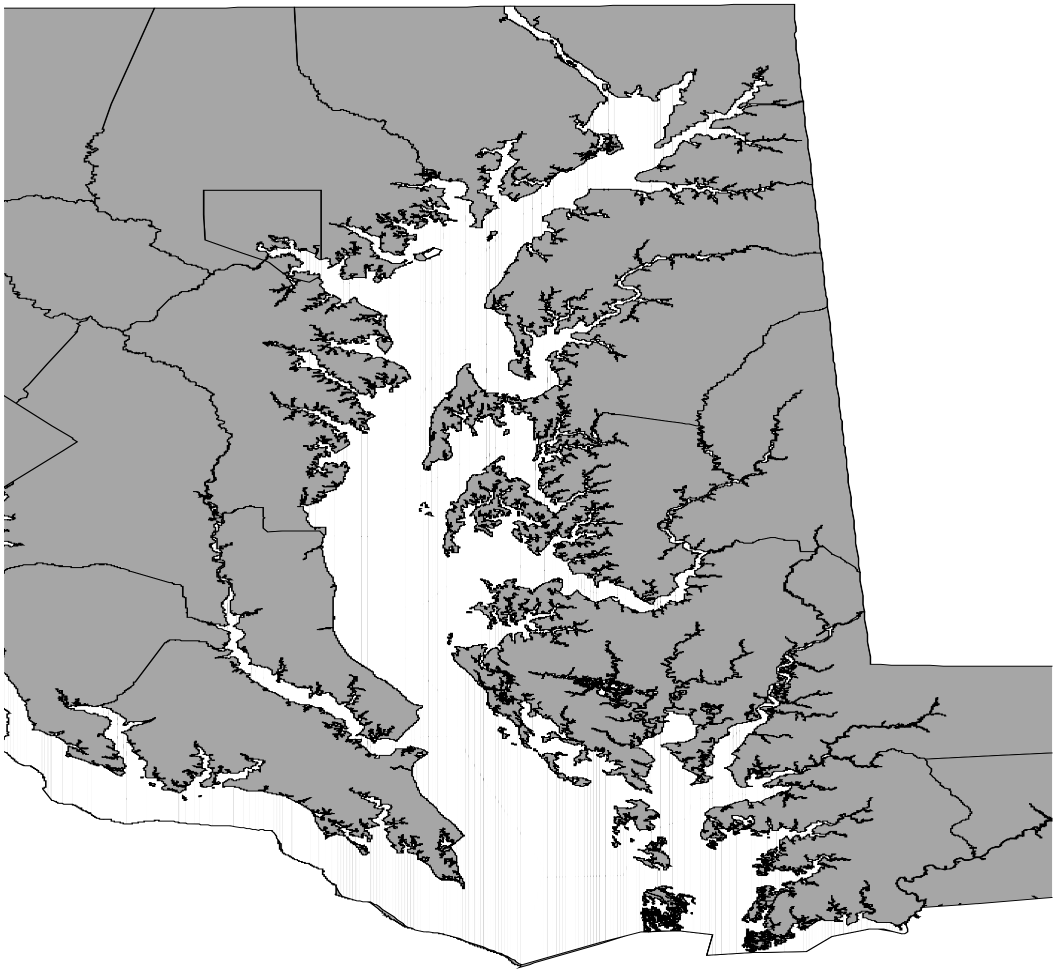

Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-8
2011 - 2012

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Governor

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

STATE: Maryland

PROJECT NO.: F-61-R-8

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2011 through October 31, 2012

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.

The Head-of-Bay (HOB) channel catfish population was assessed with a surplus production model covering the years, 1980 – 2011, and the Choptank River channel catfish stock was assessed with a catch survey analysis (CSA; 1993 -- 2011). Trends in channel catfish populations from Nanticoke, Patuxent, and Potomac rivers were described from available relative abundance indices.

The HOB channel catfish assessment utilized a fishery dependent relative abundance index, and two fishery independent relative abundance indices, a gill net survey, and a trawl survey. The model fit the data well, but as usual, biomass and mortality ratios were more precisely estimated than absolute biomass and mortality estimates. $B:B_{msy}$ ratio in the final year was 1.55, which indicates

that the stock is not overfished, and F:F_{msy} ratio in 2011 was 0.86, which indicates that overfishing was not occurring. However, fishing mortality has trended upward since 2009.

The CSA model fit the population data moderately well. Pre-recruit (channel catfish < 355 mm) population abundance generally tracked the increase in the survey's relative abundance values, with relatively low pre-recruit abundance during 1995 – 2004, followed by relatively high pre-recruit abundance for the remainder of the time series. Post-recruit channel catfish (>355 mm) abundance varied between 200,000 and 400,000 channel catfish from 1993 – 2007. After 2007, recruited channel catfish abundance accelerated quite swiftly with the recruited population increasing from an estimated 664,000 fish in 2008 to 1.06 million fish in 2011. Instantaneous fishing mortality (F) was generally low, varying between F=0.04 and 0.15 for most of the assessment period. Average F for the entire time series was F= 0.13 and F in the final year of the assessment was 0.11. Model outputs and survey results strongly suggest that fishing mortality at recent levels is not impacting population growth.

Relative abundance indices from other river systems were largely inconclusive, but populations appear to be stable. Nanticoke River commercial fishery CPUE's were quite variable and exhibited no discernable trend. Young-of-year production, as determined from a seine survey was also not definitive, but production was more consistent during 1989 –1997 than in recent years. Patuxent River channel catfish landings have been trendless throughout the past 25 years. Only the fish pot relative abundance index provided a complete enough time series to warrant investigation, and it has been trending downward since 2006. Young-of-year production, as determined from a seine survey indicated that the last years of high juvenile abundance were in 2001 and 2003. The Potomac River drift gill net survey indicated that the biomass index was below the 75th percentile since 2005. Young-of-year production, as determined from a seine survey indicated low and intermittent juvenile production since 1985. Commercial landings have been relatively stable at lower levels since 2002.

Populations of American shad in Maryland continue to be impacted by predation, by-catch and turbine mortality. The surplus production model population estimate of American shad abundance in the lower Susquehanna River exhibited no significant trend over the times series (1986-2012), but population abundance has been steadily increasing since 2007. Estimates of hook and line GM CPUE vary without trend over the time series in the lower Susquehanna River (1984-2012) and the Potomac River (1996-2012). In the Nanticoke River, GM CPUE was the highest in the time series (1988-2012). The percentage of repeat spawners continues to increase in the lower Susquehanna and Nanticoke rivers. Juvenile American shad indices have improved in the Potomac River, but generally remain low in Maryland tributaries.

The age structure of hickory shad in a Susquehanna River tributary remains consistent, with a wide range of ages and a high percentage of older fish. The arcsine-transformed proportion of these repeat spawners (sexes combined) has not changed significantly over the time series (2004-2012; r^2 = 0.028, P = 0.67; Figure 18), although the total percentage of repeat spawners in 2012 (64.0%) was the lowest total percent of repeat spawners of the time series (2004-2012).

According to the most recent ASMFC stock assessment, the coast wide meta-complex of river herring stocks on the U.S. Atlantic coast is depleted to near historic lows. River herring age structure in the Nanticoke River appears to be truncating, especially for blueback herring. Observed declines in length-at-age generally occur toward the end of the time series. The GM CPUE for juvenile alewife and blueback herring decreased in 2012 in all Maryland tributaries. Due to Amendment 2 to the ASMFC FMP for American shad and river herring, it is not legal to harvest river herring within the jurisdiction of Maryland. This moratorium on river herring 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. Maryland's commercial weakfish harvest declined to 378 pounds in 2011, and was the lowest catch on record. The 2012 mean length for weakfish from the onboard pound net survey was 284mm TL. The 2011 length frequency distribution and RSD analysis indicate that only smaller weakfish were available in Maryland waters. The charter boat CPUE has significantly declined from 1993-2011.

Summer flounder mean length from the pound net survey was 338 mm TL in 2012, the ninth lowest mean value in the 20 year survey. Relative stock densities in the 2012 onboard pound net survey indicated a slight decrease in the stock and quality categories with a corresponding increase in the preferred category compared to 2011. Charter boat CPUE has declined from 1993 - 2003, but has been relatively stable for the past eight years. The NMFS 2011 coast wide stock assessment concluded that summer flounder stocks were not overfished, overfishing was not occurring and the rebuilding target has been met as of 2010.

Mean length of bluefish from the pound net survey in 2012 was 298 mm TL, less than the time series mean. Length distribution and RSD analysis indicated a slight shift to larger bluefish in 2012. Recreational and commercial bluefish harvest increased in 2011, but still remained below the long term mean. The 2011 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 2012 was 274 mm TL; this was the third lowest value of the 20 year time series. For Atlantic croaker from the onboard pound net survey the $RSD_{perferred}$ category decreased, with a corresponding slight increase occurring in the remaining RSD categories. Maryland Atlantic croaker total commercial harvest increased in 2011 to 704,019 pounds; while the 2011 recreational harvest estimated of 554,206 fish decreased compared to 2010. Compared to 2010, the 2011 charter boat geometric catch per angler decreased to 4.66 fish per angler, but was still above the long term mean.

Spot mean length decreased in 2012 and was the lowest value on record. The spot juvenile index spiked to the time series high in 2010, declined to near the time series low in 2011, but rose in 2012 to the eighth highest value in the 24 year time series. Commercial harvests increased sharply in 2009 and remained high through 2011, while the recreational estimate dropped well bellow the time series mean. The charter boat geometric mean catch per angler increased in 2011, but was still the fourth lowest value of the 19 year time series.

Resident / premigratory striped bass sampled in the Chesapeake Bay during the summer – fall 2011 pound net and hook and line commercial fisheries ranged from 1 to 13 years of age. Three year old (2008 year-class), four year old (2007 year-class), five year old (2006 year-class), six year old (2005 year-class) and seven year old (2004 year-class) striped bass dominated biological samples taken from pound nets. These five year-classes comprised 88% of the sample. Check station sampling determined that the majority of the pound net and hook-and-line fishery harvest was composed of four to seven year old individuals from the 2004 through 2007 year-classes.

The 2011-2012 commercial striped bass drift gill net fishery harvest was comprised primarily of fish 4, 5, 6 and 7 years old from the 2005 through 2008 year-classes. Striped bass from the 2007 year-class (five year old fish) composed 47% of the total drift gill net harvest. The 2007 and 2006 (ages 5 and 6) cohorts accounted for 71% of the total harvest while age groups 8 to 11 year-old fish contributed 2% to the total. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 3 to 11 (2001 to 2009 year-classes).

Fish harvested during the 2011-2012 Atlantic coast fishing season ranged from age 4 (2008 year-class) to age 21 (1991 year-class). Fourteen year-classes were represented in the sampled harvest. Approximately 72% of striped bass harvested were ages 7 through 10. Striped bass were recruited into the Atlantic coast fishery as young as age 4, but due to the 24 inch minimum size limit, few fish younger than age 6 were harvested, which is similar to previous years. Based on the estimated catch-at-age, the most common age harvested during the 2011-2012 Atlantic coast harvest was age 9 (2003 year-class), which represented 34% of the fishery. Large contributions were also made by the 2004 year-class (age 8) and the 2005 year- class (age 7), which represented 16% and 13% of the fishery, respectively.

The spring, 2012 spawning stock survey indicated that there were 18 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 19 years old. Male striped bass ranged in age from 2 to 15 years old, with age 8 and age 9 fish (2004 and 2003 year-classes) being the most abundant component of the male striped bass spawning stock. The majority of females were ages 9 to 14, with most female collected at age 9 (2003 year-class). During the spring, 2012 spawning season, the contribution of age 8 and older females to the female spawning stock increased to 80%.

The 2012 striped bass juvenile index, the annual measure of striped bass spawning success in Chesapeake Bay, was 0.9, the lowest index measured in survey's 59-year history. This is significantly lower than the long-term average juvenile index of 12.0. Highly variable spawning success is a hallmark of striped bass populations. Typically, several years of average reproduction are interspersed with occasional large and small year-classes. Spawning success is heavily influenced by environmental conditions such as flow rates and water temperature. In 2011, biologists documented one of the most successful striped bass spawns on record and these 1-year-old fish are very abundant. The successful spawning years of 1989, 1996, and 2001 were also followed by below-average or poor years.

Several other species of anadromous fish, such as white perch, yellow perch, and river herring, experienced low reproductive success in 2012, pointing to large-scale environmental conditions as the probable cause because warm winters and dry springs are unfavorable spawning conditions for anadromous fish. However, the survey documented increased reproduction of species that spawn offshore or in higher salinity bay water, like Atlantic croaker and bay anchovies. During this year's survey, biologists identified and counted more than 31,000 fish of 54 different species. DNR biologists have monitored the reproductive success of striped bass and other species in Maryland's portion of the Chesapeake Bay annually since 1954

During the 2012 trophy season, biologists intercepted 209 fishing trips, interviewed 447 anglers, and examined 130 striped bass. The average total length of striped bass sampled was 863 mm total length (mm TL) (34.0 inches). The average weight was 6.7 kg (14.7 lbs). Striped bass sampled from the trophy fishery ranged in age from 5 to 17 years old. The 2003 year-class (age 9) and 2004 year-class (age 8) were the most frequently observed cohorts. Average catch rate based on angler interviews was 0.2 fish per hour.

Maryland Department of Natural Resources biologists continued to tag and release striped bass in 2012 in support of the US FWS coordinated interstate, coastal population study for growth and mortality. A total of 688 striped bass were tagged and released with USFWS internal anchor tags. Of this sample, 682 were tagged in the Potomac River and the upper Chesapeake Bay area during the spring spawning stock assessment survey. A total of 6 striped bass were tagged during an abbreviated 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 catches. 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 John Collier and crew of the *R/V Laidly*, for their assistance during the winter trawl survey.

Striped bass were collected for portions of this study from commercial pound nets owned and operated by Maryland Watermen's Association commercial captains and their crews. 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 Boarman, on the Potomac River, and Michael Cannan, on the Upper Chesapeake Bay.

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PROJECT NO. 1
JOB NO. 1

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The primary objective of Job 1 was to provide data and analysis from routine monitoring of the following resident species: white perch (*Morone americana*), yellow perch (*Perca flavescens*), channel catfish (*Ictalurus punctatus*) and white catfish (*Ameiurus catus*) from selected tributaries in the Maryland portion of 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

<u>Upper Chesapeake Bay Winter Trawl</u>

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 2011 through February 2012.

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.

Choptank River Fishery Independent Sampling

In 2012, 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 23 February through 2 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 4 February 2012 in and around Middle River, 16 February 2012 in Sassafras River, and 20 February 2012 in Northeast River (Figures 3, 4, 5). All yellow perch were measured and sexed (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River Fishery Dependent Sampling

From 22 February 2012 to 30 April 2012, resident species were sampled from pound nets set by commercial fishermen on the Nanticoke River. Previous years have included fyke net samples. This segment of the survey was completed in coordination with Project 2, Job 1 of this grant. Nets were set from Barren Creek (35.7 rkm) downstream to Monday's Gut (30.4 rkm; Figure 6). Net sites and dates fished were at the discretion of the commercial fishermen. 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 2011 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 7-9
Yellow perch	Tables 11-14 and Figures 10-13
Channel catfish	Tables 15-17 and Figures 14-16
White catfish	Tables 18-20 and Figures 17-19

Growth

White perch	Tables 21-22
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White perch	Table 26
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Recruitment

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Relative Abundance

White perch	Tables 28-29
Yellow perch	Tables 30-31 and Figure 25
Channel catfish	Figures 26-27
White catfish	Figure 28

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Figure 1. Upper Chesapeake Bay winter trawl survey locations, December 2011 – February 2012. Different symbols indicate each of 6 different sampling rounds.

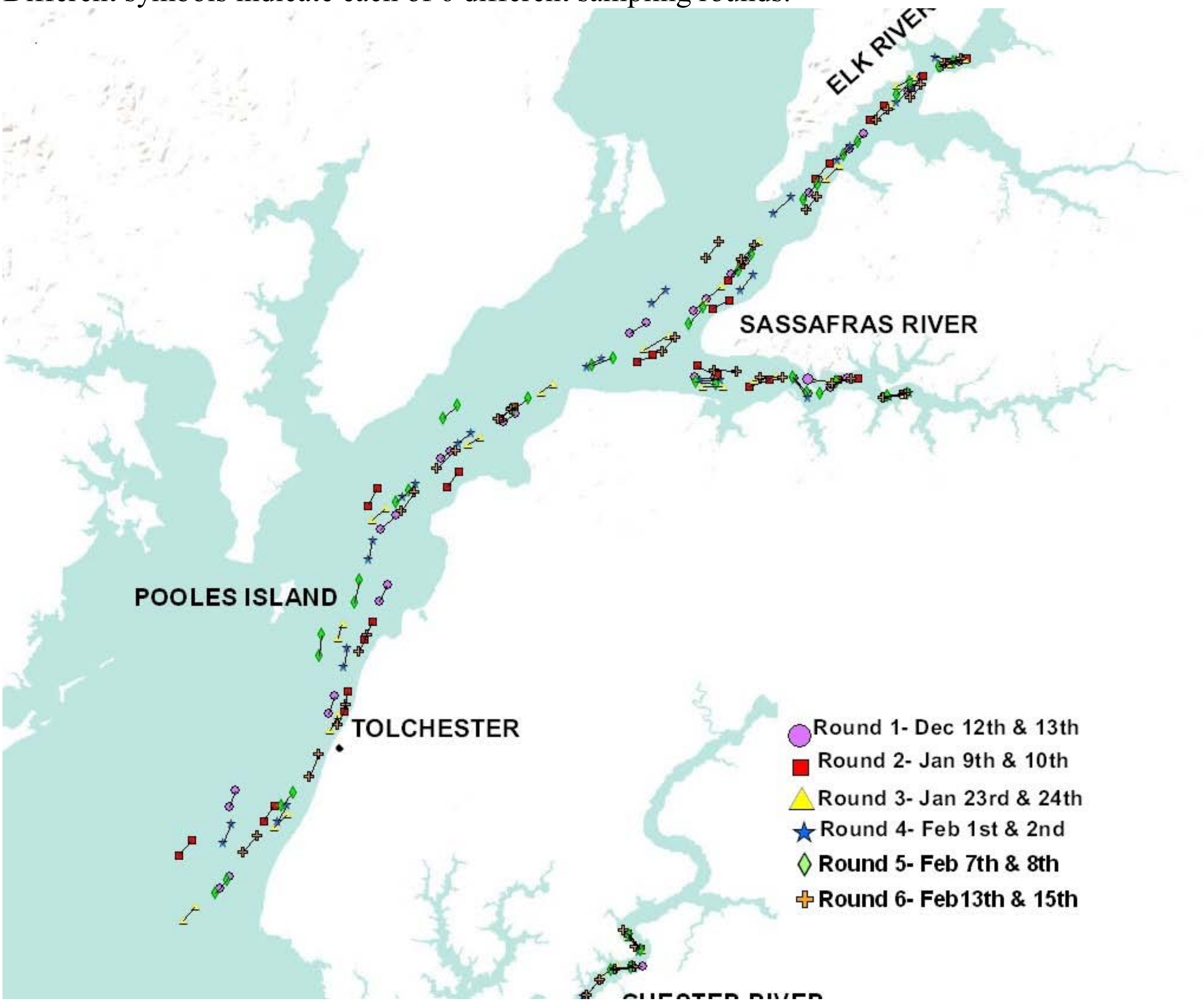


Figure 2. Choptank River fyke net locations, 2012. Circles indicate sites.

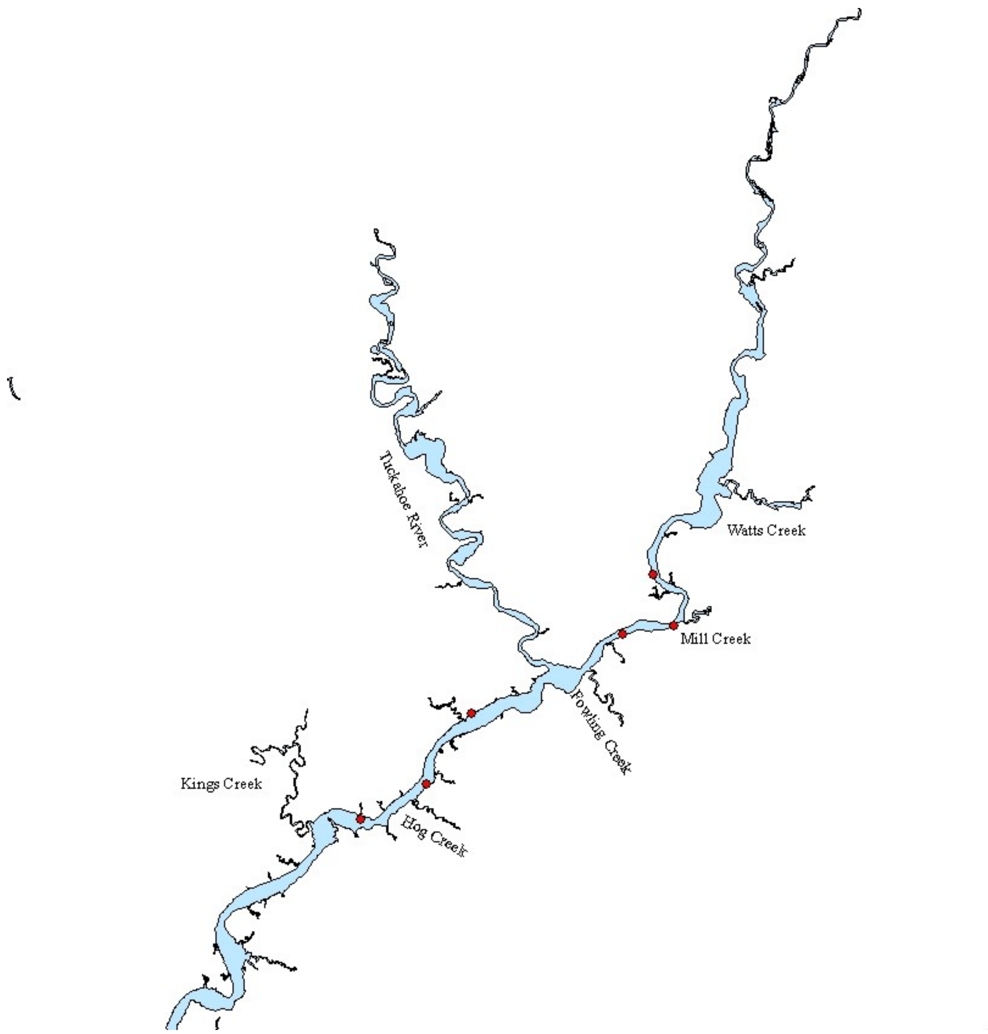


Figure 3. Commercial yellow perch fyke net sites sample during 2012 in Middle and Back rivers. Circles indicate sites.

Figure 4. Commercial yellow perch fyke net sites sample during 2012 in the Sassafras River. Circles indicate fyke net locations.

Figure 5. Commercial yellow perch fyke net sites sample during 2012 in the Northeast River. Black lines indicate the geographic range of fyke net locations.

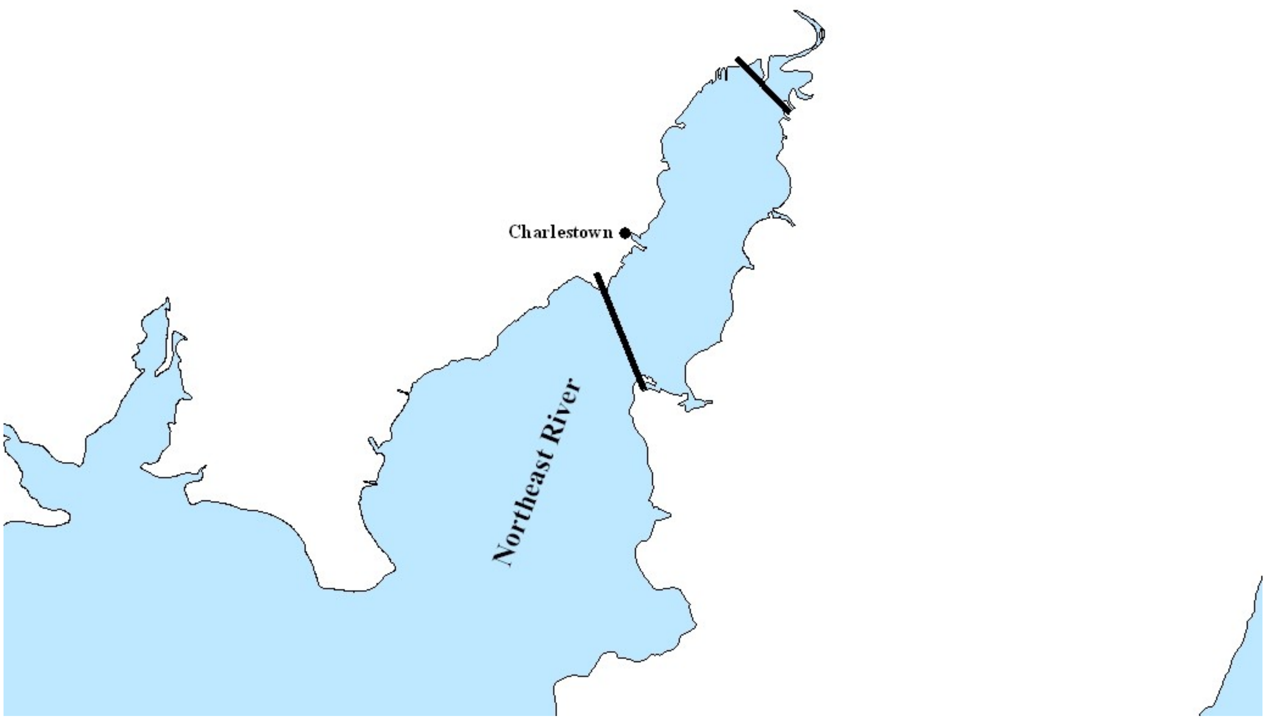


Figure 6. Commercial fyke net and pound net sites sample during 2012 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

Table 1. White perch catch-at-age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2012.

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

Table 2. White perch catch-at-age matrix from Choptank River fyke net survey, 2000 – 2012.

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

Table 3. White perch catch-at-age matrix from Nanticoke River fyke and pound net survey, 2000 – 2012. 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

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2012.

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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2012.

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	1088	20	0	259	578	5	12	0

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2012.

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

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2012. 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

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2012. 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

Figure 7. White perch length-frequency from 2012 upper Chesapeake Bay winter trawl survey.

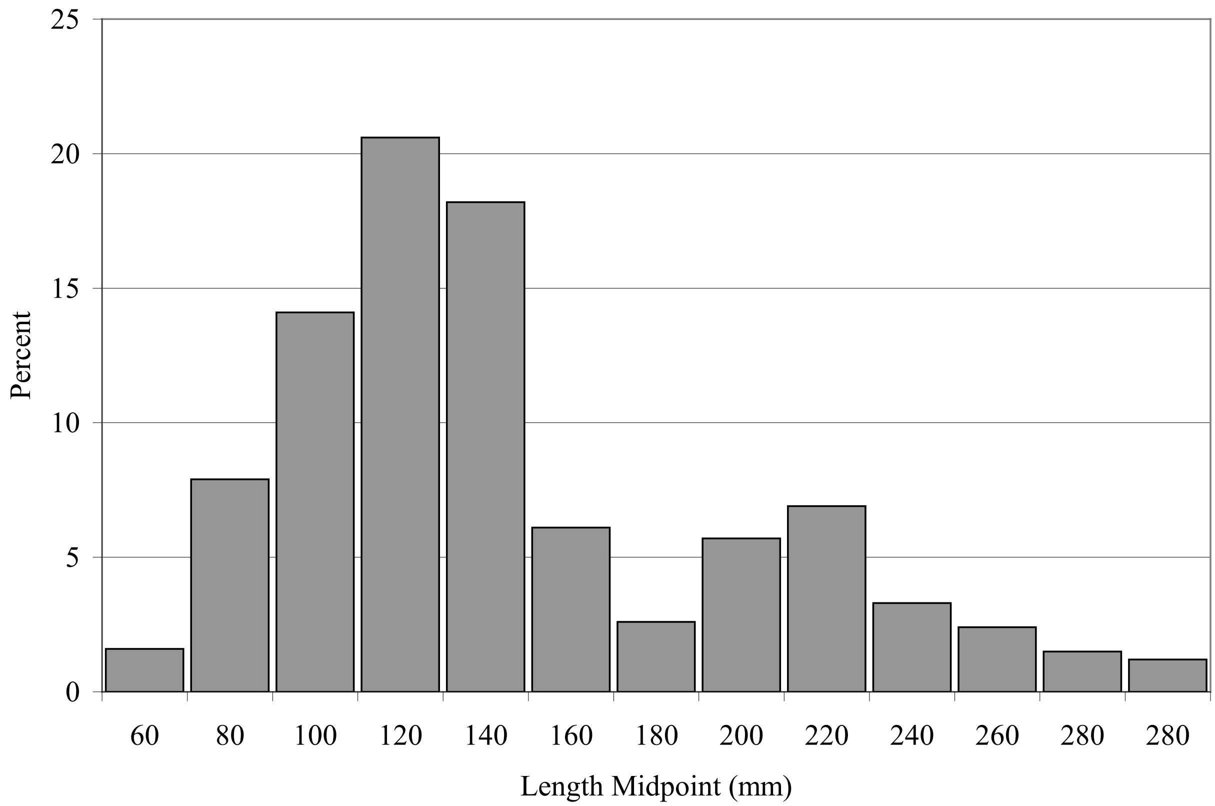


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2012. Minimum length cut-offs in parentheses.

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

Figure 8. White perch length-frequency from 2012 Choptank River fyke net survey.

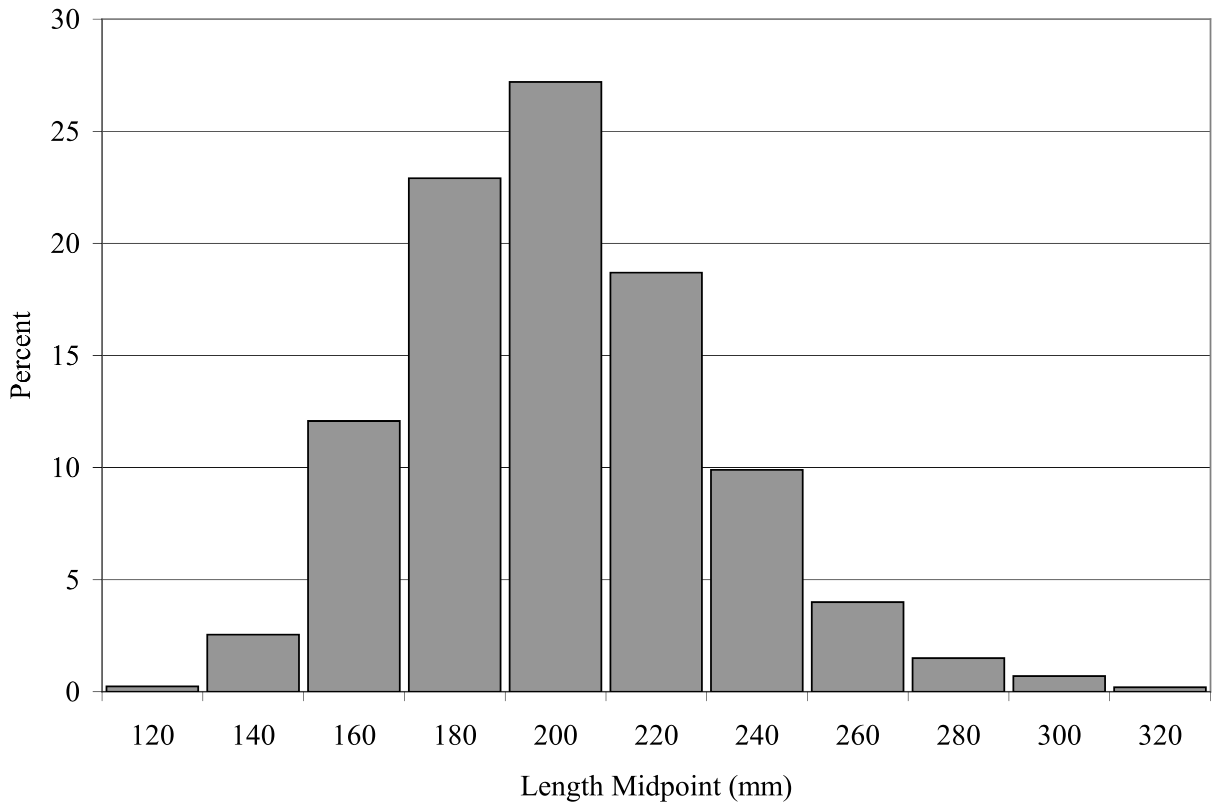


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2012. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

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

Figure 9. White perch length-frequency from 2012 Nanticoke River fyke and pound net survey.

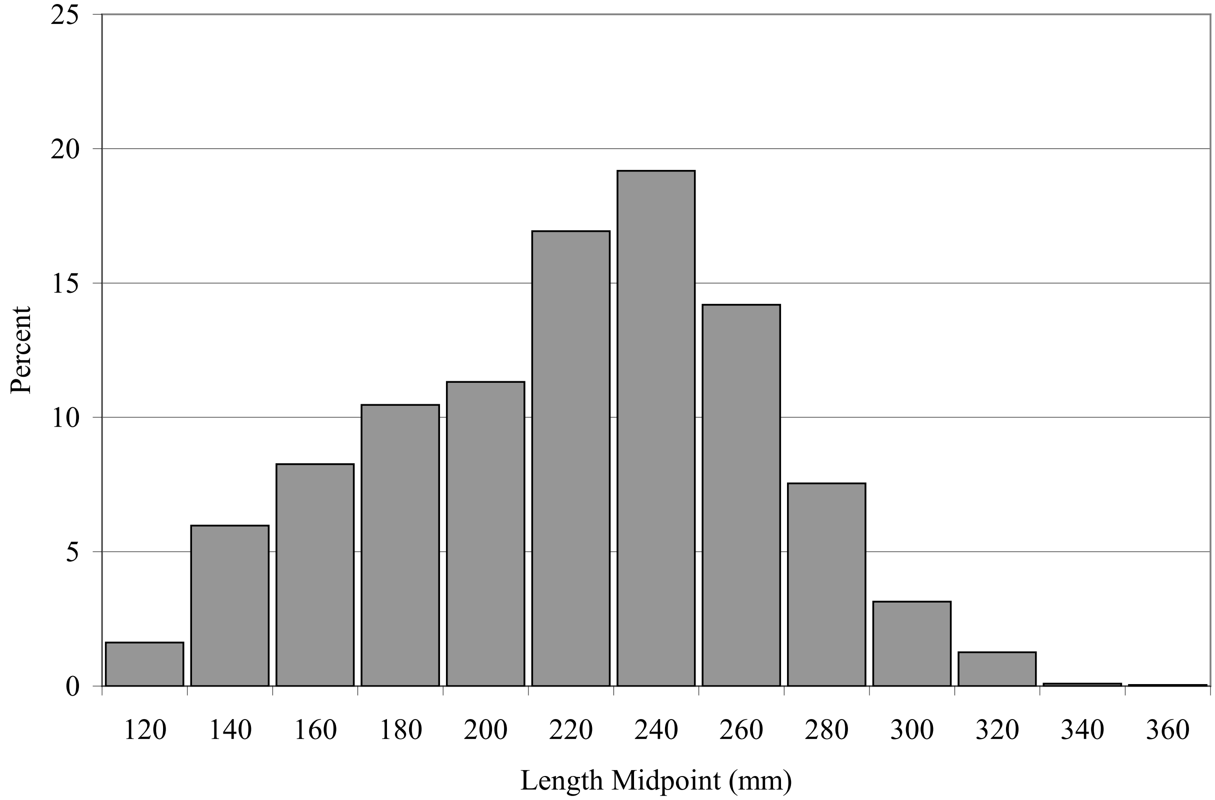


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2012. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length-frequency from the 2012 upper Chesapeake Bay winter trawl survey.

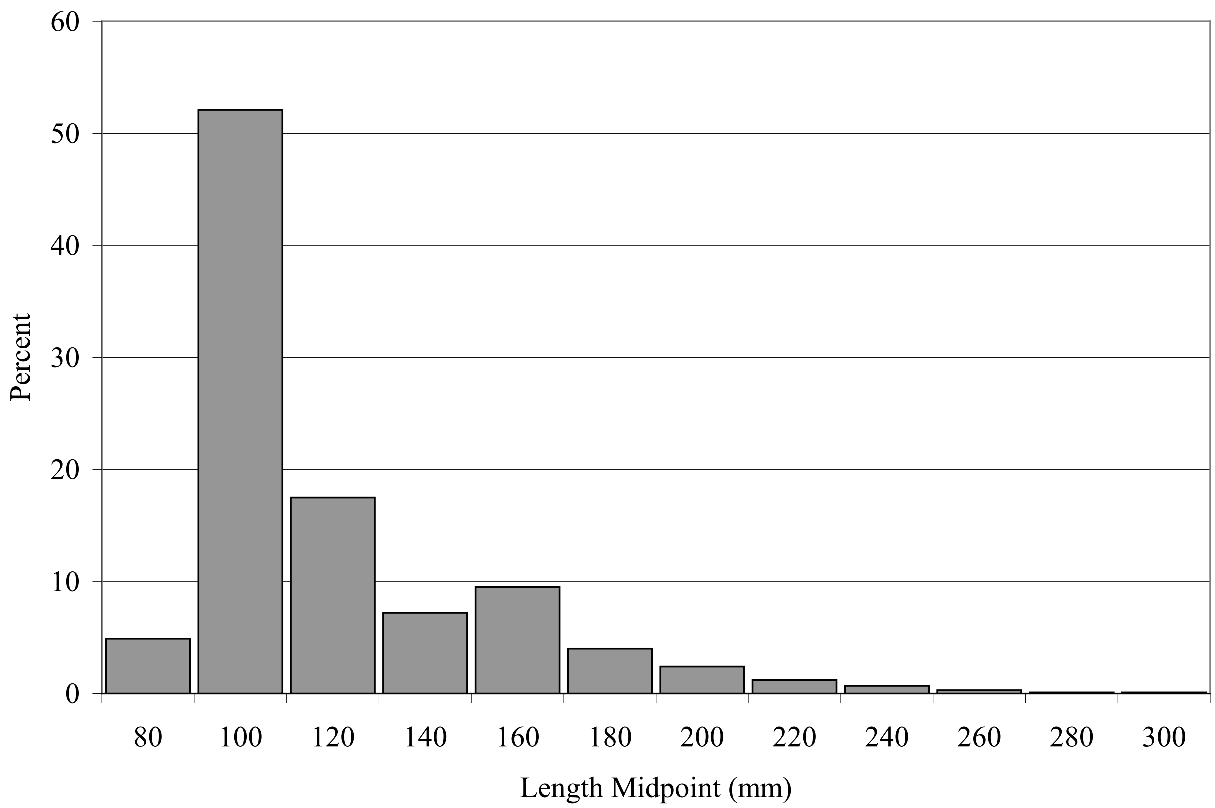


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2012. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length-frequency from the 2012 Choptank River fyke net survey.

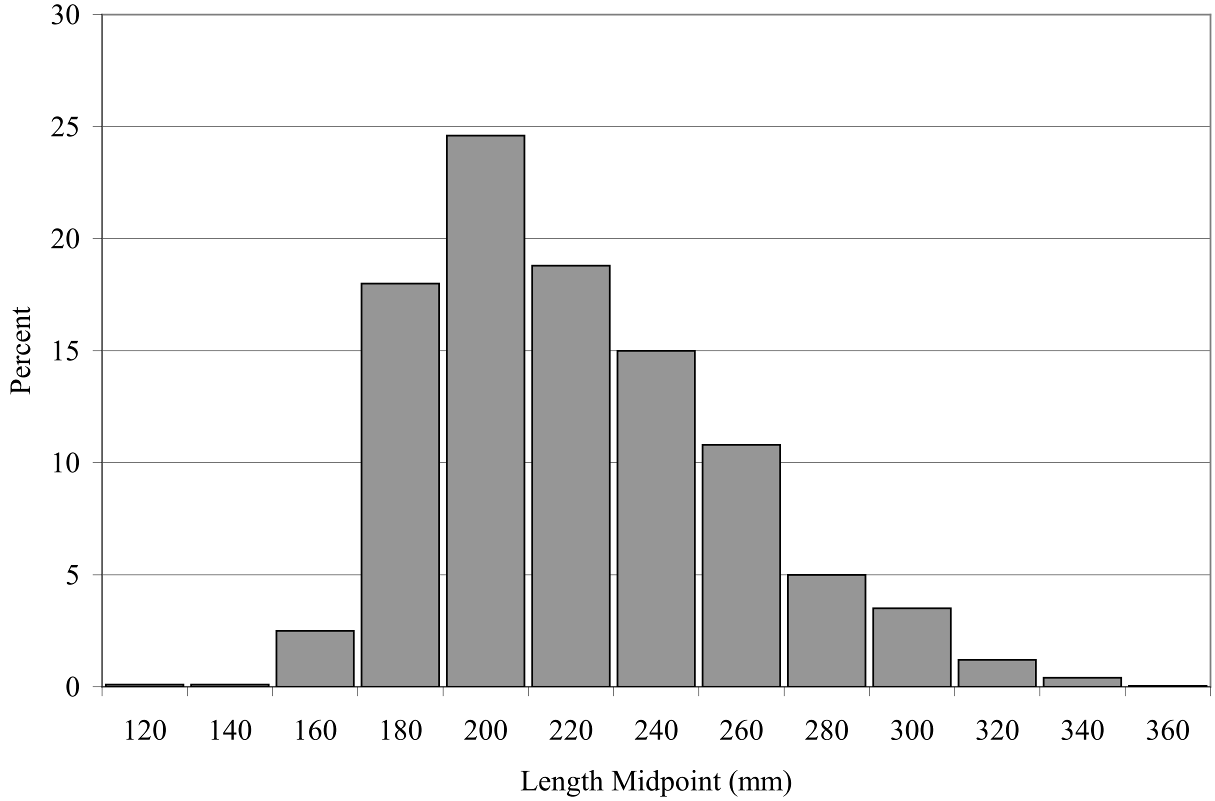


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2012. Minimum length cut-offs in parentheses.

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

Figure 12. Yellow perch length frequency from the 2012 upper Chesapeake commercial fyke net survey.

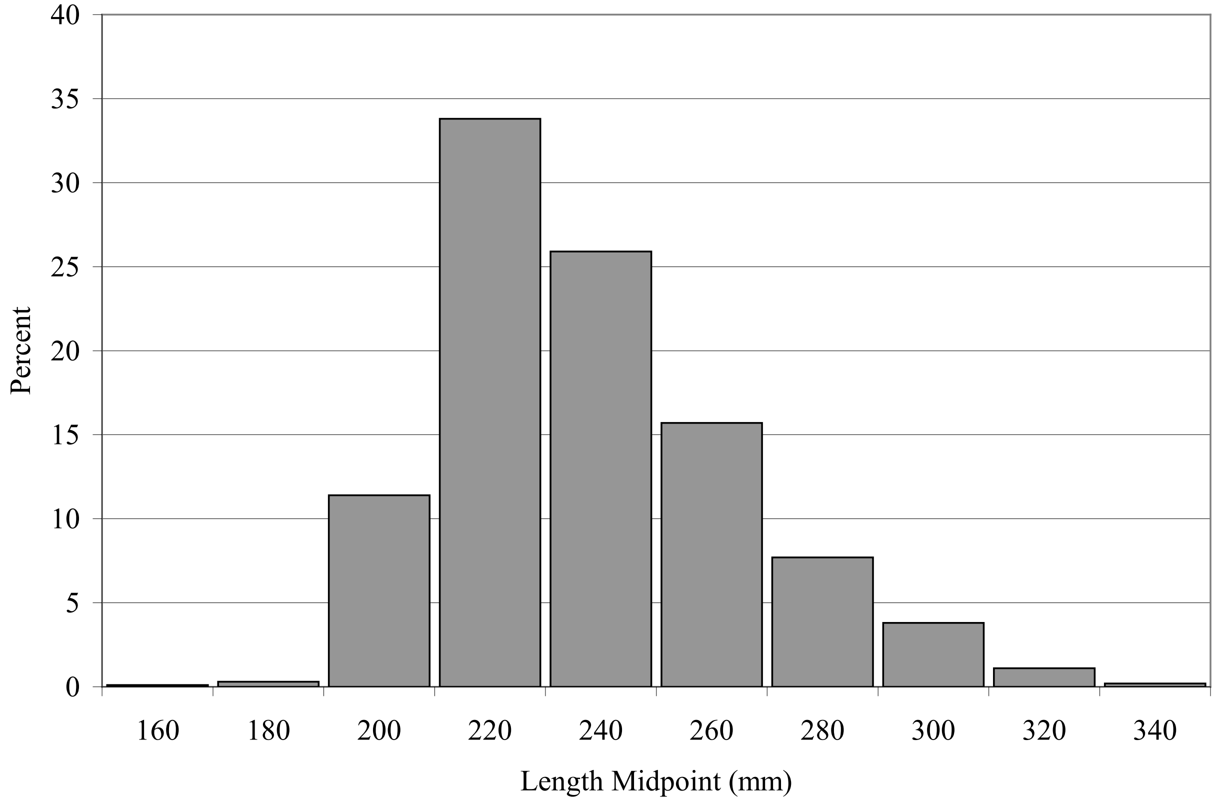


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2012. Minimum length cut-offs in parentheses; 2007-- 2009 includes Marshyhope River data.

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

Figure 13. Yellow perch length frequency from the 2012 Nanticoke River survey fyke and pound net survey.

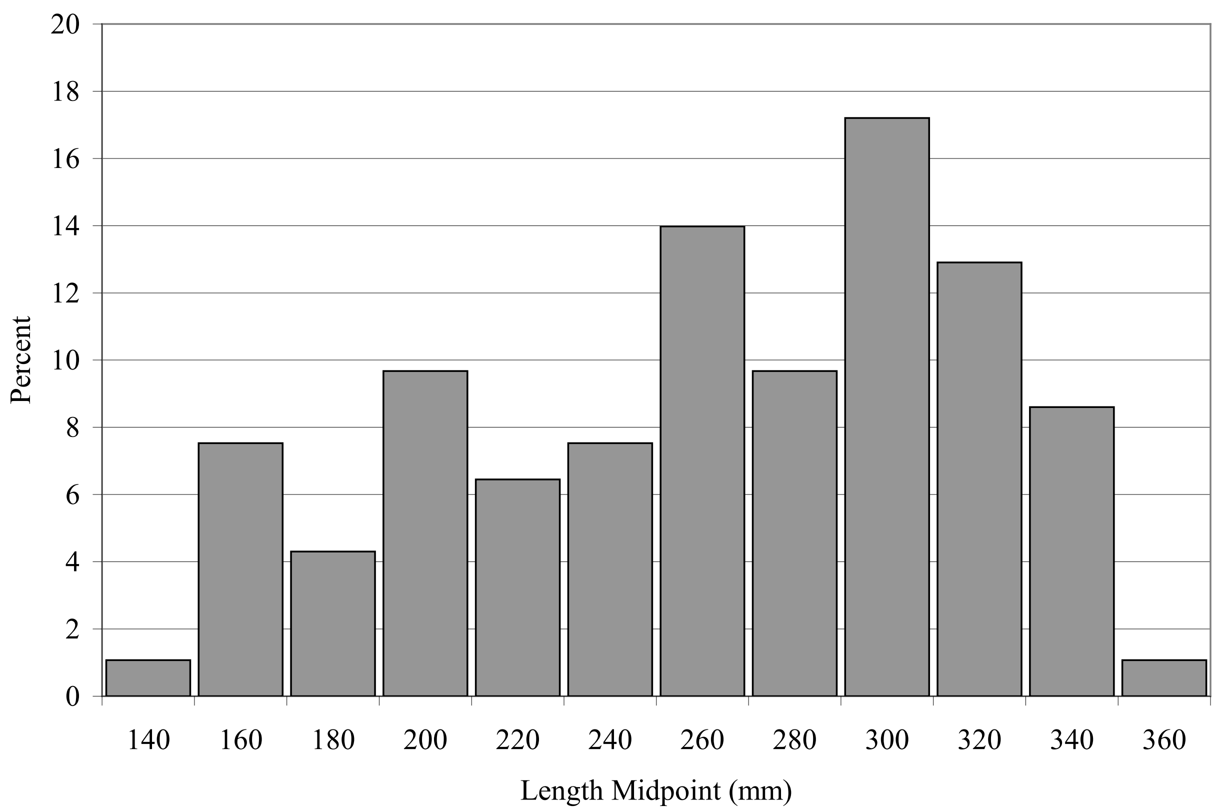


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2012. Minimum length cut-offs in parentheses.

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

Figure 14. Length frequency of channel catfish from the 2012 upper Chesapeake Bay winter trawl survey.

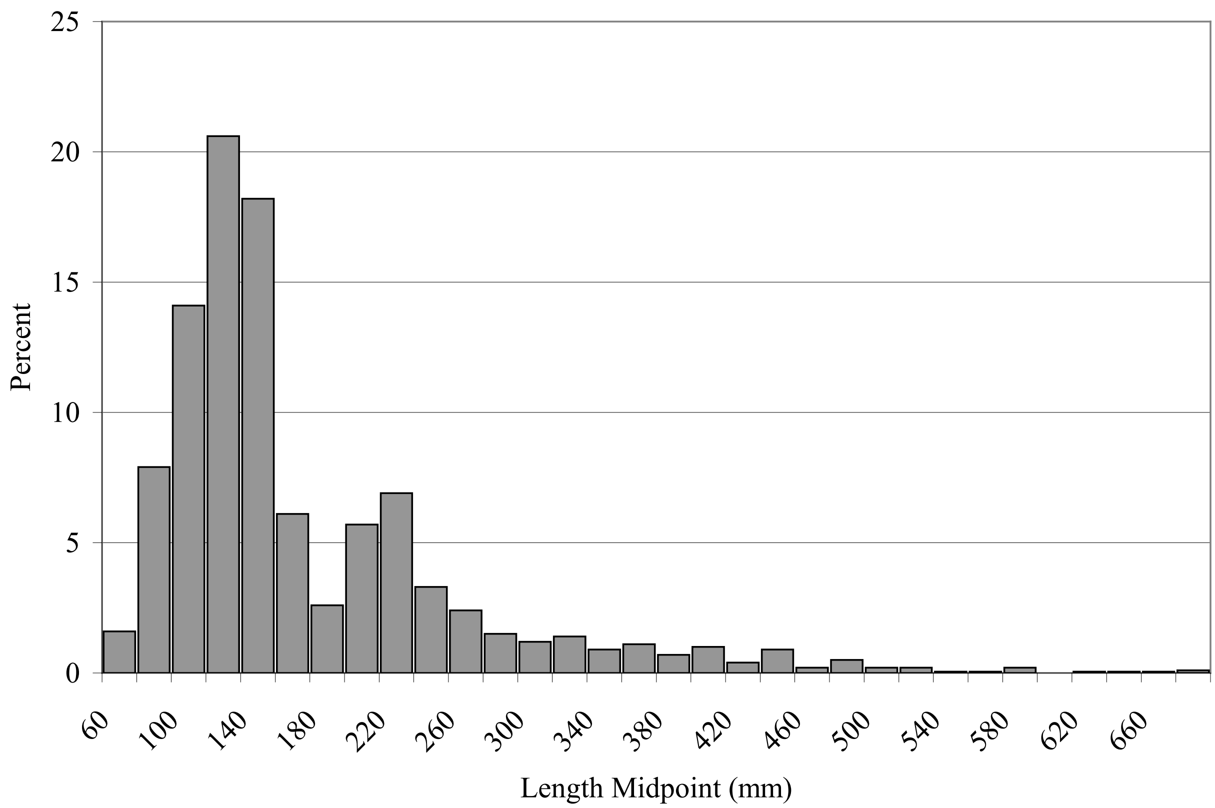


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2012. Minimum length cut-offs in parentheses.

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

Figure 15. Channel catfish length frequency from the 2012 Choptank River fyke net survey.

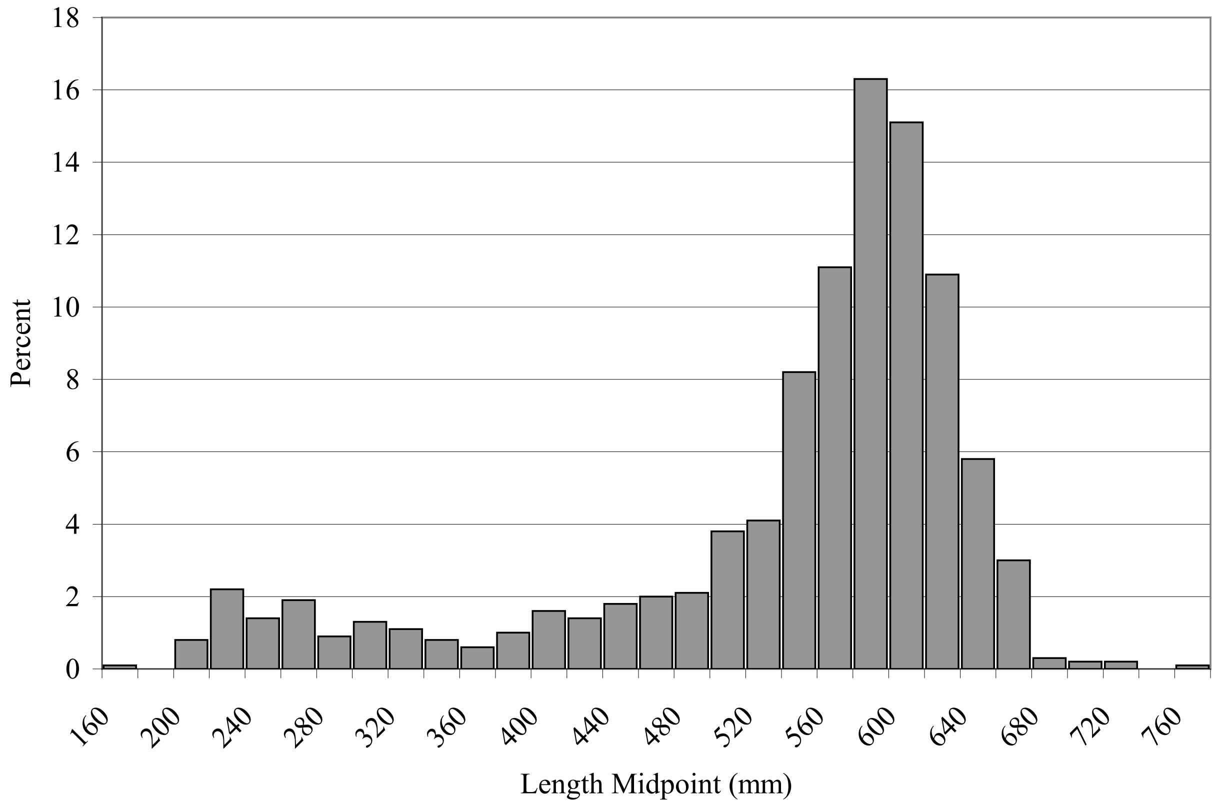


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2012. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 16. Channel catfish length frequency from the 2012 Nanticoke River fyke and pound net survey.

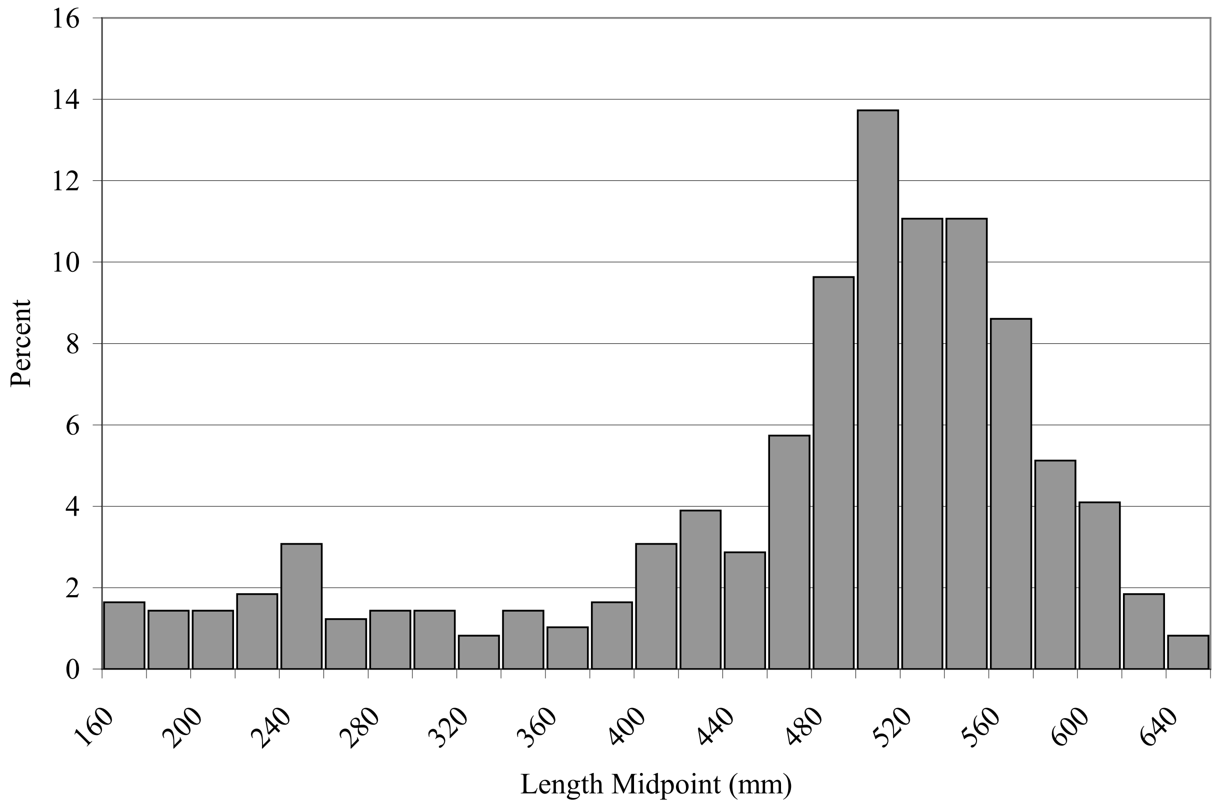


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2012. Minimum length cut-offs in parentheses.

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

Figure 17. White catfish length frequency from the 2012 upper Chesapeake Bay winter trawl survey.

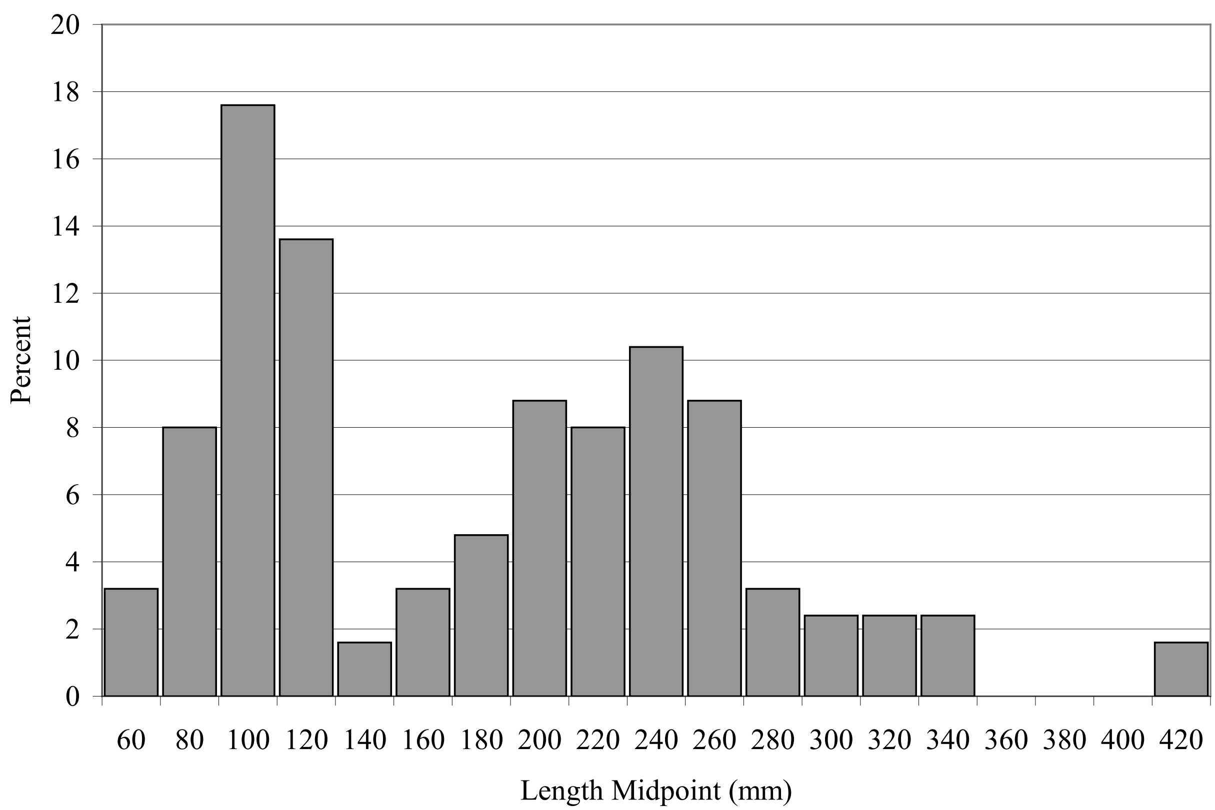


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2012. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2012 Choptank River fyke net survey.

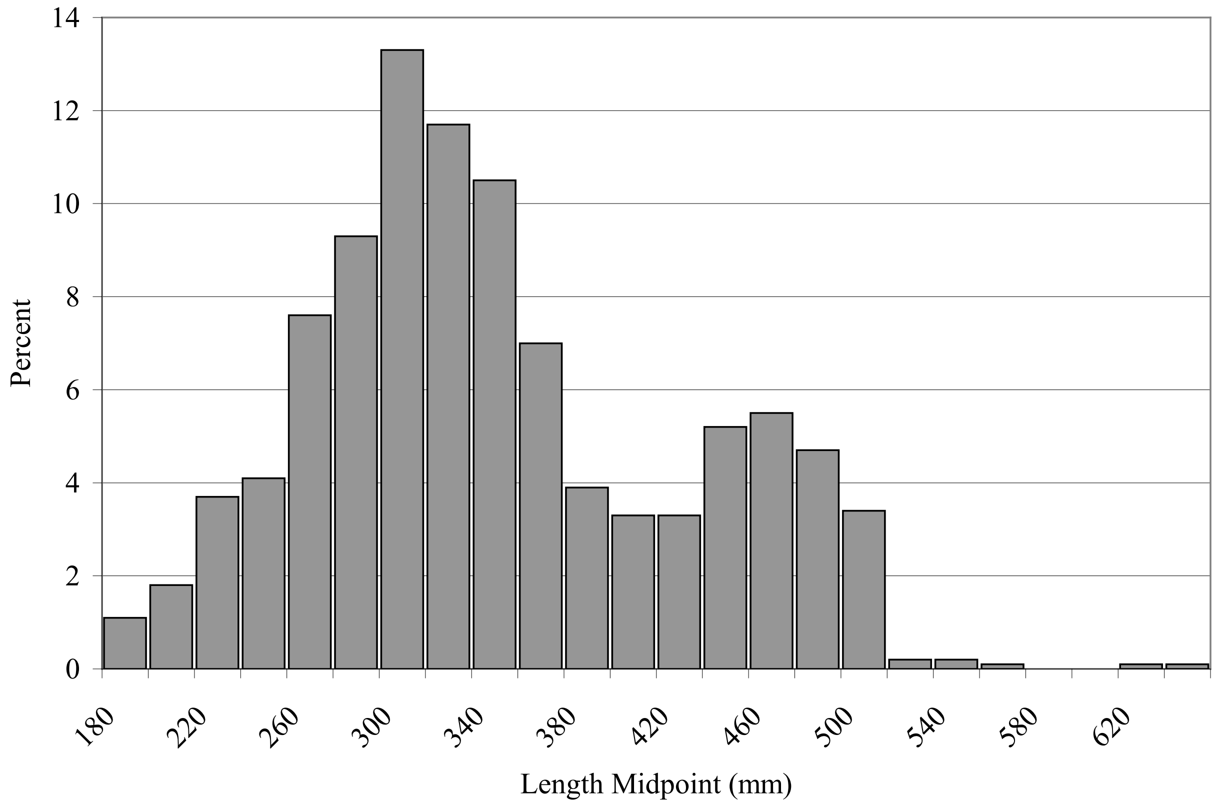


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2012. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 19. White catfish length frequency from the 2012 Nanticoke River fyke and pound net survey.

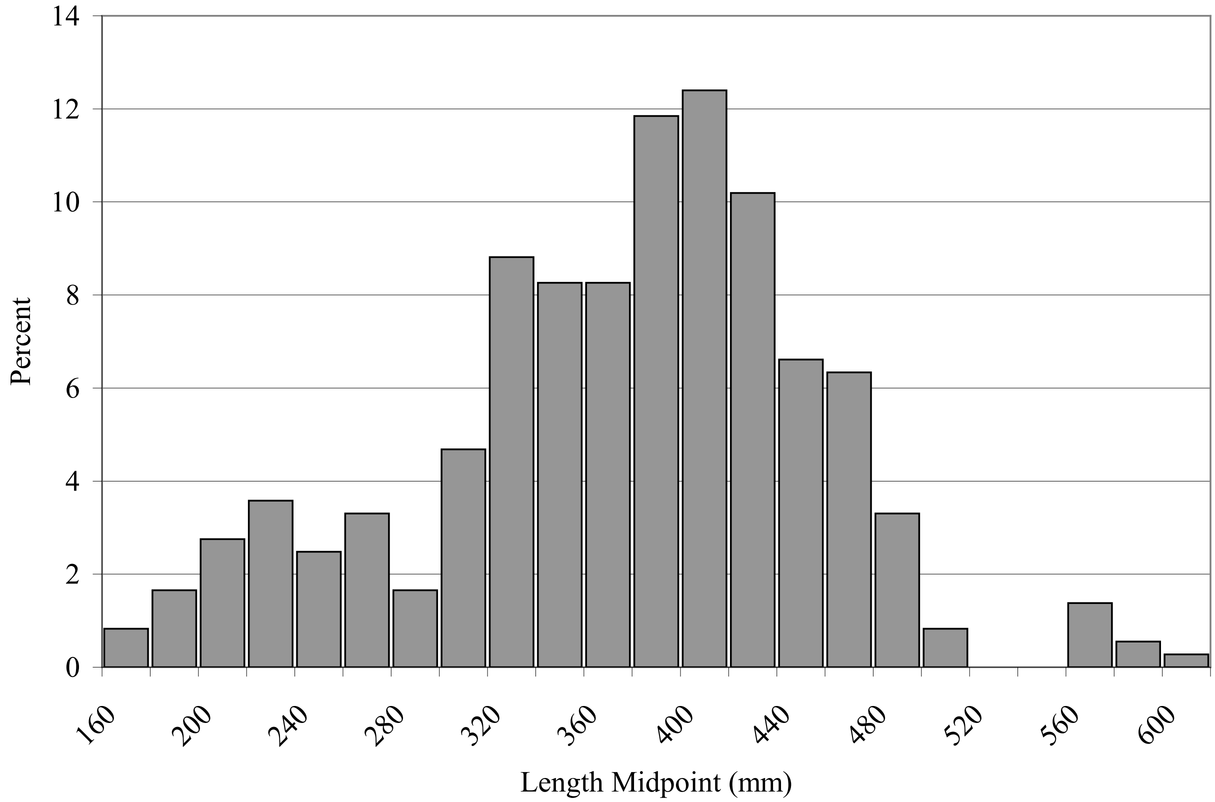


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	Allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2004	F	6.4×10^{-6}	3.17		NSF	
	M	NSF			NSF	
	Combined	4.5×10^{-6}	3.23		NSF	
2005	F	4.8×10^{-6}	3.23	288	0.36	0.00
	M	4.8×10^{-6}	3.22	374	0.10	-2.10
	Combined	3.8×10^{-6}	3.27	304	0.25	-1.60
2006	F	NSF	285	0.36	0.40	
	M	NSF	275	0.42	0.60	
	Combined	7.8×10^{-5}	2.69	273	0.4	0.60
2007	F	1.6×10^{-5}	3.00	269	0.33	0.28
	M	5.8×10^{-5}	2.74	247	0.32	0.06
	Combined	1.9×10^{-5}	2.96	265	0.31	0.15
2008	F	3.0×10^{-6}	3.29	317	0.23	-1.44
	M	3.7×10^{-6}	3.25	227	0.32	-1.98
	Combined	2.2×10^{-6}	3.35	284	0.28	-0.89
2009	F	2.8×10^{-6}	3.32	338	0.20	-1.33
	M	2.5×10^{-6}	3.32	225	0.49	-0.77
	Combined	1.9×10^{-6}	3.38	281	0.32	-0.17
2010	F	4.0×10^{-6}	3.26	312	0.18	-1.38
	M	4.2×10^{-6}	3.23		NSF	
	Combined	2.6×10^{-6}	3.33		NSF	
2011	F	2.3×10^{-6}	3.35		NSF	
	M	2.4×10^{-6}	3.34	217	0.49	0.44
	Combined	2.0×10^{-6}	3.38		NSF	
2012	F	6.9×10^{-6}	3.17	264	0.47	0.81
	M	4.5×10^{-6}	3.23	227	0.39	-0.21
	Combined	3.1×10^{-6}	3.31	251	0.46	0.68
2000 – 2012	F	4.5×10^{-6}	3.23	303	0.20	-1.41
	M	5.7×10^{-6}	3.18	241	0.26	-1.24
	Combined	3.2×10^{-6}	3.29	288	0.21	-1.25

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) alpha	beta	(von Bertalanffy) L-inf	K	t_0
2003	F			386	0.11	-2.90
	M	NA		263	0.30	-0.21
	Combined			329	0.16	-1.90
2004	F	5.3×10^{-6}	3.22	322	0.25	-0.30
	M	2.4×10^{-6}	3.35	288	0.21	-1.50
	Combined	2.6×10^{-6}	3.35	335	0.18	-1.20
2005	F	2.3×10^{-6}	3.36	313	0.23	-0.53
	M	NSF		313	0.14	-2.65
	Combined	1.50×10^{-6}	3.44	321	0.17	-1.60
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

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
2003	F	NA		264	0.82	0.36
	M	NA		263	0.35	-0.8
	Combined	NA		255	0.5	-0.7
2004	F	NA		306	0.41	-0.4
	M	NA		253	0.34	-1.2
	Combined	NA		259	0.51	-0.5
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
2000 – 2012	F	7.6×10^{-6}	3.09	350	0.28	-1.29
	M	2.9×10^{-6}	3.25	296	0.16	-3.36
	Combined	5.1×10^{-6}	3.15	271	0.35	-1.38

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
2003	F	6.68×10^{-7}	3.53	298	0.47	0.03
	M	NSF		246	0.44	-1.1
	Combined	4.14×10^{-7}	3.61	275	0.53	-0.1
2004	F	1.18×10^{-6}	3.43	297	0.75	1.14
	M	NSF		256	0.37	-2.5
	Combined	7.08×10^{-7}	3.52	273	1.04	1.35
2005	F	4.40×10^{-7}	3.62	358	0.25	-0.7
	M	5.61×10^{-7}	3.55	244	0.41	-0.5
	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	-2
	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
1998 – 2012	F	4.5×10^{-6}	3.20	305	0.30	-1.28
	M	3.5×10^{-6}	3.22	244	0.36	-2.28
	Combined	2.1×10^{-6}	3.33	262	0.54	-0.36

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
2003	F			324	0.49	-0.3
	M	NA	273	0.38	-1.4	
	Combined			298	0.56	-0.6
2004	F			326	0.43	-1.1
	M	NA	284	0.32	-3.4	
	Combined			290	0.68	-0.5
2005	F	NSF	332	0.56	-0.1	
	M	3.40 X 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 X 10^{-6}	3.38	346	0.35	-0.8
	M	7.37 X 10^{-6}	3.10		NSF	
	Combined	1.18 X 10^{-6}	3.45	308	0.42	-0.8
2008	F	3.37 X 10^{-6}	3.26	325	0.63	0.28
	M	6.79 X 10^{-6}	3.10	259	0.92	0.45
	Combined	9.96 X 10^{-7}	3.46	285	0.90	0.55
2009	F	3.0 X 10^{-5}	2.87	NSF		
	M	7.5 X 10^{-5}	2.67	292	0.40	-0.01
	Combined	1.1 X 10^{-5}	3.05	317	0.32	-1.10
2010	F	NSF			NSF	
	M	NSF			NSF	
	Combined	NSF			NSF	
2011	F	5.4 X 10^{-5}	2.74		NSF	
	M	3.3 X 10^{-6}	3.23		NSF	
	Combined	1.6 X 10^{-5}	2.95		NSF	
2012	F	1.9 X 10^{-6}	2.93	327	.053	0.08
	M	1.8 X 10^{-6}	3.34	311	.034	-0.41
	Combined	8.6 X 10^{-6}	3.07	312	.063	0.43
2000 –2012	F	9.42 X 10^{-6}	3.07	347	0.30	-1.20
	M	1.1 X 10^{-5}	3.01	294	0.34	-1.11
	Combined	3.7 X 10^{-6}	3.23	307	0.40	-0.84

Table 26. Estimated instantaneous fishing mortality rates (F) for white perch. Based on catch curve analysis of ages 6 – 10+. NR= not reliable; NA=not available; MIN= minimal, at or near M estimate.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Choptank	0.46	0.1	0.58	0.58	0.40	MIN	0.35	0.99	0.29	0.08
Nanticoke	0.31	NR	NR	0.22	0.18	0.16	0.12	0.66	NR	NR
Upper Bay trawl	0.13	NA	0.50	0.12	0.19	0.26	0.54	0.76	0.51	0.08

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

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Choptank[1]	0.05	NR	0.08	MIN	0	NR	0.17	MIN	0.56	0.12
Upper Bay[2]	0.30	0.30	0.31	0.10	0.14	0.02	0.14	0.19	0.24	0.28

[1]Based on ratio of CPUE of ages 4-10+ (year t) to CPUE of ages 3 – 10+ (year t-1) except 2002 estimate where all available ages were used, and 2009 estimate where ratio of ages 5 - 10 and 4 - 10 were used.

[2]N-weighted population F from Piavis and Webb in publ.

Figure 20. Baywide young-of-year relative abundance index for white perch, 1962 – 2012, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

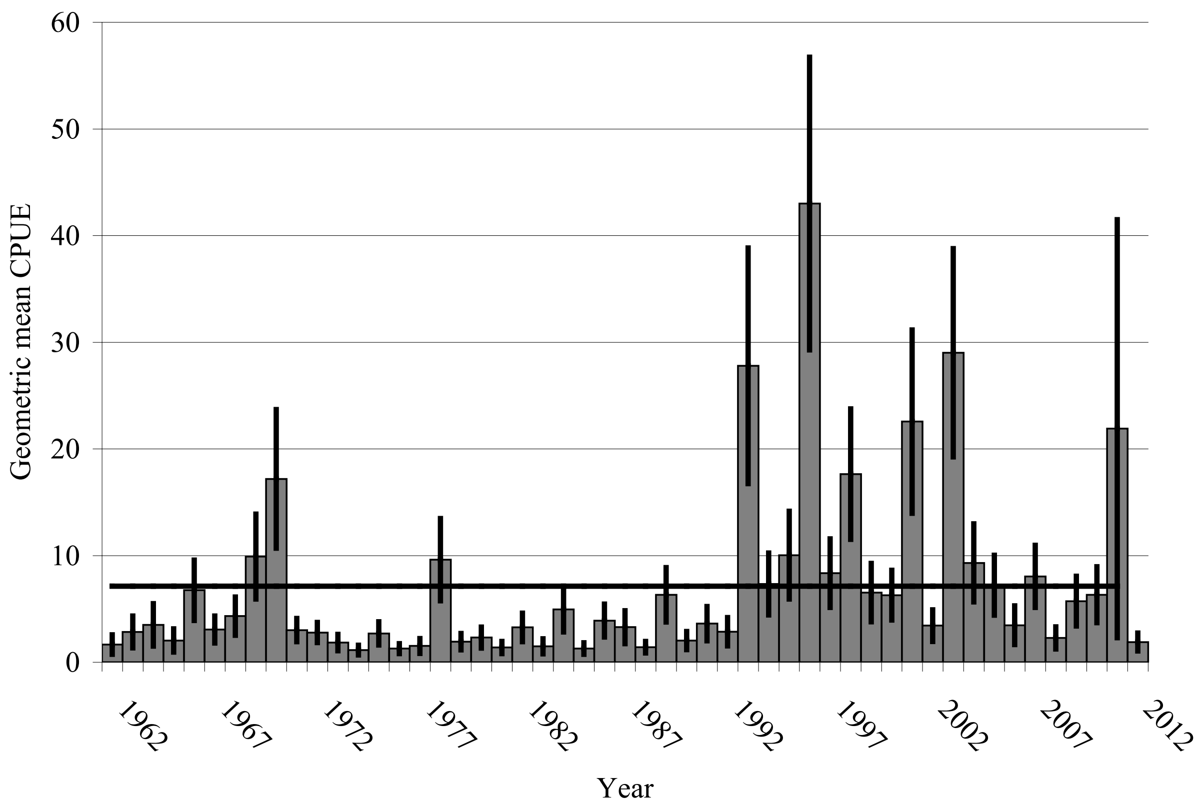


Figure 21. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

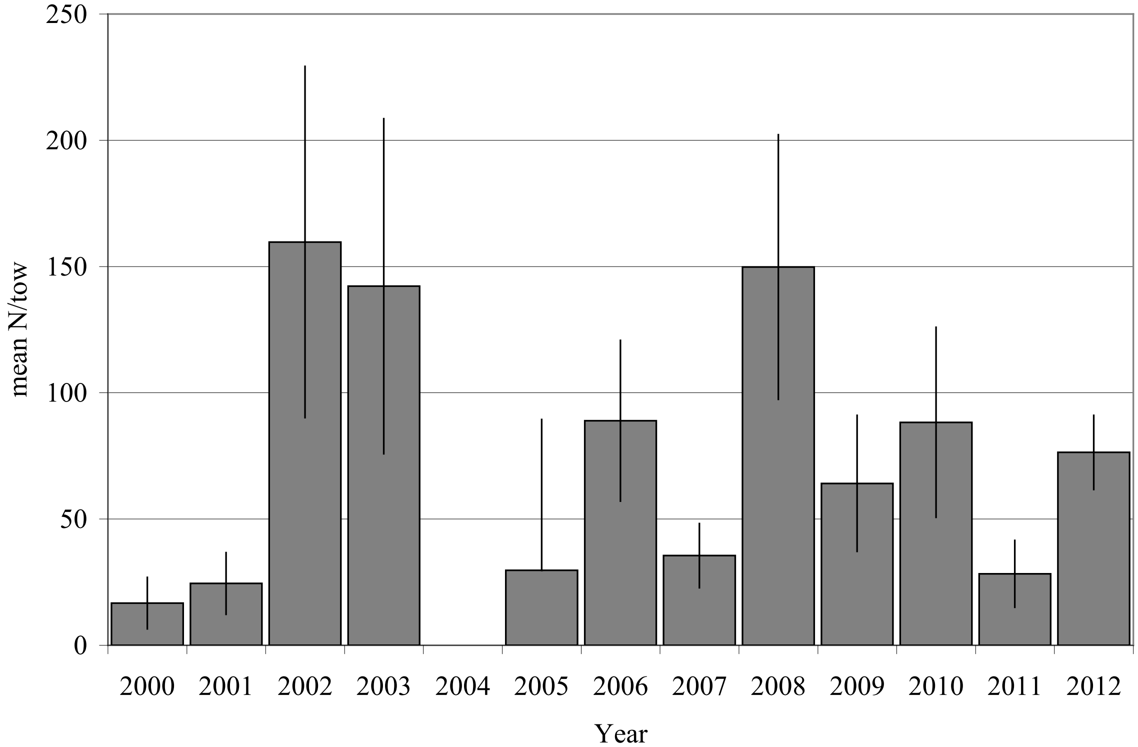


Figure 22. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2012, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

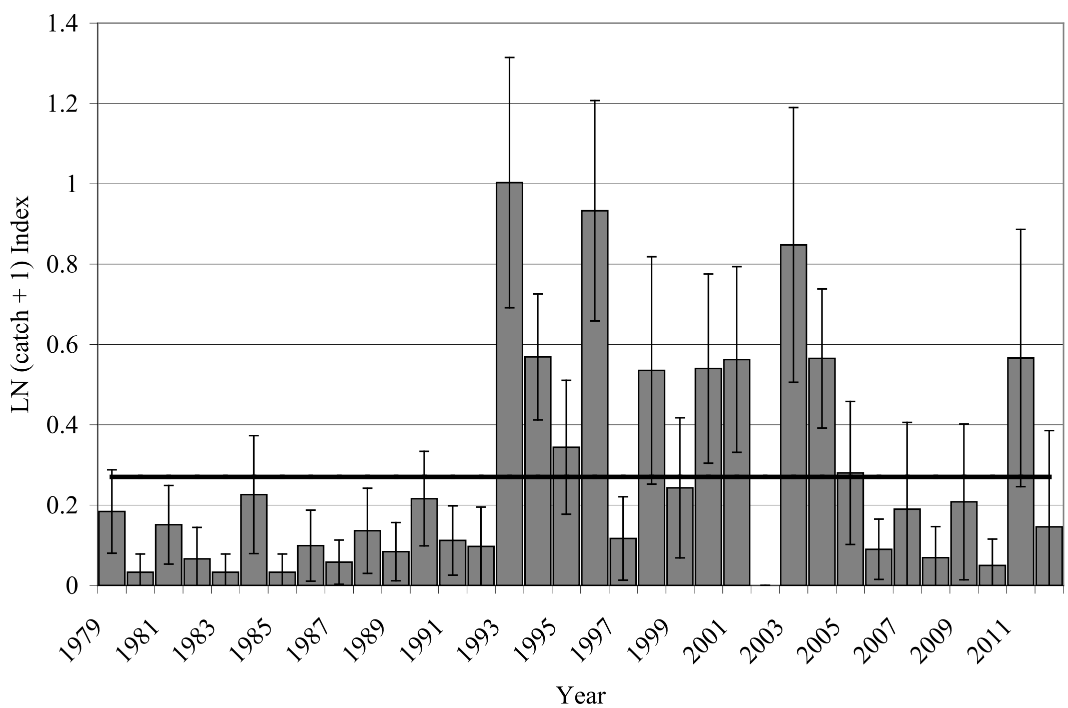


Figure 23. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Horizontal line=time series average. Not sampled in 2004, small sample sizes 2003 and 2005.

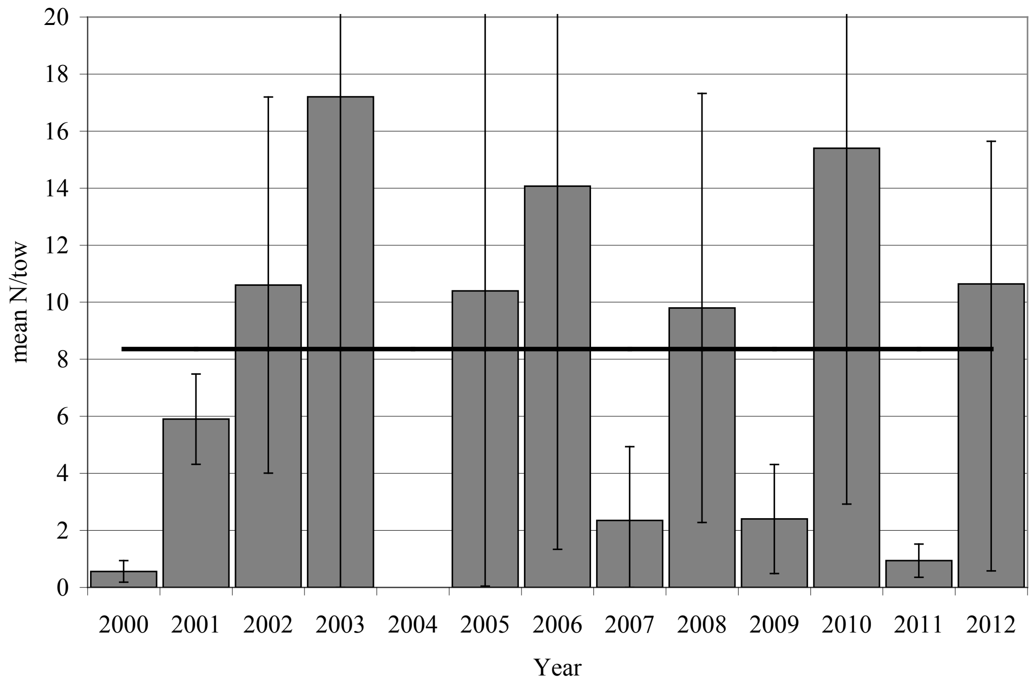


Figure 24. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

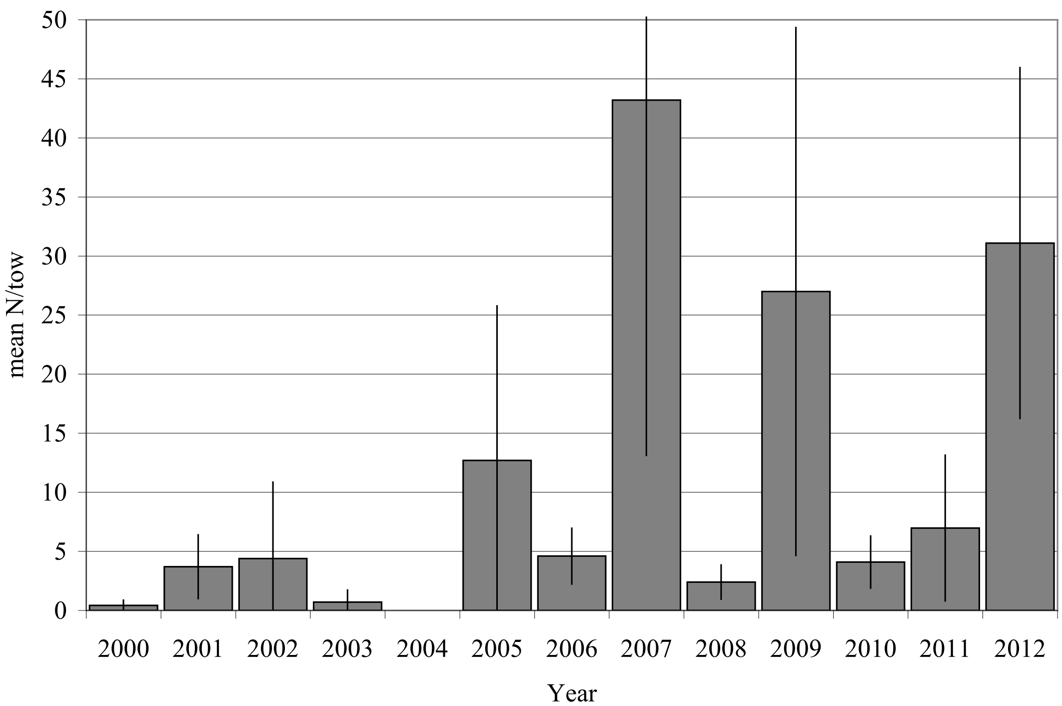


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2012.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	Total effort
2000	16.7	118.8	53.9	34.8	13.1	7.8	10.7	1.2	1.1	0.7	258.7	79
2001	24.5	47.1	75.7	14.5	22.1	4.8	11.6	12.3	2.5	1.7	217.3	114
2002	159.7	1.4	33.4	13.8	21.4	9.1	17.7	9.7	2.5	5.8	274.6	110
2003	83.3	156.1	28.7	13.1	18.2	20.9	73.9	1.7	0.0	9.9	405.8	20
2004	NOT SAMPLED											
2005	22.6	39.2	10.7	19.7	5.0	1.8	0.6	5.6	0.6	0.3	106.1	43
2006	88.9	29.4	70.3	21.1	15.6	4.3	2.6	2.6	0.6	1.2	236.6	108
2007	35.5	23.9	17.3	33.9	19.5	4.7	5.4	0.4	0.4	1.9	142.9	71
2008	149.8	25.1	64.8	48.8	15.3	5.3	2.1	2.3	0.9	0.9	315.2	108
2009	64.9	180.3	7.6	33.0	62.1	52.4	1.3	18.1	3.8	0.7	424.2	90
2010	88.3	69.8	82.0	2.8	26.5	21.2	35.1	2.8	4.5	6.9	339.9	56
2011	32.9	39.0	27.7	37.4	9.1	20.7	11.3	11.5	0.6	2.0	192.3	66
2012	71.5	24.7	12.0	5.9	6.1	6.6	11.8	5.3	7.1	2.1	153.1	143

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2012.

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

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2012.

YEAR	AGE											
	1	2	3	4	5	6	7	8	9	10+	Sum CPE	Total effort
2000	0.6	1.0	0.2	1.1	0.0	0.2	0.1	0.0	0.0	0.1	3.1	79
2001	5.9	0.4	0.7	0.1	0.4	0.0	0.0	0.0	0.0	0.0	7.5	114
2002	10.6	7.7	0.8	1.6	0.1	0.8	0.0	0.1	0.0	0.0	21.7	110
2003	17.2	49.2	152.5	16.4	21.8	1.4	8.8	0.0	0.7	0.0	268.0	20
2004	NOT SAMPLED											
2005	10.4	7.4	0.0	1.6	0.2	0.0	0.0	0.0	0.0	0.0	19.7	43
2006	14.1	16.1	6.8	0.0	1.4	0.2	0.0	0.1	0.0	0.0	38.6	108
2007	2.4	2.1	5.4	1.6	1.0	0.4	0.0	0.0	0.0	0.0	12.9	71
2008	9.8	2.4	5.3	4.7	1.2	0.0	0.0	0.0	0.0	0.0	23.3	108
2009	2.4	11.7	0.6	1.3	1.2	0.3	0.0	0.0	0.0	0.0	17.4	90
2010	15.4	1.8	4.6	0.3	0.5	0.2	0.1	0.0	<0.1	0.0	22.9	56
2011	0.9	3.1	0.5	2.0	0.0	0.3	0.1	0.0	0.0	0.0	6.9	66
2012	10.6	4.3	1.5	0.1	0.1	<0.1	0.0	0.4	0.0	0.0	17.1	107

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2012.

YEAR	AGE										Sum CPE	Total effort
	1	2	3	4	5	6	7	8	9	10+		
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

Figure 25. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2012. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

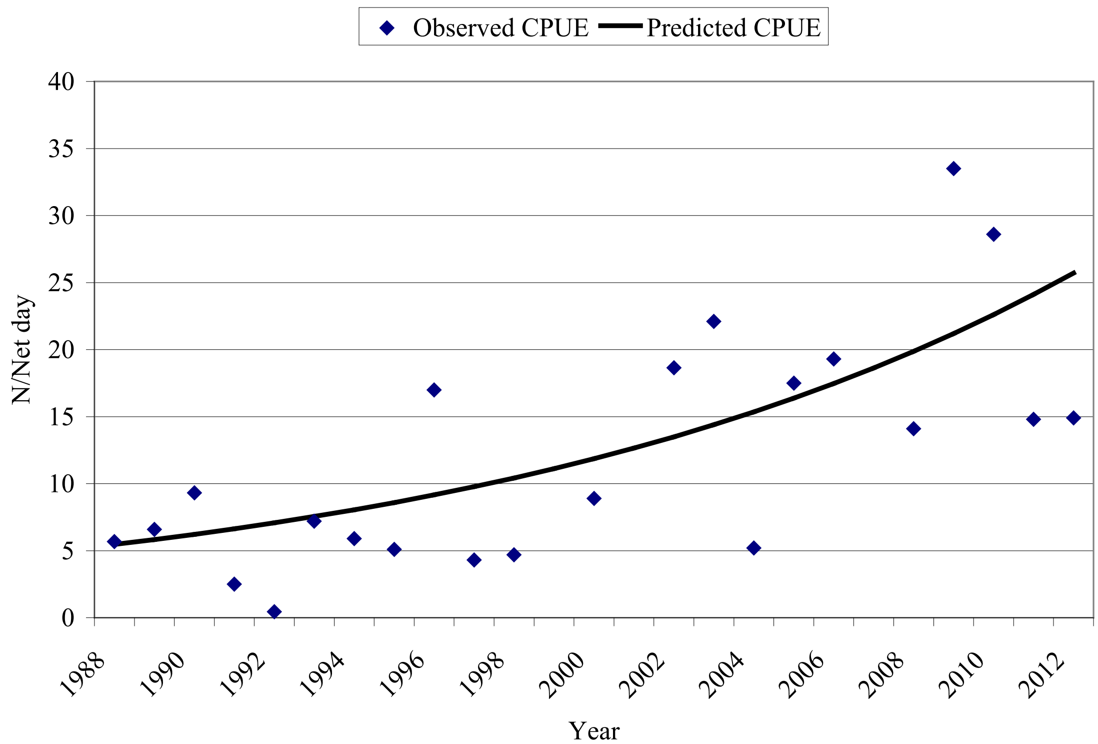


Figure 26. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2012. Not surveyed in 2004, small sample sizes in 2003 and 2005.

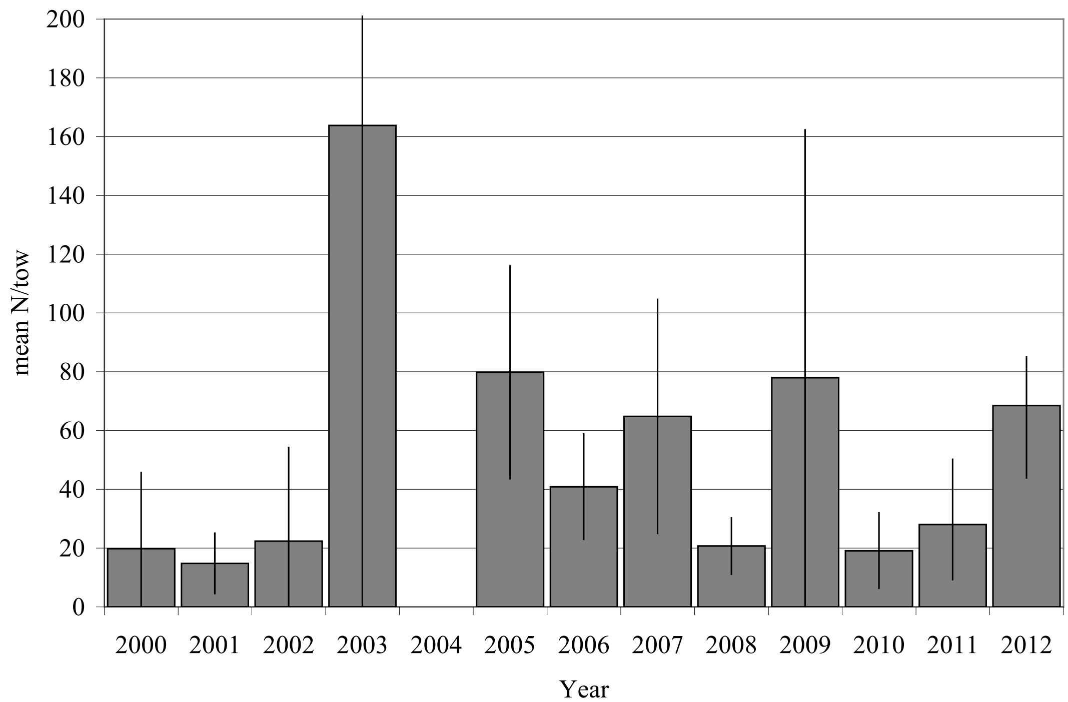


Figure 27. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2012. Horizontal line indicates time series average relative abundance.

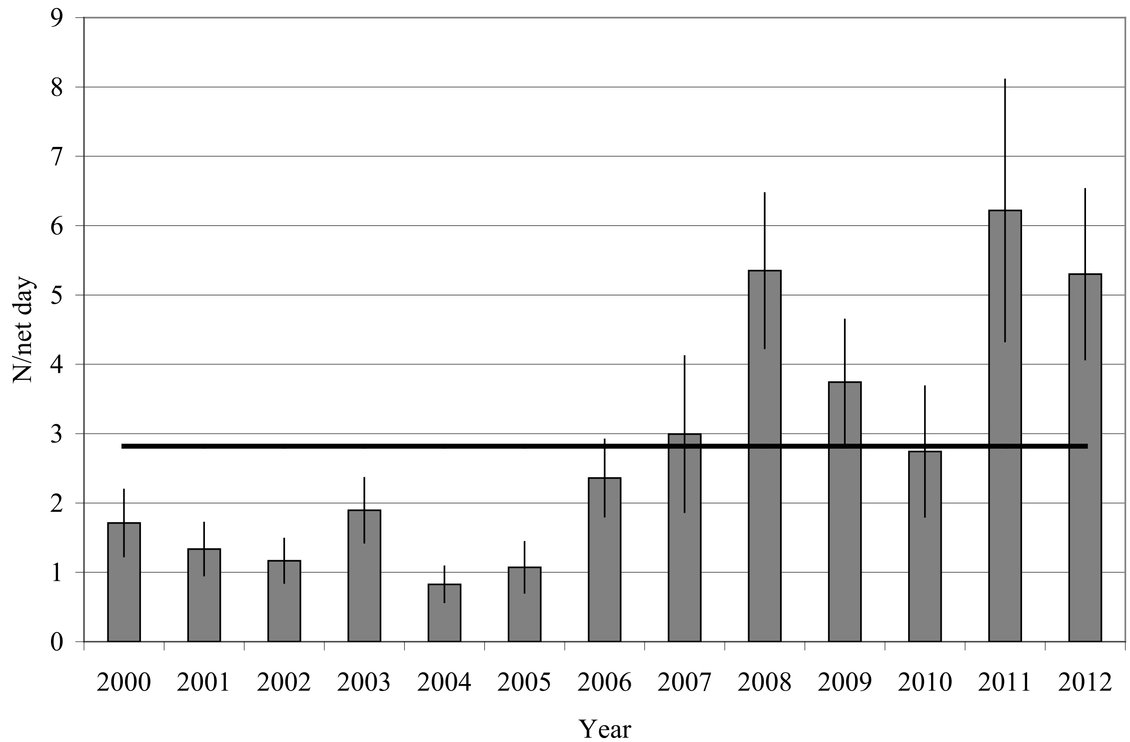
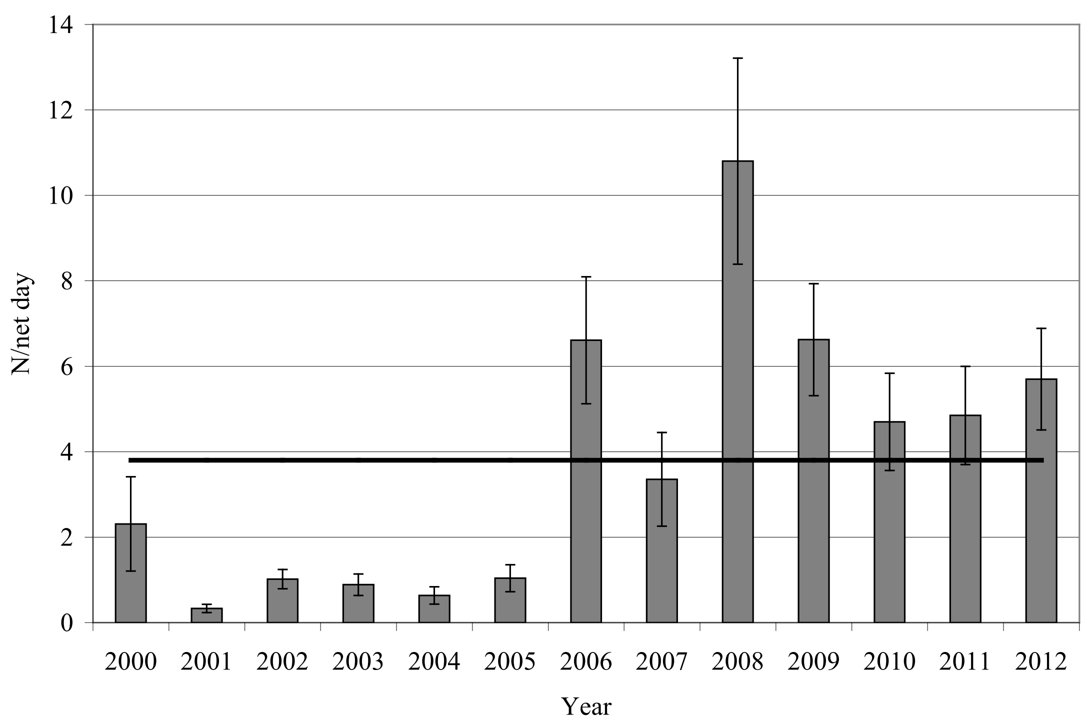


Figure 28. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2012. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

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

Channel catfish are important to recreational and commercial fishers throughout Maryland's portion of the Chesapeake Bay. The Marine Recreational Information Program (MRIP) produces estimates of recreational catch with fair precision (National Oceanic and Atmospheric Administration, personal communication, January 10, 2013). Estimated channel catfish recreational harvest (MRIP) averaged 240,600 lbs during 1982

– 2011; for the five year period, 2007 – 2011, average recreational catfish harvest was 417,100 lbs (73% above the long term average). In 2011, channel catfish was the third largest recreational harvest in Maryland (by weight), trailing only striped bass and white perch.

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

Commercial channel catfish harvest peaked in 1996 at 2.45 million lbs and declined to 723,000 lbs by 2007 before rising to near record levels of 2.17 million lbs in 2011. Channel catfish commercial landings (by weight) were second only to Atlantic menhaden during 2011. Areas above the Chesapeake Bay bridges accounted for 64% of the total Maryland commercial harvest in 2011, and averaged 60% of total landings during the five year period, 2007 – 2011.

Channel catfish populations were last assessed in 2009 (Piavis and Webb 2010). This Job is an update of the 2009 assessment. The 2009 assessment attempted to describe population dynamics in 3 systems, the Head-of-Bay (HOB; areas north of the Preston Lane Memorial Bridges), Choptank River, and Potomac River. However, the one-way trip nature of the Potomac River catfish indices made fitting population models unreliable. For this report, channel catfish populations were modeled with a surplus production model for the HOB, and a Catch-Survey Analysis (CSA) for the Choptank River. For other systems, indices of relative abundance (fishery dependent and fishery independent, when available) were utilized to illustrate trends in population abundance.

METHODS

Bay-wide Landings

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

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

Head-of-Bay Surplus Production Model

Surplus production models fit biomass estimates to the equation

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

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

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

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

where I is the estimated index, q is catchability and e^{ε} is the lognormal residual error. This form simplified the solution by not having to solve for a catchability parameter for each index. In this closed form, average catchability for each index was $e^{(1/n)\,\Sigma\,\ln(I_t / B_t)}$.

The log function to be maximized was simply the sum of all log-likelihoods multiplied by a weighting factor.

The log-likelihood function for an individual index is

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

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

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

Maximum Sustainable Yield = $rK/4$

$B_{msy} = K/2$

$F_{msy} = r/2$

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

Model Inputs

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

The fishery dependent commercial fyke net index was derived from MD DNR Fisheries Service commercial landings database. Effort data for these gear types were available from 1980 – 1984, 1990, and 1992 – 2011. An index of effort was constructed to standardize landings because commercial catch reporting was completed monthly and not on a per trip basis. The index was nominal fishing effort, or simply the total number of nets declared by fishers in any month. Only fishers that reported catfish harvest > 500 lbs were used for relative abundance estimates. This eliminated fishers that were not targeting channel catfish. The final annual index was total pounds harvested divided by total nominal effort.

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

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

where W is weight (g) and L is total length (cm). The average weight per gill net set and mesh size was then multiplied by the total number captured per mesh size and net set. The final index was the geometric mean weight per net set standardized to 1000-gill net yards × hours.

The fishery independent HOB winter trawl survey provided channel catfish relative abundance for the HOB (Figure 2). Species count data from this survey (2000-2002; 2006 - 2011) were transformed to biomass per tow with the same allometric equation utilized in the drift gill net index formulation. The index was geometric mean channel catfish biomass per tow for channel catfish greater than 355 mm. Observation of commercial fishing practices suggested that fish < 355 mm are not marketable.

Total removals by the commercial and recreational fisheries were estimated on a regional basis. Removals from HOB were easily obtained from the commercial landings data base because fishermen are required to submit landings by system. Recreational landings from HOB were estimated as the proportion of inland recreational landings (MRIP data) to bay-wide commercial landings, for all years pooled, multiplied by annual HOB commercial landings.

Uncertainty

Bootstrapping, or resampling residuals and adding them to the natural logarithm of the expected indices, and re-exponentiating the values was used to quantify model uncertainty (n = 1,000 trials). Mean, median, standard deviation and coefficient of variation were calculated for all fitted parameters and each estimate of annual biomass and F. Confidence intervals (80% CI) were determined from cumulative percent distributions of the bootstrapped parameter estimates.

Choptank River Catch-Survey Analysis (CSA)

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

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

where R is the post-recruit abundance, P is the pre-recruit abundance, M is instantaneous natural mortality, C is harvest, 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 abundance by a survey catchability (q) such that:

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

and,

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

where Φ is a scalar relating the pre-recruit catchability to post-recruit catchability.

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

$$r_{t+1} = (r_t + p_t / \Phi)e^{-M} - qC_t e^{-M_t(1-T_t)} \quad [7]$$

Adding a process error term (ε) into [7] yields

$$r_{t+1} = (r_t + p_t / \Phi)e^{-M} - qC_t e^{-M_t(1-T_t)\mathrm{E}} \quad [8]$$

Measurement error (η and δ) is similarly incorporated into [5] and [6]

$$p_t = P_t q e \eta \quad [9]$$

$$r_t = R_t q \Phi e^{\delta} \quad [10]$$

Collie and Kruse (1998) advocated using a single error model structure. The all-observation error structure produced similar results to the mixed error model and was less likely to be over parameterized (Collie and Kruse 1998). This approach produced the objective function to be minimized:

$$\mathrm{SSQ} = \lambda_\eta \Sigma \eta^2 + \lambda_\delta \Sigma \delta^2 \quad [11]$$

This yields i+1 parameters to be estimated with i-2 df. The model was compiled in a Microsoft Excel spreadsheet and the Solver routine was used to fit the model.

