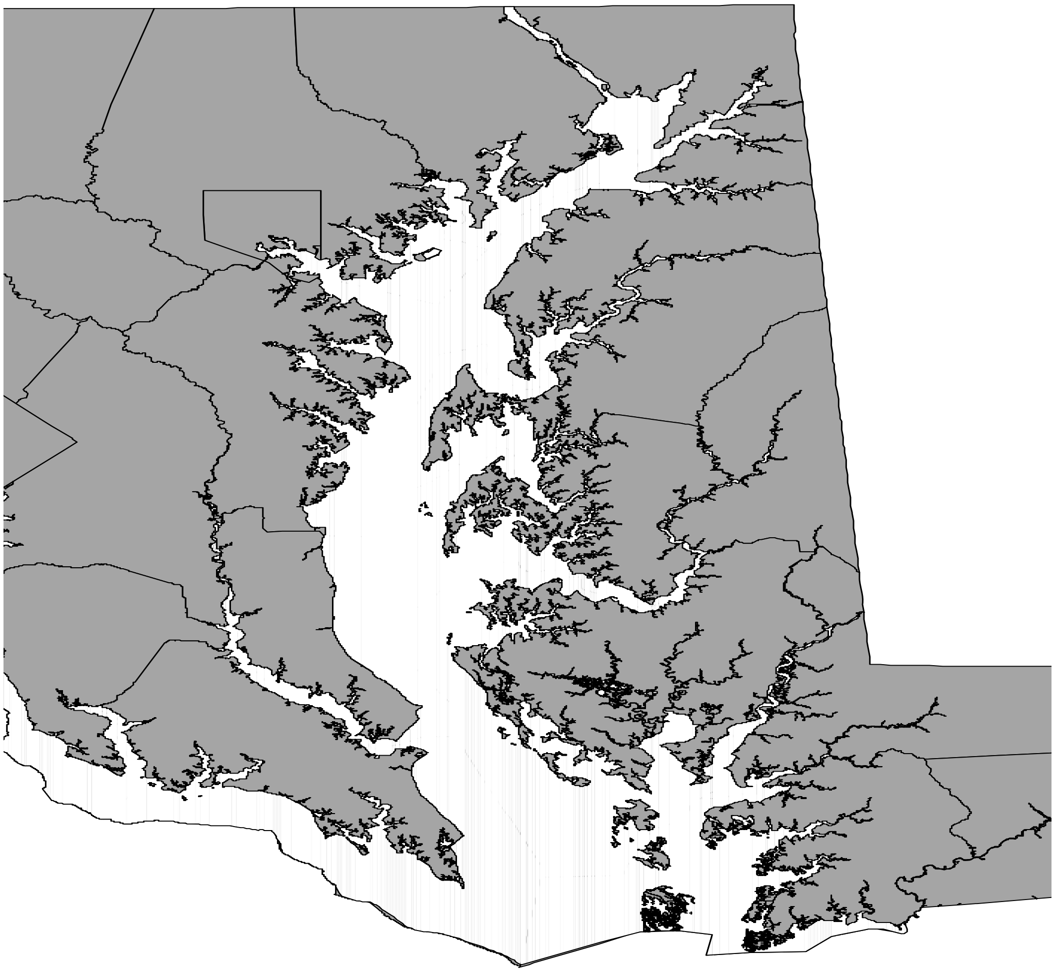

Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-7
20010 - 2011

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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

STATE: Maryland

PROJECT NO.: F-61-R-7

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PROJECT TITLE: Chesapeake Bay Finfish Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2010 through October 31, 2011

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 recruitment, relative abundance, age and size structure, 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.

White perch stocks from the upper Chesapeake Bay and Choptank River were each assessed with a Catch Survey Analysis (CSA) based on a fishery independent trawl survey in the upper Bay (2000 -- 2011) and a fishery independent fyke net survey in the Choptank River (1989 -- 2011). Lower Chesapeake Bay populations were assessed by inspecting catch per unit effort (CPUE) trends of fishery dependent gears (drift gill net, fyke net, and pound net) and trends in young-of-year production (fishery independent seine survey; 1962 – 2011). Another fishery independent data source, a drift gill net survey designed to document striped bass spawning stock abundance, was probably not indicative of white perch abundance.

White perch population abundance in the upper Chesapeake Bay decreased from 11.2

million fish in 2000 to 5.9 million fish in 2007 before rebounding to a time series high of 13.8 million fish in 2010. Post-recruit abundance (white perch > 202 mm TL) also declined from 9 million fish in 2000 to 2.8 million fish in 2005, but increased to a time series high in 2011 of 9.1 million fish. Fishing mortality was below proposed F_{target} for all years.

The Choptank River CSA model indicated expanding population abundance. Total abundance increased form 1.4 million fish in 1989 to 7.4 million white perch in 2010. Post-recruit abundance varied early in the time series with a time series low of 0.79 million white perch in 1994. Since 1998, post-recruit population abundance grew steadily to 5.5 million fish in 2011. Instantaneous fishing mortality was relatively high during 1992 – 1999, averaging F = 0.64 with a high F = 1.05 in 1997. Increased pre-recruit abundance and decreasing F after 1999 allow for the population growth indicated by the CSA.

The lower Bay white perch assessment was qualitative in nature. Fishery dependent indices of relative abundance were not identical, but they did provide a general indication of stock trends. All three fishery dependent indices showed a generally increasing trend up to 2002 or 2004, followed by a decline. The decline persisted until around 2007 with the indices showing either a flat or increasing population through 2010. The population bottom in 2007 and possible recovery through 2010 is almost identical to the upper Bay CSA results. The recent history of the CPUE indices suggest that white perch are not overfished because the indices have been above average in at least 50% - 90% of the last 10 year period, depending on the fishery dependent gear type. A fishery independent young-of-year survey in the lower Chesapeake Bay indicated several strong year-classes, recently, and that recent production more resembled the time period of the 1960’s rather than the poor production of the 1970’s and early 1980’s.

Although populations of American shad in Maryland continue to be impacted by predation, bycatch and turbine mortality, American shad indices of abundance and the percent of repeat spawners are increasing in the Susquehanna and the Potomac Rivers. Both the Petersen estimate and the surplus production model exhibited an increasing trend in American shad abundance in the Susquehanna River since 1986. No significant trends in CPUE are observed for American shad in the Nanticoke River. Juvenile American shad indices have improved in the Potomac River and baywide, but generally remain low.

Hickory shad age structure remains consistent, with a wide range of ages and a high percentage of older fish. In 2011, an unusually large number of hickory shad were passed at the East Fish Lift (Conowingo Dam), and CPAH in Deer Creek was the second highest in the 13 year time series.

In general, juvenile alewife indices decreased and juvenile blueback indices increased in 2011 in Maryland waters. Adult river herring indices of abundance remain low, as did commercial landings of river herring in Maryland. Due to Amendment 2 to the ASMFC FMP for American shad and river herring, it is no longer legal to harvest river herring within the jurisdiction of Maryland. The new 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 fell steadily from 475,348 fish in 2000 to 493 fish in 2006, and have remained very low (2,833 fish in 2010). Maryland's commercial weakfish harvest declined to 2,148 pounds in 2010, and was the lowest catch on record. The 2011 mean length for weakfish from the onboard pound net survey was 236mm TL, the lowest of the time series. 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 form 1993-2010.

Summer flounder mean length from the pound net survey was 359 mm TL in 2011, the third highest mean value the 19 year survey. Relative stock densities in the 2011 onboard pound net survey indicated a slight decrease in the stock and memorable categories with a corresponding increase in the quality category compared to 2010. Charter boat CPUE has declined from 1993 - 2003, but have been relatively stable for the past seven years. The NMFS 2008 coast wide stock assessment concluded that summer flounder stocks were not overfished, and overfishing was not occurring.

Mean length of bluefish from the pound net survey in 2011 was 245 mm TL, below the time series mean. Length distribution and RSD analysis indicated a continued dominance of smaller bluefish in 2011. Recreational and commercial bluefish harvest declined in 2010, and both remained below the long term mean. The 2010 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 2011 was 281 mm TL; this was the third lowest value of the 19 year time series. For Atlantic croaker from the onboard pound net survey $RSD_{memorable}$ and RSD_{trophy} fish declined in 2010 while the $RSD_{quality}$ and $RSD_{perferred}$ category increased. Maryland Atlantic croaker total commercial harvest increased in slightly 2010 to 490,067 pounds; while the 2010 recreational harvest estimated of 813,373 fish decreased compared to 2009. In contrast, the 2010 charter boat geometric catch per angler was the highest of the 18 year time series.

Spot length frequency distribution in 2010 was similar to that of 2011, but the mean length decrease to below the time series average. Juvenile indexes have been lower in recent years, spiked to the time series high in 2010, but fell to the second lowest value in 2011. Commercial harvests increased sharply in 2009 and remained high in 2010, while the recreational estimate dropped well bellow the time series mean. The charter boat geometric mean catch per angler also decreased in 2010, to the second lowest value of the 18 year time series.

Resident / premigratory striped bass sampled in the Chesapeake Bay during the summer – fall 2010 pound net and hook and line commercial fisheries ranged from 1 to 14 years of age. Three year old (2007 year-class), four year old (2006 year-class), five year old (2005 year-class) and six year old (2004 year-class) striped bass dominated samples taken from pound nets, comprising 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 six year old individuals from the 2004, 2005, and 2006 year-classes.

The 2009-2010 commercial striped bass drift gill net fishery harvest was comprised primarily of fish 4, 5 and 6 years old from the 2005, 2006 and 2007 year-classes. Striped bass from the 2006 year-class (five year old fish) composed 35% of the total drift gill net harvest. The 2007 and 2005 (ages 4 and 6) cohorts accounted for 45% of the total harvest while age groups 8 to 13 year-old fish contributed 6% to the total. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 4 to 12 (1999 – 2007 year-classes).

The spring, 2011 spawning stock survey indicated that there were 17 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 16 years old. Male striped bass ranged in age from 2 to 16 years old, with age 8 fish (2003 year-class) being the most abundant component of the male striped bass spawning stock. The majority of females were ages 8 to 13, with equal numbers of females collected at ages 8 (2003 year-class), 10 (2001 year-class), and 13 (1998 year-class). In 2011, age 8 and older females comprised 70% of the female spawning stock.

The 2011 striped bass juvenile index, the annual measure of striped bass spawning success in Chesapeake Bay, was 34.6. This is significantly higher than the long-term average of 11.9 and the fourth highest measured in survey's 58 year history. A total of 4,565 juvenile striped bass were collected at permanent stations in 2011. 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 spring flow rates and water temperature. The strong 2011 year-class shows that the spawning stock is capable of producing a large year-class when conditions are favorable. During the 2011 survey, biologists identified and counted more than 59,000 fish of 47 different species. The survey also documented an increase in the abundance of juvenile blueback herring and near-record white perch reproduction. 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 2011 trophy season, biologists intercepted 362 fishing trips, interviewed 824 anglers, and examined 234 striped bass. The average total length of striped bass sampled was 890 mm total length (mm TL) (35.0 inches), which was significantly smaller than that observed from 2008-2010, but was similar to 2002-2005. The average weight was 7.3 kg (16.1 lbs). Most fish sampled from the trophy fishery were between six and sixteen years old. The 2003 year-class (age 8) and 2001 year-class (age 10) were the most frequently observed cohorts, each constituting 29% of the sampled harvest. Average catch rate based on angler interviews was 0.3 fish per hour.

Maryland Department of Natural Resources biologists continued to tag and release striped bass in 2011 in support of the US FWS coordinated interstate, coastal population study for growth and mortality. A total of 1,447 striped bass were tagged and released with USFWS internal anchor tags. Of this sample, 1,339 were tagged in the Chesapeake Bay during the spring spawning stock assessment survey. A total of 108 striped bass were tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise.

APPROVAL

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The Maryland Department of Natural Resources (MD DNR) would like to thank the Maryland Watermen's Association commercial captains and their crews who allowed us to sample their commercial 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 Michael Cannan and Robert Boarman.

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SURVEY TITLE: CHESAPEAKE BAY FINFISH/HABITAT INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 1
JOB NO. 1

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

METHODS

I. Field Operations

Upper Chesapeake Bay Winter Trawl

The upper Chesapeake Bay winter bottom trawl survey is designed to collect fishery-independent data for the assessment of population trends of white perch, yellow perch, channel catfish, and white catfish. For 2011, 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 2010 through February 2011.

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.

Choptank River Fishery Independent Sampling

In 2011, 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 21 February through 6 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 17 February 2011 in Gunpowder River and 19 February 2011 in and around Back River and Middle River (Figures 3,4). All yellow perch were measured and sexed (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River Fishery Dependent Sampling

From 2 March 2011 to 29 April 2011, resident species were sampled from fyke nets and pound nets set by commercial fishermen on the Nanticoke River. This segment of the survey was completed in coordination with Project 2, Job 1 of this grant. Nets were set from Barren Creek (35.7 rkm) downstream to Monday's Gut (30.4 rkm; Figure 5). 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 6-8
Yellow perch	Tables 11-14 and Figures 9-12
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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 2010 – February 2011. Different symbols indicate each of 6 different sampling rounds.

Figure 2. Choptank River fyke net locations, 2011. Circles indicate sites.

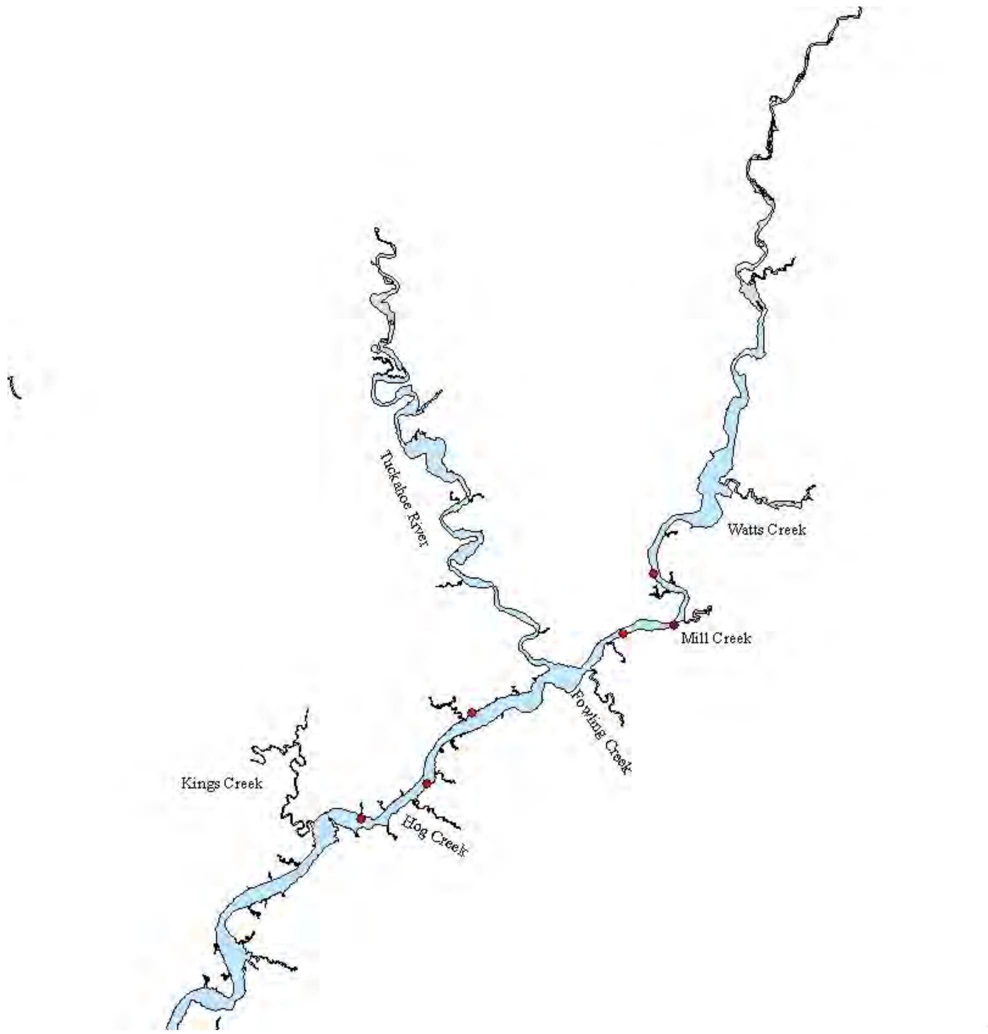


Figure 3. Commercial yellow perch fyke net sites sampled during 2011 in Gunpowder River. Circles indicate sites.

Figure 4. Commercial yellow perch fyke net sites sample during 2011 in Middle and Back rivers. Circles indicate sites.

Figure 5. Commercial fyke net and pound net sites sample during 2011 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

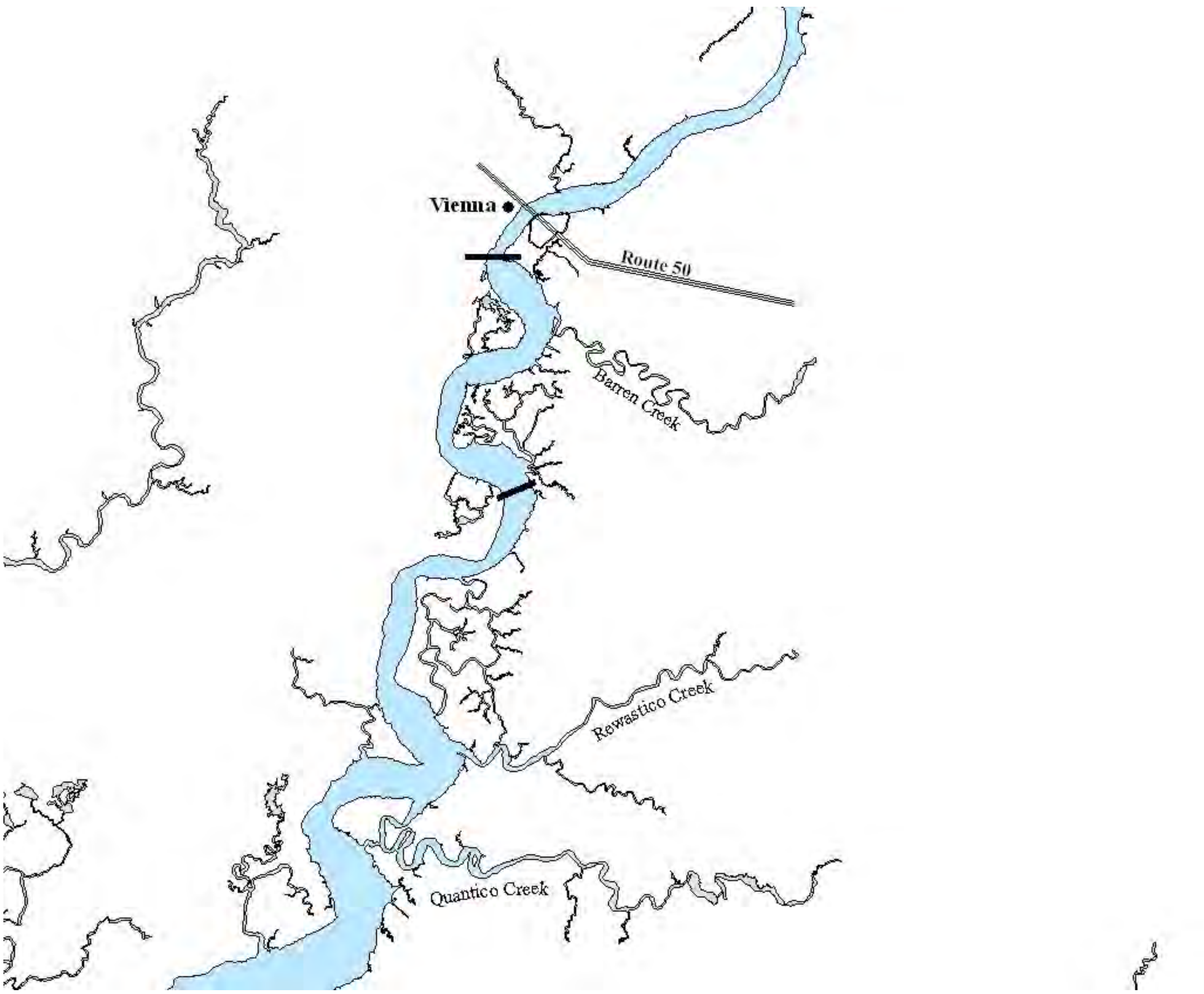


Table 1. White perch catch-at-age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2011.

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

Table 2. White perch catch-at-age matrix from Choptank River fyke net survey, 2000 – 2011.

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

Table 3. White perch catch-at-age matrix from Nanticoke River fyke and pound net survey, 2000 – 2011. 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

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2011.

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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2011.

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

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2011.

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

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2011. 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

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2011. 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

Figure 6. White perch length-frequency from 2011 upper Chesapeake Bay winter trawl survey.

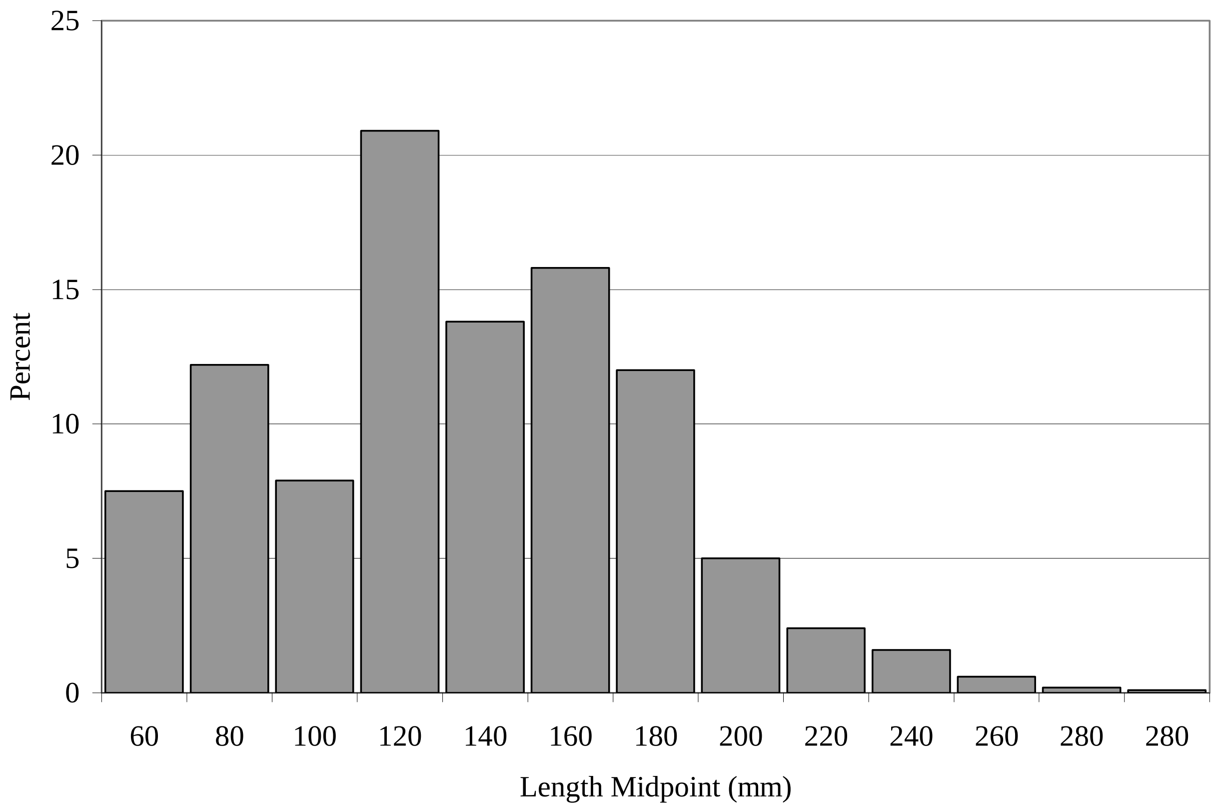


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2011. Minimum length cut-offs in parentheses.

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

Figure 7. White perch length-frequency from 2011 Choptank River fyke net survey.

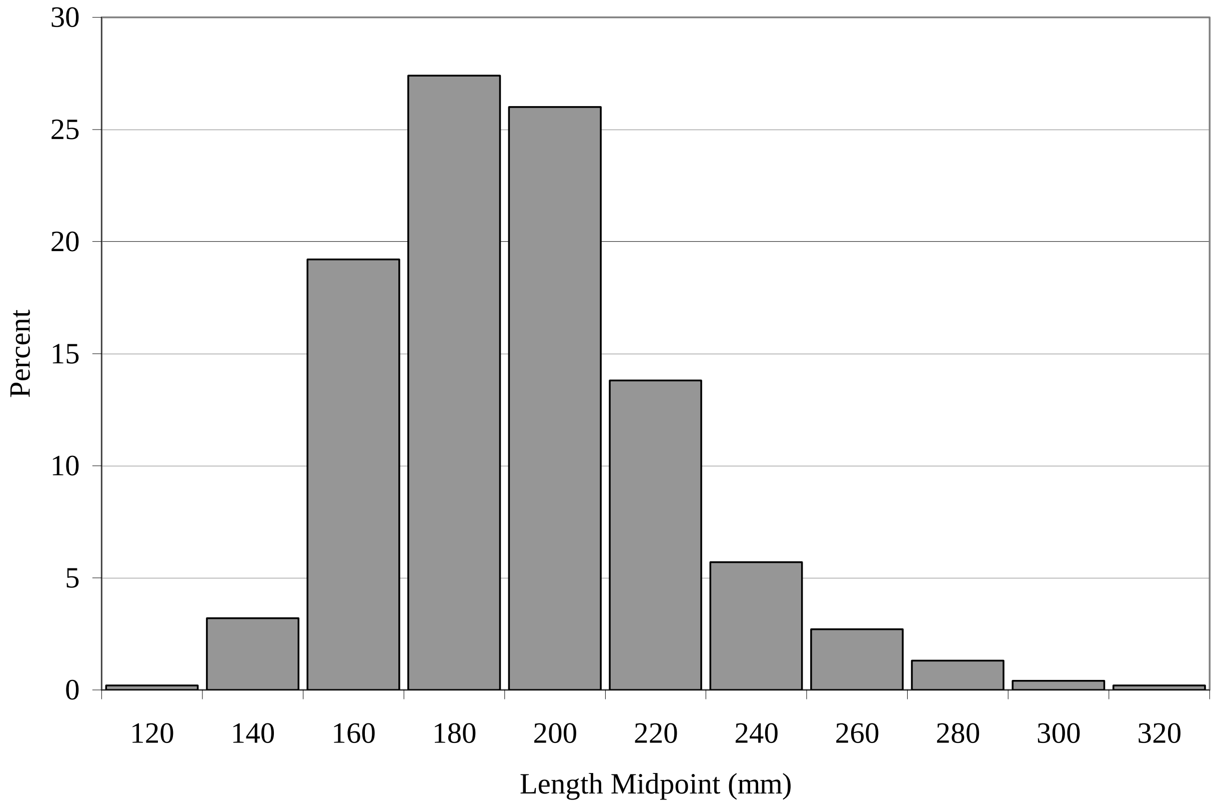


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2011. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

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

Figure 8. White perch length-frequency from 2011 Nanticoke River fyke and pound net survey.

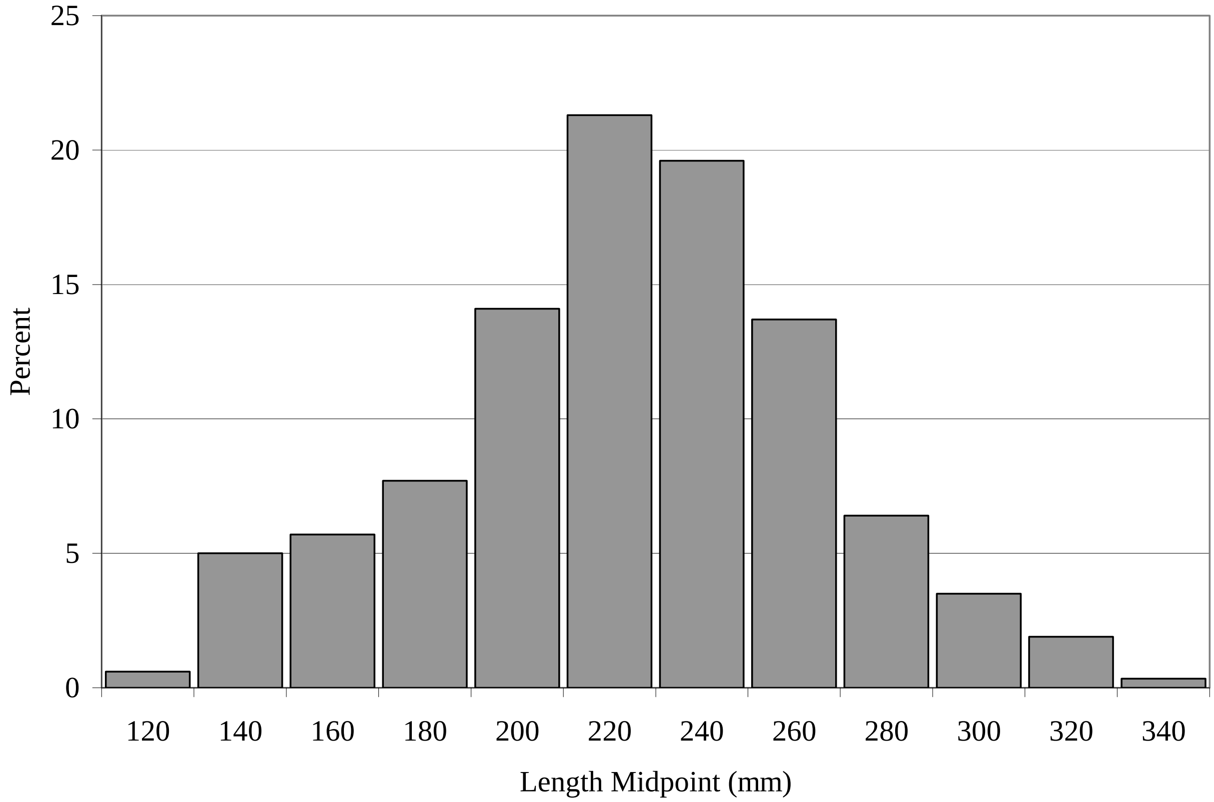


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2011. Minimum length cut-offs in parentheses.

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

Figure 9. Yellow perch length-frequency from the 2011 upper Chesapeake Bay winter trawl survey.

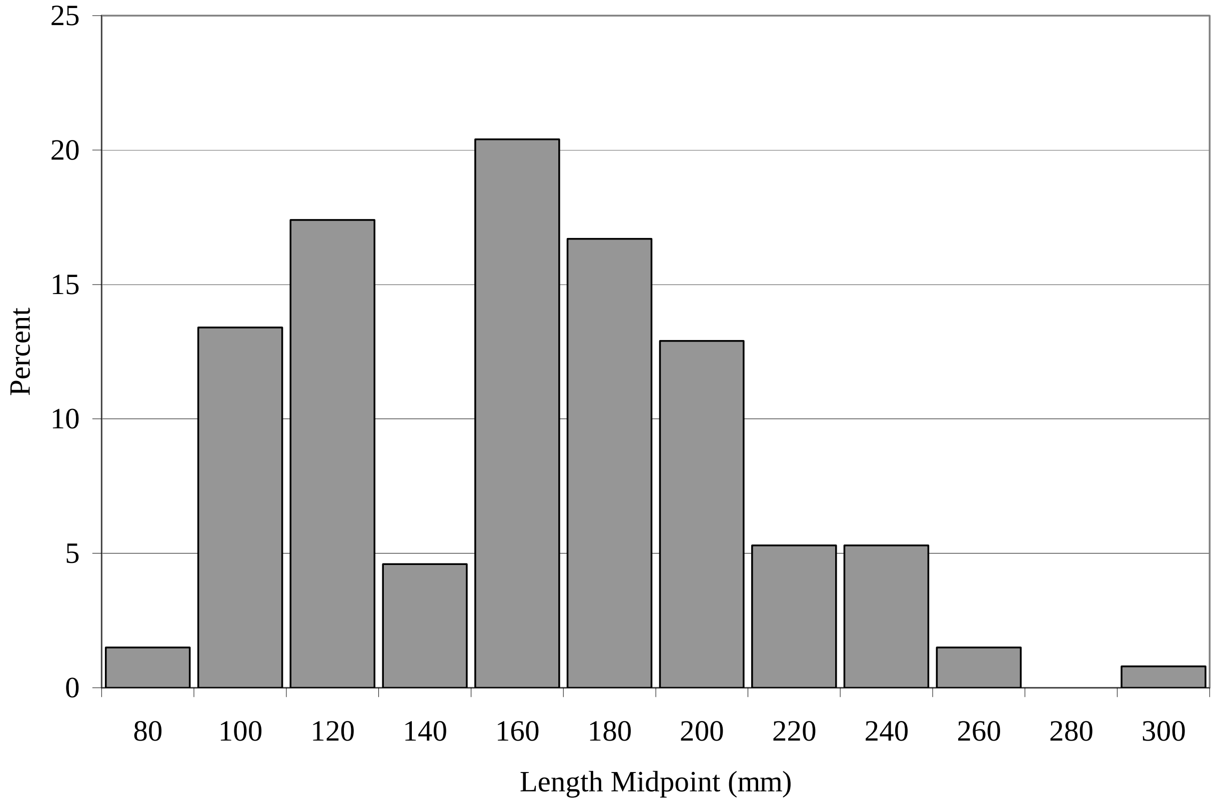


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2011. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length-frequency from the 2011 Choptank River fyke net survey.

