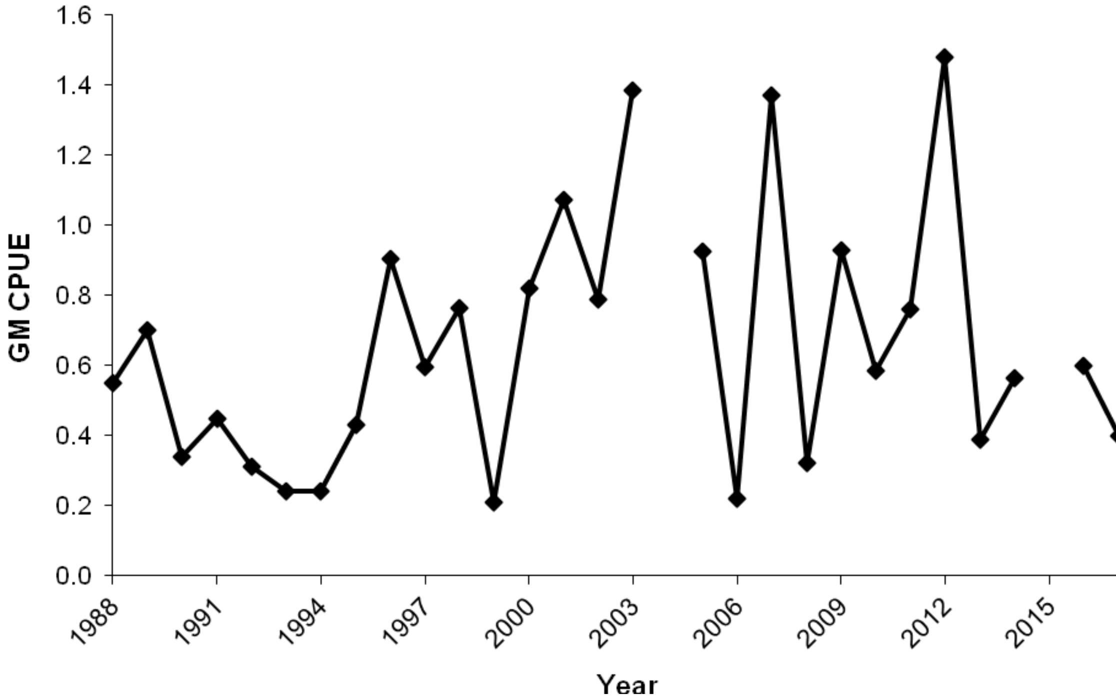


Figure 14. American shad mean CPUE (fish per 914 square meters of experimental drift gill net per hour fished) from the Potomac River, 1996-2018.

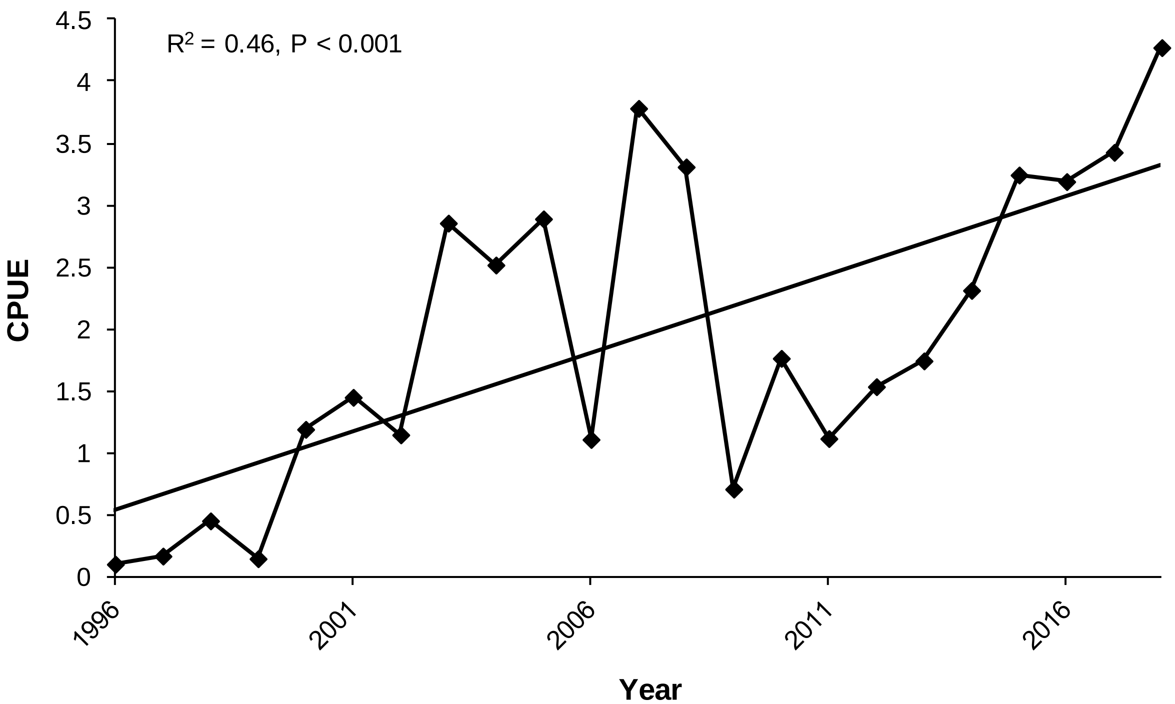


Figure 15. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic with 95% confidence limits, 1986-2018.

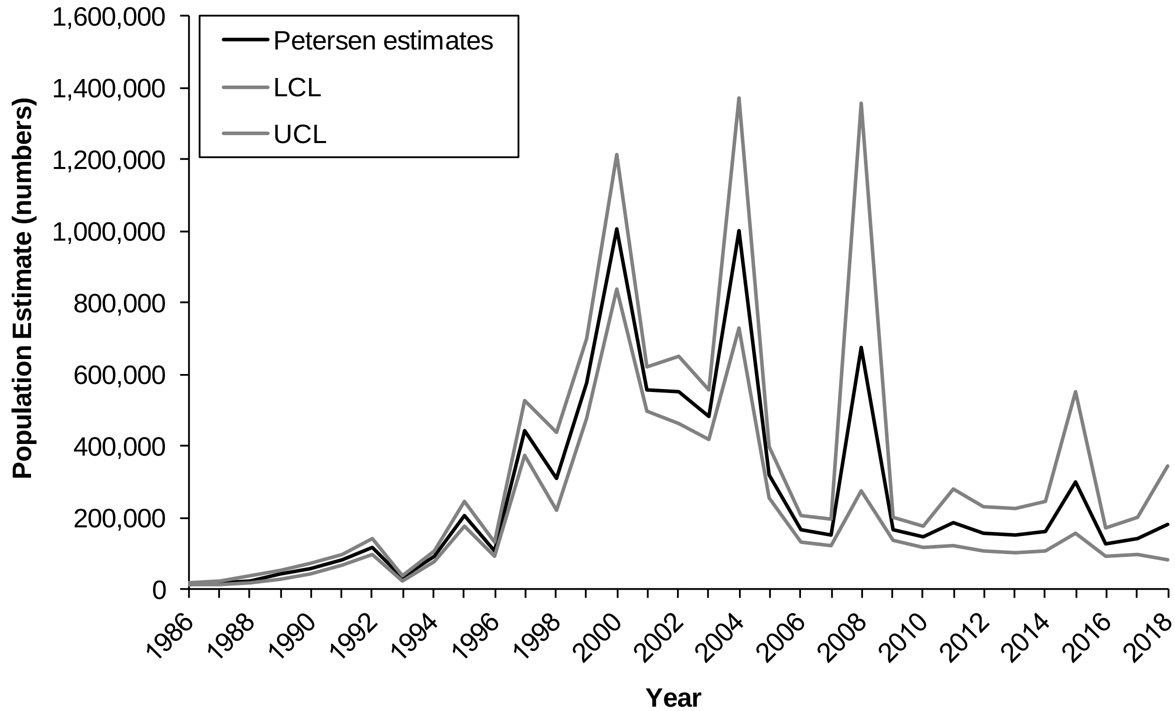


Figure 16. Conowingo Dam tailrace adult American shad abundance estimates from the surplus production model (SPM), 1986-2018.

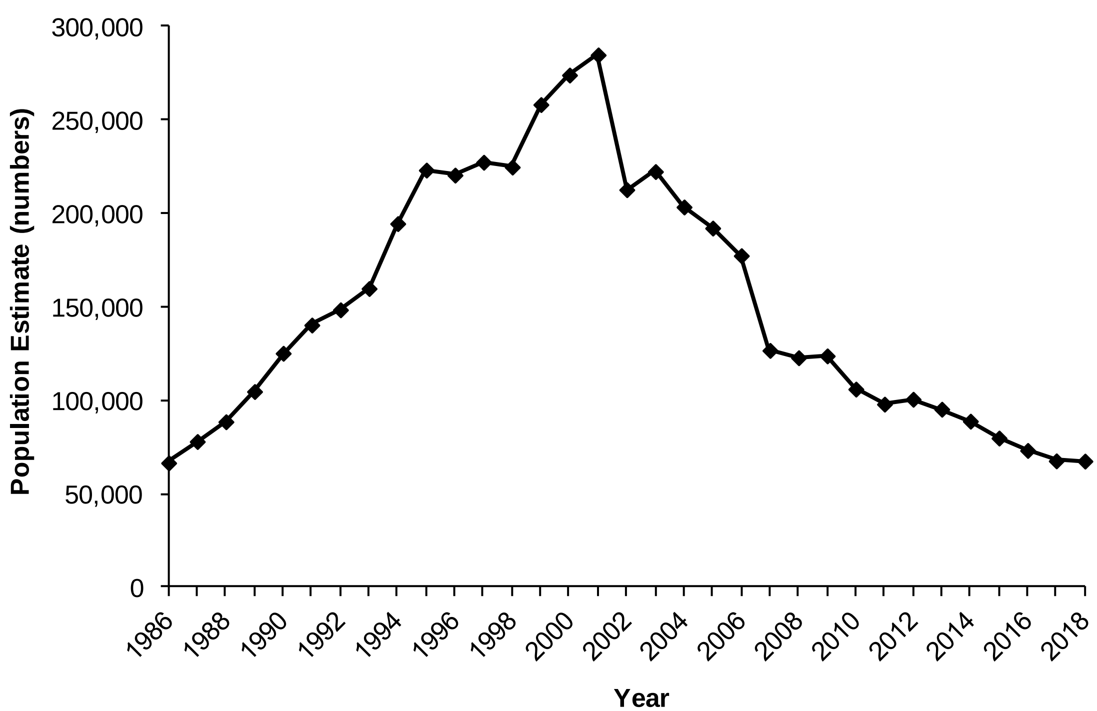


Figure 17. Baywide juvenile American shad geometric mean CPUE (catch per haul), 1959-2018.

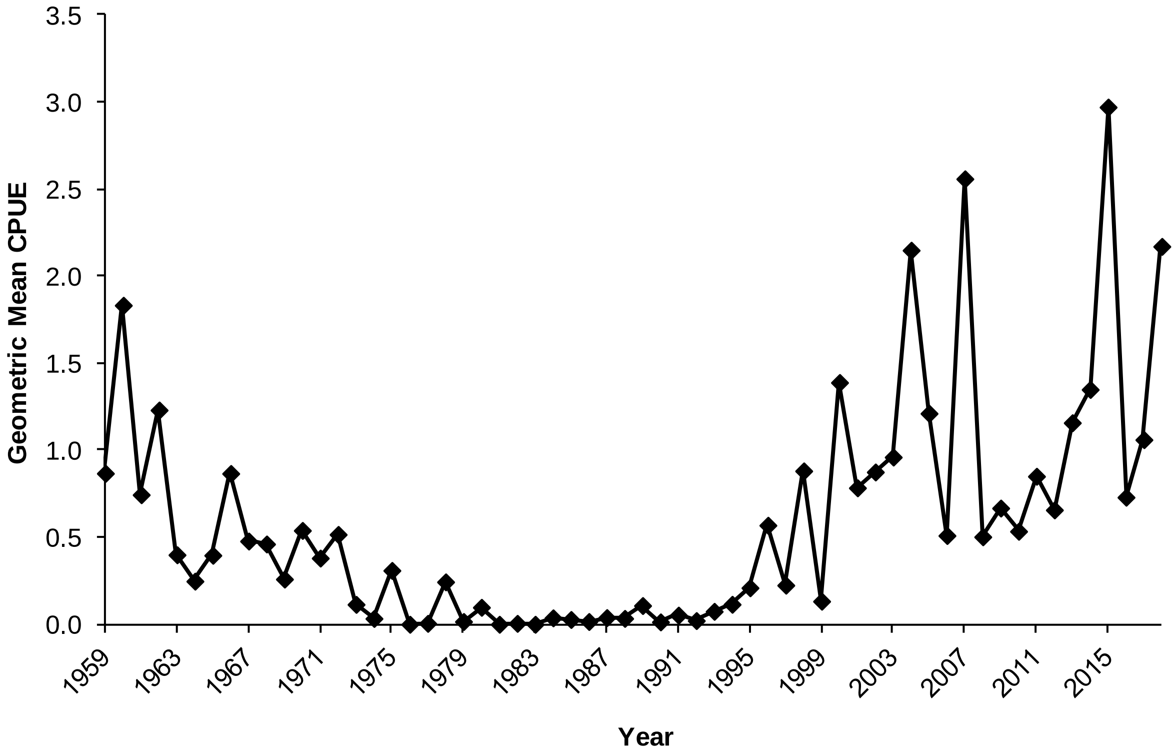


Figure 18. Upper Chesapeake Bay juvenile American shad geometric mean CPUE (catch per haul), 1959-2018.

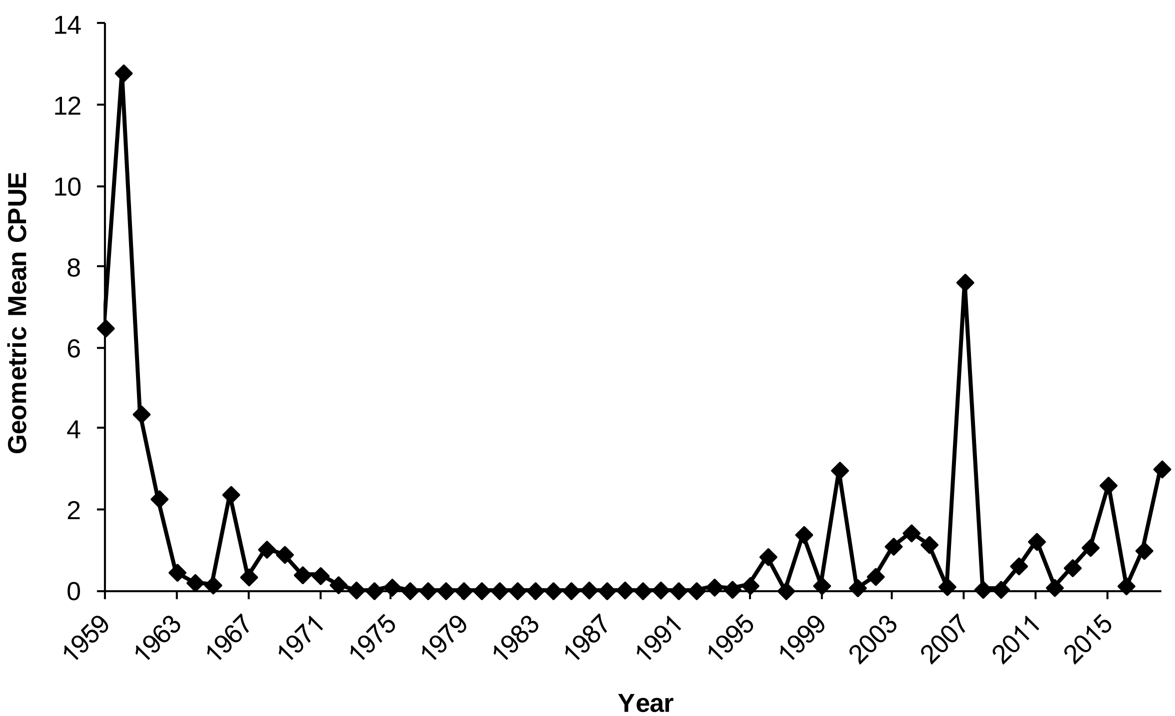


Figure 19. Potomac River juvenile American shad geometric mean CPUE (catch per haul), 1959-2018.

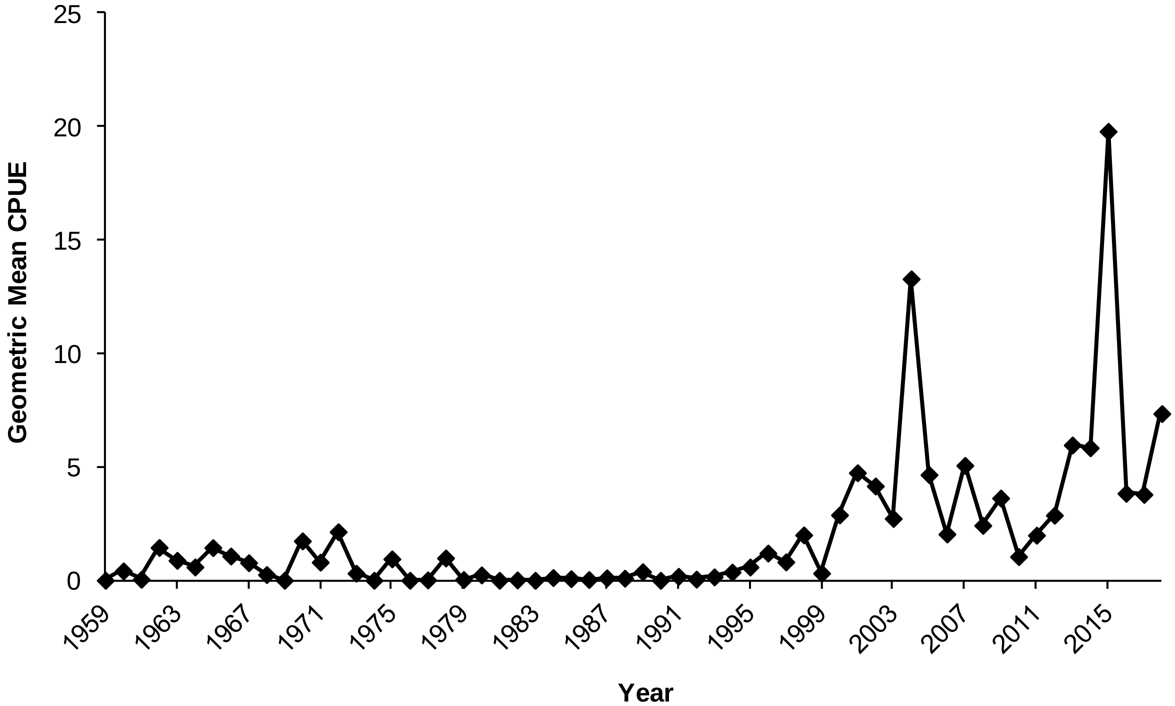


Figure 20. Nanticoke River juvenile American shad geometric mean CPUE (catch per haul), 1959-2018.

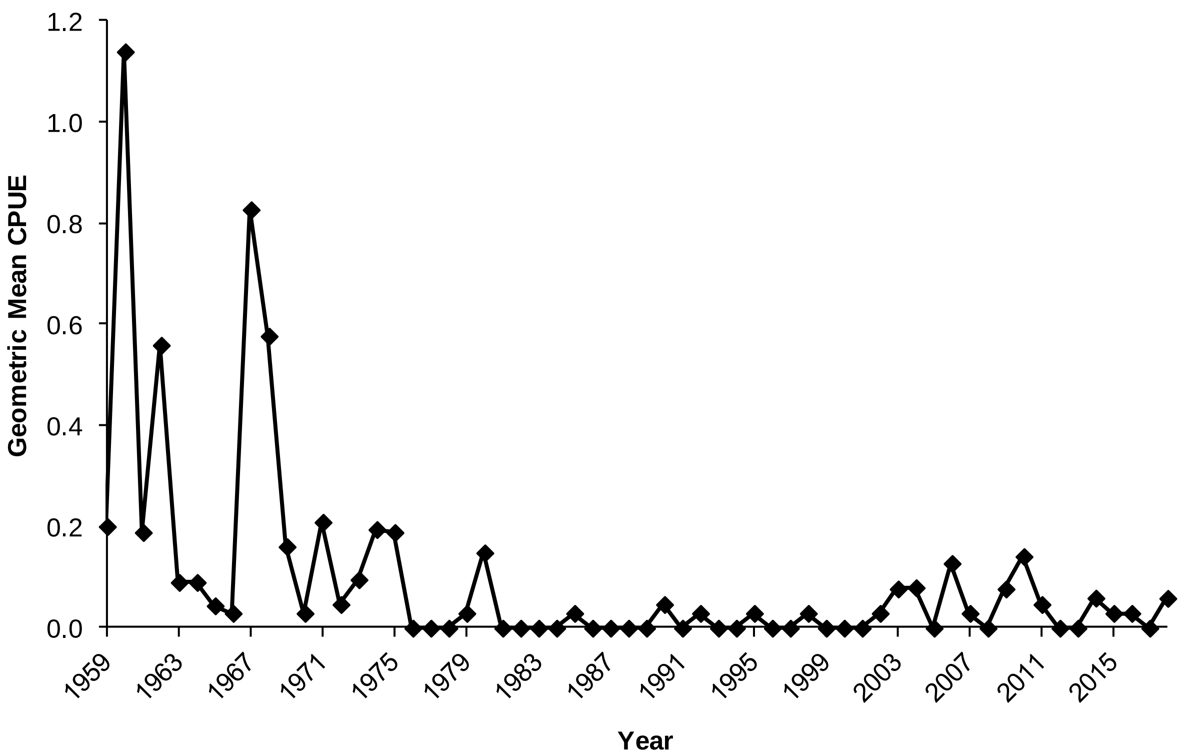


Figure 21. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from the Susquehanna River and Deer Creek (a lower Susquehanna River tributary), 2004-2018.

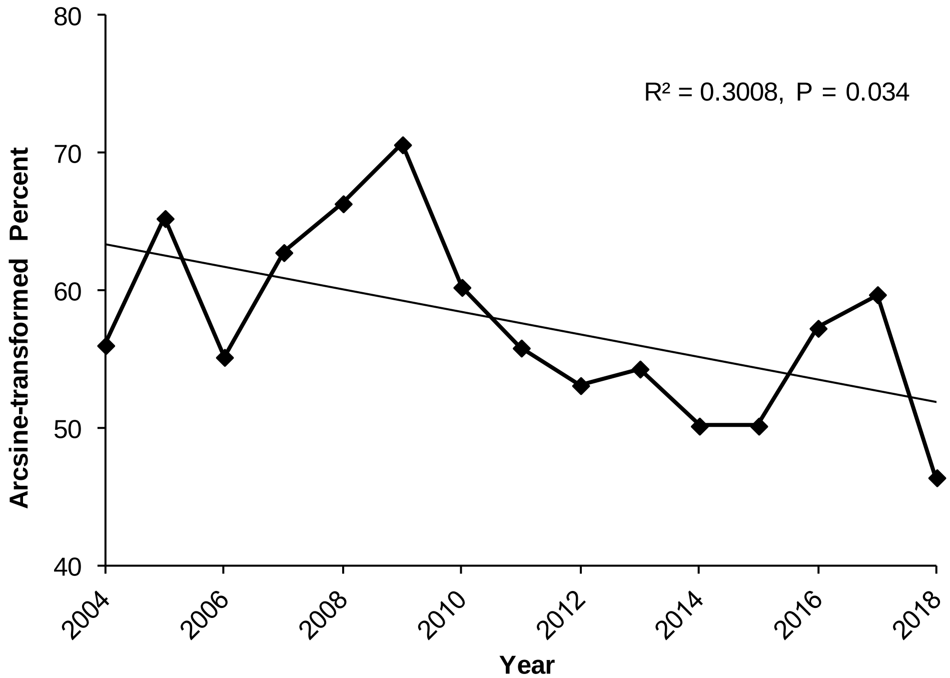


Figure 22. Arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1990-2018.

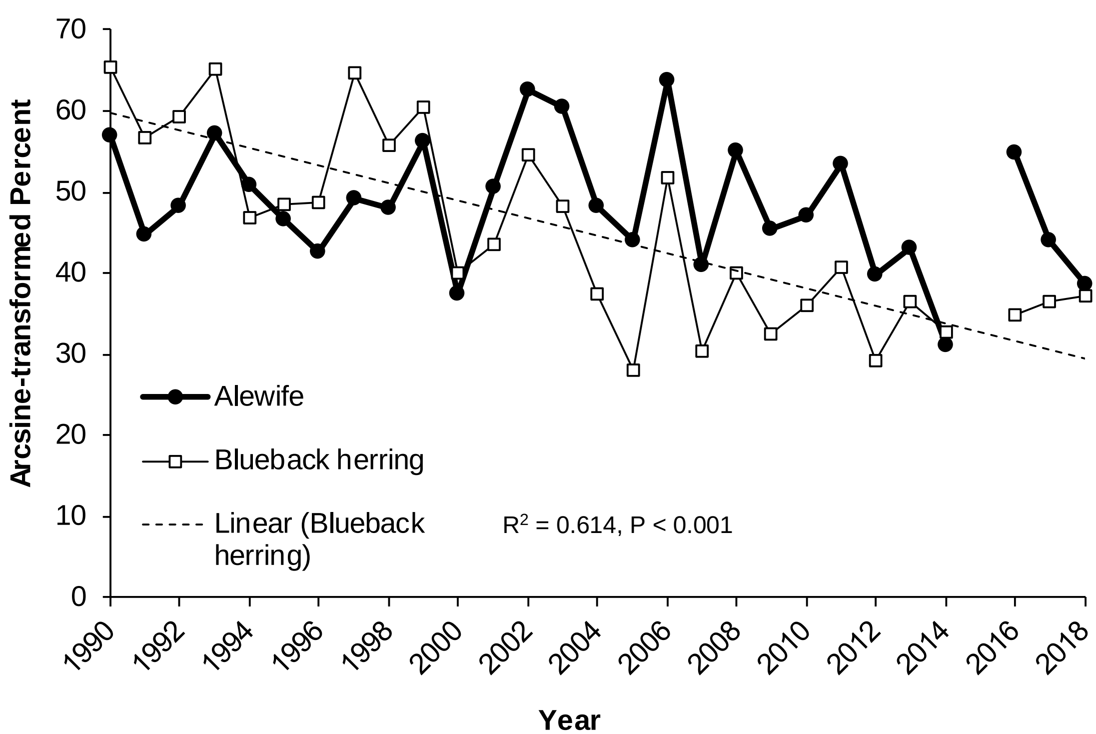


Figure 23. Mean fork length (mm) of adult alewife and blueback herring from the Nanticoke River, 1989-2018.

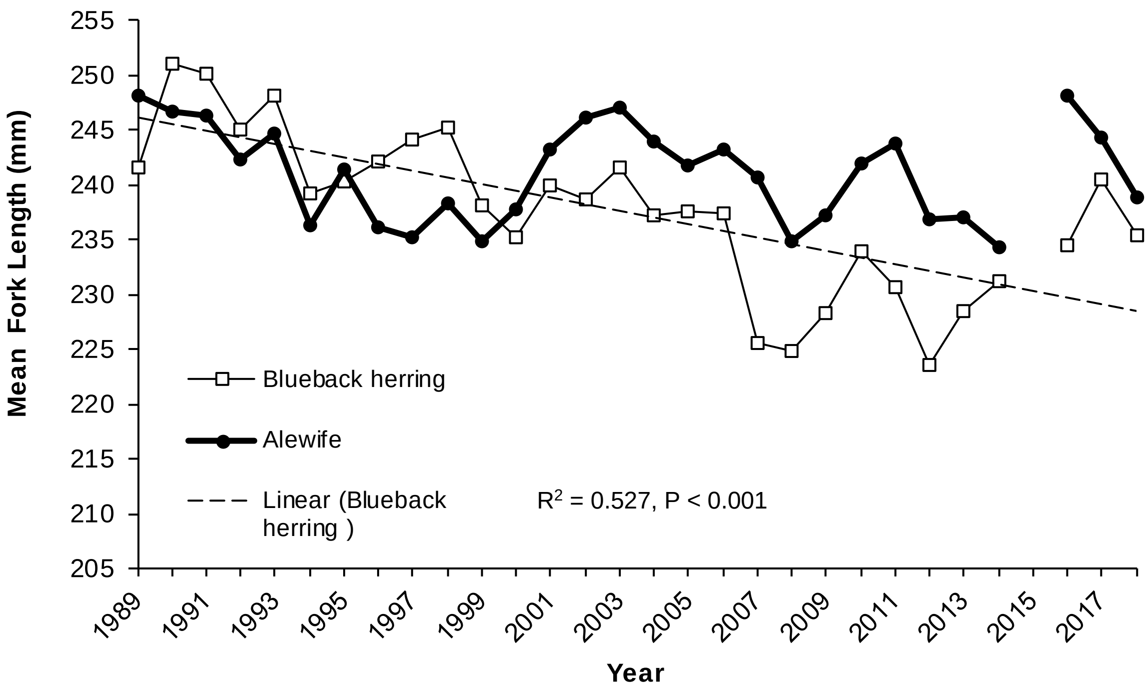


Figure 24. Percent catch-at-age by year of alewife from the North East River, 2013-2018.

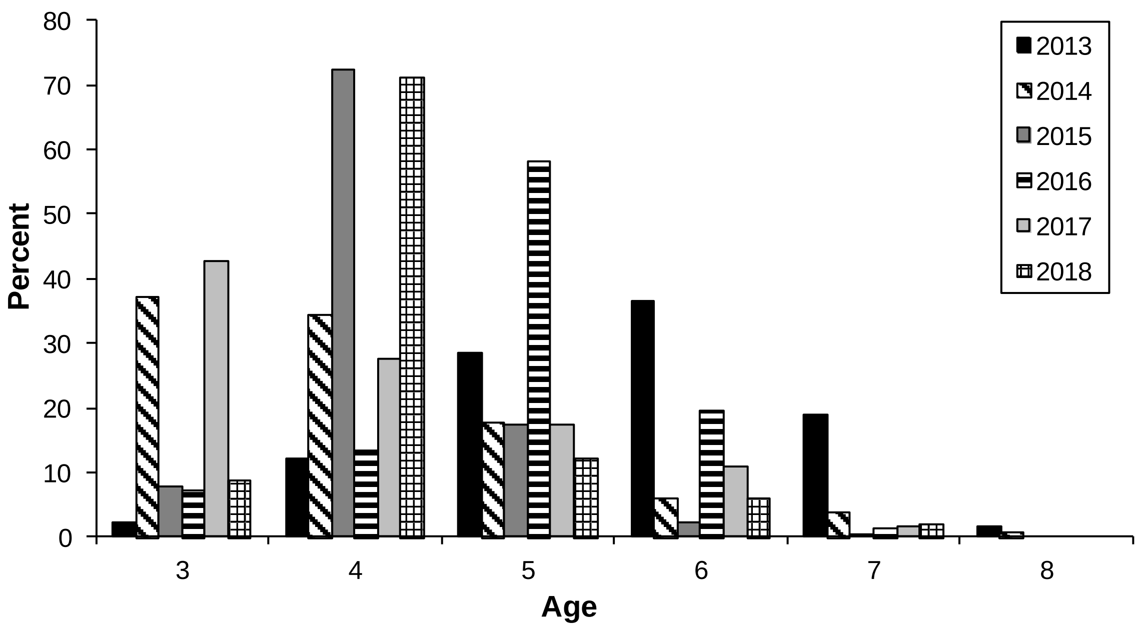


Figure 25. Percent catch-at-age by year of blueback herring from the North East River, 2013-2018.

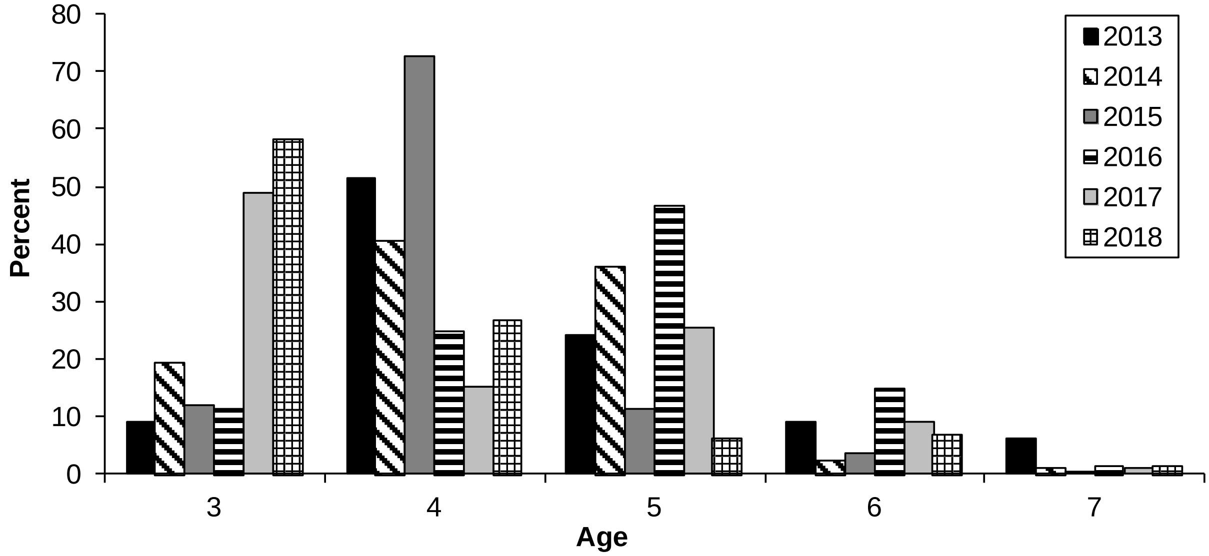


Figure 26. Geometric mean CPUE (catch per net day) of adult alewife and blueback herring from Nanticoke River fyke nets, 1989-2018. No fyke nets were fished in 2012 and 2015.

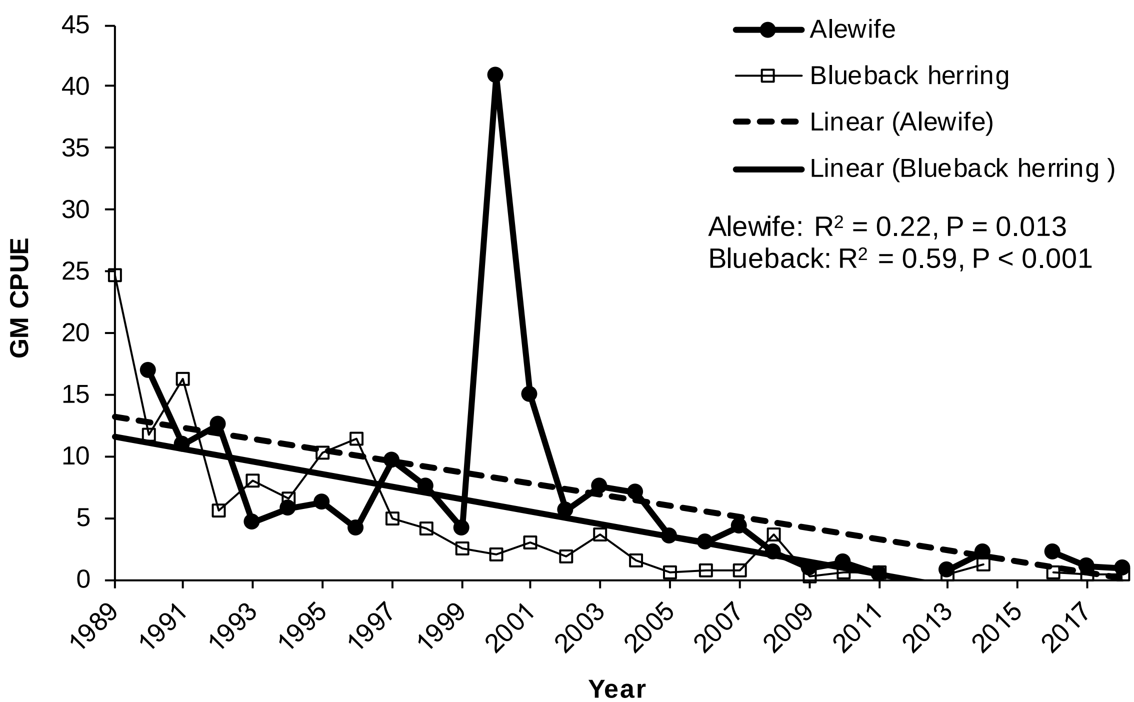


Figure 27. North East River catch per day of alewife and blueback herring, plotted with surface water temperature for 2018.

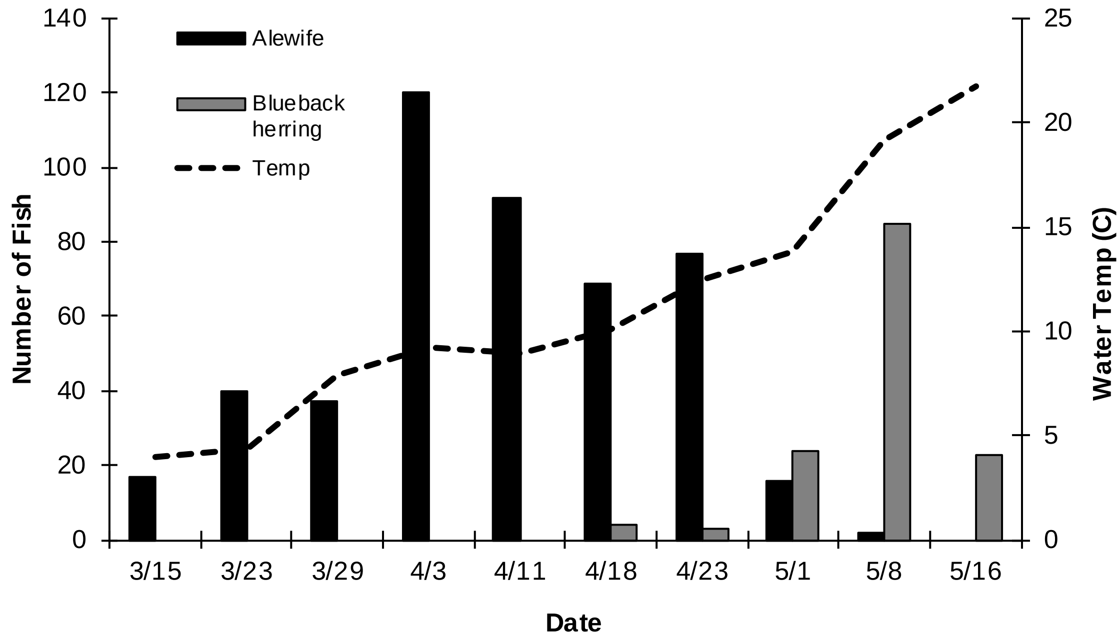


Figure 28. Percent of total catch by mesh size of alewife from the North East River, 2013-2018.

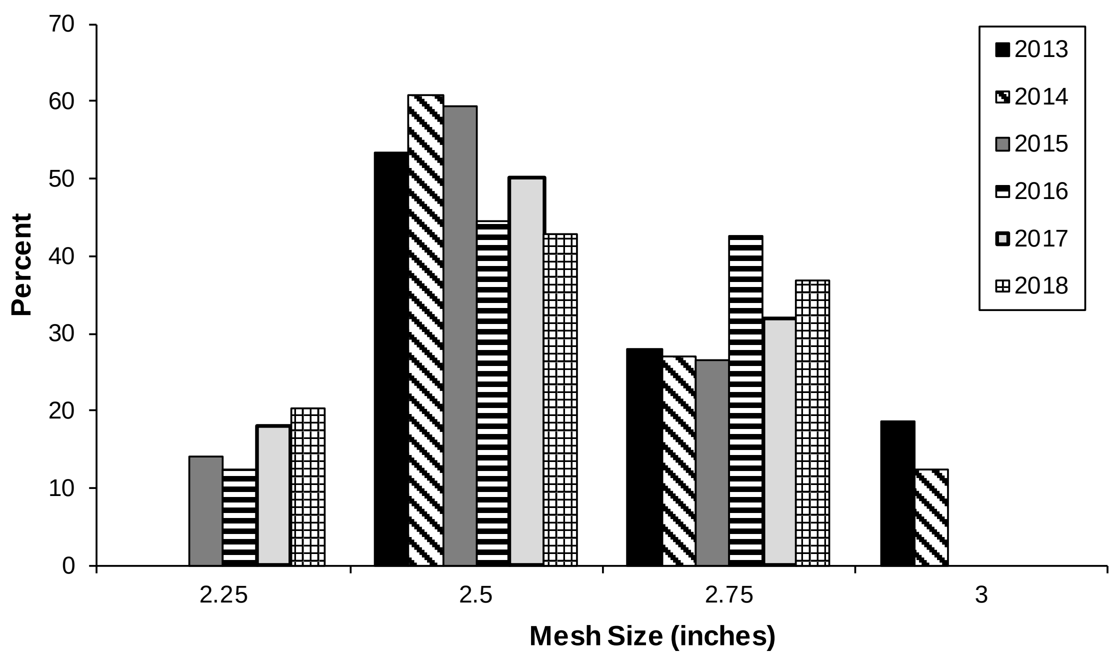


Figure 29. Percent of total catch by mesh size of blueback herring from the North East River, 2013-2018.

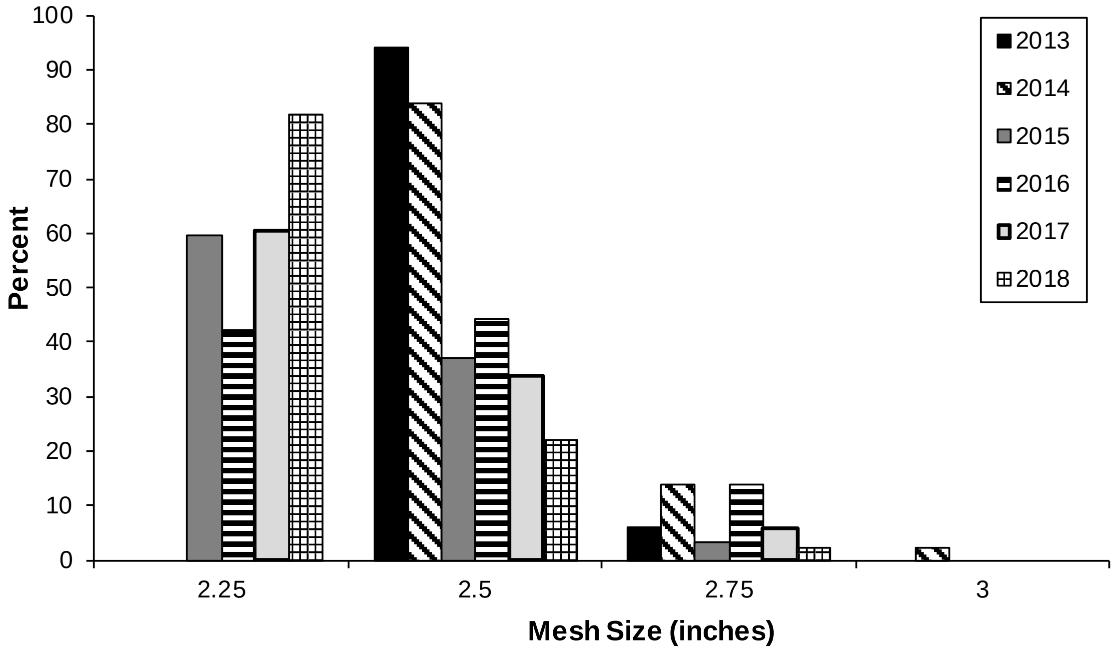


Figure 30. Alewife and blueback herring CPUE (number of fish caught per set of experimental gill net per hour fished) from the North East River gill net survey, 2013-2018. Catch was pooled across the 2.5" and 2.75" mesh panels for all years.

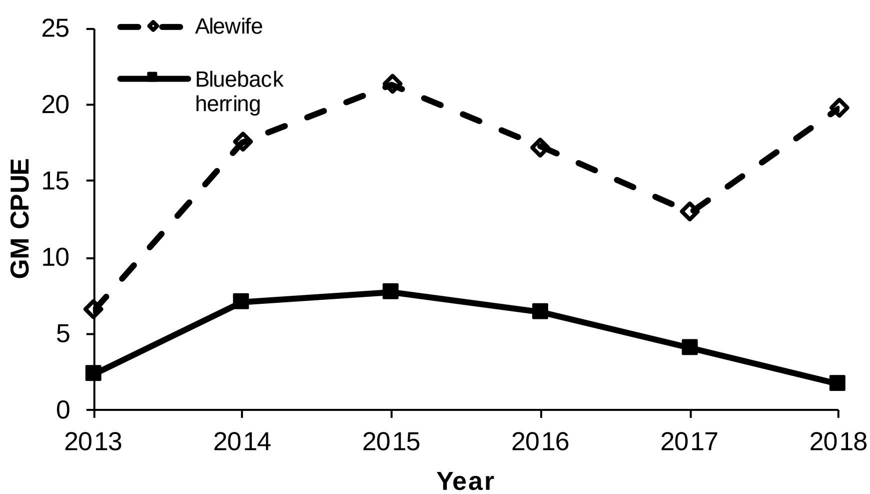


Figure 31. Alewife and blueback herring CPUE (number of fish caught per set of experimental gill net per hour fished) from the North East River gill net survey, 2015-2018. Catch was pooled across the 2.25", 2.5", and 2.75" mesh panels for all years.

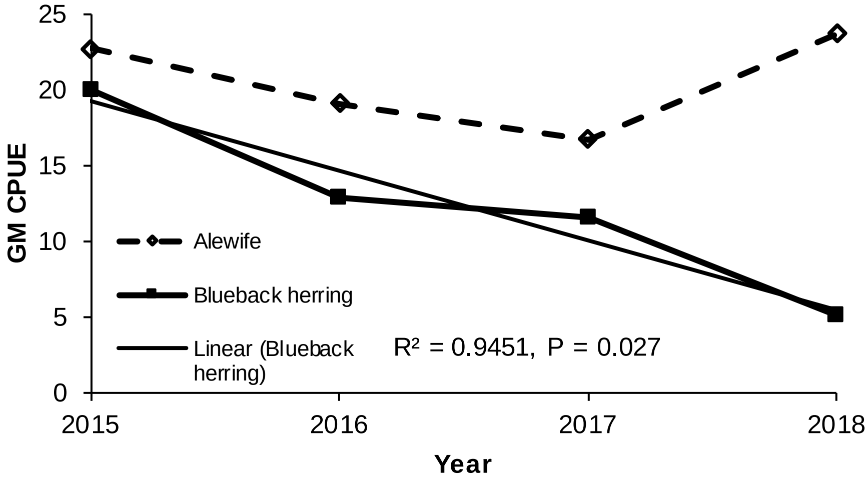


Figure 32. Upper Bay juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2018.

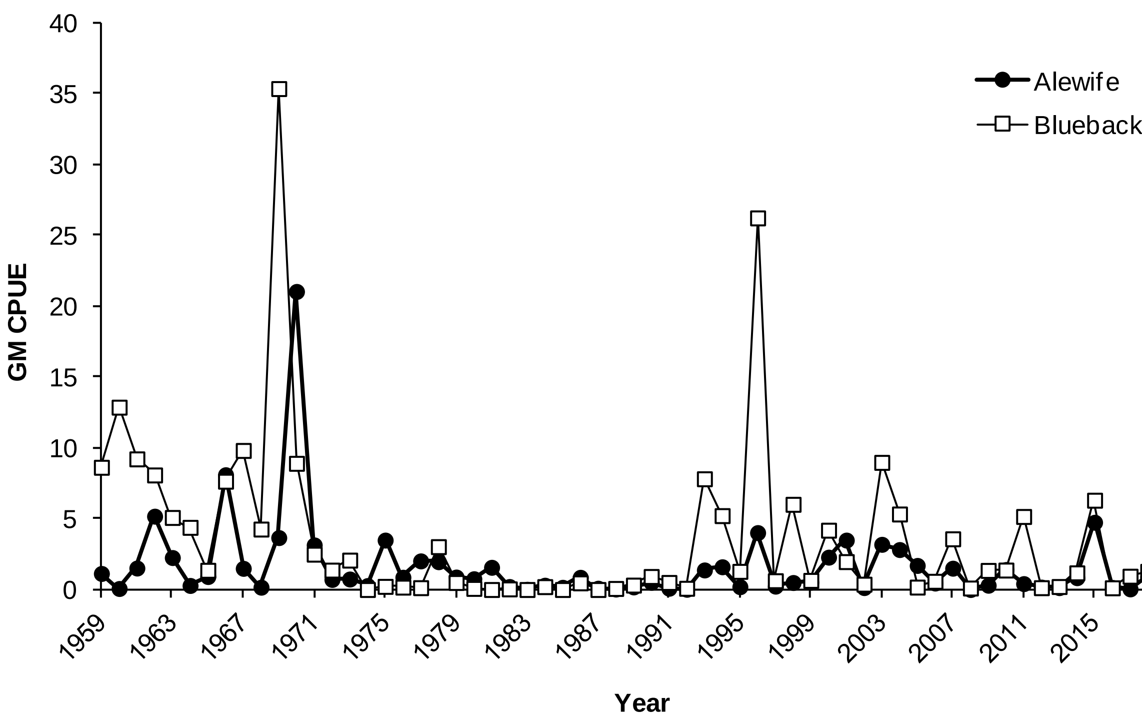
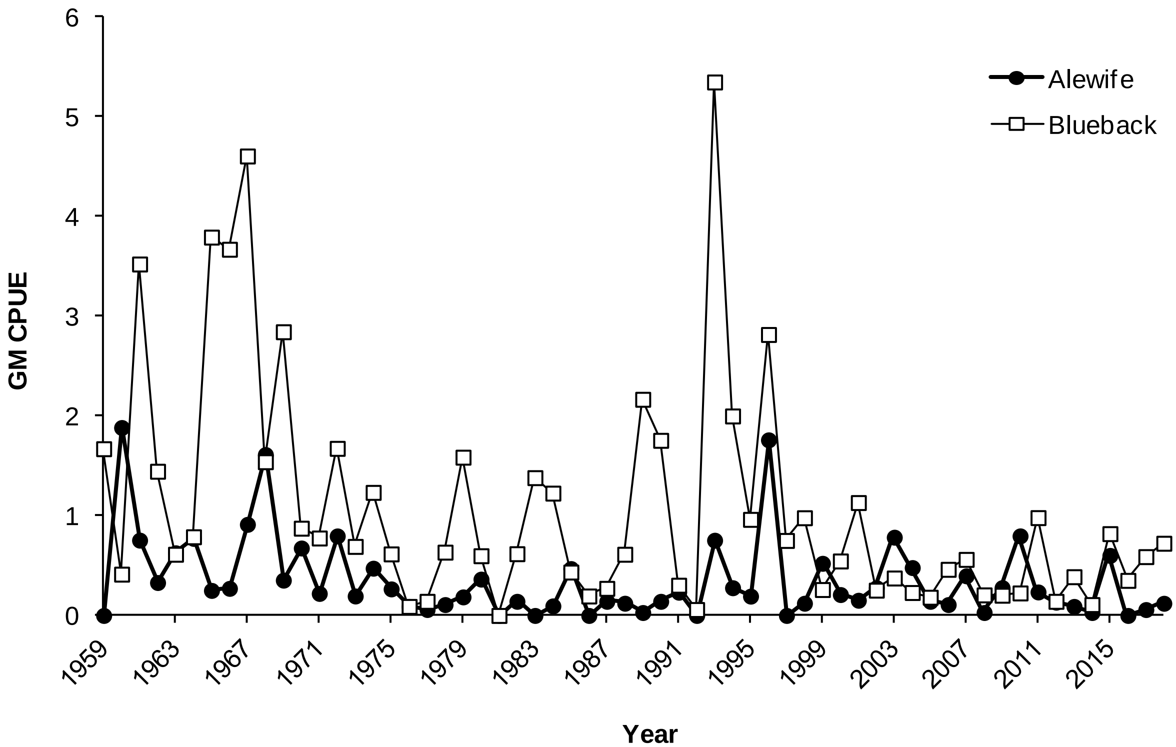


Figure 33. Nanticoke River juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2018.



PROJECT NUMBER 2
JOB NUMBER 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 26 years of this survey (1993-2018). Potomac River sampling was not conducted in 2009 due to a lack of cooperating fishermen. Sampling resumed in 2010. In 2018, commercial pound nets were sampled inside the mouth of the Potomac River and in Chesapeake Bay just north of the Potomac River (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 and Sassafras Rivers in 2018 (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 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 or 2018, 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 2018 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. The MTI Corporation model number EQ-IPDB40305 impregnated diamond cutting blades were 101.6 millimeters in diameter and 0.35 millimeters thick. 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 from an imaginary line crossing from Howell Point to Jenkins Creek downstream to the river mouth (Figure 2). Sampling dates in 2013 were from mid-June to mid-September. Logistical issues in 2016 resulted in missing one week in June, one week in August and only completing two of the four sets one week in July. Sampling was extended one week into September in 2016 to help compensate for the lost sets. In 2017 only three sets were completed on one sampling day in June and one sampling day in August due to mechanical issues with the sampling vessel. 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 is 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. 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.

Two new sets of net were constructed prior to the 2018 sampling season and were used exclusively throughout the season. The sections of 7.6 centimeter and 8.9 centimeter mesh were mixed up during construction, and when completed one set of nets contained two 7.6 centimeter panels and the other net consisted of two 8.9 centimeter panels (instead of one of each as intended). This error was not discovered until the first sampling trip of

2019, therefore all sets in 2018 used the incorrectly constructed nets. The sampling routine was to stagger the two net set times to have both sets of net in the water at the same time to allow retrieval and reset of the first prior to picking up the second. This leads to a pattern of setting and retrieval that is sometimes interrupted by not being able to set a net while one is in the water due to distance between set locations and/or large catches increasing processing time. These instances can be determined by comparing net set and retrieval times, both of which are recorded for each set. Catches of Atlantic menhaden differ both in number captured and length frequency between the two panels, so Atlantic menhaden catch and mean length per net panel was used to determine which panels were mislabeled. Analysis of Atlantic menhaden catch, coupled with set and retrieval time were used to differentiate the 7.6 centimeter and 8.9 centimeter panels, and the database was corrected accordingly. Since both net sets were fished alternately, the overall annual CPUE was minimally impacted, if at all.

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, and 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 December 2018. Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2017. 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 in 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 2018 charter log book data had not been finalized, only data through 2017 was utilized for analysis.

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 = 3,125) determined from 2003-2017 Chesapeake Bay pound net survey data, and June through September 2003-2017 measurements of age zero Atlantic croaker (n=333) from the MD DNR Blue Crab Trawl Survey's Tangier Sound samples (Chris Walstrum MD DNR personnel communication 2017). 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 2003-2017 were L_∞ = 384 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 2018. 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 2018, weakfish from 2003 through 2018 and Atlantic menhaden from 2005 through 2018. 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 2018. 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 panel 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 May 31, 2018 through September 21, 2018 (Table 1). Spotted seatrout was the only target species not encountered during this time period. Twenty non-target species were also encountered in 2018 (Table 2). One seafood dealer sampling trip was conducted at a single dealer on the eastern shore of Chesapeake Bay on September 7, 2018, five of the target species were encountered. Another seafood dealer sampling trip was conducted on June 8, 2018, but no fish were encountered. The Choptank River fisheries independent gill net survey was conducted once per week from June 7, 2018 to August 28, 2018. Eight of the target species and eleven non-target species were captured in 2018 (Table 3).

Weakfish

Sixteen weakfish were sampled in the 2018 pound net survey, a decrease from 2017 and the second lowest number sampled in the 26 year time series. Weakfish mean length in 2018 was 265 millimeters TL, the sixth lowest value of the time series (Table 4). Sample size in 2018 was not adequate to determine weakfish size structure using length frequency distribution, but lengths did fall within a range similar to 2016 and 2017 (Figure 4). Males and females each accounted for 50% of the 16 weakfish in which sex was determined. Mean length and weight were similar for both sexes, with females averaging 269 millimeters TL and 217 grams and males averaging 262 millimeters TL and 212 grams. Only two weakfish were encountered during seafood dealer sampling (Table 6).

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 2018, with far fewer large weakfish being encountered. Only two of the 16 weakfish sampled in the 2018 pound net survey were above the commercial size limit of 305 millimeters TL (12 inches) and none would have met the recreational size limit of 331 millimeters TL (13 inches). Both of the seafood dealer sampled weakfish met the commercial length limit, but only one would have been legal recreationally.

Three weakfish were captured and measured in the Choptank River gill net survey in 2018, with lengths ranging from 274 to 281 millimeters TL. Only one weakfish was captured in 2015 and 2017, two in 2016 and none were encountered in 2013 or 2014 (Table 3). All seven weakfish captured by the survey were in the 6.4 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 2017 Maryland Chesapeake Bay commercial weakfish harvest of 219 pounds was an increase from 2016, but still over two orders of magnitude below the 1981 – 2017

Maryland Chesapeake Bay average of 42,501 pounds per year (Figure 5). 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 348 pounds per year. Maryland recreational anglers harvested an estimated 9,170 weakfish (PSE = 73.2) from inland waters during 2017, with an estimated weight of 5,922 pounds (PSE = 57.8; Figure 5). The number of weakfish harvested by the recreational fishery in 2017 was well below the time series mean harvest of 291,534 fish and was the seventh lowest value of the 1981-2017 time series. According to the MRIP estimates, Maryland anglers released 41,674 (PSE = 43.8) weakfish from inland waters in 2017, a decrease compared to 2016 (116,130 PSE = 77.9), and still below the time series mean estimate of 299,009 fish per year. Estimated recreational harvest decreased steadily from 741,758 fish in 2000 to 763 in 2006, and has fluctuated at a very low level from 2007 through 2017. 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, making it likely the low abundance, and not current regulations, are primarily responsible for the low total harvest. The reported harvest from Maryland charter boat captains has ranged from 829 to 75,011 weakfish from 1993 to 2017 (Figure 6), with a sharp decline occurring in 2003, and the lowest value occurring in 2014. Reported charter boat harvest has slowly increased since 2014, reaching 2,152 fish in 2017, but was still an order of magnitude lower than the long term mean (23,330 weakfish per year).

The weakfish juvenile GM was stable from 2013 to 2015, with values just below the time series mean, but declined to the fourth and third lowest values of the 30 year time series in 2016 and 2017, respectively (Figure 7). The 2018 index value increased to 1.03 fish per tow, but was still well below the time series mean of 2.77 fish per tow (Figure 7). 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 15 fish in 2018. Seventy-three percent of sampled weakfish were age one, 19% were age two, and 8% were age three (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 (Table 6). The 2014 age sample size was too small to make valid comparisons (six fish). No age three plus fish were sampled in 2015 through 2017, and only one in 2018, but low sample size could have led to missed age classes.

Mortality estimates for 2006 through 2012 and 2014 through 2018 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 7), 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 Stock Assessment Workshop, completed by ASMFC in 2016, utilized a Bayesian model with time-varying M and spatial heterogeneity (ASMFC 2016). This assessment indicated weakfish biomass was very low; F was low and M was high but decreasing in 2014, the terminal year of the assessment. The stock was classified as depleted due to high M, not F. 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 2004-2018. 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 4). The 2018 mean length increased to 250 mm TL (n = 125, Table 4), but was still the second lowest value of the time series. The 2017 mean length was influenced by an unusually large number of small flounder. 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 (Figure 8). 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 and 2018 length distributions were bimodal, with 2017 peaking at the 130 and 250 millimeter length groups and 2018 peaking at the 190 and 290 millimeter length groups (Figure 8). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches to the 2018 recreational size limit of 420 millimeter TL indicated three percent of the 125 sampled flounder were of legal size in 2018, compared to 2% in 2017, none in 2016, 9% in 2015, 4% in 2014 and 10% in 2013. No summer flounder were encountered during fish house sampling in 2018.

In 2018, four summer flounder were captured in the Choptank River gill net survey ranging in length from 187 to 228 millimeters TL (Table 3). One specimen was captured in the 6.4 centimeter mesh two in the 8.9 centimeter mesh and one in the 10.2 centimeter mesh. Only thirteen summer flounder have been encountered in the six years of the survey.

The 2017 Maryland Chesapeake Bay commercial summer flounder harvest totaled 2,859 pounds, an increase from 2016, but still the third lowest value of the 1981 – 2017 time series (Figure 9). Maryland Chesapeake Bay landings steadily decreased from 2005 to 2016, with the exception of an increase in 2014. 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 26,338 fish (PSE = 47.8) caught in 2017 was an increase from the 2016 estimate of 19,924 fish (PSE = 37.3) fish, but was still the second lowest value of the time series (Figure 9). The 2017 MRIP recreational inland waters release estimate of 771,763 fish (PSE = 29.6) decreased compared to 2016 (1,135,462 fish, PSE = 43.1; Figure 9). 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 – 2017 time series, with the highest number landed in 1993 (10,445 fish) and the lowest in 2017 (31 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 2010-2017 averaging 235 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 2013, with a terminal year of 2012 (NFSC 2013). The NMFS assessment concluded that summer flounder stocks were not overfished, and overfishing was not occurring. An update of the 2013 assessment, with data through 2015, was conducted in 2016 (Terceiro 2016), and indicated the stock was not overfished, but overfishing was occurring. Projection analysis for 2016-2018 indicated if F was reduced to the target during 2016-2018, the stock would not be overfished, but would be right at the threshold value for 2016.

Bluefish

Bluefish sampled from the onboard pound net survey averaged 291 millimeters TL during 2018, the sixth lowest value of the 26 year time series (Table 4). The pound net survey length frequency distributions have been bimodal most years (Figure 11). The 2005-2007 pound net sampling indicated a slight shift to a larger grade of bluefish, although small bluefish still dominated the population. This trend reversed in 2008 through 2011 when larger bluefish became scarce. The 2012-2015 length structure was similar to those of 2005-2007, but fewer large fish were sampled in 2016-2018, which had distributions similar to those of 2008 and 2009. 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 two bluefish were sampled from seafood dealer sampling in 2018 with lengths and weights of 368 and 297 millimeters TL and 440 and 249 grams. These two fish were smaller than the mean length of 405 millimeters TL in 2017 (n = 172; Figure 12).

Bluefish have been captured in low numbers all six years of the Choptank River gill net survey, with 11 being captured in 2018 (Table 3). Catches were slightly higher in the first three years of the survey, ranging from seven to 21 per year and lower in 2016 and 2017, at two and three fish, respectively. Bluefish lengths for all panels and years combined ranged from 218 to 500 millimeters TL (n=56), with the 11 from 2018 ranging from 240 – 391 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 panel in 2013, 2015 and 2018 with the 7.6 centimeter mesh panel accounting for the second highest catch in those years and all of the catch in 2016 (Figure 13).

Maryland's Chesapeake Bay commercial bluefish harvest in 2017 was 11,333 pounds, the second lowest value in the 1981-2017 time series, and below the average of 109,206 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 44,832 from 1990 to 2017 (Figure 14). 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 2017 harvest estimate of 167,635 fish (PSE = 45.9) decreased compared to 2016, and was the second lowest estimate of the 1981-2017 time series (Figure 14). Estimated inland recreational releases were 186,592 fish (PSE = 26.9) in 2017, well below the time series mean of 784,513 fish (Figure 14). Reported bluefish harvest from Chesapeake Bay charter boat logs ranged from 7,809 – 133,499 fish per year from 1993 to 2017, with the 2017 harvest being the lowest of the 25 year time series (Figure 15).

A stock assessment of Atlantic coast bluefish utilized a forward projecting catch at age model including data through 2014 (NFSC 2015). The assessment indicated that F was high in the late 1980s and early 1990s, declined into the late 1990s, remained fairly stable through 2010, and declined slightly through 2014. Spawning stock biomass decreased through the 1980s and early 1990s, and has generally increased since in response to decreased fishing mortality. The model indicated that overfishing is not occurring and that the stock is not overfished.

Atlantic Croaker

Atlantic croaker mean length from the onboard pound net survey increased in 2018 to 271 millimeters TL, but was still the seventh lowest value of the 26 year time series (Table 4). Only 214 Atlantic croaker were encountered in the survey in 2018, the second lowest number sampled and well below the 1,553 per year average. The onboard pound net length frequency distribution for 2018 truncated further, with 67% of all sampled fish in the 250 and 270 millimeter TL length groups, and only three percent of the sample under 230 millimeters TL (Figure 16).

Mean lengths and weights by sex for Atlantic croaker sampled from the onboard pound net survey in 2018 were 273 millimeters TL and 327 grams for females (n = 47) and 264 millimeters TL and 287 grams for males (n = 35). Pound net samples were 57% female and 43% male. Samples in which sex determination and weight were taken were not randomly selected; therefore, sex specific data may be biased.

Atlantic croaker sampled from seafood dealers had a mean total length and weight of 293 millimeters (n = 121) and 408 grams (n = 121) respectively (Table 5). The length frequency distribution from the seafood dealer samples was very similar to the onboard sampling in 2018, except for a shift up one length group, with the 270 and 290 millimeter groups combined accounting for 74% of harvested fish (Figure 17).

Atlantic croaker geometric mean catch per hour fished from the Choptank River gill net survey declined through the first three years of the survey, and remained low in recent years (Figure 18), with a maximum total catch of 476 fish in 2013, and a minimum value of eight fish in 2018. Anecdotal reports from commercial and recreational fishermen indicated Atlantic croaker catches were unusually low from the Choptank River north since 2015, but catches were somewhat better in lower 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 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 19). 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 20). Year to year length frequency comparisons were not made do to the low sample sizes in 2015 through 2018.

The 2017 Maryland Atlantic croaker Chesapeake Bay commercial harvest of 40,599 pounds was a 49% decrease from 2016, well below the 1981 to 2017 mean of 381,046 pounds per year, and was the fourth consecutive year of a 45% or greater decline in annual harvest (Figure 21). The 2017 recreational inland harvest estimate was 425,696 fish (PSE = 32.7) a 35% decrease from 2016, and well below the 1981-2017 average of 1,235,744 fish (Figure 21). The 2017 recreational release estimate of 2,379,594 fish was almost four times higher than the 2016 value (Figure 21), and was above the 1981-2017 average of 2,379,594 fish per year. Reported Atlantic croaker harvest from charter boats ranged from 2,899 – 418,313 fish per year during the 25 year time period (Figure 22), with the low value occurring in 2017, and eight 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 third highest value of the 30 year time series in 2008, but fell sharply in 2009 and remained low through 2011, before spiking again in 2012 (Figure 23). 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 increased to 2.35 fish per tow in 2017, which is near the time series mean, but fell to 1.13 in 2018. 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 2018 ranged from zero to six (n=83; Table 8). The number of Atlantic croaker sampled for length in 2018 (n=214) was applied to an age-length key for 2018 (Table 8). This application indicated ages one and two accounted for 37% of sampled fish and ages five and six accounted for 36% of sampled fish (Table 8). Age structure in 2018 remained truncated to younger fish, with no age seven plus fish and a more even distribution between ages than in recent years. 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. The contribution of strong year classes (1998, 2002, 2006, 2008 and 2012) to the catch can be seen in Table 8.

Instantaneous total mortality estimates in 2018 using Maryland growth parameters and ASMFC stock assessment growth parameters were Z = 0.71 and Z = 0.60, respectively (Table 7). Both sets of estimates indicate the same trend, with Maryland only growth parameters indicating a larger range of values (Figure 24). Total mortality estimates were relatively stable at a low level from 1999 through 2009. From 2010 to 2014 estimates of Z increased rapidly and were more variable, but generally increased through 2017 before declining slightly in 2018. Recruitment has generally been poor in recent years, leading to increased mortality rates on recent year classes, and fewer fish reaching older age 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 will likely determine whether to incorporate those changes in 2019.

Spot

The 2018 spot mean length from the onboard sampling of 180 millimeters TL declined compared to the 2017 value of 200 millimeters TL, and was the third lowest value of the 26 year time series (Table 4). Ninety-seven percent of spot encountered in the onboard pound net survey in 2018 were between 150 and 199 millimeters TL, a shift to smaller sizes and an overall all truncation of the length frequency distribution (Figure 25). Only one jumbo spot (>254 millimeter TL) was present in the 2018 onboard sampling (total measured = 1,149). Abundance of jumbo spot in the survey has been low for the past several years (0-3% of sample, 2005-2017). 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 are being harvested by the pound net fishery than observed during onboard sampling (Figure 26, Table 9). This would be expected as smaller spot are not generally marketable as food fish.

Spot catch per hour in the Choptank River gill net survey was highest in 2014, moderate in 2013 and 2017, and lowest in 2015, 2016 and 2018 (Figure 27). 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 28), accounting for over 92% of catch in 2013, 2014, 2016 and 2018, 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 six year time series. Length frequency distribution was similar in 2013 and 2014 with the 200 and 210 millimeter length groups accounting for over 60% of the catch each of those years (Figure 29). The distribution shifted toward larger fish in 2015, with only 24% of captured fish in the 200 and 210 millimeter length groups combined. The length distribution shifted to smaller fish in 2016 with 74% of captured spot being less than 200 millimeter TL, but returned to a broader distribution in 2017. The 2018 distribution shifted back toward smaller fish. These shifts are likely driven by a decrease in availability of younger spot in 2015 and older spot in 2016 due to below average recruitment, as discussed below. 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 30), but declined to 62,251 pounds in 2015, and to 17,760 pounds in 2016, the fourth lowest value of the 37 year time series. Harvest increased in 2017 to 97,075 pounds, but was still below the long term mean of 130,321 pounds per year. Maryland recreational inland harvest estimates from the MRIP indicated that spot catches since 1981 have been highly variable (Figure 30). 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 (Figure 30). The 2017 recreational inland waters harvest estimate of 3,228,230 fish (PSE = 25.9) was above the time series mean estimate of 2,676,811 fish. The release estimate of 2,287,532 fish (PSE = 27.9) was also above the time series mean of 2,077,763 fish (Figure 30). Reported spot charter boat logbook harvest from 1993 to 2017 ranged from 121,403 to 847,311 fish per year (Figure 31). The 2017 reported harvest increased to 231,027 fish, but was still below the time series mean of 443,183 fish.

Spot juvenile trawl index values from 1989-2018 were quite variable (Figure 32). 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 26 year time series, and the 2012 value increased to nearly the time series mean (Figure 32). The index values have declined since 2012 to the time series low in 2015 (0.29 fish per tow). The index values were somewhat higher for 2016 through 2018 (1.66 fish per tow in 2018), but remained below average.

In 2018, 62.2% of spot sampled from the onboard pound net survey were age zero, 37.8% were age one, and no age two plus fish were encountered (185 ages and 1,149 lengths; Table 9). The majority of spot were encountered in late August and September, after the ago zero fish grew large enough to be retained by the pound nets. Age two plus spot were also absent in 2016 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%. Two fish, sampled for length only, in both 2007 and 2011 were in length groups four to six centimeters larger than available in Maryland DNR samples. In both cases age length information from spot aged by VMRC were used. These were the only fish in the three and four year old age classes throughout the time series.

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, decrease in mean size and reduction in percent jumbo spot observed in 2005 through 2017 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. The 2018 year class was similar to the 2017 and higher than the 2014 through 2016 year classes, but was still below average and will likely lead to continued lower availability of adult spot in 2019.

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 will likely determine whether to incorporate those chances in 2019.

Red Drum

Red drum have been encountered sporadically through the 26 years of the onboard pound net survey, with none being measured in nine years and 458 being measured in 2012 (Table 4). Four red drum were measured in 2018 averaging 1,191 millimeters TL and ranging from 918 to 1,332 millimeters TL. Recreational anglers in Maryland are allowed one red drum between 18 and 27 inches TL, all of the encountered red drum exceeded the upper limit. No red drum were encountered during fish dealer sampling in 2018.

Maryland Chesapeake Bay commercial fishermen reported harvesting 379 pounds of red drum in 2017, compared to the 2013 spike of 2,923 pounds, and the 1981 to 2017 mean of 497 pounds per year (Figure 33). The high 2013 landings value was likely due to a large year class growing into the 18 – 25 inch slot limit.

The MRIP 2017 Maryland inland waters recreational harvest and release estimates were 4,943 (PSE = 86.3) and 14,148 (PSE = 64.6) red drum, respectively (Figure 33). Recreational harvest estimates have been extremely variable with zero harvest estimates for 27 of the 37 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 twelve red drum being harvested in 2017 (Figure 34). 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 three being sampled in 2018 (Table 4). 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 35). Recreational inland water harvest and release estimates from 1981 to 2017 have been variable, with harvest ranging from zero (20 years) to 11,374 fish in 1983 (Figure 35). In 2017, MRIP estimated 828 black drum were harvested (PSE = 50.3) and 2,809 were released (PSE = 59.7). 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 1993-2017 time series, with a mean catch of 369 fish per year (range = 13– 894; Figure 36). The lowest value of the time series was reported in 2017.

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 – 681 millimeters. Only nine Spanish mackerel were encountered in 2018. The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 and in 2013 (Table 4). Thirty-seven Spanish mackerel were sampled during fish house sampling with a mean length of 431 millimeters FL. Six Spanish mackerel were encountered in the gill net survey in 2018, only the second year any were encountered. One was captured in the 6.4 centimeter mesh, three in the 7.6 centimeter mesh and two in the 8.9 centimeter mesh.

The 2017 commercial harvest of Spanish mackerel in Maryland's portion of Chesapeake Bay was 787 pounds (Figure 37), and below the 1981 to 2016 mean of 4,711 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 have been variable from 1981 – 2017, with 11 years of zero harvest and a peak of 44,430 fish in 2009 (Figure 37). The 2017 estimated recreational Spanish mackerel harvest of 9,687 fish (PSE = 32.3) was almost identical to the time series mean of 9,688 fish (Figure 37). Most years have high PSE values, so these estimates are considered tenuous. Spanish mackerel charter boat harvest from 1993 to 2017 ranged from 53 – 10,638 fish per year, with a harvest of 586 fish in 2017 (Figure 38). It would appear that Spanish mackerel are providing a small but somewhat consistent opportunity for recreational anglers in Maryland's portion of Chesapeake Bay.

<u>Spotted Seatrout</u>

Spotted seatrout are rarely encountered during sampling, with annual observations ranging from zero (12 years) to 23 fish during the onboard pound net survey. None were encountered during the onboard pound net survey, gill net survey or fish house sampling in 2018 (Table 4). Commercial harvest of spotted seatrout in Maryland's portion of Chesapeake Bay averaged 2,631pounds from 1981-2017, however, 11 of 12 years had zero harvest from 1981-1992 (Figure 39). Reported 2017 commercial harvest was 15 pounds. 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 2017, including six years of zero harvest, and averaged 8,874 fish per year (Figure 39). The 2017 harvest estimate was 24,255 fish (PSE 48.1), which was the highest estimate since 1998. The high PSE values from indicate the MRIP survey does not provide reliable estimates for this species in Maryland.

Spotted seatrout harvest from 2017 charter boats was 15 fish. Reported harvest ranged from 10 – 20,003 fish per year and averaged 2,882 fish per year for the 23 year time series (Figure 40). 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.

<u>Atlantic Menhaden</u>

Mean length for Atlantic menhaden sampled onboard commercial pound nets in 2018 was 231 millimeters FL, the sixth lowest value of the 15 year time series (Table 4). No Atlantic menhaden were sampled from seafood dealers in 2018. Atlantic menhaden length frequencies from onboard sampling have varied annually (Figure 41). 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 (Figure 41). Those three size groups accounted for 83% and 77% of sampled Atlantic menhaden, respectively.

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 3). 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, and increased to the time series high in 2018 (Figure 42). The 7.6 centimeter mesh and the 6.4 centimeter mesh combined accounted for over 70% of the catch annually (Figure 43). The 7.6 centimeter mesh caught the highest proportion of Atlantic menhaden from 2014 through 2015, 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 selects 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. There was a shift to smaller lengths in 2017 compared to previous years, but the 2018 distribution shifted back toward larger fish. Mean lengths for all meshes combined displayed little inter-annual variation from 2013-2016: 2013 = 254 millimeters FL (n = 278), 2014 = 256 millimeters FL (n = 459), 2015 = 258 millimeters FL (n = 420) and 2016 = 254 millimeters FL (n = 308). Mean length did decrease to 243 millimeters (n = 361) in 2017, but reverted back to 256 millimeters FL in 2018 (n = 558).

Atlantic menhaden scale samples were taken from 188 fish in 2018 from the onboard pound net survey, but ages could only be assigned to 187 fish (Table 10). After applying the annual length frequencies (668 lengths in 2018) to the corresponding age length keys, 45% of sampled fish were age one, 30% were age two, 15% 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 2018 compared to the method used in previous years. One hundred thirty-five scale samples were taken for age from the Choptank River gill net survey in 2018, but age could only be assigned to 131 individuals. Age three accounted for 36% of sampled fish, age two accounted for 30%, age four accounted 23%, age one accounted for 6% and age five accounted for 5% of sampled Atlantic menhaden (Table 11). 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.

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. 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 season was the first year Maryland did not reach its quota.

A benchmark ASMFC Atlantic menhaden stock assessment was conducted in 2014 using the Beaufort Assessment Model which is a forward-projecting statistical catch-at-age model (SEDAR 2015). Additional data sources were explored to make more accurate selectivity and catchability assumptions, and more accurate life history information was used to inform the model. These changes led to the determination that that the stock was not experiencing overfishing and was not overfished. This is in contrast to the 2009 benchmark assessment determination of an overfished status. An assessment update was conducted in 2017 using the same model (ASMFC 2017c). This update also concluded overfishing was not occurring and the stock was not overfished.

PROJECT NUMBER 2
JOB NUMBER 2

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

2019 PRELIMINARY RESULTS – WORK IN PROGRESS

Onboard pound net survey sampling, through the 2019 portion of the reporting period, was conducted on June 4, 2019, and June 18, 2019, with one net sampled each day. During this time period the survey took length measurements from seven American Shad, 109 Atlantic menhaden, seven black drum, two blue catfish, two Spanish mackerel, 413 striped bass and seven white catfish. Subsamples for aging were collected from 40 Atlantic menhaden. Sampling continued into the next reporting period.

In 2019 no cooperating fisherman could be located for the lower Eastern Shore area. Seafood dealer sampling was conducted on June 14, 2019 at a lower Eastern Shore dealer and on June 28, 2019 at a regional dealer that collects fish from several fisherman from various locations. The Eastern Shore dealer fish were from pound netters operating in the Hooper's Island area, while gear type and area were not available from the regional dealer, but all measured fish were harvested in Maryland Chesapeake Bay waters. At the eastern shore dealer, lengths and weights were taken from 51 Atlantic Menhaden, four bluefish, ten Spanish mackerel, eight spot, 78 striped bass and two white perch. Only spot were encountered at the regional seafood dealer with 115 lengths and weights taken. Dealer sampling continued into the next reporting period.

The Choptank River gill net survey was conducted on four days for a total of 16 sites form June 7, 2019 to June 26, 2019 during the second half of the reporting period. The survey caught one Atlantic croaker, 1,277 Atlantic menhaden, two blue catfish, three channel catfish, seven harvestfish, two hogchokers, one Spanish mackerel, 208 spot, one spotted seatrout, 14 striped bass, two white catfish and 23 white perch. Sampling continued into the next reporting period.

