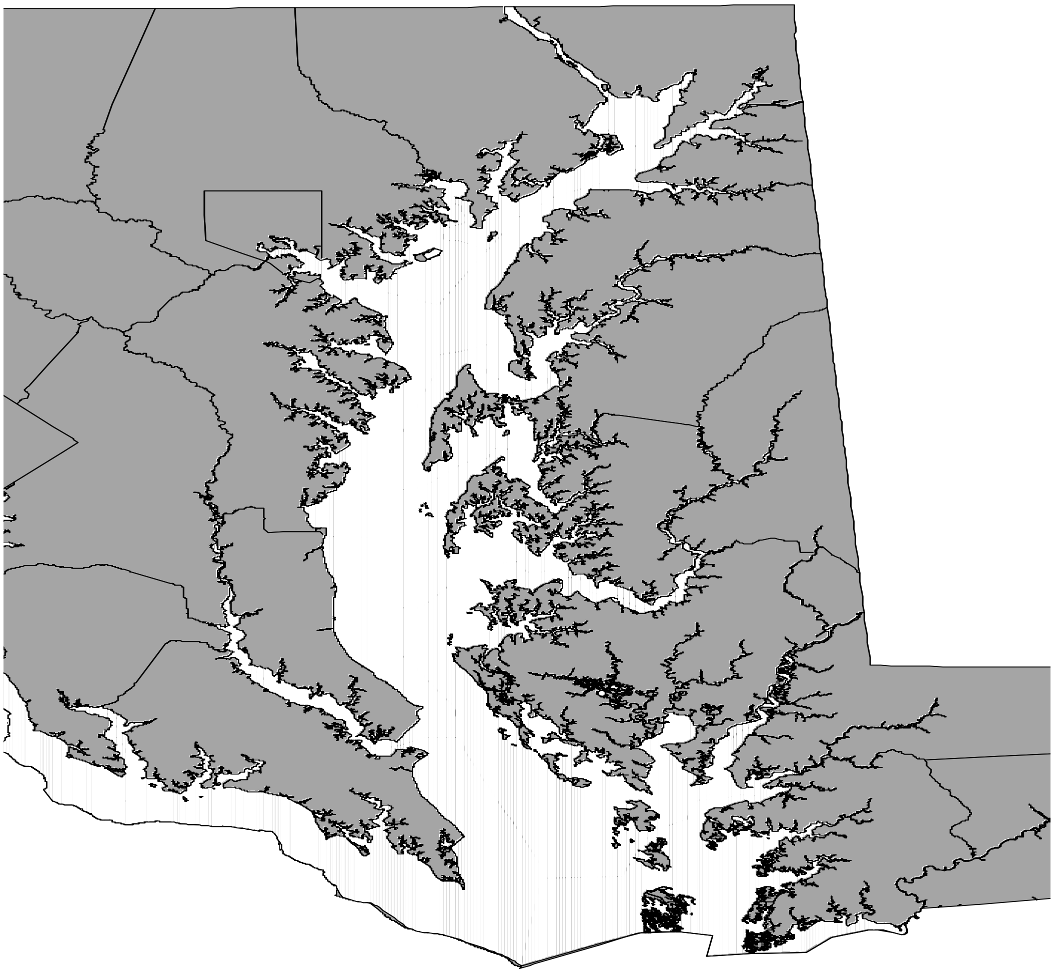

Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-10
2013 - 2014

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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

STATE: Maryland

PROJECT NO.: F-61-R-10

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2013 through October 31, 2014

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.

Individual white perch population assessments were conducted in the upper Chesapeake Bay and Choptank River utilizing a catch survey analysis (CSA) model. The lower Chesapeake Bay (areas below the Chesapeake Bay Bridges in MD) were assessed by compiling available fishery dependent relative abundance indices and a limited number of fishery independent surveys. For the upper Bay and Choptank River assessments, results were compared to proposed biological reference points (Limit F = F20% and Target F=F30%).

The upper Bay CSA utilized pre-recruit and post-recruit indices derived from the upper Bay winter trawl survey for the years 2000 – 2014. The CSA model fit the fishery independent trawl data well. Total population abundance exhibited a saddle-shaped pattern where the lowest abundance occurred midway through the time series (2004 – 2009). Recruited abundance declined drastically in 2005 and was at it lowest in 2008. Higher pre-recruit abundance, beginning in 2008, produced the rebound in abundance of post-recruit white perch. Population estimates for the terminal year (2013) was at or near the highest of the time-series. Based on the bootstrap distribution, there was only a 1.2% chance that F target was exceeded in 2013. Therefore, overfishing did not occur on the upper Bay white perch stock for the terminal year.

The Choptank River CSA utilized pre-recruit and post-recruit indices derived from the Choptank River fyke net survey (1989 – 2014). The model run for Choptank River white perch indicated that total population abundance declined after reaching a peak in 2011 (time series = 1989 – 2014). Pre-recruit abundance, the ultimate driver of exploitable biomass, was at higher levels for a large part of the time series, at least from 1997 – 2007. Since 2007, estimated pre-recruit abundance declined. Fishing mortality rates exhibited a declining trend since 1997 when F was above the proposed limit reference point. Recently, fishing mortality approached but did not exceed the target reference point in 2011, breeched it 2012, and declined to 0.40 in 2013 (target F = 0.60).

The lower Bay assessment was qualitative in nature. Fishery dependent indices of relative abundance were not identical, but they did provide a general indication of stock trends. Three fishery dependent indices showed a generally increasing trend up to 2002 or 2004, followed by a decline. The decline persisted until around 2007 with the indices showing either a flat or increasing population through 2010. The population bottom in 2007 and possible recovery through 2010 is almost identical to the upper Bay CSA results. The fishery independent indices somewhat corroborated the fishery dependent fyke net and drift gill net indices. High relative abundance values occurred 2004 – 2006 and 2011 – 2013 for the fishery independent gill net survey. Given that the fyke net, drift gill net and experimental drift gill net surveys had 6 – 7 years of the 10 year period, 2004 – 2013 at or above average CPUE, overfishing likely did not occur.

Atlantic coast wide Alosine stocks are near historic lows. Predation, bycatch, turbine mortality, and limited access to prime spawning habitat continue to impact Alosine populations in Maryland’s portion of Chesapeake Bay and its tributaries. In 2014, measures of abundance for American Shad in the lower Susquehanna River increased, but remain well below time series peak values observed in the early 2000’s. Relative abundance of American shad in the Potomac (1996-2014) and Nanticoke Rivers (1988-2014) have significantly increased over the time series, and remained at or above average in 2014. Juvenile abundance indices in the Potomac River have improved since 2000 and continue to be the highest in Maryland’s portion of Chesapeake Bay.

Hickory shad age structure in the Susquehanna River was previously very consistent with 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 has been declining in recent years (2009-2014).

River herring age structure in the Nanticoke River appears to be truncating and mean length is declining, especially for blueback herring. Conversely, the juvenile abundance indices indicate alewife and blueback herring increased baywide in 2014. The moratorium on river herring enacted by the State of Maryland in 2012 should promote an increased spawning stock, leading to increased production of juvenile river herring.

Weakfish have experienced a sharp decline in abundance coast wide. Recreational catch estimates by the NMFS for Maryland declined from 475,348 fish in 2000 to 237 fish in 2011, and has remained low through 2013, with an estimated 1,834 weakfish harvested. Maryland's commercial weakfish harvest increased the past two years from the time series low of 378 pounds in 2011 to 3,518 pounds in 2013, but was still well below the time series mean harvest of 605,309 pounds. The 2014 mean length for weakfish from the onboard pound net survey was 334mm TL, but only six fish were sampled. The charter boat CPUE value was the lowest of the time series, and has significantly declined from 1993-2013.

Summer flounder mean length from the pound net survey was 268 mm TL in 2014, the lowest mean value the 22 year survey. The 2014 length frequency distribution was skewed toward smaller fish. Charter boat CPUE declined from 1993 - 2003, but was relatively stable form 2004 to 2013. The NMFS 2013 coast wide stock assessment concluded that summer flounder stocks were not overfished, overfishing was not occurring.

Mean length of bluefish from the pound net survey in 2014 was 319 mm TL, and was above the time series mean. The length distribution indicated a slight shift to larger bluefish in 2014. Recreational and commercial bluefish harvest gave conflicting signals in 2013, with commercial harvest declining three fold and the recreational harvest estimate nearly doubling. The 2012 coast wide stock assessment update indicated the stock was not overfished and overfishing is not occurring.

The mean length of Atlantic croaker examined from the pound net survey in 2014 was 249 mm TL; this was the fourth lowest value of the 22 year time series. Maryland 2013 Atlantic croaker total commercial harvest and recreational harvest estimate values of 844,570 pounds and 1,038,745 fish, respectively, were similar to the 2012 values. The 2013 charter boat geometric catch per angler of 4.73, was above the long term mean and similar to 2011 and 2012 values.

Spot mean length decreased in 2014, remaining below the long term mean. Commercial harvests increased sharply in 2013 after a marked decline in 2012. The recreational harvest estimate increased in 2013, but remained bellow the time series mean. The charter boat geometric mean catch per angler has been highly variable in recent years, reaching the time series high in 2013, which was proceed by a very low value in 2012. The spot juvenile index spiked to the time series high in 2010, declined to near the time series low in 2011, rose in 2012 to the eighth highest value in the 25 year time series, and declined again in 2013 and 2014.

Resident / premigratory striped bass sampled from pound nets in the Chesapeake Bay during the summer – fall 2013 ranged in age from 2 to 10 years old. Two year old (2011 year-class), three year old (2010 year-class), four year old (2009 year-class), five year old (2008 year-class), and six year old (2007 year-class) striped bass dominated biological samples taken from pound nets. These five year-classes comprised 97.7% 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 eight year old striped bass from the 2005 through 2010 year-classes and comprised 99.1% of the sampled harvest.

The 2013-2014 commercial striped bass drift gill net fishery harvest was comprised primarily of fish 4, 5, 6 and 7 years old from the 2007 through 2010 year-classes. Striped bass from the 2009 year-class (five year old fish) composed 37% of the total drift gill net harvest. The 2008 and 2007 (ages 6 and 7) cohorts accounted for 42% of the total harvest while age groups 8 to 13 year-old fish contributed 14% to the total. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 4 to 13 years old (2001 to 2010 year-classes).

Fish harvested during the 2013-2014 Atlantic coast fishing season ranged from age 5 (2009 year-class) to age 16 (1998 year-class). Twelve year-classes were represented in the sampled harvest. Approximately 90% of striped bass harvested were ages 6 through 11. Striped bass were recruited into the Atlantic coast fishery as young as age 5. However, due to the 24 inch minimum size limit, few fish younger than age 6 were harvested, similar to previous years. Based on the estimated catch-at-age, the most common age harvested during the 2013-2014 Atlantic coast harvest was age 11 (2003 year-class), which represented 31% of the landings. Large contributions were also made by the 2004 year-class (age 10) and the 2005 year- class (age 9), which represented 17% and 16% of the fishery, respectively.

The spring 2014 spawning stock survey indicated that there were 17 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 18 years old. Male striped bass ranged in age from 2 to 16 years old and females ranged in age from 6 to 18, with age 11 (2003 year-class) females the year-class most commonly observed. During the spring 2014 spawning season, age 8 and older females made up 80% of the female spawning stock. Females from the dominant 1996 year-class are still 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 11.0 in 2014. This was nearly equal to the 61-year average of 11.7, indicating a healthy level of striped bass reproduction. 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 abundance.

During the 2014 survey, biologists collected over 60,000 fish of 56 species, including 1,454 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 3-year-old fish are currently very abundant in the Chesapeake Bay. The Juvenile Survey data is also used to assess spawning success of other important species. In addition to striped bass, American shad, blueback herring, and white perch are other species that experienced successful reproduction in 2014**.**

During the 2014 spring recreational trophy season, biologists intercepted 209 fishing trips, interviewed 580 anglers, and examined 211 striped bass. The average total length of striped bass sampled was 946 mm total length (mm TL) (37.2 inches). The average weight was 9.1 kg (20.1 lbs). Striped bass sampled from the trophy fishery ranged in age from 7 to 18 years old. The 2003 (age 11) and 2004 (age 10) year-classes were the most frequently observed cohorts sampled from the spring recreational fishery. In 2014, the average private boat catch rate based on angler interviews was 0.3 fish per hour, the same rate as in 2013.

Maryland Department of Natural Resources biologists continued to tag and release striped bass in spring, 2014 in support of the US FWS coordinated interstate, coastal population study for growth and mortality. A total of 1,118 striped bass were tagged and released with USFWS internal anchor tags between March through May 2014 in Maryland. Of this sample, 336 were tagged in the Potomac River and 782 were tagged in the upper Chesapeake Bay area during the spring spawning stock assessment survey. A total of 921 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 four sampling areas; Sassafras River (SAS), Elk River (EB), upper Chesapeake Bay (UB), and middle Chesapeake

Bay (MB). Eighteen sampling stations, each approximately 2.6 km (1.5 miles) in length and variable in width, were created throughout the study area (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 3 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 2013 through February 2014.

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. During 2012, 107 of the scheduled 108 hauls were completed. In 2013, ice-cover prevented the sampling of several Upper Bay sites allowing the completion of 86 of the scheduled 108 hauls. In 2014, ice-cover once again prevented the sampling of several Upper Bay sites allowing the completion of 60 of the scheduled 108 hauls.

Choptank River Fishery Independent Sampling

In 2014, 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 6 March through 16 April (Figure 2). These nets contained a 64 mm stretch-mesh body and 76 mm stretch-mesh in the wings (7.6 m long) and leads (30.5 m long). Nets were set perpendicular to the shore with the wings at 45° angles.

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

Upper Chesapeake Bay Fishery Dependent Sampling

Commercial fyke net catches were sampled for yellow perch on 3 March 2014 in Patapsco and Back Rivers, 8 March 2014 in Bush River, 15 March 2014 in Sassafras River. (Figures 3, 4, 5, 6). 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

From 28 March 2014 to 29 April 2014, resident species were sampled from pound nets and fyke nets set by commercial fishermen on the Nanticoke River. This segment of the survey was completed in coordination with Project 2, Job 1 of this grant. Nets were set from Barren Creek (35.7 rkm) downstream to Monday's Gut (30.4 rkm; Figure 7). Net sites and dates fished were at the discretion of the commercial fishermen. All yellow perch caught were sexed, measured for total length and a non-random sample of otoliths removed for age determination. Thirty randomly selected white perch from the fyke nets were sexed and measured and a subsample was processed for age determination (otoliths). A bushel of unculled, mixed catfish species was randomly selected, identified as channel or white catfish and total lengths measured.

The 2014 sampling season was severely truncated due to snow and ice conditions. As such, the yellow perch run had finished before sampling was initiated. In addition, sample sizes for channel catfish and white catfish were also very low.

II. Data compilation

Population Age Structures

Population age structures were determined for yellow perch and white perch from the Choptank and Nanticoke rivers and the 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, Nanticoke River, and upper Bay commercial fyke net surveys 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, Nanticoke 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. Current Nanticoke River yellow perch rates were not estimated because of unequal recruitment rates, varying annual sample sizes, and an inability to assign associated effort data to catches. Instantaneous mortality rates for yellow perch from upper Bay commercial samples were calculated with a statistical catch-at-age model (see Project 1, Job2).

Recruitment

Recruitment data were provided from age 1+ 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 which provided a good index of juvenile abundance. Therefore, only the Howell Pt., Ordinary Pt., Tim's Creek, Elk Neck Park, Parlor Pt., and Welch Pt. permanent sites were used to determine the yellow perch juvenile relative abundance index. However, the Ordinary Pt. seine site was lost because of bulkhead construction and the replacement site was not included in the index. This index is reported as an average $\log_e$ (catch+1) index. White perch and channel catfish 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 target species was determined as the grand mean abundance from all surveys where reliable effort data were available. For white perch and yellow perch, relative abundance as CPUE at age was determined from the catch-at-age matrices. Fyke net effort for yellow perch 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.

RESULTS

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

Population Age Structures

White perch	Tables 1-3
Yellow perch	Tables 4-7

Population Length Structures

White perch	Tables 8-10 and Figures 8-10
Yellow perch	Tables 11-14 and Figures 11-14
Channel catfish	Tables 15-17 and Figures 15-17
White catfish	Tables 18-20 and Figures 18-20

Growth

White perch	Tables 21-22
Yellow perch	Tables 23-25

Mortality

White perch	Table 26
Yellow perch	Table 27

Recruitment

White perch	Figures 21-22
Yellow perch	Figures 23-24
Channel catfish	Figure 25

Relative Abundance

White perch	Tables 28-29
Yellow perch	Tables 30-31 and Figure 26
Channel catfish	Figures 27-28
White catfish	Figure 29

CITATIONS

Gablehouse, D. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management. 4:273-285.

Microsoft Corporation. 1993. User's Guide Microsoft Excel 5.0. Microsoft Press, Redmond, WA.

Palisades Corporation. 2001. Evolver The genetic algorithm solver for Microsoft Excel. Newfield, NY.

Piavis, P. and E. Webb, III. in publication. Assessment of upper Chesapeake Bay yellow perch stocks with a statistical catch-at-age model. Fisheries Technical Report Series. Maryland Department of Natural Resources, Fisheries Service. Annapolis, Maryland.

Sadzinski, R., A. Jarzynski, P. Piavis, and M. Topolski. 2002. Stock assessment of selected adult resident and migratory finfish in Maryland's Chesapeake Bay. MD Department of Natural Resources, Federal Aid Annual Report F-54-R, Annapolis, MD.

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Figure 1. Upper Chesapeake Bay winter trawl survey locations, December 2013 – February 2014. Different symbols indicate each of 6 different sampling rounds.

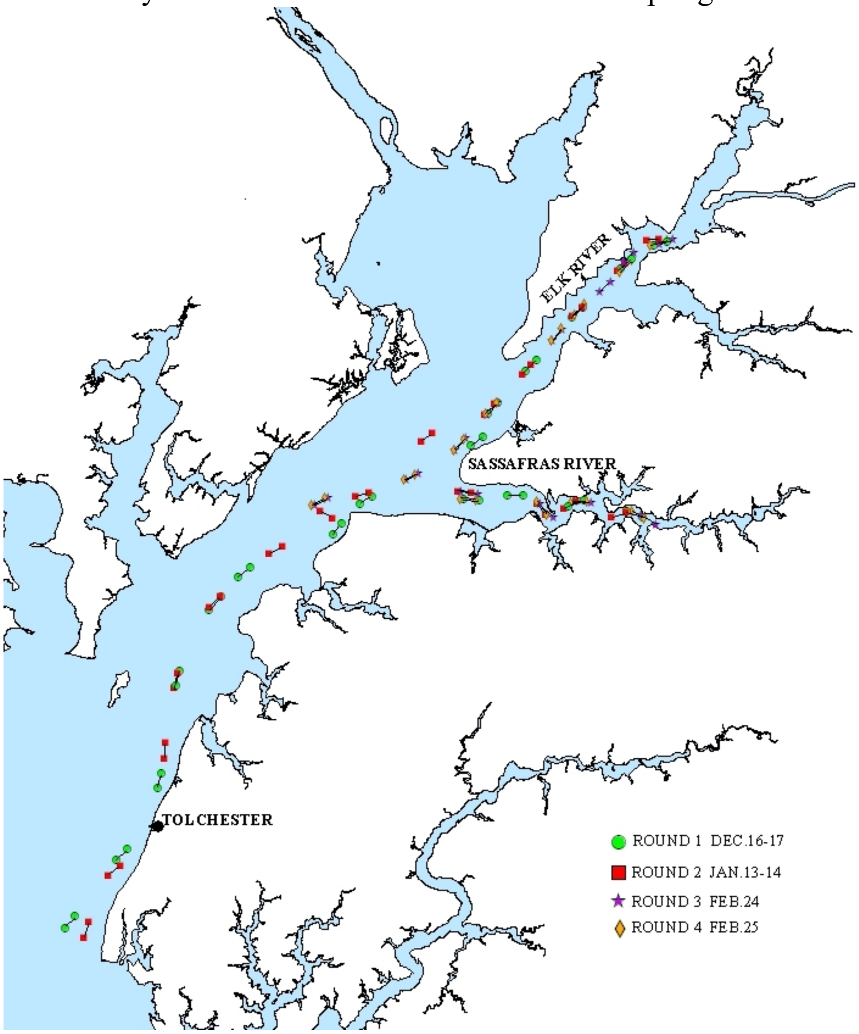


Figure 2. Choptank River fyke net locations, 2014. Circles indicate sites.

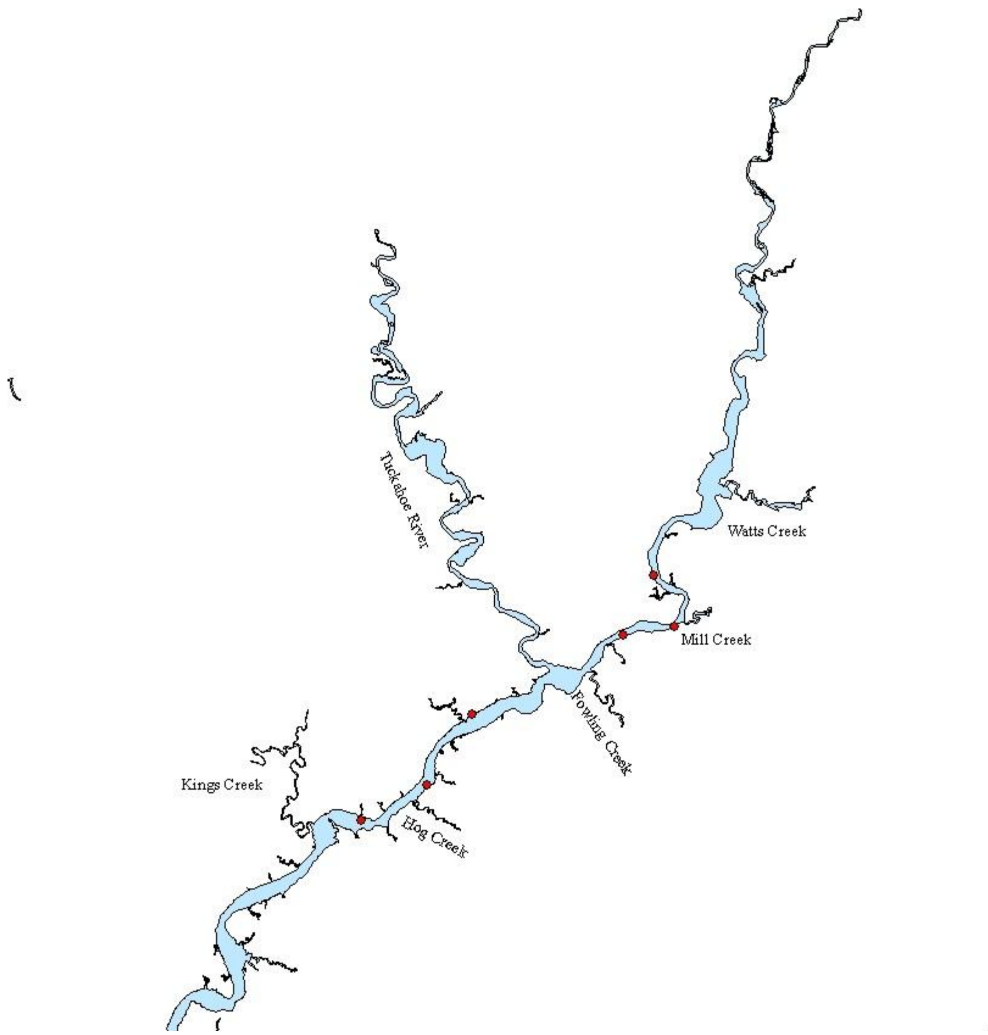


Figure 3. Commercial yellow perch fyke net sites sampled during 2014 in Patapsco River. Circles indicate sites.

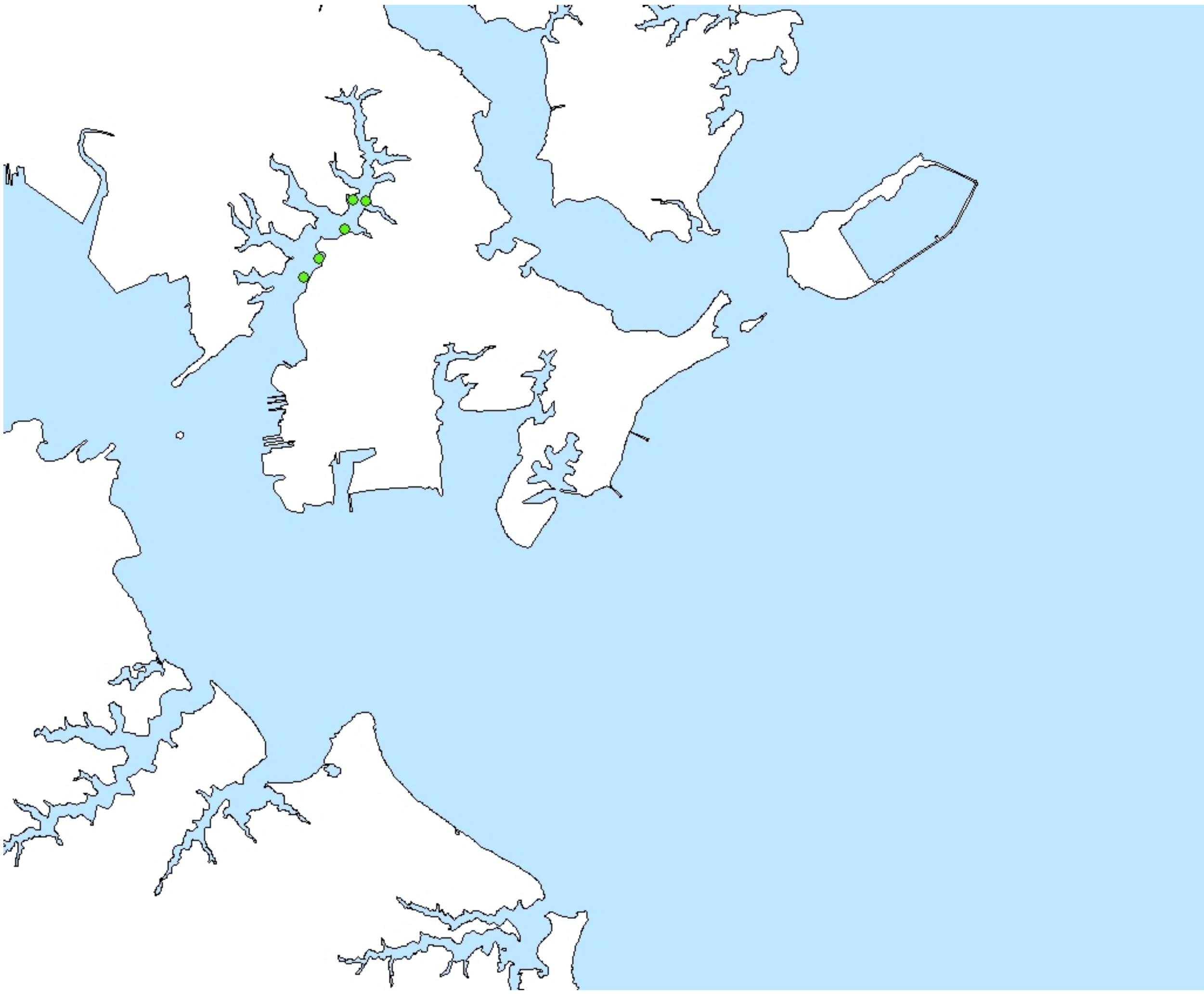


Figure 4. Commercial yellow perch fyke net sites sampled during 2014 in Back River and Seneca Creek. Circles indicate fyke net locations.

Figure 5. Commercial yellow perch fyke net sites sampled during 2014 in Bush River. Black circles indicate fyke net locations.

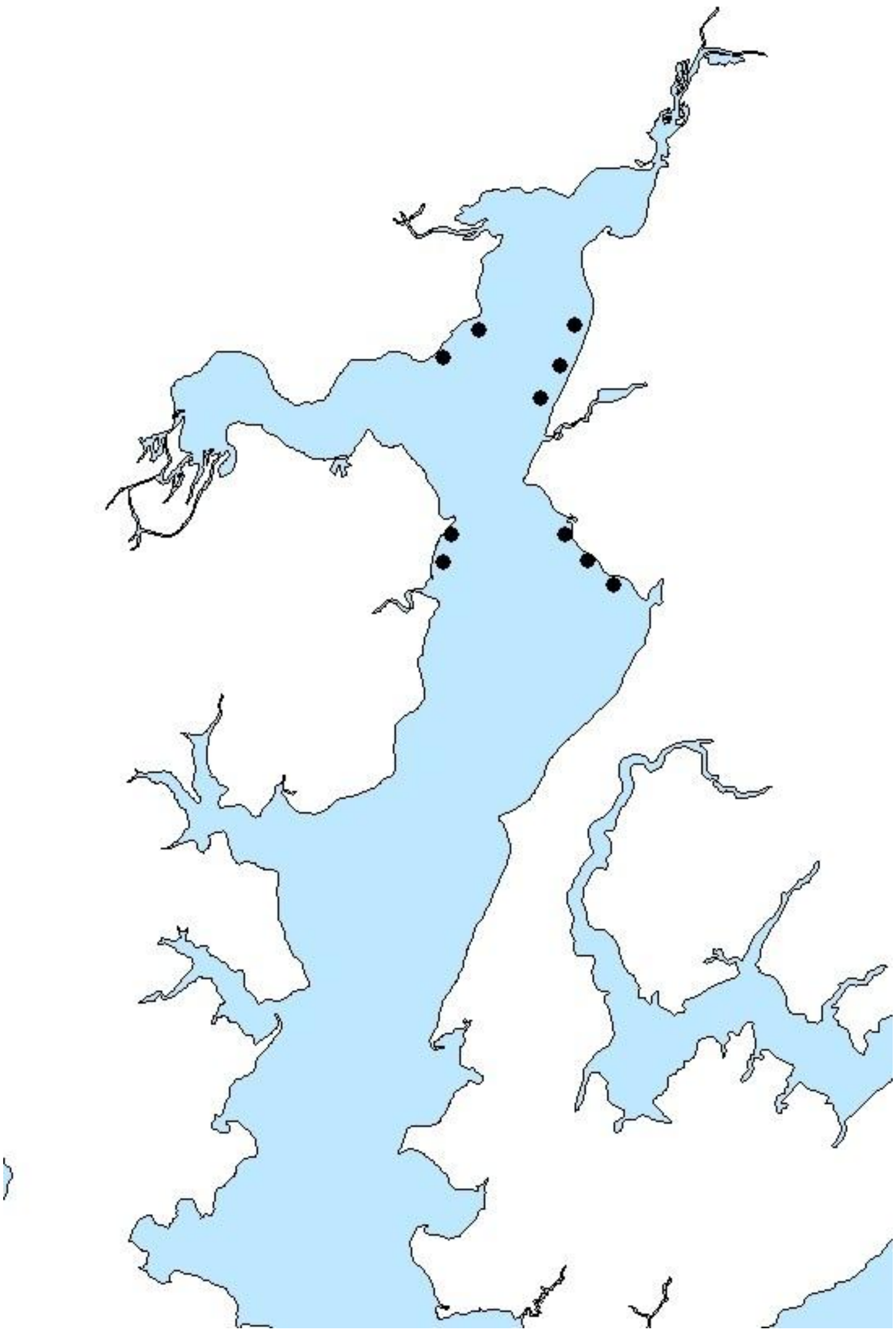


Figure 6. Commercial yellow perch fyke net sites sampled during 2014 in Sassafras River

Figure 7. Commercial fyke net and pound net sites sampled during 2014 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

Table 1. White perch catch-at-age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2014.

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

Table 2. White perch catch-at-age matrix from Choptank River fyke net survey, 2000 – 2014.

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

Table 3. White perch catch-at-age matrix from Nanticoke River fyke and pound net survey, 2000 – 2014. 2007 -- 2009 include Marshyhope River data.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
2000	0	42	593	6,074	6,471	2,813	1,942	365	81	0
2001	0	0	681	796	3,262	1,822	689	785	94	38
2002	0	5	1,469	1,927	504	2,124	1,132	632	244	135
2003	0	97	318	2,559	1,567	446	994	652	180	175
2004	0	6,930	3,892	12,215	3,259	1,835	1,297	1,361	443	886
2005	0	826	1,302	5,847	3,903	5,288	2,400	1,237	1,497	2,582
2006	0	0	5,759	3,280	5,298	3,488	3,590	1,287	861	799
2007	0	497	1,948	12,876	727	6,236	2,260	2,716	977	1,573
2008	0	33	902	1,188	2,780	824	1,457	665	593	496
2009	0	70	1,351	4,135	2,117	6,216	1,188	1,651	889	1,470
2010	0	101	273	155	414	315	1,113	88	143	166
2011	0	933	1,625	7,817	1,167	4,433	1,750	5,133	1.050	3,034
2012	4	134	387	176	539	214	330	57	276	85
2013	5	418	1,342	1,587	270	615	433	671	207	723
2014	0	0	1,511	1,444	1,191	372	601	154	464	531

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2014.

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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2014.

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

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2014.

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

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2014. 2007 -- 2009 include Marshyhope River data.

YEAR	AGE									
	1	2	3	4	5	6	7	8	9	10+
1999	0	10	1,072	323	295	22	0	4	14	22
2000	0	0	16	561	78	83	7	0	0	0
2001	0	2	36	114	737	48	36	3	0	0
2002	0	128	9	60	36	940	39	24	6	0
2003	0	17	123	2	49	2	45	1	2	0
2004	0	7	58	93	0	1	10	21	1	0
2005	0	59	6	34	35	0	1	0	4	0
2006	0	56	381	18	34	50	4	3	6	5
2007	0	38	244	291	37	32	16	0	0	2
2008	0	36	238	144	148	25	9	4	2	7
2009	0	37	374	660	336	126	9	0	11	0
2010	0	0	0	3	6	5	0	0	0	0
2011	0	2	6	31	22	20	10	2	0	0
2012	0	28	12	8	11	15	14	4	1	0
2013	0	17	42	25	4	4	8	4	1	0
2014	LATE START ONLY 22 YELLOW PERCH COLLECTED									

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2014. 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

Figure 8. White perch length-frequency from 2014 upper Chesapeake Bay winter trawl survey.

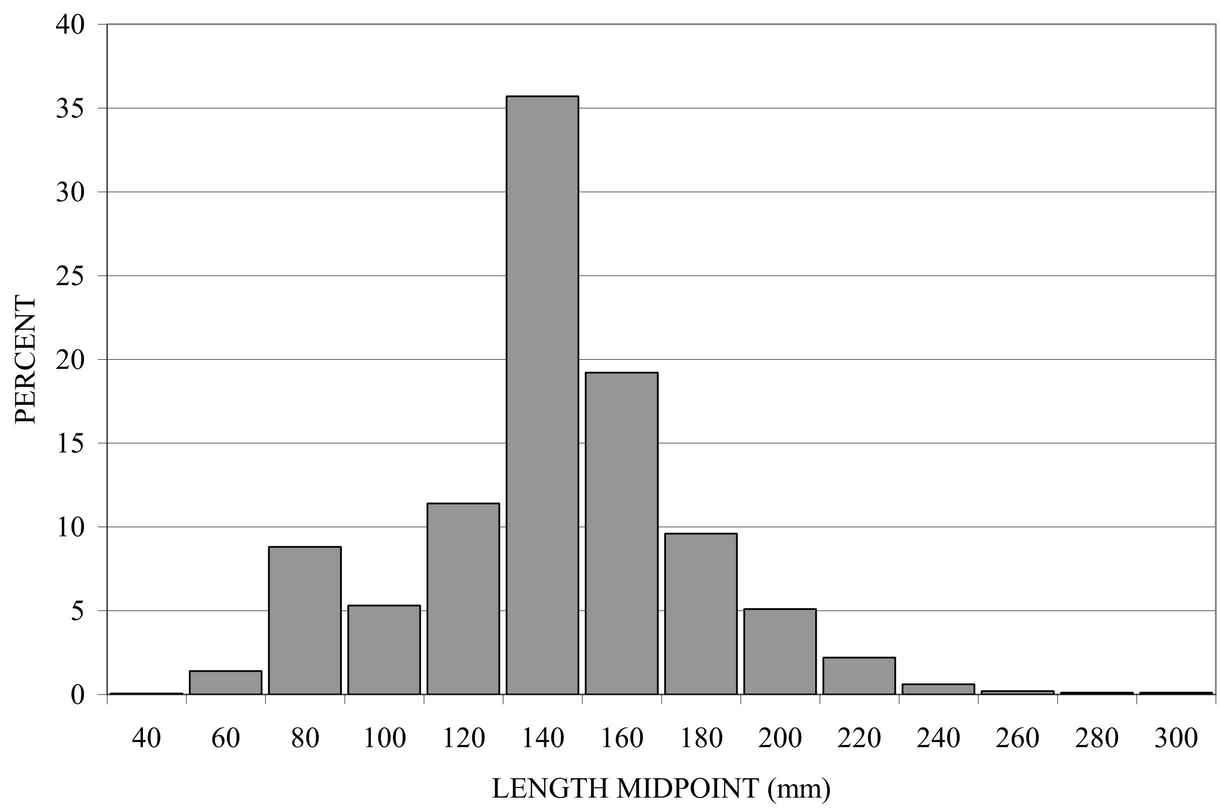


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2014. Minimum length cut-offs in parentheses.

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

Figure 9. White perch length-frequency from 2014 Choptank River fyke net survey.

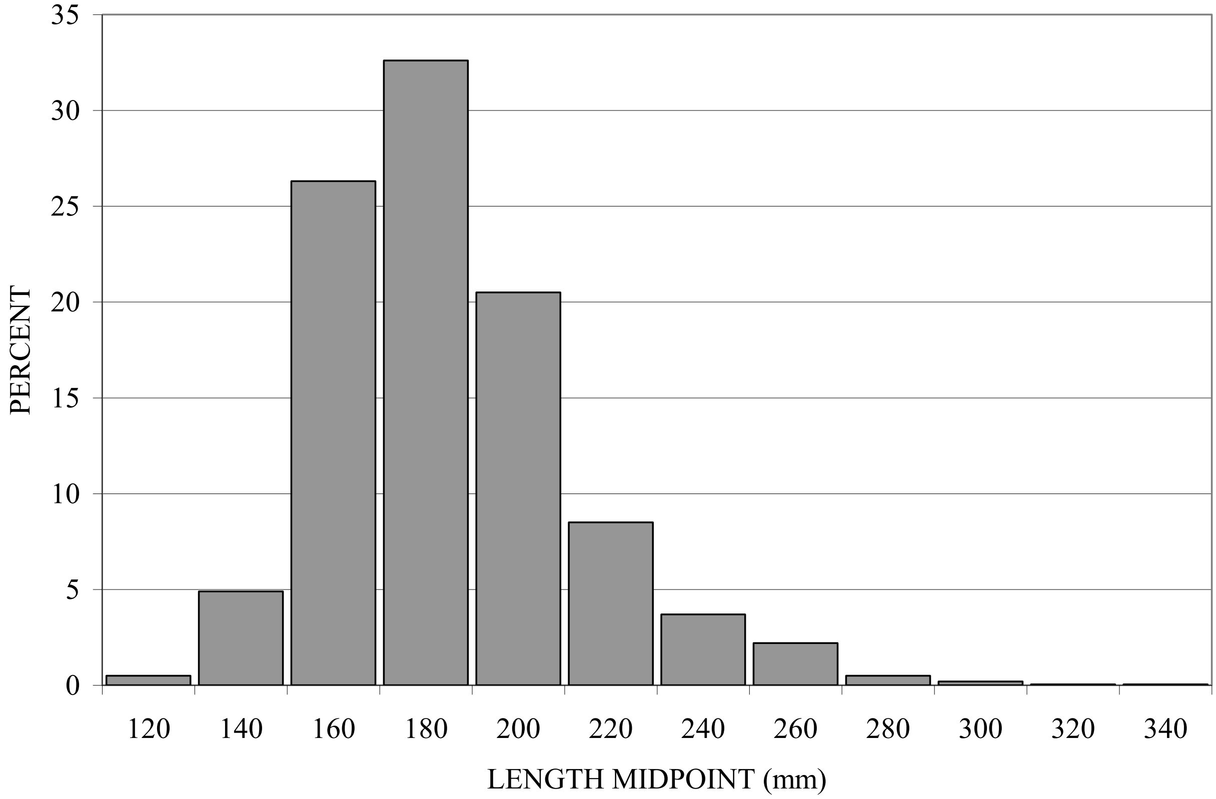


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2014. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

Year	**Stock** (125 mm)	**Quality** (200 mm)	**Preferred** (255 mm)	**Memorable** (305 mm)	**Trophy** (380 mm)
1995	56.3	35.4	5.2	3.0	0.0
1996	37.8	54.2	7.3	0.7	0.0
1997	37.5	58.4	4.0	<0.1	0.0
1998	30.4	63.1	6.4	<0.1	0.0
1999	37.2	57.7	5.0	<0.1	0.0
2000	31.3	58.9	9.7	<0.1	0.0
2001	26.2	60.7	12.5	0.6	0.0
2002	32.4	52.9	14.3	0.4	0.0
2003	26.4	60.6	11.9	1.1	0.0
2004	23.0	61.0	14.0	2.0	0.0
2005	25.3	52.8	19.3	2.6	0.0
2006	26.1	56.7	16.3	<0.1	0.0
2007	36.3	52.4	10.0	1.4	0.0
2008	36.2	50.9	12.2	0.7	0.0
2009	33.6	53.2	12.2	1.0	0.0
2010	22.0	53.6	23.1	1.1	0.2
2011	25.1	53.0	19.1	2.7	0.0
2012	30.4	47.7	19.9	2.0	0.0
2013	23.6	49.8	23.2	3.4	0.0
2014	30.7	54.7	13.1	1.5	0.0

Figure 10. White perch length-frequency from 2014 Nanticoke River fyke and pound net survey.

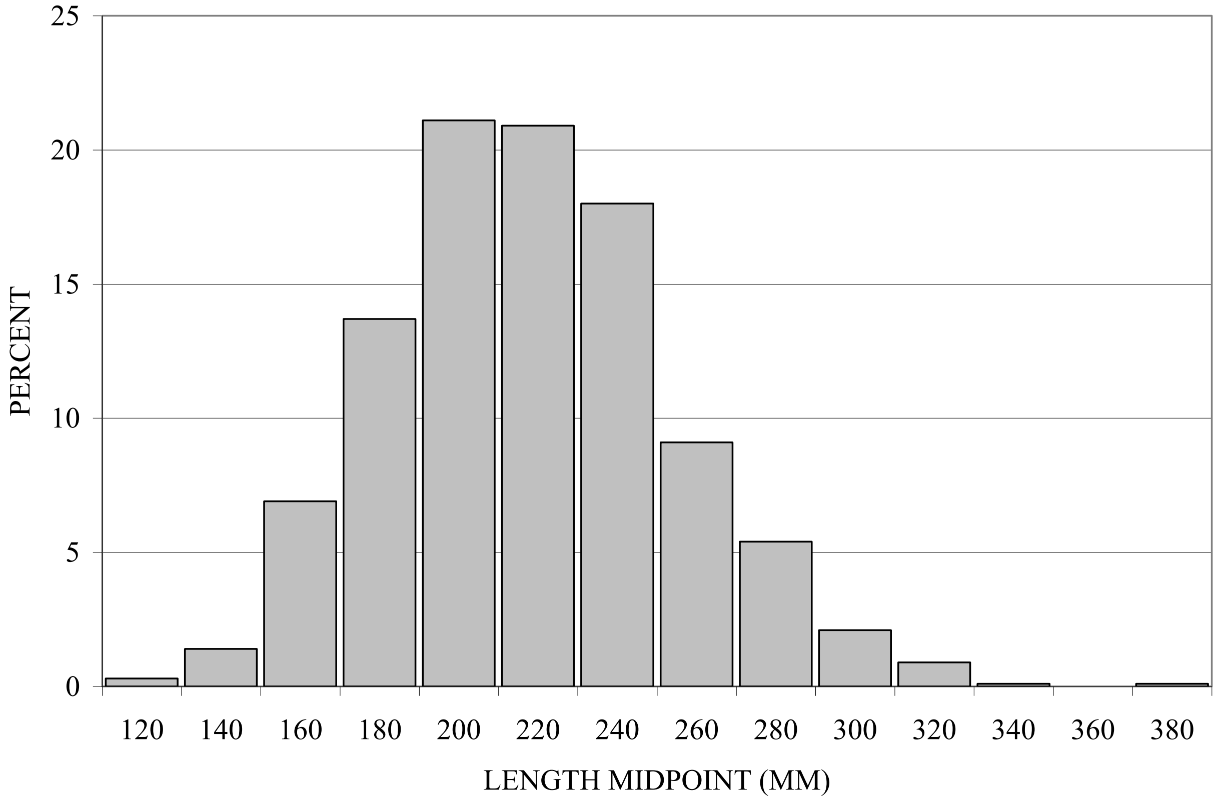


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2014. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length-frequency from the 2014 upper Chesapeake Bay winter trawl survey.

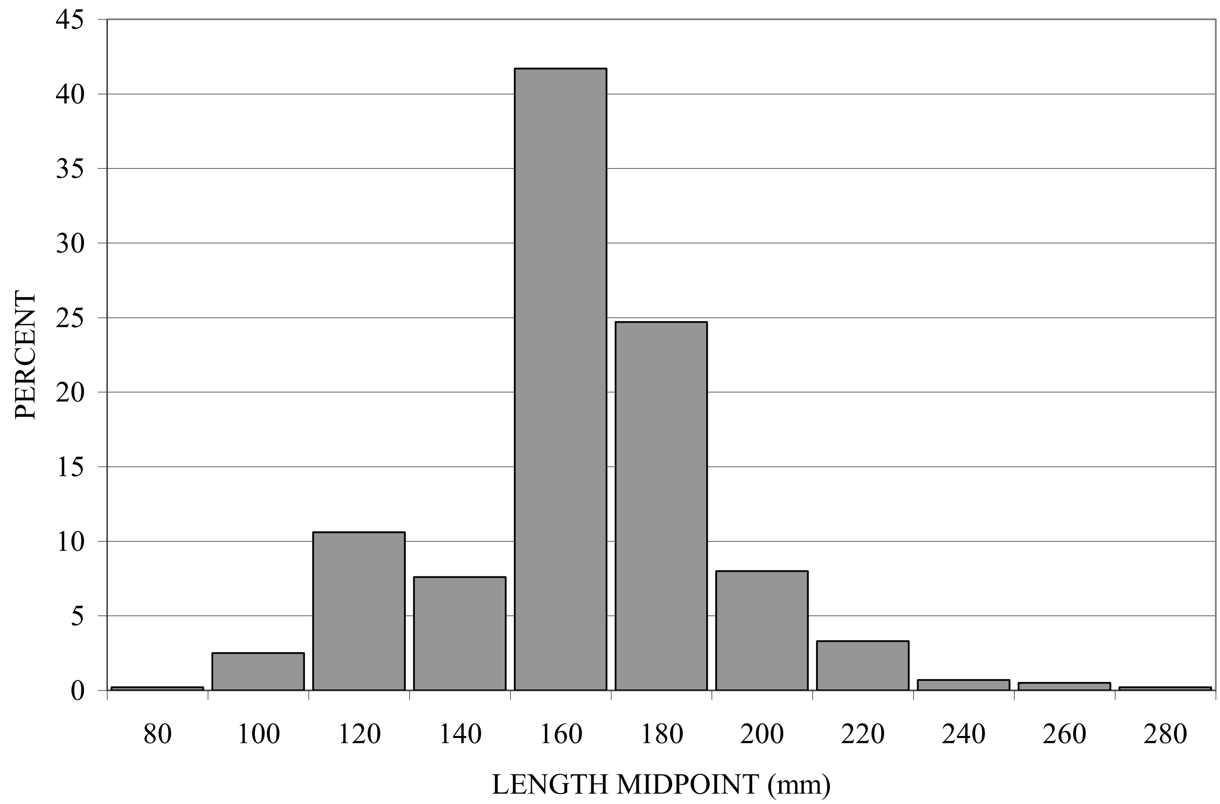


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2014. Minimum length cut-offs in parentheses.

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

Figure 12. Yellow perch length-frequency from the 2014 Choptank River fyke net survey.

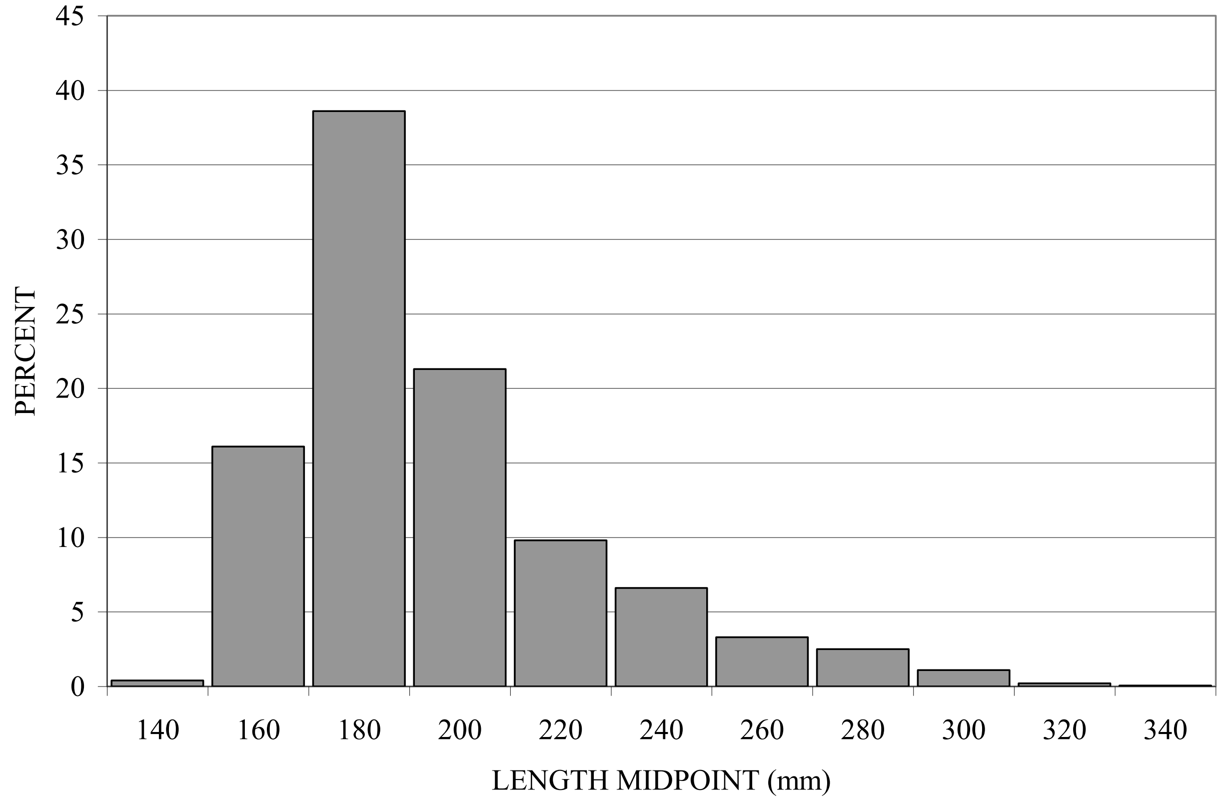


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2014. Minimum length cut-offs in parentheses.

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

Figure 13. Yellow perch length frequency from the 2014 upper Chesapeake commercial fyke net survey.

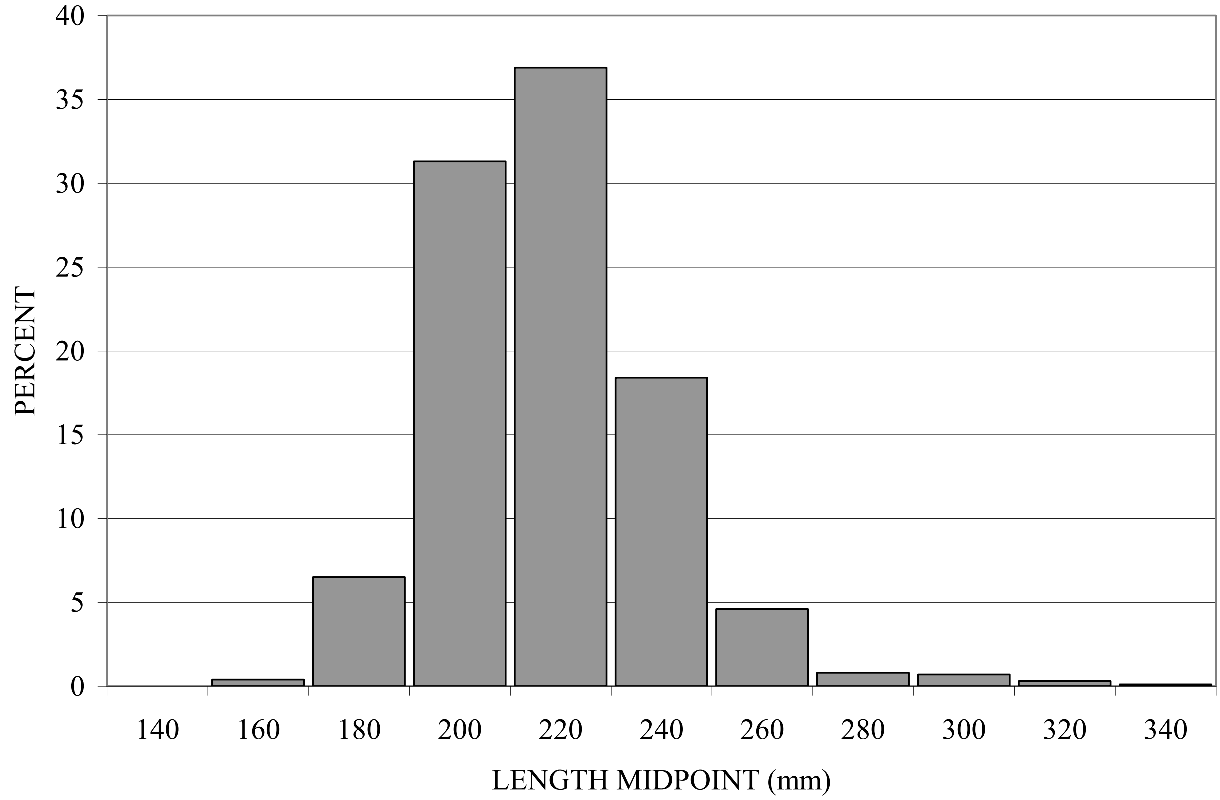


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2014. Minimum length cut-offs in parentheses; 2007-- 2009 includes Marshyhope River data.

Year	**Stock** (140 mm)	**Quality** (216 mm)	**Preferred** (255 mm)	**Memorable** (318 mm)	**Trophy** (405 mm)
1999	12.4	28.8	55.6	3.2	0.0
2000	3.1	19.5	72	5.2	0.0
2001	2.4	22.2	66.6	8.9	0.0
2002	2.9	18.9	62.5	15.7	0.0
2003	10.9	46.6	36.3	6.2	0.0
2004	1.6	27.2	60.7	10.5	0.0
2005	16.2	33.8	38.7	11.3	0.0
2006	4.1	34.1	57.1	4.7	0.0
2007	15.7	21.8	57.1	5.4	0.0
2008	27.4	25.0	42.1	5.5	0.0
2009	9.0	28.0	53.9	9.0	0.0
2010	0.0	14.3	78.6	7.1	0.0
2011	2.2	15.0	75.3	7.5	0.0
2012	24.7	16.1	44.1	15.0	0.0
2013	22.9	15.2	57.1	4.8	0.0
2014	9.1	13.6	77.3	0.0	0.0

Figure 14. Yellow perch length frequency from the 2014 Nanticoke River survey fyke and pound net survey.

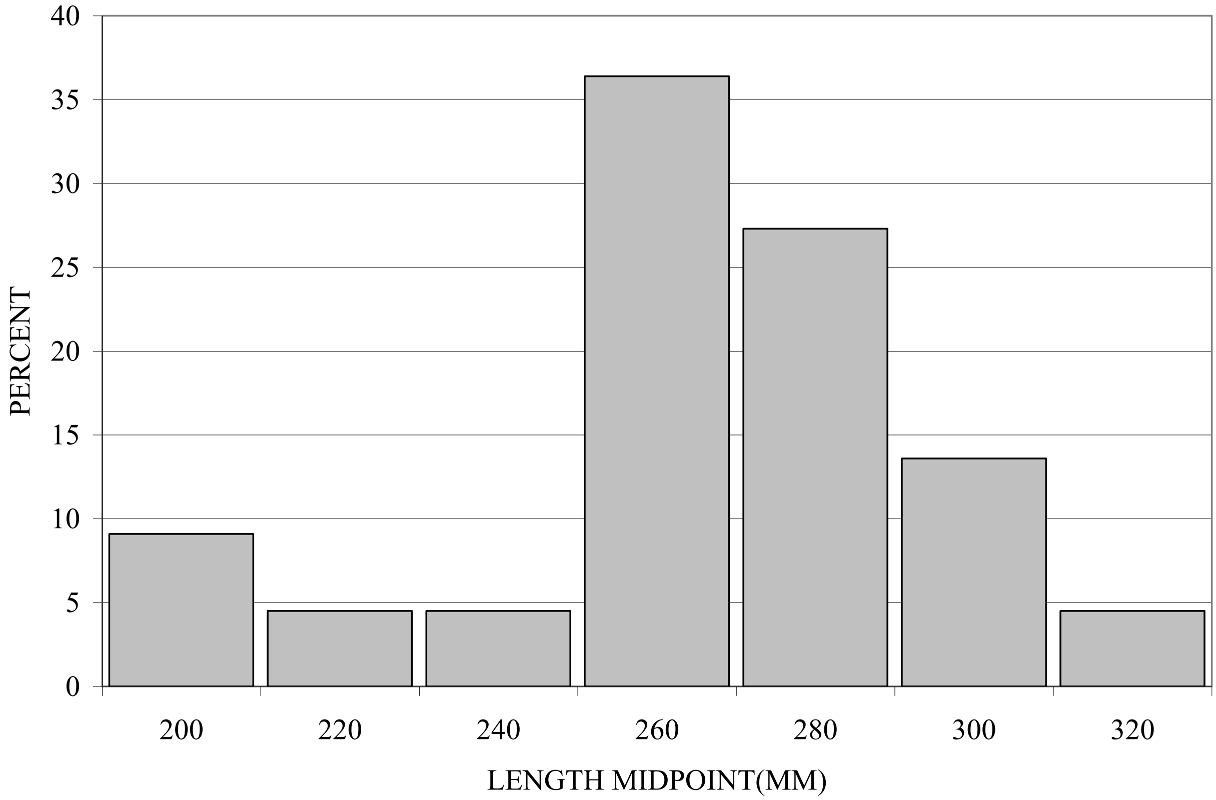


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2014. Minimum length cut-offs in parentheses.

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

Figure 15. Length frequency of channel catfish from the 2014 upper Chesapeake Bay winter trawl survey.

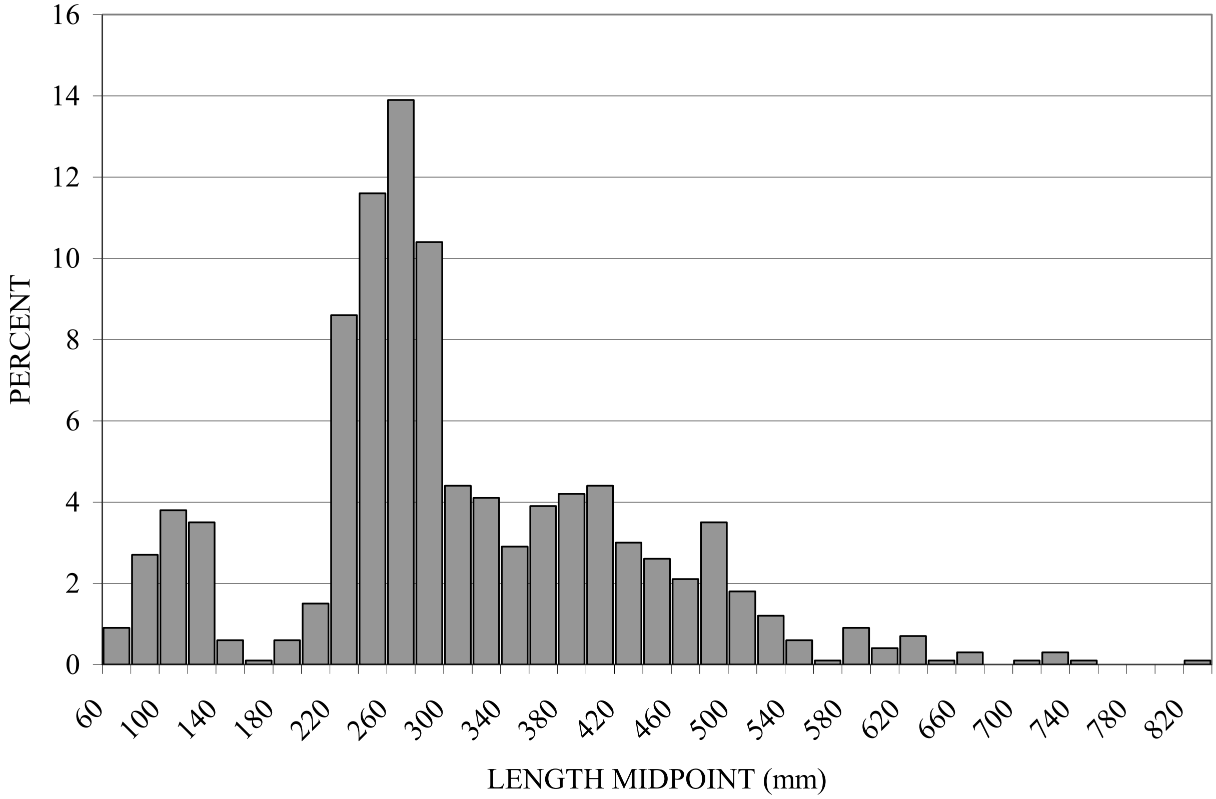


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2014. Minimum length cut-offs in parentheses.

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

Figure 16. Channel catfish length frequency from the 2014 Choptank River fyke net survey.

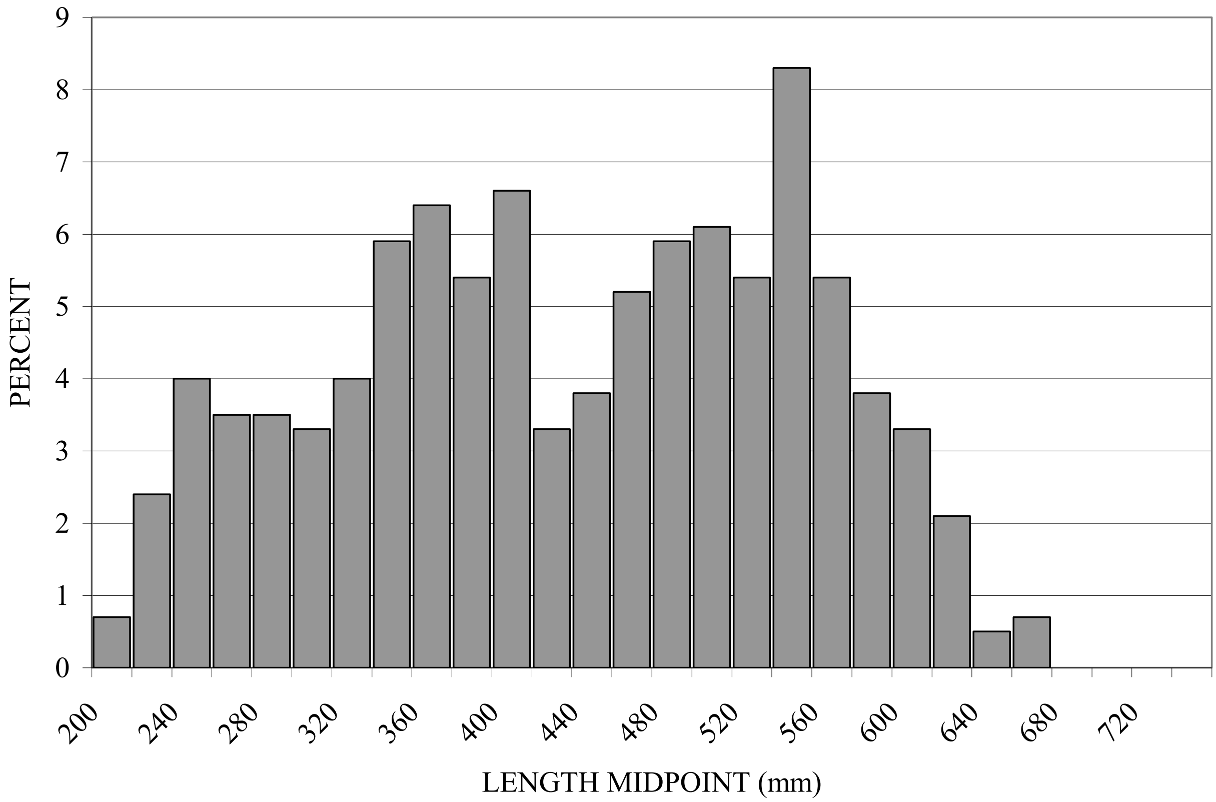


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2014. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

Year	**Stock** (255 mm)	**Quality** (460 mm)	**Preferred** (510 mm)	**Memorable** (710 mm)	**Trophy** (890 mm)
1995	72.3	19.4	8.2	0.0	0.0
1996	65.8	23.8	10.4	0.0	0.0
1997	62.2	27.5	10.2	0.0	0.0
1998	60.3	27.7	12.0	0.0	0.0
1999	80.6	14.6	4.7	0.0	0.0
2000	70.9	22.1	7.1	0.0	0.0
2001	70.2	22.9	6.9	0.0	0.0
2002	56.4	31.1	12.5	0.0	0.0
2003	52.3	29.2	18.4	0.0	0.0
2004	60.8	27.8	11.5	0.0	0.0
2005	48.8	30.6	20.6	0.0	0.0
2006	63.7	23.0	13.3	0.0	0.0
2007	67.4	22.8	9.8	0.0	0.0
2008	69.4	17.8	12.6	0.3	0.0
2009	66.5	18.4	15.1	0.0	0.0
2010	45.0	23.3	30.0	1.7	0.0
2011	74.1	13.0	13.0	0.0	0.0
2012	22.5	30.2	47.3	0.0	0.0
2013	32.5	27.3	49.2	0.0	0.0
2014	10.0	17.0	73.0	0.0	0.0

Figure 17. Channel catfish length frequency from the 2014 Nanticoke River fyke and pound net survey.

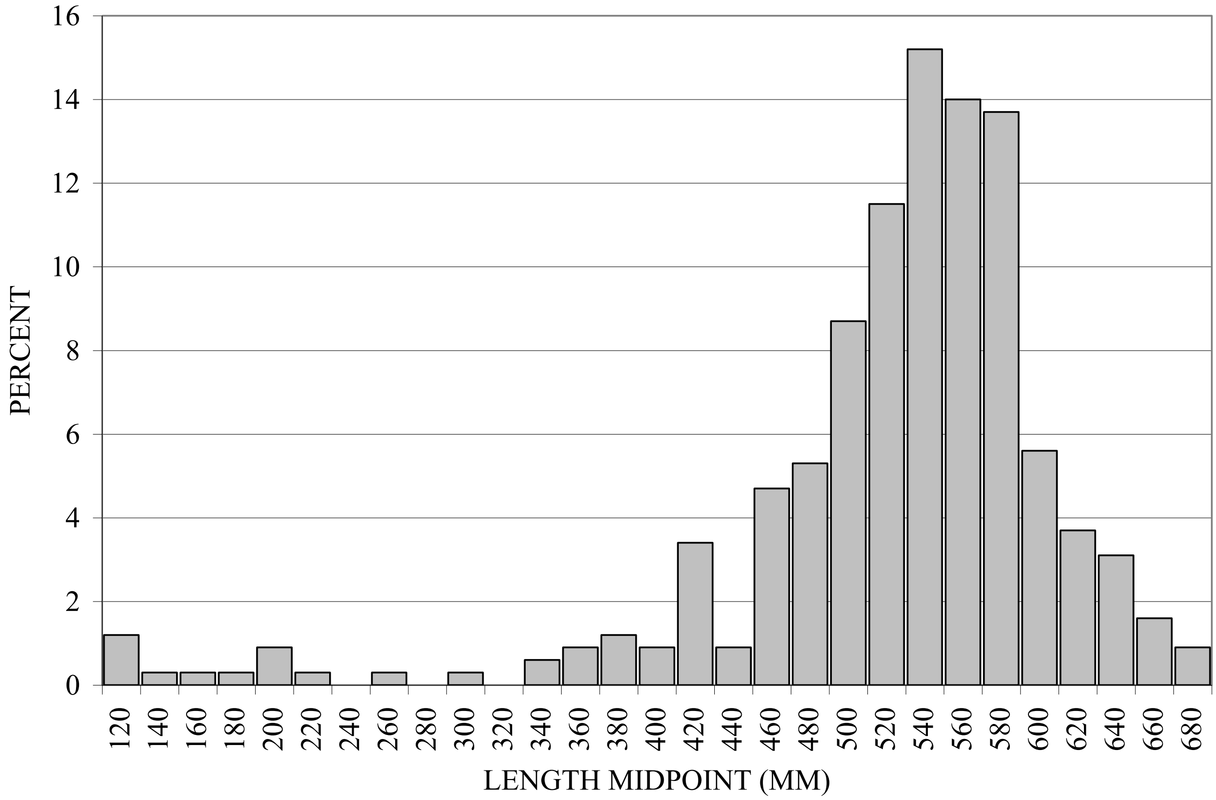


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2014. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2014 upper Chesapeake Bay winter trawl survey.

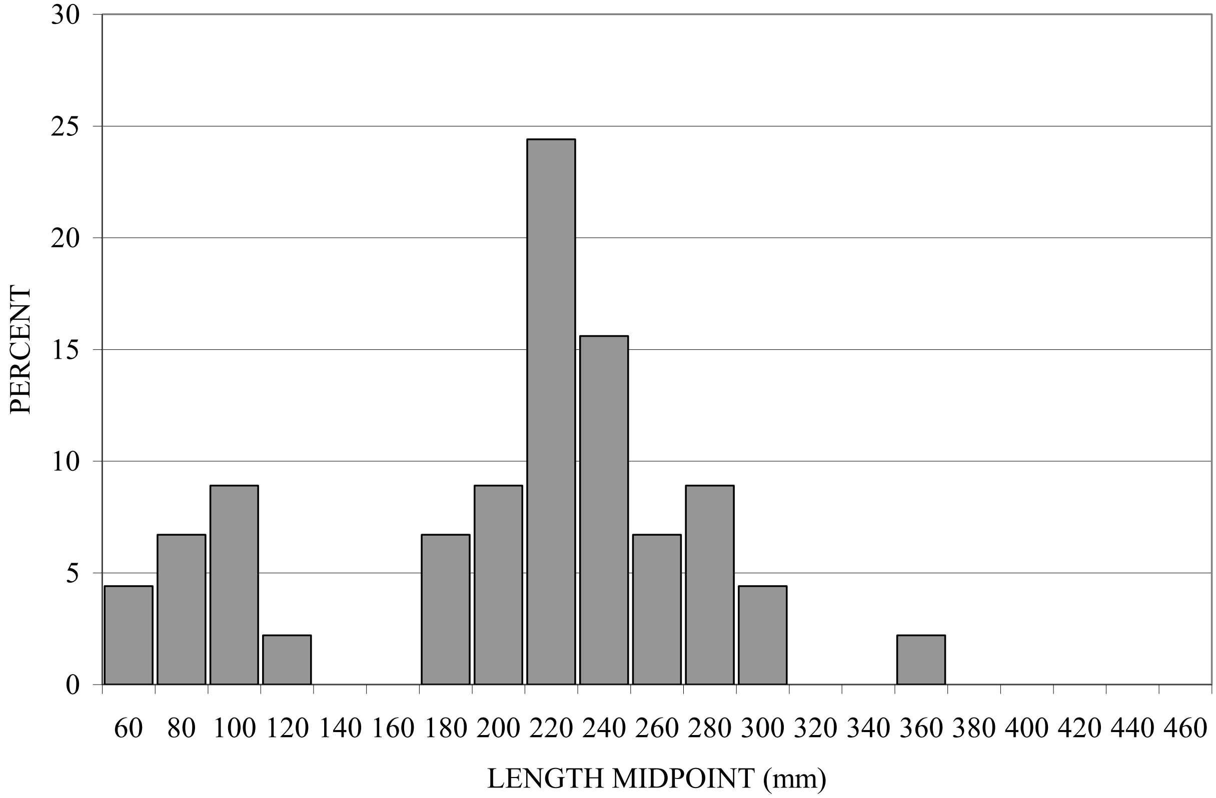


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2014. Minimum length cut-offs in parentheses.

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

Figure 19. White catfish length frequency from the 2014 Choptank River fyke net survey.

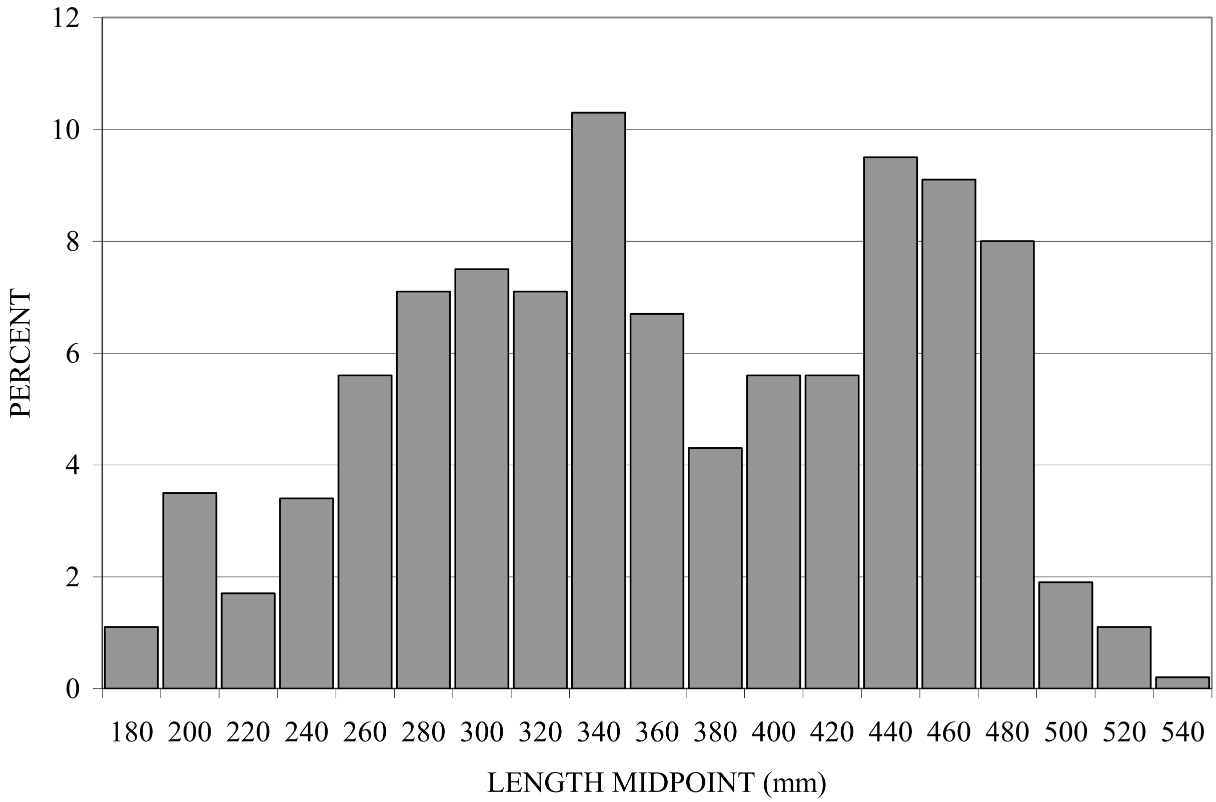


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2014. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

Year	**Stock** (165 mm)	**Quality** (255 mm)	**Preferred** (350 mm)	**Memorable** (405 mm)	**Trophy** (508 mm)
1995	35.7	32.8	14.3	16.6	0.6
1996	42.4	36.9	10.5	9.6	0.6
1997	42.1	37.4	10.9	8.2	1.4
1998	27.9	48.2	17.4	6.0	0.0
1999	41.0	34.5	14.4	10.1	0.0
2000	39.9	42.1	12.0	6.0	0.0
2001	46.2	28.2	16.0	9.0	0.6
2002	37.0	34.6	15.2	12.8	0.5
2003	17.6	32.4	23.5	25.0	1.5
2004	13.2	45.3	34.9	6.6	0.0
2005	47.0	30.3	13.6	9.1	0.0
2006	70.0	21.1	4.3	4.6	0.0
2007	40.0	37.3	14.7	8.0	0.0
2008	62.5	24.1	8.5	4.6	0.3
2009	55.8	21.8	10.5	10.5	1.4
2010	21.4	25.0	14.3	28.6	10.7
2011	43.7	43.7	5.7	5.7	6.9
2012	11.9	25.8	29.6	30.5	2.2
2013	25.4	23.9	16.4	29.4	5.0
2014	10.5	29.7	19.2	38.0	2.6

Figure 20. White catfish length frequency from the 2014 Nanticoke River fyke and pound net survey.

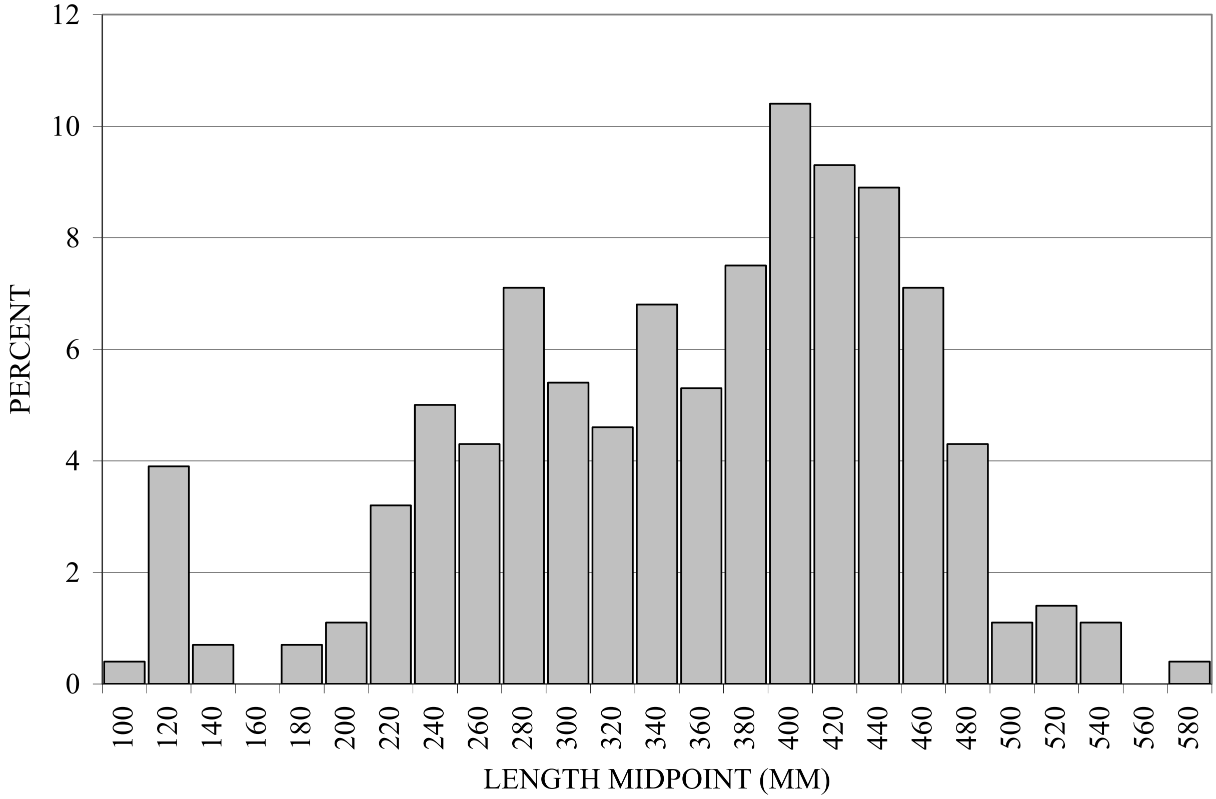


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	Allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2006	F	NSF	285	0.36	0.40	
	M	NSF	275	0.42	0.60	
	Combined	7.8 X 10^{-5}	2.69	273	0.4	0.60
2007	F	1.6 X 10^{-5}	3.00	269	0.33	0.28
	M	5.8 X 10^{-5}	2.74	247	0.32	0.06
	Combined	1.9 X 10^{-5}	2.96	265	0.31	0.15
2008	F	3.0 X 10^{-6}	3.29	317	0.23	-1.44
	M	3.7 X 10^{-6}	3.25	227	0.32	-1.98
	Combined	2.2 X 10^{-6}	3.35	284	0.28	-0.89
2009	F	2.8 X 10^{-6}	3.32	338	0.20	-1.33
	M	2.5 X 10^{-6}	3.32	225	0.49	-0.77
	Combined	1.9 X 10^{-6}	3.38	281	0.32	-0.17
2010	F	4.0 X 10^{-6}	3.26	312	0.18	-1.38
	M	4.2 X 10^{-6}	3.23		NSF	
	Combined	2.6 X 10^{-6}	3.33		NSF	
2011	F	2.3 X 10^{-6}	3.35		NSF	
	M	2.4 X 10^{-6}	3.34	217	0.49	0.44
	Combined	2.0 X 10^{-6}	3.38		NSF	
2012	F	6.9 X 10^{-6}	3.17	264	0.47	0.81
	M	4.5 X 10^{-6}	3.23	227	0.39	-0.21
	Combined	3.1 X 10^{-6}	3.31	251	0.46	0.68
2013	F	8.9 X 10^{-6}	3.10	320	0.13	-4.78
	M	4.8 X 10^{-6}	3.19	245	0.20	-3.64
	Combined	3.8 X 10^{-6}	3.25	284	0.16	-3.66
2014	F	5.9 X 10^{-6}	3.18	278	0.34	-0.40
	M	1.2 X 10^{-6}	3.46	223	0.56	0.37
	Combined	2.9 X 10^{-6}	3.30	255	0.42	0.12
2000 – 2014	F	3.2 X 10^{-6}	3.29	306	0.18	-1.84
	M	5.0 X 10^{-6}	3.20	243	0.23	-1.98
	Combined	5.0 X 10^{-6}	3.21	288	0.20	-1.60

Table 22. White perch growth parameters from Nanticoke River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	(allometry)		(von Bertalanffy)		
		alpha	beta	L-inf	K	t_0
2006	F			311	0.22	-1.41
	M	NA		279	0.19	-2.54
	Combined			321	0.16	-2.60
2007	F	6.2×10^{-6}	2.76	299	0.23	-0.81
	M	1.0×10^{-6}	3.08	282	0.24	-0.79
	Combined	3.4×10^{-6}	2.87	297	0.23	-0.70
2008	F	4.1×10^{-6}	3.25	295	0.35	0.23
	M	8.0×10^{-6}	3.12	254	0.38	-0.20
	Combined	3.6×10^{-6}	3.27	288	0.32	-0.16
2009	F	3.4×10^{-6}	3.28	285	0.33	0.47
	M	1.4×10^{-4}	2.58	273	0.18	-1.70
	Combined	5.9×10^{-6}	3.18	284	0.25	-0.33
2010	F	1.7×10^{-6}	3.41	345	0.16	-1.36
	M	3.4×10^{-5}	2.85	275	0.25	-0.46
	Combined	2.7×10^{-6}	3.32	318	0.18	-1.03
2011	F	1.6×10^{-6}	3.42	313	0.25	-0.20
	M	7.8×10^{-6}	3.13	265	0.26	-0.31
	Combined	1.5×10^{-6}	3.43	293	0.24	-0.39
2012	F	4.5×10^{-6}	3.25	NSF		
	M	1.0×10^{-5}	3.08	318	0.16	-1.56
	Combined	2.9×10^{-6}	3.32	344	0.14	-1.83
2013	F	7.7×10^{-6}	3.14	307	0.28	-0.49
	M	1.7×10^{-5}	2.99	285	0.22	-1.19
	Combined	6.2×10^{-6}	3.18	300	0.24	-0.91
2014	F	1.5×10^{-5}	2.60	311	0.25	-0.62
	M	6.5×10^{-5}	2.73	260	0.47	0.60
	Combined	5.4×10^{-5}	2.77	295	0.25	-0.55
2000 - 2014	F	9.3×10^{-6}	3.11	316	0.20	-1.19
	M	2.0×10^{-5}	2.95	278	0.22	-1.25
	Combined	6.5×10^{-6}	3.17	306	0.20	-1.24

Table 23. 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		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2005	F	NA		293	0.64	-0.5
	M	NA		244	0.63	0.1
	Combined	NA		258	0.45	-1.6
2006	F	NA		297	.36	-1.05
	M	NA		291	.24	-1.09
	Combined	NA		290	.26	-2.00
2007	F	2.3×10^{-5}	2.88	308	0.52	0.19
	M	1.3×10^{-5}	2.97	279	0.29	-1.40
	Combined	1.1×10^{-5}	3.02	277	0.54	-0.01
2008	F	5.8×10^{-6}	3.12	322	0.43	-0.12
	M	1.1×10^{-5}	3.00	253	0.26	-2.82
	Combined	8.1×10^{-6}	3.06	289	0.40	-0.59
2009	F	8.7×10^{-6}	3.06	315	0.40	-0.63
	M	2.8×10^{-6}	3.26	288	0.35	-0.24
	Combined	4.4×10^{-6}	2.18	308	0.29	-1.71
2010	F	1.3×10^{-5}	2.97		NSF	
	M	4.7×10^{-6}	3.16		NSF	
	Combined	9.9×10^{-6}	3.02		NSF	
2011	F	1.2×10^{-6}	3.02		NSF	
	M	4.7×10^{-6}	3.17		NSF	
	Combined	3.2×10^{-6}	3.25		NSF	
2012	F	7.0×10^{-6}	3.08	374	0.18	-2.22
	M	1.5×10^{-6}	3.37	257	0.29	-2.62
	Combined	6.7×10^{-6}	3.09	295	0.32	-1.38
2013	F	9.2×10^{-6}	3.02	294	0.53	-0.28
	M	1.7×10^{-5}	2.92	322	0.10	-6.35
	Combined	1.5×10^{-5}	2.94	267	0.53	-0.48
2014	F	1.5×10^{-5}	2.94	285	0.94	1.57
	M	9.7×10^{-6}	3.03	272	0.33	-0.59
	Combined	1.5×10^{-5}	2.94	271	0.68	0.94
2000 – 2014	F	1.1×10^{-5}	3.00	310	0.33	-0.92
	M	4.0×10^{-6}	3.19	296	0.16	-3.39
	Combined	7.8×10^{-6}	3.07	271	0.37	-1.24

Table 24. 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
2005	F	4.40×10^{-7}	3.62	358	0.25	-0.7
	M	5.61×10^{-7}		3.55	244	0.41
	Combined	1.69×10^{-7}	3.79	256	0.64	0.32
2006	F	5.15×10^{-5}	2.75	288	0.34	-2
	M	4.75×10^{-5}		2.73	240	0.41
	Combined	4.72×10^{-5}	2.75	244	0.6	-2
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
1998 – 2014	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 25. Yellow perch growth parameters from upper Nanticoke 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
2005	F	NSF	332	0.56	-0.1	
	M	3.40×10^{-5}	2.84	286	0.68	0.1
	Combined	NSF	342	0.35	-1.1	
2006	F	NA	313	0.73	0.3	
	M			297	0.57	-0.1
	Combined			301	0.78	0.4
2007	F	1.80×10^{-6}	3.38	346	0.35	-0.8
	M	7.37×10^{-6}	3.10		NSF	
	Combined	1.18×10^{-6}	3.45	308	0.42	-0.8
2008	F	3.37×10^{-6}	3.26	325	0.63	0.28
	M	6.79×10^{-6}	3.10	259	0.92	0.45
	Combined	9.96×10^{-7}	3.46	285	0.90	0.55
2009	F	3.0×10^{-5}	2.87	NSF		
	M	7.5×10^{-5}	2.67	292	0.40	-0.01
	Combined	1.1×10^{-5}	3.05	317	0.32	-1.10
2010	F	NSF			NSF	
	M	NSF			NSF	
	Combined	NSF			NSF	
2011	F	5.4×10^{-5}	2.74		NSF	
	M	3.3×10^{-6}	3.23		NSF	
	Combined	1.6×10^{-5}	2.95		NSF	
2012	F	1.9×10^{-6}	2.93	327	.053	0.08
	M	1.8×10^{-6}	3.34	311	.034	-0.41
	Combined	8.6×10^{-6}	3.07	312	.063	0.43
2013	F	1.3×10^{-5}	3.00	321	0.69	0.78
	M	2.6×10^{-6}	3.29	294	0.43	0.15
	Combined	9.5×10^{-6}	3.06	308	0.80	0.93
2014	F	NA			NA	
	M	NA			NA	
	Combined	NA			NA	
2000 –2014	F	9.3×10^{-6}	3.07	343	0.33	-0.99
	M	9.9×10^{-6}	3.04	292	0.36	-0.90
	Combined	4.0×10^{-6}	3.22	306	0.42	-0.69

Table 26. Estimated instantaneous fishing mortality rates (F) for white perch. NR= not reliable; NA=not available; MIN= minimal, at or near M estimate.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Choptank	0.18	0.20	0.18	0.16	0.12	0.20	0.38	0.54	0.32	MIN
Nanticoke	NR	0.22	0.18	0.16	0.12	0.66	NR	NR	0.08	MIN
Upper Bay	0.56	0.47	0.72	0.22	0.22	0.42	0.42	0.22	0.35	MIN

Table 27. Estimated instantaneous fishing mortality rates (F) for yellow perch. NR= not reliable; MIN=minimal, at or near M estimate.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Choptank[1]	0.08	MIN	0	NR	0.17	MIN	0.56	0.12	MIN	MIN
Upper Bay[2]	0.29	0.19	0.20	0.04	026	0.36	0.42	0.38	0.26	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 and 2014 estimate where ratio of ages 5 - 10 and 4 - 10 were used.
[2]Fully recruited F from Piavis and Webb in publ.

Figure 21. Baywide young-of-year relative abundance index for white perch, 1962 – 2014, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

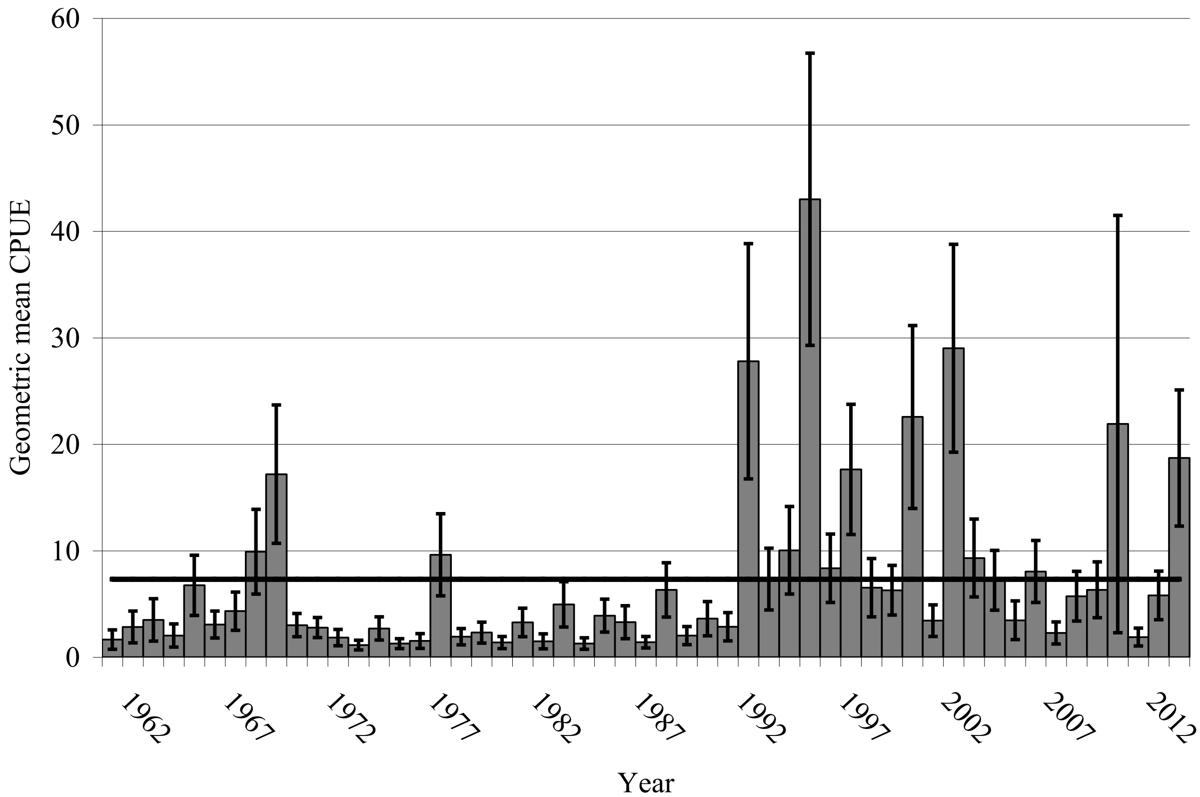


Figure 22. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

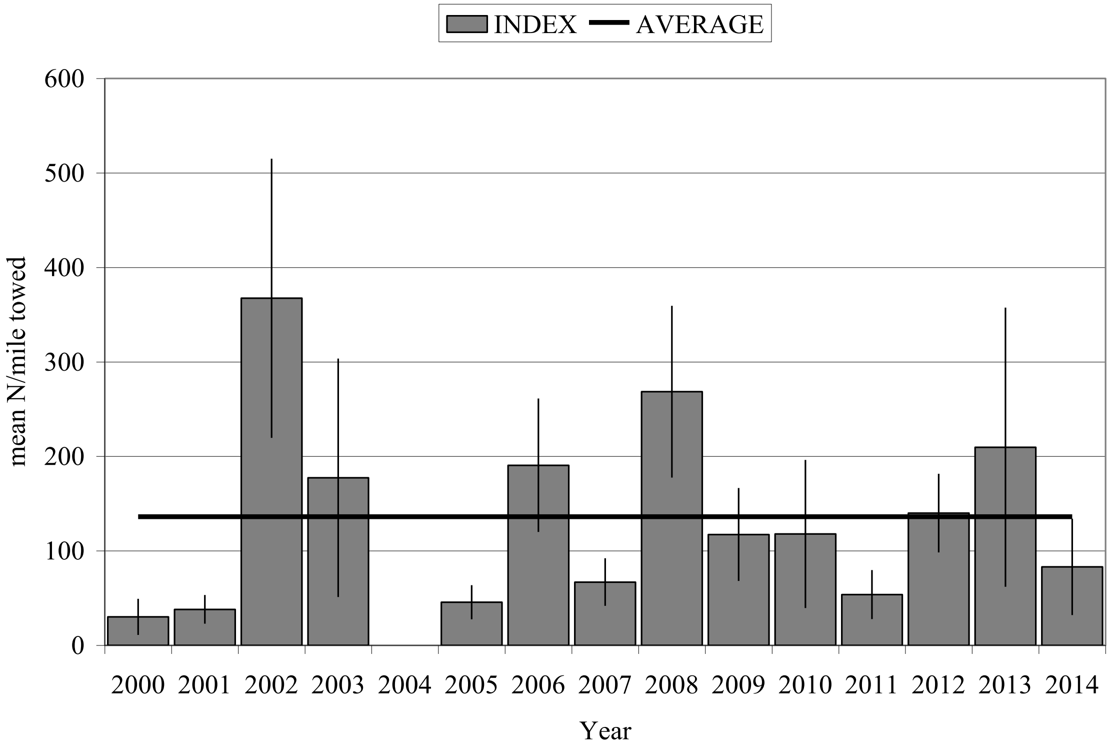


Figure 23. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2014, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

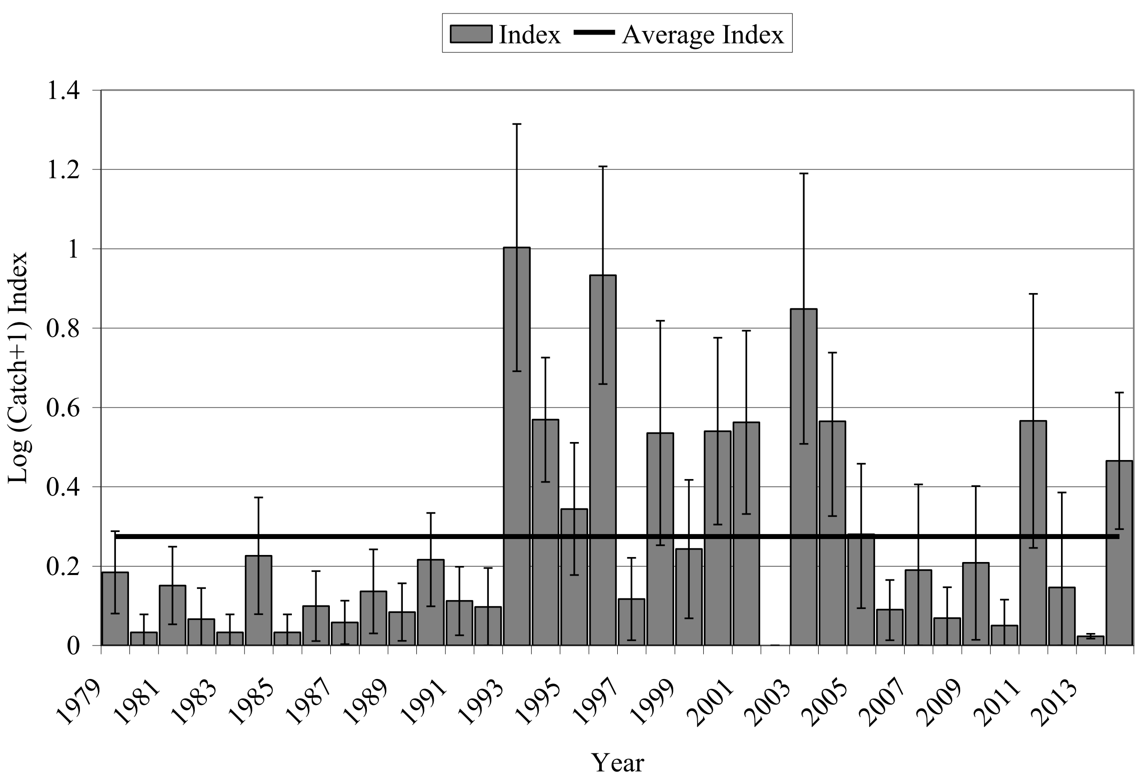


Figure 24. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

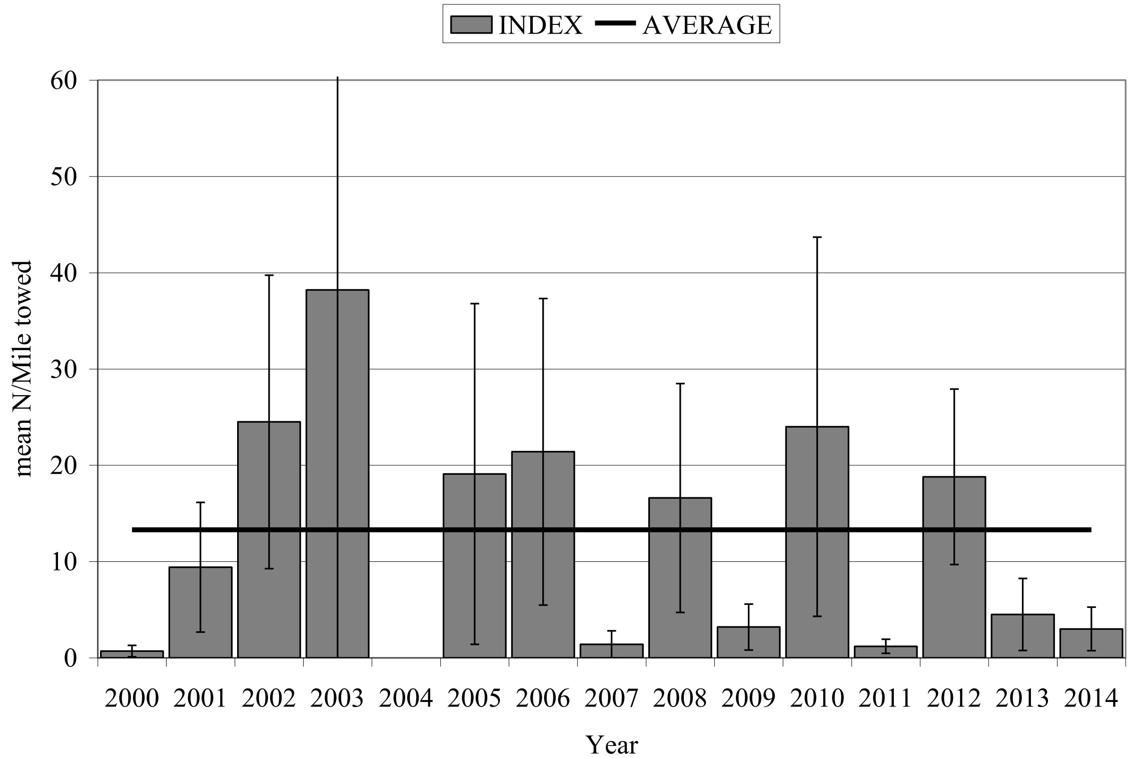


Figure 25. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

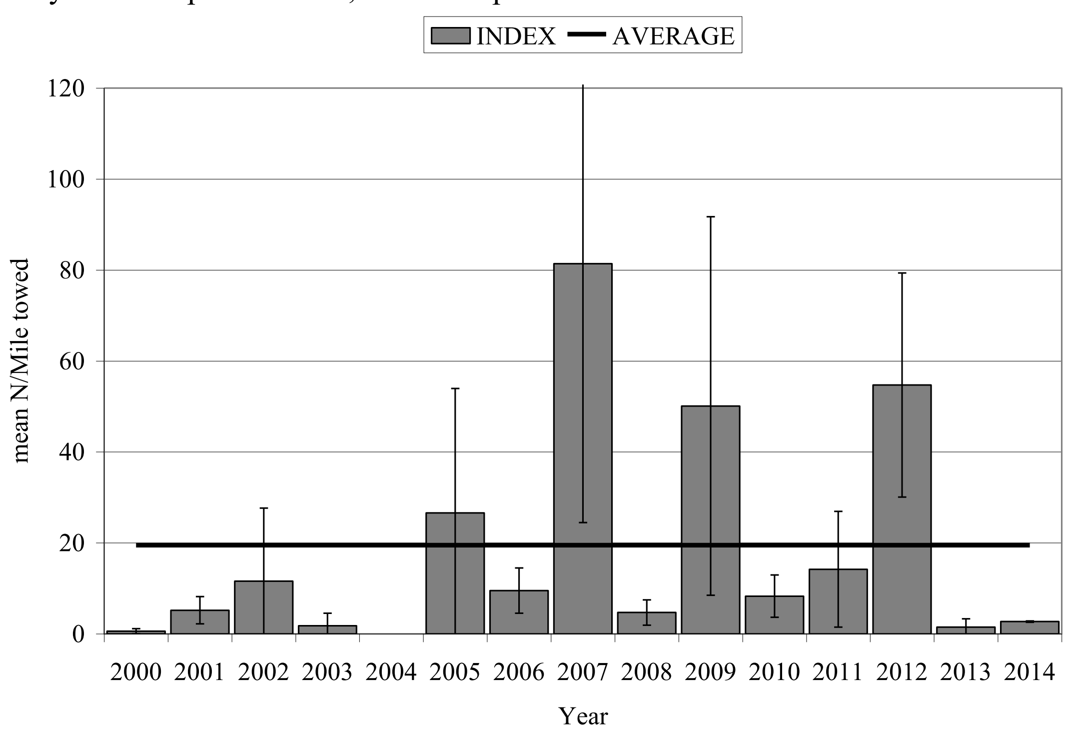


Table 28. White perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2014.

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	495.2	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	216.9	56
2006	192.1	63.2	153.2	47.2	36.7	10.2	6.3	6.1	1.5	2.7	519.2	108
2007	67.0	44.3	31.8	61.6	34.9	8.4	9.2	0.8	0.6	3.0	261.6	149
2008	268.5	44.7	113.3	84.5	25.7	8.8	3.5	3.8	1.4	1.4	555.6	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	178.0	138.5	163.4	5.6	52.6	41.7	68.9	5.8	9.5	13.9	677.9	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	139.9	45.9	19.9	8.6	9.6	9.8	16.7	7.3	10.3	3.1	271.1	107
2013	209.7	301.8	35.8	79.0	71.9	362.8	41.5	49.8	11.7	29.6	1,193.6	86
2014	83.1	44.0	427.2	69.9	46.1	21.5	43.4	14.4	8.3	9.9	767.8	60

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2014.

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

Table 30. Yellow perch relative abundance (N/MILE TOWED) and number of tows from the upper Chesapeake Bay winter trawl survey, 2000 – 2014.

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

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2014.

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

Figure 26. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2014. Effort standardized from 1 March – 95% total catch date. Trendline statistically significant at P<0.001.

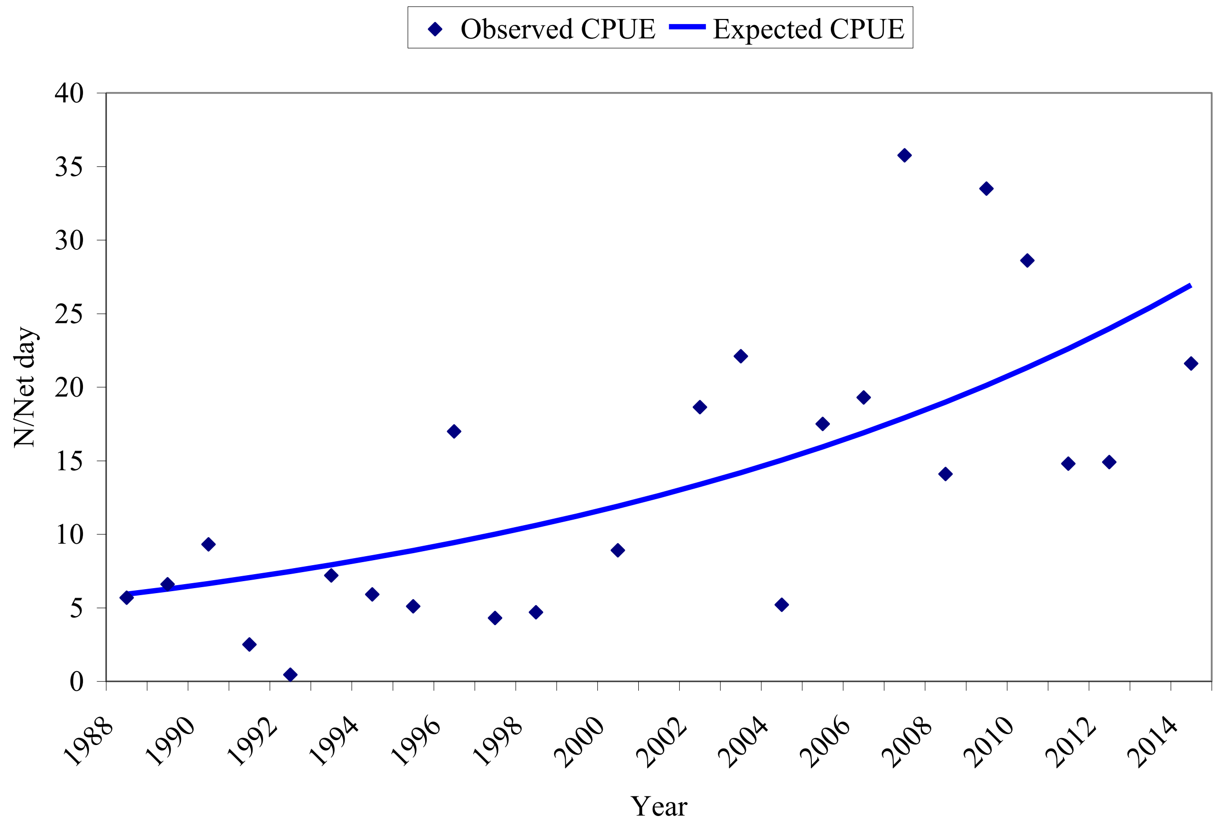


Figure 27. Channel catfish relative abundance (N/mile towed) from the upper Chesapeake Bay winter trawl survey, 2000-2014. Not surveyed in 2004, small sample sizes in 2003 and 2005.

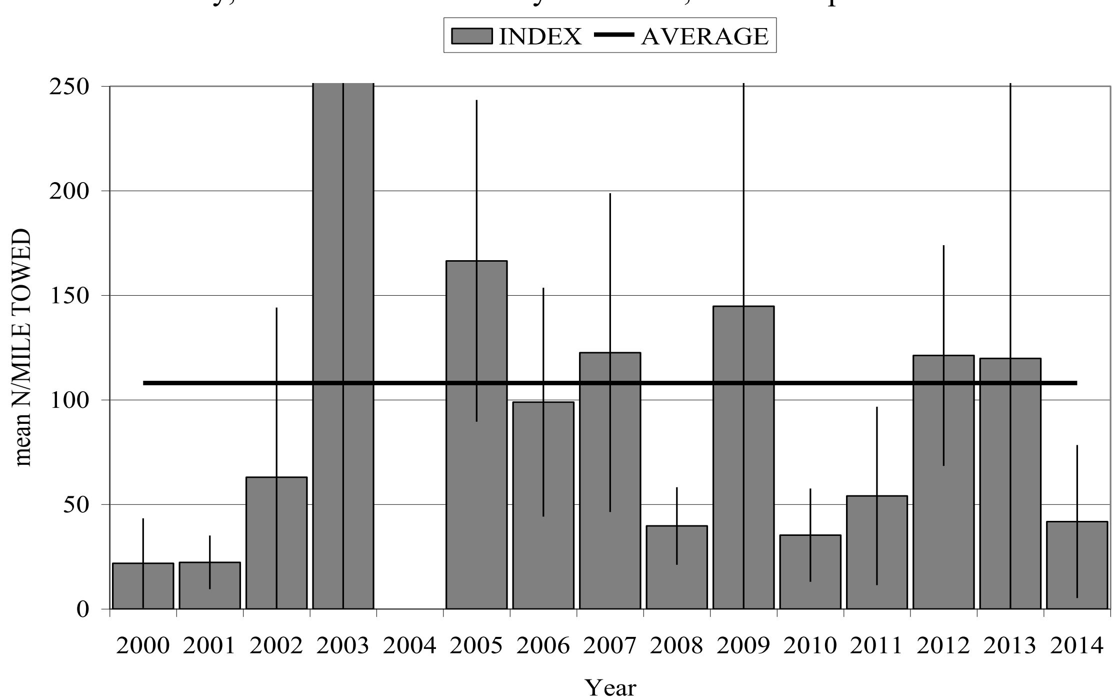


Figure 28. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2014. Horizontal line indicates time series average relative abundance.