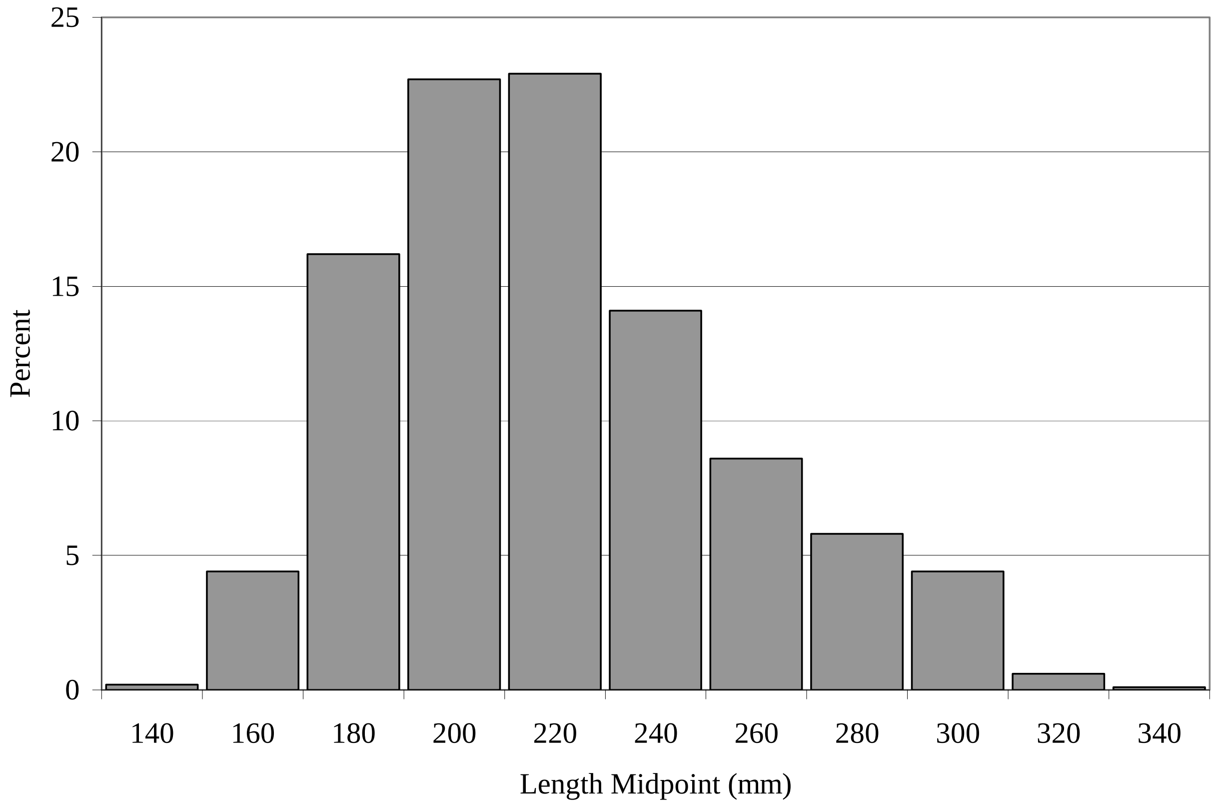


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2011. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length frequency from the 2011 upper Chesapeake commercial fyke net survey.

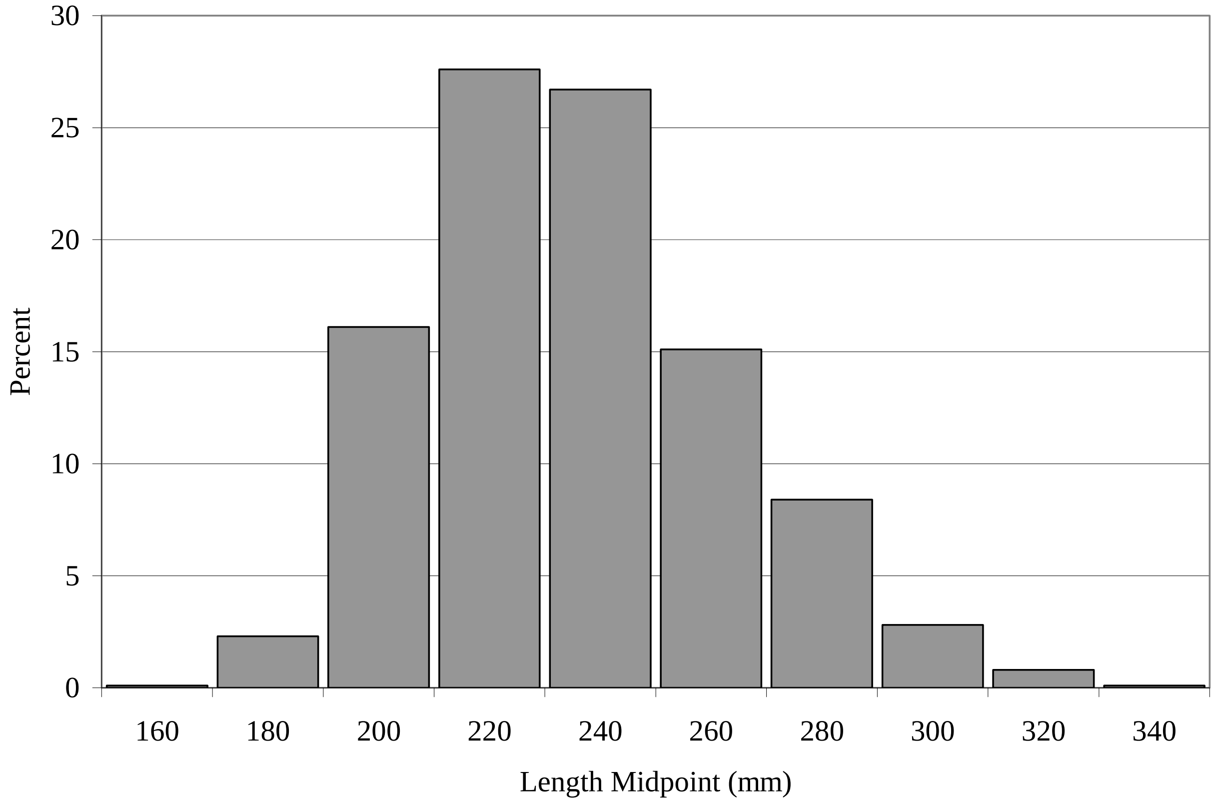


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2011. Minimum length cut-offs in parentheses; 2007-- 2009 includes Marshyhope River data.

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

Figure 12. Yellow perch length frequency from the 2011 Nanticoke River survey fyke and pound net survey.

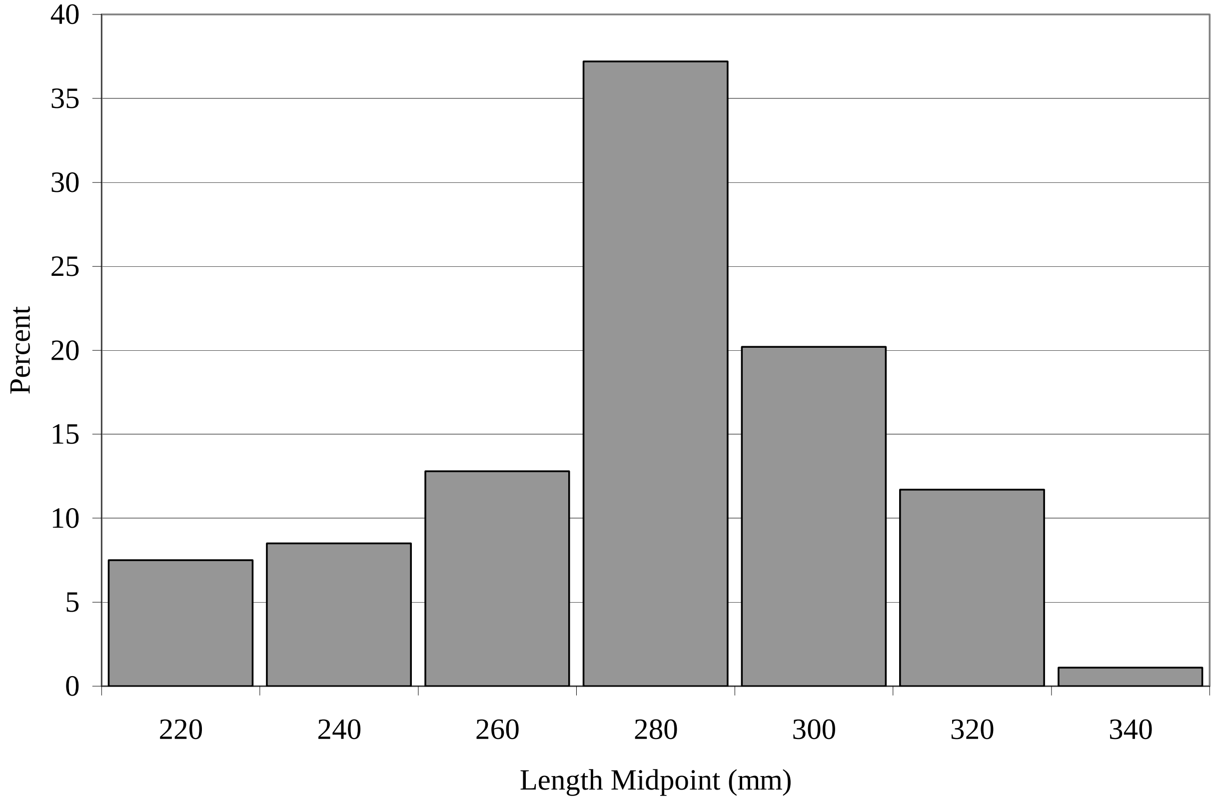


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2011. Minimum length cut-offs in parentheses.

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

Figure 13. Length frequency of channel catfish from the 2011 upper Chesapeake Bay winter trawl survey.

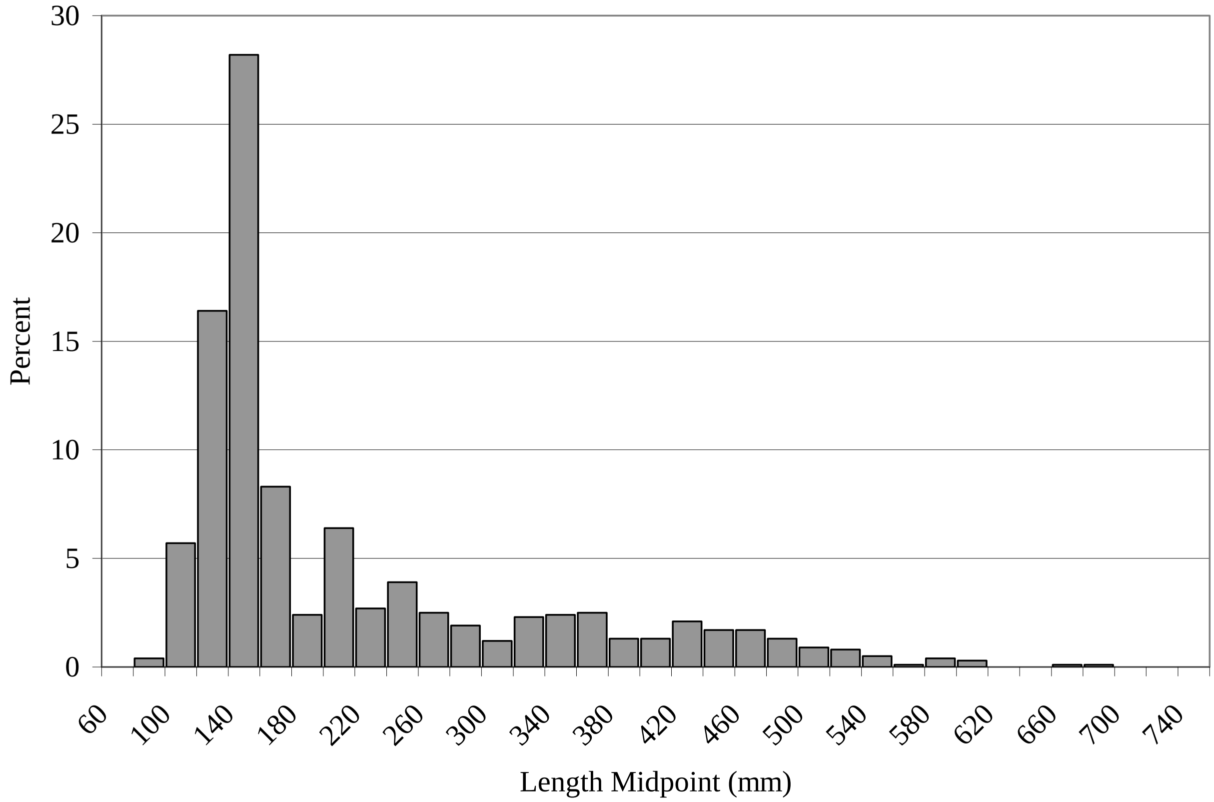


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2011. Minimum length cut-offs in parentheses.

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

Figure 14. Channel catfish length frequency from the 2011 Choptank River fyke net survey.

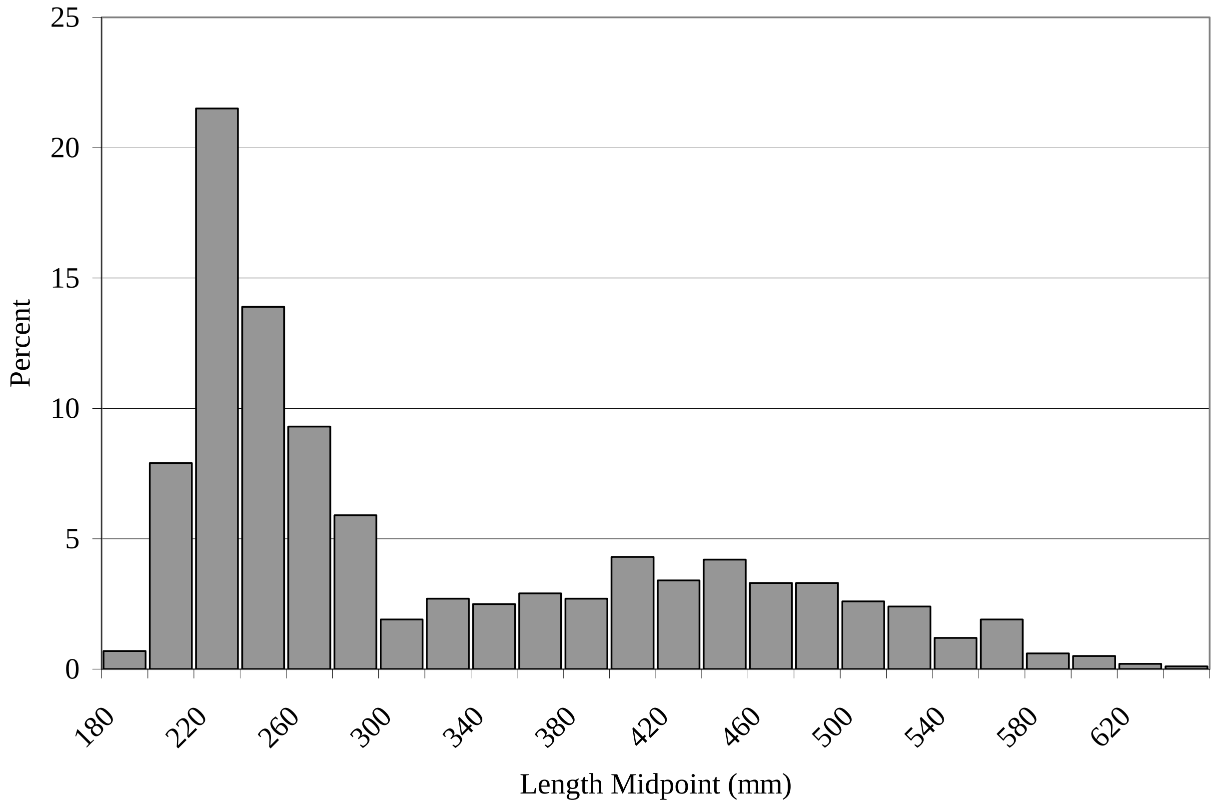


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2011. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 15. Channel catfish length frequency from the 2011 Nanticoke River fyke and pound net survey.

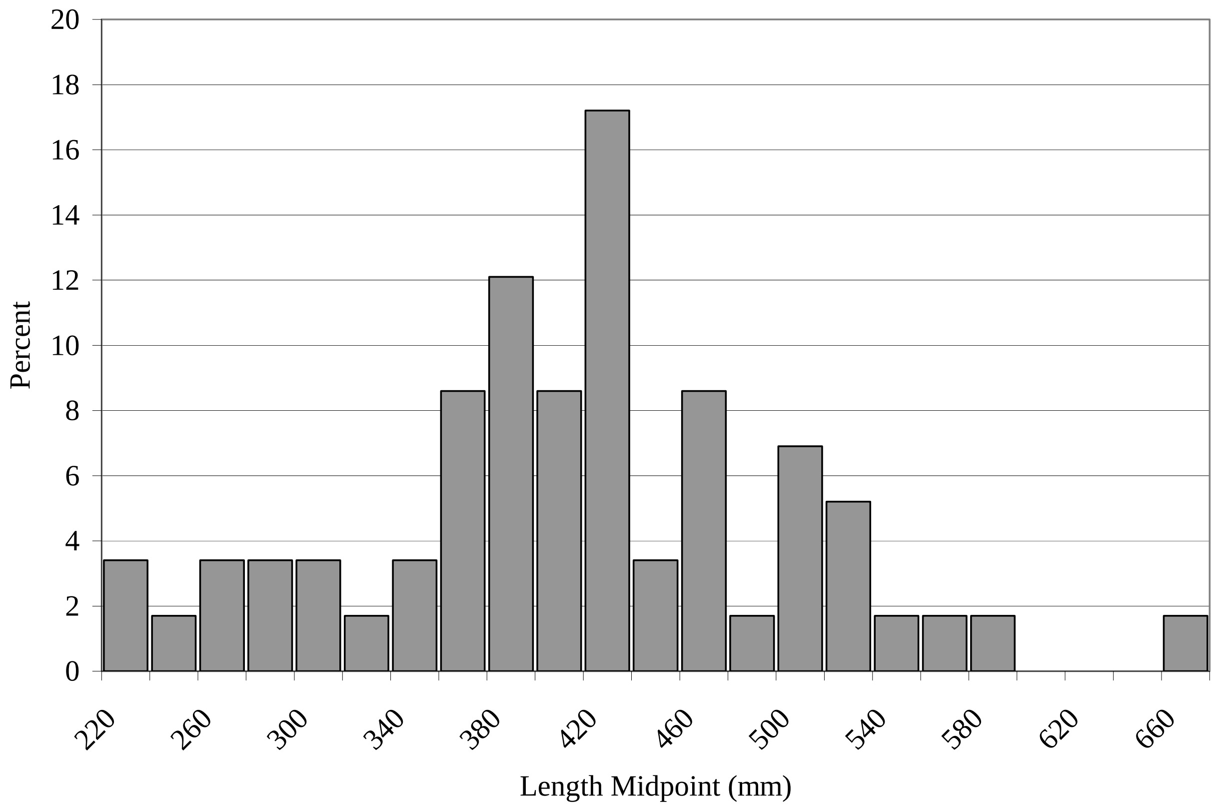


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2011. Minimum length cut-offs in parentheses.

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

Figure 16. White catfish length frequency from the 2011 upper Chesapeake Bay winter trawl survey.

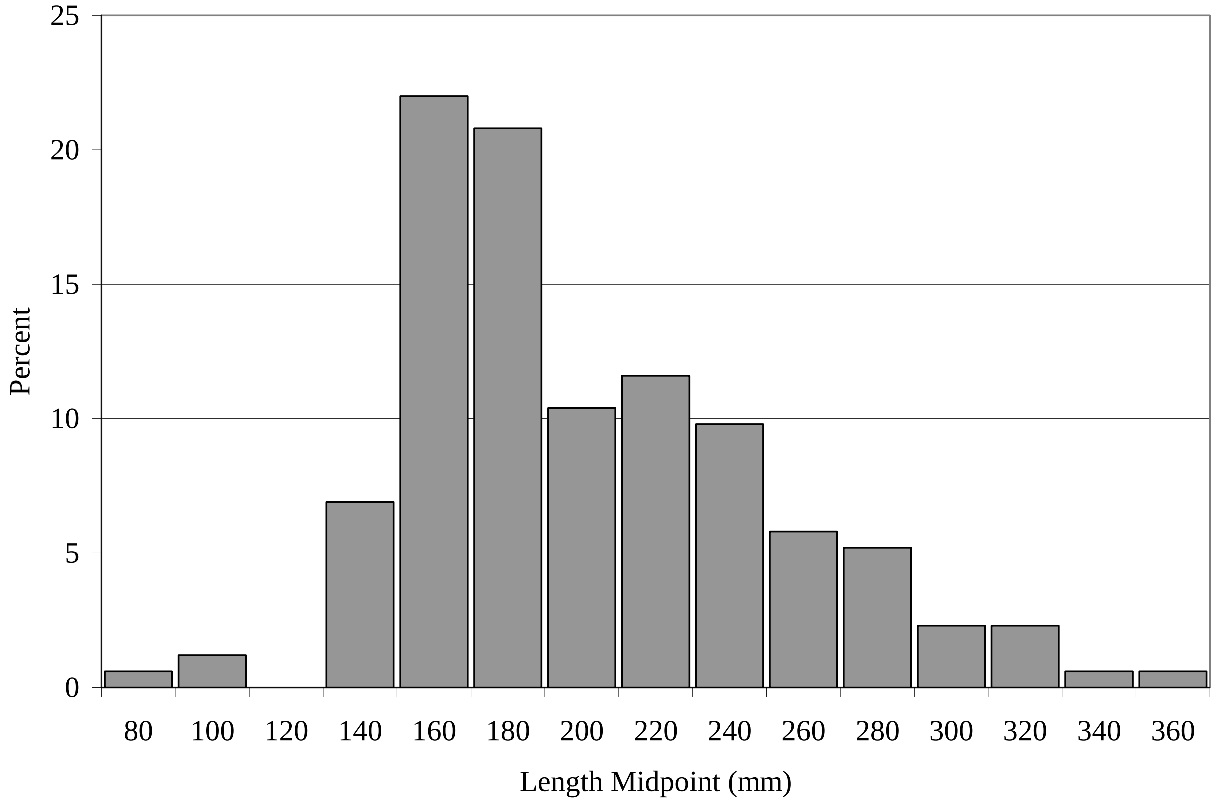


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2011. Minimum length cut-offs in parentheses.

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

Figure 17. White catfish length frequency from the 2011 Choptank River fyke net survey.

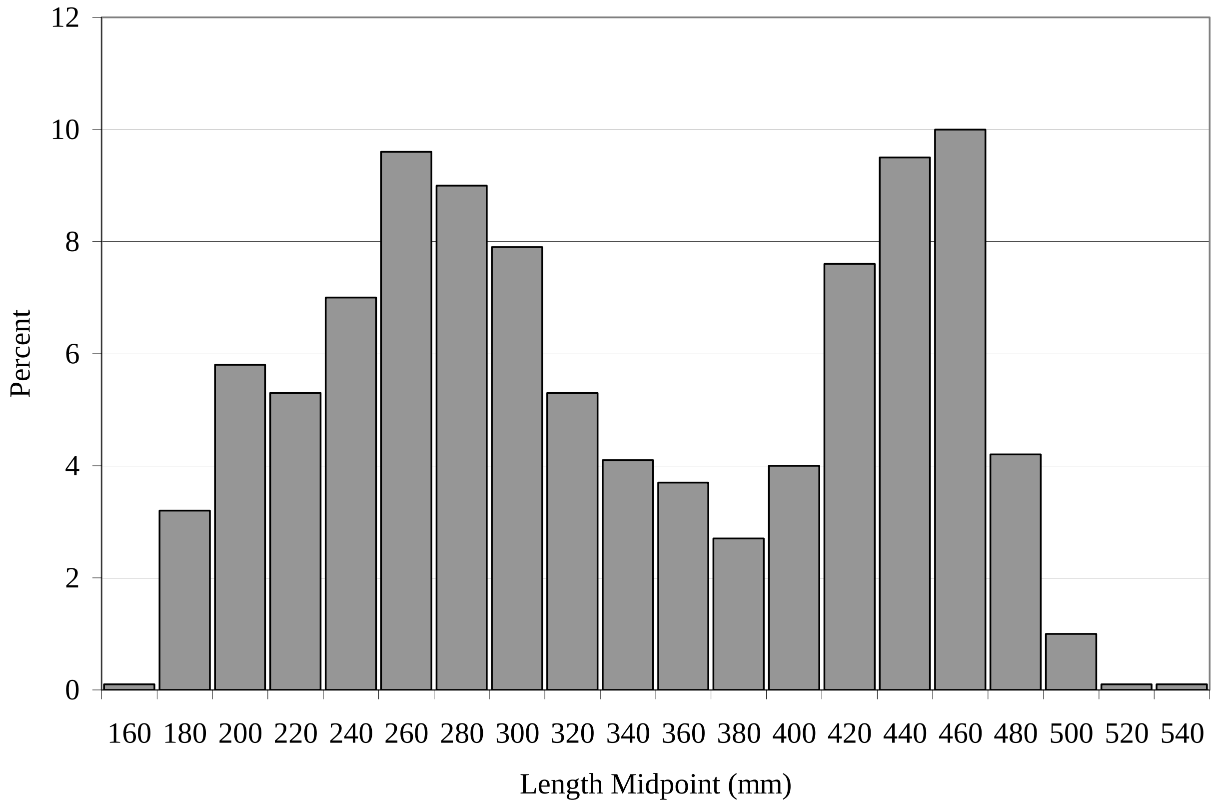


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2011. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2011 Nanticoke River fyke and pound net survey.

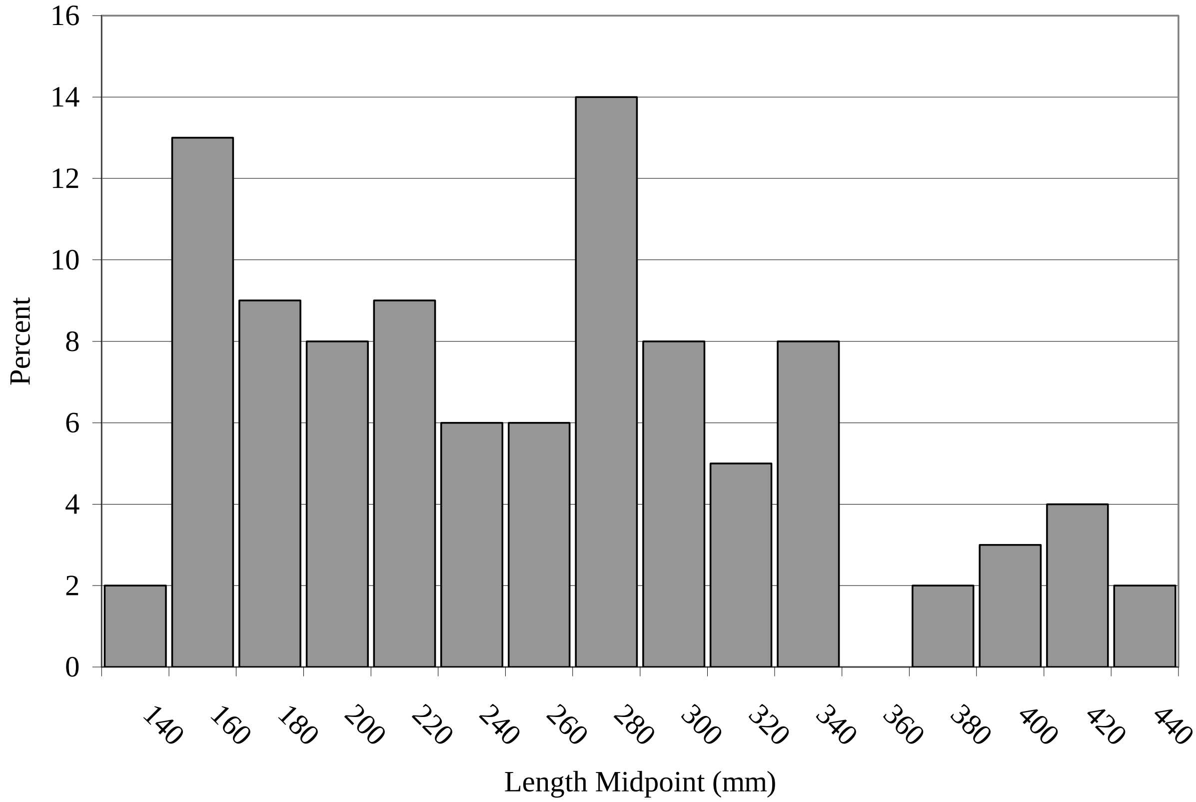


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

Sample Year	Sex	Allometry		von Bertalanffy		
		alpha	beta	L-inf	K	t_0
2000	F	2.1×10^{-5}	2.95	267	0.39	0.92
	M	2.2×10^{-5}	2.92	236	0.4	0.79
	Combined	1.3×10^{-5}	3.04	271	0.33	0.71
2001	F	7.7×10^{-6}	3.14	252	0.51	-1.40
	M	2.1×10^{-4}	2.53	251	0.5	0.56
	Combined	7.0×10^{-6}	3.16	252	0.49	-1.56
2002	F	NSF			NSF	
	M	5.0×10^{-6}	3.2	224	0.34	-1.71
	Combined	NSF		298	0.12	-5.11
2003	F			286	0.37	0.54
	M	NA		247	0.34	-0.42
	Combined			277	0.32	-0.06

Table 21. Cont'd.

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	
2000 – 2011	F	4.1×10^{-6}	3.25	306	0.19	-1.56
	M	5.6×10^{-6}	3.18	242	0.26	-1.32
	Combined	3.0×10^{-6}	3.30	292	0.20	-1.39

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

Sample Year	Sex	(allometry)		(von Bertalanffy)		
		alpha	beta	L-inf	K	t_0
2000	F	2.0×10^{-4}	2.56	272	0.50	1.10
	M	1.4×10^{-4}	2.60	288	0.24	-0.60
	Combined	7.7×10^{-5}	2.72	280	0.36	0.51
2001	F			380	0.10	-2.80
	M	NA			NSF	
	Combined				NSF	
2002	F	1.3×10^{-6}	3.48	328	0.17	-2.50
	M	1.9×10^{-6}	3.40	286	0.22	-1.40
	Combined	1.1×10^{-6}	3.50	327	0.17	-2.20
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

Table 22. Cont'd.

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
2000 – 2011	F	5.9×10^{-6}	3.19	269	0.24	-1.03
	M	2.2×10^{-5}	2.94	298	0.2	-0.91
	Combined	4.8×10^{-6}	3.22	306	0.23	-0.68

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
2000	F	NA		277	0.53	-0.2
	M	NA		268	0.26	-1.6
	Combined	NA		264	0.42	-0.9
2001	F	NA		329	0.32	-0.5
	M	NA		308	0.18	-2.2
	Combined	NA		278	0.4	-0.5
2002	F	NA		336	0.23	-2.2
	M	NA		270	0.3	-1.6
	Combined	NA		264	0.5	-0.8
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

Table 23. Cont'd.

2007	F	$2.3\ X\ 10^{-5}$	2.88	308	0.52	0.19
	M	$1.3\ X10^{-5}$	2.97	279	0.29	-1.40
	Combined	$1.1\ X\ 10^{-5}$	3.02	277	0.54	-0.01
2008	F	$5.8\ X\ 10^{-6}$	3.12	322	0.43	-0.12
	M	$1.1\ X\ 10^{-5}$	3.00	253	0.26	-2.82
	Combined	$8.1\ X\ 10^{-6}$	3.06	289	0.40	-0.59
2009	F	$8.7\ X\ 10^{-6}$	3.06	315	0.40	-0.63
	M	$2.8\ X\ 10^{-6}$	3.26	288	0.35	-0.24
	Combined	$4.4\ X\ 10^{-6}$	2.18	308	0.29	-1.71
2010	F	$1.3\ X\ 10^{-5}$	2.97		NSF	
	M	$4.7\ X\ 10^{-6}$	3.16		NSF	
	Combined	$9.9\ X\ 10^{-6}$	3.02		NSF	
2011	F	$1.2\ X\ 10^{-6}$	3.02		NSF	
	M	$4.7\ X\ 10^{-6}$	3.17		NSF	
	Combined	$3.2\ X\ 10^{-6}$	3.25		NSF	
2000 – 2011	F	$6.7\ X\ 10^{-6}$	3.10	306	0.34	-0.94
	M	$3.0\ X\ 10^{-6}$	3.25	292	0.17	-3.04
	Combined	$3.8\ X\ 10^{-6}$	3.21	263	0.41	-0.98

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
1998	F	NSF	301	0.32	-1.9	
	M	$6.7\ X\ 10^{-6}$	3.11	275	0.33	-2.0
	Combined	$5.9\ X\ 10^{-7}$	3.57	286	0.38	-1.7
1999	F	$4.1\ X\ 10^{-6}$	2.8	272	0.45	-0.9
	M	$8.83\ X\ 10^{-6}$	3.06	226	1.47	1.17
	Combined	$2.1X\ 10^{-5}$	2.92	252	1.07	0.99
2000	F	NSF	272	0.62	0.62	
	M	$8.39\ X\ 10^{-7}$	3.48	246	0.39	-1.9
	Combined	NSF	254	0.82	0.86	
2001	F	NSF	283	0.27	-2.7	
	M	$9.37\ X\ 10^{-7}$	3.45	230	0.5	-1
	Combined	NSF	240	1.14	0.85	

Table 24 Cont'd.

2002	F	NA		329	0.21	-2.9
	M	NA		249	0.38	-1.1
	Combined	NA		266	0.48	-1.1
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
1998 – 2011	F	4.7×10^{-6}	3.19	305	0.30	-1.28
	M	2.5×10^{-6}	3.28	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
2000	F	NSF	378	0.31	0.1	
	M	4.30×10^{-5}	2.71	373	0.16	-2.3
	Combined	8.53×10^{-7}	3.46	370	0.27	-0.4
2001	F			317	0.43	-0.4
	M	NA	276	0.34	-1.8	
	Combined			290	0.38	-1.8
2002	F	1.22×10^{-6}	3.44	313	0.52	-0.6
	M	1.10×10^{-5}	3.03	278	0.49	-1.0
	Combined	2.69×10^{-7}	3.71	299	0.39	-1.7
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	3.40×10^{-5}	2.84	286	0.68	0.1
	Combined	NSF	342	0.35	-1.1	
2006	F	NA	313	0.73	0.3	
	M			297	0.57	-0.1
	Combined			301	0.78	0.4
2007	F	1.80×10^{-6}	3.38	346	0.35	-0.8
	M	7.37×10^{-6}	3.10		NSF	
	Combined	1.18×10^{-6}	3.45	308	0.42	-0.8
2008	F	3.37×10^{-6}	3.26	325	0.63	0.28
	M	6.79×10^{-6}	3.10	259	0.92	0.45
	Combined	9.96×10^{-7}	3.46	285	0.90	0.55
2009	F	3.0×10^{-5}	2.87	NSF		
	M	7.5×10^{-5}	2.67	292	0.40	-0.01
	Combined	1.1×10^{-5}	3.05	317	0.32	-1.10

Table 25. Cont'd.