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Table 1. Areas sampled number of sampling trips, mean surface water temperature and mean surface salinity by month for the onboard pound net survey in 2018.

Area	Month	Number of Samples	Mean Water Temp. C	Mean Salinity (ppt)
Point Lookout	May	2	23.6	10.0
Point Lookout	June	2	23.8	10.0
West Bay	June	1	25.5	10.2
Chester River	June	1	24.2	4.7
Point Lookout	July	4	26.0	10.4
Point Lookout	August	3	27.3	8.5
Chester River	August	1	25.4	3.8
Point Lookout	September	4	28.2	8.8
Chester River	October	1	23.3	4.7
Sassafrass River	November	1	6.9	0.1

Table 2. List of non-target species observed during the 2018 onboard pound net survey.

Common Name	Scientific Name
Atlantic spadefish	*Chaetodipterus faber*
Black sea bass	*Centropristis striata*
Blue catfish	*Ictalurus furcatus*
Butterfish	*Peprilus triacanthus*
Channel catfish	*Ictalurus punctatus*
Cobia	*Rachycentron canadum*
Cownose ray	*Rhinoptera bonasus*
Florida pompano	*Trachinotus carolinus*
Gizzard shad	*Dorosoma cepedianum*
Harvestfish	*Peprilus alepidotus*
Hogchoker	*Trinectes maculates*
Ladyfish	*Bodianus rufus*
Northern kingfish	*Menticirrhus saxatilis*
Northern puffer	*Sphoeroides maculatus*
Northern searobin	*Prionotus carolinus*
Silver perch	*Bairdiella chrysoura*
Striped bass	*Morone saxatilis*
Striped burrfish	*Chilomycterus schoepfi*
White catfish	*Ameiurus catus*
White perch	*Morone americana*

Table 3. Total catch by species in numbers from the Choptank River gill net survey, 2013 – 2018.

Common Name	2013	2014	2015	2016	2017	2018
Atlantic Croaker	476	269	21	32	53	8
Atlantic Menhaden	1,584	2,247	1,782	1,171	1,292	2,257
Black Drum	0	0	0	1	0	0
Blue Crab	34	44	165	127	107	107
Bluefish	11	22	7	3	3	11
Butterfish	0	2	2	0	0	1
Gizzard Shad	180	231	188	36	28	12
Harvestfish	0	0	0	2	2	13
Hickory Shad	0	0	0	0	1	3
Hogchoker	3	39	6	6	14	5
Northern Kingfish	1	9	0	1	1	0
Spanish Mackerel	0	0	0	1	0	6
Spot	272	749	222	109	298	154
Striped Bass	16	33	14	50	76	103
Summer Flounder	2	0	0	2	5	4
Weakfish	0	0	1	3	1	3
White Perch	18	41	55	64	67	8
Total Catch	2,597	3,686	2,463	1,608	1,948	2,695

Table 4. Mean length (millimeter TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993-2018.

	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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Spotted Seatrout																										
mean length		448	452			541	460								414	464	262		361	436	456	499	487	625	464	
std. dev.		86	42				134								43	72	22		142	112	29	70			51	
n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3	10	23	0	4	8	5	4	1	1	3	0
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
std. dev.		175	454	20		182				190	20	212		228	95	238	84	345	188		236	150	171	429		350
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5	13	3	3	1	4	14	4	4	0	3

Table 4. 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
Red Drum																										
mean length						302	332	648		316	506	647	353	366	658	361			678	318	469	954		340	549	1,191
std. dev.							71			44		468		21	40	57			18	71	39			10	105	162
n	0	0	0	0	0	1	16	1	0	177	1	2	1	16	2	21	0	0	2	458	16	1		3	19	4
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
std. dev.			34	62				34	34	81	63	95	33	35	51	59	53			74	36		41	16	54	144
n			44	27	1	1		49	19	20	11	8	373	445	158	18	7	0	0	107	331	1	3	10	9	9
Menhaden (Fork Length)																										
mean length												262	282	238	243	246	245	232	213	243	251	223	219	208	217	231
std. dev.												28	36	42	41	29	40	36	39	25	31	38	28	42	24	24
n												213	1,052	826	854	826	366	836	773	755	762	775	864	732	723	668

Table 5. Mean length (millimeter TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay seafood dealer sampling in 2017- 2018.

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

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 2003-2018.

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

Table 7. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999–2018.

		Growh parameters From MD only	Growh parameters From ASMFC SA
Year	Weakfish	Atlantic Croaker	Atlantic Croaker
1999	0.74	0.31	0.34
2000	0.4	0.34	0.36
2001	0.62	0.26	0.28
2002	0.58	0.27	0.27
2003	0.73	0.37	0.40
2004	1.29	0.29	0.32
2005	1.44	0.25	0.27
2006	*	0.21	0.24
2007	*	0.24	0.31
2008	*	0.25	0.29
2009	*	0.40	0.38
2010	*	0.56	0.47
2011	*	0.69	0.55
2012	*	0.69	0.89
2013	1.55	0.76	0.83
2014	*	1.45	1.02
2015	*	1.27	0.87
2016	*	1.64	1.11
2017	*	1.45	1.00
2018	*	0.71	0.60

* Insufficient sample size to calculate 2006 – 2012, 2014 - 2018 weakfish estimates.

Table 8. 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, 1999-2018.

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

Table 9. 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, 2007-2018.

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

Table 10. Atlantic menhaden percentage at age, number of age samples and number of length samples by year using, pound net length and age data, 2005-2018.

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

Table 11. 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, 2015-2018.

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

Figure 1. Onboard pound net survey and fish house sampling site locations for 2018.

Figure 2. The Choptank River gill net survey sampling site locations for 2018.

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

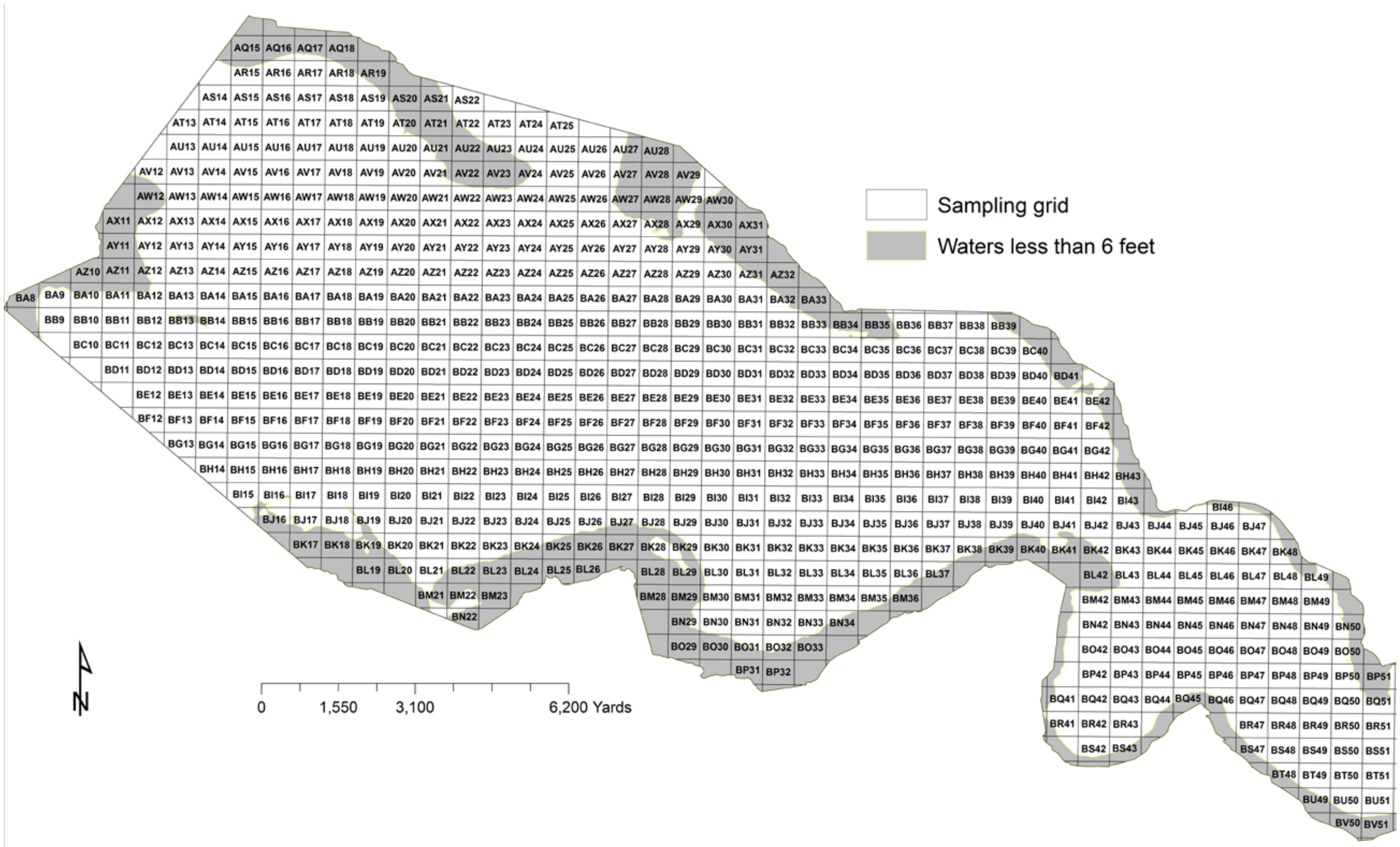


Figure 4. Weakfish length frequency distributions from onboard pound net sampling, 2009-2018. Note: 2011 210 millimeter length group was truncated to preserve scale, actual value is 50% and 2018 270 millimeter length group was truncated to preserve scale, actual value is 44%.

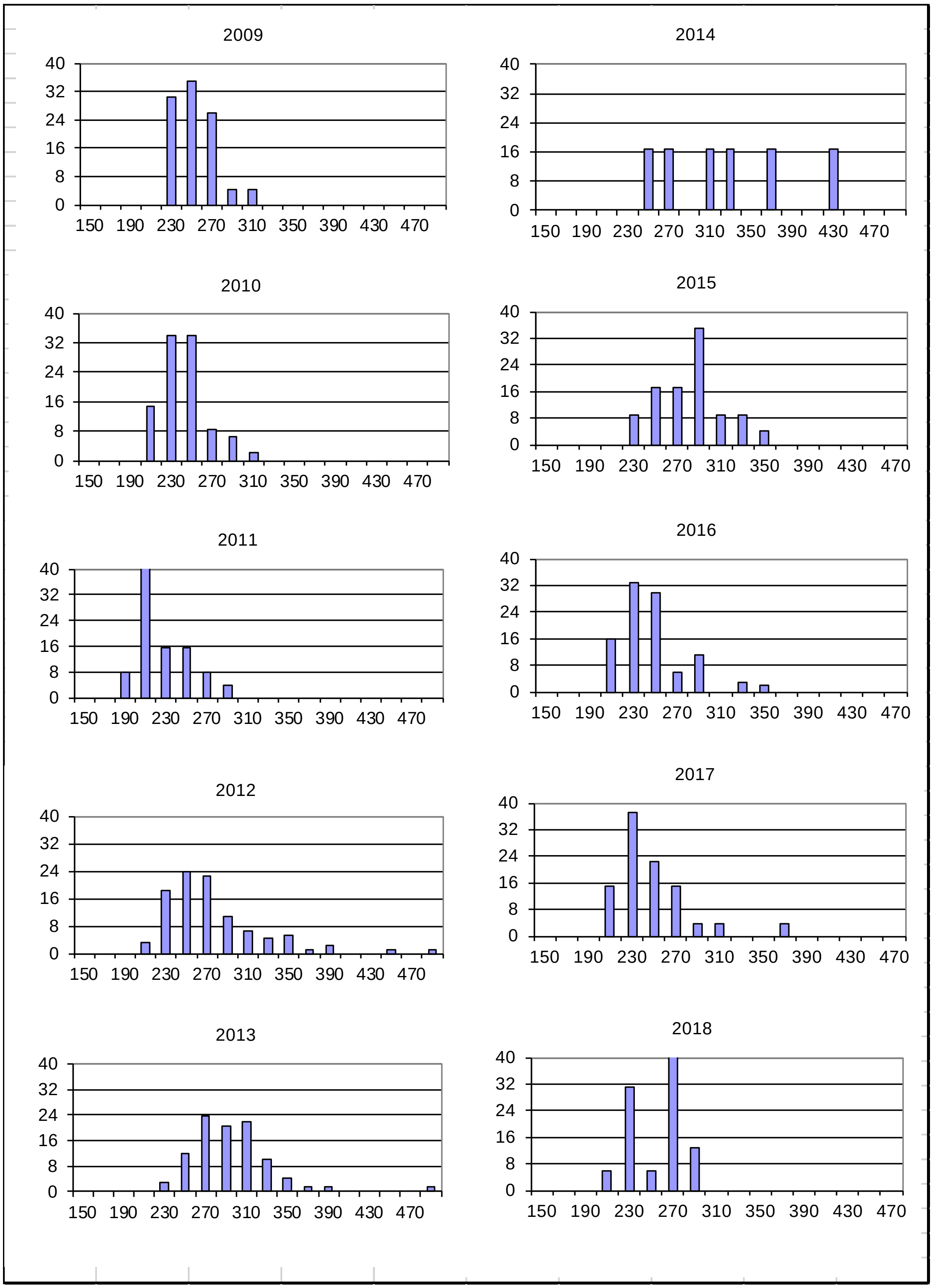


Figure 5. Maryland's commercial landings of weakfish in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational weakfish harvest and release estimates in numbers from 1981-2017.

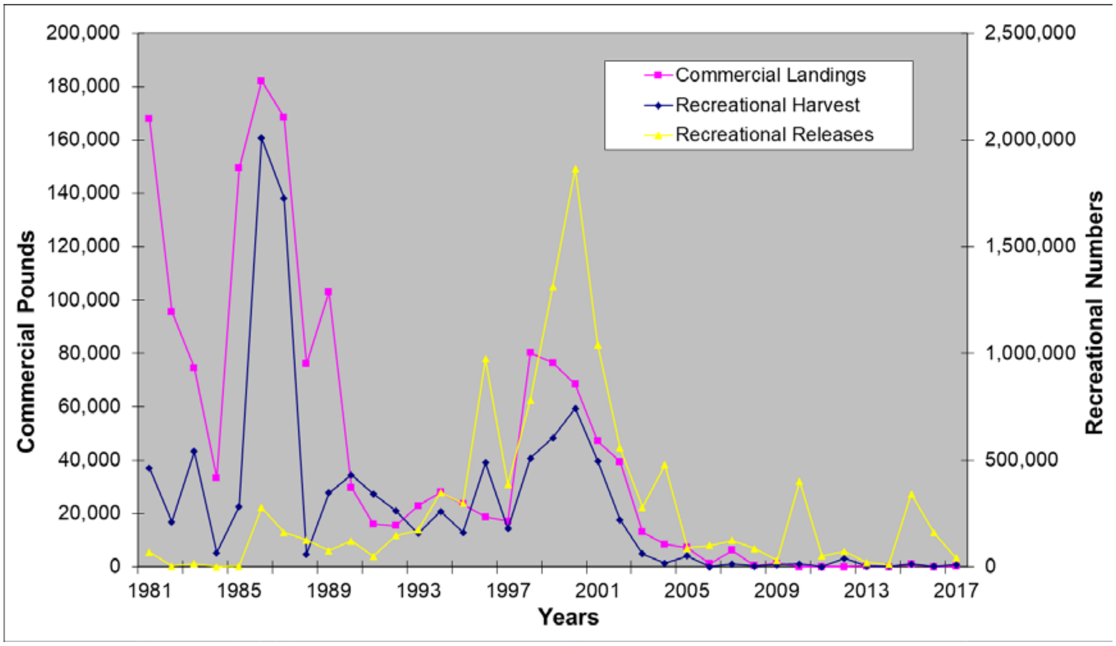


Figure 6. Maryland Charter boat log book weakfish harvest in numbers and the number of anglers participating in trips catching weakfish, 1993-2017.

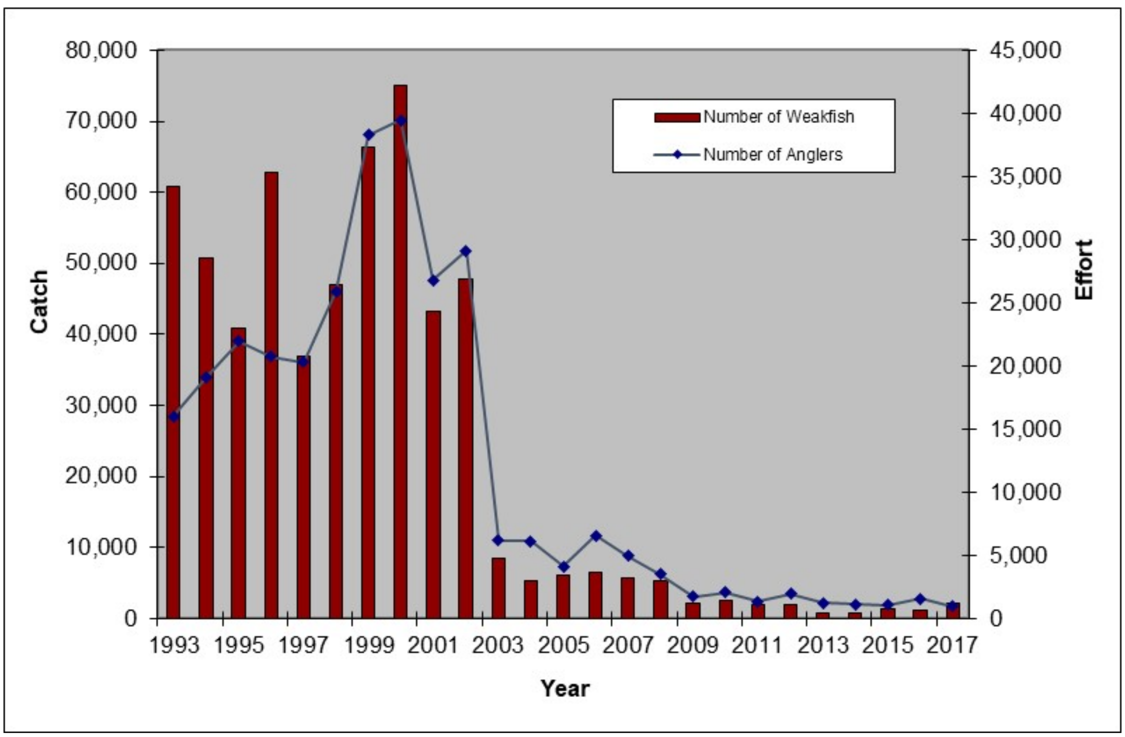


Figure 7. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989-2018.

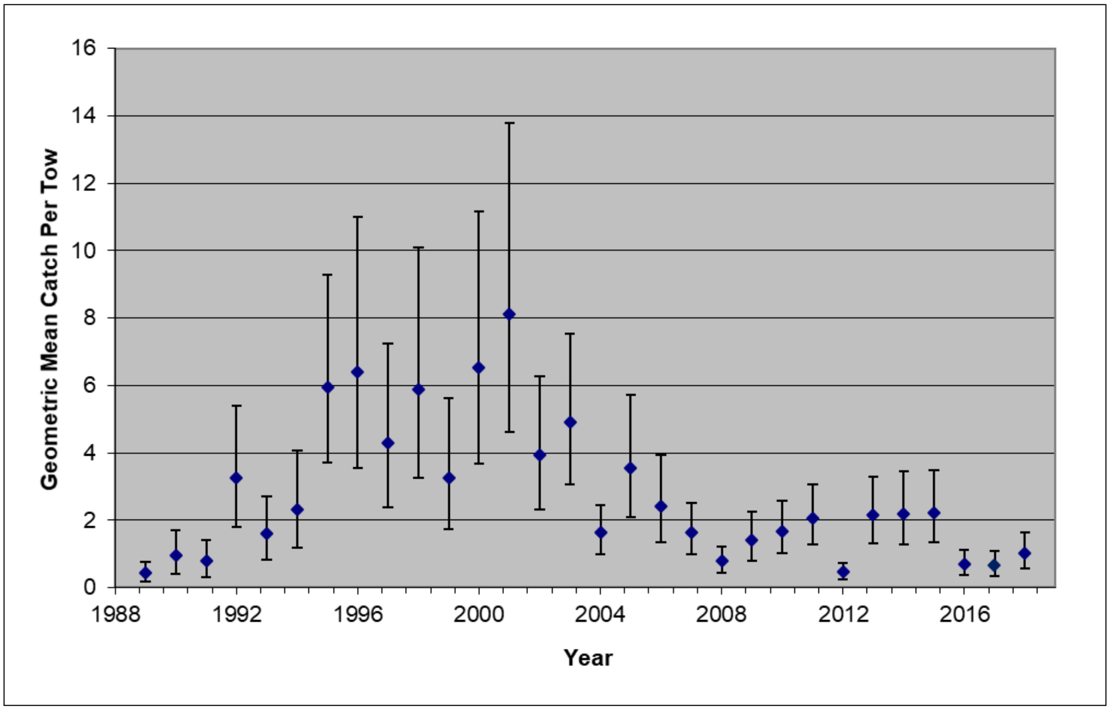


Figure 8. Summer flounder length frequency distributions from onboard pound net sampling, 2009-2018.

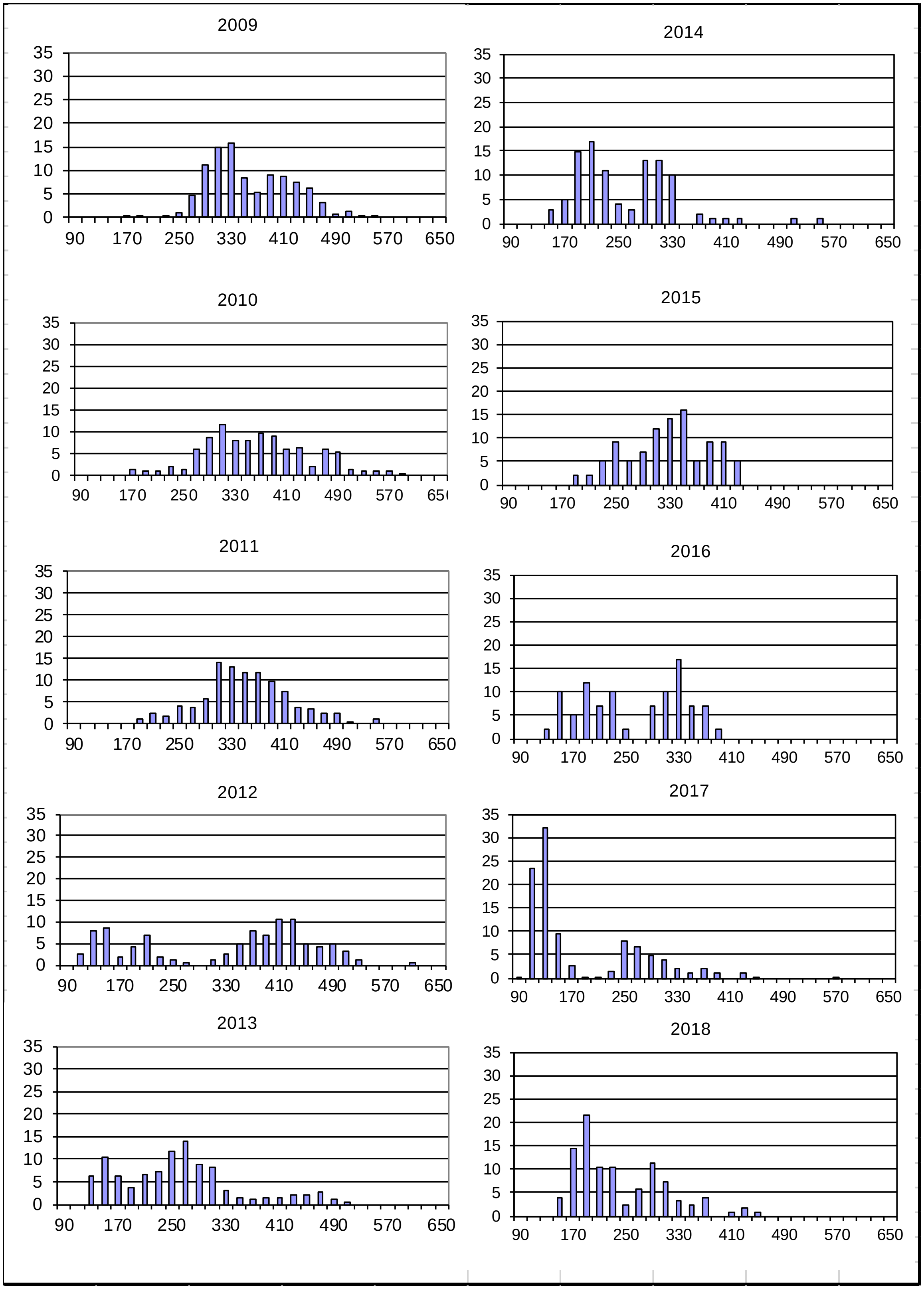


Figure 9. Maryland's commercial landings of summer flounder in pounds from the Chesapeake Bay and the MRIP Maryland summer flounder inland recreational harvest and release estimates in numbers from 1981-2017.

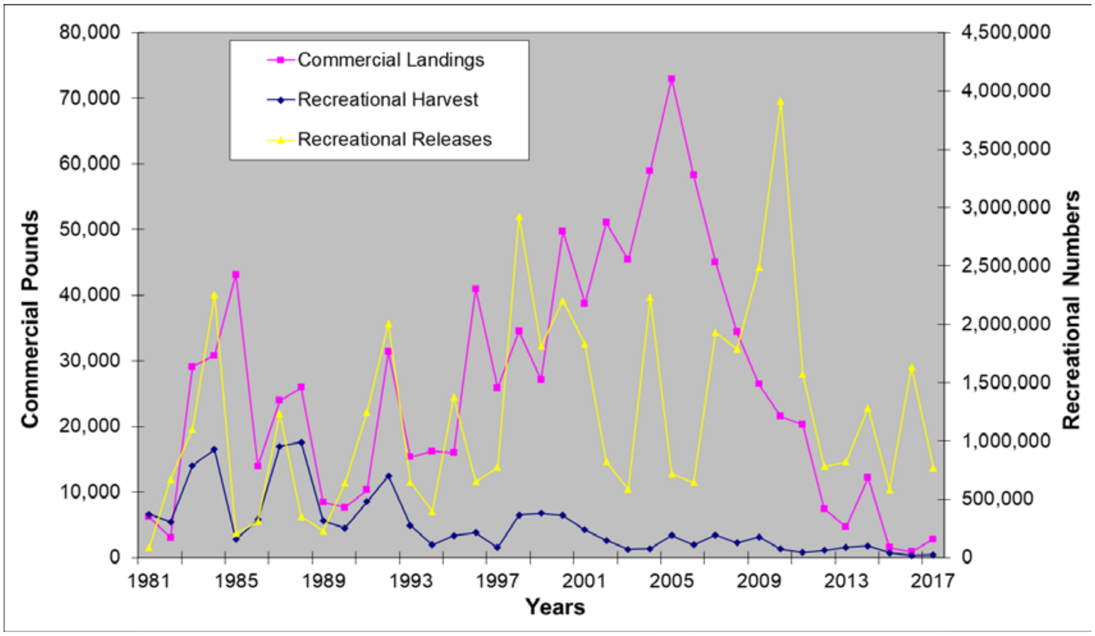


Figure 10. Maryland Charter boat log book summer flounder harvest in numbers and the number of anglers participating in trips catching summer flounder, 1993-2017.

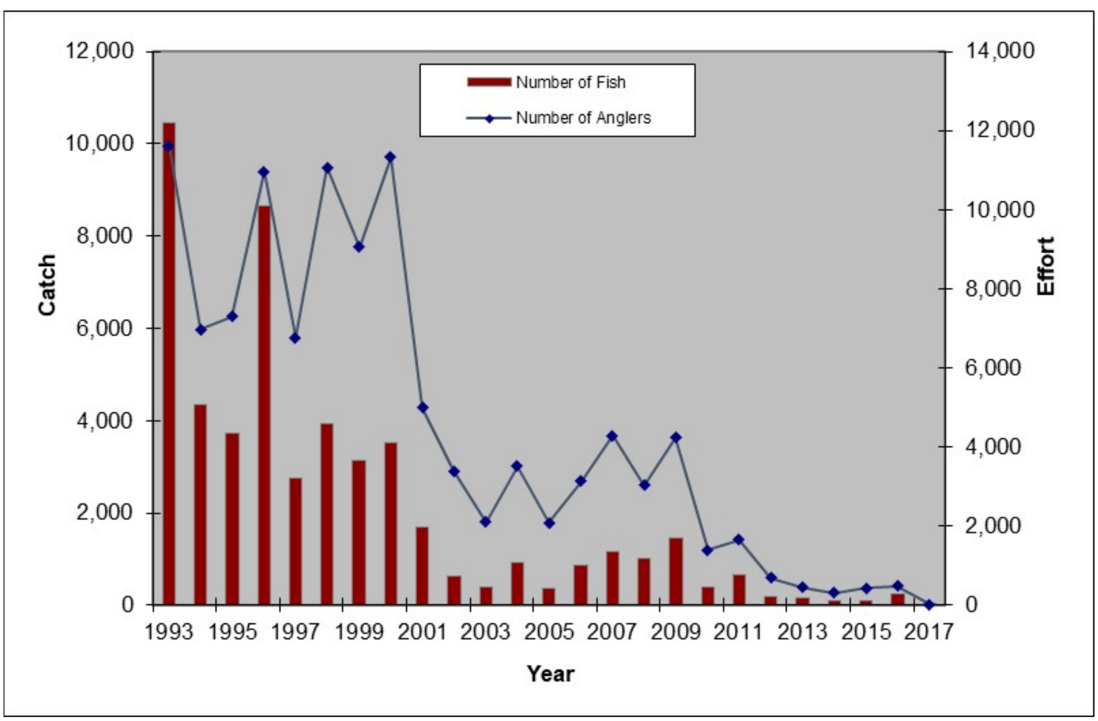


Figure 11. Bluefish length frequency distributions from onboard pound net sampling, 2009-2018.

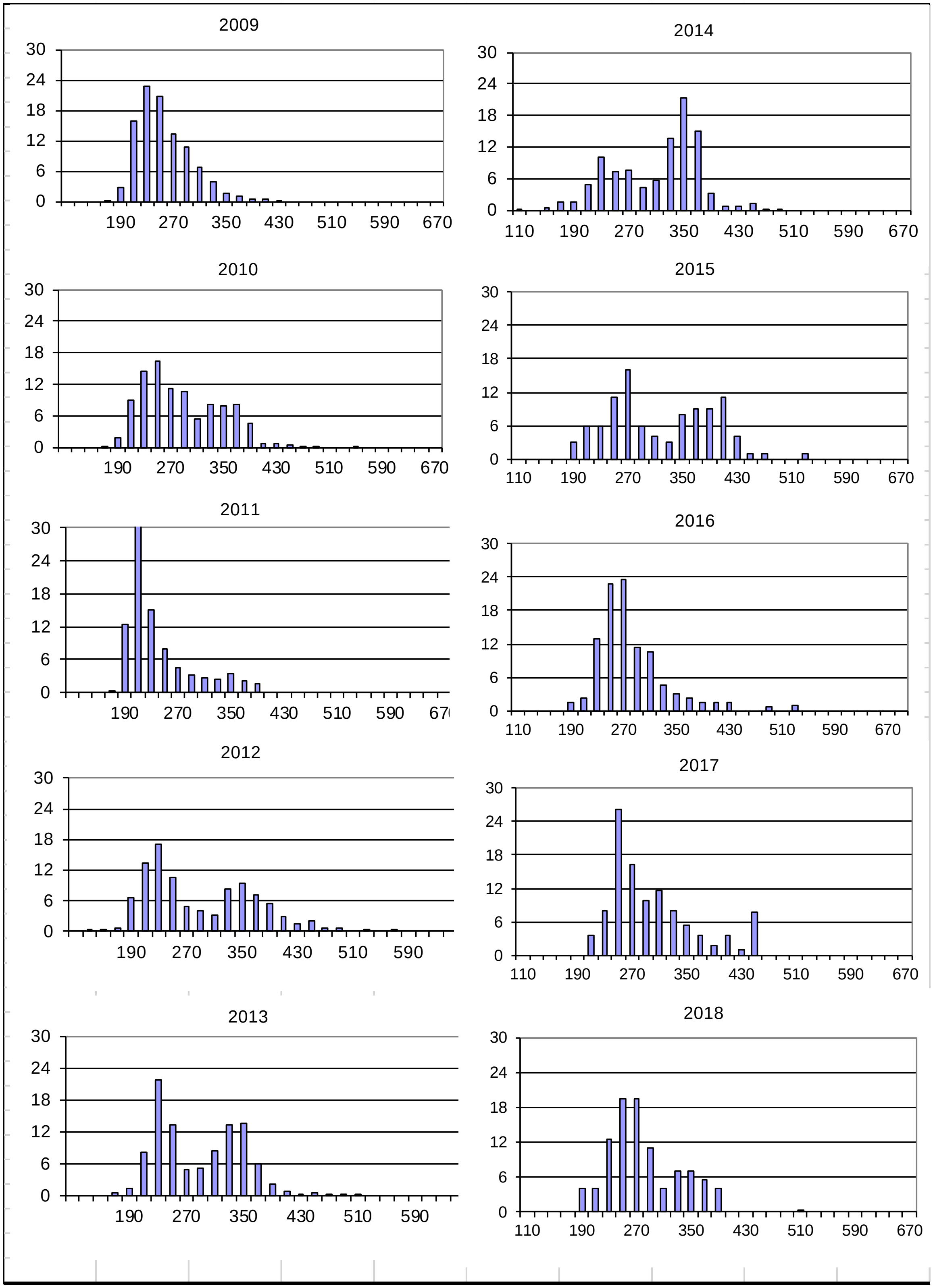


Figure 12. Bluefish length frequency distributions from seafood dealer sampling in 2017 and 2018.

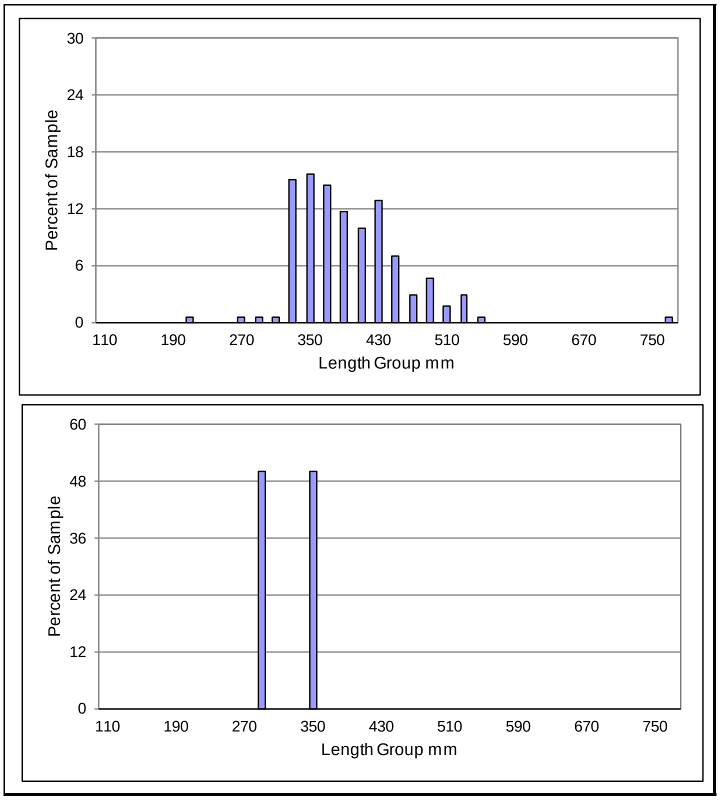


Figure 13. Proportion of bluefish catch by mesh size and year for the Choptank River gill net survey, 2013-2018.

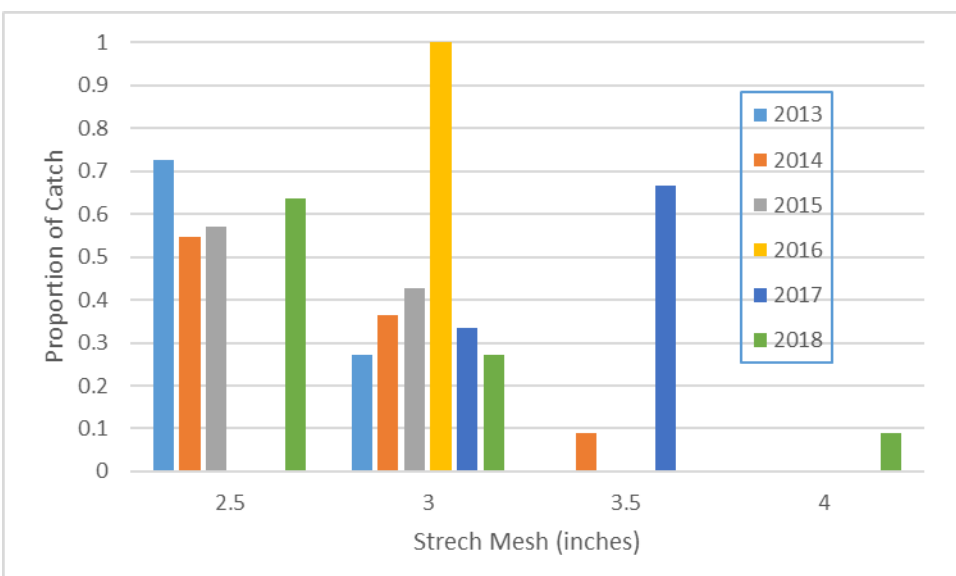


Figure 14. Maryland's commercial landings of bluefish in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational bluefish harvest and release estimates in numbers from 1981-2017.

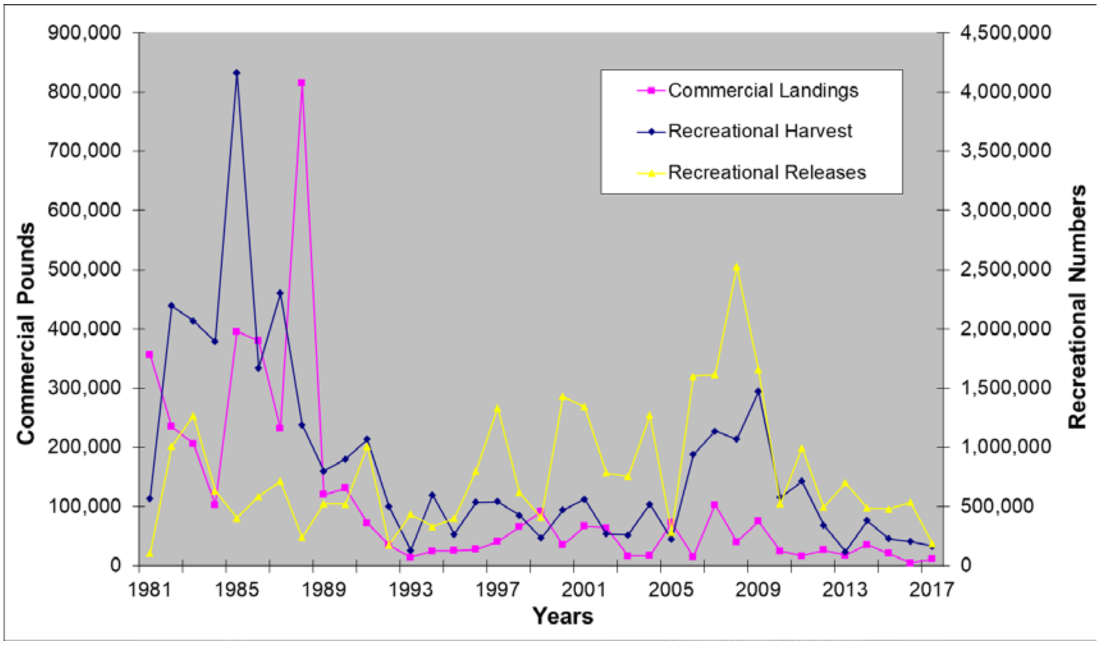


Figure 15. Maryland Charter boat log book bluefish harvest in numbers and the number of anglers participating in trips catching bluefish, 1993-2017.

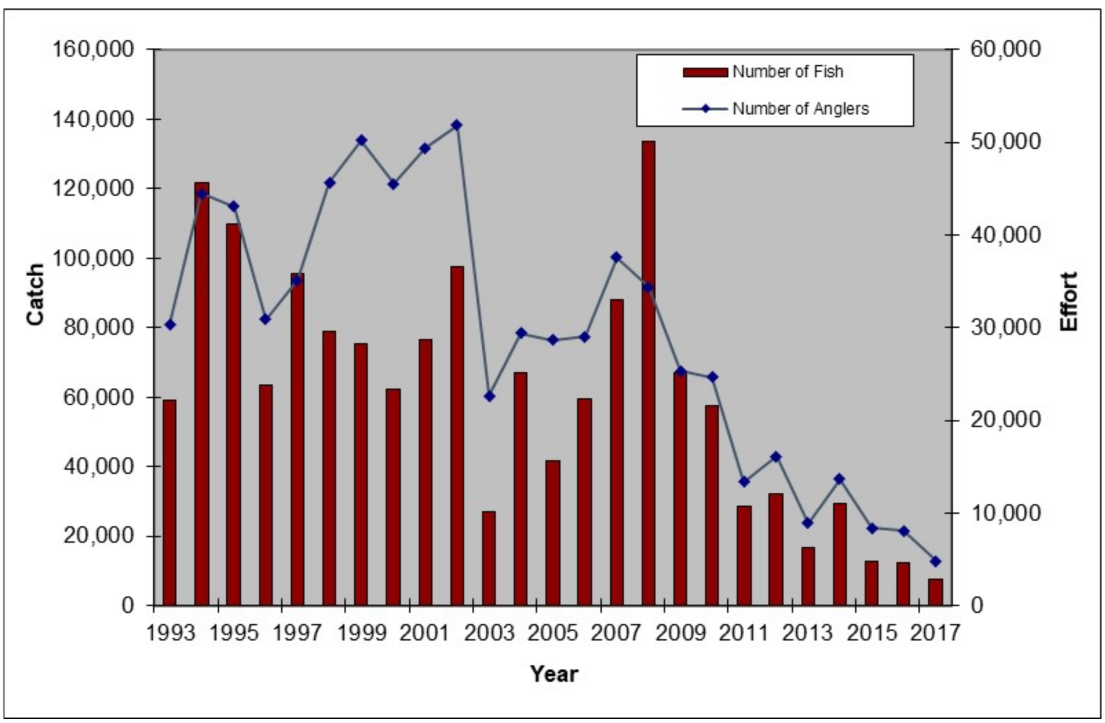


Figure 16. Atlantic croaker length frequency distributions from onboard pound net sampling, 2009-2018.

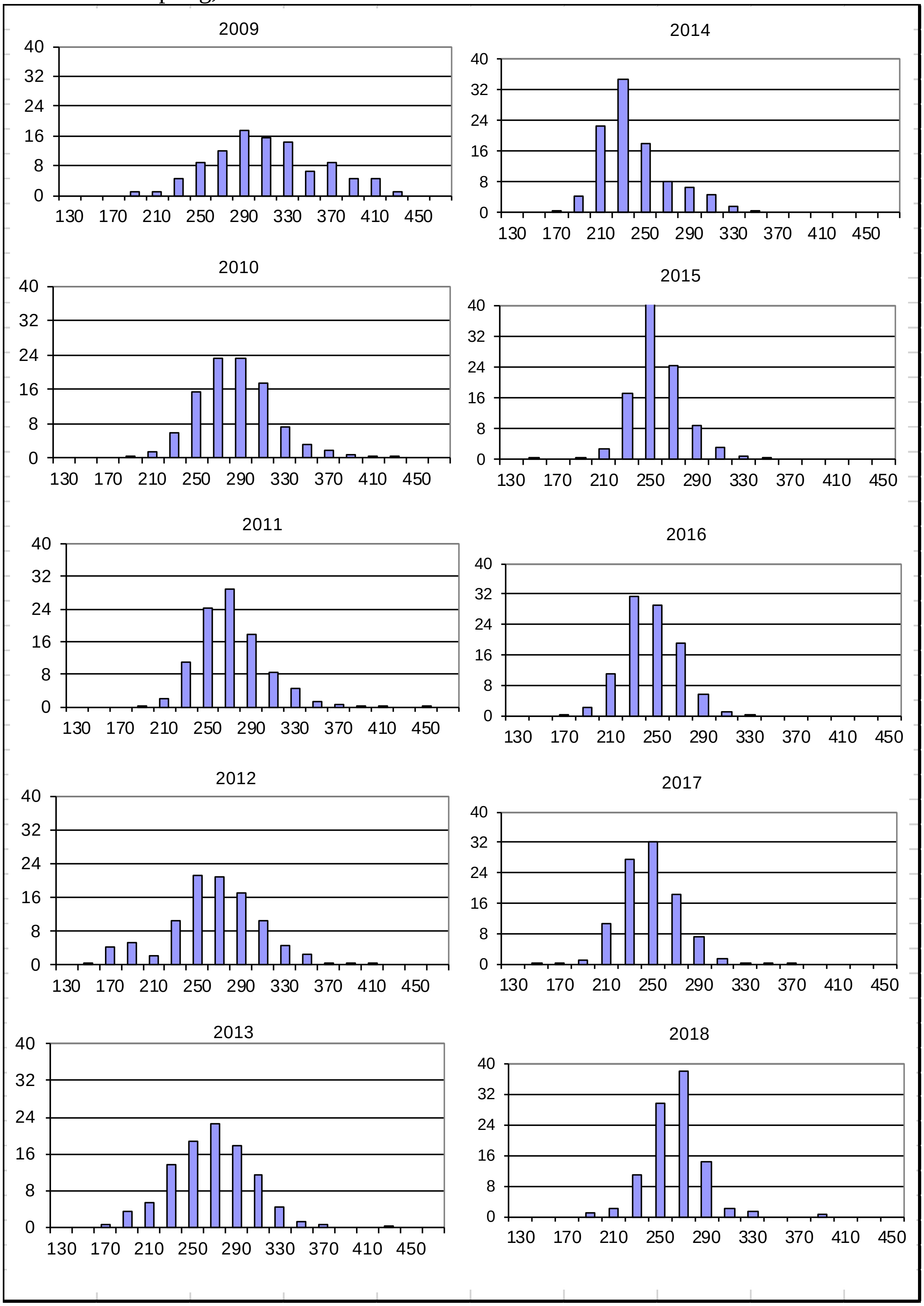


Figure 17. Atlantic croaker length frequency distributions from seafood dealer sampling in 2017 and 2018.

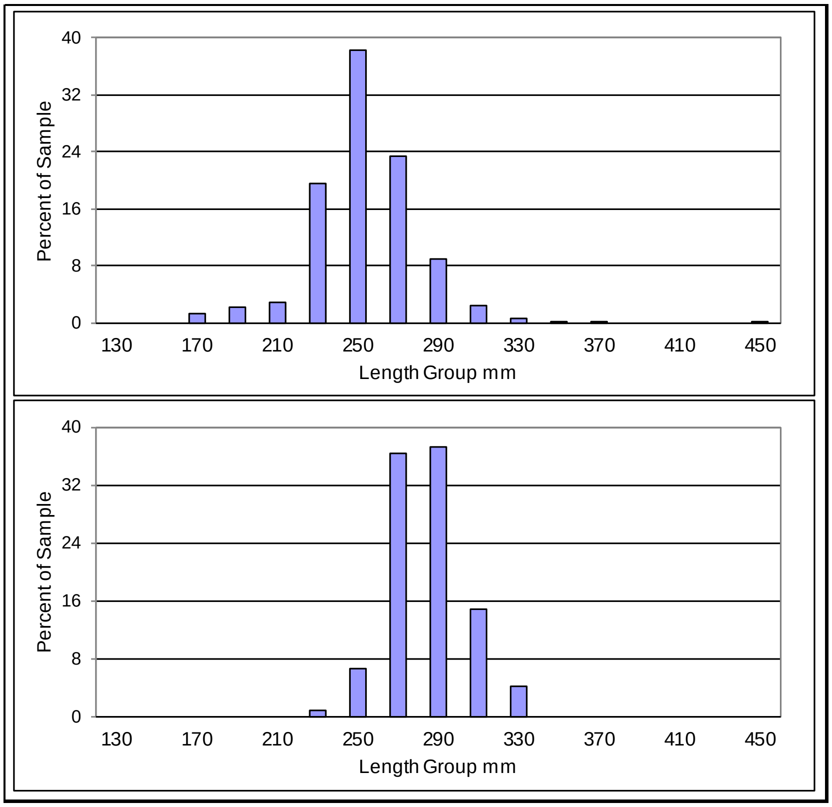


Figure 18. Geometric catch per hour of Atlantic croaker for the Choptank River gill net survey, 2013-2018.

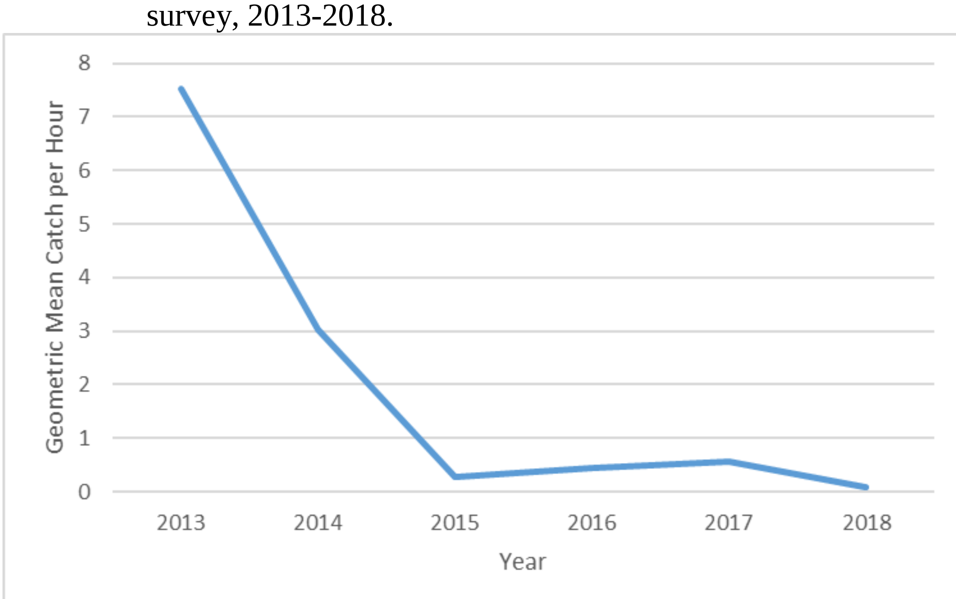


Figure 19. Proportion of Atlantic croaker catch by mesh size and year for the Choptank River gill net survey, 2013-2018.

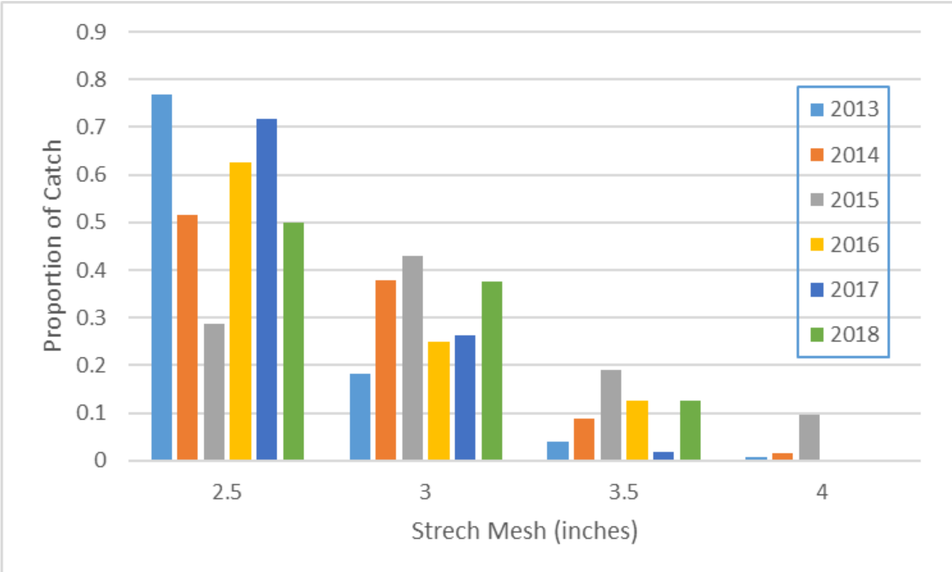


Figure 20. Atlantic croaker length frequency distribution from the Choptank River gill net survey by stretched mesh size in inches, 2013-2018 combined.

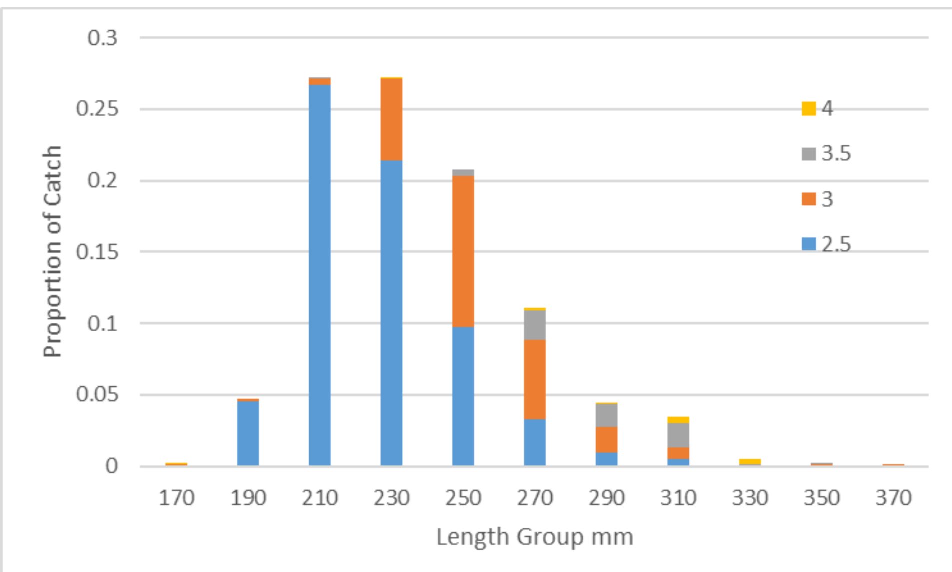


Figure 21. Maryland's commercial landings of Atlantic croaker in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational Atlantic croaker harvest and release estimates in numbers from 1981-2017.

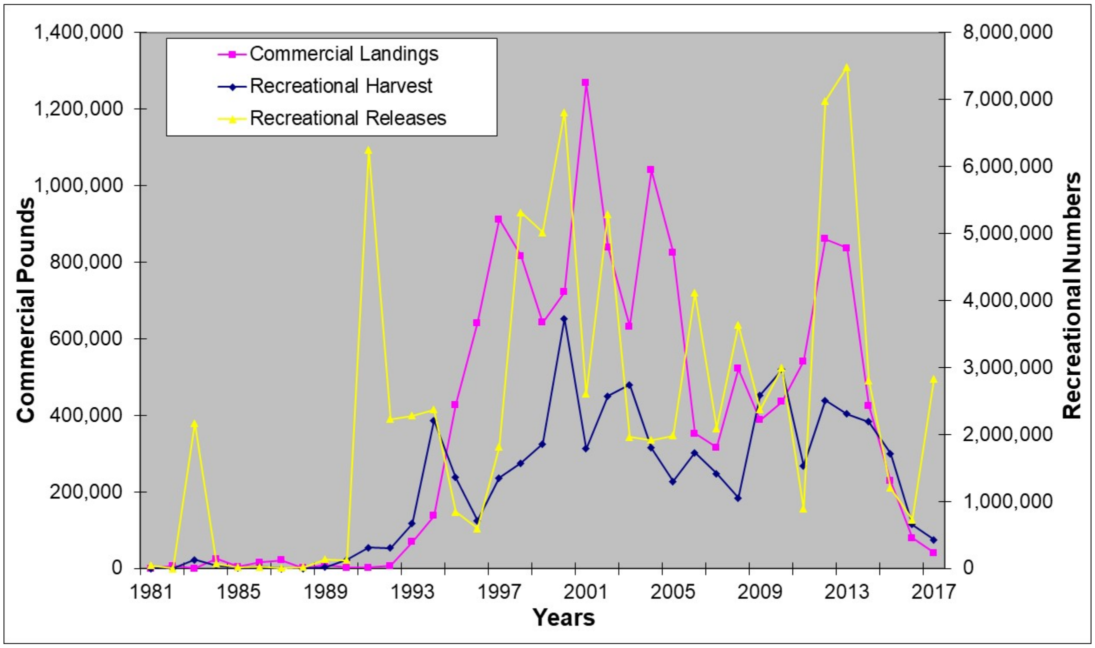


Figure 22. Maryland Charter boat log book Atlantic croaker harvest in numbers and the number of anglers participating in trips catching Atlantic croaker, 1993-2017.

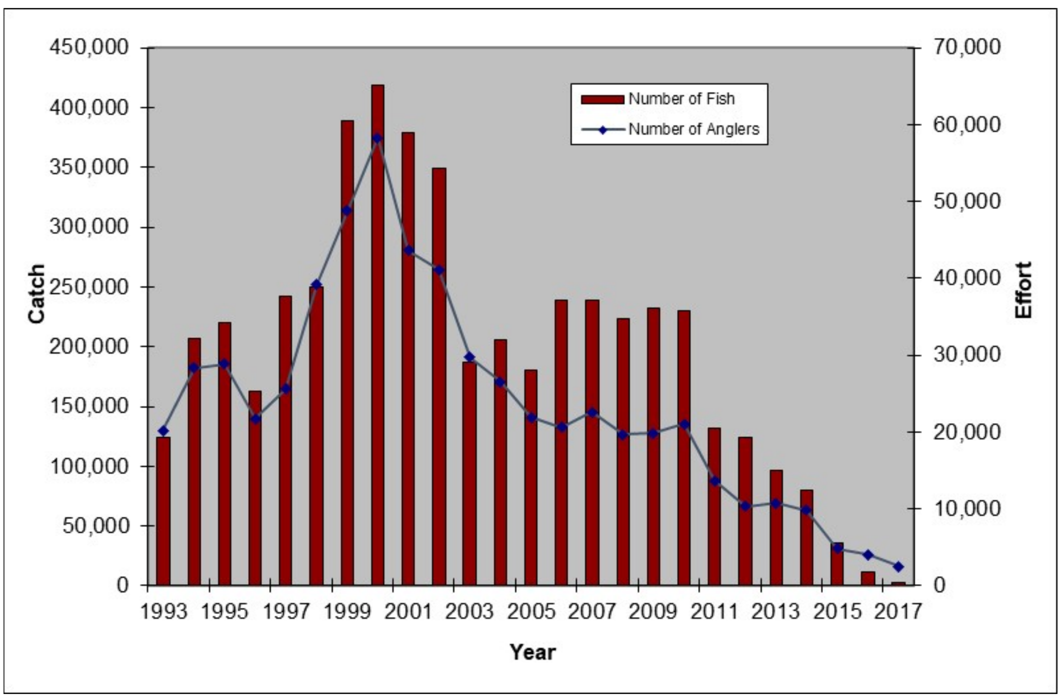


Figure 23. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989-2018. 1998 data point was omitted for scale (GM 1998 = 30.05 -9.02, +12.72).

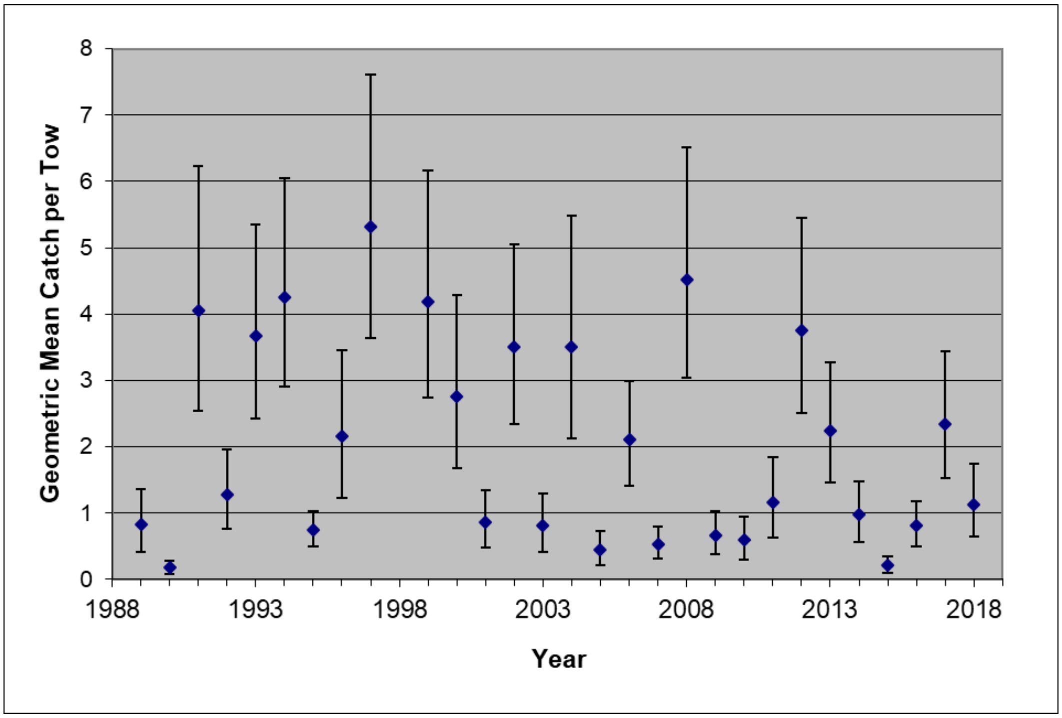


Figure 24. Atlantic croaker total mortality estimates using Maryland age data to derive growth parameters and using the growth parameters from the ASMFC 2017 stock assessment, 1999 - 2018.

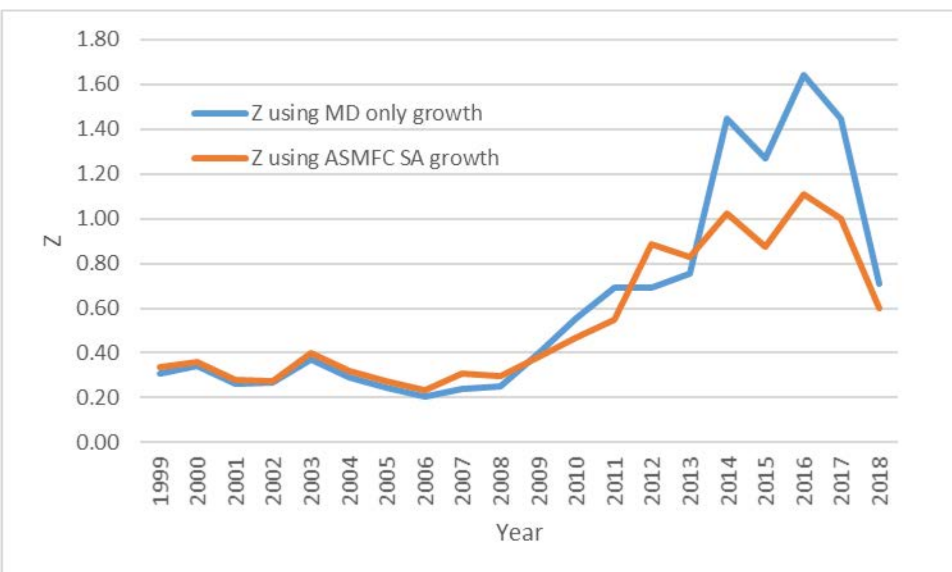


Figure 25. Spot length frequency distributions from onboard pound net sampling, 2009-2018.

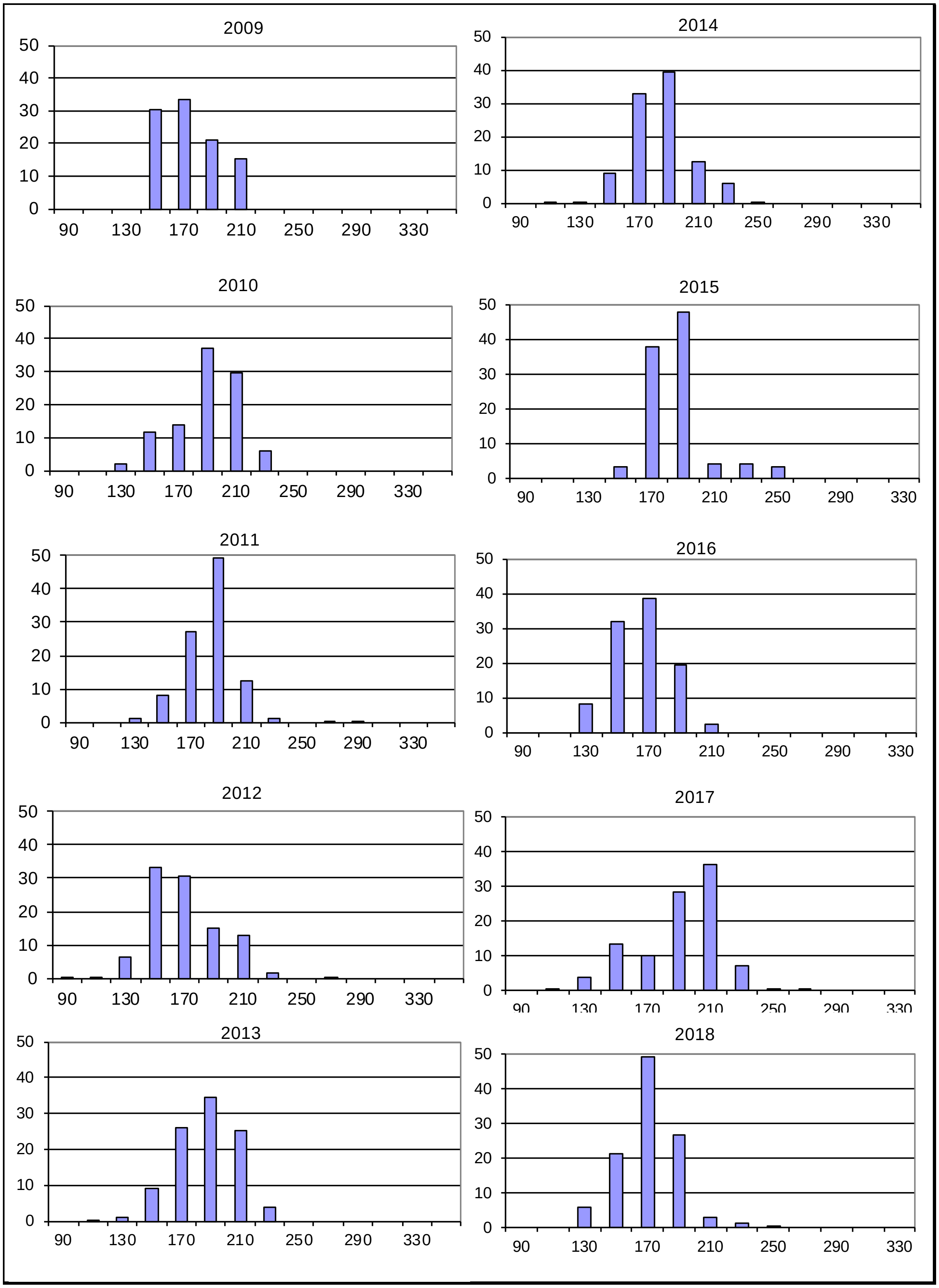


Figure 26. Spot length frequency distributions from seafood dealer sampling in 2017 and 2018.

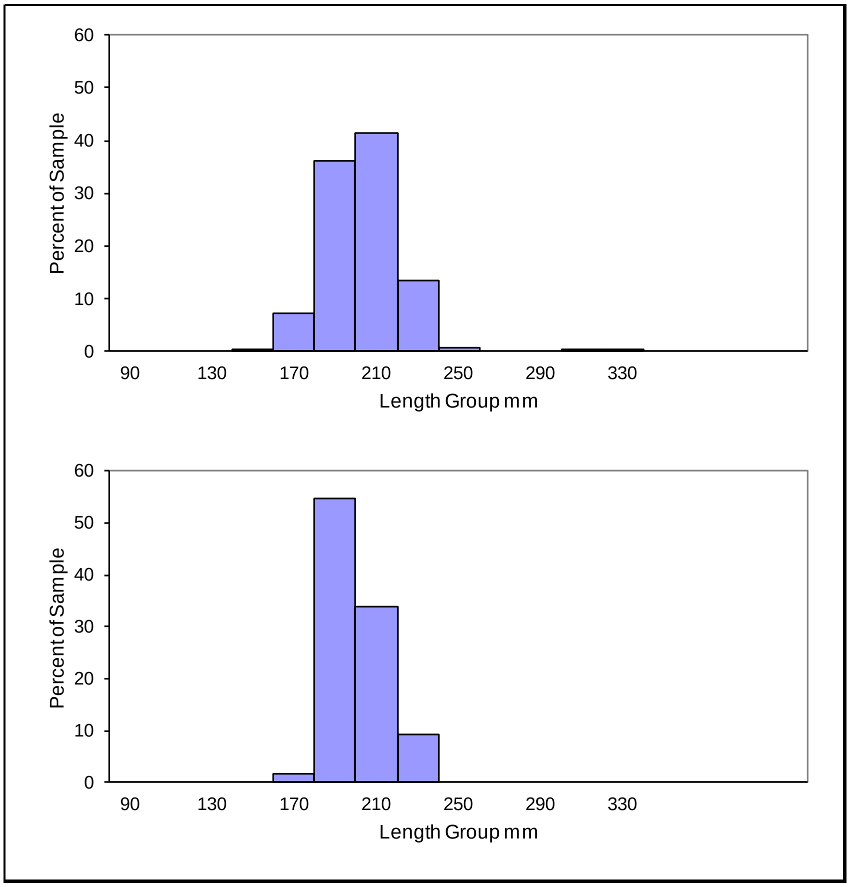


Figure 27. Geometric catch per hour of spot for the Choptank River gill net survey, 2013-2018.

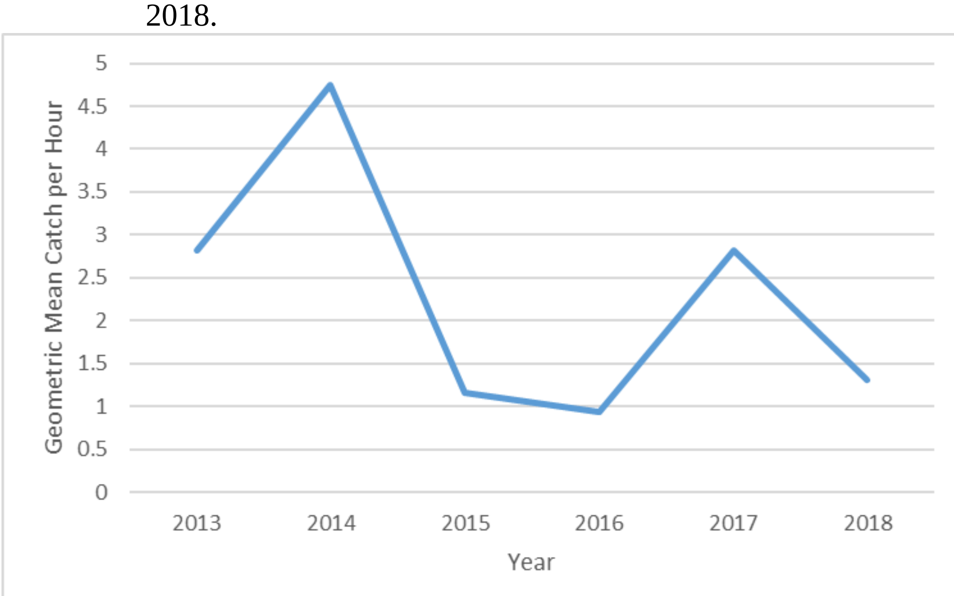


Figure 28. Proportion of spot captured in the Choptank River gill net survey by mesh size and year, 2013-2018.

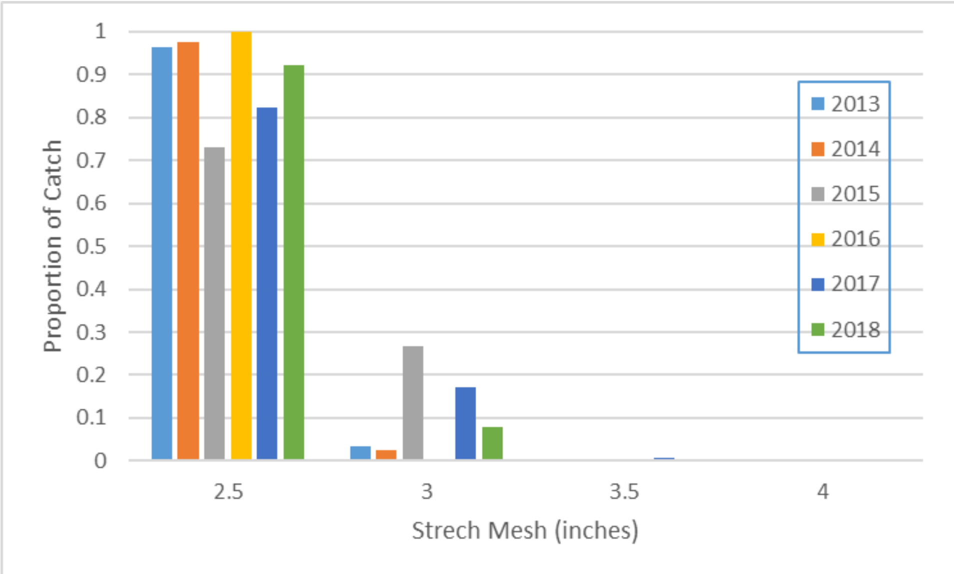


Figure 29. Spot length frequency distributions from the Choptank River gill net survey for 2013-2018.

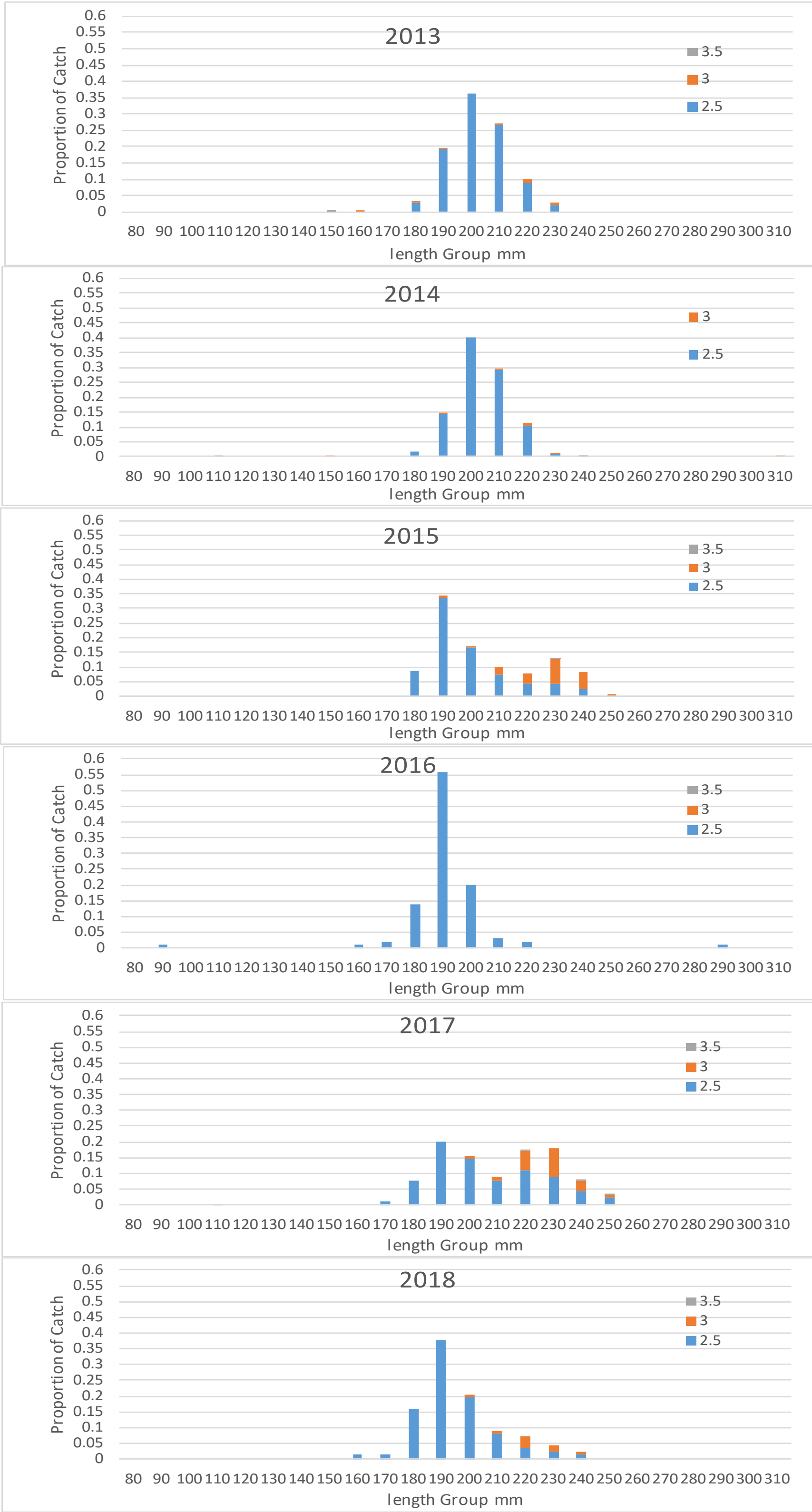


Figure 30. Maryland's commercial landings of spot in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational spot harvest and release estimates in numbers from 1981-2017.

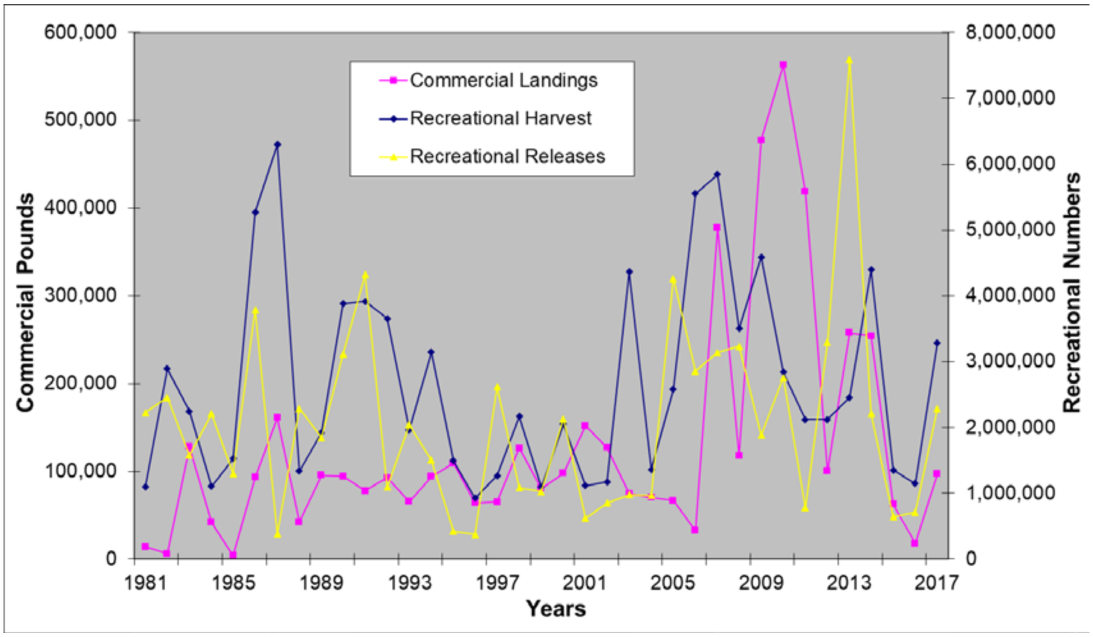


Figure 31. Maryland Charter boat log book spot harvest in numbers and the number of anglers participating in trips catching spot, 1993-2017.

