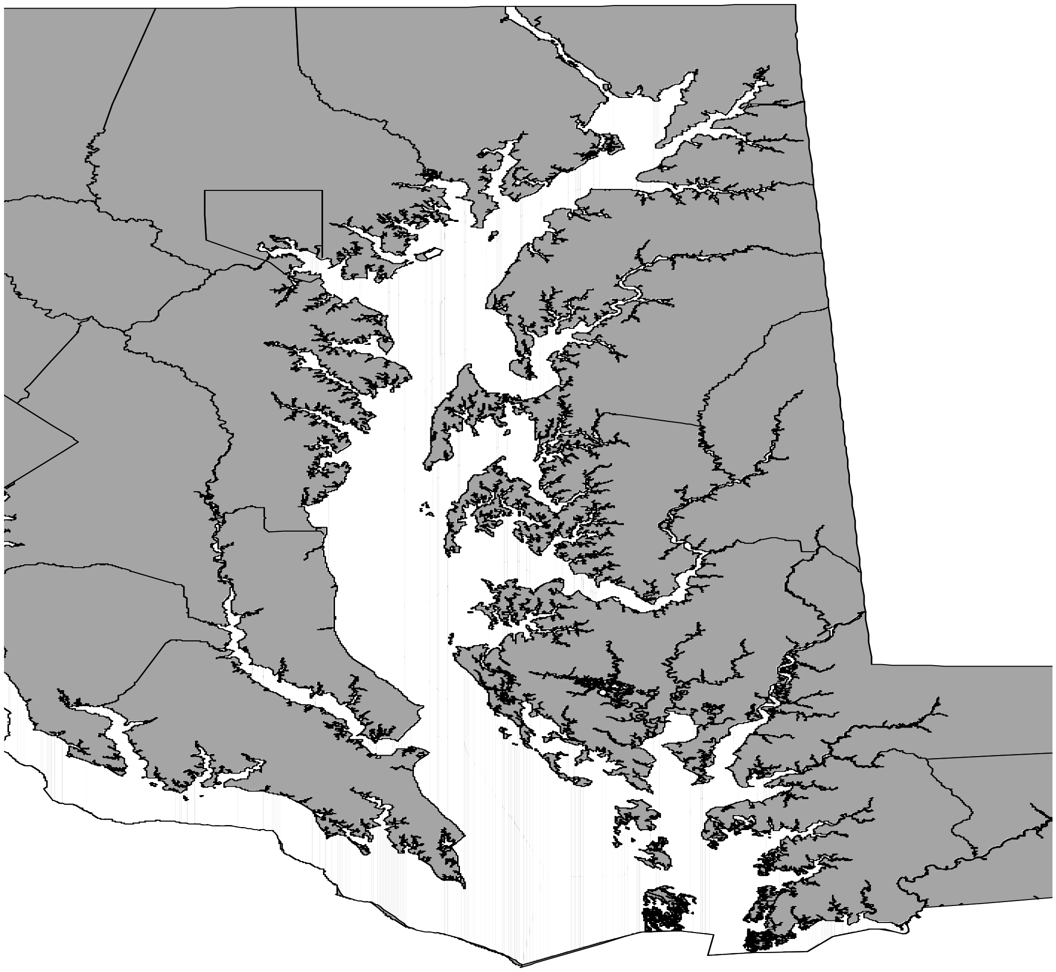

Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-11
2014 - 2015

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Governor

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

STATE: Maryland

PROJECT NO.: F-61-R-11

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 7, 2014 through January 31, 2016

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 a reference point for future fisheries management considerations.

Channel catfish population dynamics were assessed in the Head-of-Bay (HOB), Choptank River, Nanticoke River, Pocomoke River, Potomac River, and Patuxent River. These systems accounted for 87% of the commercial channel catfish landings in 2014; therefore, these systems provide the bulk of sportfishing opportunities for recreational fishermen. The HOB assessment utilized a surplus production model incorporating 2 fishery independent indices of relative abundance and 1 fishery dependent index. Results indicated moderate mortality and a biomass estimate approximately 30% above conservation targets. Fishing mortality was close to fully exploited. Recreational fishermen in the upper Bay assessment region harvested an estimated average of 445,000 pounds annually from 2010 – 2014, attesting to the popularity of channel catfish as a sportfish.

The Choptank River channel catfish assessment utilized a Catch Survey Analysis (CSA) model to assess abundance and fishing mortality. The Choptank River fyke net survey provided informative data on pre-recruit and post-recruit relative abundance (CPUE) from 1993 – 2015. Population trajectory was relatively flat from 1993 – 2005, but increased rapidly to a peak in 2011 at nearly 1.6 million fish. Total population abundance in 2015 was estimated slightly more than 900,000 channel catfish. Instantaneous fishing mortality rates averaged 0.14 and was 0.17 in 2014. The decline in abundance from 2011 – 2015 provided the model with more contrast, enabling a better model fit than a previous attempt to model the population in 2013.

Nanticoke, Pocomoke, Patuxent, and Potomac Rivers were analyzed for trends in abundance. Commercial fishery independent data were generally the only indicators at hand. The Nanticoke and Pocomoke rivers exhibited similar recent trends. These included a strong increasing trend in relative abundance from 2011 through 2014, and time-series highs in 2014. The Patuxent River analysis indicated relative abundance figures slightly below or at the 75th percentile from 2012 – 2014. This suggests that the population is at least stable under current fishing mortality. The Potomac River and Maryland tributaries continued a multi-decadenal decline. Blue catfish, an invasive species in Potomac River, may not have been the initial cause of the decline, but may be deterring population recovery.

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 27 April through 29 May 2015, and 279 were successfully scale-aged. The 2010 (age 5) year class was the most abundant for male and female American shad in 2015. Estimates of abundance for American Shad in the lower Susquehanna River continued to increase in 2015, but remained well below time series peak values observed in the early 2000's. Relative abundance of American shad in the Potomac River (1996-2015) increased significantly over the time series, and remained above average in 2015. In previous years, biologists worked with commercial waterman to collect alosine stock composition data from the Nanticoke River, but due to ice conditions on the river, commercial watermen were unable to set their nets in 2015. American shad juvenile abundance indices increased baywide in 2015. The Potomac River American shad juvenile abundance index was the highest index on record since this survey began in 1954, and continues to be the highest in Maryland's portion of Chesapeake Bay.

The age structure of hickory shad from Susquehanna River was previously very consistent, containing a wide range of ages, however since 2011 a smaller percentage of older fish have been present, suggesting it may be truncating. The arcsine-transformed proportion of repeat spawners (sexes combined) has not changed significantly over the time series (2004-2014), although it has been declining in recent years (2009-2015).

A multi-panel experimental anchored sinking gill net was deployed in the North East River from 2013-2015 to asses the river herring spawning stock in the upper Chesapeake Bay. River herring relative abundance in the North East River increased from 2013-2015, and a strong 2011 year-class (age 4) recruited to the spawning stock in 2015. The juvenile abundance indices indicated alewife and blueback herring increased baywide in 2015.

Weakfish have experienced a sharp decline in abundance coast wide. Recreational harvest estimates for inland waters by the NMFS for Maryland waters declined from 471,142 fish in 2000 to 754 in 2006, and has fluctuated at a very low level from 2007 through 2014, with an estimated 1,062 weakfish harvested in 2014. The 2014 Maryland Chesapeake Bay commercial weakfish harvest of 62 pounds was well below the 1981 – 2014 Maryland Chesapeake Bay average of 46,214 pounds per year. The 2015 mean length for weakfish from the onboard pound net survey was 293 mm TL (n=23), slightly lower than the long term mean. One weakfish measuring 157 mm TL was captured in the Choptank River gill net survey in 2015, and none were encountered in 2013 or 2014.

Summer flounder mean length from the pound net survey was 331 mm TL (n=43) in 2015, similar to the long term mean. The 2015 length frequency distribution shifted back toward larger fish after being skewed toward smaller fish in 2013 and 2014. No summer flounder were captured in the Choptank River gill net survey in 2015. The NMFS 2014 coast wide stock assessment concluded that summer flounder stocks were not overfished, but overfishing was occurring.

Mean length of bluefish from the pound net survey in 2015 was 327 mm TL (n=392), and was above the time series mean. The length distribution indicated a slight shift to larger bluefish in 2015. Only seven bluefish were captured in the Choptank River gill net survey in 2015. Bluefish have been encountered in low numbers all three years of the survey. Recreational and commercial bluefish harvest were both 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 pound net survey in 2015 was 265 mm TL (n=942), and was the fourth lowest value of the 23 year time series. Atlantic croaker age structure from pound net samples (n=127) indicated fewer older fish, with no age eight plus fish sampled. Atlantic croaker catches from the Choptank River gill net survey declined steadily each year of the survey; 476 fish in 2013, 269 fish in 2014 and 21 fish in 2015. Maryland 2014 Atlantic croaker Chesapeake Bay commercial harvest and inland waters recreational harvest estimate values declined from 2013, but were still above their long term means. The Atlantic croaker juvenile index has decreased steadily since 2012 to the second lowest value of the 27 year time series in 2015.

The 2015 spot mean length of 194 mm TL (n=127) was the same as in 2014, remaining below the long term mean, and length frequency was truncated. Spot aged from the onboard pound net survey (n=76) were predominately age one, with no fish over age two. Spot catch in the Choptank River gill net survey was highest in 2014 and similar in 2013 and 2015. Chesapeake Bay commercial spot harvest was similar in 2013 and 2014. The inland waters recreational harvest estimate in 2014 was below the time series mean. The spot juvenile index declined to near the time series low in 2011, rose in 2012 to the eighth highest value in the 27 year time series, but declined since to the time series low in 2015.

Resident / premigratory striped bass sampled from pound nets in the Chesapeake Bay during the summer – fall 2014 ranged in age from 1 to 12 years old. Three year old (2011 year-class), striped bass dominated biological samples taken from pound nets and contributed 56% of the sample. Check station sampling determined that the majority of the commercial pound net and hook-and-line fishery harvest was composed of three to six year old striped bass from the 2008 through 2011 year-classes and comprised 86% of the sampled harvest.

The 2013-2014 commercial striped bass drift gill net fishery harvest was comprised primarily of fish 4, 5, 7 and 8 years old from the 2007 through 2011 year-classes and comprised 59% of the total havest. Striped bass from the 2009 year-class (six year old fish) composed 28% of the total drift gill net harvest. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 4 to 14 years old (2001 to 2011 year-classes).

Fish harvested during the 2014-2015 Atlantic coast fishing season ranged from age 4 (2011 year-class) to age 15 (2000 year-class). Eleven year-classes were represented in the sampled harvest. Approximately 96% of striped bass harvested were ages 5 through 12. Striped bass were recruited into the Atlantic coast fishery as young as age 4. However, due to the 24 inch minimum size limit, few fish younger than age 5 were harvested. Based on the estimated catch-at-age, the most common age harvested during the 2014-2015 Atlantic coast harvest was age 6 (2009 year-class), which represented 22% of the landings.

The spring 2015 spawning stock survey indicated that there were 18 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 19 years old. Male striped bass ranged in age from 2 to 18 years old and females ranged in age from 4 to 19, with age 12 (2003 year-class) females the year-class most commonly observed. During the spring 2015 spawning season, age 8 and older females made up 82% of the female spawning stock. Females from the once dominant 1996 year-class are still present and contributing to the spawning stock in both the Upper Bay and the Potomac River.

The striped bass juvenile index, a measure of striped bass spawning success in Chesapeake Bay, was 24.2 in 2015. This is approximately twice the long-term average of 11.9, and the eighth highest ever measured by the survey. MD DNR biologists have conducted the Young-of-Year Survey annually since 1954 to track the reproductive success of striped bass, which can vary greatly from year to year, and help predict future population abundance.

During the 2015 survey, biologists collected over 70,000 fish of 50 species, including 3,194 juvenile striped bass, at 22 survey sites in the four major spawning systems: the Choptank, Nanticoke, and Potomac rivers, and the Upper Bay. Juvenile indices are calculated as the average catch of young-of-year fish per sample. In 2011, biologists documented one of the most successful striped bass spawns on record and these 4-year-old fish are currently very abundant in the

Chesapeake Bay. The survey also documented healthy reproduction for other species of fish that return to freshwater to spawn. Juvenile American shad, under a harvest ban in Maryland since 1980, were collected in record numbers. Reproductive success of river herring was above average. The juvenile index for white perch, a species very popular with anglers, ranked the third-highest on record.

During the 2015 spring recreational trophy season, biologists intercepted 261 fishing trips, interviewed 546 anglers, and examined 177 striped bass. The average total length of striped bass sampled was 935 mm total length (mm TL). The average weight was 8.6 kg. Striped bass sampled from the trophy fishery ranged in age from 6 to 18 years old, similar to 2014. The 2003 (age 12) and 2004 (age 11) and 2005 (age 10) year-classes were the most frequently observed cohorts sampled from the spring recreational fishery. In 2015, the average private boat catch rate based on angler interviews was 0.17 fish per hour, while charter boat mean catch per hour was 0.96 fish per hour.

Maryland Department of Natural Resources biologists continued to tag and release striped bass in spring, 2015 in support of the US FWS coordinated interstate, coastal population study for growth and mortality. A total of 1,652 striped bass were tagged and released with USFWS internal anchor tags between March through May 2015 in Maryland. Of this sample, 608 were tagged in the Potomac River and 1,044 were tagged in the upper Chesapeake Bay area during the spring spawning stock assessment survey. A total of 1,375 striped bass were tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise.

APPROVAL

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ACKNOWLEDGEMENTS

The Maryland Department of Natural Resources (MD DNR) would like to thank the Maryland Watermen's Association commercial captains and their crews who allowed us to sample their commercial harvest. We also wish to thank RMC Environmental Services personnel for their aid in acquiring tag returns and catch data from the fish lifts at Conowingo Dam. Appreciation is also extended to MD DNR Hatchery personnel, Brian Richardson and staff for otolith analysis of juvenile and adult American shad and to Connie Lewis, Fisheries Statistics, for providing commercial landings. We would also like to thank Captain Rick Younger and crew of the *R/V Kerhin*, and Captain Michael Hulme and crew of the *R/V Rachel* Carson 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 Thomas W. Fletcher, Jr., on the Upper Chesapeake Bay.

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CONTENTS

SURVEY TITLE: CHESAPEAKE BAY FINFISH/HABITAT INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 1
JOB NO. 1

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The primary objective of Job 1 was to provide data and analysis from routine monitoring of the following resident species: white perch (*Morone americana*), yellow perch (*Perca flavescens*), channel catfish (*Ictalurus punctatus*) and white catfish (*Ameiurus catus*) from selected tributaries in the Maryland portion of the 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; 4 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 24 sampling stations were approximately 2.6 km (1.5 miles) in length and variable in width (Figure 1). Each sampling station was divided into west/north or east/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 in the wings and 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 December 2014 through February 2015.

Trawl sites have been consistent throughout the survey, but 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.

Choptank River Fishery Independent Sampling

In 2015, six experimental fyke nets were set in the Choptank River to sample the four resident species from this system. 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 12 March through 15 April (Figure 2). This was at least 2 weeks later than normal years due to total ice coverage in Choptank River during winter 2015. 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 and yellow perch were removed for age determination.

Upper Chesapeake Bay Fishery Dependent Sampling

Commercial fyke net catches were sampled for yellow perch on 15 March 2015 in Gunpowder River and 16 March 2015 in Bush River (Figures 3, 4). All yellow perch were measured and sexed (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River Fishery Dependent Sampling

No samples from the Nanticoke River were available in 2015. The cooperating commercial fishermen that normally provide samples did not fish in 2015 because of the extreme winter and subsequent ice conditions. For historical white perch, channel catfish, and white catfish data, specific to Nanticoke River see Piavis and Webb (2015).

II. Data compilation

Population Age Structures

Population age structures were determined for yellow perch and white perch from Choptank River and upper Chesapeake Bay (trawl and commercial sampling separately). Age-at-length keys for yellow perch and white perch (separated by sex) from the Choptank River fyke net survey, and upper Bay commercial fyke net survey (yellow perch only) were constructed by determining the proportion-at-age per 20-mm length group and applying that proportion to the total number-at-length. For the upper Bay trawl survey, an age-length key was constructed in 10 mm increments and the age-at-length key was applied to individual hauls. Total number by sex were added together to get total numbers at age.

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 over time and weight in relation to length were described with standard fishery equations. The allometric growth equation (weight (g) = α*length (mmTL)^3) 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, Excel Solver (Microsoft Corporation 1993), or Evolver genetic tree algorithms (Palisades Corporation 2001). Growth data for target species encountered in the trawl survey were not compiled due to the size selectivity of the gear.

Mortality

Catch curves for Choptank River and upper Chesapeake Bay white perch were based on $\log_e$ transformed catch-per-unit-effort (CPUE) data for ages 6 -10 for males and females. The slope of the line was -Z and M was assumed to be 0.20. Instantaneous fishing mortality (F) was Z-M.

Choptank River yellow perch mortality was estimated with a ratio method to determine survivorship (S), where S = (CPUE ages 4 – 10+ in year t)/(CPUE ages 3-10+ in year t-1). Total instantaneous mortality (Z) was $-\log_e$ (S), and F=Z-M where M was assumed to be 0.25. The only exception to this method was the 2002 estimate where all age-classes were used for the survivorship estimate. Instantaneous mortality rates for yellow perch from the upper Bay commercial samples were calculated with a statistical catch-at-age model 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.

Relative Abundance

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, CPUE from 1 March to the 95% catch end time was utilized for time-trend analysis.

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 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 new 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 1-2
Yellow perch	Tables 3-5

Population Length Structures

White perch	Tables 6-7 and Figures 5-6
Yellow perch	Tables 8-10 and Figures 7-9
Channel catfish	Tables 11-12 and Figures 10-11
White catfish	Tables 13-14 and Figures 12-13

Growth

White perch	Table 15
Yellow perch	Tables 16-17

Mortality

White perch	Table 18
Yellow perch	Table 19

Recruitment

White perch	Figures 14-15
Yellow perch	Figures 16-17
Channel catfish	Figure 18

Relative Abundance

White perch	Tables 20-21
Yellow perch	Tables 22-23 and Figure 19
Channel catfish	Figures 20-21
White catfish	Figure 22

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LIST OF FIGURES

Figure 1. Upper Chesapeake Bay winter trawl survey locations, December 2014 – February 2015. Different symbols indicate each of 6 different sampling rounds.

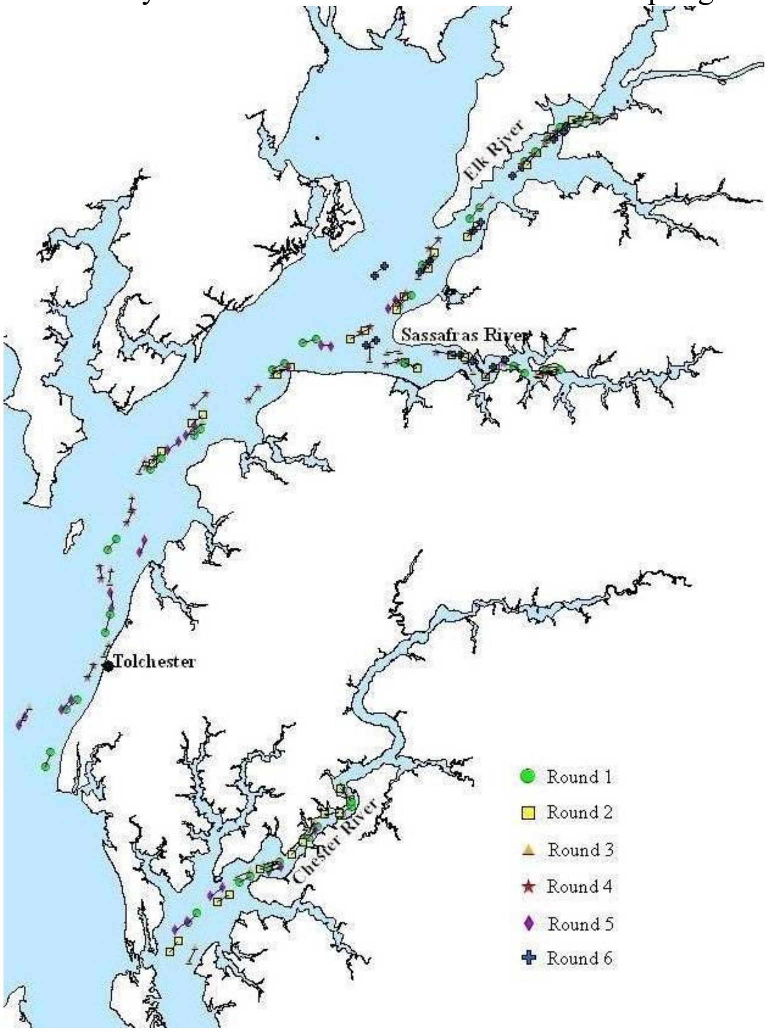


Figure 2. Choptank River fyke net locations, 2015. Circles indicate sites.

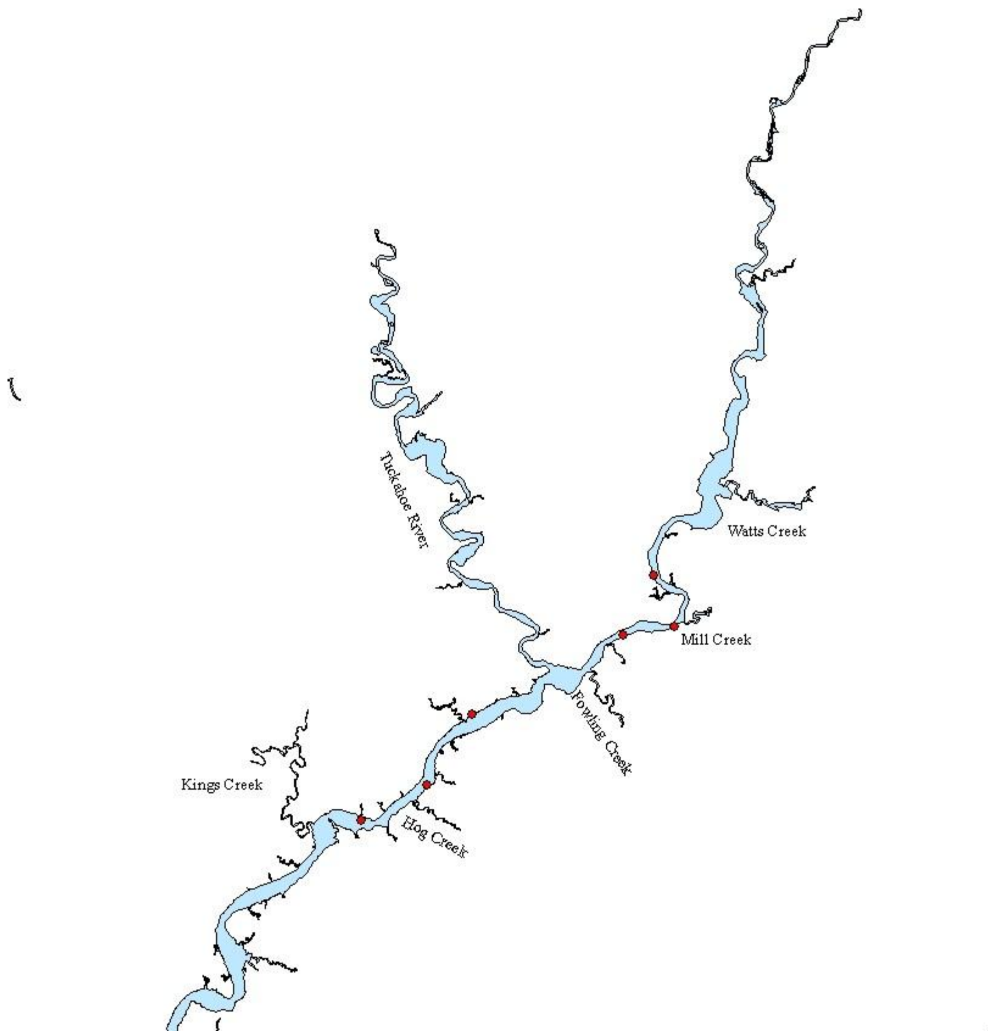


Figure 3. Commercial yellow perch fyke net sites sampled during 2015 in Gunpowder River. Circles indicate sites.

Figure 4. Commercial yellow perch fyke net sites sampled during 2015 in Bush River. Black circles indicate fyke net locations.

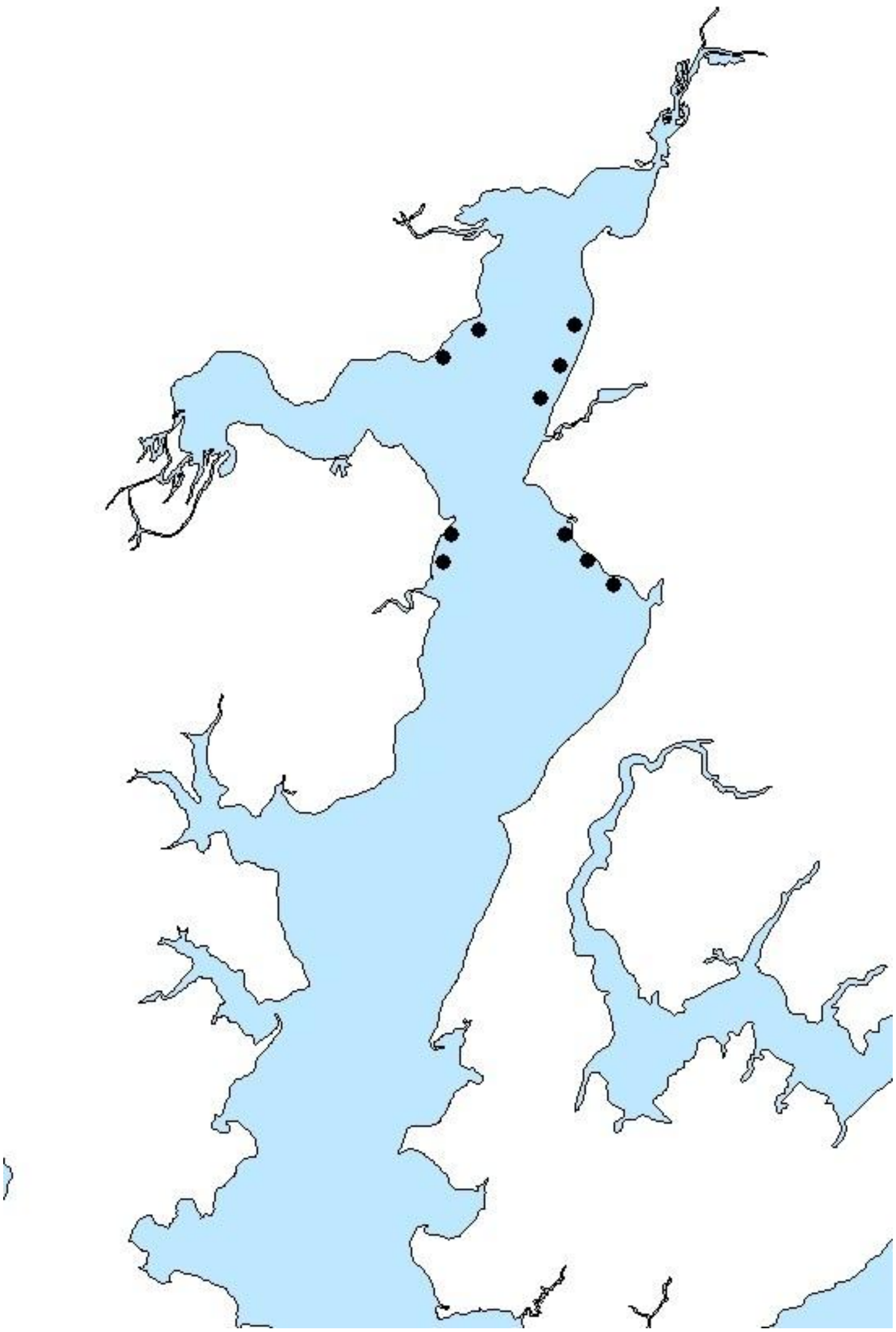


Table 1. White perch catch-at-age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2015.

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

Table 2. White perch catch-at-age matrix from Choptank River fyke net survey, 2000 – 2015.

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

Table 3. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2015.

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

Table 4. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2015.

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	210	34	2,534	426	188	2	2	10	3

Table 5. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2015.

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

Table 6. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2015. 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

Figure 5. White perch length-frequency from 2015 upper Chesapeake Bay winter trawl survey.

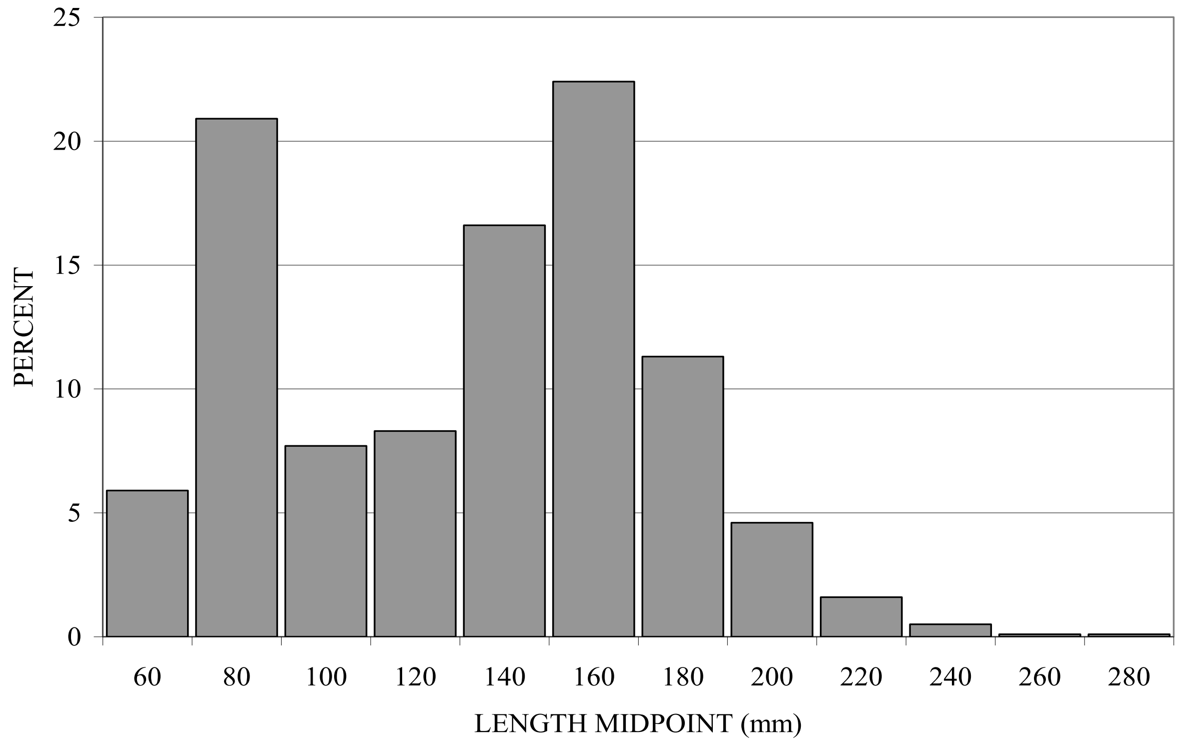


Table 7. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2015. Minimum length cut-offs in parentheses.

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

Figure 6. White perch length-frequency from 2015 Choptank River fyke net survey.

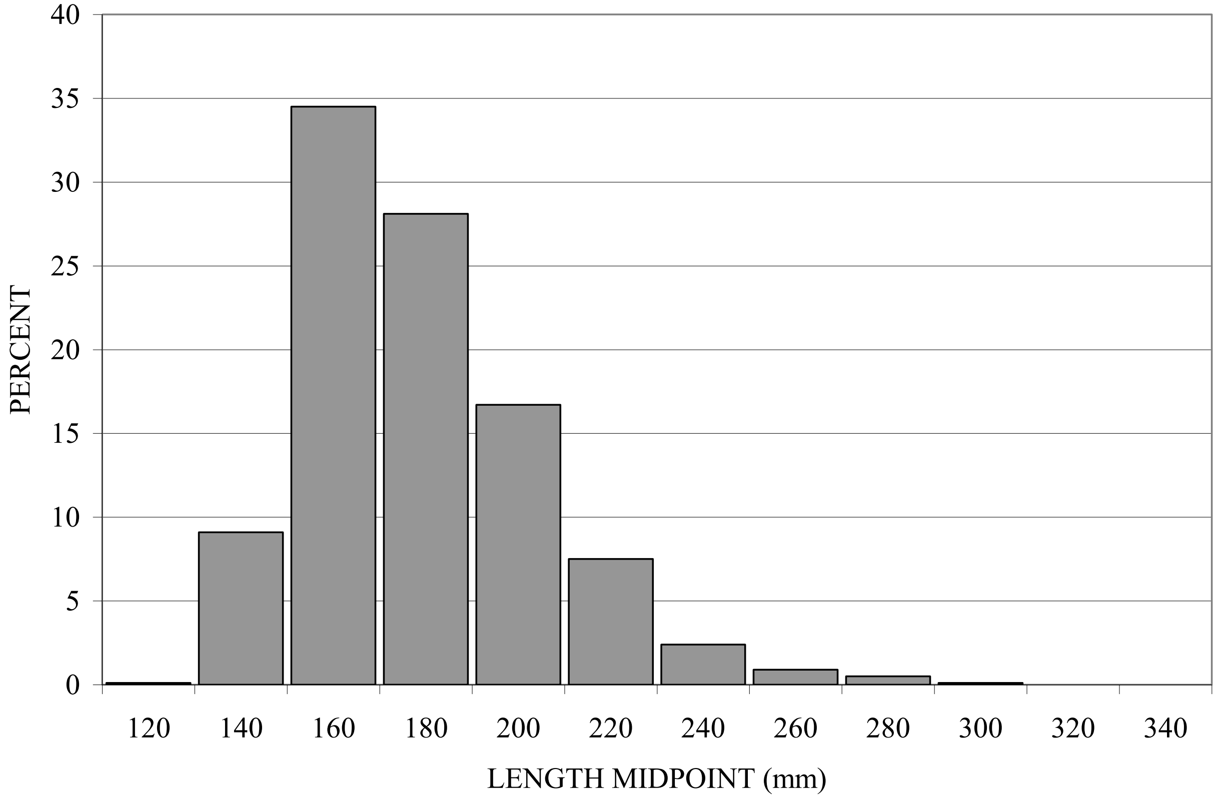


Table 8. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2015. Minimum length cut-offs in parentheses.

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

Figure 7. Yellow perch length-frequency from the 2015 upper Chesapeake Bay winter trawl survey.

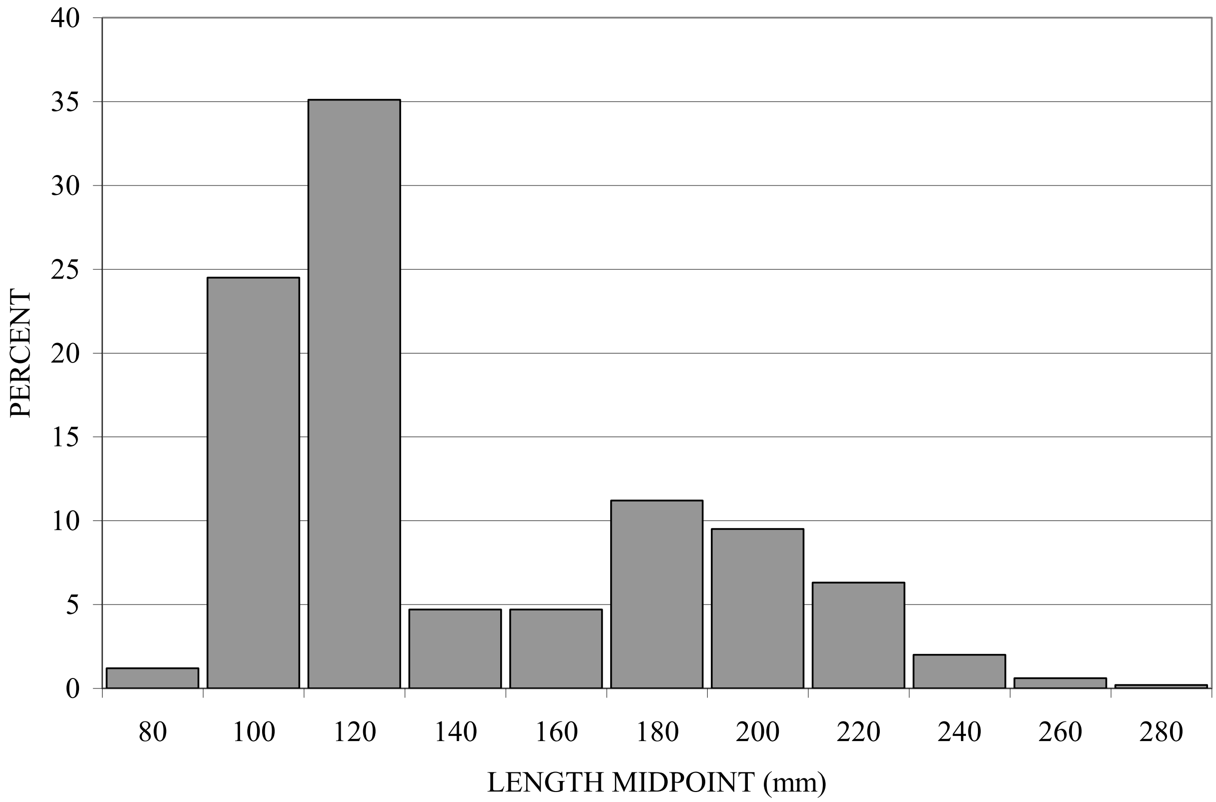


Table 9. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2015. Minimum length cut-offs in parentheses.

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

Figure 8. Yellow perch length-frequency from the 2015 Choptank River fyke net survey.

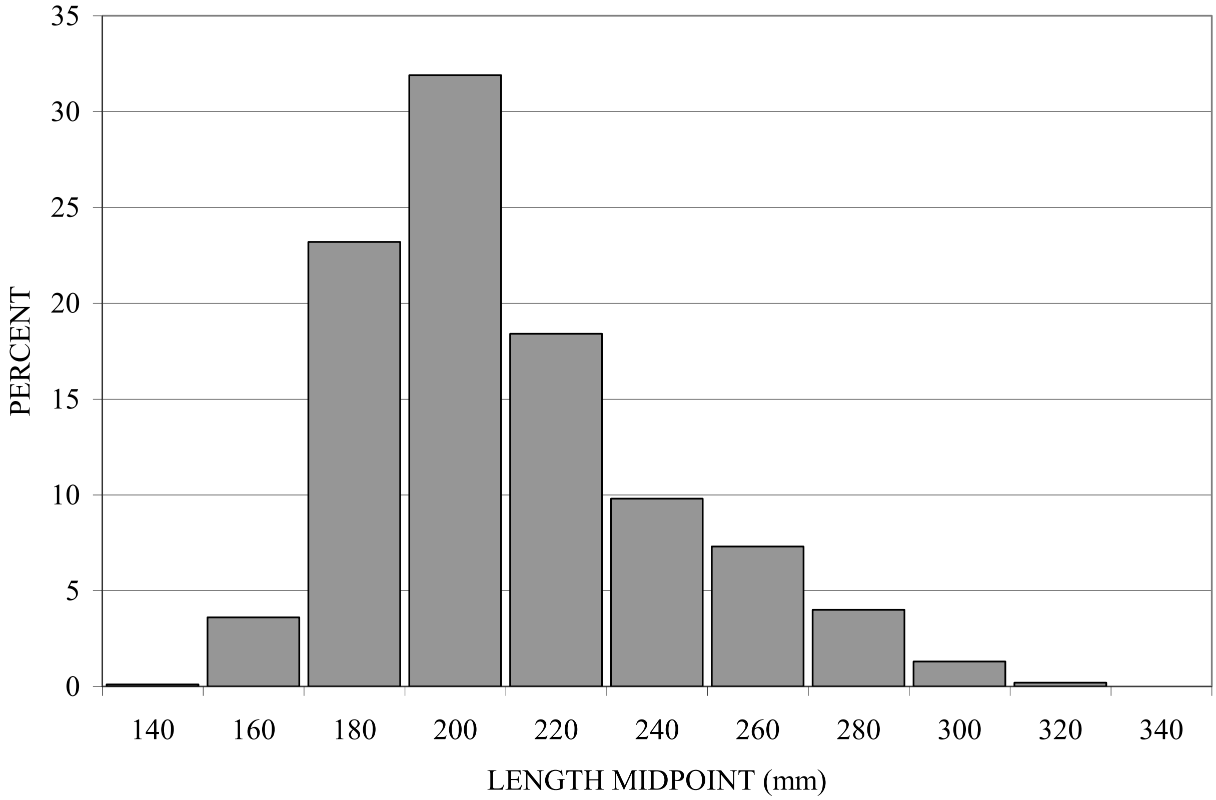


Table 10. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2015. Minimum length cut-offs in parentheses.

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

Figure 9. Yellow perch length frequency from the 2015 upper Chesapeake commercial fyke net survey.

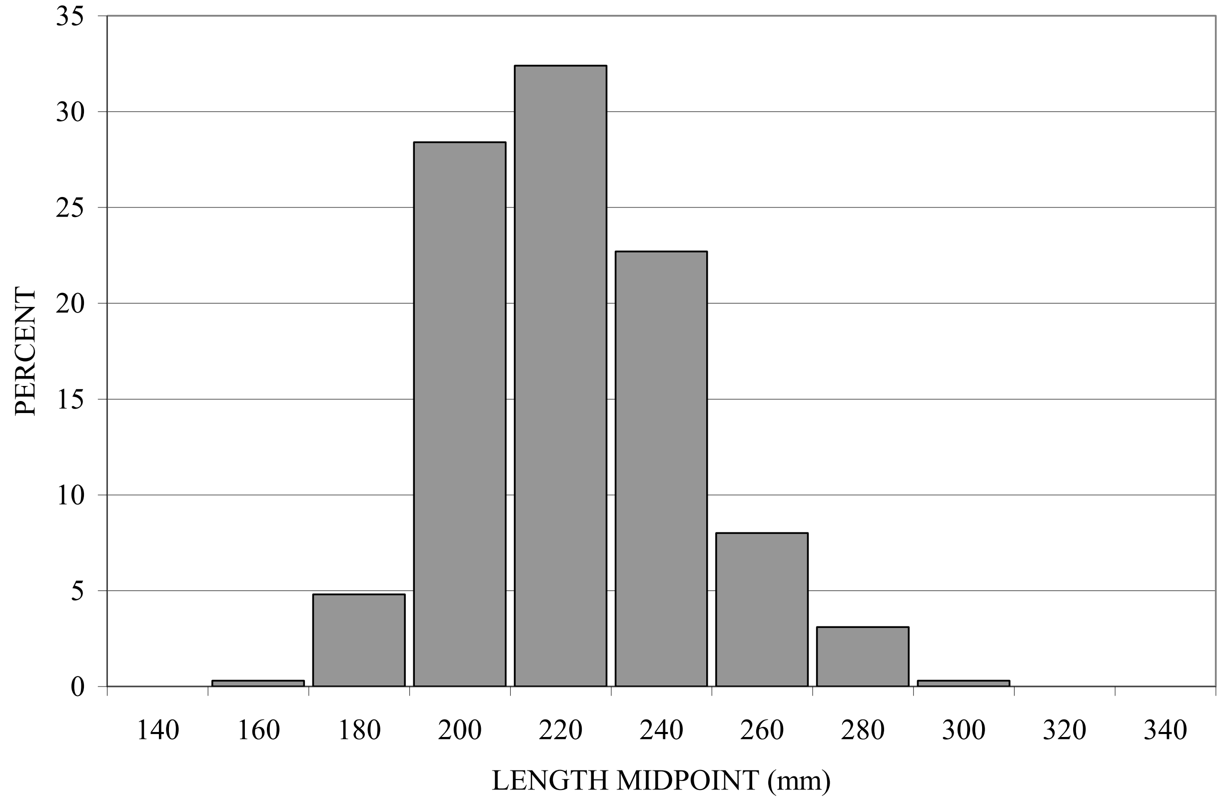


Table 11. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2015. Minimum length cut-offs in parentheses.

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

Figure 10. Length frequency of channel catfish from the 2015 upper Chesapeake Bay winter trawl survey.

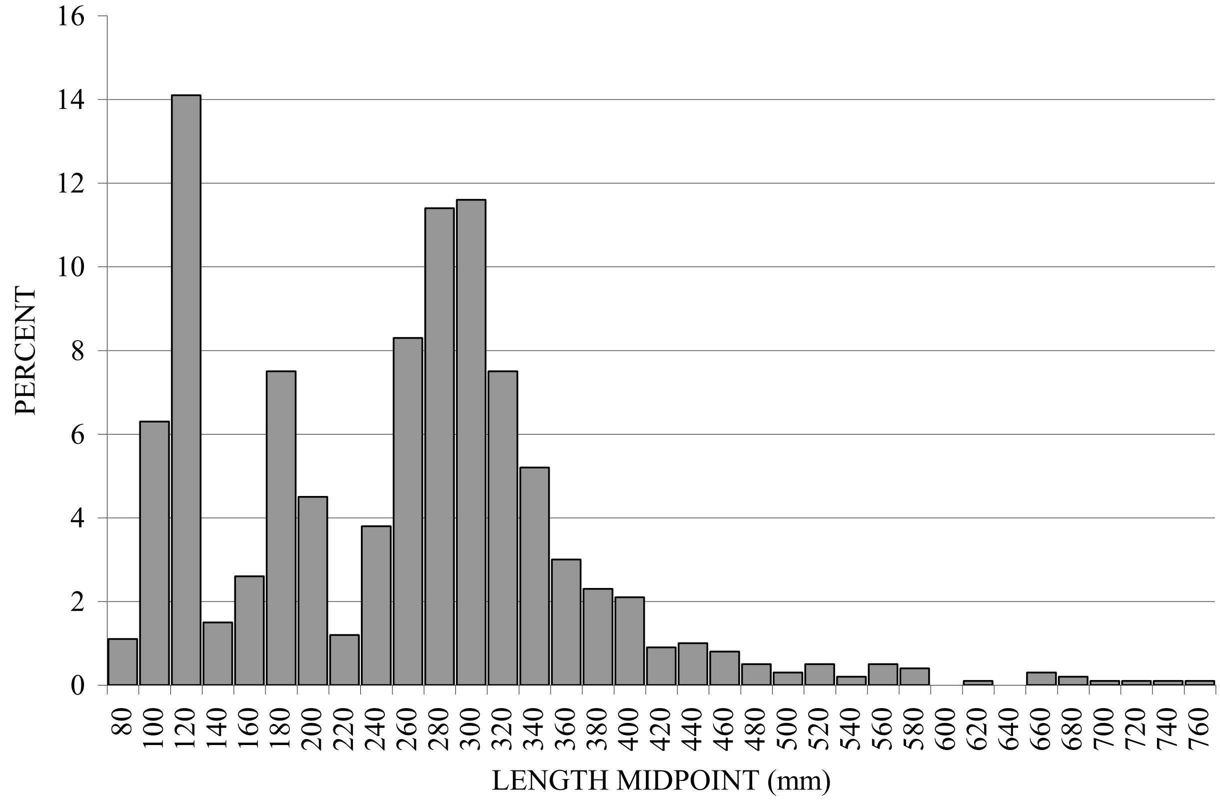


Table 12. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2015. Minimum length cut-offs in parentheses.

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

Figure 11. Channel catfish length frequency from the 2015 Choptank River fyke net survey.

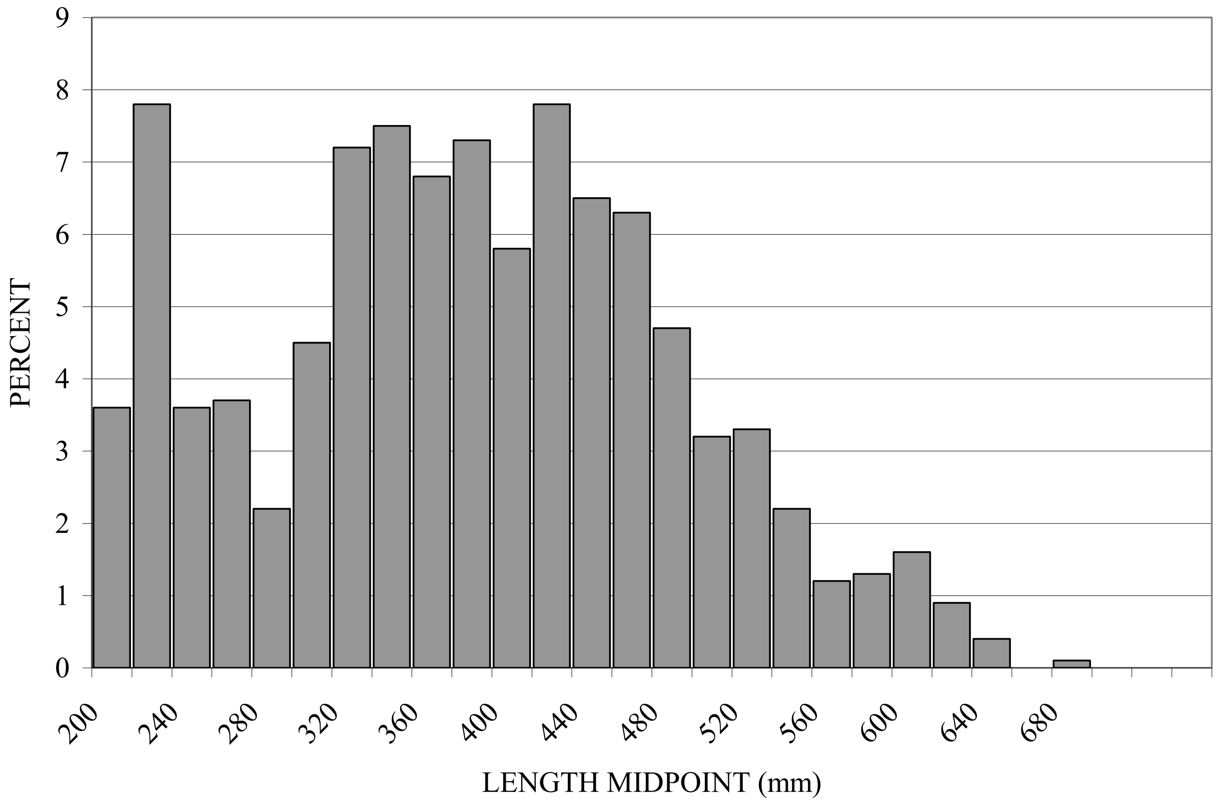


Table 13. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2015. Minimum length cut-offs in parentheses.

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

Figure 12. White catfish length frequency from the 2015 upper Chesapeake Bay winter trawl survey.

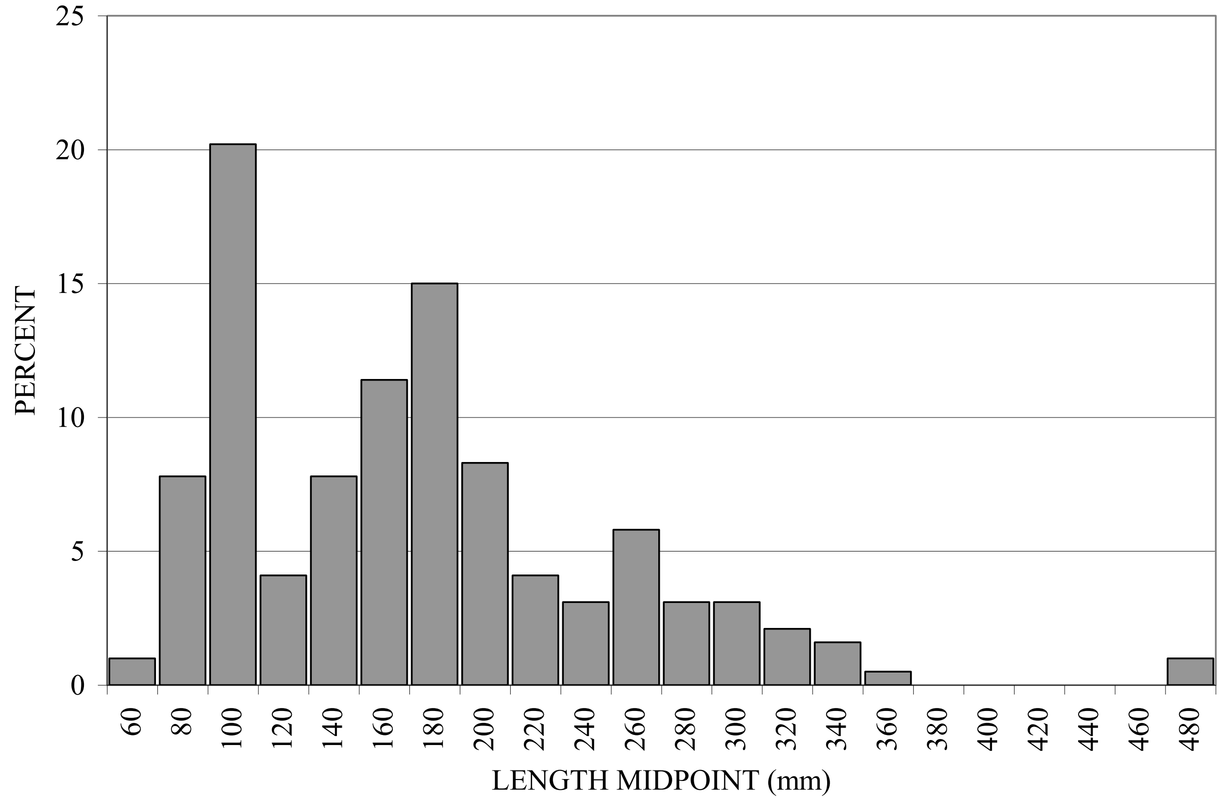


Table 14. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2015. Minimum length cut-offs in parentheses.

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

Figure 13. White catfish length frequency from the 2015 Choptank River fyke net survey.

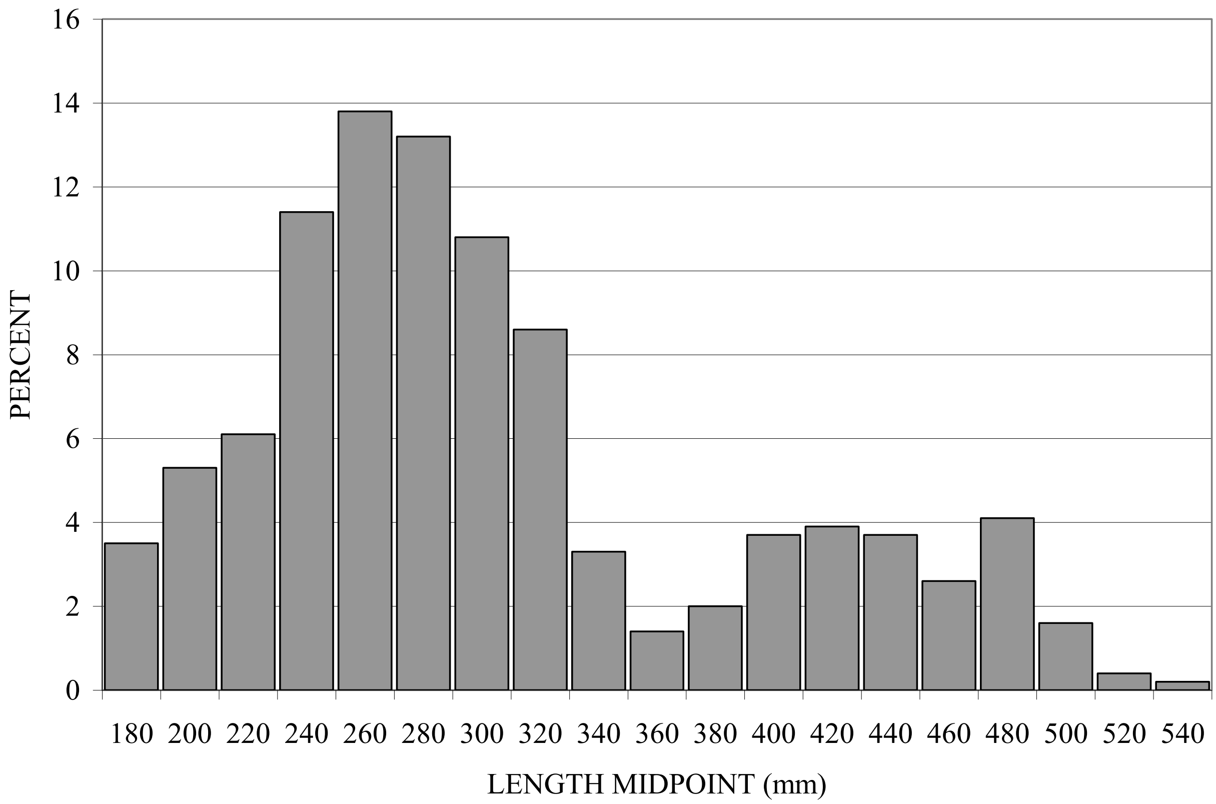


Table 15. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	Allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2007	F	1.6×10^{-5}	3.00	269	0.33	0.28
	M	5.8×10^{-5}	2.74	247	0.32	0.06
	Combined	1.9×10^{-5}	2.96	265	0.31	0.15
2008	F	3.0×10^{-6}	3.29	317	0.23	-1.44
	M	3.7×10^{-6}	3.25	227	0.32	-1.98
	Combined	2.2×10^{-6}	3.35	284	0.28	-0.89
2009	F	2.8×10^{-6}	3.32	338	0.20	-1.33
	M	2.5×10^{-6}	3.32	225	0.49	-0.77
	Combined	1.9×10^{-6}	3.38	281	0.32	-0.17
2010	F	4.0×10^{-6}	3.26	312	0.18	-1.38
	M	4.2×10^{-6}	3.23		NSF	
	Combined	2.6×10^{-6}	3.33		NSF	
2011	F	2.3×10^{-6}	3.35		NSF	
	M	2.4×10^{-6}	3.34	217	0.49	0.44
	Combined	2.0×10^{-6}	3.38		NSF	
2012	F	6.9×10^{-6}	3.17	264	0.47	0.81
	M	4.5×10^{-6}	3.23	227	0.39	-0.21
	Combined	3.1×10^{-6}	3.31	251	0.46	0.68
2013	F	8.9×10^{-6}	3.10	320	0.13	-4.78
	M	4.8×10^{-6}	3.19	245	0.20	-3.64
	Combined	3.8×10^{-6}	3.25	284	0.16	-3.66
2014	F	5.9×10^{-6}	3.18	278	0.34	-0.40
	M	1.2×10^{-6}	3.46	223	0.56	0.37
	Combined	2.9×10^{-6}	3.30	255	0.42	0.12
2015	F	2.3×10^{-6}	2.92		NSF	
	M	3.2×10^{-6}	3.23		NSF	
	Combined	1.3×10^{-5}	3.03	287	0.20	-1.63
2000 – 2015	F	5.3×10^{-6}	3.20	305	0.19	-1.88
	M	4.9×10^{-6}	3.20	243	0.23	-1.98
	Combined	3.42×10^{-6}	3.28	287	0.20	-1.63

Table 16. 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.

Sample Year	Sex	allometry alpha	allometry beta	von Bertalanffy L-inf	K	t_0
2007	F	$2.3 X 10^{-5}$	2.88	308	0.52	0.19
	M	$1.3 X10^{-5}$	2.97	279	0.29	-1.40
	Combined	$1.1 X 10^{-5}$	3.02	277	0.54	-0.01
2008	F	$5.8 X 10^{-6}$	3.12	322	0.43	-0.12
	M	$1.1 X 10^{-5}$	3.00	253	0.26	-2.82
	Combined	$8.1 X 10^{-6}$	3.06	289	0.40	-0.59
2009	F	$8.7 X 10^{-6}$	3.06	315	0.40	-0.63
	M	$2.8 X 10^{-6}$	3.26	288	0.35	-0.24
	Combined	$4.4 X 10^{-6}$	2.18	308	0.29	-1.71
2010	F	$1.3 X 10^{-5}$	2.97		NSF	
	M	$4.7 X 10^{-6}$	3.16		NSF	
	Combined	$9.9 X 10^{-6}$	3.02		NSF	
2011	F	$1.2 X 10^{-6}$	3.02		NSF	
	M	$4.7 X 10^{-6}$	3.17		NSF	
	Combined	$3.2 X 10^{-6}$	3.25		NSF	
2012	F	$7.0 X 10^{-6}$	3.08	374	0.18	-2.22
	M	$1.5 X 10^{-6}$	3.37	257	0.29	-2.62
	Combined	$6.7 X 10^{-6}$	3.09	295	0.32	-1.38
2013	F	$9.2 X 10^{-6}$	3.02	294	0.53	-0.28
	M	$1.7 X 10^{-5}$	2.92	322	0.10	-6.35
	Combined	$1.5 X 10^{-5}$	2.94	267	0.53	-0.48
2014	F	$1.5 X 10^{-5}$	2.94	285	0.94	1.57
	M	$9.7 X 10^{-6}$	3.03	272	0.33	-0.59
	Combined	$1.5 X 10^{-5}$	2.94	271	0.68	0.94
2015	F	$1.7 X 10^{-5}$	2.94	361	0.20	-1.51
	M	$2.1 X10^{-6}$	3.32	310	0.11	-6.67
	Combined	$9.6 X 10^{-6}$	3.04	385	0.13	-2.76
2000 – 2015	F	$1.2 X 10^{-5}$	3.00	313	0.31	-1.07
	M	$3.7 X 10^{-6}$	3.21	294	0.16	-3.38
	Combined	$7.8 X 10^{-6}$	3.07	274	0.34	-1.38

Table 17. Yellow perch growth parameters from upper Chesapeake Bay fyke nets for males, females, and sexes combined. NA=data not available NSF=no solution found.

Sample Year	Sex	allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2007	F	1.96×10^{-6}	3.35	325	0.34	-0.09
	M	4.38×10^{-6}	3.18	240	0.61	0.61
	Combined	6.68×10^{-7}	3.54	267	0.64	0.55
2008	F	7.83×10^{-6}	3.11	339	0.26	-2.14
	M	3.32×10^{-6}	3.24		NSF	
	Combined	3.89×10^{-6}	3.23	275	0.41	-1.97
2009	F	1.30×10^{-6}	3.43	294	0.43	-0.78
	M	6.09×10^{-6}	3.13	220	0.97	-0.14
	Combined	6.23×10^{-6}	3.56	245	0.90	0.13
2010	F	1.62×10^{-4}	2.57	392	0.51	0.04
	M	1.92×10^{-6}	3.34	247	0.88	0.99
	Combined	3.40×10^{-5}	2.84	296	0.66	0.40
2011	F	3.1×10^{-8}	4.10		NSF	
	M	9.4×10^{-7}	3.47		NSF	
	Combined	9.1×10^{-6}	3.90	245	0.66	-1.93
2012	F	1.4×10^{-6}	3.39	294	0.44	-0.31
	M	7.8×10^{-6}	3.06	253	0.89	1.22
	Combined	7.7×10^{-6}	3.50	269	0.73	0.53
2013	F	2.5×10^{-6}	3.31	393	0.15	-2.27
	M	1.5×10^{-5}	2.95	257	0.38	-0.02
	Combined	1.2×10^{-6}	3.44	304	0.24	-1.76
2014	F	9.0×10^{-6}	3.08	410	0.10	-4.75
	M	9.1×10^{-5}	3.05	248	0.51	-0.18
	Combined	4.8×10^{-6}	3.18	272	0.41	-0.80
2015	F					
	M					
1998 – 2015	F	4.4×10^{-6}	3.20	316	0.26	-1.64
	M	4.3×10^{-6}	3.18	250	0.32	-2.29
	Combined	2.1×10^{-6}	3.33	266	0.48	-0.61

Table 18. Estimated instantaneous fishing mortality rates (F) for white perch. NR= not reliable; NA=not available; MIN= minimal, at or near M estimate.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Choptank	0.20	0.18	0.16	0.12	0.20	0.38	0.54	0.32	MIN	0.17
Nanticoke	0.22	0.18	0.16	0.12	0.66	NR	NR	0.08	MIN	NA
Upper Bay	0.47	0.72	0.22	0.22	0.42	0.42	0.22	0.35	MIN	MIN

Table 19. Estimated instantaneous fishing mortality rates (F) for yellow perch. NR= not reliable; MIN=minimal, at or near M estimate.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Choptank[1]	MIN	MIN	NR	0.17	MIN	0.56	0.12	MIN	MIN	0.26
Upper Bay[2]	0.15	0.18	0.04	0.22	0.26	0.34	0.30	0.19	0.13	0.19

[1]Based on ratio of CPUE of ages 4-10+ (year t) to CPUE of ages 3 – 10+ (year t-1) except 2009, 2014 and 2015 estimate where ratio of ages 5 - 10 and 4 - 10 were used.

[2]Fully recruited F from Piavis and Webb in publ.

Figure 14. Baywide young-of-year relative abundance index for white perch, 1962 – 2015, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

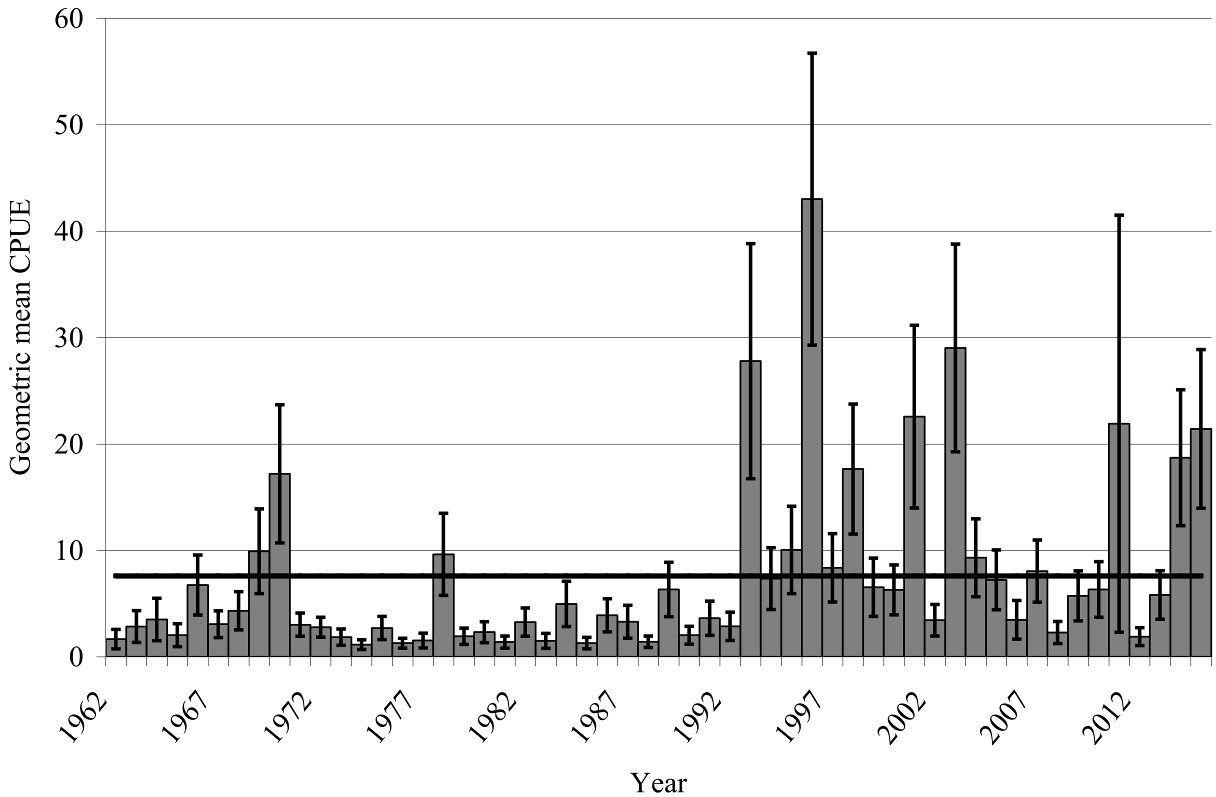


Figure 15. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

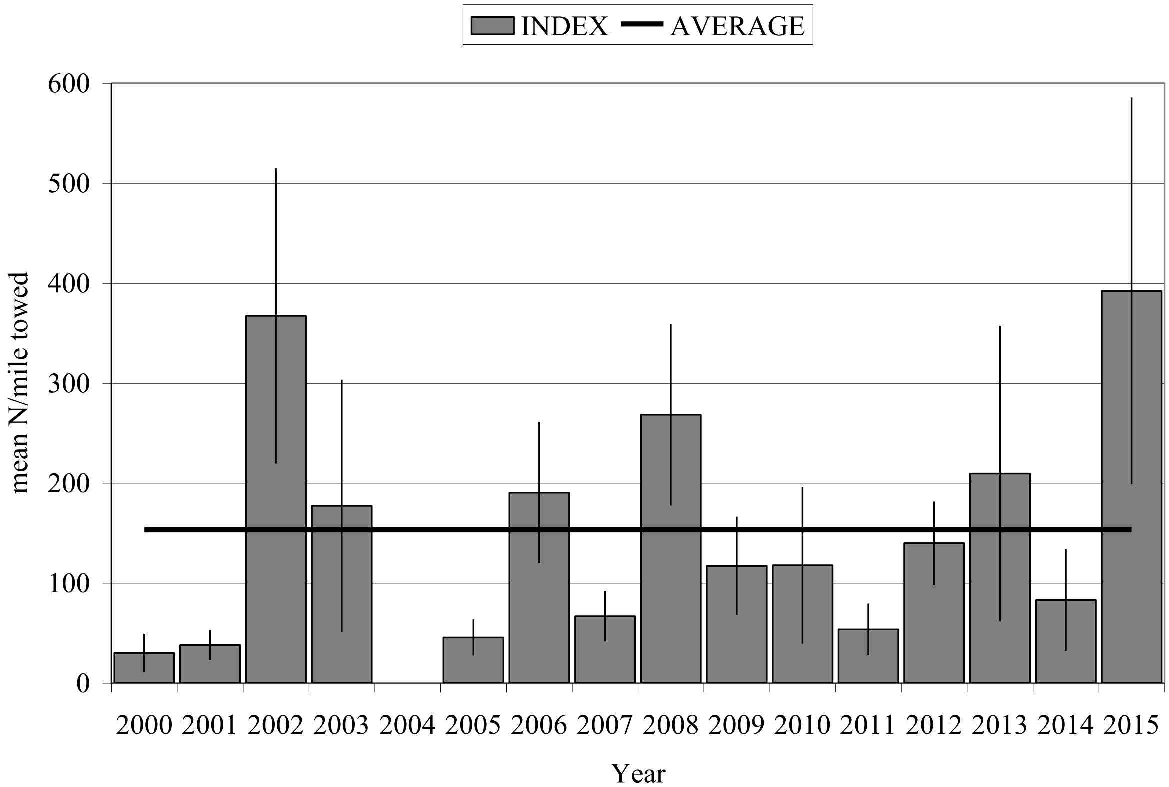


Figure 16. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2015, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

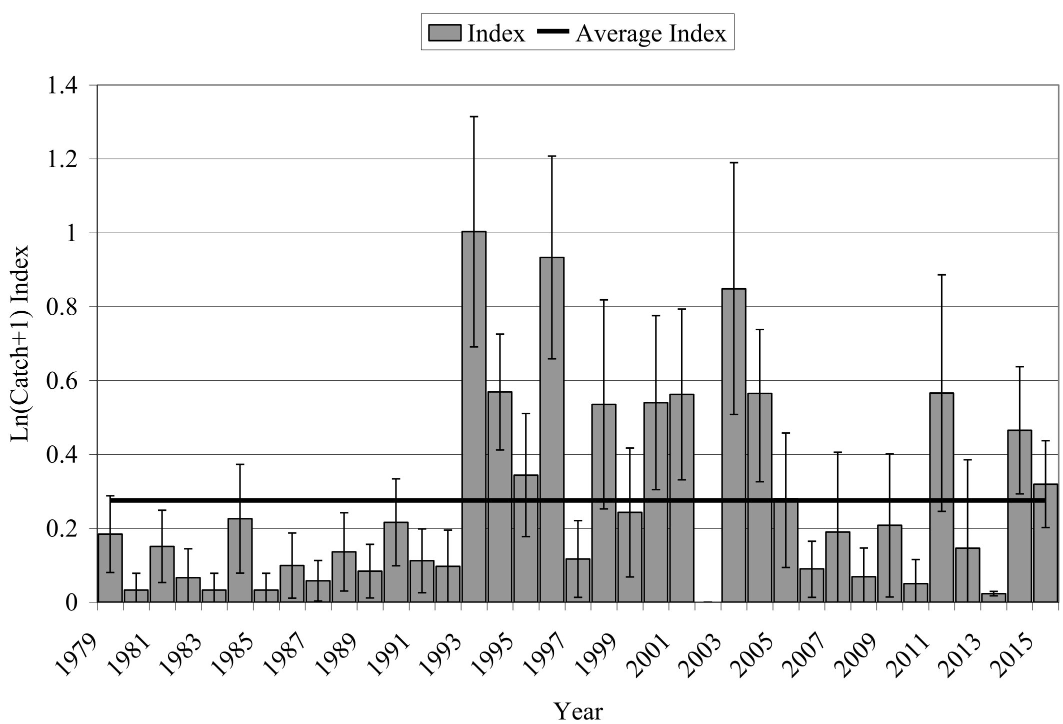


Figure 17. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

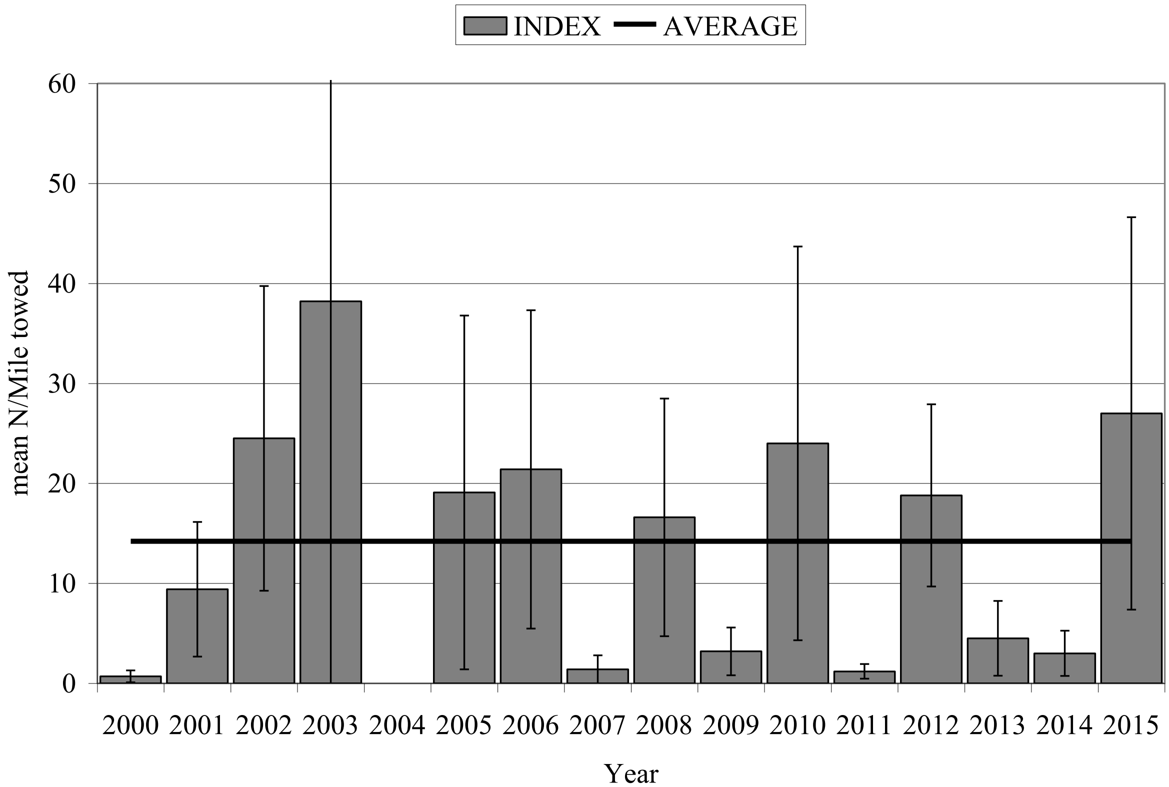


Figure 18. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

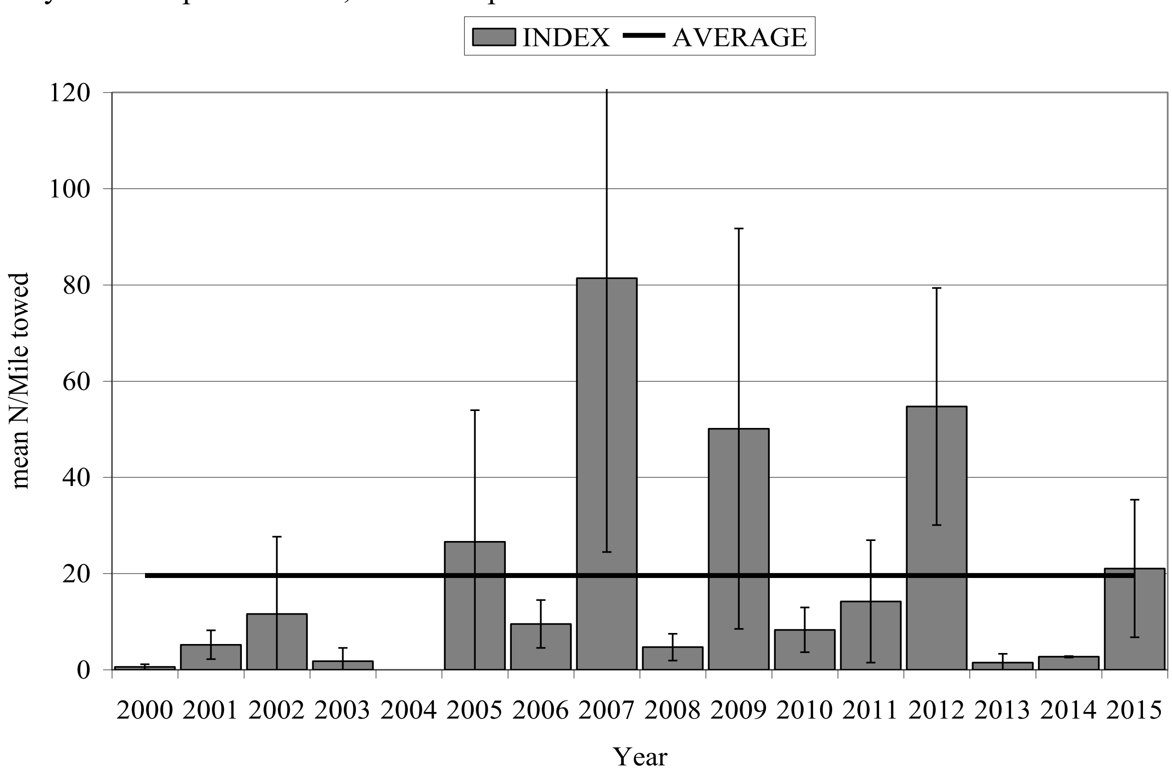


Table 20. White perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2015.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	No. Tows
2000	34.5	227.3	102.0	65.8	24.7	14.8	20.3	2.2	2.2	1.4	495.3	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	367.2	2.9	71.1	28.8	44.5	19.0	36.8	20.5	5.3	12.3	608.4	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	45.5	80.7	22.1	40.3	10.2	3.6	1.2	11.4	1.3	0.6	217.0	43
2006	192.1	63.2	153.2	47.2	35.7	10.2	6.3	6.1	1.5	2.7	518.1	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	268.5	44.7	113.3	84.5	25.7	8.8	3.5	3.8	1.4	1.4	555.7	108
2009	118.5	324.6	13.7	59.4	112.1	95.2	2.3	33.4	7.2	1.4	767.8	90
2010	177.9	138.5	163.4	5.6	52.6	41.7	68.9	5.8	9.5	13.9	678.0	56
2011	53.7	70.5	51.2	68.9	16.9	38.9	21.6	22.9	1.3	4.6	350.5	66
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	392.3	266.6	314.9	576.6	126.0	64.5	67.8	80.9	45.3	48.0	1,982.8	107

Table 21. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2015.

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

Table 22. Yellow perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2015.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	No. Trawls
2000	0.9	1.5	0.2	1.6	0.1	0.3	0.1	0.0	0.0	0.1	4.8	79
2001	9.4	0.6	1.0	0.2	0.6	<0.1	0.0	<0.1	0.0	0.0	12.0	114
2002	24.3	17.3	1.7	3.6	0.3	1.8	0.0	0.2	0.1	0.0	49.3	110
2003	38.3	135.7	422.1	46.3	61.6	4.0	24.8	0.0	2.0	0.0	734.8	20
2004	NOT SAMPLED											
2005	18.8	13.7	<0.1	3.1	0.4	<0.1	<0.1	0.0	<0.1	0.0	36.4	43
2006	23.8	34.3	15.8	0.0	3.3	0.4	0.0	0.4	0.0	0.0	78.0	108
2007	3.6	3.3	8.4	2.4	1.5	0.6	0.1	<0.1	0.0	0.0	20.0	71
2008	17.0	4.1	9.1	8.0	2.1	0.0	0.0	0.0	0.0	0.0	40.3	108
2009	4.3	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	19.1	6.5	2.2	0.1	0.1	0.1	0.0	0.7	0.0	0.0	28.8	107
2013	4.7	9.4	2.7	1.1	0.1	<0.1	<0.1	0.0	0.1	0.0	18.3	86
2014	3.0	0.0	15.5	6.8	0.8	0.0	0.1	0.1	0.1	0.0	26.3	60
2015	27.0	1.2	0.0	16.3	1.8	0.4	0.0	0.0	0.0	0.0	46.6	85

Table 23. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2015.

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

Figure 19. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2015. Effort standardized from 1 March – 95% total catch date. Trendline statistically significant at P<0.001.

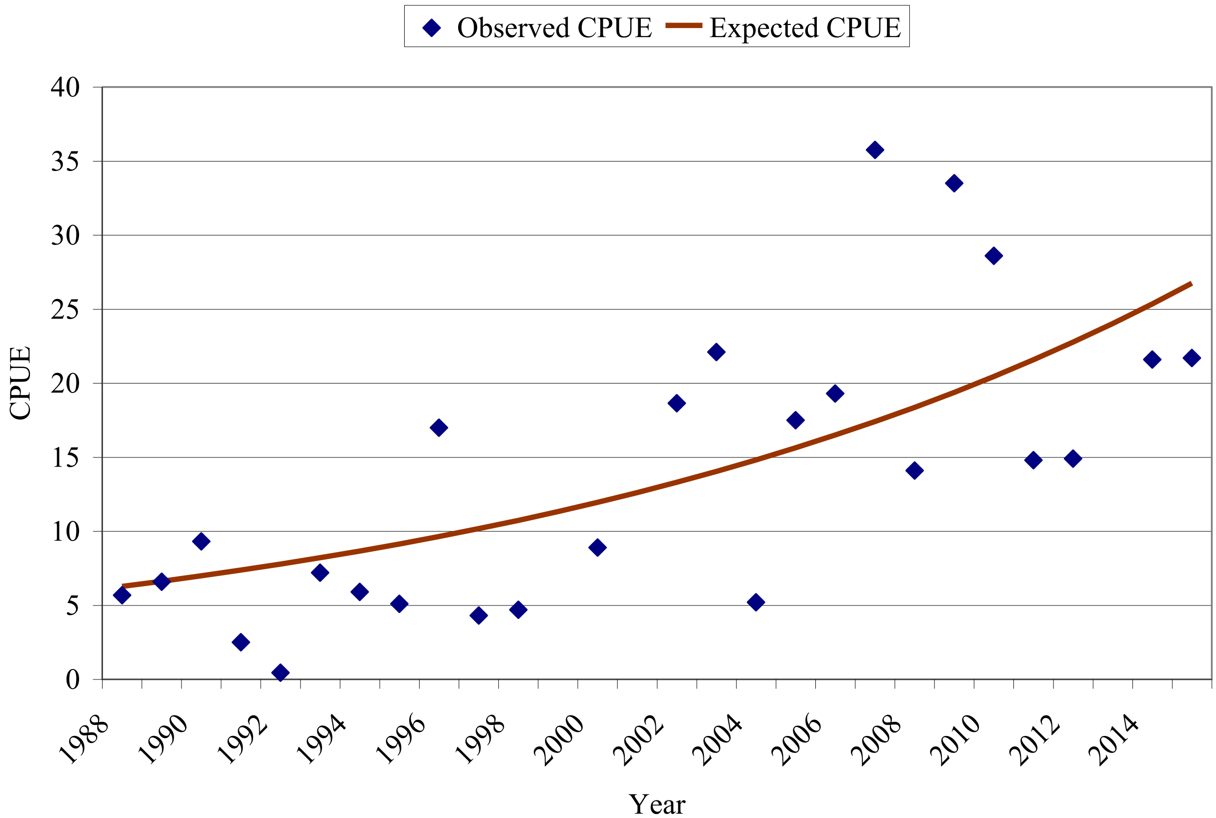


Figure 20. Channel catfish relative abundance (N/mile towed) from the upper Chesapeake Bay winter trawl survey, 2000-2014. Not surveyed in 2004, small sample sizes in 2003 and 2005.

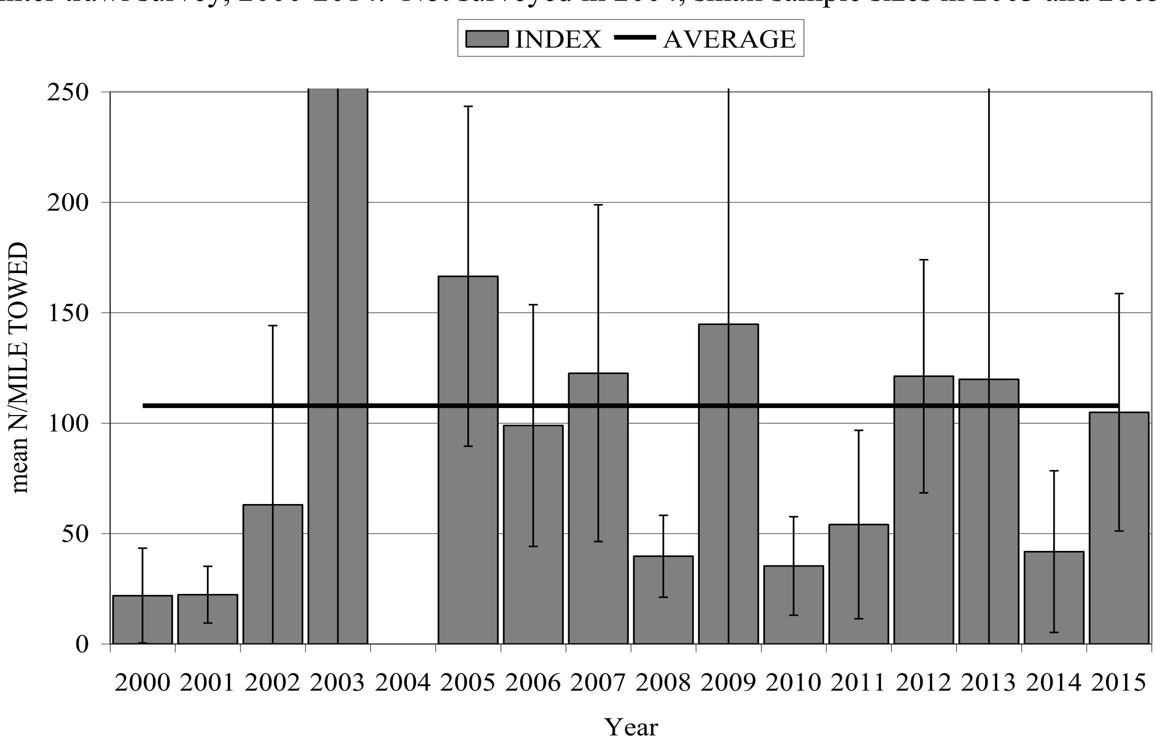


Figure 21. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2015. Horizontal line indicates time series average relative abundance.

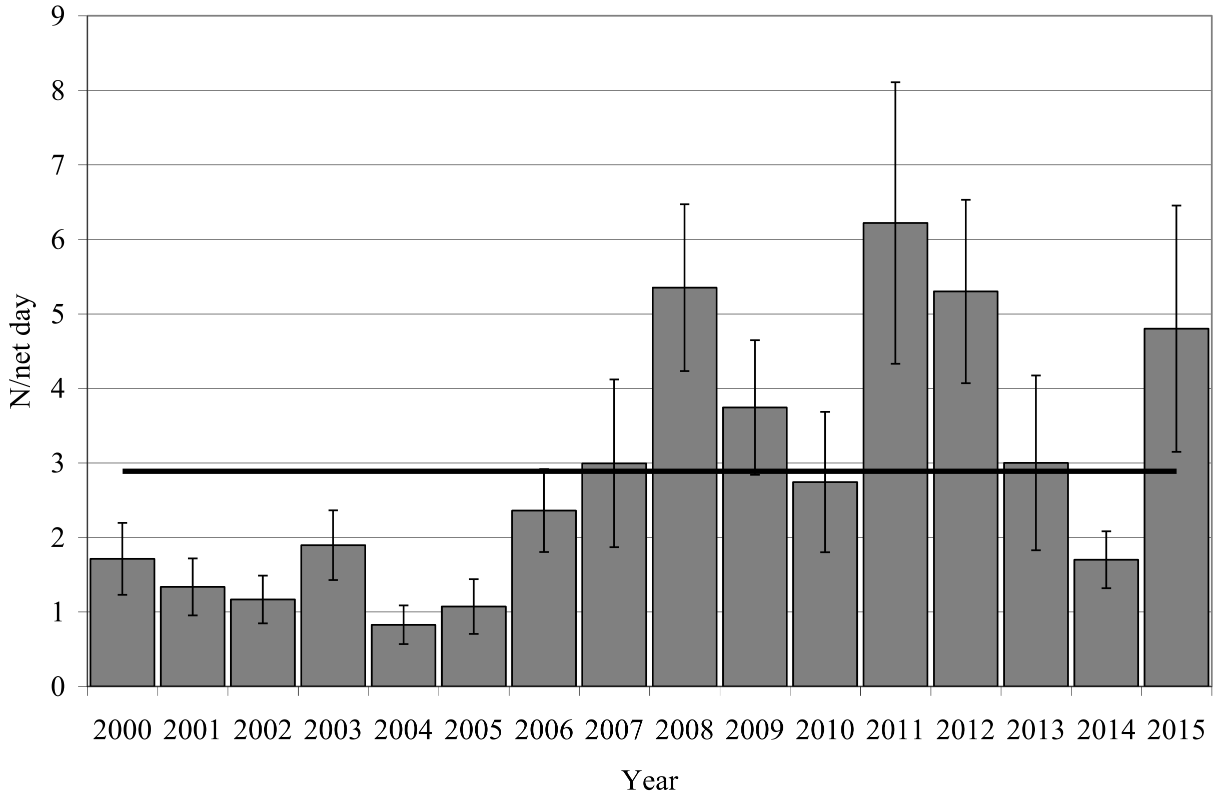
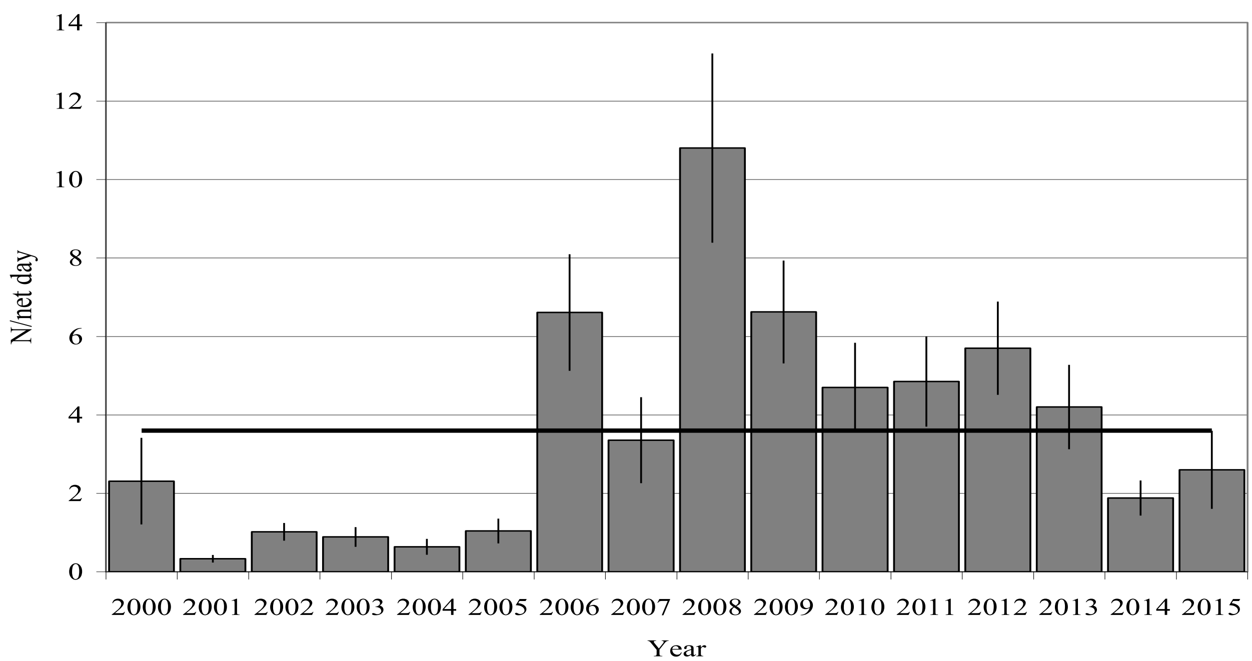


Figure 22. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2015. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF CHANNEL CATFISH IN MARYLAND WITH SPECIAL EMPHASIS ON HEAD-OF-BAY STOCKS

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The objective of Job 2 was to assess channel catfish (*Ictaluras 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 the 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 the Chesapeake Bay. The Marine Recreational Information Program (MRIP) produces estimates of recreational catch with fair precision (National Oceanic and Atmospheric Administration, personal communication, January 10, 2016). Estimated channel catfish recreational harvest (MRIP) averaged 273,857 lbs during 1982

– 2014; for the five year period, 2010 – 2014, average recreational catfish harvest was 571,828 lbs (108% above the long term average). In 2014, channel catfish was the third largest recreational harvest in Maryland (by weight), trailing only striped bass and white perch.

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 lbs, slightly above the previous peak in 1996 (2.41 million lbs). Channel catfish commercial landings (by weight) were second only to Atlantic menhaden during 2014. Areas above the Chesapeake Bay bridges accounted for 50% of the total Maryland commercial harvest in 2014.

Channel catfish populations were last assessed in 2012 (Piavis and Webb 2013). This Job is an update of the 2012 assessment. The 2012 assessment described population dynamics in two systems, the Head-of-Bay (HOB; areas north of the Preston Lane Memorial Bridges), and 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 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 (*Ameiurus 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 and flathead catfish. 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 inverse variance 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 available indices of relative abundance available for modeling purposes. There were three fishery dependent indices (commercial CPUE's 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 fishery independent drift gill net survey, and the bottom trawl survey.

The fishery dependent commercial fyke net index was derived from MD DNR Fisheries Service commercial landings database. Effort data for these gear types were available from 1980 – 1984, 1990, and 1992 – 2014. 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 lbs 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 the 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 the 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 1000-gill net yards × hours.

The fishery independent HOB winter trawl survey provided channel catfish relative abundance for the HOB (Figure 2). Species count data from this survey (2000-2002; 2006 - 2014) were transformed to biomass per tow with the same allometric equation utilized in the drift gill net index formulation. The index was geometric mean channel catfish biomass per tow 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. Two 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 2 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 = 1,000 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:

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

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:

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

and,

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

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

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

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 356 mm TL. Post-recruit white perch were those fish greater than 355 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, January 2016). 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 1,000 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 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, 2016). 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. However, the Potomac index was included as a numbers based index instead of transforming to a biomass index as required by the surplus production model. Data encompassed the time period 1984 – 2015.

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. Baywide recreational landings estimates have varied greatly over the period 1983 – 2014 (Figure 5). A time series low was estimated in 1988, but recreational landings trended upward through 1996, corresponding to the rise in commercial landings. Recreational landings during the period 1997 – 2006 were notably low, but a general rebound occurred during 2007 – 2014. In 2014, an estimated 888,517 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 dome-shaped pattern for much of the assessment time-period. However, landings increased from 0.4 million pounds to more than 2 million pounds over the period 2006 – 2012 (commercial and recreational combined; Figure 6). Since 2012, landings have remained high relative to time series values. The model included three biomass indices, a fishery dependent fyke net index (1980 – 1984, 1990, 1991 – 2014), and two fishery independent indices (the gill net survey, 1985 – 2014; and the winter trawl survey, 2000 – 2014). 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 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 8). The winter trawl survey also validated the increased biomass over the last 4 years of the assessment period (Figure 9), but this index and the gill net index suggested that biomass was at its highest in 2014 whereas the fyke net index suggested some decline.

The model fit the data well. Estimated parameters r, K, and B_0 were 0.58, 10.7 million pounds, and 3.0 million pounds, respectively. Biomass increased from 3.0 million pounds in 1980 to 8.8 million pounds in 1989. Channel catfish biomass then trended lower to 5.2 million pounds in 2000, but nearly doubled to 9.0 million pounds in 2008. The period 2009 – 2014 had biomass estimates ranging from 6.7 million pounds to 8.7 million pounds. The final year biomass estimate (2014) was 6.8 million pounds (Figure 10). Instantaneous fishing mortality (F) peaked from 1996 – 1999, but then fell to low levels during 2004 – 2010. Instantaneous fishing mortality in the final year of the assessment (2014) was estimated to be 0.28 (Figure 10). Over the course of the assessment, F averaged 0.20. Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ *K* or 5.3 million pounds. F_{msy} was estimated as ½ *r* or 0.29. Maximum sustainable yield was estimated *rK*/4, or 1.6 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 surplus biomass and moderate F between 1983 and the mid 1990's. Fishing mortality then rose to unsustainable levels for five years during 1995 − 1999, that is, the $F:F_{msy}$ ratio was greater than 1.0 (Figure 11). 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 1.28 and 0.97, respectively. Based on these point estimates, the HOB channel catfish stock is not overfished and overfishing is not occurring, but may be considered fully exploited.

Bootstrapping provided estimates of uncertainty for this model (Table 1). The bootstrap procedure produced 993 valid trials out of 1,000 attempts (99.3%). The intrinsic rate of increase (*r*) was estimated with moderate precision (CV=31%). Estimates of *K* and B_0 were less precisely estimated with CV's equal to 38% and 44%, 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 25% − 44%. In contrast, the ratio $B:B_{msy}$ was very precisely estimated in all years (CV range = 8% −

19%). Comparisons of the confidence intervals also demonstrate the increased precision of the ratio estimates (Figures 12). Coefficients of variation of annual fishing mortality estimates ranged from 21% − 50%. However, the maximum occurred in the first year, based on the highly variable B_0 estimate. In contrast, the ratio $F:F_{msy}$ was precisely estimated in all years (CV range = 18% − 31%). Comparisons of the confidence intervals also demonstrate the increased precision of the ratio estimates (Figures 13). In the final year of the assessment (2014), there was only a 2.1% chance that channel catfish biomass was below B_{msy}, and a 46% chance that overfishing was occurring (*i.e.*, $F:F_{msy} > 1.0$).

Choptank River Catch-Survey Analysis (CSA)

Total channel catfish removals the from Choptank River, in numbers, was estimated for the assessment time period 1993 – 2014. Commercial and recreational harvest was generally low during 1993 – 2004, ranging from 18,000 – 48,000 fish, except for the nearly 100,000 fish estimated for 1999. After 2004, harvest increased substantially, averaging 131,000 fish from 2005 – 2014 (Figure 14). 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 15). The post-recruit index had a similar pattern, but the higher relative abundance of the recruited fish did not begin until 2008 and ended the time series with the three highest relative abundance values in the last four years of the of the survey (Figure 16).

The CSA model fit the population data very well. Catchability of the survey (q) was estimated as 2.1×10^{-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 for the remainder of the time series (Figure 17). Post-recruit channel catfish abundance varied between 200,000 and 400,000 channel catfish from 1993 – 2007 (Figure 18). After 2007, recruited channel catfish abundance accelerated quite swiftly with the recruited population increasing from an estimated 584,000 fish in 2008 to 1.2 million fish in 2012. Total population abundance (pre-recruit and post-recruit combined) varied between 300,000 – 550,000 channel catfish during 1993 – 2008. Total abundance rose to 1.6 million channel catfish by 2011, and declined to 926,000 by 2015. Over the time-series, total population averaged 673,000 channel catfish and total abundance been above the average since 2008 (Figure 19). Instantaneous fishing mortality (F) was generally low, varying between 0.04 and 0.15 for most of the assessment period (Figure 20). Average F for the entire time series was 0.14 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 determined 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 (1,000 trials; Table 2). Survey catchability (q) was precisely estimated (CV=2%). Coefficients of variation for pre-recruit abundance estimates ranged from 23% – 29% . Coefficients of variation for post-recruit abundance were more variable than the pre-recruit abundances. Coefficients of variation ranged from 15% – 38%.

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 145,0000 pounds (Figure 21). Since 2011, landings increased to a time-series high in 2014 of more than 180,000 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 22). Relative abundance was at or above the 75th percentile in last five year period, 2011 – 2014.

Pocomoke River channel catfish had previously not been investigated due to low or no commercial landings, and therefore, perceived lower availability to recreational fishermen. 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. In the final year of available data (2014), commercial channel catfish landings exceeded 300,000 pounds (Figure 23). 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. The relative abundance index was above the 75th percentile in 3 of the last 4 years of available data (Figure 24).

Patuxent River channel catfish data included commercial fishery landings and a fishery dependent relative abundance. Patuxent River landings have been trendless but generally stable around 80,000 pounds annual since 1999 (Figure 25). 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 – 2002, and again during 2005 -- 2007 (Figure 26). Since 2012, the relative abundance index has trended upwards, hovering around the 75th percentile level.

Potomac River channel catfish landings, as report to Potomac River Fishery Commission (PRFC), had to be adjusted for difference 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 the present. Landings have been below 150,000 pounds since 2003 (Figure 27). The fishery independent Potomac River drift gill net survey indicated that the biomass index was below the 75th percentile since 2005 and has been at or below the median relative abundance in 8 of the last 10 years (Figure 28). No fishery dependent relative abundance indices could be calculated. After 2003, catches became sparse and/or intermittent for various gears.

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. 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. These areas accounted for 59% of total MD commercial channel catfish harvest in 2014, down from 77% in 2011 (Piavis and Webb 2013). Channel catfish populations in Nanticoke, Pocomoke, Patuxent, and Potomac rivers were assessed through qualitative examination of available relative abundance data. These four systems accounted for 28% of the 2014 commercial landings in 2014, up from 14% in 2011.

The HOB surplus production model indicated a period of population increase from 1980 – 1988 followed by a decline through 2000 (estimated as 5.2 million pounds). Since 2000, population biomass peaked again at 9 million pounds in 2008, and averaged 7.1 million pounds over the last 5 year period, 2007 – 2011. The results of the current model, through 2011, closely mimic the previous assessment (Piavis and Webb 2013). For example, the 2011 $B:B_{msy}$ ratio was the same between the 2 models, and the 2011 $F:F_{msy}$ ratio was determined to be 0.86 in the previous assessment, whereas the current model estimated the ratio as 0.90.

Maximum sustainable yield (MSY) was identified as 1.56 million pounds. Total estimated removals never exceeded MSY during the expansion/plateau phase of channel catfish abundance (1980 – 1993). Conversely, total estimated removals exceeded MSY in each year during the period when the population contracted (1994 – 2000). Recently, harvest (commercial and recreational) was above MSY in 2011, 2012 and 2014. The population biomass during 2014 was 28% higher than B_{msy} (B_{msy} = the population biomass that can sustain harvest at MSY), and therefore, not overfished. Bootstrap analysis indicated only a 2% chance that the stock is overfished.

Inspection of the trajectories of F moved opposite that of biomass. As F increased, the population biomass stabilized until F increased beyond F_{msy}, at which point population biomass contracted. Conversely, the period beginning in 2000 had F rates below F_{msy} and population biomass expanded. In the final year of the assessment, the $F:F_{msy}$ ratio was 0.97. $F:F_{msy}$ ratios less than 1.0 indicate that overfishing is not occurring. Similar to the $B:B_{msy}$ ratio, the F ratio is a more robust estimate of the status of F than absolute values (Prager 1994). Bootstrap analysis indicated a 46% chance that overfishing was occurring in HOB during 2014. Given the nearness of the point estimated to 1, and the fact that harvests have generally been above MSY the status of the recreational and commercial fisheries is more appropriately classified as fully exploited.

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, and 2014. Given expected growth rates, the increased biomass in recent years is attributed to the higher juvenile production of the 2004, 2006 and 2008 year-classes (see Project 1 Job 1, Figure 18). The 2011 and 2014 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. 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 compared to the 2012 assessment (Piavis and Webb 2013).

No biological reference points exist to determined overfished or overfishing status, but given that exploitable channel catfish abundance is above the time series average, current F levels seem reasonable. Additionally, total removals and population abundance are distinctly similar, and F has been in a very tight range. Therefore, it appears that the commercial and recreational fisheries are taking essentially a fixed percentage of the surplus population, suggesting that effort has remained reasonably stable. The 2015 pre-recruit index, although not modeled, is well above average. These fish should recruit to the exploitable population by 2017, adding to the exploitable population.

Channel catfish relative abundance trends in Nanticoke, Pocomoke, Patuxent, and Potomac rivers were quite different among the four systems. The two lower eastern shore rivers (Nanticoke and Pocomoke) showed evidence of strong population growth over the last four years. The Potomac River channel catfish population has been below historical levels for quite some time, while the Patuxent River population appears relatively stable at the 75th percentile of relative abundance in 2014 after 7 years under that benchmark.

Nanticoke River and Pocomoke River fishery dependent indices of relative abundance provide the only fishery data to assess the populations. In the case of Nanticoke River, a reasonable fishery has existed over the available time series. The increase in landings and corresponding increase in relative abundance suggest population expansion. However, the case of the Pocomoke River channel catfish landings and fishery dependent relative abundance indices are quite different in that there has not been a fishery of any magnitude over the last 30 years. Given the lack of fishery independent data it is unclear whether the nascent channel catfish fishery in Pocomoke River is due to population expansion, or if a new commercial fishery based on demand was created. The commercial effort during the four years of higher landings has remained relatively stable, arguing for population expansion. Regardless of the underlying reasons for the increased fishery dependent statistics, it appears that both the Nanticoke River and Pocomoke River offer recreational fishermen two productive areas.

Patuxent River channel catfish populations look fairly stable. From 2003 – 2014, landings hovered around 75,000 – 100,000+ pounds for 9 of those 12 years. Notably lower landings occurred in 2009 – 2011, possibly due to lower juvenile production. The relative abundance index was near the 75th percentile of the time series in 2012 and 2014, and if this benchmark is taken as a conservative historical norm, the population appears stable.