2010	F	NSF			NSF	
	M	NSF			NSF	
	Combined	NSF			NSF	
2011	F	5.4×10^{-5}	2.74		NSF	
	M	3.3×10^{-6}	3.23		NSF	
	Combined	1.6×10^{-5}	2.95		NSF	
2000 –2011	F	6.2×10^{-6}	3.15	348	0.29	-1.30
	M	1.4×10^{-5}	2.98	295	0.32	-1.32
	Combined	2.5×10^{-6}	3.30	307	0.39	-0.96

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.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Choptank	0.25	0.46	0.1	0.58	0.58	0.40	MIN	0.35	0.99	0.29
Nanticoke	0.44	0.31	NR	NR	0.22	0.18	0.16	0.12	0.66	NR
Upper Bay trawl	0.51	0.13	NA	0.50	0.12	0.19	0.26	0.54	0.76	0.51

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

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Choptank[1]	0.03	0.05	NR	0.08	MIN	0	NR	0.17	MIN	0.56
Upper Bay fyke[2]	0.89	0.30	0.30	0.31	0.10	0.14	0.02	0.14	0.19	0.24

[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 19. Baywide young-of-year relative abundance index for white perch, 1962 – 2011, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

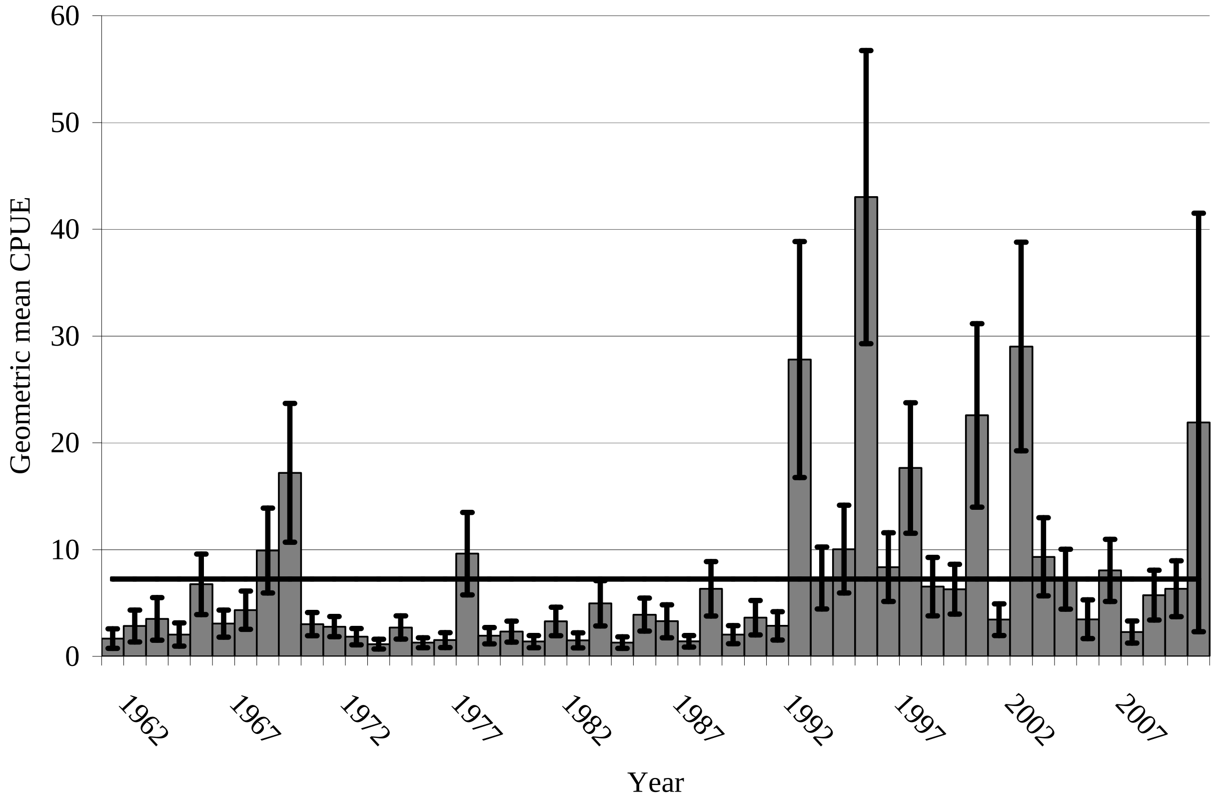


Figure 20. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

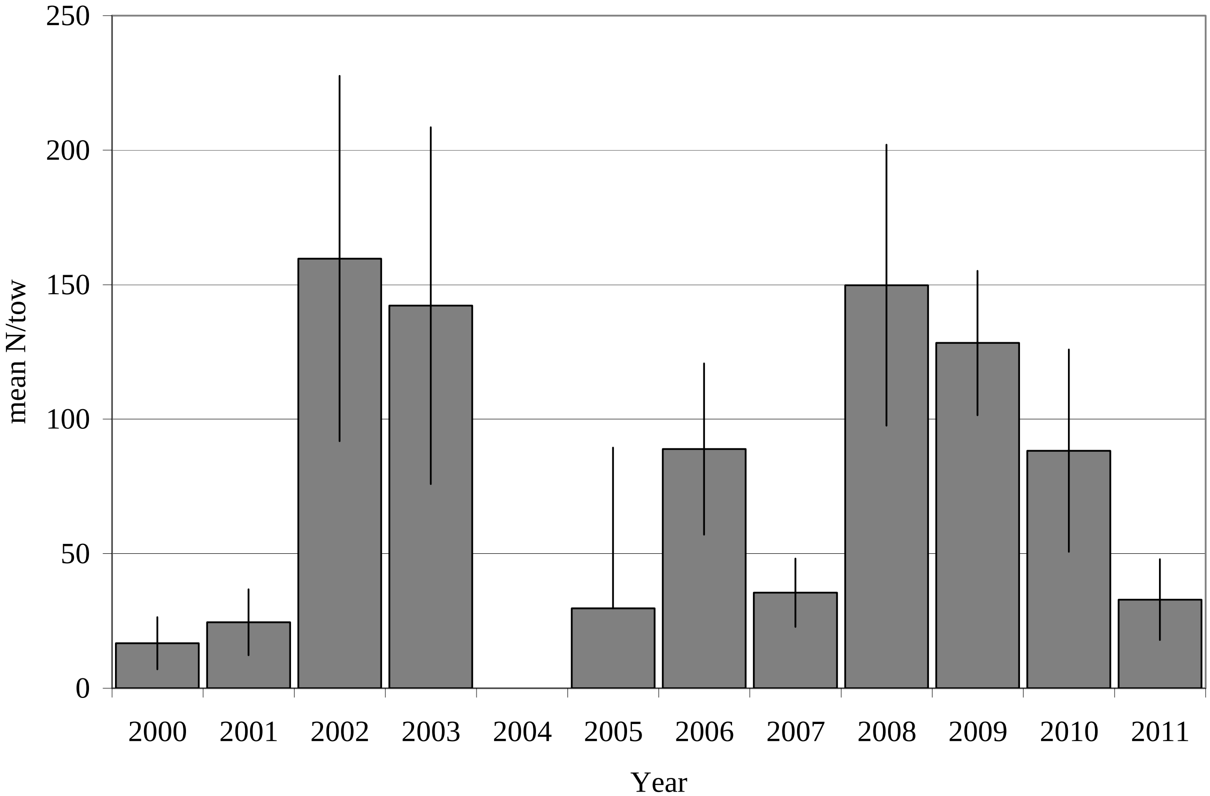


Figure 21. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2011, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

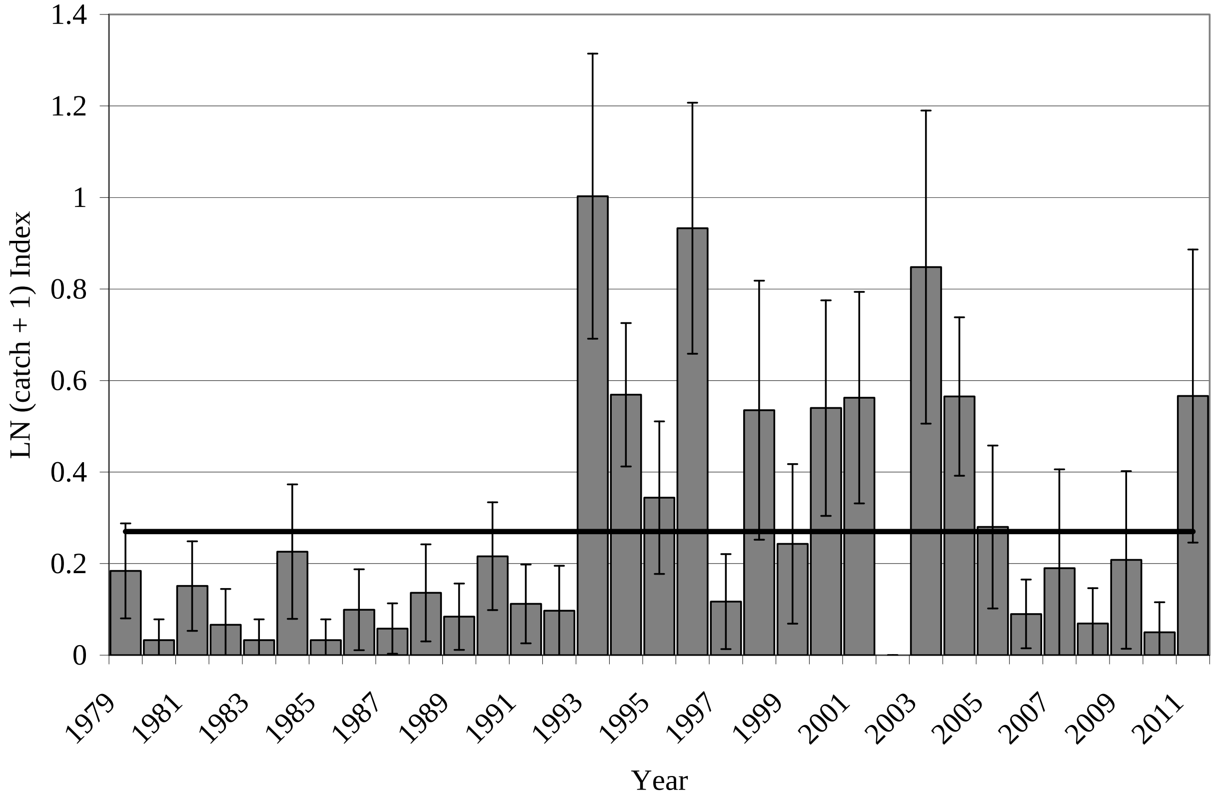


Figure 22. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Horizontal line=time series average. Not sampled in 2004, small sample sizes 2003 and 2005.

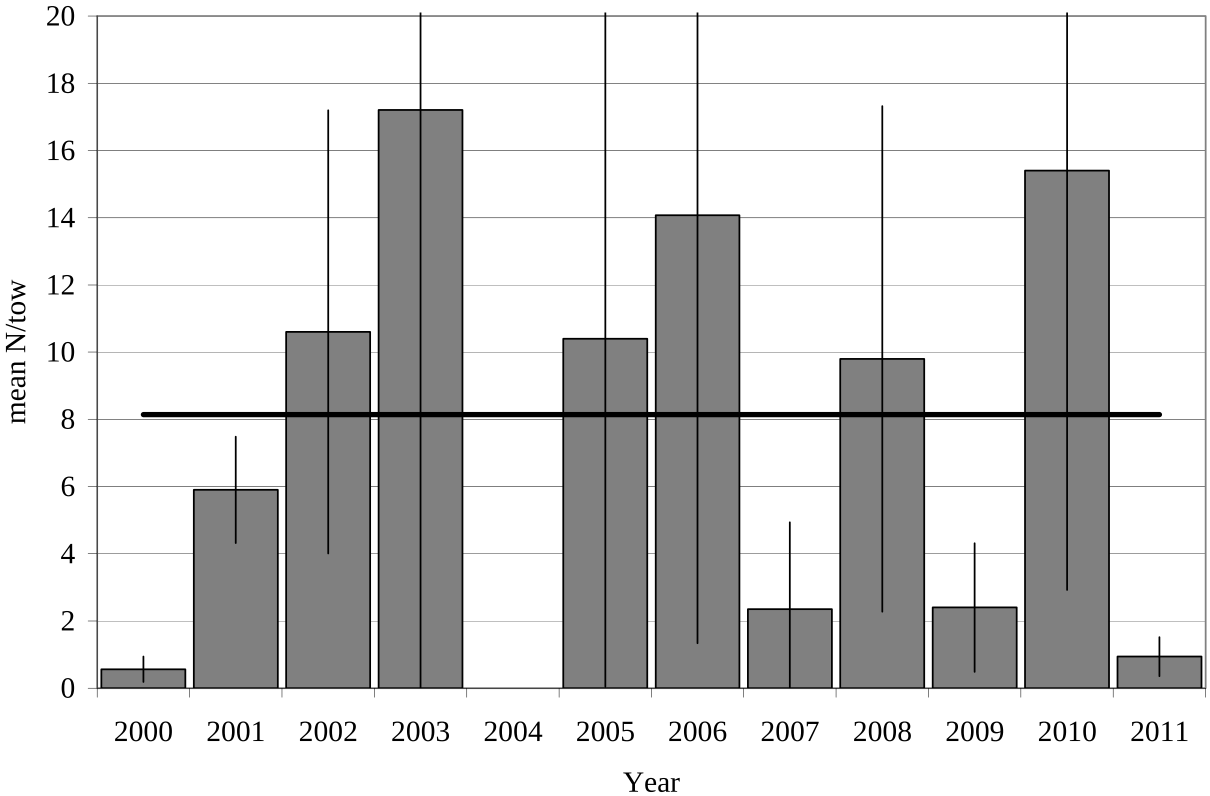


Figure 23. Bay-wide young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average. Error bars = 95% confidence intervals.

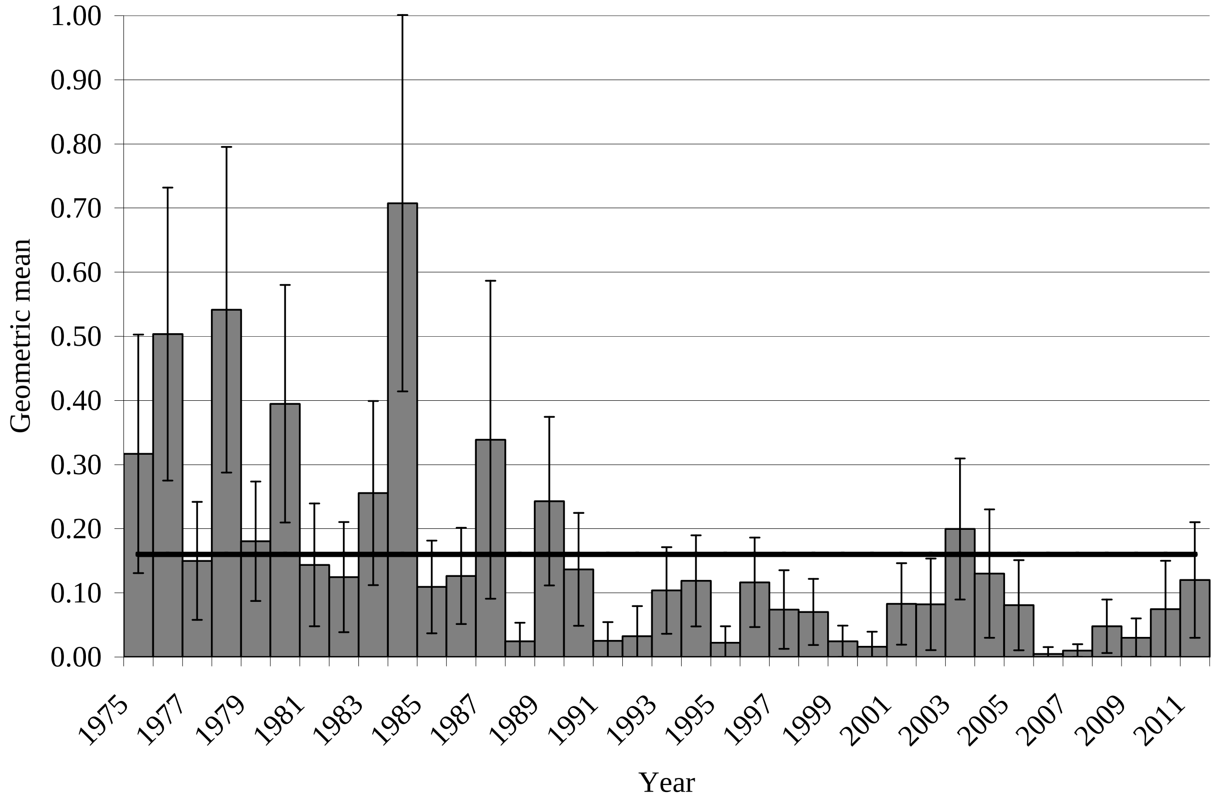


Figure 24. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

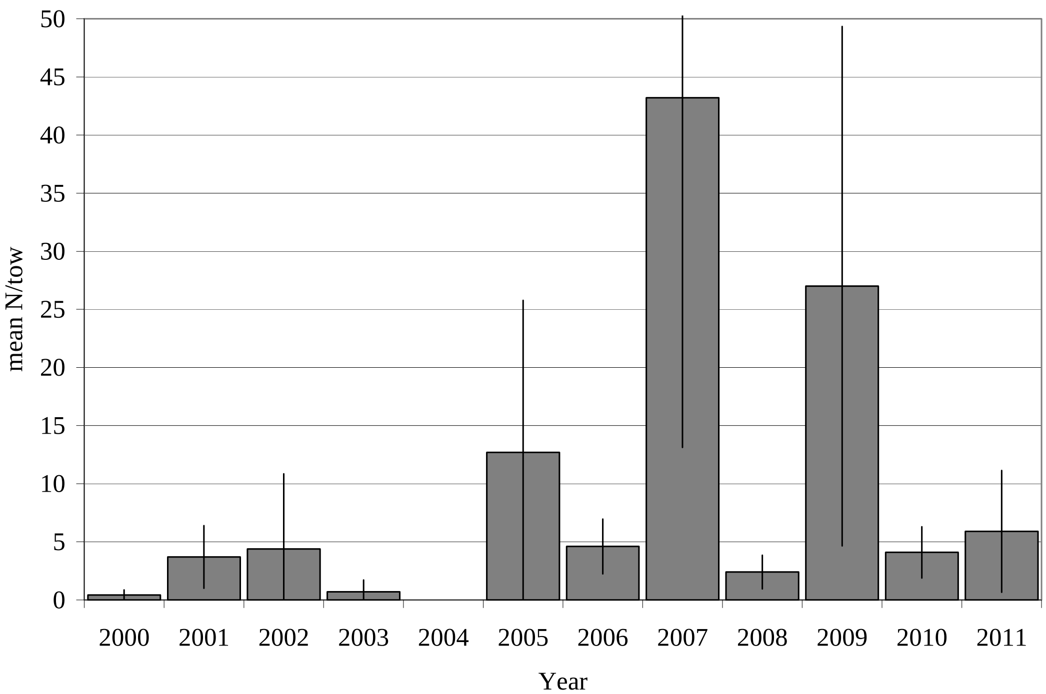


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2011.

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

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2011.

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

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2011.

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

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2011.

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

Figure 25. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2011. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

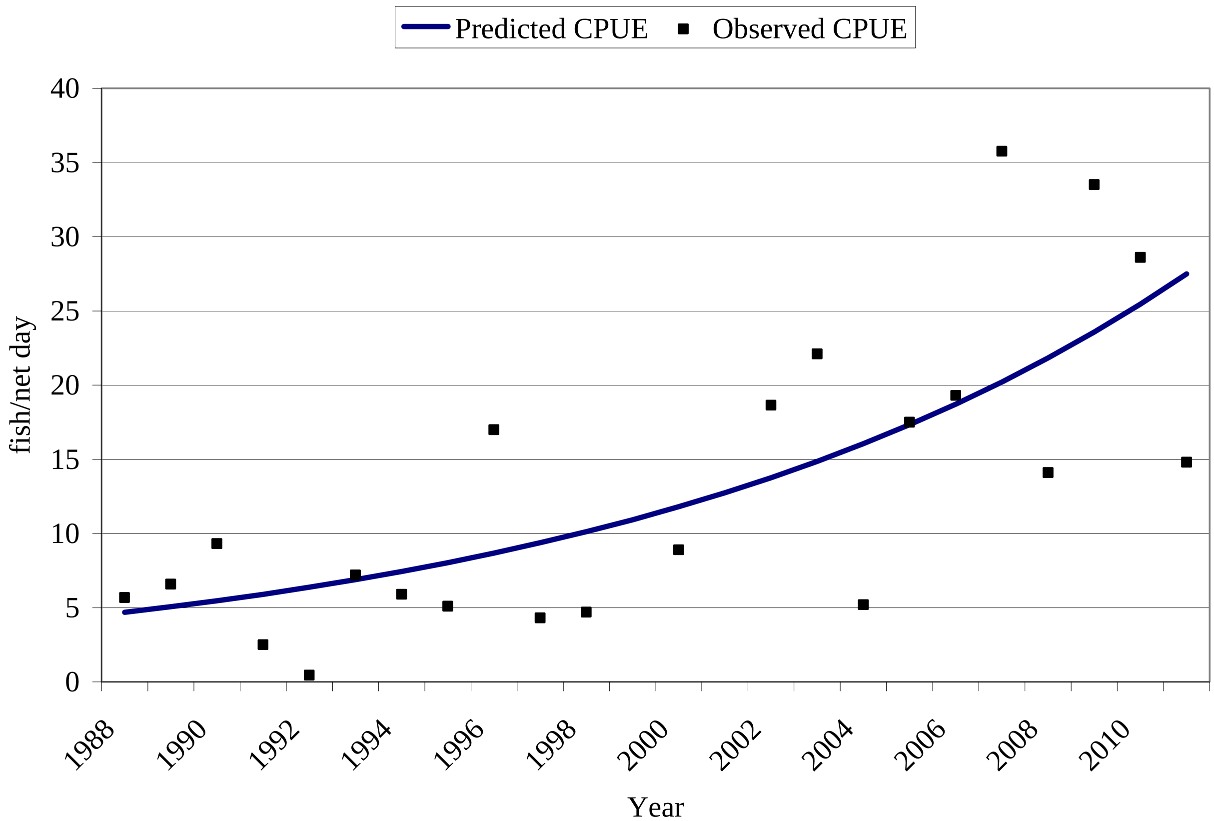


Figure 26. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2011. Not surveyed in 2004, small sample sizes in 2003 and 2005.

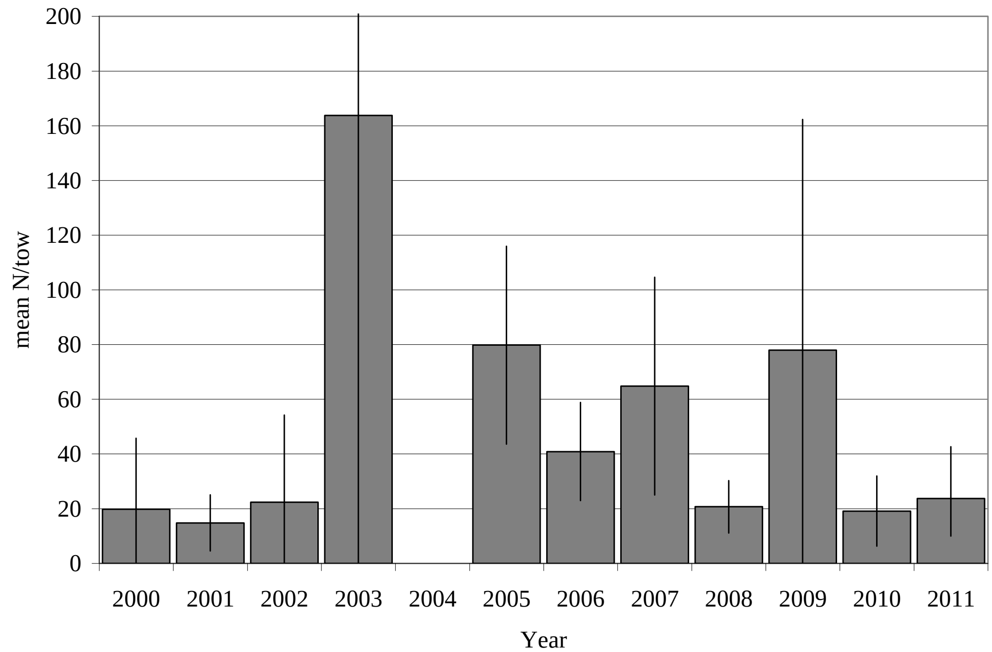


Figure 27. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2011. Horizontal line indicates time series average relative abundance.

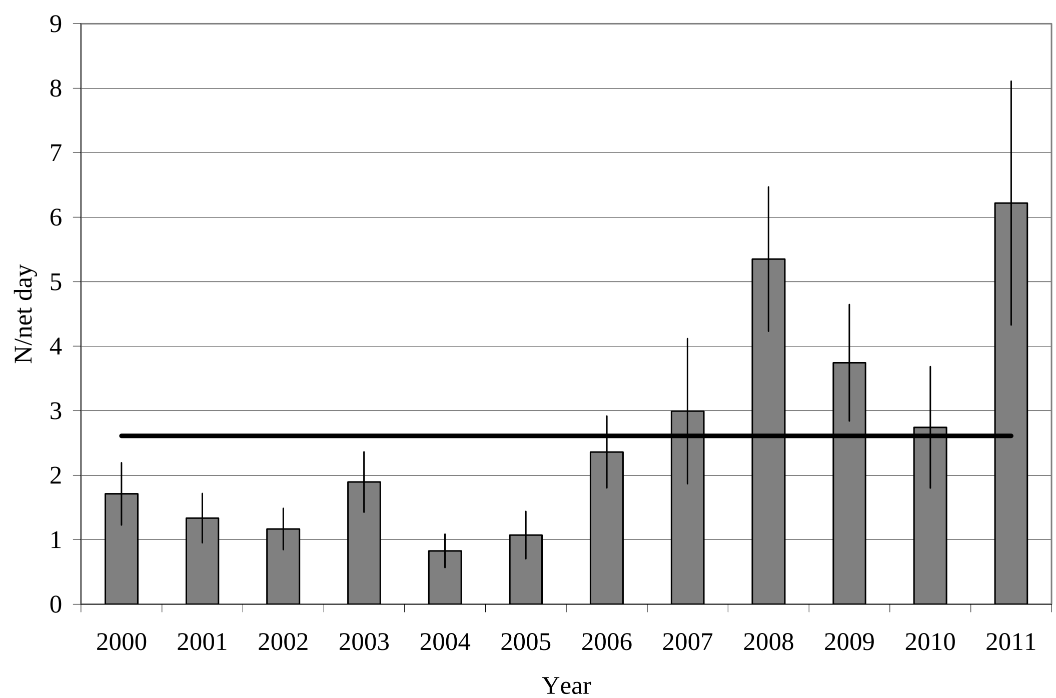
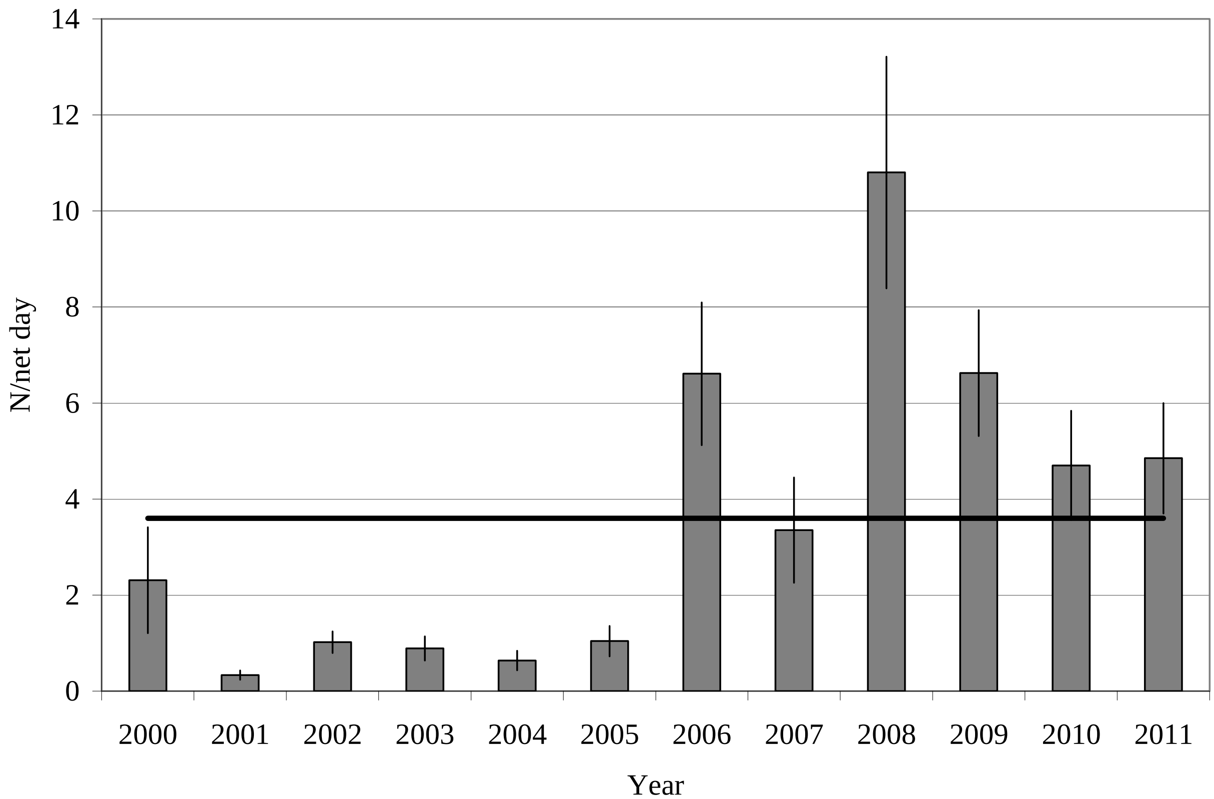


Figure 28. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2011. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

White perch fisheries are important in the Chesapeake Bay region. Based on the Marine Recreational Fisheries Statistics Survey (MRFSS; National Marine Fisheries Service, personal communication), Maryland's 2010 recreational white perch landings were 976,000 pounds, and averaged 773,000 pounds from 2006 – 2010. The 2010 recreational white perch harvest was the 3rd highest in the time-series (1981 – 2010), with the three highest annual landings occurring since 2005. White perch also support a robust commercial fishery in Maryland. Commercial white perch landings were 1.65 million pounds in 2010 and averaged 951,000 pounds from 2006 – 2010.

Maryland's white perch stocks were last assessed in 2009 (Piavis and Webb 2009). For that assessment, a surplus production model was used to assess baywide white perch stocks for the period 1980 - 2005, and a Catch Survey Analysis (CSA) was used to describe white perch population dynamics in the Choptank River for the period 1989 - 2005. The 2011 assessment utilized a different modeling approach in order to assess white perch on a more regional basis. A CSA model described population dynamics in the upper Chesapeake Bay from 2000 – 2010. The CSA model was also utilized to describe the population dynamics of white perch in Choptank River as in the previous assessment. The data poor status of lower Bay stocks necessitated a qualitative approach of inspecting fishery dependent relative abundance indices and fishery independent indices, including a young-of-year index from the Estuarine Juvenile Finfish Survey (EJFS; Project 2 Job 3 Task 3), and an adult white perch relative abundance index from the Potomac River Striped Bass Spawning Stock Survey, a drift gill net survey (SBSSS; Project 2, Job 3, Task 2).

Model results were compared against proposed biological reference points (Piavis and Webb 2006) to determine overfishing status in the upper Bay and Choptank River. In addition, this updated assessment will provide important information regarding management of this species, particularly in the upcoming preparation of the Chesapeake Bay White Perch Fisheries Management Plan.

METHODS

Catch Survey Analysis Model Structure

Model Description

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

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

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

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

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

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

and,

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

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

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

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

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

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

This assessment reparameterized the model to allow for missing survey data (Mensil 2003a). Instead of solving for expected survey indices, this model searches and solves for actual pre-recruit abundance (P) and the first year's post-recruit abundance (R_1). Subsequent post-recruit abundance is determined from equation [1].

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

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

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

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

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

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

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

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

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

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

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

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

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

Inputs

The CSA assessed white perch dynamics for two systems, the upper Chesapeake Bay covering all areas north of the Preston Lane Memorial Bridges, and the Choptank River. Upper Chesapeake Bay commercial white perch landings accounted for 37% of total Maryland Chesapeake Bay landings. Commercial landings from Choptank River accounted for 20% of total baywide landings in 2010.

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

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

1 and 2). Time of removals (T) was set at mid-year (0.5). All of the above inputs were utilized for both the upper Bay assessment and the Choptank River assessment.

Harvest estimates were determined for the commercial and recreational fisheries. Commercial harvesters are required to submit monthly landings reports by river system, in pounds, to the Maryland Department of Natural Resources (Lewis 2010). Numbers of commercially harvested white perch were determined by dividing pounds harvested (by gear type) by estimated average weight of legal white perch for both assessments. Average legal weight by gear type was determined from several sources. Average length of fyke net caught white perch was taken from Fisheries Service survey nets in the Choptank and Nanticoke rivers. Annual allometric equations were applied to the annual average length to determine average weight. For the Choptank River assessment, average length of white perch caught in the gill net fishery was determined from data collected between 1989 - 1994 and 1996 by the MDNR Fisheries Service SBSSS gill net survey in the Choptank River. Data from the MDNR Fisheries Service upper Bay SBSSS was utilized for the 1995 and 1997 –2010 mean length estimates. The method for determining commercial removals for the upper Chesapeake Bay was the same, but only the SBSSS gill net survey results from 2000 – 2010 were needed to determine average length from the gill net fishery.

Recreational white perch harvest for upper Chesapeake Bay and Choptank River were estimated from total inland harvest estimates from the MRFSS (National Marine Fisheries Service personal communication). 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 each assessment area's commercial landings to estimate recreational landings in this system. Negligible release losses were assumed for all fisheries.