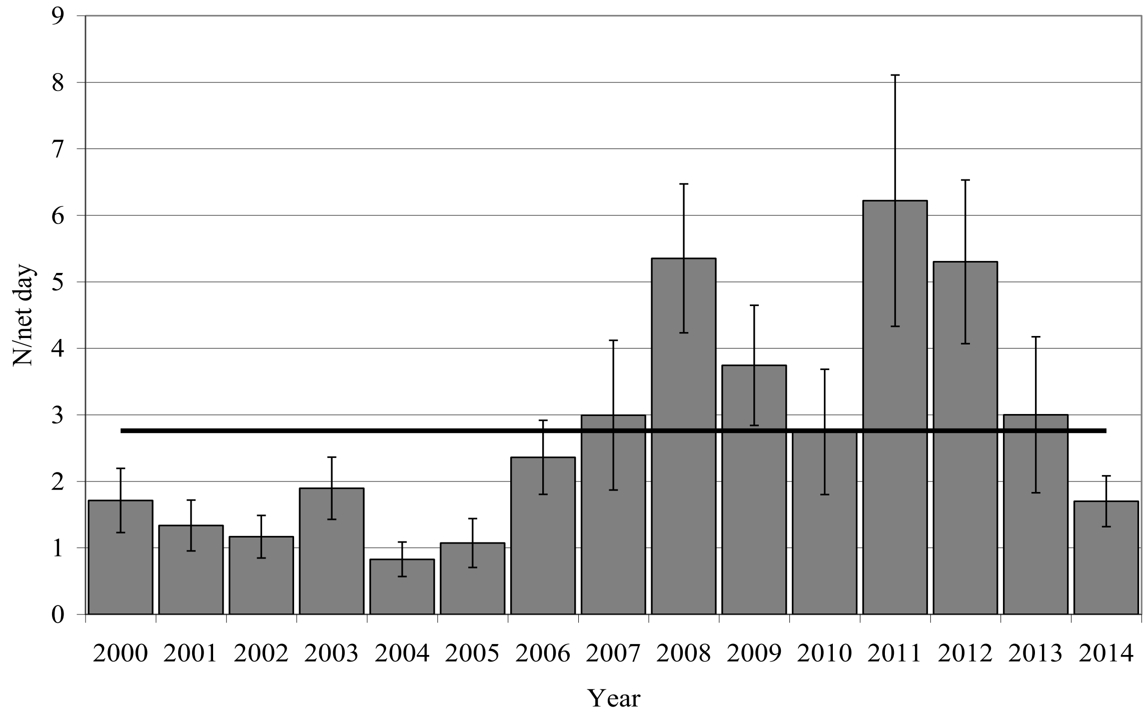
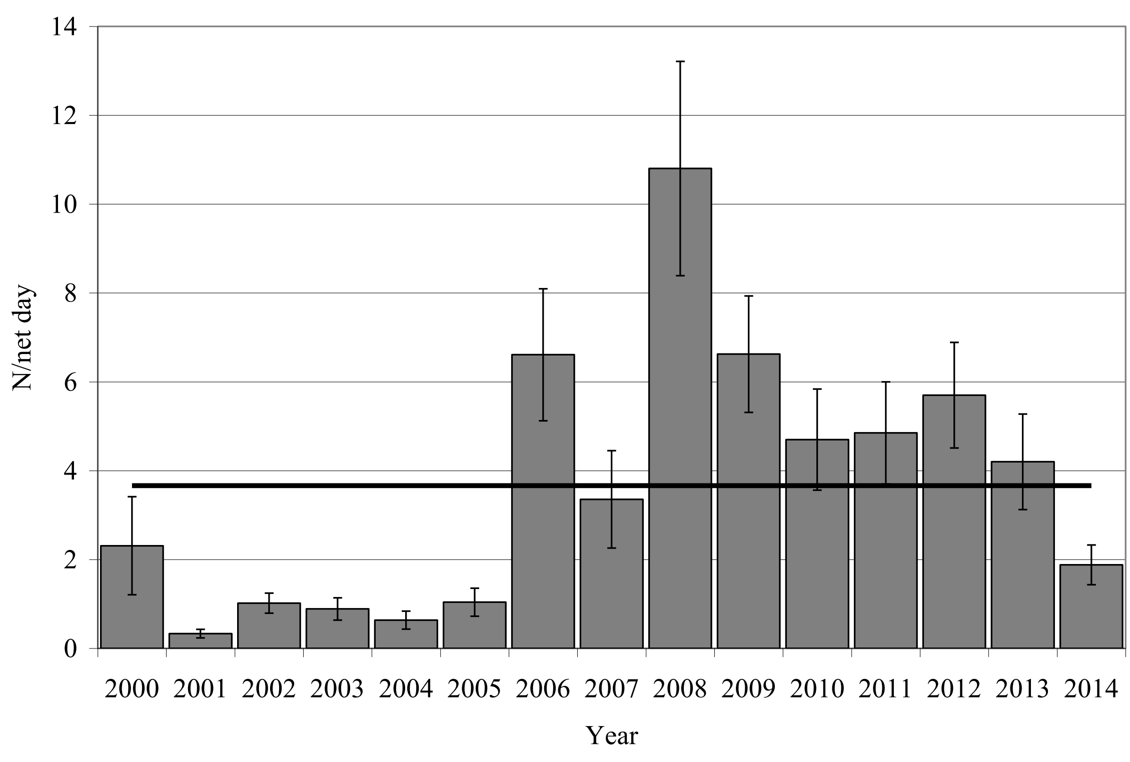


Figure 29. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2014. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

Population Assessment Of White Perch In Maryland With Special Emphasis On Choptank River Stocks

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The objectives of Job 2 were to assess white perch stock size, describe trends in recruitment and mortality, and compare current fishing mortality estimates with previously identified biological reference points (Piavis and Webb 2006). White perch (*Morone americana*) are semi-anadromous fish that inhabit east coast ecosystems from South Carolina to Nova Scotia and are especially abundant in Chesapeake Bay. In Maryland, white perch migrate into tributaries to spawn in March and April. Spawning normally occurs when water temperatures reach 12 - 14°C and at salinities less than 4.2 ppt (Setzler-Hamilton 1991).

White perch fisheries are important in the Chesapeake Bay region. Based on the Marine Recreational Information Program (MRIP; National Marine Fisheries Service, personal communication), Maryland's 2013 recreational white perch landings (inland only) were 897,000 pounds, and averaged 748,000 pounds from 2009 – 2013. The 2013 recreational white perch harvest was the highest since a peak of > 1.2 million pounds in 2010. The three highest annual landings since 1981 occurred in 2006, 2007, and 2010. White perch also support a robust commercial fishery in Maryland. Commercial white perch landings were 1.25 million pounds in 2013 and averaged 1.61 million pounds from 2009 – 2013.

Maryland's white perch stocks were last assessed in 2011 (Piavis and Webb 2012). The 2011 assessment modeled upper Bay white perch dynamics with a Catch-Survey Analysis (CSA) based on MDDNR winter trawl fishery independent data (see Job 1) for the years 2000 -- 2011. The CSA model was also utilized to describe the population dynamics of white perch in Choptank River based on fishery independent MDDNR fyke net survey data (1989 – 2011). The data poor status of lower Bay stocks necessitated a qualitative approach of inspecting fishery dependent relative abundance indices and fishery independent indices, including a young-of-year index from the Estuarine Juvenile Finfish Survey (EJFS; Project 2 Job 3 Task 3), and an adult white perch relative abundance index from the Potomac River Striped Bass Spawning Stock Survey which is a drift gill net survey (SBSSS; Project 2, Job 3).

The current assessment utilized the identical framework/models as the 2011 assessments with the addition of 3 more years of data. Model results were compared against proposed biological reference points (Piavis and Webb 2006) to determine overfishing status in the upper Bay and Choptank River. In addition, this updated assessment provided important information regarding management of this species, particularly in the upcoming preparation of the Chesapeake Bay White Perch Fisheries Management Plan.

METHODS

Catch Survey Analysis Model Structure

Model Description

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

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

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

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

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

$$r_t = R_t\, q \qquad [2]$$

and,

$$p_t = P_t\, q\, \Phi \qquad [3]$$

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

$$\Phi = s_p/s_r \qquad [4]$$

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 [2] and [3] into equation [1] yields

$$r_{t+1} = (r_t + p_t / \Phi) e^{-M} - q C_t e^{-Mt(1 - Tt)} \qquad [5]$$

This assessment reparameterized the model to allow for missing survey data (Mensil 2003a). 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 [1].

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

$$q_{avg} = e^{(1/n) * \sum (\log_e (n_t / N_t)} \qquad [6]$$

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

$$p_{exp,\,t} = P_t/(q_{avg} * \Phi) \qquad [7]$$

$$r_{exp,\,t} = R_t/q_{avg} \qquad [8].$$

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

$$SSQ = W_p * \sum (\log_e (p_{obs,\,t}) -(\log_e (p_{exp,\,t}))^2 + W_r * \sum (\log_e (r_{obs,\,t}) -(\log_e (r_{exp,\,t}))^2 \; [9]$$

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

$$h_t = C_t / ((P_t + R_t) * e^{-Mt*Tt}) \quad [10]$$

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

$$F_t = -\log_e (1-h_t). \quad [11]$$

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

Inputs Common to both Assessments

The CSA model requires an estimate of M, Φ (a scalar relating pre-recruit selectivity to post recruit selectivity (equation [4]), survey indices of pre-recruit (p_t) and post-recruit (r_t) abundance, and total removals (C_t). Pre-recruits were those white perch between 185 and 202 mm TL. Post-recruit white perch were those fish greater than 202 mm TL because the commercial fishery operates under a 203 mm TL minimum size limit. The pre-recruit length range was selected because that range of sublegal white perch will likely recruit to the fishery in the following year.

Natural mortality was set at a constant M = 0.2 for both analyses. This value was selected based on the maximum white perch longevity from age studies from all Maryland Department of Natural Resources (MDNR) Fisheries Service surveys. The scalar Φ was 1.0 for both assessments based on length frequency diagrams of catches from the upper Bay winter trawl survey and the Choptank River fyke net survey (Figures 1 and 2). Time of removals (T) was set at mid-year (0.5).

Upper Chesapeake Bay Catch Survey Analysis Model

Fishery Independent Catch per Unit Effort Indices

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. Eighteen sampling stations, each approximately 2.6 km (1.5 miles) in length and variable in width, were created throughout the study area (Figure 3). Data were not available for the 2003 sampling season due to ice coverage, and the retirement of the vessel captain prevented us from sampling during 2004. The study area was divided into four sampling areas; Sassafras River (4 sites), Elk River (4 sites), upper Chesapeake Bay (6 sites), and middle Chesapeake Bay (4 sites). 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 3 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. All species caught were identified and counted. A minimum of 50 fish per species were sexed and measured. 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. In addition, when white perch catches were greater than 50 fish, the proportion of pre-recruit white perch (185 mm -- 202 mm) and the proportion of post-recruit white perch (>202 mm) were determined and the total number of each phase was derived by multiplying the proportion by the total white perch catch per statute mile.

Removals

Harvest estimates (removals) were determined for upper Chesapeake Bay commercial and recreational fisheries. Commercial harvesters are required to submit daily landings by river system and gear type (Lewis 2010). There are 3 primary commercial gears: fyke nets, pound nets, and drift gill nets. Average length of fyke net and pound net harvest was estimated from Fisheries Service surveys in Choptank River (fyke nets) and Nanticoke River (fyke and pound nets). Average length of white perch in the drift gill net fishery was estimated from the Fisheries Service Striped Bass Spawning Stock Survey (SBSSS). The SBSSS is a drift gill net survey in the spring of each year centered in the upper Bay (see Project 2 Job 3). Average weight for all subfisheries were determined by applying average lengths to annual allometric equations (Job 1). Numbers of commercially caught white perch were determined by dividing gear specific harvest (pounds) by the estimated average weight of the gear specific catch.

Recreational white perch harvest for upper Chesapeake Bay was estimated from angler intercept and effort data compiled by MRIP (National Marine Fisheries Service personal communication). Data were queried to include only those counties bordering the upper Bay to formulate an area-specific catch estimate (in numbers). Inspection of CV's of estimates indicated that these data were suitable for inclusion in our analysis.

Uncertainty

The model was bootstrapped 10,000 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 varitation (CV), and bias were calculated for q and each estimate of P_t and R_t, exclusive of the terminal year. Confidence intervals (80%)

were determined from cumulative percent distributions of the bootstrapped parameter estimates. In addition, retrospective analyses were conducted on the data by eliminating one year's data, running the model, then eliminating two year's data. The results for population size and F from each model run were plotted to determine the degree of precision that occurred in the final year's estimates.

Choptank River Catch Survey Analysis Model

Fishery Independent Catch per Unit Effort Indices

Fyke nets sampled resident and anadromous fishes and were fished two to three times per week. Fisheries Service fyke nets were located from river km 65.4 to km 78.1 (Figure 4). The Choptank River is tidal and generally fresh at the five survey sites. However, during the severe drought of 2001 - 2002, salinity increased to 6 ppt, but has never exceeded white perch tolerance limits (18 ppt; Setzler-Hamilton 1991).

Fyke net bodies were constructed of 64 mm stretch-mesh and 76 mm stretch-mesh for both the wings (7.6 m long) and leads (30.5 m long). Nets were set perpendicular to the shore with the wings positioned approximately 45° from the lead. In some instances, the leads were shortened where river depth exceeded practical deployment. Generally, fyke net bodies were located in 1.3 - 3.0 m water depth.

Net hoops were brought aboard first to ensure that all fish were retained. Fish were then removed and placed into a sorting tank and identified. All fish were counted and a subsample of 30 white perch was sexed and measured (mm TL).

Effort varied considerably as the project moved from a pilot phase to a more integrated monitoring program for white perch, yellow perch, channel catfish, and white catfish. Only two fyke net sets were monitored during 1989 - 1991. Three fyke net sets were used during 1992, and five fyke net sets were fished from 1993 to 2005. Locations were consistent during 1993 - 2005, except for the uppermost net where conflicts arose with commercial gear. This necessitated moving this net set approximately 500 m down stream. In 2006, an additional fyke net site was added.

Removals

For the Choptank River assessment, average length of white perch caught in the gill net fishery was determined from data collected between 1989 - 1994 and 1996 by the MDNR Fisheries Service SBSSS gill net survey in the Choptank River. Data from the MDNR Fisheries Service upper Bay SBSSS was utilized for the 1995 and 1997 –2013 mean length estimates. Length data from the Choptank River fyke net survey were utilized to characterize mean lengths of legal white perch from the pound net and fyke net fisheries. Average lengths were transformed to average weight with annual allometric equations (Job 1). Total numbers harvested was estimated as total catch by gear type divided by average weight of legal white perch.

The same approach for estimating recreational removals in upper Chesapeake Bay was attempted for Choptank River, but annual CV's were generally too poor throughout the time-series. Therefore, we selected the annual Choptank River specific estimates with CV's less than 40%. For those years, a ratio of Choptank recreational harvest : baywide recreational harvest was determined. Those values were averaged and used as a multiplier and applied to annual baywide catch estimates to then estimate recreational removals in Choptank River.

Uncertainty

The model was bootstrapped 10,000 times by resampling residuals and adding them to the natural logarithm of the expected index values, then re-exponentiating the values. Mean, median, CV, and bias were calculated for q and each estimate of P_t and R_t, exclusive of the terminal year. Confidence intervals (80%) were determined from cumulative percent distributions of the bootstrapped parameter estimates. In addition, retrospective analyses were conducted on the data by eliminating one year's data, running the model, then eliminating two year's data. The results for population size and F from each model run were plotted to determine if biases occurred in the final year's estimates.

Lower Chesapeake Bay Relative Abundance Indices

Fishery Dependent

Fishery dependent relative abundance indices were calculated from the 3 primary commercial fishing gears: fyke nets, pound nets, and drift gill nets. The MDNR commercial landings database was queried for landings and effort for the three main gear types for all areas below the Preston Lane Memorial Bridges. All license holders reporting more than 1,000 pounds landed per month were included in the index. Total effort for fixed gear (fyke nets and pound nets) was calculated as the number of nets fished during any one month. Drift gill net effort was 1,000 gill net feet per hour. Catch-per-unit effort (CPUE) was total pounds landed divided by total effort. Effort records were intermittent throughout the earlier portion of the time series, but in general, data were available from 1980 – 1985, 1990 and 1992 – 2013.

Fishery Independent

Fishery independent relative abundance indices were calculated from the EJFS seine survey. The index was the geometric mean of the number of juvenile white perch +1 from all sites below the Bay Bridges from 1962 – 2014.

Fisheries Service has conducted a striped bass drift gill net survey in the Potomac River since 1985 (Project 2 Job 3). Catch data for white perch from the survey were used to formulate a geometric mean index (N), restricted to white perch caught in mesh sizes less than 5-inch stretched mesh from March through May.

RESULTS

Upper Chesapeake Bay Catch Survey Analysis Model

Estimated total white perch removals by the commercial and recreational fisheries in the upper Bay declined from over 2.8 million white perch in 2000 to just under 1.1 million white perch in 2008 (Figure 5). Landings rose rapidly to 2.9 million fish in 2010 and 2.7 million white perch in 2013. Pre-recruit CPUE's from the fishery independent trawl survey declined from 2001 through 2007, but rebounded to high levels after 2009 (Figure 6). The 2013 CPUE was the highest in the time-series. Post-recruit white perch CPUE's mimicked the decline in landings, falling from high values in 2000 to the lowest in the time-series in 2007 (Figure 7). The CPUE's were higher during 2010 – 2013 than the 2005 – 2008 period.

Total population abundance (pre- and post-recruits combined) decreased from about 11.0 million white perch in 2001 to 4.4 million fish in 2007 (Figure 8). Total abundance rose from 4.4 million fish in 2007 to 10.2 million white perch in 2013. Pre-recruit abundance (185 mm TL – 202 mm TL) ranged from 751,000 white perch in 2004 to over 5.5 million in 2001 and 2013, and averaged 3.4 million during 2000 – 2013. The 2013 estimate was 7.8 million fish, but that value is not fit by the model, it is simply the observed terminal p_t divided by $q_{avg.}$ Therefore, it is considered a very rough estimate. Post-recruit white perch abundance ranged from 1.8 million white perch in 2008 to 6.9 million fish in 2003, and averaged 4.5 million fish. Instantaneous fishing mortality (F) varied throughout the time-series from F=0.22 (2008 and 2009) to F=0.72 (2007; Figure 9). Final year F was 0.35 and averaged 0.39 during 2000 – 2013.

Plots of observed versus expected survey indices tracked well for the time-series (Figures 6, 7). Plots of residuals also illustrate these results. Pre-recruit residuals were generally acceptable, but there was a bias toward all positive residuals in the last 5 years. However, many of these residuals were small (Figure 10). The post-recruit residuals were also indicative of a good fit, but one year (2007) produced a fairly large negative residual (Figure 11). A pattern of 4 consecutive positive residuals were also evident (2008 – 2011).

A suite of biological reference points were determined for Chesapeake Bay white perch in a previous assessment (Piavis and Webb 2006). Spawning stock biomass per recruit analysis determined maximum spawning potential (MSP) reference points. Given the early time at first maturity, $F_{30\%}$ (target) and $F_{20\%}$ (limit) MSP reference points appear appropriate. Target F and limit F were 0.6 and 1.12, respectively. Estimated F marginally exceeded target F in 2007, but has been fairly low since that time (Figure 9).

Bootstrap evaluation of the model indicated precise results. Of the 10,000 bootstrap trials, over 97% were successful. Catchability was very precisely estimated

(CV=9.05%). Pre-recruit abundance fit very well with CV's ranging from 10% in 2003 to 24% in 2013 (Table 1). Post-recruit white perch abundance estimates were slightly less precise than the pre-recruit estimates, but they were still regarded as precise (Range= 18.3% -- 36.7%). Confidence intervals (80%) of pre-recruit and post-recruit abundance were determined from bootstrap samples (Figures 12, 13).

Retrospective analysis indicated that the model was somewhat optimistic. Abundance estimates for both the pre-recruits and post-recruits were 16% and 19% higher in the t-2 retrospective run than the 2014 model run, respectively (Figures 14, 15). Instantaneous fishing mortality (F) was underestimated by 25% from the t-2 run to the 2014 run (Figure 16).

Choptank River Catch Survey Analysis Model

Total removals by the commercial and recreational fisheries from the Choptank River rose nearly linearly from 250,000 white perch in 1989 to a peak removal of 1.5 million fish in 1997 (Figure 17). Recently, removals have rebounded from 381,000 in 2009 to over 1 million fish in both 2011 and 2012. Pre-recruit fishery independent CPUE values showed a generally increasing trend over a large portion of the time series, but the index has declined since 2007 (Figure 18). Post-recruit white perch CPUE was flat from 1989 – 1998 (Figure 19). The post-recruit index exhibited an increasing trend from 1998 – 2010 before declining during 2011 – 2014.

Choptank River white perch data fit the CSA model well. Total population abundance in numbers increased from 964,000 white perch in 1989 to 1.8 million fish in 2014 (Figure 20). Pre-recruit abundance (185 mm – 202 mm) ranged from 400,000 white perch in 1989 to 1.2 million in 2010 before declining to 896,000 in 2013. Post-recruit white perch abundance ranged from 517,000 white perch in 1994 to 2.5 million fish in 2010. Terminal year (2014) estimate was 986,000. Instantaneous fishing mortality (F) increased through 1997 followed by a general decline through 2010 (Figure 21). Since 2010, F increased; final year F was 0.38.

Plots of observed versus expected survey indices tracked well for a large portion of the time series, but the model results failed to track an increasing pre-recruit index during 2006 – 2009 (Figure 18). The model fit the observed post-recruit CPUE index very well (Figure 19). Plots of residuals also illustrate these results. The pre-recruit residuals exhibit a pattern of largely negative residuals for the first 10 years and turn positive for the remaining time period. The largest positive residuals occurred over the later portion of the time series (Figure 22). Post-recruit residuals are fairly evenly distributed except that the largest negative residuals occurred later in the time-series (Figure 23).

Comparing the derived F with the proposed biological reference points indicated that overfishing did occur for at least a small portion of the time-series. Target F was exceeded several years in the 1990's, and F exceeded the limit in 1997. However, F has been below the target 2001 -- 2013, except for 2012 (Figure 21).

Bootstrap evaluation of the model indicated precise results. Of the 10,000 bootstrap trials, over 99% were successful. Catchability was very precisely estimated at 3% (CV). Pre-recruit abundance fit very well with CV's, ranging from 18% in 1997 to 32% in 2011 (Table 2). CV's of fully recruited white perch ranged from 12% in 2010 to 26% in 1994. Confidence intervals (80%) of pre-recruit and post-recruit abundance were also determined from bootstrap samples (Figures 24, 25).

Retrospective analysis indicated that the model was only slightly optimistic. Abundance estimates for both the pre-recruits and post-recruits were approximately 8% and 18% higher in the t-2 retrospective run than the 2014 model run, respectively (Figures 26, 27). Instantaneous fishing mortality (F) was underestimated by 27% from the t-2 run to the 2014 run (Figure 28).

Lower Chesapeake Bay Relative Abundance Indices

Fishery Dependent

Fishery dependent relative abundance indices produced somewhat similar signals. Fyke net CPUE varied, but relative abundance generally increased from 1992 – 2007. Recent years' CPUE's were at or above average (Figure 29). Six of the final 10 years had relative abundance values at or above the time series average. The lower Bay pound net relative abundance index mimicked the fyke net index to some degree with the same parabolic shape after 1992 (visual inspection; Figure 30). However, the inflexion point of the pound net index is around 2002 where the fyke net inflexion point would be more likely around 2004. Four of the final 10 years had relative abundance values at or above the time series average. The drift gill net relative abundance index exhibited a similar pattern where the index rose from 1992 to 2003 and then declined through 2007 (Figure 31). The gill net index then increased through 2012. The final year of available data (2013) indicated that CPUE values were slightly below average. Seven of the final 10 years had relative abundance values at or above the time series average.

Fishery Independent

An adult white perch relative abundance index was derived from a striped bass spawning stock survey (drift gill net) in Potomac River. The index was generally noisy, but corroborated the fishery dependent indices' signal of high abundance around 2004 – 2005 with a decline through 2009 (a time series low; Figure 32). As with the fishery dependent relative abundance values, the fishery independent survey indicated higher relative abundance 2011 – 2013. Similar to the commercial metrics, six of the ten years, 2004 – 2013, were above average.

A juvenile abundance index was derived from a long-term seine survey. Sites from the lower Bay produced strong recruitment from the early 1990's through the mid 2000's (Figure 33). The index trended lower during 2005 – 2010, but recruitment levels were more similar to the late 1960's than the period of extended poor recruitment (1971 – 1986). Recruitment appeared strong in 2011 and 2014. An eight year moving average was also estimated to encompass the majority of the fish in the population. This exercise indicated a stable population at middling levels.

DISCUSSION

The catch survey analysis (CSA) can be a powerful assessment tool when catch-at-age data is limiting or non-existent (Collie and Sissenwine 1983; Mesnil 2003b). Published CSA assessments have focused on various crab and shrimp species because of the difficulty in aging invertebrates (Cadrin et al 1999; Collie and Kruse 1993; Zheng et al 1997). Simulation studies have documented the CSA's utility, but it is less widely implemented for finfish stocks despite the fact that the initial publication of the model dealt with haddock and flounder stocks (Collie and Sissenwine 1983). Surplus production modeling and CSA modeling were compared on synthetic data sets that mimicked the life history and fisheries of Gulf of Maine northern shrimp (Cadrin 2000).

Results indicated that CSA was superior to surplus production models in assessing stock size. As with many fisheries models, the CSA performed best when there was contrast in population size over time and was sensitive to imprecise survey data.

The CSA assessed white perch dynamics for two systems, the upper Chesapeake Bay covering all areas north of the Preston Lane Memorial Bridges, and the Choptank River. Upper Chesapeake Bay commercial white perch landings accounted for 39% of total Maryland Chesapeake Bay landings, and commercial landings from Choptank River accounted for 13% of total baywide landings in 2013 (52% of statewide total). Recreational removals in upper Bay accounted for, on average 61% of the baywide recreational harvest over the 2 year period, 2012 and 2013. Recreational removals in Choptank River accounted for, on average 9% of the baywide recreational harvest over the 2 year period, 2012 and 2013. Therefore, these two systems accounted for 70% of the recreational harvest during that time period.

Upper Chesapeake Bay Assessment

The CSA model fit the fishery independent trawl data well. Total population abundance exhibited a saddle-shaped pattern where the lowest abundance occurred midway through the time series (2004 – 2009). Recruited abundance declined drastically in 2005 and was at it lowest in 2008. Higher pre-recruit abundance, beginning in 2008, produced the rebound in abundance of post-recruit white perch. The relatively low pre-recruit abundance in 2003 – 2007 occurred simultaneously to F rates at or above proposed target F's. Continued fishing pressure while recruitment was impaired conspired to cause the decline in post-recruit abundance. It is possible that the lack of data produced artificially low estimates in 2003 and 2004, but fishery removals declined in 2008, so the chances of improper estimation of these data points is relatively low. The follow through of lower landings, which of course are independent of the data points, corroborates the low recruitment estimated during the years when the survey was idled. Hyperstability within the population may have kept landings high until 2008 when recruited population abundance finally capitulated to poor recruitment and increased F. Improved recruitment in the later portion of the time series produced larger post recruit abundance. This “grow your way lower F” scenario explains how recreational and commercial removals increased to 2 – 3 million fish annually while F rates dropped to a range of 0.2 – 0.4.

Estimated fishing mortality (F) marginally exceed the proposed target in 2007, and was very close in 2004 and 2005. Since 2007, F rates have been safely below the proposed target. Limit F has never been approached. Based on the bootstrap distribution, there was only a 1.2% chance that F target was exceeded in 2013. Therefore, overfishing did not occur on the upper Bay white perch stock for the terminal year.

Choptank River Assessment

The model run for Choptank River white perch indicated that total population abundance declined after reaching a peak in 2011 (time series = 1989 – 2014). Pre-recruit abundance, the ultimate driver of exploitable biomass, was at higher levels for a large part of the time series, at least from 1997 – 2007. Since 2007, estimated pre-recruit abundance declined. The previous assessment, covering 1989 – 2011, indicate an increasing trend in pre-recruit abundance despite falling CPUE indices, 2006 – 2011 (Piavis and Webb 2012). In that assessment, the authors cautioned that the model was not fitting the lower CPUE values and management advice may change given more data. The 2014 assessment did in fact force the model to fit the lower pre-recruit abundances for that later time period.

Post-recruit abundance showed dramatic increases from the early 2000's through 2011. Removals were fairly variable throughout the survey, with < 800,000 removals prior to 1997. During the period 1997 – 2004, removals ranged from 800,000 to about 1.5 million. Removals were generally < 800,000 since 2004, but estimates for 2011 and 2012 were in excess of 1 million fish annually.

Fishing mortality rates exhibited a declining trend since 1997 when F was above the proposed limit reference point. Recently, fishing mortality approached but did not exceed the target reference point in 2011, breeched it 2012, and declined to 0.40 in 2013 (target F = 0.60). Estimated F rates are not statistically derived from the model, so a fair degree of uncertainty remains due to the deterministic approach of estimating F. Stock specific estimates of F from age data or other methods need to be investigated for comparisons to biological reference points.

Diagnostics of model precision, bootstrap metrics, retrospective analysis, and residual plotting suggest that the model fit the data very well. However, the worrisome pattern of residuals in the pre-recruit index persisted; this pattern was evident in the 2008 assessment (Piavis and Webb 2009) and in 2011 (Piavis and Webb 2012). Alternate model runs were made by shortening the time series (due to increased DNR fyke effort after 1993) and up-weighting the pre-recruit index. These model runs did lessen the residual pattern and population estimates were generally within 10% of the base run. The

10% difference did fall within the confidence limits of the base model, so we adopted the base run of equal weighting and 1989 – 2014 data range for the current assessment.

Lower Chesapeake Bay Assessment

The lower Bay assessment was qualitative in nature. Fishery dependent indices of relative abundance were not identical, but they did provide a general indication of stock trends. All three fishery dependent indices showed a generally increasing trend up to 2002 or 2004, followed by a decline. The decline persisted until around 2007 with the indices showing either a flat or increasing population through 2010. The population bottom in 2007 and possible recovery through 2010 is almost identical to the upper Bay CSA results. The fyke net and gill net indices indicated high relative abundance (the highest in the time series) in 2012 followed by a decline to at or near average CPUE in 2013. The pound net index suggested low relative abundance in both 2012 and 2013. The pound net fishery is probably the most opportunistic fishery of the three. The drift gill net fishery and fyke net fishery are more likely targeting white perch and as such may be more indicative of population trends.

The fishery independent indices somewhat corroborated the fishery dependent fyke net and drift gill net indices. High relative abundance values occurred 2004 – 2006 and 2011 – 2013 for the fishery independent gill net survey. Given that the fyke net, drift gill net and experimental drift gill net surveys had 6 – 7 years of the 10 year period, 2004 – 2013 at or above average CPUE, overfishing likely did not occur, Similarly, the young-of year index indicated a period of high productivity from the mid 1990’s through 2004. The 8 year moving average, utilized as a proxy for population trends for 1 – 8 year old white perch, suggested that abundance did decline after 2003, but remained considerably higher than the period 1971 – 1992.

CITATIONS

Cadrin, S. 2000. Evaluating two assessment methods for Gulf of Maine northern shrimp based on simulations. Journal of Northwest Atlantic Fisheries Science. 27:119-132.

Cadrin, S., S. Clark, D. Schick, M. Armstrong, D. McCarron, and B. Smith. 1999. application of catch-survey models to the northern shrimp fishery in the Gulf of Maine. North American Journal of Fisheries Management. 19:551-568.

Collie, J.S. and G.H. Kruse. 1993. Estimating King Crab abundance from commercial catch and research survey data. Canadian Special Publication in Fisheries and Aquatic Sciences 125:73-83.

Collie, J.S. and M.P. Sissenwine. 1983. Estimating population size from relative abundance data measured with error. Canadian Journal of Fisheries and Aquatic Sciences. 40:1871-1879.

Lewis, C. 2010. Maryland Interjurisdictional Fisheries Statistics. Maryland Department of Natural Resources Fisheries Service Report 3-IJ-132. Annapolis, Maryland.

Mensil, B. 2003a. Catch-Survey Analysis (CSA): A very promising method for stock assessment, particularly when age data are missing or uncertain. ICES Working Document. 29 January – 5 February, 2003. Copenhagen, Denmark.

Mensil, B. 2003b. The catch-survey (CSA) method of fish stock assessment: an evaluation using simulated data. Fisheries Research. 63:193-212.

Piavis, P and E. Webb III. 2012. Population assessment of white perch in Maryland with special emphasis on Choptank River stocks. *In* Chesapeake Bay finfish and habitat investigations. Maryland Department of Natural Resources. Report F-61-R. Annapolis, Maryland.

Piavis, P and E. Webb III. 2009. Population assessment of white perch in Maryland with special emphasis on Choptank River stocks. *In* Chesapeake Bay finfish and habitat investigations. Maryland Department of Natural Resources. Report F-61-R. Annapolis, Maryland.

Piavis, P and E. Webb III. 2006. Population assessment of white perch in Maryland with special emphasis on Choptank River stocks. *In* Chesapeake Bay finfish and habitat investigations. Maryland Department of Natural Resources. Report F-61-R. Annapolis, Maryland.

Setzler-Hamilton, E.M. 1991. White Perch. In: Funderburk, Mihursky, Jordan, and Riley, eds. Habitat Requirements for Chesapeake Bay Living Resources. Chesapeake Research Consortium, Solomons, MD.

Zheng, J., M. Murphy, and G. Kruse. 1997. Application of a catch-survey analysis to king crab stocks near Pribilof and St. Matthew Islands. Alaska Fisheries Research Bulletin. 4, 62-74.

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Figure 31. Lower Chesapeake Bay fishery dependent white perch gill net index, 1980 – 2013.

Figure 32. Potomac River fishery independent gill net survey white perch index, 1985—2013.

Figure 33. Lower Chesapeake Bay young-of-year white perch seine index, 1962 – 2014.

Table 1. Uncertainty parameters for upper Chesapeake Bay white perch CSA model.(q=catchability)

Estimate/Parameter	Estimate	Mean	Median	CV	Bias[1]
q	6.04E-06	6.33E-06	6.31E-06	9.5	-4.3
Pre-Recruit N 2000	4,286,074	4,288,410	4,286,932	22.4	0.0
Pre-Recruit N 2001	5,578,298	5,579,757	5,598,575	21.4	-0.4
Pre-Recruit N 2002	3,942,487	3,942,174	3,946,322	22.0	-0.1
Pre-Recruit N 2003	1,400,621	1,390,717	1,394,314	10.1	0.5
Pre-Recruit N 2004	1,334,425	1,323,839	1,327,433	11.5	0.5
Pre-Recruit N 2005	2,986,777	2,976,583	2,984,895	22.1	0.1
Pre-Recruit N 2006	2,685,232	2,658,850	2,666,336	22.1	0.7
Pre-Recruit N 2007	1,715,547	1,699,297	1,700,072	22.7	0.9
Pre-Recruit N 2008	4,094,253	4,096,649	4,079,809	23.1	0.4
Pre-Recruit N 2009	4,723,431	4,718,043	4,711,139	22.9	0.3
Pre-Recruit N 2010	3,644,568	3,644,280	3,634,453	23.2	0.3
Pre-Recruit N 2011	3,470,843	3,483,192	3,466,286	23.3	0.1
Pre-Recruit N 2012	2,616,622	2,605,331	2,603,323	23.9	0.5
Pre-Recruit N 2013	5,556,530	5,544,277	5,534,618	24.0	0.4
Post-Recruit N 2000	5,457,160	5,329,375	5,348,894	23.8	2.0
Post-Recruit N 2001	5,378,026	5,275,316	5,245,714	23.6	2.5
Post-Recruit N 2002	6,816,075	6,733,179	6,705,474	18.4	1.6
Post-Recruit N 2003	6,889,223	6,821,097	6,743,966	16.7	2.2
Post-Recruit N 2004	4,324,631	4,260,746	4,194,473	22.2	3.1
Post-Recruit N 2005	2,622,329	2,561,356	2,503,815	31.6	4.7
Post-Recruit N 2006	2,615,770	2,557,504	2,495,543	29.5	4.8
Post-Recruit N 2007	2,723,894	2,654,590	2,579,006	26.3	5.6
Post-Recruit N 2008	1,773,427	1,703,382	1,629,503	36.7	8.8
Post-Recruit N 2009	3,848,976	3,793,590	3,749,971	22.5	2.6
Post-Recruit N 2010	5,627,406	5,577,649	5,530,488	19.3	1.8
Post-Recruit N 2011	4,958,310	4,917,337	4,860,334	22.7	2.0
Post-Recruit N 2012	4,525,730	4,502,295	4,435,703	25.0	2.0
Post-Recruit N 2013	4,649,143	4,620,711	4,556,532	23.6	2.0
Post-Recruit N 2014	5,878,744	5,845,434	5,764,937	25.2	2.0

[1]Bias as defined as est-median/median

Table 2. Uncertainty parameters for Choptank River white perch CSA model. (q=catchability).

Estimate/Parameter	Estimate	Mean	Median	CV	Bias1
q	2.29E-05	2.34E-05	2.34E-05	2.6	-2.3
Pre-Recruit N 1989	401,863	424,050	412,607	30.8	-2.6
Pre-Recruit N 1990	1,003,086	990,023	982,603	22.1	2.1
Pre-Recruit N 1991	514,700	532,937	519,128	30.3	-0.9
Pre-Recruit N 1992	787,451	791,145	781,675	25.0	0.7
Pre-Recruit N 1993	835,184	837,854	828,857	23.2	0.8
Pre-Recruit N 1994	1,065,698	1,064,418	1,053,721	21.1	1.1
Pre-Recruit N 1995	1,053,423	1,062,034	1,049,914	23.1	0.3
Pre-Recruit N 1996	1,456,727	1,454,724	1,441,121	20.8	1.1
Pre-Recruit N 1997	1,603,767	1,593,654	1,591,221	17.9	0.8
Pre-Recruit N 1998	1,115,697	1,126,805	1,109,513	24.5	0.6
Pre-Recruit N 1999	1,669,124	1,649,126	1,641,595	20.0	1.7
Pre-Recruit N 2000	1,012,561	1,026,920	1,008,238	27.0	0.4
Pre-Recruit N 2001	1,362,827	1,354,853	1,339,461	24.5	1.7
Pre-Recruit N 2002	1,138,479	1,152,159	1,125,520	28.0	1.2
Pre-Recruit N 2003	1,594,621	1,576,668	1,556,375	25.0	2.5
Pre-Recruit N 2004	1,384,825	1,392,304	1,373,769	27.0	0.8
Pre-Recruit N 2005	1,504,994	1,498,965	1,470,854	27.2	2.3
Pre-Recruit N 2006	1,382,550	1,382,568	1,349,262	28.6	2.5
Pre-Recruit N 2007	1,535,034	1,516,539	1,485,353	28.5	3.3
Pre-Recruit N 2008	1,119,420	1,132,861	1,098,713	31.2	1.9
Pre-Recruit N 2009	981,642	994,174	959,996	31.5	2.3
Pre-Recruit N 2010	1,272,503	1,255,979	1,231,575	27.9	3.3
Pre-Recruit N 2011	666,746	689,154	663,287	32.3	0.5
Pre-Recruit N 2012	668,300	691,674	670,731	30.6	-0.4
Pre-Recruit N 2013	895,730	926,568	898,712	29.4	-0.3
Recruit N 1989	563,097	537,591	529,093	25.1	6.4
Recruit N 1990	560,997	558,279	550,421	21.7	1.9
Recruit N 1991	907,412	894,492	885,316	18.9	2.5
Recruit N 1992	744,358	748,711	741,936	19.7	0.3
Recruit N 1993	653,153	659,742	651,241	22.5	0.3
Recruit N 1994	517,127	524,708	514,298	26.2	0.6
Recruit N 1995	672,431	677,590	663,217	24.7	1.4
Recruit N 1996	705,639	716,912	703,259	25.4	0.3
Recruit N 1997	863,327	870,917	849,483	25.8	1.6
Recruit N 1998	644,742	642,677	627,868	27.1	2.7
Recruit N 1999	898,751	906,155	886,855	23.6	1.3
Recruit N 2000	1,074,978	1,064,666	1,052,833	22.6	2.1
Recruit N 2001	977,415	980,730	965,640	22.6	1.2
Recruit N 2002	1,205,327	1,201,512	1,186,629	21.4	1.6
Recruit N 2003	1,357,158	1,365,235	1,344,869	20.1	0.9
Recruit N 2004	1,613,861	1,605,774	1,588,394	19.7	1.6
Recruit N 2005	1,553,957	1,553,461	1,532,483	20.1	1.4
Recruit N 2006	1,891,109	1,885,767	1,870,056	18.5	1.1
Recruit N 2007	2,233,987	2,229,628	2,209,099	16.4	1.1
Recruit N 2008	2,521,743	2,503,032	2,488,717	15.3	1.3
Recruit N 2009	2,499,386	2,495,071	2,483,762	14.2	0.6
Recruit N 2010	2,505,191	2,511,918	2,497,313	13.2	0.3
Recruit N 2011	2,484,644	2,476,623	2,468,656	12.0	0.6
Recruit N 2012	1,607,723	1,619,502	1,612,753	14.8	-0.3
Recruit N 2013	864,576	893,358	881,271	22.3	-1.9
Recruit N 2014	985,670	1,034,482	1,013,777	22.9	-2.8

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

Figure 1. Length frequency of white perch from upper Chesapeake Bay trawl survey, 2014.

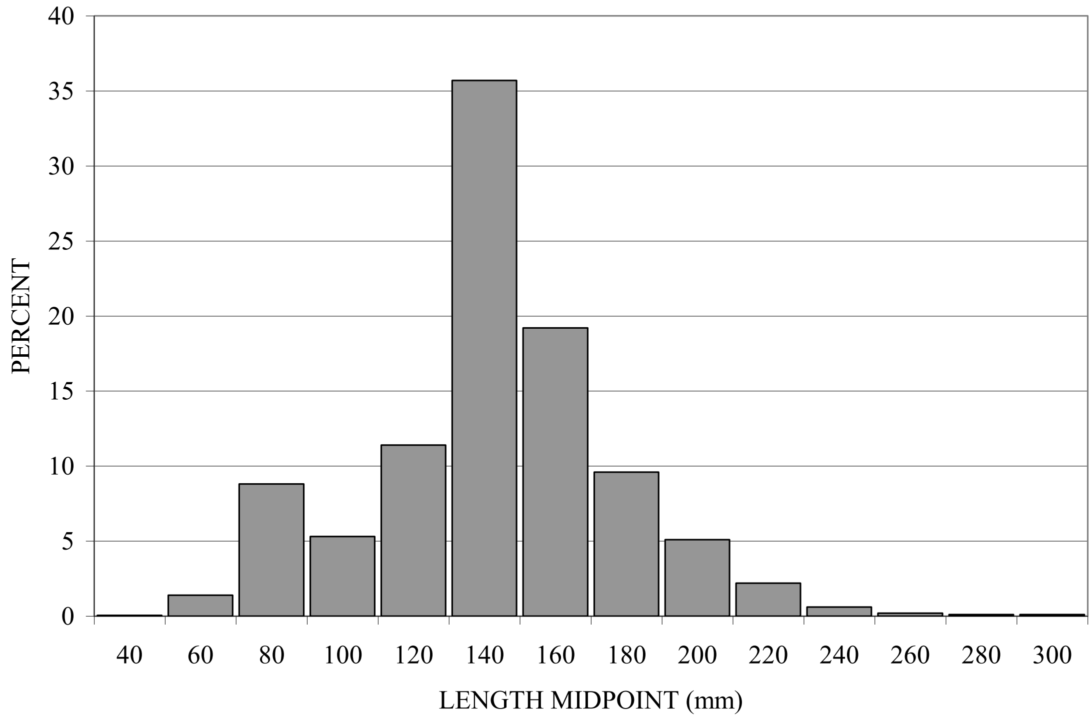


Figure 2. Length frequency of white perch from Choptank River fyke net survey, 2014.

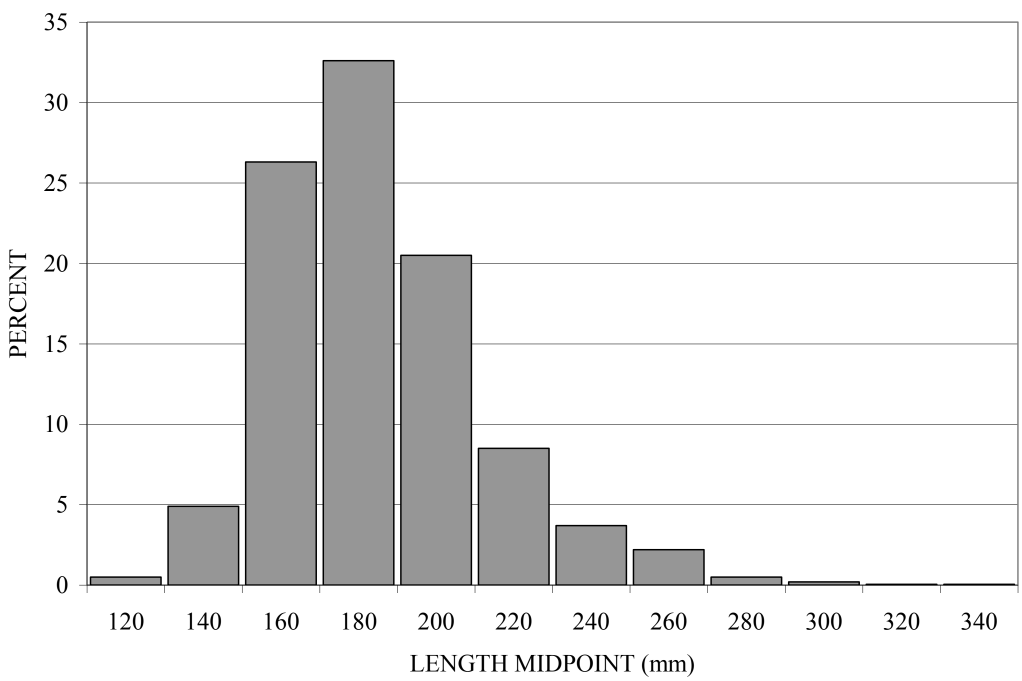


Figure 3. Upper Chesapeake Bay trawl sites, 2014.

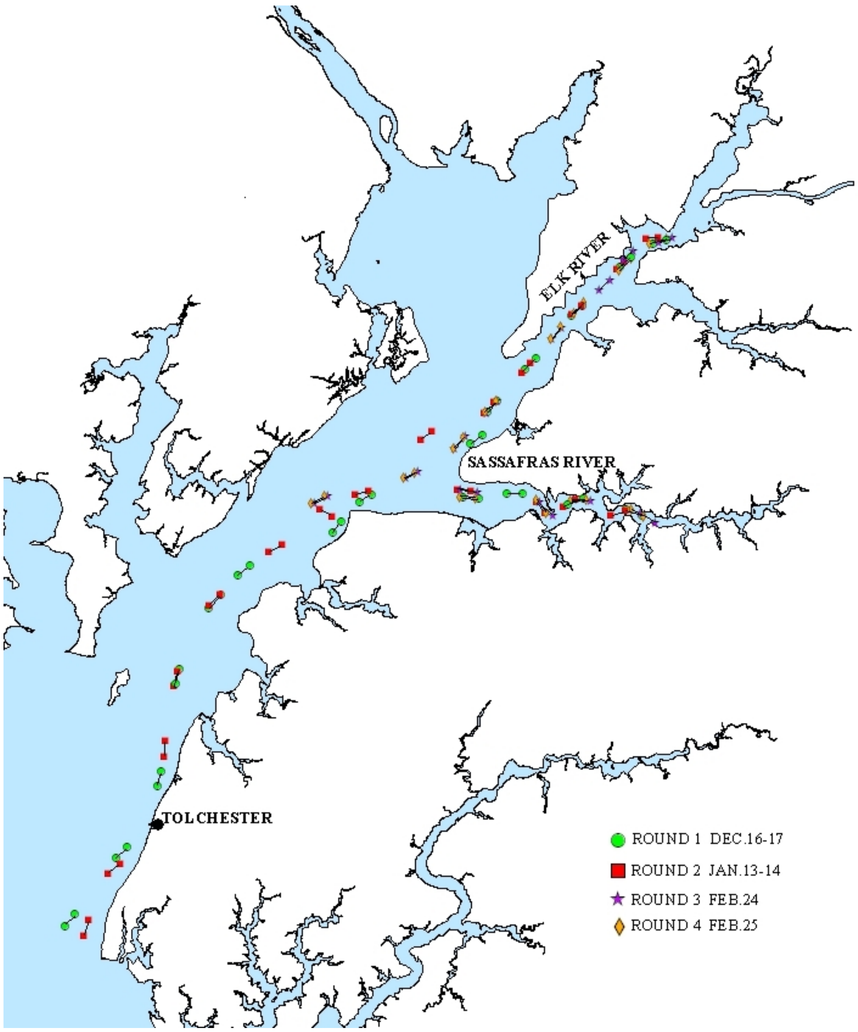


Figure 4. Choptank River fyke net sites (circles), 2014.

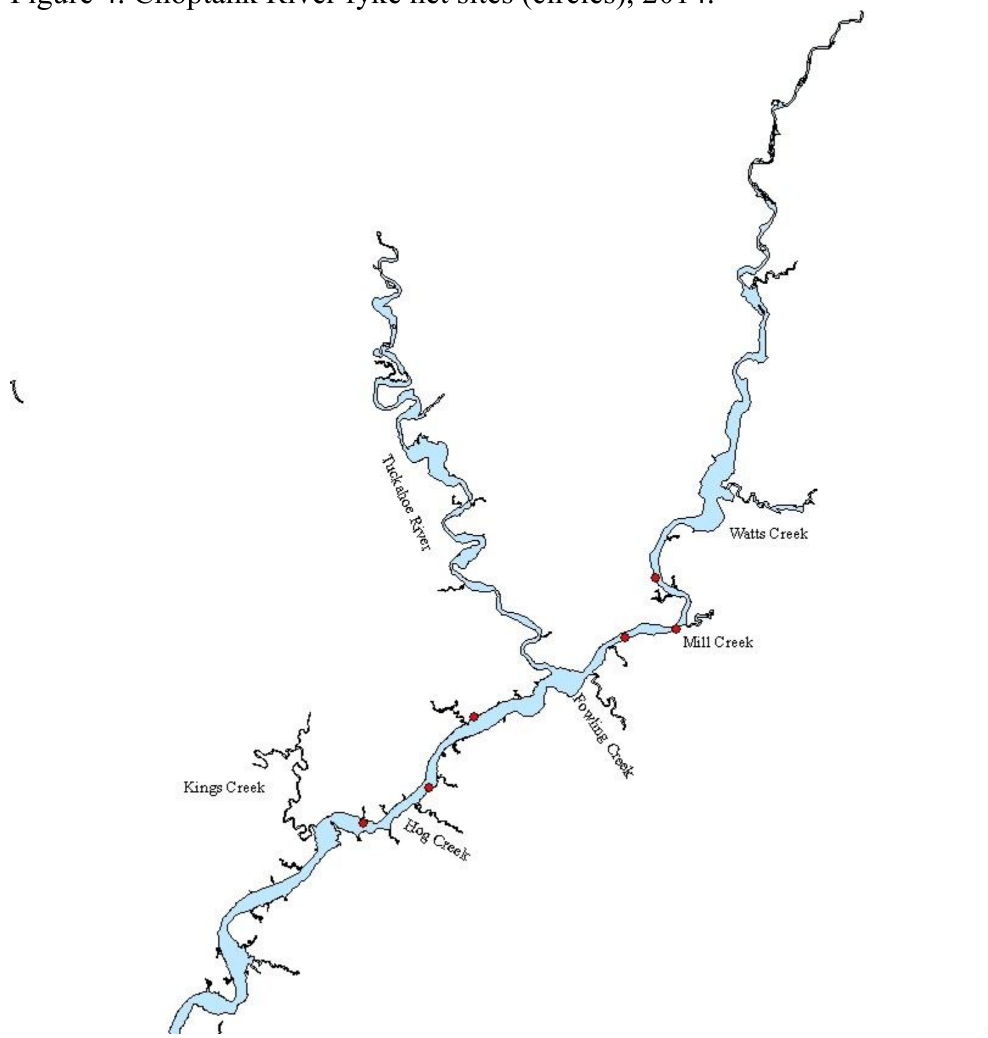


Figure 5. Estimated upper Chesapeake Bay white perch removals (commercial and recreational), 2000 – 2013.

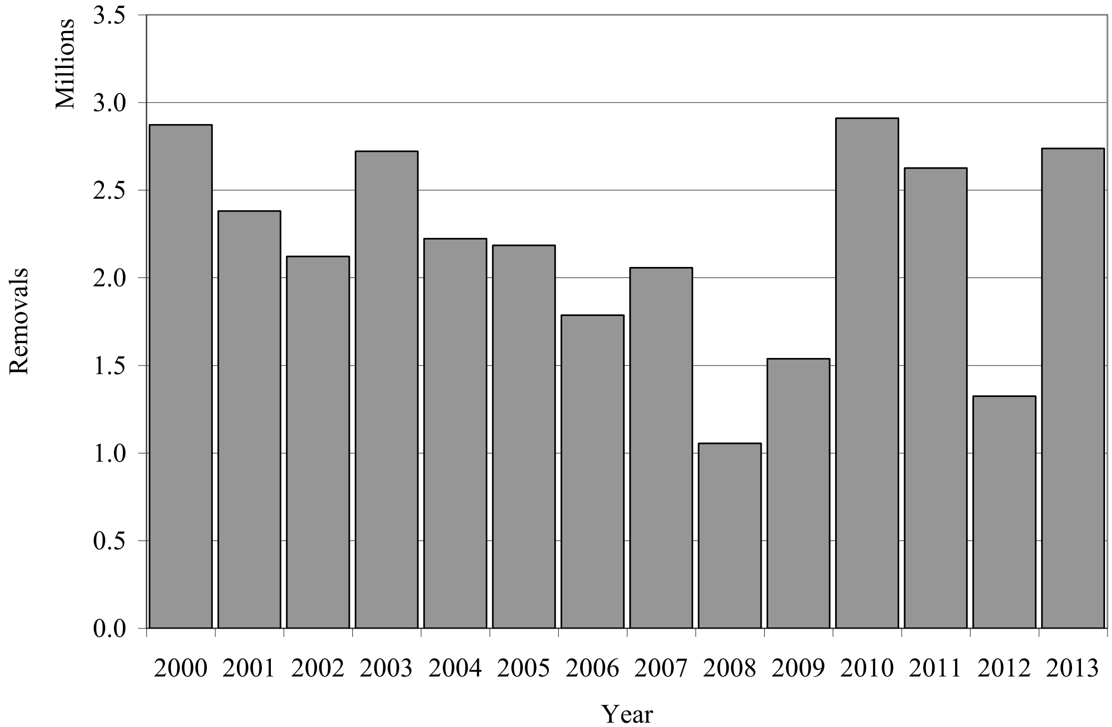


Figure 6. Observed and expected white perch pre-recruit indices from upper Chesapeake Bay trawl survey, 2000 – 2013.

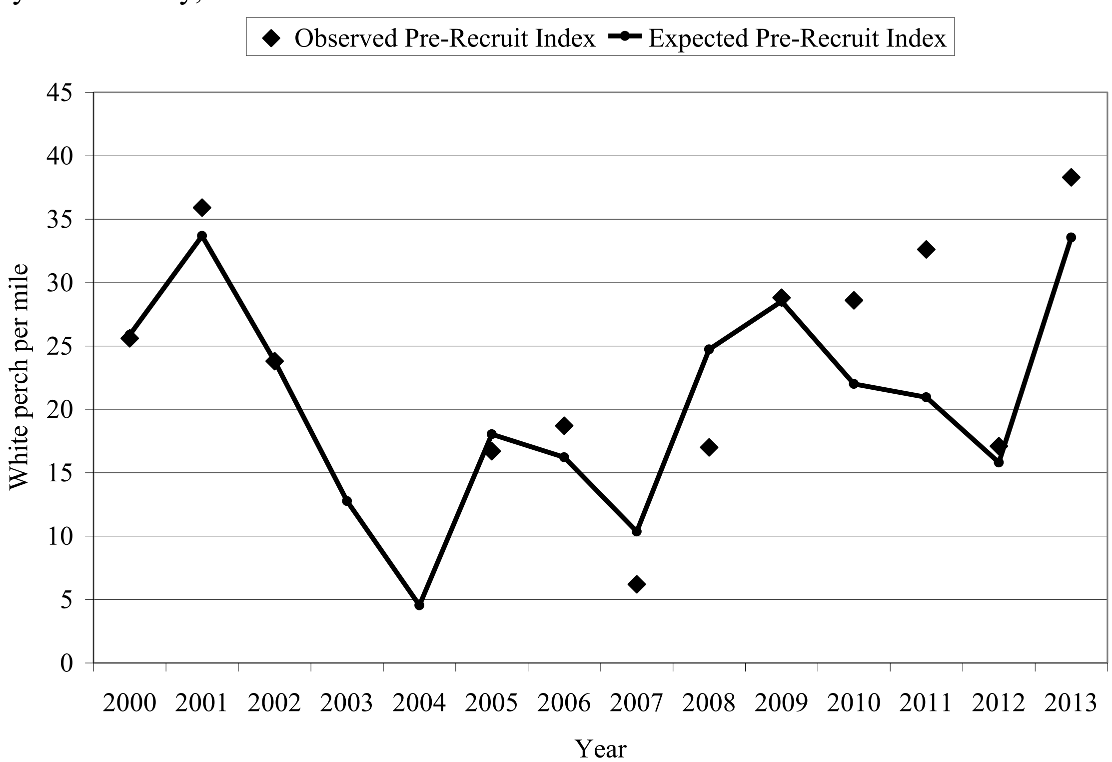


Figure 7. Observed and expected white perch post-recruit indices from upper Chesapeake Bay trawl survey, 2000 – 2014.

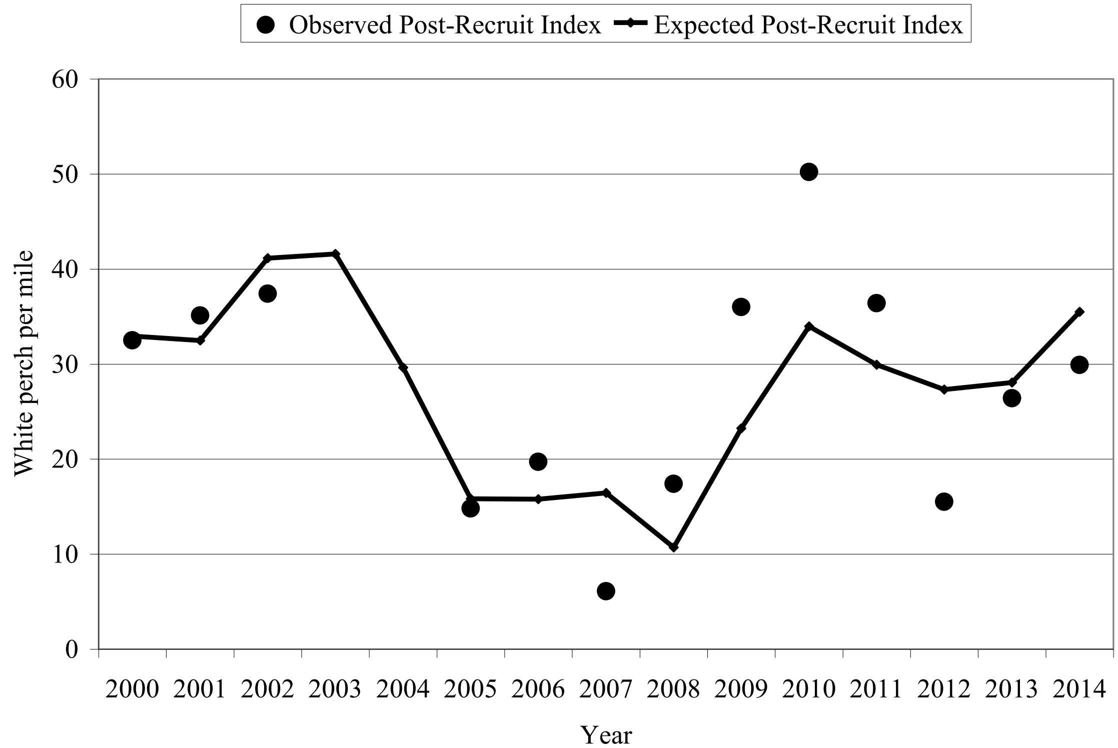


Figure 8. Total population estimate of upper Chesapeake Bay white perch from Catch Survey Analysis, 2000 – 2013.

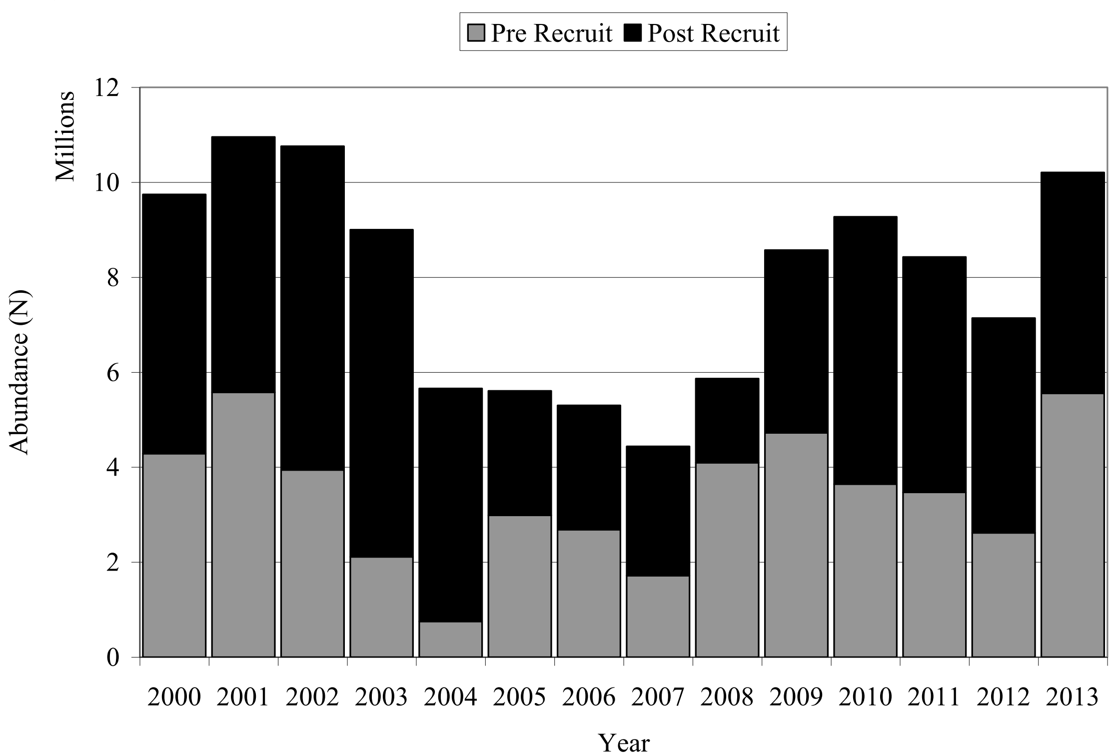


Figure 9. Instantaneous fishing mortality (F) of upper Chesapeake Bay white perch and proposed biological reference points for F, 2000—2013.

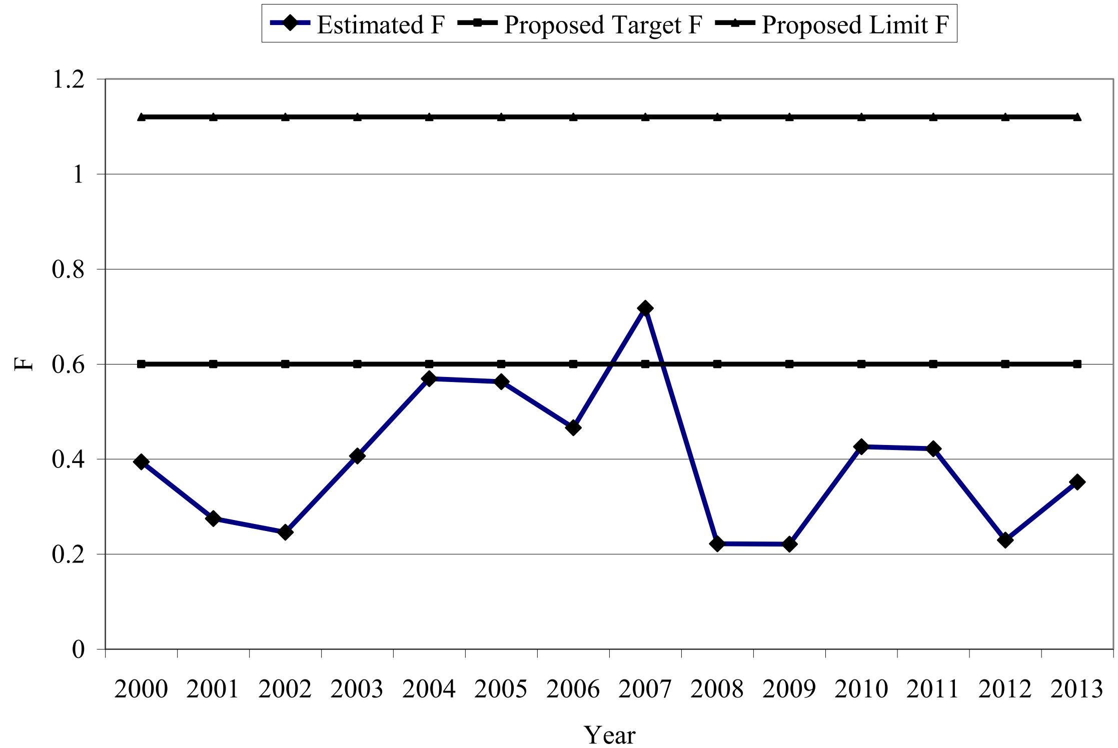


Figure 10. Pre-recruit residuals from upper Chesapeake Bay Catch Survey Analysis of white perch.

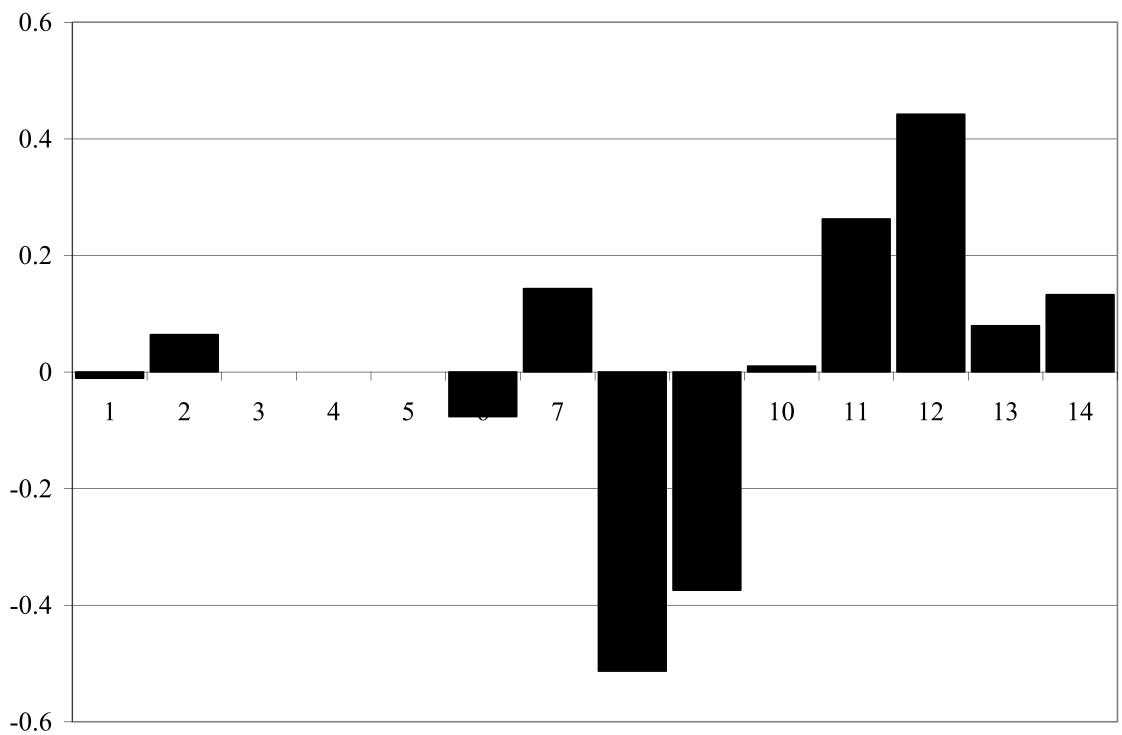


Figure 11. Post-recruit residuals from upper Chesapeake Bay Catch Survey Analysis of white perch.

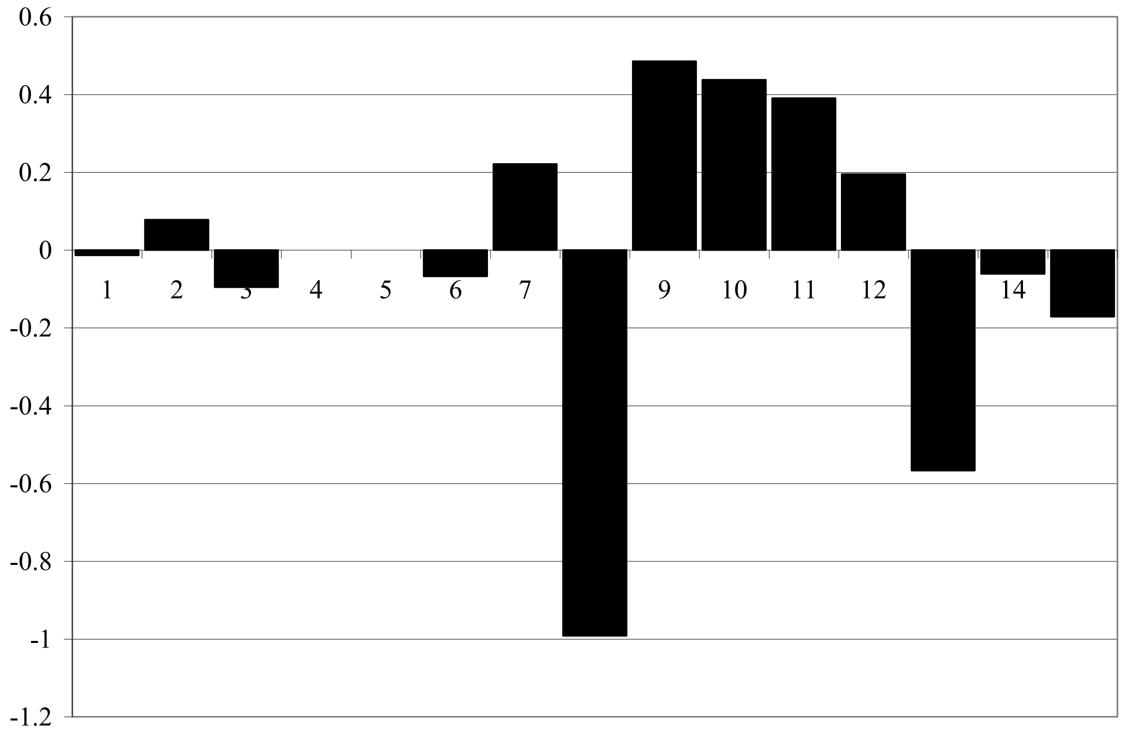


Figure 12. Bootstrap derived confidence intervals (80 %) for upper Chesapeake Bay pre-recruit white perch.

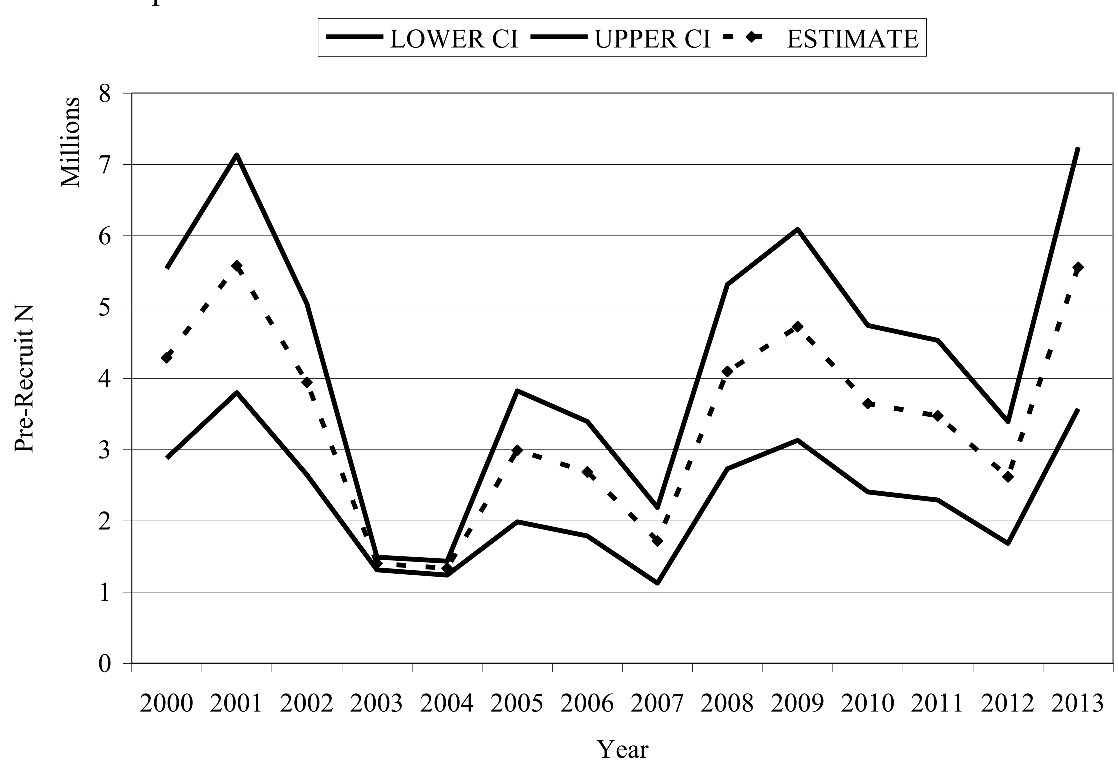


Figure 13. Bootstrap derived confidence intervals (80 %) for upper Chesapeake Bay post-recruit white perch.

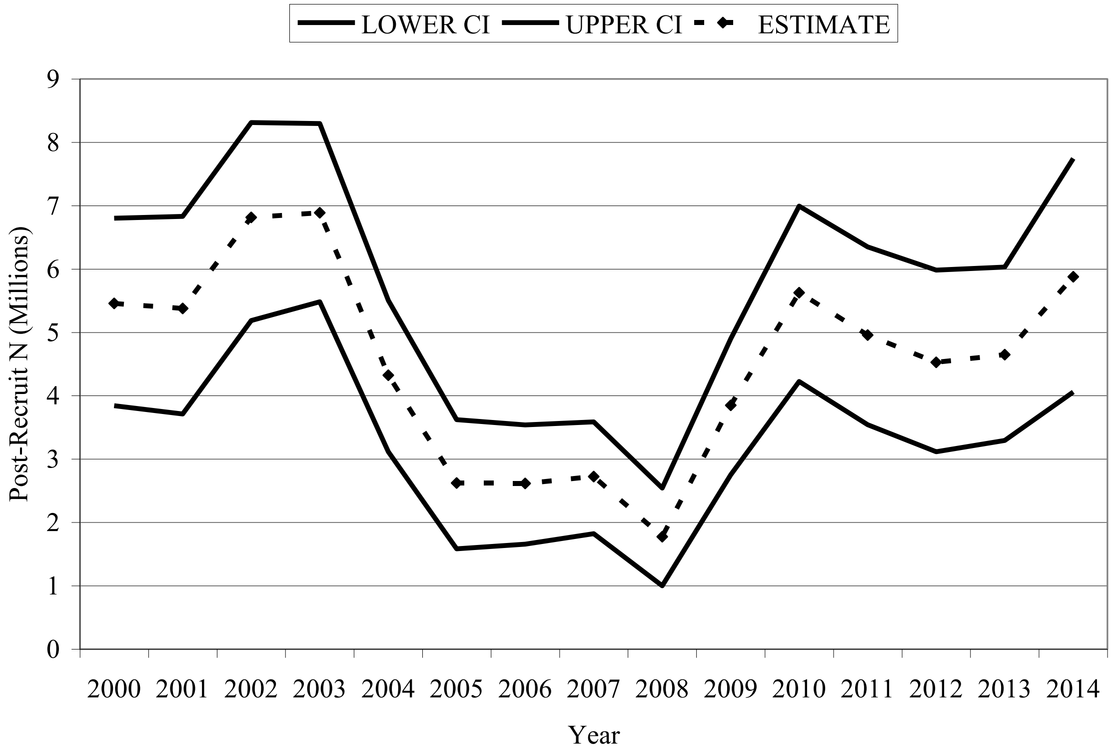


Figure 14. Retrospective analysis of upper Chesapeake Bay pre-recruit white perch estimates from Catch Survey Analysis.

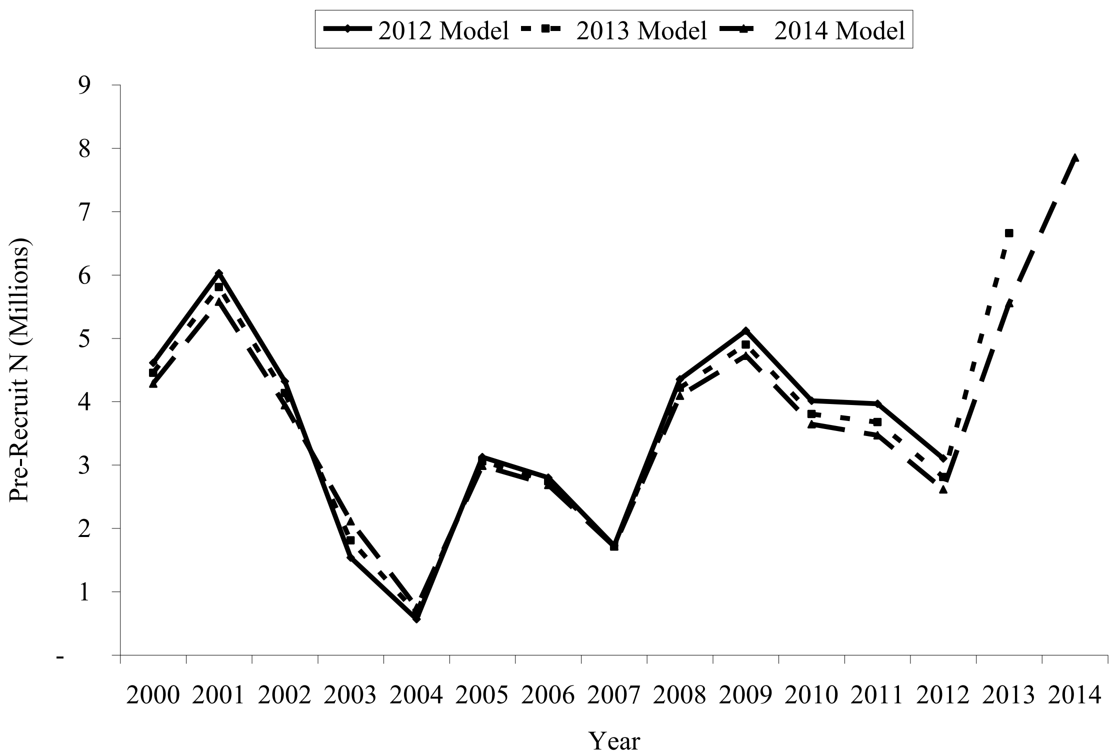


Figure 15. Retrospective analysis of upper Chesapeake Bay post-recruit white perch estimates from Catch Survey Analysis.

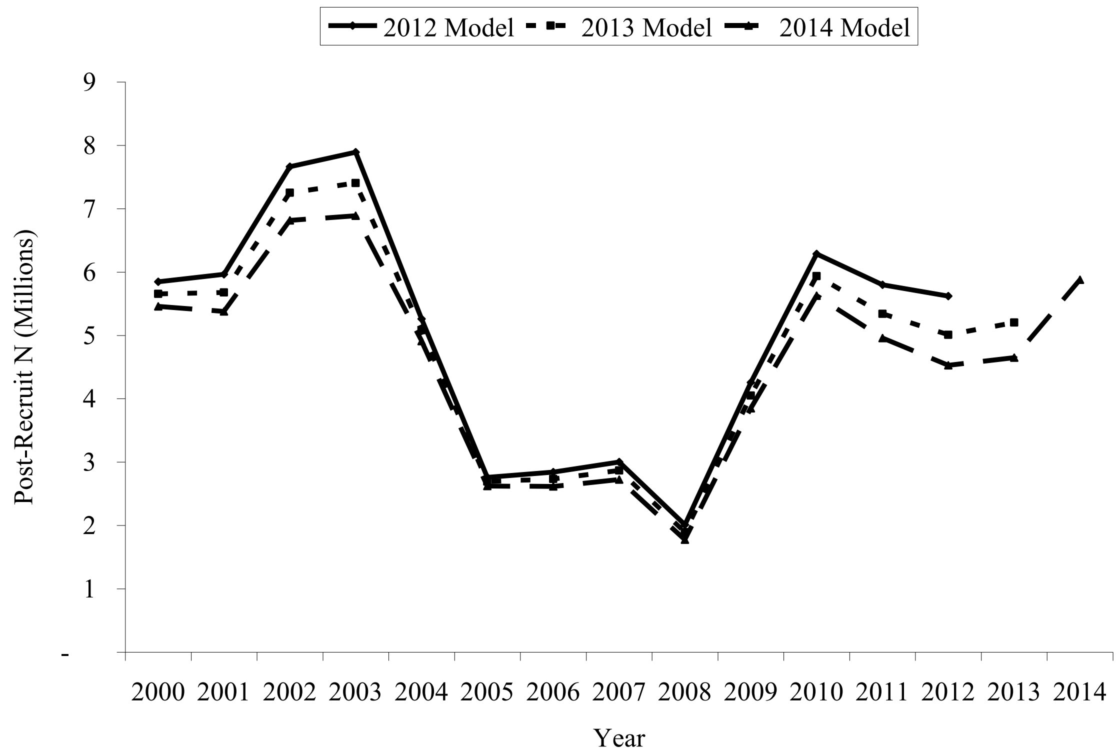


Figure 16. Retrospective analysis of upper Chesapeake Bay instantaneous fishing mortality estimates of white perch from Catch Survey Analysis.

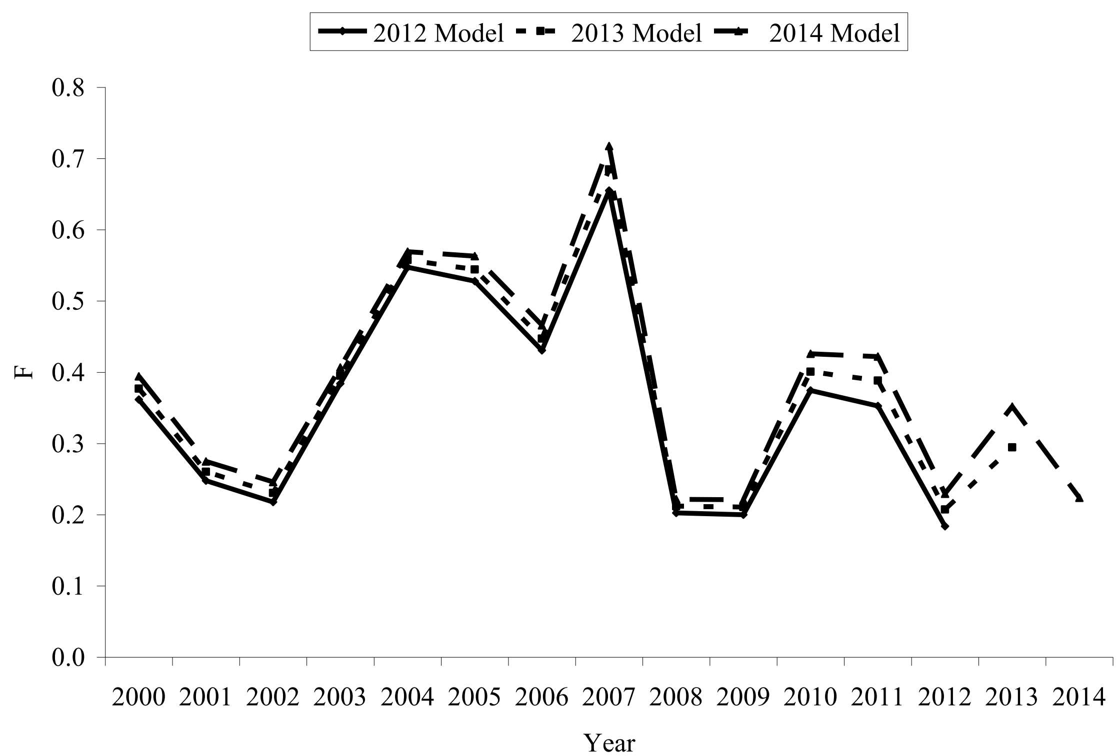


Figure 17. Estimated Choptank River white perch removals (commercial and recreational), 2000 – 2013.

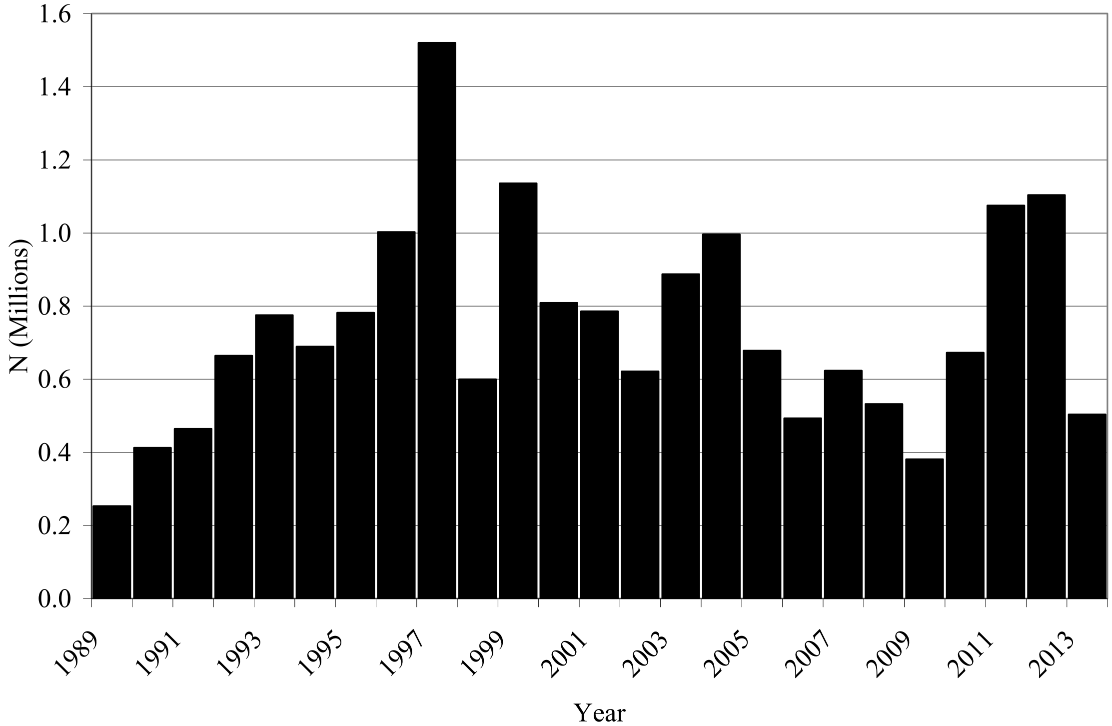


Figure 18. Observed and expected Choptank River pre-recruit white perch fyke indices, 1989—2013.

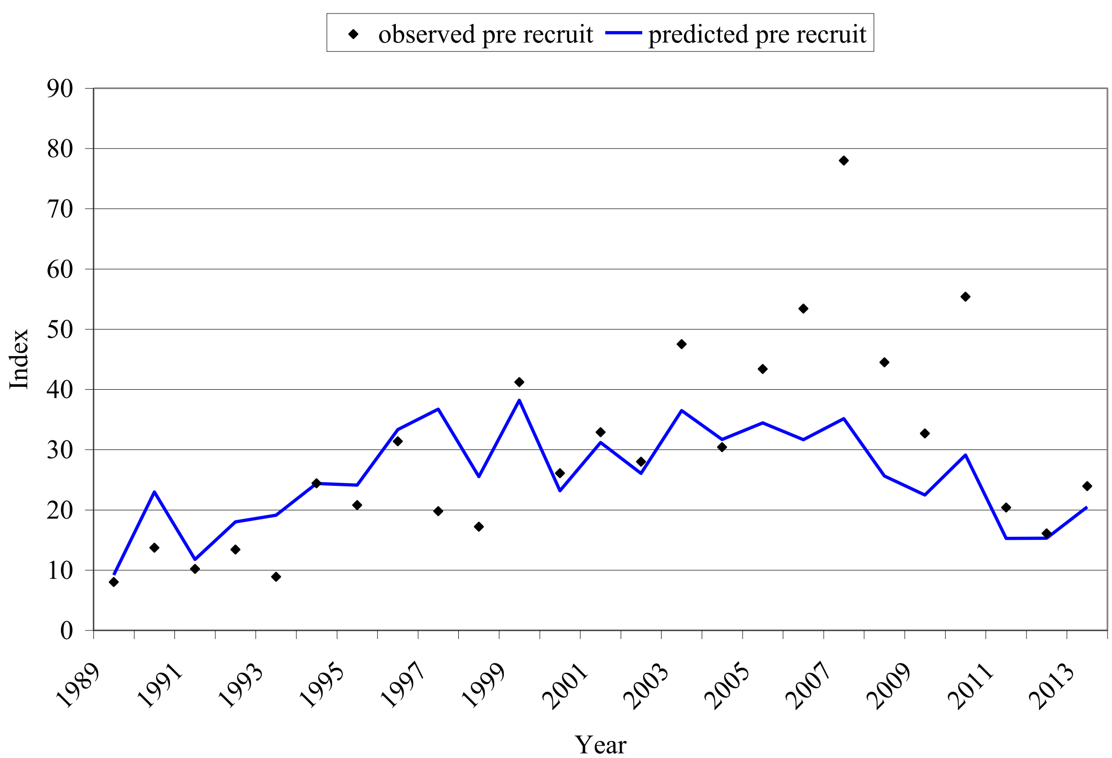


Figure 19. Observed and expected Choptank River post-recruit white perch fyke indices, 1989—2014.

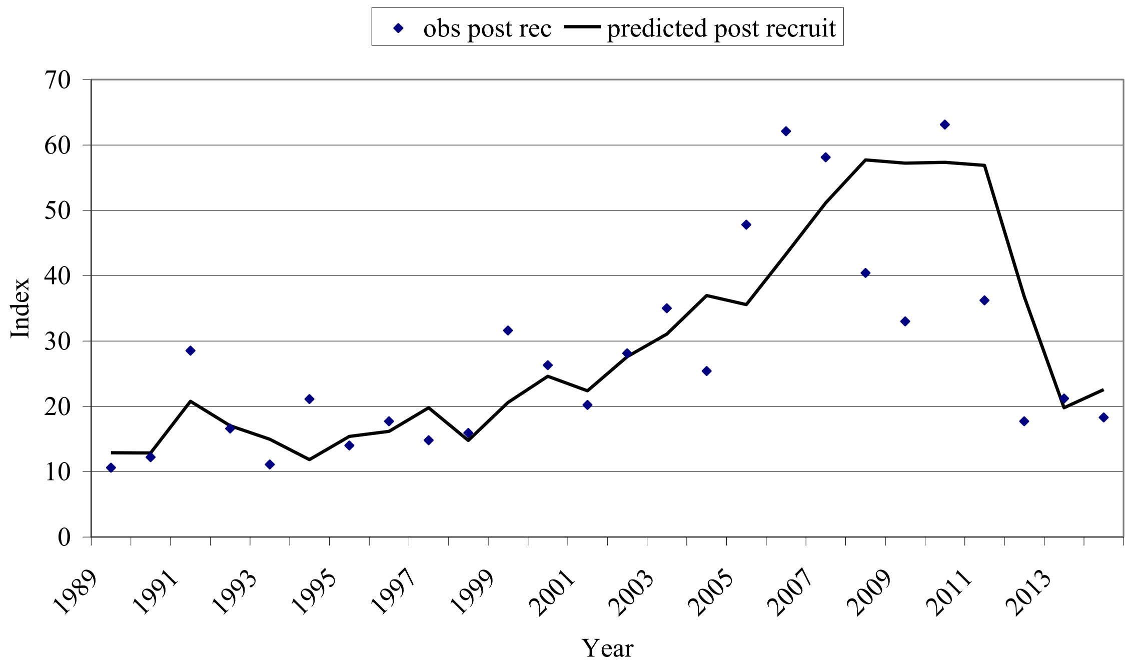


Figure 20. Estimated population abundance of pre-recruit and post-recruit white perch in the Choptank River, 1989 – 2014.

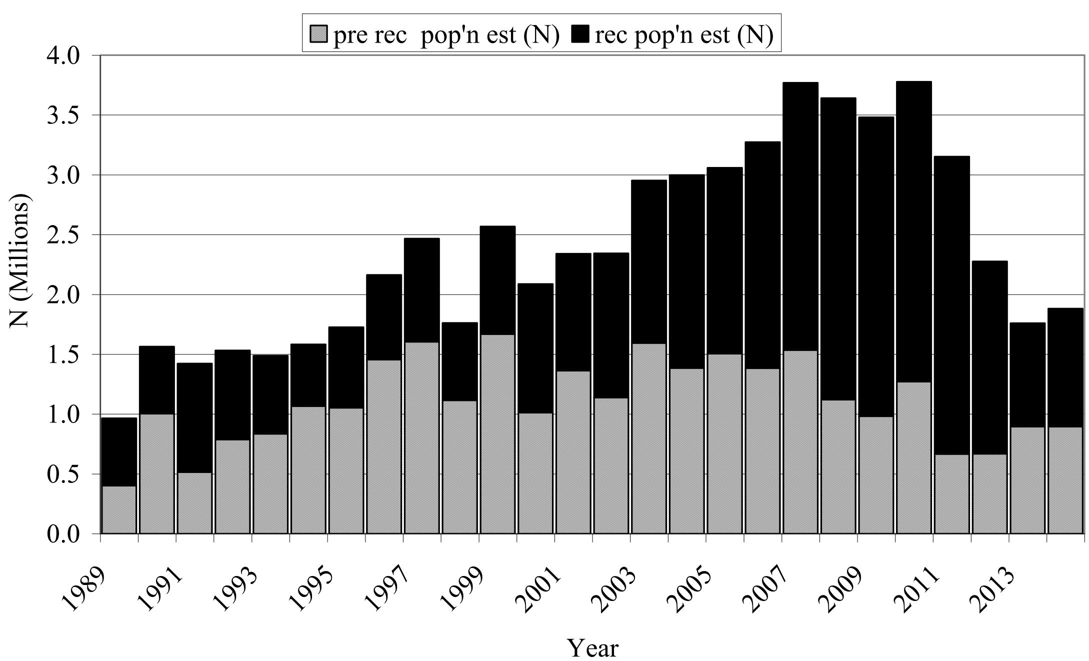


Figure 21. Instantaneous fishing mortality (F) of Choptank River white perch and proposed biological reference points for F, 2000—2013.

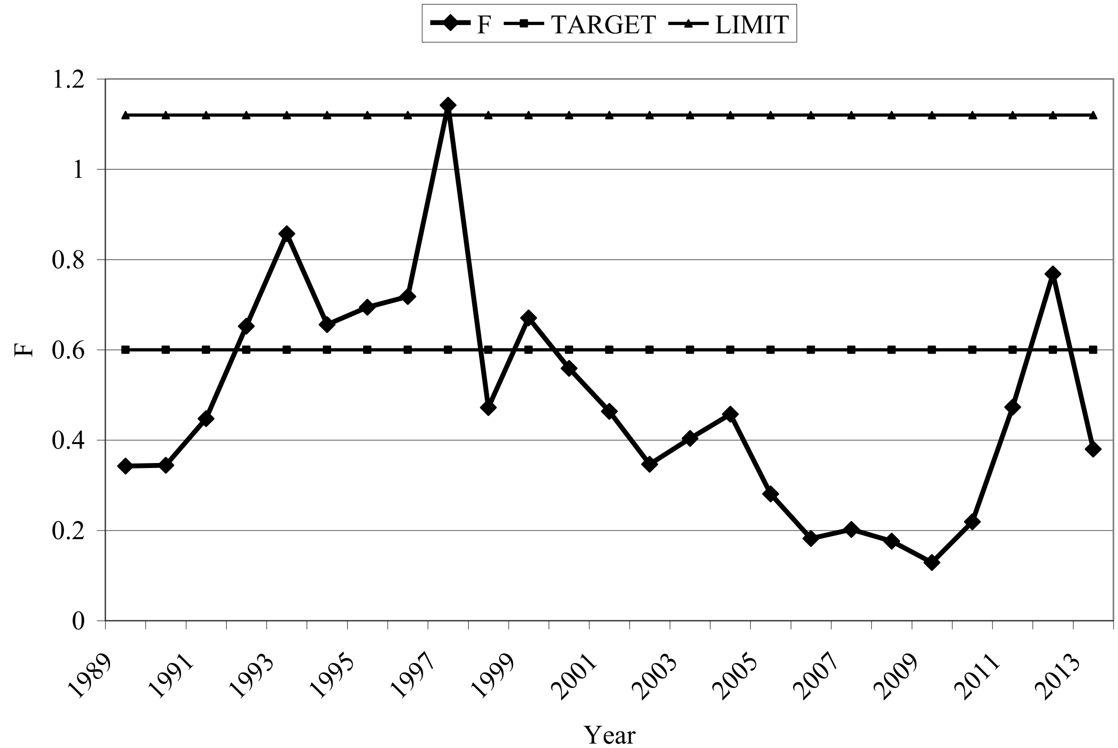


Figure 22. Pre-recruit residuals from Catch Survey Analysis of Choptank River white perch.

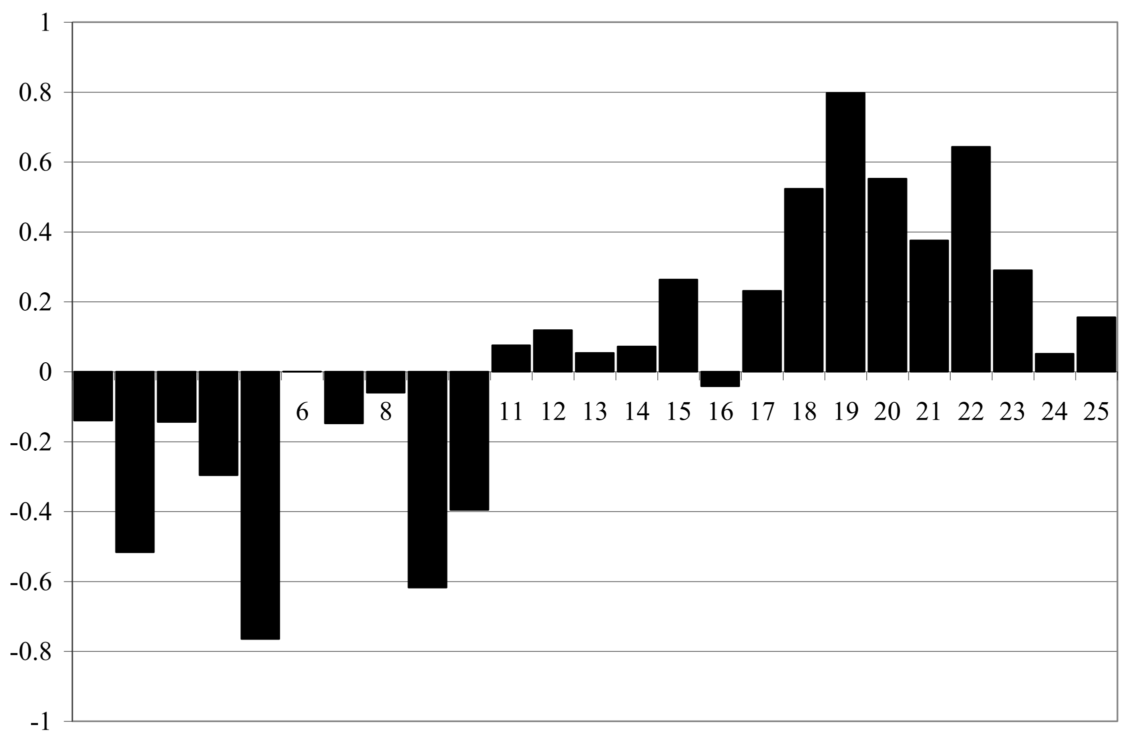


Figure 23. Post-recruit residuals from Catch Survey Analysis of Choptank River white perch.

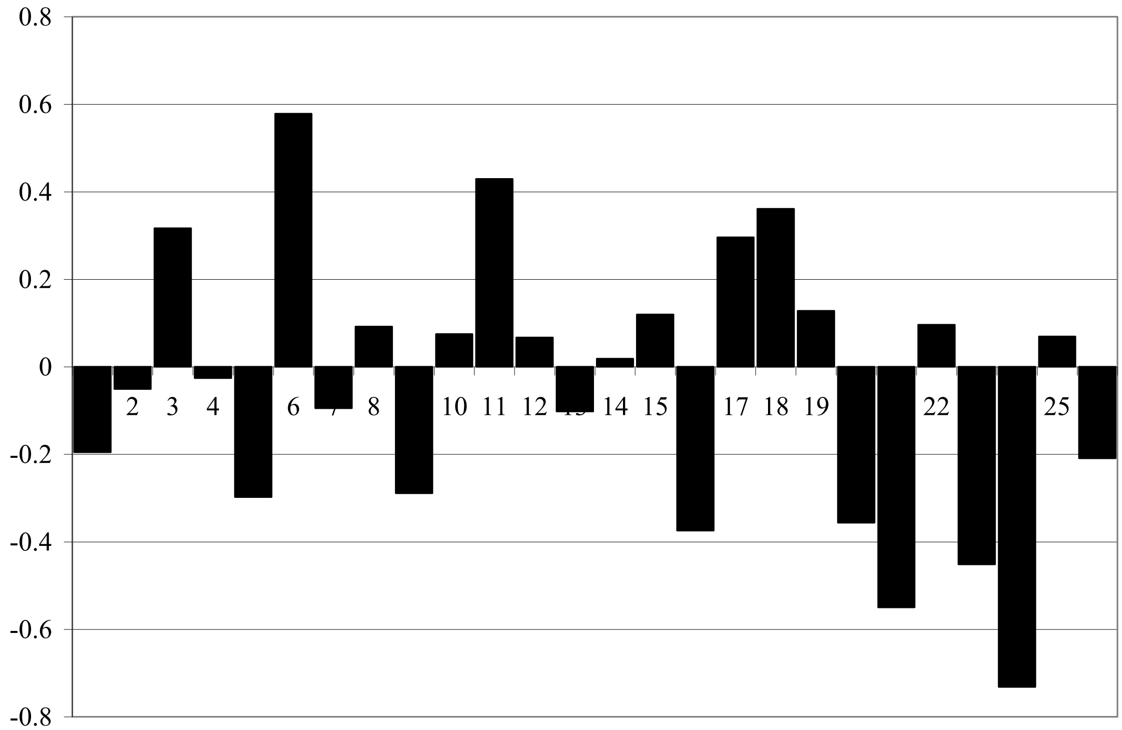


Figure 24. Bootstrap derived confidence intervals (80 %) for Choptank River pre-recruit white perch.

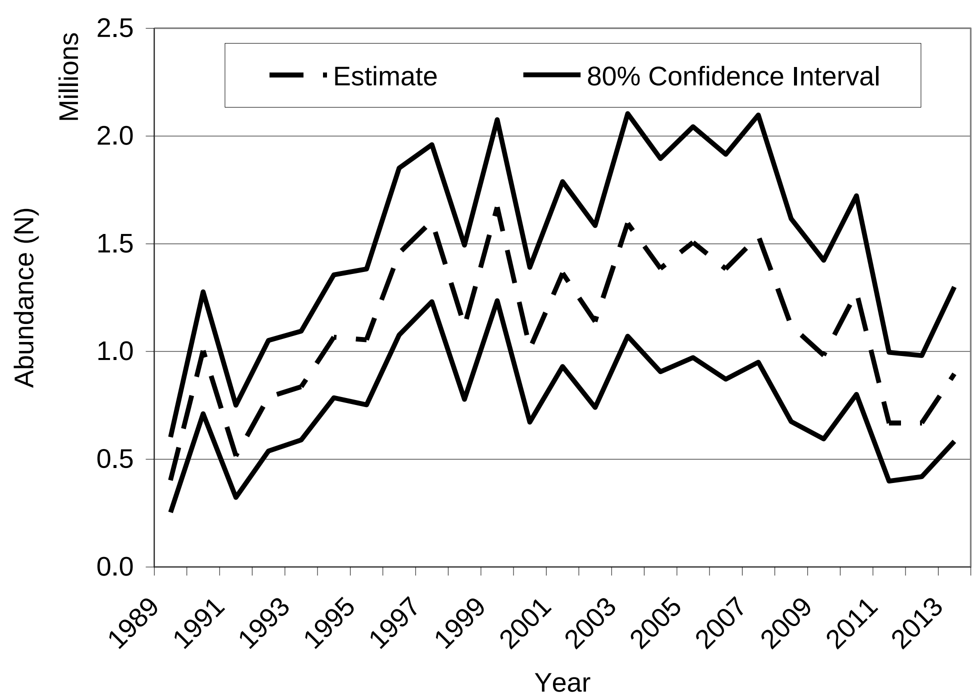


Figure 25. Bootstrap derived confidence intervals (80 %) for Choptank River post-recruit white perch.

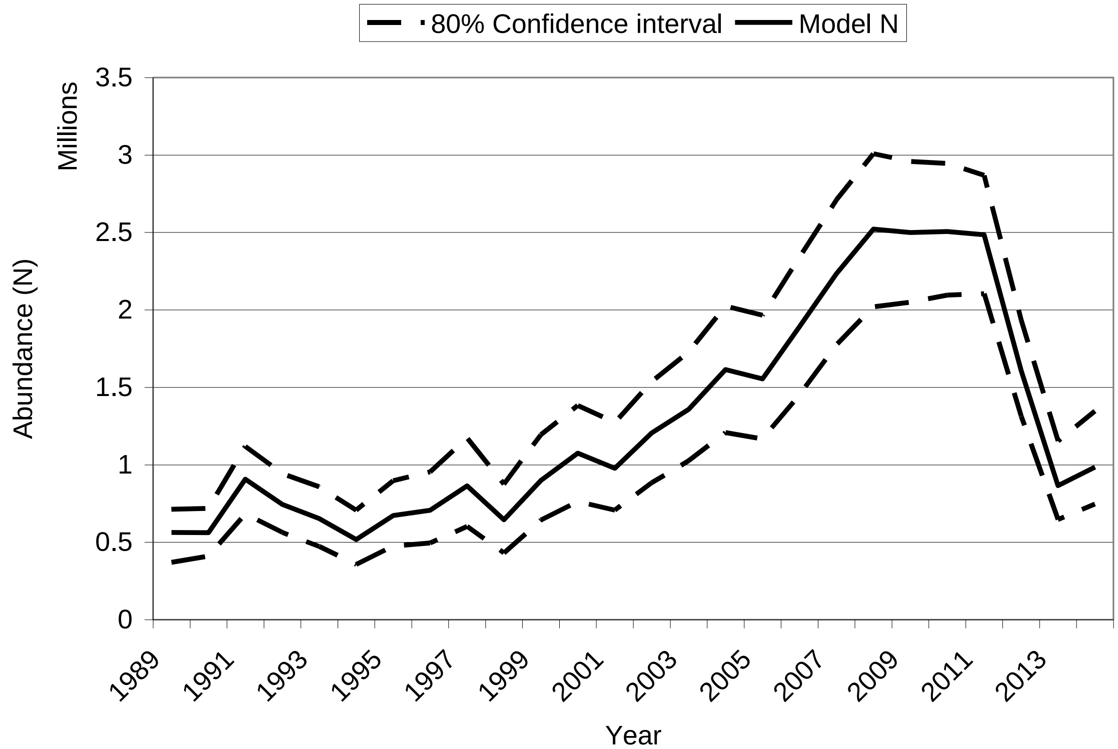


Figure 26. Retrospective analysis of Choptank River pre-recruit white perch estimates from Catch Survey Analysis.

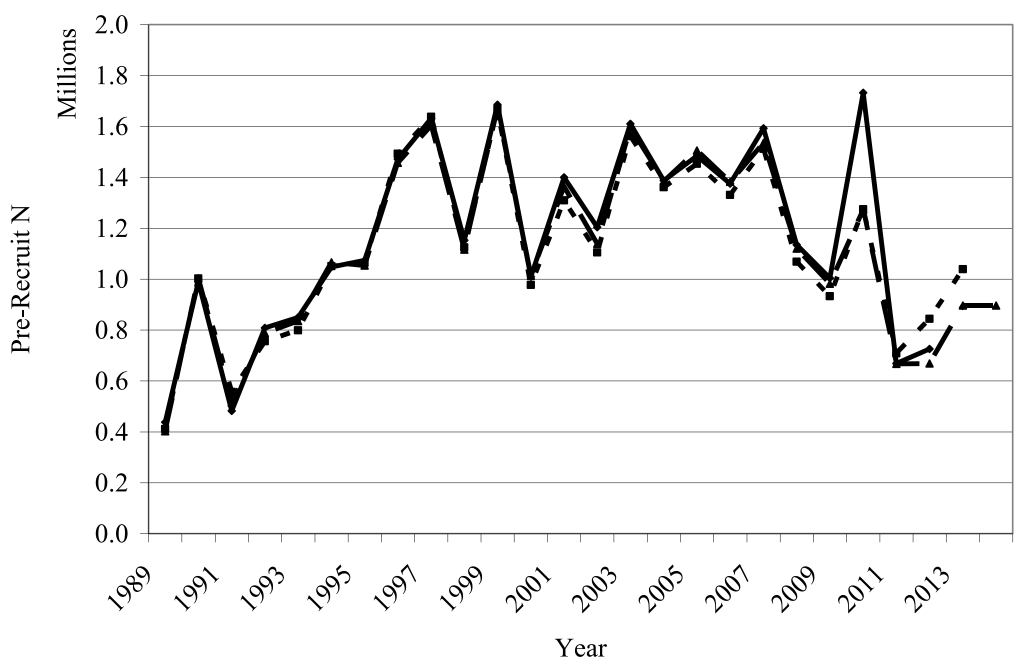


Figure 27. Retrospective analysis of Choptank River post-recruit white perch estimates from Catch Survey Analysis.