Population size of fully recruited fish (R_t) for the Choptank River was estimated as r_t/q and the population size of pre-recruits (P_t) was $p_t / \Phi q$. Harvest rate h was estimated as

$$h_t = C_t / [(P_t + R_t) e^{-M_t T_t} . \quad [12]$$

Total instantaneous fishing mortality (F) was

$$F_t = -\log_e (1 - h_t) . \quad [13]$$

Model Inputs

Pre-recruit and post-recruit indices of abundance were determined from MD DNR Fisheries Service fyke net catches (Figure 3; Project 1 Job 1). Pre-recruits were those channel catfish < 356 mm. Post-recruit channel catfish were those fish > 355 mm TL. Numbers of pre-recruit and post-recruit channel catfish were determined for each fyke net visit by applying the proportion of pre-recruit and post-recruit channel catfish from the length subsample to the total catch. Numbers of pre- and post-recruit channel catfish from each net lift were divided by gear soak time. The final indices were the arithmetic mean of each net CPUE.

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

Recreational channel catfish harvest for the Choptank River was estimated from total inland harvest estimates from the MRIP (National Marine Fisheries Service, personal communication, January 10, 2013). The proportion of recreational to commercial landings was determined by dividing total recreational inland landings by bay-wide commercial landings. That proportion was applied to Choptank River commercial landings to estimate recreational landings in this system. Negligible release losses were assumed for all fisheries.

Relative catchability of pre-recruits (Φ) was set at 1.0 because length-frequencies indicated that channel catfish were recruited to the survey gear. Natural mortality (*M*) was 0.20. An initial catchability for the runs was set at 5.0×10^{-6}. The fraction of year that the survey preceded the fishery (T) was 0.5.

Uncertainty

The model was bootstrapped 5,000 times by resampling residuals and adding them to the natural logarithm of the expected index values, and then re-exponentiating the values. Mean, median, standard deviation and CV's 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.

Other Areas

Previous attempts to fit population models to other areas have failed, largely due to lack of fishery independent surveys (Piavis and Webb 2010). Qualitative methods to describe population trends in Nanticoke, Patuxent, and Potomac rivers were employed.

Landings

Channel catfish landings were determined from MD DNR commercial landings database for the Nanticoke and Patuxent rivers. Adjustments due to changes in the species reporting requirements were identical to the bay-wide landings discussed above. The Potomac River Fisheries Commission (PRFC) provided commercial landings from the Potomac River (Potomac River Fisheries Commission, personal communication, February 20, 2013). Catfish landings were identified to species from 2003 – 2012. From 1985 – 2002, catfish were coded as mixed (white catfish and channel catfish) and bullhead species. Channel catfish landings for the period 1985 – 2002 were estimated as mixed catfish landings × proportion of channel catfish of total catfish landings during the nearest 5 year period, 2003 – 2007 (0.85). From 1964 – 1984, catfish landings were reported as mixed bullhead and catfish species. Channel catfish landings for the period 1964 – 1984 were estimated as catfish landings × proportion of channel catfish of total landings during the period 1985 – 2002.

Fishery Dependent Relative Abundance Indices

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

Fishery Independent Relative Abundance Indices

A gill net survey designed to estimate spawning stock biomass of striped bass in Potomac River (SBSSS) was utilized to describe population trends (Figure 1). This survey is analogous to the drift gill net survey in HOB that was included in the HOB surplus production model. However, the Potomac index was included as a numbers based index instead of transforming to a biomass index as required by the surplus production model. Data encompassed the time period 1984 – 2012.

Channel catfish juvenile recruitment was determined from the Estuarine Juvenile Finfish Survey (EJFS; Project 2, Job 3, Task 3). The EJFS is designed to estimate young-of-year striped bass (*Morone saxatilis*) relative abundance, but it has proved valuable in determining year-class strength of other species as well. Relative juvenile abundance indices were available for the Nanticoke, Potomac, and Patuxent rivers (Figure 4).

RESULTS

Landings

Baywide commercial landings generally varied between 400,000 pounds and 700,000 pounds from 1929 through the mid-1970's (Figure 5). Landings increased rapidly from 1976 through 1996 to a time series maximum of 2.4 million pounds. Since 1996, landings decreased to a recent low in 2007, and then increased to a near time series high in 2011. The 2011 harvest was 2.1 million pounds. Baywide recreational landings estimates have varied greatly over the period 1983 – 2011 (Figure 6). A time series low was estimated in 1988, but recreational landings trended upward through 1996, corresponding to the rise in commercial landings. Recreational landings during the period 1997 – 2007 were notably low, but a general rebound occurred during 2007 – 2011.

Head-of-Bay Surplus Production Model

Total estimated fishery removals from HOB, by weight, exhibited a dome-shaped pattern for much of the assessment time-period (1980 – 2011). However, landings increased from 0.4 million pounds to 1.7 million pounds over the period 2005 – 2011 (commercial and recreational combined; Figure 7). The model included three biomass indices, a fishery dependent fyke net index (1980 – 1984, 1990, 1991 – 2011), and two fishery independent indices (the gill net survey, 1985 – 2011; and the winter trawl survey, 2000 – 2011). The fyke net index exhibited a bimodal pattern with one peak in 1990 and a broader peak covering the years 2006 – 2009 (Figure 8). The fishery independent gill net survey indicated relatively high index values during 1985 – 1987, a time period where no fyke net index was available. The gill net index corroborated the higher fyke net index during the last three years of the time series (Figure 9). The winter trawl survey also validated the increased biomass over the last 4 years of the assessment period (Figure 10), but this index suggested that biomass was at its highest in 2011 whereas the fyke net index and gill net index suggested some decline over the period 2010 – 2011.

The model fit the data well. Estimated parameters r, K, and B_0 were 0.68, 8.7 million pounds, and 2.2 million pounds, respectively. Biomass increased from 2.2 million pounds in 1980 to 7.5 million pounds in 1989. Channel catfish biomass then trended lower to 3.8 million pounds in 2000, but nearly doubled to 7.6 million pounds in 2010. The final year biomass estimate (2011) was 6.8 million pounds (Figure 11). Instantaneous fishing mortality (F) peaked from 1996 – 1999, but then fell to low levels during 2004 – 2010. Instantaneous fishing mortality in the final year of the assessment (2011) was estimated to be 0.29 (Figure 11). Over the course of the assessment, F averaged 0.24. Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ *K* or 4.4 million pounds. F_{msy} was estimated as ½ *r* or 0.34. Maximum sustainable yield was estimated *rK*/4, or 1.5 million pounds.

Previous studies have indicated that the absolute values for biomass and fishing mortality from surplus production models may not be particularly precise, but the ratios of $B:B_{msy}$ and $F:F_{msy}$ are particularly robust (Prager 1994). Ratios of $B:B_{msy}$ and $F:F_{msy}$ indicated a period of increasing surplus biomass and moderate F between 1983 and the mid 1990's. Fishing mortality then rose to unsustainable levels for six of nine years during 1995 − 2003, that is, the $F:F_{msy}$ ratio was greater than 1.0 (Figure 12). After 2003, the $F:F_{msy}$ ratio declined and the $B:B_{msy}$ ratio increased. The $B:B_{msy}$ and $F:F_{msy}$ ratios in the final year of the assessment were 1.55 and 0.86, respectively. Based on these point estimates, the HOB channel catfish stock is not overfished and overfishing is not occurring.

Bootstrapping provided estimates of uncertainty for this model (Table 1). The bootstrap procedure produced 983 valid trials out of 1,000 attempts (98.3%). The intrinsic rate of increase (*r*) was precisely estimated (CV=29%). Estimates of *K* and B_0 were less precisely estimated with CV's equal to 35% and 40%, respectively. Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than *r* and *K* in model outputs and subsequent management advice. Coefficients of variation of annual biomass estimates ranged from 19% − 37%. In contrast, the ratio $B:B_{msy}$ was very precisely estimated in all years (CV range = 6% − 19%). Comparisons of the confidence intervals also demonstrate the increased precision of the ratio estimates (Figures 13 and 14). Coefficients of variation of annual fishing mortality estimates ranged from 19% − 48%. In contrast, the ratio $F:F_{msy}$ was precisely estimated in all years (CV range = 12% − 28%). Comparisons of the confidence intervals also demonstrate the increased precision of the ratio estimates (Figures 15 and 16). In the final year of the assessment (2011), there was only a 0.7% chance that channel catfish biomass was below B_{msy}, and a 5.9% chance that overfishing was occurring (*i.e.*, $F:F_{msy} > 1.0$).

Choptank River Catch-Survey Analysis (CSA)

Total channel catfish removal the from Choptank River, in numbers, was estimated for the assessment time period 1993 – 2011. Commercial and recreational harvest was generally low during 1993 – 2004, ranging from 20,000 – 50,000 fish, except for the nearly 100,000 fish estimated for 1999. After 2004, harvest increased substantially, ending in 2011 at a time series high (Figure 17). The model included two indices from a MD DNR Fisheries Service fishery independent fyke net survey. One index was a pre-recruit relative abundance index and the other was a post-recruit relative abundance index. The pre-recruit index remained in a low range, relative to the entire time series, from 1995 – 2006. The pre-recruit index increased after 2006, more than doubling the previous high relative abundance value (Figure 18). The post-recruit index indicated a similar pattern, but the higher relative abundance of the recruited fish did not begin until 2008 and ended the time series with the four highest relative abundance values in the last five years of the of the survey (Figure 19).

The CSA model fit the population data moderately well. Catchability of the survey (q) was estimated as 1.85×10^{-6}. Pre-recruit population abundance generally tracked the increase in the survey's relative abundance values, with relatively low pre-recruit abundance during 1995 – 2004, followed by relatively high pre-recruit abundance for the remainder of the time series (Figure 20). Post-recruit channel catfish abundance varied between 200,000 and 400,000 channel catfish from 1993 – 2007 (Figure 20). After 2007, recruited channel catfish abundance accelerated quite swiftly with the recruited population increasing from an estimated 664,000 fish in 2008 to 1.06 million fish in 2011. Instantaneous fishing mortality (F) was generally low, varying between 0.04 and 0.15 for most of the assessment period (Figure 21). Average F for the entire time series was 0.13 and F in the final year of the assessment was 0.11. No F-based, biomass-based, or abundance-based biological reference points have been determined for Chesapeake Bay area channel catfish stocks. Therefore, no conclusions may be definitively drawn regarding overfishing or overfished status for Choptank River channel catfish stocks. Model outputs and survey results strongly suggest that fishing mortality at recent levels is not impacting population growth.

Bootstrapping provided estimates of uncertainty for this model (5,000 trials; Table 2). Survey catchability (q) was precisely estimated (CV=22%). Coefficients of variation for pre-recruit abundance estimates ranged from 34% – 41% with some of the highest CV's in the last 5 years of the assessment. Coefficients of variation for post-recruit abundance were more variable than the pre-recruit abundances. Coefficients of variation ranged from 29% – 52%. Again, a temporal trend is evidenced where the higher CV's occur in the latter years of the assessment. Total population size (pre-recruit and post-recruit abundances) provided a better fit, with CV's ranging from 28% – 41%. Fishing mortality estimates were also precisely estimated with CV's ranging from 23% –

36%. Graphs of confidence intervals for population estimates and F estimates indicate that in general, population estimates may be biased high, and F may be biased low (Figures 22 – 25). In addition these graphs also depict the temporal uncertainty in the population estimates in the latter part of the time series.

Other Areas

Nanticoke River channel catfish data included commercial fishery landings, fishery dependent relative abundance, and a fishery independent seine survey. Commercial landings from 1987 – 2011 were variable ranging form just under 20,000 pounds to 145,0000 pounds (Figure 26). Commercial fishery CPUE's were quite variable and exhibited no discernable trend (Figures 27, 28). Young-of-year production, as determined from the EJFS seine survey is also not definitive, but production was more consistent during 1989 –1997 than in recent years (Figure 29).

Patuxent River channel catfish data included commercial fishery landings, fishery dependent relative abundance, and a fishery independent seine survey. Patuxent River landings have been trendless throughout the past 25 years (Figure 30). Only the fish pot relative abundance index provided a complete enough time series to warrant investigation. Relative abundance values have been trending downward since 2006 (Figure 31). Young-of-year production, as determined from the EJFS seine survey indicated that the last years of high juvenile abundance were in 2001 and 2003 (Figure 32). No juvenile channel catfish were encountered in 2006, 2008, 2010, or 2012.

Potomac River channel catfish landings, as report to Potomac River Fishery Commission, had to be adjusted for difference in reporting requirements similar to landings from the MD DNR commercial database. Estimated landings of channel catfish from Potomac River showed a peak in 1964, a relatively broad peak in the mid 1980's followed by a rapid decline with landings generally less than 100,000 pounds since 1991 (Figure 33). The Potomac River drift gill net survey indicated that the biomass index was below the 75th percentile since 2005 (Figure 34). Young-of-year production, as determined from the EJFS seine survey, indicated low and intermittent juvenile production since 1985 (Figure 35).

DISCUSSION

Channel catfish provide valuable recreational and commercial fisheries while occupying an important ecological niche among brackish-tidal fresh ecosystems in Maryland's portion of the Chesapeake Bay. The primary objective of this Job was to describe trends in channel catfish abundance throughout the Bay region. Model runs proved informative for HOB and Choptank River channel catfish populations. These areas accounted for 77% of total MD commercial channel catfish harvest. Channel catfish populations in Nanticoke, Patuxent, and Potomac rivers were assessed through qualitative examination of available relative abundance data.

The HOB surplus production model indicated a period of population increase from 1980 – 1989 followed by a decline through 2000 (estimated as 3.8 million pounds). Since 2000, population biomass increased to an average of 7.1 million pounds over the last 5 year period, 2007 – 2011. These results generally mimic the original model run (Piavis and Webb 2010).

Maximum sustainable yield (MSY) was identified as 1.48 million pounds. Total estimated removals were above MSY in only 2 years during the expansion/plateau phase of channel catfish abundance (1980 – 1993). Total estimated removals exceeded MSY in each year except 2000 during the period when the population contracted (1994 – 2000). Recently, harvest (commercial and recreational) was above MSY in 2003 and 2011. The population biomass during 2011 was 55% higher than B_{msy} (B_{msy} = the population biomass that can sustain harvest at MSY), given that the $B:B_{msy}$ ratio for 2011 was 1.55. A $B:B_{msy}$ ratio greater than 1.0 indicates that the stock is not overfished. This metric has proven more robust than absolute biomass values from surplus production modeling (Prager 1994). The robustness of the ratio estimates becomes evident with the inspection of uncertainty parameters. Confidence intervals are tighter around B ratio estimates (CV range: 6% – 19%) than absolute B estimates (CV range: 19% – 37%).

Inspection of the trajectories of F moved opposite that of biomass. As F increased, the population biomass stabilized until F increased beyond F_{msy}, at which point population biomass contracted. Conversely, the period beginning in 2000 had F rates below F_{msy} and population biomass expanded. In the final year of the assessment, the $F:F_{msy}$ ratio was 0.86. $F:F_{msy}$ ratios less than 1.0 indicate that overfishing is not occurring. Similar to the $B:B_{msy}$ ratio, the F ratio is a more robust estimate of the status of F than absolute values (Prager 1994).

The winter trawl survey (Project 1 Job 1) has limited temporal coverage, but the trawl survey results indicated strong year-classes for the 2004, 2006, 2008, and 2011 cohorts. Given expected growth rates, the increased biomass in recent years is attributed to the higher juvenile production of the 2004 and 2006 year-classes. The 2008 and 2011 year-classes should sustain population expansion for future years if the commercial and recreational fisheries remain stable.

The Choptank River assessment was the first assessment of channel catfish using a CSA. Population trajectories indicated an expanding population which closely tracked our experimental fyke net indices. No biological reference points exist to determined overfished or overfishing status, but given that populations are estimated at time series highs, overfishing is unlikely to have occurred for extended periods of time in the Choptank River channel catfish fishery.

Uncertainty analysis indicated that abundance parameters were only moderately estimated. Relative abundance indices for both pre- and post-recruit fish were at baseline levels compared to values later in the time series. The abundance increase over the last few years provides the only contrast in population size. Magnusson and Hilborn (2007) investigated what population trajectories and models provided informative fishery management advice. Although the authors did not investigate CSA type models, results indicated that fishery population models that performed the best did so when there were sustained contrasting periods of population abundance. Given that our results show a relatively recent increase in abundance, a full population cycle may help increase precision.

Channel catfish relative abundance trends in Nanticoke, Patuxent, and Potomac rivers are largely uninformative, but general trends are evident. Fishery dependent CPUE's in Nanticoke River have been hovering around the 75th percentile for several years indicating a generally stable population. Patuxent River fishery dependent CPUE's and Potomac River fishery independent CPUE's have been below the 75th percentile for some time. Meaningful population increases are unlikely, given that juvenile indices in all three systems have been weak over the last several years. However, juvenile indices reported from seine catches may not be the best indicator of juvenile production (Piavis and Webb 2010).

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

Parameter/Year	Estimate	Mean	Median	Std Dev	C.V.
r	0.679	0.655	0.678	0.195	0.288
K	8,731,750	9,664,473	9,153,815	3,367,350	0.348
B_0	2,249,834	2,619,064	2,428,093	1,038,700	0.397
B_{1981}	2,821,114	3,231,434	3,046,373	1,136,196	0.352
B_{1982}	3,652,119	4,096,747	3,883,035	1,218,638	0.297
B_{1983}	4,654,158	5,105,782	4,884,121	1,268,241	0.248
B_{1984}	5,373,523	5,779,725	5,571,109	1,287,020	0.223
B_{1985}	6,077,590	6,424,085	6,216,390	1,302,695	0.203
B_{1986}	6,259,858	6,560,064	6,366,858	1,339,972	0.204
B_{1987}	6,627,386	6,922,635	6,730,080	1,370,500	0.198
B_{1988}	7,115,460	7,423,628	7,242,488	1,424,805	0.192
B_{1989}	7,474,514	7,815,591	7,653,198	1,516,023	0.194
B_{1990}	6,874,531	7,269,466	7,107,412	1,623,843	0.223
B_{1991}	6,422,310	6,869,635	6,685,288	1,631,443	0.237
B_{1992}	6,600,940	7,080,139	6,878,927	1,618,894	0.229
B_{1993}	6,419,896	6,918,528	6,707,599	1,638,142	0.237
B_{1994}	6,479,235	6,994,993	6,767,826	1,643,919	0.235
B_{1995}	6,022,445	6,549,684	6,312,031	1,663,016	0.254
B_{1996}	5,533,883	6,074,234	5,828,579	1,650,997	0.272
B_{1997}	4,431,561	4,982,211	4,728,953	1,628,196	0.327
B_{1998}	4,396,059	4,961,798	4,680,998	1,616,503	0.326
B_{1999}	3,918,258	4,494,430	4,207,879	1,609,432	0.358
B_{2000}	3,814,214	4,404,857	4,073,018	1,629,558	0.370
B_{2001}	4,382,048	4,981,695	4,664,610	1,662,089	0.334
B_{2002}	4,707,414	5,285,731	4,985,547	1,665,146	0.315
B_{2003}	5,389,065	5,931,705	5,641,595	1,659,903	0.280
B_{2004}	4,966,816	5,453,140	5,170,563	1,650,481	0.303
B_{2005}	5,562,602	6,026,080	5,751,897	1,644,692	0.273
B_{2006}	6,536,262	6,961,828	6,667,953	1,643,980	0.236
B_{2007}	6,923,565	7,312,886	7,050,980	1,692,339	0.231
B_{2008}	7,350,280	7,756,405	7,499,247	1,749,995	0.226
B_{2009}	7,161,607	7,609,118	7,359,249	1,847,713	0.243
B_{2010}	7,210,083	7,711,917	7,460,331	1,898,155	0.246
B_{2011}	6,780,867	7,325,968	7,070,692	1,961,292	0.268

Table 1. (Continued)

Parameter/Year	Estimate	Mean	Median	Std Dev	C.V.
F_{1980}	0.288	0.291	0.264	0.140	0.481
F_{1981}	0.181	0.177	0.166	0.065	0.370
F_{1982}	0.129	0.124	0.121	0.037	0.296
F_{1983}	0.178	0.171	0.168	0.043	0.249
F_{1984}	0.140	0.136	0.134	0.029	0.215
F_{1985}	0.194	0.191	0.189	0.038	0.199
F_{1986}	0.143	0.142	0.141	0.029	0.201
F_{1987}	0.094	0.094	0.093	0.018	0.190
F_{1988}	0.078	0.078	0.077	0.014	0.187
F_{1989}	0.196	0.195	0.191	0.041	0.209
F_{1990}	0.236	0.236	0.227	0.062	0.262
F_{1991}	0.165	0.163	0.158	0.041	0.254
F_{1992}	0.215	0.210	0.205	0.051	0.240
F_{1993}	0.187	0.183	0.178	0.045	0.245
F_{1994}	0.282	0.275	0.268	0.069	0.251
F_{1995}	0.345	0.338	0.326	0.097	0.287
F_{1996}	0.594	0.591	0.554	0.223	0.377
F_{1997}	0.419	0.417	0.387	0.165	0.396
F_{1998}	0.591	0.590	0.543	0.256	0.434
F_{1999}	0.513	0.510	0.468	0.221	0.433
F_{2000}	0.266	0.259	0.247	0.094	0.363
F_{2001}	0.307	0.297	0.285	0.097	0.328
F_{2002}	0.184	0.178	0.173	0.051	0.287
F_{2003}	0.413	0.402	0.391	0.114	0.284
F_{2004}	0.190	0.186	0.182	0.051	0.276
F_{2005}	0.074	0.073	0.072	0.017	0.230
F_{2006}	0.118	0.116	0.116	0.024	0.203
F_{2007}	0.082	0.081	0.081	0.017	0.205
F_{2008}	0.143	0.141	0.140	0.029	0.208
F_{2009}	0.123	0.121	0.119	0.028	0.232
F_{2010}	0.196	0.193	0.189	0.046	0.238
F_{2011}	0.293	0.289	0.279	0.081	0.280

Table 1. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	C.V.
$(B/B_{MSY})_{1980}$	0.515	0.536	0.527	0.100	0.186
$(B/B_{MSY})_{1981}$	0.646	0.671	0.665	0.123	0.184
$(B/B_{MSY})_{1982}$	0.837	0.864	0.853	0.161	0.187
$(B/B_{MSY})_{1983}$	1.066	1.091	1.077	0.209	0.192
$(B/B_{MSY})_{1984}$	1.231	1.240	1.238	0.221	0.178
$(B/B_{MSY})_{1985}$	1.392	1.380	1.393	0.221	0.160
$(B/B_{MSY})_{1986}$	1.434	1.404	1.436	0.195	0.139
$(B/B_{MSY})_{1987}$	1.518	1.481	1.517	0.189	0.128
$(B/B_{MSY})_{1988}$	1.630	1.587	1.625	0.185	0.117
$(B/B_{MSY})_{1989}$	1.712	1.667	1.709	0.173	0.104
$(B/B_{MSY})_{1990}$	1.575	1.537	1.564	0.133	0.087
$(B/B_{MSY})_{1991}$	1.471	1.448	1.463	0.118	0.081
$(B/B_{MSY})_{1992}$	1.512	1.496	1.513	0.122	0.081
$(B/B_{MSY})_{1993}$	1.470	1.459	1.473	0.113	0.077
$(B/B_{MSY})_{1994}$	1.484	1.476	1.488	0.113	0.077
$(B/B_{MSY})_{1995}$	1.379	1.376	1.381	0.100	0.073
$(B/B_{MSY})_{1996}$	1.268	1.271	1.269	0.096	0.075
$(B/B_{MSY})_{1997}$	1.015	1.031	1.021	0.103	0.100
$(B/B_{MSY})_{1998}$	1.007	1.029	1.014	0.114	0.111
$(B/B_{MSY})_{1999}$	0.897	0.928	0.910	0.131	0.142
$(B/B_{MSY})_{2000}$	0.874	0.910	0.891	0.153	0.168
$(B/B_{MSY})_{2001}$	1.004	1.040	1.021	0.176	0.169
$(B/B_{MSY})_{2002}$	1.078	1.109	1.097	0.186	0.168
$(B/B_{MSY})_{2003}$	1.234	1.254	1.256	0.199	0.158
$(B/B_{MSY})_{2004}$	1.138	1.146	1.159	0.174	0.152
$(B/B_{MSY})_{2005}$	1.274	1.275	1.290	0.192	0.150
$(B/B_{MSY})_{2006}$	1.497	1.482	1.499	0.206	0.139
$(B/B_{MSY})_{2007}$	1.586	1.552	1.585	0.176	0.114
$(B/B_{MSY})_{2008}$	1.684	1.645	1.683	0.161	0.098
$(B/B_{MSY})_{2009}$	1.640	1.605	1.640	0.126	0.079
$(B/B_{MSY})_{2010}$	1.651	1.624	1.652	0.115	0.071
$(B/B_{MSY})_{2011}$	1.553	1.535	1.549	0.092	0.060

Table 1. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	C.V.
$(F/F_{MSY})_{1980}$	0.848	0.840	0.820	0.210	0.250
$(F/F_{MSY})_{1981}$	0.532	0.525	0.515	0.126	0.240
$(F/F_{MSY})_{1982}$	0.379	0.377	0.368	0.096	0.255
$(F/F_{MSY})_{1983}$	0.523	0.527	0.511	0.146	0.277
$(F/F_{MSY})_{1984}$	0.411	0.421	0.404	0.120	0.284
$(F/F_{MSY})_{1985}$	0.572	0.592	0.564	0.167	0.282
$(F/F_{MSY})_{1986}$	0.422	0.440	0.418	0.118	0.267
$(F/F_{MSY})_{1987}$	0.278	0.289	0.276	0.074	0.257
$(F/F_{MSY})_{1988}$	0.230	0.239	0.229	0.058	0.241
$(F/F_{MSY})_{1989}$	0.577	0.596	0.574	0.128	0.214
$(F/F_{MSY})_{1990}$	0.695	0.711	0.698	0.127	0.179
$(F/F_{MSY})_{1991}$	0.485	0.491	0.485	0.082	0.167
$(F/F_{MSY})_{1992}$	0.632	0.635	0.628	0.104	0.164
$(F/F_{MSY})_{1993}$	0.551	0.551	0.546	0.085	0.155
$(F/F_{MSY})_{1994}$	0.830	0.828	0.824	0.122	0.148
$(F/F_{MSY})_{1995}$	1.016	1.009	1.014	0.140	0.139
$(F/F_{MSY})_{1996}$	1.749	1.733	1.749	0.270	0.156
$(F/F_{MSY})_{1997}$	1.235	1.216	1.228	0.212	0.175
$(F/F_{MSY})_{1998}$	1.739	1.715	1.717	0.364	0.212
$(F/F_{MSY})_{1999}$	1.509	1.486	1.478	0.356	0.240
$(F/F_{MSY})_{2000}$	0.784	0.768	0.764	0.180	0.235
$(F/F_{MSY})_{2001}$	0.903	0.890	0.882	0.218	0.245
$(F/F_{MSY})_{2002}$	0.543	0.539	0.529	0.132	0.245
$(F/F_{MSY})_{2003}$	1.216	1.222	1.183	0.313	0.256
$(F/F_{MSY})_{2004}$	0.559	0.566	0.544	0.139	0.245
$(F/F_{MSY})_{2005}$	0.219	0.223	0.214	0.054	0.245
$(F/F_{MSY})_{2006}$	0.348	0.357	0.344	0.084	0.236
$(F/F_{MSY})_{2007}$	0.242	0.249	0.241	0.052	0.208
$(F/F_{MSY})_{2008}$	0.421	0.431	0.418	0.079	0.185
$(F/F_{MSY})_{2009}$	0.361	0.367	0.359	0.057	0.156
$(F/F_{MSY})_{2010}$	0.577	0.581	0.573	0.082	0.140
$(F/F_{MSY})_{2011}$	0.863	0.863	0.863	0.107	0.123

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

Parameter/Year	Estimate	Mean	Median	Std Dev	CV
q	1.85E-06	2.16E-06	2.19E-06	4.77E-07	0.221
Pre-Recruit 1993	101,595	100,559	92,171	40,577	0.404
Pre-Recruit 1994	316,238	297,941	279,696	100,228	0.336
Pre-Recruit 1995	65,634	64,680	59,944	23,545	0.364
Pre-Recruit 1996	78,966	78,659	72,997	29,971	0.381
Pre-Recruit 1997	20,696	20,680	19,172	7,821	0.378
Pre-Recruit 1998	36,260	36,603	33,993	13,636	0.373
Pre-Recruit 1999	96,360	100,482	93,262	35,625	0.355
Pre-Recruit 2000	178,617	166,470	153,832	62,212	0.374
Pre-Recruit 2001	66,616	64,523	59,737	24,312	0.377
Pre-Recruit 2002	52,342	51,391	47,666	19,694	0.383
Pre-Recruit 2003	187,214	179,899	166,454	70,751	0.393
Pre-Recruit 2004	63,482	62,327	57,941	23,994	0.385
Pre-Recruit 2005	224,734	221,814	204,670	83,745	0.378
Pre-Recruit 2006	276,295	270,202	249,740	105,216	0.389
Pre-Recruit 2007	520,434	491,965	452,239	191,903	0.390
Pre-Recruit 2008	658,633	629,197	578,751	248,905	0.396
Pre-Recruit 2009	574,665	563,424	516,412	229,798	0.408
Pre-Recruit 2010	371,201	367,107	339,080	146,601	0.399
Pre-Recruit 2011	737,275	733,489	670,468	295,111	0.402
Post-Recruit 1993	218,647	186,474	172,077	85,420	0.458
Post-Recruit 1994	244,226	217,038	202,840	80,856	0.373
Post-Recruit 1995	441,531	404,291	379,300	116,201	0.287
Post-Recruit 1996	398,701	367,430	343,261	107,117	0.292
Post-Recruit 1997	361,367	335,513	310,513	102,812	0.306
Post-Recruit 1998	294,084	272,904	250,830	88,529	0.324
Post-Recruit 1999	234,328	217,268	196,348	80,092	0.369
Post-Recruit 2000	181,047	170,454	145,268	84,153	0.494
Post-Recruit 2001	278,624	260,007	233,493	107,228	0.412
Post-Recruit 2002	272,933	255,977	230,623	102,200	0.399
Post-Recruit 2003	241,904	227,243	203,796	95,496	0.420
Post-Recruit 2004	308,347	290,354	260,212	122,668	0.422
Post-Recruit 2005	271,513	255,836	228,206	114,740	0.448
Post-Recruit 2006	302,012	286,785	253,707	146,053	0.509
Post-Recruit 2007	369,851	352,396	311,445	184,875	0.525
Post-Recruit 2008	664,130	626,531	564,530	275,783	0.440
Post-Recruit 2009	950,114	895,230	814,146	383,669	0.429
Post-Recruit 2010	1,109,139	1,055,001	955,081	454,308	0.431
Post-Recruit 2011	1,061,724	1,014,047	911,008	458,810	0.452

Table 2. (Continued).

Parameter/Year	Estimate	Mean	Median	Std Dev	CV
Total N 1993	320,241	287,033	269,692	98,759	0.344
Total N 1994	560,464	514,979	484,455	141,928	0.276
Total N 1995	507,165	468,971	439,451	130,834	0.279
Total N 1996	477,667	446,089	415,554	125,575	0.282
Total N 1997	382,062	356,193	329,231	108,130	0.304
Total N 1998	330,344	309,507	283,956	97,825	0.316
Total N 1999	330,688	317,750	286,987	102,785	0.323
Total N 2000	359,664	336,924	304,541	130,968	0.389
Total N 2001	345,240	324,529	293,562	124,827	0.385
Total N 2002	325,275	307,368	278,729	116,640	0.379
Total N 2003	429,119	407,142	370,326	149,827	0.368
Total N 2004	371,829	352,680	318,933	140,143	0.397
Total N 2005	496,247	477,650	437,249	178,390	0.373
Total N 2006	578,307	556,987	506,969	225,807	0.405
Total N 2007	890,285	844,362	768,634	336,842	0.399
Total N 2008	1,322,763	1,255,727	1,156,690	468,615	0.373
Total N 2009	1,524,779	1,458,654	1,336,612	554,893	0.380
Total N 2010	1,480,340	1,422,108	1,296,256	560,392	0.394
Total N 2011	1,798,999	1,747,536	1,599,135	686,374	0.393
F 1993	0.071	0.089	0.085	0.031	0.343
F 1994	0.039	0.045	0.045	0.010	0.230
F 1995	0.041	0.047	0.047	0.011	0.228
F 1996	0.079	0.090	0.091	0.021	0.229
F 1997	0.062	0.071	0.072	0.017	0.243
F 1998	0.143	0.167	0.169	0.044	0.261
F 1999	0.402	0.470	0.481	0.130	0.277
F 2000	0.055	0.066	0.066	0.020	0.302
F 2001	0.035	0.042	0.041	0.012	0.296
F 2002	0.096	0.114	0.113	0.035	0.303
F 2003	0.131	0.155	0.153	0.048	0.310
F 2004	0.114	0.138	0.135	0.046	0.336
F 2005	0.297	0.359	0.344	0.133	0.370
F 2006	0.247	0.303	0.287	0.120	0.396
F 2007	0.093	0.113	0.109	0.040	0.355
F 2008	0.131	0.157	0.151	0.053	0.335
F 2009	0.118	0.140	0.136	0.047	0.335
F 2010	0.132	0.158	0.153	0.056	0.354
F 2011	0.109	0.129	0.124	0.046	0.355

Figure 1. Head-of-Bay and Potomac River fishery independent drift gill net sampling locations, 1985 -- 2011.

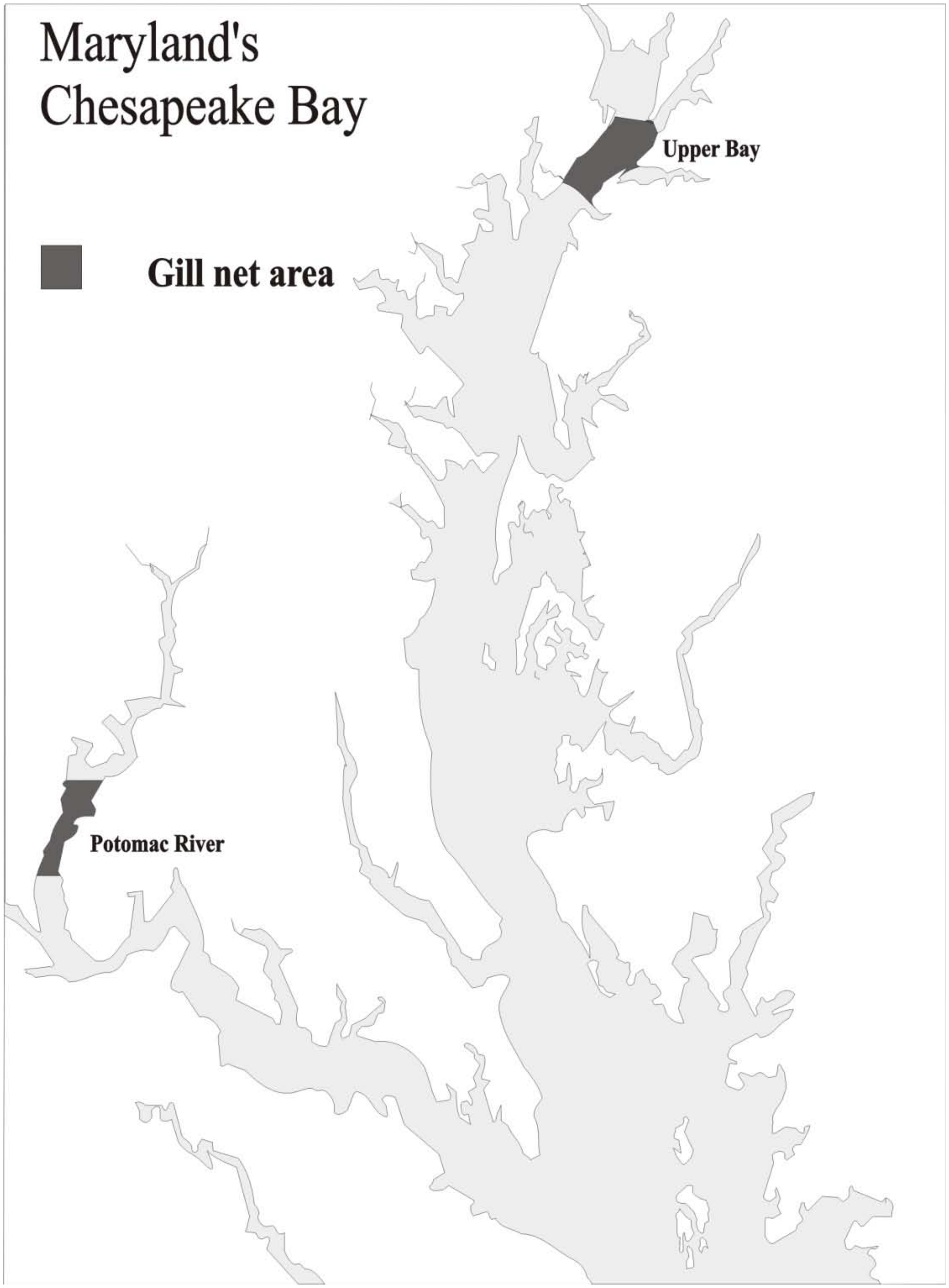


Figure 2. Head-of-Bay winter trawl sites, 1999 -- 2012 (triangles=main bay sites, squares=Elk River sites, circles=Sassafras River sites).

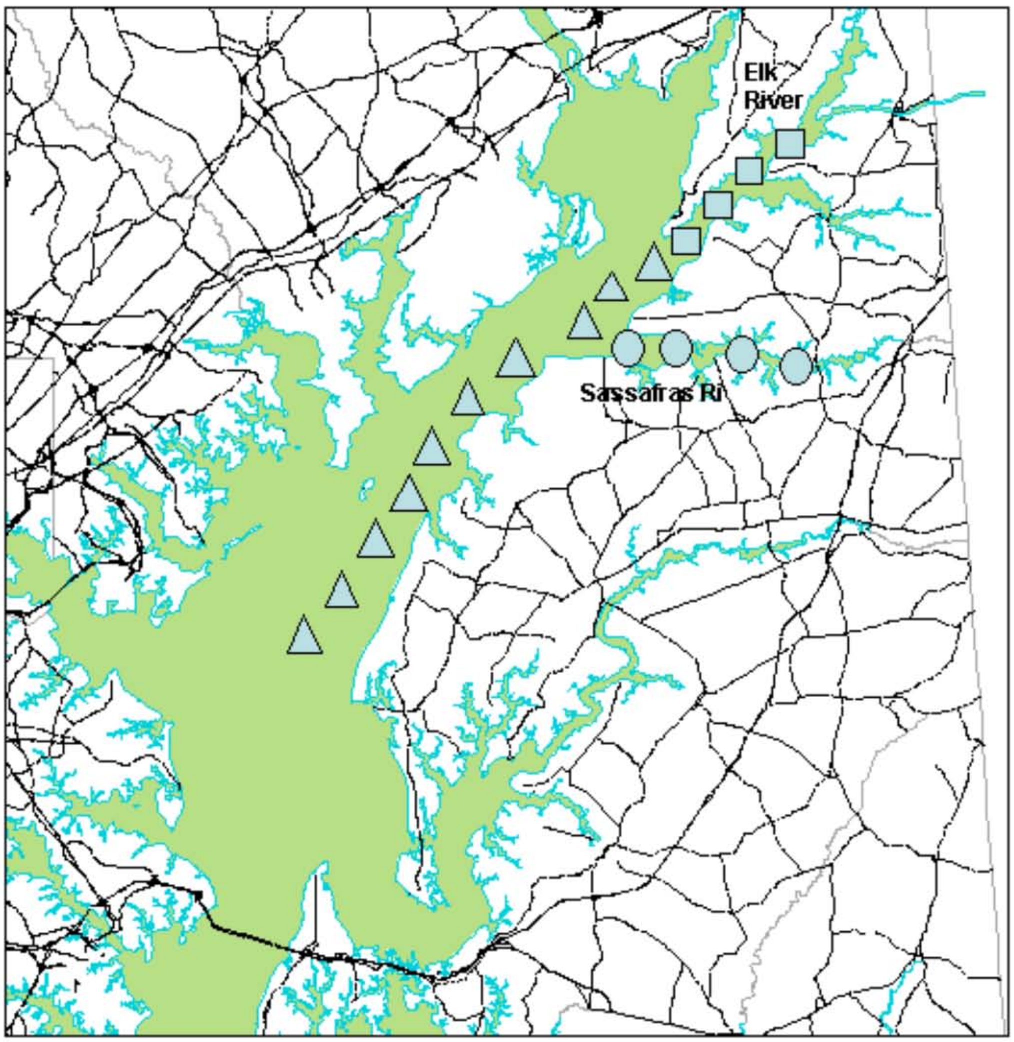


Figure 3. Choptank River fyke net locations, 2011. Circles indicate sites.

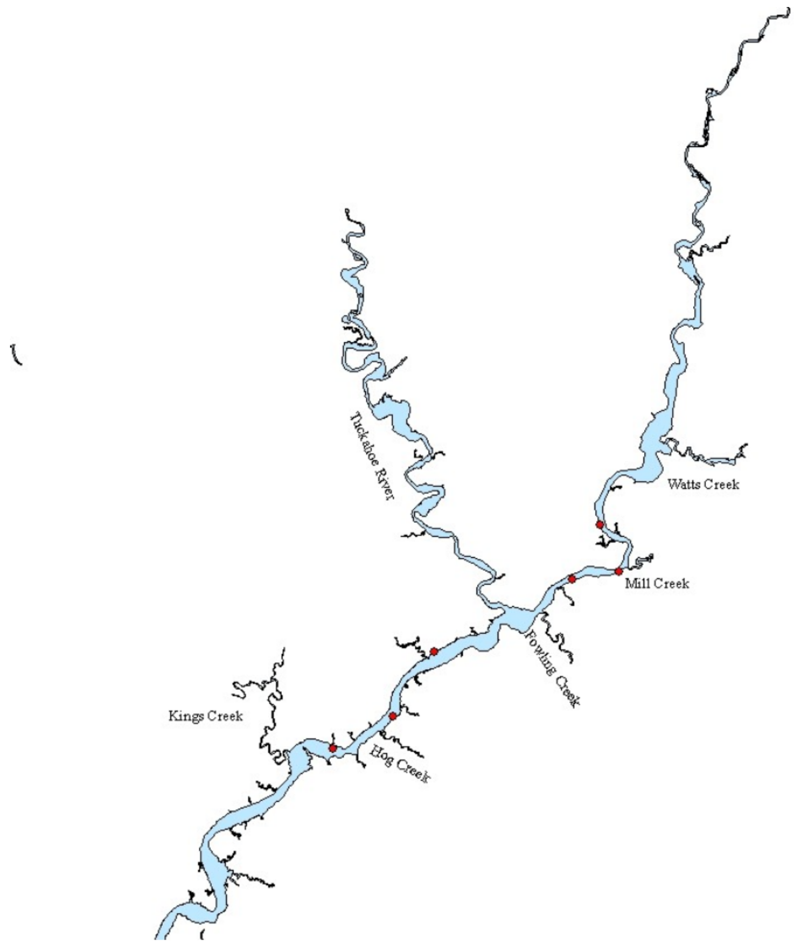


Figure 4. Estuarine Juvenile Finfish Survey seine site locations, 1962 -- 2012.

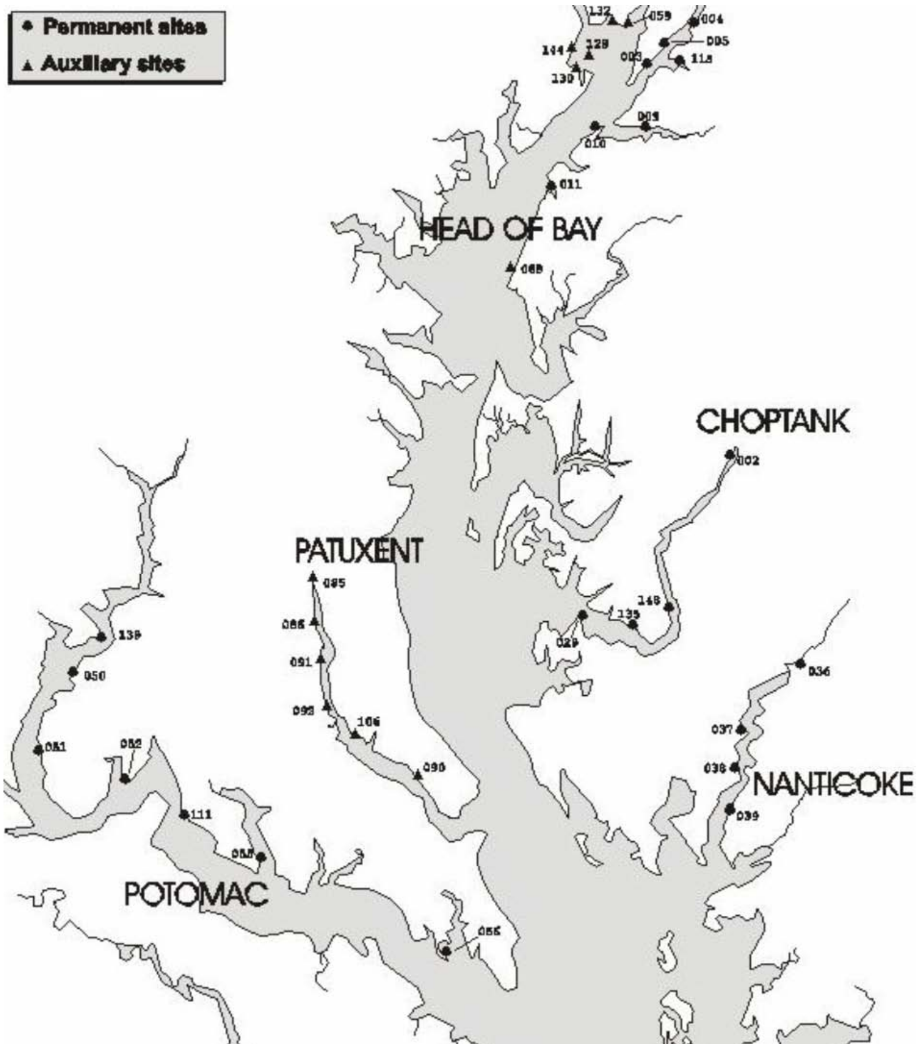


Figure 5. Adjusted Maryland commercial channel catfish landings, 1929 – 2011.

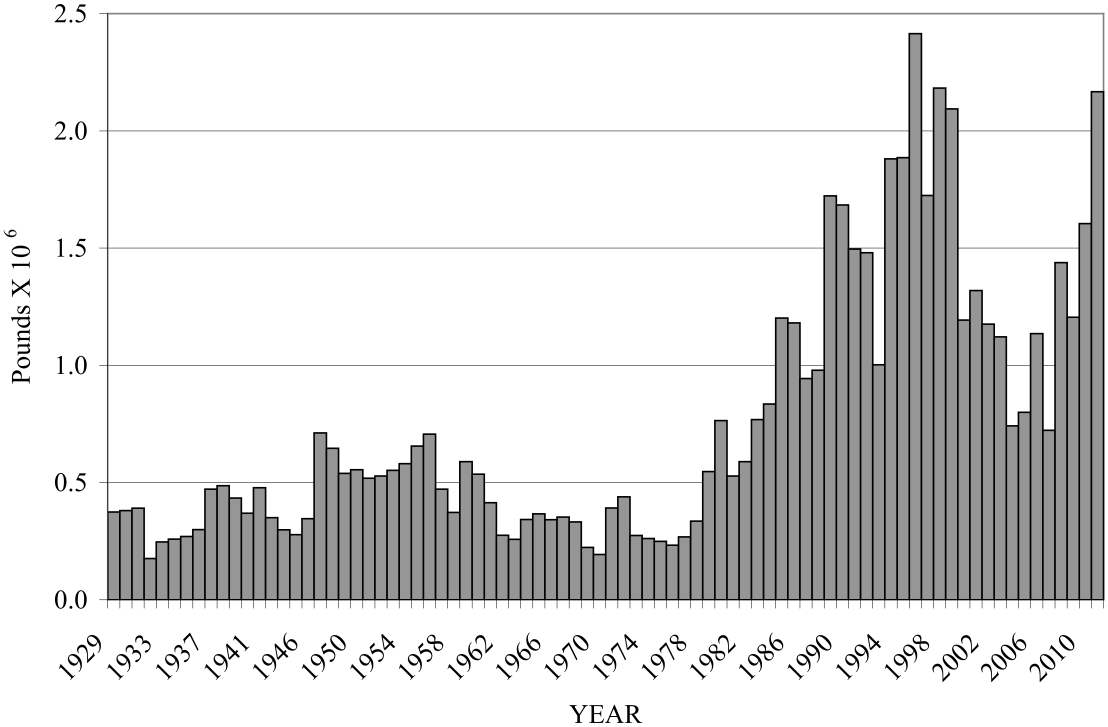


Figure 6. Estimated channel catfish landings from the recreational fishery, 1983 – 2011. Error bars = 1 standard error.

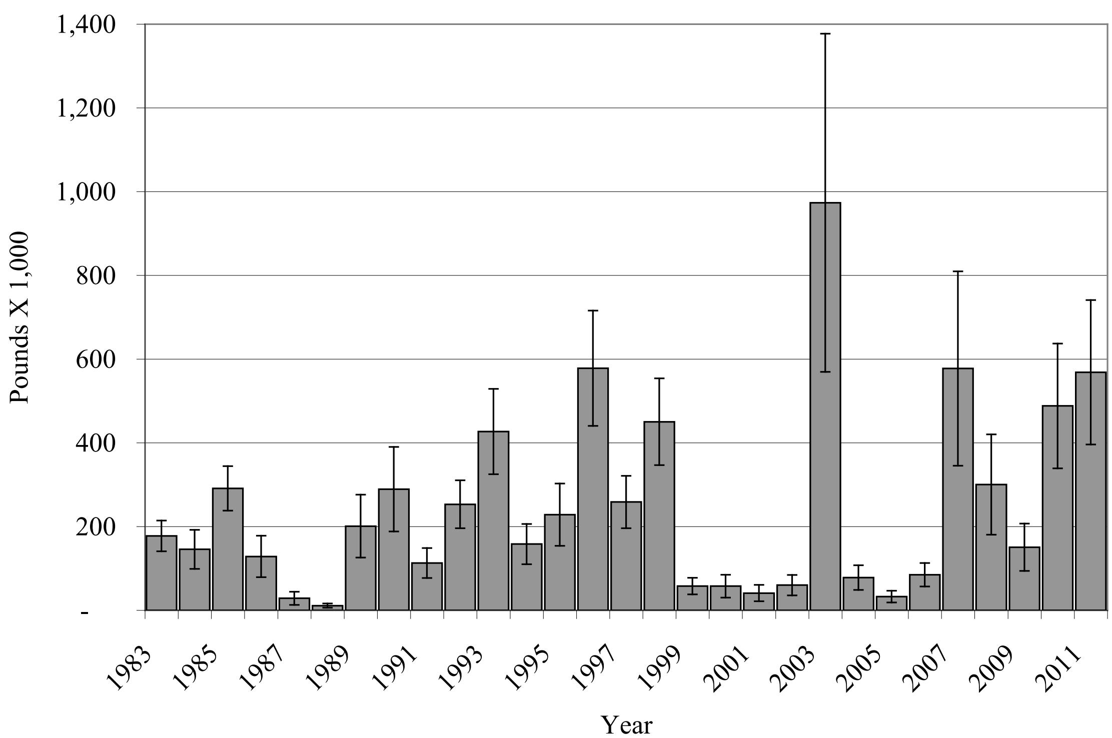


Figure 7. Head-of Bay channel catfish removals from commercial and recreational fisheries, 1980 – 2011.

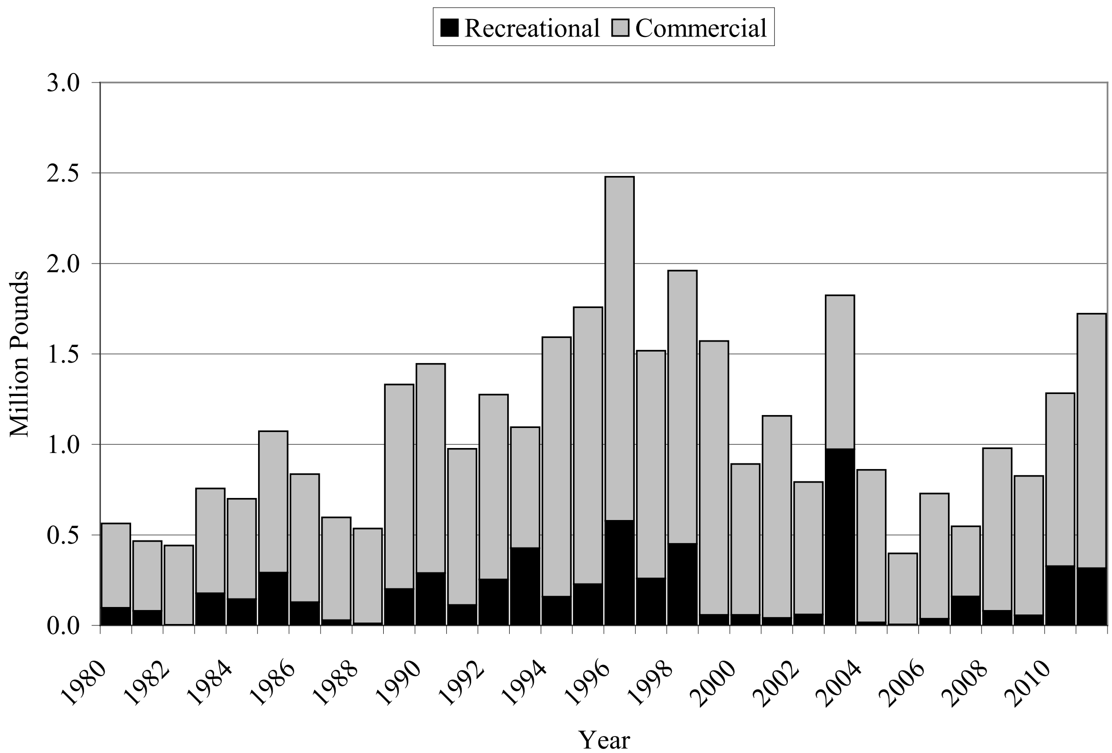


Figure 8. Observed and expected HOB commercial fyke net index, 1980 – 2011.

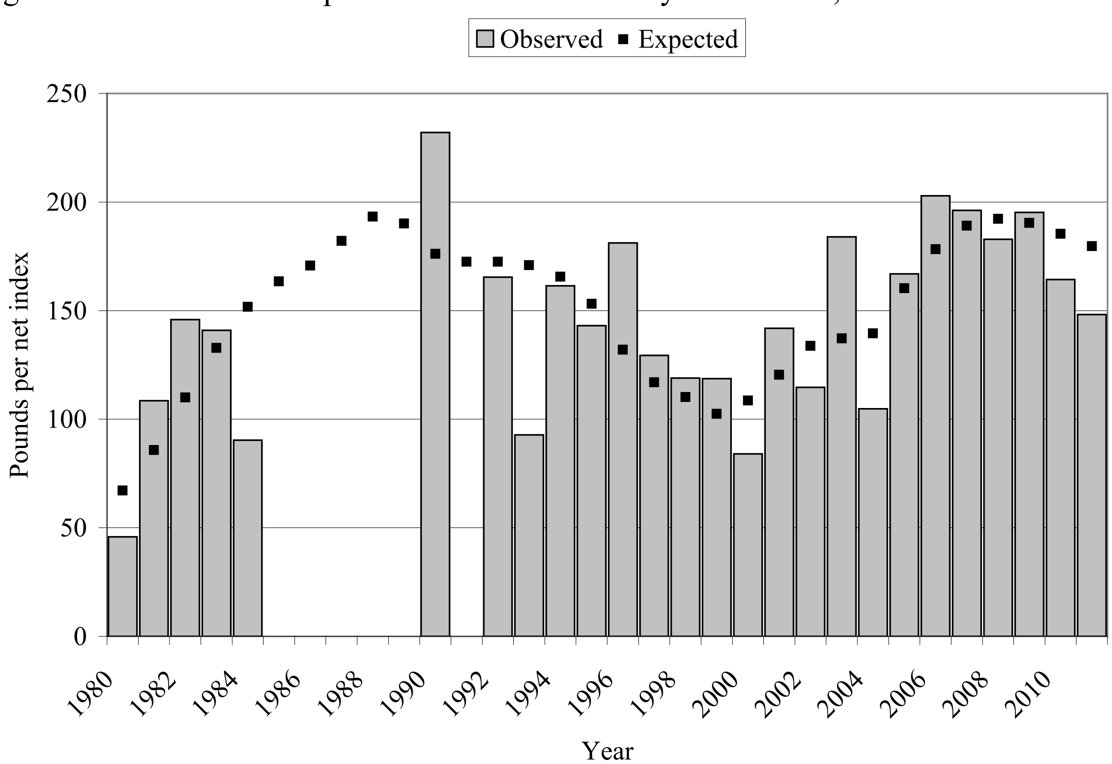


Figure 9. Observed and expected biomass index from HOB gill net survey, 1985 – 2011.

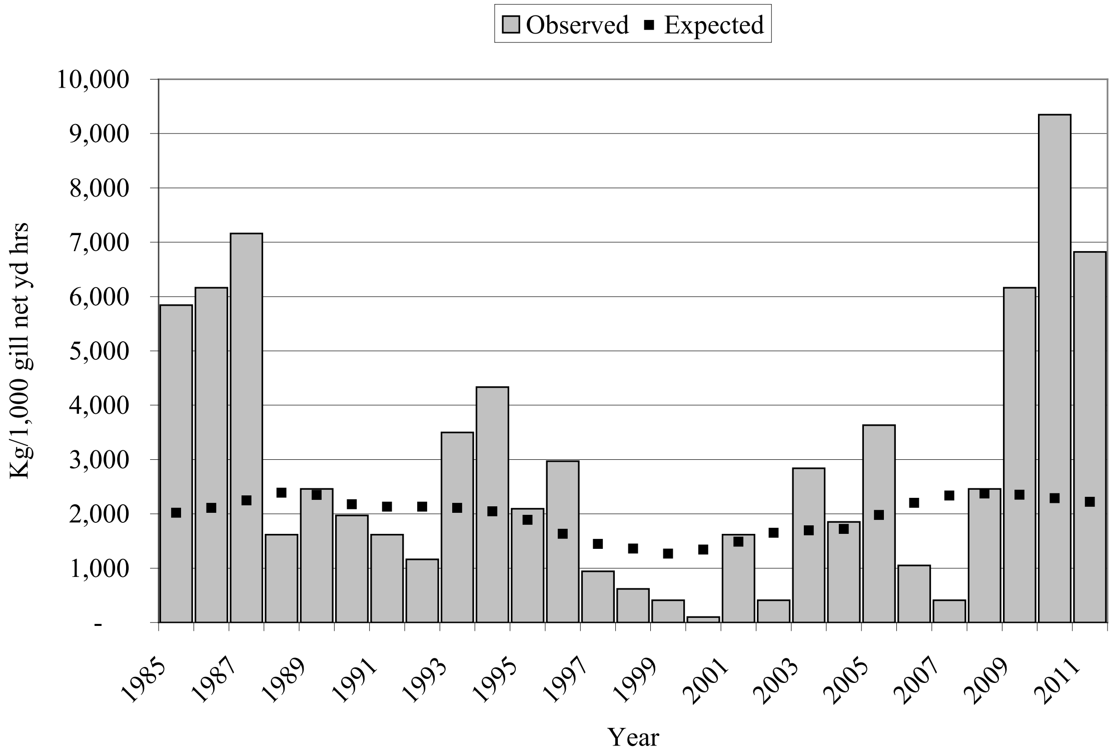


Figure 10. Observed and expected channel catfish biomass index from upper Bay winter trawl survey, 2000 – 2002 and 2006 – 2011.

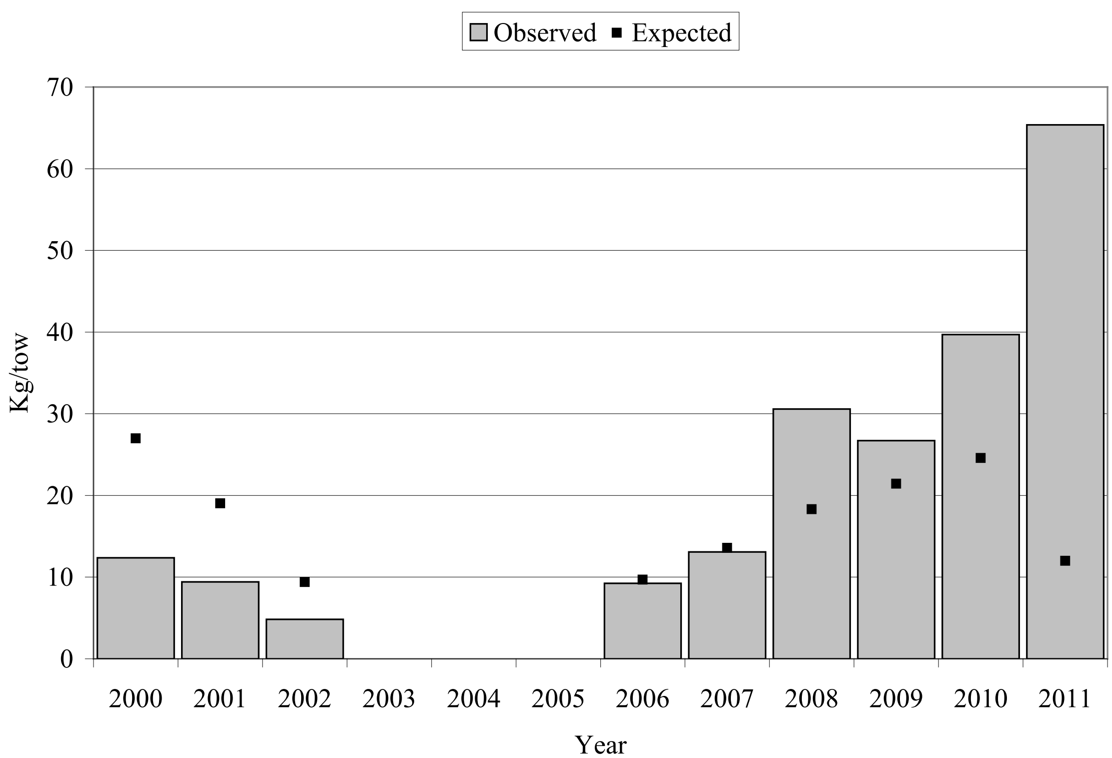


Figure 11. Biomass and fishing mortality estimates from Head-of-Bay channel catfish surplus production model.

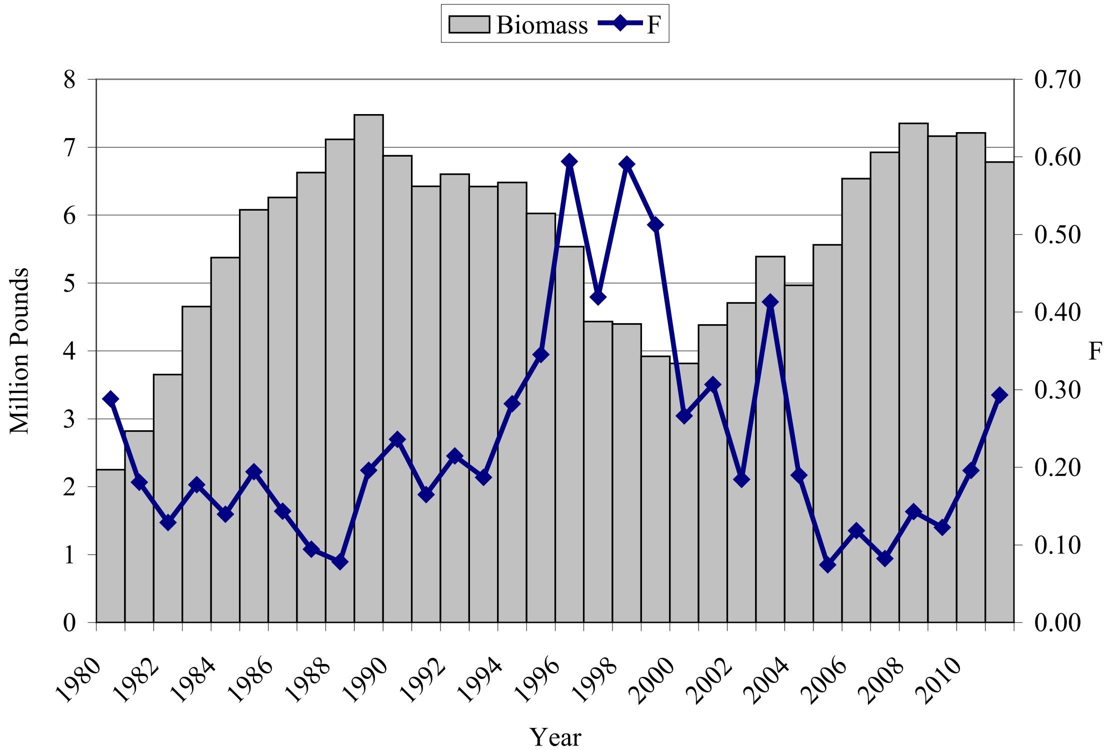


Figure 12. Biomass and fishing mortality ratios from Head-of-Bay channel catfish surplus production model.

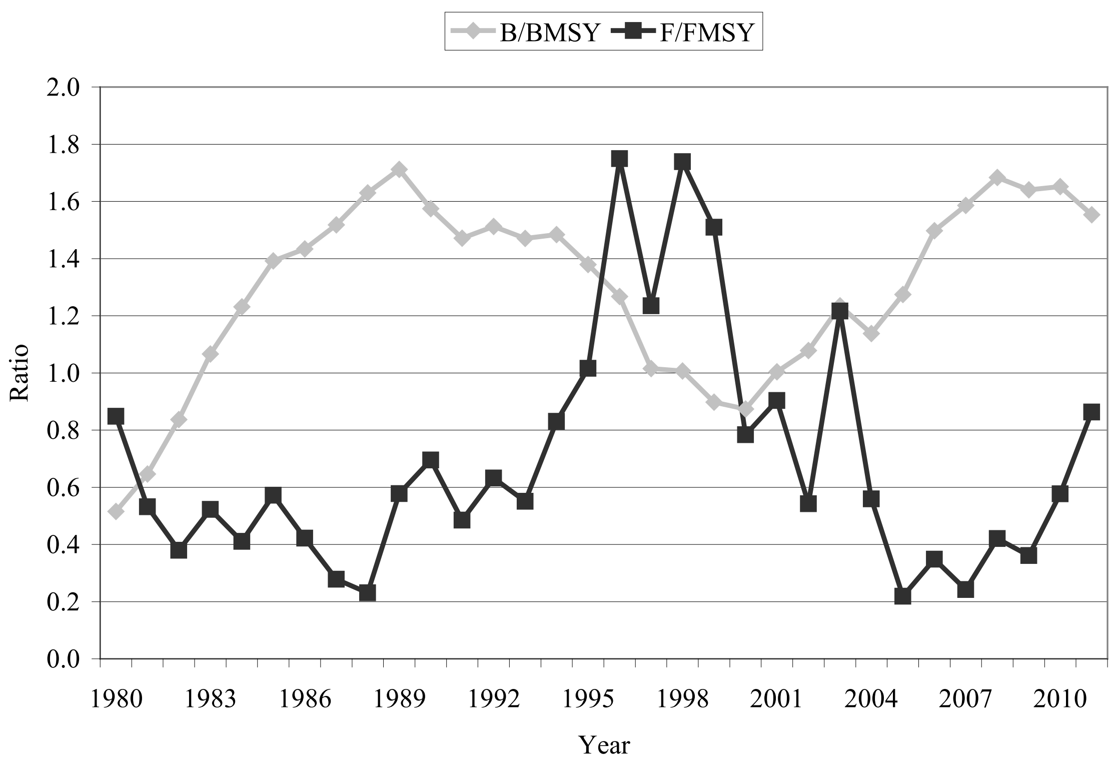


Figure 13. Biomass estimate and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

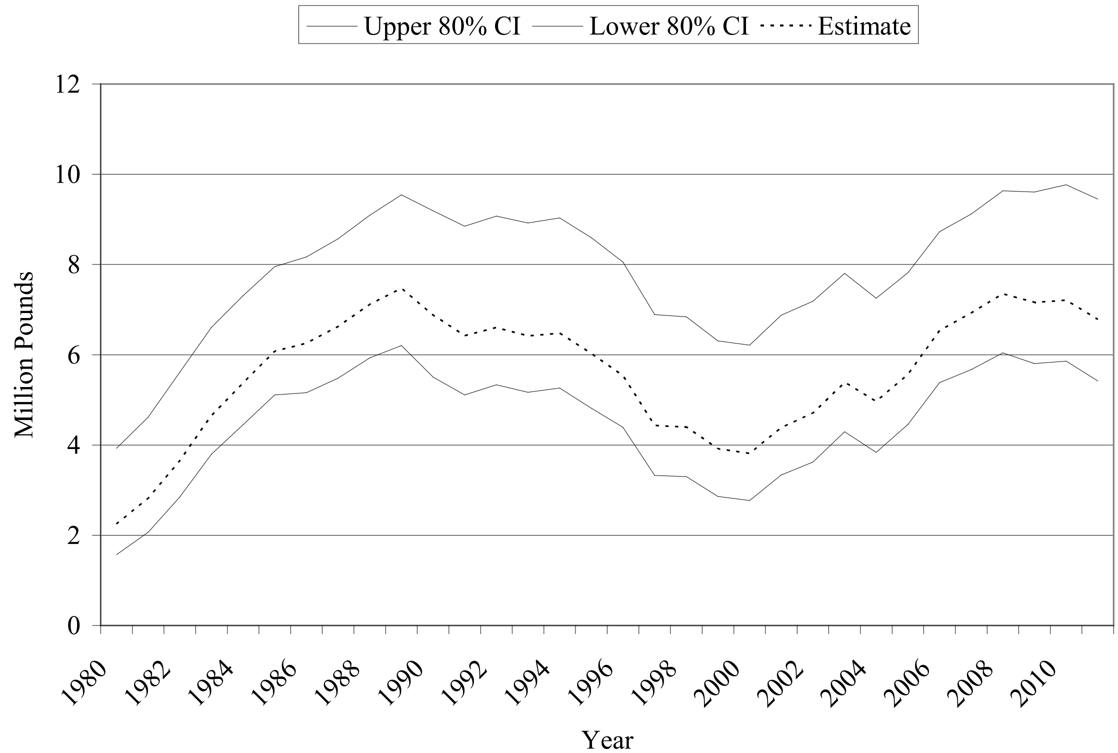


Figure 14. Biomass ratio and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

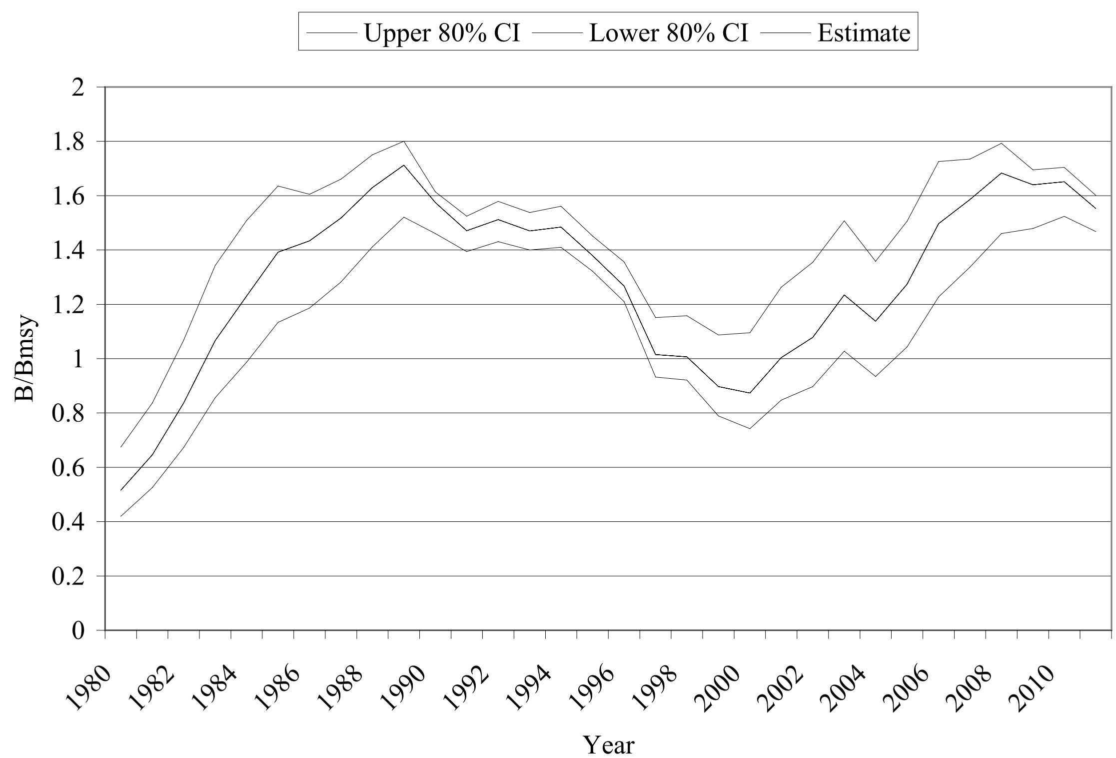


Figure 15. Fishing mortality and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

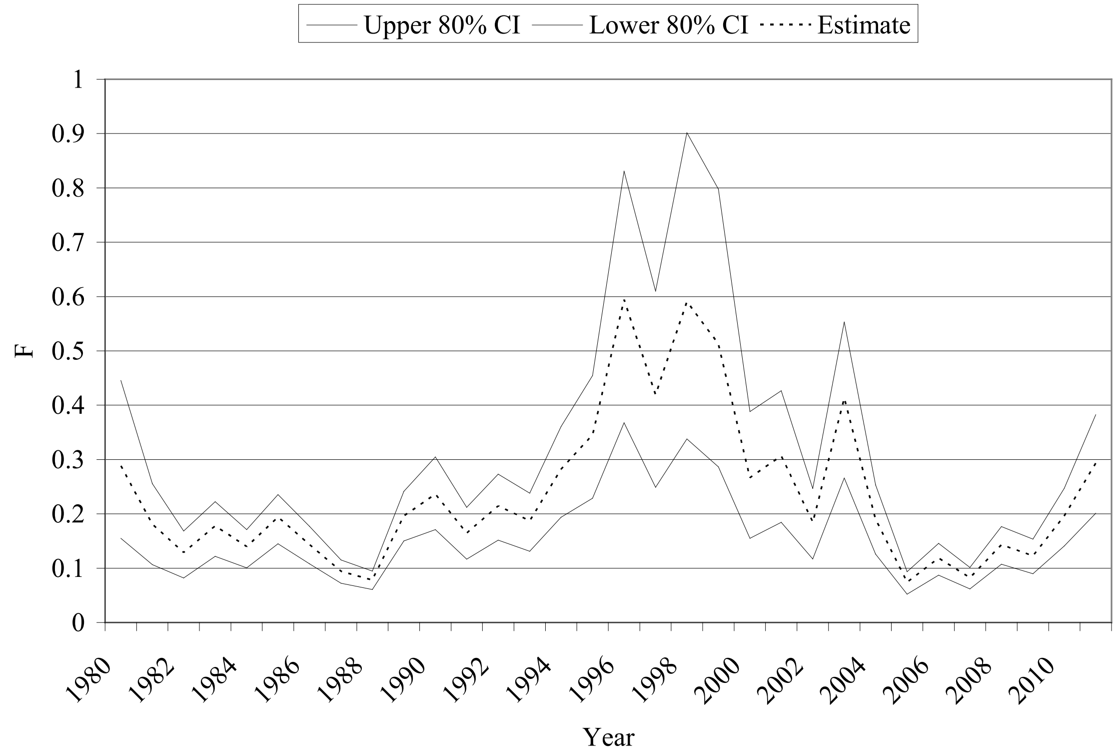


Figure 16. Fishing mortality ratio and 80% confidence intervals from Head-of-Bay channel catfish surplus production model.

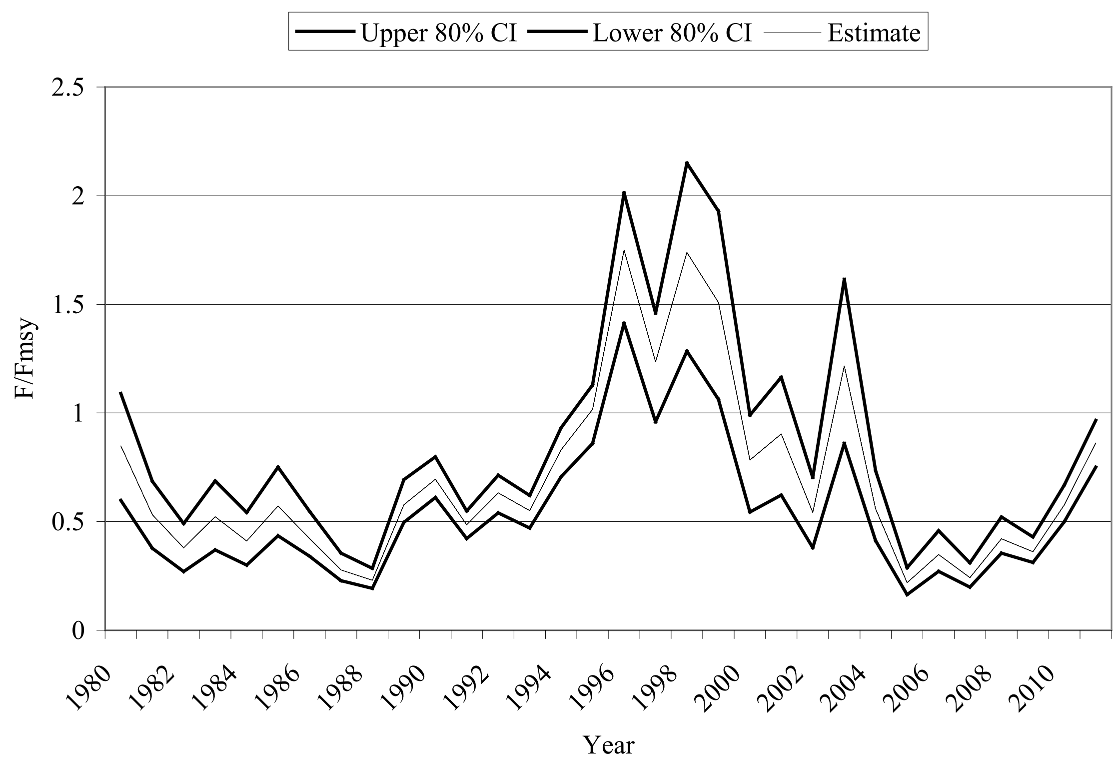


Figure 17. Choptank River channel catfish removals from commercial and recreational fisheries, 1993 – 2011

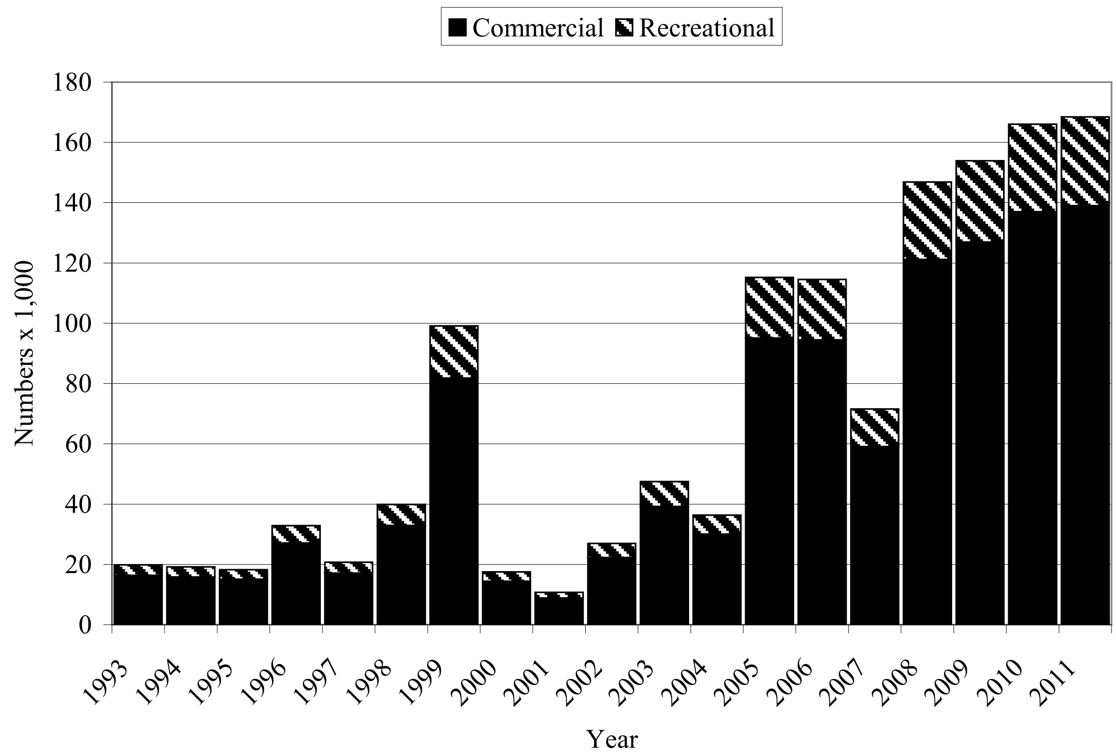


Figure 18. Observed and expected pre-recruit channel catfish index from Choptank River catch survey analysis.

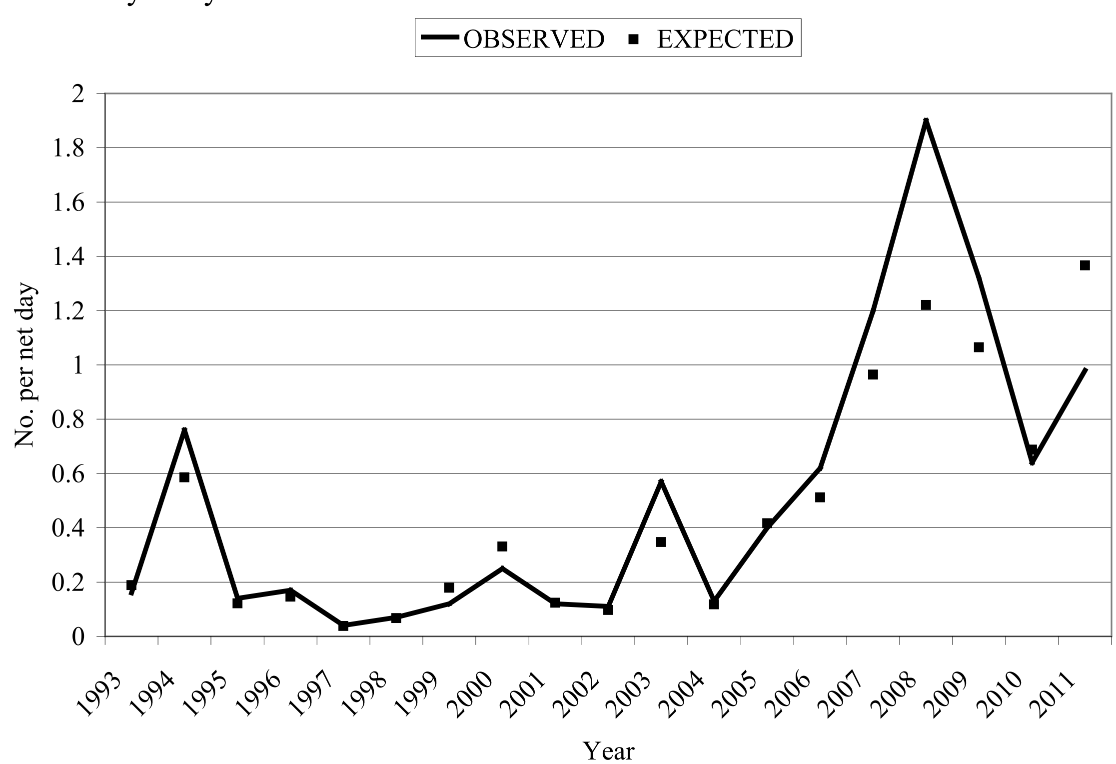


Figure 19. Observed and expected post-recruit channel catfish index from Choptank River catch survey analysis.

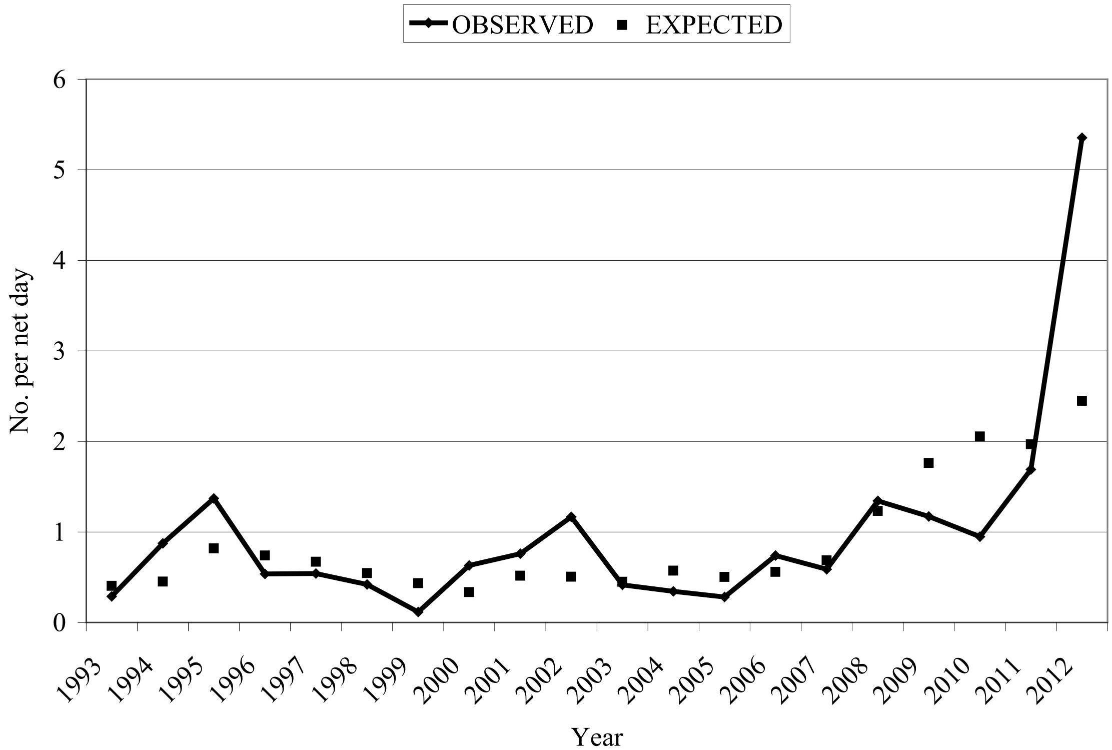


Figure 20. Estimated pre-recruit and post-recruit channel catfish abundance from Choptank River catch survey analysis.

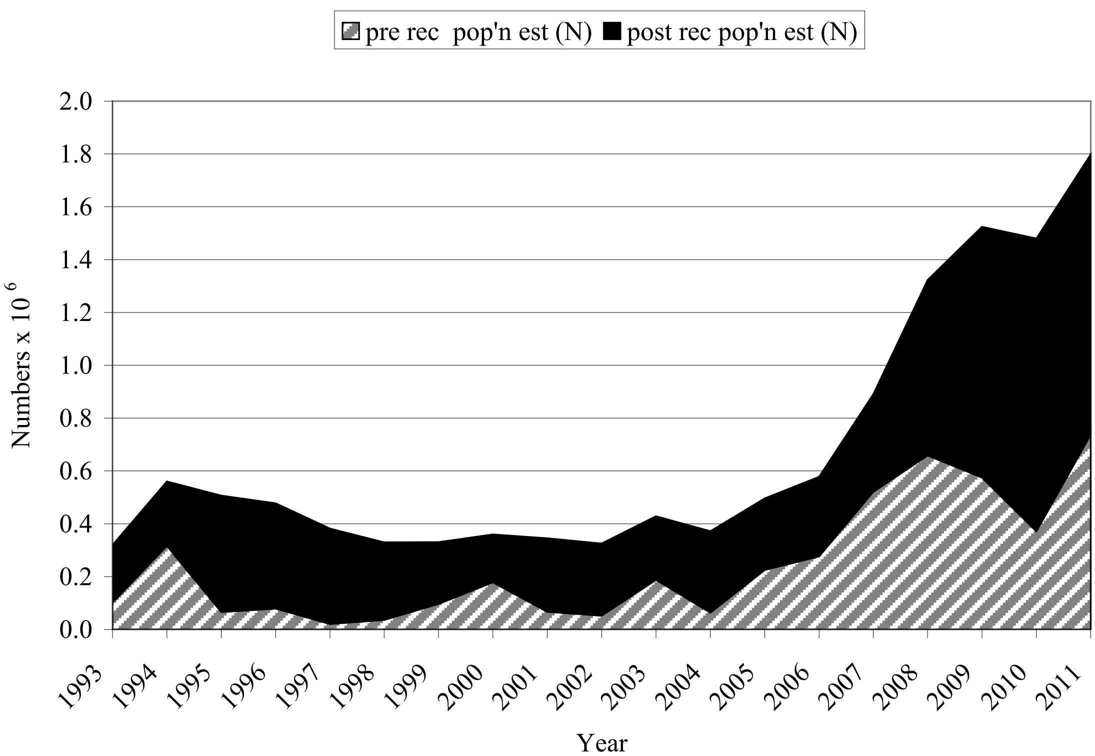


Figure 21. Estimated fishing mortality for Choptank River channel catfish from a catch survey analysis.

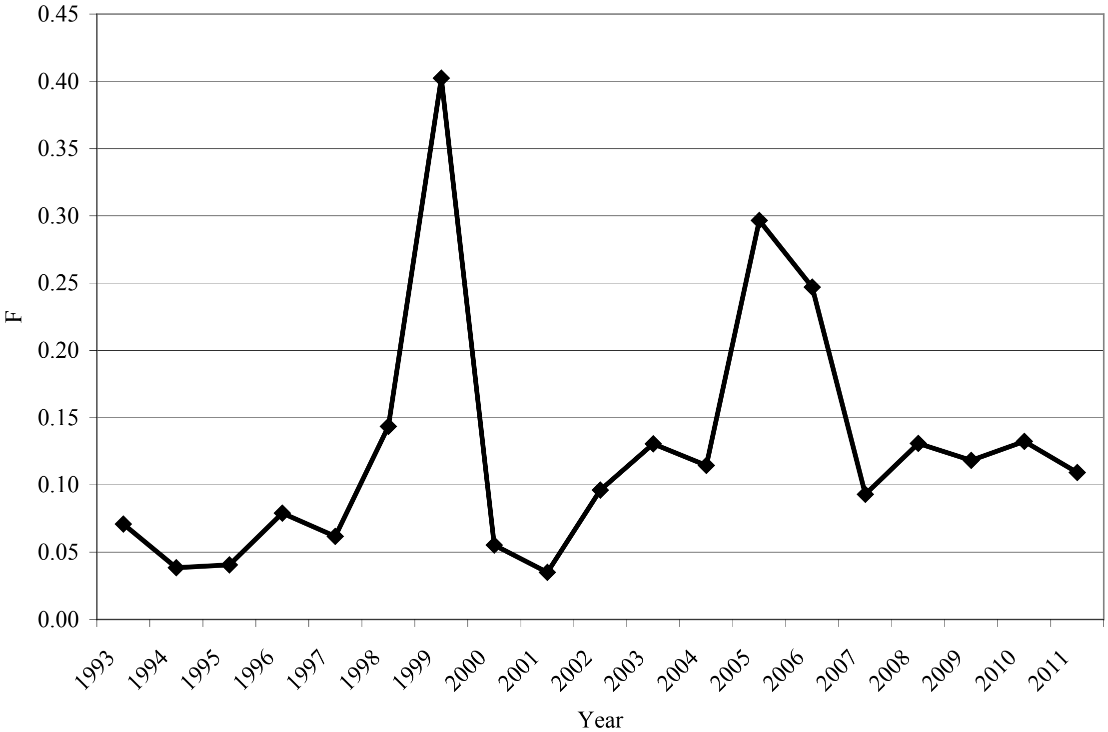


Figure 22. Choptank River channel catfish pre-recruit abundance with 80% confidence intervals from catch survey analysis.

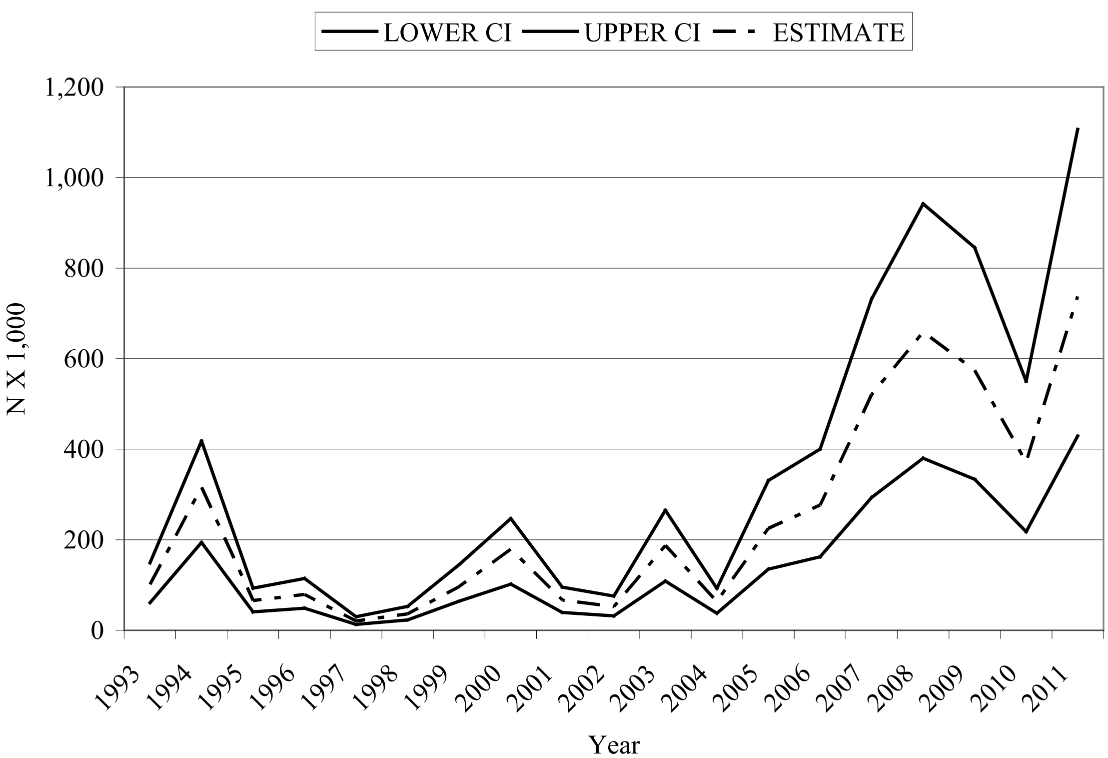


Figure 23. Choptank River channel catfish post-recruit abundance with 80% confidence intervals from catch survey analysis.

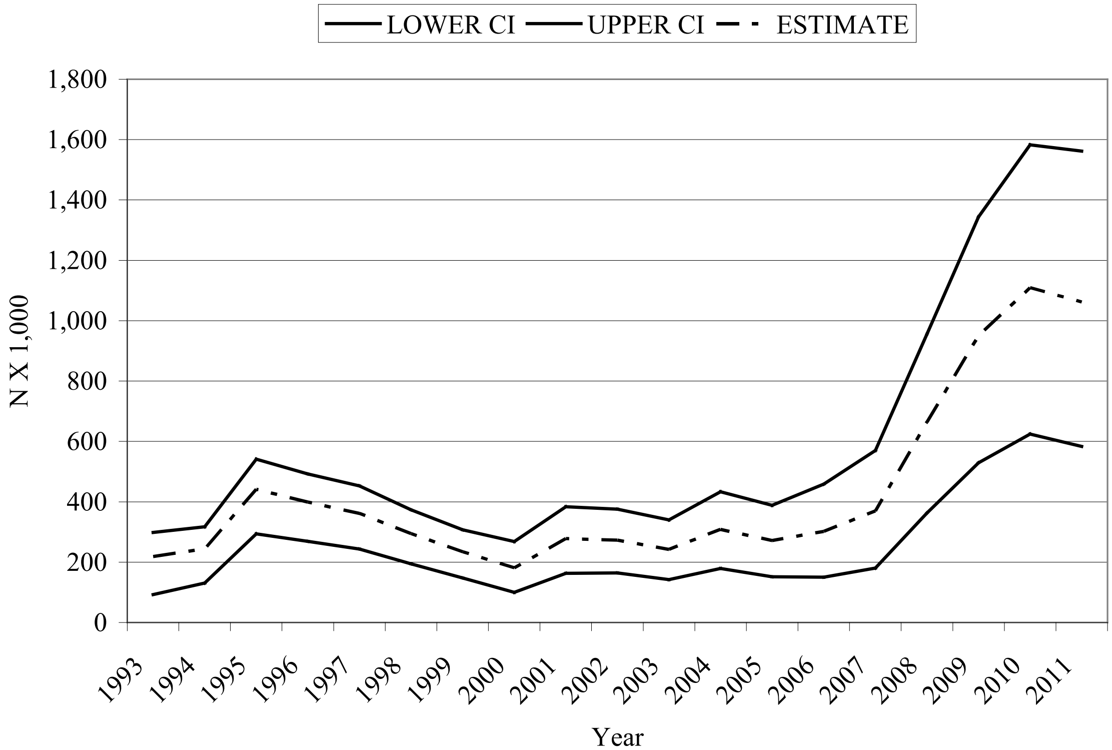


Figure 24. Total channel catfish population abundance estimates and 80% confidence intervals from Choptank River catch survey analysis.

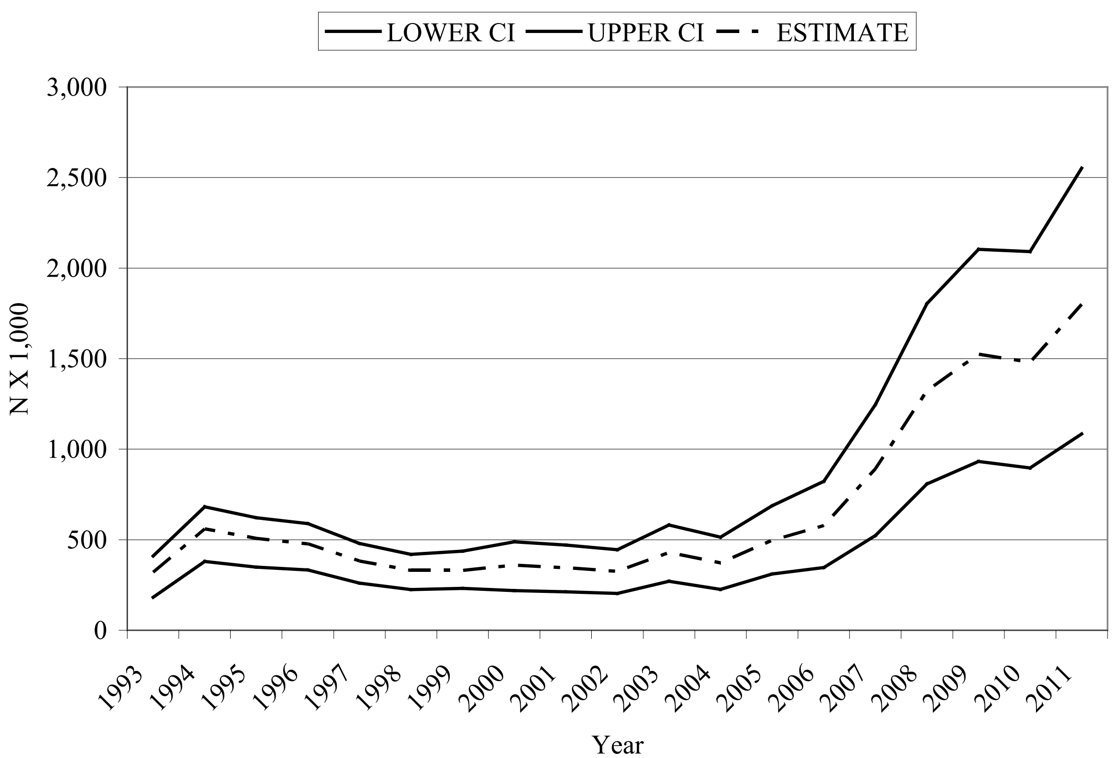


Figure 25. Estimated fishing mortality and 80% confidence intervals for Choptank River channel catfish from catch survey analysis.

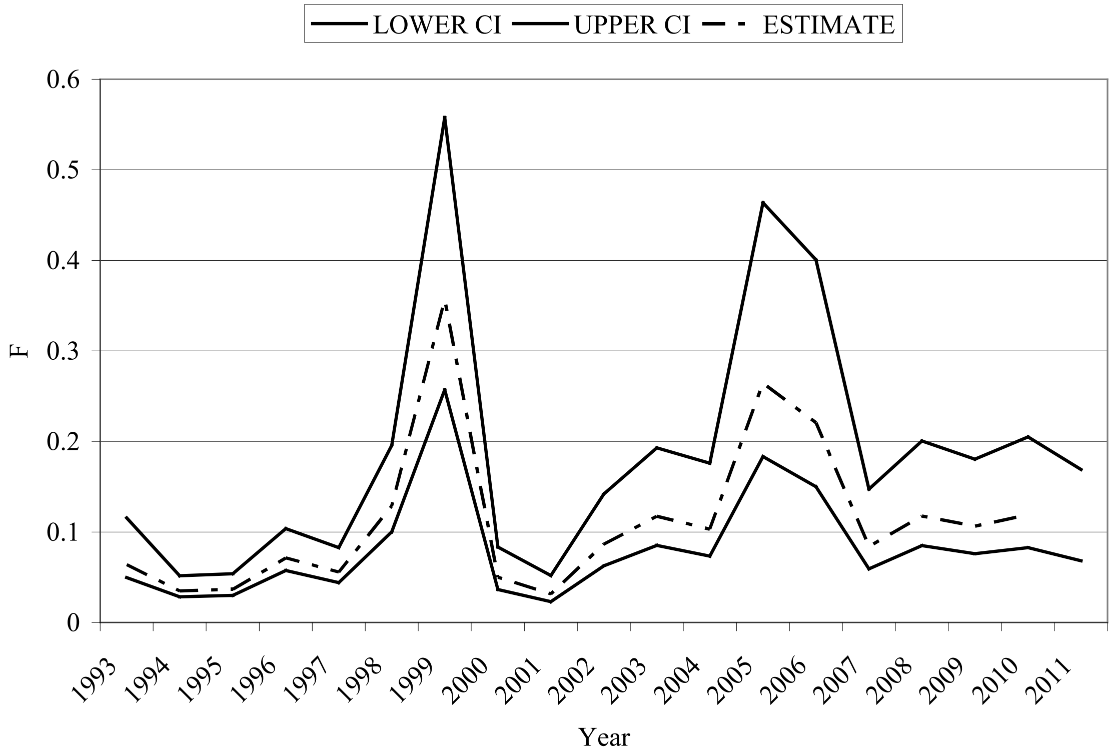


Figure 26. Nanticoke River channel catfish commercial landings, 1987 – 2011.

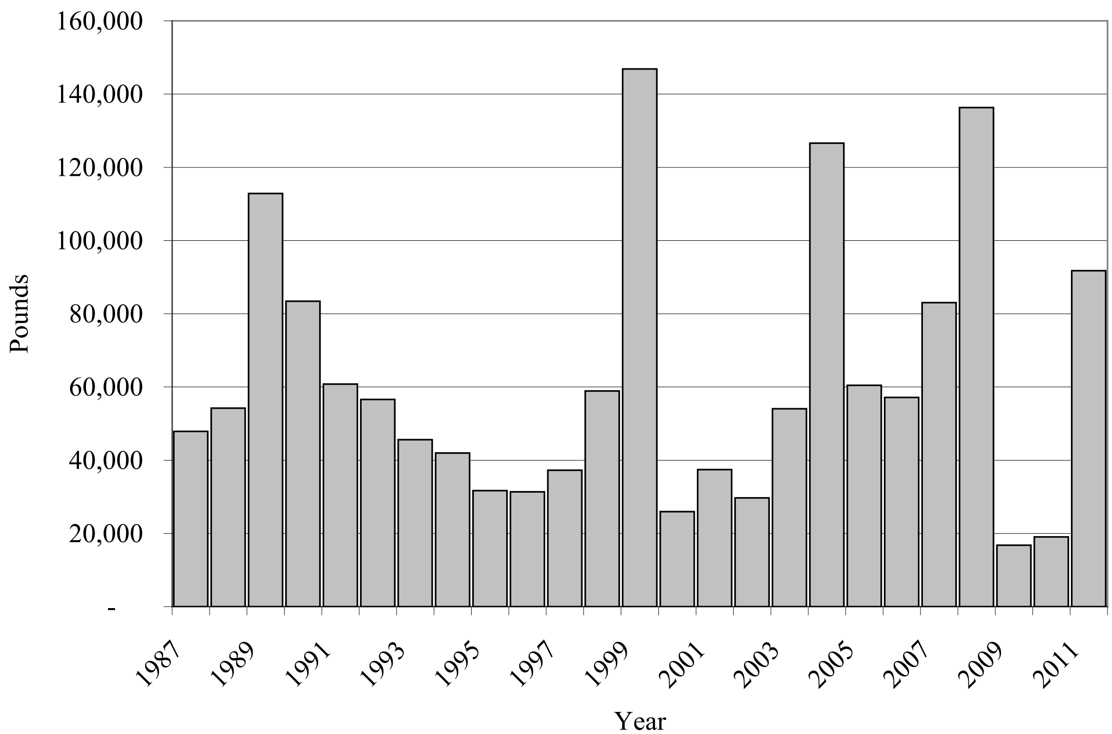


Figure 27. Nanticoke River commercial fish pot channel catfish relative abundance and 75th percentile, 1980 – 2011. Anomalous 2008 value truncated for scale (1,141).