Upper Chesapeake Bay Catch Survey Analysis Model

Fishery Independent Catch per Unit Effort Indices

The upper Chesapeake Bay winter bottom trawl survey is designed to collect fishery-independent data for the assessment of population trends of white perch, yellow perch, channel catfish, and white catfish. Eighteen sampling stations, each approximately 2.6 km (1.5 miles) in length and variable in width, were created throughout the study area (Figure 3). Data were not available for the 2003 sampling season due to ice coverage, and the retirement of the vessel captain prevented us from sampling during 2004. The study area was divided into four sampling areas; Sassafras River (4 sites), Elk River (4 sites), upper Chesapeake Bay (6 sites), and middle Chesapeake Bay (4 sites). Each sampling station was divided into west/north or east/south halves by drawing a line parallel to the shipping channel. Sampling depth was divided into two strata; shallow water (< 6 m) and deep water (>6 m). Each site visit was then randomized for depth strata and the north/south or east/west directional components.

The winter trawl survey employed a 7.6 m wide bottom trawl consisting of 7.6 cm stretch-mesh in the wings and body, 1.9 cm stretch-mesh in the cod end and a 1.3 cm stretch-mesh liner. Following the 10-minute tow at approximately 3 knots, the trawl was retrieved into the boat by winch and the catch emptied into either a culling board or large tub if catches were large. All species caught were identified and counted. A minimum of 50 fish per species were sexed and measured. If catches were prohibitively large to process, total numbers were extrapolated from volumetric counts. Volumetric subsamples were taken from the top of the tub, the middle of the tub, and the bottom of the tub. In addition, when white perch catches were greater than 50 fish, the proportion of pre-recruit white perch (185 mm -- 202 mm) and the proportion of post-recruit white perch (>202 mm) were determined and the total number of each phase was derived by multiplying the proportion by the total white perch catch per tow.

Uncertainty

The model was bootstrapped 1,000 times by resampling residuals and adding them to the natural logarithm of the expected index values, then re-exponentiating the values. Mean, median, standard deviation and coefficient of varitation (CV) were calculated for q and each estimate of P_t and R_t, exclusive of the terminal year. Confidence intervals (80%) were determined from cumulative percent distributions of the bootstrapped parameter estimates. In addition, retrospective analyses were conducted on the data by eliminating one year's data, running the model, then eliminating two year's data. The results for population size and F from each model run were plotted to determine if biases occurred in the final year's estimates.

Choptank River Catch Survey Analysis Model

Fishery Independent Catch per Unit Effort Indices

Fyke nets sampled resident and anadromous fishes, and were fished two to three times per week. Fisheries Service fyke nets were located from river km 65.4 to km 78.1 (Figure 4). The Choptank River is tidal and generally fresh at the five survey sites.

However, during the severe drought of 2001 - 2002, salinity increased to 6 ppt, but has never exceeded white perch tolerance limits (18 ppt; Setzler-Hamilton 1991).

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

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

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

Uncertainty

The model was bootstrapped 1,000 times by resampling residuals and adding them to the natural logarithm of the expected index values, then re-exponentiating the values. Mean, median, standard deviation and CV were calculated for *q* and each estimate of P_t and R_t, exclusive of the terminal year. Confidence intervals (80%) were determined from cumulative percent distributions of the bootstrapped parameter estimates. In addition, retrospective analyses were conducted on the data by eliminating one year's data, running the model, then eliminating two year's data. The results for population size and F from each model run were plotted to determine if biases occurred in the final year's estimates.

Lower Chesapeake Bay Relative Abundance Indices

Fishery Dependent

Fishery dependent relative abundance indices were calculated from the 3 primary fishing gears: fyke nets, pound nets, and drift gill nets. The MDNR commercial landings database was queried for landings and effort for the three main gear types for all areas below the Preston Lane Memorial Bridges. All license holders reporting more than 1,000 pounds landed per month were included in the index. Total effort for fixed gear (fyke nets and pound nets) was calculated as the number of nets fished during any one month. Drift gill net effort was 1,000 gill net feet per hour. Catch-per-unit effort (CPUE) was total pounds landed divided by total effort.   Effort records were intermittent throughout the earlier portion of the time series, but in general, data were available from 1980 – 1985, 1990 and 1992 – 2010.

Fishery Independent

Fishery independent relative abundance indices were calculated from the EJFS seine survey. The index was the geometric mean of the number of juvenile white perch +1 from all sites below the Bay Bridges from 1962 – 2011.

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

RESULTS

Upper Chesapeake Bay Catch Survey Analysis Model

Estimated total white perch removals by the commercial and recreational fisheries in the upper Bay declined from over 3 million pounds in 2000 to just under 1 million pounds in 2008 (Figure 5). Landings rose rapidly to 1.6 million pounds in 2009 and 2.5 million pounds in 2010. Pre-recruit CPUE's from the fishery independent trawl survey declined from 2001 through 2007, but rebounded to high levels in 2009 and 2010 (Figure 6). Post-recruit white perch CPUE's mimicked the decline in landings, falling from high values in 2000 to the lowest in the time-series in 2007 (Figure 7). The CPUE's then increased from 2008 through 2011.

Total population abundance (pre- and post-recruits combined) decreased from 12.5 million white perch in 2002 to 5.5 million fish in 2004 (Figure 8). Total abundance rose from 5.5 million fish in 2004 to 13.8 million white perch in 2010. Pre-recruit abundance (185 mm TL – 202 mm TL) ranged from 425,000 white perch in 2004 to 6.2 million in 2009, and averaged 3.8 million during 2000 – 2011. The 2011 estimate was 6.5 million fish, but that value is not fit by the model, it is simply the observed terminal p_t divided by $q_{avg.}$ Therefore, it is considered a very rough estimate. Post-recruit white perch abundance ranged from 2.7 million white perch in 2005 to 9.0 million fish in 2000 and 2011, and averaged 6.0 million fish. Instantaneous fishing mortality (F) varied throughout the time-series from F=0.14 (2008) to F=0.49 (2004; Figure 9). Final year F was 0.22 and averaged 0.31 during 2000 – 2010.

Plots of observed versus expected survey indices tracked well for the time-series (Figures 6, 7). Plots of residuals also illustrate these results. Pre-recruit residuals did not exhibit any obvious patterns, and all residuals were relatively small (Figure 10). The post-recruit residuals were also indicative of a good fit, but one year (2007) produced a fairly large negative residual (Figure 11).

A suite of biological reference points were determined for Chesapeake Bay white perch in a previous assessment (Piavis and Webb 2006). Spawning stock biomass per recruit analysis determined maximum spawning potential (MSP) reference points. Given the early time at first maturity, $F_{30\%}$ (target) and $F_{20\%}$ (limit) MSP reference points appear appropriate. Target F and limit F were 0.6 and 1.12, respectively. Target F was never exceeded (Figure 9).

Bootstrap evaluation of the model indicated precise results. Pre-recruit abundance fit very well with CV's ranging from 17% in 2002 to 22% in 2001 (Table 1). For the 2 years when trawling did not occur (2003 and 2004), CV's were predictably high (58% and 63%, respectively). Post-recruit white perch abundance estimates were also very precise, with CV's ranging from 19% in 2000 to 32% in 2008. The post-recruit CV's for the years of missing data were acceptable (22% and 20%). The CV's of total abundance ranged from 13% to 21%, and catchability CV was 15%. Confidence intervals (80%) of pre-recruit and post-recruit abundance were determined from bootstrap samples (Figures 12, 13).

Retrospective analysis indicated that the model was somewhat optimistic. Abundance estimates for both the pre-recruits and post-recruits were 10% and 16% higher in the t-1 retrospective run than the 2011 model run, respectively (Figures 14, 15). Instantaneous fishing mortality (F) was underestimated by 17% from the t-1 run to the 2011 run (Figure 16).

Choptank River Catch Survey Analysis Model

Total removals by the commercial and recreational fisheries from the Choptank River were below 500,000 white perch early in the time-series, but increased to a peak removal of over 2 million fish in 1997 (Figure 17). Landings were generally stable from 2000 – 2005, but they were quite erratic from 2005 – 2010, exhibiting a slightly declining trend. Pre-recruit fishery independent CPUE values showed a generally increasing trend over a large portion of the time series (Figure 18). Post-recruit white perch CPUE was flat from 1989 – 1998 (Figure 19). The post-recruit index exhibited an increasing trend from 1998 – 2011.

Choptank River white perch data fit the CSA model well. Total population abundance in numbers increased from 1.4 million white perch during 1989 to 7.4 million fish in 2010 (Figure 20). Pre-recruit abundance (185 mm – 202 mm) ranged from 597,000 white perch in 1989 to 2.6 million in 2010. Post-recruit white perch abundance ranged from 827,000 white perch in 1989 to 4.7 million fish in 2010. Instantaneous fishing mortality (F) increased through 1997 followed by a general decline through 2010 (Figure 21). Final year F was 0.09.

Plots of observed versus expected survey indices tracked well for a large portion of the time series, but the model results failed to track an increasing pre-recruit index in the final 6 years (Figure 18). Similarly the expected post-recruit index failed to capture a declining index value over the last 5 years of the assessment (Figure 19). Plots of residuals also illustrate these results. The pre-recruit residuals exhibit a pattern of largely negative residuals for the first 10 years and turn positive for the remaining time period. The largest positive residuals occurred over the later portion of the time series (Figure 22). Post-recruit residuals are fairly evenly distributed except for the final four years where the residuals are all negative (Figure 23).

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

Bootstrap evaluation of the model indicated precise results. Pre-recruit abundance fit very well with CV's, ranging from 17% in 1997 to 27% in 2010 (Table 2). CV's of fully recruited white perch ranged from 13% in 2010 to 26% in 1989. CV's of F ranged from 14% to 20%. Catchability was very precisely estimated at 6% (CV). Confidence intervals (80%) of pre-recruit and post-recruit abundance were also determined from bootstrap samples (Figures 24, 25).

Retrospective analysis indicated that the model was somewhat optimistic, not unexpected given the residual patterns described above. Abundance estimates for both the pre-recruits and post-recruits were approximately 12% and 10% higher in the t-2 retrospective run than the 2010 model run, respectively (Figures 26, 27). Although graphically hard to discern, F was underestimated by 10% from the t-2 run to the 2010 run (Figure 28).

Lower Chesapeake Bay Relative Abundance Indices

Fishery Dependent

Fishery dependent relative abundance indices produced somewhat similar signals. Fyke net CPUE varied, but relative abundance generally increased from 1992 – 2004 before declining throughout the remainder of the time series (Figure 29). Nine of the final 10 years had relative abundance values higher than the time series average. The lower Bay pound net relative abundance index mimicked the fyke net index to some degree with the same parabolic shape after 1992 (visual inspection; Figure 30). However, the inflexion point of the pound net index is around 2002 where the fyke net inflexion point would be more likely around 2004. Five of the final 10 years had relative abundance values at or above the time series average. The drift gill net relative abundance index exhibited a similar pattern where the index rose from 1992 to 2003 and then declined through 2007 (Figure 31). The gill net index then increased through 2010, compared to the fyke net and pound net indices which showed either an uneven increase or no increase in relative abundance. Seven of the final 10 years had relative abundance values at or above the time series average.

Fishery Independent

An adult white perch relative abundance index was derived from a striped bass spawning stock survey (drift gill net) in Potomac River. The index was generally noisy, but corroborated the fishery dependent indices signals of high abundances around 2004 – 2005 with a decline through 2009 (a time series low; Figure 32).

A juvenile abundance index was derived from a long-term seine survey. Sites from the lower Bay produced strong recruitment levels from the early 1990's through the mid 2000's (Figure 33). The index trended lower during 2005 – 2010, but recruitment levels were more similar to the late 1960's than the period of extended poor recruitment (1971 – 1986).

DISCUSSION

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

Upper Chesapeake Bay Assessment

The CSA model fit the fishery independent trawl data well. The upper Bay population decreased from 2000 but rebounded by 2010 to time-series highs. Precision was generally good, except for the two years where no fishery independent data were available. Mensil (2003b) suggested a 10 year minimum time frame for CSA with no more than 25% missing data. Our model run had 9 years of data and 2 years of missing data. The model in its present form is at or near the required minimum data inputs. In addition, the two years of missing data are consecutive which may make fitting the trend that much more difficult. Confidence intervals produced from bootstrapping indicated that the model derived (missing) points were biased low, suggesting a conservative estimation. Retrospective analysis corroborated this trend in that each successive model run elevated the point estimate somewhat.

Estimated fishing mortality (F) never exceeded the proposed biological reference points F_{target} and F_{limit}. The highest F rate was 0.49 (F_{limit} proposed at F = 0.60). Therefore, overfishing was not occurring. Overfished status cannot be evaluated because no stock recruitment relationship has been determined and CSA does not produce MSY estimates.

Choptank River Assessment

Relative abundance (fyke net CPUE) analysis with a CSA indicated a growing population in Choptank River, both in pre-recruit and post-recruit white perch numbers. Uncertainty analysis indicated fairly precise results. Post-recruit abundance increased throughout the course of the survey. This is generally consistent with Fisheries Service CPUE indicators but the expected estimates were higher for the last 4 years of the survey than the observed values. Inaccurate estimation of total removals may cause this discrepancy: if total removals are underestimated more post-recruit fish live through to the next year and are accumulated in the estimates. In addition, the retrospective analysis indicated somewhat optimistic results, in that the estimates were overestimated by 10%.

Fishing mortality rates have declined since 1997. There is unquantifiable uncertainty in the F estimates, mainly from a lack of specific data on white perch recreational harvest in the Choptank River. Harvest levels were estimated from Bay-wide MRFSS, scaled down to a Choptank River specific estimate based on a percentage of commercial landings. Total harvest would be biased if this assumption was invalid. Stock specific estimates of F from age data or other methods need to be investigated for comparison to biological reference points.

Examination of the Choptank River population trajectory and F rates are constructive in determining biological reference points. For example, the population continued to increase with F estimates in the 0.4 – 0.85 range. Given the resilience of white perch, $F_{30\%}$ (0.60) could provide enough spawning stock to maintain and increase population levels. This level should be considered as a target F rate. Fishing mortality rates have been at or below F=0.60 since 2000, roughly the same time when the population began its exponential increase in abundance.

Lower Chesapeake Bay Assessment

The lower Bay assessment was qualitative in nature. Fishery dependent indices of relative abundance were not identical, but they did provide a general indication of stock trends. All three fishery dependent indices showed a generally increasing trend up to 2002 or 2004, followed by a decline. The decline persisted until around 2007 with the indices showing either a flat or increasing population through 2010. The population bottom in 2007 and possible recovery through 2010 is almost identical to the upper Bay CSA results. The recent history of the CPUE indices suggest that white perch are not overfished because the indices have been above average in at least 50% - 90% of the last 10 year period, depending on the fishery dependent gear type.

The fishery independent indices gave mixed signals. The gill net survey indicated relatively high CPUE's during 2004 – 2006, a time period where the fishery dependent indices suggested population declines. The young-of year survey produced high CPUE values in 2001, 2003, and 2004. These year-classes could have caused the increased fishery dependent CPUE's after 2007. The fact that this increase in the fishery independent gill net survey did not occur suggests that either those year-classes were not recruited to the gear or that the timing and protocol of the survey are inappropriate for assessing white perch stocks.

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Table 1. Uncertainty parameters for upper Chesapeake Bay white perch CSA model.(q=catchability, R2000-R2010=pre-recruit abundance 2000 - 2010, and N2000-N2011=post-recruit abundance 2000 – 2011).

Parameter/Year	Estimate	Mean	Median	Std dev	C.V.
q	2.08E-06	2.23E-06	2.20E-06	3.28E-07	0.147
R2000	2,213,729	2,130,577	2,099,055	444,630	0.209
R2001	5,661,879	5,389,114	5,365,330	1,187,458	0.220
R2002	5,203,630	4,937,512	4,916,514	849,364	0.172
R2003	905,222	1,239,191	1,106,176	720,208	0.581
R2004	425,347	937,781	780,317	596,778	0.636
R2005	3,089,713	2,928,175	2,906,020	543,672	0.186
R2006	2,891,329	2,748,845	2,749,442	539,468	0.196
R2007	2,032,176	1,940,734	1,942,385	404,797	0.209
R2008	5,182,969	5,009,953	5,073,660	1,017,622	0.203
R2009	6,183,923	5,962,978	6,032,966	1,284,782	0.215
R2010	5,386,714	5,245,380	5,244,426	1,073,558	0.205
N2000	9,006,117	8,448,356	8,504,951	1,589,516	0.188
N2001	6,304,820	5,780,084	5,820,304	1,432,246	0.248
N2002	7,336,762	6,683,825	6,817,458	1,598,690	0.239
N2003	8,285,950	7,533,490	7,619,788	1,690,770	0.224
N2004	5,051,549	4,708,919	4,733,684	919,674	0.195
N2005	2,753,357	2,892,380	2,857,973	606,704	0.210
N2006	3,218,474	3,200,041	3,203,006	784,369	0.245
N2007	3,897,344	3,765,595	3,752,976	881,157	0.234
N2008	3,131,920	2,949,187	2,958,300	931,921	0.316
N2009	5,924,827	5,633,564	5,616,634	1,354,950	0.241
N2010	8,423,602	8,004,242	7,967,217	1,865,440	0.233
N2011	9,053,118	8,594,061	8,597,427	2,114,780	0.246

Table 2. Uncertainty parameters for Choptank River white perch CSA model. (q=catchability, R2000-R2010=pre-recruit abundance 2000 - 2010, and N2000-N2011=post-recruit abundance 2000 – 2011).

Parameter/Year	Estimate	Mean	Median	Std Dev	CV
q	1.52E-05	1.58E-05	1.57E-05	9.87E-07	0.062
R1989	597,406	620,939	618,845	160,862	0.259
R1990	1,346,010	1,303,986	1,297,632	264,944	0.203
R1991	721,328	737,855	728,114	185,801	0.252
R1992	1,071,441	1,067,982	1,057,839	228,108	0.214
R1993	971,830	974,912	974,516	214,920	0.220
R1994	1,403,621	1,385,186	1,363,437	286,360	0.207
R1995	1,434,850	1,432,950	1,422,965	304,934	0.213
R1996	1,985,092	1,948,454	1,939,061	375,921	0.193
R1997	2,043,787	2,036,929	2,038,028	346,601	0.170
R1998	1,507,666	1,508,635	1,495,979	348,763	0.231
R1999	2,368,106	2,305,113	2,293,346	439,632	0.191
R2000	1,442,241	1,457,528	1,454,417	326,729	0.224
R2001	1,944,471	1,913,749	1,885,911	414,700	0.217
R2002	1,621,844	1,618,983	1,600,158	383,143	0.237
R2003	2,251,654	2,211,629	2,176,972	488,958	0.221
R2004	1,954,775	1,941,219	1,915,822	458,992	0.236
R2005	2,263,899	2,208,683	2,193,133	517,788	0.234
R2006	2,189,760	2,218,048	2,194,094	555,404	0.250
R2007	2,568,966	2,539,905	2,500,444	639,063	0.252
R2008	1,913,274	1,978,360	1,970,537	500,987	0.253
R2009	1,759,938	1,843,048	1,813,772	490,879	0.266
R2010	2,660,031	2,823,236	2,815,958	753,345	0.267
N1989	827,318	754,408	745,050	192,584	0.255
N1990	850,718	810,292	812,856	168,128	0.207
N1991	1,327,015	1,259,511	1,249,898	219,069	0.174
N1992	1,200,243	1,158,507	1,153,087	193,680	0.167
N1993	996,980	959,977	955,320	179,867	0.187
N1994	791,057	763,286	754,172	172,828	0.226
N1995	1,101,912	1,064,082	1,054,715	233,846	0.220
N1996	1,107,211	1,074,682	1,059,339	246,708	0.230
N1997	1,386,674	1,330,045	1,313,636	297,151	0.223
N1998	979,169	927,190	916,204	235,736	0.254
N1999	1,408,482	1,366,719	1,354,172	292,431	0.214
N2000	1,606,963	1,521,196	1,503,330	331,405	0.218
N2001	1,564,124	1,506,419	1,501,961	309,302	0.205
N2002	1,833,289	1,760,892	1,748,057	362,697	0.206
N2003	2,114,289	2,052,672	2,046,886	373,192	0.182
N2004	2,612,192	2,528,975	2,514,296	436,652	0.173
N2005	2,554,457	2,475,226	2,462,628	452,212	0.183
N2006	3,124,143	3,014,067	3,000,115	496,534	0.165
N2007	3,814,586	3,747,623	3,732,457	546,275	0.146
N2008	4,198,913	4,120,295	4,104,046	617,199	0.150
N2009	4,429,343	4,418,264	4,402,355	610,865	0.138
N2010	4,721,584	4,780,558	4,745,472	606,902	0.127
N2011	5,510,747	5,692,653	5,646,501	779,609	0.137

Figure 1. Length frequency of white perch from upper Chesapeake Bay trawl survey, 2011.

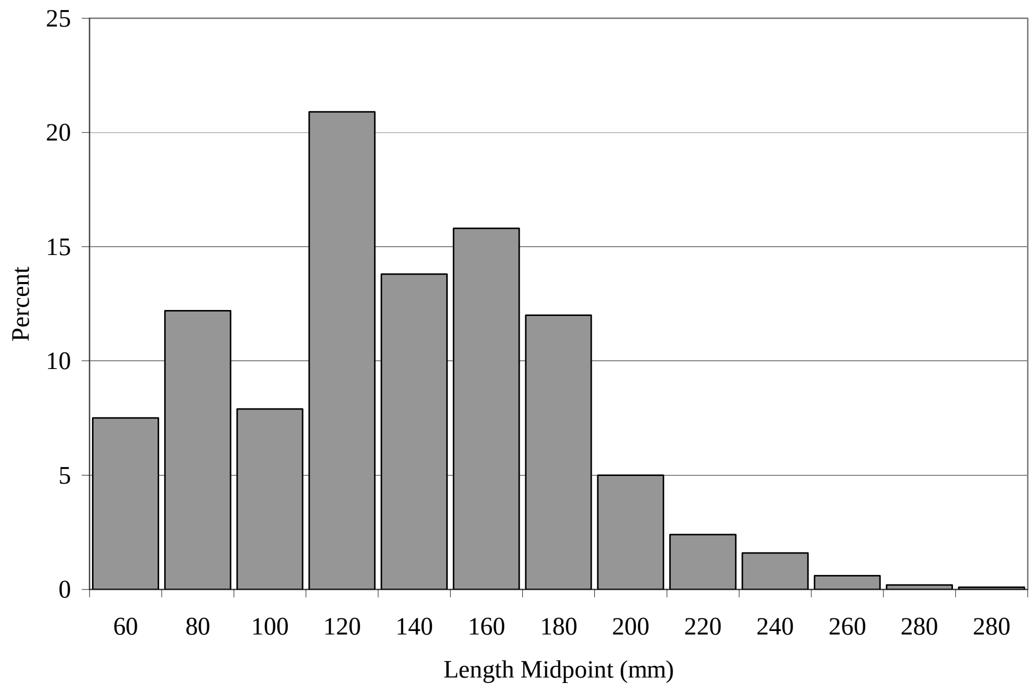


Figure 2. Length frequency of white perch from Choptank River fyke net survey, 2011.

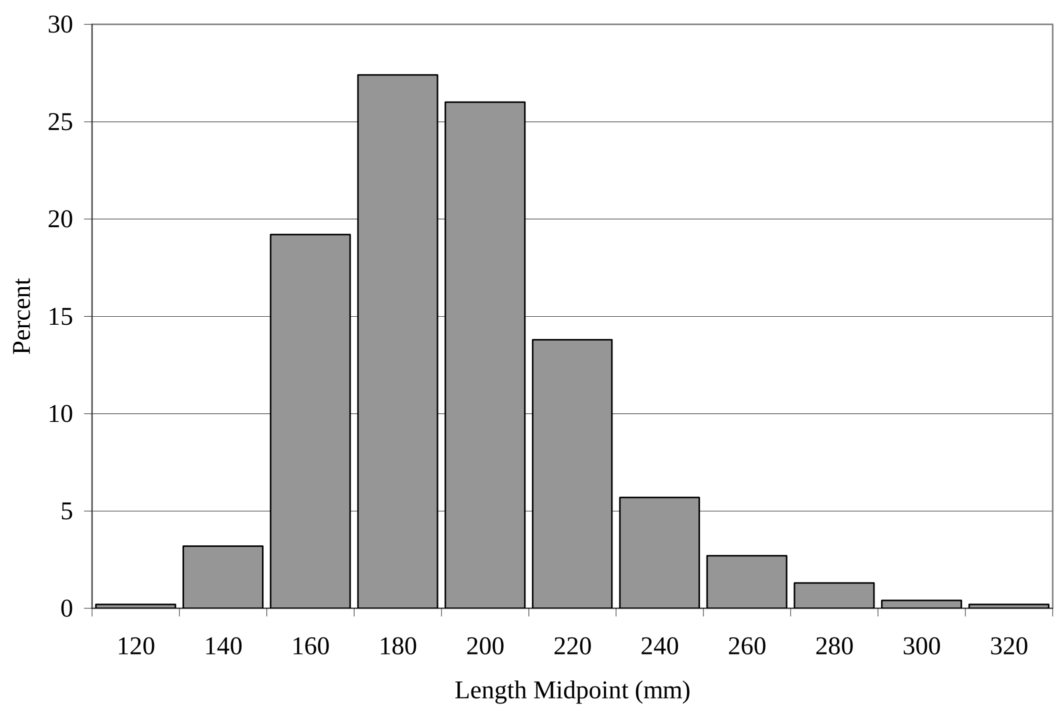


Figure 3. Upper Chesapeake Bay trawl sites, 2010.

Figure 4. Choptank River fyke net sites (circles), 2011.

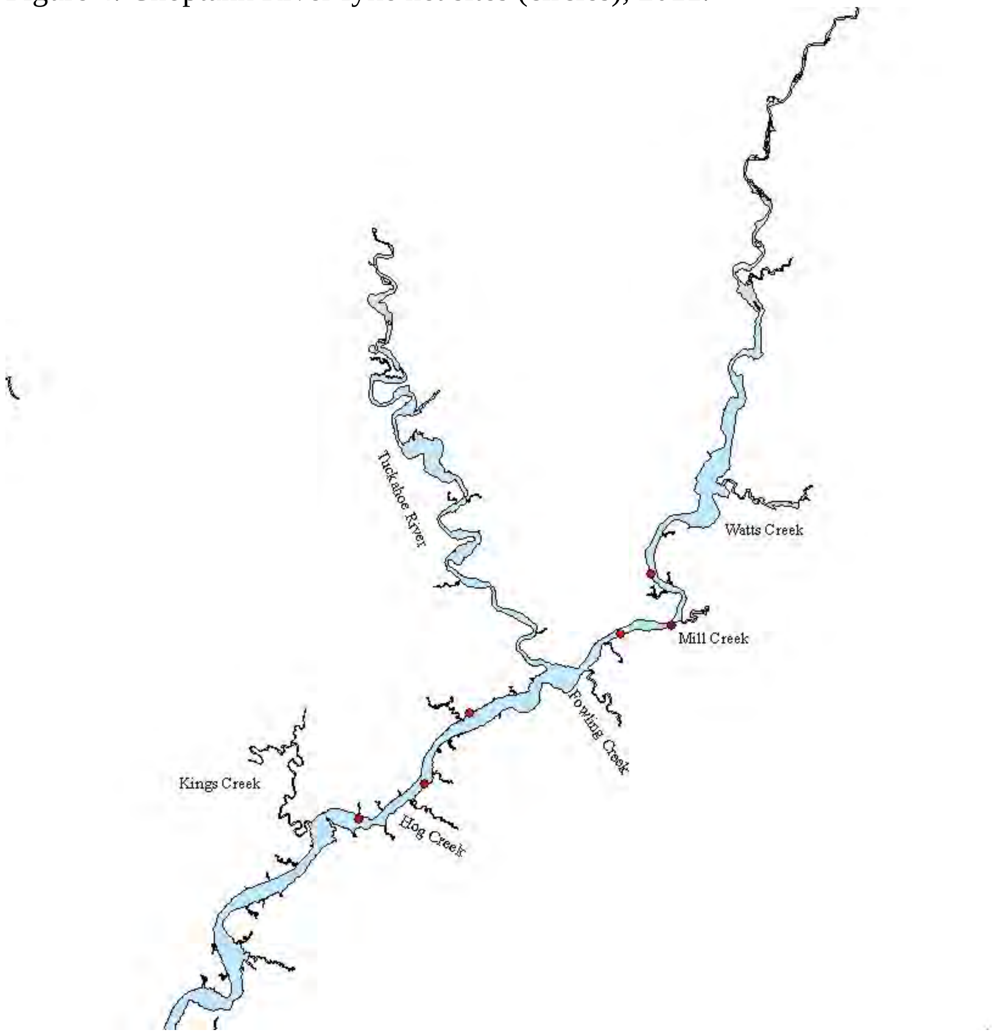


Figure 5. Estimated upper Chesapeake Bay white perch removals (commercial and recreational), 2000 – 2010.

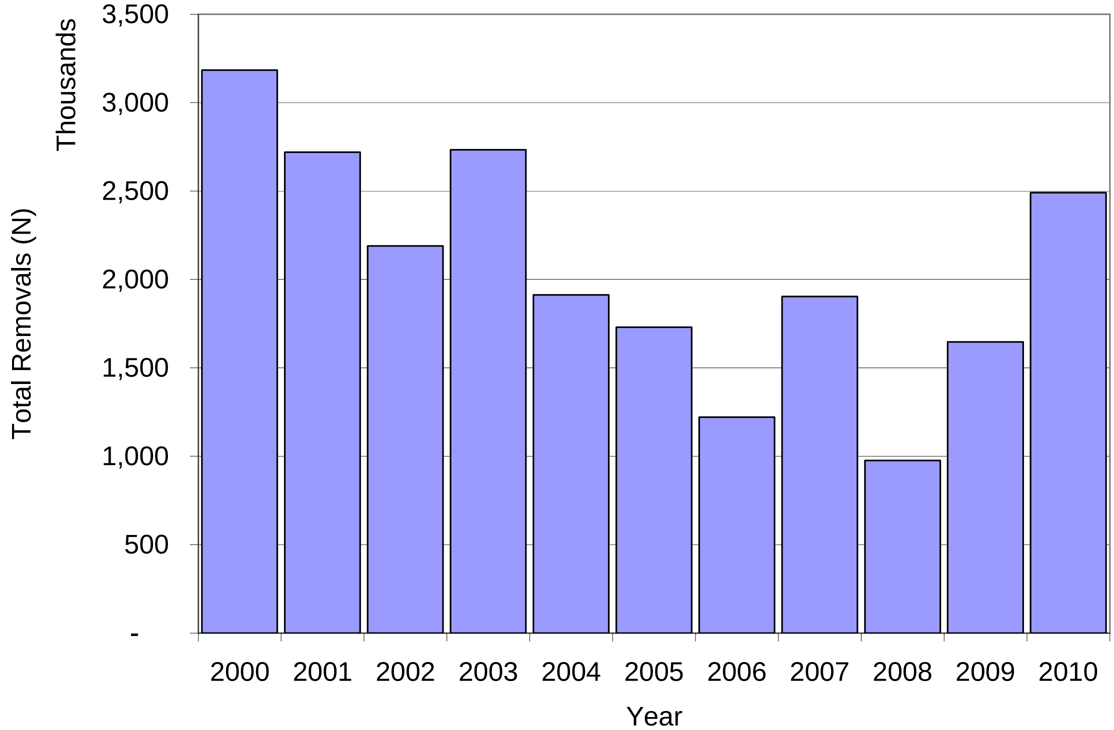


Figure 6. Observed and expected white perch pre-recruit indices from upper Chesapeake Bay trawl survey, 2000 – 2010.

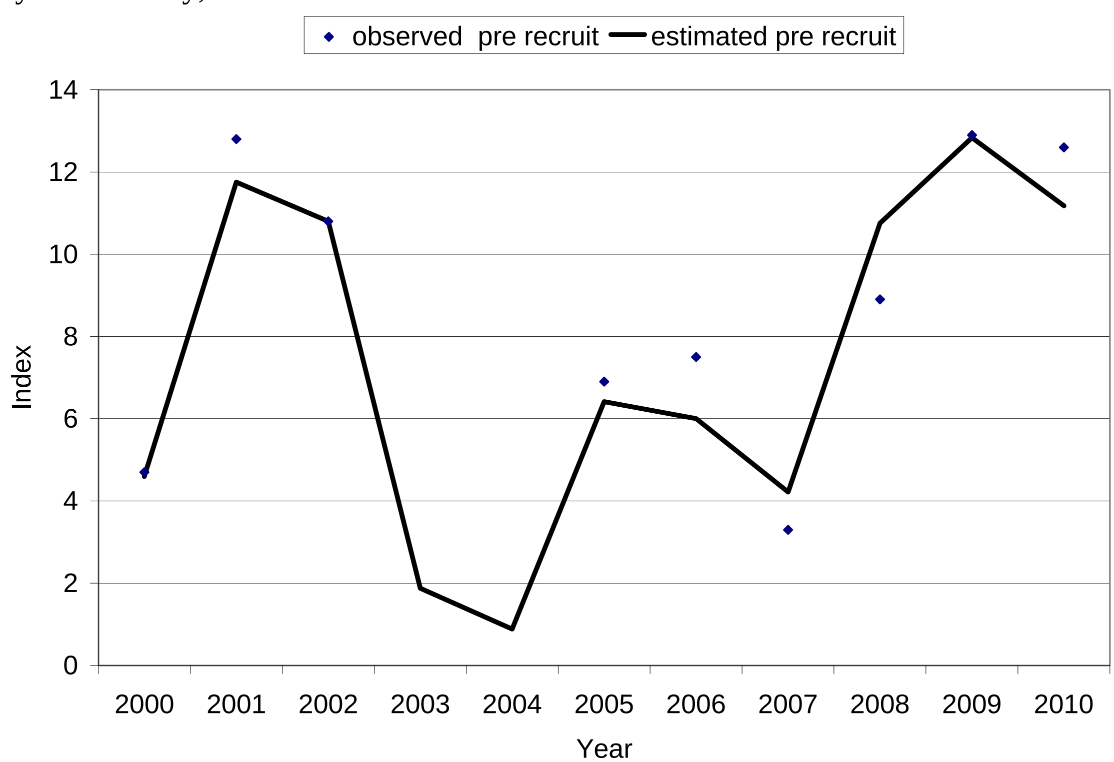


Figure 7. Observed and expected white perch post-recruit indices from upper Chesapeake Bay trawl survey, 2000 – 2011.