Potomac River channel catfish commercial landings experienced a prolonged decline since 1987. Since 2003, the average commercial landings were 75% below the

1987 – 1990 average landings. The fishery independent gill net biomass index indicated population contraction from relatively high levels during 2001 – 2004. Over the last four years (2012 – 2015), the index was below the median and for the 10 year time period, 2006 – 2015, the index was at or below the median in 8 years. Although the gill net survey and the landings are somewhat at odds as to when peak population abundance occurred, both concur that channel catfish population abundance is considerably lower.

Potomac River channel catfish populations may be impacted by the invasive blue catfish (*Ictalurus furcatus)*. Blue catfish have been colonizing Potomac River for at least 20 years, and support a recreational fishery. Commercial fishermen now land more than 500,000 pounds per year from the Potomac River mainstem (PRFC, personal communication). In 2014, the Maryland state record blue catfish was caught in the Potomac drainage, at 84 pounds. Invasive blue catfish may be impacting channel catfish via both direct predation and interspecific competition. All of the four "other areas' investigated appear to have varying degrees of blue catfish colonization. During 2014, commercial fishermen reported harvesting 12,000 and 13,000 pounds of blue catfish from Nanticoke River and Patuxent River, respectively. Maryland DNR along with other governmental and non-governmental agencies have been collecting blue catfish diet data and other baseline data to document the impact of invasive catfish in Maryland. Upon completion, these studies will provide a more synoptic view of the impacts on channel catfish.

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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	0.584	0.617	0.598	0.194	-2.3	0.314
K	10,661,493	11,427,571	10,451,831	4,290,057	2.0	0.375
B_0	2,969,019	3,178,045	2,886,028	1,390,913	2.9	0.438
B_{1981}	3,634,039	3,859,960	3,543,091	1,544,080	2.6	0.400
B_{1982}	4,547,718	4,797,645	4,453,773	1,715,761	2.1	0.358
B_{1983}	5,519,909	5,784,846	5,419,073	1,858,334	1.9	0.321
B_{1984}	6,345,262	6,586,867	6,195,847	1,926,673	2.4	0.293
B_{1985}	7,147,804	7,334,608	6,943,135	1,968,086	2.9	0.268
B_{1986}	7,540,083	7,661,948	7,296,909	2,014,770	3.3	0.263
B_{1987}	7,938,702	8,026,177	7,634,250	2,064,521	4.0	0.257
B_{1988}	8,407,622	8,482,690	8,108,603	2,123,777	3.7	0.250
B_{1989}	8,785,541	8,867,436	8,510,820	2,203,994	3.2	0.249
B_{1990}	8,266,457	8,377,953	8,025,991	2,300,668	3.0	0.275
B_{1991}	7,896,039	8,065,655	7,678,212	2,333,560	2.8	0.289
B_{1992}	8,007,218	8,225,128	7,809,270	2,348,475	2.5	0.286
B_{1993}	7,885,180	8,135,936	7,698,736	2,376,514	2.4	0.292
B_{1994}	8,243,068	8,523,920	8,072,524	2,399,004	2.1	0.281
B_{1995}	7,530,813	7,827,343	7,362,909	2,449,320	2.3	0.313
B_{1996}	6,897,696	7,228,626	6,750,276	2,451,728	2.2	0.339
B_{1997}	5,928,140	6,287,373	5,794,431	2,442,357	2.3	0.388
B_{1998}	5,880,436	6,260,706	5,744,883	2,446,854	2.4	0.391
B_{1999}	5,519,975	5,910,971	5,393,755	2,445,919	2.3	0.414
B_{2000}	5,170,257	5,565,364	5,057,008	2,462,817	2.2	0.443
B_{2001}	5,676,156	6,066,412	5,562,403	2,501,097	2.0	0.412
B_{2002}	5,821,440	6,186,596	5,681,991	2,505,760	2.5	0.405
B_{2003}	6,443,393	6,775,939	6,259,446	2,513,539	2.9	0.371
B_{2004}	6,861,734	7,143,681	6,602,377	2,501,869	3.9	0.350
B_{2005}	7,392,079	7,628,156	7,112,469	2,492,448	3.9	0.327
B_{2006}	8,302,555	8,499,258	7,984,705	2,491,620	4.0	0.293
B_{2007}	8,640,272	8,802,716	8,312,828	2,532,872	3.9	0.288
B_{2008}	8,957,735	9,135,194	8,629,454	2,584,769	3.8	0.283
B_{2009}	8,685,452	8,897,267	8,403,664	2,658,016	3.4	0.299
B_{2010}	8,739,532	9,006,734	8,475,963	2,693,763	3.1	0.299
B_{2011}	8,273,765	8,584,945	8,033,375	2,739,594	3.0	0.319
B_{2012}	7,439,363	7,797,105	7,223,077	2,748,911	3.0	0.353
B_{2013}	6,704,767	7,102,158	6,511,682	2,728,329	3.0	0.384
B_{2014}	6,842,760	7,268,229	6,693,329	2,706,498	2.2	0.372

Table 1. (Continued)

Parameter/Year	Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
F_{1980}	0.220	0.251	0.227	0.128	-3.1	0.508
F_{1981}	0.143	0.156	0.147	0.062	-2.7	0.398
F_{1982}	0.129	0.136	0.132	0.044	-2.2	0.325
F_{1983}	0.142	0.147	0.144	0.040	-2.0	0.275
F_{1984}	0.116	0.120	0.119	0.029	-2.5	0.240
F_{1985}	0.148	0.153	0.153	0.034	-3.1	0.223
F_{1986}	0.126	0.131	0.130	0.029	-3.4	0.219
F_{1987}	0.094	0.098	0.098	0.021	-4.0	0.214
F_{1988}	0.082	0.085	0.085	0.018	-3.7	0.212
F_{1989}	0.177	0.185	0.183	0.043	-3.4	0.230
F_{1990}	0.194	0.205	0.200	0.056	-3.2	0.272
F_{1991}	0.148	0.156	0.152	0.042	-3.0	0.270
F_{1992}	0.175	0.183	0.180	0.048	-2.7	0.262
F_{1993}	0.113	0.117	0.116	0.030	-2.5	0.258
F_{1994}	0.247	0.257	0.253	0.068	-2.3	0.264
F_{1995}	0.295	0.313	0.303	0.100	-2.6	0.321
F_{1996}	0.426	0.461	0.437	0.181	-2.7	0.392
F_{1997}	0.311	0.338	0.319	0.135	-2.6	0.399
F_{1998}	0.390	0.426	0.402	0.172	-2.8	0.404
F_{1999}	0.423	0.468	0.435	0.204	-2.8	0.435
F_{2000}	0.227	0.247	0.232	0.097	-2.5	0.393
F_{2001}	0.284	0.307	0.291	0.115	-2.3	0.374
F_{2002}	0.172	0.184	0.177	0.063	-2.6	0.343
F_{2003}	0.182	0.192	0.187	0.060	-3.1	0.313
F_{2004}	0.140	0.148	0.146	0.043	-4.1	0.288
F_{2005}	0.057	0.060	0.060	0.015	-3.9	0.255
F_{2006}	0.093	0.097	0.097	0.022	-4.0	0.233
F_{2007}	0.077	0.080	0.080	0.019	-3.9	0.235
F_{2008}	0.132	0.138	0.137	0.033	-3.9	0.241
F_{2009}	0.108	0.113	0.111	0.029	-3.4	0.260
F_{2010}	0.173	0.181	0.179	0.048	-3.3	0.265
F_{2011}	0.263	0.279	0.273	0.085	-3.3	0.306
F_{2012}	0.322	0.346	0.333	0.123	-3.4	0.354
F_{2013}	0.218	0.233	0.226	0.080	-3.2	0.345
F_{2014}	0.284	0.299	0.291	0.098	-2.5	0.328

Table 1. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
$(B/B_{MSY})_{1980}$	0.557	0.547	0.540	0.098	3.2	0.179
$(B/B_{MSY})_{1981}$	0.682	0.675	0.666	0.120	2.4	0.178
$(B/B_{MSY})_{1982}$	0.853	0.853	0.847	0.157	0.7	0.184
$(B/B_{MSY})_{1983}$	1.035	1.043	1.044	0.201	-0.8	0.193
$(B/B_{MSY})_{1984}$	1.190	1.197	1.204	0.227	-1.2	0.190
$(B/B_{MSY})_{1985}$	1.341	1.337	1.362	0.238	-1.6	0.178
$(B/B_{MSY})_{1986}$	1.414	1.394	1.435	0.224	-1.4	0.160
$(B/B_{MSY})_{1987}$	1.489	1.459	1.508	0.215	-1.3	0.147
$(B/B_{MSY})_{1988}$	1.577	1.540	1.596	0.208	-1.2	0.135
$(B/B_{MSY})_{1989}$	1.648	1.606	1.664	0.195	-0.9	0.122
$(B/B_{MSY})_{1990}$	1.551	1.504	1.545	0.157	0.3	0.104
$(B/B_{MSY})_{1991}$	1.481	1.443	1.470	0.143	0.8	0.099
$(B/B_{MSY})_{1992}$	1.502	1.473	1.500	0.144	0.1	0.098
$(B/B_{MSY})_{1993}$	1.479	1.454	1.475	0.137	0.3	0.094
$(B/B_{MSY})_{1994}$	1.546	1.527	1.552	0.144	-0.4	0.094
$(B/B_{MSY})_{1995}$	1.413	1.390	1.401	0.120	0.8	0.086
$(B/B_{MSY})_{1996}$	1.294	1.277	1.277	0.116	1.3	0.091
$(B/B_{MSY})_{1997}$	1.112	1.099	1.090	0.125	2.0	0.114
$(B/B_{MSY})_{1998}$	1.103	1.096	1.087	0.139	1.5	0.126
$(B/B_{MSY})_{1999}$	1.035	1.032	1.022	0.154	1.3	0.149
$(B/B_{MSY})_{2000}$	0.970	0.968	0.957	0.173	1.4	0.179
$(B/B_{MSY})_{2001}$	1.065	1.066	1.055	0.194	0.9	0.182
$(B/B_{MSY})_{2002}$	1.092	1.091	1.088	0.206	0.3	0.188
$(B/B_{MSY})_{2003}$	1.209	1.206	1.214	0.221	-0.5	0.183
$(B/B_{MSY})_{2004}$	1.287	1.277	1.292	0.220	-0.3	0.172
$(B/B_{MSY})_{2005}$	1.387	1.369	1.395	0.219	-0.6	0.160
$(B/B_{MSY})_{2006}$	1.557	1.533	1.570	0.222	-0.8	0.145
$(B/B_{MSY})_{2007}$	1.621	1.584	1.632	0.195	-0.7	0.123
$(B/B_{MSY})_{2008}$	1.680	1.641	1.689	0.179	-0.5	0.109
$(B/B_{MSY})_{2009}$	1.629	1.589	1.631	0.149	-0.1	0.094
$(B/B_{MSY})_{2010}$	1.639	1.608	1.643	0.140	-0.2	0.087
$(B/B_{MSY})_{2011}$	1.552	1.524	1.542	0.121	0.6	0.079
$(B/B_{MSY})_{2012}$	1.396	1.373	1.376	0.111	1.4	0.081
$(B/B_{MSY})_{2013}$	1.258	1.242	1.238	0.115	1.6	0.093
$(B/B_{MSY})_{2014}$	1.284	1.277	1.277	0.121	0.5	0.095

Table 1. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	Bias[1]	C.V.
$(F/F_{MSY})_{1980}$	0.753	0.796	0.788	0.201	-4.5	0.252
$(F/F_{MSY})_{1981}$	0.491	0.510	0.502	0.124	-2.3	0.243
$(F/F_{MSY})_{1982}$	0.442	0.456	0.446	0.119	-0.9	0.261
$(F/F_{MSY})_{1983}$	0.485	0.500	0.481	0.143	0.9	0.286
$(F/F_{MSY})_{1984}$	0.399	0.412	0.391	0.124	1.9	0.302
$(F/F_{MSY})_{1985}$	0.507	0.528	0.497	0.161	2.0	0.306
$(F/F_{MSY})_{1986}$	0.430	0.450	0.423	0.133	1.8	0.296
$(F/F_{MSY})_{1987}$	0.323	0.338	0.318	0.096	1.8	0.285
$(F/F_{MSY})_{1988}$	0.280	0.292	0.277	0.079	1.3	0.271
$(F/F_{MSY})_{1989}$	0.605	0.630	0.601	0.157	0.5	0.249
$(F/F_{MSY})_{1990}$	0.663	0.690	0.670	0.152	-1.1	0.221
$(F/F_{MSY})_{1991}$	0.506	0.523	0.512	0.110	-1.1	0.211
$(F/F_{MSY})_{1992}$	0.600	0.615	0.603	0.128	-0.6	0.208
$(F/F_{MSY})_{1993}$	0.386	0.394	0.388	0.080	-0.3	0.202
$(F/F_{MSY})_{1994}$	0.846	0.860	0.848	0.169	-0.2	0.197
$(F/F_{MSY})_{1995}$	1.011	1.032	1.028	0.189	-1.7	0.183
$(F/F_{MSY})_{1996}$	1.458	1.502	1.512	0.292	-3.6	0.194
$(F/F_{MSY})_{1997}$	1.065	1.098	1.103	0.228	-3.4	0.208
$(F/F_{MSY})_{1998}$	1.337	1.384	1.379	0.318	-3.0	0.230
$(F/F_{MSY})_{1999}$	1.449	1.519	1.495	0.401	-3.0	0.264
$(F/F_{MSY})_{2000}$	0.777	0.811	0.793	0.222	-2.0	0.274
$(F/F_{MSY})_{2001}$	0.974	1.020	0.988	0.301	-1.4	0.295
$(F/F_{MSY})_{2002}$	0.590	0.618	0.592	0.187	-0.3	0.303
$(F/F_{MSY})_{2003}$	0.622	0.652	0.619	0.203	0.6	0.311
$(F/F_{MSY})_{2004}$	0.480	0.504	0.478	0.157	0.5	0.311
$(F/F_{MSY})_{2005}$	0.197	0.206	0.194	0.062	1.3	0.303
$(F/F_{MSY})_{2006}$	0.317	0.331	0.312	0.096	1.6	0.292
$(F/F_{MSY})_{2007}$	0.263	0.274	0.259	0.073	1.5	0.266
$(F/F_{MSY})_{2008}$	0.452	0.468	0.448	0.114	0.9	0.243
$(F/F_{MSY})_{2009}$	0.368	0.379	0.368	0.083	0.0	0.218
$(F/F_{MSY})_{2010}$	0.591	0.604	0.592	0.123	-0.1	0.203
$(F/F_{MSY})_{2011}$	0.902	0.922	0.913	0.172	-1.2	0.187
$(F/F_{MSY})_{2012}$	1.103	1.129	1.132	0.210	-2.6	0.186
$(F/F_{MSY})_{2013}$	0.748	0.762	0.765	0.145	-2.2	0.191
$(F/F_{MSY})_{2014}$	0.972	0.985	0.986	0.198	-1.4	0.201

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

Estimate/Parameter	Estimate	Mean	Median	CV	Bias1
q	2.10E-06	2.13E-06	2.13E-06	0.015	-1.1
Recruit N 1993	190,708	184,372	173,486	0.382	9.9
Recruit N 1994	214,796	211,619	206,678	0.275	3.9
Recruit N 1995	393,645	381,836	375,625	0.171	4.8
Recruit N 1996	355,002	345,640	342,519	0.157	3.6
Recruit N 1997	320,564	313,891	311,183	0.148	3.0
Recruit N 1998	259,475	254,352	252,199	0.151	2.9
Recruit N 1999	203,699	200,300	198,557	0.159	2.6
Recruit N 2000	154,941	151,301	149,219	0.217	3.8
Recruit N 2001	246,486	242,709	238,694	0.187	3.3
Recruit N 2002	242,693	239,995	237,413	0.165	2.2
Recruit N 2003	213,620	211,775	209,066	0.161	2.2
Recruit N 2004	271,791	270,092	264,949	0.178	2.6
Recruit N 2005	237,431	236,125	231,875	0.176	2.4
Recruit N 2006	263,070	261,898	257,344	0.219	2.2
Recruit N 2007	320,218	318,879	311,073	0.232	2.9
Recruit N 2008	584,107	576,063	558,914	0.211	4.5
Recruit N 2009	836,289	818,839	803,883	0.196	4.0
Recruit N 2010	972,809	957,803	947,708	0.174	2.6
Recruit N 2011	931,019	917,174	906,703	0.166	2.7
Recruit N 2012	1,155,195	1,144,384	1,134,561	0.165	1.8
Recruit N 2013	937,065	930,972	922,908	0.169	1.5
Recruit N 2014	696,738	693,015	688,212	0.186	1.2
Recruit N 2015	555,970	555,929	552,603	0.194	0.6
Pre-Recruit N 1993	93,587	96,043	93,100	0.269	0.5
Pre-Recruit N 1994	287,180	275,932	268,112	0.252	7.1
Pre-Recruit N 1995	60,146	60,521	59,020	0.238	1.9
Pre-Recruit N 1996	72,828	74,040	71,158	0.261	2.3
Pre-Recruit N 1997	19,227	19,642	19,285	0.231	-0.3
Pre-Recruit N 1998	33,459	34,430	33,488	0.238	-0.1
Pre-Recruit N 1999	95,104	94,056	90,112	0.273	5.5
Pre-Recruit N 2000	165,469	164,496	157,639	0.282	5.0
Pre-Recruit N 2001	61,819	62,300	60,723	0.256	1.8
Pre-Recruit N 2002	48,035	48,480	47,336	0.246	1.5
Pre-Recruit N 2003	170,850	170,618	160,456	0.283	6.5
Pre-Recruit N 2004	58,410	58,514	57,217	0.244	2.1
Pre-Recruit N 2005	211,253	211,127	199,862	0.277	5.7
Pre-Recruit N 2006	254,614	254,151	242,230	0.285	5.1
Pre-Recruit N 2007	472,328	463,842	442,190	0.286	6.8
Pre-Recruit N 2008	599,629	586,359	564,446	0.272	6.2
Pre-Recruit N 2009	521,976	521,098	501,468	0.265	4.1
Pre-Recruit N 2010	347,888	345,984	334,298	0.260	4.1
Pre-Recruit N 2011	666,116	666,757	634,834	0.282	4.9
Pre-Recruit N 2012	137,258	140,627	137,041	0.234	0.2
Pre-Recruit N 2013	58,297	59,842	58,399	0.230	-0.2
Pre-Recruit N 2014	107,801	111,474	108,468	0.242	-0.6

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

Figure 1. Head-of-Bay and Potomac River fishery independent drift gill net sampling locations, 1985 -- 2015.

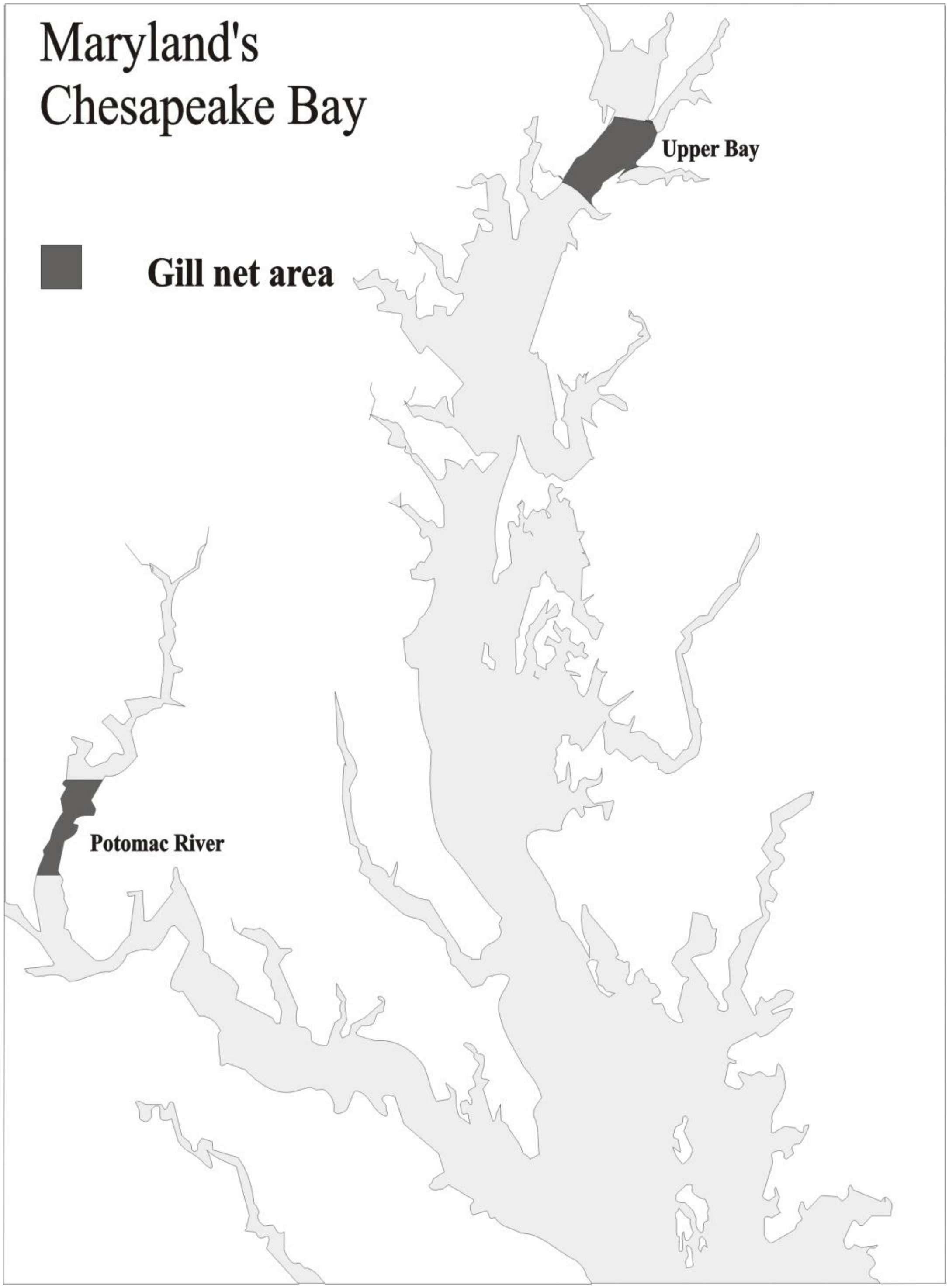


Figure 2. Head-of-Bay winter trawl sites, 1999 -- 2015 (triangles=main bay sites, squares=Elk River sites, circles=Sassafras River sites).

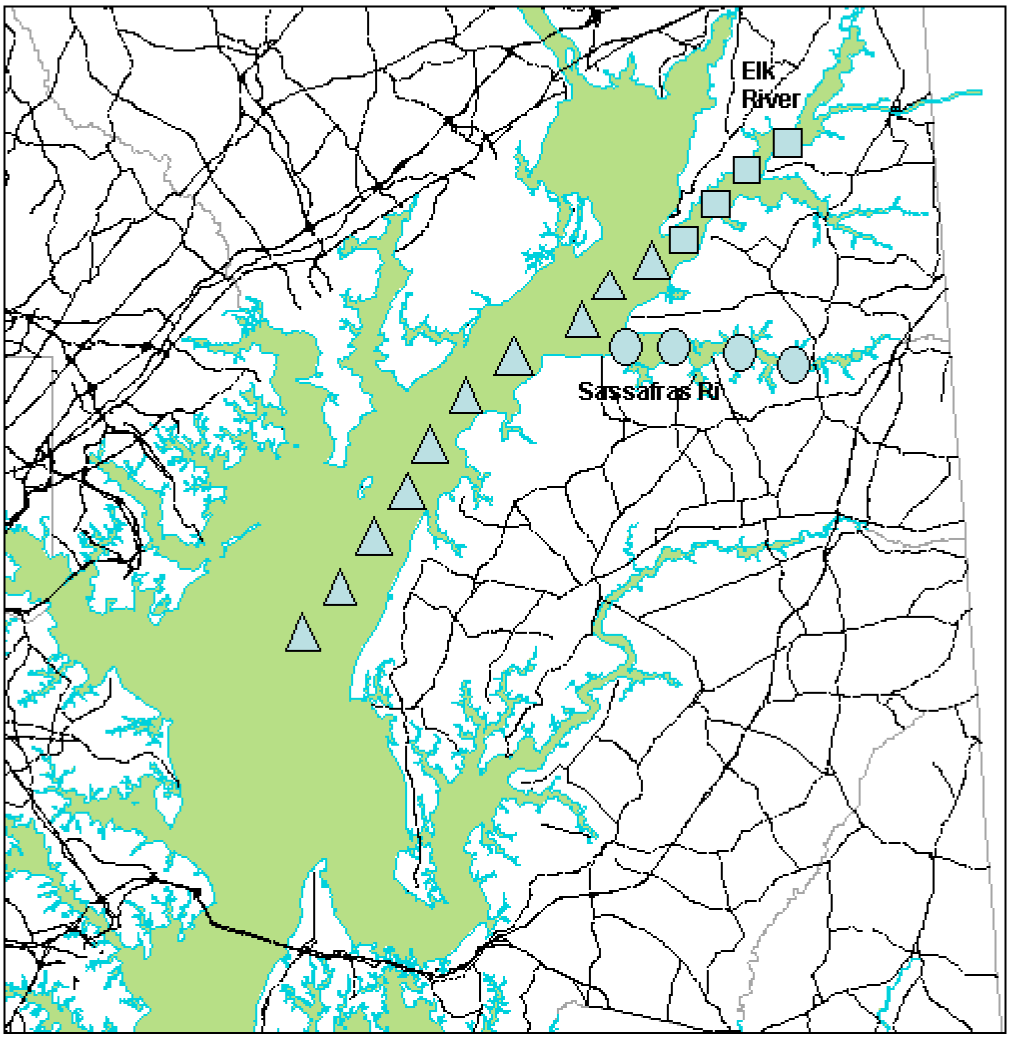


Figure 3. Choptank River fyke net locations, 2015. Circles indicate sites.

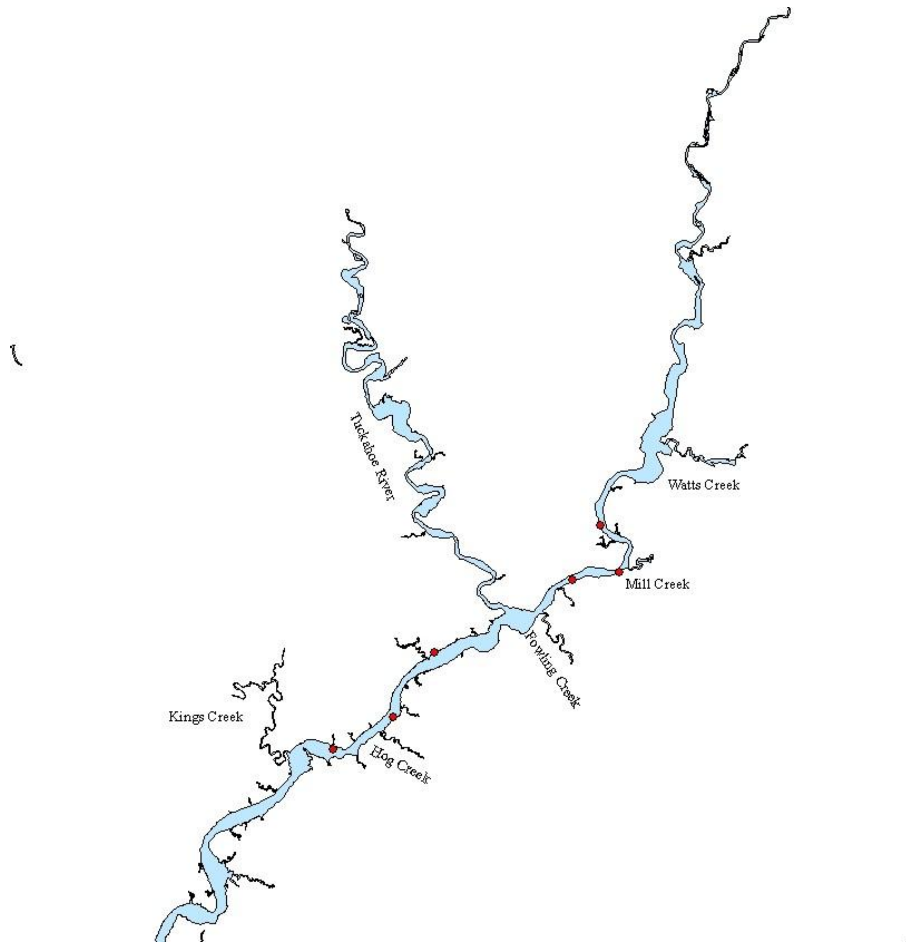


Figure 4. Adjusted Maryland commercial channel catfish landings, 1929 – 2014.

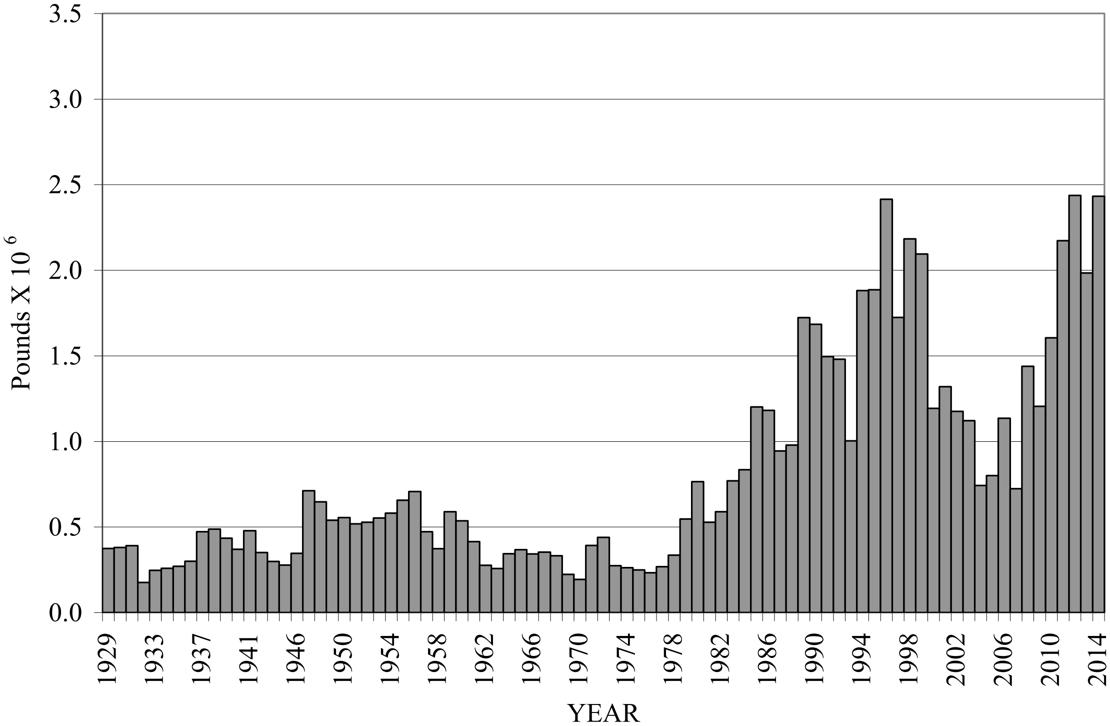


Figure 5. Estimated channel catfish landings from the recreational fishery, 1983 – 2014. Error bars = 1 standard error.

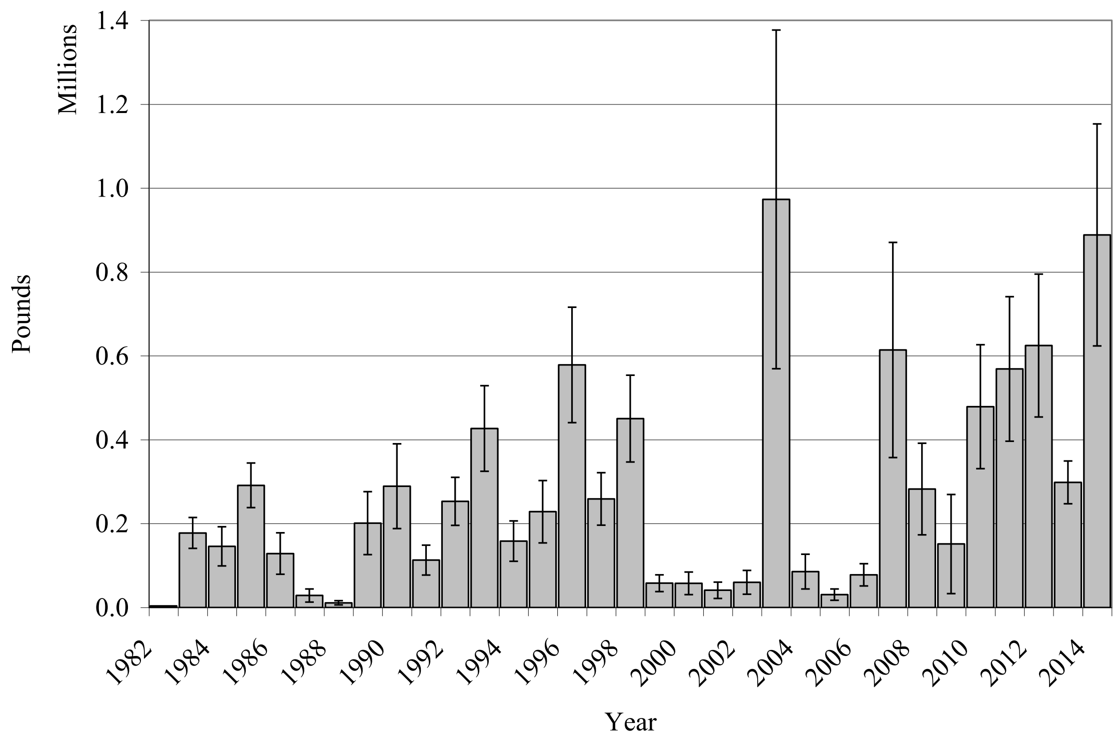


Figure 6. Head-of Bay channel catfish removals from commercial and recreational fisheries, 1980 – 2014.

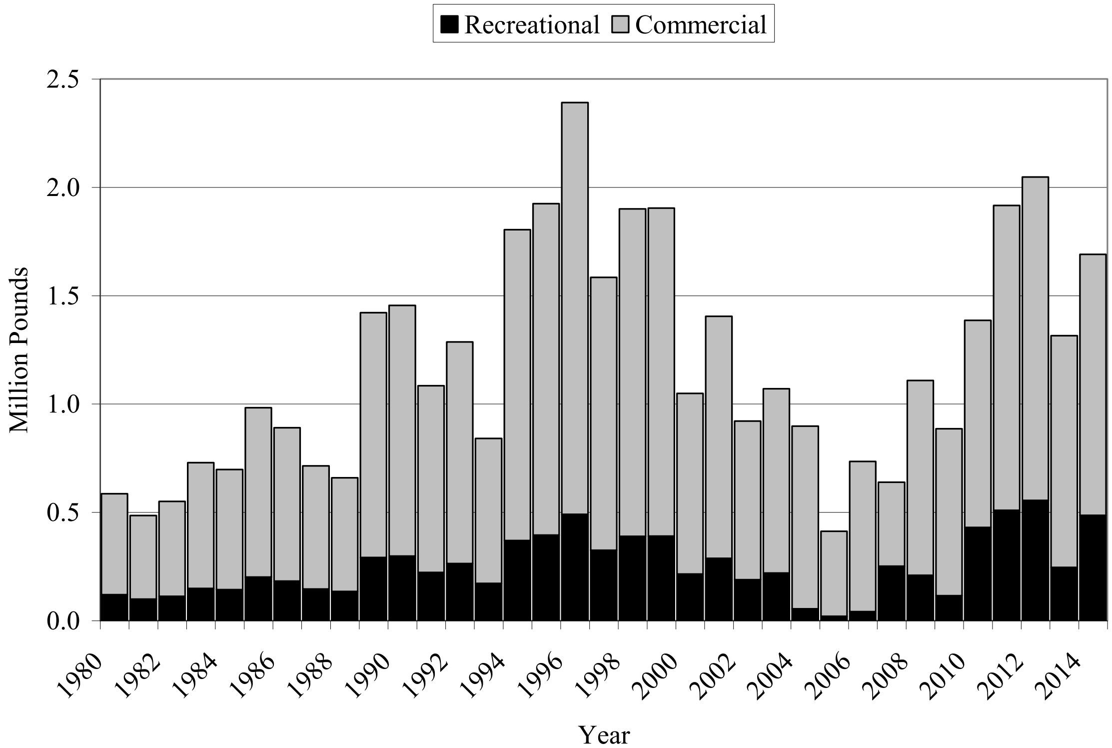


Figure 7. Observed and expected HOB commercial fyke net index, 1980 – 2014.

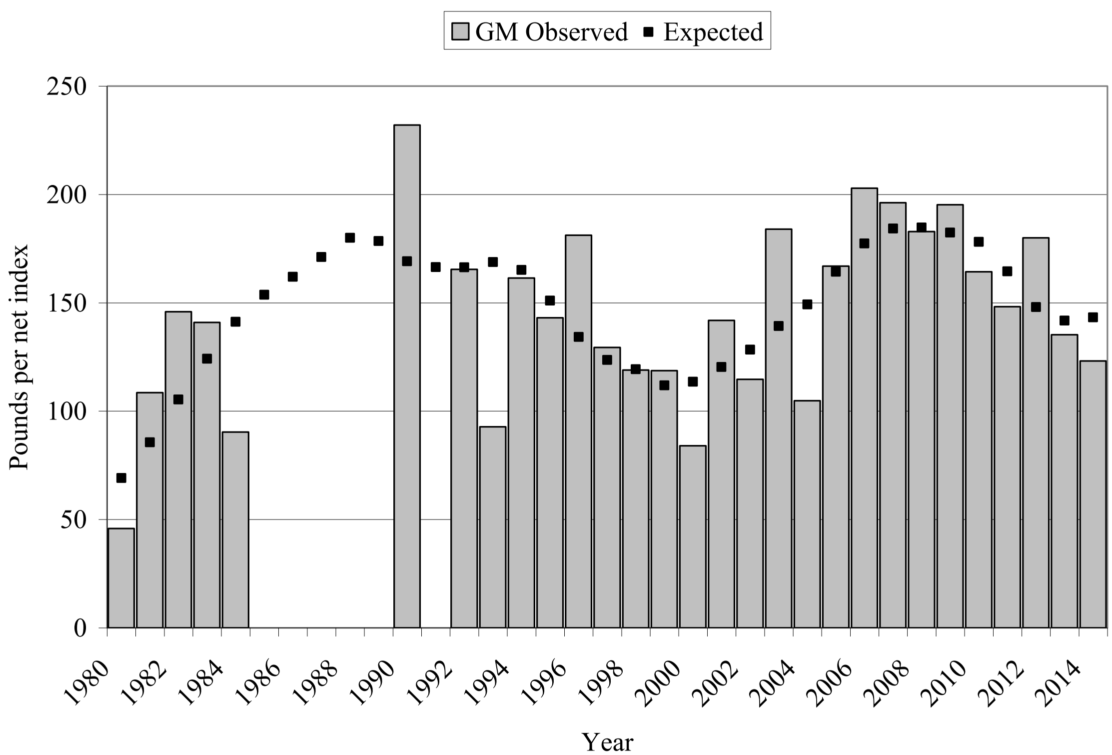


Figure 8. Observed and expected biomass index from HOB gill net survey, 1985 – 2014.

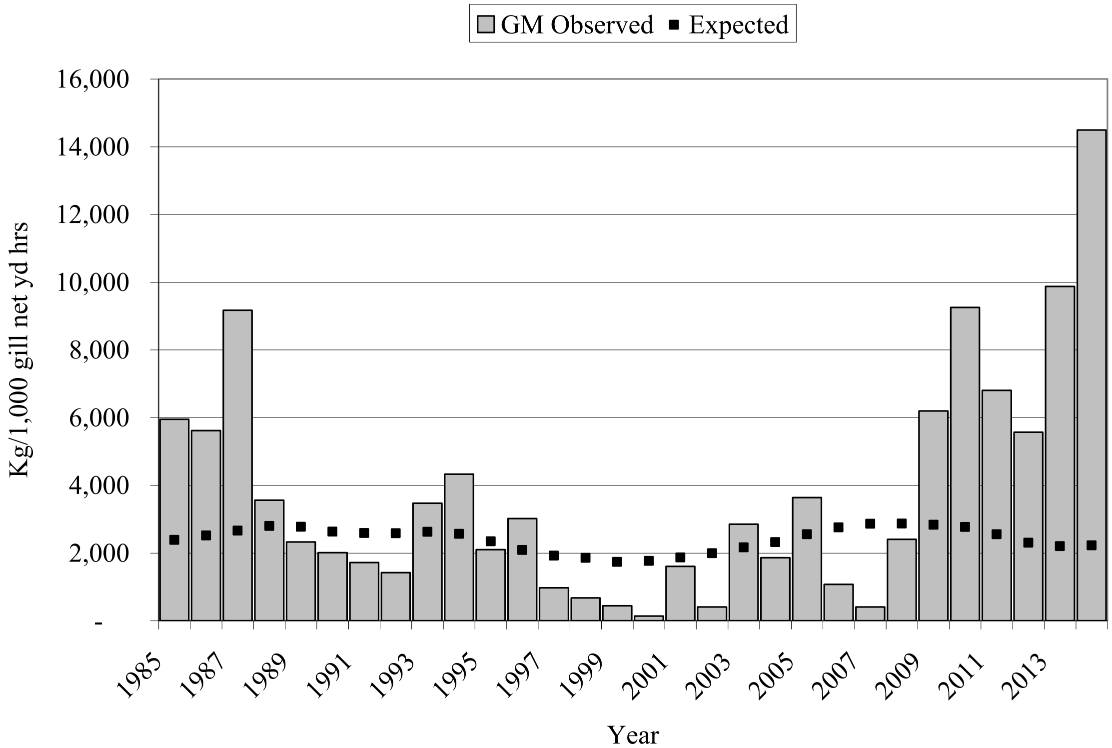


Figure 9. Observed and expected channel catfish biomass index from upper Bay winter trawl survey, 2000 – 2002 and 2006 – 2014.

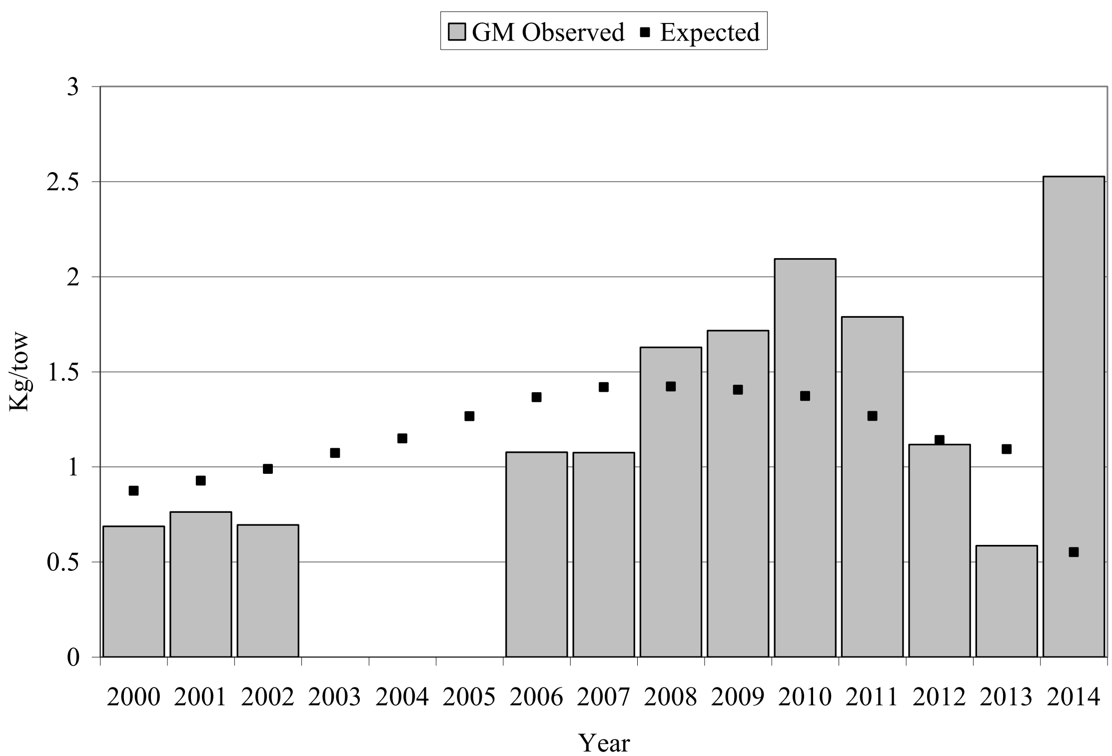


Figure 10. Biomass and fishing mortality estimates from Head-of-Bay channel catfish surplus production model.

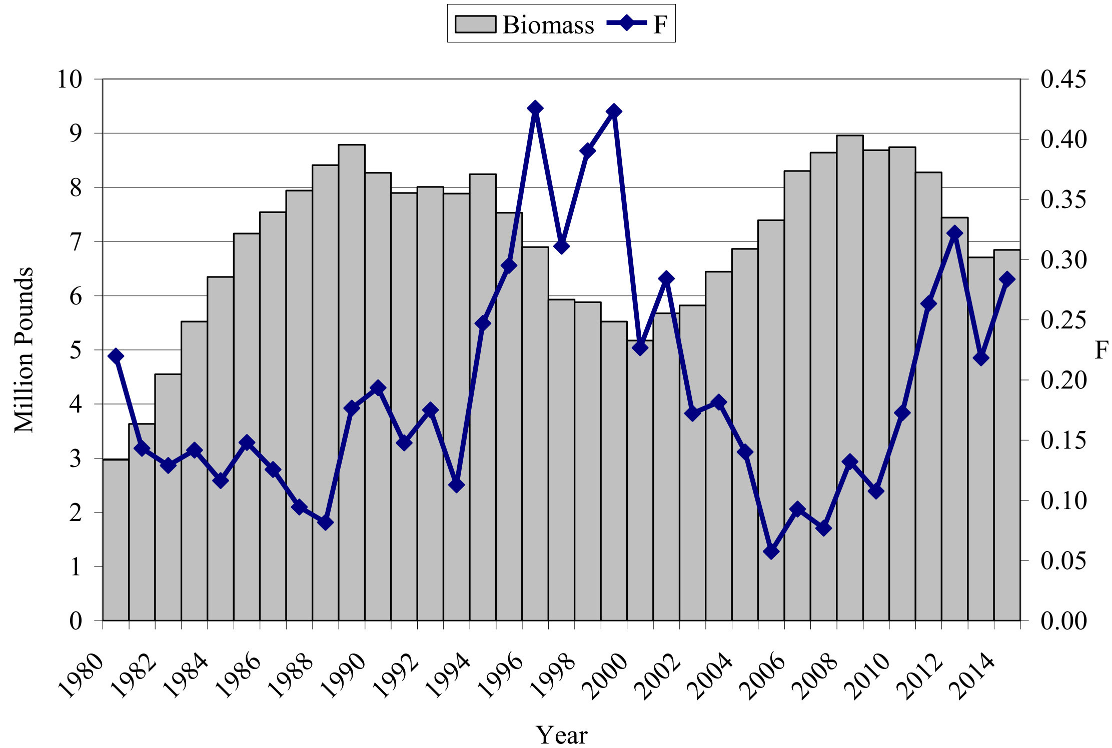


Figure 11. Biomass and fishing mortality ratios from Head-of-Bay channel catfish surplus production model.

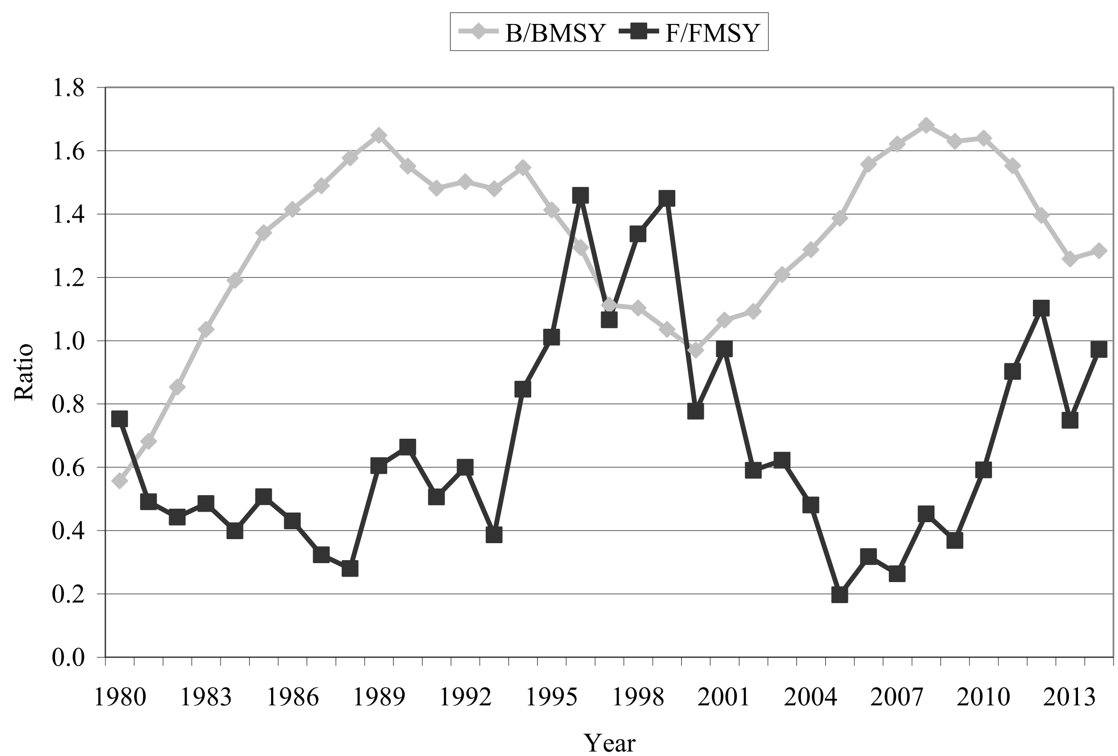


Figure 12. Biomass ratio and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

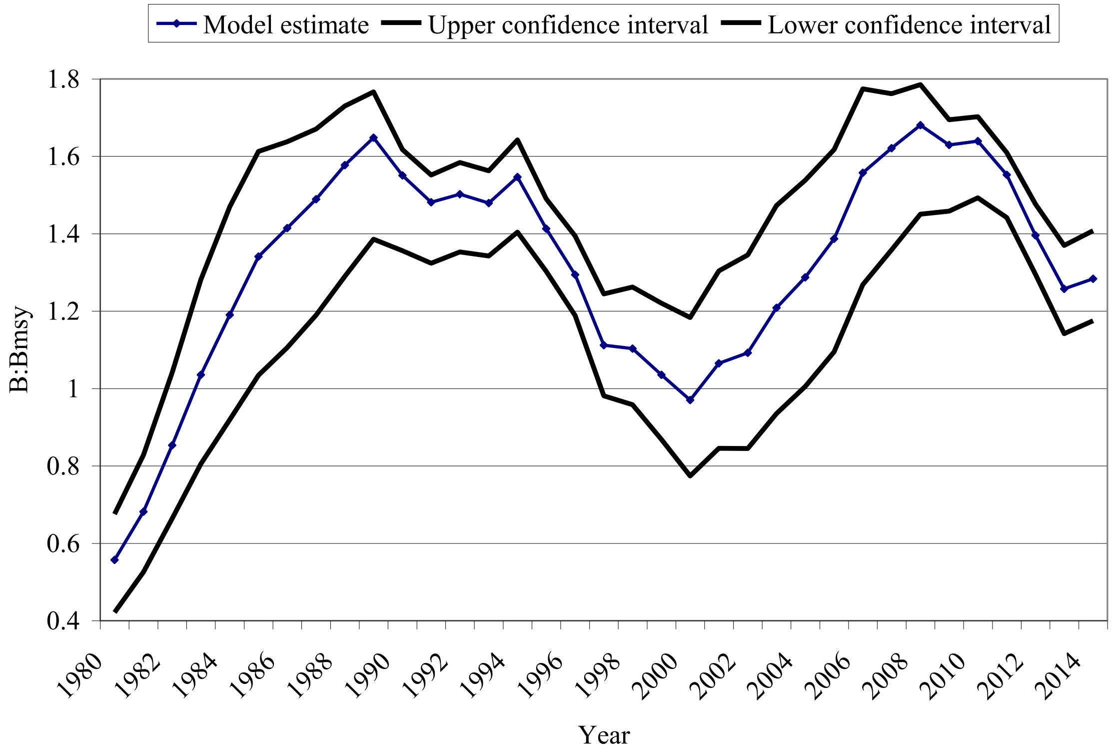


Figure 13. Fishing mortality ratio and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

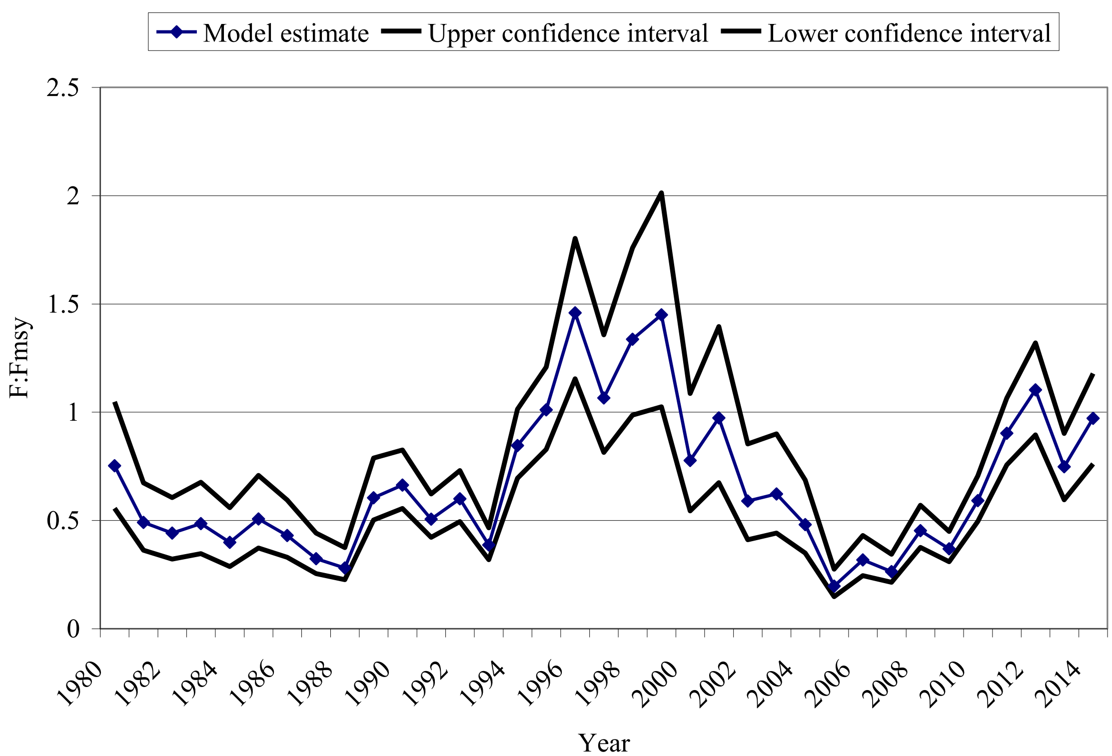


Figure 14. Choptank River channel catfish removals from commercial and recreational fisheries, 1993 – 2014.

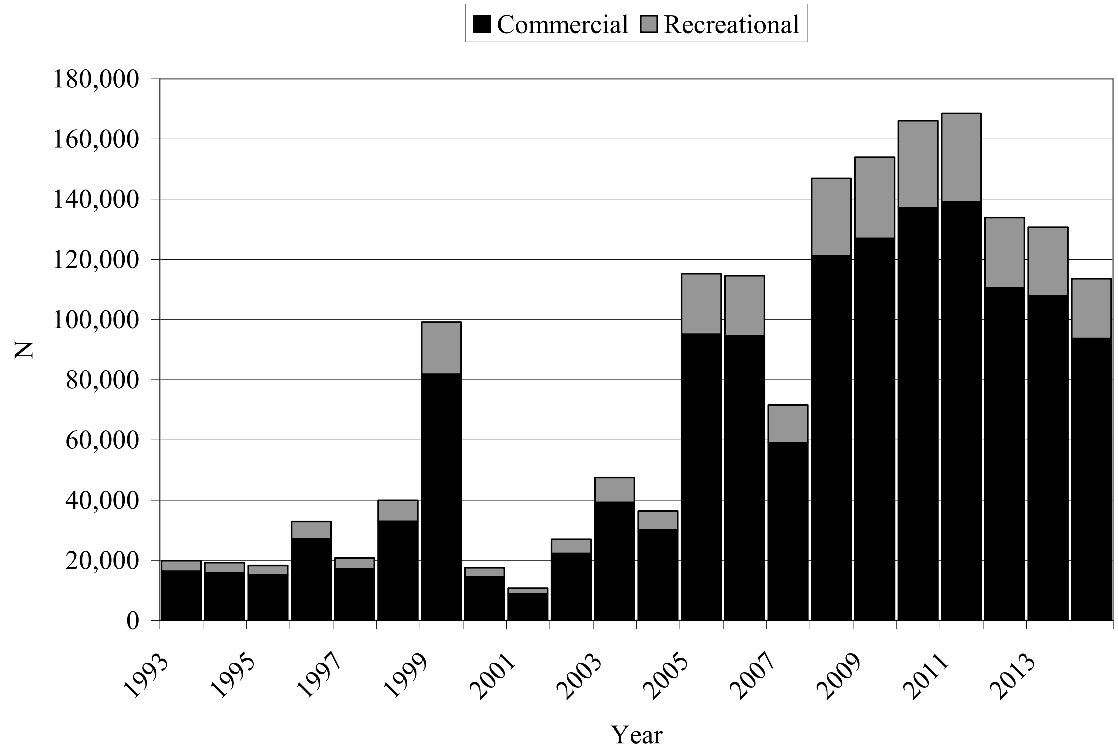


Figure 15. Observed and expected pre-recruit channel catfish index from Choptank River catch survey analysis.

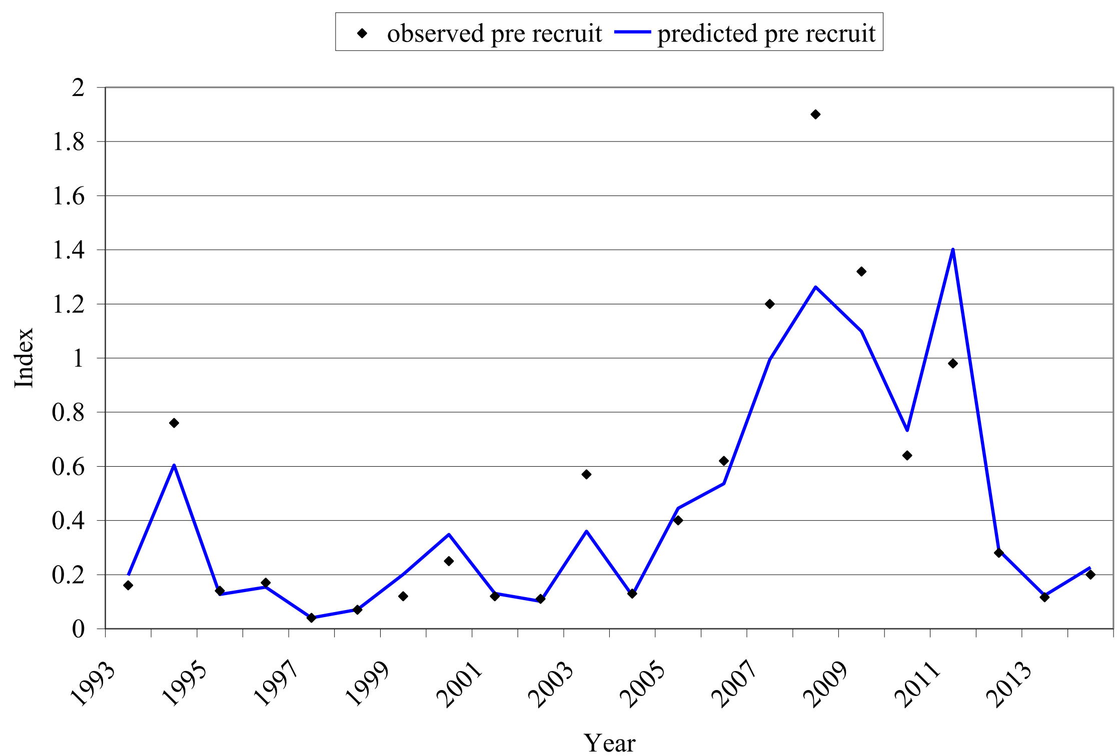


Figure 16. Observed and expected post-recruit channel catfish index from Choptank River catch survey analysis.

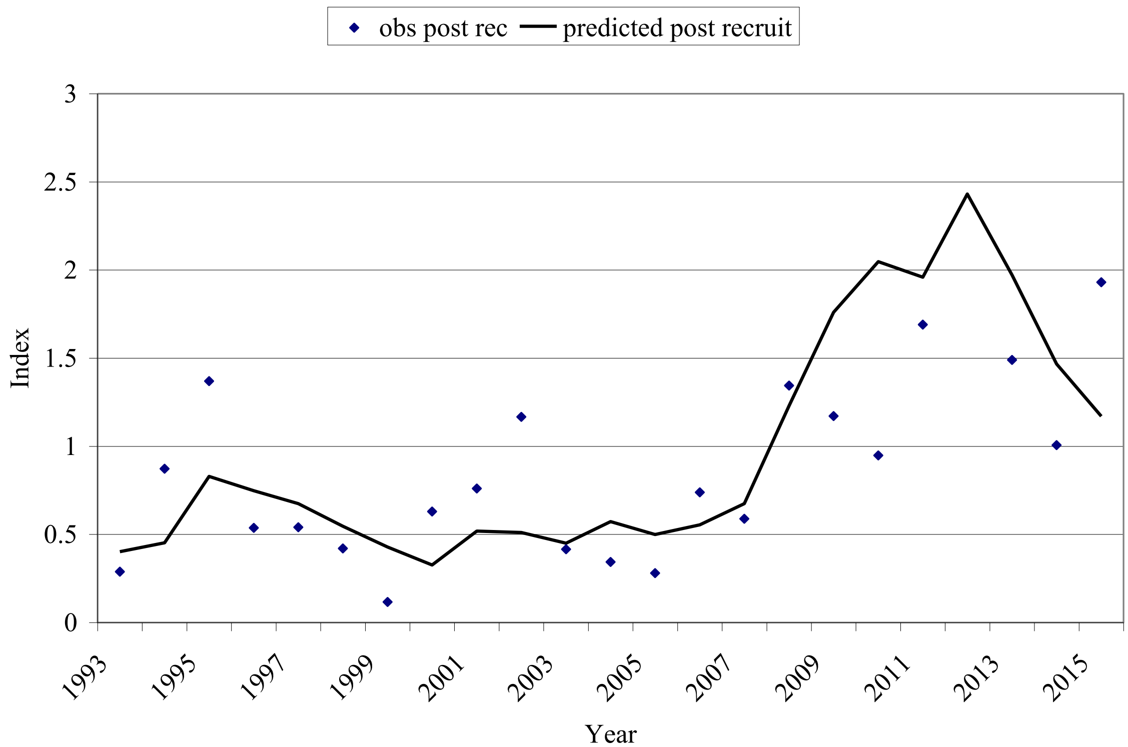


Figure 17. Choptank River channel catfish pre-recruit abundance with 80% confidence intervals from catch survey analysis.

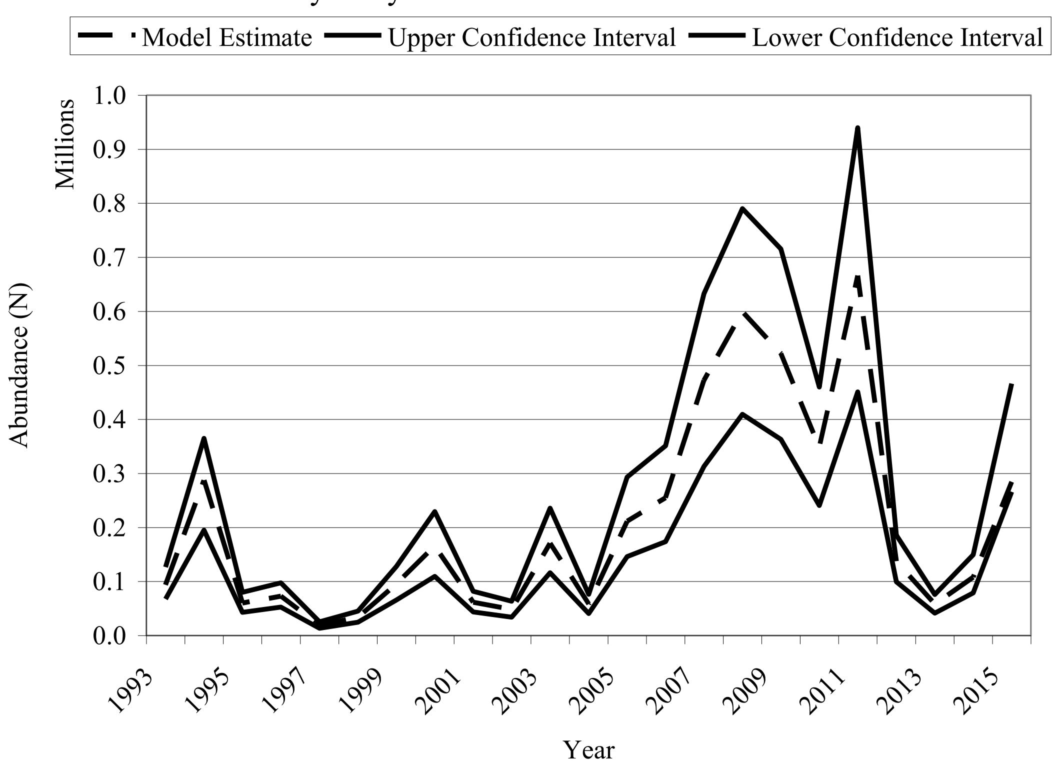


Figure 18. Choptank River channel catfish post-recruit abundance with 80% confidence intervals from catch survey analysis.

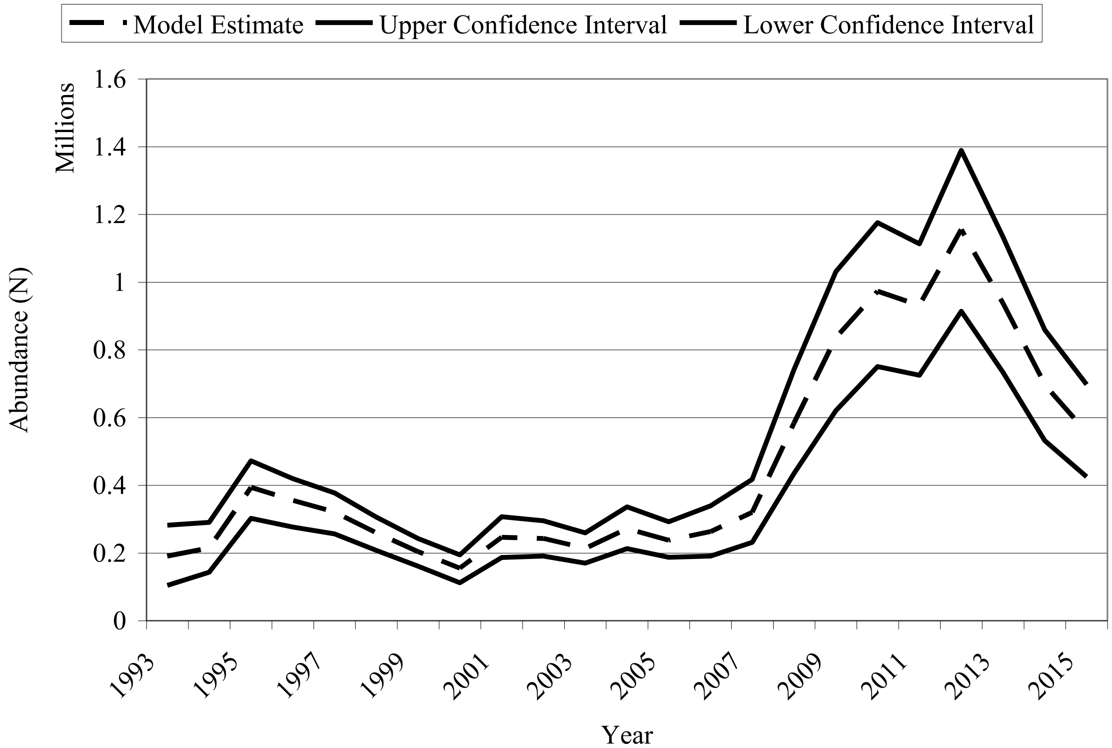


Figure 19. Total channel catfish population abundance estimates and 80% confidence intervals from Choptank River catch survey analysis.

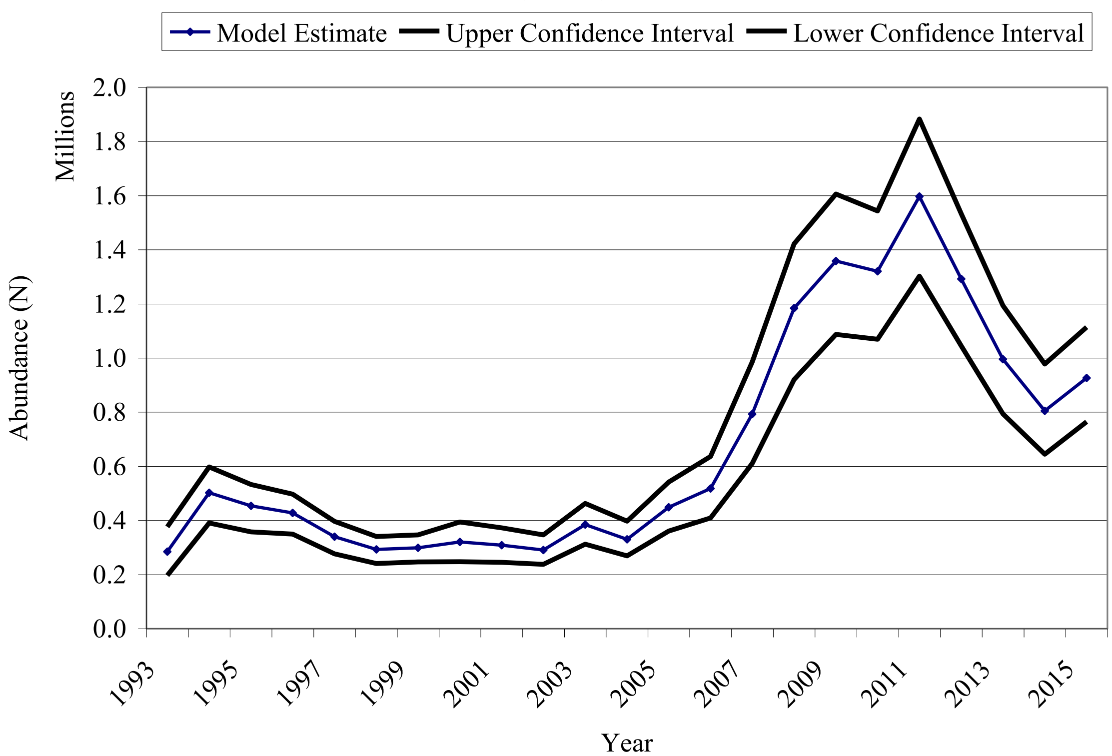


Figure 20. Estimated fishing mortality and 80% confidence intervals for Choptank River channel catfish from catch survey analysis.

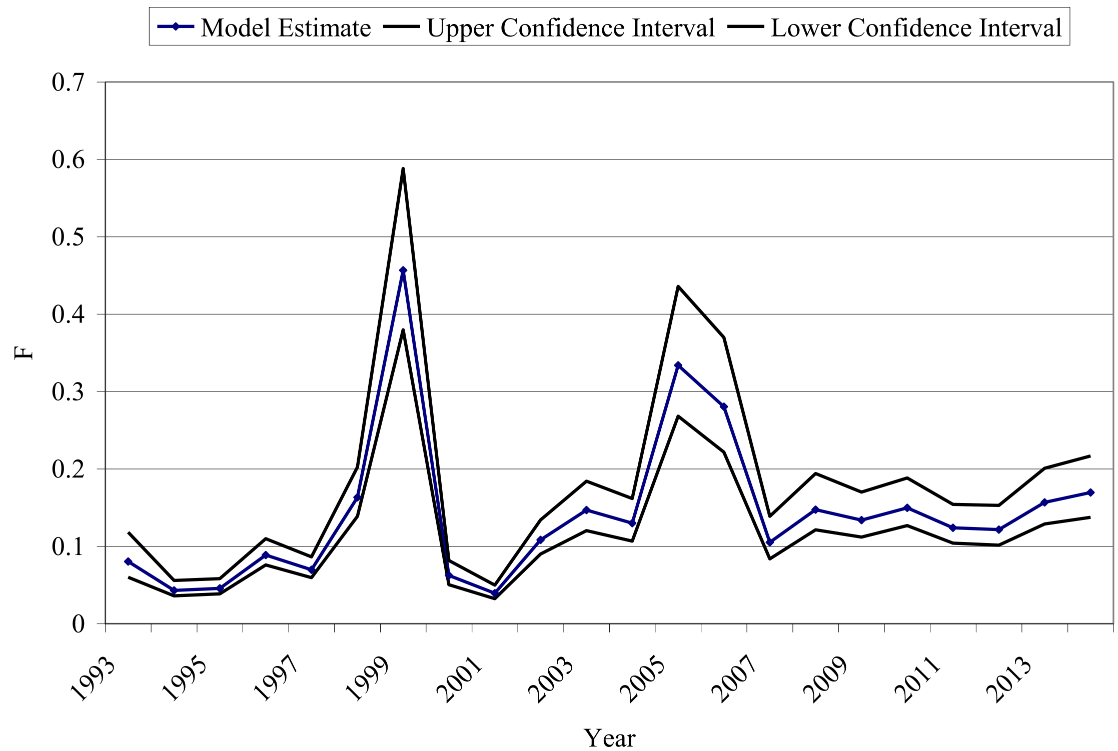


Figure 21. Nanticoke River channel catfish commercial landings, 1987 – 2014.

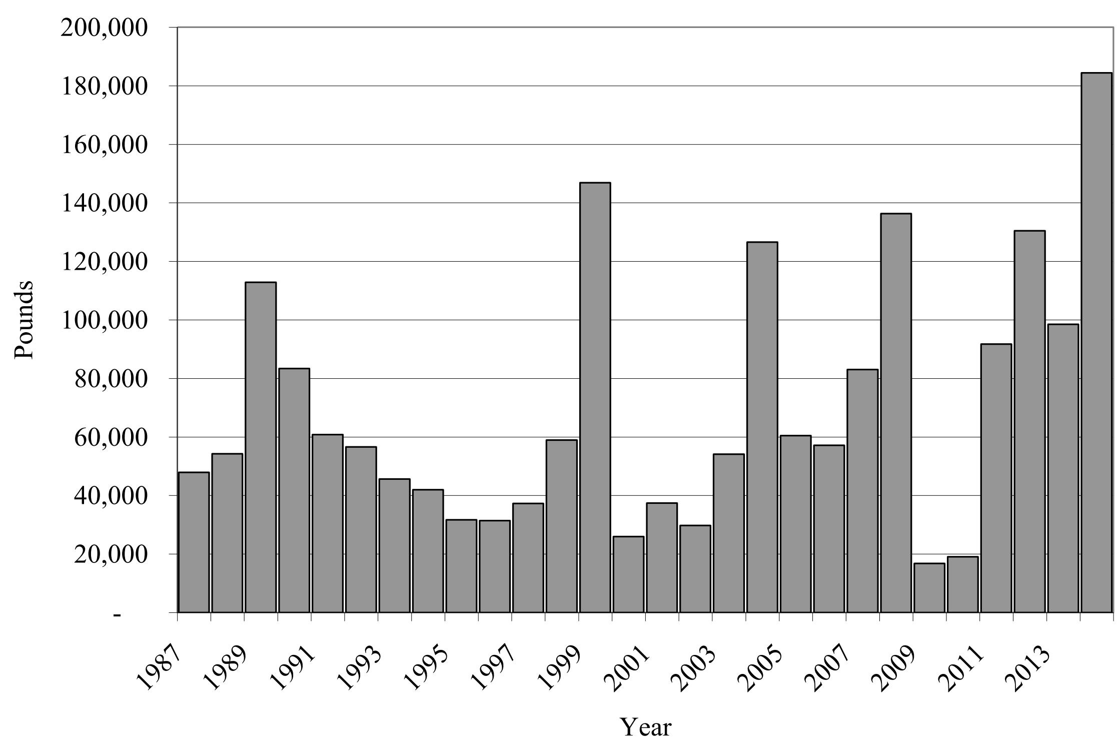


Figure 22. Nanticoke River commercial fish pot channel catfish relative abundance and 75th percentile, 1980 – 2014.

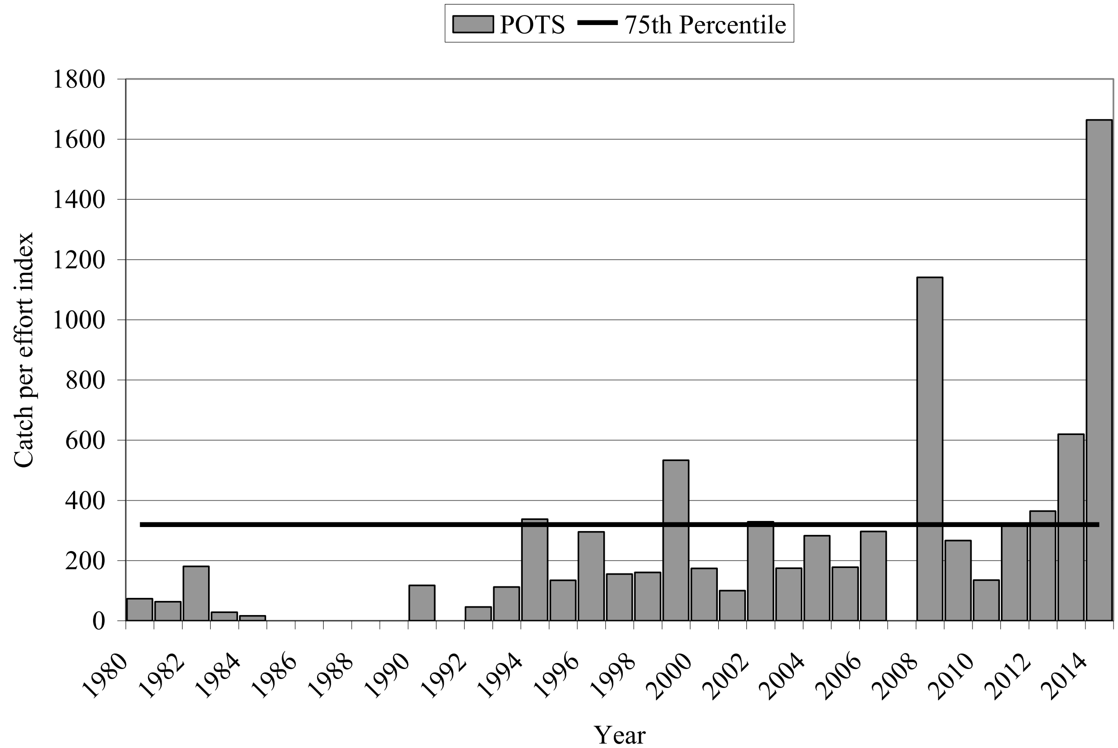


Figure 23. Pocomoke River channel catfish commercial landings, 2003 – 2014.

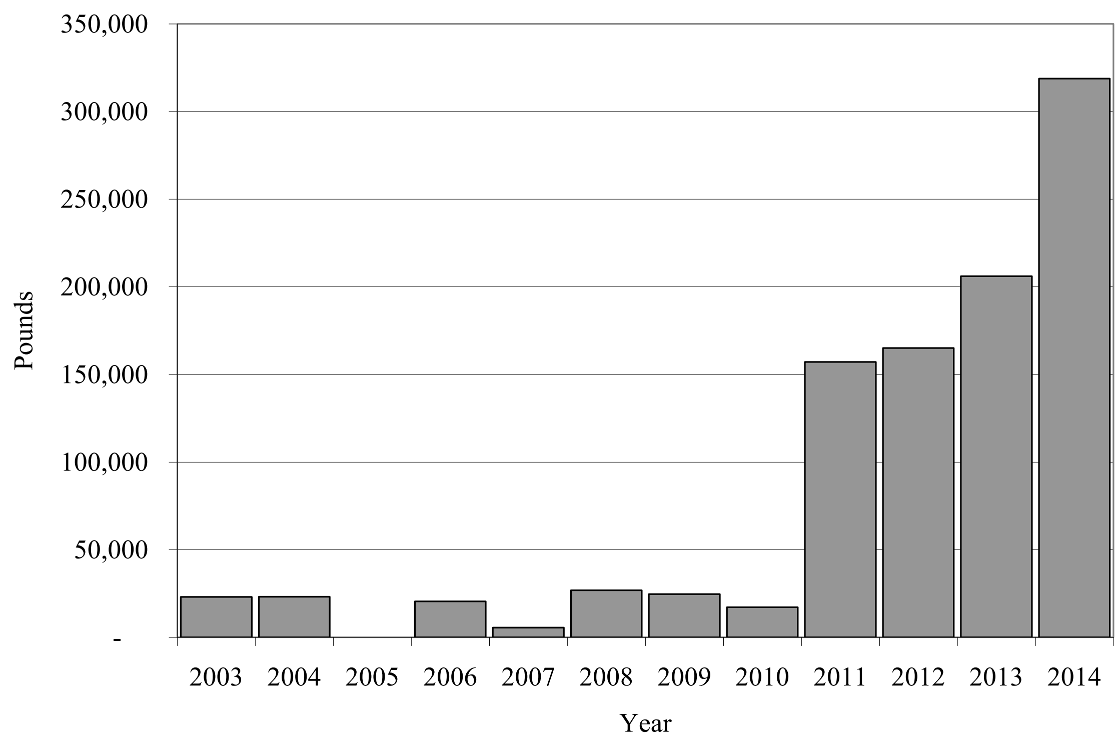


Figure 24. Pocomoke River commercial fish pot and fyke net channel catfish relative abundance and 75th percentile, 2003 – 2011.

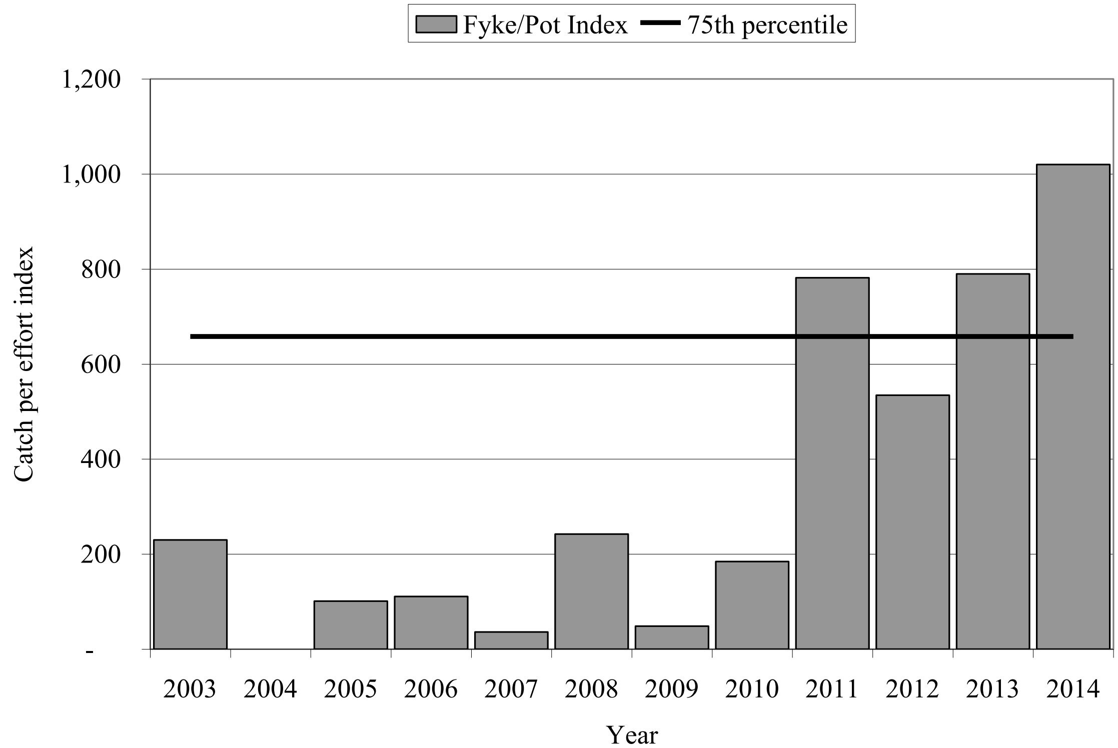


Figure 25. Patuxent River channel catfish commercial landings, 1987 – 2014.

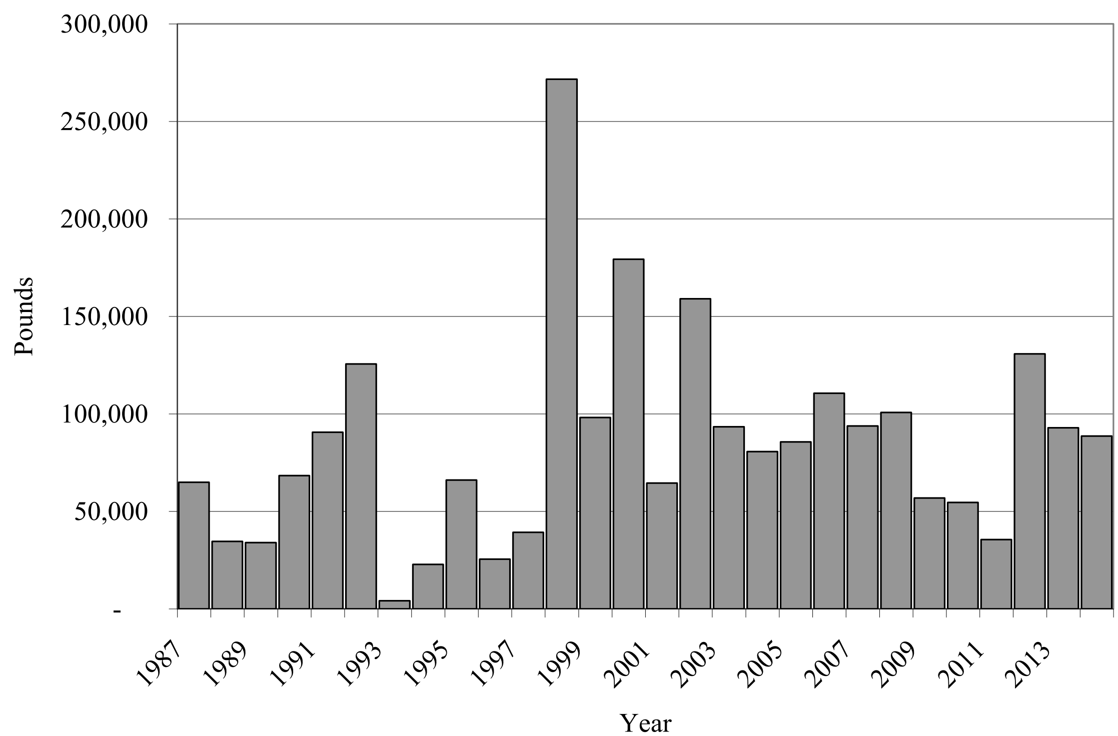


Figure 26. Patuxent River commercial fish pot/fyke net channel catfish relative abundance and 75th percentile, 1990 – 2014.

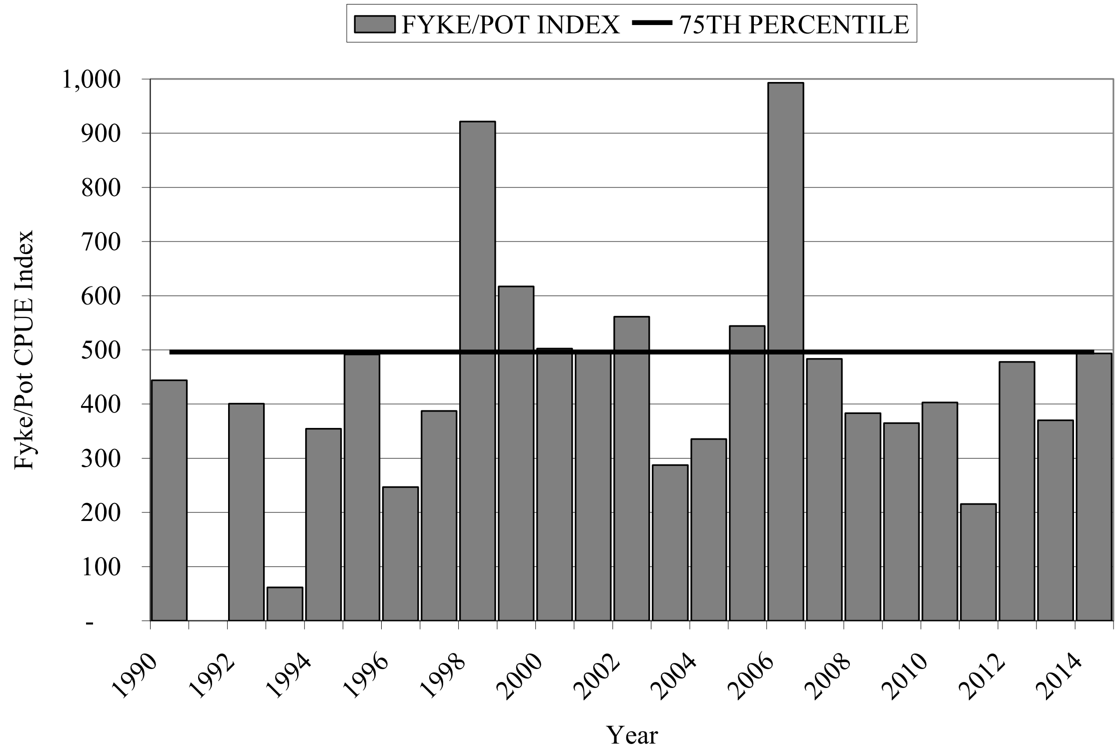


Figure 27. Potomac River channel catfish commercial landings, 1987 – 2014. Data from Potomac River Fishery Commission and MD DNR.

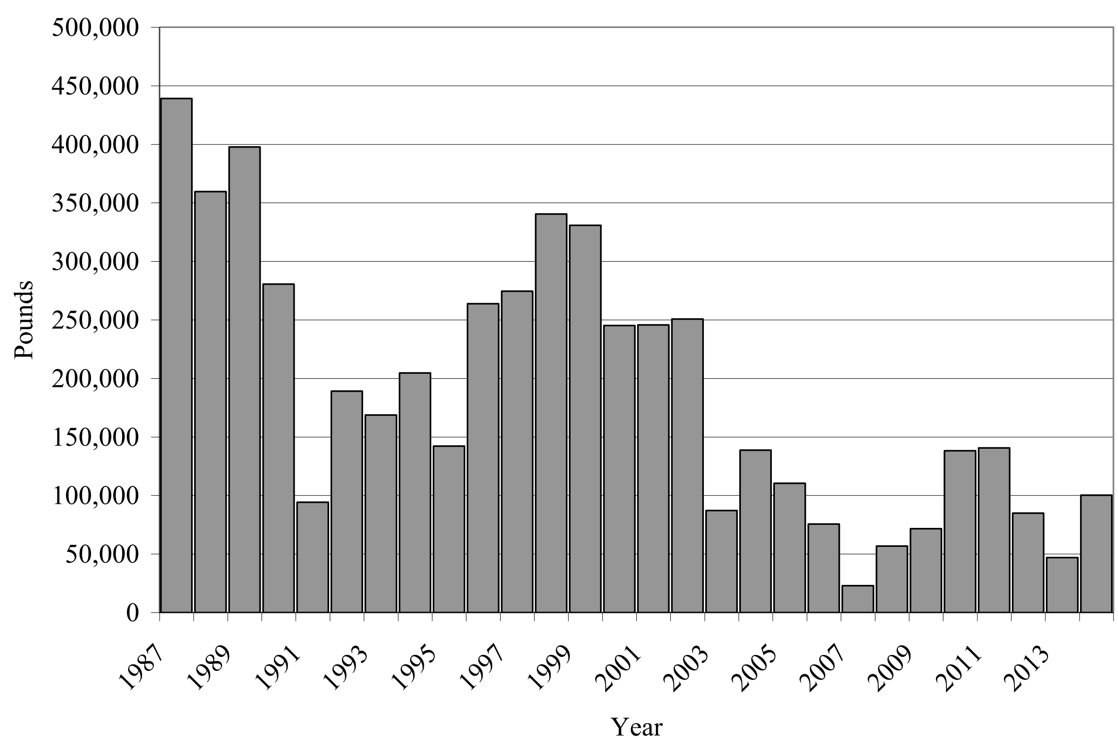
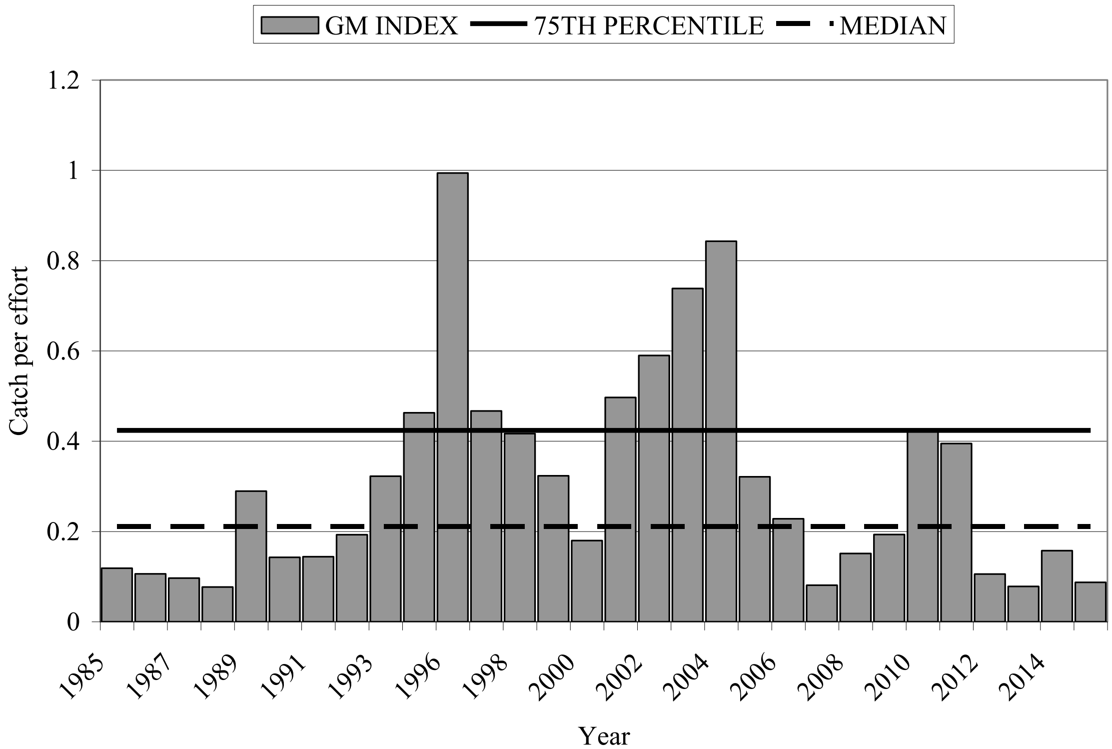


Figure 28. Channel catfish biomass index from Potomac River gill net survey, 1985 – 2014.



PROJECT NO. 2
JOB NO. 1

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

Prepared by
Genine K. Lipkey 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 (MDNR) utilizing both fishery independent and dependent sampling gear. On the Susquehanna River, biologists independently sampled adult American shad by hook and line fishing in the lower 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). In previous years, biologists have worked with commercial waterman to collect alosine stock composition data from the Nanticoke River, but due to ice conditions on the river commercial watermen were unable to set their nets. Hickory shad abundance was assessed in a tributary to the Susquehanna River (Deer Creek) by the MDNR Restoration and Enhancement Program, and river herring were independently sampled using an experimental gill net in the North East River. The 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), Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC), and Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team.

METHODS

Data Collection

Susquehanna River

Adult American shad were angled by MDNR staff from the Conowingo Dam tailrace on the lower Susquehanna River two to four times per week from 27 April through 29 May 2015 (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 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 MDNR 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 4' x 10' 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 MDNR hook and line survey in the current and previous years.

A non-random roving creel survey provided catch and effort data from the recreational anglers in the Conowingo Dam tailrace, concurrent with the MDNR 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 spent fishing for American shad in the lower Susquehanna River (including the Conowingo tailrace and Deer Creek) 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 MDNR's website (http://dnrweb.dnr.state.md.us/fisheries/surveys/login.asp).

Due to the low number of hickory shad typically observed by this project, MDNR's Restoration and Enhancement Program provided additional hickory shad data (2004-2015) from their brood stock collection. Hickory shad were collected in Deer Creek (a Susquehanna River tributary) for hatchery brood stock and were sub-sampled for age, repeat spawning marks, sex, length and weight. In 2004 and 2005, fish were collected using hook and line fishing. More recently fish have been collected by a combination of electrofishing and hook and line fishing (2006-2015).

Nanticoke River

No commercial pound or fyke nets were surveyed due to ice conditions on the Nanticoke River in 2015. Ichthyoplankton sampling was conducted on the Nanticoke River in cooperation with the Fish Habitat & Ecosystem Program (Federal Aid Grant F-63-R, Segment 2, Job 1, Section 3) twice per week from 2 April to 28 April 2015. 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 2). The ichthyoplankton net was constructed of 500 µm mesh net with a 500 mm metal ring opening. The net was towed into 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 in the Susquehanna and Nanticoke Rivers. American shad were captured in gill nets targeting striped bass that were fished 32 days from 1 April to 12 May 2015. 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 from 2013-2015. The gill net was fished at four randomly chosen sites once a week for 10 weeks from mid-March to mid-May. Sampling locations were randomly assigned from a grid superimposed on a map of the system (Figure 5). The grid consisted of 112, 0.04 square mile quadrants. Sampling sites were subsequently randomized for depth, to determine if the net would be set in shallow or deeper water within the quadrant. Four alternate sites were also randomly chosen and used in cases where the chosen site was unable to be sampled. For example, if depth was below 6 feet at a given site, the next available alternate site was selected.

Individual net panels were 100 feet long and 6 feet deep. The panels were constructed of 0.33 mm diameter monofilament twine in 2.5, 2.75 and 3 inch mesh. The net had a 1/2-3/8 inch poly-foamcore float line and a 50 pound lead line. Nets were hung with 200 feet of stretch netting for every 100 feet of net.

In 2015, the 3 inch mesh panel was replaced with a 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 tied together 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 encountered per panel for ageing and spawning history analysis. 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 at the Conowingo Dam in the Susquehanna River and gill netted in the Potomac River. Hickory shad male-female ratios were derived from data provided by the MDNR Restoration and Enhancement Program's brood stock collection on the Susquehanna River. Male-female ratios were also derived for alewife herring and blueback herring captured by experimental gill nets in the North East River.

Alosine scales collected from all rivers were aged following "Massachusetts Division of Marine Fisheries Age and Growth Laboratory: Fish Aging Protocols" (Elzey et al., 2015) as suggested by Atlantic states' ageing experts after ASMFC held the "2013 River Herring Ageing Workshop" (ASMFC 2013). Age determination from scales was attempted for all American shad and river herring samples. A minimum of four scales per sample were cleaned, mounted between two glass slides and read for age and spawning history using a Bell and Howell MT-609 microfiche reader. The scale edge was counted as a year-mark 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. Hickory shad scales from the Susquehanna River were aged by the MDNR Restoration and Enhancement Program. Repeat spawning marks were counted on all alosine scales during ageing.

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 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 also calculated from the data collected by the logbook survey (i.e. paper logbook data and online angler reports were combined). The roving creel survey was used to calculate a CPAH for American shad in the Conowingo Dam tailrace. In the Potomac River, the SBSSS calculated CPUE as the number of fish caught per 1,000 square yards of experimental drift gill net per hour fished.

The North East River gill net CPUE was estimated separately for alewife and blueback herring using catch from the 2.5 and 2.75 inch 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 8 weeks of the survey, as the run typically tails off in early May. Conversely, the last 6 weeks of catch and effort data were summed to calculate the blueback CPUE, since the run does not typically begin until early April. Catch was pooled across the mesh sizes indicated and CPUE was reported as the number of fish caught per set of experimental gill net per hour fished. When using a gill net to capture fish, the mesh sizes utilized influence the size of fish that are captured. This can cause length bias in the sample, which is not completely eliminated even when multiple mesh sizes are fished simultaneously (Hamely 1975). Therefore, it is advised to estimate and correct for gill net selectivity by indirectly estimating selectivity curves for each mesh size fished (Millar and Fryer 1999). Selectivity corrections will be made to the length frequencies and CPUEs of the North East gill net survey as time allows for them to be developed.

While CPUE is one of the most commonly used measure of abundance, it can fluctuate year to year 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 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 include: surface water temperature (°C), river flow in thousands of cubic feet per second as measured by the USGS Water Resources station 01578310 Susquehanna River at Conowingo, MD (USGS 2015), the number of small generation units operating, the number of large generation units operating, 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, M is the number of fish tagged minus 3% tag loss, and R is the number of tagged fish recaptured at the EFL excluding recaps of previous years' tags. C is corrected to include only fish that were lifted after tagging began in the tailrace. 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. Observations at the WFL were omitted to avoid double counting beginning in 2001, as it became protocol for some fish captured at the WFL to be returned to the tailrace. Calculation of 95% confidence limits (N*) for the Peteresen 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 a surplus production model). 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 estimates and proportional bycatch of American shad in the ocean fisheries.

The SPM required starting values for the initial population (B_0) in 1985 (set as 7,876 by the Petersen statistic for this year; calculation described above), a carrying capacity estimate, set as 3,040,551 fish, which was three times the highest Petersen estimate of the time series, an estimate of the intrinsic rate of growth (set as 0.50), and a bycatch coefficient (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 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

Catch curve analysis was used to estimate total instantaneous mortality (Z) of adult American and hickory shad in the Susquehanna River. The number of repeat spawning marks was used in this estimation instead of age because ageing techniques for American shad scales are tenuous (McBride et al. 2005). Therefore, the Z calculated for these fish represents mortality associated with repeat spawning. Assuming that consecutive spawning occurred, the ln-transformed spawning group frequency was plotted against the corresponding number of times spawned:

$$\ln(S_{fx} + 1) = a + Z * W_{fx}$$

where S_{fx} is number of fish with 1,2,...*f* spawning marks in year *x*, *a* is the y-intercept, and W_{fx} is frequency of spawning marks (1,2,...*f*) in year *x*. Using Z, annual mortality (A) for American Shad was obtained from a table of exponential functions and derivatives (Ricker 1975). This calculation of Z may bias mortality high if skip spawning is occurring (ASMFC 2012).

Juvenile Abundance

The MDNR Estuarine Juvenile Finfish Seine Survey (EJFS; Project 2, Job 3, Task 3) provided juvenile indices (geometric mean catch per haul) for alewife herring and blueback herring from fixed stations within the Nanticoke River and the 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 small sample sizes.

RESULTS

Ichthyoplankton

Ichthyoplankton tows were conducted on 8 days in 2015. Fertilized alosine eggs and/or larvae were present at 27.6% of tow stations in 2015 (Table 1). Salinity at tow stations ranged from 0.1 to 3.2 ppt. An absence of observed fertilized eggs and/or larvae occurred from 2006-2008, and in 2012. Alosine egg and/or larvae presence was highest in 2010 (43%).

American Shad

Sex, Age and Stock Composition

The male-female ratio of adult American shad captured by hook and line from the Conowingo tailrace was 1:0.78. Of the 308 fish sampled by this gear, 279 were successfully scale-aged (Table 2). Males were present in age groups 3-6 and females were found in age groups 3-8. The 2010 (age 5) year-class was the most abundant for males and females, accounting for 40% of males and 52% of females (Table 2). Thirty-eight percent of males and 65% of females were repeat spawners. The percentages of repeat spawners for both males and females decreased in 2015, after a steady increase from 2008-2014 (Figure 4). The arcsine-transformed proportion of these repeat spawners (sexes combined) has significantly increased over the time series (1984-2015; $r^2 = 0.49$, $P < 0.001$; Figure 5). Analysis by PFBC of 150 American shad otoliths collected from the WFL at Conowingo Dam showed that 90 (69%) were wild fish and 59 (40%) were hatchery produced fish in 2015. Similar hatchery contribution was seen in 2013 (37%) and 2014 (44%).

The male-female ratio for adult American shad captured in the Potomac River was 1:0.64. Of the 127 American shad collected, 120 were successfully aged (Table 2). Males and females were present in age groups 3-7. The most abundant year-class for males was the 2010 (age 5) year-class at 47%. The 2009 and 2010 year-classes (age 5 and 6, respectively) were the most abundant year-classes for females in the sample at 45%. Sixty-four percent of males and 68% 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 (2002-2015; $r^2 = 0.01$, $P = 0.72$; Figure 6).

Adult Relative Abundance

Sampling at the Conowingo Dam occurred for 12 days in 2015. A total of 308 adult American shad were encountered by the gear; all of these fish were captured by MDNR staff from a boat; no shore sampling occurred in 2015. Peak catch by hook and line (107 fish) occurred on 8 May 2015 at a surface water temperature of 18°C. MDNR staff tagged 298 (97%) of the sampled fish. No tagged American shad recaptures were reported from either commercial fishermen or recreational anglers in 2015. However, one American shad tagged in 2014 was recaptured by MDNR anglers while fishing in the tailrace.

The EFL operated for 46 days between 3 April and 31 May 2015. Of the 8,341 American shad that passed at the EFL, 85% (7,127 fish) passed between 1 May and 15 May 2015. Peak passage was on 13 May; 1,154 American shad were recorded on this date. Seven of the American shad counted at the EFL counting windows were identified as being tagged in 2015 and two were identified as being tagged in 2014 (Table 3).

The Conowingo WFL operated for 19 days between 29 April and 27 May 2015. The 875 captured American shad were retained for hatchery operations, sacrificed for characterization data collection, or returned alive to the tailrace. Peak capture from the WFL was on 13 May, same as the EFL, when 298 American shad were collected. Eight tagged American shad were recaptured by the WFL in 2015, 1 was tagged in 2014 and 7 were tagged in 2015 (Table 3).

The various model configurations explored for developing a GAM for the hook and line index and how each model performed are summarized in Table 4. Due to observed collinearity of day of the year with surface water temperature, day of the year was removed from the model. The number of small generation units operating and the number of large generation units operating had large VIF values (>3) and were also 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 indicates temperature has a greater effect on catch than flow (Table 4). The model results also indicate that both models 2 and 3 are acceptable. Model 2 is slightly over-dispersed, while model 3 is slightly under-dispersed. It was suggested that being slightly under-dispersed would be better than being over-dispersed (Laura Lee, North Carolina Department of Environment and Natural Resources, pers. comm.), therefore model 3 was chosen as the best fit model. A bootstrap procedure could be used to test the predictive ability of models 2 and 3, and evaluate model performance by fitting a linear regression to the observed versus predicted values. A bootstrap evaluation will be further developed as time allows.