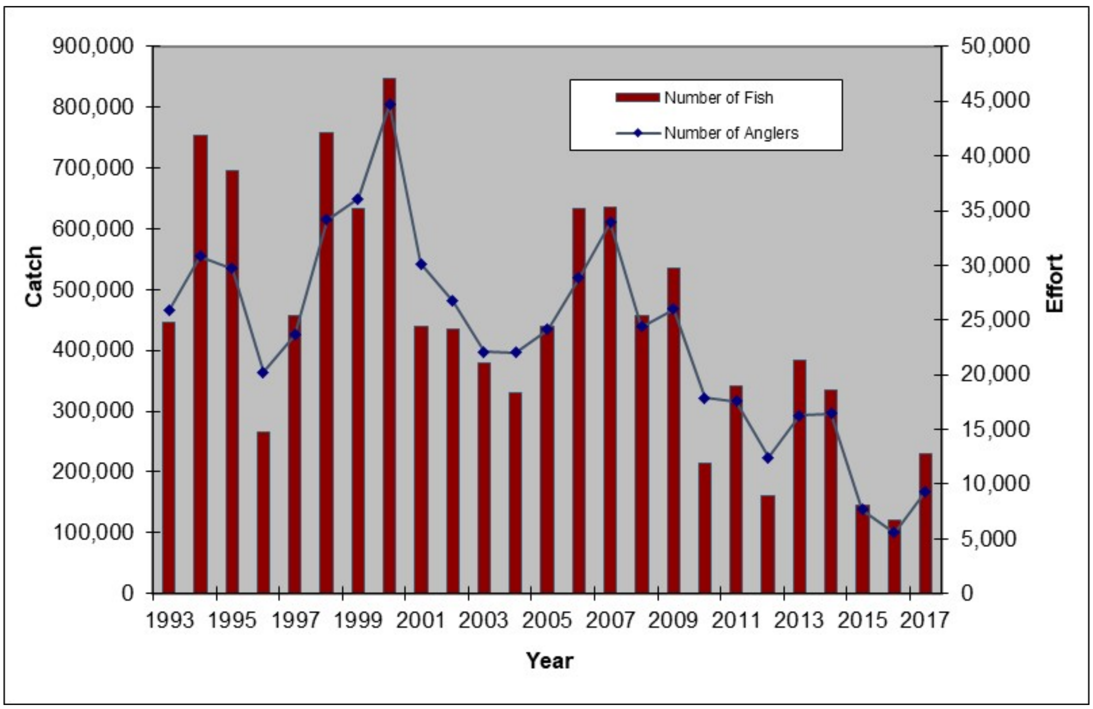


Figure 32. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989-2018.

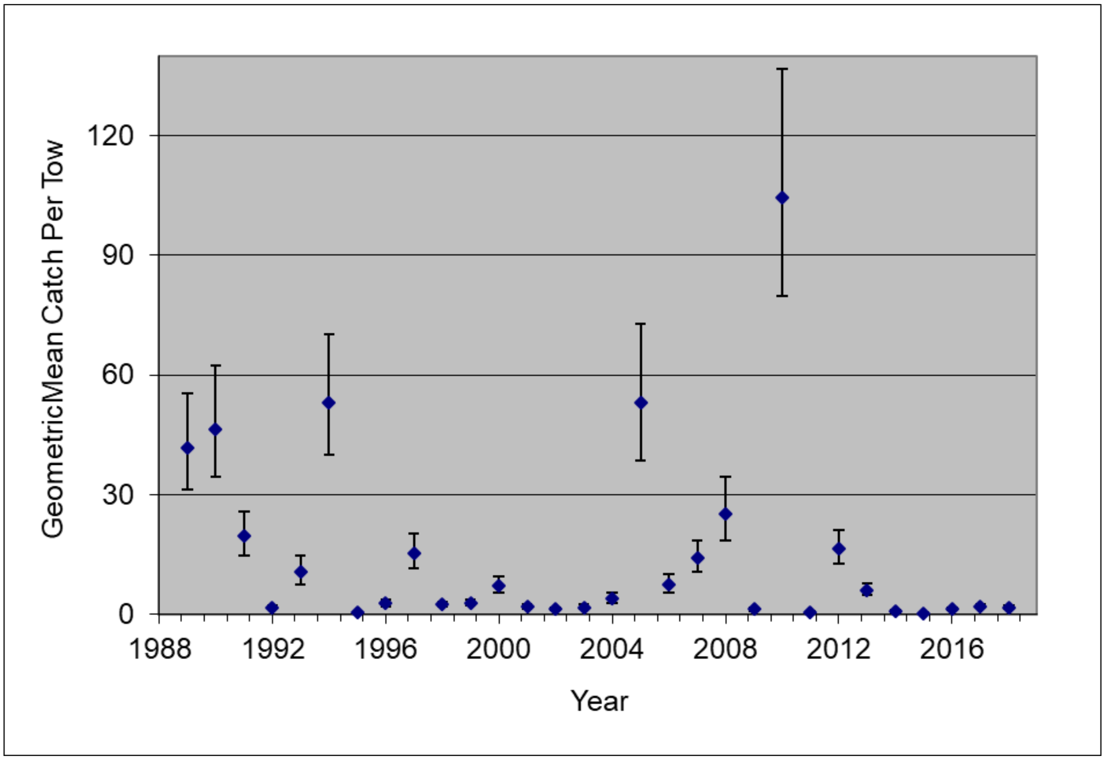


Figure 33. Maryland's commercial landings of red drum in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational red drum harvest and release estimates in numbers from 1981-2017.

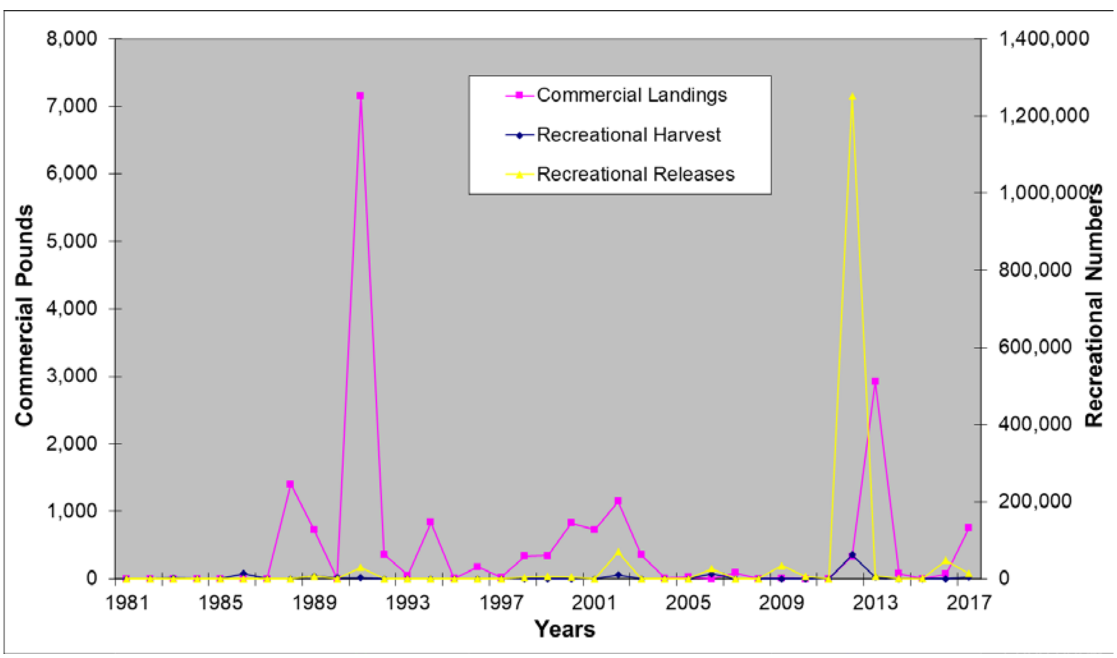


Figure 34. Maryland Charter boat log book red drum harvest in numbers and the number of anglers participating in trips catching red drum, 1993-2017.

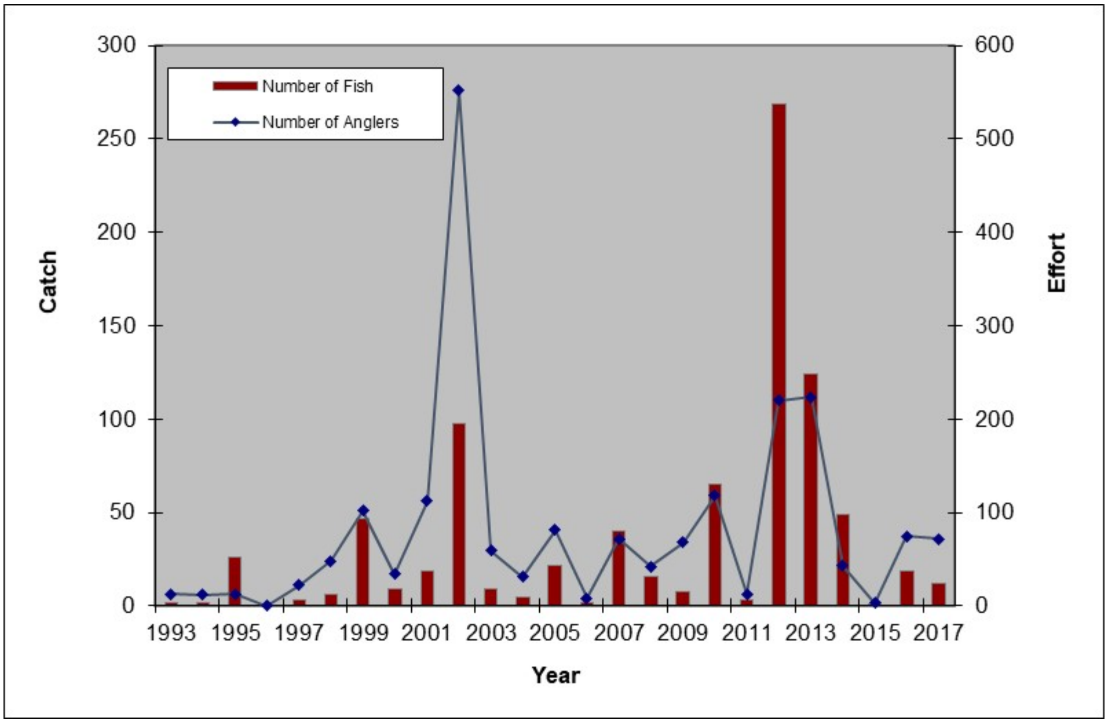


Figure 35. Maryland's commercial landings of black drum in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational black drum harvest and release estimates in numbers from 1981-2017.

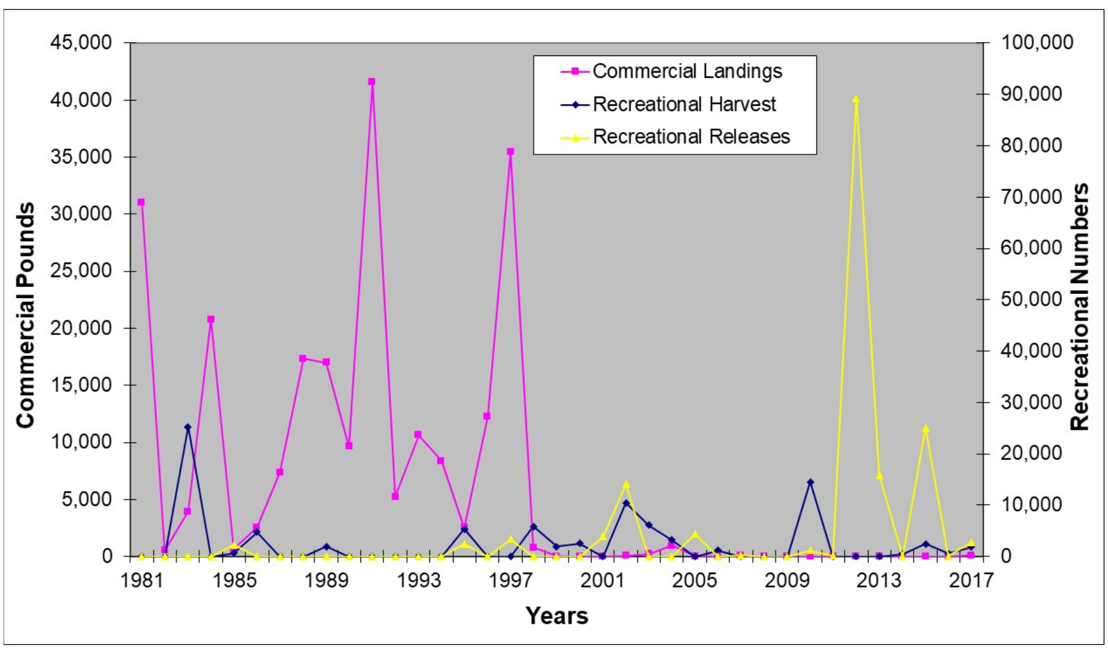


Figure 36. Maryland Charter boat log book black drum harvest in numbers and the number of anglers participating in trips catching black drum, 1993-2017.

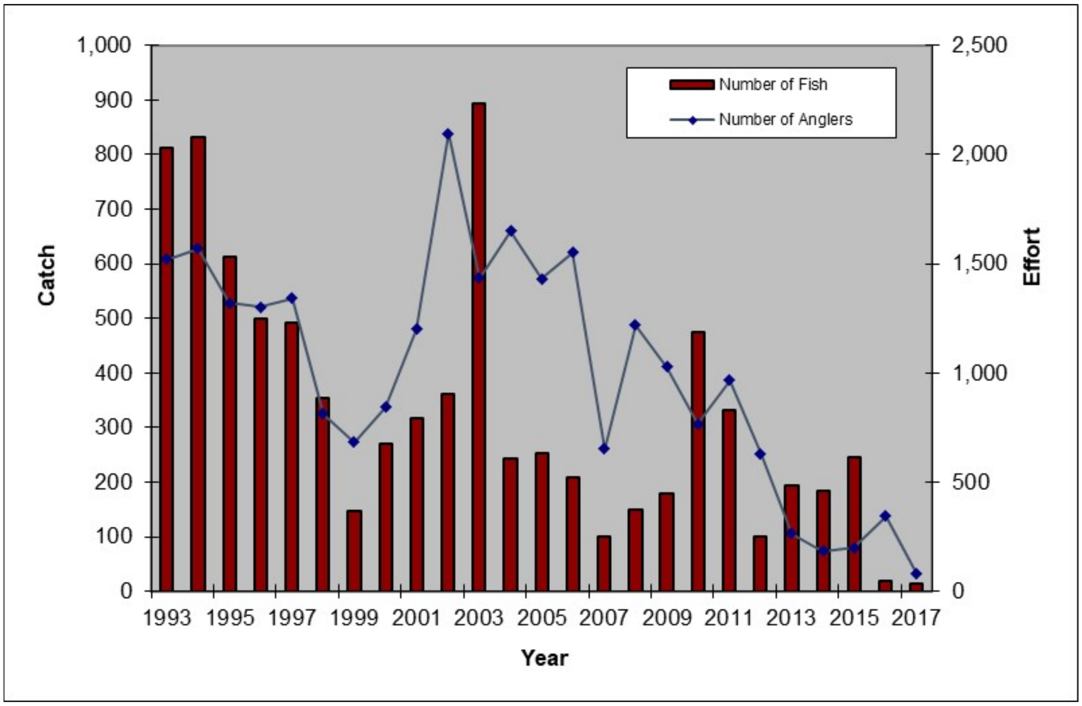


Figure 37. Maryland's commercial landings of Spanish mackerel in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational Spanish mackerel harvest and release estimates in numbers from 1981-2017.

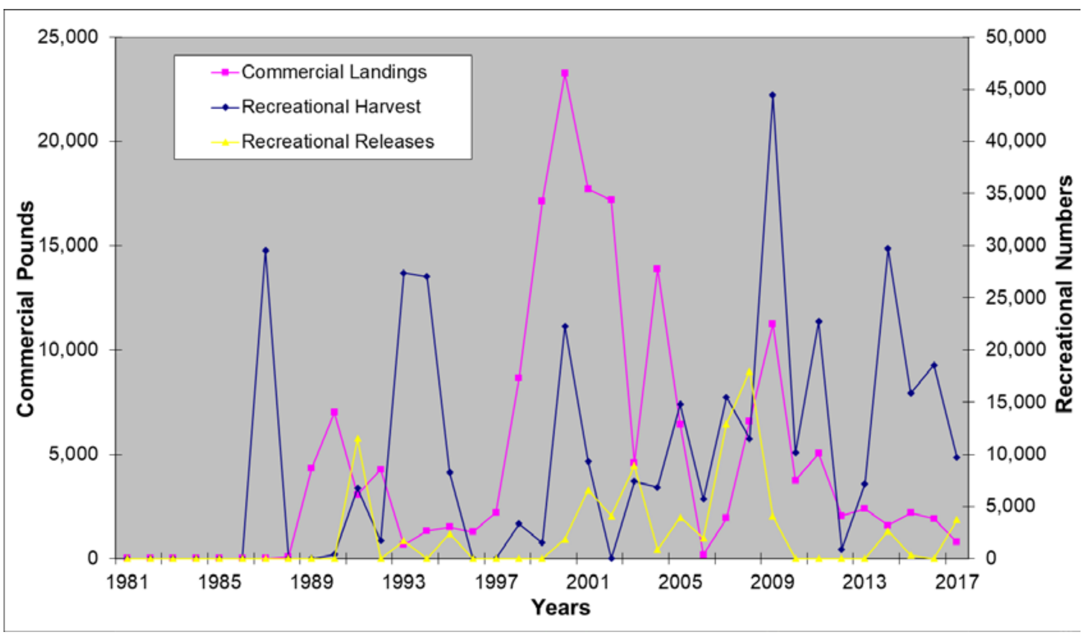


Figure 38. Maryland Charter boat log book Spanish mackerel harvest in numbers and the number of anglers participating in trips catching Spanish mackerel, 1993-2017.

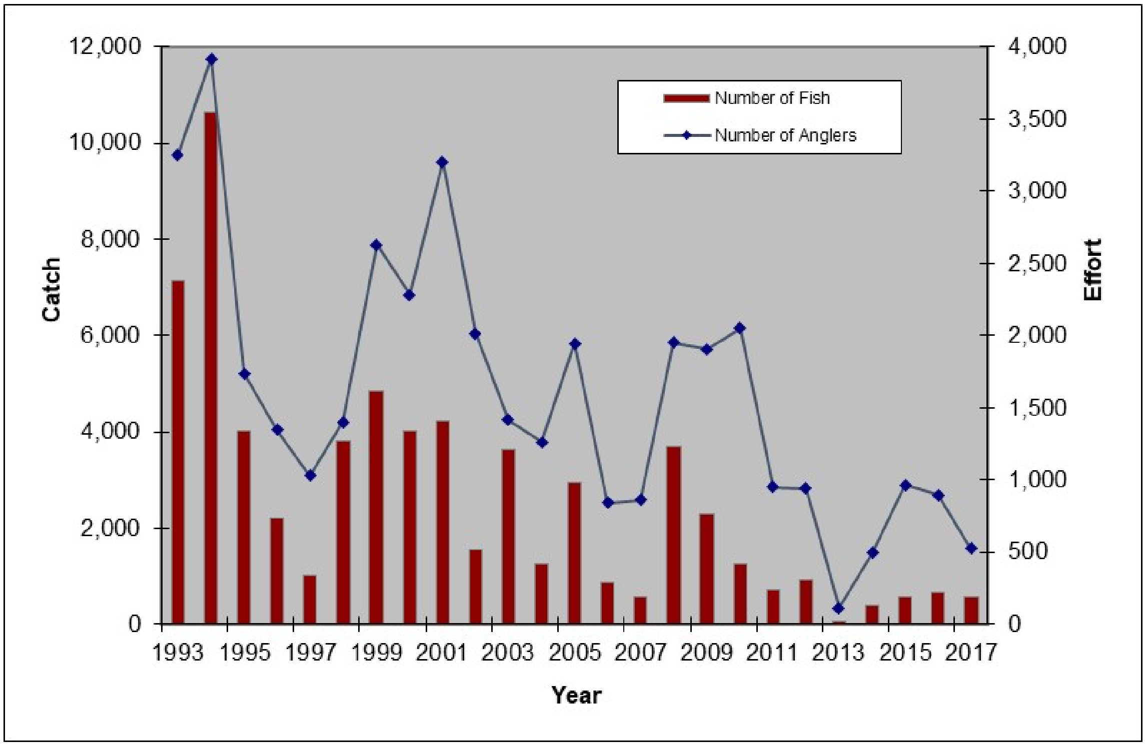


Figure 39. Maryland's commercial landings of spotted seatrout in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational spotted seatrout harvest and release estimates in numbers from 1981-2017.

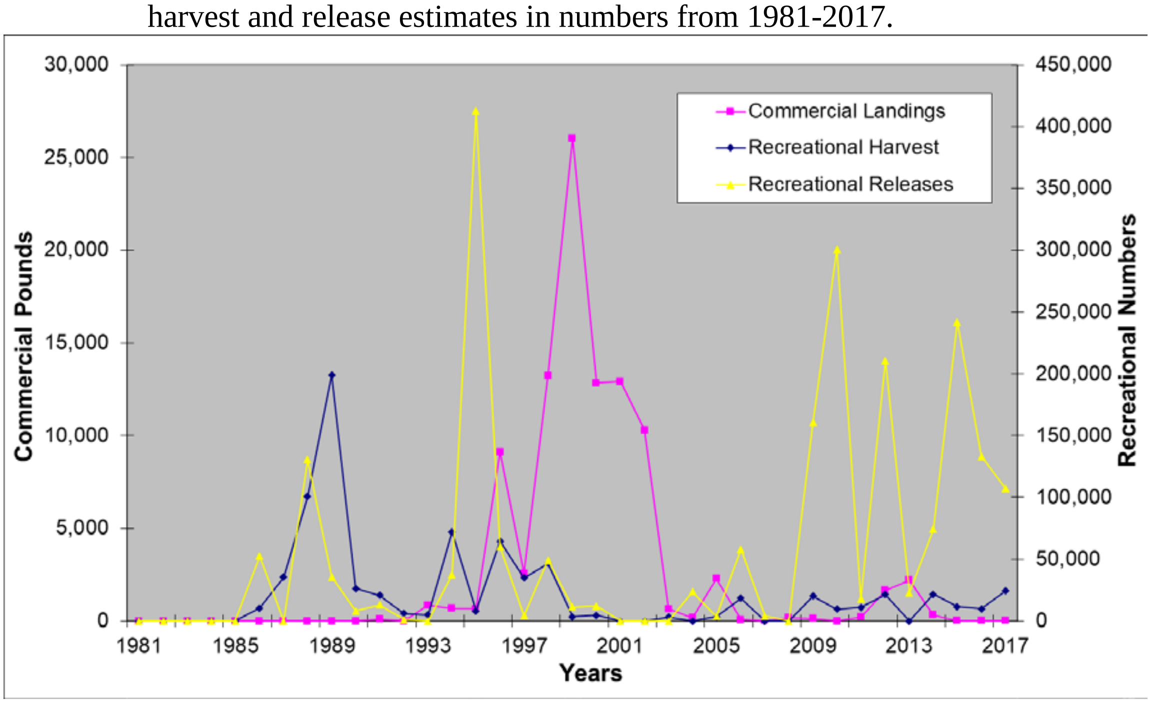


Figure 40. Maryland Charter boat log book spotted seatrout harvest in numbers and the number of anglers participating in trips catching spotted seatrout, 1993-2017.

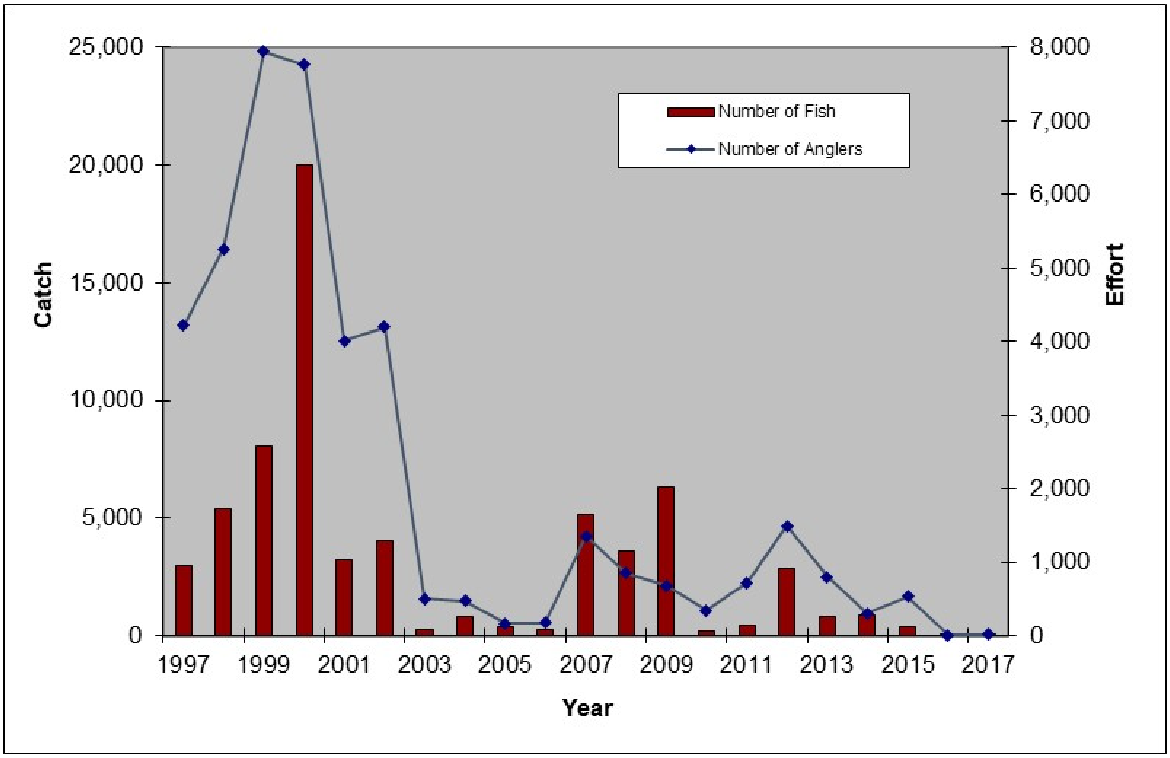


Figure 41. Atlantic menhaden length frequency distributions from onboard pound net sampling, 2009-2018, in 2012 the 230 FL value is 40 percent.

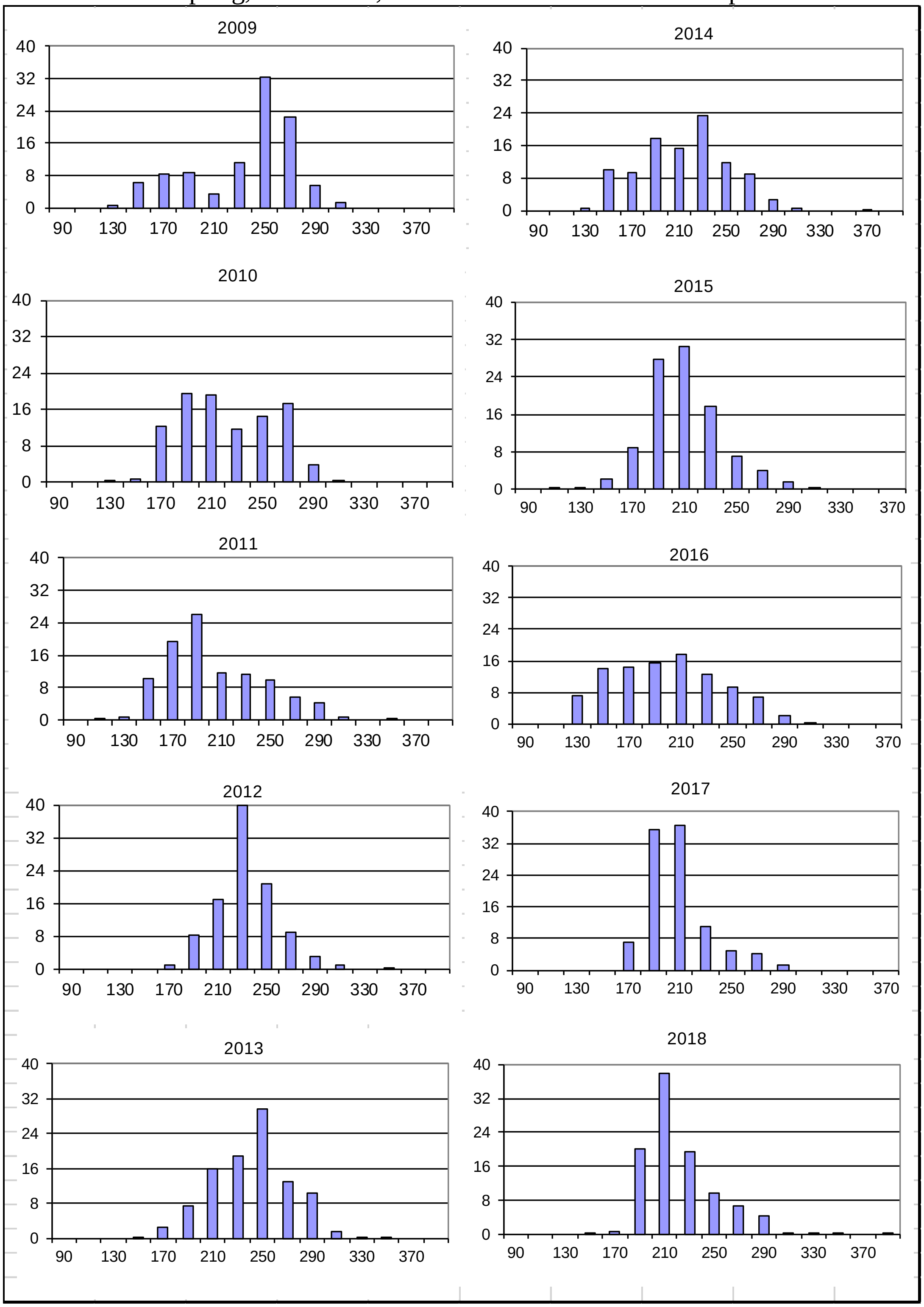


Figure 42. Geometric catch per hour of Atlantic menhaden for the Choptank River gill net survey, 2013-2018.

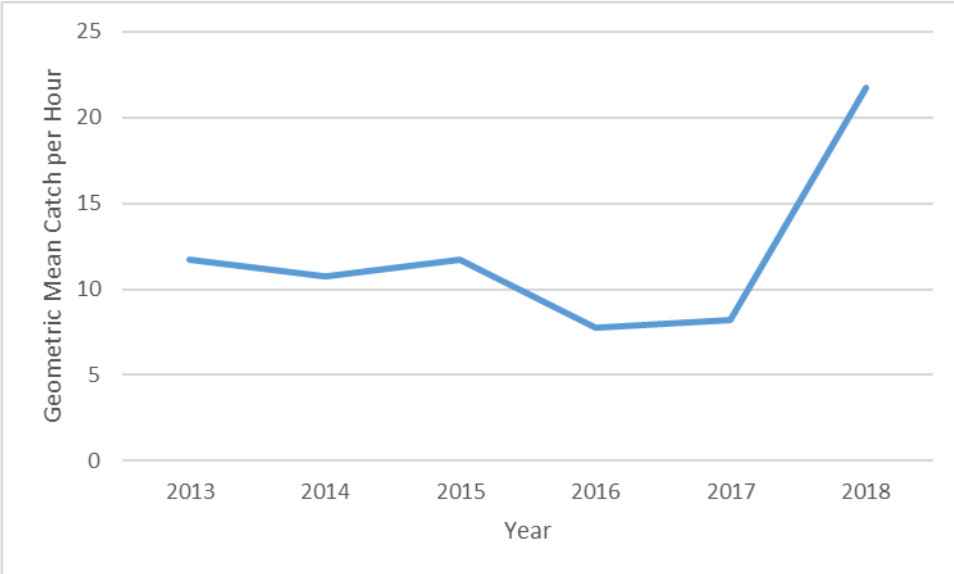


Figure 43. Atlantic menhaden proportion of catch by panel and year from the Choptank River gill net survey, 2013-2018.

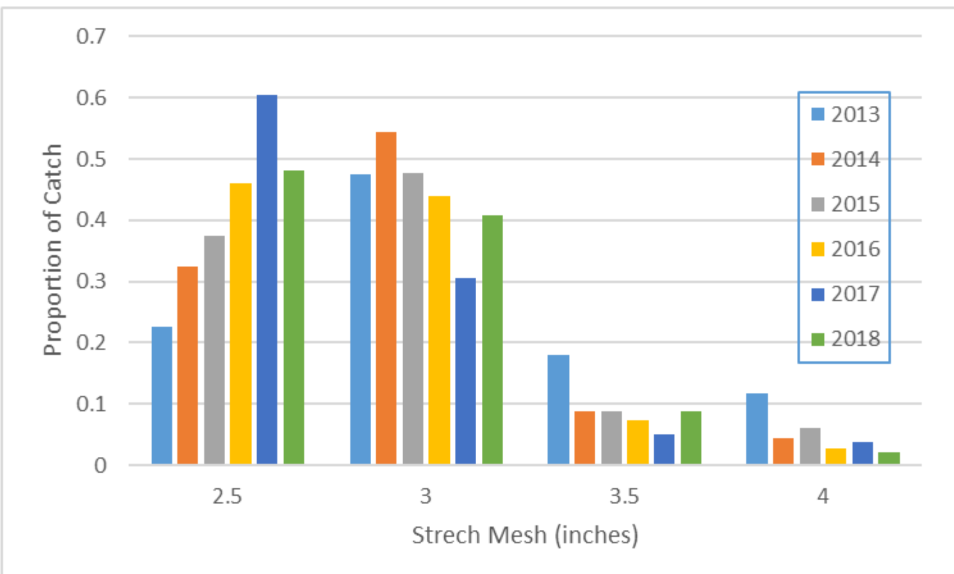


Figure 44. Atlantic menhaden length frequency distributions from the Choptank River gill net survey by year, 2013-2018.

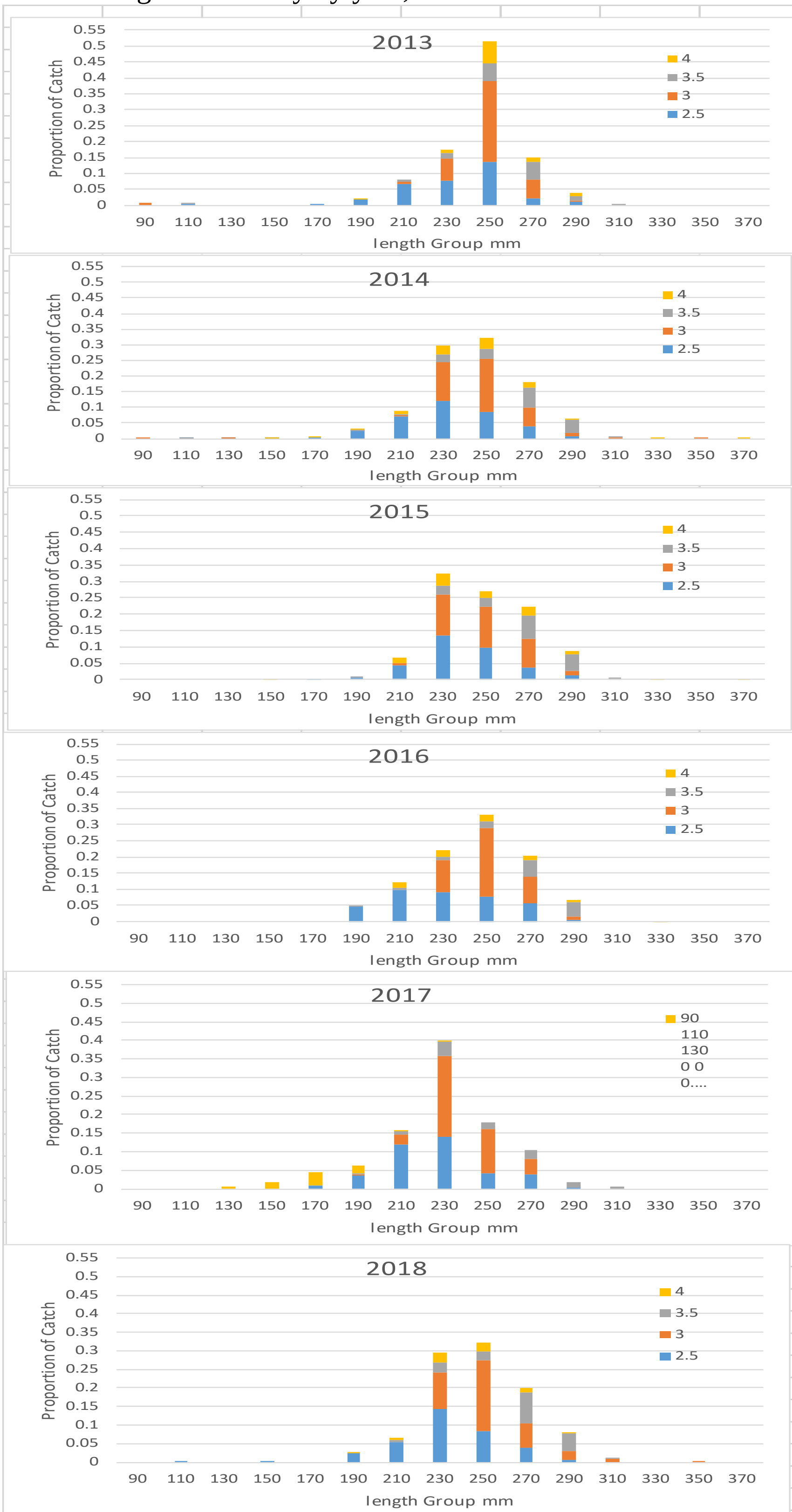
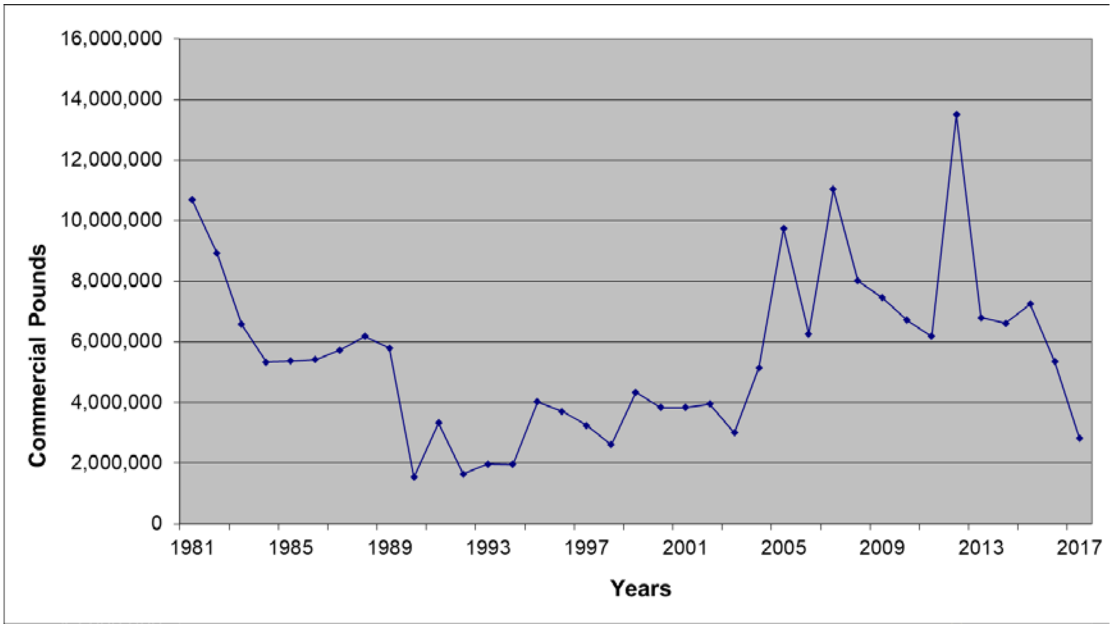


Figure 45. Maryland's Chesapeake Bay commercial landings for Atlantic menhaden from 1981-2017.



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 characterize the size and age structures of the 2017 Maryland striped bass *Morone saxatilis* commercial summer/fall fishery. The 2017 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 2017 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 2017 common pool fishery was open two days each in June and July, and one day each in August, September, and October. 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 2017 commercial summer/fall fishery were used to characterize the length and age structure of the summer/fall 2017 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 one to six times per month from June through November 2017 (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 2017, 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.

<u>Commercial summer/fall check station monitoring</u>

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 2017 (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 2017 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 2017.

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 2017 striped bass pound net study, a total of 6,023 striped bass were sampled from four pound nets in the upper Bay and two pound nets in the lower Bay. The six nets were sampled a total of 19 times during the study (Table 1).

Striped bass sampled from pound nets ranged from 277-902 mm TL, with a mean length of 475 mm TL (Figure 2). In 2017, 39% of striped bass collected from full net samples were less than the commercial minimum legal size of 18 inches (457 mm) TL and 52% of fish from partially sampled nets were sub-legal.

Ages were determined for 96 striped bass sampled from pound nets. Mean total length of the aged sub sample are presented in Table 2. Striped bass sampled from pound nets ranged from 2 to 13 years of age when the combined age length key was applied to the entire sample (Table 3, Figure 2). Age 2 fish from the above average 2015 year-class contributed 23% of the sample. Age 6 fish from the above average 2011 year-class contributed 17% in 2017, which was lower than the contribution in the previous year (32%). Striped bass age 6 and older comprised 21% of the sample, which was higher than their contribution in the previous year (10%; Figure 3).

Commercial summer/fall check station monitoring

A total of 1,988 striped bass were sampled at summer/fall check stations in 2017. The mean length of sampled striped bass was 581 mm TL. Length frequencies of legal sized striped bass (n=3,077) 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 444 to 920 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 2017 summer/fall fishery are shown in Tables 4 and 5.

Striped bass in the 450-550 mm length groups accounted for 53% 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 13% to the overall harvest. Historically, these fish have not been available in large numbers during the summer (MD DNR 2002).

The 2017 summer/fall reported harvest accounted for 56%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2017 with 809,094 pounds landed (see Project 2, Job 3, Task 5A). Landings reported by the MD DNR commercial reporting section were 196,538 pounds for hook and line gear and 612,556 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 2017 catch-at-age in pounds and numbers of fish for the summer/fall fishery is presented in Table 6. A thirteen 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. Mean weight-at-age was obtained for the Age 13 fish from the ASMFC Compliance Report (Durell 2017). By weight, the majority (85%) of the harvest was composed of four to six year-old striped bass. Striped bass from the above average 2011 (age 6) year class contributed 37% to the harvest and were the highest contribution to the fishery. Striped bass from the 2012 year class (age 5) contributed the second highest percentage to the harvest (35%). Striped bass age 8 and older contributed 7% to the overall harvest in 2017, which was similar to 2016 (6%).

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 53% of the 2017 summer/fall harvest

(Figure 5). A higher percentage of fish >630 mm TL were harvested in 2017 (34%) compared to 2016 (18%). In 2017, 96 fish from pound net monitoring and 121 fish from check station sampling were aged. Younger fish (age 4 to 6) 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= 662 mm and WT=3.05 kg) in November and smaller in October (TL=545 mm and WT=1.61 kg, respectively). Lengths and weights were similar in June, July and August (TL=562 mm, 560 mm, 564 mm and WT=1.85 kg, 1.83 kg, 1.83 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

2018 PRELIMINARY RESULTS – WORK IN PROGRESS

Commercial pound net monitoring

During the 2018 striped bass pound net study, a total of 4,868 striped bass were sampled and 605 scale samples were collected for ageing 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.

Striped bass sampled from pound nets ranged from 255-882 mm TL, with a mean length of 485 mm TL. A breakdown of catch by age will be available in the next F-61 Chesapeake Bay Finfish Investigations report.

Commercial summer/fall check station monitoring

A total of 2,086 striped bass were sampled and 501 scale samples were collected for ageing at summer/fall check stations in 2018. The mean length of sampled striped bass was 575 mm TL. Striped bass sampled from the summer/fall fishery ranged from 443 to 926 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.

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Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2017 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	23.2	7.5	571
	Middle	-	-	-	-
	Lower	1	22.2	8.9	211
July	Upper	2	27.5	7.1	985
	Middle	-	-	-	-
	Lower	-	-	-	-
August	Upper	1	23.6	8.5	285
	Middle	-	-	-	-
	Lower	-	-	-	-
September	Upper	3	23.5	2.8	662
	Middle	-	-	-	-
	Lower	1	23.9	12.6	485
October	Upper	5	18.6	7.8	1141
	Middle	-	-	-	-
	Lower	1	19.4	15.6	597
November	Upper	2	8.4	1.7	587
	Middle	-	-	-	-
	Lower	1	13.9	16.0	499

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2017.

Year-class	Age	n	Mean Length (mm TL)	Lower CL	Upper CL
2015	2	22	331	314	348
2014	3	15	417	397	438
2013	4	6	449	371	526
2012	5	11	524	493	556
2011	6	23	632	595	670
2010	7	6	718	632	805
2009	8	4	806	695	917
2008	9	4	839	754	924
2007	10	2	860	*	*
2006	11	1	826	*	*
2005	12	1	863	*	*
2004	13	1	853	*	*

*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 2017. Sum of columns may not equal due to rounding.

Year-class	Age	Pound Net Monitoring	
		Number Sampled at Age (n)	Percent of Total
2015	2	1,359	22.6
2014	3	1,180	19.6
2013	4	828	13.7
2012	5	1,385	23.0
2011	6	1,030	17.1
2010	7	138	2.3
2009	8	61	1.0
2008	9	27	0.4
2007	10	12	0.2
2006	11	2	<0.1
2005	12	1	<0.1
2004	13	1	<0.1
Total		**6,023**	**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 2017.

Year-class	Age	n	Mean Length (mm TL)	Lower CL	Upper CL
2014	3	1	444	-	-
2013	4	7	505	462	547
2012	5	15	526	499	552
2011	6	34	696	675	717
2010	7	16	771	733	809
2009	8	15	781	747	814
2008	9	12	823	787	859
2007	10	17	855	836	875
2006	11	2	872	*	*
2005	12	2	823	*	*

*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 2017.

Year-class	Age	n	Mean Weight (kg)	Lower CL	Upper CL
2014	3	1	0.88	-	-
2013	4	7	1.23	0.88	1.58
2012	5	15	1.37	1.09	1.65
2011	6	34	3.37	3.05	3.69
2010	7	16	4.52	3.86	5.17
2009	8	15	4.68	4.05	5.30
2008	9	12	5.70	4.93	6.47
2007	10	17	6.02	5.59	6.45
2006	11	2	7.04	*	*
2005	12	2	5.96	*	*

*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 2017.

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
2014	3	19,410	2.4	10,005	5.2
2013	4	104,581	12.9	38,567	20.1
2012	5	280,081	34.6	92,732	48.4
2011	6	301,690	37.3	40,607	21.2
2010	7	47,593	5.9	4,776	2.5
2009	8	29,399	3.6	2,849	1.5
2008	9	15,045	1.9	1,197	0.6
2007	10	8,316	1.0	627	0.3
2006	11	1,024	0.1	66	<0.1
2005	12	1,588	0.2	121	0.1
2004**	13	366	<0.1	26	<0.1
Total*		**809,094**	**100.0**	**191,572**	**100.0**

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

** 2004 year class fish were not encountered in the subsample. Mean weight-at-age was obtained from ASMFC 2017 Compliance Report to calculate landings in pounds of fish and numbers of fish.

Table 7. Duncan's multiple range test for mean length by month for the Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2017. 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	November	662	220
B	September	614	424
C	August	564	495
C	June	562	267
C	July	560	211
D	October	545	371

Table 8. Duncan's multiple range test for mean weight by month for the Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2017. 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	November	3.05	220
B	September	2.42	423
C	June	1.85	267
C	July	1.83	210
C	August	1.83	495
D	October	1.61	370

Figure 1. Locations of Chesapeake Bay commercial summer/fall check stations sampled from June through November 2017.

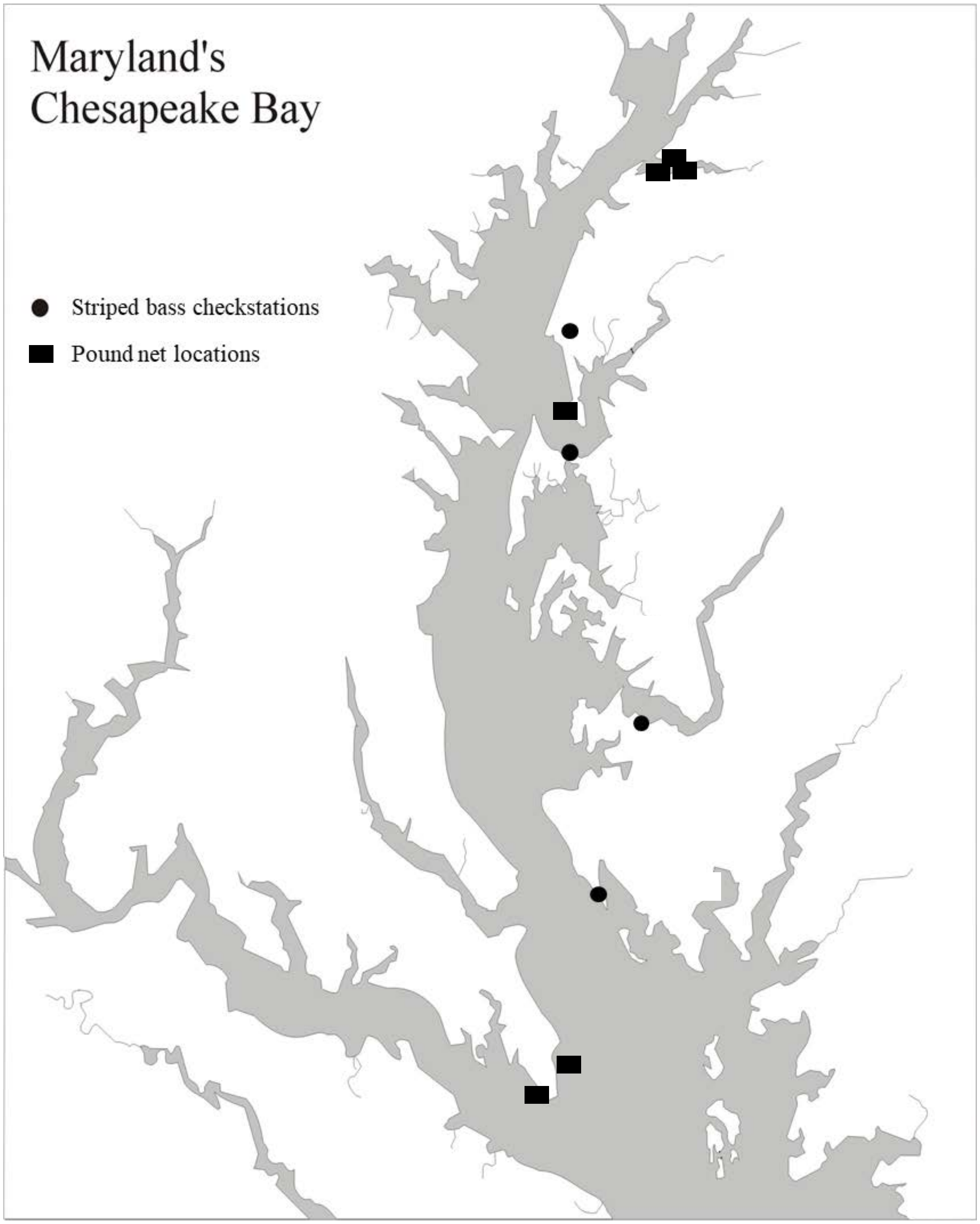
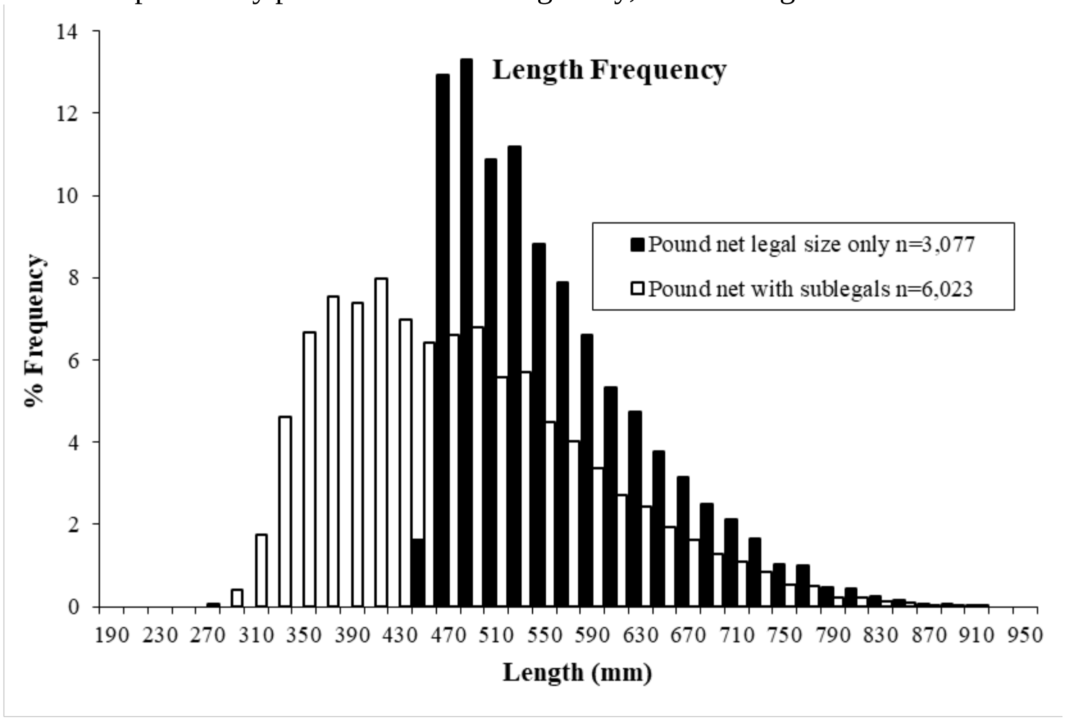
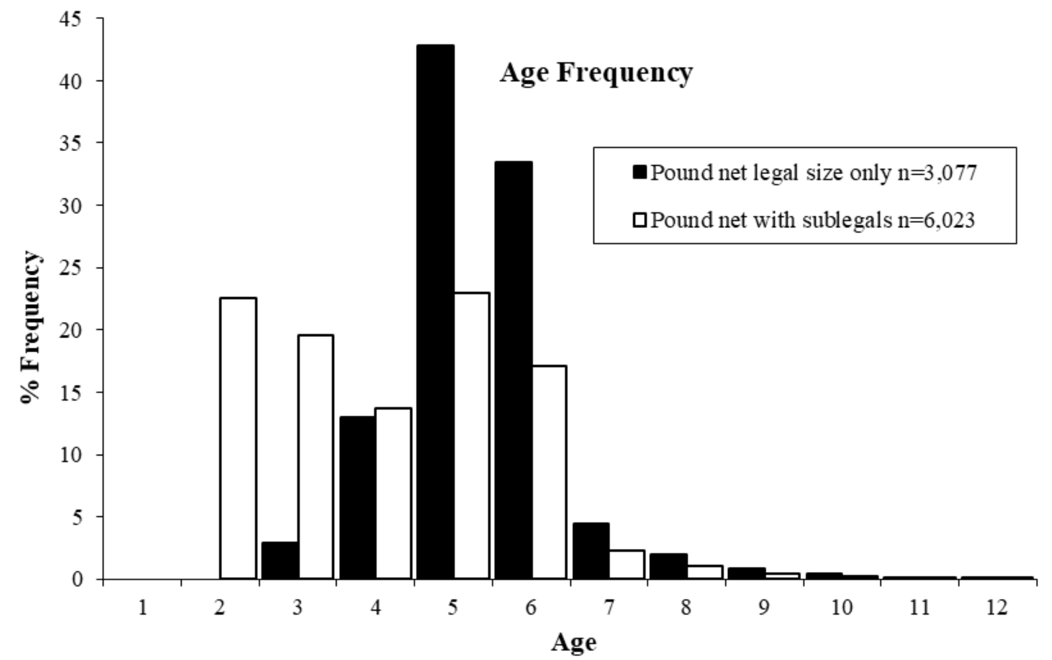


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, June through November 2017.





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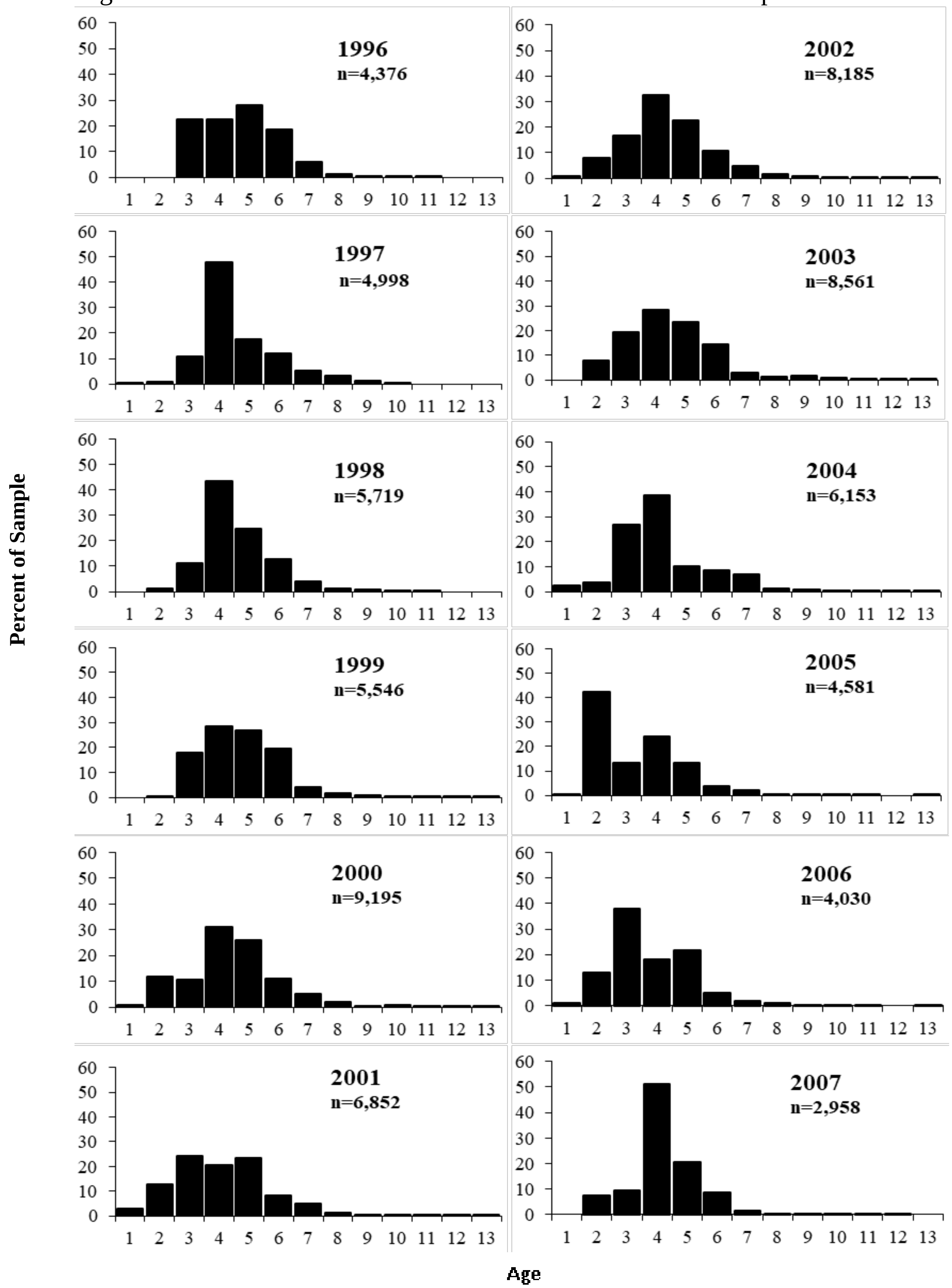
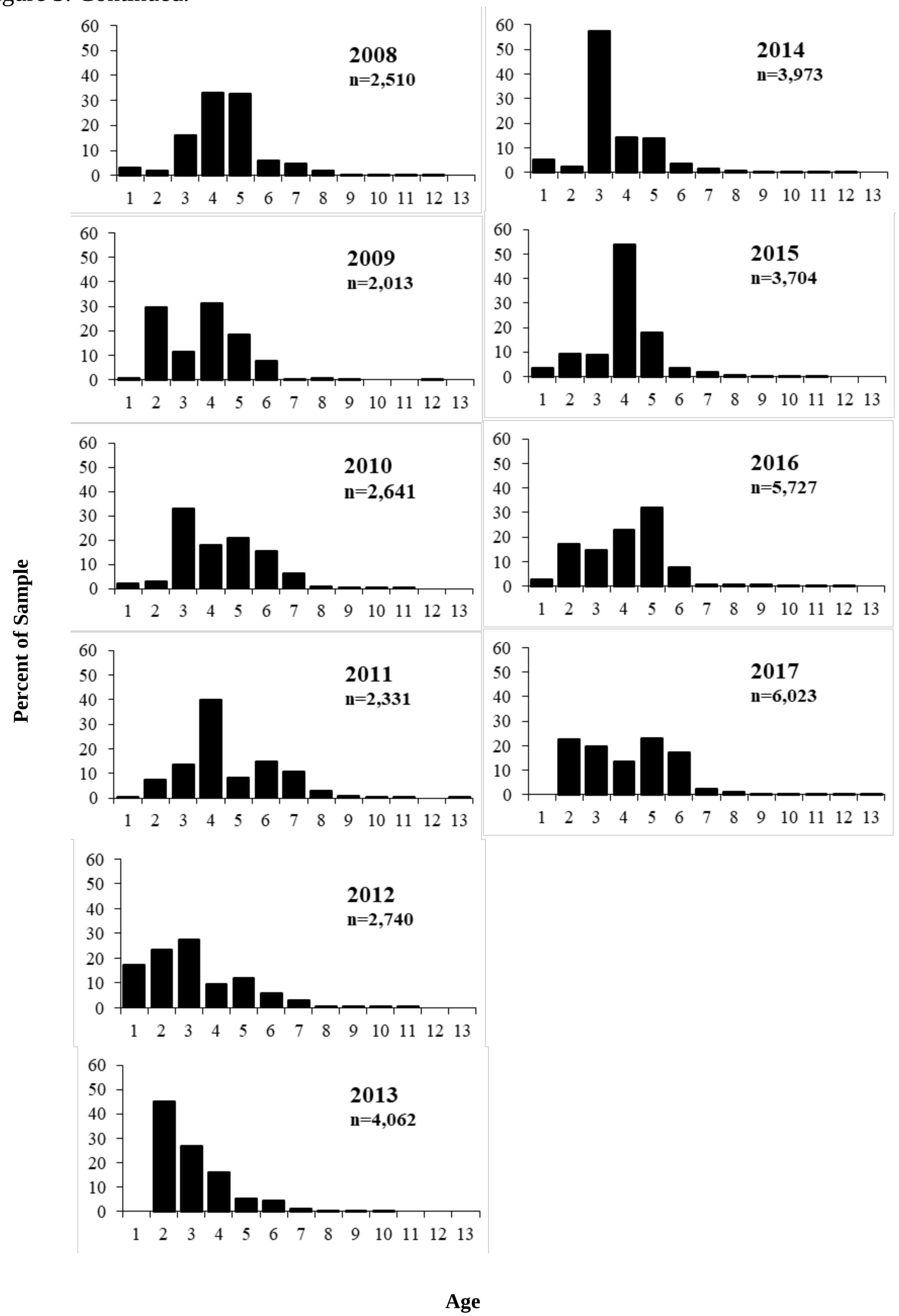


Figure 3. Continued.



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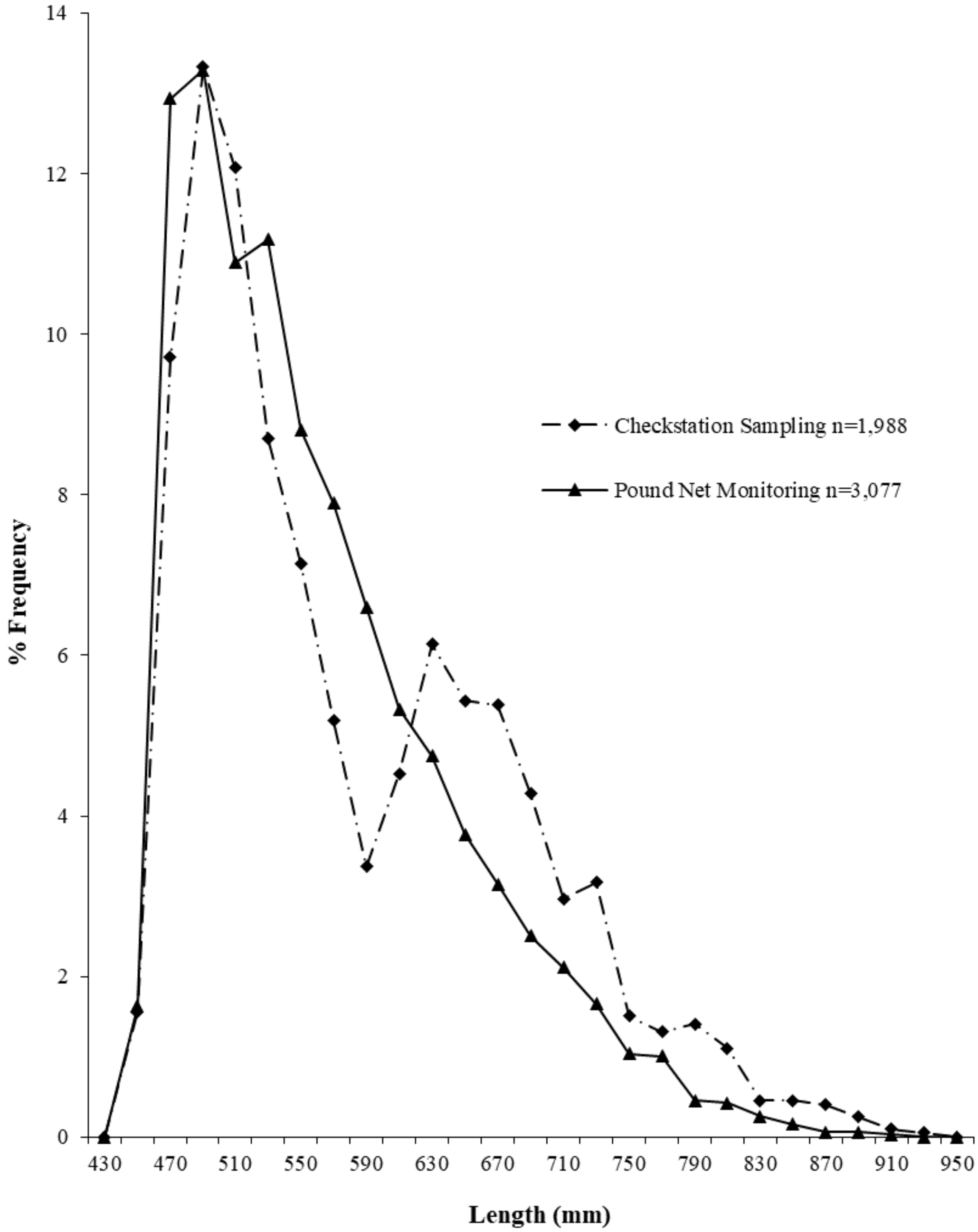

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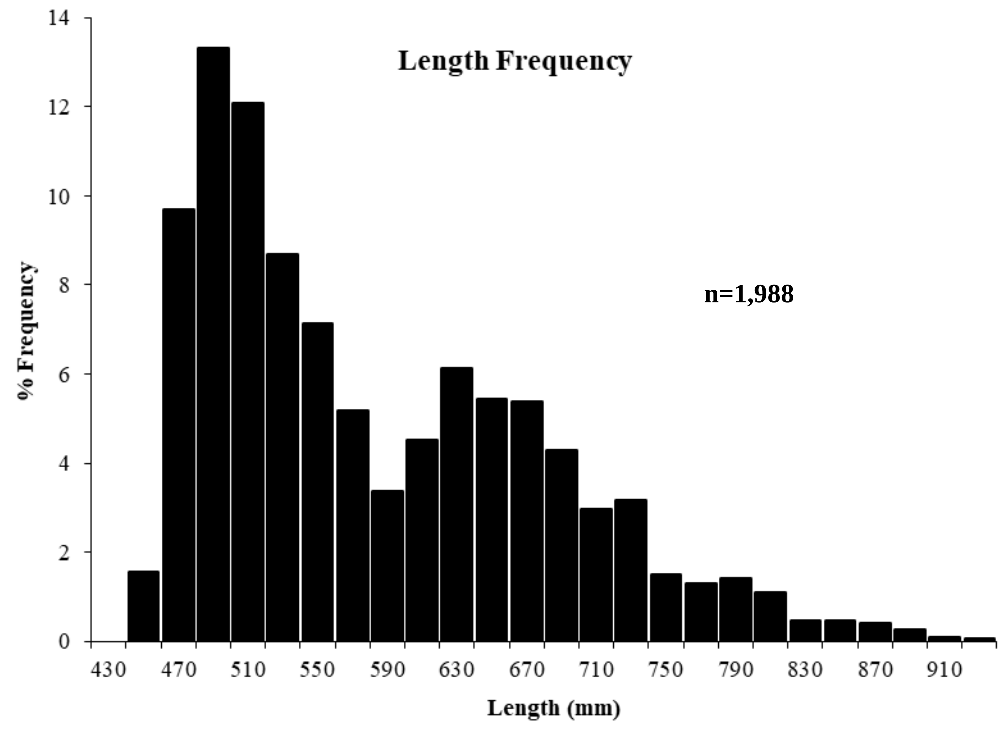


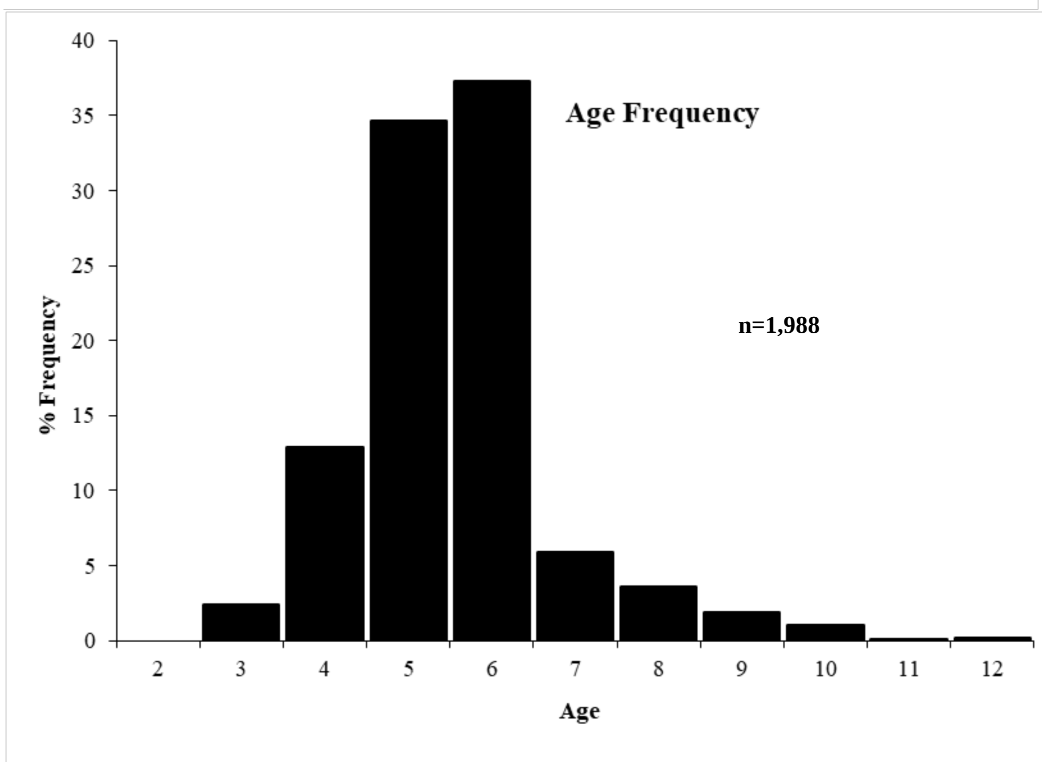


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, June through November 2017.

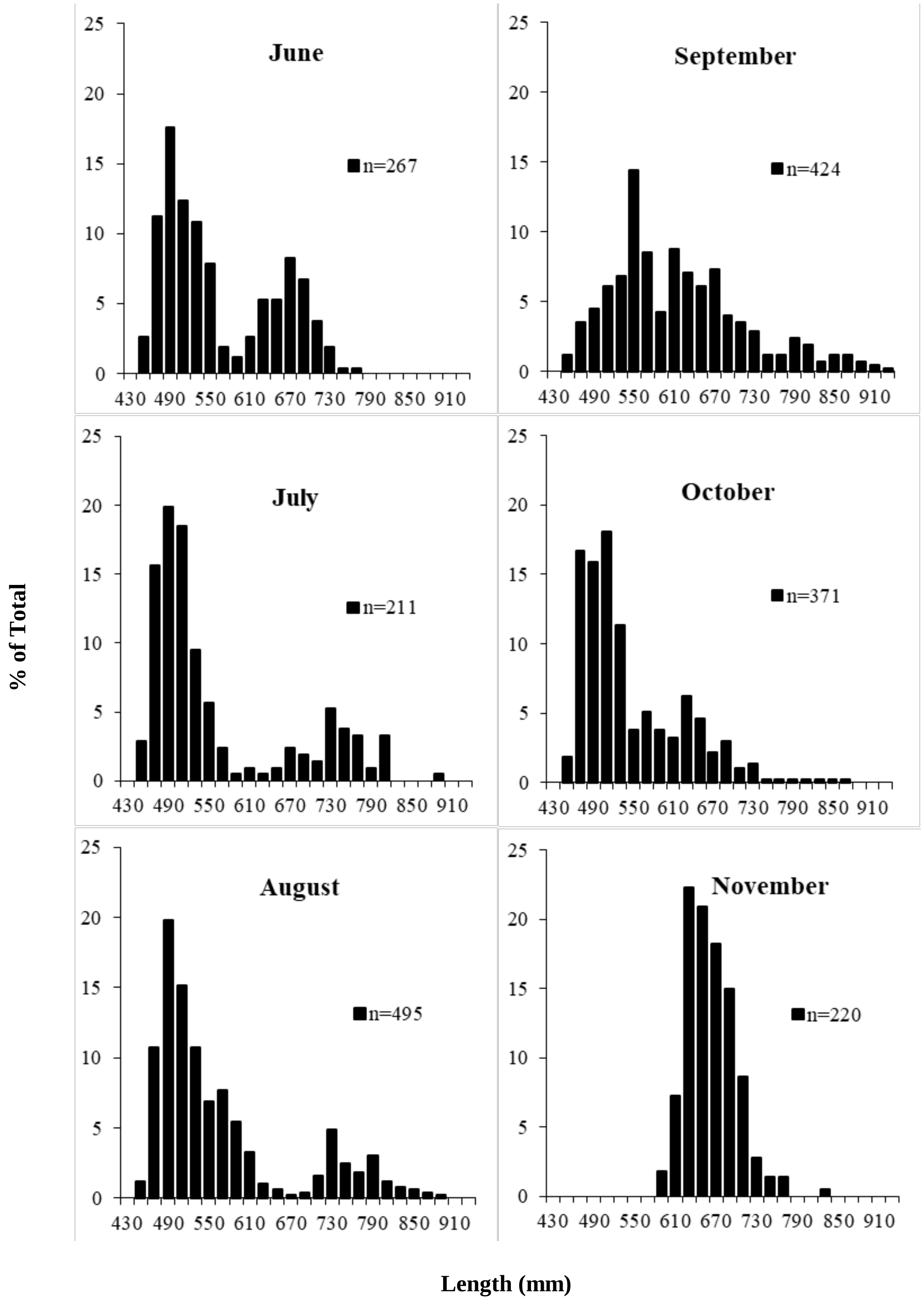
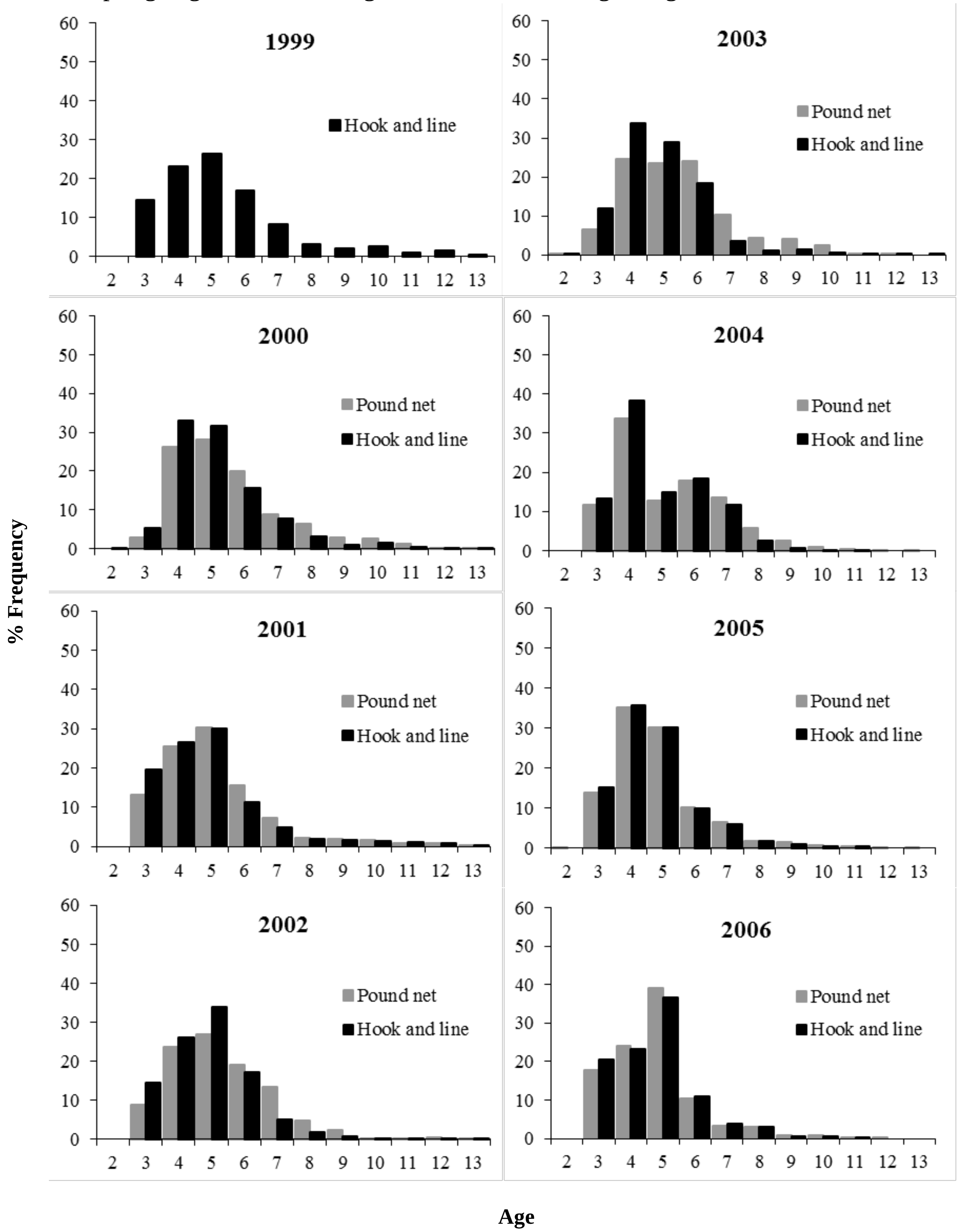


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, 1999 through 2017. Note-pound net check station sampling began in 2000 and gears are combined beginning in 2014.