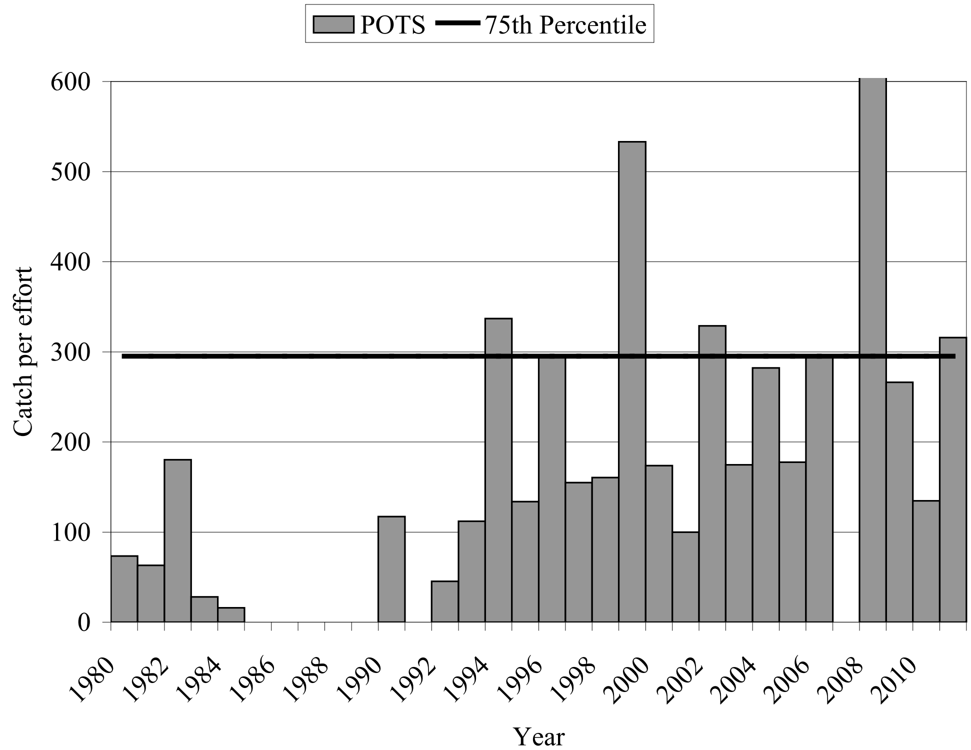


Figure 28. Nanticoke River commercial fish fyke net channel catfish relative abundance and 75th percentile, 1980 – 2011. Anomalous 1999 value truncated for scale (1,056).

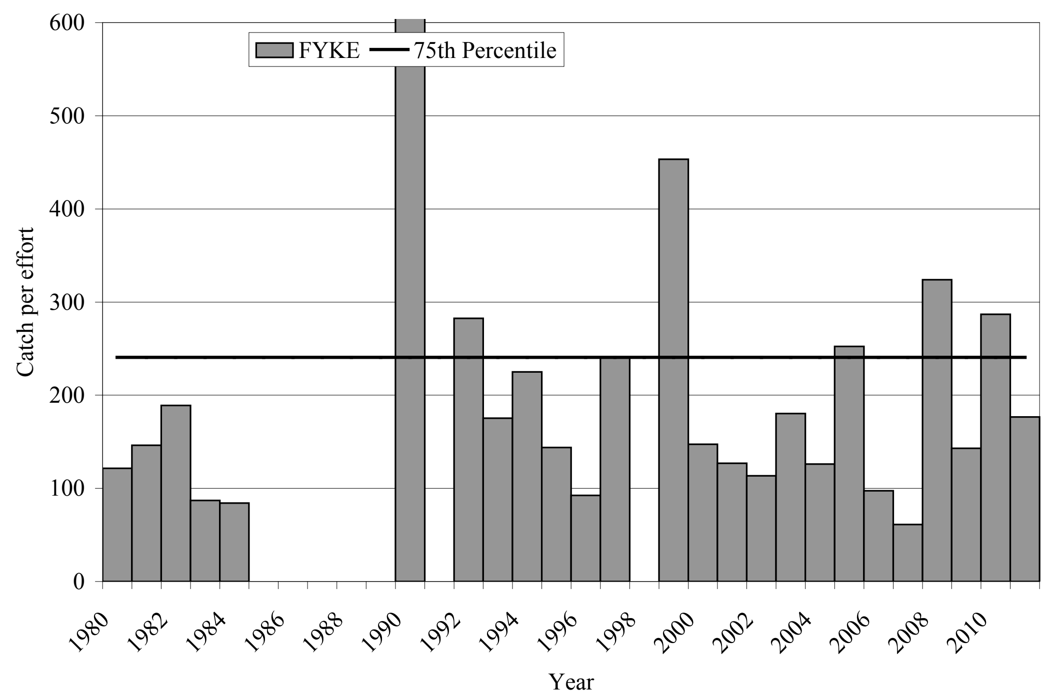


Figure 29. Nanticoke River channel catfish young-of-year from Estuarine Juvenile Finfish Survey, 1975 – 2012.

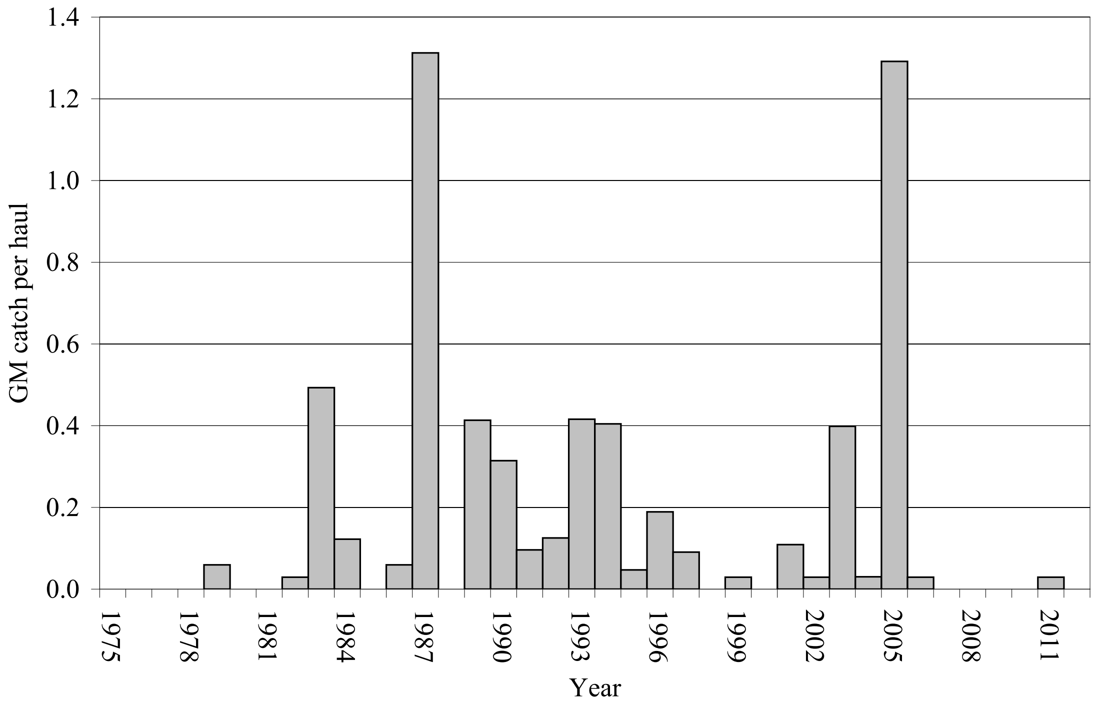


Figure 30. Patuxent River channel catfish commercial landings, 1987 – 2011.

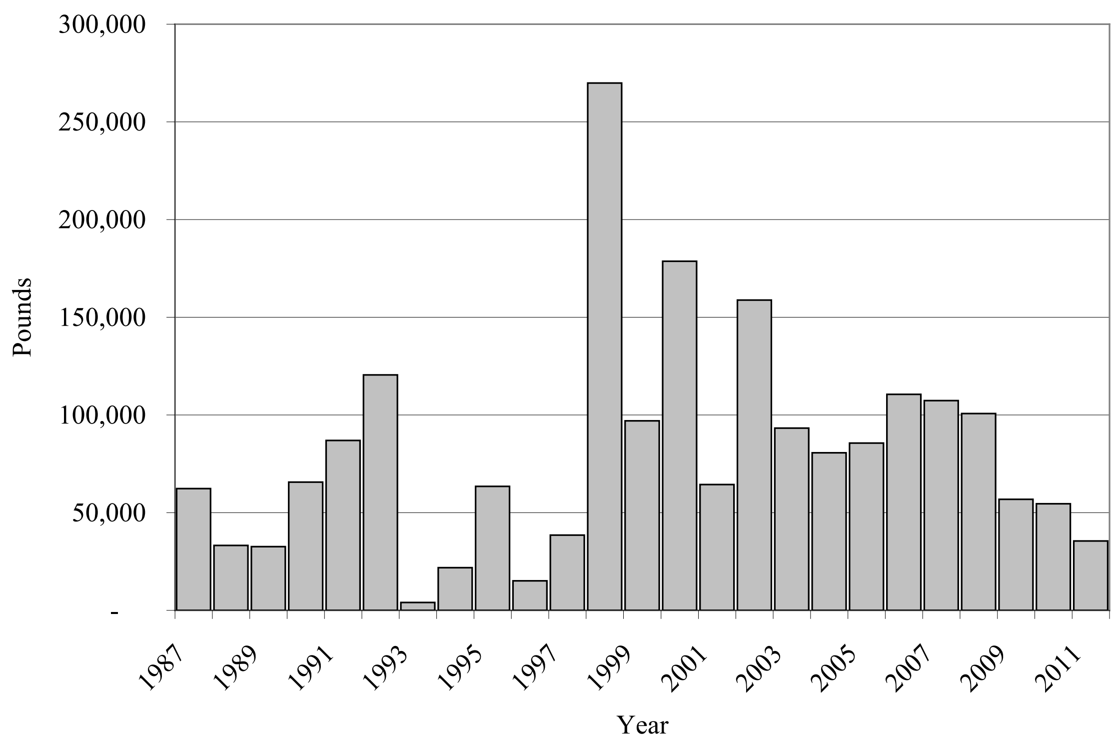


Figure 31. Patuxent River commercial fish pot channel catfish relative abundance and 75th percentile, 1981 – 2011.

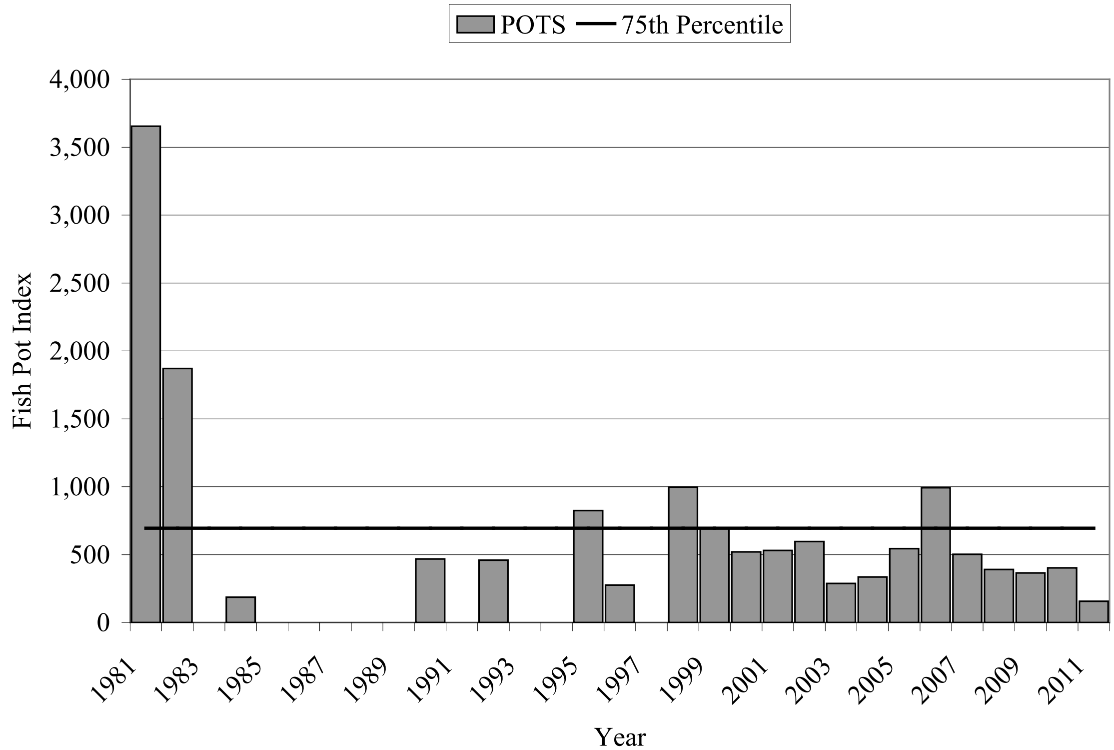


Figure 32. Patuxent River channel catfish young-of-year from Estuarine Juvenile Finfish Survey, 1983 – 2012.

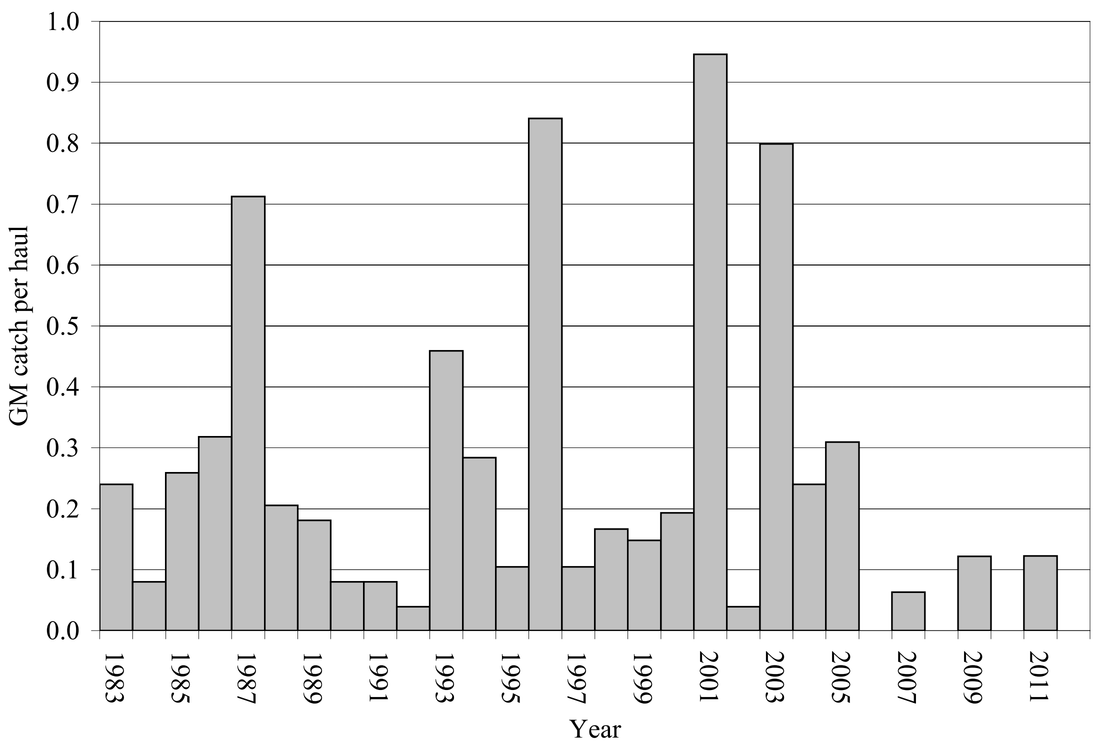


Figure 33. Potomac River channel catfish commercial landings, 1964 – 2012. Data from Potomac River Fishery Commission.

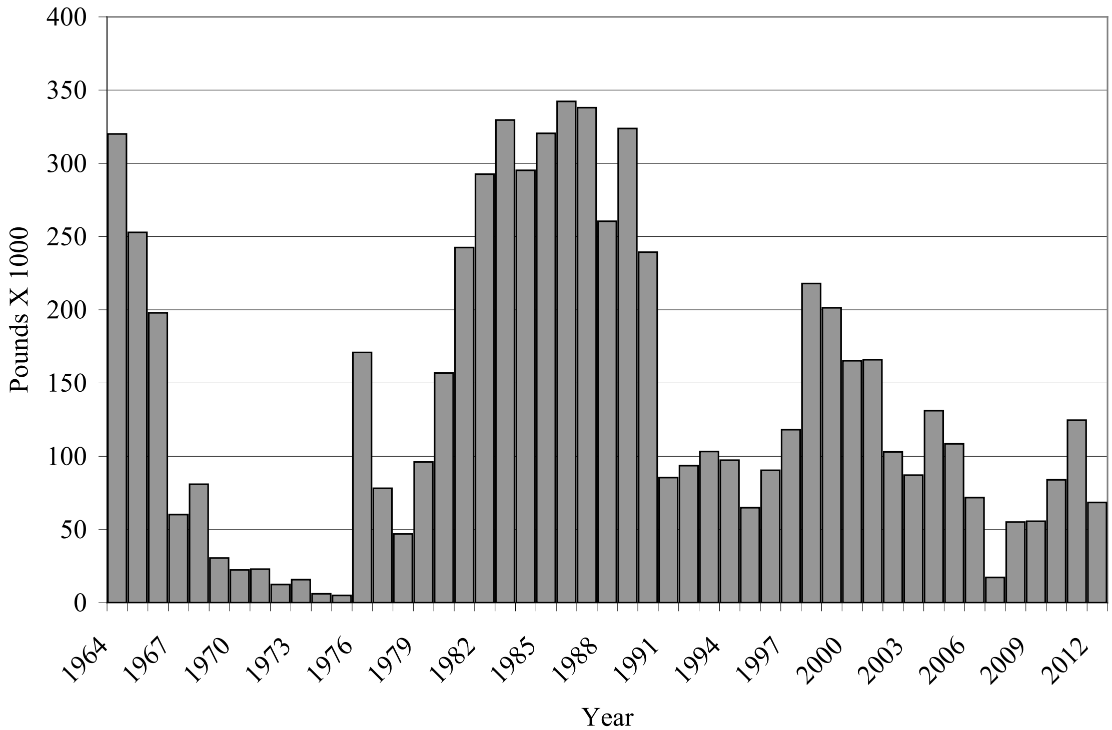


Figure 34. Channel catfish biomass index from Potomac River gill net survey, 1985 – 2011.

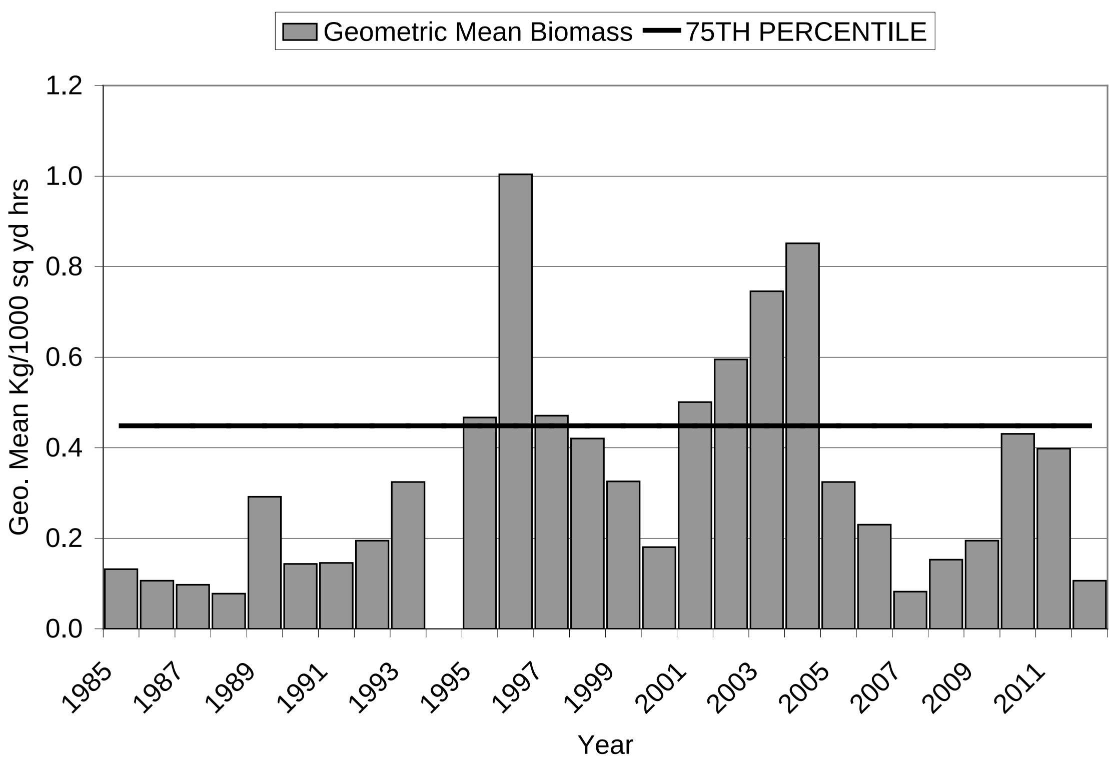
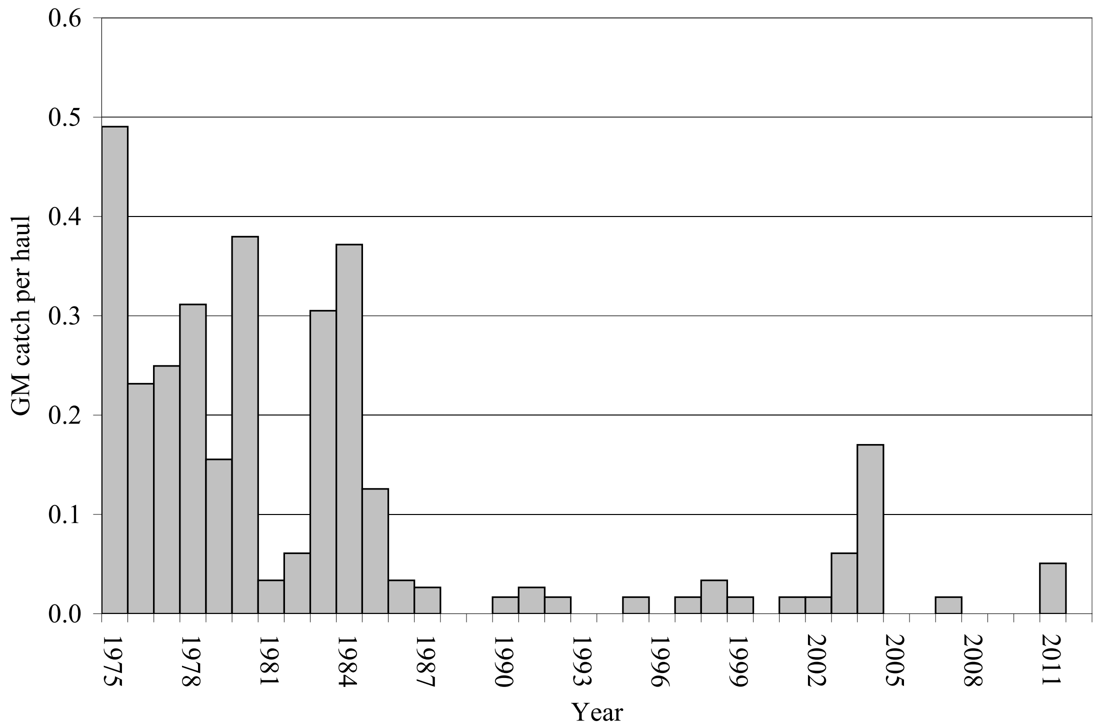


Figure 35. Potomac River channel catfish young-of-year from Estuarine Juvenile Finfish Survey, 1975 – 2012.



PROJECT NO. 2
JOB NO. 1

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

Prepared by
Karen M. Capossela 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) using both fishery dependent and independent sampling gear. On 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. Survey biologists also independently sampled ichthyoplankton. Similar data were collected for adult American shad in the lower Susquehanna River below the Conowingo Dam, and hickory shad abundance was assessed in a tributary to the Susquehanna River (Deer Creek). Summer sampling targeted juvenile alosines in the Chester River.

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), Chesapeake Bay Program's Living Resources Committee and Maryland Sea Grant Ecosystem-Based Fisheries Management Program.

METHODS

Data Collection

Susquehanna River

Adult American shad were angled by MDNR staff from the Conowingo Dam tailrace on the lower Susquehanna River two times per week from 4 April 2012 through 30 May 2012 (Figure 1). Two rods were fished simultaneously; each rod was rigged with two shad darts and lead weight was added when required to achieve proper depth. All American shad were sexed (by expression of gonadal products), total length (mm TL) and fork length (mm FL) were measured and scales were removed below the insertion of the dorsal fin for ageing and spawning history analysis. Fish in good physical condition (including unspent or ripe females) were tagged with Floy tags (color-coded to identify the year tagged) and released. A MDNR hat was given to fishers as a reward for returned tags.

Scales collected from all rivers for American shad, hickory shad and river herring were aged using Cating's method (Cating 1953). 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. Two readers aged all scales separately, and then jointly re-aged any scales that were assigned different ages. If agreement about an age could not be reached, the scales were not included in the age structure analysis. Hickory shad scales from the Susquehanna River were aged by the Restoration and Enhancement Program. Repeat spawning marks were counted on all alosine scales during ageing.

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 tagged in the current year and in previous years.

Recreational data from a non-random roving creel survey were collected from anglers in the Conowingo Dam tailrace during the MDNR American shad hook and line survey. In this survey, stream bank anglers were interviewed about American shad catch 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), North East Creek and Big Elk Creek.

Due to the low number of hickory shad typically observed by this project, MDNR's Susquehanna Restoration and Enhancement Program provided additional hickory shad data (2004-2012) 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 the present.

Nanticoke River

Four commercial pound nets were surveyed for American shad, hickory shad and river herring between 22 February and 30 April 2012 (Figure 2). Cooperating commercial watermen did not use fyke nets in 2012. 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 (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 samples were 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 2 April to 30 April 2012 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 for two minutes at approximately two knots. At the conclusion of the tow, the contents were flushed down into a masonry jar for presence/absence determination.

Chester River

Juvenile American shad, hickory shad and river herring were sampled once every two weeks in the Chester River from 12 July to 20 September 2012 with a 30.5 m x 1.2 m x 6.4 mm mesh haul seine and a 4.9 m semi-balloon otter trawl. The trawl was constructed of treated nylon mesh netting measuring 38 mm stretch-mesh in the body and 33 mm stretch-mesh in the codend, with an untreated 12 mm stretch-mesh knotless mesh liner. The 16' headrope was equipped with floats and the footrope was equipped with a 3.2 mm chain. The net used 0.61 m long by 0.30 m high trawl doors attached to a 6.1 m bridle leading to a 24.4 m towrope. Trawls were towed in the same direction as the tide. Each seine site was located on a beach directly across from a trawl site. The six paired seine and trawl sites were located a minimum of 0.5 miles apart on the Chester River (Figure 4). Sites were selected based on the availability of seinable beaches and historical spawning importance. All collected alosines were counted and measured (FL and TL).

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 26 March to 7 May 2012. All American shad were sexed, measured (TL and FL), 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 angled at the Conowingo Dam in the Susquehanna River. Male-female ratios were also derived for American shad, 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.

Age determination from scales was attempted for all American shad and river herring samples collected from the Susquehanna, Nanticoke and Potomac Rivers. All readable American shad scales were aged. In 2012, we increased the number of alewife and blueback herring measured at each site by 50%. Approximately 30% of measured river herring were aged, and an age-length key was used to covert from number at length to number at age. The percentages of repeat spawners by species and system (sexes combined) were arcsine-transformed (in degrees) before looking for linear trends over time. For all statistics, significance was determined at $\alpha = 0.05$.

All hatchery produced juvenile American shad stocked in Maryland, Delaware and the Susquehanna basin have unique fluorescent OTC marks. Otolith examination by the Pennsylvania Fish and Boat Commission (PFBC) and the DE DFW indicated the percent of non-hatchery fish present from American shad collected in the WFL and 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 and hickory shad in the Susquehanna River were also calculated from the shad logbooks. The roving creel survey was used to calculate a CPAH for American shad.

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. This report follows these historical protocols.

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 and WFL, M is the number of fish tagged minus 3% tag loss, and R is the number of tagged fish recaptured.

Overestimation of abundance by the Petersen statistic (due to low recapture rates) necessitated the additional use of a biomass surplus production model (SPM; Macall 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 bycatch mortality in the Atlantic herring fishery in the previous year (equivalent to catch in a surplus production model). The dynamics of this population are governed by the logistic growth curve. 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). Assumptions include proportional bycatch of American shad in the Atlantic herring fishery and accurate adult American shad turbine mortality estimates. The SPM required starting values for the initial population in 1985 (set as 7,876 by the Petersen statistic for this year; calculation described above), a caring capacity estimate (set as 3,040,551 fish, which was three times the highest Petersen estimate of the time series), and an estimate of the intrinsic rate of growth (set as 0.50). These starting values were adjusted by the model during the fitting procedure.

Mortality

Catch curve analysis was used to estimate total instantaneous mortality (Z) of adult American shad and river herring in the Nanticoke River. Additionally, Z was calculated 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) was obtained from a table of exponential functions and derivatives (Ricker 1975).

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

CPUE for seine and trawl surveys on the Chester River were not calculated for juvenile alosine species due to historically low catches of these species in this river. However, the numbers of American shad, hickory shad and river herring captured by these gear types are reported. 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

Fertilized clupeid eggs and/or larvae were not found in any of the ichthyoplankton tows in 2012 (n = 86; Table 1). Salinity at tow stations ranged from 0.1 to 4.8 ppt. An absence of observed fertilized eggs and/or larvae also occurred from 2006-2008. The available data indicate that clupeid egg and/or larvae presence was highest in 2010 (43%; 2005-2012).

American Shad

Sex, Age and Stock Composition

The male-female ratio of adult American shad captured by hook and line from the Conowingo tailrace was 1:0.72. Of the 191 fish sampled by this gear, 177 were successfully scale-aged (Table 2). Males were present in age groups 3-6 and females were found in age groups 3-8. The 2007 year-class (age 5) and the 2006 year-class (age 6) were the most abundant for males and females, respectively, accounting for 45% of males and 46% of females (Table 2). Thirty-four percent of males and 73% of females were repeat spawners. Past percentages of repeat spawners for both males and females were low, particularly before 1997 (Figure 5), but the arcsine-transformed proportion of these repeat spawners (sexes combined) has significantly increased over the time series (1984-2012; $r^2 = 0.45$, $P < 0.001$; Figure 6). Of the 129 readable adult American shad otoliths collected from the WFL at Conowingo Dam in 2012, 71% were classified as non-hatchery fish (M. Hendricks PA Fish and Boat Comm., pers. comm. 2012).

The male-female ratio for adult American shad captured in the Nanticoke River was 1:0.5. Of the 178 American shad collected from the Nanticoke pound and fyke nets in 2012, 172 were subsequently aged (Table 2). Males were present in age groups 3-7 and females were found in age groups 4-7. The most abundant year-classes by sex were the 2007 year-class (age 5) for both males (40%) and females (46%; Table 2). Forty percent of males and 56% 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, (1988-2012; $r^2 = 0.35$, $P = 0.002$; Figure 7). Fifty-two adult American shad otoliths collected from the Nanticoke River were sent to DE DFW for OTC analysis in 2012. Forty-nine of the 52 scales were readable, and results indicated that 55% were non-hatchery fish (M. Stangl, pers. comm. 2012).

The male-female ratio for adult American shad captured in the Potomac River was 1:1.22. Of the 71 American shad collected, 67 were successfully aged (Table 2). Males were present in age groups 4-7 and females were present in age groups 5-8. The most abundant year-classes by sex were the 2007 year-class (age 5) for males (47%) and the 2006 year class (age 6) for females (34%). Thirty-four percent males and 60 % 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 (2002-2012; $r^2 = 0.054$, $P = 0.49$; Figure 8).

Adult Relative Abundance

Sampling at the Conowingo Dam occurred for 18 days in 2012. A total of 226 adult American shad were encountered by the gear; 217 of these fish were captured by MDNR staff from a boat and the remaining 9 were captured by shore anglers. MDNR staff tagged 190 (84%) of the sampled fish. To remain consistent with historical calculations, only the 217 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.

The EFL operated for 62 days between 2 April and 5 June. The 2012 season was the third longest season of EFL operation and had the highest number of lifts since the EFL became operational in 1991. Of the 22,143 American shad that passed at the EFL, 39% (8,665 fish) passed between 22 April and 11 May. Peak passage was on 24 April; 1,710 American shad were recorded on this date. Twenty-four of the American shad counted at the EFL counting windows were identified as being tagged in 2012; only 2 fish passed that were tagged in 2011 (Table 3).

The Conowingo WFL operated for 37 days between 23 April and 1 June. The 1,486 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 5 May when 135 American shad were collected. The four tagged American shad recaptured by the WFL in 2012 were fish tagged in 2012 (Table 3).

The Petersen statistic estimated 150,743 American shad in the Conowingo Dam tailrace in 2012, and the SPM estimated a population of 111,500 fish. Despite differences in yearly estimates, the overall population trends derived from each method are similar (Figure 9). Specifically, SPM estimates declined from 2001 to 2007 and increased from 2008 to 2012.

Petersen estimates follow a similar pattern if the high levels of uncertainty in 2004 and 2008 (due to low recapture rates) are considered.

Estimates of hook and line GM CPUE vary without trend over the time series (1984-2012; $r^2 = 0.11$, $P = 0.07$). Abundance is particularly variable from 2007-2012 and remains below the high indices observed from 1999 to 2002 (Figure 10). The Conowingo Dam combined lift GM CPUE significantly increased over the time series (1980-2012; $r^2 = 0.33$, $P < 0.001$); the GM CPUE decreased steadily from 2002 to 2008, increased from 2009 through 2011, and decreased in 2012 (Figure 11).

Fifty-eight interviews were conducted over five days during the creel survey at the Conowingo Dam Tailrace. The CPAH in 2012 was the third lowest since the start of the survey in 2001 (Table 4), and CPAH has decreased over the time series (2001-2012; $r^2 = 0.46$, $P = 0.02$). Five anglers returned logbooks in 2012; four logbooks contained information from fishing trips in the lower Susquehanna River. Although American shad CPAH calculated from shad logbook data decreased significantly over the time series (1999-2012; $r^2 = 0.35$, $P = 0.03$), CPAH has steadily increased since 2009 (Table 5).

The 2012 Nanticoke River pound net GM CPUE was the highest it has been since the start of the survey in 1988. The GM CPUE significantly increased over the time series (1988-2012; $r^2 = 0.24$, $P = 0.07$, Figure 12). The Potomac River CPUE increased significantly over the time series (1996-2012; $r^2 = 0.23$, $P = 0.053$), although CPUE in each of the past four years has been lower than the CPUE in 2007 and 2008 (Figure 13).

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in Z = 0.61 (A = 45.7%). The Nanticoke

River mortality estimate was Z = 0.82 (A = 56.0%). Estimated American shad mortalities (in numbers) from Maryland waters are presented in Table 6.

Juvenile Abundance

No juvenile American shad were captured in seines or trawls in the Chester River in 2012 (Table 7). Data provided by the EJFS indicated that juvenile American shad indices decreased in 2012 baywide, in the upper Chesapeake Bay, and in the Nanticoke River (Figures 14-16). In contrast, the Potomac River index increased in 2012 and remains above the time series mean (Figure 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 = 22) was not large enough to draw meaningful conclusions about sex and age composition. However, 1,014 hickory shad were sampled by the brood stock collection survey in Deer Creek. The male-female ratio was 2.06:1. Of the total fish captured by this survey, 200 were successfully aged. Males were present in age groups 3-6 and females were found in age groups 3-7. The most abundant year-classes by sex were the 2008 year-class (age 4) for both males (42.6%) and females (33.8%; Table 8). Hickory shad sampled from 2004 to 2012 ranged from 2 to 9 years of age, with ages 3 through 8 present every year except for 2012 (Table 9). The 2012 sampling year was the only year of the times series where only ages 3 to 7 were present. The arcsine-transformed proportion of these repeat spawners (sexes combined) has not changed significantly over the time series (2004-2012; $r^2 = 0.028$, $P = 0.67$; Figure 18). However, the total percent of repeat spawners in 2012 (64.0%) is the lowest of the time series (2004-2012; Table 10).

Relative Abundance

Shad logbook data indicated that hickory shad CPAH did not vary significantly over the time series (1998-2012; $r^2 = 0.13$, $P = 0.18$); however, hickory shad CPAH decreased in 2012 (Table 11). On the Nanticoke River, only 22 fish were captured by pound nets.

Mortality

Total instantaneous mortality in the Susquehanna River (Deer Creek) was estimated as Z = 0.68. This estimate is less than the 2010 Z estimate (Z = 0.74) but similar to the 2011 Z estimate (Z = 0.67). Annual mortality in 2012 was estimated as A = 49.3%.

Juvenile Abundance

During the 2012 sampling in the Chester River, no juvenile hickory shad were collected in the seine or the trawl (Table 7). The last time this survey encountered no hickory shad in either gear was 2008 (2007-2012). The 2011 catch remains the highest for both seines (n = 6) and trawls (n = 9) from 2007-2012.

Alewife and Blueback Herring

Sex, Age and Stock Composition

The 2012 male-female ratio for Nanticoke River alewife herring was 1:1.7. Of the 533 alewives sampled, 166 were subsequently aged. Age groups 3-7 were present and the 2007 year-class (age 5, sexes combined) was the most abundant, accounting for 33.3% of the total catch. Females were most abundant at age 5 and males at age 4 (Table 12). The 2012 male-female ratio for Nanticoke River blueback herring was 1:0.78. Of the 403 blueback herring sampled, 136 were subsequently aged. Blueback herring were present from ages 2-7 and the 2008 year-class (age 4, sexes combined) was the most abundant, accounting for 42.9% of the sample (Table 12).

For the Nanticoke River, 40.8% of alewife herring and 23.7% of blueback herring were repeat spawners (sexes combined; Table 12). There was no trend in the arcsine-transformed proportion of alewife herring repeat spawners over the time series (1989-2012; $r^2 < 0.007$ P = 0.70); however, blueback herring exhibited a decreasing trend over the same time series (1989-2012; $r^2 = 0.61$, $P < 0.001$; Figure 19). For male alewife and blueback herring, 75.3% and 77.4% were first time spawners, respectively; 49.7% of female alewife and 74.9% of female blueback herring were first time spawners.

Mean length-at-age was calculated for aged fish only. Mean length-at-age for female alewife herring from the Nanticoke River is greater than the corresponding mean length-at-age for males (Table 13). Female blueback herring mean length-at-age is also greater than the corresponding male mean length-at-age (Table 14). Age structure appears to be truncating, especially for blueback herring, and observed declines in mean length-at-age generally occur toward the end of the time series (Tables 13 and 14). The lengths of female alewife herring at ages 4 to 8 and male alewife herring at ages 4 to 7 have decreased significantly since 1989 (Table 15). The lengths of female blueback herring at ages 3 to 7 and male blueback herring at ages 3 to 7 have significantly decreased since 1989 (Table 15).

Adult Relative Abundance

Fyke nets were not fished in the Nanticoke River in 2012 and no data are available for this year. Our protocol has been to only calculate alewife and blueback herring CPUE from fyke net data because pound nets were not consistently set in ideal habitat for river herring. As of

2011, the GM CPUE for Nanticoke River alewife herring captured in fyke nets varied without trend over the time series (1990-2011; $r^2 = 0.14$, $P = 0.09$; Figure 20); in contrast, the GM CPUE for blueback herring decreased over the time series (1989-2011; $r^2 = 0.64$, $P < 0.001$; Figure 20). As of 30 May 2012, 290 pounds of river herring were reported landed, despite the closure of the fishery (there was no differentiation between species in the commercial river herring fishery). Total commercial landings for river herring in Maryland waters were at multi-decadenal lows before the closure of the fishery (Figure 21).

Mortality

Total instantaneous mortality for Nanticoke River alewife herring (sexes combined) was estimated as Z = 1.10 (A = 66.7%). Total instantaneous mortality for Nanticoke River blueback herring (sexes combined) was Z = 1.43 (A = 76.1%). No estimates of M and F were calculated for 2012 because the fishery for river herring closed on 26 December 2011.

Juvenile Abundance

Juvenile seining in the Chester River produced no juvenile alewife or blueback herring. (Table 7). Data provided by the EJFS indicated that the GM CPUE for juvenile alewife and blueback herring in the Nanticoke River and upper Bay decreased in 2012 (Figures 22-23). This contrasts with the increase observed in blueback herring indices in both the Nanticoke River and upper Bay in 2011.

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 does appear to be increasing in the lower Susquehanna, particularly since 2007 (SPM estimate). This follows a period (2002 to 2007) when calculated indices of abundance generally decreased (including the hook and line CPUE, logbook CPAH and creel CPAH). Despite this trend in abundance, the 2012 hook and line CPUE was the lowest it has been since 1986 and there is no significant trend in CPUE over time. 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. The Potomac River CPUE is increasing (1996-2012); however, the CPUE in the Nanticoke River shows no significant trend (1988-2011), which suggests uneven area-wide recovery.

The Petersen estimate and the SPM are both useful techniques for providing estimates of American shad abundance at the Conowingo Dam. The SPM likely underestimates American shad abundance. For example, the estimated Conowingo Dam lift efficiency (defined as annual number of American shad lifted at Conowingo Dam divided by population estimate) was as high as 98.7% in 2004, and it is unlikely that the dam passed nearly 100% of the fish in the Conowingo Dam tailrace. The Petersen statistic likely overestimates the population, especially in years of low recapture of tagged fish. However, the trends (rather than the actual numbers) produced by the estimate/model should be emphasized when assessing the population at the Conowingo Dam in the Susquehanna River.

Scales are the only validated ageing structures for determining the age of American shad (Judy 1960, McBride et al. 2005). However, 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). We will remain consistent with historical ageing methods until alternative ageing structures are investigated.

The percent of repeat spawning American shad below the Conowingo Dam has increased over time, particularly since the truck and transport to locations above Safe Harbor Dam ceased in 1997 when the EFL was automated. The percent of repeat spawners was generally less than 10% in the early 1980s in the Conowingo Dam tailrace (Weinrich et al. 1982). In contrast, 50% of aged American shad at the Conowingo Dam were repeat spawners in 2012, and, on average, 27% of aged fish were repeat spawners over the past five 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. The same trend occurs in the Potomac River, where there is no history of truck and transport and dams: the average percent of repeat spawners was 17% in the 1950s (Walburg and Sykes 1957), and is currently 48%. 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, and/or reductions in natural mortality.

The 2012 calculated Z for American shad in the Conowingo Dam tailrace (Z=0.61) is below the Z_{30} established for rivers in neighboring states (range=0.62−0.76), with the exception of the Hudson River (Z_{30}=0.54; ASMFC 2007). The 2012 calculated Z for American shad in the Nanticoke River (Z=0.82) is greater than the Z_{30} established for all rivers in neighboring states (range=0.54−0.76; ASMFC 2007). The Z_{30} established for northern rivers (North Carolina to Maine; Z_{30}=1.93) is greater than the 2012 Z for the Conowingo Dam tailrace and the Nanticoke River (ASMFC 2007). These calculated mortality estimates may be maximum rates because repeat spawning marks are assessed during the spawning season after fish have returned to freshwater but before developing a new spawning mark.

No juvenile American shad have been captured in the Chester River trawls or seines since 2005. Baywide juvenile American shad indices decreased in 2012, as did juvenile indices in the upper Chesapeake Bay and the Nanticoke River. Only the juvenile index in the Potomac River increased in 2012. Other juvenile surveys in the Chesapeake Bay tributaries (from Maryland to Virginia [Virginia Institute of Marine Science, pers. comm.]) observed low numbers of a variety of juvenile anadromous species in 2012, suggesting poor recruitment. This low reproductive success is likely due to natural variability in weather conditions. 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 recently introduced 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. No hickory shad were observed in the EFL in 2012. 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 (1998-2012). 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.

Hickory shad age structure has remained relatively consistent, with a wide range of ages and a high percentage of older fish. 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 has remained relatively consistent over the 2004-2012 time series, with the percent of repeat spawners ranging between 64-89%.

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 to 2009 (Richardson 2009). Maryland stocking and sampling of American shad in the Nanticoke River ended in 2009.

Estimates of Z are attributable solely 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. Sampling would need to be initiated prior to 1 June in order to accurately assess hickory shad juvenile production.

Alewife and Blueback Herring

Alewife and blueback herring numbers have drastically declined for the same reasons discussed previously for American and hickory shad. According to the most recent stock assessment, the coastwide meta-complex of river herring stocks on the U.S. 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). The depleted status indicates that there was evidence for declines in abundance due to a variety of factors, but the relative importance of these factors in stock reduction could not be determined (ASMFC 2012). River herring were also deemed depleted in the Nanticoke River (ASMFC 2012). This assessment corresponds with the low commercial river herring landings observed in previous years in both the Nanticoke River and the entire state of Maryland. Specifically, the truncating age structure for river herring may be a sign of excessive mortality rates.

Juvenile alewife and blueback production in the Nanticoke River and upper Bay has generally been erratic, with frequent declines in abundance to very low levels. In 2012, alewife and blueback herring CPUE decreased for juveniles in both of these regions. Juvenile alewife and blueback herring indices decreased in all regions in 2012, according to Maryland's EFJS survey; no river herring were encountered in the Patuxent River (Project 2, Job 3, Task 3).

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 as legally caught in waters not under Maryland jurisdiction. The expectation is that the new 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.

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Table 1. Percentage of sites with clupeid eggs or larvae and number of sites sampled in the Nanticoke River (2005-2012).

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

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 in 2012.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	4	0	1	0	5	0
4	31	5	1	0	32	5
5	46	15	14	5	60	20
6	22	15	34	25	56	40
7	0	0	23	23	23	23
8	0	0	1	1	1	1
Totals	103	35	74	54	177	89
Percent Repeats	34.0%		73.0%		50.3%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	5	0	0	0	5	0
4	38	3	4	0	42	3
5	44	22	26	10	70	32
6	23	18	21	16	44	34
7	1	1	6	6	7	7
8	0	0	0	0	0	0
Totals	111	44	57	32	170	76
Percent Repeats	39.6%		56.1%		45.2%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	0	0	0	0	0	0
4	4	0	0	0	4	0
5	14	4	11	4	25	8
6	9	3	12	7	21	10
7	3	3	9	7	12	10
8	0	0	3	3	3	3
Totals	30	10	35	21	65	31
Percent Repeats	33.3%		60.0%		47.7%	

Table 3. Number of recaptured American shad in 2012 at the Conowingo Dam East and West Fish Lifts by tag color and year.

East Lift		
Tag Color	Year Tagged	Number Recaptured
Orange	2012	24
Green	2011	2
West Lift		
Tag Color	Year Tagged	Number Recaptured
Orange	2012	4

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, 2001-2012. Due to sampling limitations, no data were available for 2011.

Year	Number of Interviews	Hours Fished for American Shad	American Shad Catch	American Shad CPAH
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49
2006	78	227.3	305	1.34
2007	30	107.5	128	1.19
2008	16	32.5	24	0.74
2009	40	85.0	120	1.41
2010	36	64.0	114	1.78
2011				
2012	58	189.0	146	0.77

Table 5. Catch (numbers), effort (hours fished) and catch-per-angler-hour (CPAH) from spring logbooks for American shad, 1999-2012.

Year	Number of Returned Logbooks	Hours Fished for American Shad	American Shad Catch	American Shad CPAH
1999	7	160.5	463	2.88
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	4	177.5	491	2.77

Table 6. Estimated adult American shad mortalities (in numbers) in Maryland waters (1997-2012). Lower Susquehanna River (below the Conowingo Dam) abundance estimates are derived from the surplus production model (SPM). 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	159,878
1998	0	16,152	1,300	4,200	Unknown	18,526	39,908	161,430
1999	0	43,455	3,136	4,200	Unknown	13,623	64,414	193,920
2000	0	60,452	3,102	4,200	Unknown	4,834	72,588	207,028
2001	0	130,876	2,607	4,200	Unknown	2,347	140,030	205,924
2002	0	40,142	2,837	4,200	Unknown	1,882	49,061	134,373
2003	0	50,224	2,160	4,200	Unknown	621	57,205	129,196
2004	0	29,911	1,218	4,200	Unknown	220	35,549	111,931
2005	0	42,873	1,412	4,200	Unknown	0	48,485	109,654
2006	0	41,201	1,696	4,200	Unknown	0	95,582	94,790
2007	0	14,120	1,737	4,200	Unknown	0	20,057	77,166
2008	0	7,075	1,477	4,200	Unknown	0	12,752	80,208
2009	0	15,490	1,566	4,200	Unknown	0	21,256	90,989
2010	0	21,793	1,219	4,200	Unknown	0	27,212	98,743
2011	0	5,159	1,038	4,200	Unknown	0	10,397	103,500
2012	0	8,714	710	4,200	Unknown	0	13,952	111,550

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 juvenile alosines captured by species in seines and trawls on the Chester River, 2007-2012.

Seine

	2007	2008	2009	2010	2011	2012
American Shad	0	0	0	0	0	0
Hickory Shad	0	0	0	5	9	0
Alewife	1	1	18	2	19	0
Blueback	334	36	19	28	1,214	0

Trawl

	2007	2008	2009	2010	2011	2012
American Shad	0	0	0	0	0	0
Hickory Shad	3	0	1	0	6	0
Alewife	33	12	27	11	6	0
Blueback	1	0	5	0	0	0

Table 8. 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 2012.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	40	0	13	0	53	0
4	55	42	24	18	79	60
5	28	28	21	21	49	49
6	6	6	9	9	15	15
7	0	0	4	4	4	4
8	0	0	2	2	0	0
Totals	129	76	87	66	200	128
Percent Repeats	58.9%		73.2%		64.0%	

Table 9. Percent of hickory shad by age and number sampled from the brood stock collection survey in Deer Creek (Susquehanna River tributary) by year, 2004-2012.

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	2.78	0.93	
2012	200		26.5	39.5	24.5	7.5	2.0		

Table 10. Percent repeat spawning hickory shad (sexes combined) by year from the brood stock collection survey in Deer Creek (Susquehanna River tributary), 2004-2012.

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

Table 11. Catch (numbers), effort (hours fished) and catch-per-angler-hour (CPAH) from spring logbooks for hickory shad, 1998-2012.

Year	Number of Returned Logbooks	Hours Fished for Hickory Shad	Hickory Shad Catch	Hickory Shad CPAH
1998	19	600.0	4,980	8.30
1999	15	817.0	5,115	6.26
2000	14	655.0	3,171	14.8
2001	13	533.0	2,515	4.72
2002	11	476.0	2,433	5.11
2003	14	635.0	3,143	4.95
2004	18	750.0	3,225	4.30
2005	19	474.0	2,094	4.42
2006	20	766.0	4,902	6.40
2007	17	401.0	3,357	8.37
2008	22	942.0	5,465	5.80
2009	15	561.0	2,022	3.60
2010	16	552.0	1,956	3.54
2011	9	224.3	1,802	8.03
2012	5	190.0	866	4.56

Table 12. Catch-at-age and repeat spawners by sex and age for adult alewife and blueback herring sampled from the Nanticoke River in 2012. Approximately 30% of measured river herring were aged, and an age-length key was used to covert from number at length to number at age.

Alewife Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	33	0	36	0	70	0
4	76	4	85	0	160	4
5	65	24	111	74	175	94
6	20	20	74	67	94	87
7	0	0	26	26	26	26
8	0	0	0	0	0	0
9	0	0	0	0	0	0
Totals	194	47	332	167	526	214
Percent Repeats	24.3%		50.4%		40.8%	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	4	0	0	0	4	0
3	44	0	24	0	68	0
4	101	7	71	9	172	16
5	63	30	64	28	127	58
6	14	14	13	4	27	18
7	0	0	3	3	3	3
8	0	0	0	0	0	0
Totals	226	51	175	44	401	95
Percent Repeats	22.6%		25.1%		23.7%	

Table 13. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2012.

Males

Year	Age								
	2	3	4	5	6	7	8	9	10
1989		230	236	243	256	261			
1990		221	231	244	250	263	264		
1991		224	234	240	251	260	243		
1992		216	228	238	247	254			
1993		208	225	239	246	248	246		
1994		207	219	231	239	246			
1995		214	226	238	246	251	244		
1996	212	219	228	238	242	263			
1997		213	228	233	240		252		
1998		217	225	238	243	254			
1999		211	222	233	238	244			
2000		220	228	238	258				
2001		225	234	240	247				
2002		225	233	241	244	248			
2003		228	239	245	251				
2004		228	242	251	250				
2005		214	226	236	252	252			
2006		219	223	235	242				
2007		219	227	235	248				
2008		216	217	229	235	278			
2009		221	224	231	241				
2010		221	224	232	248				
2011		215	229	233	244				
2012		215	217	230	241				

Females

Year	Age								
	2	3	4	5	6	7	8	9	10
1989		229	244	253	267	277	286		
1990		225	238	253	261	274	283	286	
1991		227	243	251	263	270	273	286	
1992		223	240	248	256	265	276	279	
1993		225	233	247	256	265	277		
1994		219	228	243	254	258	270		
1995		221	235	252	263	268	274		280
1996		219	231	250	257	267	268	260	
1997		228	234	242	253	267	271		
1998		224	235	245	255	264		277	
1999		220	229	242	250	260	272		
2000		237	237	250	257	270			
2001		239	243	249	256	266	270		
2002		226	238	248	255	260	263		
2003		240	239	250	260	263			
2004		235	249	259	262	270			
2005			233	243	257	267	272		
2006		228	240	247	256	264	277		
2007		220	236	247	256	265	269		
2008		217	231	238	248	256	276	279	
2009		215	231	242	252	261			
2010			234	245	257	251			
2011		226	236	247	256	268	275		
2012		218	233	249	260	263			

Table 14. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2012.

Year	Age								
	2	3	4	5	6	7	8	9	10
1989		218	227	234	245	259	262	279	
1990		218	232	239	249	258	263	270	
1991		217	229	237	247	258	260	273	
1992		212	224	235	245	251	260	256	
1993		205	224	237	247	256	262	261	
1994		213	223	238	250	256			
1995		220	226	233	247	256			
1996	205	219	230	240	244	270	261		
1997		212	225	238	241	247	257		
1998		212	225	233	245	253			
1999		200	222	232	239	251			
2000		219	225	235	246	249			
2001		218	231	235	250				
2002		217	229	234	243				
2003	215	230	240	238					
2004	216	231	234	245	250				
2005		222	226	238					
2006		209	224	235	236	270			
2007		207	221	227	266				
2008		206	216	220					
2009		214	219	231					
2010		219	227		228				
2011		206	220	226	234				
2012	212	207	217	229	229				

Females

Year	Age								
	2	3	4	5	6	7	8	9	10
1989		227	236	244	257	271	279	297	
1990			241	252	262	271	281	286	291
1991		228	238	251	260	264	273	285	
1992		230	230	250	260	264	272	281	
1993		220	236	246	259	269	277	290	296
1994		215	226	245	260	272	282	277	
1995		228	235	248	260	264	270		
1996		218	238	249	257	275	278		
1997		226	242	247	254	268	276	290	
1998			233	246	257	265	281		
1999		219	236	244	253	273			
2000		227	231	243	260	269	275		
2001		219	242	248	260	273			
2002		220	235	246	257	260			
2003	224	235	248	252	264	283			
2004		236	245	254	262	262			
2005		241	236	248	264				
2006		204	235	242	246				
2007		217	221	246	247	266			
2008		213	227	234	252	251	261		
2009		227	232	242	260	278			
2010			243	238	247				
2011		201	240	238	251	262			
2012		213	230	244	249	256			

Table 15. Regression statistics for length by age and sex over time for alewife and blueback herring (1989-2012). Only ages with consistent representation over time were considered. Bolded values indicate significant changes in length-at-age over time.

Alewife	Males				Females			
Age	N	Slope	r^2	*P*	N	Slope	r^2	*P*
3	391	-0.115	0.00432	0.194	122	-0.21	0.0199	0.121
4	1389	-0.386	0.0573	< **0.001**	1276	-0.313	0.0429	< **0.001**
5	1137	-0.39	0.0562	< **0.001**	1711	-0.27	0.0341	< **0.001**
6	473	-0.393	0.0608	< **0.001**	1092	-0.261	0.034	< **0.001**
7	70	-0.937	0.178	<**0.001**	353	-0.377	0.0772	< **0.001**
8					96	-0.518	0.0735	**0.008**

Blueback	Males				Females			
Age	N	Slope	r^2	*P*	N	Slope	r^2	*P*
3	216	-0.32	0.069	<**0.001**	57	-0.496	0.156	**0.002**
4	905	-0.337	0.0558	< **0.001**	790	-0.13	0.00556	0.036
5	966	-0.277	0.0263	< **0.001**	955	-0.275	0.0322	< **0.001**
6	657	-0.583	0.0681	< **0.001**	699	-0.448	0.0399	< **0.001**
7	281	-0.602	0.03	**0.004**	341	-0.406	0.0349	<**0.001**
8	90	-0.259	0.00247	0.641	111	-0.43	0.0198	0.141
9	21	-4.561	0.258	**0.019**	33	-0.0055	<0.0001	0.996

Figure 1. Conowingo Dam Tailrace (Susquehanna River) hook and line sampling location for American shad in 2012.

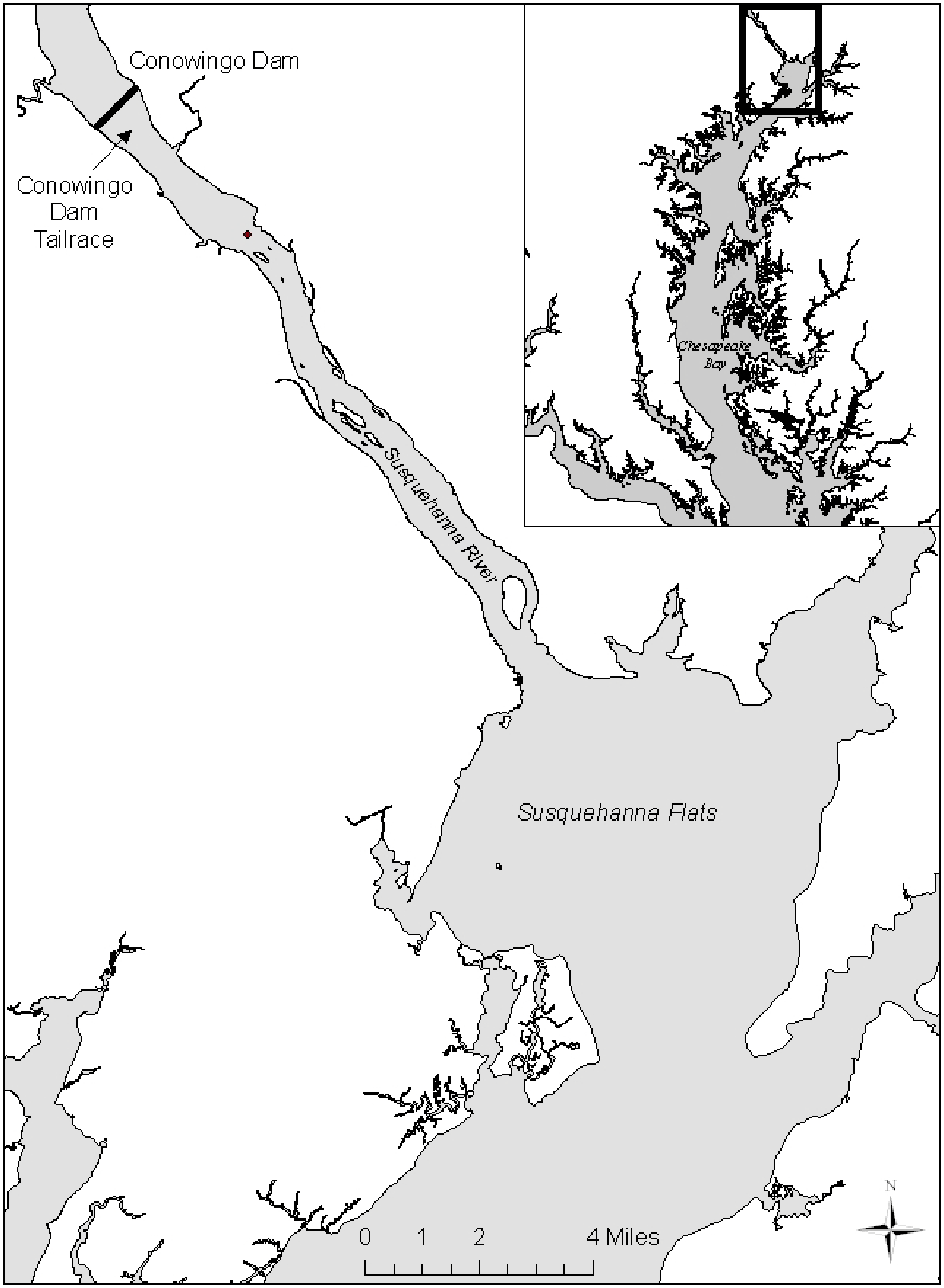


Figure 2. Nanticoke River pound net sites for adult alosine sampling in 2012. The Mill Creek pound net site used for calculating American shad CPUE is identified.

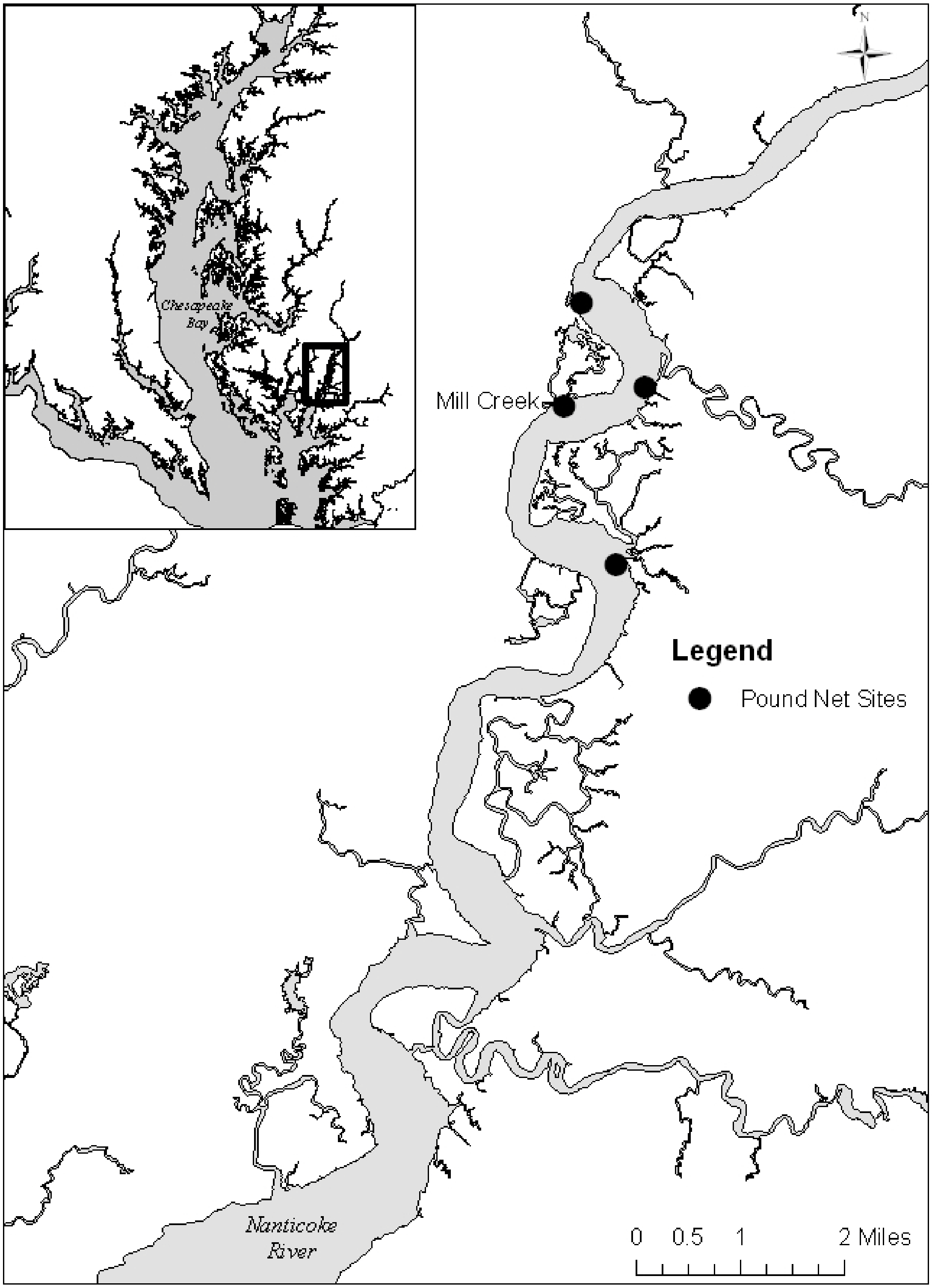


Figure 3. Nanticoke River sites for alosine ichthyoplankton sampling in 2012.

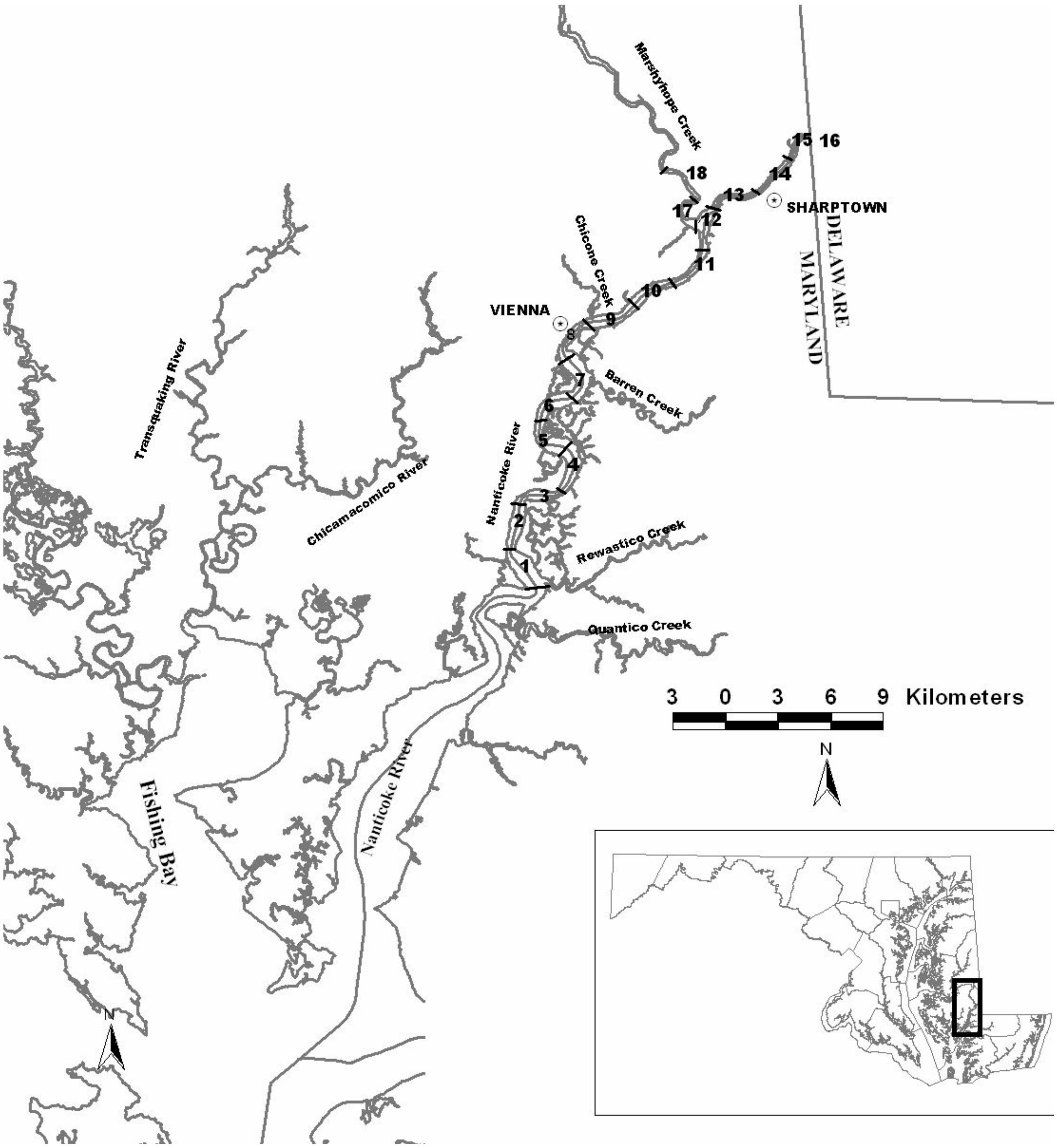


Figure 4. Chester River sampling sites for juvenile alosine species in 2012. Each black circle indicates the approximate location of a paired seine and trawl site.

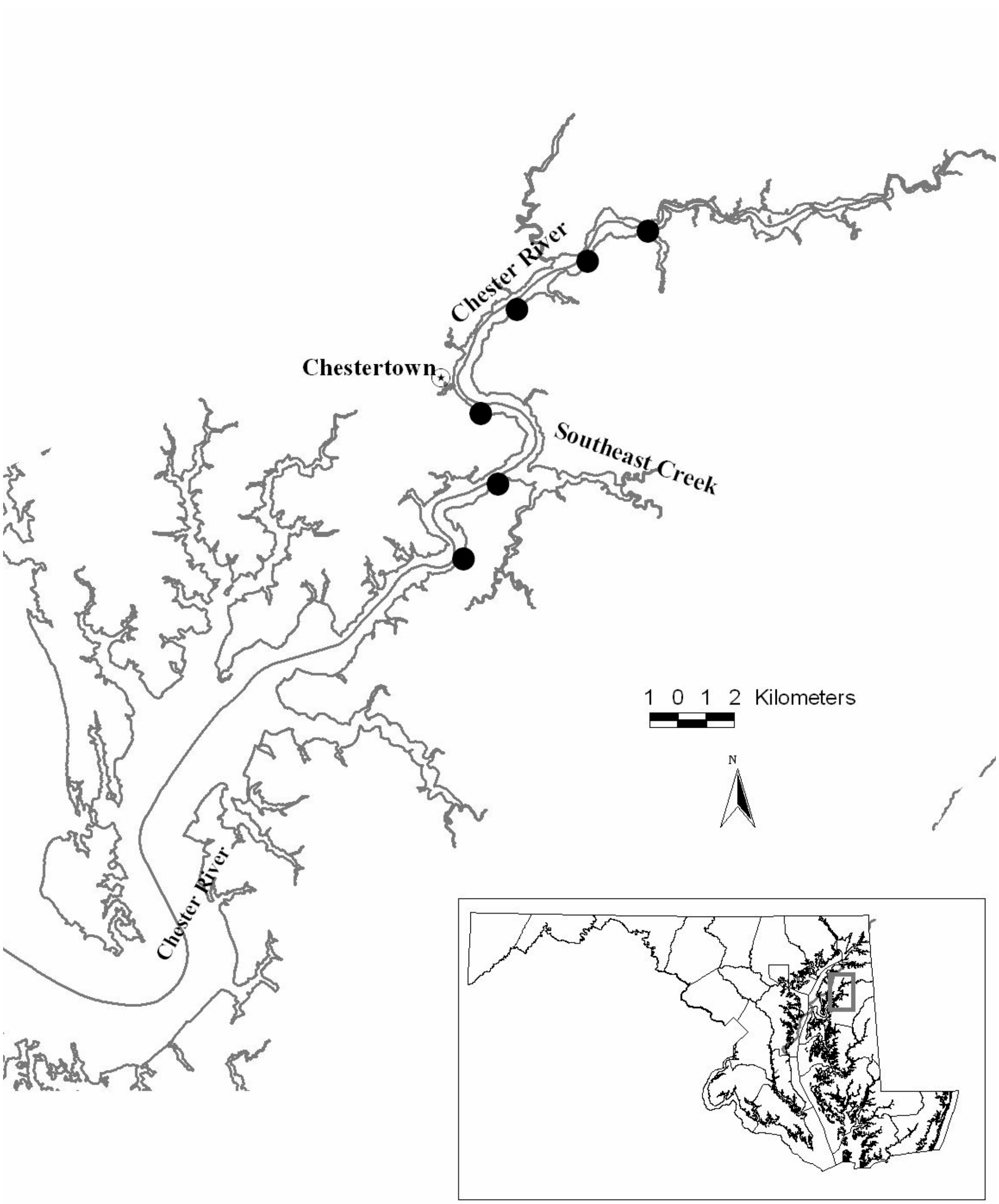


Figure 5. Percent of American shad repeat spawners by sex collected in the Conowingo Dam tailrace (1982-2012).

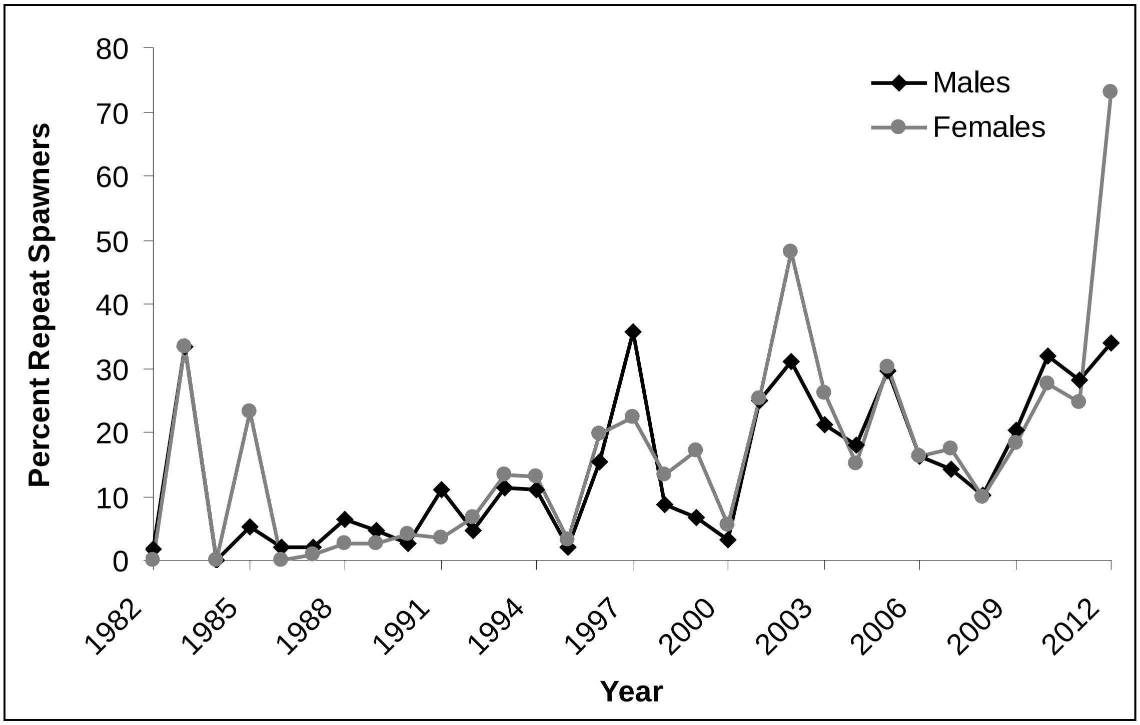


Figure 6. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2012.

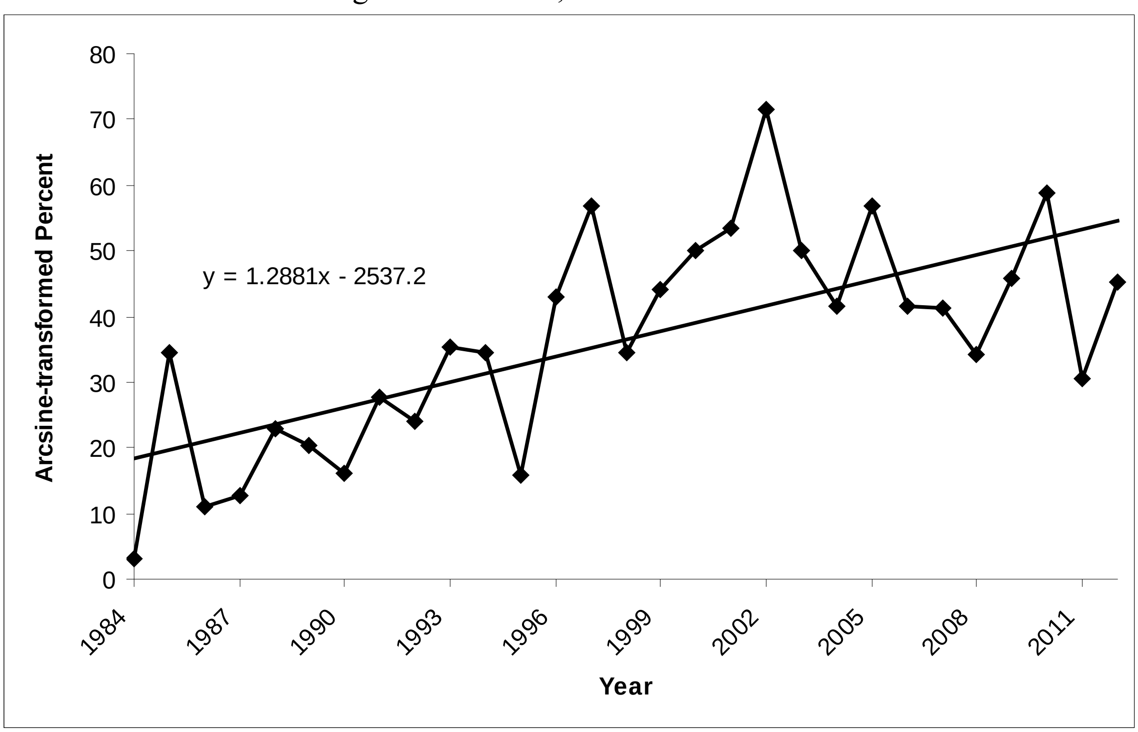


Figure 7. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River, 1988-2012.

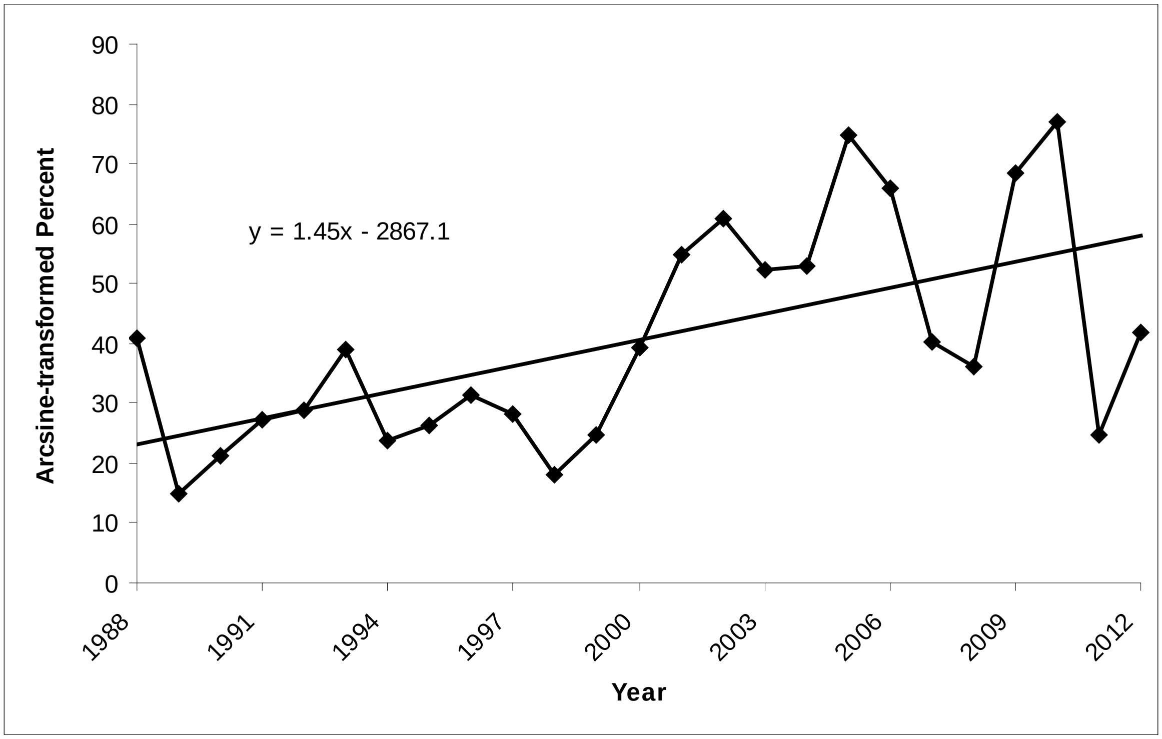


Figure 8. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River, 2002-2012.

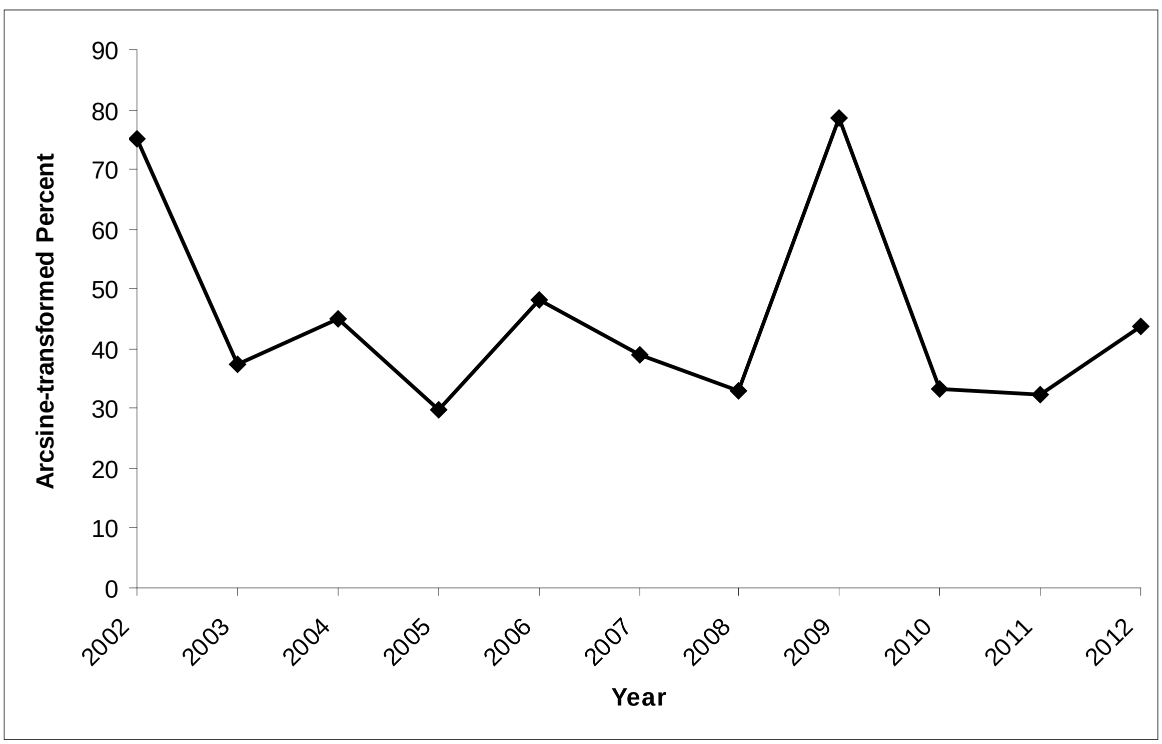


Figure 9. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic and the surplus production model (SPM), 1986-2012.

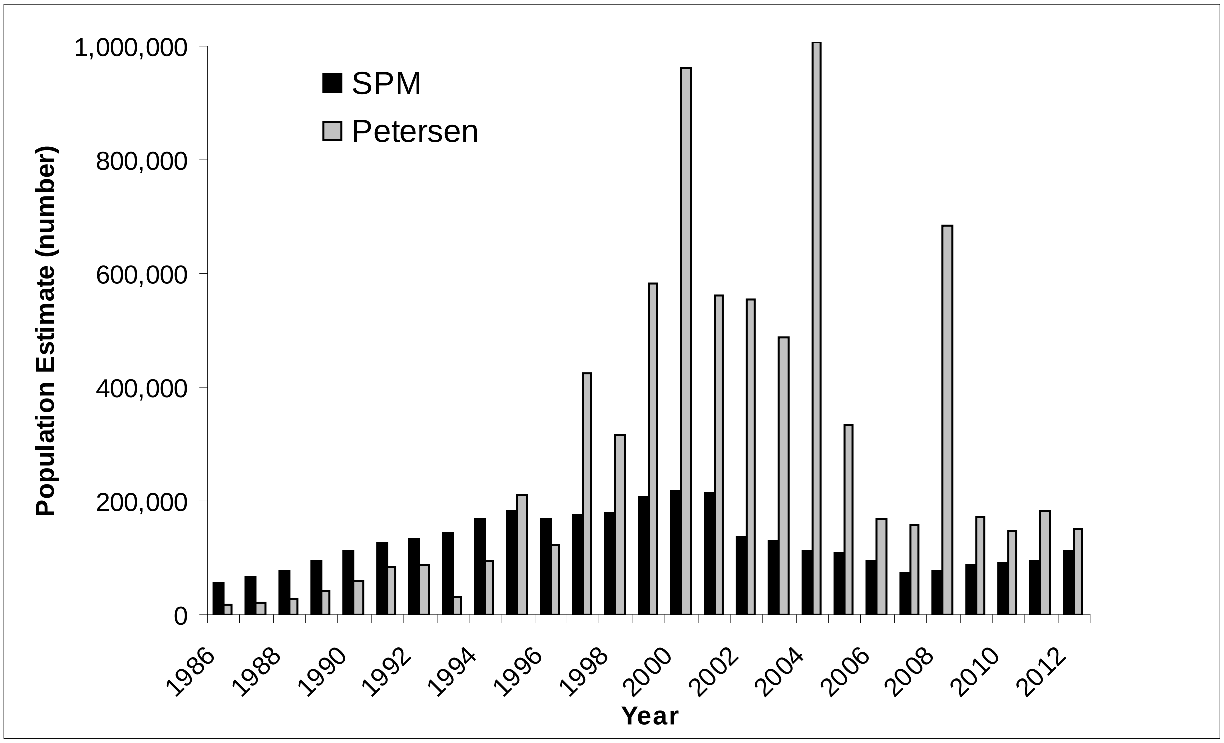


Figure 10. American shad geometric mean CPUE (fish per boat hour) from the Conowingo Dam tailrace hook and line sampling, 1984-2012.

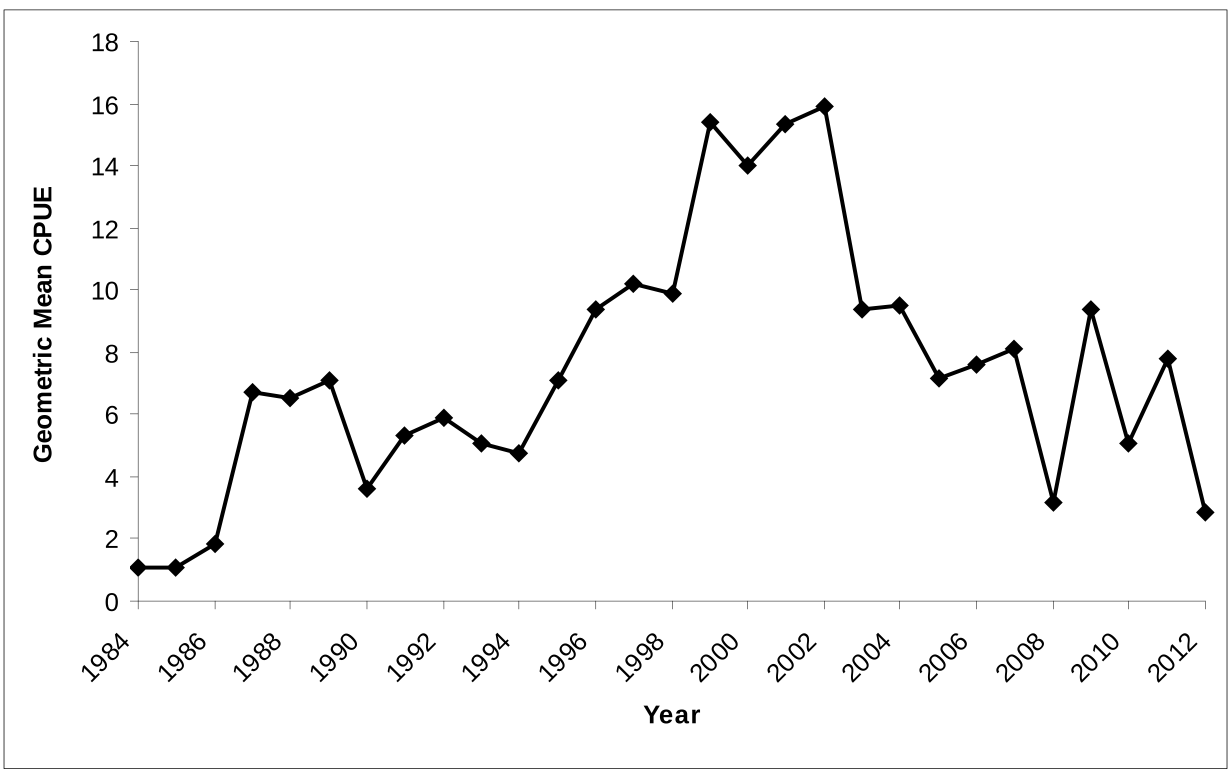


Figure 11. American shad geometric mean CPUE (fish per lift hour) from the East and West Fish Lifts at the Conowingo Dam, 1980-2012.

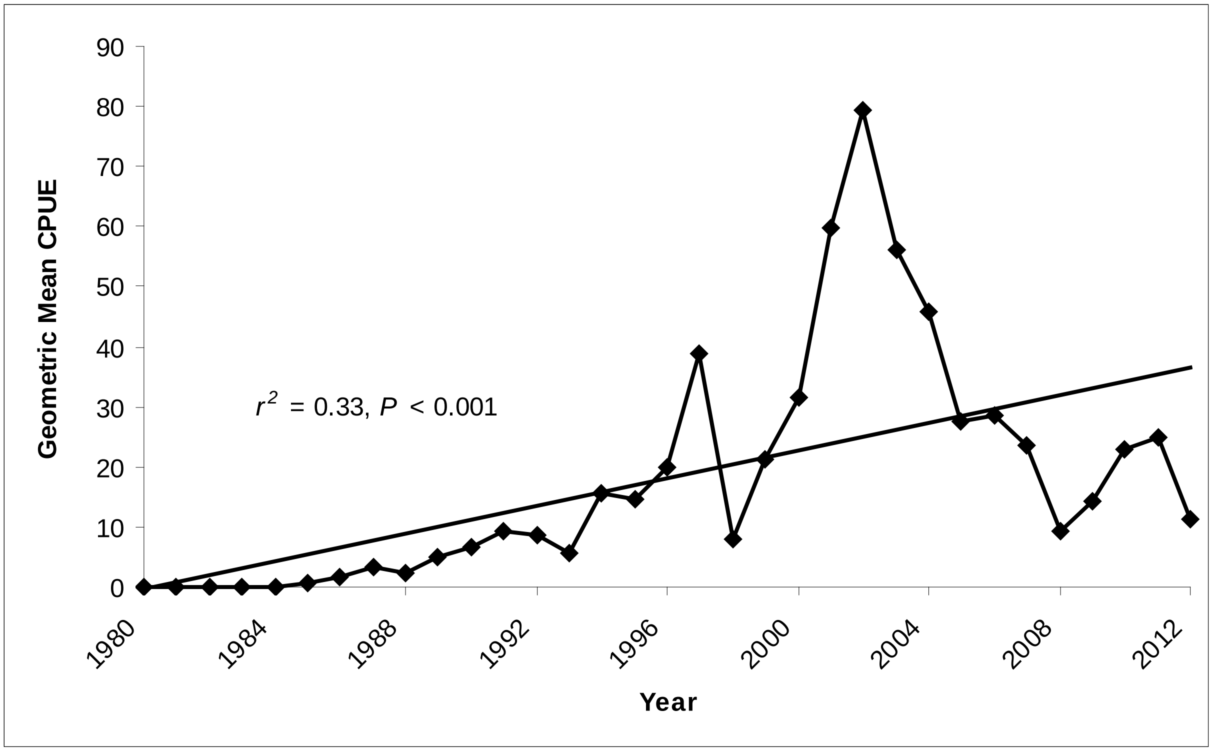


Figure 12. American shad geometric mean CPUE (fish per net day) from the Mill Creek pound net in the Nanticoke River, 1988-2012. No pound nets were fished in 2004.

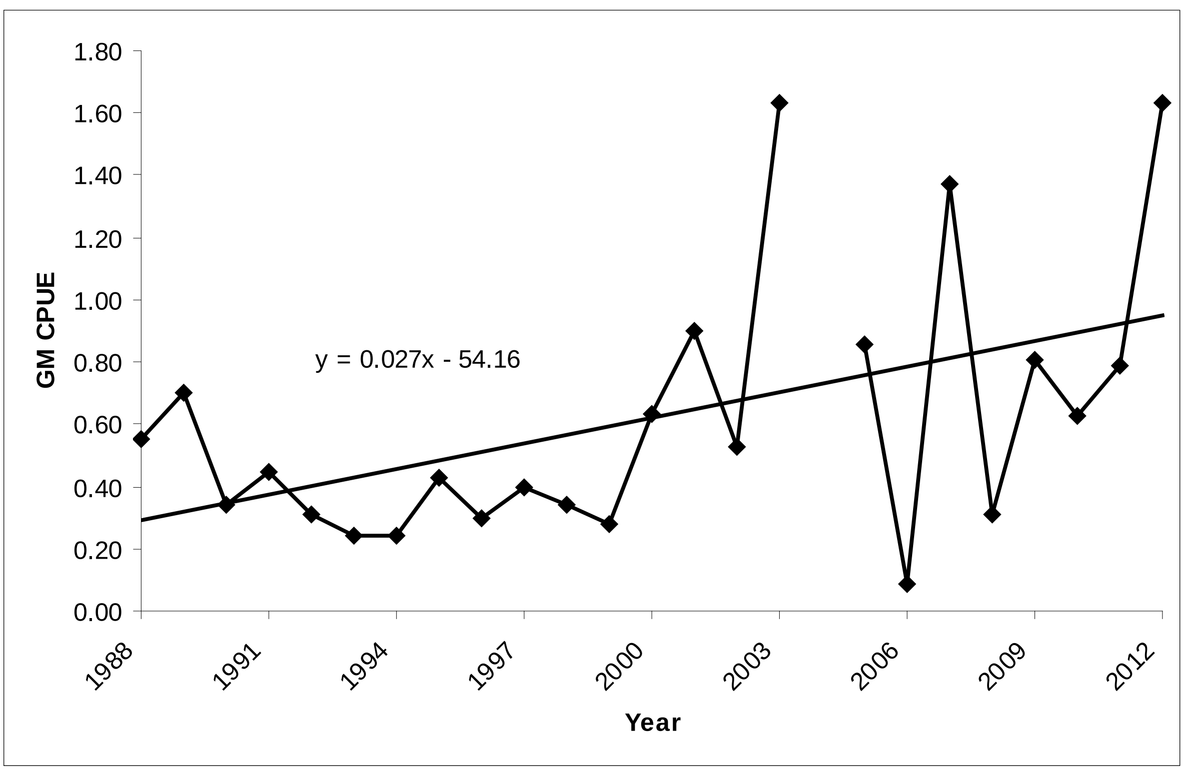


Figure 13. American shad geometric mean CPUE (fish per 1000 square yards of experimental drift gill net per hour fished) from the Potomac River, 1996-2012.

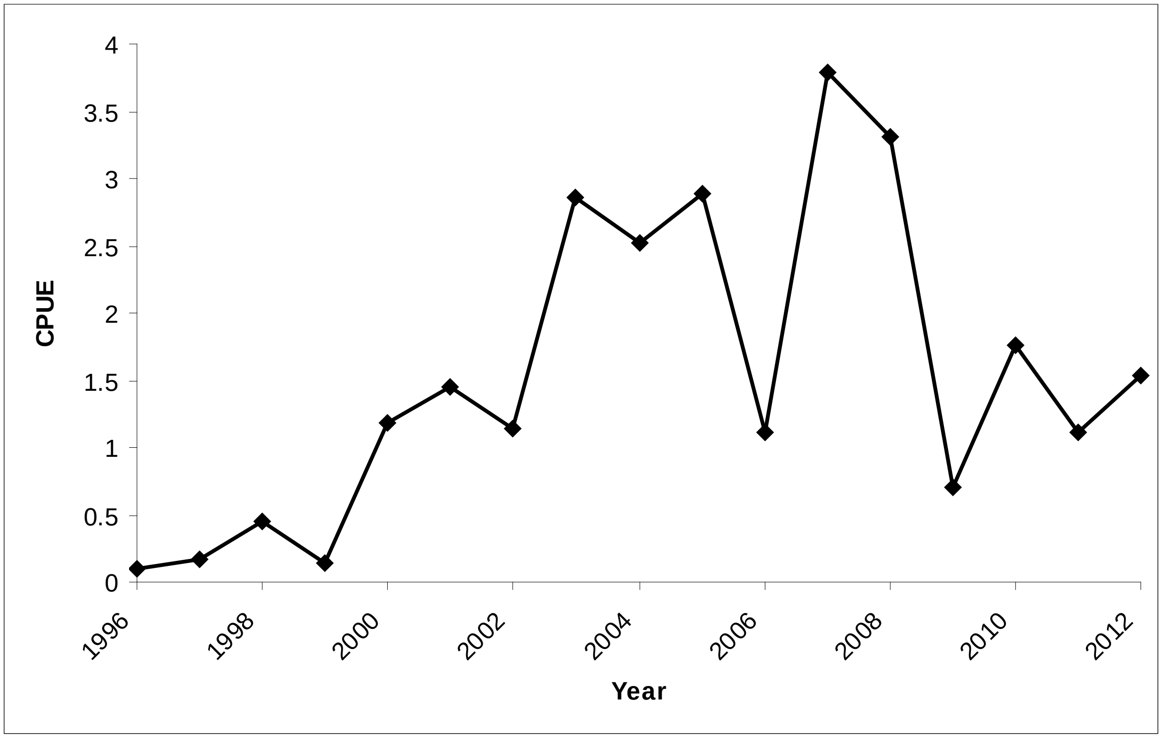


Figure 14. Baywide juvenile American shad geometric mean CPUE (catch per haul), 1959-2012.

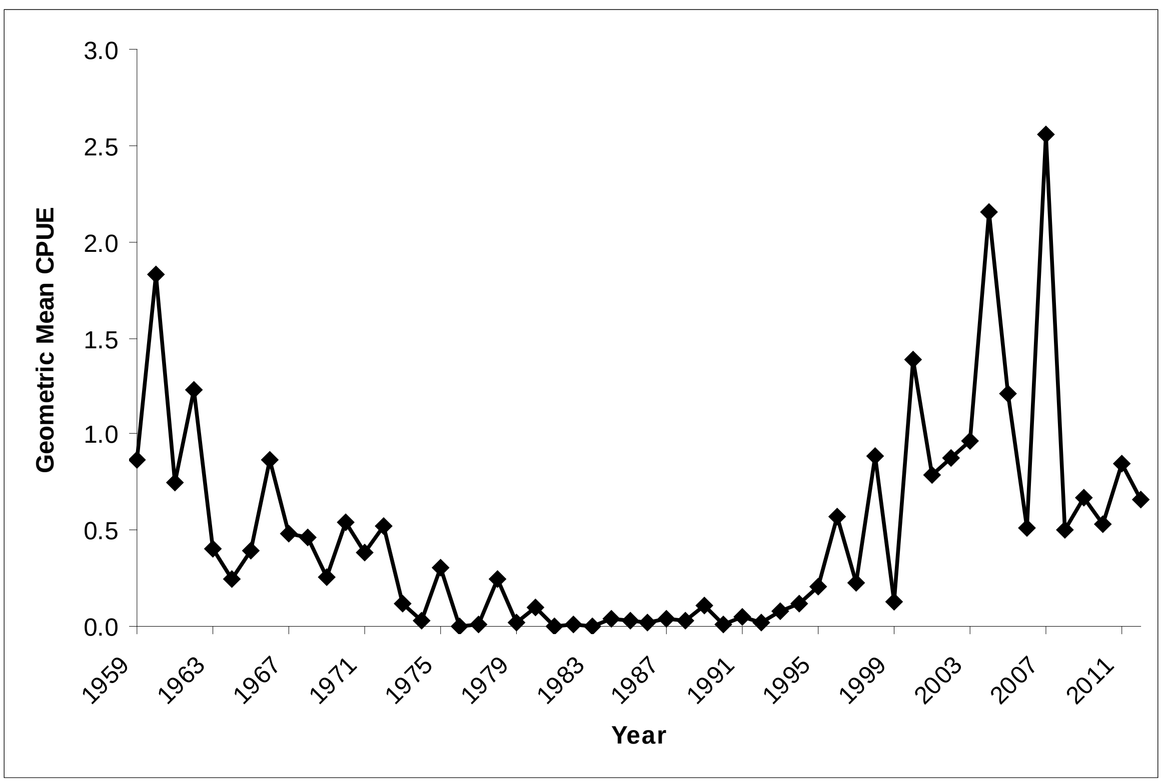


Figure 15. Upper Chesapeake Bay juvenile American shad geometric mean CPUE (catch per haul), 1959-2012.

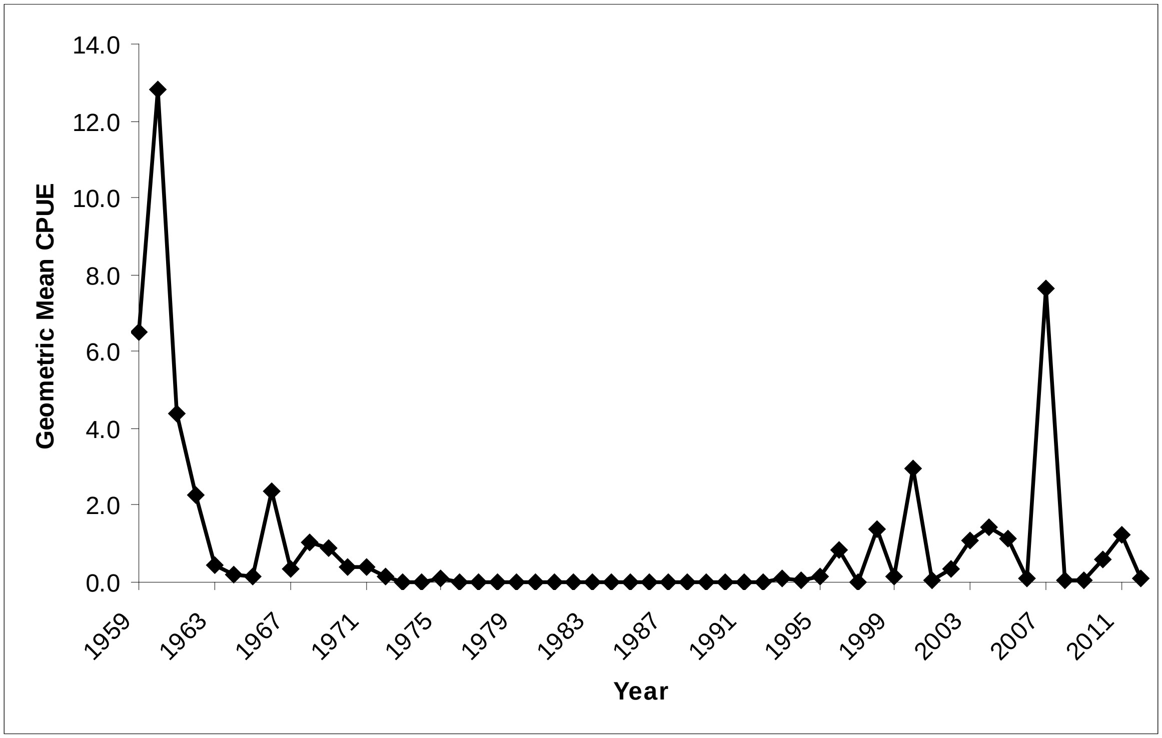


Figure 16. Nanticoke River juvenile American shad geometric mean CPUE (catch per haul), 1959-2012.