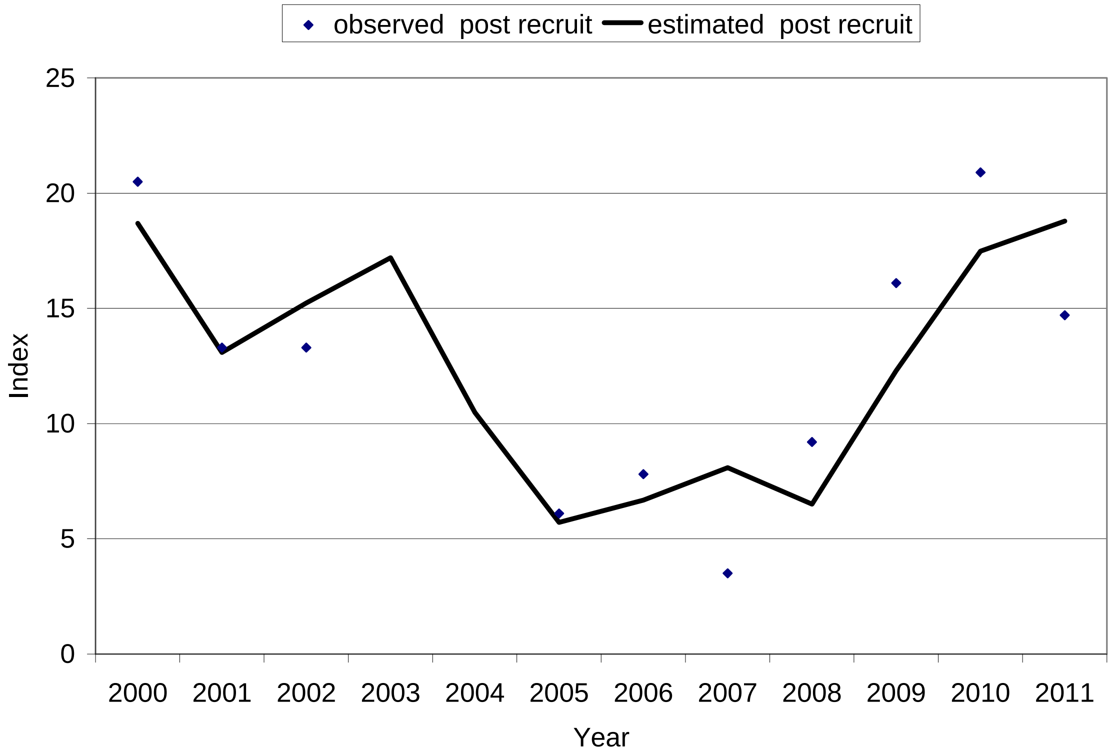


Figure 8. Total population estimate of upper Chesapeake Bay white perch from Catch Survey Analysis, 2000 – 2010.

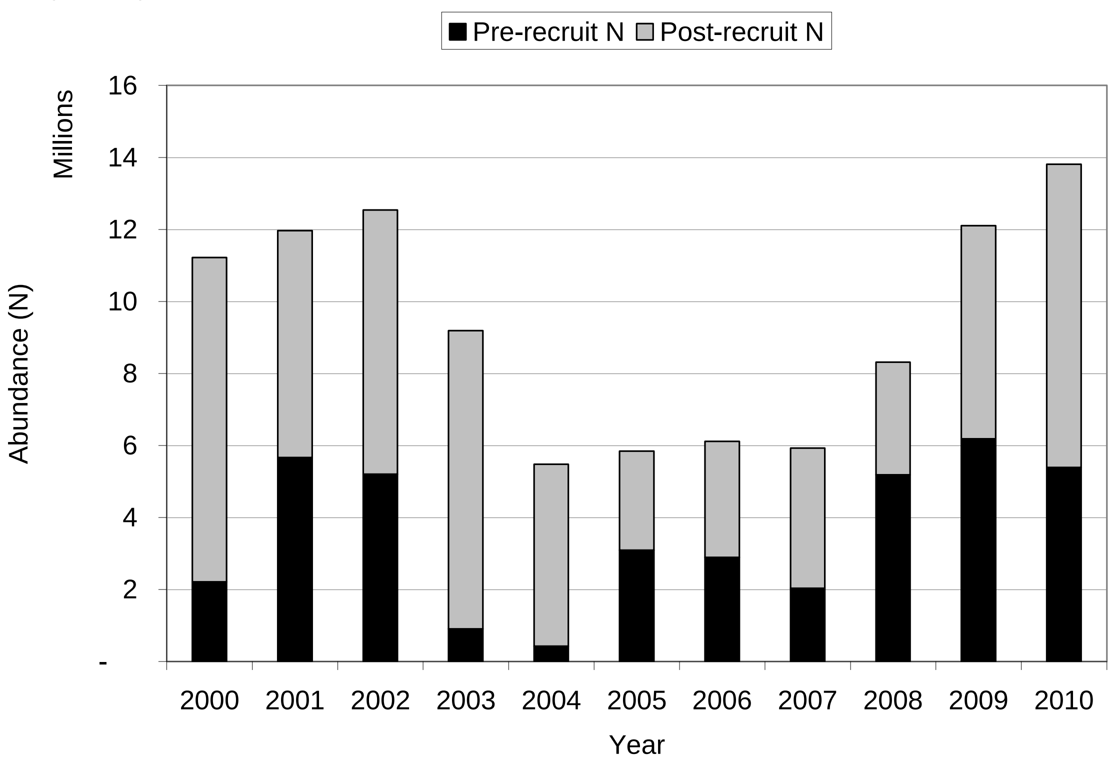


Figure 9. Instantaneous fishing mortality (F) of upper Chesapeake Bay white perch and proposed biological reference points for F, 2000—2010.

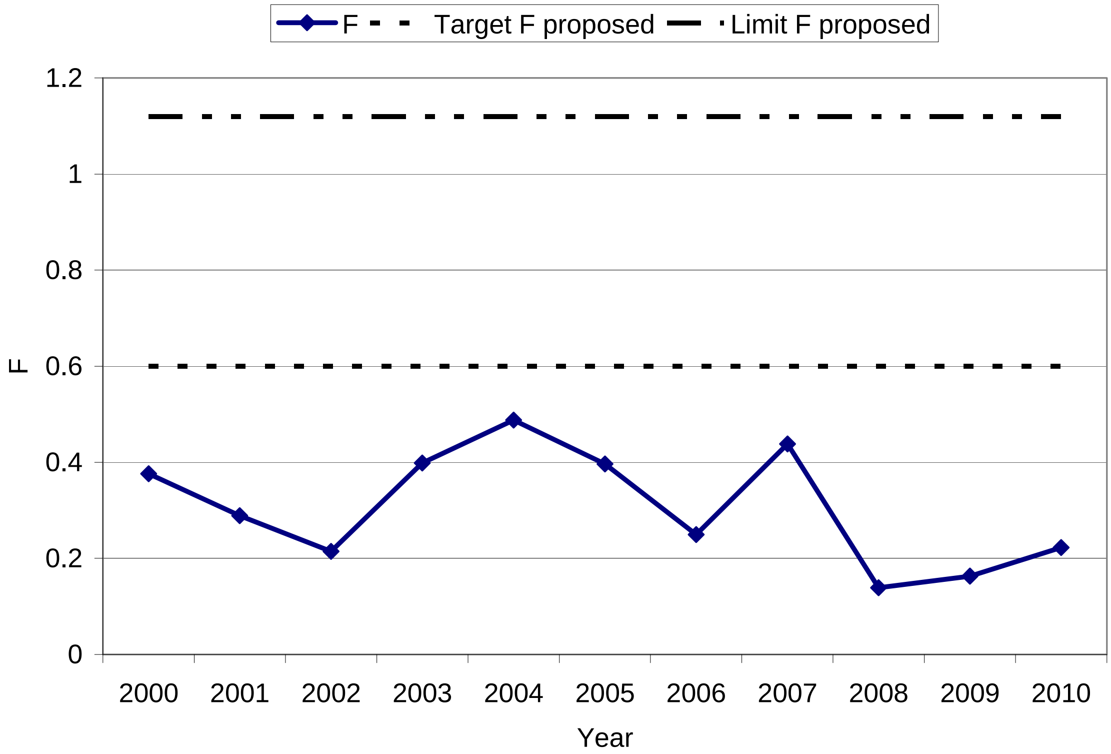


Figure 10. Pre-recruit residuals from upper Chesapeake Bay Catch Survey Analysis of white perch.

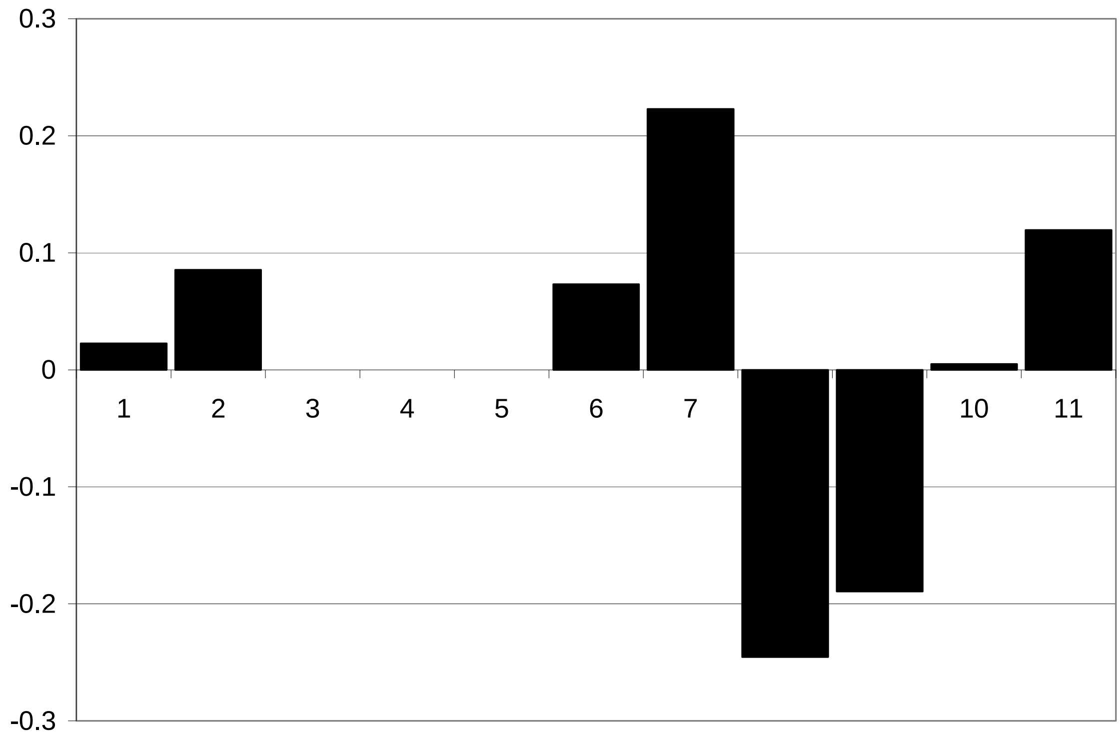


Figure 11. Post-recruit residuals from upper Chesapeake Bay Catch Survey Analysis of white perch.

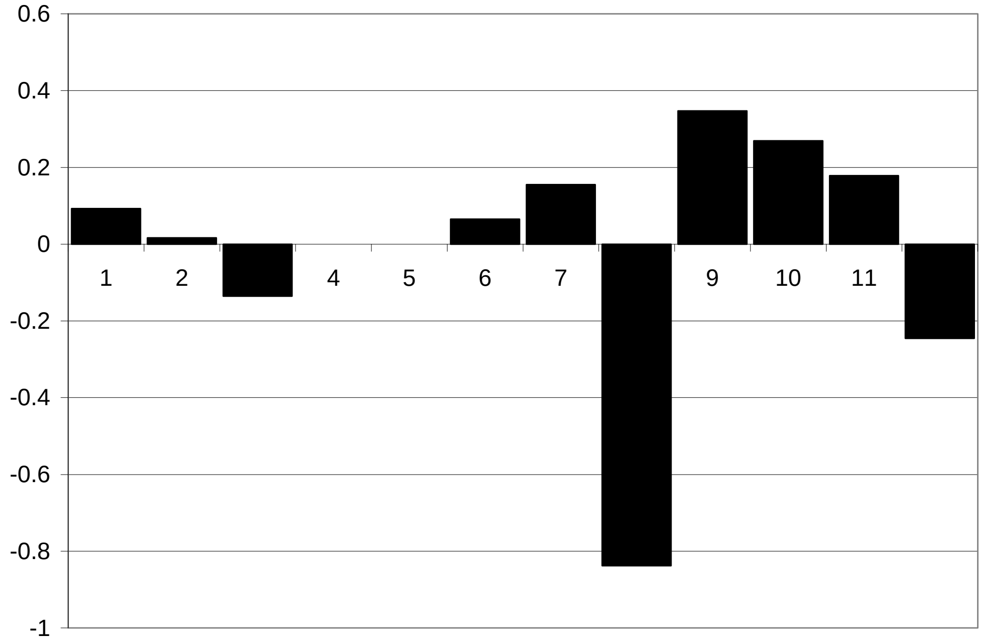


Figure 12. Bootstrap derived confidence intervals (80 %) for upper Chesapeake Bay pre-recruit white perch.

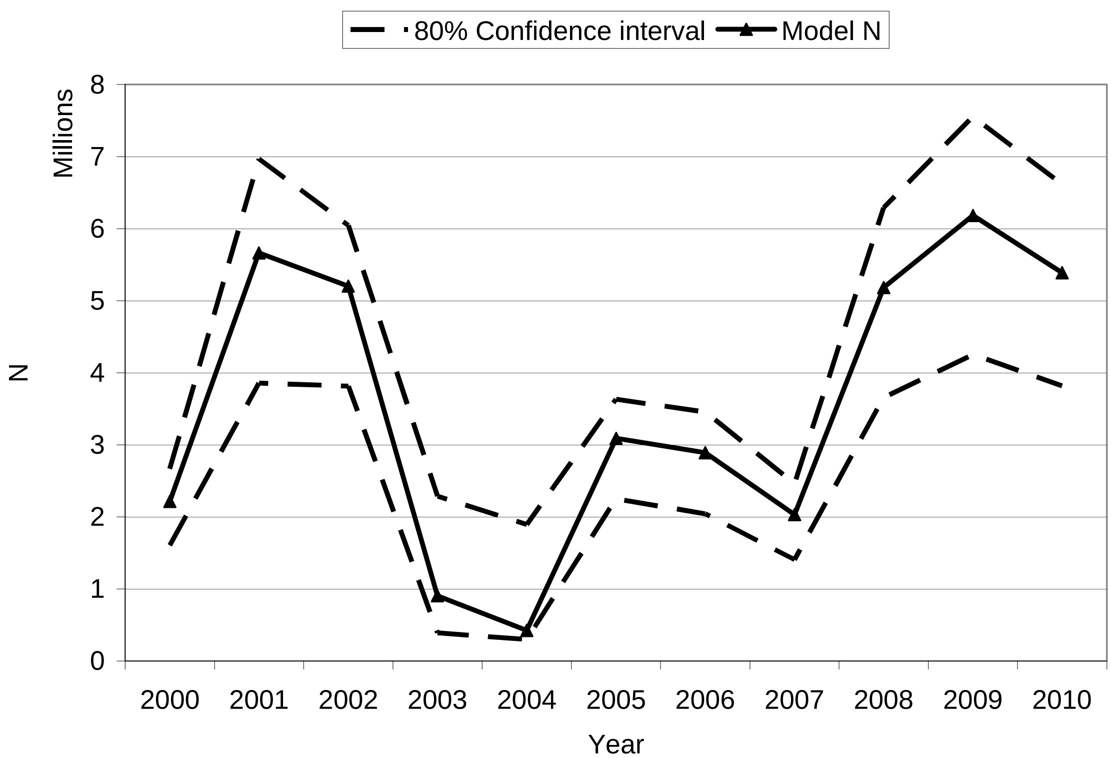


Figure 13. Bootstrap derived confidence intervals (80 %) for upper Chesapeake Bay post-recruit white perch.

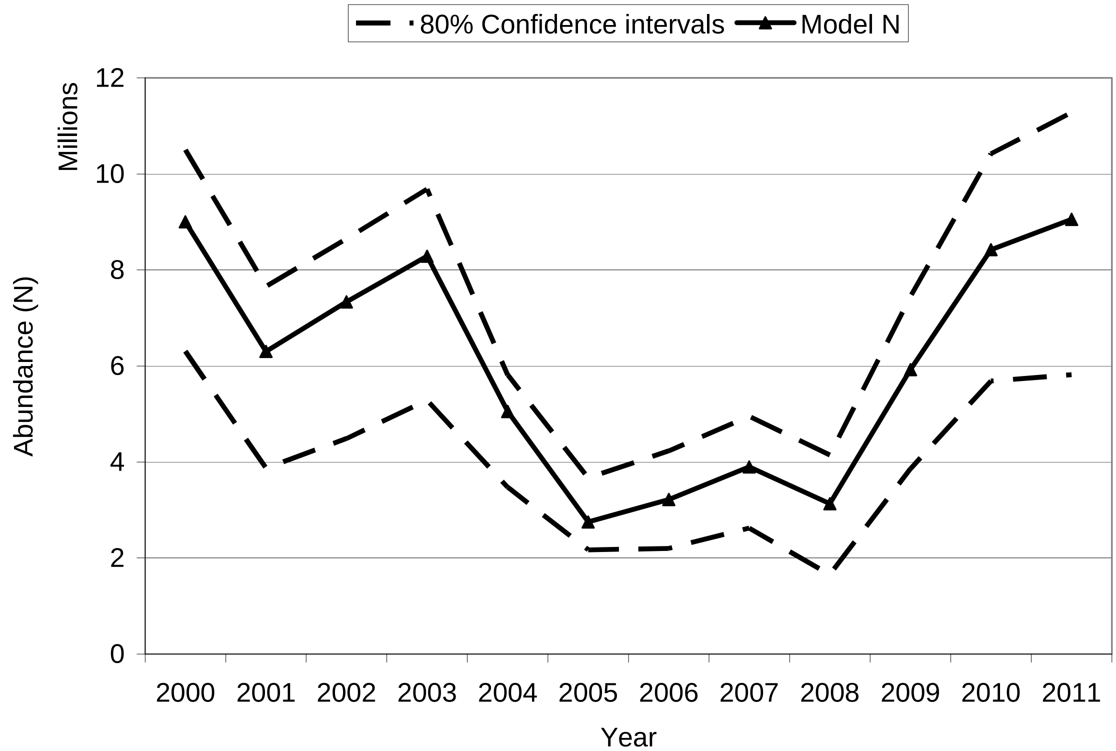


Figure 14. Retrospective analysis of upper Chesapeake Bay pre-recruit white perch estimates from Catch Survey Analysis.

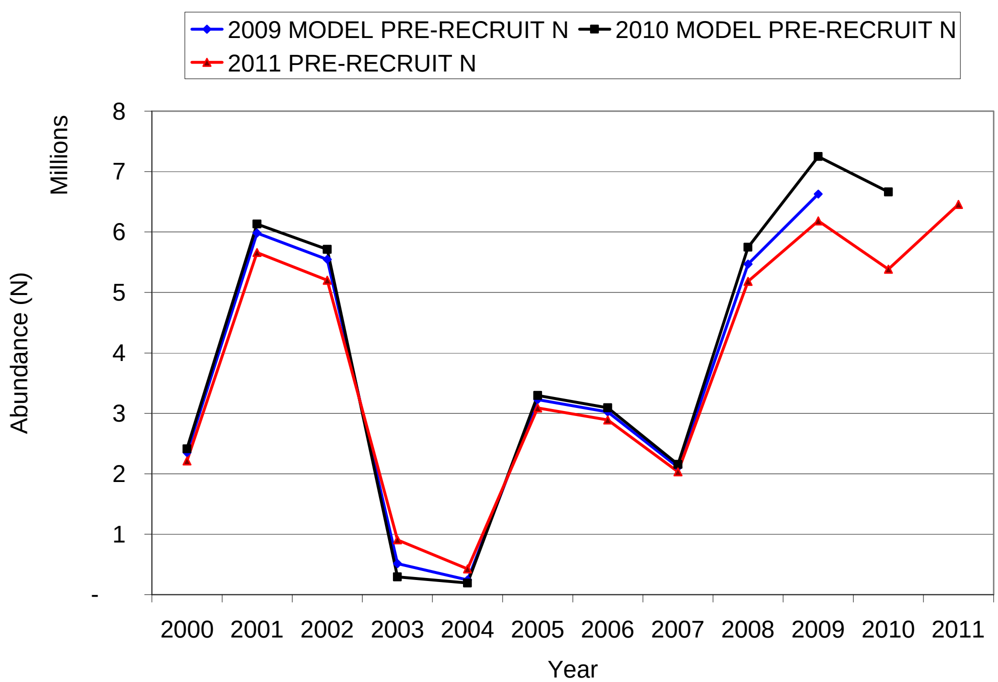


Figure 15. Retrospective analysis of upper Chesapeake Bay post-recruit white perch estimates from Catch Survey Analysis.

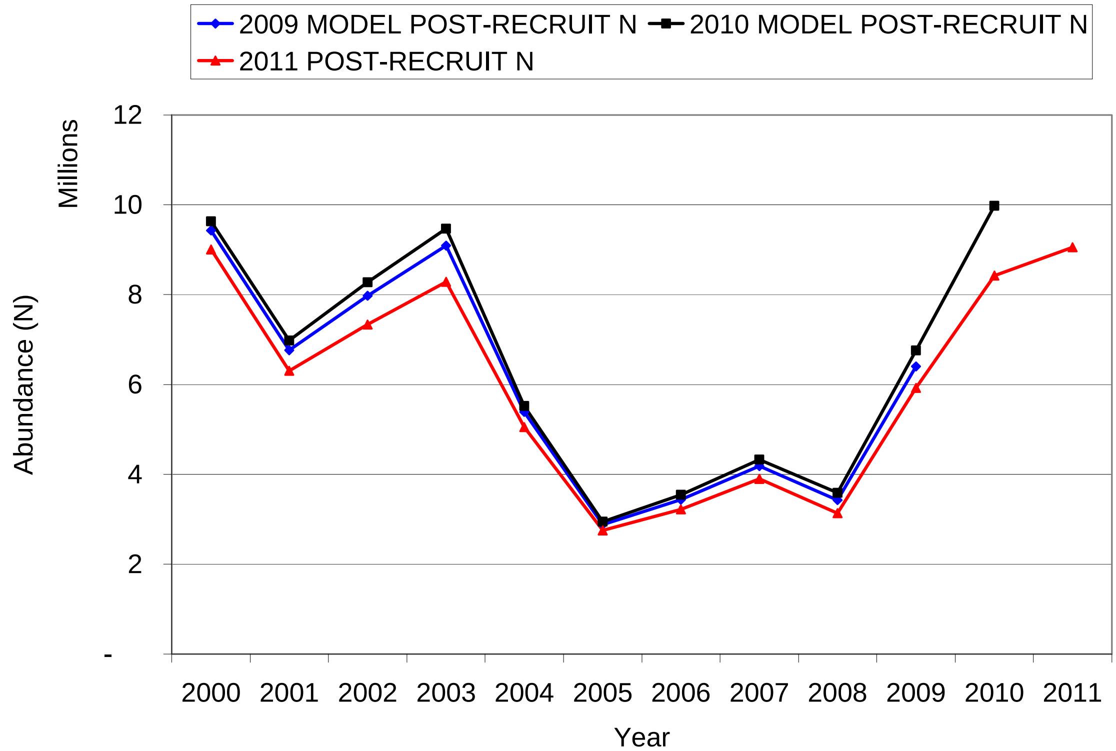


Figure 16. Retrospective analysis of upper Chesapeake Bay instantaneous fishing mortality estimates of white perch from Catch Survey Analysis.

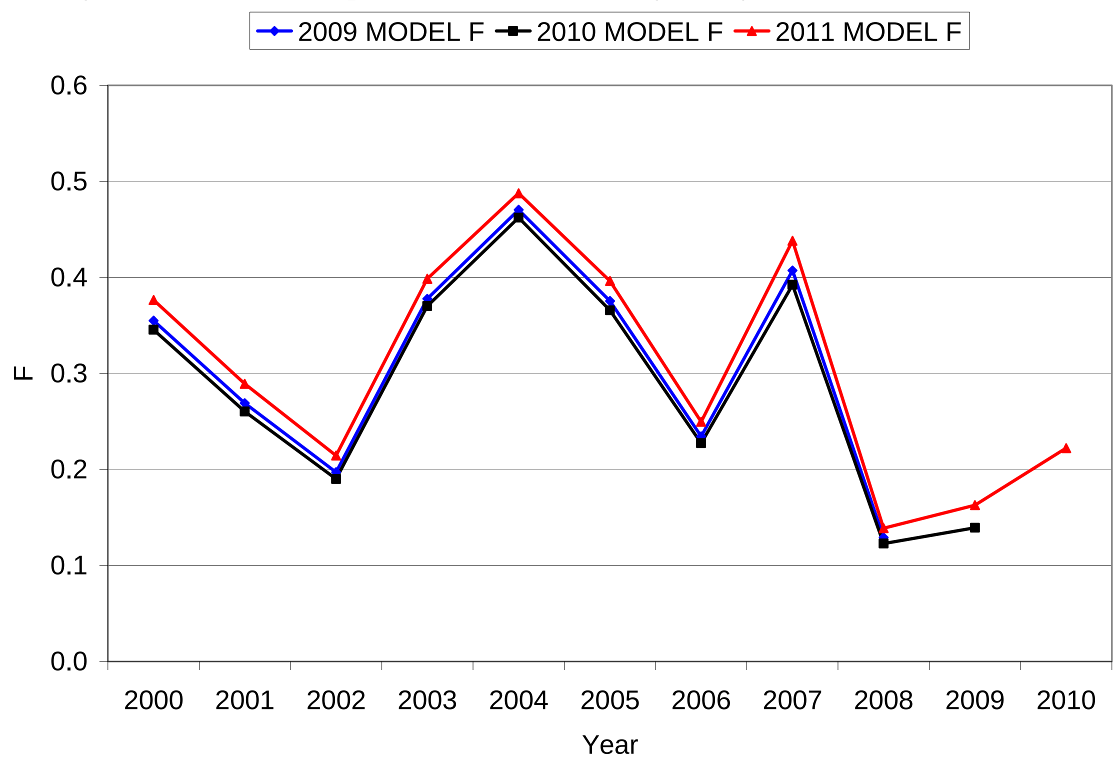


Figure 17. Estimated Choptank River white perch removals (commercial and recreational), 2000 – 2010.

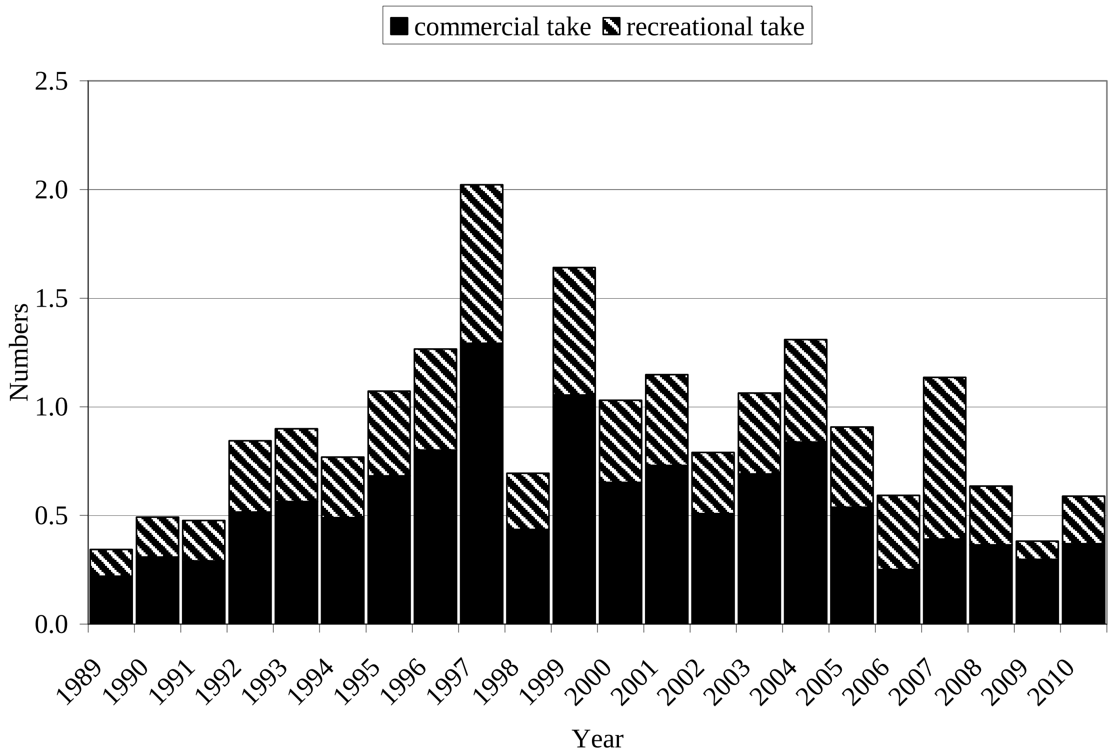


Figure 18. Observed and expected Choptank River pre-recruit white perch fyke indices, 1989—2010.

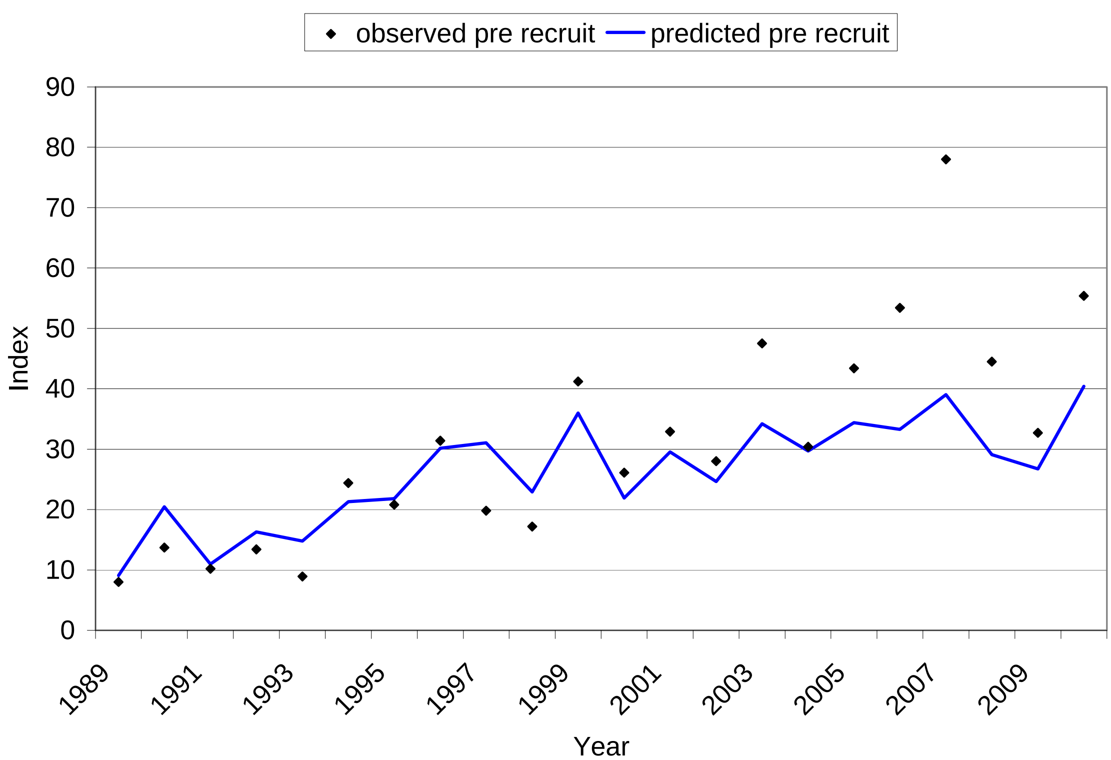


Figure 19. Observed and expected Choptank River post-recruit white perch fyke indices, 1989—2011.

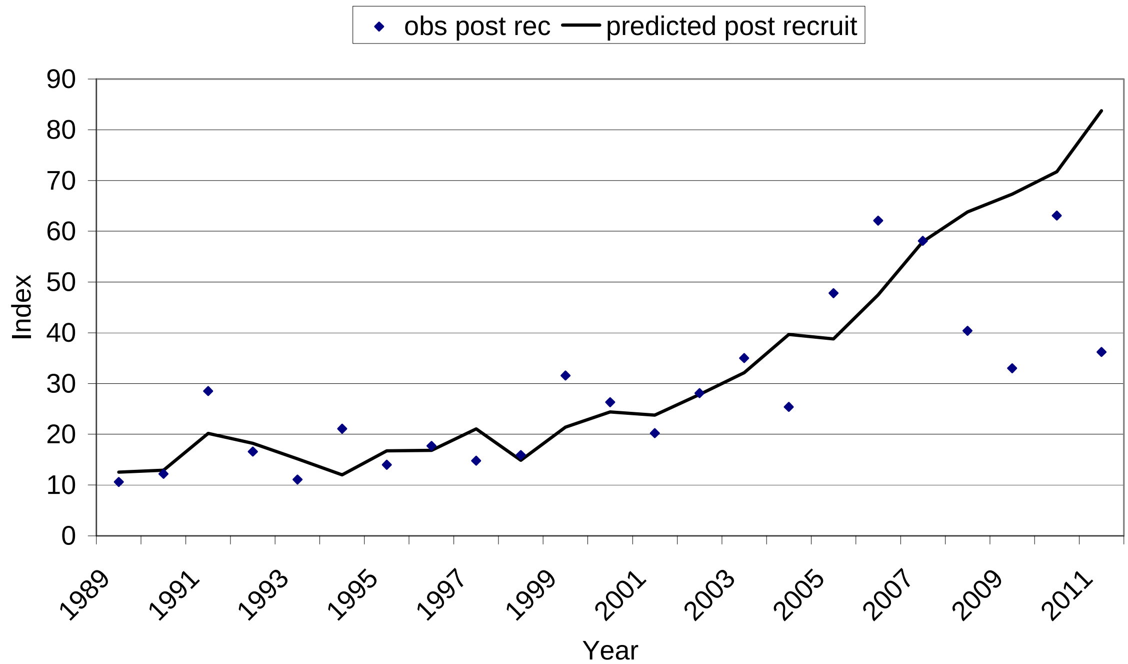


Figure 20. Estimated population abundance of pre-recruit and post-recruit white perch in the Choptank River, 1989 – 2011.