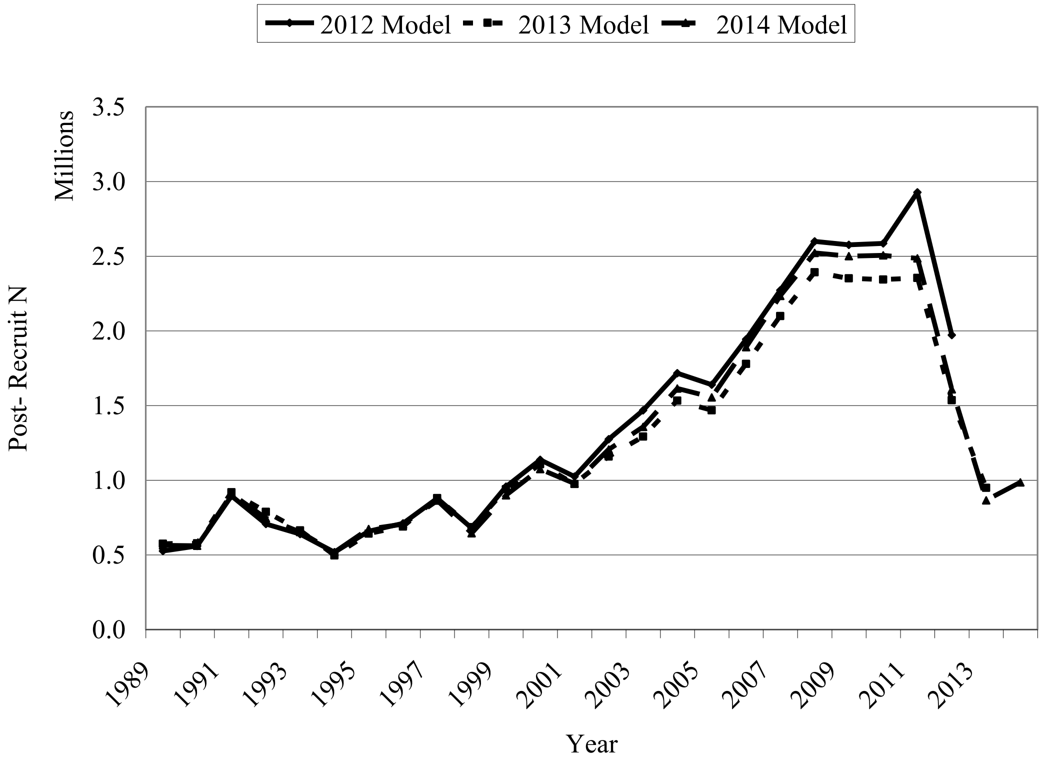


Figure 28. Retrospective analysis of Choptank River instantaneous fishing mortality estimates of white perch from Catch Survey Analysis.

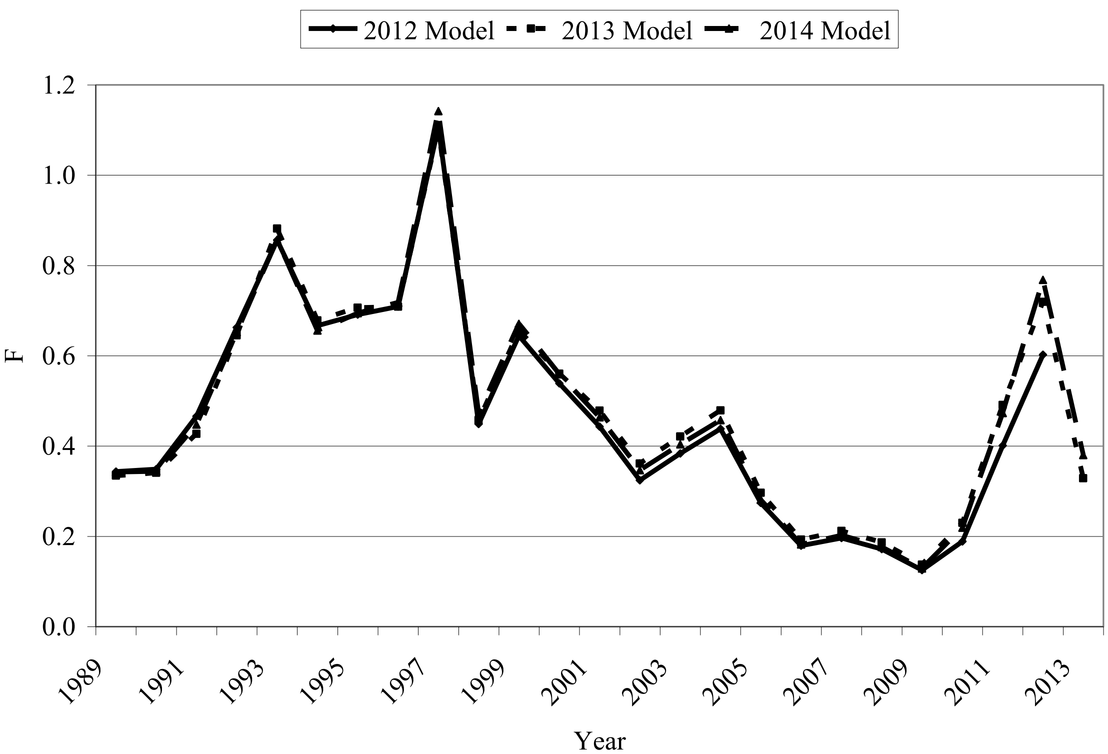


Figure 29. Lower Chesapeake Bay fishery dependent white perch fyke net index, 1980 – 2013. Horizontal line = time-series average.

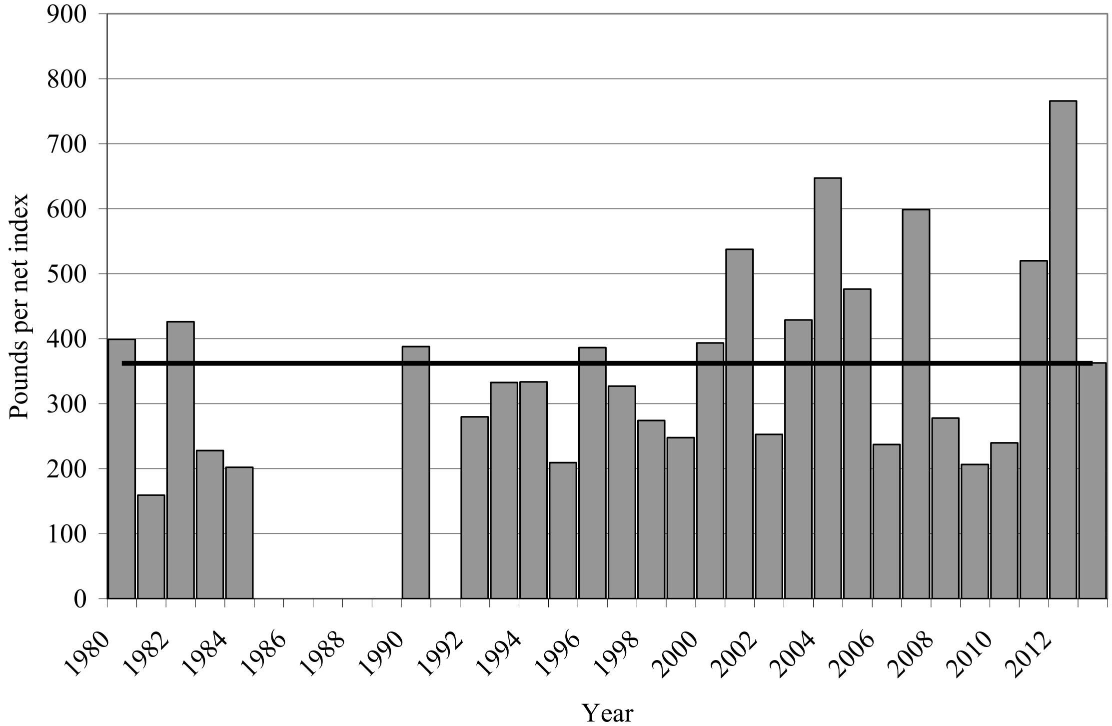


Figure 30. Lower Chesapeake Bay fishery dependent white perch pound net index, 1981 – 2013. Horizontal line = time-series average.

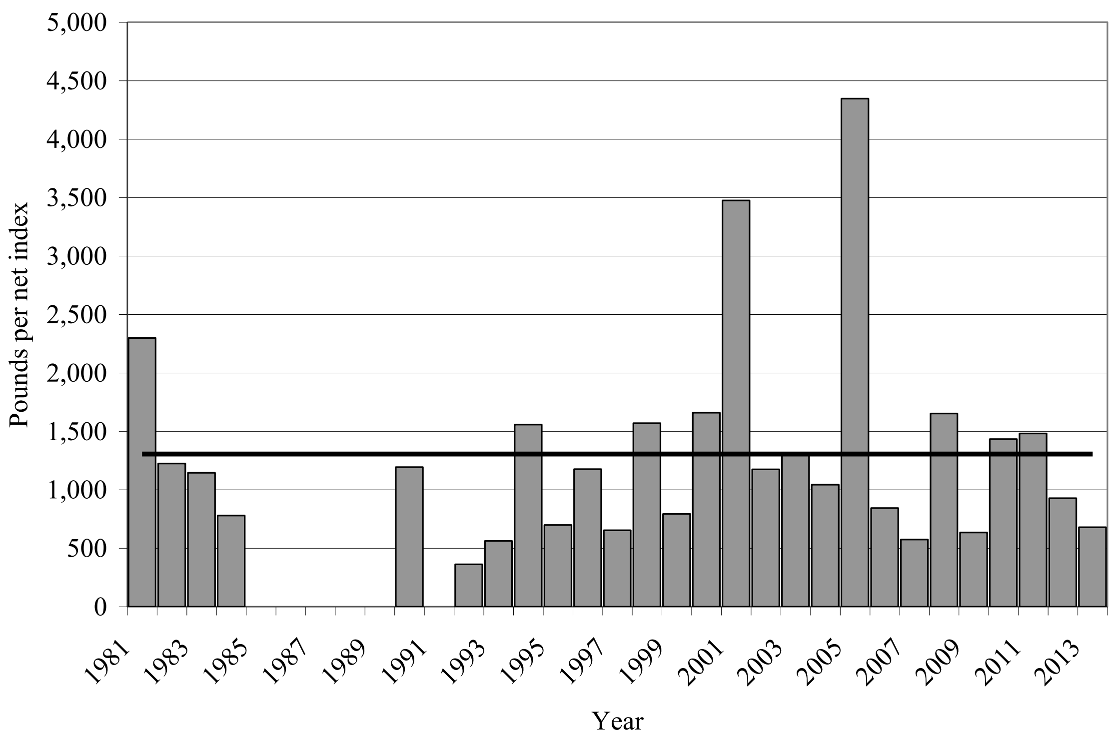


Figure 31. Lower Chesapeake Bay fishery dependent white perch gill net index, 1980 – 2013. Horizontal line = time-series average

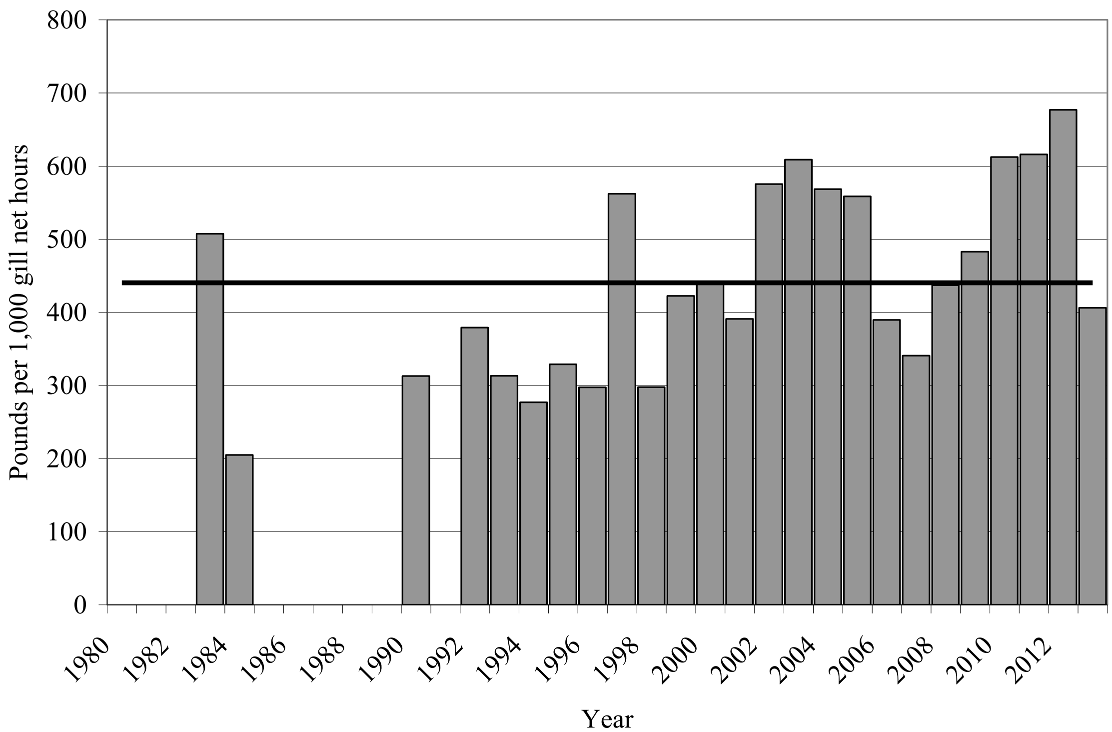


Figure 32. Potomac River fishery independent gill net survey white perch index, 1985— 2014. Horizontal line = time-series average.

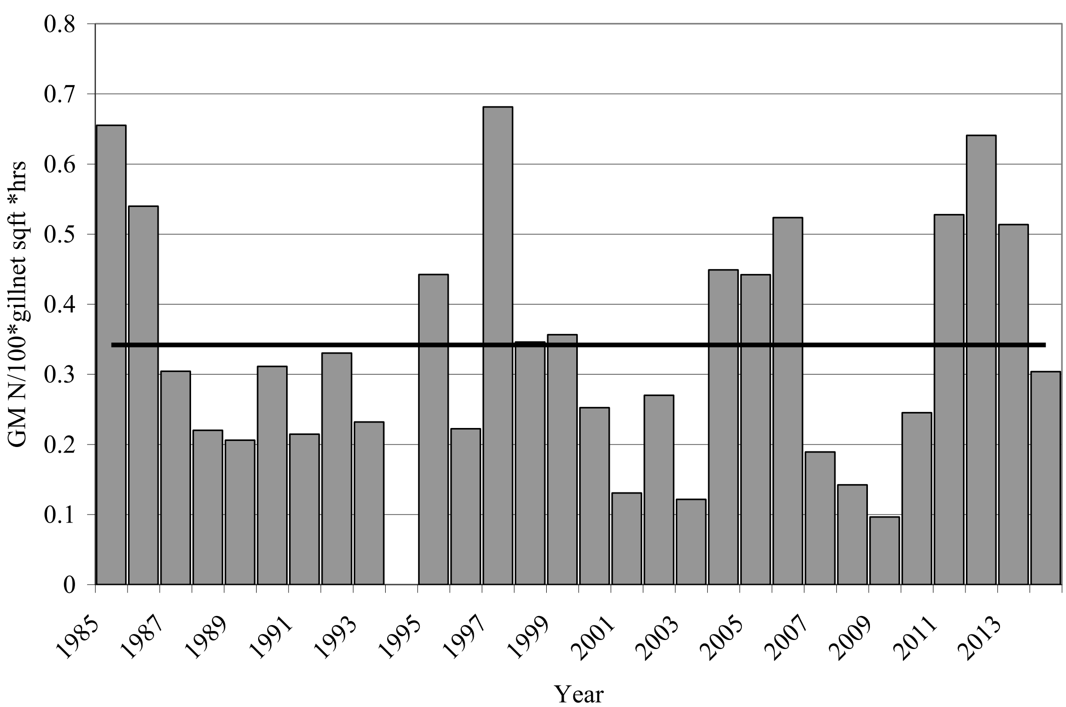
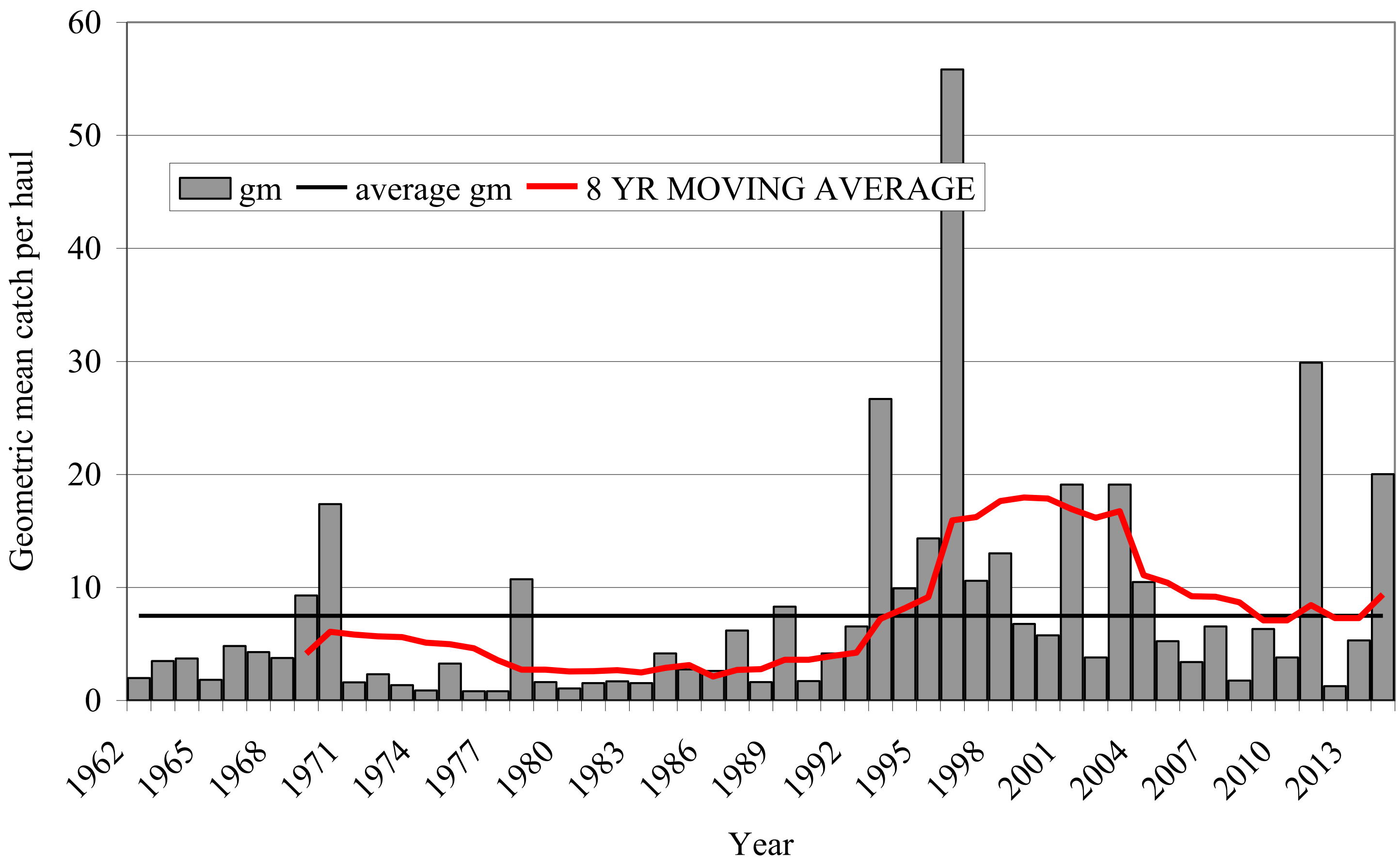


Figure 33. Lower Chesapeake Bay young-of-year white perch seine index, 1962 – 2014.



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 sex, age and stock composition data. Hickory shad abundance was assessed in a tributary to the Susquehanna River (Deer Creek) by the MDNR Restoration and Enhancement Program. In the Nanticoke River, biologists worked with commercial fishermen to collect sex, age and stock composition data and to estimate relative abundance of adult American shad, hickory shad and river herring, and independently sampled ichthyoplankton. Survey biologists collected similar data for adult American shad in the Potomac River utilizing fishery-independent gill nets (SBSSS; Project 2, Job 3, Task 2).

The data collected during this study 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 30 April through 3 June 2014 (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 the Susquehanna River (including the Conowingo tailrace and Deer Creek) and North East Creek. 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 (2004-2014) from their brood stock collection. Hickory shad were collected in Deer Creek (a Susquehanna River tributary) for hatchery brood stock and were subsampled for age, repeat spawning marks, sex, length and weight. In 2004 and 2005, fish were collected using hook and line fishing; fish have been collected using electrofishing gear from 2006 to present.

Nanticoke River

Two commercial pound nets and five commercial fyke nets were surveyed for American shad, hickory shad and river herring between 28 March and 29 April 2014 (Figure 2). Fish captured from these nets were sorted according to species and transferred to the survey boat for processing. All nets were sampled two days per week during the survey period. Fish were sexed (by expression of gonadal products), measured to the nearest mm (TL and FL), and scales were removed below the insertion of the dorsal fin for ageing and spawning history analysis. Otoliths from dead adult American shad were removed and sent to the Delaware Division of Fish and Wildlife (DE DFW) for OTC analysis.

Ichthyoplankton sampling was conducted in cooperation with the Fish Habitat & Ecosystem Program (Federal Aid Grant F-63-R, Segment 2, Job 1, Section 3) twice per week from **7** April to 29 April 2014 in the Nanticoke River. The presence/absence of alosine eggs or larvae was noted (time and field conditions prevented species identification of alosine eggs or larvae). These samples were collected following historical methodology: the river was divided into eighteen one-mile cells and ten of these cells were randomly selected during each sampling day (Figure 3). The ichthyoplankton net was constructed of 500 μm mesh net with a 500 mm metal ring opening. The net was towed 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 from 3 April to 13 May 2014. 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.

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, captured in pound and fyke nets in the Nanticoke River and gill netted in the Potomac River. Male-female ratios were also derived for alewife herring and blueback herring captured by pound and fyke nets in the Nanticoke River. Due to the low number of hickory shad captured in the Nanticoke River survey, 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.

Alosine scales collected from all rivers were aged using Cating's method (Cating 1953) and 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 nonhatchery fish present from American shad collected in the WFL and Maryland's portion of the Nanticoke River, respectively.

Adult Relative Abundance

Catch-per-unit-effort (CPUE) from the Conowingo Dam tailrace was calculated as the number of adult fish captured per boat hour. We computed a combined lift CPUE as the total number of adult fish lifted per hour of lifting at the EFL and WFL. The geometric mean (GM) of adult American shad CPUE for both the tailrace area and the lifts was then calculated as the average LN (CPUE + 1) for each fishing/lifting day, transformed back to the original scale. In addition, the relative abundance (GM CPUE) of American shad, alewife herring and blueback herring in the Nanticoke River was calculated as the average LN (CPUE + 1) for each net day by gear type, transformed back to the original scale. No CPUE was calculated for hickory shad in the Nanticoke River due to the low number encountered by both gear types over the time series. Instead, the number of hickory shad captured by gear type is reported. 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. Catch-per-angler-hour (CPAH) for American shad angled in the Susquehanna River and hickory shad angled in the Susquehanna and North East Rivers were also calculated from the data collected by shad logbooks combined with online angler survey data. The roving creel survey was used to calculate a CPAH for American shad in the Conowingo Dam tailrace.

Historically, CPUE for American shad from the Nanticoke was only calculated with data from one pound net that was most consistently sampled over the time series (Mill Creek). Similarly, alewife and blueback herring CPUE were only calculated with fyke net data because pound nets were not consistently set in ideal habitat for river herring. Therefore, the number and location of fyke nets used for this calculation varies across the time series. This report follows these historical protocols.

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 shad and river herring in the Nanticoke River, and for 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).

Natural and fishing mortality were not estimated for any alosine species because American shad, hickory shad and river herring fisheries are closed in Maryland. Commercial landings, commercial and recreational bycatch, and EFL and WFL mortalities were considered when estimating the minimum total losses of adult American shad in Maryland waters.

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 7 days in 2014. Fertilized alosine eggs and/or larvae were present at 24.2% of tow stations in 2014 (Table 1). Salinity at tow stations ranged from 0.1 to 2.5 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 1:1.15. Of the 437 fish sampled by this gear, 428 were successfully scale-aged (Table 2). Males were present in age groups 3-7 and females were found in age groups 4-9. The 2009 (age 5) and 2008 (age 6) year-classes were the most abundant for males and females, respectively, accounting for 49% of males and 45% of females (Table 2). Sixty-five percent of males and 84% of females were repeat spawners. The percentages of repeat spawners for both males and females have steadily increased since 2008 (Figure 4), and the arcsine-transformed proportion of these repeat spawners (sexes combined) has significantly increased over the time series (1984-2014; $r^2 = 0.50$, $P < 0.001$; Figure 5). Analysis by PFBC of American shad otoliths collected from the WFL at Conowingo Dam was not complete for last year's report; therefore the 2013 otolith analysis is included here. In 2013, 154 otoliths were readable, and of those 97 (63%) were wild fish and 57 (37%) were hatchery produced fish. In 2014, 101 otoliths were readable, and of those 56 (56%) were wild fish and 45 (44%) were hatchery produced fish.

The male-female ratio for adult American shad captured in the Nanticoke River was 1:0.71. Eighty-one American shad were collected from the Nanticoke pound and fyke nets in 2014 and 65 were subsequently aged (Table 2). Males were present in age groups 4-7 and females were found in age groups 4-9. The 2008 year-class (age 6) was the most abundant year-class for both males (36%) and females (52%; Table 2). Seventy-nine percent of males and 89% of females were repeat spawners. The arcsine-transformed proportion of Nanticoke River repeat spawning American shad (sexes combined) has significantly increased over the time series, (1988-2014; $r^2 = 0.40$, $P < 0.001$; Figure 6). Analysis by DE DFW of American shad otoliths collected from the Nanticoke River was not complete for last year's report; therefore the 2013 otolith analysis is included here. In 2013, all 15 otoliths were readable, and of those 80% were wild fish. In 2014, 48 otoliths were readable, and of those 34 (71%) were wild fish and 14 (29%) were from hatchery production.

The male-female ratio for adult American shad captured in the Potomac River was 1:1.6. Of the 107 American shad collected, 105 were successfully aged (Table 2). Males were present in age groups 5-7 and females were present in age groups 5-8. The most abundant year-class for males and females was the 2008 (age 6) year-class (49% and 64%, respectively). Eighty-five percent of males and 77% 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 (2002-2014; $r^2 = 0.003$, $P = 0.86$; Figure 7).

Adult Relative Abundance

Sampling at the Conowingo Dam occurred for 14 days in 2014. A total of 487 adult American shad were encountered by the gear; 421 of these fish were captured by MDNR staff from a boat and the remaining 66 were captured by shore anglers. MDNR staff tagged 427 (97%) of the sampled fish. To remain consistent with historical calculations, only the 421 fish captured from the boat were used to calculate the hook and line CPUE. No tagged American shad recaptures were reported from either commercial fishermen or recreational anglers in 2014, however one American shad tagged in 2013 was recaptured by MDNR anglers while fishing in the tailrace.

The EFL operated for 54 days between 4 April and 7 June 2014. Of the 10,425 American shad that passed at the EFL, 86% (8,936 fish) passed between 26 April and 13 May 2014. Peak passage was on 13 May; 3,043 American shad were recorded on this date. Twenty of the American shad counted at the EFL counting windows were identified as being tagged in 2014 and four were identified as being tagged in 2013 (Table 3).

The Conowingo WFL operated for 27 days between 22 April and 30 May 2014. The 513 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 29 April when 290 American shad were collected. No tagged American shad were recaptured by the WFL in 2014 (Table 3).

Estimates of hook and line GM CPUE vary without trend over the time series (1984-2014; r^2 = 0.07, P = 0.16). Abundance is particularly variable from 2007-2014, but remains below the high indices observed from 1999 to 2002 (Figure 8). The Conowingo Dam combined lift GM CPUE significantly increased over the time series (1980-2014; r^2 = 0.199, P = 0.007), but has declined since 2011 to very low levels (Figure 9).

Eighty-one interviews were conducted over seven days during the creel survey at the Conowingo Dam Tailrace. The CPAH increased in 2014 (Table 4), but has decreased over the time series (2001-2014; r^2 = 0.44, P = 0.01). Nine anglers returned logbooks in 2014; all but one logbook contained information from fishing trips in the lower Susquehanna River. 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 the fourth lowest in the time series and has decreased significantly over the time series (2000-2014; r^2 = 0.51, P = 0.003; Table 5). It should be noted that for years 2000 through 2002, which report the highest CPAH values (Table 5), two separate logbooks were used for American and hickory shad, and not all anglers returned both logbooks. Beginning in 2003, to allow anglers to record data on both shad species if encountered, a combined logbook was distributed. 2014 was the first year online angler data was used in the CPAH calculation.

The 2014 Nanticoke River pound net GM CPUE was similar to 2013. However, the GM CPUE, while highly variable, significantly increased over the time series (1988-2014; $r^2 = 0.16$, $P = 0.04$, Figure 10). The Potomac River CPUE also increased significantly over the time series (1996-2014; $r^2 = 0.22$, $P = 0.04$), and was above the time series mean for the past two years (Figure 11).

Population Estimates

The Petersen statistic estimated 163,609 American shad in the Conowingo Dam tailrace in 2014 with an upper confidence limit of 246,502 fish and a lower confidence limit of 107,699 fish. 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 118,883 American shad in the Conowingo Dam in 2014 and produced realistic estimates of the model parameters r, K and B_0 ($r = 0.45$, $K = 5{,}023{,}091$, $B_0 = 58{,}755$).

Despite differences in yearly estimates, the overall population trends derived from each population model are similar (Figures 12 and 13). 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 showed no specific trend (2008-2014; Figure 13). Petersen estimates follow a similar pattern if the high levels of uncertainty in 2004 and 2008 (due to low recapture rates) are considered (Figure 12).

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in Z = 0.71 (A = 50.8%). The Nanticoke River total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in Z = 0.34 (A = 28.8%). Estimated American shad mortalities (in numbers) from Maryland waters are presented in Table 6.

Juvenile Abundance

Data provided by the EJFS indicated that juvenile American shad indices increased in 2014 baywide, in the upper Chesapeake Bay, and in the Nanticoke River (Figures 14-16), and remained about the same in the Potomac River (Figure 17). The Potomac River index remains above the time series mean (Figure 16) and is greater than all other system indices (Figures 14-17). Juvenile indices were not corrected for hatchery contribution.

Hickory Shad

Sex, Age and Stock Composition

The number of hickory shad captured from the Nanticoke River (n=28) was not large enough to draw meaningful conclusions about sex and age composition. However, 602 hickory shad were sampled by the brood stock collection survey in Deer Creek. The male-female ratio was 1:0.7. Of the total fish captured by this survey, 100 were successfully aged. Males and females were present in age groups 3-6 (Table 7). The most abundant year-class by sex was the 2009 year-class (age 4) for females (49%) and the 2008 year-class (age 5) for males (43%; 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 (2004-2014; $r^2 = 0.22$, $P = 0.15$; Figure 18), but has decreased since 2009. The total percent of repeat spawners in 2014 (59.0%) was the lowest of the time series (2004-2014; 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; $r^2 = 0.13$, $P = 0.16$); however, hickory shad CPAH decreased in 2014 (Table 10). On the Nanticoke River, only 28 fish were captured by pound and fyke nets, but this is the greatest number of hickory shad encountered by this survey since its inception.

Mortality

Total instantaneous mortality in the Susquehanna River (Deer Creek) was estimated as Z = 0.36. This estimate is much less than the 2013 Z estimate (Z = 0.78) but similar to natural mortality estimated by Hoenig's (1983) equation ($\ln(M_x) = 1.46 - 1.01\{\ln(t_{max})\}$) based on a t_{max} of 9 (M = 0.47). Annual mortality in 2014 was A = 30%, based on the Z estimate.

Juvenile Abundance

The MDNR Estuarine Juvenile Finfish Seine Survey (EJFS; Project 2, Job 3, Task 3) do not report juvenile indices for hickory shad because they are caught in such low numbers. Therefore, there is no data available on hickory shad juvenile abundance to report for 2014.

Alewife and Blueback Herring

Sex, Age and Stock Composition

The 2014 male-female ratio for Nanticoke River alewife herring was 1:1.2. Of the 573 alewives sampled, 283 were subsequently aged. Ages 3-8 were present and the 2009 year-class (age 5, sexes combined) was the most abundant, accounting for 51% of the total catch (Table 11). The 2014 male-female ratio for Nanticoke River blueback herring was 1:0.83. Of the 463 blueback herring sampled, 261 were subsequently aged. Blueback herring were present from ages 3-7 and the 2010 year-class (age 4, sexes combined) was the most abundant, accounting for 46% of the sample (Table 12). Blueback herring ages 9 – 11 have not been observed since 2000, which is evident in the decrease of the percent of blueback herring ages 6 and older observed in recent years (Table 12).

For the Nanticoke River, 25.8% of alewife herring and 34.9% of blueback herring were repeat spawners (sexes combined). There was no trend in the arcsine-transformed proportion of alewife herring repeat spawners over the time series (1989-2014; $r^2 = 0.078$ $P = 0.18$); however, blueback herring exhibited a decreasing trend over the same time series (1989-2014; $r^2 = 0.63$, $P < 0.001$; Figure 19). For male alewife and blueback herring, 74.1% and 70.6% were first time spawners, respectively. Seventy two percent of female alewife and 59.2% of female blueback herring were first time spawners.

Mean length (FL mm) of alewife herring from the Nanticoke River has varied without trend since the inception of this survey (1989 – 2014; $r^2 = 0.14$, $P = 0.06$) while, blueback herring mean length (FL mm) has significantly decreased across the time series (1989 – 2014; $r^2 = 0.73$, $P < 0.001$; Figure 20).

Adult Relative Abundance

Data from five fyke nets on the Nanticoke River were used to calculate relative abundance of river herring in 2014. The GM CPUE for Nanticoke River alewife herring captured in fyke nets has decreased over the time series (1990-2014; $r^2 = 0.18$, $P = 0.04$; Figure 21). The GM CPUE for blueback herring has also decreased over the time series (1989-2014; $r^2 = 0.62$, $P < 0.001$; Figure 21). The river herring fishery closed on 26 December 2011. As of 31 December 2014, no river herring were recorded landed in Maryland in 2014. Prior to the closure of the fishery, total commercial landings for river herring in Maryland waters were at multi-decadal lows (Figure 22). Due to the difficult nature of discerning alewife from blueback, there was no differentiation between species in the commercial river herring fishery landing reports.

Mortality

Total instantaneous mortality for Nanticoke River alewife herring (sexes combined) was estimated as Z = 1.32 (A = 73.29%). Total instantaneous mortality for Nanticoke River blueback herring (sexes combined) was Z = 1.37 (A = 74.59%). These values are well above the Nanticoke River $Z_{40\%}$ reference point of 0.93 for alewife herring and 0.92 for blueback herring, established in the most recent coastwide stock assessment for river herring (ASMFC 2012), indicating total mortality for river herring from the Nanticoke River remains high.

Juvenile Abundance

Data provided by the EJFS indicated that the upper bay alewife and blueback herring juvenile GM CPUE increased in 2014, while the Nanticoke River alewife and blueback herring juvenile GM CPUE remained low in 2014 (Figures 23-24). Over the past five years the highest juvenile GM CPUE for alewife and blueback herring were observed in 2010 and 2011, respectively for both of these systems.

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).

The population size of American shad in the lower Susquehanna appears to be relatively stable over the past seven years (2007-2014; 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 increased in 2014, with the exception of the combined lift CPUE. Gizzard shad are increasing in abundance in the Susquehanna drainage and may reduce the number of lifted American shad by using the lifts themselves, thus affecting lift CPUE, which has been decreasing since 2011. The Potomac River CPUE (1996-2014) and the Nanticoke River CPUE (1988-2014) have both increased over time. These trends suggest there is some improvement in the Nanticoke and Potomac Rivers, 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 in recent years (2007-2014), albeit at low levels. The SPM likely underestimates American shad abundance, while the Petersen statistic likely overestimates the population, especially in years of low recapture of tagged fish. Regardless, the SPM population estimates were within the Petersen confidence intervals for the last three years. 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.

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), and Cating's method of using transverse grooves is no longer recommended. Comparisons of American shad scales from different populations show different groove frequencies to the freshwater zone and first three annuli (Duffy et al. 2011). Ageing other hard structures such as otoliths produces higher age agreement between readers compared to scales (Elzey at al. 2015, 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, 75% of aged American shad at the Conowingo Dam were repeat spawners in 2014, and, on average, 54% 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 80%. 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 (1989-2014; Figure 6), and James Rivers (2000-2002; Olney et al., 2003).

Historically, calculated Z for American shad in the lower Susquehanna River has been well above the target Z_{30} (1984 – 2005; ASMFC 2007). The 2014 mortality estimate continues this pattern, with a calculated Z for American shad in the Conowingo Dam tailrace (Z=0.71) being above the Z_{30} established for rivers in neighboring states (range=0.54−0.64), with the exception of Albemarle Sound, NC (Z_{30}=0.76; ASMFC 2007). The 2014 mortality estimate for the Nanticoke River was considerably lower (Z=0.34), consistent with relative abundance estimates indicating improvement in this river. 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 Nanticoke River in 2014. The juvenile index in the Potomac River slightly decreased in 2014, but continues to be greater than all other systems. This suggests weather conditions were more favorable for successful recruitment in 2014. Fish lifted above the Conowingo Dam may reduce the number of potential spawners due to turbine mortality, and inefficient lift facilities above the

Conowingo Dam may also prevent spawners from reaching optimal spawning habitat above the York Haven Dam, thus affecting juvenile production. Predation by apex predators, particularly striped bass and the invasive flathead and blue catfish, may also affect juvenile survival.

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. Only two hickory shad were observed in the EFL in 2014. 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 and 2010 according to shad logbook data collected from Deer Creek anglers (1998-2014). Hickory shad are sensitive to light and generally strike artificial lures more frequently when flows are somewhat elevated and the water is slightly turbid. Consequently, the low CPAH for hickory shad in 2009 may be directly related to the low flow and clear water conditions encountered by Deer Creek anglers and observed by MDNR staff during that spring season.

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 three years (2012-2014) have seen no hickory shad over the age of 7. In 2014, 88% 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 was 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.

Hickory shad relative abundance metrics in the Nanticoke River (pound and fyke net CPUE) are tenuous, presumably because of gear avoidance. Therefore, relative abundance analysis for hickory shad in the Nanticoke River was discontinued. Extensive spring electrofishing conducted in conjunction with Maryland stocking efforts in the Nanticoke River watershed concluded that stocks increased in this system from 2002-2009 (Richardson 2009).

Estimates of Z are primarily attributed to M because only a catch and release fishery exists for hickory shad in Maryland. The high percent of repeat spawners is also indicative of very low bycatch mortality. 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 in the Nanticoke River. Blueback herring further exhibit declines in mean length and percent repeat spawners, both of which are characteristics of a declining population undergoing excessive mortality rates (Beverton and Holt 1957). 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. Further declines in the abundance of alewife since this assessment indicate they are not recovering and are still experiencing high levels of mortality.

Because river herring landings along the east coast have decreased significantly, ASMFC passed Amendment 2 of the ASMFC Interstate Fishery Management Plan for American Shad and River Herring. This amendment 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. It is no longer legal to possess river herring within the jurisdiction of Maryland unless the possessor has a bill of sale identifying the river herring were legally caught in waters not under Maryland jurisdiction. The expectation is that the moratorium on river herring will lead to increased production of juvenile river herring, and (in three to five years) an increase in the spawning stock.

Juvenile alewife and blueback production in the upper bay did, in fact, increase in 2014. However, production in the Nanticoke River remained low. In General, abundance for both species remains at low levels.

LITERATURE CITED

ASMFC. 2012. River herring benchmark stock assessment. Volume I. Arlington, VA. 392 pp.

ASMFC. 2009. Atlantic coast diadromous fish habitat: a review of utilization, threats, recommendations for conservation, and research needs. Washington, D. C. 465 pp.

ASMFC. 2007. American shad stock assessment report for peer review. Volume III. Washington, D. C. 546 pp.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investigations Series II, Marine Fisheries, Great Britain Ministry of Agriculture, Fisheries and Food 19.

Cating, J.P. 1953. Determining age of American shad from their scales. U.S. Fish and Wildlife Service Fishery Bulletin 85:187-199.

Chapman, D.G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. Univ. Calif. Publ. Stat. 1:131-160.

Crecco, V. A. and M. Gibson. 1990. Stock assessment of river herring from selected Atlantic coast rivers. Special Report No. 19 of the Atlantic States Marine Fisheries Commission.

Duffy, W.J., R.S. McBride, K. Oliveira and M.L. Hendricks. 2012. Otolith age validation and growth estimation from oxytetracycline-marked and recaptured American shad. Transactions of the American Fisheries Society 141: 1664-1671.

Duffy, W.J., R.S. McBride, S.X. Cadrin and K. Oliveira. 2011. Is Cating's methods of transverse groove counts to annuli applicable for all stocks of American shad? Transactions of the American Fisheries Society 140:1023-1034.

Elzey, S.P., K.A. Rogers and K.J Trull. 2015. Comparison of 4 aging structures in the American shad (*Also sapidissima*). Fishery Bulletin 113:47-54.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fisheries Bulletin 82:898-903.

Judy, M.H. 1960. Validity of age determination from scales of marked American shad. U.S. Fish and Wildlife Service Fishery Bulletin 185:161-170.

McBride, R.S., M.L. Hendricks and J.E. Olney. 2005. Testing the validity of Cating's (1953) method for age verification of American shad using scales. Fisheries 30:10-18.

Macall, A.D. 2002. Use of known-biomass production models to determine productivity of west coast groundfish stocks. North American Journal of Fisheries Management 22:272-279.

Olney, J. E., D.A. Hopler Jr, T.P. Gunter Jr, K.L. Maki, and J.M. Hoenig. 2003. Signs of recovery of American shad in the James River, Virginia. *American Fisheries Society Symposium*. Eds. K. E. Limburg, and J. R. Waldman. 35: 323-329.

Richardson, B. R., C. P. Stence, M. W. Baldwin and C.P. Mason. 2009. Restoration of American shad and hickory shad in Maryland's Chesapeake. 2008 Final Progress Report. Maryland Department of Natural Resources, Report F-57-R. Annapolis, Maryland.

Richardson, B., R.P. Morin, M. W. Baldwin and C.P. Stence. 2004. Restoration of American shad and hickory shad in Maryland's Chesapeake. 2003 Final Progress Report. Maryland Department of Natural Resources, Report F-57-R. Annapolis, Maryland.

Ricker, W. E. 1975. *Computation and interpretation of biological statistics of fish populations*. Fisheries Research Board of Canada Bulletin 191.

Walburg, C.H. and J.E. Sykes. 1957. Shad fishery of Chesapeake Bay with special emphasis on the fishery of Virginia. Research Report 48. U.S. Government Printing Office, Washington, D.C.

Weinrich, D.W., A. Jarzynski and R. Sadzinski. 2008. Project 2, Job 1. Stock assessment of adult and juvenile anadromous species in the Chesapeake Bay and select tributaries. Maryland Department of Natural Resources, Federal Aid Annual Report F-61-R-4, Annapolis, Maryland.

Weinrich, D.W., M.E. Dore and W.R. Carter III. 1982. Job II. Adult population characterization. *in* Investigation of American shad in the upper Chesapeake Bay 1981. Maryland Department of Natural Resources, Federal Aid Annual Report F-37-R, Annapolis, Maryland.

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Table 1. Percentage of sites with clupeid eggs or larvae and number of sites sampled in the Nanticoke River (2005-2014).

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

Table 2. Number of adult American shad and repeat spawners by sex and age sampled from the Conowingo Dam tailrace (hook and line), Nanticoke River (gears combined) and Potomac River (gill net) in 2014.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	3	0	0	0	3	0
4	50	11	5	3	55	14
5	97	76	89	61	186	137
6	45	39	104	97	149	136
7	4	4	30	30	34	34
8	0	0	0	0	0	0
9	0	0	1	1	1	1
Totals	199	130	229	192	428	322
Percent Repeats	65.3%		83.8%		75.2%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
4	8	2	1	0	9	2
5	12	11	6	5	18	16
6	14	13	14	13	28	26
7	4	4	4	4	8	8
8	0	0	1	1	1	1
9	0	0	1	1	1	1
Totals	38	30	27	24	65	54
Percent Repeats	78.9%		88.9%		83.1%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
5	11	6	6	4	17	10
6	20	19	41	31	61	50
7	10	10	14	11	24	21
8	0	0	3	3	3	3
Totals	41	35	64	49	105	84
Percent Repeats	85.4%		76.6%		80.0%	

Table 3. Number of recaptured American shad in 2014 at the Conowingo Dam East and West Fish Lifts by tag color and year.

East Lift		
Tag Color	Year Tagged	Number Recaptured
Pink	2013	4
Yellow	2014	20
West Lift		
Tag Color	Year Tagged	Number Recaptured
NA	NA	0

Table 4. Catch (numbers), effort (hours fished) and catch-per-angler-hour (CPAH) from the recreational creel survey in the Susquehanna River below Conowingo Dam, 2001-2014. Due to sampling limitations, no data were available for 2011.

Year	Number of Interviews	Hours Fished for American Shad	American Shad Catch	Catch Per Angler Hour
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
2011				
2012	58	189.0	146	0.77
2013	63	161.8	107	0.66
2014	81	273.8	312	1.14

Table 5. Catch (numbers), effort (hours fished) and catch-per-angler-hour (CPAH) from spring logbooks for American shad, 2000-2014. Multiple logbooks were used from 2000 until 2003, when a single logbook was utilized to collect data on both shad species. Beginning in 2014, data from Maryland's Volunteer Angler Shad Survey was combined with logbook data.

Year	Number of Participants	Total Reported Angler Hours	American Shad Catch	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

Table 6. Estimated adult American shad mortalities (in numbers) in Maryland waters (1997-2014). Lower Susquehanna River (below the Conowingo Dam) abundance estimates are derived from the surplus production model. West Fish Lift mortality includes mortality due to day-to-day operations.

Year	Total Commercial Landings in Maryland's Portion of Chesapeake Bay	Conowingo Dam East Fish Lift Mortality[1]	Conowingo Dam West Fish Lift Mortality	Estimated Commercial Chesapeake Bay Bycatch Mortality [2]	Recreational Bycatch Mortality	Ocean Commercial Landings [3]	Minimum Total Losses	Conowingo Dam Tailrace Abundance Estimate
1997	0	43,790	2,274	4,200	Unknown	24,859	75,123	161,162
1998	0	16,152	1,300	4,200	Unknown	18,526	39,908	162,044
1999	0	43,455	3,136	4,200	Unknown	13,623	64,414	192,232
2000	0	60,452	3,102	4,200	Unknown	4,834	72,588	202,516
2001	0	130,876	2,607	4,200	Unknown	2,347	140,030	199,217
2002	0	40,142	2,837	4,200	Unknown	1,882	49,061	124,230
2003	0	50,224	2,160	4,200	Unknown	621	57,205	117,980
2004	0	29,911	1,218	4,200	Unknown	220	35,549	99,311
2005	0	42,873	1,412	4,200	Unknown	0	48,485	96,498
2006	0	41,201	1,696	4,200	Unknown	0	95,582	79,303
2007	0	14,120	1,737	4,200	Unknown	0	20,057	57,393
2008	0	7,075	1,477	4,200	Unknown	0	12,752	57,201
2009	0	15,490	1,566	4,200	Unknown	0	21,256	64,088
2010	0	21,793	1,219	4,200	Unknown	0	27,212	65,286
2011	0	5,159	1,038	4,200	Unknown	0	10,397	60,578
2012	0	8,714	710	4,200	Unknown	0	13,952	70,872
2013	0	5,341	447	4,200	Unknown	0	9,541	80,910
2014	0	4,548	507	4,200	Unknown	0	8,748	118,883

1 Estimated to be 100% of fish passing above Holtwood Dam and 25% turbine mortality of fish passing back through Conowingo Dam.
2 Extrapolated from American shad observed mortalities from pound nets in the upper Chesapeake Bay.
3 Reported numbers were calculated by multiplying total pounds by an estimated four pounds per fish.

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 2014.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	9	0	2	0	11	0
4	20	6	17	6	37	12
5	28	25	12	10	40	35
6	8	8	4	4	12	12
Totals	65	39	35	20	100	59
Percent Repeats	60.0%		57.1%		59.0%	

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, 2004-2014.

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	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	
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	0.93	
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			

Table 9. Percent repeat spawning hickory shad (sexes combined) by year from the brood stock collection survey in Deer Creek (Susquehanna River tributary), 2004-2014.

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

Table 10. Catch (numbers), effort (hours fished) and catch-per-angler-hour (CPAH) from spring logbooks for hickory shad, 1998-2014. Multiple logbooks were used from 1998 until 2003, when a single logbook was utilized to collect data on both shad species. Beginning in 2014, data from Maryland's Volunteer Angler Shad Survey was combined with logbook data.

Year	Number of Logbooks/Anglers	Total Reported Angler Hours	Hickory Shad Catch	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

Table 11. Percent catch-at-age for adult alewife herring sampled from the Nanticoke River from 1989 - 2014. Age 6+ includes ages 6 – 11.

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

* Indicates years where not all fish were aged. An age-length key was subsequently used to assign ages to those fish based on size.

Table 12. Percent catch-at-age for adult blueback herring sampled from the Nanticoke River from 1989 - 2014. Age 6+ includes ages 6 – 11.

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

[*] Indicates years where not all fish were aged. An age-length key was subsequently used to assign ages to those fish based on size.

Figure 1. Conowingo Dam Tailrace (Susquehanna River) hook and line sampling location for American shad in 2014.

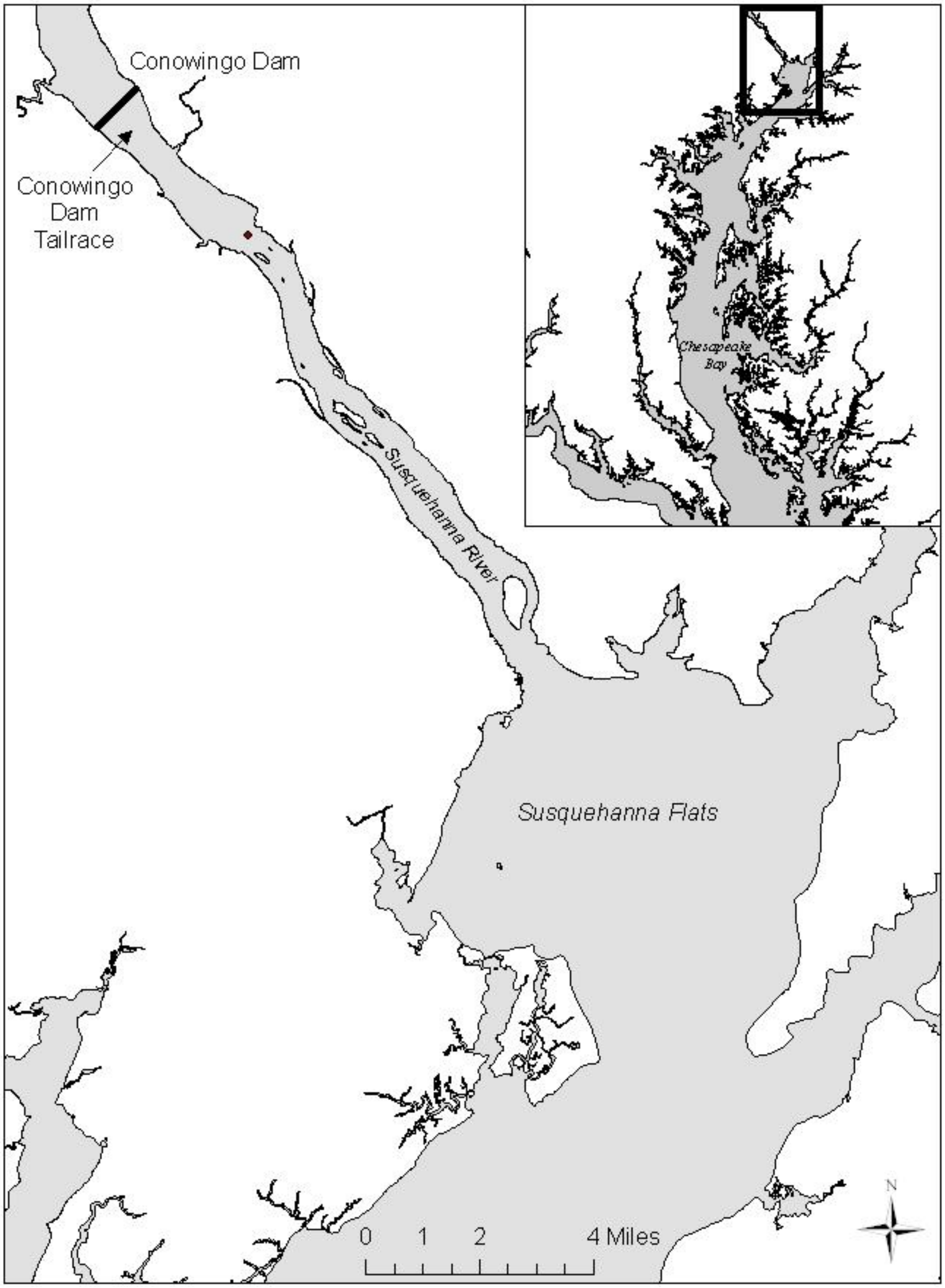

Figure 2. Nanticoke River pound and fyke net sites for adult alosine sampling in 2014. The Mill Creek pound net site used for calculating American shad CPUE is identified.

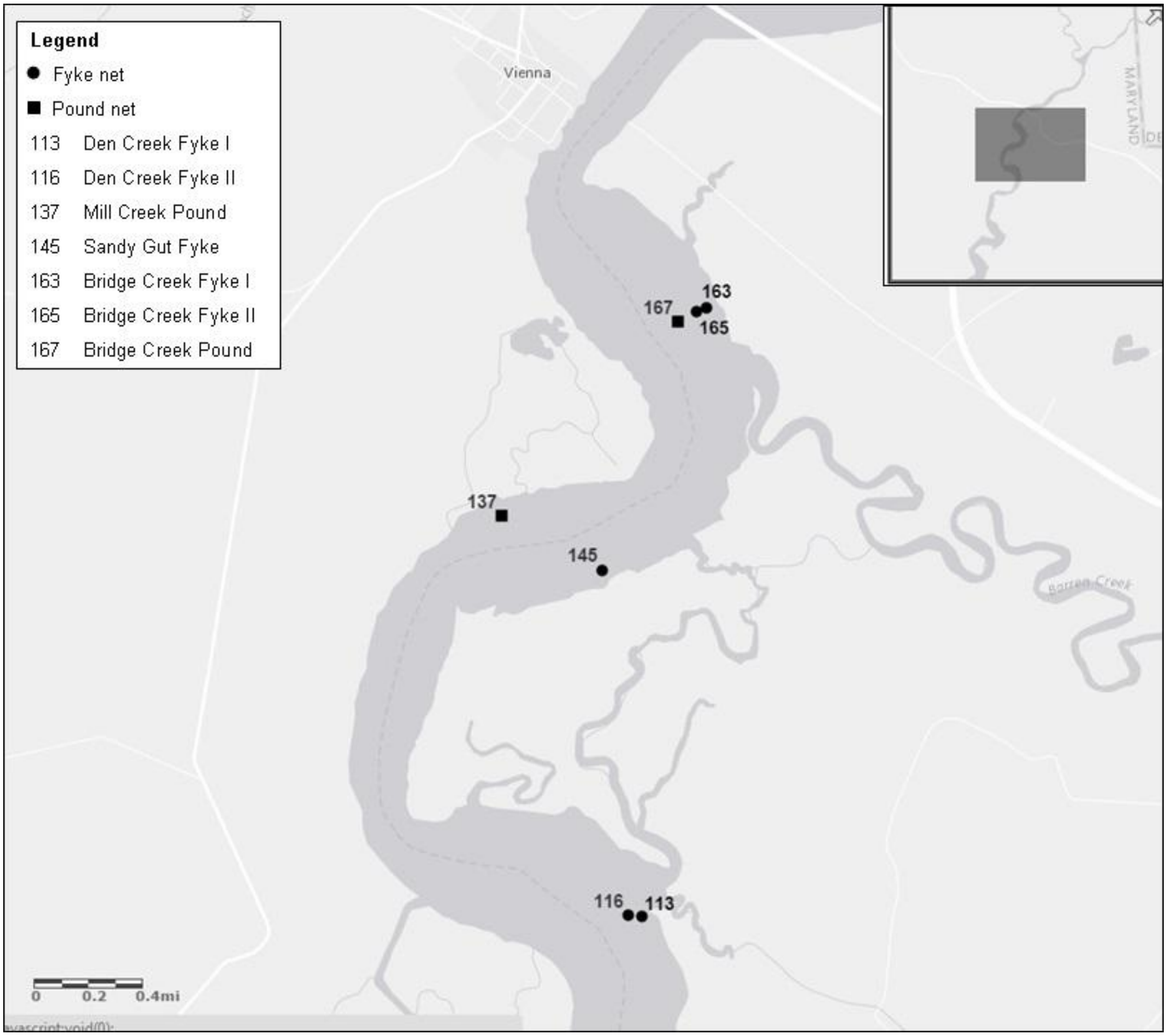

Figure 3. Nanticoke River sites for alosine ichthyoplankton sampling in 2014.

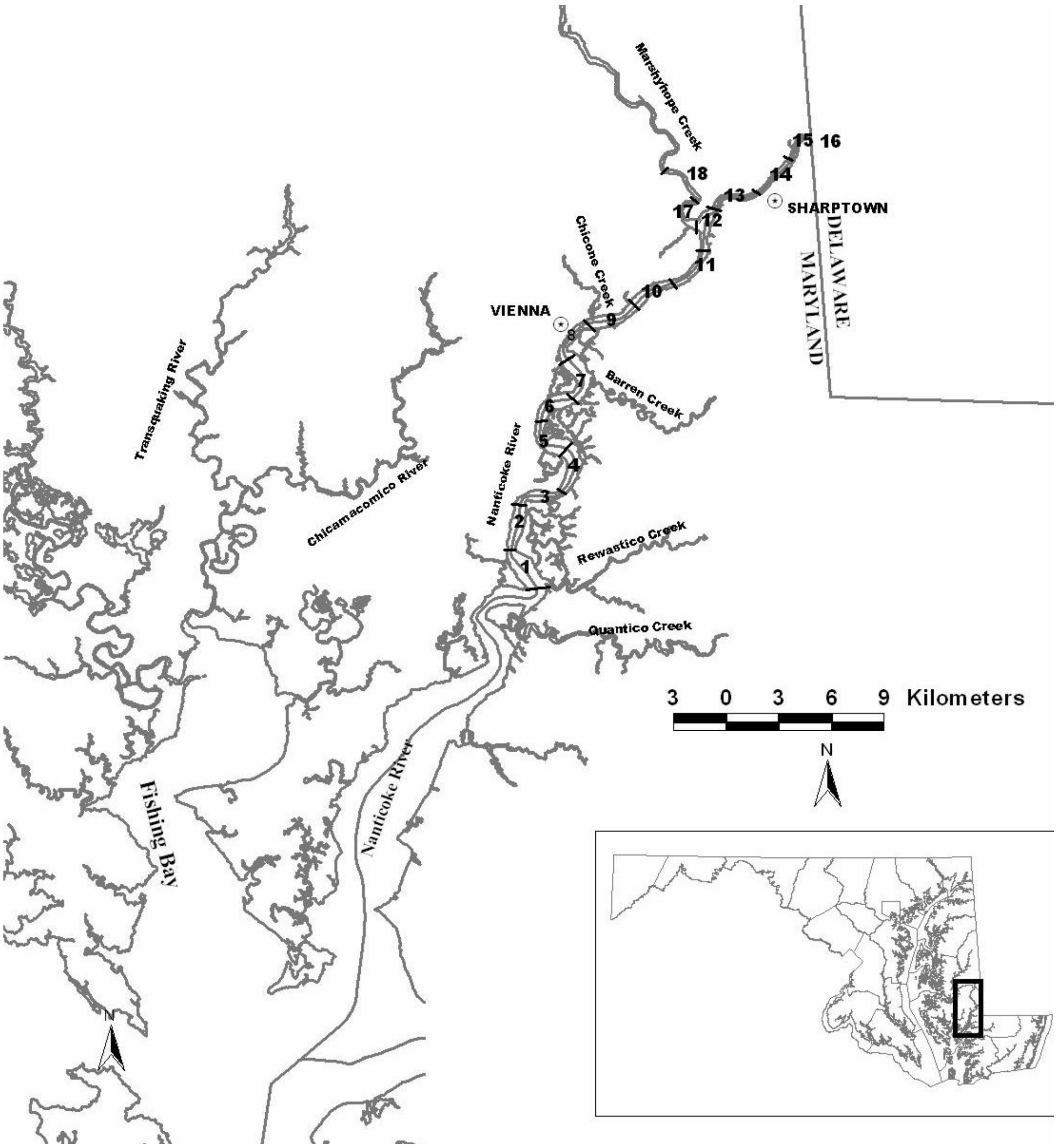

Figure 4. Percent of American shad repeat spawners by sex collected in the Conowingo Dam tailrace (1982-2014).

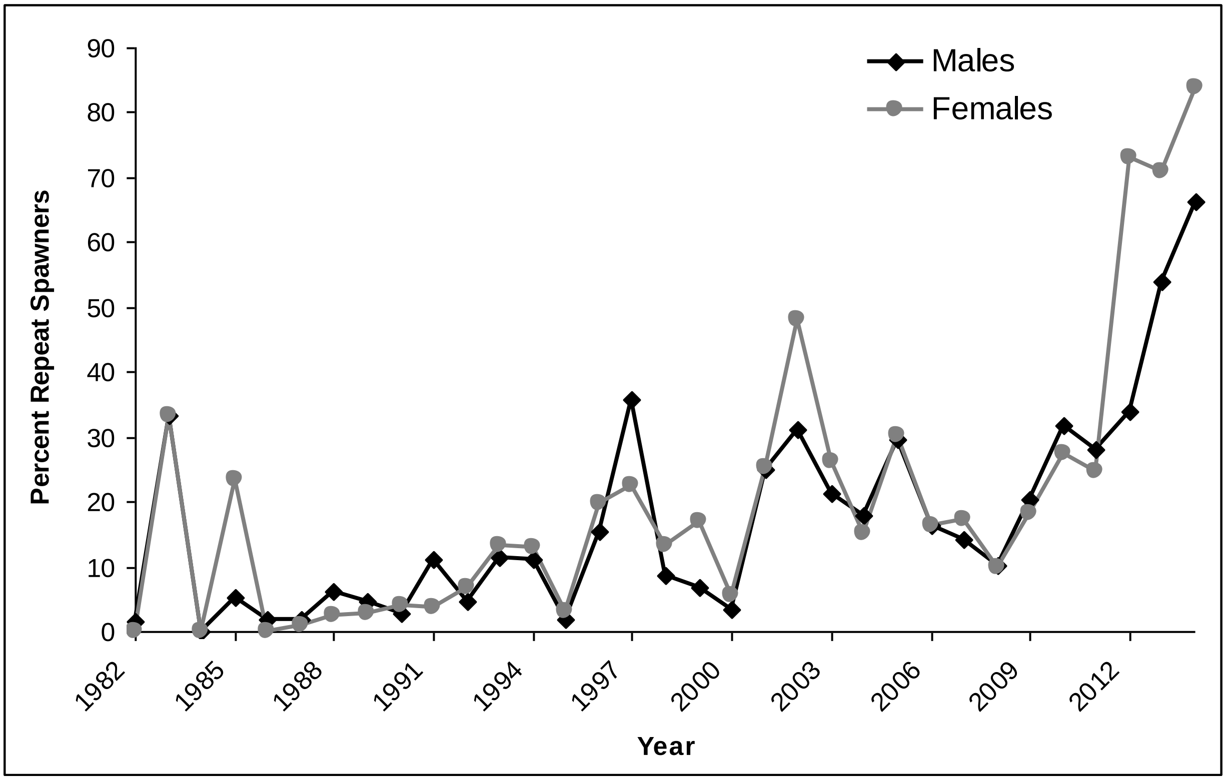

Figure 5. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2014.

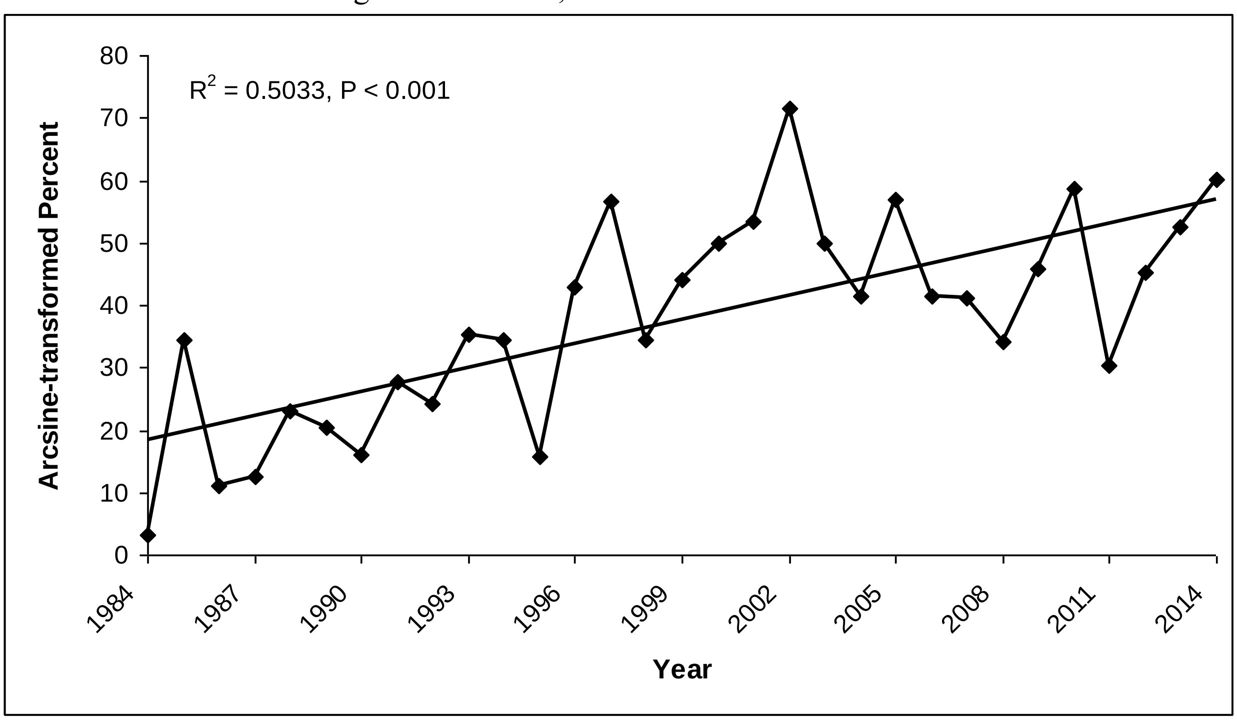

Figure 6. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River, 1988-2014.

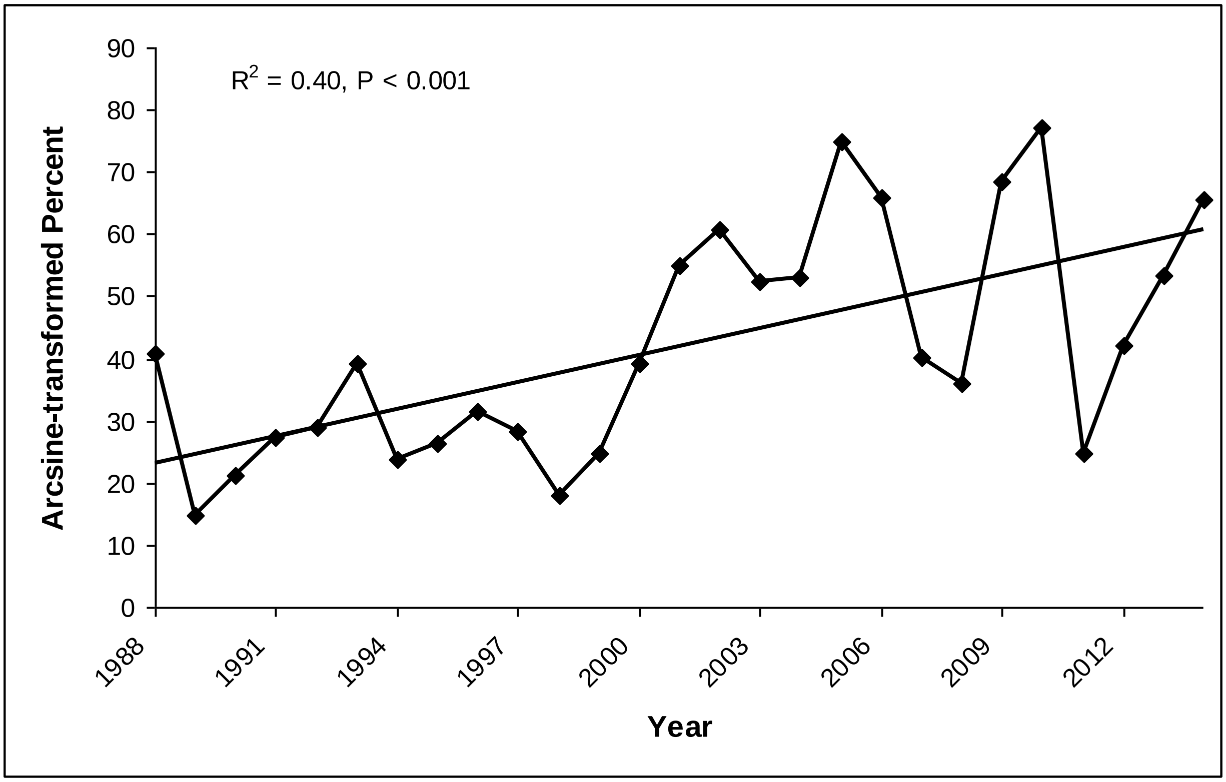

Figure 7. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River, 2002-2014.

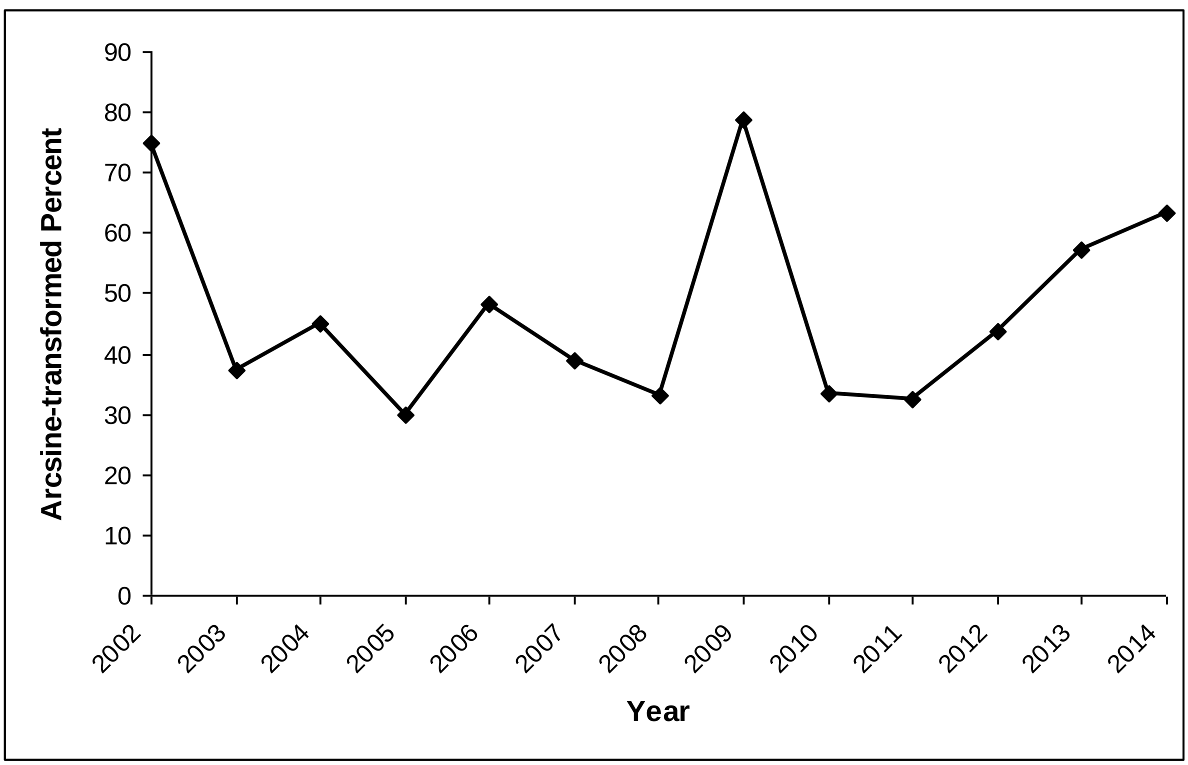

Figure 8. American shad geometric mean CPUE (fish per boat hour) from the Conowingo Dam tailrace hook and line sampling, 1984-2014.

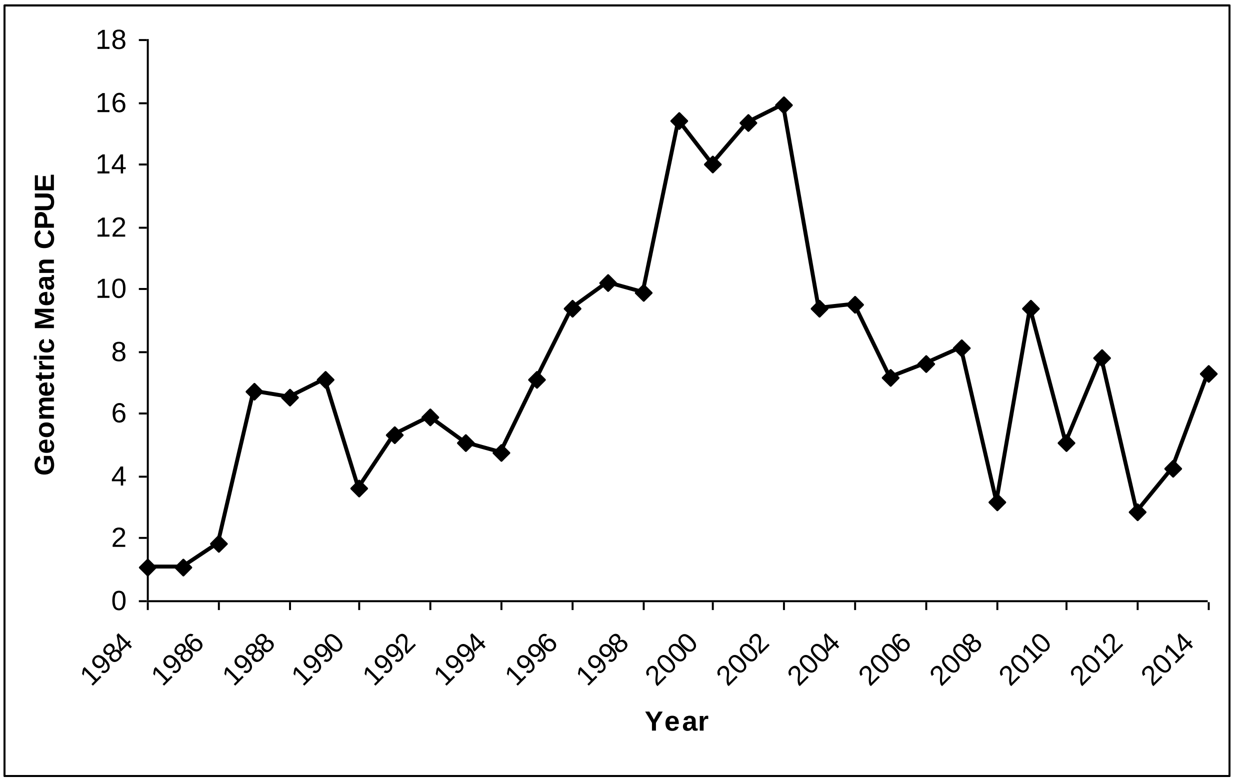

Figure 9. American shad geometric mean CPUE (fish per lift hour) from the East and West Fish Lifts at the Conowingo Dam, 1980-2014.

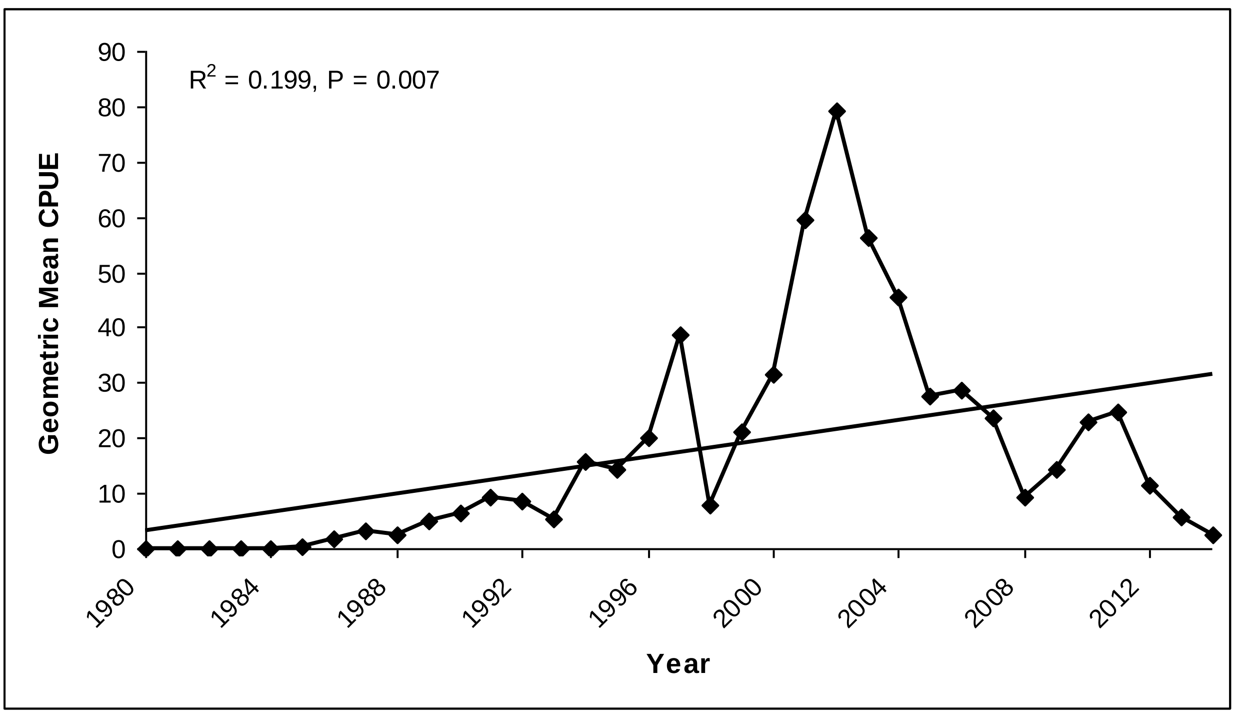

Figure 10. American shad geometric mean CPUE (fish per net day) from the Mill Creek pound net in the Nanticoke River, 1988-2014. No pound nets were fished in 2004.

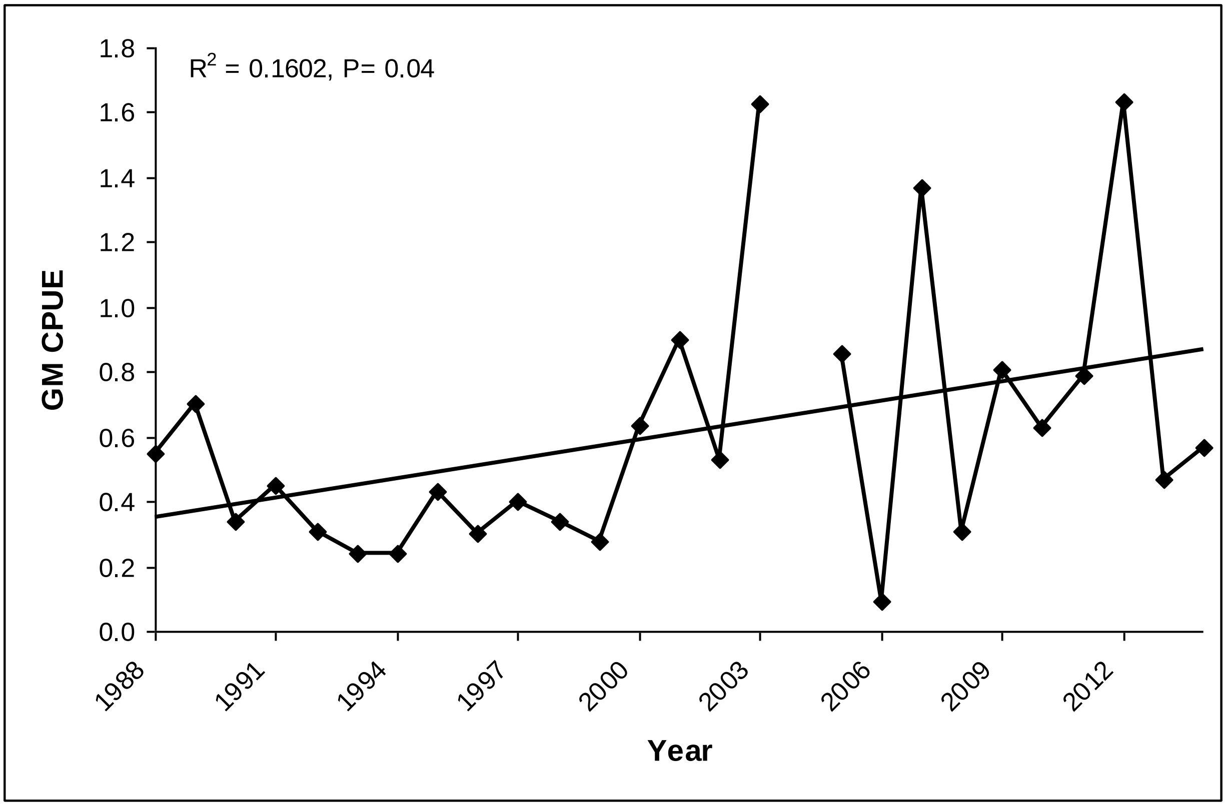

Figure 11. American shad geometric mean CPUE (fish per 1,000 square yards of experimental drift gill net per hour fished) from the Potomac River, 1996-2014.

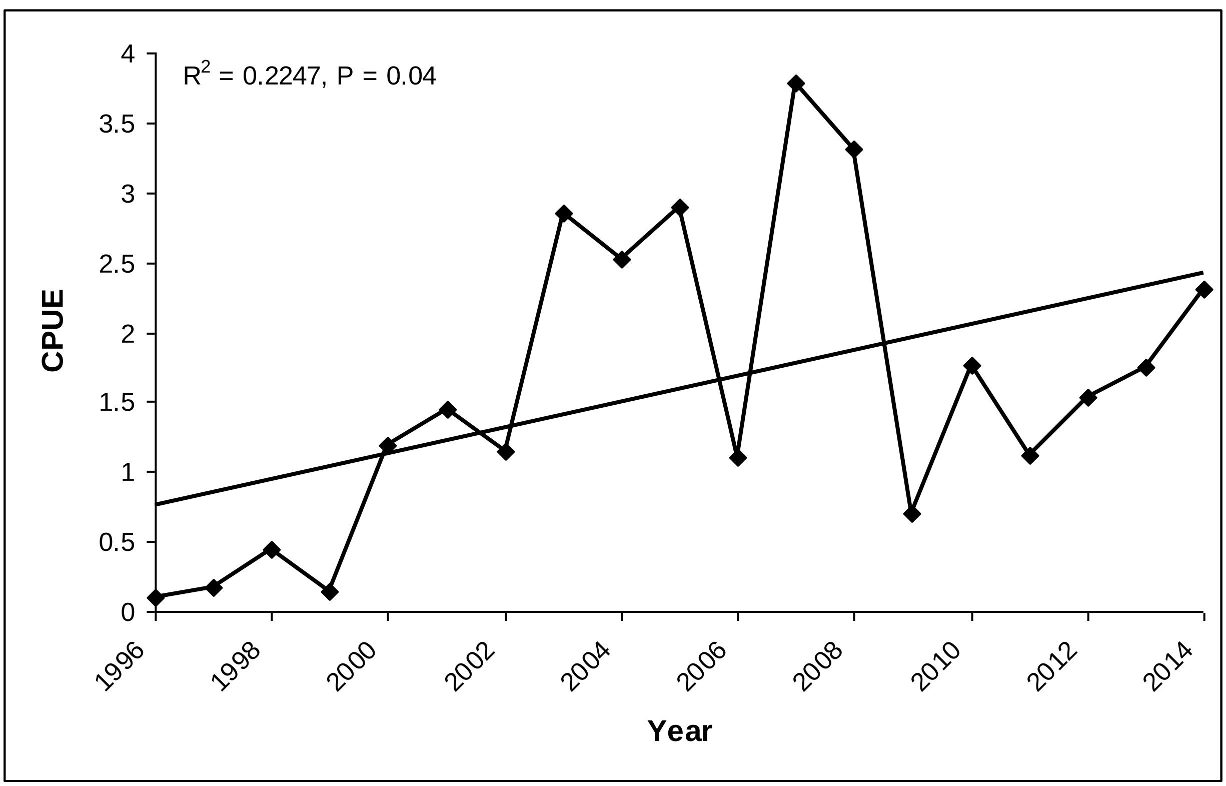

Figure 12. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic with 95% confidence limits, 1986-2014.

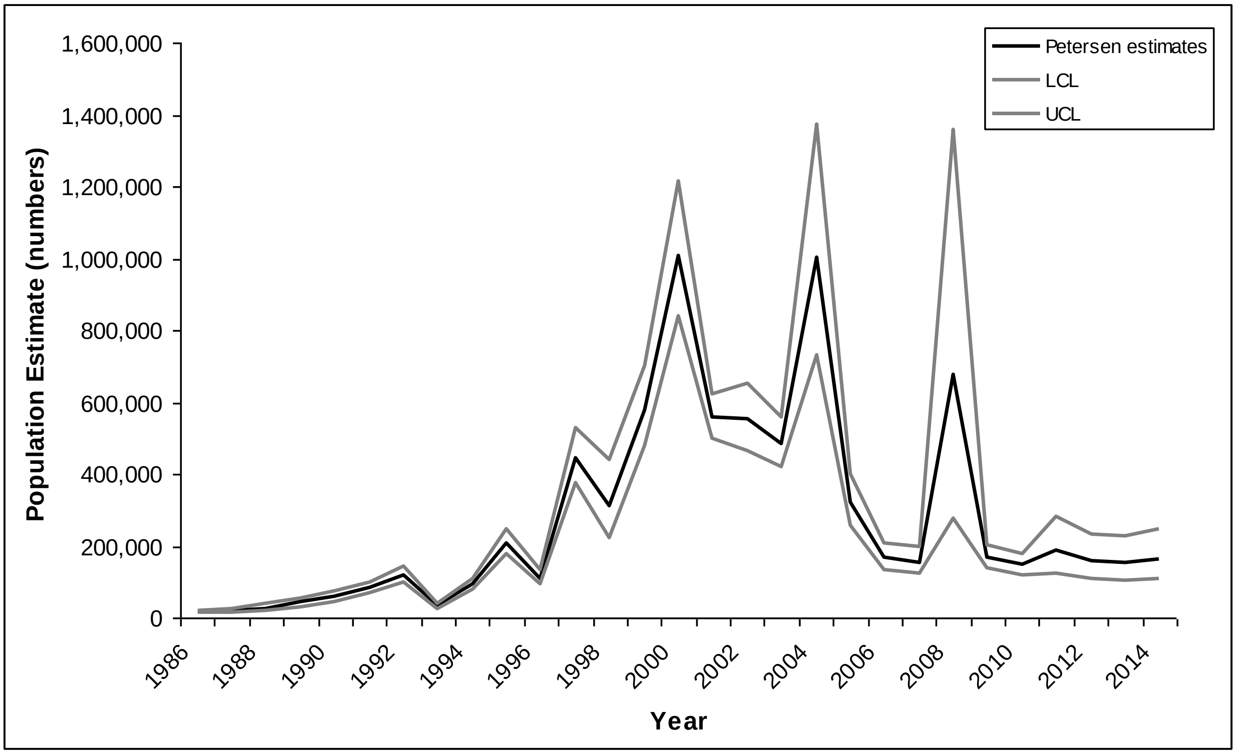

Figure 13. Conowingo Dam tailrace adult American shad abundance estimates from the surplus production model (SPM), 1986-2014.

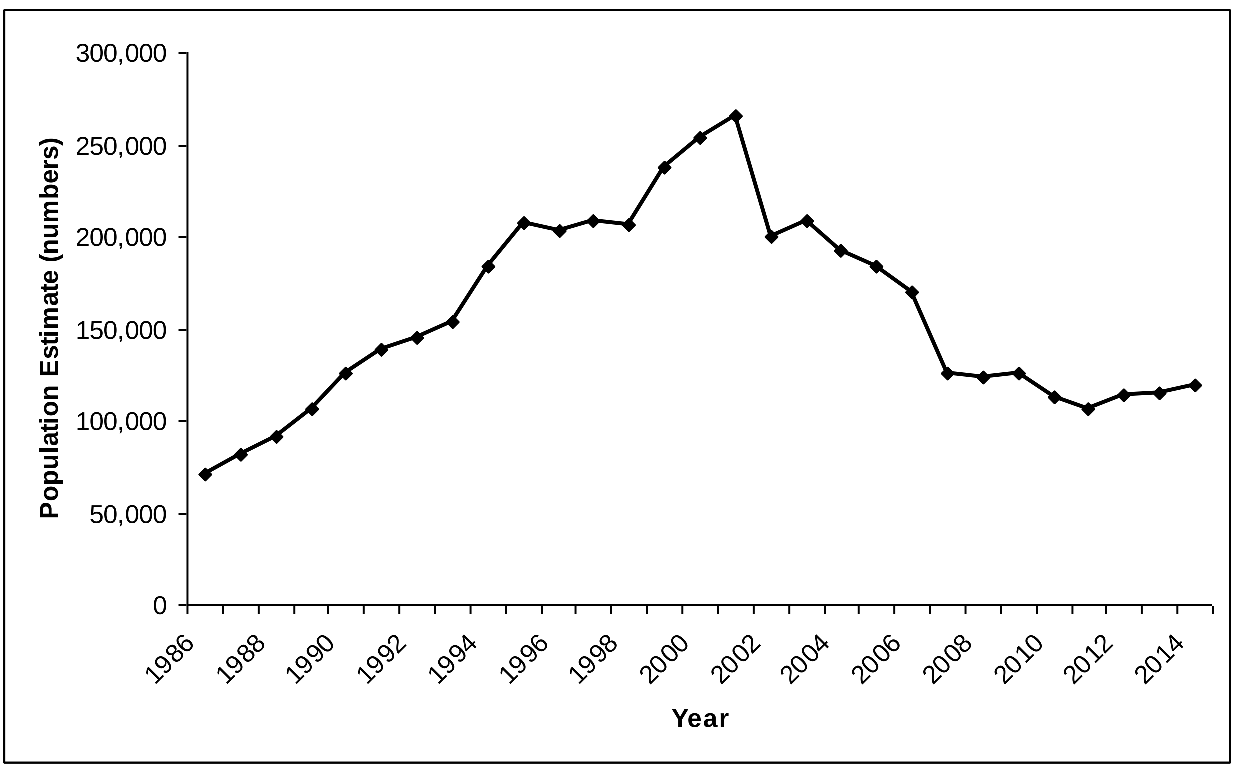

Figure 14. Baywide juvenile American shad geometric mean CPUE (catch per haul), 1959-2014.

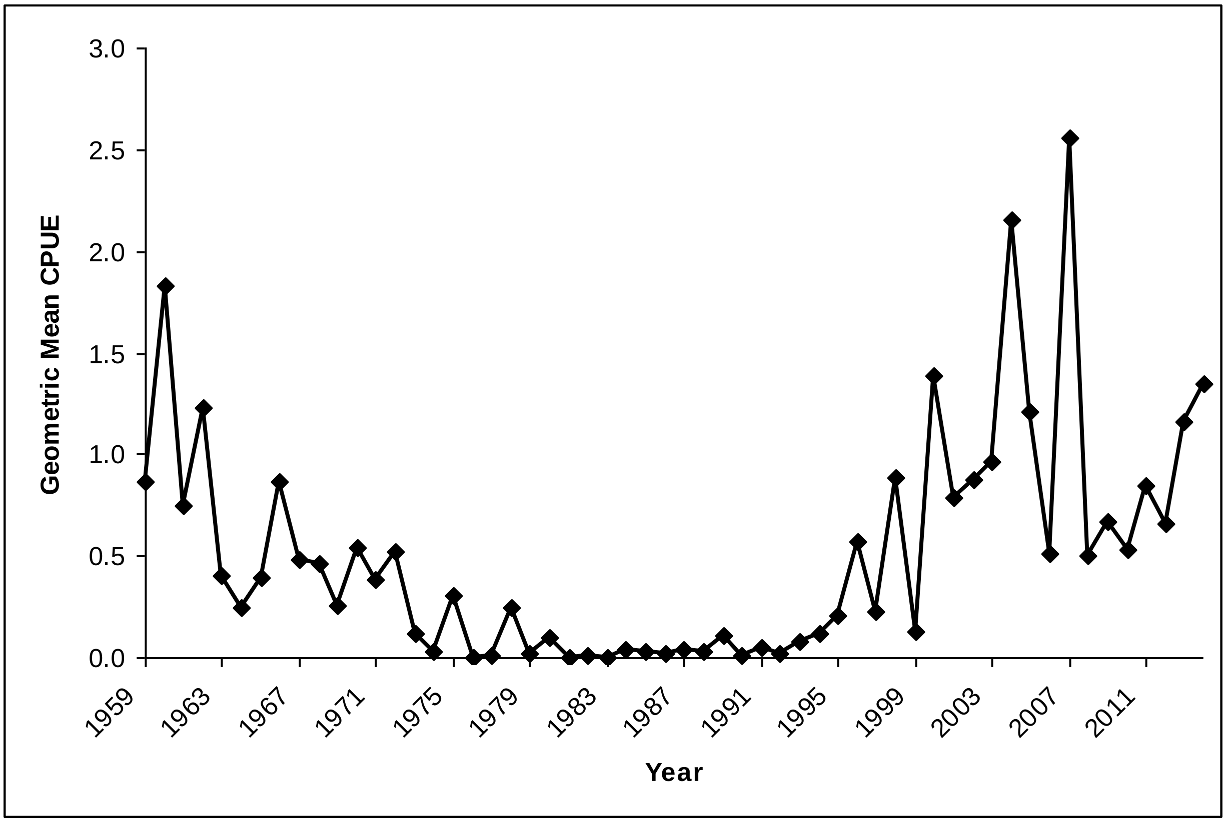

Figure 15. Upper Chesapeake Bay juvenile American shad geometric mean CPUE (catch per haul), 1959-2014.

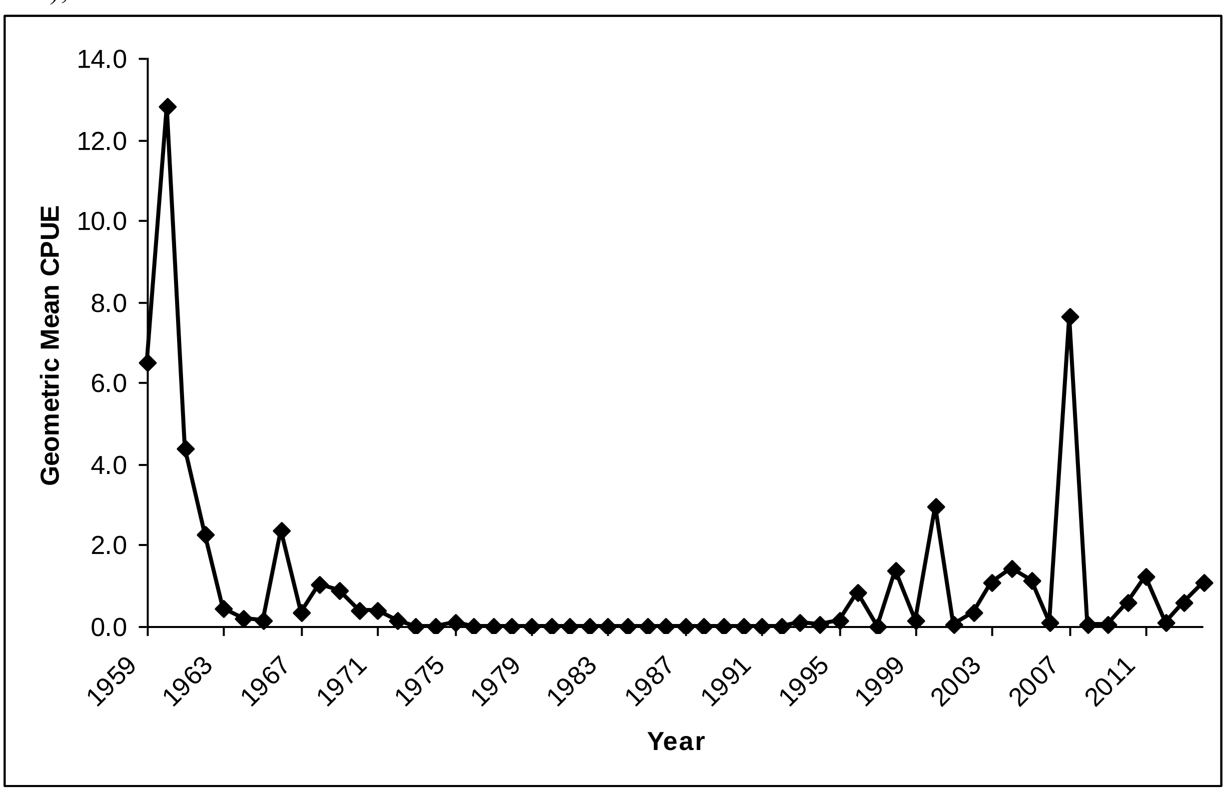

Figure 16. Nanticoke River juvenile American shad geometric mean CPUE (catch per haul), 1959-2014.

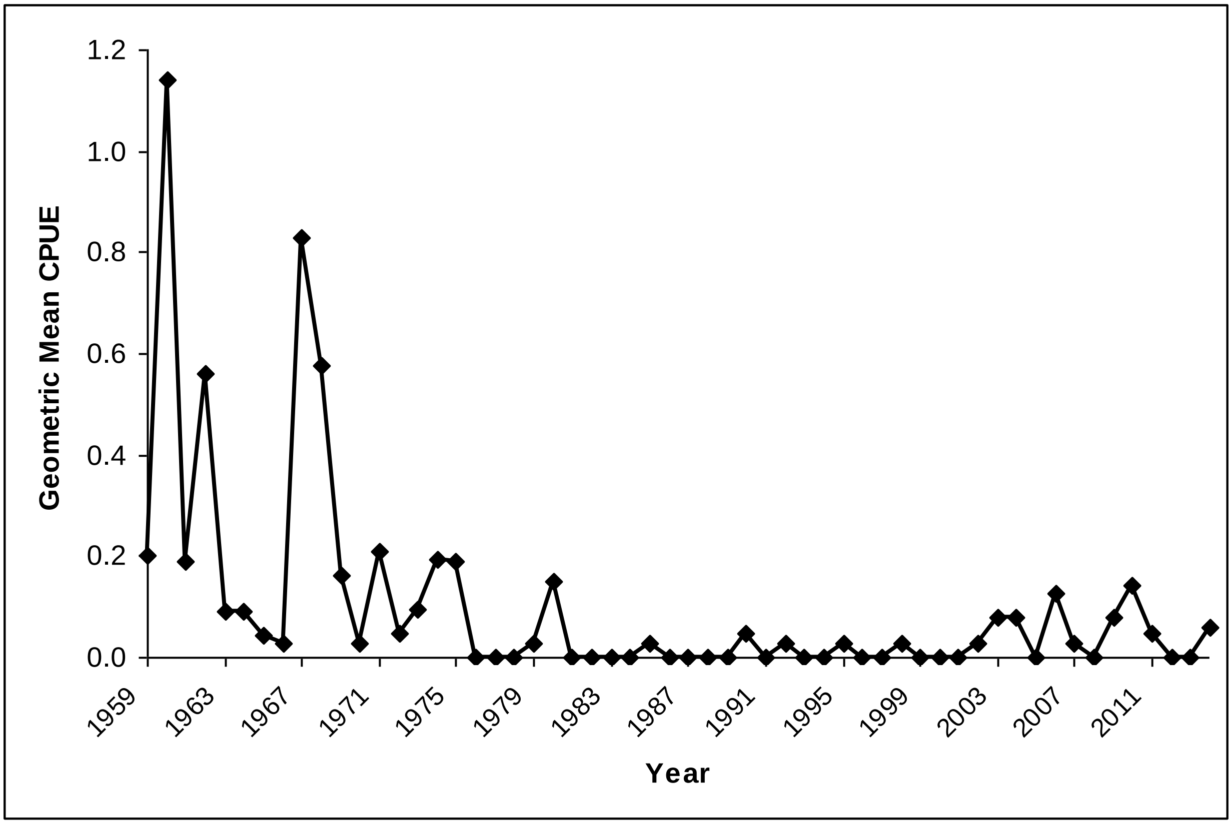

Figure 17. Potomac River juvenile American shad geometric mean CPUE (catch per haul), 1959-2014.

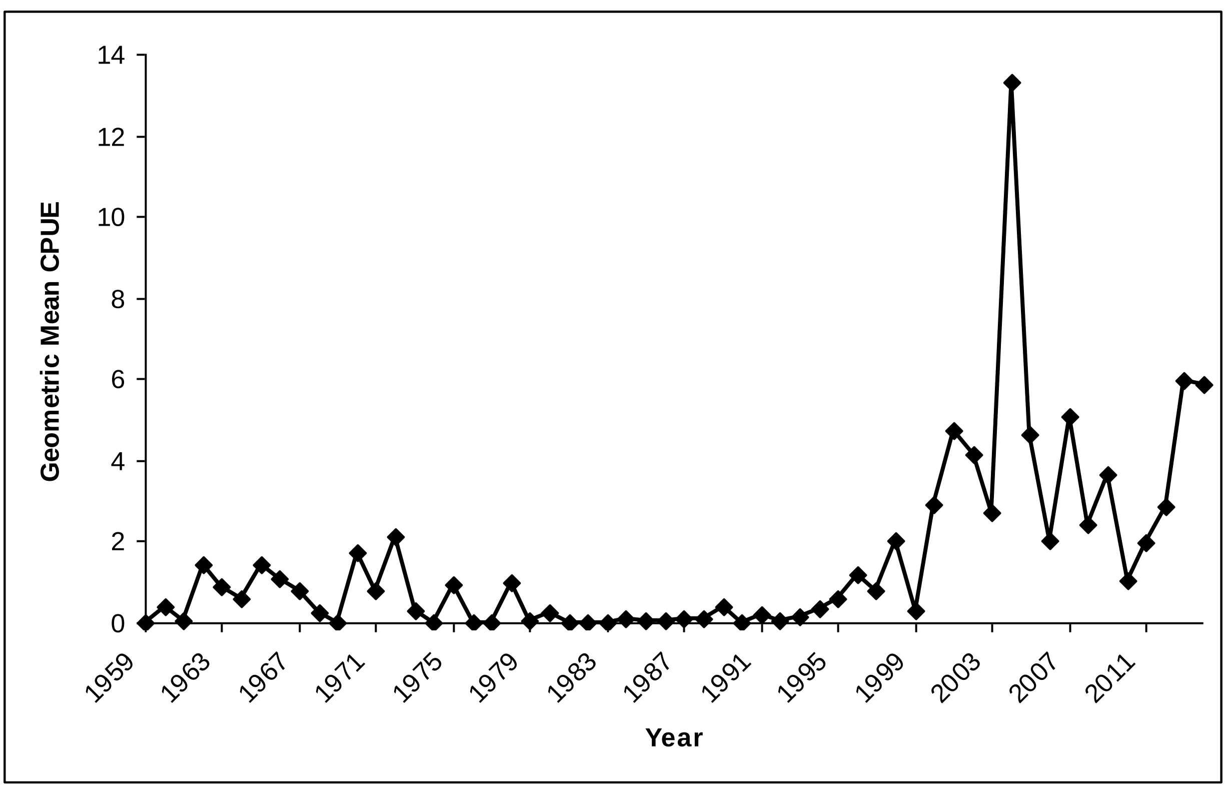

Figure 18. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from Deer Creek (Susquehanna River tributary), 2004-2014.

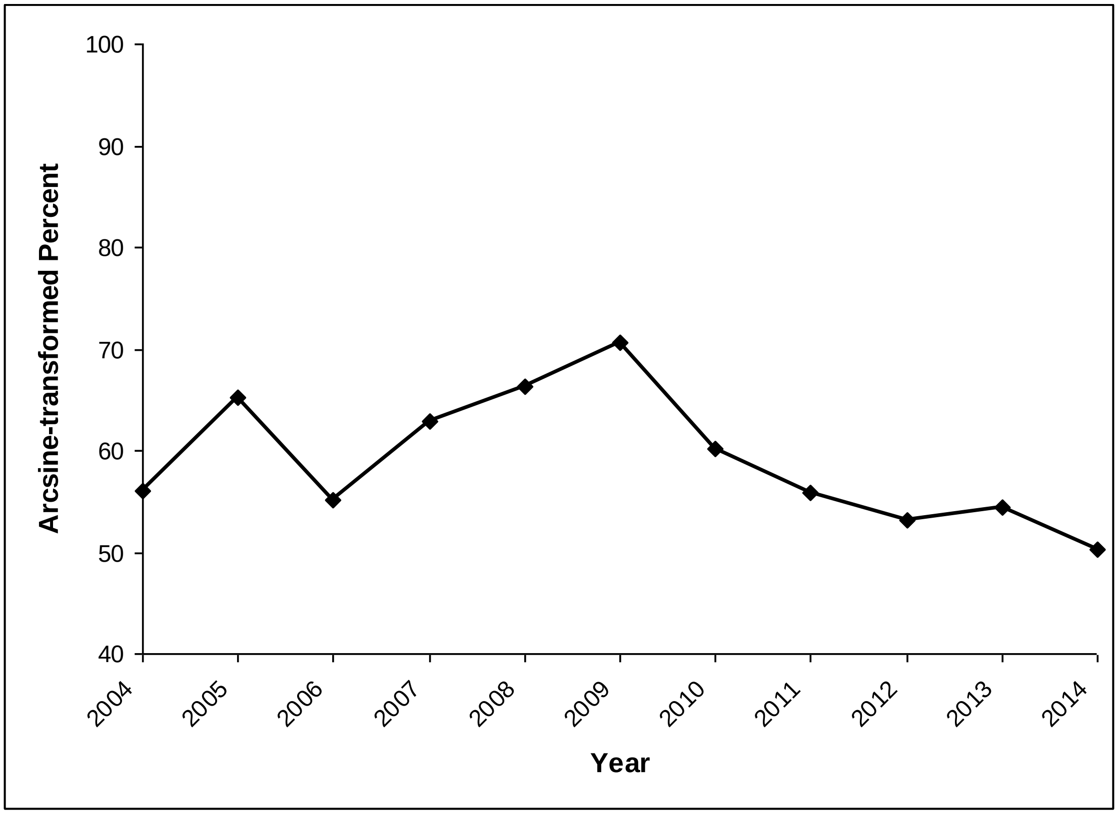

Figure 19. Arcsine-transformed percentages of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1989-2014.

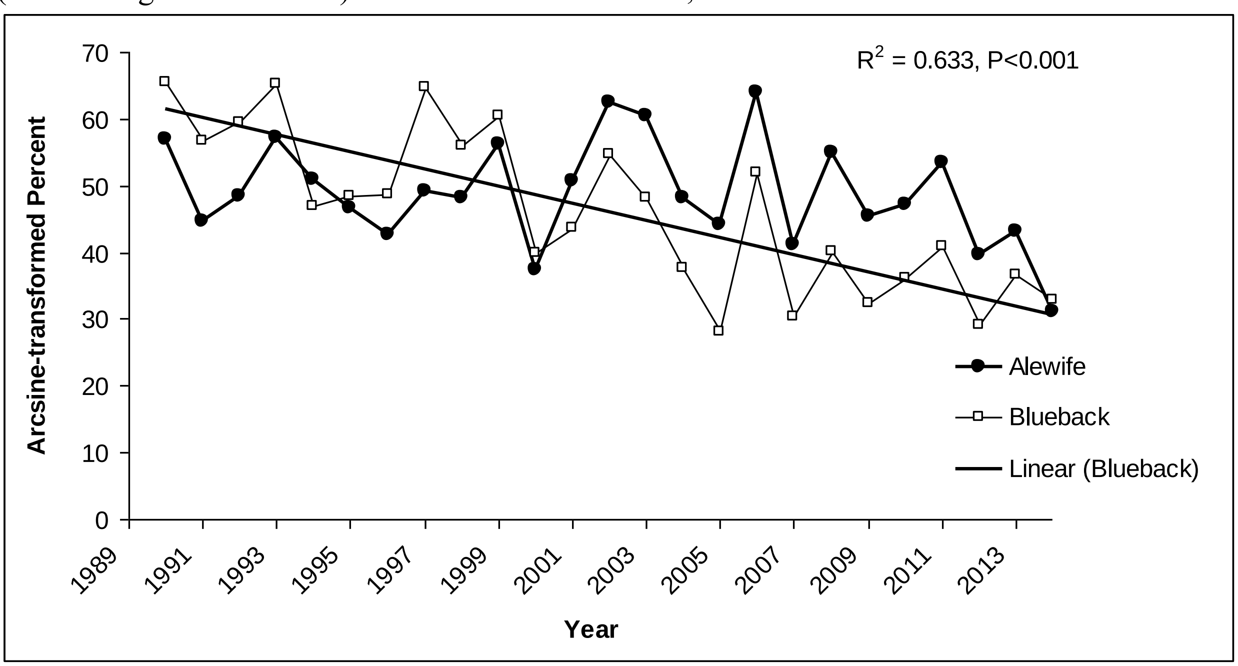

Figure 20. Mean length (FL mm) of adult alewife and blueback herring from the Nanticoke River, 1989-2014.