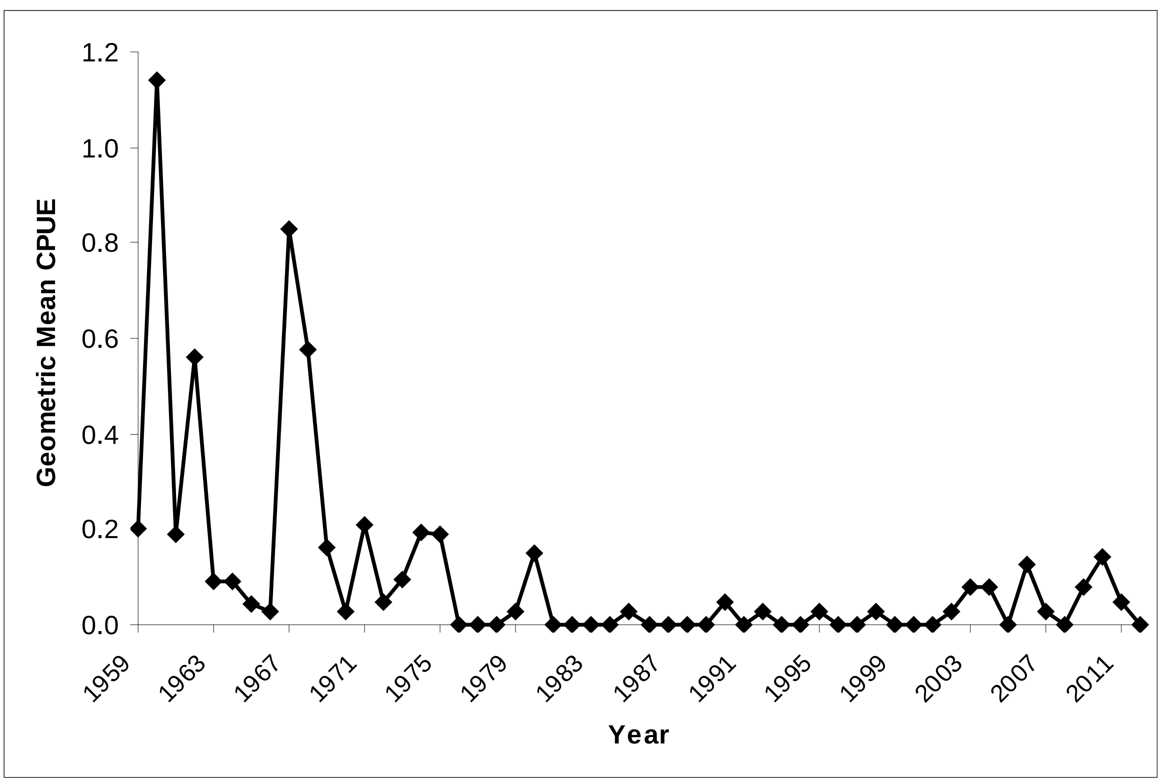


Figure 17 . P otomac R iver juvenile A merican shad geometric m ean CPUE (catch per ha ul), 1959-2012.

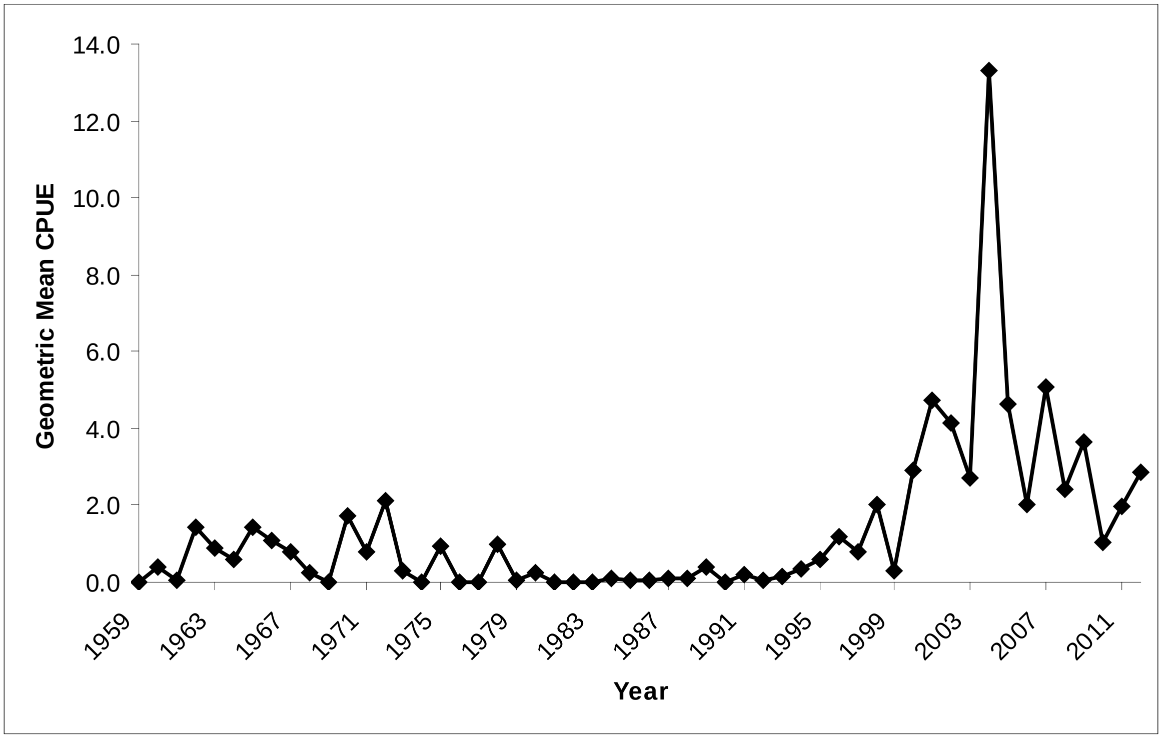


Figure 18. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from Deer Creek (Susquehanna River tributary), 2004-2012.

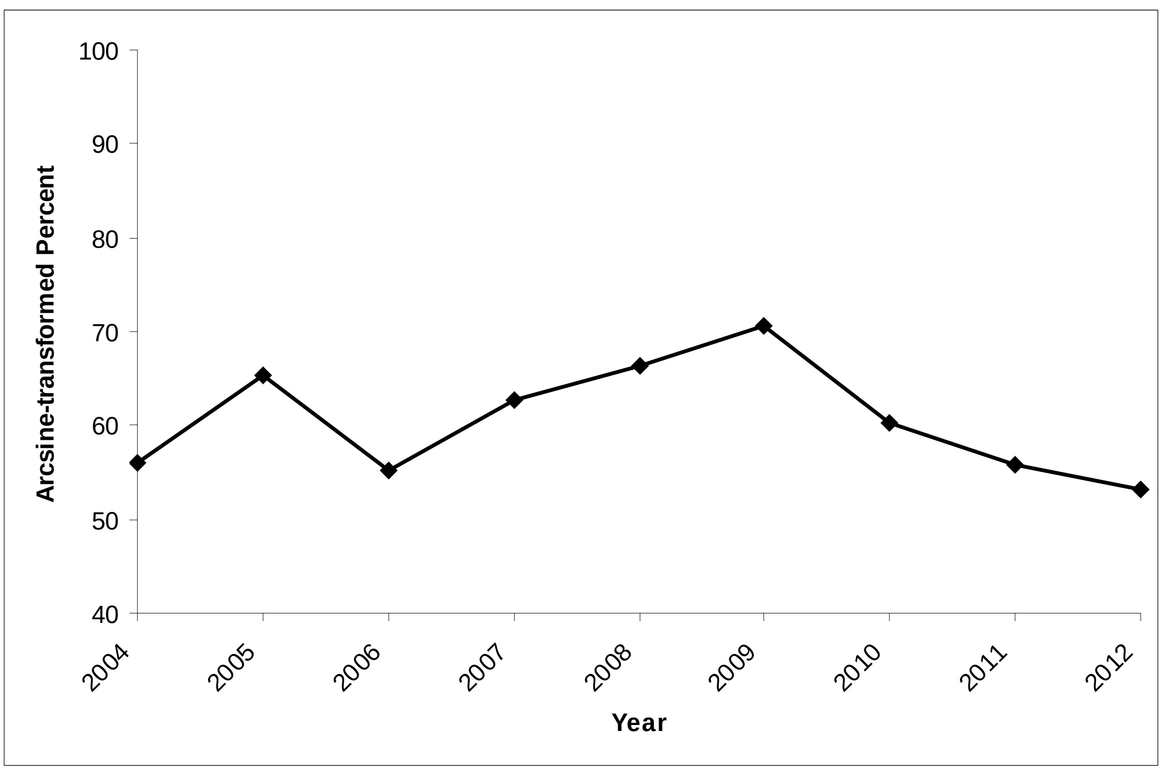


Figure 19. Arcsine-transformed percentages of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1989-2012.

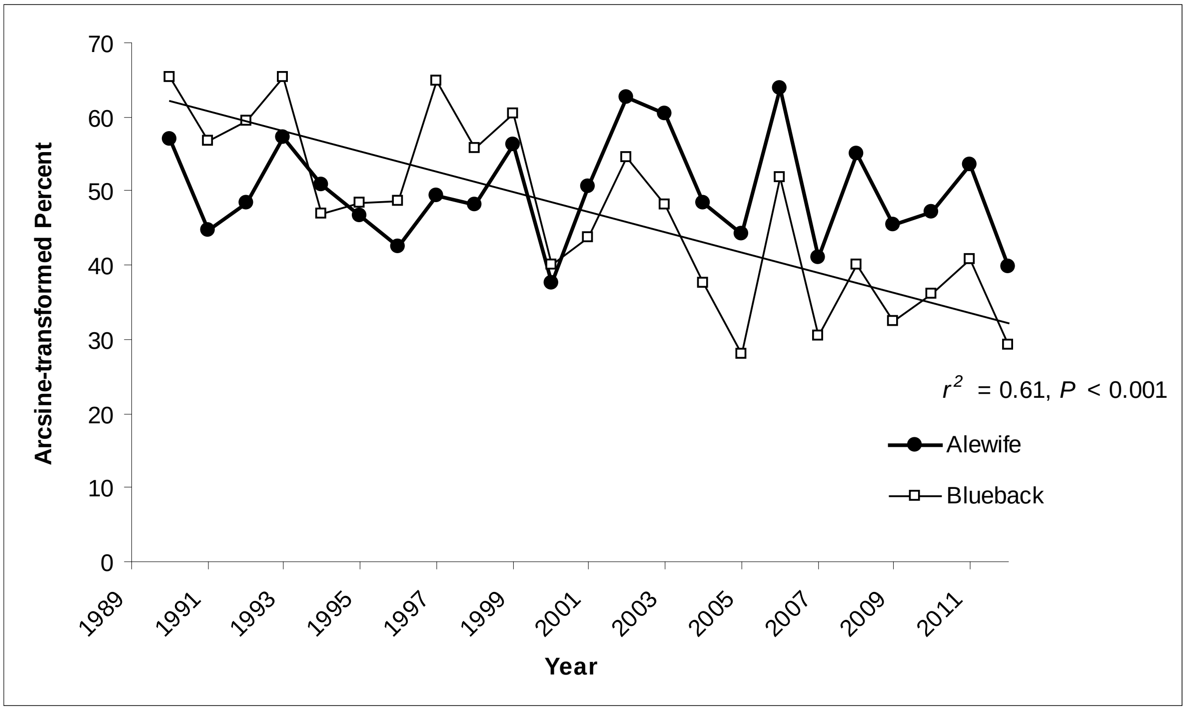


Figure 20. Geometric mean CPUE (catch per net day) of adult alewife and blueback herring from Nanticoke River fyke nets, 1989-2011. No fyke nets were fished in 2012. The CPUE for blueback herring is significantly declining over the time series.

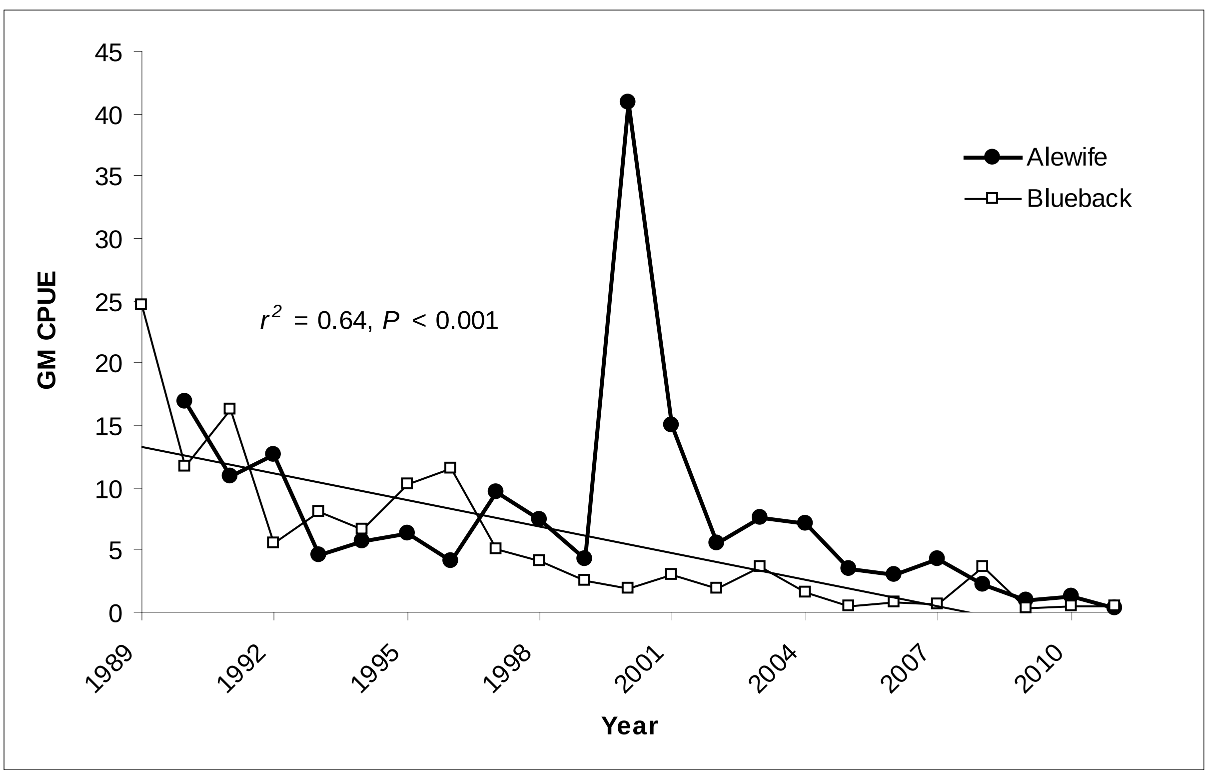


Figure 21. Maryland's commercial river herring landings, 1929-2012.

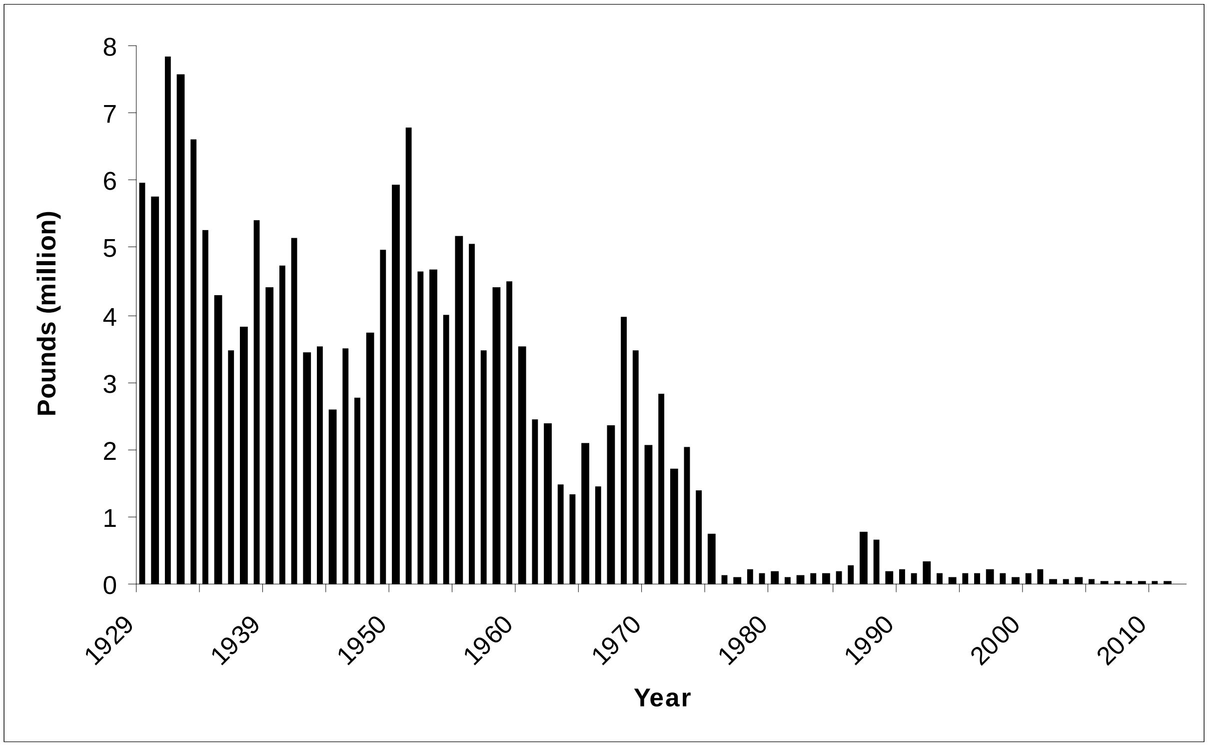


Figure 22. Nanticoke River juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2012.

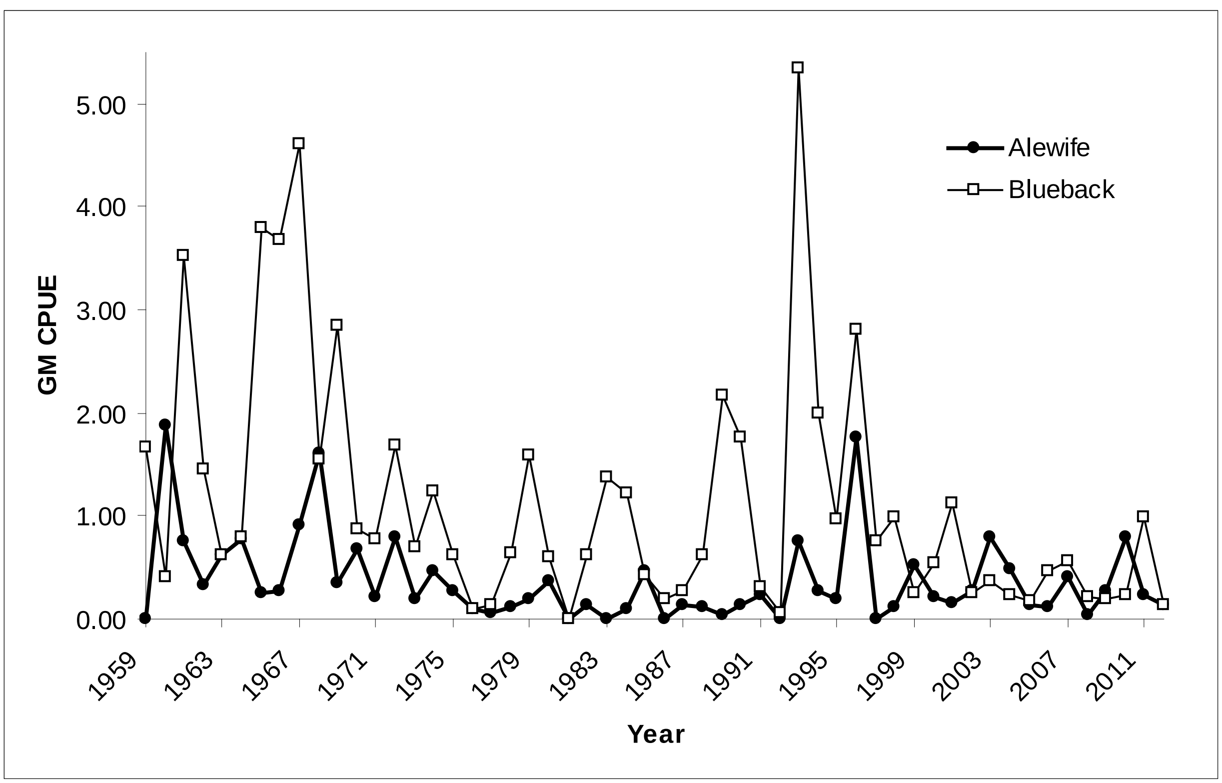
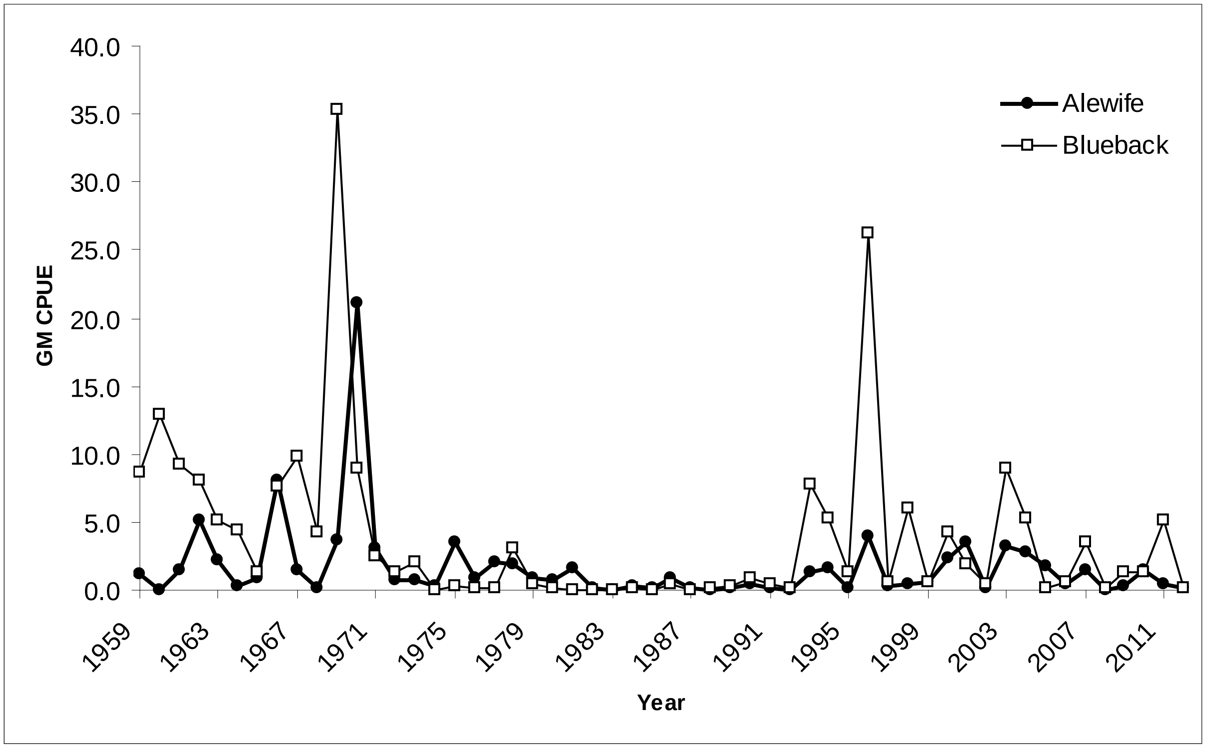


Figure 23. Upper Bay juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2012.



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 voluntary cooperation of pound net fishermen. Pound nets from the lower Chesapeake Bay and Potomac River have been consistently monitored throughout the 20 years of this survey (1993-2012). 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. Five commercial pound nets were sampled at the Potomac River and Chesapeake Bay between cove Point and Point No Point in 2012 (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. In 2012 additional data was gathered from a commercial gill net fisherman in Fishing Bay, this supplemented the pound net data. Two circle gillnets (3 ¼ inch mesh, 1000 ft in length, and 6 ft deep) were sampled on July 1st. Only Atlantic croaker and spotted seatrout were caught.

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 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, 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 and 2012 were aged by MD DNR biologists. 2010 Atlantic croaker ages from SC DNR were compared to the MD DNR ages to evaluate consistency between agencies. Left otoliths were sectioned and read by SC DNR and the right otoliths were sectioned and read by MD DNR, meaning any observed differences were for the entire aging process, not just differences in reader interpretation. Forty six otoliths were compared and there was 96% agreement in Atlantic croaker ages. All spot otoliths from 2012 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. 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. If the left otolith was damaged, missing or miss cut the right otolith was substituted.

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 m in 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 January 17, 2013. Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2011. 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. Log (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 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 2012 charter log book data had not been finalized, only data through 2011 was utilized for analysis.

Instantaneous total mortality rates 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). Von Bertalanffy parameters for croaker mortality estimates were derived from pooled ages (otoliths; n = 2,284) determined from 2003-2012 Chesapeake Bay pound net survey data, and June through September 2003-2012 measurements of age zero croaker (n=197) from MD DNR Blue Crab Trawl Survey Tangier Sound samples (Chris Walstrum MD DNR personnel communication 2008). 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 weakfish were L_∞ = 840 mm TL and K= 0.08. L_c was 305 mm TL. Parameters for Atlantic croaker estimates from 2003-2012 were L_∞ = 413.7 mm TL and K= 0.321, while L_c for Atlantic croaker was 229 mm TL.

Relative stock density (RSD) was used to characterize length distributions for weakfish, summer flounder, bluefish and Atlantic croaker (Gablehouse 1984). Only onboard pound net sampling was utilized for this analysis. Incremental RSD's group fish into five broad descriptive 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%, minimum quality length is 36 - 41%, minimum preferred length is 45 - 55%, minimum memorable length is 59 - 64% and minimum trophy length is 74 - 80% of the world record lengths. Minimum lengths for the target species were assigned from either the cut-offs listed by Gablehouse (1984) or derived from world record lengths recorded by the International Game Fish Association (Table 1).

Length frequency distributions were constructed for summer flounder, Atlantic croaker and spot, utilizing onboard sampling length data divided into 20 mm length groups. In order to detect differences gill net caught fish and pound net caught fish, length frequency distributions were calculated separately. Only Atlantic croaker sample size was adequate to construct length frequency distributions for both gears.

Length-at-age keys were constructed for weakfish and Atlantic croaker using age samples through 2012. Age and length data were assigned to 20mm TL 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 2012 and weakfish from 2003 through 2012. Age length keys for spot were constructed for 2007 through 2012. 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 27 cm 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 2006).

RESULTS and DISCUSSION

The Potomac River and the Cheasapeake Bay were sampled from May 22, 2012 through September 11, 2012 (Table 2). All target species, and twenty non-target species (Table 3) were encountered during this time period.

Weakfish

Ninety three weakfish were sampled in the 2012 pound net survey, the eighth lowest catch of the 20 year time series. Weakfish mean length in 2012 was 284 mm TL, an increase from the 2011 mean length of 236 mm TL, just below the time series annual mean length of 295mm TL (Table 4). Weakfish RSD results for 2012 were 11% $RSD_{quality,}$ 2% $RSD_{preferred}$ and RSD_{stock} accounting remaining catch (Table 5). This follows three consecutive years in which all sampled weakfish were in the RSD_{stock} category. The 2012 onboard pound net survey length frequency distribution corroborated the shift to larger sizes with 65% of sampled weakfish in the 230 to 270 mm TL groups (Figure 2).

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 14 and 22 of 93 weakfish above the recreational and commercial size limits, respectively.

In 2012, females accounted for 74% of fish sampled from the pound net survey (n=52). Female mean TL and mean weight were 289 mm TL and 250g, respectively, while males averaged 282 mm TL and 212g. In 2011, females averaged 242 mm TL and 147g and accounted for 65% of fish sampled (n=23), while male mean length and weight were 233 mm TL and 127g, respectively.

Total Maryland commercial weakfish harvest (Chesapeake Bay and Atlantic Ocean combined) in 2011 declined to 378 pounds, with the Chesapeake Bay portion decreasing from 40 pounds in 2010 to 24 pounds in 2011 (Figures 3 and 4). The 2011 total harvest was the lowest of the 82 year time series and was well below Maryland's average of 620,020 pounds per year. Maryland recreational anglers harvested an estimated 237 weakfish (PSE = 91) during 2011, with an estimated weight of 134 pounds (PSE = 89.3; Figure 5). The number of weakfish harvested by the recreational fishery in 2011 represented a 20 fold decrease compared to the 2010 estimate (4,784), and was the lowest of the 1981-2011 time series. According to the MRIP estimates, Maryland anglers released 18,500 (PSE = 46.8) weakfish in 2011, a more than 8 fold decrease from 2010 (162,733, PSE = 46.8). Estimated recreational harvest decreased steadily from 475,348 fish in 2000 to near zero in 2006, and recovered slightly in 2007 and 2010 before dropping back to near zero in 2011. Both the recreational harvest estimates and the reported commercial landings in 2010 and 2011 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 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 2,042 to 75,154 weakfish from 1993 to 2011 (Figure 6), with a dramatic decline occurring in 2003. The reported charter boat harvest had the same trend as the reported commercial harvest ($R^2 = 0.64$, $P < 0.001$) and the statewide MRIP estimate ($R^2 = 0.81$, $P < 0.001$), but not the inland for hire only MRIP estimate. Of the 27,734 entries reported, only one was not included in this analysis since the CPA exceeded 200. The 2011 geometric mean of 0.58 weakfish per angler was the third lowest mean of the time series (Figure 7). The geometric mean CPA has declined significantly from 1993 – 2011 ($R^2 = 0.81$, $P < 0.001$).

The 2012 weakfish juvenile GM decreased after increasing for three straight years, and was the 2nd lowest value in the 24 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. 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 71 fish in 2012. 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, with 46% of sampled fish being age two plus, indicating a shift back toward slightly older weakfish (Table 6).

Mortality estimates for 2007 through 2012 could not be calculated because of extremely low sample size, while instantaneous total mortality estimates calculated for 2005 and 2006 were Z = 1.44 and Z = 1.35, respectively (Table 7). Maryland's length-based estimates 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 2004-2012. Mean total lengths have ranged from the time series high of 374 mm TL in 2005 and 2010 to the time series low of 286 mm TL in 2006 (Table 4). The 2012 mean length of 338 mm TL decreased compared to 2011, it was the ninth lowest of the 20 year time series. This decrease is primarily attributed a greater proportion of juveniles, as indicated by the length frequency analysis below. Relative stock densities in the 2012 onboard pound net survey indicated a decrease in the stock and quality categories with a corresponding large increase in the preferred category compared to 2011 (Table 8). The 2012 percentage of summer flounder in the preferred category and above was the highest in the 20 year time series. The length frequency distribution from the onboard sampling was bimodal in 2012 peaking at the 130 to 150 and 410 to 430 mm TL length groups, representing an expansion in smaller sized fish (Figure 9). There was also an increase in the proportion of fish greater than or equal to the 356 mm TL minimum commercial size limit in 2012 (60%) compared to 2011 (51%). The number of summer flounder sampled in 2012 was the lowest of the 20 years surveyed (Table 4). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches to the 2012 recreational size limit of 432 mm TL indicated a greater proportion of legal fish in the stock during 2012 (28%) compared to 2011 (4%).

Maryland's commercial summer flounder harvest totaled 144,580 pounds in 2011, the 5^{th} lowest in the 49 year time series (Figure 10). The long-term (1962 – 2011) commercial harvest average is 412,949 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 (Figures 10 and 11). The recreational harvest estimate of 15,347 (PSE = 44.8) fish caught in 2011 ranked 31^{st} out of the 31 year time series, and declined 39% from the 2010 estimate of 25,215 (PSE = 35.7) fish (Figure 12). The 2011 MRIP recreational release estimate of 472,536 (PSE = 23.5) fish was the 18^{th} highest of the 1981 - 2011 time series, representing a drop back down to 1996 values (Figure 12). This is consistent with the RSD analysis and onboard length frequency distributions, that indicate a decrease in fish greater than the minimum recreational size limit in 2011. The recreational fishery has been subject to increasingly restrictive regulations in the past several years, which most likely reduced harvest rates.

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 2011 harvest dipped three percent to 14,008 the second highest in the 19 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 did significantly decline ($R^2 = 0.46$, $P = 0.0013$) over the entire time series (Figure 14), but has been relatively stable for the past eight years.

A coast wide stock assessment using the Age Structured Assessment Program (ASAP) was conducted in 2008, and updated in 2011(NFSC 2008, Terceiro 2011). The assessment indicated that summer flounder recruitment along the Atlantic coast declined from a peak in 1983 to the time series low in 1988 (NFSC 2008). The ASAP model estimated recruitment for 2009 at 60 million fish, above the long term mean of 43 million fish (NFSC 2008, Terceiro 2011). The NMFS coastal assessment found that F varied from F = 1.1 to F = 2.0 from 1982 to 1996, but has remained below 1.0 since 1996. F was estimated to be 0.22 in 2010, below the threshold, and the estimated 2010 SSB of 132.8 million pounds was slightly above the target level of 132.4 million pounds. The NMFS assessment concluded that summer flounder stocks were not overfished, overfishing was not occurring, and the rebuilding target has been met as of 2010 (NFSC 2008, Terceiro 2011).

Bluefish

Bluefish sampled from the onboard pound net survey averaged 298 mm TL during 2012, an increase from the 2011 mean of 245 mm TL (Table 4). The 2012 mean length was below the 20 year time series mean of 302 mm. Ninety-two percent of sampled bluefish were in the RSD_{stock} category and 7.9% were in the $RSD_{quality}$ category (Table 9), indicating an increase in larger bluefish compared to 2010. 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 a minor peak in the 230 mm TL group (Figure 15).

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 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 by 33% in 2011 to 70,383 pounds, and remained below the 1929-2011 average of 171,408 pounds (Figure 16). The 2011 catch ranked 57th in the 82 year time series. Total commercial landings fluctuated without trend from 42,662 to 157,436 pounds from 1993 – 2011 (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 1998 while Atlantic Ocean and coastal bay catches remained stable. 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 2011 estimate of 259,286 (PSE = 25.6) fish harvested decreased slightly compared to 2010 (272,764 fish, PSE = 17.6), and was well below the time series average of 852,601 fish. Estimated recreational releases increased by two and half fold in 2011 to 408,323 (PSE = 27.5) compared to 2010 (161,424 fish, PSE = 30.6), still lower then the time series mean of 541,923 fish (Figure 17).

Reported bluefish harvest from charter boat logs ranged from 27,667 – 134,828 fish per year from 1993 to 2011, 2011 harvest declined for the third consecutive year to 30,176 fish (Figure 18). Harvest from charter boat logs generally tracked with state wide MRIP estimates, but regression analysis indicated no significant trend with recreational estimates or commercial landings. Two of the 70,182 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 2011 (Figure 19).

A stock assessment of Atlantic coast bluefish utilizing the forward projecting catch at age (ASAP) model was produced in 2010, and revised in 2012 (Shepherd and Nieland 2010, NMFS 2012). 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 22.5 million age-0 bluefish, with the exception of a relatively large 2006 cohort estimated as 35.2 million fish. Recruitment during 2009-2011 was below average (Shepherd and Nieland 2010, NMFS 2012). 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 poor recruitment.

Atlantic croaker

Atlantic croaker mean length from the onboard pound net survey decreased for the third year to 274 mm TL, and was the third lowest value of the 20 year time series (Table 4). Gill net caught fish were also measured during onboard sampling for the first time in 2012, with a mean length of 296 mm TL (n = 571) and a mean weight of 381 g (n = 61). Fifty percent of the Atlantic croaker from onboard pound net sampling in 2012 were in the $RSD_{preferred}$ category, a decrease over 2011. All other RSD categories increased slightly in 2012 (Table 10). The onboard pound net length frequency distribution for 2012 indicated an increase in the smaller croaker, but otherwise was very similar to the 2011 distribution, with the primary peak occurring in the 250 and 270 mm length groups (Figure 20). Onboard gill net length frequency peaked in the 270 and 290 mm length groups with catches dropping off quickly for both smaller and large fish (Figure 21). This could be an indication of net selectivity, or an artifact of the sample being from a single catch (one fisherman on one day).

Atlantic croaker sampled from gill nets in 2012 mean lengths and weights by sex were 295 mm TL and 375 g for females (n = 47) and 308 mm TL and 400 g for males (n = 14). Gill net samples were 77% female and 23% male, but sample size was low, so these percentages may not reflect the actual male to female composition of the gill net harvest. Pound net samples were not randomly selected, therefore no sex specific analysis was conducted.

During 2011, the Maryland Atlantic croaker total commercial harvest of 704,019 pounds (Chesapeake Bay and Atlantic Ocean combined) increased 44% compared to 2010 (Figure 22). The 2011 harvest was still below the 1929-2011 average of 1,042,700 pounds. The 2011 recreational harvest estimate was 554,206 fish (PSE = 22.3) a 51% decrease from 2010, the lowest value since 1993, and was below the 1981-2011 average of 756,175 fish (Figure 23). The 2011 recreational release estimate decreased 64% compared to 2010 (Figure 23), and was well below the 1981-2011 average of 1,241,139 fish.

Reported Atlantic croaker harvest from charter boats ranged from 127,664 – 448,789 fish during the 19 year time period (Figure 24). The charter boat log book harvest trended with the statewide MRIP estimates ($R^2 = 0.37$, $P = 0.0055$), but not with the Chesapeake Bay commercial landings or for hire inland only MRIP estimates. The MRIP for hire inland only estimates did, however, follow the same general trend. Twelve of the 51,044 entries were not used to calculate the GM because of CPA values exceeding 200 fish. The geometric mean catch per angler increased significantly ($R^2 = 0.44$, $P = 0.0021$) from 1993 to 2011, with relatively stable values prior to 2004 and generally increased values since 2004 (Figure 25). Following three years of steadily increasing values, the 2011 GM of 4.66 fish per angler was a decrease from 2010, but was still 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 (Figure 26). The 2012 GM increased to 3.8 fish per tow, and was above the 24 year time series mean of 3.4 fish per tow, and was the 7th highest value of the time series. Atlantic croaker recruitment has been linked to environmental factors including winter temperature in nursery areas (Lankford and Targett 2001, Hare and Able 2007);

prevailing winds, currents and hurricanes during spawning; and larval ingress (Montane and Austin 2005, Norcross and Austin 1986). Because of these strong environmental influences, high spawning stock biomass may not result in good recruitment.

Ages derived from pound net caught Atlantic croaker otoliths in 2012 ranged from 0 to 8 (n=255; Table 11). The number of Atlantic croaker sampled for length in 2012 (n=1,842) was applied to an age-length key for 2012 (Table 11). This application indicated that 34% of the fish were age four, 22% were age two, 22% were age three, 10% were age zero and 6% were age five. The remaining age groups each accounted for three percent or less of the fish sampled (Table 11). Atlantic croaker greater than six years old have become less abundant in recent years than in the mid 2000s. The contribution of strong year classes (1998, 2002, 2006 and 2008) to the catch can also been seen in Table 11. The abundance of age zero fish in the pound net catch in 2012 appears to corroborate the above average juvenile trawl index. Instantaneous total mortality in 2012 was Z = 0.80, very similar to 2010 (Z = 0.81), and ended a trend of increasing mortality since the 1999-2012 time series low of 0.30 in 2006 (Table 7).

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 in 2012 to 179 mm TL (n=1,508), the lowest value of the 18 year time series (Table 4). The onboard sampling length frequency distribution in 2012 shifted to smaller length fish (Figure 27). The 150 and 160 mm TL groups accounted for 64 % of sampled spot. One jumbo spot (>254 mm TL) was present in the 2012 onboard sampling accounting for less than 0.1 % of the sample. Abundance of jumbo spot in the survey have been low for the past several years (0-3% of sample, 2005-2011). This followed good catches in the early part of the decade (10% in 2003, 13% in 2004).

Commercial harvest in 2011 decreased slightly to 552,985 pounds (Figure 28), the 5th highest catch of the 82 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 the past three years. 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 2010 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.

Maryland recreational harvest estimates from the MRIP indicated that spot catches since 1981 have been variable (Figure 29). Recreational harvest ranged from 300,000 fish in 1988 to 3,800,000 fish in 1986 and 2007, while the number released fluctuated from 200,000 in 1999 to 2,700,000 in 1986 (Figure 29). The 2011 recreational harvest estimate (912,704 fish; PSE = 19) decreased 22% compared to 2010, dropping well below the time series mean estimate of 1,630,015 fish, and marked the 8th lowest value of the 31 year time series. The release estimate of 296,513 fish (PSE = 18.6) decreased 74% compared to 2010, and was the 4th lowest estimate of the 31 year time series (Figure 29).

Reported spot charter boat logbook harvest from 1993 to 2010 ranged from 217,052 to 848,492 fish per year (Figure 30). The 2011 reported harvest was the fourth lowest of the 19 year time series and follows the lowest value in 2010. 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-four of the 44,056 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 and generally increased from 2002 – 2007. The CPA has remained above average from 2008 -2011 with the exception of 2010, which had the second lowest value in the 18 year time series (Figure 31).

Spot juvenile trawl index values from 1989-2012 were quite variable (Figure 32). The 2010 GM value of 104.5 spot per tow was the highest value of the time series, but declined to the second lowest value of the 23 year time series in 2011. The juvenile index increased to 16.4 spot per tow in 2012, just below the time series mean of 18.3 (Figure 32).

In 2012 age one spot accounted for 60% of the sample with 39% being age zero and the remaining 1% being age two (Table 12). 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 2010 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. Commercial harvest may not have been as affected since there appeared to be an increase of spot caught for live bait, many of which may have been age zero. Virginia and North Carolina voiced concern over decreasing spot harvests in their waters, and ASMFC's spot Plan Review Team continues to monitor catch and biological information to determine if additional management action is necessary. Given the popularity of spot as a recreational finfish, other indicators of stock status should be developed to ensure production is exceeding harvest and losses due to natural mortality. No stock assessment has been completed for spot; primarily do to lack of necessary data.

Red Drum

Red drum have been encountered sporadically through the 20 years of the onboard pound net survey, with 458 being measured in 2012 (Table 4). The number of red drum sampled from the onboard sampling also spiked in 2002 at 177 fish (Table 4); however, none were measured from 1993 to 1998, 2001 or in 2009 and 2010. Red drum mean length from the 2012 onboard sampling was 318 mm TL, indicating the fish were primarily juveniles (most likely age one fish). Three of the sampled red drum were over the maximum recreational and commercial size limits of 27 and 25 inches respectively, and the remaining 455 were below the 18 inch minimum size limit in place for both sectors.

Maryland commercial fishermen reported harvesting no red drum in 2011, and only 19 pounds in 2010 (Figure 33). Average harvest from 2004 to 2011 was 27 pounds per year, compared to 700 pounds per year from 1998 to 2003. However, lower harvest since 2003 may not reflect an actual decline in abundance, since more liberal regulations were in effect during previous years. 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 MRIP estimated that recreational fishermen did not harvest or catch and release any red drum in 2011 (Figure 34). Recreational harvest estimates have been extremely variable ranging from zero (23 of the 31 years in the 1981 - 2011 time series) to 12,804 fish (in 1986, PSE=67.4). Peak number of red drum releases occurred in 2002 at 18,412 fish (Figure 34). Anecdotal information regarding 2012 recreational catches indicate juvenile red drum were plentiful throughout much of Maryland's portion of Chesapeake Bay and its tributaries. Catches were commonly reported on fishing message boards on the internet and in local news papers. Nearly all of the reports were of sub-legal fish in the 10 to 14 inch range, indicating a strong 2011 year class.

Maryland charter boat captains reported harvesting red drum in every year from 1993 - 2010, except for 1996. Catches were low for all years, ranging from zero to 99 fish, with a mean of 20 red drum per year (Figure 35). The low reported catch 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 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 only one being sampled in 2012 (Table 4). Lengths throughout the time series have ranged from 244 to 1330 mm TL. The one fish measured in 2012 was 997 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 2011 have been variable, ranging from zero to over 13,000 fish in 1983 (Figure 37). In 2011, MRIP estimated no black drum were harvested and 7,971 (PSE = 78.8) were released by recreational anglers. The harvest estimates are somewhat tenuous, since the MRIP survey is unlikely to accurately represent a small, short lived seasonal fishery such as the black drum fishery in Maryland.

Examination of the charter boat logs revealed black drum were harvested in all years of the 1993-2011 time series, with a mean catch of 407 fish per year (range = 104 – 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 ($R^2 = 0.68$, $P < 0.001$) throughout the time series, but did increase slightly in 2009 and leveled off in 2010 and 2011 (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, only FL has been taken, to be consistent with data collected by other state and federal agencies. During this time period FL from the onboard sampling has ranged from 208 – 681 mm. One hundred seven Spanish mackerel were encountered in 2012, with a mean length of 318 mm FL (Table 4). The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 (Table 4).

The 2011 commercial harvest of Spanish mackerel in Maryland was 5,054 pounds, a 33% increase from 2010 (3,806 pounds; Figure 40), and below the 1965 to 2011 mean of 6,359 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 – 2011 were variable, ranging from 0 – 20,049 fish with an average of 8,686 fish taken. In 2011, an estimated 10,544 (PSE = 52.6) Spanish mackerel were harvested, nearly double the 2010 estimate of 5,580 fish (PSE = 55.5, Figure 39). Due to the high PSE values, these estimates are considered tenuous.

Spanish mackerel charter boat harvest from 1993 to 2010 ranged from 563 – 10,653 fish per year (Figure 42). The charter boat log book harvest did trend significantly with the MRIP for hire inland only estimates ($R^2 = 0.58$, $P < 0.01$) and the statewide MRIP estimates ($R^2 = 0.50$, $P < 0.01$), but not the Chesapeake Bay commercial landings. The geometric mean CPA varied without trend (Figure 43). It would appear that Spanish mackerel are providing a small and somewhat consistent opportunity for recreational anglers in Chesapeake Bay.

Spotted Seatrout

Spotted seatrout are rarely encountered during sampling. Eight were measured from the onboard sampling in 2012 with a mean length of 436 mm TL (Table 4). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 6,497 pounds from 1991-2011 (Figure 44). Reported 2011 harvest was 585 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. Catches increased in 2009 to 11,680 fish, the highest value since 1998 (Figure 45). The 2010 estimate decreased to 3,146 (PSE = 71) and was similar in 2011 (3,058 fish PSE = 66), but the high PSE values from 2009 to 2011 indicate the MRIP survey does not provide reliable estimates for this species in Maryland.

Spotted seatrout harvest from 2011 charter boats was 1,762 fish. Reported harvest ranged from 224 – 20,030 fish per year and averaged 4,187 fish per year for the 15 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, but has declined the past three years (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 2012 was 243 mm FL, near the mean of 245 mm FL for the 2004 to 2012 time series (Table 4). 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, with 40% of sampled fish in the 230 mm FL size group.

Atlantic menhaden scale samples were taken from 375 fish in 2012, but ages could only be assigned to 355 fish (Table 13). 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 13). 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 greater then age four made up 2% to 4.5% of the population form 2005 to 2012.

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 a record high of 12.6 million pounds. Average commercial harvest from 1935-2011 was 4.1 million pounds. The 2011 commercial harvest decreased for the fourth straight year, but was still the 16th highest of the 76 year time series (6.9 million pounds), with 95% of harvest from the Chesapeake Bay (Figure 49).

An update of the ASMFC Atlantic menhaden stock assessment was conducted in 2012 using data through 2011 (ASMFC 2012). The assessment indicated that recruitment was generally low and population fecundity declined since the late 1990s. Fishing mortality increased in 2010 and 2011 and the population is currently experiencing overfishing when compared to the population benchmarks. Amendment 2 of the ASMFC Fisheries Management Plan for Atlantic menhaden is being finalized and will require reductions in harvest to end overfishing and increase the abundance of this important prey species.

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Table 1. Minimum lengths (mm TL) for relative stock density categories.

Species	Stock	Quality	Preferred	Memorable	Trophy
Weakfish	205	340	420	555	705
Summer Flounder	180	320	400	552	670
Bluefish	240	430	540	705	885
Atlantic croaker	125	185	255	305	390

Table 2. Areas sampled, number of sampling trips, mean water temperature and mean salinity by month for 2012.

Area	Month	Number of Samples	Mean Water Temp. C	Mean Salinity (ppt)
Point Lookout	May	1	20.5	13.2
Central Bay	May	1	24.5	12.3
East Bay	May	1	24.3	9.2
Point Lookout	June	2	22.7	10.2
Central Bay	June	2	24.2	9.8
East Bay	June	1	23.6	8.1
Point Lookout	July	2	28.0	14.2
Central Bay	July	2	27.6	12.6
West Bay	July	3	27.3	12.4
Point Lookout	August	2	27.0	16.2
Central Bay	August	1	27.1	15.3
East Bay	August	1	27.1	15.1
West Bay	August	2	27.6	15.7
Point Lookout	September	1	25.0	16.7
Central Bay	September	1	27.1	15.1
East Bay	September	1	27.2	15.1
West Bay	September	2	27.0	15.3

Table 3. List of non-target species observed during the 2012 onboard pound net survey.

Common Name	*Scientific Name*
American shad	*Alosa sapidissima*
Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic herring	*Clupea harengus*
Butterfish	*Peprilus triacanthus*
Common carp	*Cyprinus carpio*
Cownose ray	*Rhinoptera bonasus*
Crevalle jack	*Caranx hippos*
Florida pompano	*Trachinotus carolinus*
Gizzard shad	*Dorosoma cepedianum*
Harvestfish	*Peprilus alepidotus*
Hogchoker	*Trinectes maculates*
Northern kingfish	*Menticirrhus saxatilis*
Northern puffer	*Sphoeroides maculatus*
Northern searobin	*Prionotus carolinus*
Oyster toadfish	*Opsanus tau*
Silver perch	*Bairdiella chrysoura*
Southern kingfish	*Menticirrhus americanus*
Striped bass	*Morone saxatilis*
Striped burrfish	*Chilomycterus schoepfi*
White perch	*Morone americana*

T able 4. Mean length (mm TL, unless otherwise noted), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993 - 2012.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Weakfish																				
mean length	276	291	306	293	297	337	334	361	334	325	324	273	278	290	275	276	262	253	236	284
std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42	52	22	24	24	48
n	435	642	565	1431	755	1234	851	333	76	196	129	326	304	62	61	42	23	47	26	93
Summer flounder																				
mean length	347	309	297	335	295	339	325	347	358	324	353	327	374	286	341	347	368	374	359	338
std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66	72	64	84	67	130
n	209	845	1669	930	818	1301	1285	1565	854	486	759	577	499	1274	1056	982	277	197	213	161
Bluefish																				
mean length	312	316	323	307	330	343	306	303	307	293	320	251	325	311	318	260	265	297	245	298
std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70	41	43	60	48	77
n	45	621	912	619	339	378	288	398	406	592	223	581	841	1422	1509	2676	1181	493	290	877
Atlantic croaker																				
mean length	233	259	286	294	301	310	296	302	317	279	287	311	317	304	307	298	320	295	281	274
std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54	62	50	34	31	42
n	471	1081	974	2190	1450	1057	1399	2209	733	771	3352	1653	2398	1295	2963	1532	91	1970	1764	1842
Spot																				
mean length	184	207	206	235	190	230	213	230	239	184	216	208	197	191	208	198	185	201	193	179
std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23	21	21	22	18	24
n	309	451	158	275	924	60	572	510	126	681	1354	882	2818	2195	519	1195	33	51	582	1508
Spotted Seatrout																				
mean length		448	452			541	460								414	464	262		361	436
std. dev.		86	42				134								43	72	22		142	112
n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3	10	23	0	4	8
Black Drum																				
mean length		1106	741	353		1074				435	475	780	1130	1031	1144	875	1147	1061	978	997
std. dev.		175	454	20		182				190	20	212		228	95	238	84	345	188	
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5	13	3	3	1

Table 4. Continued.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Red Drum																				
mean length						302	332	648		316	506	647	353	366	658	361			678	318
std. dev.							71			44		468		21	40	57			18	71
n	0	0	0	0	0	1	16	1	0	177	1	2	1	16	2	21	0	0	2	458
Spanish Mackerel (Total Length)																				
mean length	261	391	487	481	520	418	468	455												
std. dev.	114	55	38	55		45	82	66												
n	3	78	39	27	1	4	45	35												
Spanish Mackerel (Fork Length)																				
mean length			418	401	437	379		386	406	422	405	391	422	439	436	407	418			393
std. dev.			34	62				34	34	81	63	95	33	35	51	59	53			74
n			44	27	1	1		49	19	20	11	8	373	445	158	18	7	0	0	107
Menhaden (Fork Length)																				
mean length												262	282	238	243	246	245	232	213	243
std. dev.												28	36	42	41	29	40	36	39	25
n												213	1052	826	854	826	366	836	773	755

Table 5. Relative stock density of weakfish from Chesapeake Bay summer onboard pound net survey, 1993 - 2012.

Year	Stock	Quality	Preferred	Memorable	Trophy
1993	89	10	1	<1	
1994	90	9	1		<1
1995	74	23	3		
1996	77	22	1		
1997	90	9	1		
1998	58	39	2	<1	
1999	61	33	5	<1	
2000	48	29	20	2	
2001	58	35	5	1	
2002	73	18	8		<1
2003	67	30	2	<1	
2004	96	3	1		
2005	94	5	1		
2006	95	5			
2007	94	3	3		
2008	90	5	5		
2009	100				
2010	100				
2011	100				
2012	87	11	2		

Table 6. Percentage of weakfish by age and year, number of age samples and number of length samples by year, using pound net length and age data 2003-2012.

Year	Age 1	Age 2	Age 3	Age 4	# of Ages	# of Lengths
2003	8.81	72.57	15.69	2.94	48	129
2004	55.90	39.20	4.90		59	326
2005	39.80	55.20	4.80	0.30	109	304
2006	70.10	22.20	7.60	0.10	62	62
2007	67.80	24.20	7.90	0.10	61	61
2008	85.71	7.14	7.14		41	42
2009	77.27	22.73			22	22
2010	100.00				45	47
2011	80.77	15.38			26	27
2012	54.18	42.34	3.47		71	93

Table 7. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2012.

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Weakfish	0.74	0.4	0.62	0.58	0.73	1.29	1.44	1.35	*	*	*	*	*	*
Atlantic croaker	0.45	0.46	0.36	0.36	0.52	0.42	0.35	0.30	0.37	0.37	0.52	0.67	0.81	0.80

* Insufficient data to calculate 2007 - 2012 weakfish estimates.

Table 8. Relative stock density of summer flounder from Chesapeake Bay summer onboard pound net survey, 1993 - 2012.

Year	Stock	Quality	Preferred	Memorable	Trophy
1993	29	56	16		
1994	24	56	20	<1	
1995	68	25	6	1	
1996	25	61	13	1	
1997	47	39	14		
1998	30	57	12	<1	
1999	42	50	8	<1	
2000	22	66	12	<1	
2001	20	61	19	<1	
2002	41	35	24	<1	
2003	21	63	15	<1	
2004	23	55	21	1	
2005	20	46	33	1	
2006	57	29	14	<1	
2007	40	44	16	<1	
2008	31	47	21	1	
2009	24	43	32	<1	
2010	29	35	34	3	
2011	28	47	24	1	
2012	19	25	55	1	

Table 9. Relative stock density of bluefish from Chesapeake Bay summer onboard pound net survey, 1993 - 2012.

Year	Stock	Quality	Preferred	Memorable	Trophy
1993	90	10			
1994	97	3			
1995	98	2			
1996	97	3			
1997	96	4			<1
1998	89	6	4		
1999	92	8	<1		
2000	99	1			
2001	98	2			
2002	100	<1			
2003	96	4			
2004	99	1			
2005	79	20	1		
2006	95	5	<1		
2007	94	3	3	<1	
2008	99	1			
2009	100	<1		<1	
2010	98	2	<1		
2011	100				
2012	92	8	<1		

Table 10. Relative stock density of Atlantic croaker from Chesapeake Bay summer onboard pound net survey, 1993 - 2012.

Year	Stock	Quality	Preferred	Memorable	Trophy
1993	6	72	19	2	
1994	<1	48	42	9	<1
1995	1	21	48	28	2
1996	0	4	66	29	1
1997	7	9	32	52	1
1998	0	7	42	48	3
1999	<1	28	25	42	4
2000	0	11	49	35	5
2001	0	2	38	56	4
2002	19	14	17	47	2
2003	<1	43	17	36	3
2004	<1	3	52	39	5
2005	<1	11	26	55	7
2006	1	24	16	51	8
2007	0	17	37	37	9
2008	6	21	25	41	6
2009	0	9	30	52	10
2010	0	10	53	36	1
2011	0	18	63	19	<1
2012	3	25	50	21	1

Table 11. 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, 1999-2012.

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	0.0	34.0	22.5	3.3	9.4	4.2	16.0	6.0	4.2	0.4					180	1,399
2000	0.0	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	0.0	3.0	0.5	0.6				66	771
2003	0.0	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	0.0	0.6	54.9	5.0	5.4	6.9	23.3	3.1	0.0	0.2	0.0	0.6			161	1,653
2005	0.0	10.1	4.8	51.5	7.6	1.5	7.3	11.4	5.6	0.0	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	0.0	0.0	0.0	0.1	253	1,295
2007	0.0	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	0.0	30.9	8.5	37.4	11.1	7.8	1.8	2.2	0.3						222	1,381
2010	0.0	1.2	25.7	8.7	36.5	15.8	9.4	0.9	1.3	0.3	0.0	0.3			267	2,516
2011	0.0	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

Table 12. 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, 2007-2012.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Ages	Lengths
2007	21.26	75.03	3.32	0.00	0.39	98	519
2008	20.77	78.62	0.61	0.00	0.00	206	1201
2009	7.75	90.70	1.55	0.00	0.00	232	614
2010	5.87	90.12	4.01	0.00	0.00	91	300
2011	0.37	99.39	0.23	0.01	0.00	173	582
2012	39.46	59.80	0.74	0.00	0.00	230	1408

Table 13. 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, 2005-2012.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	# Aged	# Measured
2005		2.74	25.86	42.61	25.64	3.15			345	1,061
2006		40.44	28.27	18.36	9.70	2.62	0.60		289	826
2007		22.64	37.44	24.70	10.72	3.95	0.55		379	854
2008		16.60	44.55	29.36	7.27	1.94	0.28		385	826
2009	0.40	16.79	24.92	38.04	17.15	2.72			258	512
2010		42.98	30.61	14.93	8.26	2.50	0.60		388	836
2011		38.03	31.41	19.88	9.12	1.57			392	773
2012		14.51	56.74	21.45	4.26	1.80	0.77	0.48	355	755

Figure 1. Summer sampling area map for 2012.

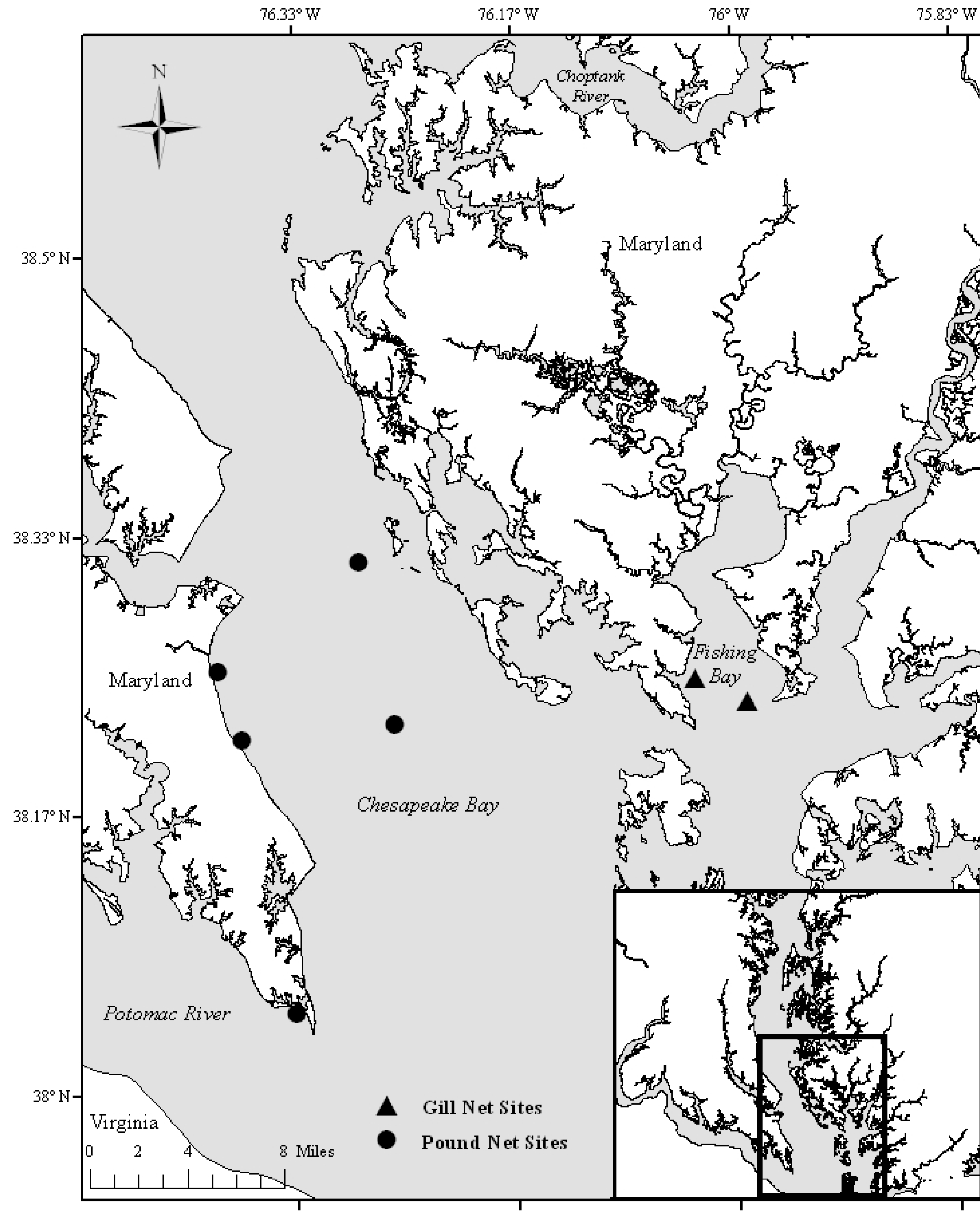


Figure 2. Weakfish length frequency distributions from onboard pound net sampling, 2009-2012.

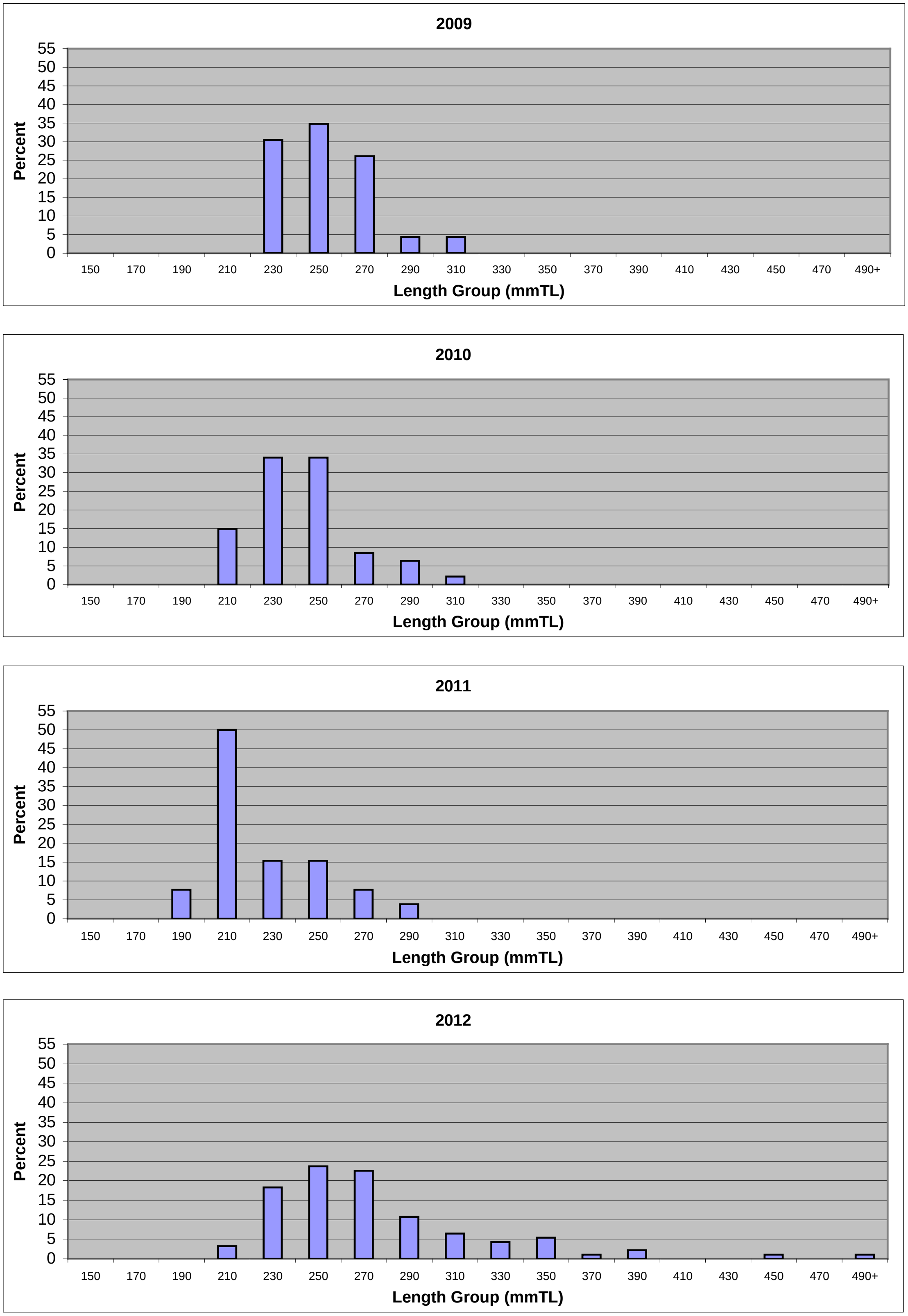


Figure 3. Maryland commercial weakfish harvest by area, 1929-2011.

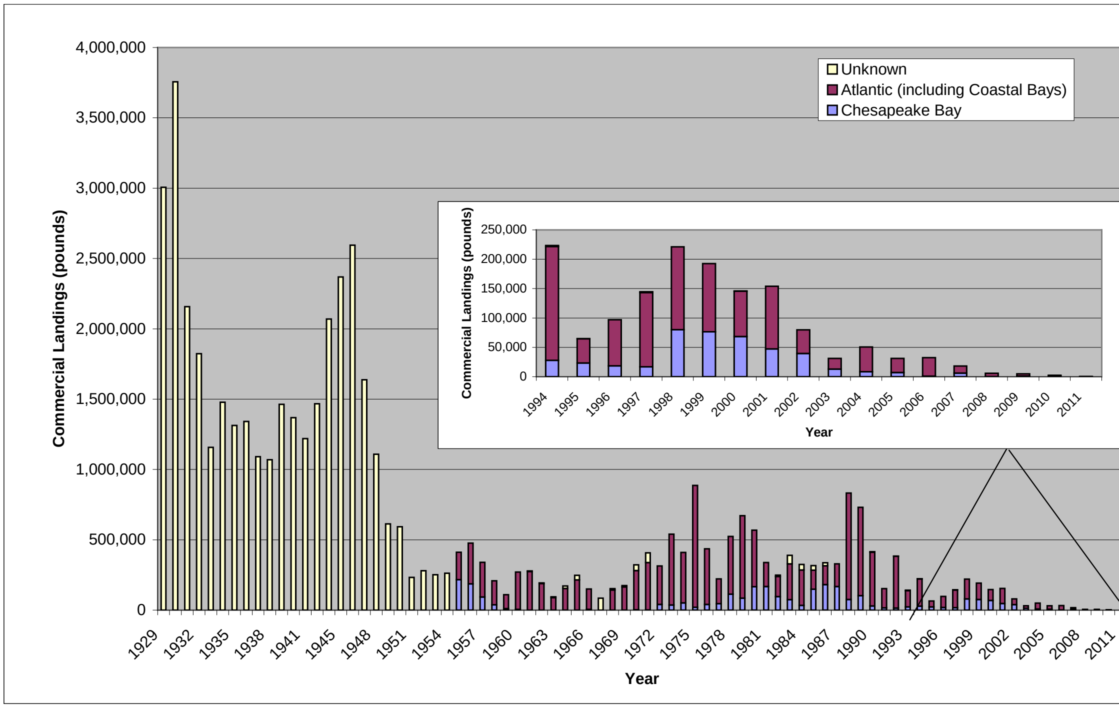


Figure 4. Maryland commercial weakfish harvest in the Chesapeake Bay, 1955-2011.

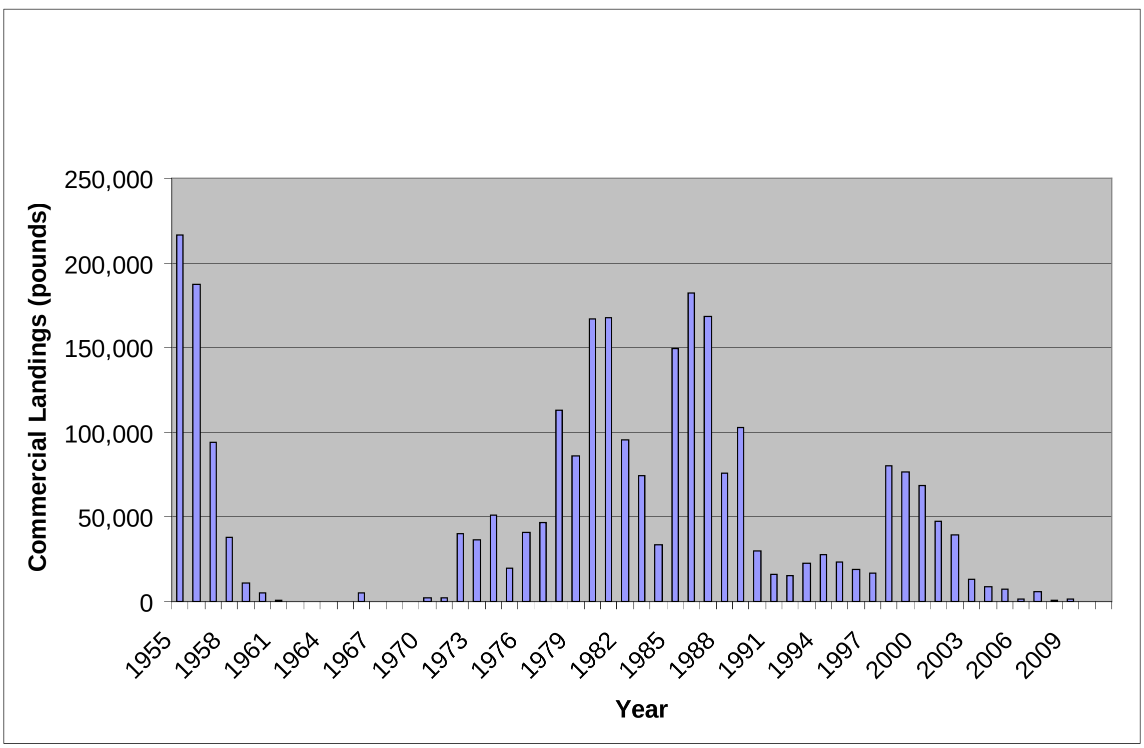


Figure 5. Estimated Maryland recreational weakfish harvest and releases for 1981-2011 (Source: MRIP, 2013).

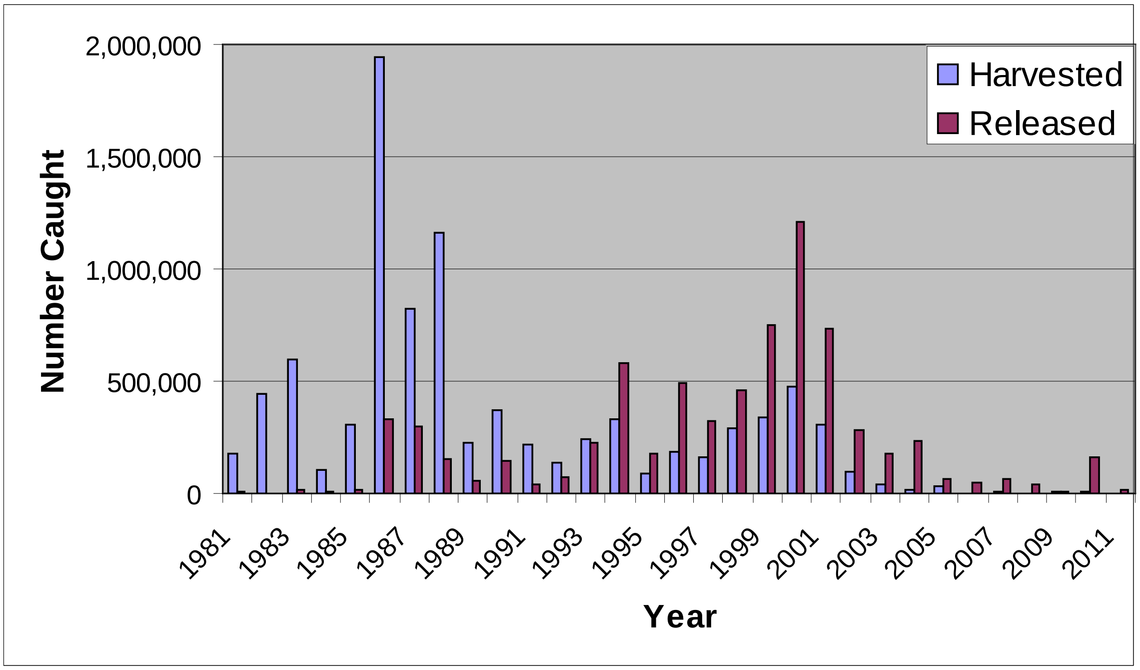


Figure 6. Weakfish statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2011.

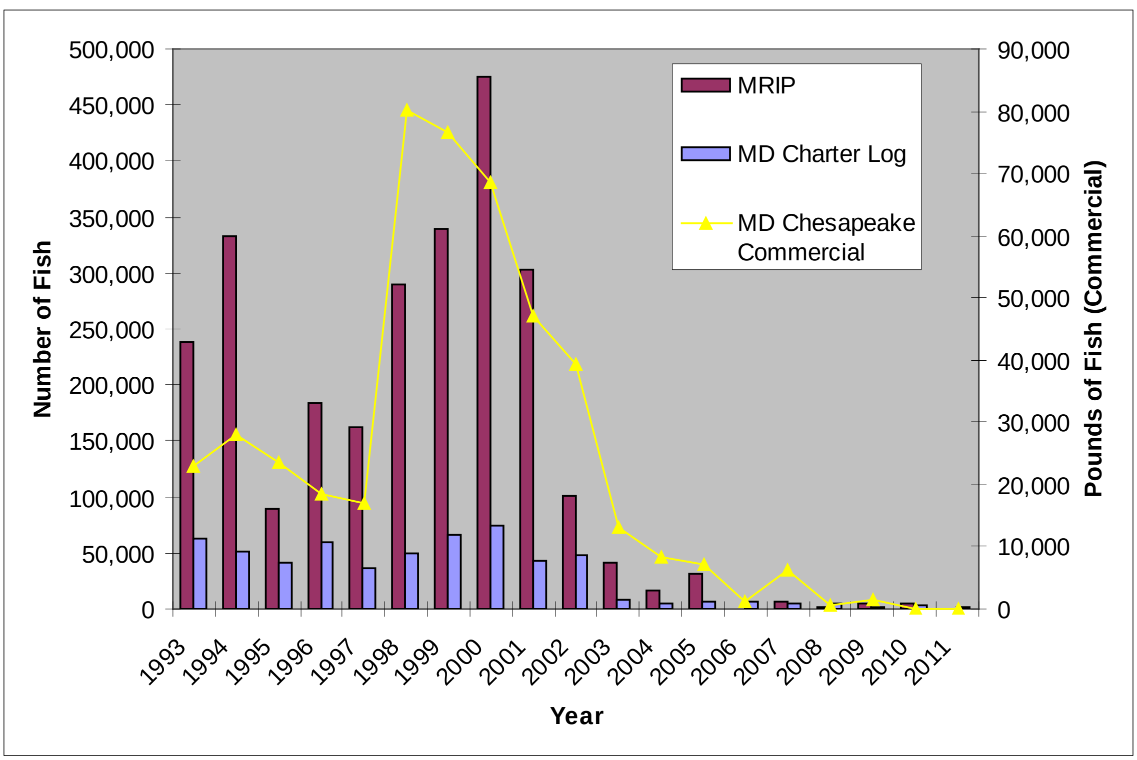


Figure 7. Weakfish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2011.

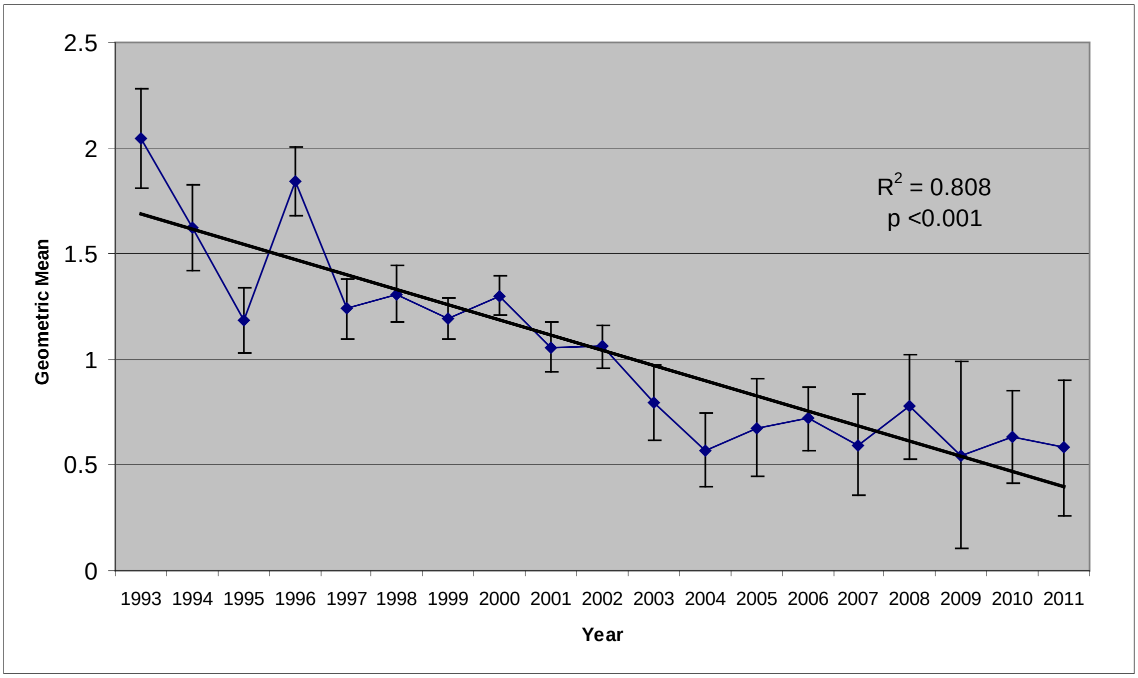


Figure 8. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2012.

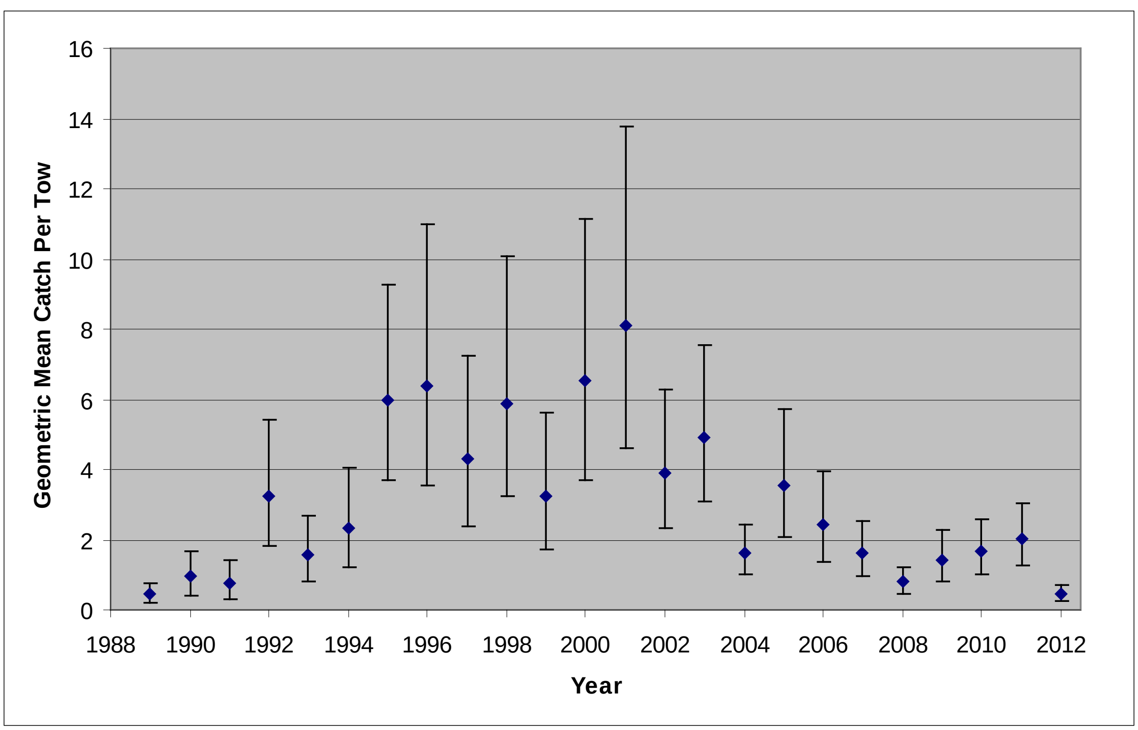


Figure 9.   Summer flounder length frequency distributions from onboard pound net sampling, 2009-2012.

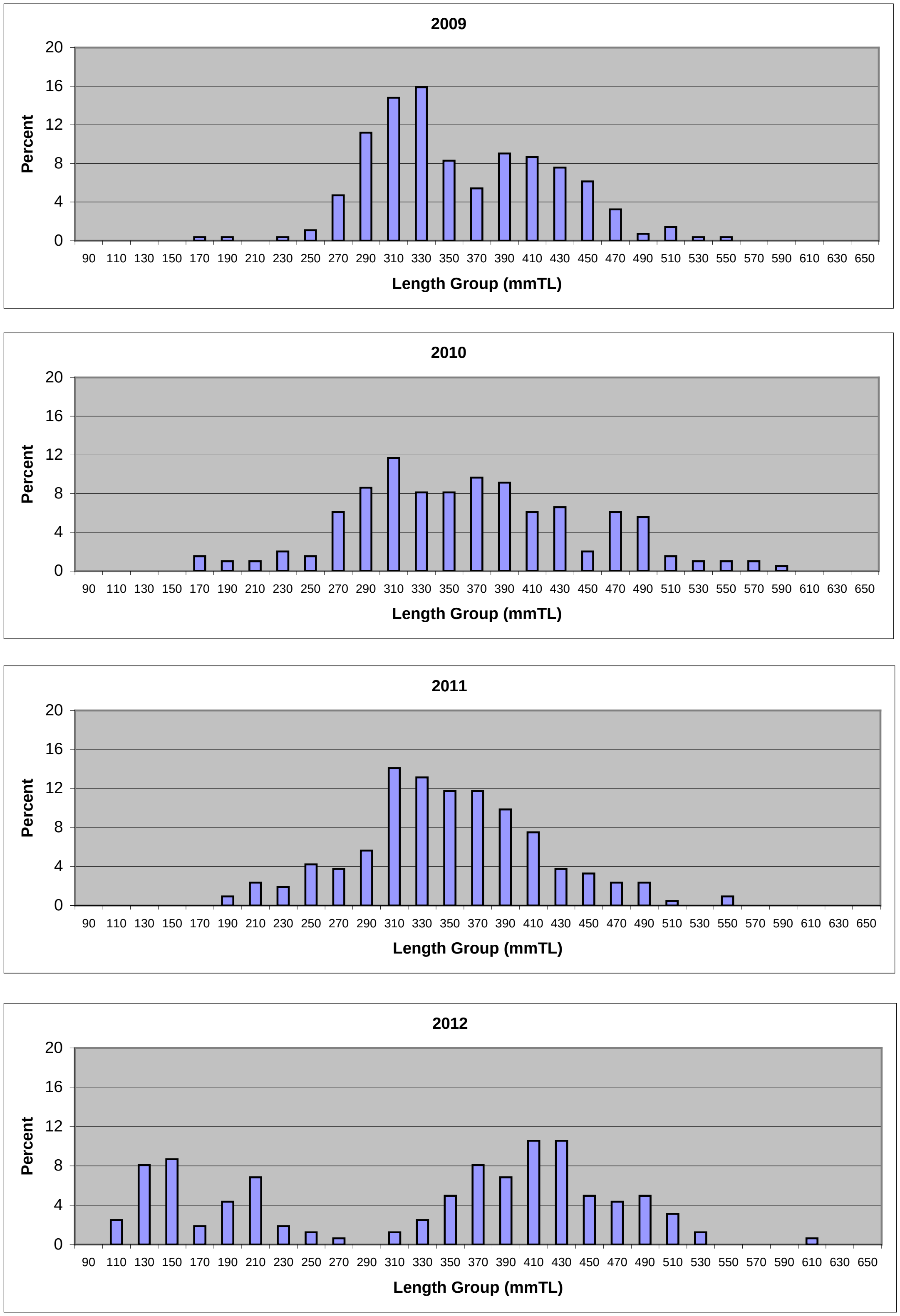


Figure 10. Maryland commercial summer flounder harvest by area, 1962-2011.

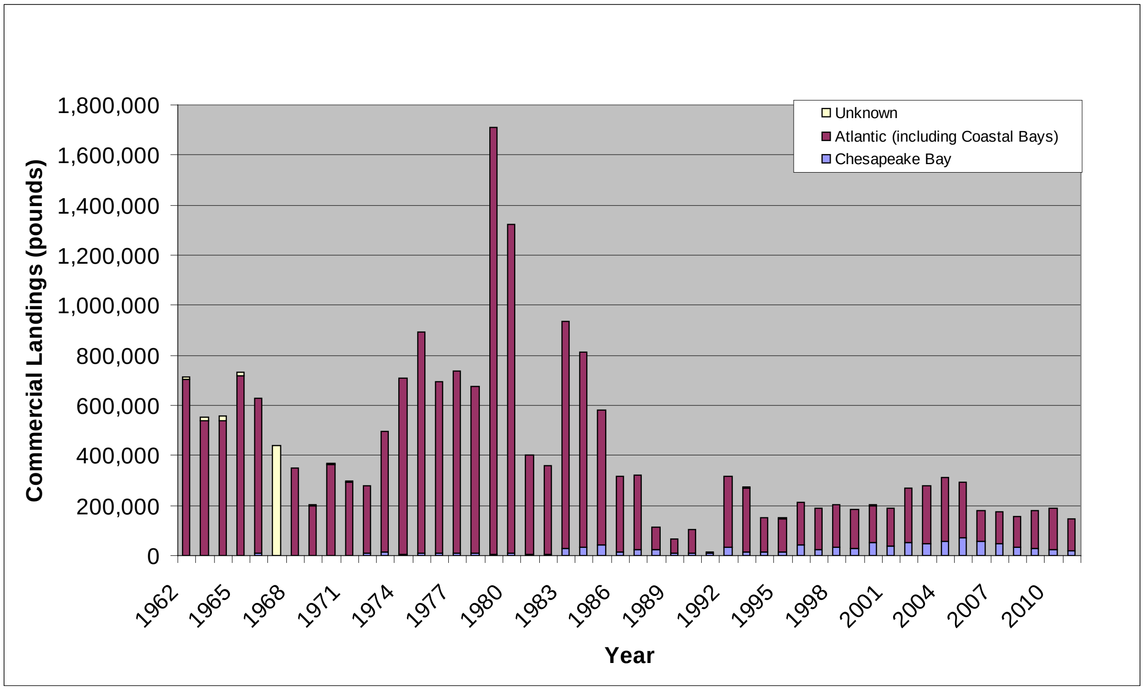


Figure 11. Maryland commercial summer flounder harvest in the Chesapeake Bay, 1962-2011.

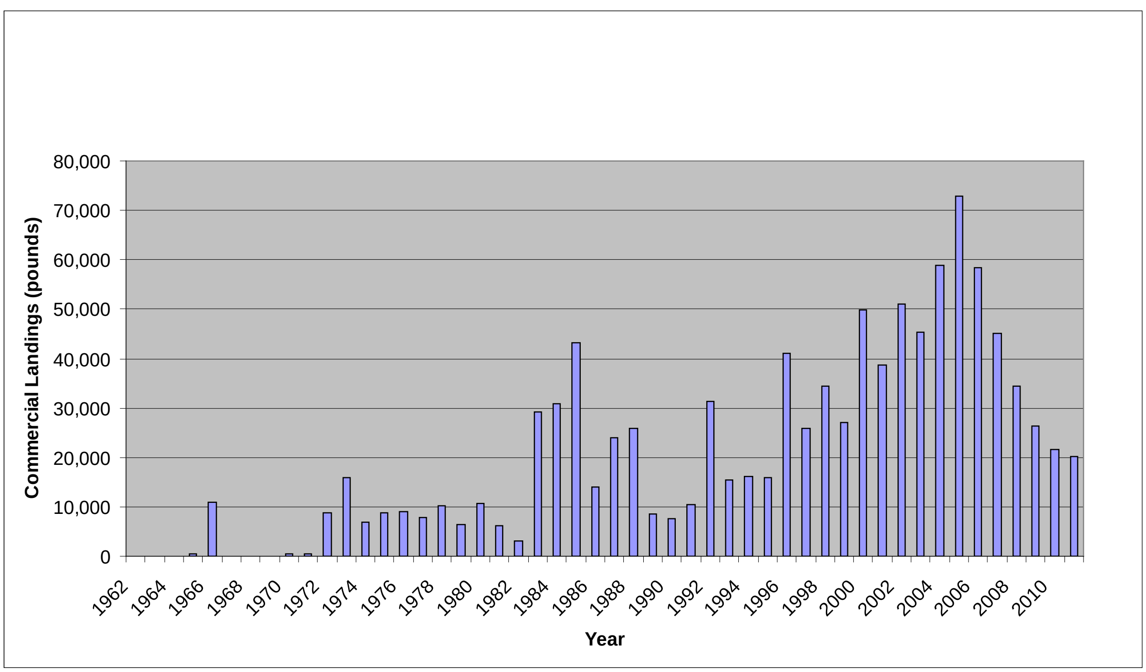


Figure 12. Estimated Maryland recreational summer flounder harvest and releases for 1981-2011 (Source: MRIP, 2013).

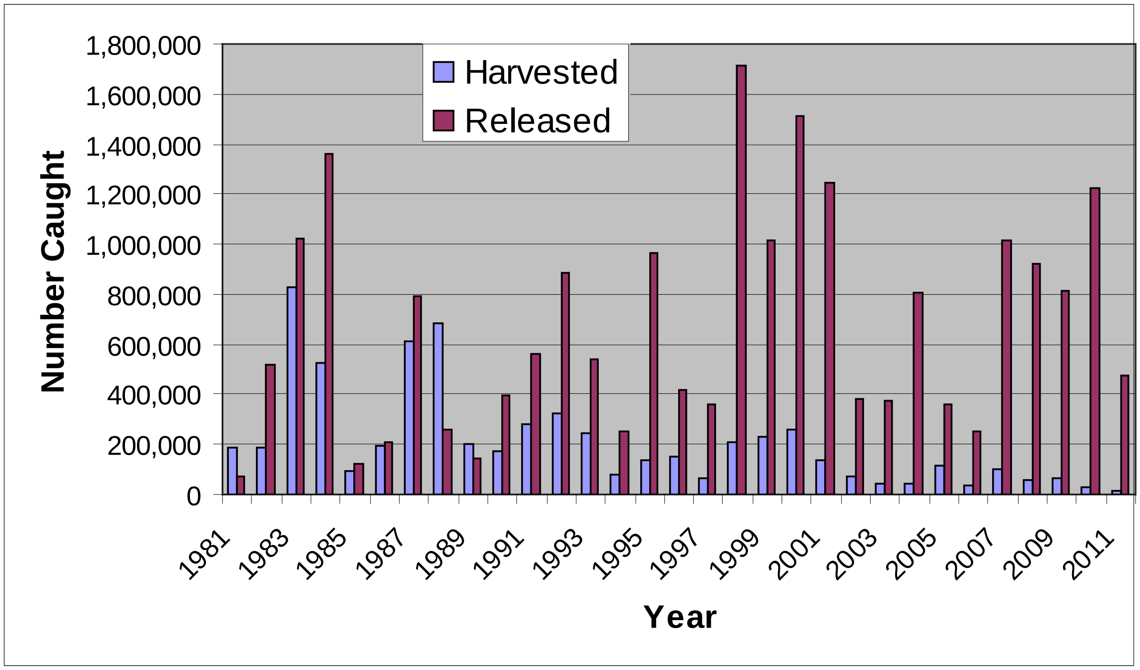


Figure 13. Summer Flounder statewide MRIP harvest and reported charter boat harvest from Maryland logbooks in numbers, 1993-2011.

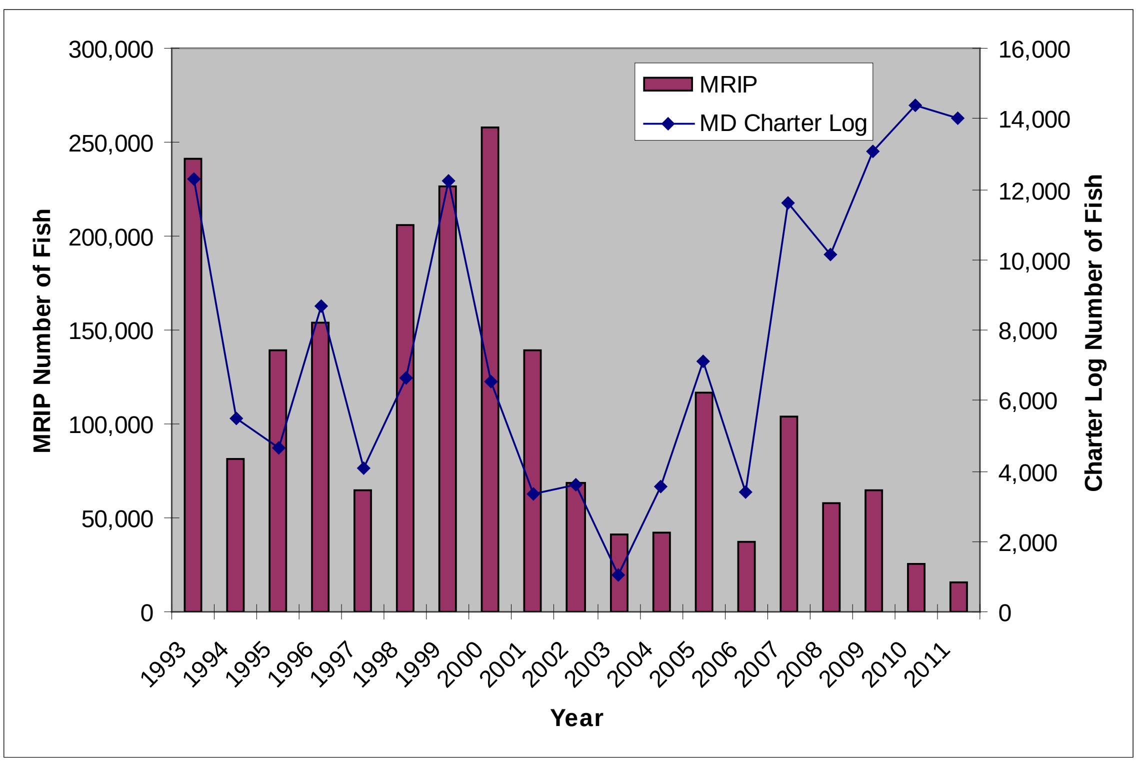


Figure 14. Summer flounder geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2011.

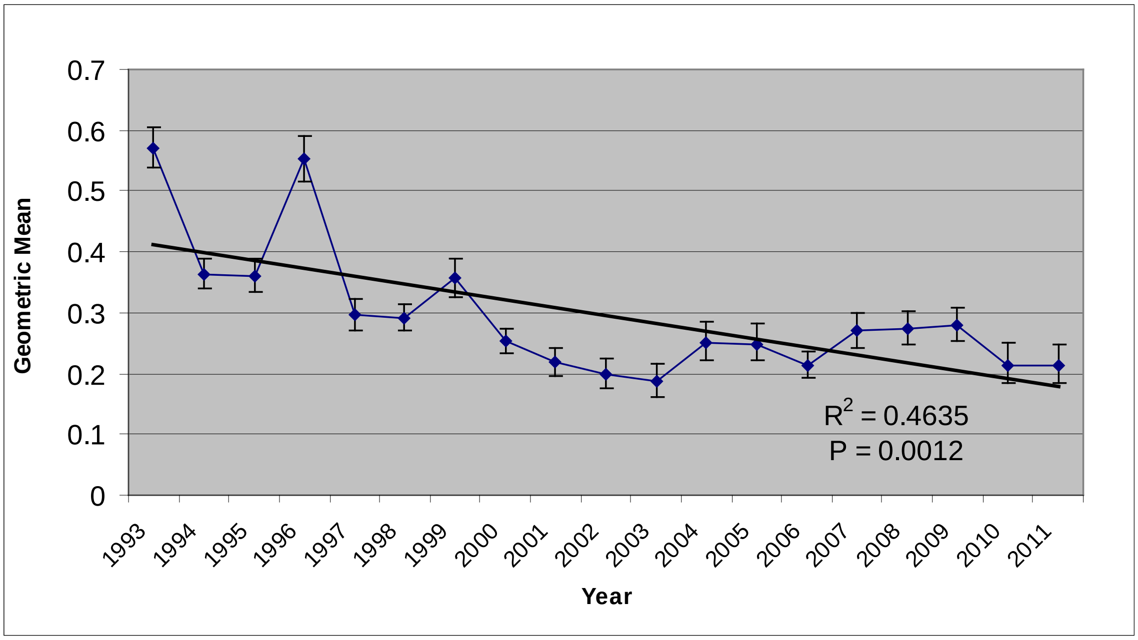
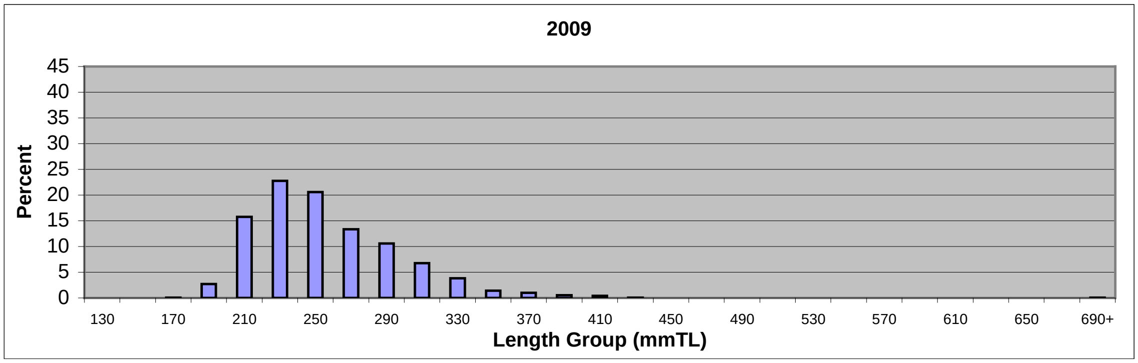
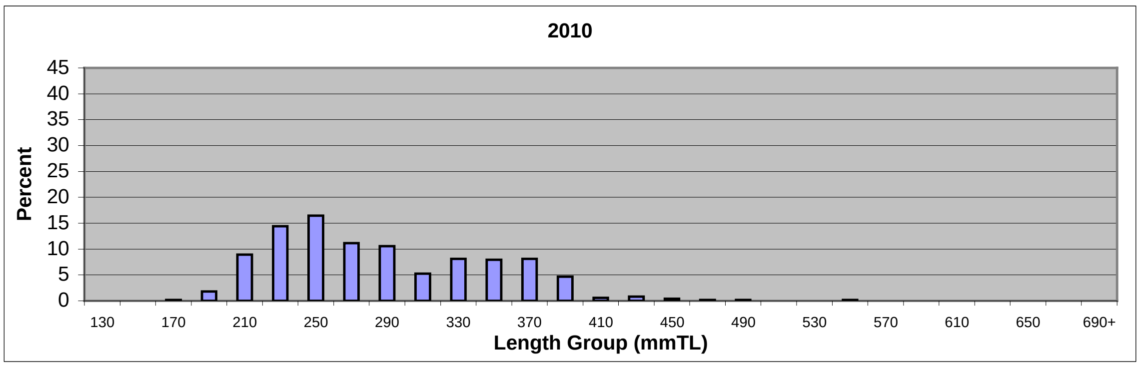
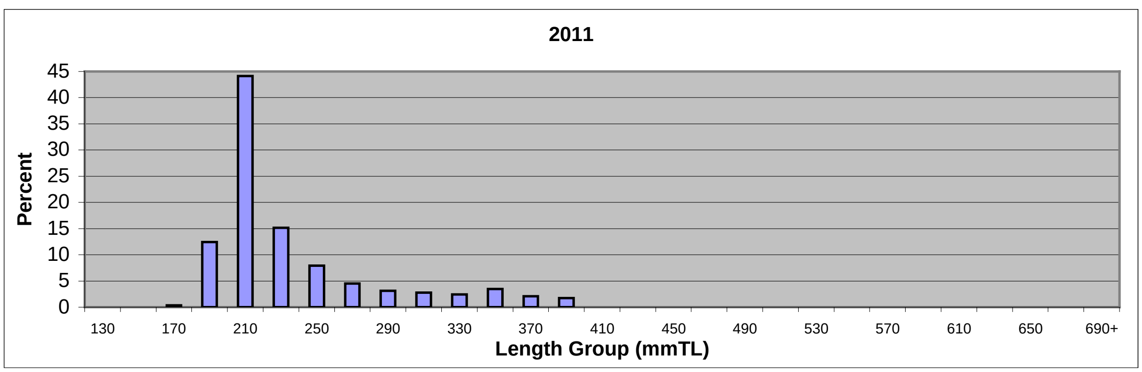


Figure 15. Bluefish length frequency distributions from onboard pound net sampling, 2009-2012.







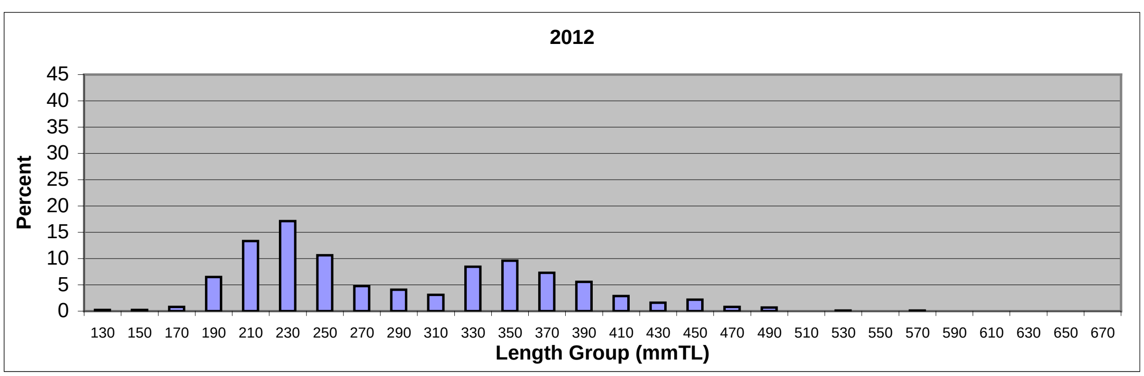


Figure 16. Maryland commercial bluefish harvest by area, 1929-2011.

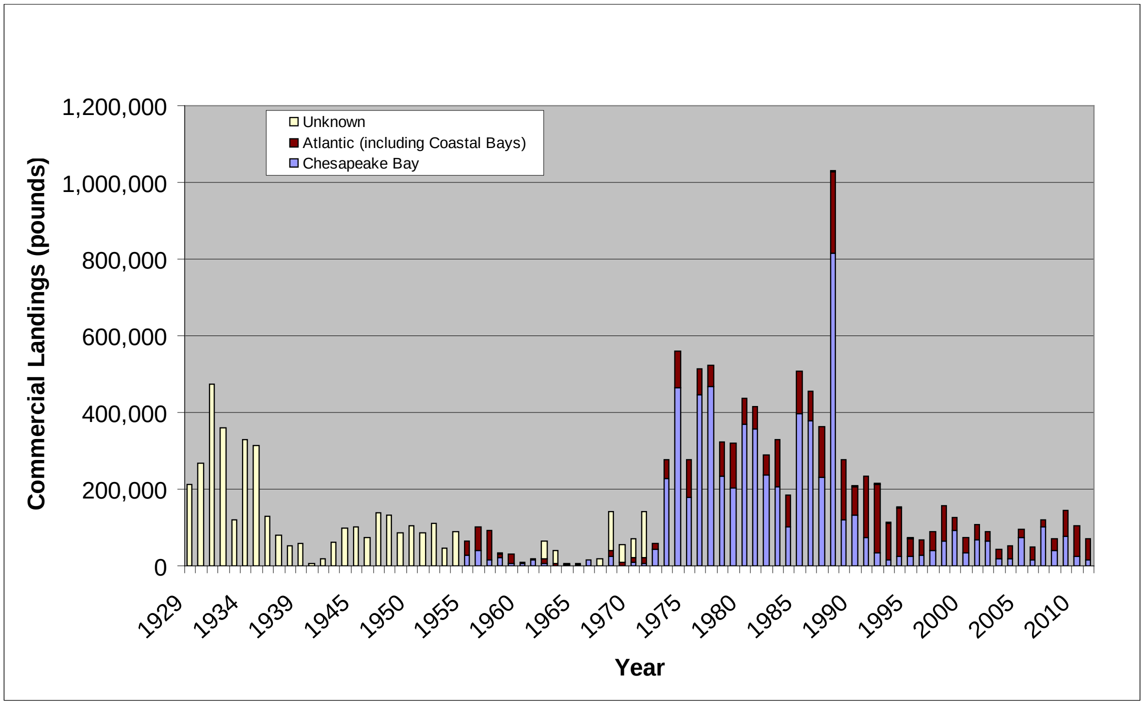


Figure 17. Estimated Maryland recreational bluefish harvest and releases for 1981-2011 (Source: MRIP, 2013).