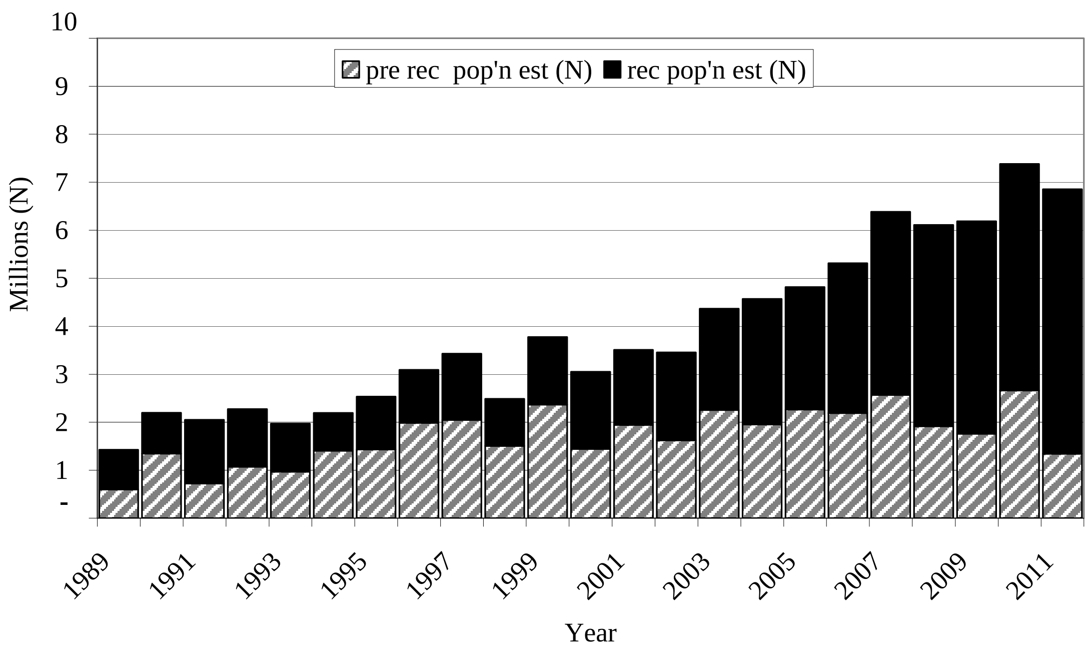


Figure 21. Instantaneous fishing mortality (F) of Choptank River white perch and proposed biological reference points for F, 2000—2010.

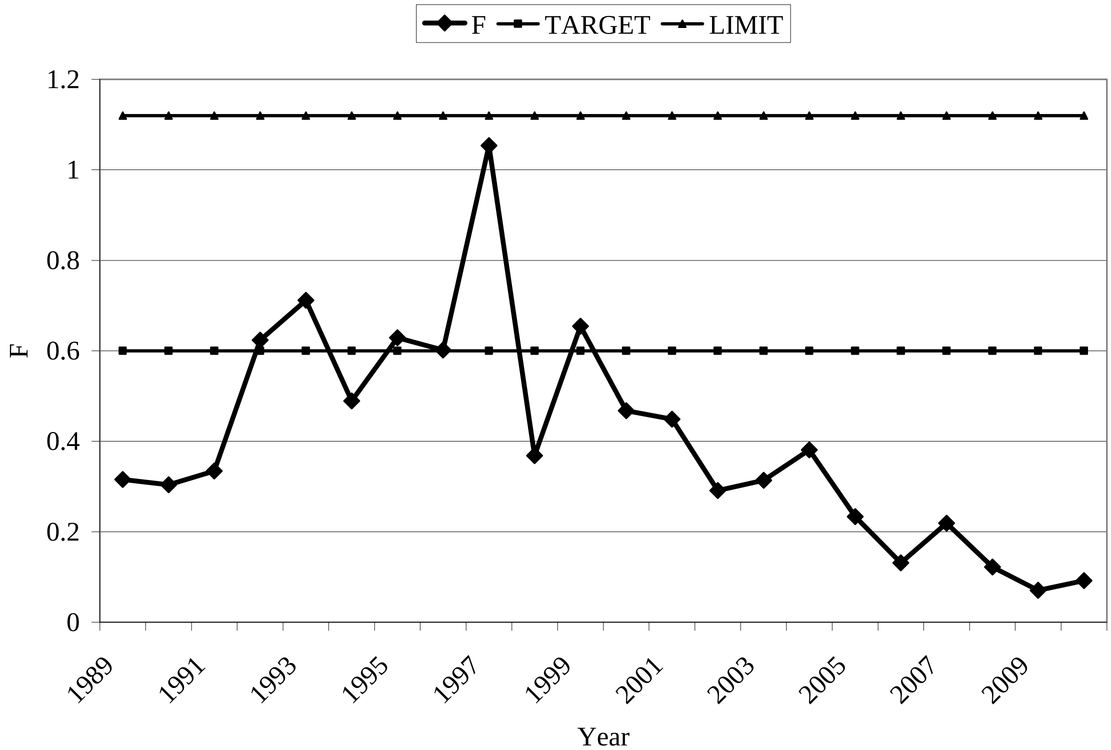


Figure 22. Pre-recruit residuals from Catch Survey Analysis of Choptank River white perch.

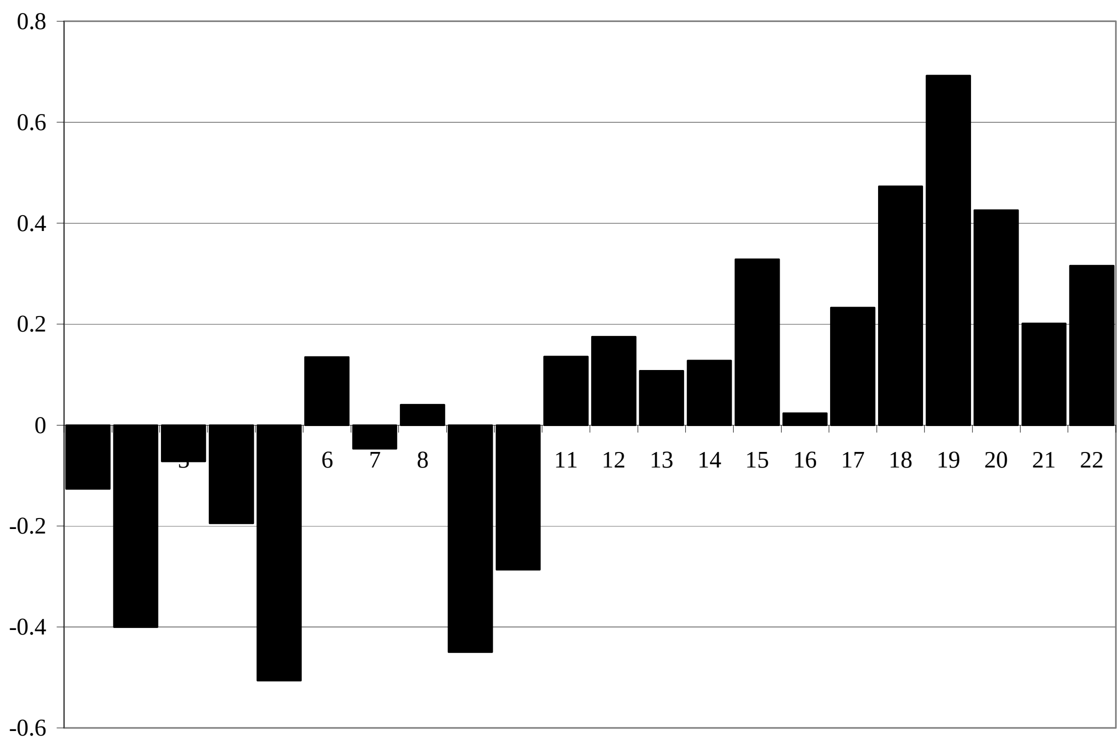


Figure 23. Post-recruit residuals from Catch Survey Analysis of Choptank River white perch.

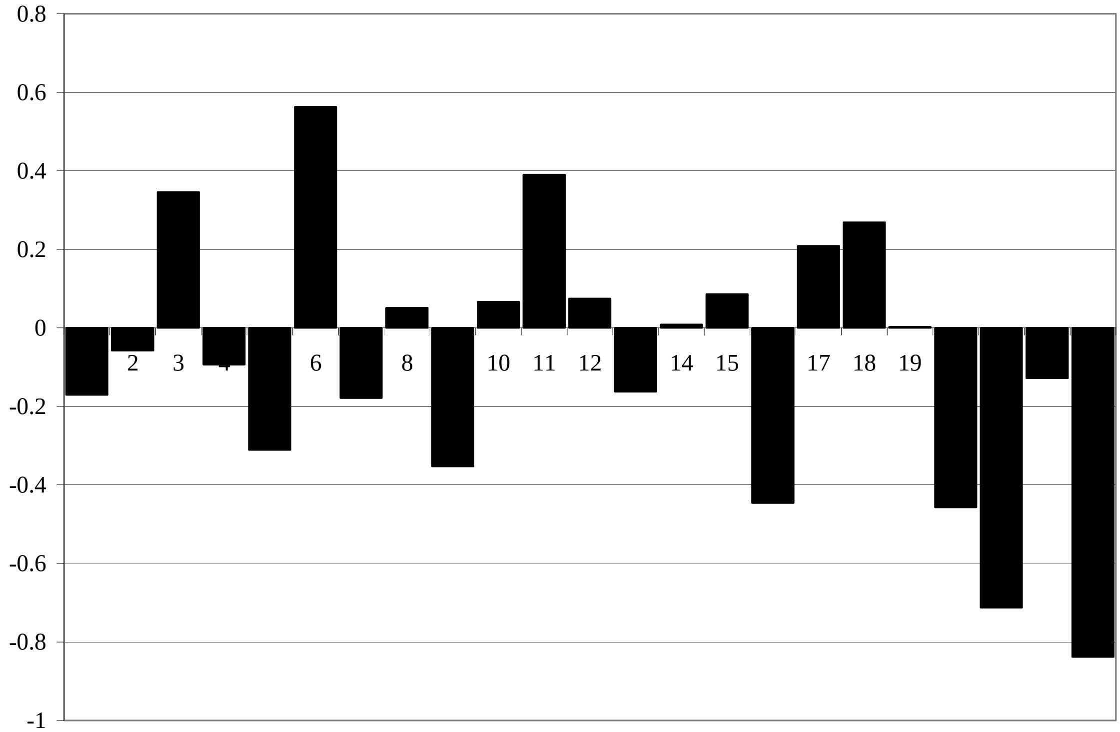


Figure 24. Bootstrap derived confidence intervals (80 %) for Choptank River pre-recruit white perch.

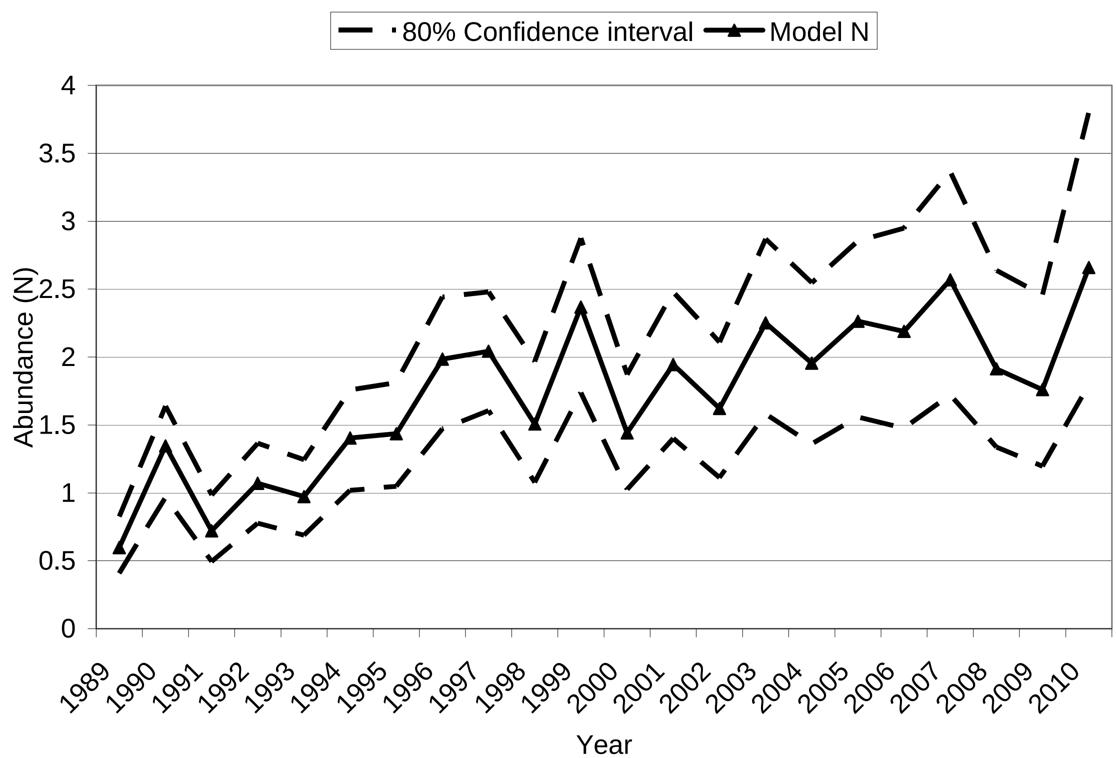


Figure 25. Bootstrap derived confidence intervals (80 %) for Choptank River post-recruit white perch.

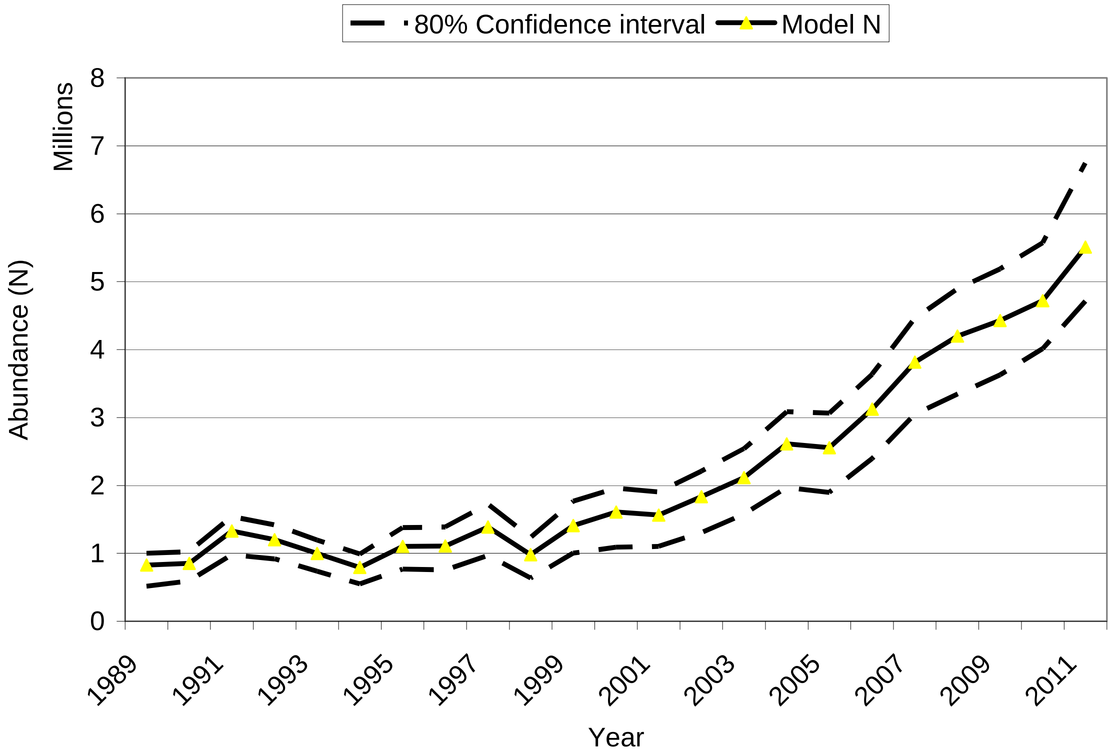


Figure 26. Retrospective analysis of Choptank River pre-recruit white perch estimates from Catch Survey Analysis.

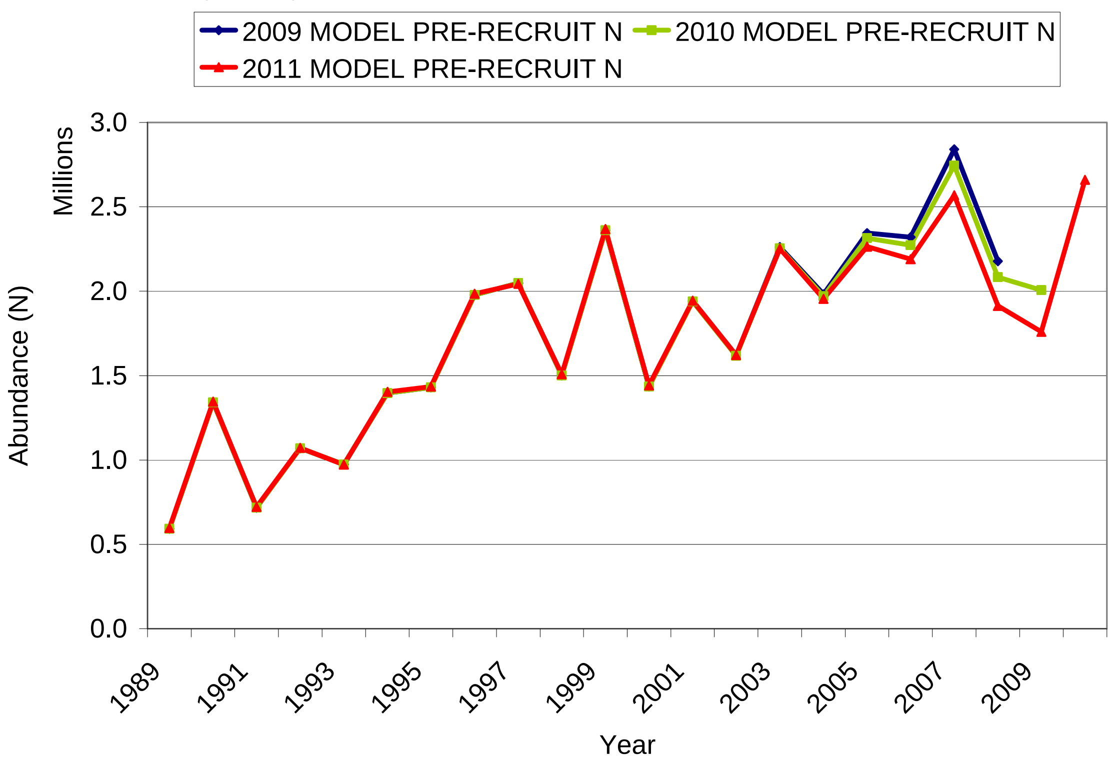


Figure 27. Retrospective analysis of Choptank River post-recruit white perch estimates from Catch Survey Analysis.

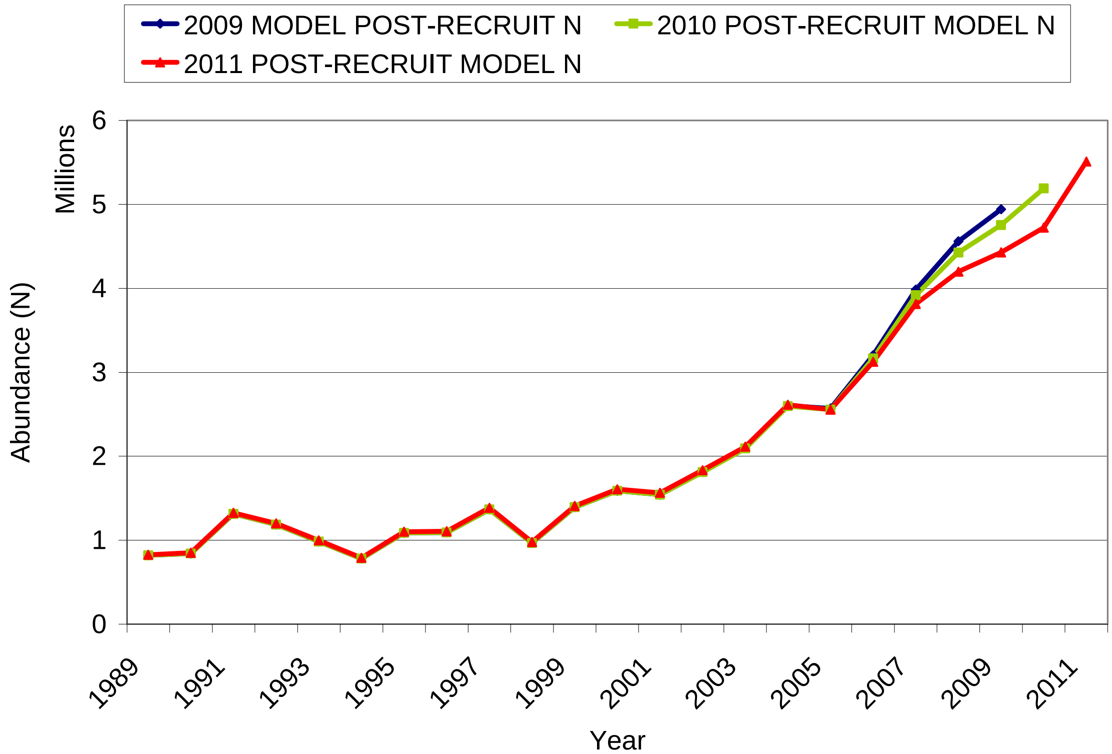


Figure 28. Retrospective analysis of Choptank River instantaneous fishing mortality estimates of white perch from Catch Survey Analysis.

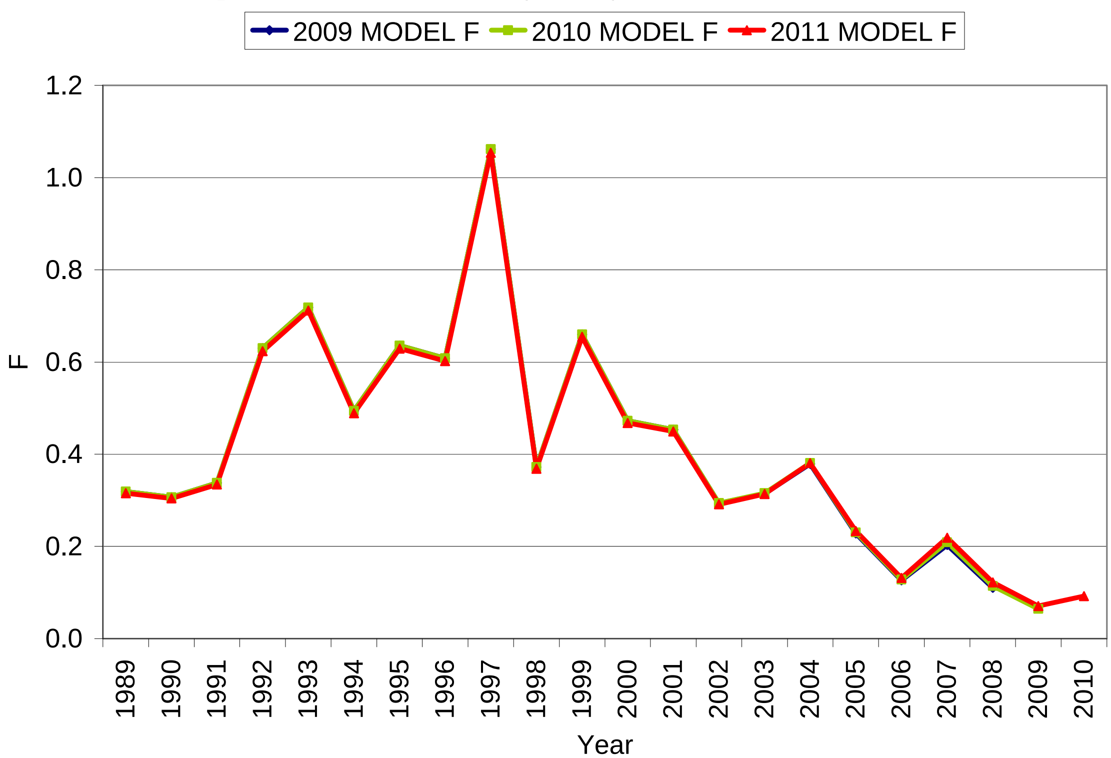


Figure 29. Lower Chesapeake Bay fishery dependent white perch fyke net index, 1980 – 2010. Horizontal line = time-series average.

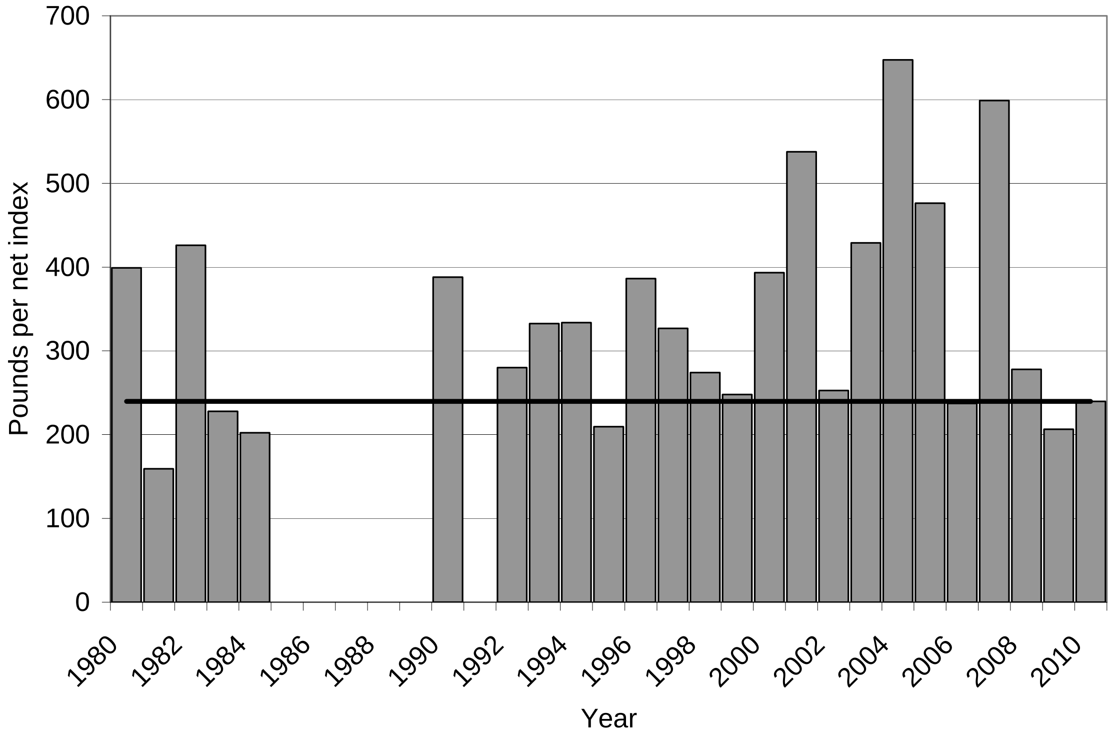


Figure 30. Lower Chesapeake Bay fishery dependent white perch pound net index, 1981 – 2010. Horizontal line = time-series average.

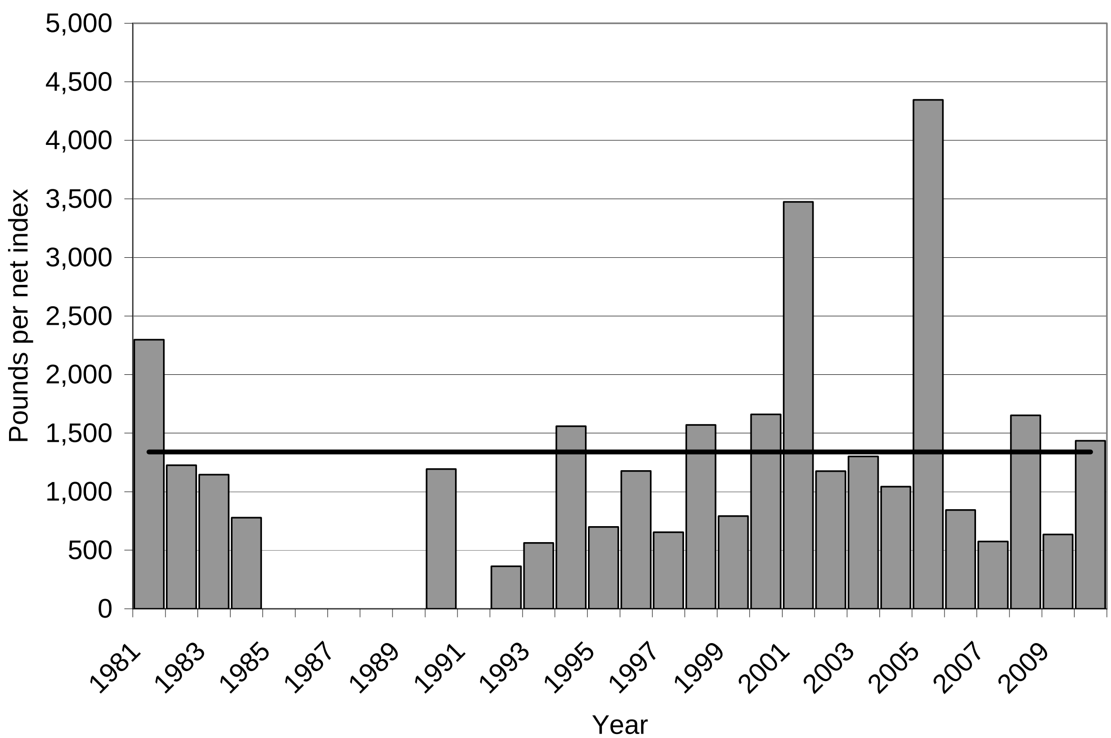


Figure 31. Lower Chesapeake Bay fishery dependent white perch gill net index, 1980 – 2010. Horizontal line = time-series average.

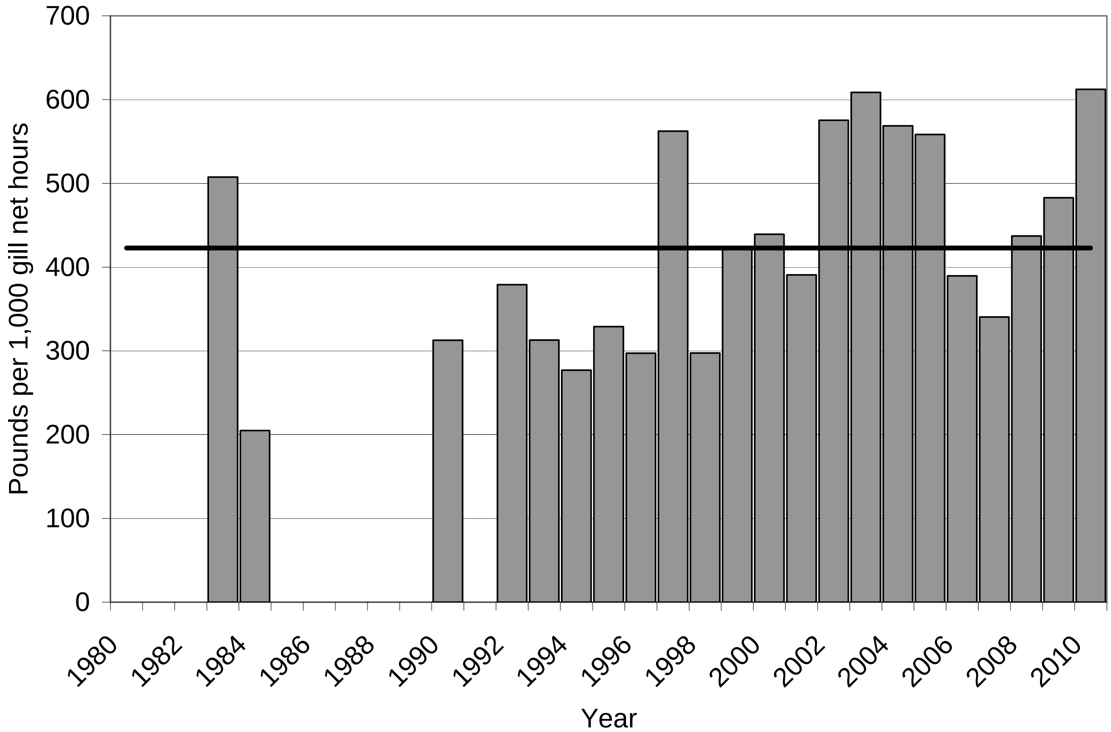


Figure 32. Potomac River fishery independent gill net survey white perch index, 1985—2010. Horizontal line = time-series average.