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 log of effort as an offset, and a negative binomial response distribution. This model showed no obvious signs of pattern in the residuals (Figure 7). The annual hook and line CPUE generated using the best fit GAM shows abundance is variable from 2007-2015, with an increase in recent years, but remains below the high indices observed from 1999-2002 (Figure 8).

The Conowingo Dam lifts provide another opportunity to measure American shad abundance in this region for comparison to the hook and line index. Both the run count of fish lifted at Conowingo Dam and the combined lift GM CPUE, for years when both the East and West Fish lift were operating, mirror the hook and line index (Figure 9). Like all relative measures of abundance there are caveats to accepting these indices as indicative of true abundance. Run counts at Conowingo Dam are affected by the lift efficiency and river flows, while the GM CPUE is affected by the number and frequency of lifts. All three indices measured in this region of the Susquehanna River show a broad general trend that abundance was low in the 1990s, increased to a peak in the early 2000s and has since declined to low levels of abundance (Figure 8 and 9). However, the increase observed in the hook and line index in recent years is not apparent in the other two indices.

Sixty-four interviews were conducted over five days during the creel survey at the Conowingo Dam Tailrace. The CPAH increased in 2015 (Table 5), but has decreased over the time series (2001-2015; $r^2 = 0.36$, $P = 0.02$). The coefficient of determination from this analysis indicates the data only has a marginal fit to the predicted linear model, there is a lot of variability in the data, or perhaps a different model should be explored.

Three anglers returned logbooks in 2015. Additionally, eight anglers participated online by recording their trips through MDNR's Volunteer Angler Shad Survey. American shad CPAH calculated from shad logbook data combined with data from MDNR's Volunteer Angler Shad Survey was similar to the 2014 CPAH estimate (2.05; Table 6). Online angler data was included in the CPAH calculation for the second time in 2015. The logbook CPAH estimate of adult American shad relative abundance has decreased significantly over the time series (2000-2014; $r^2 = 0.51$, $P = 0.003$; Table 6).

There was a slight decrease in the fishing effort by the SBSSS in the Potomac River in 2015. The program reduced the length of three mesh panels (3, 3.75, and 4.5 inches) from 150 feet to 75 feet in an attempt to catch fewer blue catfish. Gill net surveys that specifically target American shad typically use mesh sizes of 5 to 5.5 inches (Richardson et al., 2009), so the changes made to the SBSSS gill net most likely had minimal affect on American shad catch and therefore CPUE. The Potomac River CPUE significantly increased over the time series (1996-2015; $r^2 = 0.29$, $P = 0.01$), and was above the time series mean for the past two years (Figure 10).

Population Estimates

The Petersen statistic estimated 302,909 American shad in the Conowingo Dam tailrace in 2015 with an upper confidence limit of 552,595 fish and a lower confidence limit of 156,386 fish (Figure 11). The SPM with the lowest sum of squares that best represented American shad in the Conowingo Dam utilized the CPUE from the hook and line survey, and used the Atlantic herring and mackerel combined landings to estimate bycatch losses. This run estimated a population of 139,973 American shad in the Conowingo Dam in 2015 and produced realistic estimates of the model parameters r, K and B_0 ($r = 0.56$, $K = 1{,}005{,}502$, $B_0 = 54{,}176$; Figure 12).

Despite differences in yearly estimates, the overall population trends derived from each population model are similar (Figures 11 and 12). Specifically, the SPM showed an increasing population size from the beginning of the time series to a peak in 2001, followed by a decline through 2007. Since 2007 the population size has shown a slight increase in recent years (2012-

2015; Figure 12). Petersen estimates follow a similar pattern if the high levels of uncertainty in 2004 and 2008 (due to low recapture rates) are considered (Figure 11), although they show a greater increase towards the end of the time series compared to the SPM estimates.

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in Z = 1.03 (A = 64.3%) in 2015, which is much higher than both the 2013 (Z = 0.67) and the 2014 (Z = 0.71) estimates.

Juvenile Abundance

The juvenile American shad baywide abundance index provided by the EJFS was the highest value since this survey began in 1954 (Figure 13), and American shad juvenile indices increased in all other sampled tributaries, with the exception of the Nanticoke River (Figures 14-16). The Potomac River index dramatically increased in 2015, remains above the time series mean (Figure 14), and is greater than all other system indices (Figures 13-16). Juvenile indices were not corrected for hatchery contribution.

Hickory Shad

Sex, Age and Stock Composition

In Deer Creek, 590 hickory shad were sampled by the broodstock collection survey. The male-female ratio was 1:0.84. Of the total fish captured by this survey, 113 were successfully aged. Males and females were present in age groups 2-6 (Table 7). The most abundant year-class was the 2011 year-class (age 4) for males (41%) and females (47%, Table 8). Since 2012 no hickory shad of ages greater than 7 have been observed (Table 8). The arcsine-transformed proportion of repeat spawners (sexes combined) has not changed significantly over the time series (2004-2015; r^2 = 0.32, P = 0.06; Figure 17), but has decreased since 2009. The total percent of repeat spawners in 2015 (59.0%) remains the same as last year, at the lowest percentage of the time series (2004-2015; Table 9).

Relative Abundance

Shad logbook and Volunteer Angler Shad Survey data indicated that hickory shad CPAH did not vary significantly over the time series (1998-2014; r^2 = 0.13, P = 0.16). Hickory shad CPAH was the lowest year on record since 1998 when this survey began (Table 10). However, there were considerably fewer fishing trips for hickory shad in 2015, and the fewest hours spent fishing for hickory shad on record. With the extended cold temperatures and the wet start to spring, fishing opportunities during the Hickory shad run may have been limited in 2015.

Mortality

Total instantaneous hickory shad mortality in the Susquehanna River (Deer Creek) was estimated as Z = 0.68. This estimate is similar to the 2013 Z estimate (Z = 0.78), but much higher than the 2014 estimate (Z = 0.36). The large fluctuations in the estimated values of natural mortality by catch curve warranted exploration of another method for comparison, such as Hoenig's (1983) equation ($\ln(M_x) = 1.46 - 1.01\{\ln(t_{max})\}$). Based on a t_{max} of 9, Hoenig's (1983) equation estimates natural mortality at M = 0.47, which is similar to the 2014 estimate.

Alewife and Blueback Herring

The gill net survey in the North East River caught increasingly more alewife and blueback herring each year from 2013 to 2015. With the addition of the 2.25 inch mesh panel blueback herring catch more than doubled, approaching alewife herring catch numbers in 2015 (Figure 18). The timing of the alewife and blueback herring run for 2015 can be seen in Figure 19. A majority of the alewife herring were caught in the 2.5 inch mesh for all years (Figure 20). Alewife ranged in size from 201-310 mm FL. A majority of the blueback were caught in the 2.5 inch mesh prior to the addition of the 2.25 inch mesh, which caught a majority of the blueback in 2015 (Figure 21). Blueback ranged in size from 208-270 mm FL.

Sex, Age and Stock Composition

Since the inception of this survey, more female alewife herring have been encountered by the gear than male alewife herring. Male-female ratios for alewife herring were observed as high as 1:3.6 (2013). The same is true of blueback herring. An age-length key was generated to assign an age structure to the entire catch for years when the catch was above 300 fish per species. Age-length keys were developed for alewife herring in 2014 and 2015, and in 2015 for blueback herring. Alewife herring of ages 3-8 were present for all years with the exception of 2015 when alewife herring were between the ages 3-7. The 2011 alewife herring year-class began to return to the North East River to spawn beginning in 2014 at the age of 3 (mostly males), and was the most abundant year class in 2015 at the age of 4, comprising 72.2% of the sample (Figure 22). Blueback herring were present from ages 3-7 from 2013 through 2015, and age 4 (sexes combined) was the most abundant age for all years. Similar to alewife herring, the 2011 year-class (age 4 in 2015) for blueback herring was most abundant, accounting for 72.7% of the sample (Figure 23). For the North East River, 45.8% of alewife herring and 29.8% of blueback herring were repeat spawners (sexes combined).

While hook and line fishing for American shad in the Conowingo tailrace it is not uncommon to capture river herring. In 2015, any river herring encountered were measured to the nearest mm FL and TL, sexed, and scales were taken to support a research project for George Mason University (GMU). Samples were collected by MDNR and were aged by GMU. Seven blueback herring were captured, four females and three males, ranging in size from 219 – 248 mm FL, and ages 3 – 5, with one sample marked as regenerated.

Adult Relative Abundance

Catch-per-unit-effort estimates made for alewife and blueback herring separately from the pooled 2.5 and 2.75 inch mesh catch indicate an increasing abundance of both alewife and blueback herring from 2013 – 2015 (Figure 24). Discretion should be used when interpreting these results as they have not been corrected for selectivity bias of the mesh sizes.

Mortality

Table 12 shows the total instantaneous mortality for North East River alewife and blueback herring (sexes combined) for all three years of the gill net survey. Sample size for blueback herring in 2013 was too small to calculate a reliable mortality estimate. The 2015 total instantaneous mortality estimates for both alewife and blueback herring from the North East River were high ($Z = 1.31$ and $Z = 1.71$, respectively). These estimates may be greater than the previous year due to the large 2011 year class which recruited to the fishery in 2015.

Juvenile Abundance

Data provided by the EJFS indicated that the upper bay alewife and blueback herring juvenile GM CPUE increased in 2015, while the Nanticoke River alewife and blueback herring juvenile GM CPUE remained low in 2015 (Figures 25-26).

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 the 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).

Peak capture of American shad in the Conowingo tailrace by hook and line occurred almost a week before peak passage was observed at the East and West Fish Lifts in 2015. Surface water temperature for peak capture by hook and line was within the optimal migration temperature for American shad (17 – 19°C, Legget and Walburg 1972) at 18°C, whereas peak passage at the lifts occurred at 21°C; above the optimal migration temperature and just above the optimal temperature for spawning (14-20°C, Stier and Crance 1985). This suggests migration of American shad past Conowingo Dam on the Susquehanna was occurring outside optimal temperatures in 2015, which is ultimately not conducive to successful spawning. 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.

The population size of American shad in the lower Susquehanna appears to be relatively stable over the past eight years (2007-2015; SPM estimate), although at a much lower level than the peak observed from 2000-2001 and compared to historical abundance. This follows a period

(2001-2007) when calculated indices of abundance generally decreased (including the hook and line CPUE, lift CPUE, logbook CPAH and creel CPAH).

The calculated indices of abundance in the lower Susquehanna River all continued to increase in 2015, with the exception of the run count at Conowingo dam, which showed a decline in 2015. Gizzard shad are increasing in abundance in the Susquehanna drainage and may reduce the number of lifted American shad by using the lifts themselves. The Potomac River CPUE (1996-2015) has increased over time, which indicates there is some improvement in the Potomac River, while the Susquehanna River continues to be significantly impacted.

The Petersen estimate and the SPM are both useful techniques for providing estimates of American shad abundance at the Conowingo Dam. Both models show the population to be relatively stable (2007-2015), with gradual increases in the last 2–3 years. The SPM likely underestimates American shad abundance, while the Petersen statistic likely overestimates the population, especially in years of low recapture of tagged fish. Trends, rather than the actual numbers, produced by the models should be emphasized when assessing the population at the Conowingo Dam in the Susquehanna River. The trends in these population estimates indicate that the population has stabilized at some low level, likely limited by the available spawning habitat below Conowingo and stocking success. The PFBC data currently estimates stocking contributes approximately 40% of the adult American shad population in the Conowingo tailrace.

Ageing American shad using scales is common practice, as it the only non-lethal ageing structure for this fish. However, ageing accuracy has been called into question by many (ASMFC 2007). Ageing other hard structures such as otoliths produces higher age agreement between readers compared to scales (Duffy et al. 2012). 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 has increased over time, particularly since the truck and transport to locations above Safe Harbor Dam ceased in 1997 when the EFL was automated. The percent of repeat spawners was generally less than 10% in the early 1980s in the Conowingo Dam tailrace (Weinrich et al. 1982). In contrast, 50% of aged American shad at the Conowingo Dam were repeat spawners in 2015, and, on average, 60% of aged fish were repeat spawners over the past four years. Turbine mortality for dams above the Conowingo Dam is considered to be 100%, and the end of truck and transport in 1997 may have resulted in more fish surviving to return in following years, which also indicates that fewer adults are reaching optimal spawning habitat above Safe Harbor Dam. However, the same trend occurs in the Potomac River, a free flowing river, unimpeded by dam construction: the average percent of repeat spawners was 17% in the 1950s (Walburg and Sykes 1957), and is currently 67%. Increased repeat spawning in both 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 show increasing trends in repeat spawners include the Merrimack (1999-2005; ASMFC 2007), Nanticoke (Lipkey and Jarzynski 2014), and James Rivers (2000-2002; Olney et al., 2003).

Historically, calculated Z for American shad in the lower Susquehanna River has been above the target Z_{30} (1984 – 2005; ASMFC 2007). The 2015 mortality estimate continues this pattern, with a calculated Z for American shad in the Conowingo Dam tailrace (Z=1.03) being well above the Z_{30} established for rivers in neighboring states (range=0.54−0.76, ASMFC 2007).

As previously mentioned these calculated mortality estimates may be high if skip spawning is occurring (ASMFC 2012).

Juvenile American shad indices increased baywide, in the upper Chesapeake Bay and the Potomac River in 2015. The juvenile index in the Potomac River was the highest index on record since this survey began in 1954. This suggests favorable environmental conditions and a successful spawn for American shad in 2015.

Hickory Shad

Hickory shad stocks have drastically declined due to the loss of habitat, 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 are historically observed using the EFL in the Susquehanna River. A notable exception was in 2011 when 20 hickory shad were counted at the EFL counting window. Despite the traditionally low number of hickory shad observed passing the Conowingo Dam, Deer Creek (a tributary to the Susquehanna River) has the greatest densities of hickory shad in Maryland (Richardson et al. 2009). Catch rates exceed four fish per hour for all years except 2009, 2010 and 2015 according to shad logbook data collected from anglers (1998-2015). There were considerably fewer fishing trips for hickory shad in 2015, and the fewest hours spent fishing for hickory shad on record. With the extended cold temperatures and the wet start to spring, fishing opportunities during the Hickory shad run may have been limited in 2015.

Previously, hickory shad age structure has remained relatively consistent, with a wide range of ages and a high percentage of older fish, although the past four years (2012-2015) have seen no hickory shad over the age of 7. In 2015, 95% of fish were age 5 or younger and no hickory shad were observed over the age of 6. This suggests the age structure of hickory shad has become truncated in recent years. Ninety percent of hickory shad from the upper Chesapeake Bay spawn by age four, and this stock generally consists of few virgin fish (Richardson et. al 2004). Repeat spawning in 2014 and 2015 were the lowest of the time series, which coincides with fewer hickory shad reaching those older ages. 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.).

Hickory shad adults 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 sensitivity to light 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 have drastically declined for the same reasons discussed previously for American and hickory shad. The most recent stock assessment, released in 2012, showed the coastwide meta-complex of river herring stocks on the US Atlantic coast is depleted to near historic lows, and declines in the mean length of at least one age were observed in most rivers examined (ASMFC 2012). This assessment corresponds with the low indices of abundance for both species observed in the Nanticoke River by this project through 2014. Crecco and Gibson (1990) found alewife herring in the Nanticoke River to be fully exploited and severely depleted prior to the start of MDNR fishery-dependent sampling in this river. However, relative abundance in the North East River show signs of improvement for both blueback and alewife herring from 2013-2015. Without a reference point for this river, the significance of this improvement is unclear.

Mortality estimates for alewife and blueback herring in the North East River are high, especially for blueback herring. 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 blueback herring estimated by this project.

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 eliminates any directed in-river mortality experienced by these species, and there are a number of efforts underway to reduce incidental catch mortality 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 shad on the Atlantic herring and mackerel fleets (Federal Register 2014a, 2014b). The expectation is that these efforts to reduce fishing mortality on river herring will lead to increased spawning stock, with a corresponding increase in production of juvenile river herring.

The population age structure for the North East River is similar to that of other river herring populations in the region (Hilton et al. 2015), but should be interpreted with caution as the ASMFC River Herring Ageing Workshop (2013) found precision between states and even within ageing labs to be low and highly variable. 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.

Juvenile alewife and blueback production in the upper bay increased in 2015, as would be expected with a moratorium in place and appropriate environmental conditions during the spawn and hatching periods. The 2015 upper bay GM CPUE was the highest index since 1970. Production in the Nanticoke River increased as well, but not as dramatically as in the upper bay.

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Table 1. Percentage of sites with clupeid eggs or larvae and number of sites sampled in the Nanticoke River (2005-2015).

Year	Total Sites	Percent of Sites with Clupeid Eggs/Larvae
2005	80	5.0
2006	80	0.0
2007	78	0.0
2008	109	0.0
2009	97	8.2
2010	70	42.9
2011	73	32.9
2012	86	0.0
2013	69	21.7
2014	62	24.2
2015	76	27.6

Table 2. Number of adult American shad and repeat spawners by sex and age sampled from the Conowingo Dam tailrace (hook and line) and Potomac River (gill net) in 2015.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	19	0	2	1	21	1
4	59	12	22	8	81	20
5	60	35	66	44	126	79
6	14	11	29	22	43	33
7	0	0	7	6	7	6
8	0	0	1	1	1	1
9	0	0	0	0	0	0
Totals	152	58	127	82	279	140
Percent Repeats	38.2%		64.6%		50.2%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	3	0	1	0	4	0
4	7	2	3	1	10	3
5	21	13	34	24	55	37
6	8	8	34	24	42	32
7	6	6	3	2	9	8
Totals	45	29	75	51	120	80
Percent Repeats	64.4%		68.0%		66.7%	

Table 3. Number of recaptured American shad in 2015 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
Yellow	2014	2	Yellow	2014	1
Blue	2015	7	Blue	2015	7

Table 4. 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	429	45.34	44.8%	10.04	6341.43
2	Temp + Flow	Tweedie	429	35.88	46.6%	2.72	3640.97
3	Temp + Flow	Negative Binomial	429	35.51	42.6%	0.84	3683.65
4	Temp	Poisson	429	36.78	42.2%	10.22	6523.36
5	Temp	Tweedie	429	33.53	45.3%	2.73	3645.69
6	Temp	Negative Binomial	429	33.60	41.3%	0.84	3687.81

Table 5. Catch, effort and catch-per-angler-hour (CPAH) from the recreational creel survey in the Susquehanna River below Conowingo Dam, 2001-2015. 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

Table 6. Catch, effort and catch-per-angler-hour (CPAH) from spring logbooks for American shad, 2000-2015. Multiple logbooks were used from 2000 until 2003. 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
2000	10	404.0	3,137	7.76
2001	8	272.5	1,647	6.04
2002	8	331.5	1,799	5.43
2003	9	530.0	1,222	2.31
2004	15	291.0	1035	3.56
2005	12	258.5	533	2.06
2006	16	639.0	747	1.17
2007	10	242.0	873	3.61
2008	14	559.5	1,269	2.27
2009	15	378.0	967	2.56
2010	16	429.5	857	2.00
2011	9	174.0	413	2.37
2012	5	180.5	491	2.77
2013	6	217.3	313	1.44
2014	16	228.0	467	2.05
2015	11	154.0	348	2.18

Table 7. Number of adult hickory shad and repeat spawners by sex and age sampled from the brood stock collection survey in Deer Creek (Susquehanna River tributary) in 2015.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	1	0	0	0	1	0
3	19	0	15	0	34	0
4	23	20	26	19	49	39
5	10	9	13	13	23	22
6	3	3	3	3	6	6
Totals	56	32	57	35	113	67
Percent Repeats	57.1%		61.4%		59.3%	

Table 8. Percent of hickory shad by age and number sampled from the brood stock collection survey in Deer Creek (Susquehanna River tributary) by year, 2004-2015.

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			

Table 9. Percent repeat spawning hickory shad (sexes combined) by year from the brood stock collection survey in Deer Creek (Susquehanna River tributary), 2004-2015.

Year	N	Percent Repeats
2004	80	68.8
2005	80	82.5
2006	178	67.4
2007	139	79.1
2008	149	83.9
2009	118	89.0
2010	240	75.4
2011	216	68.5
2012	200	64.0
2013	193	74.1
2014	100	59.0
2015	113	59.3

Table 10. Catch, effort and catch-per-angler-hour (CPAH) from logbooks for hickory shad, 1998-2015. Multiple logbooks were used from 1998 until 2003. Since 2014, data from Maryland's Volunteer Angler Shad Survey has been combined with logbook data.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad	Catch Per Angler Hour
1998	19	600	4,980	8.30
1999	15	817	5,115	6.26
2000	14	655	3,171	14.8
2001	13	533	2,515	4.72
2002	11	476	2,433	5.11
2003	14	635	3,143	4.95
2004	18	750	3,225	4.30
2005	19	474	2,094	4.42
2006	20	766	4,902	6.40
2007	17	401	3,357	8.37
2008	22	942	5,465	5.80
2009	15	561	2,022	3.60
2010	16	552	1,956	3.54
2011	9	224	1,802	8.03
2012	6	198	867	4.38
2013	6	259	1,679	6.49
2014	19	275	1,204	4.38
2015	15	197	371	1.88

Table 11. Counts of species (other than alewife and blueback) captured in the North East River gill net survey from 2013-2015.

Species	2013	2014	2015
Striped Bass	39	39	42
White Perch	287	227	1,273
Menhaden	145	145	476
Gizzard Shad	2,617	850	104
Goldfish	2	0	2
Carp	2	1	2
White Sucker	3	1	1
White Catfish	1	1	0
Brown Bullhead	66	132	78
Channel Catfish	17	45	50
Largemouth Bass	1	0	1
Pumpkinseed	1	1	2
Walleye	0	1	0
Hickory Shad	19	25	5
American Shad	0	2	0
Blue catfish	0	0	1
Golden shiner	0	0	1
Quilback	0	0	2
Yellow Perch	0	0	6

Table 12. Total instantaneous mortality for North East River alewife and blueback herring (sexes combined) for 2013-2015. Sample size for blueback herring in 2013 was too small to calculate a reliable mortality estimate.

Species	2013	2014	2015
Alewife Herring	0.81	1.10	1.31
Blueback Herring	-	0.98	1.71

Figure 1. Conowingo Dam Tailrace (Susquehanna River) hook and line sampling location for American shad in 2015.

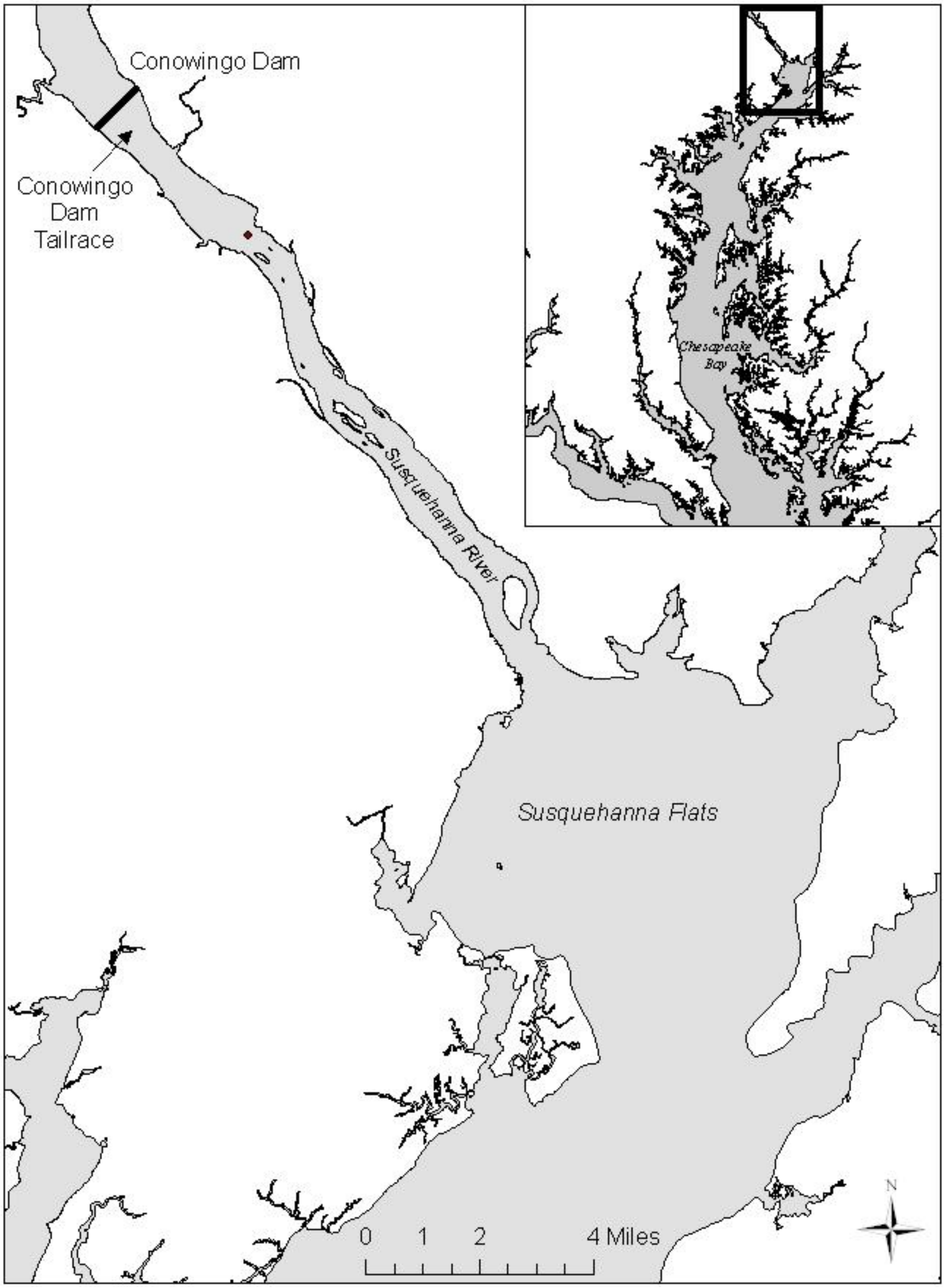


Figure 2. Nanticoke River sites for alosine ichthyoplankton sampling in 2015.

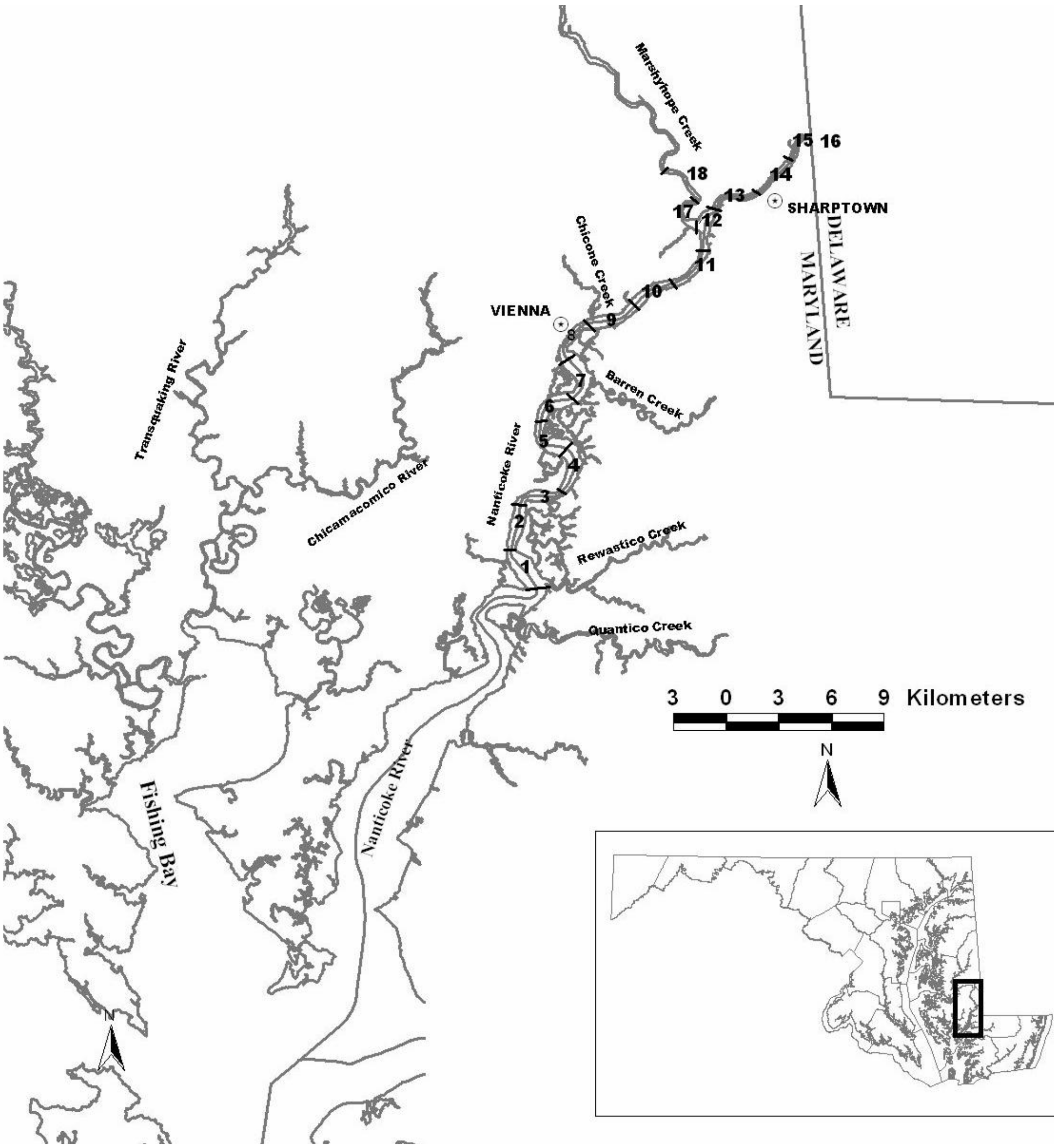


Figure 3. Grid of 1000ft x 1000ft squares overlaid on a map of the North East River from which sites were randomly chosen for the North East River sinking gill net survey, 2013-2015.

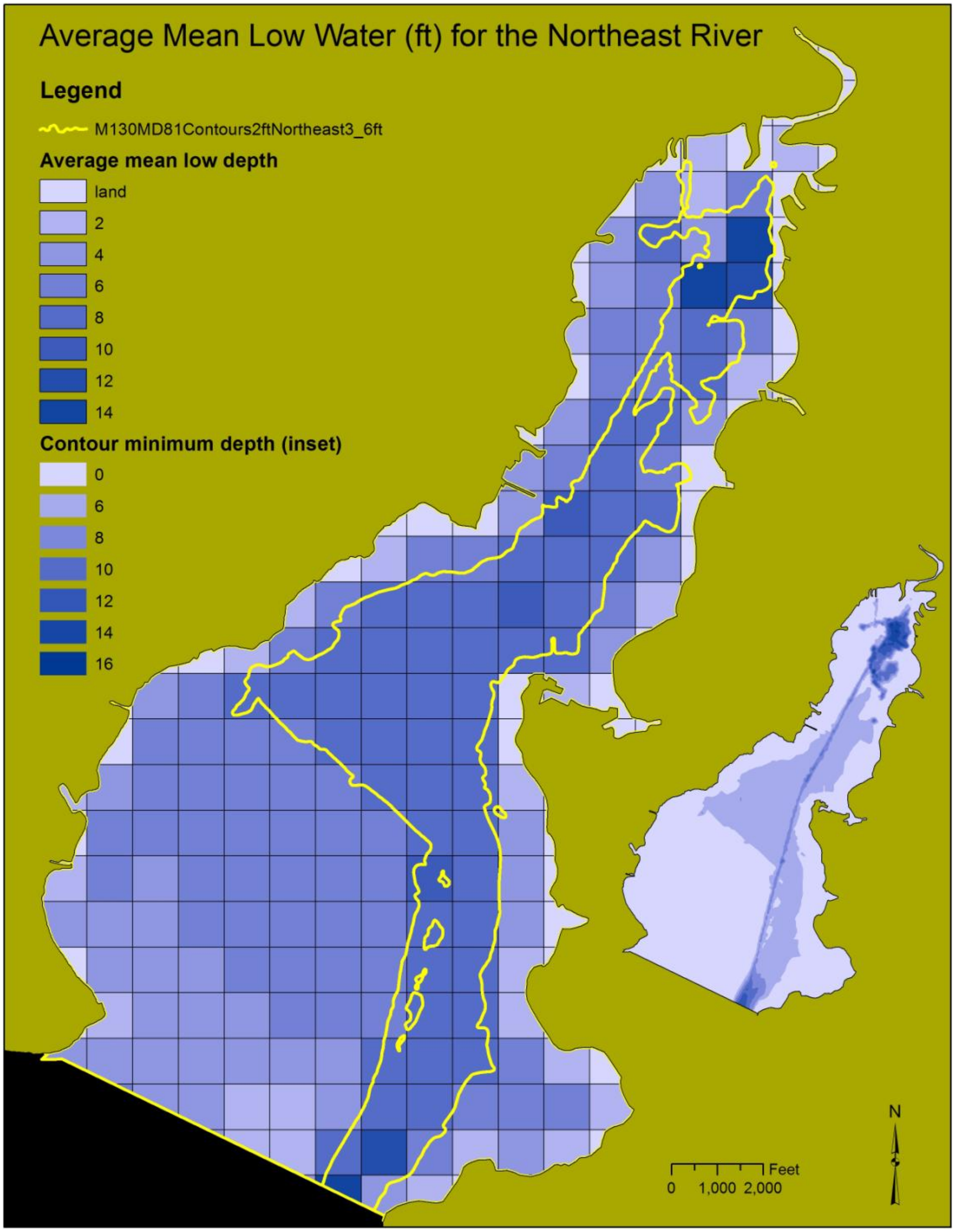


Figure 4. Percent of American shad repeat spawners by sex collected in the Conowingo Dam tailrace (1982-2015).

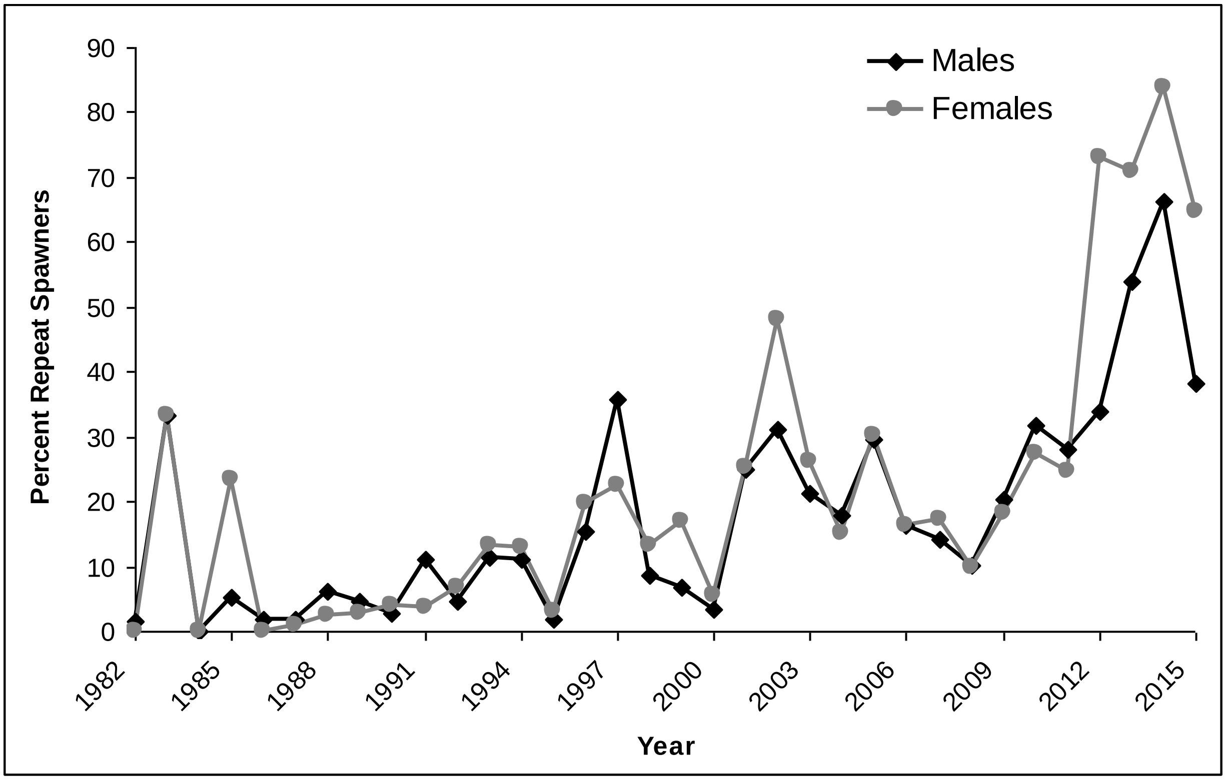


Figure 5. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2015.

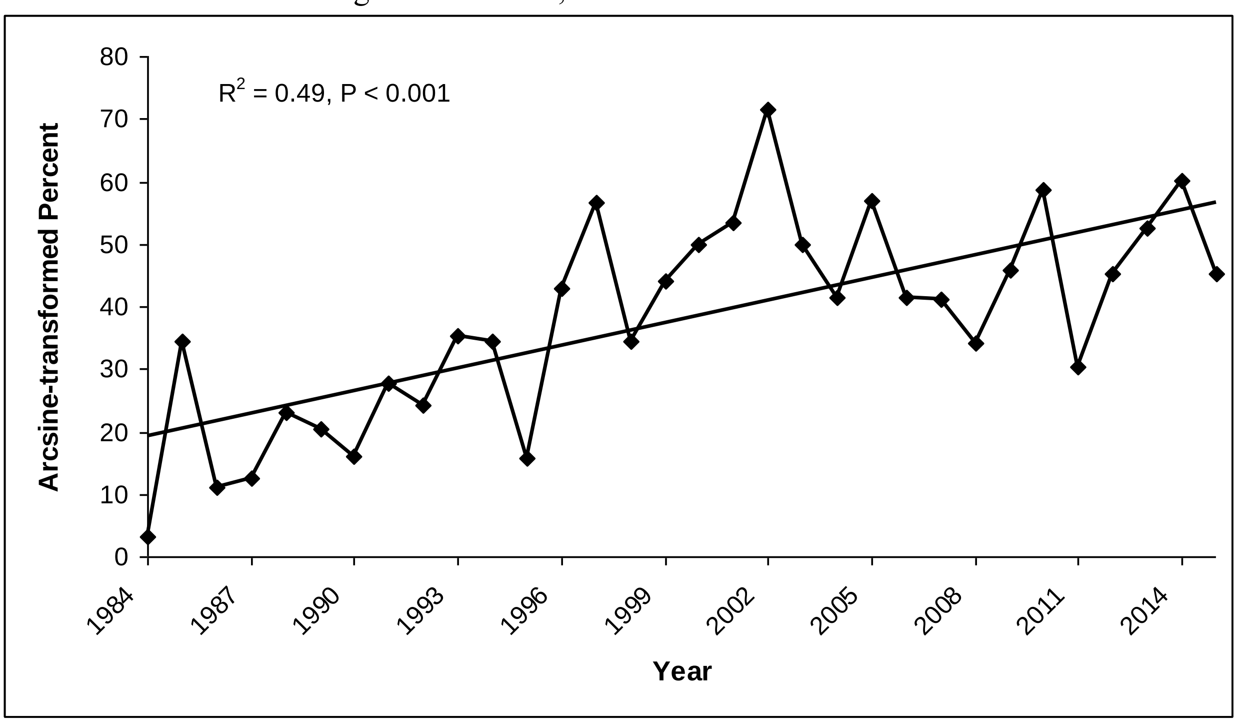


Figure 6. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River, 2002-2015.

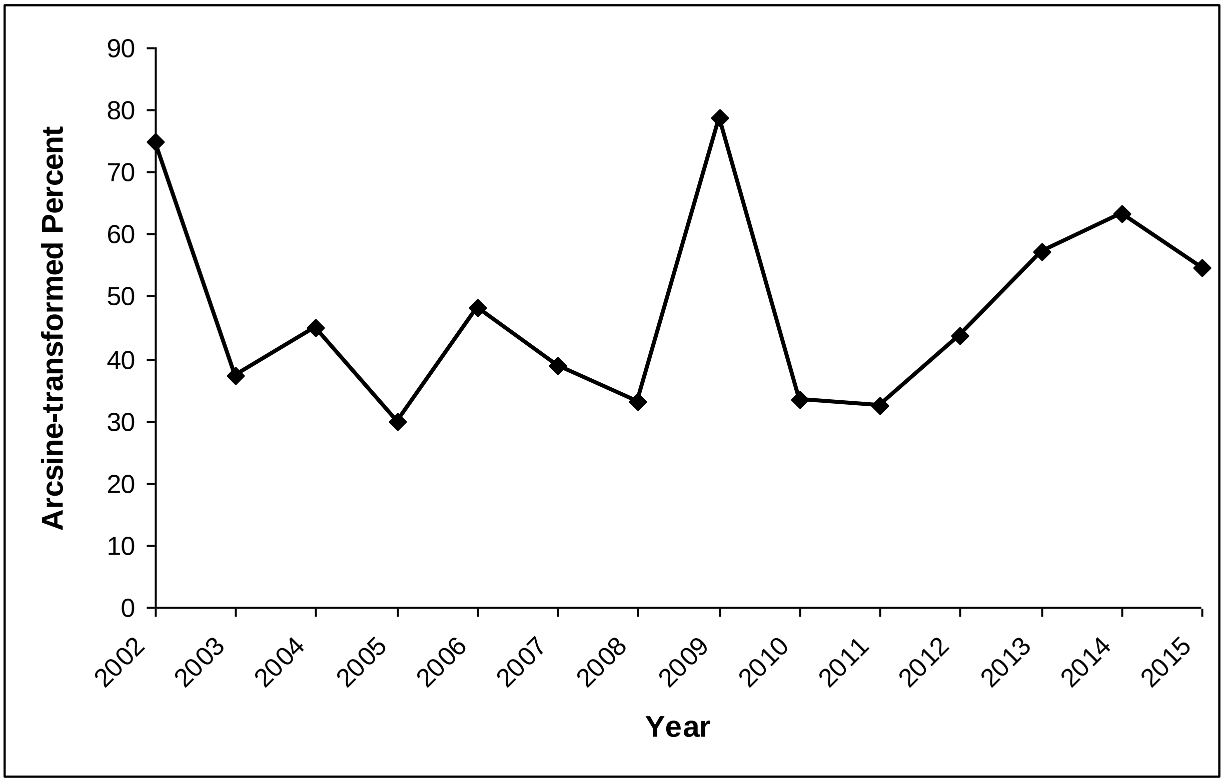


Figure 7. Pearson residuals from the best fit generalized additive model (GAM) used to standardize the Susquehanna River hook and line catch per unit effort (CPUE) index.

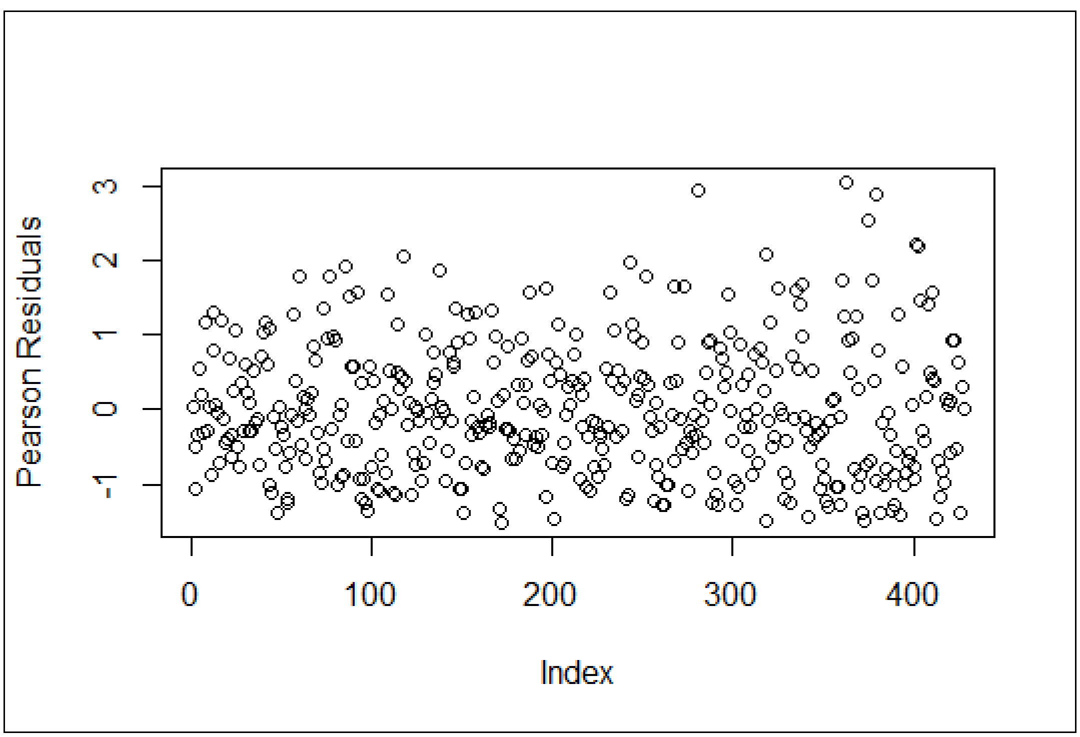


Figure 8. American shad standardized CPUE with 95% confidence intervals estimated by a generalized additive model for the Conowingo Dam tailrace hook and line sampling, 1987-2015.

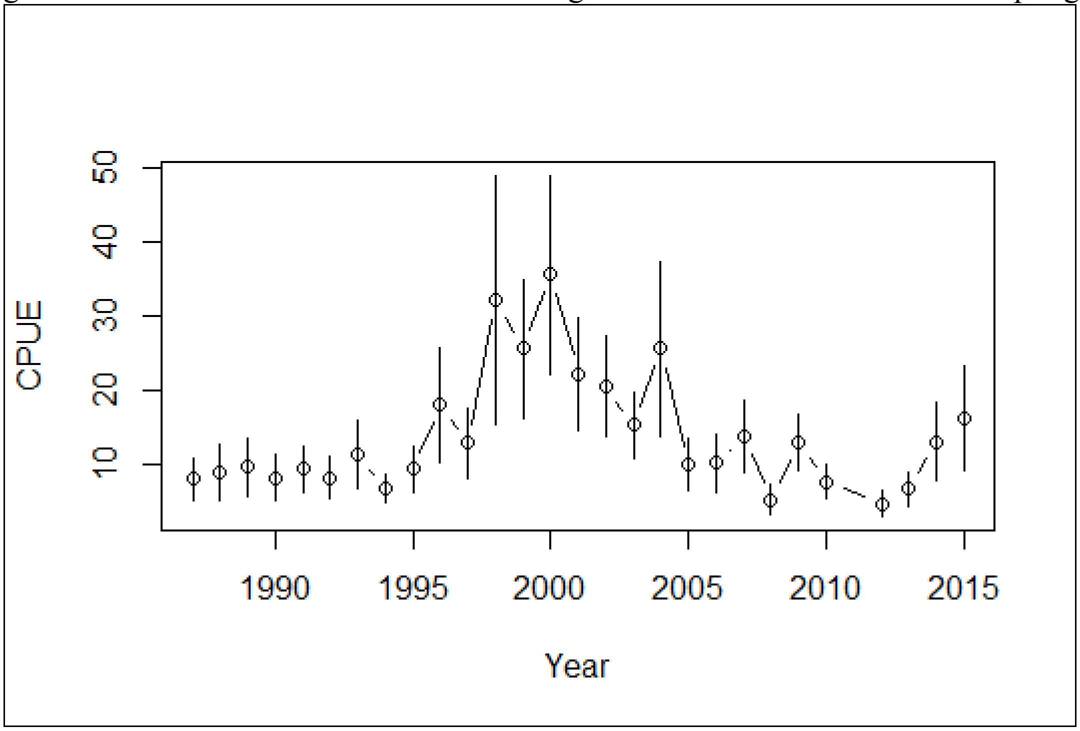


Figure 9. American shad geometric mean CPUE (fish per lift hour) and the total number of American shad lifted at the East and West Fish Lifts at the Conowingo Dam, 1991-2015.

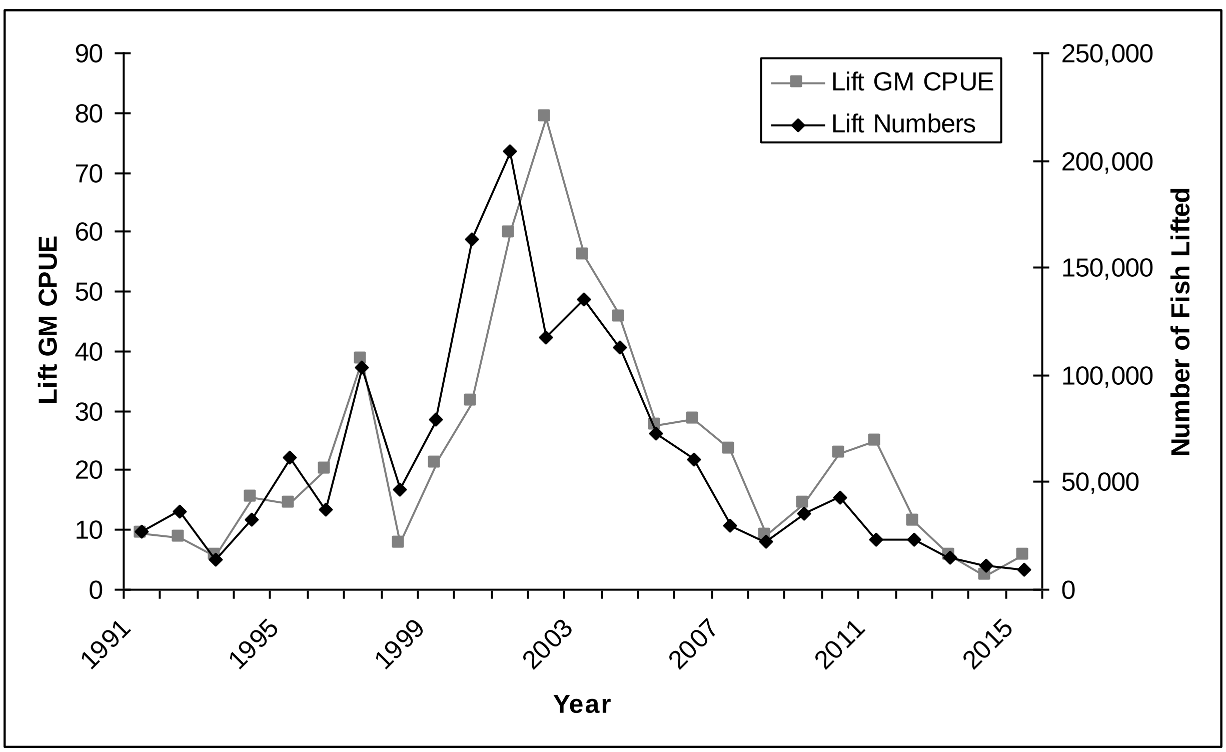


Figure 10. American shad geometric mean CPUE (fish per 1,000 square yards of experimental drift gill net per hour fished) from the Potomac River, 1996-2015.

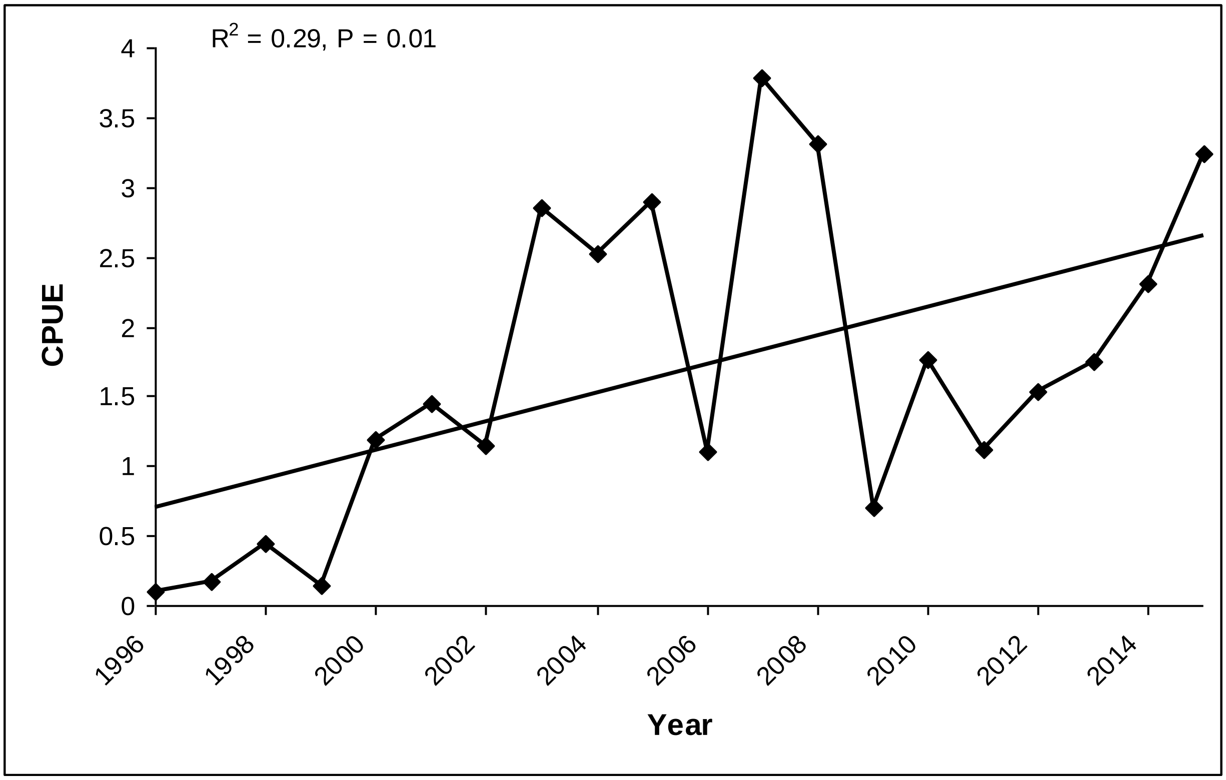


Figure 11. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic with 95% confidence limits, 1986-2015.

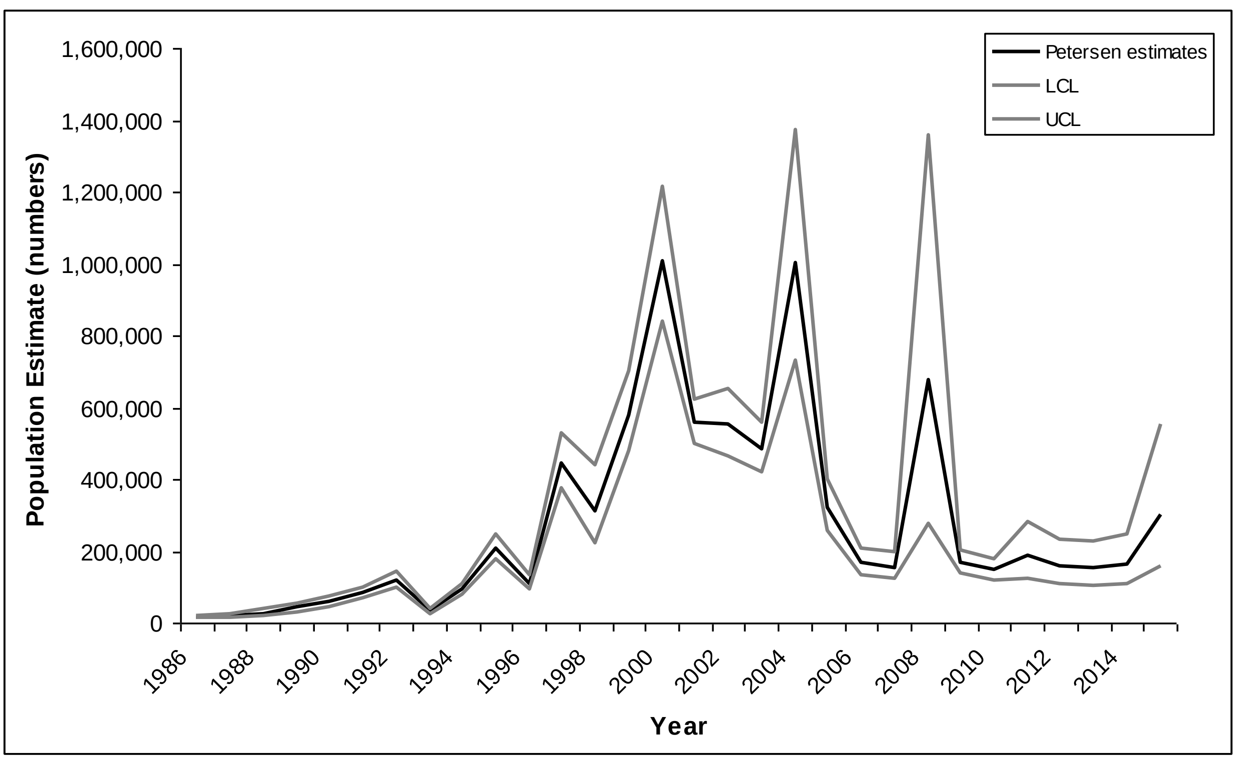


Figure 12. Conowingo Dam tailrace adult American shad abundance estimates from the surplus production model (SPM), 1986-2015.

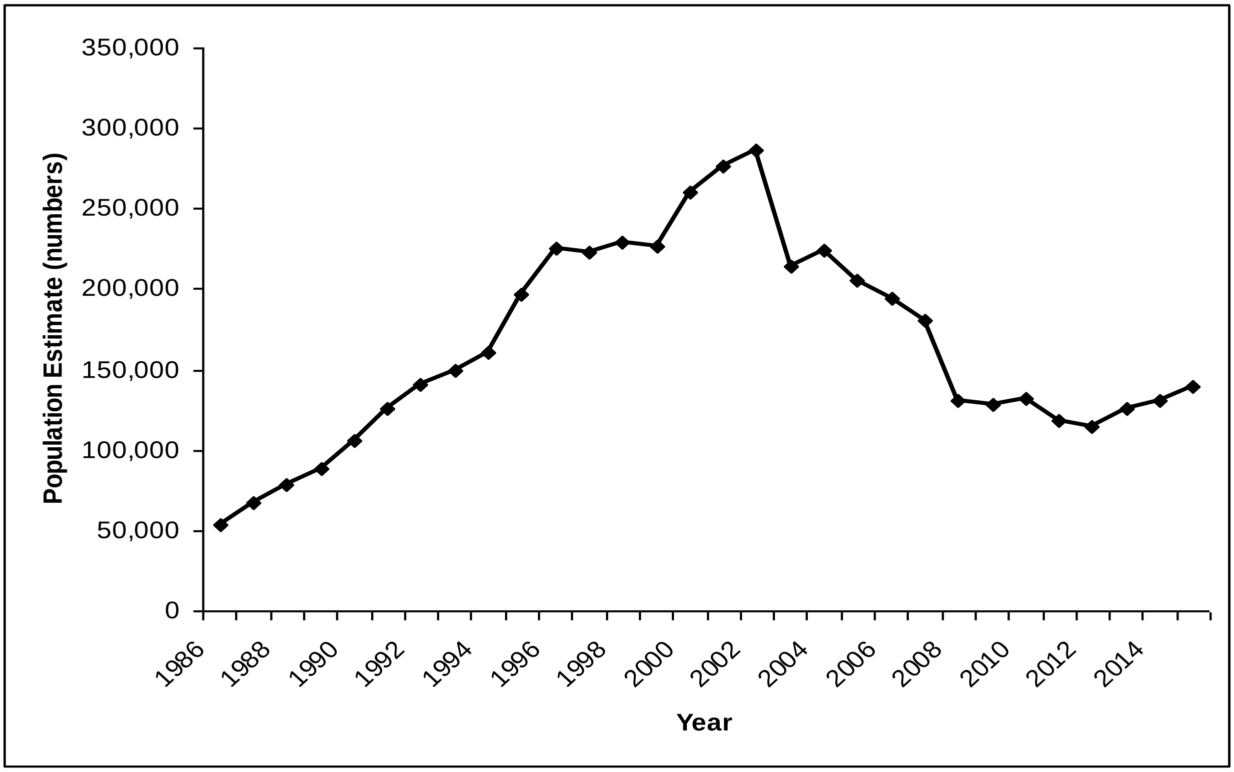


Figure 13. Baywide juvenile American shad geometric mean CPUE (catch per haul), 1959-2015.

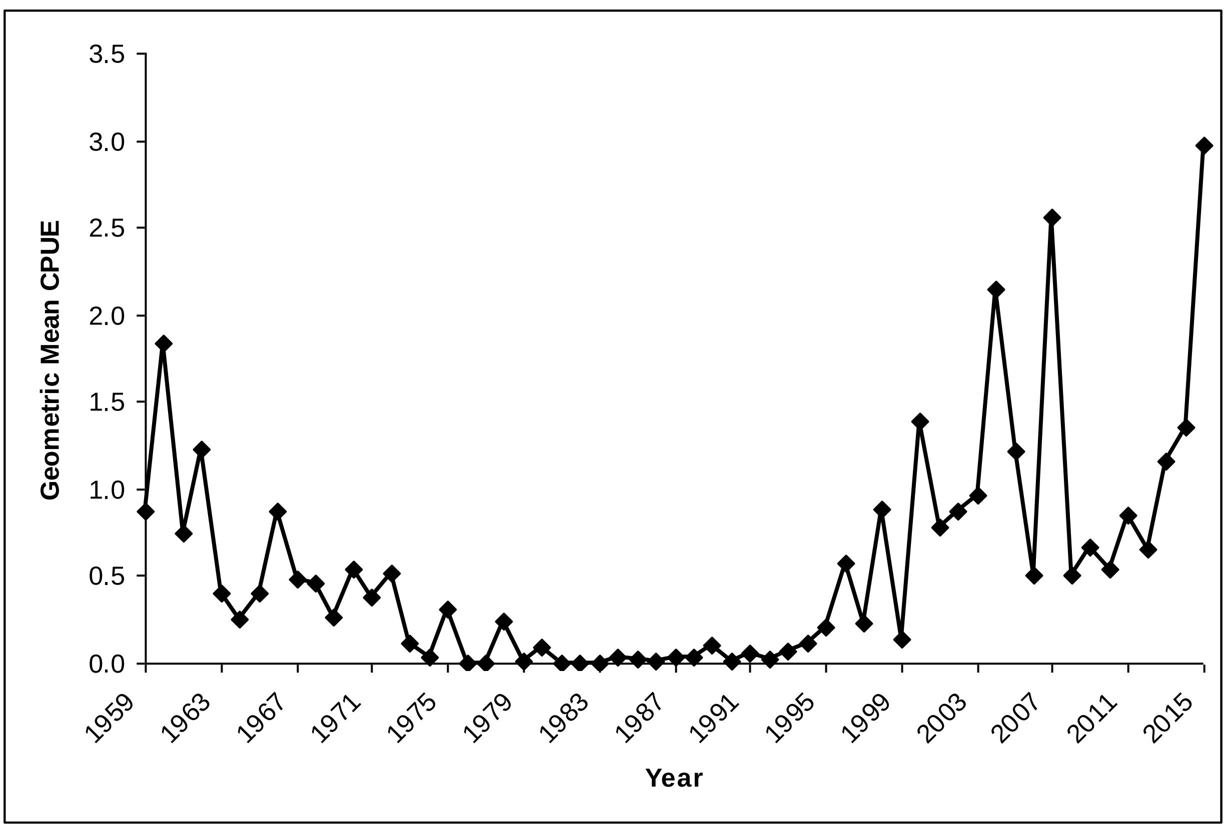


Figure 14. Upper Chesapeake Bay juvenile American shad geometric mean CPUE (catch per haul), 1959-2015.

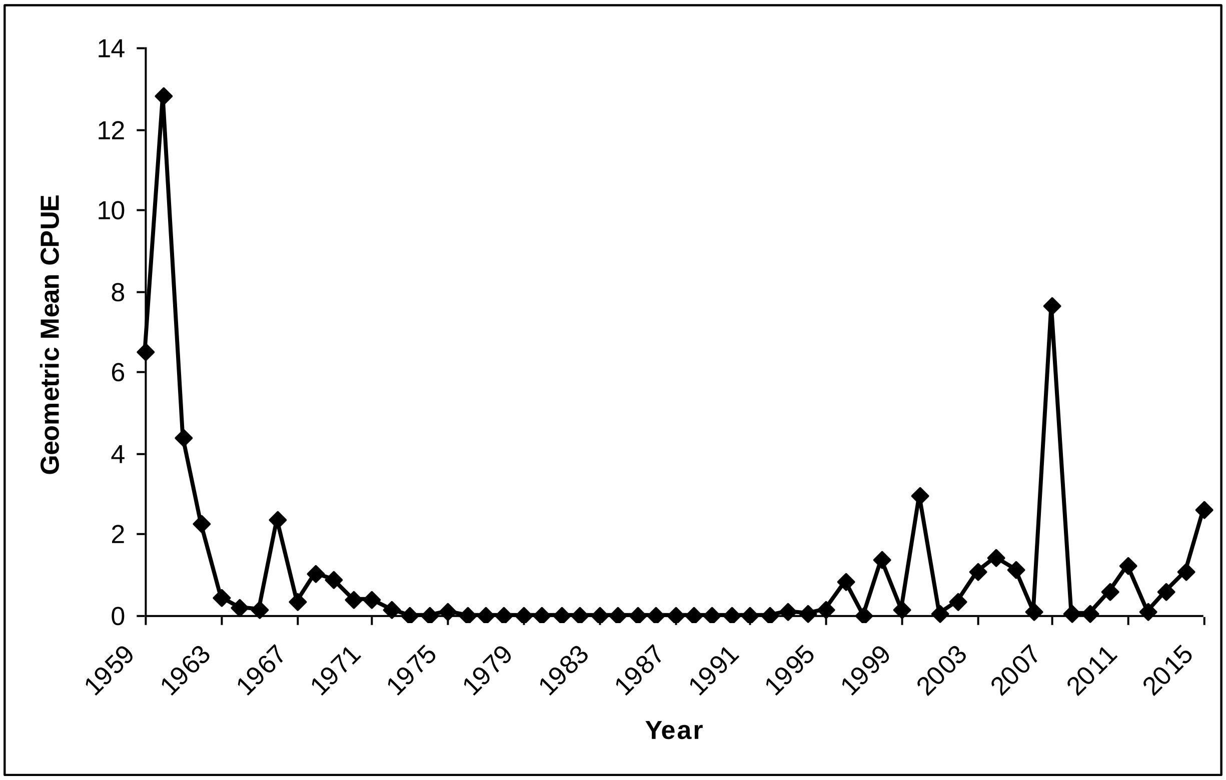


Figure 15. Potomac River juvenile American shad geometric mean CPUE (catch per haul), 1959-2015.

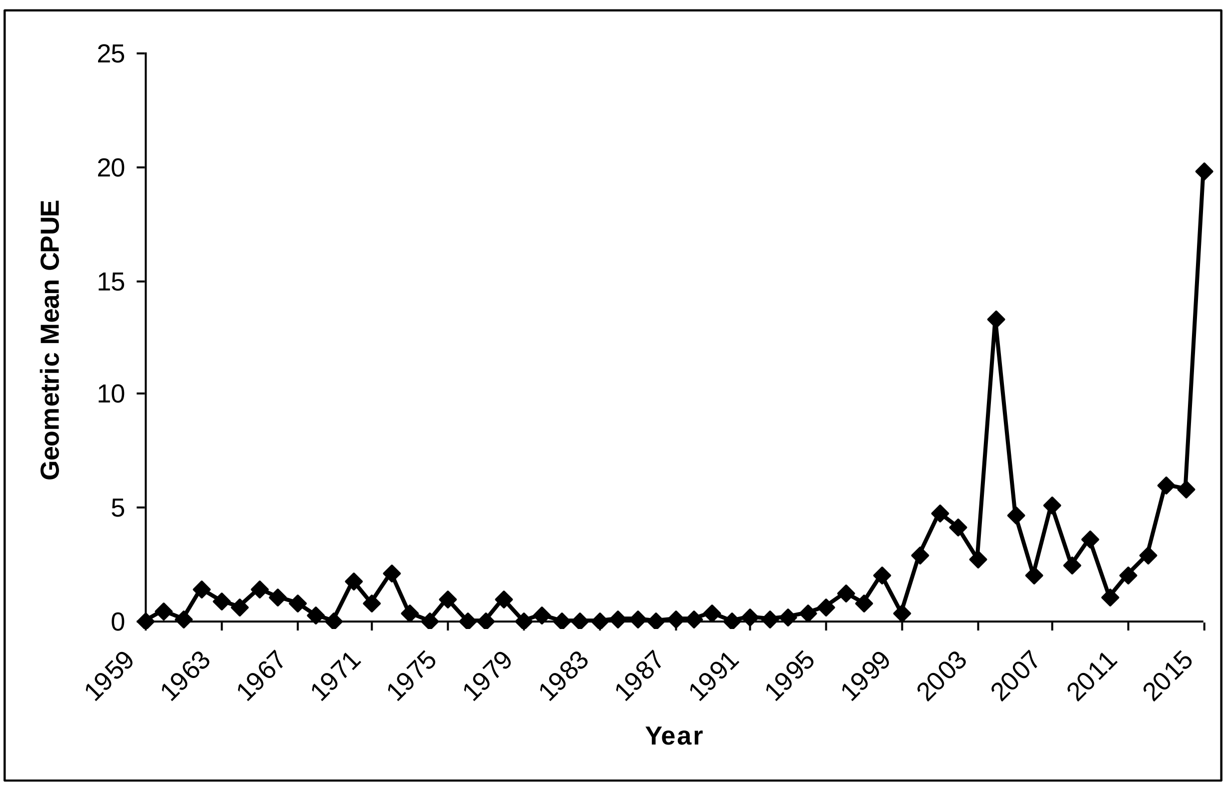


Figure 16. Nanticoke River juvenile American shad geometric mean CPUE (catch per haul), 1959-2015.

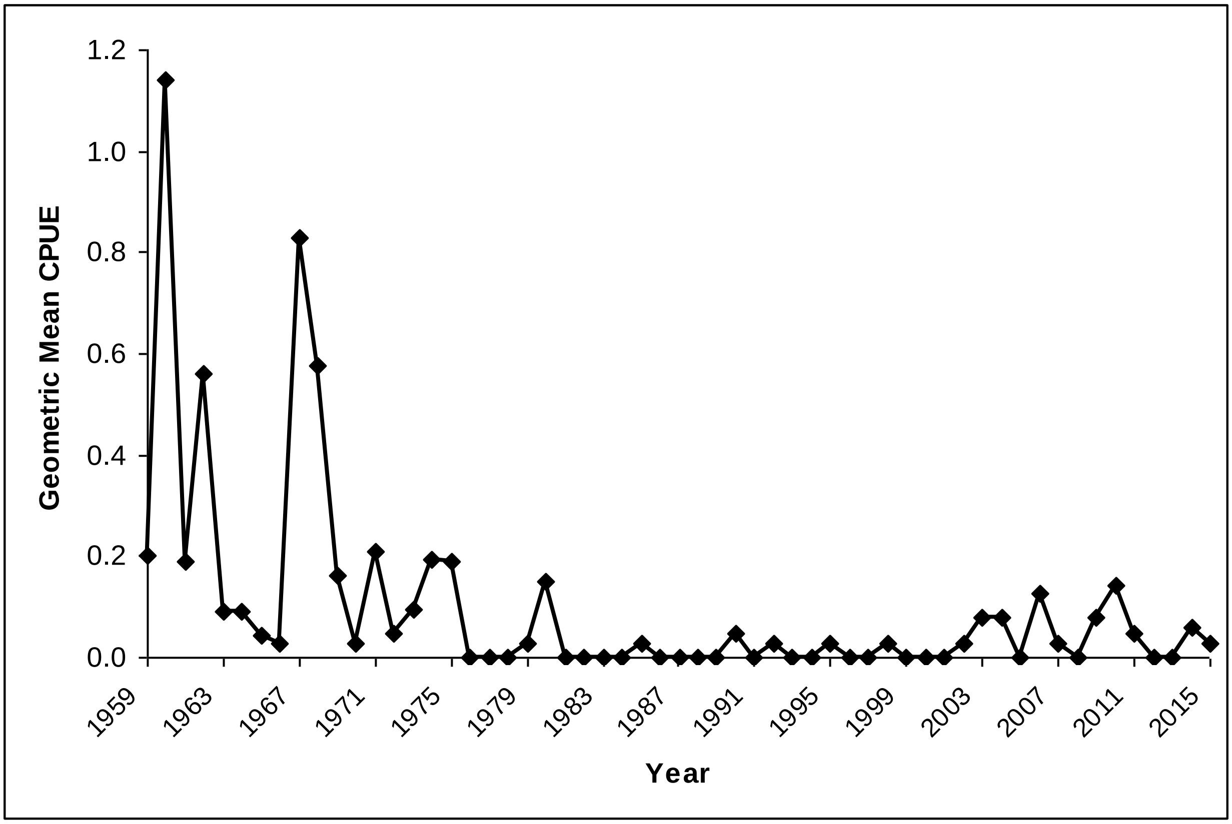


Figure 17. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from Deer Creek (Susquehanna River tributary), 2004-2015.

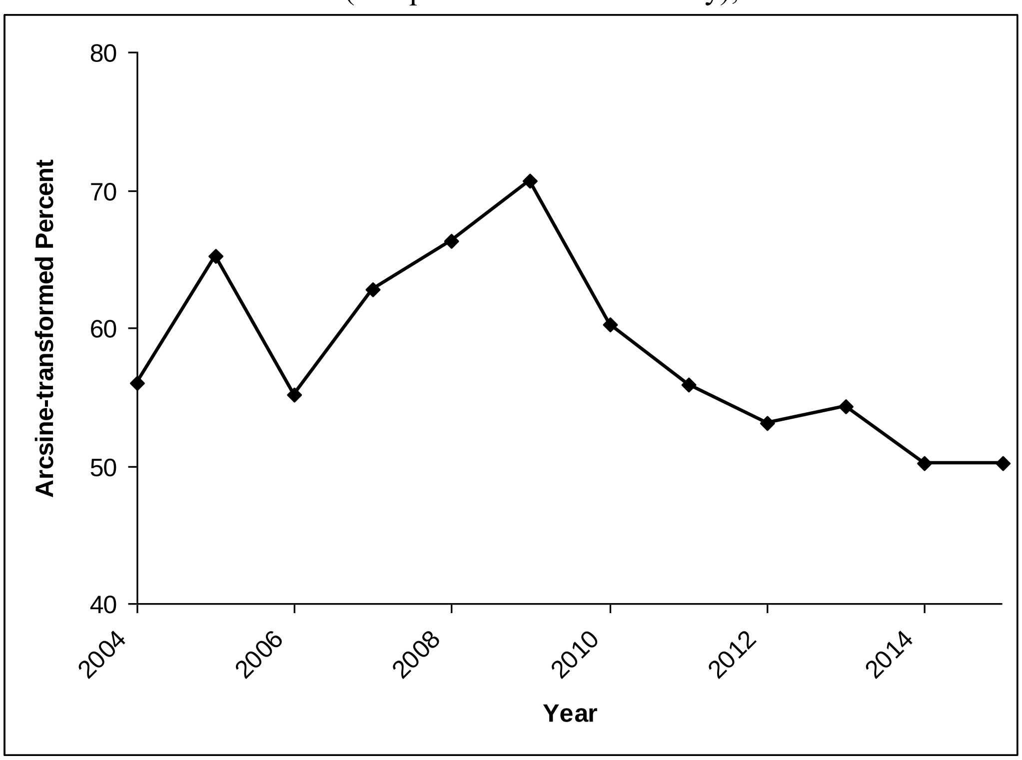


Figure 18. Total catch of alewife herring (AH) and blueback herring (BH) by the North East River gill net survey, 2013-2015.

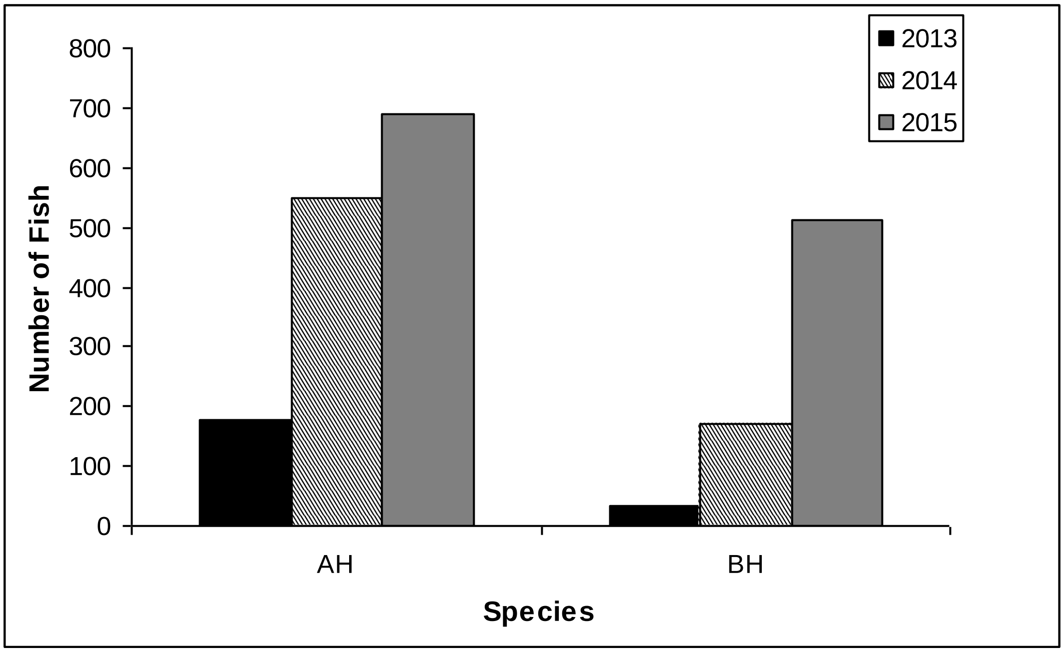


Figure 19. North East River catch per day of alewife and blueback herring, plotted with surface water temperature for 2015.

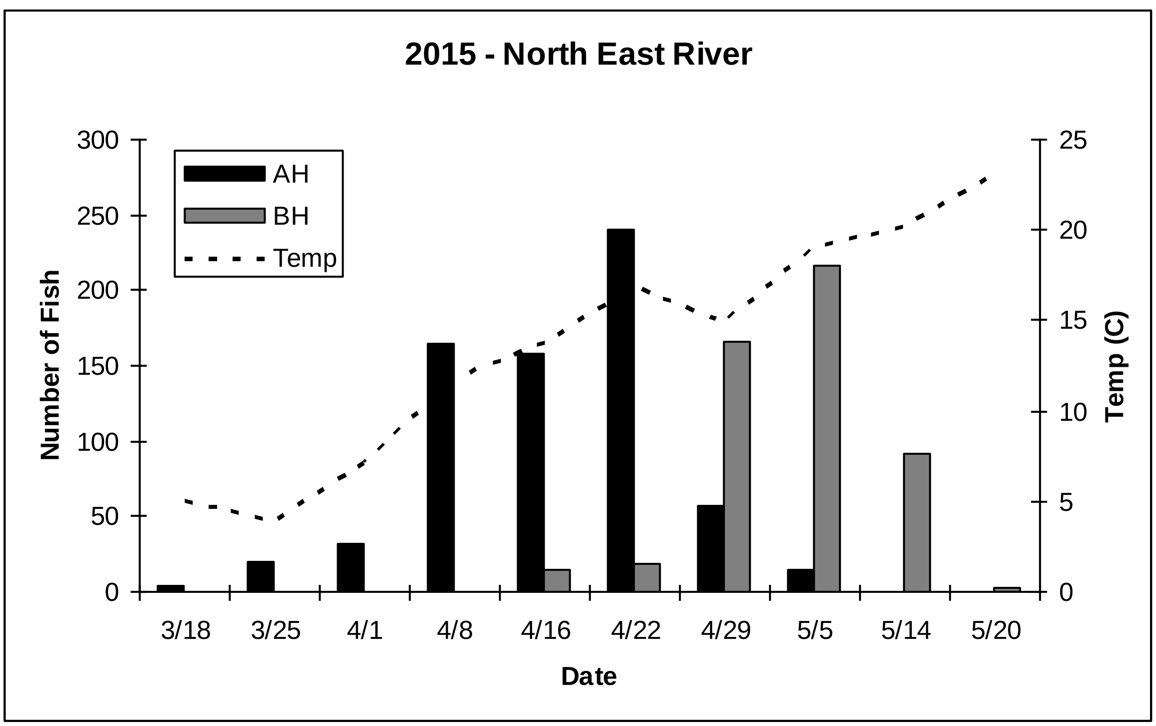


Figure 20. Percent of total catch by mesh size of alewife herring from the North East River, 2013-2015.

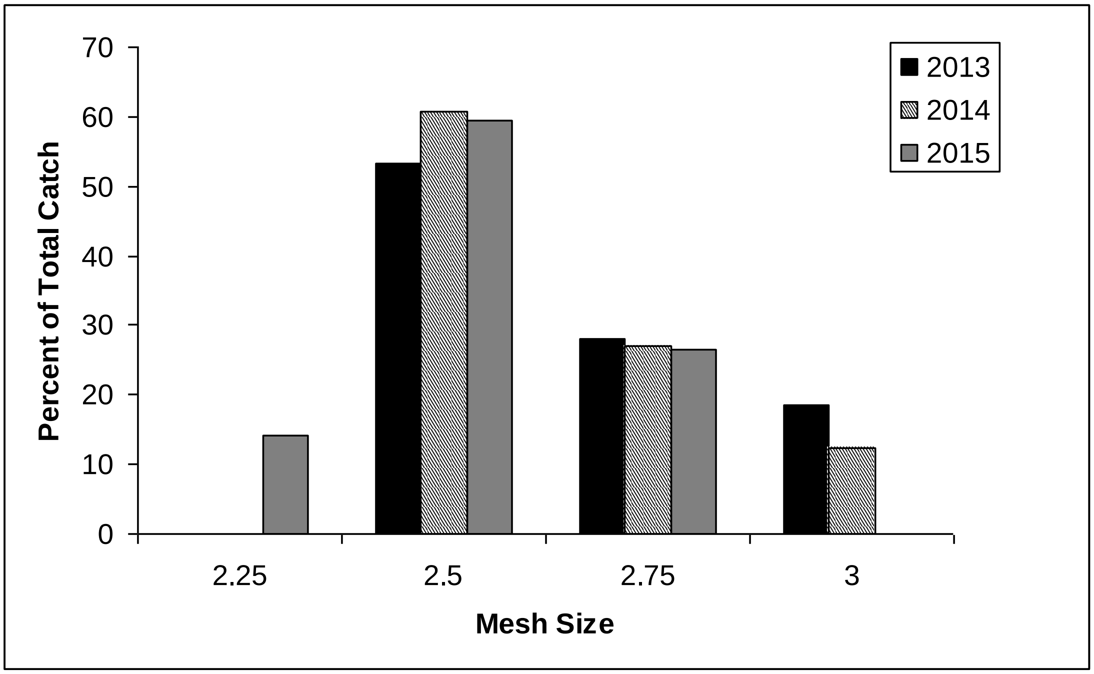


Figure 21. Percent of total catch by mesh size of blueback herring from the North East River, 2013-2015.

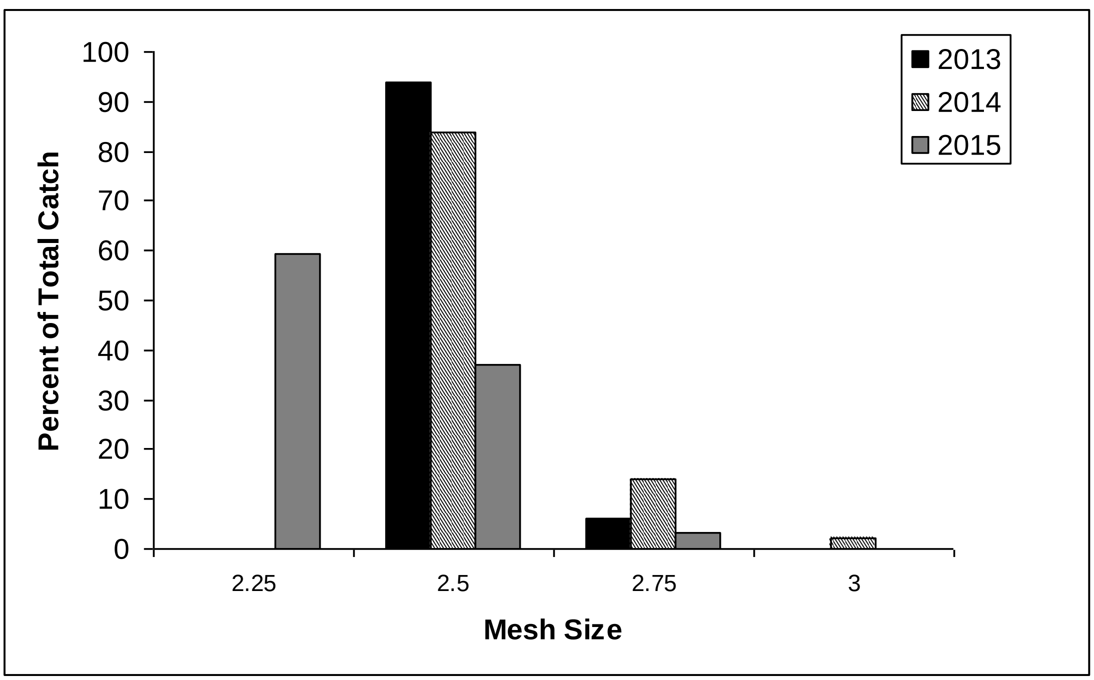


Figure 22. Percent catch-at-age by year of alewife herring from the North East River, 2013-2015.

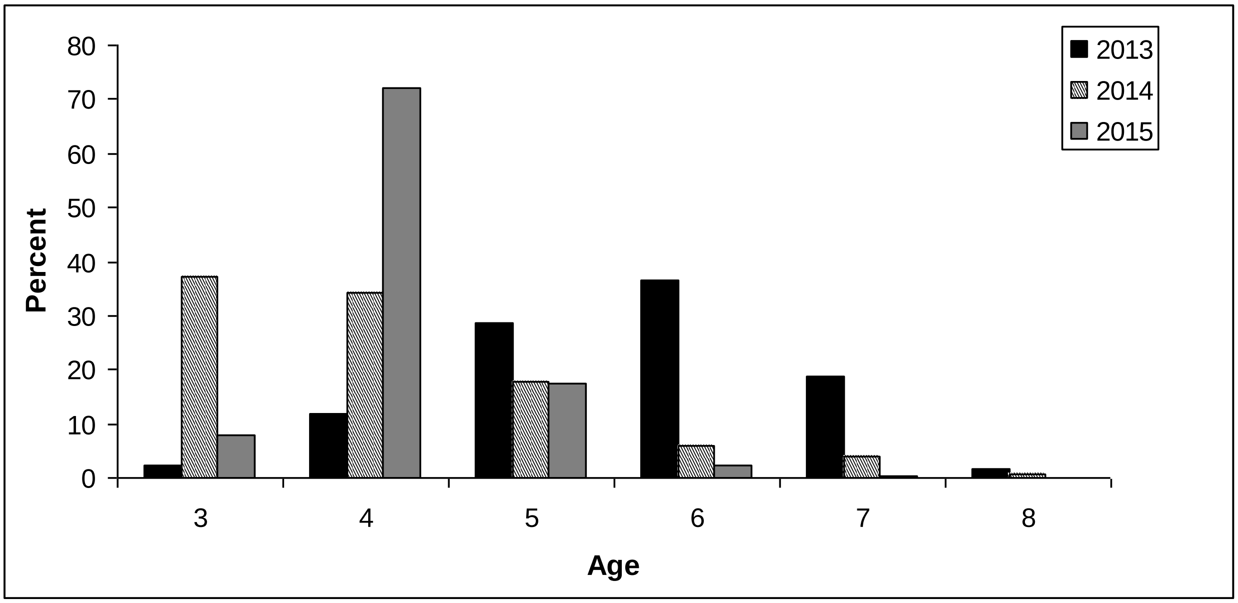


Figure 23. Percent catch-at-age by year of blueback herring from the North East River, 2013-2015.

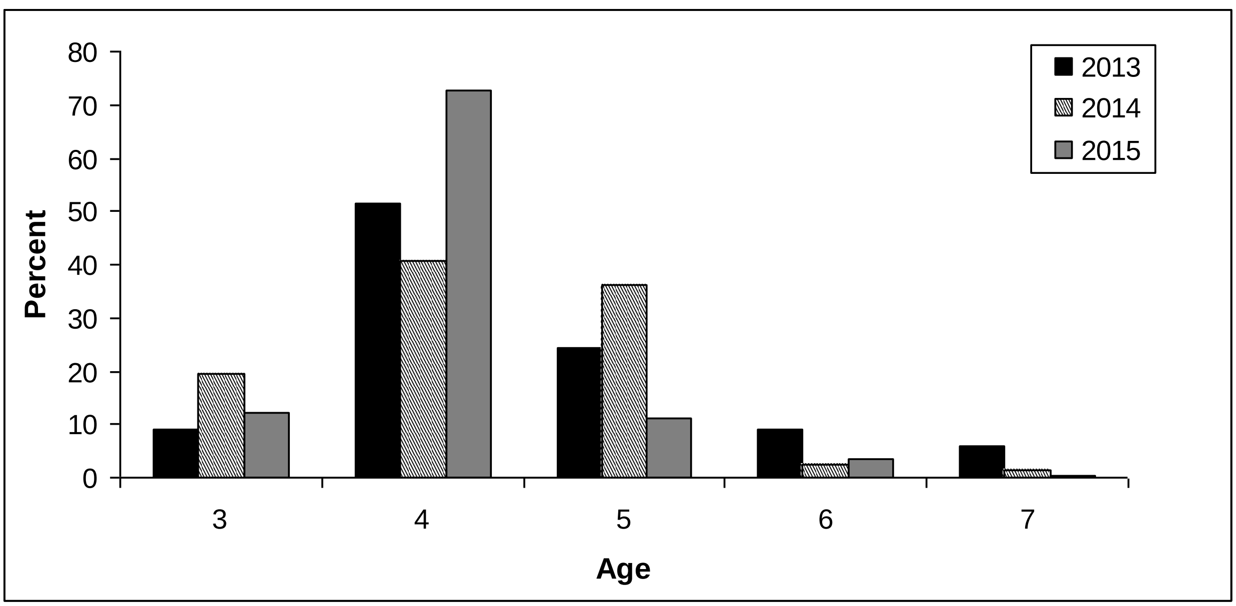


Figure 24. Alewife and blueback herring CPUE (number of fish caught per set of experimental gill net per hour fished) from the North East River gill net survey, 2013-2015. Catch was pooled across the 2.5 and 2.75" mesh panels for all years.

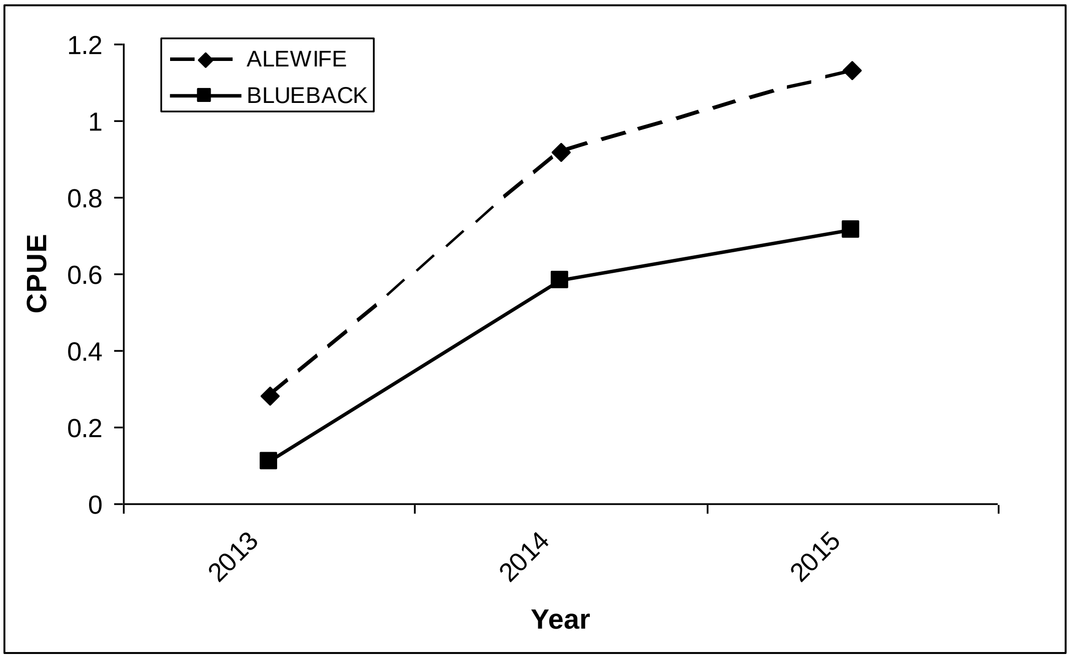


Figure 25. Upper Bay juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2015.

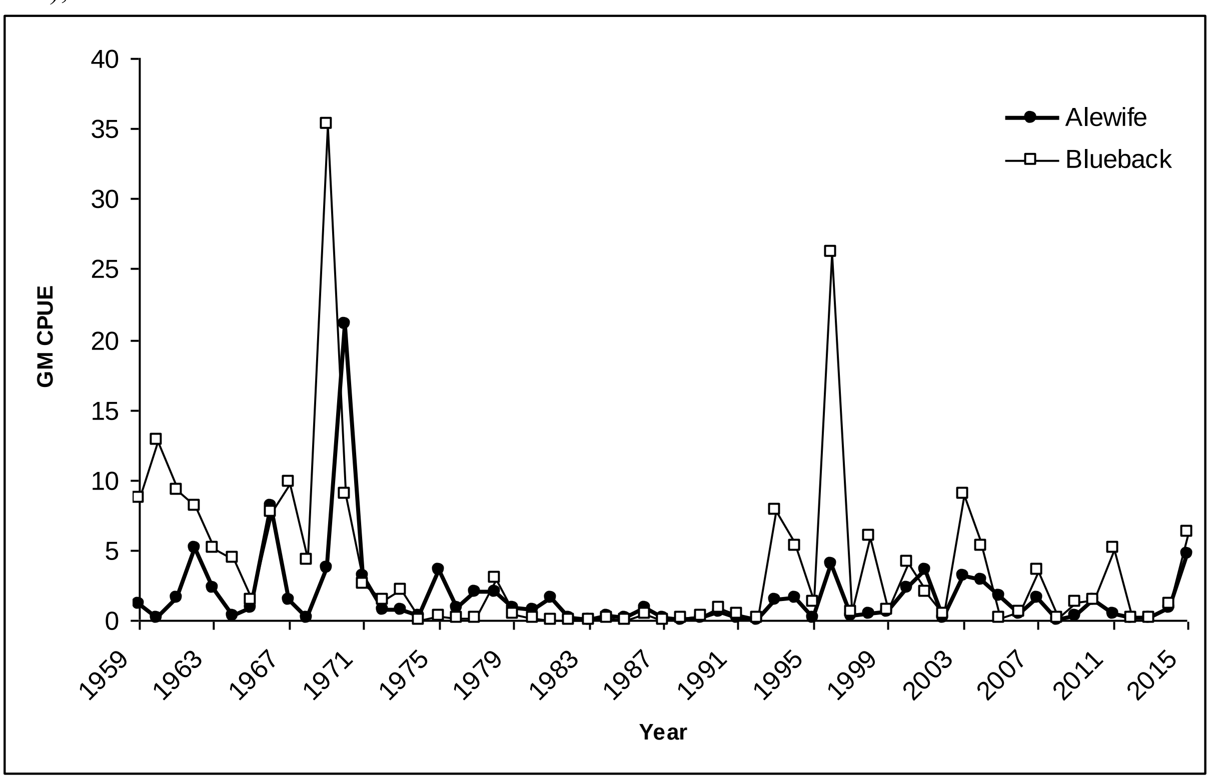
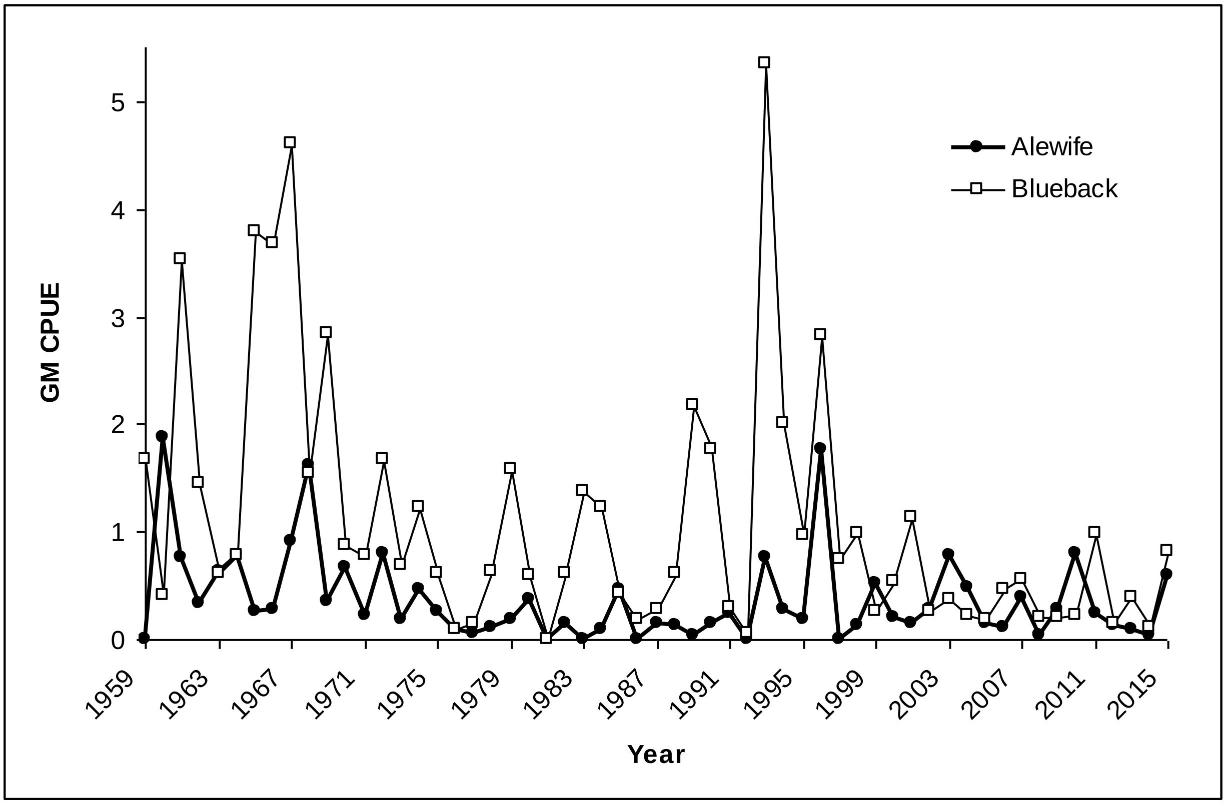


Figure 26. Nanticoke River juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2015.



PROJECT NO. 2
JOB NO. 2

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

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

INTRODUCTION

The primary objective of Project 2 Job 2 was to characterize recreationally important migratory finfish stocks in Maryland's Chesapeake Bay by age, length, weight, growth and sex. Weakfish (*Cynoscion regalis*), bluefish (*Pomatomus saltatrix*), Atlantic croaker (*Micropogonias undulates*), summer flounder (*Paralichthys dentatus*) and spot (*Leiostomus xanthurus*) are very important sport fish in Maryland's Chesapeake Bay. Red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), spotted seatrout (*Cynoscion nebulosus*) and Spanish mackerel (*Scomberomorus maculates*) 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 sport fish (Hartman and Brandt 1995, Overton et al 2000).

The Maryland Department of Natural Resources (MD DNR) has conducted summer pound net sampling for these species 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 for the Chesapeake Bay, the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC).

This information is also utilized by the MD DNR in managing the state's valuable migratory finfish resources through the regulatory/statutory process.

METHODS

Data Collection

The onboard pound net survey relies on cooperation of pound net fishermen. Pound nets from the lower Chesapeake Bay and Potomac River have been monitored throughout the 23 years of this survey (1993-2015). However, since no cooperating fishermen could be located on the lower Potomac River, sampling was not conducted in this area for 2009, but sampling resumed in 2010. In 2015 commercial pound nets were sampled at the mouth of Potomac River, Hooper Straight, the mouth of the Nanticoke 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. The commercial fishermen set all nets sampled as part of their regular fishing routine. Net soak time and manner in which they were fished were consistent with the fisherman's day-to-day operations.

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 (ppt), GPS coordinates (NAD 83), date and hours fished were also recorded at each net. Hours fished was not entered in the data base if the net was not emptied on the day of sampling or the previous day fished.

Otoliths were taken and weight (g), TL (mm) and sex were determined from a sub sample of weakfish, spot and Atlantic croaker. Prior to 2011, Atlantic croaker and weakfish otoliths were processed and aged by the South Carolina Department of Natural Resources (SC DNR). Otoliths from 2011 to 2015 were aged by MD DNR biologists. All spot otoliths from 2015 were processed and aged by MD DNR, as in previous years. For all three species, the left otolith from each specimen was mounted to a glass slide for sectioning. If the left otolith was damaged, missing or miss cut the right otolith was substituted. Otoliths were mounted in Crystalbond 509 and were sectioned with a Buehler IsoMet® Low Speed Saw using two blades separated by a 0.4 mm spacer. The Buehler 15 HC diamond wafering blades are 101.6 mm in diameter and 0.3048 mm thick. The 0.4 mm sections were then mounted on microscope slides and viewed under a microscope at 5X to 6X 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, except in 2013. In 2013 two readers made initial age evaluations, but due to logistical limitations only one reader reexamined structures in which annuli counts differed. Menhaden scales were aged by two MD DNR 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 and spawning history using an Anacomp Inc. Micron 385 microfiche reader. In 2015 the Atlantic States marine Fisheries Commission (ASMFC) conducted an

Atlantic menhaden aging workshop. It was determined that MD DNR 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, therefore Atlantic menhaden ages prior to 2015 may be biased high.

A fishery independent gill net survey targeting adult Atlantic croaker, spot, bluefish and Atlantic menhaden 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. The survey uses a simple random design in which the river has been divided into a block grid, with each block being a 547m square (Figure 3). An experimental gill net constructed of four 30.5m by 1.8m net panels with stretch mesh sizes of 6.4 cm (2.5 inches), 7.6 cm (3.0 inches), 8.9 cm (3.5 inches) and 10.2 cm (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 1.2m gap. Nets were rigged to sink using 5/8 inch float core line and 65 lb. lead core line and mesh constructed of number 8 monofilament netting, except for the 6.4 cm mesh which was constructed of number 4 monofilament. Four sampling blocks were sampled each day beginning approximately 30 minutes prior to sunrise. A GPS unit was used to find 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 1.5m or more than 12.2 meters to avoid net inefficiency at shallow sites or potential areas of hypoxia at deeper sites. Nets soaked for one hour prior to retrieval.

Immediately following deployment of each set of nets the time, weather, wind speed (knots), wind direction, tidal stage, water temperature (°C), salinity (ppt) and secchi disk readings (meters) were recorded. All fish were enumerated by species and mesh size in which they were captured. All Atlantic croaker, spot, bluefish, white perch, striped bass, weakfish and summer founder 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 for the first five fish for each mesh panel each day (not each site).

Juvenile indices were calculated for weakfish, Atlantic croaker and spot from the MD DNR Blue Crab Trawl Survey data. This survey utilizes a 4.9 m semi-balloon otter trawl with a body and cod end of 25-mm-stretch-mesh and a 13-mm-stretch-mesh cod end liner towed for 6 min at 4.0-4.8 km/h. The systems sampled included the Chester River, Eastern Bay, Choptank River and 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 - October. Juvenile 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 on January 6, 2015. Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2014. 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. Inland 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 was from Chesapeake Bay for the target species. Since the 2015 charter log book data had not been finalized, only data through 2014 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 mm TL and K= 0.08. L_c was 305 mm TL. Von Bertalanffy parameters for croaker mortality estimates were derived from pooled ages (otoliths; n = 2,850) determined from 2003-2015 Chesapeake Bay pound net survey data, and June through September 2003-2015 measurements of age zero croaker (n=333) from MD DNR Blue Crab Trawl Survey Tangier Sound samples (Chris Walstrum MD DNR personnel communication 2015). 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 2003-2014 were L_{∞} = 389.40 mm TL and K= 0.40, while L_c for Atlantic croaker was 229 mm TL.

Annual length frequency distributions were constructed when sample size was sufficient for summer flounder, Atlantic croaker, weakfish, bluefish, spot and Atlantic menhaden, utilizing 20 mm length groups for both the onboard pound net and Choptank River gill net surveys. Length-at-age keys were constructed for weakfish, Atlantic croaker and Atlantic menhaden using age samples through 2015. Age and length data were assigned to 20 mm 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 croaker in 2000 and 2002 through 2015, weakfish from 2003 through 2015 and Atlantic menhaden from 2005 through 2015. Age length keys for spot were constructed for 2007 through

2015. Age and length data were assigned to 10 mm TL groups for spot and then the length-at-age key was applied to the length frequency to determine the proportion at age by year. It was necessary to supplement MD DNR spot ages with Virginia Marine Recourses Commission (VMRC) spot age data for a small number of fish greater than 270 mm in the 2007, 2011 and 2012 samples.

Chesapeake Bay juvenile indices were calculated as the geometric mean (GM) catch per tow. 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 10.4 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 the Chesapeake Bay from May 26, 2015 through September 15, 2015 (Table 1). Red drum was the only target species not encountered during this time period. Twenty non-target species (Table 2) were encountered in 2015. The Choptank River fisheries independent gill net survey was conducted once per week from June 6, 2015 to August 27, 2015, with the exception of the second week in July, due to mechanical problems with the sample vessel. Five of the target species and 6 non-target species were captured in 2015 (Table 3).

Weakfish

Twenty-three weakfish were sampled in the 2015 pound net survey, the second lowest number observed in the 23 year time series. Weakfish mean length in 2015 was 293 mm TL, similar to the long term mean of 297 mm TL, but the low sample size limits the value of such comparisons (Table 4). The 2015 length frequency distribution remained truncated, with 16 of the 23 weakfish between 250 and 309 mm TL (Figure 4). Sex ratios and mean length by sex were not calculated due to low sample size.

Chesapeake Bay weakfish length-frequencies were truncated during 1993 – 1998, while those for 1999 and 2000 contained considerably more weakfish greater than 380 mm TL. However, this trend reversed from 2001 to 2015, with far fewer large weakfish being encountered. Thirteen percent of the 23 weakfish sampled in the 2015 pound net survey were above the recreational size limit of 331 mm TL (13 inches), and 35% were above the commercial size limit of 305 mm TL (12 inches).