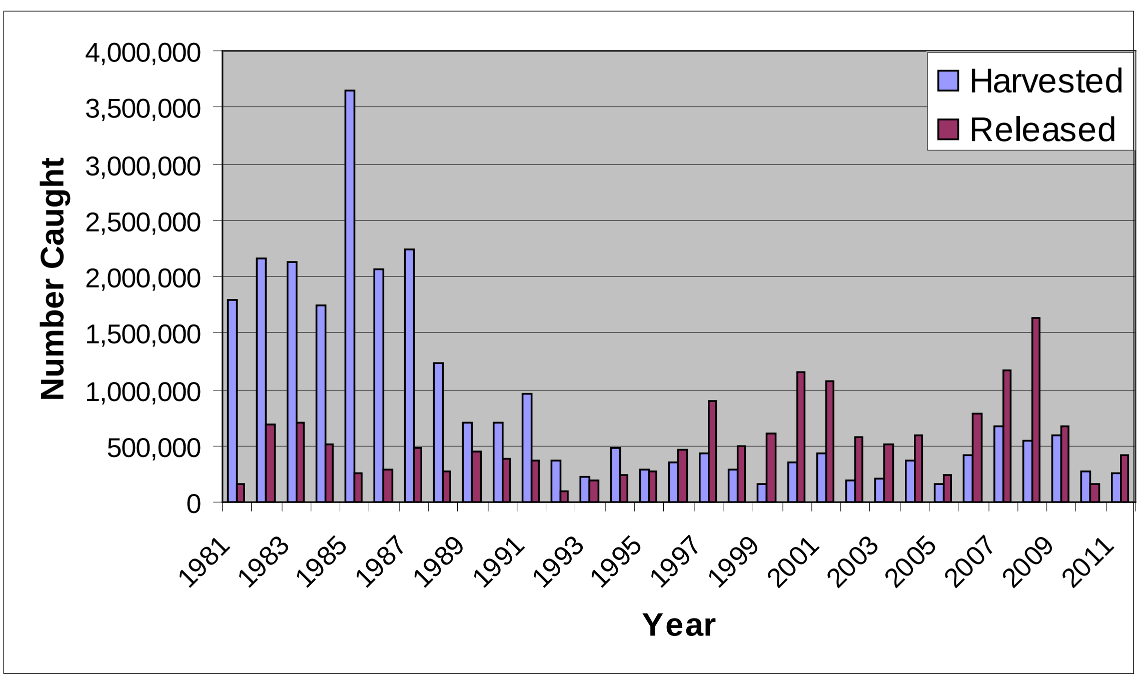


Figure 18. Bluefish statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2011.

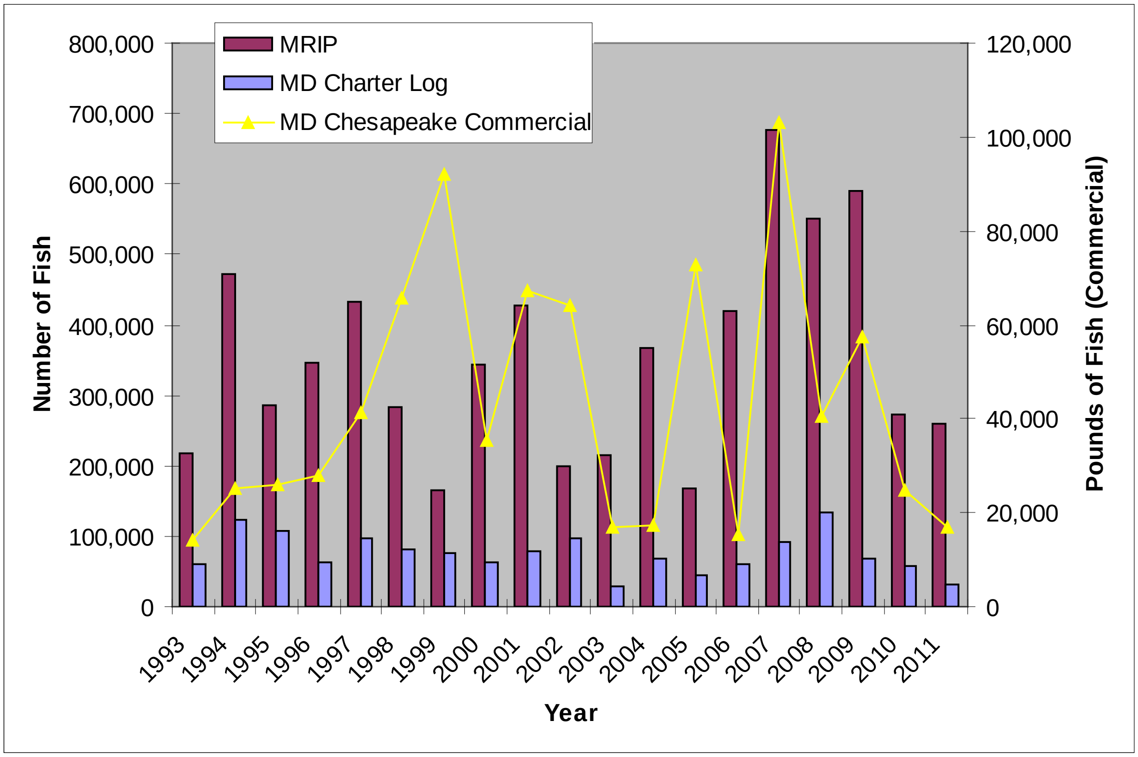


Figure 19. Bluefish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2011.

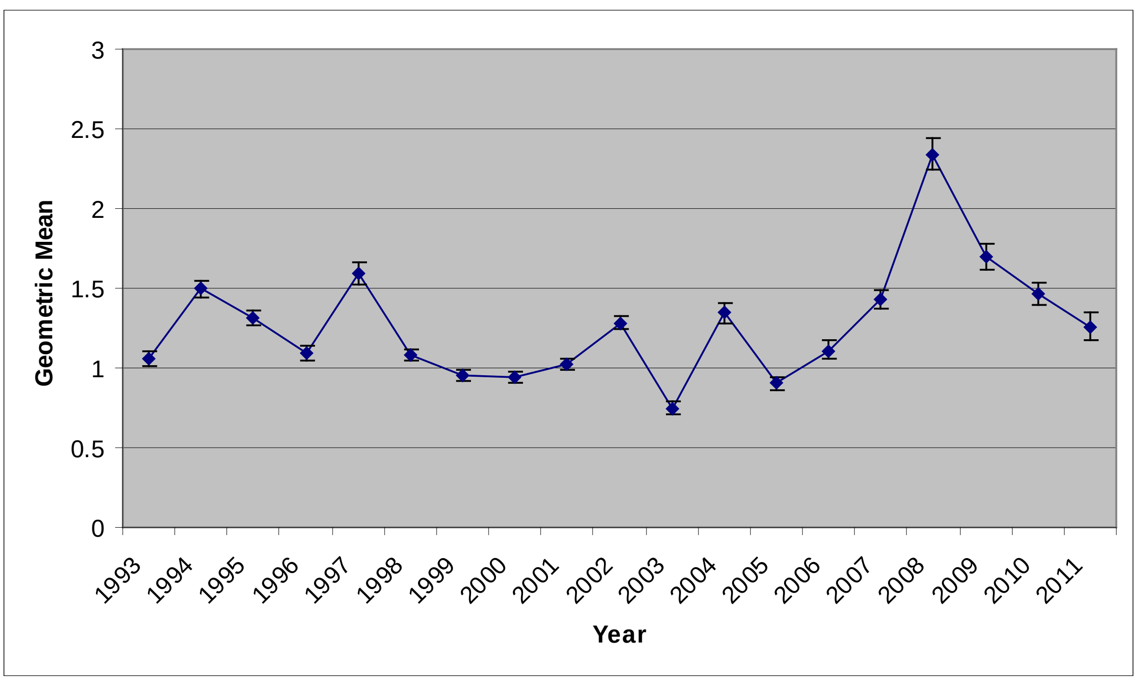


Figure 20. Atlantic croaker length frequency distributions from onboard pound net sampling, 2009-2012.

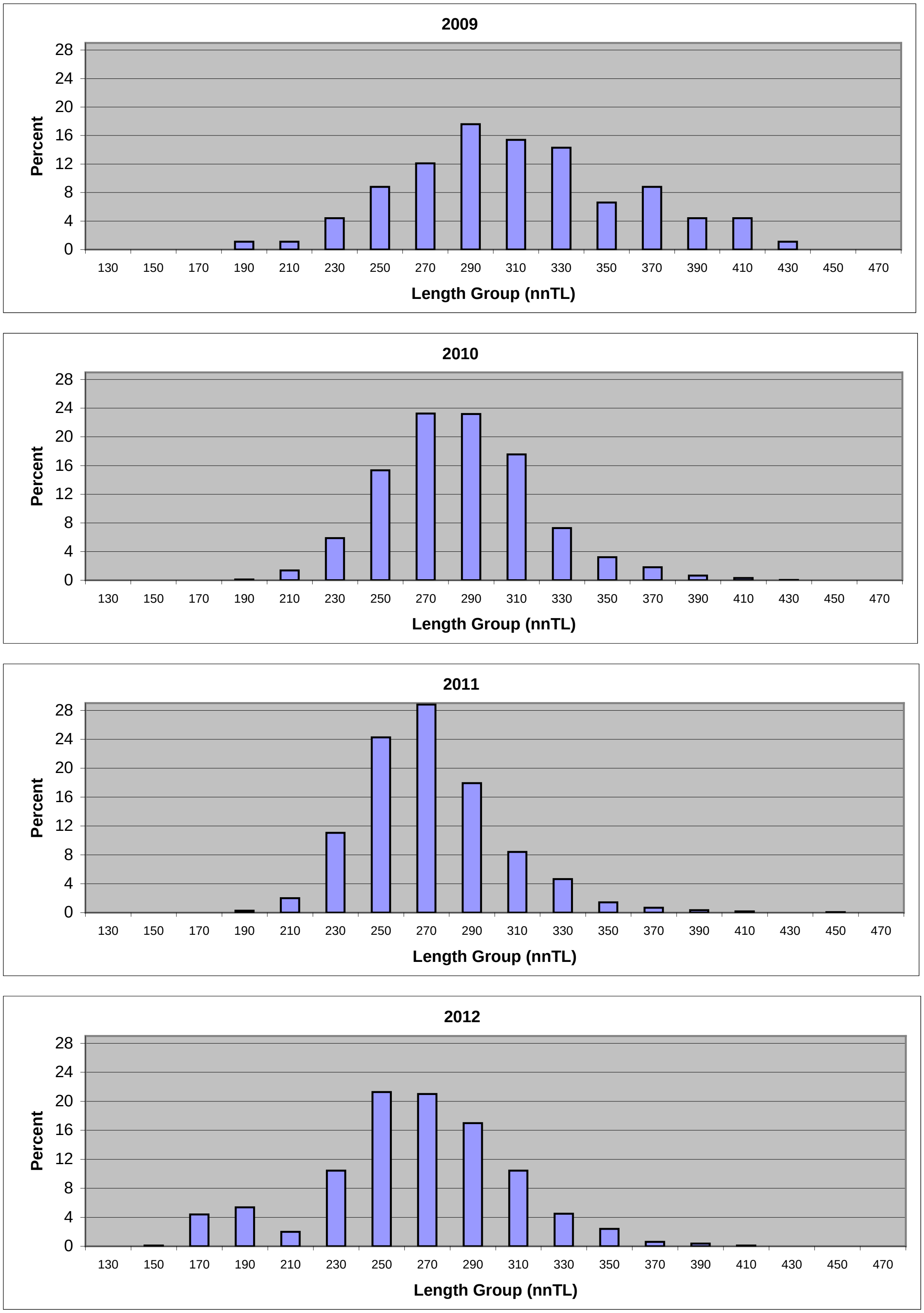


Figure 21. Atlantic croaker length frequency distribution from onboard gill net sampling for 2012.

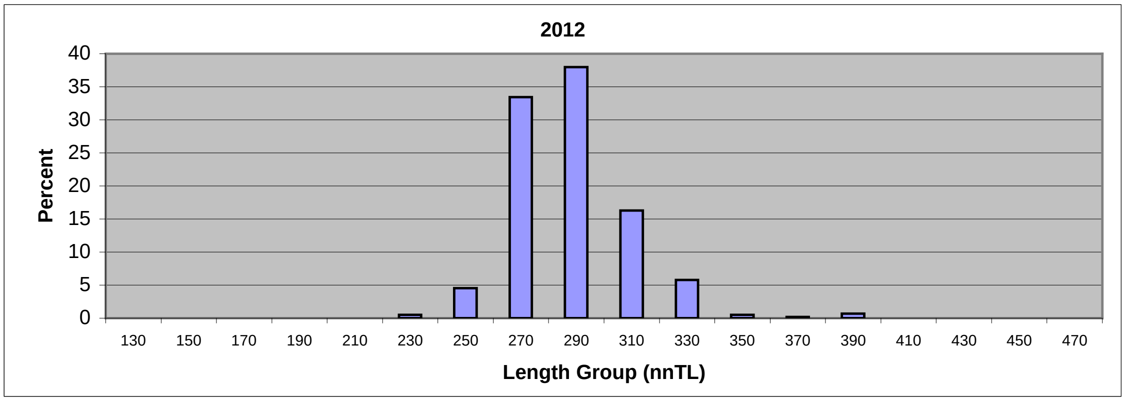


Figure 22. Maryland commercial Atlantic croaker harvest by area, 1929-2011.

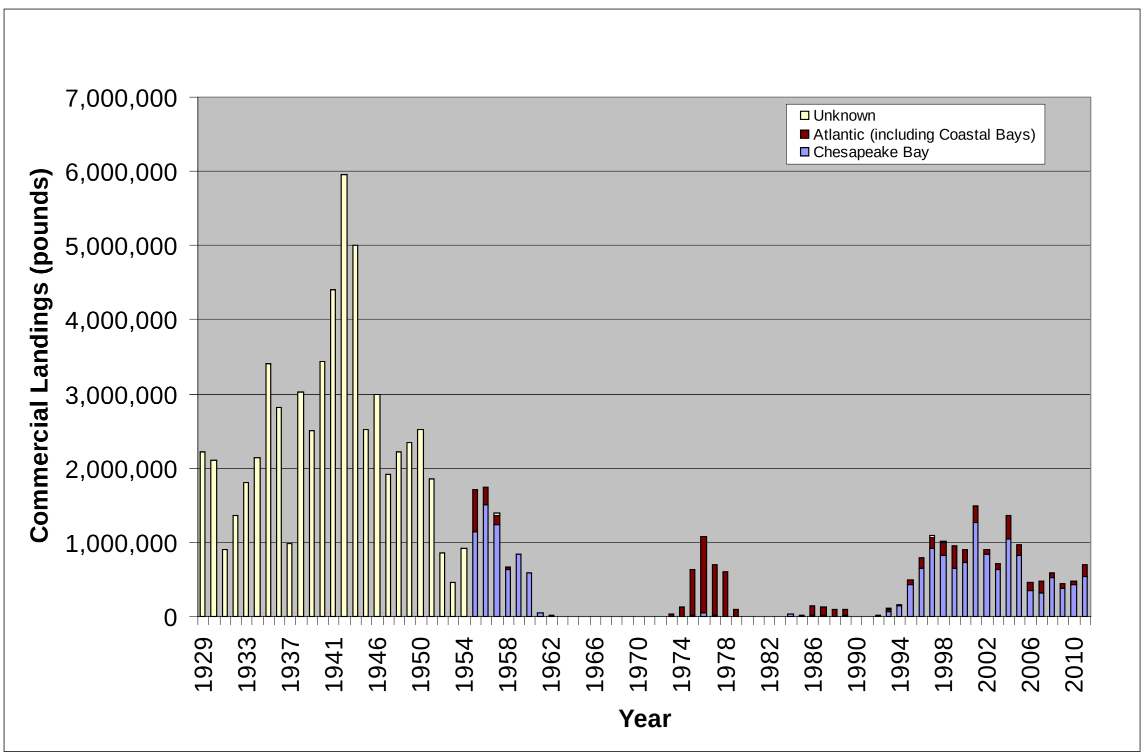


Figure 23. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2011 (Source: MRIP, 2013).

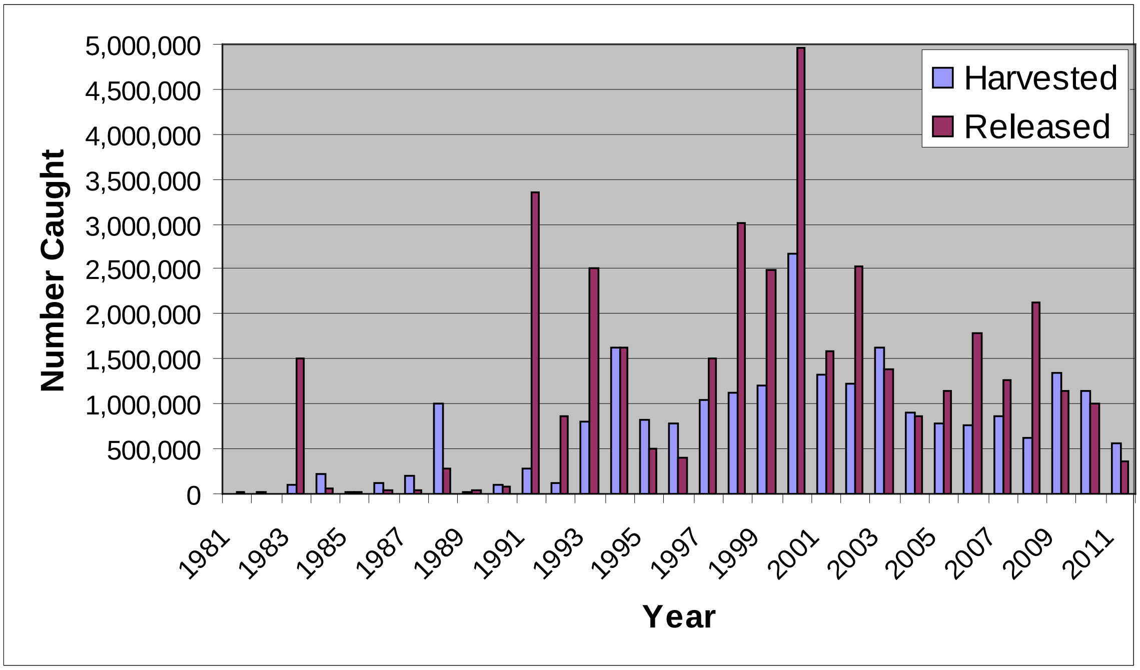


Figure 24. Atlantic croaker statewide MRIP harvest, MRIP for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2011.

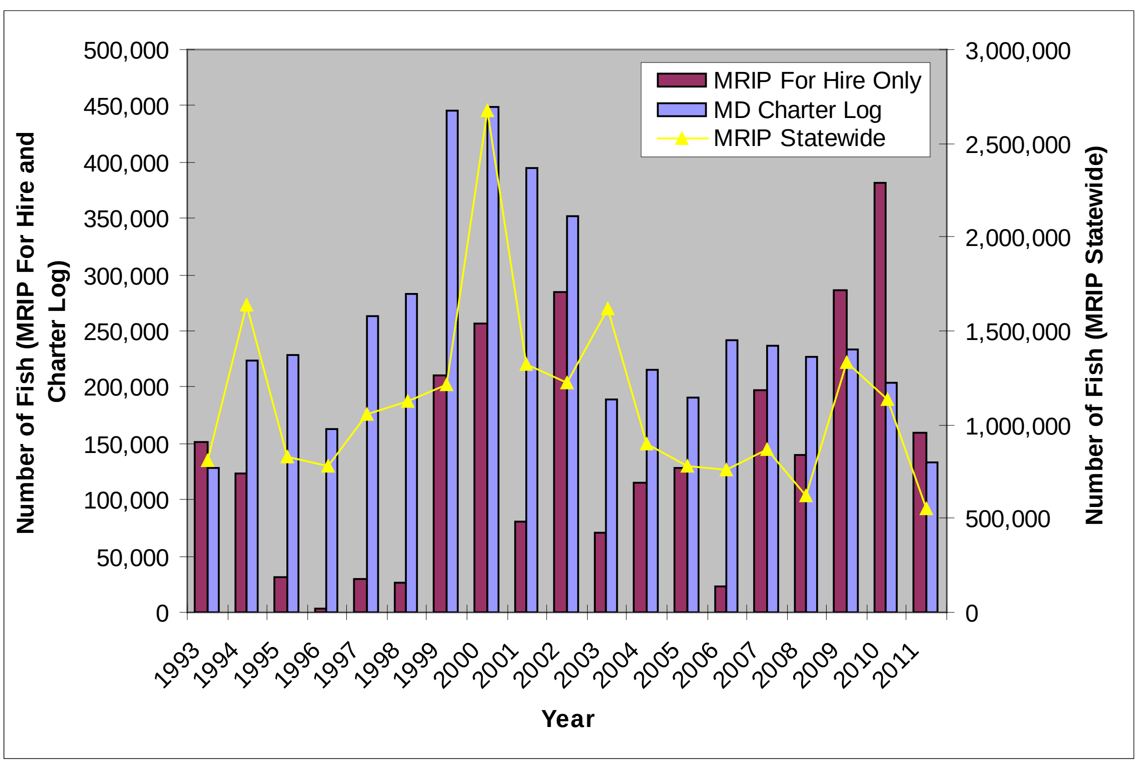


Figure 25. Atlantic croaker geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2011.

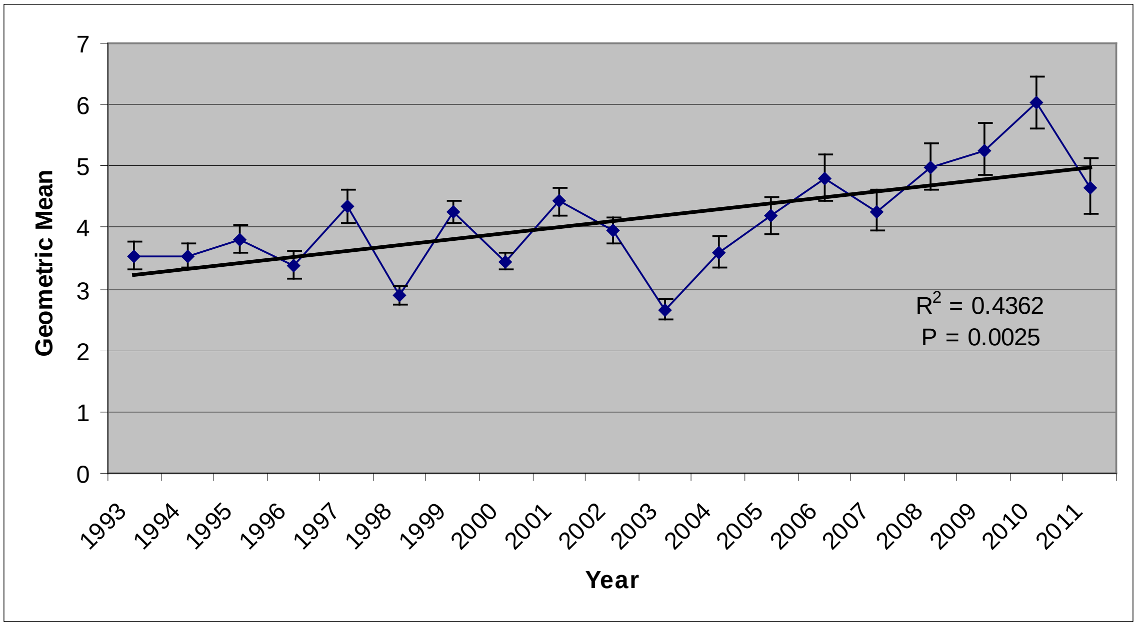


Figure 26. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2012. 1998 data point was omitted for scale (GM 1998 = 30.05 -9.02, +12.72).

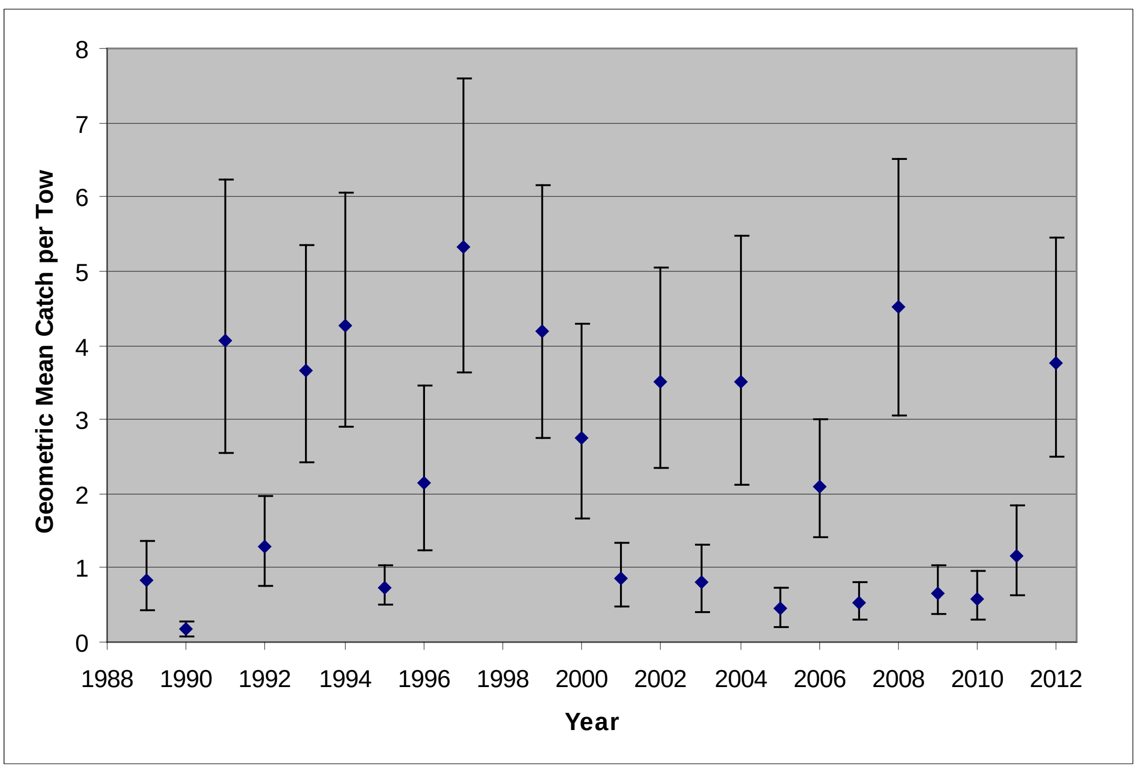


Figure 27. Spot length frequency distributions from onboard pound net sampling, 2009-2012.

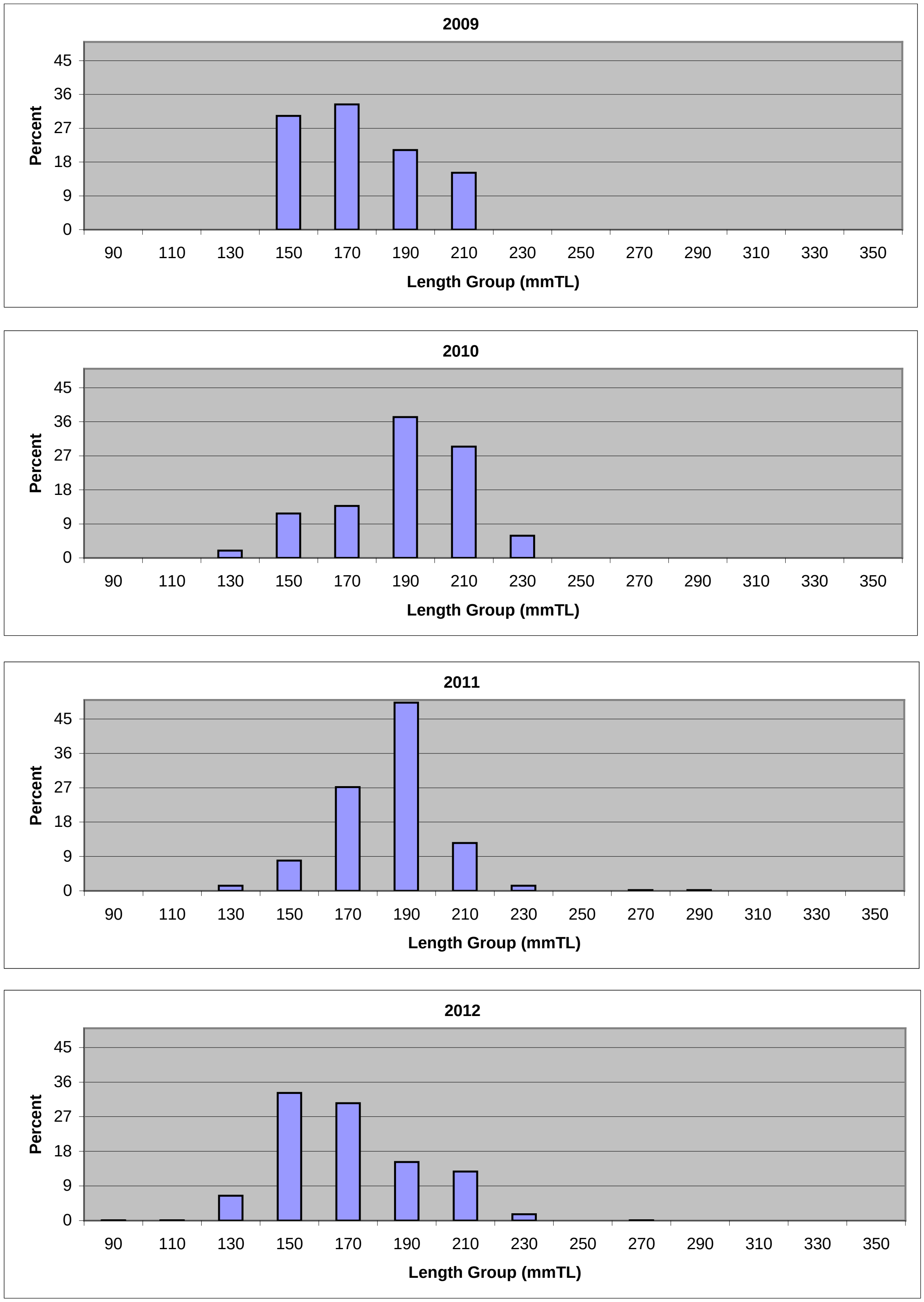


Figure 28. Maryland commercial spot harvest by area, 1929-2011.

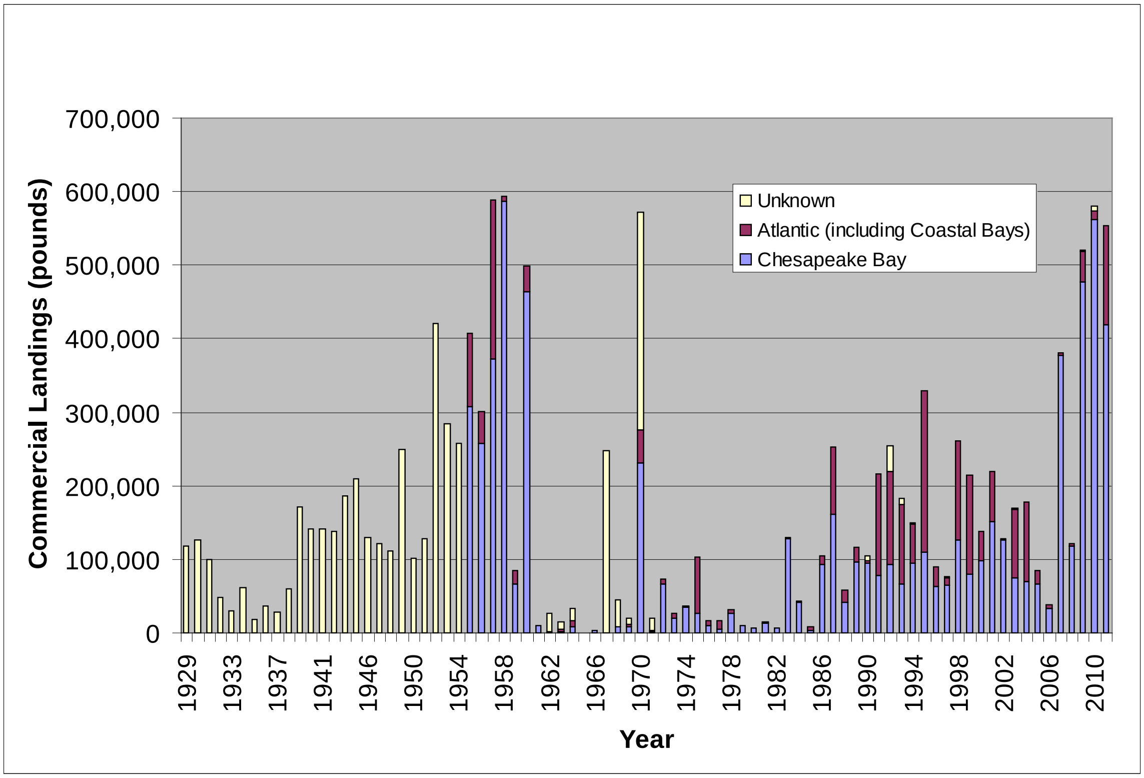


Figure 29. Estimated Maryland recreational spot harvest and releases for 1981-2011 (Source: MRIP, 2013).

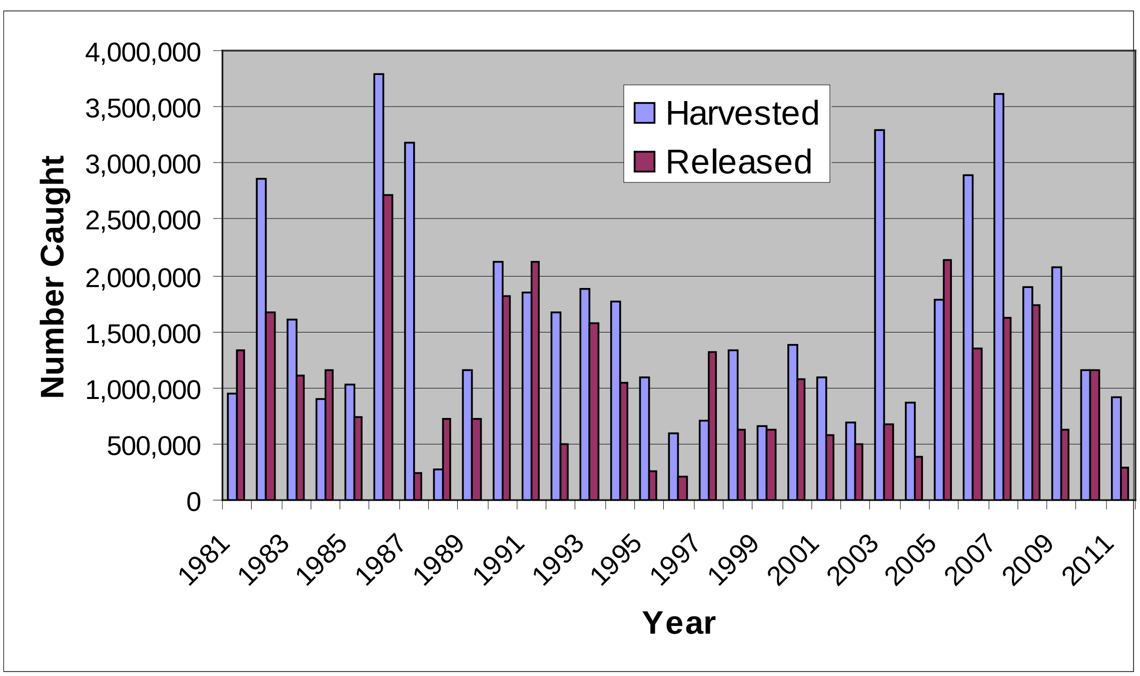


Figure 30. Spot statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2011.

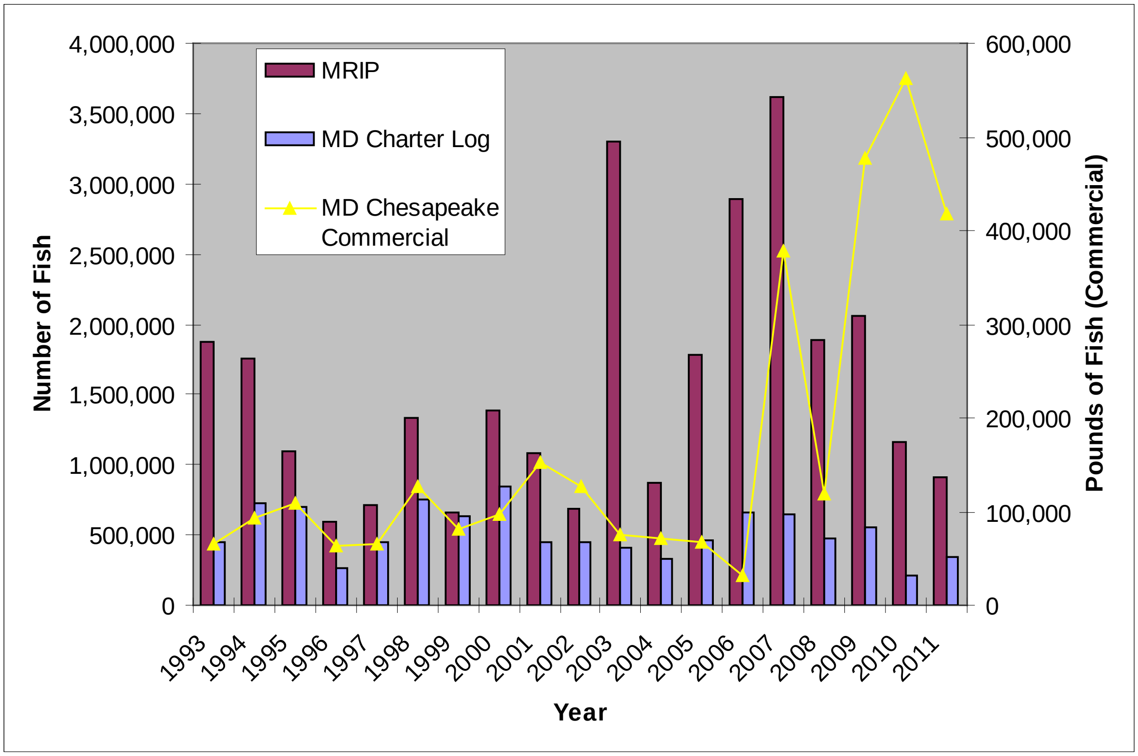
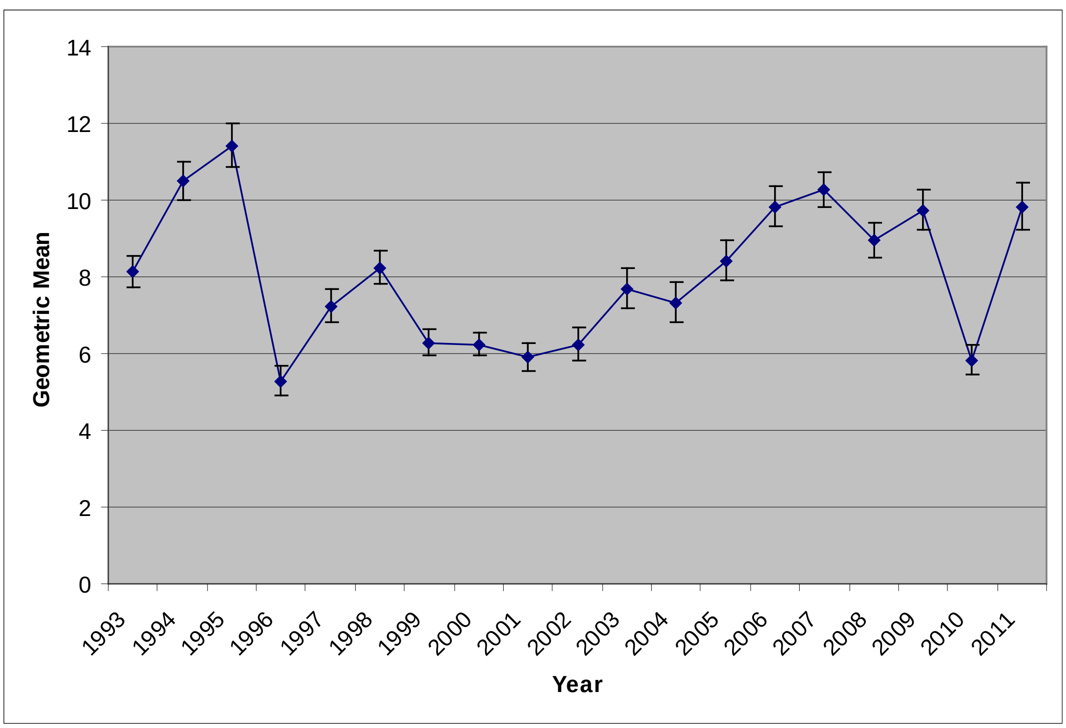


Figure 31. Spot geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2011.



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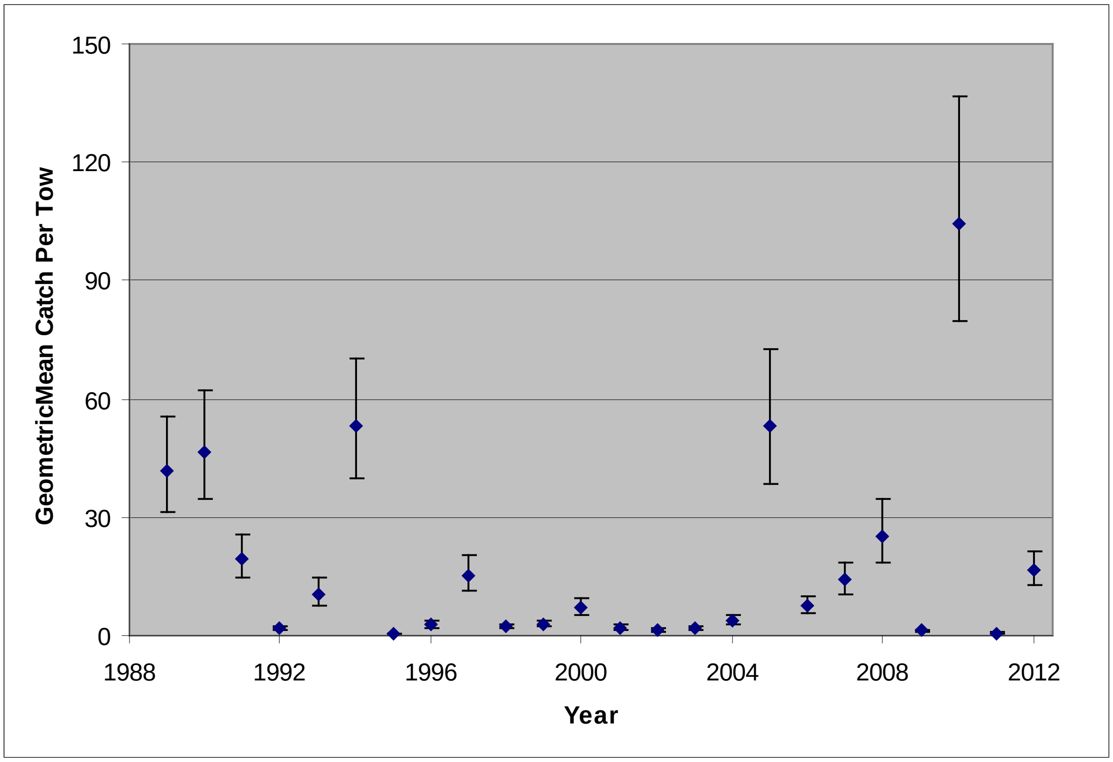

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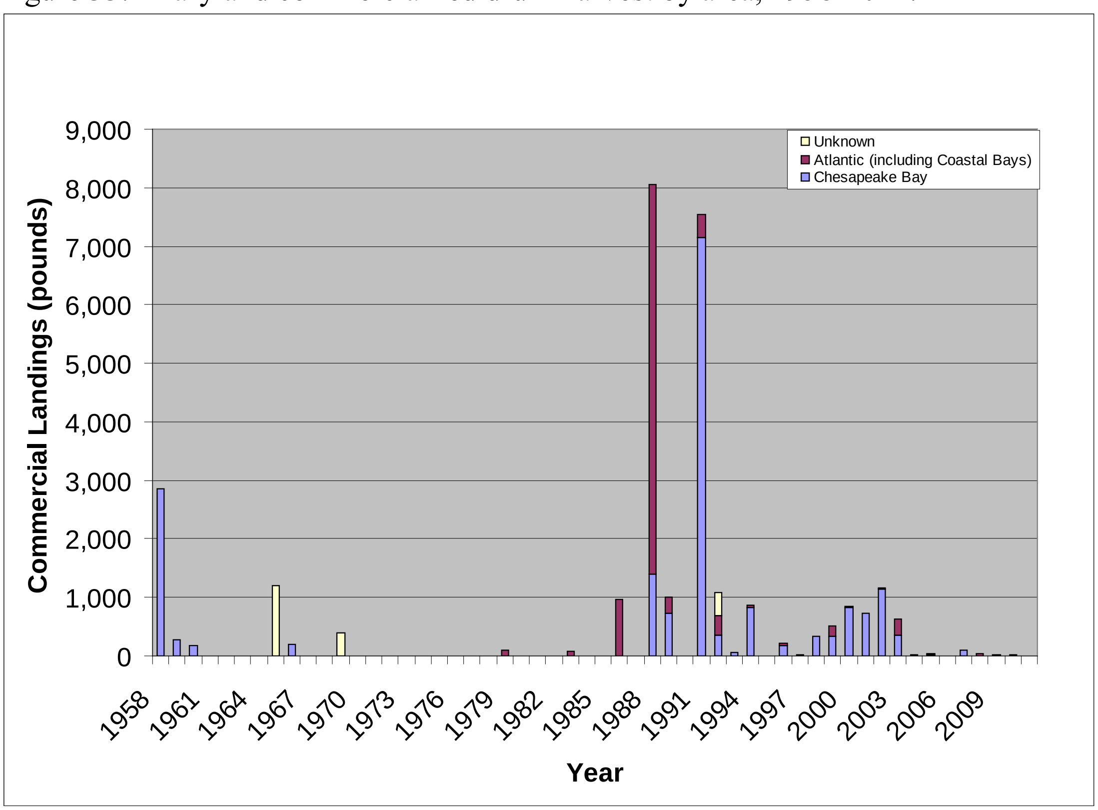

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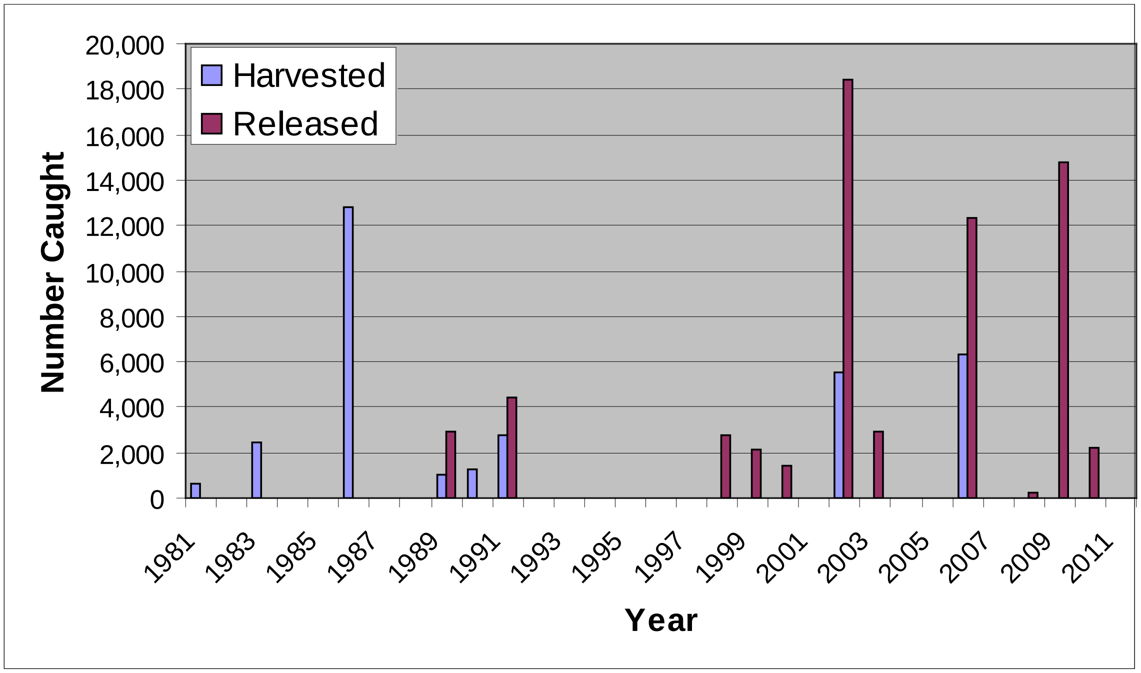

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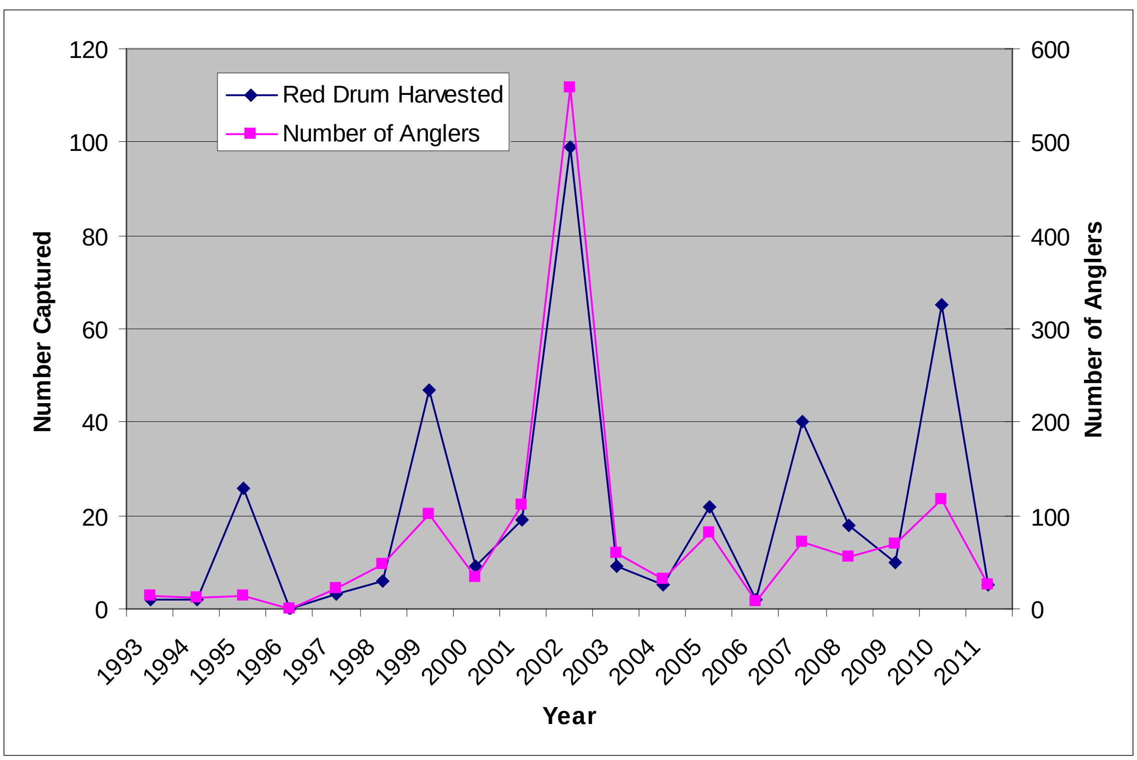

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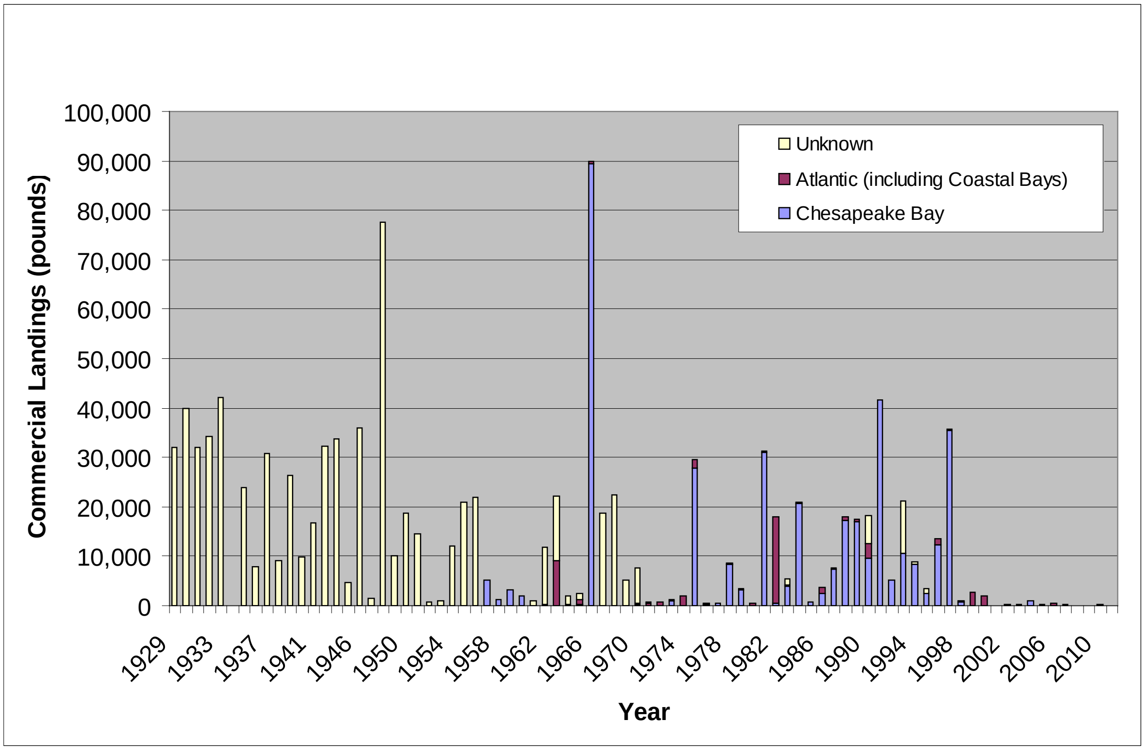

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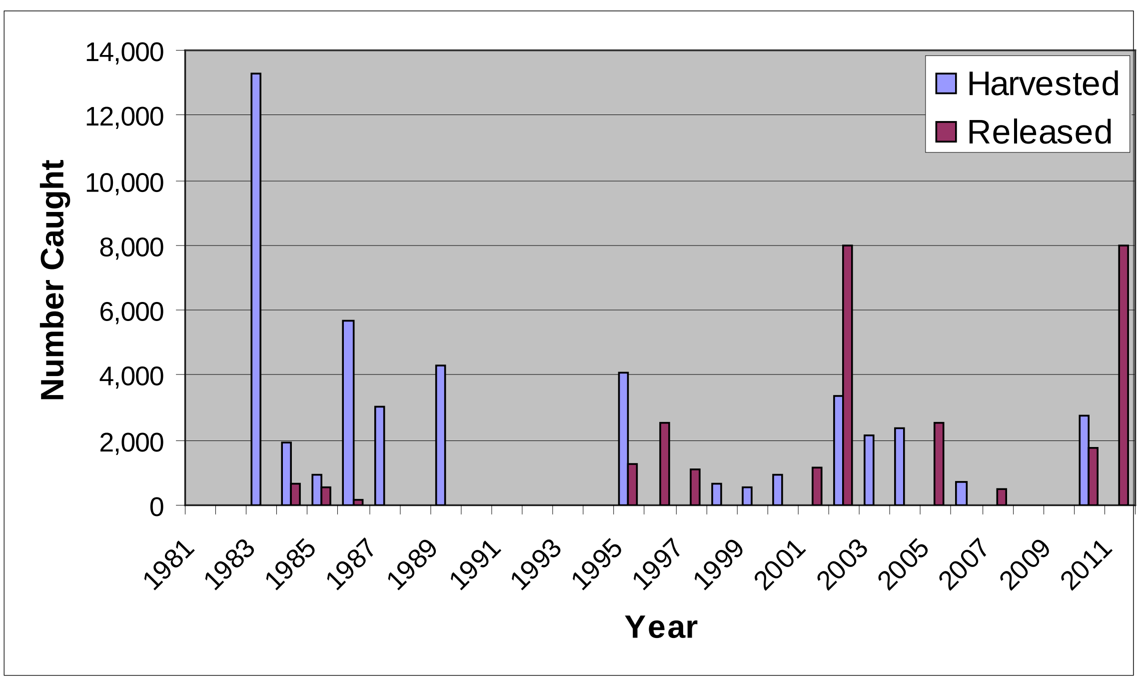

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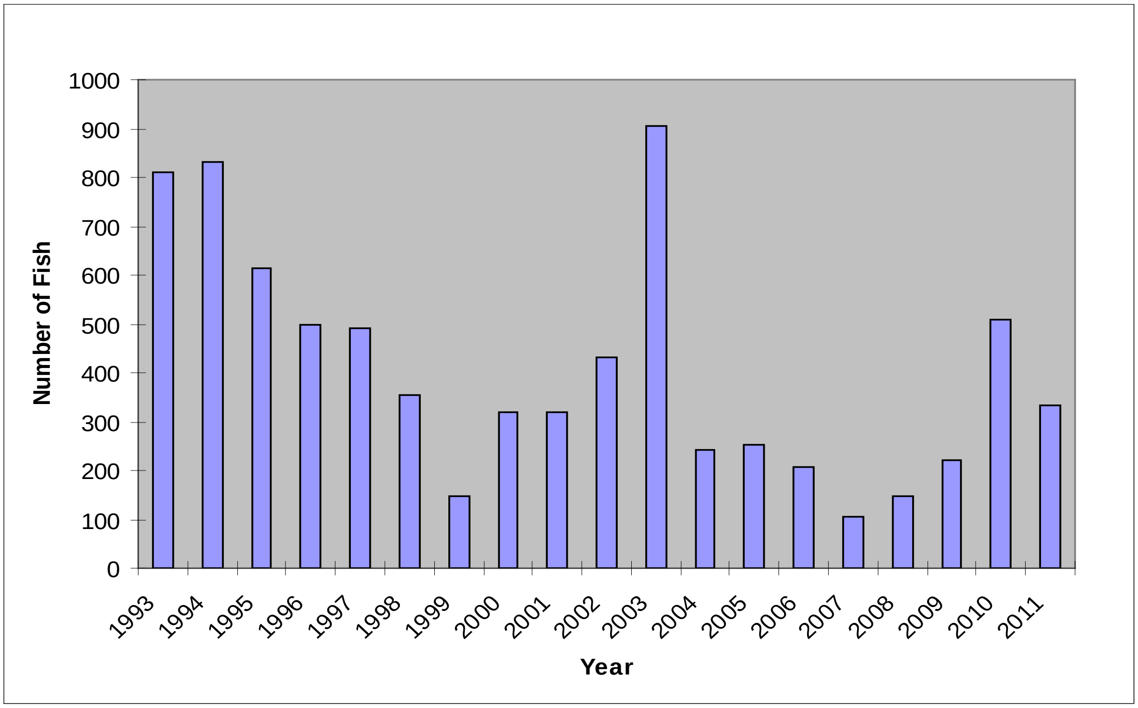

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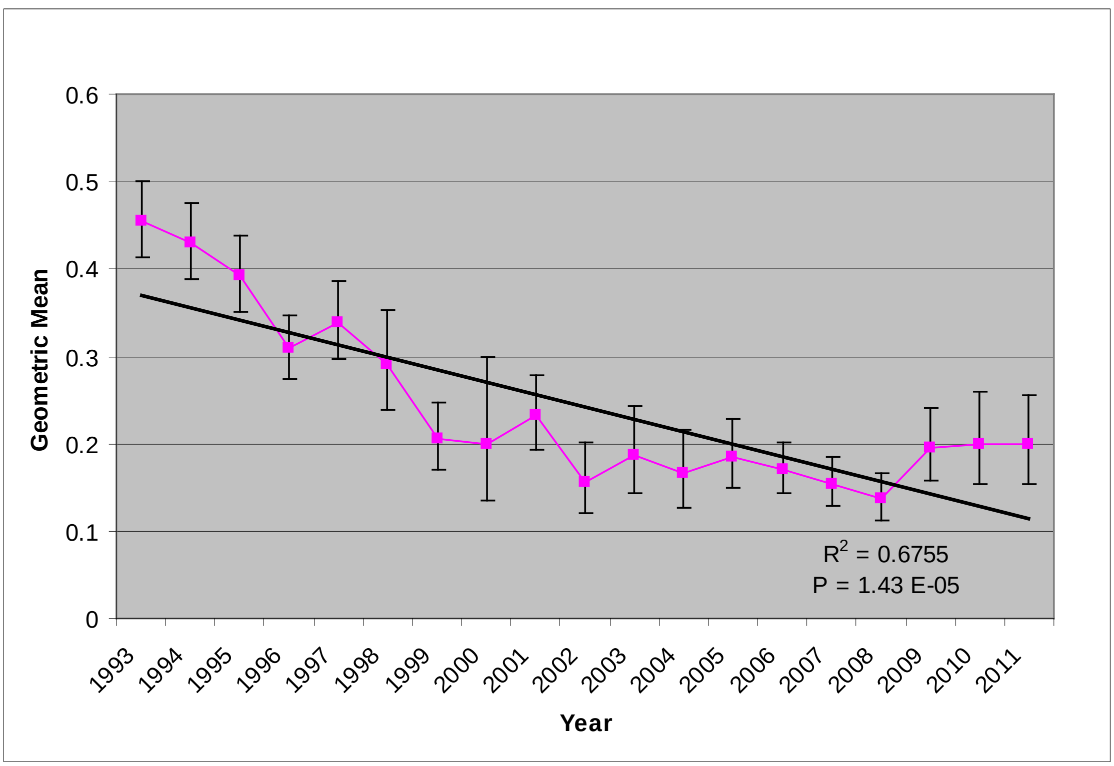

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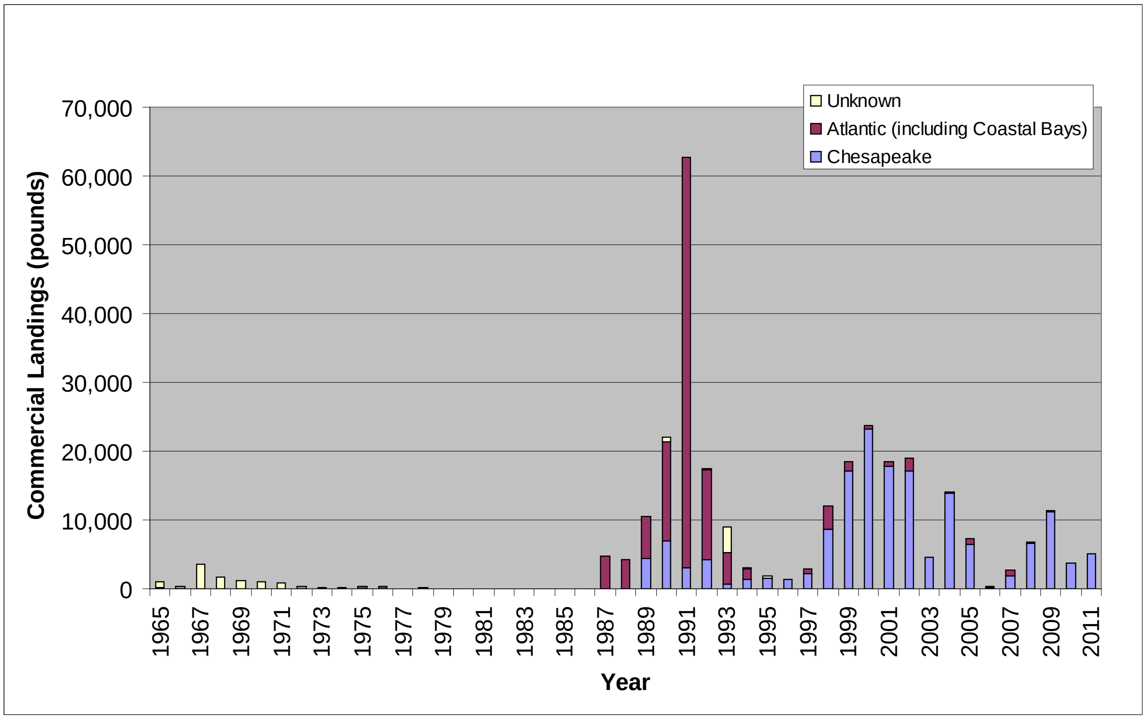

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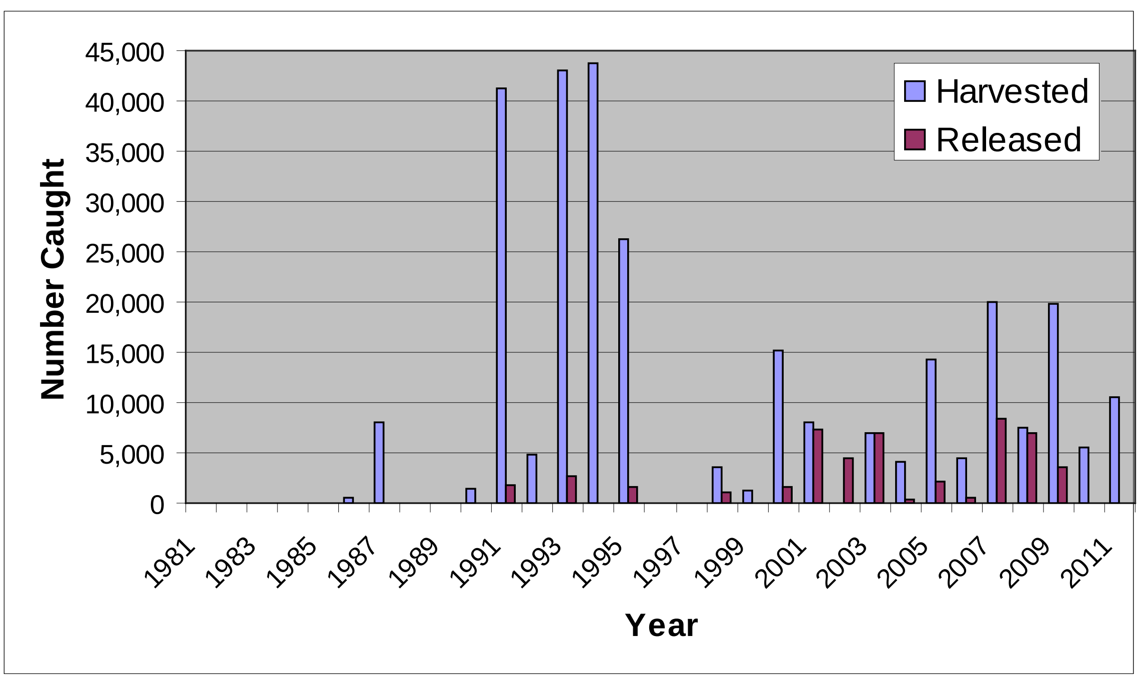

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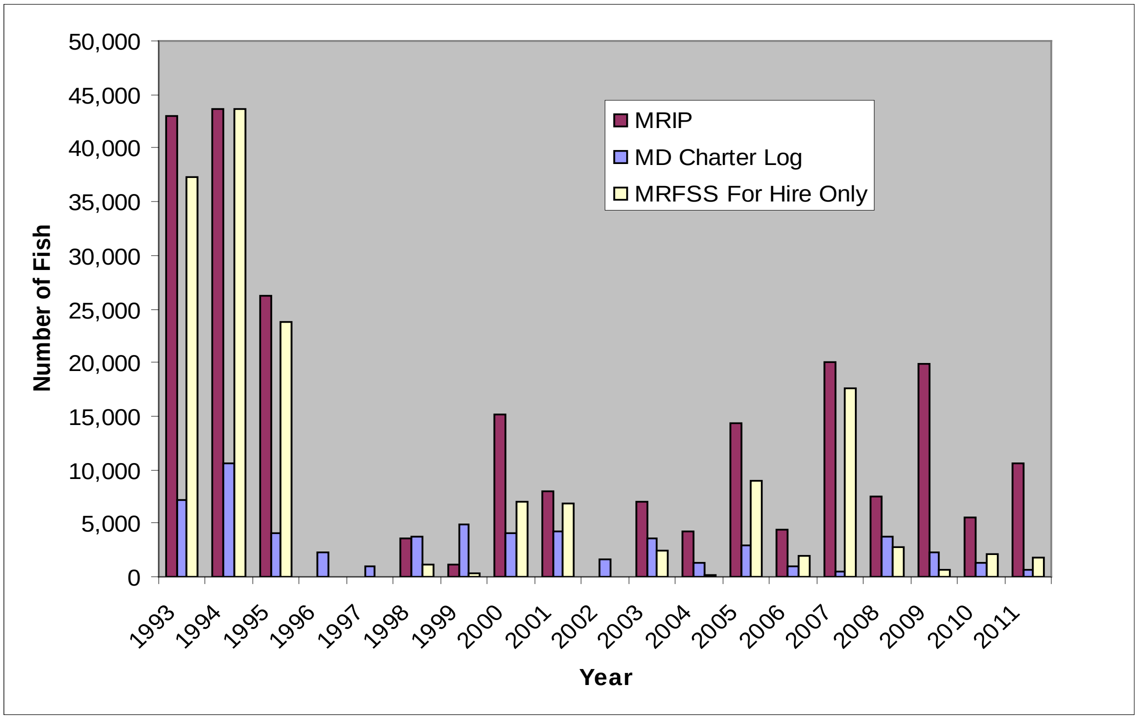

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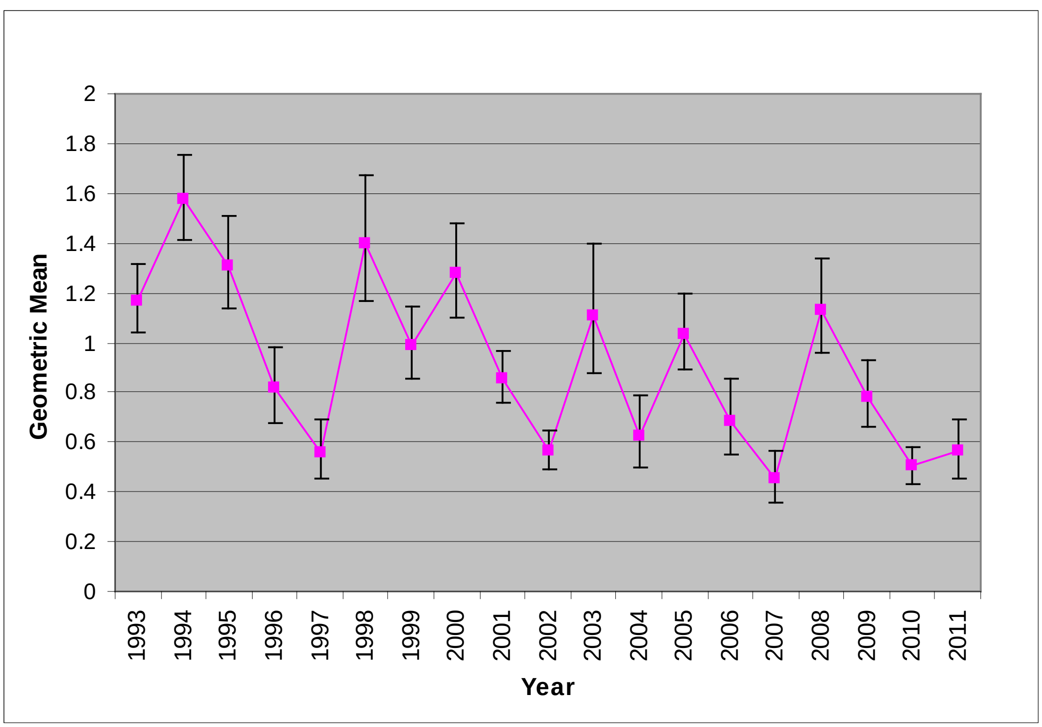

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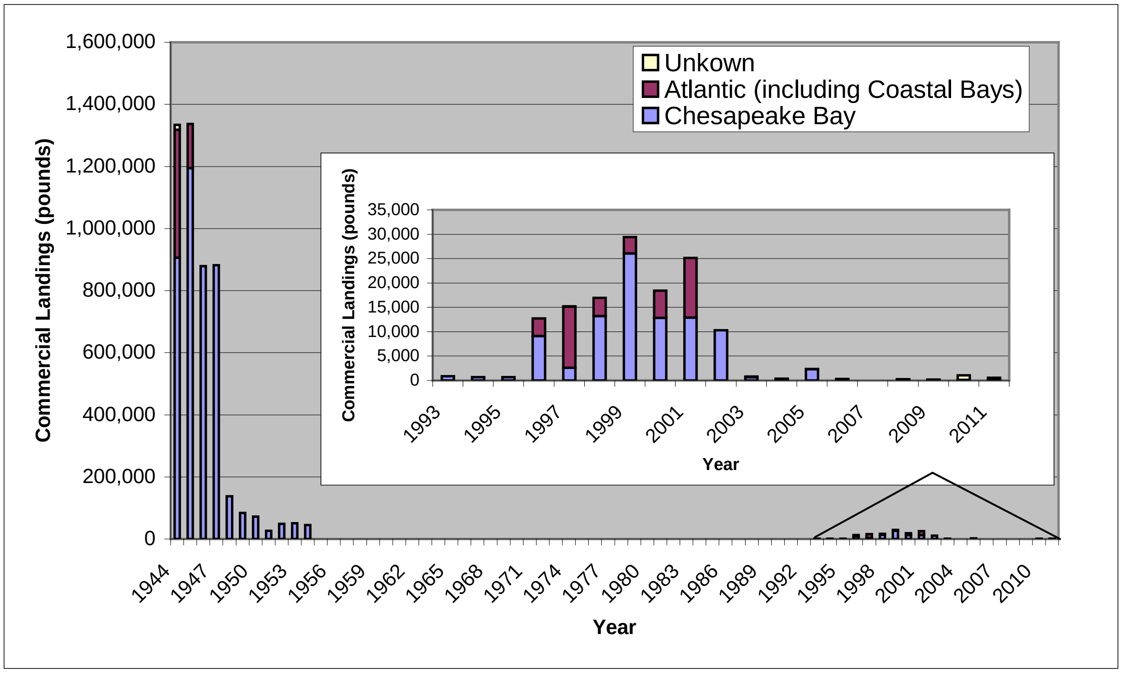

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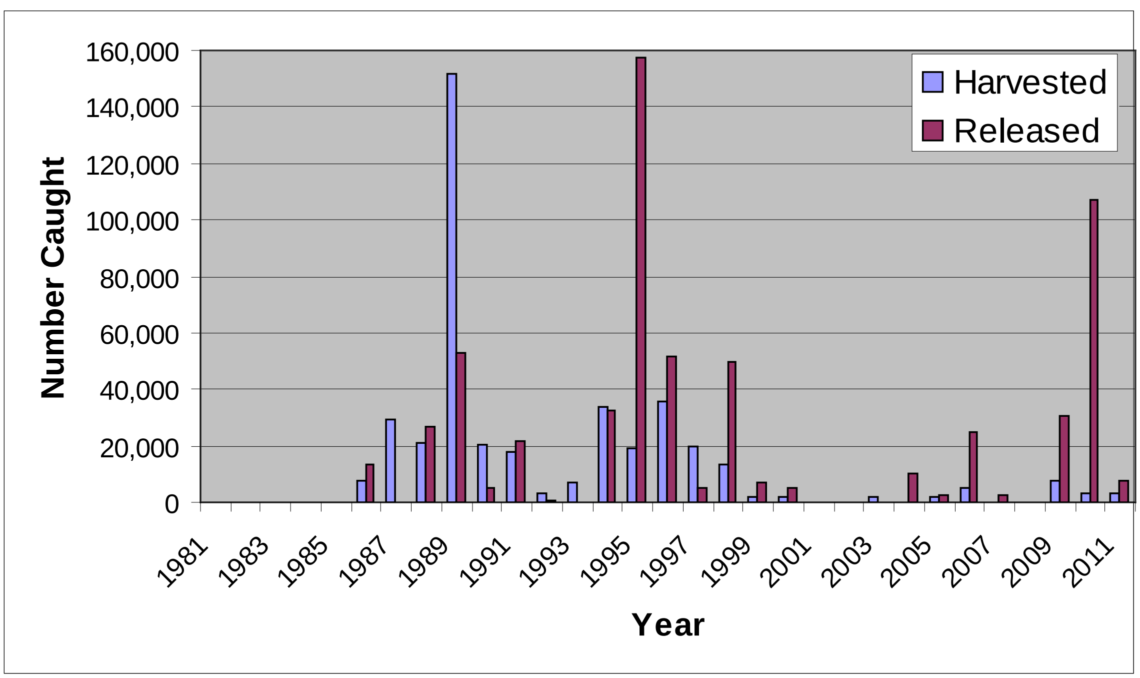

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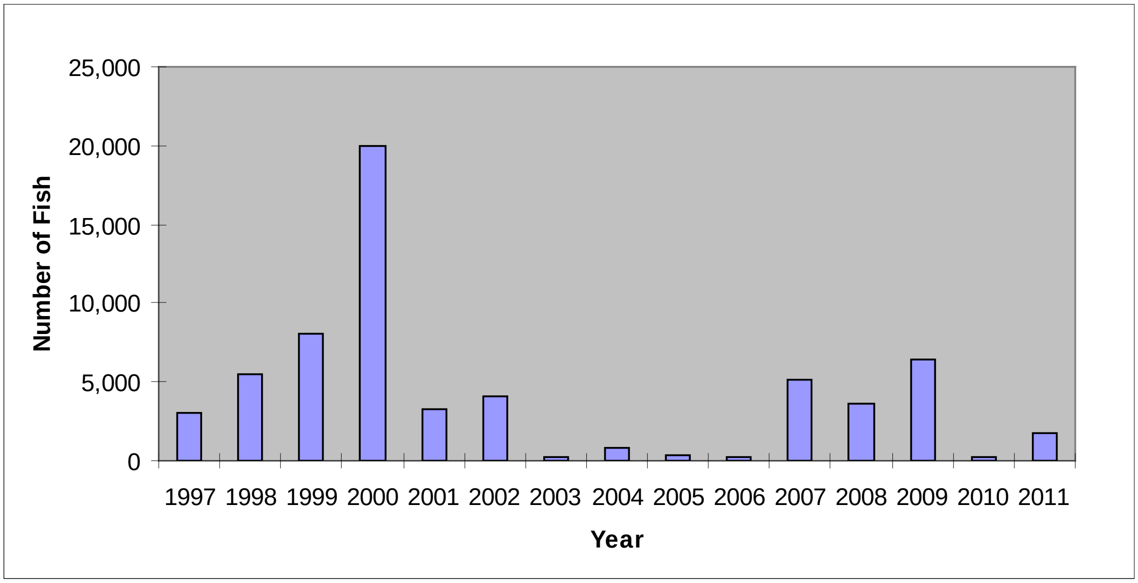

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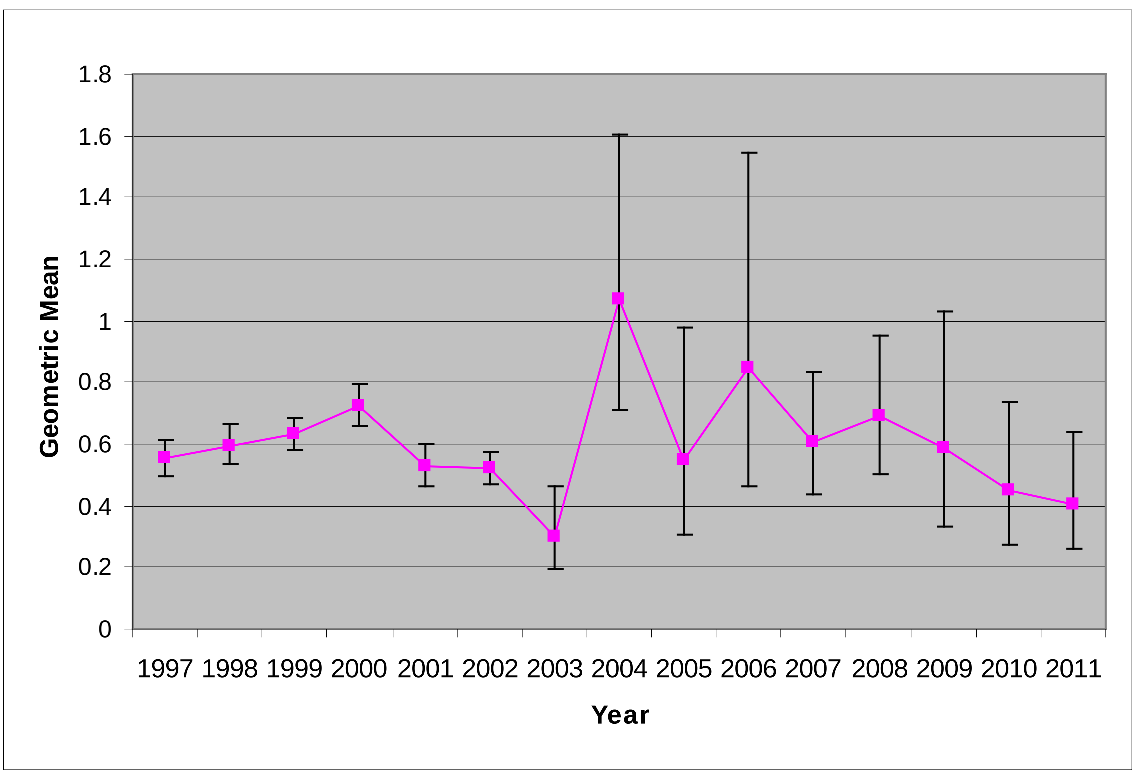

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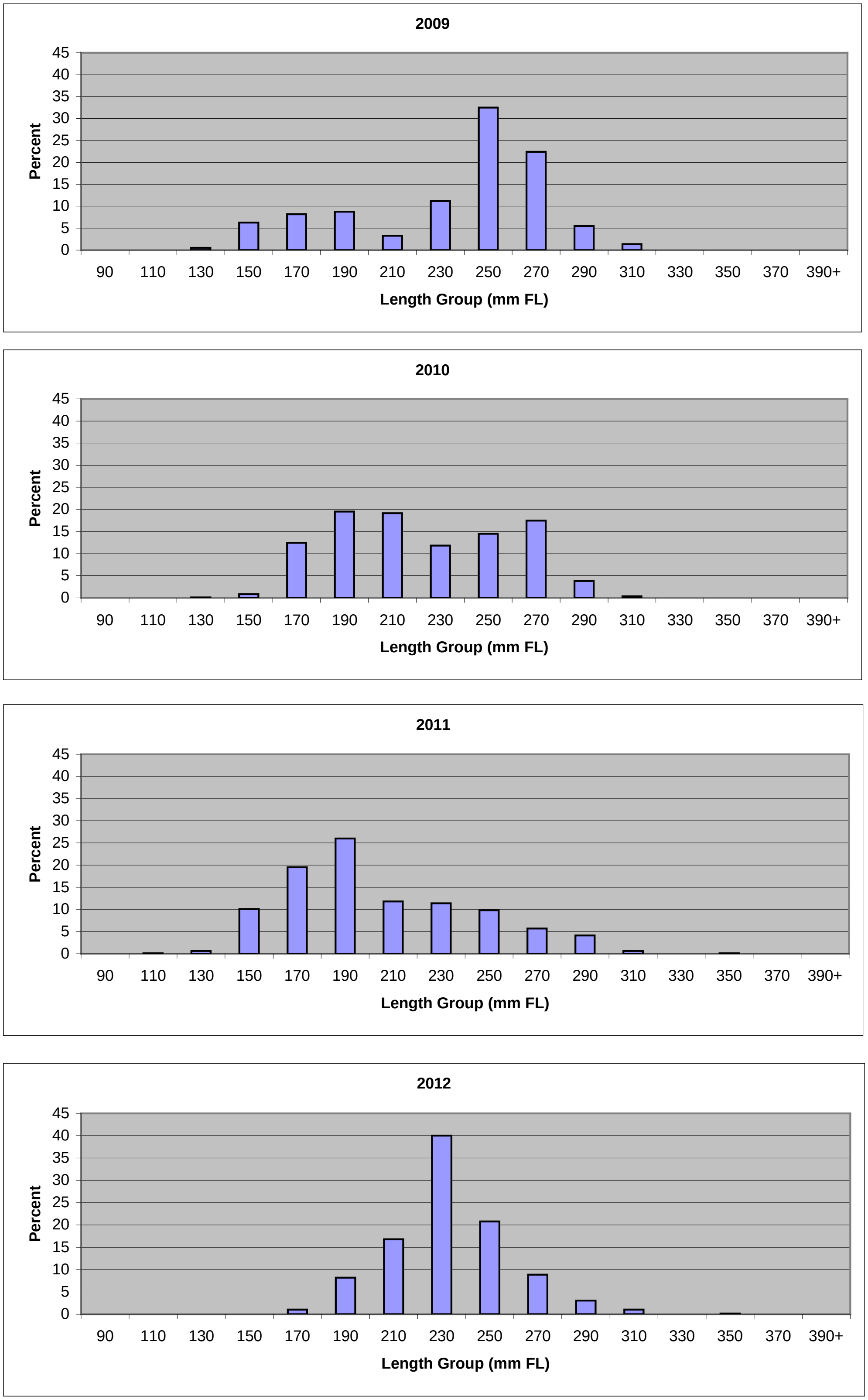

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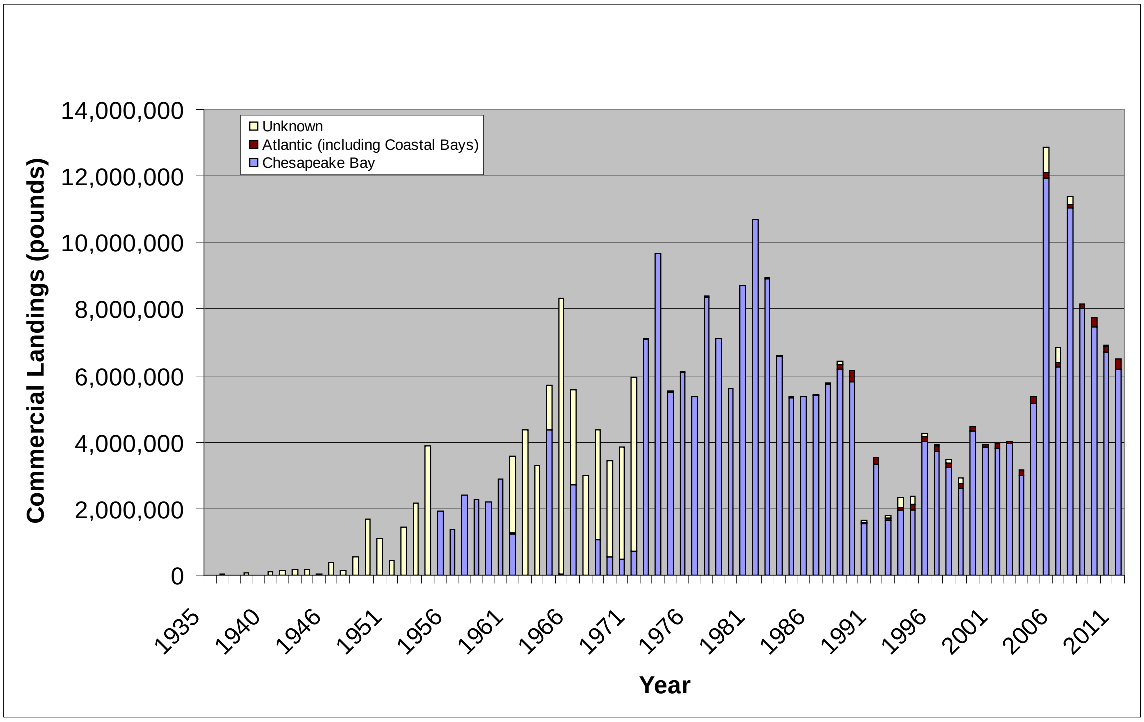

PROJECT NO. 2
JOB NO 3.
TASK NO. 1A

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 2011 Maryland striped bass (*Morone saxatilis)* commercial pound net and hook-and-line harvest. The 2011 pound net season ran from 1 June through 30 November while the commercial hook-and-line fishery was open from 7 June through 8 November. The commercial hook-and-line fishery was closed the entire month of August. 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 2011 commercial fisheries seasons were used to characterize the length and age structure of the entire 2011 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 structure.

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 bias 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 2011 (Table 1). The pound nets sampled were not randomly selected, but were chosen according to watermen's schedules and the best chance of attaining fish. During 2011, 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-millimeter 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 2011 (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 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-millimeter 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 length 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 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 age-length key. 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 age-length key. The catch-at-age for each fishery was calculated by applying the age-length key to the hook-and-line and pound net length frequencies, and expanding the resulting age distribution to the landings.

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 2011 hook-and-line and pound net fisheries was also compared to previous years.

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 2011 striped bass pound net study, a total of 2,331 striped bass were sampled from one pound net in the upper Bay and five pound nets in the lower Bay. The six nets were sampled a total of 14 times during the study.

Striped bass sampled from pound nets ranged from 198-861 mm TL, with a mean length of 514 mm TL (Figure 2). In 2011, 32% of striped bass collected from full net samples were less than the minimum legal size of 18 inches TL, while 25% of fish from partially sampled nets were sub-legal. Mean total lengths of the aged sub-sample from pound nets are presented in Table 2.

Striped bass sampled from pound nets, ranged from 1 to 13 years of age (Table 3, Figure 2). Four year-old fish from the above average 2007 year-class contributed 40% in 2011; more age 4 fish than in 2010 (31%) and 2009 (18%). Age 5 fish from the below average 2006 year-class contributed 8% of the sample, lower than age 5 fish in 2010 (21%) (Figure 3, Table 3). Age 3 fish contributed 14% in 2011, which is lower than the contribution in 2010 (33%). Striped bass age 6 and over were more common in 2011, and accounted for 30% of the sample; more than their contribution in 2009 (9%) and 2010 (23%). Fish age 8 and older composed 4% of the sample in 2011, which was higher than 2009 (1%) and 2010 (1%). Length frequencies of legal sized striped bass 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 1,431 striped bass were sampled at hook-and-line check stations in 2011. The mean length of sampled striped bass was 554 mm TL. Striped bass sampled from the hook-and-line fishery ranged from 434 to 895 mm TL (Figure 5) and from 3 to 11 years of age (Figure 5).

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 59% of the hook-and-line harvest, lower than 2010 (69%; Figure 5). Fish >630 mm TL contributed 8% to the total harvest. 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, and contributed 3% to the overall harvest (Figure 6). Historically, these fish have not been available in large numbers during the summer (MDDNR 2002). Approximately 1% of the harvest was sub-legal (< 457 mm TL). Mean lengths-at-age and weights-at-age for the 2011 combined hook-and-line and pound net fisheries are shown in Tables 4 and 5.

The 2011 hook-and-line harvest accounted for 23%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2011 (see Project 2, Job 3, Task 5A). The estimated 2011 catch-at-age of the hook-and-line fishery is presented in Table 6. The majority of the harvest was composed of four to seven year-old striped bass (93%). Striped bass from the 2007 (age 4) and 2005 (age 6) year-classes contributed 48% and 21%, respectively. Fish from the strong 2003 year-class (age 8) accounted for 3% of the total, less than in 2010 (11%). Striped bass from the below average 2006 year-class (age 5) contributed 10%, which was lower than their contribution in 2010 (Figure 7). Fish from the 2004 year-class (age 7) contributed 15% to the hook-and-line harvest, less than in 2010 (21%). Striped bass age 8 and older contributed 4% to the overall harvest in 2011, similar to 2010 (4%).

Pound net check station sampling

A total of 1,128 striped bass were sampled at pound net check stations in 2011. Striped bass sampled ranged from 453 to 916 mm TL (Figure 5). Striped bass sampled from the pound net fishery ranged from 3 to 11 years of age. Striped bass in the 450-550 mm TL length groups accounted for 51% of the 2011 pound net harvest, which is lower than 2010 (77%; Figure 5). The contribution of striped bass in the 570-630 mm TL length groups increased from 18% in 2010 to 32% in 2011. Fish >630 mm TL composed 17% of the sample, three times that of 2010 (5%). In general, a number of large fish were available to the 2011 pound net fishery (Figure 6). Mean lengths-at-age and weights-at-age from the 2011 hook-and-line and pound net fisheries combined, are shown in Tables 4 and 5, respectively.

The pound net fishery accounted for 33%, by weight, of the Maryland Chesapeake Bay 2011 commercial harvest (see Proj. 2, Job 3, Task 5A). The estimated 2011 catch-at-age for the pound net fishery is presented in Table 6. Fish age three to six contributed 75% of the 2011 total pound net harvest. The contribution of eight year-old fish from the 2003 year-class was lower in the pound net harvest in 2011 than in 2010, contributing 7% to the total harvest (Figure 7). Striped bass age 8 and over composed 10% of the 2011 harvest, much higher than the contribution in 2010 (2%). Sub-legal striped bass (< 457 mm TL) composed 0.1% of the total pound net harvest.

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 51% and 59% of the 2011 pound net and hook-and-line fisheries, respectively. There were more large fish (>530 mm) harvested in 2011 compared to 2010 (71% for both fisheries; Figure 5). In 2011, 120 fish from pound net monitoring and 99 fish from check station sampling were aged. Younger fish (age 3 to 6) were abundant, accounting for the majority of the harvest (Figure 7). Length frequencies of legal-sized fish sampled from pound nets and all fish from check stations were almost identical (Figure 4).

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.

An ANOVA with a Duncan's Post Hoc Test (SAS 2006) was performed to compare lengths and weights of striped bass harvested between fisheries and months in 2011. Striped bass 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 June/July and the smallest in September. Striped bass sampled in June/July were significantly longer than fish harvested in September/October/November. No lengths were available for August (season closed). Striped bass sampled in June/July were significantly heavier than fish harvested in September/October. No weights were available for August (season closed) or November (scale malfunction).

In the pound net check station monitoring, the longest and heaviest fish were harvested in October and the smallest in July. Striped bass November and August were similar in length, but significant differences in length were evident in every other month. Striped bass from June and October were significantly heavier than all other months. Striped bass from August and November were significantly heavier than July and September.

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Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2011 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**
	Upper	1	24.0	3.8	181
June	Middle	-	-	-	-
	Lower	1	25.4	9.1	132
	Upper	1	27.3	6.3	167
July	Middle	-	-	-	-
	Lower	-	-	-	-
	Upper	1	27.3	8.4	195
August	Middle	-	-	-	-
	Lower	-	-	-	-
	Upper	-	-	-	-
September	Middle	-	-	-	-
	Lower	4	23.4	10.6	428
	Upper	1	19.2	3.9	288
October	Middle	-	-	-	-
	Lower	2	14.3	8.8	406
	Upper	1	12.5	4.5	167
November	Middle	-	-	-	-
	Lower	2	11.7	8.0	367

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2011.

Year-class	Age	n	Mean length (mm TL)	STD	STDERR	LCLM	UCLM
2010	1	6	232	36	15	195	269
2009	2	21	322	52	11	298	346
2008	3	13	403	37	10	381	425
2007	4	22	488	68	14	458	518
2006	5	6	580	103	42	477	683
2005	6	8	654	62	22	603	705
2004	7	15	668	78	20	625	711
2003	8	9	762	59	20	718	806
2002	9	7	771	39	15	736	806
2001	10	7	793	30	12	766	820
2000	11	5	791	57	25	726	856
1998	13	1	844	-	-	-	-

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, June through November 2011.

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2010	1	13	0.54
2009	2	174	7.48
2008	3	318	13.65
2007	4	935	40.10
2006	5	197	8.45
2005	6	344	14.75
2004	7	248	10.62
2003	8	66	2.82
2002	9	17	0.73
2001	10	14	0.62
2000	11	6	0.24
1998	13	1	0.02
Total		**2,331**	**100.00**

Table 4. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) for ages 3-14 sampled from commercial pound net and hook-and-line fisheries in Maryland's Chesapeake Bay, June through November 2011.

Year-class	Age	n	Mean Length (mm TL)	STD	STDERR	LCLM	UCLM
2008	3	3	465	6	3	450	479
2007	4	14	507	52	14	476	537
2006	5	7	612	34	13	580	643
2005	6	17	622	61	15	591	653
2004	7	14	690	80	21	644	737
2003	8	21	743	80	18	707	780
2002	9	9	795	73	24	739	851
2001	10	11	828	39	12	802	855
2000	11	3	837	65	38	674	999

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 2011. Mean weights are weighted by the sample n-at-length in each age.

Year-Class	Age	n Aged	Weighted Mean weight* (kg)
2008	3	3	0.8
2007	4	13	1.2
2006	5	6	2.3
2005	6	13	2.5
2004	7	14	3.2
2003	8	21	4.0
2002	9	9	5.2
2001	10	11	5.8
2000	11	3	6.3

* Mean weights-at-age were calculated based on the age-length key and length and weight measurements of individual fish.

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 2011.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Pounds of Fish	Percent of Total	Landings in Pounds of Fish	Percent of Total
2009	2	103	0.1	0	0
2008	3	10,746	2.4	16,094	2.5
2007	4	211,851	48.0	277,766	42.9
2006	5	41,995	9.5	64,448	9.9
2005	6	91,389	20.7	125,169	19.3
2004	7	65,940	14.9	101,153	15.6
2003	8	14,089	3.2	43,097	6.6
2002	9	2,622	0.6	8,981	1.4
2001	10	1,785	0.4	7,907	1.2
2000	11	903	0.2	3,498	0.5
1999	12	0	0.0	0	0.0
1998	13	0	0.1	0	0.0
1997	14	0	0.1	0	0.0
Total*		**441,422**	**100.0**	**648,113**	**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 2011.

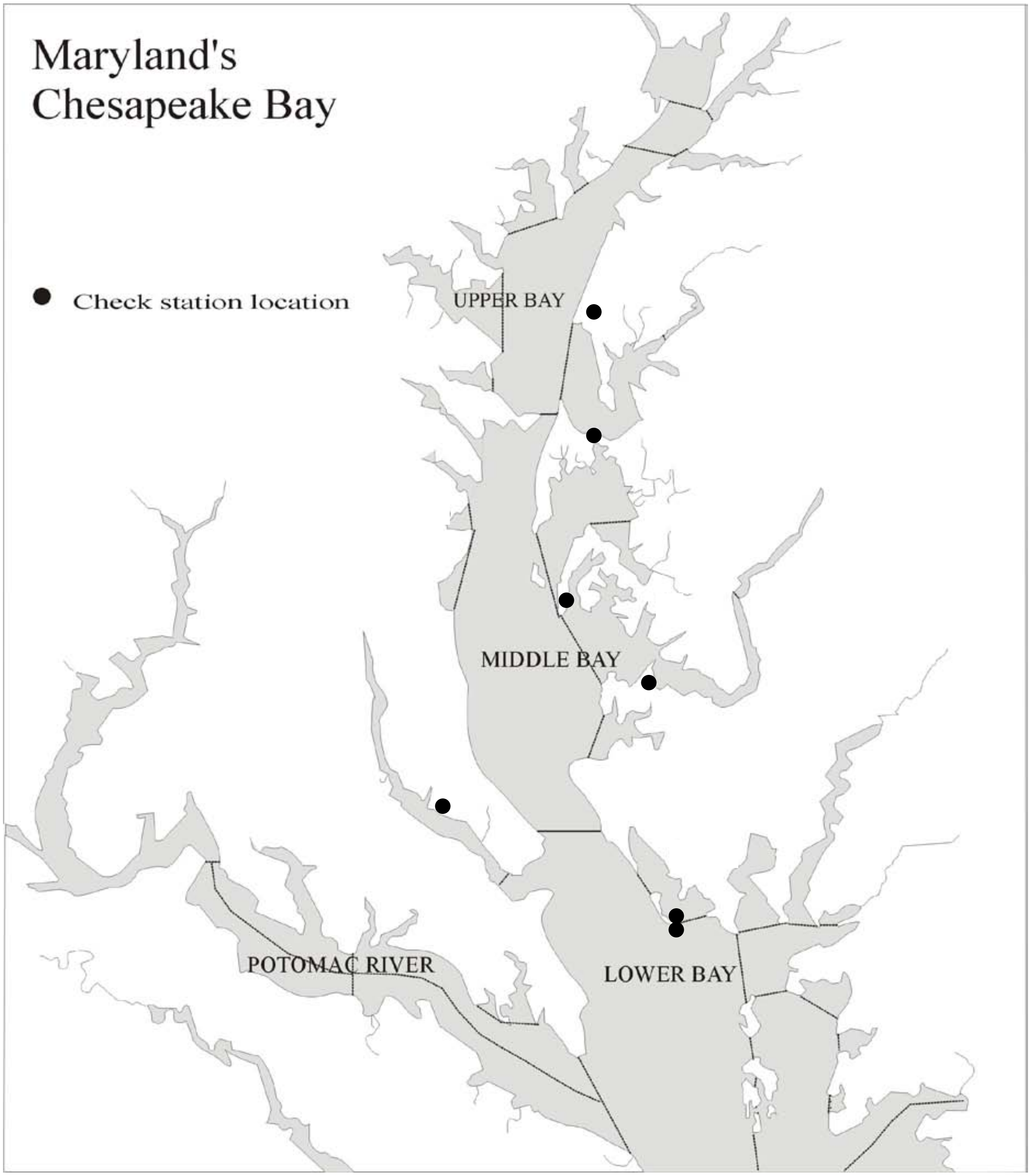
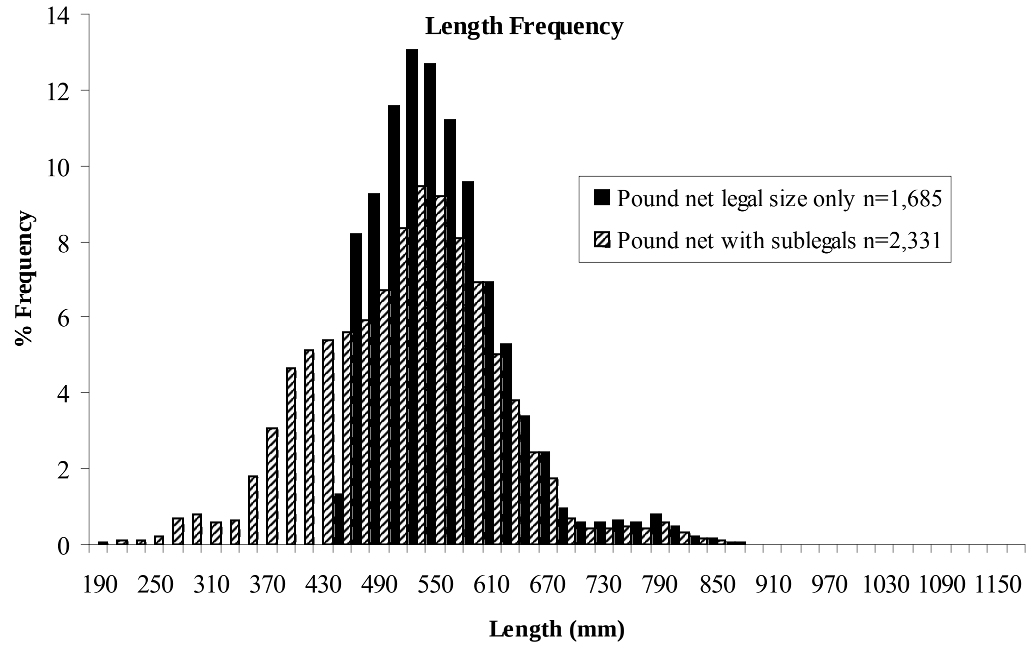


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, June through November 2011.