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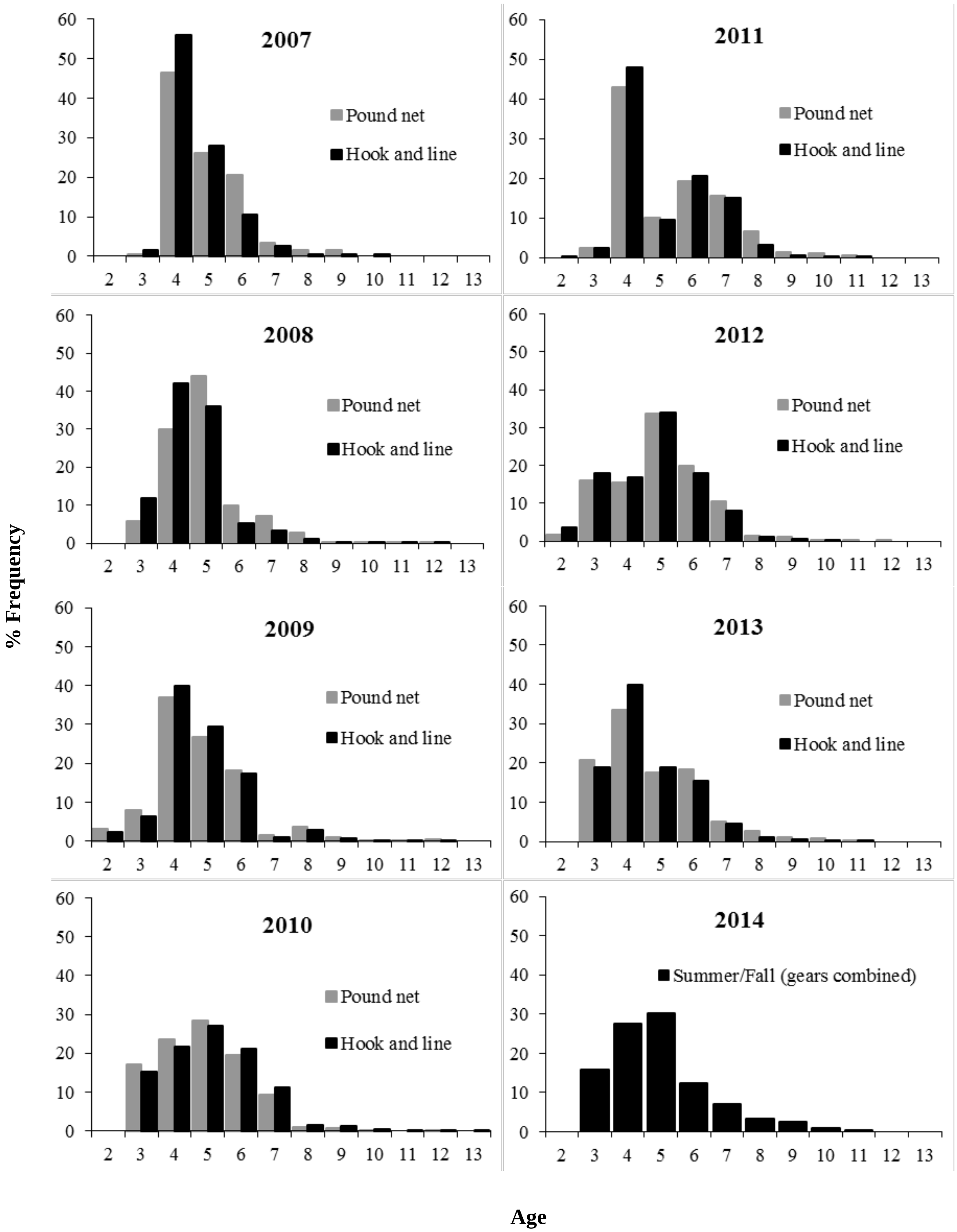

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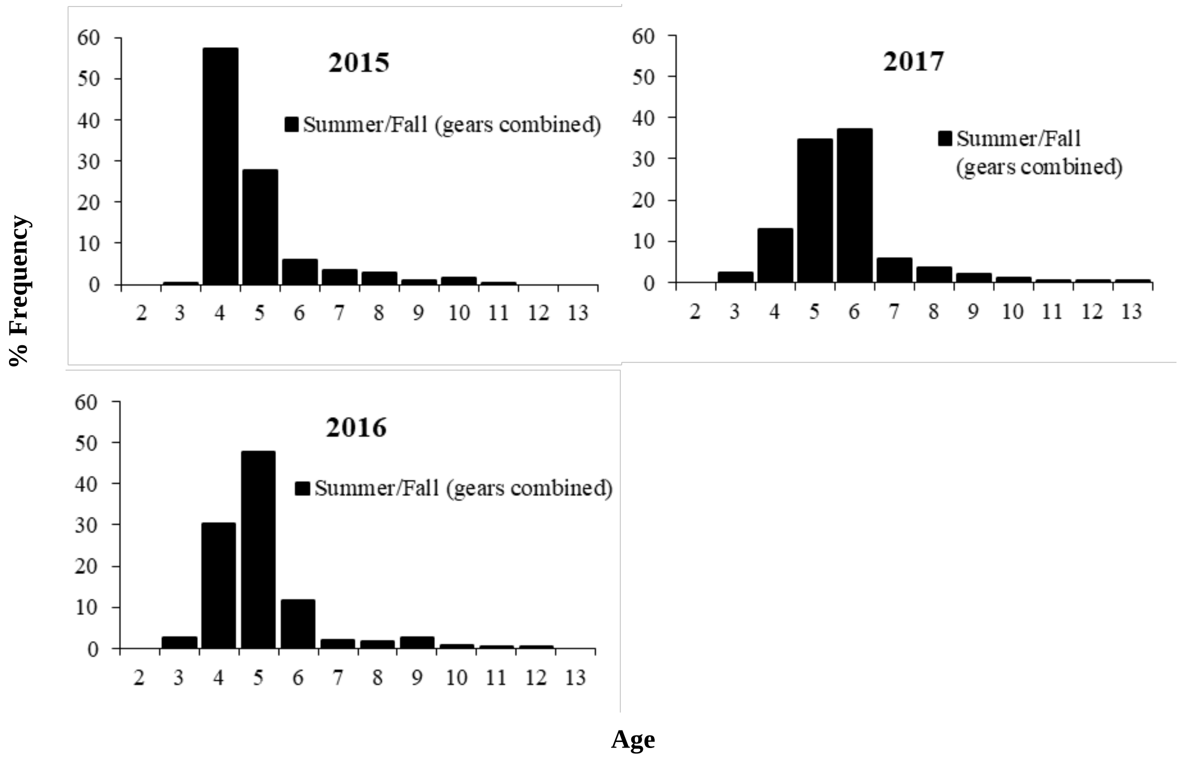
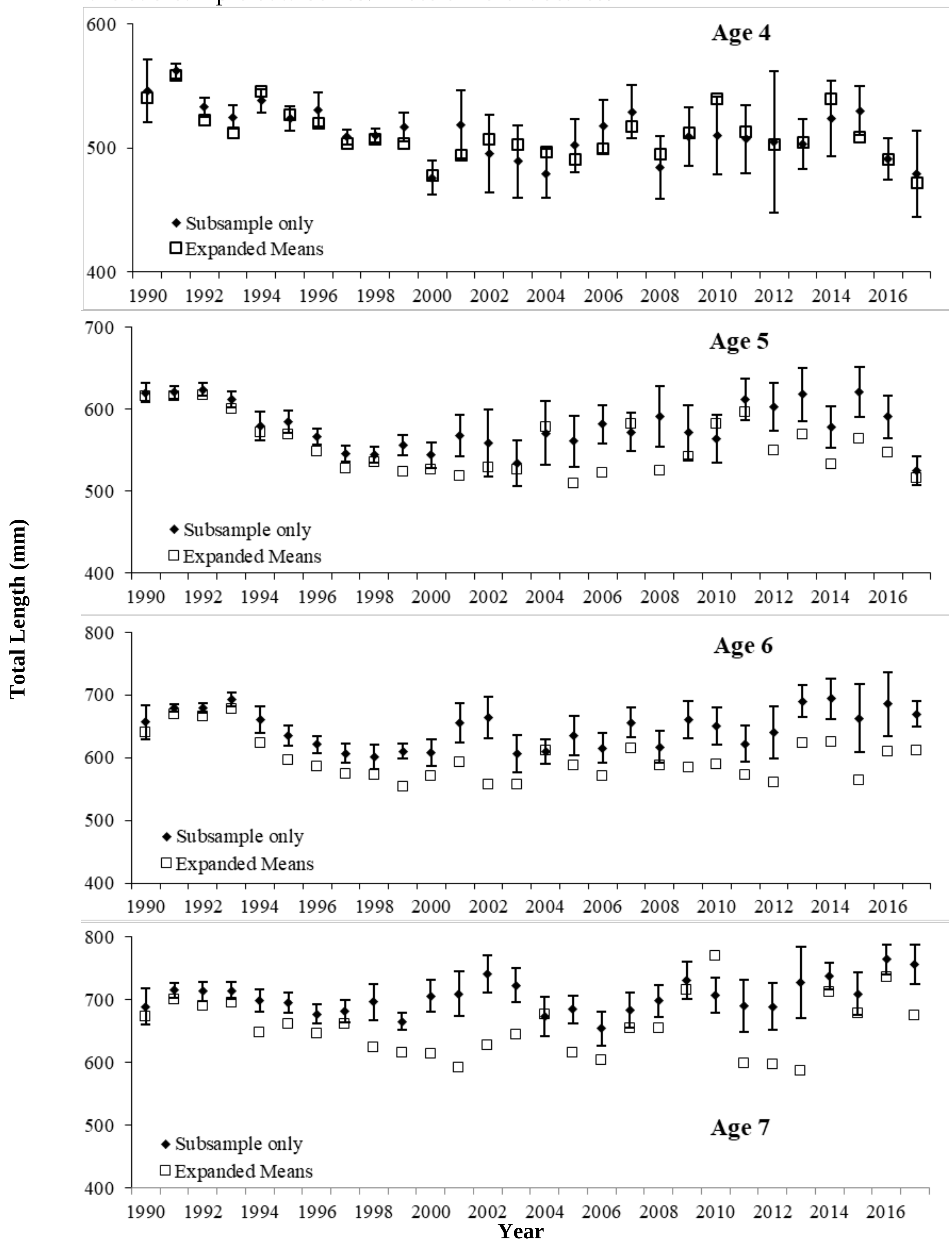


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for age 4, 5, 6, and 7 striped bass sampled from Maryland Chesapeake Bay pound nets and commercial summer/fall check stations, 1990 through 2017. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to 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 to characterize the size and age structure of striped bass (*Morone saxatilis*) sampled from the December 1, 2017 – February 28, 2018 commercial drift gill net fishery. 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.

In 2014, Maryland's Chesapeake Bay commercial fisheries switched to an individual transferable quota (ITQ) system (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. This fishery was only open for one day in December, three days in January and four 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 were 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 were randomly chosen to be aged. Approximately twice as many scales as ages per 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 2017-2018 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 2017 – February 2018 gill net season, the year used for age calculations was 2018.

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 2017-2018 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 2,720 striped bass were sampled and 159 striped bass were aged from the harvest between December 2017 - February 2018. 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 on Tilghman Island (Figure 1). Check stations were visited by biologists five times in December, five times in January, and eight 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 2017-2018 season was estimated by dividing reported monthly harvest weight by the mean monthly weight of check station samples. Total reported landings were 524,579 pounds and the estimated number of fish was 68,743 (Table 1). According to the catch-at-age analysis, the 2017-2018 commercial drift gill net harvest consisted primarily of age 7 striped bass from the 2011 year-class (61%; Table 2). The 2010 and 2012 year-classes (ages 8 and 6) composed an additional 24% of the total harvest. The contribution of fish older than age 9 (8%) was higher than in the 2016-2017 harvest (2%). The youngest fish observed in the 2017-2018 sampled harvest were age 3 from the 2015 year class (0.1%).

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 3 (2015 year-class), with an expanded mean length and weight of 489 mm TL and 1.22 kg, respectively. The 2011 year-class (age 7) was most commonly observed in the sampled landings and had an expanded mean length and weight of 648 mm TL and 3.34 kg, respectively. The expanded mean length and weight of the oldest fish in the aged subsample (age 13, 2005 year-class) were 850 mm TL and 7.35 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 570-730 mm length groups. Sub-legal fish have occasionally been sampled in previous years but, none <457 mm TL (18 inches) were observed in 2017-2018 sampling.

Time-series of subsampled and expanded mean lengths and weights for the period 1994-2018 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

2018-2019 WINTER STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

2018-2019 SEASON PRELIMINARY RESULTS

A total of 3,526 striped bass were sampled and 862 scale samples were collected from the harvest between December 2018 - February 2019. The mean length of sampled striped bass was 614 mm TL. Striped bass sampled from the winter fishery ranged from 444 to 858 mm TL. 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, six times in January, and five 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 of harvest-, length-, and weight-at-age will be provided in the next F-61 Chesapeake Bay Finfish Investigations report.

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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 - 2018 (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.

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 - 2018 (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.

Table 1. Reported pounds harvested, check station average weights, and estimated fish harvested by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2017 - February 2018.

Month	**Harvest (lbs)**	**Check station average wt. (lb)**	**Estimated # harvested**
December 2017	116,863	7.52	15,513
January 2018	269,632	8.10	33,264
February 2018	138,084	6.91	19,965
Total*	**524,579**		**68,743**

* 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 2017 - February 2018.

Year-class	**Age**	**Catch**	**Percentage of the catch**
2015	3	80	<1
2014	4	1,206	2
2013	5	3,466	5
2012	6	5,378	8
2011	7	41,932	61
2010	8	10,865	16
2009	9	4,657	7
2008	10	872	1
2007	11	192	<1
2006	12	45	<1
2005	13	51	<1
Total*		**68,743**	**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 2017 - February 2018.

Year-class	Age	n fish aged	Mean TL (mm) of subsample	Estimated # at-age in sample	Expanded mean TL(mm)
2015	3	1	486	3	489
2014	4	11	493	48	508
2013	5	7	550	137	588
2012	6	12	597	213	606
2011	7	66	684	1,659	648
2010	8	23	739	430	683
2009	9	19	790	184	705
2008	10	11	825	35	777
2007	11	6	853	8	848
2006	12	1	828	2	826
2005	13	2	851	2	850
Total*		**159**		**2,720**	

* 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 2017 - February 2018.

Year-class	Age	n fish aged	Mean WT (kg) of subsample	Estimated # at-age in sample	Expanded mean weight (kg)
2015	3	1	1.25	3	1.22
2014	4	11	1.29	48	1.48
2013	5	7	2.03	137	2.49
2012	6	12	2.79	213	2.76
2011	7	66	3.96	1,659	3.34
2010	8	23	5.00	430	3.90
2009	9	19	6.02	184	4.29
2008	10	11	7.21	35	5.69
2007	11	6	7.68	8	7.35
2006	12	1	7.47	2	6.82
2005	13	2	7.62	2	7.35
Total*		**159**		**2,720**	

* 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 2017 - February 2018.

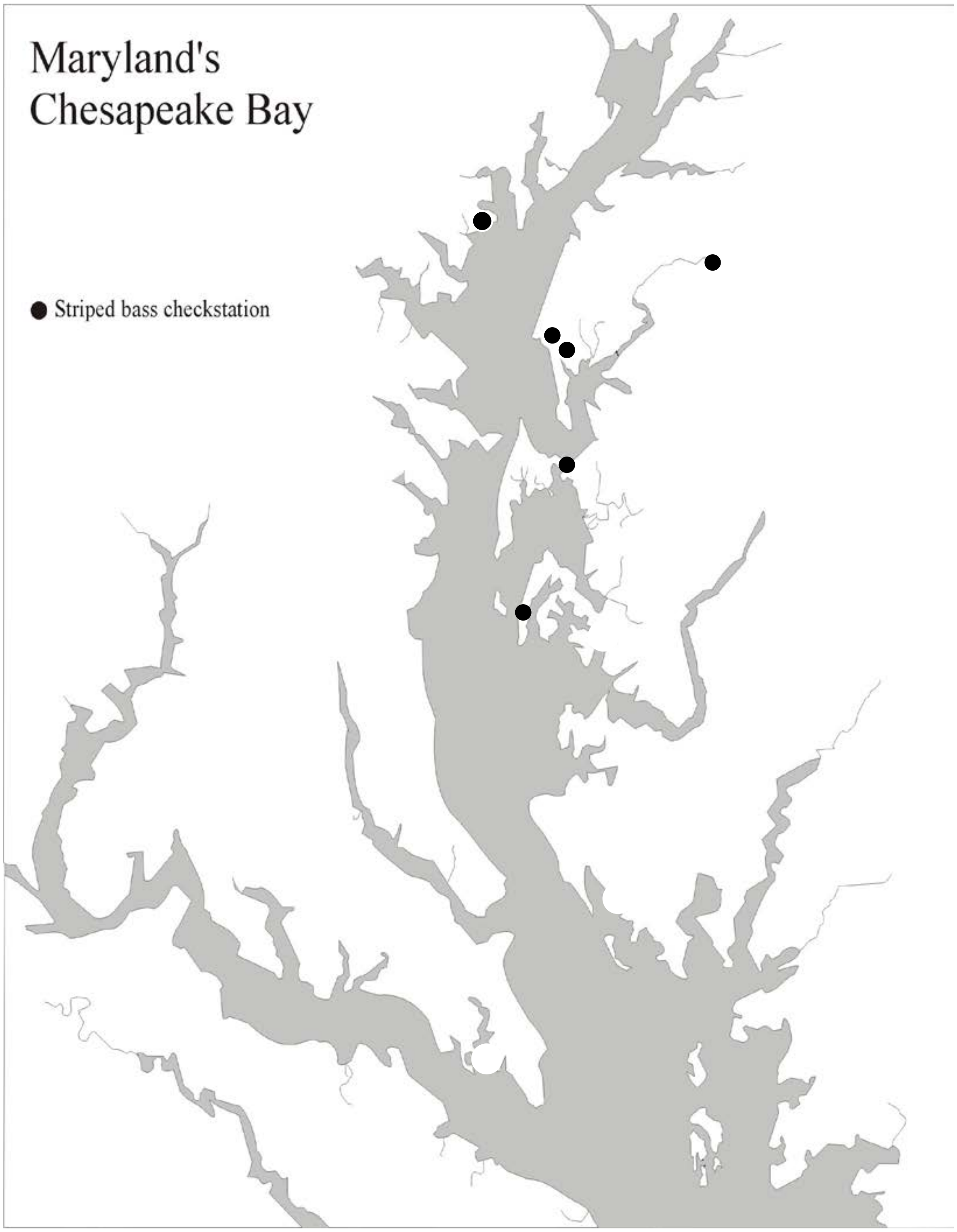
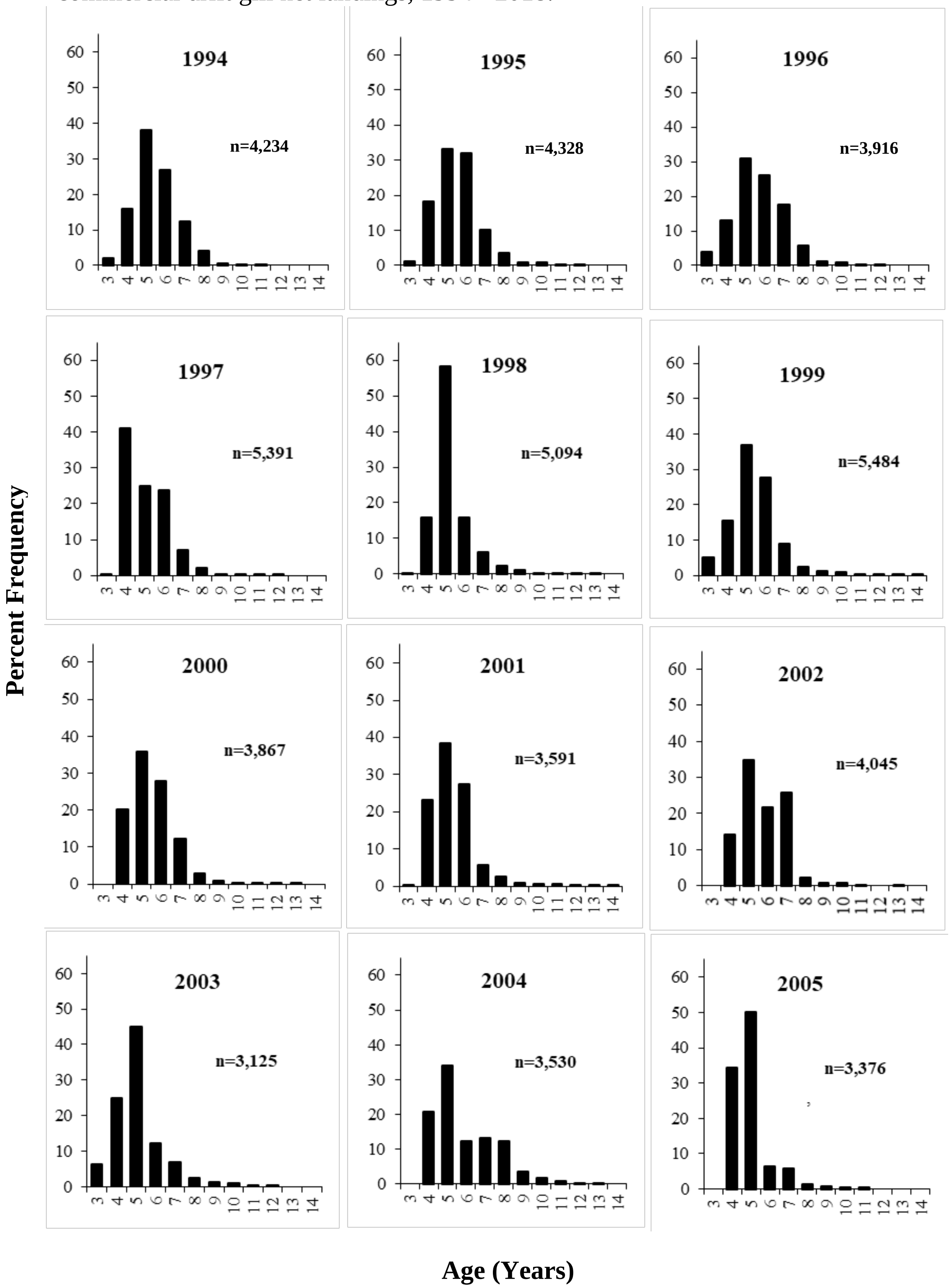


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994 - 2018.



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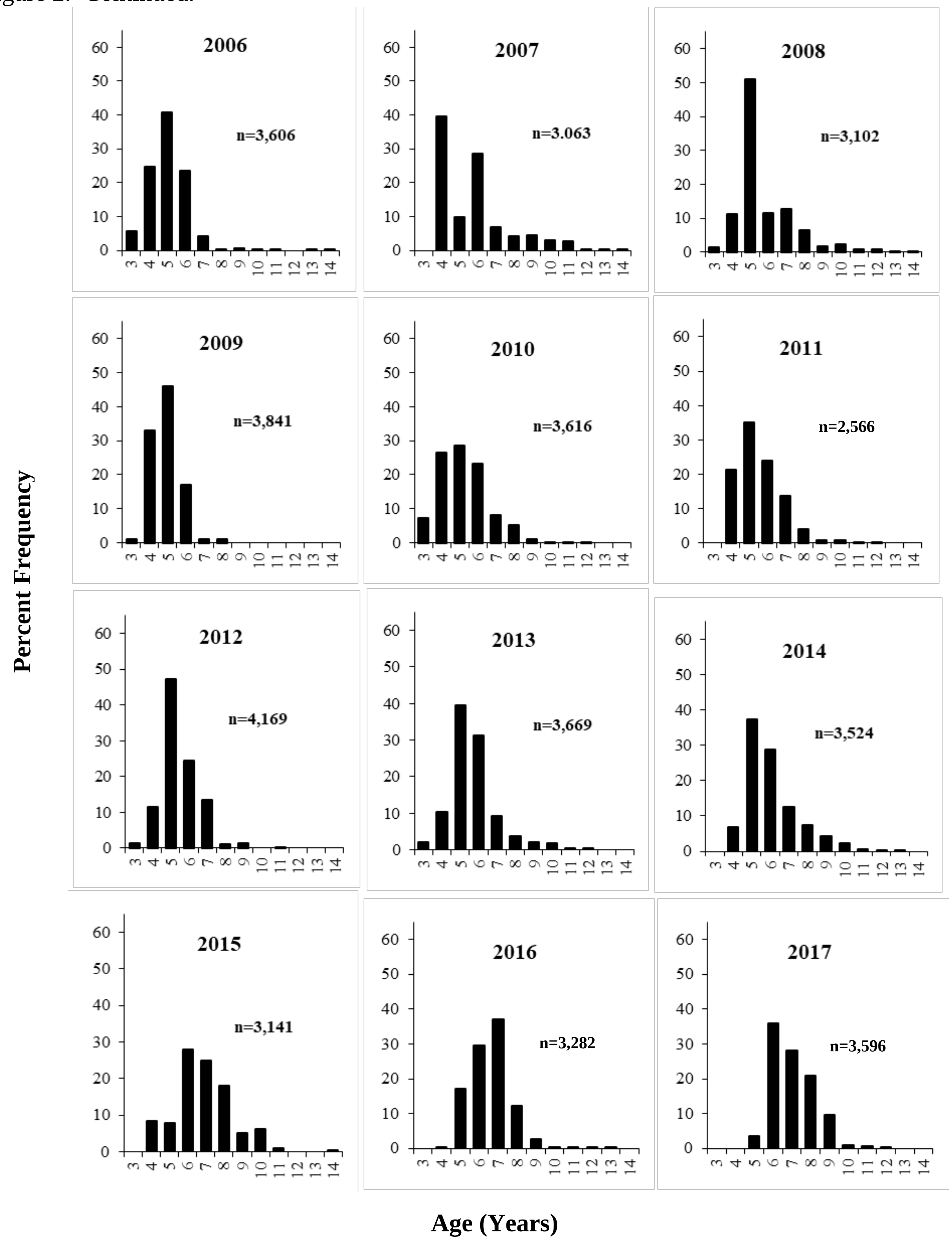

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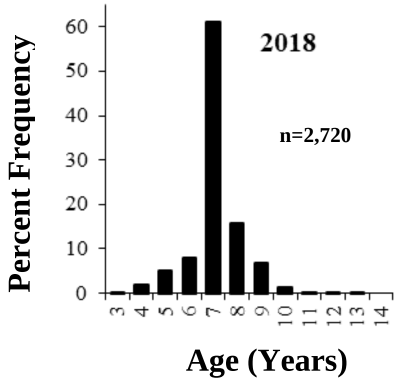


Figure 3. Length frequency distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2017 - February 2018.

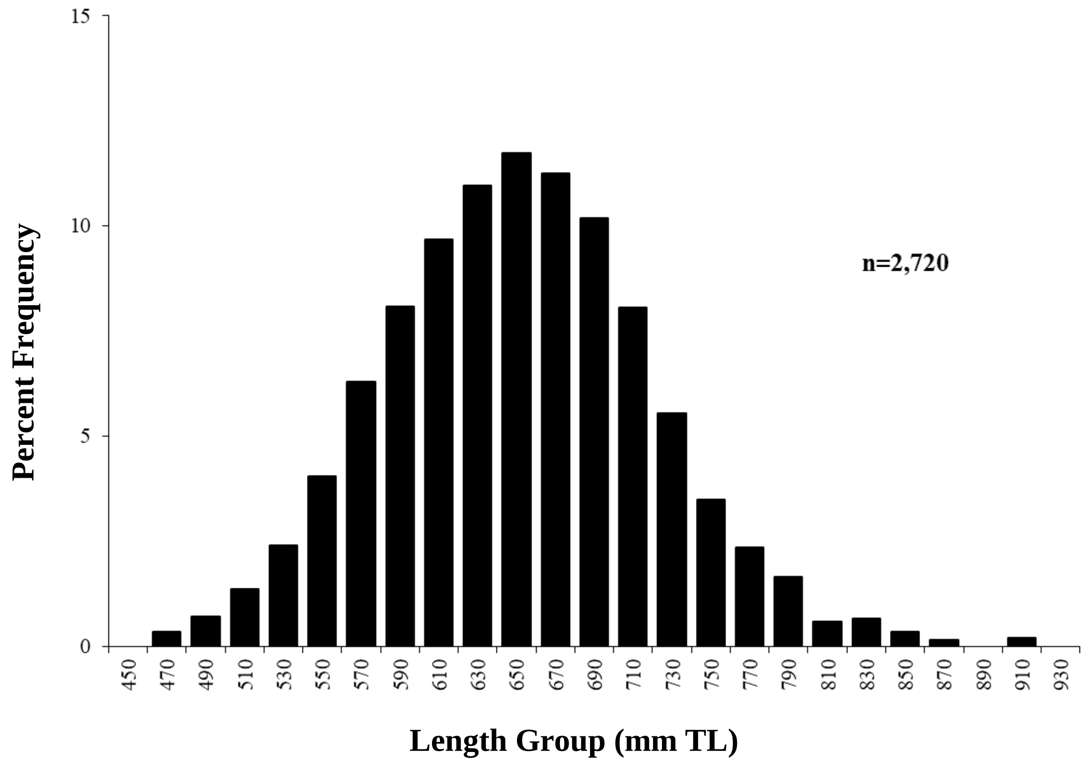
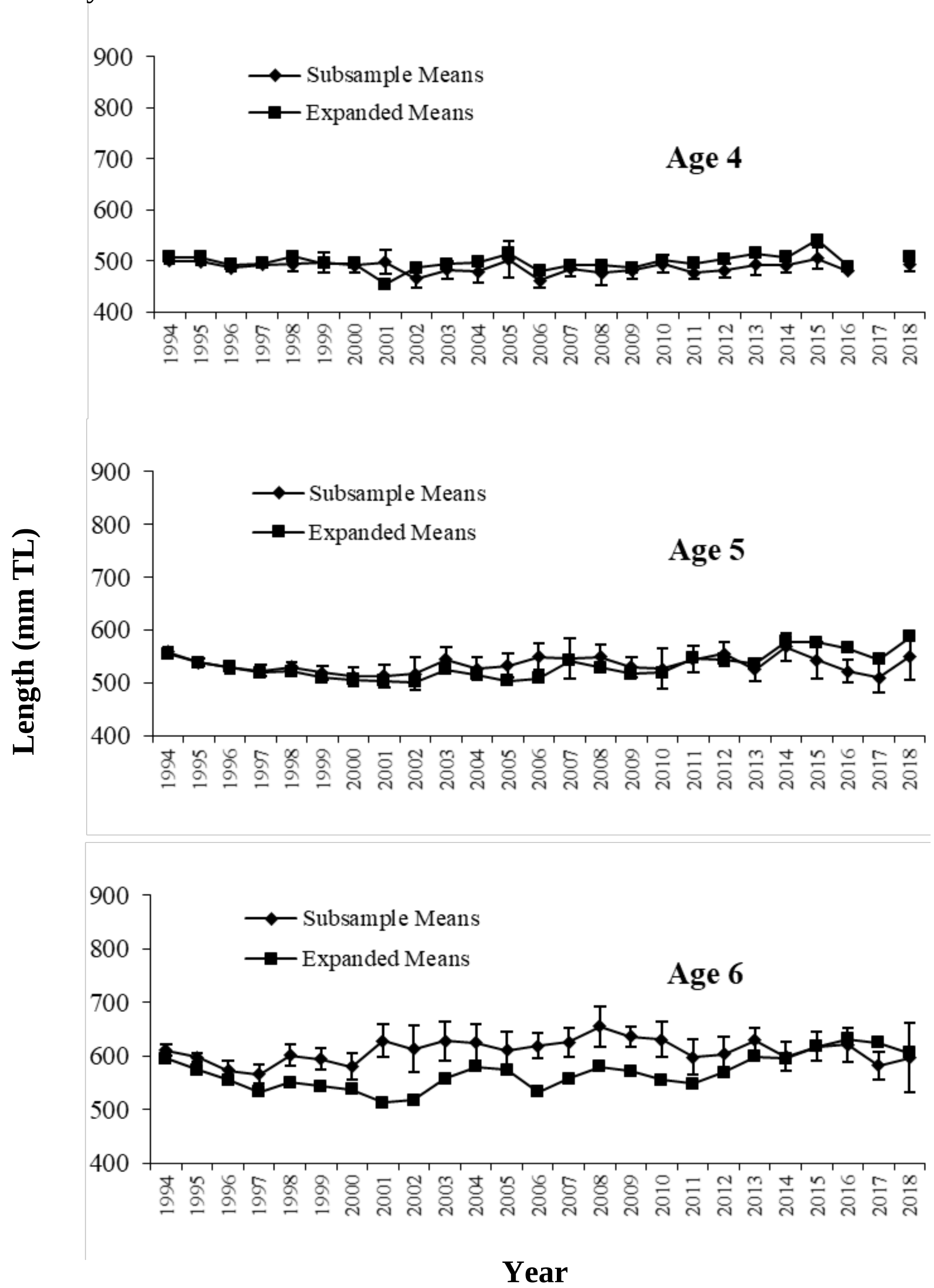


Figure 4. Mean total lengths (mm TL) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994 - 2018 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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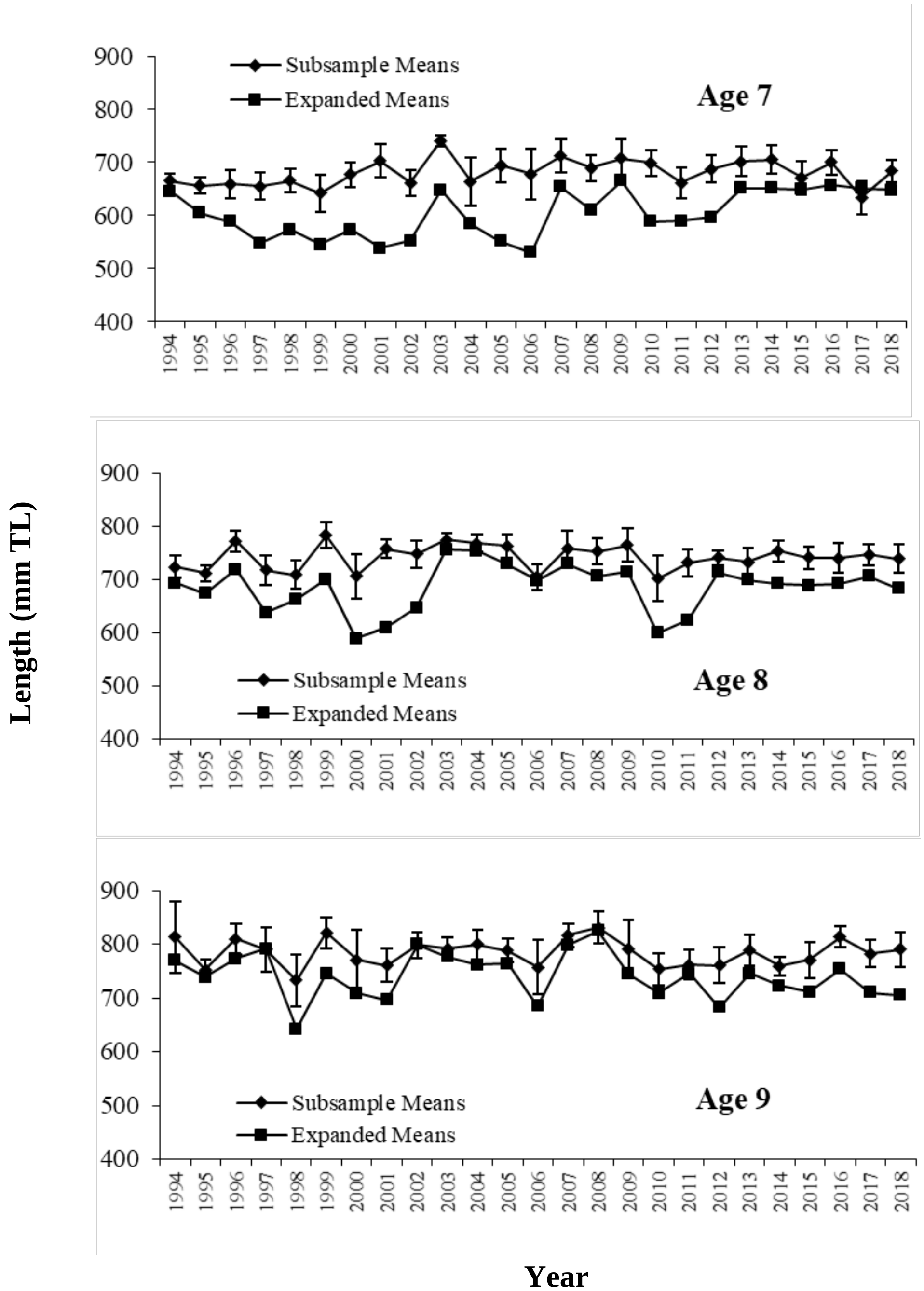
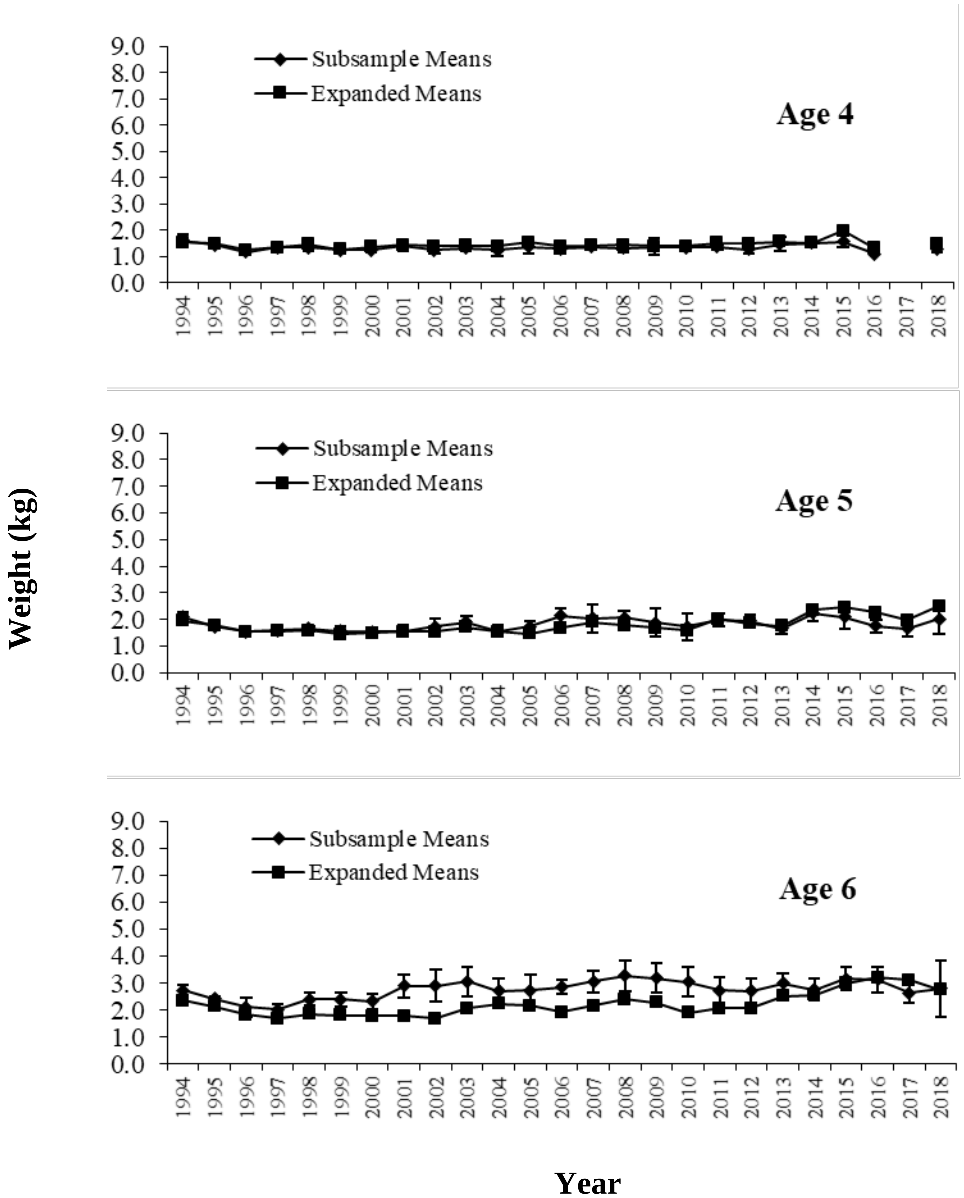


Figure 5. Mean weights (kg) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994 - 2018 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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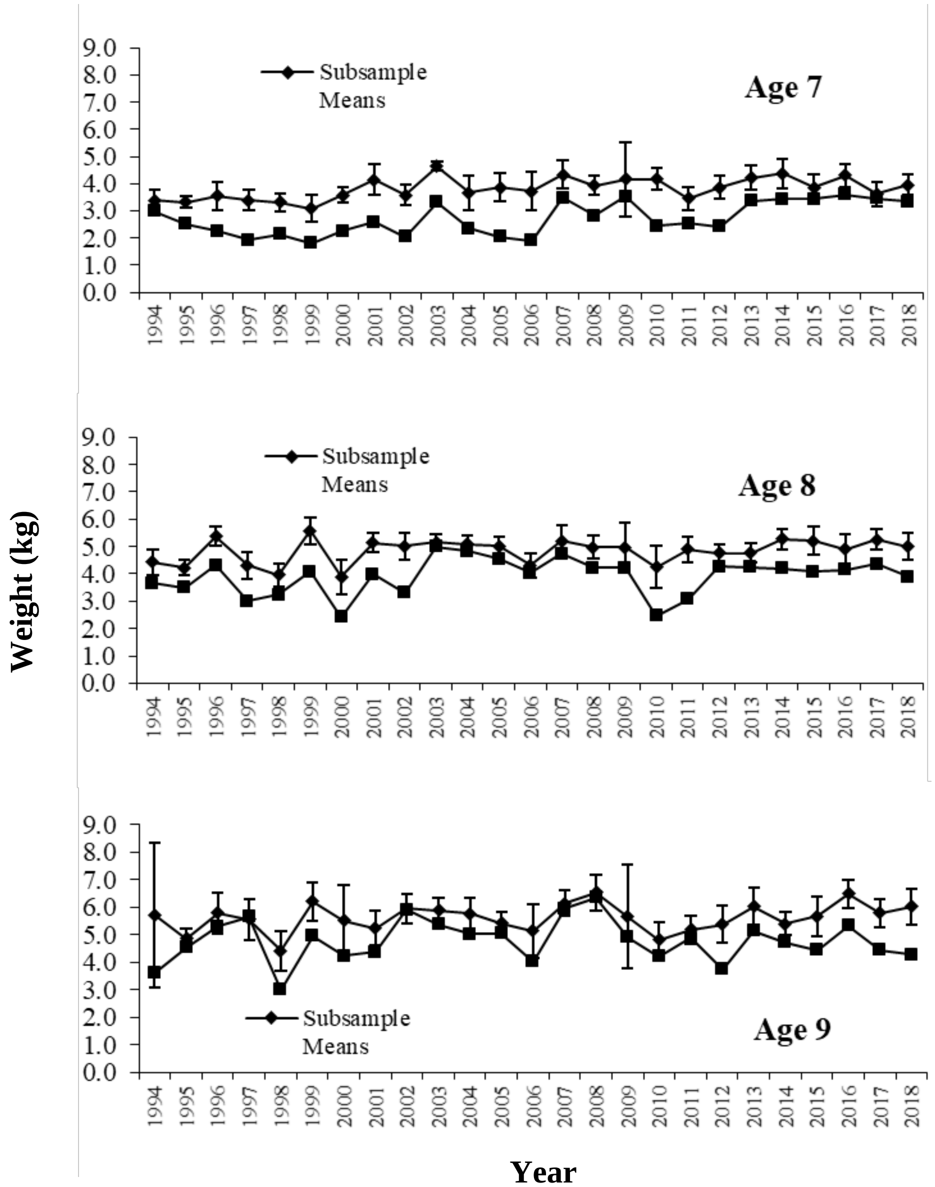

PROJECT NO. 2
JOB NO. 3
TASK NO. 1C

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 characterize the size and age structure of commercially harvested striped bass from Maryland's Atlantic coast. Trawls and gill nets were permitted during the Atlantic season within state waters (to 3 miles offshore). The 2018 season opened October 1, 2017 and ended May 31, 2018. The 2018 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 2017 – May 2018 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 2017 – May 2018 Atlantic fishery, the year used for age calculations was 2018. 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 3,638 fish landed during the 2017 – 2018 Atlantic coast season (Table 1) (Chris Jones, Data Management and Quota Monitoring Program, Personal Communication). This was a slight increase over the previous two years, but still 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 twelve days between November 2017 and May 2018. A total of 380 fish was measured for length and weight, and fish ages were determined directly from 218 scale samples. Commercial fishermen have a limited area to harvest striped bass (~62 square miles) within Maryland waters. During the 2018 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 seventeen year-classes were represented in the sampled harvest, ranging from age 4 (2014 year-class) to age 20 (1998 year-class) (Table 1; Figure 2). The most frequent age represented in the catch-at-age estimate was age 7, the 2011 year-class, which represented 22% 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 13 (2005 year-class) fish were also significant contributors to the sample population at 17% (Table 1; Figure 2).

Striped bass sampled at Atlantic coast check stations during the 2017 – 2018 season had a mean length of 919 mm TL and mean weight of 9.3 kg. The sample length distribution was bimodal and ranged from 595 to 1174 mm TL (Figure 3). The weight of fish sampled ranged from 2.3 to 21.8 kg. Age 7 striped bass (2011 year-class), the most abundant age group sampled, had a mean length of 742 mm TL and mean weight of 4.2 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

2018-2019 SEASON PRELIMINARY RESULTS – WORK IN PROGRESS

A total of 187 striped bass were sampled and 187 scale samples were collected from the harvest between October 2018 - May 2019. The average length was 920 mm and ranged in length from 617 mm to 1192 mm TL. The average weight was 9.54 kg and ranged in weight from 2.27 kg to 18.60 kg. Fish were sampled at two check stations in Ocean City, MD. Check stations were visited by biologists one time in November, one time in December, six times in April, and eight times in May.

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 is ongoing and complete results of harvest-, length-, and weight-at-age will be provided in the next F-61 Chesapeake Bay Finfish Investigations report.

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Table 3. Mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, October 2017 – May 2018. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

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Figure 2. Age distribution of striped bass sampled from the Atlantic coast fishery, 2007 – 2018 seasons.

Figure 3. Length distribution of striped bass sampled from the Atlantic coast fishery, 2007 – 2018 seasons. *Note different x and y-axis scale for 2015 – 2018.

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 – 2018 (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.

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 – 2018 (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.

Table 1. Estimated harvest-at-age of striped bass (numbers of fish) landed by the Maryland Atlantic coast commercial fishery, October 2017 – May 2018.

Year-Class	Age	Number of Fish	Percent
2014	4	69	1.9
2013	5	158	4.3
2012	6	92	2.5
2011	7	812	22.3
2010	8	190	5.2
2009	9	124	3.4
2008	10	142	3.9
2007	11	328	9.0
2006	12	106	2.9
2005	13	633	17.4
2004	14	341	9.4
2003	15	336	9.2
2002	16	176	4.8
2001	17	85	2.3
2000	18	26	0.7
1999	19	10	0.3
1998	20	12	0.3
Total*		3,640	100

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

Table 2. Mean total lengths (mm TL) by year-class of striped bass sampled from Atlantic coast fishery, October 2017 – May 2018. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

Year-Class	**Age**	**n Fish Aged**	**Mean TL (mm)**	**LCL**	**UCL**
2014	4	4	637	594	681
2013	5	10	639	619	660
2012	6	6	707	643	770
2011	7	53	742	724	759
2010	8	15	780	736	824
2009	9	9	836	742	931
2008	10	10	948	892	1003
2007	11	18	979	934	1024
2006	12	6	990	932	1047
2005	13	29	1029	1002	1057
2004	14	18	1060	1016	1104
2003	15	19	1096	1069	1124
2002	16	11	1077	1020	1135
2001	17	6	1133	1077	1188
2000	18	2	1121	1032	1210
1999	19	1	1152		
1998	20	1	1128		
Total		**218**			

Table 3. Mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, October 2017 – May 2018. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

Year-Class	**Age**	**n Fish Aged**	**Mean Weight (kg)**	**LCL**	**UCL**
2014	4	4	2.9	2.3	3.6
2013	5	10	3.1	2.7	3.5
2012	6	6	3.7	2.9	4.6
2011	7	53	4.2	3.9	4.4
2010	8	15	5.3	4.4	6.3
2009	9	9	6.7	4.6	8.7
2008	10	10	9.2	7.6	10.9
2007	11	18	9.9	8.9	10.8
2006	12	6	11.5	9.7	13.4
2005	13	29	12.0	10.9	13.1
2004	14	18	13.3	11.8	14.8
2003	15	19	15.1	14.4	15.9
2002	16	11	14.6	12.5	16.7
2001	17	6	18.0	14.8	21.1
2000	18	2	16.1		
1999	19	1	16.0		
1998	20	1	15.9		
Total		**218**			

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

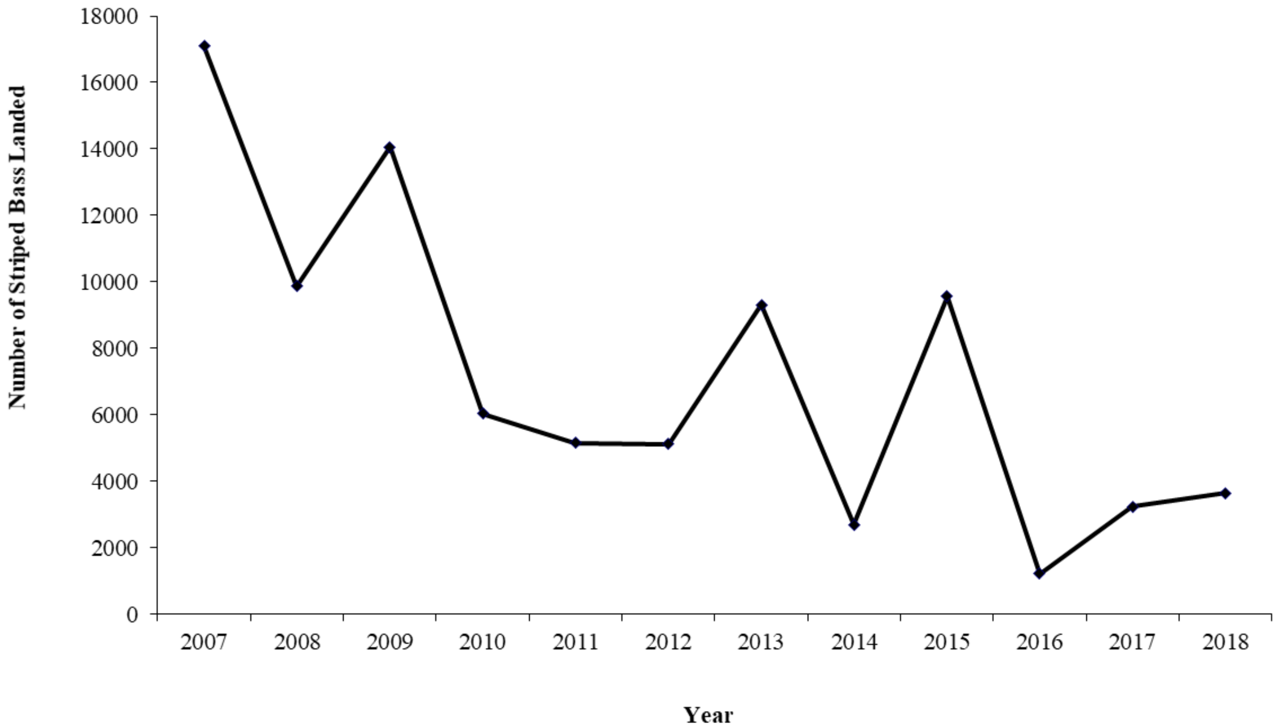


Figure 2. Age distribution of striped bass sampled from the Atlantic coast fishery, 2007 – 2018 seasons.

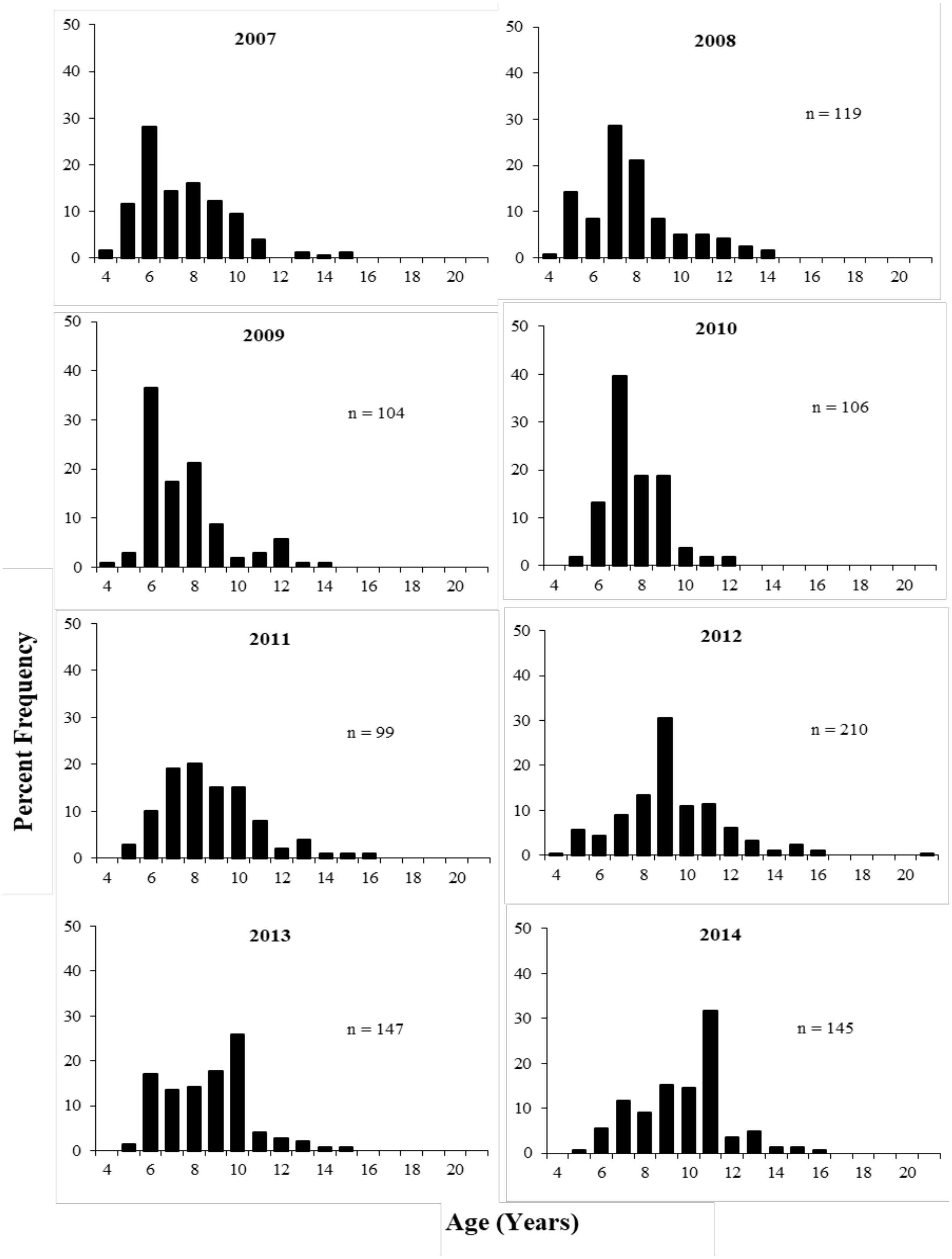


Figure 2. Continued.

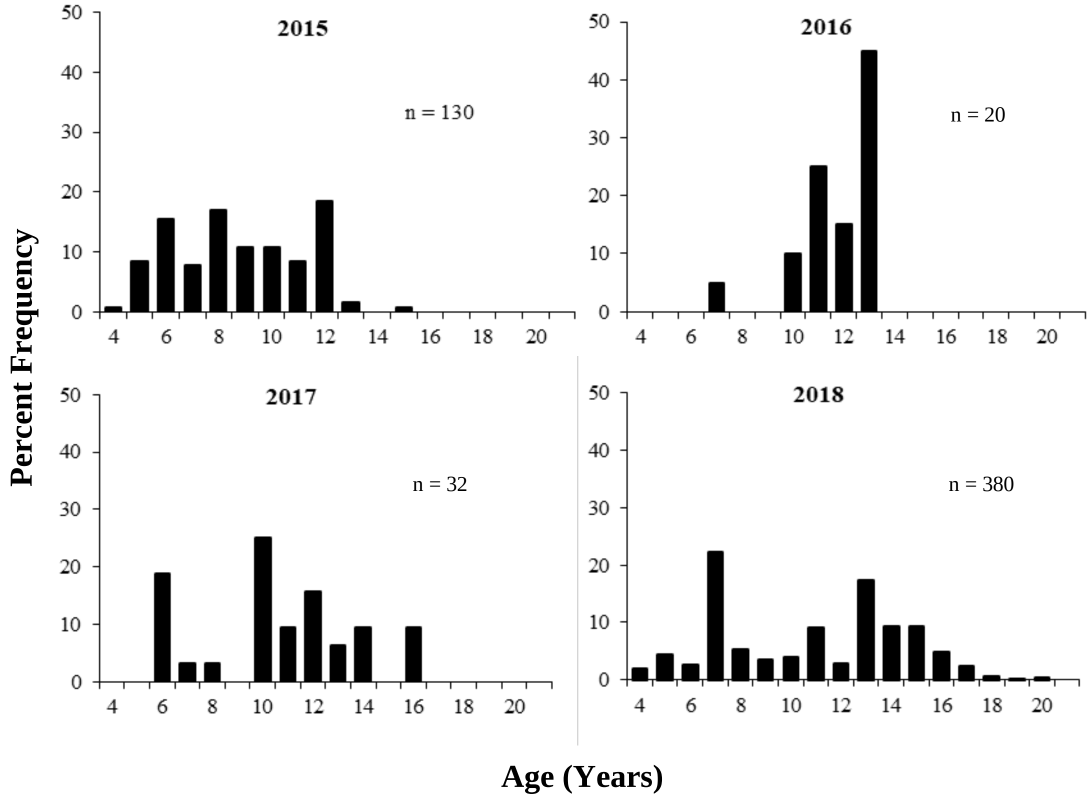


Figure 3. Length distribution of striped bass sampled from the Atlantic coast fishery, 2007 – 2018 seasons. *Note different x and y-axis scale for 2015 – 2018.

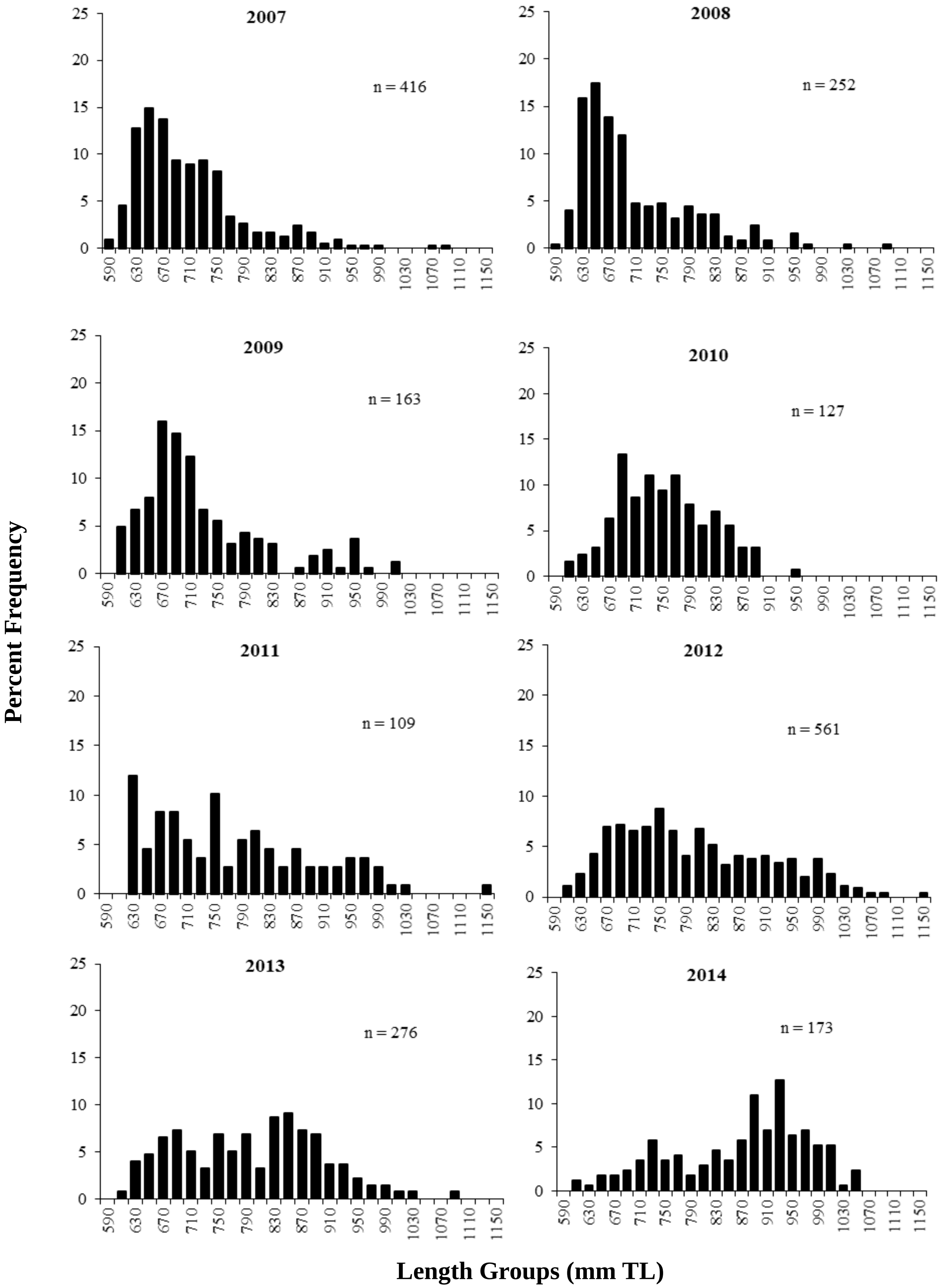


Figure 3. Continued

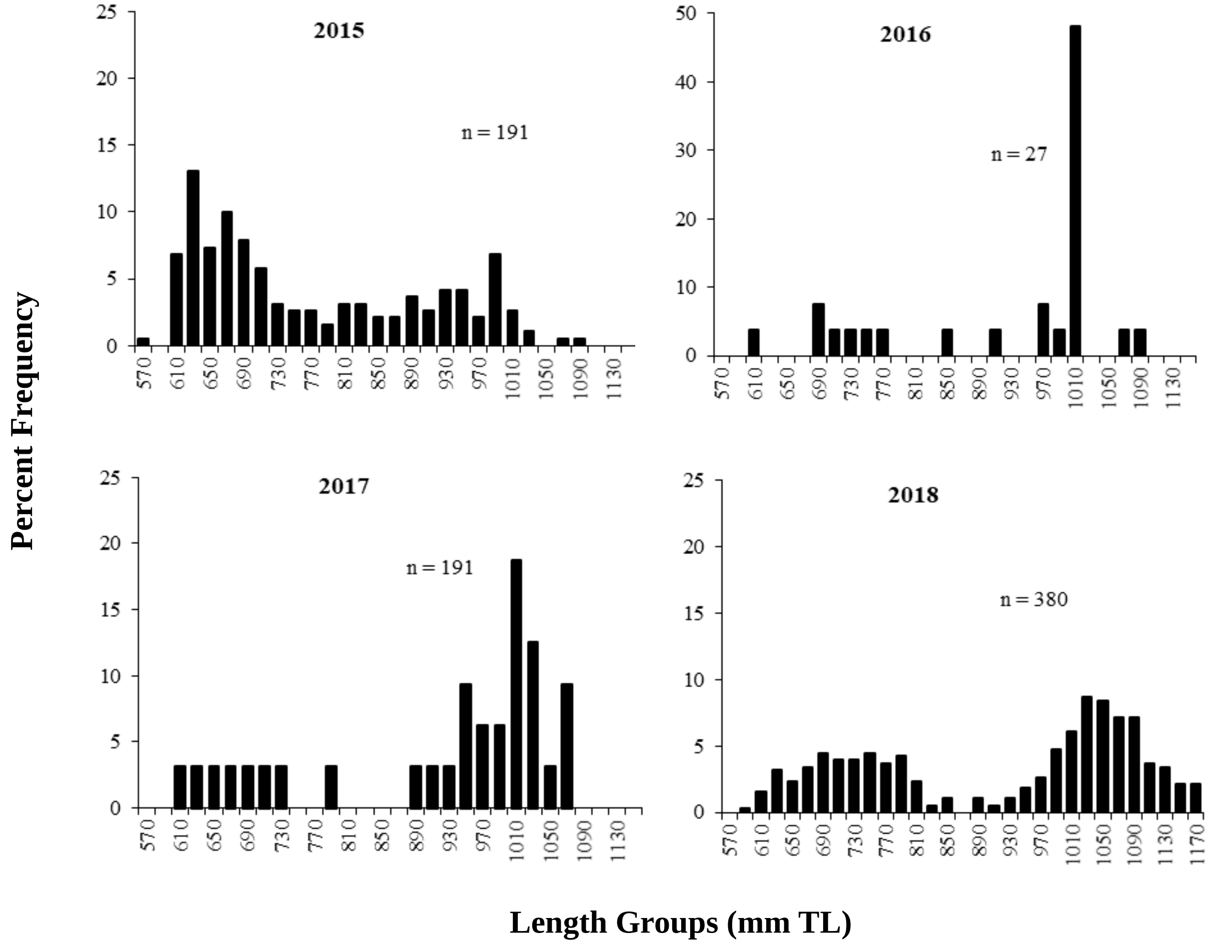


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2007 – 2018 (95% confidence intervals included when permitted by sample size). Expanded means (estimated 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.

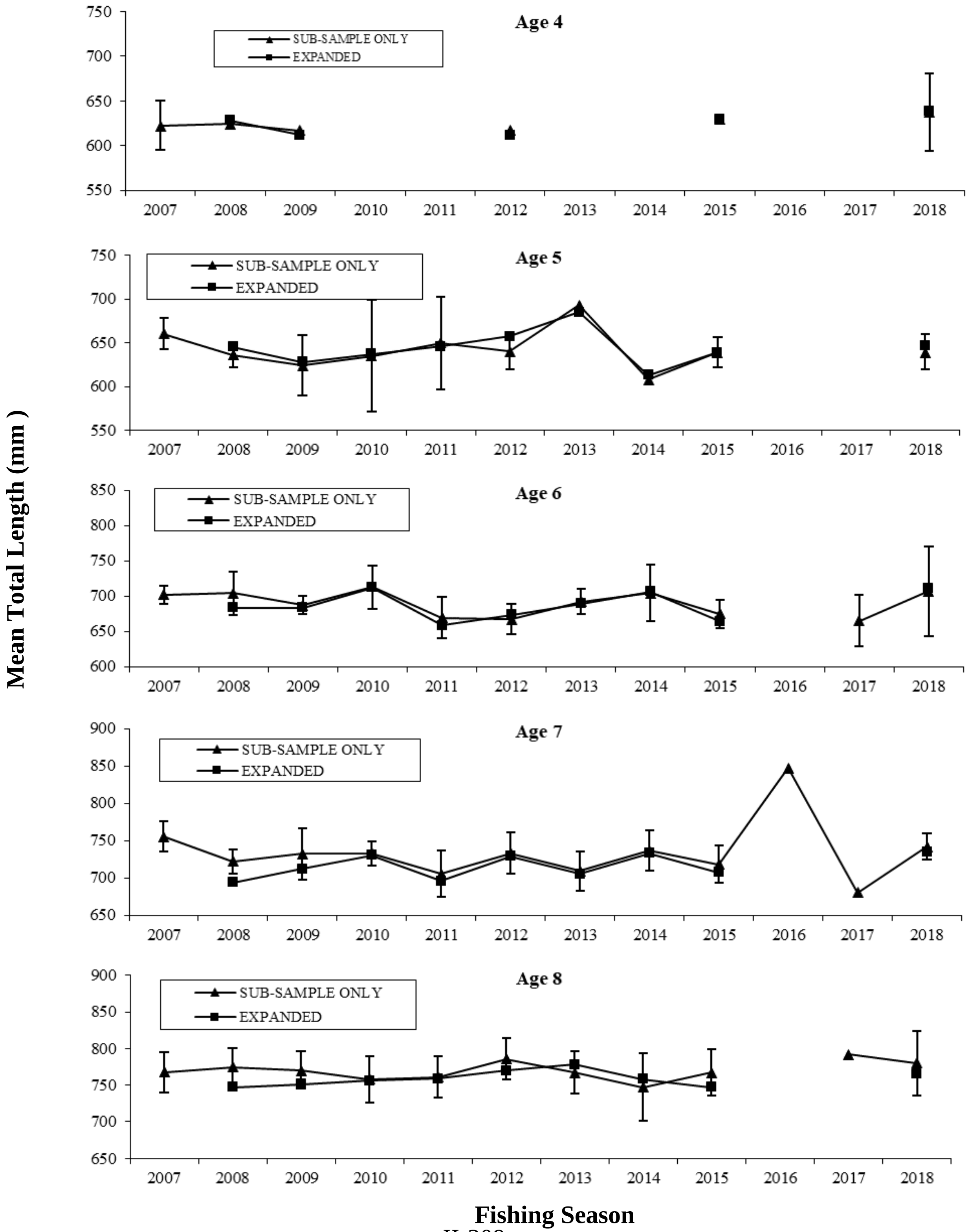


Figure 4. Continued

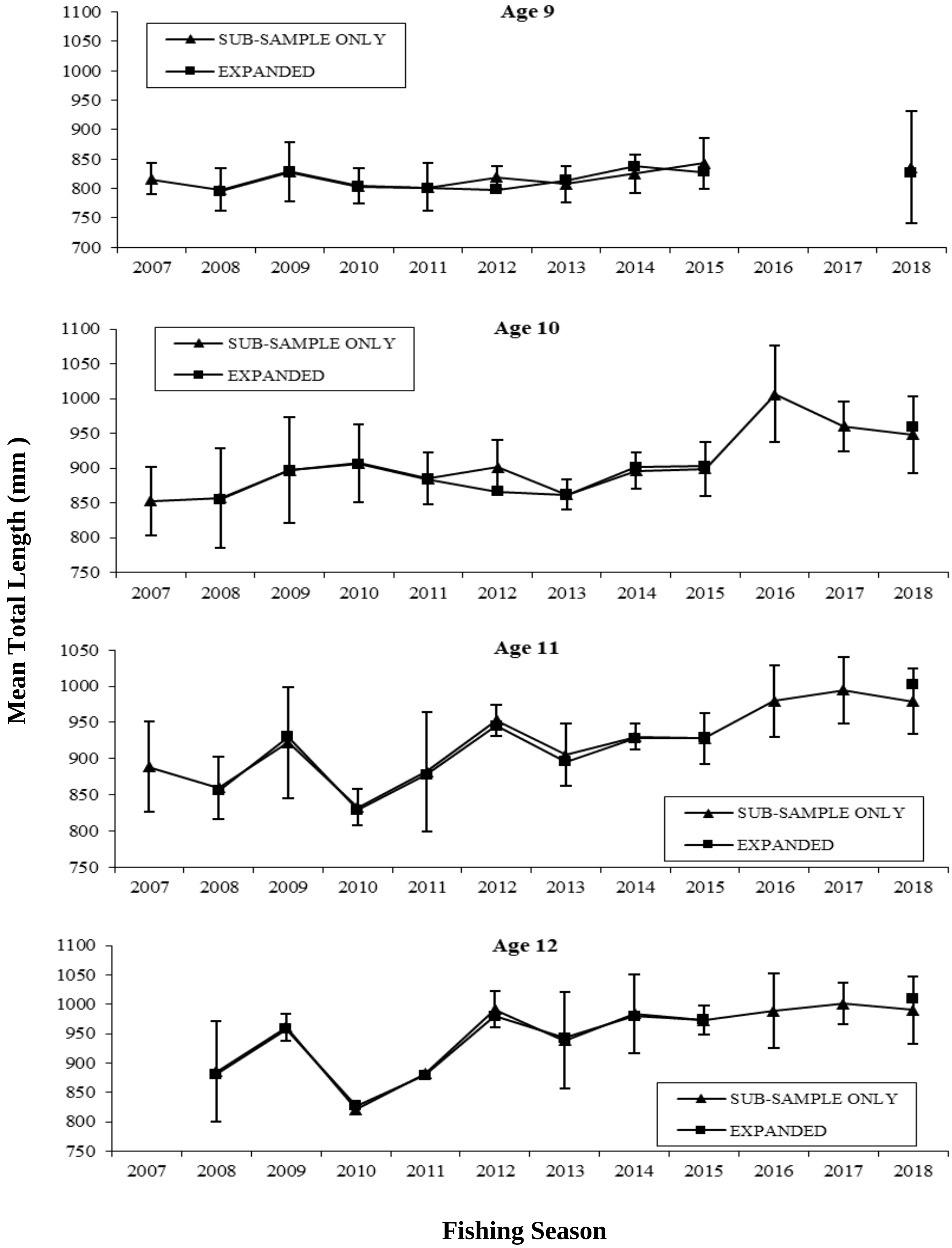


Figure 5. Mean weight (kg) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2007 – 2018 (95% confidence intervals included when permitted by sample size). Expanded means (estimated from entire sample) are also shown, but were not calculated in 2016 and 2017 as all samples were chosen for aging. *Note different y-axis scales.