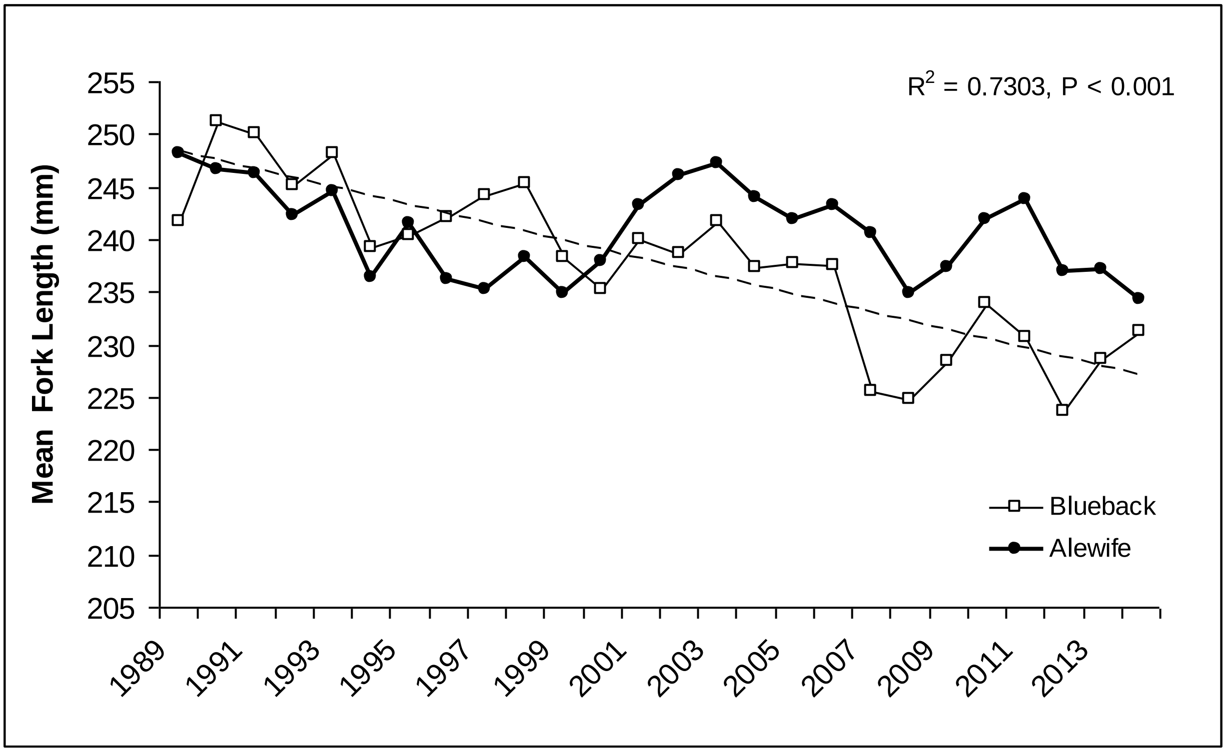

Figure 21. Geometric mean CPUE (catch per net day) of adult alewife and blueback herring from Nanticoke River fyke nets, 1989-2014. No fyke nets were fished in 2012.

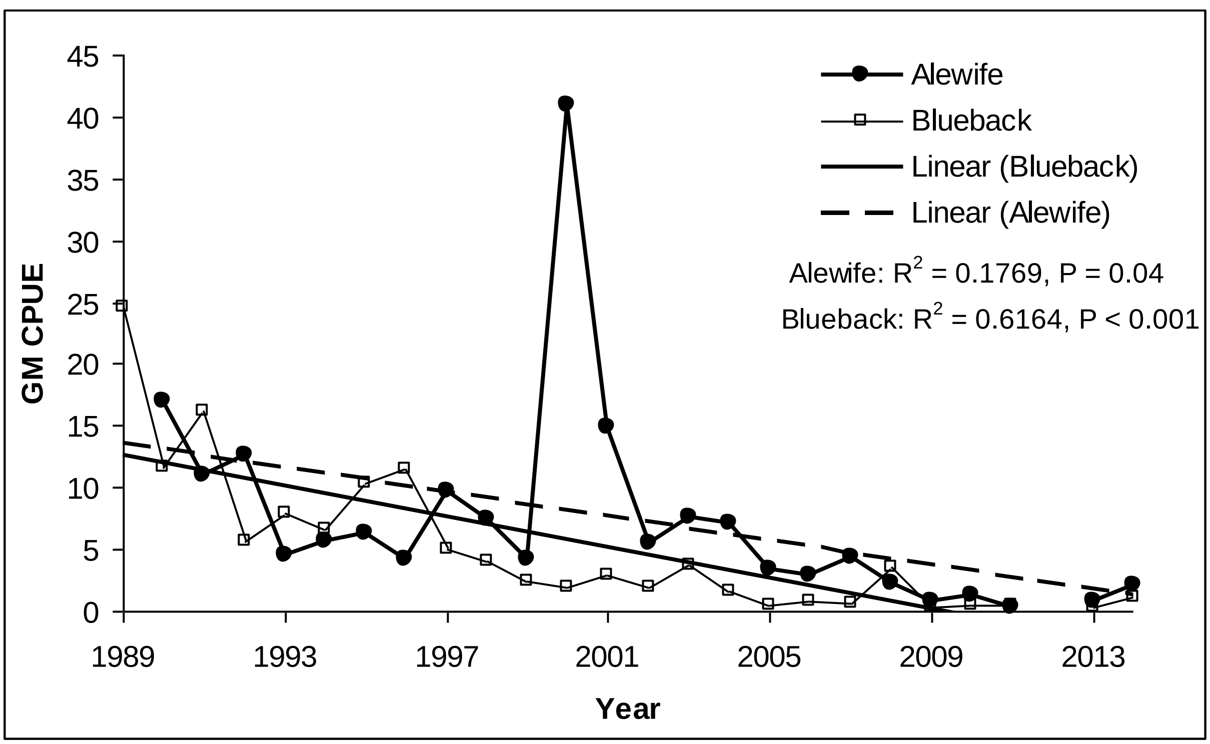

Figure 22. Maryland's commercial river herring landings, 1929-2014. The commercial river herring fishery has been closed since 26 December 2011.

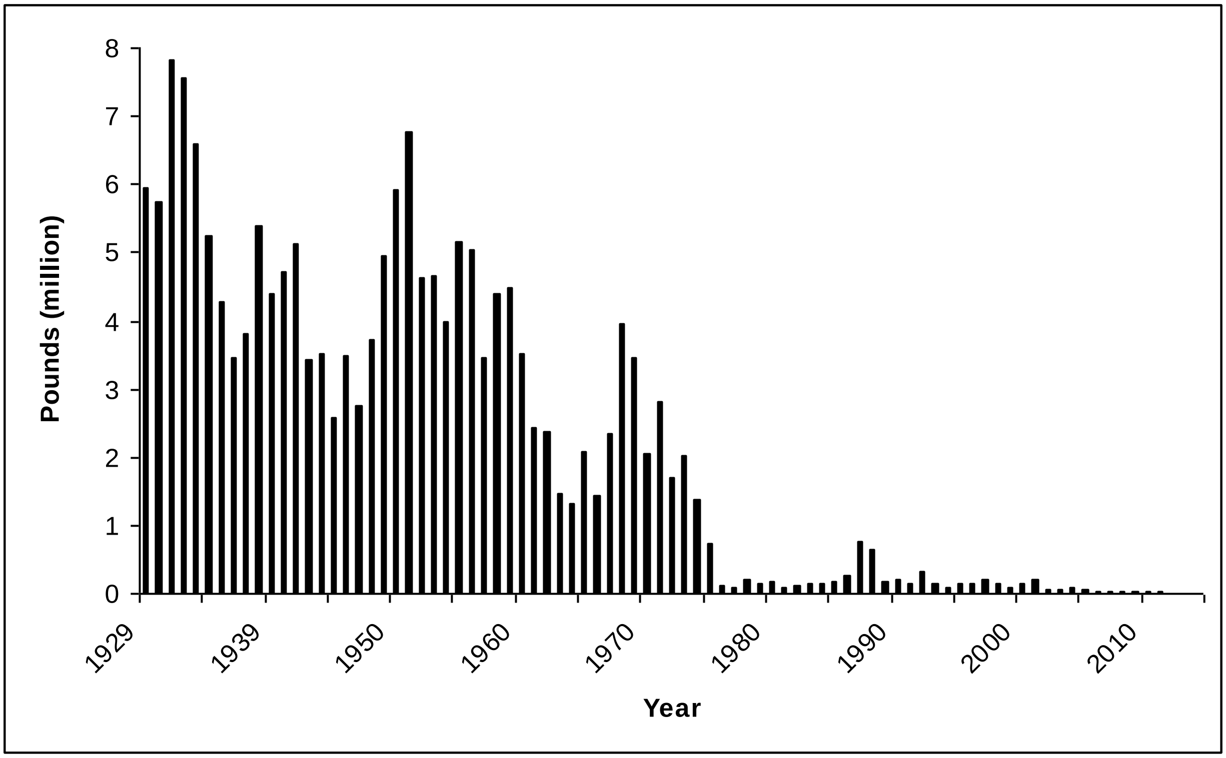

Figure 23. Nanticoke River juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2014.

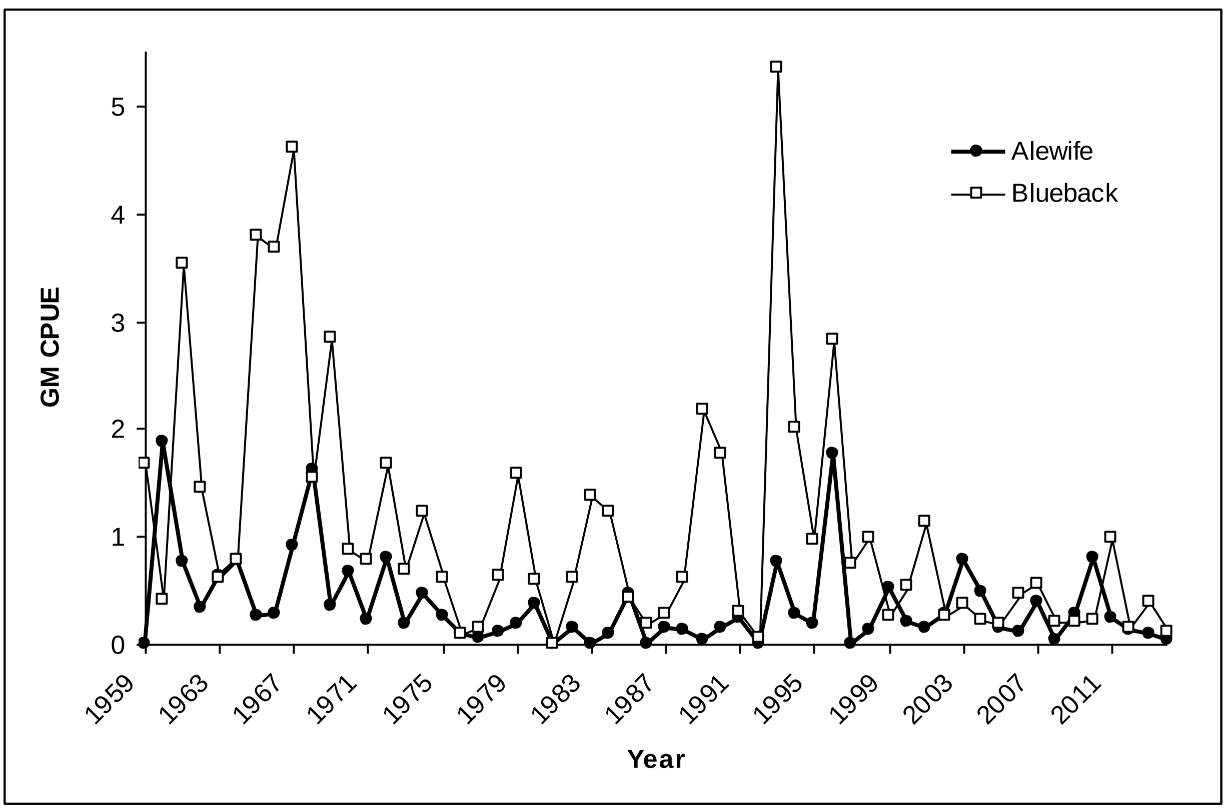

Figure 24. Upper Bay juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2014.

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. The data collected from this effort 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 consistently monitored throughout the 22 years of this survey (1993-2014). 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 2014 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 mm total length (TL) except for Spanish mackerel, which were measured to the nearest mm fork length (FL). Fifty randomly selected menhaden were measured to the nearest mm FL each day, when available, and scale samples were taken from 10 to 25 of the measured fish. Menhaden scales were aged by two MD DNR biologists. Water temperature (°C), salinity (ppt), GPS coordinates (NAD 83), date and hours fished were also recorded at each net.

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 2014 were aged by MD DNR biologists. All spot otoliths from 2014 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.

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 harvest 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 December 6, 2014. Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2013. Harvest from Maryland's commercial reporting system was divided by area into Chesapeake Bay, Atlantic Ocean (including coastal bays) and unknown areas.

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. Chesapeake Bay geometric mean catch per angler (CPA) indices were derived for eight of the ten target species. No indices were calculated for red drum due to small sample size, or menhaden, since it is not recreationally harvested. Geometric mean catch / angler trip compared to year was analyzed using linear regression to identify significant trends in relative abundance. The statewide MRIP estimates include all anglers (private and for hire) and all areas (Chesapeake Bay, Coastal Bays and Atlantic Ocean). All Maryland charter boat data was from Chesapeake Bay for the target species. The MRIP for hire inland only estimates do not include the Atlantic Ocean and are only for anglers that paid another individual to take them fishing, and may be more comparable to the charter boat log data. Numbers of fish harvested by charter boats for each species was compared to statewide MRIP recreational catch estimates (numbers), MRIP inland only for hire estimates (numbers), and reported Chesapeake Bay commercial landings (pounds), using linear regression, with P values of 0.01 or less were considered significant. Since the 2014 charter log book data had not been finalized, only data through 2013 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 = 2,724) determined from 2003-2014 Chesapeake Bay pound net survey data, and June through September 2003-2014 measurements of age zero croaker (n=314) from MD DNR Blue Crab Trawl Survey Tangier Sound samples (Chris Walstrum MD DNR personnel communication 2014). 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_∞ = 391.36 mm TL and K= 0.397, while L_c for Atlantic croaker was 229 mm TL.

Length frequency distributions were constructed for summer flounder, Atlantic croaker, weakfish, bluefish, spot and Atlantic menhaden, utilizing onboard sampling length data divided into 20 mm length groups. Length-at-age keys were constructed for weakfish, Atlantic croaker and Atlantic menhaden using age samples through 2014. Age and length data were assigned to 20mm 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 2014, weakfish from 2003 through 2014 and Atlantic menhaden from 2005 through 2014. Age length keys for spot were constructed for 2007 through 2014. Age and length data were assigned to 10mm 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).

RESULTS and DISCUSSION

The Potomac River and the Chesapeake Bay were sampled from May 27, 2014 through September 2, 2014 (Table 1). All target species, and 21 non-target species (Table 2) were encountered during this time period.

Weakfish

Only six weakfish were sampled in the 2014 pound net survey, the lowest catch of the 22 year time series. Weakfish mean length in 2014 was 332 mm TL, an increase from 2013, but the extremely low sample size limits the value of such comparisons (Table 3). Sample size was insufficient to construct a meaningful length frequency distribution for 2014, with no more than one fish in any size group. (Figure 2). Sex ratios and mean length by sex were not calculated do 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 2011, with far fewer large weakfish being encountered. All of the weakfish sampled in the 2011 pound net survey were below the recreational size limit of 331 mm TL (13 inches) and the commercial size limit of 305 mm TL (12 inches). This trend ended in 2012, with 15% and 24% of 93 weakfish above the recreational and commercial size limits, respectively. Larger weakfish remained available in 2013 with 15% and 46% of 67 weakfish above the recreational and commercial size limits, respectively. While sample size was low in 2014, two of the six fish captured were above thee recreational size limit and four above the commercial size limit.

Total Maryland commercial weakfish harvest (Chesapeake Bay and Atlantic Ocean combined) in 2013 increased to 3,158 pounds, with the Chesapeake Bay portion only accounting for 247 pounds (Figures 3 and 4). The 2013 total harvest was still the fourth lowest of the 84 year time series, and was well below Maryland's average of 605,309 pounds per year. Maryland recreational anglers harvested an estimated 1,834 weakfish (PSE = 91) during 2013, with an estimated weight of 3,518 pounds (PSE = 99; Figure 5). The number of weakfish harvested by the recreational fishery in 2013 was well below the time series mean harvest of 285,918 fish and, was the second lowest value of the 1981-2013 time series. According to the MRIP estimates, Maryland anglers released 10,078 (PSE = 54) weakfish in 2013, a decrease compared to 2012 (24,898, PSE = 58). Estimated recreational harvest decreased steadily from 475,348 fish in 2000 to near zero in 2006, and has fluctuated at a very low level from 2007 through 2013. 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 848 to 75,154 weakfish from 1993 to 2013 (Figure 6), with a dramatic decline occurring in 2003, and the lowest value occurring in 2013. The reported charter boat harvest had the same trend as the reported commercial harvest (R^2 = 0.67, $P < 0.001$), the statewide MRIP estimate (R^2 = 0.82, $P < 0.001$) and the inland for hire only MRIP estimate (R^2 = 0.33, P = 0.0096). The 2013 geometric mean of 0.44 weakfish per angler was the lowest value of the time series (Figure 7). Of the 28,255 entries reported, only one was not included in this analysis since the CPA exceeded 200. The geometric mean CPA has declined significantly from 1993 – 2013 (R^2 = 0.82, $P < 0.001$).

The weakfish juvenile GM in 2014 increased compared to 2013, and was the 12th highest value in the 26 year time series (Figure 8). 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. This lack of recruitment may explain poor commercial and recreational harvest in recent years. 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 six fish in 2014. Weakfish from age one to three were present. 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 4). The 2014 age sample size was too small to make valid comparisons to previous years.

Mortality estimates for 2006 through 2012 and 2014 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 = 1.35 and Z = 1.55, respectively (Table 5), 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.

Summer flounder

Summer flounder pound net survey mean lengths have varied widely from 2004-2014. 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 3). The 2014 mean length was the lowest of the 22 year time series. 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 9). The 2013 length frequency distribution was heavily skewed toward smaller fish, with 25% of sampled fish in the 250 and 270 mm TL length groups and 66% below 290 mm in length. The 2014 distribution was similar to the 2013 distribution; with 58% of fish below 290 mm TL. This shift to smaller fish may indicate stronger year classes in 2013 and 2014. The number of summer flounder sampled in 2014 was the lowest of the 22 years surveyed (Table 3). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches to the 2014 recreational size limit of 407 mm TL indicated only 4% of sampled summer flounder were of legal size in 2014, a decline compared to 2013(11%), 2012 (41%) and 2011 (22%).

Maryland's commercial summer flounder harvest totaled 174,055 pounds in 2013, just over double the 2012 value (Figure 10). The long-term mean commercial harvest is 401,977 pounds. In recent years the commercial flounder fishery has been managed by quota, with varying regulations and season closures to ensure the quota was not exceeded. The majority of the Maryland commercial flounder harvest comes from the Atlantic Ocean and coastal bays, with Chesapeake Bay landings steadily decreasing since 2005 (Figures 10 and 11). The recreational harvest estimate of 51,140 (PSE = 23) fish caught in 2013 ranked 27th in the 33 year time series, and more than doubled from the 2013 estimate of 22,617 (PSE = 32) fish (Figure 12). The 2013 MRIP recreational release estimate of 280,403 (PSE = 17) fish ranked 25th in the 1981- 2013 time series (Figure 12). The recreational fishery has been subject to more restrictive regulations in recent years, which most likely contributed to lower harvest rates compared to historic levels.

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 13). The harvest decreased in 2012 to 5,060 fish. The 2013 catch was similar to 2012 at 5,483 fish, the ninth lowest value in the 21 year time series. Linear regression indicated no significant trend between the charter boat catch and the statewide MRIP estimate, the commercial landings or the for hire inland only MRIP estimate. This is not surprising, since the majority of the commercial harvest occurs in the Atlantic Ocean, and the MRIP inland estimate includes both the coastal bays and the Chesapeake Bay, and the charter logs are all from the Chesapeake Bay. The geometric mean index significantly declined ($R^2 = 0.52$, $P < 0.001$) over the entire time series (Figure 14), but was relatively stable from 2004 to 2011.

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. Projection analysis for the 2013- 2015 indicated there is little chance of the stock becoming overfished, or over fishing occurring through 2015. F decreased through 2012, while SSB increased through 2010 to an estimated 53,156 mt and was estimated to be 51,238 mt in 2012.

Bluefish

Bluefish sampled from the onboard pound net survey averaged 319 mm TL during 2014, the highest value since 2005 (Table 3), and was above the 22 year time series mean of 302 mm. The pound net survey length frequency distribution shifted to larger size bluefish in 2012, lengths were mostly distributed between the 190 to 370 mm TL groups with peaks in the 230 and 350 mm TL groups (Figure 15). The 2013 distribution was similar to 2012 in range of lengths, but was a little more centralized around the peaks. The 2014 distribution also indicate two peaks in the same size ranges, but the 350 mm peak is much stronger than in previous years.

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 - 2014 length structure was similar to those of 2005 – 2007. 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.

Maryland bluefish commercial harvest decreased over three fold in 2013 to 48,865 pounds, and was well below the 1929-2013 average of 169,894 pounds per year (Figure 16). The 2013 catch ranked 74th in the 84 year time series. Total commercial landings fluctuated without trend from 42,662 to 166,786 pounds from 1993 – 2013 (Figure 16). The majority of Maryland's commercial bluefish harvest from 1972 through 1988 came from the Chesapeake Bay. However, Chesapeake Bay catches declined after 1988 while Atlantic Ocean and coastal bay catches remained somewhat stable through the 1990s. Harvest in both regions has fluctuated since 2000. Recreational harvest estimates for bluefish were high through most of the 1980's, but have fluctuated at a lower level since 1991 (Figure 17). The 2013 estimate of 55,544 (PSE = 22) fish harvested was less than half of the 2012 estimate (113,698 fish, PSE = 36), and was well below the time series average of 806,507 fish. Estimated recreational releases nearly doubled in 2013 to 260,957 fish (PSE = 26) compared to 2012 (138,459 fish PSE = 58), and was well below the time series mean of 512,183 fish (Figure 17).

Reported bluefish harvest from charter boat logs ranged from 17,184 – 134,828 fish per year from 1993 to 2013. The 2013 harvest of 17,184 fish was the lowest of the time series (Figure 18). Harvest from charter boat logs tracked with state wide MRIP estimates (R^2 = 0.36, P = 0.004), but no significant trend with for hire recreational estimates or commercial landings. Two of the 74,461 entries were not used in indices calculations because of excessively high CPA's (>300). The geometric mean catch per angler varied in a narrow range from 1993 to 2007, increased to the time series high in 2008, but then declined from 2009 to 2013 (Figure 19).

A stock assessment of Atlantic coast bluefish utilized ASAP in 2010, a forward projecting catch at age model (Shepherd and Nieland 2010), which was updated in 2012 (Wood 2013). The assessment indicated that F was steady at a low rate since 2000. Recruitment estimated in the ASAP model has remained relatively constant since 2000 at around 20 million age-0 bluefish, with the exception of a relatively large 2006 cohort estimated as 35.1 million fish. Recruitment during 2010 and 2011 was below average (Shepherd and Nieland 2010, Wood 2013). The model indicated that overfishing is not occurring and that the stock is not overfished, but projected spawning stock biomass declines over the next few years due to recent poor recruitment.

Atlantic croaker

Atlantic croaker mean length from the onboard pound net survey was 249 mm TL in 2014, and was the fourth lowest value of the 22 year time series (Table 3). The onboard pound net length frequency distribution for 2014 indicated a continued decrease in larger croaker, with no croaker in the 370 mm and larger length groups (Figure 20). Thirty-five percent of the sampled croaker were in the 230 mm size group.

Mean lengths and weights by sex for Atlantic croaker sampled from pound nets in 2013 were 280 mm TL and 312 g for females (n = 123) and 287 mm TL and 324 g for males (n = 62). Pound net samples were 67% female and 33% male. Pound net samples, in which sex determination and weight were taken, were not randomly selected; therefore sex specific data may be biased.

The 2013 Maryland Atlantic croaker total commercial harvest of 844,570 pounds (Chesapeake Bay and Atlantic Ocean combined) decreased 7% after increasing for three consecutive years (Figure 21). The 2013 harvest was below the 1929-2013 average of 1,038,745 pounds, but was well above the 1950-2013 average of 519,205 pounds. The 2013 recreational harvest estimate was 1,155,539 fish (PSE = 15.3) an 18% increase from 2012, the 8th highest value of the 33 year time series, and was above the 1981-2013 average of 775,036 fish (Figure 22). The 2013 recreational release estimate of 2,905,536 fish increased 68% compared to 2012 (Figure 22), and was above the 1981-2012 average of 1,306,422 fish.

Reported Atlantic croaker harvest from charter boats ranged from 93,155 – 448,789 fish during the 21 year time period (Figure 23), with the low value occurring in 2013. The charter boat log book harvest trended with the statewide MRIP estimates ($R^2 = 0.31$, $P = 0.0087$), but not with the Chesapeake Bay commercial landings or for hire inland only MRIP estimates. Twenty-two of the 54,603 entries were not used to calculate the GM because of CPA values exceeding 200 fish. The geometric mean catch per angler increased (R^2 = 0.44, P = 0.0010) from 1993 to 2013, with relatively stable values prior to 2004 and generally increasing values since 2004 (Figure 24). Following three years of steadily increasing values, the 2011 GM decreased compared to 2010. The 2013 GM of 4.66 was similar to the 2011 and 2012 values, and was above the long term mean.

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 25). The GM decreased in 2013 and again in 2014, to 1.0 fish per tow, and was the 10th lowest value of the 26 year time series. Atlantic croaker recruitment has been linked to environmental factors including winter temperature in nursery areas (Lankford and Targett 2001, Hare and Able 2007); prevailing winds, currents and hurricanes during spawning; and larval ingress (Montane and Austin 2005, Norcross and Austin 1986). Because of these strong environmental influences, high spawning stock biomass may not result in good recruitment, and a high degree of variability can be expected.

Ages derived from pound net caught Atlantic croaker otoliths in 2014 ranged from 1 to 9 (n=193; Table 6). The number of Atlantic croaker sampled for length in 2014 (n=1,436) was applied to an age-length key for 2014 (Table 6). This application indicated that 68% of the fish were age two, 15% were age four, 7% were age five, and 6% were age one. The remaining age groups each accounted for two percent or less of the fish sampled (Table 6). Atlantic croaker greater than six years old have become less abundant in recent years compared to the mid 2000s. 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 also been seen in Table 6. Instantaneous total mortality in 2014 was Z = 1.63 (Table 5). Total mortality estimates had been fairly stable from 2011 through 2013, after increasing steadily from 2006, the time series low, through 2011. The high 2014 mortality estimate from the length based approach is likely inflated by the sudden influx of the strong 2012 year class (smaller age 2 fish), which dominated the length frequency distribution.

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).

Spot

Spot mean length from the onboard sampling decreased slightly in 2014 to 194 mm TL (n=420), and was below the mean value of 204 mm TL for the 22 year time series (Table 3). The onboard sampling length frequency distribution in 2014 shifted slightly toward smaller length fish compared to 2013, but remained truncated relative to the distributions of the early to mid 2000s (Figure 26). The 170 and 190 mm TL groups accounted for 72 % of sampled spot. Only one jumbo spot (>254 mm TL) was present in the 2014 onboard sampling. Abundance of jumbo spot in the survey has been low for the past several years (0-3% of sample, 2005-2012). This followed good catches in the early part of the decade (10% in 2003, 13% in 2004).

Commercial harvest in 2013 increased three fold to 336,020 pounds, compared to 2012 (Figure 27), the11th highest catch of the 84 year time series. Commercial harvest peaked in the 1950's with catches nearing 600,000 pounds. Harvest then fell sharply and remained low, except for a few spikes, rebounding to moderate levels from the mid 1980s through the late 2000s, and returning to near time series high values in 2009-2011. Chesapeake Bay commercial harvest had been fairly steady from 2003-2005 ranging from 66,865 to 74,722 pounds before declining to 23,500 pounds in 2006. An unusually sharp increase in 2007 and 2009 through 2011 can be attributed to a large increase in gill net harvest, which accounted for 95% of the 2007 spot harvest (380,648 pounds), 90% of the 2009 harvest (467,595 pounds), 87% of the 2010 harvest (507,091 pounds) and 61% in 2011 (388,533 pounds), compared to 43% of the 2006 harvest (16,420 pounds). The reported spot harvest, excluding gill net landings, for 2007 (19,703 pounds) was similar to the 2006 non-gill net harvest of 21,354 pounds. In 2008 gill nets accounted for 48% of commercial harvest, with an increasing catch in non-gill net fisheries (62,934 pounds). The 2009 non-gill net harvest was similar to 2008 (52,556 pounds), but the 2011 non-gill net harvest increased and was primarily from fish pots (134,058 pounds, 24% of total harvest). This would seem to indicate the recent spike in gill net landings was due to increased effort directed at spot, likely triggered by market demand and/or the decreased availability of other more desirable species. The 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 2013 gill nets and fish pots accounted for 59% of harvest and 33% of harvest, respectively.

Maryland recreational harvest estimates from the MRIP indicated that spot catches since 1981 have been highly variable (Figure 28). Recreational harvest ranged from 377,964 fish in 1988 to 3,789,769 fish in 1986, while the number released fluctuated from 208,897 in 1996 to 2,720,343 in 1986 (Figure 28). The 2013 recreational harvest estimate of 945,972 fish (PSE = 17) increased 23% compared to 2012, remaining well below the time series mean estimate of 1,599,856 fish. The release estimate of 2,621,931 fish (PSE = 15) increased more than two fold compared to 2012, and was the second highest release value of the 33 year time series (Figure 28).

Reported spot charter boat logbook harvest from 1993 to 2013 ranged from 160,881 to 848,492 fish per year (Figure 29). The 2013 reported harvest of 372,140 fish was below the time series mean of 492,191 fish. The charter boat log book harvest did not significantly trend with the MRIP for hire inland only estimates, the Chesapeake Bay commercial landings or statewide MRIP estimates. This is not surprising, since charter boat captains sometimes have clients catch spot to use as bait for larger predatory species. MRIP surveys may not accurately account for spot used as bait, while the commercial harvest tends to be more incidental some years and directed in others. Twenty-nine of the 48,495 charter log book entries were not utilized because of greatly inflated CPA values (>300). The geometric mean CPA was highest in 1995, stable at a relatively low level from 1999 – 2002, generally increased from 2002 – 2007, and remained above average in

2008 and 2009 (Figure 30). The CPA alternated between very low values in 2010 and 2012 and a very high value in 2011 and 2013.

Spot juvenile trawl index values from 1989-2014 were quite variable (Figure 31). The 2010 GM value of 104.5 spot per tow was the highest value of the time series, the 2011 value declined to the second lowest of the 26 year time series, and increased to nearly the time series mean in 2012 (Figure 31). The index values declined in 2013 and 2014, with the 2014 value being the 3rd lowest of the time series.

In 2014 88.5% of sampled fish were age one, 6.5% were age two, and the remaining 4.0% were age zero (161 ages and 420 lengths; Table 7). This represents an expansion in ages from 2013, when 96.4% of sampled fish were age one, and no age two plus fish were encountered. In 2012 age one spot accounted for 60% of the sample with 39% being age zero and the remaining 1% being age two. 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 2014 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 farther 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 and 2014 could lead to lower availability of spot in 2015. No stock assessment has been completed for spot; primarily do to lack of necessary data. 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, using data through 2013, did not indicate the stock was in need of management action.

Red Drum

Red drum have been encountered sporadically through the 22 years of the onboard pound net survey, with none being measured in 8 years and 458 being measured in 2012 (Table 3). One red drum was measured in 2014 with a total length of 954 mm. This fish was larger than the recreational and commercial size limit slots of 18 - 27 and 18- 25 inches TL respectively. 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 commercial fishermen reported harvesting 3,222 pounds of red drum in 2013, the highest level of harvest since 1991 (Figure 32). Average harvest from 2004 to 2012 was 61 pounds per year, compared to 519 pounds per year from 1994 to 2002. These time frames are the nine years before and after a 2003 regulation change. Prior to the regulation change to an 18 – 25 inch slot limit with a 5 fish bag limit in 2003, Maryland commercial fishermen were allowed to harvest one fish over 27 inches per day. Most of these fish were much larger than 27 inches which consequently led to higher harvest values by weight. The higher 2013 landings value was likely do to a large year class growing into the slot limit.

The MRIP estimated that recreational fishermen harvested and released 2,134 (PSE = 45) and 2,207 (PSE = 42) red drum respectively in 2013 (Figures 33 and 34). Recreational harvest estimates have been extremely variable with zero harvest estimates for 23 of the 33 years, and very high PSE values. 2012 recreational harvest and 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 - 2013, except for 1996. Harvest was low for all years, ranging from zero to a high of 271 fish in 2012, with a mean of 37 red drum per year, and 127 being harvested in 2013 (Figure 35). The low reported annual harvest indicated red drum were available in Maryland's portion of Chesapeake Bay, but the low numbers confirm the species limited availability to recreational anglers, as also indicated by the annual MRIP estimates. No annual indices were generated because of low sample sizes. 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 fourteen being sampled in 2014 (Table 3). Lengths throughout the time series have ranged from 244 to 1,330 mm TL. The mean length in 2014 was 1,080 mm TL. Commercial harvest of black drum was banned for Maryland's portion of Chesapeake Bay in 1999, but some fish are still harvested along the Atlantic coast (Figure 36). Recreational harvest and release estimates from 1981 to 2013 have been variable, ranging from zero to over 13,000 fish in 1983 (Figure 37). In 2013, MRIP estimated no black drum were harvested and 6,414 (PSE = 26) were released by recreational anglers. 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.

Examination of the charter boat logs revealed black drum were harvested in all years of the 1993-2013 time series, with a mean catch of 383 fish per year (range = 101 – 905; Figure 38). Charter harvest had no significant trend to either the state wide or inland for hire only MRIP estimates. The geometric mean significantly declined ($R^2 = 0.64$, $P < 0.001$) throughout the time series, but most of the decline occurred from 1993 through 2002, with values varying in a narrower range in the past 12 years (Figure 39).

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 one Spanish mackerel was encountered in 2014. The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 and in 2013 (Table 3).

The 2013 commercial harvest of Spanish mackerel in Maryland was 2,392 pounds, a 35% decrease from 2012 (3,644 pounds; Figure 40), and below the 1965 to 2013 mean of 6,223 pounds per year. Commercial harvest was very low from 1965 – 1986 with no catches greater than 3,600 pounds including six years of zero harvest. Commercial harvest has been somewhat more stable since 1987 with a peak of 62,688 pounds in 1991. Since 1996, the majority of Spanish mackerel harvest has come from Chesapeake Bay, but during the 1987 – 1995 time period Atlantic Ocean catches dominated. Recreational harvest estimates peaked in the early to mid 1990's with three years of approximately 40,000 fish harvested (Figure 41). This followed a period of seven out of ten annual estimates with zero fish captured. Harvest estimates for 1998 – 2013 were variable, ranging from 0 – 20,049 fish with an average of 7,965 fish taken. In 2013, an estimated 2,905 (PSE = 101) Spanish mackerel were harvested (Figure 41). Due to the high PSE values, these estimates are considered tenuous.

Spanish mackerel charter boat harvest from 1993 to 2013 ranged from 53 – 10,653 fish per year, with the 2013 harvest being the time series low (Figure 42). The charter boat log book harvest did trend significantly with the MRIP for hire inland only estimates (R^2 = 0.59, P < 0.001) and the statewide MRIP estimates (R^2 = 0.52, P < 0.001), but not the Chesapeake Bay commercial landings. The geometric mean CPA was variable with a declining trend (R^2 = 0.42, P = 0.001; Figure 43). It would appear that

Spanish mackerel are providing a small but somewhat consistent opportunity for recreational anglers in Chesapeake Bay.

<u>Spotted Seatrout</u>

Spotted seatrout are rarely encountered during sampling, with annual observations ranging from zero (11 years) to 23 fish. Four were measured from the onboard pound net survey in 2014 with a mean length of 499 mm TL (Table 3). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 6,120 pounds from 1991-2013 (Figure 44). Reported 2013 harvest was 2,428 pounds, well below the 1991- 2011 mean. Recreational harvest estimates indicated a modest fishery during the mid 1980's and mid 1990's. However, catches became very low to nonexistent from the late 1990's to 2005, with a slight upswing in 2006 before returning to zero in 2007 and 2008. Harvest increased in 2009 to 11,680 fish, the highest value since 1998 (Figure 45). The 2010 and 2012 harvest estimates ranged from 3,058 to 6,032 fish, but returned to zero in 2013. The high PSE values from 2009 to 2012 indicate the MRIP survey does not provide reliable estimates for this species in Maryland.

Spotted seatrout harvest from 2013 charter boats was 826 fish. Reported harvest ranged from 224 – 20,030 fish per year and averaged 3,912 fish per year for the 17 year time series (Figure 46). No harvest was reported from 1993 to 1996, but it is not clear if spotted seatrout were not reported at that time or none were captured. The charter boat log book harvest did not trend significantly with the MRIP for hire inland only estimates, the statewide MRIP estimates or the Chesapeake Bay commercial landings. The geometric mean CPA varied without significant trend (Figure 47). 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 the MRIP.

Atlantic Menhaden

Mean length for Atlantic menhaden sampled from commercial pound nets in 2014 was 223 mm FL, the second lowest value of the 2004 to 2014 time series (Table 3). Menhaden length frequencies from onboard sampling for 2006 and 2007 were very similar and robust compared to 2005. However, the 2008 length frequency distribution was more concentrated around the mean, with a lower proportion of smaller and larger fish than the previous two years. In 2009 the distribution expanded, but was still dominated by larger fish (Figure 48). The 2010 and 2011 length distribution indicated a shift to smaller fish, and a more even distribution of lengths. The 2012 distribution returned to a more truncated distribution similar to 2008. The 2013 distribution broadened slightly peaking in the 250 mm FL size group. The range of sizes remained the same in 2014, with a more even distribution and a higher proportion of smaller fish.

Atlantic menhaden scale samples were taken from 236 fish in 2014, but ages could only be assigned to 229 fish (Table 8). 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 8). 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 age distribution was skewed toward younger fish with 33% being age one and 36% being age two.

Atlantic menhaden commercial harvest in Maryland increased from 7,000 pounds in 1935 to over 8 million pounds in 1965 (Figure 49). Commercial harvest remained above 3 million pounds until 1990 when harvest dropped to 1.7 million pounds, slowly increased, and spiked in 2005 to 12.6 million pounds. Average commercial harvest from 1935-2011 was 4.2 million pounds. The 2012 commercial harvest increased to the time series high of 13.7 million pounds, with 98% of harvest from the Chesapeake Bay (Figure 49). A coastwide 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 2013 landings of 7,071,038 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 (BAM), 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.

CITATIONS

ASMFC. 2002. Amendment 2 to the Interstate Fisheries Management Plan for Red Drum. Washington, D.C. 159p.

ASMFC. 2010. Atlantic Croaker 2010 Benchmark Stock Assessment. Atlantic States Marine Fisheries Commission. Washington, D.C. 366p.

ASMFC. 2012. Amendment 2 to the Interstate Fishery Management Plan for Atlantic Menhaden. Atlantic States Marine Fisheries Commission. Washington, D.C. 102p.

Chesapeake Bay Program. 1993. Chesapeake Bay Black Drum Fishery Management Plan. U.S. Environmental Protection Agency. CBP/TRS 110/94.

Crecco. 1996. Evidence of offshore displacement of Atlantic coast bluefish based on commercial landings and fishing effort. Report to the Stock Assessment Workshop Coastal/Pelagic Subcommittee. 24 p.

Davis, G. R., B. K. Daugherty, and J. F. Casey. 1995. Analysis of blue crab, Callinectes sapidus, stocks in the Maryland portion of the Chesapeake Bay from summer trawl data. Maryland Department of Natural Resources, Annapolis, Maryland.

Hare, J.A. and K.W. Able. 2007. Mechanistic links between climate and fisheries along the east coast of the United States: explaining population outbursts of Atlantic croaker (Micropogonias undulatus). Fisheries Oceanography 16:1, 31-45.

Hartman, K.J. and S.B. Brandt. 1995. Trophic resource partitioning, diets and growth of sympatric estuarine predators. Transactions of the American Fisheries Society. 124:520-537.

Jarzynski, T., P. Piavis and R. Sadzinski. 2000. Stock assessment of selected adult resident and migratory finfish in Maryland's Chesapeake Bay. *In* Stock Assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay. Maryland Department of Natural Resources, Report F-54-R. Annapolis, Maryland.

Kahn D. M., J. Uphoff, B. Murphy, V. Crecco, J. Brust, R. O'Reilly, L. Paramore, D. Vaughan and J. de Silva. 2005. Stock Assessment of Weakfish Through 2003, A Report to the ASMFC Weakfish Technical Committee. ASMFC

Lankford, Jr., T.E. and T.E. Targett. 2001. Low-temperature tolerance of age-0 Atlantic croakers: Recruitment implications for U.S. mid-Atlantic stocks. Transactions of the American Fisheries Society. 130:236-249.

Montane, M.M., and H.M. Austin. 2005. Effects of hurricanes on Atlantic croaker (*Micropogonias undulatus*) recruitment to Chesapeake Bay. Pp. 185-192. In Hurricane

Isabel in Perspective. K. Sellner, ed. Chesapeake Research Consortium, CRC Publication 05-160, Edgewater, MD.

Norcross, B.L., and H.M. Austin. 1986. Middle Atlantic Bight meridional wind component effect on bottom water temperature and spawning distribution of Atlantic croaker. Continental Shelf Research 8(1):69–88.

Northeast Fisheries Science Center (NFSC). 2013. Summary Report of the 57th Northeast Regional Stock Assessment Review Committee. 47p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Northeast Fisheries Science Center (NFSC). 2009. 48th Northeast Regional Stock Assessment Workshop (48th SAW) Assessment Summary Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-10; 58 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Overton, A.S., E.B. May, J. Griffin and F.J. Margraf. 2000. A bioenergetics approach for determining the effect of increased striped bass population on its prey and health in the Chesapeake Bay. Maryland Cooperative Fish and Wildlife Research Unit. Princess Anne, MD. 20p.

SAS. 2010. SAS 9.3. Copyright © 2010 SAS Institute Inc., Cary, NC, USA.

SEDAR. 2015. SEDAR 40 Atlantic Menhaden Stock Assessment Report. SEDAR, North Charleston SC. 643pp. available online at: http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=40.

Shepherd GR, Nieland J. 2010. Bluefish 2010 stock assessment update. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 10-15; 33 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Ssentongo, G. and P. Larkin. 1973. Some simple methods of estimating mortality rates of exploited fish populations. Journal of the Fisheries Research Board of Canada. 30:695-698.

Wood A. 2013. Bluefish 2012 Stock Assessment Update. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 13-07; 32 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026

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Table 1. Areas sampled number of sampling trips, mean surface water temperature and mean surface salinity by month for 2014.

Area	Month	Number of Samples	Mean Water Temp. C	Mean Salinity (ppt)
Point Lookout	May	1	22.4	8.0
Point Lookout	June	2	24.9	12.6
Hooper Strait	June	3	24.1	13.1
Nanticoke	June	3	24.2	13.3
Point Lookout	July	3	26.2	13.2
Nanticoke	July	2	26.5	13.1
Point Lookout	August	2	25.6	15.6
Nanticoke	August	2	25.5	15.4
West Bay	September	2	26.4	16.5

Table 2. List of non-target species observed during the 2014 onboard pound net survey.

Common Name	Scientific Name
American shad	*Alosa sapidissima*
Atlantic spadefish	*Chaetodipterus faber*
Butterfish	*Peprilus triacanthus*
Channel catfish	*Ictalurus punctatus*
Common Carp	*Cyprinus carpio*
Cownose ray	*Rhinoptera bonasus*
Gizzard shad	*Dorosoma cepedianum*
Hickory shad	*Alosa mediocris*
Hogchoker	*Trinectes maculates*
Inshore lizardfish	*Synodus foetens*
Longnose gar	*Lepisosteus osseus*
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. Mean length (mm TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993 - 2014.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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
std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42	52	22	24	24	48	33	65
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
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
std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66	72	64	84	67	130	89	73
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
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
std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70	41	43	60	48	77	59	62
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
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
std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54	62	50	34	31	42	36	31
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
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
std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23	21	21	22	18	24	20	20
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
Spotted Seatrout																						
mean length		448	452			541	460								414	464	262		361	436	456	499
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
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
std. dev.		175	454	20		182				190	20	212		228	95	238	84	345	188		236	150
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5	13	3	3	1	4	14

Table 3. Continued.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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	
std. dev.	114	55	38	55		45	82	66													37	
n	3	78	39	27	1	4	45	35													124	
Spanish Mackerel (Fork Length)																						
mean length			418	401	437	379		386	406	422	405	391	422	439	436	407	418			393	428	536
std. dev.			34	62				34	34	81	63	95	33	35	51	59	53			74	36	
n			44	27	1	1		49	19	20	11	8	373	445	158	18	7	0	0	107	331	1
Menhaden (Fork Length)																						
mean length												262	282	238	243	246	245	232	213	243	251	223
std. dev.												28	36	42	41	29	40	36	39	25	31	38
n												213	1,052	826	854	826	366	836	773	755	762	775

Table 4. 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 2003-2014.

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

Table 5. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2014.

	Species	
Year	Weakfish	Atlantic Croaker
1999	0.74	0.39
2000	0.4	0.42
2001	0.62	0.33
2002	0.58	0.34
2003	0.73	0.46
2004	1.29	0.37
2005	1.44	0.31
2006	*	0.26
2007	*	0.31
2008	*	0.32
2009	*	0.48
2010	*	0.66
2011	*	0.81
2012	*	0.80
2013	1.55	0.87
2014	*	1.63

* Insufficient data to calculate 2006 - 2012 and 2014 for weakfish estimates.

Table 6. 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, 1999-2014.

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

Table 7. 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, 2007-2014.

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

Table 8. Atlantic menhaden proportion at age in percentage, using pound net length and age data, number of age samples and number of length samples by year, 2005-2014.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	# Aged	# Measured
2005		2.7	25.9	42.6	25.6	3.2			345	1,061
2006		40.4	28.3	18.4	9.7	2.6	0.6		289	826
2007		22.6	37.4	24.7	10.7	4.0	0.6		379	854
2008		16.6	44.6	29.4	7.3	1.9	0.3		385	826
2009	0.4	16.8	24.9	38.0	17.2	2.7			258	512
2010		43.0	30.6	14.9	8.3	2.5	0.6		388	836
2011		38.0	31.4	19.9	9.1	1.6			392	773
2012		14.5	56.7	21.5	4.3	1.8	0.8	0.5	355	755
2013		23.9	27.7	24.3	16.0	6.5	1.4	0.2	315	762
2014		33.0	36.2	18.7	10.0	2.2			229	775

Figure 1. Summer pound net sampling area map for 2014.

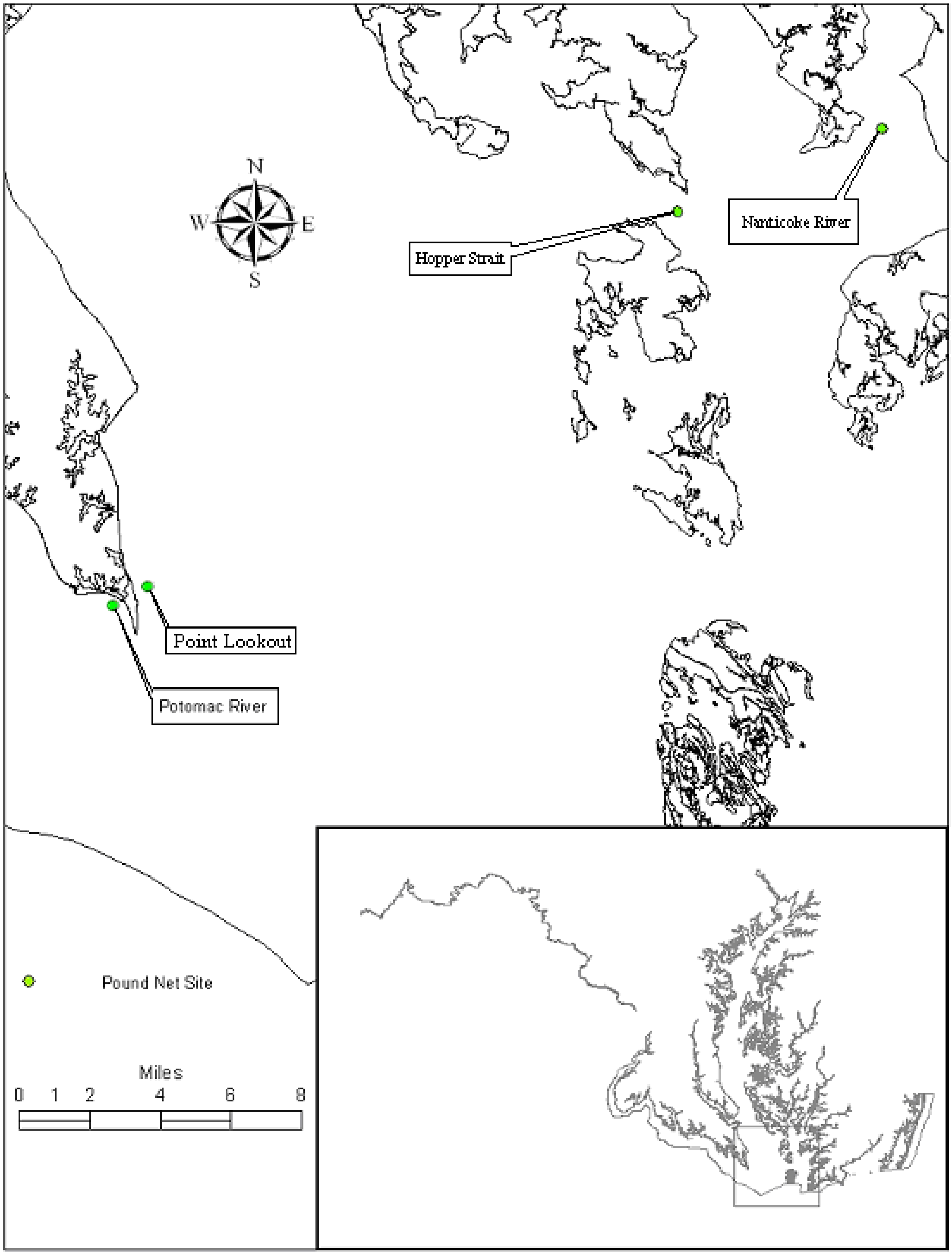

Figure 2. Weakfish length frequency distributions from onboard pound net sampling, 2005-2014. Note: 2011 210 mm length group was truncated to preserve scale, actual value is 50%.

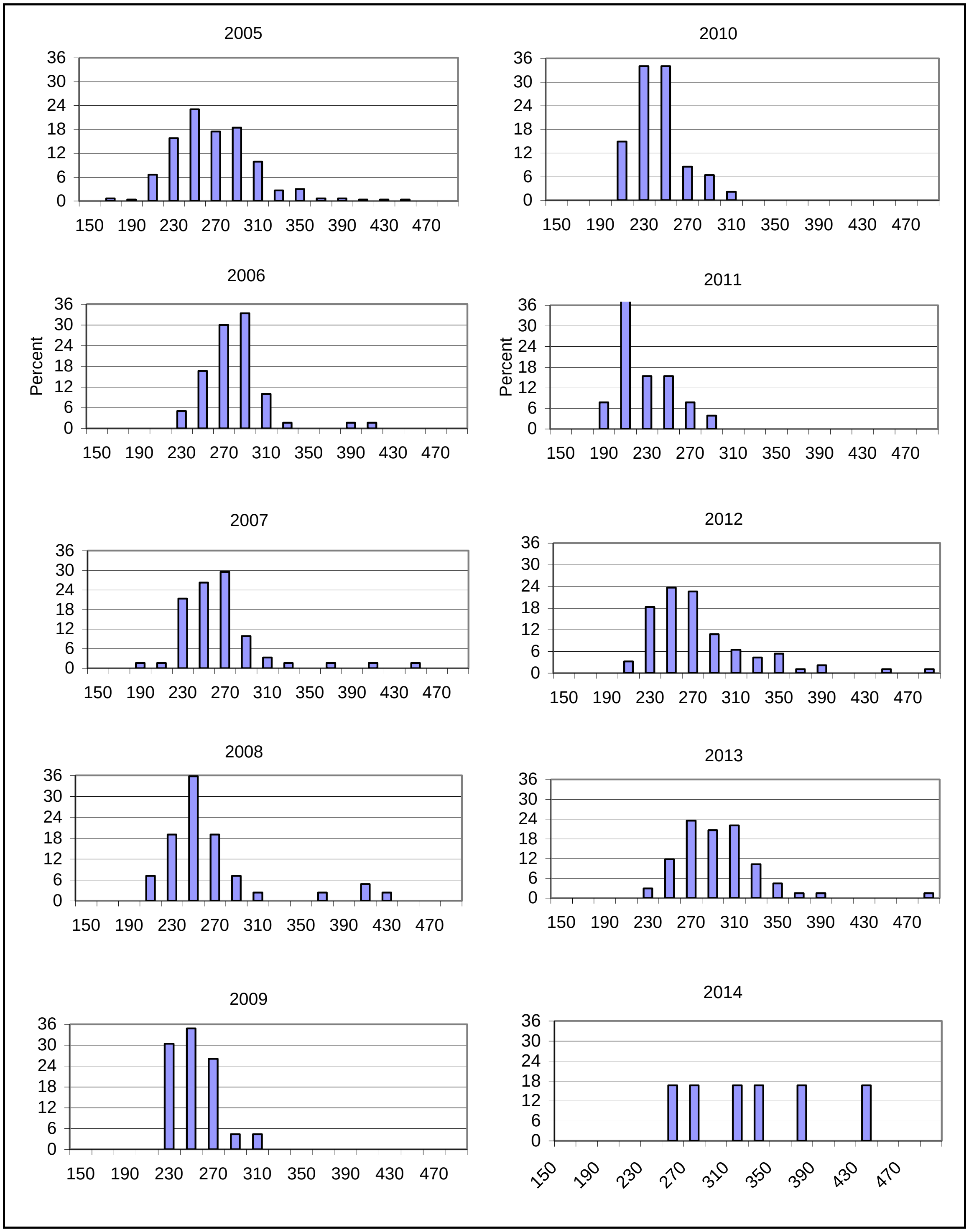

Figure 3. Maryland commercial weakfish harvest by area, 1929-2013.

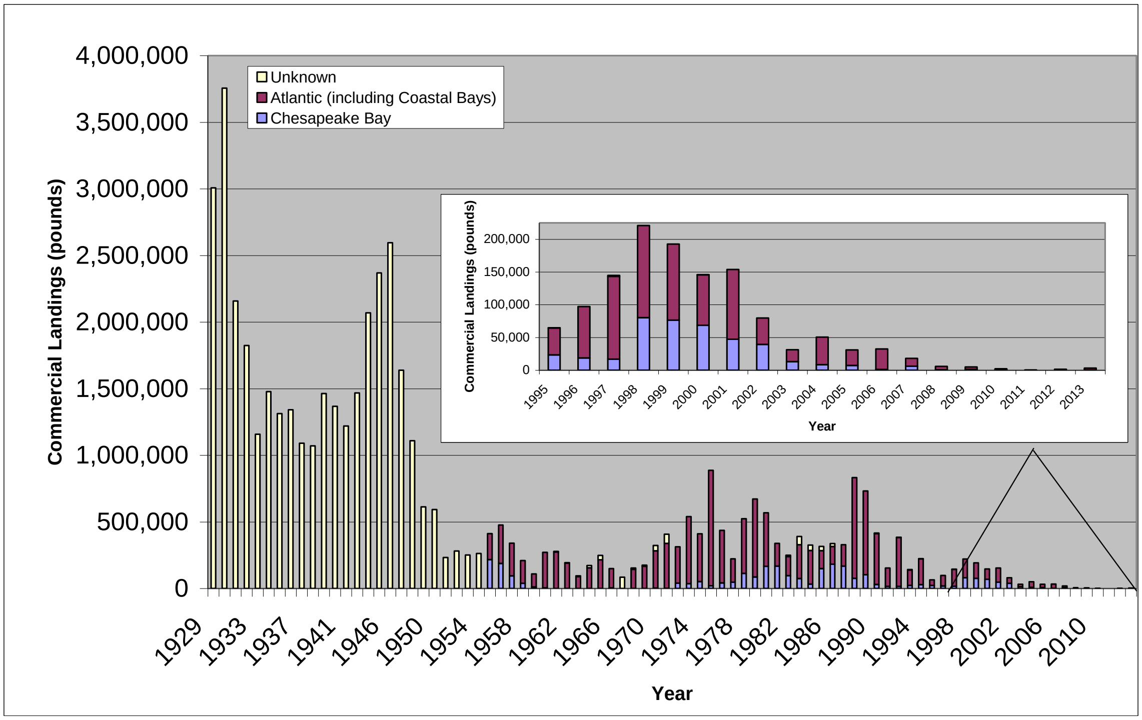

Figure 4. Maryland commercial weakfish harvest in the Chesapeake Bay, 1955-2013.

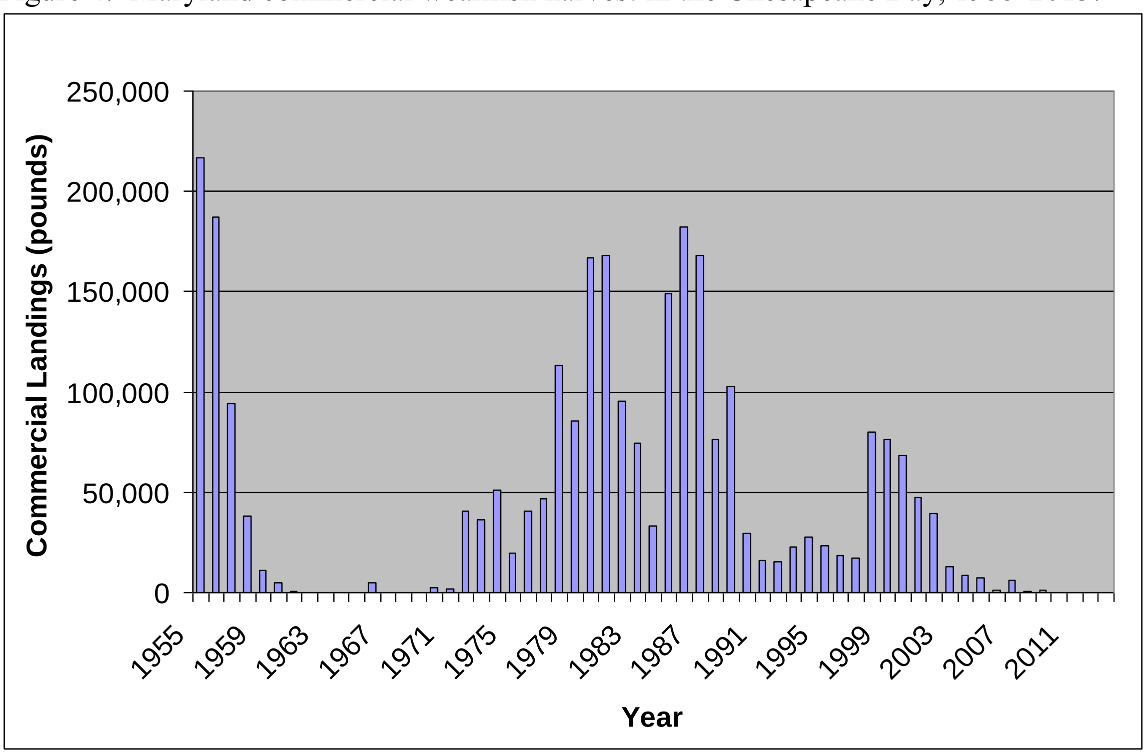

Figure 5. Estimated Maryland recreational weakfish harvest and releases for 1981-2013 (Source: MRIP, 2015).

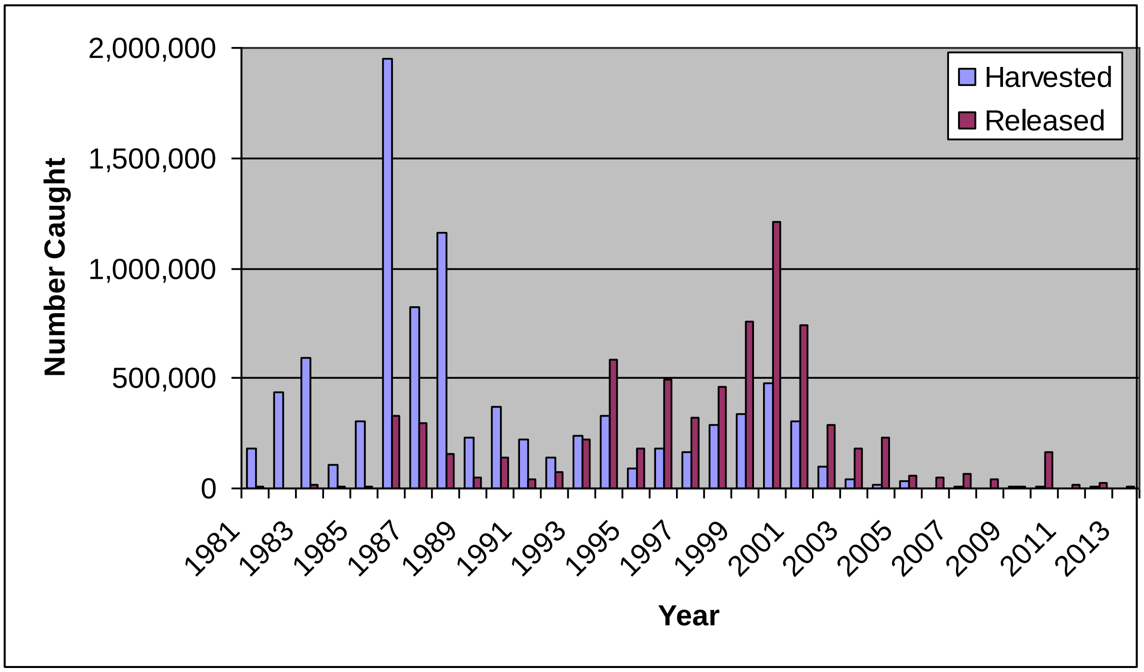

Figure 6. Weakfish statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2013.

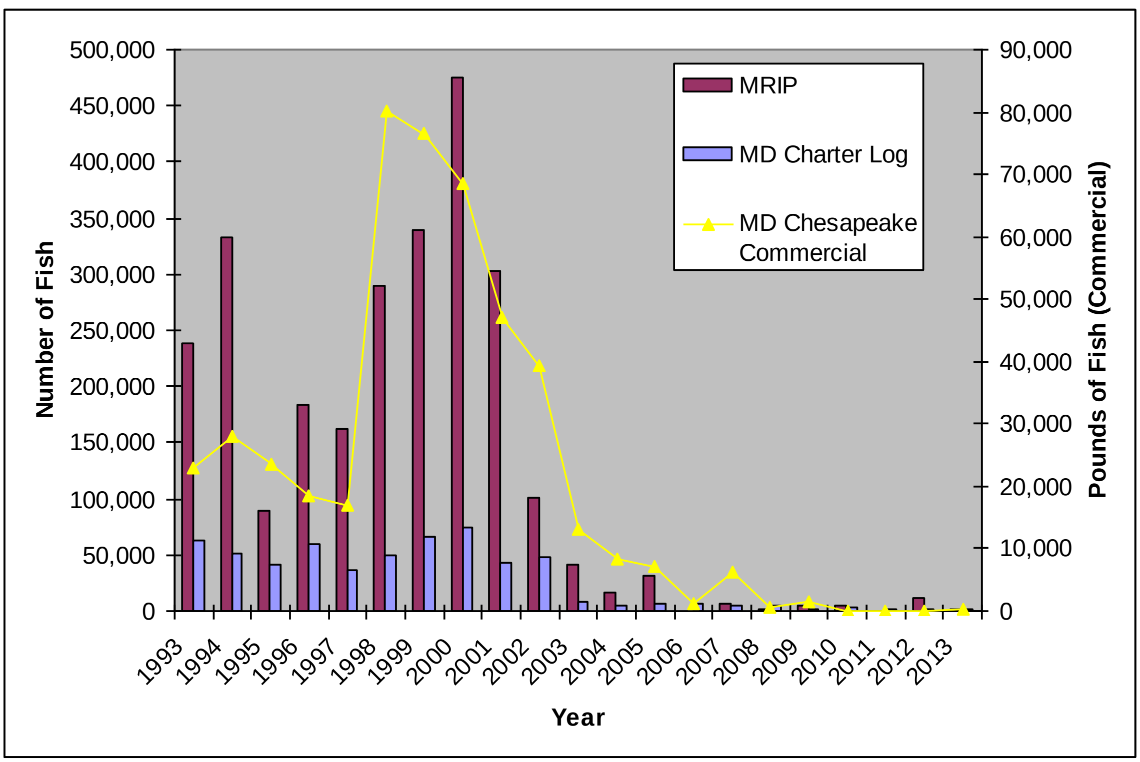

Figure 7. Weakfish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

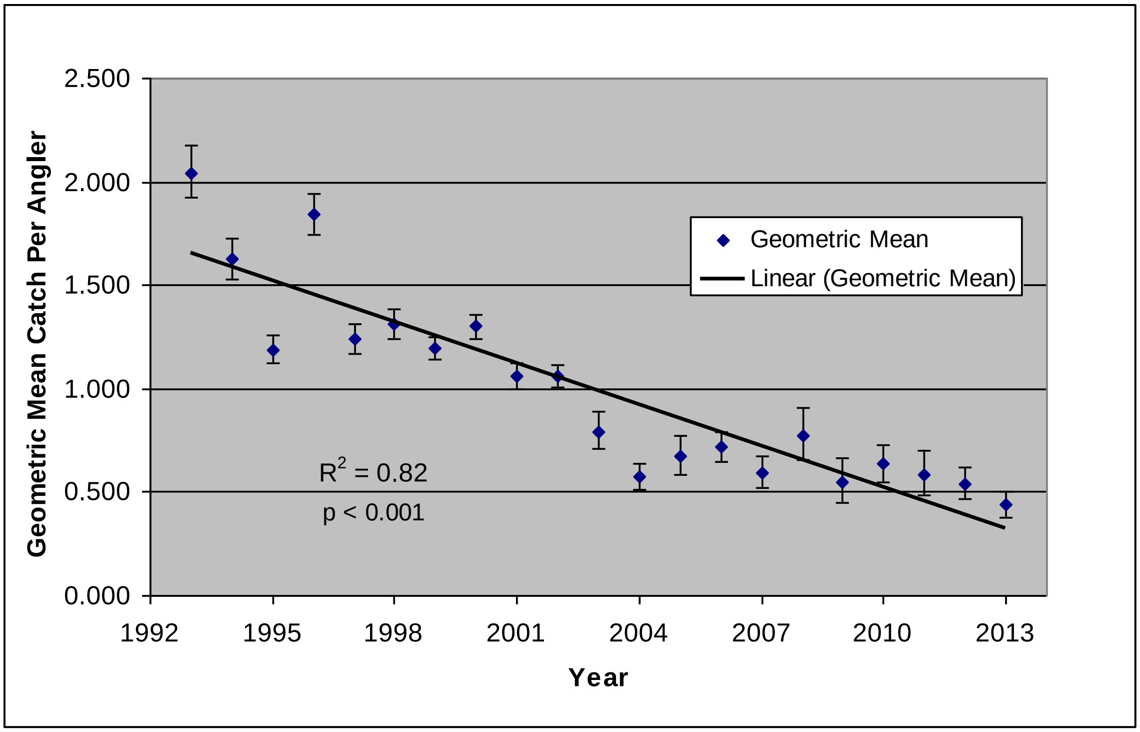

Figure 8. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2014.

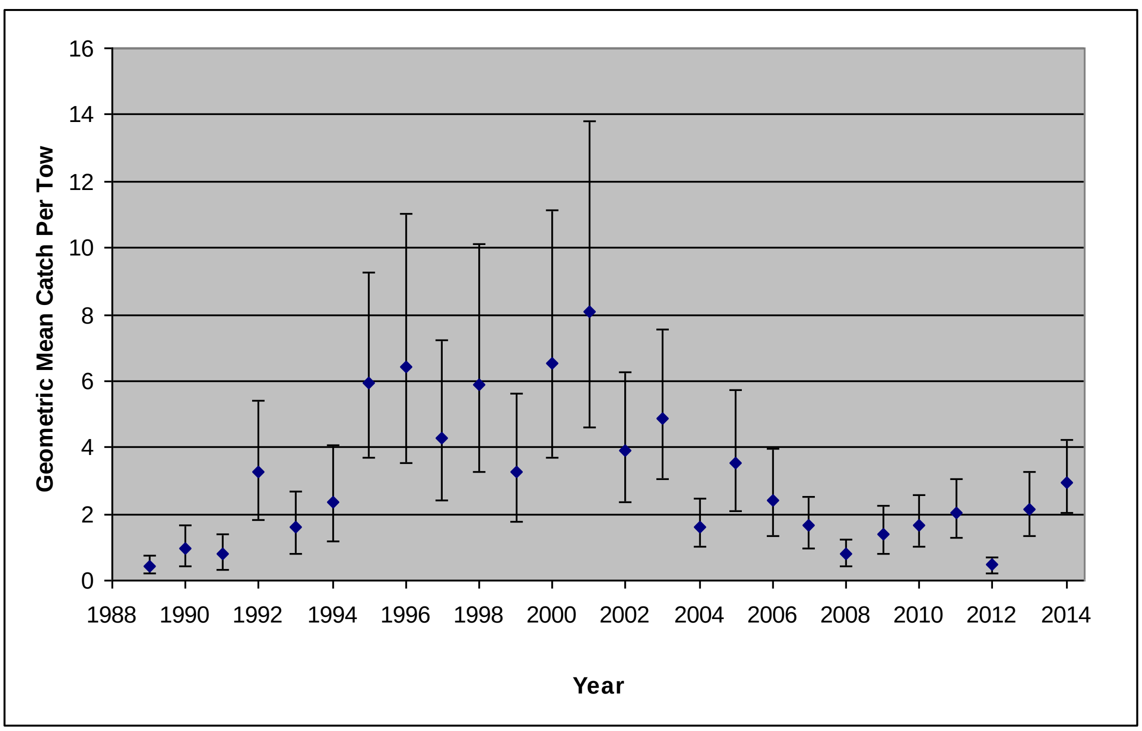

Figure 9. Summer flounder length frequency distributions from onboard pound net sampling, 2005-2014.

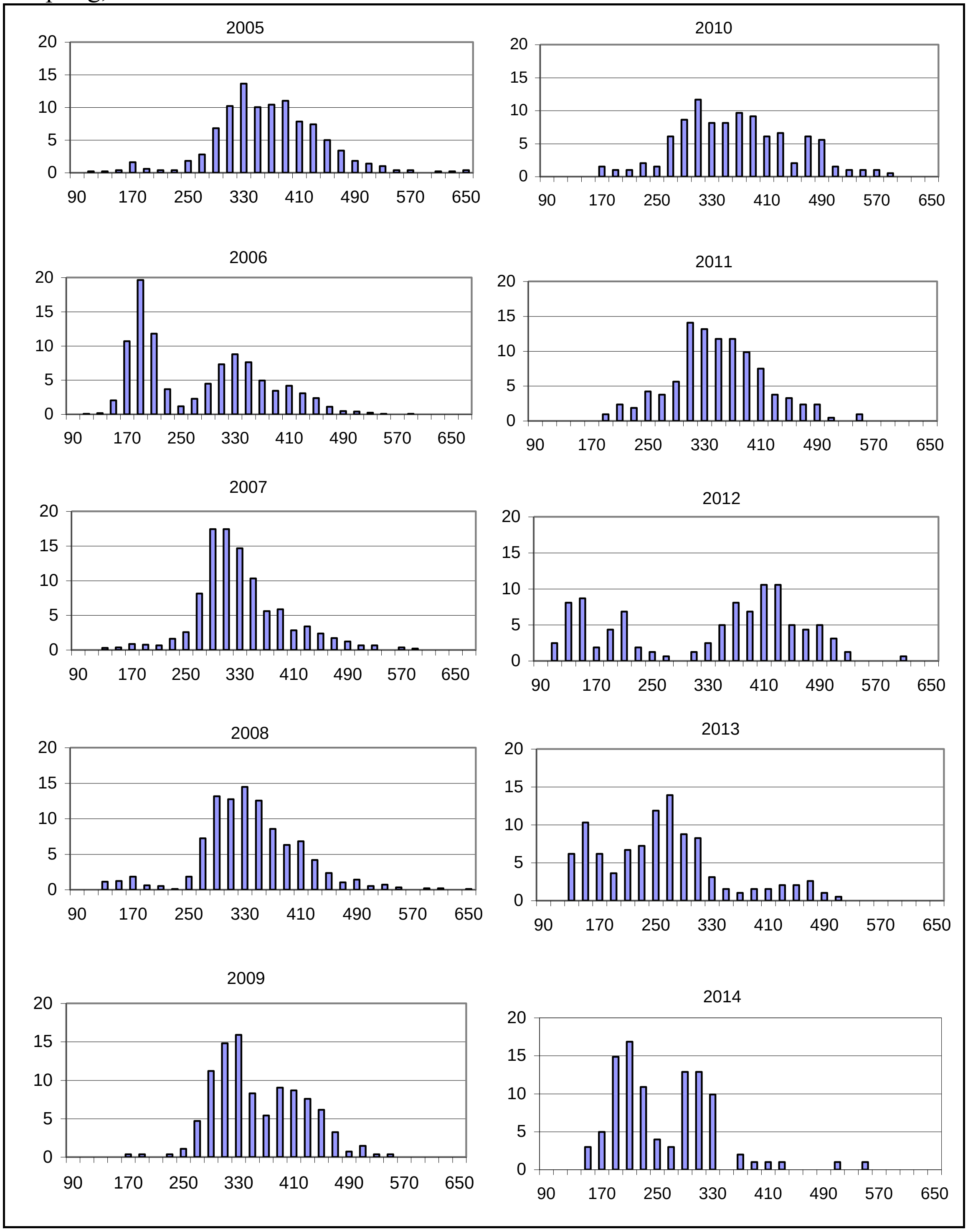

Figure 10. Maryland commercial summer flounder harvest by area, 1962-2013.

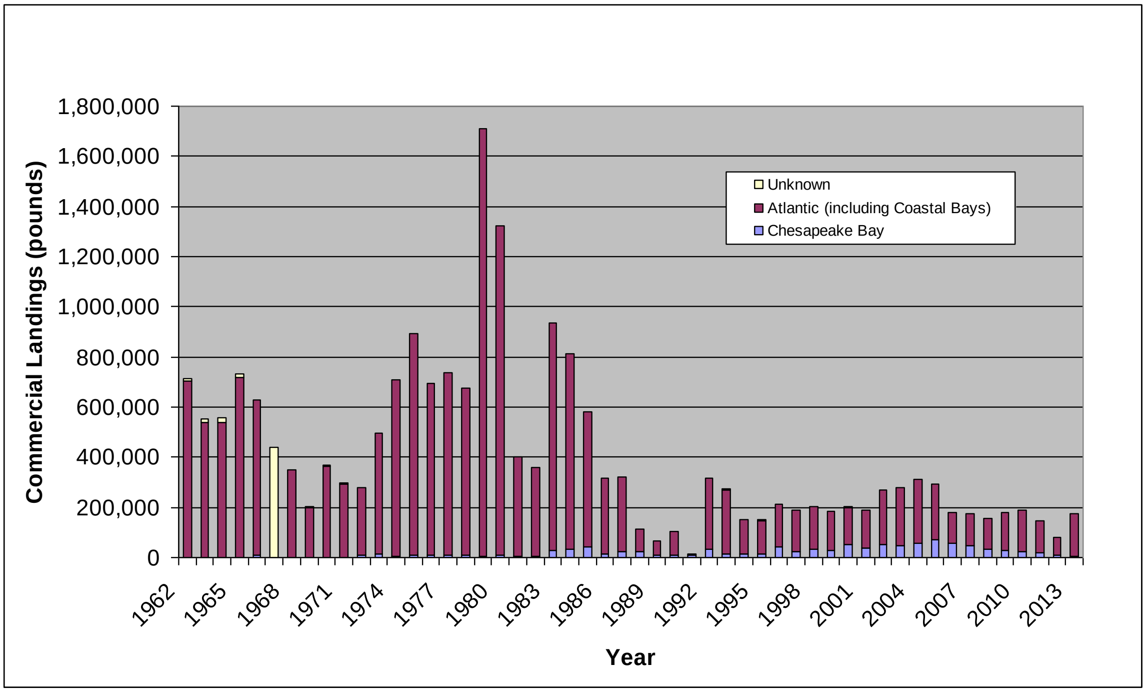

Figure 11. Maryland commercial summer flounder harvest in the Chesapeake Bay, 1962-2014.

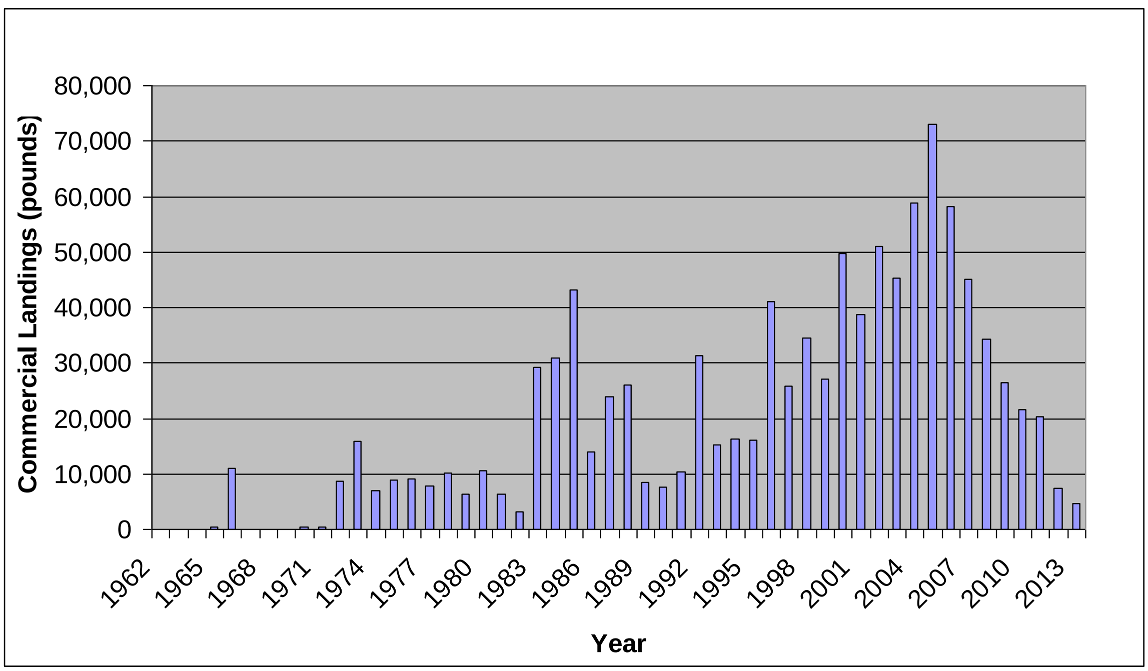

Figure 12. Estimated Maryland recreational summer flounder harvest and releases for 1981-2013 (Source: MRIP, 2015).

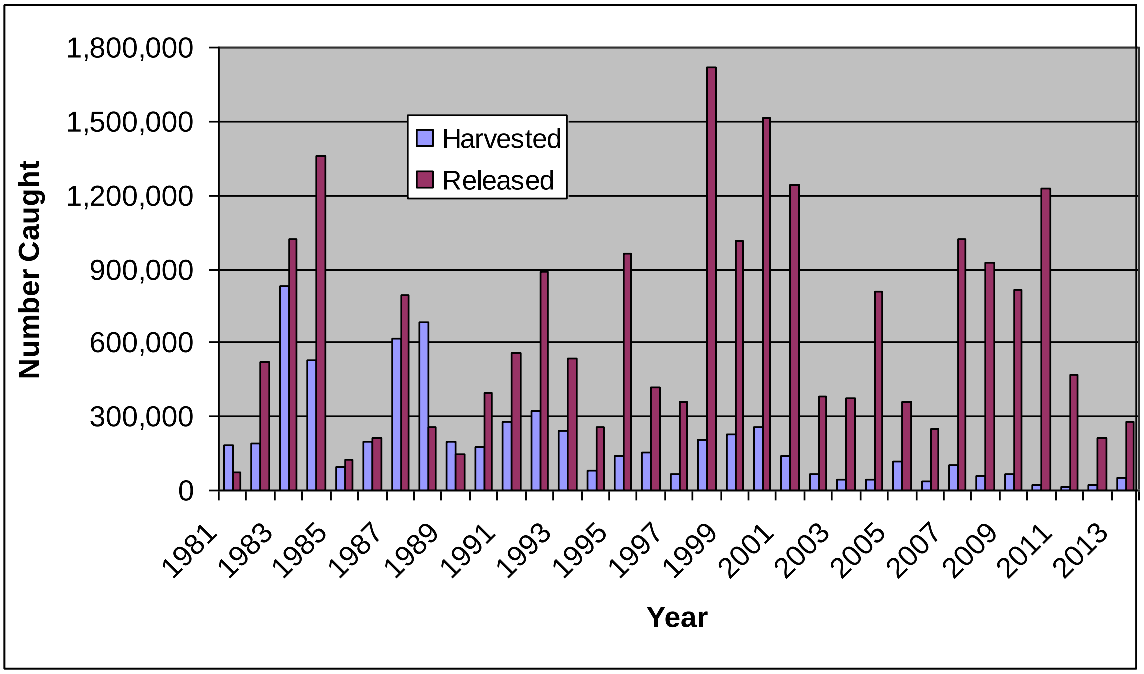

Figure 13. Summer Flounder statewide MRIP harvest and reported charter boat harvest from Maryland logbooks in numbers, 1993-2013.

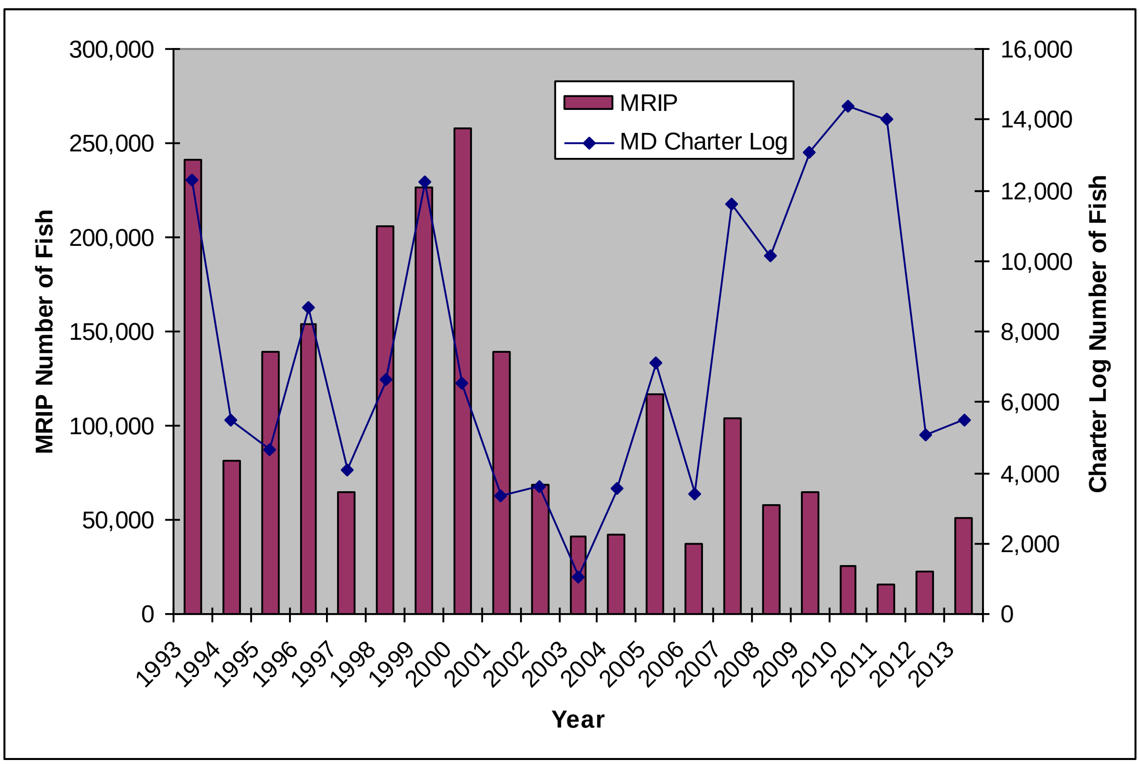

Figure 14. Summer flounder geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

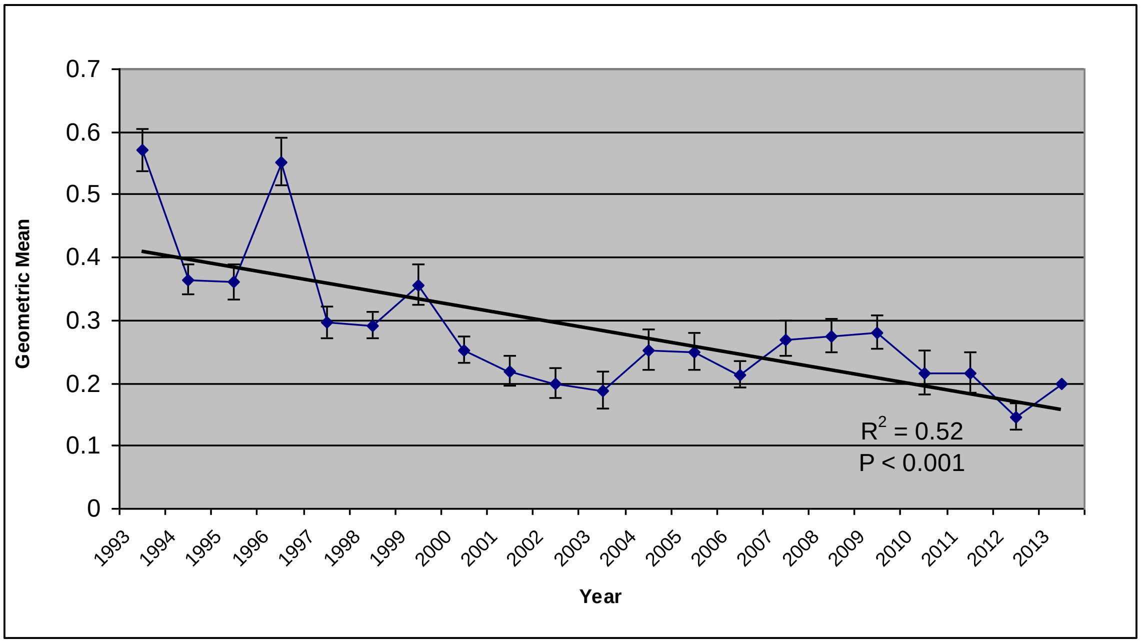

Figure 15. Bluefish length frequency distributions from onboard pound net sampling, 2005-2014.

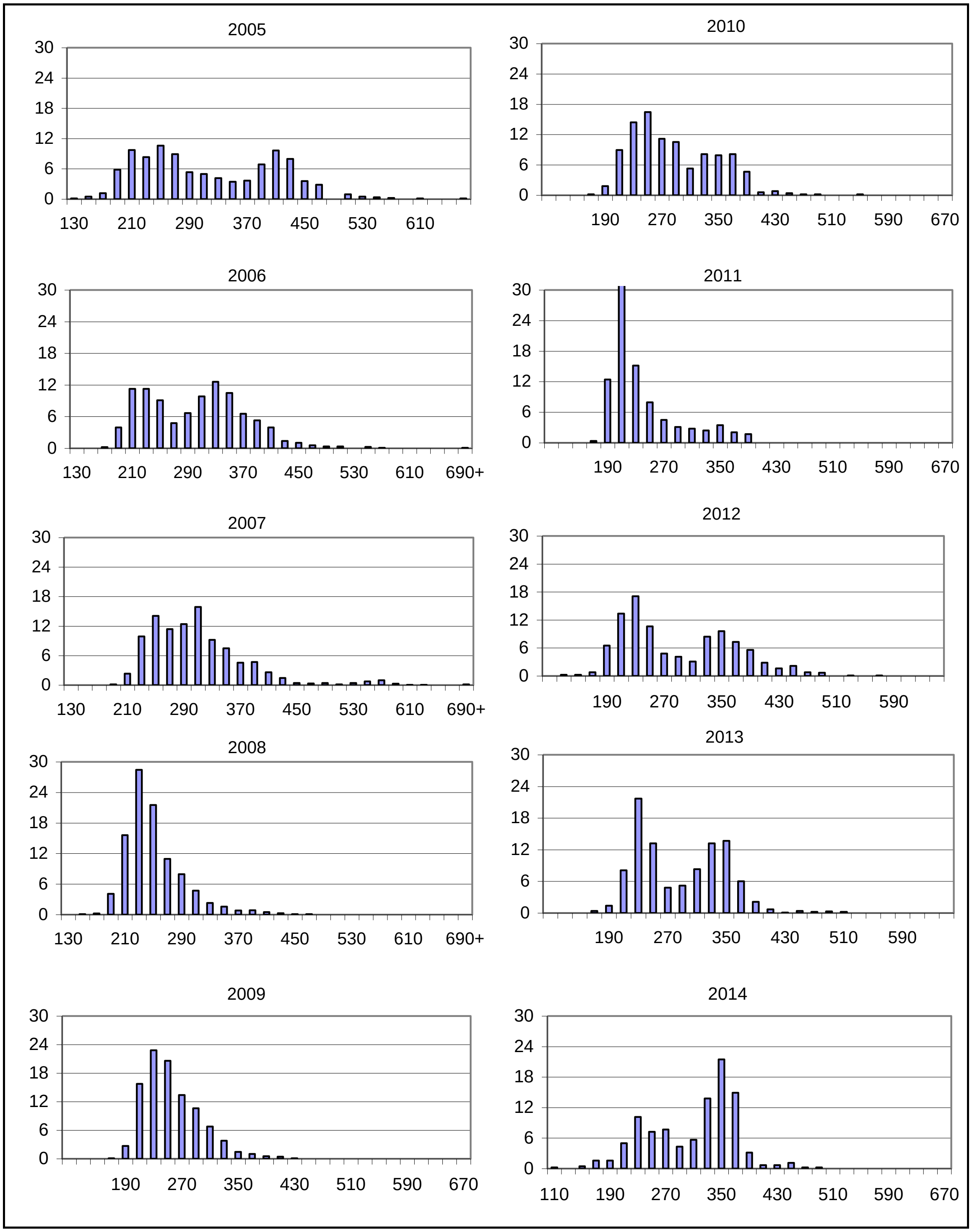

Figure 16. Maryland commercial bluefish harvest by area, 1929-2013.

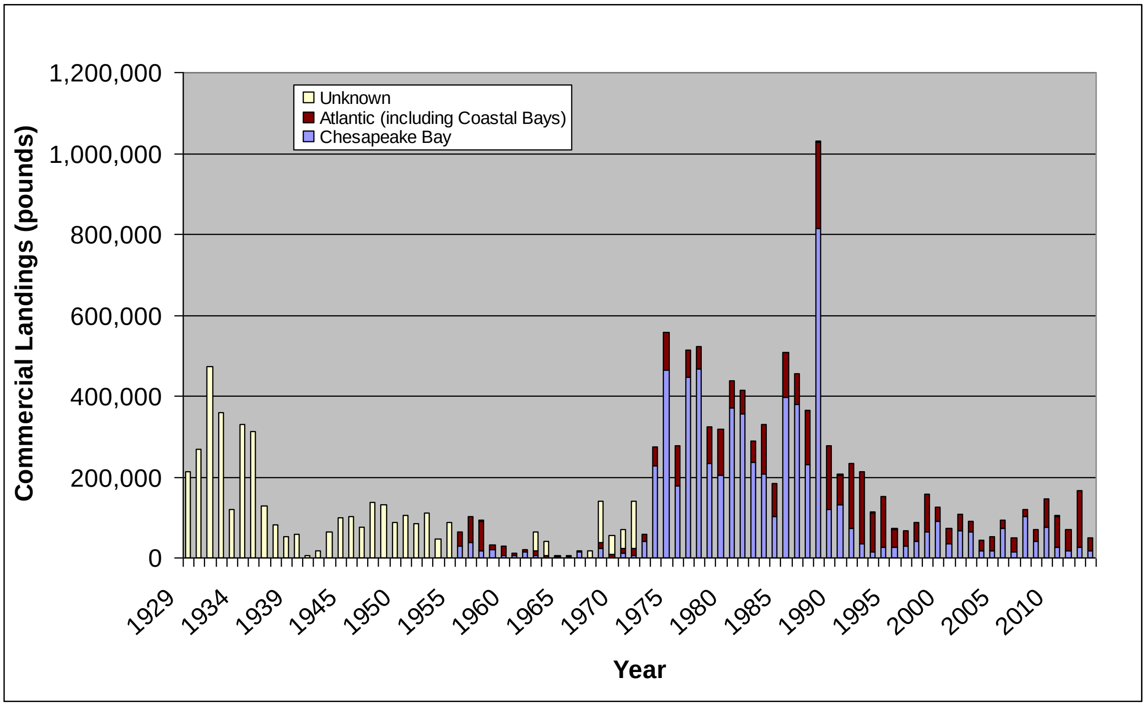

Figure 17. Estimated Maryland recreational bluefish harvest and releases for 1981-2013 (Source: MRIP, 2015).

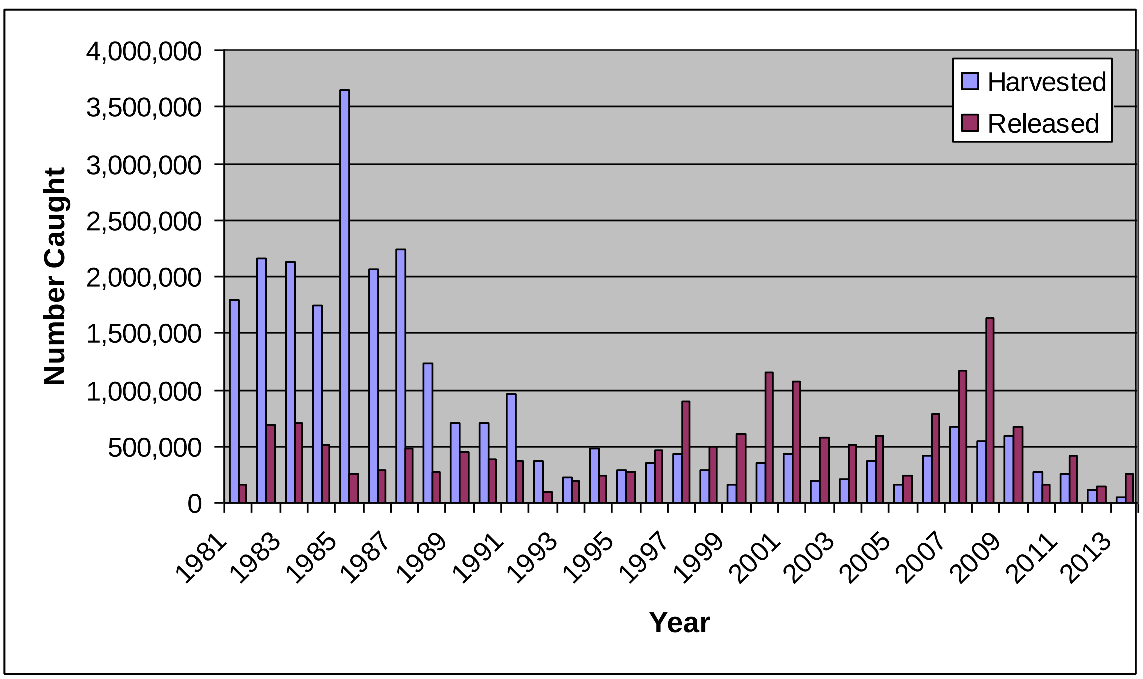

Figure 18. Bluefish statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2013.

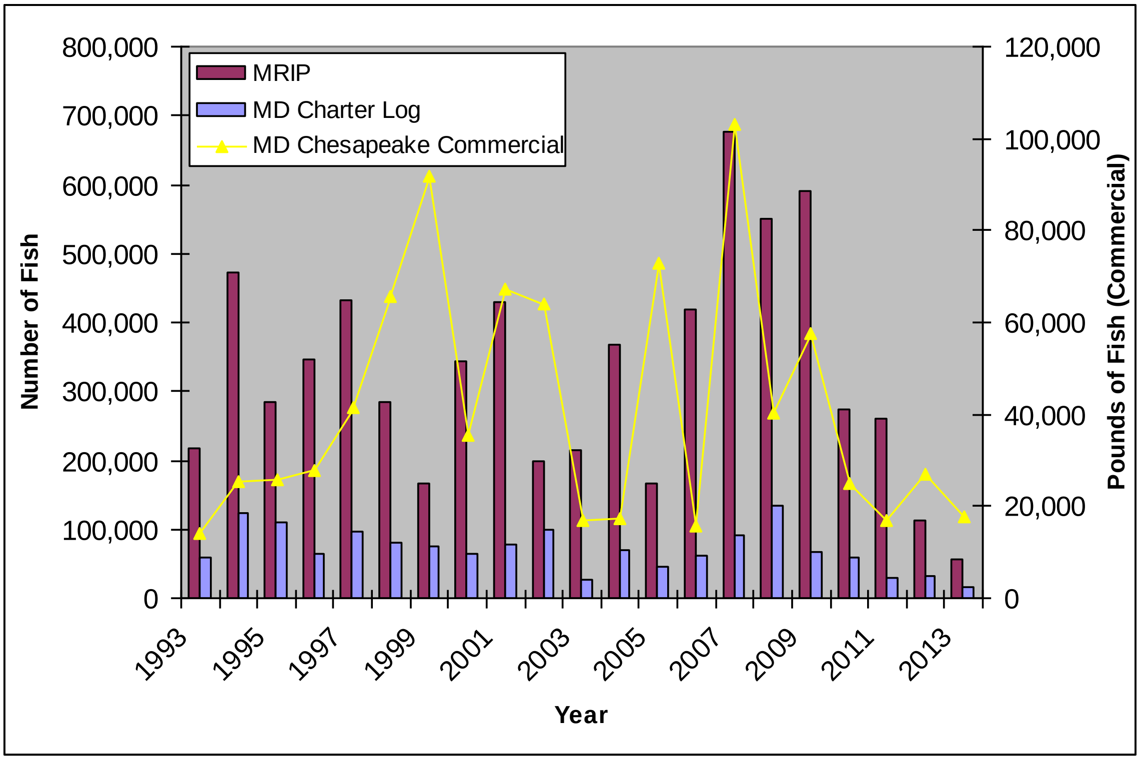

Figure 19. Bluefish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

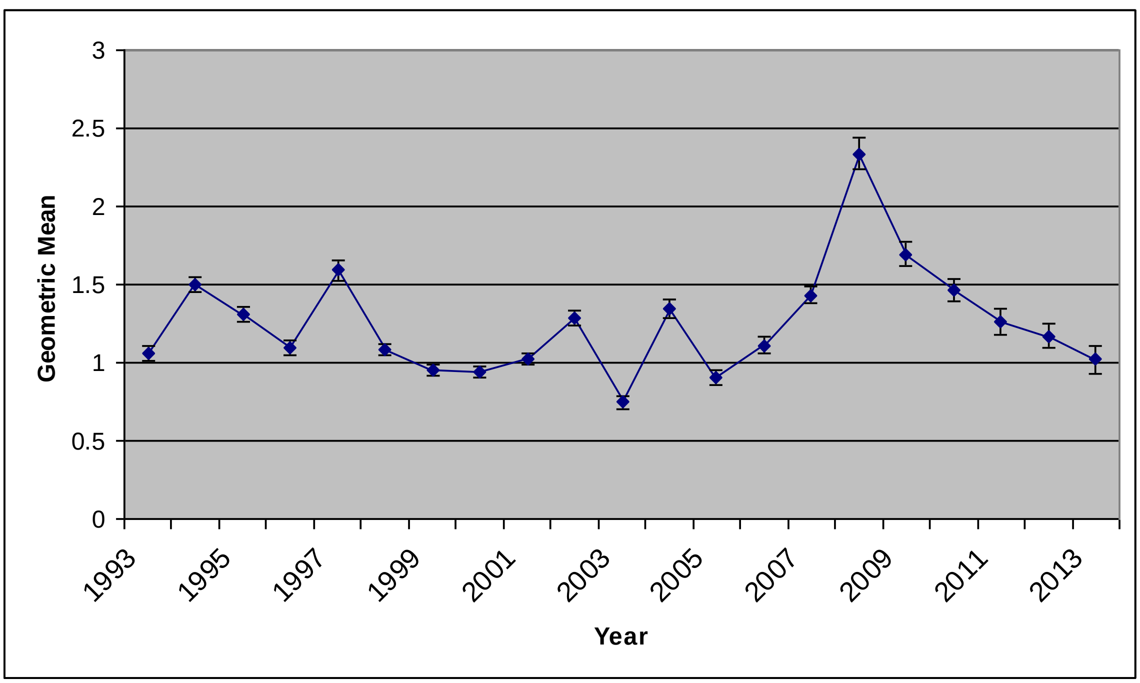

Figure 20. Atlantic croaker length frequency distributions from onboard pound net sampling, 2005-2014.

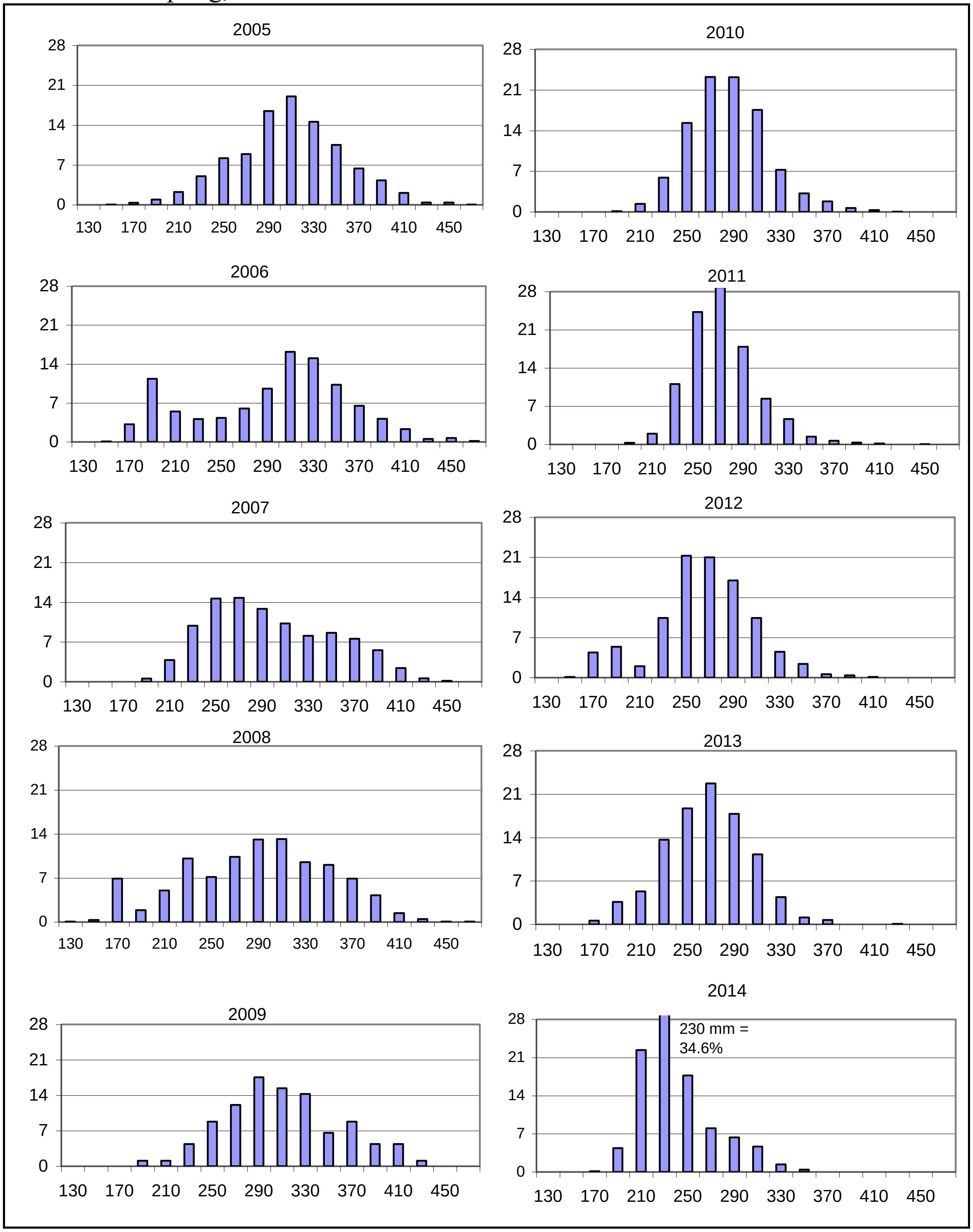

Figure 21. Maryland commercial Atlantic croaker harvest by area, 1929-2013.

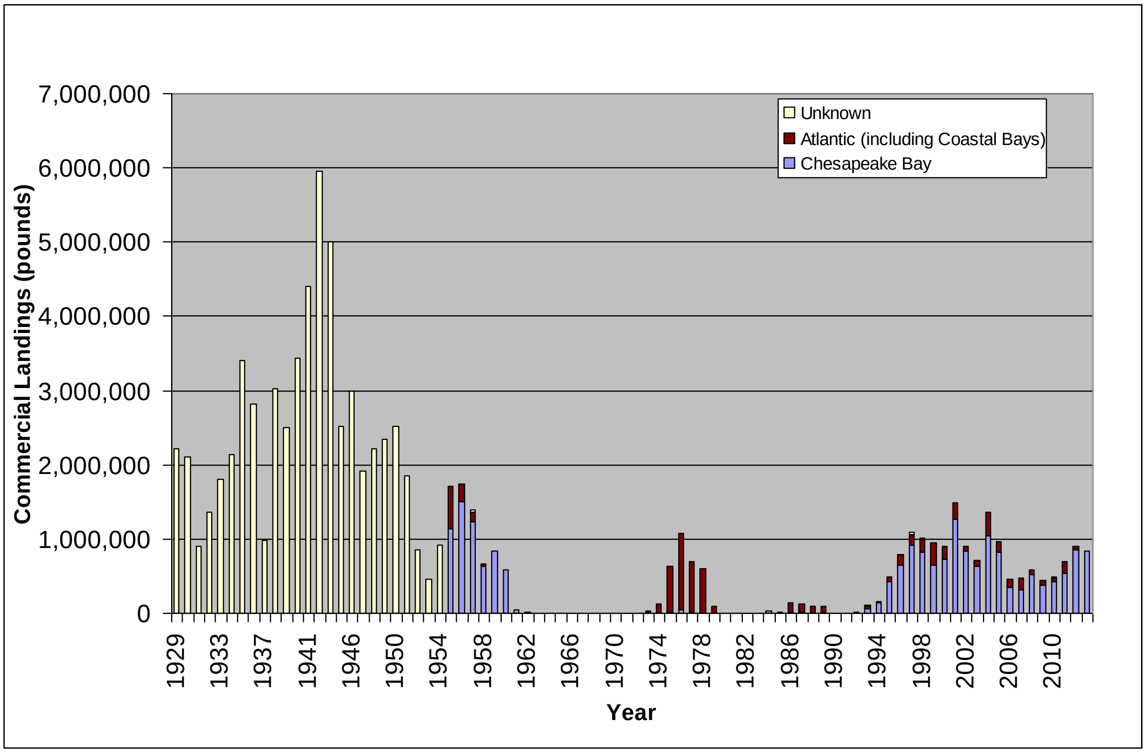

Figure 22. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2013 (Source: MRIP, 2015).

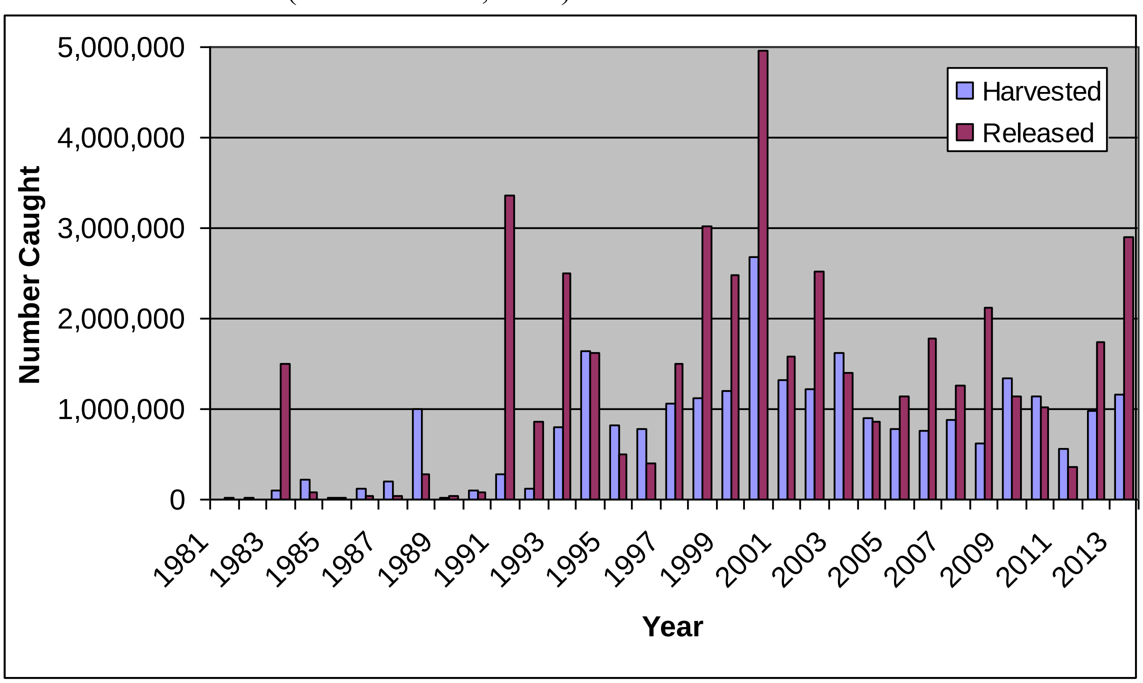

Figure 23. Atlantic croaker statewide MRIP harvest, MRIP for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2013.