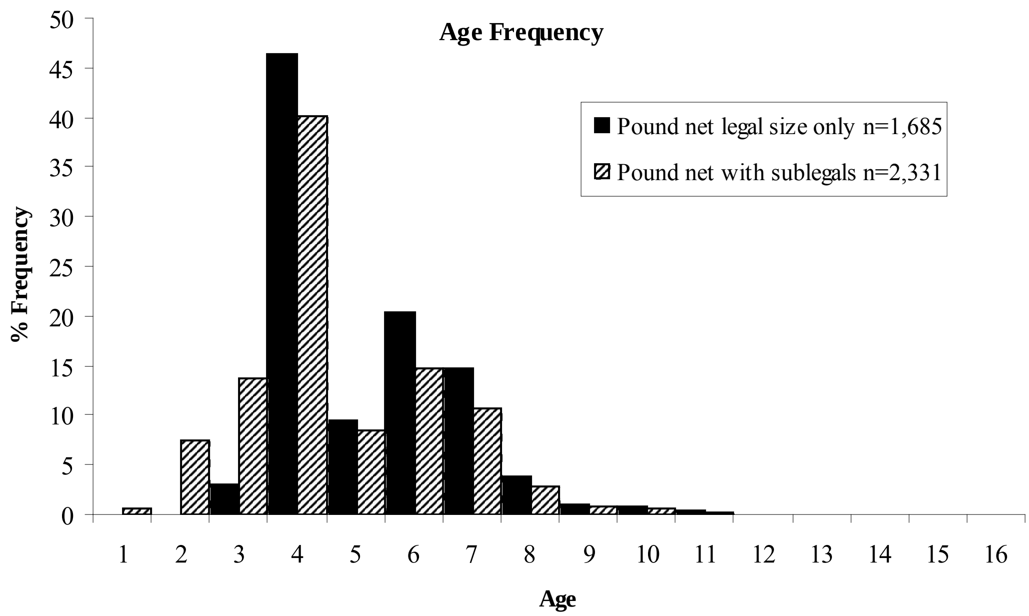
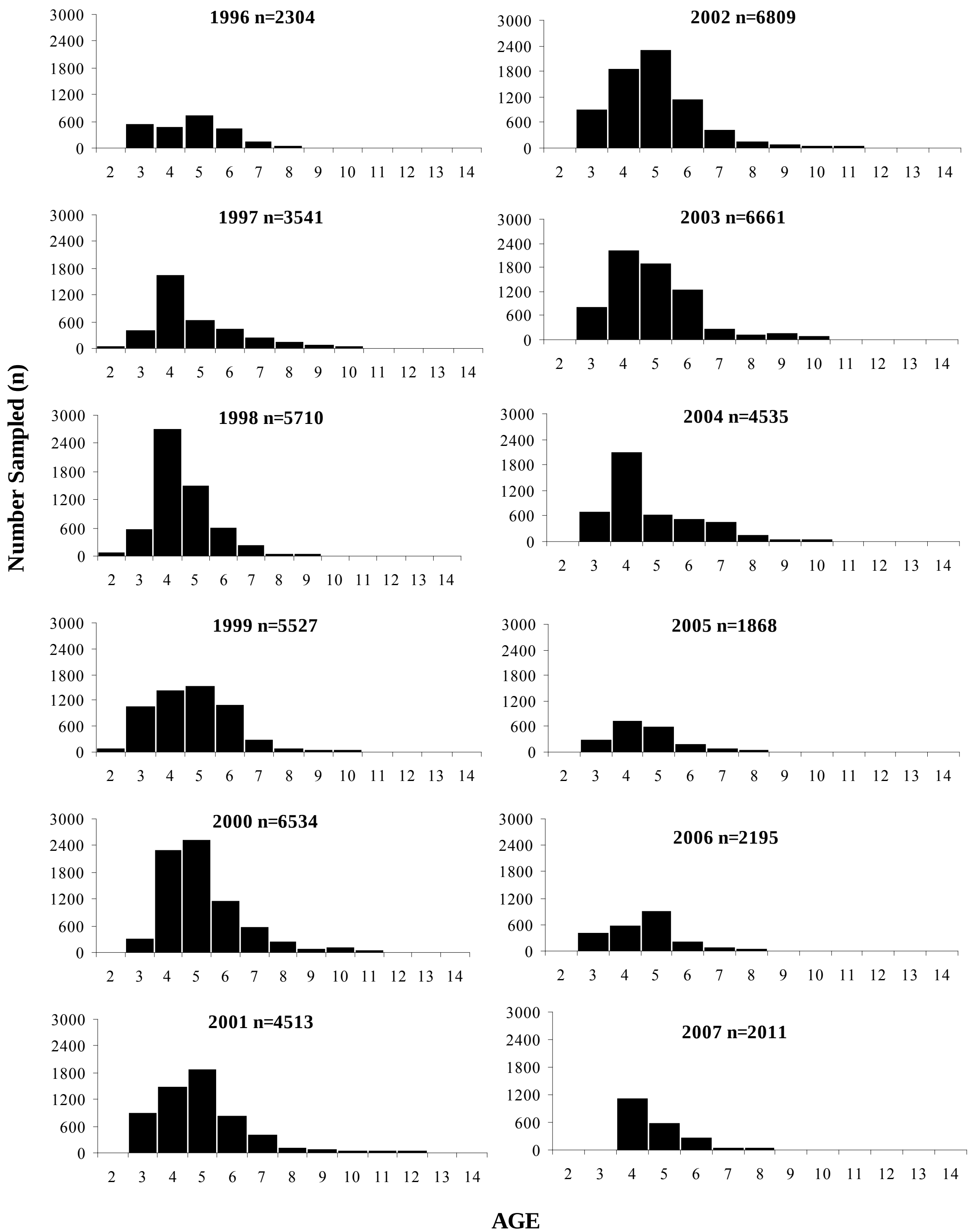


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2011.



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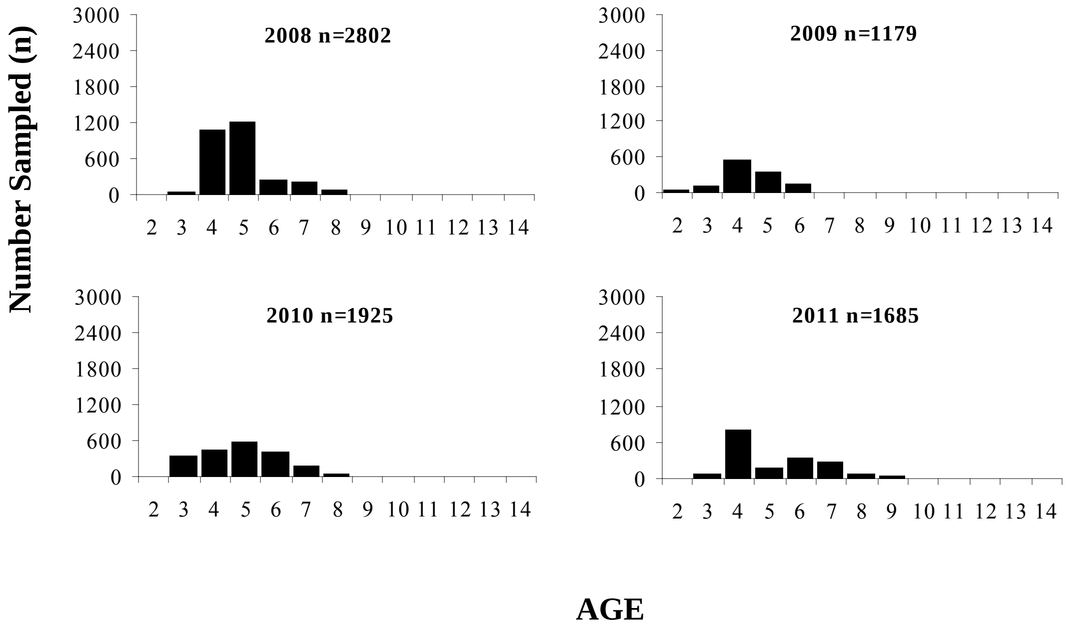


Figure 4. Length frequency of striped bass sampled during the 2011 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2011. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

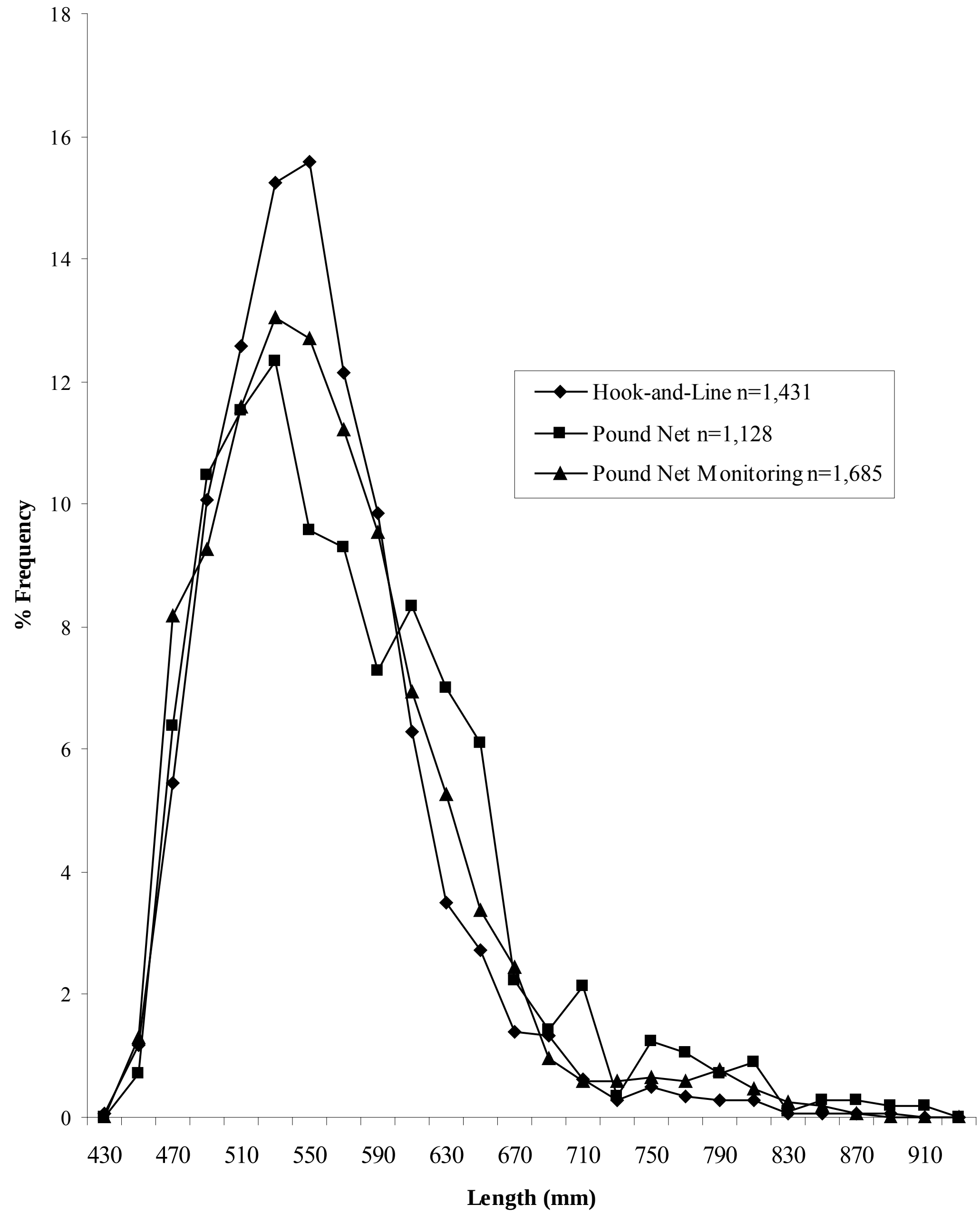
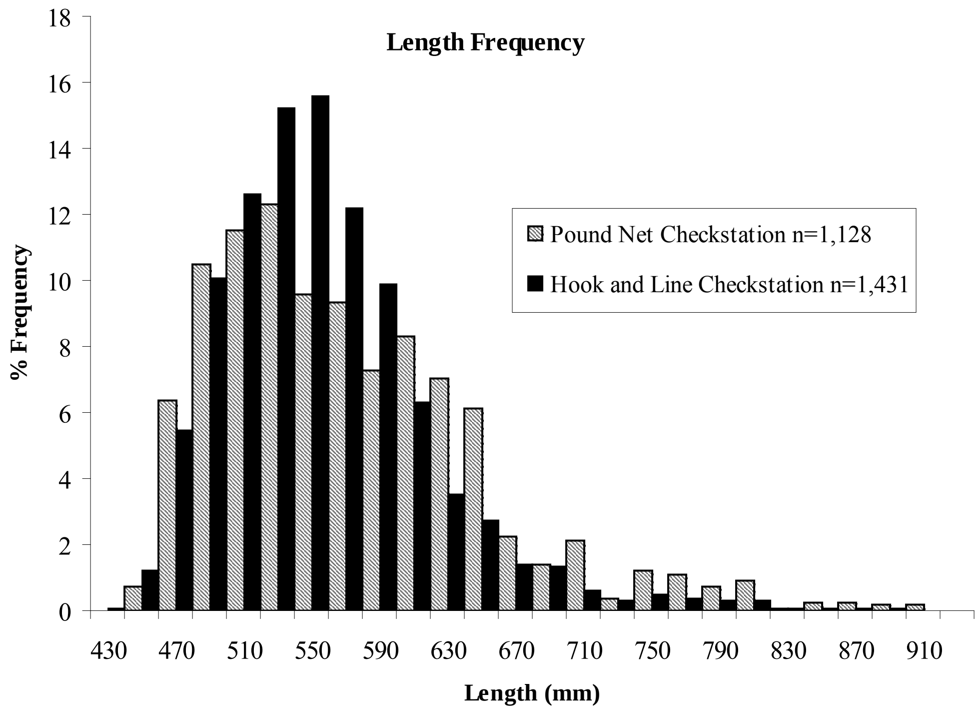


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2011.



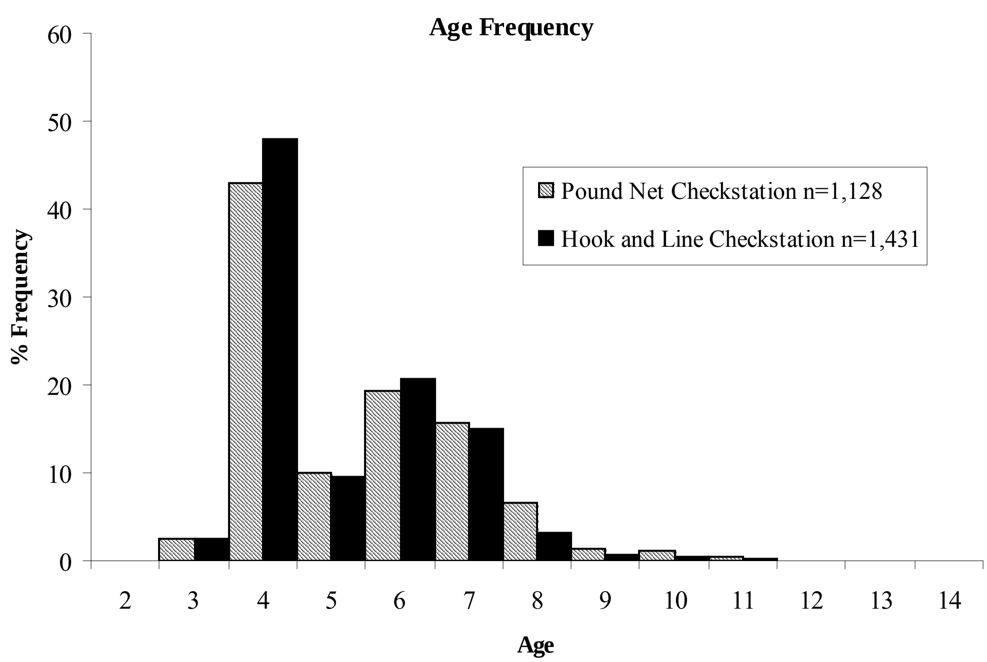
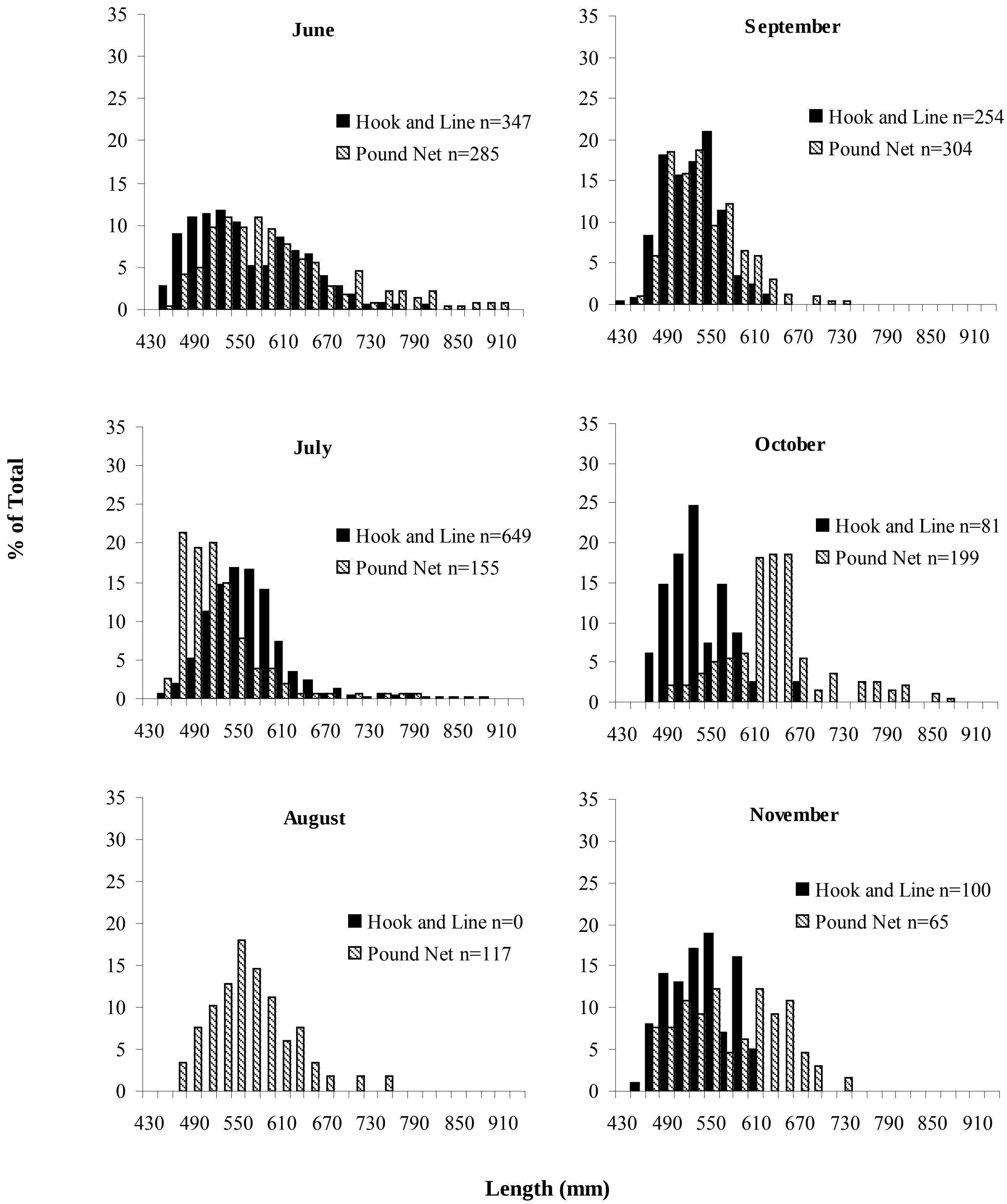


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2011.



*No fish for August Hook and Line, season was closed for entire month.

Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2011. Note-pound net check station sampling began in 2000.

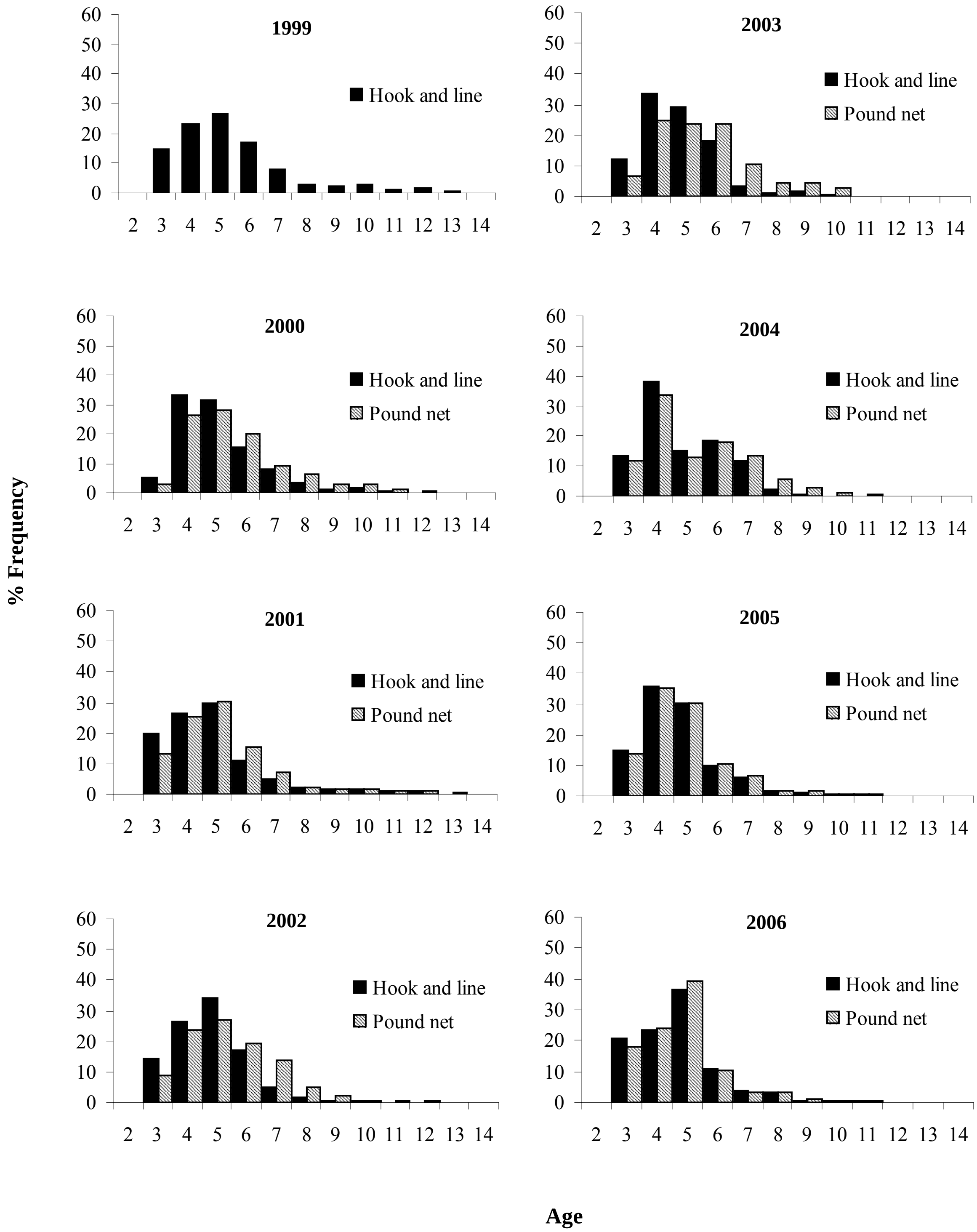


Figure 7. Continued.

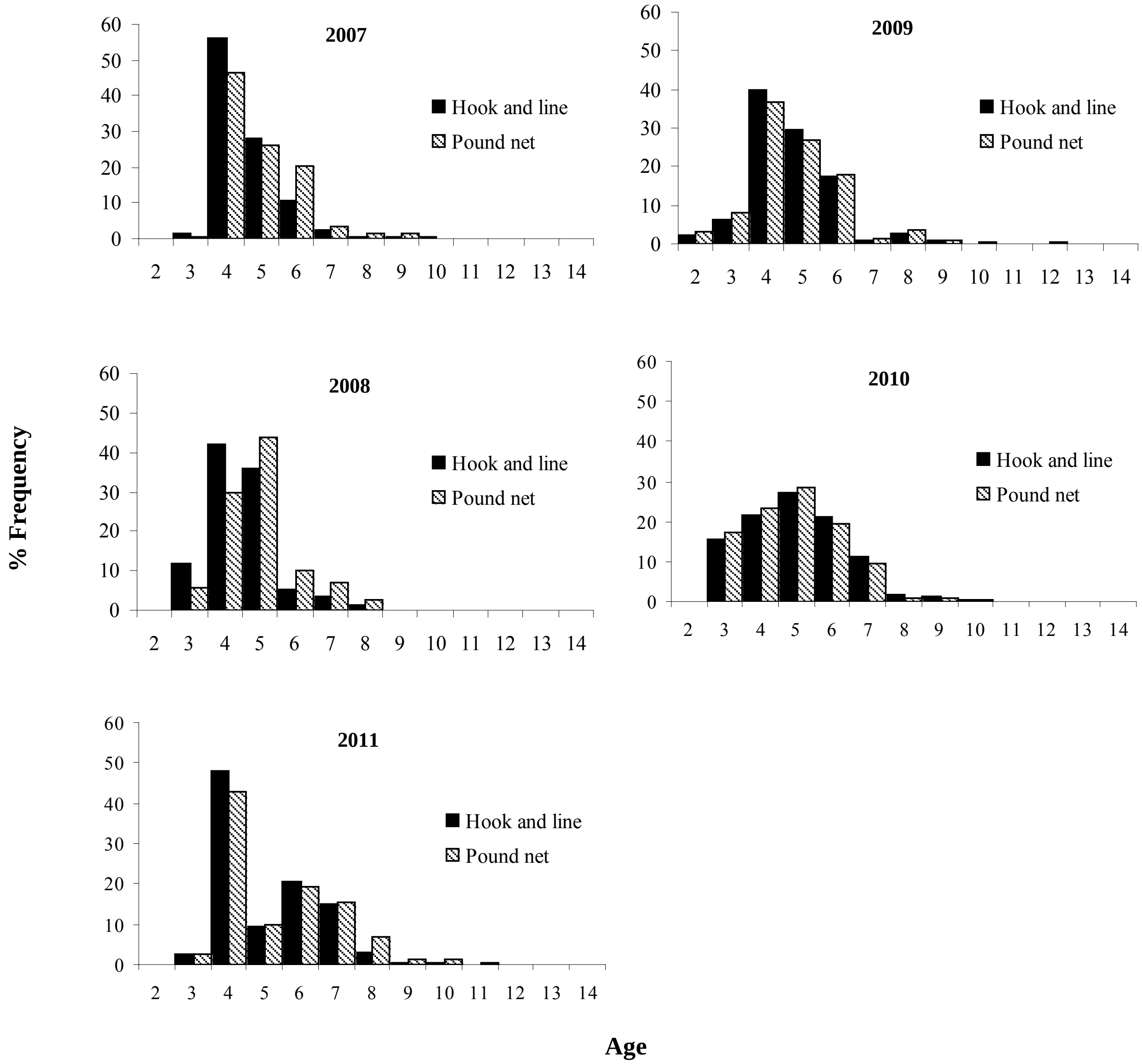
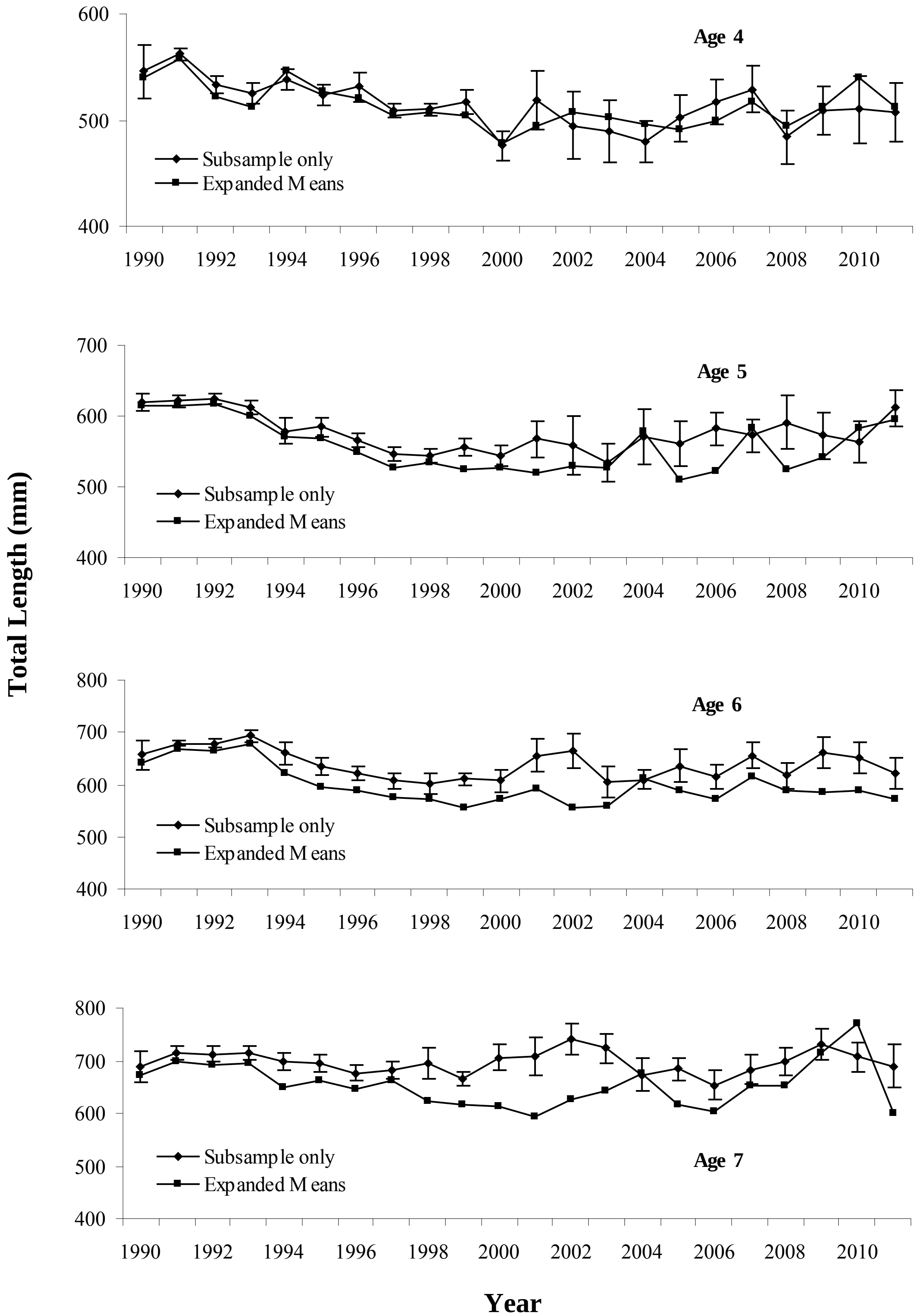


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations, 1990 through 2011. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating means. The 95% confidence intervals are shown around points in the sub-sample data series. (1990-2007 edited). 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 6, 2011 - February 29, 2012 commercial drift gill net fishery. This fishery targets resident/pre-migratory Chesapeake Bay striped bass and accounts for approximately 40-50% of the 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 also contributed to the construction of the Maryland catch-at-age matrix utilized in the Atlantic States Marine Fisheries Commission (ASMFC) coastal striped bass stock assessment.

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 station 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; one medium-use station was sampled for every three visits to a high-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. Sampling was distributed as evenly as possible between northern and eastern geographic areas of the Chesapeake Bay. The northern-most check station sampled in this survey was located in Millington, 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, attempts were made to measure (mm TL) and weigh (kg) a random sample of at least 300 striped bass per visit. 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 sub-sample 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 5 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 2011-2012 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 2011 – February 2012 gill net season, the year used for age calculations was 2012.

Mean lengths and weights at-age were calculated by year-class for the aged sub-sample of fish. Mean length-at-age and weight-at-age were also estimated for each year-class using an expansion method (Hoover 2008). 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) suggest that the sub-sample means-at-age are often biased. Expanded means were calculated with an age-length key and a probability table that applied ages from the sub-sample 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 2011-2012 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 sub-samples, 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

The winter drift gill net commercial fishery accounted for 45% of the total Maryland Chesapeake Bay commercial harvest, by weight. A total of 4,169 striped bass were sampled and 114 striped bass were aged from the harvest between December 2011 - February 2012. The gill net season was open for 9 days in December, 8 days in January, and 8 days in February due to high catch rates.

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). The majority of fish landed in most years 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 overall landings of striped bass in this fishery were calculated from the ASMFC compliance report template.

According to the estimated catch-at-age analysis, the 2011-2012 commercial drift gill net harvest consisted primarily of striped bass from the 2007 year-class (age 5; Table 1), which composed 47% of the total harvest. The 2008 and 2006 year-classes (ages 4 and 6) composed an additional 35% of the total harvest, while ages 8 and older contributed only 2% to the total. The contribution of fish greater than 8 years old was lower than the 2010-2011 harvest (6%) and the 2009-2010 harvest (6%). The youngest fish observed in the 2011-2012 sampled harvest were age 3.

Mean lengths and weights-at-age of the aged sub-sample 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 for smaller fish and slightly lower for larger fish than sub-sample means. Striped bass were recruited into the 2011-2012 winter gill net fishery at age 3 (2009 year-class), with an expanded mean length and weight of 489 mm TL and 1.37 kg. The 2007 year-class (age 5) was most commonly observed in the sampled landings with an expanded mean length and weight of 544 mm TL and 1.84 kg, respectively. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 11, 2001 year-class) were 891 mm TL and 9.37 kg, respectively.

The length frequency distributions by check station area are presented in Figure 3. The length frequency distributions were dominated by fish in the 490-610 mm TL range. Sub-legal fish (<457 mm) composed less than 1% of the bay-wide sampled harvest.

Time series of sub-sampled and expanded mean lengths and weights for the period 1994-2012 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, 7, 8, and 9 are more variable, likely due to smaller sample sizes or greater range of lengths and weights for each age group.

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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 2011 - February 2012.

Year-class	**Age**	**Catch**	**Percentage of the catch**
2009	3	2,681	1
2008	4	23,230	11
2007	5	96,149	47
2006	6	49,581	24
2005	7	27,271	13
2004	8	2,123	1
2003	9	2,887	1
2002	10	0	0
2001	11	49	0
Total*		**203,971**	**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 2011-February 2012.

Year-class	Age	n fish aged	Mean TL (mm) of aged sub-sample	Estimated # at-age in sample	Expanded mean TL (mm)
2009	3	3	463	55	489
2008	4	11	482	475	504
2007	5	22	555	1,965	544
2006	6	12	603	1,013	569
2005	7	25	688	557	597
2004	8	22	741	43	713
2003	9	18	760	59	682
2002	10	0	-	0	-
2001	11	1	891	1	891
Total*		**114**		**4,169**	

* 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 2011-February 2012.

Year-class	Age	n fish aged	Mean weight (kg) of aged sub-sample	Estimated # at-age in sample	Expanded mean weight (kg)
2009	3	3	1.21	55	1.37
2008	4	11	1.28	475	1.49
2007	5	22	1.94	1,965	1.84
2006	6	12	2.71	1,013	2.07
2005	7	25	3.87	557	2.43
2004	8	22	4.76	43	4.28
2003	9	18	5.39	59	3.76
2002	10	0	-	0	-
2001	11	1	9.37	1	9.37
Total*		**114**		**4,169**	

* 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 2011-February 2012.

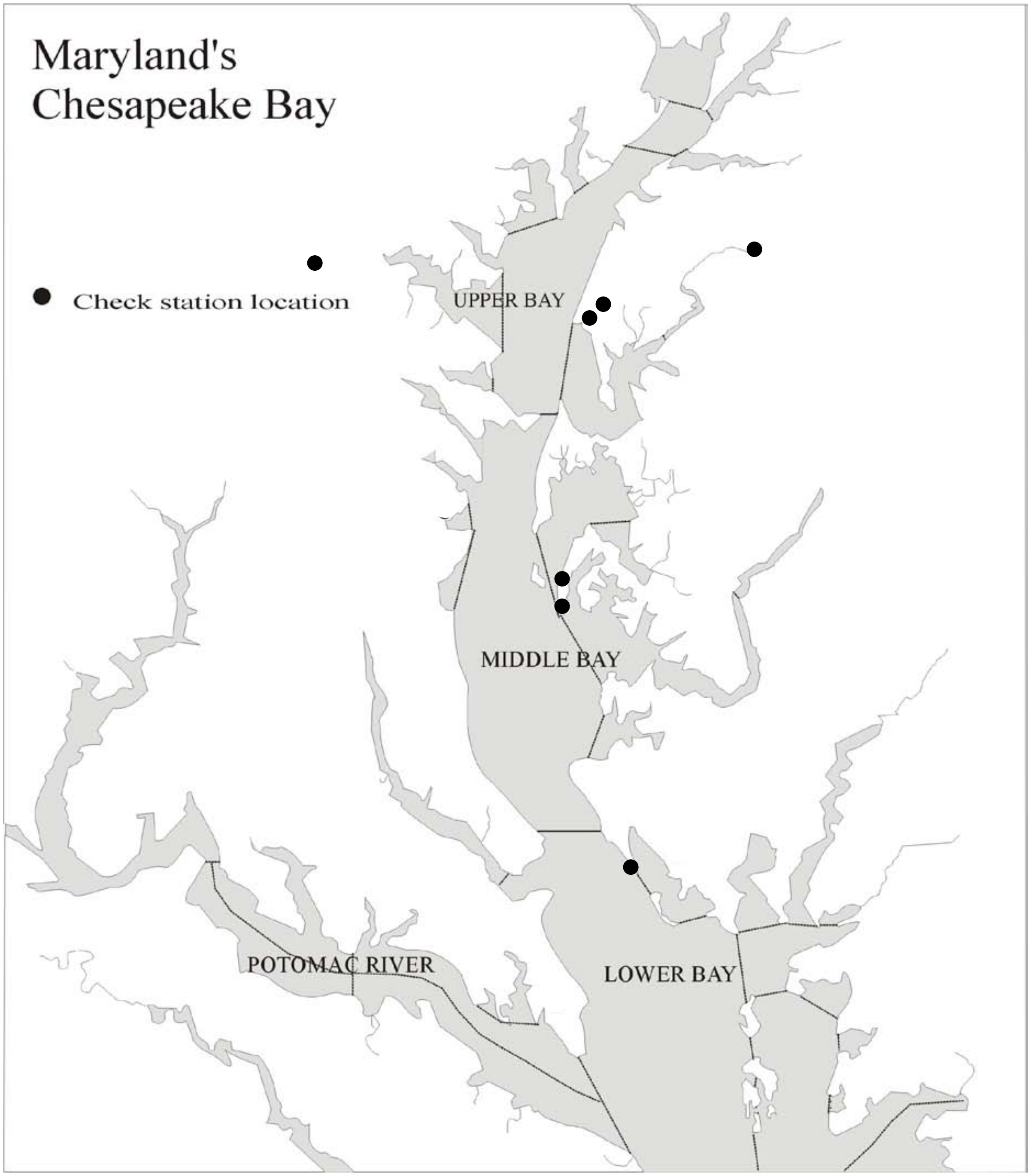


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2012.

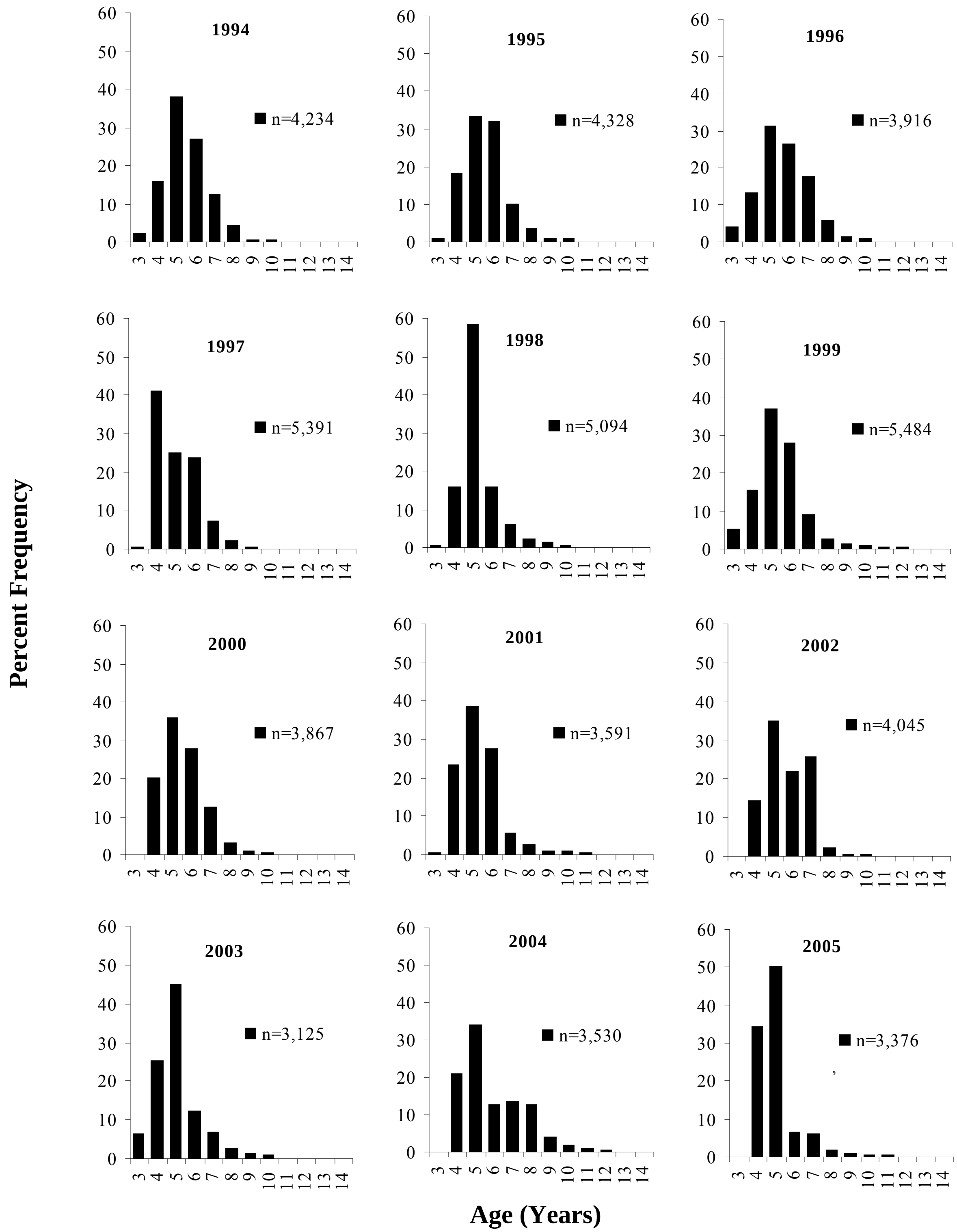


Figure 2. Continued.

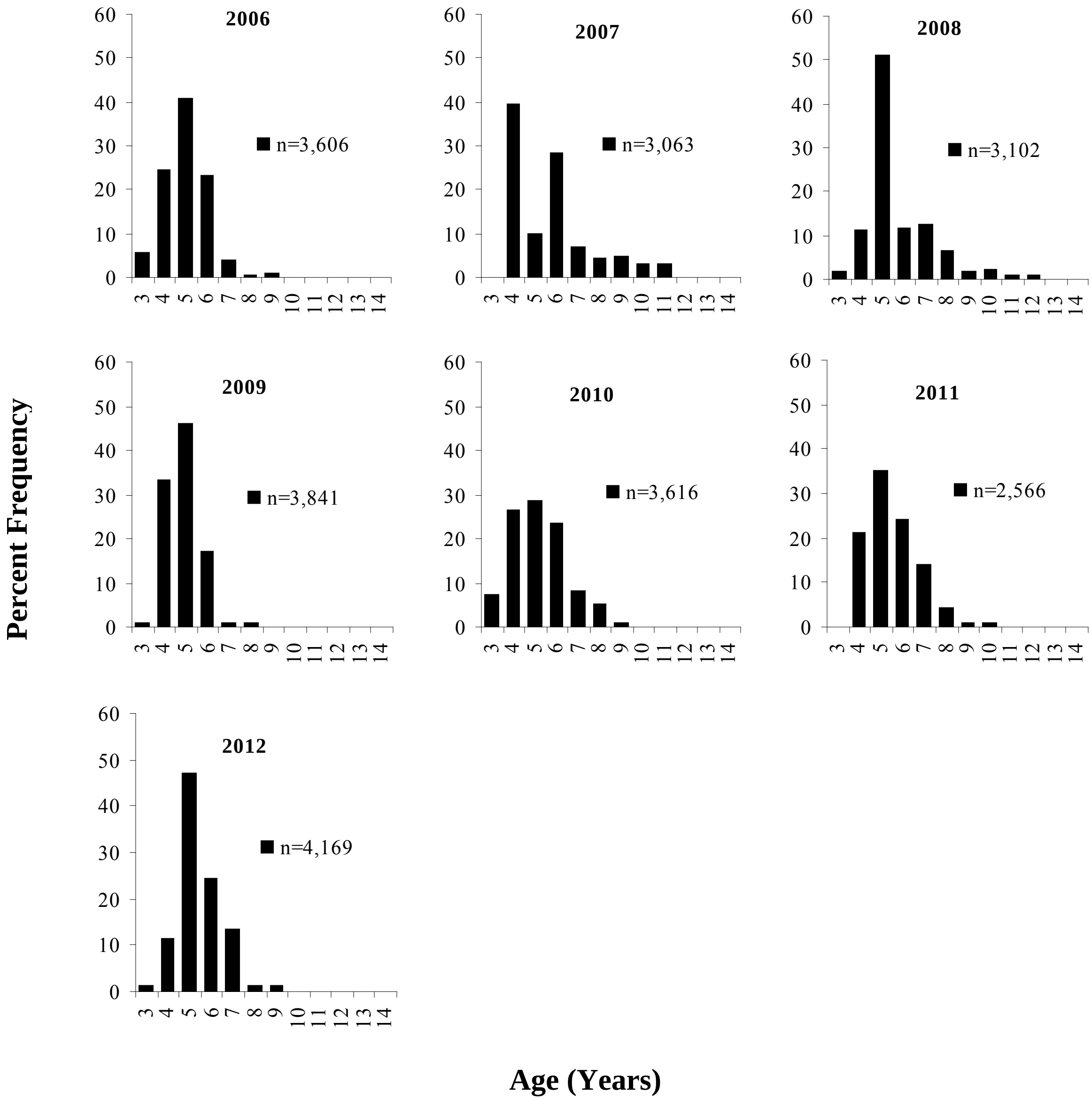


Figure 3. Length frequency distributions of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2011-February 2012.

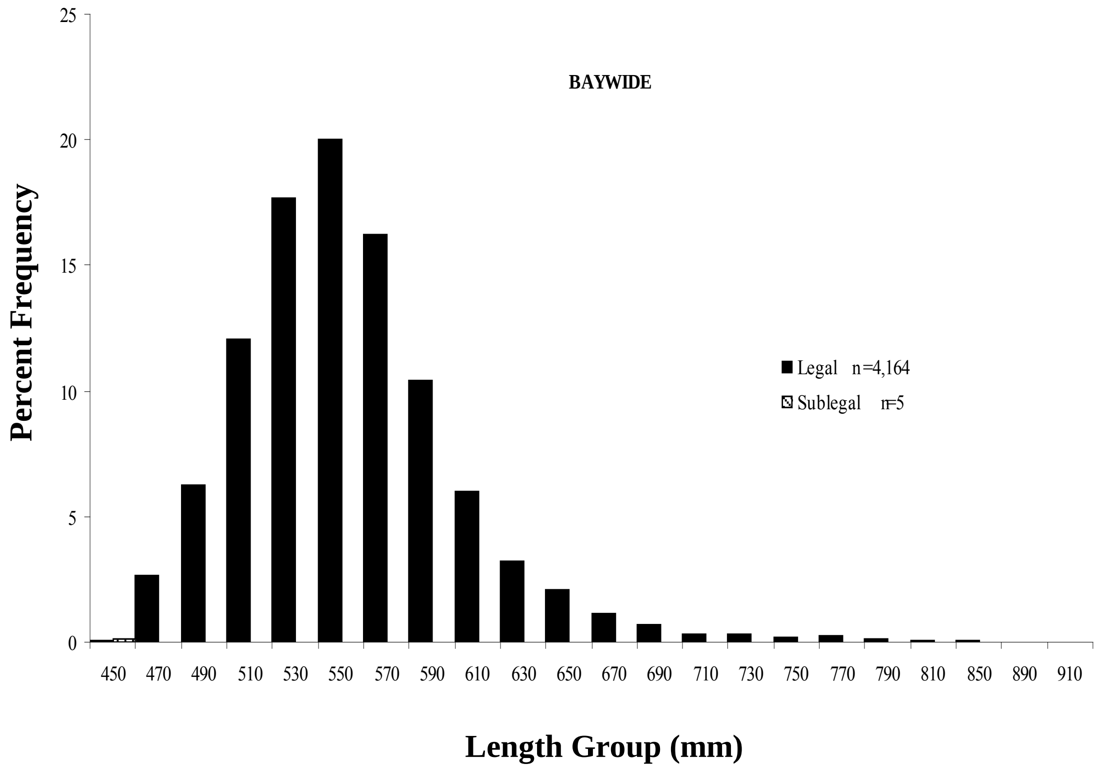


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2012 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.

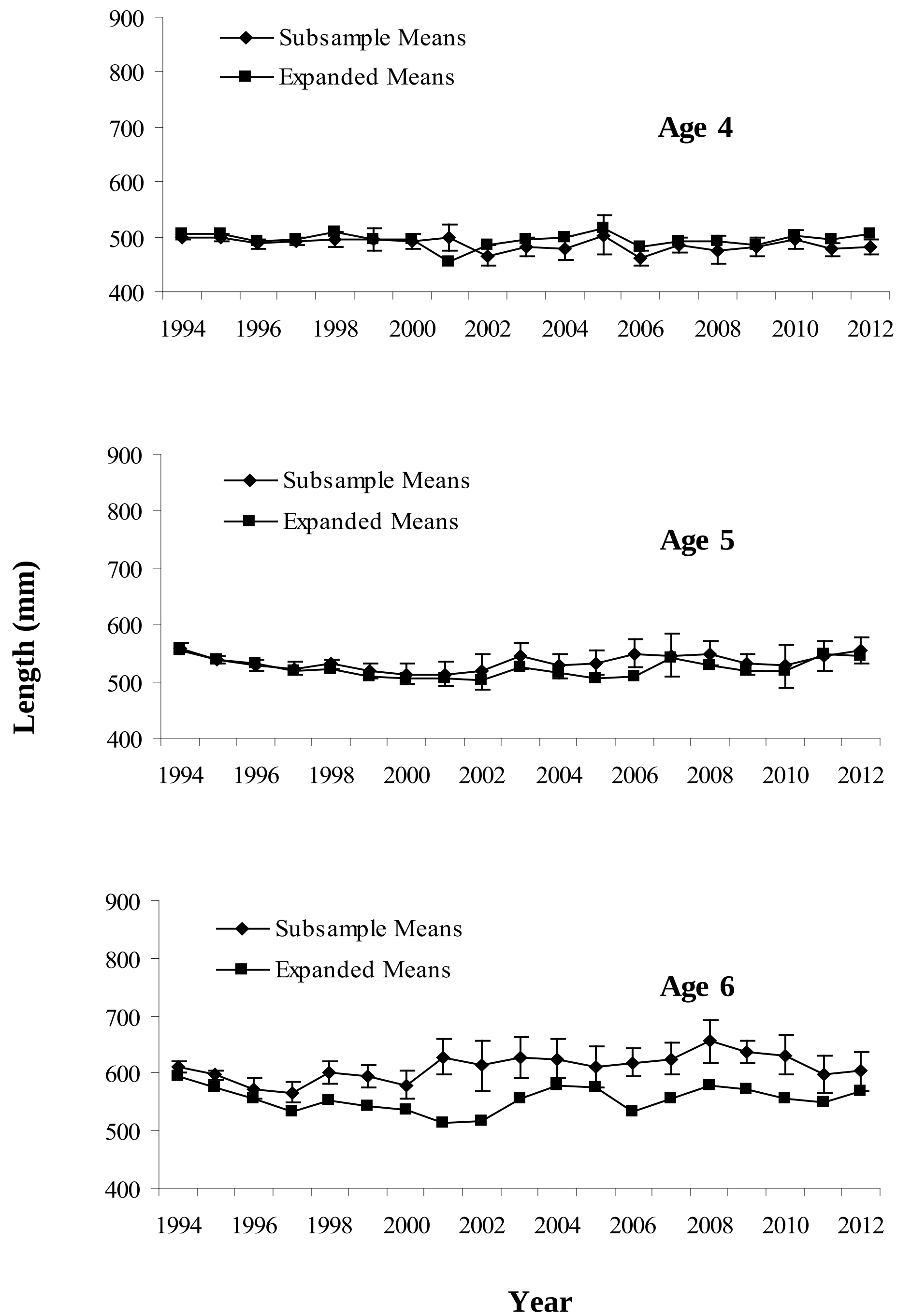


Figure 4. Continued.

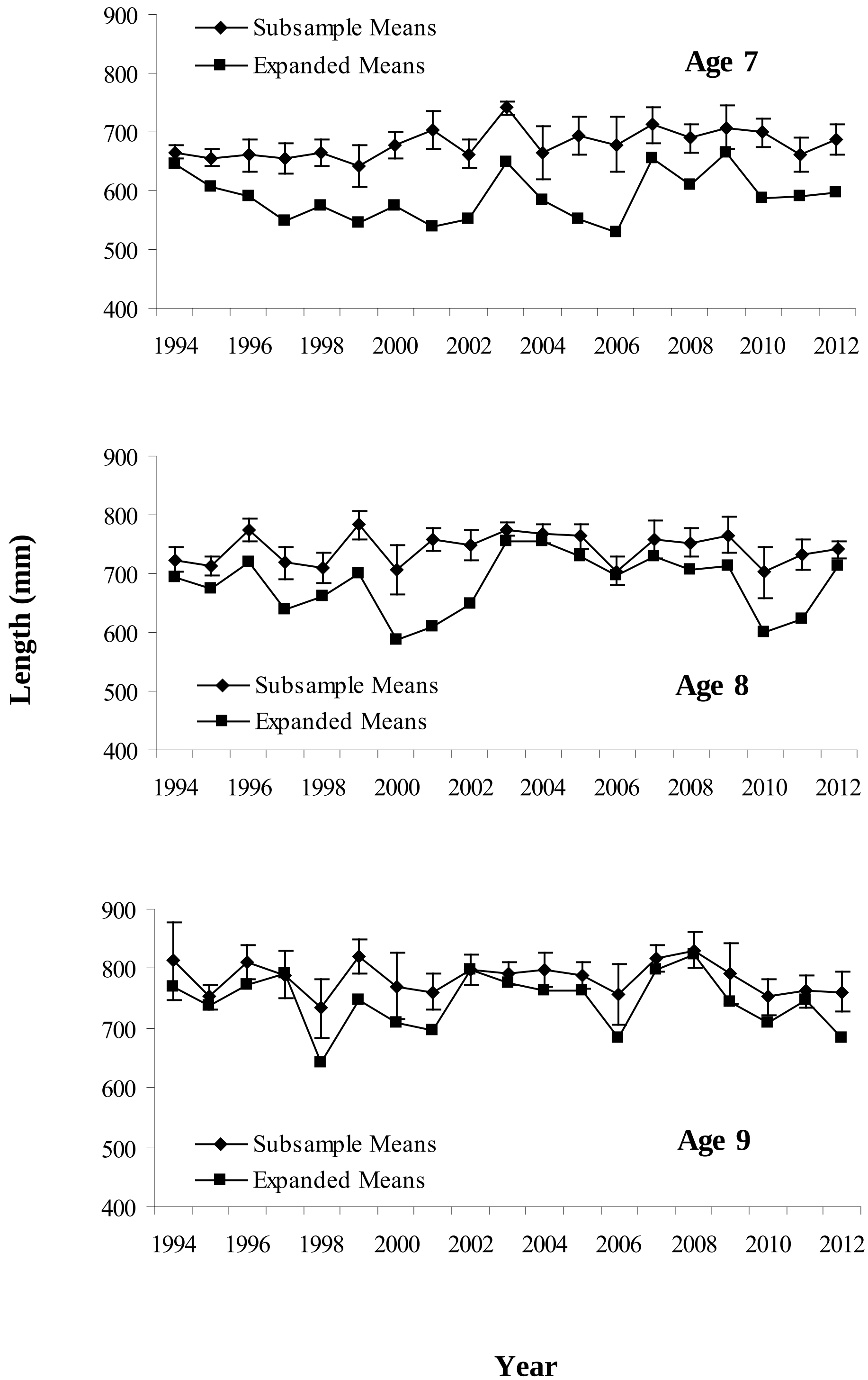


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2012 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.

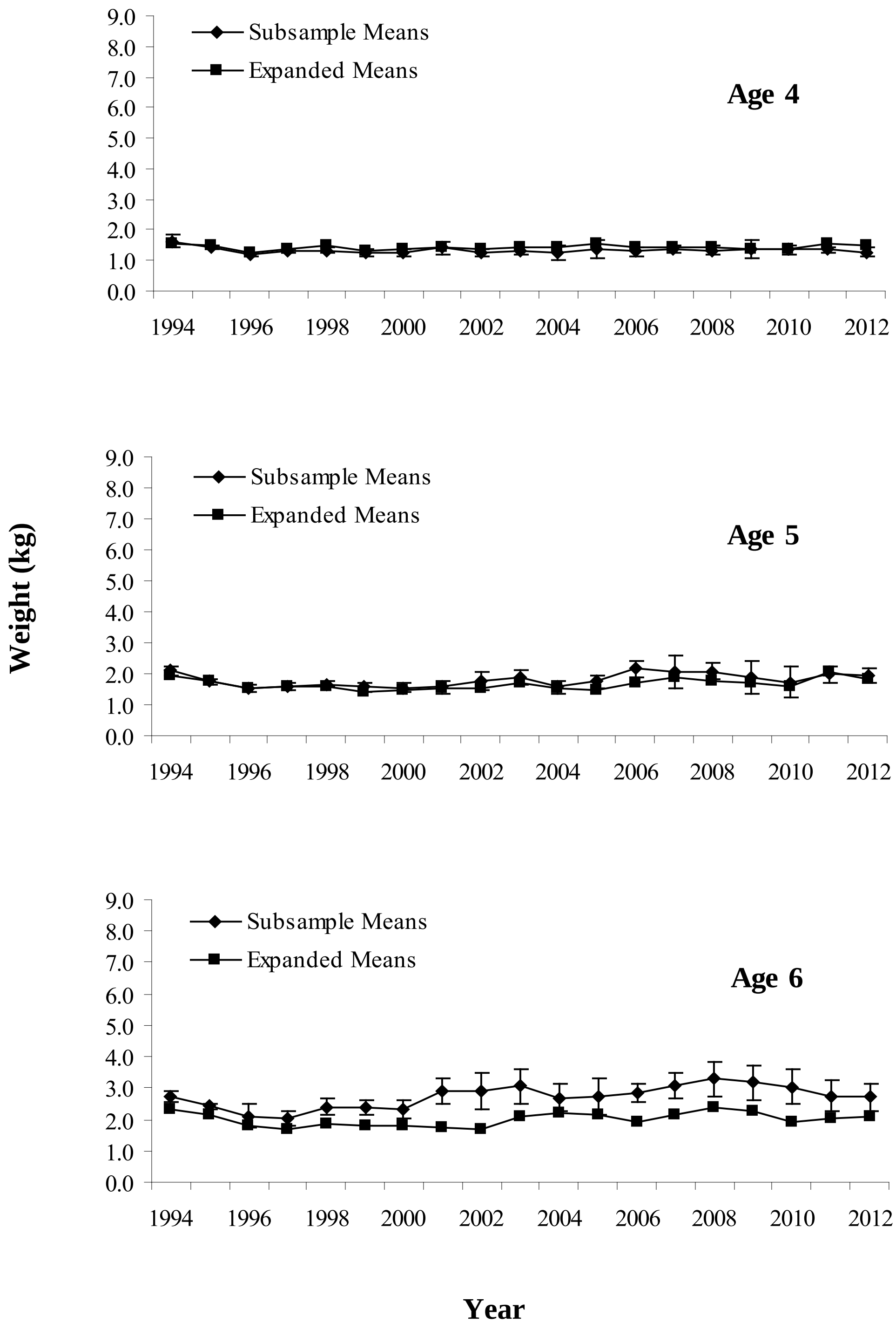
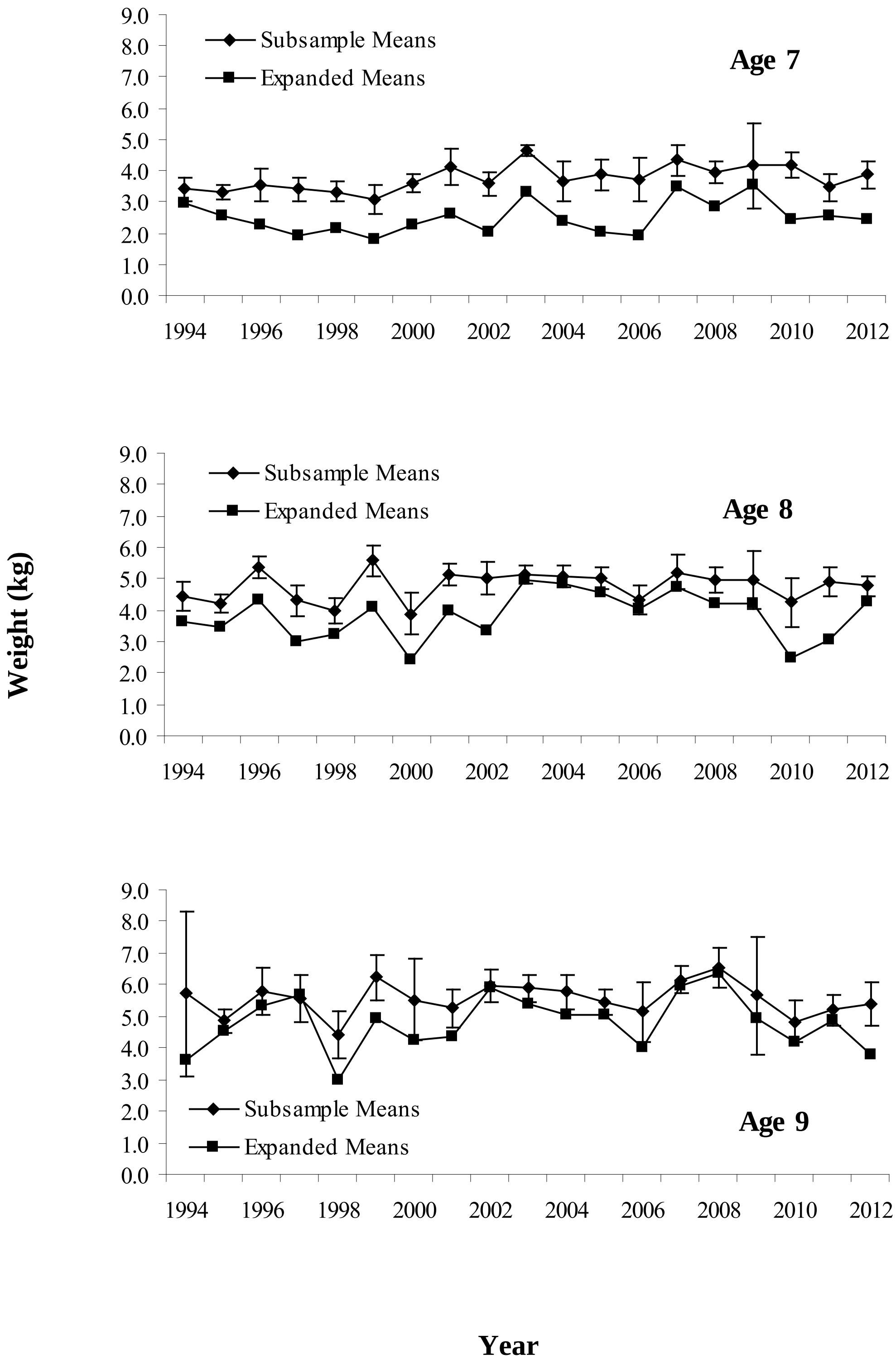


Figure 5. Continued.



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

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Amy Batdorf

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, 2011 and April 30, 2012. 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 2011-April 2012 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 comprises only 6% of Maryland's total commercial harvest quota. 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 alternated between these two check stations as fish came in during the season. Catches were typically intermittent and personnel sampled when fish were available. A monthly sample target of 150 fish was established for November, December, and January, because of 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.

<u>Analytical procedures</u>

Age composition of the sample was estimated via two-stage sampling (Kimura 1977, Quinn and Desiro 1999). In stage one, a random sample of lengths was taken from the total catch from November 2011 through April 2012. For stage two, a sub-sample of scales from Atlantic coast striped bass was 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 2011 -April 2012 Atlantic fishery, the year used for age calculations was 2012. 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 2011 through April 2012 was estimated by applying the sample age distribution to the total landings.

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

Sampling at coastal check stations was conducted on twenty-seven days between November 2011 and April 2012. A total of 561 fish were measured and weighed and the ALK was developed from 210 scale samples. This is the largest sample obtained from the Atlantic fishery in the time series. Because this fishery is largely a bycatch fishery, fish were harvested intermittently and are often difficult to intercept at the check stations.

Fish harvested during the 2011-2012 Atlantic coast fishing season ranged from age 4 (2008 year-class) to age 21 (1991 year-class) (Figure 1). Most (72%) striped bass harvested were ages 7 through 10 (Table 1). Striped bass were recruited into the Atlantic coast fishery as young as age 4, but due to the 24 inch minimum size limit, few fish younger than age 6 were harvested, which is similar to previous years.

Fourteen year classes were represented in the sampled harvest. Based on the estimated catch-at-age, the most common age harvested during the 2011-2012 Atlantic coast harvest was age 9 (2003 year-class), which represented 34% of the fishery (Table 1). Large contributions were also made by the 2004 year class (age 8) and the 2005 year class (age 7), which represented 16% and 13% of the fishery, respectively.

Striped bass sampled at Atlantic coast check stations during the 2011-2012 season had a mean length of 800 mm TL and mean weight of 5.6 kg. The length distribution of fish harvested in the 2011-2012 season ranged from 610 to 1270 mm TL (Figure 2). The weight distribution of the fish harvested ranged from 2.4 to 22.1 kg.

The sub-sample means-at-age and the expanded means-at-age for both length and weight were very similar (Tables 2 and 3, Figures 3 and 4). In 2012, 210 of the 561 fish (37%) sampled were aged. Because a high proportion of the total sample was aged, the expanded mean lengths and weights-at-age were similar to means of the aged sub-sample, and generally within the 95% confidence limits. Recently recruited age 5 fish had an expanded mean length of 657 mm TL and expanded mean weight of 3.1 kg. Age 9 striped bass, the most abundant age harvested, had an expanded mean length of 798 mm TL and expanded mean weight of 5.3 kg (Figure 1). Age 8 striped bass, the next most abundant year-class harvested, had an expanded mean length of 770 mm TL and an expanded mean weight of 4.8 kg.

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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 2011-April 2012.

Year-Class	Age	Catch	Percent
2008	4	9	0.2
2007	5	301	5.9
2006	6	351	6.9
2005	7	684	13.4
2004	8	795	15.5
2003	9	1729	33.8
2002	10	462	9.0
2001	11	404	7.9
2000	12	193	3.8
1999	13	81	1.6
1998	14	20	0.4
1997	15	61	1.2
1996	16	18	0.4
1991	21	9	0.2
	Total	**5,117**	**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 2011-April 2012. 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)
2008	4	1	617	---	---	1	617
2007	5	12	640	620	660	33	657
2006	6	9	667	646	689	38	673
2005	7	19	733	705	761	75	729
2004	8	28	786	758	814	87	770
2003	9	64	819	799	839	190	798
2002	10	23	901	862	941	51	866
2001	11	24	953	932	974	44	945
2000	12	13	991	960	1023	21	980
1999	13	7	1004	984	1024	9	1002
1998	14	2	1060	679	1441	2	1056
1997	15	5	1034	957	1111	7	1021
1996	16	2	1078	989	1167	2	1079
1991	21	1	1260	---	---	1	1260
Total		**210**				**561**	

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2011-April 2012. 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)
2008	4	1	2.8	---	---	1	2.8
2007	5	12	2.8	2.6	3.0	33	3.1
2006	6	9	3.1	2.9	3.3	38	3.3
2005	7	19	4.2	3.7	4.6	75	4.1
2004	8	28	4.9	4.5	5.4	87	4.8
2003	9	64	5.8	5.3	6.2	190	5.3
2002	10	23	7.7	6.8	8.6	51	6.8
2001	11	24	8.9	8.4	9.4	44	8.7
2000	12	13	10.0	8.9	11.1	21	9.6
1999	13	7	10.9	9.3	12.5	9	10.7
1998	14	2	12.4	---	---	2	11.9
1997	15	5	13.1	8.7	17.4	7	11.9
1996	16	2	13.1	8.6	17.5	2	13.0
1991	21	1	22.1	---	---	1	22.1
Total		**210**				**561**	

Figure 1. Age distribution of striped bass sampled from the Atlantic coast fishery, 2006-2012 seasons.

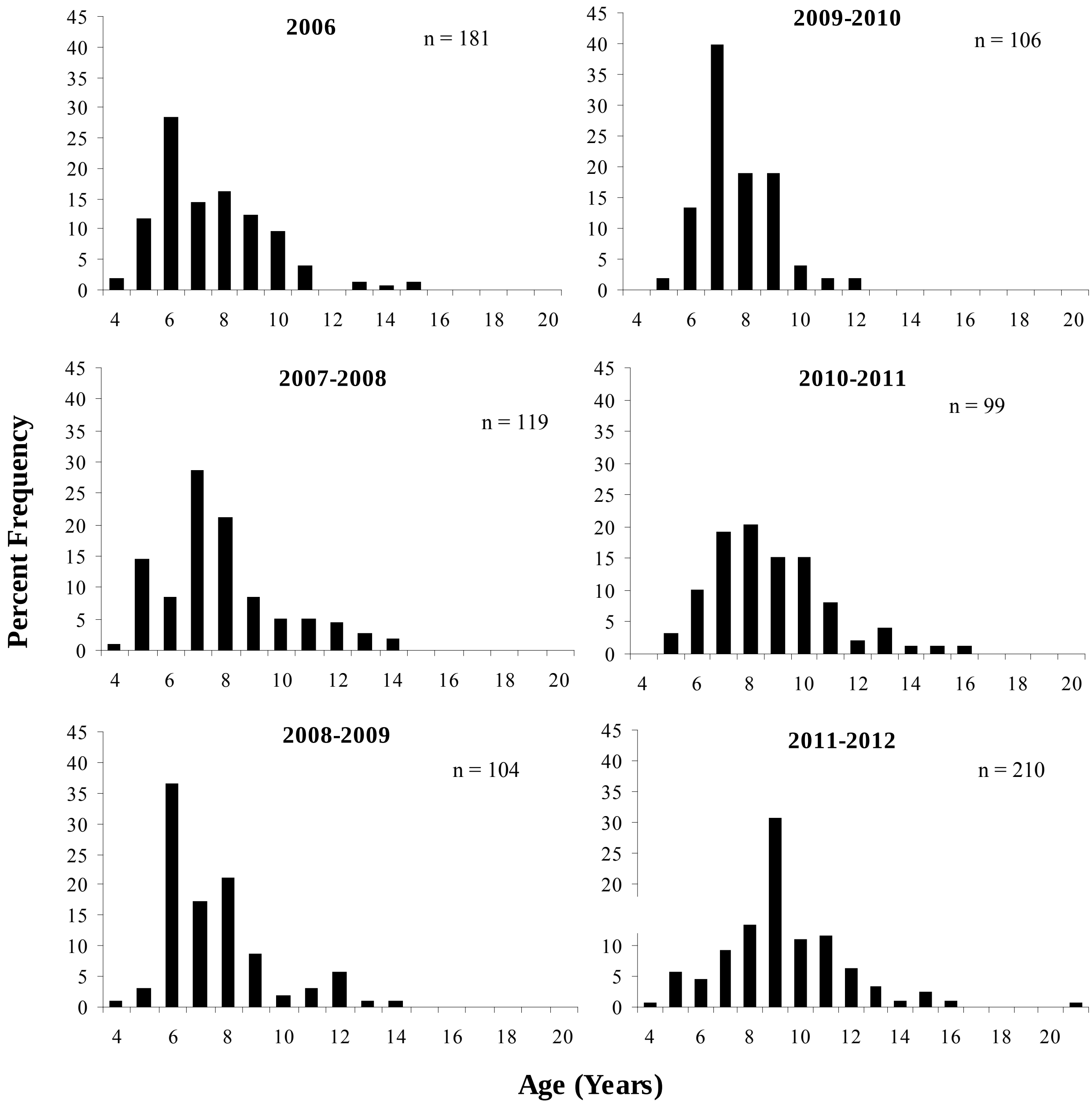


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, 2006-2012 seasons.

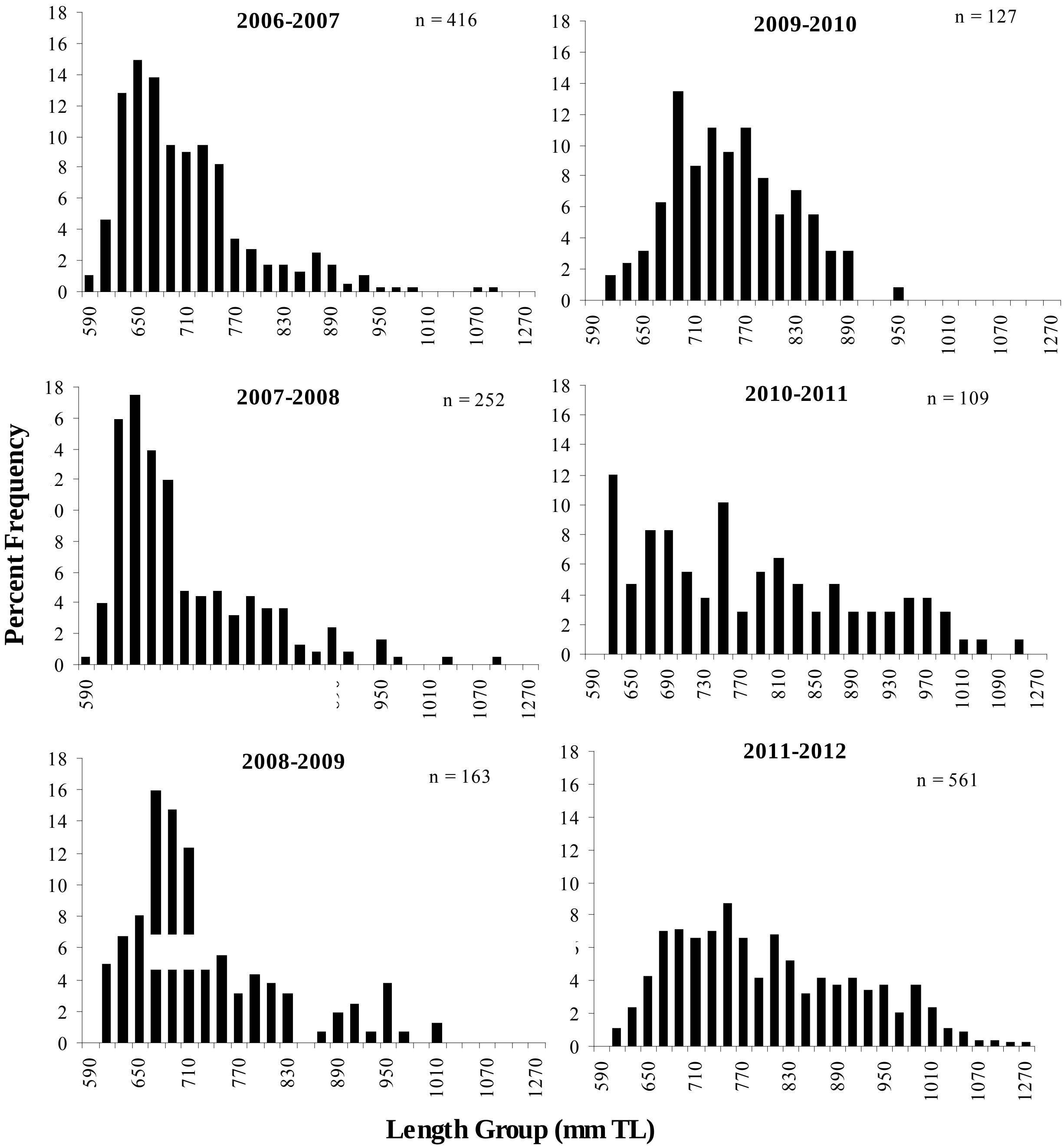


Figure 3. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2012 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences in scales on the y-axis.

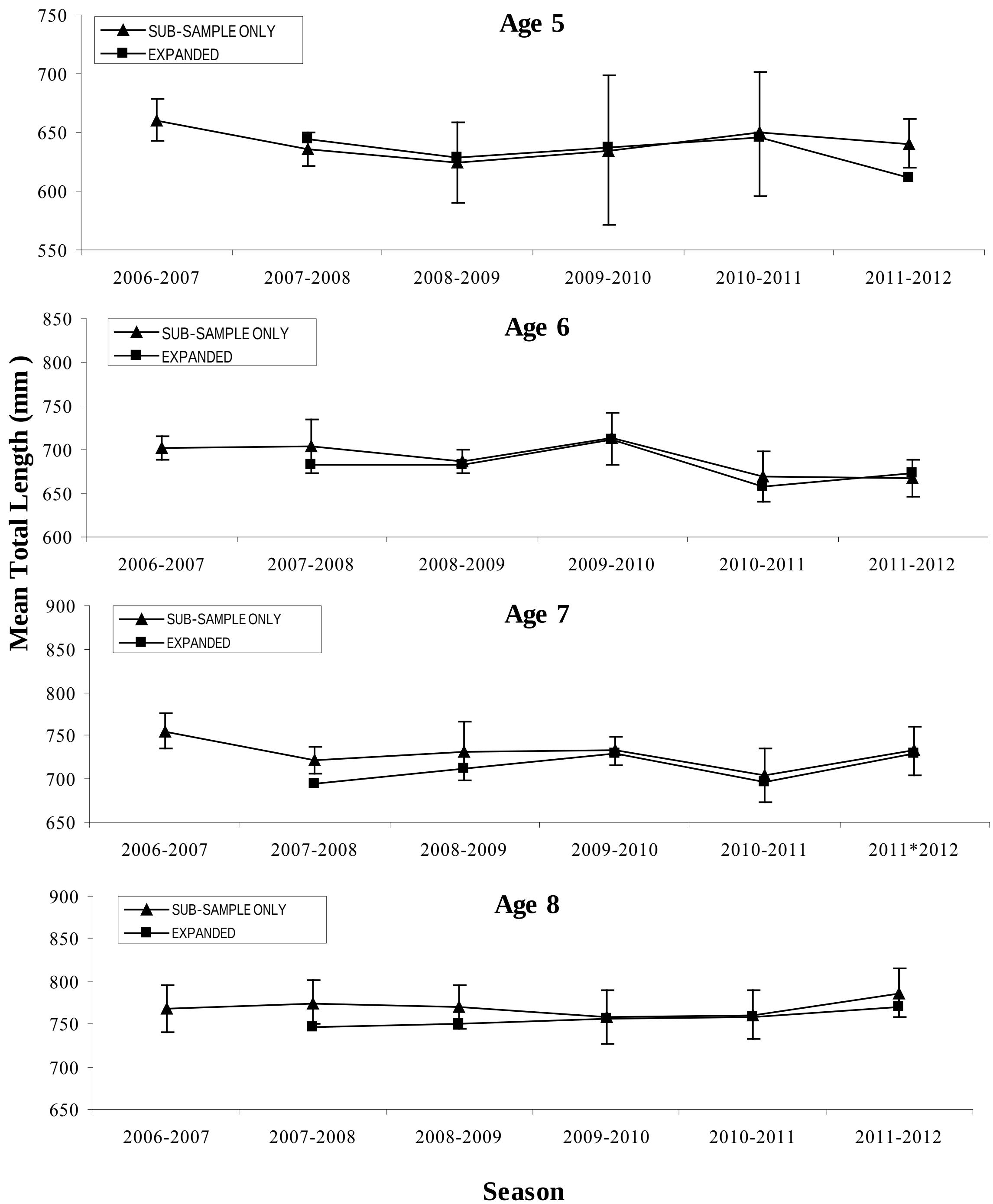


Figure 3. Continued

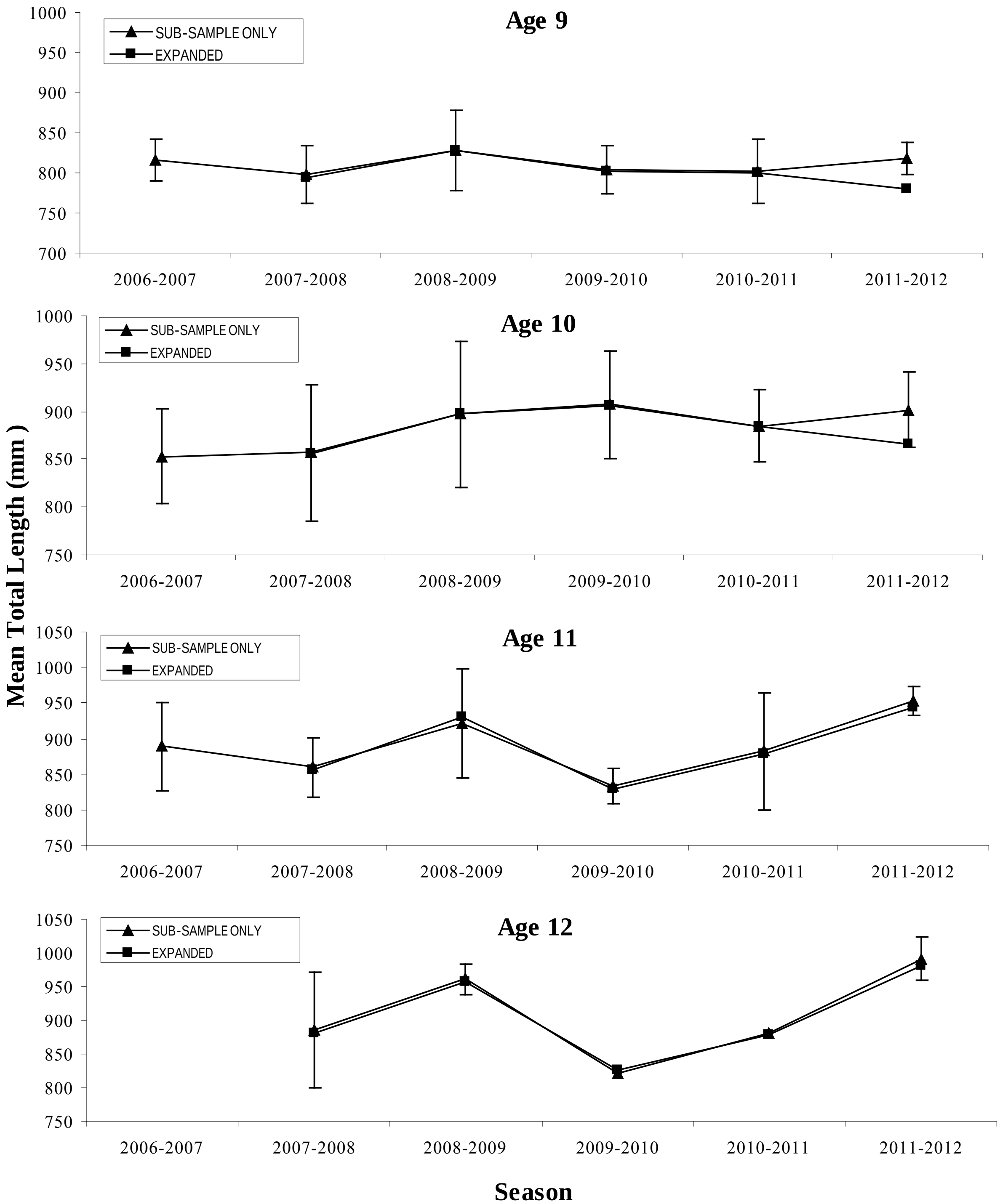


Figure 4. Mean weight (kg) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2012 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences of scale on the y-axis.

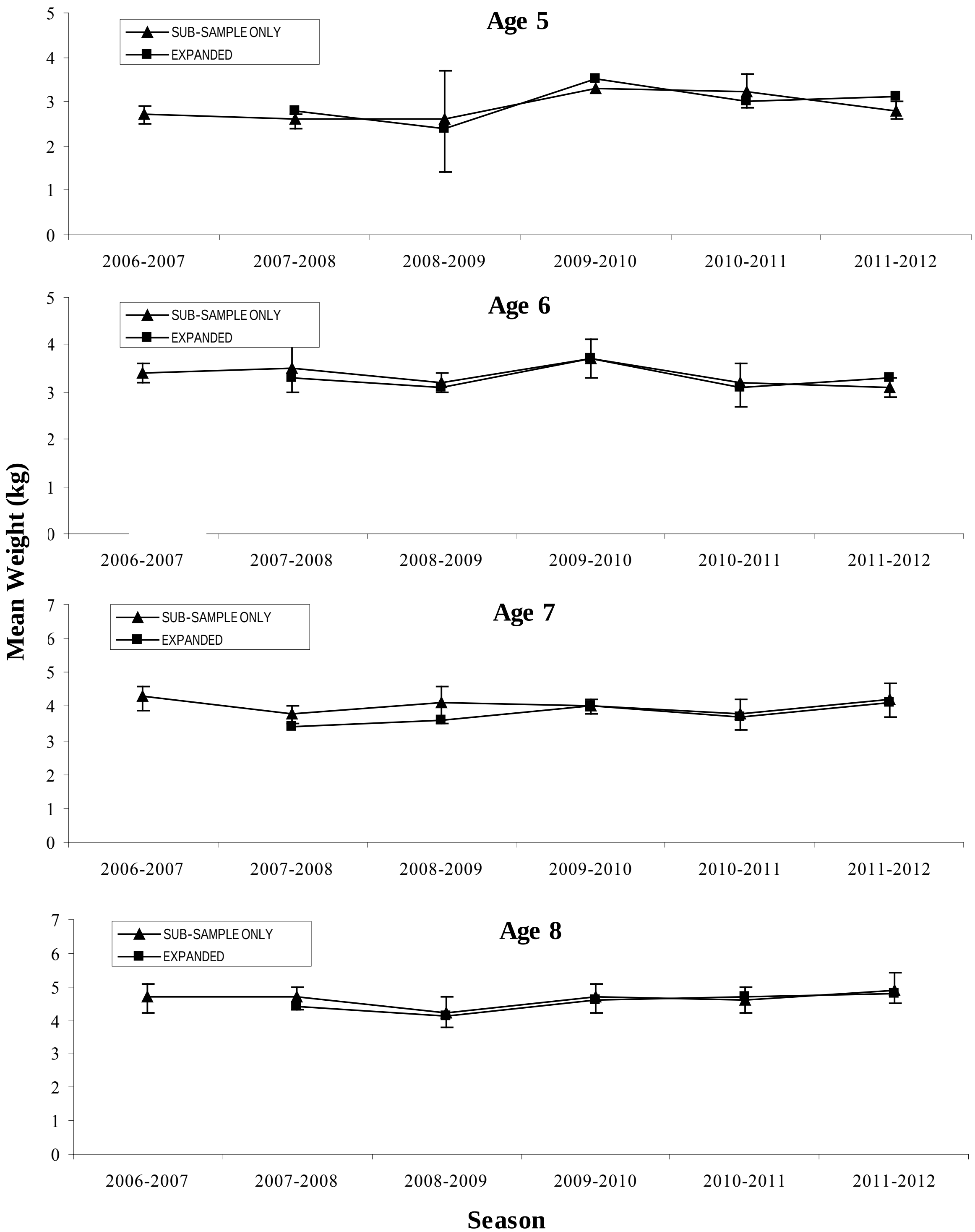
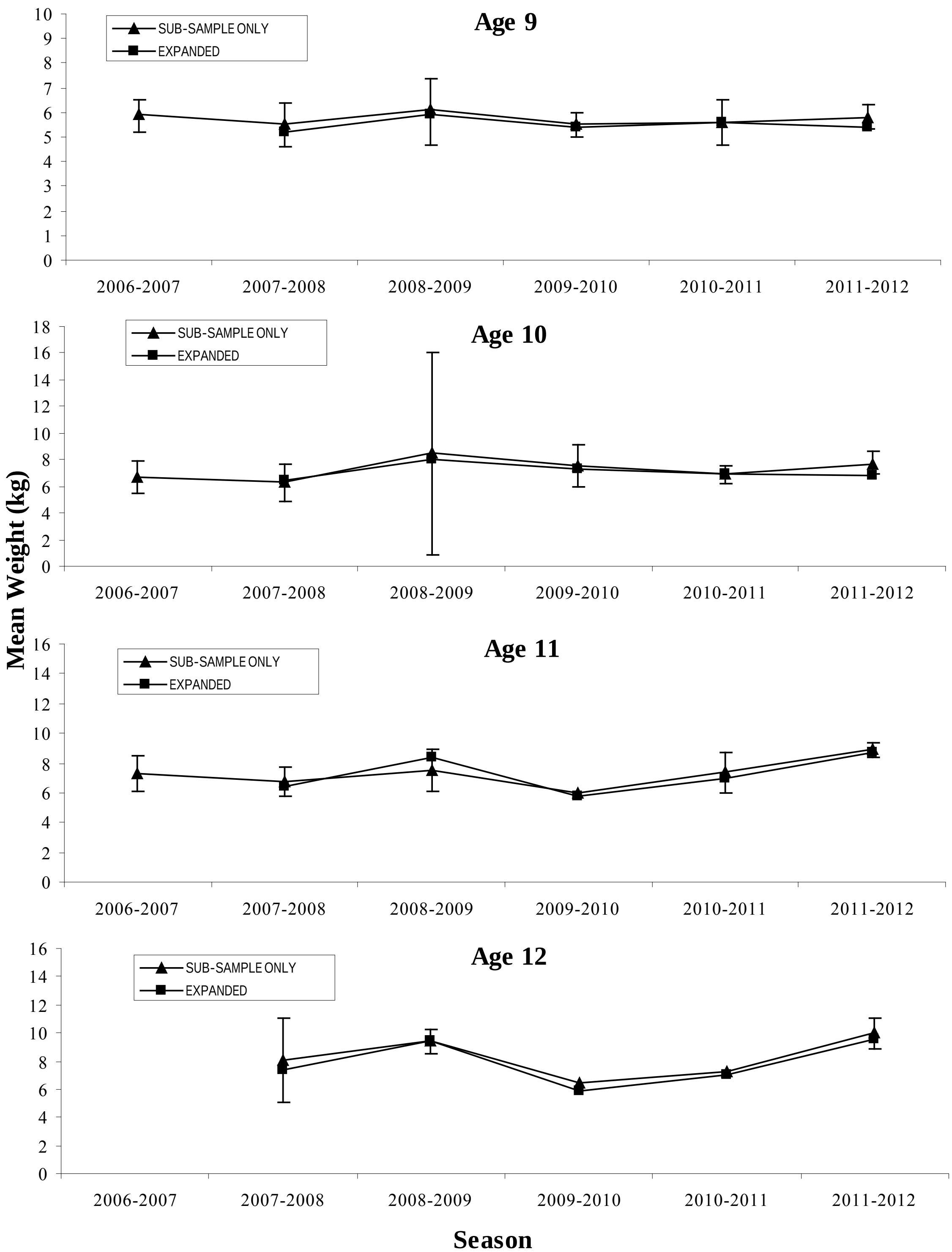


Figure 4. Continued



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Angela Giuliano and 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 2012 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 2012 (Figure 1). Gill nets were fished 6 days per week, weather permitting, from late March through May. In the Potomac River, sampling was conducted from March 26 to May 7 for a total of 30 sample days. In the Upper Bay, sampling was conducted from March 30 to May 18 with a total of 37 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. The order of panels within the suite of nets was randomized with gaps of 5 to 10 feet between each panel. Overall soak times for each panel ranged from 4 to 109 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, between the lateral line and the first dorsal fin. 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 'snap-shot' 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):

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

RESULTS AND DISCUSSION

CPUEs and variance

A total of 624 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 2012 un-weighted CPUE for Potomac females (22) ranked fourteenth of 27 years in the time series, below the series average of 27, but was double the value from 2011 (Table 2). The un-weighted CPUE for Potomac males (123) ranked twenty-fourth in the time-series, and well below the average of 433. The three values in that time series lower than 2012 have all occurred within the last seven years. The Upper Bay female CPUE (87) was the highest in the 28 year time series and well above the time series average of 37 (Table 4). The un-weighted CPUE for Upper Bay males (252) was ranked twenty-third in the time series, a decrease from the last several years and well below the time series average of 445 (Table 5). The Choptank River has not been sampled since 1996 (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 2012 selectivity-corrected, total, weighted CPUE (265) was twenty-seventh in the 28 year time series and well below the time series average of 487.

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 2012 age-specific CPUEs were all below 0.20 and indicated a small variance in CPUE. Historically, 80% of the CV values were less than 0.10 and 89% 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.

In both systems, males dominated both the un-weighted and weighted (Tables 12 and 13), total CPUEs. However, in 2012, the female contribution in each system was higher than usual. In the Upper Bay, females made up 26% of the un-weighted and weighted total CPUEs, and 15% on the Potomac. Historically the female contribution is usually less than 10% in each system. Three year old males from the 2009 year-class contributed 20% of the total weighted CPUE and 21% of the un-weighted in 2012. Potomac River fish only contributed 30% to the total un-weighted and 21% to the weighted CPUEs, unlike in 2011 when they contributed 53% to the un-weighted and 41% to the weighted CPUEs, respectively.

The 2009 year-class replaced the 2007 year-class as the largest contributor to male CPUE, making up 23% of the Upper Bay male CPUEs and 36% of the Potomac male CPUEs. In the Potomac River, 75% of the male CPUEs were made up of fish age 5 and younger. The Upper Bay male CPUEs were more evenly distributed over a wide range of ages.

Female CPUEs were distributed across many year-classes in both systems. Four year old females were again present in the Potomac River, but not in the Upper Bay. In the Upper Bay, female fish age 7 and younger made up only 16% of the female CPUEs, while on the Potomac River these young females contributed 45% to the female CPUEs. The 15+ age group, which includes the record 1996 year-class was the largest contributor (22%) to the female Upper Bay CPUEs, followed by age 9 females from the above average 2003 year-class (17%). In the Potomac River, the contribution of the 15+ females to the female CPUEs was lower (14% to un-weighted and 13% to weighted). The highest contribution to female CPUE in the Potomac River was from age 6 fish from the below average 2006 year-class, which contributed 22% to the female CPUEs.

Temperature and catch patterns

The NOAA National Climatic Data Center (2012) documented January through April of 2012 as the warmest on record and driest since 1985 for Maryland. Due to the warm weather, both systems started at the earliest date in the time series. 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 ranged from 13.6°C to 19.2°C. The survey started with the water temperature at 16.6°C, the highest starting temperature in the 27 year time series. While water temperatures increased a few degrees over the course of the survey, they were fairly stable throughout. Female CPUE peaked between April 13 and April 20 (Figure 2). This peak in female CPUE corresponds roughly with a peak of male CPUE on April 17, suggesting possible spawning activity. As opposed to previous years when males are present in the survey area after females, male CPUEs were almost nonexistent past April 21 despite the presence of some females still on the spawning grounds. Because the water temperatures at the beginning of the survey were above the 14°C needed to initiate spawning (Fay et al. 1983), it is possible that some spawning activity occurred prior to the start of the survey.

Surface water temperatures on the Upper Bay during the spawning survey ranged from 11.7°C to 20.8°C. Upper Bay water temperatures increased gradually throughout the spawning survey. Water temperatures surpassed 14°C on April 17. Peaks in female CPUE occurred on April 8, 17, and 20 (Figure 3). These dates also had the highest CPUEs for male striped bass in the Upper Bay. These observations suggest spawning activity in early to mid-April. Similar to the Potomac River, CPUEs for both sexes dropped off after April 21 suggesting the majority of spawning activity had concluded by this date.

Length composition of the stock

In 2012, 808 male and 172 female striped bass were measured. On the Potomac River, 313 male and 40 female striped bass were sampled; 495 males and 132 females were sampled from the Upper Bay (Figure 4). The mean length of female striped bass in 2012 (929 ± 21 mm TL) was larger than the mean length of male striped bass (578 ± 12 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 (492 ± 15 mm TL) and upper Bay (613 ± 16 mm TL) were significantly different (P<0.0001) in 2012. The majority of males caught on the Potomac River in 2012 were between 390 and 590 mm TL while the Upper Bay male length distribution was much wider and included many more fish between 610 and 830 mm TL (Figure 4).

Male striped bass on the Potomac ranged from 290 to 1138 mm TL. The length distribution was heavily influenced by the contribution of striped bass from the 2007 through 2010 year-classes. Male striped bass between 390 and 590 mm TL composed 71% of the Potomac River male catch in 2012 (Figure 4). The uncorrected Potomac male CPUE peaked between 330 and 470 mm TL, representing a combination of the 2008, 2009 and 2010 year-classes (Figure 5). The selectivity-corrected Potomac male CPUE peaked between 330 and 390 mm TL, increasing the contribution of the younger 2009 and 2010 year-classes. This could indicate that the smaller fish are not captured efficiently in the sampling gear

Male striped bass on the Upper Bay ranged from 268 to 1087 mm TL. Sizes of male Upper Bay fish were evenly distributed with one distinct peak between 770 and 830 mm TL. This peak coincides with the above average 2003 year-class (Figure 4). Male striped bass CPUE in the Upper Bay was higher across a wide range of sizes, whereas the majority of the Potomac River male CPUE occurred between 290 and 650 mm TL (Figure 5). The prominent year-classes of 2009, 2007, 2005, 2003, and 2001 were clearly visible in the selectivity-corrected CPUEs. These year-classes, with the exception of 2009, were all above average.

Female striped bass sampled from the Potomac River and Upper Bay in 2012 were not significantly different in mean total length (P=0.84). Female striped bass sampled from the Potomac ranged from 468 to 1197 mm TL (mean=924 ± 55 mm TL), while females sampled in the Upper Bay ranged from 544 to 1196 mm TL (mean=931 ± 22 mm TL; Figure 4).

There were few discernable peaks in female CPUE by length group the Potomac River in 2012. The CPUE observed in the 470 mm TL length group represents the one 4 year old female caught on the Potomac River. The selectivity-corrected CPUE peaks in the 530 through 730 mm TL length groups are a combination of six and seven year old females (Figure 6). The remainder of the Potomac River female CPUE was distributed over length groups from 870 to 1190 mm TL.

In the Upper Bay, female corrected and uncorrected CPUEs covered a wide range of length groups. Application of the selectivity model to the data corrected the catch upward in the extreme ends of the length distribution where few fish were encountered. Large numbers of females were captured in 2012, resulting in a higher than normal CPUEs. The youngest female, in the 550 mm TL length group, was from the 2007 year-class. Peaks in selectivity-corrected CPUEs between 610 and 670 mm TL were composed of fish from the 2005 and 2006 year-classes. The peaks in the larger size groups were a combination of 11 to 19 year old fish from the 2001 through 1993 year-classes.

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 2012 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 the extremes in age, sample sizes are 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). No differences between sample areas were detected in LAA for either sex in 2012 ($P>0.05$) except for 6 and 14 year old males. Six year old males were significantly longer on the Upper Bay (641 mm TL) than the Potomac (572 mm TL, $P=0.05$). Fourteen year old males were significantly larger on the Potomac (1138 mm TL) than the Upper Bay (991 mm TL, $P=0.03$), however the Potomac sample size was just one fish which may not be representative of all 14 year old male fish on the Potomac River.

When comparing LAA between years, only gill net fish were used. Male and female LAA has been relatively stable since the mid 1990s (Figures 7 and 8). Mean lengths of males were similar in 2011 and 2012 for all ages except for age 7 (ANOVA, $\alpha=0.05$, $P=0.003$). Mean lengths of females were similar in 2011 and 2012 for all ages that could be tested except for age 12 (ANOVA, $\alpha=0.05$, $P=0.03$).

Age composition of the stock

During the 2012 survey, eighteen age-classes, ranging from 2 to 19 were encountered (Tables 14 and 15). Male striped bass ranged from ages 2 to 15, with ages 8 and 9 fish (2004 and 2003 year-classes) being the most abundant male cohorts. The majority of females were ages 9 to 14, with most of the females collected at age 9 (2003 year-class). 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 2012, the largest increase in age-specific CPUE was indicated by the age 11 (2001 year-class) cohort. While all age-specific CPUEs for age 8 and younger showed a decline in 2012, the majority for fish age 9 and older showed an increase. The 1996 year-class has now moved into the 15+ age group, and their contribution is still evident (Figure 9).

In 2012, the contribution of age 8+ females to the female spawning stock increased 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. 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 (ASMFC 2011).

The percentage of the overall sample (males and females combined) age 8 and older has been variable since 1997 (Figure 11). However the 2012 value of 41% is the highest in the 28 year time series. The percentage of age 8+ fish is heavily influenced by strong year-classes and shows cyclical variations (Figure 9). While the percentage of age 8+ females showed a modest increase in 2012, the sexes-combined sample of age 8+ fish showed a large increase. This was due to a combination of a large number of older males encountered in the Upper Bay and low recruitment to the spawning stock of three year-classes since 2005.

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 (ASMFC 2011). The MD DNR estimate of ISP generated from the upper Bay has been variable, but in 2012 the ISP value of 799 was the highest on record, well above the time-series average of 301 (Table 16, Figure 12). The 2012 Potomac River female ISP increased slightly to 150, but was still well below the time series average of 231.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2012.

	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	0	2	0	**2**	0	0	0	**0**
310	2	3	0	**5**	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	3	3	0	**6**	0	0	0	**0**
430	3	3	0	**6**	0	0	1	**1**
450	3	3	0	**6**	0	0	6	**6**
470	3	3	1	**7**	0	1	8	**9**
490	3	3	0	**6**	0	0	9	**9**
510	3	3	0	**6**	0	0	9	**9**
530	3	3	0	**6**	0	1	9	**10**
550	3	3	0	**6**	1	0	7	**8**
570	6	5	0	**11**	0	0	10	**10**
590	5	5	0	**10**	2	0	5	**7**
610	5	5	0	**10**	0	0	6	**6**
630	5	5	0	**10**	3	0	5	**8**
650	8	2	0	**10**	0	1	2	**3**
670	10	0	0	**10**	3	1	4	**8**
690	9	1	0	**10**	2	1	4	**7**
710	10	0	5	**15**	1	1	4	**6**
730	10	0	5	**15**	2	1	1	**4**
750	8	0	3	**11**	0	0	0	**0**
770	8	2	5	**15**	1	0	0	**1**
790	10	1	4	**15**	2	0	2	**4**
810	8	3	5	**16**	1	0	5	**6**
830	6	4	5	**15**	4	0	4	**8**
850	10	0	1	**11**	5	0	10	**15**
870	5	3	4	**12**	5	3	7	**15**
890	6	2	2	**10**	9	1	5	**15**
910	2	0	1	**3**	7	3	5	**15**
930	8	1	0	**9**	10	0	5	**15**
950	1	0	0	**1**	6	4	5	**15**
970	5	1	1	**7**	8	3	2	**13**
990	2	0	0	**2**	9	2	4	**15**
1010	0	3	0	**3**	9	4	0	**13**
1030	4	0	0	**4**	3	1	0	**4**
1050	3	0	0	**3**	8	2	1	**11**
1070	1	0	0	**1**	1	2	1	**4**
1090	1	0	0	**1**	7	1	1	**9**
1110	0	0	0	**0**	1	2	0	**3**
1130	0	1	0	**1**	2	1	0	**3**
1150	0	0	0	**0**	1	0	0	**1**
1170	0	0	0	**0**	1	0	0	**1**
1190	0	0	0	**0**	3	2	0	**5**
1210	0	0	0	**0**	0	0	0	**0**
Total	**195**	**85**	**42**	**322**	**117**	**38**	**147**	**302**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2012 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	3.0	**22**
Average																**27**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2012 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.	8.9	7.8	4.8	1.7	2.2	4.0	0.8	0.6	0.0	**167**

						6										
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**
Average																**433**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985-2012 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**
Average																**37**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985-2012 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**
Average																**445**

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 (1985–2012) 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	**387**
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	**397**
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	**352**
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	**283**

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	**400**
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	**455**
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	2.6	**611**
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	9.5	**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	13.4	**265**
Average																**487**

Table 9. Lower confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2012) 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	*

* 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 (1985–2012) 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	*

* 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 (1985–2012) 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	*

* Note: CV values >1.00 are noted by shadings. 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, late March through May 2012. 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
2011	1	0.0	0.0	0.0	0.0	0.0	0.0
2010	2	31.8	6.6	0.0	0.0	19.0	12.8
2009	3	101.2	20.9	0.0	0.0	44.4	56.8
2008	4	43.7	9.0	1.0	0.0	15.1	27.7
2007	5	44.3	9.1	1.4	1.5	13.9	27.5
2006	6	33.2	6.8	4.7	6.8	6.4	15.3
2005	7	40.8	8.4	2.6	6.2	6.0	26.0
2004	8	39.0	8.0	1.1	6.4	4.8	26.7
2003	9	42.9	8.8	1.6	15.4	4.1	21.8
2002	10	13.0	2.7	1.0	5.8	1.4	4.8
2001	11	28.3	5.8	1.6	8.8	2.1	15.8
2000	12	23.2	4.8	1.8	9.3	1.3	10.8
1999	13	7.6	1.6	0.8	4.5	0.6	1.7
1998	14	12.9	2.7	1.0	3.8	4.1	4.0
≤1997	15+	23.0	4.7	3.0	19.2	0.0	0.7
Total		484.7		21.6	87.5	123.2	252.4
% of Total				4	18	25	52
% of Sex				20	80	33	67
% of System				15	26	85	74

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, late March through May 2012. 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
2011	1	0.0	0.0	0.0	0.0	0.0	0.0
2010	2	15.2	5.7	0.0	0.0	7.3	7.8
2009	3	52.0	19.6	0.0	0.0	17.1	34.9
2008	4	23.2	8.8	0.4	0.0	5.8	17.0
2007	5	23.7	9.0	0.5	0.9	5.4	16.9
2006	6	17.8	6.7	1.8	4.2	2.5	9.4
2005	7	23.1	8.7	1.0	3.8	2.3	16.0
2004	8	22.6	8.5	0.4	3.9	1.8	16.4
2003	9	25.0	9.5	0.6	9.4	1.6	13.4
2002	10	7.4	2.8	0.4	3.6	0.5	3.0
2001	11	16.5	6.2	0.6	5.4	0.8	9.7
2000	12	13.6	5.1	0.7	5.7	0.5	6.7
1999	13	4.4	1.6	0.3	2.7	0.2	1.0
1998	14	6.7	2.5	0.4	2.3	1.6	2.5
≤1997	15+	13.4	5.1	1.1	11.8	0.0	0.5
Total		264.7		8.3	53.8	47.5	155.1
% of Total				3	20	18	59
% of Sex				13	87	23	77
% of System				15	26	85	74

* 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, late March through May 2012.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2010	2	POTOMAC	9	326	301	350	32	11
		UPPER	2	320	244	396	8	6
		COMBINED	11	325	305	344	28	9
2009	3	POTOMAC	16	400	379	420	39	10
		UPPER	15	376	353	398	40	10
		COMBINED	31	388	373	403	41	7
2008	4	POTOMAC	4	463	336	590	80	40
		UPPER	13	446	403	489	71	20
		COMBINED	17	450	414	486	71	17
2007	5	POTOMAC	13	535	510	561	43	12
		UPPER	9	536	489	582	61	20
		COMBINED	22	536	514	558	50	11
2006	6	POTOMAC	10	572	537	607	49	15
		UPPER	8	641	568	714	87	31
		COMBINED	18	603	565	640	75	18
2005	7	POTOMAC	9	618	597	638	27	9
		UPPER	27	646	618	674	70	14
		COMBINED	36	639	617	660	63	11
2004	8	POTOMAC	4	672	544	800	81	40
		UPPER	43	748	729	772	79	12
		COMBINED	47	742	718	767	81	12
2003	9	POTOMAC	7	824	791	857	36	14
		UPPER	43	777	754	800	74	11
		COMBINED	50	784	763	804	71	10
2002	10	POTOMAC	3	855	781	929	30	17
		UPPER	8	850	790	910	72	25
		COMBINED	11	851	810	893	61	19
2001	11	POTOMAC	4	839	776	901	39	20
		UPPER	11	917	861	974	84	25
		COMBINED	15	896	851	942	82	21
2000	12	POTOMAC	3	974	862	1086	45	26
		UPPER	5	984	897	1072	70	31
		COMBINED	8	981	932	1029	59	21
1999	13	POTOMAC	2	992	782	1201	23	17
		UPPER	1	1042	-	-	-	-
		COMBINED	3	1008	925	1092	34	19
1998	14	POTOMAC	1	1138	-	-	-	-
		UPPER	9	991	950	1032	54	18
		COMBINED	10	1006	957	1055	69	22
1997	15	POTOMAC	0	-	-	-	-	-
		UPPER	1	1043	-	-	-	-
		COMBINED	1	1043	-	-	-	-

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, late March through May 2012.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2008	4	POTOMAC	1	468	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	468	-	-	-	-
2007	5	POTOMAC	0	-	-	-	-	-
		UPPER	1	544	-	-	-	-
		COMBINED	1	544	-	-	-	-
2006	6	POTOMAC	4	647	527	767	75	38
		UPPER	3	655	510	801	59	34
		COMBINED	7	651	592	709	63	24
2005	7	POTOMAC	2	697	290	1104	45	32
		UPPER	6	657	620	695	36	14
		COMBINED	8	667	635	700	39	14
2004	8	POTOMAC	0	-	-	-	-	-
		UPPER	6	794	711	876	79	32
		COMBINED	6	794	711	876	79	32
2003	9	POTOMAC	5	908	861	955	38	17
		UPPER	32	866	838	895	80	14
		COMBINED	37	872	847	898	76	13
2002	10	POTOMAC	4	928	854	1002	47	23
		UPPER	18	939	917	961	44	10
		COMBINED	22	937	918	957	44	9
2001	11	POTOMAC	8	964	919	1008	53	19
		UPPER	12	966	941	990	38	11
		COMBINED	20	965	945	985	43	10
2000	12	POTOMAC	4	1031	960	1102	45	22
		UPPER	13	1031	999	1062	53	15
		COMBINED	17	1031	1005	1056	50	12
1999	13	POTOMAC	0	-	-	-	-	-
		UPPER	9	1040	1002	1079	50	17
		COMBINED	9	1040	1002	1079	50	17
1998	14	POTOMAC	3	1081	830	1331	101	58
		UPPER	7	1039	1001	1078	41	16
		COMBINED	10	1052	1008	1096	62	19
1997	15	POTOMAC	2	1090	931	1248	18	13
		UPPER	4	1078	945	1211	83	42
		COMBINED	6	1082	1013	1150	65	27
1996	16	POTOMAC	4	1080	988	1172	58	29
		UPPER	3	1119	981	1257	56	32
		COMBINED	7	1097	1045	1148	56	21
1995	17	POTOMAC	1	1197	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	1197	-	-	-	-
1994	18	POTOMAC	0	-	-	-	-	-
		UPPER	2	1158	695	1622	52	37
		COMBINED	2	1158	695	1622	52	37
1993	19	POTOMAC	0	-	-	-	-	-
		UPPER	1	1196	-	-	-	-
		COMBINED	1	1196	-	-	-	-

Table 16. Index of spawning biomass 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	64.93	25.90
1986	151.95	45.70
1987	400.49	88.84
1988	250.32	63.60
1989	120.29	80.54
1990	98.42	62.52
1991	109.38	138.65
1992	274.95	379.35
1993	278.52	420.88
1994	87.26	Not Sampled
1995	547.66	293.77
1996	347.87	391.57
1997	240.42	362.33
1998	155.86	226.78
1999	168.44	280.82
2000	192.75	325.22
2001	479.14	272.49
2002	276.46	398.94
2003	563.41	118.46
2004	376.19	530.23
2005	469.68	195.80
2006	406.22	458.23
2007	418.54	263.27
2008	228.60	162.78
2009	482.52	189.77
2010	279.71	212.79
2011	167.56	105.43
2012	799.21	149.96
Average	**301.31**	**231.28**

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, late March - May 2012.