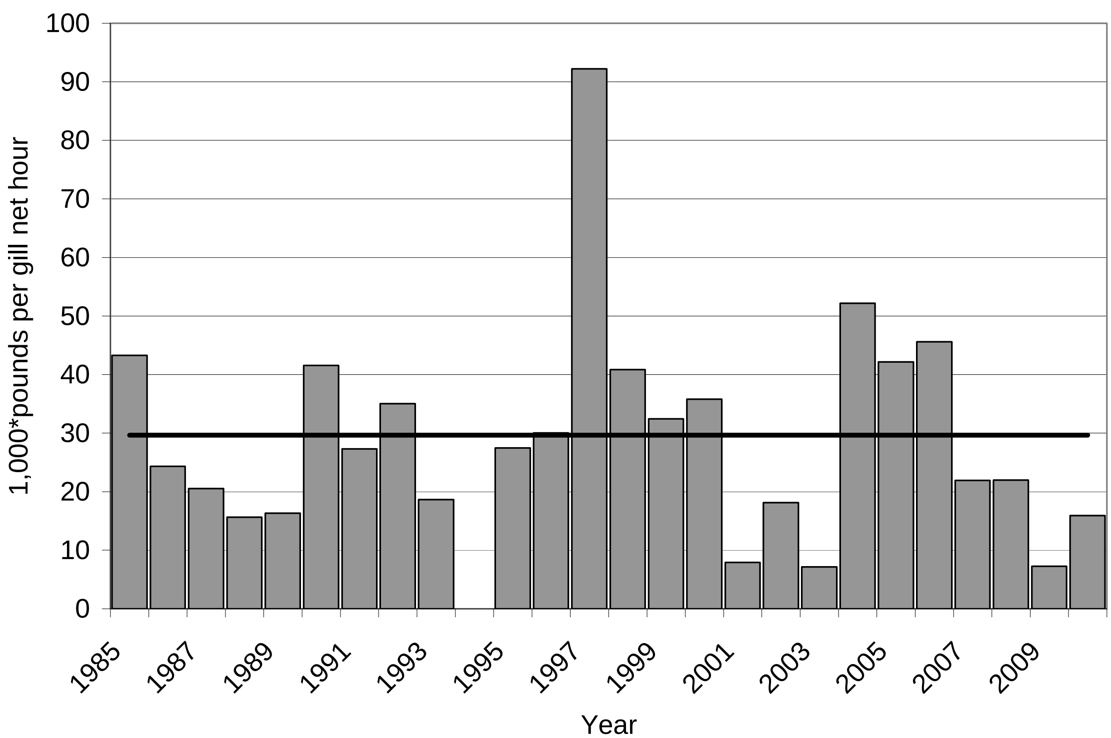
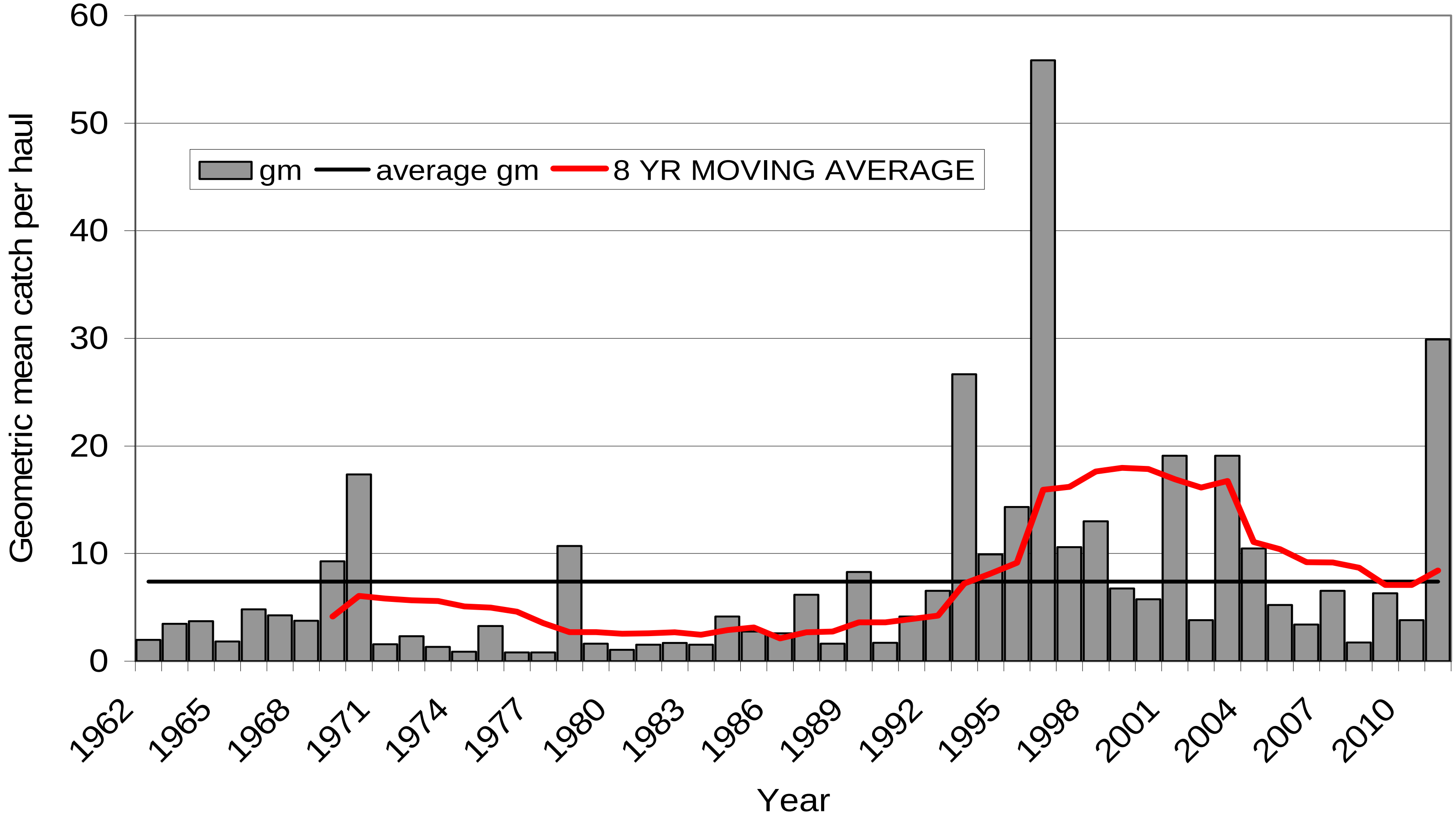


Figure 33. Lower Chesapeake Bay young-of-year white perch seine index, 1962 – 2011.



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, survey biologists independently sampled ichthyoplankton. Biologists also worked with commercial fishermen to collect sex, age and stock composition data and to estimate abundance of adult American shad, hickory shad and river herring in the Nanticoke River. 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 to five times per week (Figure 1). In 2011, this hook and line survey was conducted from 10 May through 18 May. 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.

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 recaptured 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 returning American shad.

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 and hickory shad catch and hours spent fishing. A voluntary logbook survey also provided location, catch and hours spent fishing for American and hickory shad in the Susquehanna River for each participating angler. Nine anglers returned logbooks in 2011.

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 (2004-2011) 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 and two commercial fyke nets were surveyed for American shad, hickory shad and river herring between 2 March and 29 April 2011 (Figure 2). Fish captured from these nets were sorted according to species and transferred to the survey boat for processing. All nets were sampled one to two days per week during the 40-day 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 twice per week from 1 April to 29 April 2011 in the lower Nanticoke River, and 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 (J. Mowrer, MDNR pers. comm.; 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 biweekly in the Chester River from 18 July to 28 September 2011 with a 30.5 m x 1.2 m x 6.4 mm mesh haul seine and a 16’ headrope bottom trawl. 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. 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.

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. American shad scales 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. 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, and 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 $\alpha = 0.05$.

Mean length-at-age was calculated by sex for American shad captured by hook and line at the Conowingo Dam, and for alewife and blueback herring from the Nanticoke River. Linear regressions were used to examine trends in American shad and alewife and blueback herring mean lengths by age and sex over time (1980-2011 and 1989-2011, respectively) for ages with consistent representation.

Speir and Mowrer's (1987) maturity schedule calculation was used to determine the percentage of alewife and blueback herring age at maturity by sex in the Nanticoke River. This schedule was calculated as:

$$AG_m = AG_r + 1/ AG_n + 1$$

where AG_m is the percent of an age group that is mature, AG_r is the number of repeat spawners in the next oldest age group, and AG_n is the total number of fish in the oldest age group.

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 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 both the roving creel survey and the shad logbooks.

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 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, predation by striped bass 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 an annually proportional consumption of American shad by striped bass, proportional bycatch of American shad in the Atlantic herring fishery, and correct adult American shad turbine mortality estimates. The SPM required an initial population estimate in 1985, which was set as the 1985 Petersen statistic (calculation described above).

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).

American and hickory shad fisheries are closed in Maryland, but river herring fisheries were open until 26 December 2011. Therefore, river herring natural mortality (M) was estimated using Hoenig's equation (Hoenig 1983):

$$\ln(M) = 1.46 - 1.01 [\ln(t_{max})]$$

where t_{max} is the maximum age observed over the time series. Because Z is the sum of M and fishing mortality (F), an estimate of F was obtained by subtraction. To estimate the minimum total losses of adult American shad in Maryland waters, commercial landings, commercial and recreational bycatch, and EFL and WFL mortalities were considered.

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 baywide, 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 alosine eggs and/or larvae were found in 32.9% of the ichthyoplankton tows (n = 73). Salinity at tow stations ranged from 0.1 to 3.5 ppt. The continued presence of fertilized eggs and/or larvae provides evidence of successful alosine reproduction in the Nanticoke River.

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 1:2.28. Of the 197 fish sampled by this gear, 172 were successfully scale-aged (Table 1). Males were present in age groups 4-6 and females were found in age groups 4-7. The 2006 year-class (age 5) was the most abundant for both sexes, accounting for 50% of males and 52.5% of females (Table 1). Twenty-eight percent of males and 24.6% of females were repeat spawners. The arcsine-transformed proportion of these repeat spawners (sexes combined) has significantly increased over the time series (1984-2011; r^2 = 0.46, P < 0.001; Figure 5). Male American shad generally return to the Susquehanna River at an earlier age than females (1980-2011; Table 2). Mean length-at-age for females is greater than the corresponding mean length-at-age for males (Table 2); mean length has significantly decreased for male American shad at ages 4-6 and for female American shad at ages 4-7 since 1980 (Table 3; Figures 6, 7). The majority of the declines in mean length occurred in the beginning of the time series, with more recent values becoming fairly stable. Of the 135 adult American shad otoliths collected from the WFL at Conowingo Dam in 2011, 61.5% were classified as non-hatchery fish (M. Hendricks PA Fish and Boat Comm., pers. comm. 2011).

The male-female ratio for adult American shad captured in the Nanticoke River was 2.48:1. Of the 76 American shad collected from the Nanticoke pound and fyke nets in 2011, 63 were subsequently aged (Table 1). Males were present in age groups 3-6 and females were found in age groups 4-7. The most abundant year-classes by sex were the 2007 year-class (age 4) for males (54.3%) and the 2006 year-class (age 5) for females (52.9%; Table 1). Thirteen percent of males and 29.4% 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, despite the decrease in repeat spawners observed in 2011 (1988-2011; r^2 = 0.38, P = 0.001; Figure 8). Fifty-five adult American shad otoliths collected from the Nanticoke River were sent to DE DFW for OTC analysis. Fifty-one of the 55 scales were readable, and results indicated that 84.2% were non-hatchery fish (M. Stangl, pers. comm.).

The male-female ratio for adult American shad captured in the Potomac River was 0.76:1. Of the 58 American shad collected, 56 were successfully aged (Table 1). Males were present in age groups 3-6 and females were present in age groups 4-7. The most abundant year-classes by sex were the 2006 year-class (age 5) for males (33.3%) and the 2005 year class (age 6) for females (40.6%). Only 8.3% of males were repeat spawners; in contrast, 43.8% 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 (2002-2011; r^2 = 0.064, P = 0.48; Figure 9).

Adult Relative Abundance

Sampling at the Conowingo Dam was restricted in 2011 due to heavy rains and high river flows. Only 197 adult American shad were sampled from the Conowingo tailrace over 7 sampling days; 125 of these fish were captured by MDNR staff from a boat and the remaining 72 were captured by shore anglers. MDNR staff tagged 196 (99.5%) of the sampled fish. To remain consistent with historical calculations, only the 125 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.

Operation of the EFL was delayed for most of April 2011 due to river water temperatures being less than 50.0°F and the onset of high river flows in excess of 100,000 cubic feet per second (cfs). The EFL operated for only 15 days between 25 April and 19 May. EFL operations ceased on 19 May due to the lack of successful American shad passage upstream at the Holtwood Dam facility. Of the 20,571 American shad that passed at the EFL, 87% (17,900 fish) passed between 11 May and 16 May. Peak passage was on 14 May when 5,013 American shad were recorded. Twenty of the American shad counted at the EFL counting windows were identified as being tagged in 2011; only 4 fish passed that were tagged in 2010 (Table 4).

In 2011, the Conowingo WFL operated for 15 days between 13 May and 5 June. The 3,074 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 16 May when 1,185 American shad were collected. Four of the six tagged American shad recaptured by the WFL in 2011 were fish tagged in 2011; the other two recaptured fish were tagged in 2010 (Table 4).

The Petersen statistic estimated 186,330 American shad in the Conowingo Dam tailrace in 2011, and the SPM estimated a population of 103,500 fish. Despite differences in yearly estimates, the overall population trends derived from each method are similar (Figure 10). Specifically, SPM estimates declined from 2001 to 2007 and increased from 2008 to 2011.

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 have significantly increased over the time series (1984-2011; $r^2 = 0.21$, $P = 0.01$), although abundance is variable from 2005-2011 and remains below the high indices observed from 1999 to 2002 (Table 5; Figure 11). The Conowingo Dam combined lift GM CPUE significantly increased over the time series (1980-2011; $r^2 = 0.38$, $P < 0.001$); however, the GM CPUE decreased steadily from 2002 to 2008 before increasing slightly from 2009 through 2011 (Figure 12). The Potomac River CPUE increased significantly over the time series (1996-2011; $r^2 = 0.27$, $P = 0.04$), although CPUE in each of the past 3 years has been lower than the CPUE in 2007 and 2008 (Figure 13).

Due to the limited number of sampling days in 2011, we did not obtain enough data from the angler-based roving creel survey at the Conowingo Dam tailrace to calculate CPAH. Data from previous years are included in Table 6. Although American shad CPAH calculated from shad logbook data decreased significantly over the time series (1999-2011; $r^2 = 0.38$, $P = 0.03$), CPAH has remained relatively level since 2008 (Table 7).

Nanticoke River pound and fyke net GM CPUE have both shown no trend over the time series (1988-2011; $r^2 = 0.15$, $P = 0.07$, Figure 14; $r^2 = 0.0007$, $P = 0.90$, Figure 15). In 2011, American shad abundance increased in the pound net, but decreased in fyke nets.

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in Z = 1.40 (A = 73.5%). The Nanticoke River mortality estimate was Z = 1.09 (A = 66.4%). Estimated American shad mortalities (in numbers) from Maryland waters are presented in Table 8.

Juvenile Abundance

No juvenile American shad were captured in seines or trawls in the Chester River in 2011 (Table 9). Data provided by the EJFS indicated that while baywide juvenile American shad production increased in 2011, it remained below the time series high of 2007 (Figure 16). Similarly, juvenile American shad indices in the upper Chesapeake Bay increased over the past two years but still remained low (Figure 17). The Nanticoke River indices have been low since the late 1970s and remain low (Figure 18). In contrast, Potomac River indices were low in the 1980s but peaked in 2004 and remain above the time series mean (Figure 19). 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 = 12) was not large enough to draw meaningful conclusions about sex and age composition. However, 1,648 hickory shad were sampled by the brood stock collection survey in Deer Creek. The male-female ratio was 1.41:1. Of the total fish captured by this survey, 216 were successfully aged. Males were present in age groups 3-7 and females were found in age groups 3-8. The most abundant year-classes by sex were the 2008 year-class (age 3) for males (34.9%) and the 2007 year-class (age 4) for females (33.3%; Table 10). Hickory shad sampled from 2004 to 2011 ranged from 2 to 9 years of age, with ages 3 through 8 present every year (Table 11). The arcsine-transformed proportion of these repeat spawners (sexes combined) has not changed significantly over the time series (2004-2011; r^2 = 0.028, P = 0.69; Figure 20). However, the percent of repeat spawning males in 2011 (63.6%, Table 10) was lower than the percent of repeat spawning males in 2010 (74.4%), and the total percent of repeat spawners in 2011 (68.5%) was the second lowest total percent from 2004 to 2011 (Table 12).

Relative Abundance

Shad logbook data indicated that hickory shad CPAH did not vary significantly over the time series (1998-2011; $r^2 = 0.11$, $P = 0.25$); however, hickory shad CPAH increased in 2011 and is the highest it has been since 2007 (Table 13). On the Nanticoke River no hickory shad were encountered in fyke nets, and only eight fish were captured by pound nets.

Mortality

Total instantaneous mortality in the Susquehanna River (Deer Creek) was estimated as Z = 0.67. This estimate is less than the 2010 Z estimate (Z = 0.74). Annual mortality was estimated as A = 48.8%.

Juvenile Abundance

During the 2011 sampling in the Chester River, 9 juvenile hickory shad were collected in the seine and 6 juvenile hickory shad were collected in the trawl (Table 9). Although the number of hickory shad captured was low, the 2011 catch was the highest for both seines and trawls over the past five years.

Alewife and Blueback Herring

Sex, Age and Stock Composition

The 2011 male-female ratio for Nanticoke River alewife herring was 1:2.7. Of the 185 alewives sampled, 181 were subsequently aged. Age groups 3-8 were present and the 2007 year-class (age 4, sexes combined) was the most abundant, accounting for 32.0% of the total catch. Females were most abundant at age 6 and males at age 4 (Table 14). The 2011 male-female ratio for Nanticoke River blueback herring was 1:1.22. Of the 131 blueback herring sampled, 122 were subsequently aged. Blueback herring were present from ages 3-7 and the 2007 year-class (age 4, sexes combined) was the most abundant, accounting for 54.9% of the sample. Both males and females were most abundant at age 4 (Table 14).

For the Nanticoke River, 64.6% of alewife herring and 45.1% of blueback herring were repeat spawners (sexes combined; Table 14). There was no trend in the arcsine-transformed proportion of alewife herring repeat spawners over the time series (1989-2011; $r^2 < 0.001$ P = 0.93); however, blueback herring exhibited a decreasing trend over the same time series (1989-2011; $r^2 = 0.56$, $P < 0.001$; Figure 21). Using Speir and Mowrer's (1987) maturity schedule calculation, 75.5% of male alewife and 83.9% of male blueback herring were mature by age 4; 56.8% of female alewife and 84.8% of female blueback herring were mature by age 4.

Mean length-at-age for female alewife herring from the Nanticoke River are greater than the corresponding male mean length-at-age (Table 15). Female blueback herring mean length-at-age are also greater than the corresponding male mean length-at-age, except at age 3 (Table 16). Age structure appears to be truncating, especially for blueback herring. The mean length for female alewife herring at ages 6 and 7 have decreased significantly since 1989, but mean length has not changed significantly for male alewife herring over this same time series (Table 17; Figures 22, 23). Mean length for female blueback herring at ages 5 and 6 and males blueback herring at age 5 have significantly decreased since 1989 (Table 17; Figures 24, 25). Observed declines in mean length generally occur toward the end of the time series.

Adult Relative Abundance

The GM CPUE for Nanticoke River alewife herring captured in fyke nets has varied without trend over the time series (1990-2011; r^2 = 0.14, P = 0.09; Figure 26); in contrast, the GM CPUE for blueback herring has decreased over the time series (1989-2011; r^2 = 0.64, P < 0.001; Figure 27). The total reported Nanticoke River commercial river herring landings (species combined) have varied without trend since 1980 (r^2 = 0.12, P < 0.06) but have remained below the time series mean (49,701 pounds) since 2004 (Figure 28). Total commercial landings for river herring in Maryland waters remain at multi-decadenal lows (Figure 29); there is no differentiation between species in the commercial river herring fishery.

Mortality

Total instantaneous mortality for Nanticoke River alewife herring (sexes combined) was estimated as Z = 0.73 (A = 51.8%). Because the historical t_{max} for alewife herring from the Nanticoke River is 10 years, M = 0.42 and F = 0.31. Total instantaneous mortality for Nanticoke River blueback herring (sexes combined) was Z = 1.01 (A = 63.6%). Because the historical t_{max} for Nanticoke River blueback herring is 10 years, M = 0.42 and F = 0.59.

Juvenile Abundance

Juvenile seining in the Chester River produced 19 juvenile alewife herring and 1,214 juvenile blueback herring. A majority of the blueback herring catch (96%) occurred during the three August seining dates. Six alewife and no blueback herring were encountered by trawls (Table 9). Data provided by the EJFS indicated that the Nanticoke River alewife herring juvenile GM CPUE decreased in 2011, and that the blueback herring juvenile index was the highest it has been since 2001 (Figure 30). The baywide juvenile index for alewife herring remains low;

however, the 2011 blueback herring juvenile index was the eighth highest since 1969 (Figure 31).

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).

American shad abundance has increased at the Conowingo Dam in the Susquehanna River since the 1980s: hook and line CPUE (1984-2011) and combined lift CPUE (1980-2011) have increased over their respective time series. 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. However, the Petersen statistic and SPM estimates of American shad abundance at the Conowingo Dam tailrace (1986-2011) support the observed increasing trends in CPUE. Despite the overall increasing trends, a period of decreasing abundance is evident in all estimates between 2002 and 2007, including logbook CPAH. The Potomac River CPUE is also increasing (1996-2011); 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 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 has increased over time. 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, 26% of aged American shad at the Conowingo Dam were repeat spawners in 2011, and, on average, 20% of aged fish were repeat spawners over the past five years. The same trend occurs in the Potomac River: the average percent of repeat spawners was 17% in the 1950s (Walburg and Sykes 1957), and is currently 28.6%.

Total instantaneous mortality rates for Chesapeake Bay stocks of American shad in 2011 (Conowingo Dam tailrace and Nanticoke River) are within the range of reported Z estimates from other studies (ASMFC 2007). These 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 at least 2005. New sampling strategies and/or locations will be considered to better meet the objectives of this project in the future. Baywide juvenile American shad indices increased slightly in 2011, as did juvenile indices in the upper Chesapeake Bay. Indices in both locations have been low for the past four years, and have also been declining in the Potomac River since 2004. 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 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 2011: 20 hickory shad were counted at the EFL counting window, which is more than three times the previous high in 2002. 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 (1998-2011). 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. Catch rates have been quite variable overall, but CPAH in 2011 was the fourth highest CPAH of the 14 year time series.

Hickory shad age structure has remained consistent, with a wide range of ages and a high percentage of older fish. Ninety percent of hickory shad from the upper Chesapeake Bay spawned by age four, and this stock generally consists of few virgin fish (Richardson et. al 2004). Repeat spawning has remained relatively consistent over the 2004-2011 time series, with the percent of repeat spawners ranging between 67-89%.

Hickory shad relative abundance metrics in the Nanticoke River (pound and fyke net CPUE) are tenuous, presumably because of hickory gear avoidance. Therefore, relative abundance analysis for hickory shad in the Nanticoke River was discontinued. Extensive spring electrofishing conducted in the Nanticoke River watershed concluded that stocks have increased in this system from 2002 to 2009 (Richardson 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, alewife herring are “fully exploited” and blueback herring are “partially exploited” in the Nanticoke River (ASMFC 1990). A new stock assessment is scheduled to be released in 2012, but preliminary results indicate that river herring commercial landings are at historic lows and that mean length and age have decreased on a coastwide level (ASMFC 2008). This assessment corresponds with the low commercial river herring landings observed in both the Nanticoke River and the entire state of Maryland, as well as the low indices of abundance in the Nanticoke River. 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 baywide has generally been erratic, with frequent declines in abundance to very low levels. In 2011, alewife herring CPUE decreased for juveniles in both of these regions, while blueback herring CPUE increased. According to the 2011 EJFS survey of Maryland, juvenile alewife herring indices decreased in all regions except for the Choptank, Potomac and Patuxent Rivers; blueback herring juvenile indices increased in all of the sampled regions, with the Patuxent River having the highest index since the survey in this river began in 1983 (Project 2, Job 3, Task 3). The higher indices for blueback herring correspond with the high number of juvenile blueback herring observed in the Chester River in 2011.

Because river herring landings along the east coast have decreased significantly, ASMFC passed Amendment 2 of the ASMFC Interstate Fishery Management Plan for American Shad and River Herring. This amendment required states to develop and implement a sustainable fishery plan for jurisdictions wishing to maintain an open commercial or recreational fishery. Due to the decline in and persistently low levels of river herring in Maryland, a moratorium on the possession of river herring went into effect on 26 December 2011. It is no longer legal to possess river herring within the jurisdiction of Maryland unless the possessor has a bill of sale identifying the river herring were legally caught in waters not under Maryland jurisdiction. The expectation is that the 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. 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 2011.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	0	0	0	0	0	0
4	18	0	14	0	32	0
5	25	7	64	10	89	17
6	7	7	40	16	47	23
7	0	0	4	4	4	4
8	0	0	0	0	0	0
Totals	50	14	122	30	172	44
Percent Repeats	28.0%		24.6%		25.6%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	6	0	0	0	6	0
4	25	0	4	0	29	0
5	12	4	9	3	21	7
6	3	2	3	1	6	3
7	0	0	1	1	1	1
8	0	0	0	0	0	0
Totals	46	6	17	5	63	11
Percent Repeats	13.0%		29.4%		17.5%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	7	0	0	0	7	0
4	7	0	3	0	10	0
5	8	0	12	2	20	2
6	2	2	13	8	15	10
7	0	0	4	4	4	4
8	0	0	0	0	0	0
Totals	24	2	32	14	56	16
Percent Repeats	8.3%		43.8%		28.6%	

Table 2. Mean length-at-age by sex for American shad sampled at the Conowingo Dam, 1980-2011.

Males

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1980		381	427	462	495					
1981	292	363	417	470						
1982		384	411	460	458					
1983				413						
1984		332	381	434	470					
1985		360	387	426	450					
1986		324	395	430	440					
1987	238	341	379	431	433					
1988	288	332	395	440	490					
1989		347	371	435	473					
1990	250	345	389	419	473	495				
1991	250	343	378	412	445	480	530			
1992	275	319	375	406	430	451				
1993		325	371	414	434	455				
1994		351	381	409	449	505	540			
1995		336	375	412	452	483				
1996		340	379	427	456					
1997		341	378	420	458	472				
1998	280	346	387	411	442	455				
1999	287	338	371	405	427			460		
2000		344	381	417	452	450				
2001		350	394	419	456	476				
2002		346	379	419	454	455				
2003		361	389	415	450	447		480		
2004		350	392	424	440					
2005		355	383	416	447	467	485			
2006		348	388	416	461	468				
2007		358	387	418	448	465	503			
2008		355	383	414	434					
2009		351	380	400	429					
2010		361	392	413	436	445				
2011			384	417	445					

Table 2 continued. Mean length-at-age by sex for American shad sampled at the Conowingo Dam, 1980-2011.

Females

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1980			447	479	528	524				
1981			464	487	512					
1982			436	471	527					
1983			472	459	470					
1984			403	468	492	551				
1985		349	424	457	496	511				
1986		387	431	470	518					
1987		387	413	466	505					
1988		384	428	466	524					
1989		340	421	474	521	526				
1990		360	414	444	493	538				
1991			410	436	471	516	550			
1992			407	434	457	496	540			
1993			399	427	454	476	493			
1994			411	433	470	484				
1995			408	437	471	502	485			
1996		355	416	447	484	499				
1997		362	402	451	481	506	516			
1998			419	439	466	485	525	562		
1999		420	406	440	463	473		540	505	
2000			415	446	478	497	498		540	
2001		359	421	449	479	502	523			
2002			423	455	482	504	509			
2003			420	442	473	500		510		
2004			429	454	473	515	518	520		
2005			427	452	474	498	546			
2006		354	419	446	467	483	494	519		
2007			422	447	471	502	514	526		
2008			419	442	469	484		506		
2009			415	442	467	483	503			
2010			422	444	464	502	515			
2011			417	442	462	485				

Table 3. Regression statistics for American shad mean length by age and sex over time (1980-2011). Only ages with consistent representation over time were considered. Bolded values indicate significant changes in mean length-at-age over time.

	Males				Females			
Age	N	Slope	r^2	*P*	N	Slope	r^2	*P*
3	30	-0.003	< 0.001	0.9925				
4	31	-0.523	0.1431	**0.0359**	32	-0.625	0.1361	**0.0377**
5	32	-1.121	0.4188	**< 0.001**	32	-0.945	0.3688	**< 0.001**
6	30	-0.884	0.2255	**0.0080**	32	-1.607	0.4762	**< 0.001**
7					26	-1.290	0.3403	**0.002**

Table 4. Number of recaptured American shad in 2011 at the Conowingo Dam East and West Fish Lifts by tag color and year.

East Fish Lift		
Tag Color	Year Tagged	Number Recaptured
Green	2011	20
Pink	2010	4
West Fish Lift		
Tag Color	Year Tagged	Number Recaptured
Green	2011	4
Pink	2010	2

Table 5. Catch (numbers), effort (hours fished) and CPUE from Conowingo Dam tailrace hook and line sampling for American shad, 1982-2011.

Year	Total Catch	Hours fished	CPUE	GM CPUE
1982	88	N/A	N/A	N/A
1983	11	N/A	N/A	N/A
1984	126	52	2.42	1.07
1985	182	85	2.14	1.05
1986	437	147.5	2.96	1.85
1987	399	108.8	3.67	6.71
1988	256	43	5.95	6.54
1989	276	42.3	6.52	7.09
1990	309	61.8	5	3.6
1991	437	77	5.68	5.29
1992	383	62.75	6.1	5.05
1993	264	47.5	5.56	4.8
1994	498	88.5	5.63	5.22
1995	625	84.5	7.4	7.1
1996	446	44.25	10.08	9.39
1997	607	57.75	10.51	10.2
1998	337	23.75	14.19	9.86
1999	823	52	15.83	15.94
2000	730	35.75	20.42	13.98
2001	972	65.75	14.78	15.12
2002	812	60	13.53	15.94
2003	774	69.3	11.17	9.4
2004	474	38.75	12.23	9.48
2005	412	57.92	7.11	9.2
2006	360	33.75	10.28	7.61
2007	468	52.91	8.85	8.13
2008	164	39.85	4.12	3.14
2009	668	58.5	11.42	9.38
2010	485	62	8.45	3.79
2011	125	13.5	9.26	7.67

Table 6. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2010. Due to sampling limitations, no data were available for 2011.

Year	Number of Interviews	Total Fishing Hours	Total Catch of American Shad	Mean Number of American shad caught per hour
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49
2006	78	227.3	305	1.34
2007	30	107.5	128	1.19
2008	16	32.5	24	0.74
2009	40	85.0	120	1.41
2010	36	64.0	114	1.78

Table 7. Catch (numbers), effort (hours fished) and catch per angler hour from spring logbooks for American shad, 1999-2011.

Year	Total Reported Angler Hours	Total Number of American Shad	Catch Per Angler Hour
1999	160.5	463	2.88
2000	404	3,137	7.76
2001	272.5	1,647	6.04
2002	331.5	1,799	5.43
2003	530	1,222	2.31
2004	291	1035	3.56
2005	258.5	533	2.06
2006	639	747	1.17
2007	242	873	3.61
2008	559.5	1,269	2.27
2009	378	967	2.56
2010	429.5	857	2.00
2011	174	413	2.37

Table 8. Estimated adult American shad mortalities (in numbers) in Maryland waters. Reported Conowingo Dam tailrace abundance estimates are derived from the surplus production model (SPM).

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 (SPM)
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]	4,200	Unknown	0	27,212	98,743
2011	0	5,159	1,038 [5]	4,200	Unknown	0	10,397	103,500

[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 Nanticoke River.
[3] Reported numbers were calculated by multiplying total pounds by an estimated four pounds per fish.
[4] Includes 7 West Fish Lift mortalities from day to day operations.
[5] Includes 3 West Fish Lift mortalities from day to day operations.

Table 9. Number of juvenile alosines captured by species in seines and trawls on the Chester River, 2007-2011.

Seine

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

Trawl

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

Table 10. Number of adult hickory shad and repeat spawners by sex and age sampled from the brood stock collection survey in Deer Creek in 2011.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	45	0	20	0	65	0
4	36	35	29	28	65	63
5	36	35	23	23	59	58
6	10	10	9	9	19	19
7	2	2	4	4	6	6
8	0	0	2	2	2	2
Totals	129	82	87	66	216	148
Percent Repeats	63.6%		75.9%		68.5%	

Table 11. Percent of hickory shad by age and number sampled from the brood stock collection survey in Deer Creek by year, 2004-2011.

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	

Table 12. Percent repeat spawning hickory shad (sexes combined) by year from the brood stock collection survey in Deer Creek, 2004-2011.

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

Table 13. Catch (numbers), effort (hours fished) and catch per angler hour from spring logbooks for hickory shad, 1998-2011.

Year	Total Reported Angler Hours	Total Number of Hickory Shad	Catch Per Angler Hour
1998	600.0	4,980	8.30
1999	817.0	5,115	6.26
2000	655.0	3,171	14.8
2001	533.0	2,515	4.72
2002	476.0	2,433	5.11
2003	635.0	3,143	4.95
2004	750.0	3,225	4.30
2005	474.0	2,094	4.42
2006	766.0	4,902	6.40
2007	401.0	3,357	8.37
2008	942.0	5,465	5.80
2009	561.0	2,022	3.60
2010	552.0	1,956	3.54
2011	224.3	1,802	8.03

Table 14. Number of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2011.

Alewife Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	6	0	2	0	8	0
4	17	3	41	1	58	4
5	15	15	35	33	50	48
6	11	11	42	42	53	53
7			10	10	10	10
8			2	2	2	2
9						
Totals	49	29	132	88	181	117
Percent Repeats	59.2%		66.7%		64.6%	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	8	0	1	0	9	0
4	30	4	37	5	67	9
5	13	13	20	20	33	33
6	5	5	7	7	12	12
7			1	1	1	1
8						
9						
Totals	56	22	66	33	122	55
Percent Repeats	39.3%		50.0%		45.1%	

Table 15. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2011.

Males

Year	Age									
	2	3	4	5	6	7	8	9	10	11
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					

Females

Year	Age									
	2	3	4	5	6	7	8	9	10	11
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			

Table 16. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2011.

Males

Year	Age									
	2	3	4	5	6	7	8	9	10	11
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					

Females

Year	Age									
	2	3	4	5	6	7	8	9	10	11
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				

Table 17. Regression statistics for alewife and blueback herring mean length by age and sex over time (1989-2011). Only ages with consistent representation over time were considered. Bolded values indicate significant changes in mean length-at-age over time.