One weakfish measuring 157 mm TL was capture in the Choptank River gill net survey in 2015, and none were encountered in 2013 or 2014 (Table 3). 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 coastwide stock are likely causes of weakfish being rarely encountered by the survey.

The 2014 Maryland Chesapeake Bay commercial weakfish harvest of 62 pounds was well below the 1981 – 2014 Maryland Chesapeake Bay average of 46,214 pounds per year (Figure 5). Harvest was higher in the 1980s averaging 121,732 pounds per year, but has been extremely low the past 5 years averaging 81 pounds per year. Maryland recreational anglers harvested an estimated 1,062 weakfish (PSE = 59.2) from inland waters during 2014, with an estimated weight of 2,144 pounds (PSE = 76.3; Figure 5). The number of weakfish harvested by the recreational fishery in 2014 was well below the time series mean harvest of 180,996 fish and, was the third lowest value of the 1981-2014 time series. According to the MRIP estimates, Maryland anglers released 4,134 (PSE = 66.0) weakfish from inland waters in 2014, a decrease compared to 2013 (9,852, PSE = 55.5). Estimated recreational harvest decreased steadily from 471,142 fish in 2000 to 754 in 2006, and has fluctuated at a very low level from 2007 through 2014. 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 3 fish to 1 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. The reported harvest from Maryland charter boat captains has ranged from 831 to 75,154 weakfish from 1993 to 2014 (Figure 6), with a sharp decline occurring in 2003, and the lowest value occurring in 2014.

The weakfish juvenile GM in 2015 was similar to the 2013 and 2014 values, and was the median value of the 27 year time series (Figure 7). Weakfish juvenile abundance generally increased from 1989 to 1996 in Pocomoke and Tangier sounds, remaining 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 19 fish in 2015, and an additional four were measured. Forty-seven percent of sampled weakfish were age one, and 53% were age two (Table 5). 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 0 to 30% age two plus fish and no age 3 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 5). The 2014 age sample size was too small to make valid comparisons (six fish). No age three plus fish were sampled in 2015, but low sample size could have led to missed ages.

Mortality estimates for 2006 through 2012, 2014 and 2015 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 6), 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).

The most recent weakfish Stock Assessment Workshop conducted by ASMFC in 2009 utilized various models to determine natural mortality (M), fishing mortality (F) and current biomass (NFSC 2009). This assessment indicated weakfish biomass was extremely low; F was moderate and M was high and increasing (NFSC 2009). 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, is directly related to a coast wide stock decline. A coastwide benchmark stock assessment was initiated by ASMFC in 2015, and is scheduled for peer review in 2016.

<u>Summer flounder</u>

Summer flounder pound net survey mean lengths have varied widely from 2004-2015. Mean total lengths have ranged from the time series high of 374 mm TL in 2005 and 2010 to the time series low of 268 mm TL in 2013 and 2014 (Table 4). The 2015 mean length of 336 mm TL was similar to the 23 year time series mean of 331 mm TL. The length frequency distributions from the onboard sampling from 2004-2012 were either bimodal with peaks at the 130 to 150 and between 310 to 430 mm TL length groups, or more normal in distribution with a singular peak between the 310 to 430 mm TL length groups (Figure 8). The 2013 and 2014 length frequency distributions were heavily skewed toward smaller fish, with 66% and 58% below 290 mm TL in length respectively. The 2015 distribution shifted to larger fish, but fish over 450 mm TL were absent from the survey. The number of summer flounder sampled in 2015 was the lowest of the 23 years surveyed (Table 4). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches to the 2015 recreational size limit of 407 mm TL indicated 14% of sampled summer flounder were of legal size in 2015, an increase compared to 2014 (4%) and 2013 (11%), but lower than 2012 (41%) and 2011 (22%).

The 2014 Maryland Chesapeake Bay commercial summer flounder harvest totaled 12,203, an increase from 2013 (4,705 pounds), but was still below the 1981 – 2014 mean of 28,160 pounds per year (Figure 9). 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 Maryland Chesapeake Bay landings steadily decreased from 2005 to 2013 (Figure 9). The recreational inland harvest estimate of 68,277 (PSE = 65.2) fish caught in 2014 was an increase from the 2013 estimate of 38,754 (PSE = 18) fish (Figure 9). The 2014 MRIP recreational inland waters release estimate of 592,097 (PSE = 38.3) also increased compared to 2013 (244,500 fish, PSE = 18.4; Figure 9). The recreational inland fishery is primarily 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 summer flounder charter boat harvest has been variable, but generally increased to the time series high of 14,371 fish in 2010 from the 2003 low of 1,051 fish (Figure 10). The harvest decreased in 2012 to 5,060 fish. The 2013 and 2014 catches were similar to 2012 at 5,483 and 5,209 fish respectively.

A coast wide stock assessment using the Age Structured Assessment Program (ASAP) was conducted in 2013, (NFSC 2013), with a terminal year of 2012. 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 2014, was conducted in 2015 (Terceiro 2015), and indicated the stock was not overfished fished, but overfishing was occurring. Projection analysis for 2015-2018 indicated that overfishing was likely to occur in 2015, but if F is reduced to the target for 2016-2018 the stock would not become overfished.

Bluefish

Bluefish sampled from the onboard pound net survey averaged 327 mm TL during 2015, the highest value since 2005 (Table 4), and was above the 23 year time series mean of 303 mm. The pound net survey length frequency distributions have been bimodal most years (Figure 11). The 2005-2007 pound net sampling indicated a small 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, with 2015 indicating a higher proportion of larger fish. 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.

Bluefish have been captured in low numbers all three years of the Choptank River gill net survey (Table 3). Bluefish lengths for all panels and years combined ranged from 218 to 500 mm TL (n=39). Sample size was too small to make meaningful comparisons to length by net mesh size. Bluefish were most often captured in the 6.4 mm mesh panel with the 7.6 mm mesh panel accounting for the second highest catch (Figure 12).

Maryland bluefish Chesapeake Bay commercial harvest in 2014 was 35,834 pounds, well below the 1981-2014 average of 117,819 pounds per year (Figure 13). Chesapeake Bay commercial landings higher in the 1980s averaging 321,402 pounds per year, but have been variable since and only averaging 46,474 from 1990 to 2014 (Figure 13). Recreational inland harvest estimates for bluefish were high through most of the 1980's, but have fluctuated at a lower level since 1991 (Figure 13). The 2014 estimate of 153,242 (PSE = 25.1) fish harvested was a threefold increase over 2013, but was well below the 1981 – 2014 mean of 330,350 fish. Estimated inland recreational releases were 140,892 fish in 2014, well below the time series mean of 412,601 fish (Figure 13).

Reported bluefish harvest from charter boat logs ranged from 17,184 – 134,828 fish per year from 1993 to 2014. The 2014 harvest of 30,512 fish was below the 22 year time series mean of 68,801 fish per year (Figure 14).

A stock assessment of Atlantic coast bluefish utilized ASAP in 2015, a forward projecting catch at age model utilizing data through 2014 (NFSC 2015). The assessment indicated that F was high in the late 1980 and early 1990s, declined into the late 1990s, remained fairly stable through 2010, and has 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 was 265 mm TL in 2015, and was the fourth lowest value of the 23 year time series (Table 4). The onboard pound net length frequency distribution for 2015 indicated a continued increase in smaller croaker, with 41% of all sampled fish in the 250 mm TL size group and no croaker in the 370 mm and larger length groups (Figure 15).

Mean lengths and weights by sex for Atlantic croaker sampled from pound nets in 2015 were 285 mm TL and 332 g for females (n = 91) and 280 mm TL and 290 g for males (n = 34). Pound net samples were 73% female and 27% male. Pound net samples, in which sex determination and weight were taken, were not randomly selected; therefore sex specific data may be biased.

Atlantic croaker catches from the Choptank River gill net survey declined steadily each year of the survey, 476 fish in 2013, 269 fish in 2014 and 21 fish in 2015.

Anecdotal reports from commercial and recreational fishermen indicated croaker catches were unusually low from the Choptank River north, but catches were good in Tangier sound and the Potomac River. The large decline in catch in 2015 may be a localized low abundance event and not an indication of availability in Maryland waters in general. The 6.4 cm mesh net caught the highest proportion of Atlantic croaker, all years pooled, with proportion of catch declining with increased mesh size, and shifting to larger mesh sizes each year, indicating a shift to larger fish in recent years (Figure 16). This trend likely is tracking the large 2012 year class through the fishery and is indicating the lack of small fish due to poor recruitment in 2013 and 2014, as discussed below. Length frequency shifted to longer fish as mesh sized increased (Figure 17).

The 2014 Maryland Atlantic croaker Chesapeake Bay commercial harvest of 425,667 pounds was a 49.1% decrease from 2013, but was still above the 1981 to 2014 mean of 404,422 pounds (Figure 18). The 2014 recreational inland harvest estimate was 1,078,303 fish (PSE = 19.3) a 5.4% decrease from 2013, and was above the 1981-2014 average of 693,381 fish (Figure 18). The 2014 recreational release estimate of 1,146,192 fish decreased 60.7% compared to 2013 (Figure 18), but was near the 1981-2014 average of 1,233,540 fish. Reported Atlantic croaker harvest from charter boats ranged from 81,188 – 448,789 fish per year during the 22 year time period (Figure 19), with the low value occurring in 2014.

Since 1989, the Atlantic croaker juvenile indices have varied without trend, with the highest values occurring in the late 1990s. This index increased to the third highest value of the 24 year time series for 2008, but fell sharply in 2009 and remained low through 2011, before spiking again in 2012 (Figure 20). The GM has steadily decreased since 2012 to the 2nd lowest value of the 27 year time series in 2015 (0.21 fish per tow). 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 pound net caught Atlantic croaker otoliths in 2015 ranged from 1 to 7 (n=126; Table 7). The number of Atlantic croaker sampled for length in 2015 (n=942) was applied to an age-length key for 2015 (Table 7). This application indicated that 82% of the fish were age three, 7% were age two, and 7% were age five. The remaining age groups each accounted for three percent or less of the fish sampled (Table 7). 2015 was the first year (of the 16 with age samples) that did not have any fish greater than seven years of age or any one year old fish. 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 7. Instantaneous total mortality in 2015 was Z = 1.41 (Table 6). Total mortality estimates had been fairly stable from 2011 through 2013, after increasing steadily from the time series low in 2006 through 2011. The high 2014 (Z = 1.61) and 2015 mortality estimates from the length based approach are likely somewhat inflated by the sudden influx of the strong 2012 year class, which dominated the length frequency distribution. However the lack of older larger fish does indicate increased mortality and/or poor recruitment of year classes prior to 2012. The fishery is currently being supported primarily by a single year class.

In 2010, the ASMFC Atlantic Croaker Technical Committee completed a stock assessment using a statistical catch at age model using data through 2008 (ASMFC 2010). The assessment indicated decreasing F and rising SSB since the late 1980's. Estimated values of F, SSB and biological reference points were too uncertain to be used to determine stock status. However, the ratio of F to F_{MSY} (the F needed to produce maximum sustainable yield) was deemed reliable and was used to determine that overfishing is not occurring. It is not possible to be confident with regard to stock status, particularly a biomass determination until the discards of Atlantic croaker from the South Atlantic shrimp trawl fishery can be adequately estimated and incorporated into the stock assessment (ASMFC 2010). A benchmark coastwide stock assessment has been initiated by ASMFC, with projected completion in late 2016.

Spot

Spot mean length from the onboard sampling has been stable the past three years, 196 mm TL in 2013 and 194 mm TL in 2014 and 2015 (Table 4). Eighty-six percent of spot encountered in the onboard pound net survey were between 170 and 209 mm TL, and the length frequency distribution remained truncated relative to the distributions of the early to mid-2000s (Figure 21). Three jumbo spot (>254 mm TL) were present in the 2015 onboard sampling (2.4 % of spot sampled). Abundance of jumbo spot in the survey has been low for the past several years (0-3% of sample, 2005-2014). This followed good catches in the early part of the decade (10% in 2003, 13% in 2004).

Spot catch in the Choptank River gill net survey was highest in 2014 (749 fish) and similar in 2013 and 2015 (272 and 222 fish, respectively). The 6.4 cm mesh captured the majority of spot each year (Figure 22), accounting for over 95% of catch in 2013 and 2014. The 6.4 cm mesh accounted for 73% of the catch in 2015, and the 7.6 cm mesh 27% of the catch. Only one spot was captured in the 8.9 cm mesh in 2013 and 2015, and no spot were captured in the 10.5 cm mesh. Length frequency distribution was similar in 2013 and 2014 with the 200 and 210 mm length groups accounting for over 60% of catch each of those years (Figure 23). The distribution shifted toward larger fish in 2015, with only 24% of captured fish in the 200 and 210 mm length groups combined. The shift to larger fish is also evident in the increased catch in the 7.6 cm mesh in 2015. This shift is likely driven by a decrease in availability of younger spot due to below average recruitment, as discussed below.

Commercial harvest from Maryland's portion of Chesapeake Bay remained stable in 2013 and 2014, 257,881 and 254,443 pounds respectively (Figure 24), and was above the 1981 to 2014 mean of 136,611 pounds. Gill net landings for spot have been higher since 2006 than in previous years. This would seem to indicate an increased effort directed at spot, likely triggered by market demand and/or the decreased availability of other more desirable species. An increase in fish pot harvest in 2011 is likely a result of charter fishermen with commercial licenses' reporting spot caught in pots to use as live bait. In 2014 gill nets and fish pots accounted for 58% of harvest and 27% of harvest, respectively.

Maryland recreational inland harvest estimates from the MRIP indicated that spot catches since 1981 have been highly variable (Figure 24). Recreational harvest ranged from 277,964 fish in 1988 to 3,766,055 fish in 1986, while the number released fluctuated from 208,897 in 1996 to 2,615,298 in 2013 (Figure 24). The 2014 recreational inland waters harvest estimate of 1,254,029 fish (PSE = 24.2) was below the time series mean estimate of 1,541,132 fish. The release estimate of 565,679 fish (PSE = 20.6) was below the time series mean of 1,047,096 fish (Figure 24). Reported spot charter boat logbook harvest from 1993 to 2014 ranged from 160,881 to 848,492 fish per year (Figure 25). The 2014 reported harvest of 335,853 fish was below the time series mean of 485,085 fish.

Spot juvenile trawl index values from 1989-2015 were quite variable (Figure 26). 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 26). The index values have declined since 2012 to the time series low in 2015 (0.29 fish per tow).

In 2015 88% of sampled fish were age one, 9% were age zero, and the remaining 3.0% were age two (78 ages and 127 lengths; Table 8). These values are similar to the 2014 age structure. 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 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.

In a relatively short-lived species such as spot, population dynamics 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 2015 could be indicative of growth overfishing. Reduced recreational harvest and reduced proportion of age one spot in 2012 are likely due to the very poor 2011 year class and influx of the stronger 2012 years class. This is further supported by the very large number of fish estimated to be released by MRIP in 2013, which would have been age 1 fish, and the highest percentage of age two fish from the pound net survey occurring in 2014. Weak year classes in 2013 through 2015 will likely lead to lower availability of spot in 2016. In 2014 the ASMFC adopted a traffic light approach to monitor the stock and initiate management, as an interim mesure, until a stock assessment can be completed. An evaluation of ASMFC traffic light indicator in 2015, using data through 2014, did not indicate the stock was in need of management action, but levels of red were nearing the threshold in which action would be needed. The first coastwide bench mark stock assessment has been initiated, and is tentatively scheduled for completion in late 2016.

Red Drum

Red drum have been encountered sporadically through the 23 years of the onboard pound net survey, with none being measured in 9 years and 458 being measured in 2012 (Table 4). No red drum were measured in 2015. Pound net sampling indicated more red drum were available to anglers in 2012 and 2013 than in most other years, but this trend ended in 2014. The two year increased availability is like from a very strong year class using the bay as sub-adults.

Maryland Chesapeake Bay commercial fishermen reported harvesting 78 pounds of red drum in 2014, a decrease from the 2013 spike of 2,923 pounds, and below the 1981 to 2014 mean of 528 pounds (Figure 27). The high 2013 landings value was likely due to a large year class growing into the 18 – 25 inch slot limit.

The MRIP 2014 Maryland inland waters recreational harvest and release estimates were zero and 273 (PSE = 101.4) red drum respectively (Figure 27). Recreational harvest estimates have been extremely variable with zero harvest estimates for 24 of the 34 years, and very high PSE values. 2012 recreational release estimates 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 catch levels returned to lower levels in 2013.

Maryland charter boat captains reported harvesting red drum in every year from 1993-2014, except for 1996. Harvest was low for all years, ranging from zero to a high of 271 fish in 2012, with 51 red drum being harvested in 2014 (Figure 28). 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 for red drum and catches of legal size fish would be expected to 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 MD DNR onboard pound net sampling, with four being sampled in 2015 (Table 4). Lengths throughout the time series have ranged from 244 to 1,330 mm TL. The mean length in

2015 was 993 mm TL. Commercial harvest of black drum was banned for Maryland's portion of Chesapeake Bay in 1999 (Figure 29). Recreational inland water harvest and release estimates from 1981 to 2014 have been variable, with harvest ranging from zero (20 years) to 13,308 fish in 1983 (Figure 29). In 2014, MRIP estimated 239 black drum were harvested (PSE = 110.5), and none were released. 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 all years of the 1993-2014 time series, with a mean catch of 374 fish per year (range = 101 – 905; Figure 30). One hundred eight-five black drum were reported as harvested in 2014.

Spanish Mackerel

Spanish mackerel have been measured for FL, TL or both in 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 mm. Only four Spanish mackerel was encountered in 2015. The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 and in 2013 (Table 4).

The 2014 commercial harvest of Spanish mackerel in Maryland's portion of Chesapeake Bay was 1,586 pounds (Figure 31), and below the 1981 to 2014 mean of 4,983 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 peaked in 1993 and 1994 with approximately 43,000 fish harvested both years (Figure 31). This followed a period of eight out of twelve annual estimates with zero fish captured. Harvest estimates for 1998 – 2014 were variable, ranging from 0 – 20,049 fish with an average of 7,667 fish taken. In 2014, an estimated 5,494 (PSE = 54) Spanish mackerel were harvested (Figure 31). Due to the high PSE values, these estimates are considered tenuous. Spanish mackerel charter boat harvest from 1993 to 2014 ranged from 53 – 10,653 fish per year, with a harvest 383 fish in 2014 (Figure 32). It would appear that Spanish mackerel are providing a small but somewhat consistent opportunity for recreational anglers in Maryland's portion of Chesapeake Bay.

Spotted Seatrout

Spotted seatrout are rarely encountered during sampling, with annual observations ranging from zero (11 years) to 23 fish. One was measured from the onboard pound net survey in 2015 measuring of 487 mm TL (Table 4). Commercial harvest of spotted seatrout in Maryland's portion of Chesapeake Bay averaged 2,862 pounds from 1981-2014, however, 11 of 12 years had zero harvest from 1981-1992 (Figure 33). Reported 2014 harvest was 330 pounds. Recreational inland water harvest estimates indicated a modest variable fishery during the mid-1980's through the mid-1990's. Estimated harvest averaged 19,602 fish per year from 1986 to 1999, but was low from 2000 to 2014, including six years of zero harvest, and averaged 2,364 fish per year (Figure 33). The 2014 harvest estimate was 4,755 fish (PSE 67.5). The high PSE values from 2009 to 2014 indicate the MRIP survey does not provide reliable estimates for this species in Maryland.

Spotted seatrout harvest from 2014 charter boats was 871 fish. Reported harvest ranged from 224 – 20,030 fish per year and averaged 3,369 fish per year for the 20 year time series (Figure 34). 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. The recreational spotted seatrout fishery in Chesapeake Bay is prosecuted by a small group of anglers that are likely under-represented in the MRIP estimation design. This is supported by the 2007 and 2008 reported charter harvest values that approximated the time series mean coinciding with zero value estimates by MRIP.

Atlantic Menhaden

Mean length for Atlantic menhaden sampled from commercial pound nets in 2014 was 219 mm FL, the second lowest value of the 2004 to 2015 time series (Table 4). Menhaden length frequencies from onboard sampling have varied annually (Figure 35). The 2015 distribution was centered on the 190 and 210 mm FL groups, which accounted for 58% of sampled fish.

Menhaden was the most common species captured by the Choptank River gill net survey, with 1,584, 2,247 and 1,782 menhaden captured in 2013, 2014 and 2015 respectively. The 7.6 cm mesh caught the highest proportion and the 6.4 cm mesh caught the second highest proportion of Menhaden each year, and combined accounted for over 70% of the catch annually (Figure 36). Length frequency distributions from the Choptank River gill net survey indicated the gear selects slightly larger menhaden than the pound net survey (Figure 37), with the 230 and 250 mm length groups combined accounting for over 60% of the catch annually. Mean lengths for all meshes combined did not vary much annually: 2013 = 254 mm FL (n = 278), 2014 = 256 mm FL (n = 459) and 2015 = 258 mm FL (n = 420).

Atlantic menhaden scale samples were taken from 251 fish in 2015 from the onboard pound net survey, but ages could only be assigned to 245 fish (Table 9). After applying the annual length frequencies to the corresponding age length keys, age one was the dominate year-class in 2010 and 2011, accounting for 43% and 38% of pound net caught menhaden, respectively (Table 9). In 2012 age two menhaden accounted for 57% of pound net caught menhaden and age seven fish were present for the first time since aging began in 2005. Menhaden ages were more evenly distributed in 2013, with ages one, two and three accounting for 24%, 28% and 24% of pound net caught fish, respectively. The 2014 and 2015 age distributions were skewed toward younger fish. In 2015 54% of sampled fish were age two and 34% were age one, and ages three through five were also present. Corrections in Maryland's assigning of annuli following the 2015 ASMFC Atlantic menhaden aging workshop would have reduced the age estimates of some fish in 2015 compared to the method used in previous years. One hundred sixty-five scale samples were taken for age from the Choptank River gill net survey in 2015, but age could only be assigned to 157 individuals. Age two accounted for 50% of sampled fish, age three accounted for 34%, age four accounted 13% and ages one and five accounted for 2% or less of sampled menhaden. This collaborated the dominance of age two fish seen in the pound net survey, and confirmed the two surveys select slightly different portions of the population. The gill net survey had few age one fish, while 34% of pound net fish were age one.

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 6.7 million pounds from 2005 to 2014 (Figure 38). A coast wide quota was established by ASMFC during the 2013 fishing year, with individual states getting a percentage of the total allowable catch, based on historical landings. Maryland's 2014 Chesapeake Bay landings of 6,610,178 pounds would have been higher if trip limits had not been placed on the fishery, to satisfy the ASMFC requirement. Prior to 2013 the menhaden fishery in Maryland had no restrictions, aside from general commercial fishing license requirements and regulations, including a prohibition on purse seining.

A benchmark ASMFC Atlantic menhaden stock assessment was conducted in 2014 using data through 2013 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 is not experiencing overfishing and was not overfished. This is in contrast to the 2009 benchmark assessments determination of an overfished status.

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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 2015.

Area	**Month**	**Number of Samples**	**Mean Water Temp. C**	**Mean Salinity (ppt)**
Point Lookout	May	1	20.5	13.0
Point Lookout	June	5	25.2	14.9
Hooper Strait	June	2	26.4	16.5
Nanticoke	June	3	26.1	15.1
Point Lookout	July	5	27.7	15.6
Point Lookout	August	4	27.0	16.9
Hooper Strait	August	2	26.9	17.5
Nanticoke	August	1	26.1	18.6
Point Lookout	September	1	24.4	21.5
West Bay	September	1	24.8	22.0
Nanticoke	September	1	27.1	17.2

Table 2. List of non-target species observed during the 2015 onboard pound net survey.

Common Name	Scientific Name
American shad	*Alosa sapidissima*
Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic spadefish	*Chaetodipterus faber*
Butterfish	*Peprilus triacanthus*
Cownose ray	*Rhinoptera bonasus*
Crevalle jack	*Caranx hippos*
Gizzard shad	*Dorosoma cepedianum*
Ladyfish	*Bodianus rufus*
Hickory shad	*Alosa mediocris*
Hogchoker	*Trinectes maculates*
Northern puffer	*Sphoeroides maculatus*
Northern searobin	*Prionotus carolinus*
Oyster toadfish	*Opsanus tau*
Silver perch	*Bairdiella chrysoura*
Southern stingray	*Dasyatis americana*
Striped bass	*Morone saxatilis*
Striped burrfish	*Chilomycterus schoepfi*
Striped mullet	*Mugil cephalus*
White catfish	*Ameiurus catus*
White perch	*Morone americana*

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

Common Name	2013	2014	2015
Atlantic Croaker	476	269	21
Atlantic Menhaden	1,584	2,247	1,782
Blue Crab	34	44	165
Bluefish	11	22	7
Butterfish	0	2	2
Gizzard Shad	180	231	188
Hogchoker	3	39	6
Northern Kingfish	1	9	0
Spot	272	749	222
Striped Bass	16	33	14
Summer Flounder	2	0	0
Weakfish	0	0	1
White Perch	18	41	55
Total Catch	2,597	3,686	2,463

Table 4. Mean length (mm TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993-2015.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Spotted Seatrout																							
mean length		448	452			541	460								414	464	262		361	436	456	499	487
std. dev.		86	42				134								43	72	22		142	112	29	70	
n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3	10	23	0	4	8	5	4	1
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
std. dev.		175	454	20		182				190	20	212		228	95	238	84	345	188		236	150	171
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5	13	3	3	1	4	14	4

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
Red Drum																							
mean length						302	332	648		316	506	647	353	366	658	361			678	318	469	954	
std. dev.							71			44		468		21	40	57			18	71	39		
n	0	0	0	0	0	1	16	1	0	177	1	2	1	16	2	21	0	0	2	458	16	1	
Spanish Mackerel (Total Length)																							
mean length	261	391	487	481	520	418	468	455													508		343
std. dev.	114	55	38	55		45	82	66													37		
n	3	78	39	27	1	4	45	35													124		1
Spanish Mackerel (Fork Length)																							
mean length			418	401	437	379		386	406	422	405	391	422	439	436	407	418			393	428	536	437
std. dev.			34	62				34	34	81	63	95	33	35	51	59	53			74	36		41
n			44	27	1	1		49	19	20	11	8	373	445	158	18	7	0	0	107	331	1	3
Menhaden (Fork Length)																							
mean length												262	282	238	243	246	245	232	213	243	251	223	219
std. dev.												28	36	42	41	29	40	36	39	25	31	38	28
n												213	1,052	826	854	826	366	836	773	755	762	775	864

Table 5. 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 2003-2015.

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

Table 6. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999–2015.

	Species	
Year	Weakfish	Atlantic Croaker
1999	0.74	0.38
2000	0.4	0.42
2001	0.62	0.33
2002	0.58	0.33
2003	0.73	0.46
2004	1.29	0.36
2005	1.44	0.30
2006	*	0.26
2007	*	0.31
2008	*	0.31
2009	*	0.48
2010	*	0.65
2011	*	0.80
2012	*	0.80
2013	1.55	0.86
2014	*	1.61
2015	*	1.41

* Insufficient sample size to calculate 2006 – 2012, 2014 and 2015 weakfish estimates.

Table 7. 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, 1999-2015.

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

Table 8. 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, 2007-2015.

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

Table 9. Atlantic menhaden percentage at age, number of age samples and number of length samples by year using, pound net length and age data, 2005-2015.

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

Figure 1. Onboard pound net survey sampling site locations for 2015.

Figure 2. Choptank River gill survey net sampling site locations for 2015.

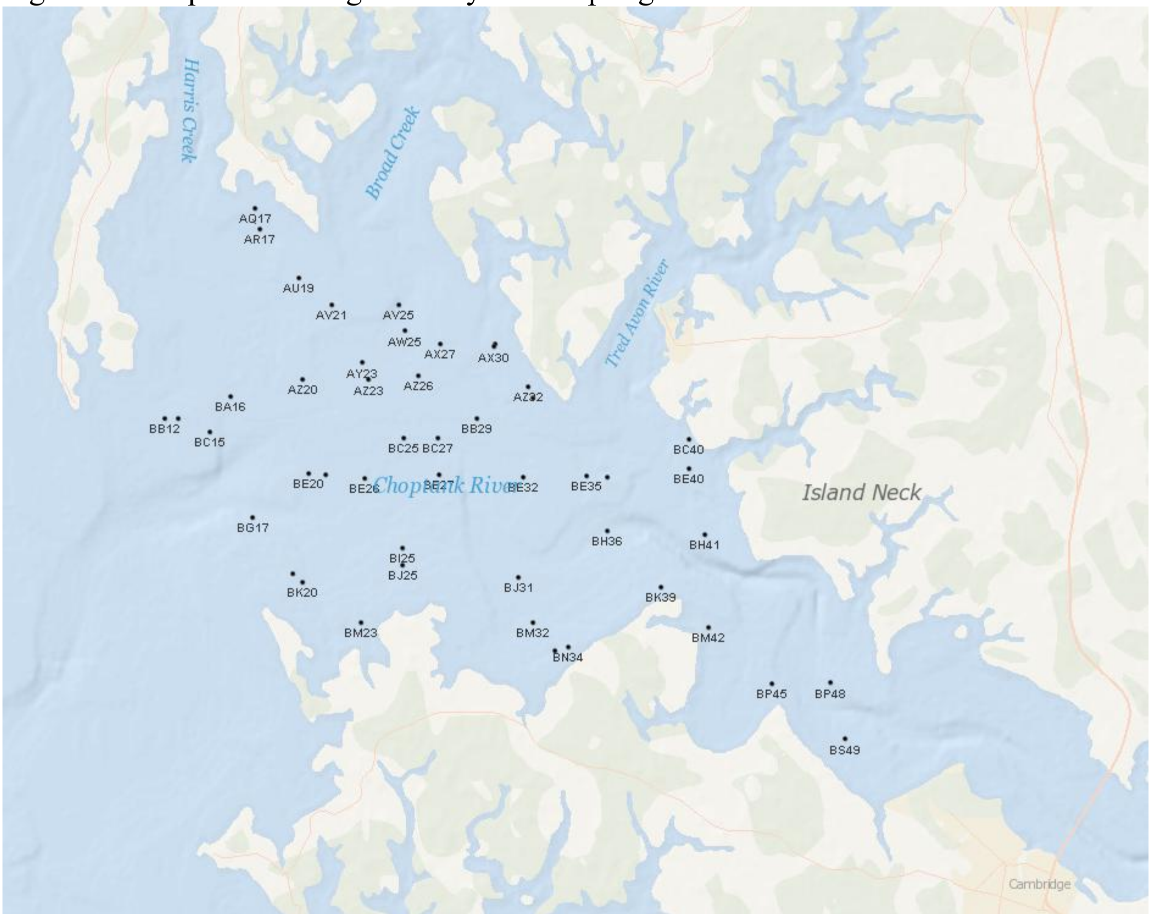


Figure 3. Choptank River gill net survey sampling grid and grid names used in all years of the survey.

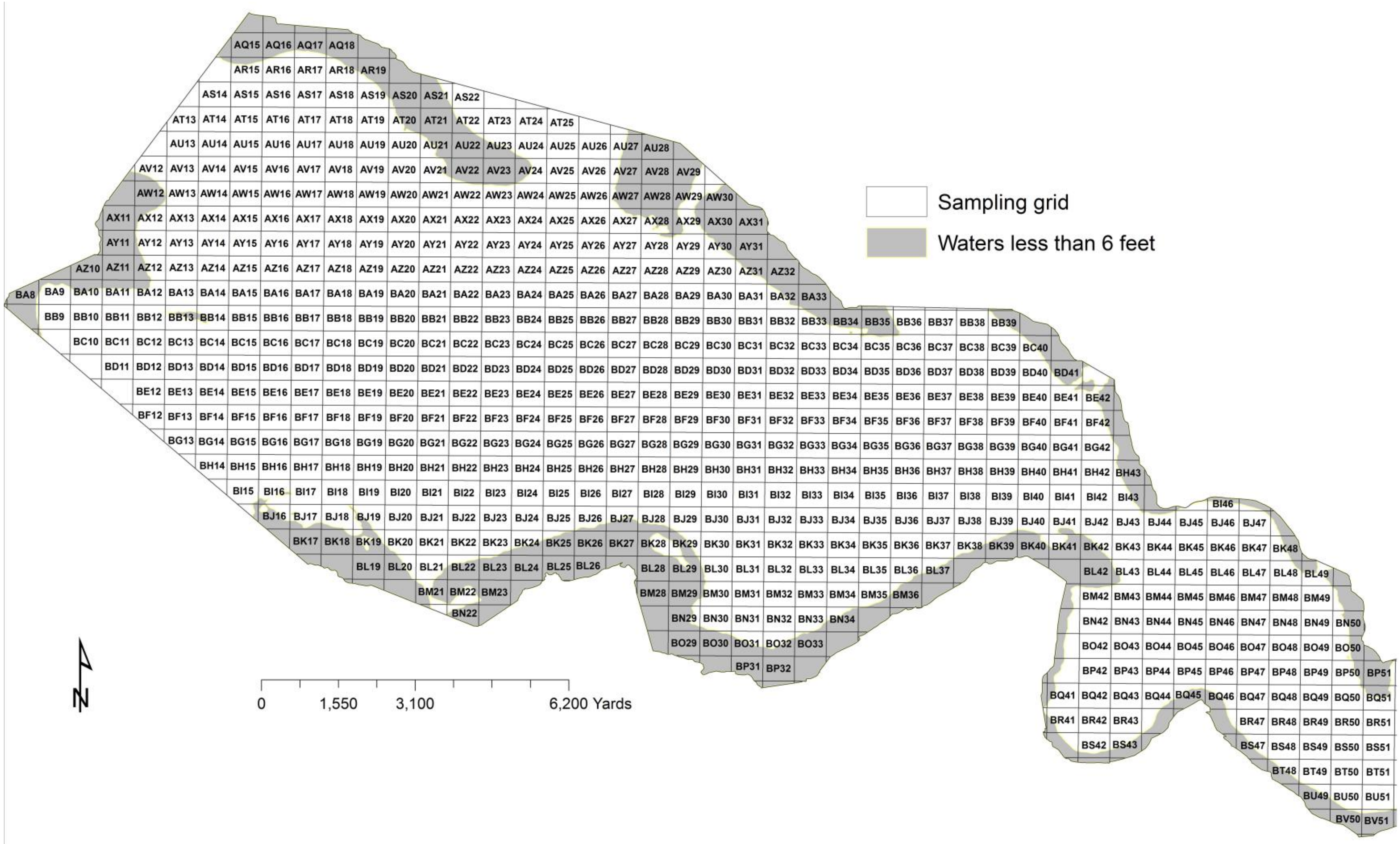


Figure 4. Weakfish length frequency distributions from onboard pound net sampling, 2005-2015. Note: 2011 210 mm length group was truncated to preserve scale, actual value is 50%.

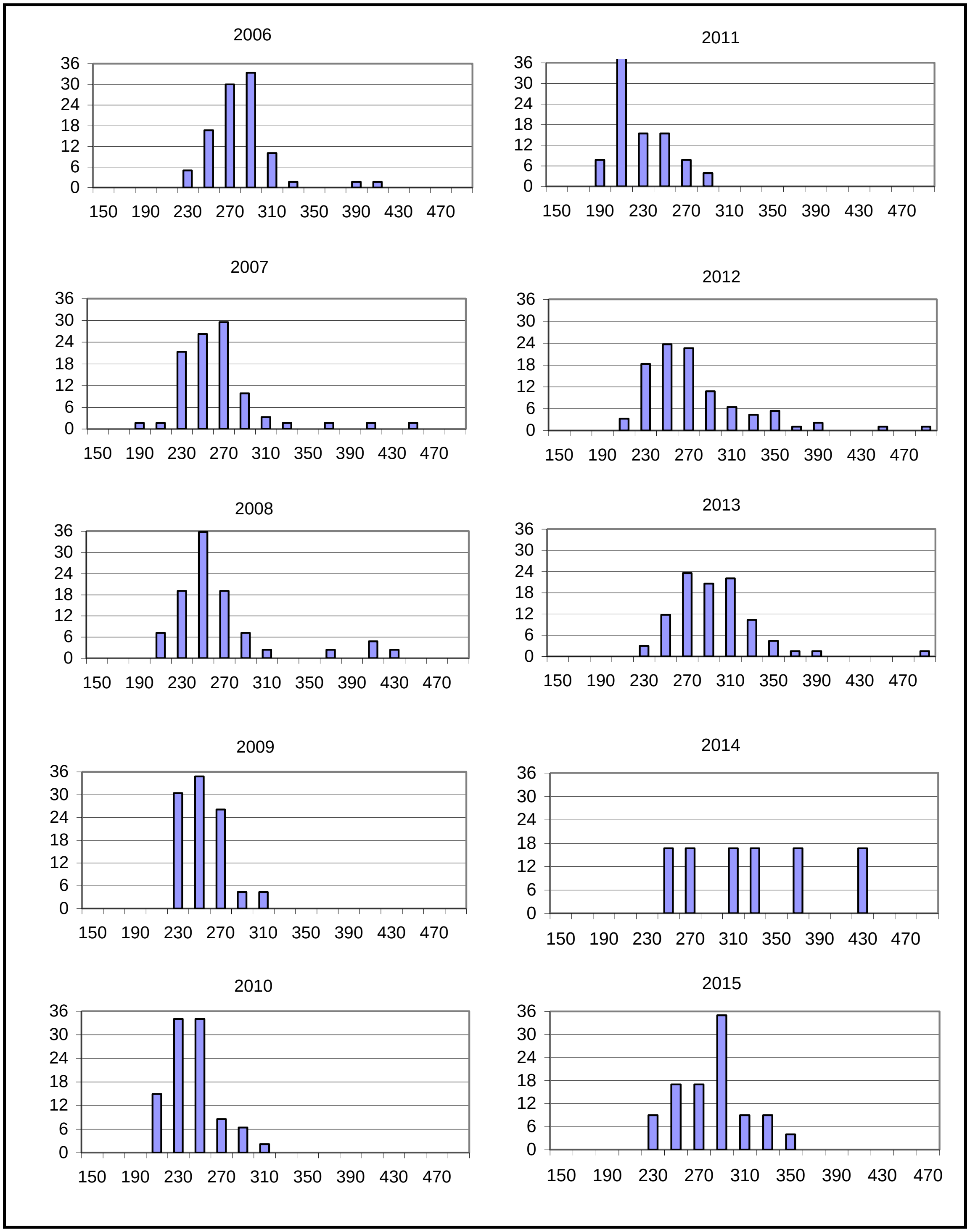


Figure 5. Maryland's commercial landings of weakfish in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational weakfish harvest and release estimates in numbers from 1981-2014.

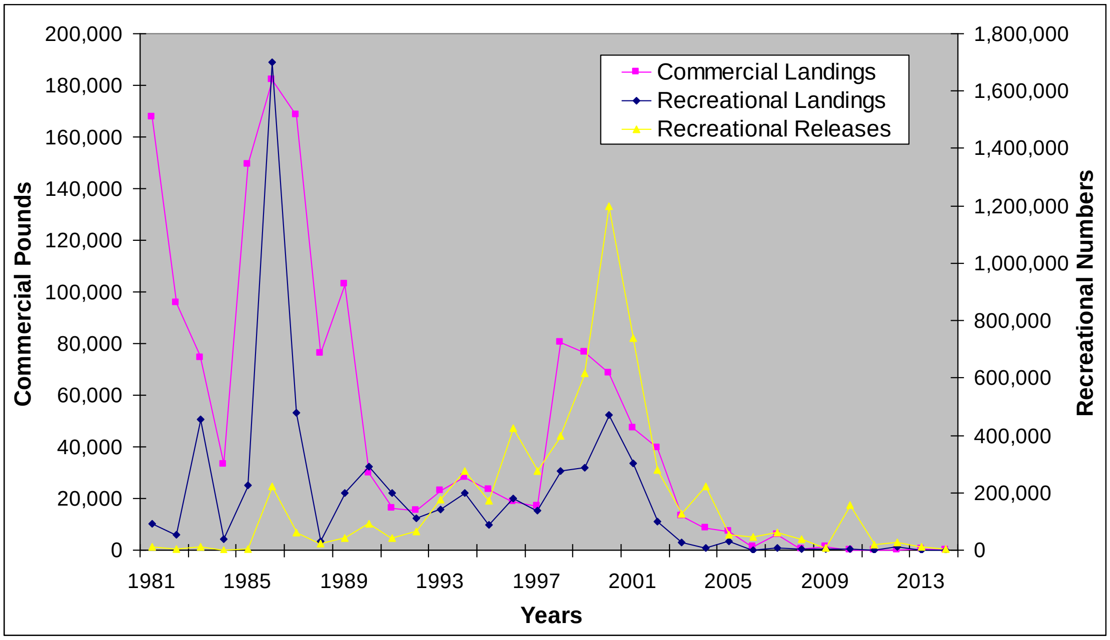


Figure 6. Maryland Charter boat log book weakfish harvest in numbers and the number of anglers participating in trips catching weakfish, 1993-2014.

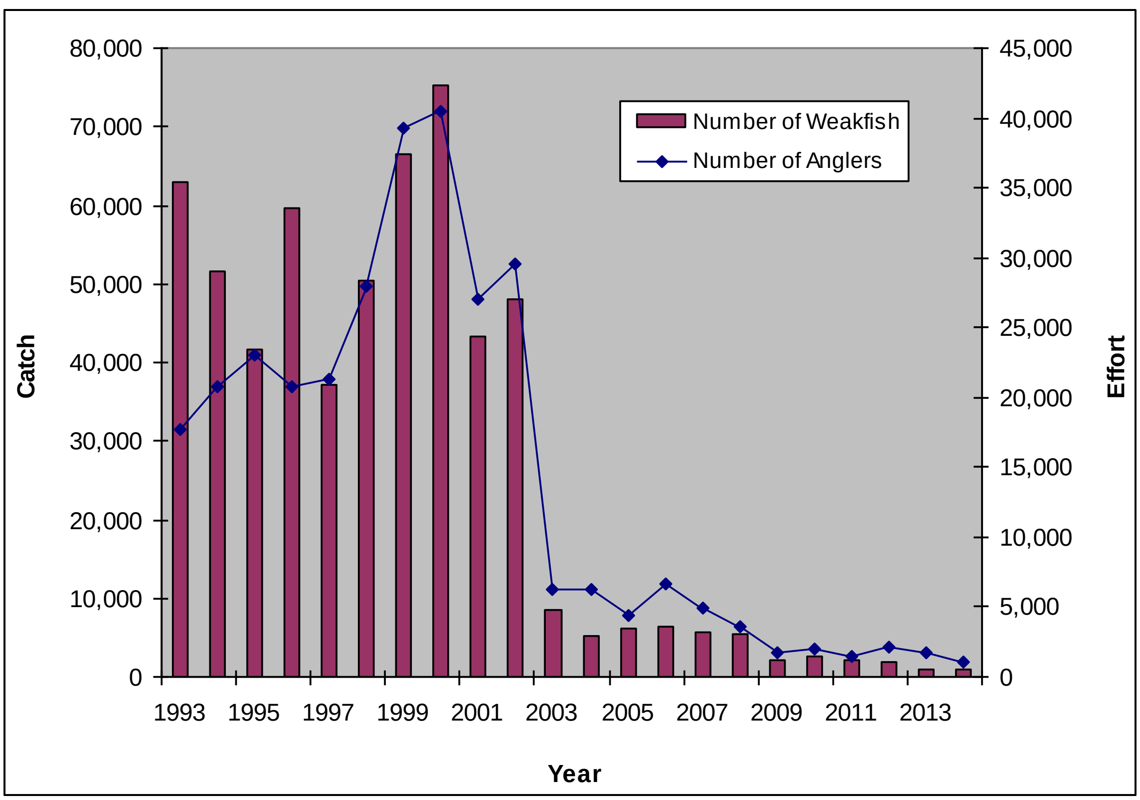


Figure 7. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989-2015.

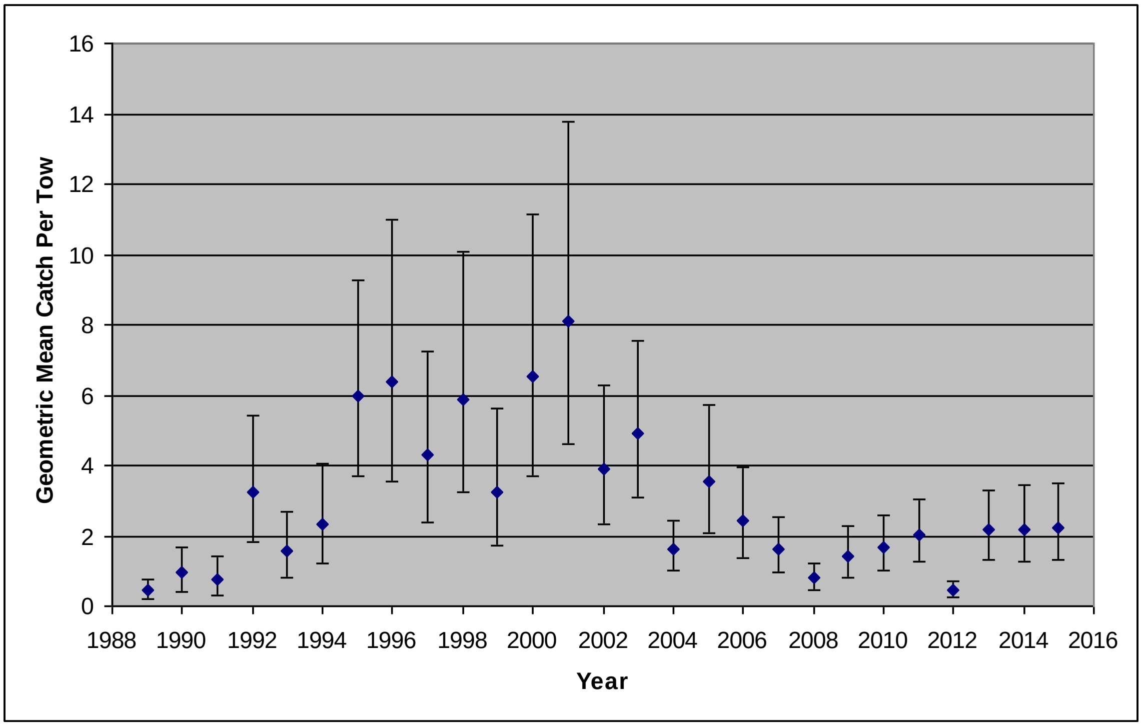


Figure 8. Summer flounder length frequency distributions from onboard pound net sampling, 2005-2015.

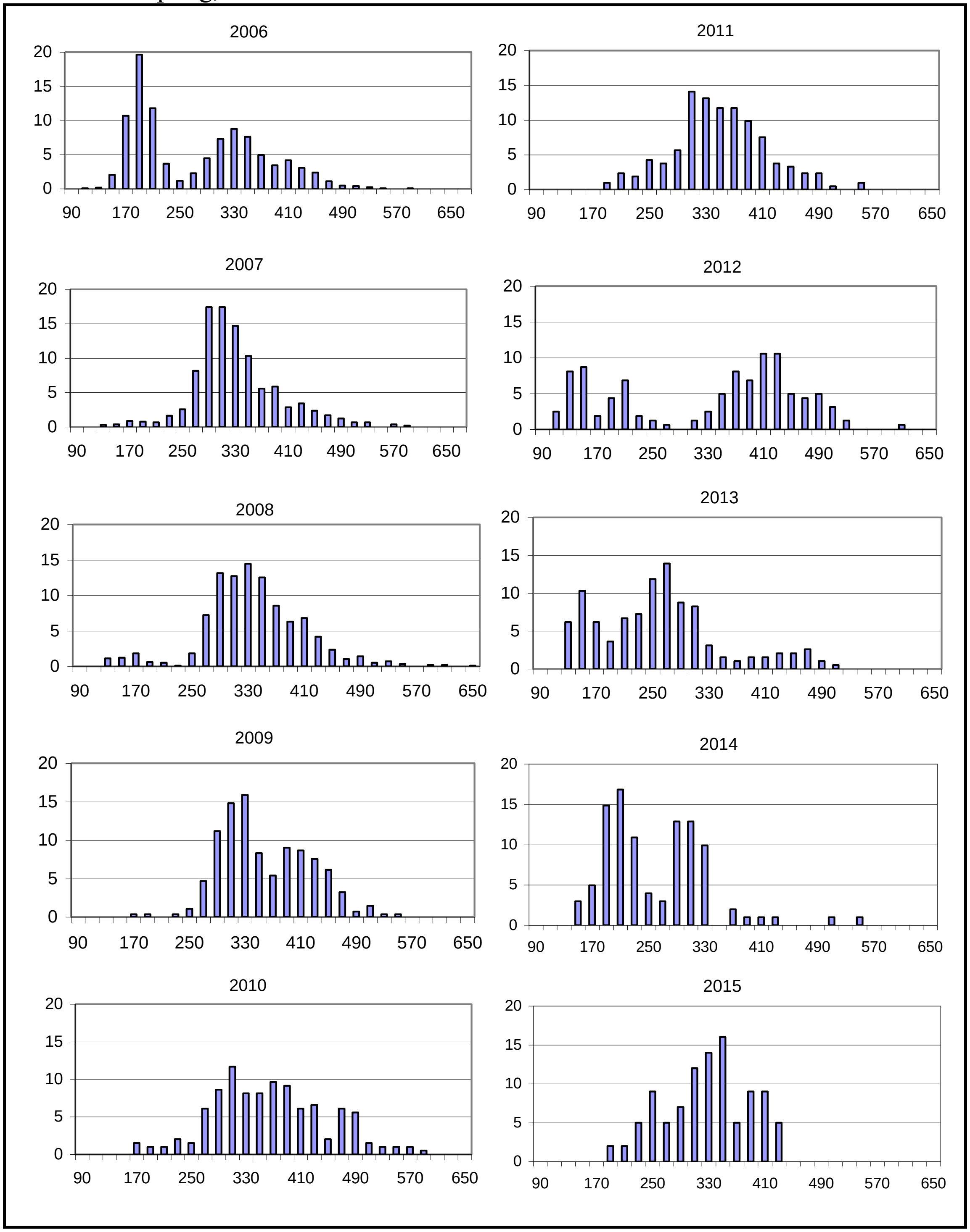


Figure 9. Maryland's commercial landings of summer flounder in pounds from the Chesapeake Bay and the MRIP Maryland summer flounder inland recreational harvest and release estimates in numbers from 1981-2014.

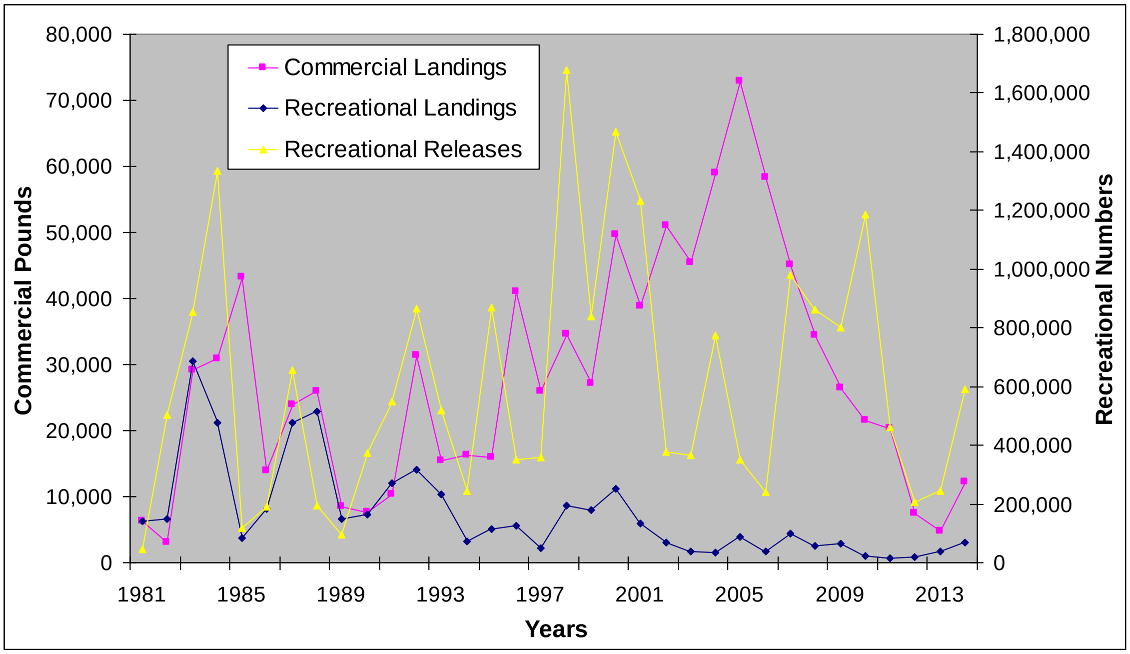


Figure 10. Maryland Charter boat log book summer flounder harvest in numbers and the number of anglers participating in trips catching summer flounder, 1993-2014.

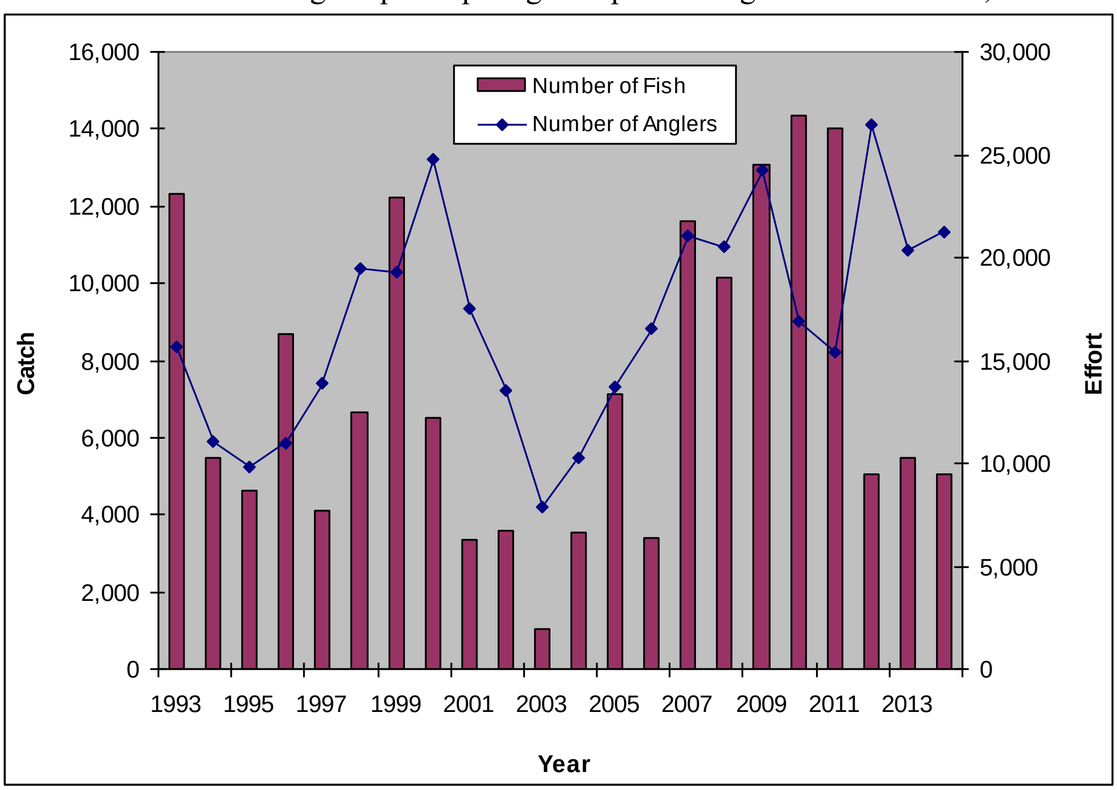


Figure 11. Bluefish length frequency distributions from onboard pound net sampling, 2005-2015.

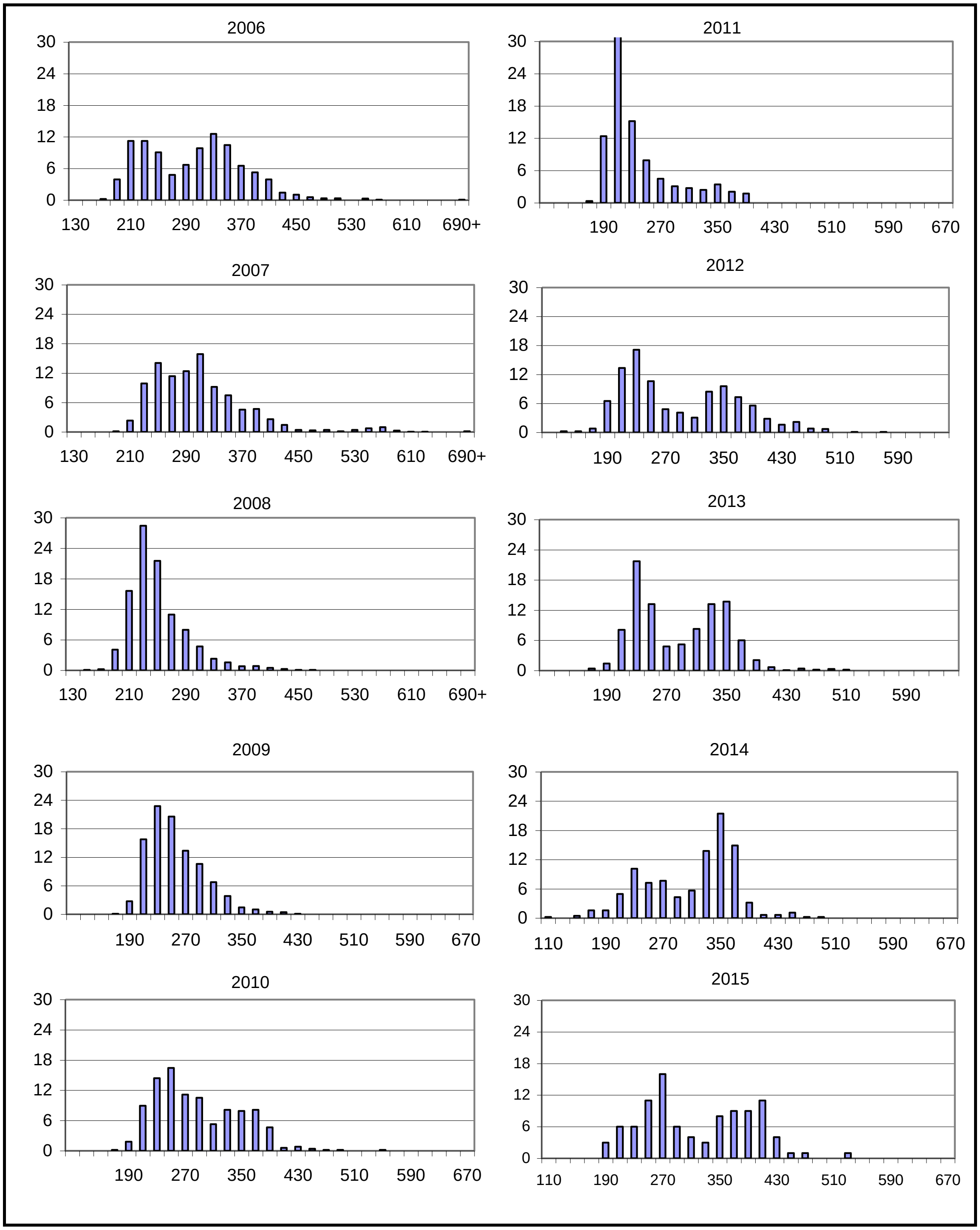


Figure 12. Proportion of bluefish catch by mesh size and year for the Choptank River gill net survey, 2013-2015.

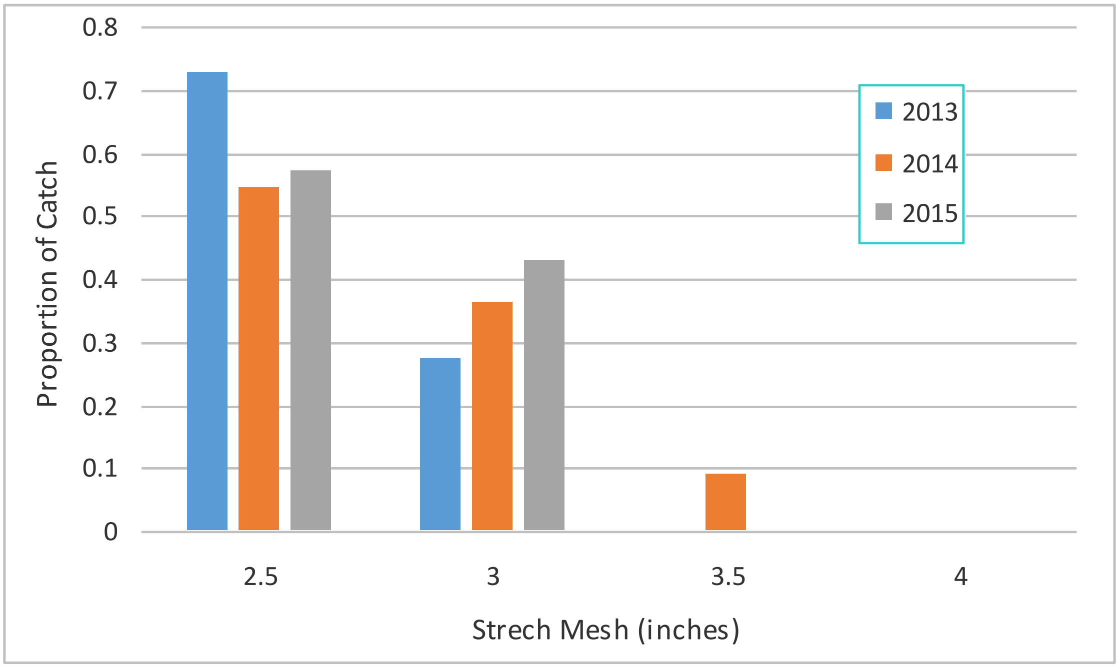


Figure 13. Maryland's commercial landings of bluefish in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational bluefish harvest and release estimates in numbers from 1981-2014.

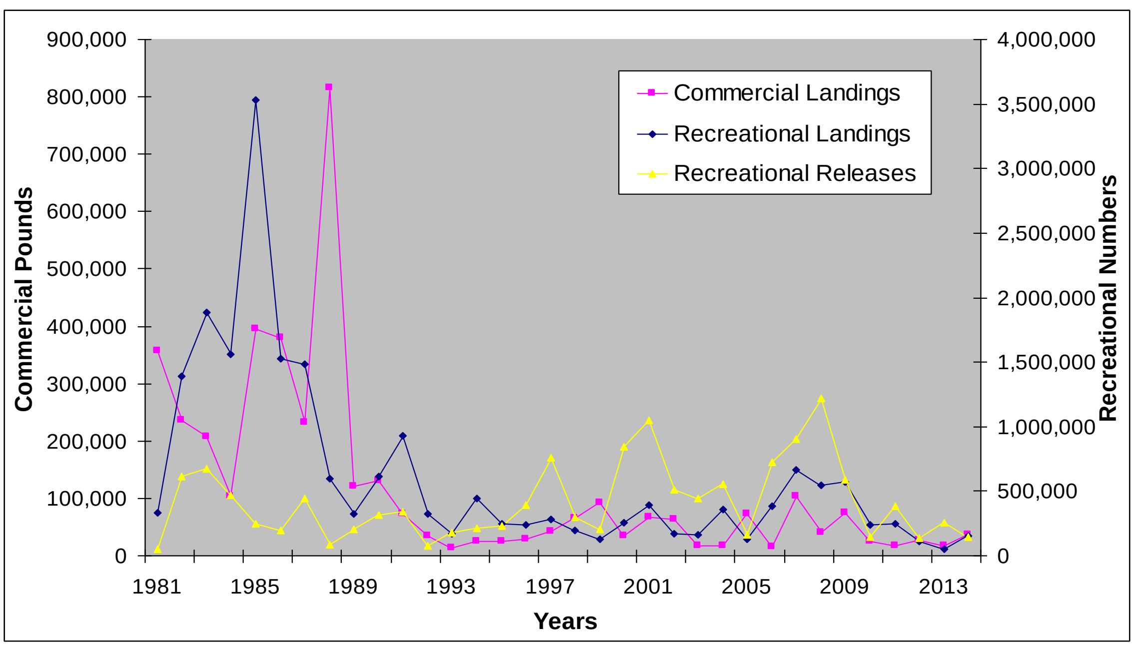


Figure 14. Maryland Charter boat log book bluefish harvest in numbers and the number of anglers participating in trips catching bluefish, 1993-2014.

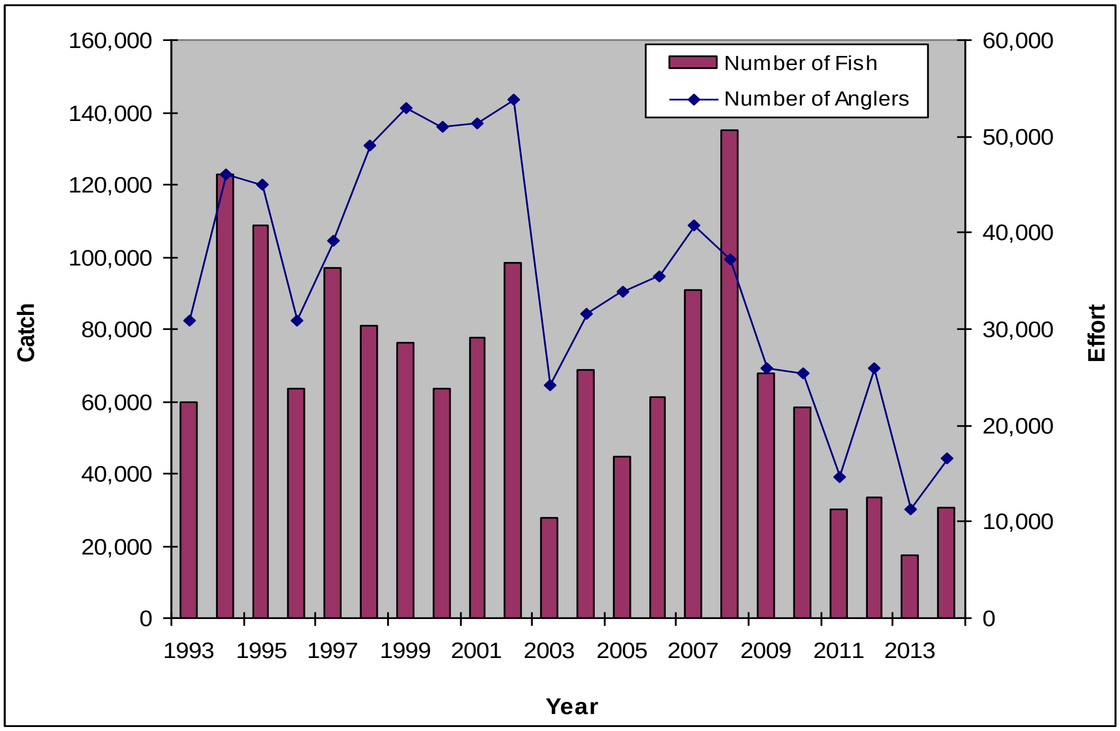


Figure 15. Atlantic croaker length frequency distributions from onboard pound net sampling, 2005-2015.

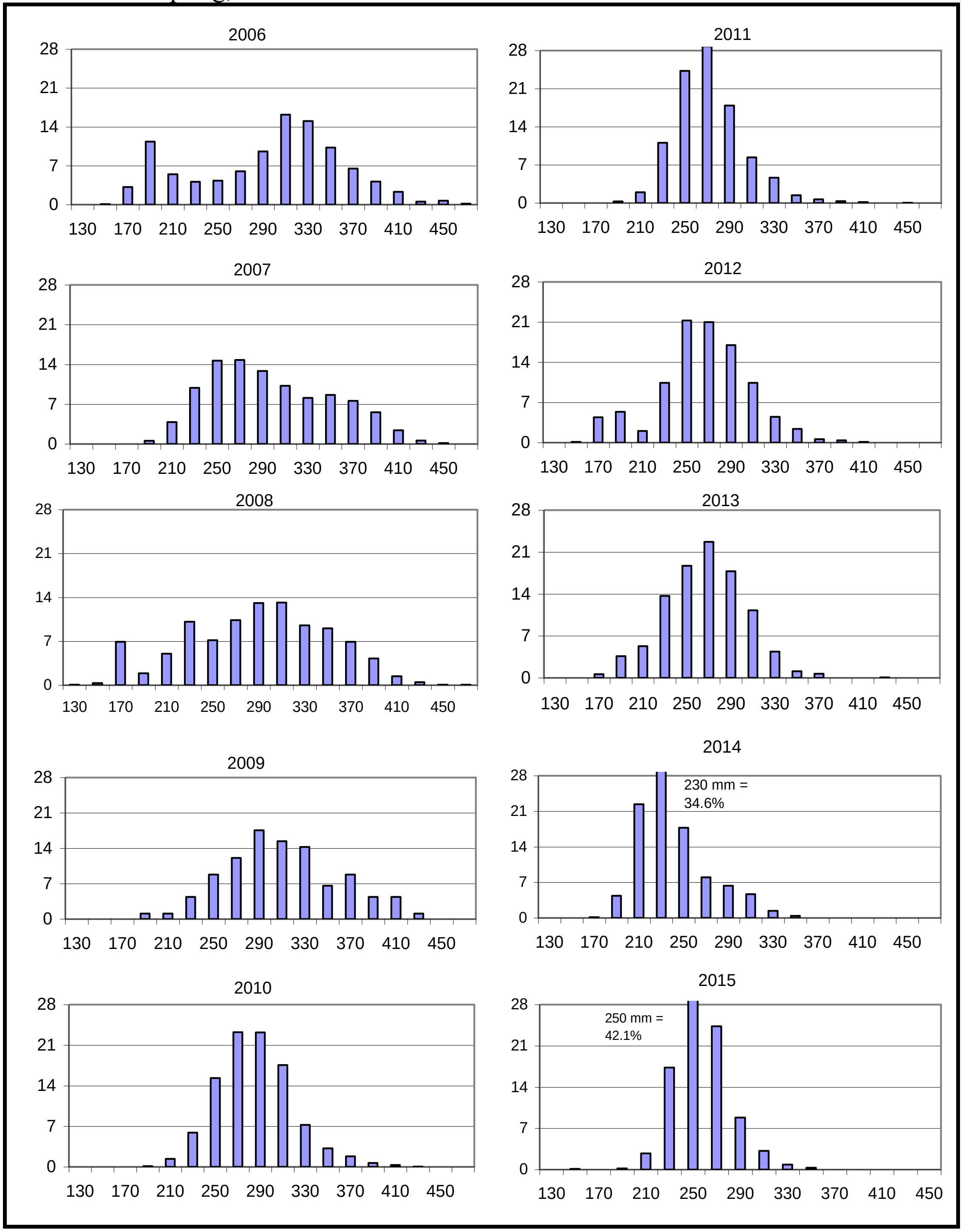


Figure 16. Proportion of Atlantic croaker catch by mesh size and year for the Choptank River gill net survey, 2013-2015.

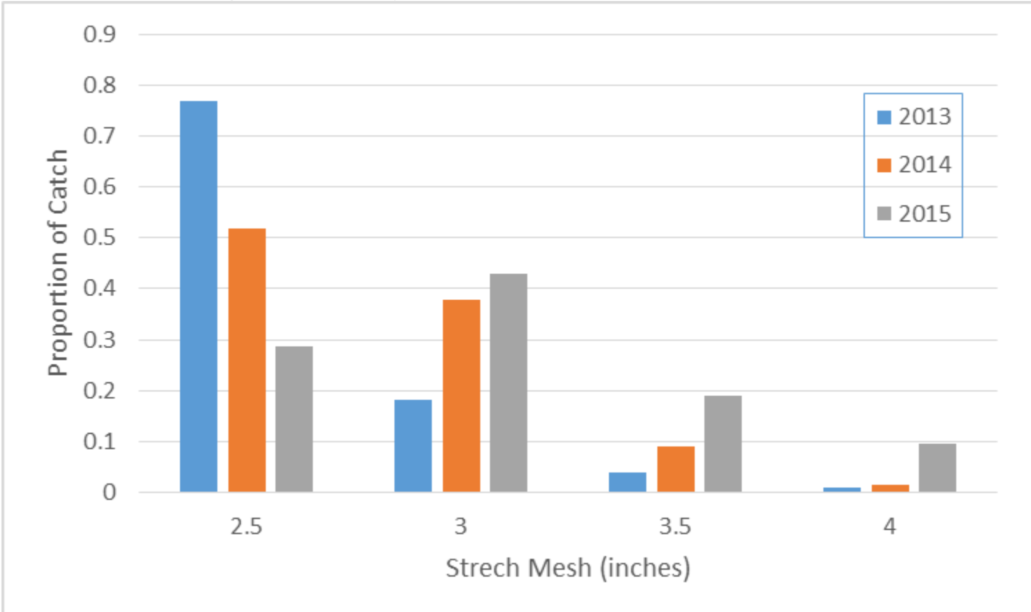


Figure 17. Atlantic croaker length frequency distribution from the Choptank River gill net survey, 2013-2015 combined.

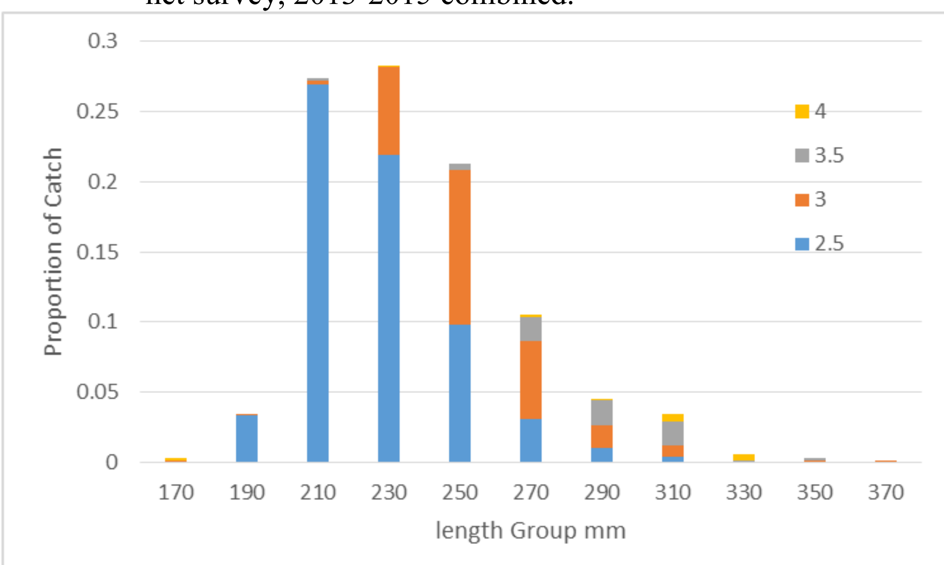


Figure 18. Maryland's commercial landings of Atlantic croaker in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational Atlantic croaker harvest and release estimates in numbers from 1981-2014.

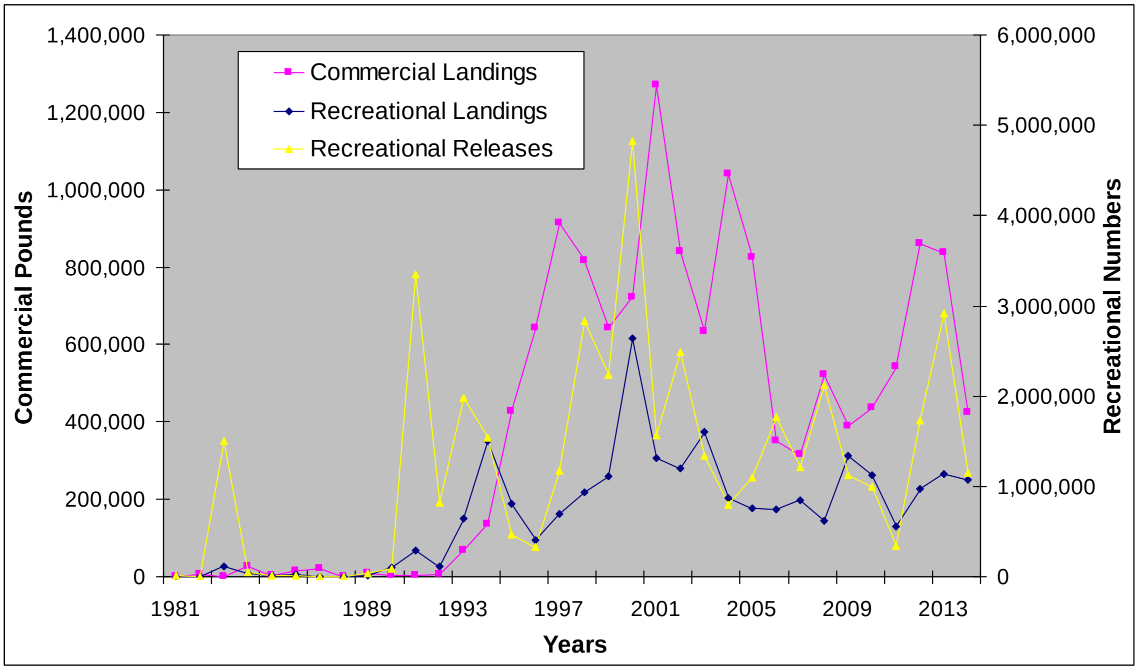


Figure 19. Maryland Charter boat log book Atlantic croaker harvest in numbers and the number of anglers participating in trips catching Atlantic croaker, 1993-2014.

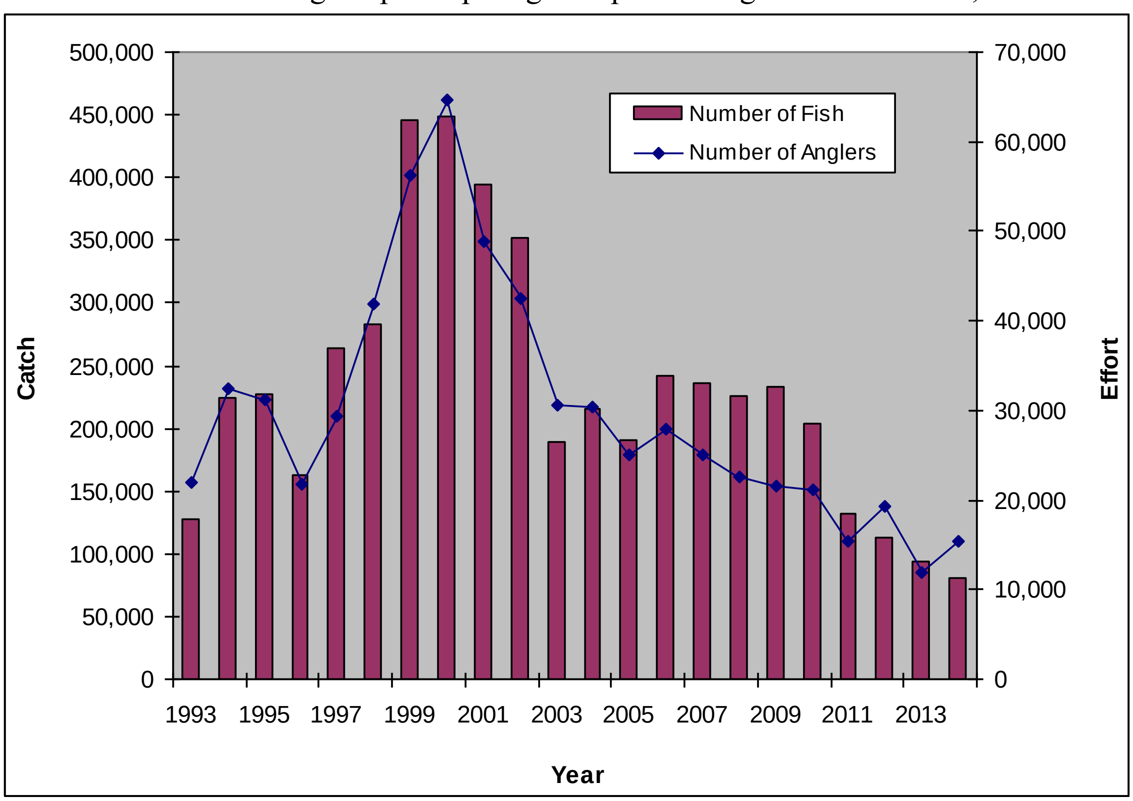


Figure 20. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989-2015. 1998 data point was omitted for scale (GM 1998 = 30.05 -9.02, +12.72).

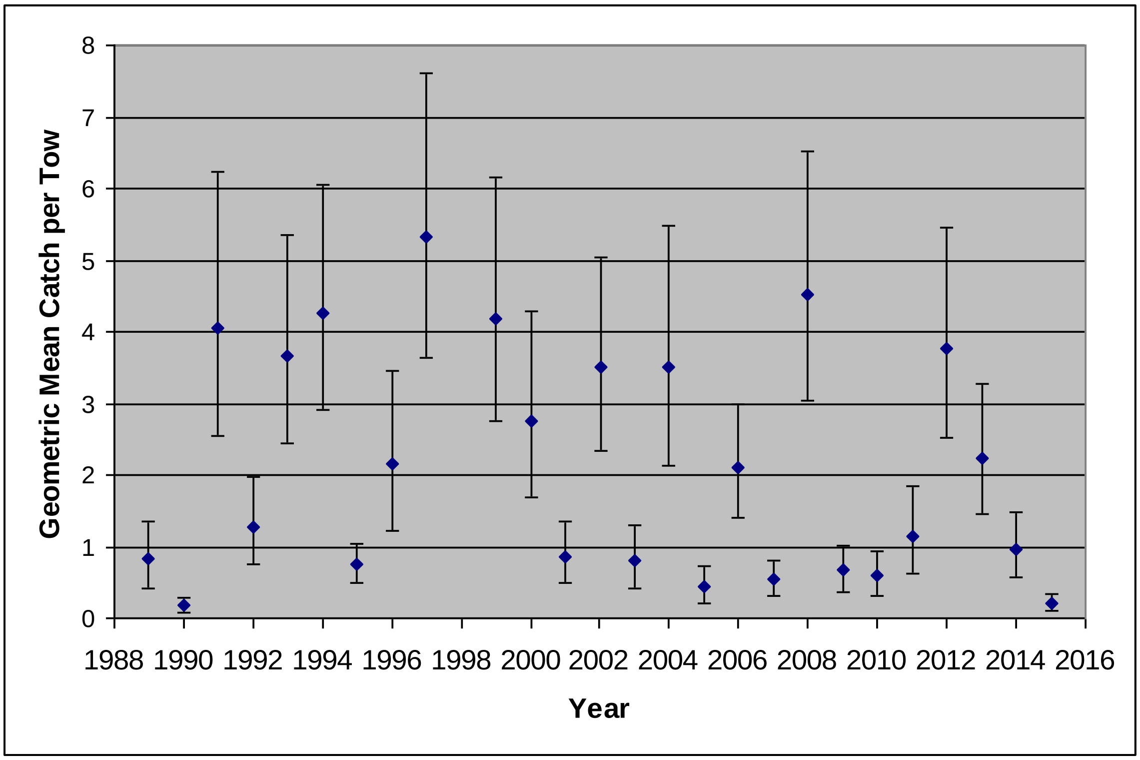


Figure 21. Spot length frequency distributions from onboard pound net sampling, 2005-2015.

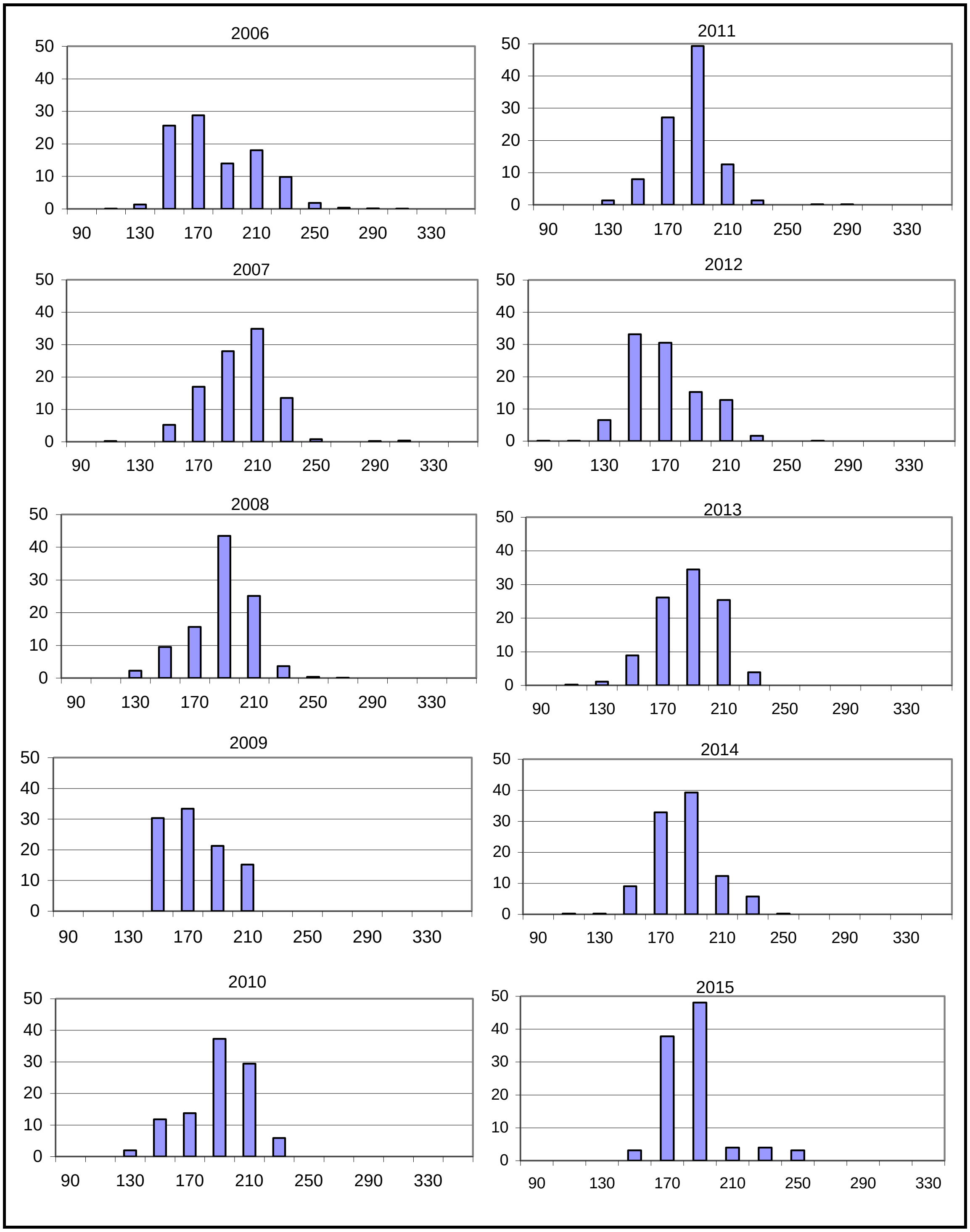


Figure 22. Proportion of spot captured in the Choptank River gill net survey by mesh size and year, 2013-1015.

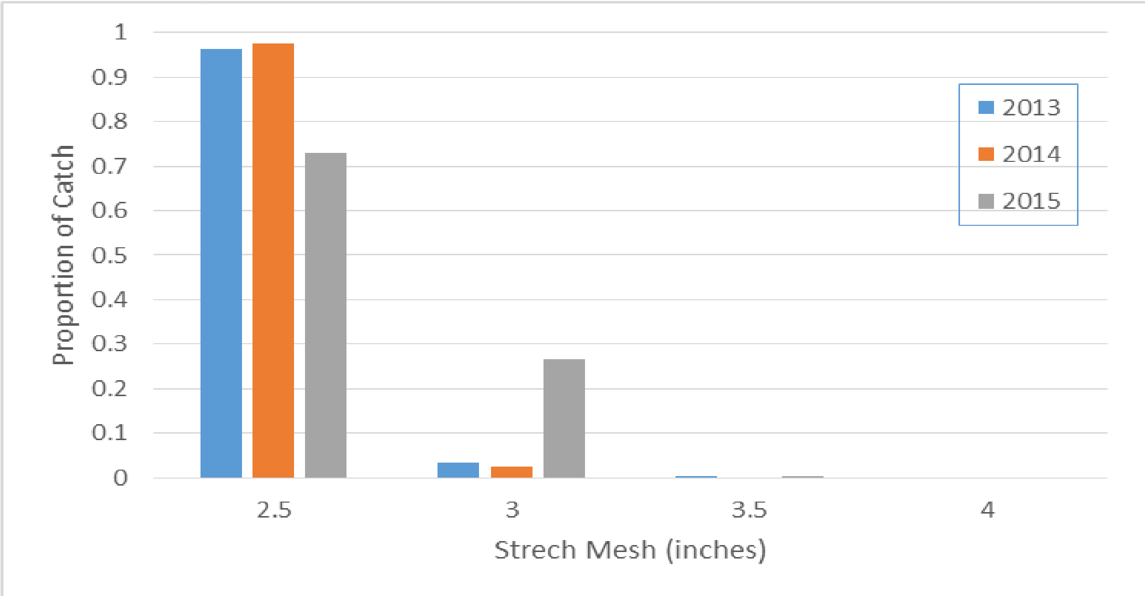


Figure 23. Spot length frequency distributions from the Choptank River gill net survey for 2013-2015.

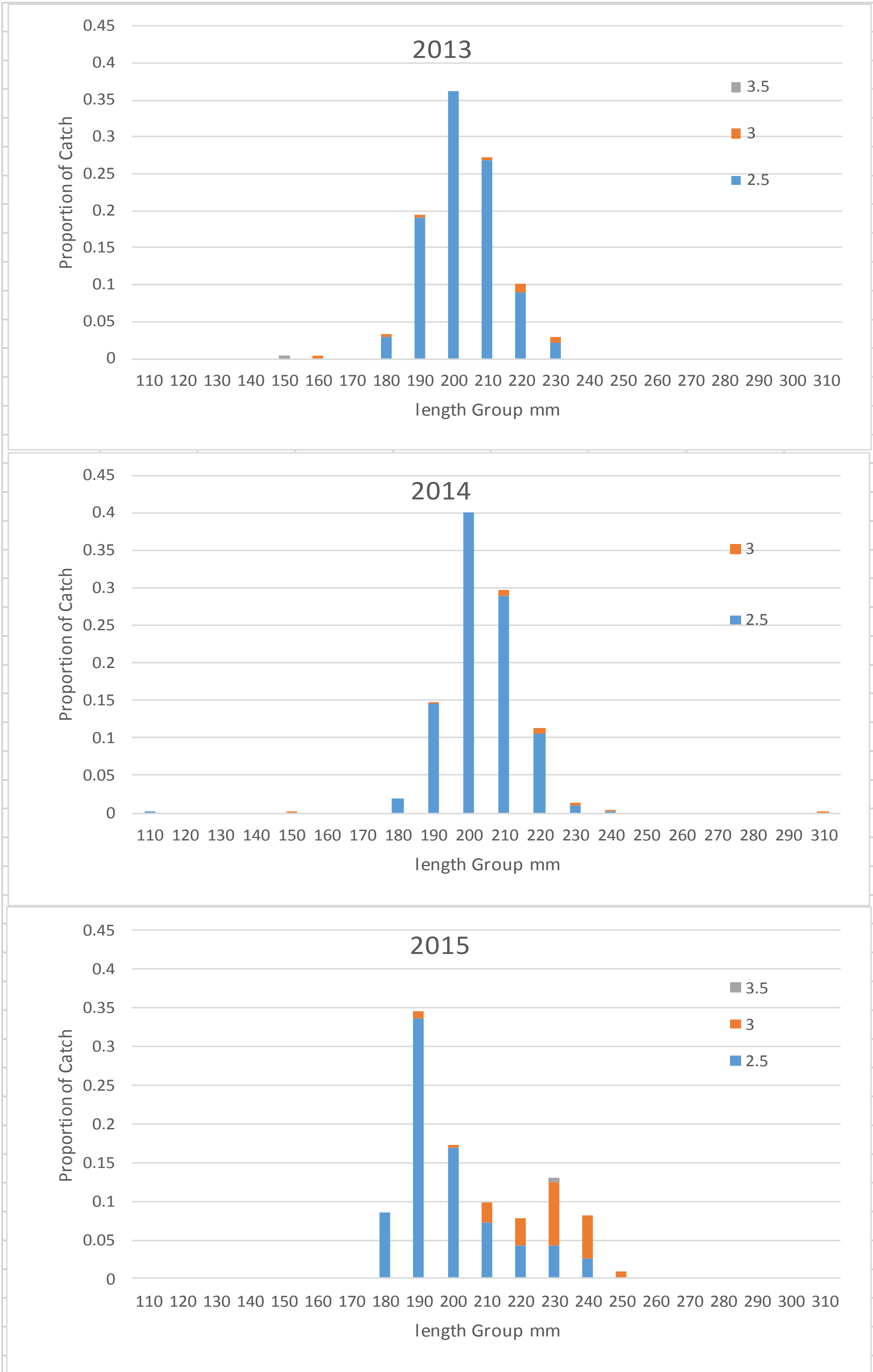


Figure 24. Maryland's commercial landings of spot in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational spot harvest and release estimates in numbers from 1981-2014.

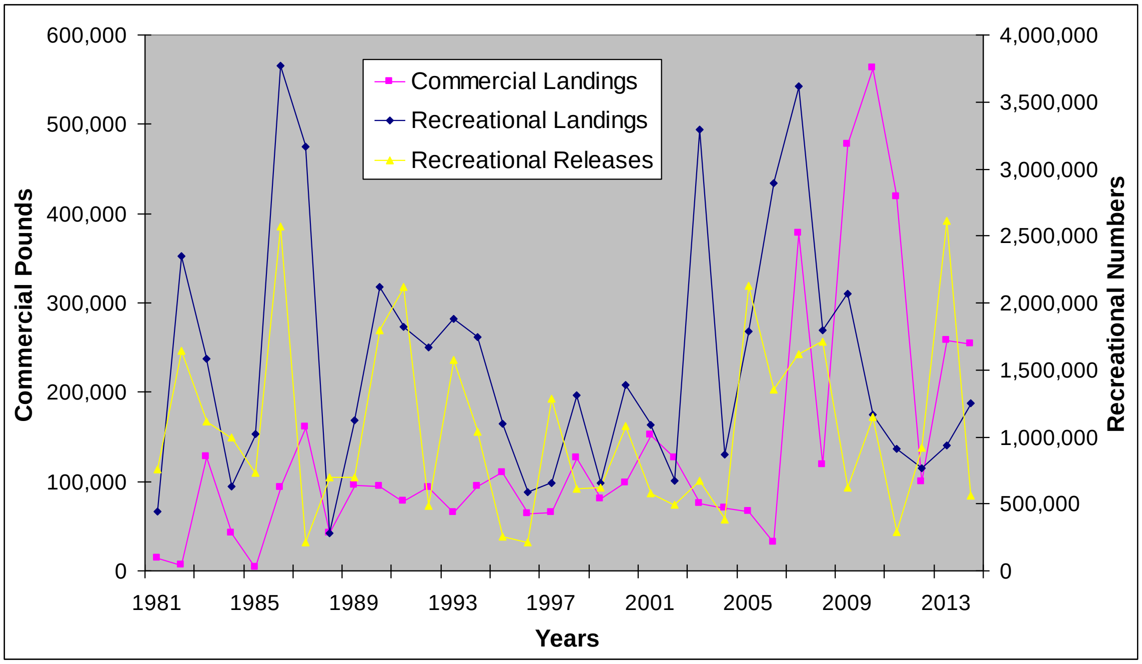


Figure 25. Maryland Charter boat log book spot harvest in numbers and the number of anglers participating in trips catching spot, 1993-2014.

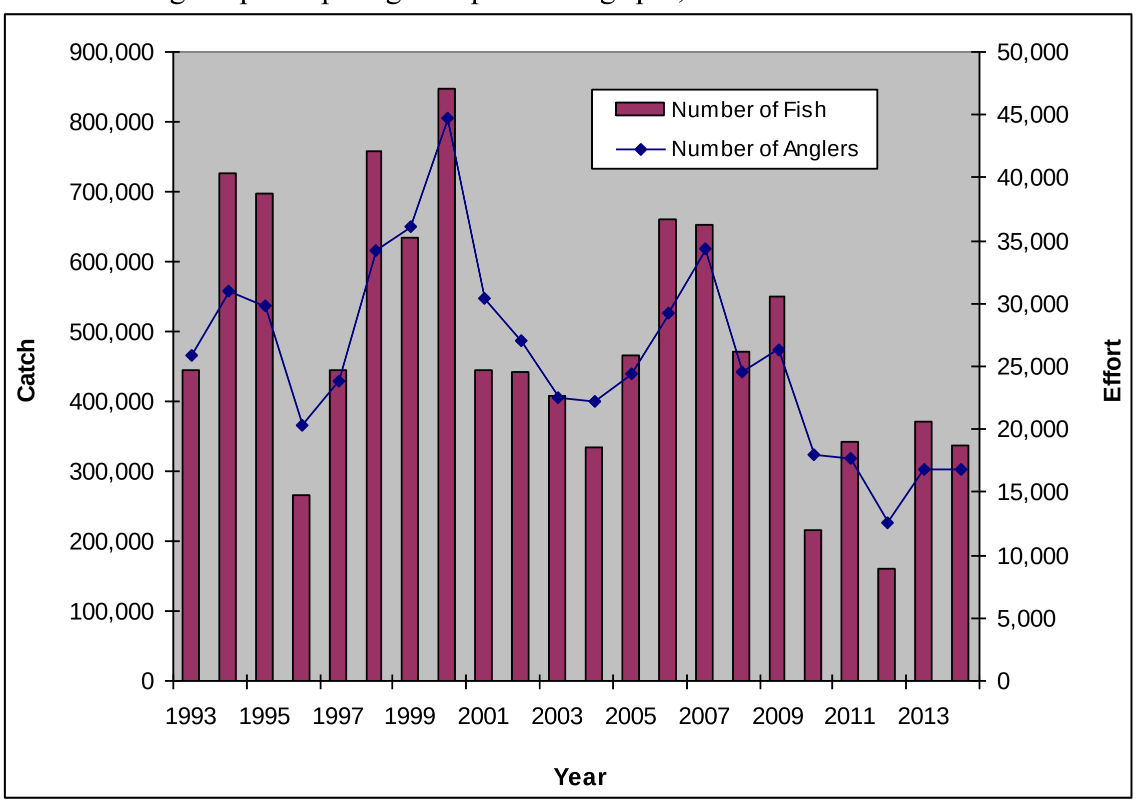


Figure 26. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989-2015.

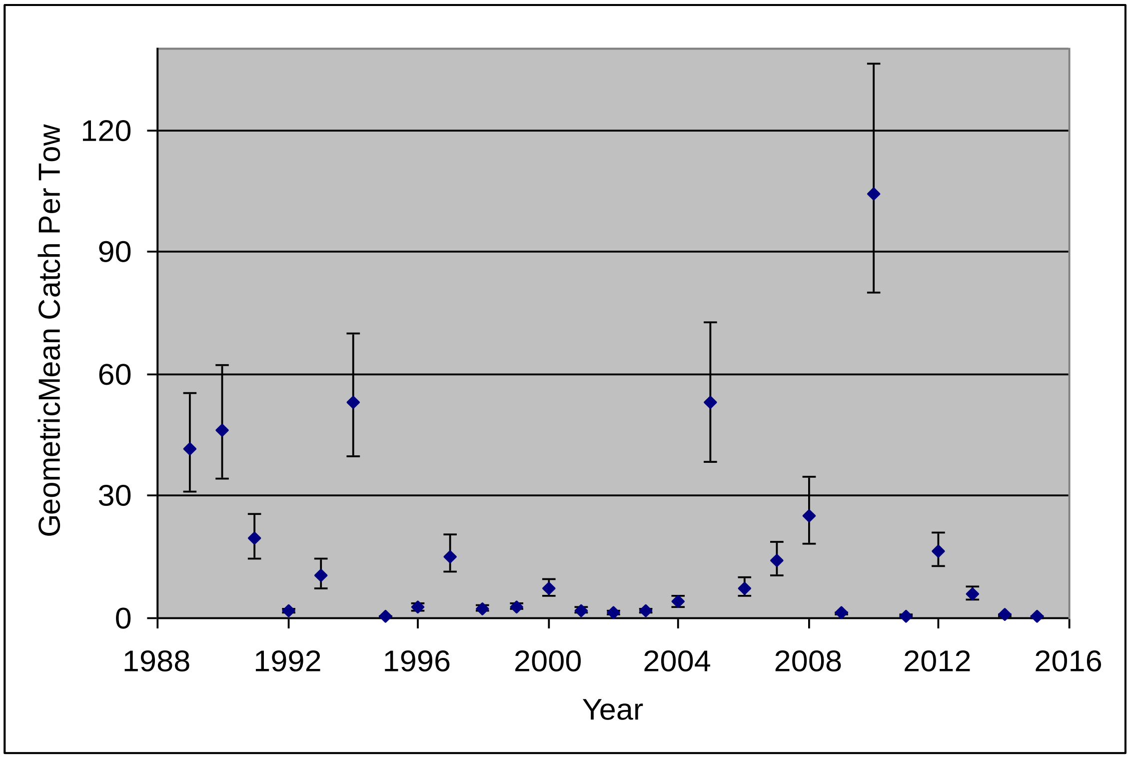


Figure 27. Maryland's commercial landings of red drum in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational red drum harvest and release estimates in numbers from 1981-2014.

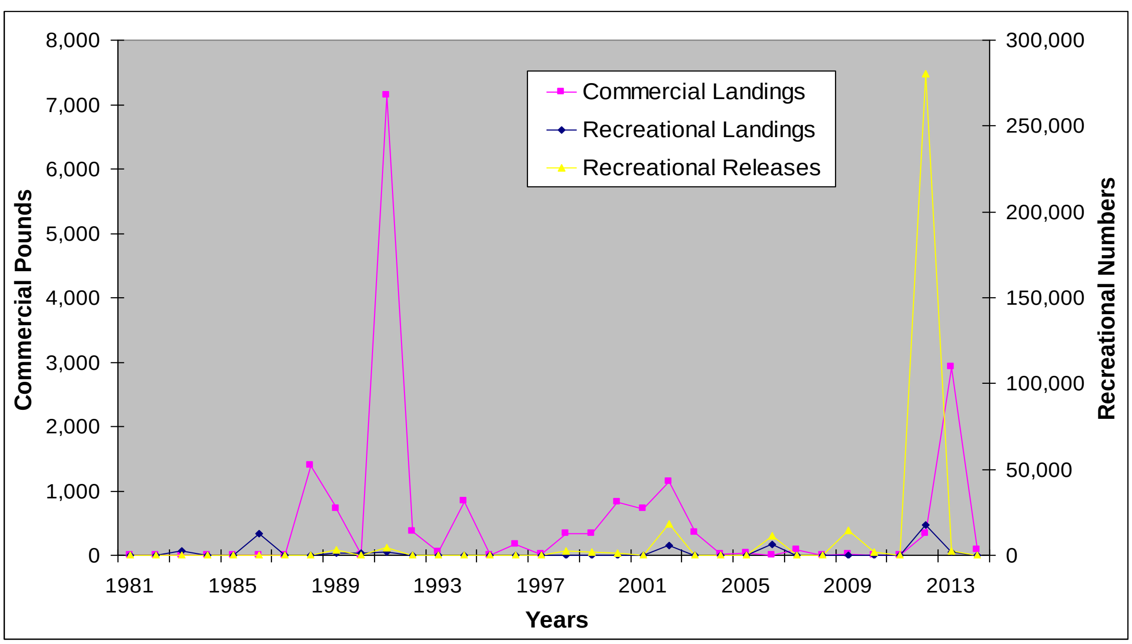


Figure 28. Maryland Charter boat log book red drum harvest in numbers and the number of anglers participating in trips catching red drum, 1993-2014.

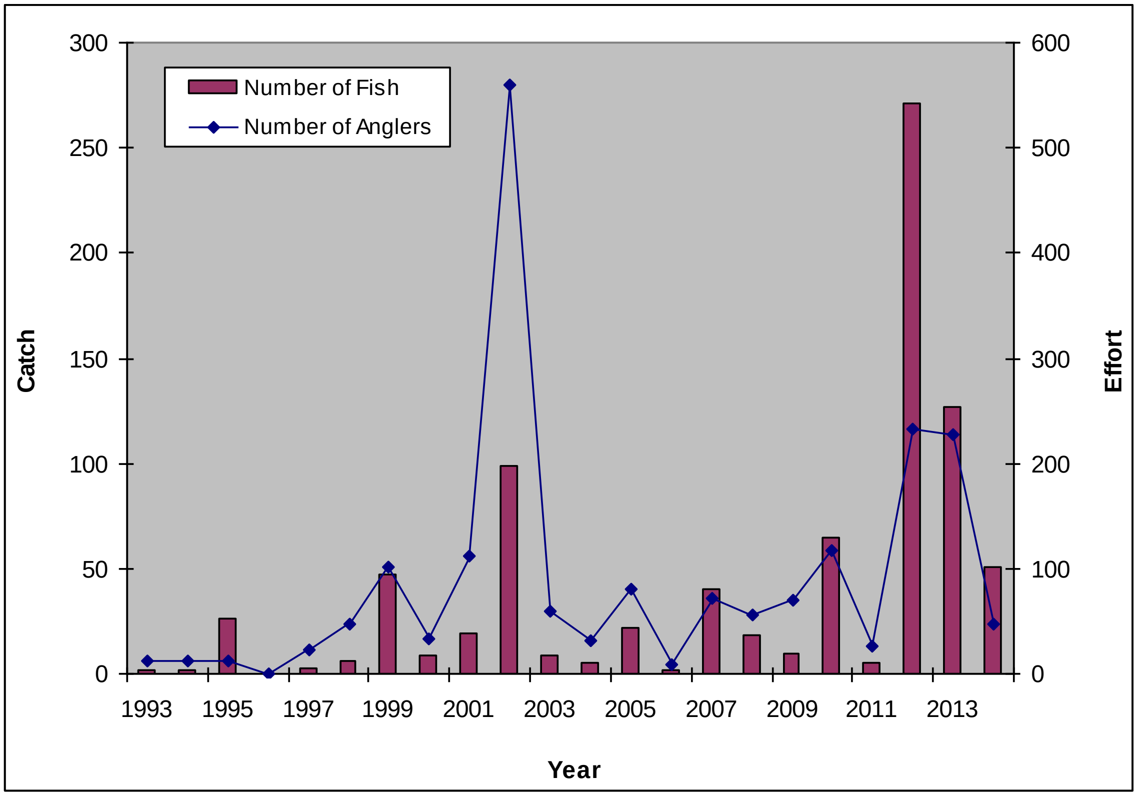


Figure 29. Maryland's commercial landings of black drum in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational black drum harvest and release estimates in numbers from 1981-2014.