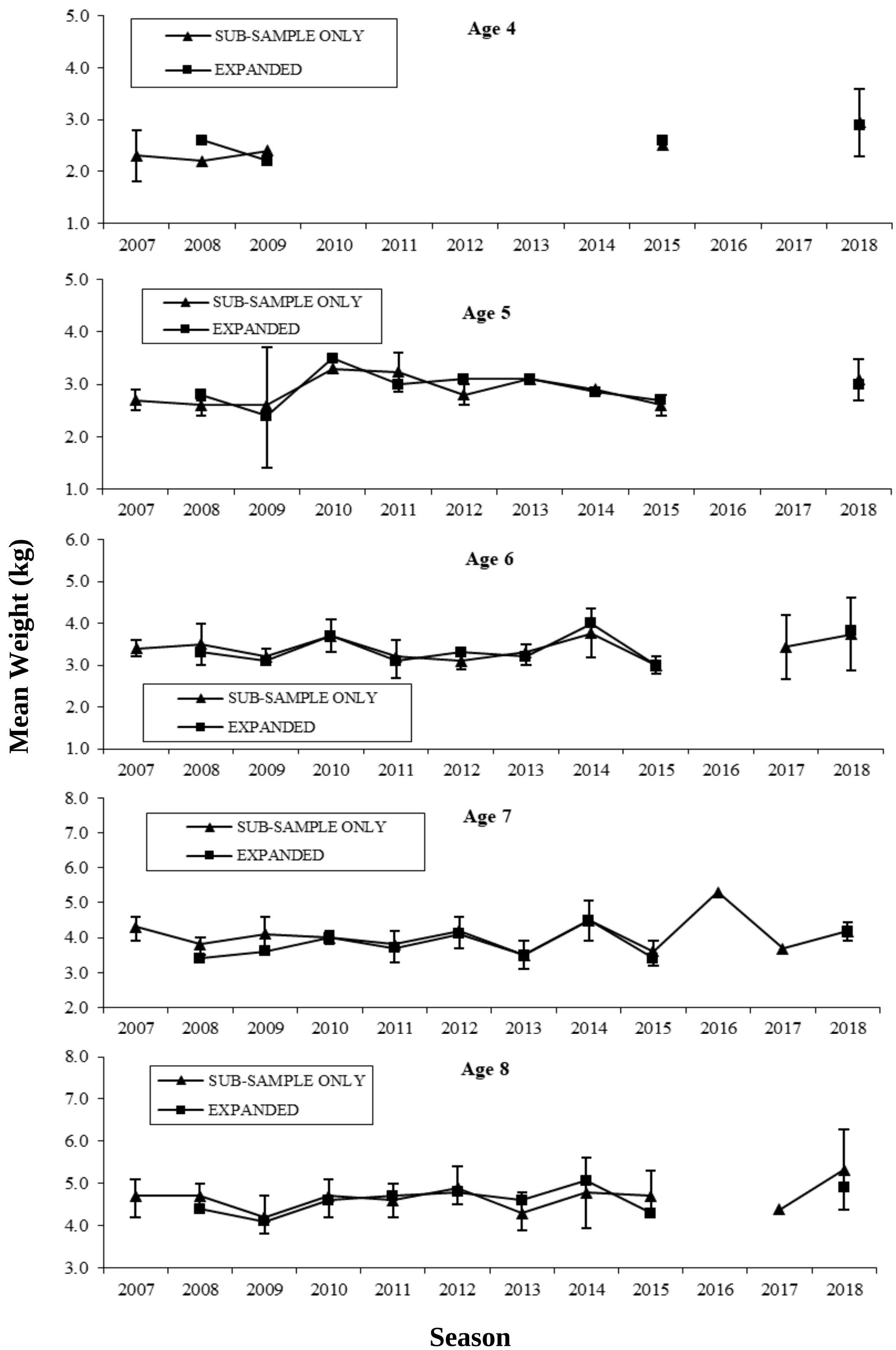
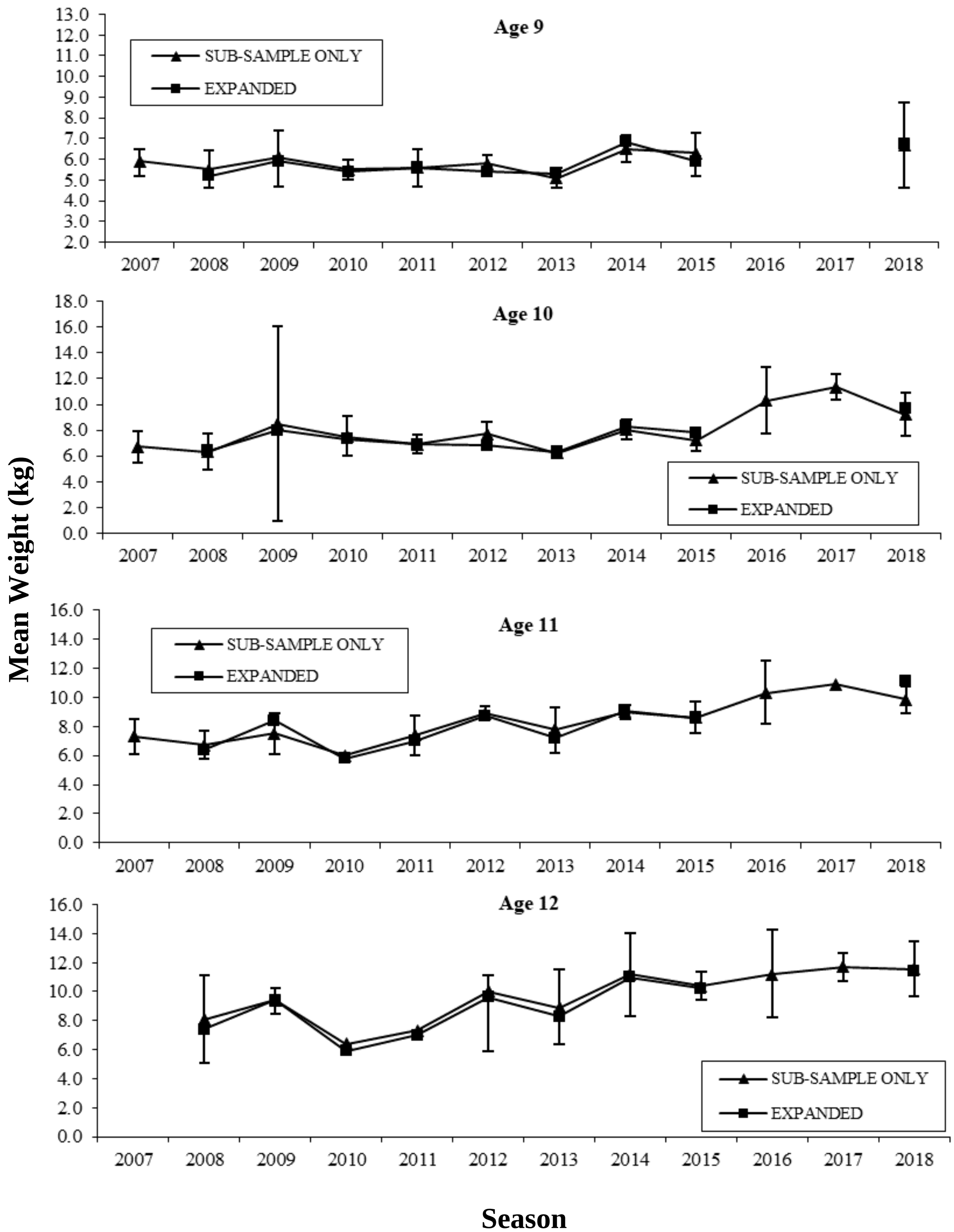


Figure 5. Continued



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 objective of Project 2, Job 3, Task 2 was to estimate relative abundance-at-age for striped bass in Chesapeake Bay during the 2018 spring spawning season. 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 2018 (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 31 sample days. In the Upper Bay, sampling was conducted from April 5 to May 18 for a total of 37 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. 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. Between each panel, there were gaps of 5 to 10 feet. Overall soak times for each panel ranged from 11 to 131 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, per week, for a maximum of 10 scale samples per length group over the entire season. Scales were also 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 patterns and 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 469 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 2018 un-weighted CPUEs decreased relative to the previous year. Female catches were unusually low on the Potomac in 2018. The 2018 un-weighted CPUE for Potomac females (8) was the second lowest value in the time-series, well below the average of 26 (Table 2). The un-weighted CPUE for Potomac males (527) was the only increase observed, and was above the time-series average of 433 (Table 3). The Upper Bay female CPUE (37) was below the time-series average (43) for the first time in seven years and ranked 18th in the 34 years of the survey (Table 4). The un-weighted CPUE for Upper Bay males (479) was slightly lower than 2017, and above the average of 457 (Table 5). The abundant 2011 year-class (age 7 fish) held the highest 2018 age-class CPUE values for female fish in both systems. Age 3 and 4 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 2018 selectivity-corrected, total, weighted CPUE (523) ranked 11th in the 34 year survey, above the time-series average of 495.

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 2018 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.

The above-average 2015 year-class was the most prevalent cohort in the spawning stock this year, composing 36% of the total CPUE, followed closely by the 2014 year-class at 27%. Upper Bay fish made up 61% of the total CPUE. Males were most frequently encountered, composing 95% 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 50%, followed by the 2014 year-class at 28%. In the Upper Bay, the 2015 year-class contributed 30% to the male CPUE and the 2014 year-class contributed 28%. Older males were not frequently encountered. In both systems, 67% of the male CPUE was made up of fish ages 4 and younger.

Historically the female contribution has been less than 10% to each system's CPUE. The female contribution to the Upper Bay CPUE was 7%, and 1% to the Potomac CPUE. Female CPUEs were distributed across many year-classes in both systems, with 7 year-old female fish from the 2011 year-class contributing the most to each system's female CPUE (24% in Potomac, 27% in Upper Bay). Females from the age 15+ group, comprised mainly of 15 year old fish from the 2003 year-class contributed similarly in both systems (24% in Potomac, 27% in Upper Bay). One 22 year-old female from the dominant 1996 year-class was sampled in the Upper Bay.

Temperature and catch patterns

Daily surface water temperature on the Potomac River was 9°C at the start of the survey, and increased to 14°C through the month of April. Water temperature was 20°C when the survey ended on May 10. Female CPUEs were low through the entire survey (Figure 2). Catches were slightly more concentrated during the last week of April, as water temperature began to steadily rise. The largest peaks in male CPUE were also observed during the last week of April and into early May, as water temperatures warmed and passed the 14°C mark necessary to initiate spawning (Fay et al., 1983).

Upper Bay surface water temperatures remained cold for the month of April, not reaching spawning temperatures in the survey area until the beginning of May. The Conowingo Dam was discharging water at above average rates for the majority of April, which kept water temperatures down. The survey began at 9°C, slowly increased through April, then quickly increased in May to 21°C by the 15th. The highest catches of females occurred on April 14, 17 and 18, coinciding with a small spike in water temperature (Figure 3) and a decrease in dam discharge. Female catches remained low, but consistent, for the remainder of the survey. The first peak in male CPUE was on April 17, coinciding with the high female catches. The largest peak in male CPUE occurred on April 27, as the water warmed to 13°C. Good catches continued into the first week of May as temperatures increased rapidly.

Length composition of the stock

In 2018, a total of 2,426 striped bass was measured. On the Potomac River, 748 male and 22 female striped bass were measured; 1,563 males and 93 females were measured from the

Upper Bay (Figure 4). The mean length of female striped bass (962 ± 35 mm TL) was significantly larger than the mean length of male striped bass (456 ± 5 mm TL, P < 0.0001), consistent with the known biology of the species. Mean lengths are presented with 2 standard errors.

Mean lengths of male striped bass collected from the Potomac River (433 ± 7 mm TL) were significantly shorter than those sampled in the Upper Bay (467 ± 6 mm TL, P < 0.0001). This difference is also evident in the length distributions of male fish (Figure 4).

Male striped bass on the Potomac ranged from 260 to 1122 mm TL. Small males between 330 and 470 mm TL composed 73% of the Potomac River male catch in 2018, representing fish from the above average 2015 and 2014 year-classes (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 284 to 1070 mm TL. The peak in the length frequency between 330-450 mm TL (57% of catch; Figure 4) likely represents the younger males from the 2015 and 2014 year-classes. Male CPUE in the Upper Bay was more evenly distributed among length groups than in the Potomac, and mainly represented the 2015 through 2011 year-classes (Figure 5).

Female striped bass sampled from the Potomac River (959 ± 74 mm TL) in 2018 were similar in length to those in the Upper Bay (963 ± 40 mm TL; P=0.922). Female striped bass on the Potomac ranged from 673 to 1224 mm TL, while females sampled in the Upper Bay ranged from 497 to 1263 mm TL (Figure 4). Length distributions in both systems displayed similar bimodal patterns. The peaks in both systems between 670 and 750 are young females from the 2011 year-class. The larger peaks between 990 and 1070 mm TL likely represent the 2005 through 2001 year-classes.

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, representing 17 year-classes (Figure 6). The large peak in selectivity-corrected CPUE at 630 mm resulted from one fish caught in small mesh net, with a low selectivity for its size group. The peaks in the uncorrected CPUEs at 670 and 1050 mm TL represented the above-average 2011 and 2005 year-classes, respectively. Application of the selectivity model to the data corrected the catch upward in the larger end of the length distributions, where fewer fish were available and likely not captured efficiently.

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 2018 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 2018, Potomac River female sample sizes were small. 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 2018 ($\alpha > 0.05$). Age 9 female fish were significantly longer on the Upper Bay (968 mm TL) than the Potomac River (803 mm TL, $P=0.0486$). Age 5 males were significantly shorter on the Upper Bay (501 mm TL) than the Potomac River (588 mm TL, $P=0.034$).

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 2017 and 2018 for all ages except for age 6 (P=0.017) and age 7 (P<0.0001). Six year-old males in 2018 were significantly shorter than 6 year-olds in 2017. Age 7 males in 2018 were significantly shorter than 7 year-old fish were in 2017. Mean lengths of females were similar in 2017 and 2018 for all ages except age 6 (P=0.0106), age 14 (P=0.035) and age 16 (P=0.0029). Age 14 females in 2018 (1086 mm TL) were significantly longer than age 14 fish in 2017 (1049 mm TL).

Age composition of the stock

Eighteen age-classes, ranging from 2 to 22 were encountered (Tables 14 and 15). Of the 223 male fish aged from the survey (Table 1), ages 7 and 3 (2011 and 2015 year-classes) were the most commonly encountered. On the Potomac River, the males encountered ranged from age 2 through 14, while on the Upper Bay, males ages 3 through 14 were captured. Females ranged in age from 7 to 19 on the Potomac River, and 5 to 22 on the Upper Bay. Of the 105 aged female scales (Table 1), age 15 females from the above average 2003 year-class were most commonly observed, followed by age 7 females from the dominant 2011 year-class. One female from the largest year-class recorded in Maryland, 1996, was sampled on the Upper Bay.

The abundance of ages 2 to 5 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 2017, nine of the fourteen age-specific CPUEs decreased in 2018. The contribution of the 15+ age group has been strong for the past nine years, driven by older females (Figure 9).

The contribution of age 8+ females to the total female CPUE decreased slightly from last year to 63% (Figure 10). 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. Their contribution to the spawning stock has been fairly stable (61-66%), but below the time-series average (71%) for the last three years, likely due to low reproduction in the late 2000s and the recruitment of the young 2011 year-class (age 7 in 2018) females to the spawning stock.

The percentage of the overall sample (males and females combined) age 8 and older has been variable since 1997 (Figure 11). The 2018 value of 10% was the lowest since 1999. 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, 2013, and 2011 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), but Maryland's Chesapeake Bay estimates showed an increase from 2011 to 2015. 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 2018 ISP value of 323 was well below the high values of that previous period, and below the time-series average of 353 (Table 16, Figure 12). The 2018 Potomac River female ISP of 73 was the lowest value since 1990.

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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

2019 PRELIMINARY RESULTS

Data collected during the 2019 spring spawning season are currently being analyzed. In the Potomac River in 2019, 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.

Scale samples are currently being processed and aged, therefore no CPUE estimates are available at this time. A total of 766 scales were collected for use in creating the sex-specific ALKs. In the Potomac River, a total of 459 striped bass were sampled, 448 males, 10 females and one of unknown sex. Of those 459 fish, 306 (67%) were tagged with U. S. Fish and Wildlife Service internal anchor tags. In the Upper Bay, at total of 1,687 striped bass were captured, 1,596 males, 90 females and one of unknown sex. Of the 1,687 fish encountered, 798 (47%) were tagged.

Male striped bass on the Potomac ranged from 291 to 1087 mm TL, with a mean of 469 mm TL. Male striped bass on the Upper Bay ranged from 221 to 1044 mm TL, with a mean of 466 mmd TL. Female striped bass sampled from the Potomac ranged from 858 to 1206 mm TL, with a mean of 1088 mm TL. Upper Bay female striped bass ranged from 506 to 1322 mm TL, and had a mean of 955 mm TL.

The final, complete analyses of the spring 2019 spawning stock survey data will appear in the next F-61 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**
250	0	1	0	**1**	0	0	0	**0**
270	0	1	0	**1**	0	0	0	**0**
290	3	3	0	**6**	0	0	0	**0**
310	3	3	0	**6**	0	0	0	**0**
330	3	3	0	**6**	0	0	0	**0**
350	3	3	0	**6**	0	0	0	**0**
370	3	4	0	**7**	0	0	0	**0**
390	3	3	0	**6**	0	0	0	**0**
410	3	2	0	**5**	0	0	0	**0**
430	3	4	0	**7**	0	0	0	**0**
450	3	2	0	**5**	0	0	0	**0**
470	3	3	0	**6**	0	0	2	**2**
490	3	3	0	**6**	1	0	2	**3**
510	4	3	0	**7**	2	0	5	**7**
530	2	3	0	**5**	0	0	2	**2**
550	3	3	0	**6**	1	0	6	**7**
570	5	5	0	**10**	0	0	3	**3**
590	5	5	0	**10**	1	0	3	**4**
610	5	5	0	**10**	1	0	1	**2**
630	5	6	0	**11**	1	0	1	**2**
650	5	4	0	**9**	2	0	2	**4**
670	5	5	0	**10**	6	1	3	**10**
690	7	4	0	**11**	2	1	1	**4**
710	12	2	0	**14**	3	1	5	**9**
730	11	5	0	**16**	1	2	1	**4**
750	5	1	2	**8**	1	1	1	**3**
770	8	3	2	**13**	0	0	0	**0**
790	4	0	1	**5**	1	0	1	**2**
810	2	0	1	**3**	0	1	0	**1**
830	1	0	3	**4**	0	0	0	**0**
850	1	1	1	**3**	0	0	0	**0**
870	1	0	2	**3**	2	0	1	**3**
890	1	0	1	**2**	0	0	2	**2**
910	1	0	2	**3**	0	0	3	**3**
930	2	0	0	**2**	1	0	2	**3**
950	0	0	2	**2**	0	1	5	**6**
970	0	0	2	**2**	1	0	8	**9**
990	2	0	1	**3**	6	1	6	**13**
1010	1	0	0	**1**	6	0	10	**16**
1030	0	0	3	**3**	5	5	4	**14**
1050	0	0	0	**0**	8	1	7	**16**
1070	1	0	0	**1**	8	3	7	**18**
1090	0	0	0	**0**	5	1	3	**9**
1110	0	0	0	**0**	4	0	9	**13**
1130	0	1	0	**1**	5	0	3	**8**
1150	0	0	0	**0**	2	1	4	**7**
1170	0	0	0	**0**	2	1	1	**4**
1190	0	0	0	**0**	1	0	1	**2**
1210	0	0	0	**0**	2	0	0	**2**
1230	0	0	0	**0**	0	1	0	**1**
1250	0	0	0	**0**	1	0	1	**2**
1270	0	0	0	**0**	1	0	1	**2**
1290	0	0	0	**0**	0	0	1	**1**
Total	**132**	**91**	**23**	**246**	**83**	**22**	**118**	**223**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2018 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**
Average																**26**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2018 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**
Average																**433**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985-2018 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**
Average																**43**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985-2018 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**
Average																**457**

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 (1985–2018) 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**
Average																**495**

Table 9. Lower confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2018) 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	*

* 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 (1985–2018) 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	*

* 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 (1985–2018) 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	*

* 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 2018. 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
2017	1	0.0	0.0	0.0	0.0	0.0	0.0
2016	2	3.6	0.3	0.0	0.0	1.8	1.8
2015	3	406.3	38.7	0.0	0.0	261.2	145.1
2014	4	283.1	27.0	0.0	1.1	148.3	133.7
2013	5	58.1	5.5	0.0	1.9	23.5	32.7
2012	6	50.2	4.8	0.0	1.2	18.8	30.2
2011	7	153.4	14.6	1.9	9.9	51.9	89.7
2010	8	18.4	1.8	0.4	2.1	6.2	9.7
2009	9	15.9	1.5	0.9	1.6	2.3	11.1
2008	10	4.8	0.5	0.1	1.2	0.3	3.1
2007	11	7.5	0.7	0.9	1.4	0.4	4.8
2006	12	3.9	0.4	0.1	0.6	2.2	1.0
2005	13	10.6	1.0	0.7	3.2	2.2	4.5
2004	14	22.5	2.1	0.6	2.5	8.1	11.3
≤2003	15+	11.7	1.1	1.9	9.8	0.0	0.0
Total		1050.2		7.6	36.5	527.2	478.8
% of Total				0.7	3.5	50.2	45.6
% of Sex				17.3	82.7	52.4	47.6
% of System				1.4	7.1	98.6	92.9

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, April through May 2018. 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
2017	1	0.0	0.0	0.0	0.0	0.0	0.0
2016	2	1.8	0.3	0.0	0.0	0.7	1.1
2015	3	189.9	36.3	0.0	0.0	100.7	89.2
2014	4	140.0	26.8	0.0	0.7	57.2	82.2
2013	5	30.3	5.8	0.0	1.2	9.1	20.1
2012	6	26.5	5.1	0.0	0.7	7.2	18.5
2011	7	81.9	15.7	0.7	6.1	20.0	55.1
2010	8	9.8	1.9	0.2	1.3	2.4	6.0
2009	9	9.0	1.7	0.4	1.0	0.9	6.8
2008	10	2.9	0.5	0.1	0.7	0.1	1.9
2007	11	4.3	0.8	0.3	0.9	0.1	3.0
2006	12	1.9	0.4	0.0	0.4	0.9	0.6
2005	13	5.9	1.1	0.3	2.0	0.9	2.8
2004	14	11.8	2.3	0.2	1.5	3.1	7.0
≤2003	15+	6.8	1.3	0.7	6.0	0.0	0.0
Total		522.8		2.9	22.5	203.2	294.2
% of Total				0.6	4.3	38.9	56.3
% of Sex				11.6	88.4	40.8	59.2
% of System				1.4	7.1	98.6	92.9

* 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 2018.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2016	2	POTOMAC	2	289	269	308	2	2
		UPPER	0	-	-	-	-	-
		COMBINED	2	289	269	308	2	2
2015	3	POTOMAC	21	360	335	385	56	12
		UPPER	17	344	320	368	47	11
		COMBINED	38	353	336	370	52	8
2014	4	POTOMAC	14	452	416	489	64	17
		UPPER	13	436	411	462	42	12
		COMBINED	27	445	423	466	54	10
2013	5	POTOMAC	7	588	530	646	62	24
		UPPER	5	501	429	573	58	26
		COMBINED	12	552	505	598	73	21
2012	6	POTOMAC	7	557	529	584	30	11
		UPPER	6	574	518	630	53	22
		COMBINED	13	565	540	589	41	11
2011	7	POTOMAC	30	650	628	672	60	11
		UPPER	48	652	629	675	78	11
		COMBINED	78	651	635	667	71	8
2010	8	POTOMAC	7	719	641	797	84	32
		UPPER	15	730	699	760	56	14
		COMBINED	22	726	698	755	64	14
2009	9	POTOMAC	1	686	-	-	-	-
		UPPER	13	747	709	785	63	17
		COMBINED	14	743	706	779	63	17
2008	10	POTOMAC	1	763	-	-	-	-
		UPPER	3	832	577	1087	103	59
		COMBINED	4	815	671	959	91	45
2007	11	POTOMAC	0	-	-	-	-	-
		UPPER	5	857	742	972	93	41
		COMBINED	5	857	742	972	93	41
2005	13	POTOMAC	0	-	-	-	-	-
		UPPER	6	888	792	983	91	37
		COMBINED	6	888	792	983	91	37
2004	14	POTOMAC	1	1122	-	-	-	-
		UPPER	1	1070	-	-	-	-
		COMBINED	2	1096	*	*	*	*

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

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 2018.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2013	5	POTOMAC	0	-	-	-	-	-
		UPPER	2	503	433	572	8	6
		COMBINED	2	503	433	572	8	6
2012	6	POTOMAC	0	-	-	-	-	-
		UPPER	2	546	*	*	*	*
		COMBINED	2	546	*	*	*	*
2011	7	POTOMAC	6	714	683	746	30	12
		UPPER	14	678	644	713	59	16
		COMBINED	20	689	664	714	54	12
2010	8	POTOMAC	0	-	-	-	-	-
		UPPER	9	805	686	924	155	52
		COMBINED	9	805	686	924	155	52
2009	9	POTOMAC	1	803	-	-	-	-
		UPPER	5	968	901	1034	54	24
		COMBINED	6	940	854	1027	83	34
2008	10	POTOMAC	1	1034	-	-	-	-
		UPPER	2	970	*	*	*	*
		COMBINED	3	991	858	1124	54	31
2007	11	POTOMAC	4	1013	947	1078	41	21
		UPPER	4	1013	955	1072	37	18
		COMBINED	8	1013	983	1043	36	13
2006	12	POTOMAC	0	-	-	-	-	-
		UPPER	2	1043	*	*	*	*
		COMBINED	2	1043	*	*	*	*
2005	13	POTOMAC	3	1029	943	1115	35	20
		UPPER	7	1061	1047	1074	15	6
		COMBINED	10	1051	1033	1069	25	8
2004	14	POTOMAC	3	1084	1068	1099	6	4
		UPPER	9	1086	1049	1124	48	16
		COMBINED	12	1086	1060	1112	41	12
2003	15	POTOMAC	3	1136	895	1377	97	56
		UPPER	21	1095	1073	1118	50	11
		COMBINED	24	1100	1077	1124	56	11
2002	16	POTOMAC	0	-	-	-	-	-
		UPPER	1	1026	-	-	-	-
		COMBINED	1	1026	-	-	-	-
2001	17	POTOMAC	0	-	-	-	-	-
		UPPER	4	1191	1124	1258	42	21
		COMBINED	4	1191	1124	1258	42	21
1999	19	POTOMAC	1	1168	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	1168	-	-	-	-
1996	22	POTOMAC	0	-	-	-	-	-
		UPPER	1	1263	-	-	-	-
		COMBINED	1	1263	-	-	-	-

* 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
Average	**353**	**229**

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, spring 2018.

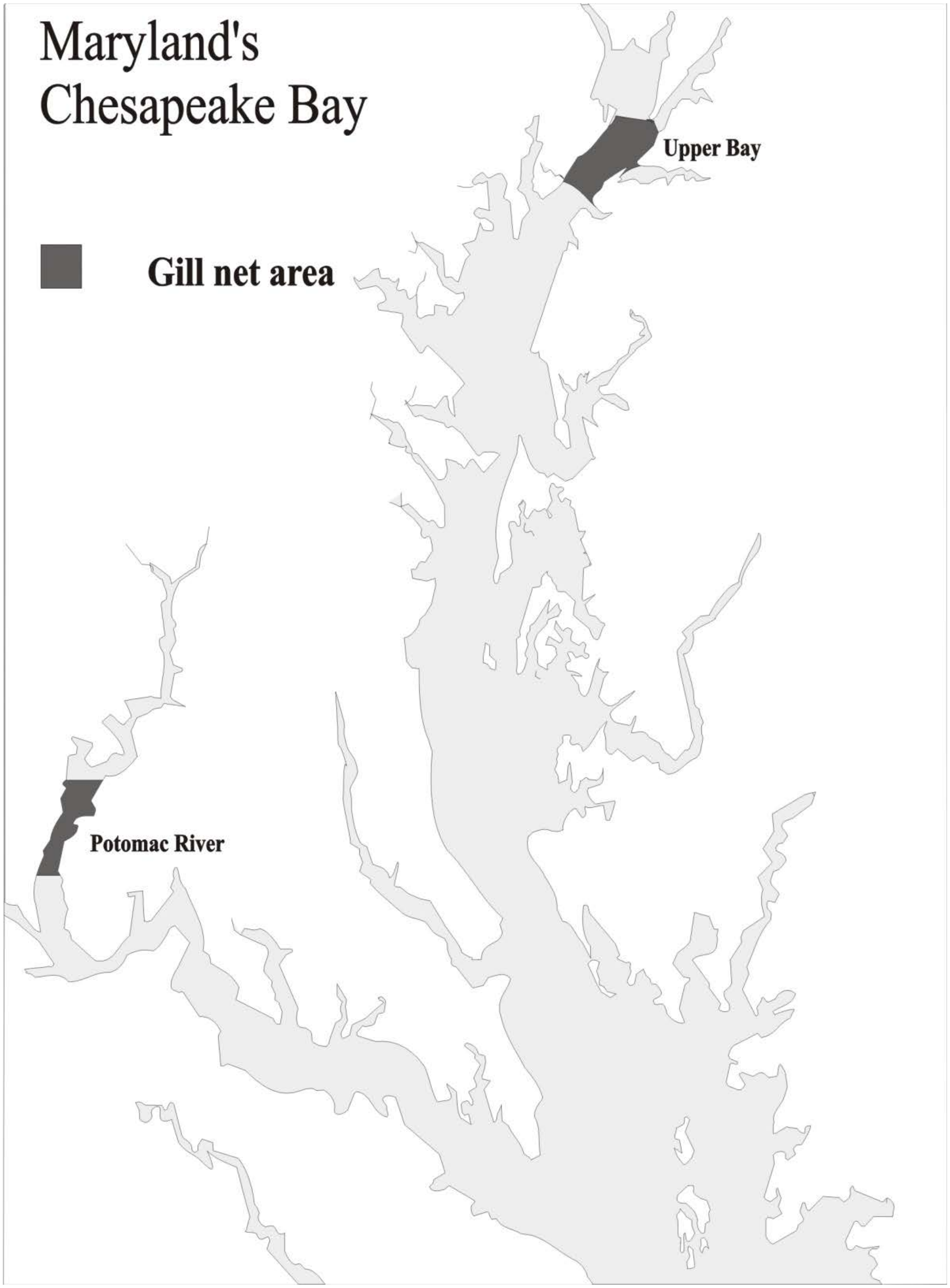
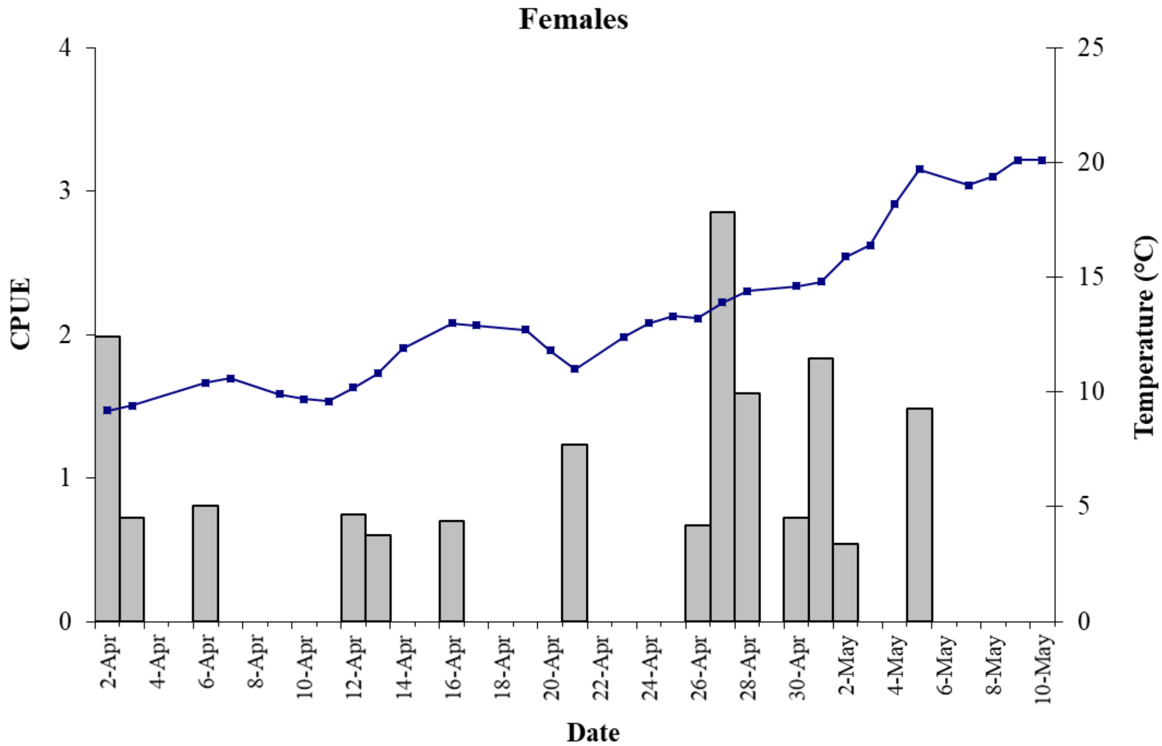


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water temperature in the spawning reach of the Potomac River, April through May 2018. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.



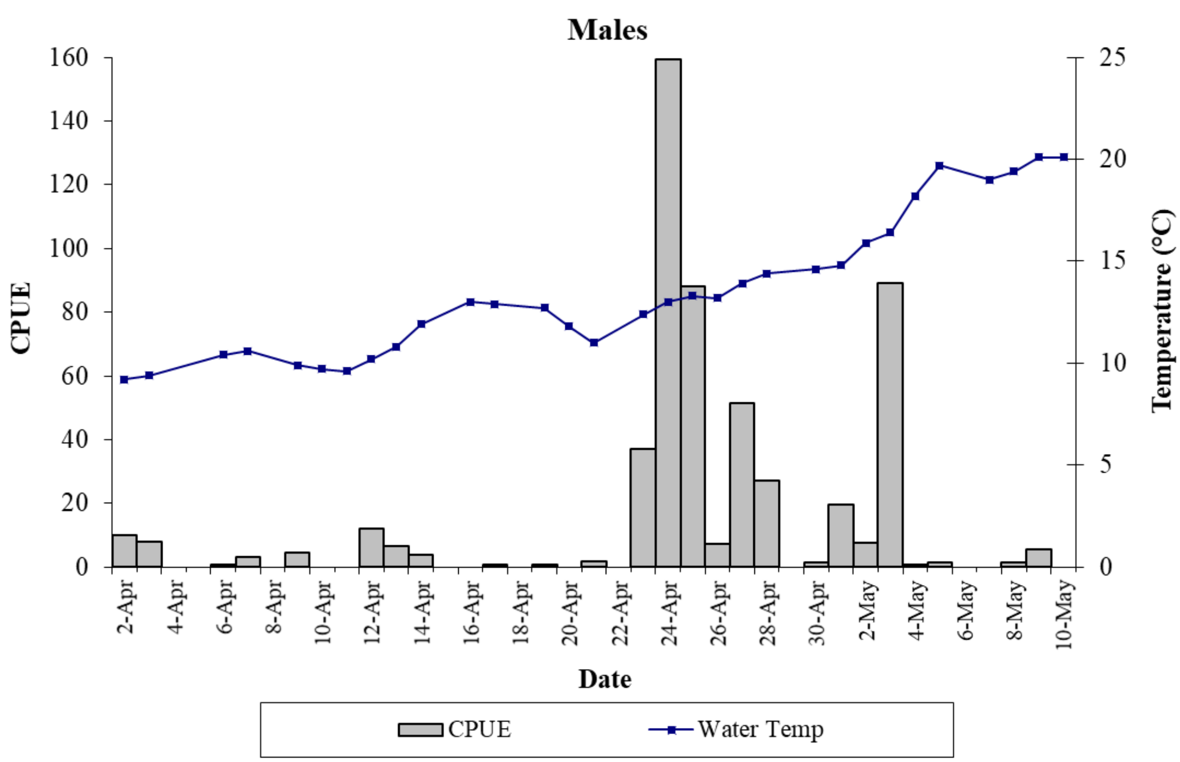
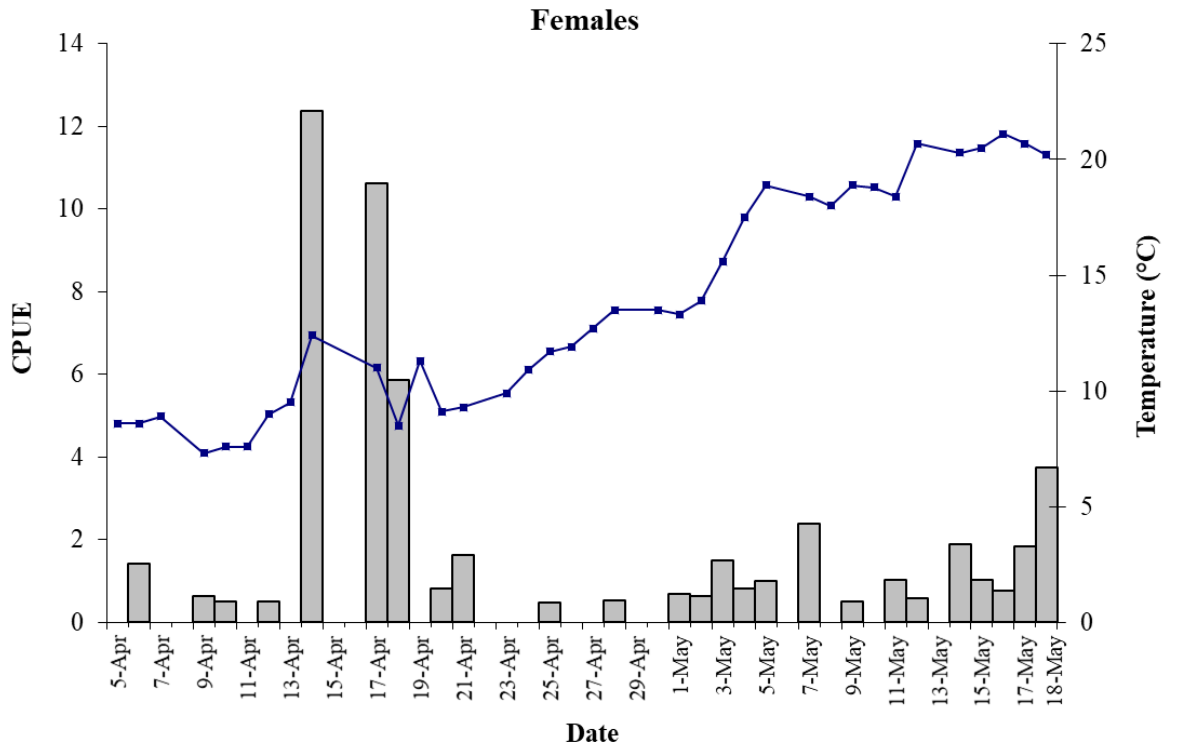


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water temperature in the spawning reach of the Upper Chesapeake Bay, April through May 2018. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.



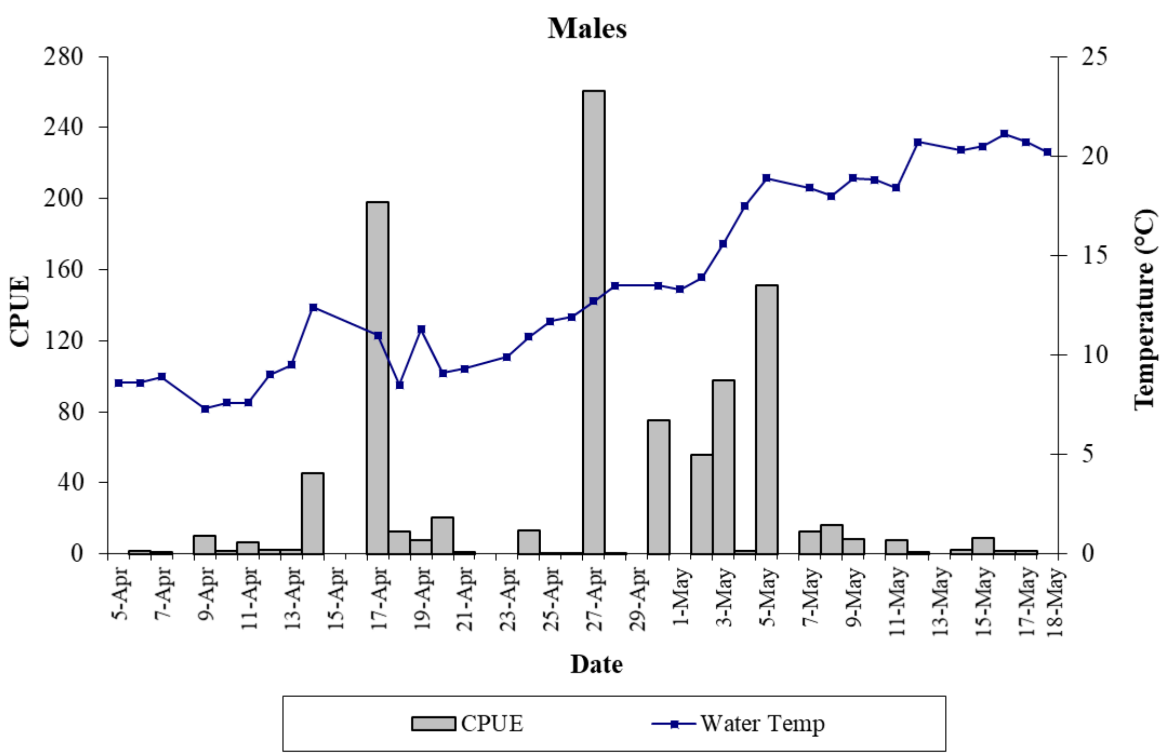
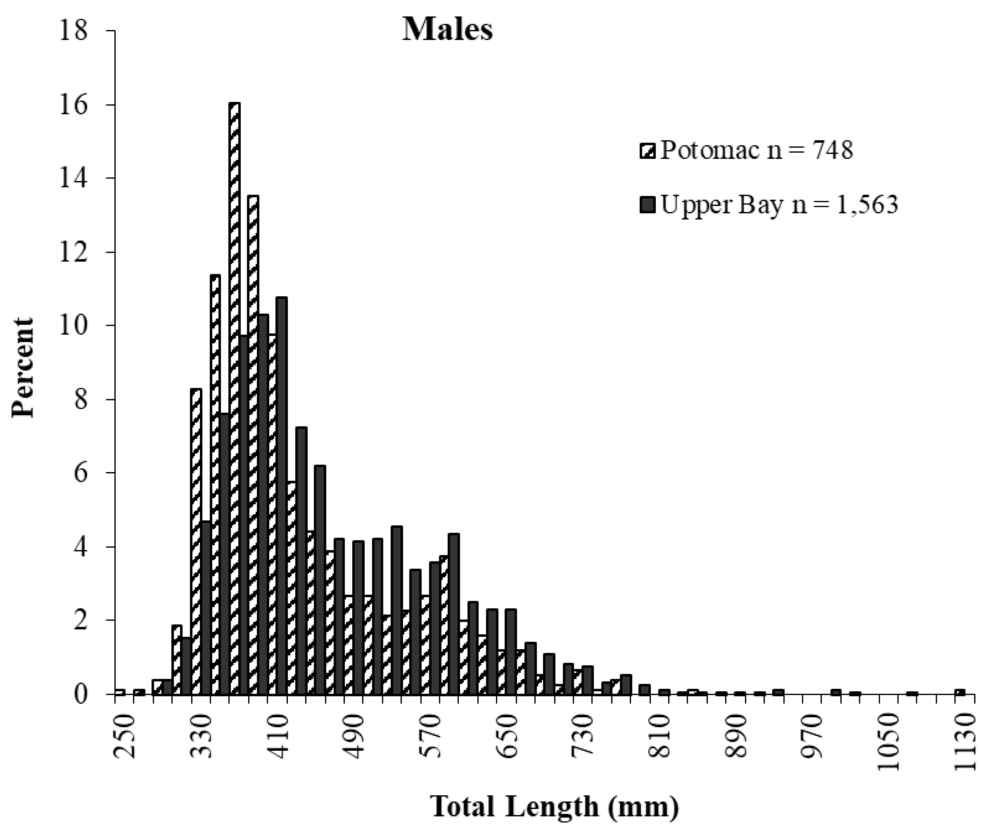


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, April through May 2018. Note different scales.



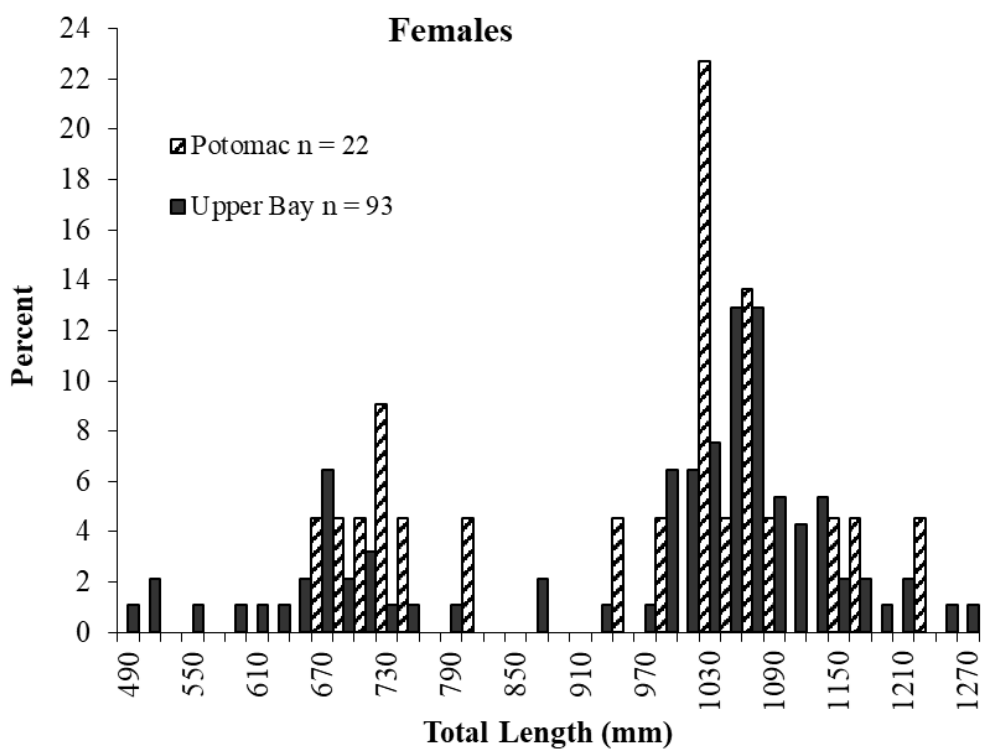


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2018. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.

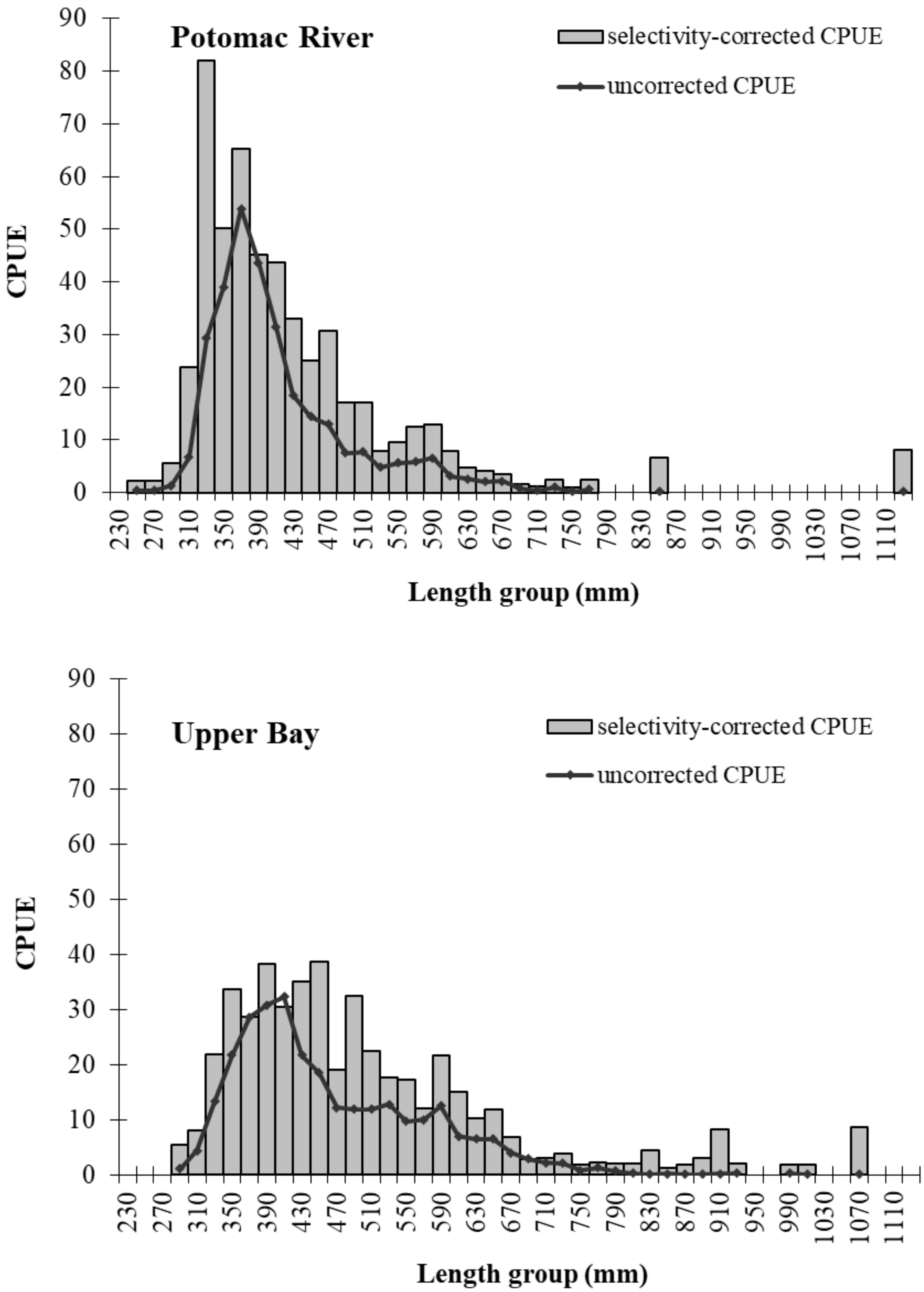
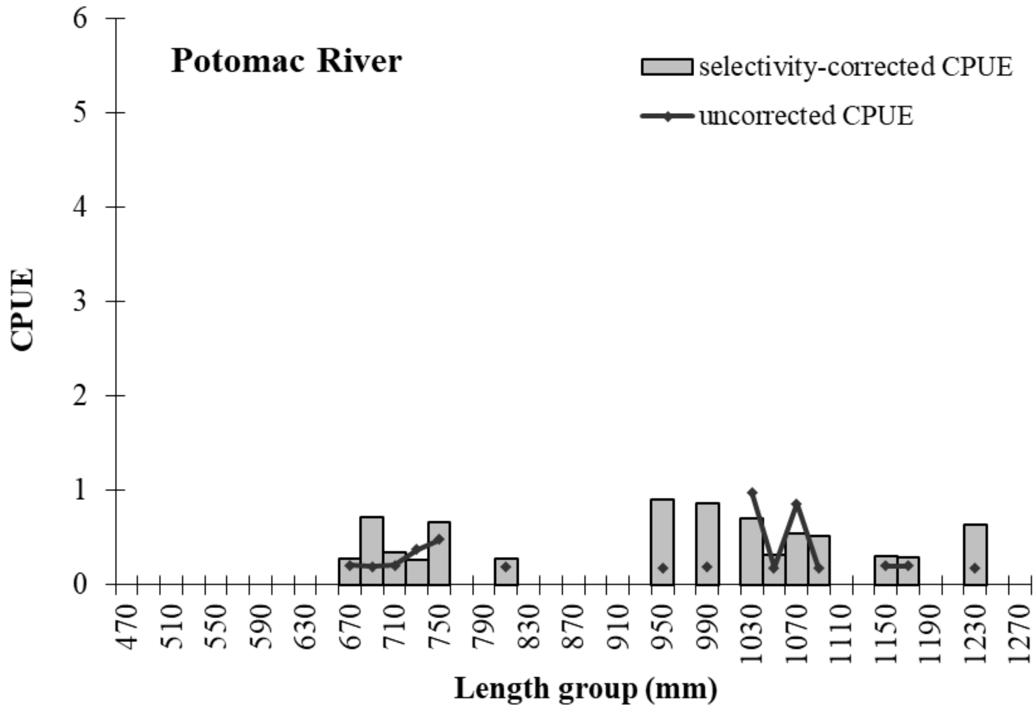


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2018. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



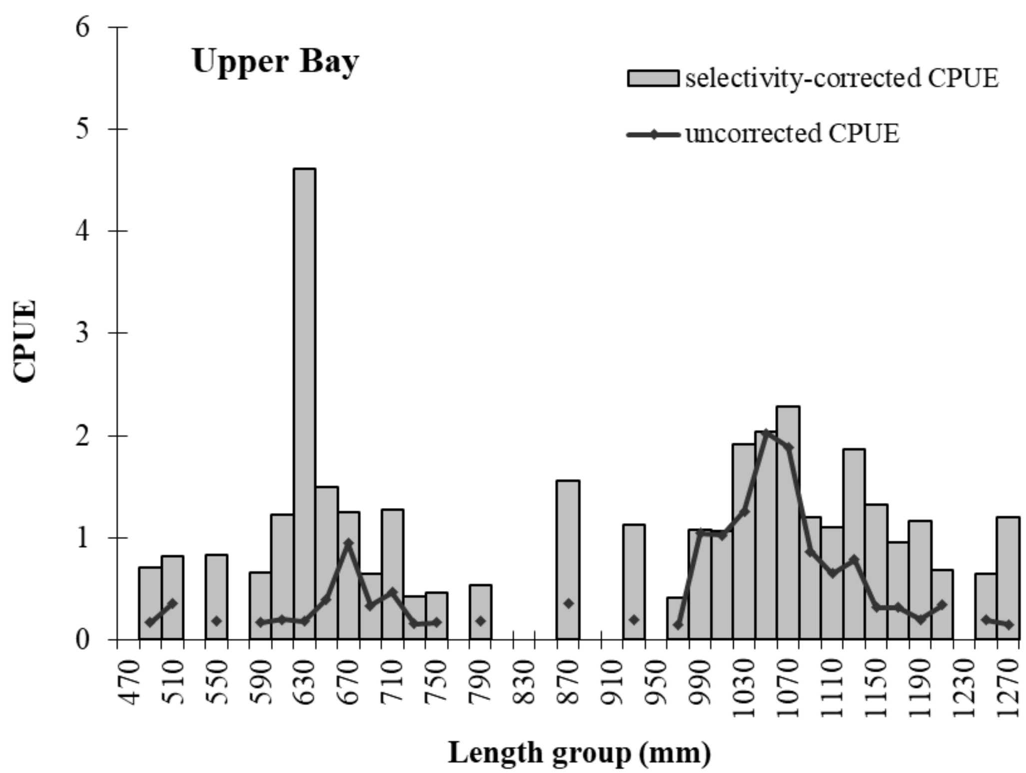


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during March through May, 1985-2018. Error bars are ± 2 standard errors (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

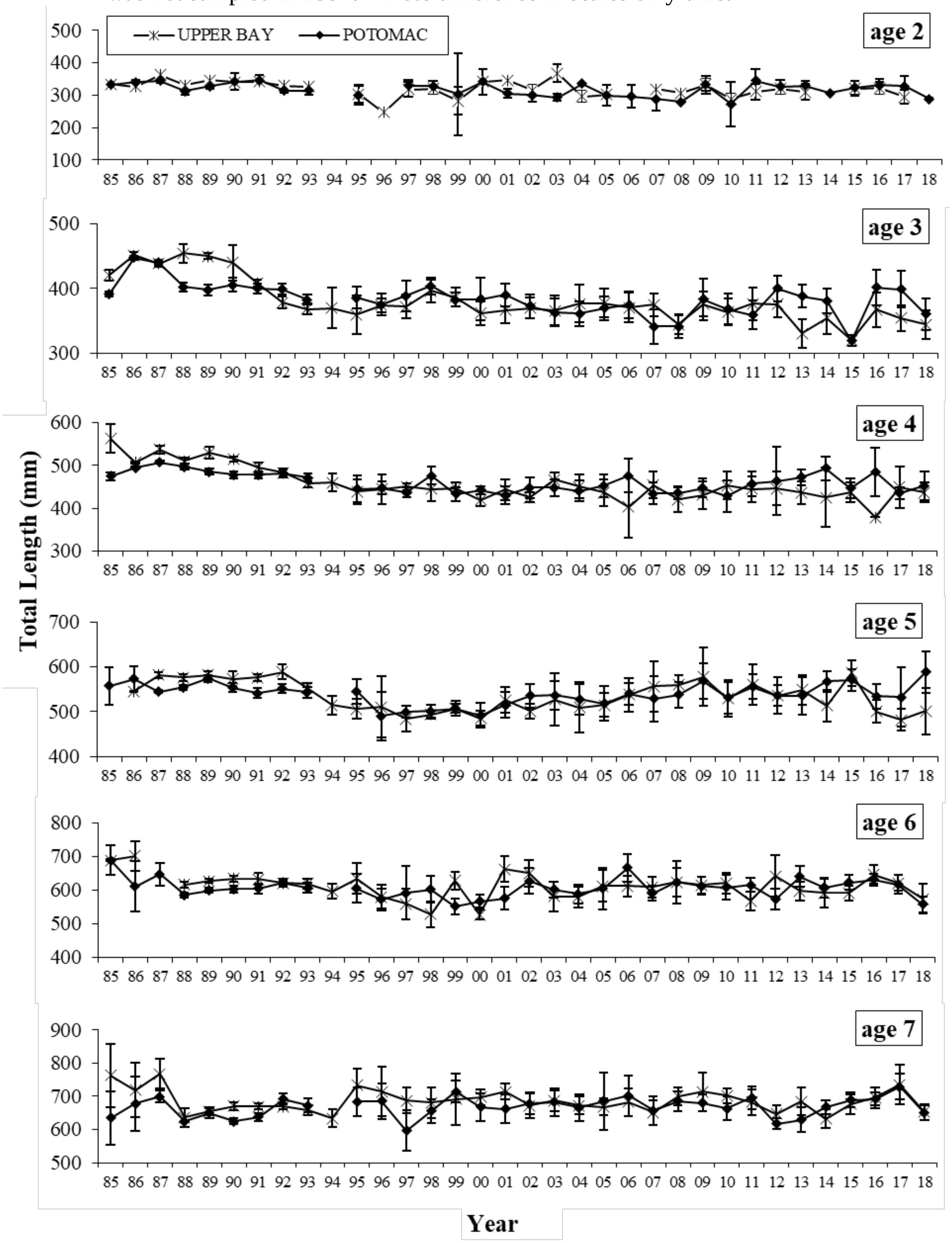


Figure 7. Continued.

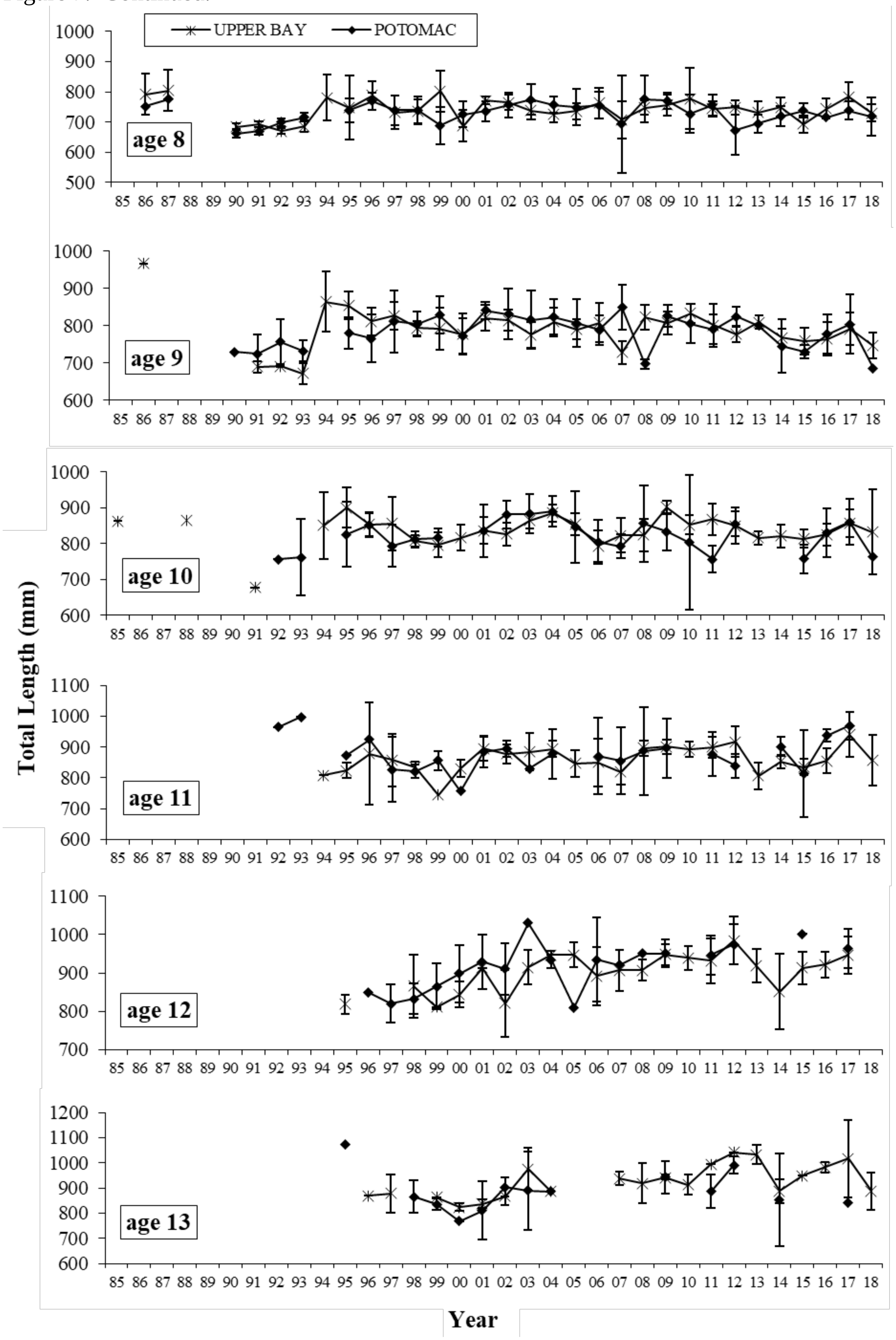


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during March through May, 1985–2018. Error bars are ± 2 standard errors (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

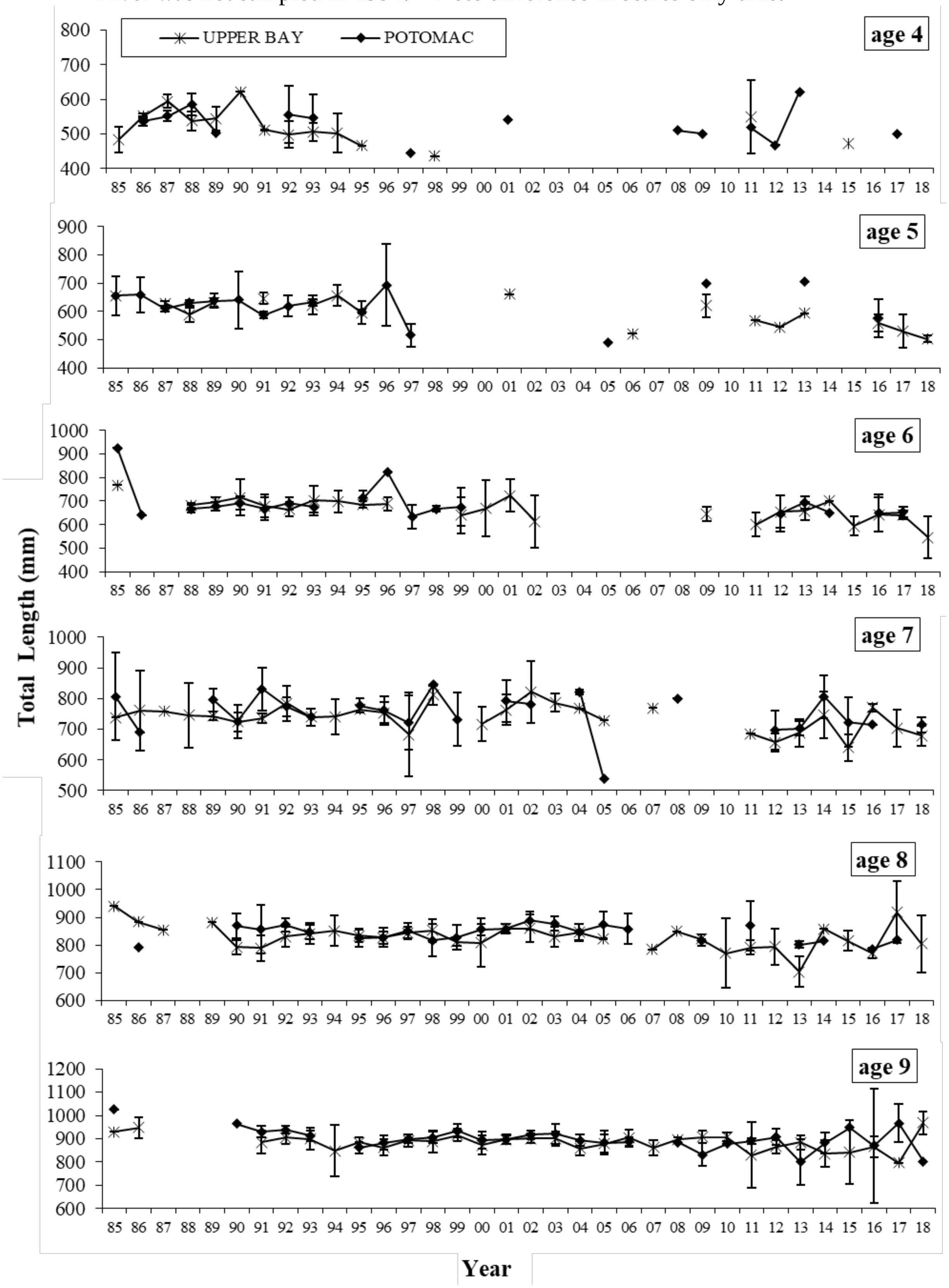


Figure 8. Continued.

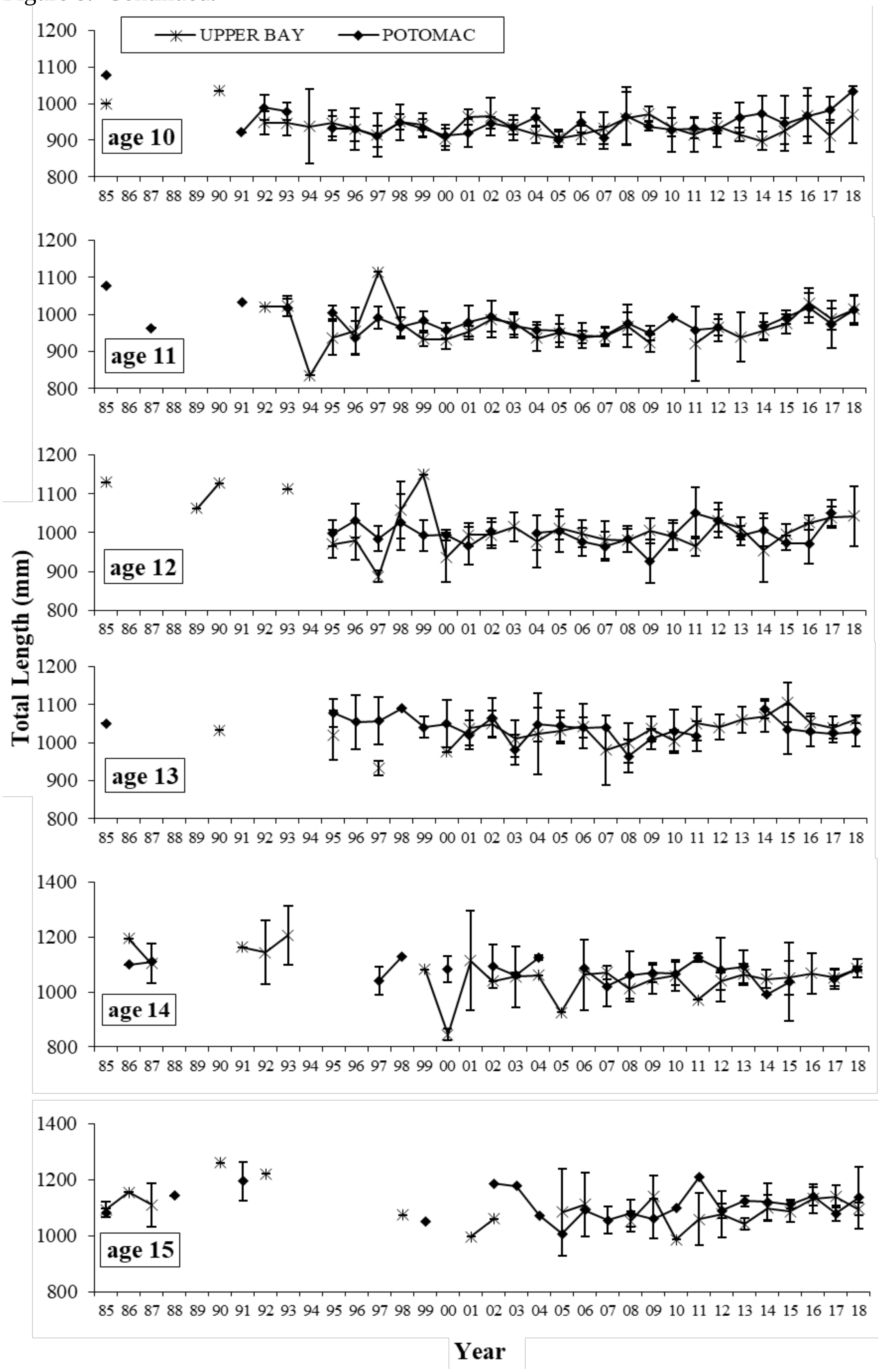


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15+. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

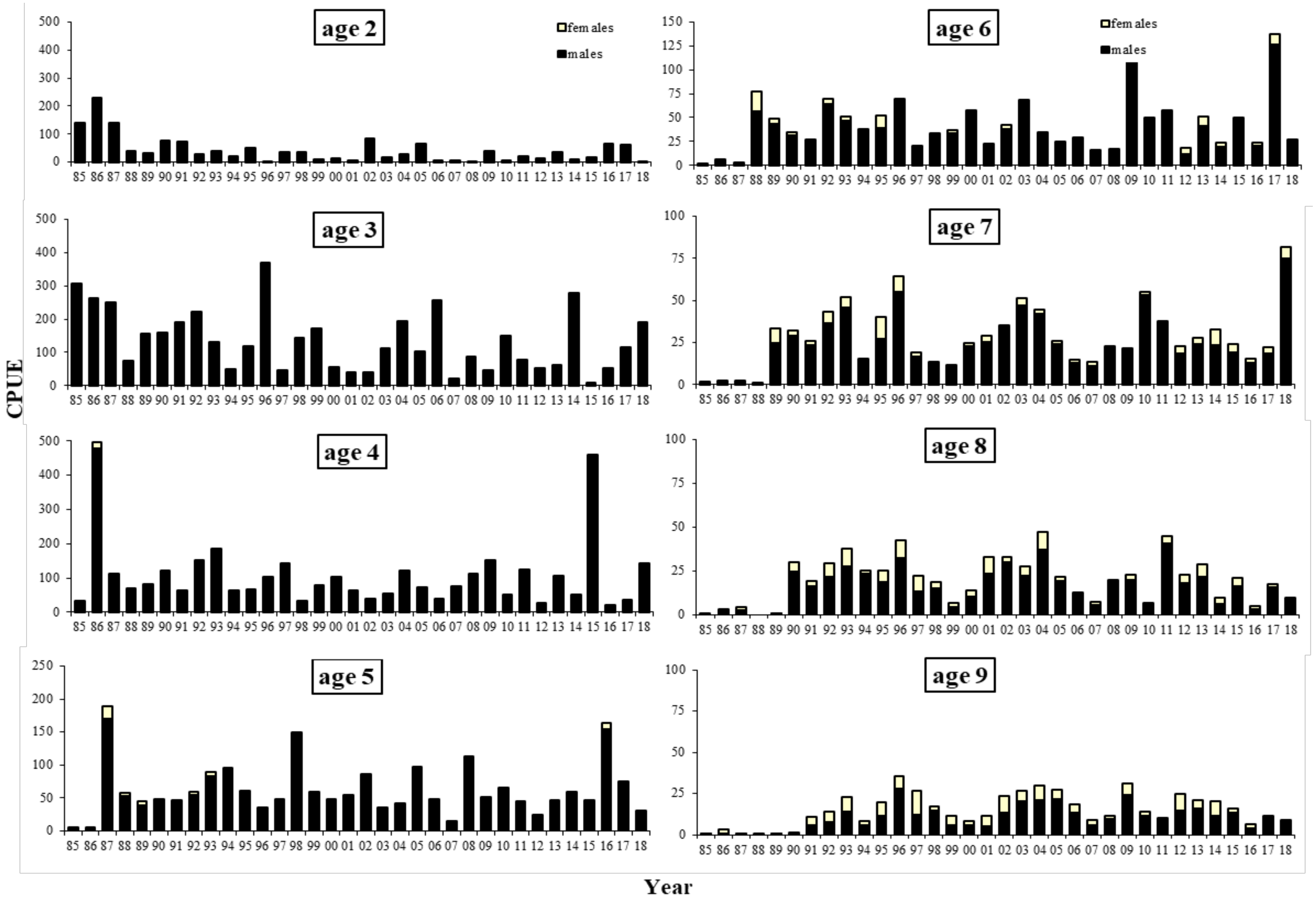


Figure 9. Continued.

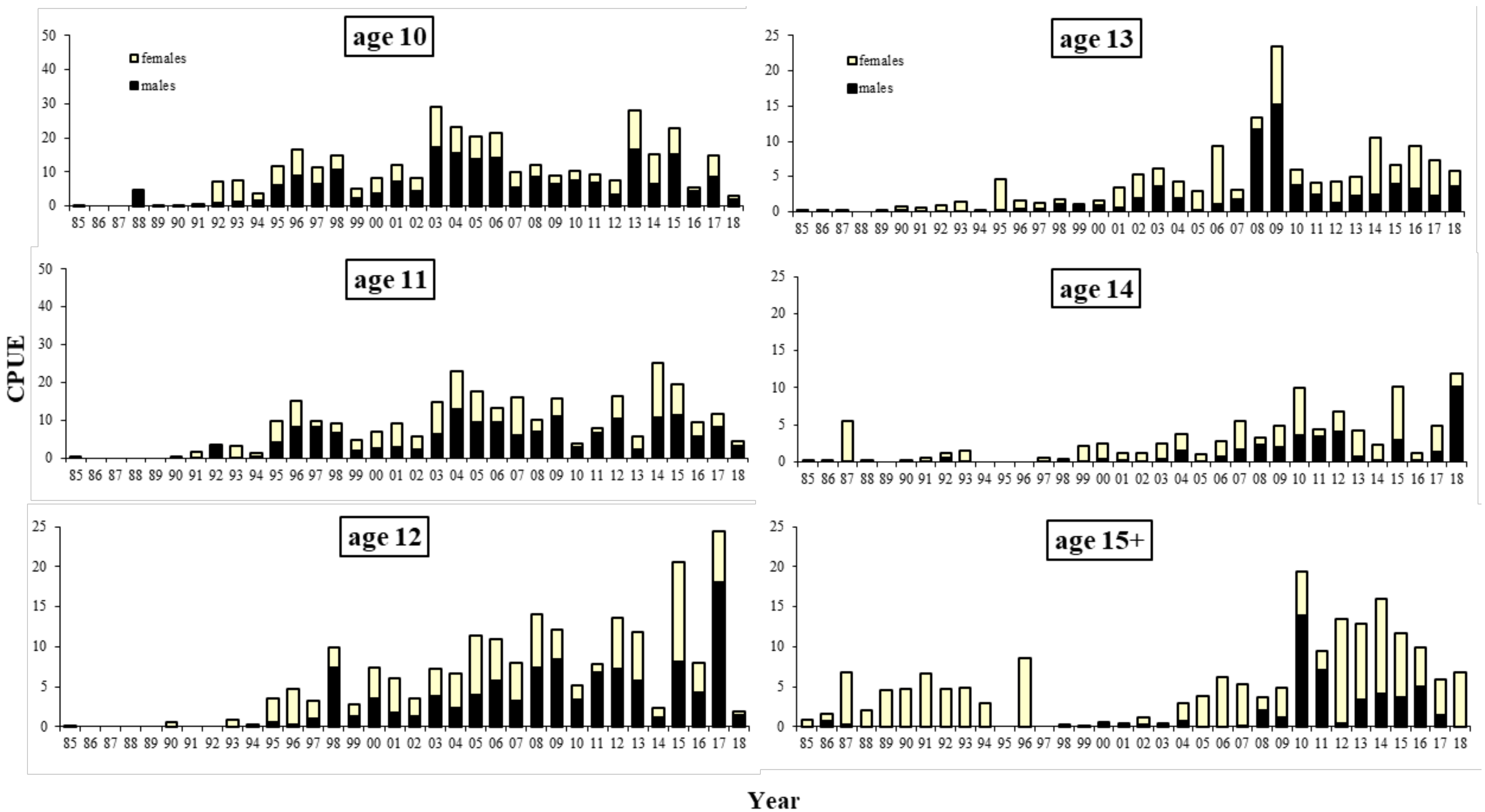
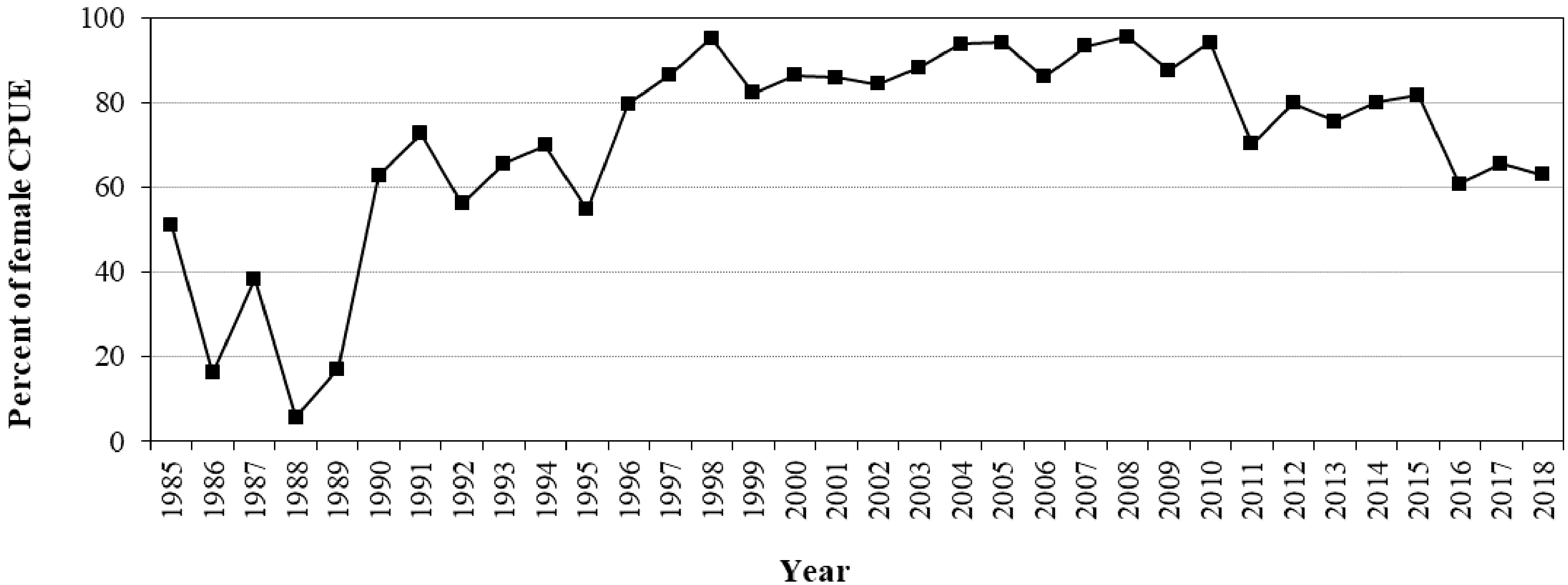
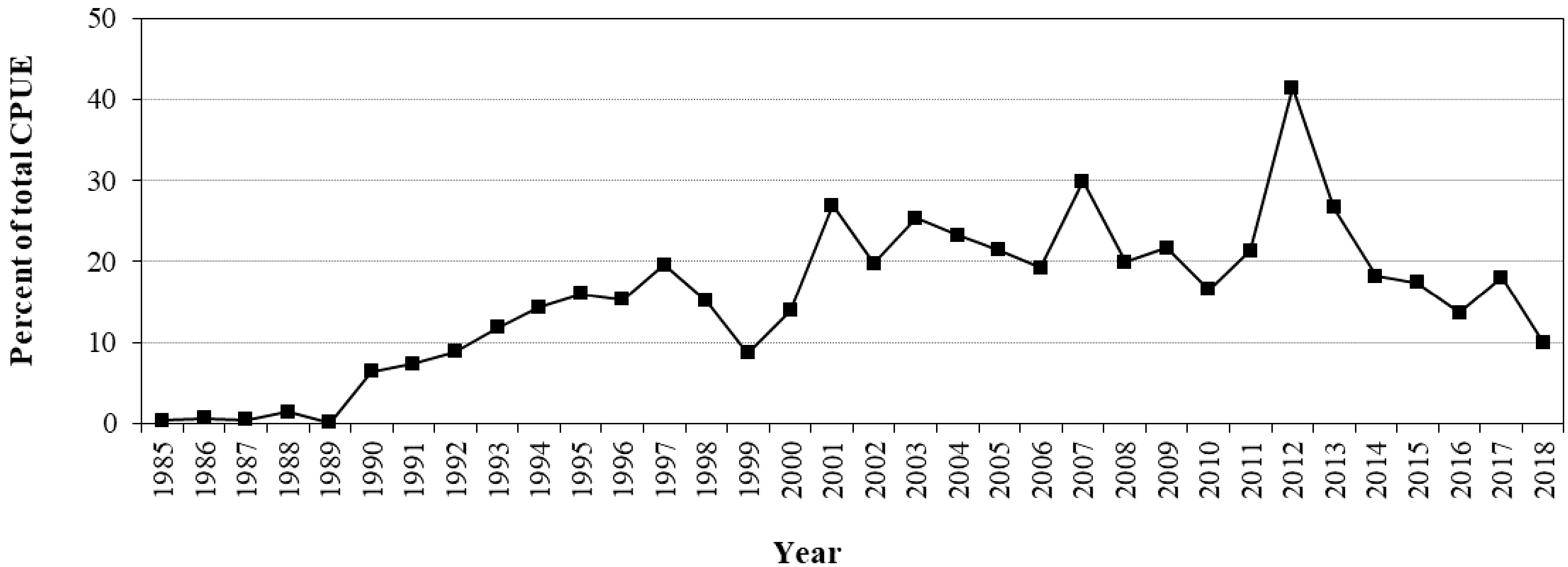


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, March through May, 1985-2018 (Choptank River to 1996). Effort is standardized 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.