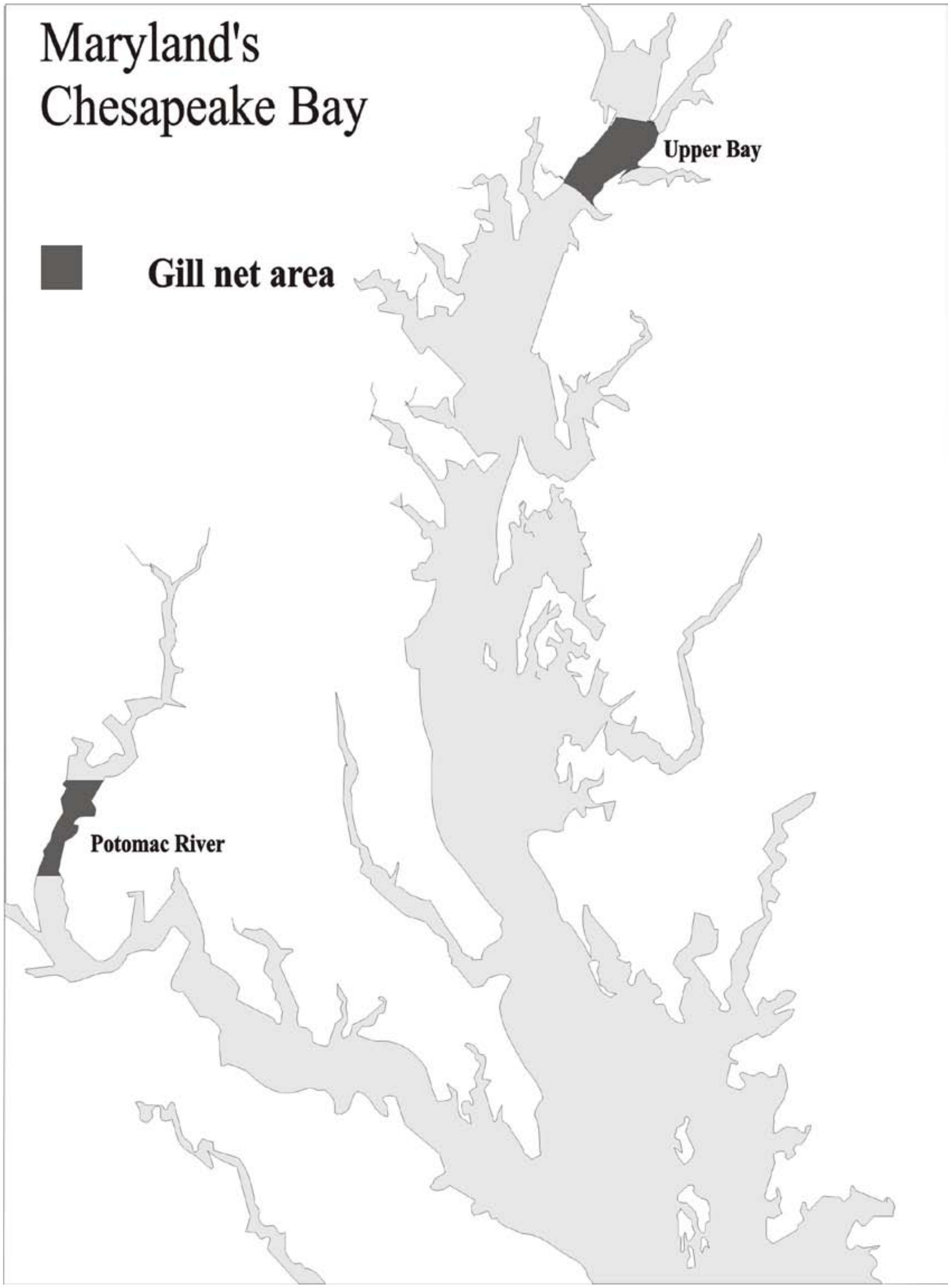


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, late March through May 2012. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

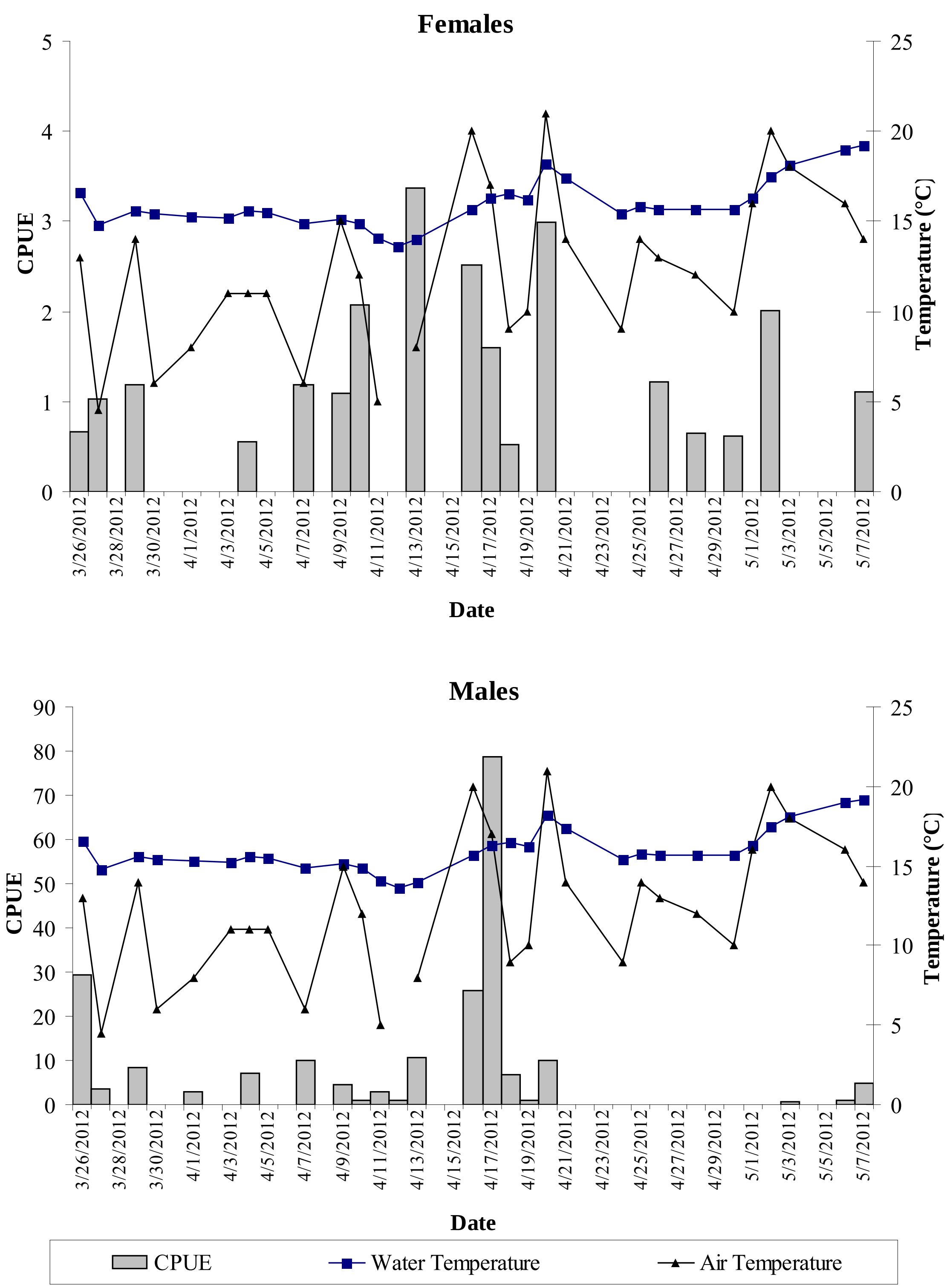


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Upper Chesapeake Bay, late March through May 2012. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

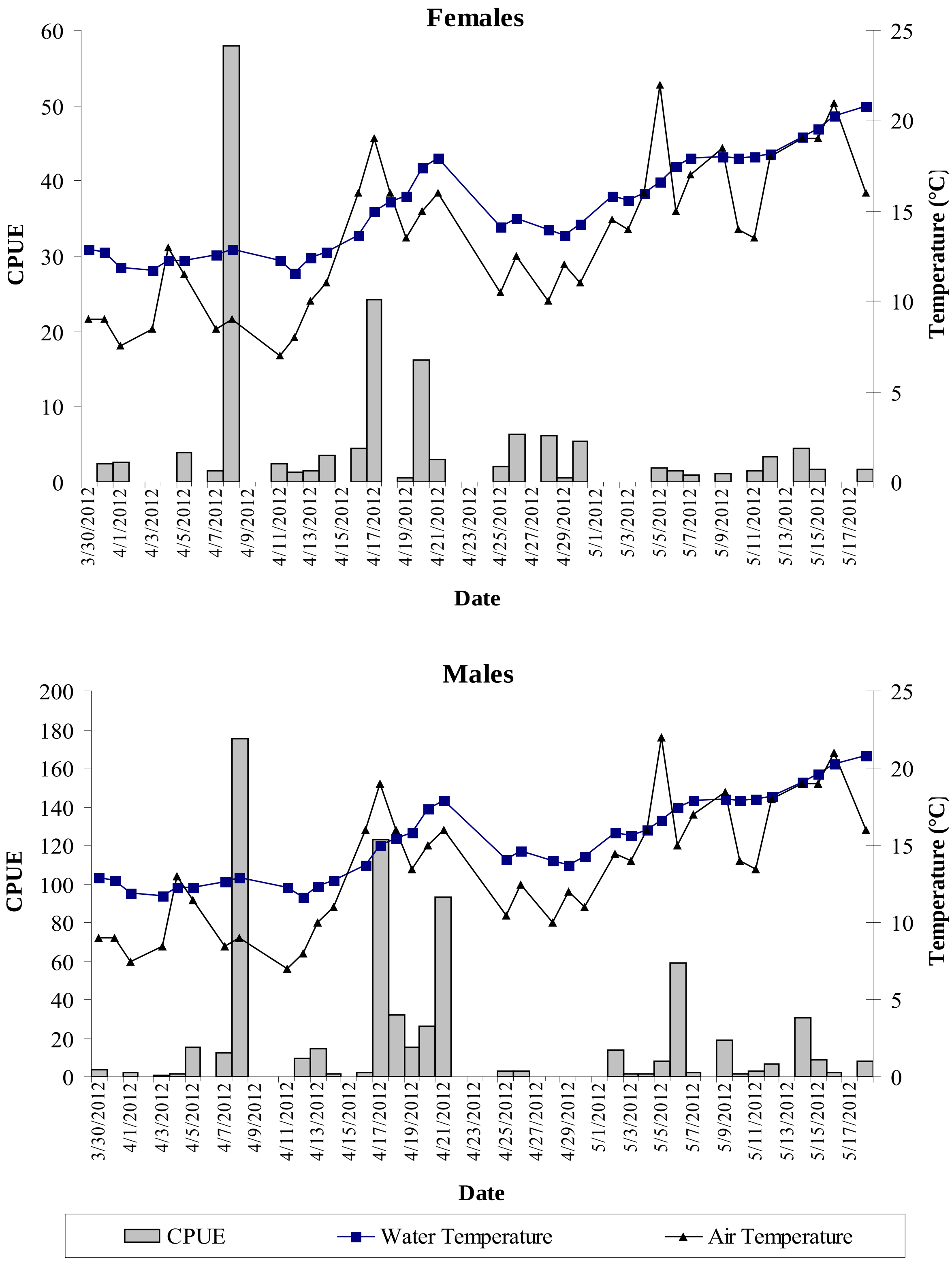
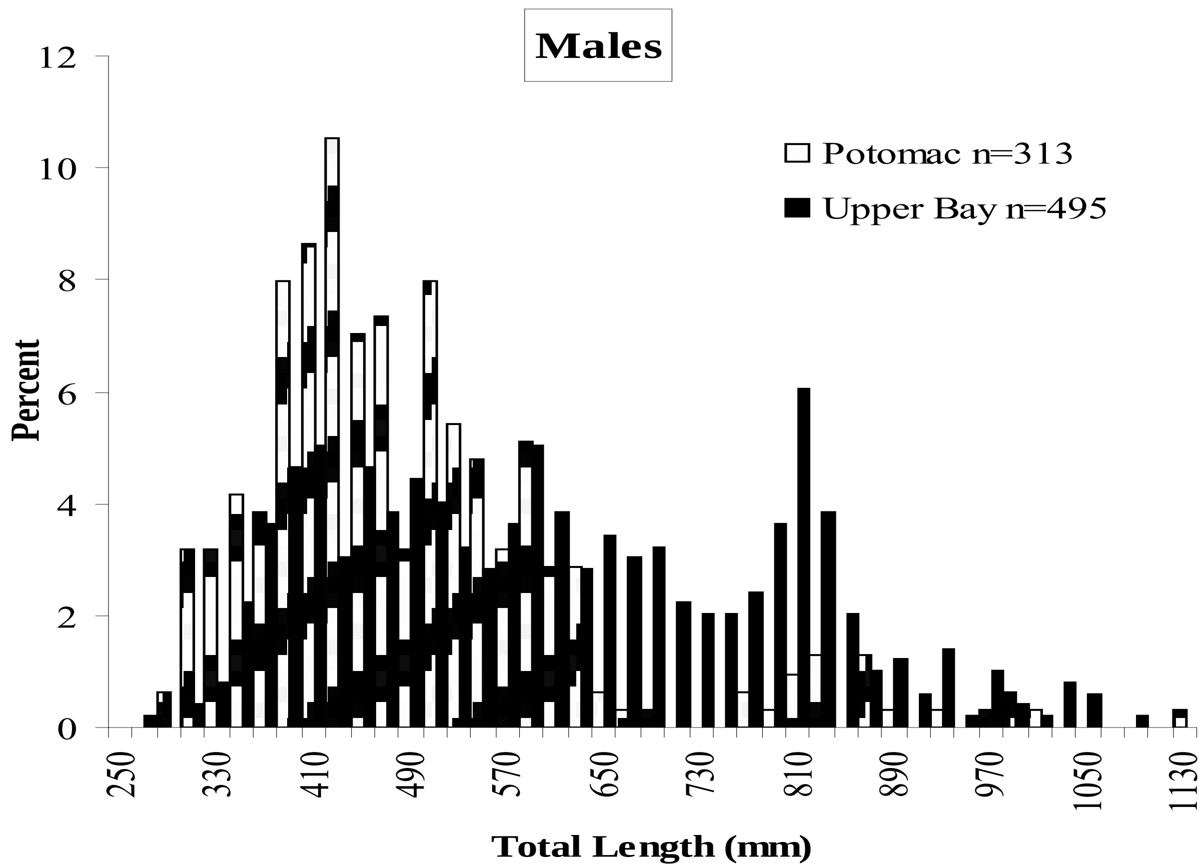


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, late March through May 2012. Note different scales.



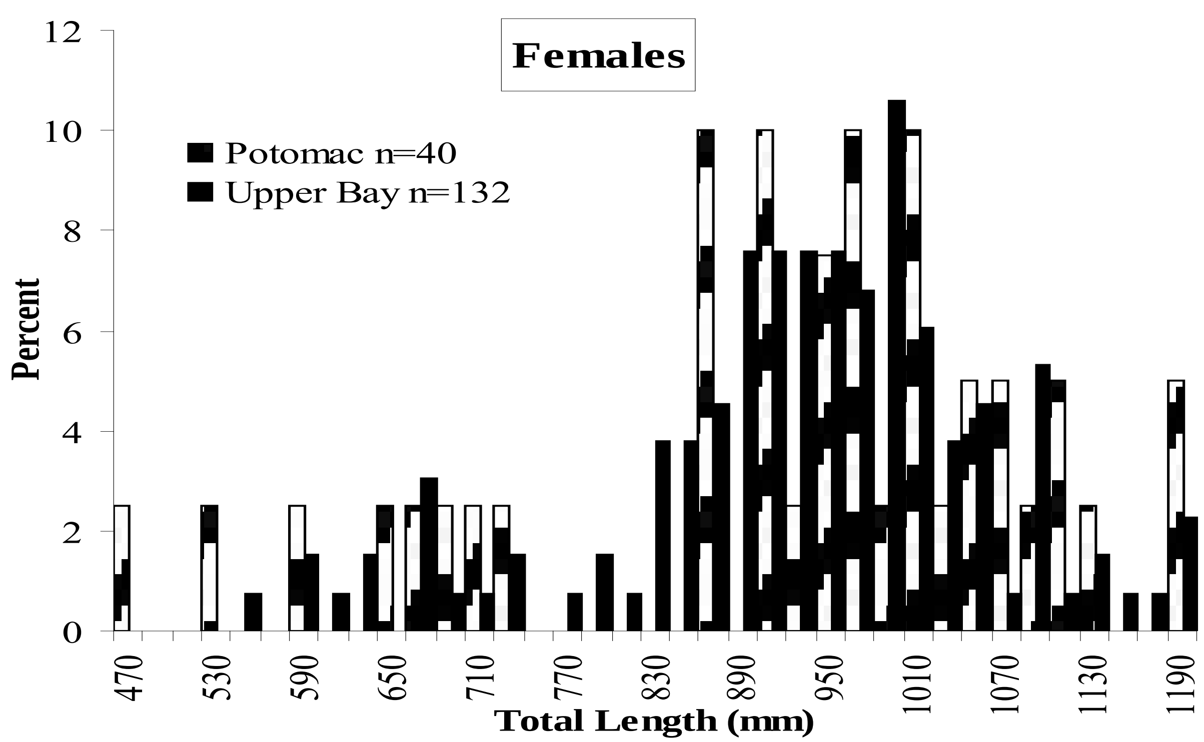
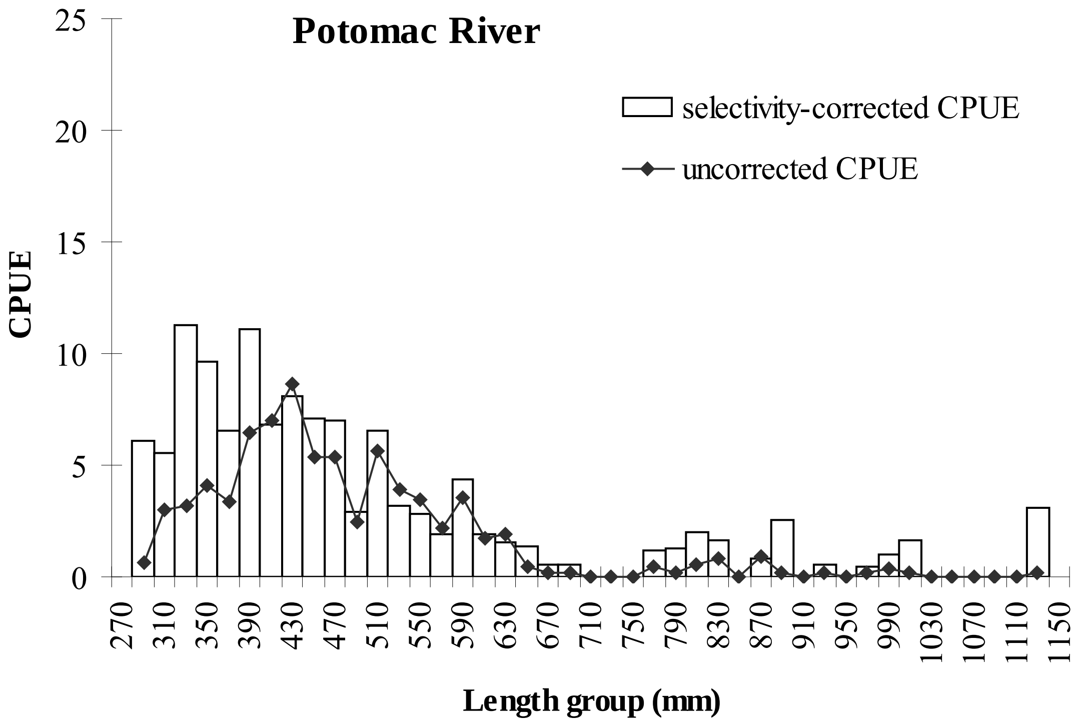


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, late March - May 2012. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



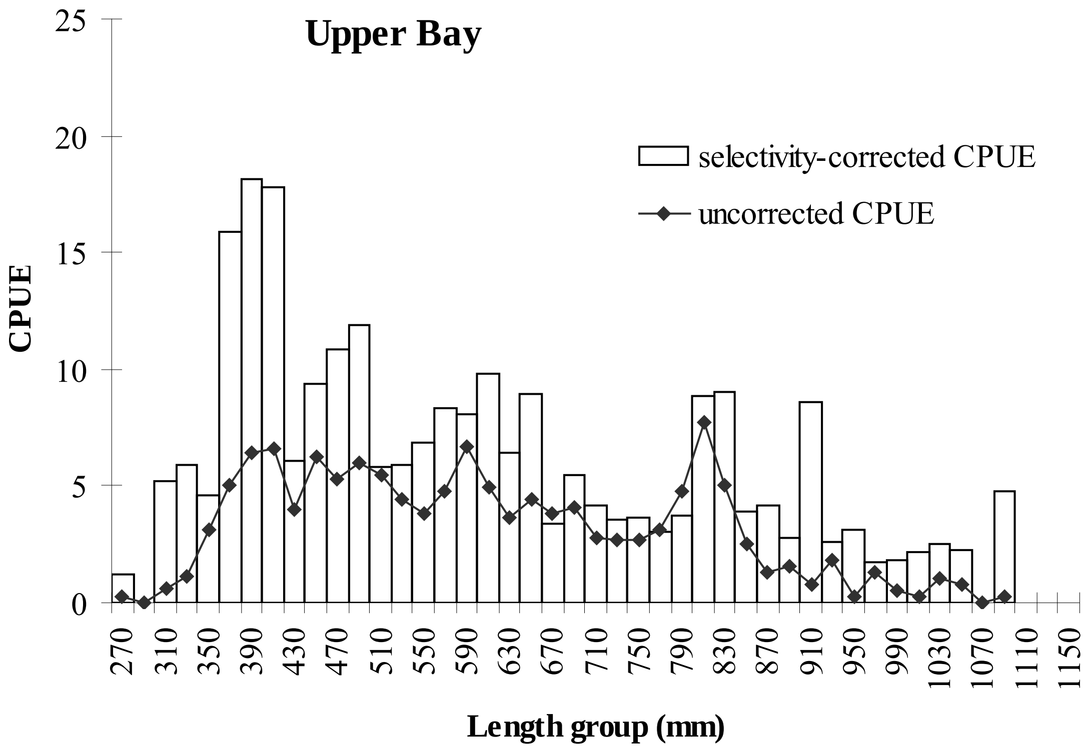
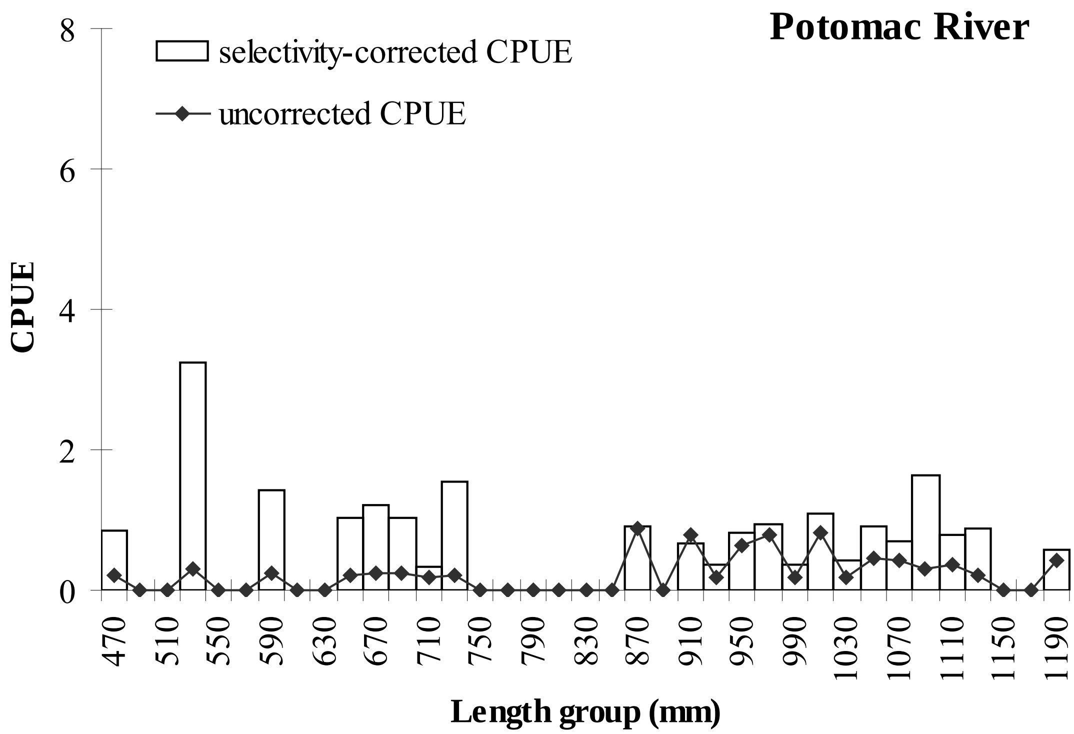


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, late March - May 2012. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



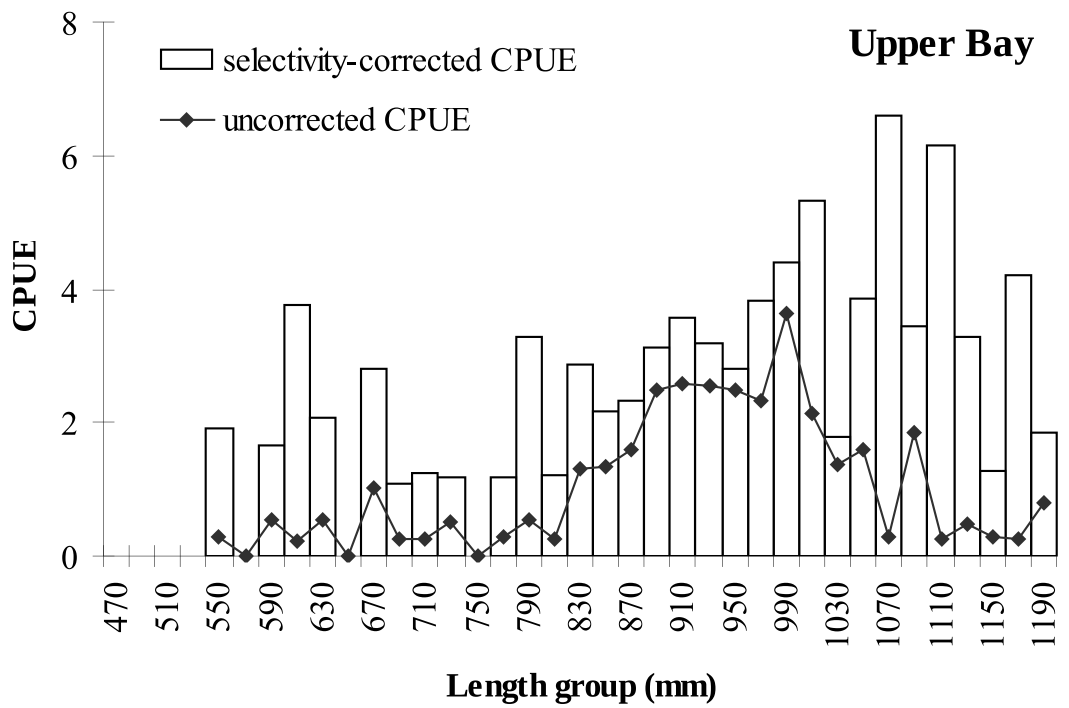


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during late March through May, 1985-2012. Error bars are ± 2 standard errors (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

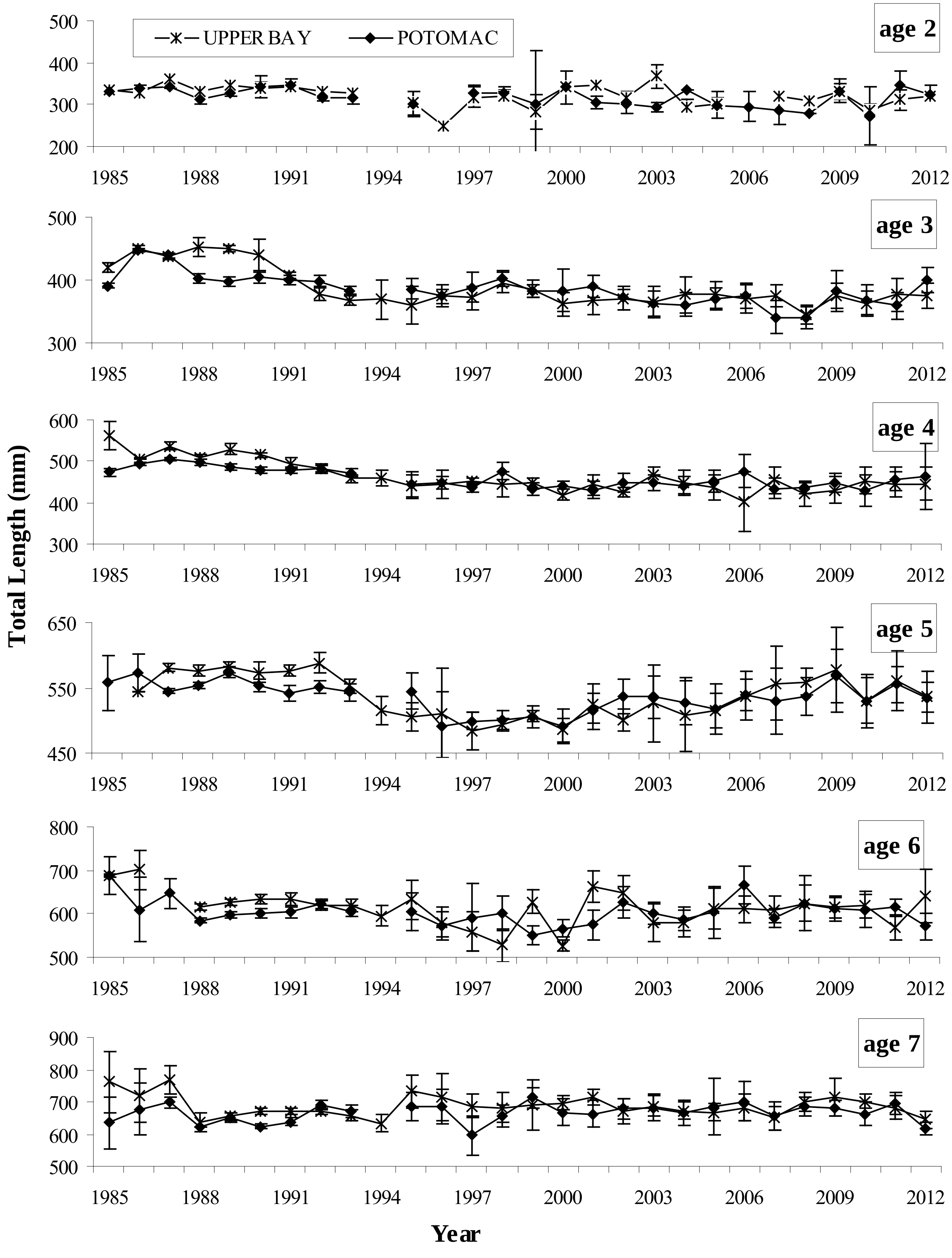


Figure 7. Continued.

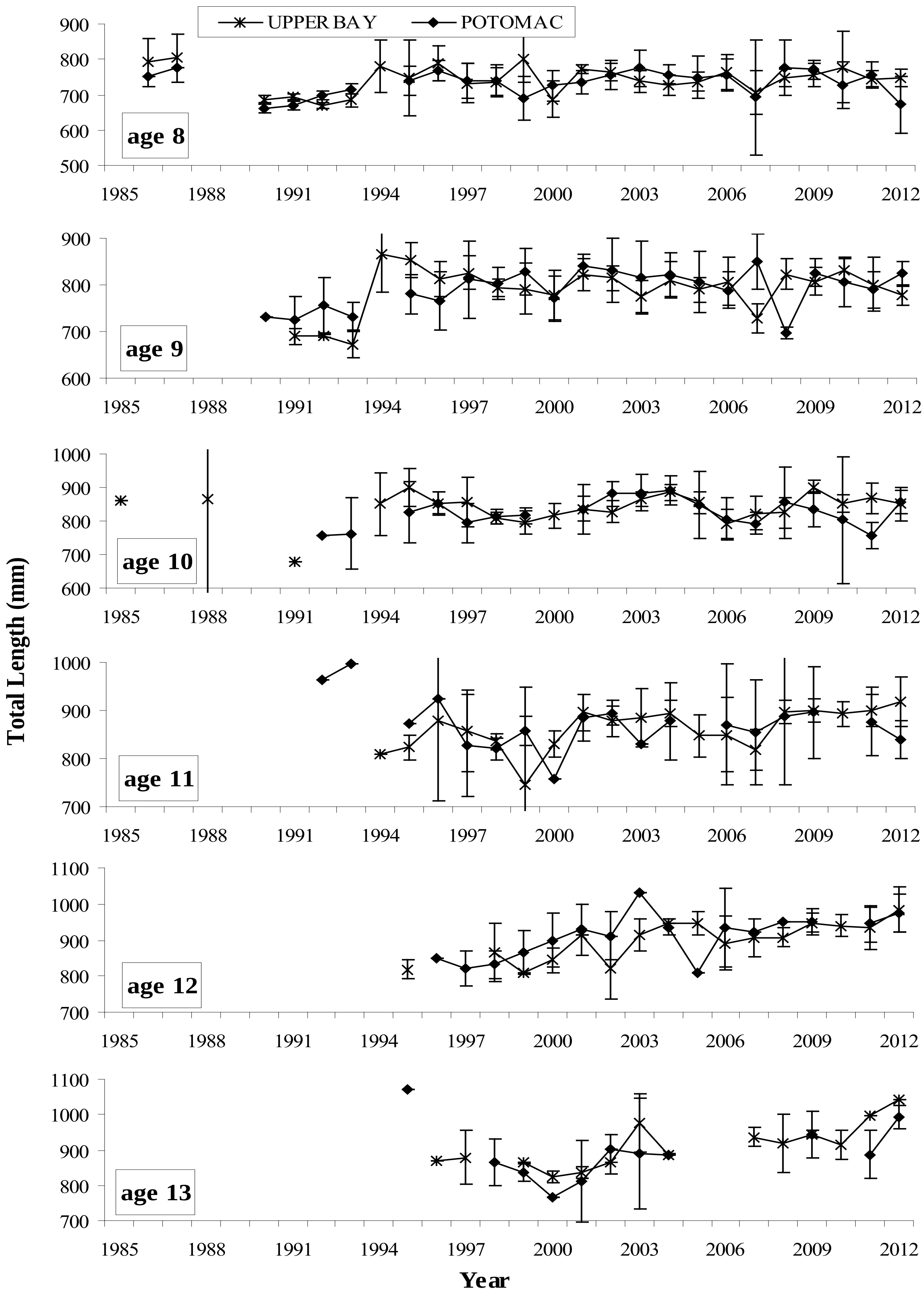


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during late March through May, 1985–2012. Error bars are ± 2 standard errors (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

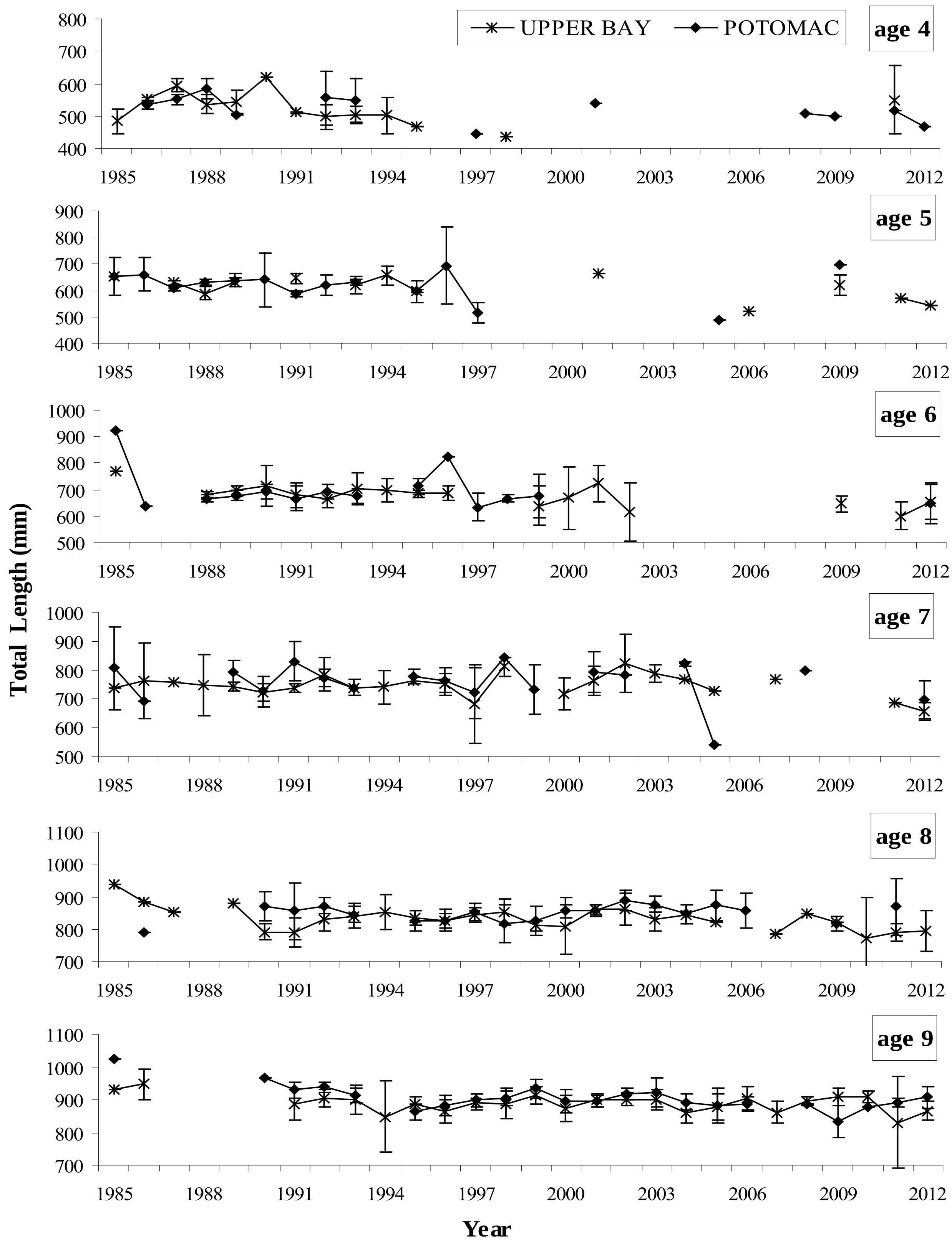


Figure 8. Continued.

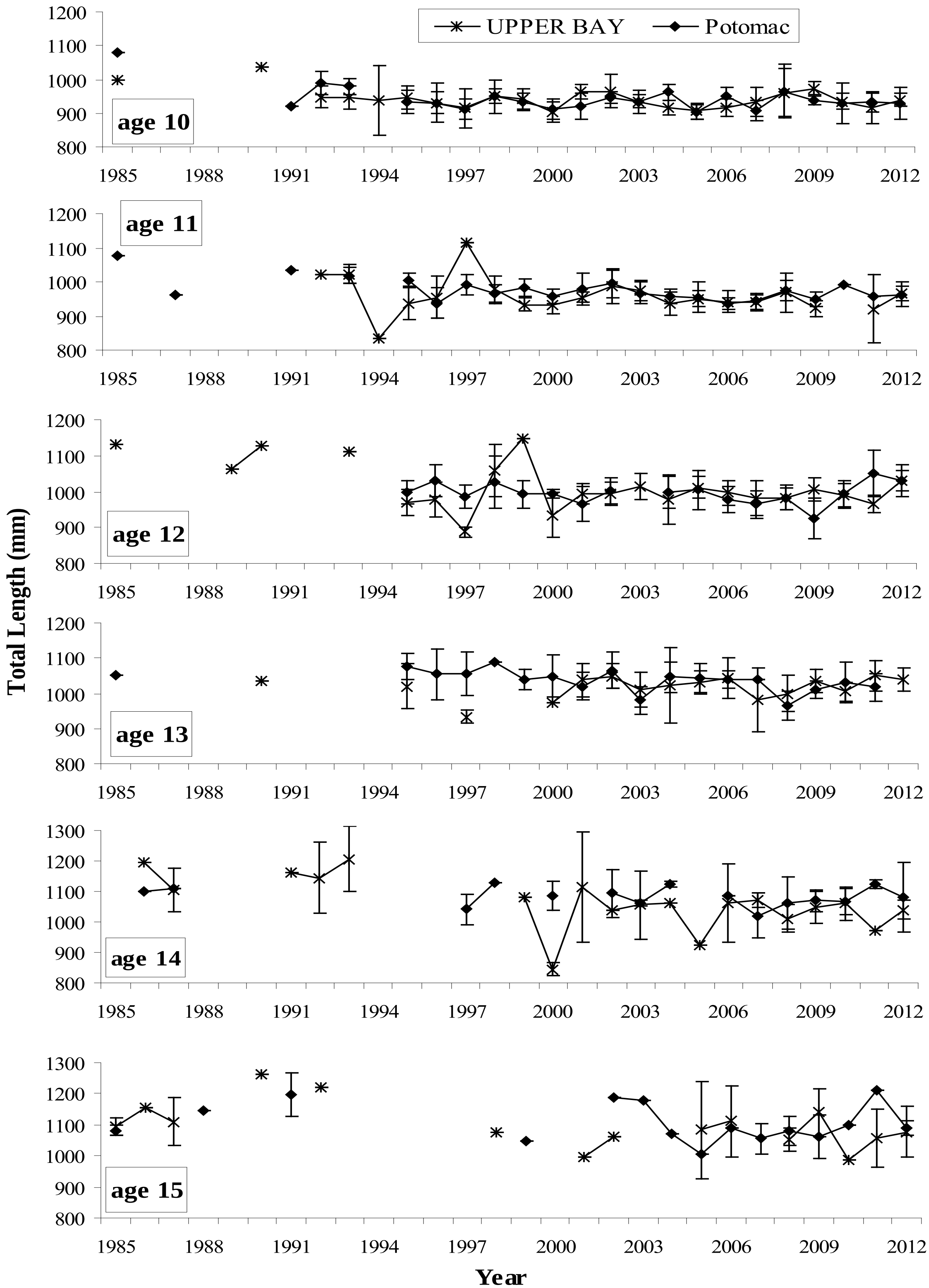


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

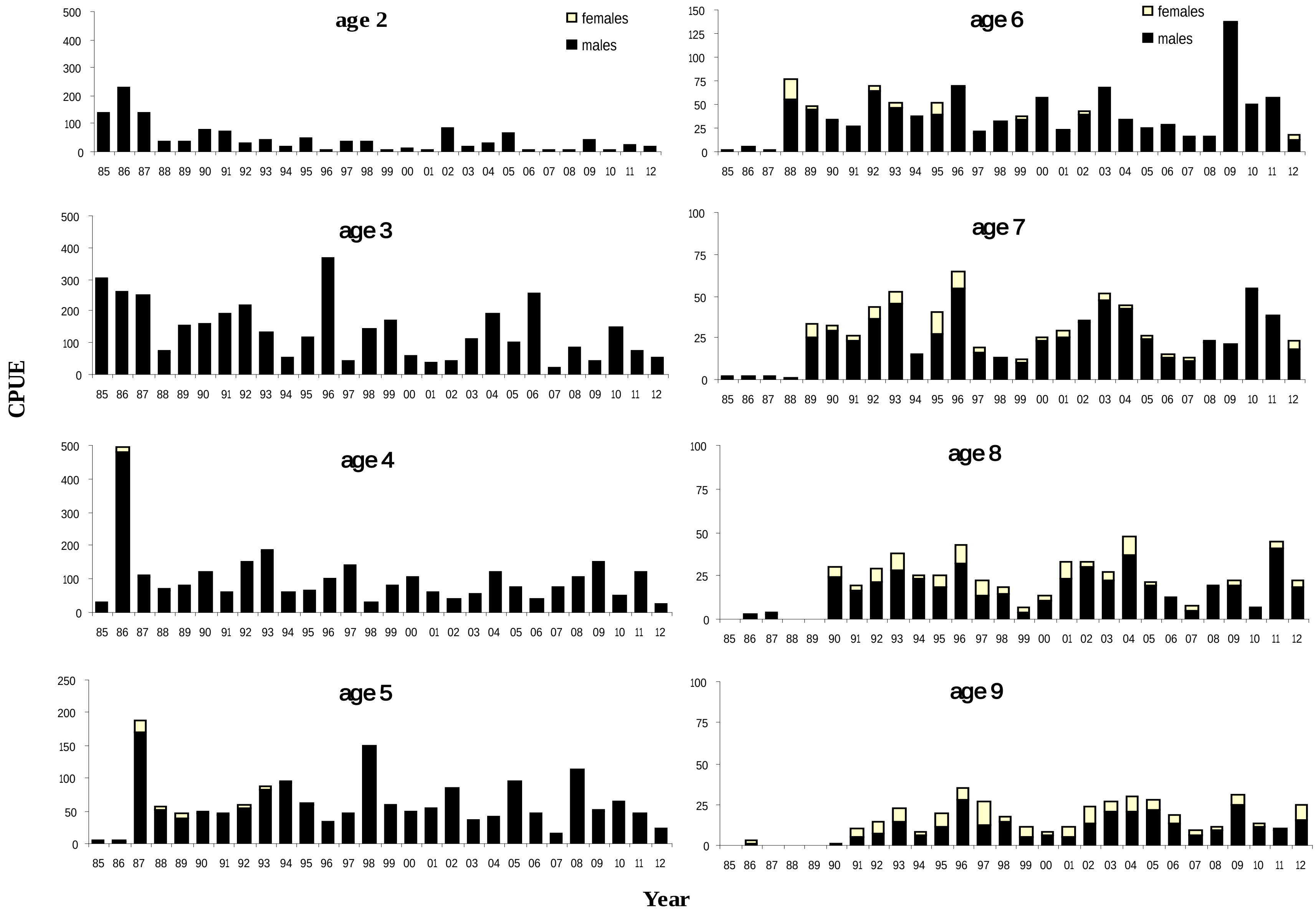


Figure 9. Continued.

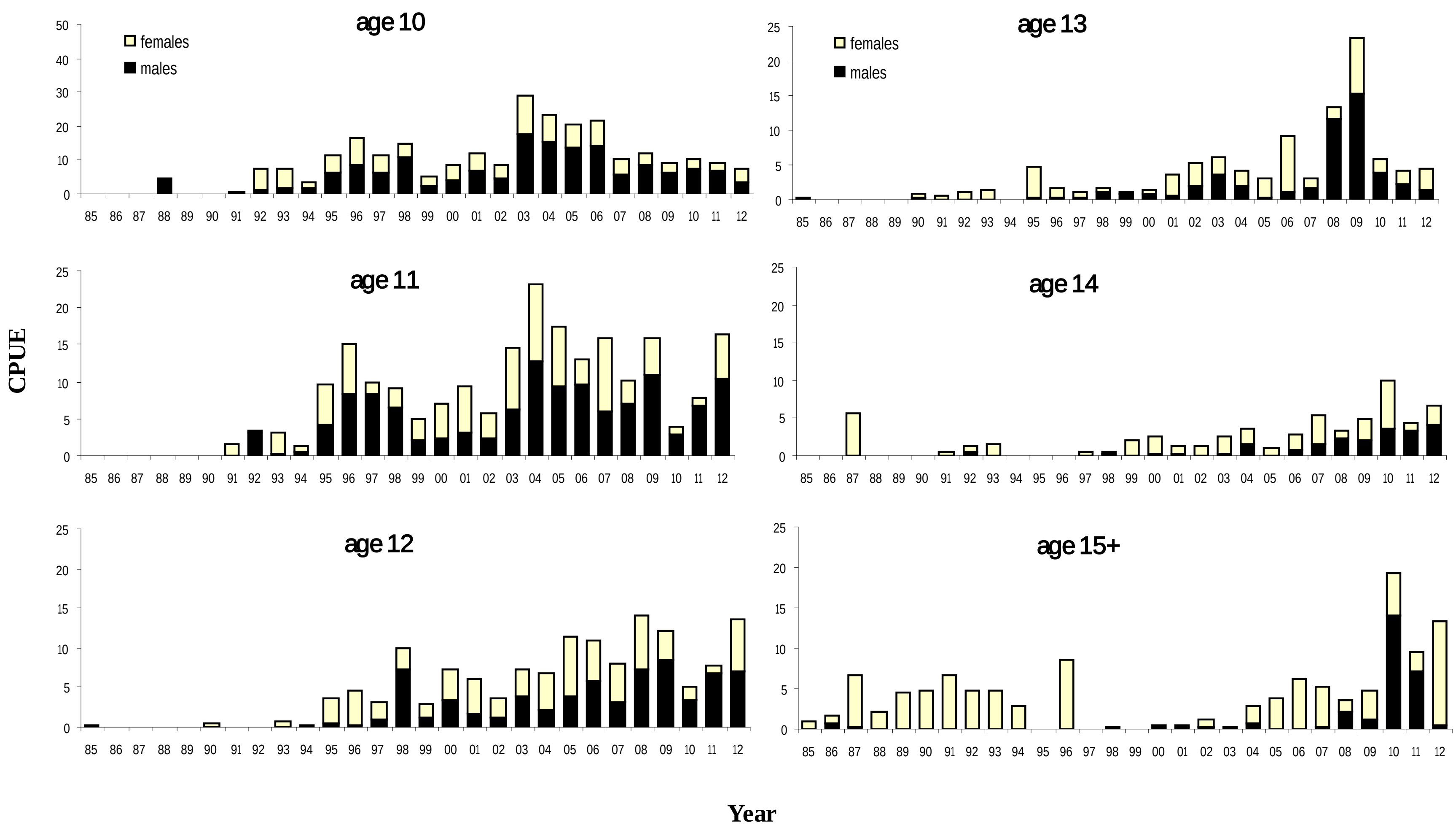
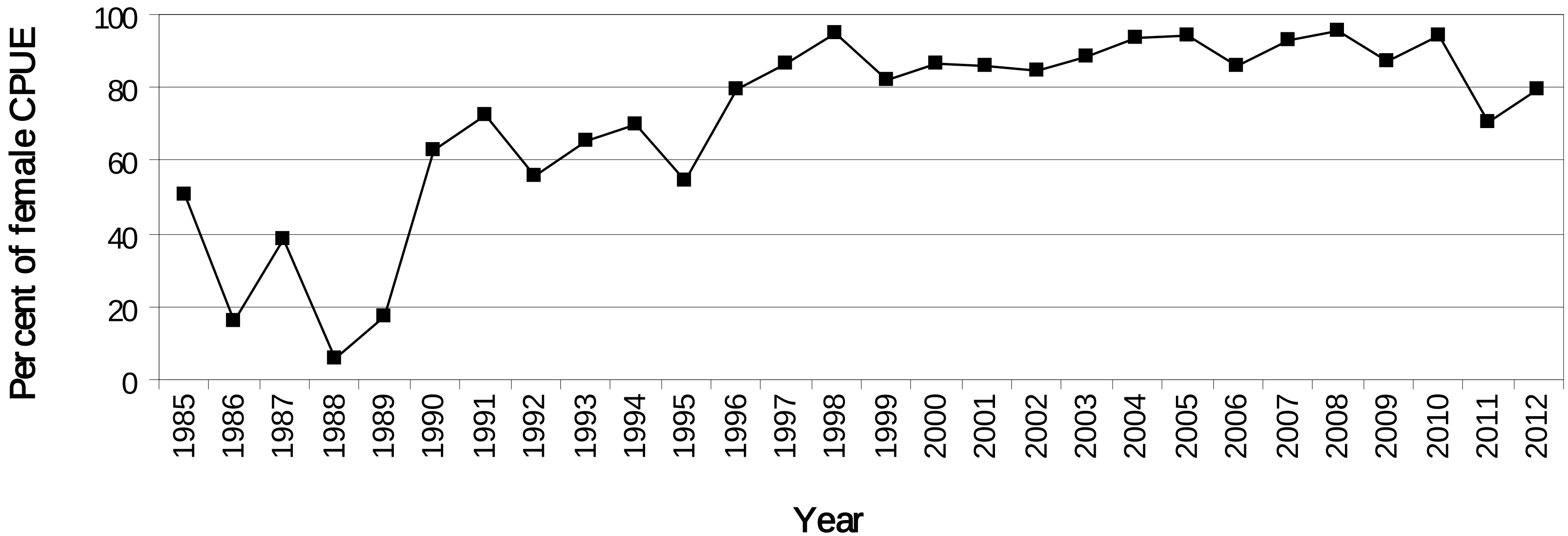
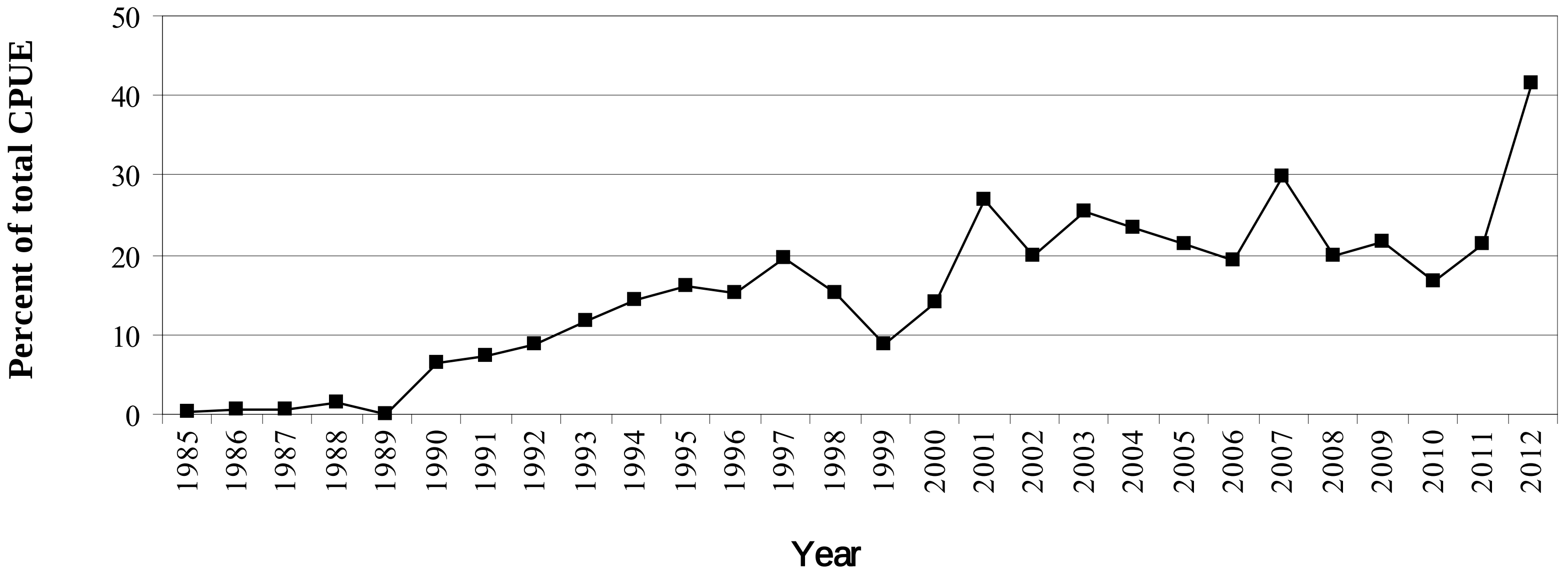


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, late March through May, 1985-2012 (Choptank River to 1996). Effort is 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.*



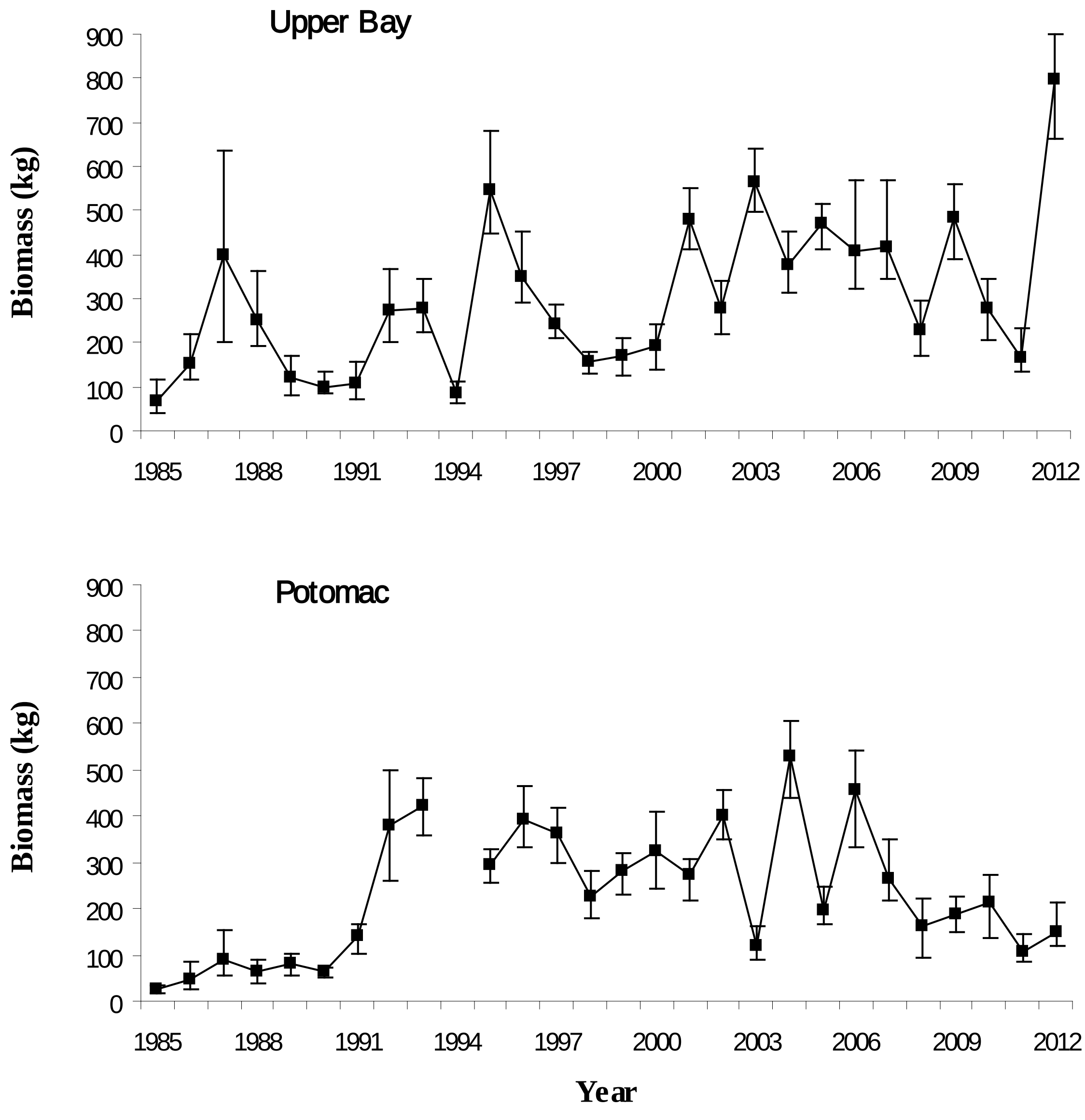
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385 (Hollis 1967).

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, late March through May, 1985-2012 (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. 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 late March through May, 1985-2012. 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. Recent erosion at the Worton Creek site (site #11) in the Head of Bay area prompted the establishment of an auxiliary site directly across the creek called Handy Point (site #164). Handy Point will be assessed as an eventual replacement for Worton Creek.

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) and the Patuxent River (Table 1, Figure 1).

Sample Protocol

A 30.5-m x 1.24-m bagless beach seine of untreated 6.4-mm bar mesh was set by hand. One end was held on shore while the other was fully stretched perpendicular from the beach and swept with the current. Ideally, the area swept was equivalent to a 729 m^2 quadrant. When depths of 1.6-m or greater were encountered, the offshore end was deployed along this depth contour. An estimate of distance from the beach to this depth was recorded.

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

Additional data were collected at each site and sample round. These included: time of first haul, maximum distance from shore, weather, maximum depth, surface water temperature (^oC), tide stage, surface salinity (ppt), primary and secondary bottom substrates, and submerged aquatic vegetation within the sample area (ranked by quartiles). Dissolved oxygen (DO), pH, and turbidity (Secchi disk) were added in 1997. All data 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 117 YOY striped bass was collected at permanent stations in 2012, with individual samples yielding between 0 and 12 fish. The AM (0.9) and GM (0.49) were both the lowest in their respective time-series (Table 2 and 3, Figures 2 and 3). The PPHL was 0.35, indicating that 35% of samples produced juvenile striped bass (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 2012 $\log_e$-mean was significantly lower than 46 years of the time-series, and indiscernible from the seven lowest years.

System Means

Head of Bay - In 42 samples, 28 juveniles were collected at the Head of Bay sites for an AM of 0.7, less than the time-series average (11.7) and the TPA of 17.3 (Table 2, Figure 5). The GM of 0.44 was also below 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 2012 Head of Bay $\log_e$-mean significantly less than 44 years of the time-series, and indiscernible from the smallest 11 year-classes of the time-series.

Potomac River - A total 72 juveniles was collected in 42 samples on the Potomac River. The AM of 1.7 was less than the TPA (9.2) and the time-series average (8.3) (Table 2, Figure 5). The GM of 0.95 was also less than the time-series average (3.62) and TPA (3.93) (Table 3, Figure 7). Analysis of variance of $\log_e$-means indicated significant differences among years (ANOVA: P<0.0001). Duncan's multiple range test (p=0.05) ranked the 2012 Potomac River year-class significantly smaller than 26 years, and not significantly different than the 29 other years of the time-series.

Choptank River - A total of 3 juveniles was collected in 24 Choptank River samples. The AM of 0.1 was lower than the time-series average of 21.6 and the TPA of 10.8 (Table 2, Figure 5). The GM of 0.08 was also lower than its time-series average (8.12) 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) ranked the 2012 Choptank River year-class significantly smaller than 41 years, and indiscernible from 14 years of the time series.

Nanticoke River - A total of 14 juveniles was collected in 24 samples on the Nanticoke River. The AM of 0.6 was below the time-series average (8.4) and TPA (8.6) (Table 2, Figure 5). The GM of 0.37 was also less than its time-series average (3.76) 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 2012 index significantly smaller than 27 years of the time-series. The 2012 index was statistically indiscernible from the remaining 28 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 39 juveniles were caught in 21 samples, resulting in an AM of 1.9 and a GM of 0.71. Both indices were less than their respective time-series averages (Table 5).

On the **Patuxent River**, one YOY striped bass was caught in 18 samples for an AM of 0.1 and a GM of 0.04. Both Patuxent River indices were less than their respective time-series averages and medians (Table 5).

DISCUSSION

By all measures, striped bass recruitment in Maryland's Chesapeake Bay was very poor in 2012. The bay-wide AM and GM indices were both the lowest in the history of the survey (Tables 2 and 3). Duncan's multiple range test (p=0.05) found the 2012 $\log_e$-mean was indiscernible from the seven smallest year-classes on record (1959, 1980, 1981, 1983, 1985, 1988, and 1990). YOY striped bass occurred in only 35% of the samples (PPHL=0.35), another indication of a small year-class and the lowest observed since 1959 (Table 4, Figure 4).

Recruitment was below average in all individual systems. The 2012 year-class was among the smallest ever recorded in the Head of Bay (5th percentile), Choptank River (lowest on record), and Nanticoke River (2nd percentile) as measured by geometric means. The Potomac River performed slightly better with a GM at the 21st percentile of the time-series.

High variability in annual spawning success is a hallmark of striped bass populations, which are known for producing occasional dominant year-classes under optimal spawning conditions. The disparity in spawning success between 2011 (among the best years on record) and 2012 (the worst year on record) may be attributable to differing weather conditions during the spawning season in those years. Ulanowicz and Polgar (1980) speculated that high variability in annual recruitment is due primarily to extrinsic environmental factors. Boynton et al (1977) noted that recruitment may not be limited by the number of striped bass on the Potomac River spawning grounds, and demonstrated that dominant year-classes were associated with colder than normal winters and higher than normal spring river flows. Consistent with these hypotheses, temperature and precipitation in the months before and during the 2011 and 2012 spawns were markedly different according to the NOAA National Climatic Data Center (NCDC). The NCDC (2012) ranked the period January-April 2011, a year of high recruitment, colder and wetter than normal. The NCDC ranked January-April

2012, a year of very low recruitment, the warmest on record and the driest since 1985. Furthermore, the pattern of recruitment success in 2011 followed by subsequent recruitment failure in 2012 was also apparent in other anadromous species documented by the MDDNR seine survey (http://dnr.maryland.gov/fisheries/juvindex/). This points to the influence of extrinsic environmental factors that were not conducive to the success of anadromous spawning behavior in general in 2012.

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 [$\log_e$ (catch+1)]. 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=0.606, $p \leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was: $C_1=(0.18916)(C_0)- 0.07263$, 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 (0.30) was less than the index of 0.37 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 such as 2011. Lower than expected abundance of age 1 striped bass may be an indication of density-dependent processes operating at high levels of abundance, such as cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

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LIST OF FIGURES

Table 1. Maryland juvenile striped bass survey sample sites.

Site Number	River or Creek	Area or Nearest Land Mark
	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
11	Worton Creek	Mouth of Tim’s Creek, west shore
* 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 Land Mark
	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
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 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
Average	11.7	8.3	21.6	8.4	11.8
TPA*	17.3	9.2	10.8	8.6	12.0

* TPA (target period average) is the average from 1959 through 1972.

Table 3. Maryland juvenile striped bass survey geometric mean 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
Average	5.55	3.62	8.12	3.76	4.22
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
Average	12.1	212.6	1.46	92.48	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
Average	25.05	6.78		5.67	2.69	
Median	3.25	1.91		3.21	1.71	

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	N/A

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

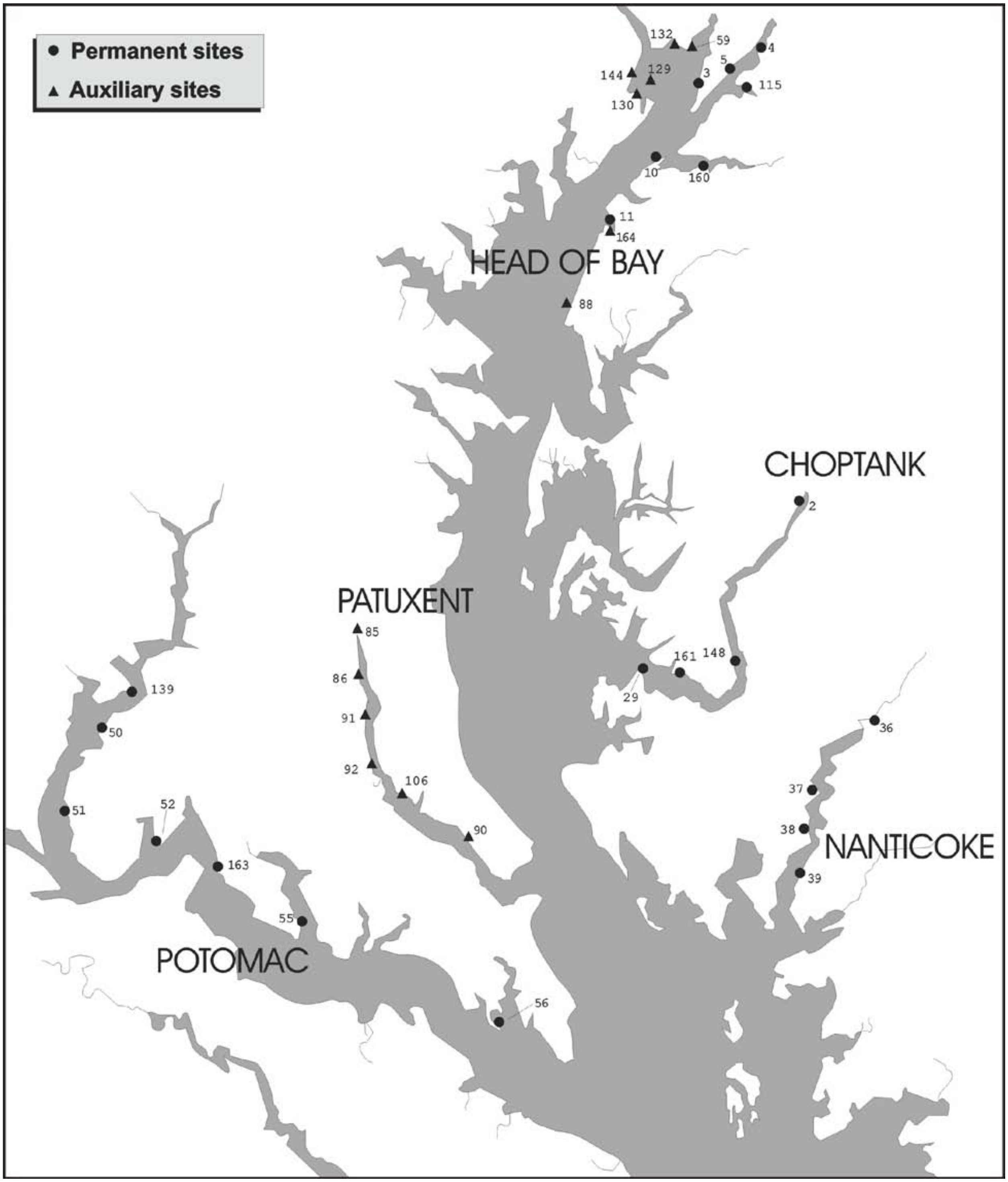


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

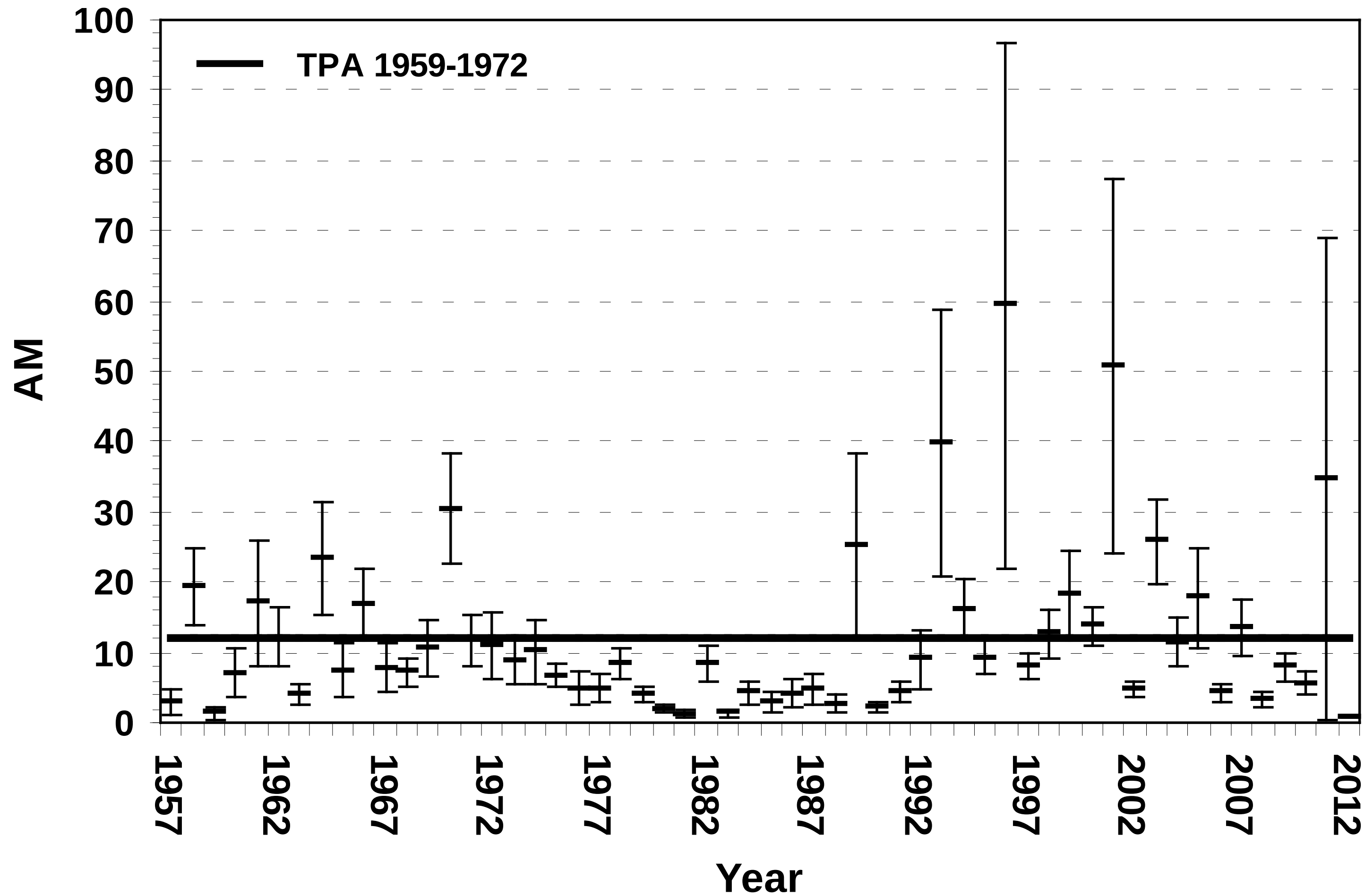


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

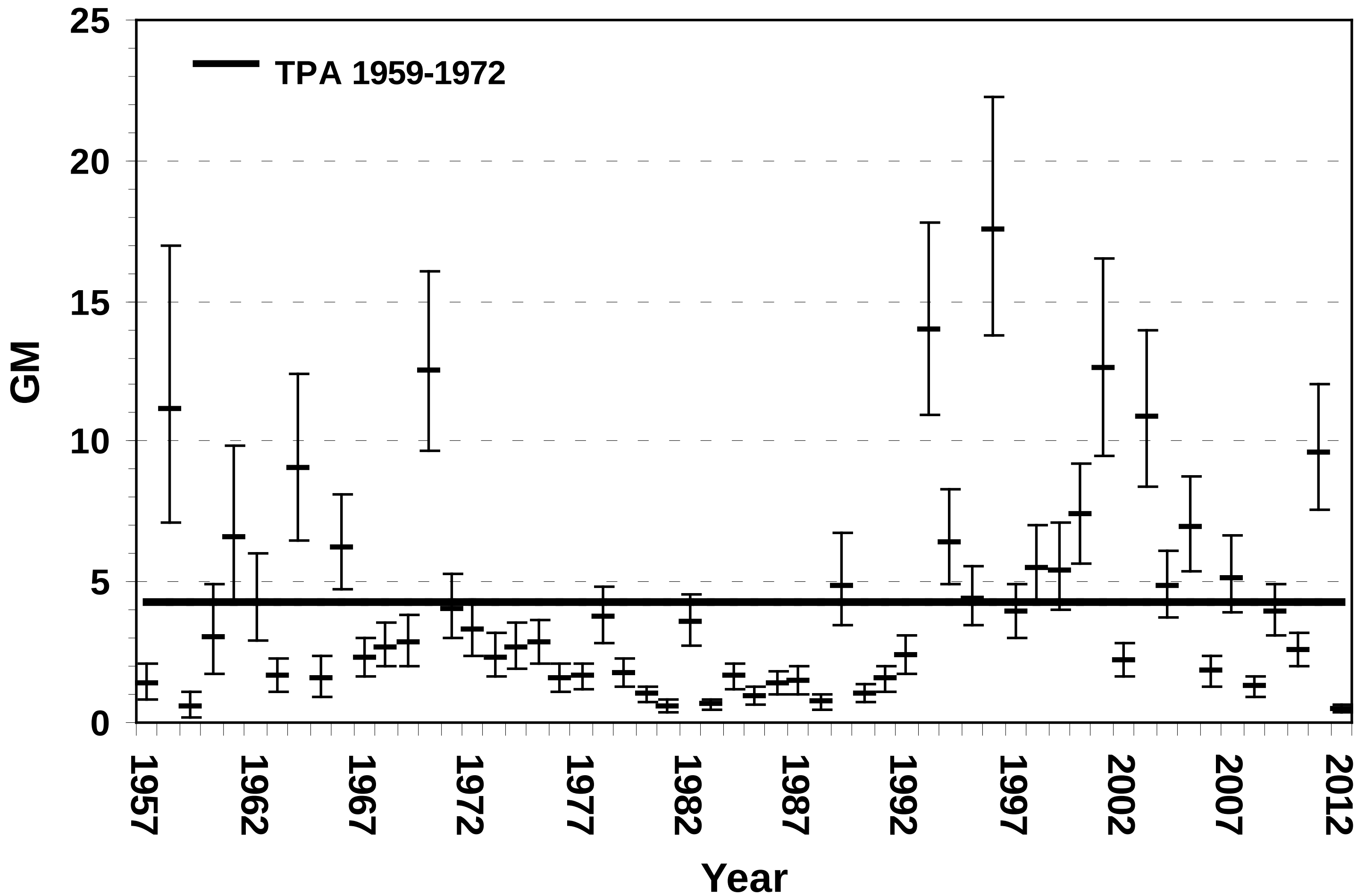


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

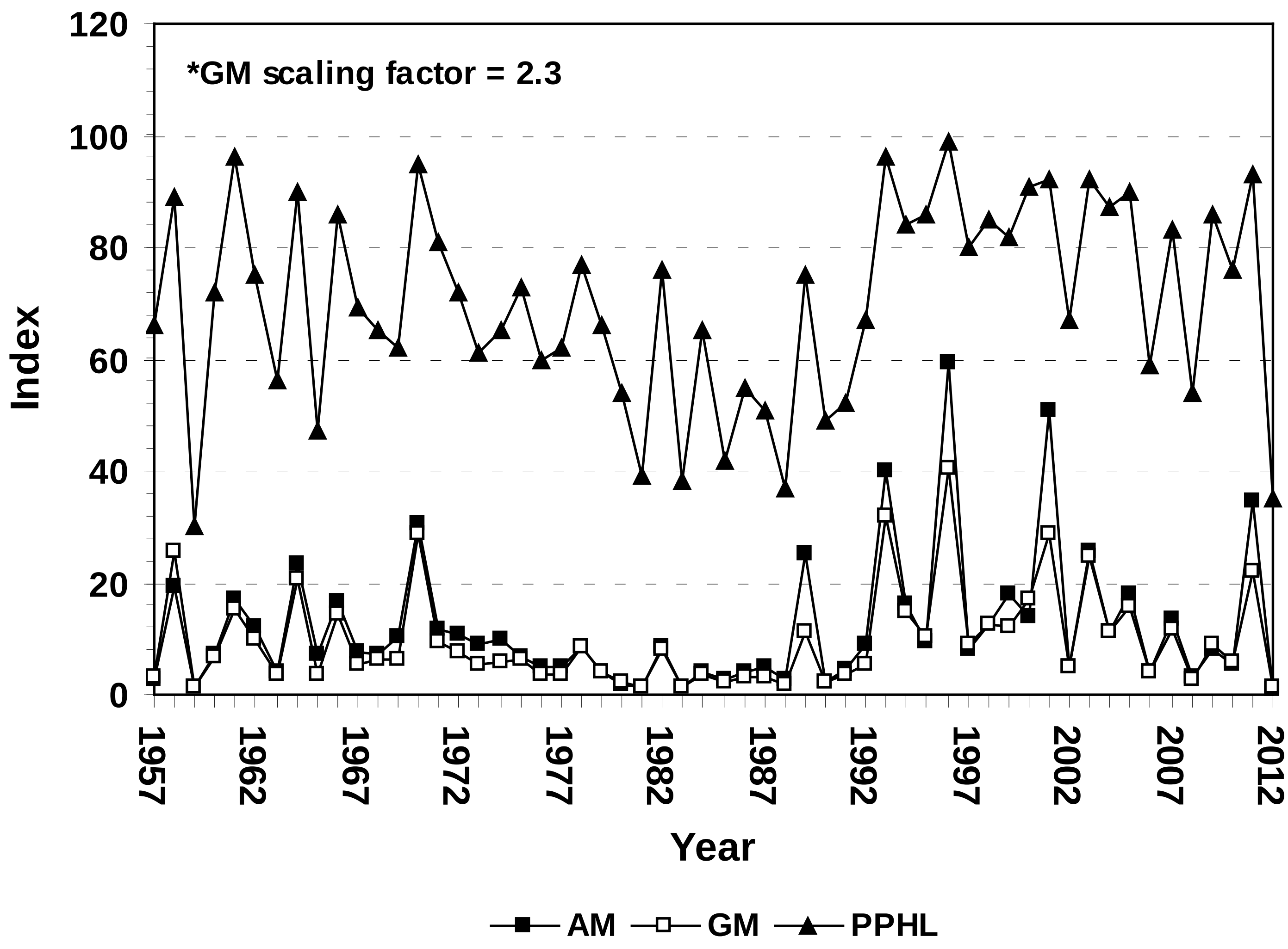


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

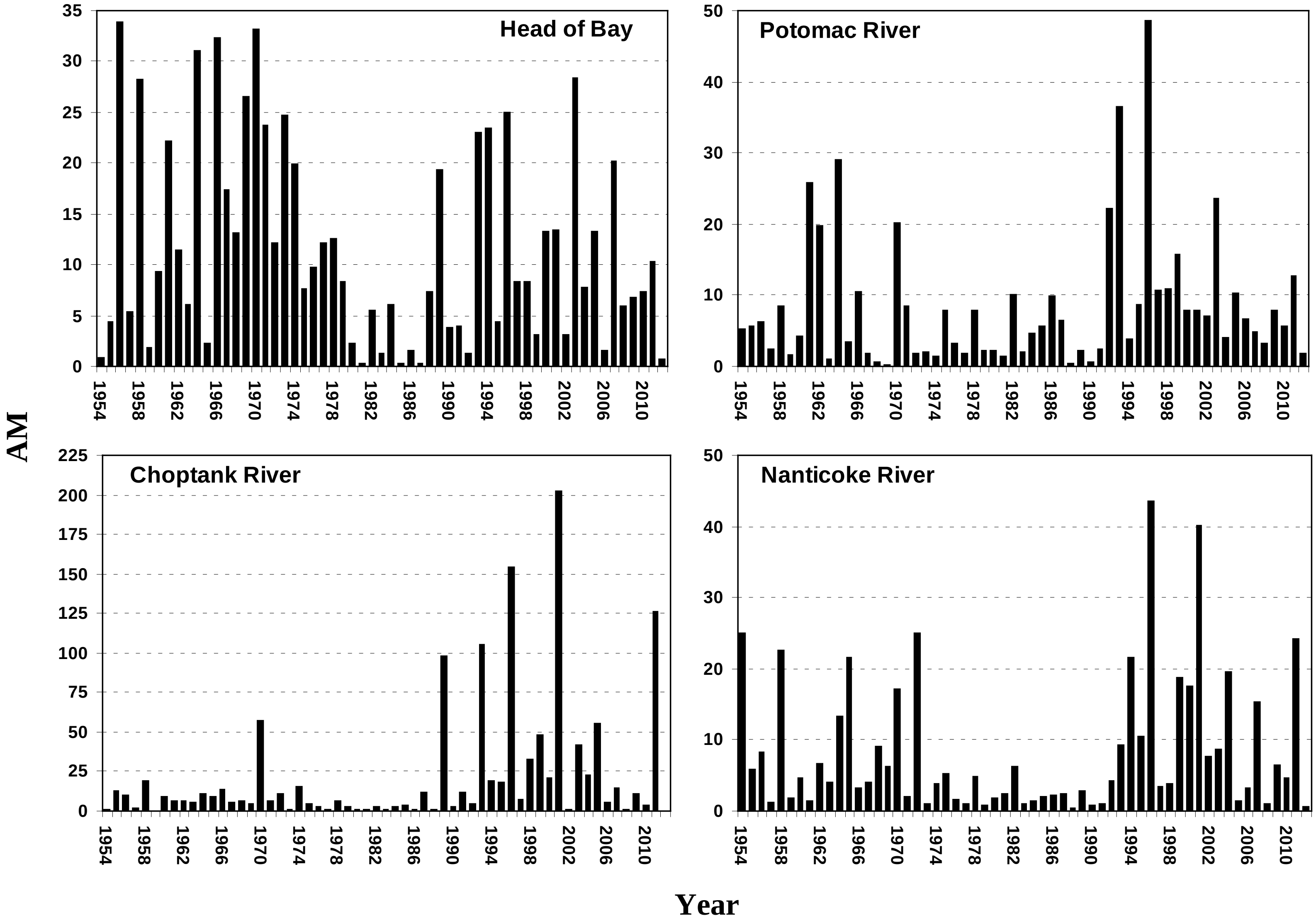


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

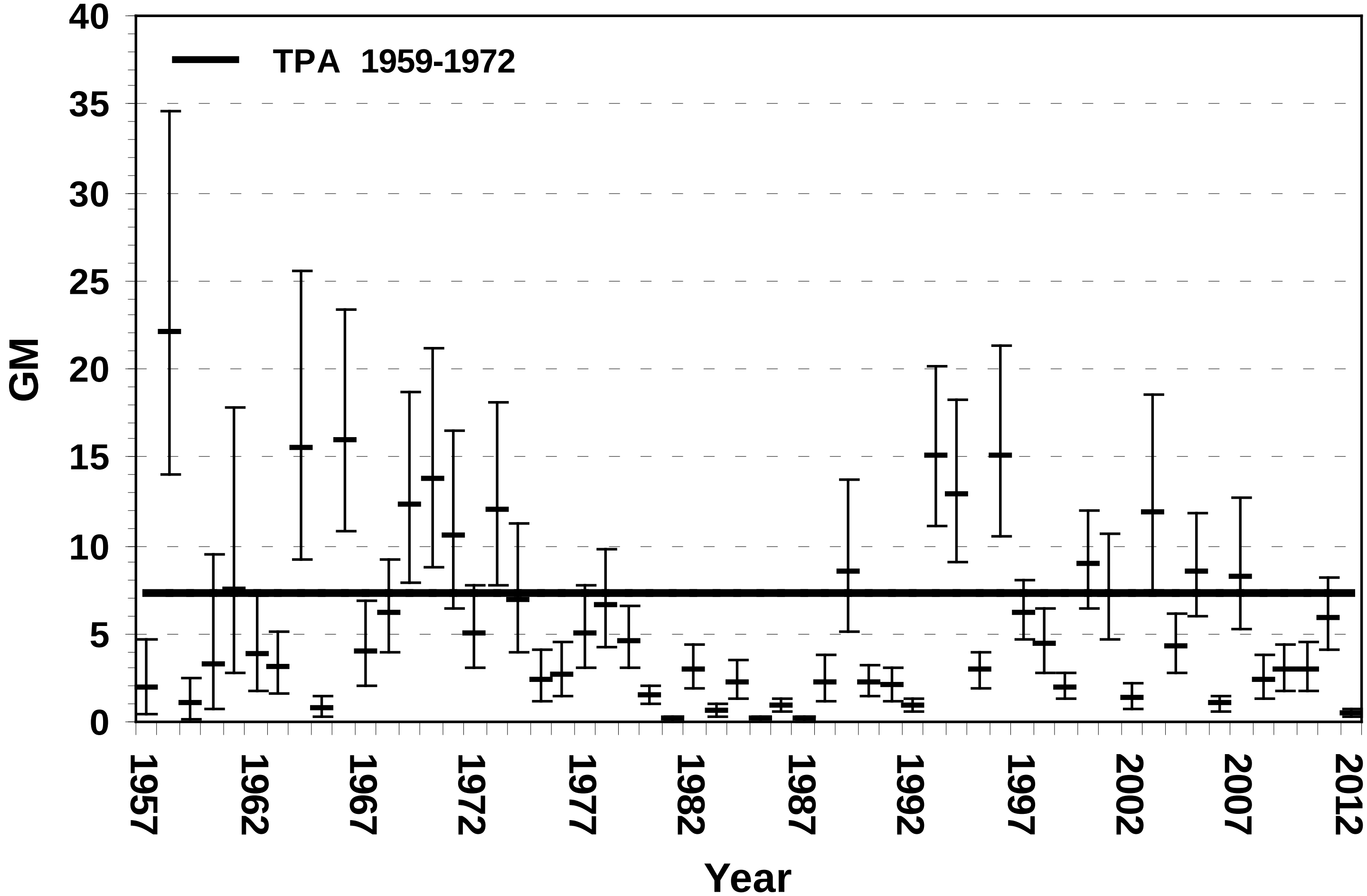


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

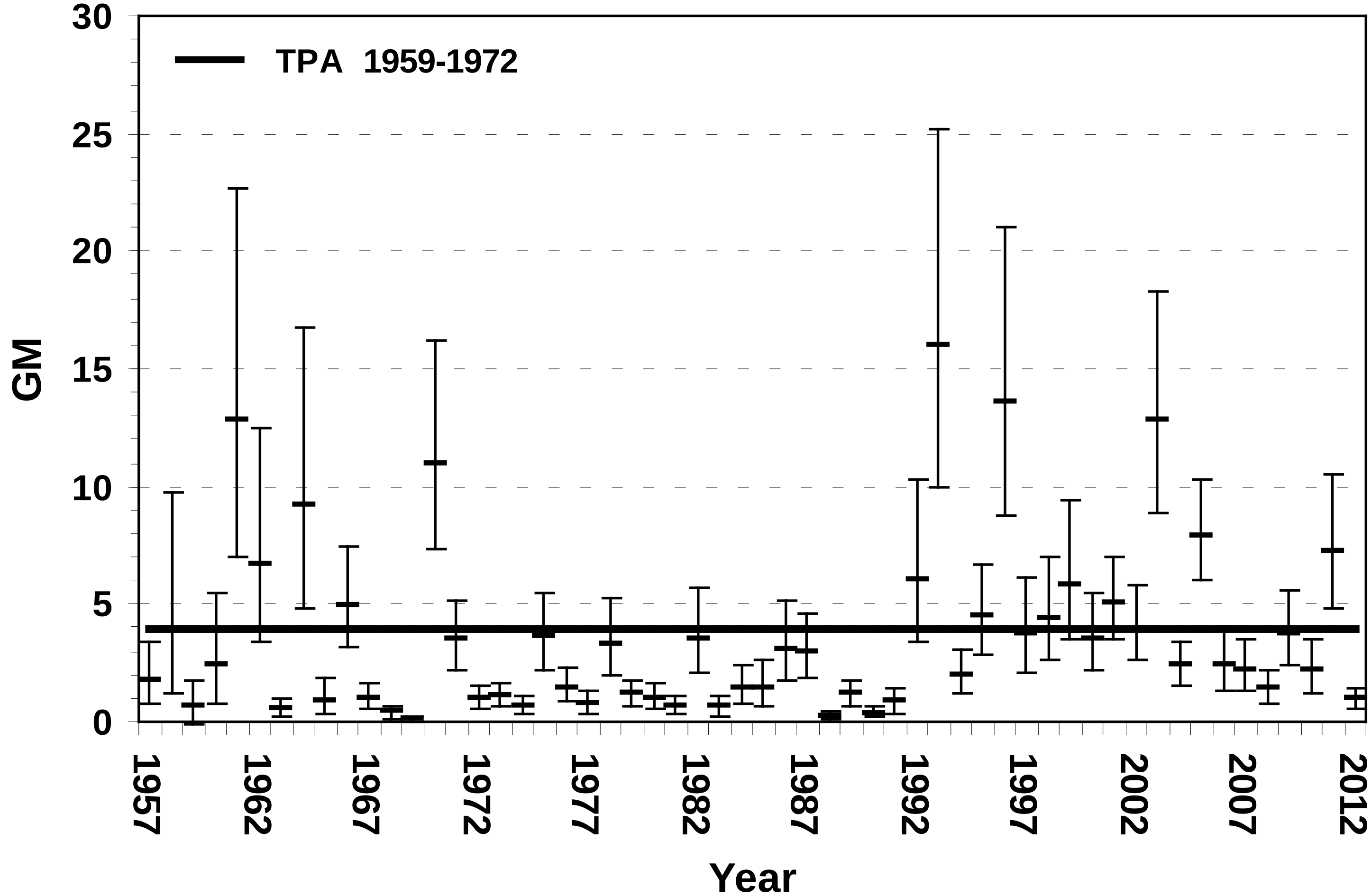


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

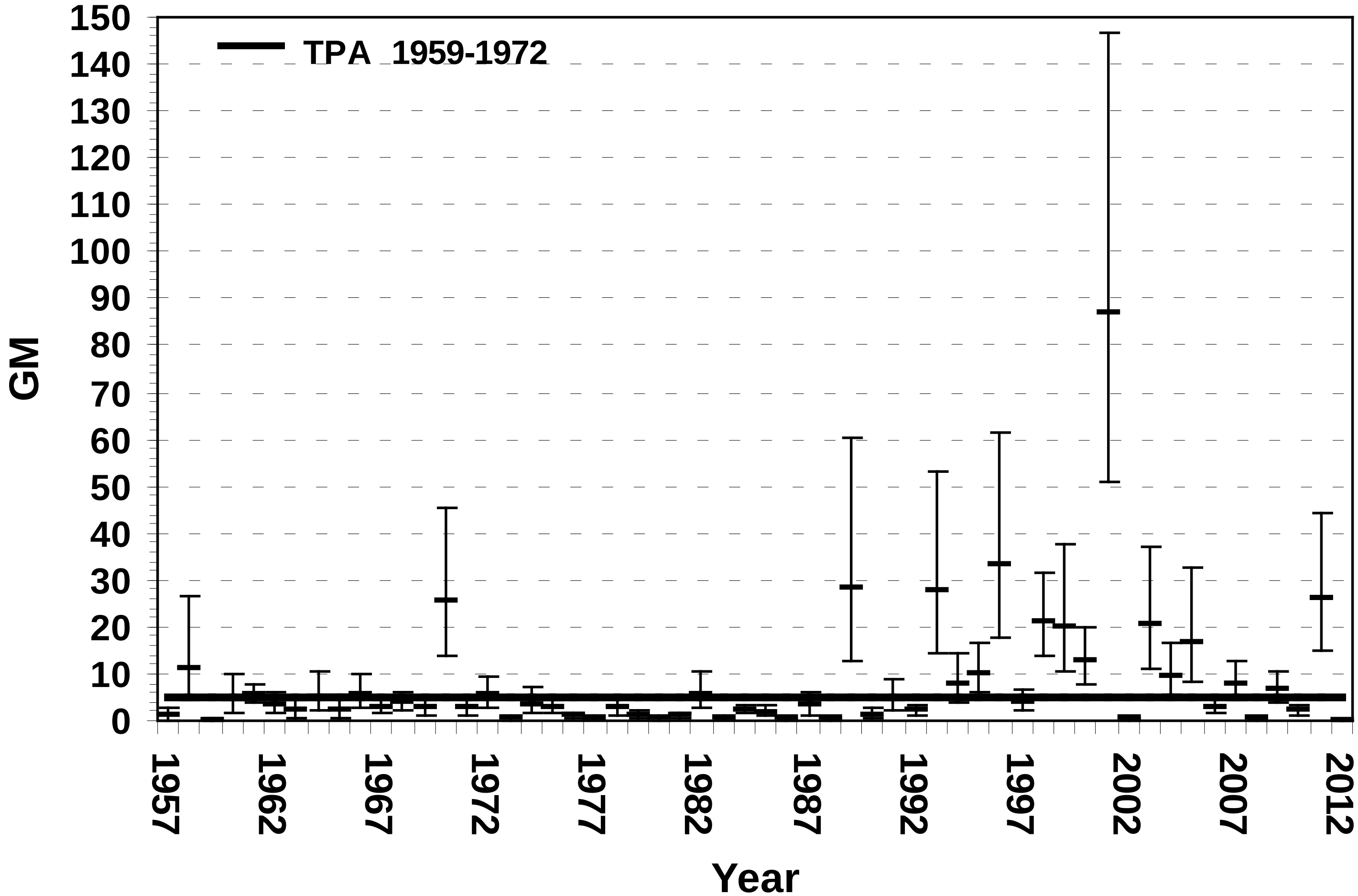


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

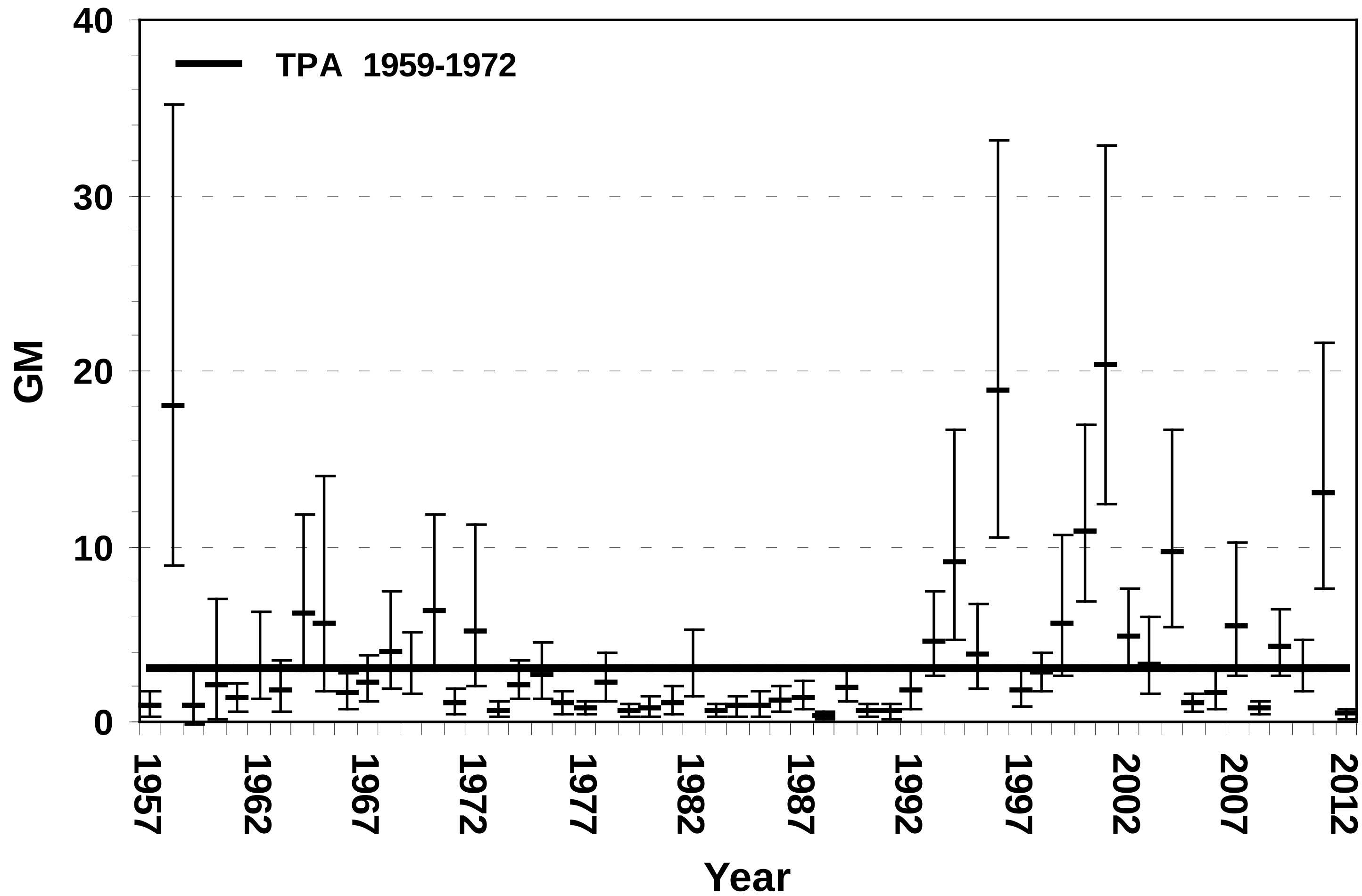


Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

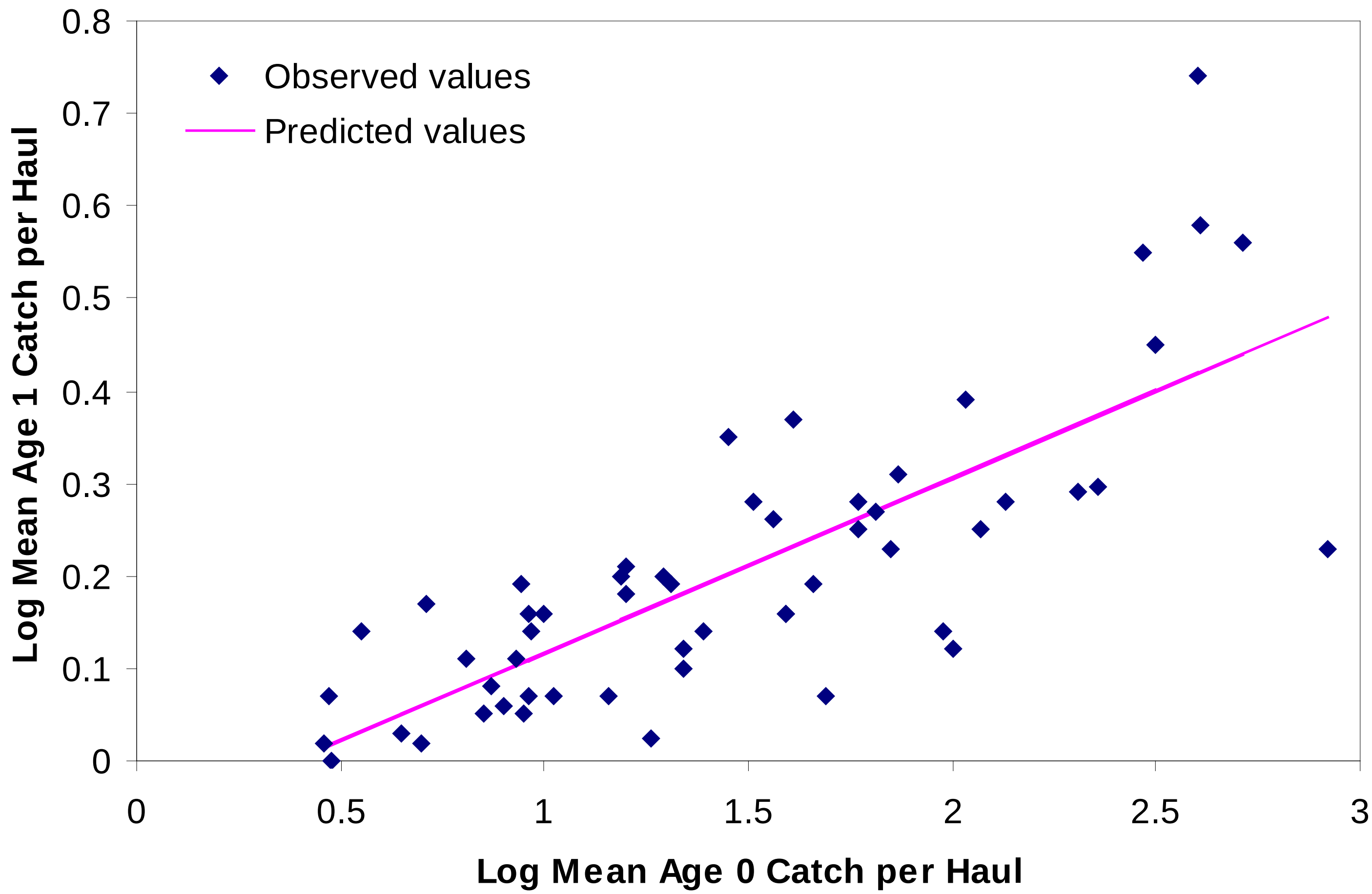
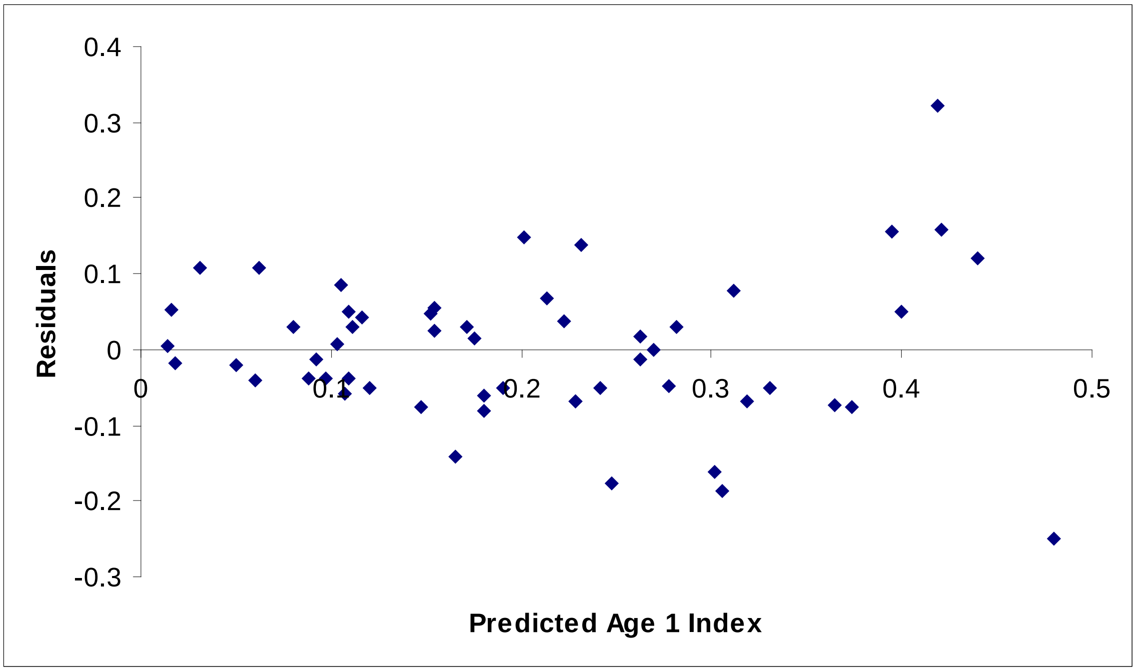
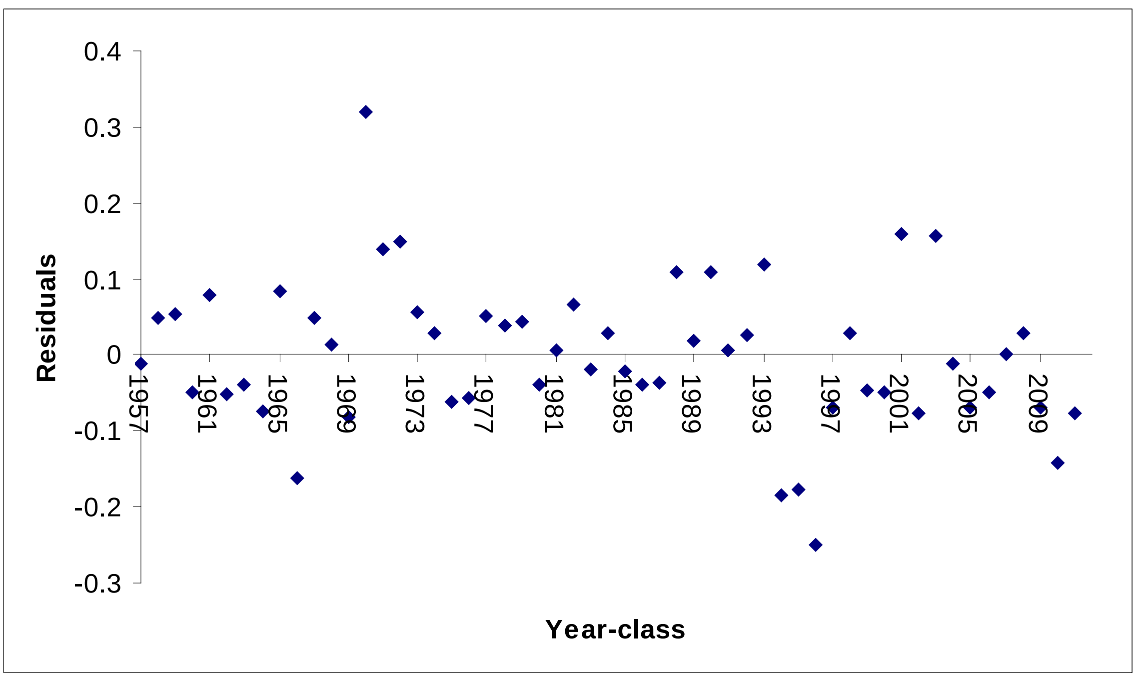


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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

STRIPED BASS TAGGING

Prepared by Beth A. Versak

INTRODUCTION

The primary objective of Project 2, Job 3, Task 4 was to summarize all striped bass tagging activities in Maryland's portion of the Chesapeake Bay and the North Carolina cooperative tagging cruise, during the time period of summer 2011 through spring 2012. The Maryland Department of Natural Resources (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 Atlantic coast striped bass stocks.