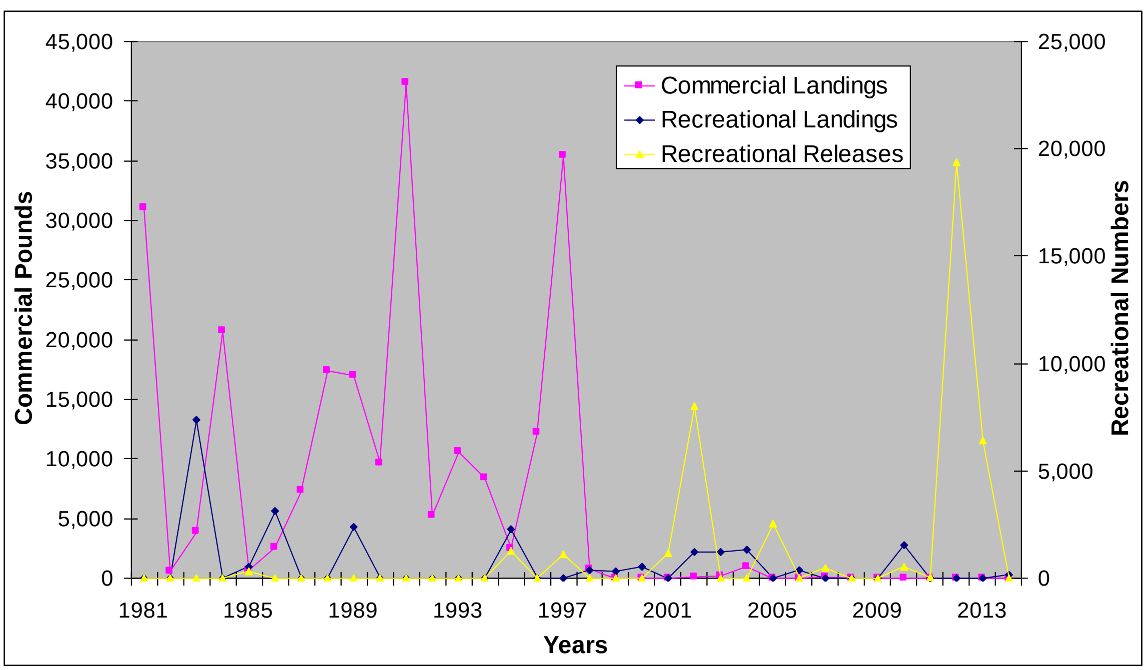


Figure 30. Maryland Charter boat log book black drum harvest in numbers and the number of anglers participating in trips catching black drum, 1993-2014.

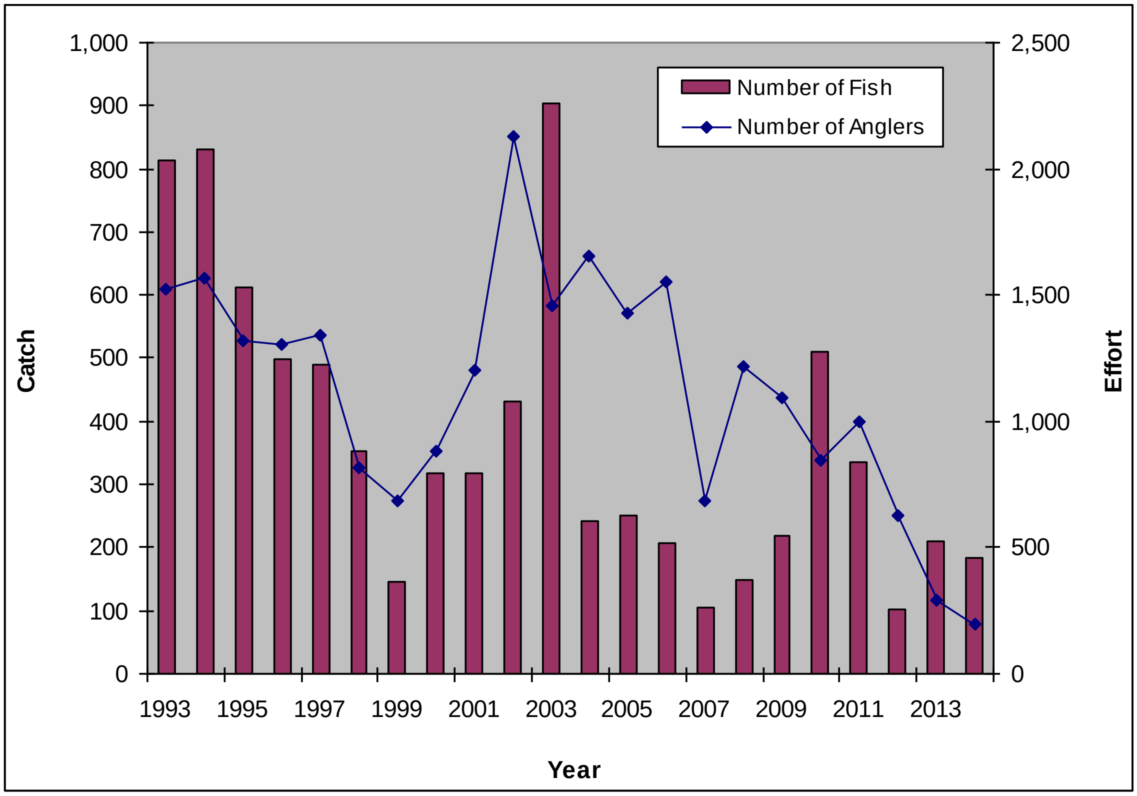


Figure 31. Maryland's commercial landings of Spanish mackerel in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational Spanish mackerel harvest and release estimates in numbers from 1981-2014.

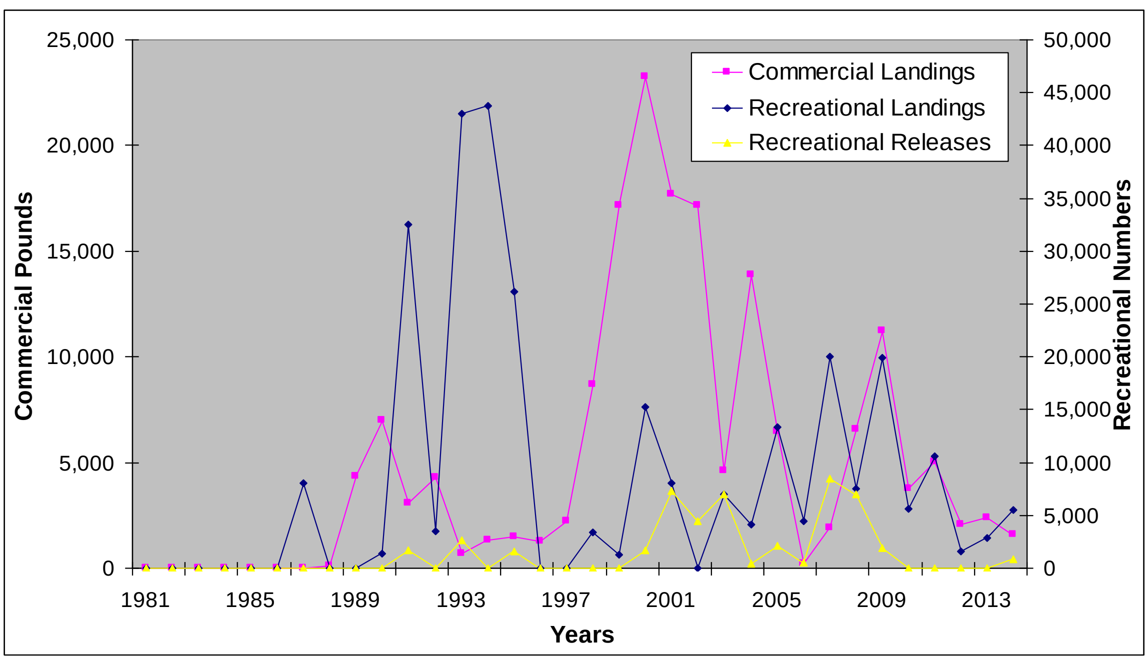


Figure 32. Maryland Charter boat log book Spanish mackerel harvest in numbers and the number of anglers participating in trips catching Spanish mackerel, 1993-2014.

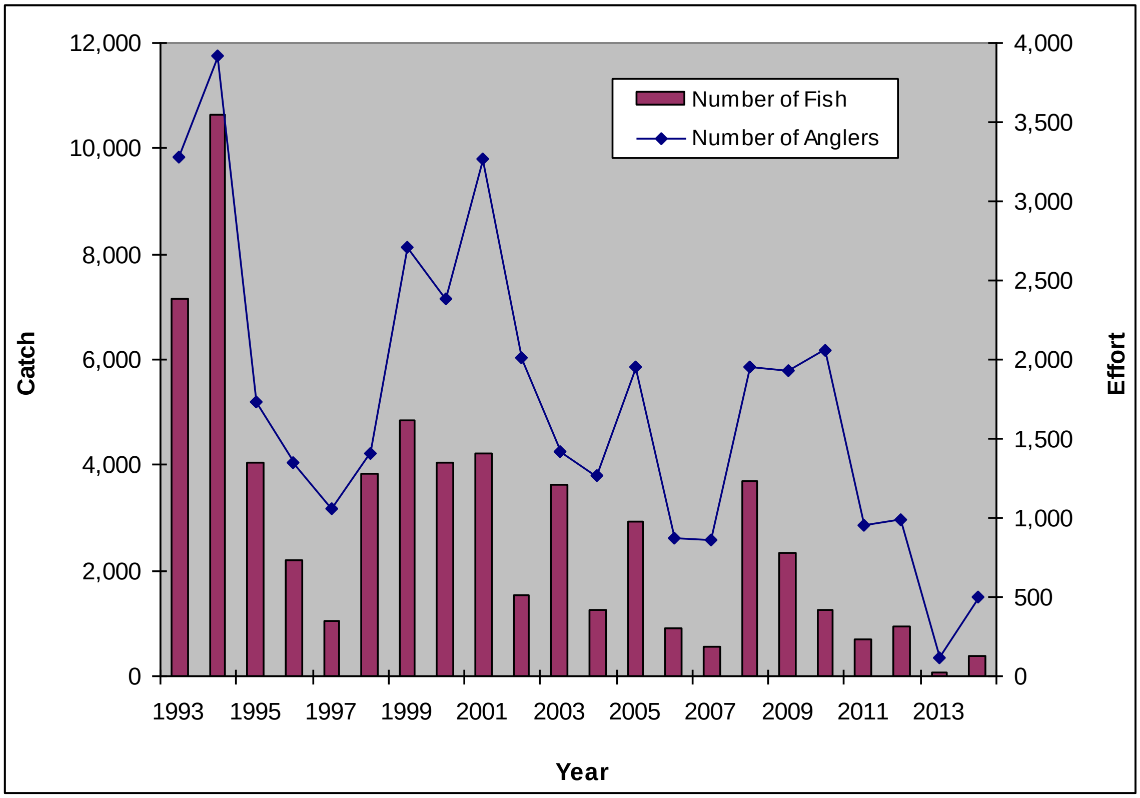


Figure 33. Maryland's commercial landings of spotted seatrout in pounds from the Chesapeake Bay and the MRIP Maryland inland recreational spotted seatrout harvest and release estimates in numbers from 1981-2014.

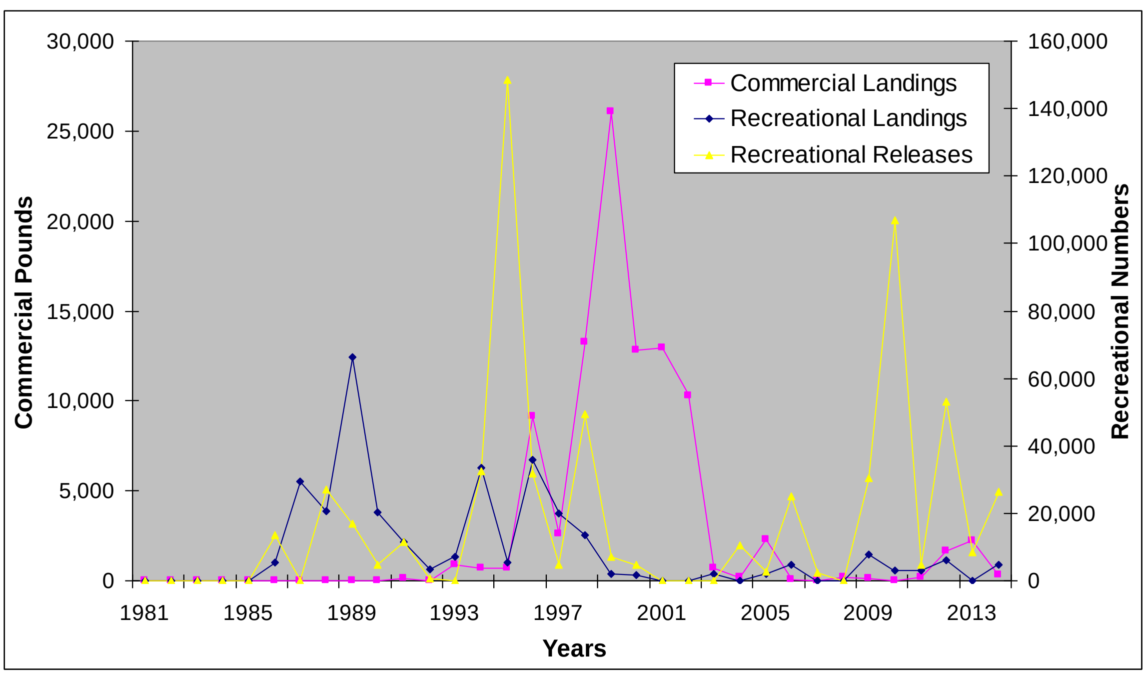


Figure 34. Maryland Charter boat log book spotted seatrout harvest in numbers and the number of anglers participating in trips catching spotted seatrout, 1993-2014.

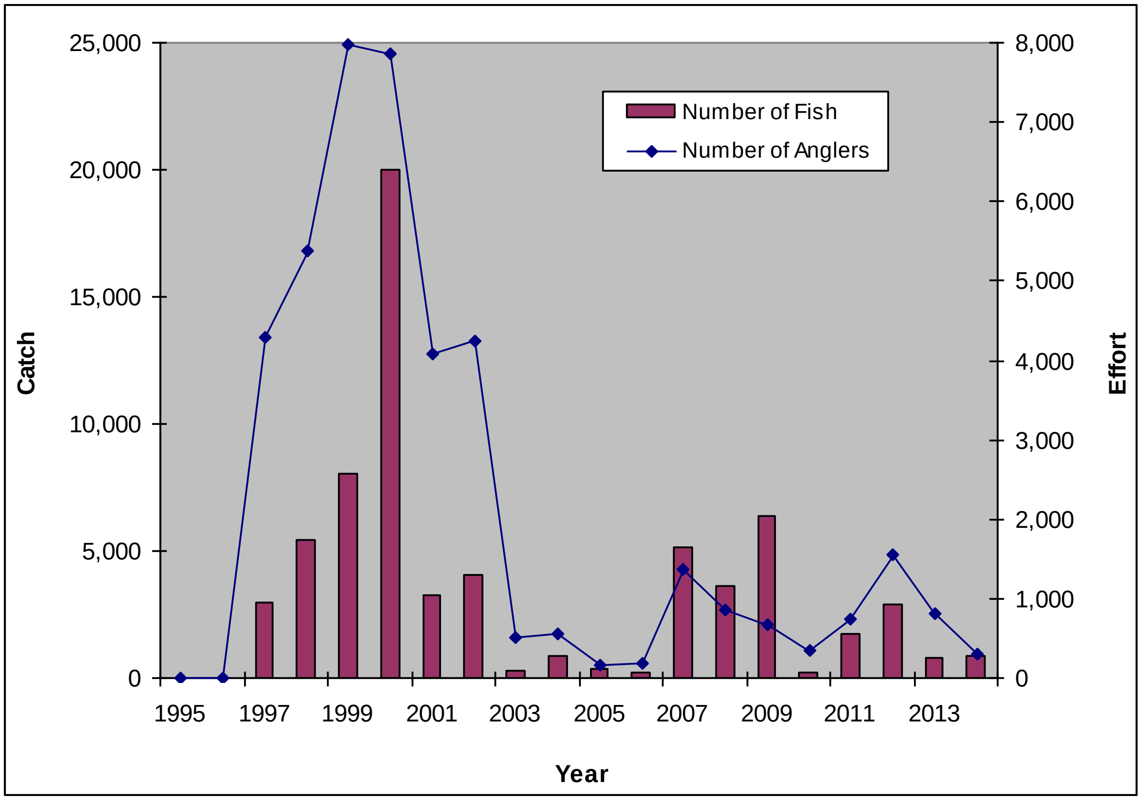


Figure 35. Menhaden length frequency distributions from onboard pound net sampling, 2005-2015.

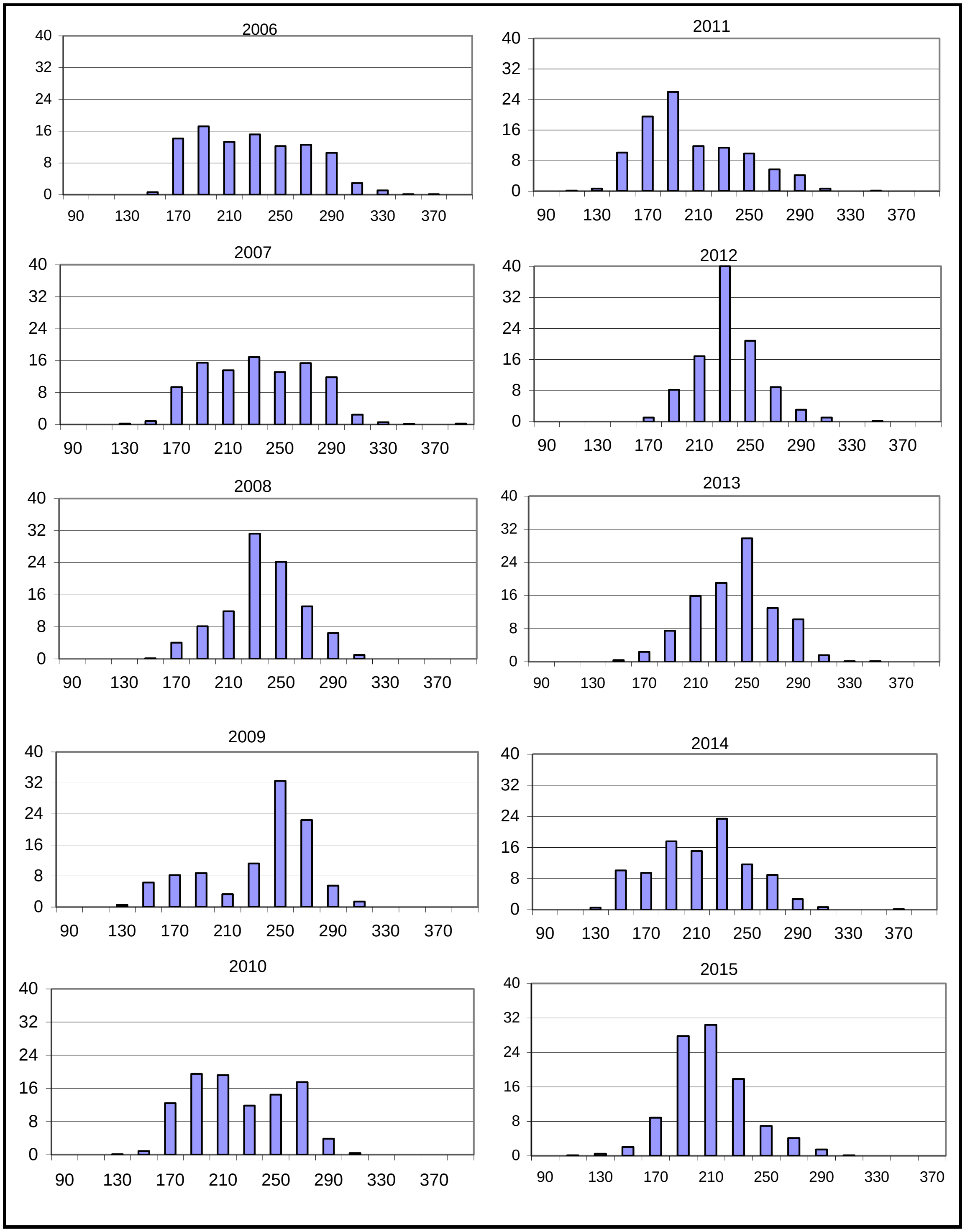


Figure 36. Atlantic menhaden proportion of catch by panel and year from the Choptank River gill net survey, 2013-2015.

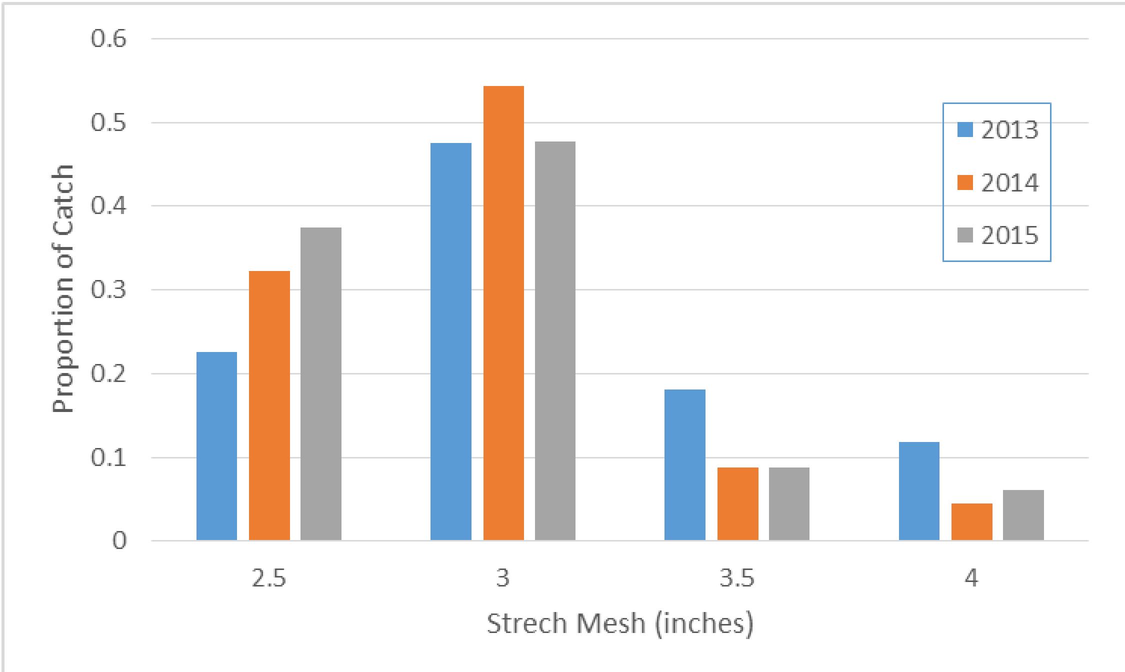


Figure 37. Atlantic menhaden length frequency distributions from the Choptank River gill net survey by year, 2013-2015.

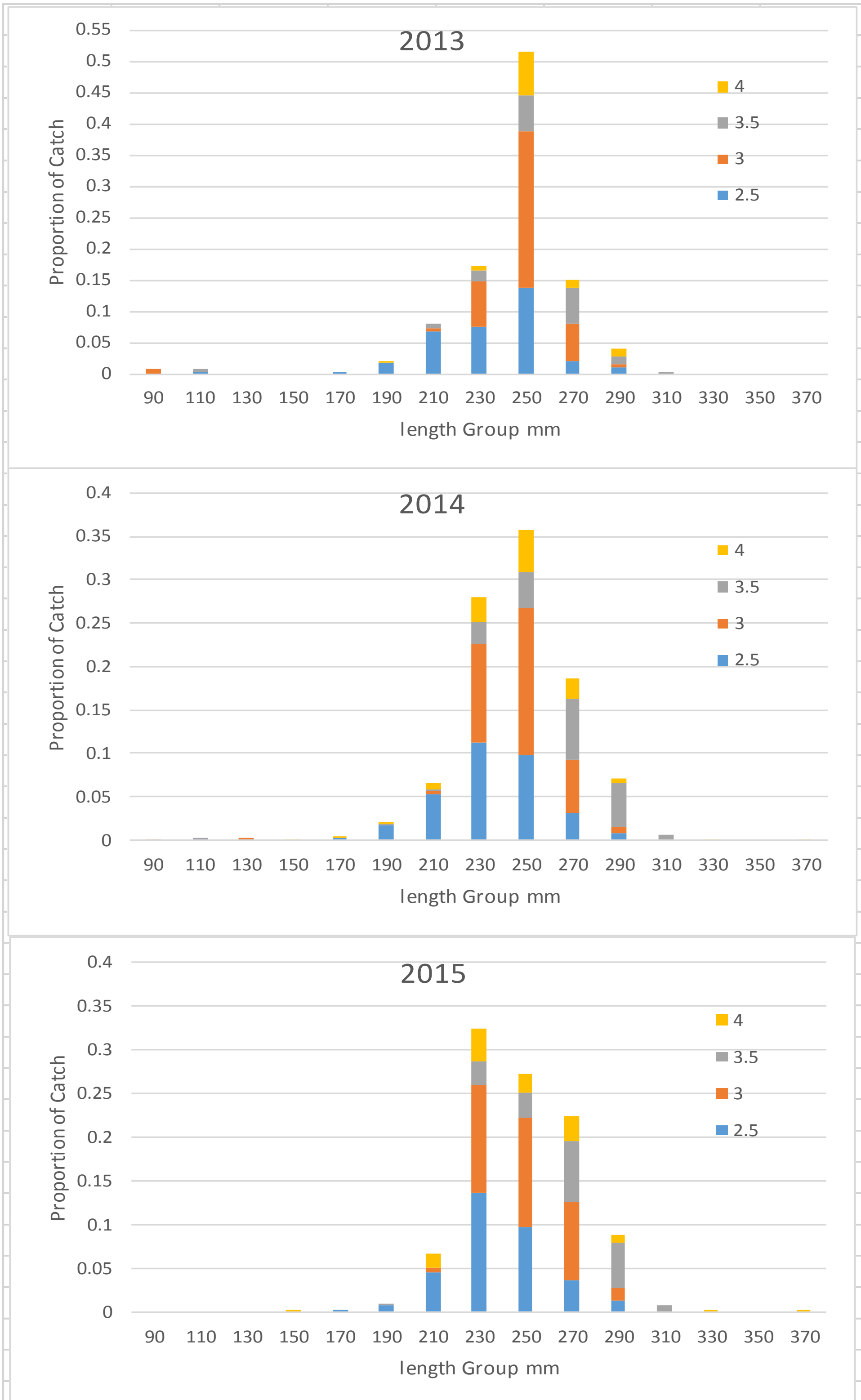
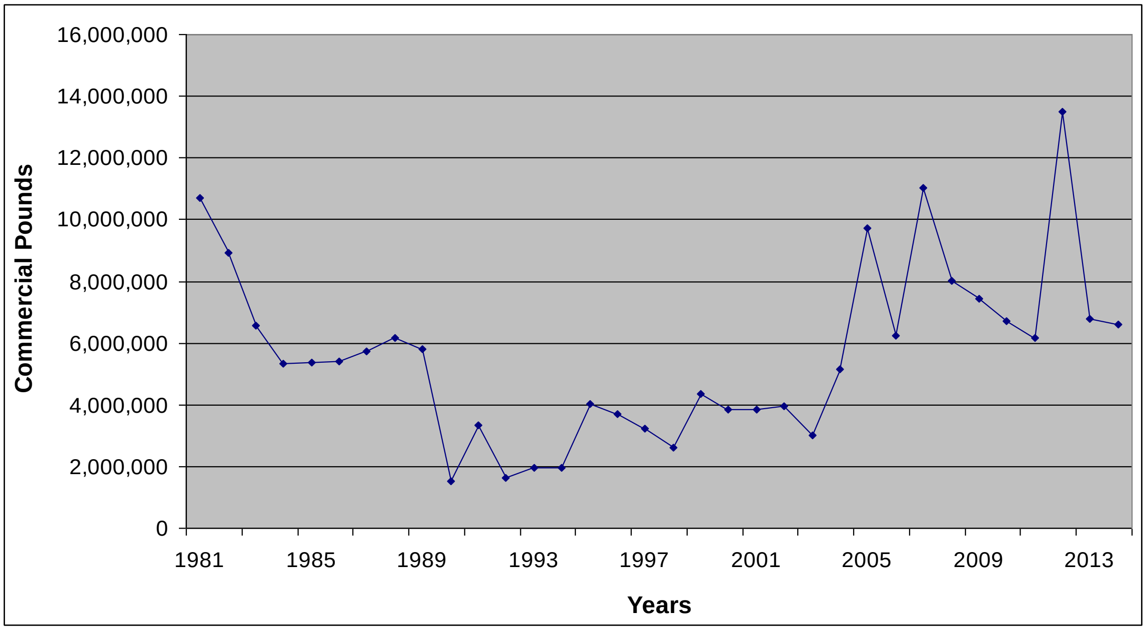


Figure 38. Maryland's Chesapeake Bay commercial landings for Atlantic menhaden from 1981-2014.



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

SUMMER – FALL STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

Prepared by Jeffrey R. Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1A was to characterize the size and age structures of the 2014 Maryland striped bass *Morone saxatilis* commercial summer/fall fishery. The commercial fishery during the summer/fall in 2014 operated on a combination of a common pool fishery and individual transferable quota (ITQ) system (see Project 2, Job 3, Task 5A). The 2014 ITQ commercial summer/fall fishery was open from 1 June through 31 December. The season typically runs from 1 June to 30 November, but was extended to allow fisherman the opportunity to catch their entire quota. The common pool fishery was open four days in June, two days in July, four days in August, five days in September, seven days in October, and three days in November. These fisheries targeted resident/pre-migratory striped bass. Harvested fish were sampled at commercial check stations and additional fish were sampled by visiting pound nets throughout the season.

In addition to characterizing the size and age structure of the commercial harvest, 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 2014 commercial fishery season were used to characterize the length and age structure of the entire 2014 Chesapeake Bay commercial harvest and the majority of the recreational harvest.

METHODS

Commercial pound net monitoring

Before sampling was implemented at check stations in 2000, fish were sampled directly 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 by-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. The validity of this assumption was questioned with the realization that commercial fishermen sometimes removed fish over 650 mm TL from nets prior to Fisheries Service (FS) 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 1-4 times per month from June through November 2014 (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 2014, striped bass were sampled from pound nets in the upper and lower Bay. Whenever possible, all striped bass in each pound net were measured in order to investigate by-catch. A full net sample was not possible when pound nets contained too many fish to be transferred to Fisheries Service 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 three fish per 10 mm length group per month, up to 700 mm TL, and from all striped bass greater than 700 mm TL. Other data recorded included latitude and longitude, date the net was last fished, depth, surface salinity, surface water temperature, air temperature, Secchi depth (m), and whether the net was fully or partially sampled.

Commercial summer/fall check station monitoring

All striped bass harvested in Maryland's commercial striped bass fisheries are required to pass through a MD DNR approved check station (see Project 2, Job 3, Task 5A). Check stations across Maryland were sampled for summer/fall harvested fish each month from June through November 2014 (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. Therefore, the combined fishery will be referred to as the summer/fall fishery for sampling purposes. An overall sample target was established based on the combined hook and line and pound net targets from previous years. This resulted in a monthly 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 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 dispersed 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 650 mm TL (maximum 4 samples per length group per month) and from all fish greater than 650 mm TL (subsample of 5 fish per 10 mm length group per trip was used if a high number of large fish were encountered).

Analytical Procedures

Scale ages from the pound net and check station surveys were combined and applied to all fish sampled. The number of scales read per length group varied depending on the size of the fish. The decision to apply ages from the pound net fishery to hook-and-line fish was based on the study by Fegley (2001) in which striped bass sampled from pound nets and from commercial hook-and-line check stations were examined for possible differences in length at age. An analysis of covariance (Sokal and Rohlf 1995) test failed to detect an age*gear interaction ($P>0.05$, $F=0.8532$). Striped bass harvested by each gear exhibited statistically indistinguishable 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, 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. Scales from check station surveys and pound net monitoring were combined to create the ALK. Approximately twice as many scales 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 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 2014 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 2014.

Mean lengths- and weights-at-age of striped bass landed in the summer/fall fishery were derived by applying ages to all sampled fish, and weighting the means on the length distribution at each age. Mean lengths- and weights-at-age were calculated by year-class for the aged sub-sample of fish. Mean lengths-at-age and weights-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. Age-specific length distributions based on the aged sub-sample are often different than the age-specific length distribution based on the entire length sample. Bettoli and Miranda (2001) suggested that the sub-sample means-at-age are often biased. The two calculation methods would result in equal means only if the length distributions for each age-class were normal, which rarely occurs in these data. Finally, length frequencies from the pound net monitoring and check station samples were examined.

RESULTS and DISCUSSION

Commercial pound net monitoring

During the 2014 striped bass pound net study, a total of 3,973 striped bass were sampled from five pound nets in the upper Bay and four pound net in the lower Bay (Table 1). The nine nets were sampled a total of 16 times during the study.

Striped bass sampled from pound nets ranged from 256-941 mm TL, with a mean length of 455 mm TL (Figure 2). In 2014, 75% of striped bass collected from full net samples were less than the minimum legal size of 18 inches (457 mm) TL, while 51% of fish from partially sampled nets were sub-legal. Mean total lengths of the aged sub-sample from pound nets are presented in Table 2.

Striped bass sampled from pound nets ranged from 1 to 12 years of age (Table 3, Figure 2). Age 1 fish of the 2013 year class contributed 6% of the sample. Age 2 fish from the record low 2012 year class contributed 3% to the sample. Age 3 fish from the above-average 2011 year-class contributed 56% of the sample. Age 4 fish contributed 15% in 2014, which was lower than the contribution in 2013 (27%). Striped bass age 6 and over accounted for 7% of the sample, which was similar to their contribution in 2013 (7%) and 2012 (10%; Figure 3). Fish age 8 and older composed 1% of the sample in 2014, which was similar to 2013 (1%) and 2012 (1%). Length frequencies of legal sized striped bass (n=1,670) sampled at pound nets were almost identical to length distributions from the check stations (Figure 4).

Commercial summer/fall check station monitoring

A total of 2,311 striped bass were sampled at summer/fall check stations in 2014. The mean length of sampled striped bass was 565 mm TL. Striped bass sampled from the summer/fall fishery ranged from 446 to 886 mm TL and from 3 to 11 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 for the 2014 summer/fall fishery are shown in Tables 4 and 5.

The length frequency and ages of the sampled fish were applied to the total summer/fall fishery harvest. Striped bass in the 450-550 mm length groups accounted for 57% of the summer /fall harvest (Figure 5). As in past years, few large fish were available to the summer/fall fishery. Striped bass over 700 mm TL were harvested throughout the season (Figure 6), but contributed only 9% to the overall harvest. Historically, these fish have not been available in large numbers during the summer (MDDNR 2002).

The 2014 summer/fall reported harvest accounted for 49%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2014 with 883,495 pounds landed (see Project 2, Job 3, Task 5A). Landings reported by the MD DNR commercial reporting section were 218,987 pounds for hook and line gear and 664,508 pounds for pound net gear. The combined length frequency for the summer/fall fishery was applied to the reported total catch. The estimated 2014 catch-at-age in pounds and numbers of fish for the summer/fall fishery is presented in Table 6. The majority of the harvest was composed of three to six year-old striped bass (86%). Striped bass from the above average 2011 (age 3) year class contributed 16% to the harvest. Striped bass from the 2009 (age 5) year-class contributed the highest percentage at 30%. Fish from the strong 2003 year-class (age 11) accounted for less than 1% of the total, similar to 2013 (<1%). Striped bass age 8 and older contributed 7% to the overall harvest in 2014, which was higher than 2013 (2%).

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 57% of the 2014 summer/fall harvest. A larger percentage of fish >630 mm TL were harvested in 2014 (20%) compared to 2013 (9% for hook-and-line and 12% for pound net; Figure 5). In 2014, 89 fish from pound net monitoring and 106 fish from check station sampling were aged. Younger fish (age 3 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 (Figure 4). Mean lengths-at-age have remained nearly the same since 2000 (Figure 8).

A Duncan's multiple range test (SAS 2006) performed on lengths and weights of striped bass harvest between months (p=0.05, Tables 7 and 8). Striped bass were significantly different in length in all months, except between June and July and July and November. The largest mean length occurred in June and July with no significant difference. All other months were significantly different, except between July and November. There were fewer significant differences in weight. The heaviest fish were in November, June and July with no significant different. All other months were significantly different from each other.

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Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2014 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	25.6	6.7	709
	Middle	-	-	-	-
	Lower	-	-	-	-
July	Upper	1	26.4	5.9	459
	Middle	-	-	-	-
	Lower	-	-	-	-
August	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	3	25.5	-	292
September	Upper	2	22.8	11.1	548
	Middle	-	-	-	-
	Lower	1	22.5	14.1	255
October	Upper	2	16.9	8.5	387
	Middle	-	-	-	-
	Lower	1	20.3	15.7	355
November	Upper	3	9.1	3.4	681
	Middle	-	-	-	-
	Lower	1	11.4	14.4	287

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2014.

Year-class	Age	n	Mean Length (mm TL)	Lower CL	Upper CL
2013	1	10	295	264	326
2012	2	3	350	232	469
2011	3	37	396	378	413
2010	4	9	500	454	547
2009	5	10	569	540	598
2008	6	5	649	628	671
2007	7	5	689	600	779
2006	8	2	753	*	*
2005	9	2	796	*	*
2004	10	1	845	*	*
2003	11	4	866	772	959
2002	12	1	906	*	*

*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 2014.

Year-class	Age	Pound Net Monitoring	
		Number Sampled at Age (n)	Percent of Total
2013	1	239	6.0
2012	2	128	3.2
2011	3	2,202	55.5
2010	4	590	14.9
2009	5	555	14.0
2008	6	144	3.6
2007	7	67	1.7
2006	8	24	0.6
2005	9	16	0.4
2004	10	4	0.1
2003	11	1	0.0
2002	12	1	0.0
Total*		**3,973**	**100.0**

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

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 2014.

Year-class	Age	n	Mean Length (mm TL)	Lower CL	Upper CL
2011	3	4	487	443	531
2010	4	7	554	503	605
2009	5	11	587	538	636
2008	6	16	708	665	752
2007	7	22	748	727	769
2006	8	9	732	688	777
2005	9	20	795	765	824
2004	10	13	806	780	832
2003	11	4	845	814	876

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 2014.

Year-class	Age	n	Mean Weight (kg)	Lower CL	Upper CL
2011	3	4	1.1	0.6	1.5
2010	4	7	1.7	0.9	2.6
2009	5	11	1.9	1.3	2.5
2008	6	16	3.6	2.8	4.4
2007	7	22	4.3	3.9	4.7
2006	8	9	3.8	3.0	4.5
2005	9	20	5.3	4.7	5.9
2004	10	13	5.6	5.1	6.0
2003	11	4	6.2	4.2	8.1

Table 6. Estimated catch-at-age of striped bass landed by Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2014.

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
2011	3	141,331	15.9	59,913	27.9
2010	4	243,263	27.6	63,782	29.7
2009	5	266,578	30.2	64,318	30.0
2008	6	108,764	12.3	13,628	6.4
2007	7	61,703	7.0	6,524	3.0
2006	8	28,558	3.2	3,454	1.6
2005	9	23,118	2.6	1,982	0.1
2004	10	7,996	0.9	654	0.0
2003	11	2,185	0.2	160	0.0
Total*		**883,945**	**100.0**	**214,415**	**100.0**

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

Table 7. Duncan's multiple range test for mean length by month at Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2014. Months with the same Duncan grouping letter are not significantly different in mean length.

Duncan Grouping	Month	Mean Length (mm)	Number of Fish Sampled
A	June	594	346
A, B	July	591	498
B	November	580	205
C	October	555	724
D	August	541	234
E	September	521	304

Table 8. Duncan's multiple range test for mean weight by month at Maryland Chesapeake Bay commercial summer/fall fishery, June through November 2014. Months with the same Duncan grouping letter are not significantly different in mean weight.

Duncan Grouping	Month	Mean Weight (kg)	Number of Fish Sampled
A	November	2.26	204
A	June	2.24	346
A	July	2.17	498
B	October	1.74	724
C	August	1.41	234
D	September	1.24	304

Figure 1. Locations of Chesapeake Bay commercial summer/fall check stations sampled from June through November 2014.

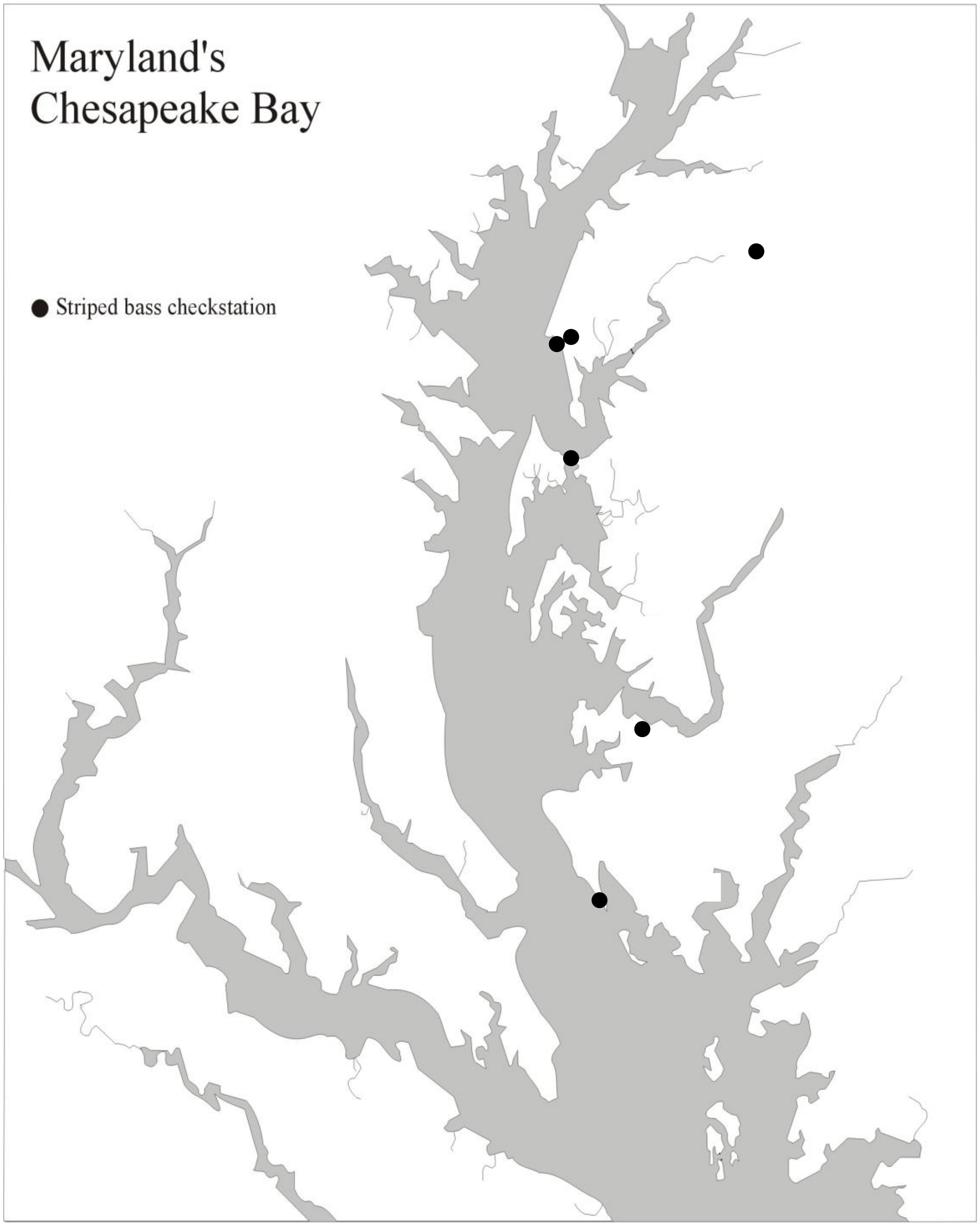
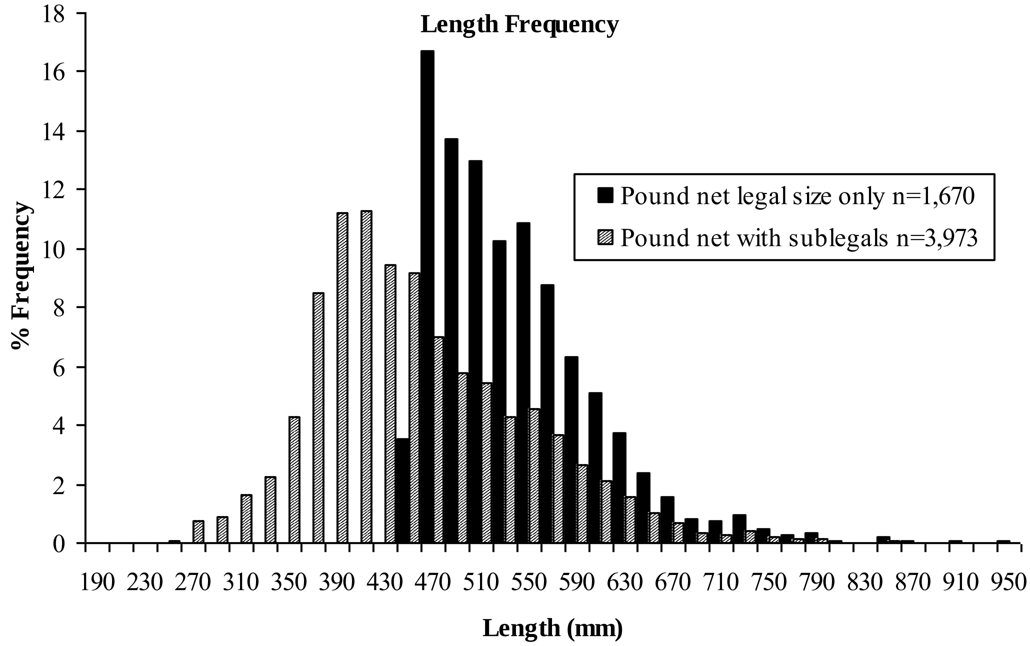


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, June through November 2014.



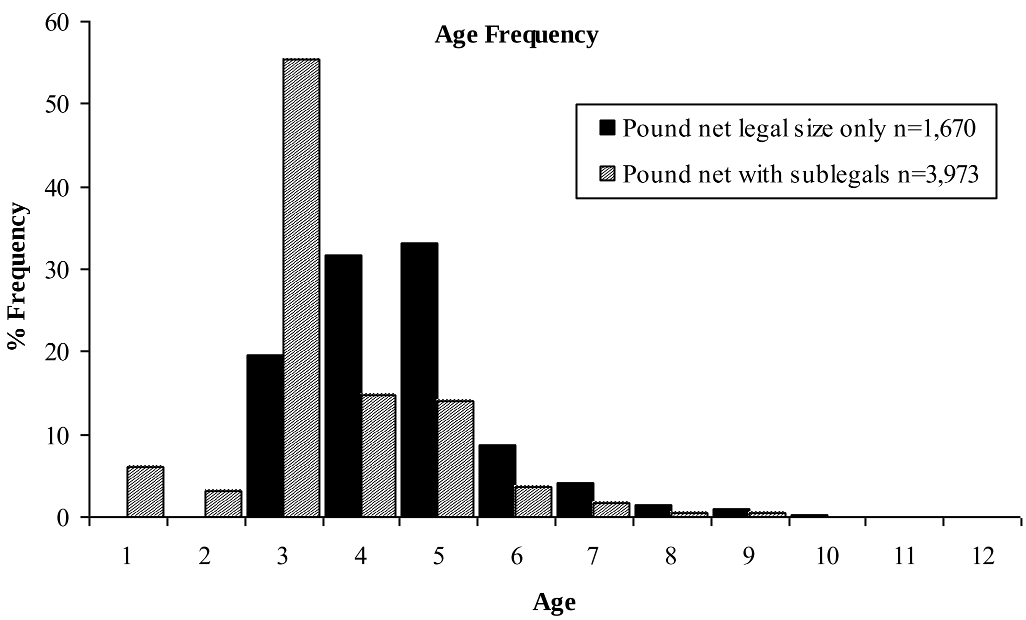


Figure 3. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2014. *Note partial net sampling for legal sized fish was conducted from 1996 to 1999. Full net samples started in 2000.

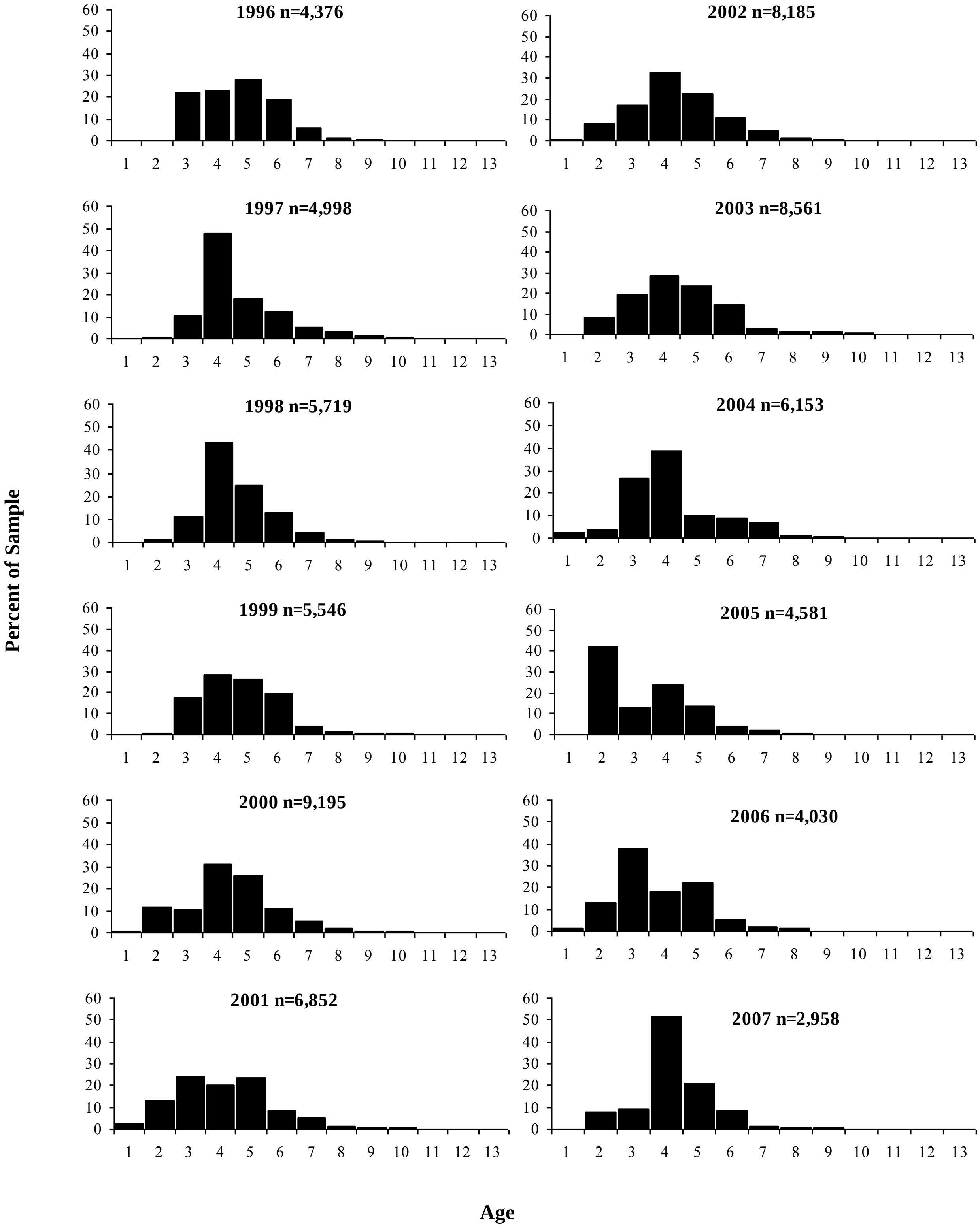


Figure 3. Continued.

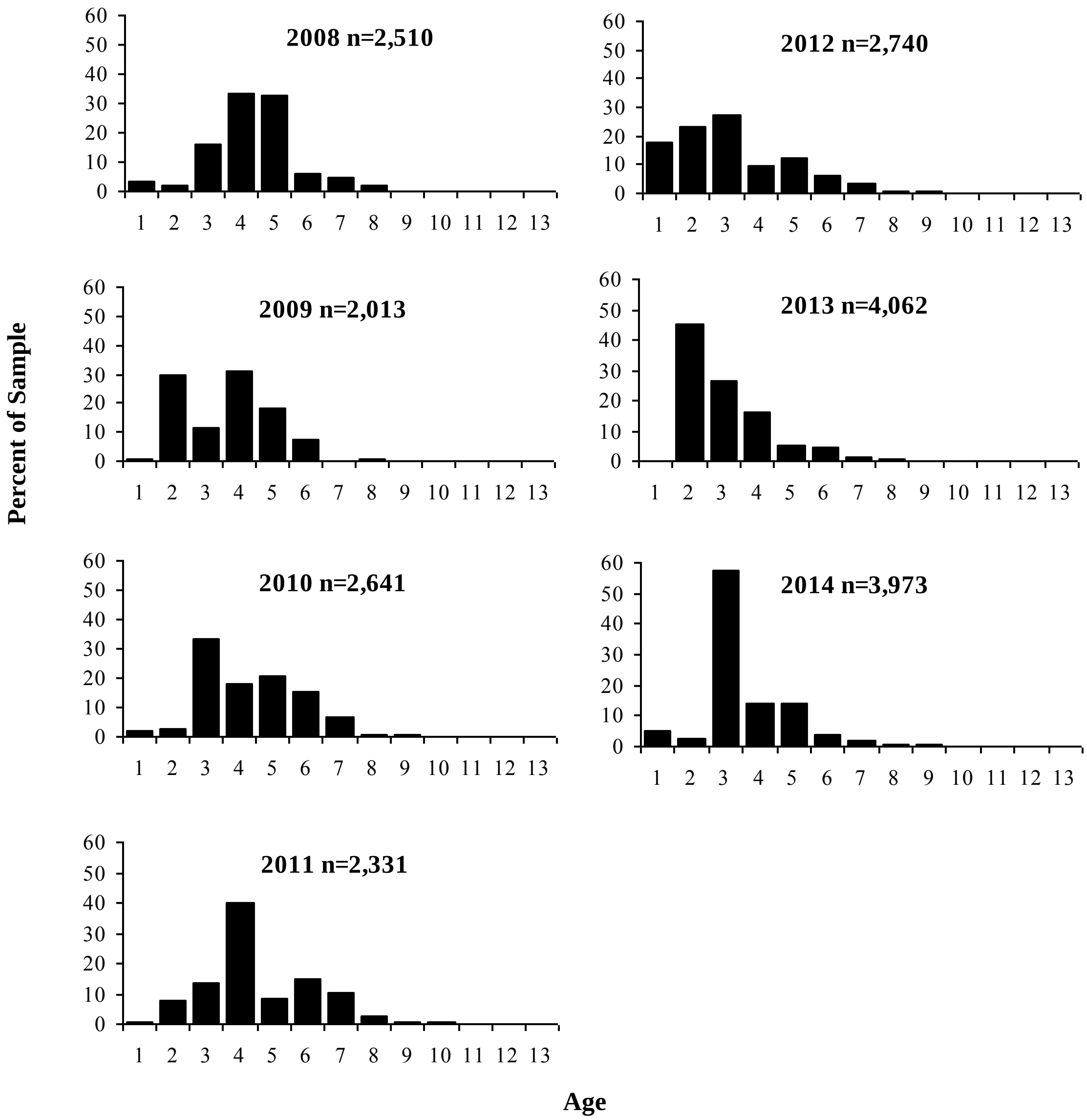


Figure 4. Length frequency of striped bass sampled during the 2014 pound net monitoring and the summer/fall check station surveys. All fish were sampled from June through November 2014. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

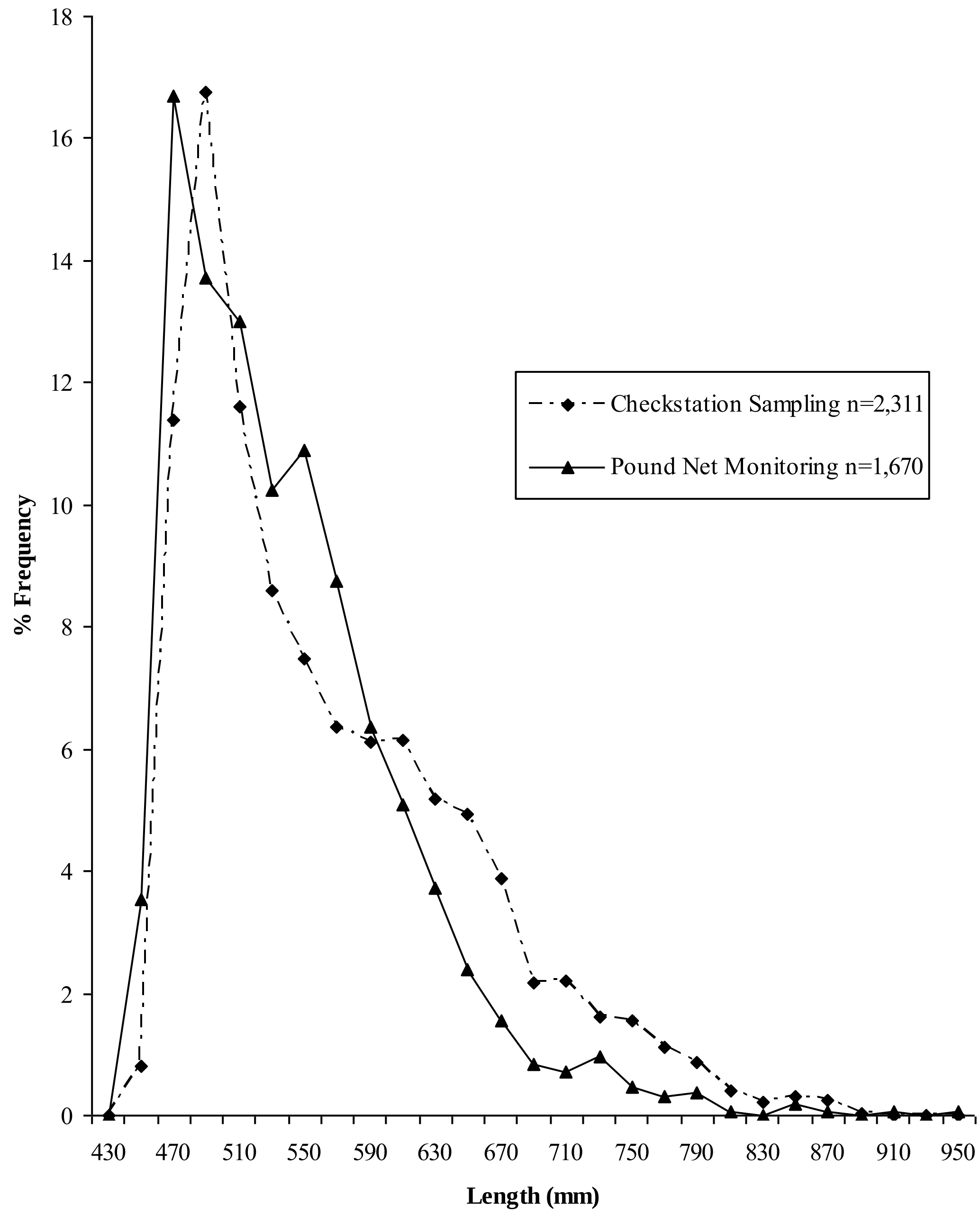


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, June through November 2014.

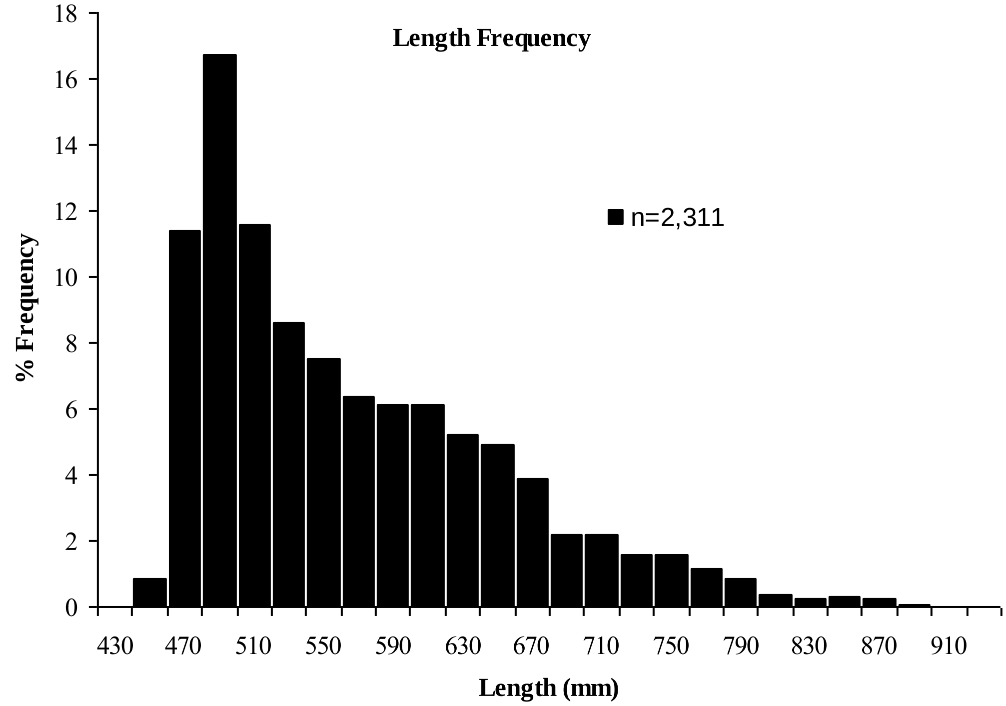


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, June through November 2014.

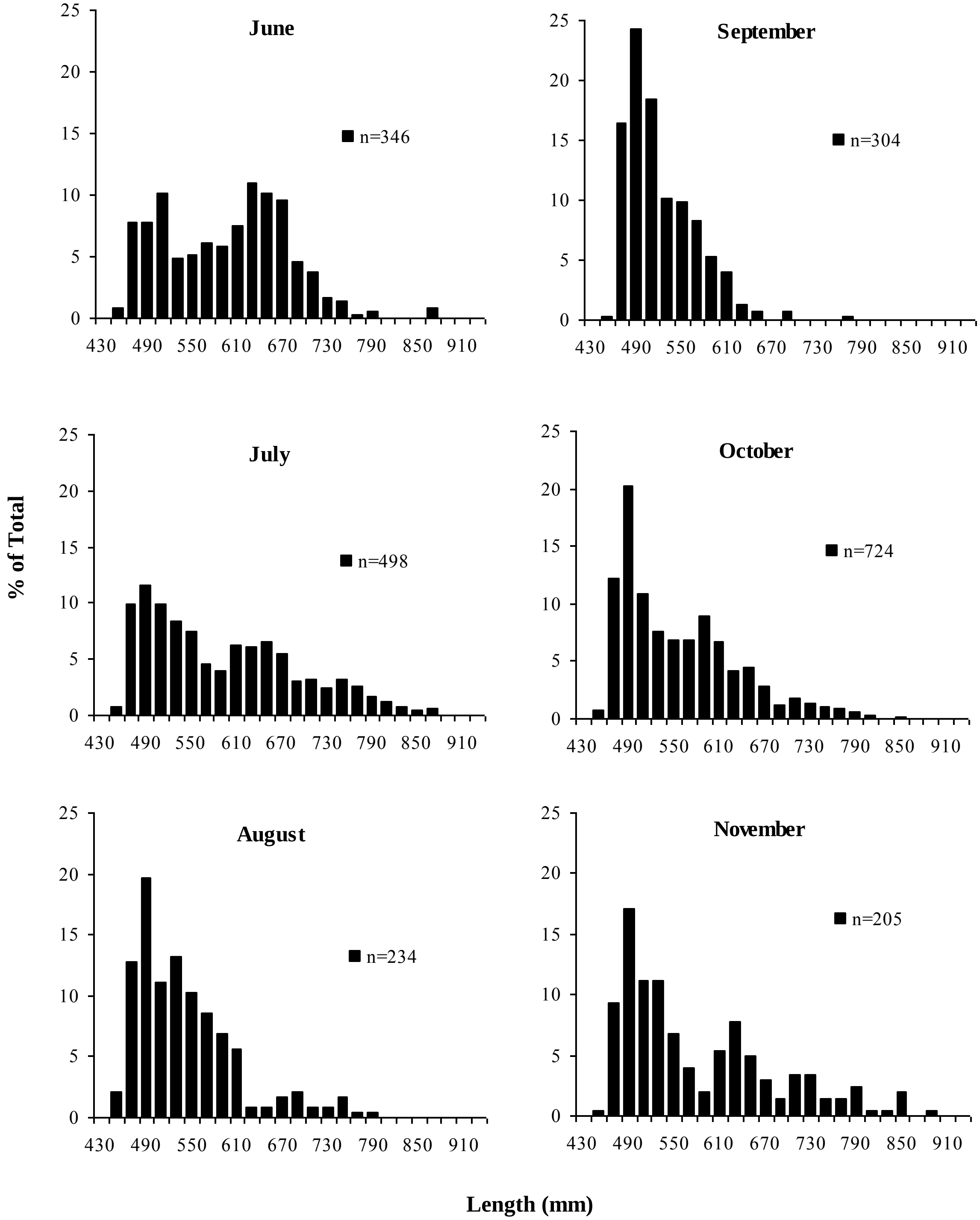


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial summer/fall check stations, 1999 through 2014. Note-pound net check station sampling began in 2000.

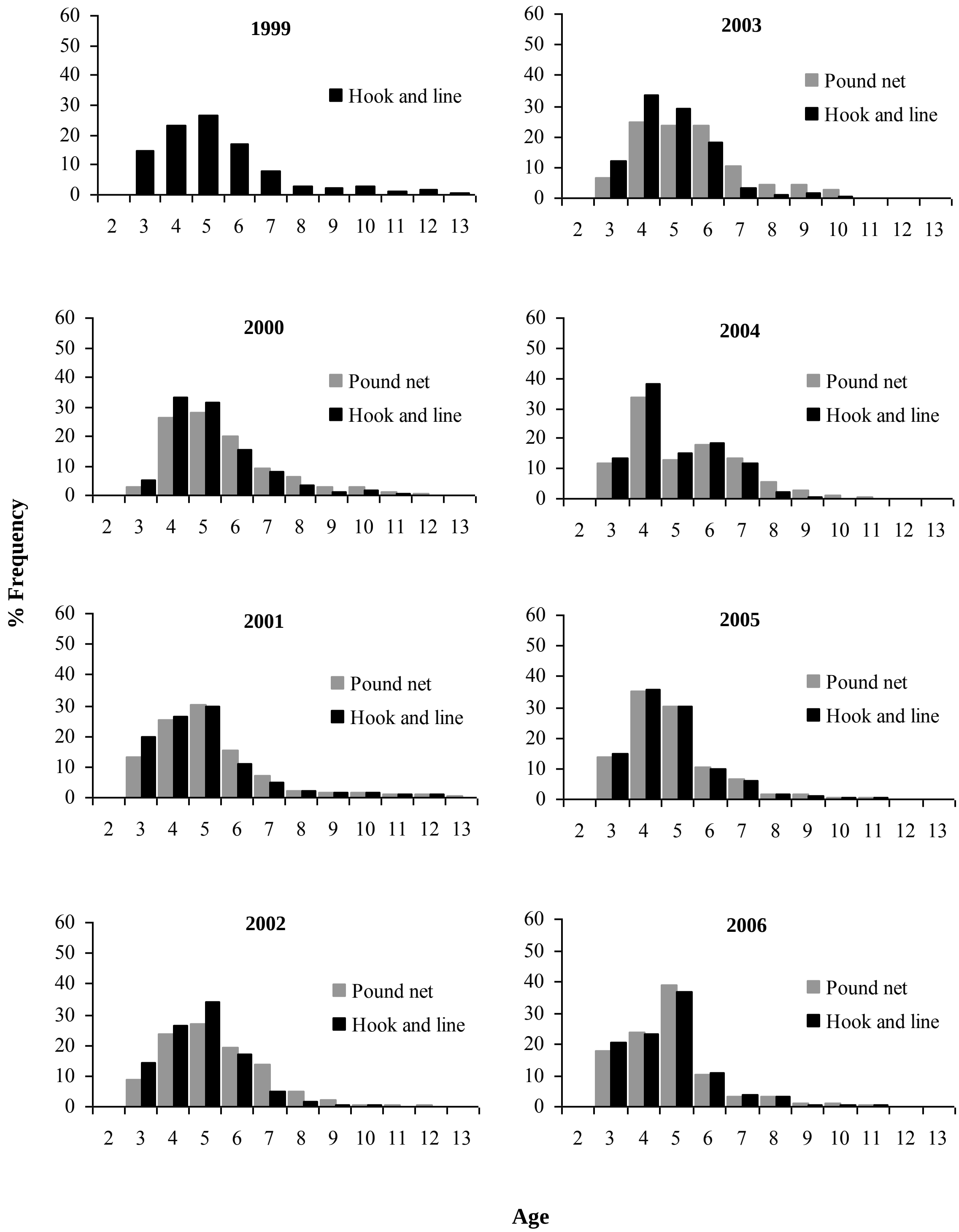


Figure 7. Continued.

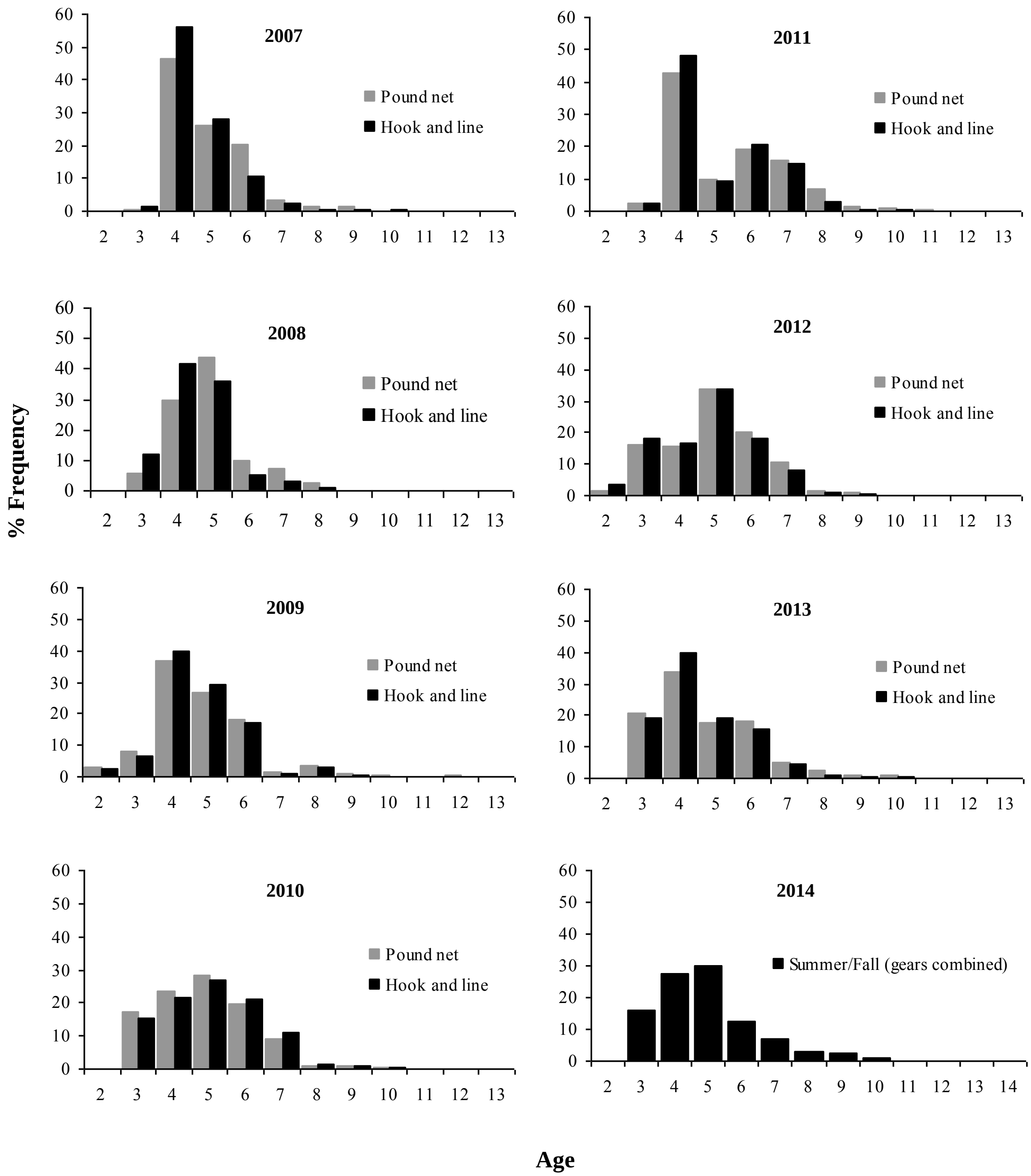
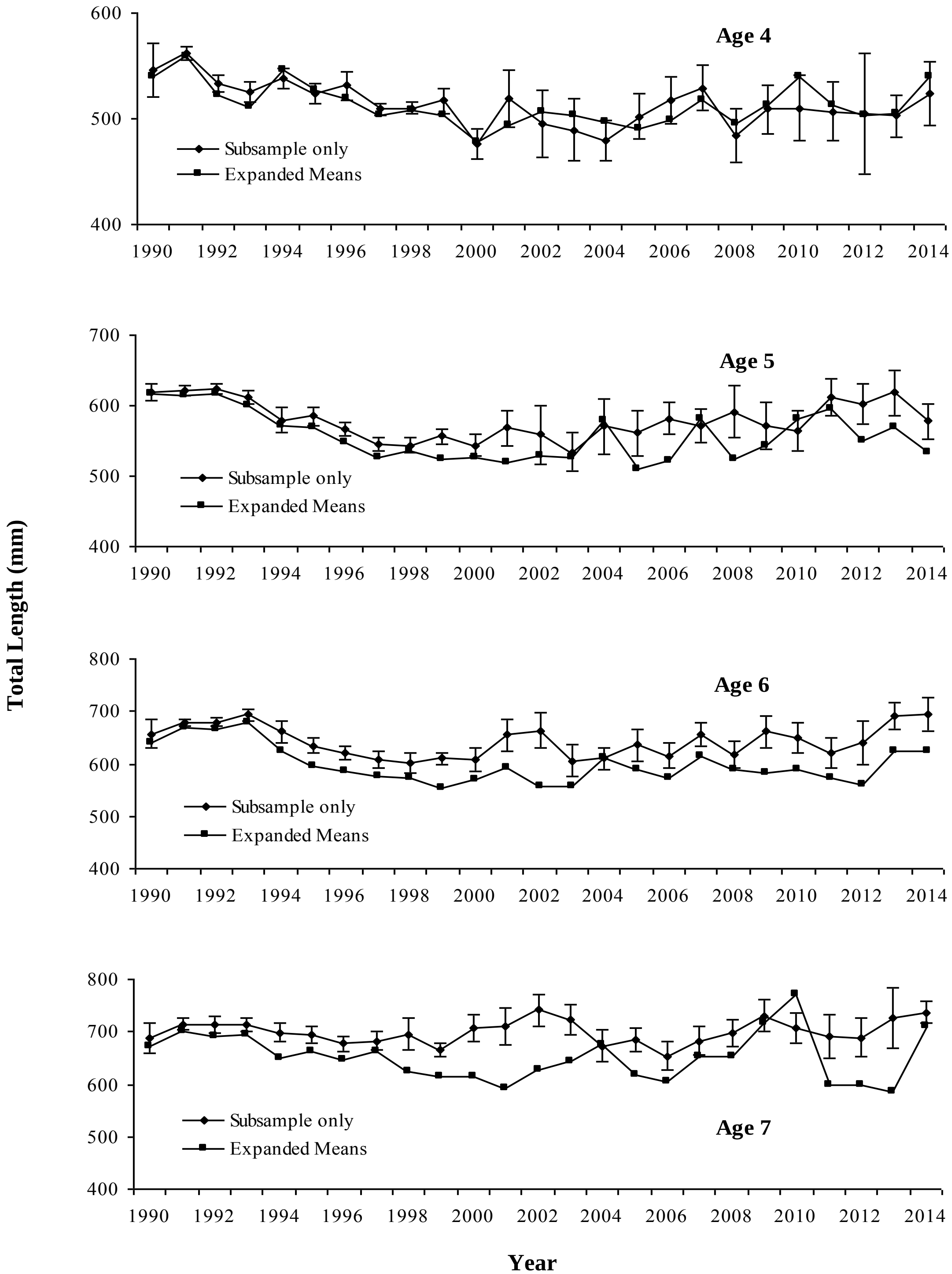


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial summer/fall check stations, 1990 through 2014. Mean lengths were calculated by using sub-sampled ages only and by expanding ages 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 R. 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, 2014 - March 13, 2015 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. The drift gill net ITQ season was extended in 2015 to March 13th due to ice conditions on the Chesapeake Bay. 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 8 days in December, 6 days in January and 2 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 entire 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). At each check station a random sample of at least 300 striped bass per visit were measured (mm TL) and weighed (kg). On days when fewer than 300 fish were checked in, all individuals were sampled. 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 five 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 for 400-700 mm and 10 scales per length group for >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 2014-2015 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 2014 – March 2015 gill net season, the year used for age calculations was 2015.

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 2014-2015 harvest was compared to that of previous years beginning with the 1993-1994 gill net season. Trends in growth were examined by plotting actual mean length-at-age and mean weight-at-age of aged subsamples, with confidence intervals, by year, for individual age-classes. Expanded mean lengths-at-age and weights-at-age were also plotted on the same time series graph for comparison.

RESULTS and DISCUSSION

A total of 3,141 striped bass were sampled and 153 striped bass were aged from the harvest between December 2014 - March 2015. 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 Tilghman Island (Figure 1). Check stations were visited by biologists 5 times in December, 6 times in January, 3 times in February, and 2 times in March.

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 (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 between years based on year-class strength.

The number of fish landed for the 2014-2015 season was estimated by dividing reported monthly harvest weight by the mean monthly weight of check station samples. Total reported landings were 769,074 pounds and the reported number of fish was 145,827. According to the catch-at-age analysis, the 2014-2015 commercial drift gill net harvest consisted primarily of age 6 striped bass from the 2009 year-class (28%; Table 1). The 2011, 2010, 2008, and 2007 year-classes (ages 4, 5, 7, and 8) composed an additional 59% of the total harvest, while ages 9 and older contributed 13% to the total. The contribution of fish older than 9 years was higher than in the 2013-2014 harvest (7%). The youngest fish observed in the 2014-2015 sampled harvest were age 4 from the above average 2011 year class (8%).

Mean lengths and weights-at-age of the aged subsample and the estimated means from the expansion technique are presented in Tables 2 and 3. Expanded mean lengths and weights-at-age were generally slightly higher than subsample means for 4-5 year old fish and slightly lower for fish age 6 and older. Striped bass were recruited into the winter gill net fishery beginning at age 4 (2011 year-class), with an expanded mean length and weight of 541 mm TL and 1.99 kg, respectively. The 2009 year-class (age 6) was most commonly observed in the sampled landings and had an expanded mean length and weight of 618 mm TL and 3.00 kg, respectively. The expanded mean length and weight of the oldest fish in the aged subsample (age 14, 2001 year-class) were 905 mm TL and 9.45 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 610-710 mm TL range. Although sub-legal fish have occasionally been sampled in previous years, none were observed in 2014-2015 sampling.

Time series of subsampled and expanded mean lengths and weights for the period 1994-2015 are shown in Figures 4 and 5 for fish ages 4 through 9, which generally make up 95% or more of the harvest. Mean length-at-age and weight-at-age for age 4 and 5 striped bass have been relatively constant. Mean length-at-age and weight-at-age for ages 6 through 9 are more variable, likely due to smaller sample sizes or greater range of lengths and weights for each age group.

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Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2014 - March 2015.

Year-class	**Age**	**Catch**	**Percentage of the catch**
2011	4	12,359	8
2010	5	11,475	8
2009	6	40,941	28
2008	7	36,429	25
2007	8	26,358	18
2006	9	7,438	5
2005	10	8,991	6
2004	11	1,444	1
2003	12	344	0
2001	14	46	0
Total*		**145,827**	**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 the Maryland Chesapeake Bay commercial drift gill net landings, December 2014-March 2015.

Year-class	**Age**	**n fish aged**	**Mean TL (mm) of aged subsample**	**Estimated # at-age in sample**	**Expanded mean TL (mm)**
2011	4	18	505	266	541
2010	5	11	543	247	577
2009	6	27	618	883	618
2008	7	27	671	784	649
2007	8	30	741	568	689
2006	9	12	771	160	711
2005	10	16	774	194	720
2004	11	7	815	31	762
2003	12	4	837	7	818
2001	14	1	905	1	905
Total*		**153**		**3,141**	

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

Table 3. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2014-March 2015.

Year-class	Age	n fish aged	Mean weight (kg) of aged subsample	Estimated # at-age in sample	Expanded mean weight (kg)
2011	4	18	1.58	266	1.99
2010	5	11	2.10	247	2.46
2009	6	27	3.15	883	3.00
2008	7	27	3.86	784	3.44
2007	8	30	5.20	568	4.08
2006	9	12	5.68	160	4.44
2005	10	16	5.63	194	4.59
2004	11	7	7.26	31	5.48
2003	12	4	7.70	7	6.75
2001	14	1	9.70	1	9.45
Total*		**153**		**3,141**	

* 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 2014-March 2015.

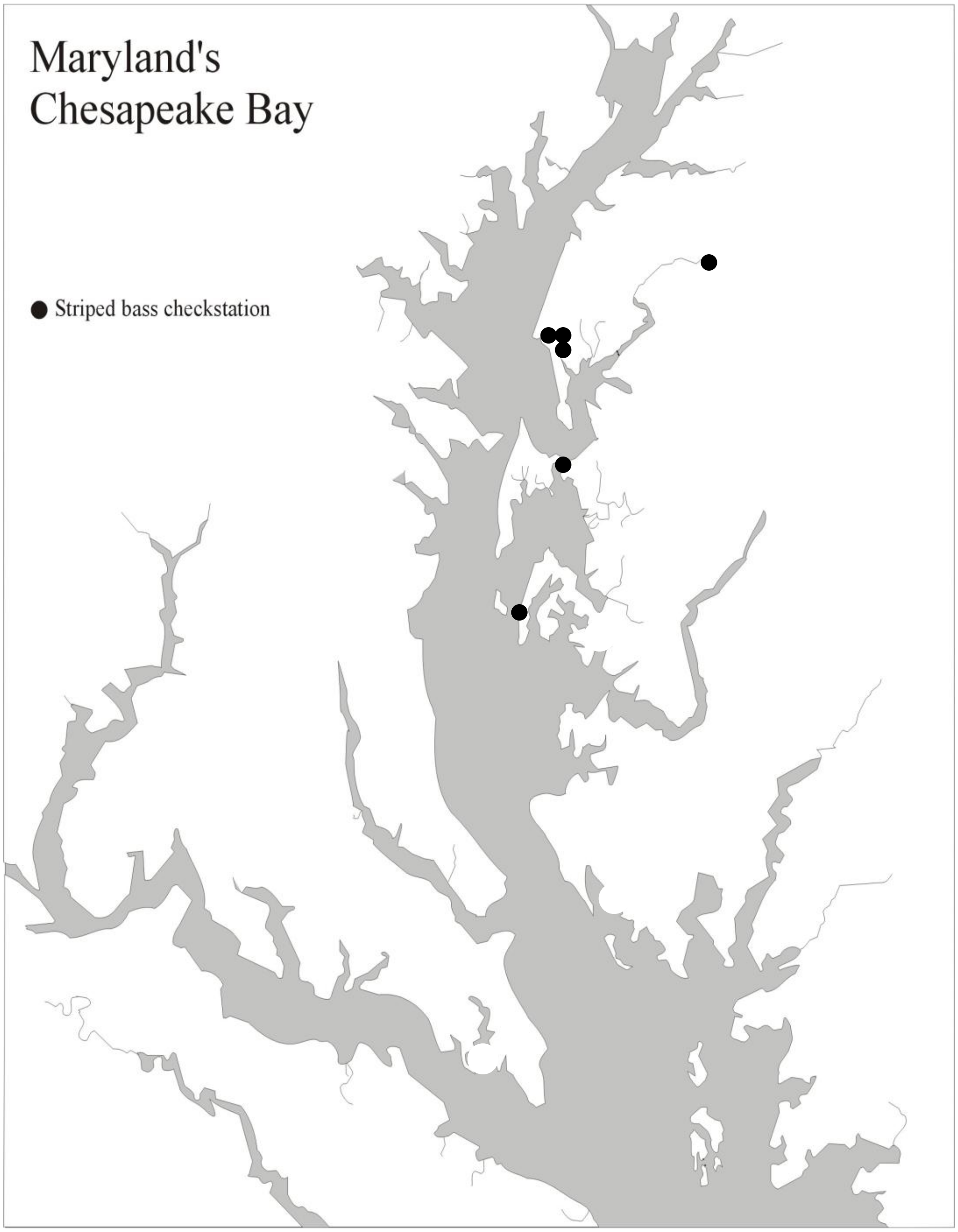


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2015.

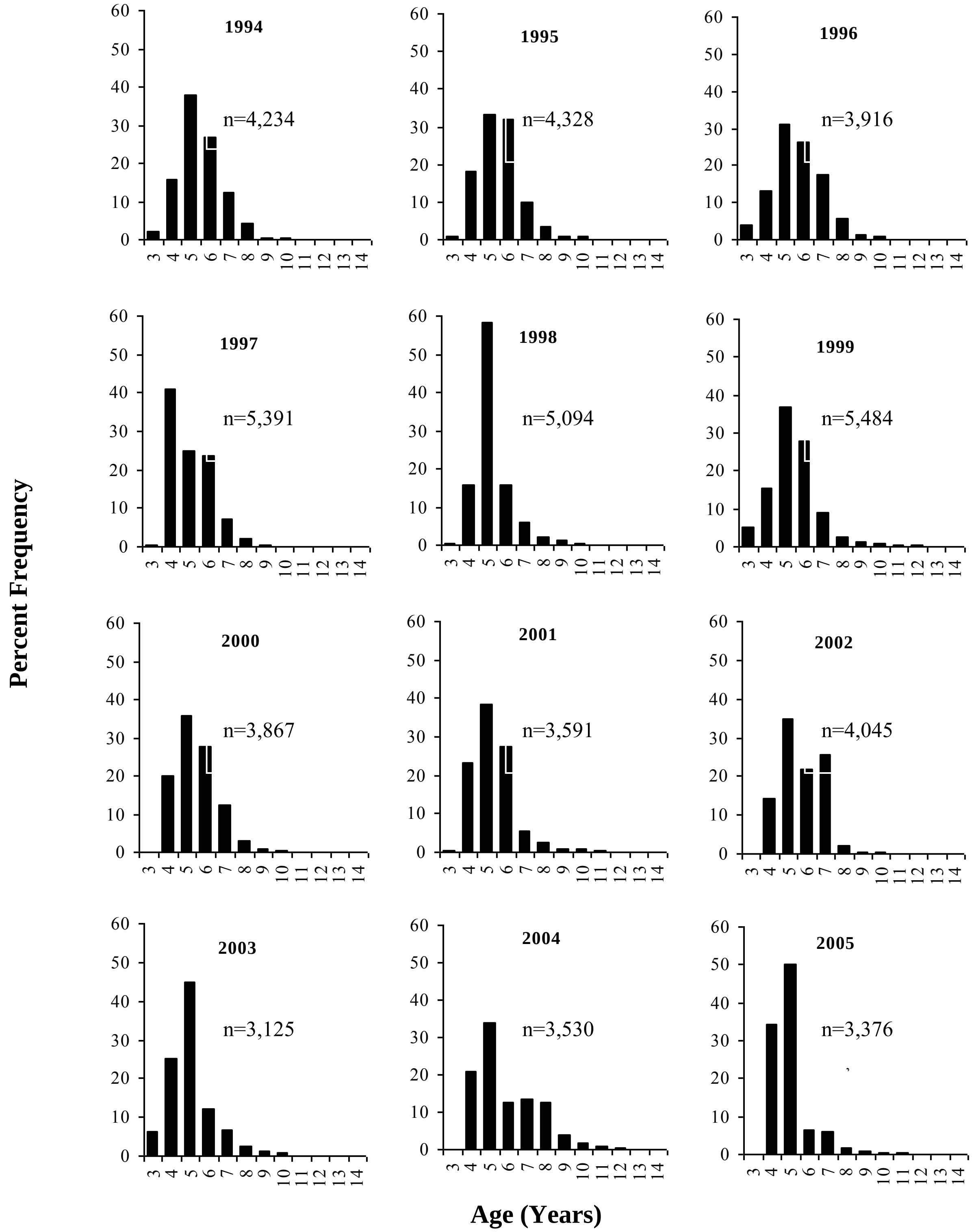


Figure 2. Continued.

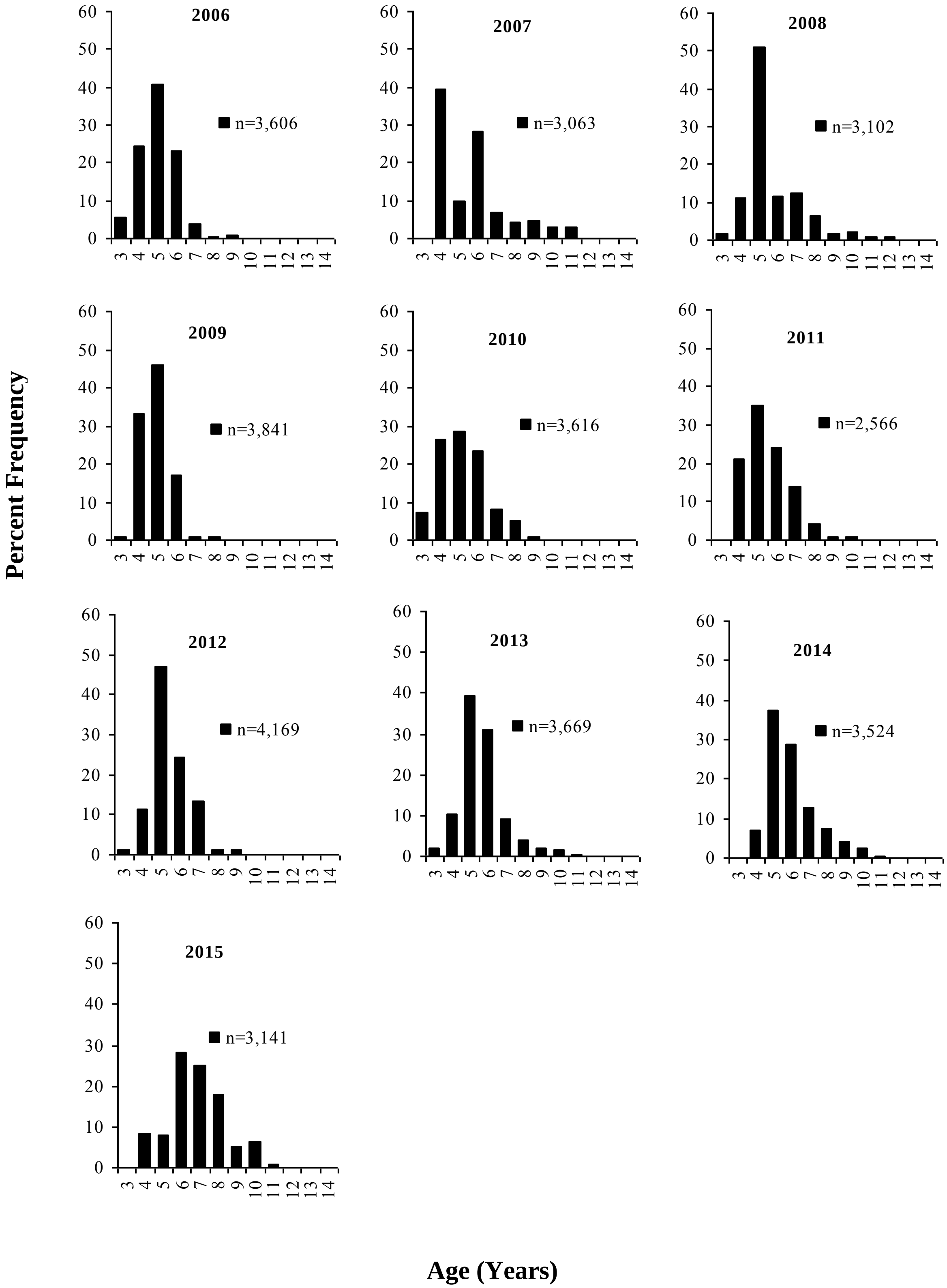


Figure 3. Length frequency distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2014-March 2015.

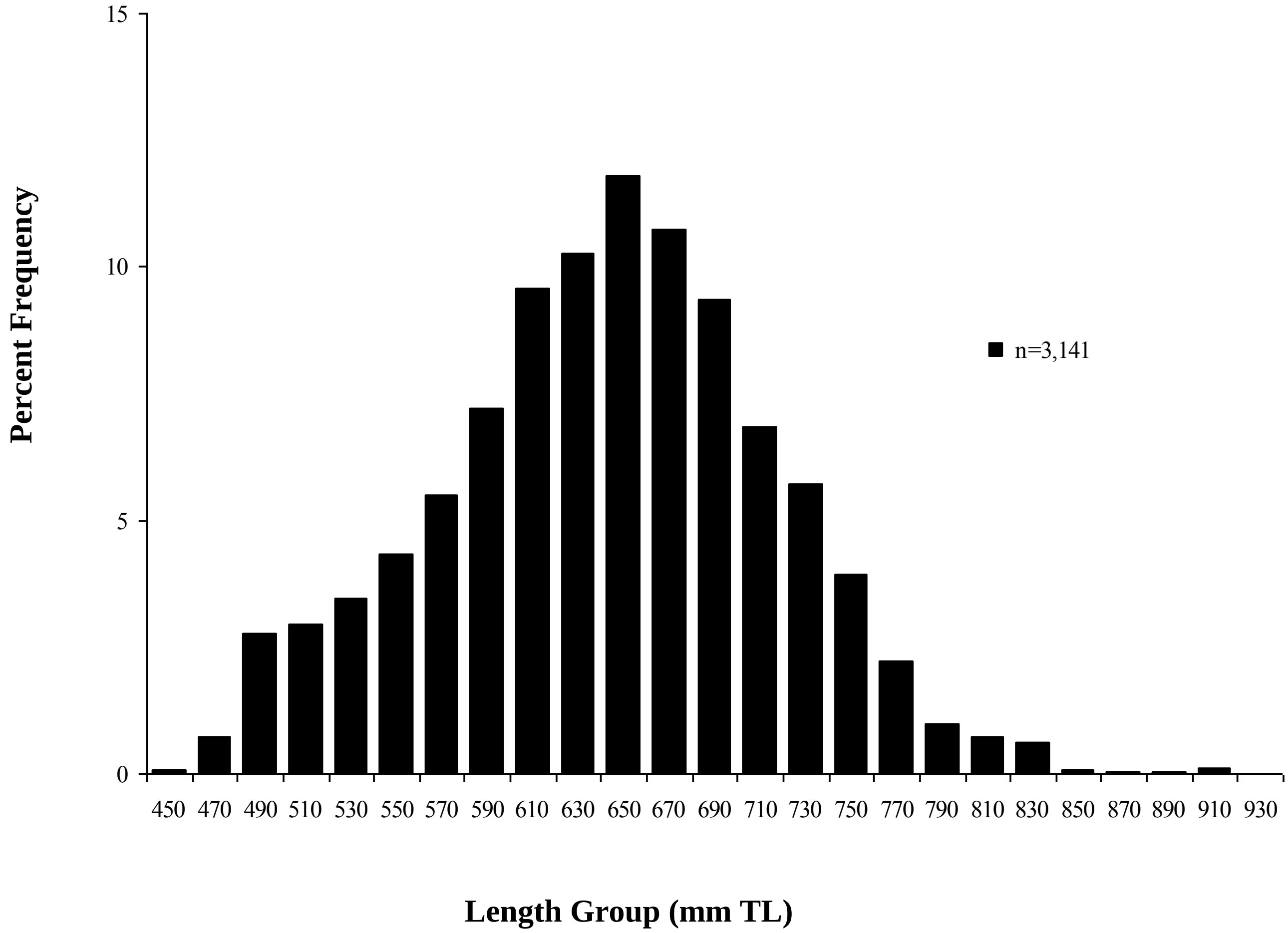
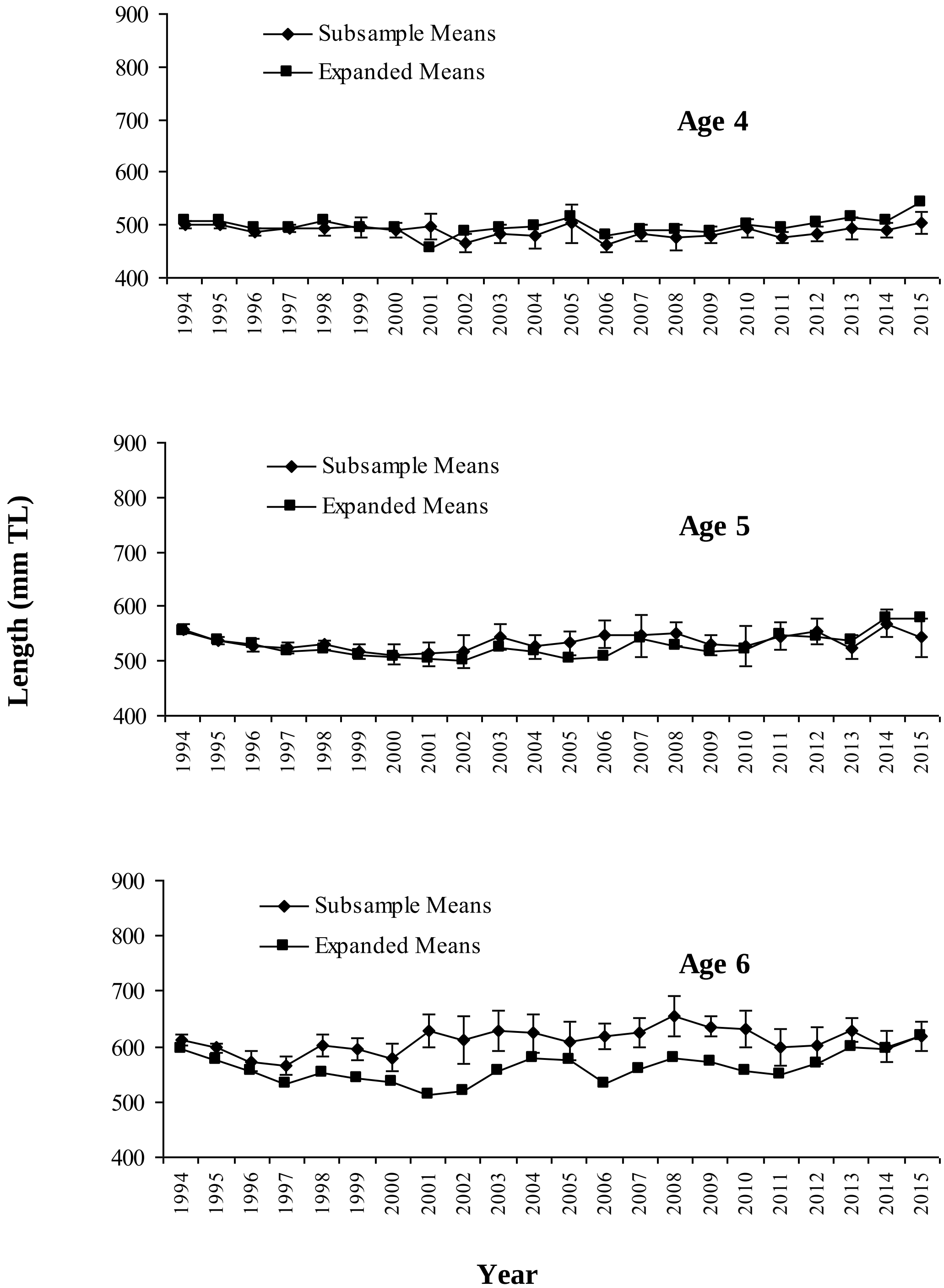


Figure 4. Mean total lengths (mm TL) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2015 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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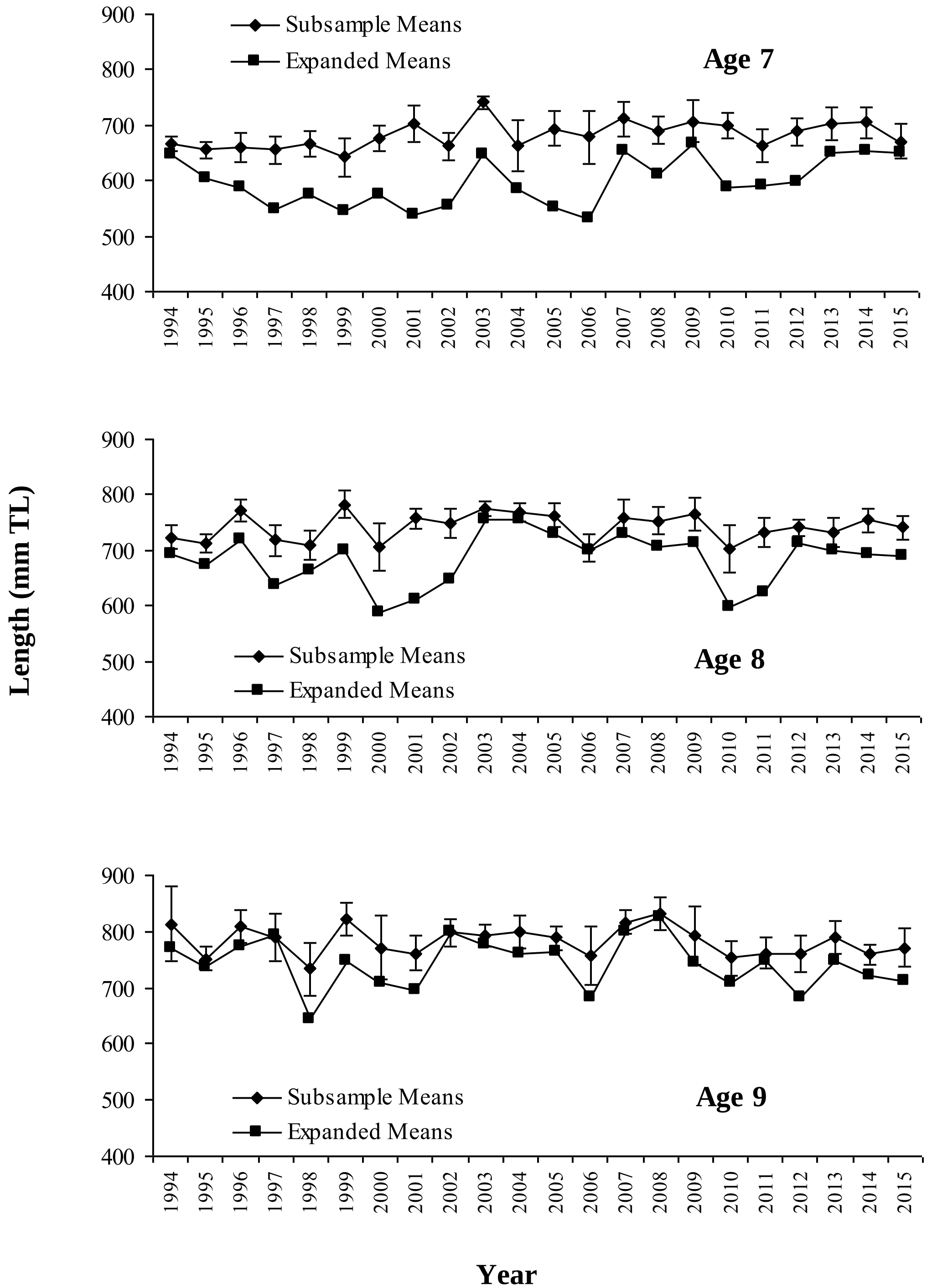
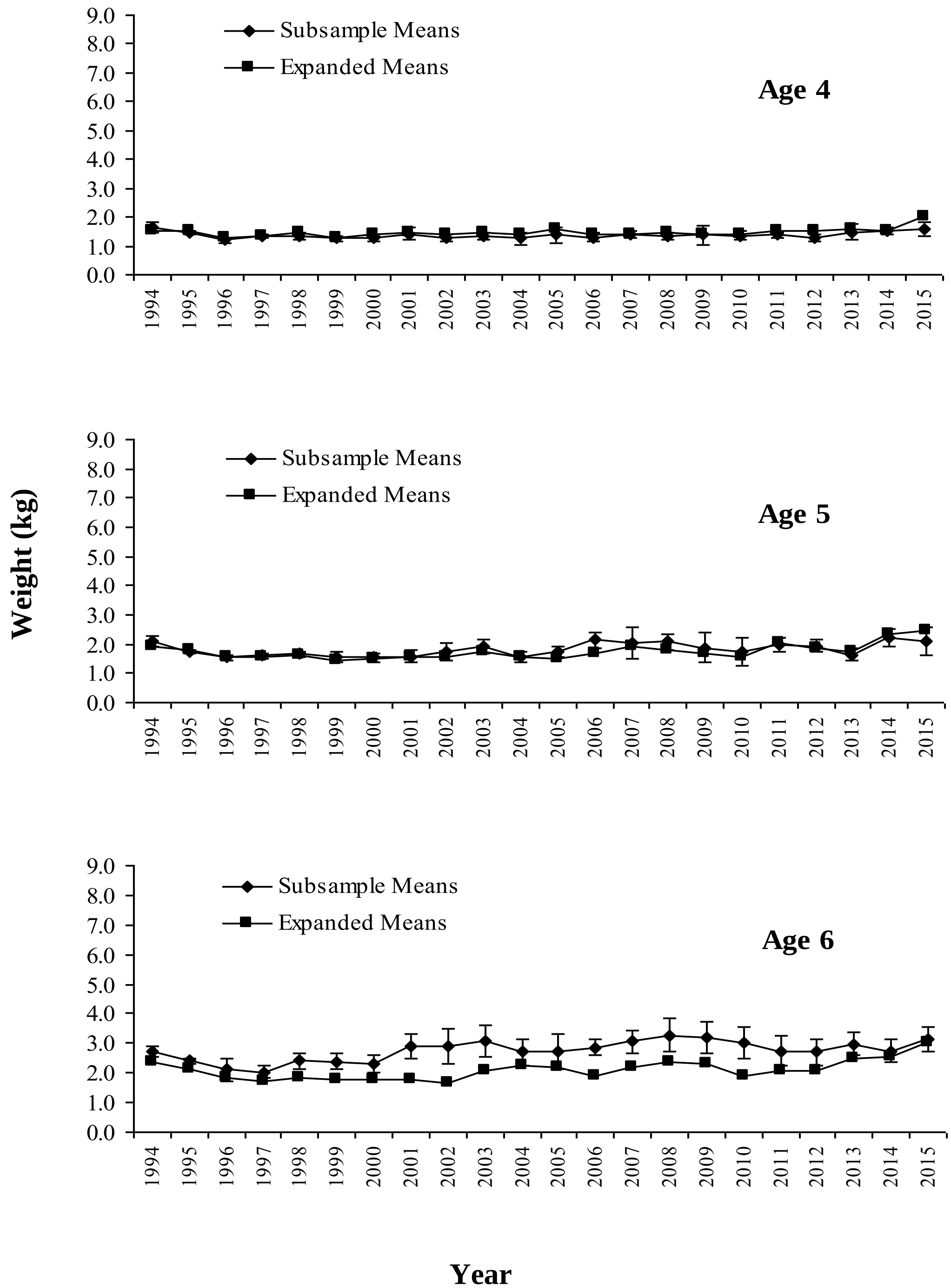


Figure 5. Mean weights (kg) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2015 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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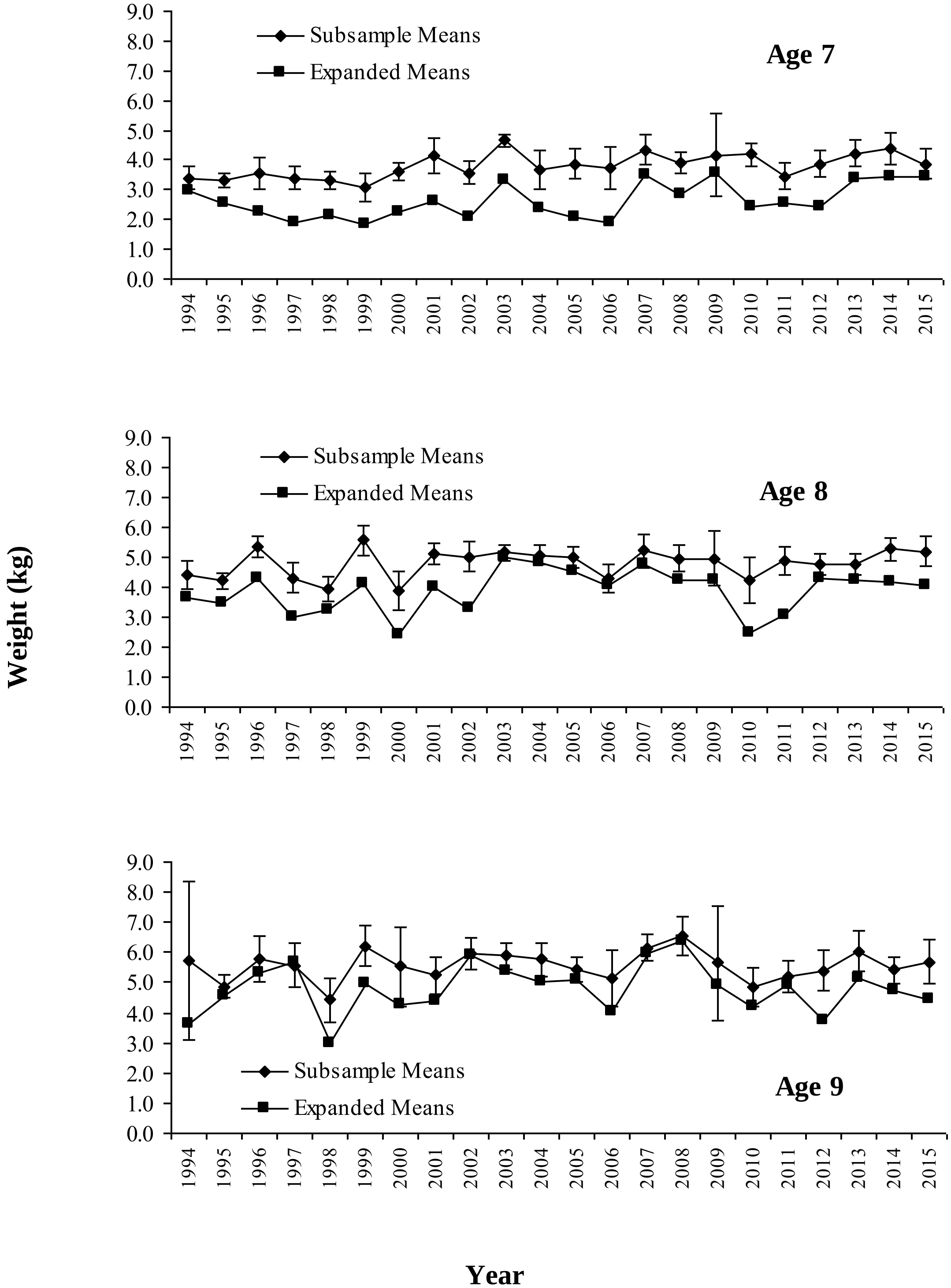

PROJECT NO. 2
JOB NO. 3
TASK NO. 1C

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Ryan P Hastings

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, which occurred between November 1, 2014 and April 30, 2015. The 2015 Atlantic striped bass season was subject to a reduction in annual quota under Addendum IV to Amendment 6 of the Atlantic Striped Bass Interstate Fishery Management Plan (Giuliano et al. 2014). This fishery was managed with a 24 inch total length (TL) minimum size limit and an annual quota of 90,727 pounds. Although this report covers the November 2014-May 2015 fishing season, the quota is managed by calendar year. Maryland's Atlantic coast fishery is not as large as the Chesapeake Bay commercial fishery and its annual quota composes only 7% of Maryland's ocean and bay quotas combined. Monitoring of the coastal fishery began in 2006 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 2005-2015 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 for November, December, and January, because a previous analysis of check station logs showed that 90% of the harvest occurs during these months. 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 impressions of the scales placed 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 November 2014-May 2015 Atlantic fishery, the year used for age calculations was 2015. These ages were then used to construct the age-length key (ALK). The resulting ALK was applied to the sample length frequency to generate a sample age distribution for all fish sampled at check stations. The age distribution of the Atlantic coast harvest from November 2014 through May 2015 was estimated by applying the sample age distribution to the total landings as reported from the check stations.