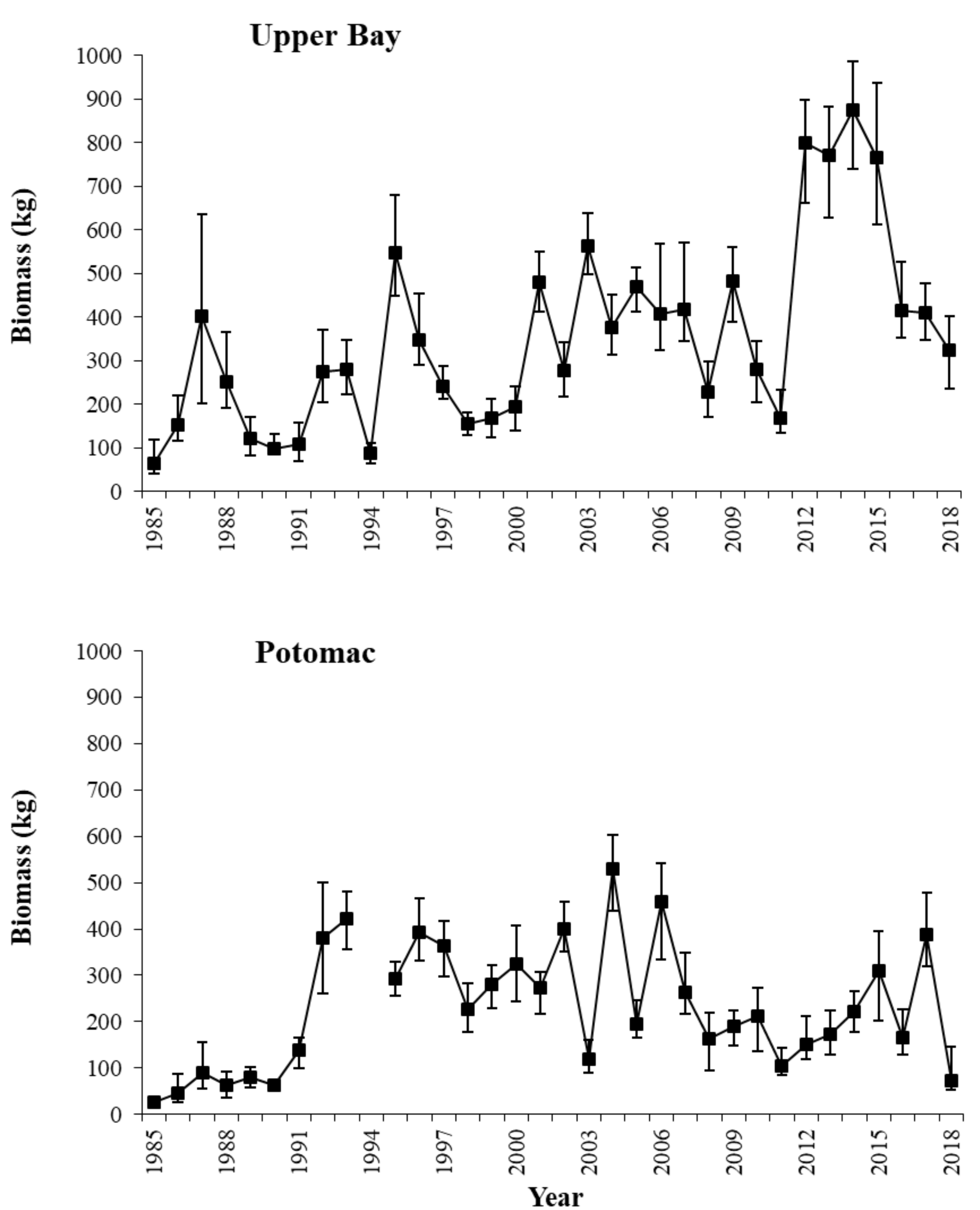
* Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385. (Hollis 1967).

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, 1985-2018 (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, 1985-2018. 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 three Head of Bay sampling sites were necessary in 2018. Welch Pt (#4) could not be sampled due to thick submerged aquatic vegetation and was replaced by Oldfield Pt (#31) approximately 1.5 miles downstream. The auxiliary site Spoil Island (#58) was lost to erosion and replaced by a new site on Fishing Battery Island (#168) approximately 0.7 miles southeast. The auxiliary site Tyding's Estate (#144) could not be sampled due to thick submerged aquatic vegetation and matted algae. No suitable replacement was 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. The area swept was previously reported as a 729 m^2 quadrant, based on the area of a quarter-circle with a radius of 30.5 m. However, recent field trials showed that 492 m^2 is a more realistic estimate under ideal field conditions. When depths of 1.6 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 does not exist (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 ± 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 population 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 $p=0.05$ level. Duncan's multiple range test was used to differentiate means.

RESULTS

Bay-wide Means

A total of 1,951 YOY striped bass was collected at permanent stations in 2018, with individual samples yielding between 0 and 106 fish. The AM (14.8) and GM (6.96) were both above their respective time-series averages and TPAs (Tables 2 and 3, Figures 2 and 3). The PPHL was 0.91, indicating that 91% of samples produced juvenile striped bass. The PPHL was greater than 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 ($p=0.05$) found that the 2018 $\log_e$-mean was significantly smaller than just seven years of the time-series.

System Means

Head of Bay - In 42 samples, 1,018 juveniles were collected at the Head of Bay sites for an AM of 24.2, greater than the time-series average (11.9) and the TPA (17.3) (Table 2, Figure 5). The GM of 14.48 was greater than the time-series average (5.82) 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 2018 Head of Bay $\log_e$-mean indiscernible from the best 18 year-classes of the time-series and significantly greater than the remaining 43 year-classes in the time-series.

Potomac River - A total of 231 juveniles was collected in 42 samples on the Potomac River. The AM of 5.5 was lower than both the time-series average (8.1) and TPA (9.2) (Table 2, Figure 5). The GM of 2.97 was also below the time-series average (3.59) 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 ($p=0.05$) ranked the 2018 Potomac River year-class significantly smaller than nine other years, but indiscernible from 34 years of the time-series. The 2018 Potomac year-class was significantly larger than 18 years of the time-series.

Choptank River - A total of 488 juveniles was collected in 24 Choptank River samples. The AM of 20.3 was near the time-series average of 20.9 and greater than the TPA (10.8) (Table 2, Figure 5). The GM of 8.85 was greater than its time-series average (8.05) and TPA (5.00) (Table 3, Figure 8). Differences among years were significant (ANOVA: $P<0.0001$). Duncan's multiple range test ($p=0.05$) found the 2018 Choptank River year-class significantly smaller than just eight years of the time-series, and significantly larger than 30 years of the time-series.

Nanticoke River - A total of 214 juveniles was collected in 24 samples on the Nanticoke River. The AM of 8.9 was nearly equal to the time-series average (9.0) and greater than the TPA (8.6) (Table 2, Figure 5). The GM of 5.78 was greater than its time-series average (4.09) 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 ($p=0.05$) found the 2018 index significantly greater than 29 years of the time-series and significantly smaller than just four years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 151 juveniles were caught in 12 samples, resulting in an AM of 12.6, and a GM of 7.37. Both indices exceeded their respective time-series averages (Table 5).

On the **Patuxent River**, 125 YOY striped bass were caught in 18 samples. The AM of 6.94 and GM of 2.65 were both less than their respective time-series averages, but greater than their respective time-series medians (Table 5).

DISCUSSION

By several measures, striped bass recruitment in Maryland's portion of Chesapeake Bay was above average in 2018. The AM and GM were at or above the 75^{th} percentile of their respective time-series, and YOY striped bass were distributed widely, occurring in 91% of samples collected. This marks the third time in the past five years that the survey has documented above-average striped bass recruitment.

Recruitment in individual systems was variable. For the second consecutive year, recruitment in the Head of Bay system was strong. The 2018 Head of Bay GM ranked in the 90^{th} percentile of the time-series. Head of Bay samples produced the highest frequency of positive hauls at 98%. GM indices in the Choptank and Nanticoke rivers were ranked above their 75^{th} percentiles. Recruitment in the Potomac River, however, was less successful. The AM and GM estimators in the Potomac were approximately equal to the median values of their 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% ($P \leq 0.001$) 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 59% of the variability ($r^2 = 0.59$, $p \leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was: $C_1 = (0.18)(C_0) - 0.0639$, 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 (0.09) was lower than the predicted index of 0.28. The relatively large, negative residual indicates that survival during the first winter of the 2017 year-class was worse 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 small and average sized year-classes. This was not the case, however , for the average-sized 2017 year-class, which was overestimated by the regression equation at age 1. 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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Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

Figure 11. Residuals of age 1 and age 0 striped bass regression.

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
* 132	Susquehanna Flats	0.2 miles east of Poplar Point
* 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
* 90	Patuxent River	Peterson Point

* 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
Average	11.9	8.1	20.9	9.0	11.8
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
Average	5.85	3.59	8.05	4.09	4.33
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
Average	11.9	206.1	1.47	91.23	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
Average	22.0	6.07		5.9	2.97	
Median	4.1	2.08		3.6	2.02	

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	N/A

Figure 1. Maryland Chesapeake Bay juvenile striped bass survey site locations.

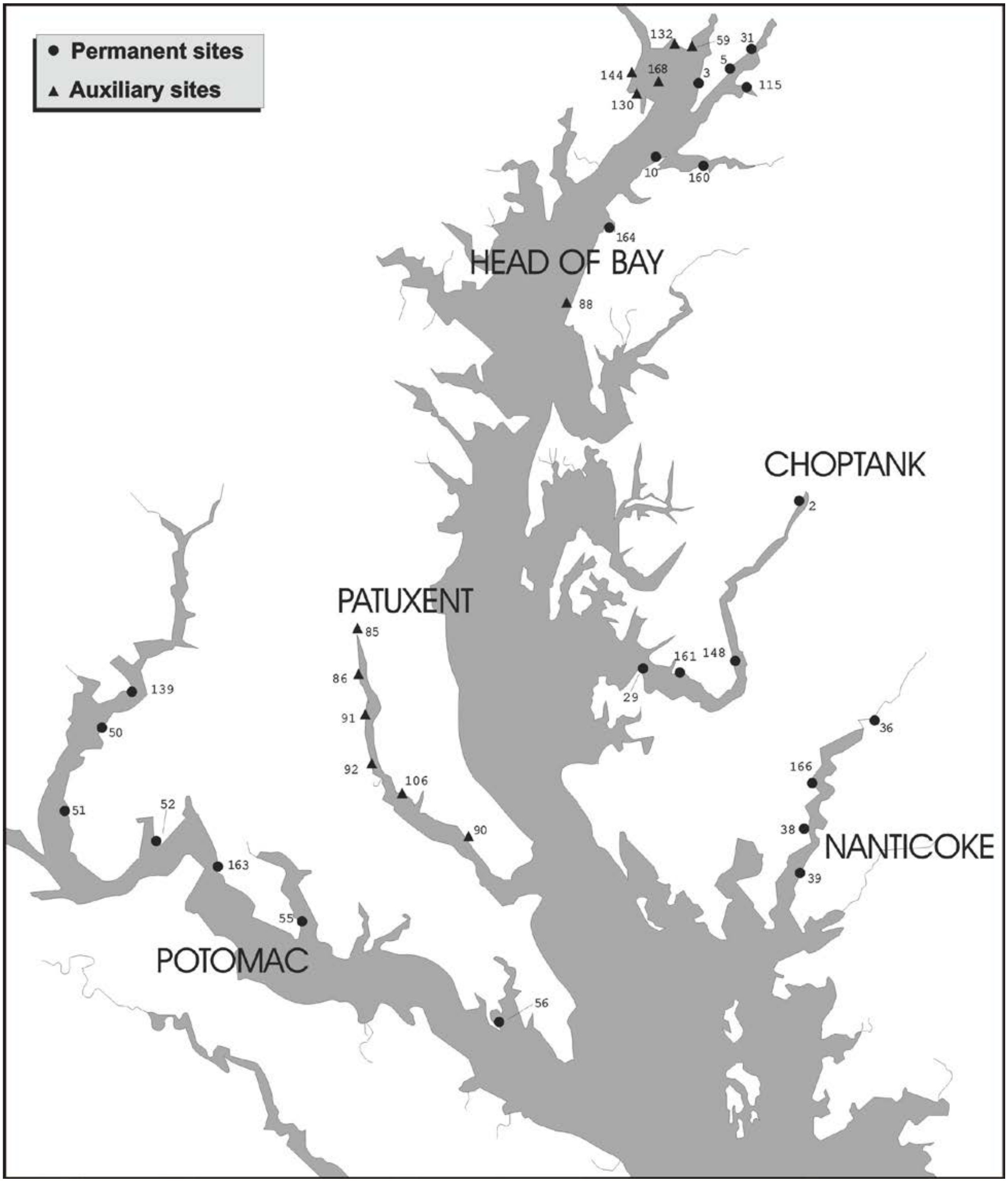


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

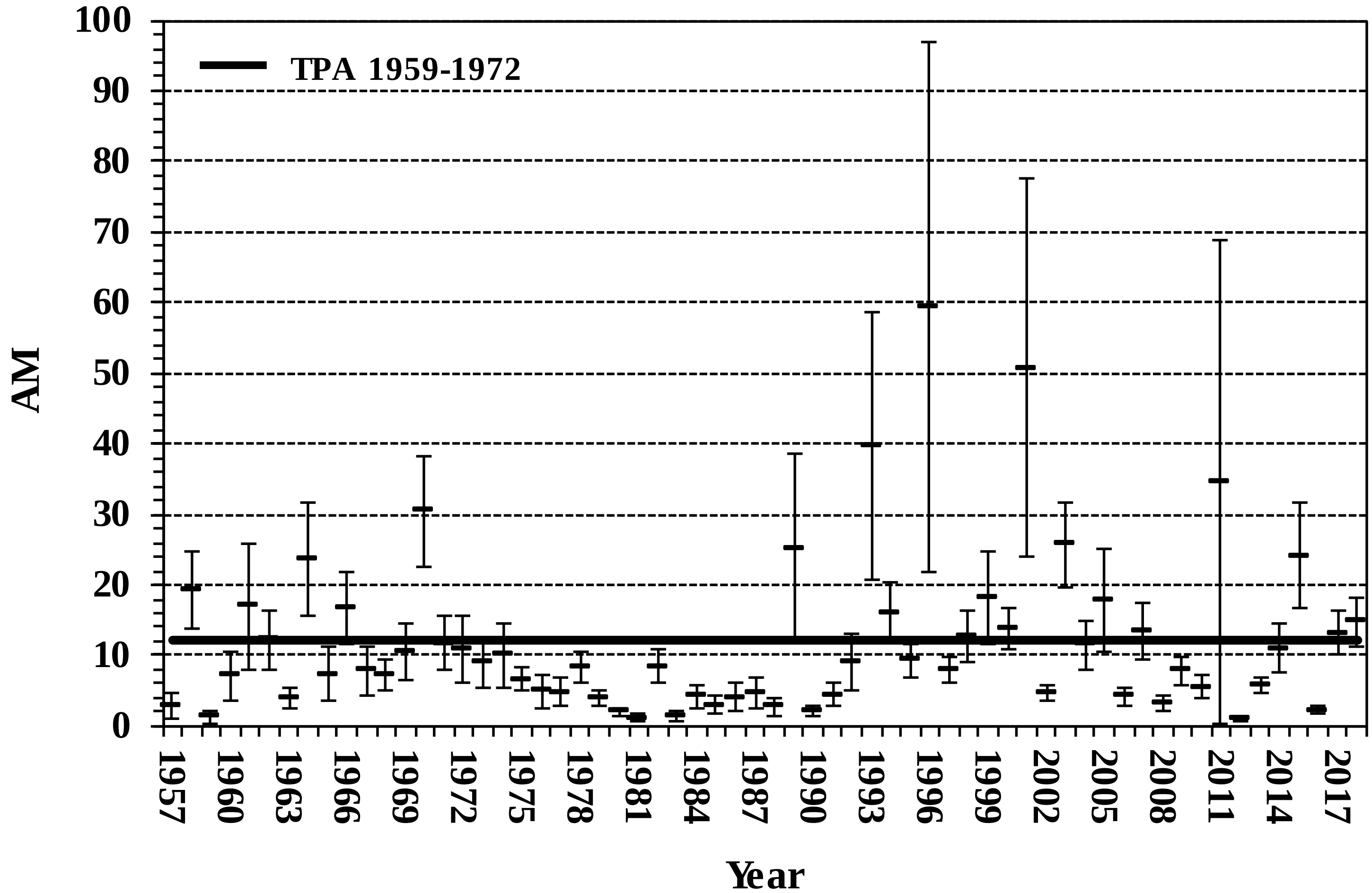


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

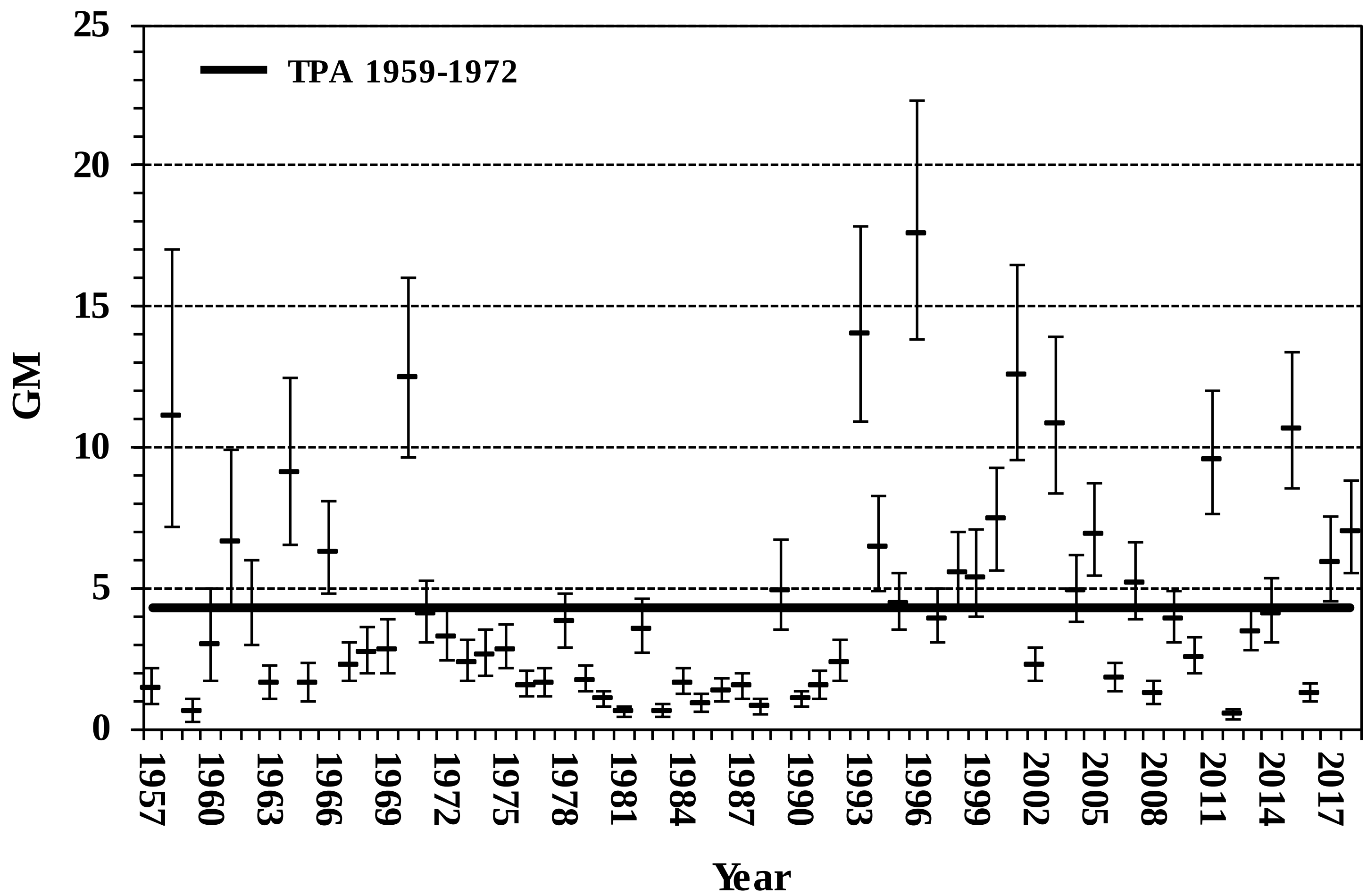


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

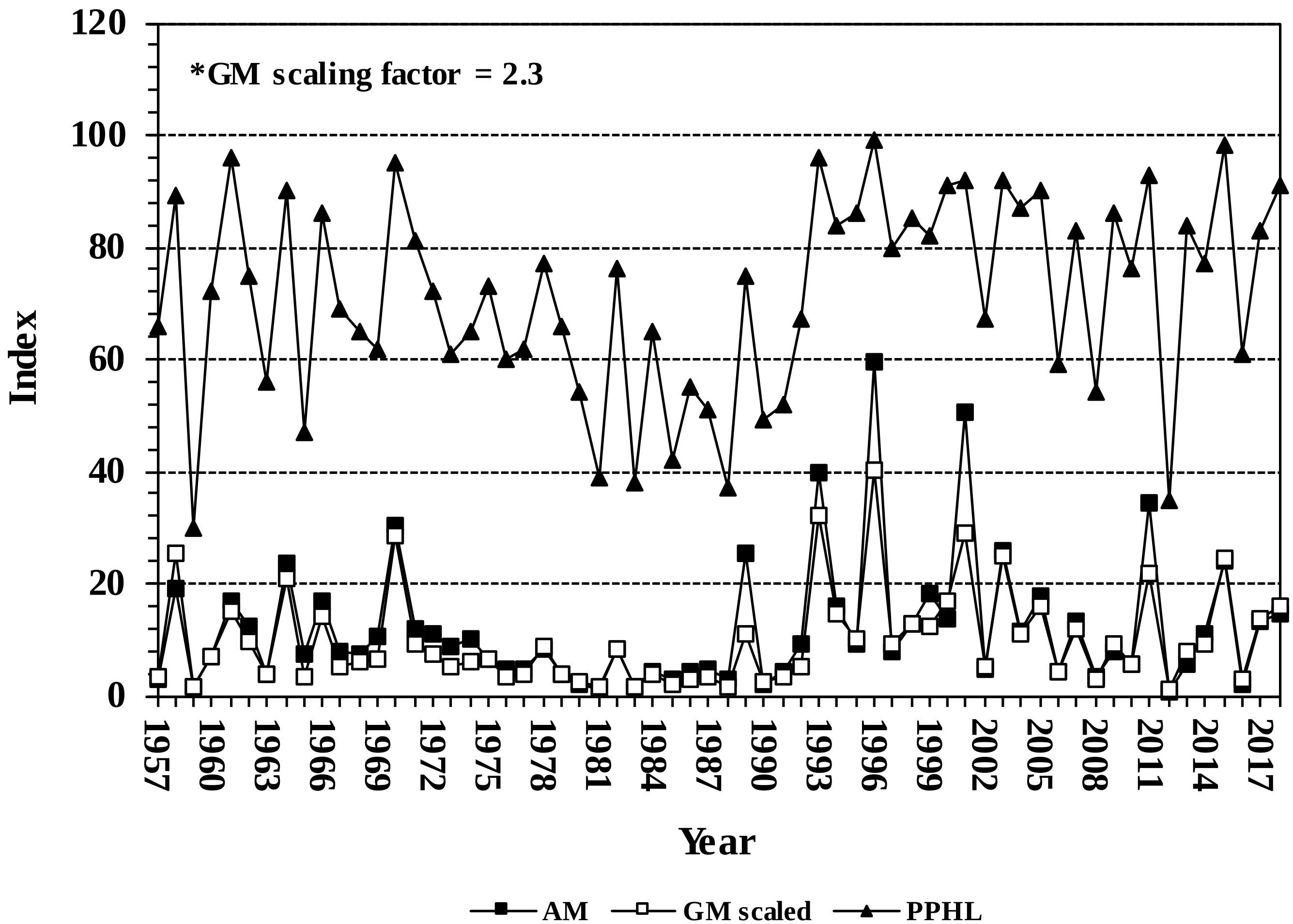


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

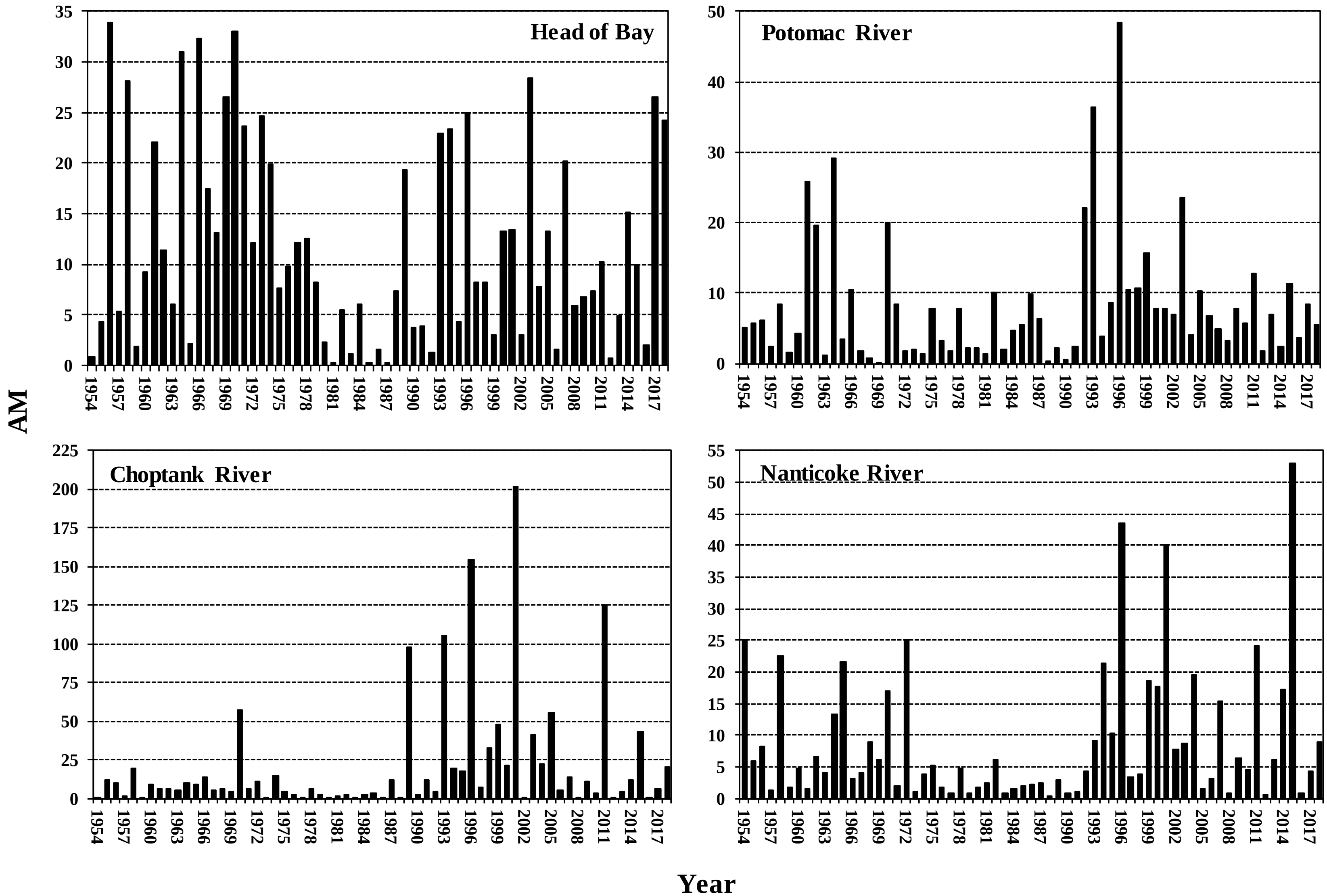


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

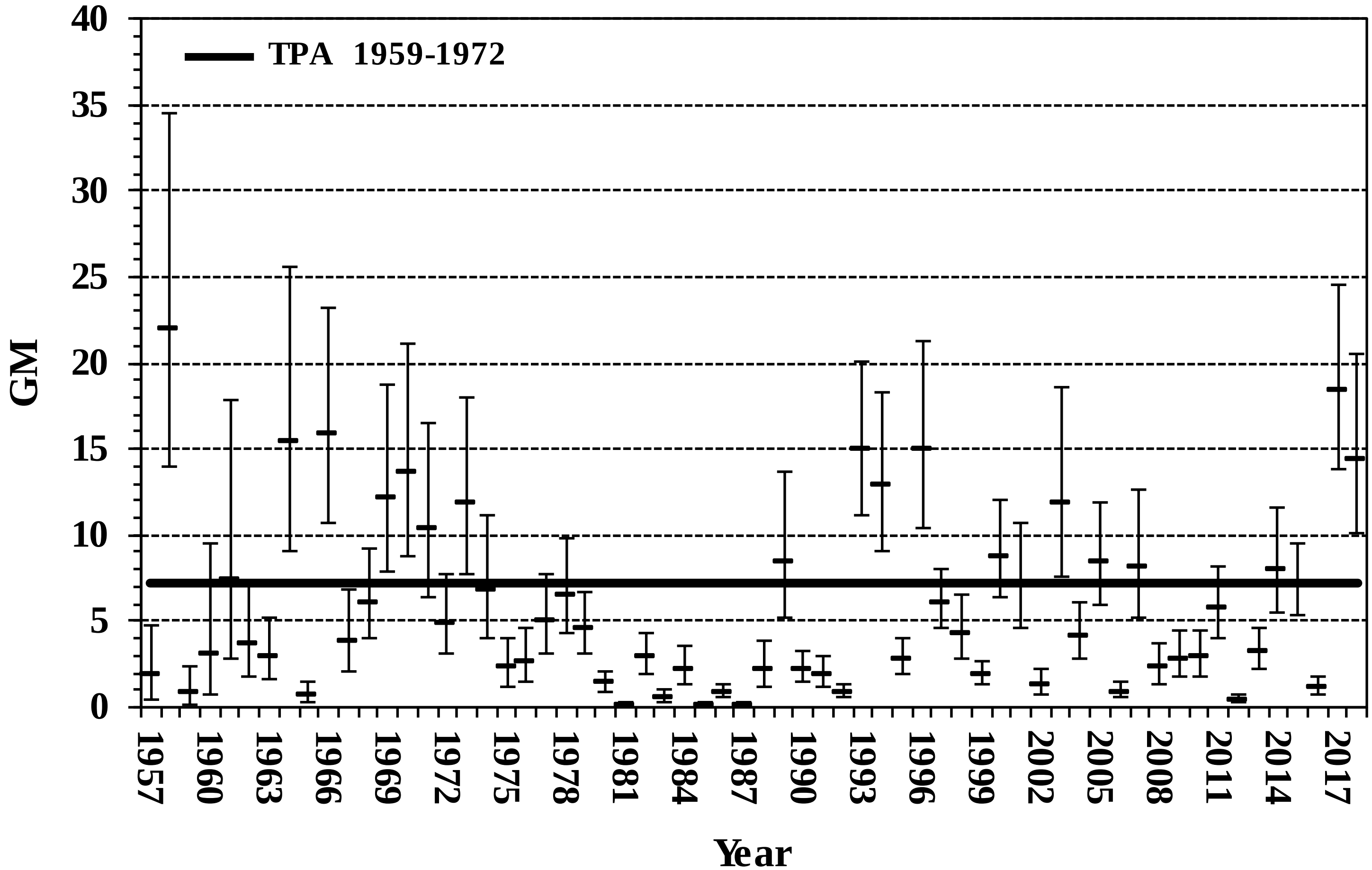


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

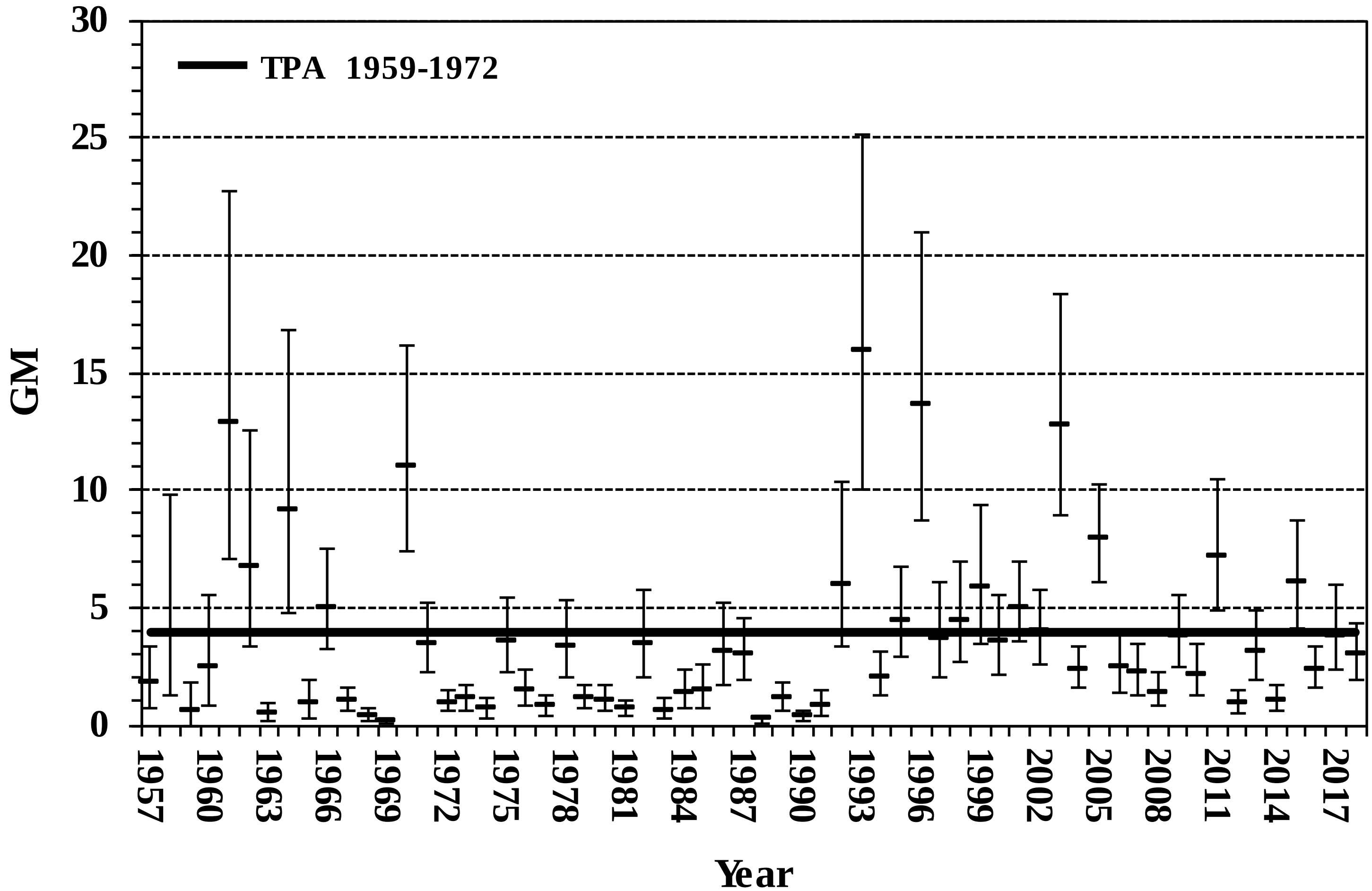


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

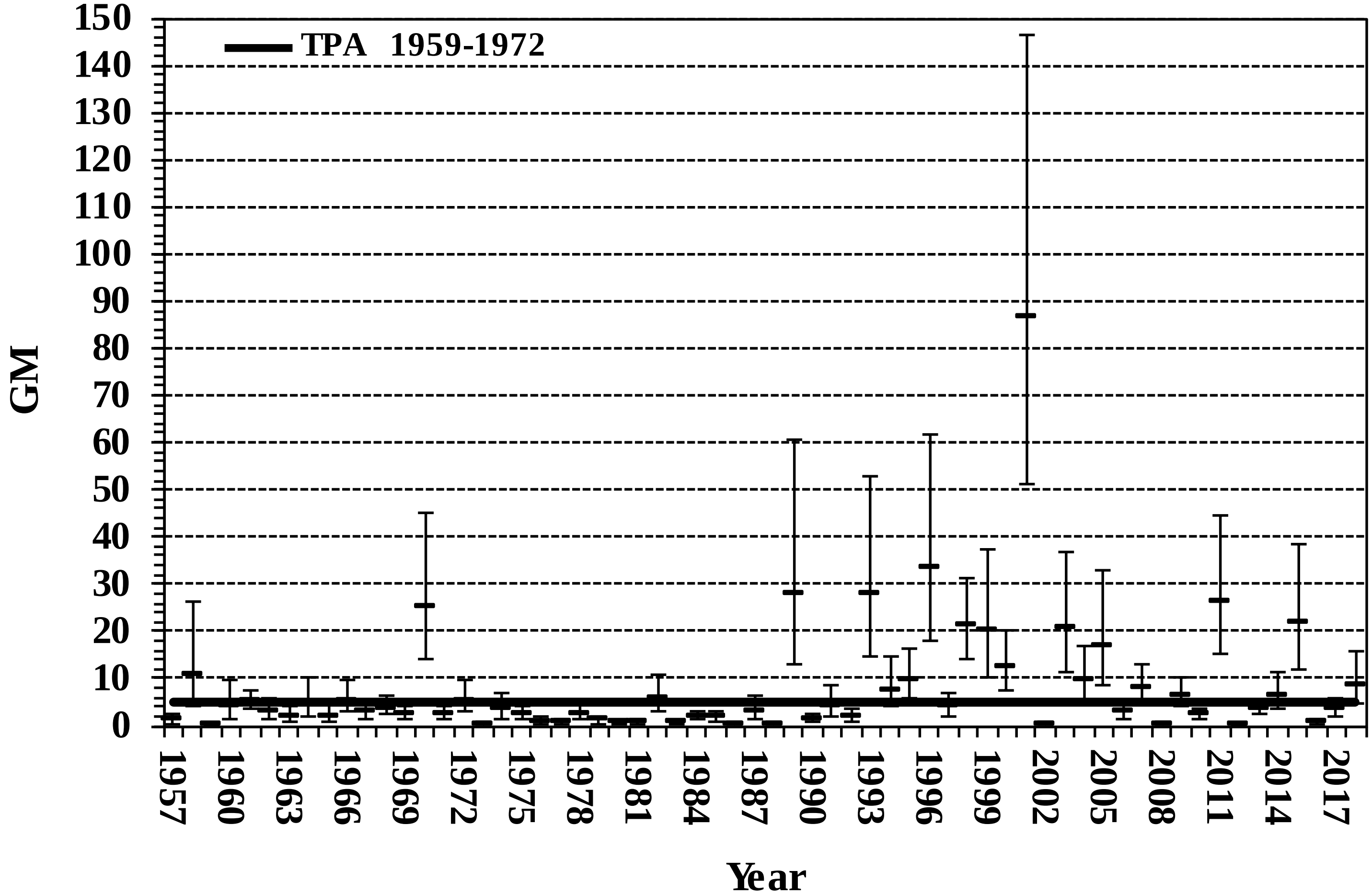


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

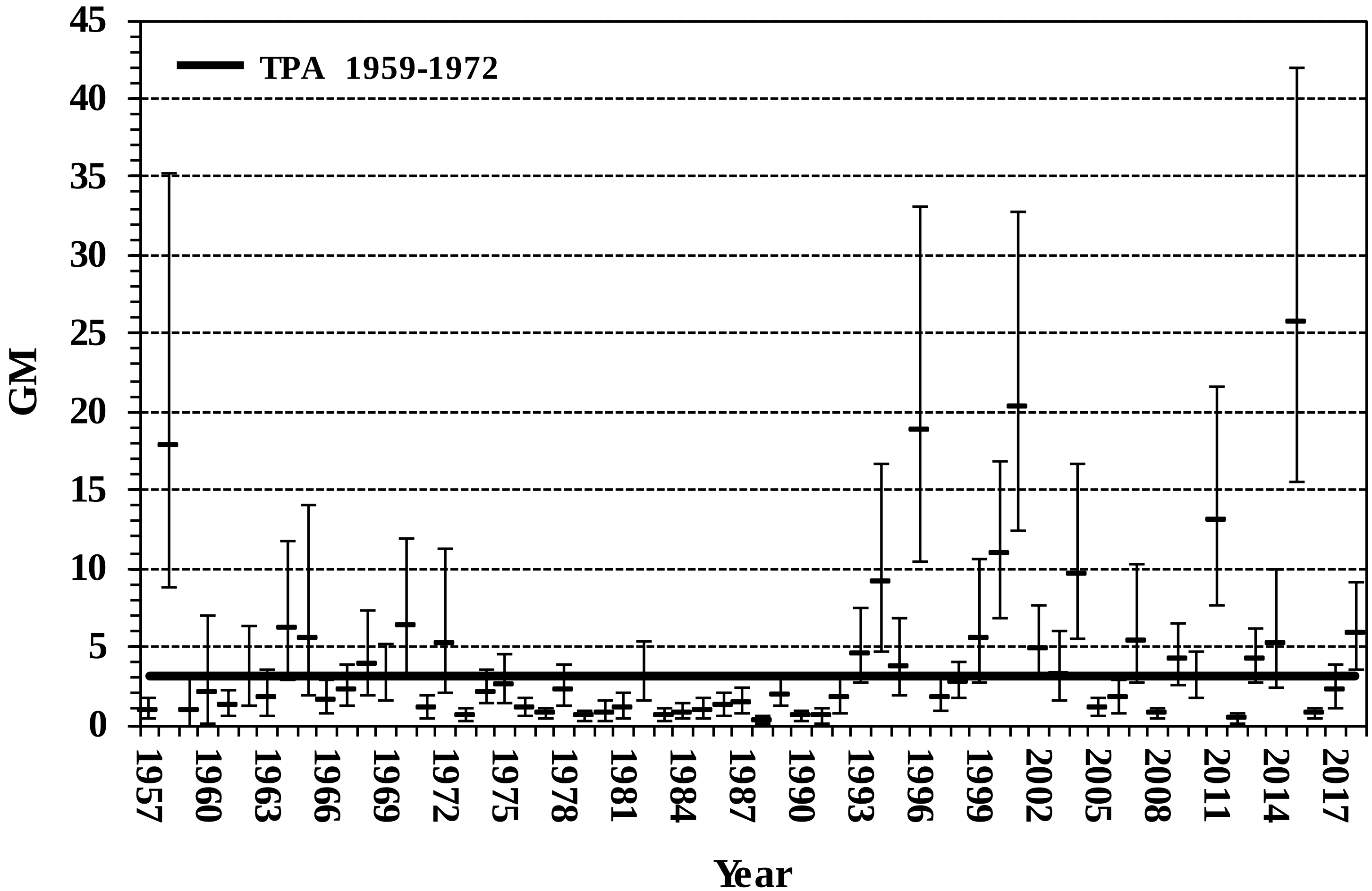


Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

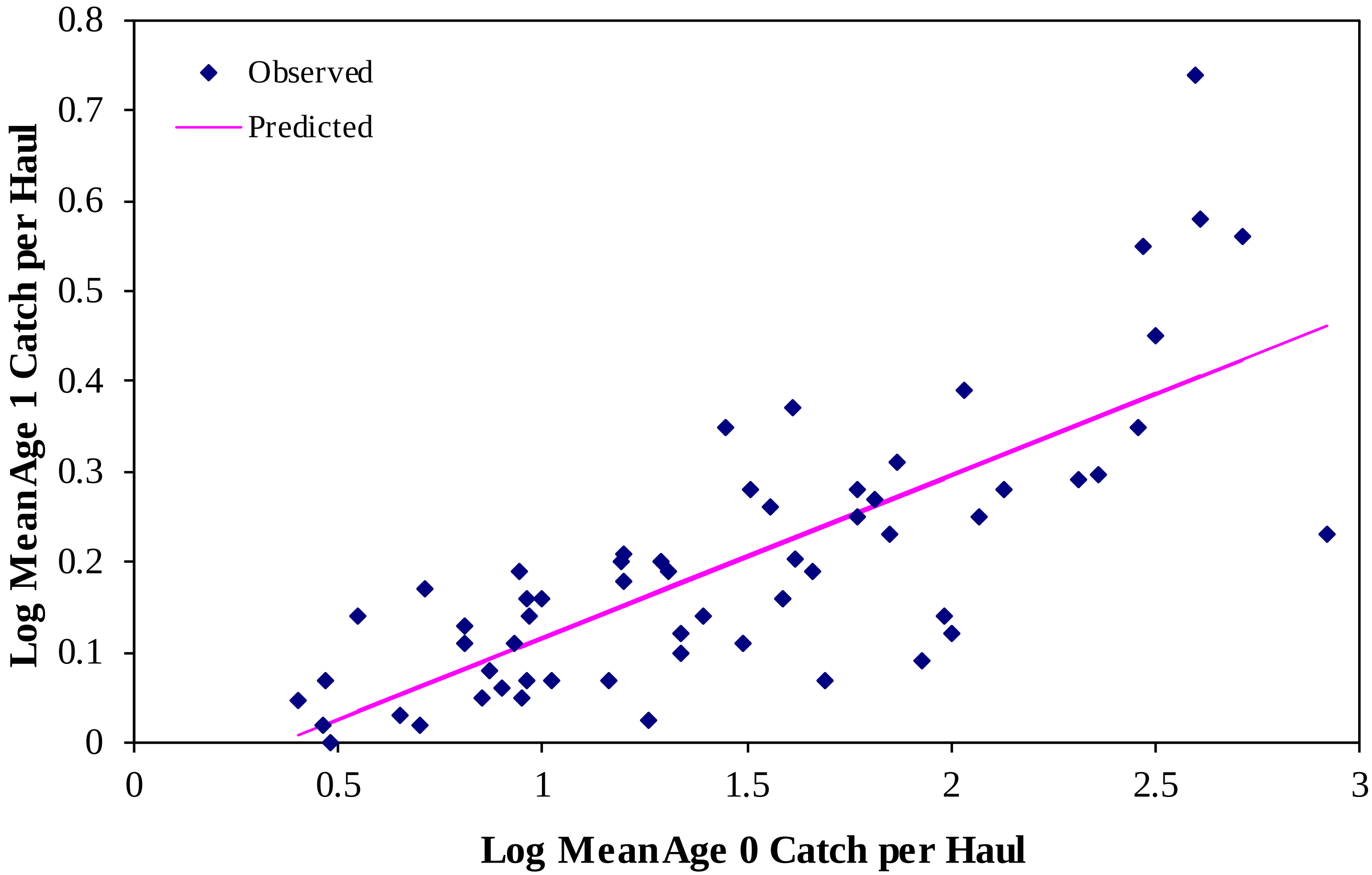
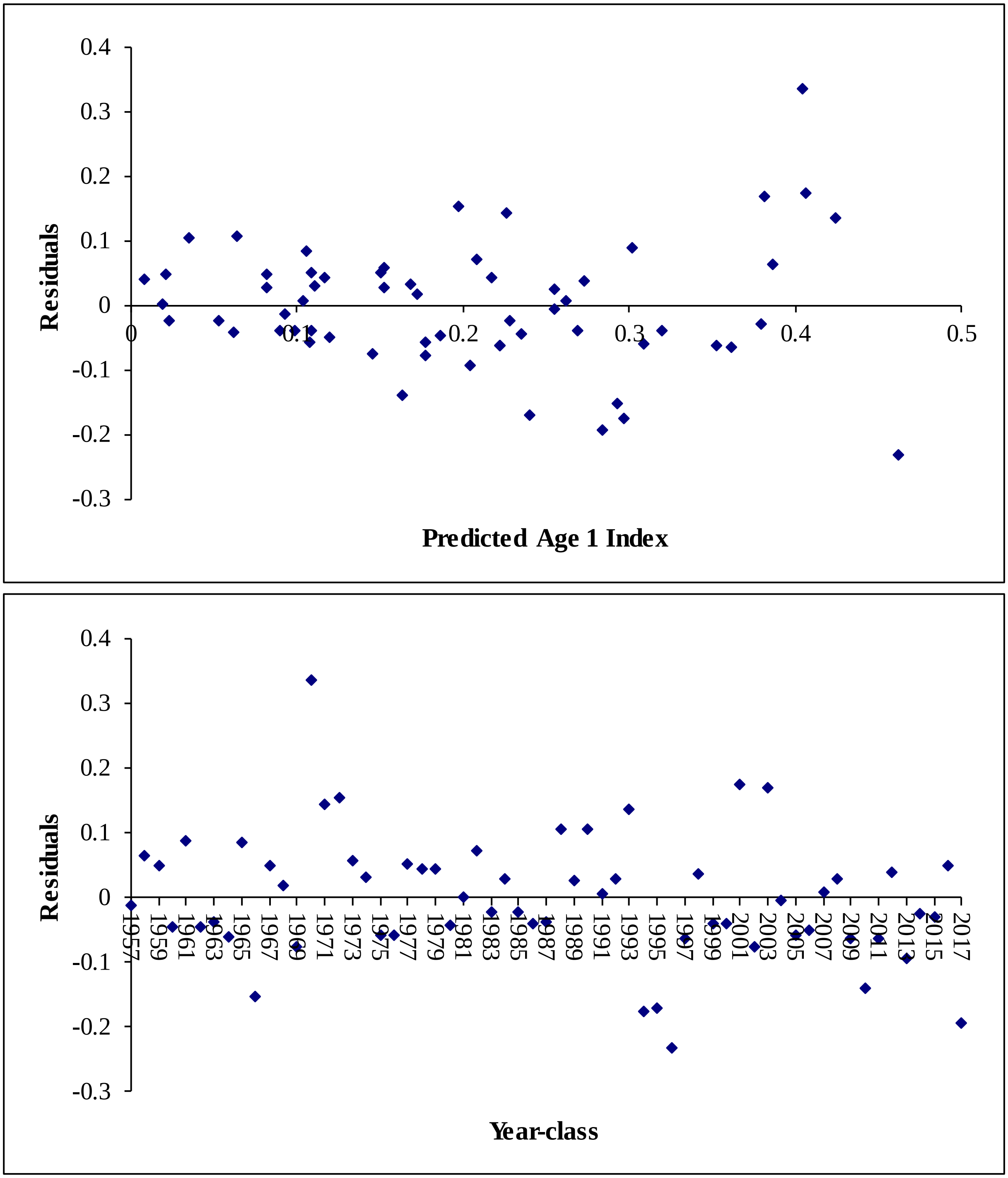


Figure 11. Residuals of age 1 and age 0 striped bass regression.



PROJECT NO. 2
JOB NO. 3
TASK NO. 4

STRIPED BASS TAGGING

Prepared by Beth A. Versak

INTRODUCTION

The primary objective of Project 2, Job 3, Task 4 was to summarize striped bass tagging activities in Maryland's portion of the Chesapeake Bay in 2018. 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 2018, 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 2018, funding was obtained to conduct only the hook and line component of the offshore tagging cruise. 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), North Carolina Department of Environmental Quality, MD DNR, Atlantic States Marine Fisheries Commission (ASMFC), U. S. Coast Guard, Potomac River Fisheries Commission, North Carolina Wildlife Resources Commission and North Carolina State University.

Fishing was conducted onboard a contracted sportfishing vessel departing from Virginia Beach, VA. Sampling was conducted during 10 fishing trips, between January 24 and February 15, 2018. Six lines with custom-made tandem parachute rigs were trolled at 2 to 3 knots, in depths of 45 to 98 feet (14 to 30 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 2018 data.

Estimates for Maryland's spawning stock are broken into two size groups: ≥457 mm TL (18 inches) and ≥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 2018 will not be completed until after March 27, 2019.

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 18, 2018. A total of 2,427 striped bass were sampled and 1,080 (44%) 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 on 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 2018 (540 mm TL) was significantly greater (t-value = -9.11, $P<0.0001$) than that of the sampled population (480 mm TL) (Figure 2). This was also evident in the significant difference of the two length frequencies ($D=0.186$, $P<0.0001$).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2018 data) will be used to estimate an instantaneous fishing mortality rate on resident fish for the 2018-2019 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Estimates of survival and fishing mortality for the 2018 Chesapeake Bay spawning stock, as well as the resident stock, will be presented in a future report of the ASMFC Striped Bass Tagging Subcommittee.

<u>North Carolina cooperative offshore tagging activities</u>

The primary objective of the offshore tagging trips was to apply tags to as many striped bass as possible. The majority of fish sampled in recent years were encountered in federal waters off the mouth of Chesapeake Bay.

In 2018, 695 striped bass were encountered and 667 (96%) were tagged (Table 2). The mean lengths of all fish sampled and of those tagged were the same, 1046 mm TL (t-value = 0.11, P=0.915, Figure 3). The mean total length of striped bass tagged in 2018 (1046 mm TL) was significantly greater than the length of fish tagged from the 2017 hook and line trips (1022 mm TL, t-value = -5.06, P<0.0001). Length distributions between the two years were also different (D=0.205, P<0.0001). Estimates of survival and mortality based on fish tagged in the 2018 North Carolina 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

2019 PRELIMINARY RESULTS

Spring tagging

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. 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). 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.

North Carolina cooperative offshore tagging activities

In 2019, 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 16 and February 14, 2019.

While fishing with hook and line, 91 striped bass were encountered and 89 (98%) were tagged. The mean length of all fish sampled was 1033 mm TL and of those tagged was 1034 mm TL. Estimates of survival and fishing mortality based on fish tagged in the 2019 North Carolina study will be presented in a future report of the ASMFC Striped Bass Tagging Subcommittee.

The final, complete analyses of the 2019 striped bass tagging activities will appear in the next F-61 Chesapeake Bay Finfish Investigations report.

CITATIONS

Jiang H., K. H. Pollock, C. Brownie, J. M. Hoenig, R. J. Latour, B. K. Wells, and J. E. Hightower. 2007. Tag return models allowing for harvest and catch and release: evidence of environmental and management impacts on striped bass fishing and natural mortality rates. North American Journal of Fisheries Management 27:387-396.

Northeast Fisheries Science Center (NEFSC). 2019. 66th Northeast Regional Stock Assessment Workshop (66th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 19-08; 1170 p.

SAS. 1990. SAS Institute Inc., SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2. SAS Institute Inc., Cary, North Carolina. 1989. 846 pp.

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Figure 3. Length frequency of striped bass measured and tagged during the cooperative offshore tagging cruise, January - February 2018.

Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, April - May 2018.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	4/2/18 - 5/10/18	771[b]	369	606501 – 606869
Upper Chesapeake Bay	4/5/18 - 5/18/18	1,656[c]	711	543255 – 543300 602325 – 602989
Spring spawning survey totals:		2,427	1,080	

[a] Not all tags in reported sequences were applied; some were lost, destroyed, or applied out of order.

[b] Total sampled includes one fish with no total length and one USFWS recapture.

[c] Total sampled includes one recapture from a MD fishing contest.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2018 cooperative offshore tagging cruise.

System	Gear	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences
Nearshore Atlantic Ocean (Near MD, VA, NC coasts)	Hook & Line	1/24/18 – 2/15/18	695	667	607001 – 607667

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2018.

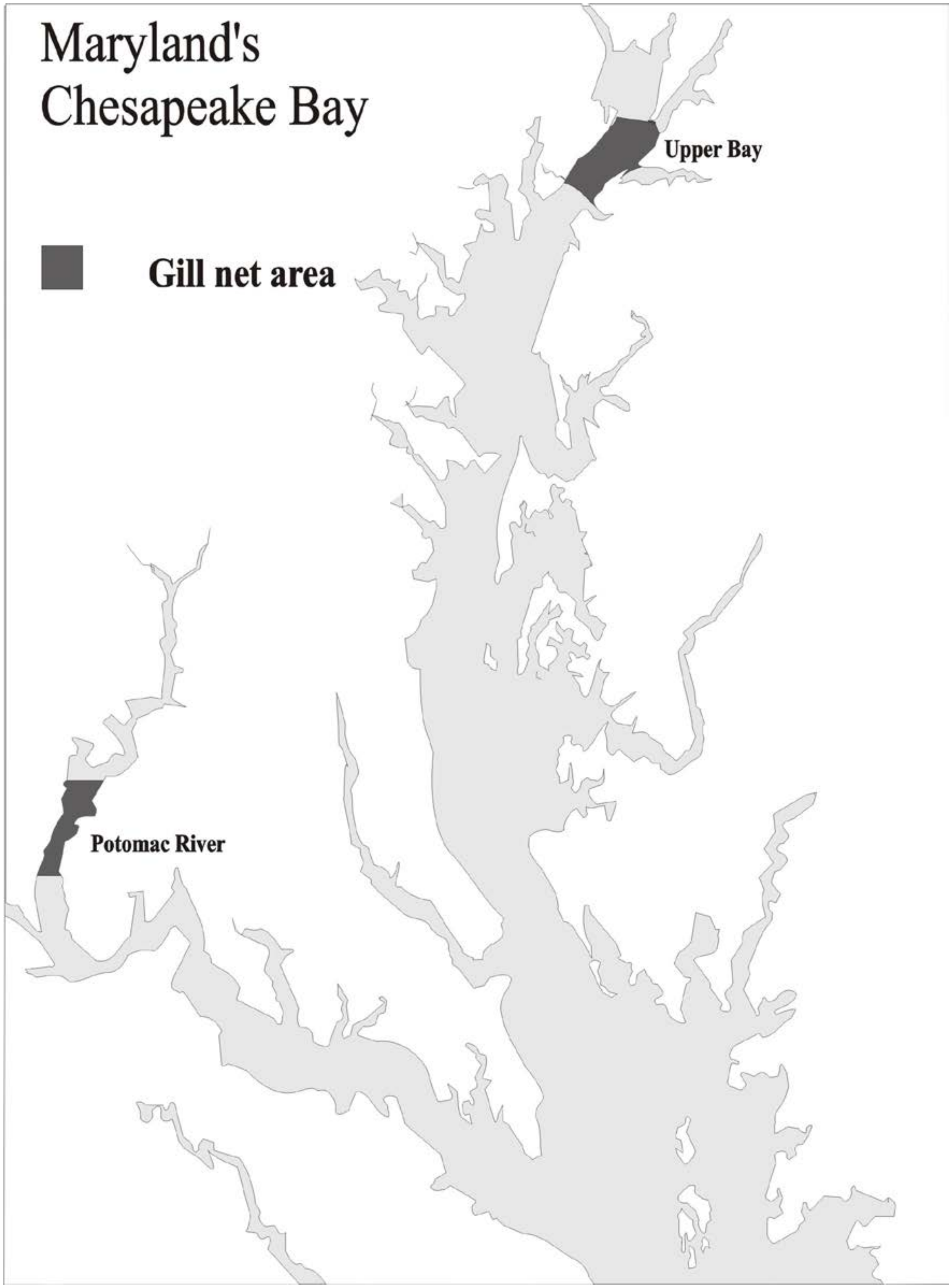


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay, April - May 2018.

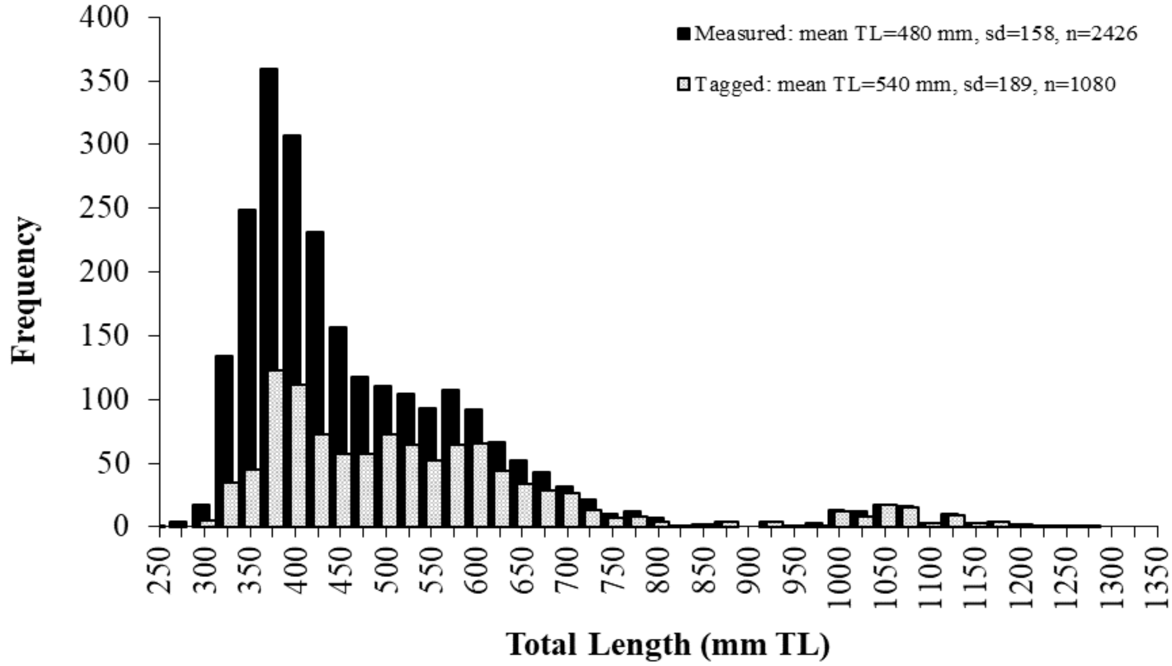
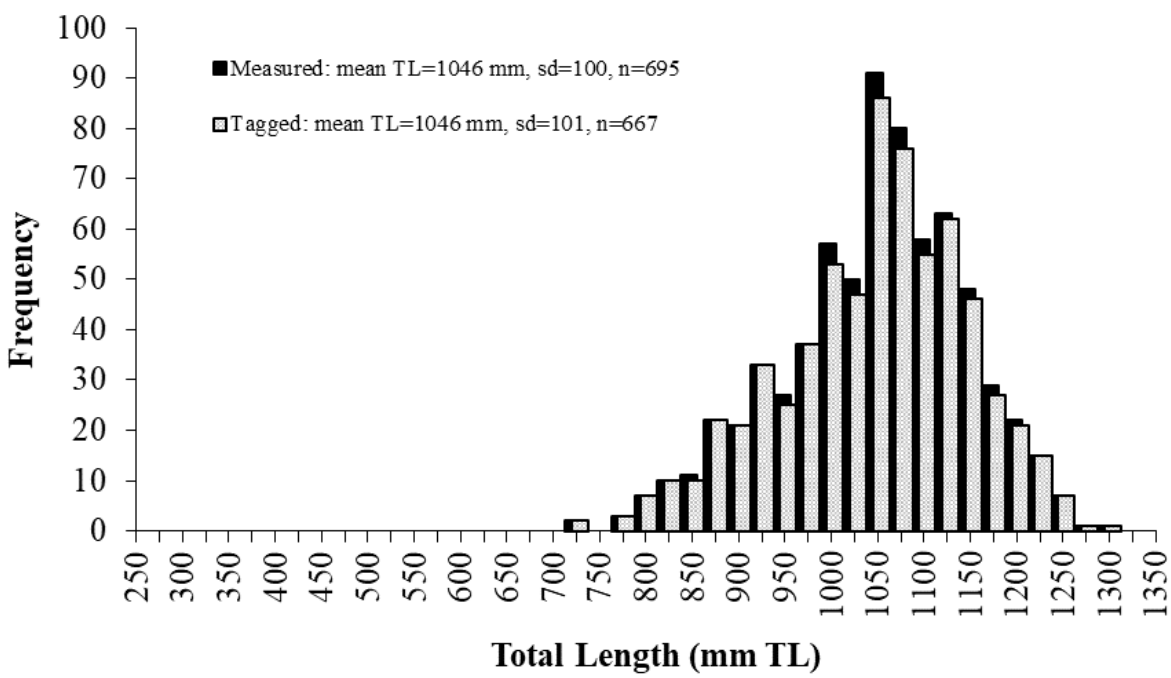


Figure 3. Length frequency of striped bass measured and tagged during the cooperative offshore tagging cruise, January – February 2018.



PROJECT NO. 2
JOB NO. 3
TASK NO. 5A

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Eric Q. Durell

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 5A were to quantify the commercial striped bass harvest in 2017 and describe the harvest monitoring conducted by the Maryland Department of Natural Resources (MD DNR). Maryland completed its twenty-eighth year of commercial fishing under the quota system since the striped bass fishing moratorium was lifted in 1990. The commercial fishery receives 42.5% of the state's total annual Chesapeake Bay striped bass quota. The commercial quota system is based on a calendar year.

The official 2017 commercial quota for Maryland's Chesapeake Bay and tributaries was 1,471,888 pounds. This was identical to the 2016 quota and 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.

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 2017 commercial fishery operated on a combination of a Common Pool and the ITQ system, with 98% 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 46,129 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 2017 ITQ commercial summer/fall fishery opened on June 1 and closed on December 30. Hook-and-line gear was permitted Monday – Thursday; haul seines were permitted Monday – Friday; and pound nets were permitted Monday – Saturday. The Chesapeake Bay 2017 ITQ drift gill net season was split, with the first segment from January 1 through February 28, 2017 and the second segment from December 1 through December 29, 2017, Monday – Friday. The Common Pool fishery was open by public notice as follows: 3 days in January; 2 days each in February, June, and July; 1 day each in August, September, October, and 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, 2017 and October 1 through December 31, 2017, 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 log sheets, 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 log sheets, 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 log sheets. 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, 1,439,760 pounds of striped bass were harvested in 2017. This harvest was 32,128 pounds, or 2%, under the quota. The reported number of fish landed was 306,324 (Table 2). The Chesapeake drift gill net fishery landed 44% of the total landings by weight, followed by the pound net fishery at 43% and the hook-and-line fishery with 14% of the total Bay landings. No striped bass were harvested with haul seines.

Maryland's Atlantic coast landings were reported at 3,518 striped bass, weighing 80,457 pounds (Table 2). The gill net fishery made up 99% of the Atlantic harvest, by weight, with the remainder from the trawl fishery.

Comparisons of Average Weight

The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 4.70 pounds when calculated from the check station log sheets and 6.61 pounds when measured by biologists (Table 3). Mean weights by specific gear type or season ranged from 3.79 to 6.36 pounds from check station log sheets, and 4.52 to 7.92 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 (3.79 lbs) were taken by pound nets, according to check station log sheets.

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 24.06 pounds (Table 3). The average weight calculated from the check station log sheets was similar at 22.87 pounds. Average weights calculated from check station reports indicate that fish harvested by trawl were heavier than those harvested by gill net. 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). The majority of the commercial striped bass harvest in Chesapeake Bay has historically been by drift gill net. The hook-and-line fishery generally harvests the least of the three major Chesapeake Bay gears. (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). In a departure from recent history, the 2017 Atlantic harvest was dominated by the drift gill net fishery for the second consecutive year (Table 4, Figure 5).

Commercial CPUE Trends

In Chesapeake Bay, pound nets were the most efficient striped bass harvest gear in 2017. Pound net and drift gill net fisheries have exhibited opposing trends in recent years. Pound net CPUE (477) eclipsed drift gill net CPUE (425) for the first time since 2009 (Figure 6). After a steady rise in CPUE since 2012, drift gill net CPUE declined for the second year in a row. The hook-and-line fishery CPUE (200) increased slightly relative to last year but has been fairly constant since 2011. All gear-specific CPUEs were above their respective time-series averages.

CPUE for both Atlantic gears increased relative to 2016 (Figure 6). After a precipitous decline in 2016, trawl CPUE increased slightly to 118 but is still a fraction of the long-term average. Primarily due to large harvests in April and May, Atlantic gill net CPUE increased to 562, the highest value of the time-series (Figure 3, Table 5). Low catches in recent years have sparked speculation that fish are concentrating farther offshore and outside the permitted fishing zone. Commercial harvest is limited to state waters, within 3 miles of shore.

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Figure 6. Maryland's Chesapeake Bay and Atlantic Ocean striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990-2017. Trips were defined as days on which striped bass were landed. Note different scales.

Table 1. Striped bass commercial regulations by gear type for the 2017 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	209	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 46,129; No ITQ Quota	203	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 46,129; No ITQ Quota	308	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	35	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 2017 calendar year.

Area	Gear Type	Pounds[1]	Number of Fish[1]	Trips[2]
Chesapeake Bay[3]	Haul Seine	0	0	0
	Pound Net	612,556	161,831	1,283
	Hook-and-Line	196,538	45,263	985
	Gill Net	630,666	99,230	1,485
	Chesapeake Total	**1,439,760**	**306,324**	**3,753**
Atlantic Coast	Trawl	1,181	35	10
	Gill Net	79,276	3,483	141
	Atlantic Total	**80,457**	**3,518**	**151**
Maryland Totals		**1,520,217**	**309,842**	**3,904**

1. Data from check station log sheets.

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 2017 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	3.79	4.52 (4.40-4.64)	1,985
	Hook-and-Line	4.34		
	Gill Net	6.36	7.92 (7.82-8.01)	3,155
	Chesapeake Total Harvest	**4.70**	**6.61 (6.52-6.69)**	**5,140**
Atlantic Coast	Trawl	33.74	24.06 (22.67-25.45)	218
	Gill Net	22.76		
	Atlantic Total Harvest	**22.87**	**24.06 (22.67-25.45)**	**218**

1. Data from check station log sheets, 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 2017.

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

Table 5. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2017.

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
Average	155	276	290	213	634
5 year avg	182	399	468	298	980

Figure 1. Map of the 2017 Maryland authorized commercial striped bass check stations.

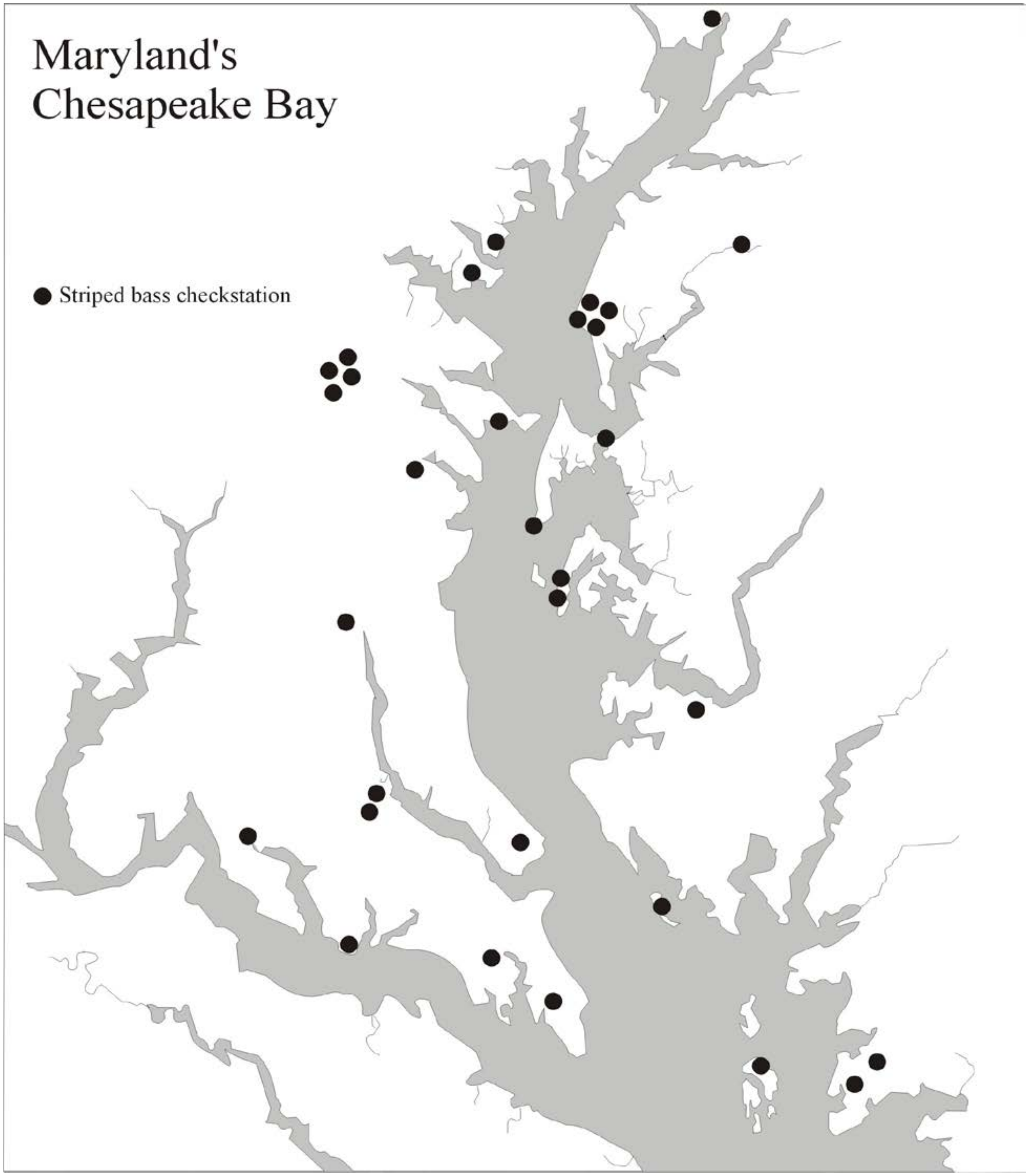
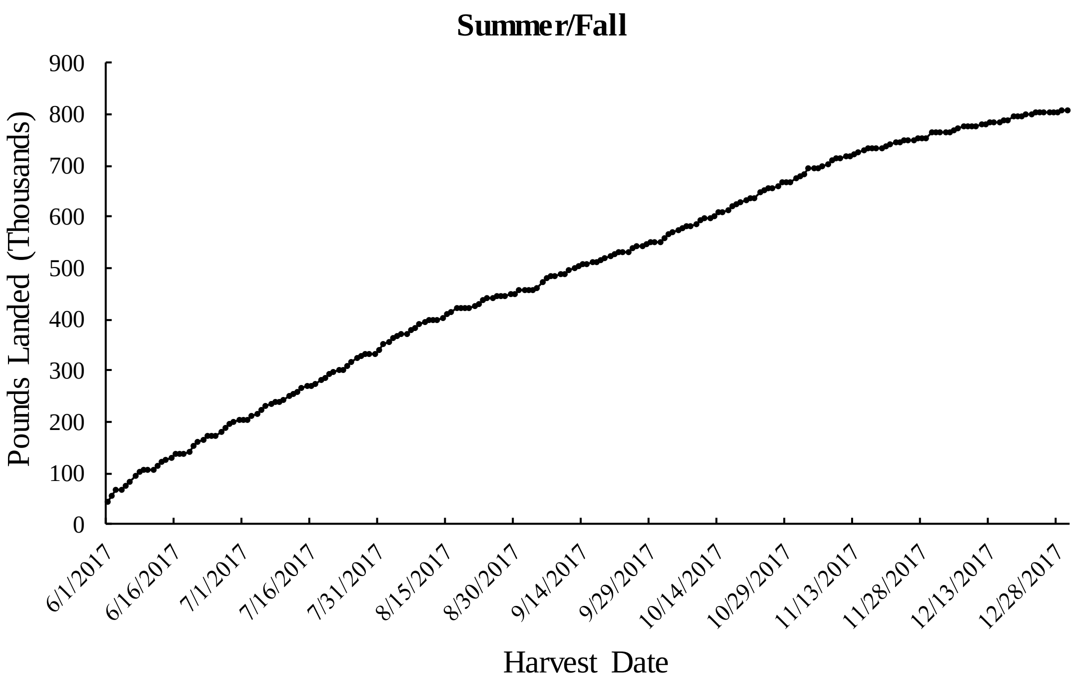
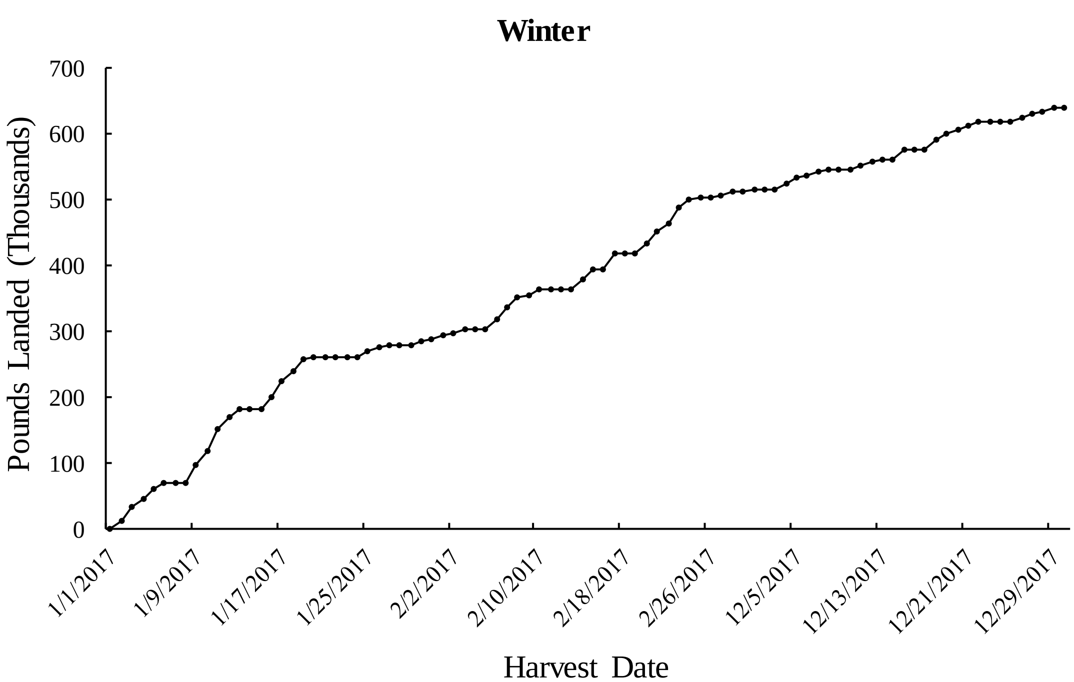


Figure 2. Maryland's Chesapeake Bay summer/fall (pound net and hook-and-line) and winter (gill net) fisheries cumulative striped bass landings from check station reports for calendar year 2017. Note different scales.