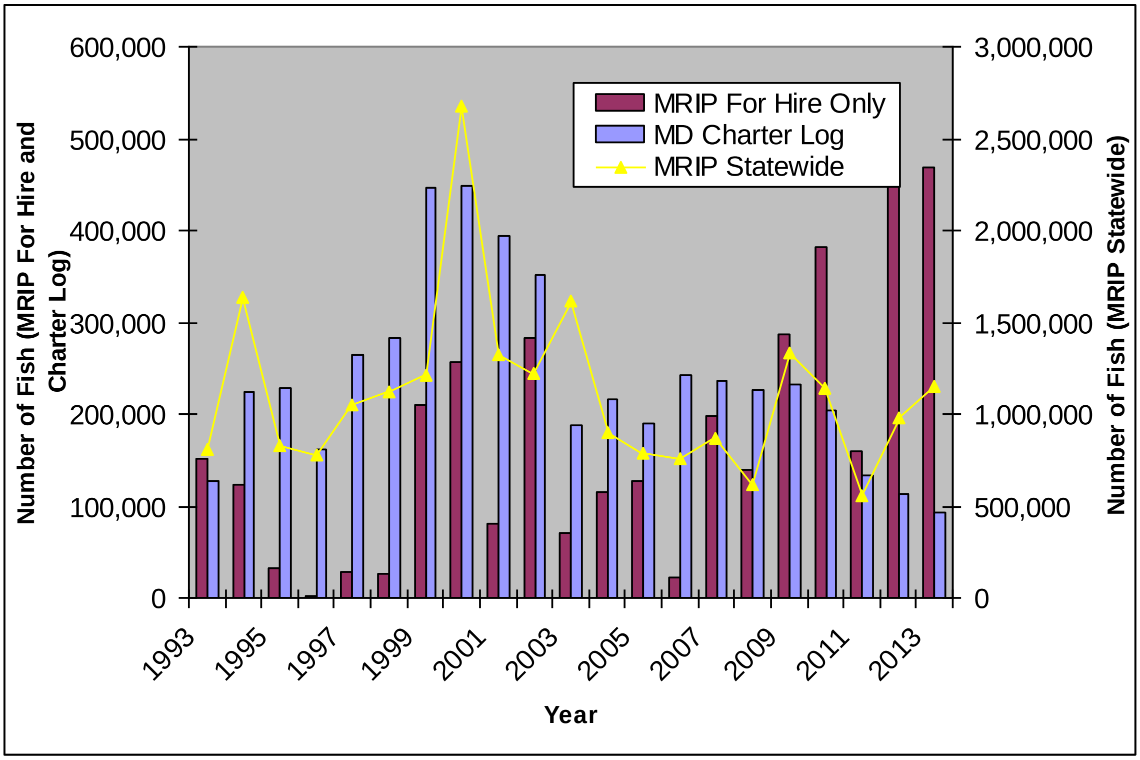

Figure 24. Atlantic croaker geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

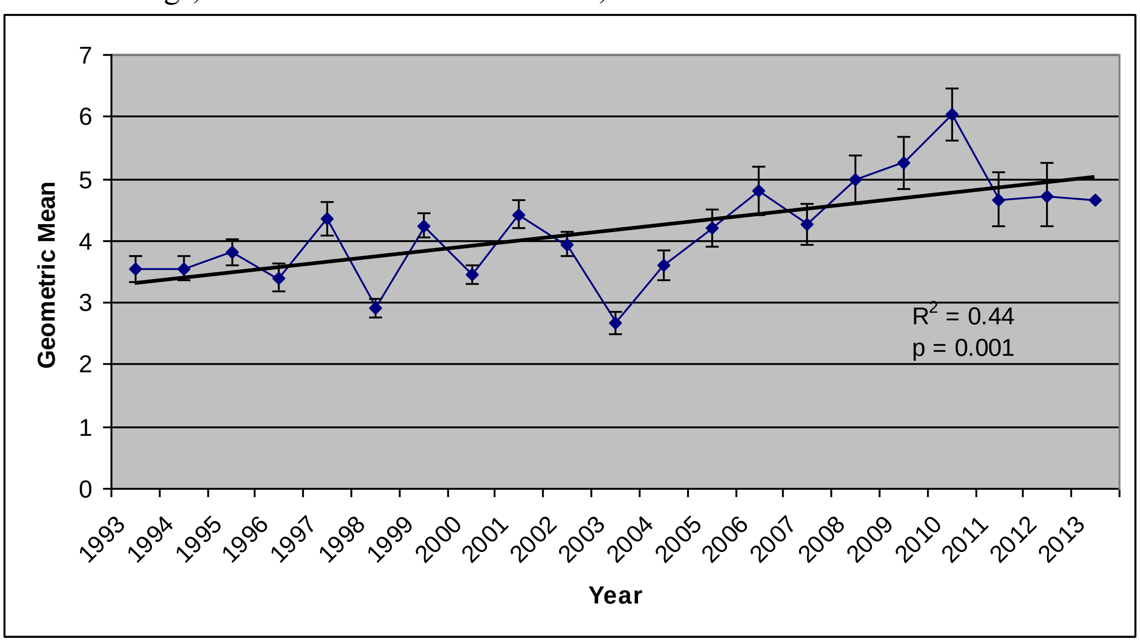

Figure 25. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2014. 1998 data point was omitted for scale (GM 1998 = 30.05 -9.02, +12.72).

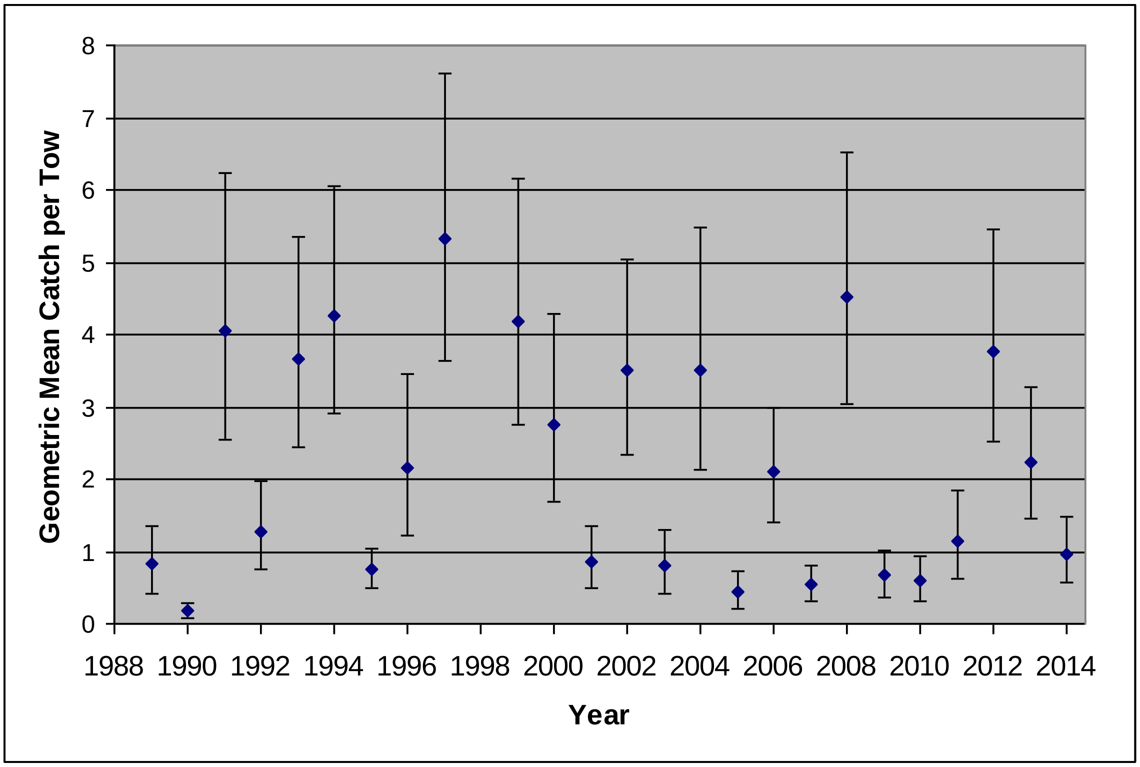

Figure 26. Spot length frequency distributions from onboard pound net sampling, 2005-2014.

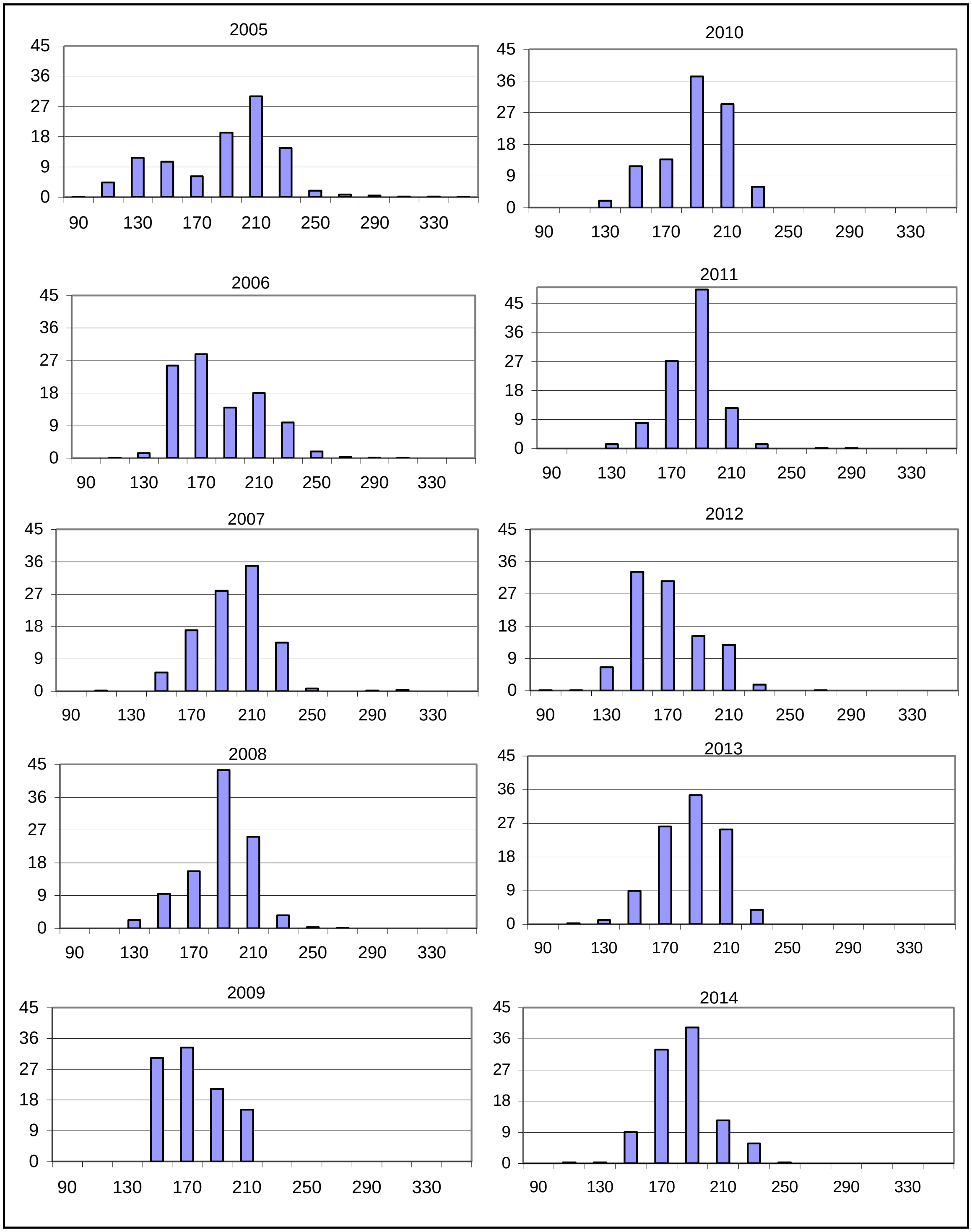

Figure 27. Maryland commercial spot harvest by area, 1929-2013.

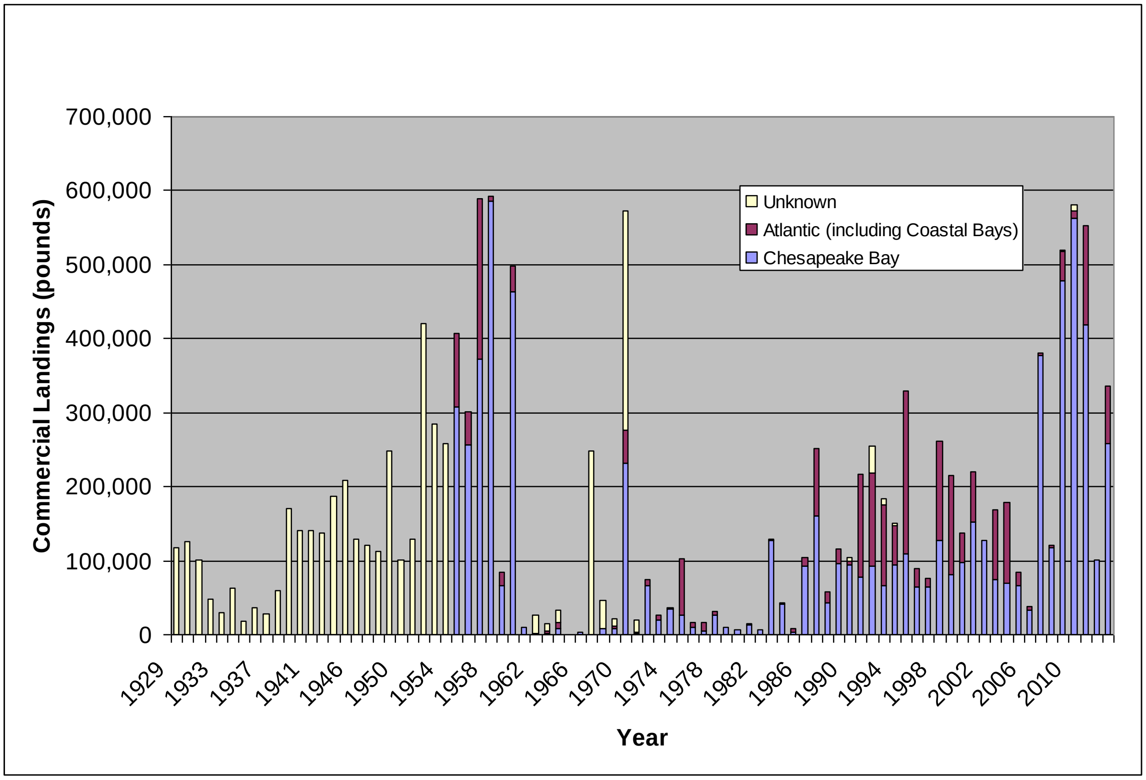

Figure 28. Estimated Maryland recreational spot harvest and releases for 1981-2013 (Source: MRIP, 2015).

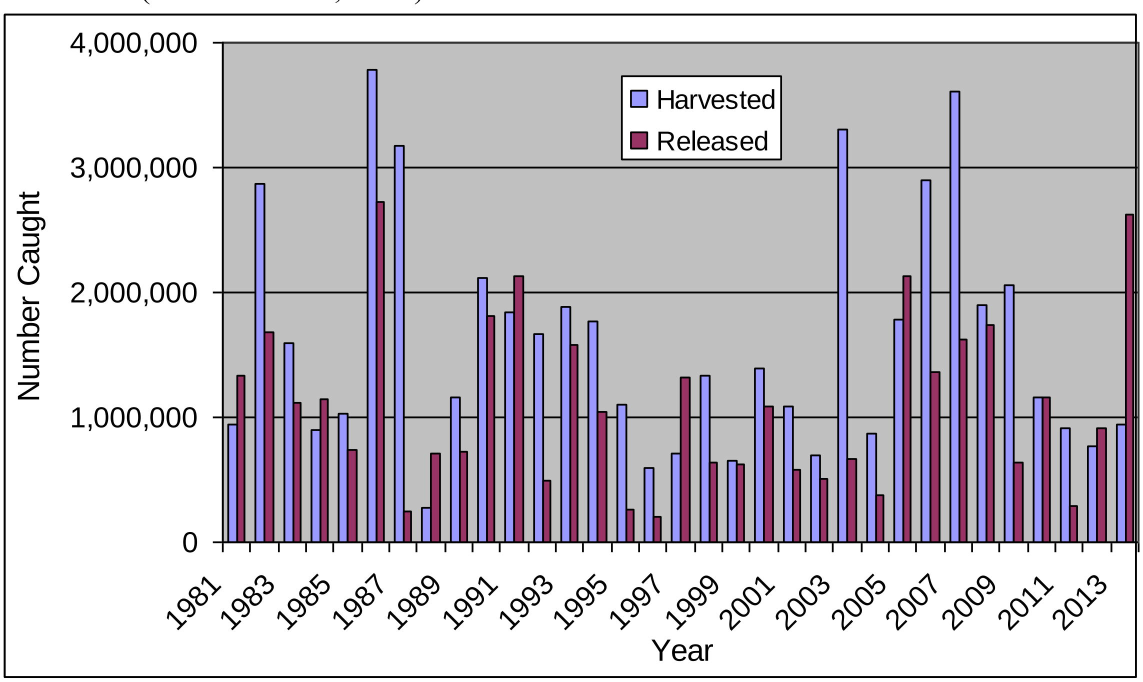

Figure 29. Spot statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2013.

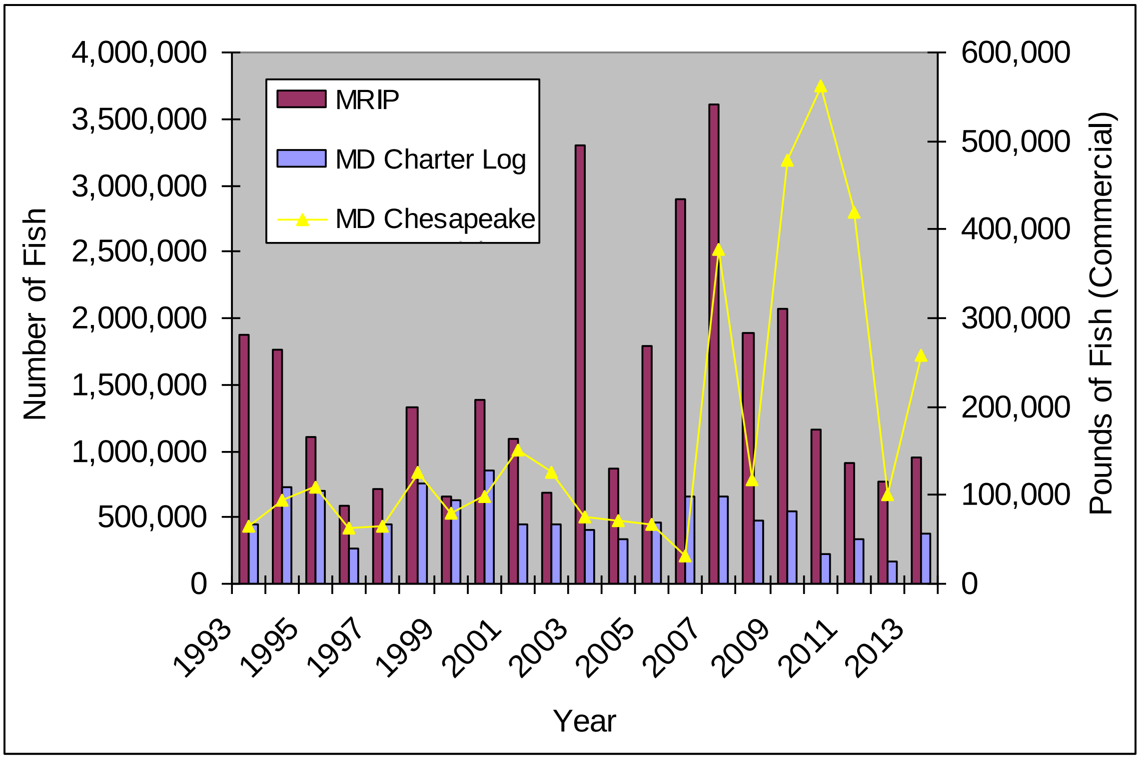

Figure 30. Spot geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

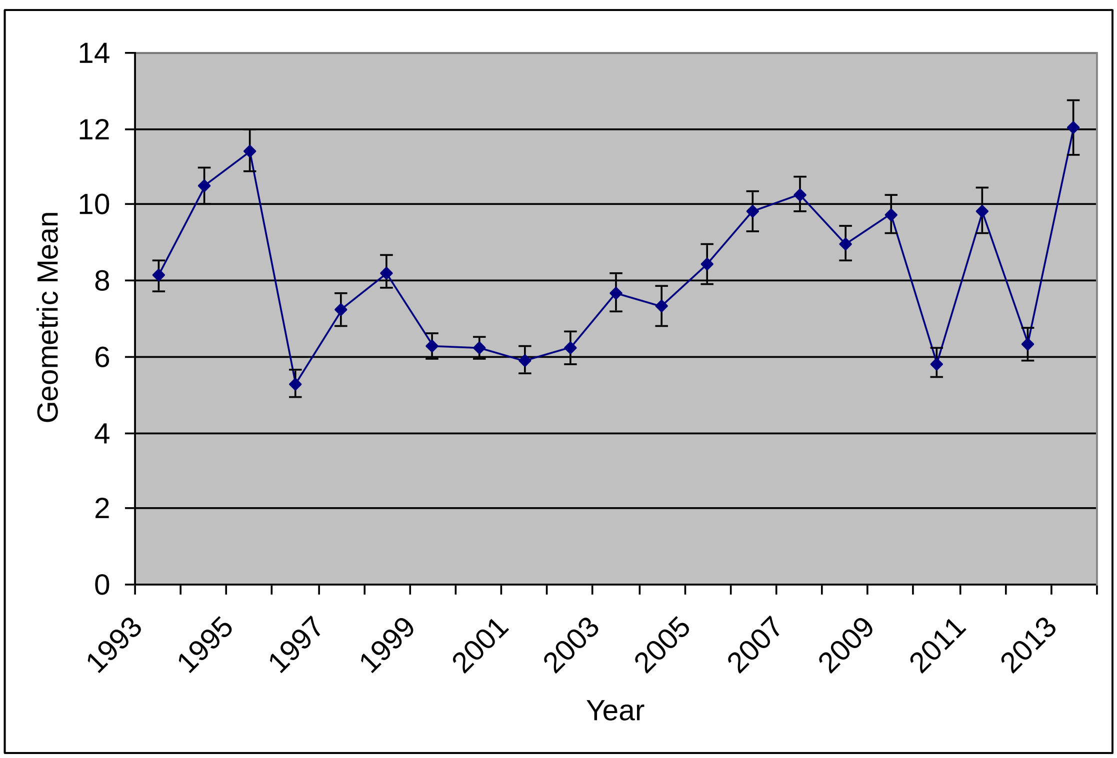

Figure 31. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2014.

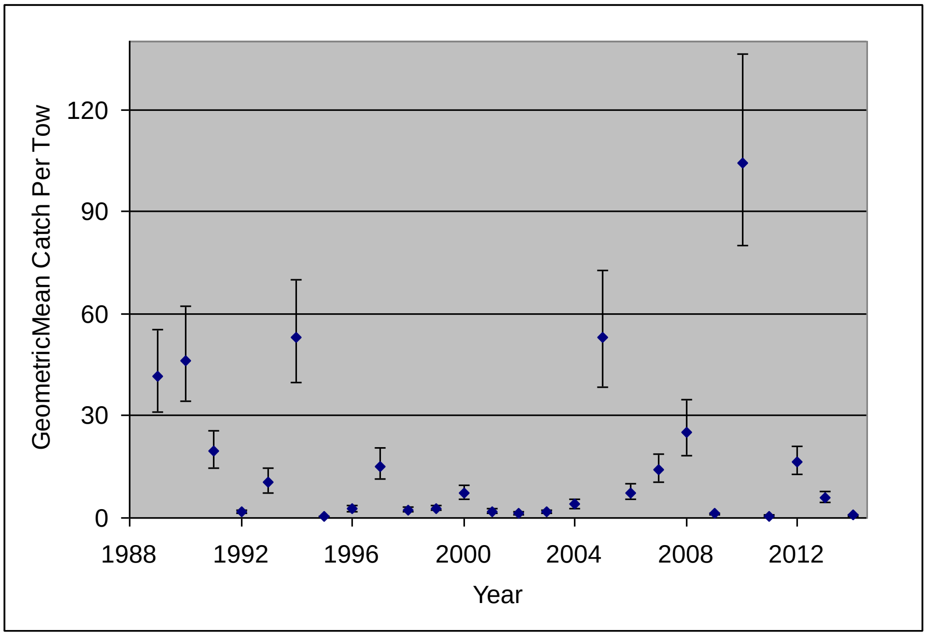

Figure 32. Maryland commercial red drum harvest by area, 1958-2013.

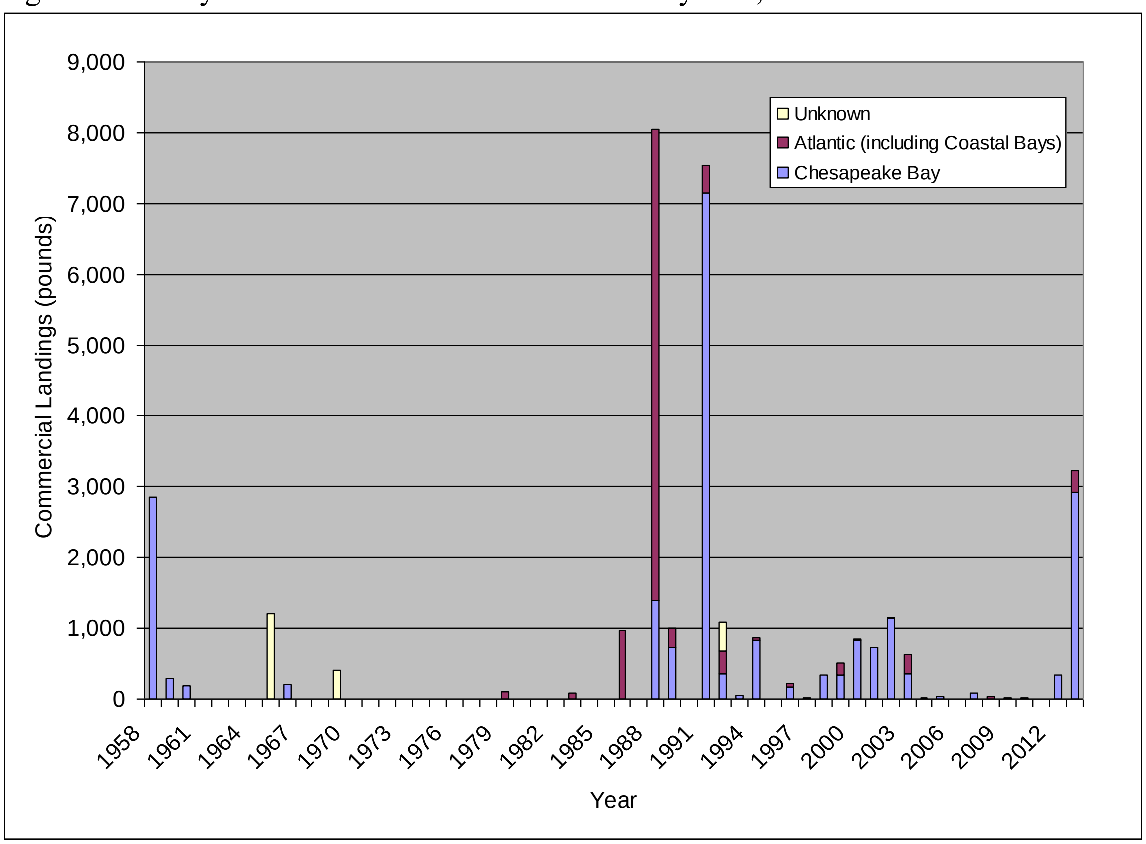

Figure 33. Estimated Maryland recreational red drum harvest for 1981-2013 (Source: MRIP, 2015).

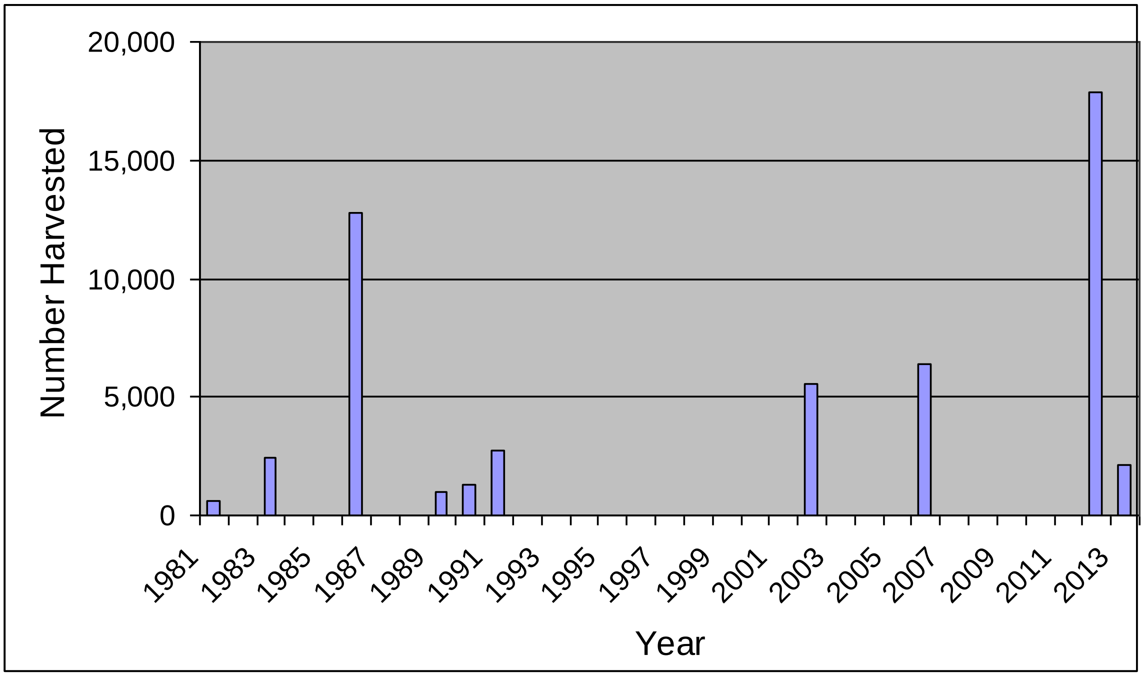

Figure 34. Estimated Maryland recreational red drum released for 1981-2013 (Source: MRIP, 2015). 2012 vale of 280,171 was truncated to preserve scale.

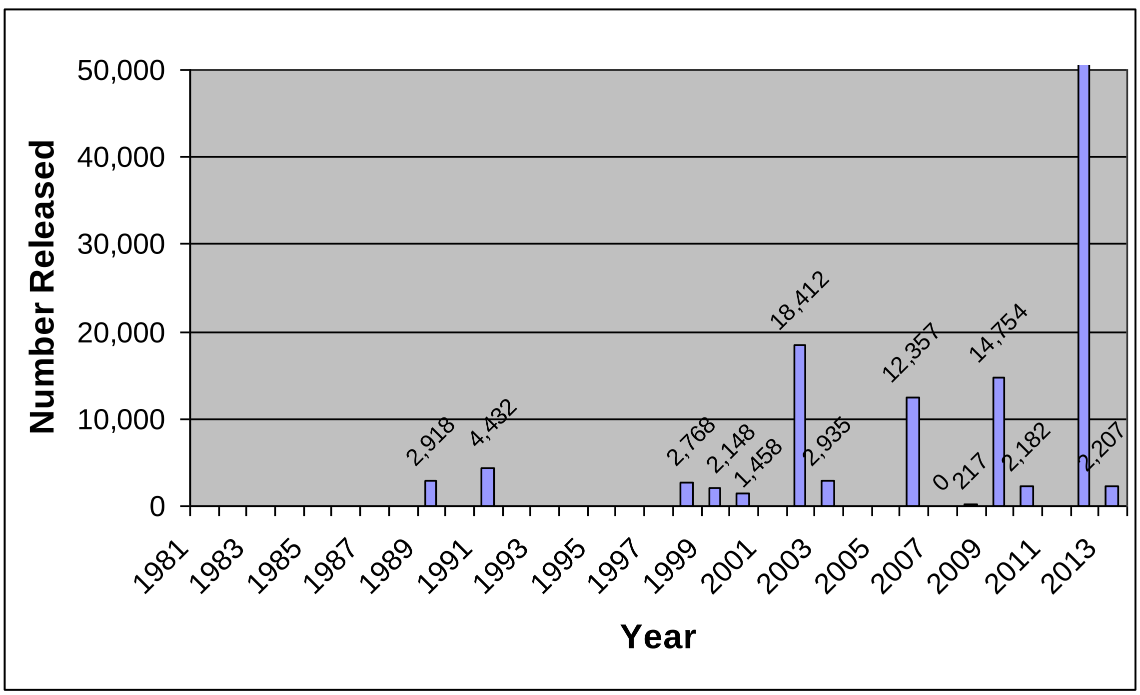

Figure 35. Number of red drum harvested and the number of anglers catching red drum from the Maryland Charter boat logs, 1993-2013.

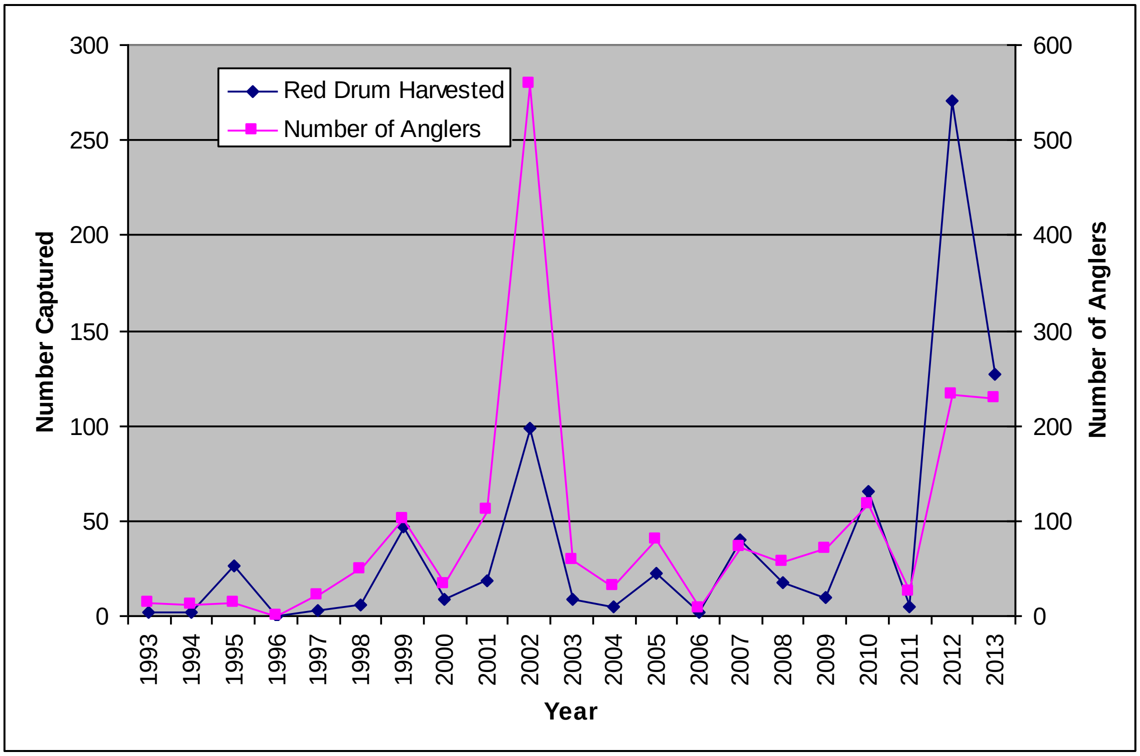

Figure 36. Maryland commercial black drum harvest by area, 1929-2013.

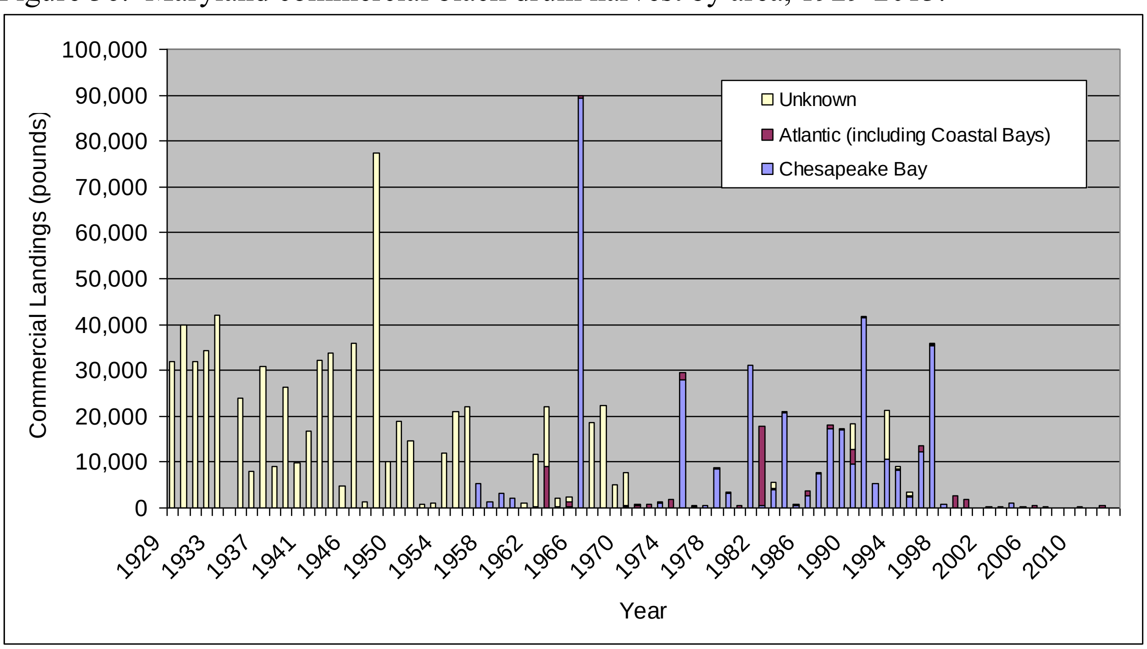

Figure 37. Estimated Maryland recreational black drum harvest and releases for 1981-2013 (Source: MRIP, 2015).

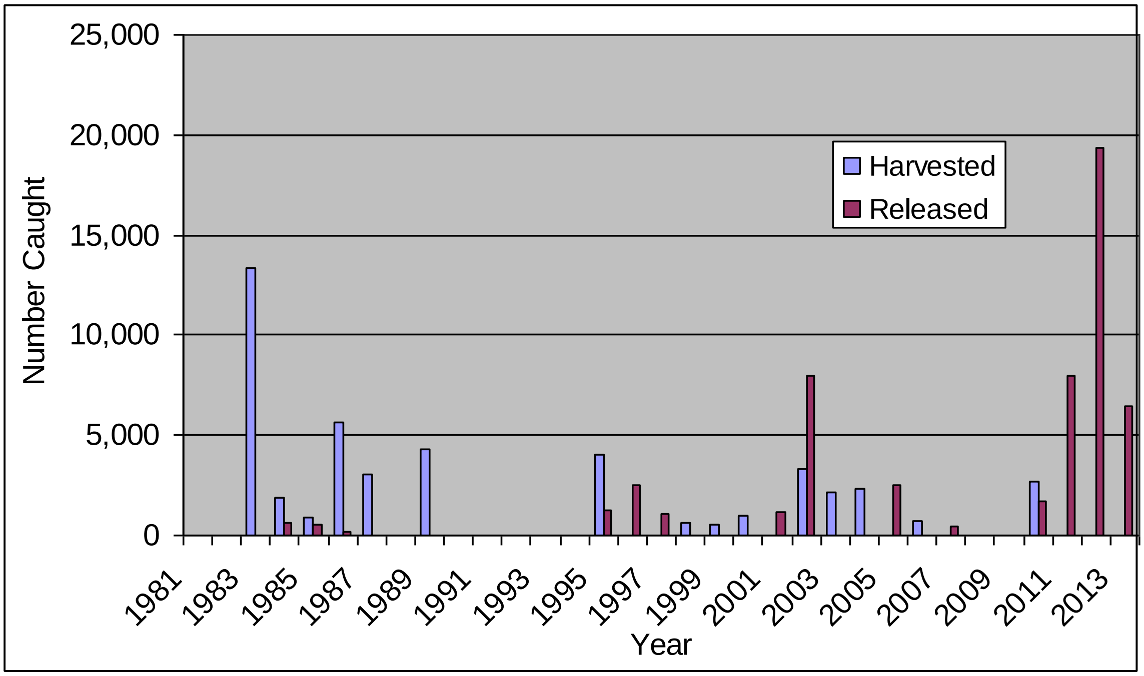

Figure 38. Reported Maryland charter boat harvest for black drum in numbers, 1993-2013.

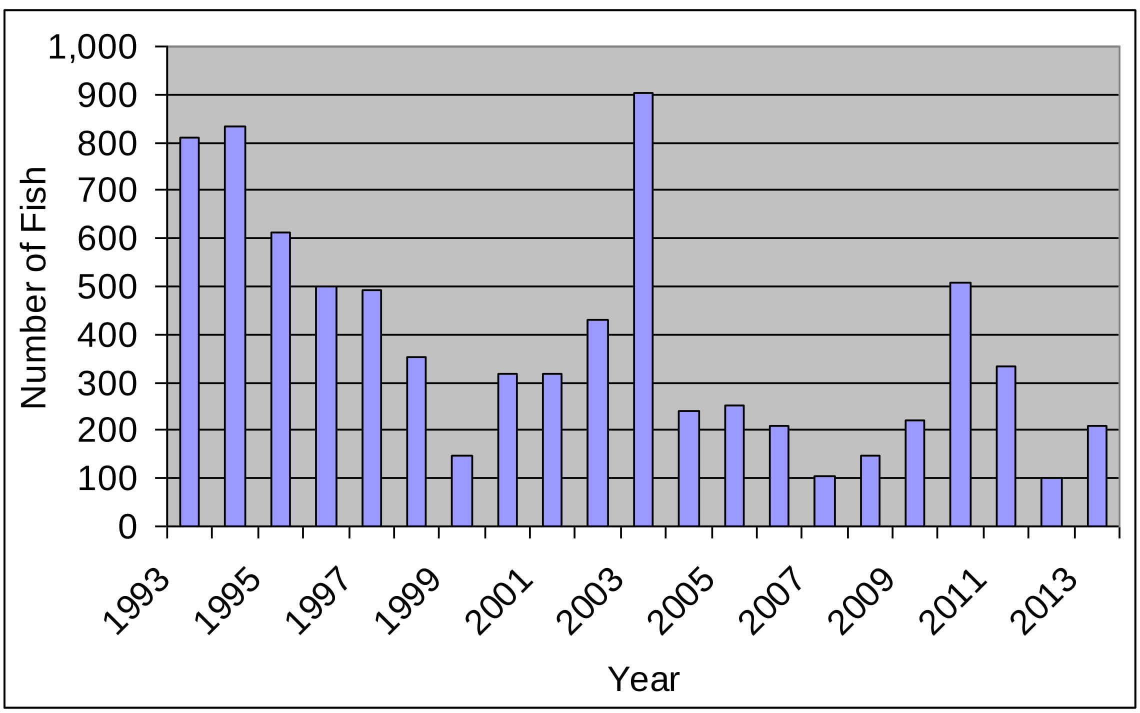

Figure 39. Black drum geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

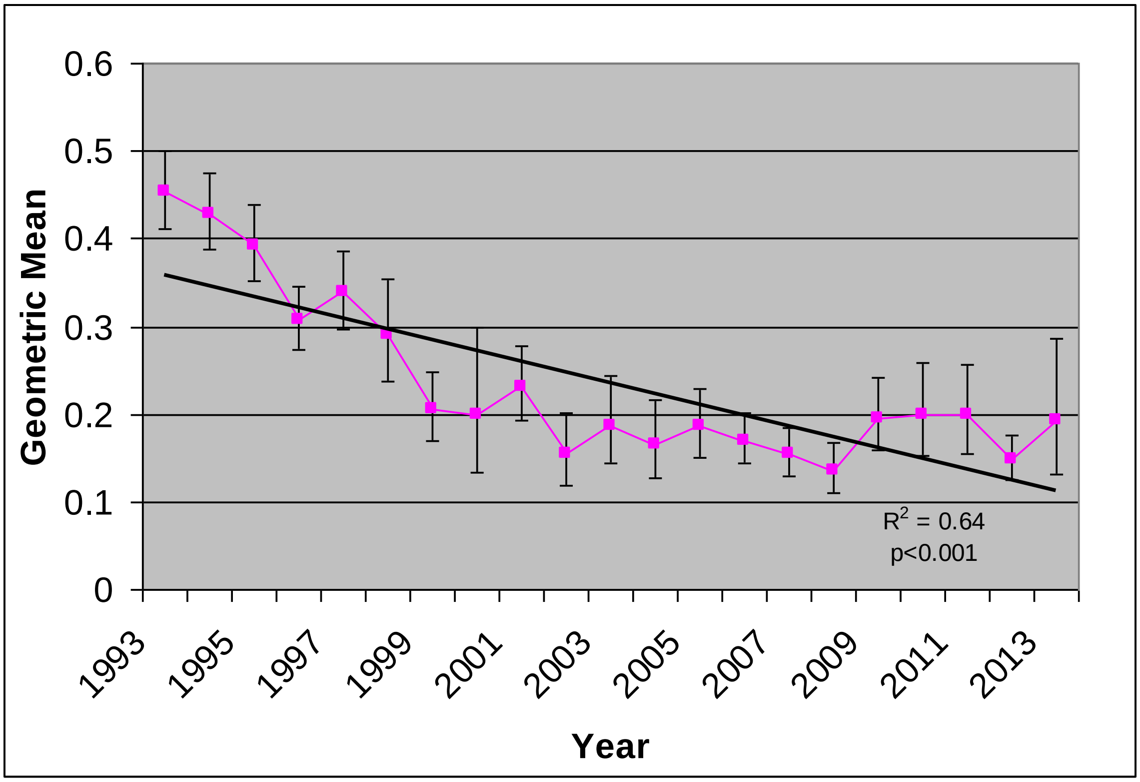

Figure 40. Maryland commercial Spanish mackerel harvest by area, 1965-2013.

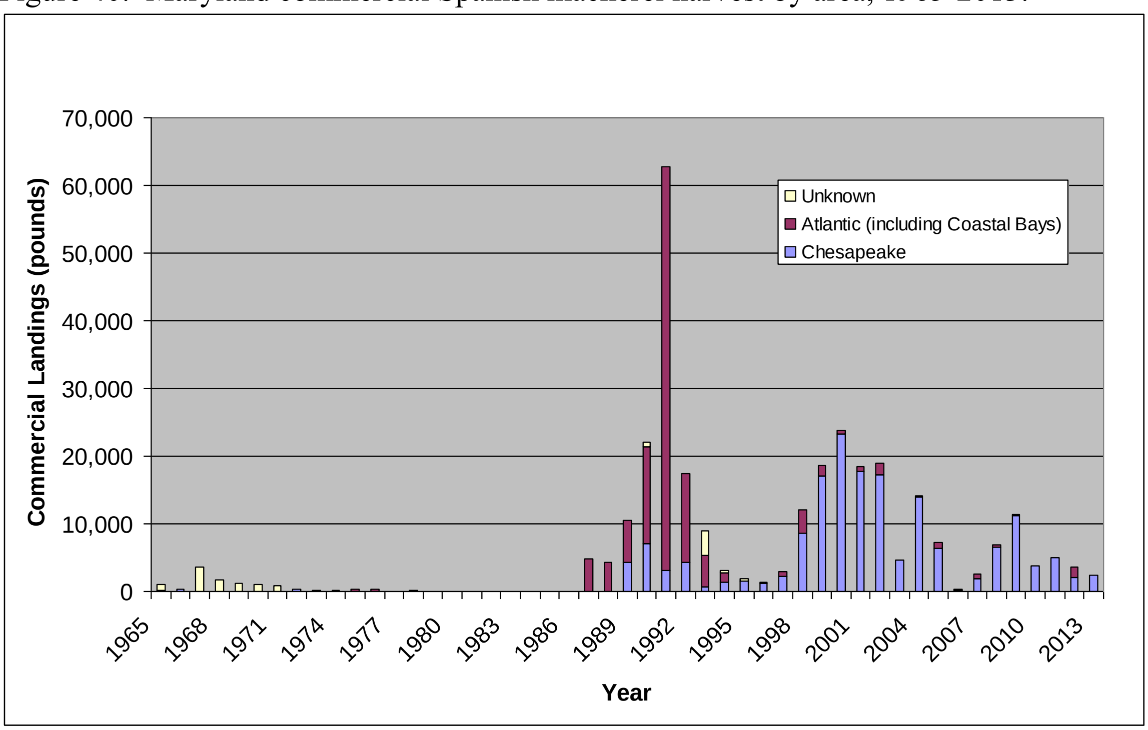

Figure 41. Estimated Maryland recreational Spanish mackerel harvest and releases for 1981-2013 (Source: MRIP, 2015).

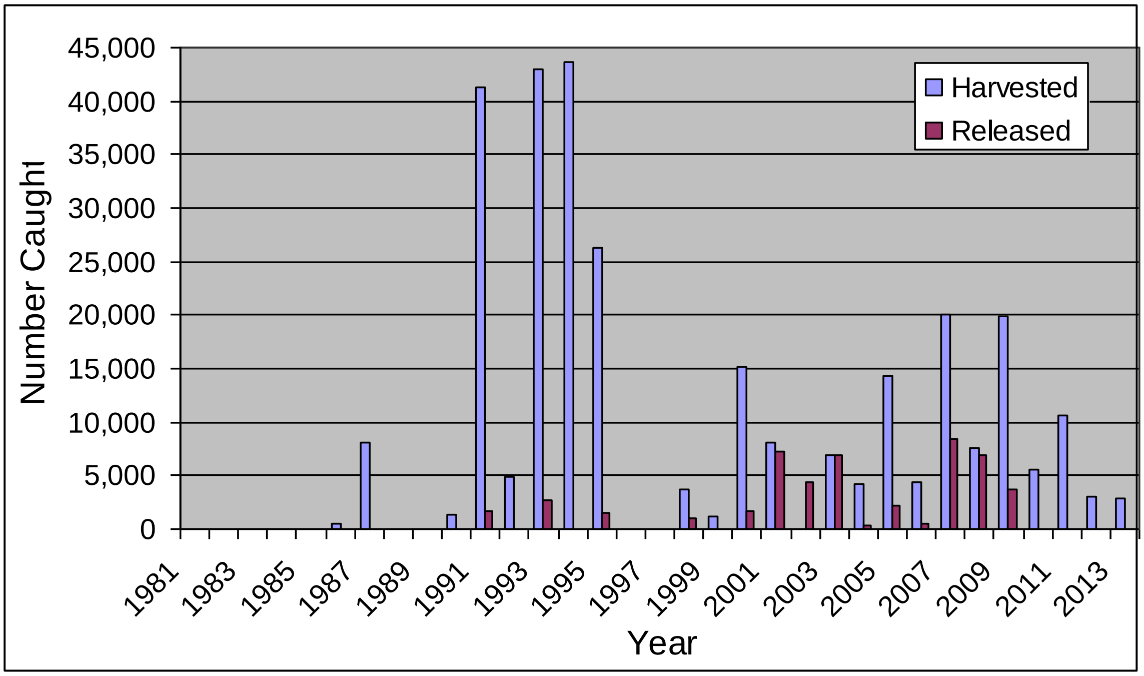

Figure 42. Spanish mackerel statewide MRIP harvest, MRIP for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2013.

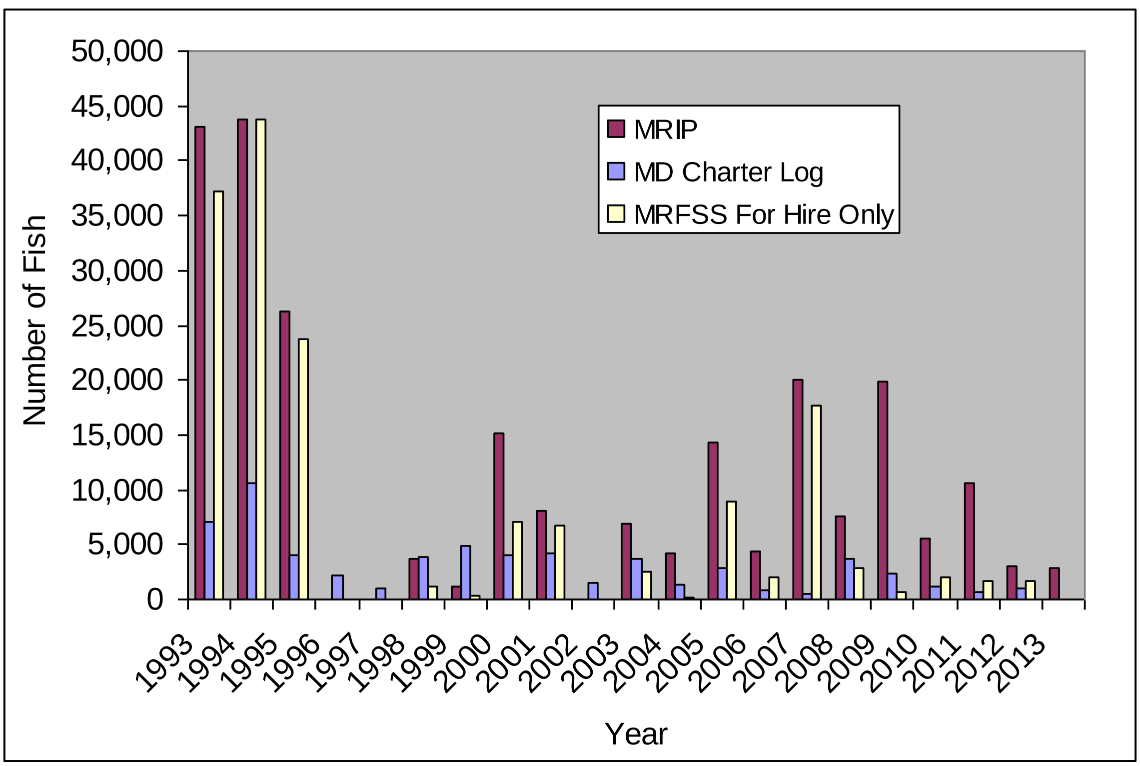

Figure 43. Spanish mackerel geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

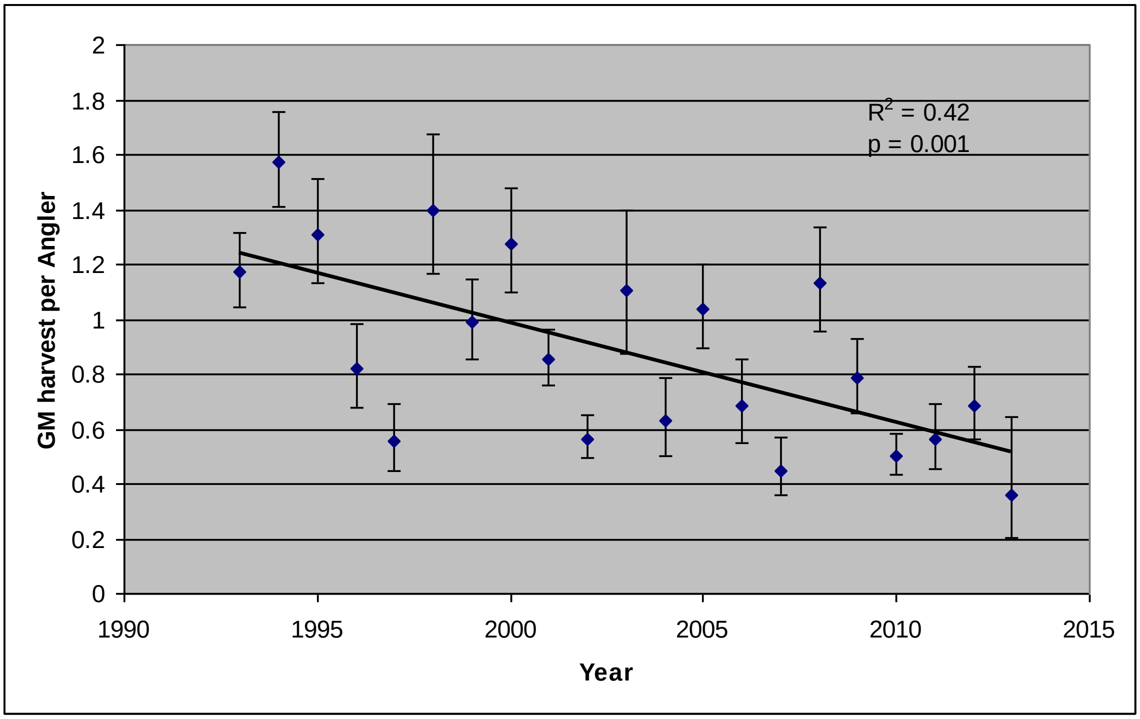

Figure 44. Maryland commercial spotted seatrout harvest by area, 1944-2013.

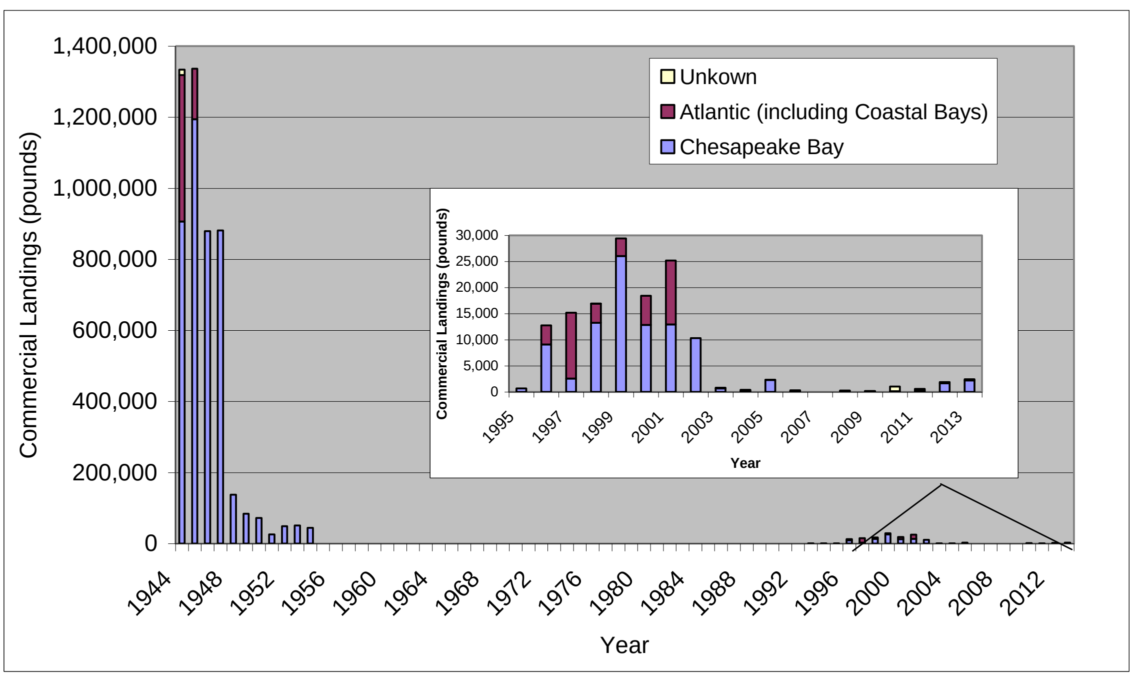

Figure 45. Estimated Maryland recreational spotted seatrout harvest and releases for 1981-2013 (Source: MRIP, 2015).

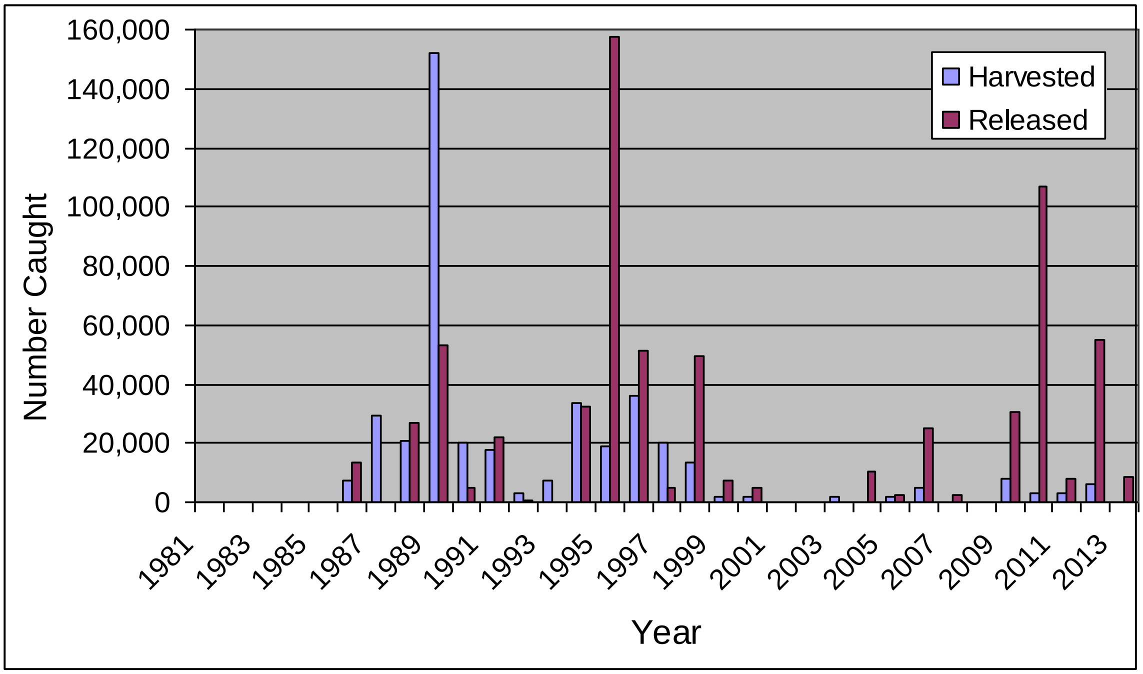

Figure 46. Reported Maryland charter boat harvest for spotted seatrout in numbers, 1993-2013.

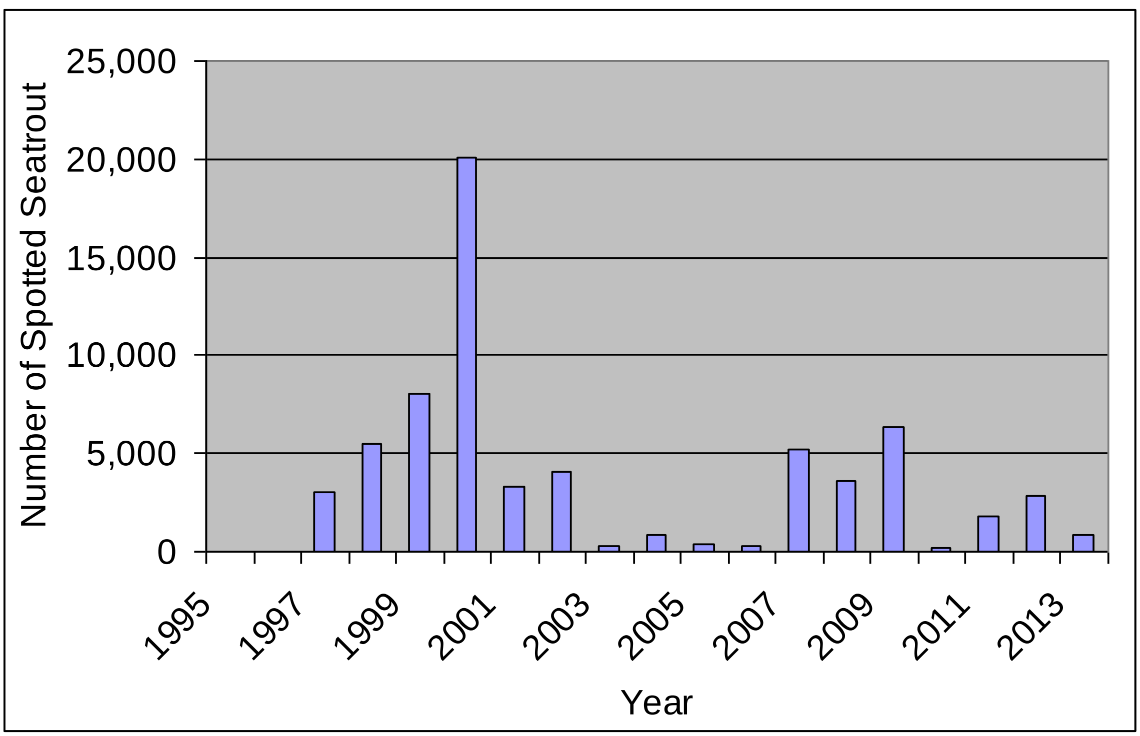

Figure 47. Spotted seatrout geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2013.

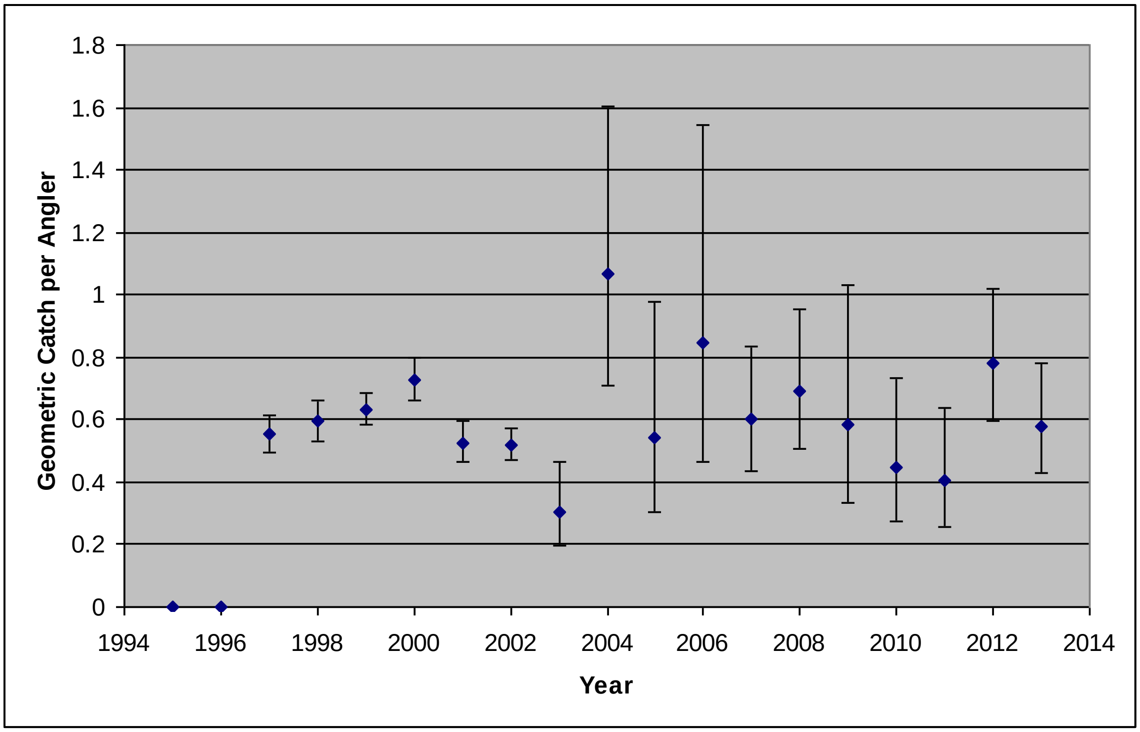

Figure 48. Menhaden length frequency distributions from onboard pound net sampling, 2005-2014.

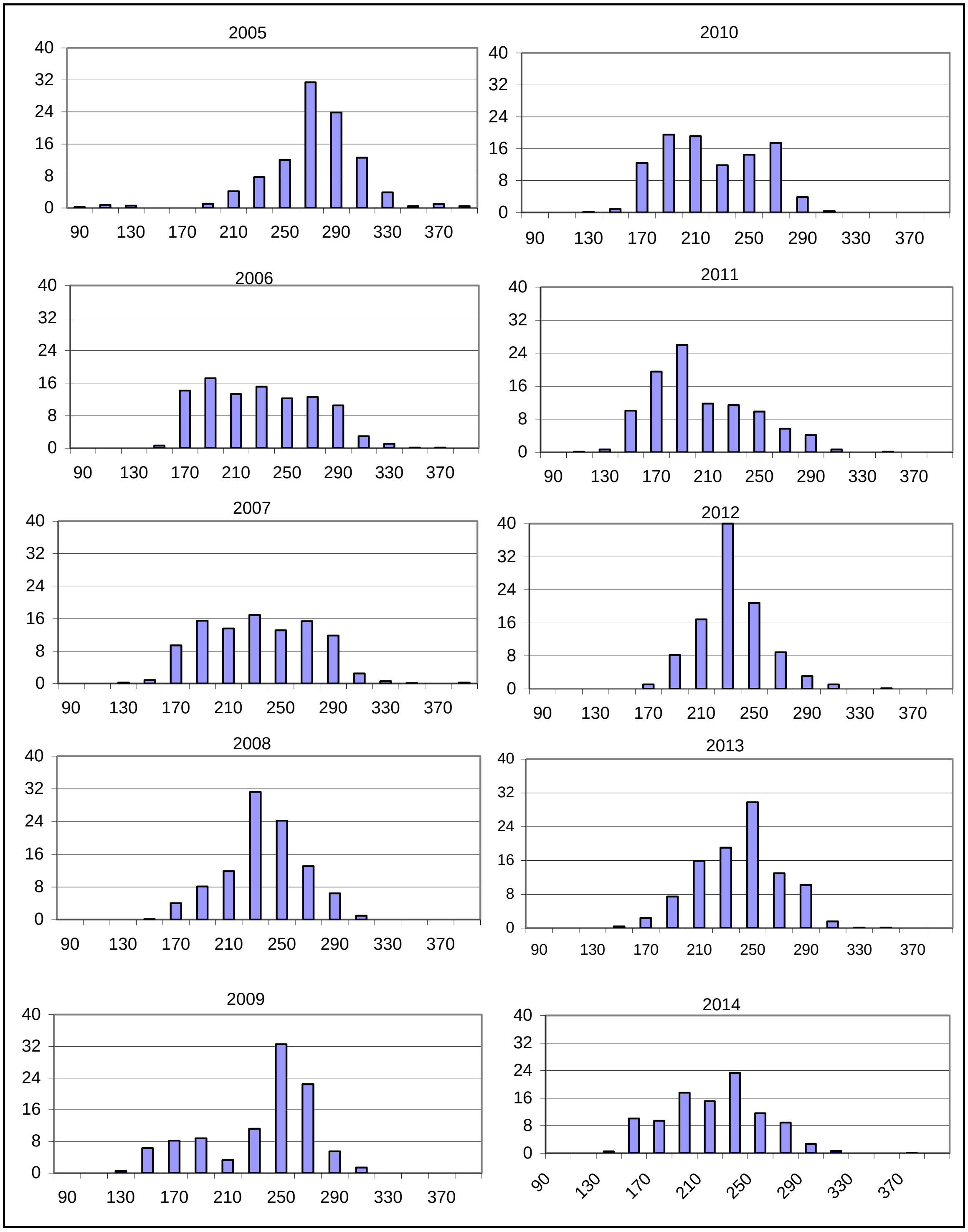

Figure 49. Maryland commercial Atlantic menhaden harvest by area, 1935-2013.

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

SUMMER – FALL STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

Prepared by Jeffrey Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1A was to characterize the size and age structures of the 2013 Maryland striped bass (Morone saxatilis) commercial pound net and hook-and-line harvest. The 2013 pound net season ran from 1 June through 30 November while the commercial hook-and-line fishery was open from 10 June through 26 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 2013 commercial fisheries seasons were used to characterize the length and age structure of the entire 2013 Chesapeake Bay commercial harvest and the majority of the recreational harvest (Fegley 2001).

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 monthly from June through November 2013 (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 2013, 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. Full net sampling was not possible when pound nets contained too many fish to be transferred to FS boats. If a full net could not be sampled, a random sub-sample was taken.

At each net sampled, all 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 pound net/hook-and-line fisheries monitoring (check station)

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 pound net and hook-and-line harvested fish each month from June through November 2013 (Figure 1). For the pound net fishery, sample targets were established of 100 fish per month from June through August and 200 fish per month for September through November. This monthly allocation reflects consistent historic patterns of harvest levels, which normally increase in the fall to twice summer levels. For the hook-and-line fishery, a sample target of 400 fish per month was established over the six-month season, since historical landings exhibited no clear monthly pattern. Target sample sizes for both fisheries were based on sample sizes 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 from striped bass less than 650 mm TL and from all striped bass greater than 650 mm TL from pound net and hook-and-line harvested fish. Scales taken from the pound net monitoring survey were combined with check station scales for ageing.

Analytical Procedures

Scale ages from the pound net and check station surveys were 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 indicated no age*gear interaction (P>F=0.8532). Striped bass harvested by each gear exhibited 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 pound net and hook-and-line 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. 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 each fishery was calculated by applying the ALK to the hook-and-line and pound net length frequencies, and expanding the resulting age distribution to the landings. Landings are derived from mandatory reports submitted by commercial fisherman to MD DNR (see Project 2, Job 3, Task 5a).

In order to examine recruitment into the pound net and hook-and-line fisheries, the age structure of the harvest over time was examined. The age structure of the harvest for the 2013 hook-and-line and pound net fisheries 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 fisheries and months in 2013.

Mean lengths- and weights-at-age of striped bass landed in the commercial pound net and hook-and-line fisheries 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

Pound net monitoring

During the 2013 striped bass pound net study, a total of 4,062 striped bass were sampled from five pound nets in the upper Bay and one pound net in the lower Bay (Table 1). The six nets were sampled a total of 16 times during the study.

Striped bass sampled from pound nets ranged from 229-906 mm TL, with a mean length of 416 mm TL (Figure 2). In 2013, 86% of striped bass collected from full net samples were less than the minimum legal size of 18 inches (457 mm) TL, while 62% 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 2 to 10 years of age (Table 3, Figure 2). Typically, age 1 fish are observed in the sample, however, due to the weak year class in 2012, none were present in 2013 sampling. Age 2 fish from the above-average 2011 year-class contributed 45% of the sample. Age 3 fish contributed 27% in 2013, which was the same as the contribution in 2012 (27%). Striped bass age 6 and over accounted for 7% of the sample, less than their contribution in 2012 (10%) and 2011 (30%; Figure 3). Fish age 8 and older composed 1% of the sample in 2013, which was similar to 2012 (1%) and lower than 2011 (4%). Length frequencies of legal sized striped bass (n=1,326) sampled at pound nets were almost identical to length distributions from the check stations (Figure 4).

Hook-and-line check station sampling

A total of 1,957 striped bass were sampled at hook-and-line check stations in 2013. The mean length of sampled striped bass was 541 mm TL. Striped bass sampled from the hook-and-line fishery ranged from 441 to 889 mm TL and from 3 to 11 years of age (Figure 5). Approximately 1% of the sampled harvest was sub-legal (<457 mm TL).

The length frequency and ages of the sampled fish were applied to the total harvest. Striped bass in the 470-550 mm length groups accounted for 67% of the hook-and-line harvest, similar to 2012 (69%; Figure 5). As in past years, few large fish were available to the hook-and-line fishery. Striped bass over 700 mm TL were harvested throughout the season (Figure 6), but contributed only 3% to the overall harvest. Historically, these fish have not been available in large numbers during the summer (MDDNR 2002). Mean lengths-at-age and weights-at-age for the 2013 combined hook-and-line and pound net fisheries are shown in Tables 4 and 5.

The 2013 hook-and-line harvest accounted for 23%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2013 with 382,783 pounds landed (see Project 2, Job 3, Task 5A). The estimated 2013 catch-at-age of the hook-and-line fishery is presented in Table 6. The majority of the harvest was composed of three to six year-old striped bass (93%). Striped bass from the 2009 (age 4) year-class contributed the highest percentage at 40%. Fish from the strong 2003 year-class (age 10) accounted for less than 1% of the total, similar to 2012 (<1%). Striped bass age 8 and older contributed 2% to the overall harvest in 2013, similar to 2012 (2%).

Pound net check station sampling

A total of 514 striped bass were sampled at pound net check stations in 2013. Striped bass sampled ranged from 448 to 914 mm TL (Figure 5). Striped bass sampled from the pound net fishery ranged from 3 to 11 years of age, same as the hook-and-line fishery. Sub-legal striped bass (< 457 mm TL) made up 1.2% of the sample. Striped bass in the 450-550 mm TL length groups accounted for 62% of the 2013 pound net harvest, which is similar to 2012 (63%; Figure 5). The contribution of striped bass in the 570-630 mm TL length groups in 2013 (26%) was similar to 2012 (28%). Fish >630 mm TL composed 12% of the sample, similar to 2012 (9%). Some large fish were available to the 2013 pound net fishery in certain months, but fewer than previous years. Mean lengths-at-age and weights-at-age from the combined 2013 hook-and-line and pound net fisheries are shown in Tables 4 and 5, respectively.

The pound net fishery accounted for 32%, by weight, of the Maryland Chesapeake Bay 2013 commercial harvest with 531,599 pounds landed (see Proj. 2, Job 3, Task 5A). The estimated 2013 catch-at-age for the pound net fishery is presented in Table 6. Fish age three to six contributed 90% of the 2013 total pound net harvest. Two year old striped bass (2011 year class), which are harvested rarely in this fishery, did not contribute any fish to the harvest (Figure 7). The contribution of the 2003 year-class was similar in the pound net harvest in 2013 and 2012, contributing 1% to the total harvest (Figure 7). Striped bass age 8 and over composed 5% of the 2013 harvest, more than the contribution in 2012 (3%).

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 62% and 69% of the 2013 pound net and hook-and-line fisheries, respectively. A similar number of large fish (>630 mm) were harvested in 2013 compared to 2012 (9% for hook-and-line and 12% for pound net; Figure 5). In 2013, 119 fish from pound net monitoring and 97 fish from check station sampling were aged. Younger fish (age 3 to 7) were abundant, accounting for the majority of the harvest (Figure 7). Length frequencies of legal-sized fish sampled from pound nets and all fish from check stations were almost identical (Figure 4).

The mean lengths of 4, 5, and 6 year-old legal-sized striped bass (≥457 mm TL) decreased during the period 1990 to 2000 (Figure 8). Since 2001, there was no apparent trend for mean lengths of striped bass aged 4 to 6.

A Duncan's multiple range test (SAS 2006) performed on lengths and weights of striped bass harvest between fisheries and months indicated that fish were significantly ($P<0.05$) longer and heavier from the pound net fishery than the hook-and-line fishery. During the hook-and-line fishery, the longest and heaviest fish were sampled in October and the smallest in July and September. Striped bass sampled in October were significantly longer than all other months. August and November fish were significantly longer than June, July and September. Striped bass sampled in October were significantly heavier than fish harvested in any other month. Striped bass harvested in June and August were similar in weight. Weights in July, September, and November were significantly different than all other months.

In the pound net check station monitoring, the longest and heaviest fish were harvested in November. All other months were not significantly different in length or weight.

CITATIONS

Barker, L.S., B. Versak, and L. Warner. 2004. Scale allocation procedure for Chesapeake Bay striped bass spring spawning stock assessment. Fisheries Technical Memorandum No. 31. Maryland Department of Natural Resources. 11pp.

Betolli, P.W., L.E Miranda . 2001. Cautionary note about estimating mean length-at-age with sub-sampled data. North American Journal of Fisheries Management 21:425-428.

Fegley, L.W. 2001. 2000 Maryland Chesapeake Bay Catch at Age for Striped Bass - Methods of Preparation. Technical Memo to the Atlantic States Marine Fisheries Commission. Maryland Department of Natural Resources. 19pp.

Hornick H.T., B.A. Versak, and R.E. Harris, 2005. Estimate of the 2004 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources, Fisheries Service, Resource Management Division, Maryland. 11 pp.

Kimura, D.A. 1977. Statistical assessment of the age-length key. Journal of the Fisheries Research Board of Canada. 34:317-324.

MD DNR 2002. Summer – fall stock assessment and commercial fishery monitoring. In Maryland Dept. of Natural Resources – Investigation of Striped Bass in Chesapeake Bay, Annual Report, USFWS Federal Aid Project F-42-R-14.

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

SAS. 2006. Statistical Analysis Systems, Inc Enterprise Guide 4.1. Cary, NC.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry – Third Edition. W.H. Freeman & Company. New York.

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Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2013 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	1	23.8	7.6	250
	Middle	-	-	-	-
	Lower	-	-	-	-
July	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	2	26.3	11.8	553
August	Upper	3	25.6	7.4	973
	Middle	-	-	-	-
	Lower	1	25.5	12.5	248
September	Upper	2	20.6	10.8	805
	Middle	-	-	-	-
	Lower	-	-	-	-
October	Upper	3	20.2	6.6	406
	Middle	-	-	-	-
	Lower	2	18.4	14.7	431
November	Upper	1	12.5	12.2	199
	Middle	-	-	-	-
	Lower	1	11.0	16.3	197

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2013.

Year-class	Age	n	Mean length (mm TL)	Lower CL	Upper CL
2011	2	50	319	303	334
2010	3	21	412	387	438
2009	4	8	538	472	604
2008	5	6	592	535	649
2007	6	17	688	645	732
2006	7	6	739	657	820
2005	8	3	737	596	877
2004	9	4	746	650	842
2003	10	4	846	776	916

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, June through November 2013.

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2011	2	1,827	44.98
2010	3	1,086	26.74
2009	4	647	15.94
2008	5	218	5.36
2007	6	190	4.69
2006	7	58	1.42
2005	8	23	0.58
2004	9	6	0.15
2003	10	6	0.14
Total		**4,062**	**100.00**

Table 4. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) sampled from commercial pound net and hook-and-line fisheries in Maryland's Chesapeake Bay, June through November 2013.

Year-class	Age	N	Mean Length (mm TL)	Lower CL	Upper CL
2010	3	4	506	436	576
2009	4	14	503	481	525
2008	5	14	618	582	654
2007	6	25	690	664	717
2006	7	11	727	663	791
2005	8	11	727	687	766
2004	9	8	793	756	830
2003	10	8	814	750	878
2002	11	2	829	664	994

Table 5. Mean weight-at-age (kg) of legal-size striped bass (≥457 mm TL/18 in TL) sampled from commercial pound net and hook-and-line fisheries in Maryland's Chesapeake Bay, June through November 2013.

Year-Class	Age	N	Mean Weight (kg)	Lower CL	Upper CL
2010	3	4	1.3	0.5	2.1
2009	4	14	1.1	1.0	1.3
2008	5	14	2.3	1.8	2.8
2007	6	25	3.3	2.9	3.7
2006	7	11	4.0	3.0	5.0
2005	8	11	4.0	3.4	4.7
2004	9	8	5.1	4.3	5.9
2003	10	8	5.5	4.6	6.5
2002*	11	2	6.1	--	--

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

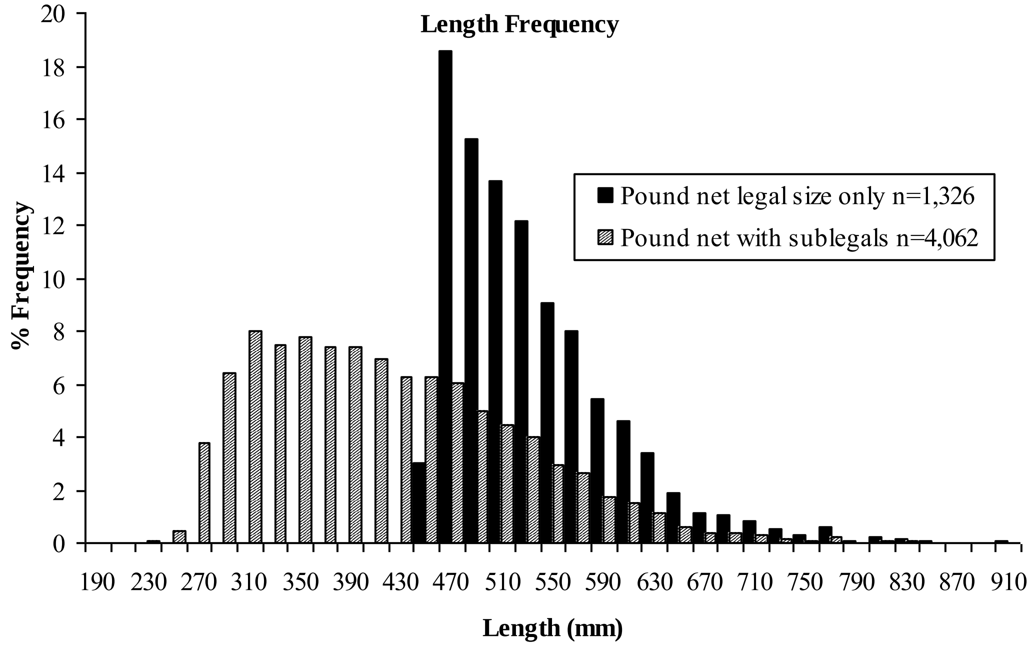
Table 6. Estimated catch-at-age of striped bass landed by Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2013.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Pounds of Fish	Percent of Total	Landings in Pounds of Fish	Percent of Total
2010	3	72,566	19.0	109,779	20.7
2009	4	152,957	40.0	178,489	33.6
2008	5	72,566	19.0	93,267	17.5
2007	6	58,875	15.4	97,498	18.3
2006	7	17,799	4.6	26,663	5.0
2005	8	4,303	1.1	13,998	2.6
2004	9	1,956	0.5	5,840	1.1
2003	10	1,565	0.4	5,031	0.9
2002	11	196	0.1	1,034	0.2
Total*		**382,783**	**100.0**	**531,599**	**100.0**

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

Figure 1. Locations of Chesapeake Bay commercial pound net and hook-and-line check stations sampled from June through November 2013.

Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, June through November 2013.



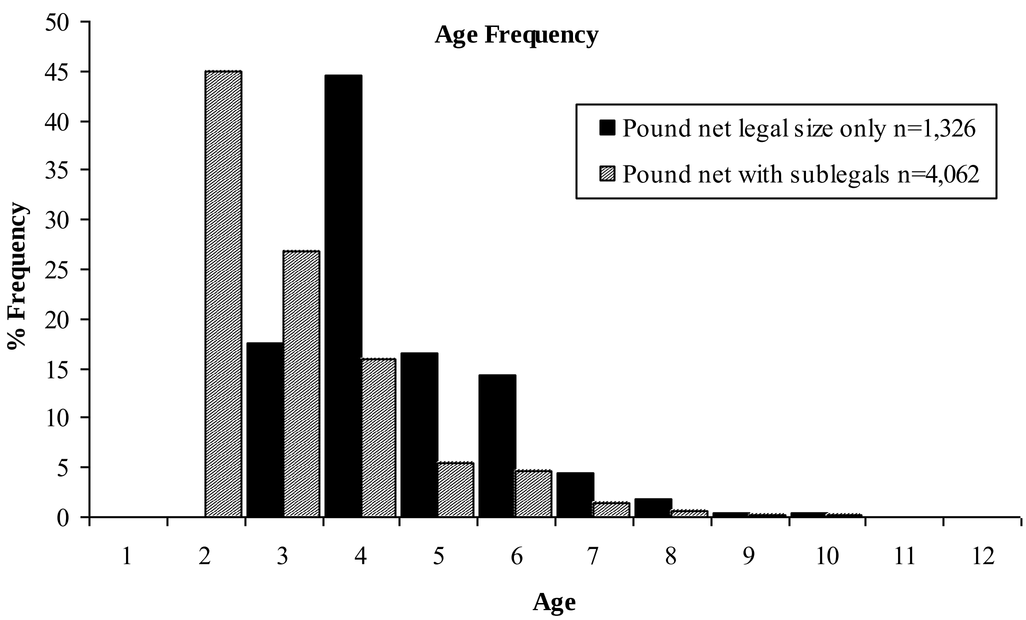


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2013.

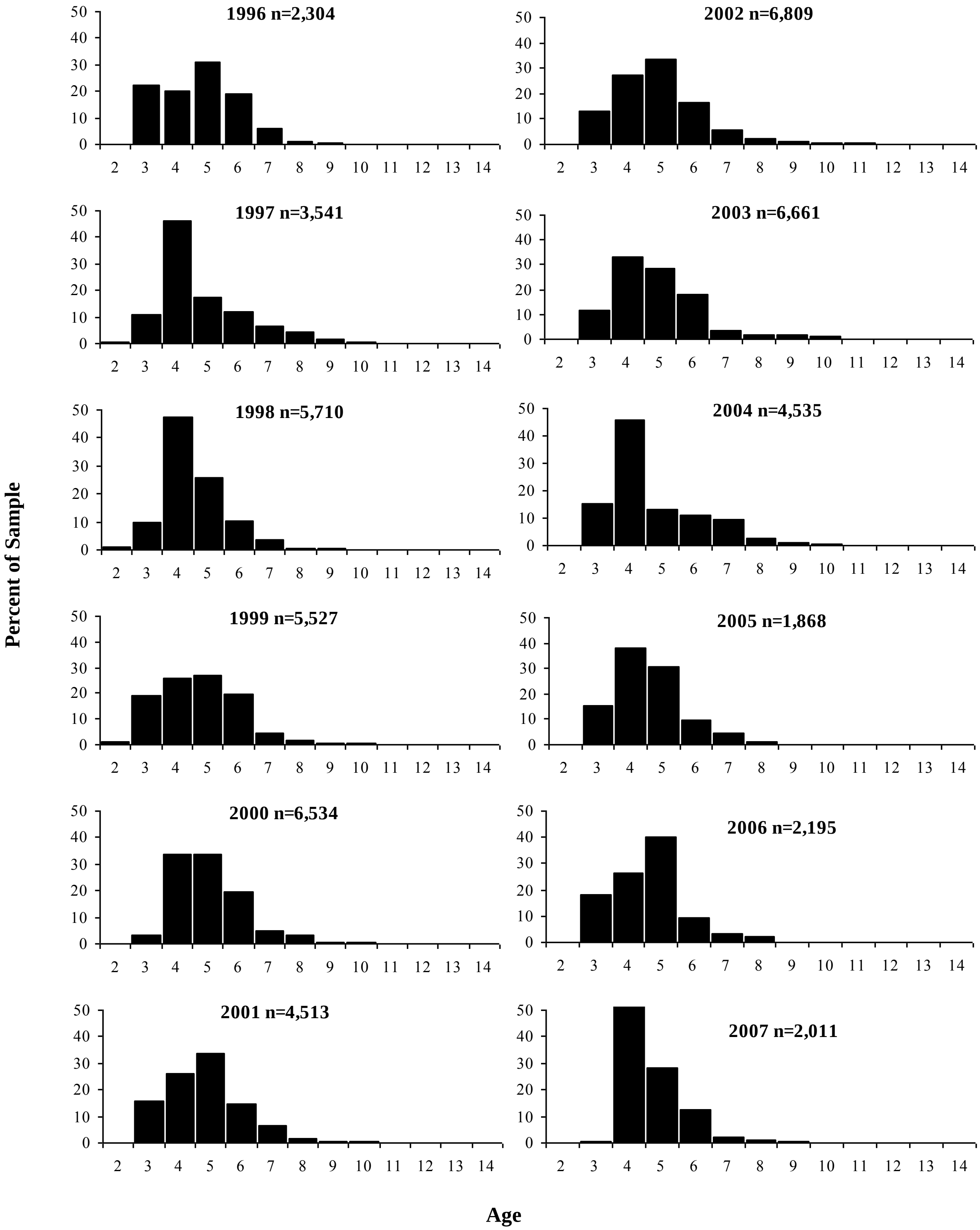


Figure 3. Continued.

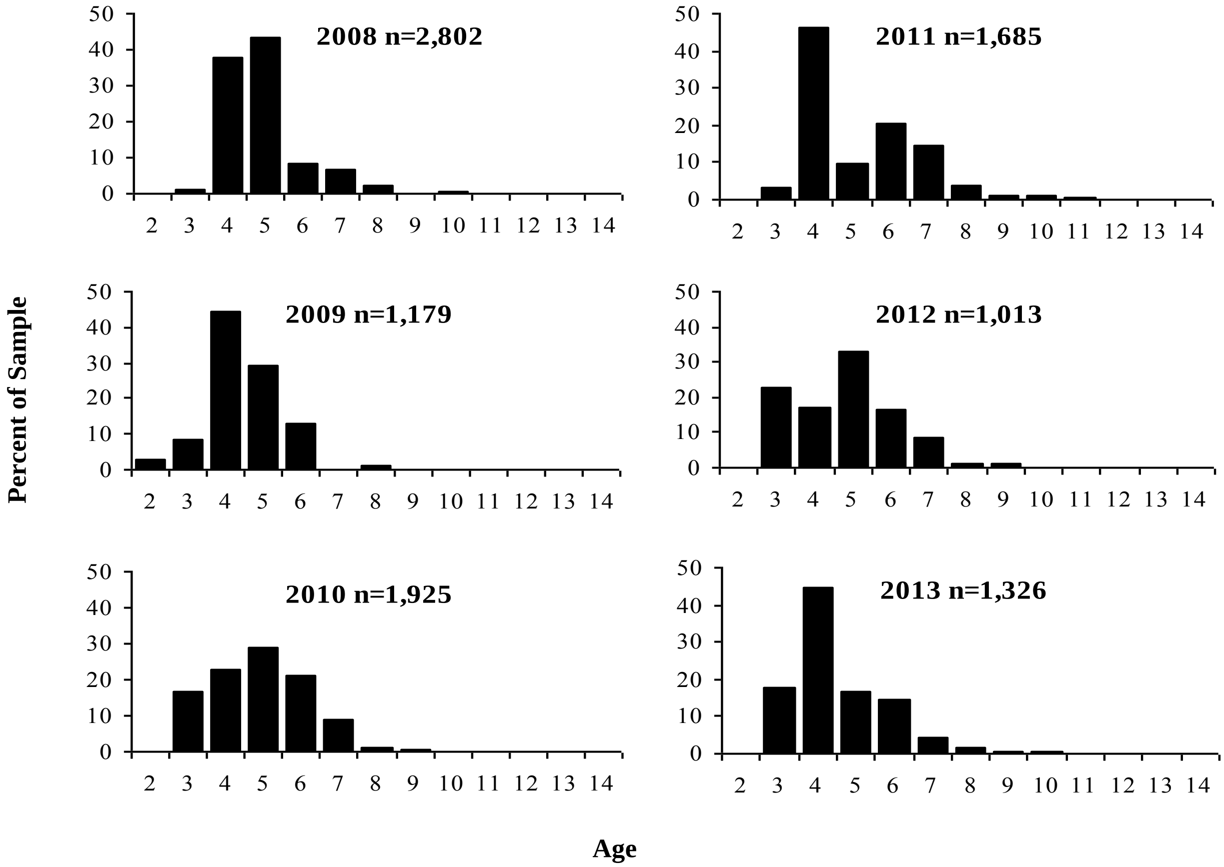


Figure 4. Length frequency of striped bass sampled during the 2013 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2013. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

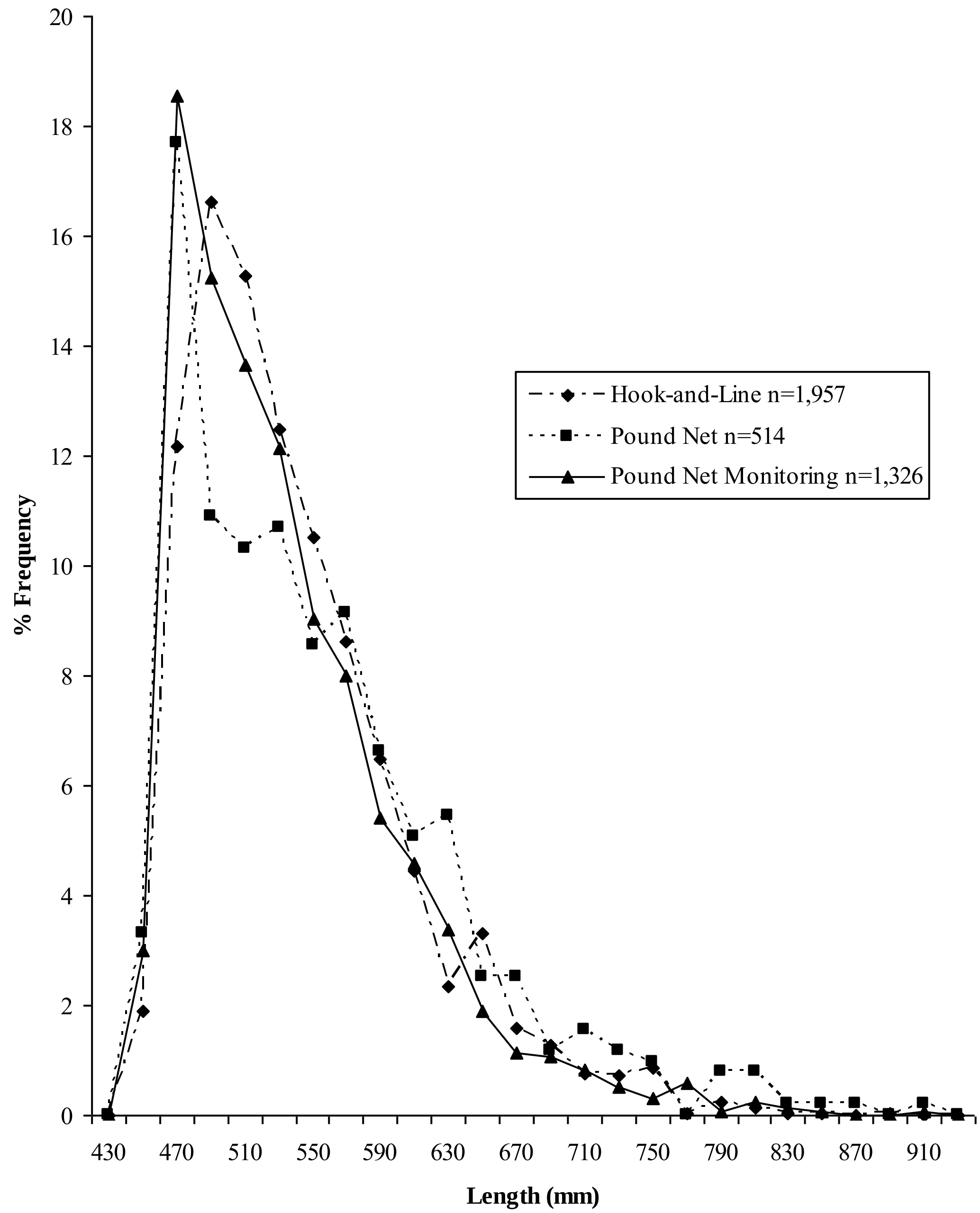
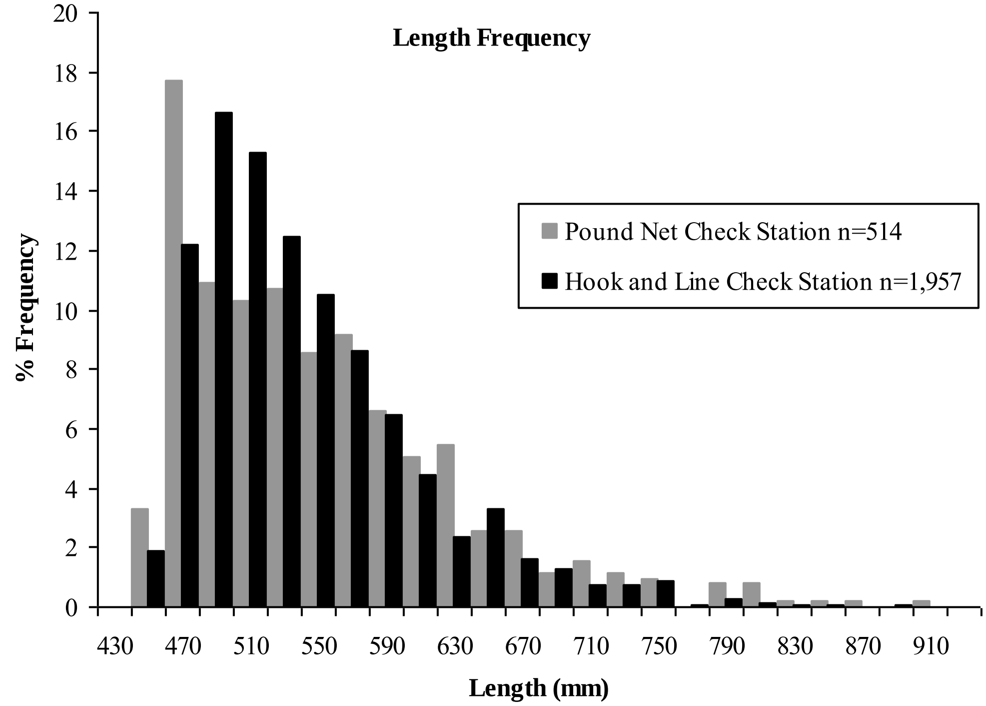


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2013



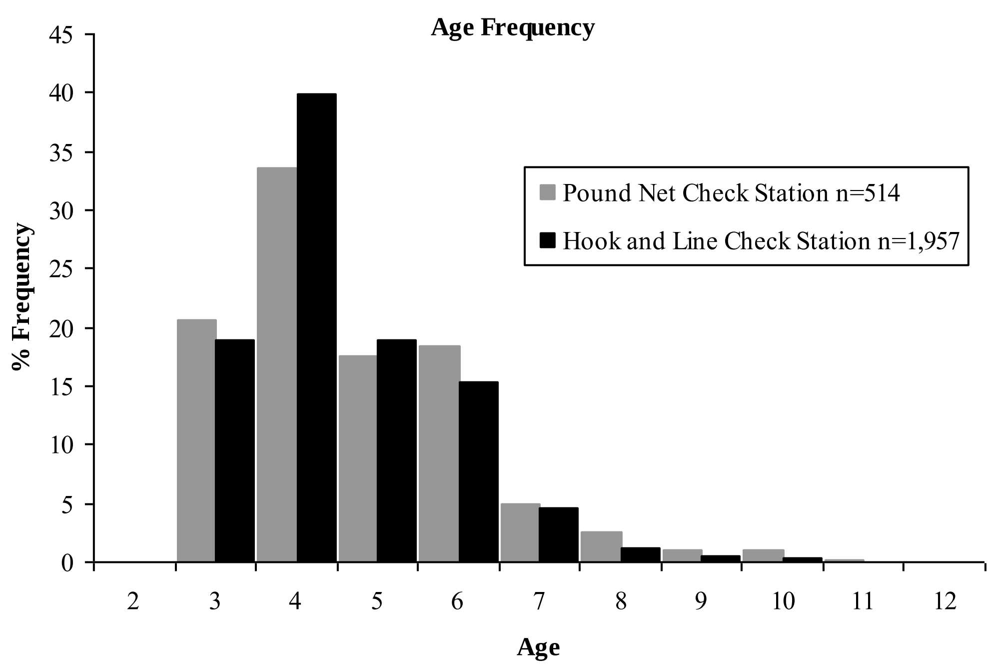


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2013. *Note – July pound net not included due to a sample size of 1.

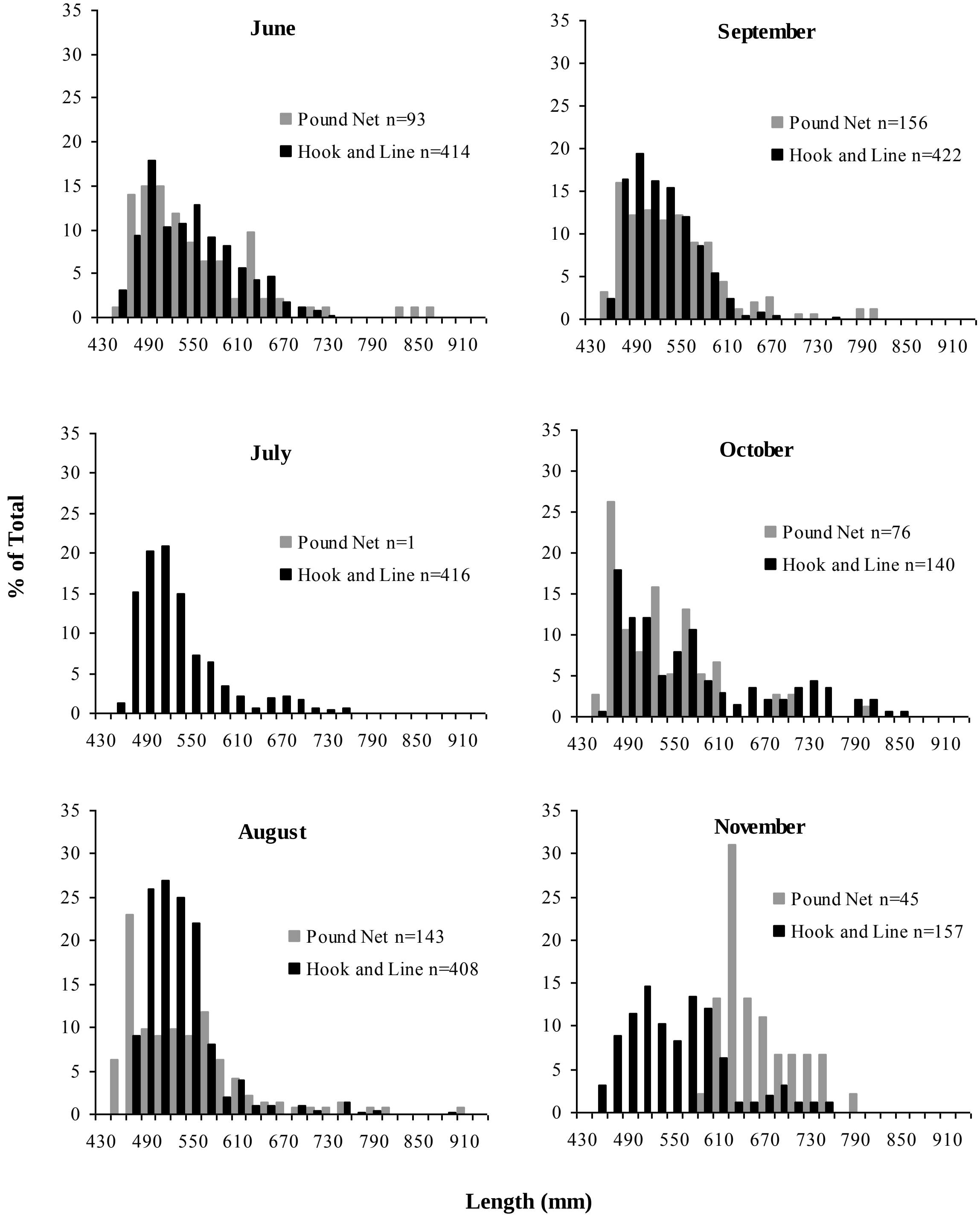


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial

hook-and-line and pound net check stations, 1999 through 2013. Note-pound net check station sampling began in 2000.

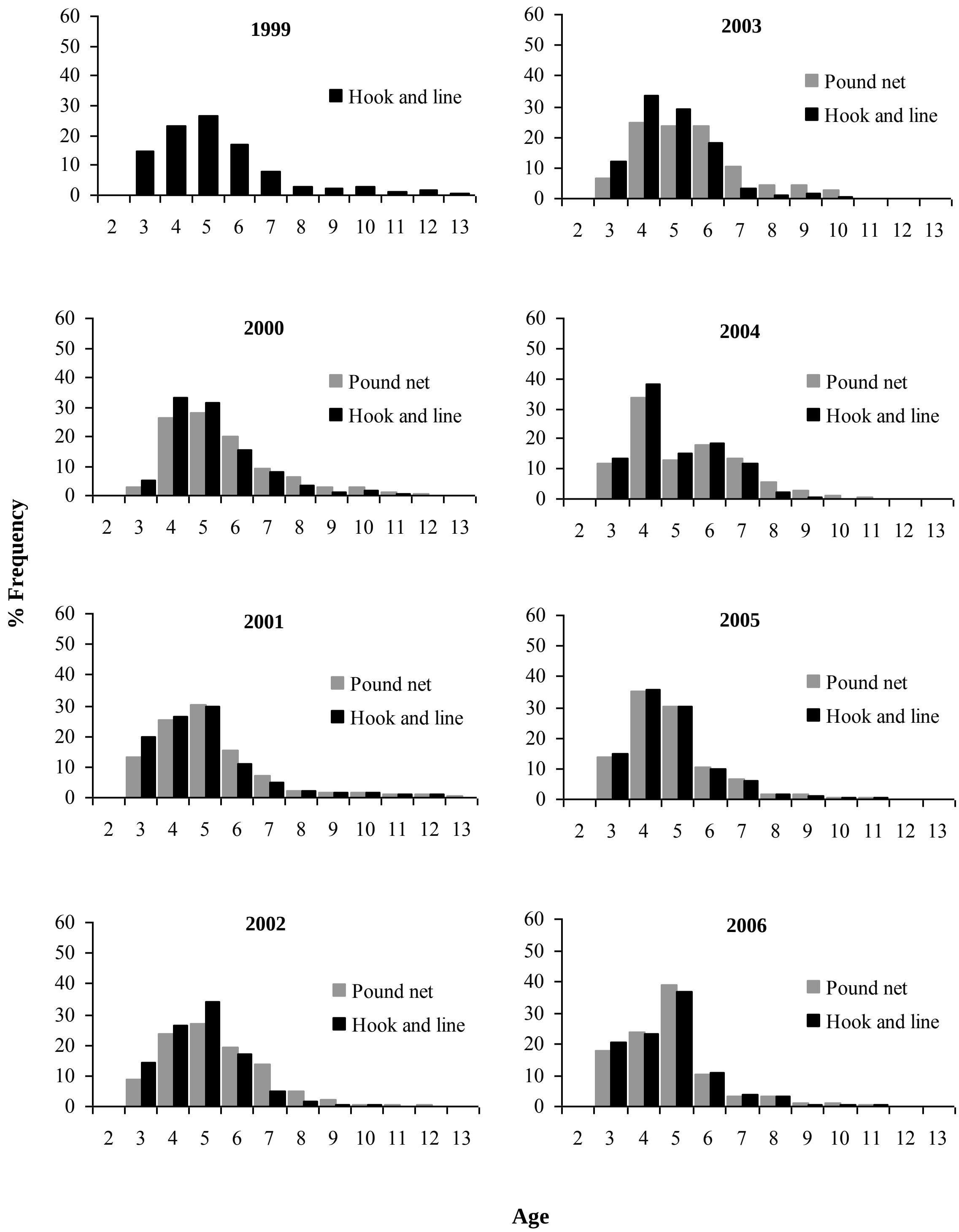


Figure 7. Continued.