Mean lengths- and weights-at-age were calculated by year-class for the sub-sample of fish. Mean lengths-at-age and mean weights-at-age were also estimated for each year-class using an expansion method. 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. An ANOVA with a Duncan's Multiple Range Test (SAS 2006) was performed to compare weights of striped bass harvested between sample years.

RESULTS and DISCUSSION

This fishery is largely by-catch from the commercial spiny dogfish fishery. Consequently, fish were harvested intermittently and were often difficult to intercept at the check stations. Sampling at coastal check stations was conducted on nine days between November 2014 and January 2015. A total of 191 fish were measured and weighed and the ALK was developed from 130 scale samples.

Check stations reported 9,562 fish landed during the 2014-2015 Atlantic coast season (Table 1) (Chris Jones, Data Management and Quota Monitoring Program, Personal Communication). The catch-at-age estimate determined that landings ranged from age 4 (2011 year-class) to age 15 (2000 year-class) (Figure 1). Most (96%) striped bass harvested were ages 5 through 12 (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. A small proportion (2.2%) of striped bass harvested was age 4, demonstrating the magnitude of the 2011 year-class.

Eleven year-classes were represented in the sampled harvest. Based on the estimated catch-at-age, the most common age harvested during the 2014-2015 Atlantic coast fishery was age 6 (2009 year-class), which represented 23% of the landings (Table 1). Large contributions were also made by the above average 2003 (age 12) and 2007 year-classes (age 8) and the below average 2010 (age 5) year-class, which represented 14%, 14% and 17% of the fishery, respectively.

Striped bass sampled at Atlantic coast check stations during the 2014-2015 season had a mean length of 770 mm TL and mean weight of 5.2 kg. The sample length distribution ranged from 576 to 1,099 mm TL (Figure 2). The weight distribution from the sample of fish harvested ranged from 2.2 to 18.3 kg.

Due to a high proportion of the total sample being aged, the expanded mean lengths- and weights-at-age were similar to means of the aged sub-sample, and within the 95% confidence limits (Tables 2 and 3, Figures 3 and 4). Age 6 striped bass (2009 year class) were the most abundant age group harvested, with an expanded mean length of 664 mm TL and expanded mean weight of 3.0 kg (Figures 3 and 4). This age group is considered recently recruited and was smaller in weight than the 2014 age 6 group (N_{2014} =8, N_{2015} = 20, $P<0.005$) (Figure 3). Age 5 striped bass, the next most abundant year-class harvested had an expanded mean length of 639 mm TL and expanded mean weight of 2.7 kg (Tables 2 and 3).

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Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Atlantic coast commercial fishery, November 2014-May 2015.

Year-Class	Age	Number of Fish	Percent
2011	4	209	2.2
2010	5	1,585	16.6
2009	6	2,181	22.8
2008	7	662	6.9
2007	8	1,345	14.1
2006	9	783	8.2
2005	10	745	7.8
2004	11	573	6.0
2003	12	1,321	13.8
2002	13	107	1.1
2001	14	0	0.0
2000	15	50	0.5
Total*	-	9,562	100

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

Table 2. Sub-sample and expanded mean total lengths (mm TL) by year-class of striped bass sampled from Atlantic coast fishery, November 2014-May 2015. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

Year-Class	Age	n Fish Aged	Mean TL (mm) of Aged Sub-sample	LCL	UCL	Estimated # at-age in Sample	Expanded Mean TL (mm)
2011	4	1	630	-	-	4	630
2010	5	11	639	622	656	32	639
2009	6	20	675	654	695	44	664
2008	7	10	718	694	743	13	707
2007	8	22	767	736	799	27	747
2006	9	14	843	800	886	16	828
2005	10	14	899	860	938	15	903
2004	11	11	928	893	963	11	929
2003	12	24	973	949	997	26	974
2002	13	2	963	442	1,484	2	964
2000	15	1	1,005	-	-	1	1,007
Total		**130**				**191**	

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2014-May 2015. Includes the lower and upper 95% confidence limits (LCL and UCL, respectively).

Year-Class	Age	n Fish Aged	Mean Weight (kg) of Aged Sub-sample	LCL	UCL	Estimated # at-age in Sample	Expanded Mean Weight (kg)
2011	4	1	2.5	-	-	4	2.6
2010	5	11	2.6	2.4	2.8	32	2.7
2009	6	20	3.0	2.8	3.2	44	3.0
2008	7	10	3.6	3.2	3.9	13	3.4
2007	8	22	4.7	4.2	5.3	27	4.3
2006	9	14	6.3	5.2	7.3	16	5.9
2005	10	14	7.2	6.4	8.1	15	7.8
2004	11	11	8.6	7.5	9.7	11	8.6
2003	12	24	10.4	9.4	11.4	26	10.2
2002	13	2	10.9	-	-	2	10.1
2000	15	1	12.5	-	-	1	12.3
Total		**130**				**191**	

Figure 1. Age distribution of striped bass sampled from the Atlantic coast fishery, 2006-2015 seasons.

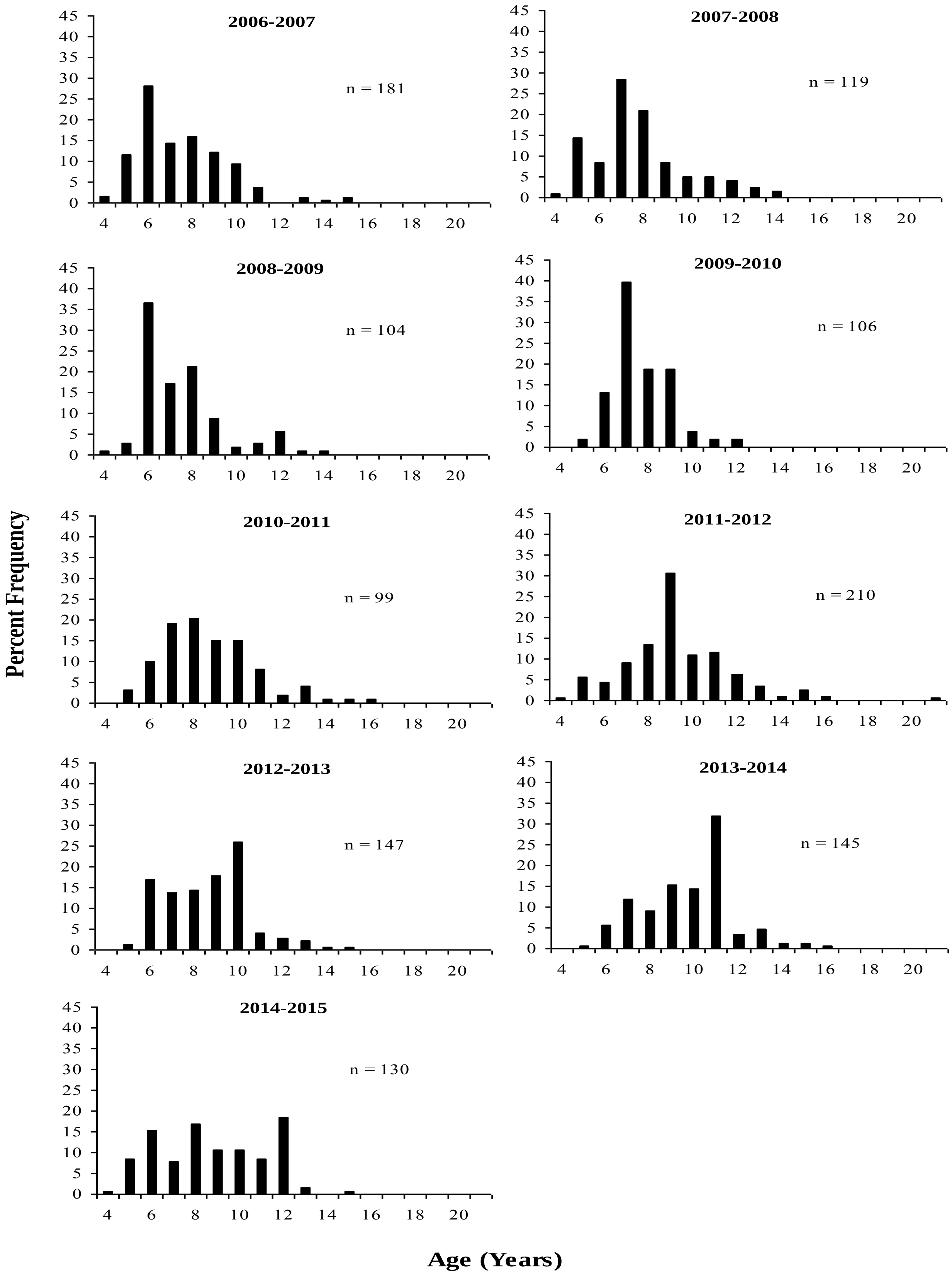


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, 2006-2015 seasons.

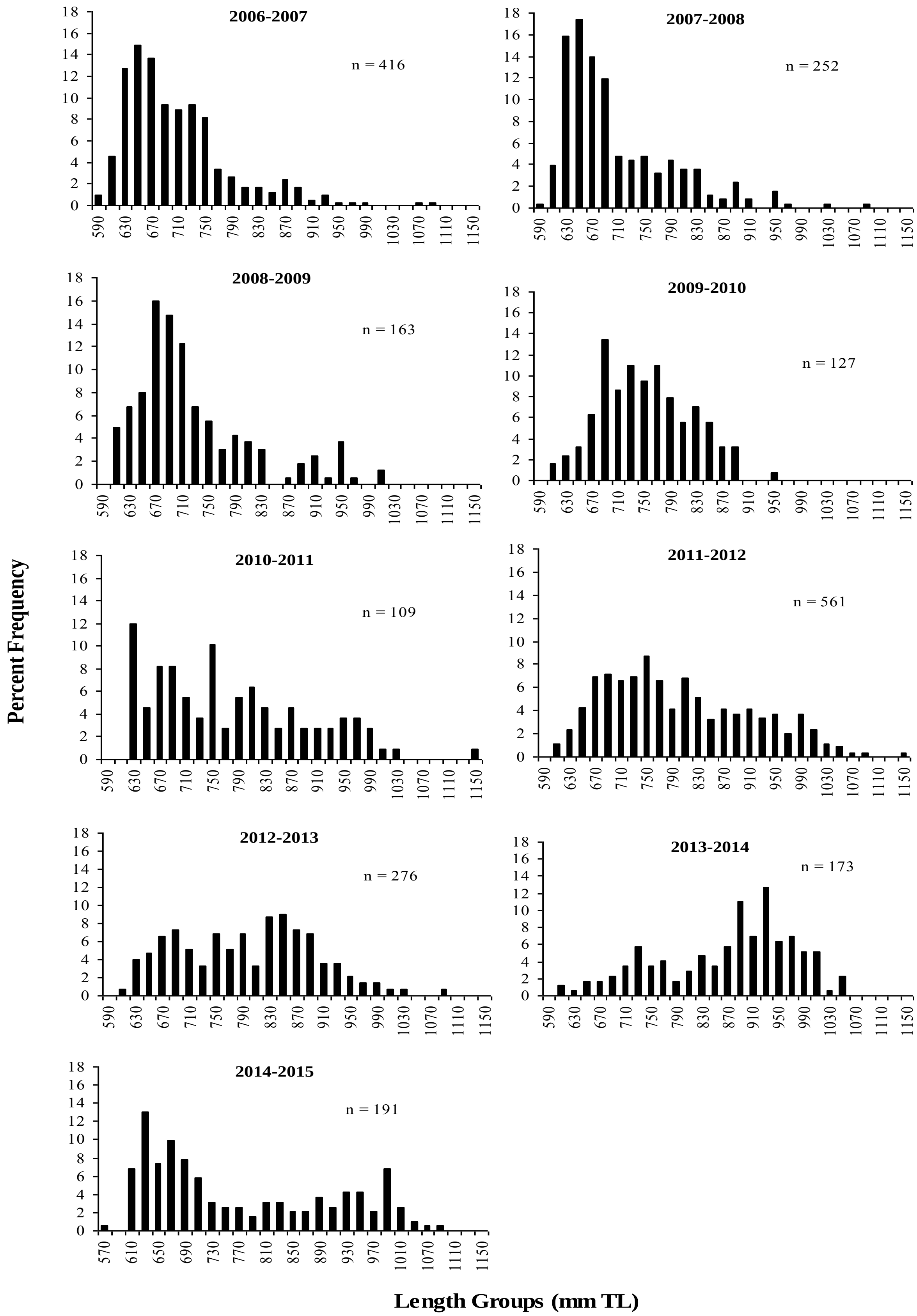
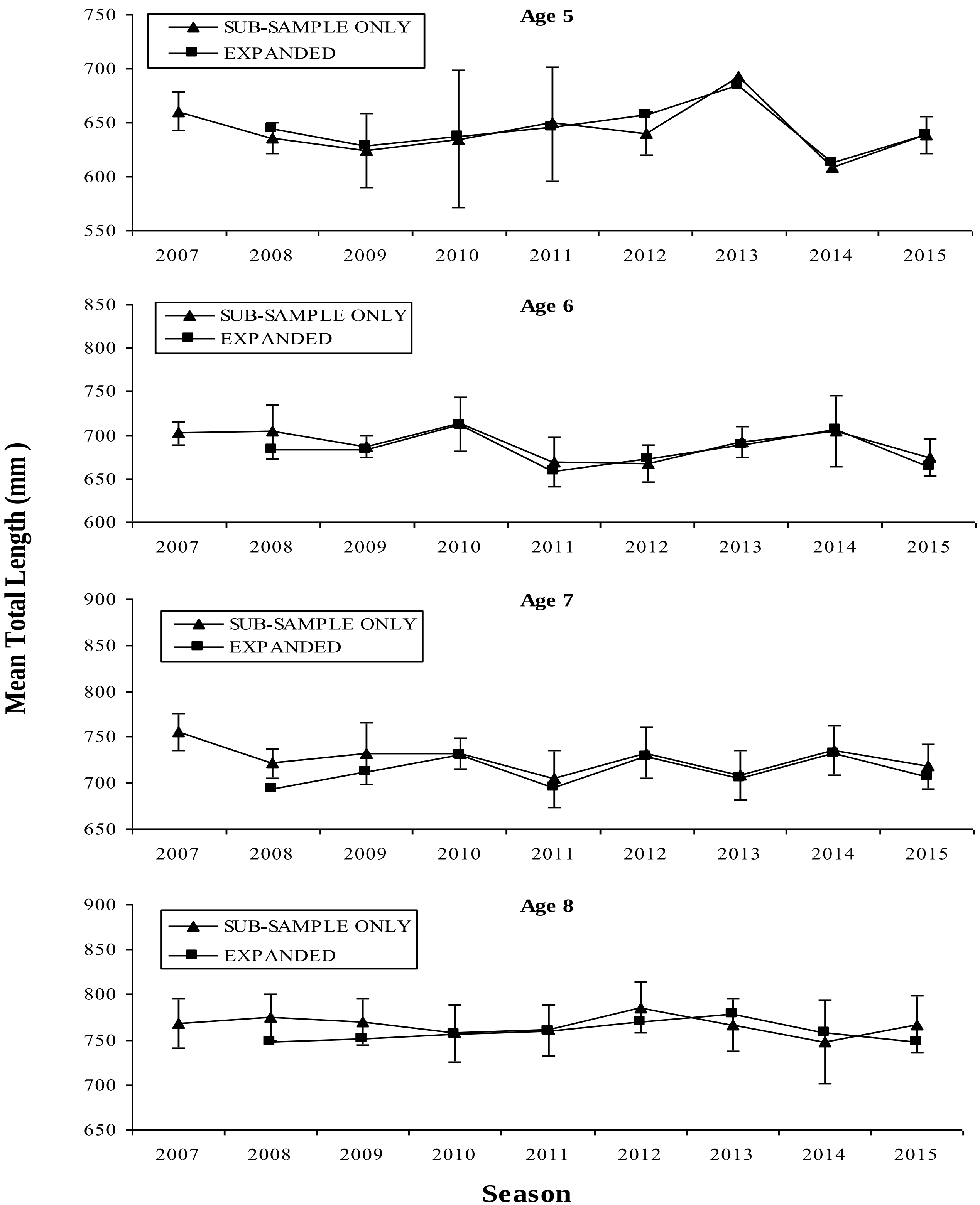


Figure 3. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2015 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences in scales on the y-axis.



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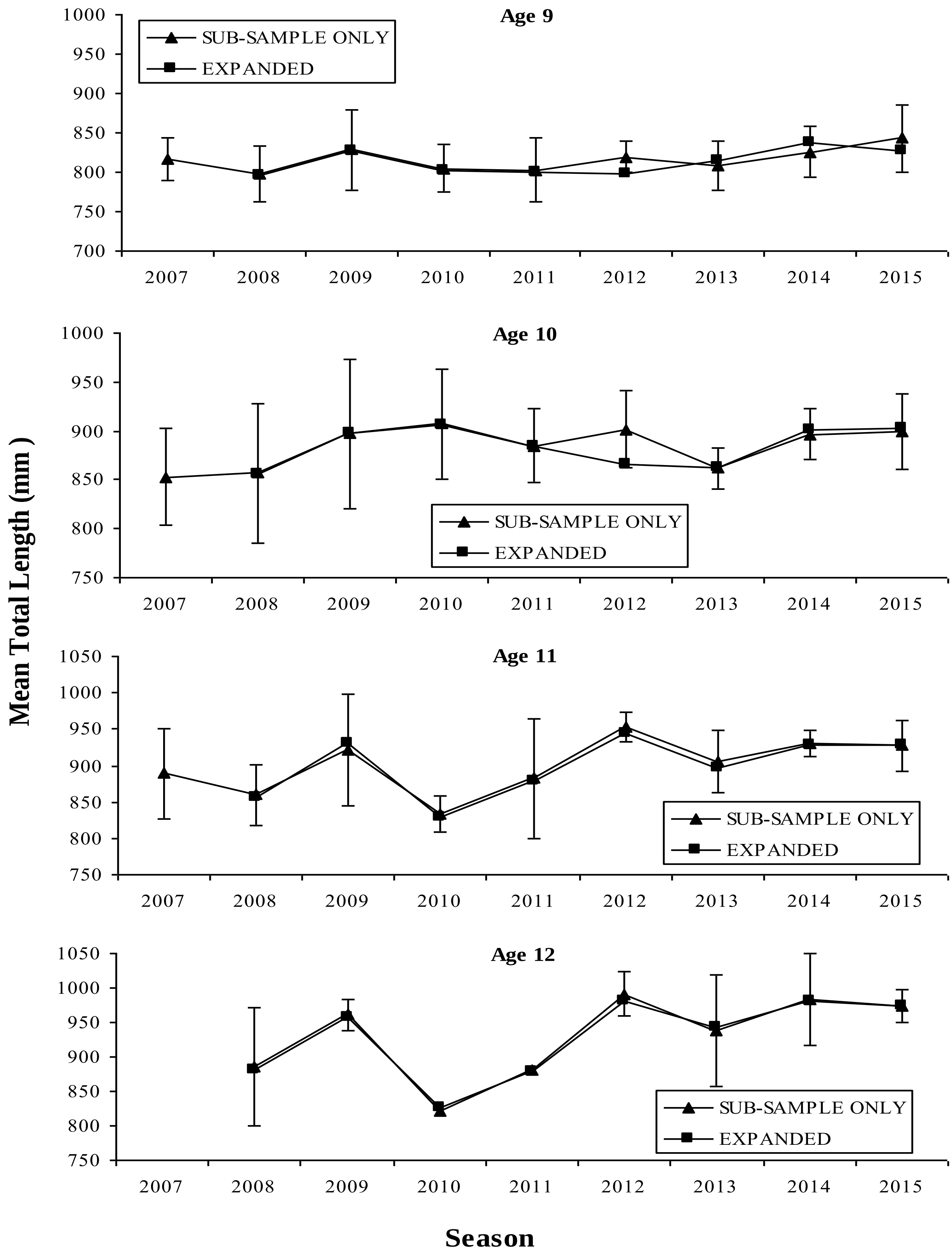

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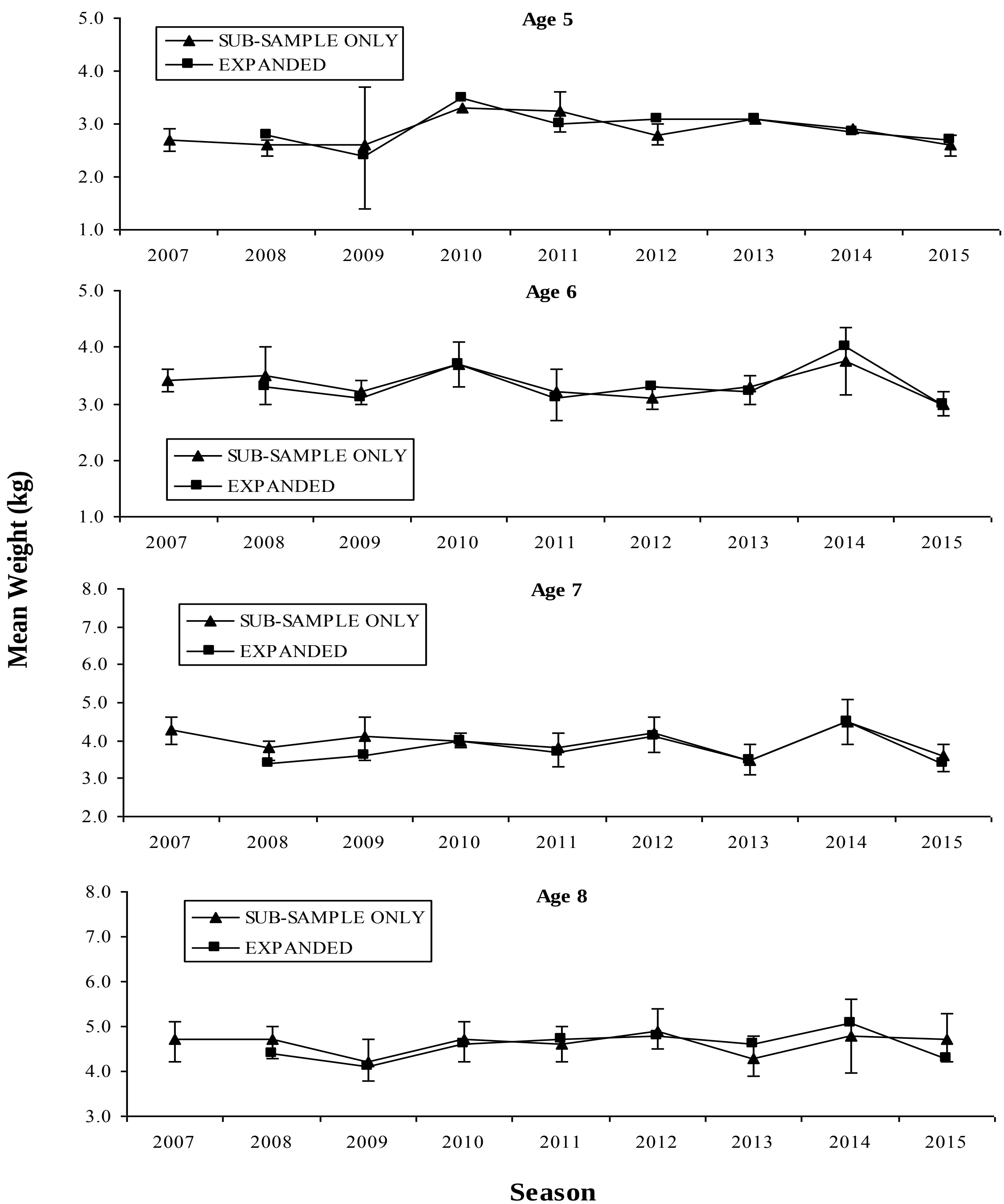

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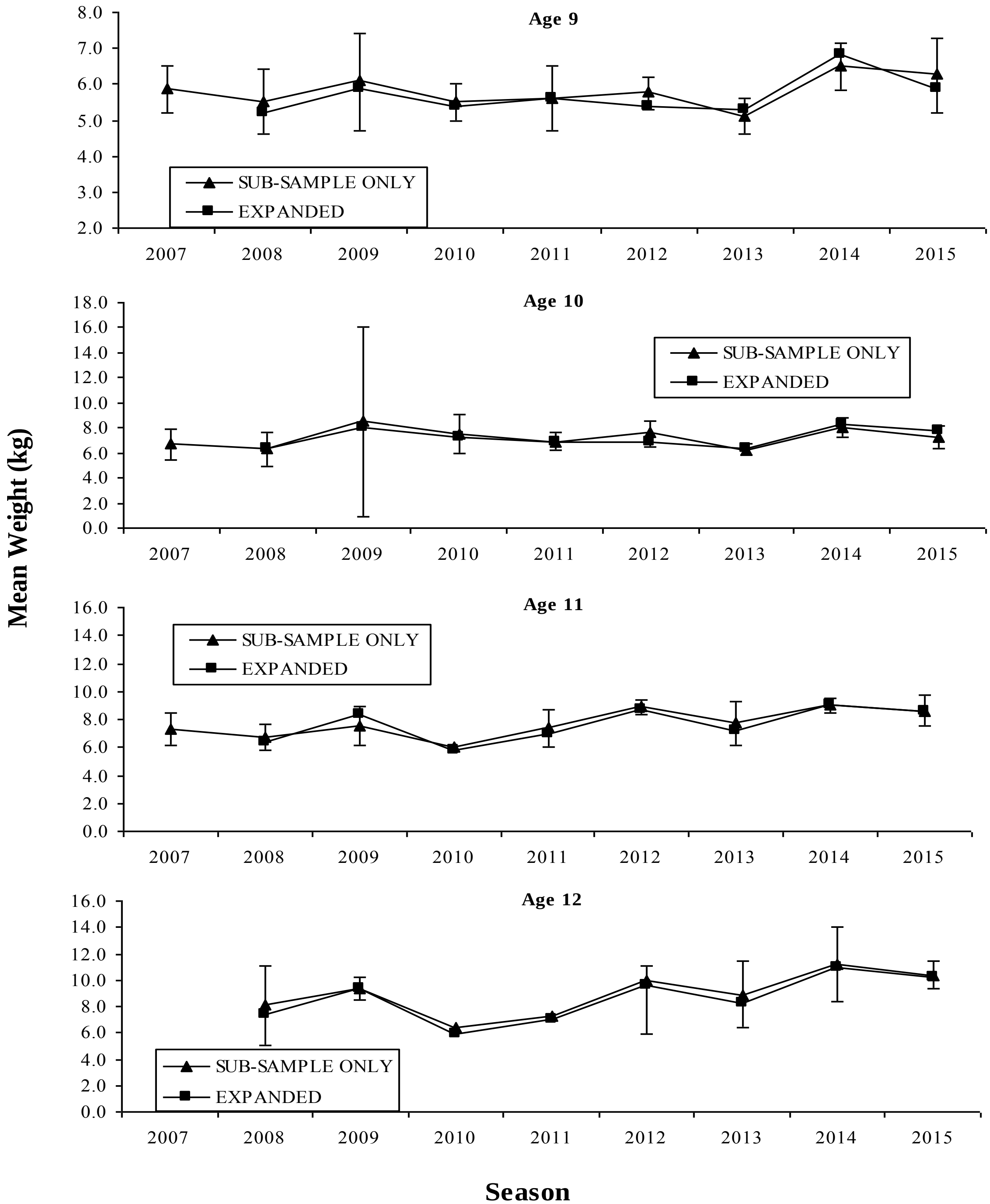

PROJECT NO. 2
JOB NO. 3
TASK NO. 2

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Beth A. Versak

INTRODUCTION

The primary objective of Project 2, Job 3, Task 2 was to generate estimates of relative abundance-at-age for striped bass in Chesapeake Bay during the 2015 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 produce up to 90% of the Atlantic coastal stock (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 2015 (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 1 to May 12 for a total of 32 sample days. In the Upper Bay, sampling was conducted from April 8 to May 12 for a total of 26 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. In both systems, all 10 panels were fished twice daily unless weather prohibited a second set. Between each panel, there were gaps of 5 to 10 feet. Overall soak times for each panel ranged from 6 to 126 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 quadrants, while the Upper Bay grid consisted of 31, 1-square-mile quadrants. GPS equipment, buoys, and landmarks were used to locate the appropriate quadrant in the field. Once in the designated quadrant, 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. These two sex-specific selectivity coefficients have been used since 2000.

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 pooled 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):

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

  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 616 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.

The 2015 un-weighted CPUE for Potomac females (29), ranked tenth of 30 years in the time series, was just above the series average of 26 (Table 2). The un-weighted CPUE for Potomac males (814) ranked fourth in the time series and was the highest value since the 1980s (Table 3). Male CPUE doubled for the second year in a row, and was almost twice the average (433). The Upper Bay female CPUE (87) dropped slightly from last year's all-time high to the third highest in the 31 year time series, but still more than double the time series average of 42 (Table 4). The un-weighted CPUE for Upper Bay males (578) also increased, ranking seventh in the time series, and above the average of 456 (Table 5). The abundant 2011 year-class was the source of the increase in male CPUE in both systems, with the four year-old Potomac male CPUE (614) being the highest individual age-class value recorded in that system. 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 2015 selectivity-corrected, total, weighted CPUE (734) ranked third in the 31 year time series. It was the highest value since 1996 and well above the time series average of 496.

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 2015 age-specific CPUEs were all at or below 0.15 indicating a small variance in CPUE. Historically, 82% of the CV values were less than 0.10 and 90% 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 un-weighted CPUEs by year-class, and those weighted by spawning area, respectively. In most cases, the percentages by age, sex, and area are similar for the un-weighted and weighted CPUEs. Unless otherwise noted, all CPUEs and percentages discussed here are the weighted values.

The above-average 2011 year-class was the most prevalent in the spawning stock this year, comprising 63% of the total CPUE. Upper Bay fish typically dominate the total CPUE, but in 2015 the two systems were more equally represented, with the Potomac making up 45% of the total. Males were most frequently encountered, comprising 91% of the total CPUE. This again was due to the large contribution of the 2011 year-class males.

The 2011 year-class made up the majority of the male CPUE for each system (62% in the Upper Bay, 75% on the Potomac River). In the Potomac River, 95% of the male CPUE was made up of fish age 7 and younger. Similarly in the Upper Bay, 83% of the male CPUE was from ages 7 and younger.

Historically the female contribution has been less than 10% in each system. In 2015, the female contribution in the Upper Bay was 7% of that system's total CPUE, while Potomac females contributed only 2% to the Potomac total CPUE. Female CPUEs were distributed across many year-classes in both systems. Age 12 females from the above-average 2003 year-class were the largest contributor (16%) to the female Upper Bay CPUE, with age 10, 11, and 15+

each contributing 12%. In the Upper Bay, age 4 female fish from the 2011 year-class were encountered, making up 4% of that system's female CPUE. In the Potomac River, the contribution of age 12 fish from the 2003 year-class to the female CPUE was highest at 34%. Age 11 and 14 females contributed approximately 15% each.

Temperature and catch patterns

Daily surface water temperatures on the Potomac River rose gradually from 8.4°C at the start of the survey to 17.4°C on April 21, then dropped several degrees, before increasing to 22°C at the survey's end. Female CPUE showed one large peak on April 22, just prior to that drop in water temperature (Figure 2). Several large peaks in male CPUE were observed during the third week of April, when water temperatures reached the 14°C mark necessary to initiate spawning (Fay et al., 1983). Large catches of males also occurred in the first week of May when water temperatures began to increase again.

Surface water temperatures on the Upper Bay during the spawning survey ranged from 8°C to 22°C. Upper Bay water temperatures increased slowly over the survey period, not remaining above 14°C until the first week of May. Despite this, there were multiple peaks in female CPUE throughout April, and several smaller peaks in May (Figure 3). The highest catch of males occurred on April 22, and another peak in male CPUE coincided with the female peak in the first week of May.

Length composition of the stock

In 2015, 2,871 male and 168 female striped bass were measured. On the Potomac River, 1,333 male and 39 female striped bass were sampled; 1,538 males and 129 females were sampled from the Upper Bay (Figure 4). The mean length of female striped bass in 2015 (962 ± 20 mm TL) was significantly larger than the mean length of male striped bass (481 ± 4 mm TL,

$P < 0.0001$), consistent with the known biology of the species. Mean lengths are reported with 2 standard errors.

Mean lengths of male striped bass collected from the Potomac River (472 ± 5 mm TL) and Upper Bay (489 ± 6 mm TL) were significantly different ($P<0.0001$) in 2015. The 2015 length distributions of male fish were qualitatively similar in both areas, although a higher percentage of larger fish were encountered on the Upper Bay (Figure 4).

Male striped bass on the Potomac ranged from 291 to 1081 mm TL. Males between 390 and 470 mm TL composed 61% of the Potomac River male catch in 2015, representing fish from the 2011 year-class (Figure 4). The influence of these young fish was evident in the large uncorrected and selectivity-corrected CPUE peaks between 410 and 430 mm TL (Figure 5).

Male striped bass on the Upper Bay ranged from 298 to 1042 mm TL, with a peak in the length frequency between 390-470 mm TL (59% of catch; Figure 4). Male CPUE in the Upper Bay was dominated by smaller fish between 390 and 450 mm TL, representing the 2011 year-class (Figure 5). The selectivity correction increased the contribution of the abundant age 4 fish in both systems most likely because these fish were caught in a variety of mesh sizes, including some with a low selectivity for their size.

Female striped bass sampled from the Potomac River and Upper Bay in 2015 were not significantly different in mean total length ($P=0.117$). Female striped bass sampled from the Potomac ranged from 683 to 1258 mm TL (mean=987 ± 33 mm TL), while females sampled in the Upper Bay ranged from 473 to 1222 mm TL (mean=955 ± 24 mm TL; Figure 4).

Female CPUE in the Potomac River in 2015 was concentrated in the 950 to 1070 mm length groups (Figure 6), most likely representing the 2003 year-class. The largest selectivity corrected peak at 1070 mm TL resulted from a few fish caught in small mesh net, with a low selectivity for their size group. Because of this, the selectivity correction increased the CPUE to better approximate the relative abundance of those size fish in the spawning population.

In the Upper Bay, corrected and uncorrected female CPUEs covered a wide range of length groups, representing 14 year-classes (Figure 6). Application of the selectivity model to the data corrected the catch upward in the lower and upper ends of the length distribution where fewer fish were encountered and likely not captured efficiently. Similar to the last few years, large numbers of females were captured in 2015, resulting in higher than normal CPUEs. The peak in the uncorrected CPUE at 990 mm TL represented the above-average 2003 year-class.

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 2015 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 small 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. A one-way analysis of variance 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 2015 ($\alpha > 0.05$). The exceptions were 8 and 10 year old male fish. Age 8 male fish were significantly shorter on the Upper Bay (693 mm TL) than the Potomac River (738 mm TL, P=0.022). Age 10 males were significantly shorter on the Potomac River (757 mm TL) than the Upper Bay (814 mm TL, P=0.037). Lengths-at-age for female fish were statistically similar between the two areas.

Mean lengths-at-age were compared between years for each sex, areas combined. Male and female LAA has been relatively stable since the mid 1990s (Figures 7 and 8). Mean lengths of males were similar in 2014 and 2015 for all ages except for age 3 (ANOVA, α=0.05, P=0.049), age 5 (ANOVA, α=0.05, P=0.045) and age 7 (ANOVA, α=0.05, P=0.01). Mean lengths of females were similar in 2014 and 2015 for all ages except age 7 (ANOVA, α=0.05, P=0.003).

Age composition of the stock

During the 2015 survey, 18 age-classes, ranging from 2 to 19 were encountered (Tables 14 and 15). Of the 290 male fish aged from the survey (Table 1), ages 4 and 10 (2011 and 2005 year-classes) were the most commonly encountered. On the Potomac River, the males encountered ranged from age 2 through 18, while on the Upper Bay, males ages 2 through 17 were captured. Females ranged in age from 4 to 19. Of the 143 aged female scales (Table 1), age 12 (2003 year-class) was most commonly observed. Females from the dominant 1996 year-class still contributed to the spawning stock.

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 2014, the largest increase in age-specific CPUE was observed for the age 4 (2011 year-class) cohort, as those small males became more prevalent on the spawning grounds. Age 12 fish (2003 year-class) also showed a large increase in CPUE this year. The contribution of the 15+ age group has been strong over the last six years (Figure 9).

The contribution of age 8+ females to the total female CPUE increased slightly to 82% (Figure 10). 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 and 2013. Some decline is expected based on the results of the most recent coastwide stock assessment, which showed that female spawning stock biomass has been declining coastwide (Northeast Fisheries Science Center 2013). The large numbers of age 12 females encountered during the 2015 survey likely caused the increase this year.

The percentage of the overall sample (males and females combined) age 8 and older has been variable since 1997 (Figure 11). The 2015 value decreased to 17.5%, after a time series high of 41% in 2012. The percentage of age 8+ fish is heavily influenced by strong year-classes and shows cyclical variations (Figure 9). The decline in age 8+ fish this year was due to the high number of males from the above-average 2011 year-class encountered in the survey.

Historically, Chesapeake Bay estimates of female ISP, expressed as biomass, have followed trends similar to the coastal estimates. Recent estimates of spawning stock biomass (SSB) for coastal females have shown a decline over the past several years (Northeast Fisheries Science Center 2013), but Maryland's Chesapeake Bay estimates are increasing. The MD DNR estimates of ISP generated from the Upper Bay have been variable, but have remained high for the past four years. The 2015 ISP value of 765 showed a small decrease, but was still more than double the time-series average of 350 (Table 16, Figure 12). The Potomac River female ISP has been increasing since 2011 to 309 in 2015. This is the highest value in the past nine years, and above the time series average of 232.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2015.

	MALES				FEMALES			
Length group (mm)	**Upper Bay**	**Potomac River**	**Creel**	**Male Total**	**Upper Bay**	**Potomac River**	**Creel**	**Female Total**
290	1	1	0	**2**	0	0	0	**0**
310	4	2	0	**6**	0	0	0	**0**
330	4	5	0	**9**	0	0	0	**0**
350	3	0	0	**3**	0	0	0	**0**
370	3	3	0	**6**	0	0	0	**0**
390	3	3	0	**6**	0	0	0	**0**
410	3	3	0	**6**	0	0	0	**0**
430	3	3	0	**6**	0	0	0	**0**
450	3	3	0	**6**	0	0	0	**0**
470	3	3	0	**6**	1	0	0	**1**
490	3	3	0	**6**	0	0	1	**1**
510	3	3	0	**6**	0	0	3	**3**
530	4	4	0	**8**	1	0	1	**2**
550	2	5	0	**7**	0	0	5	**5**
570	5	4	0	**9**	2	0	6	**8**
590	5	4	0	**9**	0	0	3	**3**
610	5	6	0	**11**	1	0	1	**2**
630	5	5	0	**10**	1	0	3	**4**
650	6	4	0	**10**	2	0	3	**5**
670	5	5	0	**10**	0	0	4	**4**
690	4	6	0	**10**	2	1	4	**7**
710	8	8	0	**16**	2	0	2	**4**
730	9	8	0	**17**	0	1	3	**4**
750	9	8	0	**17**	0	0	4	**4**
770	7	5	1	**13**	3	1	4	**8**
790	12	0	5	**17**	1	0	6	**7**
810	8	0	5	**13**	1	0	3	**4**
830	7	2	3	**12**	5	0	4	**9**
850	6	0	3	**9**	3	0	6	**9**
870	6	0	3	**9**	3	0	4	**7**
890	8	1	5	**14**	1	0	9	**10**
910	4	0	6	**10**	1	1	19	**21**
930	6	0	0	**6**	5	0	13	**18**
950	1	1	0	**2**	8	9	4	**21**
970	4	0	0	**4**	9	6	1	**16**
990	4	0	0	**4**	10	5	3	**18**
1010	0	2	2	**4**	10	4	4	**18**
1030	2	0	1	**3**	4	2	9	**15**
1050	1	0	1	**2**	9	1	7	**17**
1070	0	0	0	**0**	7	2	3	**12**
1090	0	1	0	**1**	2	0	1	**3**
1110	0	0	0	**0**	2	3	1	**6**
1130	0	0	0	**0**	5	0	1	**6**
1150	0	0	0	**0**	1	1	2	**4**
1170	0	0	0	**0**	2	0	0	**2**
1190	0	0	0	**0**	0	0	0	**0**
1210	0	0	0	**0**	0	0	0	**0**
1230	0	0	0	**0**	1	0	1	**2**
1250	0	0	0	**0**	0	1	0	**1**
Total	**17**	**11**	**35**	**32**	**10**	**38**	**14**	**29**

	9	**1**		**5**	**5**		**8**	**1**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2015 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**
Average																**26**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2015 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.	20.	7.9	2.3	3.4	2.2	1.6	2.0	0.0	0.6	**268**

						0	9									
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**
Average																**433**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985-2015 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**
Averag																**42**

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Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985-2015 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.	19.1	34.1	106.	48.2	42.	43.	20.	5.2	2.4	1.1	1.9	0.0	0.0	**445**

		7			7		2	7	1							
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**
Averag e																**456**

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

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**
1985	0	0.0	0.0	0.0	2.2	0.8	2.9	0.8	1.0	0.4	0.0	0.6	1.3	0.5	1.0	**12**
1986	0	0.0	0.0	12.8	1.9	1.0	1.6	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	**18**
1987	0	0.0	0.0	6.8	20.7	3.3	0.6	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.5	**38**
1988	0	0.0	0.0	9.2	10.8	16.4	3.2	0.0	1.0	1.0	0.0	0.0	0.0	0.7	0.4	**43**

1989	0	0.0	0.0	17.0	31.8	22.7	39.1	3.0	0.5	0.6	0.0	0.0	0.5	0.0	0.0	**115**
1990	0	0.0	0.0	0.0	15.7	24.2	15.9	40.7	3.1	3.0	0.0	0.0	4.7	2.5	4.4	**114**
1991	0	0.0	0.0	1.3	0.8	22.9	23.1	15.5	32.9	4.8	3.4	0.0	14.1	14.1	5.1	**138**
1992	0	0.0	1.0	0.0	1.4	9.9	28.1	18.7	19.0	15.6	0.0	0.0	16.3	3.4	0.0	**113**
1993	0	0.0	0.0	3.0	0.0	5.4	15.2	30.1	23.5	19.0	8.2	1.6	2.8	5.6	2.8	**117**
1994	0	0.0	0.0	0.0	7.5	7.1	8.8	7.7	31.3	6.1	4.0	0.0	0.0	0.0	0.0	**73**
1995																
1996	0	0.0	0.0	0.0	6.9	26.4	38.3	37.0	36.5	37.5	21.6	8.7	1.1	0.0	0.0	**214**
Average																**90**

Table 7. Estimates of selectivity-corrected age-class CPE 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 (1985–2015) 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**
Average																**496**

Table 9. Lower confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2015) 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.	75.7	39.3	38.8	83.3	40.4	33.	32.	22.	7.4	5.4	3.3	3.7	0.3	*

	0						9	2	0						
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	*

* 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 (1985–2015) 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	*

* 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 (1985–2015) 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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.1	0.3	*

		5	2	1	1	3	2	1		6	3	4	4	7	
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	*

* 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 2015. 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
2014	1	0.0	0.0	0.0	0.0	0.0	0.0
2013	2	43.5	2.9	0.0	0.0	33.4	10.1
2012	3	16.7	1.1	0.0	0.0	12.9	3.8
2011	4	974.9	64.6	0.0	3.7	613.7	357.4
2010	5	94.0	6.2	0.0	2.3	49.8	41.9
2009	6	100.9	6.7	0.4	4.5	50.2	45.8
2008	7	45.6	3.0	0.9	8.0	15.5	21.3
2007	8	39.4	2.6	1.3	7.3	12.1	18.7
2006	9	29.3	1.9	0.6	3.1	9.4	16.3
2005	10	39.8	2.6	2.3	10.6	5.5	21.5
2004	11	34.4	2.3	4.0	10.7	3.0	16.6
2003	12	37.7	2.5	9.7	14.1	2.1	11.8
2002	13	11.7	0.8	1.9	3.0	0.9	5.9
2001	14	18.9	1.2	4.5	8.9	1.6	3.8
≤2000	15+	21.7	1.4	3.1	11.1	4.0	3.5
Total		1508.7		28.6	87.5	814.1	578.5
% of Total				2	6	54	38
% of Sex				25	75	58	42
% of System				3	13	97	87

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, April through May 2015. 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
2014	1	0.0	0.0	0.0	0.0	0.0	0.0
2013	2	19.1	2.6	0.0	0.0	12.9	6.2
2012	3	7.3	1.0	0.0	0.0	5.0	2.4
2011	4	458.5	62.5	0.0	2.3	236.5	219.7
2010	5	46.4	6.3	0.0	1.4	19.2	25.7
2009	6	50.4	6.9	0.2	2.8	19.3	28.1
2008	7	24.3	3.3	0.3	4.9	6.0	13.1
2007	8	21.2	2.9	0.5	4.5	4.7	11.5
2006	9	15.8	2.1	0.2	1.9	3.6	10.0
2005	10	22.7	3.1	0.9	6.5	2.1	13.2
2004	11	19.5	2.7	1.6	6.6	1.2	10.2
2003	12	20.5	2.8	3.7	8.7	0.8	7.3
2002	13	6.6	0.9	0.7	1.9	0.3	3.6
2001	14	10.2	1.4	1.7	5.5	0.6	2.3
≤2000	15+	11.7	1.6	1.2	6.8	1.5	2.2
Total		734.1		11.0	53.8	313.8	355.5
% of Total				2	7	43	48
% of Sex				17	83	47	53
% of System				3	13	97	87

* 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 2015.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2013	2	POTOMAC	5	324	298	350	21	9
		UPPER	4	321	284	357	23	11
		COMBINED	9	322	307	338	20	7
2012	3	POTOMAC	1	319	-	-	-	-
		UPPER	5	320	309	331	9	4
		COMBINED	6	320	311	328	8	3
2011	4	POTOMAC	29	446	422	471	65	12
		UPPER	29	437	413	460	62	11
		COMBINED	58	442	425	458	63	8
2010	5	POTOMAC	13	570	544	597	44	12
		UPPER	7	586	551	622	38	14
		COMBINED	20	576	556	595	42	9
2009	6	POTOMAC	15	622	599	646	43	11
		UPPER	13	591	567	614	39	11
		COMBINED	28	608	591	625	44	8
2008	7	POTOMAC	14	688	664	712	41	11
		UPPER	11	676	643	709	49	15
		COMBINED	25	683	664	701	44	9
2007	8	POTOMAC	17	738	712	763	50	12
		UPPER	12	693	662	723	48	14
		COMBINED	29	719	699	739	53	10
2006	9	POTOMAC	3	730	691	768	16	9
		UPPER	22	759	722	796	84	18
		COMBINED	25	756	723	788	79	16
2005	10	POTOMAC	8	757	710	805	57	20
		UPPER	32	814	790	839	68	12
		COMBINED	40	803	781	825	69	11
2004	11	POTOMAC	3	814	*	*	*	*
		UPPER	26	834	807	861	67	13
		COMBINED	29	832	805	859	71	13
2003	12	POTOMAC	1	1001	-	-	-	-
		UPPER	12	913	866	960	74	21
		COMBINED	13	920	875	965	75	21
2002	13	POTOMAC	0	854	-	-	-	-
		UPPER	1	948	-	-	-	-
		COMBINED	1	948	-	-	-	-
2001	14	POTOMAC	1	1006	-	-	-	-
		UPPER	2	1006	*	*	*	*
		COMBINED	3	1006	922	1090	34	20
2000	15	POTOMAC	0	-	-	-	-	-
		UPPER	1	1033	-	-	-	-
		COMBINED	1	1033	-	-	-	-
1999	16	POTOMAC	0	-	-	-	-	-
		UPPER	1	988	-	-	-	-
		COMBINED	1	988	-	-	-	-
1998	17	POTOMAC	0	-	-	-	-	-
		UPPER	1	989	-	-	-	-
		COMBINED	1	989	-	-	-	-
1997	18	POTOMAC	1	1081	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	1081	-	-	-	-

* 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 2015.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2011	4	POTOMAC	0	-	-	-	-	-
		UPPER	1	473	-	-	-	-
		COMBINED	1	473	-	-	-	-
2010	5	POTOMAC	0	-	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	0	-	-	-	-	-
2009	6	POTOMAC	0	-	-	-	-	-
		UPPER	2	594	*	*	*	*
		COMBINED	2	594	*	*	*	*
2008	7	POTOMAC	2	723	*	*	*	*
		UPPER	8	640	588	692	62	22
		COMBINED	10	657	609	705	68	21
2007	8	POTOMAC	0	-	-	-	-	-
		UPPER	5	815	764	865	41	18
		COMBINED	5	815	764	865	41	18
2006	9	POTOMAC	1	949	-	-	-	-
		UPPER	3	842	547	1137	119	69
		COMBINED	4	869	692	1045	111	55
2005	10	POTOMAC	7	946	856	1037	98	37
		UPPER	15	926	888	964	69	18
		COMBINED	22	932	898	967	78	17
2004	11	POTOMAC	6	992	968	1016	23	9
		UPPER	20	974	946	1002	59	13
		COMBINED	26	978	957	1000	53	10
2003	12	POTOMAC	12	973	952	993	32	9
		UPPER	32	997	972	1022	69	12
		COMBINED	44	990	972	1009	62	9
2002	13	POTOMAC	3	1035	897	1173	56	32
		UPPER	2	1106	781	1430	36	26
		COMBINED	5	1063	991	1135	58	26
2001	14	POTOMAC	2	1037	*	*	*	*
		UPPER	11	1052	983	1121	102	31
		COMBINED	13	1050	991	1109	98	27
2000	15	POTOMAC	2	1113	1017	1208	11	8
		UPPER	2	1087	851	1322	26	19
		COMBINED	4	1100	1064	1135	22	11
1999	16	POTOMAC	0	-	-	-	-	-
		UPPER	2	1154	842	1465	35	25
		COMBINED	2	1154	842	1465	35	25
1998	17	POTOMAC	2	1116	*	*	*	*
		UPPER	1	1165	-	-	-	-
		COMBINED	3	1132	1001	1263	53	31
1997	18	POTOMAC	0	-	-	-	-	-
		UPPER	1	1222	-	-	-	-
		COMBINED	1	1222	-	-	-	-
1996	19	POTOMAC	1	1258	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	1258	-	-	-	-

* 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
Average	**350**	**232**

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2015.

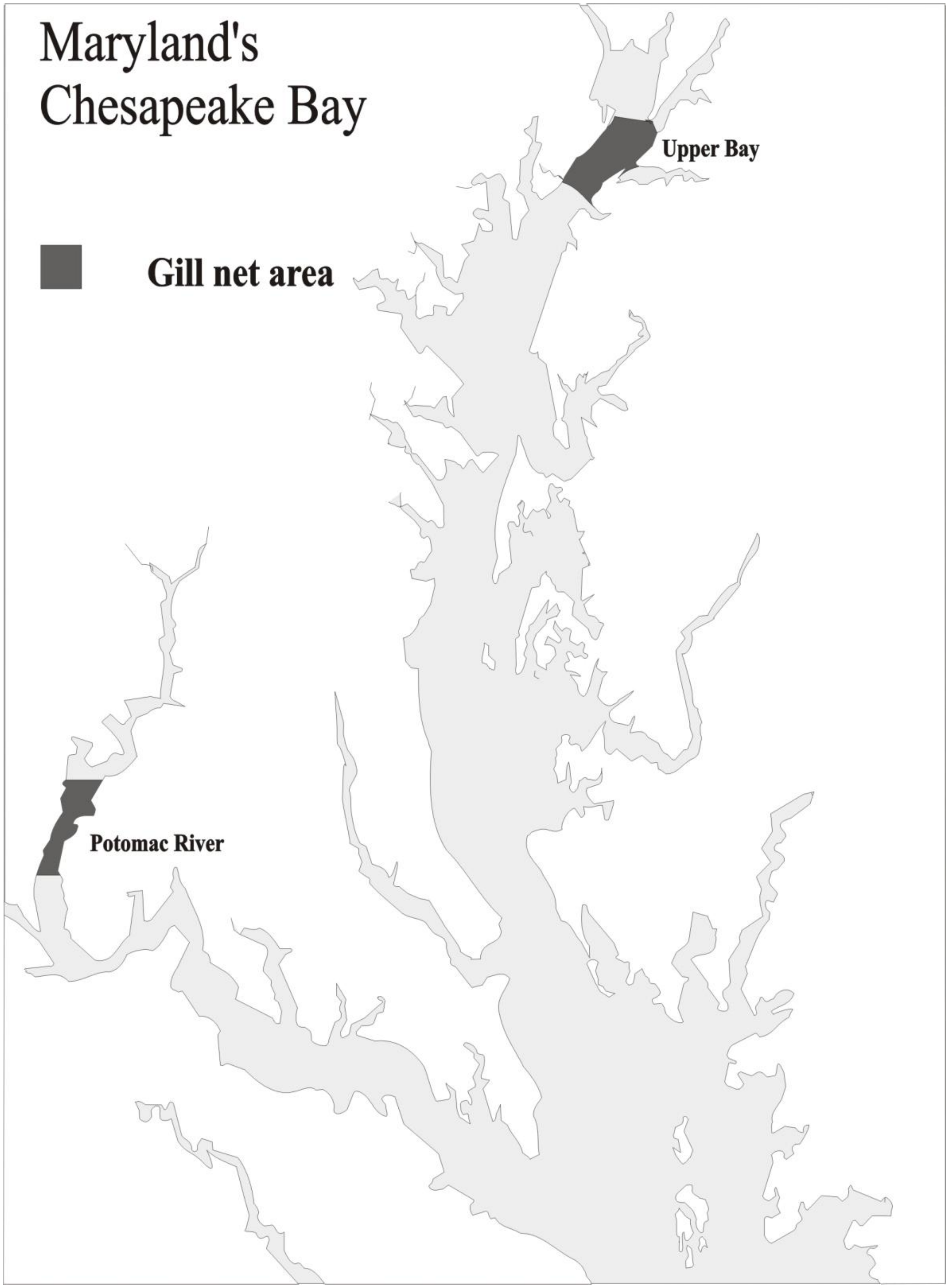
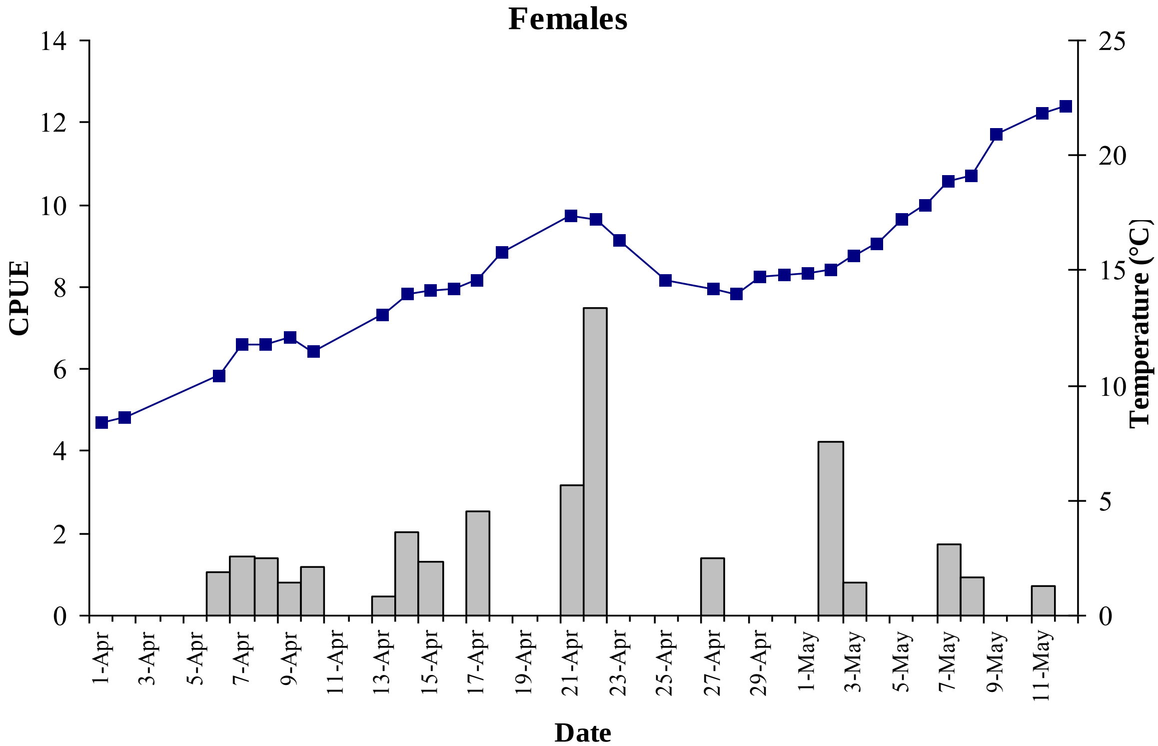


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water temperature in the spawning reach of the Potomac River, April through May 2015. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.



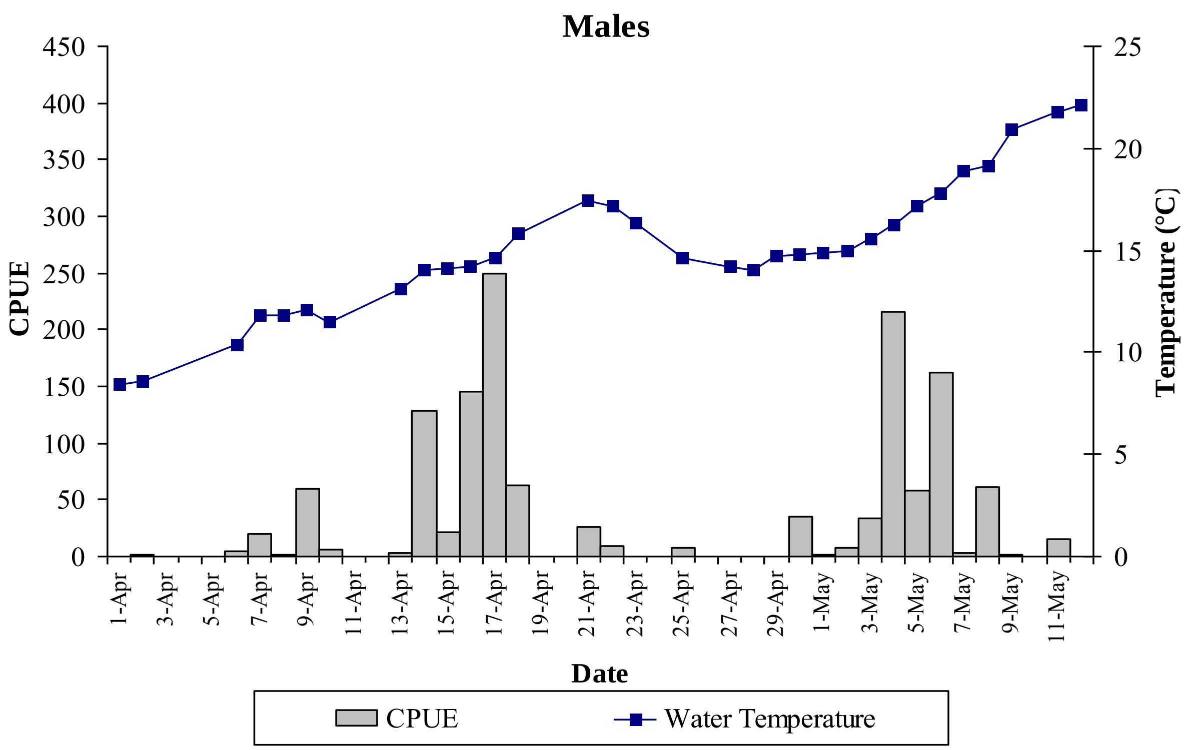


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water temperature in the spawning reach of the Upper Chesapeake Bay, April through May 2015. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

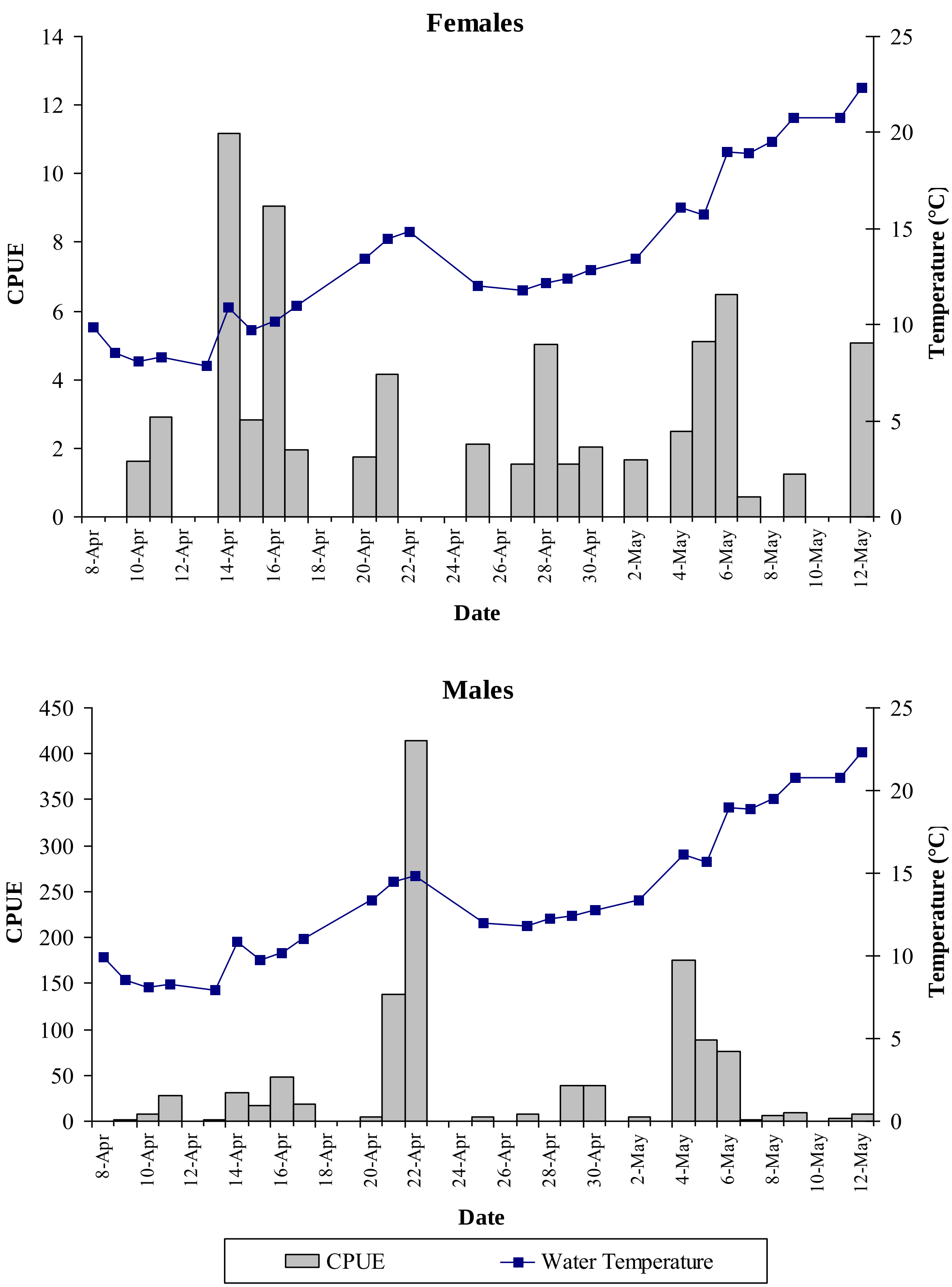
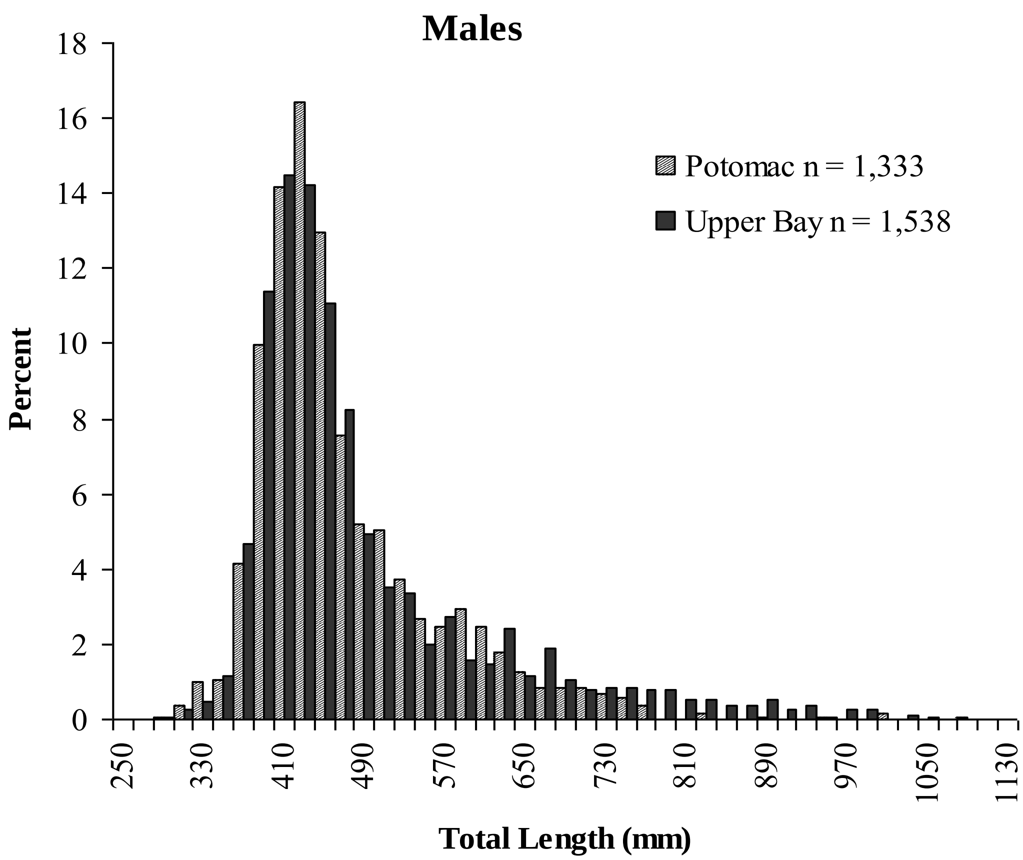


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, April through May 2015. Note different scales.



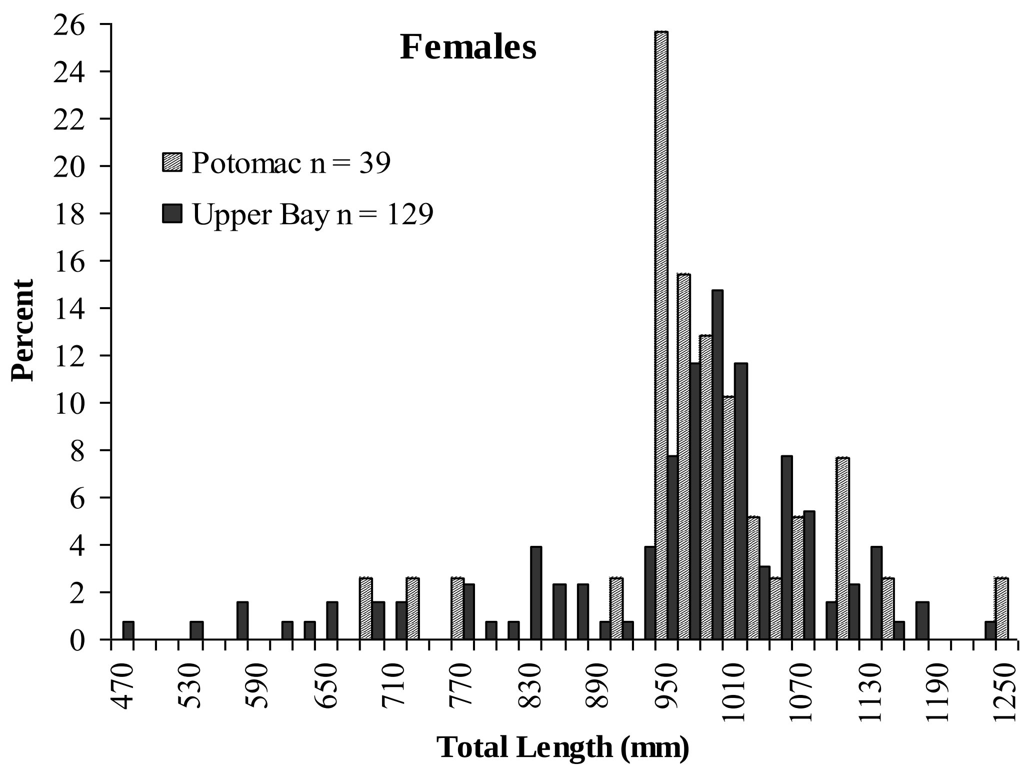
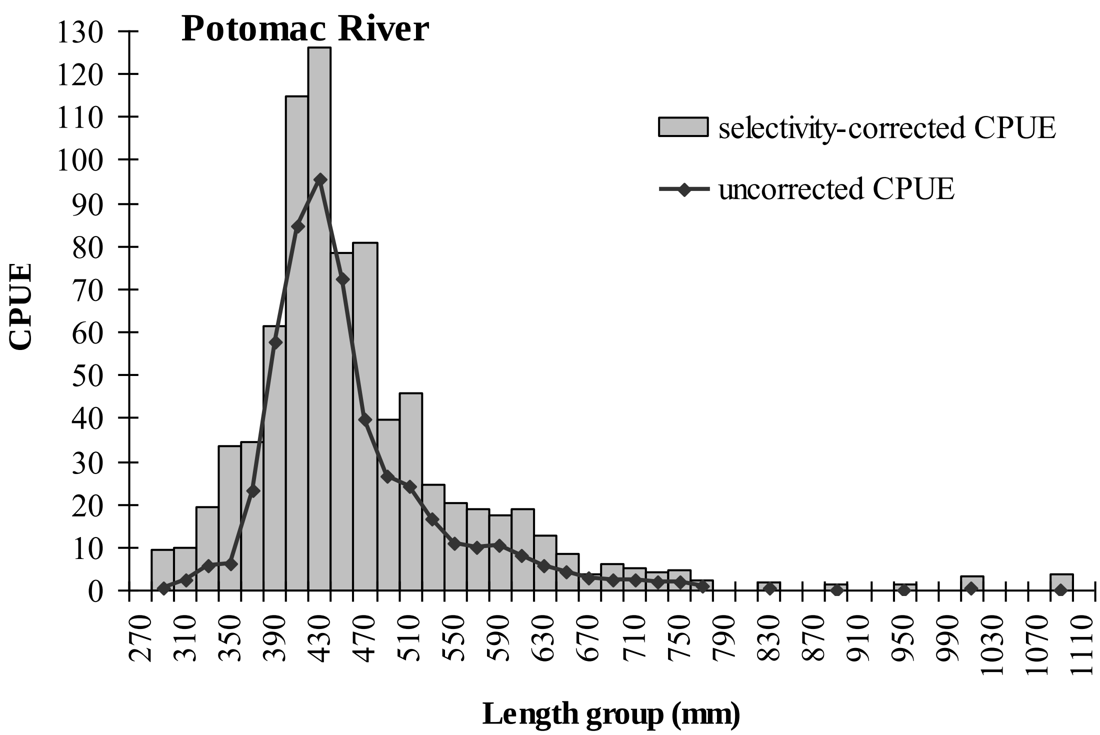


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2015. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



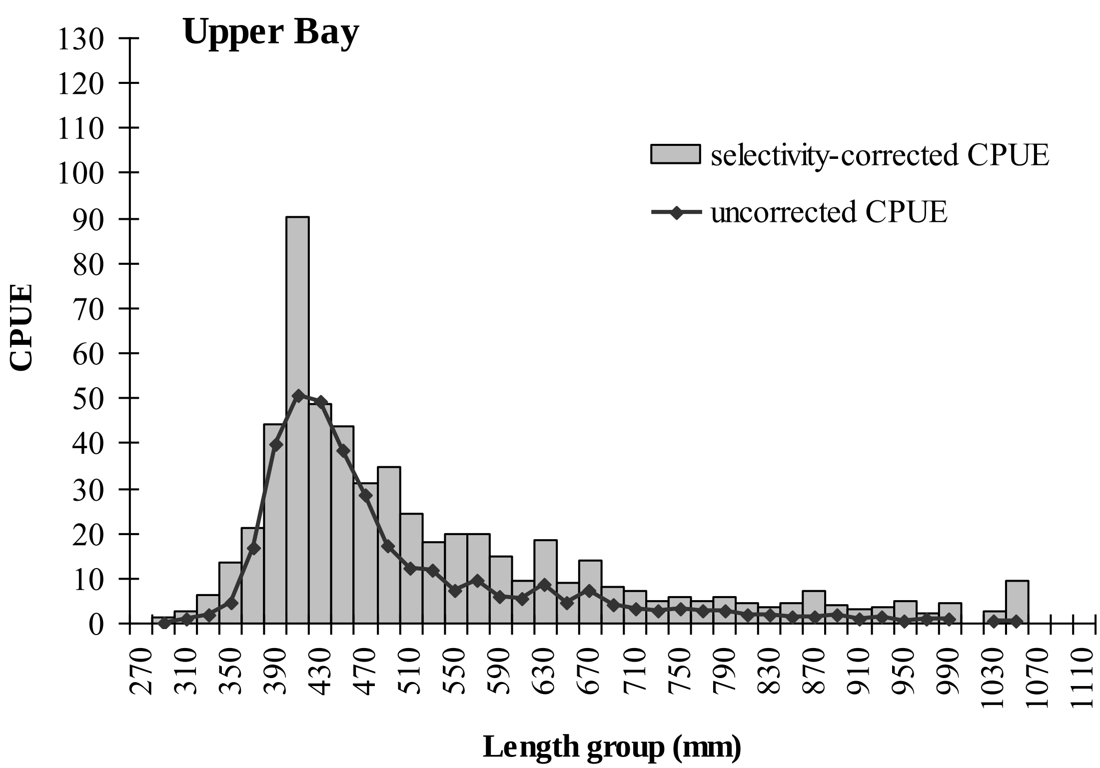
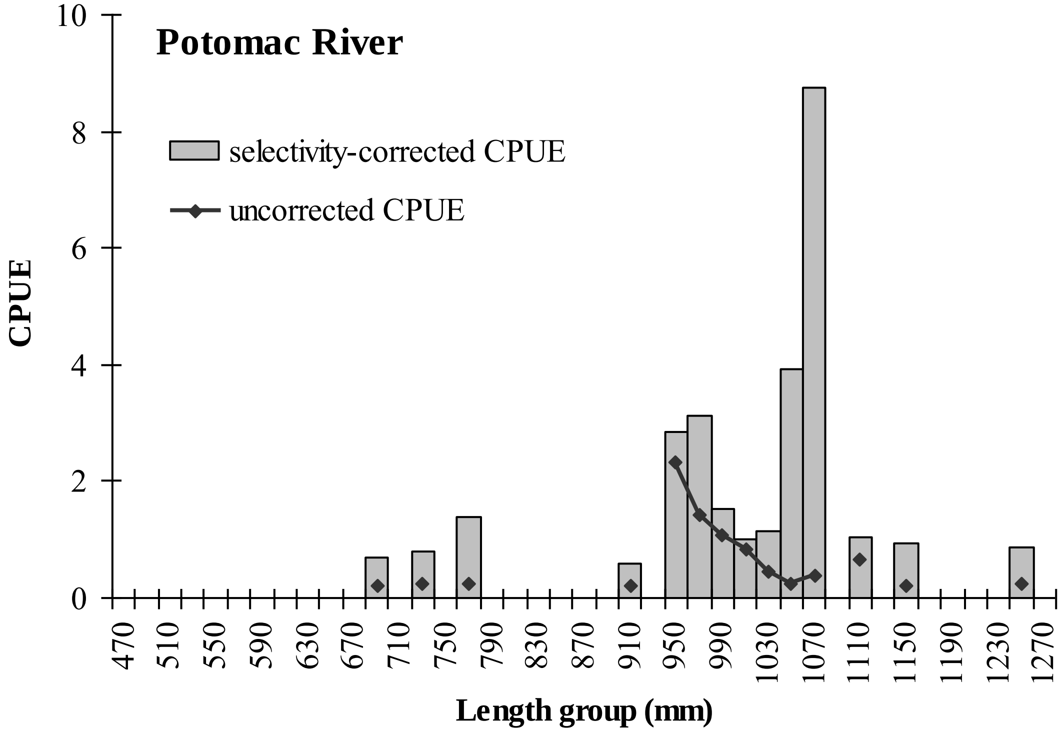


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2015. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



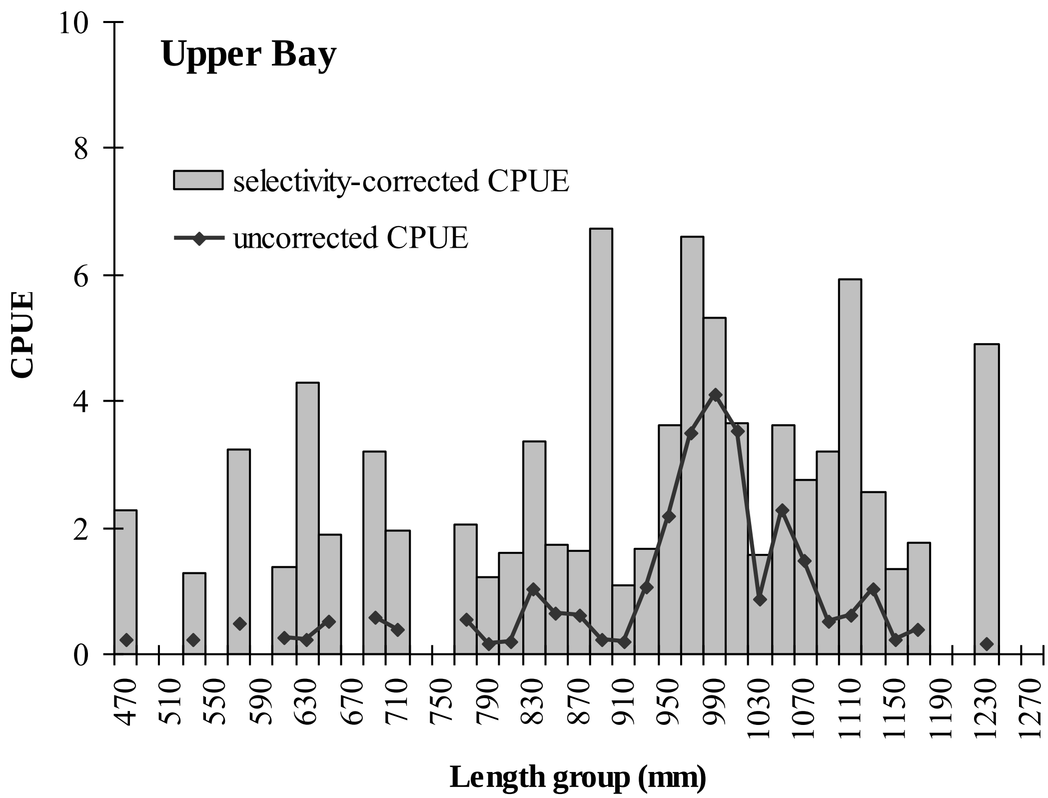


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during April through May, 1985-2015. Error bars are ± 2 standard errors (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

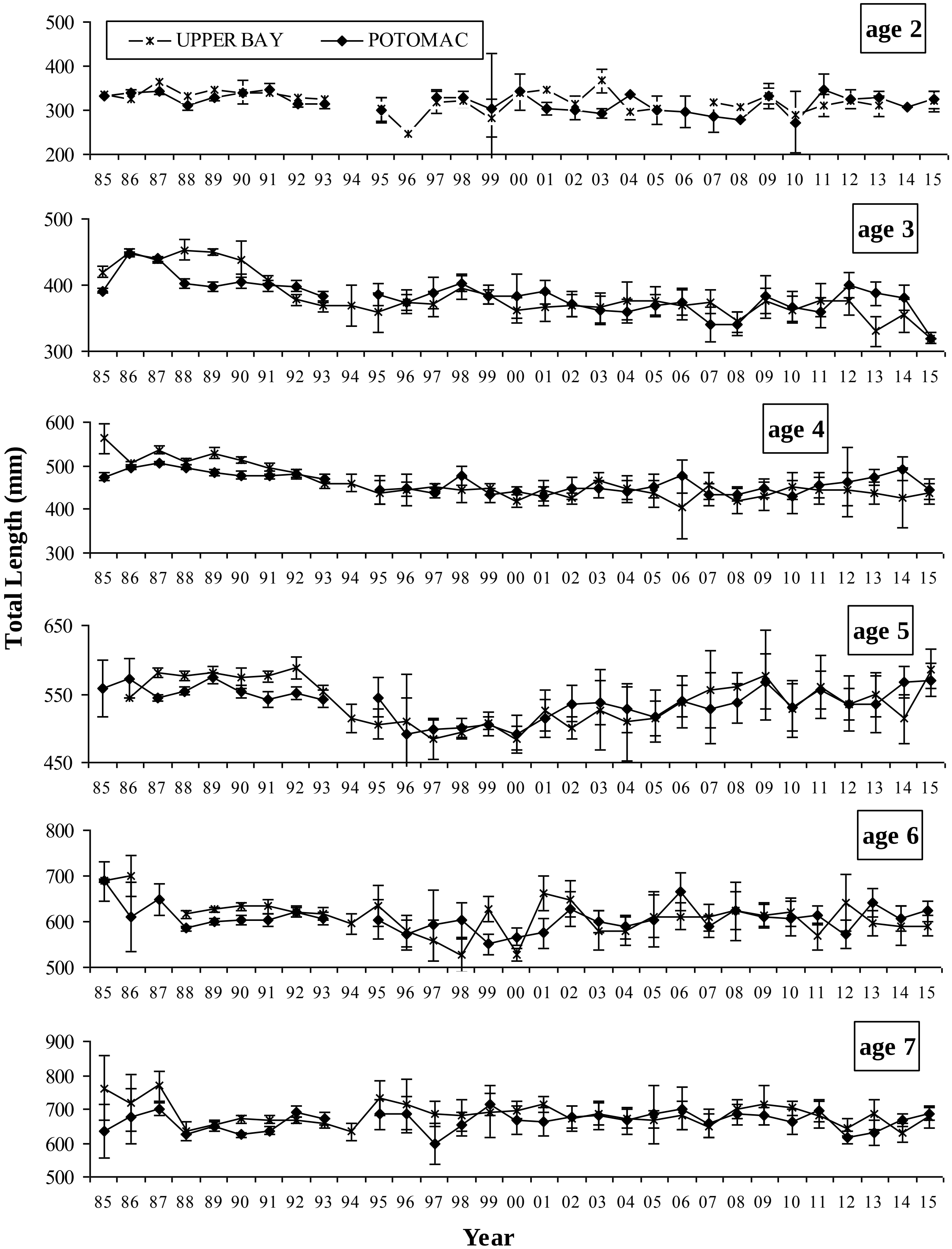


Figure 7. Continued.

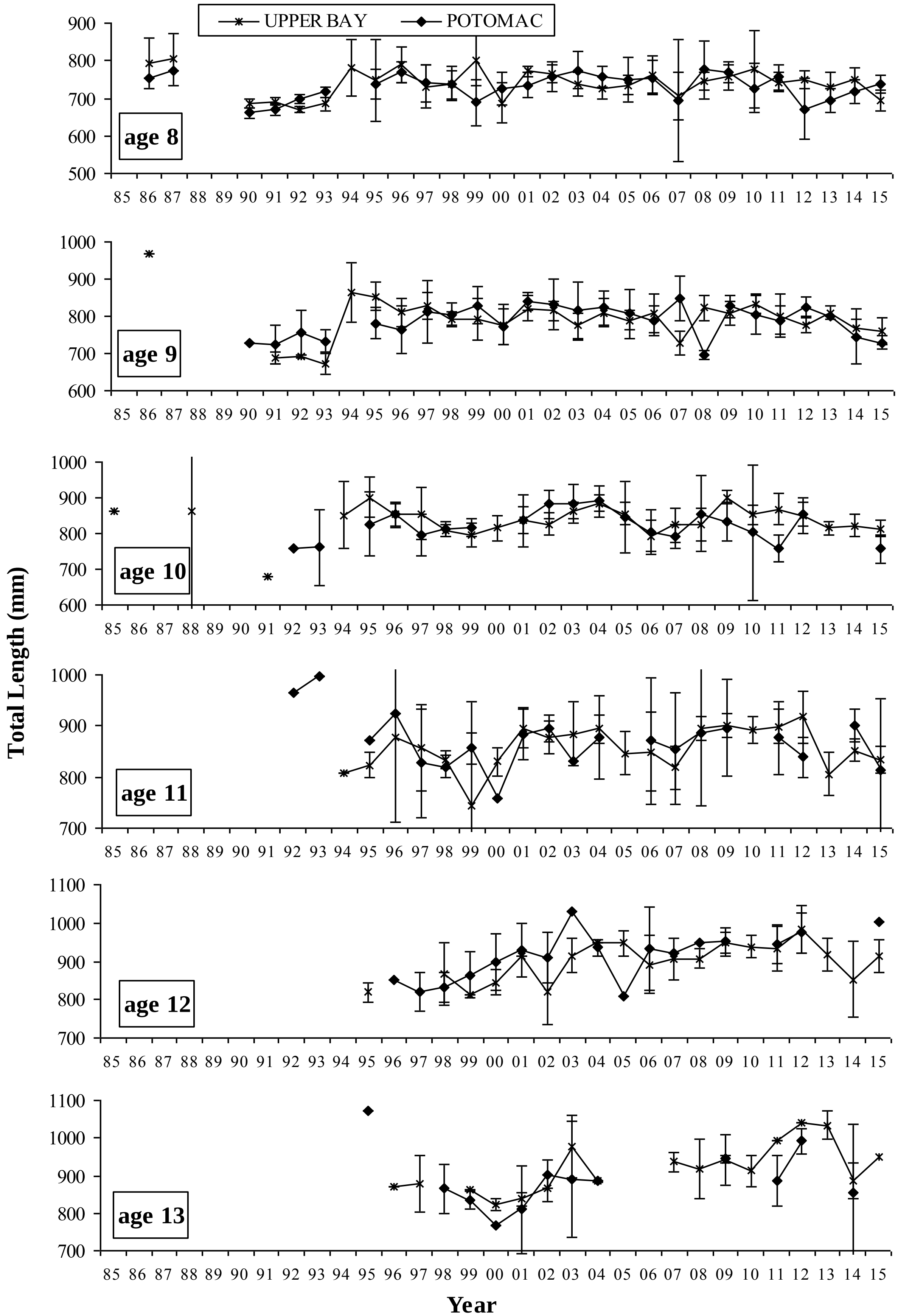


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during April through May, 1985–2015. Error bars are ± 2 standard errors (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

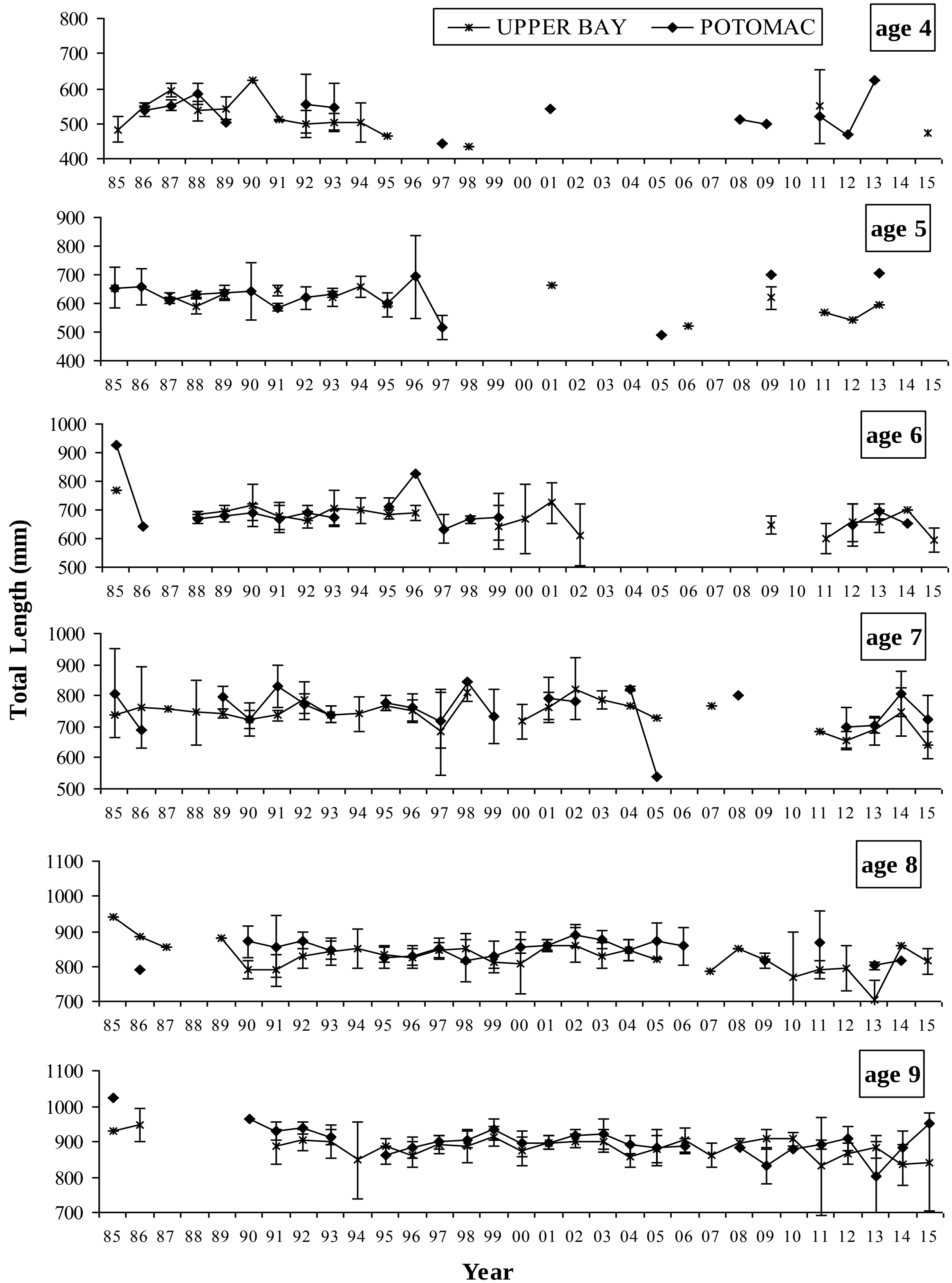


Figure 8. Continued.

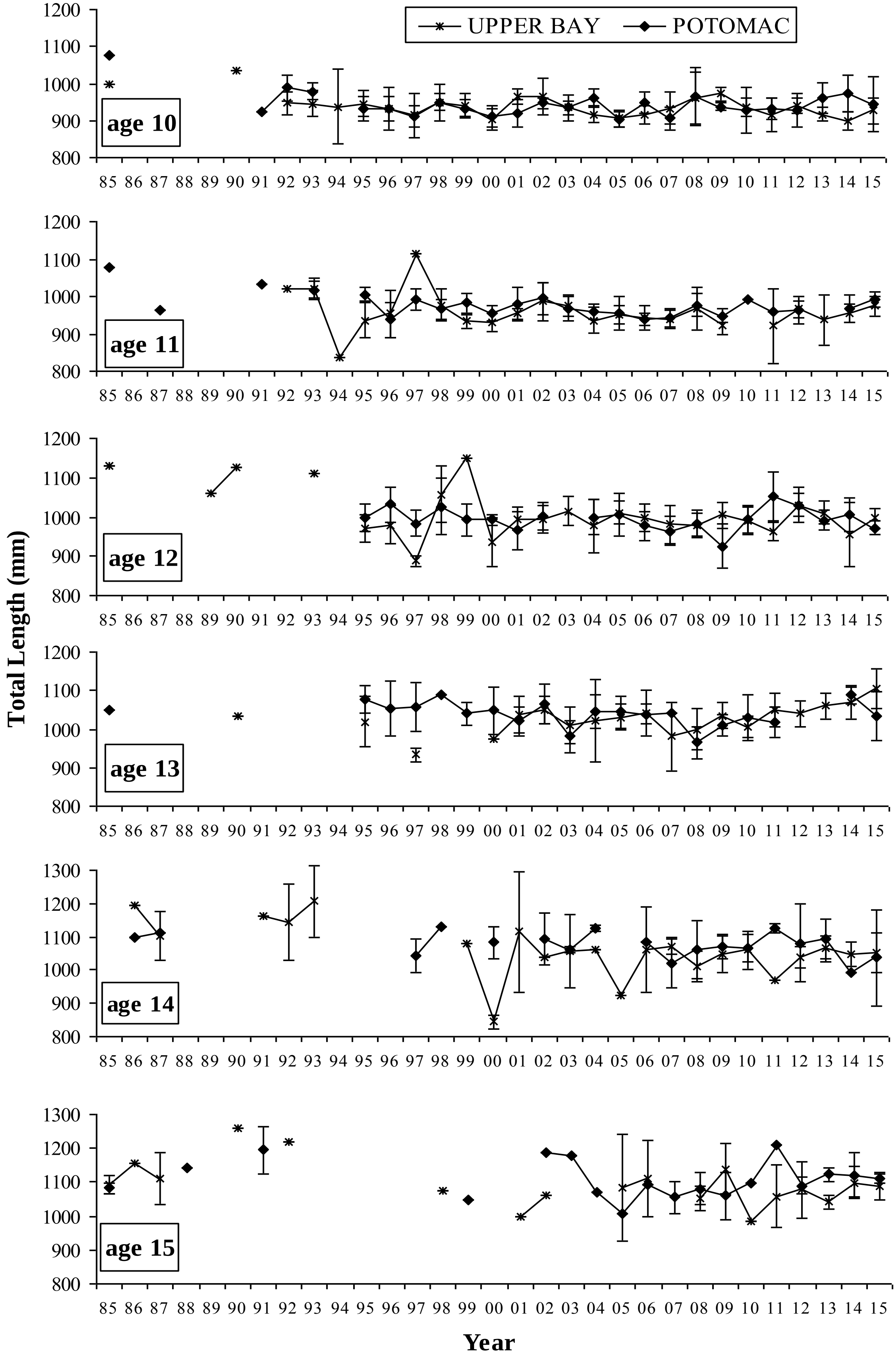


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15+. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

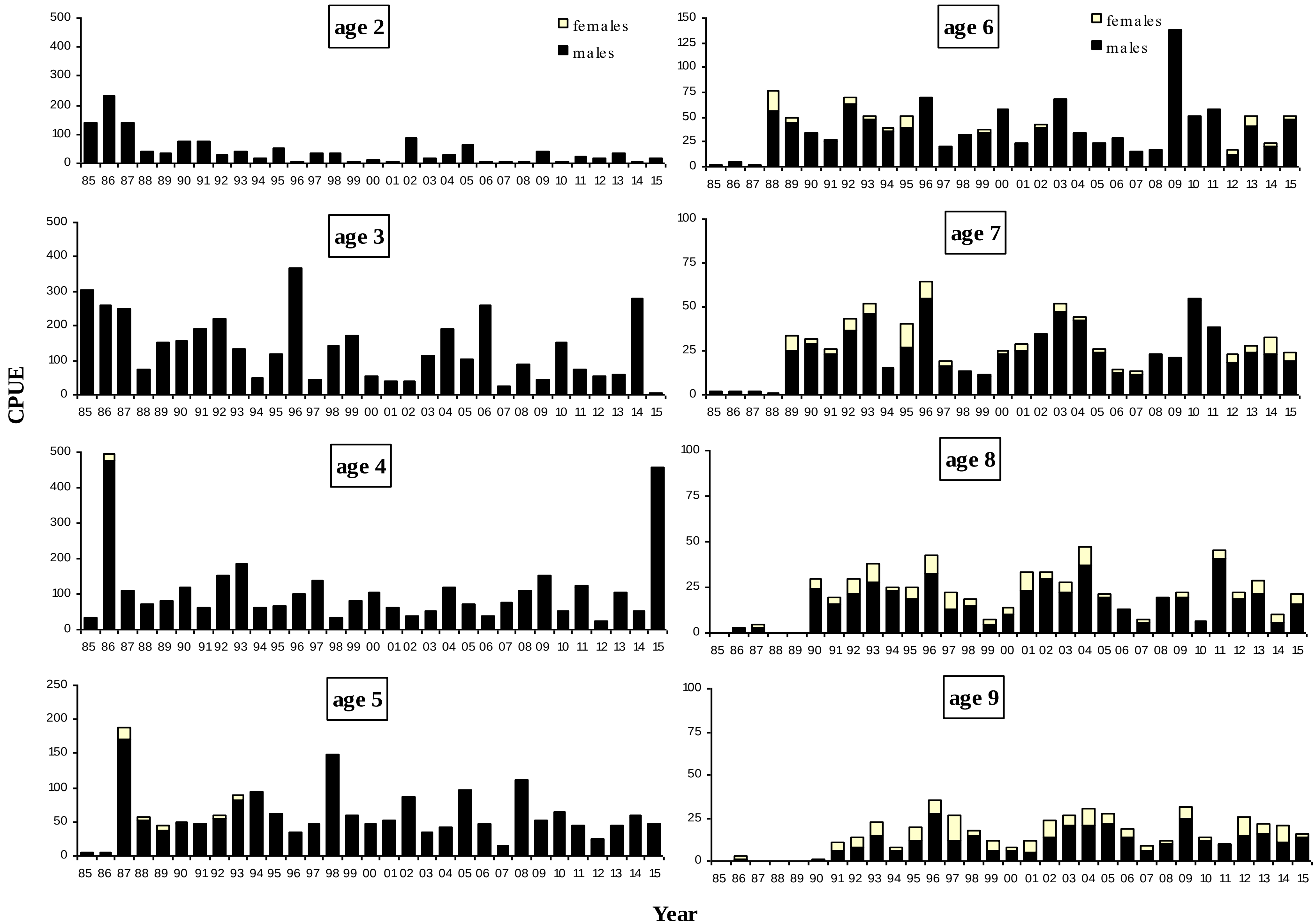


Figure 9. Continued.