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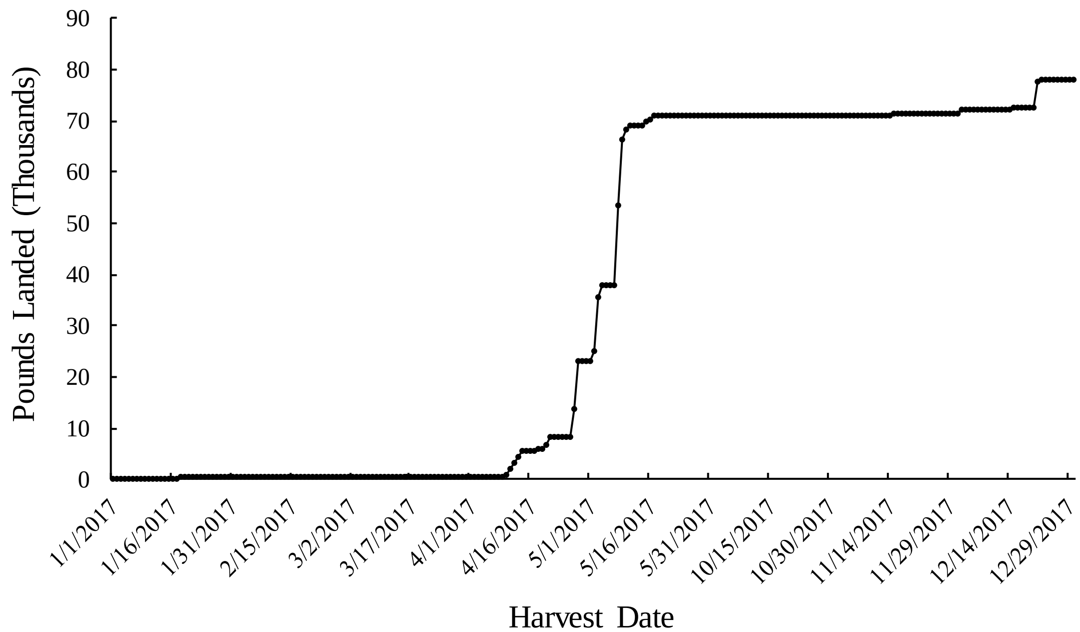

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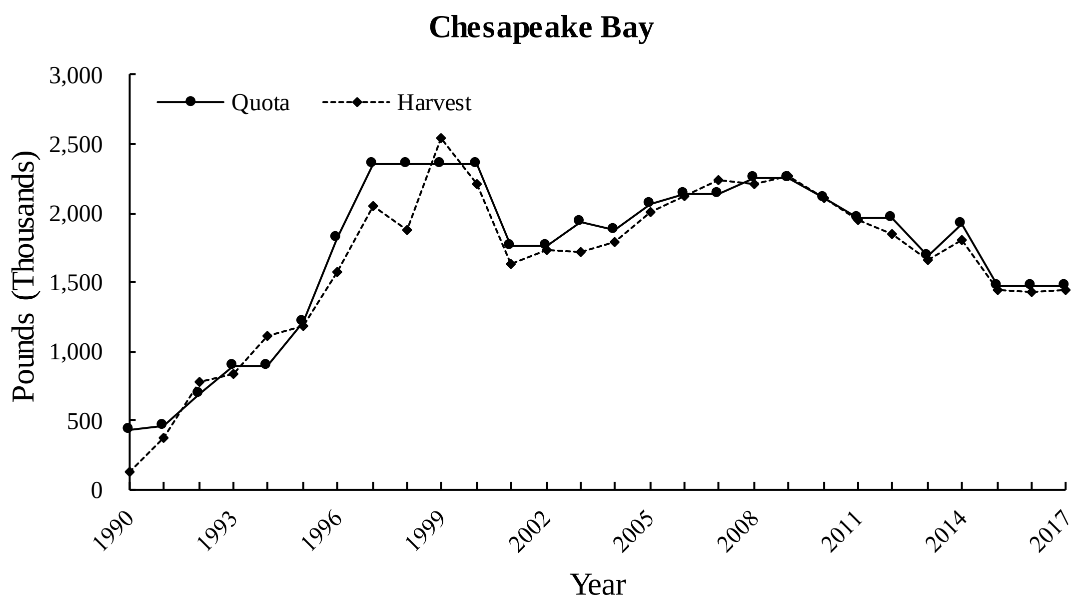


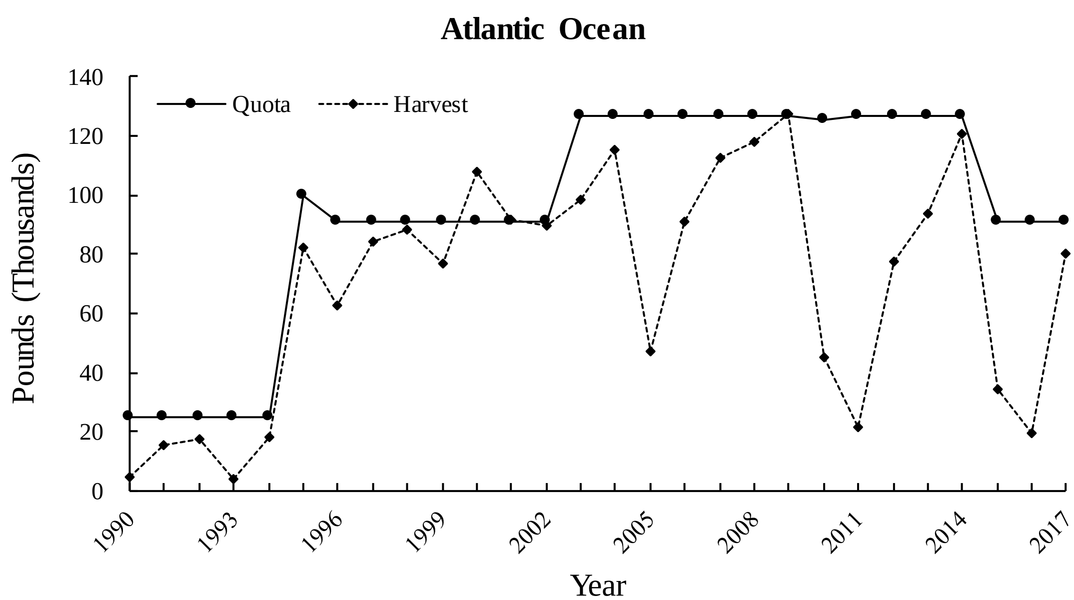
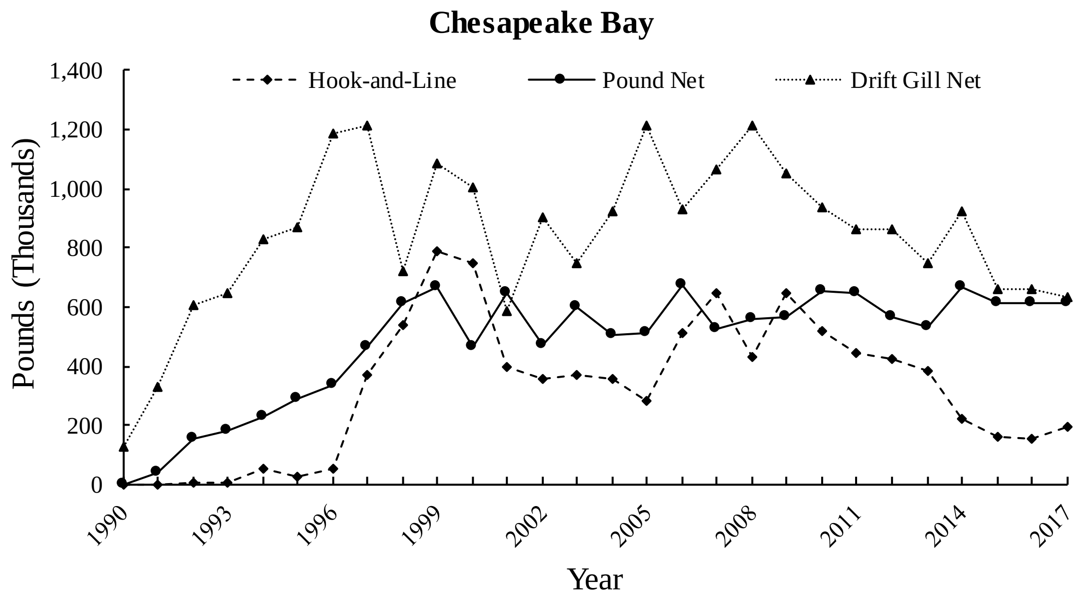


Figure 5. Maryland's Chesapeake Bay and Atlantic Ocean striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2017. Note different scales.



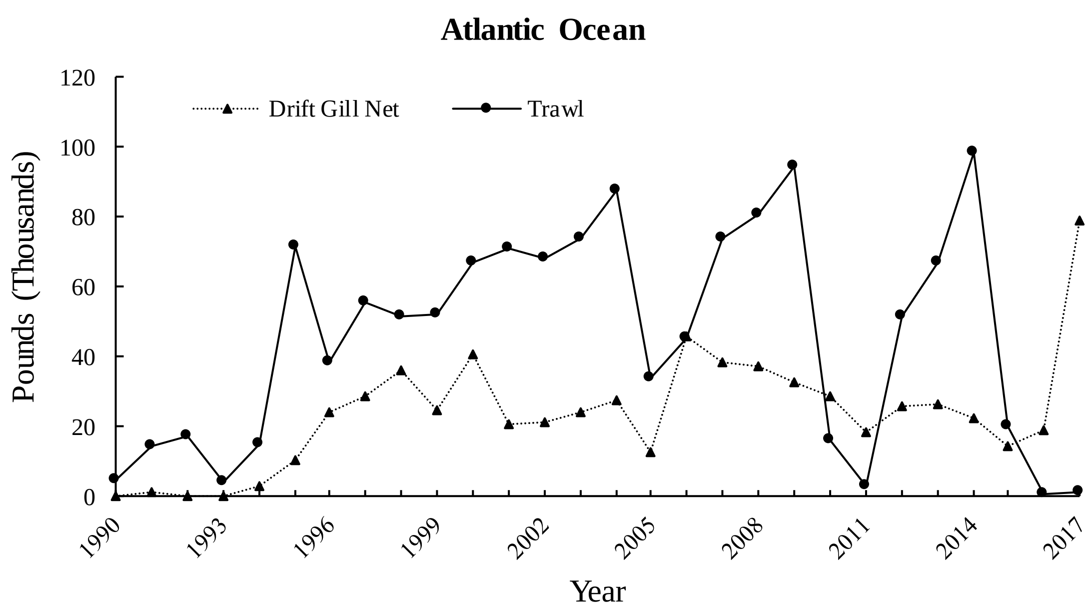
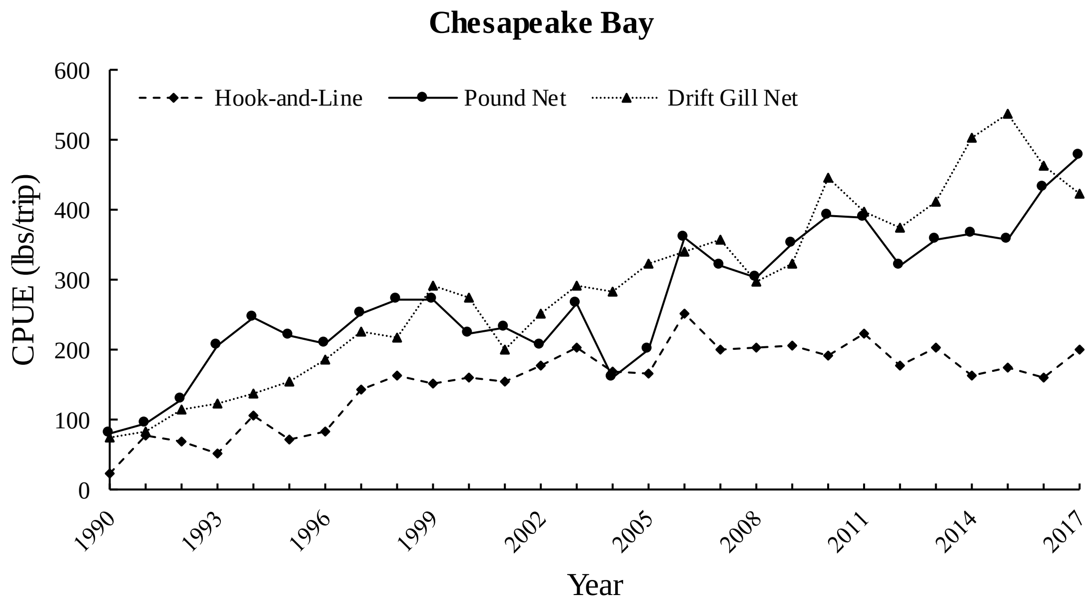
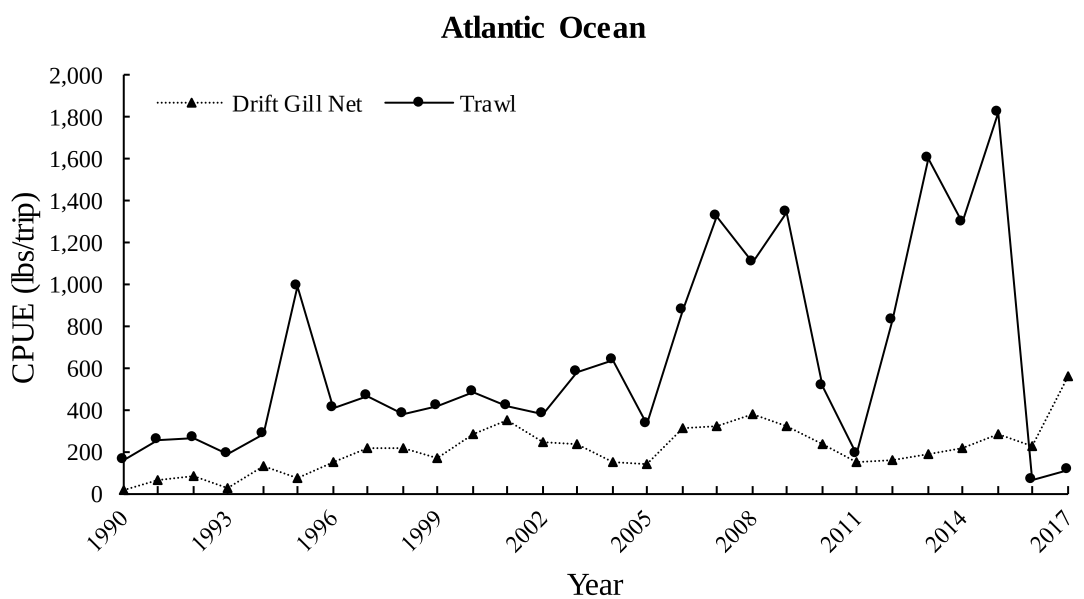


Figure 6. Maryland's Chesapeake Bay and Atlantic Ocean striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990-2017. Trips were defined as days on which striped bass were landed. Note different scales.





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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 characterize the size, age and sex composition of striped bass (*Morone saxatilis*) sampled from the 2018 spring recreational season, which began on Saturday, April 21 and continued through May 15. The secondary objective was to estimate recreational harvest rates and catch per unit effort during the spring recreational season.

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 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 2018 spring season was 24 days long (April 21 – 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 2018 Maryland and Virginia spring harvest of coastal migrant striped bass in Chesapeake Bay are reported annually to ASMFC and are available at: http://dnr.maryland.gov/fisheries/Pages/striped-bass/reports.aspx.

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 2A) 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. Charter boats sometimes caught their limit and returned to the dock as early as 10:00 AM. 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 three major charter fishing ports in 2018: Kentmorr Marina, Chesapeake Beach/Rod & Reel, and Deale/Happy Harbor (Table 2A). In previous years biologists also intercepted charter trips at Solomon’s Island/Bunky’s Charter, however, in 2018 the lack of trips booked during weekdays at this location precluded successful sampling visits. 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 2002-2018, 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 is contained in Table 4.

Biological Data Collection

Biologists approached mates of charter boats and requested permission to collect data from the catch (Table 3). 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, $\alpha=0.05$). 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 ($\alpha=0.05$) 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 number of scales aged from the creel survey has varied between years. In 2018, 184 scale samples were aged. The age structure of fish sampled by the creel survey was estimated using the 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.

In 2014, a female striped bass maturity study was added to update the female maturity schedule used in the coast wide stock assessment. The 2012 and 2013 age-length keys were used to develop sampling targets at various lengths in order to adequately characterize the maturity ogive. The female maturity study was completed in 2017. Fecundity analysis utilizing the ovary samples from the maturity study was conducted in 2017 and 2018. Complete methods and results of the female maturity and fecundity study are presented in Appendix I and Appendix II respectively.

<u>Calculation of Harvest and Catch Rates</u>

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 now submit their data electronically to MD DNR through the Standard Atlantic Fisheries Information System (SAFIS), coordinated by the Atlantic Coastal Cooperative Statistics Program (ACCSP). This submission method has become more commonly used in recent years, and in 2018 comprised 51% of the trophy season charter data. 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, but sample sizes have still exceeded 1,000 trips per year. In 2018, 16% of the charter data were excluded, resulting in 713 trips.

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 2018, there were 380 angler interviews contained in the MRIP dataset comprised of anglers intercepted from 170 private boat trips and 11 shore trips (Table 5A).

The number of charter boats intercepted, previous numbers of anglers interviewed (2002-2017), and number of striped bass examined each year are presented in Table 5B. In 2018, a total of 118 fish were examined from 41 charter trips intercepted with nonzero catch (Table 5B).

BIOLOGICAL DATA

Length and Weight

Length distribution

In the 2018 spring striped bass season, fish lengths measured from the harvest ranged from 895 mm TL to 1285 mm TL with a mean of 1037 mm TL (n=118, Table 6A). The average size of harvested striped bass has increased monotonically over time since 2012, with the exception of 2015 when a slot limit excluded the mid-size fish from the harvest (Figure 2). This could be, in large part, due to changes in the minimum size limit from 28 inches to 35 inches starting in 2016 (Table 1). However, instead of the length distribution being truncated at the minimum size limit, the length distributions in 2016, 2017 and 2018 display symmetry with a central tendency from the minimum 35 inch size limit (Figure 2). This suggests that the demographics of the striped bass stock available to anglers during the spring trophy season has shifted towards larger proportions of older and larger fish.

Mean length

The mean length of females (1044 mm TL) was greater than the mean length of males (967 mm TL), which is typical of the biology of the species (Bigelow and Schroeder 1953). Male striped bass mean length in 2018 was approximately 12% larger than the long-term average and ANOVA indicated significant differences in mean length among years ($p<0.0001$). Duncan's multiple range test ($\alpha=0.05$) found the mean length of male fish in 2018 was similar to 2016 and 2017, but significantly different than all other previous years (Table 6A). Female striped bass lengths in 2018 were also 12% 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 (α=0.05) found that the mean length in 2018 was significantly different than all previous years in the time series (Table 6A, Figure 3).

The mean daily lengths of female striped bass harvested in 2018 showed a weakly decreasing trend, however daily sample size was not adequate (n<5) to characterize mean size on 3 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 (http://dnr.maryland.gov/Fisheries/Pages/survey/index.aspx). 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 2018, anglers reported lengths for 52 striped bass caught during the trophy season and released. The mean reported length of fish caught and released was 640 mm TL (n=52).

Mean weight

Fish weights sampled during the 2018 spring striped bass season ranged from 7.0 kg to 23.9 kg. Like mean length, mean weight has also increased monotonically since 2012, with the exception of 2015 when a slot limit was in place excluding mid-size fish. The mean weight of striped bass harvested in the spring season has increased from 6.7 kg in 2012 to 11.7 kg in 2018 (Table 6B, Figure 5).

The mean weight of females (12.0 kg) was greater than the mean weight of males (8.9 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). ANOVA results indicated significant differences in mean weight among years for both females ($p<0.0001$) and males (p<0.0001). Mirroring mean length data, the results of Duncan's multiple range test (α=0.05) indicate the mean weight of female fish sampled in 2018 (12.0 kg) was significantly different than all previous years (Table 6B, Figure 5). According to Duncan's multiple range test (α=0.05) the mean weight of male striped bass (8.9 kg) in 2018 was similar to 2016 and 2017, but significantly larger than all other previous years (6.5 kg, Table 6B, Figure 5).

Age Structure

The age distribution estimated from the combined age-length key applied to lengths of striped bass sampled from the 2018 spring recreational harvest ranged from 7 to 19 years old (Figure 6). The largest contributing year-classes representing >10% of the sample were, 2003 (19.7%), 2005 (18.9%), 2007 (17.0%) and 2009 (12.7%). The oldest striped bass in the harvest was estimated to come from the 1999 year class (age 19).

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2018 spring season harvest was dominated by female striped bass (Table 7A). Sex ratios (% of females in the harvest) were calculated using three methods: 1) including fish of unknown sex in total, 2) using only known-sex fish, and 3) assuming that the unknown fish were female (Table 7B).

Calculation method did not significantly alter the proportion of females in the sampled harvest as there were only two fish of unknown sex in 2018. Similar to the five previous year, females constituted 90% of the sampled harvest. This is above the long-term average of 85% (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 during the first two weeks of May. From 2002 – 2018 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). Despite the opening day of the spring season occurring on the third Saturday in April since 2002, the 5-year average percentage of pre-spawn females in the spring season harvest was 52% in 2002-2006, 42% in 2007-2011, and 25% in 2012-2016. 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 dropped 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 spawn earlier in the season than smaller, younger individuals (Cowan et al. 1993).

Daily spawning condition of females

The percent of post-spawn females ranged from 50% in the first week of the spring season to >75% from the beginning of May until the end of the season (Figure 7). This pattern suggests that most female fish harvested in the spring season in 2018 had spawned by the beginning of May and were subsequently captured as they migrated back to the coast from spawning grounds.

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 2018. 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 2002-2018. 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.

Because of the Addendum IV requirements in place since 2015 to reduce harvest, HPT was expected to be lower as compared to previous years. The mean HPT in 2018 according to charter boat data was 2.1 fish per trip (Table 9A) which was 53% below the long term mean charter boat HPT (4.5 fish per trip) and the lowest in the time series. The mean HPT from MRIP private boat interviews of 0.1 fish per trip was 83% below the long-term mean private boat HPT (0.6 fish per trip).

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 2018 was 0.35 fish per person (Table 9B) which was a 51% reduction from the long-term mean (0.72 fish per trip). HPA for private anglers, calculated from MRIP interview data, was <0.1 fish per person 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 2018, private boats intercepted by MRIP caught an average of 0.7 fish per trip, which was 59% below the long-term average of 1.7 fish per trip (Table 10A). Charter boats caught 4.4 fish per trip, which was similar to 2017 and 28% below the long-term average (6.1 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 0.8 fish per hour.

Angler Characterization

States of residence

In 2018, 318 MRIP angler interviews were conducted during the period April 21-May 15 (Table 5A). Ten states of residence were represented in 2018 (Table 11). Most anglers were from Maryland (88%), Virginia (5%), and Pennsylvania (17%), similar to previous years.

PROJECT NO. 2
JOB NO. 3
TASK NO. 5B

CHARACTERIZATION OF THE STRIPED BASS SPRING RECREATIONAL SEASON AND SPAWNING STOCK IN MARYLAND

2019 PRELIMINARY RESULTS

Data collected during the 2019 spring recreational season (April 20-May15) are currently being analyzed. In 2019, 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.

During the 2019 spring recreational season, only 25 striped bass from 33 intercepted charter boat trips were measured, weighed, and internally examined for spawning condition. It was observed that many charter trips, which normally target striped bass, were targeting invasive blue catfish and channel catfish. Biological samples collected from examined fish for aging studies include 13 scale samples, 8 otoliths, and 1 dorsal fin spine. Female striped bass (n=20) were a mean Total Length of 1014 mm and mean weight of 11.95 kg. Internal examination revealed 90% of female striped bass harvested had recently spawned. Male striped bass (n=5) were a mean Total Length of 895 mm and a mean weight of 7.92 kg. Scale samples are currently being processed and aged, therefore no age distribution of the 2019 spring recreational harvest is available at this time.

The final, complete analyses of the spring 2019 recreational survey data will appear in the next F-61 Chesapeake Bay Finfish Investigations report.

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Table 1. History of changes made to MD DNR fishing regulations for Maryland striped bass spring trophy seasons, 1991-2018.

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**	↓	↓	↓

Table 2. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2018. 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 3. Biological data collected by the Maryland striped bass spring season creel survey, 2018.

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 4A. Variable and value combinations used to filter MRIP 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 4B. 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 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

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

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)
Mean	**923** (902-946)	**933** (912-957)	**866** (845-888)

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)
Mean	**8.3** (7.7-9.0)	**8.6** (8.0-9.2)	**6.6** (6.1-7.1)

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

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
Mean	**83** (80-86)	**85** (82-88)	**85** (83-88)

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
Mean	**--**	**36** (28-44)	**--**	**64** (56-72)

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)
Mean	1,569	**4.5** (3.9-5.0)	**0.9** (0.65-1.1)	**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)
Mean	1,569	**0.72** (0.64-0.79)	**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)
Mean	**1.6** (1.2-2.0)	**4.7** (4.3-5.0)	**0.4** (0.3-0.5)	**1.7** (1.3-2.1)	**5.0** (4.7-5.3)	**0.4** (0.3-0.5)

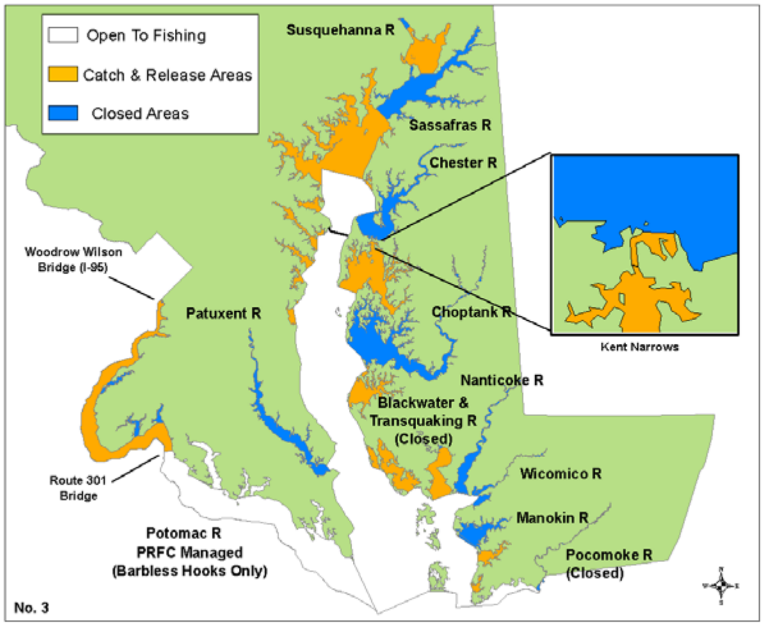
Table 10B. Charter boat mean catch, effort, and catch per hour, with 95% confidence limits, calculated from charter boat logbook data, through May 15. Catch is defined as number of fish harvested plus number of fish released. Mean hours per trip are from creel survey interview data until 2009 where the mean hours per trip are from mate interviews. SAFIS data was 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)
Mean	1,648	**6.1** (5.6-6.6)	**4.8** (4.3-5.2)	**1.4** (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 was used beginning in 2018.

State	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
AK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AL	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
AZ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CA	1	0	1	0	0	2	0	0	0	0	0	0	0	1	0	0	0
CO	0	0	1	0	1	1	0	0	1	0	1	0	0	0	2	0	0
DC	6	1	1	0	1	2	1	0	6	1	0	1	0	0	0	1	0
DE	6	7	3	0	9	8	1	0	3	1	2	0	5	2	2	10	14
FL	0	0	1	1	2	0	1	0	3	1	0	1	0	1	1	4	0
GA	1	1	0	2	2	0	0	0	0	0	0	0	0	0	0	1	1
IL	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
KY	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
KS	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0
MA	0	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1
MD	**353**	**260**	**107**	**66**	**227**	**679**	**266**	**651**	**482**	**491**	**381**	**407**	**484**	**483**	**474**	**413**	**279**
MI	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
MN	0	0	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0
MT	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0
NC	0	2	0	1	0	1	1	0	0	0	3	0	1	0	1	0	0
NJ	2	2	6	0	3	2	4	0	0	1	3	0	2	0	0	2	2
NV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
NY	4	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0
OH	0	0	0	0	0	3	1	0	1	0	1	0	1	0	0	0	0
PA	**27**	**19**	**17**	**4**	**22**	**32**	**16**	**46**	**18**	**19**	**23**	**21**	**30**	**24**	**25**	**32**	**55**
RI	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
SC	0	0	1	0	0	1	0	0	0	0	0	0	0	3	0	0	0
TN	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TX	0	1	0	0	0	0	0	0	0	0	1	2	0	0	1	0	0
VA	**48**	**31**	**30**	**13**	**56**	**71**	**29**	**44**	**42**	**23**	**26**	**20**	**39**	**27**	**49**	**31**	**16**
VT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
WA	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
WI	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0
WV	0	1	0	2	6	3	2	4	4	0	4	2	10	3	5	1	2
Intl.	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Unknown	0	0	0	0	0	0	0	0	36	0	0	0	0	0	2	0	0

Figure 1. MD DNR maps showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 21-May 3, 2018 (top) and May 4-May 15, 2018 (bottom)



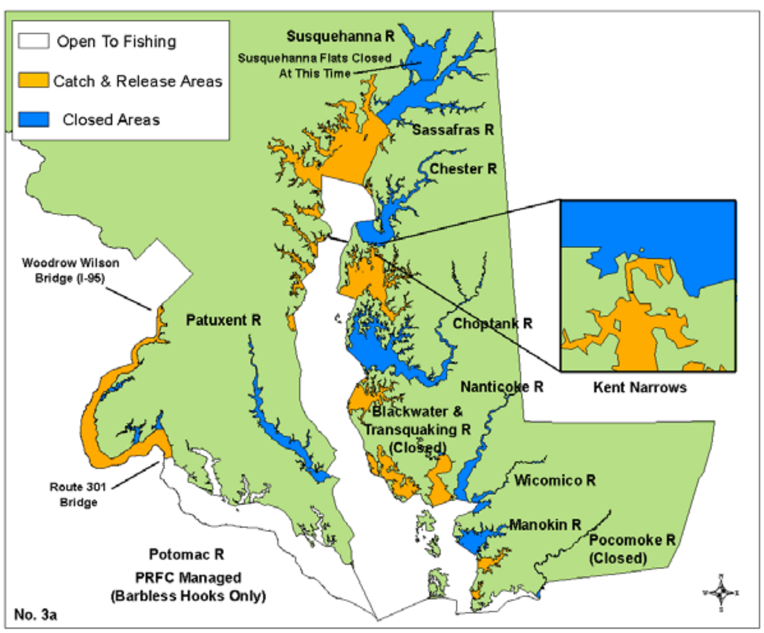


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

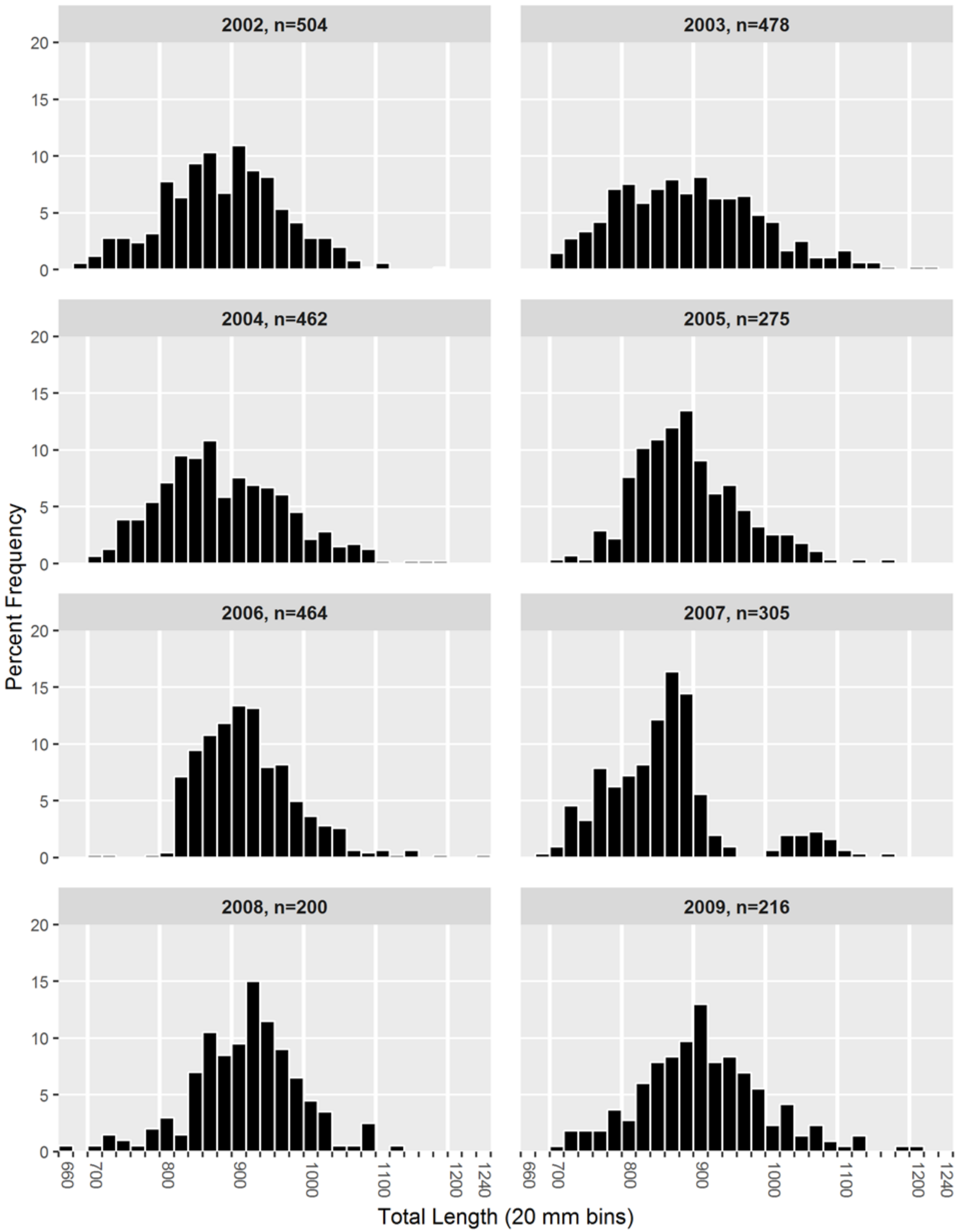


Figure 2. Continued.

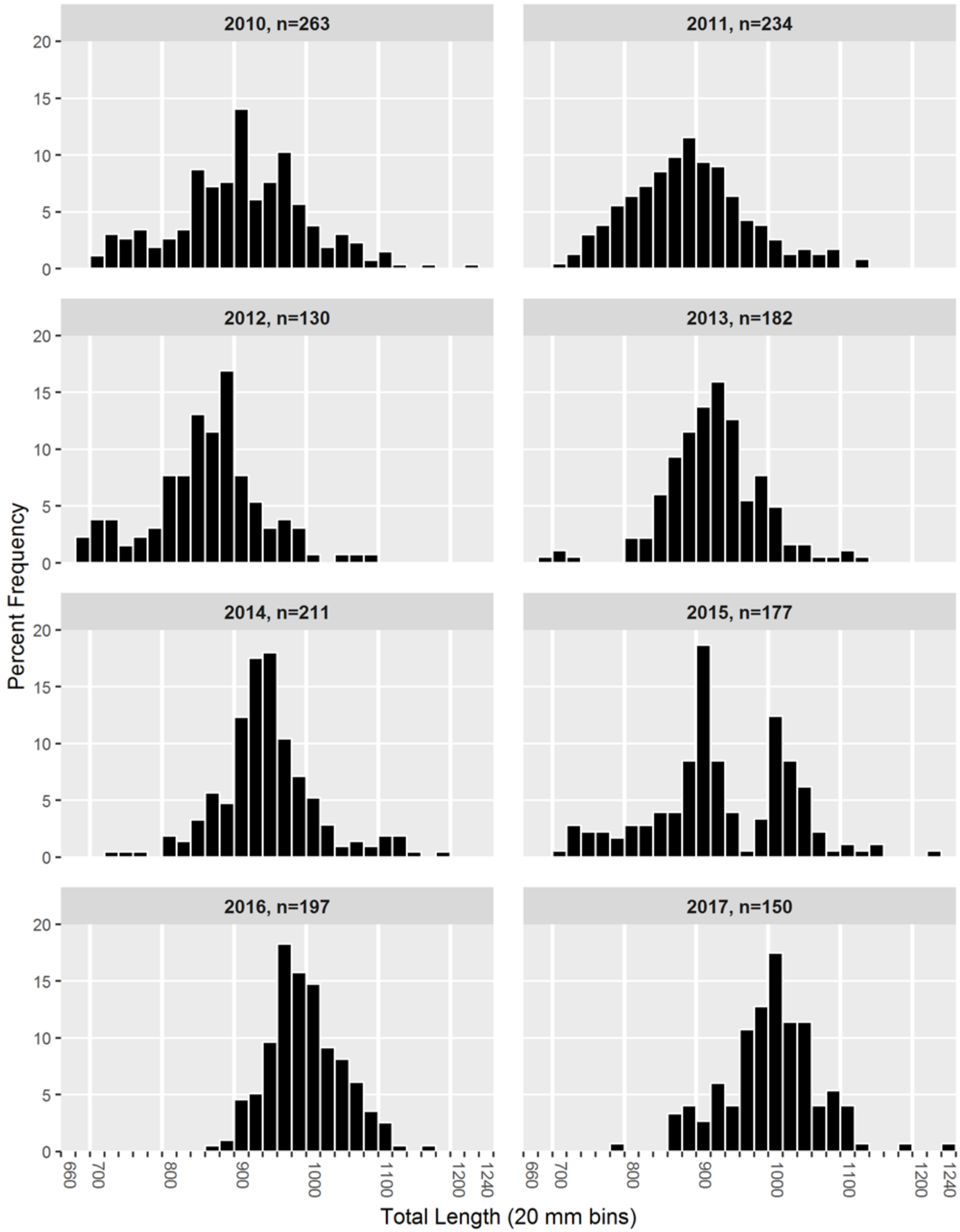


Figure 2. Continued.

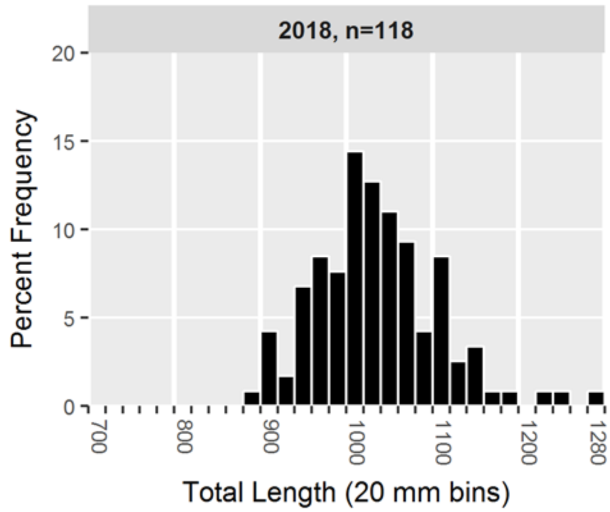


Figure 3. Mean length off female and male striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

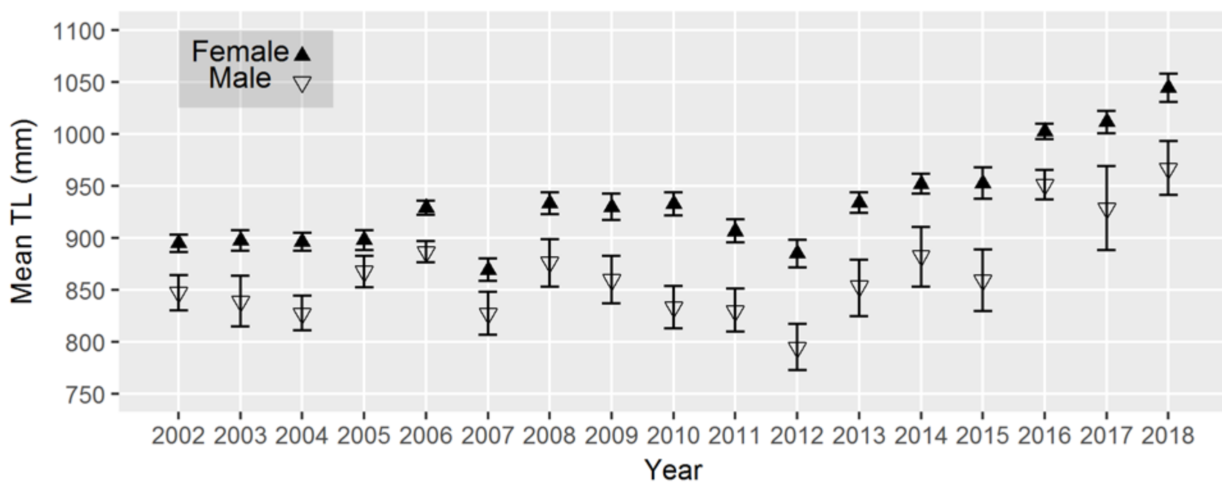


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

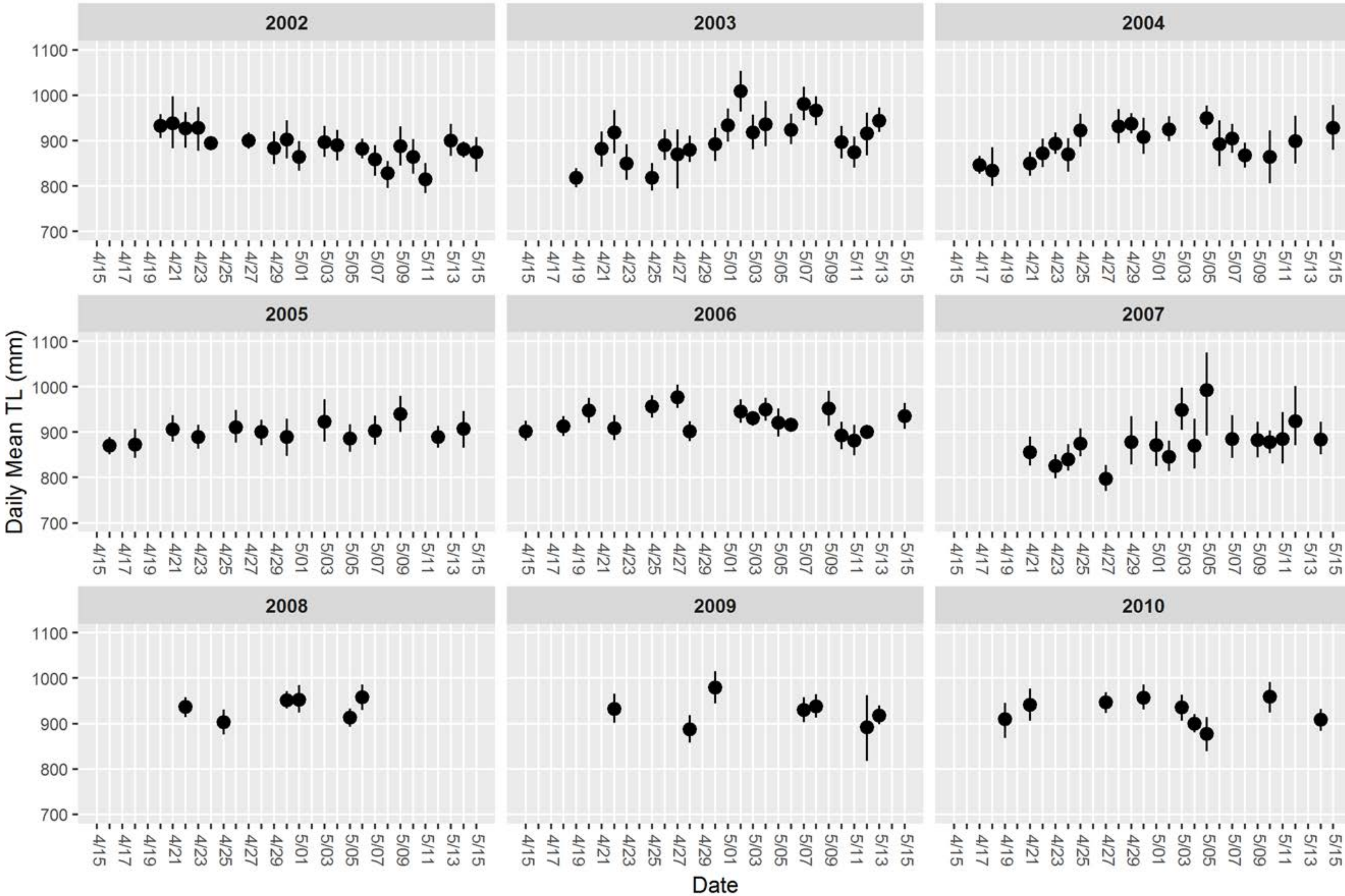


Figure 4. Continued.

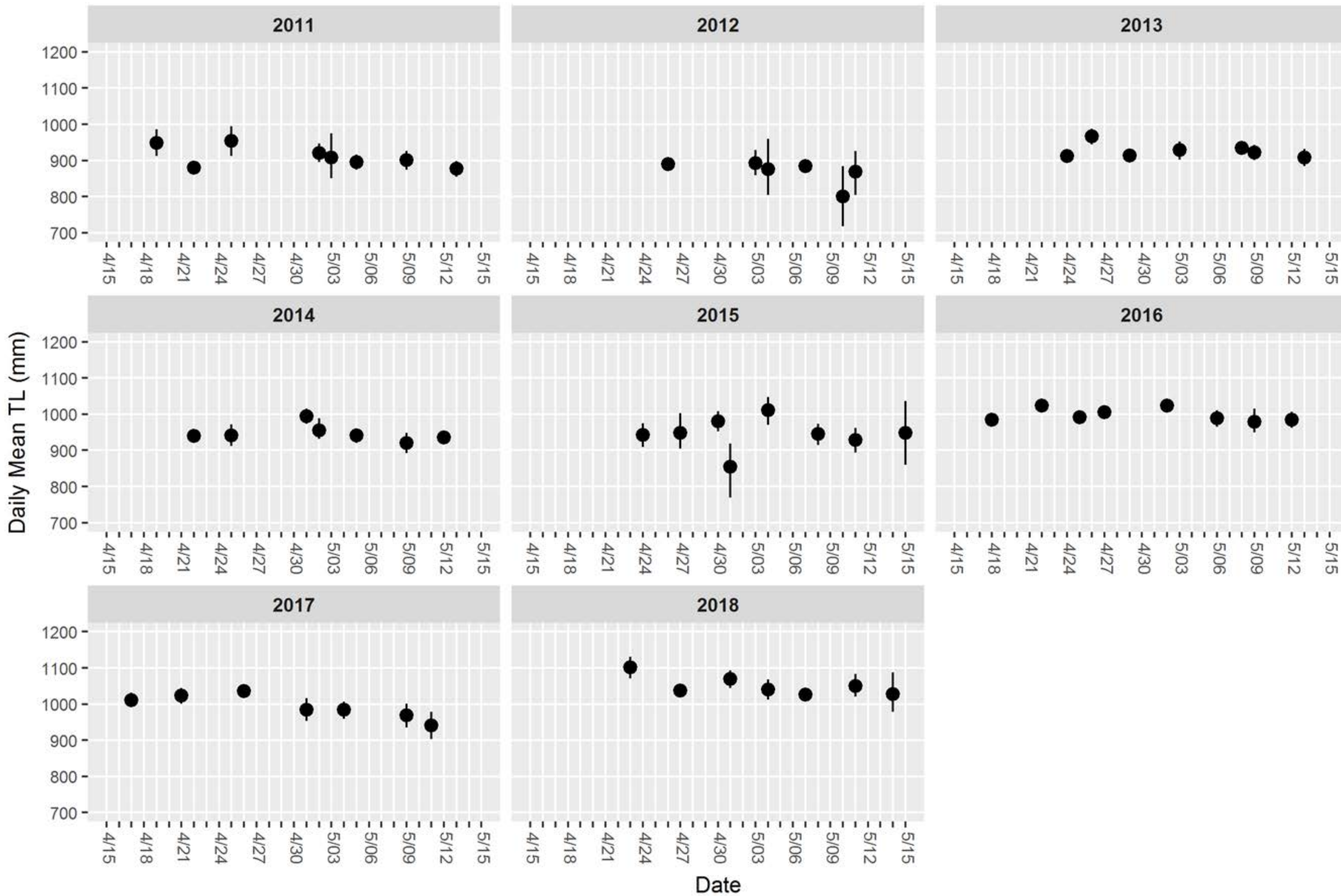


Figure 5. Mean weight of female and male striped bass (kg) with 95% confidence intervals sampled by the Maryland striped bass spring season creel survey, through May 15.

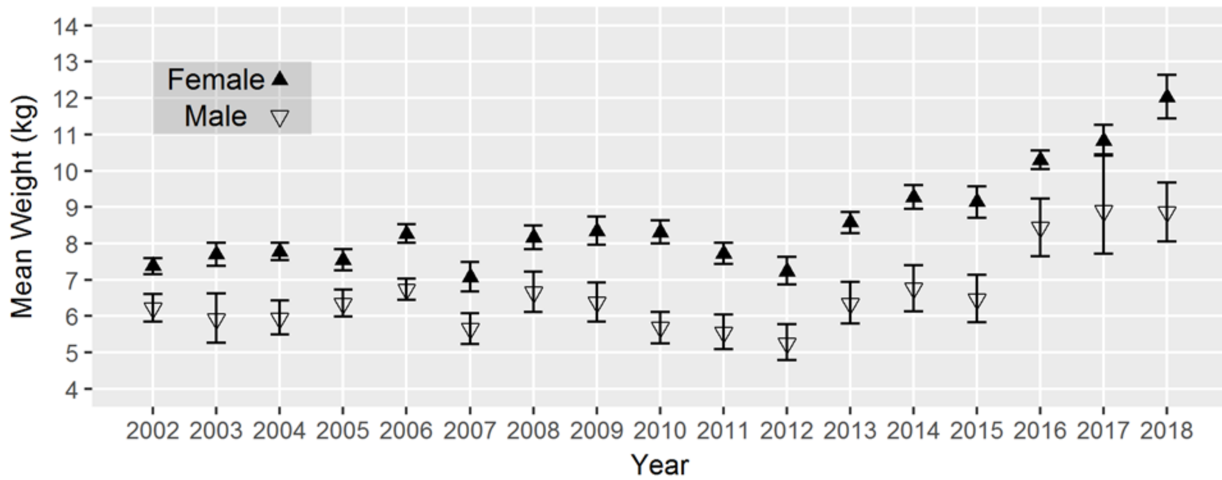


Figure 6. Estimated age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

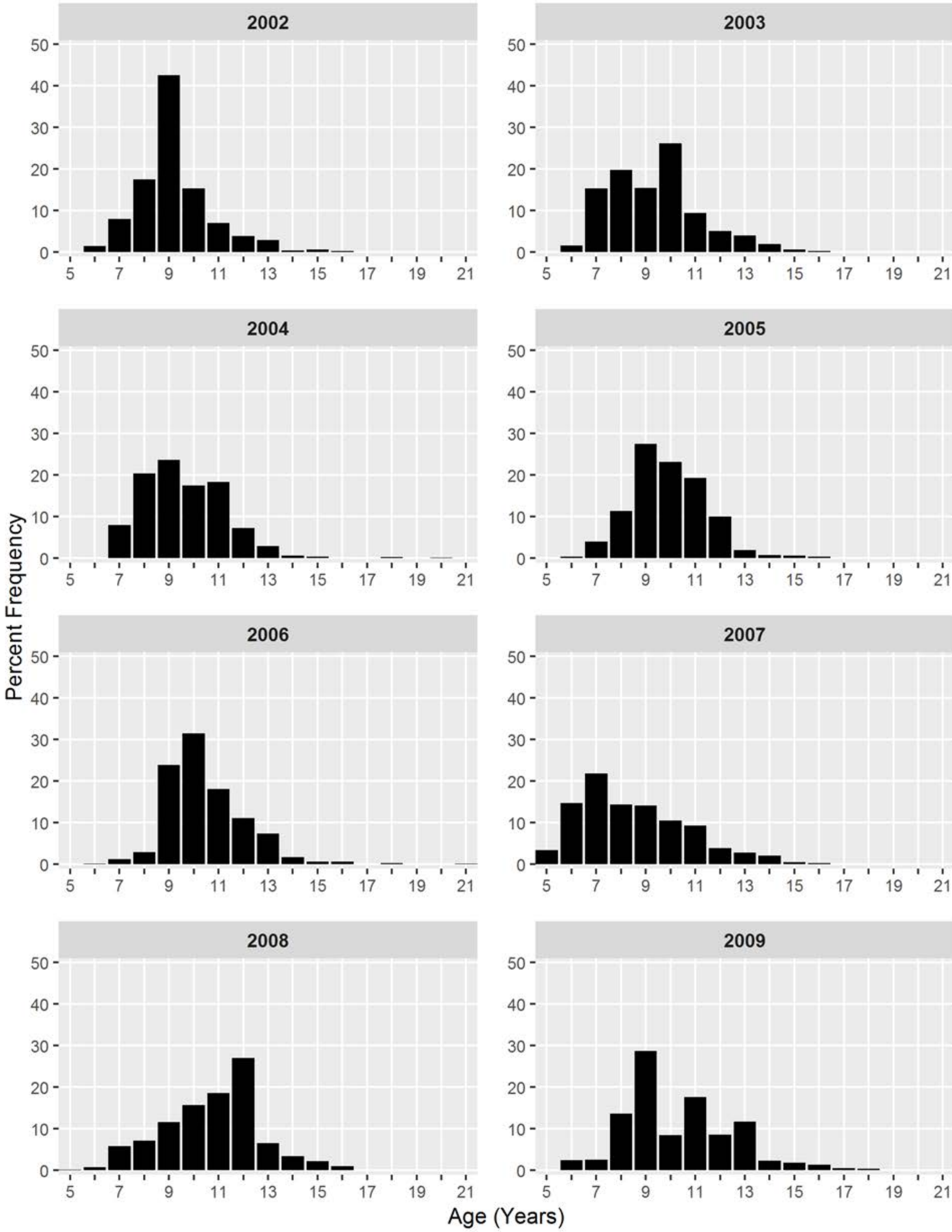


Figure 6. Continued.

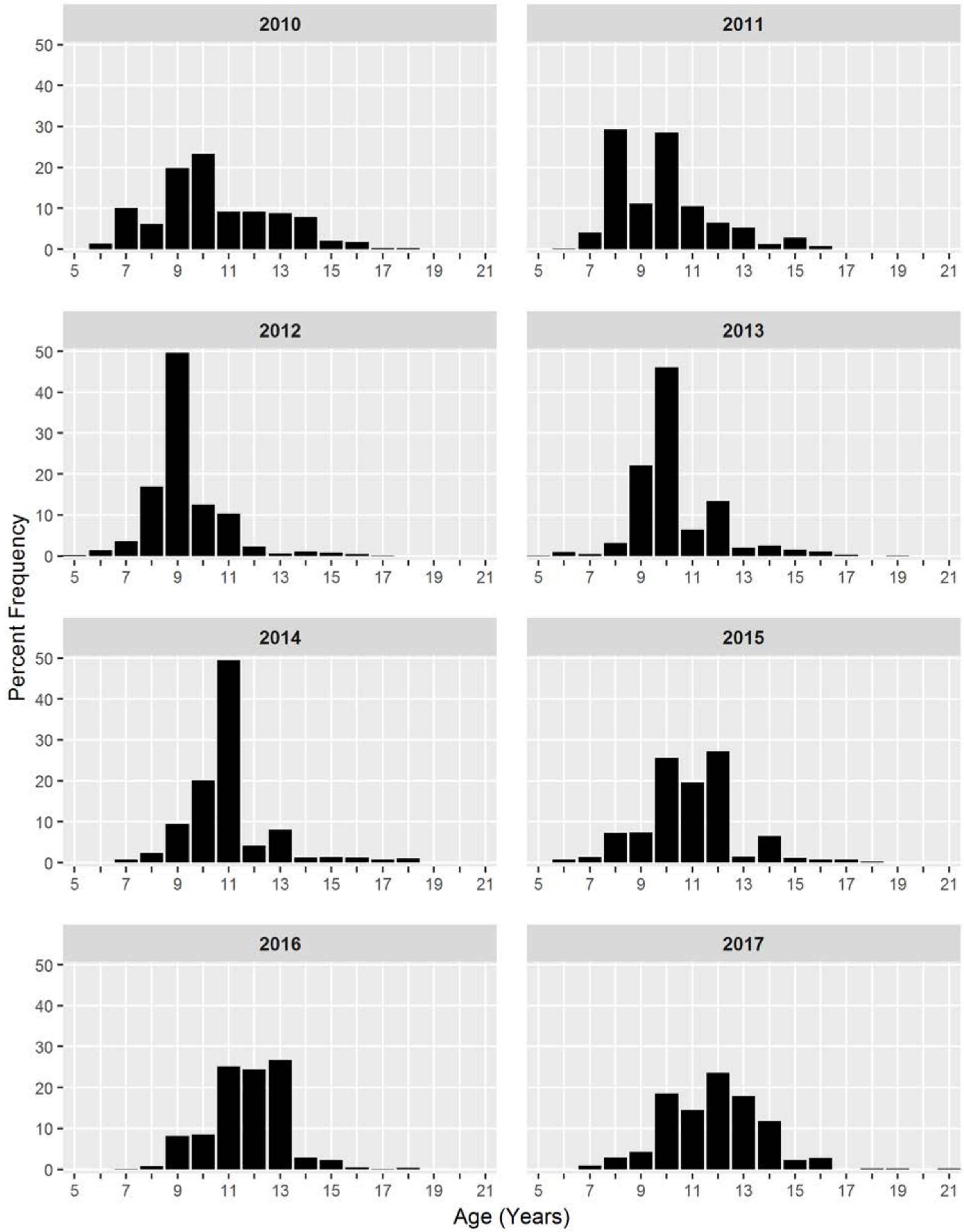


Figure 6. Continued.

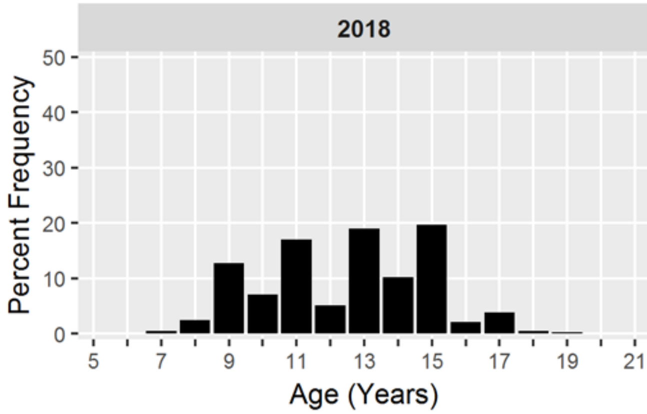


Figure 7. Daily percent of female striped bass in post-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

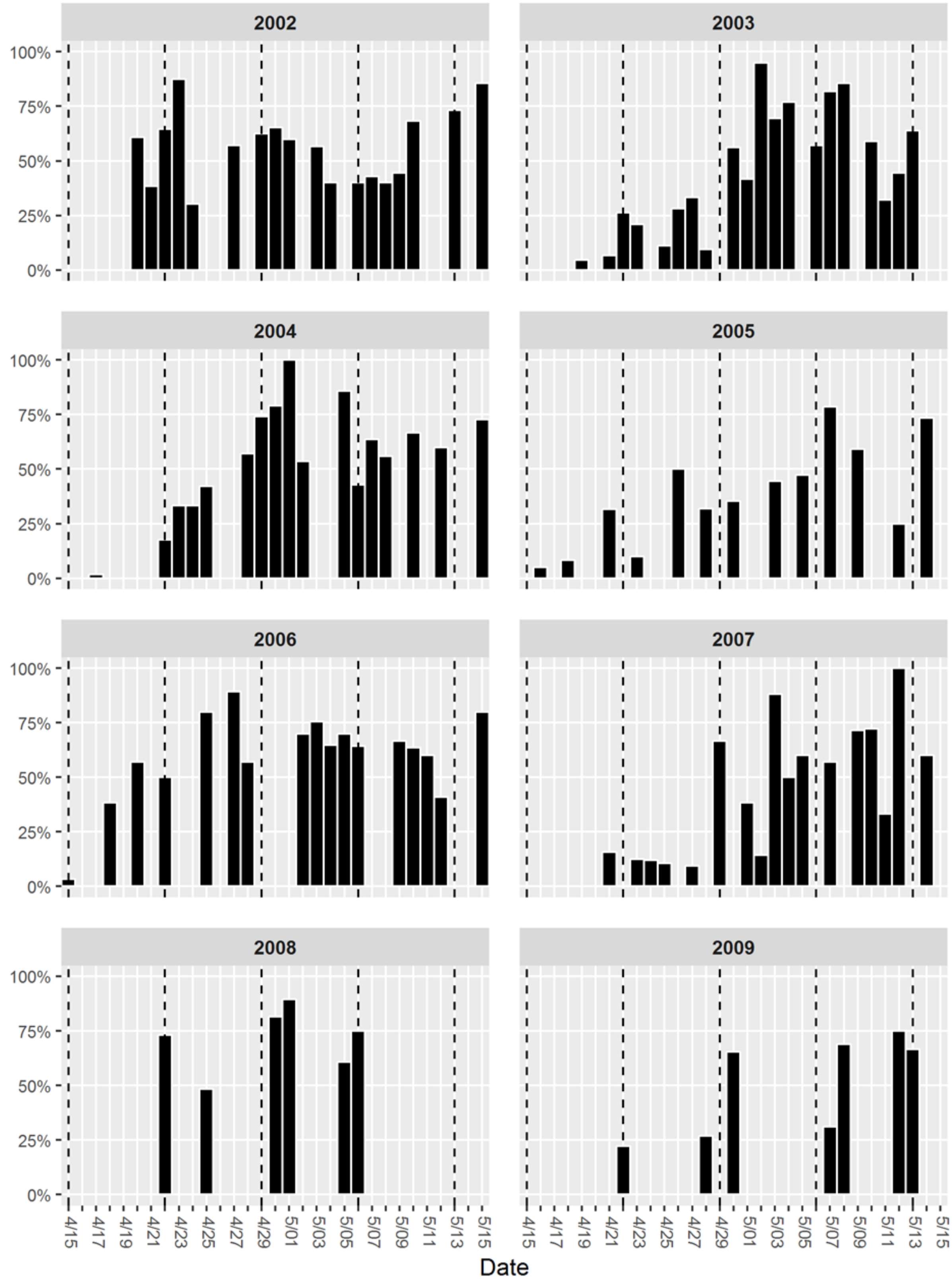


Figure 7. Continued.

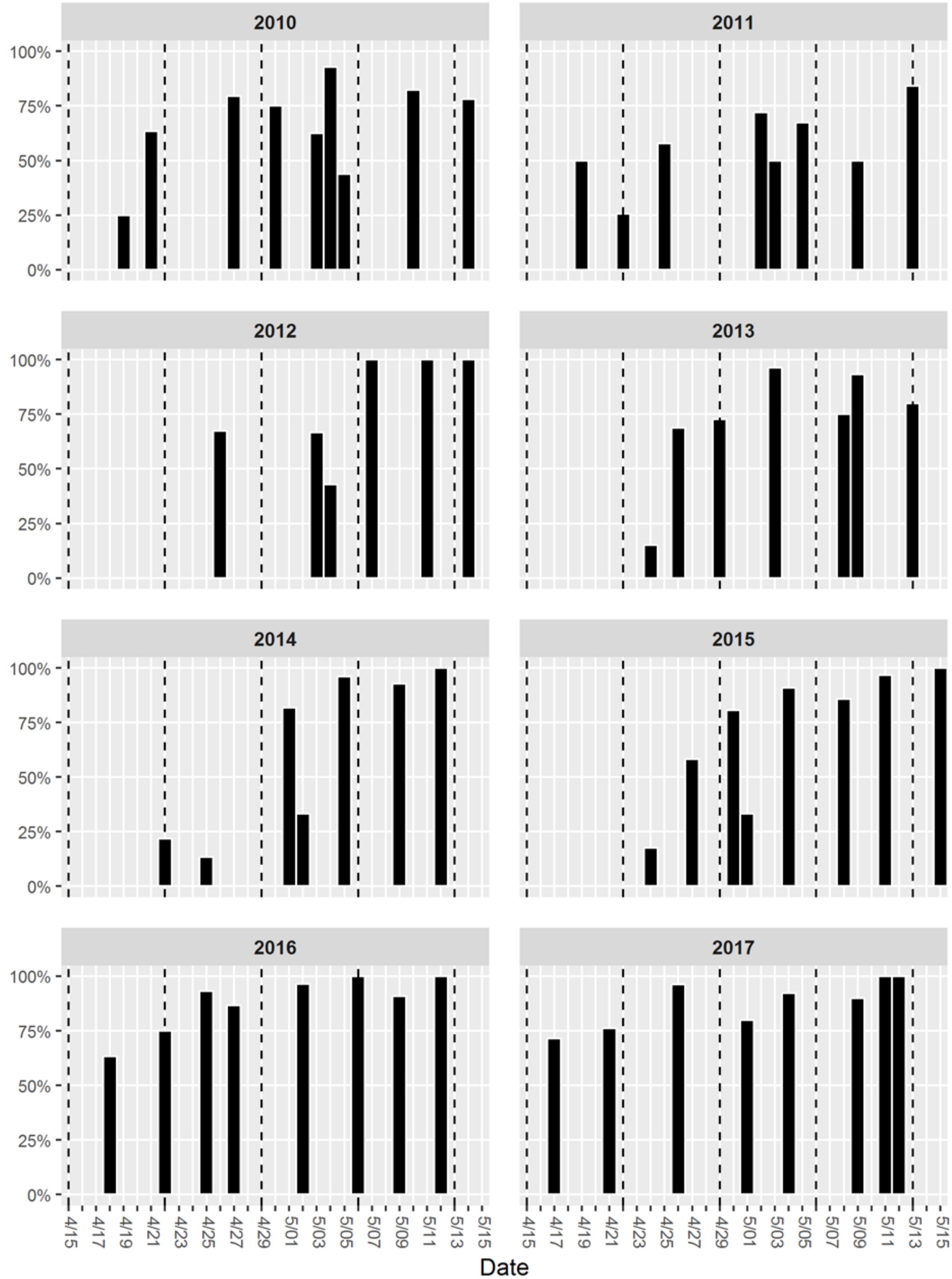
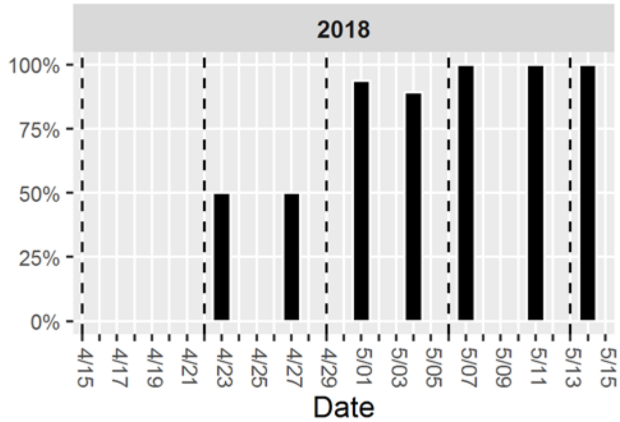


Figure 7. Continued.



APPENDIX I

Update to the Female Striped Bass Maturity Schedule

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Introduction

The 2013 striped bass benchmark stock assessment (Northeast Fisheries Science Center 2013) lists development of maturity ogives applicable to coastal migratory stocks as a moderate level research priority. The current female striped bass maturity schedule used in the stock assessment is based on a 1987 white paper by Phil Jones (Table 1).

In the white paper, data for ages 4-6 were from the Maryland spawning stock gill net survey from 1985-1987, while data for ages 7-8 appear to be from a Texas Instruments study (Texas Instruments Inc. 1980) done on the Hudson River from 1976-1979. The Maryland study estimated maturity at age by dividing female CPUE from the spawning stock survey by male CPUE while assuming the natural and fishing mortality were the same between the sexes and that all males were mature. The assumption of equivalent mortality between the sexes was valid during the time period of the study due to the moratorium. The Texas Instruments study used a gonadosomatic index (ovary weight divided by fish weight) to separate immature from mature female fish.

Both methods use an indirect, rather than histological approach, to estimate female maturity at age and the work has not been updated since the stock was rebuilt. The estimated female maturity at age is improved by using newer, standardized, and more detailed histological techniques that reflect the dynamics of a restored stock.

This report summarizes the work conducted from 2014-2016 to update the maturity schedule. The secondary goal of calculating fecundity estimates will be completed at a later date.

Methods

Determining Sampling Targets

In an attempt to sample all ages of females in the population, length group targets were established after reviewing past female age frequencies (Table 2) and length frequencies (Figure 1) from the Maryland spring creel survey. Based on sample sizes from five years of creel survey sampling, it was determined that three years of sampling (2014-2016) would be required to achieve adequate sample sizes.

The majority of the sampling effort (68%) was on fish between 520-879 mm TL. Using Maryland's 2012 and 2013 spring age-length keys, these fish should be between 5-8 years old. Sampling was focused on this size/age range to adequately characterize the steepest part of the current maturity ogive (Figure 2). However, samples were also collected at smaller and larger sizes where fish were expected to be mostly immature or all mature, respectively. The proposed target sample sizes, by 20 mm length group, as well as the number sampled, are shown in Table 3 and Figure 3. The length groups in this table and figure are midpoints (i.e. the 610 length group goes from 600-619 mm).

Sample Collection Procedures

The primary source of fish was the Maryland Department of Natural Resources (MDNR) spring creel survey, since all fish encountered were already dead and the harvest over the April through June survey included both resident and migratory fish within the spawning period (Table 4). Additional fish from the Chesapeake Bay spawning stock were collected from the spawning stock survey and other surveys in Maryland's portion of the Bay.

While the low sample sizes in the 590-830 mm length groups observed in the spring creel survey sampling (Figure 1) could be due to the two different regulatory periods during the spring (trophy season through May 15 and summer/fall season after) and angler behavior, it is also possible that fish in this size range are immature migratory females that have not yet returned to the Chesapeake Bay to spawn. By using only samples from the Chesapeake Bay, the results may be biased towards immature, premigratory fish and mature, migratory fish, while lacking immature migratory females that remain on the coast. To minimize this bias, complementary sampling was conducted by coastal states to fill in missing length groups. The New Jersey Bureau of Marine Fisheries, Rhode Island Division of Fish and Wildlife, and the Northeast Area Monitoring and Assessment Program (NEAMAP) contributed samples from their routine surveys (Table 4). Ovaries were collected from the various surveys in the months of March through July and September through December during pre-spawn, spawning and post-spawn periods (Table 5). Total length (mm TL), weight (kg), visual (macroscopic) maturity stage, and external anomalies were recorded from all fish. Scales were collected to assign ages to fish sampled, as scale ages for striped bass are generally accurate through age ten (ASMFC 2013). Maryland does not have the ability to process and read striped bass otoliths, however, otoliths were collected for future validation.

Histological procedures followed the methods from Boyd (2011). Both ovaries were carefully removed from the body cavity and weighed. One ovary was retained in cold 10% buffered formalin for up to two weeks, depending on ovary size. Formalin was used for preservation on all surveys with the exception of NEAMAP where Normalin was used. Large ovaries were cut in half and remained in formalin for a longer time to ensure complete fixation. After fixation was complete, a 4 mm thick ovary cross-section was placed into one or more labeled, standard histological cassettes and stored in 70% ethanol.

Histological Procedures

The MDNR Diagnostics & Histology Laboratory at the Cooperative Oxford Laboratory prepared MH&E-stained histological slides of ovary tissues.   Detailed laboratory procedures for the processing of ovary slides can be found in Boyd (2011).

Slides were viewed under 40X or 100X magnification through a dissecting scope, and maturity stages were assigned according to the categories defined in Brown-Peterson et al. (2011) (Table 6). Slides were examined by three biologists to determine the final maturity stage. If there was disagreement between the readers, the slides were viewed and discussed until a final stage was agreed upon.

Analytical Procedures

Brown-Peterson et al. (2011) defines immature fish as a gonadotropin independent phase and “fish enter the reproductive cycle when gonadal growth and gamete development first become gonadotropin dependent (i.e., the fish become sexually mature and enter the developing phase)" (Figure 4). While a striped bass may enter the developing phase and be physiologically mature, it does not necessarily indicate that the fish will spawn in the upcoming spawning season (Olsen and Rulifson 1992; Berlinsky et al. 1995; Boyd 2011). For this reason, the data were analyzed in two ways: as the percent mature (with developing through regenerating phases designated as mature) and as percent spawning (spawning capable through regressing phases indicating spawning is imminent or completed).

Ovary slides from fish collected in the fall/winter were essentially all immature or developing fish, with 89% of samples in the developing phase. As stated above, these fish may or may not spawn in the following spawning season. For this reason, the data were also analyzed using a subset of data from the spring and summer, a time period when spawning was occurring or just completed and the full dataset.

For samples collected from March through July, ages were calculated as the sample year minus the assigned year class. Calculation of ages for fish collected in the fall and winter (September through December) were done slightly differently. If a fish was determined to be immature in the fall/winter, it was immature the previous spring and age was calculated as above. Similarly, if a fish was regressing or regenerating in the fall/winter, it was assumed to have spawned the previous spring and age was also calculated as sample year minus year class. Difficulty arose with fish in the developing phase in the fall/winter with no readily apparent indications of previous spawning (e.g. thickened ovarian walls and/or muscle bundles). Therefore, if a fish was in the developing phase, it may or may not have spawned in the previous year. For these fish, we make the assumption that the observed developing phase is in preparation for the upcoming spawning season. For this reason, ages of fish in the developing phase from the fall and winter were advanced one year.

The maturity at age data were analyzed using logistic regression by specifying the logit link in a binomial generalized linear model (GLM) in R (R Core Team 2016).

Results

Over three years, 428 ovary samples were collected and were useable for this study (Figure 3). Of these, 307 were from Maryland's Chesapeake Bay (71.7%) and 121 were from coastal surveys (28.3%, Table 4). Lengths of all females sampled ranged from 350 to 1223 mm TL (mean=697 mm, SE=8.7 mm). Chesapeake Bay fish ranged from 350 to 1223 mm TL (mean=731 mm, SE=10.8 mm) and females sampled on the coast ranged from 350 to 1030 mm TL (mean=610 mm, SE=10.6 mm).

Ages ranged from 2 to 16, with 31% of fish from the above average 2011 year-class. The majority of fish sampled were between ages 4 and 6 (54.2%, Table 7). Sampling targets put the most sampling effort on fish approximately ages 5-8 (68%) in order to characterize the steepest part of the maturity ogive. For our dataset, 59.6% of the samples were from this age range.

Of the 428 fish sampled, 32 were immature (7.5%), 157 were developing (36.7%), 84 were spawning capable (19.6%), 12 were actively spawning (2.8%), 117 were regressing (27.3%), and 26 were regenerating (6.1%).

March-July Dataset

Most studies that examine maturity collect samples during the months of spawning. This data subset used data from March-July as spawning in Chesapeake Bay, where most of these samples were from, is known to occur into early June (Mansueti and Hollis 1963; Hollis 1967). Additionally, through July, fish that had spawned the previous spring were easily identified as being in the regressing and regenerating phases and more samples of small, immature fish were collected from pound nets. Of the 343 fish sampled in this time period, 302 were from Chesapeake Bay and 41 were from coastal states (16 from Delaware Bay, 9 from the New Jersey Ocean Trawl, and 16 from NEAMAP).

When developing fish were identified as mature, the age at 50% maturity was 3.59 years old (Figure 5). When developing fish were identified as not spawning imminently, the age at 50% maturity was 5.27 years old (Figure 6).

Full Dataset

The final dataset analyzed used data from throughout the year (March through December). This dataset included more fish from the coast, specifically samples from Rhode Island, but had the complication of how to define developing fish. Of the 428 fish sampled, 307 were from Chesapeake Bay and 121 were from coastal areas (see Table 4 for more information on sample sizes from specific surveys).

When developing fish were classified as mature, the age at 50% maturity was 3.63 years old (Figure 7). When developing fish were identified as not imminently spawning, the age at 50% maturity was 5.84 years old (Figure 8).

Discussion

The methods recommended in Brown-Peterson et al. (2011) were put forward in an effort to standardize terminology and reproductive phases across a wide variety of fish species. While the inclusion of developing fish as mature makes sense from a physiological standpoint (in the sense that that is the first reproductive phase to be gonadotropin dependent), it does not make sense from a stock assessment perspective for striped bass. Boyd (2011) specifies that for striped bass, fish in the developing phase may not necessarily spawn in the upcoming spawning season and therefore, we believe it makes more sense to treat these fish as not yet part of the spawning stock. Additionally, when developing fish were considered mature, the age of 50% maturity was very low, ranging from 3.6 -3.9 years old depending on the dataset used. This age at 50% maturity is much lower than the age that the Maryland spawning stock survey starts seeing any females on the spawning grounds. Since 1994, no females younger than age four have been caught in the spawning stock survey and only 12 four year olds have been caught in that time. We recommend using a maturity curve where developing fish are considered immature/not imminently spawning.

In general, the logistic regression equations estimate higher maturity-at-age up through age 6 as compared to the maturity schedule currently used in the stock assessment and similar maturity at age for ages 7 and above. The observed proportions mature at age for ages 4-6 are also higher than the values used currently (Table 8). Some of these differences are likely due to methodology. The previous estimates of maturity-at-age were calculated using CPUE data from the Maryland spawning stock survey and a GSI developed from fish on the Hudson River. This study utilizes histology to determine maturity which is known to be more accurate (West 1990). Additionally, those studies were conducted in the mid- to late-1980s and may have been reflective of a depressed stock. However, our observed proportions mature at age for ages 4 and 5 using the full dataset are similar to Berlinsky et al. (1995).

Despite our best efforts to include fish from the coast, it is also possible that some bias was still introduced. First, we continued to observe a bimodal distribution in our length samples (Figure 3). While this could partially be due to poor recruitment in the year classes that would span those sizes, it is also possible that we are still missing some migratory, immature fish. Second, as most of the fish were collected from the Maryland spring creel survey, these fish were subject to the minimum recreational sizes in the Chesapeake Bay (18” minimum in 2014 and 20” minimum in 2015 and 2016). To assess whether the samples were biased by the recreational size limits, comparisons were made to the length frequency sampled from Maryland’s summer/fall pound net and checkstation surveys in 2014-2016. These surveys should provide some estimate of the overall size distribution of age 4 and 5 fish in the Bay as pound nets are not size selective and the pound net survey samples both legal and sublegal fish in proportion to their availability in the net. The size frequencies, though, are sexes-combined as sex cannot be determined at that time of year and it is known that female striped bass tend to be larger at age than male striped bass after age 3 (Mansueti 1961; Mansueti and Hollis 1963; ASMFC 2013). Comparing the size frequency of samples at age from the maturity study to those collected in the pound net survey, it appears that age 4 fish sampled on the coast were larger than those sampled in the Bay (Figure 9). Most of the coastal fish were sampled in the fall from Rhode Island and may be indicative of larger age 4 fish migrating to the coast while smaller age 4 fish remain in the Bay (Dorazio et al.

1994). The Bay samples, however, generally align with the pound net survey samples indicating that the Bay sampling was not biased by the recreational size limits. Sampling of age 5 fish also showed no evidence of bias though differences in the length frequencies sampled were still observed between the Bay and coast with coastal age 5 fish being larger than Chesapeake Bay age 5 fish.