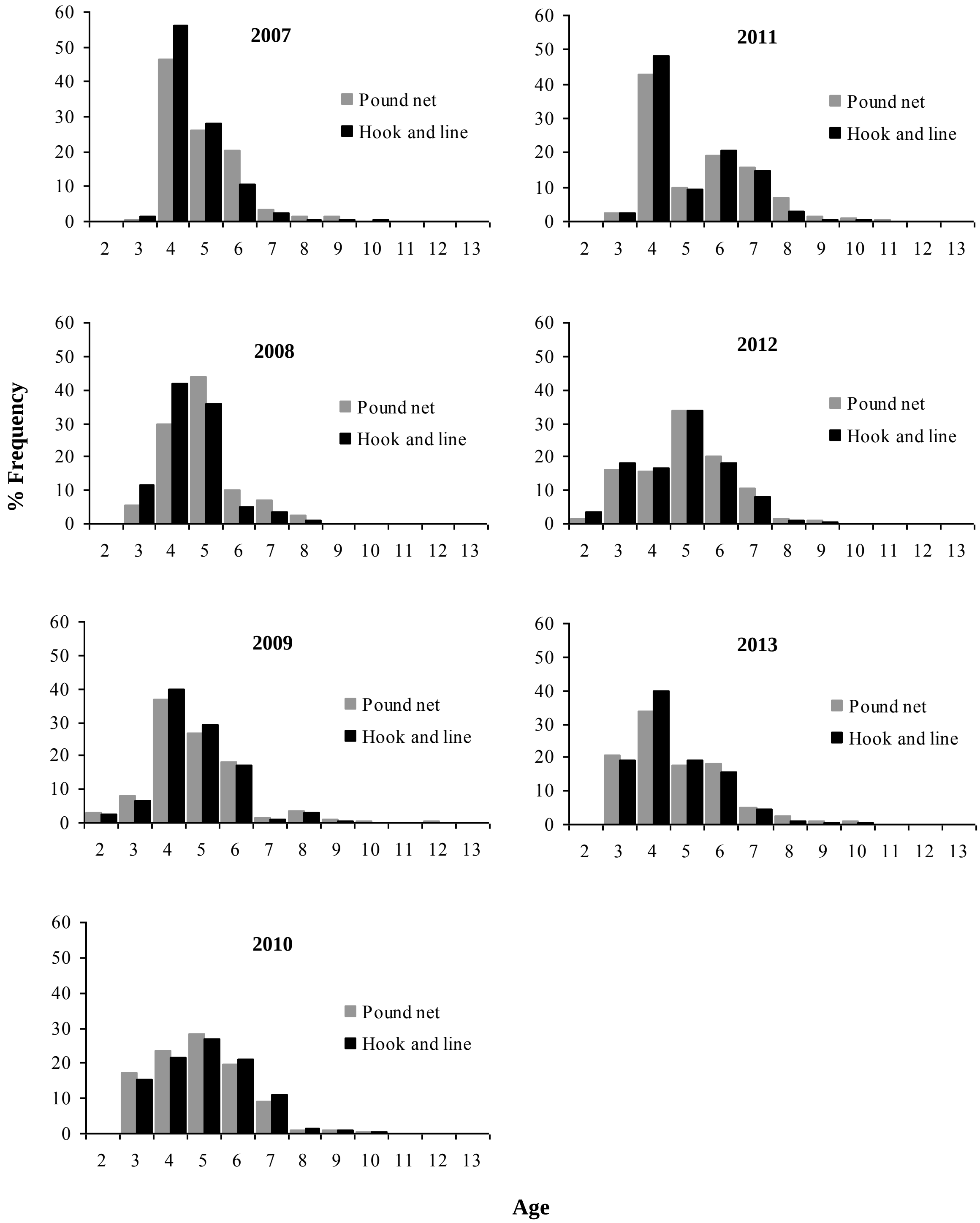
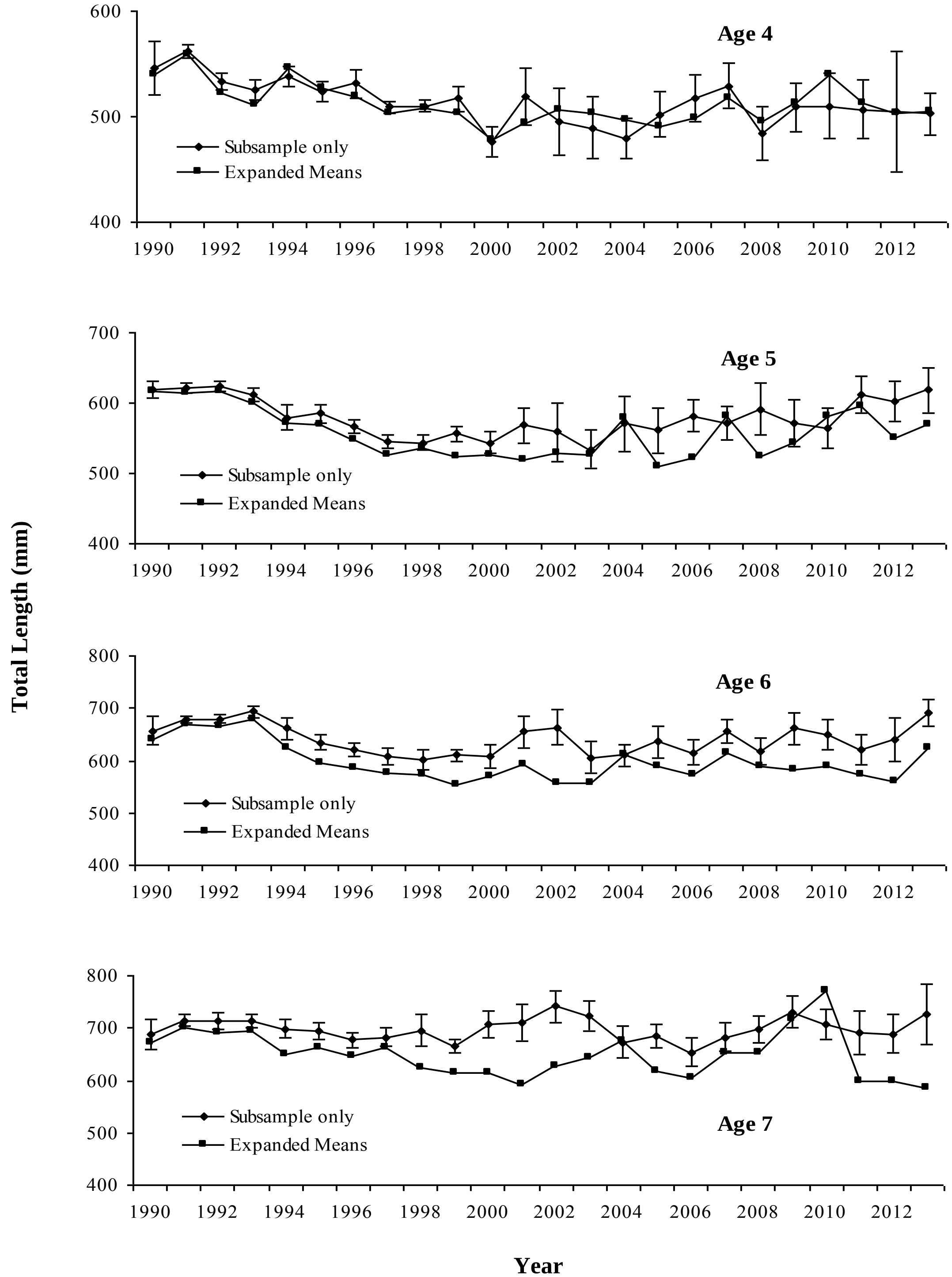


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations, 1990 through 2013. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating means. The 95% confidence intervals are shown around points in the sub-sample data series. Note different scales.



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

WINTER STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

Prepared by Jeffrey Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1B was to characterize the size and age structure of striped bass (*Morone saxatilis*) sampled from the December 10, 2013 - February 28, 2014 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. Watermen were assigned a quota for the year that they could harvest during any open season. For the January and February portion of the drift gill net fishery, fish could be harvested Monday through Friday during the entire month. A small number of watermen elected to stay in a common pool fishery, in which they shared a monthly quota, with daily harvest limits, similar to the old system. This fishery was only open a few days a month to closely monitor harvest.

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. The northern-most check station sampled in this survey was located in Middle River near Baltimore, while the southern-most station was located on Hooper's Island (Figure 1).

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, but scales were taken from all fish greater than or equal to 700 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 2013-2014 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 2013 – February 2014 gill net season, the year used for age calculations was 2014.

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 2013-2014 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 3,524 striped bass were sampled and 149 striped bass were aged from the harvest between December 2013 - February 2014. The gill net season was open for 4 days in December under the old quota system. The January and February 2014 fishery was open Monday through Friday under the new ITQ system. Watermen who elected to fish in the 2014 common pool were able to fish for 6 days in January and 5 days in February.

Commercial gill nets have been limited to mesh sizes no less than 5 and no greater than 7 inches since the fishery reopened after the 1985-1990 moratorium. As a result, the range in ages of the commercial striped bass drift gill net landings has not fluctuated greatly since the inception of MD DNR check station monitoring during the 1993-1994 gill net season (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 2013-2014 season was estimated by dividing reported monthly harvest weight by the mean monthly weight of check station samples. Total reported landings were 830,355 pounds and the reported number of fish was 145,339. According to the estimated catch-at-age analysis, the 2013-2014 commercial drift gill net harvest consisted primarily of age 5 striped bass from the 2009 year-class (37%; Table 1). The 2010, 2008 and 2007 year-classes (ages 4, 6 and 7) composed an additional 49% of the total harvest, while ages 8 and older contributed 14% to the total. The contribution of fish older than 8 years was higher than in the 2012-2013 harvest (8%) and the 2011-2012 harvest (2%). The youngest fish observed in the 2013-2014 sampled harvest were age 4.

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 (2010 year-class), with an expanded mean length and weight of 507 mm TL and 1.53 kg, respectively. The 2009 year-class (age 5) was most commonly observed in the sampled landings and had an expanded mean length and weight of 578 mm TL and 2.36 kg, respectively. The expanded mean length and weight of the oldest fish in the aged subsample (age 13, 2001 year-class) were 805 mm TL and 6.53 kg, respectively.

The length frequency of the check station samples is presented in Figure 3. The length frequency distribution was dominated by fish in the 510-650 mm TL range. Although sub-legal fish have occasionally been sampled in previous years, none were observed in 2013-14 sampling.

Time series of subsampled and expanded mean lengths and weights for the period 1994-2014 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.

CITATIONS

Barker, L.S., B. Versak, and L. Warner. 2004. Scale allocation procedure for Chesapeake Bay striped bass spring spawning stock assessment. Fisheries Technical Memorandum No. 31. Maryland Department of Natural Resources. 11pp.

Betolli, P. W., L. E. Miranda. 2001. Cautionary note about estimating mean length at age with sub-sampled data. North American Journal of Fisheries Management 21:425-428.

Fegley, L., A. Sharov, and E. Durell. 2000. A Review of the Maryland Striped Bass Commercial Gill Net Monitoring Program: An Analysis for Optimal Sample Sizes. In: Investigation of Striped Bass in Chesapeake Bay, USFWS Federal Aid Report, F-42-R-13, 1999-2000, Maryland DNR, Fisheries Service, 210pp.

Hoover, A. K. 2008. Winter Stock Assessment and Commercial Fishery Monitoring *in* Chesapeake Bay Finfish/Habitat Investigations 2008. USFWS Federal Aid Project, F-61-R-4, 2008, Job 3, Task 1B, pp II131-II148.

Kimura, D.A. 1977. Statistical assessment of the age-length key. Journal of the Fisheries Research Board of Canada. 34:317-324.

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

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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 2013 - February 2014.

Year-class	Age	Catch	Percentage of the catch
2010	4	9,948	7
2009	5	54,195	37
2008	6	41,904	29
2007	7	18,257	13
2006	8	10,587	7
2005	9	6,062	4
2004	10	3,288	2
2003	11	852	1
2002	12	87	0
2001	13	160	0
Total*		**145,339**	**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 2013-February 2014.

Year-class	Age	n fish aged	Mean TL (mm) of aged subsample	Estimated # at-age in sample	Expanded mean TL (mm)
2010	4	9	491	241	507
2009	5	24	569	1,314	578
2008	6	18	599	1,016	595
2007	7	19	705	443	652
2006	8	24	754	257	692
2005	9	18	759	147	723
2004	10	15	805	80	722
2003	11	18	845	21	842
2002	12	2	869	2	867
2001	13	2	819	4	805
Total*		**149**		**3,524**	

* 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 2013-February 2014.

Year-class	**Age**	**n fish aged**	**Mean weight (kg) of aged subsample**	**Estimated # at-age in sample**	**Expanded mean weight (kg)**
2010	4	9	1.52	241	1.53
2009	5	24	2.24	1,314	2.36
2008	6	18	2.75	1,016	2.57
2007	7	19	4.38	443	3.45
2006	8	24	5.27	257	4.19
2005	9	18	5.41	147	4.73
2004	10	15	6.61	80	4.74
2003	11	18	7.61	21	7.44
2002	12	2	8.39	2	8.43
2001	13	2	8.00	4	6.53
Total*		**149**		**3,524**	

* 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 2013-February 2014.

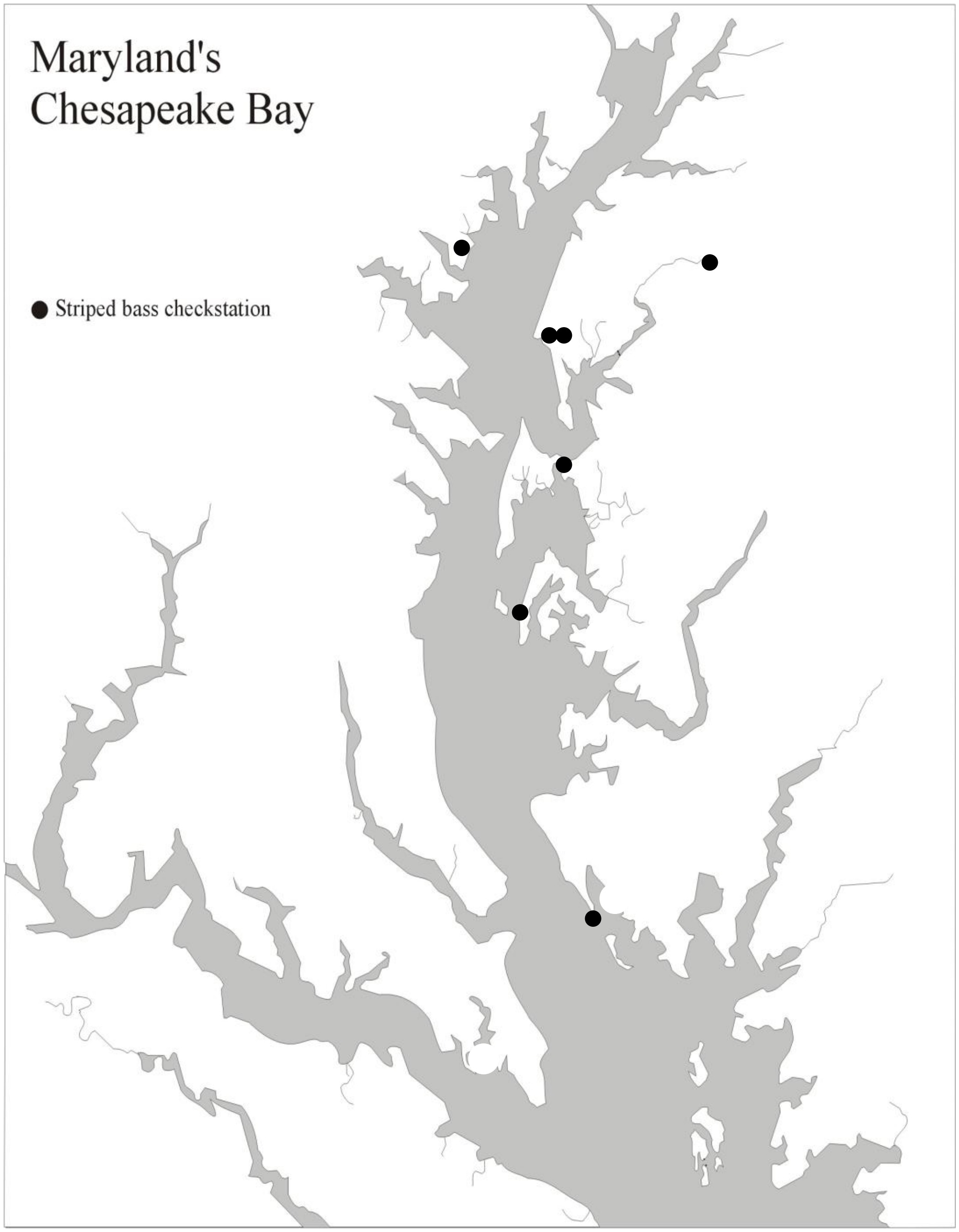
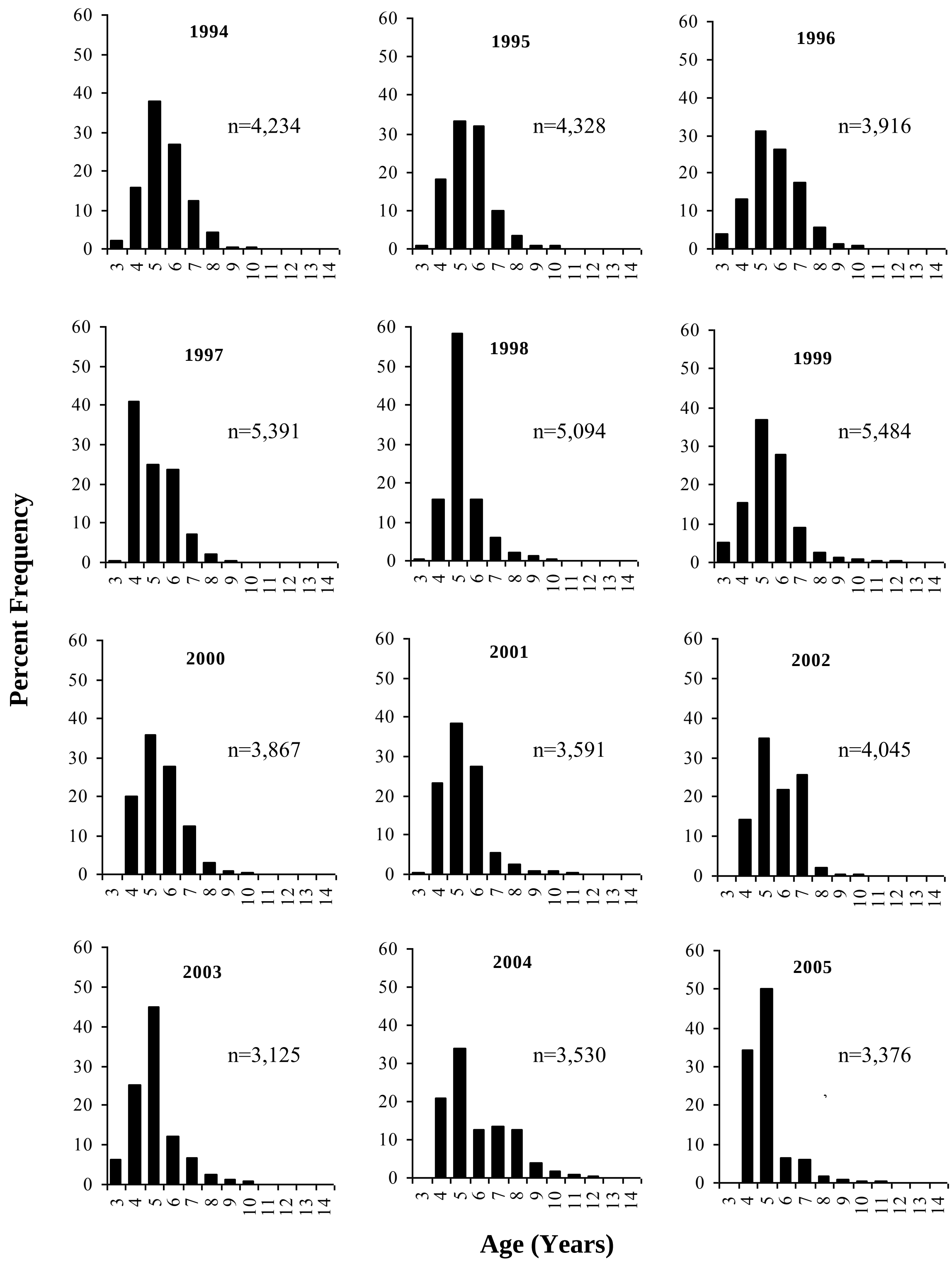


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2014.



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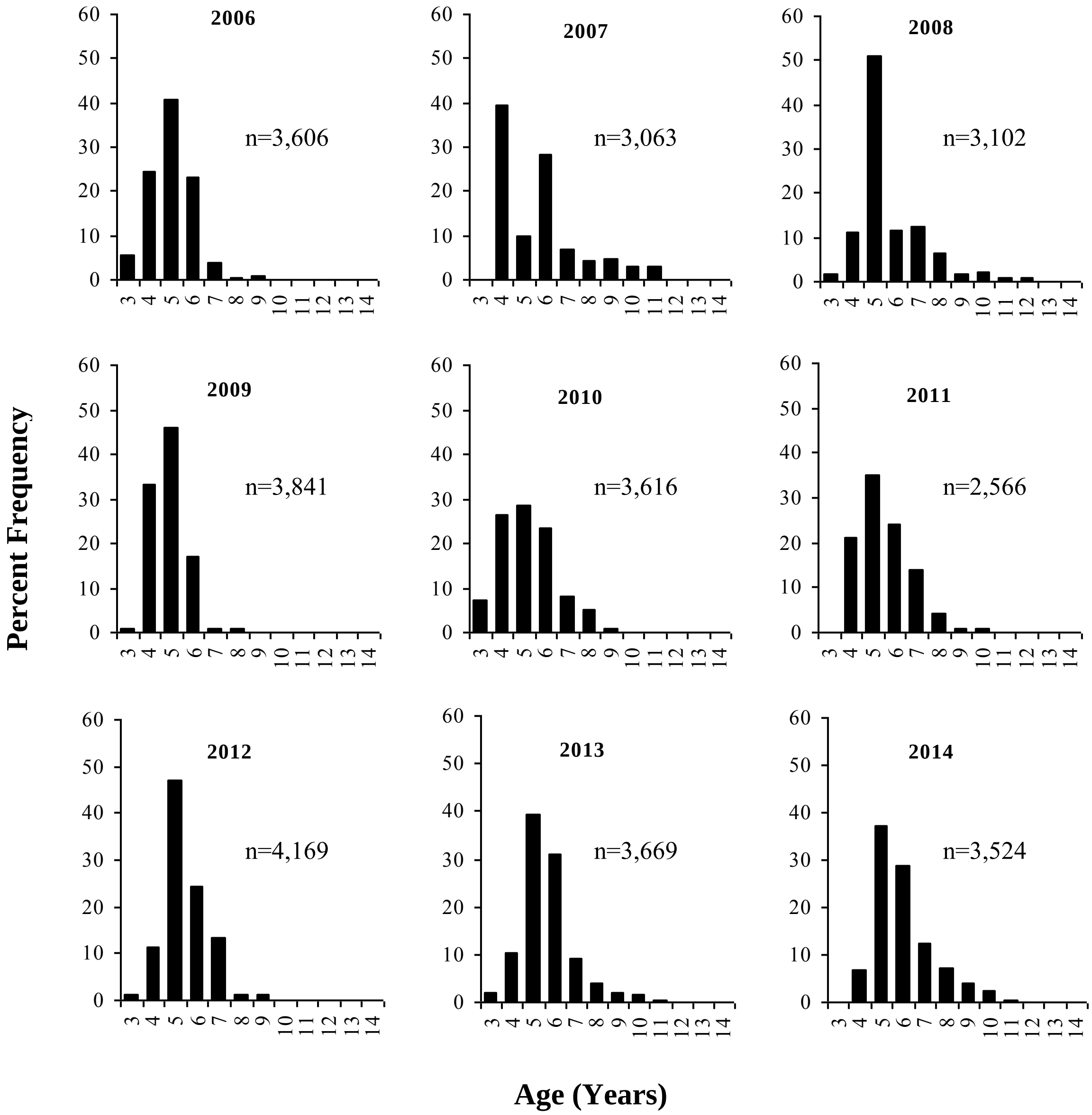


Figure 3. Length frequency distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2013-February 2014.

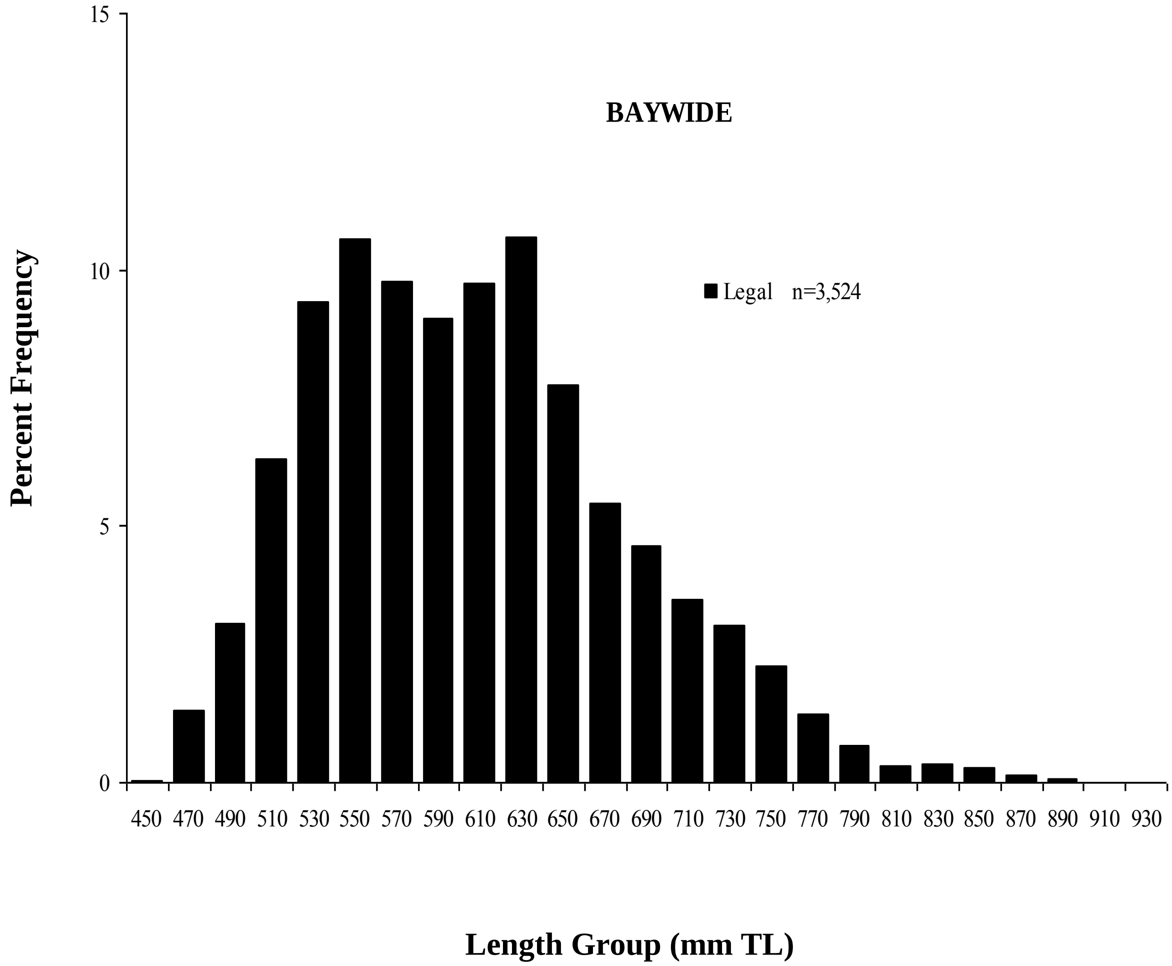


Figure 4. Mean total lengths (mm TL) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2014 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.

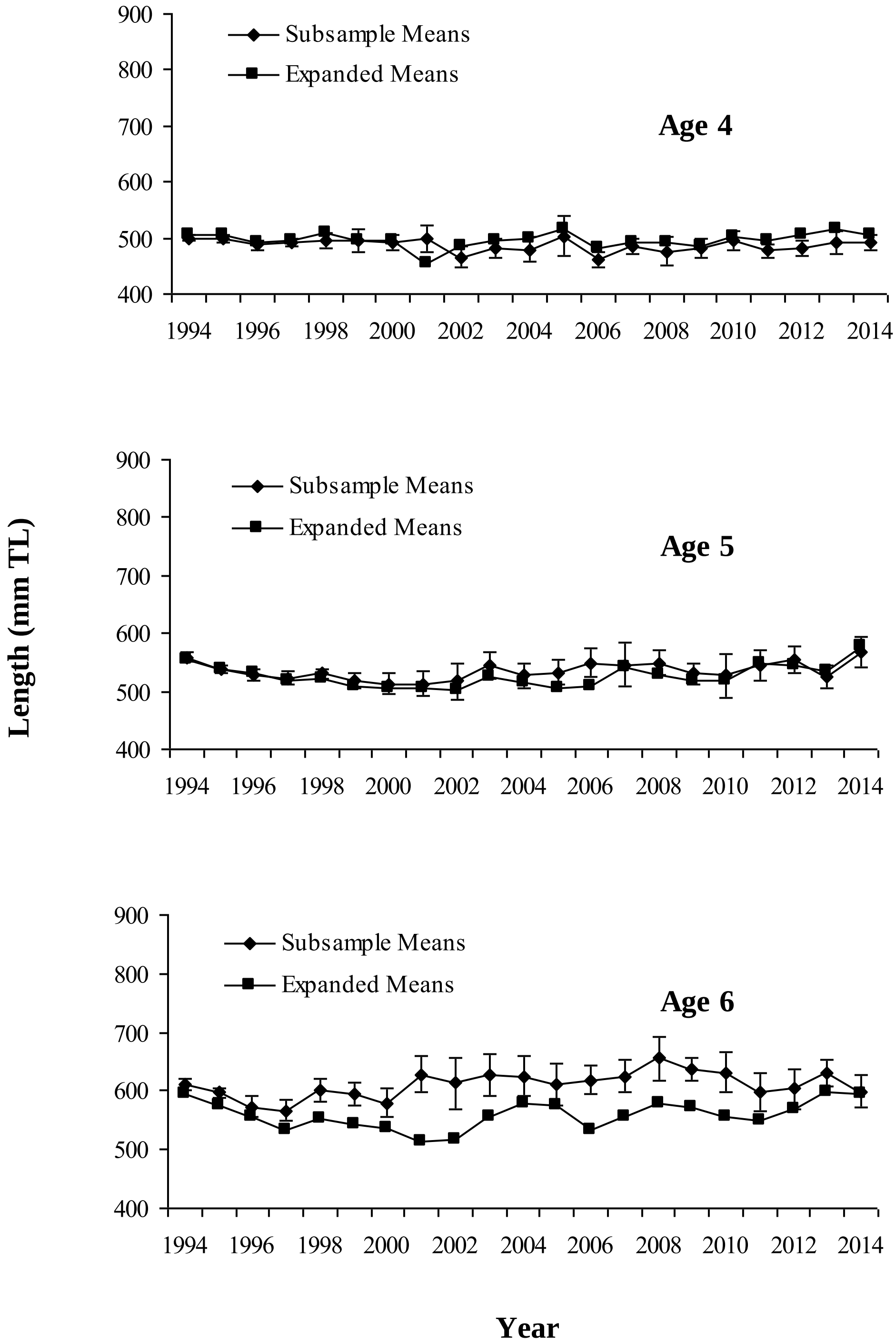


Figure 4. Continued.

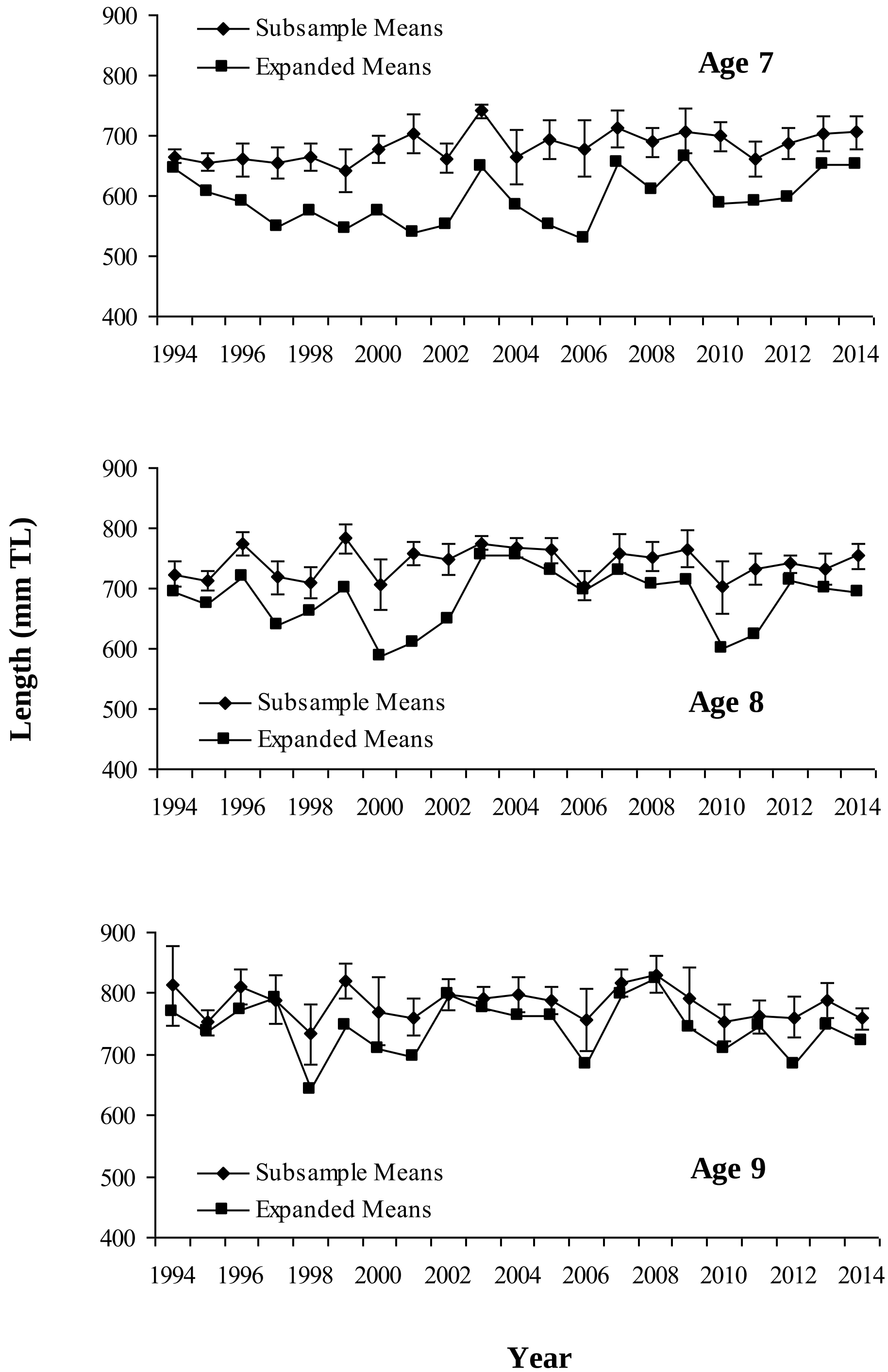


Figure 5. Mean weights (kg) of the aged subsample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2013 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.

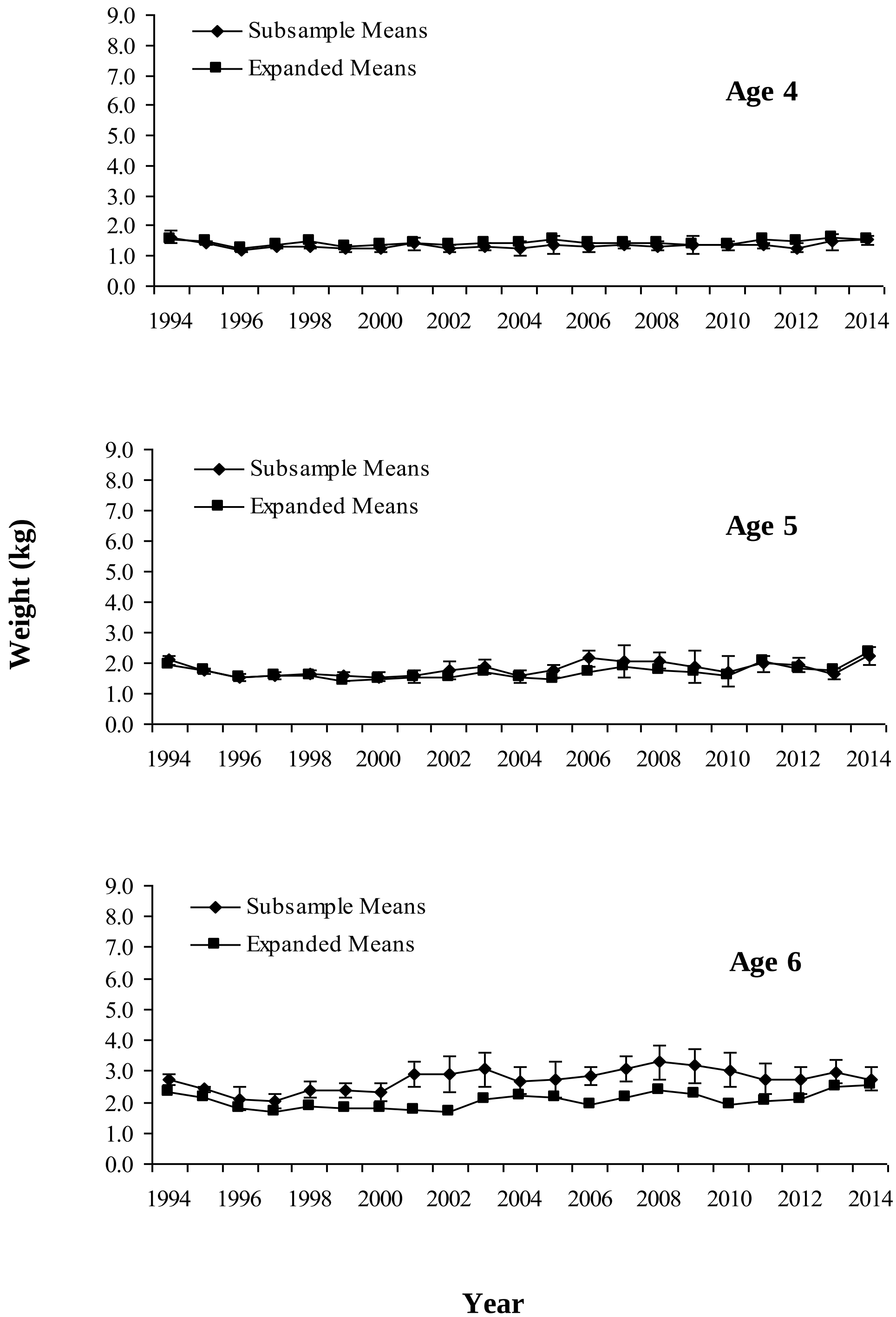
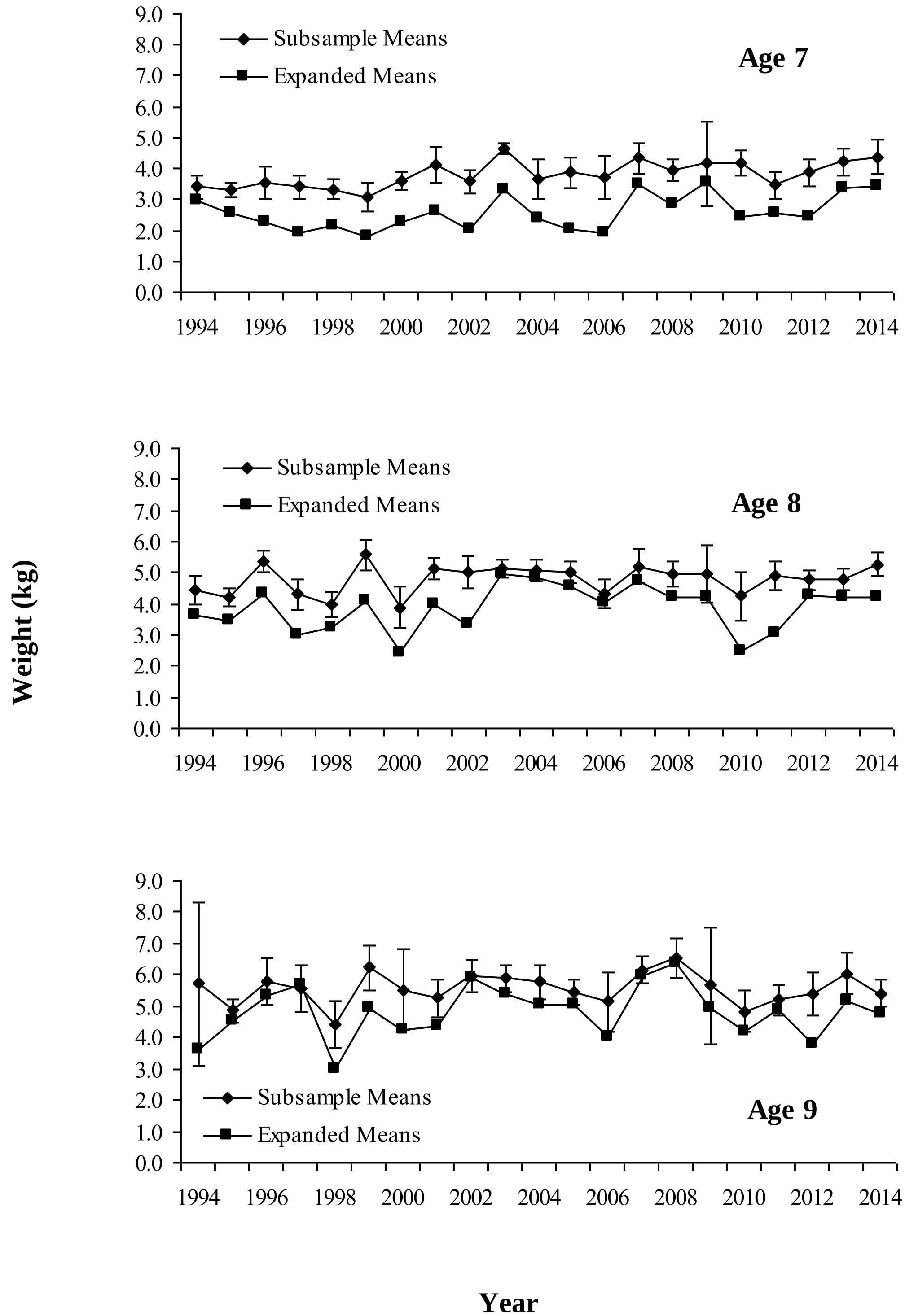


Figure 5. Continued.



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

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Jeffrey Horne

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1C was to characterize the size and age structure of commercially harvested striped bass from Maryland's Atlantic coast. Trawls and gill nets were permitted during the Atlantic season, which occurred between November 1, 2013 and May 15, 2014. This fishery was managed with a 24 inch total length (TL) minimum size limit and an annual quota of 126,396 pounds. Although this report covers the November 2013-May 2014 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 2005-2010 check station activity indicated that 81% 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 96% 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 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 2013-May 2014 Atlantic fishery, the year used for age calculations was 2014. 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 2013 through May 2014 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.

RESULTS and DISCUSSION

This fishery is largely by-catch from the commercial spiny dogfish fishery. Consequently, fish were harvested intermittently and are often difficult to intercept at the check stations. Sampling at coastal check stations was conducted on nine days between November 2013 and January 2014. A total of 173 fish were measured and weighed and the ALK was developed from 145 scale samples.

Check stations reported 2,689 fish landed during the 2013-2014 Atlantic coast season (Table 1). The catch-at-age estimate determined that landings ranged from age 5 (2009 year-class) to age 16 (1998 year-class) (Figure 1). Most (90%) striped bass harvested were ages 6 through 11 (Table 1). Striped bass recruited into the Atlantic coast fishery as young as age 5, but due to the 24 inch minimum size limit, few fish younger than age 6 were harvested, which is similar to previous years.

Twelve year-classes were represented in the sampled harvest. Based on the estimated catch-at-age, the most common age harvested during the 2013-2014 Atlantic coast fishery was age 11 (2003 year-class), which represented 31% of the landings (Table 1). Large contributions were also made by the 2004 year class (age 10) and the 2005 year class (age 9), which represented 17% and 16% of the fishery, respectively.

Striped bass sampled at Atlantic coast check stations during the 2013-2014 season had a mean length of 869 mm TL and mean weight of 7.7 kg. The sample length distribution ranged from 608 to 1058 mm TL (Table 2, Figure 2). The weight distribution from the sample of fish harvested ranged from 2.9 to 19.2 kg (Table 3).

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). Recently recruited age 6 fish had an expanded mean length of 706 mm TL and expanded mean weight of 4.0 kg (Figure 3 and 4). Age 11 striped bass, the most abundant age harvested, had an expanded mean length of 928 mm TL and expanded mean weight of 9.1 kg (Figure 3 and 4). Age 10 striped bass, the next most abundant year-class harvested, had an expanded mean length of 901 mm TL and an expanded mean weight of 8.3 kg (Figure 3 and 4).

REFERENCES

Betolli, P.W., and L.E. Miranda. 2001. Cautionary note about estimating mean length at age with sub-sampled data. N. Am. J. Fish. Manag. 21:425-428.

Kimura, D.A. 1977. Statistical assessment of the age-length key. Journal of the Fisheries Research Board of Canada. 34:317-324.

Quinn, T.J. and R.B. Desiro. 1999. Quantitative Fish Dynamics Oxford University Press.

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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 2013-May 2014.

Year-Class	**Age**	**Catch**	**Percent**
2009	5	16	0.6
2008	6	140	5.2
2007	7	326	12.1
2006	8	233	8.7
2005	9	420	15.6
2004	10	451	16.8
2003	11	839	31.2
2002	12	78	2.9
2001	13	109	4.0
2000	14	31	1.2
1999	15	31	1.2
1998	16	16	0.6
	Total*	**2,689**	**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 2013-May 2014. 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)
2009	5	1	608	---	---	1	613
2008	6	8	704	664	745	9	706
2007	7	17	736	709	763	21	733
2006	8	13	747	701	793	15	758
2005	9	22	825	793	858	27	838
2004	10	21	896	870	922	29	901
2003	11	46	930	912	948	54	928
2002	12	5	984	916	1051	5	980
2001	13	7	986	962	1009	7	986
2000	14	2	990	---	---	2	967
1999	15	2	1014	---	---	2	1013
1998	16	1	1016	---	---	1	1016
Total		**145**				**173**	

*Due to low sample sizes, the UCL and LCL listed as --- exceed known biological limits.

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2013-May 2014. 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)
2009	5	1	2.9	---	---	1	2.9
2008	6	8	3.8	3.2	4.4	9	4.0
2007	7	17	4.5	3.9	5.1	21	4.5
2006	8	13	4.8	3.9	5.6	15	5.1
2005	9	22	6.5	5.8	7.2	27	6.8
2004	10	21	8.1	7.3	8.8	29	8.3
2003	11	46	9.0	8.5	9.5	54	9.1
2002	12	5	11.2	8.3	14.0	5	11.0
2001	13	7	10.6	8.8	12.4	7	11.1
2000	14	2	10.8	---	---	2	10.1
1999	15	2	11.6	---	---	2	11.1
1998	16	1	19.2	---	---	1	19.2
Total		**145**				**173**	

*Due to low sample sizes, the UCL and LCL listed as --- exceed known biological limits.

Figure 1. Age distribution of striped bass sampled from the Atlantic coast fishery, 2006-2014 seasons.

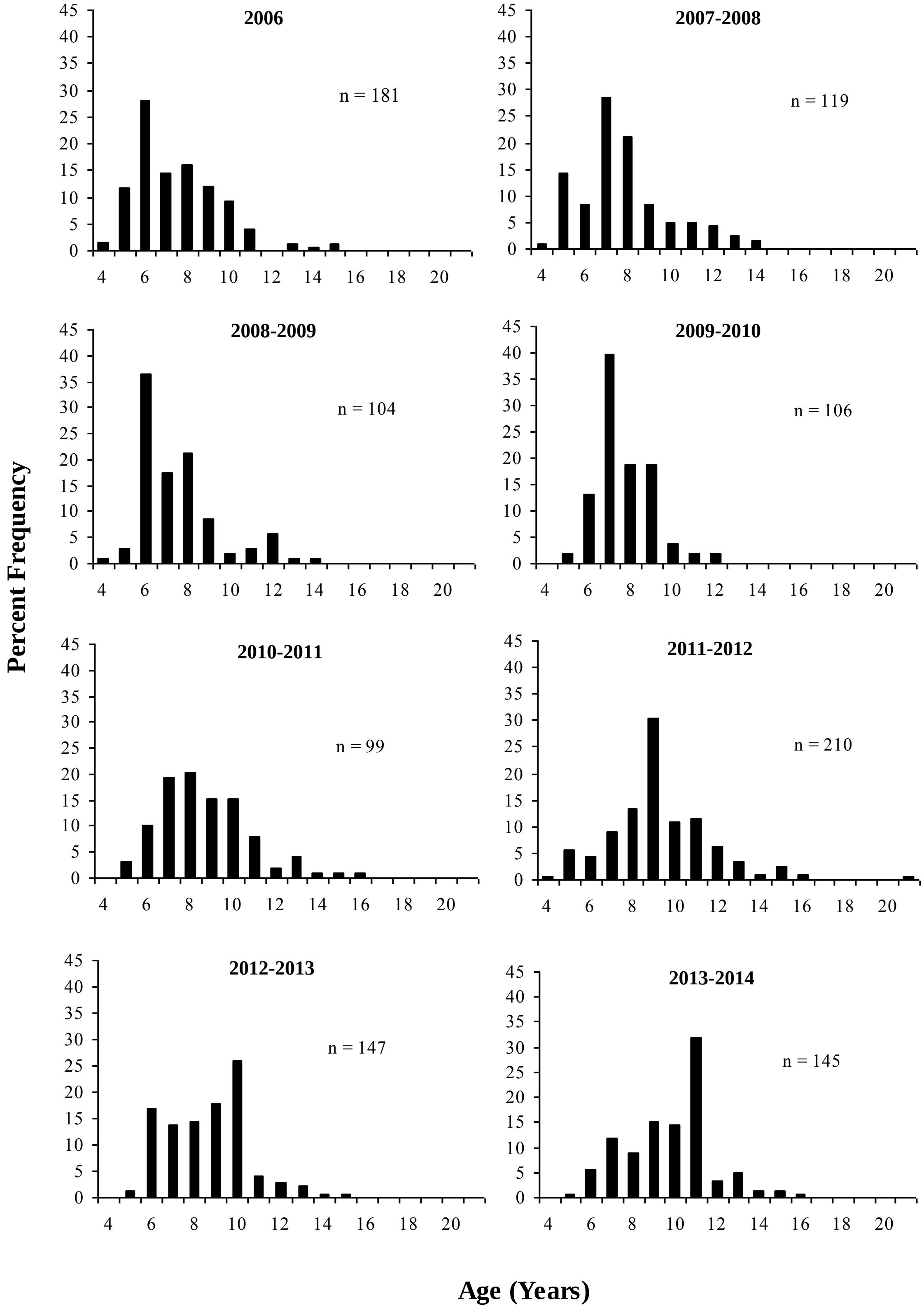


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, 2006-2014 seasons.

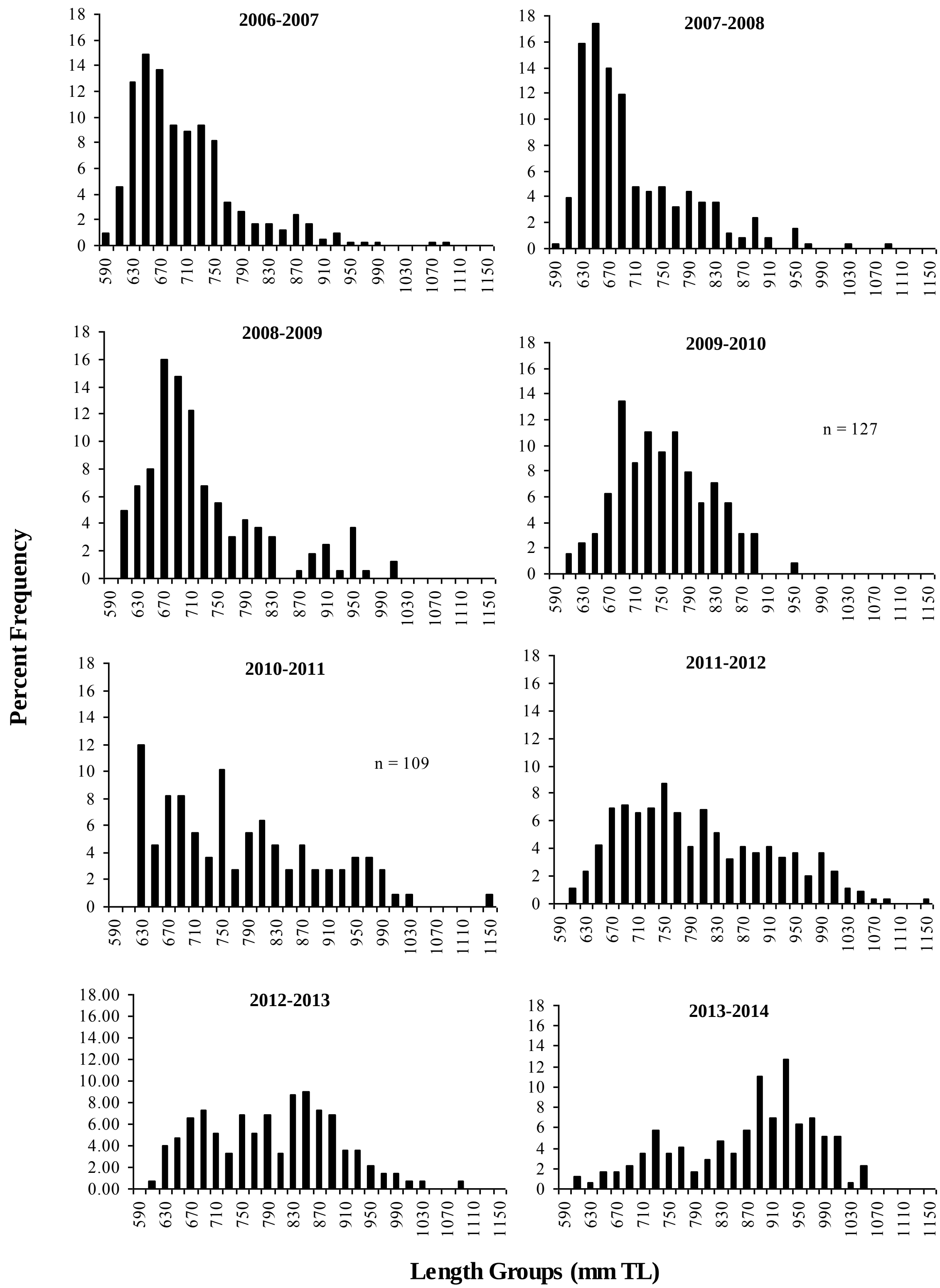


Figure 3. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2014 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences in scales on the y-axis.

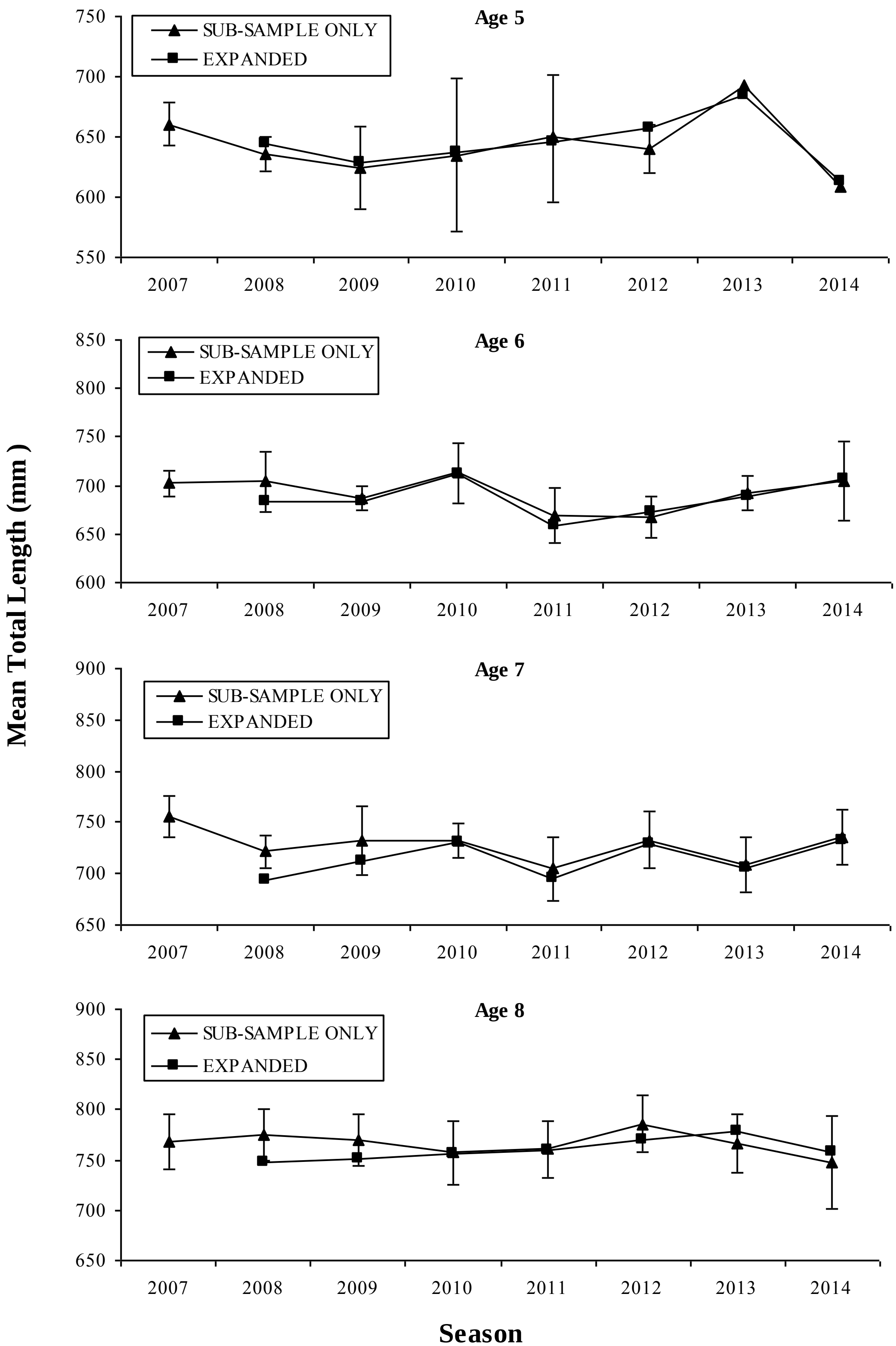
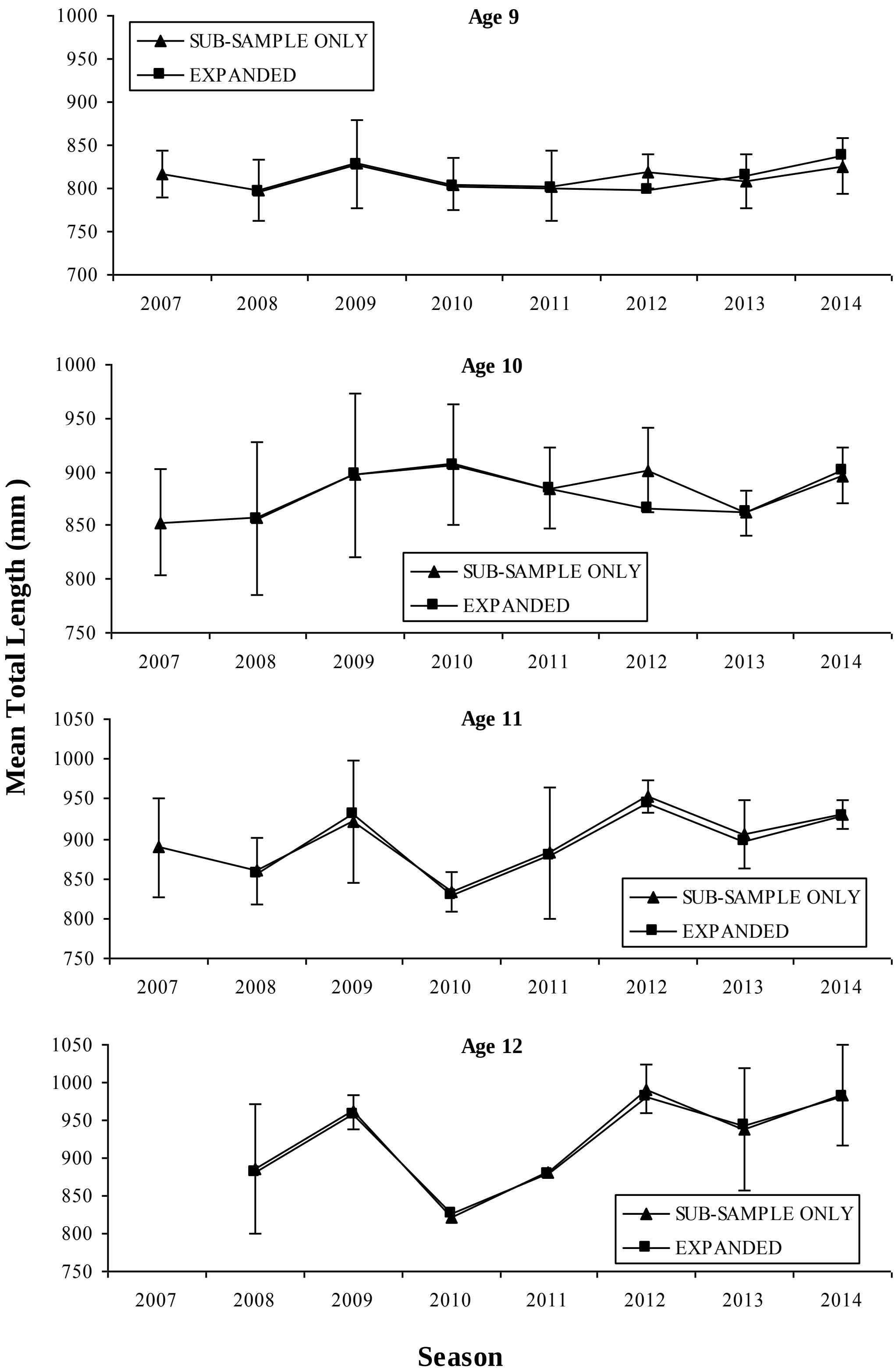


Figure 3. Continued



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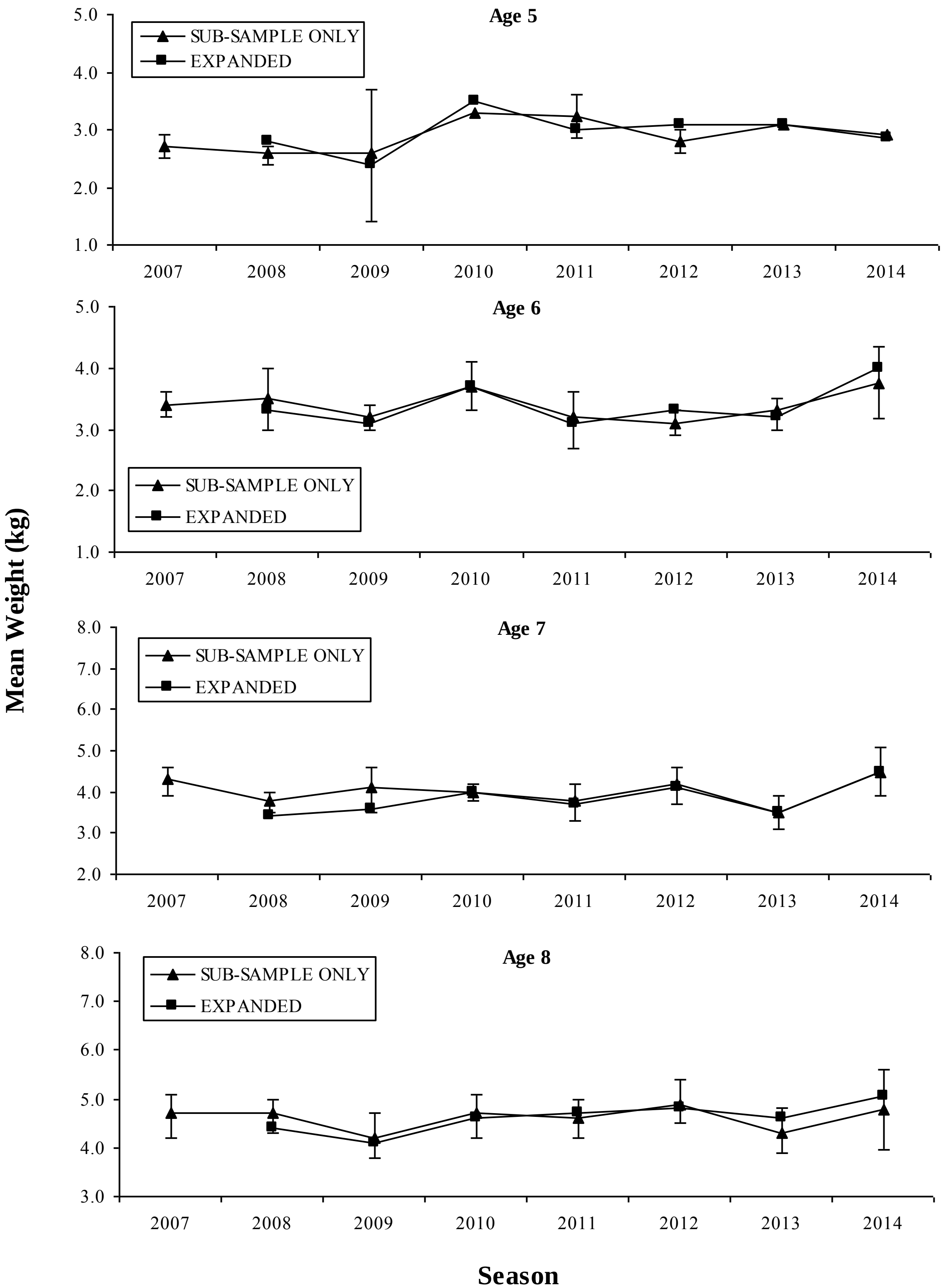
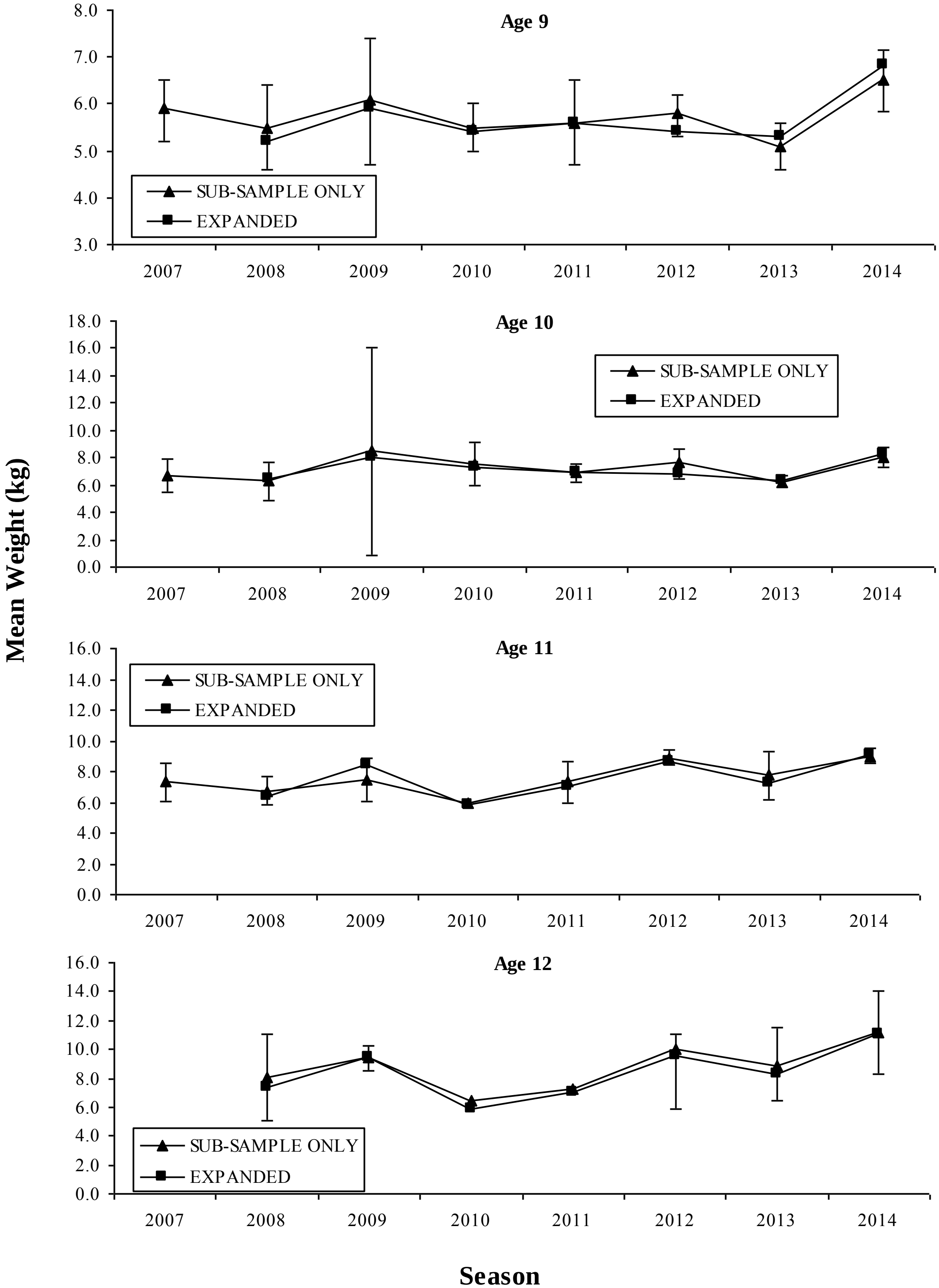


Figure 4. Continued



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Beth A. Versak

INTRODUCTION

The primary objective of Project 2, Job 3, Task 2 was to generate estimates of relative abundance-at-age for striped bass in Chesapeake Bay during the 2014 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 2014 (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 13 for a total of 33 sample days. In the Upper Bay, sampling was conducted from April 7 to May 20 with a total of 32 sample days.

Individual net panels were 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 129 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 and air 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):

  $$\ln \text{weight}_{kg} = 2.91 * \ln \text{length}_{cm} - 11.08 \qquad \text{(Equation 1)}$$

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

RESULTS AND DISCUSSION

CPUEs and variance

A total of 622 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 2014 un-weighted CPUE for Potomac females (25) ranked thirteenth of 29 years in the time series, just below the series average of 26 (Table 2). The un-weighted CPUE for Potomac males (357) ranked fourteenth in the time-series. This was more than double the value of the previous year, but still less than the average (420). Potomac male CPUEs have been below the time-series average for 14 of the last 15 years (Table 3). The Upper Bay female CPUE (104) continues to increase, and was the highest in the 30 year time series, well above the time series average of 41 (Table 4). The un-weighted CPUE for Upper Bay males (563) also increased, ranking ninth in the time series, and above the average of 452 (Table 5). The abundant 2011 year-class was the source of the increase in male CPUE in both systems. The Choptank River has not been sampled since 1996, but the results are included here for the historical record (Tables 6 and 7).

Area- and sex-specific, weighted CPUE values were pooled for use in the annual coastwide striped bass stock assessment. These indices are presented in a time series for ages one through 15+ (Table 8). The 2014 selectivity-corrected, total, weighted CPUE (557) ranked eighth in the 30 year time series and above the time series average of 488.

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 2014 age-specific CPUEs were all at or below 0.10 indicating a small variance in CPUE. Historically, 81% 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. In most cases, the percentages by age, sex, and area are very 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 50% of the total CPUE. Upper Bay fish dominated the total CPUE, making up 74% of the total. Males were also more frequently encountered, comprising 87% of the total CPUE.

Males dominated the total CPUEs for each system. The 2011 year-class made up the majority of the male CPUE (59% in the Upper Bay, 55% on the Potomac River). In the Potomac River, 93% of the male CPUE was made up of fish age 7 and younger. Similarly in the Upper Bay, 91% of the male CPUE was from ages 7 and younger.

Historically the female contribution is less than 10% in each system. In 2014, the female contribution in the Upper Bay was 16% of that system's total CPUE, while Potomac females contributed only 6% to the Potomac total CPUE. Female CPUEs were distributed across many year-classes in both systems. Age 11 females from the above-average 2003 year-class were the largest contributor (18%) to the female Upper Bay CPUE, followed by the 15+ age group (17%), which includes the record 1996 year-class. In the Upper Bay, age 7 female fish from the 2007 year-class made up 14% of that system's female CPUE. In the Potomac River, the contribution of age 11 fish from the 2003 year-class to the female CPUE was highest at 30%, followed by age 10 fish with 17%, and then the 15+ females, which contributed 13%.

Temperature and catch patterns

In both systems, wide fluctuations in air temperatures were observed, likely due to differences in daily sampling time.

Daily surface water temperatures on the Potomac River rose steadily over the course of the survey from 8.1°C to 19.7°C. Female CPUE showed one large spike on May 3, after the water temperature had been near 15°C for two weeks (Figure 2). Several large peaks in male CPUE were observed during the second half of April, when water temperatures reached the 14°C mark necessary to initiate spawning (Fay et al., 1983).

Surface water temperatures on the Upper Bay during the spawning survey ranged from 8.6°C to 20°C. Upper Bay water temperatures increased gradually during the survey period. There were multiple peaks in female CPUE throughout April, even though water temperatures did not reach 14°C until May 2 (Figure 3). Conversely, the highest catches of males occurred at the end of April and beginning of May, as water temperatures surpassed 14°C. These observations suggest spawning activity occurred throughout the timeframe of the survey.

Length composition of the stock

In 2014, 2,318 male and 176 female striped bass were measured. On the Potomac River, 827 male and 41 female striped bass were sampled; 1,491 males and 135 females were sampled from the Upper Bay (Figure 4). The mean length of female striped bass in 2014 (952 ± 16 mm TL) was larger than the mean length of male striped bass (452 ± 5 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 (464 ± 7 mm TL) and Upper Bay (445 ± 8 mm TL) were significantly different (P=0.0005) in 2014. The 2014 length distributions of male fish were similar in both areas, although a higher percentage of smaller fish were encountered on the Upper Bay (Figure 4).

Male striped bass on the Potomac ranged from 294 to 946 mm TL. Males between 330 and 530 mm TL composed 79% of the Potomac River male catch in 2014, representing fish from the 2009 through 2011 year-classes (Figure 4). The uncorrected Potomac male CPUE showed a small peak between 370 and 390 mm TL, representing the 2011 year-class (Figure 5). The influence of these young fish was evident in the large selectivity-corrected peak at 330 mm TL.

Male striped bass on the Upper Bay ranged from 264 to 1029 mm TL, with a peak in the length frequency between 310-370 mm TL (45% of catch; Figure 4). Male selectivity-corrected CPUE in the Upper Bay was high across a wide range of sizes, but the vast majority fell between 310 and 350 mm TL, representing the 2011 year-class (Figure 5). The selectivity correction increased the contribution of the abundant age 3 fish in both systems which could indicate that the smaller fish are not captured efficiently in the sampling gear.

Female striped bass sampled from the Potomac River and Upper Bay in 2014 were not significantly different in mean total length (P=0.62). Female striped bass sampled from the Potomac ranged from 651 to 1186 mm TL (mean=960 ± 35 mm TL), while females sampled in the Upper Bay ranged from 613 to 1226 mm TL (mean=950 ± 18 mm TL; Figure 4).

Female CPUE the Potomac River in 2014 was spread thinly over a number of length groups. Eleven year-classes were represented in the selectivity-corrected CPUE peaks that ranged from 650 to 1190 mm (Figure 6).

In the Upper Bay, corrected and uncorrected female CPUEs covered a wide range of length groups (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 2012 and 2013, large numbers of females were captured in 2014, resulting in higher than normal CPUEs. The largest selectivity corrected peaks at 610 and 1070 mm TL resulted from very few fish caught in small mesh net, with low selectivities for their size groups. Because of this, the selectivity correction increased the CPUEs to better approximate the relative abundance of those size fish in the spawning population. The peak in the uncorrected CPUE at 950 mm TL represents 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 2014 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 two-way analysis of variance was performed, where possible, to determine differences in LAA between areas (Upper Bay and Potomac). Few differences between sample areas were detected in LAA for either sex in 2014 ($P>0.05$). The exceptions were 10 year old females and 4 and 5 year old males. Ten year old females were significantly longer on the Potomac (974 mm TL) than the Upper Bay (898 mm TL, $P=0.024$). Age 4 male fish were significantly shorter on the Upper Bay (425 mm TL) than the Potomac River (493 mm TL, $P=0.047$). Age 5 males were also significantly shorter on the Upper Bay (513 mm TL) than the Potomac River (567 mm TL, $P=0.012$).

Lengths-at-age were compared between years for each sex. Male and female LAA has been relatively stable since the mid 1990s (Figures 7 and 8). Mean lengths of males were similar in 2013 and 2014 for all ages except for age 9 (ANOVA, α=0.05, P=0.003) and age 13 (ANOVA, α=0.05, P=0.0008). Mean lengths of females were similar in 2013 and 2014 for all ages except age 7 (ANOVA, α=0.05, P=0.022).

Age composition of the stock

During the 2014 survey, 17 age-classes, ranging from 2 to 18 were encountered (Tables 14 and 15). Male striped bass ranged from ages 2 to 16. Of the 282 male fish aged from the survey (Table 1), ages 3 and 7 (2011 and 2007 year-classes) were the most commonly encountered. On the Potomac River, the males encountered ranged from age 2 through 13, while on the Upper Bay, males ages 3 through 16 were captured. Females ranged in age from 6 to 18. Of the 141 aged female scales (Table 1), age 11 (2003 year-class) was most commonly observed. Females from the dominant 1996 year-class still contribute to the spawning stock in both systems.

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). In 2014, the largest increase in age-specific CPUE was observed for the age 3 (above average 2011 year-class) cohort, as those small males became sexually mature. The contribution of the 15+ age group has been strong over the last five years (Figure 9).

In 2014, the contribution of age 8+ females to the total female CPUE increased slightly to 80% (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 11 females encountered during the 2014 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 2014 value again decreased to 18%, 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 males from the above-average 2011 year-class recruiting to the spawning stock.

Historically, Chesapeake Bay estimates of 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 estimate of ISP generated from the Upper Bay has been variable, but the 2014 ISP value of 876 was the highest on record, and more than double the time-series average of 336 (Table 16, Figure 12). The 2014 Potomac River female ISP also increased to 222, near the time series average of 229.

CITATIONS

Barker, L. S. and A. F. Sharov. 2004. Relative abundance estimates (with estimates of variance) of the Maryland Chesapeake Bay striped bass spawning stock (1985 – 2003). A Report Submitted to the ASMFC Workshop on Striped Bass Indices of Abundance. June 30, 2004. MD DNR Fisheries Service, Annapolis, Maryland.

Barker, L. S., B. Versak, and L. Warner. 2003. Scale Allocation Procedure for Chesapeake Bay Striped Bass Spring Spawning Stock Assessment. Fisheries Technical Memorandum No. 31. MD DNR Fisheries Service, Annapolis, Maryland.

Cochran, W. G. 1977. Sampling Techniques. John Wiley and Sons. New York. 428 pp.

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic), Striped Bass. U.S. Fish and Wildlife Service. 36 pp.

Giuliano, A. M. and B. A. Versak. 2012. Characterization of Striped Bass Spawning Stocks in Maryland. In: MDDNR-Fisheries Service, Chesapeake Bay Finfish/Habitat Investigations, USFWS Federal Aid Project, F-61-R-7, pp. II-203 – II-251.

Helser, T. E., J. P. Geaghan, and R. E. Condrey. 1998. Estimating gill net selectivity using nonlinear response surface regression. Canadian Journal of Fisheries. Aquatic Sciences. 55. 1328-1337.

Hollis, E. H. 1967. An investigation of striped bass in Maryland. Final Report – Federal Aid in Fish Restoration. F-3-R. MD DNR.

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.

Richards, R. A. and P. J. Rago. 1999. A case history of effective fishery management: Chesapeake Bay striped bass. North American Journal of Fisheries Management 19:356-375.

Rugolo, L. J. and J. L. Markham. 1996. Comparison of empirical and model-based indices of relative spawning stock biomass for the coastal Atlantic striped bass spawning stock. Report to the Striped Bass Technical Committee, ASMFC.

Waller, L. 2000. Functional relationships between length and girth of striped bass, by sex. Unpublished data.

Warner, L., C. Weedon and B. Versak. 2006. Characterization of Striped Bass Spawning Stocks in Maryland. In: MDDNR-Fisheries Service, Chesapeake Bay Finfish/Habitat Investigations, USFWS Federal Aid Project, F-61-R-1, pp. II-127 – II170.

CITATIONS (continued)

Warner, L., L. Whitman and B. Versak. 2008. Characterization of Striped Bass Spawning Stocks in Maryland. In: MDDNR-Fisheries Service, Chesapeake Bay Finfish/Habitat Investigations, USFWS Federal Aid Project, F-61-R-3, pp. II-153 – II200.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2014.

	MALES				FEMALES			
Length group (mm)	**Upper Bay**	**Potomac River**	**Creel**	**Male Total**	**Upper Bay**	**Potomac River**	**Creel**	**Female Total**
270	1	0	0	**1**	0	0	0	**0**
290	6	0	0	**6**	0	0	0	**0**
310	3	3	0	**6**	0	0	0	**0**
330	3	3	0	**6**	0	0	0	**0**
350	3	3	0	**6**	0	0	0	**0**
370	3	3	0	**6**	0	0	0	**0**
390	3	3	0	**6**	0	0	0	**0**
410	4	3	0	**7**	0	0	0	**0**
430	2	3	0	**5**	0	0	0	**0**
450	3	3	0	**6**	0	0	1	**1**
470	3	3	0	**6**	0	0	6	**6**
490	3	3	0	**6**	0	0	6	**6**
510	3	3	0	**6**	0	0	4	**4**
530	5	3	0	**8**	0	0	3	**3**
550	1	3	0	**4**	0	0	7	**7**
570	5	5	0	**10**	0	0	5	**5**
590	5	5	0	**10**	0	0	5	**5**
610	5	6	0	**11**	1	0	2	**3**
630	5	4	0	**9**	0	0	4	**4**
650	6	5	0	**11**	0	1	5	**6**
670	4	5	0	**9**	1	0	3	**4**
690	6	6	0	**12**	0	0	1	**1**
710	9	3	2	**14**	3	0	2	**5**
730	9	4	2	**15**	2	0	3	**5**
750	14	1	4	**19**	1	1	0	**2**
770	6	3	2	**11**	1	1	3	**5**
790	7	1	0	**8**	1	0	0	**1**
810	10	0	0	**10**	3	1	5	**9**
830	7	0	1	**8**	2	2	2	**6**
850	10	0	3	**13**	1	1	5	**7**
870	10	1	3	**14**	8	2	9	**19**
890	11	1	0	**12**	9	2	8	**19**
910	3	1	2	**6**	7	2	10	**19**
930	5	0	3	**8**	7	3	11	**21**
950	3	1	4	**8**	10	1	12	**23**
970	0	0	0	**0**	5	5	10	**20**
990	4	0	1	**5**	5	5	9	**19**
1010	0	0	0	**0**	5	2	8	**15**
1030	1	0	0	**1**	4	2	6	**12**
1050	0	0	0	**0**	10	1	2	**13**
1070	0	0	0	**0**	2	2	3	**7**
1090	0	0	0	**0**	2	1	2	**5**
1110	0	0	0	**0**	2	3	4	**9**
1130	0	0	0	**0**	3	1	4	**8**
1150	0	0	0	**0**	2	0	1	**3**
1170	0	0	0	**0**	1	0	0	**1**
1190	0	0	0	**0**	0	1	1	**2**
1210	0	0	0	**0**	2	0	0	**2**
1230	0	0	0	**0**	1	0	0	**1**
Total	**191**	**91**	**27**	**309**	**101**	**40**	**172**	**313**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2014 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**
Average																**26**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2014 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Potomac River was not sampled in 1994.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	285.3	517.6	80.6	10.5	0.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**896**
1986	0.0	241.5	375.9	531.2	8.2	8.2	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1166**
1987	0.0	144.5	283.5	174.6	220.8	3.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	**829**
1988	0.0	18.2	107.4	63.8	75.9	81.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**347**
1989	0.0	51.9	240.9	134.5	39.1	55.2	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**543**
1990	0.0	114.2	351.8	172.8	73.8	28.3	33.8	26.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	**803**
1991	0.0	19.9	91.2	96.6	49.7	37.8	28.7	22.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0	**352**
1992	0.3	36.3	202.4	148.9	97.6	73.0	39.1	19.0	6.1	0.8	8.4	0.0	0.0	0.0	0.0	**632**
1993	0.0	30.4	141.7	133.9	101.4	83.7	62.6	43.6	21.9	1.8	0.0	0.0	0.0	0.0	0.0	**621**
1994																
1995	0.0	9.1	143.9	61.1	18.7	20.4	25.3	32.2	11.3	10.7	0.1	0.0	0.8	0.0	0.0	**334**
1996	0.0	0.0	230.6	172.9	24.8	26.8	17.7	22.7	19.3	3.6	0.6	0.8	0.0	0.0	0.0	**520**
1997	0.0	49.5	54.3	112.9	95.7	12.2	5.7	10.8	17.2	13.6	2.2	2.6	0.0	0.0	0.0	**377**
1998	0.0	72.9	200.7	29.8	128.9	49.8	16.9	11.7	4.3	9.0	8.6	5.0	2.9	0.5	0.0	**541**
1999	0.0	9.9	316.9	151.2	103.6	65.4	19.1	10.3	6.9	3.8	4.4	3.1	1.9	0.0	0.0	**696**
2000	0.0	1.9	42.2	136.8	48.5	18.1	14.8	9.8	5.5	0.0	0.1	3.7	0.1	0.4	0.9	**283**
2001	0.0	10.6	36.1	43.5	33.8	12.6	8.9	7.8	4.8	1.7	2.2	4.0	0.8	0.6	0.0	**167**
2002	0.0	27.2	75.4	48.7	52.4	23.0	20.9	7.9	2.3	3.4	2.2	1.6	2.0	0.0	0.6	**268**
2003	0.0	12.6	79.0	39.6	24.5	31.6	22.5	10.0	7.0	9.5	3.2	3.7	5.8	0.2	0.2	**249**
2004	0.0	10.5	148.8	90.4	25.9	17.6	19.5	17.2	8.4	8.1	11.5	1.8	1.1	1.6	1.6	**364**
2005	0.0	10.9	11.0	14.9	16.3	4.7	4.5	3.6	4.1	3.1	1.9	1.2	0.0	0.0	0.0	**76**
2006	0.0	8.3	127.1	20.7	33.5	14.5	6.3	6.9	8.2	9.1	7.4	4.7	0.6	0.4	0.0	**248**
2007	0.0	10.4	16.6	37.1	5.3	5.6	4.3	2.1	2.6	2.8	5.4	1.0	0.8	2.0	0.1	**96**
2008	0.0	6.1	35.8	20.1	12.0	1.7	1.8	2.3	1.1	1.2	1.3	2.5	0.4	0.0	0.2	**86**
2009	0.0	35.2	35.9	116.5	23.1	56.9	9.1	10.5	10.5	2.8	3.8	2.6	3.7	0.6	0.6	**312**
2010	0.0	3.2	104.9	58.0	49.2	29.7	23.9	1.7	6.8	3.6	0.9	1.2	1.3	0.6	0.4	**285**
2011	0.0	27.6	95.7	164.4	51.2	54.4	29.6	24.7	6.2	5.2	6.1	4.1	4.9	2.1	5.3	**481**
2012	0.0	19.0	44.4	15.1	13.9	6.4	6.0	4.8	4.1	1.4	2.1	1.3	0.6	4.1	0.0	**123**
2013	0.0	6.7	19.9	50.9	23.7	17.6	8.6	5.0	1.5	1.9	0.2	0.1	0.0	0.0	0.0	**136**
2014	0.0	1.0	196.1	40.1	55.2	18.2	19.8	3.7	9.1	4.5	6.9	0.8	1.8	0.0	0.0	**357**
Average																**420**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985-2014 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**
Average																**41**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985-2014 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	47.5	148.8	1.9	0.0	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**199**
1986	0.0	219.0	192.3	450.8	0.4	3.4	2.2	3.8	1.3	0.0	0.0	0.0	0.0	0.0	1.2	**874**
1987	0.0	131.7	231.0	68.1	138.8	0.0	2.1	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**576**
1988	0.0	52.1	38.0	61.6	37.8	36.8	0.6	0.0	0.0	7.2	0.0	0.0	0.0	0.0	0.0	**234**
1989	0.0	8.1	102.3	17.4	21.1	26.9	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**192**
1990	0.0	56.7	28.4	92.8	20.1	24.9	22.9	16.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**263**
1991	0.0	84.1	254.9	36.8	40.9	11.3	16.0	9.5	4.3	0.1	0.0	0.0	0.0	0.0	0.0	**458**
1992	0.0	22.5	193.9	150.1	19.4	52.9	27.7	19.1	7.5	0.5	0.0	0.0	0.0	0.0	0.0	**494**
1993	0.0	30.6	126.2	149.1	63.0	16.3	27.3	9.9	7.5	0.5	0.0	0.0	0.0	0.0	0.0	**430**
1994	0.0	25.4	54.5	96.3	101.8	43.2	14.5	26.8	6.4	2.1	0.3	0.0	0.0	0.0	0.0	**371**
1995	0.0	79.0	108.4	75.8	89.8	52.9	30.0	11.6	12.4	3.7	7.2	0.9	0.0	0.0	0.0	**471**
1996	0.0	6.2	433.5	57.6	23.3	86.2	59.2	34.1	29.0	11.8	12.0	0.0	0.6	0.0	0.0	**753**
1997	0.0	28.9	38.8	155.5	15.4	23.9	23.5	15.0	8.9	2.0	12.1	0.0	0.7	0.0	0.0	**325**
1998	0.0	13.0	106.6	34.6	162.0	20.9	10.0	17.1	20.9	11.9	5.4	8.7	0.0	0.0	0.0	**411**
1999	0.0	7.7	81.8	33.6	30.4	14.6	4.8	0.6	4.7	1.6	0.4	0.2	0.3	0.0	0.0	**181**
2000	0.0	22.2	64.6	83.6	47.7	80.4	28.0	10.6	6.1	6.2	3.9	3.3	1.4	0.4	0.3	**359**
2001	0.0	1.4	40.9	70.2	64.9	27.6	35.3	33.0	5.8	10.4	3.5	0.4	0.5	0.0	0.4	**294**
2002	0.0	120.7	19.1	34.1	106.7	48.2	42.2	43.7	20.1	5.2	2.4	1.1	1.9	0.0	0.0	**445**
2003	0.0	17.7	131.9	62.1	42.2	89.8	62.9	29.7	29.1	22.3	8.1	4.0	2.4	0.4	0.4	**503**
2004	0.0	40.3	221.1	140.5	52.7	44.0	56.0	49.7	28.7	20.0	13.7	2.6	2.5	1.4	0.0	**673**
2005	0.0	100.6	161.8	110.2	145.9	36.3	36.8	29.4	32.5	20.7	14.2	5.7	0.3	0.0	0.0	**694**
2006	0.0	7.0	339.9	52.2	53.6	34.3	16.9	15.5	16.6	17.3	11.0	6.3	1.3	1.0	0.0	**573**
2007	0.0	6.3	26.2	100.4	20.9	20.8	15.7	7.3	7.8	7.1	6.5	4.5	2.2	1.4	0.2	**227**
2008	0.0	1.5	117.5	163.5	175.0	26.4	35.2	28.8	14.8	13.5	10.4	10.3	18.7	3.8	3.2	**623**
2009	0.0	43.2	45.7	175.9	66.0	185.1	28.3	25.7	32.9	8.8	15.4	12.1	22.3	2.9	1.5	**666**
2010	0.0	10.2	177.8	45.6	74.8	63.6	72.1	8.4	14.8	10.1	4.1	4.7	5.4	5.4	22.5	**520**
2011	0.0	20.1	59.2	92.8	39.5	57.9	42.0	50.7	10.9	7.9	7.0	8.5	0.7	4.2	8.3	**410**
2012	0.0	12.8	56.8	27.7	27.5	15.3	26.0	26.7	21.8	4.8	15.8	10.8	1.7	4.0	0.7	**252**
2013	0.0	53.7	81.2	138.5	56.9	56.6	33.9	31.9	24.9	25.7	3.6	9.2	3.5	1.1	5.4	**526**
2014	0.0	13.2	331.5	60.6	59.3	20.6	25.3	7.5	12.6	7.8	13.2	1.5	2.7	0.4	6.7	**563**
Average																**452**

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 (1985–2014) 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**
Average																**488**

Table 9. Lower confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2014) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

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

* 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 (1985–2014) 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	*

* 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 (1985–2014) for the Maryland Chesapeake Bay striped bass spawning stock.

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

* 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 2014. 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
2013	1	0.0	0.0	0.0	0.0	0.0	0.0
2012	2	14.2	1.4	0.0	0.0	1.0	13.2
2011	3	527.5	50.3	0.0	0.0	196.1	331.5
2010	4	100.6	9.6	0.0	0.0	40.1	60.6
2009	5	116.0	11.1	0.2	1.3	55.2	59.3
2008	6	45.7	4.4	0.3	6.6	18.2	20.6
2007	7	61.6	5.9	1.8	14.7	19.8	25.3
2006	8	17.8	1.7	1.3	5.3	3.7	7.5
2005	9	37.2	3.5	2.8	12.7	9.1	12.6
2004	10	27.9	2.7	4.1	11.5	4.5	7.8
2003	11	46.0	4.4	7.3	18.6	6.9	13.2
2002	12	4.3	0.4	0.5	1.5	0.8	1.5
2001	13	18.6	1.8	2.5	11.6	1.8	2.7
2000	14	3.9	0.4	0.5	3.0	0.0	0.4
≤1999	15+	27.3	2.6	3.2	17.4	0.0	6.7
Total		1048.7		24.5	104.3	357.1	562.8
% of Total				2	10	34	54
% of Sex				19	81	39	61
% of System				6	16	94	84

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, April through May 2014. 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
2013	1	0.0	0.0	0.0	0.0	0.0	0.0
2012	2	8.5	1.5	0.0	0.0	0.4	8.1
2011	3	279.3	50.1	0.0	0.0	75.6	203.7
2010	4	52.7	9.5	0.0	0.0	15.4	37.2
2009	5	58.6	10.5	0.1	0.8	21.3	36.5
2008	6	23.9	4.3	0.1	4.1	7.0	12.7
2007	7	32.9	5.9	0.7	9.0	7.6	15.6
2006	8	9.8	1.8	0.5	3.3	1.4	4.6
2005	9	20.1	3.6	1.1	7.8	3.5	7.7
2004	10	15.2	2.7	1.6	7.0	1.7	4.8
2003	11	25.0	4.5	2.8	11.4	2.7	8.1
2002	12	2.3	0.4	0.2	0.9	0.3	0.9
2001	13	10.5	1.9	1.0	7.1	0.7	1.7
2000	14	2.3	0.4	0.2	1.9	0.0	0.2
≤1999	15+	16.0	2.9	1.2	10.7	0.0	4.1
Total		557.0		9.4	64.1	137.6	345.9
% of Total				2	12	25	62
% of Sex				13	87	28	72
% of System				6	16	94	84

* 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 2014.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2012	2	POTOMAC	1	306	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	306	-	-	-	-
2011	3	POTOMAC	21	381	361	401	44	10
		UPPER	26	354	329	380	63	12
		COMBINED	47	366	350	383	56	8
2010	4	POTOMAC	10	493	461	525	45	14
		UPPER	5	425	330	521	77	34
		COMBINED	15	471	435	506	64	16
2009	5	POTOMAC	18	567	543	591	48	11
		UPPER	14	513	475	552	66	18
		COMBINED	32	544	521	566	62	11
2008	6	POTOMAC	8	607	573	641	41	14
		UPPER	10	591	543	640	68	21
		COMBINED	18	598	570	626	56	13
2007	7	POTOMAC	15	668	646	689	39	10
		UPPER	23	632	603	660	66	14
		COMBINED	38	646	627	665	59	10
2006	8	POTOMAC	9	718	680	756	50	17
		UPPER	12	749	713	785	56	16
		COMBINED	21	736	711	761	55	12
2005	9	POTOMAC	5	746	645	847	81	36
		UPPER	32	768	743	793	70	12
		COMBINED	37	765	741	789	71	12
2004	10	POTOMAC	0	-	-	-	-	-
		UPPER	26	821	789	854	80	16
		COMBINED	26	821	789	854	80	16
2003	11	POTOMAC	2	902	699	1105	23	16
		UPPER	33	853	830	876	65	11
		COMBINED	35	856	834	878	64	11
2002	12	POTOMAC	0	-	-	-	-	-
		UPPER	2	852	*	*	70	50
		COMBINED	2	852	*	*	70	50
2001	13	POTOMAC	2	854	*	*	131	93
		UPPER	5	888	821	954	54	24
		COMBINED	7	878	812	944	71	27
2000	14	POTOMAC	0	-	-	-	-	-
		UPPER	1	986	-	-	-	-
		COMBINED	1	986	-	-	-	-
1999	15	POTOMAC	0	-	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	0	-	-	-	-	-
1998	16	POTOMAC	0	-	-	-	-	-
		UPPER	2	1007	721	1292	32	23
		COMBINED	2	1007	721	1292	32	23

* 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 2014.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2008	6	POTOMAC	1	651	-	-	-	-
		UPPER	1	701	-	-	-	-
		COMBINED	2	676	358	994	35	25
2007	7	POTOMAC	4	806	693	919	71	35
		UPPER	4	747	623	870	77	39
		COMBINED	8	776	713	840	76	27
2006	8	POTOMAC	1	815	-	-	-	-
		UPPER	1	858	-	-	-	-
		COMBINED	2	837	563	1110	30	22
2005	9	POTOMAC	5	883	821	945	50	22
		UPPER	12	835	772	898	99	29
		COMBINED	17	849	804	895	89	22
2004	10	POTOMAC	4	974	896	1051	49	24
		UPPER	20	898	871	925	58	13
		COMBINED	24	911	885	937	62	13
2003	11	POTOMAC	13	967	927	1007	66	18
		UPPER	37	956	931	981	74	12
		COMBINED	50	959	939	979	71	10
2002	12	POTOMAC	4	1007	940	1073	42	21
		UPPER	3	954	778	1131	71	41
		COMBINED	7	984	931	1037	58	22
2001	13	POTOMAC	3	1089	1036	1141	21	12
		UPPER	5	1068	1011	1125	46	21
		COMBINED	8	1076	1044	1108	38	13
2000	14	POTOMAC	1	991	-	-	-	-
		UPPER	3	1048	973	1122	30	17
		COMBINED	4	1034	974	1093	37	19
1999	15	POTOMAC	3	1121	979	1264	57	33
		UPPER	4	1099	1025	1172	46	23
		COMBINED	7	1108	1064	1153	48	18
1998	16	POTOMAC	0	-	-	-	-	-
		UPPER	4	1092	1023	1160	43	21
		COMBINED	4	1092	1023	1160	43	21
1997	17	POTOMAC	0	-	-	-	-	-
		UPPER	3	1100	939	1260	65	37
		COMBINED	3	1100	939	1260	65	37
1996	18	POTOMAC	1	1126	-	-	-	-
		UPPER	4	1200	1142	1257	36	18
		COMBINED	5	1185	1129	1241	45	20

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
Average	**336**	**229**

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2014.

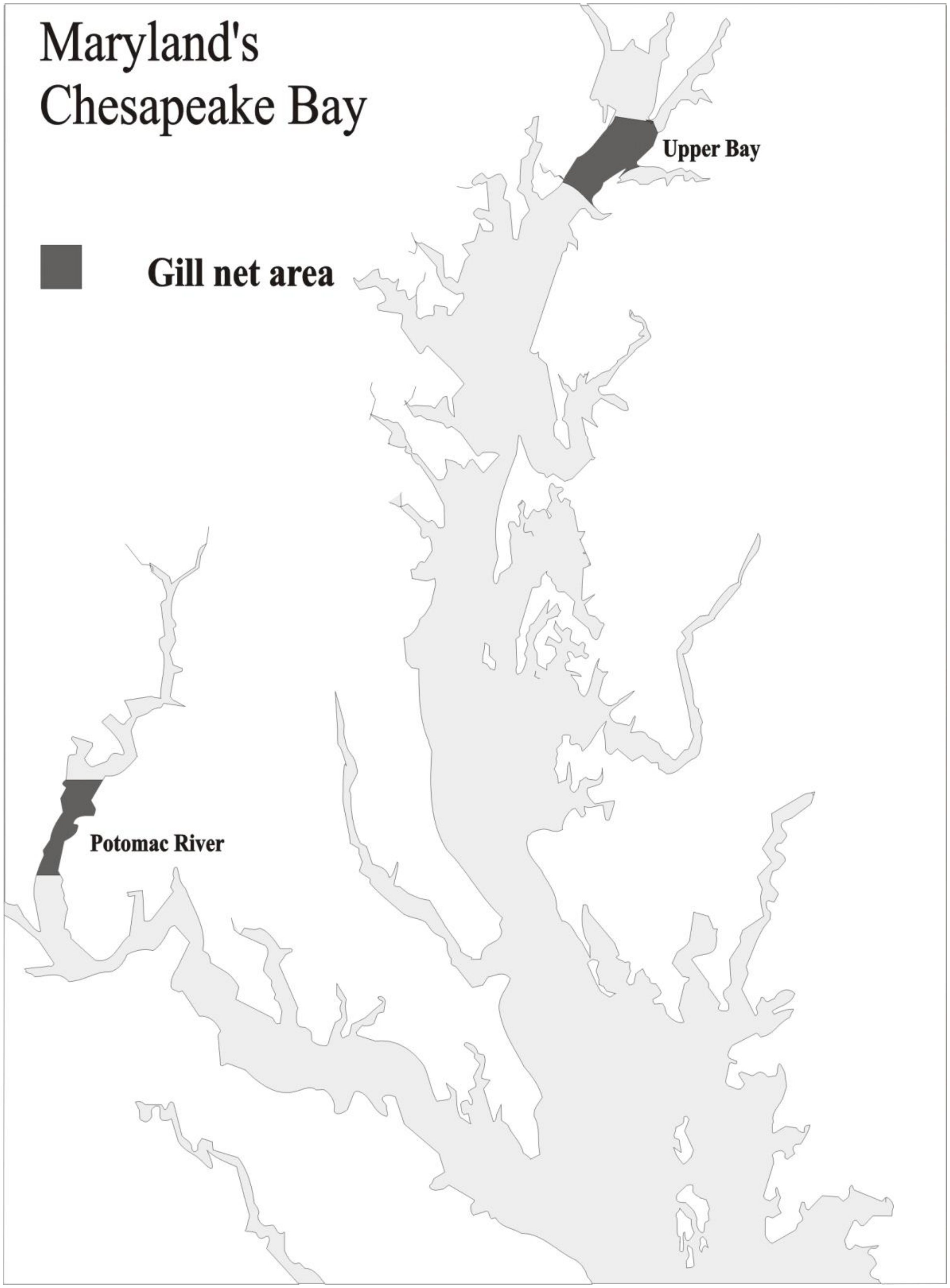


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, April through May 2014. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

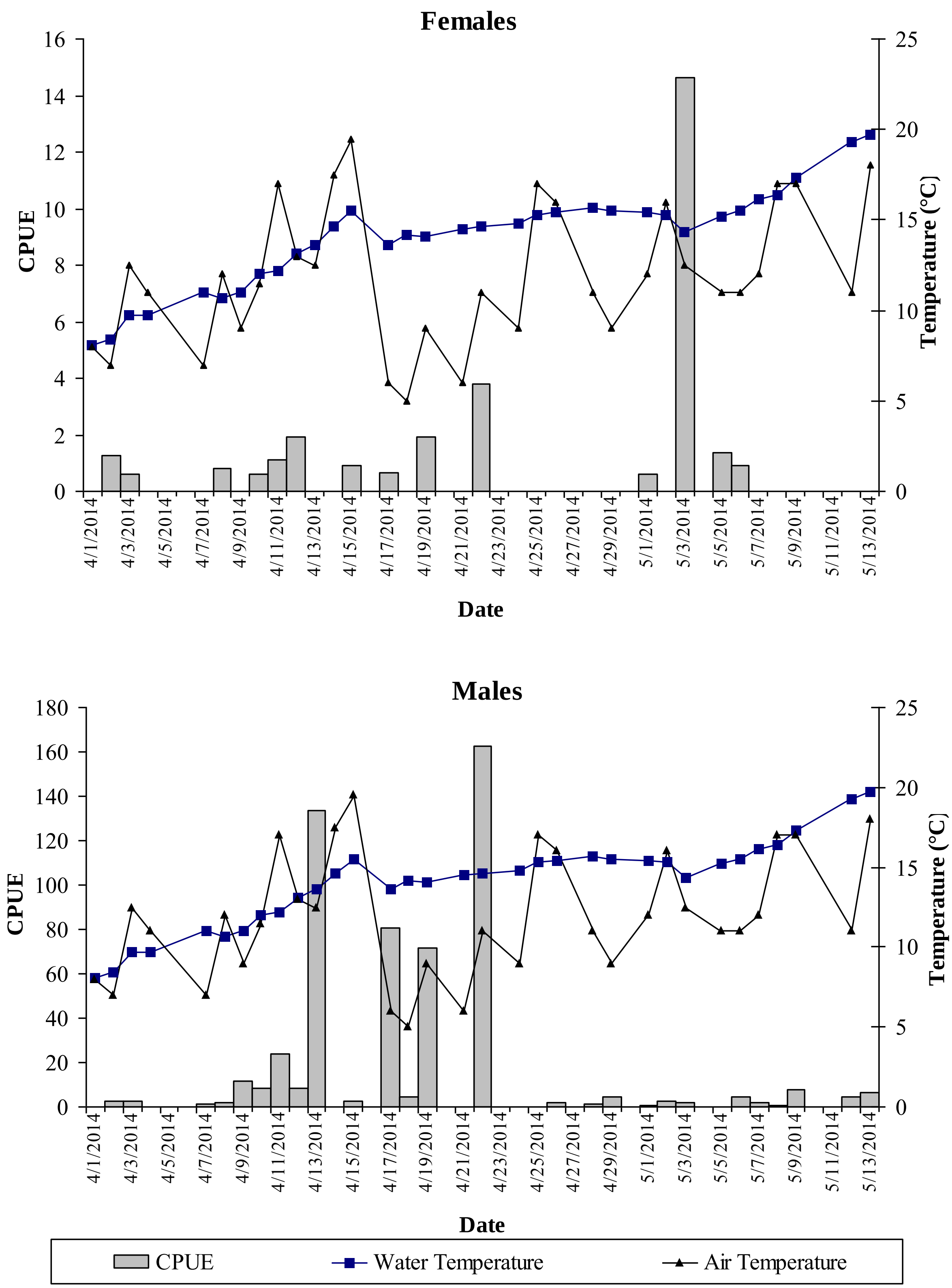


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Upper Chesapeake Bay, April through May 2014. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

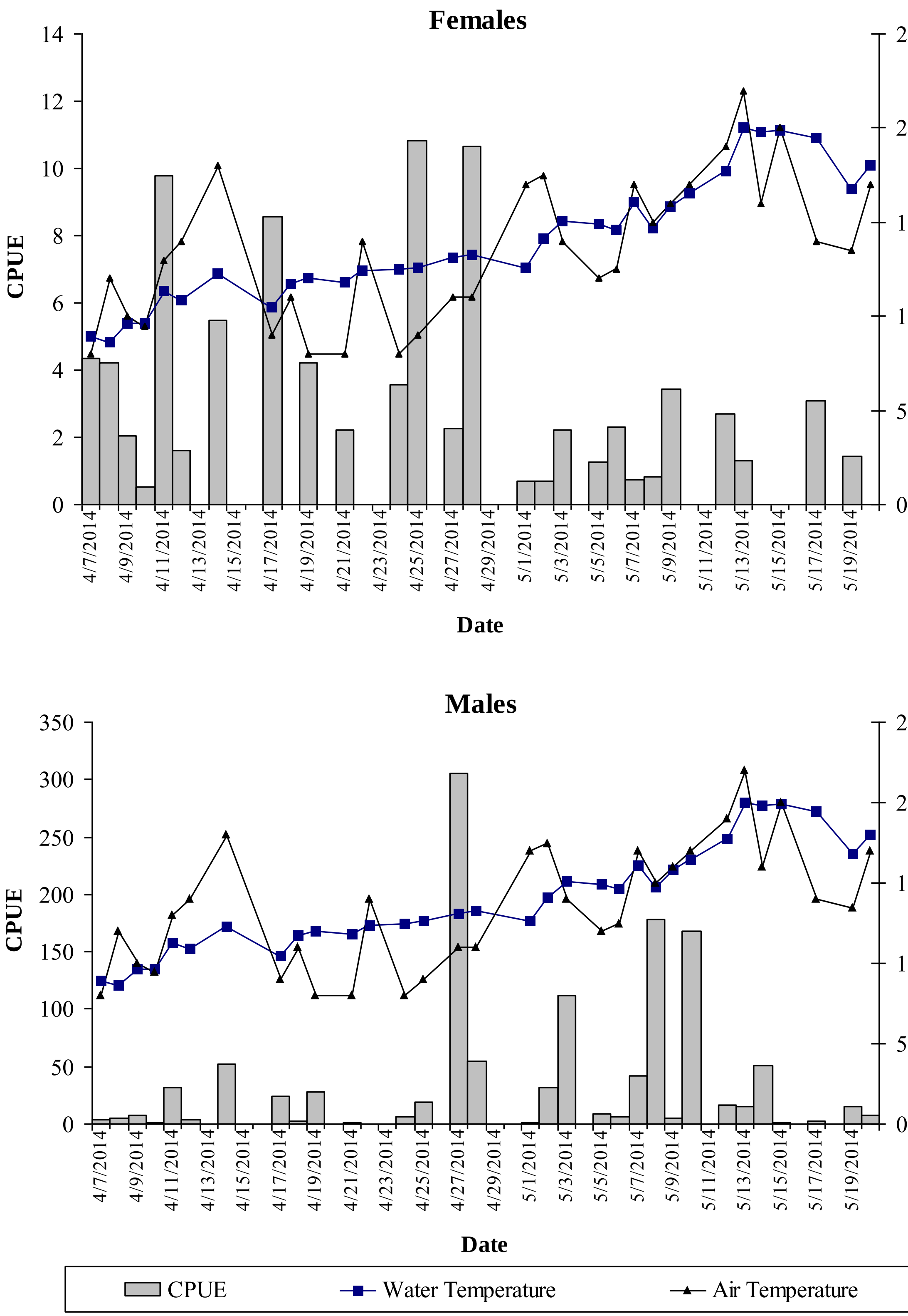
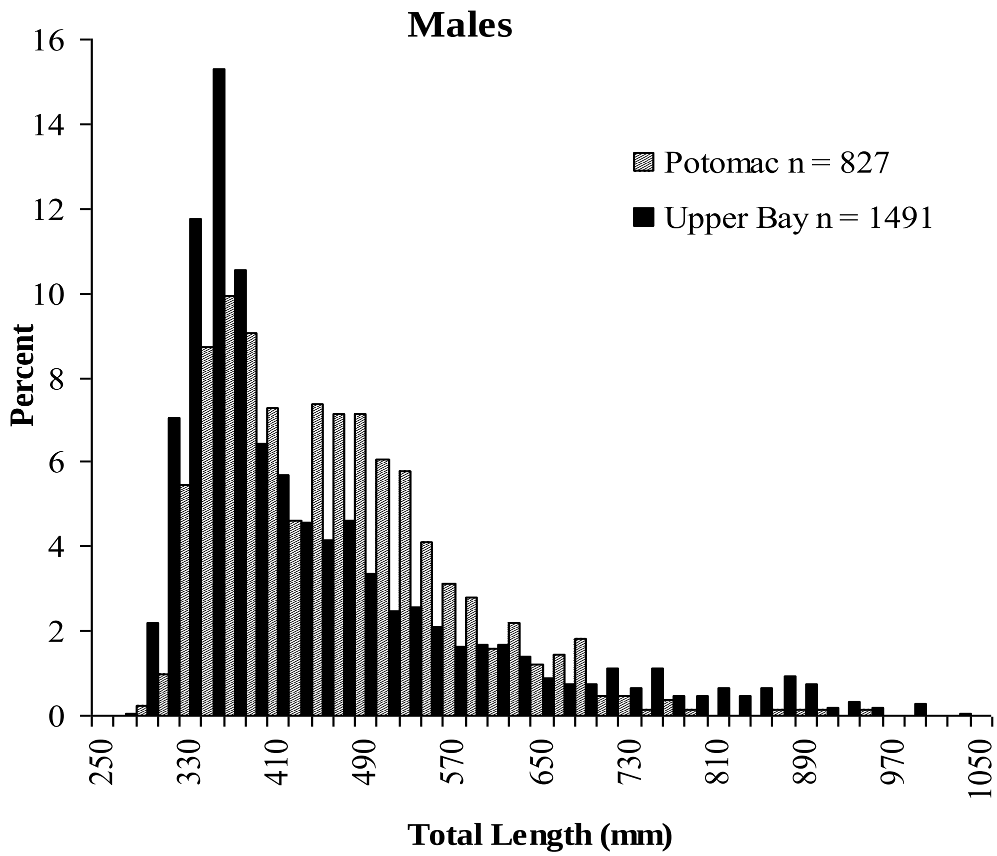


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, April through May 2014. Note different scales.