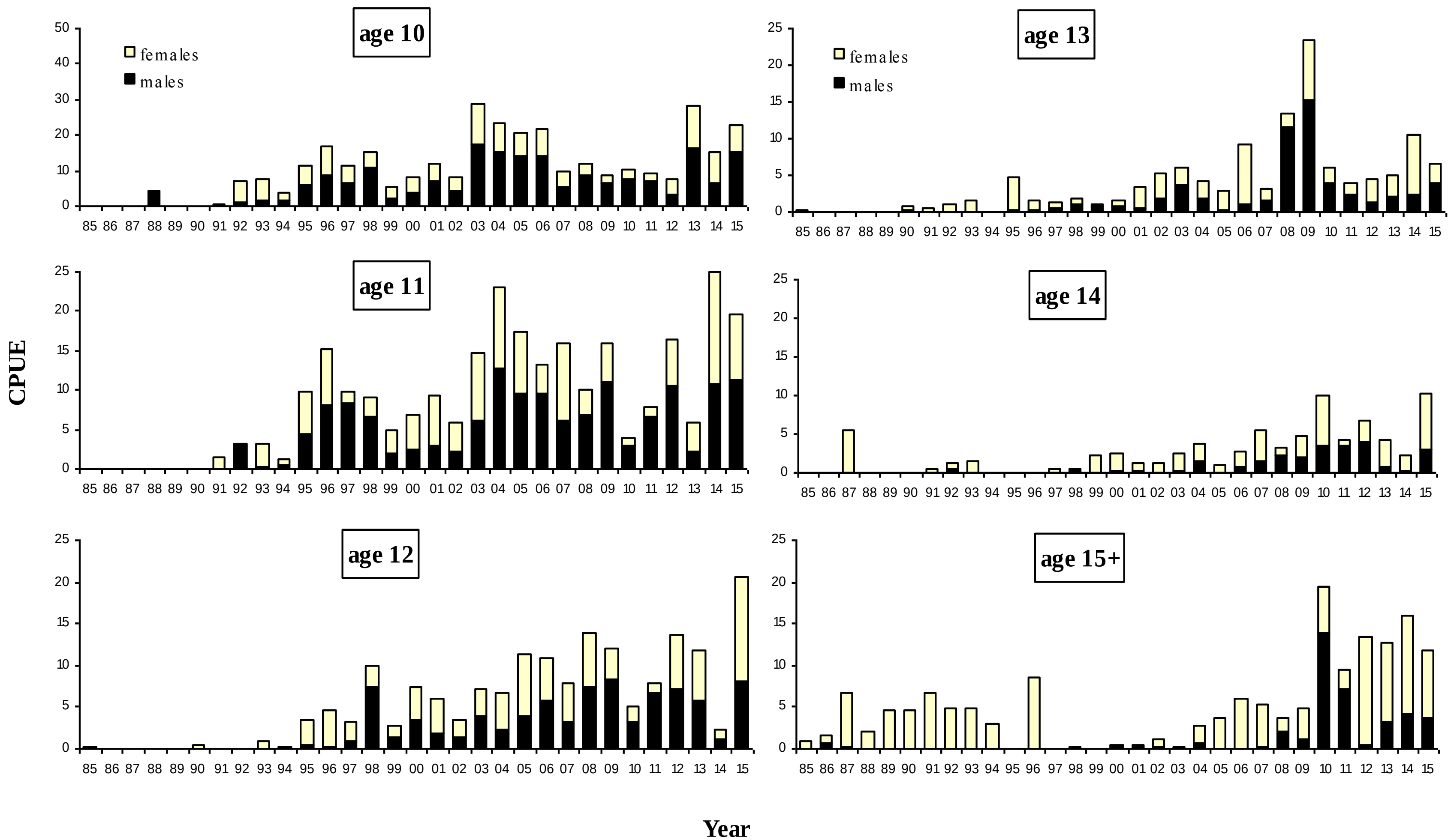
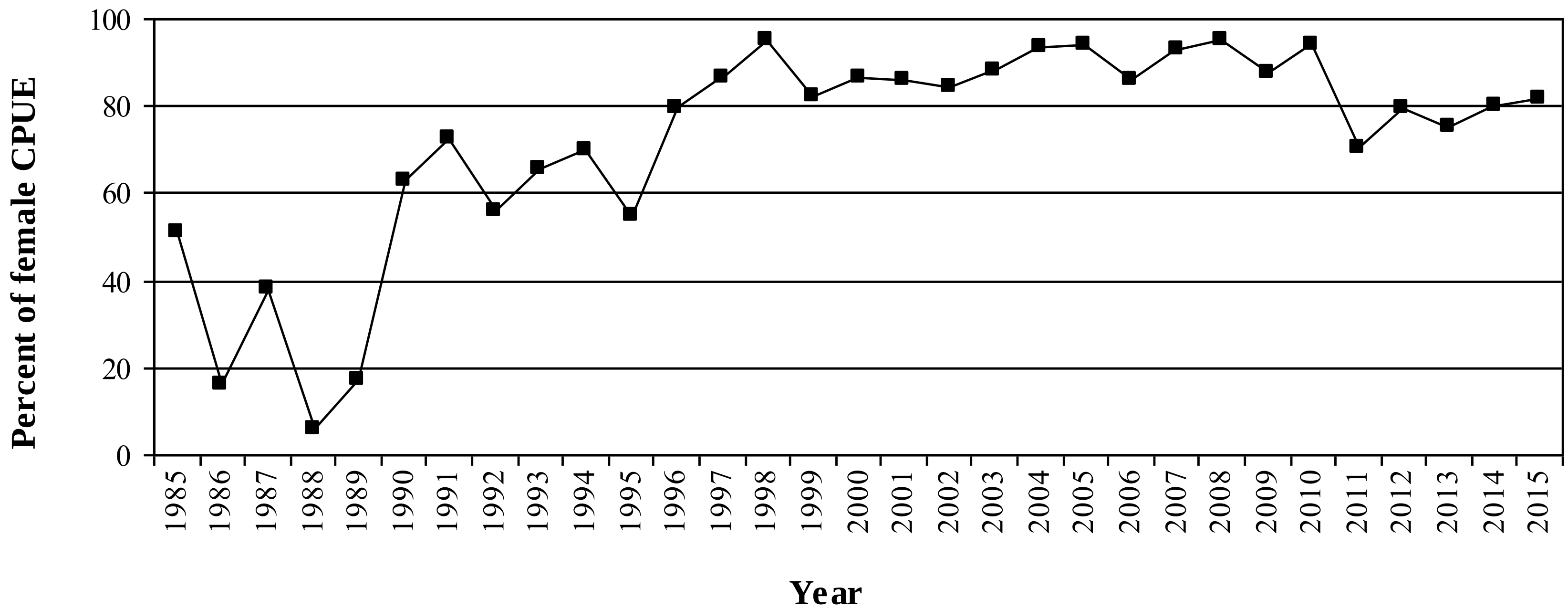
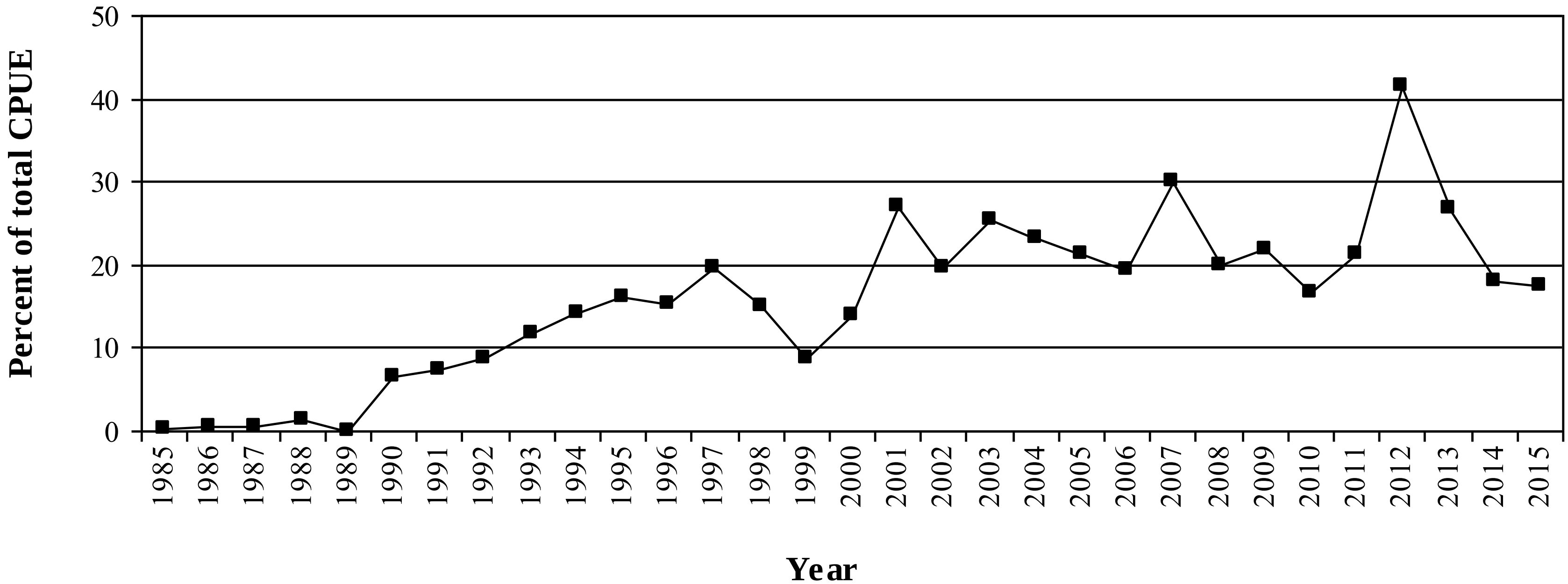


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, April through May, 1985-2015 (Choptank River to 1996). Effort is standardized 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.



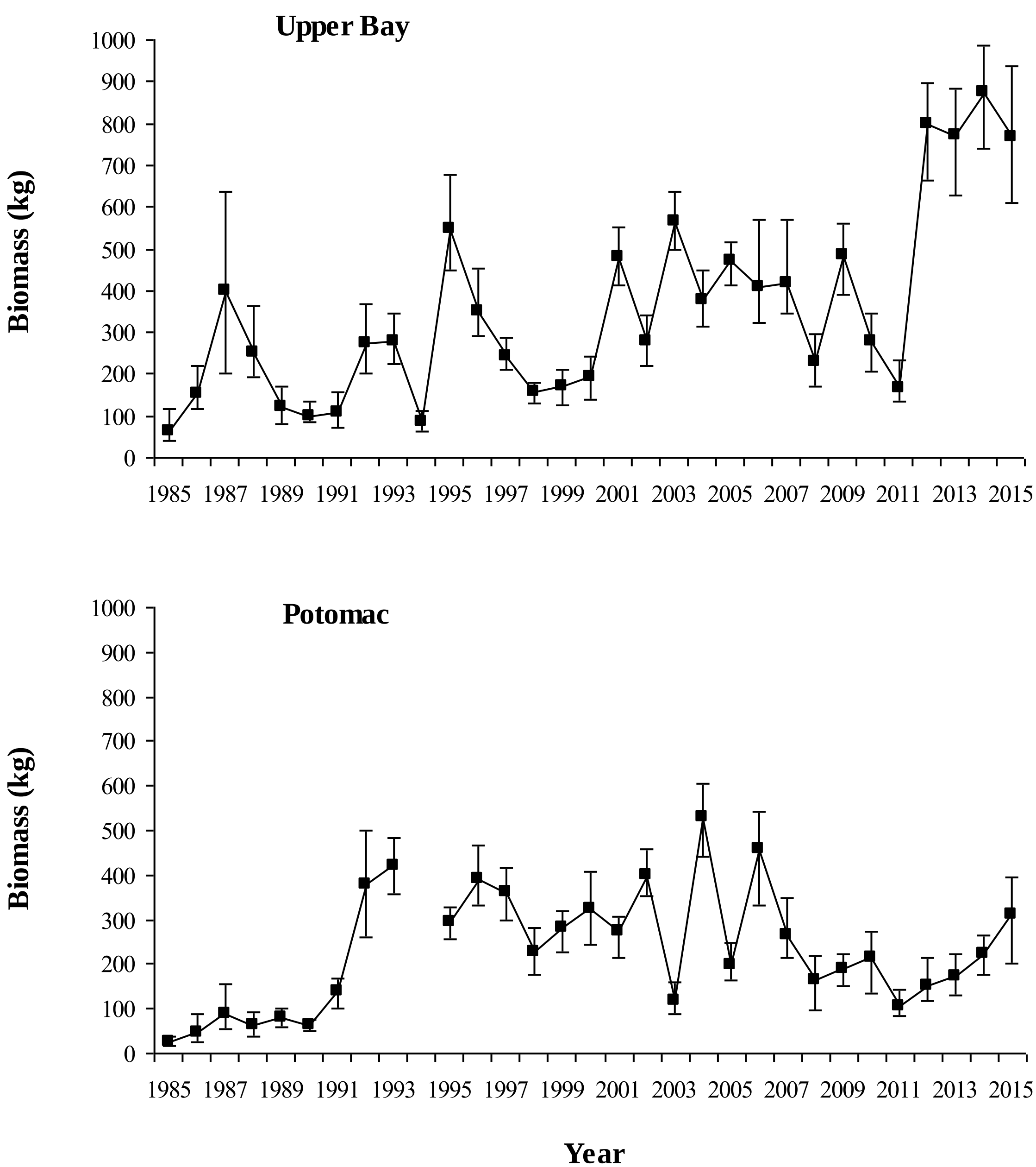
* Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385. (Hollis 1967).

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, April through May, 1985-2015 (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 April through May, 1985-2015. 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.

Sample sites have been sampled continuously since 1954, with changes in some site locations. Concrete rubble and rocky debris encountered at the Lewis Landing site (#37) on the Nanticoke River prevented deployment of the seine. The nearby sample site Opposite Red Channel Marker 26 (#166) was elevated from auxiliary to permanent status as a replacement.

From 1954 to 1961, Maryland's juvenile surveys 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 (^{o}C), 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 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 3,194 YOY striped bass was collected at permanent stations in 2015, with individual samples yielding between 0 and 368 fish. The AM (24.2) and GM (10.67) were both greater than their respective time-series averages and TPAs (Tables 2 and 3, Figures 2 and 3). The PPHL was 0.98, indicating that 98% 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 2015 $\log_e$-mean was significantly lower than just 1 year of time-series (1996), and greater than 49 years of the time-series. The 2015 year-class was indiscernible from 8 other year-classes.

System Means

Head of Bay - In 42 samples, 417 juveniles were collected at the Head of Bay sites for an AM of 9.9, less than the time-series average (11.6) and the TPA of 17.3 (Table 2, Figure 5). The GM of 7.20 exceeded both the time-series average (5.58) and was nearly equal to 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 2015 Head of Bay $\log_e$-mean significantly less than eight years of the time-series and significantly greater than 27 years of the time-series. The 2015 Head of Bay index was indiscernible from 23 other year-classes in the time-series.

Potomac River - A total of 475 juveniles was collected in 42 samples on the Potomac River. The AM of 11.3 exceeded the TPA (9.2) and the time-series average (8.3) (Table 2, Figure 5). The GM of 6.07 was also greater than the TPA (3.93) and time-series average (3.61) (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 2015 Potomac River year-class significantly smaller than four years, and significantly greater than 35 years of the time-series. The 2015 Potomac year-class was indiscernible from the remaining 19 years of the time-series.

Choptank River - A total of 1,031 juveniles was collected in 24 Choptank River samples. The AM of 43.0 was greater than the time-series average of 21.5 and the TPA of 10.8 (Table 2, Figure 5). The GM of 21.69 was also greater than its time-series average (8.23) 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 2015 Choptank River year-class significantly smaller than just one year (2001), significantly larger than 45 years of the time-series, and indiscernible from 12 other years of the time-series.

Nanticoke River - A total of 1,271 juveniles was collected in 24 samples on the Nanticoke River. The AM of 53.0 exceeded both the time-series average (9.2) and TPA (8.6) (Table 2, Figure 5). The GM of 25.71 exceeded its time-series average (4.15) and TPA (3.12) (Table 3, Figure 9). The Nanticoke River also exhibited significant differences among years (ANOVA: P<0.0001). Duncan's multiple range test (p=0.05) ranked the 2015 index significantly greater than 54 years of the time-series and indiscernible from the four highest indices of time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 95 juveniles were caught in 15 samples, resulting in an AM of 6.3, and a GM of 4.15. Both indices exceeded their respective time-series averages (Table 5).

On the **Patuxent River**, 208 YOY striped bass were caught in 18 samples. The AM of 11.6 and a GM of 4.15. Both Patuxent River indices were less than their time-series averages but greater than their respective time-series medians (Table 5).

DISCUSSION

By many measures, striped bass recruitment in Maryland's portion of the Chesapeake Bay was strong in 2015. Young-of-year striped bass occurred in 98% of samples (PPHL=0.98), a level exceeded only once in the 62-year history of the survey by the record 1996 year-class (Figure 4). The AM (24.2) and GM (10.67) ranked in the 89^{th} and 90^{th} percentiles of their respective time-series (Figures 2 and 3). Duncan's multiple range test (p=0.05) found the 2015 year-class to be significantly smaller than only the record 1996 year-class, and indiscernible from 8 of the largest year-classes ever measured in Chesapeake Bay (1993, 2001, 1970, 1958, 2003, 2011, 1964, and 2000).

Above-average recruitment was indicated in all individual systems by geometric mean indices of YOY abundance. The Nanticoke, Choptank, and Potomac rivers performed slightly better than the Head of Bay nursery area.

Nanticoke River recruitment was the highest ever measured but statistically indiscernible from four other years of strong recruitment (2001, 1996, 1958, and 2011) (Figure 9). The Choptank River GM ranked in the 90^{th} percentile of its time-series. The Potomac River GM ranked in the 85^{th} percentile of its time-series.

The Head of Bay was the only study area where the AM was below average (Table 2). The GM, however, exceeded the time-series average and was nearly equal to the TPA (Table 3, Figure 6). This was due in part to the high PPHL and low variation in individual catches of YOY striped bass. The Head of Bay GM ranked in the 72^{nd} percentile of the 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 61% of the variability ($r^2=0.61$, $p \leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was: $C_1=(0.18672)(C_0)-0.07057$, 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 (0.20) was similar to the index of 0.23 predicted by the regression analysis. Examination of residuals (Figure 11) shows that this regression equation can be used to predict subsequent yearling striped bass abundance with reasonable certainty in the case of small and average sized year-classes. Estimates of future abundance of age 1 striped bass are less reliable for dominant year-classes. Lower than expected abundance of age 1 striped bass may be an indication of density-dependent processes operating at high levels of abundance, such as cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

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LIST OF FIGURES

Table 1. Maryland juvenile striped bass survey sample sites.

Site Number	River or Creek	Area or Nearest Landmark
	HEAD OF CHESAPEAKE BAY SYSTEM	
* 58	Susquehanna Flats	North side Spoil Island, 1.9 miles south of Tyding's Park
* 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
4	Elk River	Welch Point, Elk River side
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
56	Potomac River	St. George Island, south end of bridge
55	Wicomico River	Rock Point

* 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
Average	11.6	8.3	21.5	9.2	11.9
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
Average	5.58	3.61	8.23	4.15	4.32
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
Average	11.9	209.6	1.46	92.08	0.71	0.64	0.78	
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	0.06	0.04	18	0.58	0.33	12
1984	0.61	0.39	18	0.92	0.43	12
1985	3.17	1.95	18	1.00	0.24	12
1986	2.44	1.17	18	0.92	0.54	12
1987	2.94	0.94	17	0.33	0.26	9
1988	0.59	0.40	17	1.62	1.07	21
1989	1.39	0.92	18	10.43	1.91	21
1990	0.28	0.17	18	4.95	2.24	21
1991	0.94	0.53	18	2.15	0.98	20
1992	9.50	1.85	18	0.50	0.26	20
1993	104.30	47.18	18	28.00	11.11	21
1994	4.10	2.82	18	6.30	2.31	21
1995	7.28	3.46	18	2.95	1.15	21
1996	420.39	58.11	18	12.40	4.69	20
1997	7.33	2.72	18	2.70	2.18	20
1998	13.22	7.58	18	2.94	1.51	16
1999	7.28	5.39	18	3.62	2.13	13
2000	9.67	5.03	18	8.60	5.68	15
2001	17.28	10.01	18	19.47	6.62	15
2002	1.22	0.69	18	1.00	0.42	15
2003	61.11	22.17	18	16.06	11.79	16
2004	2.11	1.29	18	7.73	4.40	15
2005	8.94	3.91	18	5.53	4.35	15
2006	1.00	0.66	18	0.67	0.31	15
2007	15.22	6.07	18	5.33	2.72	15
2008	0.33	0.24	18	3.47	2.02	15
2009	3.00	1.87	18	2.13	1.14	15

Table 5. Continued.

	Patuxent River			Head of Bay		
Year	**AM**	**GM**	**n**	**AM**	**GM**	**n**
2010	3.33	2.49	18	3.67	1.45	15
2011	42.50	13.41	18	12.29	5.75	21
2012	0.06	0.04	18	1.86	0.71	21
2013	6.00	2.63	18	4.93	2.82	15
2014	5.11	2.70	18	5.33	4.34	15
2015	11.56	4.15	18	6.33	4.15	15
Average	23.46	6.45		5.66	2.79	
Median	4.10	2.49		3.62	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	N/A

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

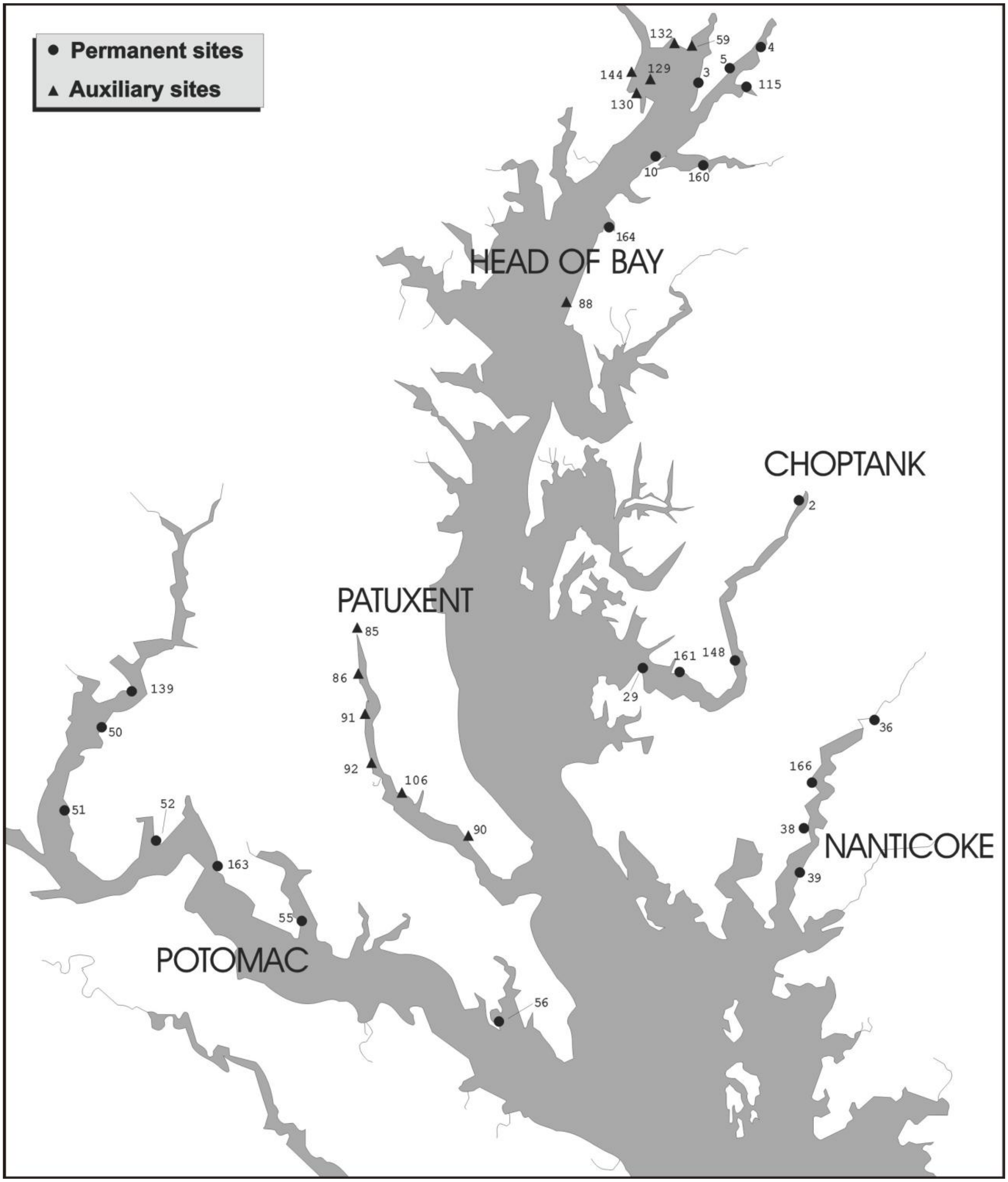


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

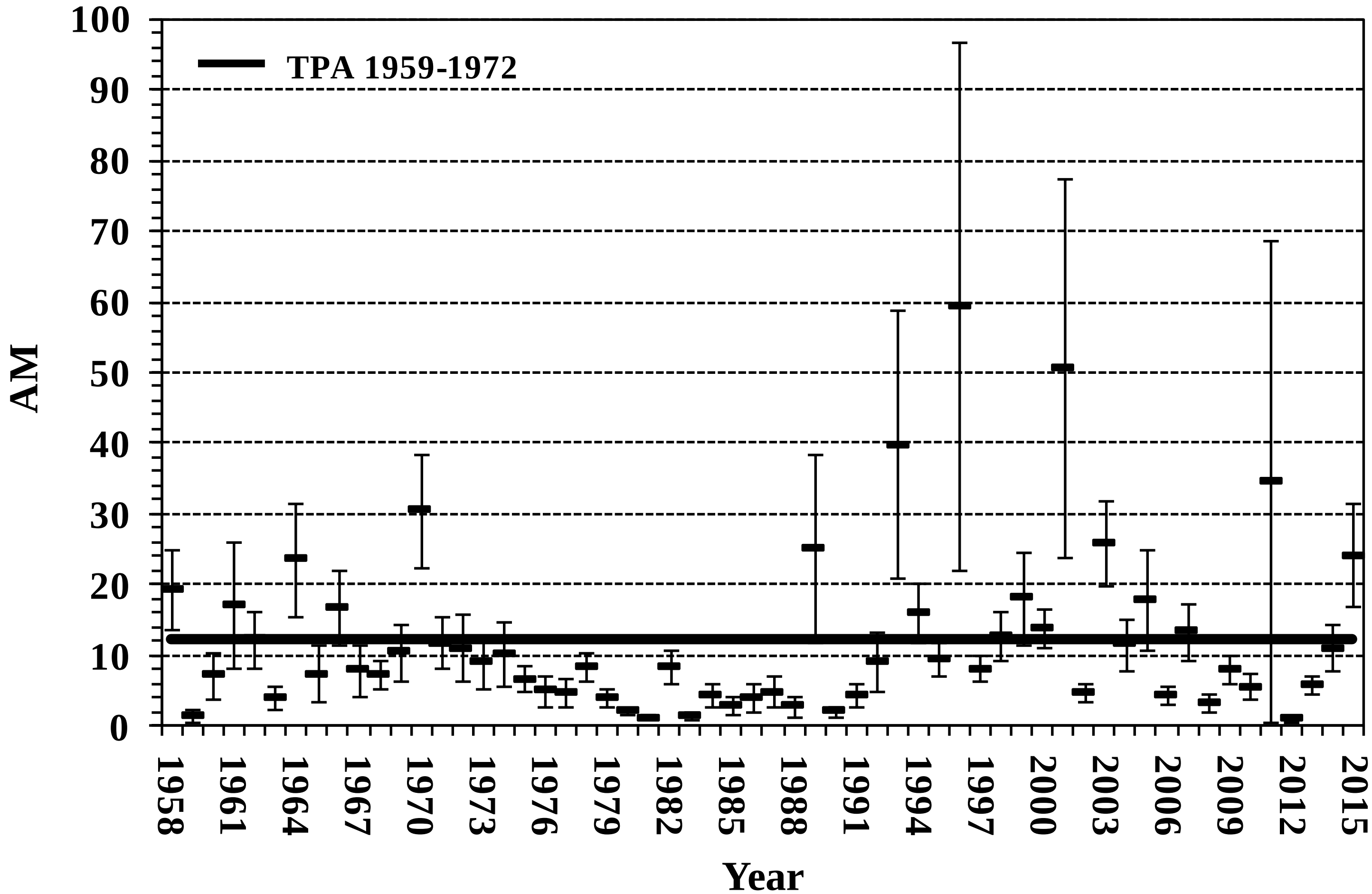


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

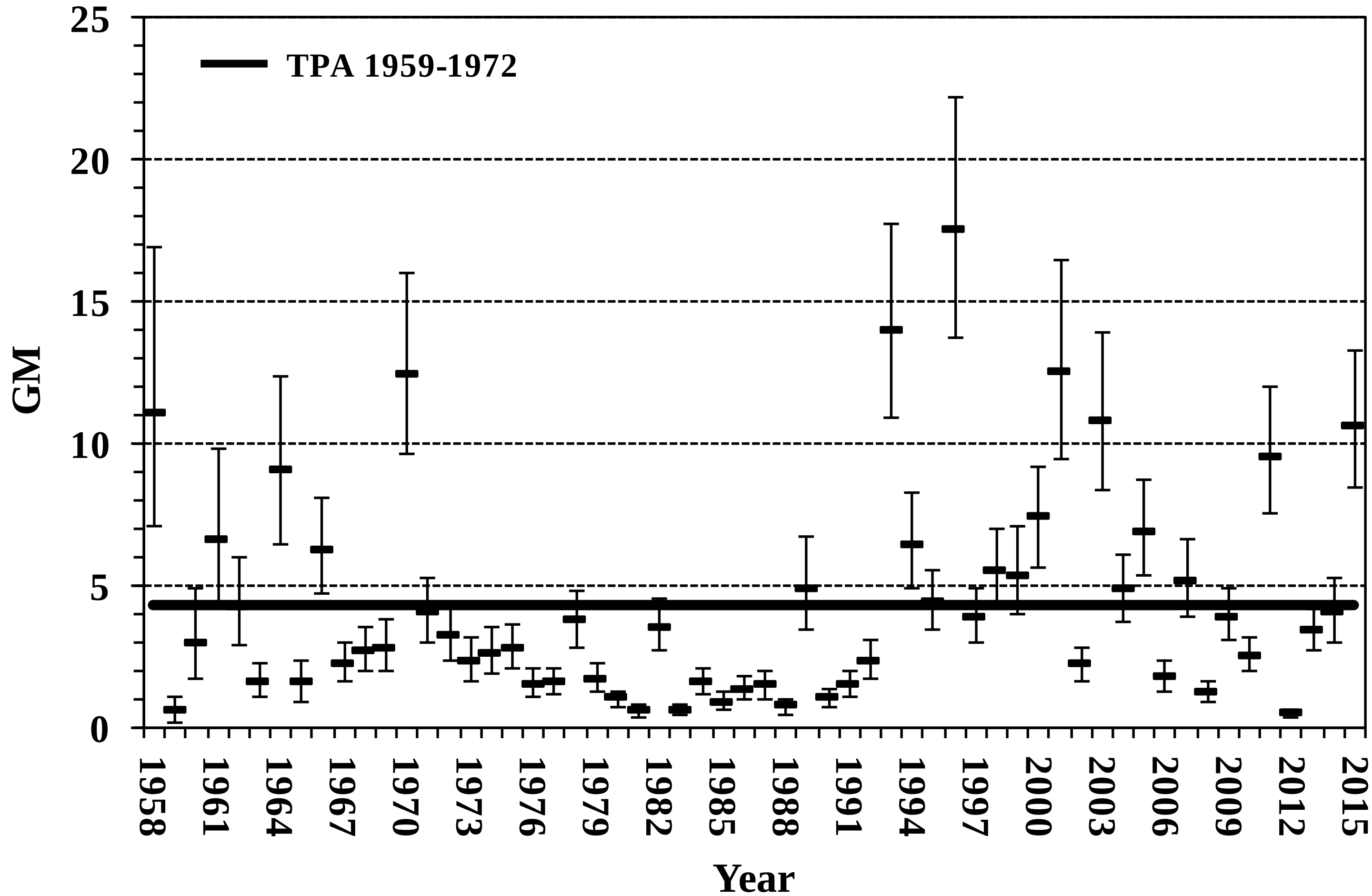


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

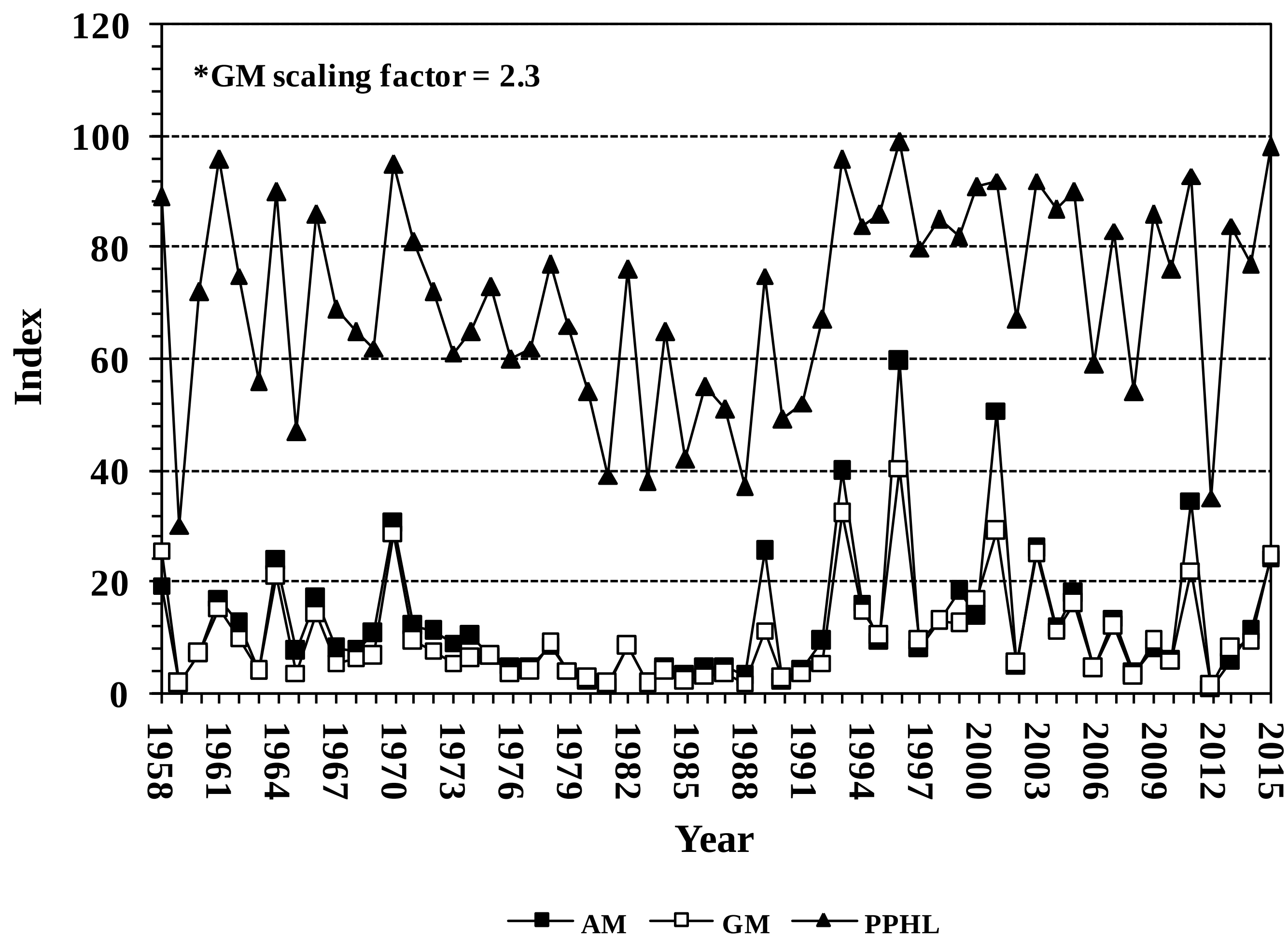


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

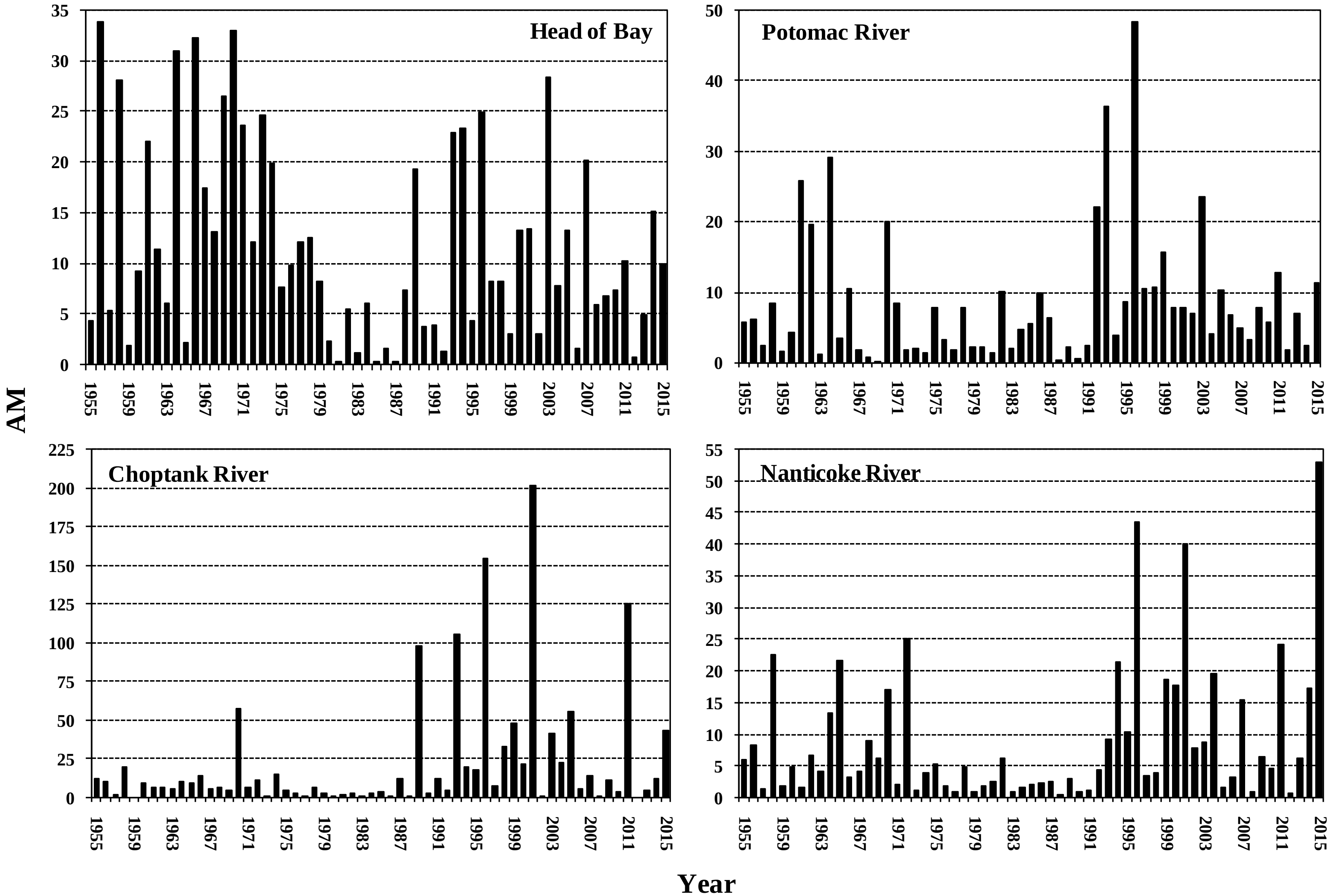


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

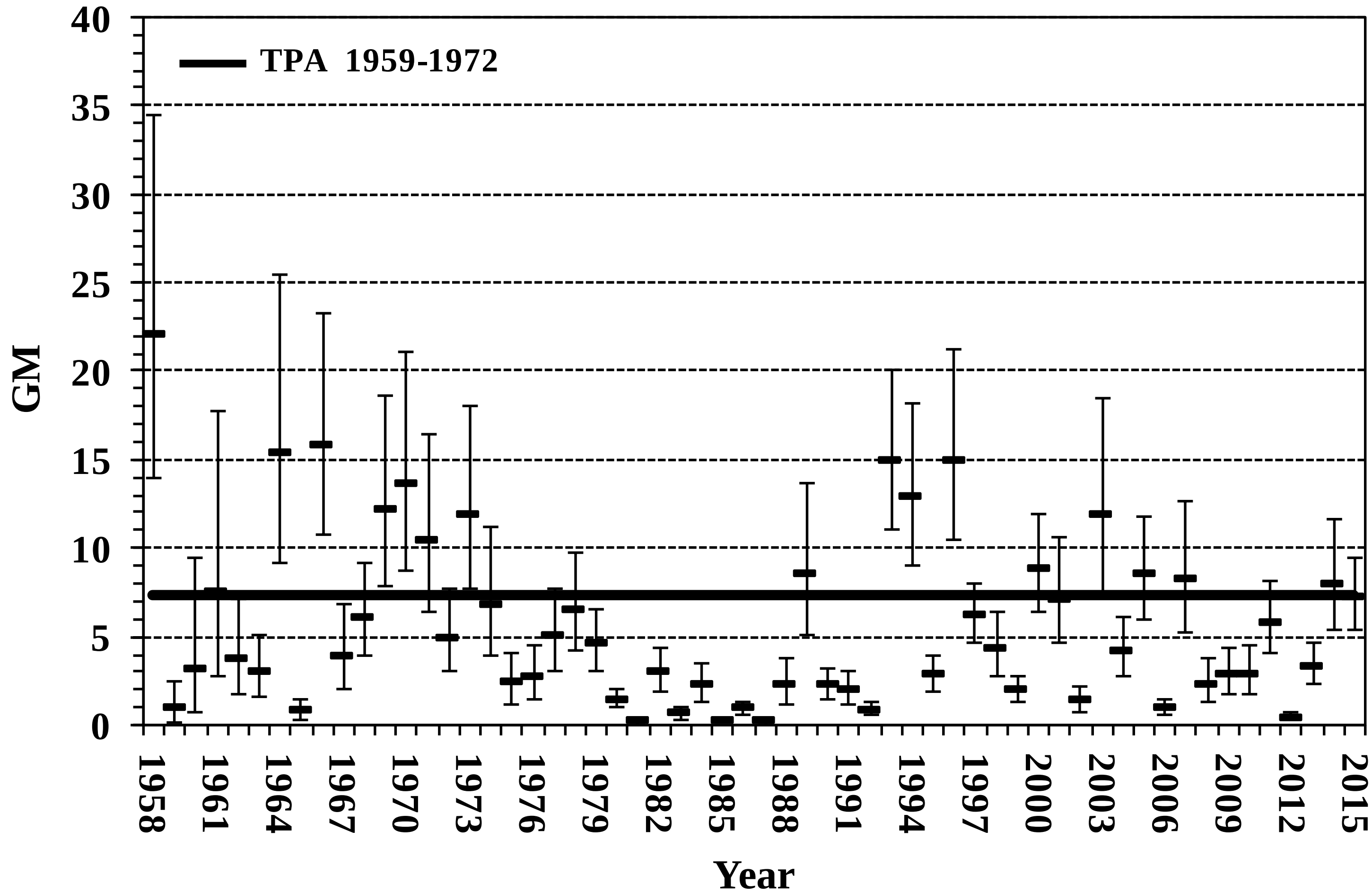


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

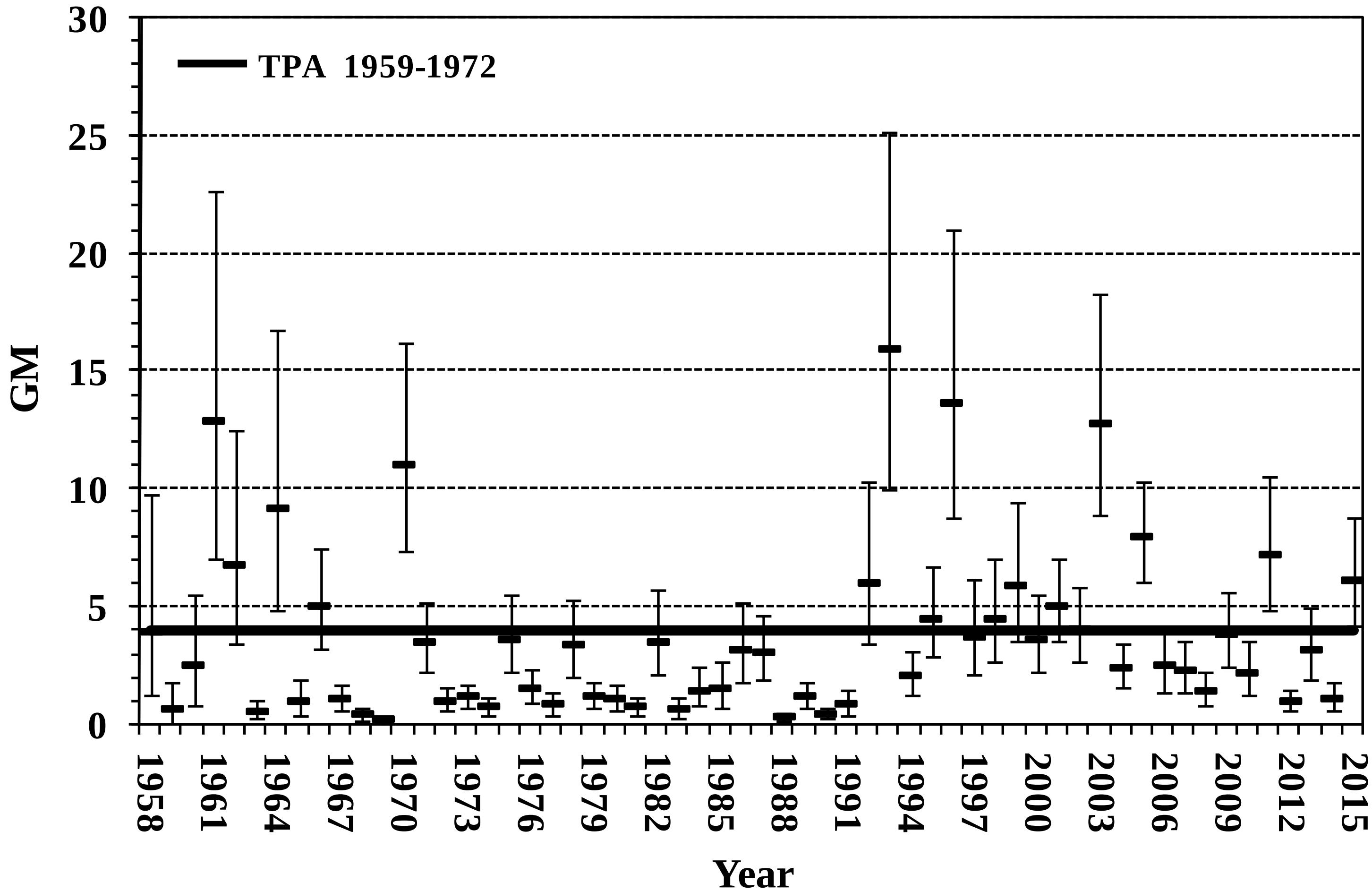


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

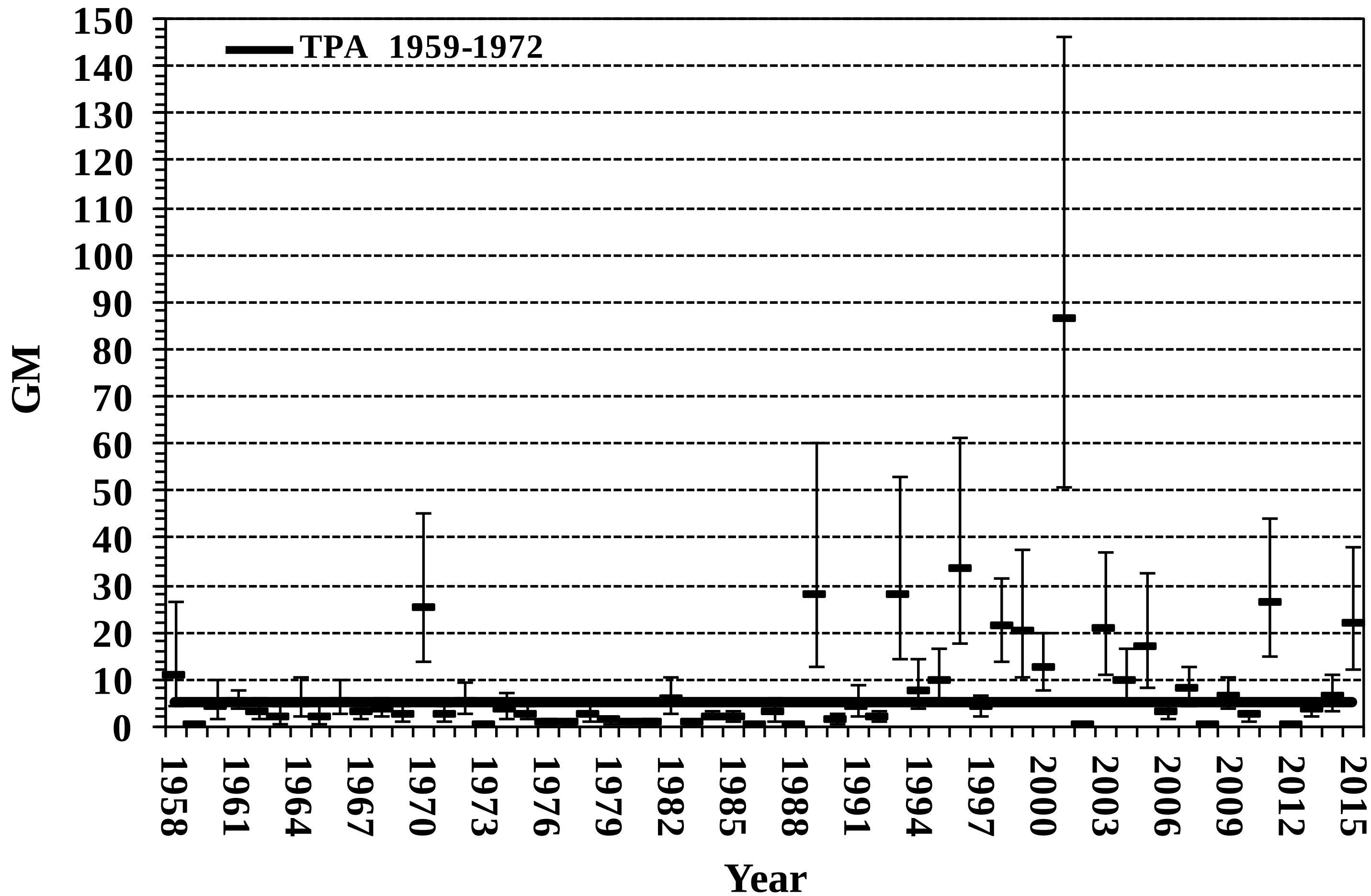


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

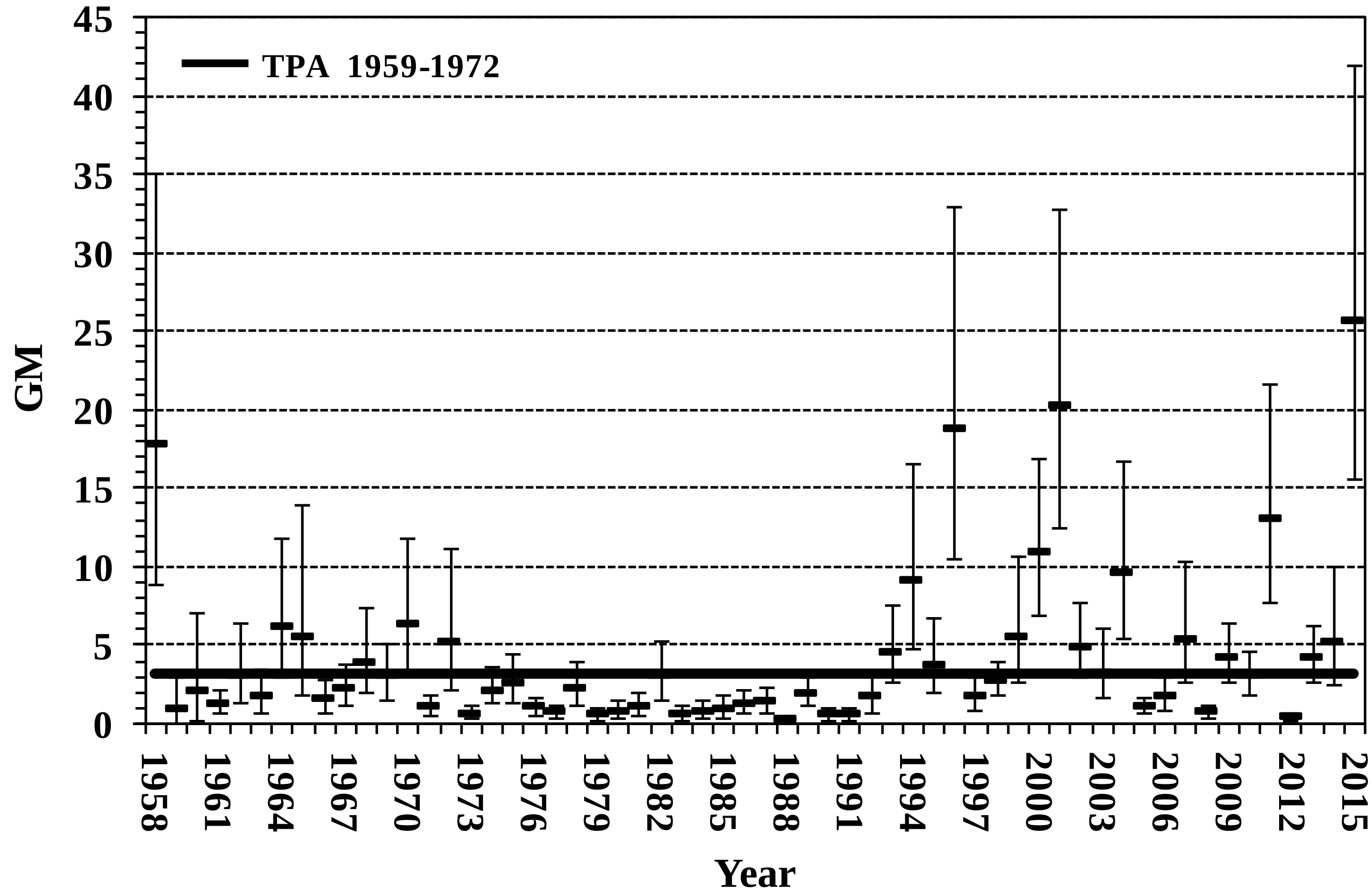


Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

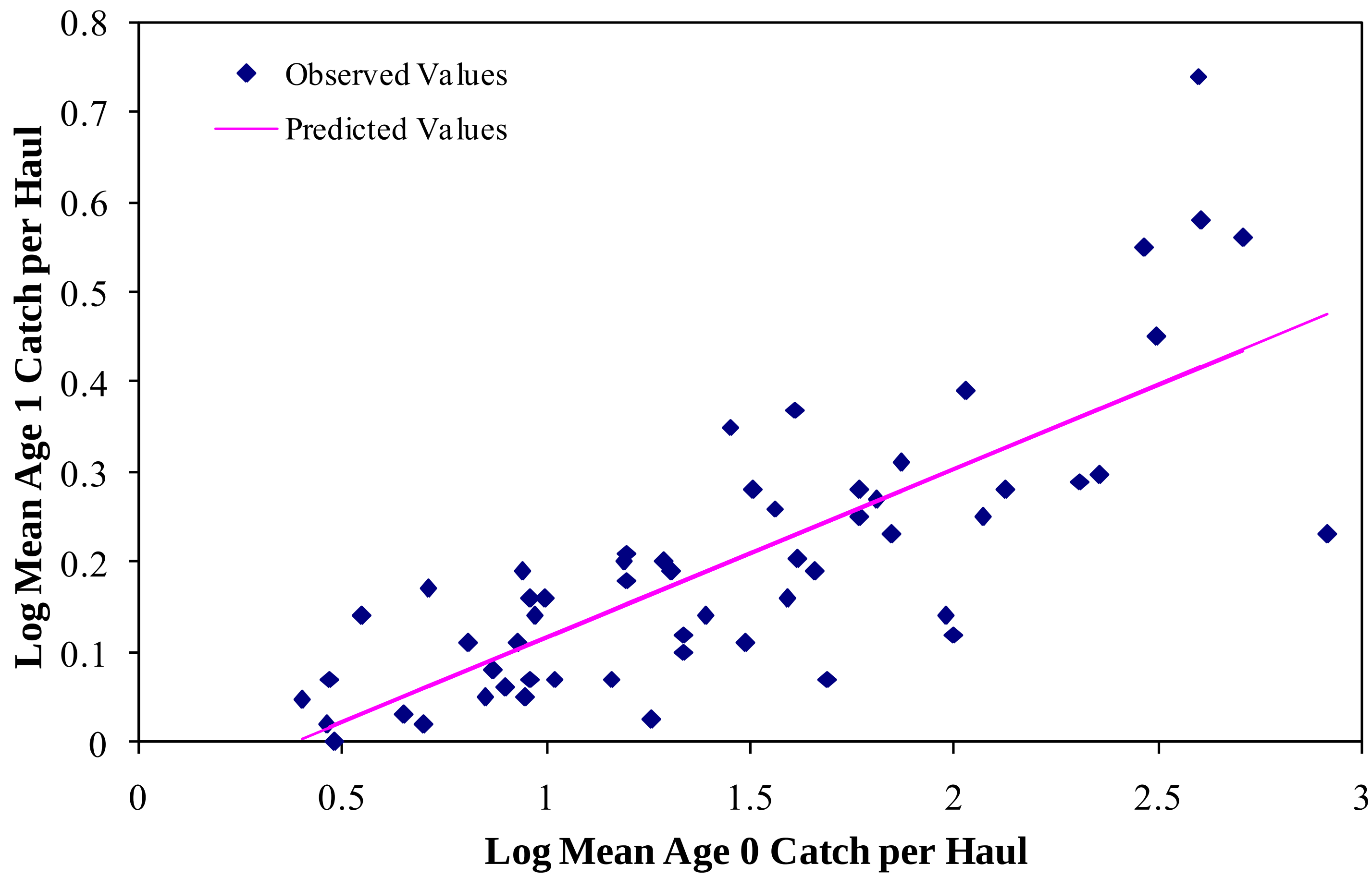
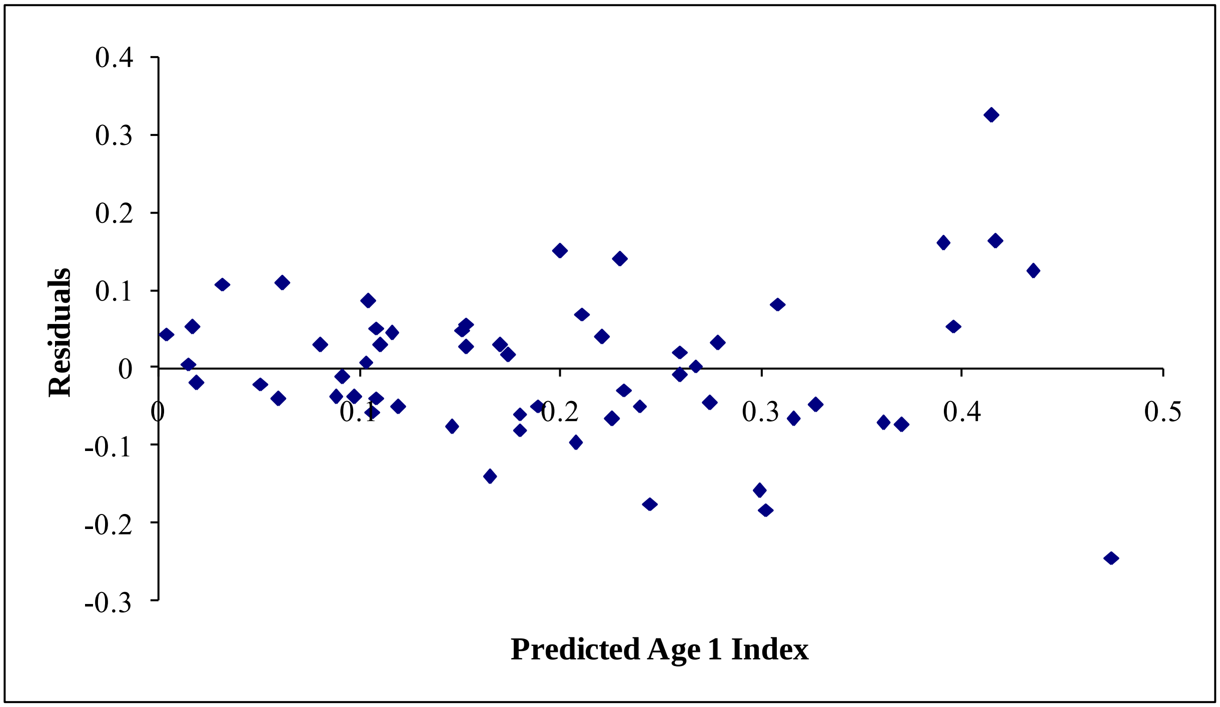
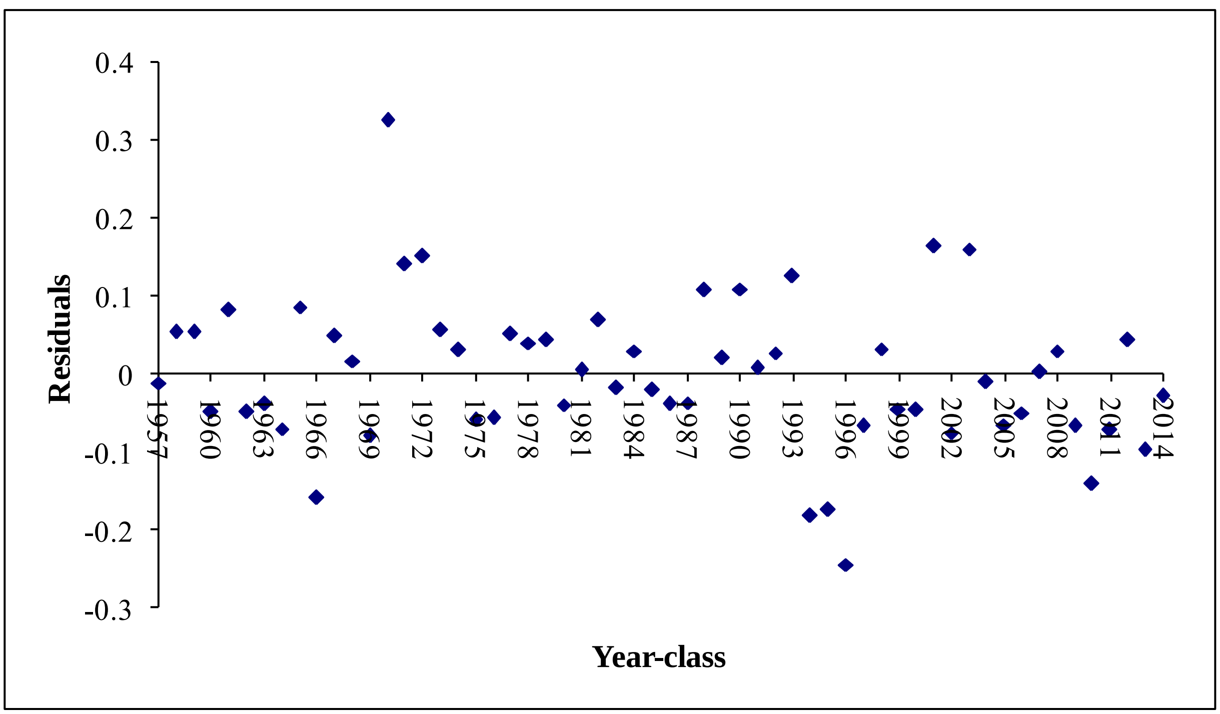


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 2015. The Maryland Department of Natural Resources (MD DNR) has been a key partner in the North Carolina cooperative winter tagging cruise and continues to maintain the long-term data set for the cruise. For these reasons, the offshore tagging cruise activities were also summarized. 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

During April through mid-May 2015, 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 (TL) to the nearest millimeter (mm) 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. No more than 10 scale samples per 10-mm length group were taken 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 2015, funding was obtained to conduct both a trawl and hook and line component of the offshore North Carolina tagging cruise. The goal was to tag as many coastal migratory striped bass as possible while they were wintering in the Atlantic Ocean off northeastern North Carolina and/or southeastern Virginia (state and federal waters). Participants in the two sampling components included USFWS, North Carolina Division of Marine Fisheries (NC DMF), East Carolina University, MD DNR, North Carolina Department of Environment and Natural Resources, National Marine Fisheries Service, Potomac River Fisheries Commission and Delaware State University.

The first phase of the tagging cruise took place from January 10 to January 18, 2015. Trawling was conducted 24 hours per day aboard the Skidaway Institute of Oceanography's Research Vessel Savannah. One 65-foot (19.7 m) head-rope Mongoose trawl was towed 152 times at speeds ranging from 2.1 to 3.8 knots at depths of 23 to 143 feet (6.9 – 43.7 m) for 0.17 to 0.5 hours.

The hook and line fishing was conducted onboard a contracted sportfishing vessel departing from Virginia Beach, VA. Sampling was conducted during 9 fishing trips, between January 11 and January 26, 2015. Between five and eight lines with custom-made tandem parachute rigs were trolled, at 1.8 to 5 knots, in depths of 50 to 80 feet (15.2 to 24.4 m).

Captured fish were placed in holding tanks equipped with an ambient water flow-through system for observation prior to tagging. Vigorous fish with no external anomalies 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 healthy 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 in Jiang et al. (2007) to estimate survival, fishing mortality and natural mortality. The candidate models run in the IRCR model are similar in structure to the models previously used in Program MARK, and are formulated based on historical changes in striped bass management. Three models were run in Program MARK as a check on the calculated total mortality (Z). Additional details on the methodologies can be found in the latest peer reviewed stock assessment report (Northeast Fisheries Science Center 2013). Further details on Program MARK methodologies can be found in Versak (2007).

Estimates for Maryland's spawning stock are broken into two size groups: $\geq$457 mm TL (18 inches) and $\geq$711 mm TL (28 inches). The recovery year began on the first day of spring tagging in the time series (March 28) and continued until March 27 of the following year. Survival and mortality estimates for fish tagged in spring 2015 will not be completed until after March 27, 2016.

Tag release and return data from spring male fish, ≥457 mm TL and <711 mm TL (18 – 28 inches TL), were used to develop annual estimates of fishing mortality for the Chesapeake Bay pre-migratory stock. Male fish 18 to 28 inches are generally accepted to compose 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 2013).

Estimates of survival, fishing mortality and recovery rates for the North Carolina cooperative tagging cruise data were calculated using the same methods as Maryland's spring tagging data. These calculations 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 1 and May 12, 2015. A total of 3,057 striped bass were sampled and 1,652 (54%) 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 2015 (554 mm TL) was significantly greater (t-value=-8.62, $P<0.0001$) than that of the sampled population (508 mm TL) (Figure 2). This difference was also evident in the significant difference of the two length frequencies ($D=0.14$, $P<0.0001$).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2015 data) will be used to estimate an instantaneous fishing mortality rate on resident fish for the 2015-2016 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Estimates of survival and fishing mortality for the 2015 Chesapeake Bay spawning stock, as well as the resident stock, will be presented in the next report of the ASMFC Striped Bass Tagging Subcommittee. Stock assessments are currently being conducted every two years.

North Carolina cooperative offshore tagging activities

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.

During the 2015 trawling portion of the cruise, 334 striped bass were captured and 333 (99.7%) were tagged (Table 2). The mean length of all fish captured and tagged on the 2015 trawling cruise was 891 mm TL. While fishing with hook and line, 1,058 striped bass were encountered and 1,042 (98%) were tagged (Table 2). The mean length of all fish captured and tagged during the hook and line sampling was 975 mm TL. The mean total length of striped bass tagged on the hook and line portion of the cruise (975 mm TL) was significantly greater than the length of fish tagged from the trawling component (891 mm TL , t-value=18.88, $P<0.0001$, Figure 3). This could be a result of the bait sizes used during the hook and line component, the ability of larger fish to swim faster to avoid the trawl, or for larger fish to outcompete the smaller fish for the trolled baits. Similarly, the KS-test results showed a significant difference in length distributions ($D=0.44$, $P<0.0001$).

The mean total length of striped bass tagged on the 2015 hook and line cruise (975 mm TL) was significantly greater than the length of fish tagged from the 2014 hook and line cruise (941 mm TL , t-value=-9.3, $P<0.0001$, Figure 3). Length distributions between the two years were also different ($D=0.25$, $P<0.0001$).

The NC DMF is presently completing age determination for the 2015 cruise via scale analysis. Estimates of survival and fishing mortality based on fish tagged in the 2015 North Carolina study will be presented in the next report of the ASMFC Striped Bass Tagging Subcommittee.

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. 2013. 57th Northeast Regional Stock Assessment Workshop (57th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 13-16; 967 pp.

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.

Versak, B. 2007. Striped Bass Tagging. In: Chesapeake Bay Finfish/Habitat Investigations. USFWS Federal Aid Project, F-61-R-3, Period covered: 2006-2007, Maryland Department of Natural Resources, Fisheries Service. Project No. 2, Job No. 3, Task No 4. pp 235-245.

LIST OF TABLES

LIST OF FIGURES

Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, April - May 2015.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	4/1/15 - 5/12/15	1,389 [b]	608	524861 – 525000 532655 – 533000 535501 – 535626
Upper Chesapeake Bay	4/8/15 - 5/12/15	1,668 [c]	1,044	535286 – 535500 540501 – 541332
Spring spawning survey totals:		3,057	1,652	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes one USFWS recapture and one fish with no total length recorded.
[c] Total sampled includes two USFWS recaptures.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2015 cooperative offshore tagging cruises.

System	Gear	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Nearshore Atlantic Ocean (Near VA-NC line)	Trawl	1/10/15 – /18/15	334	333	590001 – 590333
Nearshore Atlantic Ocean (Near VA-NC line)	Hook & Line	1/11/15 – 1/26/15	1,058 [b]	1,042	571951 – 572992
Cooperative tagging cruise totals:			1,392	1,375	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes two USFWS recaptures.

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2015.

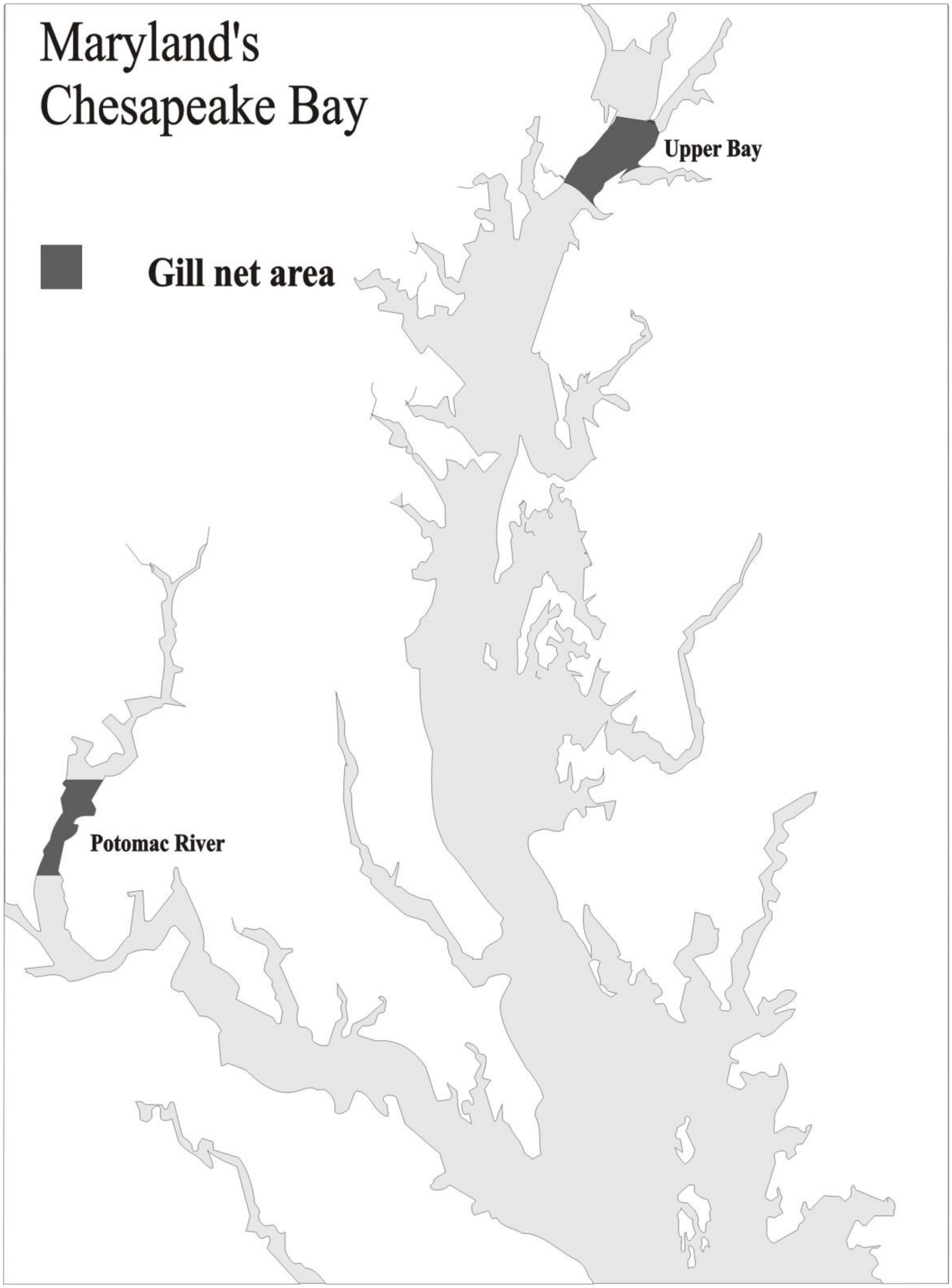


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay, April - May 2015.

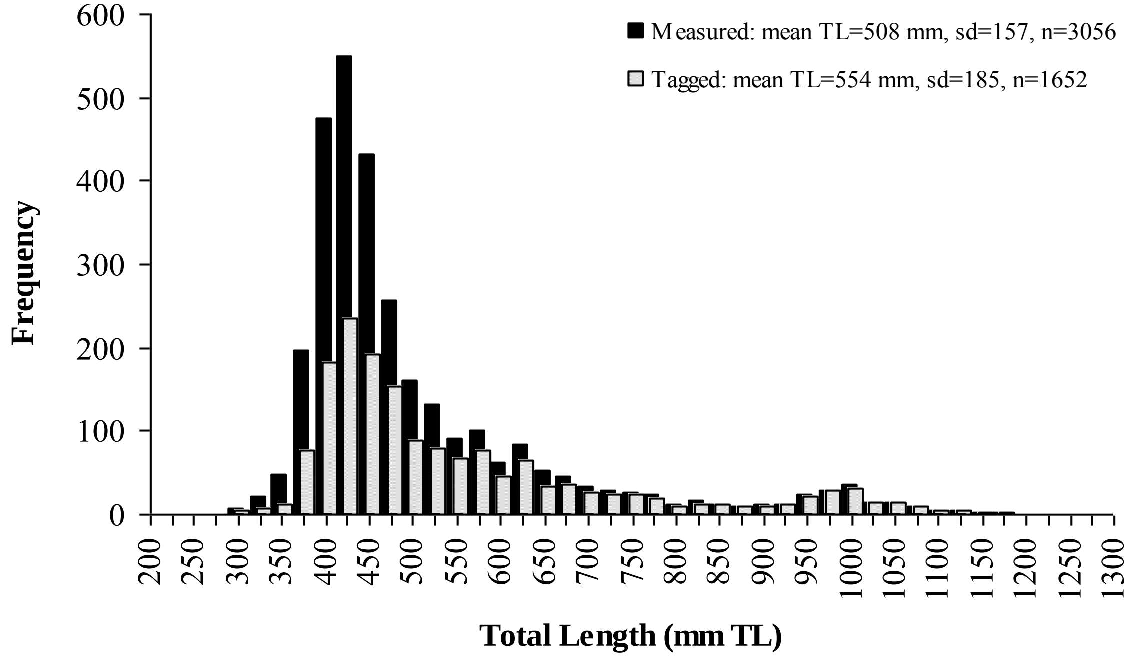
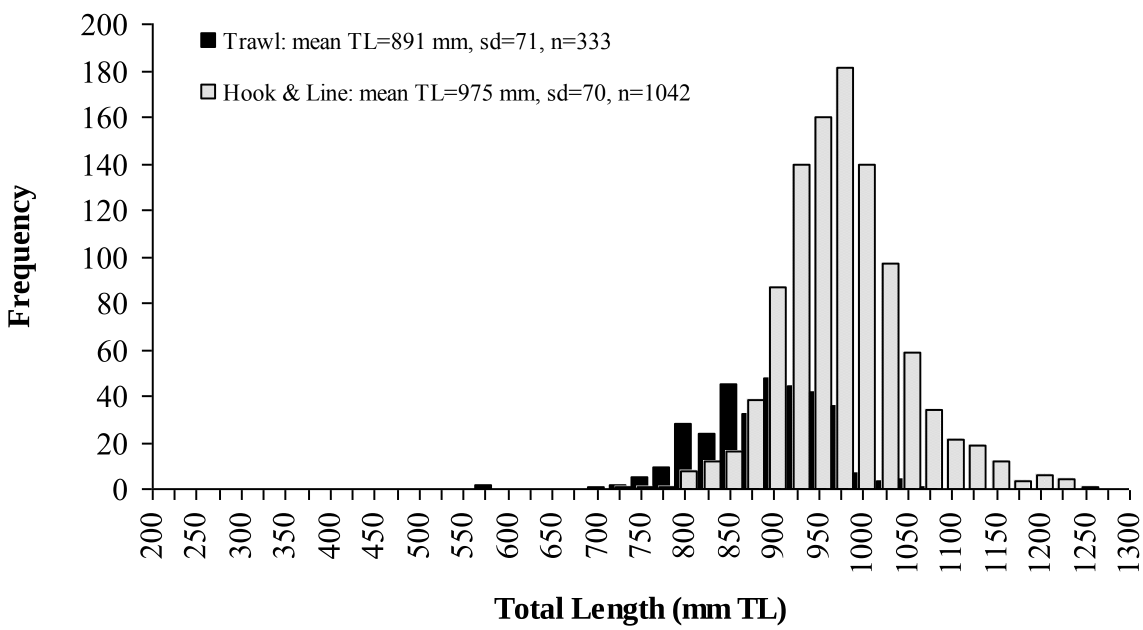


Figure 3. Length frequencies of striped bass tagged during the two components (trawl and hook and line) of the cooperative offshore tagging cruise, January 2015.



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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Ryan P. Hastings

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 5A were to quantify the commercial striped bass harvest in 2014 and describe the harvest monitoring conducted by the Maryland Department of Natural Resources (MD DNR). MD DNR changed the organization of its commercial quota system from a seasonal to a calendar year system in 1999. Maryland completed its twenty-fifth year of commercial fishing under the quota system since the striped bass fishing moratorium was lifted in 1990. The commercial fishery received 42.5% of the state's total Chesapeake Bay striped bass quota. The official 2014 commercial quota for the Chesapeake Bay and its tributaries was 1,925,421 pounds, an increase of 12% relative to 2013, with an 18 to 36 inch total length (TL) slot limit. There was a separate quota of 126,396 pounds, with a 24-inch (TL) minimum size for the state's jurisdictional waters off the Atlantic coast (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 2014 commercial fishery operated on a combination of a Common Pool and the ITQ system, with 96% of the quota in the ITQ system. ITQ participants were assigned a share of the commercial quota based partly on their harvest history. Individuals on the ITQ system were allocated a harvest for the year and could fish any open season and gear. A portion of the total commercial quota was reserved for commercial fishermen who opted to remain in the old, derby-style management. The total Common Pool quota was assigned by combing individual allocation from participants. Individuals in the Common Pool system were only allowed to fish set days during the season, and had a maximum allowable catch per day and week. Fishermen in the Common Pool system were allowed to use 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 2014 ITQ commercial summer/fall fishery (pound net, hook-and-line, and haul seine) was open from June 1 through December 31. The season typically runs from June 1 to November 30, but was extended to allow fishermen the opportunity to catch their entire quota. The hook-and-line Common Pool fishery was open four days in June, two days in July, four days in August, five days in September, seven days in October, and three days in November. The Chesapeake Bay 2014 ITQ drift gill net season was split, with the first segment from January 1 through February 28, 2014 and the second segment from December 2 through December 31, 2014, Monday through Friday. The gill net Common Pool fishery was open six days in January, five days in February, and eight days in December. The Atlantic coast fishery consisted of two gear types, drift gill net and trawl. Both gear types were permitted during the Atlantic season, which occurred in two segments: January 1 through April 30, 2014 and November 1 through December 31, 2014, Monday through 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) for striped bass fishermen were analyzed with the primary objective of presenting a post-moratoria summary of baseline data on commercial catch and CPUE.

METHODS

Beginning in July 2008, commercial finfish license holders were notified by MD DNR that participation in the striped bass fishery required a declaration of intent to fish using a specified legal gear. In 2014, license holders were instead required to declare their intent to participate in the striped bass ITQ or Common Pool system. The period of August 1-31 was established for receipt of declaration; this process is repeated for every year in which the license holder intends to fish. ITQ participants may transfer their permits and quota to other fishermen, or receive transfers, at any time during the fishing season.

MD DNR charged a fee to participants based upon the type of license held. Participants who held an Unlimited Tidal Fishing License (TFL) were required to pay $300. Participants who held an Unlimited Finfish Harvester License (FIN) were required to pay $150 and the Hook-and-Line Only License (HLI) were required to pay $100. Participants were also required to purchase a striped bass permit in addition to their license; TFL holders were required to pay $150, FIN and HLI holders were required to pay $200. Starting in August 2013, all commercial watermen are required to pay a $215 Harvester's Registration fee (Chris Jones, Pers. Comm).

All commercially harvested striped bass were required to be tagged by the 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 by gear or fishery type through multiple of the following systems: 1) Daily phone reports from check stations operated by volunteers holding fish dealer licenses; 2) daily reporting from the Atlantic Coastal Cooperative Statistics Program's (ACCSP) Standard Atlantic Fisheries

Information System (SAFIS); 3) weekly written log reports form designated check stations (Figures 2 and 3). These reports allowed MD DNR to monitor the fisheries' daily reported progress towards their respective quotas. Check stations were required to keep daily written logs detailing the activity of each fisherman, which were returned weekly by mail to MD DNR. Individual fishermen were then required to return their striped bass permit and unused tags to MD DNR at the end of the season.

In addition, individual fishermen were required to report their striped bass harvest on a monthly fishing report (MFR). MFRs were required to be returned by the 10th of the following month on a monthly basis, regardless of fishing activity. Fishermen who did not return a MFR were considered late. The names of those individuals with late reports appeared on the "Late Reports" list on the MD DNR commercial fisheries website. If the report was still not received by MD DNR 50 days after the due date, the licensee received an official violation. Two or more official violations in a 12 month period may result in a license suspension. The following information was compiled from each commercial fisherman's MFR: 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 the MD DNR Fisheries Service. 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 have more timely data, the pounds landed have come from the daily check station telephone reports, online SAFIS reports, and the weekly check station log sheets. However, all three 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.

RESULTS AND DISCUSSION

On the Chesapeake Bay and its tributaries, 1,805,698 pounds of striped bass were harvested in 2014; 119,723 pounds under the official 2014 quota. The estimated number of fish landed was 400,192 (Table 2). The Chesapeake drift gill net fishery landed 51% of the total landings by weight, followed by the pound net fishery at 37%. The hook-and-line fishery accounted for 12% of the total Bay landings.

Maryland's Atlantic coast landings were estimated at 8,481 striped bass, weighing 120,923 pounds (Table 2). The trawl fishery made up 81% of the Atlantic harvest, by weight, with the remainder from the gill net fishery.

Comparisons of Average Weight

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 did not allow biologists to descern what gear types were used to harvest striped bass sampled at check stations. Therefore, striped bass measured and weighed by biologists at check stations are combined into seasons (Summer/Fall, Winter, Atlantic).

The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 4.51 pounds when calculated from the check station log sheets and 5.73 pounds when measured by biologists (Table 3). Mean weights by specific gear type ranged from 3.58 to 5.61 pounds from check station log sheets, and were 4.08 to 6.82 pounds when measured by biologists. By either method of estimation, the largest striped bass landed in the Chesapeake Bay were taken by the drift gill net fishery. The smallest fish harvested in the Bay were taken by pound nets, with an average weight of 3.58 pounds, according to check station log sheets. No commercial fishermen participated in the haul seine fishery for the 2014 season.

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 11.33 pounds (Table 3). The average weight calculated from the check station log sheets was 14.26 pounds. Fish caught in the Atlantic trawl fishery averaged 10.70 pounds according to MD DNR check station survey estimates, and were smaller on average than those caught in the gill net fishery (14.49 pounds). The average weights of fish from the Atlantic trawl and gill net fisheries, as calculated from check station log sheets, were 14.92 and 11.93 pounds, respectively. The disparity between average weight estimates of Atlantic fish is likely due to the small sample size (n=160) collected during check station surveys. Only 27 of the 160 fish measured by biologists were caught by gill nets, further complicating comparisons.

<u>Commercial Harvest Trends</u>

Commercial striped bass harvests and quotas 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 but occasionally exceeds pound net harvest (Table 4, Figure 5).

Similar to the Chesapeake Bay fisheries, the Atlantic harvest increased in the early 1990's after the moratorium was lifted, but has been variable since 2000 (Figure 6). The Atlantic fishery has not reached its quota since 2009 (Figure 4). In almost all years since 1990, the Atlantic trawl fishery harvest has been greater than the Atlantic drift gill net harvest (Table 4, Figure 6).

<u>Commercial CPUE Trends</u>

Weight harvested by year and gear type was taken from check station log sheets. The number of fishing trips in which striped bass were landed was determined from the MFRs (Table 2). The pounds landed were divided by the number of trips to calculate an estimate of CPUE.

Chesapeake Bay gill nets and pound net fisheries experienced an increase in CPUE relative to 2013. The hook and line fishery was the only fishery to decrease in CPUE relative to 2013. The Chesapeake Bay drift gill net fishery had the highest CPUE of the Bay fisheries at 503 pounds per trip. Pound net CPUE ranked second at 367 pounds per trip. Consistent with historic trends, the hook-and-line fishery CPUE of 165 pounds per trip was the lowest of all Bay gear types (Table 5, Figure 7).

The Atlantic trawl fishery CPUE decreased from the highest value in the time-series in 2013 to 1,295 pounds per trip. The Atlantic gill net fishery CPUE was 221 pounds per trip, an increase from the 2013 CPUE of 190 (Table 5, Figure 8).

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Table 1. Striped bass commercial regulations by gear type for the 2014 calendar year.

<table>
<tr><th>Area</th><th>Gear Type</th><th>Annual Quota (pounds)</th><th>Number of Participants</th><th>Trip Limit</th><th>Minimum Size</th><th>Reporting Requirement</th></tr>
<tr><td rowspan="4">Bay and Tributaries</td><td>Pound Net</td><td>No gear-specific quotas for ITQ</td><td>172</td><td>No trip limits for ITQ; 8 Nets/license</td><td>18-36 in TL slot</td><td>Daily check station reports and monthly harvest report</td></tr>
<tr><td>Haul Seine</td><td>No gear-specific quotas for ITQ</td><td>0</td><td>No trip limits for ITQ</td><td>18-36 in TL slot</td><td>Daily check station reports and monthly harvest report</td></tr>
<tr><td>Hook-and-Line</td><td>Common Pool 30,740; No gear-specific quotas for ITQ</td><td>226 Total; 186 ITQ, 40 Common Pool</td><td>Common Pool – 300lbs/license/week, 600 lbs/vessel/day; No trip limits for ITQ</td><td>18-36 in TL slot</td><td>Daily check station reports and monthly harvest report</td></tr>
<tr><td>Gill Net</td><td>Common Pool 46,111; No gear-specific quotas for ITQ</td><td>324 Total; 285 ITQ, 39 Common Pool</td><td>Common Pool – 300lbs/license/week, 1,200lbs/vessel/day; No trip limits for ITQ</td><td>18-36 in TL slot</td><td>Daily check station reports and monthly harvest report</td></tr>
<tr><td colspan="2">Total Bay Quota</td><td>1,925,421</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Atlantic Coast</td><td>Atlantic Trawl</td><td>126,396</td><td rowspan="2">56</td><td rowspan="2">1,700 lbs/licensee/season</td><td rowspan="2">24 in TL min</td><td rowspan="2">Daily check station reports and monthly harvest report</td></tr>
<tr><td>Atlantic Gill Net</td><td>included in Trawl</td></tr>
<tr><td colspan="2">Total Maryland Quota</td><td>2,051,817</td><td colspan="4"></td></tr>
</table>

Table 2. Summary of striped bass commercial harvest statistics by gear type for the 2014 calendar year.

Area	Gear Type	Pounds[1]	Number of Fish[1]	Trips[2]
Chesapeake Bay[3]	Haul Seine	0	0	0
	Pound Net	664,508	185,387	1,813
	Hook-and-Line	218,987	50,454	1,327
	Gill Net	922,203	164,351	1,835
	Chesapeake Total Harvest	**1,805,698**	**400,192**	**4,975**
Atlantic Coast	Trawl	98,408	6,594	76
	Gill Net	22,515	1,887	102
	Atlantic Total Harvest	**120,923**	**8,481**	**178**
Maryland Totals		**1,926,621**	**408,673**	**5,153**

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 2014 calendar year. Average weights calculated by MD DNR biologists include 95% confidence intervals.

<table>
<tr><th>Area</th><th>Gear Type</th><th>Average Weight from Check Station Logs (pounds)[1]</th><th>Average Weight from Biological Sampling (pounds)[2]</th><th>Sample Size from Biological Sampling[2]</th></tr>
<tr><td rowspan="5">Chesapeake Bay[3]</td><td>Haul Seine</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Pound Net</td><td>3.58</td><td rowspan="2">4.08 (3.98-4.18)</td><td rowspan="2">2,311</td></tr>
<tr><td>Hook and Line</td><td>4.34</td></tr>
<tr><td>Gill Net</td><td>5.61</td><td>6.82 (6.73-6.91)</td><td>3,470</td></tr>
<tr><td>Chesapeake Total Harvest</td><td>4.51</td><td>5.73 (5.66-5.80)</td><td>5,781</td></tr>
<tr><td rowspan="3">Atlantic Coast</td><td>Trawl</td><td>14.92</td><td>10.70 (9.52-11.88)</td><td>133</td></tr>
<tr><td>Gill Net</td><td>11.93</td><td>14.49 (11.95-17.02)</td><td>27</td></tr>
<tr><td>Atlantic Total Harvest</td><td>14.26</td><td>11.33 (10.26-12.42)</td><td>160</td></tr>
</table>

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 2014.

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

Table 5. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2014.

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
23 yr avg	**152**	**258**	**268**	**195**	**630**
5 yr avg	**193**	**366**	**427**	**192**	**885**

Figure 1. Map of the 2014 Maryland authorized commercial striped bass check stations.

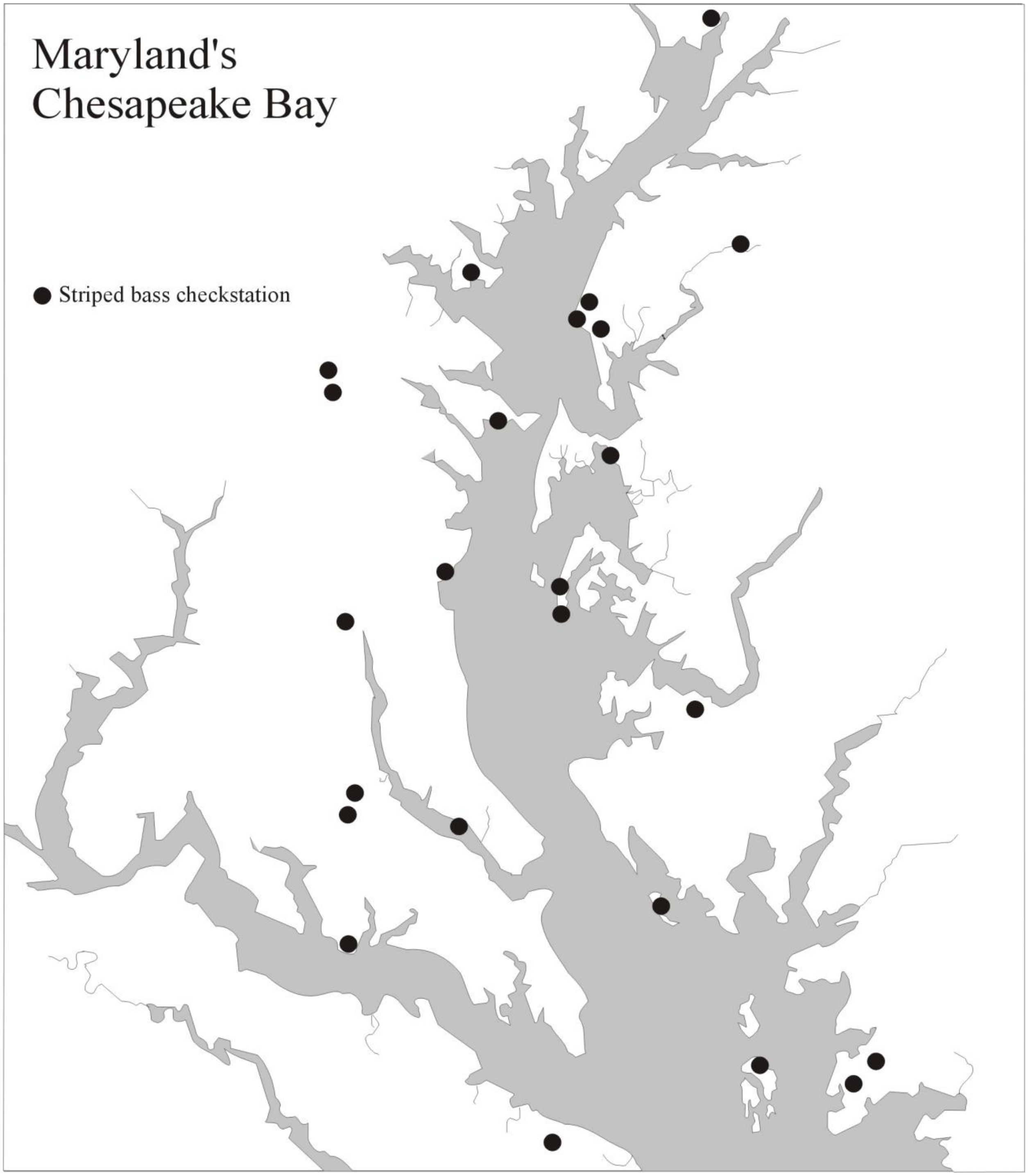


Figure 2. Maryland's Chesapeake Bay summer/fall (pound net and hook-and-line) fisheries cumulative striped bass landings from check stations reports, June-December 2014.

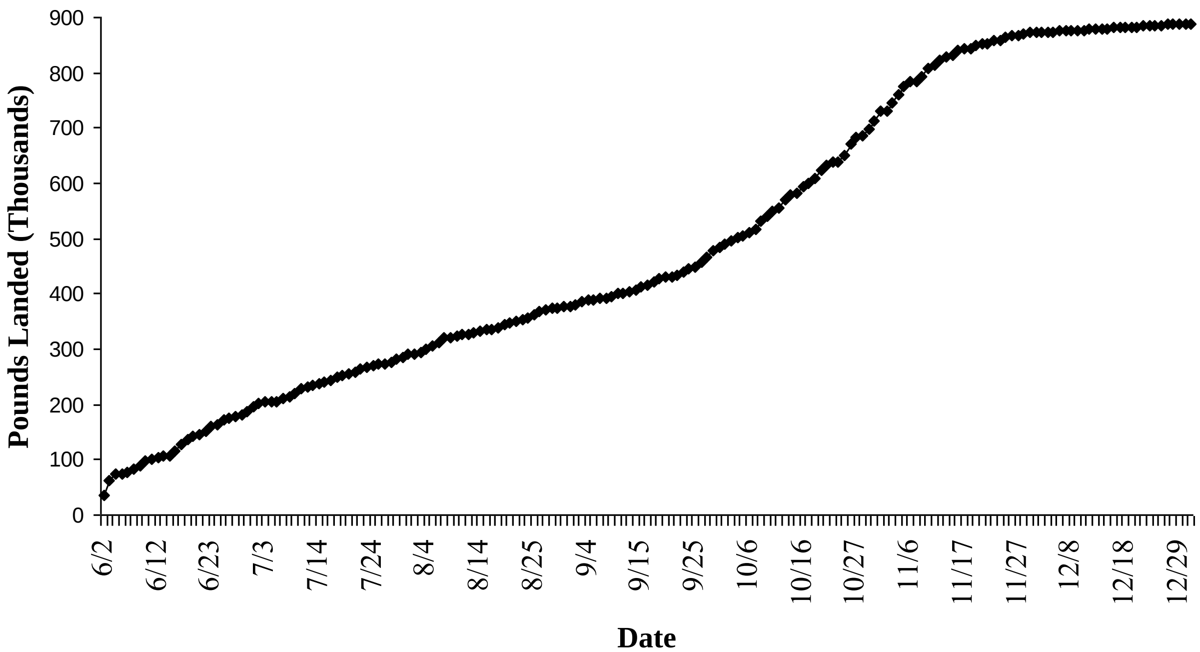
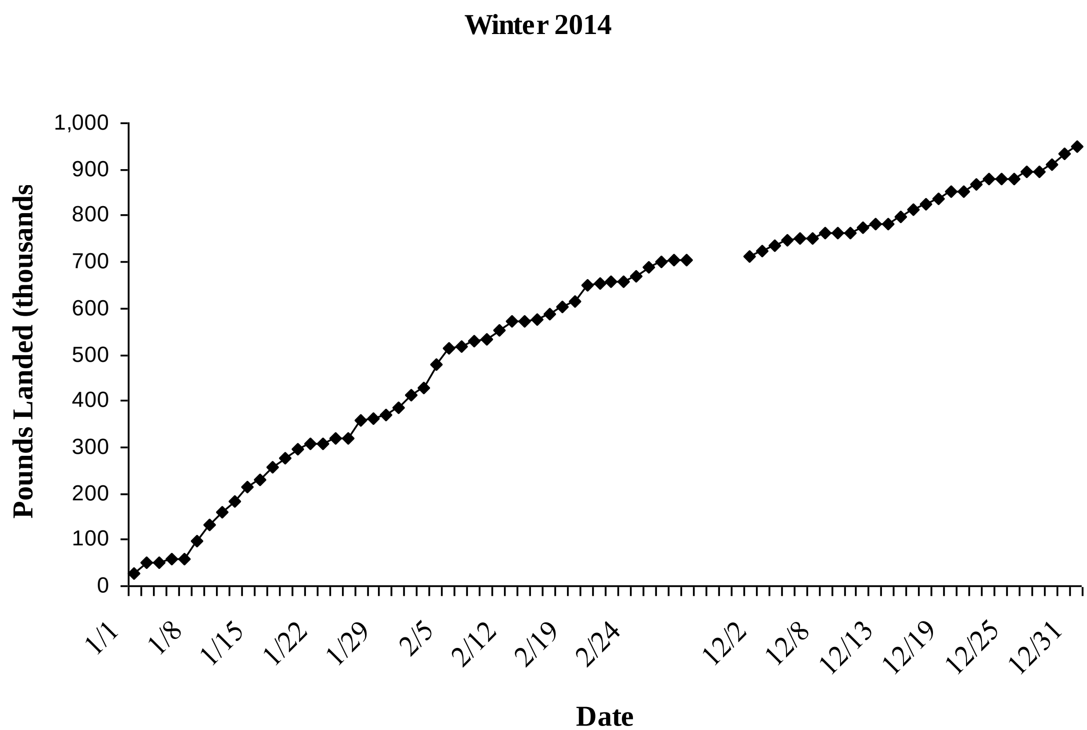


Figure 3. Maryland's Chesapeake Bay winter (gill net) and the Atlantic trawl and gill net fisheries (combined) cumulative striped bass landings from check stations reports, January-December 2014. Note different scales.



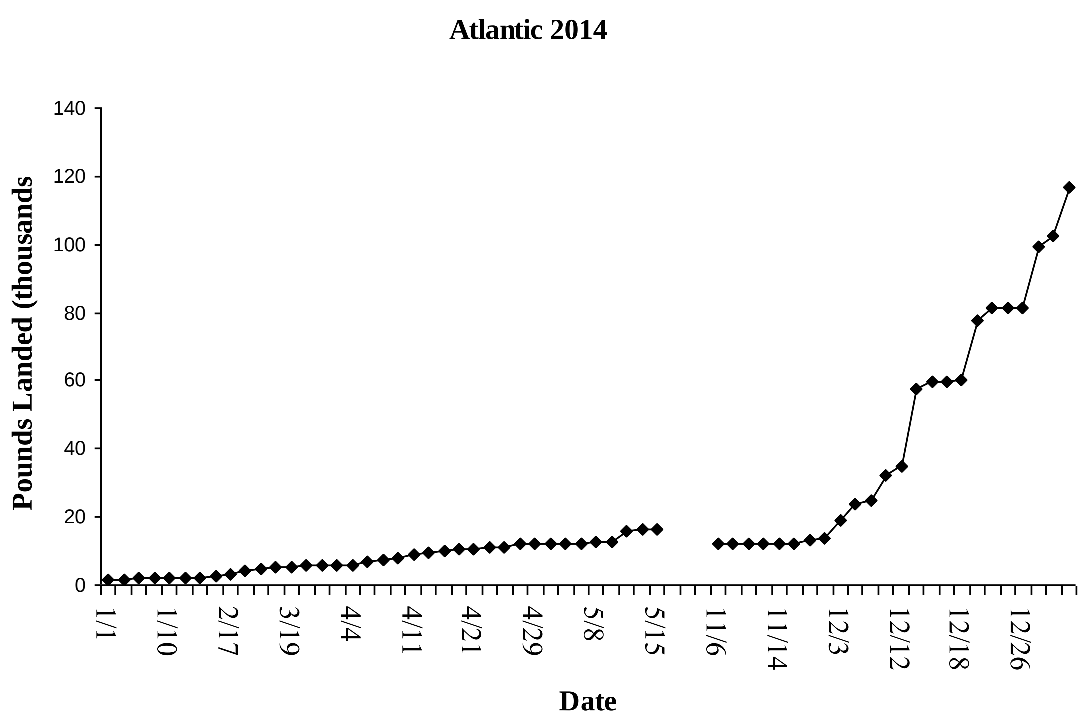
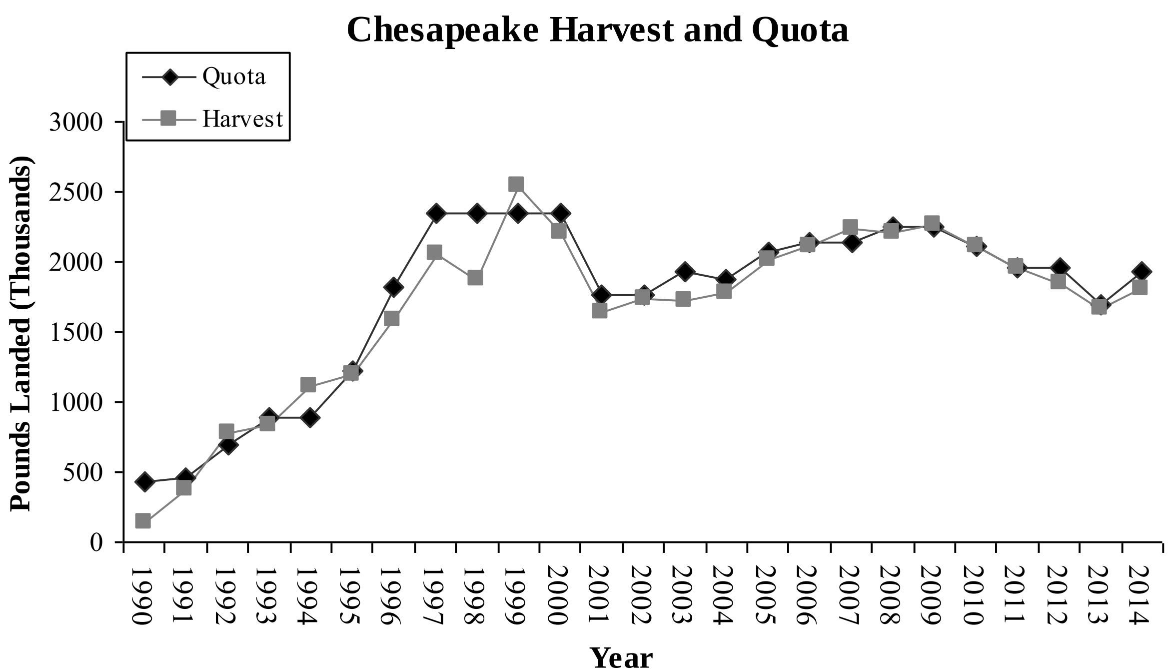


Figure 4. Maryland's Chesapeake Bay and Atlantic Ocean harvests (lbs) and quotas (lbs) for all gears, 1990-2014. Note different scales.



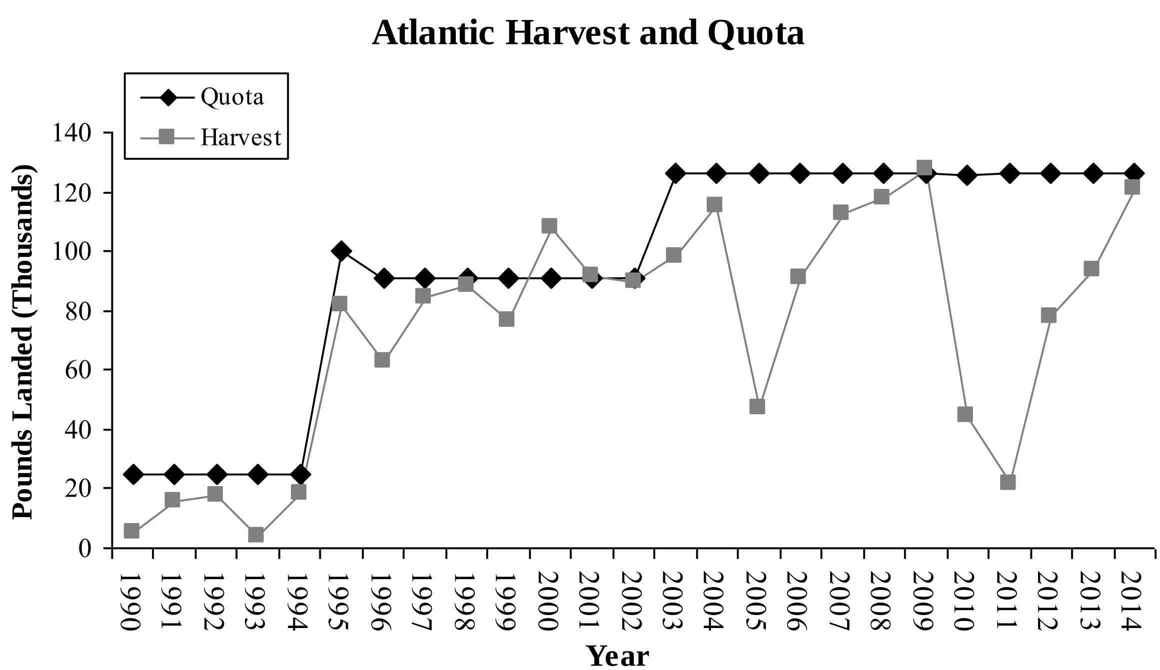


Figure 5. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2014.

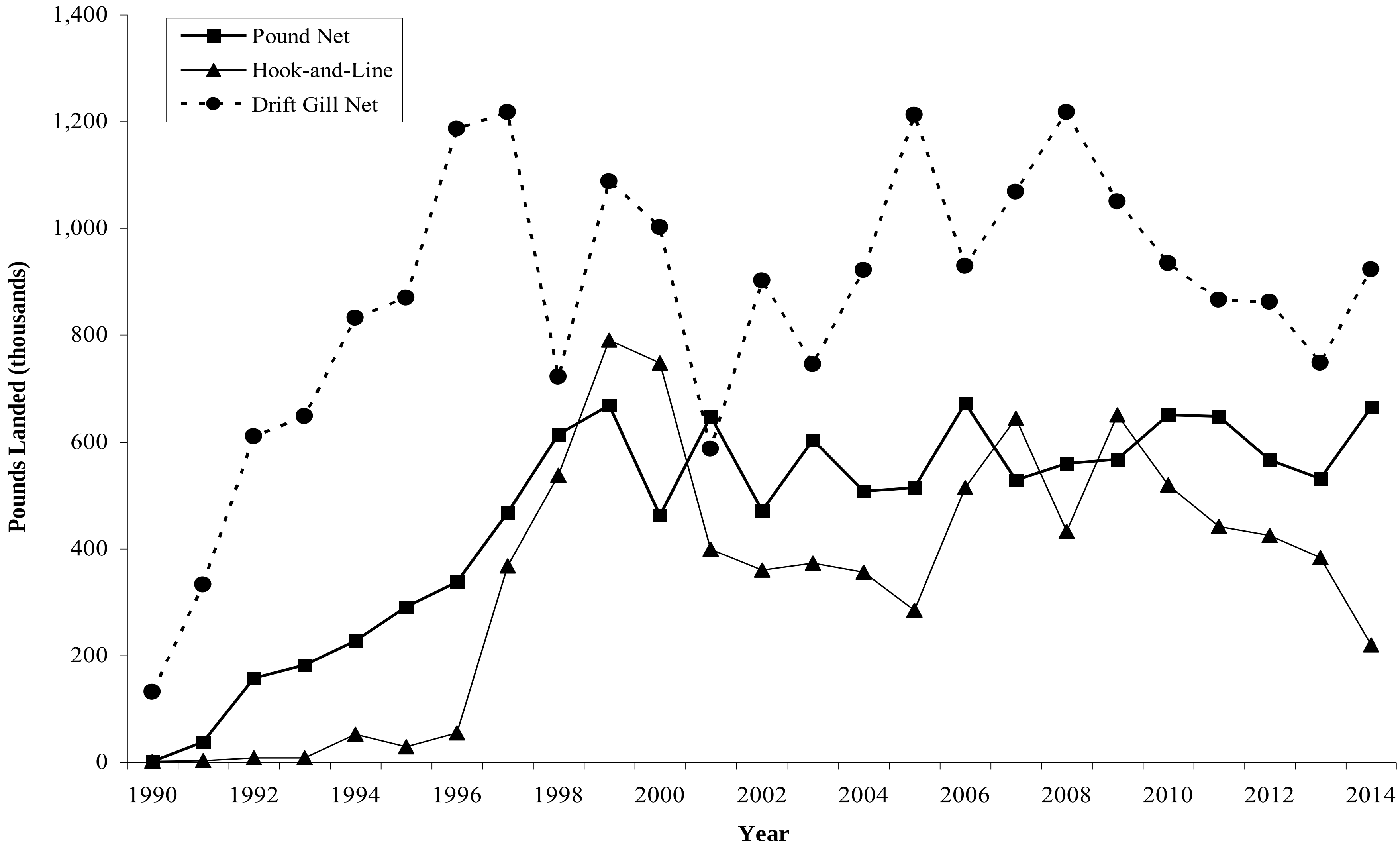


Figure 6. Maryland's Atlantic gill net and trawl fisheries total striped bass harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2014.