Assuming the Striped Bass Technical Committee and Stock Assessment Subcommittee (SAS) agrees with our suggestion to use a maturity curve where developing fish are considered immature/not imminently spawning, decisions would still need to be made on which dataset and results to use. Studies are often recommended to be done either prior to spawning (Hunter and Macewicz 2003) or prior to and during the spawning season (Murua et al. 2003). This would align best with our March-July data subset or possibly even a smaller subset. However, consideration must also be given to the distribution of fish across the study area, particularly when immature and mature individuals occur in different areas (Berlinsky et al. 1995; Hunter and Macewicz 2003; Murua et al. 2003). It is for this reason that Berlinsky et al. (1995) sampled during the spring and fall feeding migrations even though this required an assumption that maturations rates were not significantly different among stocks.

The March-July dataset includes more immature fish and spans the entire spawning season in Chesapeake Bay which is known to occur into June. However, using this smaller dataset reduces the overall sample size and the number of coastal fish included in the dataset. Use of the full dataset includes all of the fish collected coastwide, including those immature migratory females we may be missing within the Bay; however, some error is likely added by classifying older, developing fish as not imminently spawning. An examination of Figure 8, however, indicates that this is likely not an issue as most of the fish sampled above age 6 were classified as spawning capable or regressing/regenerating. This is likely due to our focus on smaller coastal fish that were between ages 5-8. To aid in deciding which dataset and results to use, a comparison of the logistic regression estimates of maturity-at-age for these two datasets as well as a comparison of the observed proportions mature-at-age in shown in Figure 10. We would recommend using the full dataset.

Acknowledgements

This study was a joint effort that included several state agencies and other programs within MD DNR. First we would like to thank Jacob Boyd of the North Carolina Division of Marine Fisheries for his consultation, advice, and histology slide expertise as we started on this project. We'd also like to thank Heather Corbett and her staff at New Jersey Department of Environmental Protection - Bureau of Marine Fisheries, Nicole Lengyel and her staff at Rhode Island Department of Environmental Management - Division of Fish and Wildlife, and Virginia Institute of Marine Science staff that run the NEAMAP cruises (Jameson Gregg, James Gartland, Rob Latour) for helping us collect additional ovaries from fish along the Atlantic coast. Additional thanks go to the MD Fish and Wildlife Health Program staff, Mark Matsche and Kevin Rosemary, for their demonstrations and knowledge on dissection and histology techniques. Finally we are very grateful for Chris Dungan and his staff (former lab manager Jud Blazek and current manager Laurinda Serafin) in the Diagnostics and Histology Laboratory for processing our many samples and providing guidance and insight throughout the study. We truly appreciate all the cooperation we received along the way.

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Table 1. Current female maturity schedule used for the striped bass stock assessment.

Age	4	5	6	7	8	9
Proportion Mature	0.04	0.13	0.45	0.89	0.94	1.0

Table 2. Number of female striped bass, by age and year, collected during the Maryland spring creel survey, 2009-2013.

Age	2009	2010	2011	2012	2013	Average
3	1	6	1	0	1	2
4	7	6	33	17	17	16
5	7	7	19	25	9	13
6	7	3	3	31	26	14
7	4	17	7	16	3	9
8	18	12	42	13	6	18
9	40	29	14	30	18	26
10	11	27	39	3	28	22
11	10	15	15	8	4	10
12	8	13	6	1	11	8
13	12	12	6	0	3	7
14	6	19	2	0	2	6
15	3	4	6	2	1	3
16	3	3	1	0	0	1
17	1	0	0	1	1	1
18	1	0	0	0	0	0
Totals	139	173	194	147	130	157

Table 3. Targets and sample sizes for maturity schedule survey, along with deficits when targets were not met.

Length Group	Target	2014 Samples	2015 Samples	2016 Samples	Total Samples	Deficit
350		1	2	0	3	
370		1	1	0	2	
390		0	0	0	0	
410		2	6	3	11	
430	10	1	4	1	6	4
450	10	2	0	1	3	7
470	10	7	1	3	11	
490	10	6	1	3	10	
510	10	4	5	3	12	
530	15	2	5	10	17	
550	15	8	10	7	25	
570	15	6	20	4	30	
590	15	4	22	7	33	
610	15	1	19	9	29	
630	15	3	10	4	17	
650	15	6	10	3	19	
670	15	4	4	4	12	3
690	15	2	7	2	11	4
710	15	2	4	3	9	6
730	15	4	4	1	9	6
750	15	0	3	3	6	9
770	15	3	4	2	9	6
790	15	0	5	4	9	6
810	15	4	4	0	8	7
830	15	2	4	3	9	6
850	15	5	6	2	13	2
870	15	5	7	4	16	
890	10	6	5	0	11	
910	10	7	5	0	12	
930	10	7	4	0	11	
950	10	7	4	0	11	
970	10	6	1	5	12	
990	10	5	3	3	11	
1010	3	1	3	1	5	
1030	3	2	0	2	4	
1050	3	0	3	1	4	
1070	3	0	3	0	3	
1090	3	1	1	1	3	
1110		0	1	0	1	
1130		0	0	0	0	
1150		0	0	0	0	
1170		0	0	0	0	
1190		0	0	0	0	
1210		0	0	0	0	
1230		0	1	0	1	
Totals	395	127	202	99	428	66

Table 4. Number of fish sampled by state and survey.

State	Survey	Months Sampled	n	Percent
Maryland				
	Spring Creel Survey	April-June	252	58.9%
	Spring Gill Net Survey	April-May	15	3.5%
	Striped Bass Pound Net Sampling	June-July	19	4.4%
	Nanticoke Spring Pound Net and Fyke Net Survey	March	2	0.5%
	Commercial Check Station Sampling	March	3	0.7%
	Fish Health Hook & Line Survey	September-November	5	1.2%
	Patapsco Gill Net Survey	June	3	0.7%
	Shad Gill Net Survey (USFWS)	April-May	8	1.9%
New Jersey				
	Delaware Bay Gill Net Survey	March-May	15	3.5%
	Ocean Trawl Survey	April-May	9	2.1%
		October	1	0.2%
	Headboat Sampling	December	13	3.0%
	Herring Survey	May	1	0.2%
Rhode Island				
	Fish Trap Survey	September-October	59	13.8%
NEAMAP				
	Ocean Trawl Survey	May	16	3.7%
		September-October	7	1.6%
Total			428	

Table 5. Number of fish sampled by month.

Month	n	Percent
March	15	3.5%
April	80	18.7%
May	151	35.3%
June	84	19.6%
July	13	3.0%
September	16	3.7%
October	54	12.6%
November	2	0.5%
December	13	3.0%
Total	428	

Table 6. Macroscopic and histological description of maturity phases used in the analysis. From Table 2 of Brown-Peterson et al. (2011). Abbreviations used in descriptions: CA = cortical alveolar; GVBD = germinal vesicle breakdown; GVM = germinal vesicle migration; OM = oocyte maturation; PG = primary growth; POF = postovulatory follicle complex; Vtg1 = primary vitellogenic; Vtg2 = secondary vitellogenic; Vtg3 = tertiary vitellogenic.

Phase	Macroscopic and Histological Features
Immature (never spawned)	Small ovaries, often clear, blood vessels indistinct. Only oogonia and PG oocytes present. No atresia or muscle bundles. Thin ovarian wall and little space between oocytes.
Developing (ovaries beginning to develop but not yet ready to spawn)	Enlarging ovaries, blood vessels becoming more distinct. PG, CA, Vtg1, and Vtg2 oocytes present. Not evidence of POFs or Vtg3 oocytes. Some atresia can be present.
	Early Developing subphase: PG and CA oocytes only.
Spawning Capable (fish are developmentally and physiologically able to spawn in this cycle)	Large ovaries, blood vessels prominent. Individual oocytes visible macroscopically. Vtg3 oocytes present or POFs present in batch spawners. Atresia of vitellogenic and/or hydrated oocytes may be present. Early stages of OM can be present.
	Actively Spawning subphase: oocytes undergoing late GVM, GVBD, hydration, or ovulation.
Regressing (cessation of spawning)	Flaccid ovaries, blood vessels prominent. Atresia (any stage) and POFs present. Some CA and/or vitellogenic (Vtg1, Vtg2) oocytes present.
Regenerating (sexually mature, reproductively inactive)	Small ovaries, blood vessels reduced but present. Only oogonia and PG oocytes present. Muscle bundles, enlarged blood vessels, thick ovarian wall and/or gamma/delta atresia or old, degenerating POFs may be present.

Table 7. Number of fish sampled by age. Ages were calculated as for the full dataset analysis (e.g. fall developing fish had their ages advanced one year).

Age	n	Percent
2	3	0.7%
3	13	3.0%
4	45	10.5%
5	131	30.6%
6	56	13.1%
7	32	7.5%
8	36	8.4%
9	13	3.0%
10	28	6.5%
11	44	10.3%
12	14	3.3%
13	8	1.9%
14	4	0.9%
16	1	0.2%
Total	428	

Table 8. Comparison of maturity at age estimates from various studies. The current maturity-at-age estimates used in the stock assessment are bolded.

Study	Merriman (1941) a	Texas Instruments (1980) b	Specker et al. (1987) b	**Jones (1987)**	Berlinsky et al. (1995)	Data Subset (this study)	Full Dataset (this study)
Area	New England	Hudson	Coastwide	**MD and Hudson**	Rhode Island	Coastwide	Coastwide
Timing	April-Nov				May-June, Sept-Nov	March-July	March-July, Sept-Dec
Age							
3	0%			**0%**	0%	0%	0%
4	27%	4%	5%	**4%**	12%	7%	9%
5	74%	21%	15%	**13%**	34%	51%	32%
6	93%	60%	45%	**45%**	77%	66%	45%
7	100%	89%	100%	**89%**	100%	90%	84%
8	100%	94%	100%	**94%**	100%	94%	89%
9	100%	100%	100%	**100%**	100%	100%	100%

a: From Berlinksy et al 1995

b: From Jones 1987

Figure 1. Average annual sample size of female fish by length group from the Maryland spring creel survey, 2009-2013.

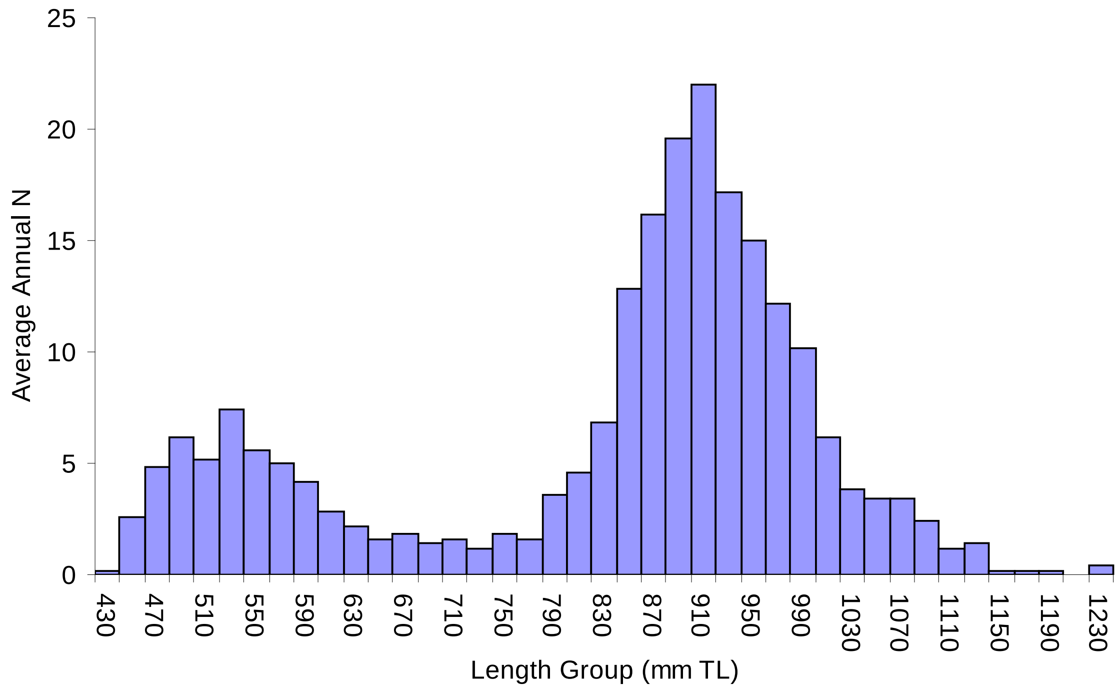


Figure 2. Current maturity ogive for female striped bass. The highlighted area indicates the age range where sampling effort was focused.

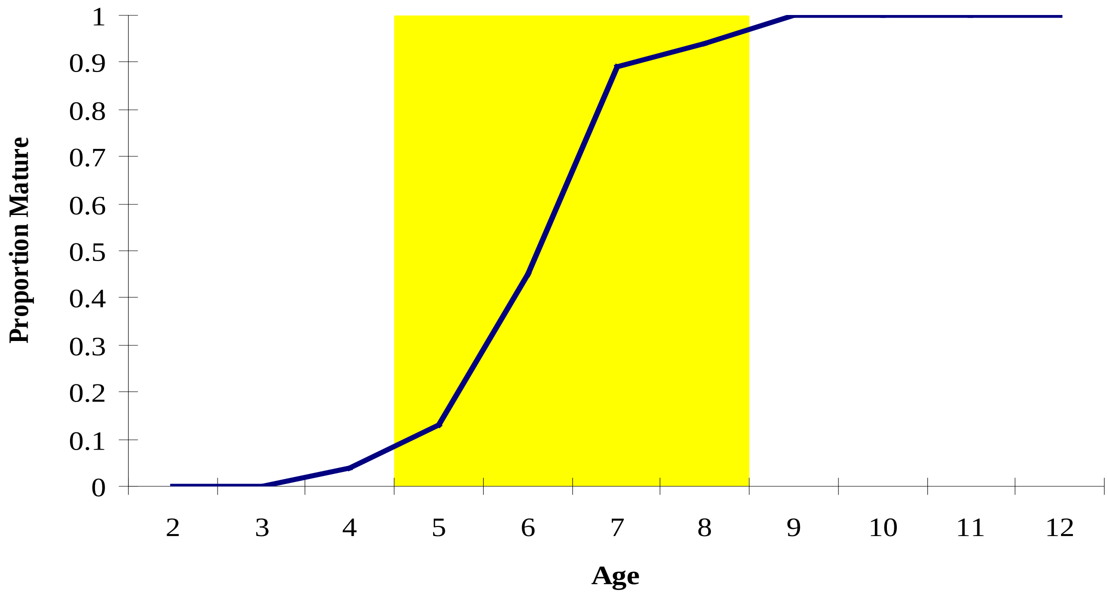


Figure 3. Samples collected vs. targets.

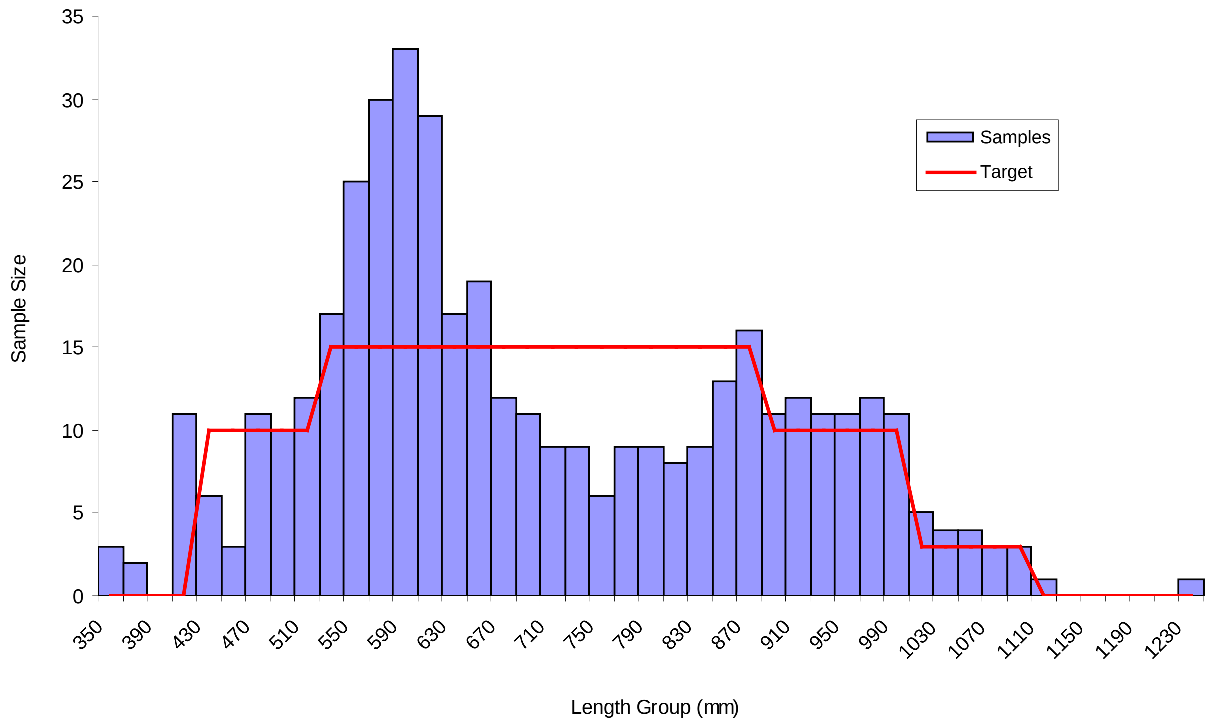


Figure 4. Conceptual model of fish reproductive phase terminology. Figure from Brown-Peterson et al. 2011.

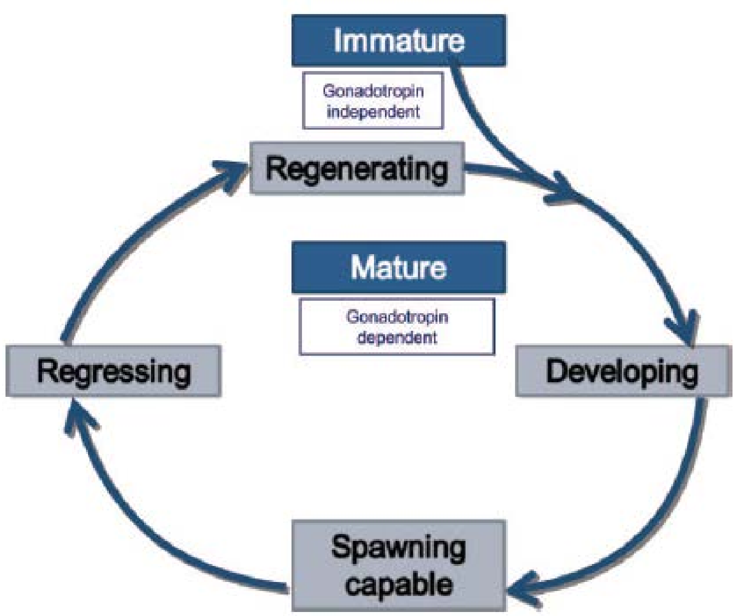


Figure 5. Estimated proportions mature, by age, for the March-July dataset when developing fish are considered mature. Top figure shows the sample size and maturity status for each fish sampled, by age, and bottom figure shows the overall observed proportion mature.

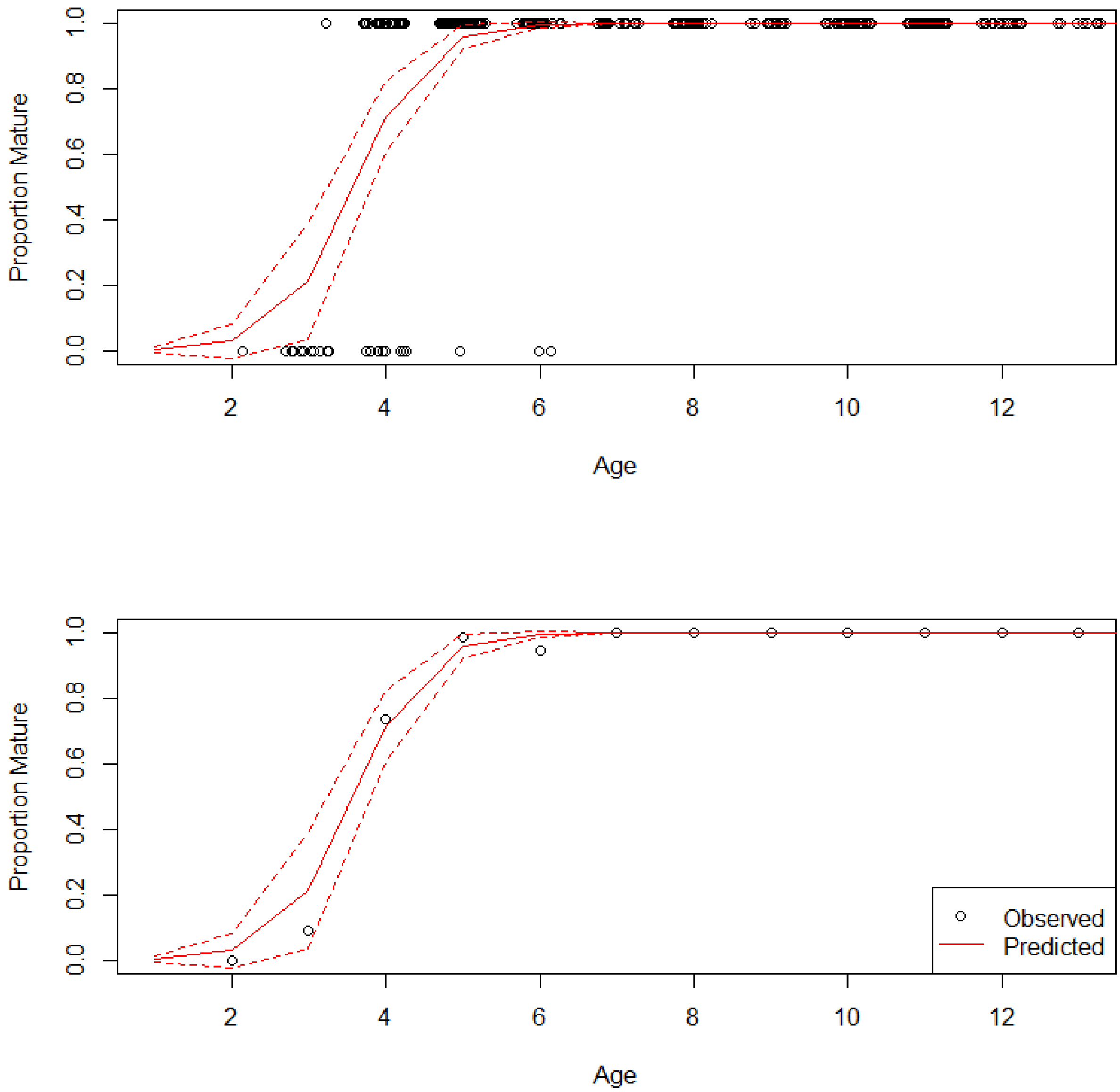
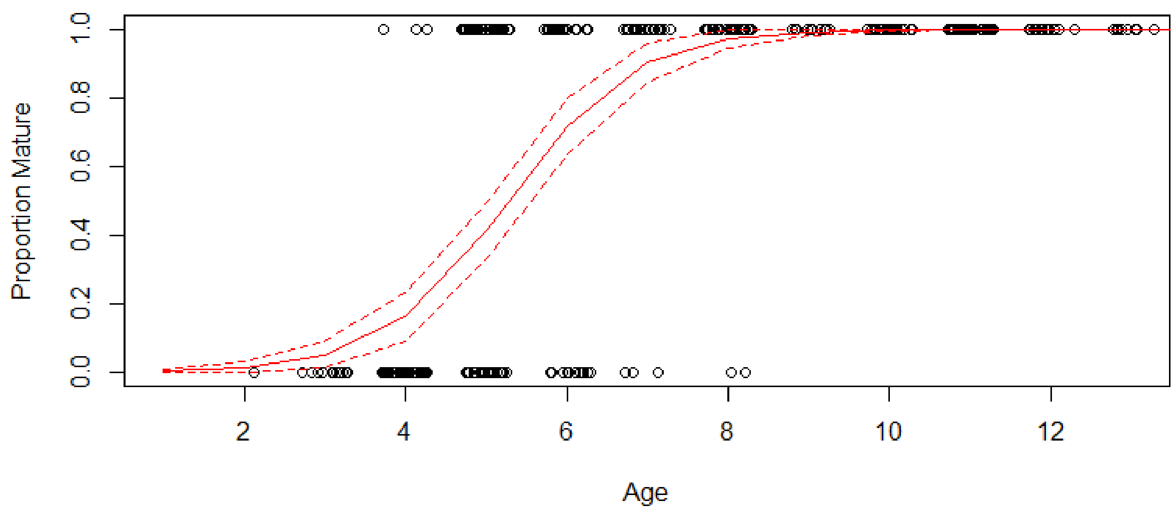


Figure 6. Estimated proportions mature, by age, for the March-July dataset when developing fish are considered not imminently spawning. Top figure shows the sample size and maturity status for each fish sampled, by age, and bottom figure shows the overall observed proportion mature.



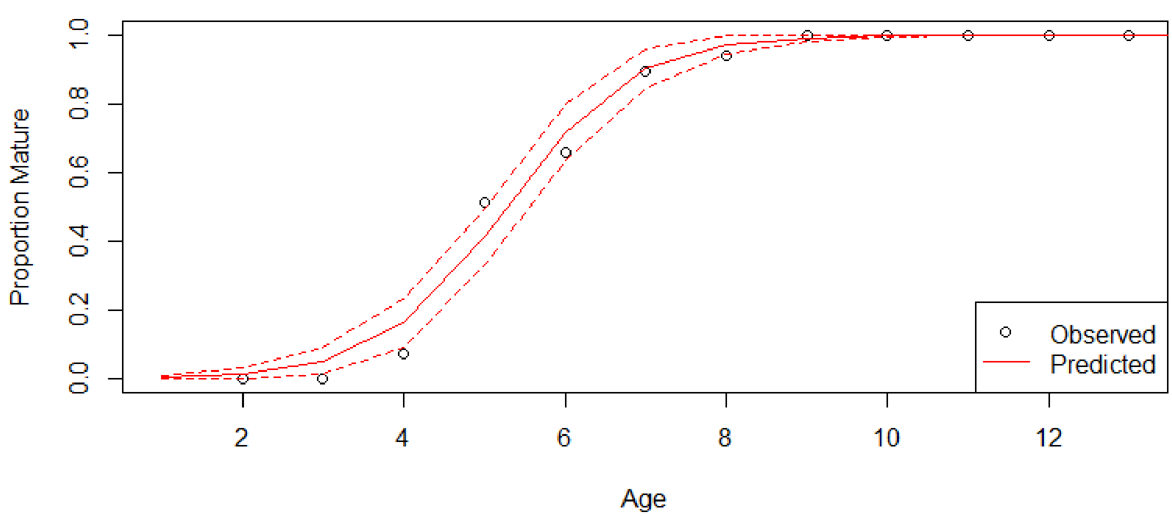


Figure 7. Estimated proportions mature, by age, for the full dataset when developing fish are considered mature. Top figure shows the sample size and maturity status for each fish sampled, by age, and bottom figure shows the overall observed proportion mature.

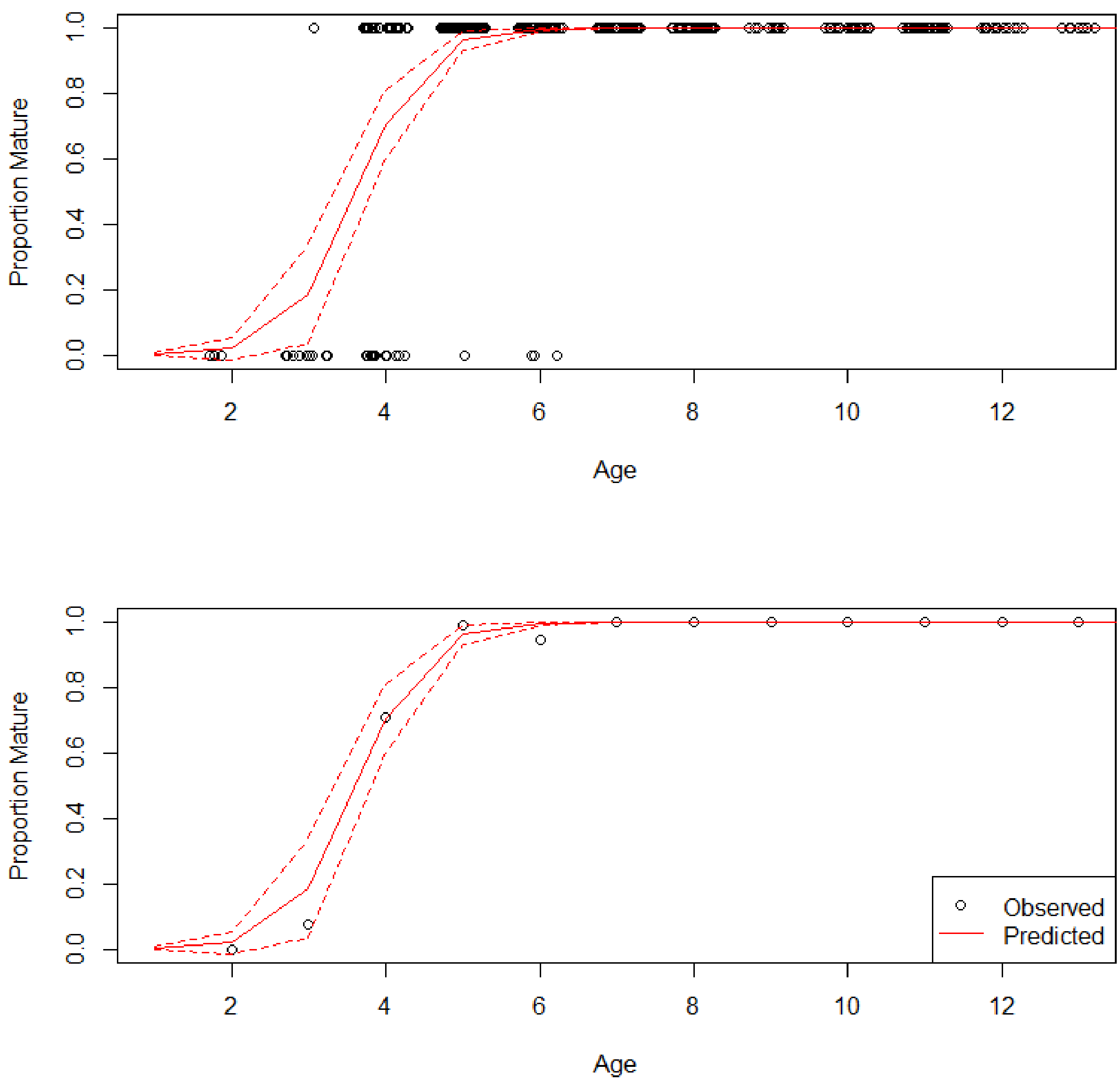
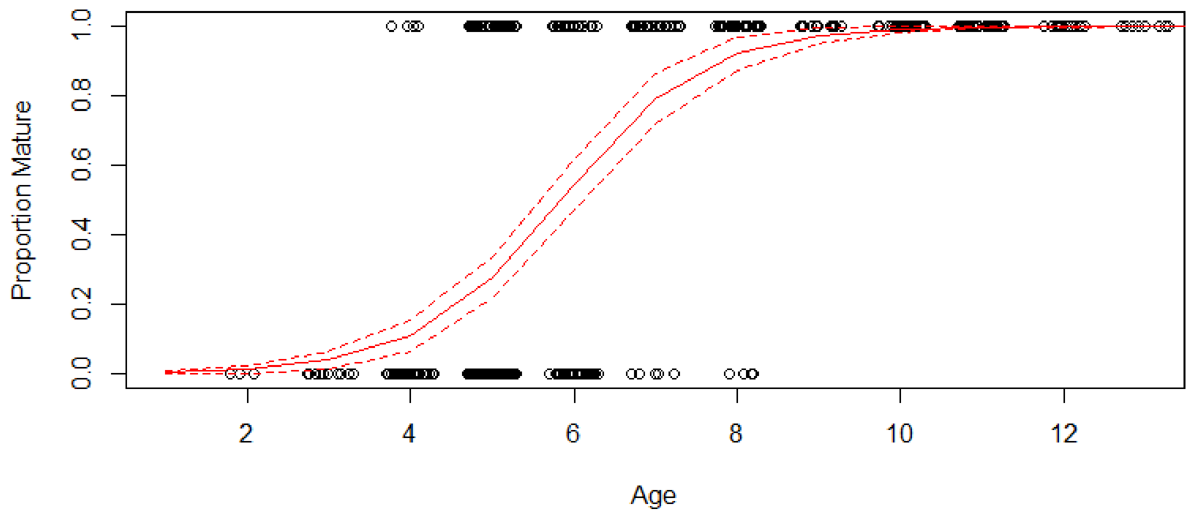


Figure 8. Estimated proportions mature, by age, for the full dataset when developing fish are considered not imminently spawning. Top figure shows the sample size and maturity status for each fish sampled, by age, and bottom figure shows the overall observed proportion mature.



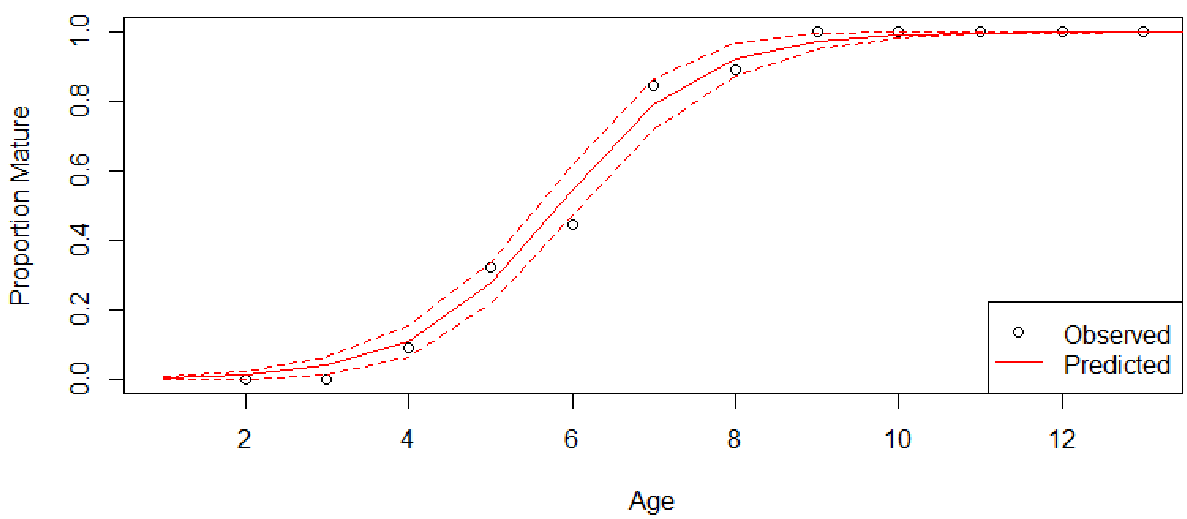


Figure 9. Comparison of the length frequencies, at age, from the summer/fall pound net and checkstation surveys (2014-2016, sexes combined) and fish sampled for the maturity study (2014-2016).

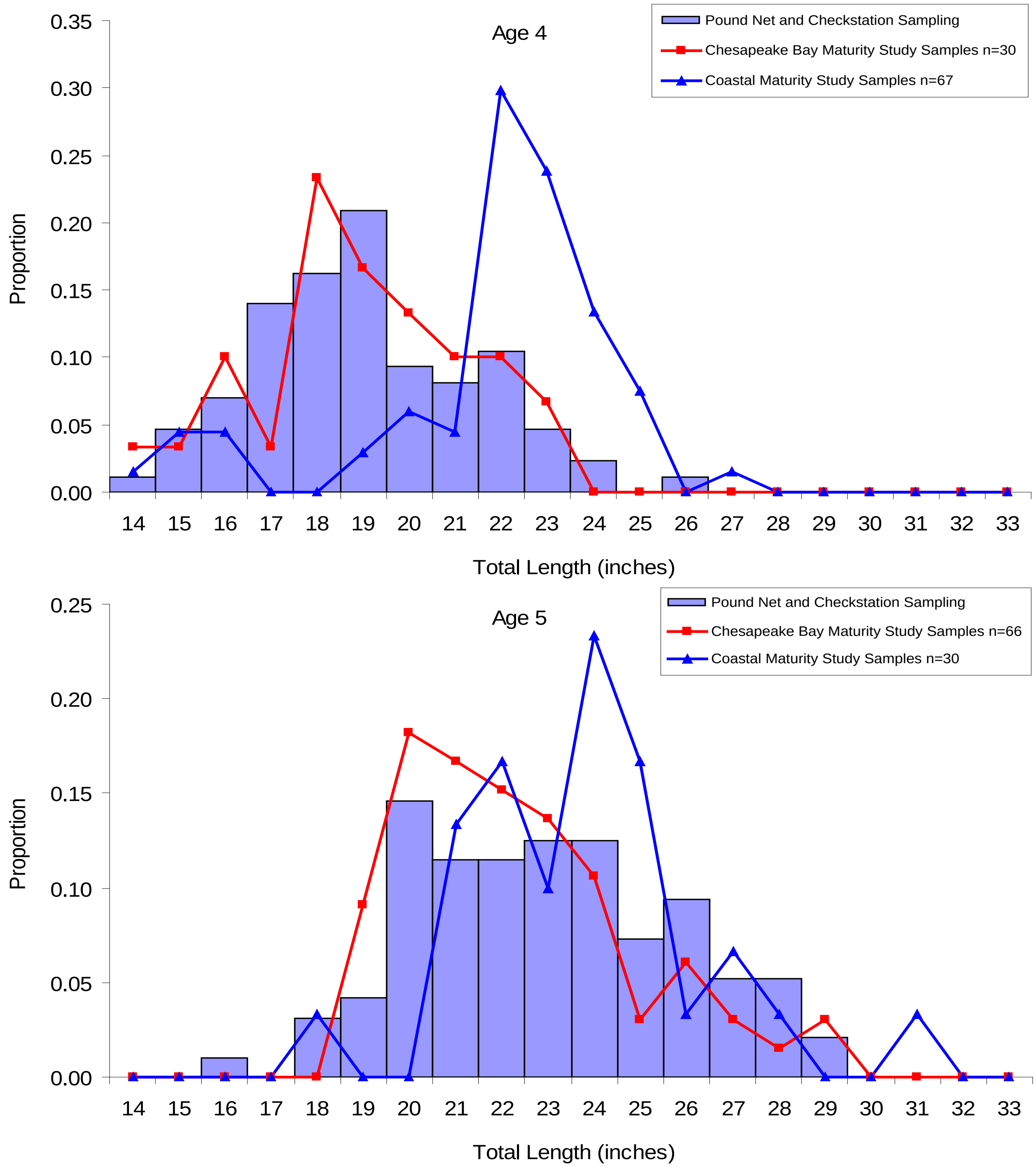
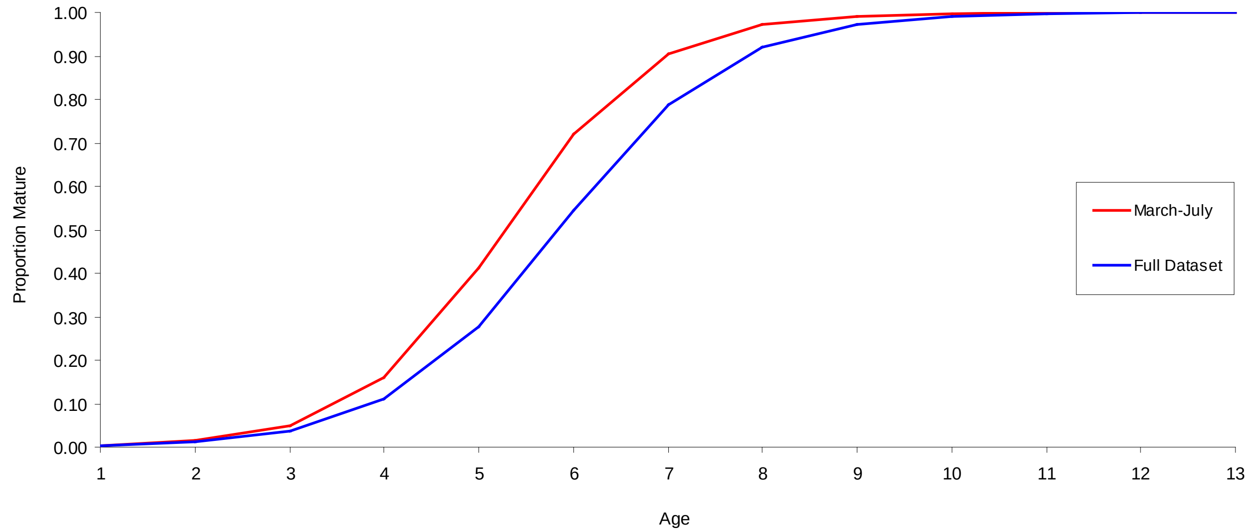
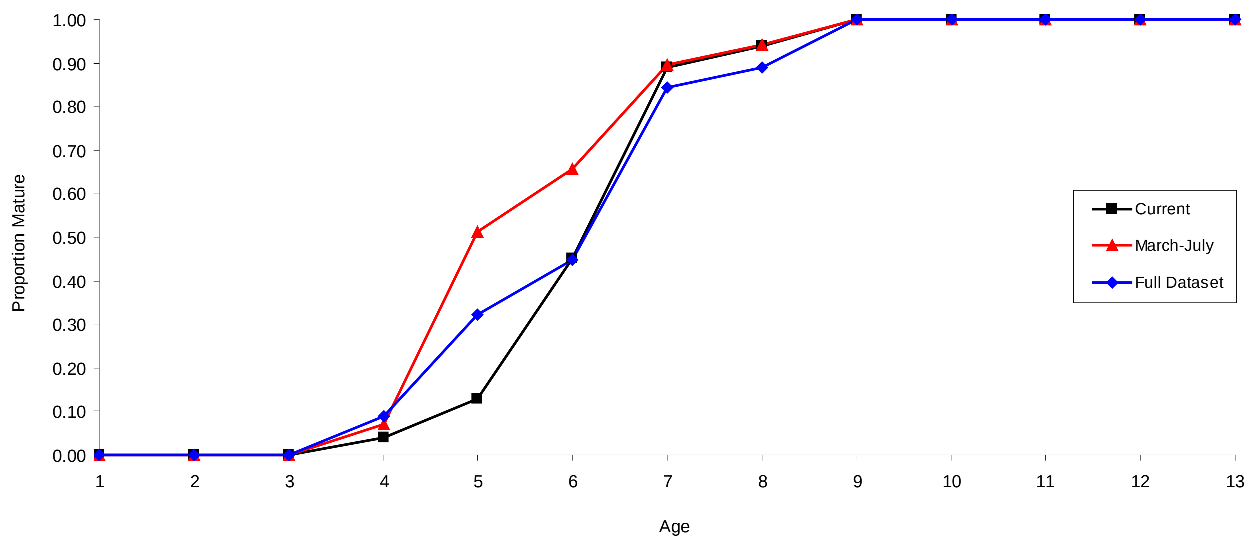


Figure 10. Comparison of the maturity at age estimates between the different data subsets when developing fish are classified as not imminently spawning. Top panel compares the logistic regression estimates. Bottom panel compares the observed proportions.





APPENDIX III

Fecundity of Striped Bass from the Maryland Portion of the Chesapeake Bay

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Introduction

Striped bass support one of the largest recreational fisheries along the U.S. Atlantic coast, with recreational landings exceeding 38 million pounds in 2017, with an additional 5 million pounds of landings coming from the commercial fishery (National Marine Fisheries Service, 2018). Following a prolonged period of recruitment failure in the 1970s, the Atlantic striped bass stock collapsed in the 1980s. After stringent management measures were enacted, including a five year fishing moratorium in some states, several record year classes were produced and the stock was declared recovered by 1995 (Richards and Rago, 1999). In the current management regime, the Atlantic striped bass stock is adaptively managed towards Spawning Stock Biomass (SSB) reference points through attempted controls on fishing mortality (Atlantic State Marine Fisheries Commission, 2003). States are able to use a combination of gear restrictions, size limits, and season lengths which result in an equivalent level of desired fishing mortality (conservation equivalency). Other state based conservation measures, for example in Maryland, include season and area closures which aim to protect the spawning migration and spawning grounds.

The use of SSB to manage the striped bass stock indicates prior acceptance of an assumed proportional relationship between female body weight and fecundity. That is, fecundity is equivalent for a given bulk weight of fish, regardless of the number of fish (isometric scaling). Previous studies of striped bass fecundity have not directly tested this assumption, although most studies have focused on the fecundity-length relationship. In the most recent study of striped bass fecundity, a linear fecundity-length model was selected, and fecundity was found to be lower over-all for larger sized striped bass as compared with previous studies (Gervasi et al., 2018). Given the cubic relationship between length and weight (i.e. $W=aL^3$) this translates to negative allometric scaling of fecundity with body weight and exponentially declining fecundity relative to body weight as striped bass grow, which is alarming if accurate.

Atlantic striped bass are an anadromous, iteroparous marine fish species. Spawning is triggered by increasing spring water temperatures, and in the Chesapeake Bay, usually occurs from April to June (Setzler et al., 1980). Females are total, determinate spawners with both high fecundity and high egg and larval mortality rates (Setzler et al., 1980). While many factors such as flow, temperature, pH, and prey availability are cited as drivers of larval survival (North and Houde, 2003; Martino and Houde, 2010), less is known about the factors influencing fecundity. Given that the Chesapeake Bay is the largest production grounds for the Atlantic striped bass stock, the monitoring of fecundity trends is critical (Berggren and Lieberman, 1978; Fabrizio, 1987; Richards and Rago, 1999).

In this study we estimate fecundity for striped bass sampled from the Maryland portion of the Chesapeake Bay over multiple years. Scaling exponents from length, weight, and fecundity power law models are compared with theoretical isometric scaling exponents. Finally, the current study is compared with previous studies conducted in the Chesapeake Bay to assess potential changes in fecundity over the last several decades.

Methods

Sample Collection

Ovary samples from striped bass were collected during 2014-2017 as part of a maturity study, and in 2018 to supplement fecundity analysis. Striped bass were measured to the nearest mm Total Length, weighed whole to the nearest 0.01 kg, and a scale sample was collected for age estimation. Only ovaries in spawning capable condition were utilized for fecundity analysis. Macroscopically, ovaries in spawning capable condition fill the body cavity and are highly vascularized, with individual oocytes visible. Microscopically, spawning capable ovaries contain oocytes in the tertiary vitellogenic stage which was confirmed through histological examination (Brown-Peterson et al, 2011). Ovary samples in spawning capable condition were obtained from April-June, although 97% were from the peak spawning months of April (64%) and May (33%). Most of the striped bass ovary samples were obtained from the Maryland spring trophy season creel survey, but were supplemented with samples from the Maryland spring spawning stock drift gillnet survey, and Maryland shad gillnet survey.

Sample Treatment

Ovary samples were weighed, fixed in 10% neutral buffered formalin, and then transferred to 70% ethanol after 14 or more days when fixation was achieved throughout the entire ovary. A ~10 gram sample of ovary was excised and placed on to a 1 mm sieve stacked on top of a 0.2 mm sieve. The sample was vigorously rinsed through the 1 mm sieve onto the 0.2 mm sieve to separate clusters of eggs. Excess water was blotted away from the bottom of the 0.2 mm sieve and two 1.0 gram subsamples were taken. Subsamples were placed in petri dishes painted matte black, and then covered with 70% ethanol. Petri dishes were then photographed with a 12.3 megapixel digital camera.

Image Analysis

Counts of eggs were determined from digital images using particle analysis in ImageJ (version 1.51j8). The following process was applied. First, digital images were cropped to remove the area outside of the petri dish (Figure 1a). The image was then converted to 8-bit and a threshold was applied to remove the image background, any egg 'shells' which tended to be a light shade of grey, and leaving all eggs represented as black particles (Figure 1b). A binary watershed algorithm was applied to the image to separate eggs with touching edges (Figure 1c). Finally, particle analysis was applied with a minimum particle size of 150 to 300 pixels depending on egg size to identify and enumerate each egg, while excluding smaller extraneous materials (Figure 1d).

Statistical Analysis

Precision of egg density estimates (number of eggs per gram) was examined with the coefficient of variation. For any sample where the coefficient of variation was greater than 10%, the egg density for the sample was re-measured with a new set of subsamples. Absolute fecundity was calculated as the product of the egg density and the total ovary weight.
Length, weight, and fecundity relationships were examined with the power law model:

$$F = aD^b$$

where D is either length or weight, b is the scaling exponent describing the proportional change in fecundity (F) with body size D, and a is a constant. With logarithmic transformation, the above power law equation takes the simple linear form:

$$ln(F) = ln(a) + b*ln(D)$$

which is convenient for model fitting using ordinary least squares linear regression.

Typical of many marine fish species, striped bass have very small eggs relative to their body size and striped bass ovaries expand to fill the body cavity when in spawning condition, therefore fecundity should be proportional to body size (isometric scaling). Since volume is three dimensional and length is one dimensional (i.e. $V=L^3$), the expected isometric value of b=3 for the fecundity length relationship. Likewise, because mass is directly proportional to volume, the relationship between body weight and fecundity has an expected isometric value of b=1, therefore a linear relationship:

$$F = aW$$

If the fitted scaling exponent deviates positively (negatively) from the isometric scaling exponent, then fecundity would be exponentially greater (lesser) in an equivalent mass of larger sized fish and population-level reproductive capacity would depend on the portfolio of female sizes in the spawning stock rather than on the aggregate biomass of females alone.

Results

Fecundity measurements were performed on 67 striped bass ranging in length from 499 mm TL to 1139 mm TL (Figure 2) and in age from 5 to 17 (Figure 3). Of these samples, 5 striped bass were missing a weight measurement, which was therefore imputed from a length-weight regression. The mean coefficient of variation of egg density for all samples was 3.65% (2.24% SD). Fecundity ranged from 187,588 in an age 5, 526 mm TL, 1.40 kg individual to 4,141,424 in an age 13, 1081 mm TL, 15.5 kg individual.

The power law equation fit to the length and fecundity data yielded the following parameters:

$$F = 0.00043*L^{3.245}$$

or, in logarithmic form:

$$ln(F) = -7.749 + 3.245*ln(L)$$

The *b* parameter value was not significantly different from the isometric value of 3, with 95% confidence intervals from 2.99 (2.5%) and 3.50 (97.5%). The logarithmic model adjusted r-squared was 0.91, and 0.89 when the r-squared value was calculated with back-transformed values.

The power law model fit to the weight and fecundity data failed to reject the null hypothesis of isometric scaling, with *b*=1.057 (95% CIs 0.98-1.13) not statistically different than 1. The fitted model parameters were:

$$F = 171{,}785*W^{1.057}$$

with an r-square of 0.89 and indicating that absolute fecundity in striped bass can be described as approximately 150-200 thousand eggs per kg of gross body weight (95% CIs 149,628-197,403).

Discussion

Given the very small size of striped bass eggs relative to body size, and the expansion of ovaries in the body cavity when in spawning condition, we tested the null hypothesis of isometric scaling between fecundity and body size with two different body size dimensions (length and weight). The fitted scaling exponents of the power law model did not differ statistically from the expected isometric scaling exponents, indicating absolute fecundity is primarily a consequence of striped bass body size and dimension. Although the fitted models had high r-square values, the residual variation in absolute fecundity is biologically substantial. The mean residual deviation was roughly 220,000 eggs in both the length-fecundity and weight-fecundity regressions, which is approximately 6% of the entire range of fecundities estimated in the study. Apart from measurement error, this residual variation in fecundity may be influenced by genetic components and by a variety of hypothetical interacting processes related to the growth and health condition of individual striped bass, such as water quality, diet, disease, and stress.

Striped bass fecundity has previously been examined in the Chesapeake Bay and the current study shows remarkable agreement with most previous studies (Figure 7). Sadler et al. (2006) found a length-fecundity scaling exponent of 3.14 which similar to the current study. Richards et al. (2002) also used a power law equation and their parameter estimates indicate a more positive allometric scaling exponent closer to 4 (3.7819), however, smaller sized mature striped bass less than approximately 750 mm Total Length were not included in the study. The second order polynomial model proposed by Goodyear (1984) is qualitatively similar in its length-fecundity predictions to the current study's proposed power-law model, except towards the ends of the size range where the current study's model predicts slightly higher fecundities.

The most recent fecundity study, conducted by Gervasi et al. (2018), found lower predicted fecundities across the size range of striped bass examined, especially in larger size striped bass, which resulted in a linear length-fecundity relationship (Figure 7). This difference between study results, may result from spatial and temporal differences where striped bass were sampled. Gervasi et al (2018) collected striped bass in the York, James, and Rappahannock rivers, whereas the current study's samples primarily came from the main stem of the upper Chesapeake Bay. The Gervasi et al (2018) study also found most of the larger sized striped bass in spawning capable condition in February and March, with maximum average fecundity observed in March and dropping off significantly in April. The current study obtained almost all of the spawning capable striped bass during the spring trophy recreational season which occurs during the peak of the spawning season in April and May.

We examined the underlying assumption of Spawning Stock Biomass (SSB), which is that reproductive capacity is dependent on the aggregate weight of mature females. The isometric scaling between fecundity and weight indicates that this assumption is valid as far as the total supply of eggs is concerned.

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Figure 1. Illustration of the image analysis process used to identify and enumerate eggs: A. cropped 8-bit image of a 1.0 gram sample, B) a threshold has been applied to the image to eliminate the background, C) binary watershed algorithm has been applied to separate touching edges, D) particle analysis identifies and enumerates eggs.

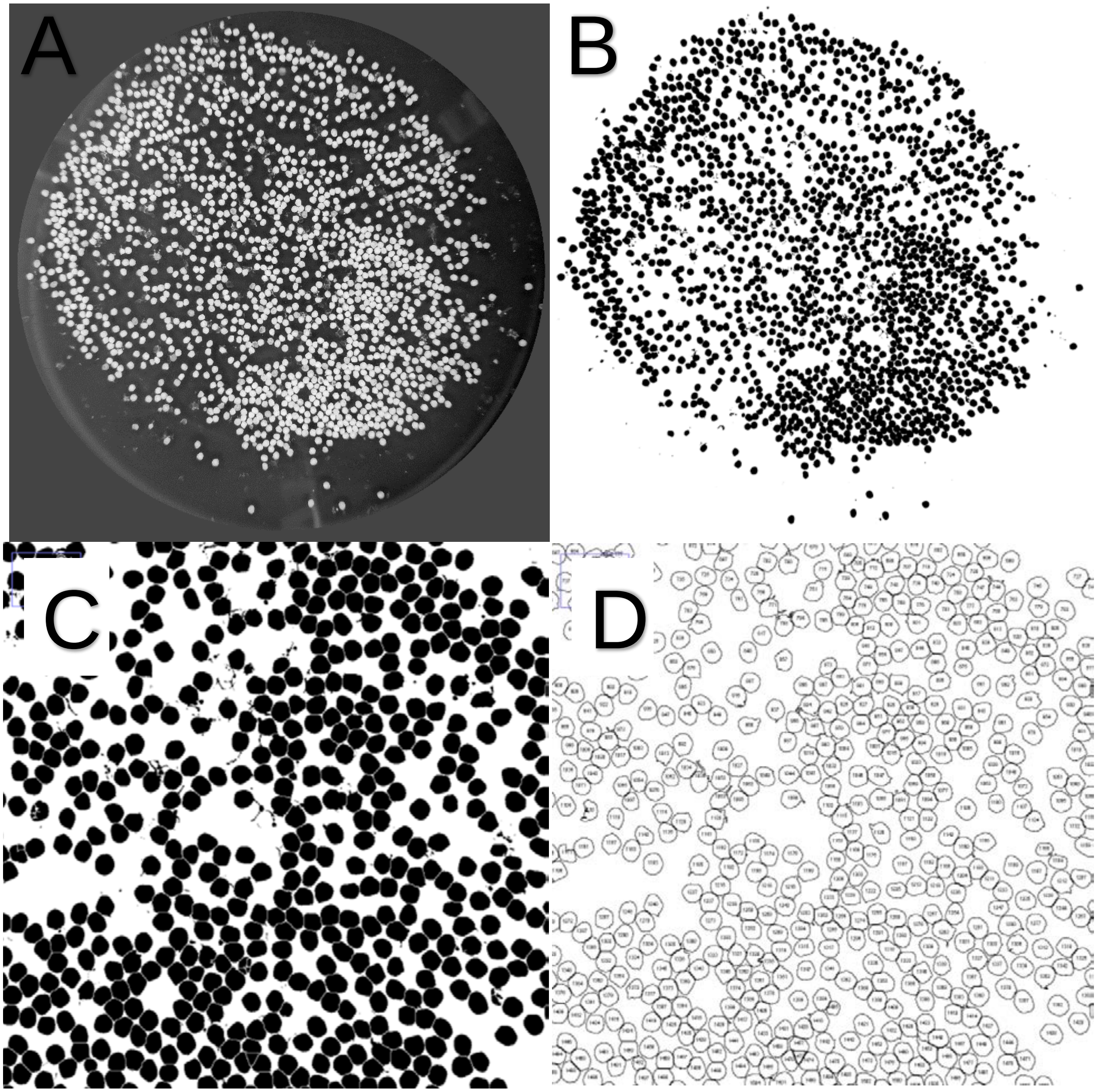


Figure 2. Length (mm Total Length) versus weight (kg) of striped bass used in fecundity analysis.

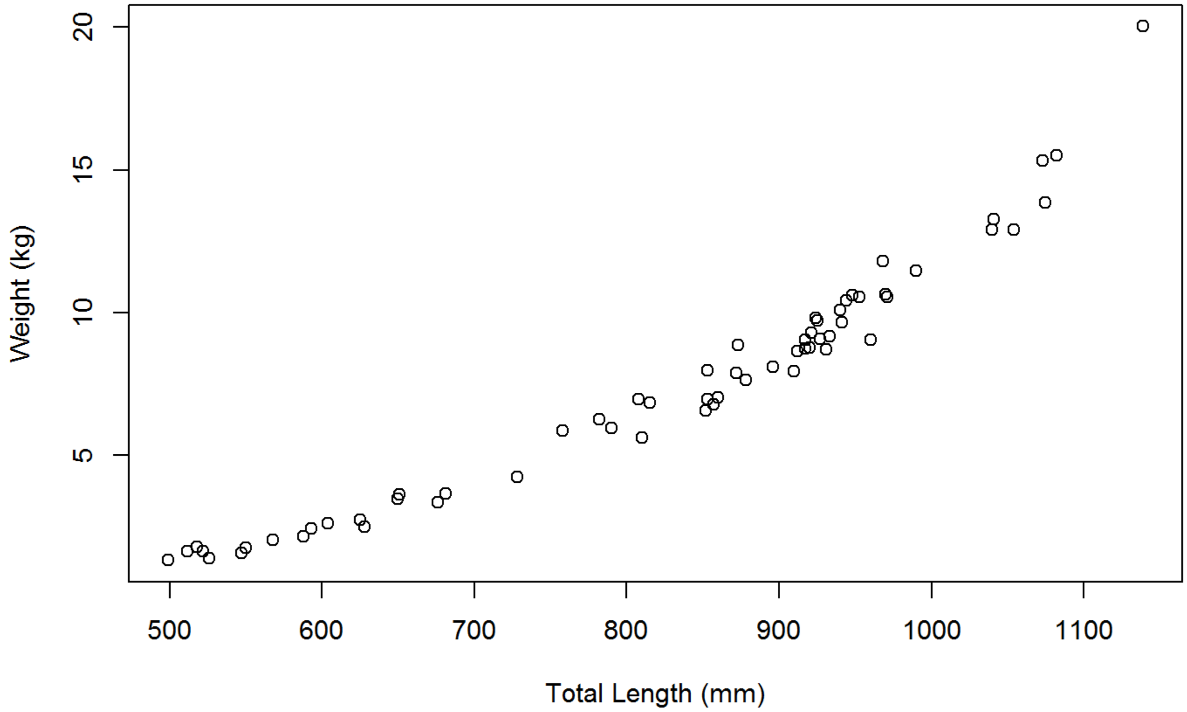


Figure 3. Length (mm Total Length) versus age of striped bass used in fecundity analysis.

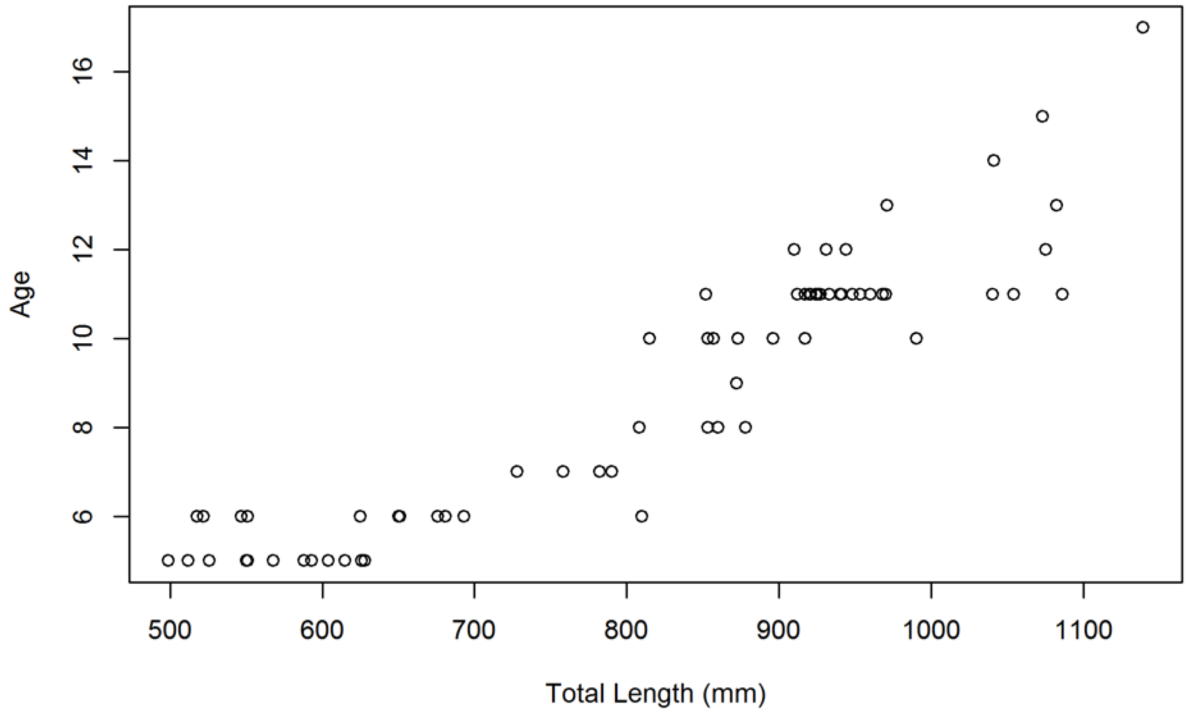


Figure 4. Length (mm Total Length) versus fecundity (number of eggs). The dashed line is power law model with the expected isometric exponent (b=3) for the length-fecundity relationship.

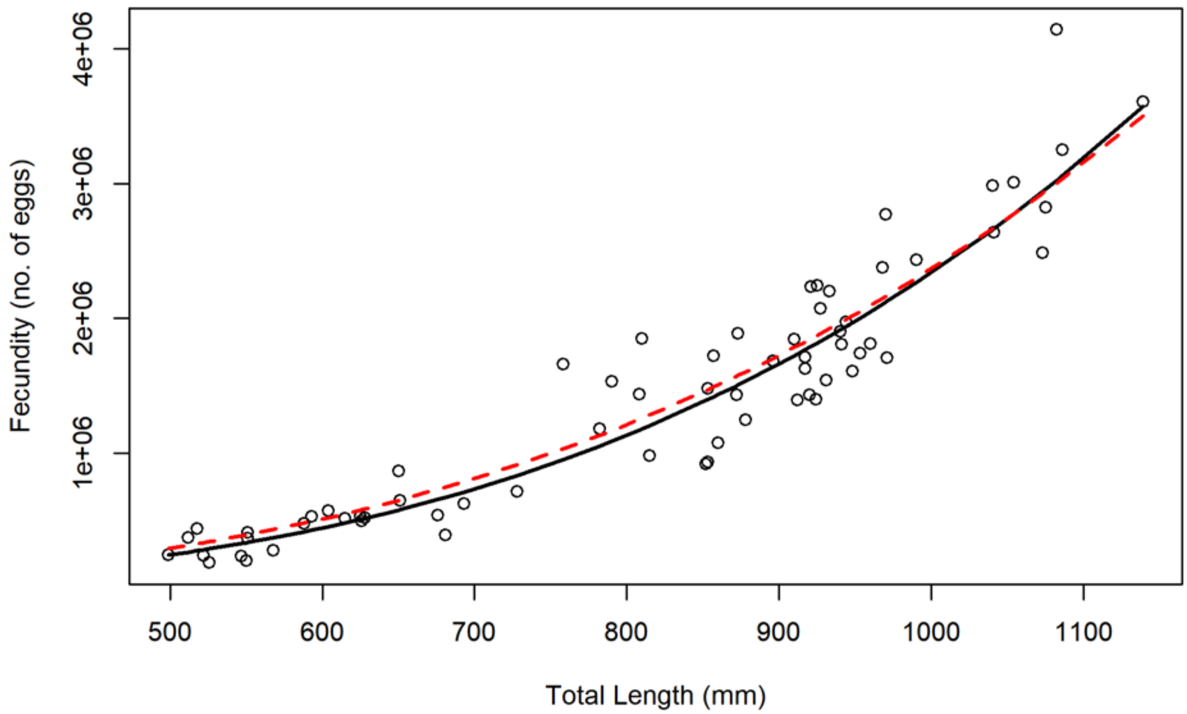


Figure 5. Weight (kg) versus fecundity (number of eggs). The dashed line is the power law model with the expected isometric exponent (b=1) for the weight-fecundity relationship.

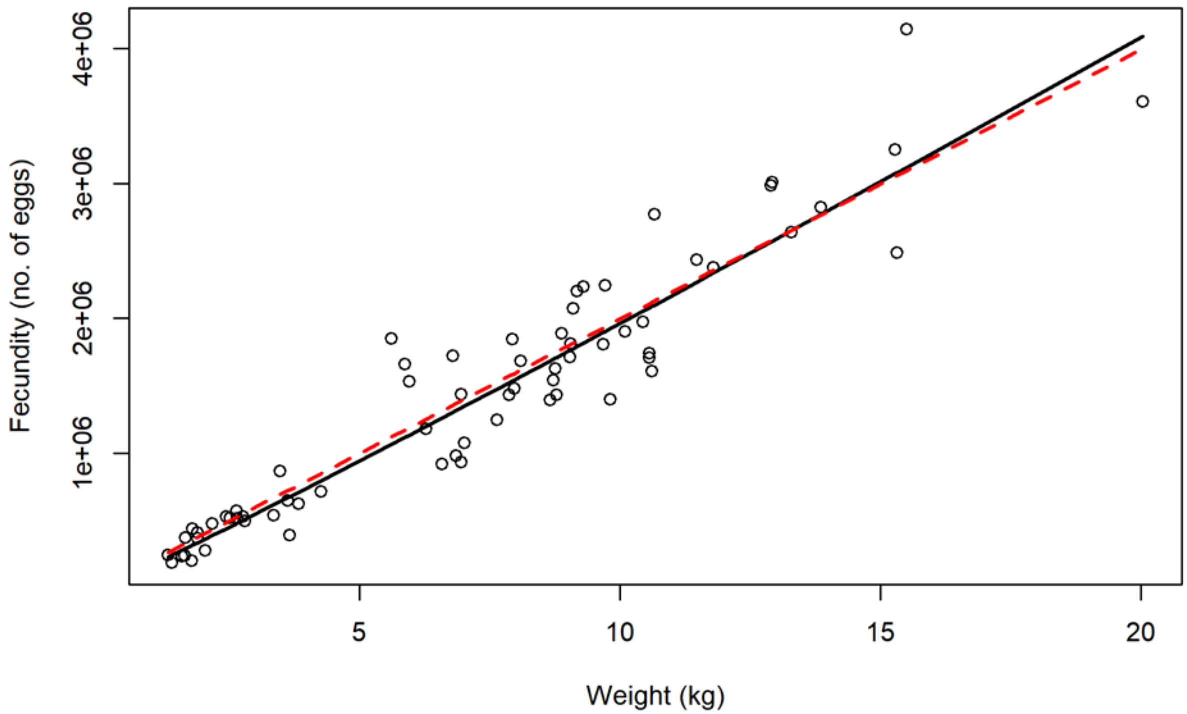


Figure 6. Age (years) versus fecundity (number of eggs).

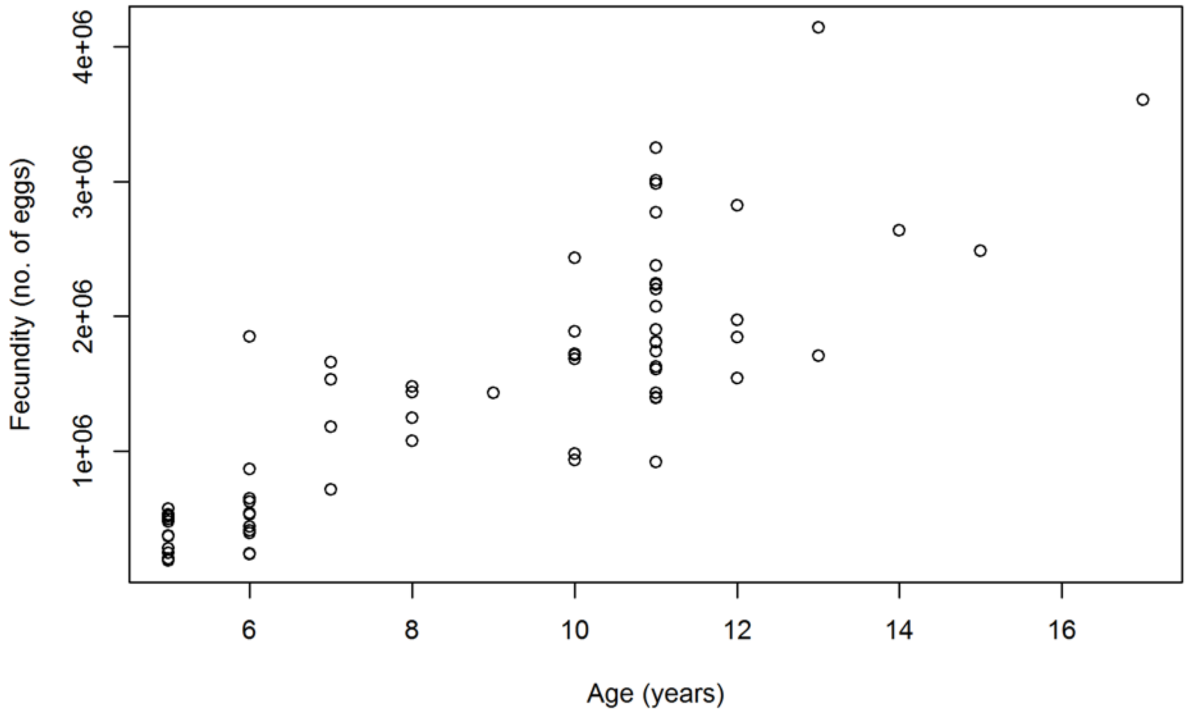
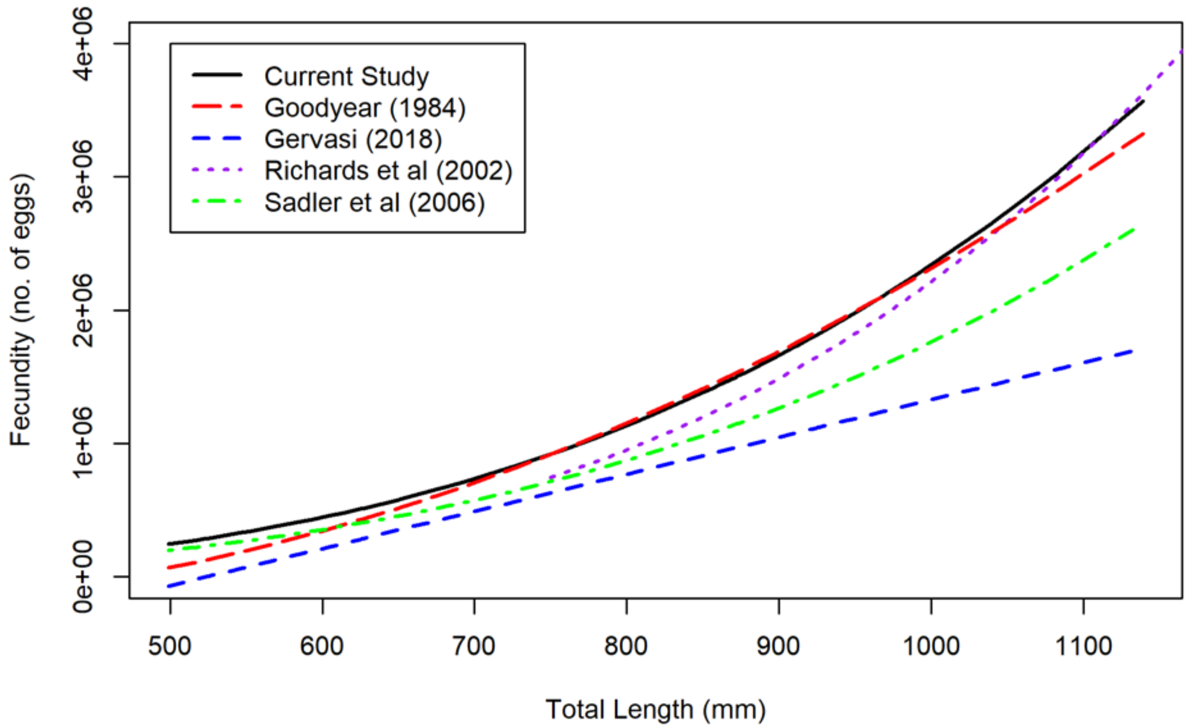


Figure 7. Comparison of striped bass fecundity-length relationships from Chesapeake Bay and tributaries including the present study, Gervasi et al. (2018), Goodyear (1984), Richards et al. (2002), and Sadler et al. (2006).



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 (SRAFRAC), 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. Alosine project staff also prepared data, analyses, and a summary report for the ongoing American shad benchmark stock assessment.

Project staff served as Maryland's representative for the Technical Expert Working Group for river herring, attending meetings. Staff also presented at the Chesapeake Bay River Herring workshop, coordinated by the Smithsonian Environmental Research Center.

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 Draft Addendum III that includes revisions to the TLA and development of 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 Plan Development 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. Staff also sat on the Plan Development Team for Amendment 1 of the ASMFC Black Drum FMP, providing analysis that lead to a Maryland regulation change being approved by the ASMFC South Atlantic Board.

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:

ASMFC Technical Committee representative prepared the Annual Red Drum Status Compliance Report for Maryland.

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 Draft Addendum III that includes revisions to the TLA and development of coast wide regulation options to be enacted, should the TLA trip management action.

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. Staff also prepared data and analysis in support of the 2019 ASMFC weakfish stock assessment update.

Aging:

A staff member attended an ASMFC sponsored aging workshop to compare aging methods and reader agreement between jurisdictions for American eel, Atlantic menhaden, striped bass, summer flounder, tautog and winter flounder

PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDINATION

2019 PRELIMINARY RESULTS – WORK IN PROGRESS

A staff member served on the Atlantic States Marine Fisheries Commission (ASMFC) Spot and Atlantic Croaker Plan Development Team in development of Draft Addendum III to each species Fisheries Management Plan. This responsibility required participating in two conference calls in the reporting period to draft and edit the documents. 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 the draft ASMFC weakfish stock assessment update document and results. Staff participated, as committee chair, in an ASMFC black Drum Technical Committee webinar to evaluate if a stock assessment was warranted in 2020. Staff also participated in two calls of the Susquehanna River Anadromous Fish Restoration Cooperative Technical Committee to discuss fish passage issues, including passage of invasive species.

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, 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 2018 to December 2018 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 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 2018 through December 2018.

Striped Bass Program Project Sites	Page Views
Juvenile Index (/juvenile-index.aspx)	1,969
Home Page (/index.aspx)	554
Volunteer Angler Survey (sb_survey.aspx)	429
Adult Spawning Stock Survey (/studies.aspx)	426
Recreational (/recreational.aspx)	248
Glossary (/glossary.aspx)	239
Commercial (/commercial.aspx)	209
Reports (/reports.aspx)	146
Biologists (/biologists.aspx)	106
Species (/species.aspx)	90
Total	4,419

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, 2018 through June 30, 2019) 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. Alex Aspinwall, VMRC. Provision of seasonal striped bass length frequencies and age-length keys from commercial and recreational fishery monitoring.

-Dr. Jerald Ault, PhD, University of Miami. Provision of Atlantic menhaden data from the Juvenile Seine Survey.

-Mr. John Bishop, Straughan Environmental Inc. Provision of Juvenile Seine Survey data from the Patuxent River.

-Ms. Bridget Butcher, Conservation Specialist, U.S. Army Adelphi Laboratory. Provision of Juvenile Seine Survey data from samples collected on U.S. Army property

-Ms. Sara Coleman, NOAA Chesapeake Bay Office. 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. Philene zu Ermgassen, PhD, The Nature Conservancy, University of Edinburgh. Provision of Juvenile Seine Survey 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 regulations.

-Mr. Joseph Grist, VMRC. Provision of striped bass juvenile survey data and recreational fishery regulations information.

-Dr. Matthew Hamilton, PhD, Georgetown University Department of Biology. Provision of biological samples from the Juvenile Seine Survey.

-Mr. Jeff Kipp, Atlantic States Marine Fisheries Commission. Provision of American shad data from the striped bass Spawning Stock Survey and the Juvenile Seine Survey.

-Dr. Matthew Ogburn, PhD, Smithsonian Environmental Research Center. Provision of biological samples and data from the Spawning Stock Survey and the Juvenile Seine Survey.

-Dr. Ryan J. Woodland, Associate Professor, Chesapeake Biological Laboratory. Provision of Juvenile Seine Survey data from the Patuxent River

Mr. Phil Zalesak, Southern Maryland Recreational Fishing Organization, Inc. Provision of striped bass harvest estimates.

-The Interjurisdictional Species Stock Assessment staff also provided biological information and related reports to twenty-four (24) 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-14

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-14, was to monitor and biologically characterize resident and migratory finfish species in the Maryland portion of the Chesapeake Bay during the 2018 – 2019 sampling season. The F-61-R Survey specifically provides 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 2018 – 2019 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 channel catfish in select tidal areas of 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 channel catfish in select tidal areas of Maryland.

Introduction

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 Job 1.

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

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed in the Upper Chesapeake Bay Winter Trawl Survey during the Survey period of July 1, 2018 through June 30, 2019.

Shortnose Sturgeon and Sea Turtle Interactions

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

2. Nanticoke River Ichthyoplankton Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during the Survey period of July 1, 2018 through June 30, 2019.

Shornose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of July 1, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles sampled or observed during the Survey period of July 1, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.

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, 2018 through June 30, 2019.