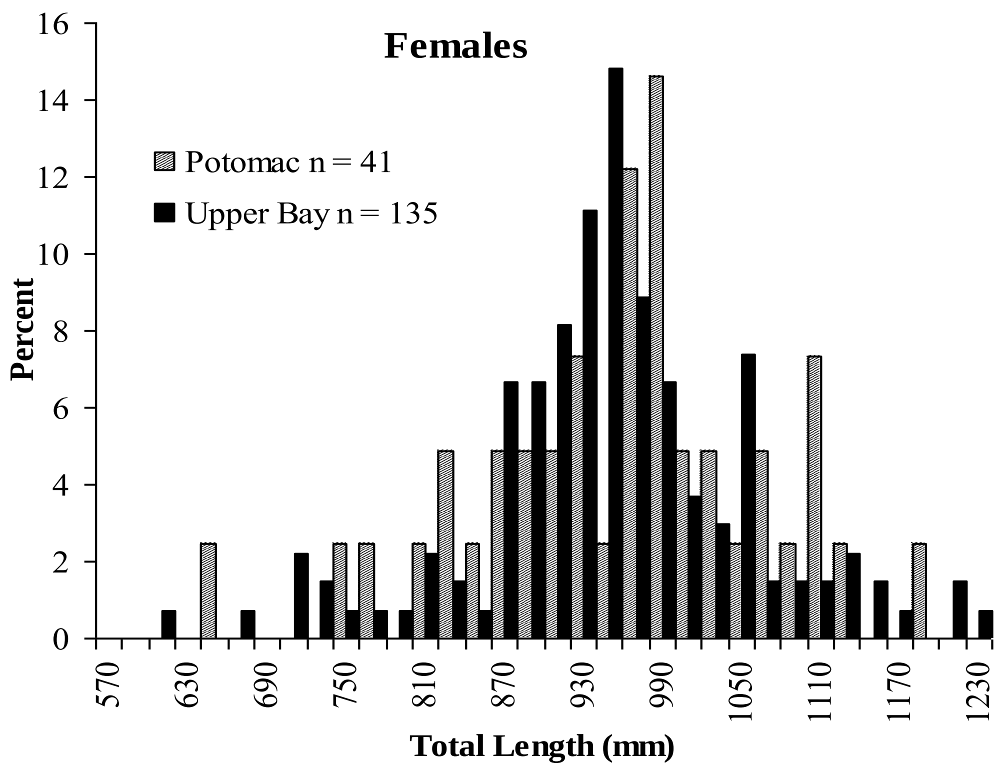
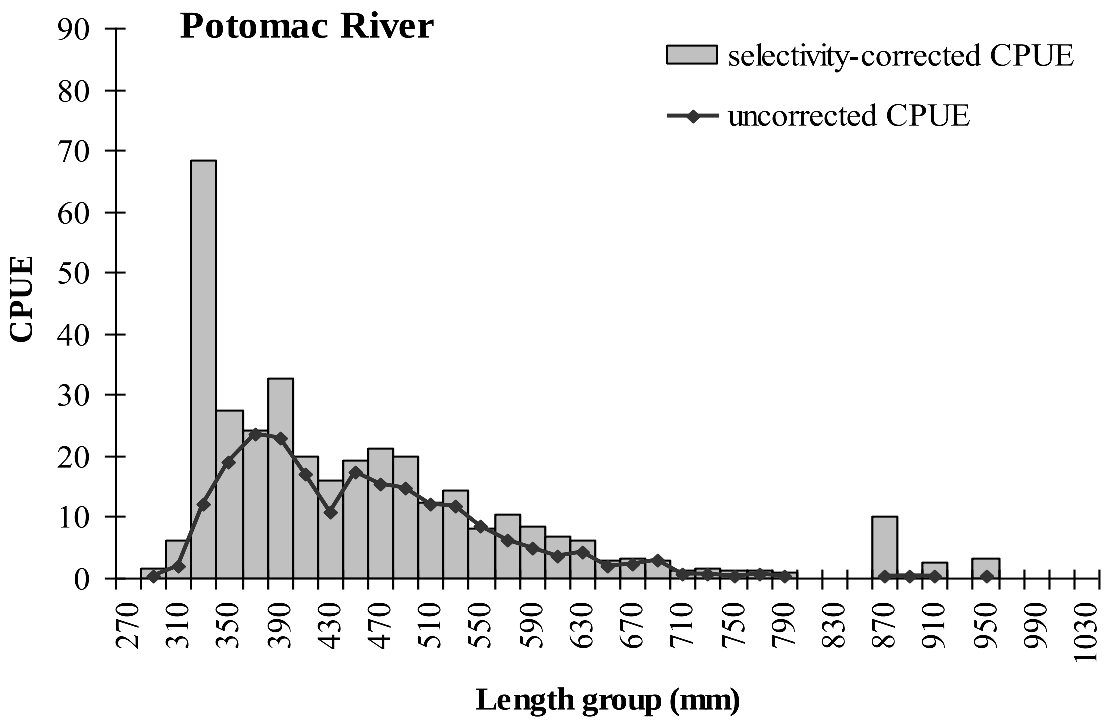


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2014. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



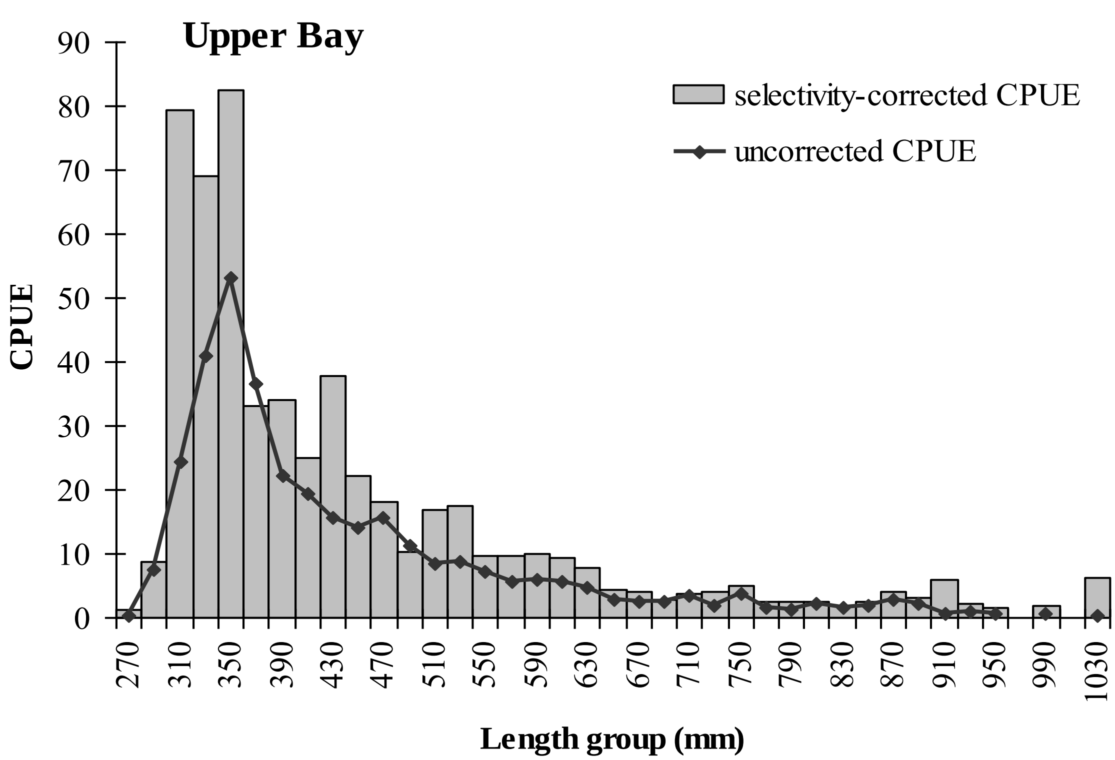
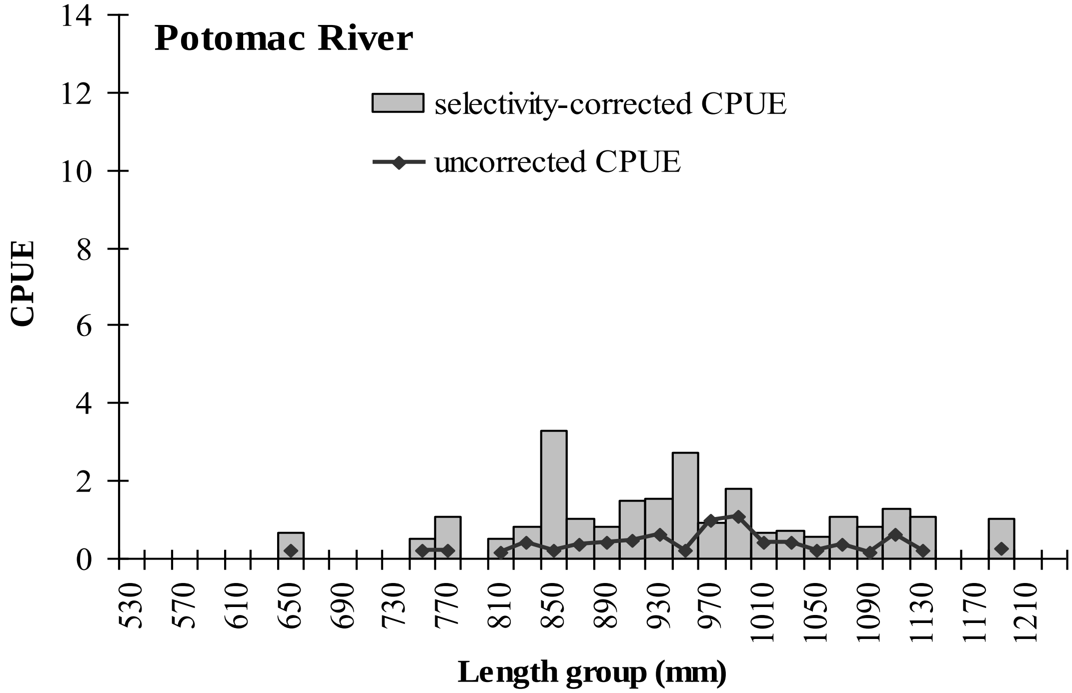


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, April - May 2014. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



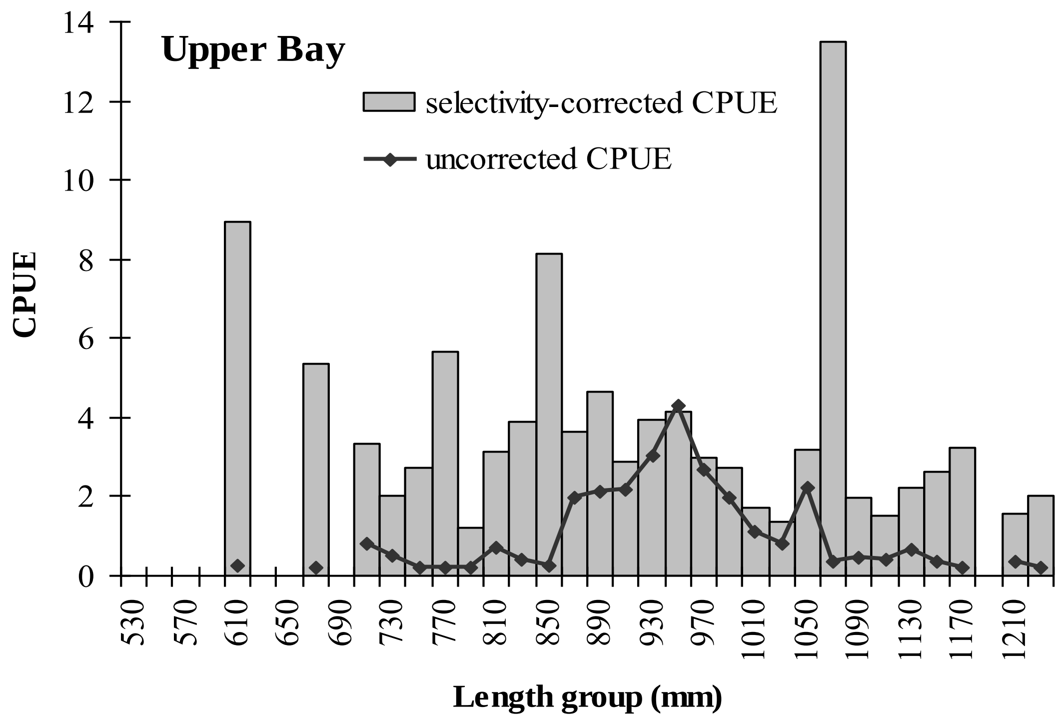


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during April through May, 1985-2014. Error bars are ± 2 standard errors (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

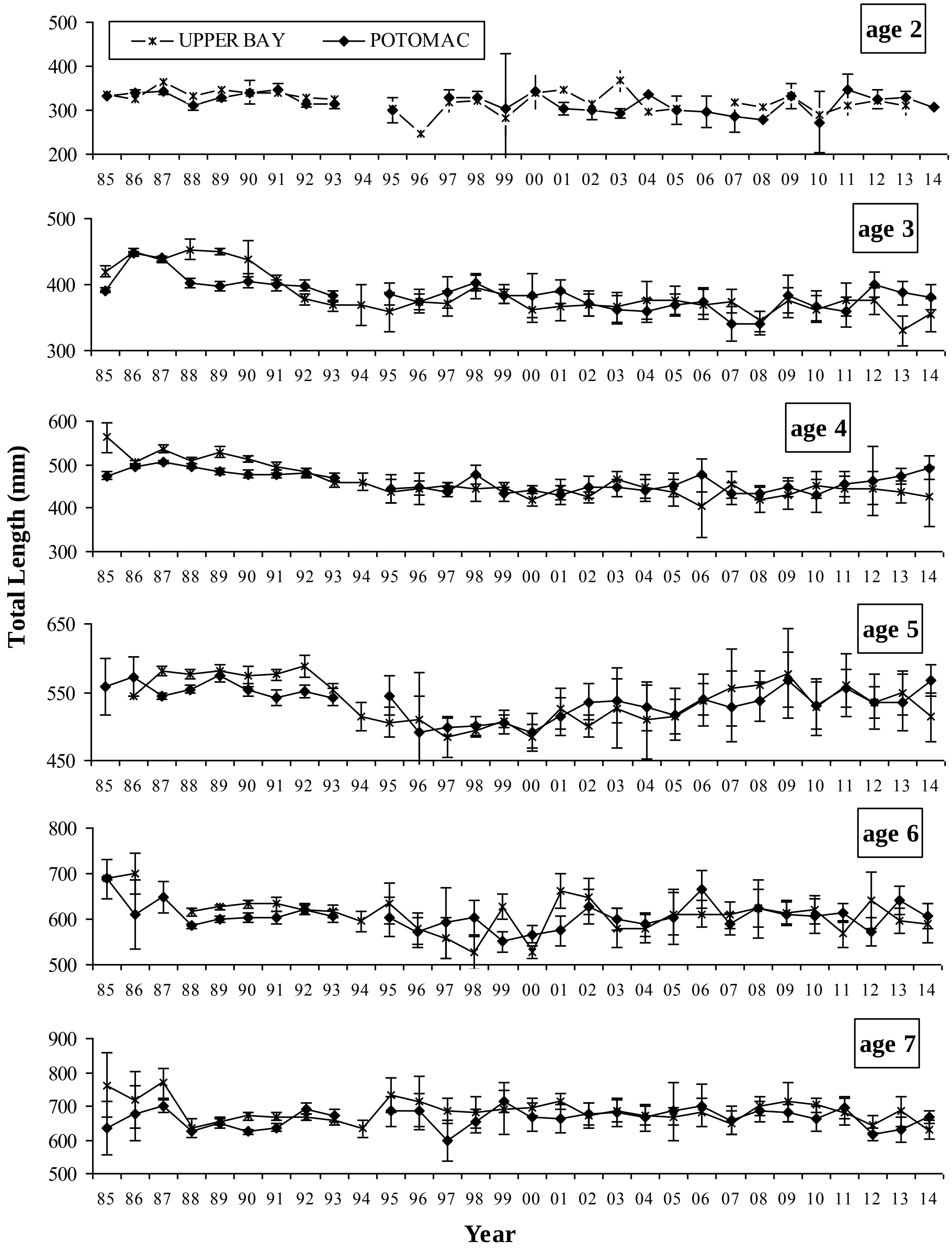


Figure 7. Continued.

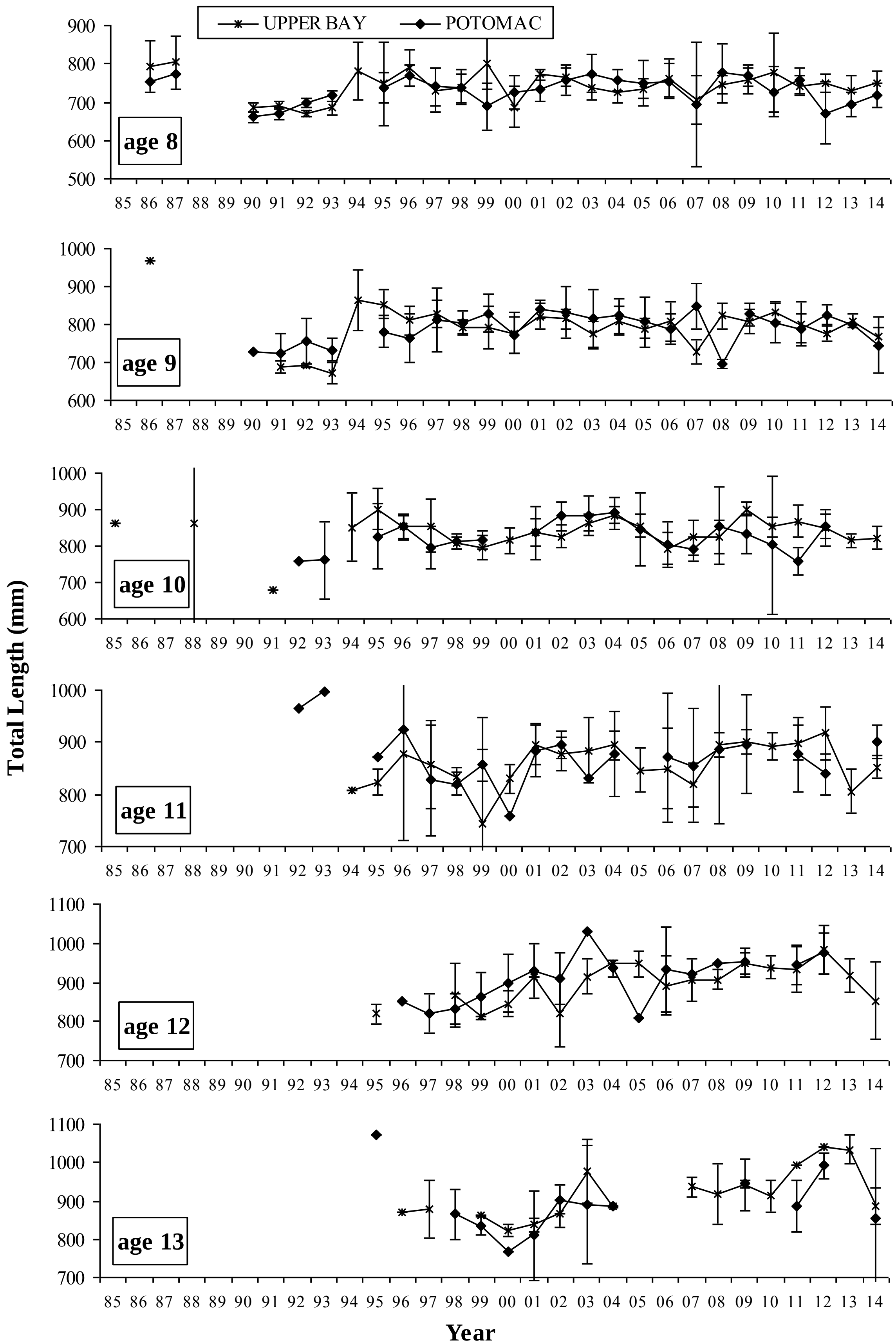


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during April through May, 1985–2014. Error bars are ± 2 standard errors (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

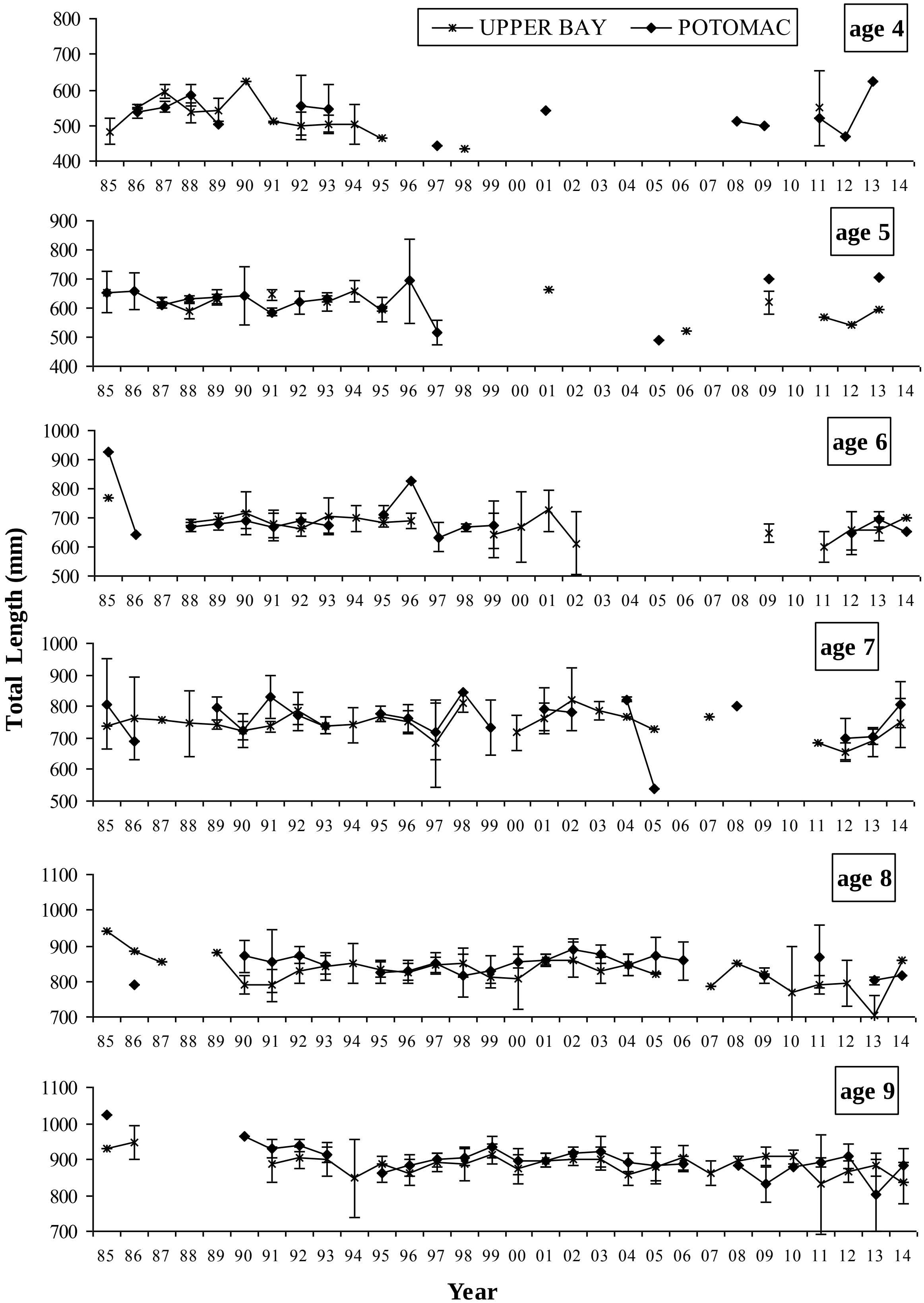


Figure 8. Continued.

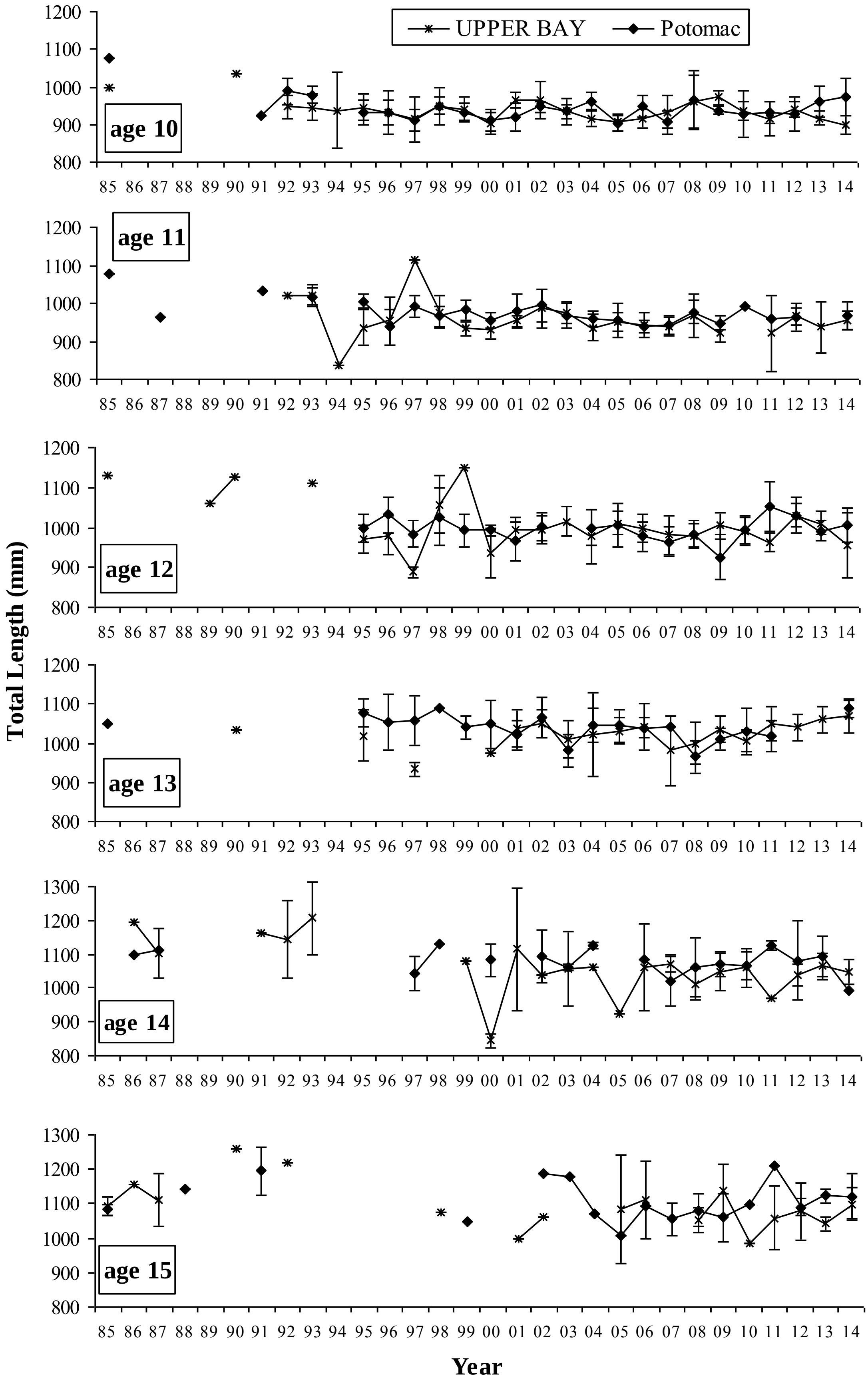


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15+. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

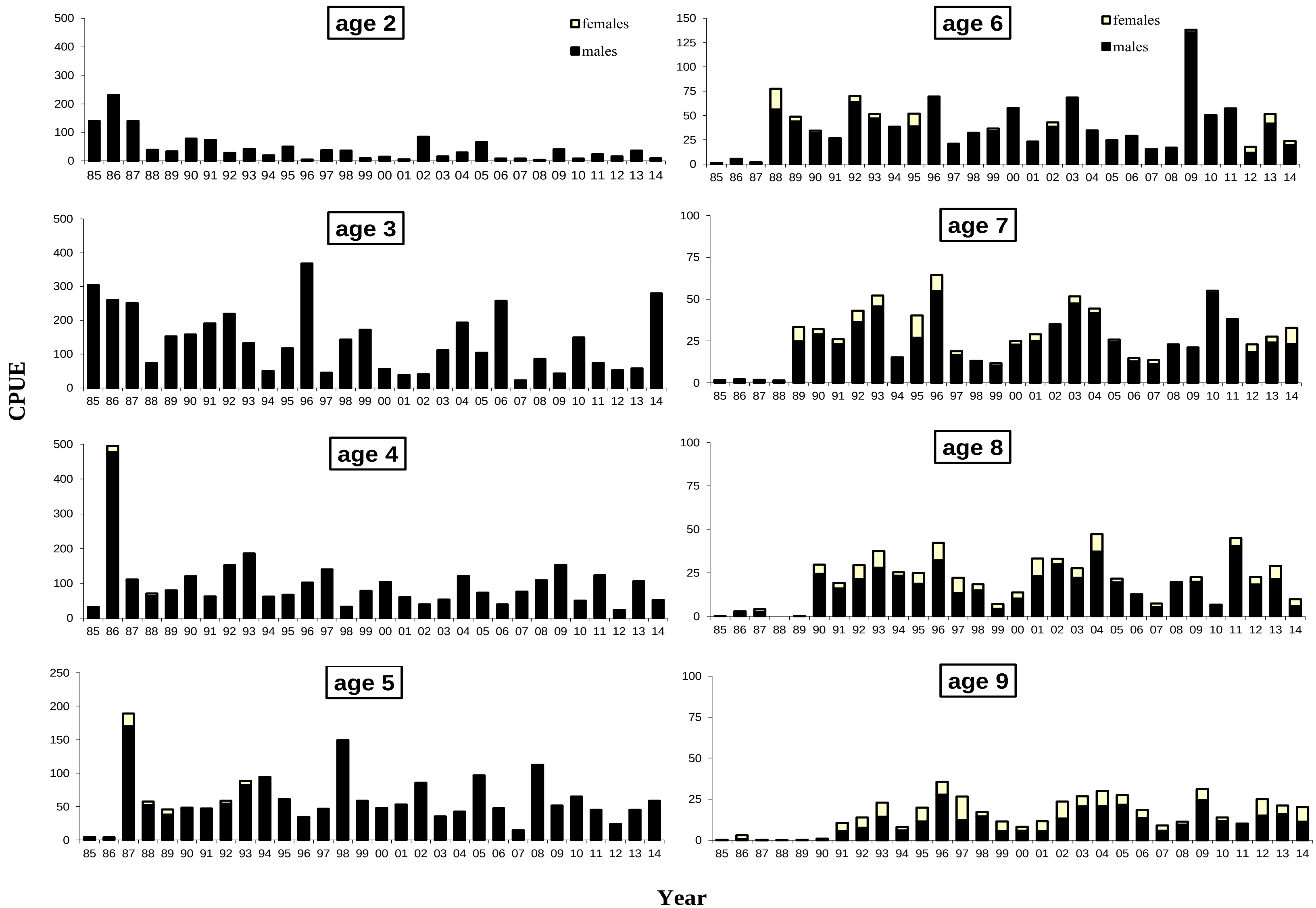


Figure 9. Continued.

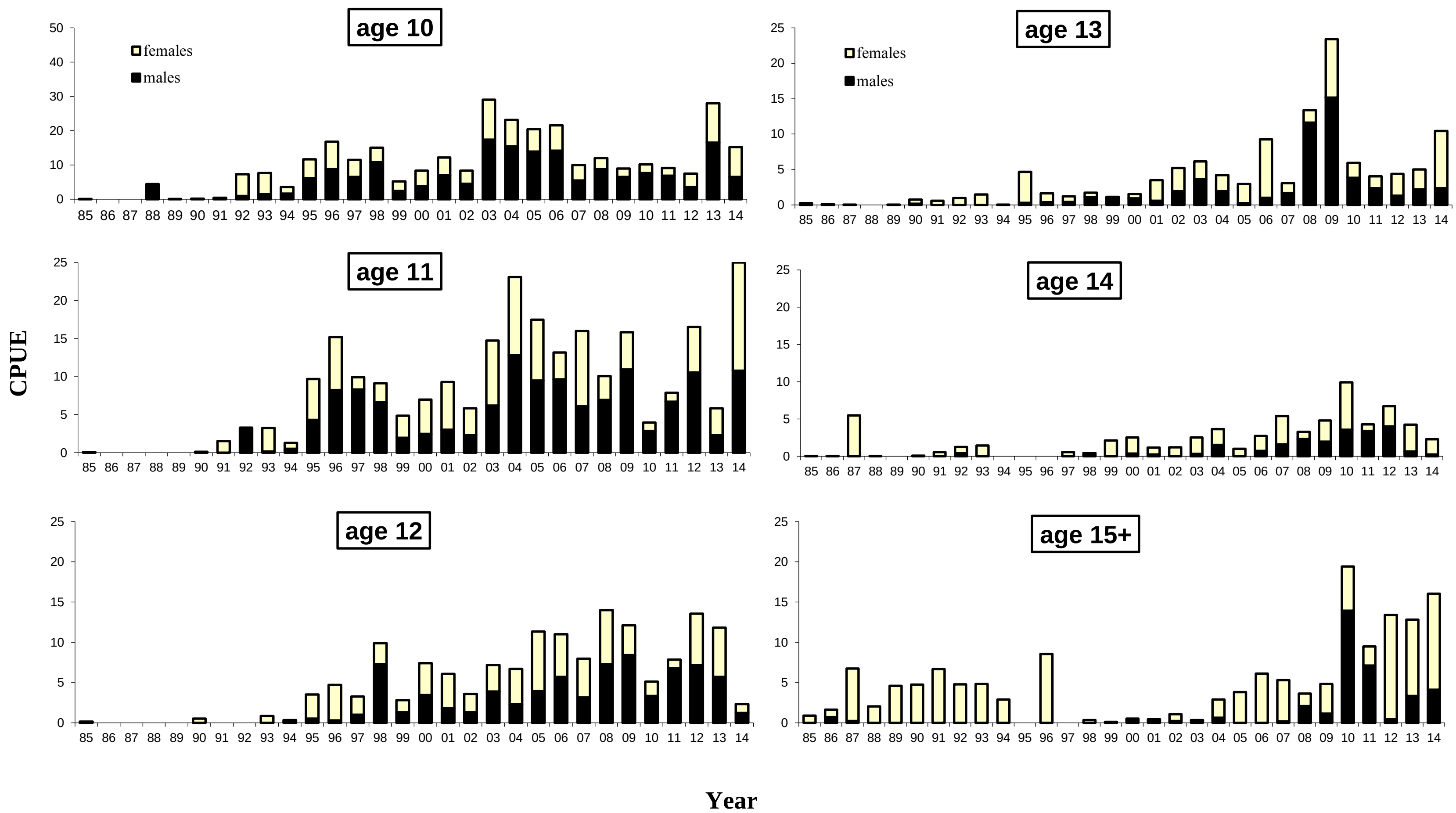
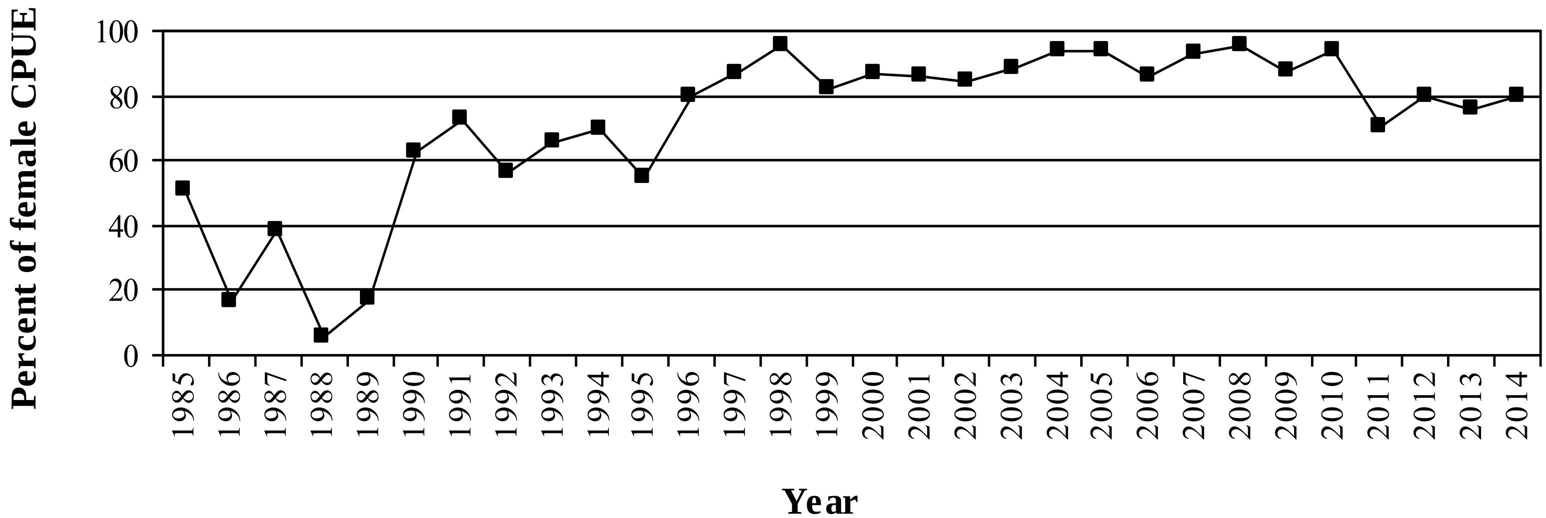
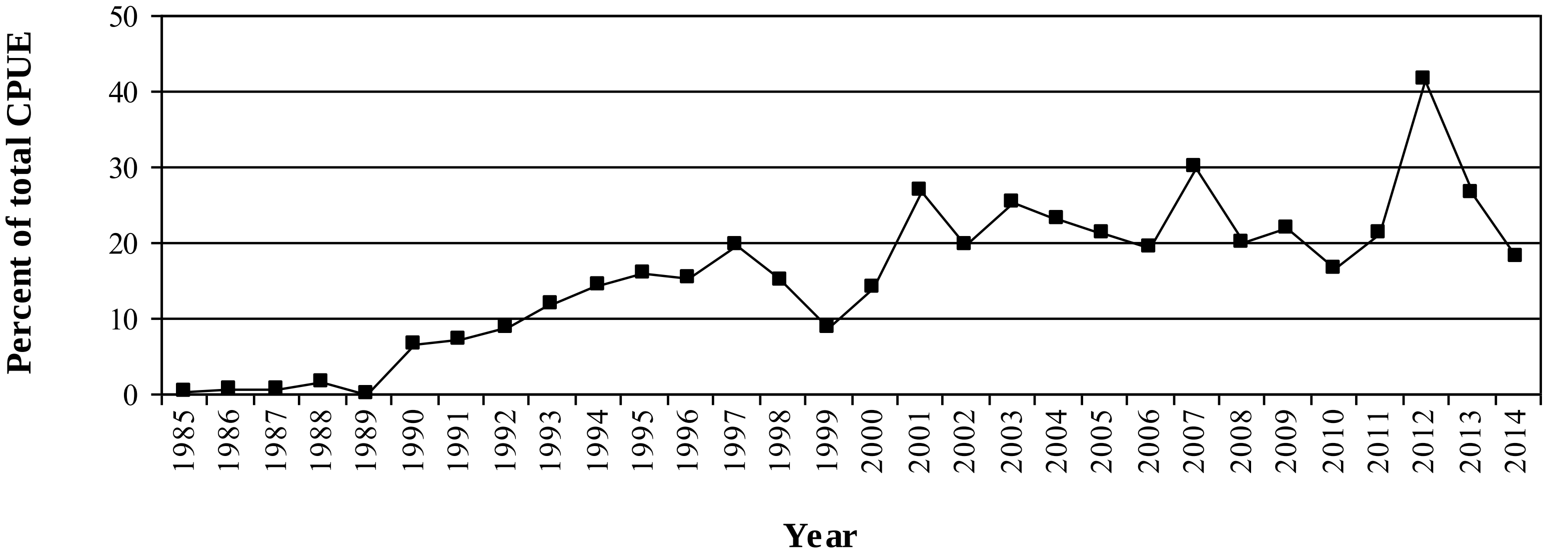


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, April through May, 1985-2014 (Choptank River to 1996). Effort is standardized 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.



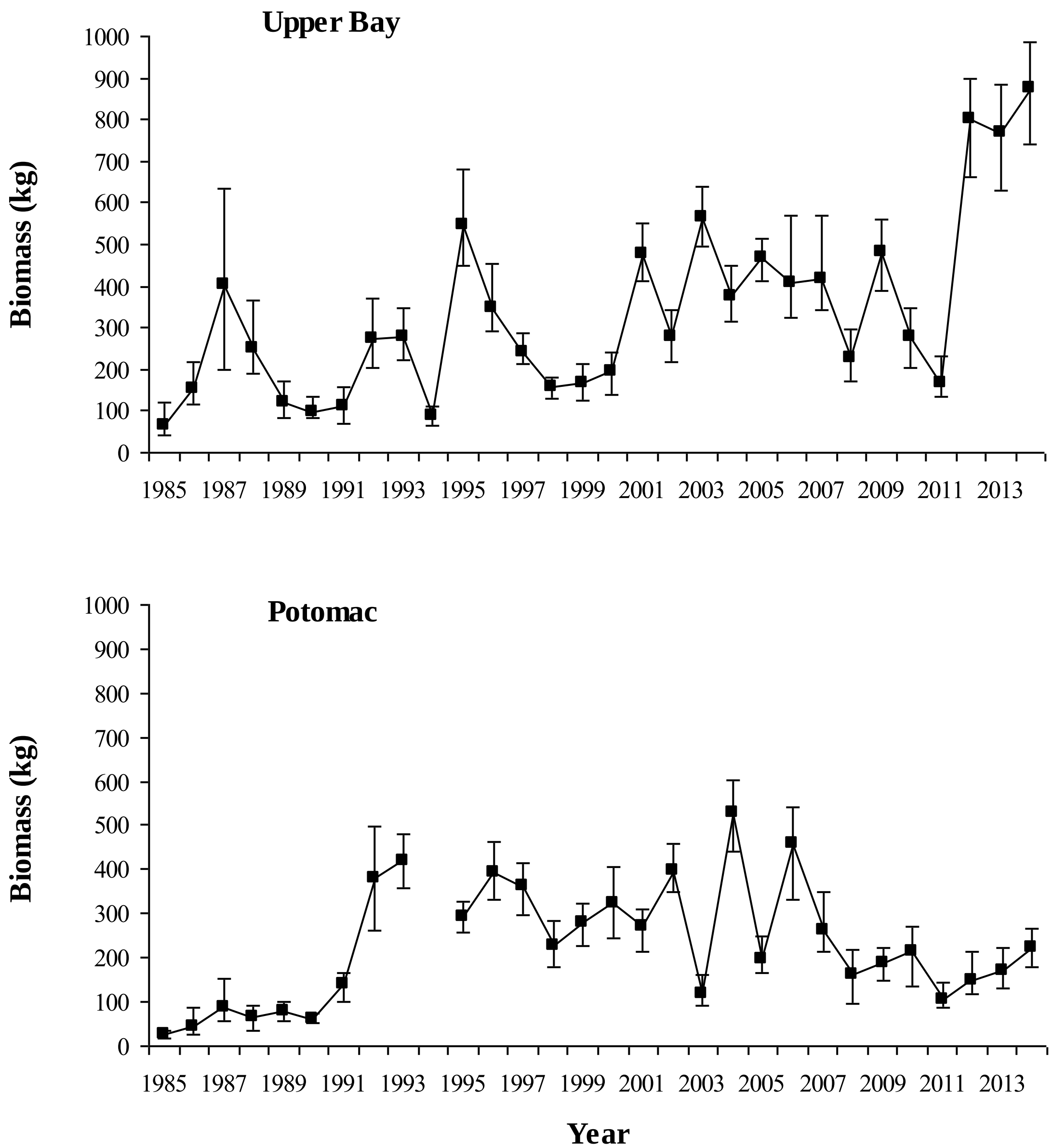
* Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385. (Hollis 1967).

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, 1985-2014 (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, 1985-2014. 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. Stations have been sampled continuously since 1954, with changes in some station locations.

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 other river systems. 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), the Patuxent River, and the Nanticoke 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 $\pm$ 2 standard errors), and provide a visual depiction of sample variability.

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

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

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

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

RESULTS

Bay-wide Means

A total of 1,454 YOY striped bass was collected at permanent stations in 2014, with individual samples yielding between 0 and 144 fish. The AM (11.0) and GM (4.06) were both nearly equal to their respective time-series averages and TPAs (Tables 2 and 3, Figures 2 and 3). The PPHL was 0.77, indicating that 77% 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 2014 $\log_e$-mean was significantly lower than 12 years of the time-series, and greater than 24 years of the time-series. The 2014 year-class was indiscernible from 21 other year-classes.

System Means

Head of Bay - In 42 samples, 639 juveniles were collected at the Head of Bay sites for an AM of 15.2, greater than the time-series average (11.7) but less that the TPA of 17.3 (Table 2, Figure 5). The GM of 8.02 exceeded both the time-series average (5.55) and 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 2014 Head of Bay $\log_e$-mean significantly less than just one year of the time-series and significantly greater than 29 years of the time-series. The 2014 Head of Bay index was indiscernible from 27 other year-classes in the time-series.

Potomac River - A total of 98 juveniles was collected in 42 samples on the Potomac River. The AM of 2.3 was less than the TPA (9.2) and the time-series average (8.2) (Table 2, Figure 5). The GM of 1.07 was also less than the TPA (3.93) and time-series average (3.57) (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 2014 Potomac River year-class significantly smaller than 27 years, and indiscernible from the remaining 30 year of the time-series.

Choptank River - A total of 301 juveniles was collected in 24 Choptank River samples. The AM of 12.5 was between the time-series average of 21.2 and the TPA of 10.8 (Table 2, Figure 5). The GM of 6.28 was also between its time-series average (8.01) 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 2014 Choptank River year-class significantly smaller than 10 years, significantly larger than 20 years of the time-series, and indiscernible from 27 other years of the time-series.

Nanticoke River - A total of 416 juveniles was collected in 24 samples on the Nanticoke River. The AM of 17.3 exceeded the time-series average (8.5) and TPA (8.6) (Table 2, Figure 5). The GM of 5.10 exceeded its time-series average (3.79) 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 2014 index significantly smaller than four years of the time-series and larger than 24 years of time-series. The 2014 Nanticoke River index was statistically indiscernible from the remaining 29 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 80 juveniles were caught in 15 samples, resulting in an AM of 5.3, which was less than its time-series average of (5.6). The GM of 4.34 was greater than the time-series average of 2.75 (Table 5).

On the **Patuxent River**, 92 YOY striped bass were caught in 18 samples for an AM of 5.1 and a GM of 2.70. Both Patuxent River indices were less than their time-series averages but greater than their respective time-series medians (Table 5).

DISCUSSION

Striped bass recruitment in Maryland's portion of the Chesapeake Bay was approximately equal to the long-term average in 2014 (Figures 2 and 3). Although YOY striped bass appeared in only 77% of samples (PPHL=0.77), this was primarily due to poor recruitment in the Potomac River. If the Potomac River is excluded from the analysis, YOY striped bass occurred in 88% of samples.

Recruitment in individual systems was variable. Recruitment was lowest in the Potomac River, which depressed the Bay-wide index to a level just below average in a year when all other systems performed well. The Head of Bay, Nanticoke River, and Choptank River all produced GM indices that exceeded their respective benchmark target period averages (TPAs).

The Potomac River was the only study area in which the juvenile index did not increase relative to 2013. Only 52% of Potomac River samples captured YOY striped bass, resulting in a GM ranked in just the 27th percentile of the time-series. This was the lowest ranked index in any system surveyed. Poor recruitment in the Potomac River appears to be the result of lethally cold water temperatures on the spawning grounds when striped bass eggs were present. Long-term water quality monitoring stations in Mattawoman Creek, located centrally in the Potomac River spawning area, recorded multiple incidents of water temperatures below 12° C, the level deemed lethal for striped bass eggs (Fay et al. 1983): April 16, 8.6° C; April 17, 11.9° C; April 24, 11.4° C. Biologists conducting spawning stock surveys (Project 2, Job 3, Task 2, this report) observed striped bass eggs visible on the surface of the Potomac River on April 19, indicating very recent spawning activity, which may have been killed by these temperature fluctuations. Lethally cold drops in water temperature during known striped bass spawning periods were not observed on the other spawning rivers surveyed (http://mddnr.chesapeakebay.net/eyesonthebay).

In contrast to the Potomac, spawning was very successful in the Head of Bay area, as indicated by above-average AM and GM indices. Duncan's multiple range test ranked Head of Bay recruitment lower than just one year of the 61 year time-series. YOY striped bass were caught with greater frequency here than any other system, occurring in 95% of samples.

The Nanticoke River produced the highest AM of any area surveyed, and the GM ranked in the 78th percentile of the 61-year time-series. Duncan's Multiple Range test ranked Nanticoke River recruitment lower than only the best 4 years of the time-series.

Although recruitment indices in the Choptank River were slightly below their time-series averages, they exceeded their respective target period averages (TPAs). Time-series averages in the Choptank are heavily influenced by very large values produced by dominant year-classes making comparisons difficult. The Choptank River GM ranked in the 71st 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: $C_1=(0.18695)(C_0)- 0.07039$, 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 (0.11) was less than the index of 0.21 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.

CITATIONS

ASMFC. 1989. Supplement to the Striped Bass Fisheries Management Plan - Amendment #4. Special Report No. 15.

Fay C.F., R.J. Neves and G.B. Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic). Striped bass. Publ. No. FWS/OBS-82/11.8. National Coastal Ecosystems Team, Division of Biological Services, US Fish and Wildlife Service, US Department of the Interior. Washington, DC.

Gibson, M.R. 1993. Historical Estimates of Fishing Mortality on the Chesapeake Bay Striped Bass Stock Using Separable Virtual Population Analysis to Market Class Catch Data. In: A Report to the ASMFC Striped Bass Technical Committee, Providence RI Meeting, July 19-20, 1993.

Goodyear, C.P. 1985. Relationship between reported commercial landings and abundance of young striped bass in Chesapeake Bay, Maryland. Transactions of the American Fisheries Society. 114: 92-96.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York, New York. 257 pp.

Heimbuch, D.G., P.W. Jones, and B.J. Rothschild. 1983. An analysis of Maryland's juvenile striped bass index of abundance. Technical Memorandum No. 6, UMCEES Ref. No. 83-51 CBL.

McConnaughey, R.A., and L.L. Conquest. 1992. Trawl survey estimation using a comparative approach based on lognormal theory. Fishery Bulletin, U.S. 91:107-118 (1993).

MD DNR. 1994. Investigation of striped bass in Chesapeake Bay. USFWS Federal Aid Performance Report. Project No. F-42-R-7. Maryland Department of Natural Resources, Maryland Tidewater Administration, Fisheries Division.

Richards, A.R. 1992. Incorporating Precision into a Management Trigger Based on Maryland's Juvenile Index. National Marine Fisheries Service, Woods Hole, MA 02543

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

SAS. 1990. SAS/STAT User's Guide, Version 6, Fourth Edition, Volumes 1 and 2. SAS Institute Inc. Cary, N.C., 27511. 1677 pp.

Schaefer, R.H. 1972. A short range forecast function for predicting the relative abundance of striped bass in Long Island waters. N.Y. Fish & Game Journal, 19 (2): 178-181.

Sokol, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman Company. 859 pp.

Wilson, H.T., and S.B. Weisberg. 1991. Design considerations for beach seine surveys. Coastal Environmental Services, Inc. 1099 Winterson Road, Suite 130 Linthicum, MD 21090. Versar, Inc. 9200 Rumsey Road, Columbia, MD 21045.

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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
37	Nanticoke River	0.3 miles above Lewis Landing
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
Average	11.7	8.2	21.2	8.5	11.7
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
Average	5.55	3.57	8.01	3.79	4.21
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
Average	11.8	210.1	1.44	92.81	0.71	0.63	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	42.5	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
Average	23.83	6.53		5.64	2.75	
Median	3.72	2.22		3.55	1.97	

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	N/A

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

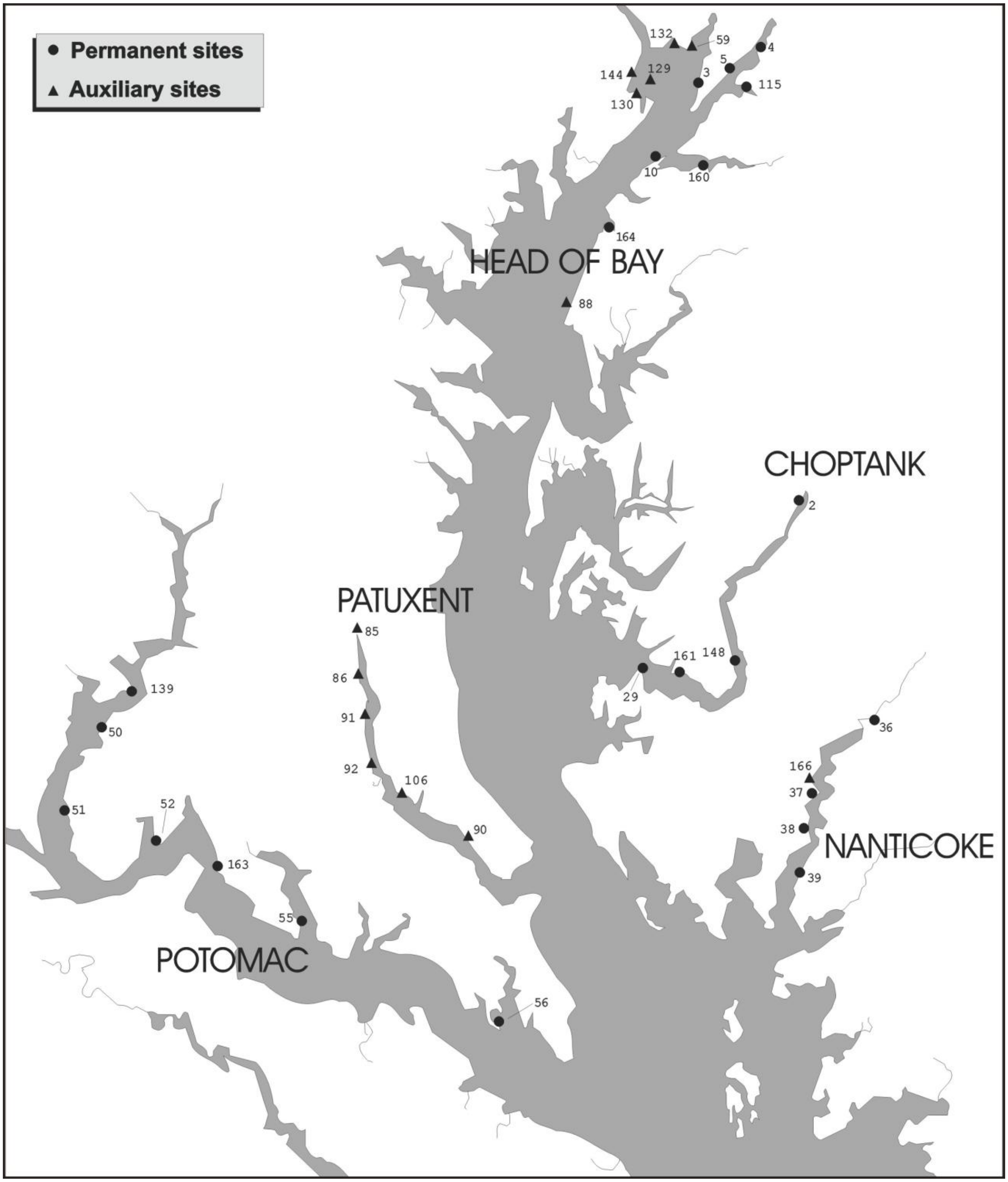


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

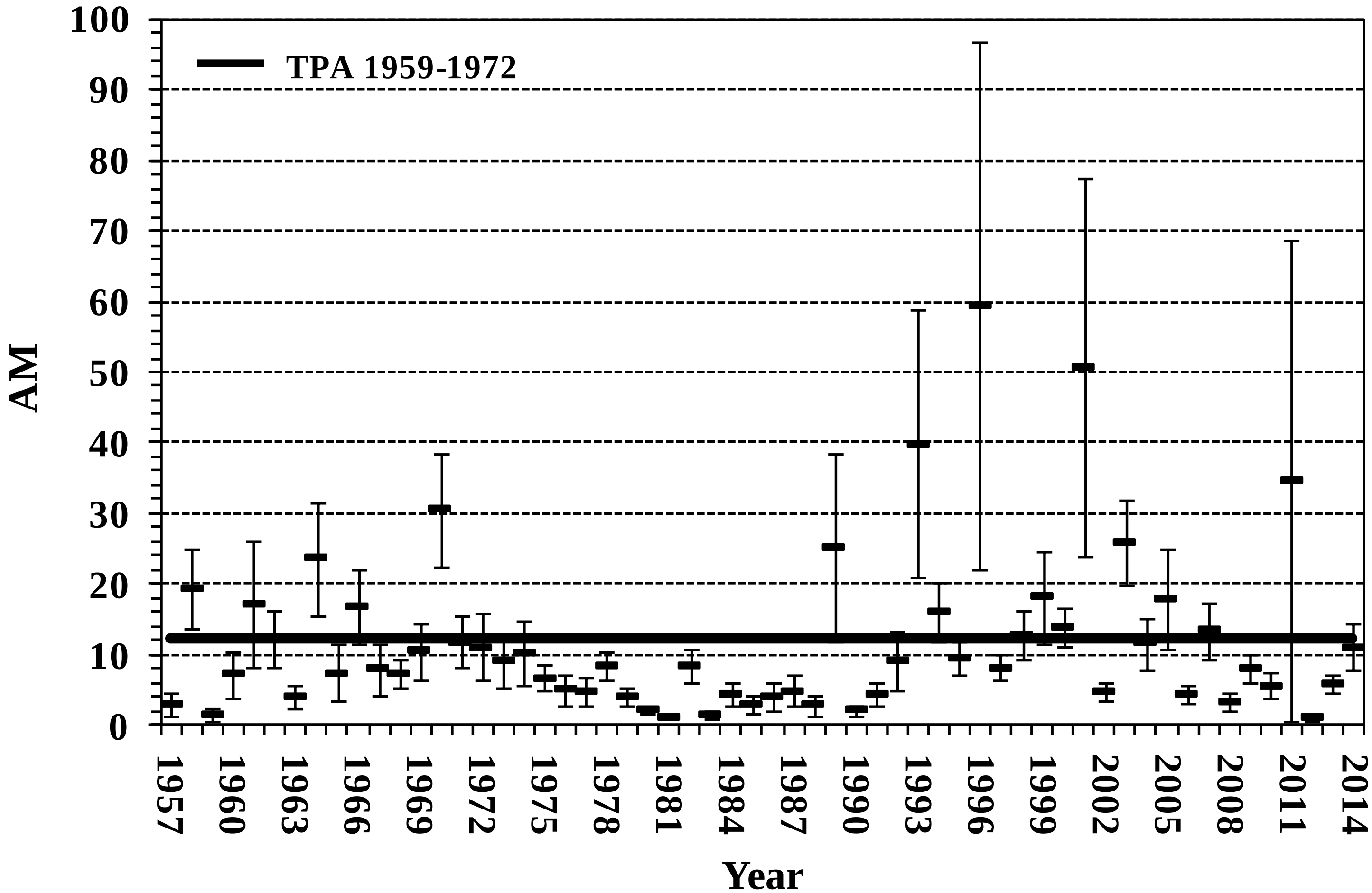


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

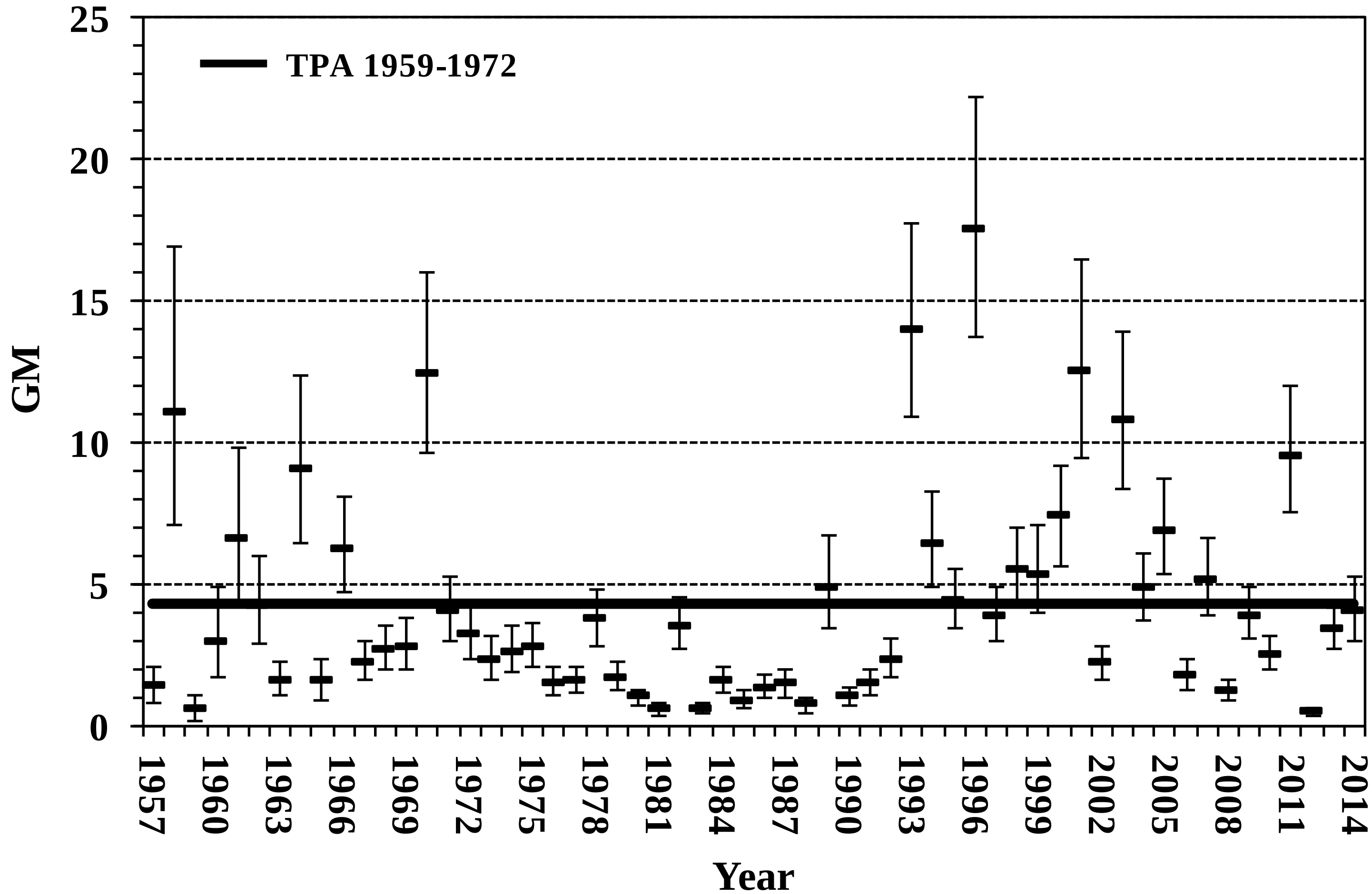


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

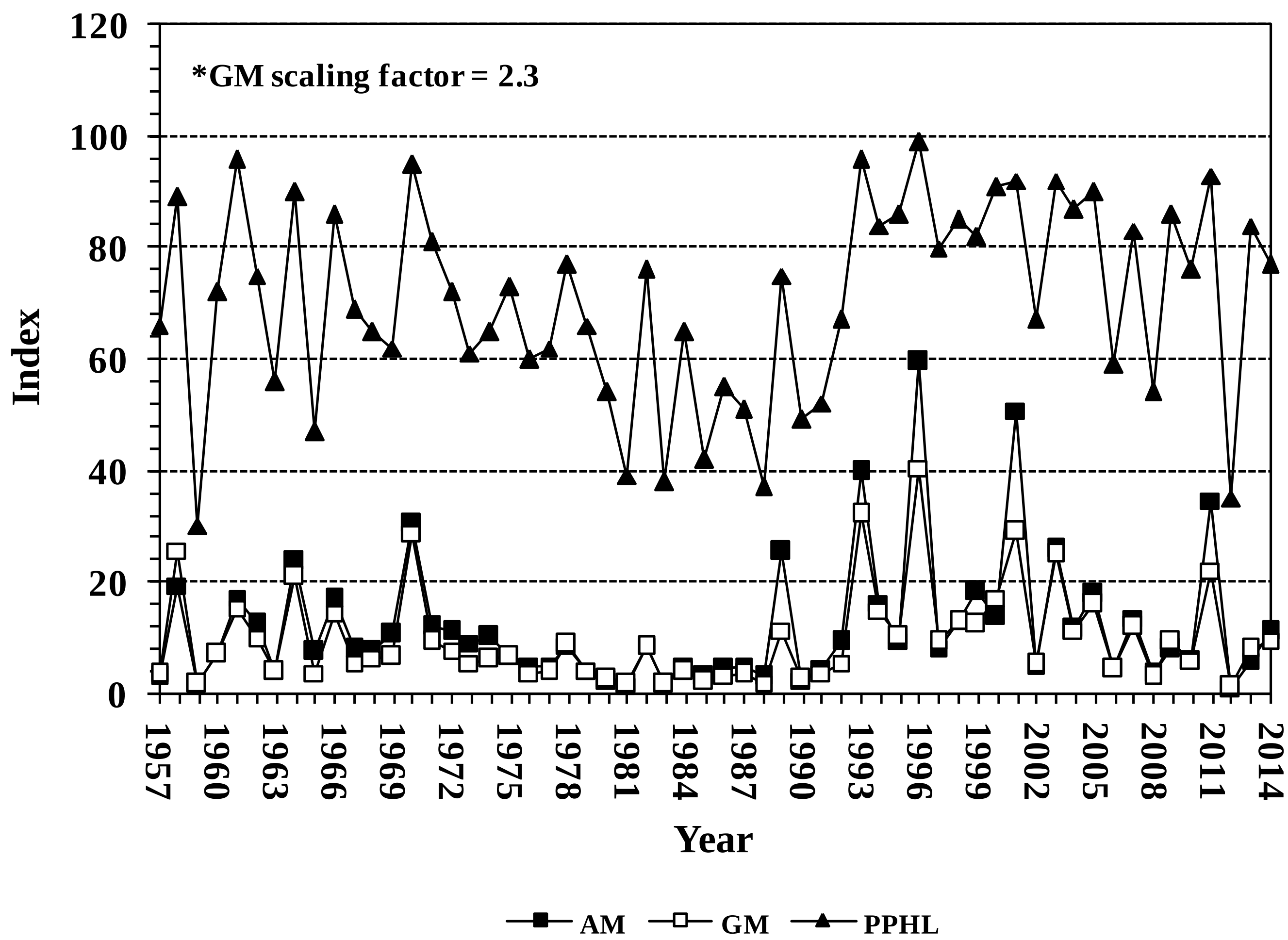


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

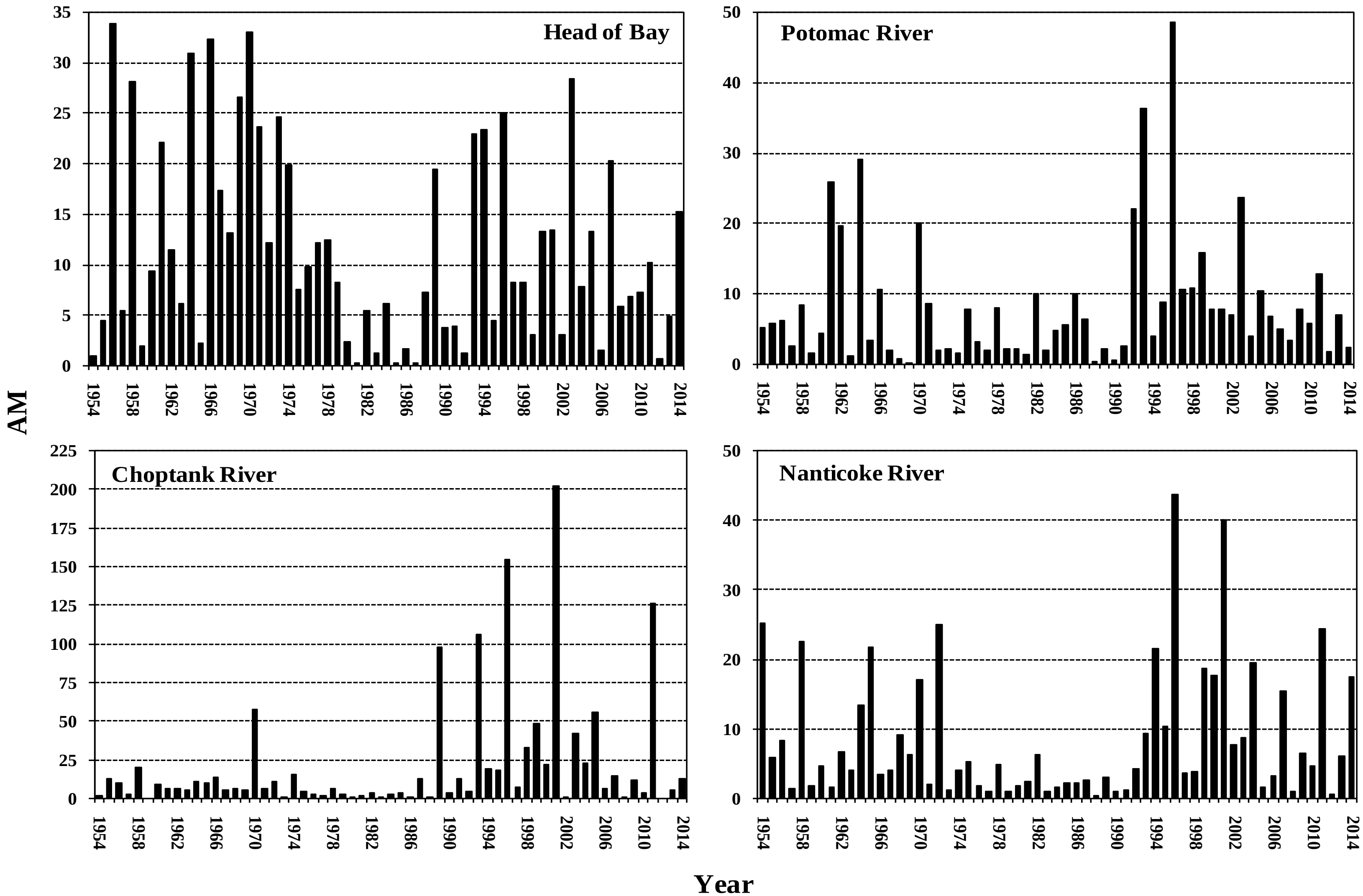


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

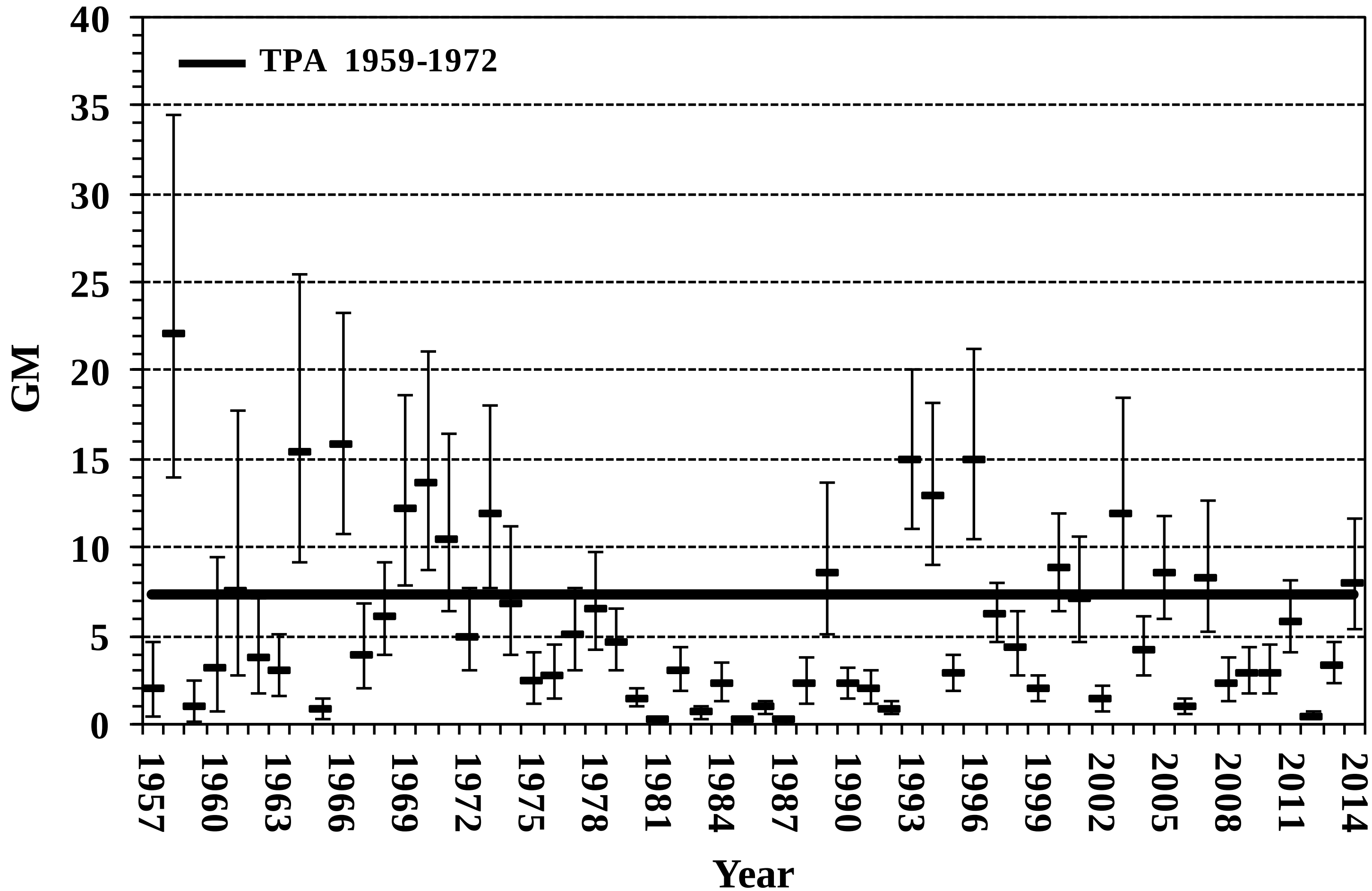
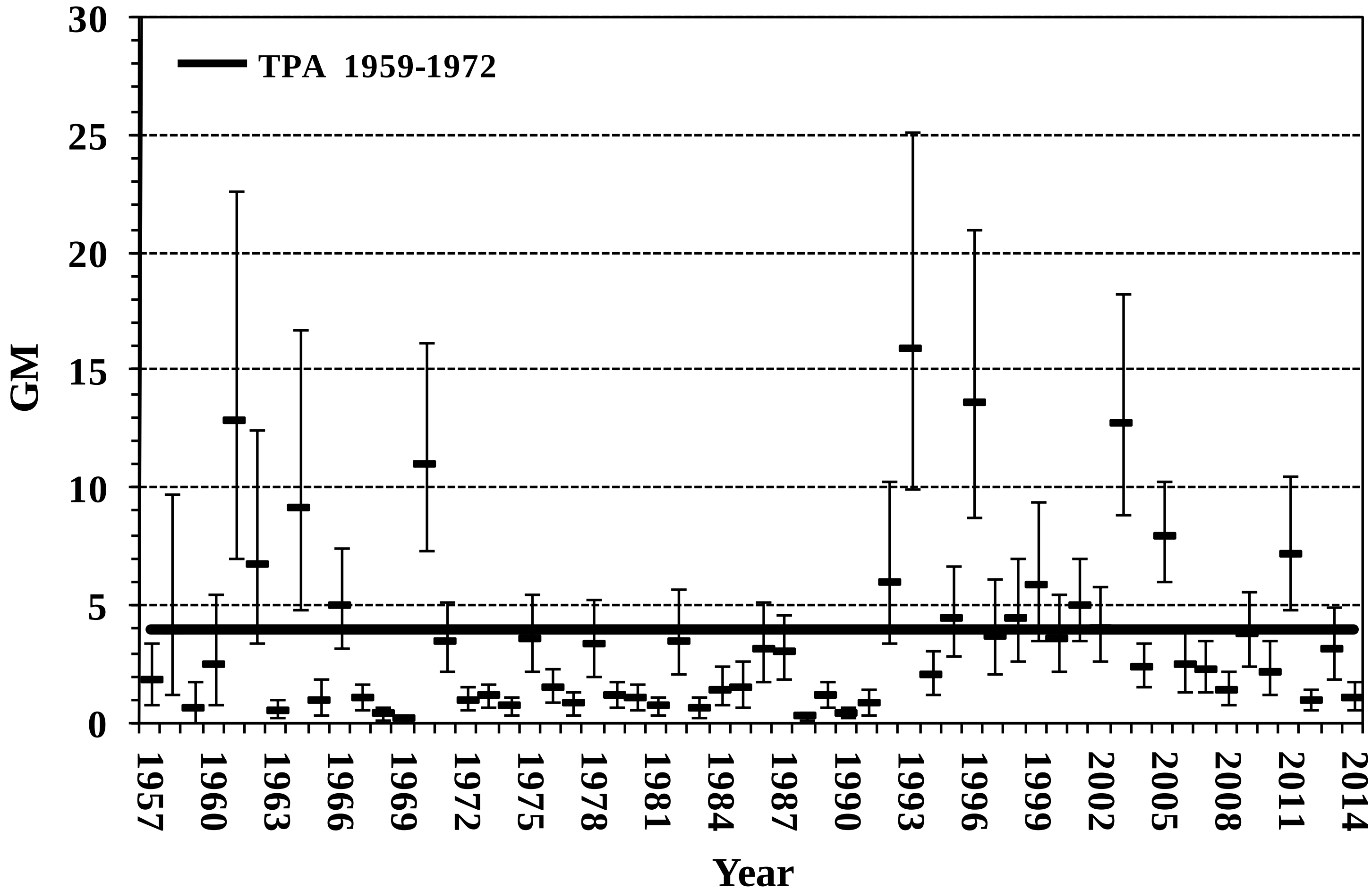


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).



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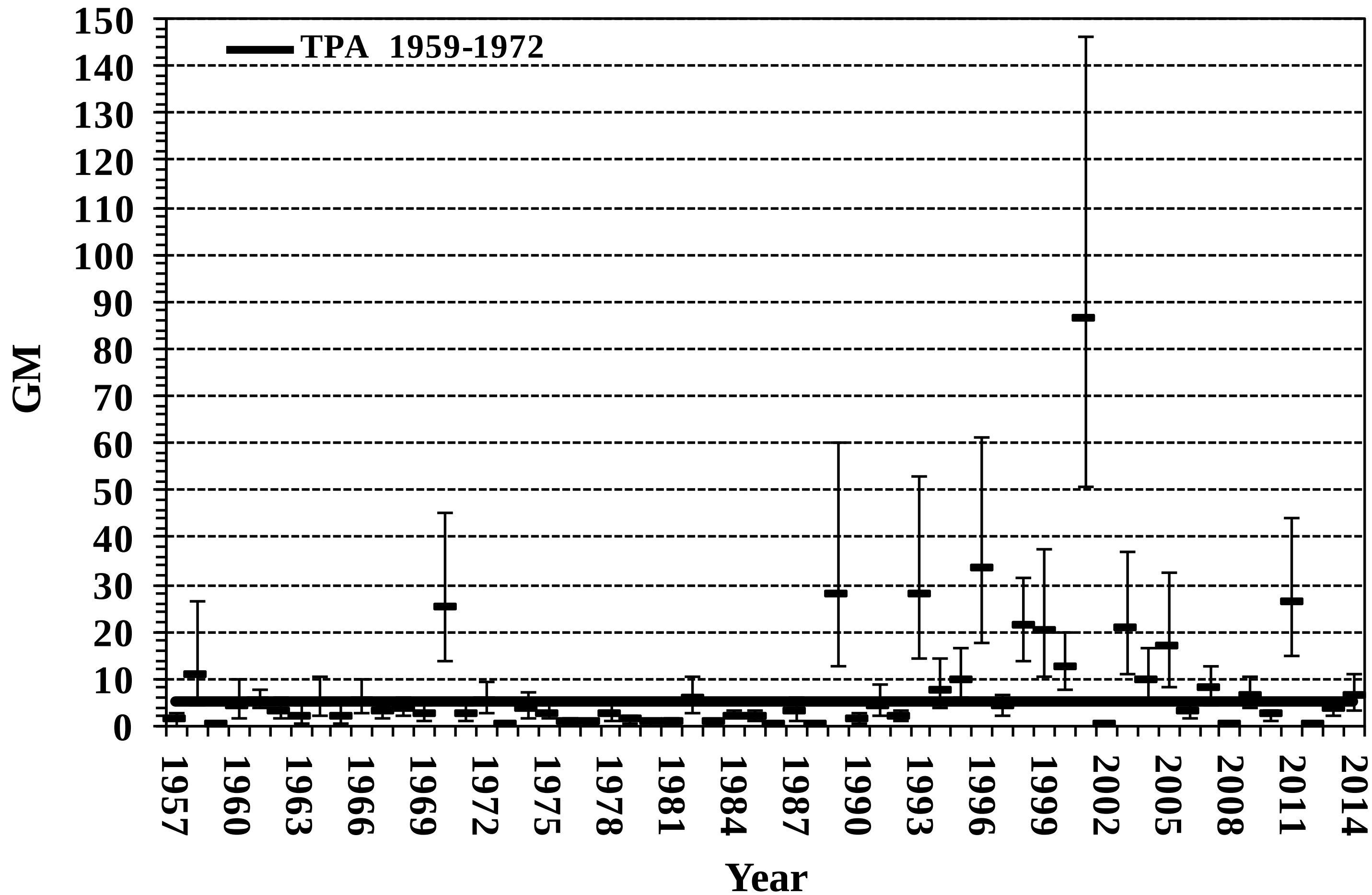


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

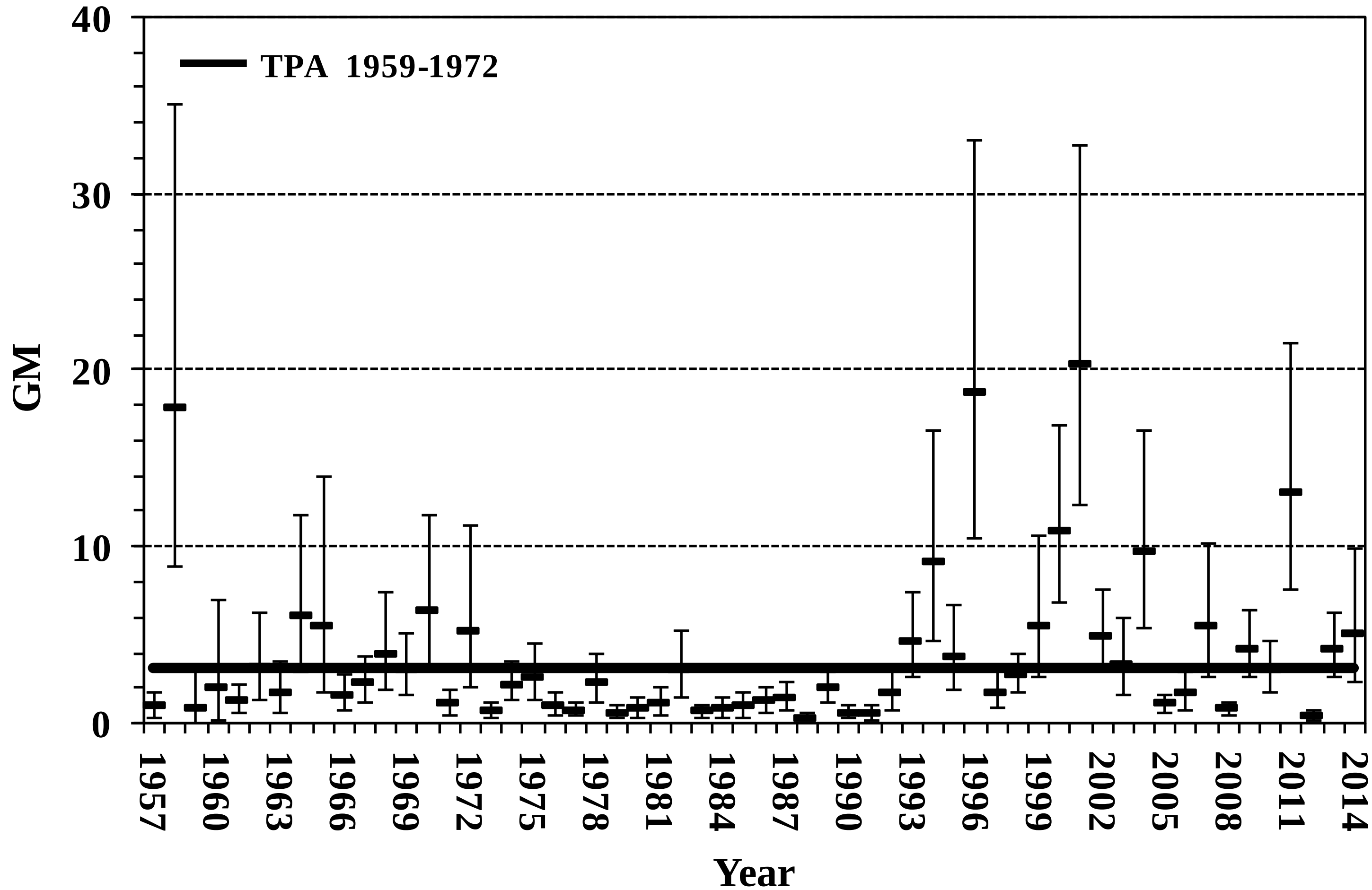


Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

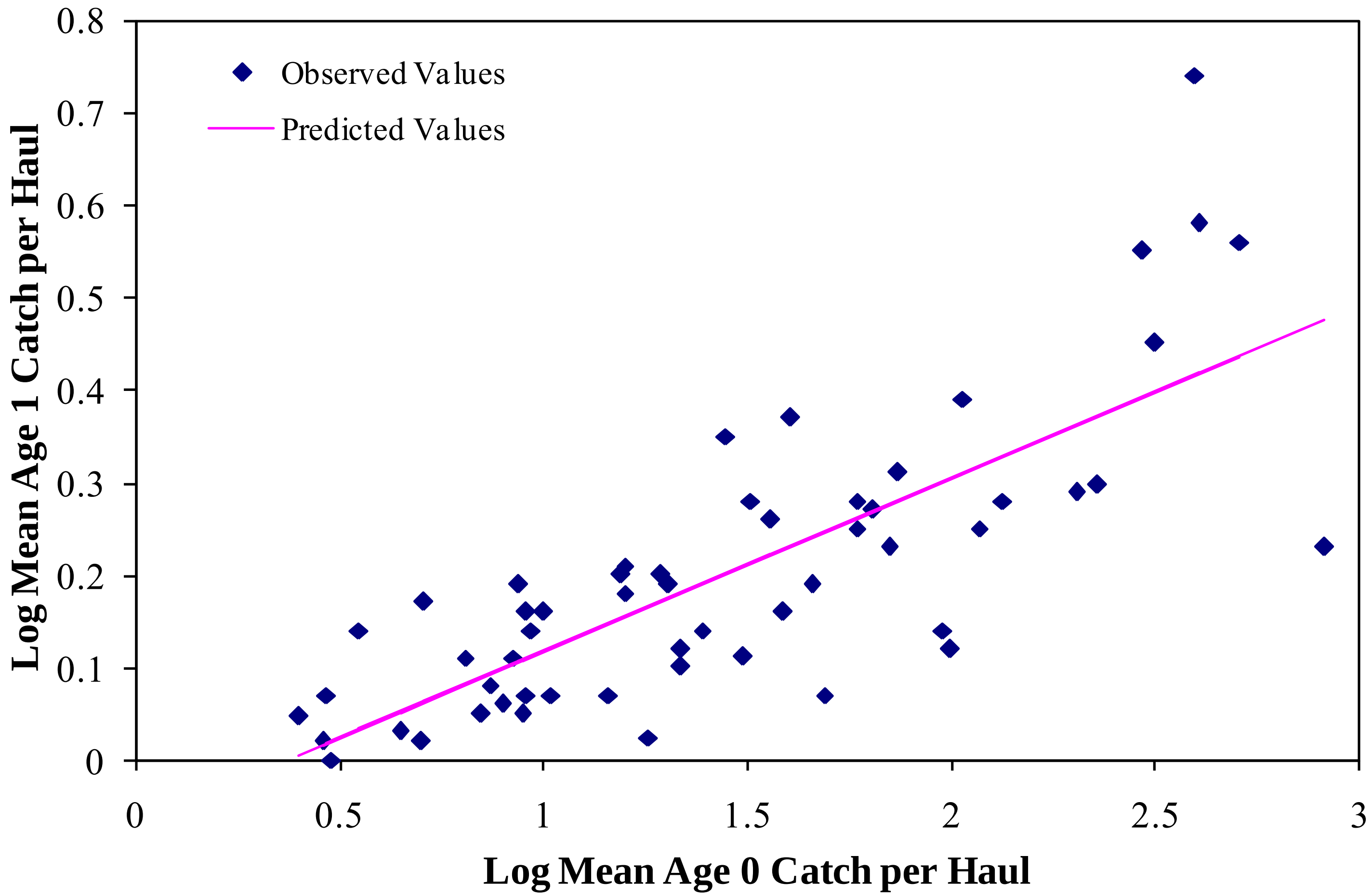
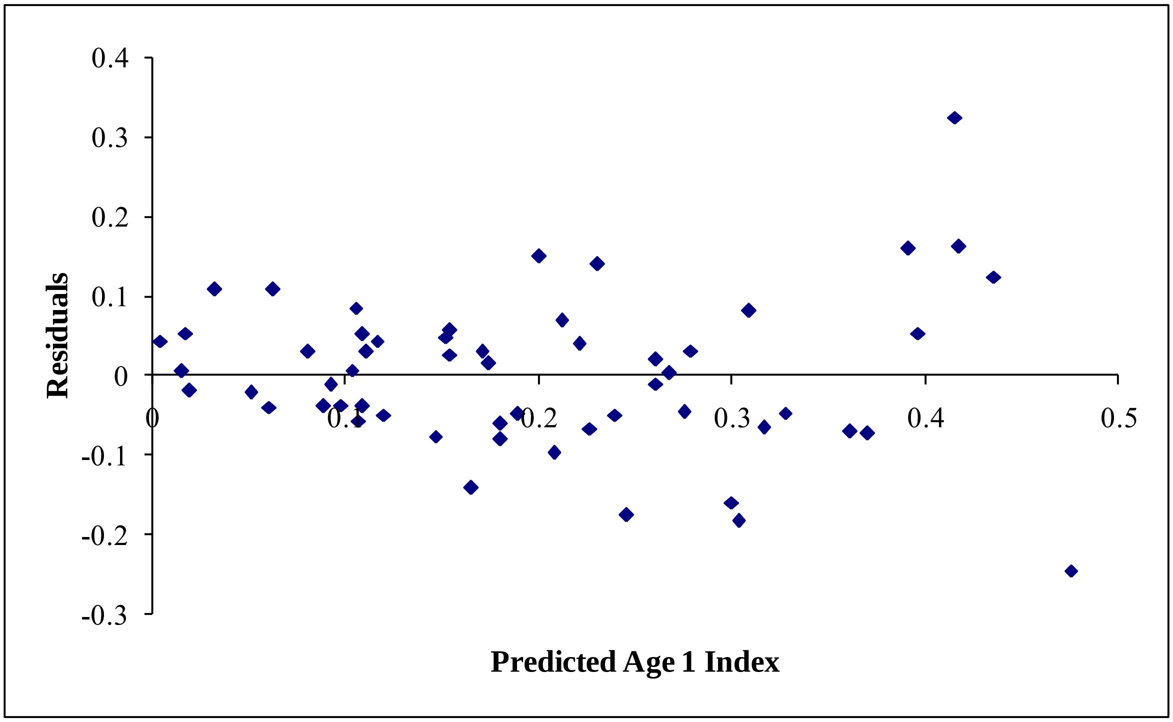
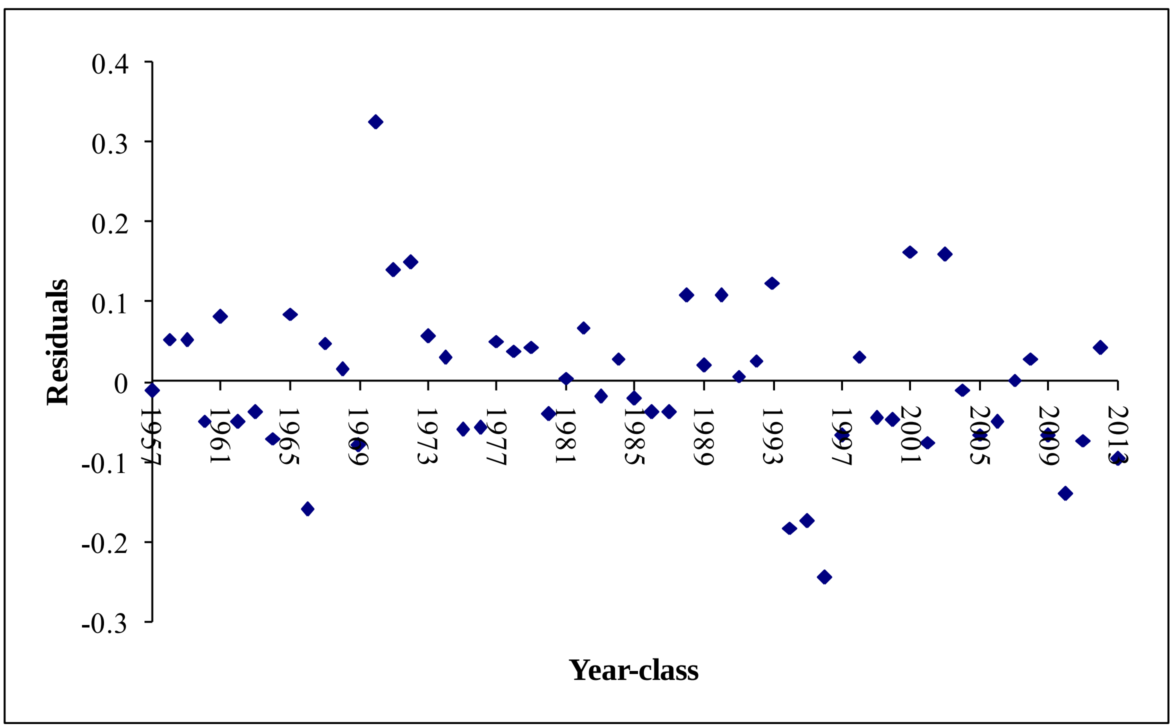


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 2014. 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 Coastal 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 2014, 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, maturation 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 and all female fish. Tagging stopped when catches dropped off or water temperature exceeded 70^{o}F.

In 2014, funding was only available to conduct a hook and line component of the offshore North Carolina tagging cruise. Funding was secured for the trawl portion of the cruise in 2015. 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 hook and line tagging trips included USFWS, North Carolina Division of Marine Fisheries (NC DMF), East Carolina University, MD DNR, Atlantic States Marine Fisheries Commission (ASMFC), North Carolina Wildlife Resources Commission, Potomac River Fisheries Commission, Virginia Institute of Marine Science, and Delaware State University.

The hook and line fishing was conducted onboard a contracted sportfishing vessel departing from Virginia Beach, VA. Sampling was conducted during 10 fishing trips, between January 27 and February 19, 2014. Between four and six lines with custom-made tandem parachute rigs were trolled, at 2 to 4 knots, in depths of 58 to 93 feet (17.7 to 28.4 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 formerly used in Program MARK. 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: ≥457 mm TL (18 inches) and ≥711 mm TL (28 inches). The recovery year began on the first day of 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 2014 will not be completed until after March 27, 2015.

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 F 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 $P \leq 0.05$.

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 20, 2014. A total of 2,538 striped bass were sampled and 1,118 (44%) were tagged as part of this long-term survey (Table 1).

On many occasions, large samples were caught in a short period of time which required fish to spend a considerable amount of time submerged in the gill net or on the boat, thereby increasing the potential for mortality. In these cases, biologists measured all fish but were only able to tag a sub-sample. Typically, these large concentrations of fish were of a smaller size and captured in small mesh panels. Larger fish were encountered less frequently, and therefore a higher proportion was tagged. This resulted in a significantly greater mean length of tagged fish than the mean length of all fish sampled. Mean total length of striped bass tagged during spring 2014 (579 mm TL) was significantly greater ($P<0.0001$) than that of the sampled population (487 mm TL) (Figure 2).

Tag releases and recaptures from both Maryland and Virginia’s sampling (combined spring 2014 data) will be used to estimate an instantaneous fishing mortality rate on resident fish for the 2014-2015 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Estimates of survival and fishing mortality for the 2014 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 tagging cruise

The primary objective 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 2014 hook and line study, 925 striped bass were encountered and 921 (99%) were tagged (Table 2). The mean length of all fish captured and tagged during the hook and line sampling was 941 mm TL. The mean total length of striped bass sampled on the 2014 hook and line cruise (941 mm TL) was significantly greater than the length of fish sampled from the 2013 hook and line cruise (931 mm TL , P=0.0112, Figure 3).

The NC DMF is presently completing age determination for the 2014 cruise via scale analysis. Estimates of survival and fishing mortality based on fish tagged in the 2014 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.

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Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, April - May 2014.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	4/1/14 - 5/13/14	886	336	524523 – 524860
Upper Chesapeake Bay	4/7/14 - 5/20/14	1,652	782	533001 – 533500 535001 – 535285
Spring spawning survey totals:		2,538 [b]	1,118	

[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.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2014 cooperative offshore tagging cruise.

System	Gear	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Nearshore Atlantic Ocean (Near VA-NC line)	Hook & Line	1/27/14 – 2/19/14	925 [b, c]	921 [b]	568928 – 569000 569101 – 569500 571001 – 571449

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

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2014.

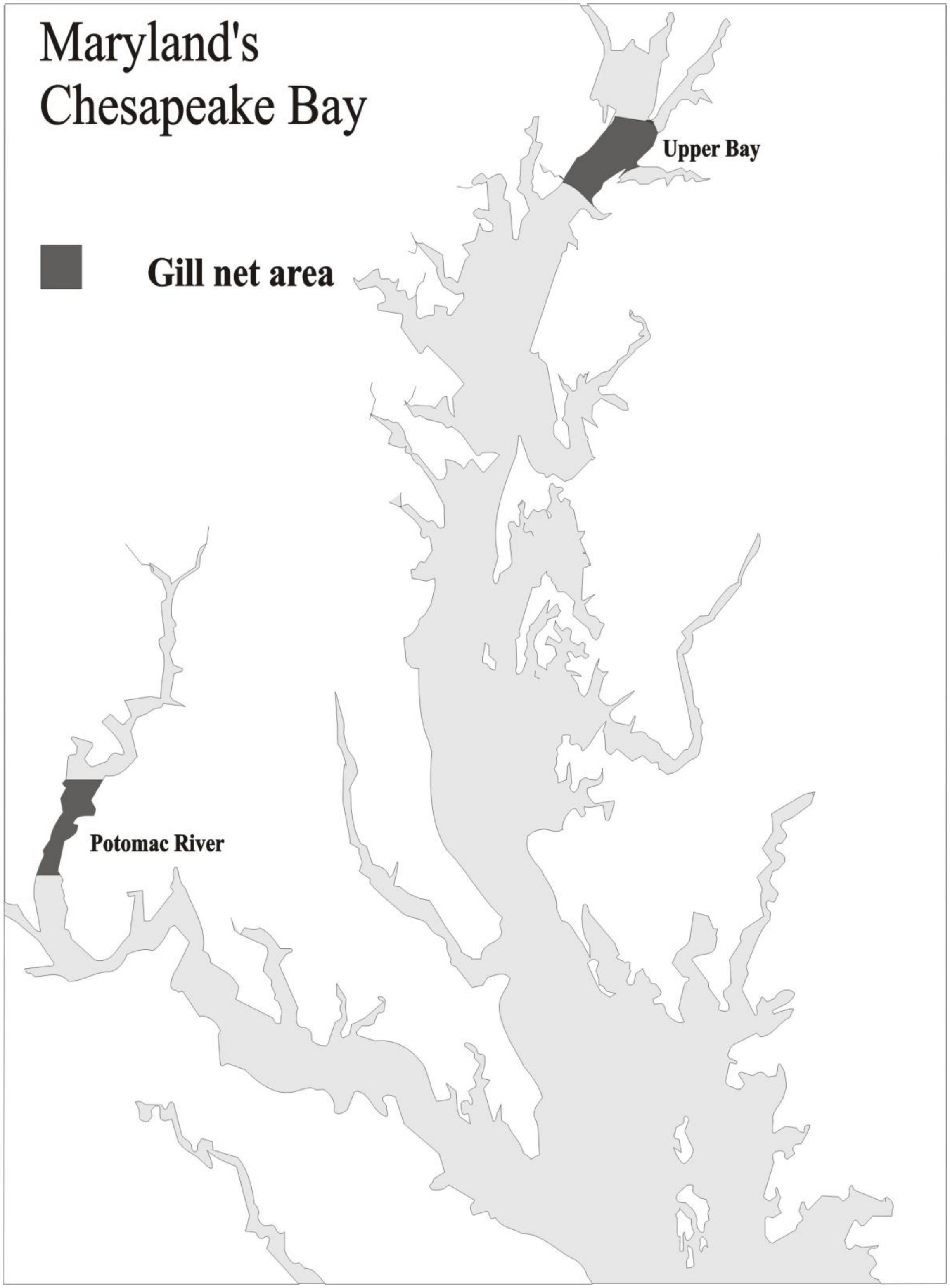


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay, April - May 2014.

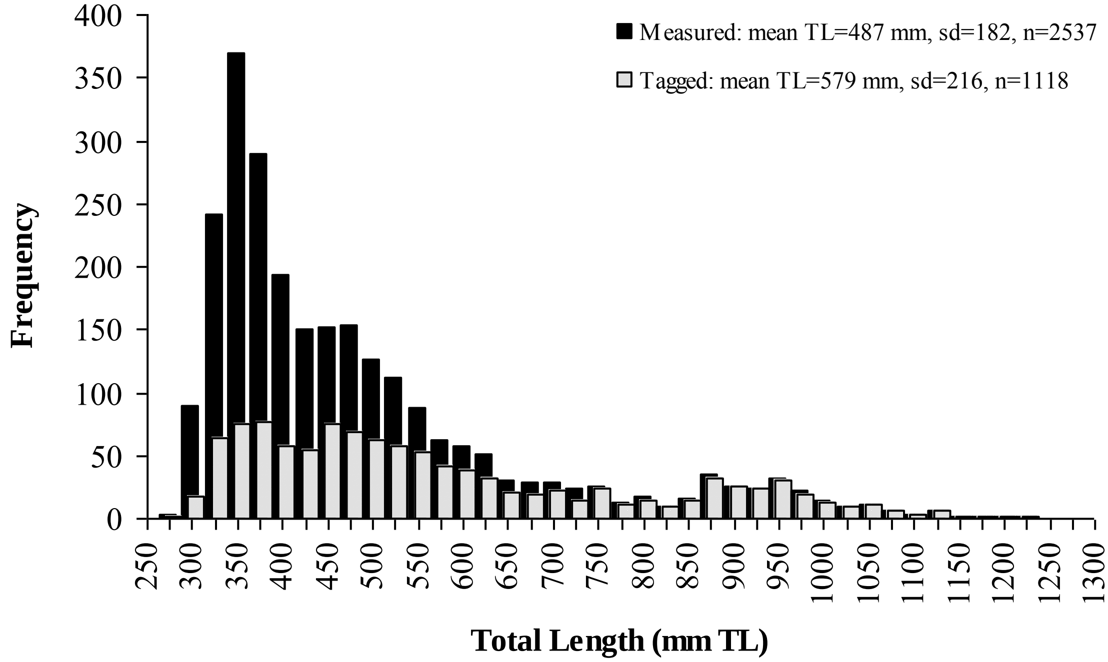
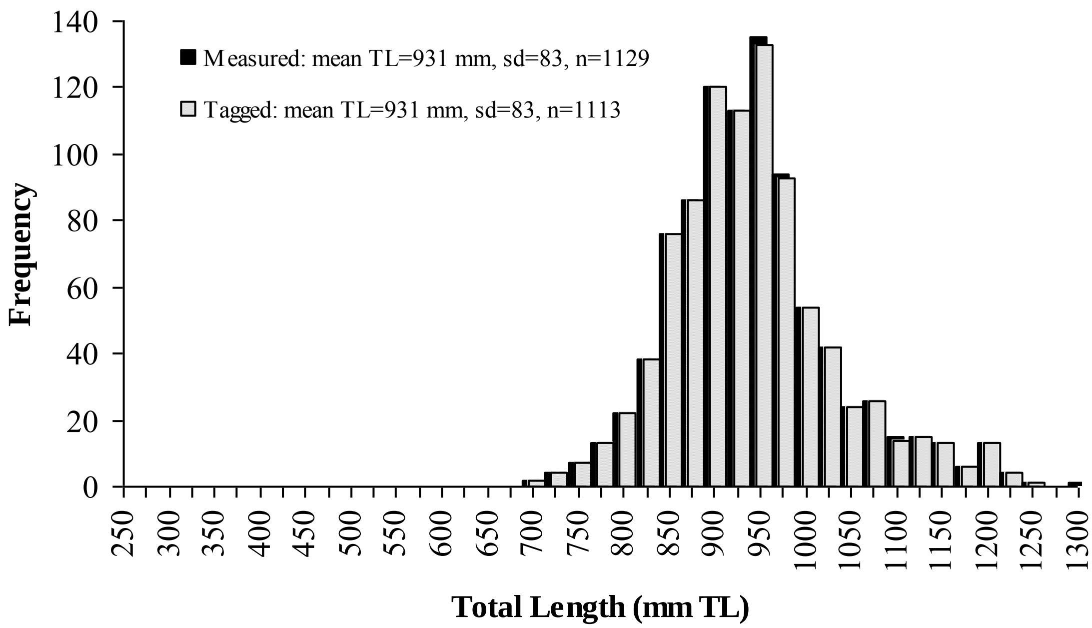


Figure 3. Length frequencies of striped bass measured and tagged during the hook and line cooperative offshore tagging cruise, January - February 2014.