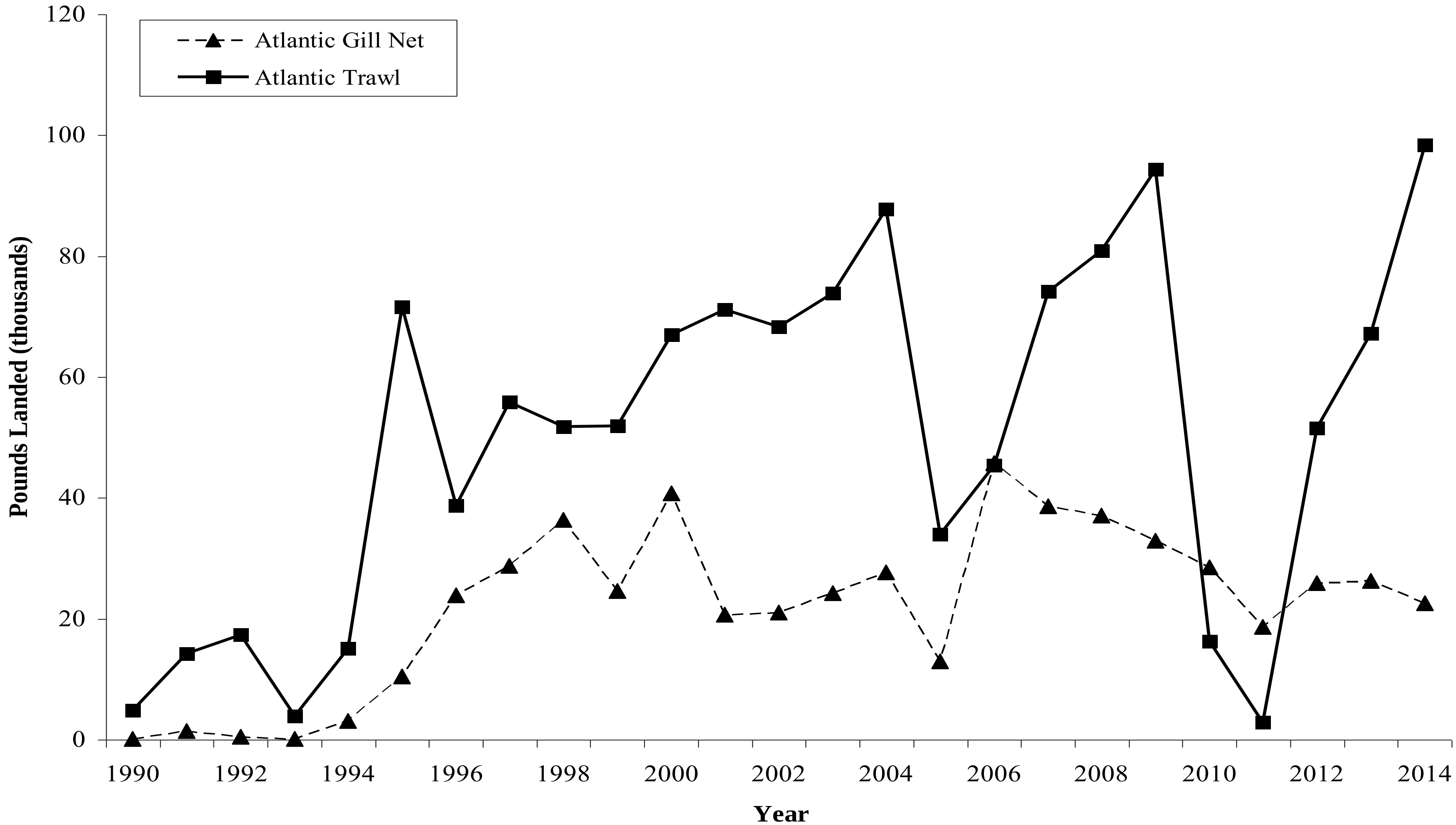


Figure 7. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990-2014. Trips were defined as days fished when striped bass catch was reported.

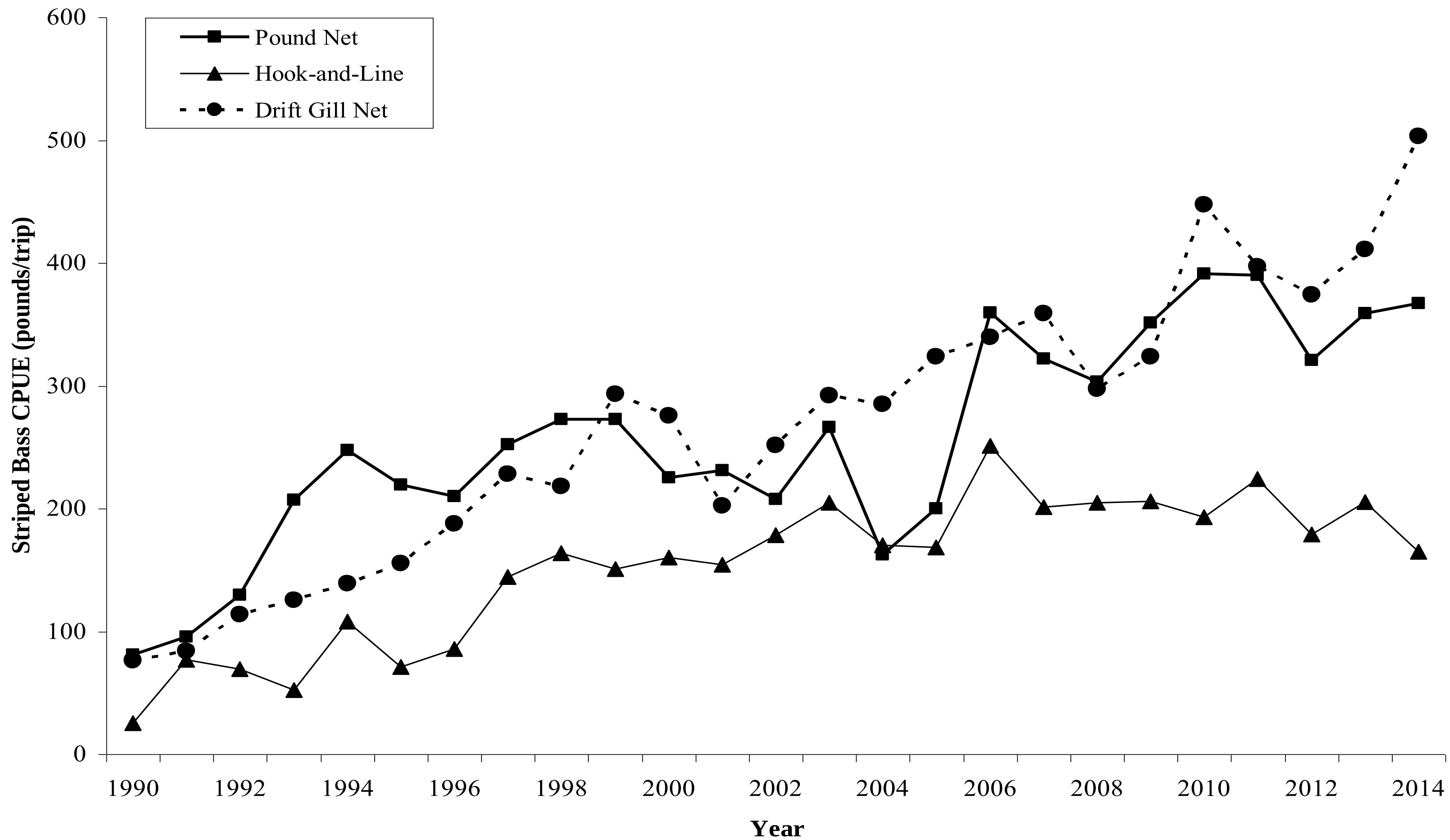
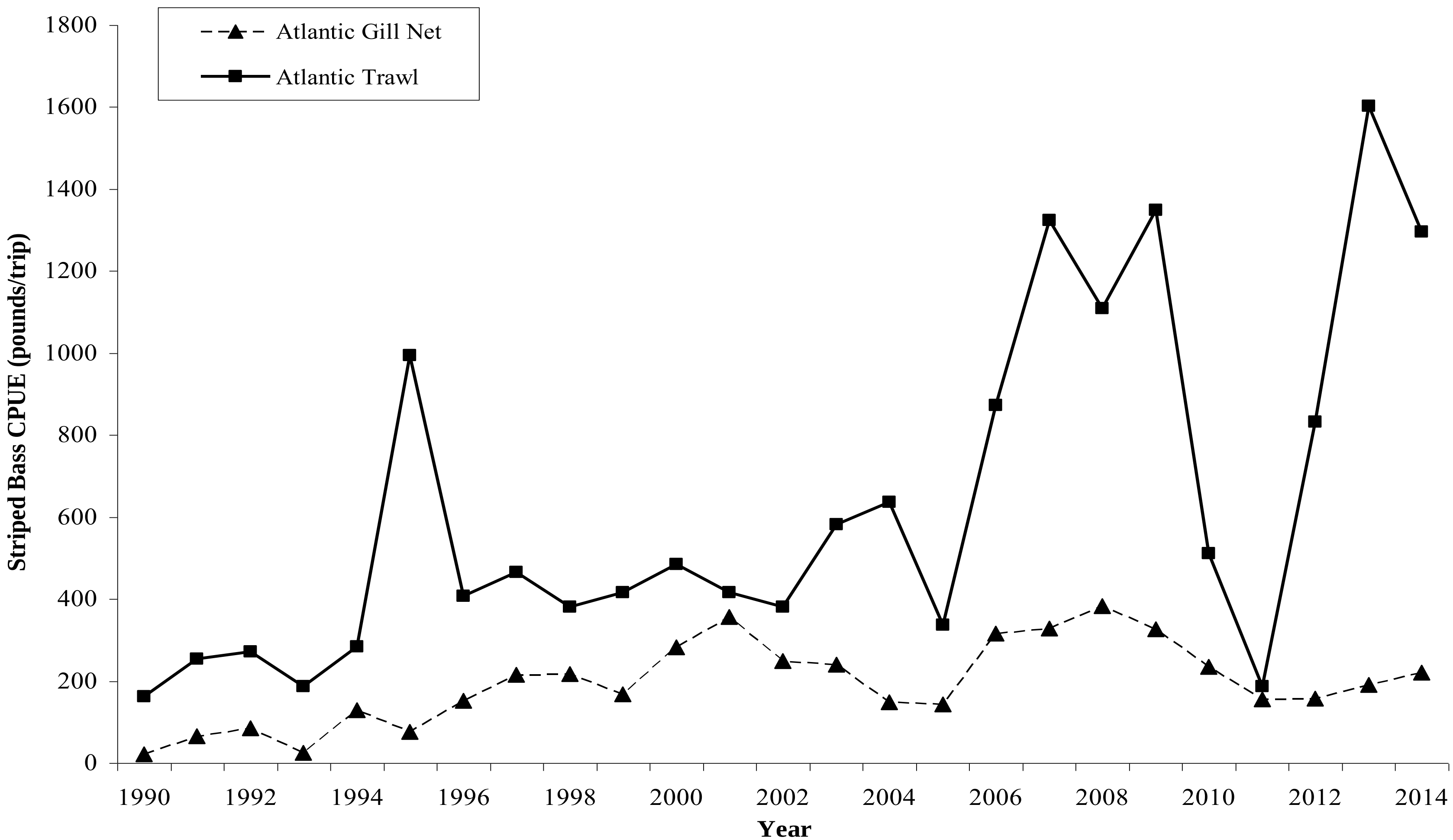


Figure 8. Maryland's Atlantic gill net and trawl fisheries striped bass catch (pounds) per trip (CPUE), 1990-2014. Trips were defined as days fished when striped bass catch was reported.



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 2015 spring recreational season, which began on Saturday, April 18 and continued through May 15. The secondary objective was to conduct a dockside creel survey to characterize the angler population. Data collected includes catch and demographic information.

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). 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. Estimates of the Maryland and Virginia spring harvest of coastal migrant striped bass in Chesapeake Bay through June 15th are reported annually by Maryland Department of Natural Resources (MD DNR) to Atlantic States Marine Fisheries Commission (ASMFC) in the Spring Migrant Harvest Report (Appendix I). 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 2015 spring season was 28 days long (April 18 – May 15), with a one fish (≥28 inches with a no-take slot between >36 and <40 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 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 five major charter fishing ports in 2015: Solomons Island/Calvert Marina, Solomons Island/Bunky's Charter Boats, Kentmorr Marina, Chesapeake Beach/Rod & Reel, and Deale/Happy Harbor (Table 2A). 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 to allow staff more time to survey private boat anglers. 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 catch rates could be calculated.

A separate creel survey was conducted at public boat ramps to specifically target private boat and shore anglers. Access sites were randomly selected from a list of five public boat ramps (Table 2B). Sites were categorized as high- or medium-use based on the experiences of creel interviewers in previous years. High- and medium-use sites were given relative weights of 2:1 for a probability-based random draw. Low-use sites have not been sampled since 2008. Public boat ramps were visited on one randomly selected weekday and one randomly selected weekend day per week. Interviewers were stationed at two sites per selected day and they remained on-site from 10:00 AM–3:00 PM or until 20 trips were intercepted, whichever came first. If no boat trailers were present and no shore anglers were encountered within 2.5 hours, the sampling day was concluded and the site was characterized as having no fishing activity. Private boat and shore anglers were only interviewed after their trip was completed.

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 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 2015, 183 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 in order to update the female maturity schedule used in the coastwide 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. Sample collection for this study continued in 2015.

Scales, otoliths, and ovaries were collected from female fish sampled on the creel survey. Both ovaries were removed and weighed to the nearest gram. One of the ovaries was randomly selected for fixation in 10% buffered formalin. Once fixed, a 4 mm cross-section from the center of the ovary was sectioned and placed in labeled tissue cassettes. The cassettes were placed in 70% ethanol for storage until taken for histological preparation. In addition, an approximately 5 cm section of ovary was placed in 70% ethanol for later fecundity analysis. All females used in the maturity study were aged using scales, and otoliths were collected, where possible, for later age validation. This is a multi-year study, and while the scale ages were included in the combined spring age-length key, the maturity and fecundity results are not available at this time.

Beginning in 2014, spleen samples were collected during the creel survey for mycobacteriosis monitoring and prevalence studies conducted and independently reported by the Cooperative Oxford Laboratory. Spleens were collected from striped bass 28 inches TL and greater that are considered part of the Atlantic coastal migratory population. Spleens were fixed in 10% buffered formalin. Once fixed, six randomly selected 4 mm cross-sections of the spleen were placed in labeled tissue cassettes. The cassettes were placed in 70% ethanol for storage until taken for histological preparation.

Calculation of Harvest and Catch Rates

Survey personnel interviewed private boat and shore anglers to obtain information from which to develop estimates of Harvest Per Trip (HPT), Harvest Per Angler (HPA), Catch Per Trip (CPT), and Catch Per Hour (CPH) (Table 4). The interview questions are provided in Appendix II. HPT was defined as the number of fish kept (harvested) for each trip. HPA was calculated by dividing the number of fish harvested on a trip by the number of anglers in the fishing party. CPT was defined as number of fish kept (harvest), plus number of fish released, for each trip. CPH was calculated by dividing the total catch by the number of hours fished for each trip.

HPT, HPA and CPT were also calculated from charter boat logbook data (Downloaded 10/28/2015). 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 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 by 2015 comprised 48% 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 2015, 15% of the charter data was excluded.

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 number of private and charter boats intercepted, number of anglers interviewed, and number of striped bass examined each year are presented in Table 5A. In 2015, there were 546 anglers interviewed comprised of anglers intercepted from 201 private boats trips, 2 charter boat trips, and 3 shore trips (Table 5A,B). A total of 177 fish were sampled from 55 intercepted charter trips. Fishing activity during the spring season was highest in the middle bay, specifically the region between the Chesapeake Bay Bridge and the mouth of the Patuxent River.

BIOLOGICAL DATA

Length and Weight

Length distribution

In the 2015 spring striped bass season, measured fish lengths ranged from 715 mm TL to 1223 mm TL with a mean of 935 mm TL (n=177, Table 6A). Although a no-take slot limit was established for the 2015 spring striped bass season between 36 inches (914 mm) and 40 inches (1016 mm) TL, 55 of the fish measured (31%) were within this range. The length distribution of harvested fish was still largely dictated by the slot limit and generated a bimodal distribution around each edge of the slot limit at the 900-919 mm TL and 1000-1019 mm TL length groups (Figure 2).

Mean length

The mean length of females (952 mm TL) was greater than the mean length of males (859 mm TL), which is typical of the biology of the species. For males, the mean length in 2015 was only ~1% greater than the long-term mean (848 mm TL). The ANOVAs indicated significant differences in mean length among years for females ($p<0.0001$) but not for males ($p>0.05$). Duncan's multiple range test for females ($\alpha=0.05$) found that the mean length for female fish in 2015 (952 mm TL) was significantly different than all other years in the time series except 2014 (Table 6A, Figure 3). Thus, 2014 and 2015 contain the largest female fish on average in the time series.

The mean daily lengths of female striped bass harvested in 2015 showed no trend as the season progressed (Figure 4). This is in contrast to mean daily length data for 2002 and 2011 and other studies, when larger females were caught earlier in the season (Goshorn et al.1992, Barker et al. 2003).

Data collected 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 2015, anglers reported lengths for 86 striped bass caught during the trophy season. The mean reported length of fish released was 752 mm TL (n=64). The mean reported length of striped bass harvested was 873 mm TL (n=22) which is below the mean length from the creel survey (935 mm TL, 921-949 95% CIs). This suggests that private anglers may be harvesting proportionally more smaller-sized striped bass than charter boat anglers.

Mean weight

Fish weights sampled during the 2015 spring striped bass season ranged from 3.6 kg to 19.5 kg. The mean weight of striped bass has generally increased over time from a mean of 7.3

kg in 2002 to a maximum of 9.1 kg in 2014 (Table 6B). The mean weight in 2015 of 8.6 kg (n=175) was the second highest in the time series behind the previous year.

The mean weight of females (9.1 kg) was greater than the mean weight of males (6.5 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). Mirroring mean length above, the ANOVAs indicated significant differences in mean weight among years for females ($p<0.0001$) but not for males ($p>0.05$). Duncan's multiple range test ($\alpha = 0.05$) found that the mean weight of female fish sampled in 2015 (9.1 kg) was not significantly different from 2014 but was significantly greater than all other years (Table 6B, Figure 5). The mean weight of males (6.5 kg) in 2015 was nominally larger than the long-term mean (6.1 kg).

<u>Age Structure</u>

The age distribution estimated from the combined age-length key applied to lengths of striped bass sampled from the 2015 spring recreational harvest ranged from 6 to 17 years old (Figure 6). The 2003 (12 years old), 2004 (11 years old) and 2005 (10 years old) year-classes were the most frequently observed cohorts, constituting 27%, 20%, and 26% of the of the sampled harvest, respectively. The harvest of the strong 2003 year class which has dominated the age distribution of the spring recreational harvest since 2012 was likely suppressed by the slot limit which mainly affects the harvest of fish aged 9 to 12 years old. The record 1996 year-class (19 years old in 2015), which dominated catches in 2005, 2006, and 2008, has now disappeared completely from the sampled harvest.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2015 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 affect the proportion of females in the sampled harvest as there was only a single fish of unknown sex in 2015. Females constituted 81% of the sampled harvest. This is lower than the previous year (92%), but close to the long-term average (84%).

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. Data from the 2015 creel survey indicated that 24% of the females caught between April 18 and May 15 were in pre-spawn condition (Table 8). This percentage is the lowest in the time series but similar to 2008, 2010, and 2012-2013. The low percentage of pre-spawn females indicates that most fish harvested had already spawned.

Daily spawning condition of females

The percent of post-spawn females ranged from 18% in the first sampling event of the spring season (April 24th) to 100% by the last day of the season (Figure 7). No fish were encountered by biologists at charter docks in the first week of the spring season. The percent of post spawn females sampled increased rapidly so that by the third week of the season over 80% of harvested females sampled had spawned. Although the percent of post-spawn fish sampled appears to drop on May 1st, there were only three fish sampled on this date. This pattern suggests that most female fish harvested in the spring season in 2015 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 2015. Because of increased focus on improving our understanding of private boat fishing effort, all but two of the trips intercepted during the trophy season in 2015 for interviews were private boat and shore trips. Creel survey interview data were used to obtain harvest rate estimates for private vessels. 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 new regulations implemented in 2015 to reduce harvest, HPT was expected to be lower as compared to recent years. Although the number of reported charter boat trips was only down by 6% from the previous year, the mean HPT in 2015 according to charter boat data was 2.8 fish per trip (Table 9A) which was 43% below the long term mean charter boat HPT (4.9 fish per trip) and the lowest in the time series. Mean HPT from private boat interviews (0.2 fish per trip) was also the lowest in its time series and 80% below the long-term mean private boat HPT (1.0 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 in 2015 to achieve harvest reduction. HPA from charter boat data in 2015 was 0.45 fish per person (Table 9B) which was a 42% reduction from the long-term mean (0.77 fish per trip). HPA for private anglers, calculated from interview data, was 0.1 fish per person (Table 9B) which was a 75% reduction from the long-term mean (0.4 fish per trip).

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 2015, private boats caught an average of 0.7 fish per trip, lower than previous years but similar to 2012. Charter boats caught 6.0 fish per trip, similar to the previous year. The private boat catch per hour (CPH) was 0.17 fish per hour while charter boats had a CPH of 0.96 fish per hour. The 2015 private boat CPH was greatly reduced from previous years. The charter boat mean CPH was similar to the previous three years but lower than early years of the time-series, particularly 2003-2009.

Angler Characterization

States of residence

In 2015, 546 anglers were interviewed during the period April 19-May 15 (Table 5A). Nine states of residence were represented in 2015 (Table 11). Most anglers were from Maryland (88%), Virginia (5%), and Pennsylvania (4%), similar to previous years.

Proportion of License Exempt Anglers

Under current license regulations, a person can purchase a boat license which allows anyone aboard the boat to fish without purchasing an individual Maryland tidal fishing license. This creates a potentially significant, but indeterminate amount of unlicensed fishing effort. Consequently, a question was added to the dockside creel survey in 2008 to determine how many anglers on each boat were license-exempt by virtue of the boat license or other reason in order to determine the amount of license-exempt effort during the spring striped bass season. In 2015, there were on average 2.6 anglers per boat and of these anglers, 1.3 were license-exempt (Table 12). These results are consistent with previous years.

Number of Lines Fished

To further characterize fishing effort, a question was added to the creel survey in 2006 and 2010-2015 about the number of fishing lines used. In 2006, six lines were fished on average per private boat and the maximum number encountered on a boat was 15. In 2015, the average number of lines fished per private boat was 7.5 and ranged from 1 to 20 lines (Table 13). This was more lines, on average, than in 2006 (6 lines) but similar to more recent years.

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Table 1. History of changes made to MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2015.

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**	**1 per person, per day**	**Main stem Chesapeake Bay, Brewerton Channel-VA State line**

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2015. 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 2B. Survey sites for the Maryland striped bass spring angler-intercept survey, 2015.

Relative Use	Access Intercept Site
High	Sandy Pt. State Park Boat Ramp and Beach
	Solomons Island Boat Ramp
Medium	Matapeake Boat Ramp
	Breezy Point Fishing Center and Ramp
	Chesapeake Beach Boat Ramp

Table 3. Biological data collected by the Maryland striped bass spring season creel survey, 2015.

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 4. Angler and catch information collected by the Maryland striped bass spring season creel survey, 2015.

Angler and Catch Data Collected
Number of hours fished
Fishing type: private boat or shore
Number of anglers on boat
Area fished: upper, middle, lower
Number of lines fished
Number of fish kept
Number of fish released
Number of anglers license exempt
State of residence

Table 5A. Numbers of trips intercepted, anglers interviewed, and fish examined by the Maryland striped bass spring season creel survey, through May 15.

Year	Trips Intercepted	Anglers Interviewed	Fish Examined
2002	187	458	503
2003	181	332	478
2004	138	178	462
2005	54	93	275
2006	139	344	464
2007	542	809	301
2008	305	329	200
2009	303	747	216
2010	238	601	263
2011	362	824	234
2012	209	447	130
2013	207	456	182
2014	258	580	211
2015	261	546	177

Table 5B. Number of trips, by type (fishing mode), intercepted by the Maryland striped bass spring season creel survey, through May 15.

Year	Charter Boat	Private Boat	Shore	Not Specified	Total
2002	140	45	0	2	187
2003	114	65	0	2	181
2004	88	42	1	7	138
2005	53	1	0	0	54
2006	101	28	10	0	139
2007	50	483	9	0	542
2008	34	265	6	0	305
2009	27	275	1	0	303
2010	45	193	0	0	238
2011	63	299	0	0	362
2012	37	172	0	0	209
2013	35	169	3	0	207
2014	48	209	1	0	258
2015	57	201	3	0	261

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)
Mean	**903** (891-916)	**915** (903-928)	**848** (835-860)

Table 6B. Mean weights 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)
Mean	**7.7** (7.4-8.0)	**8.0** (7.7-8.4)	**6.1** (5.8-6.4)

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 (Assume U were Female)
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

Table 7B. Percent females, using three different calculation methods, sampled by the Maryland striped bass spring season creel survey, through May 15.

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
Mean	**82**	**84**	**84**

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.

	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
Mean	**106**	**42**	**130**	**58**

Table 9A. Mean harvest of striped bass per trip (HPT), with 95% confidence limits, calculated from Maryland charter boat logbook data and spring season creel survey interview data, through May 15. SAFIS data were combined with the charter logbook data from 2011 through the present.

Year	Charter Trips (n)	Charter Mean HPT	Private Creel Int. Trips (n)	Private Creel Int. Mean HPT
2002	1,424	**4.7** (4.6-4.8)	44	**1.1** (0.6-1.4)
2003	1,393	**5.7** (5.6-5.8)	64	**1.1** (0.7-1.4)
2004	1,591	**5.4** (5.3-5.5)	42	**2.2** (1.7-2.8)
2005	1,965	**5.5** (5.4-5.6)	1	N/A
2006	1,934	**5.3** (5.2-5.4)	28	**1.4** (0.6-2.1)
2007	1,607	**4.3** (4.2-4.4)	483	**0.7** (0.6-0.8)
2008	1,755	**4.9** (4.8-5.1)	260	**0.6** (0.5-0.7)
2009	1,849	**5.0** (4.9-5.1)	275	**0.9** (0.7-1.0)
2010	1,986	**4.8** (4.7-4.9)	193	**1.1** (0.9-1.3)
2011	1,849	**5.0** (4.9-5.1)	298	**0.9** (0.7-1.0)
2012	1,546	**4.2** (4.0-4.4)	172	**0.5** (0.3-0.6)
2013	1,822	**4.9** (4.8-5.1)	165	**0.9** (0.7-1.1)
2014	1,481	**5.5** (5.3-5.6)	207	**0.9** (0.8-1.1)
2015	1,392	**2.8** (2.7-3.0)	206	**0.2** (0.1-0.3)
Mean	1,685	**4.9** (4.5-5.2)	187	**1.0** (0.7-1.2)

Table 9B. Mean harvest of striped bass per angler, per trip (HPA), with 95% confidence limits, calculated from Maryland charter boat logbook data and spring season creel survey interview data, through May 15. SAFIS data were combined with the charter logbook data from 2011 through the present.

Year	Charter Trips (n)	Charter Mean HPA	Private Creel Int. Trips (n)	Private Creel Int. Mean HPA
2002	1,424	**0.78** (0.76-0.79)	43	**0.4** (0.3-0.6)
2003	1,393	**0.93** (0.92-0.94)	64	**0.4** (0.3-0.5)
2004	1,591	**0.88** (0.86-0.89)	42	**0.7** (0.5-0.8)
2005	1,965	**0.88** (0.87-0.89)	1	N/A
2006	1,934	**0.86** (0.87-0.85)	27	**0.5** (0.2-0.7)
2007	1,607	**0.69** (0.68-0.71)	483	**0.3** (0.2-0.3)
2008	1,755	**0.79** (0.78-0.81)	260	**0.2** (0.2-0.3)
2009	1,849	**0.81** (0.80-0.82)	275	**0.3** (0.3-0.4)
2010	1,986	**0.76** (0.75-0.77)	193	**0.4** (0.3-0.5)
2011	1,849	**0.78** (0.77-0.80)	298	**0.3** (0.3-0.3)
2012	1,546	**0.67** (0.64-0.71)	172	**0.2** (0.1-0.2)
2013	1,822	**0.75** (0.74-0.77)	165	**0.3** (0.3-0.4)
2014	1,481	**0.82** (0.81-0.84)	207	**0.3** (0.3-0.4)
2015	1,392	**0.45** (0.43-0.47)	206	**0.1** (0.0-0.1)
Mean	1,685	**0.77** (0.71-0.83)	187	**0.4** (0.3-0.4)

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, through May 15. Catch is defined as number of fish harvested plus number of fish released.

Year	n	Mean catch/trip	Mean hours/trip	Mean catch/hour
2002	41	**1.6** (0.9-2.4)	**4.9** (4.3-5.5)	**0.3** (0.2-0.5)
2003	63	**1.8** (0.9-2.8)	**5.4** (4.8-6.0)	**0.5** (0.2-0.7)
2004	42	**3.5** (2.0-4.9)	**4.6** (3.8-5.3)	**1.0** (0.6-1.4)
2005	1	**0.0**	**2.5**	**0.0**
2006	28	**2.3** (1.1-3.5)	**4.9** (4.2-5.7)	**0.7** (0.3-1.1)
2007	483	**1.6** (1.2-2.0)	**5.0** (4.9-5.1)	**0.3** (0.2-0.4)
2008	260	**1.0** (0.7-1.3)	**4.5** (4.2-4.7)	**0.3** (0.2-0.4)
2009	275	**1.6** (1.0-2.1)	**4.7** (4.5-4.8)	**0.4** (0.2-0.5)
2010	193	**1.6** (1.2-2.0)	**4.7** (4.5-4.9)	**0.4** (0.3-0.5)
2011	298	**1.2** (1.0-1.4)	**4.4** (4.2-4.6)	**0.3** (0.2-0.4)
2012	172	**0.8** (0.5-1.1)	**4.8** (4.6-5.1)	**0.2** (0.1-0.3)
2013	165	**1.3** (1.0-1.7)	**4.4** (4.2-4.7)	**0.3** (0.2-0.4)
2014	207	**1.2** (1.0-1.4)	**4.7** (4.4-4.9)	**0.3** (0.2-0.4)
2015*	205	**0.7** (0.5-1.0)	**6.3** (4.7-9.5)	**0.2** (0.1-0.2)
Mean	187	**1.5** (1.2-1.9)	**4.9** (4.6-5.2)	**0.4** (0.3-0.5)

*One extreme outlier trip with a catch of 53 fish was excluded from mean calculation.

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)	N/A	N/A
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)
Mean	1,685	**6.4** (5.9-6.9)	**4.5** (4.0-5.0)	**1.5** (1.3-1.7)

Table 11. State of residence and number of anglers interviewed by the Maryland striped bass spring season creel survey, through May 15.

State of residence	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AL	0	0	0	0	1	0	0	0	0	0	0	1	0	0
AZ	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CA	1	0	1	0	0	2	0	0	0	0	0	0	0	1
CO	0	0	1	0	1	1	0	0	1	0	1	0	0	0
DC	6	1	1	0	1	2	1	0	6	1	0	1	0	0
DE	6	7	3	0	9	8	1	0	3	1	2	0	5	2
FL	0	0	1	1	2	0	1	0	3	1	0	1	0	1
GA	1	1	0	2	2	0	0	0	0	0	0	0	0	0
IL	0	0	0	0	1	0	0	0	0	0	0	0	0	0
KY	0	1	0	0	0	0	0	0	1	0	0	0	0	1
KS	0	0	1	0	0	0	0	0	0	0	0	0	2	0
MA	0	1	1	0	0	0	0	1	1	0	0	0	0	0
MD	**353**	**260**	**107**	**66**	**227**	**679**	**266**	**651**	**482**	**491**	**381**	**407**	**484**	**483**
MI	1	0	0	0	1	1	0	0	0	0	0	0	0	0
MN	0	0	1	0	0	0	0	0	0	4	0	0	0	0
MT	0	0	0	0	0	0	0	1	2	0	0	0	0	0
NC	0	2	0	1	0	1	1	0	0	0	3	0	1	0
NJ	2	2	6	0	3	2	4	0	0	1	3	0	2	0
NY	4	0	0	1	1	0	0	0	1	1	0	0	0	0
OH	0	0	0	0	0	3	1	0	1	0	1	0	1	0
PA	**27**	**19**	**17**	**4**	**22**	**32**	**16**	**46**	**18**	**19**	**23**	**21**	**30**	**24**
RI	2	0	1	0	0	0	0	0	0	0	1	0	0	0
SC	0	0	1	0	0	1	0	0	0	0	0	0	0	3
TN	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TX	0	1	0	0	0	0	0	0	0	0	1	2	0	0
VA	**48**	**31**	**30**	**13**	**56**	**71**	**29**	**44**	**42**	**23**	**26**	**20**	**39**	**27**
VT	0	0	0	0	0	0	0	0	0	0	0	1	0	0
WA	0	0	1	0	0	0	0	0	0	0	0	0	0	0
WI	0	0	0	1	0	0	0	0	0	0	0	0	0	0
WV	0	1	0	2	6	3	2	4	4	0	4	2	10	3
Outside U.S.	0	0	1	0	0	0	0	0	0	1	0	0	0	1
Unknown	0	0	0	0	0	0	0	0	36	0	0	0	0	0

Table 12. The average number of anglers and average number of unlicensed anglers, per boat, with 95% confidence intervals, from the 2008-2015 Maryland striped bass spring season creel survey interview data.

Year	Number of Trips Interviewed	Average Number of Anglers per Boat	Average Number of Unlicensed Anglers per Boat
2008	261	**2.8** (2.7-2.9)	**1.5** (1.3-1.6)
2009	276	**2.7** (2.6-2.8)	**1.3** (1.2-1.5)
2010	193	**2.8** (2.6-2.9)	**1.4** (1.2-1.5)
2011	298	**2.7** (2.6-2.9)	**1.5** (1.3-1.6)
2012	172	**2.6** (2.4-2.8)	**1.3** (1.1-1.5)
2013	165	**2.7** (2.6-2.9)	**1.2** (1.0-1.4)
2014	207	**2.7** (2.5-2.9)	**1.2** (1.1-1.4)
2015	206	**2.6** (2.5-2.8)	**1.3** (1.1-1.4)

Table 13. Number of lines fished by private boats.

Year	Minimum	Maximum	Mean
2006	3	15	6
2010	1	19	8
2011	2	22	8
2012	2	18	7
2013	1	25	8
2014	2	21	8
2015	1	20	7

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 18-May 15, 2015.

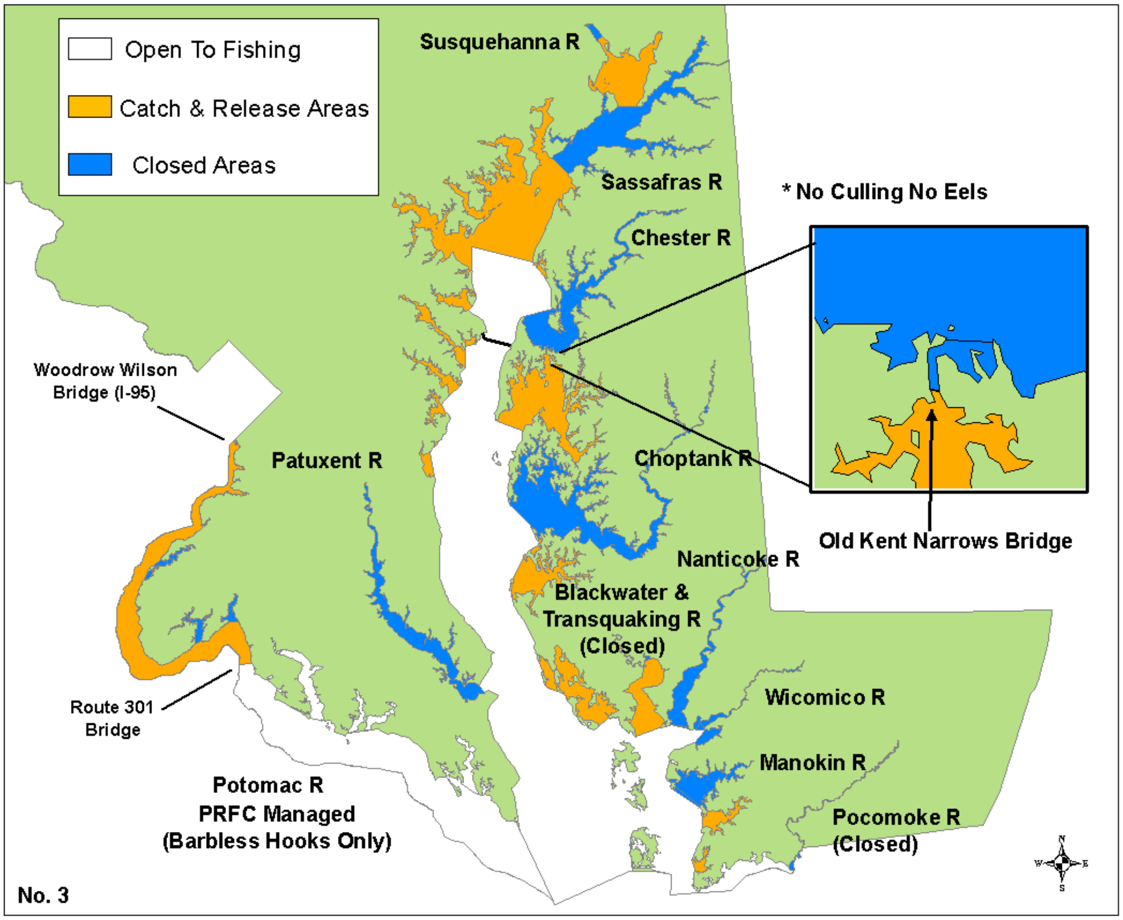


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

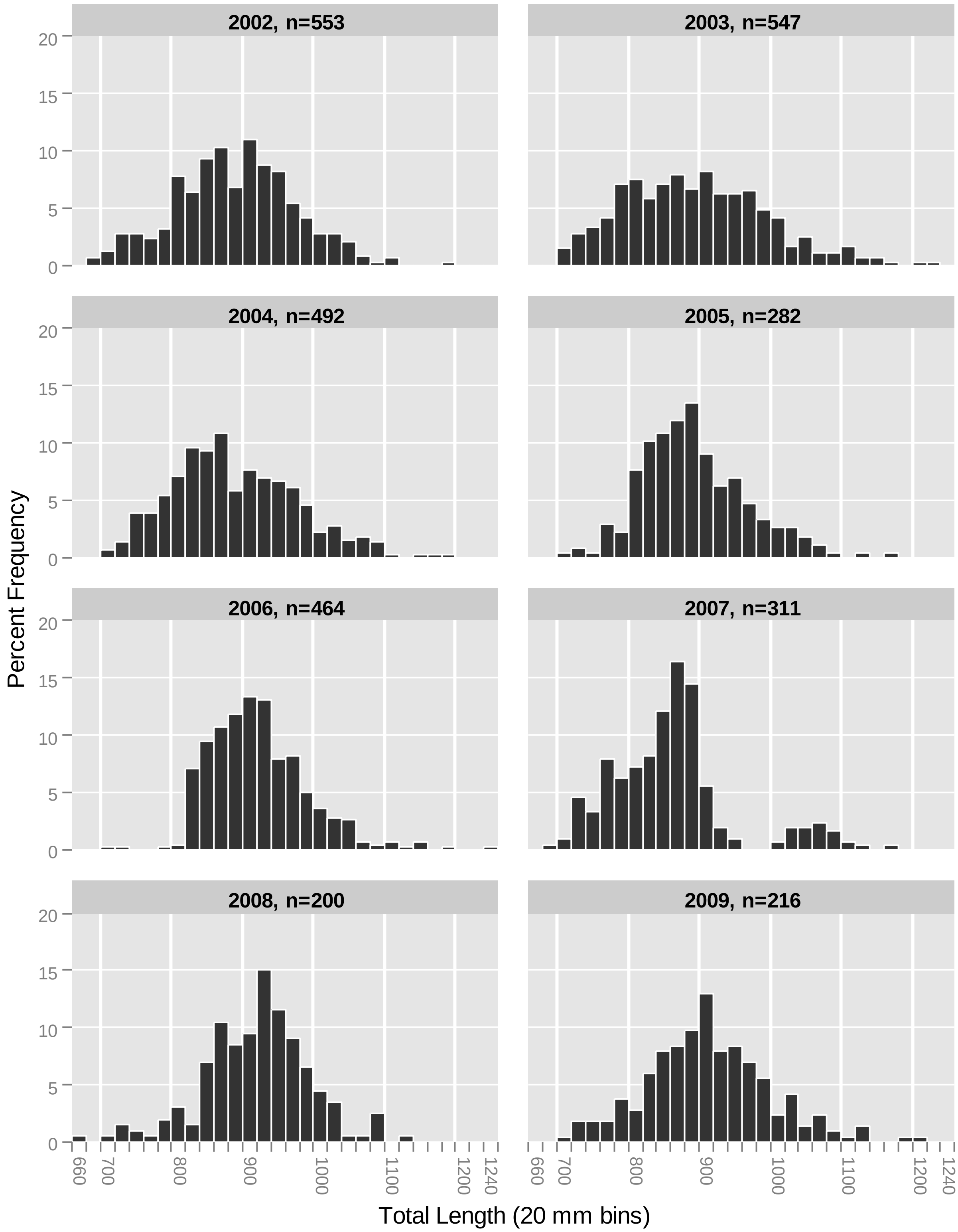


Figure 2. Continued.

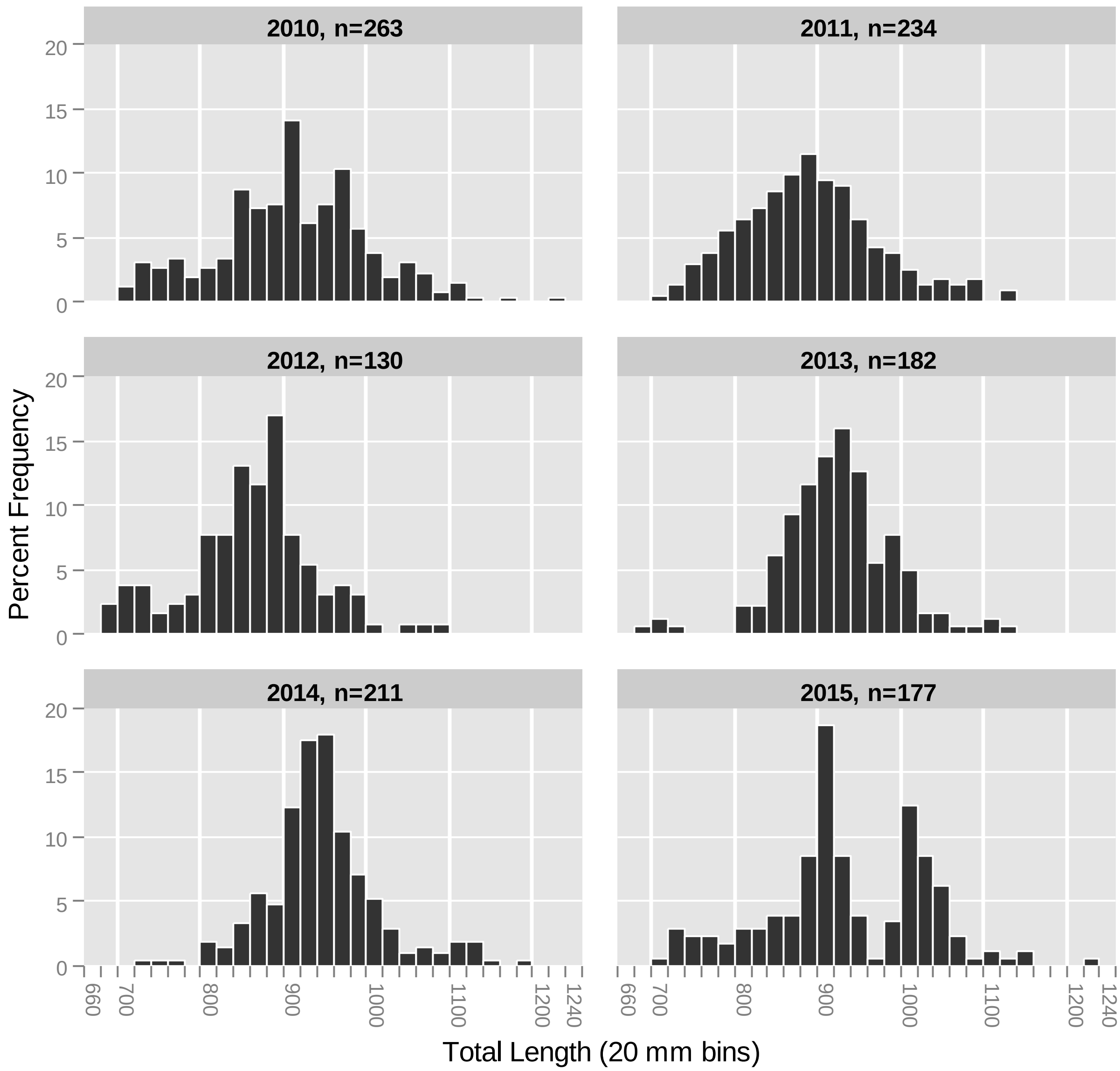


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15. Lower case letters indicate pairwise differences among years (Duncan's multiple range test, α=0.05).

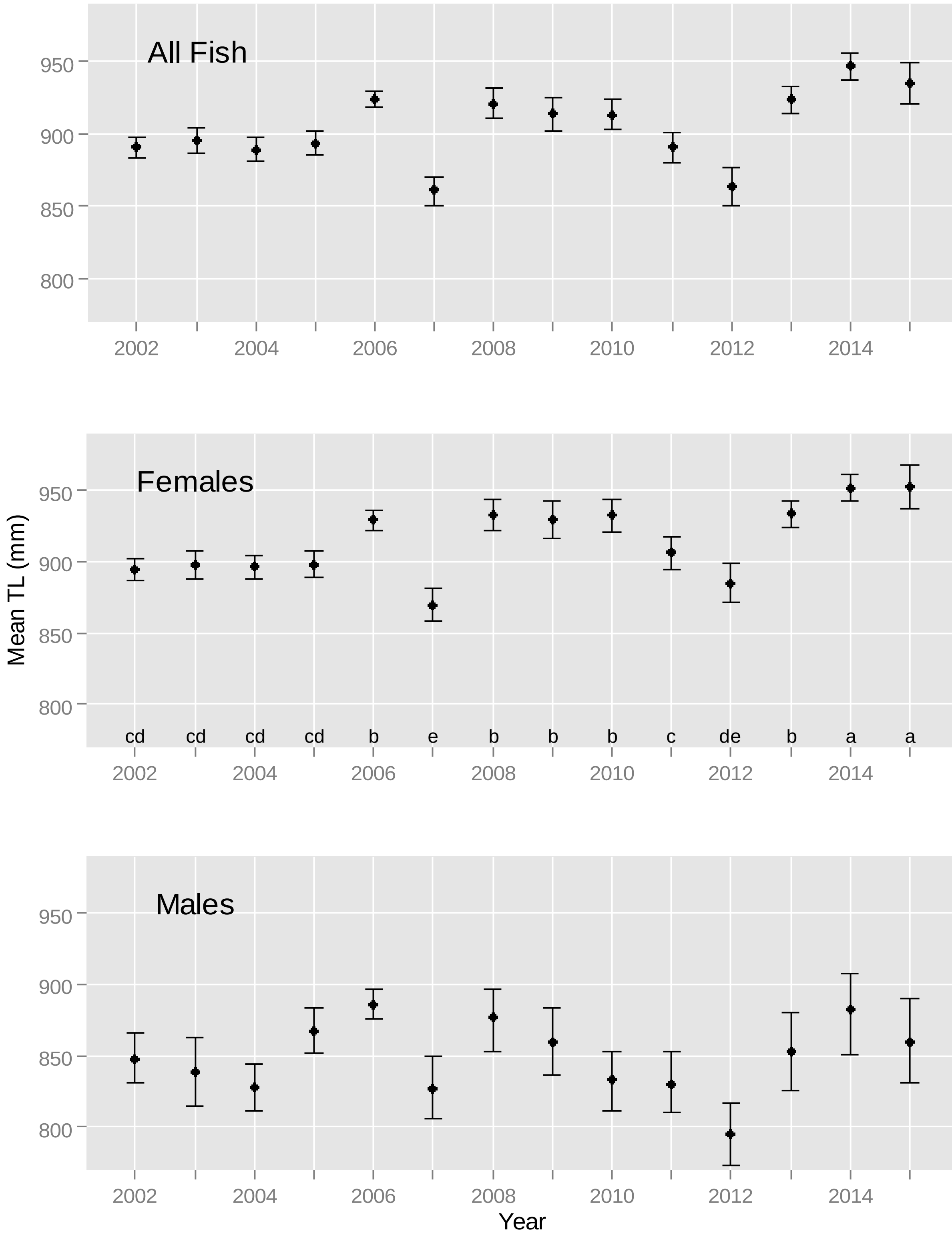


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

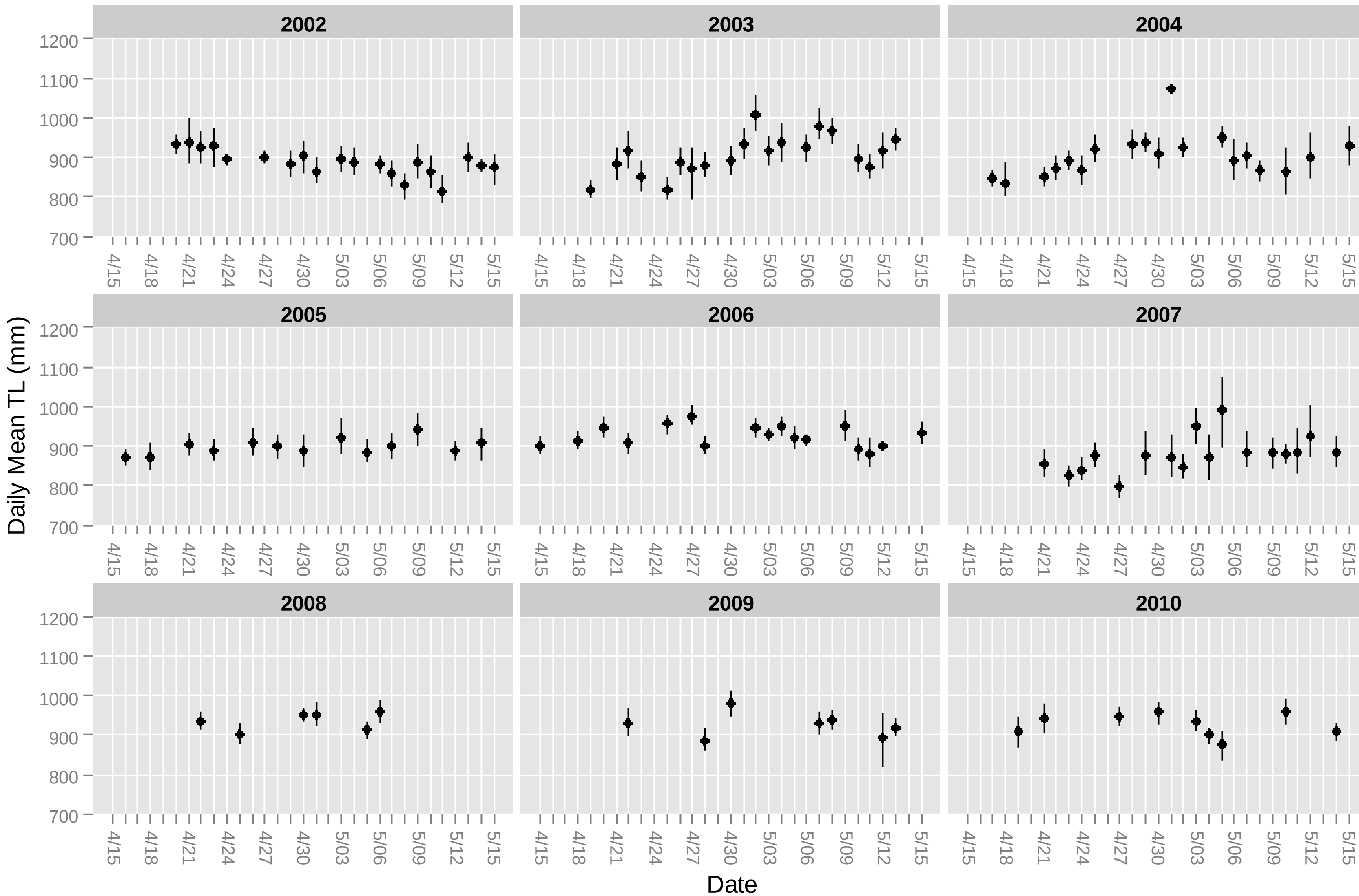


Figure 4. Continued.

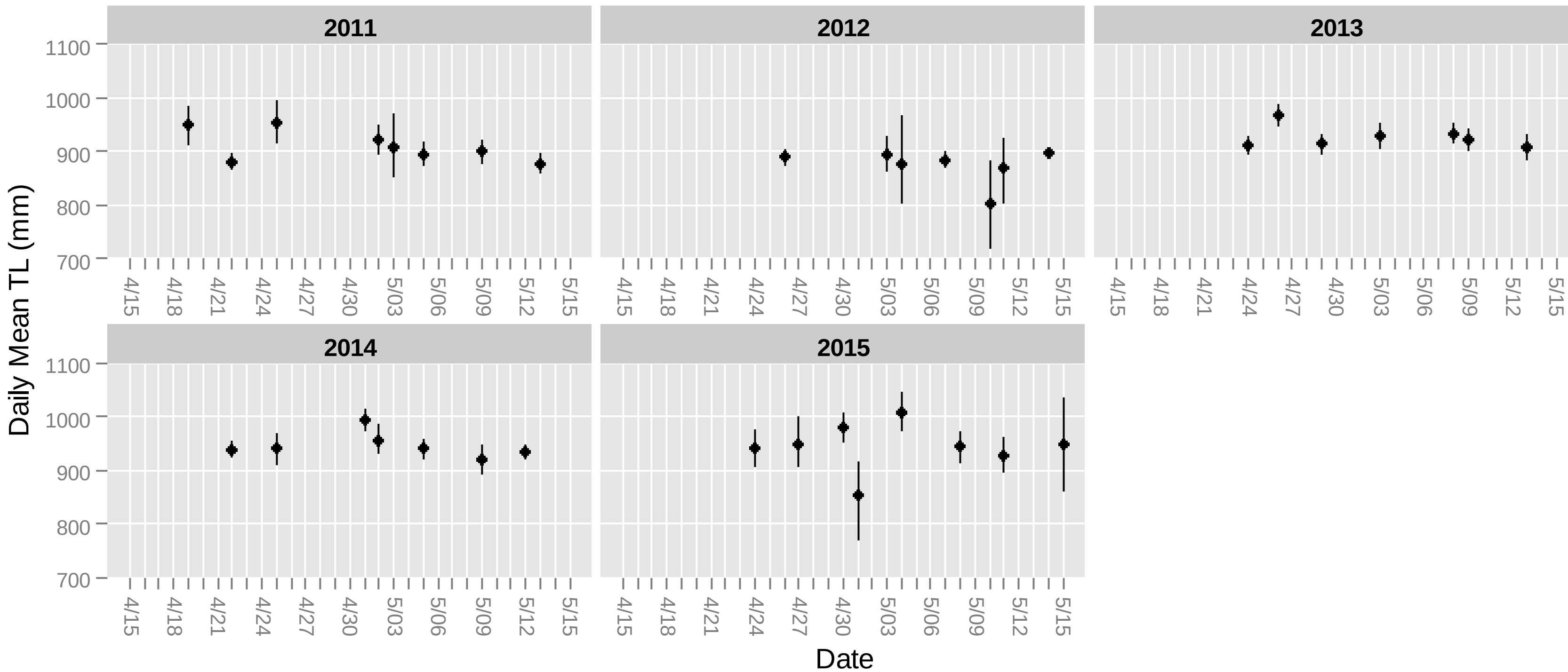


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15. Lower case letters indicate pairwise differences among years (Duncan's multiple range test, α=0.05).

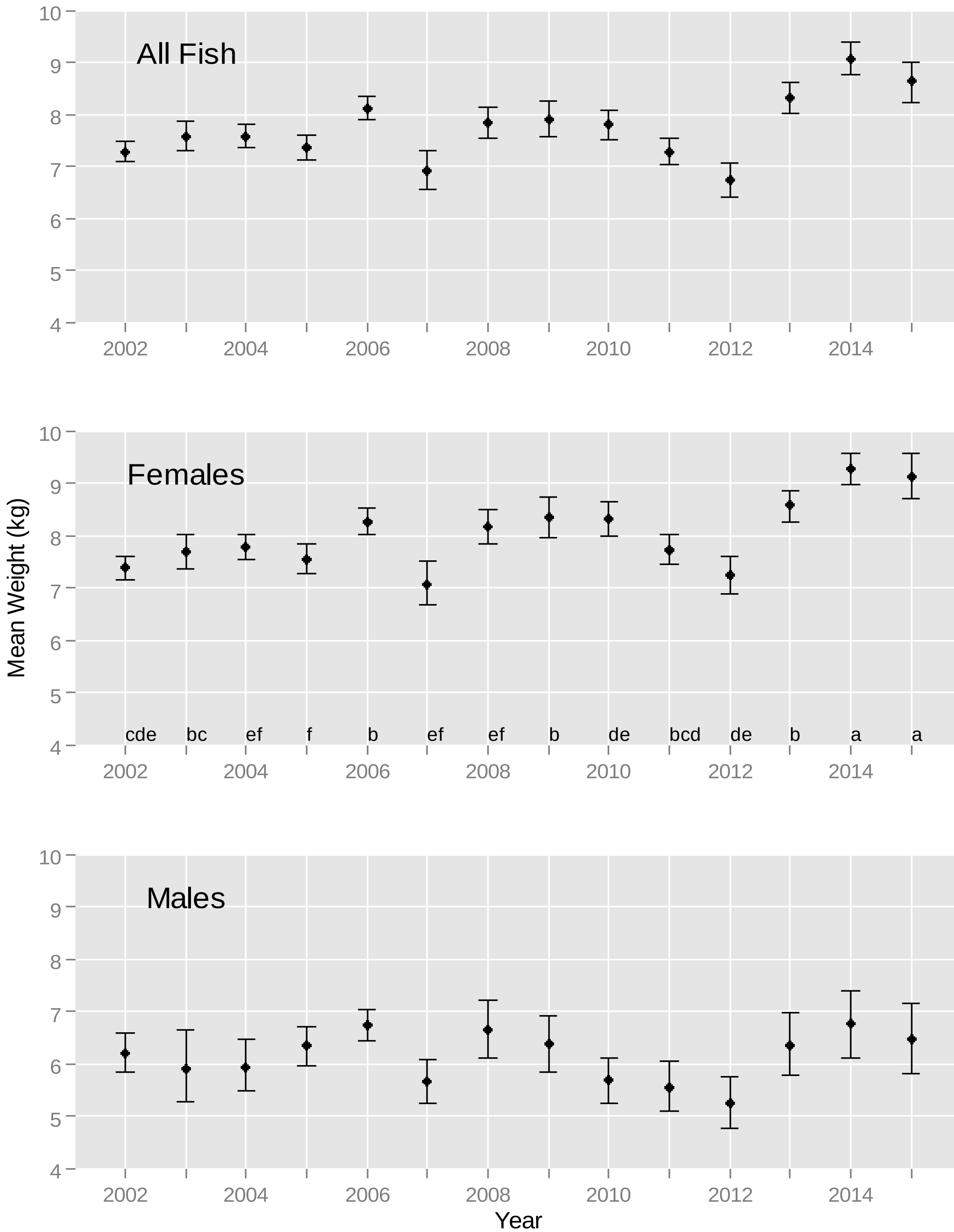


Figure 6. Estimated age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

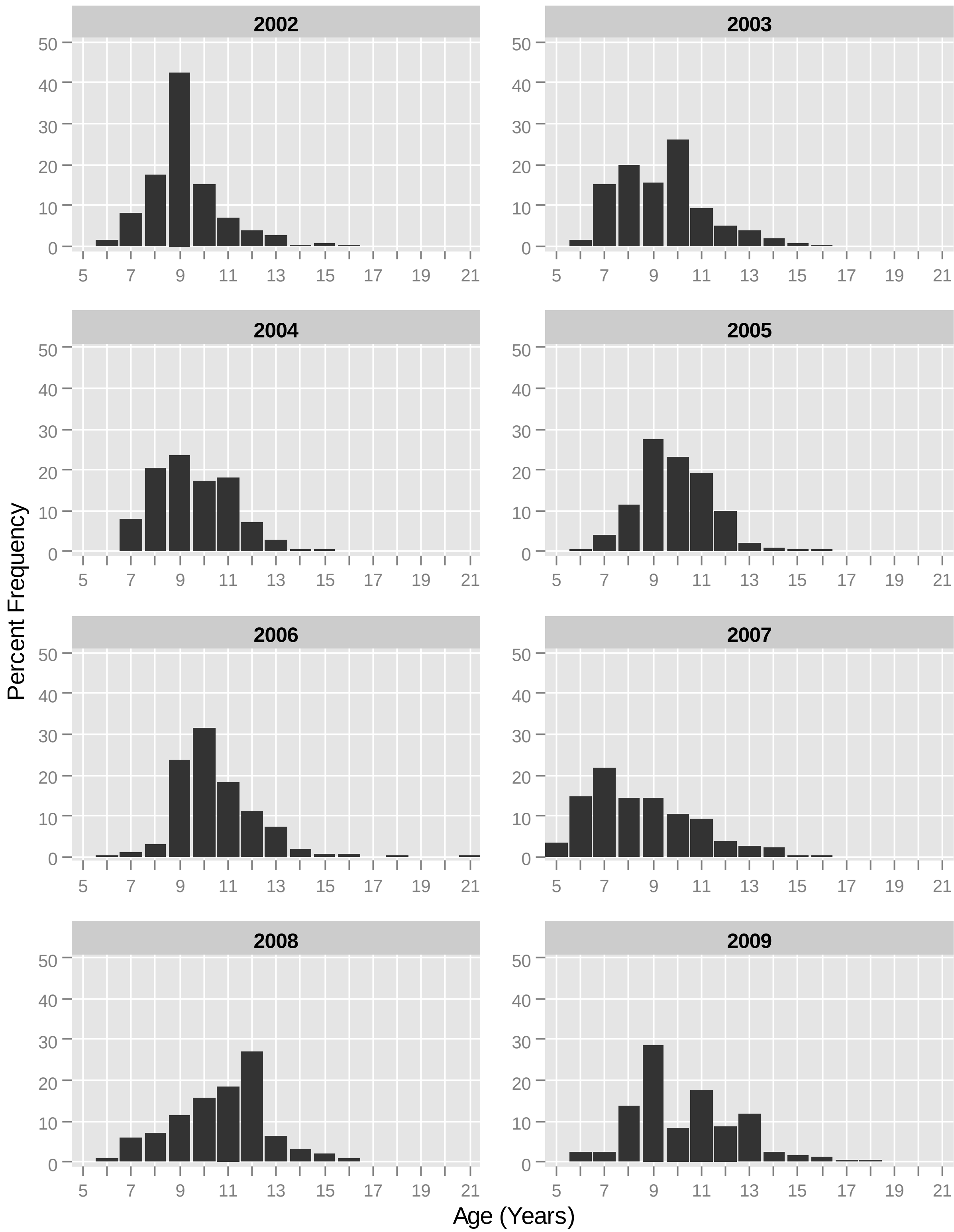


Figure 6. Continued.

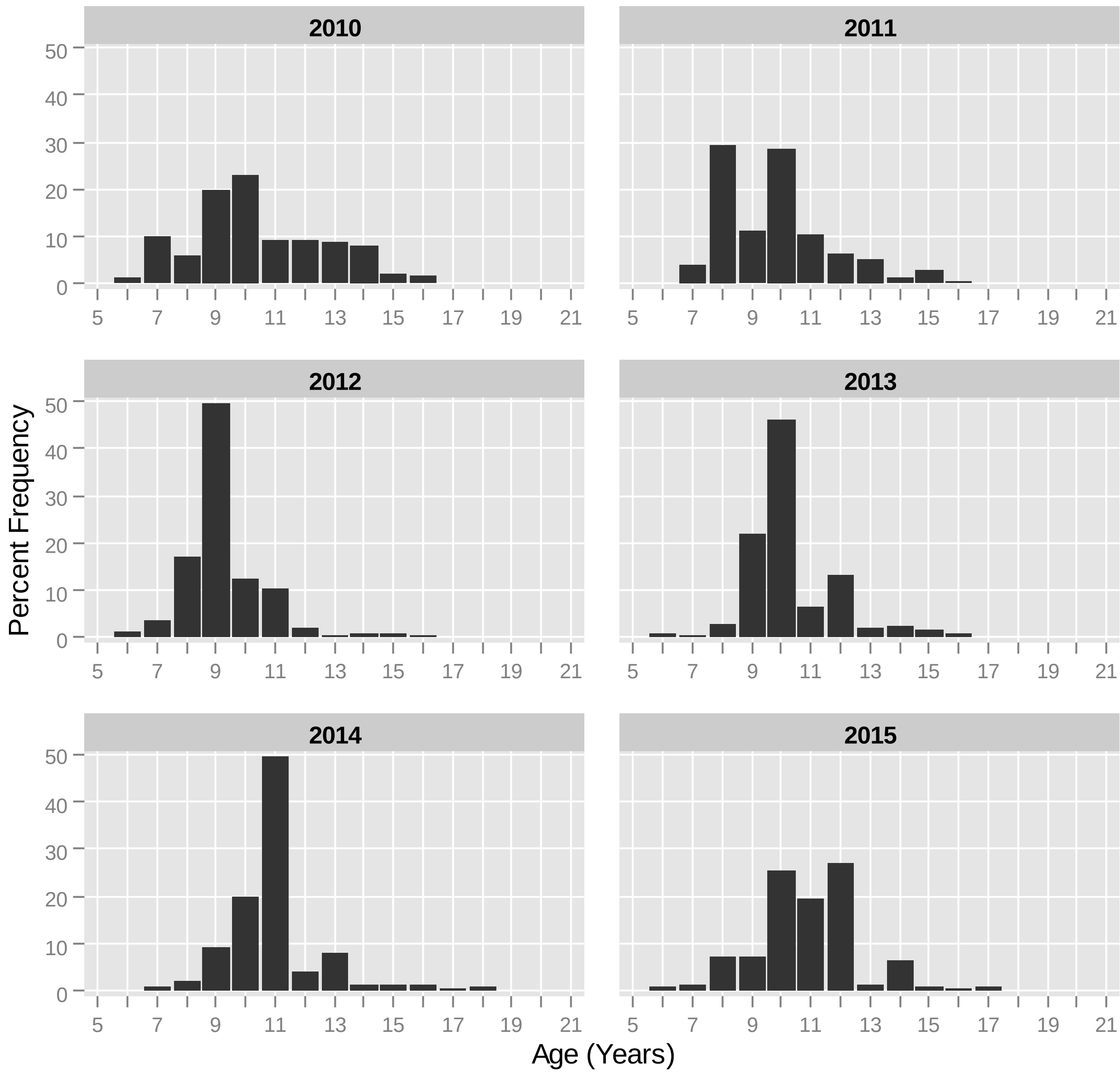


Figure 7. Daily percent of female striped bass in post-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

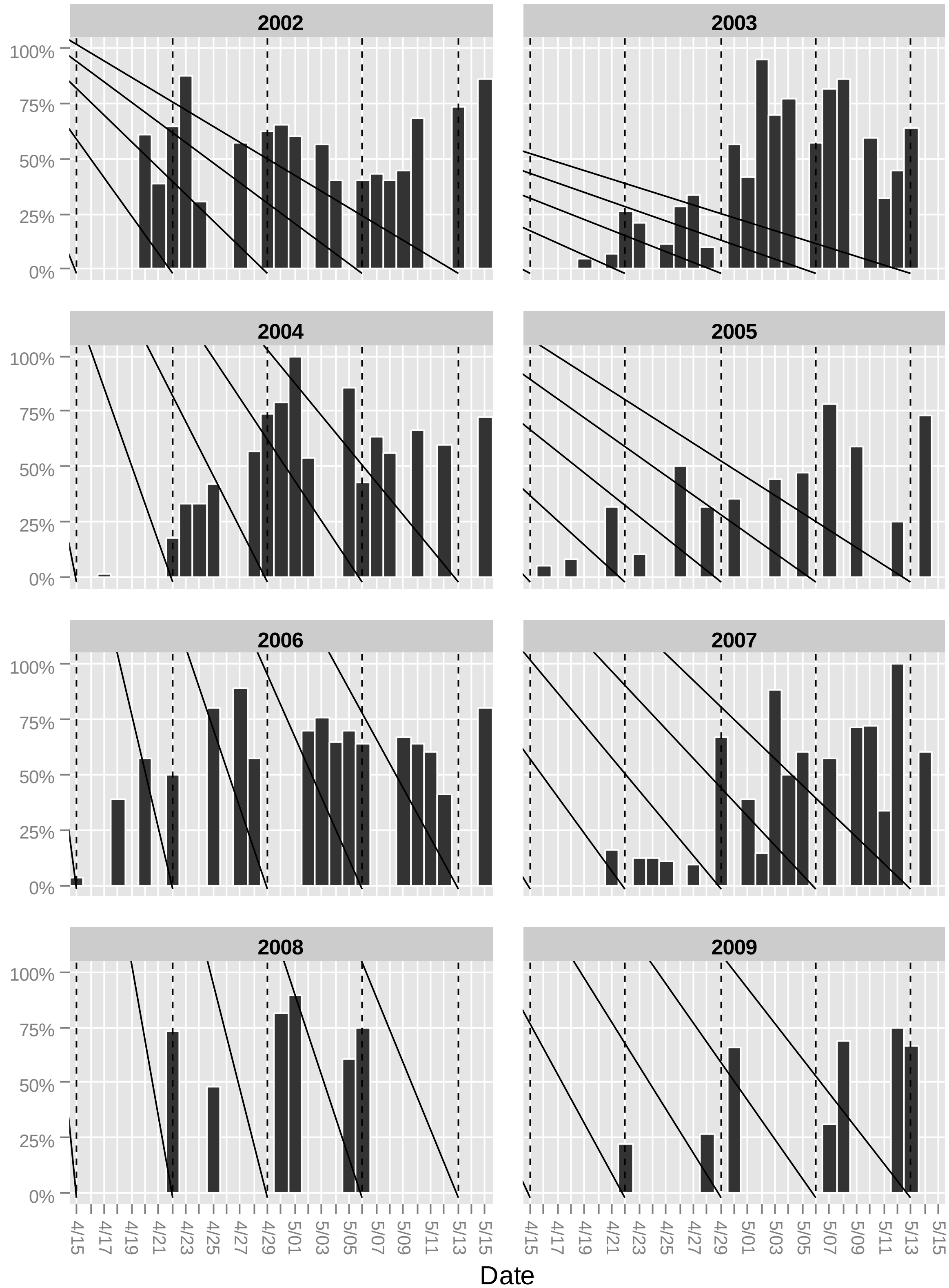
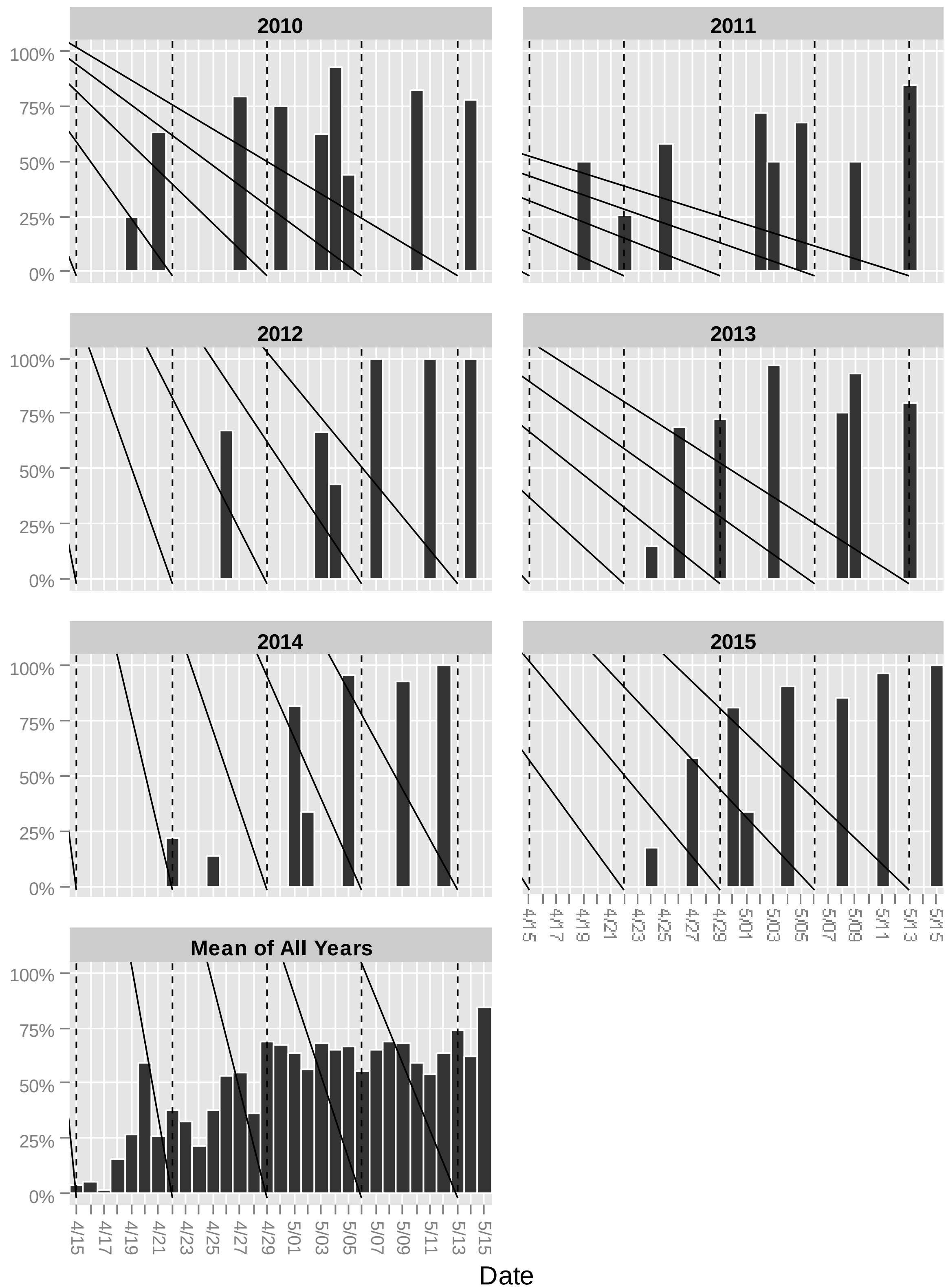


Figure 7. Continued.



APPENDIX I

Estimate of the 2015 Harvest
of Spring Coastal Migrant Striped Bass in Chesapeake Bay

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February 5, 2016

Introduction

This report presents the estimates of the 2015 Maryland and Virginia spring harvest of coastal migrant striped bass in Chesapeake Bay. The method used to determine coastal migrants in Maryland was presented in detail in Jones (2003), Barker and Sharov (2004), and Sharov et al. (2005). This report is submitted yearly to the Atlantic States Marine Fisheries Commission (ASMFC) as an appendix to the annual compliance reporting. ASMFC Addendum IV required a 25% reduction in the spring trophy season for 2015. The new Maryland regulations included a minimum size limit of 28 inches and a no take slot from 36 to 40 inches from April 18 to May 15. Addendum IV also required a 20.5% reduction in the summer/fall fishery. Maryland regulations were two fish at 20 inches (only one over 28 inches) from May 16 to December 20th. Results of the 2015 calculations are summarized in Table 1.

Methods

Estimation of harvest.

- Maryland charter boat logbook reports provided the census values of daily charter boat harvest in numbers of fish (Table 1). Due to increased online reporting of charter boat logbook data, Standard Atlantic Fisheries Information System (SAFIS) data were also used for the charter calculation.
- NOAA Marine Recreational Information Program (MRIP) survey provided preliminary estimates of harvest for Maryland private/rental boats, in numbers of fish, for Waves 2 and 3 (Table 1).
- VMRC provided the preliminary estimate of Virginia migratory striped bass harvest.

Harvest apportioned by time.

- The migrant harvest season overlaps parts of both Wave 2 and 3 of the MRIP survey. Length distribution of the harvest is known to change over this time period, so total harvest was apportioned into 2-week intervals between April 18 and June 15.
- All Wave 2 landings occurred in the last 2 weeks of the wave.
- 2-week interval proportions for Wave 3 landings were developed as the proportions of the harvest registered in the Maryland charter boat logbook reports (Table 1).
- Total Maryland striped bass harvest per interval was calculated as charter boat harvest + private/rental harvest (Table 1).

Harvest apportioned by length.

- Data from the MD DNR Volunteer Charter Boat Survey were used to develop the length frequency distribution of the Maryland charter boat catch for each 2-week interval (Table 2). Data from the Volunteer Charter Boat Survey were also used to develop the length frequency distribution for the Maryland private angler catch due to small samples of fish reported in the Volunteer Angler Survey.

- Harvest in each interval was distributed by the length frequency distribution for each 2-week interval.
- The number of migrants harvested in Maryland during the spring trophy season was determined by applying length-specific migration probabilities. These probabilities were derived from the estimate of the number of striped bass tagged on the spawning grounds in Maryland that migrate to the Atlantic coast before December of the first year at large (Dorazio et al. 1994). The result was a migrant and resident harvest estimate for each 2-week interval, distributed among interval-specific length groups (Table 3).
- The total 2015 Maryland spring harvest of coastal migrant striped bass in Chesapeake Bay was calculated as the sum of migrants over all length groups and 2-week intervals from both sectors (charter and private).
- The preliminary estimate of the migrant harvest for Virginia's portion of Chesapeake Bay was provided by VMRC, based on mandatory reporting by recreational anglers and charter boat captains.

Results and Discussion

The estimate of the 2015 Chesapeake Bay spring migrant harvest is 30,533 fish, a decrease compared to 2014 and below the 2006-2015 average of 42,351 fish (Table 4). The Maryland portion of the Chesapeake Bay migrant harvest is 30,496 migrants (Table 1). The Maryland charter boat migrant harvest is 5,771 fish. The Maryland private boat migrant harvest is 24,725 fish. The VMRC preliminary estimate of the spring 2015 migrant harvest in Virginia is 37 fish. Annual spring migrant harvest by length group is similar for 2013 and 2014 (Figure 1). As required by ASMFC Addendum IV, new regulations imposed a slot limit for April 18 to May 15 and a new minimum size for May 16-December 20 to achieve a harvest reduction in 2015. The 2015 length frequency distribution and volunteer charter survey data reflected this change in regulations (Table 2, Figure 1).

The decrease in migratory striped bass harvest relative to 2014 occurred mostly in the charter sector. The MRIP estimates of waves 2 and 3 private boat trips in 2015 were slightly less than 2014, but the waves 2 and 3 harvest estimate were similar to 2014, indicating a slight increase in private angler success (Figure 2 and 3). The MD DNR Creel Survey documented a similar increase in angler success (Figure 4). The MRIP estimates of charter boat trips and harvest decreased compared to 2014, however, harvest per trip was similar to 2014 (Figure 2 and 3).

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Dorazio, R. M., K. A. Hattala, C. B. McCollough and J. E. Skjeveland. 1994. Tag recovery estimates of migration of striped bass from spawning areas of Chesapeake Bay. Transactions of the American Fisheries Society 123: 150-163.

Jones, P. 2003. Estimates of the harvest of coastal migrant striped bass in Chesapeake Bay in the spring of 2003. Report to the ASMFC Striped Bass Technical Committee, November 2003.

Sharov, A., L. S. Barker, and L. Warner. 2005. Estimate of the 2005 Harvest and 2006 Quota for Spring Coastal Migrant Striped Bass in Chesapeake Bay. Maryland Department of Natural Resources, Annapolis MD.

Table 1. 2015 Chesapeake Bay spring striped bass migrant harvest, distributed among 2-week intervals, based on data from Maryland charter boat logbook reports, MRIP Maryland recreational harvest estimate and VMRC reported migrant harvest.* Shaded time intervals outside of the April 18th to June 15th season are shown to demonstrate partitioning of the total harvest.

	Interval	Charter Harvest (% by interval)[1]	MD Charter Harvest[1]	MD Private Harvest[2]	MD Total Harvest	MD Charter Migrants	MD Private Migrants	MD Total Migrants	VA Migrants[3]	Bay Total Migrants
Wave 2	Apr 1-17	0	0	0	0	0	0	0		
	Apr 18-30	100	1,982	6,252	8,234	1,805	5,695	7,500		
Wave 3	May 1-15	17	3,481	16,698	20,179	2,990	14,343	17,333		
	May 16-31	31	6,331	30,450	36,781	715	3,441	4,156		
	June 1-15	23	4,740	22,592	27,332	261	1,246	1,507		
	June 16-30	29	5,855	28,486	34,341					
	Wave 3 total	*100*	*20,407*	*98,226*	*118,633*					
Season total (Apr 18 – June 15)			16,534	75,992	92,526	5,771	24,725	**30,496**	**37**	**30,533**

* – Numbers may not sum due to rounding
1 – Data from MD DNR charter logbooks and SAFIS (9/15/15)
2 – Data from MRIP (retrieved from NOAA NMFS website 9/15/15)
3 – Data from VMRC (Jill Ramsey, VMRC, Pers. Comm. 9/25/15)

Table 2. Length distribution, in inches, of the 2015 Maryland striped bass spring season harvest as voluntarily reported by charter boat captains, by 2-week intervals between April 18 and June 15. Shaded areas represent no-take size groups.

Length Group	April 18-30	May 1-15	May 16-31	June 1-15	Total
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	82	27	109
21	0	0	71	41	112
22	0	0	53	35	88
23	0	0	38	34	72
24	0	0	38	22	60
25	0	0	15	12	27
26	0	0	17	12	29
27	0	0	19	12	31
28	1	2	12	7	22
29	5	13	15	6	39
30	0	11	6	5	22
31	2	6	9	5	22
32	3	6	10	4	23
33	4	15	4	0	23
34	7	38	11	2	58
35	48	113	5	0	166
36	6	25	8	0	39
37	0	0	2	0	2
38	0	3	0	0	3
39	0	2	0	0	2
40	26	75	0	0	101
41	53	84	2	0	139
42	32	55	1	0	88
43	15	15	0	0	30
44	17	19	1	0	37
45	10	5	0	0	15
46	7	3	0	0	10
47	6	1	0	0	7
48	2	1	0	0	3
49	0	0	0	0	0
50	0	1	0	0	1
51	1	3	0	0	4
52	2	0	0	0	2
53	0	0	0	0	0
54	0	0	0	0	0
55	1	0	0	0	1
56	0	0	0	0	0
n	**249**	**496**	**419**	**224**	**1,388**

Table 3. 2015 Maryland spring striped bass migrant harvest, distributed among 1 inch length groups (length as total length).*

Length Group	Apr 18-30			May 1-15		
	Charter	Private	Total	Charter	Private	Total
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	1	3	4	2	9	10
29	8	24	32	18	84	102
30	0	0	0	22	104	125
31	6	19	26	16	78	94
32	12	38	50	21	102	124
33	20	63	83	66	315	381
34	41	128	169	195	934	1,129
35	311	982	1,293	646	3,099	3,745
36	42	132	174	154	738	892
37	0	0	0	0	0	0
38	0	0	0	20	96	116
39	8	24	32	14	65	79
40	203	640	843	516	2,475	2,991
41	417	1,315	1,731	582	2,793	3,376
42	253	797	1,050	383	1,838	2,221
43	119	375	494	105	503	607
44	135	426	561	133	638	771
45	80	251	331	35	168	203
46	56	176	231	21	101	455
47	48	151	198	7	34	41
48	16	50	66	7	34	41
49	0	0	0	0	0	0
50	0	0	0	7	34	41
51	8	25	33	21	101	122
52	16	50	66	0	0	0
53	0	0	0	0	0	0
54	0	0	0	0	0	0
55	8	25	33	0	0	0
56	0	0	0	0	0	0
n	**1,805**	**5,695**	**7,500**	**2,990**	**14,343**	**17,333**

*Note: numbers may not sum due to rounding.

Table 3. 2015 Maryland spring striped bass migrant harvest, distributed among 1 inch length groups (length as total length).* Continued.

Length Group	May 16-31			June 1-15		
	Charter	Private	Total	Charter	Private	Total
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	4	18	22	2	8	10
21	5	25	31	4	20	25
22	6	31	37	6	28	34
23	7	35	43	9	44	53
24	12	57	69	10	46	56
25	8	36	44	8	40	49
26	14	65	79	13	64	77
27	24	115	139	21	101	122
28	23	112	135	19	91	110
29	44	210	254	25	117	141
30	25	122	147	30	141	171
31	53	253	306	41	195	236
32	76	368	444	43	204	247
33	38	182	219	0	0	0
34	121	584	705	31	147	178
35	62	296	358	0	0	0
36	106	510	616	0	0	0
37	28	134	162	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	30	144	173	0	0	0
42	15	72	87	0	0	0
43	0	0	0	0	0	0
44	15	72	88	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0
48	0	0	0	0	0	0
49	0	0	0	0	0	0
50	0	0	0	0	0	0
51	0	0	0	0	0	0
52	0	0	0	0	0	0
53	0	0	0	0	0	0
54	0	0	0	0	0	0
55	0	0	0	0	0	0
56	0	0	0	0	0	0
n	**715**	**3,441**	**4,156**	**261**	**1,246**	**1,508**

***Note**: numbers may not sum due to rounding.

Table 4. Harvest of migrant striped bass in the spring fishery from 1992-2015 (Individual estimates not available for all sectors prior to 2006). Average was only calculated for 2006-2015 due to techniques used to calculate migrant harvest.

Year	MD Charter Migrant Harvest	MD Private Migrant Harvest	VA Migrant Harvest	Total Migrant Harvest
1992				1,013
1993				2,719
1994				3,672
1995				42,634
1996				11,613
1997				21,222
1998				10,021
1999				17,051
2000				26,748
2001				25,728
2002				14,839
2003	43,248		242	43,900
2004	31,218		186	31,404
2005	64,345		1,319	65,664
2006	15,570	47,878	4,323	67,771
2007	9,359	26,229	740	36,328
2008	13,106	22,785	275	36,166
2009	12,740	77,799	243	90,782
2010	12,504	7,261	82	19,847
2011	13,673	22,616	145	36,434
2012	9,335	8,796	77	18,208
2013	13,724	34,810	23	48,557
2014	12,311	26,599	11	38,921
2015	5,771	24,725	37	30,533
Avg (2006-15)	**11,809**	**29,950**	**596**	**42,351**

Figure 1. Comparison of Maryland's 2013 through 2015 spring striped bass migrant harvests, apportioned by length.

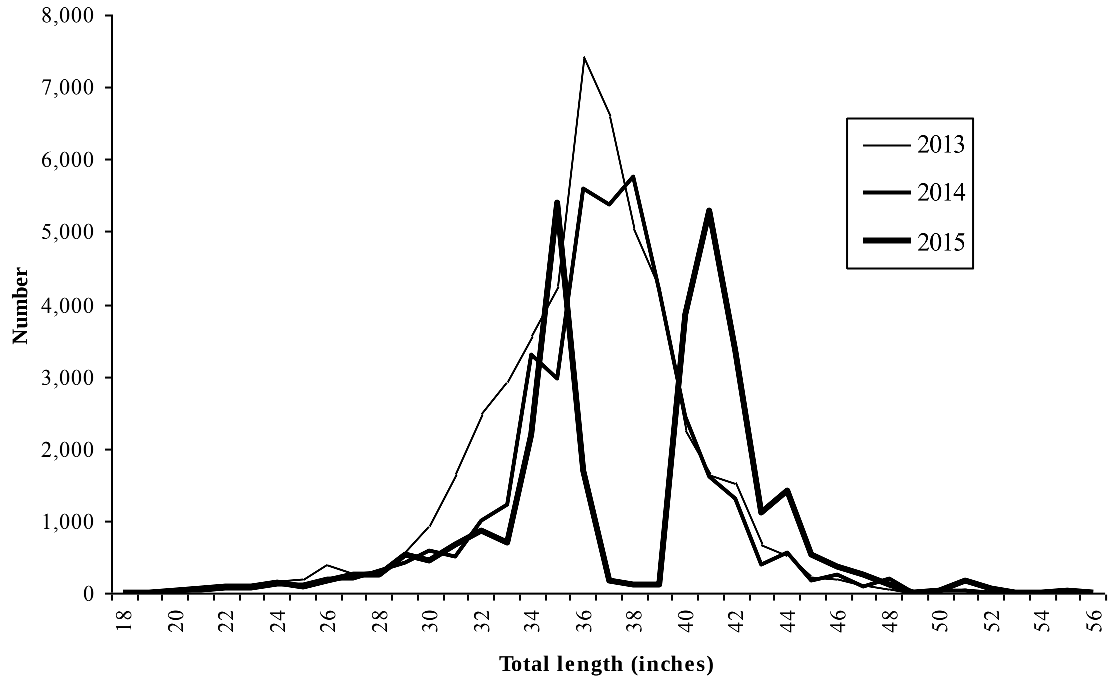


Figure 2. Total number of trips in Maryland's portion of Chesapeake Bay, Waves 2 and 3, from 1992 to 2015 for for-hire and private/rental boats according to MRFSS/MRIP data.

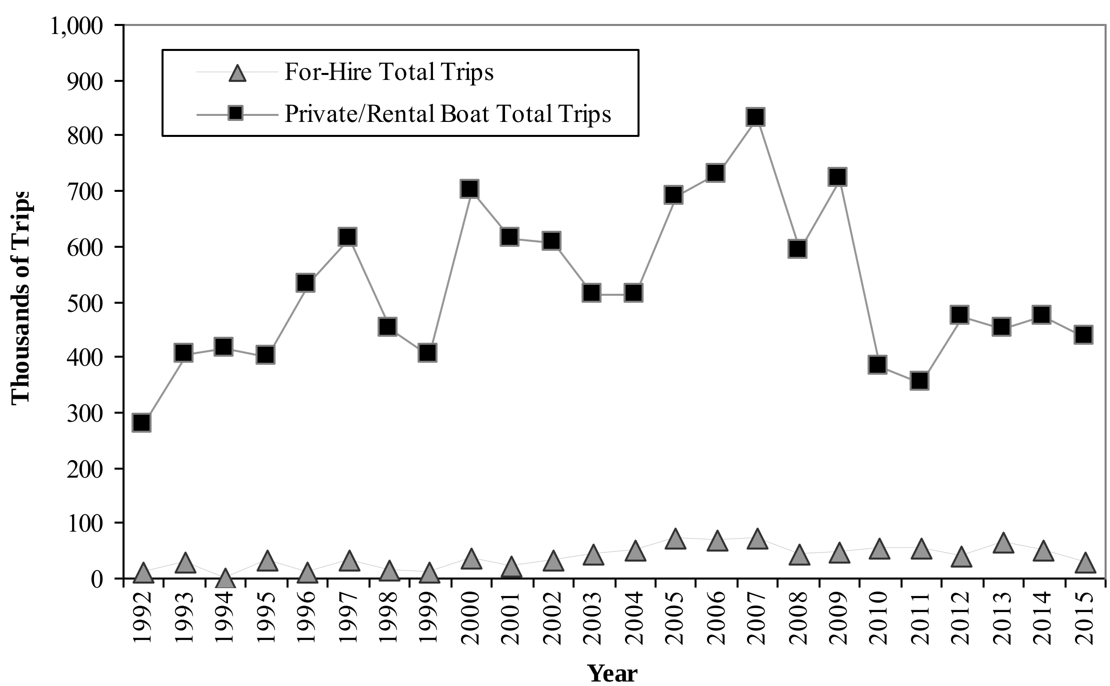


Figure 3. Harvest of striped bass in Maryland's portion of Chesapeake Bay, Waves 2 and 3, from 1992 to 2015 for for-hire and private/rental boats according to MRFSS/MRIP data. Data includes migrant and resident striped bass.

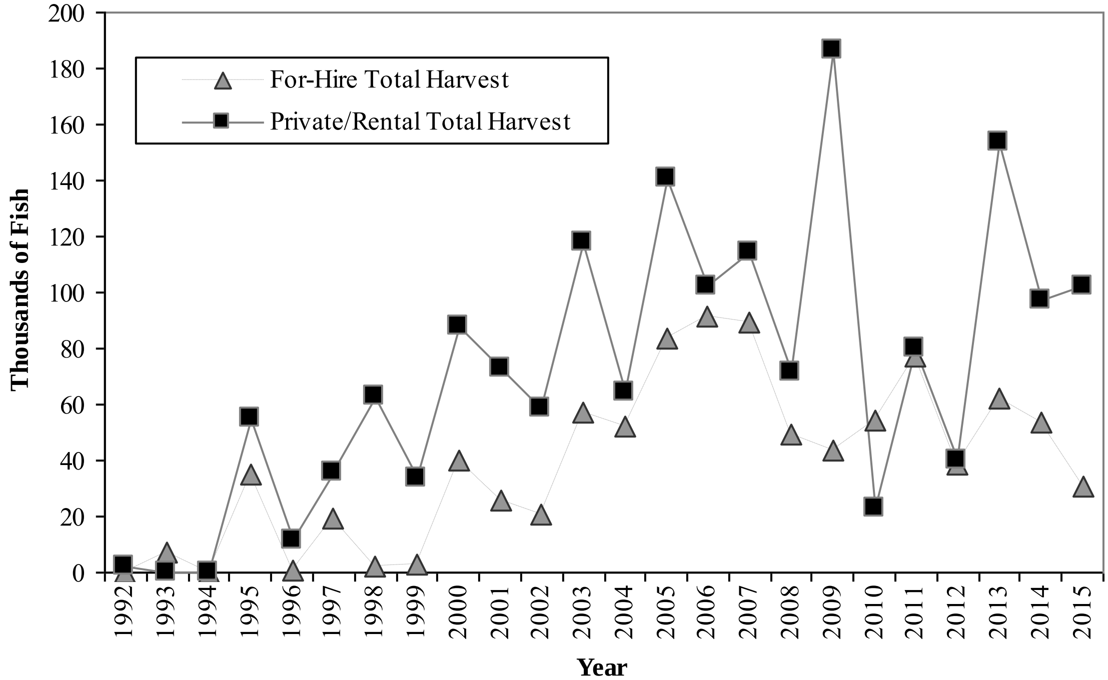
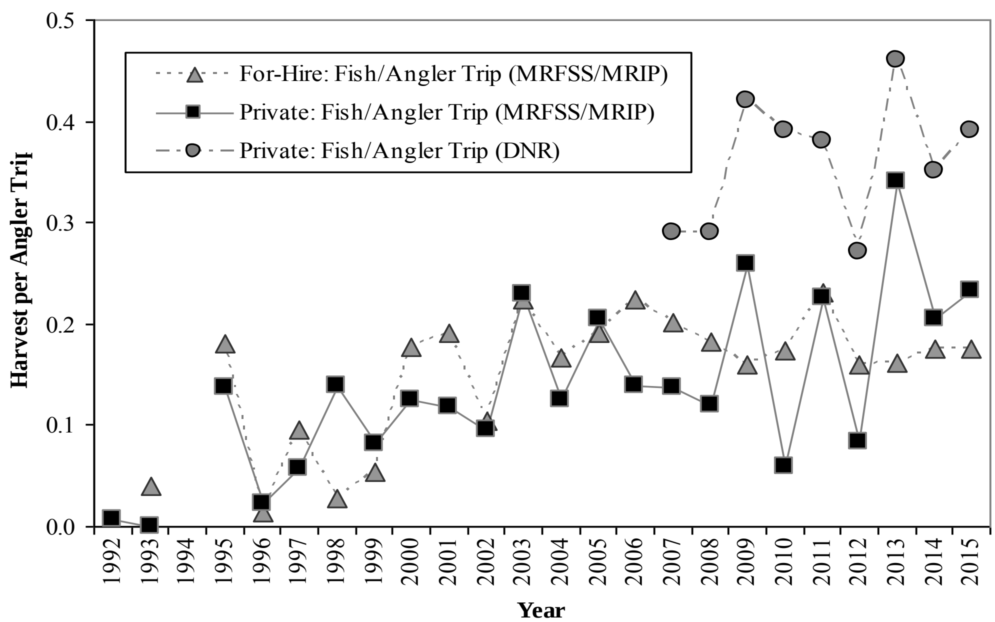


Figure 4. Harvest per angler trip of striped bass in Maryland's portion of Chesapeake Bay, Waves 2 and 3, from 1992 to 2015 for for-hire and private/rental boats according to the MRFSS/MRIP data and private boats from the DNR Creel Survey (2007-2015). Data includes migrant and resident striped bass.



<u>APPENDIX II</u>

INTERVIEW FORMAT AND QUESTIONS
MARYLAND STRIPED BASS SPRING SEASON CREEL SURVEY
MARYLAND DEPARTMENT OF NATURAL RESOURCES-FISHERIES SERVICE

1.) How many anglers were on your boat today?

2.) How many striped bass were kept by your party?

3.) How many striped bass were released by your party?

4.) How many hours did you fish today? (Line in until Lines out)

5.) How many lines were you fishing?

6.) Where did you spend most of your time fishing today? **U**, **M**, or **L** Bay: Upper Bay = above Bay Bridge, Middle Bay = Bay Bridge to Cove Pt., Lower Bay = Cove Pt. to MD/VA line at Smith Pt.

7.) What is your state of residence?

8.) a. Do you have a boat license?

b. How many anglers in your party were fishing under the boat license? (Or, how many anglers in the party have their own individual licenses?)

PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDINATION

Prepared by Eric Q. Durell, Harry Rickabaugh, Genine K. Lipkey 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.

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.

Project staff served as Maryland's representative for the Technical Expert Working Group for river herring, attending all meetings and participating in the Stock Status Subgroup.

Atlantic Croaker:

Project staff served on the Atlantic Croaker Technical Committee, and prepared the ASMFC Annual Maryland Atlantic Croaker Compliance Report. The Technical Committee representative is also a member of the Stock Assessment Subcommittee for the current benchmark stock assessment and attended the data workshop and all conference calls associated withy the assessment.

Atlantic Menhaden:

Project staff provided Atlantic menhaden data utilized for stock assessments, FMP's and shared coastal management activities with ASMFC, NMFS, USFWS and various academic institutions, and prepared the Annual Maryland Atlantic Menhaden Compliance Report required by ASMFC.

Black Drum:

ASMFC Technical Committee representative prepared the Annual Black Drum Status Compliance Report for Maryland, and currently serves as the Chair of the Technical Committee.

Bluefish:

The ASMFC Bluefish Technical Committee representative prepared the ASMFC Annual Bluefish Status Compliance Report for Maryland and provided Chesapeake Bay juvenile bluefish data to the Mid-Atlantic Fishery Management Council.

Red Drum:

ASMFC Technical Committee representative prepared the Annual Red Drum Status Compliance Report for Maryland. Project staff attended the Red Drum Stock Assessment Data and Assessment Workshops. Staff served on the Stock Assessment Life History and Tagging Subgroups, and the Stock Assessment Sub Committee.

Spanish Mackerel:

Staff prepared the Maryland Spanish Mackerel Compliance Report required by ASMFC.

Spot:

Project staff served on the Spot Plan Review Team, and prepared the ASMFC Annual Maryland Atlantic Croaker Compliance Report. The Plan Review Team member also serves on the Stock Assessment Sub Committee for the current benchmark stock assessment, and attended the data workshop and all conference calls associated with the assessment.

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. A staff member is also a member of the Stock Assessment Subcommittee, and participated in all meetings and conference calls pertaining to the current benchmark stock assessment.

Striped Bass Data Sharing and Web Page Development

To augment data sharing efforts, Striped Bass Stock Assessment program staff in 2002 developed a web page within the MD DNR web site presenting historic Juvenile Striped Bass Survey (Job 3) results. This effort has enabled the public to access SBSA program data directly. The web page, http://dnr.maryland.gov/Fisheries/Pages/striped-bass/juvenile-index.aspx, was updated in July, 2014.

Monthly visits to the Juvenile Striped Bass Survey web page by individual IP address for the period January 2015 to December 2015 are provided in Table 1. Many large or complex data requests are also handled directly by Striped Bass Stock Assessment Program staff. However, web page access to survey information has saved staff considerable time in answering basic and redundant data requests.

Table 1. Monthly visits to the Juvenile Striped Bass Survey web page, January 2015 to December 2015.

Date	Visits
January	291
February	282
March	462
April	433
May	294
June	374
July	627
August	236
September	412
October	394
November	36
December	13
Total	3,854

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), the University of Maryland, Virginia Institute of Marine Sciences, Towsan State University, and State management agencies from Delaware, Massachusetts, New York and Virginia. For the past contract year, (November 1, 2014 through January 31, 2016) the following specific requests for information have been accommodated:

- Atlantic States Marine Fisheries Commission (ASMFC).Provision of striped bass juvenile index data; updated striped bass fishery regulations; striped bass commercial fishery data, striped bass spawning stock CPUE data; current striped bass commercial fishery data; results from fishery dependent monitoring programs, and age/length keys developed from results of fishery monitoring programs. Staff also provided bluefish recruitment data in support of the benchmark stock assessment.

- Ms. Laurie Bauer, NOAA
Provision of historical fish community data in the Choptank River from the striped bass juvenile survey.

- Dr. Andre Buchheister, UMCES
Provision of current and historical forage fish abundance data from the striped bass juvenile survey.

- Mr. Jim Cummins, Interstate Commission for the Potomac River Basin,(ICPRB).
Provision of current striped bass recreational, charter, and commercial fishery data, and American shad and striped bass juvenile survey data.

- Ms. Ande Ehlen, Virginia Marine Resources Commission
Provision of current and historical striped bass commercial fishery data, Striped Bass Volunteer Angler Survey data, and age-length keys developed from fishery dependent monitoring surveys.

- Ms. Sheila Eyler, USFWS
Provision of American shad data from the striped bass spawning stock survey.

- Dr. Mary Fabrizio,VIMS, Department of Marine Sciences.Provision of current striped bass juvenile survey information.

-Ms. Alexandra Fries, UMCES
Provision of annual bay anchovy abundance data from the striped bass juvenile survey.

- Maryland Charterboat Association (MCA) Provision of striped bass fishery regulations, striped bass recreational, and charter boat harvest data.

-Mr. Marty Gary, Potomac River Fisheries Commission (PRFC).Provision of striped bass juvenile survey data, commercial harvest regulations.

-Mr. David Jasinski, Chesapeake Environmental Communication, Inc.
Provision of historical fish community data in the Choptank River from the striped bass juvenile survey.

-Dr. Erin Markin, UMCES
Provision of striped bass scale and otoliths samples, digital images of sectioned otoliths, and acetate scale impressions.

-Mr. Steve Minkkinen, USFWS
Provision of shad and herring recruitment data from the striped bass juvenile survey.

- National Marine Fisheries Service, NOAA, Chesapeake Bay Program Staff. Provision of results from fishery dependent monitoring programs, striped bass juvenile index data, and Atlantic menhaden juvenile survey data.

-Dr. Jay Nelson, Towson University Department of Biological Sciences
Provision of data and biological samples from the striped bass juvenile survey.

-Ms. Olivia Phillips, VIMS
Provision of data and biological samples from the striped bass juvenile survey.

-Ms. Jennifer Weaver, Research Planning Inc, NOAA contractor
Provision of general life history information for estuarine fish species, digital maps depicting Maryland striped bass spawning grounds, and fish abundance data from the juvenile striped bass seine survey.

-Dr. Michael Wilberg, UMCES
Provision of current and historical blue crab abundance data from the striped bass juvenile survey.

-The Interjurisdictional Project also provided related biological information, scientific literature and reports to twenty eight (28) 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-11

Prepared by Paul G. Piavis, Harry W. Rickabaugh, Eric Q. Durell, Genine K. Lipkey and Harry T. Hornick

Summary

The primary objective of the Chesapeake Bay Finfish Investigations Survey, F-61-R-11, was to monitor and biologically characterize resident and migratory finfish species in the Maryland portion of the Chesapeake Bay during the 2014 – 2015 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 2014 – 2015 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 yellow perch in Maryland with special emphasis on the Head-of-Bay stocks.

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.

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.

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 yellow perch in Maryland with special emphasis on the Head-of-Bay stocks.

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 Job1.

Research Surveys:

1. Upper Chesapeake Bay Winter Trawl
2. Fishery Dependent Yellow Perch Fyke Net Survey
3. Fishery Independent Choptank River Fyke Net Survey

1. Upper Chesapeake Bay Winter Trawl Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed in the Upper Chesapeake Bay Winter Trawl Survey during the Survey period of November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

<u>PROJECT 2</u>: **INTERJURISDICTIONAL SPECIES STOCK ASSESSMENT**

<u>JOB 1</u>: 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

<u>Atlantic Sturgeon Interactions</u>

No Atlantic sturgeon were sampled or observed during the Survey period of this project from November 7, 2014 through January 31, 2016.

<u>Shornose Sturgeon and Sea Turtle Interactions</u>

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of this project from November 7, 2014 through January 31, 2016.

2. Nanticoke River Ichthyoplankton Survey

<u>Atlantic Sturgeon Interactions</u>

No Atlantic sturgeon were sampled or observed during the Survey period of November 7, 2014 through January 31, 2016.

<u>Shornose Sturgeon and Sea Turtle Interactions</u>

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles sampled or observed during the Survey period of November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of November 7, 2014 through January 31, 2016.

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 November 7, 2014 through January 31, 2016.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of November 7, 2014 through January 31, 2016.