METHODS

Sampling procedures

During late March through May 2012, 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 water temperatures exceeded 70°F.

The 2012 cooperative tagging cruise was again conducted on a sportfishing vessel and fish were captured via hook and line. Sampling was conducted on only one day, February 16, 2012, by staff from the USFWS and the North Carolina Division of Marine Fisheries (NC DMF), with support from MD DNR. The goal of this year's sampling was to tag coastal migratory striped bass wintering in the Atlantic Ocean off northeastern North Carolina and/or southeastern Virginia (state and federal waters). Up to seven lines containing custom-made tandem parachute rigs were trolled from the 40 foot sportfishing vessel, *Smokin Gun II*, at 2.5 to 3.5 knots, in depths of 50 to 75 feet (15 to 23 m). Vigorous fish with no external anomalies were measured for total length to the nearest millimeter (mm TL) and tagged immediately after being landed in the boat. 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 ventral 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 rates from fish tagged during the spring in Maryland were estimated using two approaches, all based on historic release and recovery data. During the most recent ASMFC stock assessment, the instantaneous rates–catch and release (IRCR) model became the primary model utilized. The IRCR method 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 used in Program MARK. Additional details on the methodologies can be found in the latest stock assessment report (ASMFC 2011).

Previously, Program MARK was used to estimate survival using tag-recovery models (Brownie et al. 1985) and subsequent extensions of those models. Estimates of survival and recovery were calculated by fitting a set of candidate models, chosen "*a priori*" and based on knowledge of the biology of the species, to the observed release and recovery data (Brownie et al. 1985; Burnham et al. 1995). Further details on Program MARK methodologies can be found in Versak (2007). Survival was converted to total mortality, and a constant value of natural mortality (M=0.15) was subtracted to obtain an estimate of fishing mortality. It is believed that natural mortality in Chesapeake Bay is increasing (ASMFC 2011). Thus, the use of a constant value for M became a weakness of the MARK method.

For all methods, 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. Since survival and F estimates for fish released in spring 2012 will not be completed until after March 27, 2013, these estimates will not appear in this report.

Tag release and return data from spring male fish, ≥457 mm TL and <711 mm TL (18 – 28 inches TL), were used to develop the 2011-2012 estimate of F for Chesapeake Bay (unpublished data). 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 estimate of F. Similar to the coastwide methods, the IRCR model was utilized to calculate the Chesapeake Bay F. Further details on the methodologies can be found in the latest stock assessment report (ASMFC 2011).

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. If the 2012 cruise data are used in the upcoming assessment, the 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 $P<0.05$.

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 March 26, 2012 and May 18, 2012. A total of 983 striped bass were sampled and 682 (69%) were tagged as part of this long-term survey (Table 1). In 2012, fewer striped bass were captured in the survey than normal, which resulted in a higher proportion of fish being tagged than in previous years. However, there were still occasions when 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 2012 (660 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (630 mm TL) (Figure 2).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2011 data) were used to estimate an instantaneous fishing mortality rate (F) for the 2011-2012 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Fishing mortality estimates from the two analysis methods were below the target F=0.27 set by ASMFC (unpublished data).

Estimates of survival and fishing mortality for the 2012 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

Although a different gear was used, the primary objective of the cooperative tagging cruise remained to apply tags to as many striped bass as possible. In 2012, only six striped bass were captured and all were tagged during the cruise (Table 2). Because the sample size was so low, scales were taken from all striped bass captured, regardless of total length.

The mean length of all fish captured and tagged on the 2012 cruise was 905 mm TL. This length was significantly larger than the mean total length for the 2011 cruise (810 mm TL total sampled and tagged; $P<0.0001$). Although the sample size was small, it is not uncommon for the mean lengths to vary from year to year. Funding has been secured to conduct the 2013 cruise onboard a research trawler, as well as a sportfishing charter vessel, to ensure that gear comparison studies are done.

Estimates of survival and fishing mortality based on fish tagged in the 2012 North Carolina study will likely not be calculated due to small sample sizes.

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LIST OF FIGURES

Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, late March - May 2012.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	3/26/12 - 5/7/12	354	229	521806 – 522000 524211 – 524247
Upper Chesapeake Bay	3/30/12 - 5/18/12	629	453	518001 – 518456
Spring spawning survey totals:		983 [b, c]	682	

[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.
[c] Total sampled includes two fish with no total length recorded.

Table 2. Summary of U SFWS i nternal a nchor t ags a pplied t o s triped ba ss dur ing t he 20 12 SEAMAP cooperative tagging cruise.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences
Nearshore Atlantic Ocean (Near VA-NC line)	2/16/12	6	6	561083 – 561088
Cooperative tagging cruise totals:		6	6	

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, late March - May 2012.

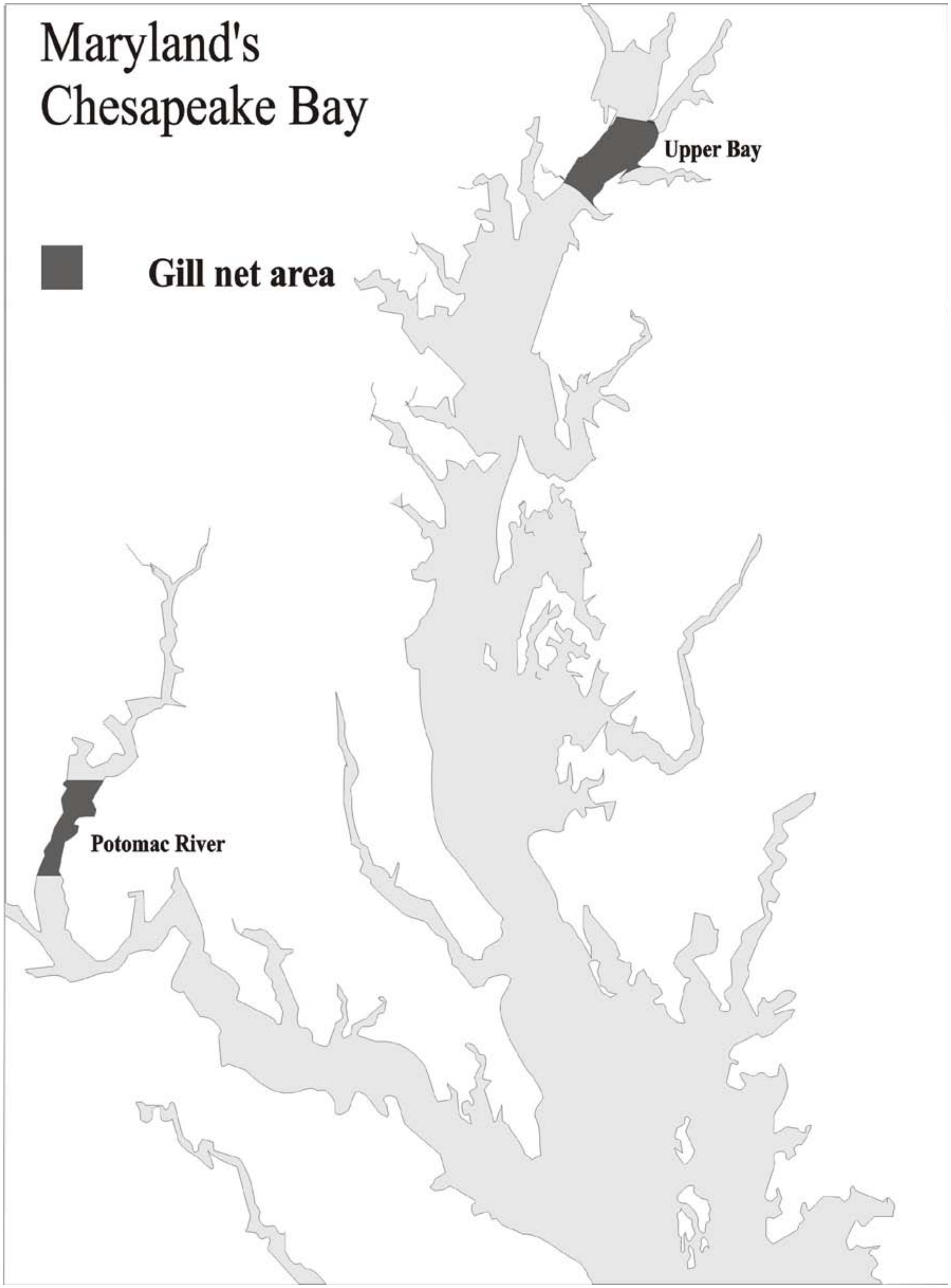
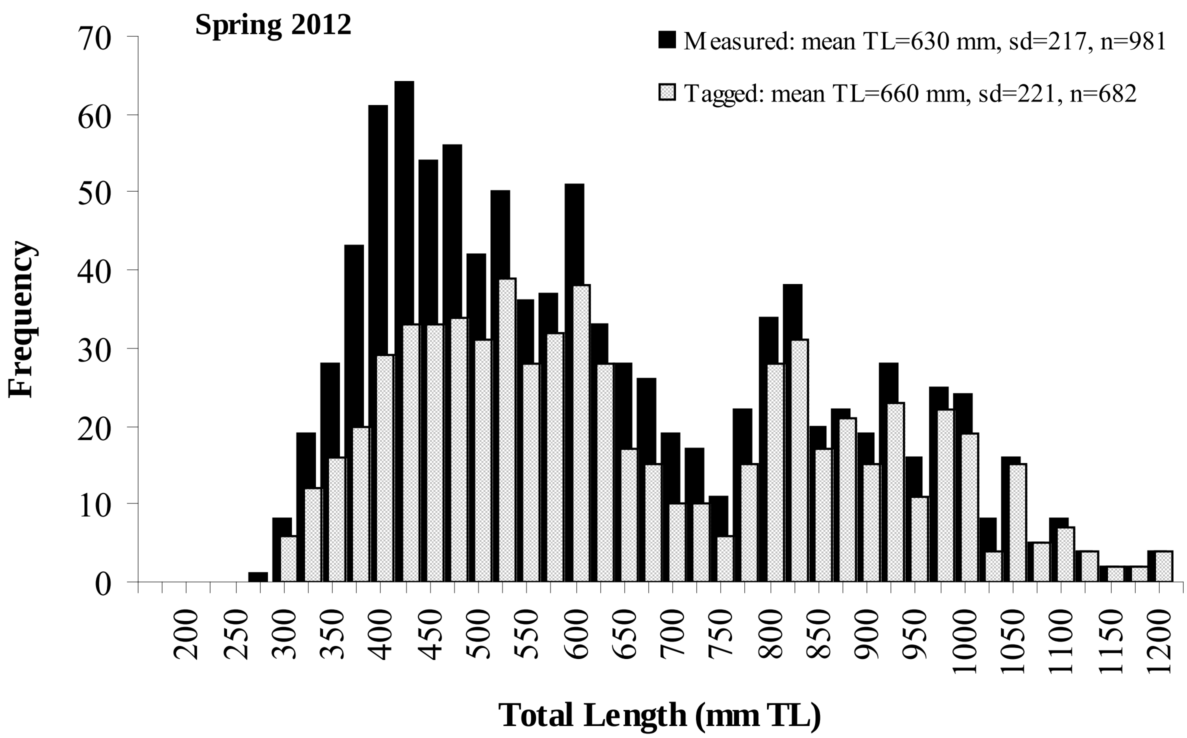


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay.



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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Amy Batdorf

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 5A were to quantify the commercial striped bass harvest in 2011 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-second 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 2011 commercial quota for the Chesapeake Bay and its tributaries was 1,963,873 pounds, a 7% decrease from 2010, with an 18 to 36 inch total length (TL) slot limit. There was a separate quota of 126,396 pounds, with a 24-inch (TL) minimum size for the state's jurisdictional waters off the Atlantic coast.

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 allotted 75% of the commercial quota. The pound net and haul seine fisheries were allotted the remaining 25%. When the allotted quota for a fishery (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, 2011, Monday through Thursday only. The pound net fishery was open from June 1 through November 30, 2011, Monday through Saturday. The haul seine fishery was open from June 7 through November 30, 2011, Monday through Friday. The Chesapeake Bay drift gill net season was split, with the first segment from January 1 through February 28, 2011 and the second segment from December 1 through December 31, 2011, 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, 2011 and November 1 through December 31, 2011, 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 the check station reports and effort data from the 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

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 to pay $100 and the Hook-and-Line only License (HLI) were required to pay $37.50 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, 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 commercial fisheries website. If the report is still not received by DNR 50 days after the report due date, the licensee received an official violation. Two or more official violations for any of the report types 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, 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 pounds of striped bass 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, 1,955,072 pounds of striped bass were harvested in 2011, 8,801 pounds under the 2011 quota. The estimated number of fish landed was 520,772 (Table 2). The Chesapeake drift gill net fishery landed 44% of the total landings by weight, followed by the pound net fishery at 33%. The hook-and-line fishery contributed 23% of the total landings and less than 1% of fish were harvested by the haul seine fishery.

Maryland's Atlantic coast landings were estimated at 2,072 striped bass, weighing 21,401 pounds (Table 2). The drift gill net fishery made up 87% of the Atlantic harvest, by weight, with the remainder from the trawl 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 4.00 pounds when calculated from the check station log sheets and 4.17 pounds when measured by biologists (Table 3), an increase from the 2010 season. Mean weights by specific gear type ranged from 3.54 to 3.97 pounds from check station log sheets, and were 3.56 to 4.44 pounds when measured by biologists. The largest striped bass landed in the Chesapeake Bay were taken by the drift gill net fishery. The average weight of fish harvested by gill net was 3.97 pounds when calculated using the log sheet data and 4.44 pounds when calculated using the MD DNR measurements.

Striped bass were also sampled at Atlantic coast check stations to characterize coastal harvest, although sample size was small (Project 2, Job 3, Task 1C, this report). Striped bass sampled from the Atlantic coast fisheries by MD DNR biologists averaged 14.95 pounds (Table 3). The average weight calculated from the check station log sheets was 10.33 pounds. Fish caught in the Atlantic trawl fishery averaged 16.87 pounds according to MD DNR estimates, and were larger on average than those caught in the gill net fishery (14.60 pounds). The average weights of fish from the Atlantic trawl and gill net fisheries, as calculated from check station log sheets, were 14.54 and 9.90 pounds, respectively.

Commercial Harvest Trends

Since the moratorium was lifted in 1990, striped bass harvests and quotas have become relatively consistent in the Chesapeake Bay (Table 4, Figure 4). The majority of the commercial striped bass harvest in Chesapeake Bay has historically been by drift gill net. Since the late

1990s, however, an increasing portion of the harvest has come from the pound net and hook-and-line fisheries. The hook-and-line fishery generally harvests the least of the three major Chesapeake Bay gears. The pound net fishery harvest increased through the early 1990s and by 1998 averaged approximately 600,000 pounds of striped bass harvested per year between 1998-2011.

Similar to the Chesapeake Bay fisheries, the Atlantic harvest has increased since the moratorium was lifted in 1990 and the fishery harvests nearly 100% of its quota; with a decline in harvest for the 2009-2011 seasons (Figure 5). In almost all years since 1990, the Atlantic trawl fishery harvest has been greater that the Atlantic drift gill net harvest with the exception of 2010 and 2011 where the gill net harvest was larger than the trawl harvest (Table 5, Figure 5). Though the Atlantic drift gill net fishery harvested very little initially after the moratorium was lifted, the harvest began to increase in 1994, likely due to increased interest in the fishery and increased abundance of the stock.

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.

The pound net fishery CPUE was 390 pounds per trip, the same as last season. The Chesapeake Bay drift gill net fishery CPUE was 397 pounds per trip, an 11% decrease from 2010 CPUE. The hook-and-line fishery CPUE was 224 pounds per trip, a 16% increase from the previous year (Table 5, Figure 6). With the exception of 2004, the hook-and-line fishery continues to have the lowest CPUE of all the Chesapeake Bay fisheries. Over the past five years, the gill net fishery had the highest average CPUE value (365 lbs per trip), followed closely by the pound net fishery (351 lbs per trip) and the hook-and-line fishery (206 lbs per trip) (Table 6, Figure 6).

The Atlantic trawl fishery CPUE was 187 pounds per trip in 2011, a 63% drop from the 2010 CPUE and significantly below the twenty-two year average of 546 pounds per trip. The 2011 CPUE for the Atlantic drift gill net fishery was 155 pounds per trip, below the twenty-two year average of 196 pounds per trip (Table 6, Figure 7).

In general, all Chesapeake Bay commercial striped bass fisheries have exhibited positive trends in CPUE estimates since the lifting of the moratorium in 1990 (Figure 6). The Atlantic drift gill net fishery has been variable with a downward trend since 2009. The Atlantic trawl fishery has also been variable, with several spikes in harvest in 1995 and from 2006-2009.

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LIST OF FIGURES

Table 1. Striped bass commercial regulations by gear type for the 2011 calendar year.

Area	Gear Type	Annual Quota (pounds)	Number of Participants	Trip Limit	Minimum Size	Reporting Requirement
Bay and Tributaries	Pound Net	490,968	222	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	750 lbs/license/day; 1,250 lbs/license/net/season	18-36 in TL slot	Monthly Harvest Report
	Hook-and-Line	589,162	149	500 lbs/license/day; 1,500 lbs/license/week; max 4 people/boat; 2 crew/licensee	18-36 in TL slot	Monthly Harvest Report
	Gill Net	883,743	761	300 lbs/licensee/day; max 4 licenses/boat	18-36 in TL slot	Monthly Harvest Report
Total Bay Quota		**1,963,873**				
Atlantic Coast	Atlantic Trawl	126,396	40	1,950 lbs/license/season for both Atlantic gears	24 in TL min	Monthly Harvest Report
	Atlantic Gill Net	included in Trawl	46			
Total Maryland Quota		**2,090,269**				

Table 2. Summary of striped bass commercial harvest statistics by gear type for the 2011 calendar year.

Area	Gear Type	Pounds[1]	Estimated[1] Number of Fish	Trips[2]
Chesapeake Bay[3]	Haul Seine	1,135	326	3
	Pound Net	646,978	177,592	1,661
	Hook-and-Line	441,422	124,841	1,972
	Gill Net	865,537	218,013	2,180
	Chesapeake Total Harvest	**1,955,072**	**520,772**	**5,816**
Atlantic Coast	Atlantic Trawl	2,806	193	15
	Atlantic Gill Net	18,595	1,879	120
	Atlantic Total Harvest	**21,401**	**2,072**	**135**
Maryland Totals		**1,976,473**	**522,844**	**5,951**

1. Data from check station log sheets.

2. Trips were determined 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 2011 calendar year. Average weights calculated by MD DNR biologists include 95% confidence intervals.

Area	**Gear Type**	**Average Weight from Check Station Logs (pounds)[1]**	**Average Weight from Biological Sampling (pounds)[2]**	**Sample Size from Biological Sampling[2]**
Chesapeake Bay[3]	Haul Seine	N/A	N/A	N/A
	Pound Net	3.64	4.03 (3.90-4.17)	1,104
	Hook-and-Line	3.54	3.56 (3.48-3.65)	1,328
	Gill Net	3.97	4.44 (4.39-4.49)	3,441
	Chesapeake Total Harvest	**4.00**	**4.17 (4.12-4.21)**	**5,873**
Atlantic Coast	Trawl	14.54	16.87 (13.56-20.18)	3
	Gill Net	9.90	14.60 (13.72-15.49)	175
	Atlantic Total Harvest	**10.33**	**14.95 (14.05-15.85)**	**207**

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 2011.

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

Table 5. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2011.

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	1325
2008	205	303	298	383	1108
2009	206	351	324	326	1348
2010	193	391	448	235	511
2011	224	390	397	155	187

Figure 1. Map of the 2011 Maryland authorized commercial striped bass check stations.

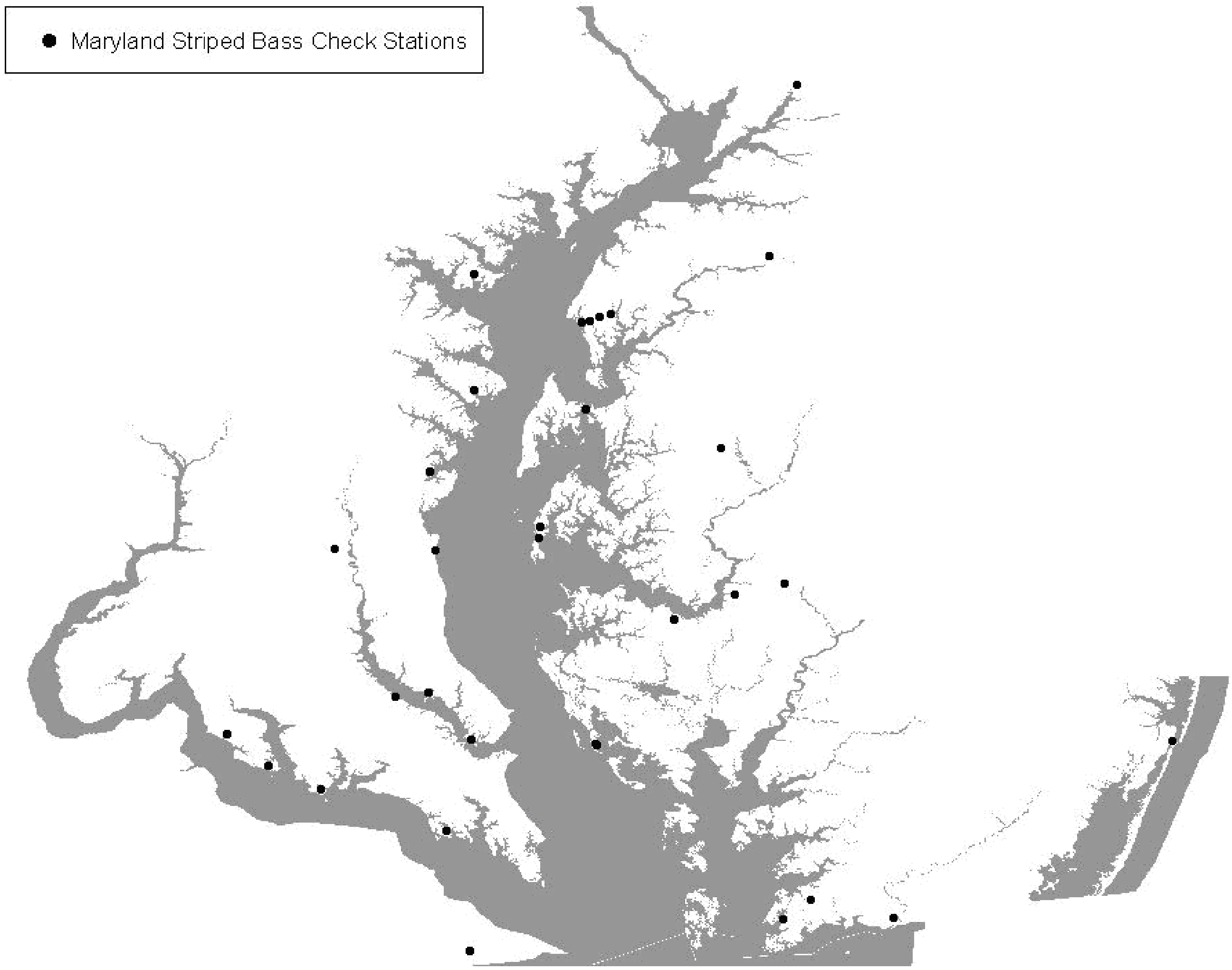


Figure 2. Maryland's Chesapeake Bay pound net and hook-and-line fisheries cumulative striped bass landings from check stations daily call-in reports, June-November 2011.

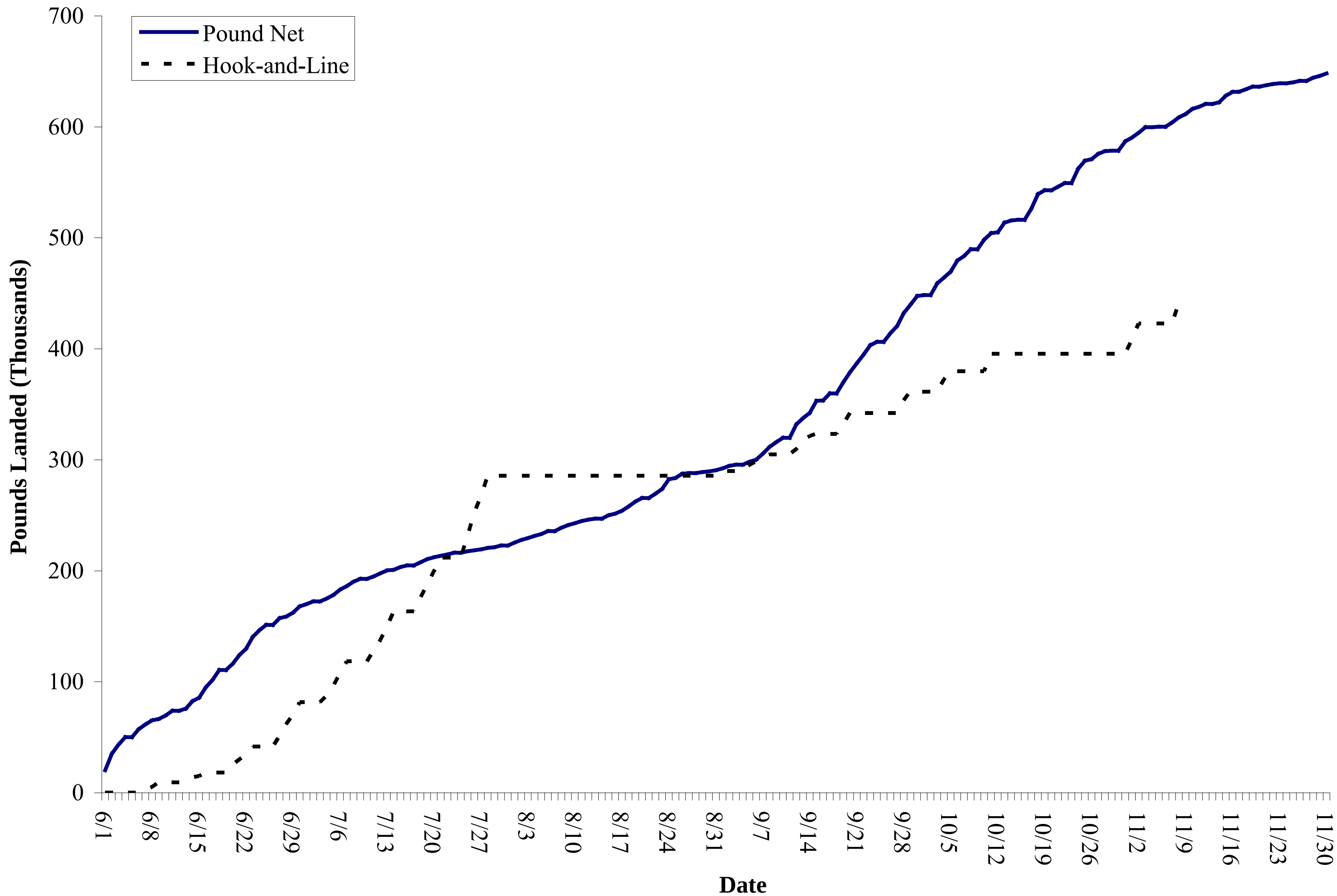
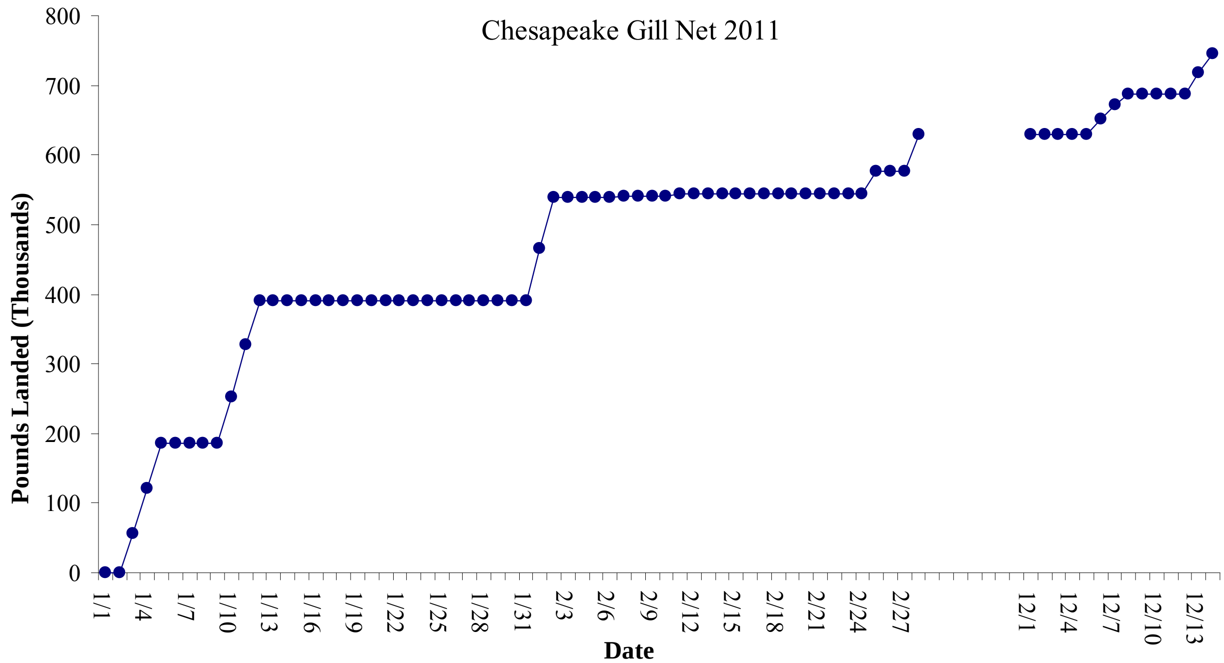


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fisheries (combined) cumulative striped bass landings from check stations' daily call-in reports, January-December 2011. Note different scales.



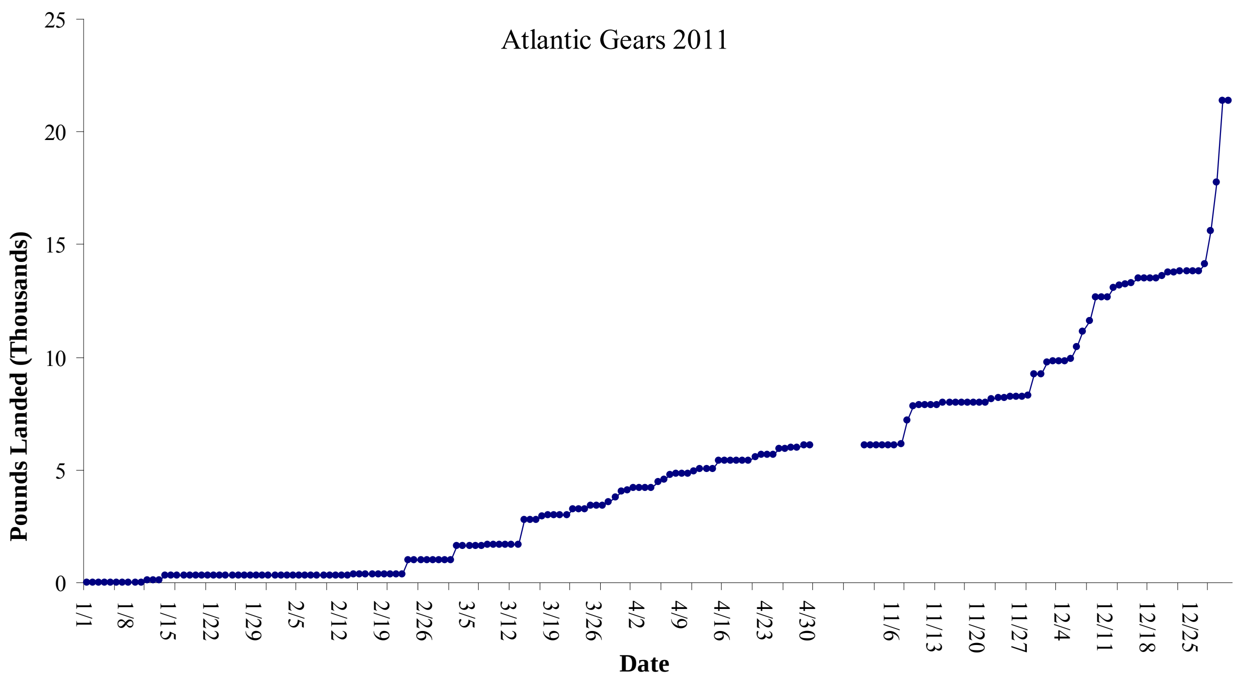


Figure 4. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990–2011.

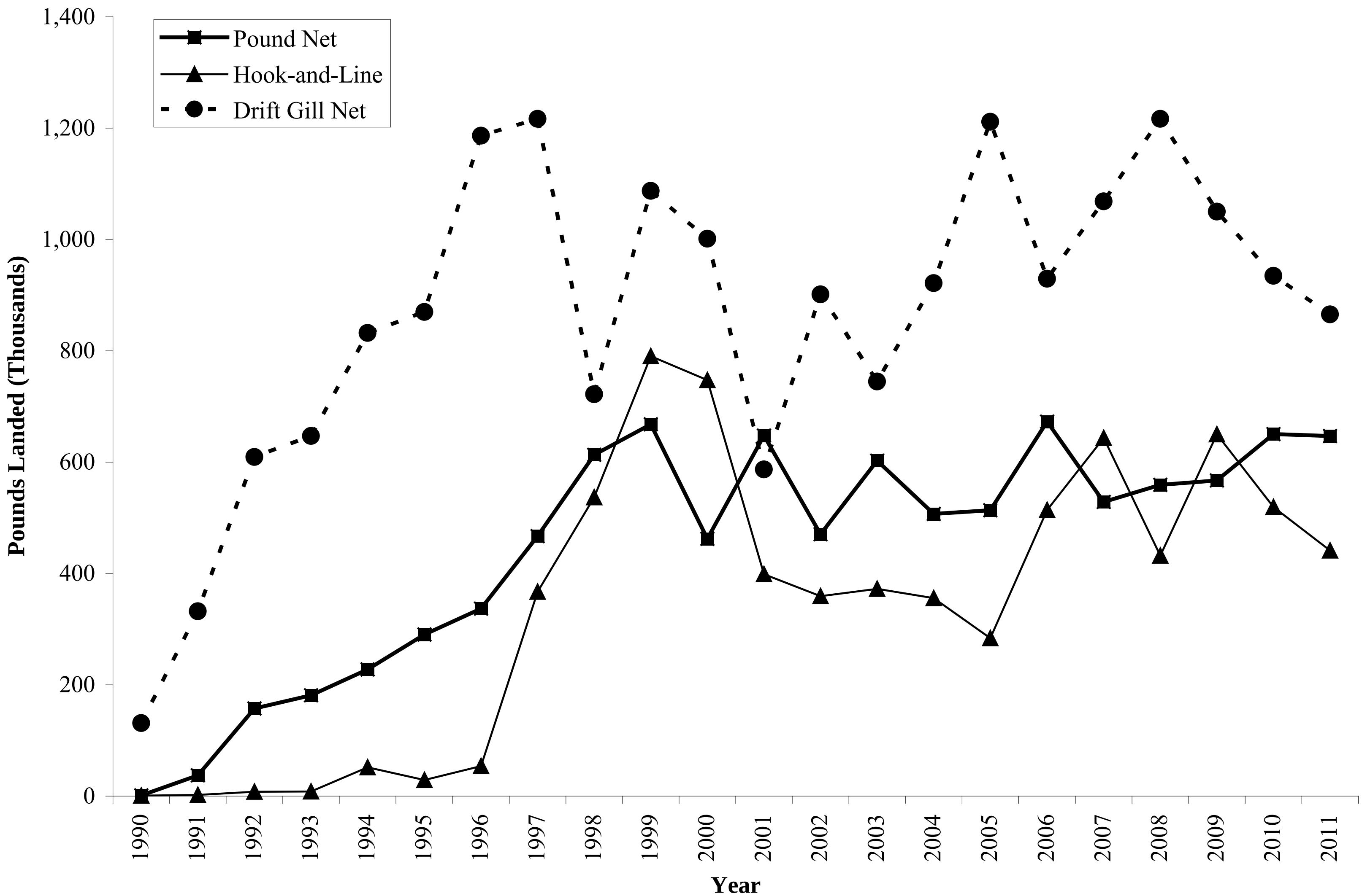


Figure 5. Maryland's Atlantic gill net and trawl fisheries total striped bass harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2011.

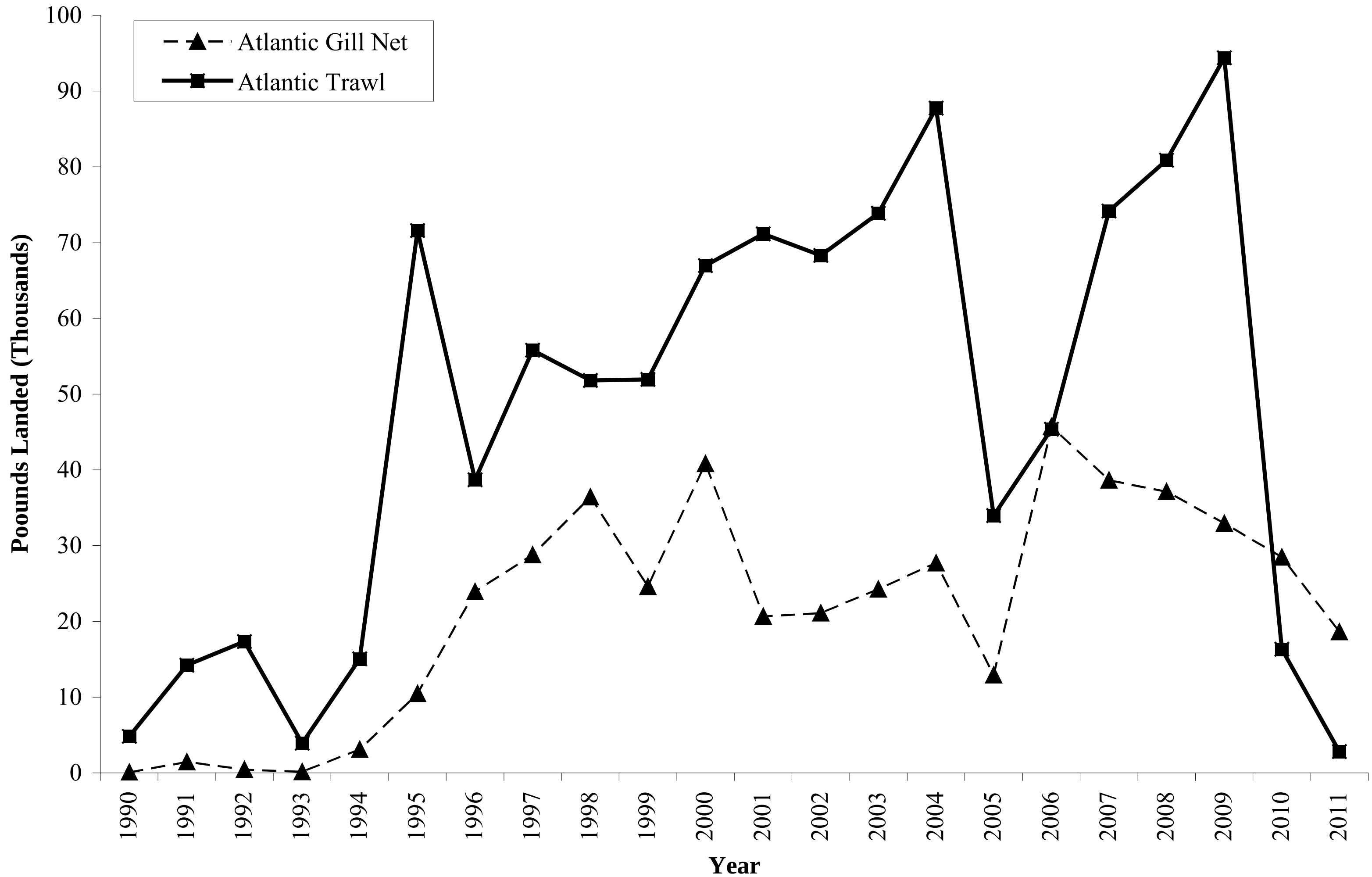


Figure 6. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990- 2011. Trips were determined as days fished when striped bass catch was reported.

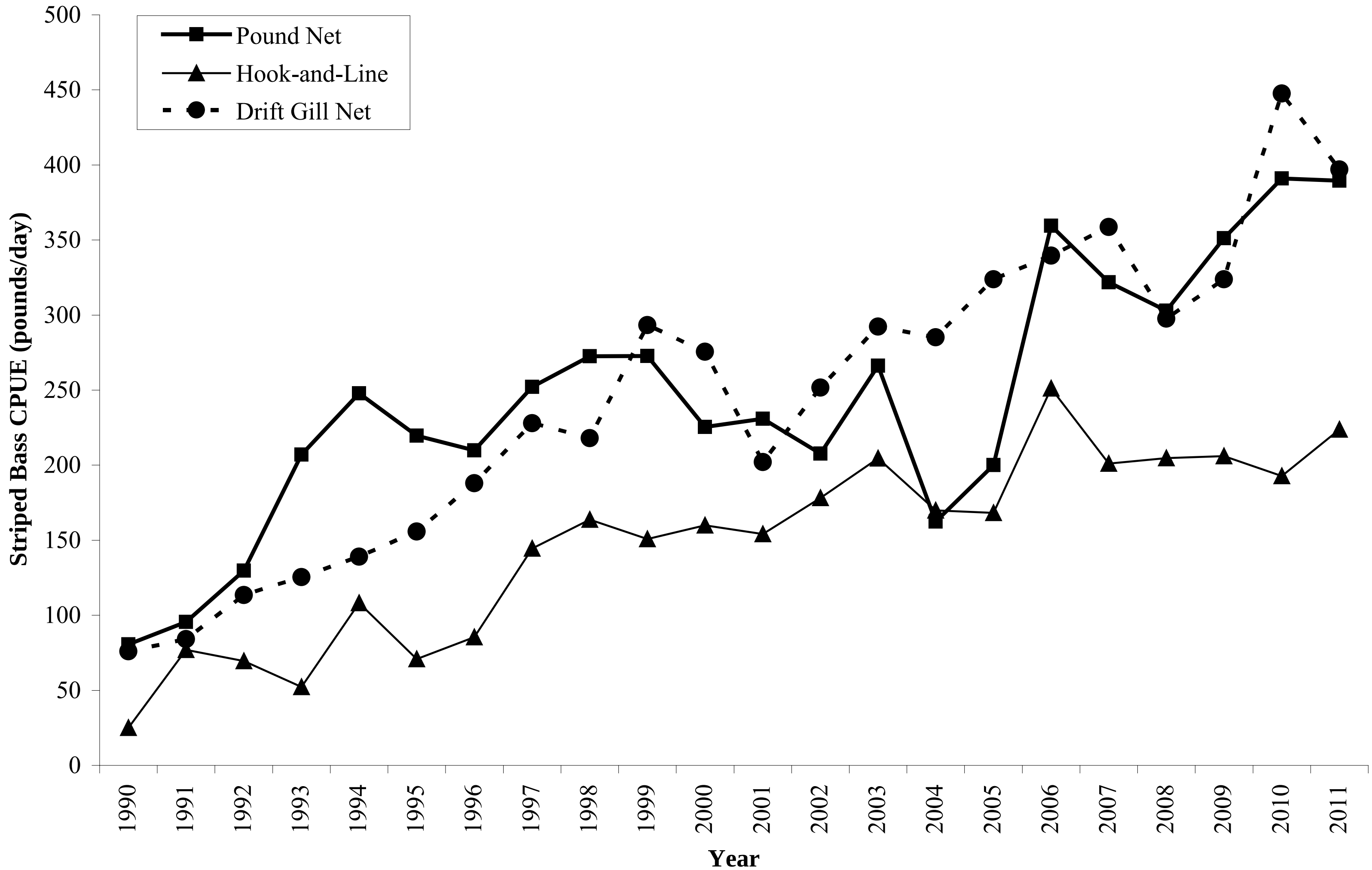
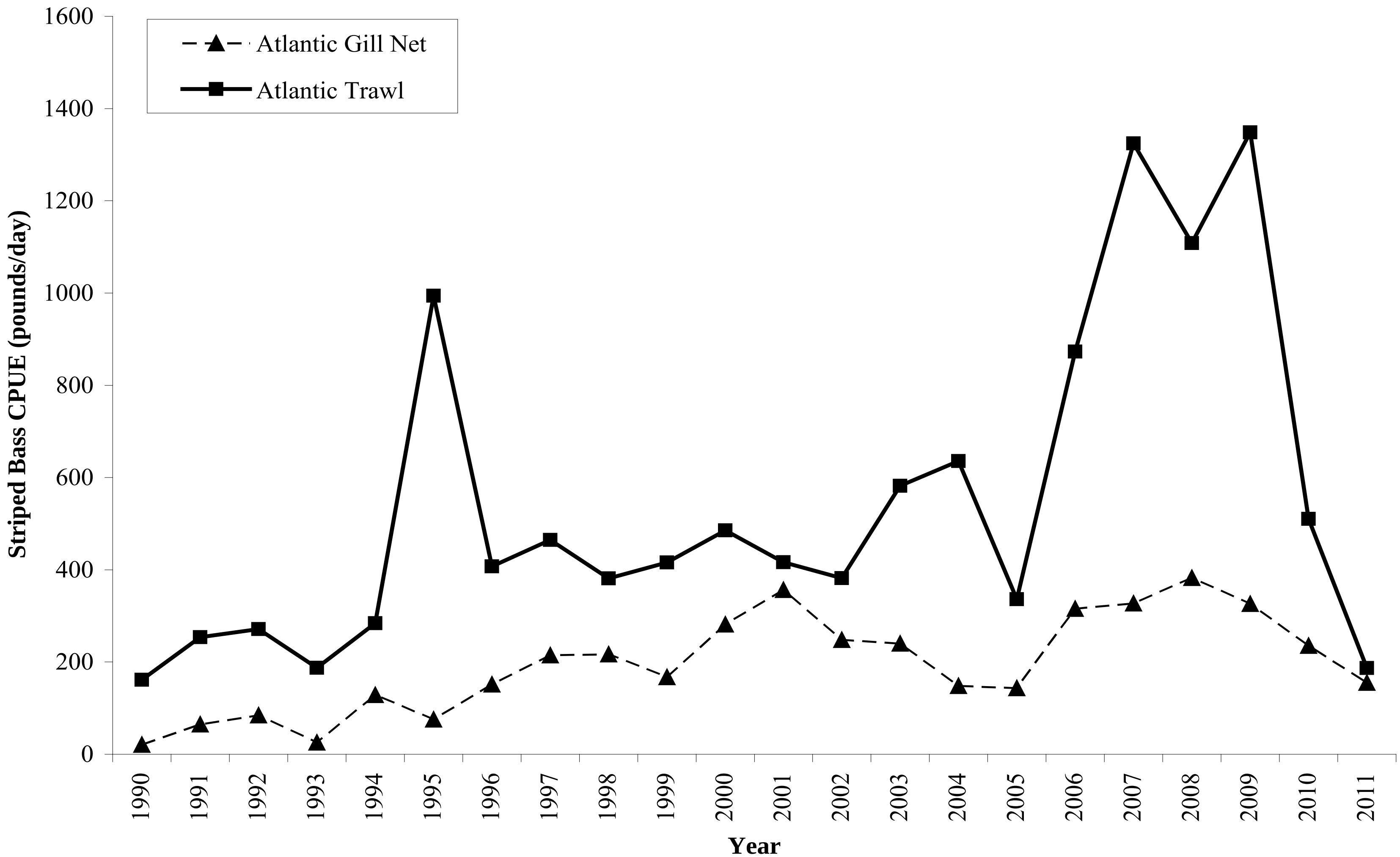


Figure 7. Maryland's Atlantic gill net and trawl fisheries striped bass catch (pounds) per trip (CPUE), 1990-2011. Trips were determined as days fished when striped bass catch was reported.



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 2012 spring recreational season, which began on Saturday, April 21 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 2012 season was 25 days long (April 21 – 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 relative abundance of the Chesapeake Bay spawning stock harvested during 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. In 2012, many trips did not return to the dock until noon or later while trying to catch their daily creel limit. Sites were not chosen by a true random draw. Biologists arrived at a chosen site between 9:00 and 10:00 AM to intercept the first wave of returning boats. If it became apparent that fishing activity from that site was minimal (i.e. most charter boats were tied up at the dock), biologists moved to the nearest site in search of higher fishing activity.

Biologists alternated between five major charter fishing ports in 2012: Solomons Island/Calvert Marina, Solomons Island/Beacon Marina, 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. 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 2012, 85 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.

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 logbooks to MD DNR indicating the days and areas fished, and numbers of striped bass caught and released. 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 logbook data has been excluded each year using this criterion, but sample sizes have still exceeded 1,000 trips per year. In 2012, 26% of the logbook 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 of boats intercepted, number of anglers interviewed, and numbers of striped bass examined each year are presented in Table 5A. In 2012, 172 private boat trips were intercepted for interviews. Fish were sampled from 37 intercepted charter trips (Table 5B). No shore anglers with completed trips were intercepted during the spring trophy season. 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

The minimum size limit for the 2012 spring striped bass season was 28 inches (711 mm) TL. Lengths ranged from 690 mm TL to 1096 mm TL. The catch was dominated by fish between 800 and 900 mm TL (31 to 35 inches, Figure 2). The majority of fish were smaller in 2011 as demonstrated by a length frequency skewed to the right.

Mean length

In 2012, the mean length for all fish (863 mm TL) was significantly smaller than that observed in any year of the survey except 2007 when there was a slot limit (Table 6A, Figure 3). The mean length of females (885 mm TL) was greater than the mean length of males (795 mm TL), which is typical of the biology of the species. The mean total length of the females was significantly smaller than that observed in 2006 and 2008-2010 but similar to other years. Mean length of males in 2012 was statistically similar to all other years of the survey except for 2002, 2005- 2006, and 2008-2009.

The mean daily lengths of female striped bass harvested in 2012 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

The mean weight of fish sampled in 2012 (6.7 kg) was significantly smaller than that observed in all years of the survey except for 2002, 2005, 2007, and 2011 (Table 6B). Based on 95% confidence intervals, the mean weight of females (7.2 kg) was significantly smaller than

2006 and 2008-2010 but statistically similar in all other years (Figure 5). The mean weight of males (5.3 kg) in 2012 was the lowest in the time series but was statistically similar to those observed in all other study years, except in 2005, 2006, and 2008. The mean weight of females (7.2 kg) was greater than the mean weight of males (5.3 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 2012 ranged from 5 to 17 years old (Figure 6). Most fish harvested were between 8 and 11 years old. The 2003 (9 years old in 2012) and 2004 (8 years old) year-classes were the most frequently observed cohorts, each constituting 50% and 17% of the sampled harvest, respectively. The strong 2003 year-class has increased annually in the harvest since 2008 and dominated the 2012 harvest with the proportion nearly doubling since last year. The record 1996 year-class (16 years old in 2012), which dominated catches in 2005, 2006, and 2008, constituted just 0.4% of the sample harvest.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2012 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 2012. Females constituted 75% of the sampled harvest. This is one of the lowest proportions of females harvested in the time series, though similar to 2008 and 2009.

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 2012 creel survey indicated that 30% of the females caught between April 21 and May 15 were in pre-spawn condition (Table 8). This percentage is lower than the average of the past nine years and one of the lowest percentages in the time series suggesting that most spawning activity was complete prior to the start of the spring season.

Daily spawning condition of females

Although the percentage of pre-spawn female striped bass appears to increase throughout the survey (Figure 7), sample sizes were very small. The percent of pre-spawn females harvested ranged from 32% to 100% on any given day. Sample sizes of female striped bass ranged from 55 female fish on the first day of sampling to zero female fish towards the end of the trophy season (mean=14 fish, median=7 fish). The peak seen on May 10 in Figure 7 was based on just two sampled fish, both of which were pre-spawn. The three sample days surrounding this date (May 7, 11, and 14) consisted of 19 female fish, all in post-spawn condition. The low numbers of female fish encountered, especially towards the end of the trophy season, suggests that spawning may have occurred early in April prior to the opening of the spring fishing season and that the larger migratory fish had already returned to the ocean. This hypothesis is supported by the spring spawning stock survey (Project 2, Job 3, Task 2) which showed that few fish remained on the spawning grounds past April 21, the opening date of the 2012 spring trophy season.

CATCH RATES AND FISHING EFFORT

Harvest Per Trip Unit Effort

Charter boat activity can be accurately characterized from existing reporting methods so no interviews of charter boat anglers were conducted in 2012. Because of increased focus on improving our understanding of private boat fishing effort, all trips intercepted in 2012 for interviews were private boat trips. Creel survey interview data were used to obtain harvest rate estimates for private vessels. Harvest per trip (HPT) was calculated from charter boat logbooks and creel survey interviews using only fish kept during each trip.

The mean HPT in 2012 according to charter boat logbooks was 4.0 fish per trip, the statistically lowest value in the time series (Table 9A). Mean HPT from private boat interviews (0.5 fish per trip) was much lower than HPT from charter boats and the lowest private boat HPT in the time series. Though it was statistically similar to the mean private boat HPT from 2002 and 2006-2008, it was significantly less than all other years.

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 logbook data in 2012 was 0.6 fish per person, significantly lower than all other years (Table 9B). HPA for private anglers, calculated from interview data, was 0.2 fish per person. While the 2012 HPA number is one of the lowest values in the time series and significantly lower than most years, the value is statistically similar to values from 2006-2008 (Table 9B).

Catch Per Unit Effort

In all years, charter boats caught 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 2012, private boats caught an average of 0.8 fish per trip, while charter boats caught 4.8 fish per trip. While the 2012 private boat catch per trip was similar to many past years, the charter logbook mean catch per trip was the lowest in the ten year time series. The private boat CPH was 0.2 fish per hour while charter boats had a CPH of 0.9 fish per hour. The 2012 private boat catch per hour was similar to all years except 2004 and the charter boat mean catch per hour was significantly lower than every year other than 2002.

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. In 2012, many captains in the lower portion of Maryland's Chesapeake Bay canceled trips towards the end of the season because of the lack of fish. Interview data showed that mean daily CPH declined slightly over time in some years, but has generally varied without trend since 2002 (Figure 8). Though there were not enough observations to make a definitive conclusion, it appears that daily CPH in 2012 varied without trend. CPH values have decreased since 2007 due to the lack of charter boat interview data. Comparing 2008-2012, however, it appears that the 2012 daily CPH values are generally lower than the other years.

Angler Characterization

States of residence

In 2012, 172 private boat trips were intercepted for interviews and 447 anglers were interviewed during the period April 21-May 15 (Table 5A and Table 5B). Twelve states of residence were represented in 2012 (Table 11). Most anglers were from Maryland (85%), Virginia (6%), 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 2012, there were on average 2.6 anglers per boat and of these anglers, 1.3 were license-exempt (Table 12). These results are remarkably consistent with previous years.

Number of Lines Fished

In order to determine fishing effort, the number of lines fished was asked in the creel survey in 2006 and 2010-2012. In 2006, six lines were fished on average per private boat and the maximum number encountered on a boat was 15. In 2012, the average number of lines fished per private boat was seven and ranged from two to 18 lines (Table 13). This was more lines, on average, than in 2006 (6 lines) but less than 2010 and 2011. In addition, the range of the number of lines fished was smaller (3-15 lines) in 2006.

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Table 1. History of MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2012.

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

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2012. 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, 2012.

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, 2012.

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, 2012.

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

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

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	TL (mm) - All fish	TL (mm) - Females	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)

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)

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

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
Mean	**80**	**83**	**83**

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
Mean	**123**	**46**	**133**	**54**

*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 logbooks and spring season creel survey interview data, through May 15.

Year	**Charter Logbook Trips (n)**	**Charter Logbook 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	1,660	**4.8** (4.7-4.9)	298	**0.9** (0.7-1.0)
2012	1,127	**4.0** (3.8-4.1)	172	**0.5** (0.3-0.6)

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

Year	Charter Logbook Trips (n)	Charter Logbook 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	1,660	**0.78** (0.77-0.80)	298	**0.3** (0.3-0.3)
2012	1,127	**0.64** (0.62-0.66)	172	**0.2** (0.1-0.2)

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)

Table 10B. Charter boat mean catch, effort, and catch per hour, with 95% confidence limits, calculated from logbook data, through May 15. Catch is defined as number of fish harvested plus number of fish released. Mean hours per trip are from creel survey interview data until 2009 where the mean hours per trip are from mate interviews.

Year	**n**	**Mean catch/trip**	**Mean hours/trip** (From creel 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	1,660	**5.7** (5.5-5.8)	**4.2** (3.5-4.9)	**1.3** (1.3-1.4)
2012	1,127	**4.8** (4.6-5.0)	**5.5** (4.9-6.1)	**0.9** (0.8-0.9)

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

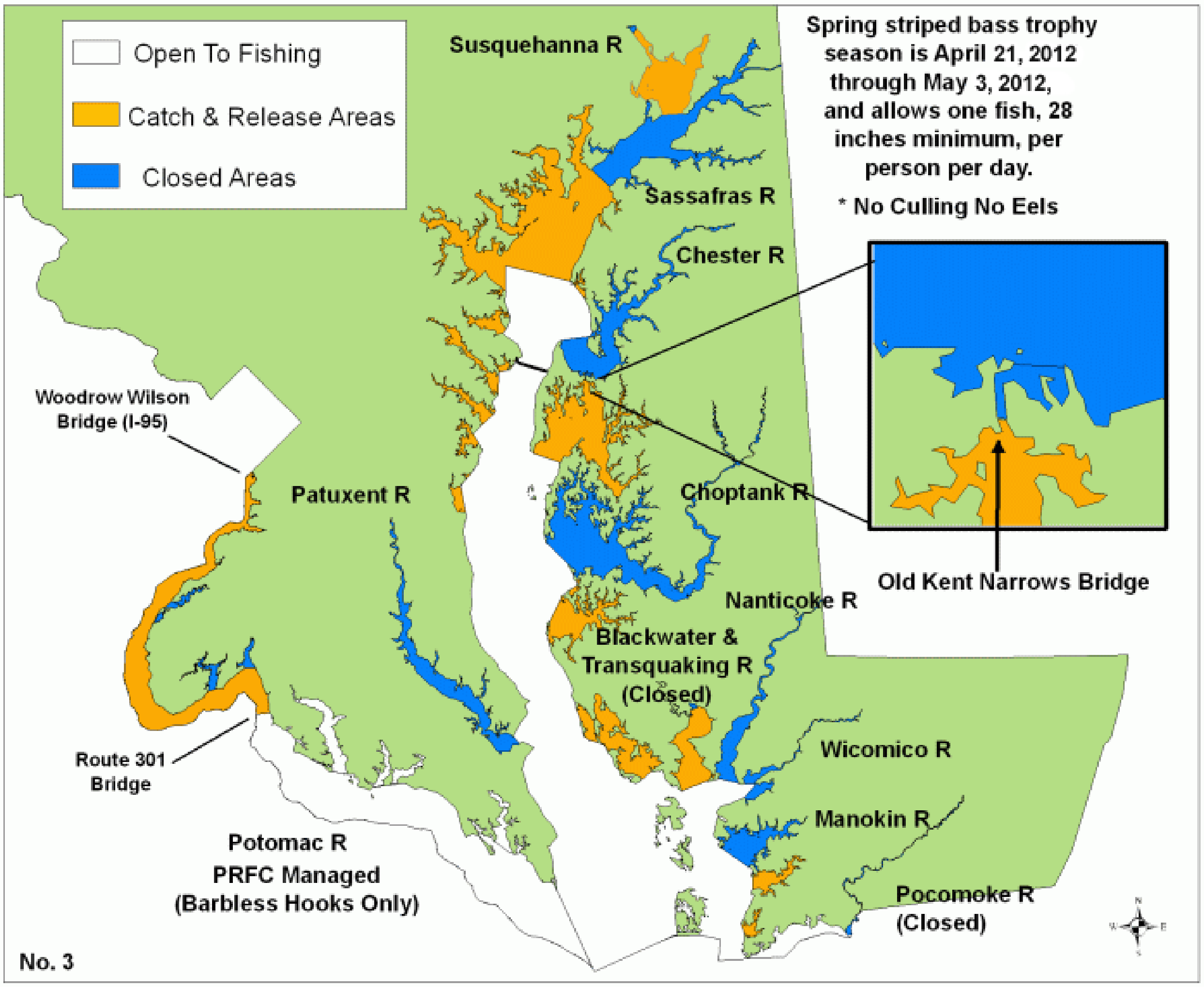
Table 12. The average number of anglers and average number of unlicensed anglers, per boat, with 95% confidence intervals, from the 2008-2012 Maryland striped bass spring season creel survey interview data.

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)

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

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 21-May 15, 2012.



* Note: The text on the map refers to the dates catch and release fishing is allowed on the Susquehanna Flats prior to the area closure May 4-15, not the dates the spring trophy fishery is open.

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

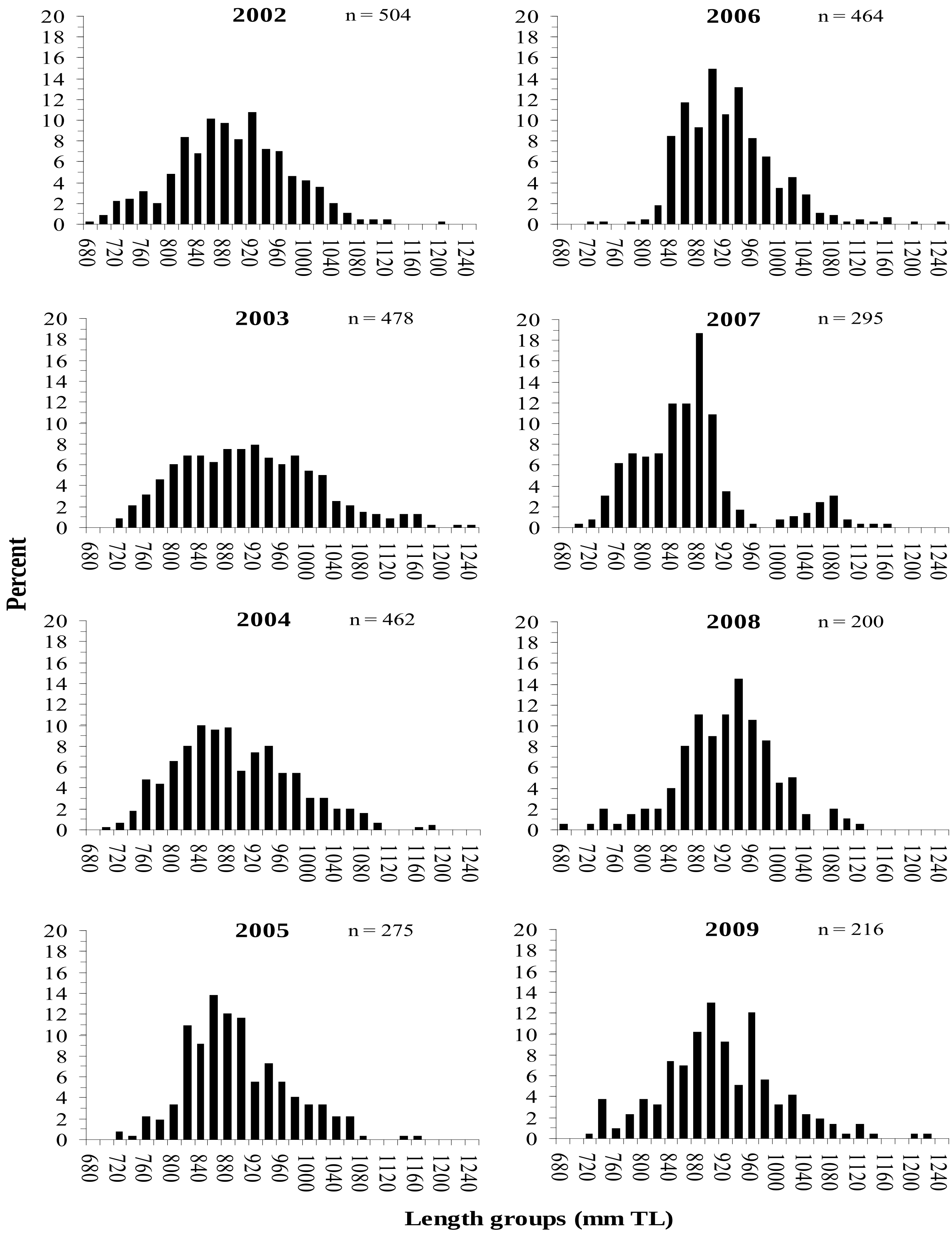


Figure 2. Continued.

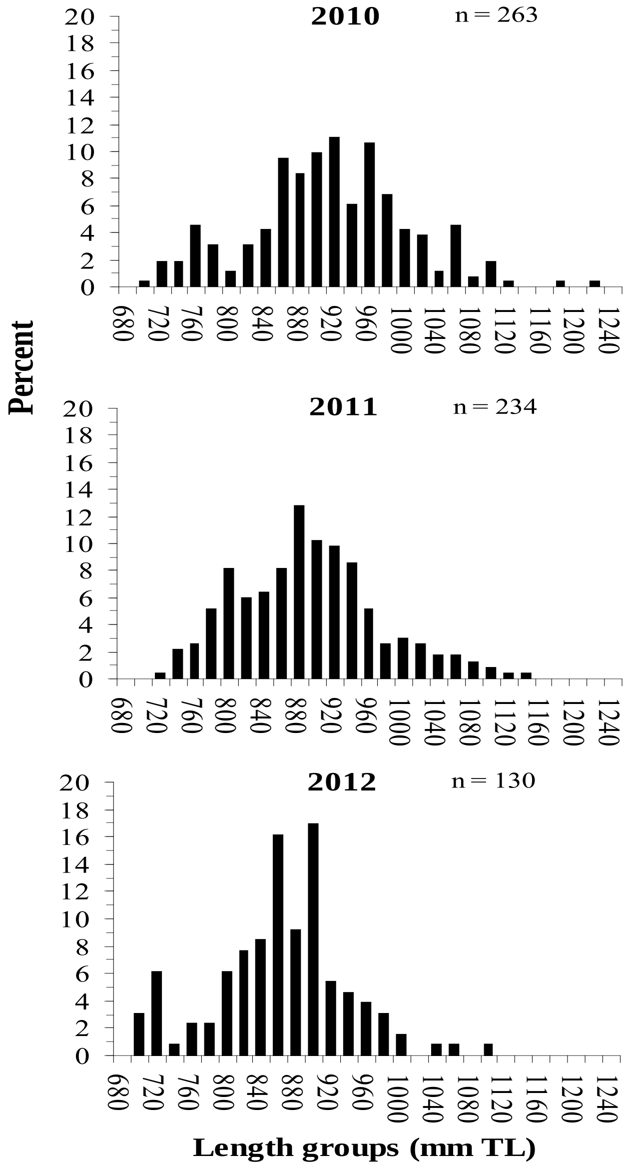


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

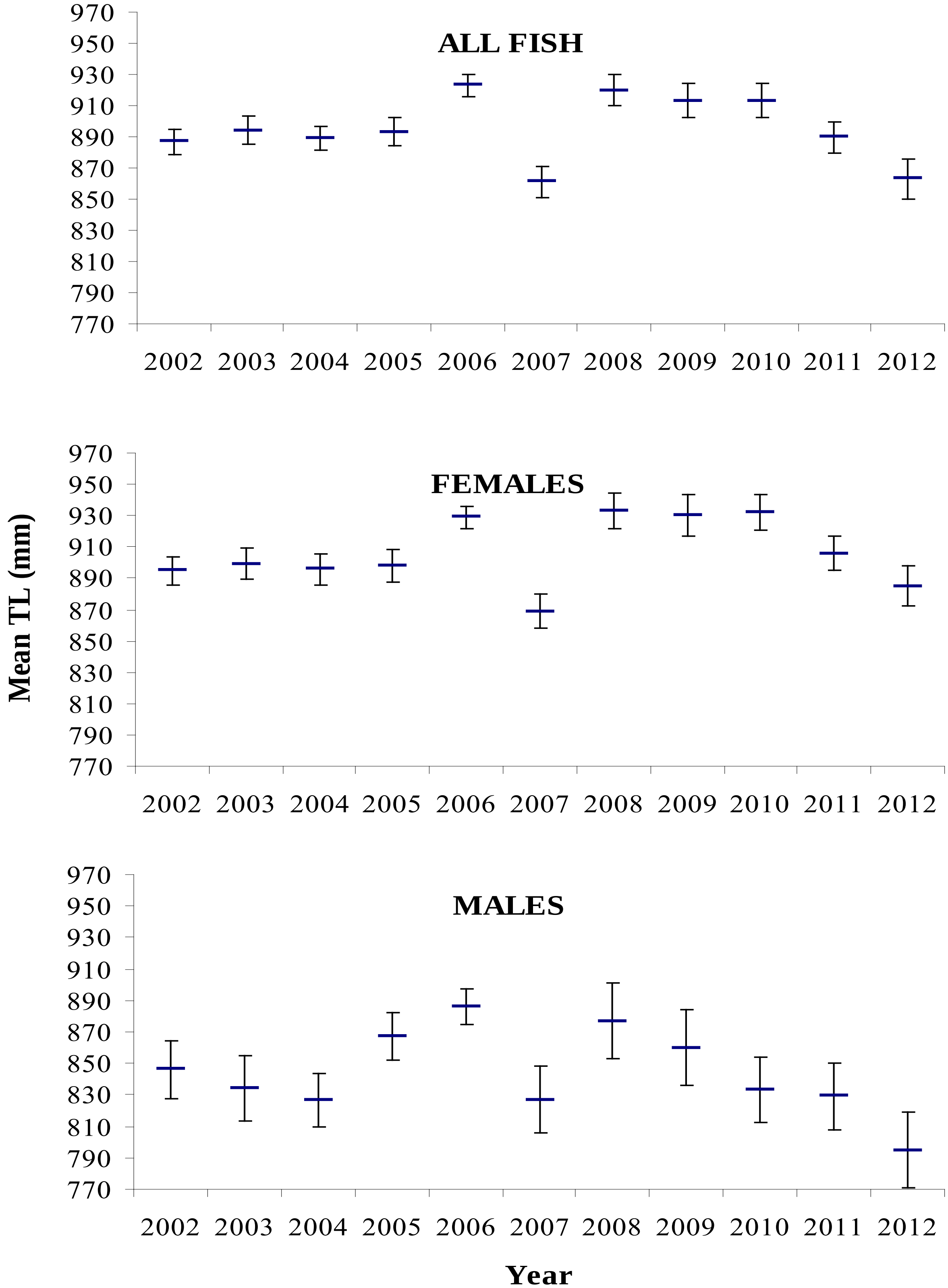


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

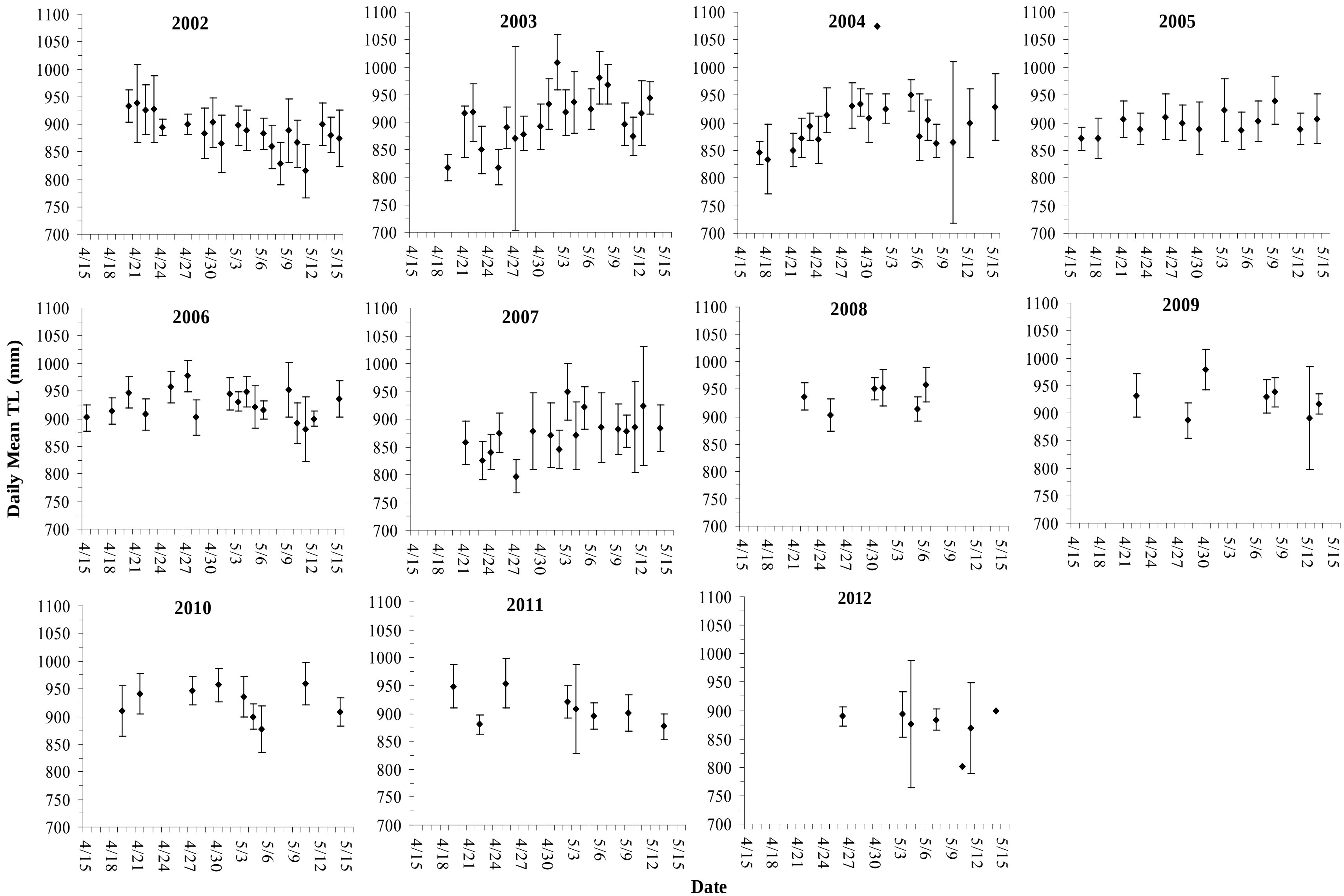


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

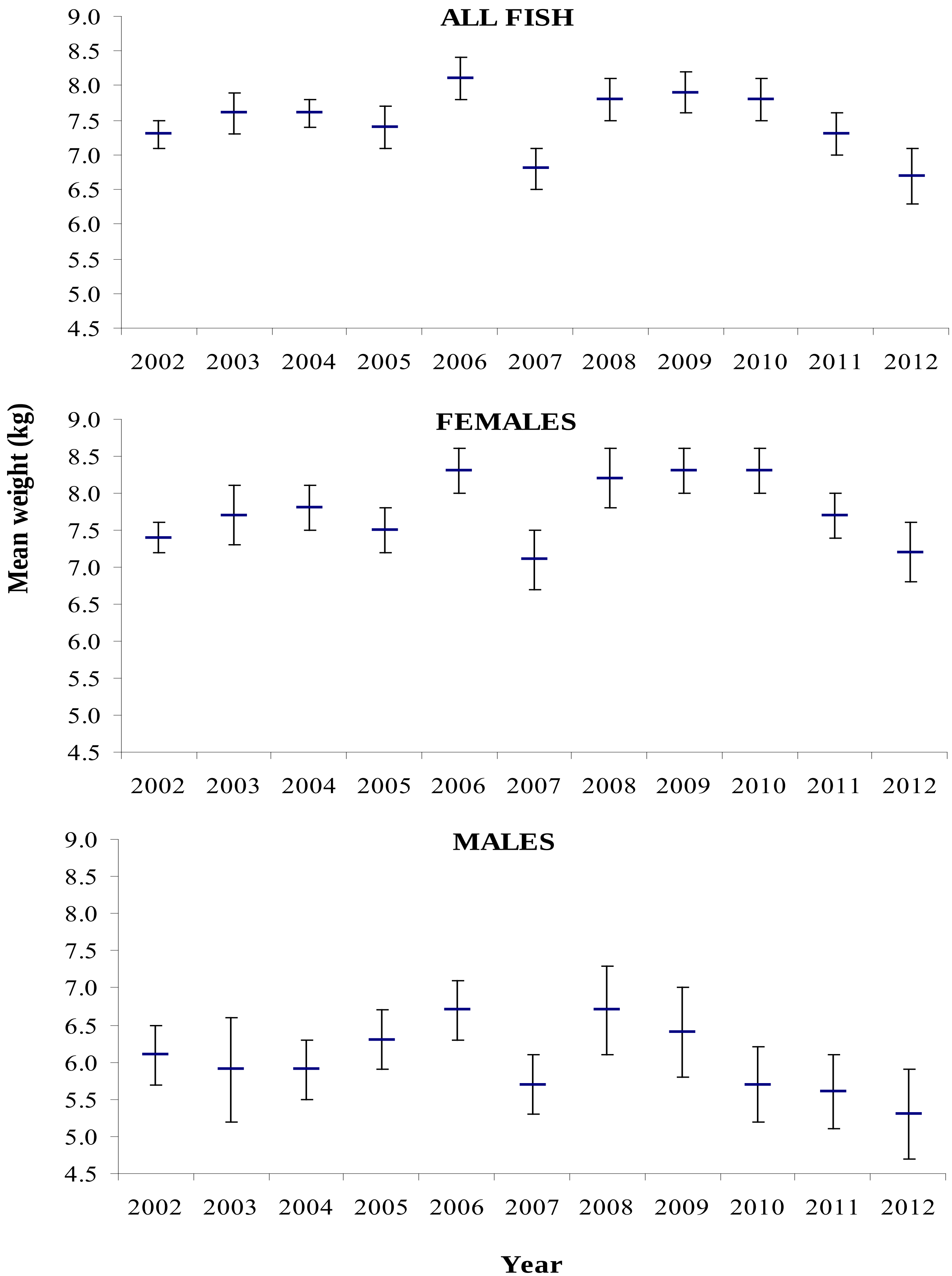


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

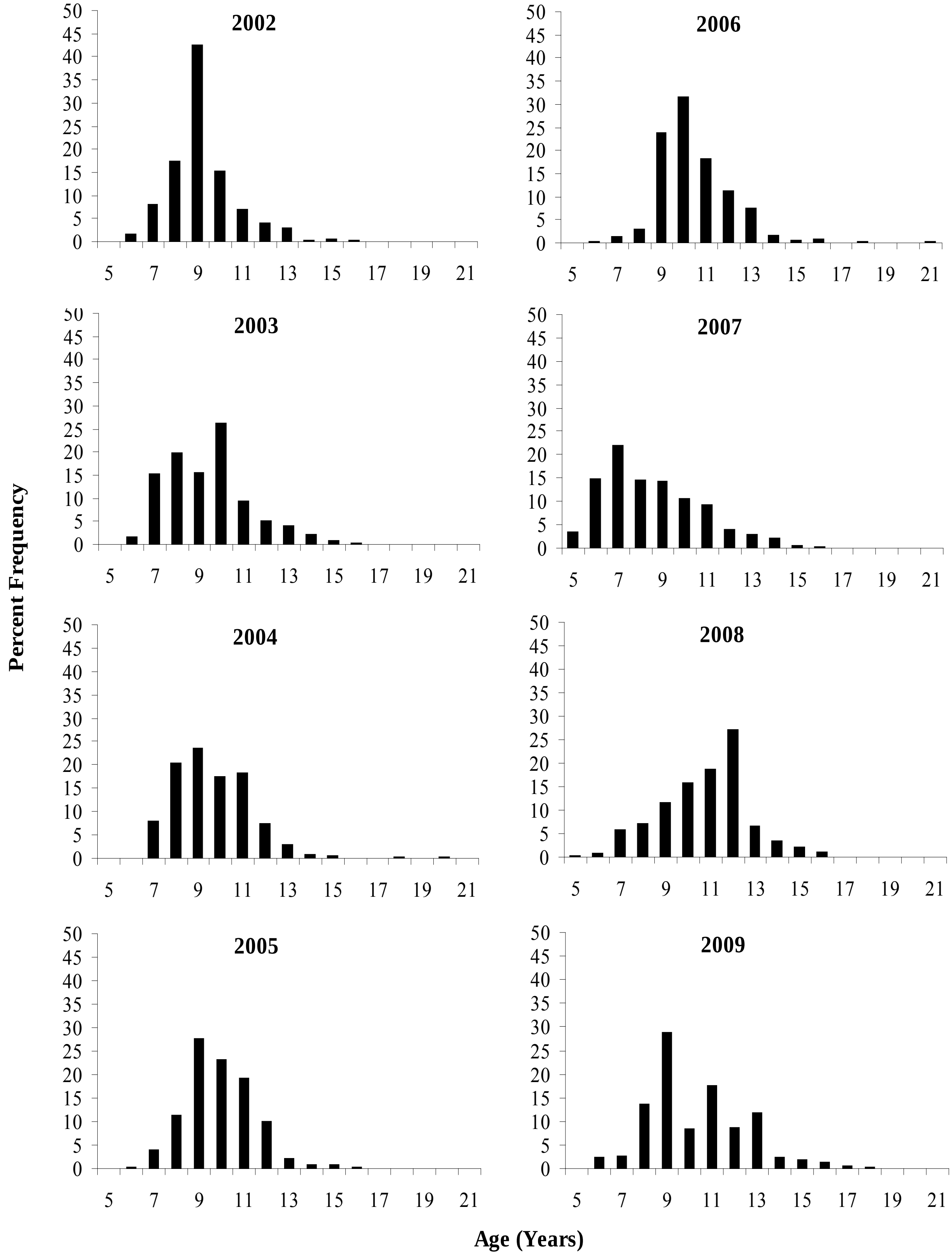


Figure 6. Continued.

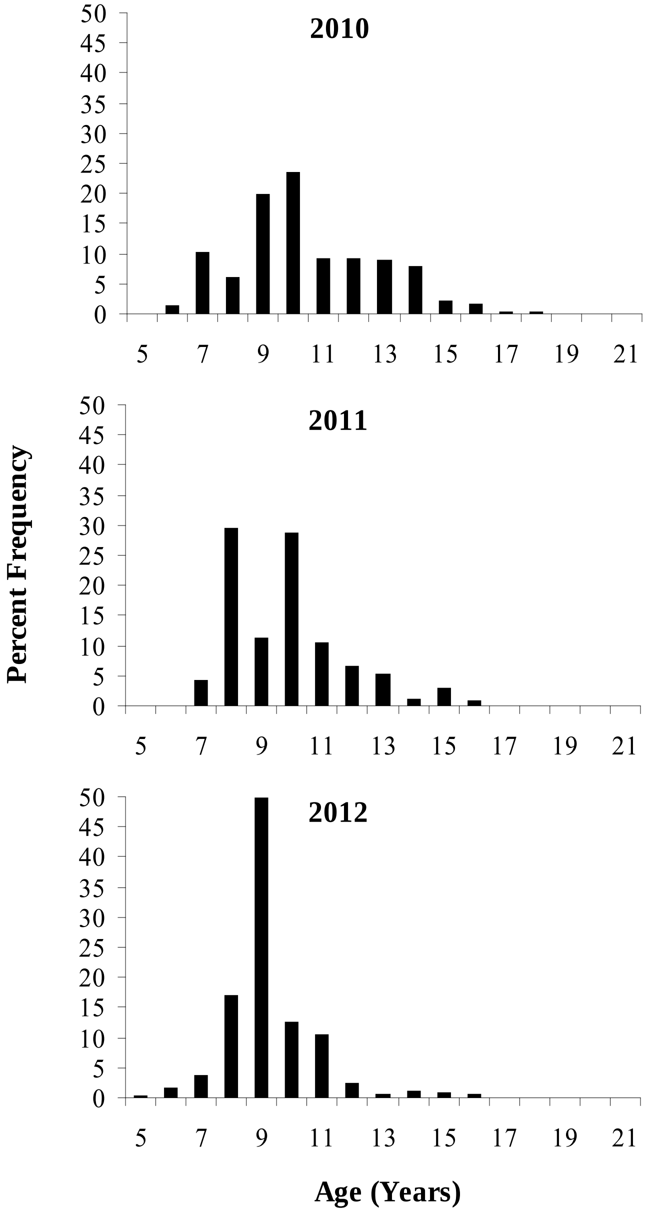


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

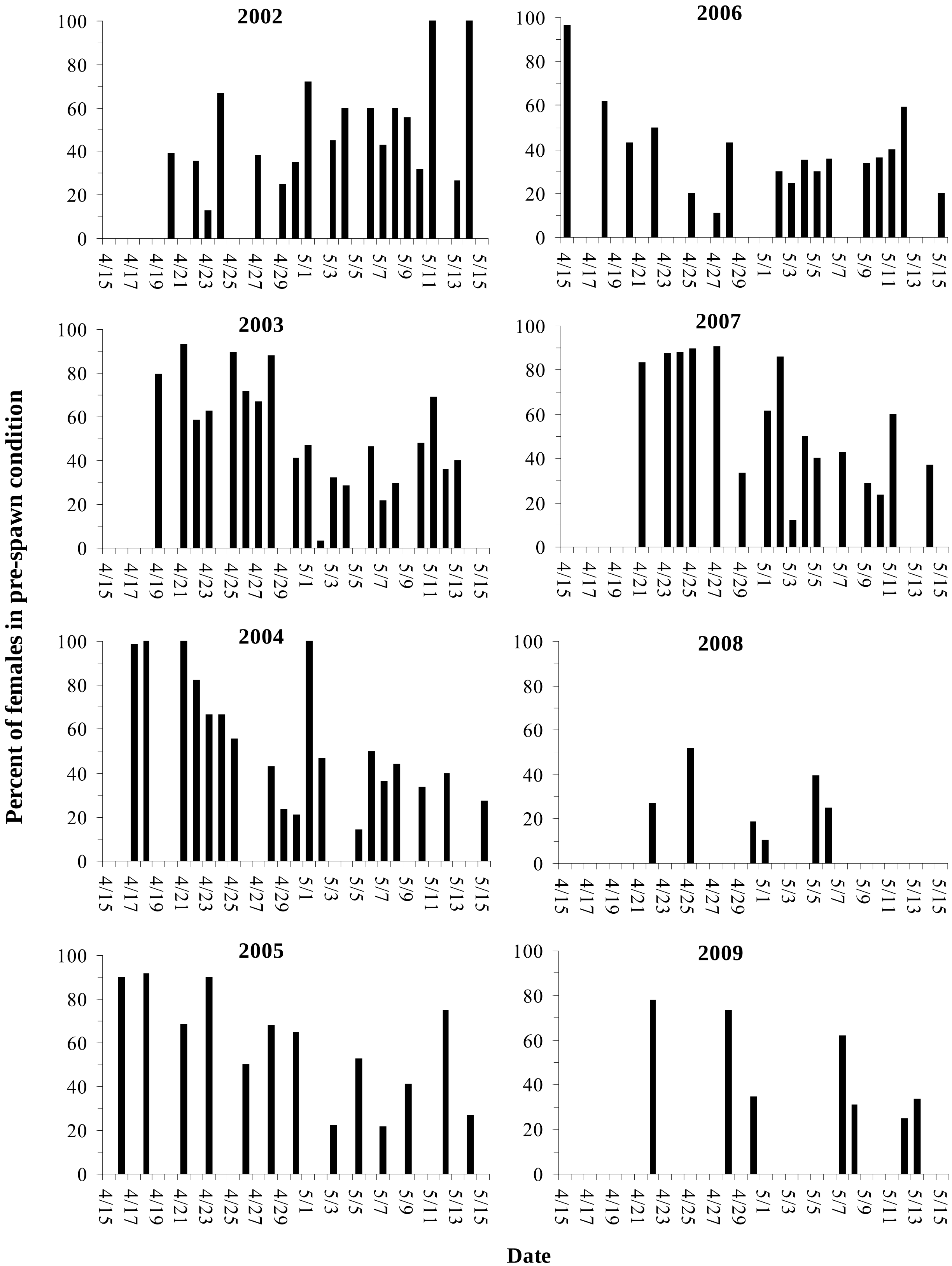


Figure 7. Continued.

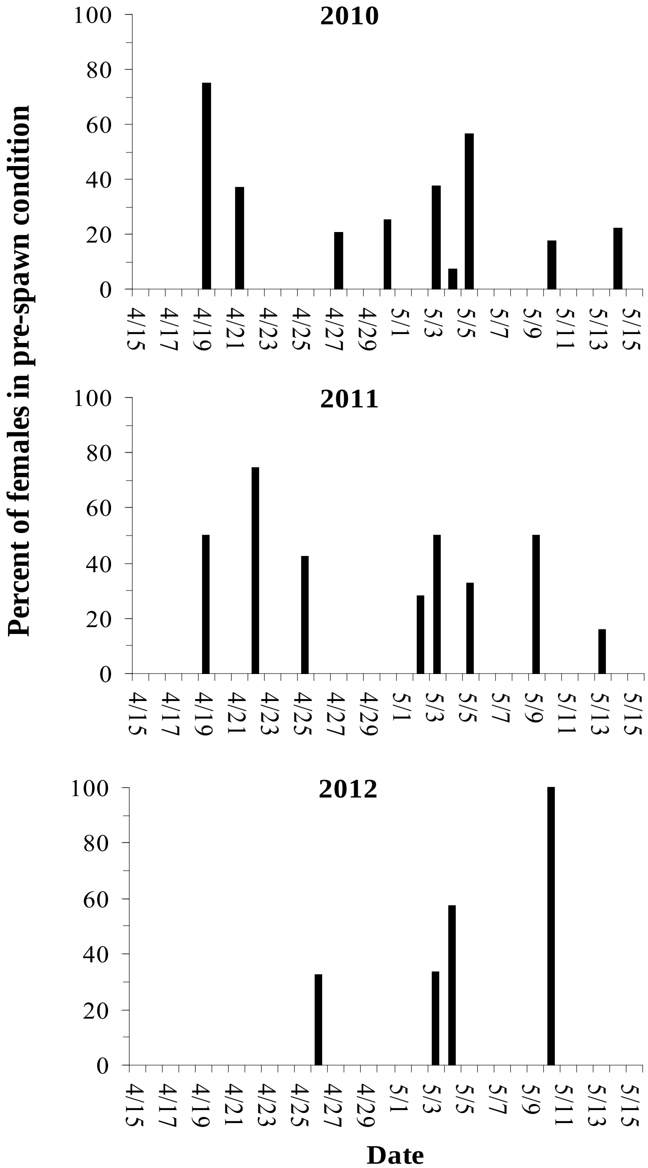
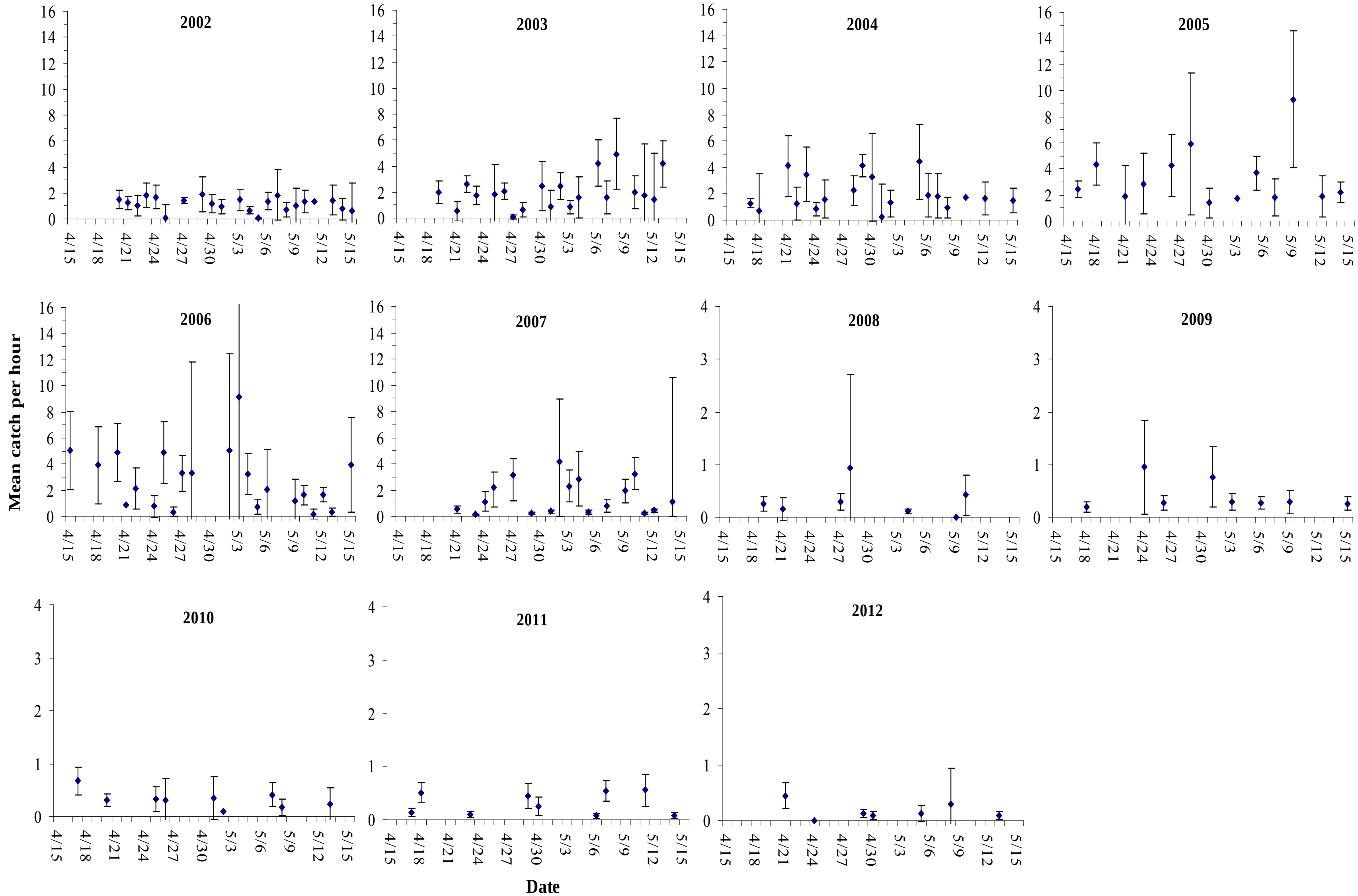


Figure 8. Daily mean catch per hour (CPH) of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15. Note different scale since 2008.



APPENDIX I

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 Harry T. Hornick and Eric Q. Durell

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.

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.

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 attended the American shad Technical Committee meetings to approve the annual state compliance report, examine the current population abundance estimates and discuss the ocean and river-specific fisheries, and prepared the Annual American Shad Status Compliance Report for Maryland.

Bluefish:

The ASMFC Bluefish Technical Committee representative provided Chesapeake Bay juvenile bluefish data to the ASMFC and the Mid-Atlantic Fishery Management Council.

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

Red Drum:

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

Weakfish:

ASMFC Weakfish Technical Committee representative for Maryland attended annual Weakfish Technical Committee meetings and prepared the ASMFC Annual Weakfish Status Compliance report

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.

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://www.dnr.maryland.gov/fisheries/Pages/striped-bass/juvenile-index.aspx, is updated annually in October.

Monthly individual visits to the Juvenile Striped Bass Survey web page by individual IP address for the period July 2012 to January 2013 are provided in Table 1. Because of a change in MD DNR Information Technology Service policy and data management, and incorporation of a new server, web site visit statistics from January 27, 2012 to July 12, 2012 were not available.

An increase in volume in October 2012 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, the web page 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, July 13, 2012 January 12, 2013.

Date	**Visits**
July 13, 2012 –Aug. 12, 2012	260
Aug. 13, 2012 – Sept. 12, 2012	275
Sept. 13, 2012 – Oct. 12, 2012	447
Oct.13, 2012 –Nov. 12, 2012	249
Nov. 13, 2012-Dec. 12, 2012	187
Dec. 12, 2012-Jan. 12, 2013	175
TOTAL	1593

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), Duke University, the University of Maryland, University of Massachusetts, Virginia Institute of Marine Sciences, Georgetown University, the Pennsylvania State University, Syracuse University, and State management agencies from Delaware, Massachusetts, New York and Virginia. For the past contract year, (November 1, 2011 through October 31, 2012) the following specific requests for information have been accommodated:

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

-Ms. Emily Argo, Duke University (PRFC).
Provision of biological samples and data from the Juvenile Striped Bass Survey.

-Dr. Robert Aguilar, Smithsonian Environmental Research Center (SERC).
Provided biological samples and data from the Juvenile Striped Bass Survey.

-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.

-Dr. Trevor Avery, Dept. of Biology, Acadia University, Nova Scotia, Canada.
Provided striped bass juveniles and the striped bass juvenile index data set

-Mr. Jim Cummins, Pennsylvania Fish and Boat Commission.
Provided American Shad data from the Juvenile Striped Bass Survey.

-Ms. Cassie Gurbiz, University of Maryland, Horn Point Laboratory.
Provided striped bass data from the Juvenile Striped Bass Survey.

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

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

-Dr. John Harrison, The Pennsylvania State University.
Provision of striped bass juvenile survey data and striped bass recreational and commercial fishery data.

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

-Dr. Desmond Kahn, Delaware Division of Fish and Wildlife.
Provision of historic Striped Bass Juvenile Survey data.

- 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. Rob O'Reilly, Virginia Marine Resources Commission.
Provision of current and historical striped bass commercial fishery data; Striped bass Voluntary Angler Survey data, results of fishery dependent monitoring programs and striped bass juvenile survey data.

-Mr. Jason Schaffler, Old Dominion University.
Provision of juvenile Atlantic menhaden biological samples and abundance indices.

-Dr. Amy Schueller, NMFS, SEFSC.
Provision of historic data from the Juvenile Striped Bass Survey

-Ms. Sara Turner, Syracuse University.
Provision of biological samples and data from the Juvenile Striped Bass Survey

-University of Maryland (U MD - CEES), Chesapeake Biological Laboratory and Horn Point Environmental Laboratory.
Provided six (6) staff and students with current striped bass juvenile index data, American shad juvenile index data, recreational and commercial landings data, and biological samples.

-Ms. Allison Watts, Virginia Marine Resources Commission..
Provision of data from the Juvenile Striped Bass Survey, MD Volunteer Angler Survey, and commercial fishery monitoring data.

-The Interjurisdictional Project also provided related biological information and reports to thirty three (33) additional scientists, students and concerned stakeholders.