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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Eric Q. Durell

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 5A were to quantify the commercial striped bass harvest in 2013 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-fourth 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 2013 commercial quota for the Chesapeake Bay and its tributaries was 1,688,966 pounds, a decrease of 14% relative to 2012, with an 18 to 36 inch total length (TL) slot limit. In 2013, 2.5% of the quota was withheld due to uncertainty in harvest reporting, resulting in an effective Chesapeake Bay striped bass quota of 1,646,742 pounds. 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.

The Chesapeake Bay commercial quota was further divided by gear type (Table 1). The hook-and-line and drift gill net fisheries were combined and initially allotted 75% of the commercial quota. The pound net and haul seine fisheries were allotted the remaining 25%. Subsequent gear-specific reallocations were made at the request of the commercial fishing industry. When the allotted quota for a specific gear type was not landed, it was transferred to another commercial fishery.

Each fishery was managed with specific seasons that could be modified by MD DNR as necessary. The hook-and-line fishery was open from June 7 through November 30, 2013, Monday through Thursday only. The pound net fishery was open from June 1 through

November 30, 2013, Monday through Saturday. The haul seine fishery was open from June 7 through November 30, 2013, Monday through Friday. The Chesapeake Bay drift gill net season was split, with the first segment from January 1 through February 28, 2013 and the second segment from December 3 through December 31, 2013, Monday through Friday. 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, 2013 and November 1 through December 31, 2013, 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. A deadline of August 31 was established for receipt of declaration; this process is repeated for every year in which the license holder intends to fish. 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. Daily allocations were established to distribute harvest over as many days as was practical, in an effort to avoid flooding the market (Table 1). Individual allocations were printed on each striped bass permit issued by MD DNR.

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 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. Each morning following a harvest day, the check station was required to telephone MD DNR and report the total pounds of striped bass checked the previous day (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 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 10^{th} 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 telephone 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 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, 1,662,180 pounds of striped bass were harvested in 2013; 26,786 pounds under the official 2013 quota. The estimated number of fish landed was 412,745 (Table 2). The Chesapeake drift gill net fishery landed 45% of the total landings by weight, followed by the pound net fishery at 32%. The hook-and-line fishery accounted for 23% of the total Bay landings.

Maryland's Atlantic coast landings were estimated at 7,608 striped bass, weighing 93,532 pounds (Table 2). The trawl fishery made up 72% 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 mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 4.03 pounds when calculated from the check station log sheets and 4.49 pounds when measured by biologists (Table 3). Mean weights by specific gear type ranged from 2.77 to 5.07 pounds from check station log sheets, and were 3.42 to 5.17 pounds when measured by biologists. At just over 5 pounds each, 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 haul seine, and averaged 2.77 pounds each according to check station log sheets. Haul seine fish were not observed by biologists surveying check stations, so no other data source is available for comparison.

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 by MD DNR biologists averaged 17.64 pounds (Table 3). The average weight calculated from the check station log sheets was 12.29 pounds. Fish caught in the Atlantic trawl fishery averaged 19.65 pounds according to MD DNR estimates, and were larger on average than those caught in the gill net fishery (17.36 pounds). The average weights of fish from the Atlantic trawl and gill net fisheries, as calculated from check station log sheets, were 13.28 and 10.33 pounds, respectively. The disparity between in average weights of Atlantic fish is likely due to the small sample size (n=168) collected during check station surveys. Only 21 of the 168 fish measured by biologists were caught by trawls, 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).

Commercial CPUE Trends

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.

All Chesapeake Bay fisheries experienced an increase in CPUE relative to 2012. The Chesapeake Bay drift gill net fishery CPUE had the highest CPUE of the Bay fisheries at 411 pounds per trip. Pound net CPUE ranked second at 359 pounds per trip. Consistent with historic trends, the hook-and-line fishery CPUE of 205 pounds per trip was the lowest of all Bay gear types (Table 5, Figure 7).

The Atlantic trawl fishery CPUE nearly doubled from 2012 to 1,602 pound per trip, the highest value in the time-series. This is nearly equal to the legal limit of 1,650 pounds per licensee per season. The Atlantic gill net fishery CPUE was 190 pounds per trip, similar to previous years (Table 5, Figure 8).

REFERENCES

Cowx, I.G. 1991. Catch effort sampling strategies: their application in freshwater fisheries management. Fishing News Books.

Goodyear, C.P. 1985. Relationship between reported commercial landings and abundance of young striped bass in Chesapeake Bay, Maryland. Transactions of the American Fisheries Society. 114:92-96.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Schaefer, R.H. 1972. A short range forecast function for predicting the relative abundance of striped bass in Long Island waters. N.Y. Fish & Game Journal, 19(2): 178-181.

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Table 1. Striped bass commercial regulations by gear type for the 2013 calendar year.

Area	Gear Type	Annual Quota (pounds)	Number of Participants	Trip Limit	Minimum Size	Reporting Requirement
Bay and Tributaries	Pound Net	540,685	101	single permit holders: 800 lbs/day; multiple permit holders 1,600 lbs/day	18-36 in TL slot	Monthly Harvest Report
	Haul Seine	included in pound net	3	500 lbs/license/day; 1,500 lbs/license/net/season	18-36 in TL slot	Monthly Harvest Report
	Hook-and-Line	397,273	128	800 lbs/license/day; 1,600 lbs/license/day; max 4 people/boat; 2 crew/licensee	18-36 in TL slot	Monthly Harvest Report
	Gill Net	708,784	622*	300 lbs/licensee/day; 1,200 lbs/boat/day; max 4 licenses/boat	18-36 in TL slot	Monthly Harvest Report
Total Bay Quota		**1,646,742**				
Atlantic Coast	Atlantic Trawl	126,396	54	1,650 lbs/licensee/season	24 in TL min	Monthly Harvest Report
	Atlantic Gill Net	included in Trawl				
Total Maryland Quota		**1,773,138**				

*Dual registered as gill net and hook-and-line

Table 2. Summary of striped bass commercial harvest statistics by gear type for the 2013 calendar year.

Area	Gear Type	Pounds[1]	Estimated[1] Number of Fish	Trips[2]
Chesapeake Bay[3]	Haul Seine	998	360	3
	Pound Net	530,601	146,169	1,479
	Hook-and- Line	382,783	118,736	1,871
	Gill Net	747,798	147,480	1,821
	Chesapeake Total Harvest	**1,662,180**	**412,745**	**5,174**
Atlantic Coast	Trawl	67,292	5,069	42
	Gill Net	26,240	2,539	138
	Atlantic Total Harvest	**93,532**	**7,608**	**180**
Maryland Totals		**1,755,712**	**420,353**	**5,354**

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 2013 calendar year. Average weights calculated by MD DNR biologists include 95% confidence intervals.

Area	Gear Type	Average Weight from Check Station Logs (pounds)[1]	Average Weight from Biological Sampling (pounds)[2]	Sample Size from Biological Sampling[2]
Chesapeake Bay[3]	Haul Seine	2.77	N/A	N/A
	Pound Net	3.63	3.67 (3.48-3.85)	514
	Hook-and-Line	3.22	3.42 (3.35-3.49)	1,952
	Gill Net	5.07	5.17 (5.10-5.25)	3,648
	Chesapeake Total Harvest	**4.03**	**4.49 (4.43-4.54)**	**6,114**
Atlantic Coast	Trawl	13.28	19.65 (16.87-22.43)	21
	Gill Net	10.33	17.36 (16.45-18.26)	147
	Atlantic Total Harvest	**12.29**	**17.64 (16.78-18.51)**	**168**

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 2013.

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	424,657	565,600	861,174	25,942	51,609
2013	382,783	530,601	747,798	26,240	67,292

Table 5. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2013.

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
Average	**152**	**253**	**258**	**194**	**602**
5 yr avg (2013-2009)	**201**	**362**	**391**	**213**	**896**

Figure 1. Map of the 2013 Maryland authorized commercial striped bass check stations.

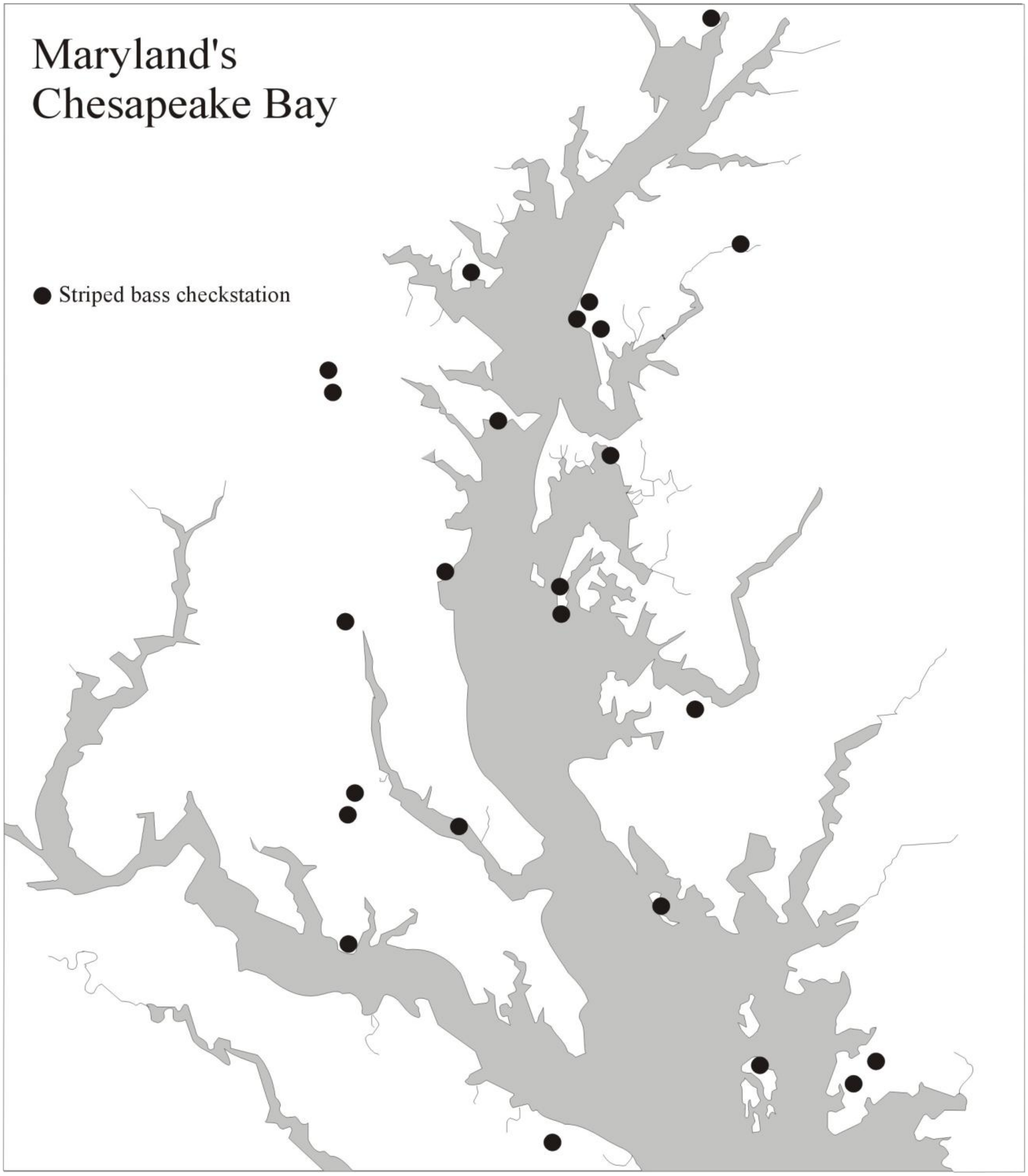
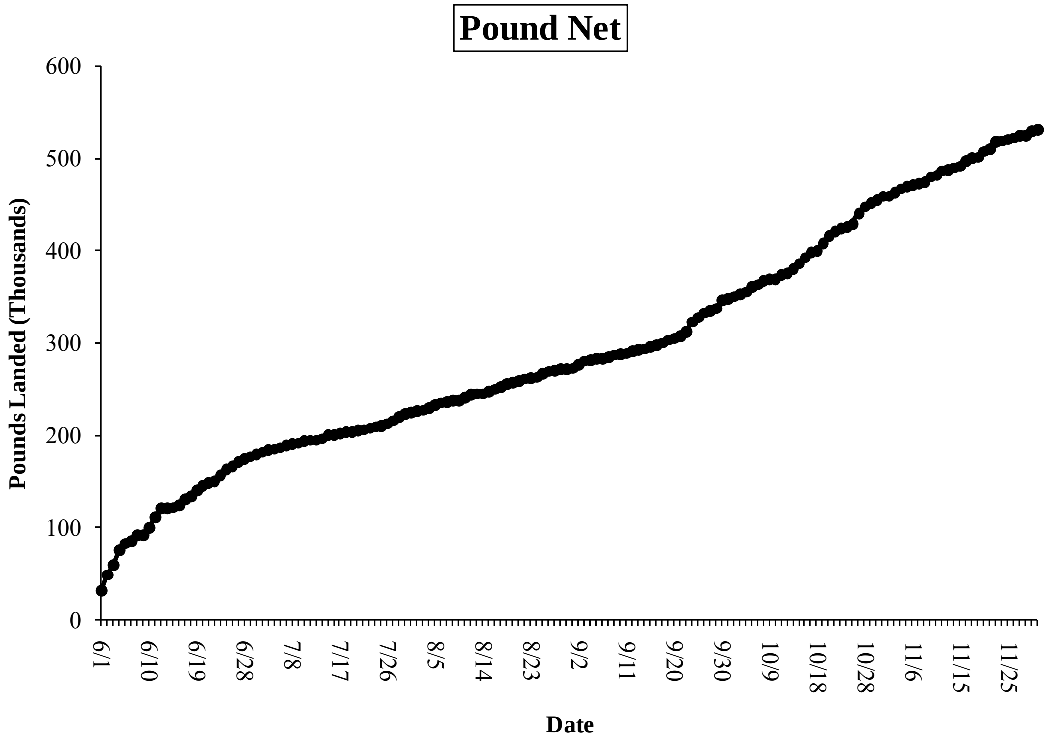


Figure 2. Maryland's Chesapeake Bay pound net and hook-and-line fisheries cumulative striped bass landings from check stations daily call-in reports, June-November 2013.



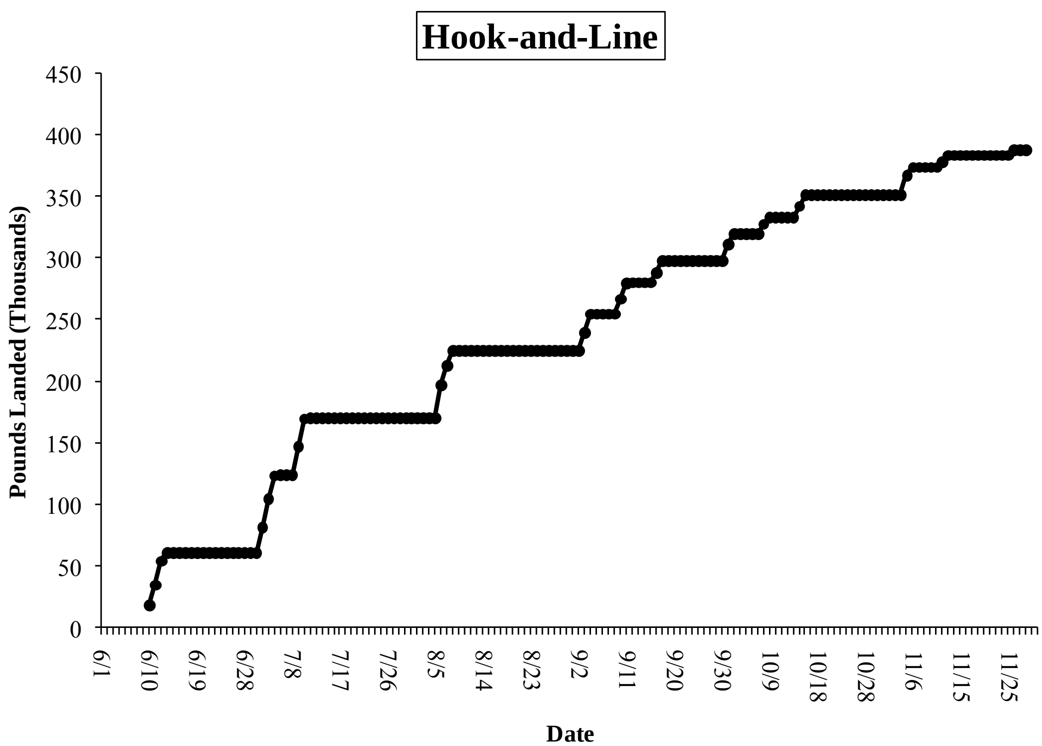
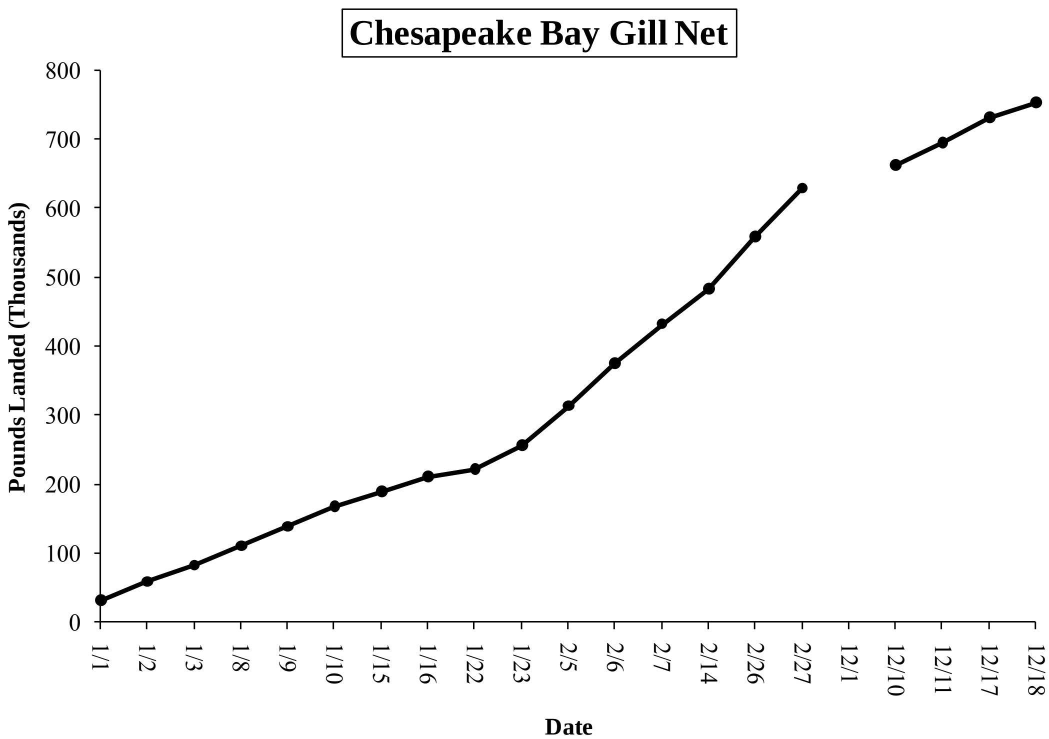


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fisheries (combined) cumulative striped bass landings from check stations' daily call-in reports, January-December 2013. Note different scales.



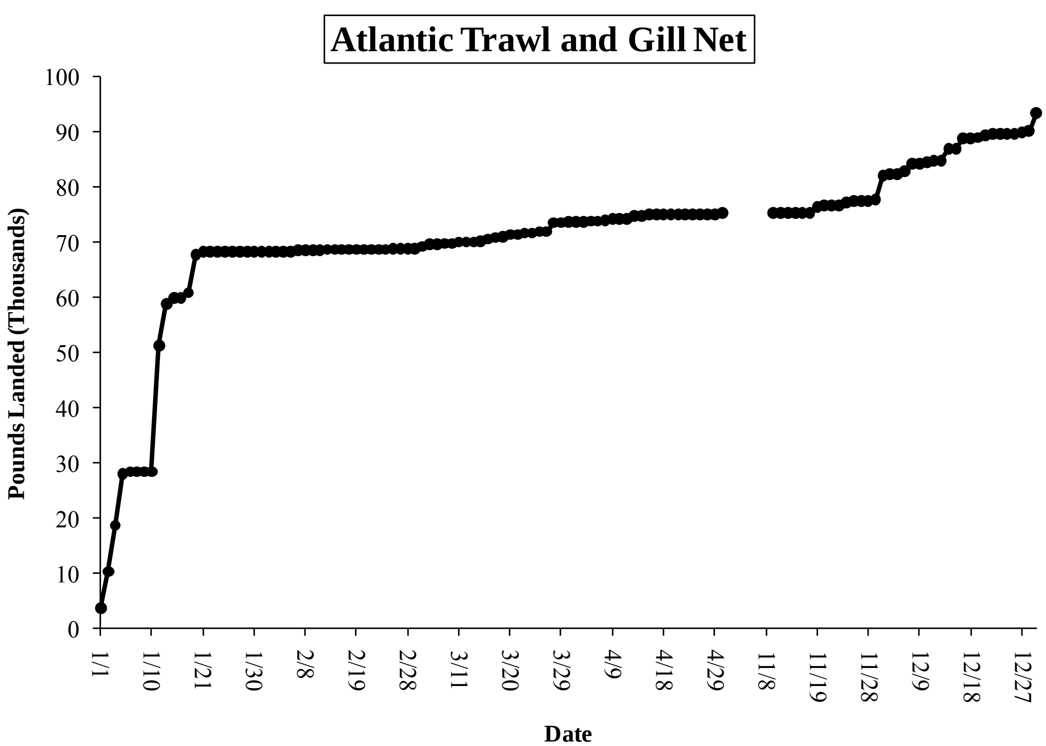
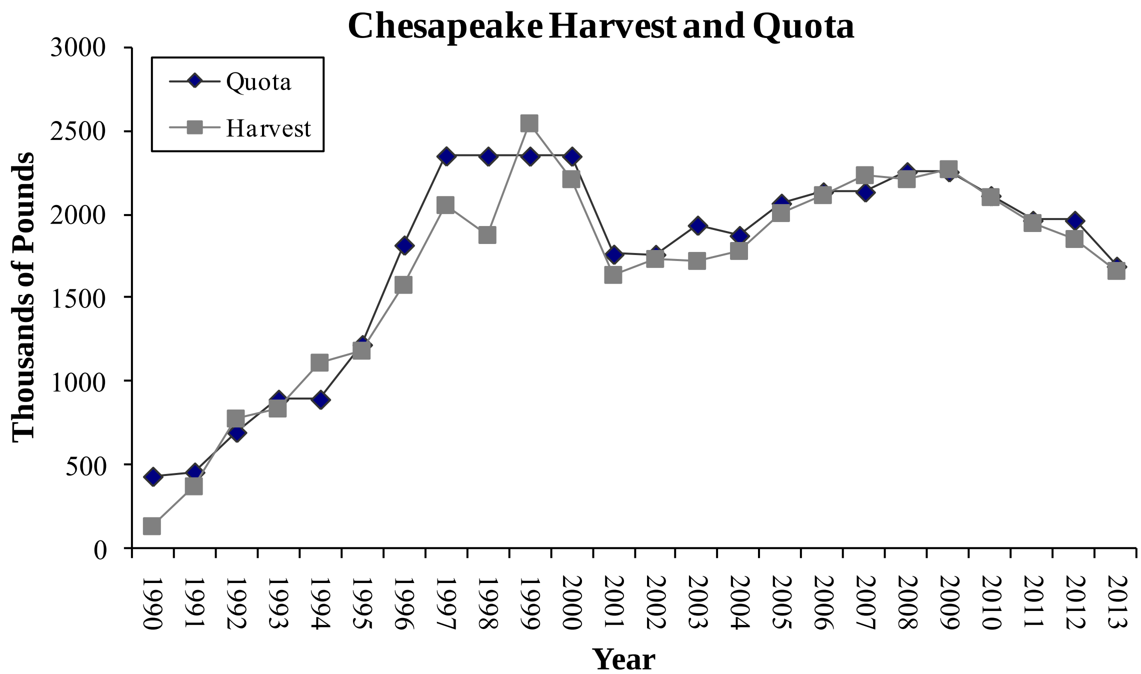


Figure 4. Maryland's Chesapeake Bay and Atlantic Ocean harvests (lbs) and quotas (lbs) for all gears, 1990-2013. Note different scales.



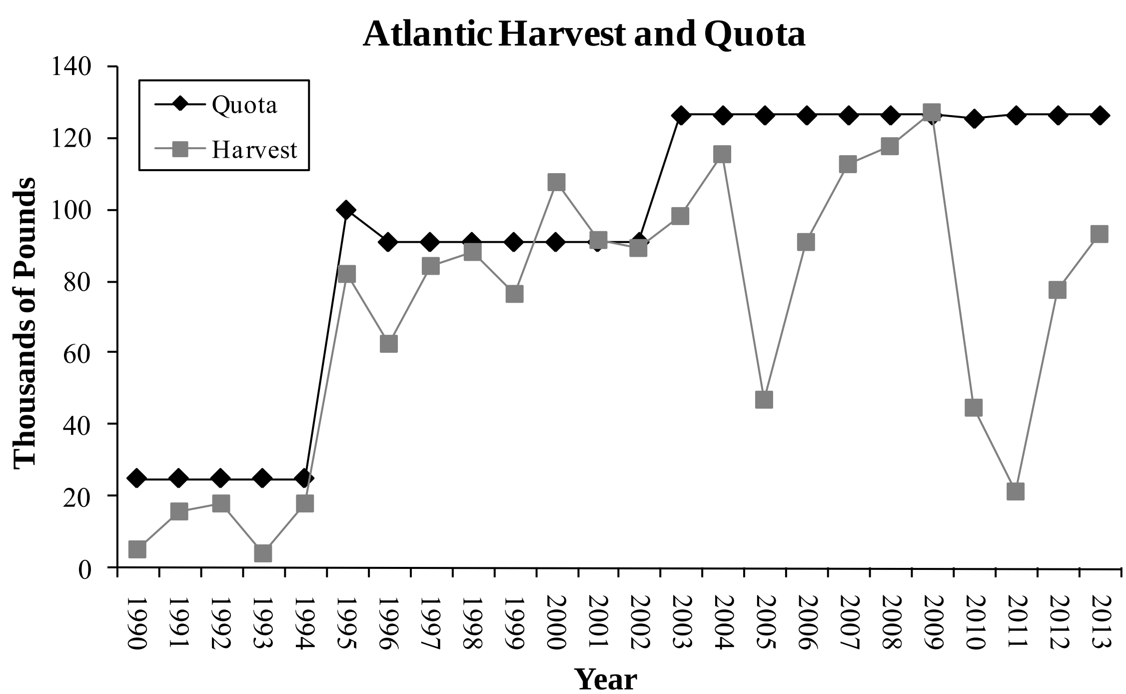


Figure 5. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2013.

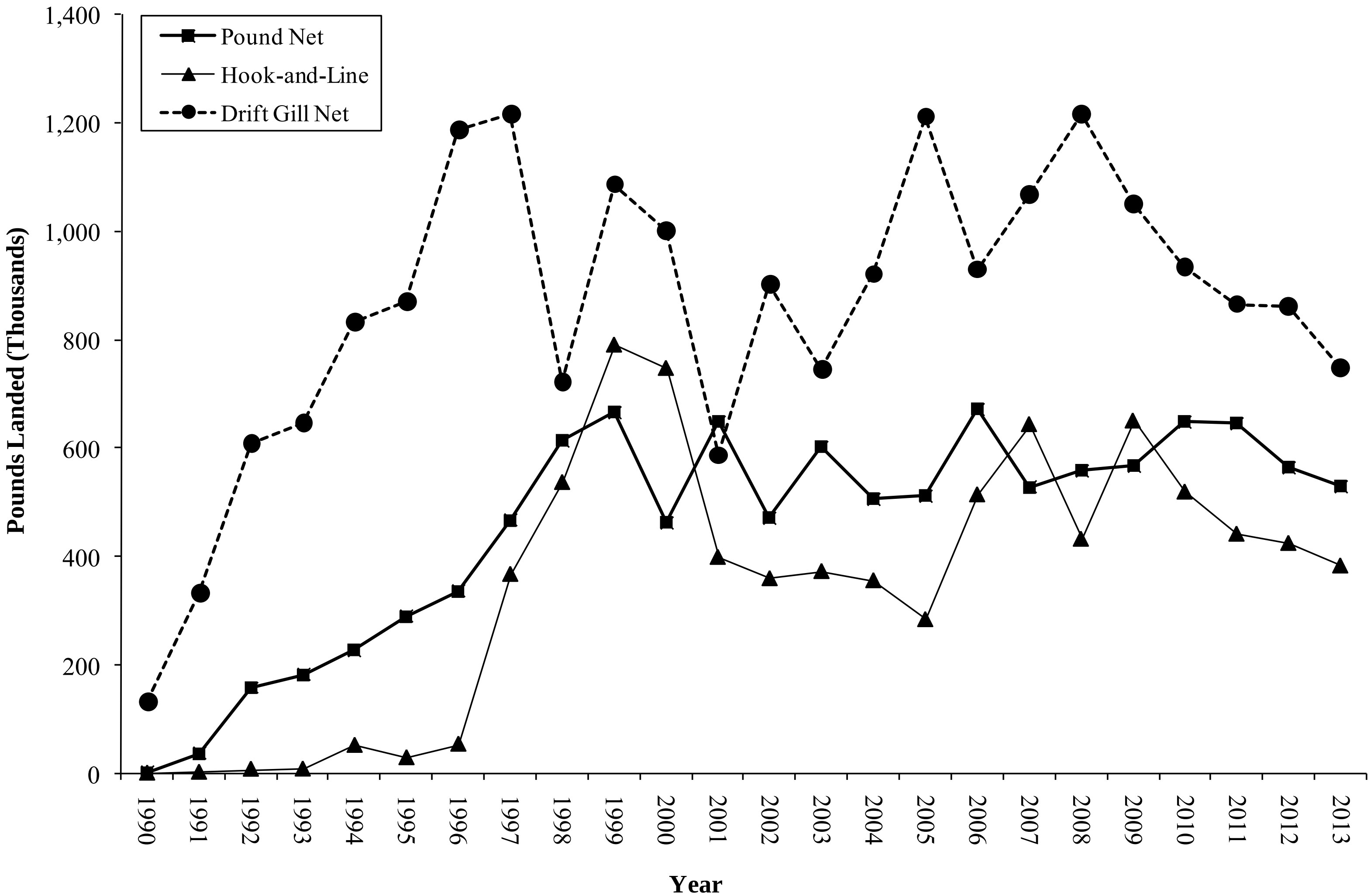


Figure 6. Maryland's Atlantic gill net and trawl fisheries total striped bass harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2013.

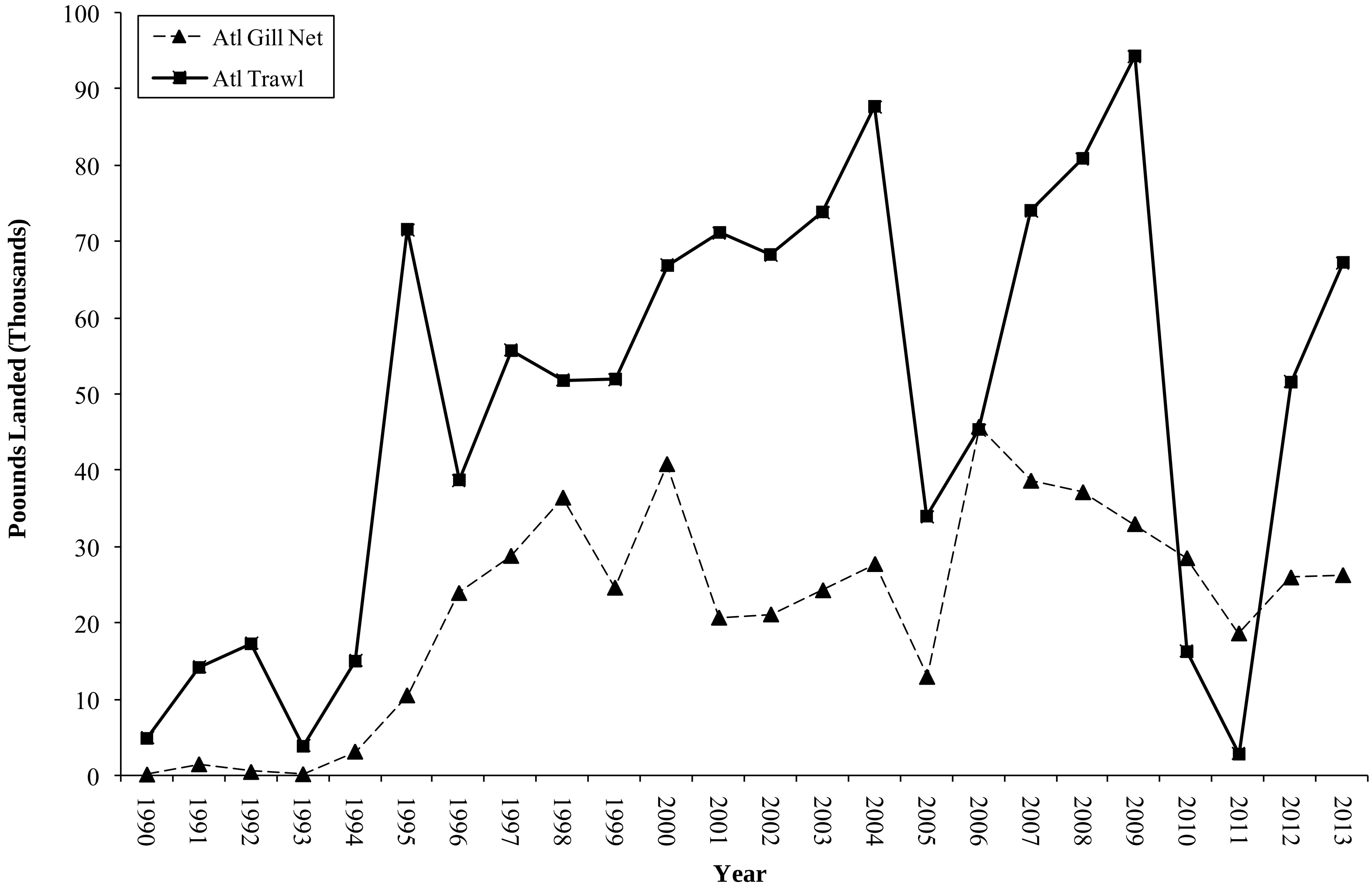


Figure 7. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990-2013. Trips were defined as days fished when striped bass catch was reported.

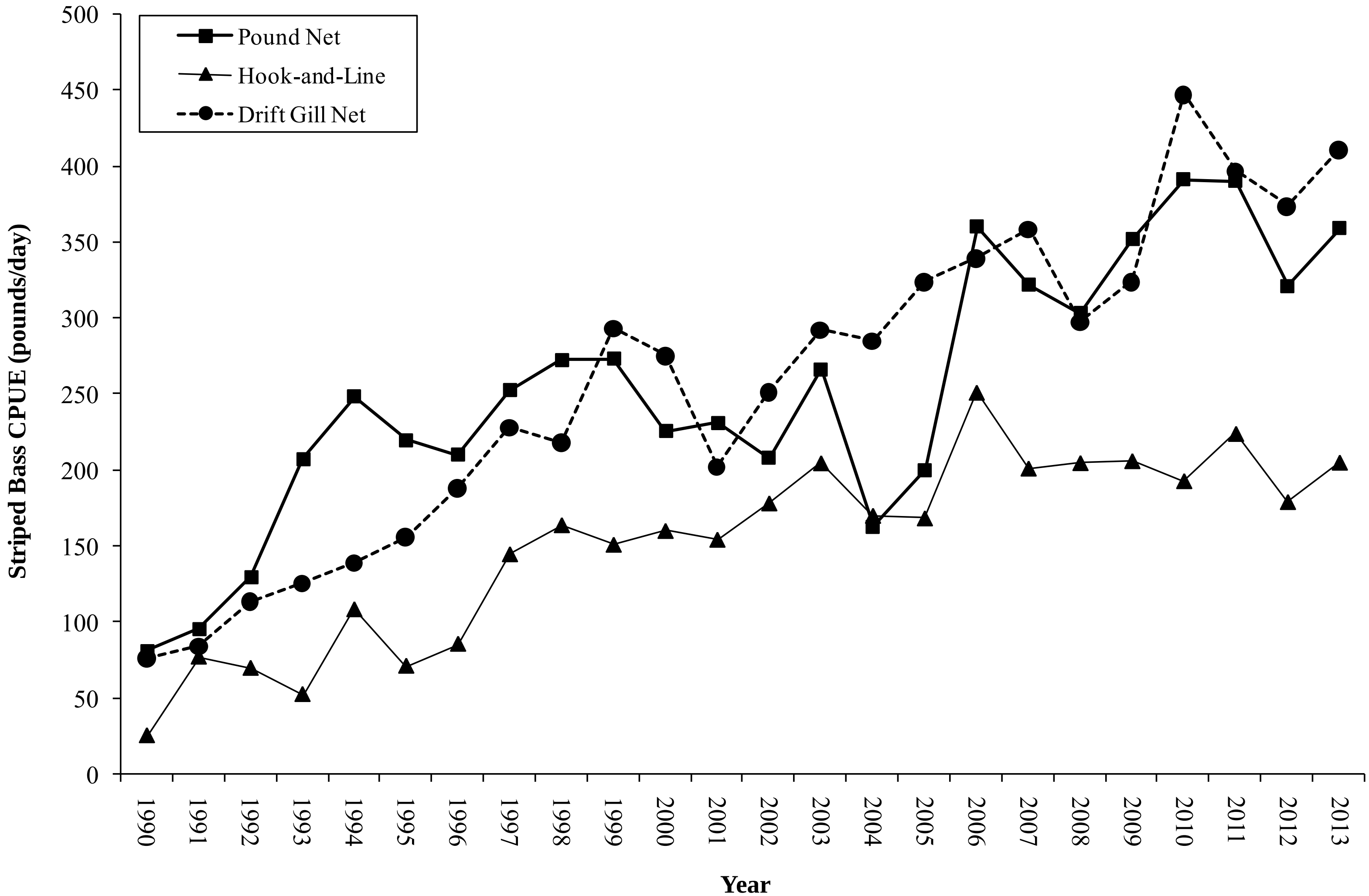
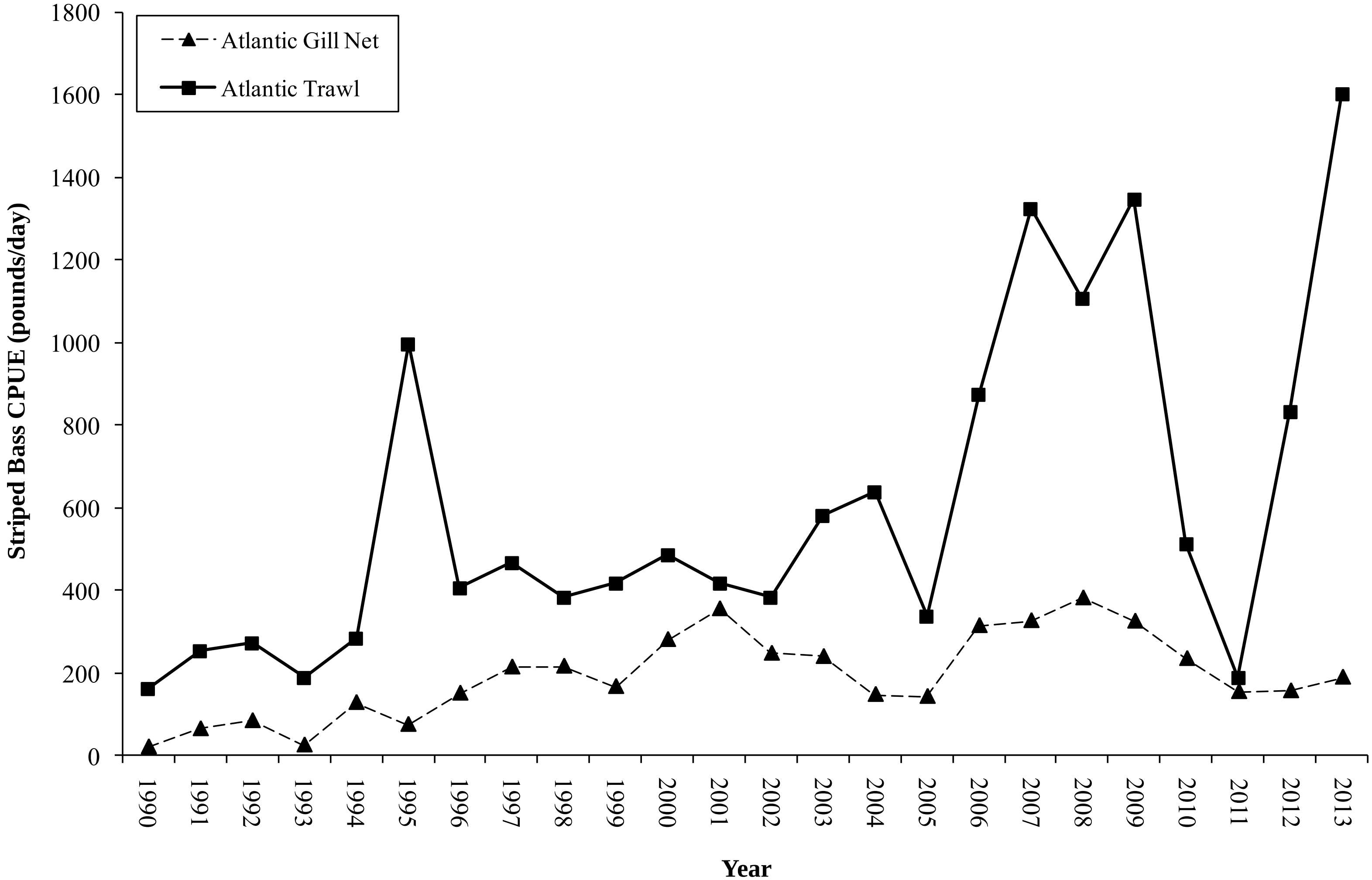


Figure 8. Maryland's Atlantic gill net and trawl fisheries striped bass catch (pounds) per trip (CPUE), 1990-2013. Trips were defined as days fished when striped bass catch was reported.



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

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

Prepared by Angela Giuliano

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 2014 spring recreational season, which began on Saturday, April 19 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. The first 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). The 2014 season was 27 days long (April 19 – May 15), with a one fish (≥ 28 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 Maryland Department of Natural Resources (MD DNR) Striped Bass Program initiated a dockside creel survey for the spring fishery in 2002. The main objectives are:

1. Develop a time-series of catch per unit effort (CPUE) of the spring trophy fishery,
2. Determine the sex ratio and spawning condition of harvested fish,
3. Characterize length and weight of harvested fish,
4. Characterize the age-distribution of harvested fish, and
5. Collect scales and otoliths to supplement MD DNR age-length keys and for an ongoing ageing validation study of older fish.

METHODS

A dockside creel survey was conducted at least two days per week at high-use charter boat marinas (Table 2A) with effort focused on collecting biological data on the catch. Because of the half-day structure of some charter trips, charter boats returned in two waves. Return times depended on how fast customers reached the creel daily limit. Charter boats sometimes caught their limit and returned to the dock as early as 10:00 AM. Sites were not chosen by a true random draw. Biologists arrived at a chosen site between 9:00 and 10:00 AM to intercept the first wave of returning boats. If it became apparent that fishing activity from that site was minimal (i.e. most charter boats were tied up at the dock), biologists moved to the nearest site in search of higher fishing activity.

Biologists alternated between five major charter fishing ports in 2014: 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, α=0.05). When significant differences were found, a Duncan's multiple range test was used to determine which years were significantly different from each other.

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 read from the creel survey has varied between years. In 2014, 172 scale samples were read. 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 a small amount 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.

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.

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 I. 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 log data. CPH was calculated using the charter boat log data and the average duration of charter boat trips from mate interview data. Charter boat captains are required to submit data to MD DNR indicating the days and areas fished, number of anglers fishing, and numbers of striped bass caught and released. In place of a paper logbook, captains can now submit their data 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 2014 comprised 44% 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 2014, 18% 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 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 2014, 209 private boats trips, 48 charter boat trips, and 1 shore trip were intercepted for either interviews or biological sampling (Table 5B). Of these, 207 private boat trips, 4 charter boat trips, and 1 shore trip were intercepted for angler interviews while fish were sampled from 44 charter trips and 2 private boat 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

Although the minimum size limit for the 2014 spring striped bass season was 28 inches (711 mm) TL, lengths ranged from 728 mm TL to 1186 mm TL. The catch was dominated by fish in the 920-960 mm TL length groups (36 to 38 inches, Figure 2).

Mean length

The ANOVA indicated significant differences in mean length across years for sexes combined and for each sex ($p<0.0001$). The Duncan's multiple range test ($p=0.05$) found that the mean length for all fish in 2014 (946 mm TL) was the largest in the time series and significantly greater than all previous years (Table 6A, Figure 3). The mean length of females (952 mm TL) was greater than the mean length of males (882 mm TL), which is typical of the biology of the species. The mean total length of females in 2014 was significantly larger than all years in the time series. For males, the mean length was the second largest in the time series but not significantly different from six other years of the time series.

The mean daily lengths of female striped bass harvested in 2014 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).

Mean weight

As with mean length above, the ANOVA indicated significant differences in mean weight across years for sexes combined and each sex ($p\leq0.0001$). The Duncan's multiple range test ($p=0.05$) found that the mean weight of fish sampled in 2014 (9.1 kg) was significantly larger than any year in the time series (Table 6B). The mean weight of females (9.3 kg) was also significantly larger than any year in the time series (Figure 5). The mean weight of males (6.8 kg) in 2014 was the largest in the time series but not significantly difference from eight other years of the time series. The mean weight of females (9.3 kg) was greater than the mean weight of males (6.8 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).

Age Structure

The age distribution of striped bass from the sampled harvest in 2014 ranged from 7 to 18 years old (Figure 6). Most fish harvested were between 9 and 13 years old. The 2003 (11 years old in 2014) and 2004 (10 years old) year-classes were the most frequently observed cohorts, constituting 50% and 20% of the sampled harvest, respectively. The strong 2003 year-class has increased annually in the harvest since 2008 and dominated the harvest since 2012. The record 1996 year-class (18 years old in 2014), which dominated catches in 2005, 2006, and 2008, constituted just 1% of the sample harvest.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2014 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 were no fish of unknown sex in 2014. Females constituted 92% of the sampled harvest. This is the highest proportion of females harvested in the time series.

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 2014 creel survey indicated that 27% of the females caught between April 19 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 pre-spawn females harvested ranged from 4% to 87% on any given day of the survey (Figure 7). The highest percentage of pre-spawn females occurred on the first two days of sampling and sharply dropped off after that. While the percentage appears high on May 2, only three females were sampled this day and two were pre-spawn.

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 2014. Because of increased focus on improving our understanding of private boat fishing effort, all but four of the trips intercepted during the trophy season in 2014 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.

The mean HPT in 2014 according to charter boat data was 5.5 fish per trip (Table 9A). While higher than recent years, it was similar to the years 2003-2006. Mean HPT from private boat interviews (0.9 fish per trip) was much lower than HPT from charter boats. The private boat HPT was similar to last year and most previous years of the survey.

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. HPA from charter boat data in 2014 was 0.82 fish per person (Table 9B). This is more fish per person than last year and the highest value since 2006. HPA for private anglers, calculated from interview data, was 0.3 fish per person, consistent with previous years of the time-series (Table 9B).

Catch Per Unit Effort

In all years, charter boats caught (kept and released) more fish per trip and per hour than 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 2014, private boats caught an average of 1.2 fish per trip, similar to many past years, while charter boats caught 5.9 fish per trip, an increase over the past two years. The private boat catch per hour (CPH) was 0.3 fish per hour while charter boats had a CPH of 1.2 fish per hour. The 2014 private boat CPH was similar to previous years of the time-series. The charter boat mean CPH improved from 2013 but was lower than early years of the time-series, particularly 2003-2008.

Mean Daily Catch Per Hour

Anecdotal information from anglers and charter boat captains in most years indicates a decrease in catch rates during the latter portion of the spring season. Interview data showed that mean daily CPH declined slightly over time in some years, but has generally varied without trend since 2002 (Figure 8). Daily CPH values have decreased since 2007 due to the lack of charter boat interview data. Though there were not enough observations to make a definitive conclusion, it appears that daily CPH in 2014 was high in the beginning of the creel survey, decreased in the middle, and increased again at the end.

Angler Characterization

States of residence

In 2014, 207 private boat trips, 4 charter boat trips, and 1 shore trip were intercepted for interviews and 580 anglers were interviewed during the period April 19-May 15 (Table 5A and Table 5B). Nine states of residence were represented in 2014 (Table 11). Most anglers were from Maryland (83%), Virginia (7%), and Pennsylvania (5%), 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 2014, there were on average 2.7 anglers per boat and of these anglers, 1.2 were license-exempt (Table 12). These results are remarkably consistent with previous years.

Number of Lines Fished

To further characterize fishing effort, a question was added to the creel survey in 2006 and 2010-2014 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 2014, the average number of lines fished per private boat was eight and ranged from two to 21 lines (Table 13). This was more lines, on average, than in 2006 (6 lines) but similar to more recent years.

CITATIONS

Alperin I.M. 1966. Dispersal, migration, and origins of striped bass from Great South Bay, Long Island. New York Fish and Game Journal 13: 79-112.

Austin H.M. and O. Custer. 1977. Seasonal migration of striped bass in Long Island Sound. New York Fish and Game Journal 24(1): 53-68.

Barker, L., E. Zlokovitz, and C. Weedon. 2003. Characterization of the Striped Bass Trophy Season and Spawning Stock in Maryland. In: MDDNR-Fisheries Service, Investigation of striped bass in Chesapeake Bay, USFWS Federal Aid Project, F-42-R-16, 2002-2003, Job 5C, pp 183-203.

Berggren T.J. and J.T. Lieberman. 1978. Relative contribution of Hudson, Chesapeake and Roanoke striped bass stocks to the Atlantic coast fishery. U. S. Natl. Mar. Fish. Serv. Fish. Bull. 76: 335-345.

Bigelow H.B. and W.C. Schroeder. 1953. Striped bass. In fishes of the Gulf of Maine. U.S. Fish and Wildlife Service, Fisheries Bulletin 74(53): 389-405. Revision of U.S. Bur. Fish Bull. No. 40.

Chapoton R.B. and J.E. Sykes. 1961. Atlantic coast migration of large striped bass as evidenced by fisheries and tagging. Trans. Am. Fish. Soc. 90: 13-20.

Dovel W.L. 1971. Fish eggs and larvae of the upper Chesapeake Bay. Nat. Resources. Istit. Spec. Rep. No. 4., Univ. of Md. 71 pp.

Dovel W.L. and J.R. Edmunds. 1971. Recent changes in striped bass (*Morone saxatilis*) spawning sites and commercial fishing areas in Upper Chesapeake Bay; possible influencing factors. Chesapeake Science 12: 33-39.

Fay C.F., R.J. Neves and G.B. Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic). Striped bass. Publ. No. FWS/OBS-82/11.8. National Coastal Ecosystems Team, Division of Biological Services, US Fish and Wildlife Service, US Department of the Interior. Washington, DC.

Goshorn D.M., R.K. Schaefer and J.H. Uphoff. 1992. Historical trends in harvest rate and female spawning condition of large striped bass during May. Fisheries Technical Report Series No. 4. Maryland DNR.

Jones P.W. and A. Sharov. 2003. A Stock Size Based Method of Estimating the Spring Coastal Migrant Striped Bass Fishery Harvest Cap in Chesapeake Bay. Maryland Department of Natural Resources, Tawes State Office Building B-2. Annapolis Maryland. 4 pages.

Kernehan R.J., M.R. Headrick and R.E. Smith. 1981. Early life history of striped bass in the Chesapeake and Delaware Canal and vicinity. Trans. Am. Fish. Soc. 110:137-150.

CITATIONS (Continued)

Mansueti R.J. 1961. Age, growth and movement of the striped bass taken in size selective fishing gear in Maryland. Chesapeake Sci. 2: 9-36.

Mansueti R.J. and E.H. Hollis. 1963. Striped bass in Maryland tidewater. Nat. Res. Instit. of the Univ. of Md., Solomons Md. Maryland Dept. of Tidewater Fisheries, Annapolis, Md.

Merriman D. 1941. Studies on the striped bass of the Atlantic coast. US Fish. Wildl. Serv. Fish. Bull. 50: 1-77.

Pearson J.C. 1938. The life history of the striped bass, or rockfish, Roccus saxatilis (Walbaum). Bull. U.S. Bur. Fish., 49 (28): 825-851.

Raney E.C. 1952. The life history of the striped bass. Bingham Oceanogr. Collect., Yale Univ. Bull. 14: 5-97.

Raney E.C. 1957. Subpopulations of the striped bass in tributaries of Chesapeake Bay. US Fish Wildl. Serv. Spec. Sci. Rep. Fish. 208: 85-107.

Schaefer R.H. 1972. A short-range forecast function for predicting the relative abundance of striped bass in Long Island waters. N.Y. Fish and Game Journal. 19(2):178-181.

Setzler E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker and J.A. Mihursky. 1980. Synopsis of biological data on striped bass. Natl. Mar. Fish. Serv., FAO Synopsis No. 121. 69 pp.

Snyder D.E. 1983. Fish eggs and larvae. In *Fisheries Techniques, p. 189*. L.A. Nielsen and D.L. Johnson, eds. Southern Printing Co., Blacksburg, Va.

Speir H., J.H. Uphoff, Jr., and E. Durell. 1999. A review of management of large striped bass and striped bass spawning grounds in Maryland. Fisheries technical memo No. 15. Maryland Department of Natural Resources, Annapolis, MD.

Tresselt, E.F. 1952. Spawning grounds of the striped bass or rock, *Roccus saxatilis* (Walbaum), in Virginia. Bingham Oceanogr. Collect.,Yale Univ.14: 98-111.

Vladykov, V.D., and D.H. Wallace, 1952. Studies of the striped bass, *Roccus saxatilis* (Walbaum), with special reference to the Chesapeake Bay region during 1936-1938. Bingham Oceanogr. Collect.,Yale Univ. 14: 132-177.

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Table 1. History of MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2014.

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	36	1 per person, per season, with permit	Main stem Chesapeake Bay, Annapolis Bay Bridge-VA State line
1993	5/01-5/31	36	1 per person, per season	Main stem Chesapeake Bay, Annapolis Bay Bridge-VA State line
1994	5/01-5/31	34	1 per person, per day, 3 per season	Main stem Chesapeake Bay, Annapolis Bay Bridge-VA State line
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	32	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
1997	4/25-5/31	32	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
1998	4/24-5/31	32	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
1999	4/23-5/31	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2000	4/25-5/31	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2001	4/20-5/31	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2002	4/20-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2003	4/19-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2004	4/17-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2005	4/16-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2006	4/15-5/15	33	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2007	4/21-5/15	28-35 or larger than 41	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2008	4/19-5/13	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2009	4/18-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2010	4/17-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2011	4/16-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2012	4/21-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2013	4/20-5/15	28	1 per person, per day	Main stem Chesapeake Bay, Brewerton Channel-VA State line
2014	4/19-5/15	28	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, 2002-2014. 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, 2014.

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, 2014.

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, 2014.

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

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

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)

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)

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

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
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
Mean	**111**	**43**	**132**	**57**

*Two female fish (1% of females sampled) were of unknown spawning condition.

Table 9A. Mean harvest of striped bass per trip (HPT), with 95% confidence limits, calculated from Maryland charter boat 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	**0.0**
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)

Table 9B. Mean harvest of striped bass per angler, per trip (HPA), with 95% confidence limits, calculated from Maryland charter boat 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	**0.0**
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)

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)

Table 10B. Charter boat mean catch, effort, and catch per hour, with 95% confidence limits, calculated from charter boat 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)

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

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

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 19-May 15, 2014.

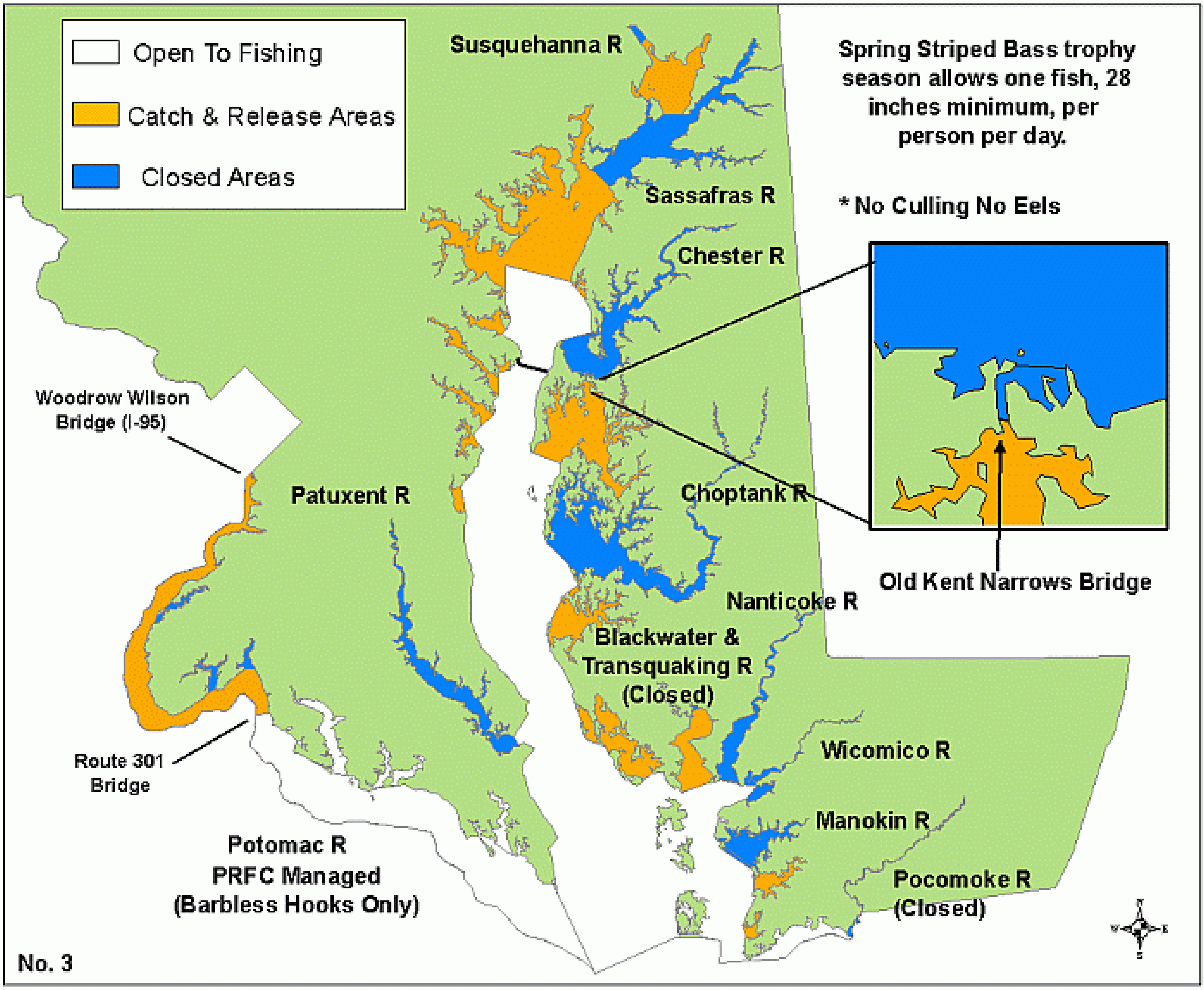


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

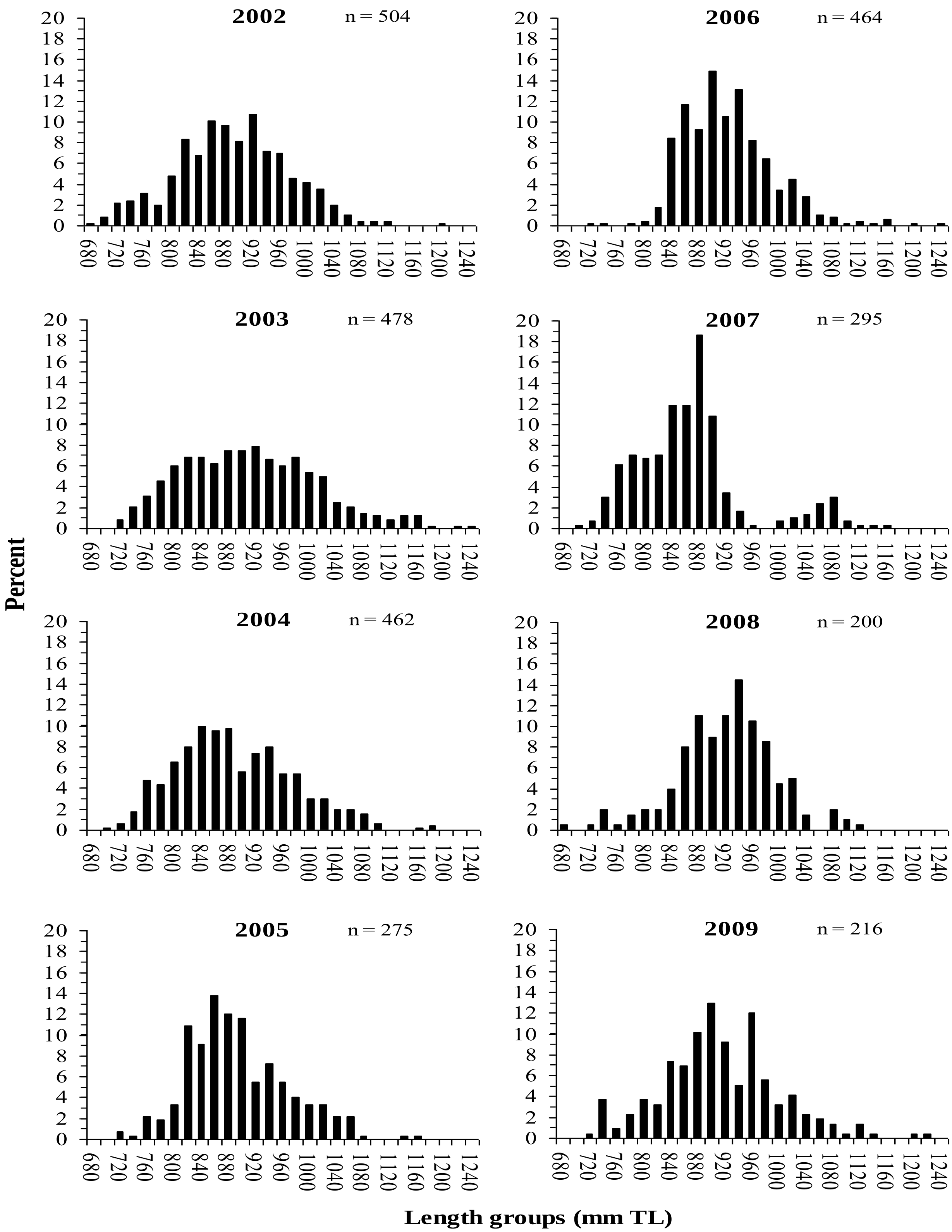


Figure 2. Continued.

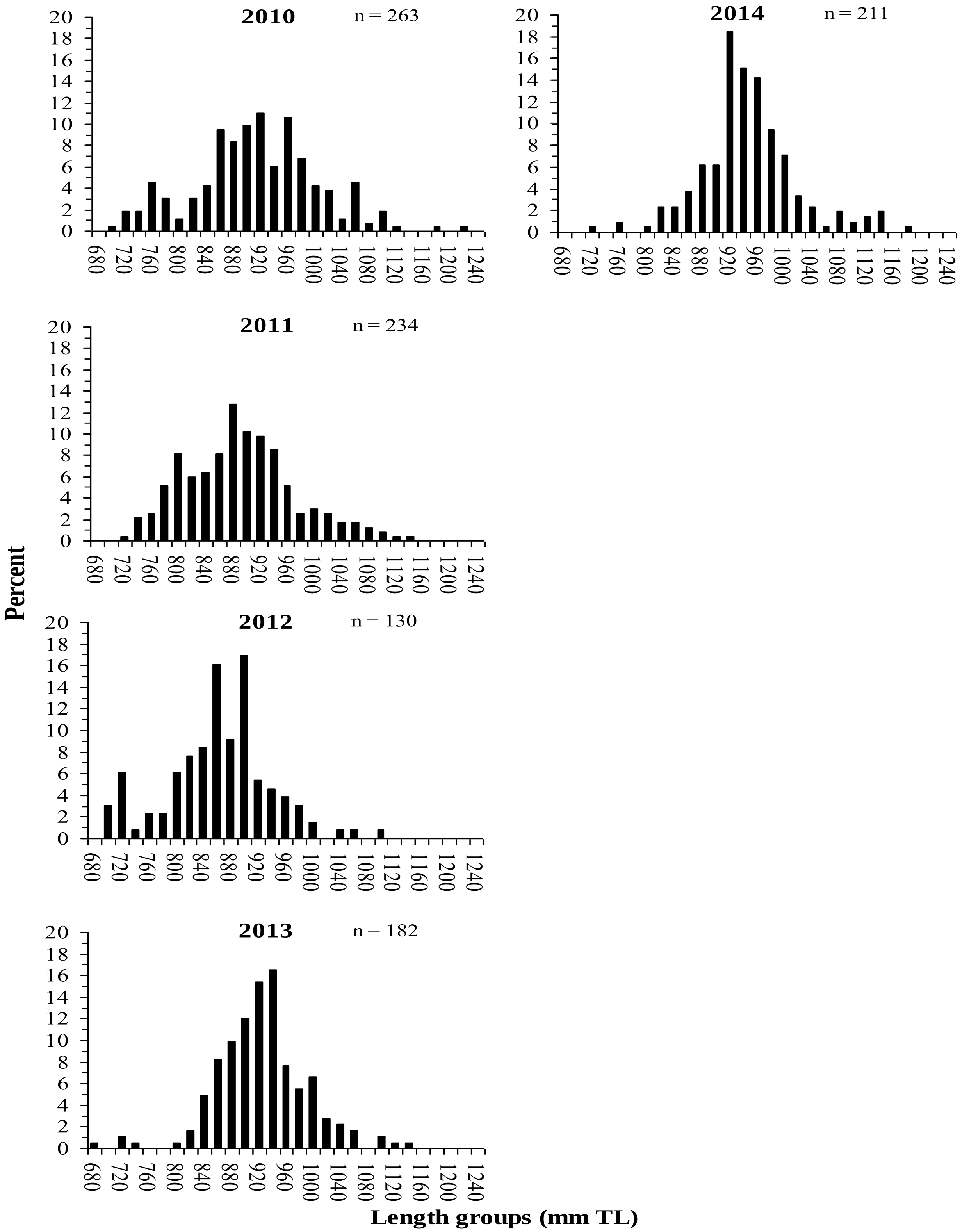


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

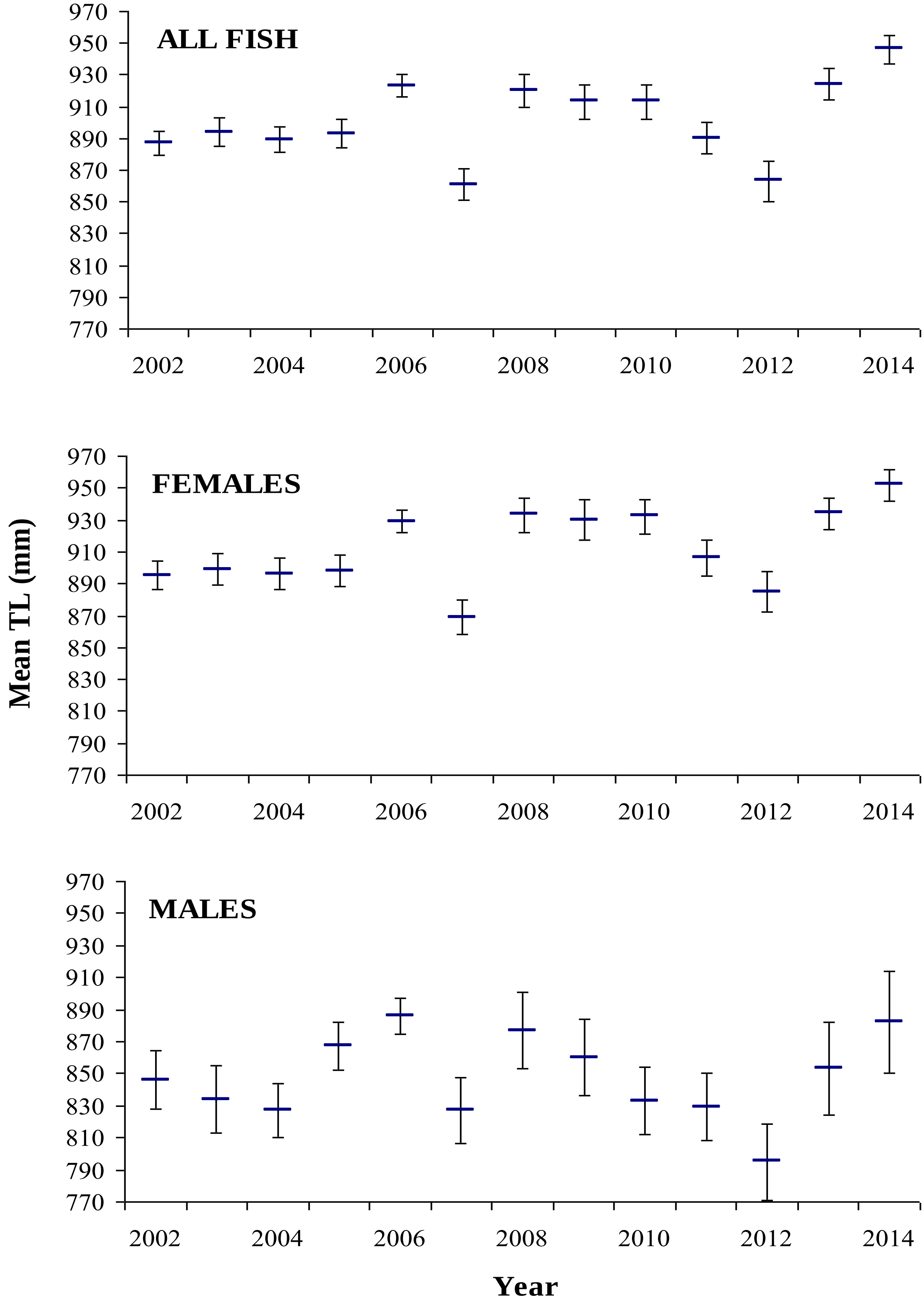


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

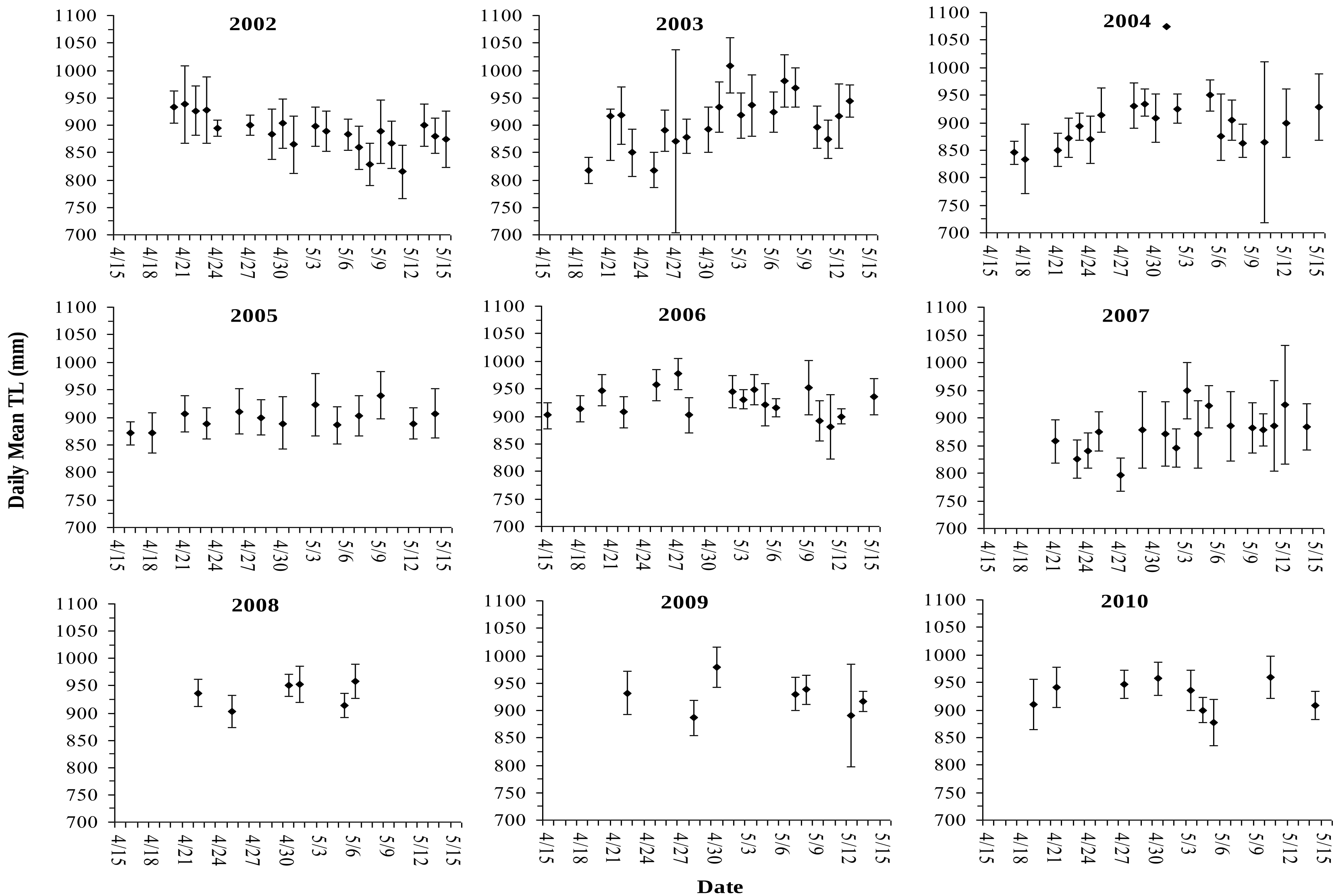


Figure 4. Continued.

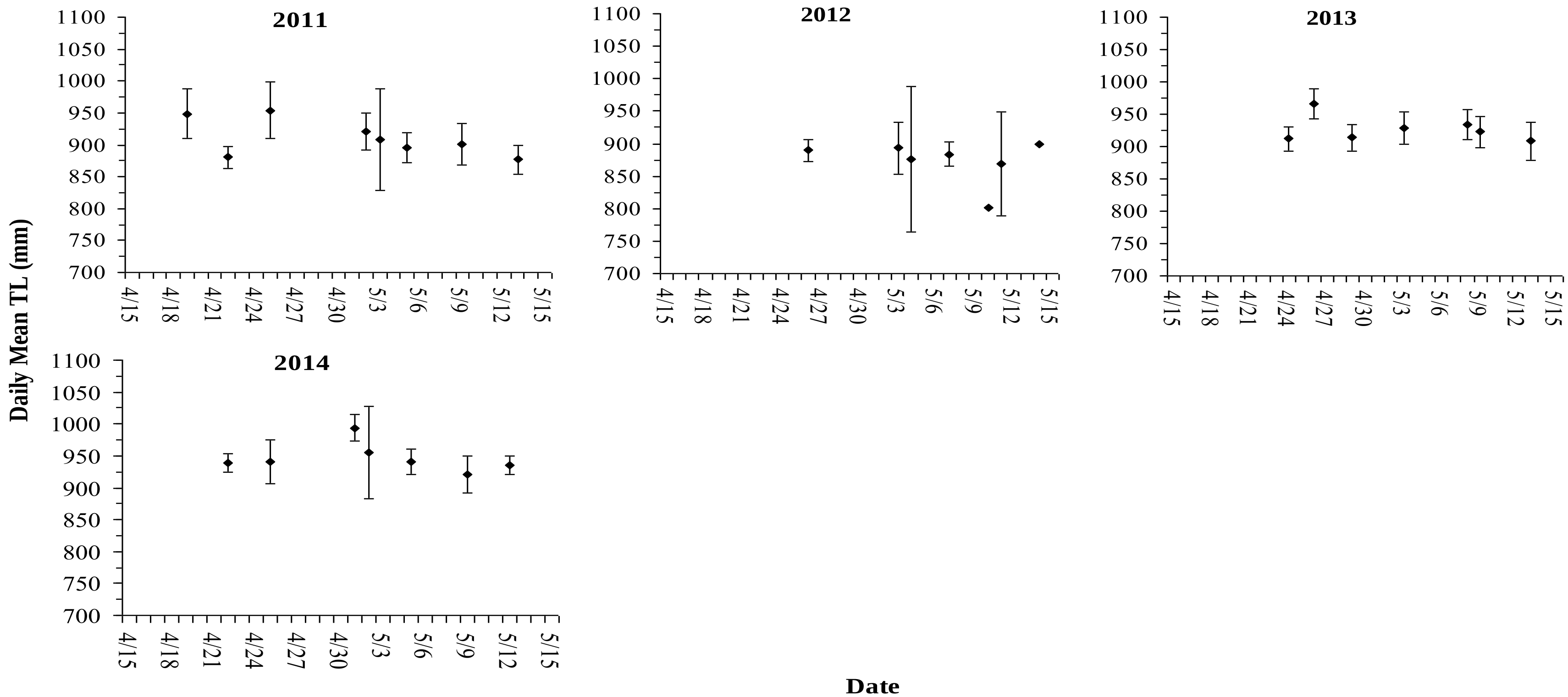


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

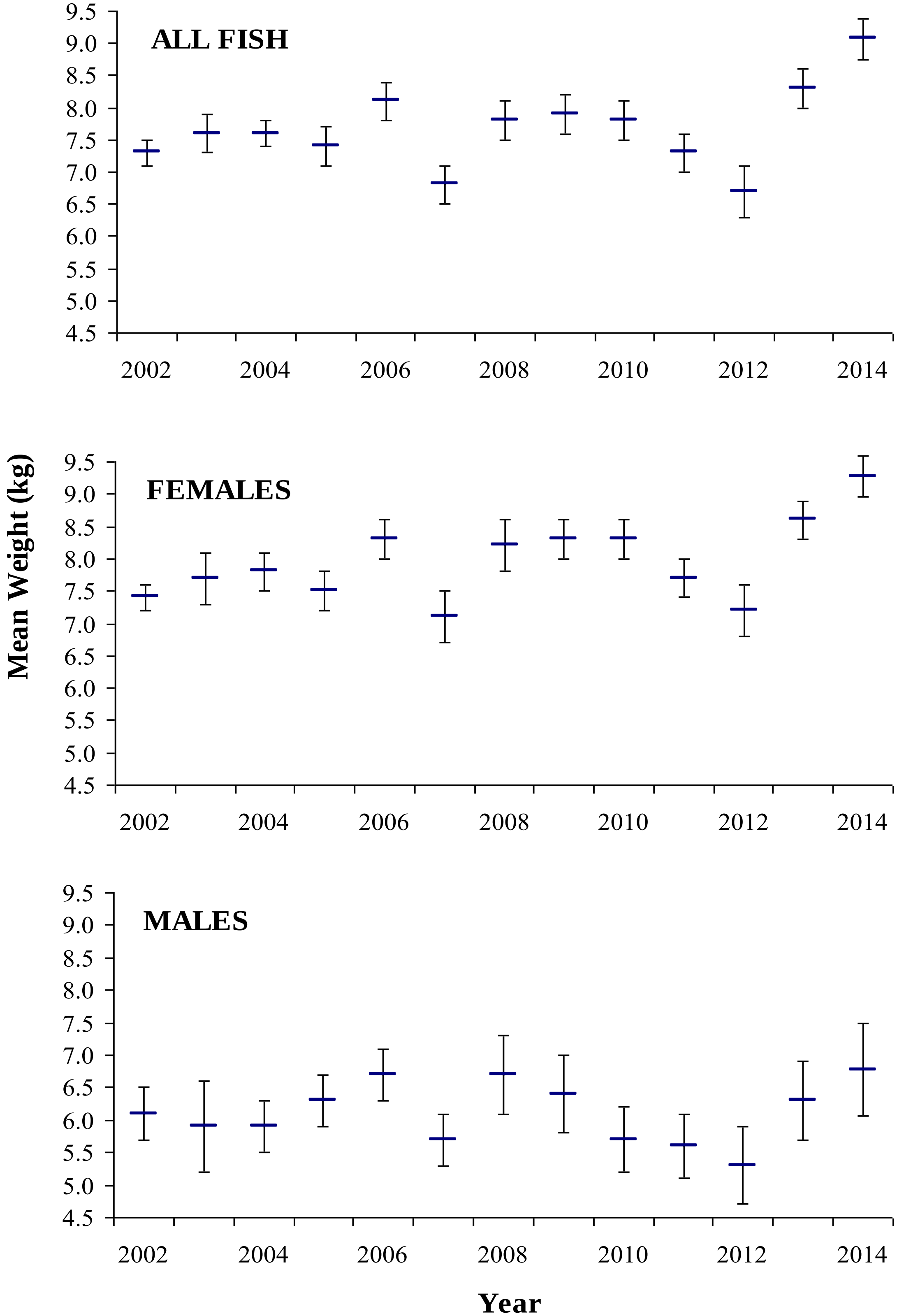


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

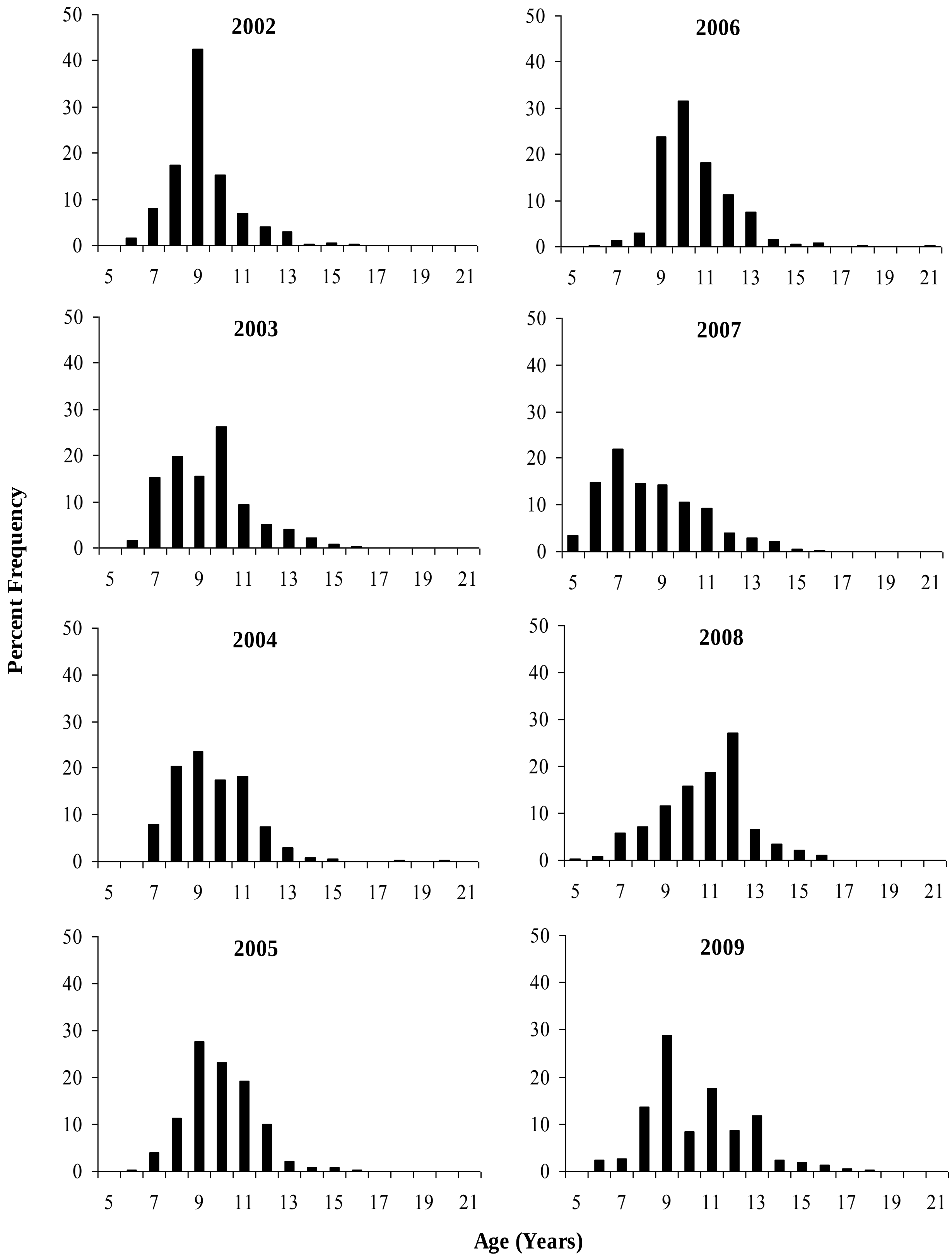


Figure 6. Continued.

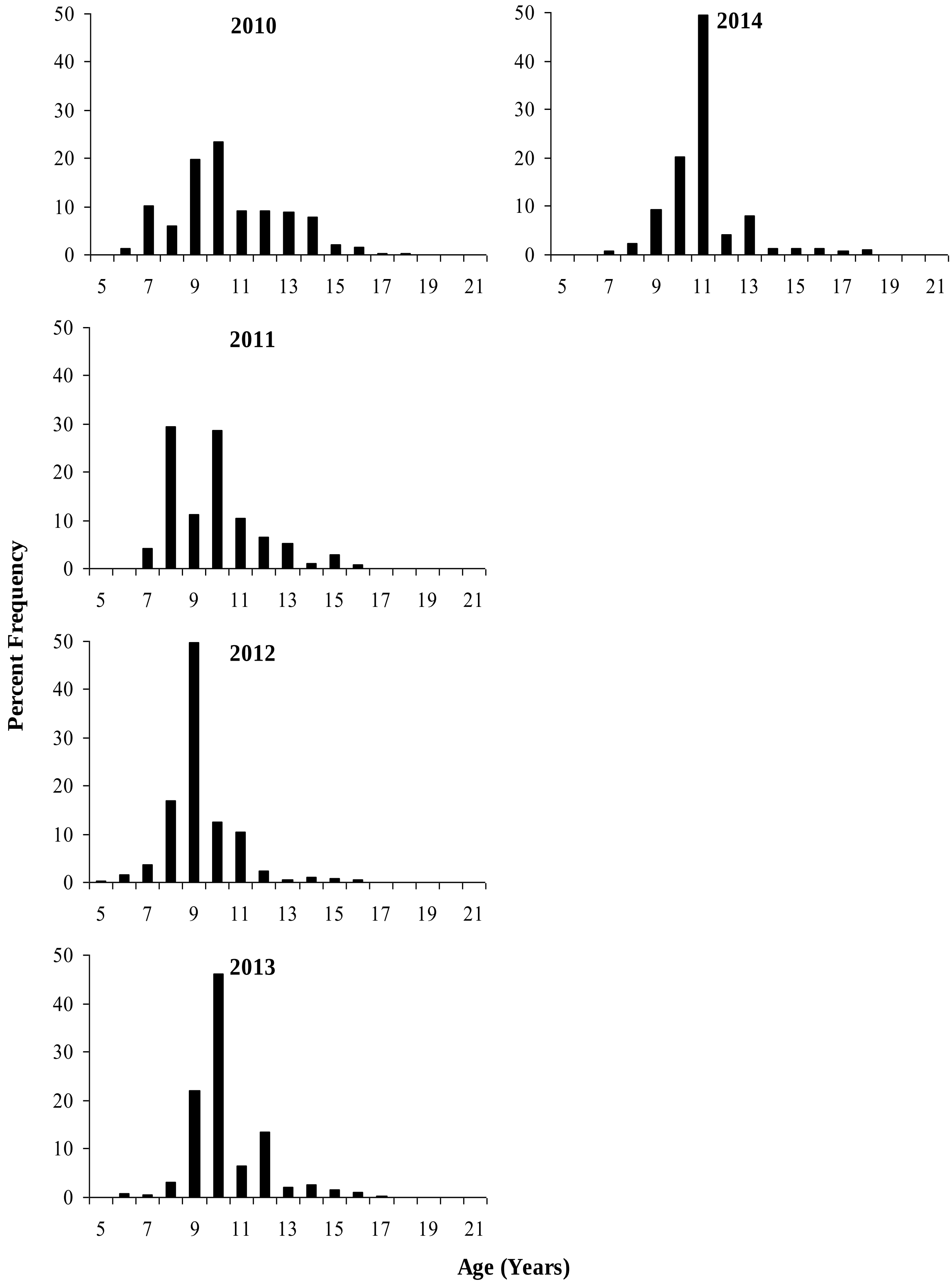


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

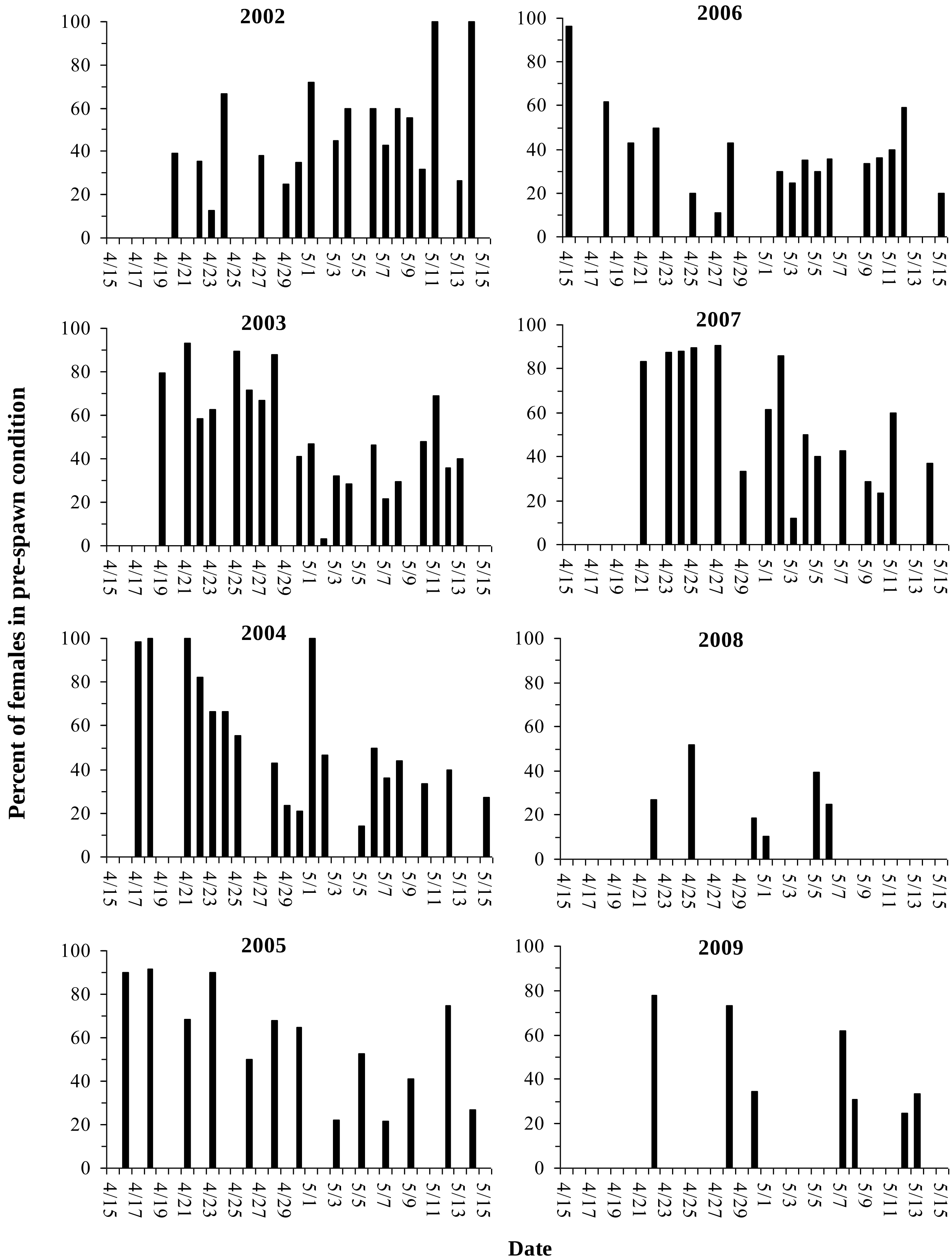


Figure 7. Continued.

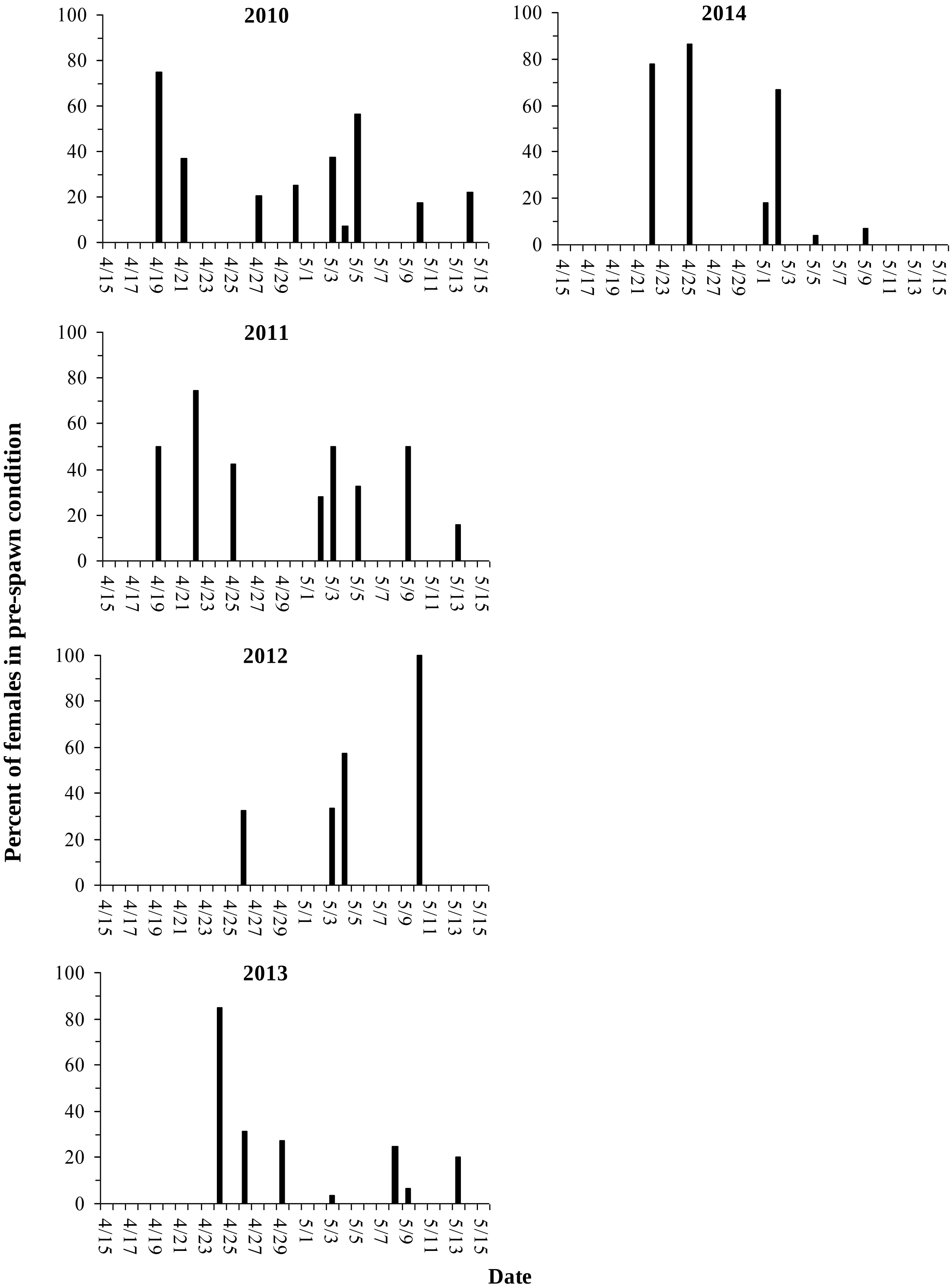


Figure 8. Daily mean catch per hour (CPH) of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15. Note different scale since 2008.

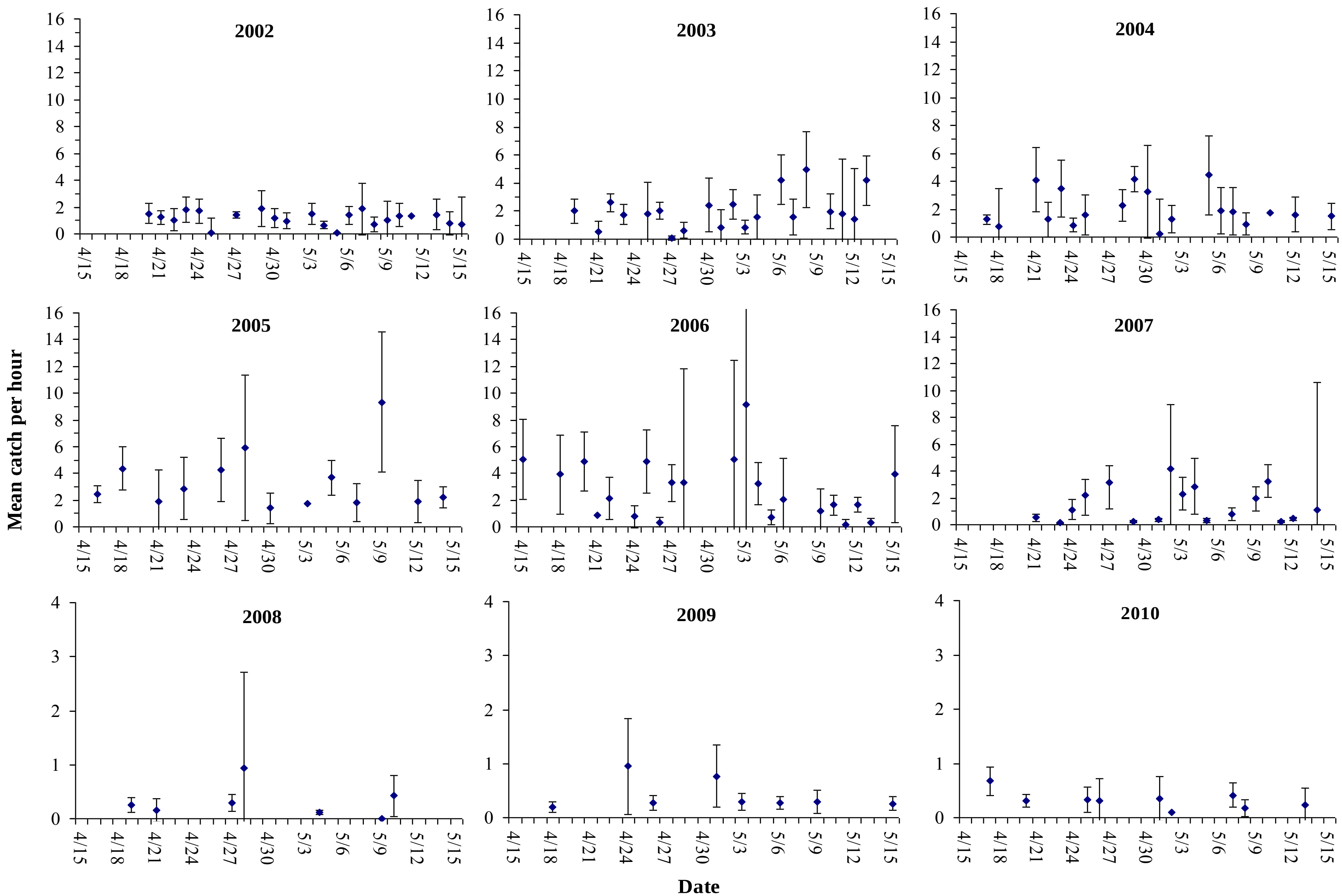
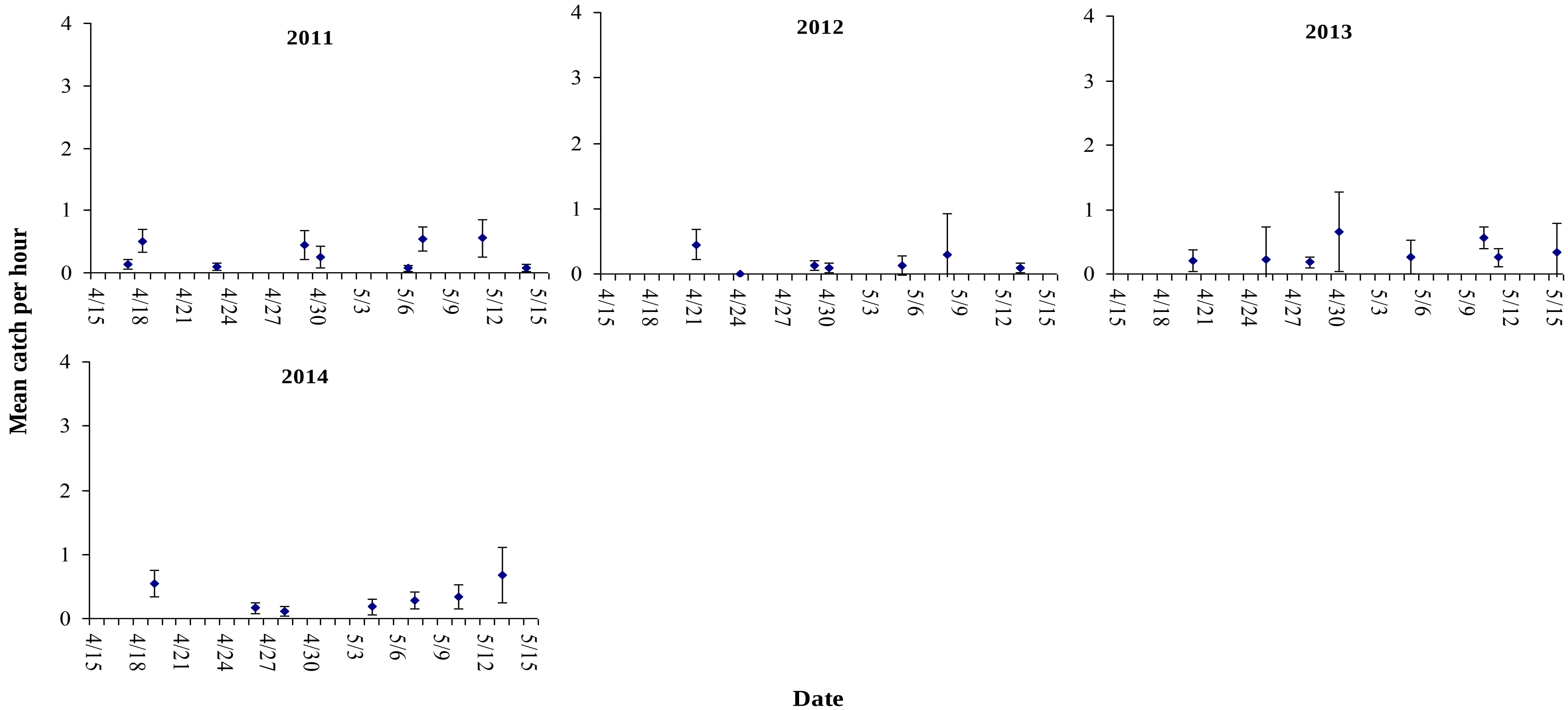


Figure 8. Continued.



<u>APPENDIX I</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, Ryan Hastings, Harry Rickabaugh 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 member helped develop the current management trigger adopted by ASMFC to monitor stock status until a more thorough stock assessment can be conducted.

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 participated in ASMFC Technical Committee conference calls finalizing the benchmark black drum stock assessment document.

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 helped develop the current management trigger adopted by ASMFC to monitor stock status, since no stock assessment of spot has been attempted to date.

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 recreated in July 2014.

Monthly page views to the Juvenile Striped Bass Survey web page for the period January 2014 to December 2014 are provided in Table 1. An increase in volume in October, 2014 coincided with publication of the juvenile survey results in the media and advertisement on the main Fisheries Service page. Many large or complex data requests are still handled directly by Striped Bass Stock Assessment Program staff. However, web page access to survey information has saved staff a considerable amount of time answering basic and redundant data requests.

Table 1. Monthly visits to the Juvenile Striped Bass Survey web page, January 2014 to December 2014.

Date	Page Views
January	449
February	481
March	451
April	418
May	450
June	488
July	278
August	363
September	420
October	956
November	366
December	327
Total	5,447

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, University of Massachusetts, Virginia Institute of Marine Sciences, Georgetown University, and State management agencies from Delaware, Massachusetts, New York and Virginia. For the past contract year, (November 1, 2013 through October 31, 2014) 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.

-Dr. Jeffrey Buckel, North Carolina State University
Provision of historical striped bass juvenile survey data and survey protocols.

-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.

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

- 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. Joseph Grist, VMRC.
Provision of striped bass length frequency and age structure information.

-Dr. Matthew Hamilton, Georgetown University.
Provision of juvenile striped bass biological samples for genetic research and abundance indices.

-Mr. Ken Hastings.
Provided striped bass commercial fishery monitoring and budget information, and ASMFC Striped Bass Compliance Report information.

-Mr. Mike Hendricks, Pennsylvania Fish & Boat Commission (PFBC).
Provision of American shad juvenile survey data from Juvenile Striped Bass 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.

-Mr. Louis-Phillipe Lapointe, Ministry of Natural Resources, Quebec, Canada
Provision of striped bass juvenile survey data , survey protocols, and Federal Aid Reports.

-Dr. Anthony Overton, Alabama A&M University, Dept. of Biological and Environmental Sciences.
Provision of juvenile striped bass biological samples and abundance data.

-Ms. Catherine Schlick, George Mason University.
Provision of historic juvenile herring abundance indices. Provided herring young-of-year samples from the Juvenile Survey.

-Ms. Sally Roman, Virginia Marine Resources Commission.
Provision of current and historical striped bass commercial fishery data; Striped bass Volunteer Angler Survey data, results of fishery dependent monitoring programs and striped bass juvenile survey data.

-Mr. James Taylor, NJDEP.
Provision of striped bass juvenile survey information.

-The Interjurisdictional Project also provided related biological information and reports to twenty one (21) 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-10

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

Summary

The primary objective of the Chesapeake Bay Finfish Investigations Survey, F-61-R-10, was to monitor and biologically characterize resident and migratory finfish species in the Maryland portion of the Chesapeake Bay during the 2013 – 2014 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 document is to summarize any interactions of these biological surveys with endangered species such as Atlantic sturgeon, shortnose sturgeon, and sea turtles. However, during the 2013 – 2014 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 1, 2013 through October 31, 2014.

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 1, 2013 through October 31, 2014.

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 1, 2013 through October 31, 2014.

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 1, 2013 through October 31, 2014.

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 1, 2013 through October 31, 2014.

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 1, 2013 through October 31, 2014.

PROJECT 2: **INTERJURISDICTIONAL SPECIES STOCK ASSESSMENT**

JOB 1: Alosa Species: Stock assessment of adult and juvenile anadromous *Alosa* in the Chesapeake Bay and select tributaries.

Research Surveys:

1. Nanticoke River Pound/Fyke Net Survey
2. Nanticoke River Ichthyoplankton Survey

1. Nanticoke River Pound/Fyke Net Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during the Survey period of this project from November 1, 2013 through October 31, 2014.

Shornose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of this project from November 1, 2013 through October 31, 2014..

2. Nanticoke River Ichthyoplankton Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during the Survey period of November 1, 2013 through October 31, 2014.

Shornose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during the Survey period of November 1, 2013 through October 31, 2014.

<u>PROJECT 2</u>:

<u>JOB 2</u>: Migratory Species: Stock assessment of selected recreationally important adult migratory finfish in Maryland's Chesapeake Bay.

Research Survey:

1. Summer Pound Net Survey:

1. Summer Pound Net Survey

<u>Atlantic Sturgeon Interactions</u>

No Atlantic sturgeon were sampled or observed during the Survey period of November 1, 2013 through October 31, 2014.

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

No shortnose sturgeon or sea turtles sampled or observed during the Survey period of November 1, 2013 through October 31, 2014..

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

1. Summer - Fall Pound Net Survey

Atlantic Sturgeon Interactions

No Atlantic sturgeon were sampled or observed during this Survey for the period of November 1, 2013 through October 31, 2014.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of November 1, 2013 through October 31, 2014.

Task 2: Characterization of striped bass spawning stocks in Maryland.

Research Survey:
1. Spring Striped Bass Experimental Drift Gill Net 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 1, 2013 through October 31, 2014.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of November 1, 2013 through October 31, 2014.

Project 2, Job 3,

Task 3: Maryland juvenile striped bass survey

Research Survey:

1. Juvenile Striped Bass Seine 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 1, 2013 through October 31, 2014.

Shortnose Sturgeon and Sea Turtle Interactions

No shortnose sturgeon or sea turtles were sampled or observed during this Survey for the period of November 1, 2013 through October 31, 2014.