Alewife	Males				Females			
Age	N	Slope	r^2	*P*	N	Slope	r^2	*P*
3	23	0.067	0.0054	0.739	21	-0.016	0.0002	0.948
4	23	-0.017	0.0353	0.391	23	-0.117	0.0232	0.488
5	23	-0.293	0.1439	0.074	23	-0.252	0.1334	0.087
6	23	-0.198	0.0552	0.281	23	-0.322	0.222	**0.029**
7					23	-0.448	0.2782	**0.010**
8					17	-0.294	0.1373	0.143

Blueback	Males				Females			
Age	N	Slope	r^2	*P*	N	Slope	r^2	*P*
3	23	-0.066	0.0035	0.788	20	-0.445	0.0836	0.216
4	23	-0.215	0.0774	0.199	23	-0.004	< 0.001	0.985
5	22	-0.380	0.2234	**0.026**	23	-0.389	0.2950	**0.007**
6	19	-0.339	0.0840	0.229	23	-0.367	0.2187	**0.024**
7					20	-0.180	0.0283	0.478

Figure 1. Conowingo Dam (Susquehanna River) hook and line sampling location for American shad in 2011.

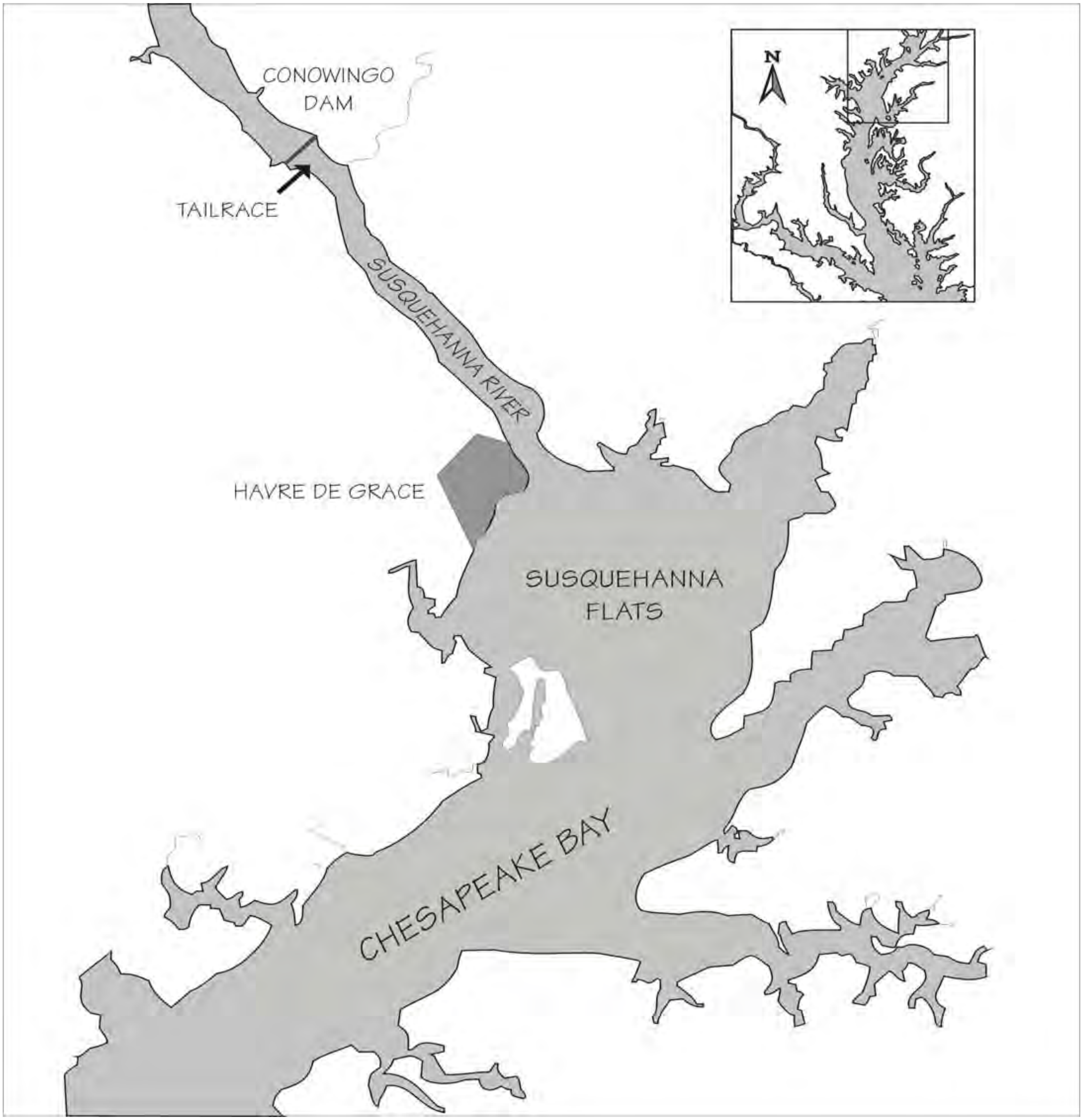


Figure 2. Nanticoke River fyke and pound net sites for adult alosine sampling in 2011.

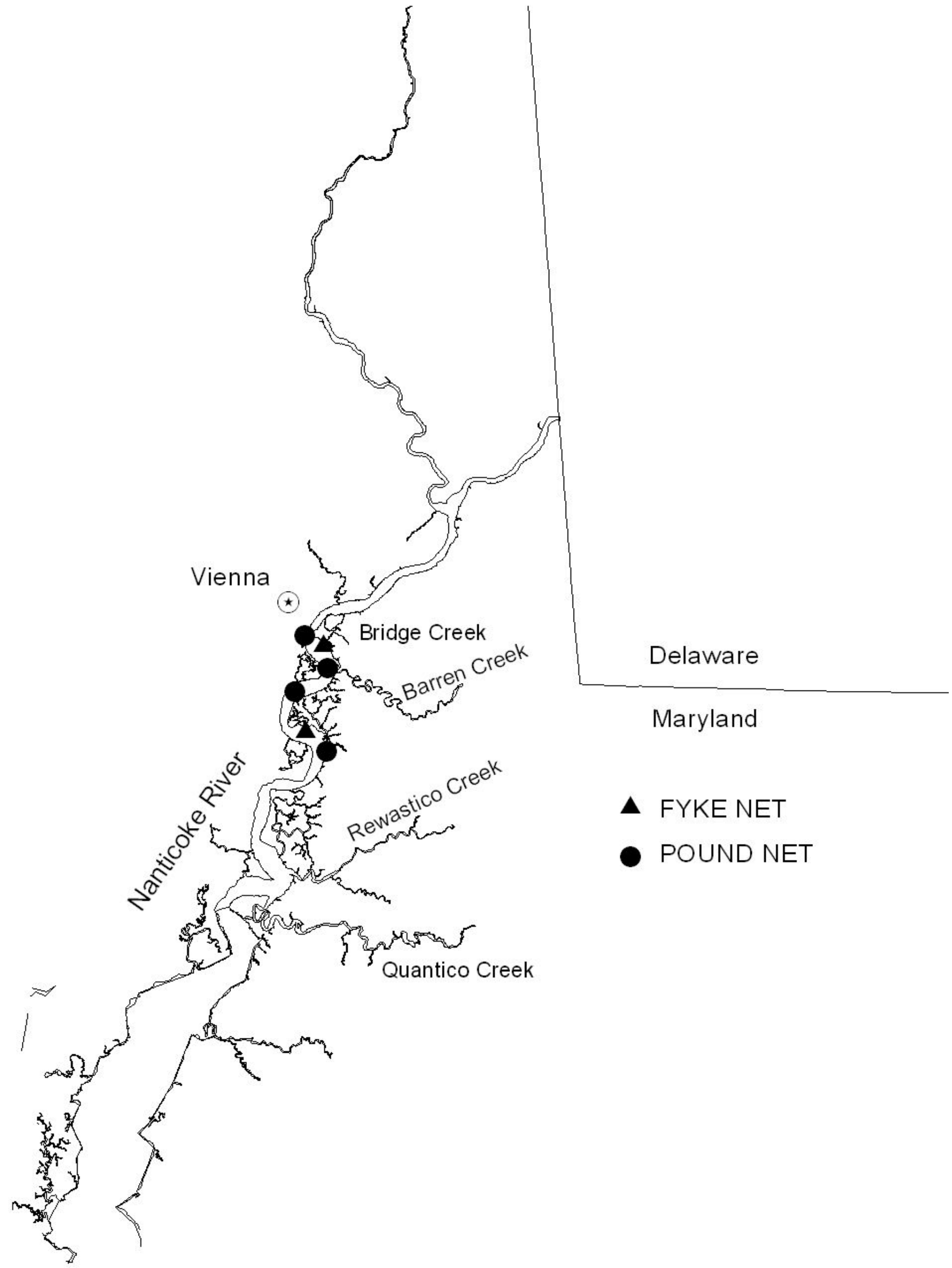


Figure 3. Nanticoke River sites for alosine ichthyoplankton sampling in 2011.

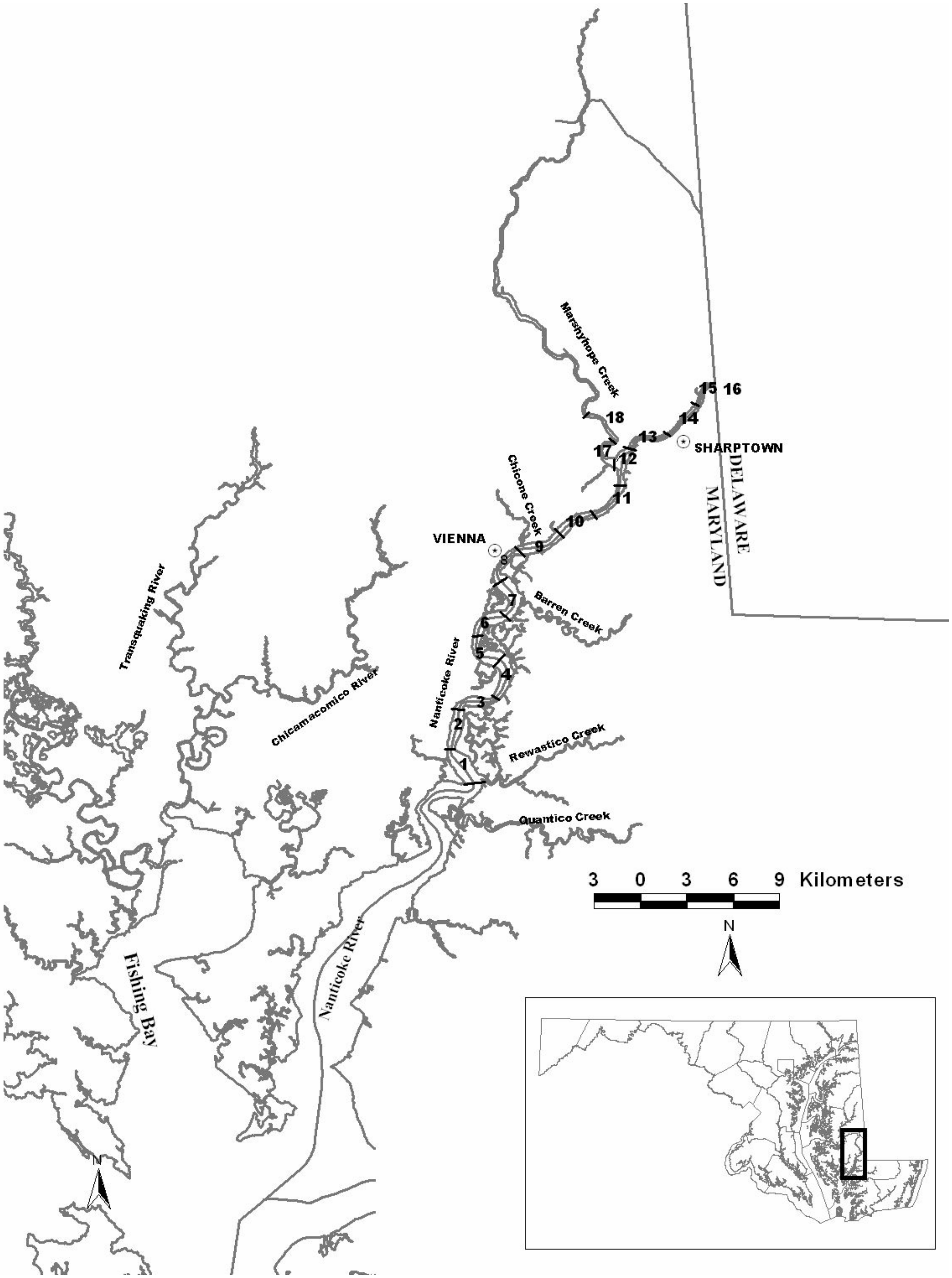


Figure 4. Chester River sampling sites for juvenile alosine species in 2011. Because each seine site was paired with a trawl site, each black circle indicates the approximate location of one seine and one trawl site.

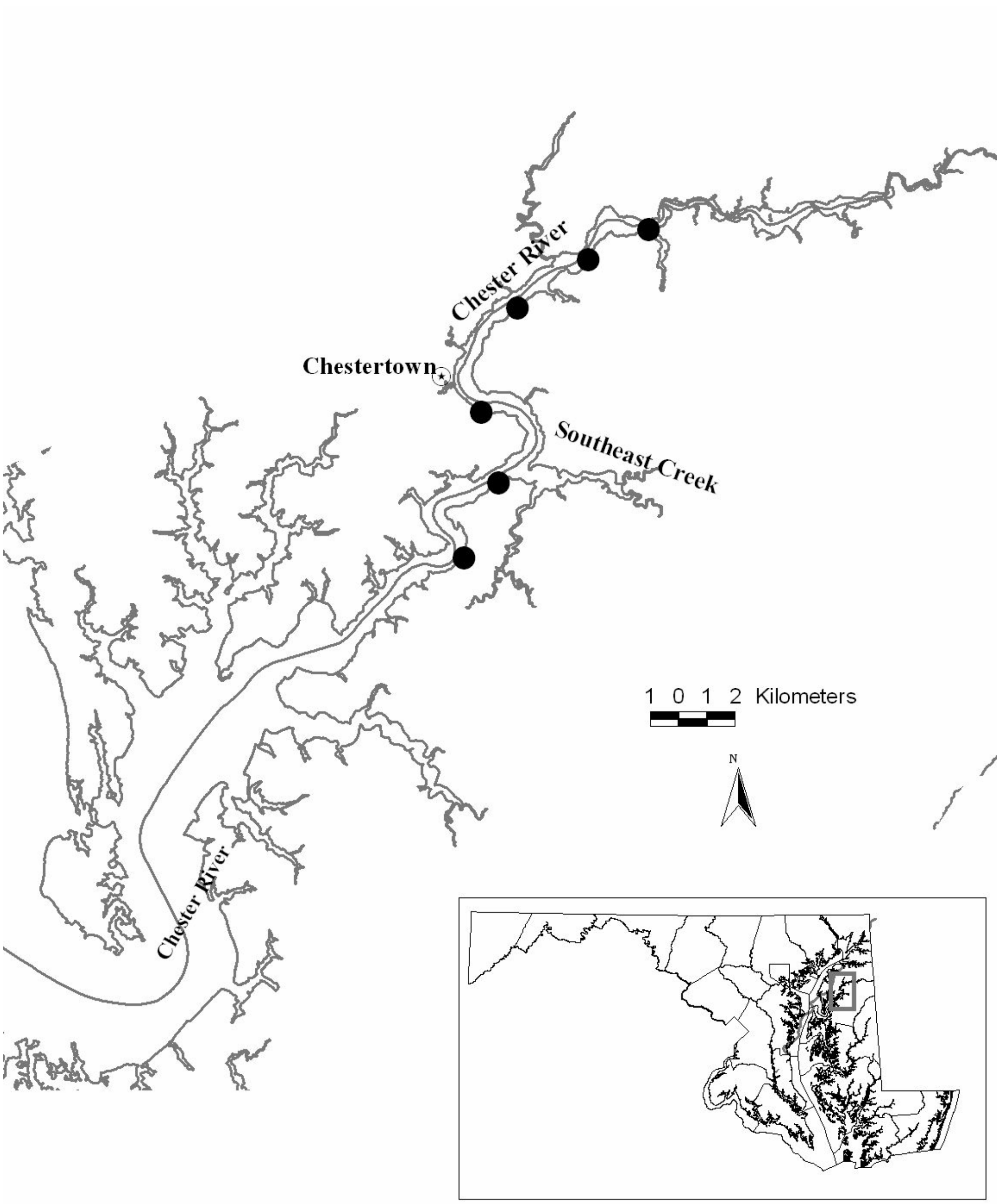


Figure 5. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2011.

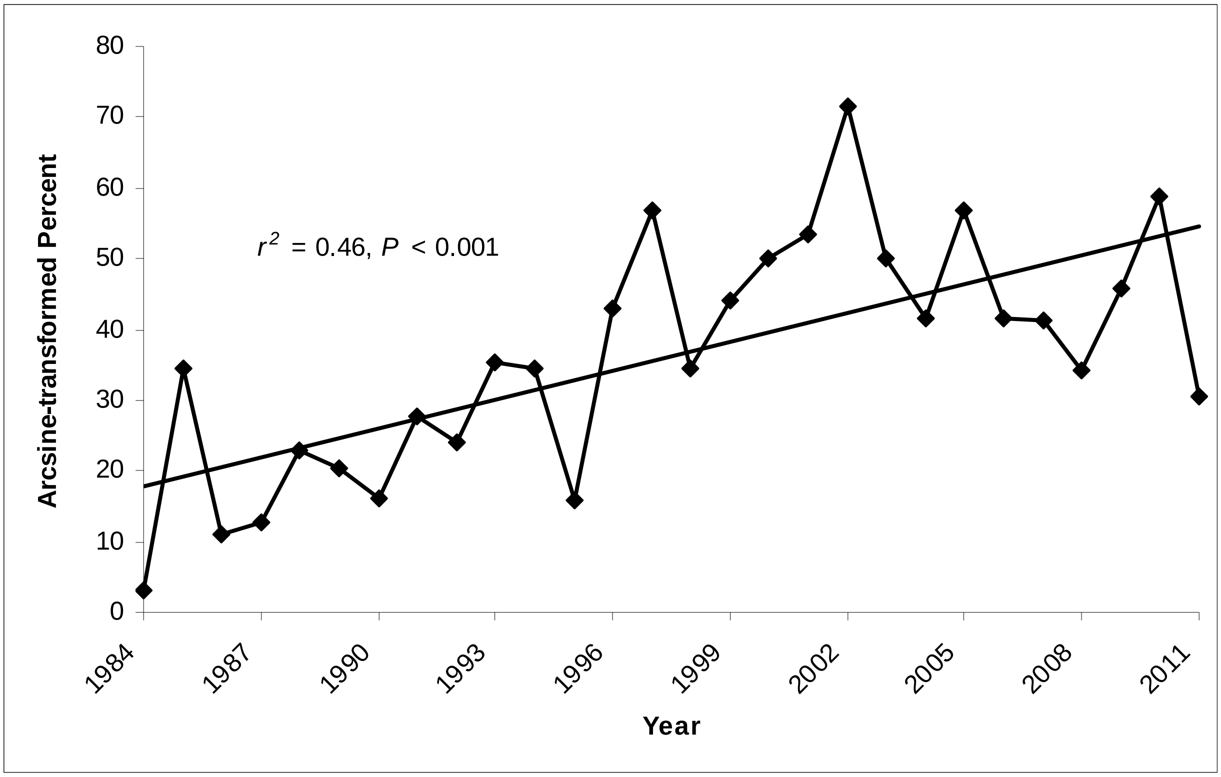


Figure 6. Mean length by age over time for male American shad sampled from the Conowingo Dam tailrace, 1980-2011. Trend lines are included for ages where mean length varies significantly over time.

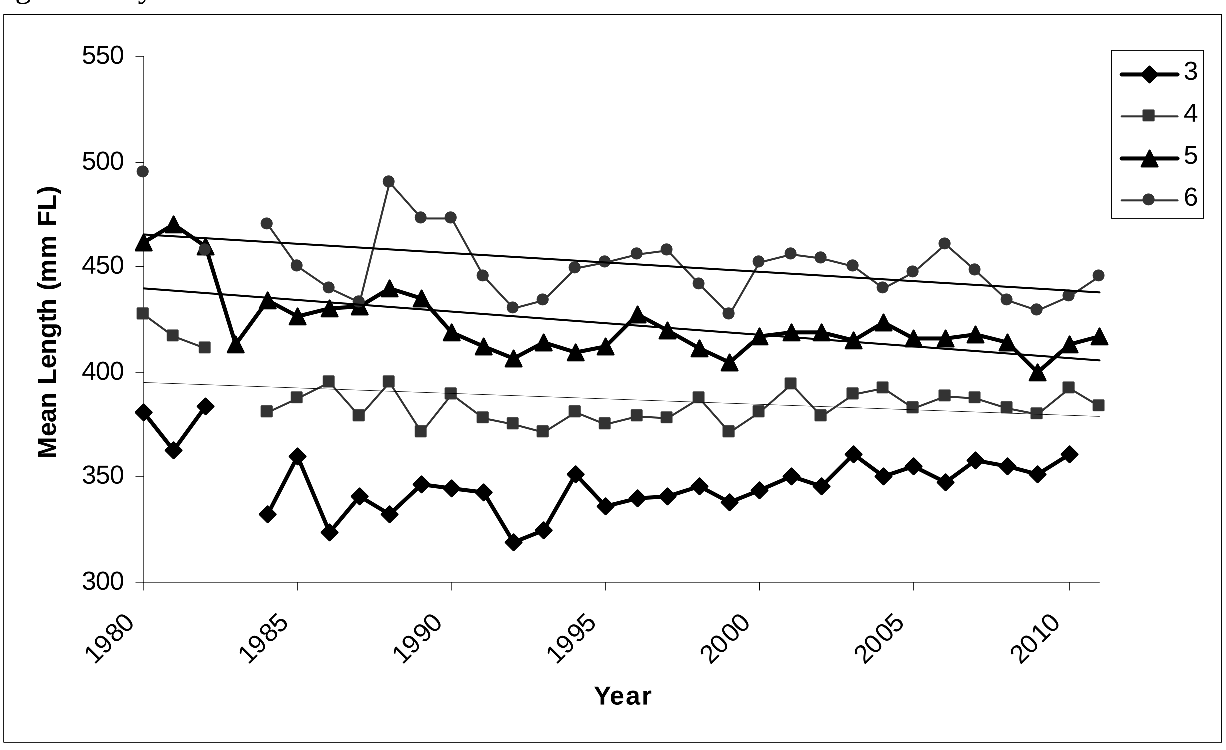


Figure 7. Mean length by age over time for female American shad sampled from the Conowingo Dam tailrace, 1980-2011. Trend lines are included for ages where mean length varies significantly over time.

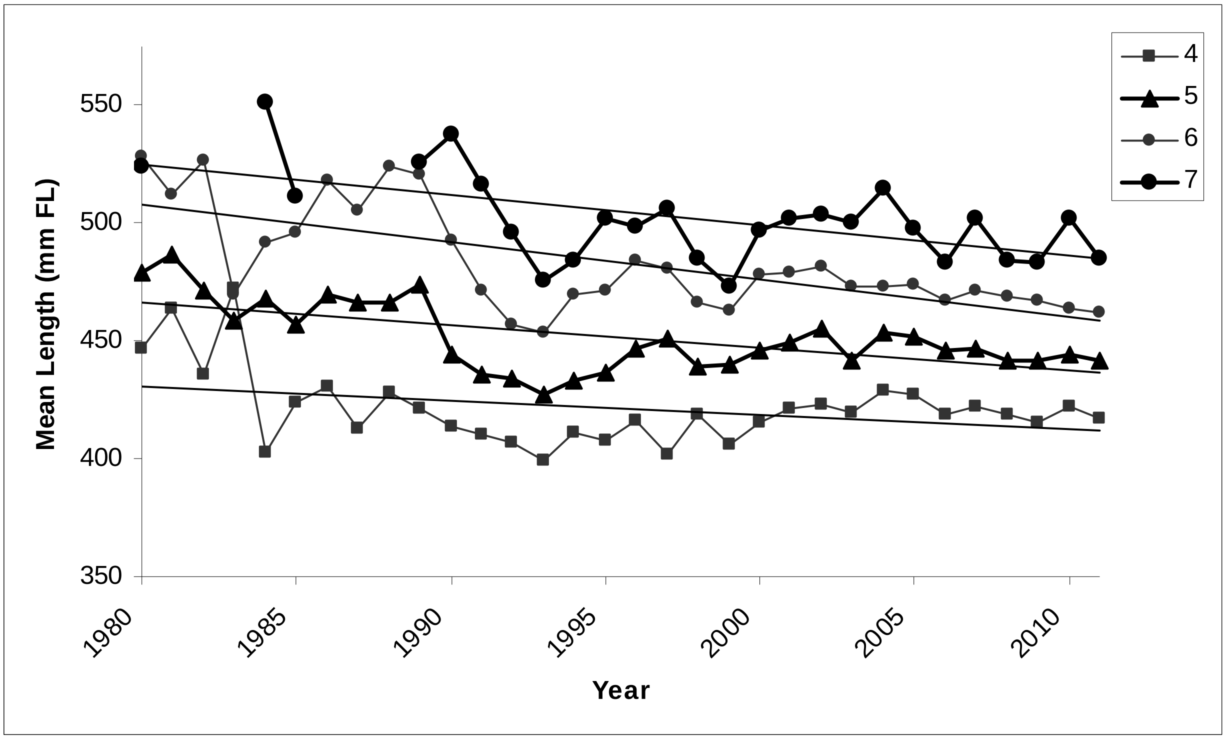


Figure 8. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River, 1988-2011.

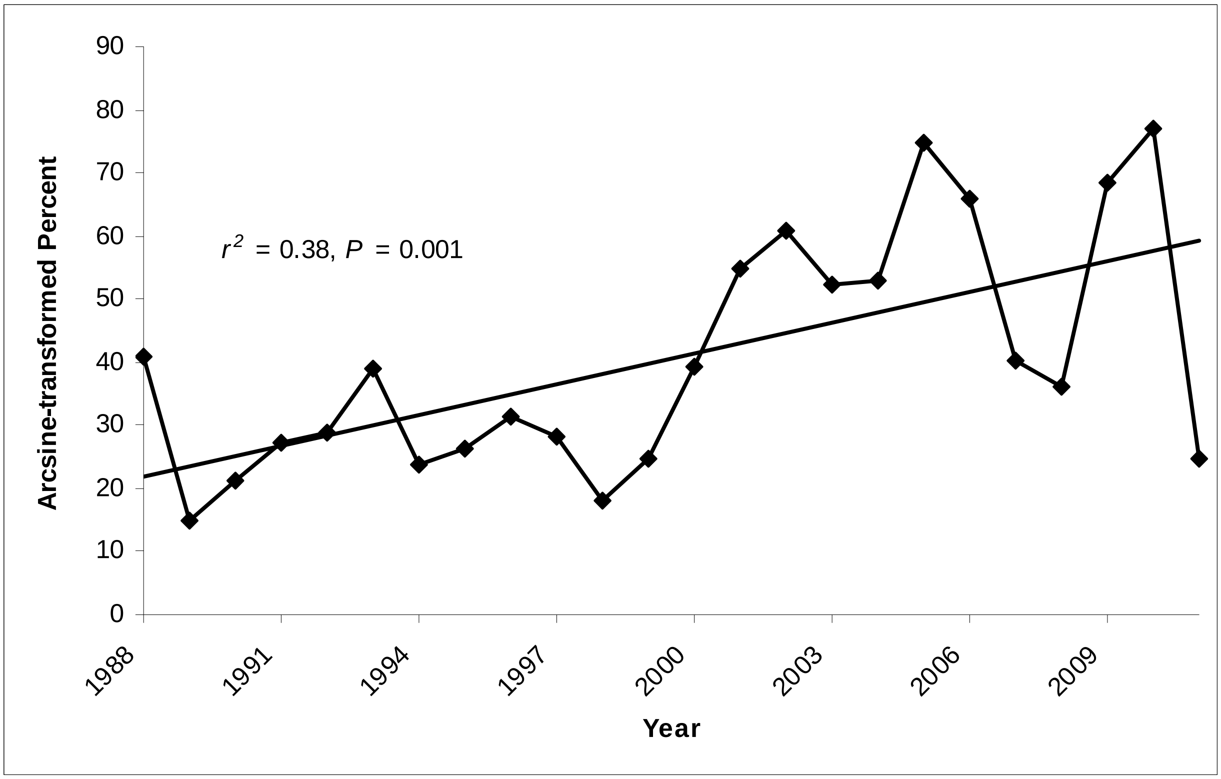


Figure 9. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River, 2002-2011.

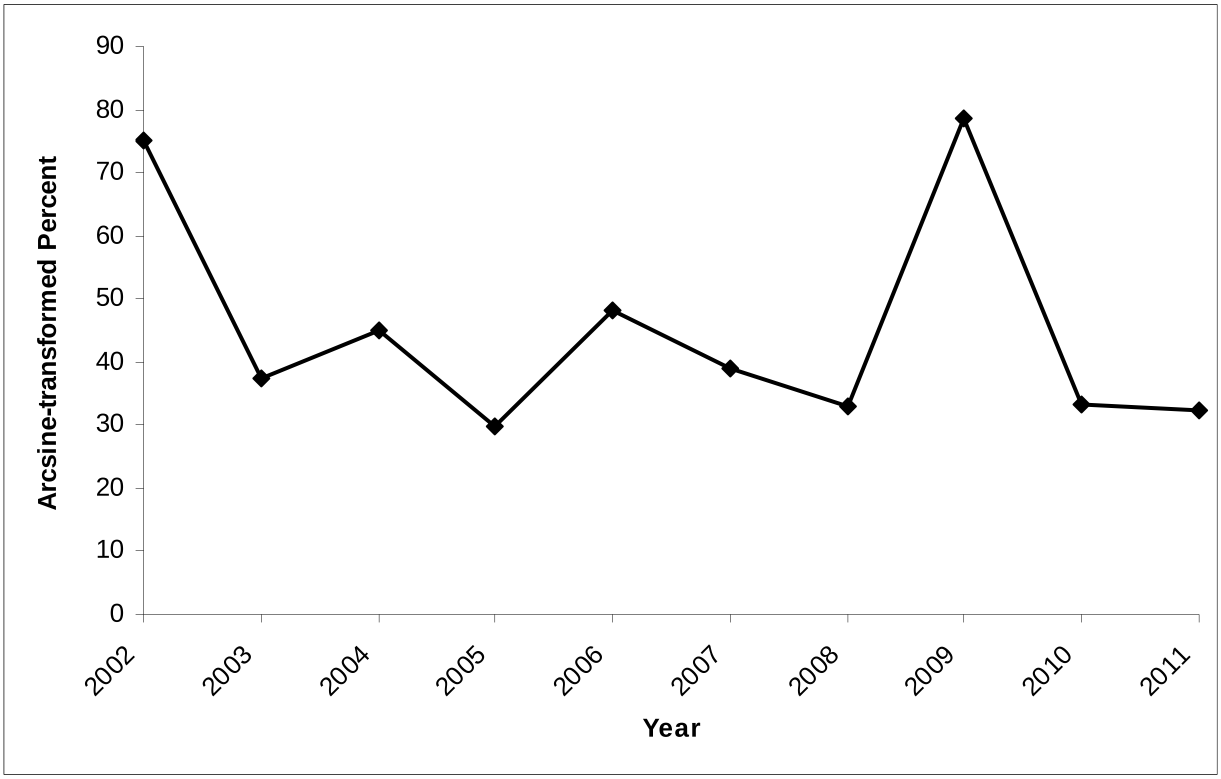


Figure 10. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic and the surplus production model (SPM), 1986-2011.

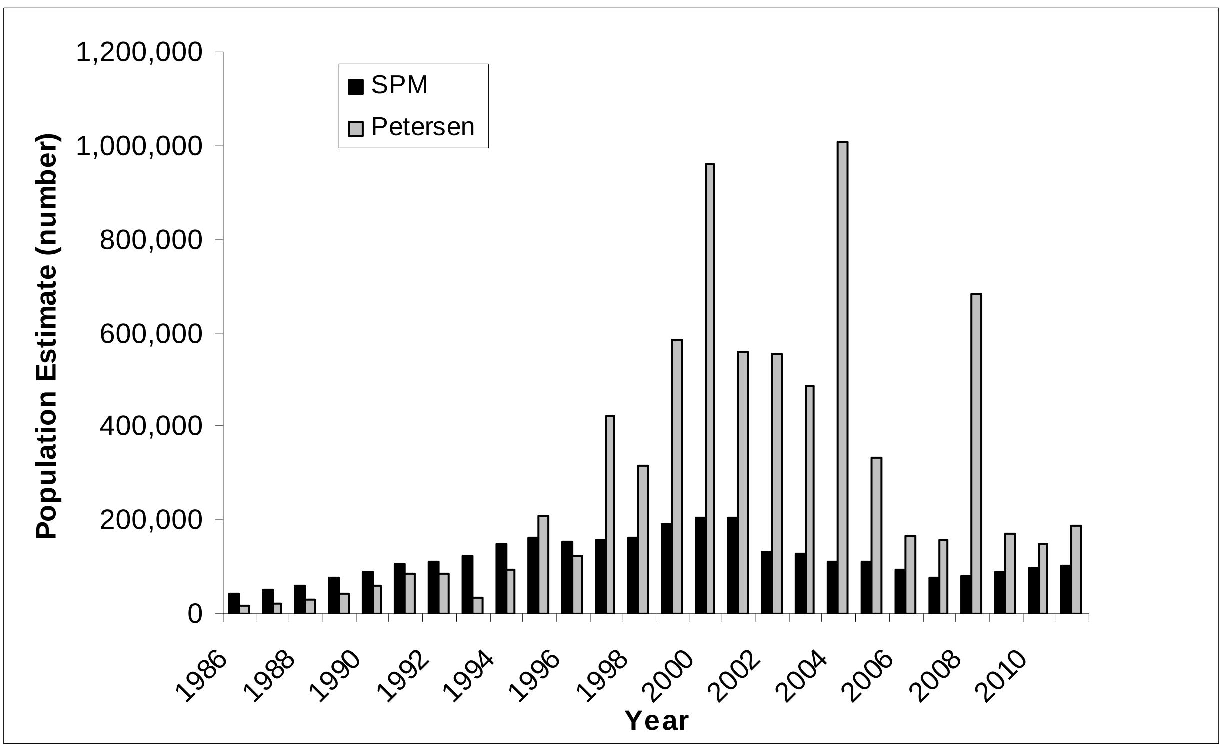


Figure 11. American shad geometric mean CPUE (fish per boat hour) from the Conowingo Dam tailrace hook and line sampling, 1984-2011.

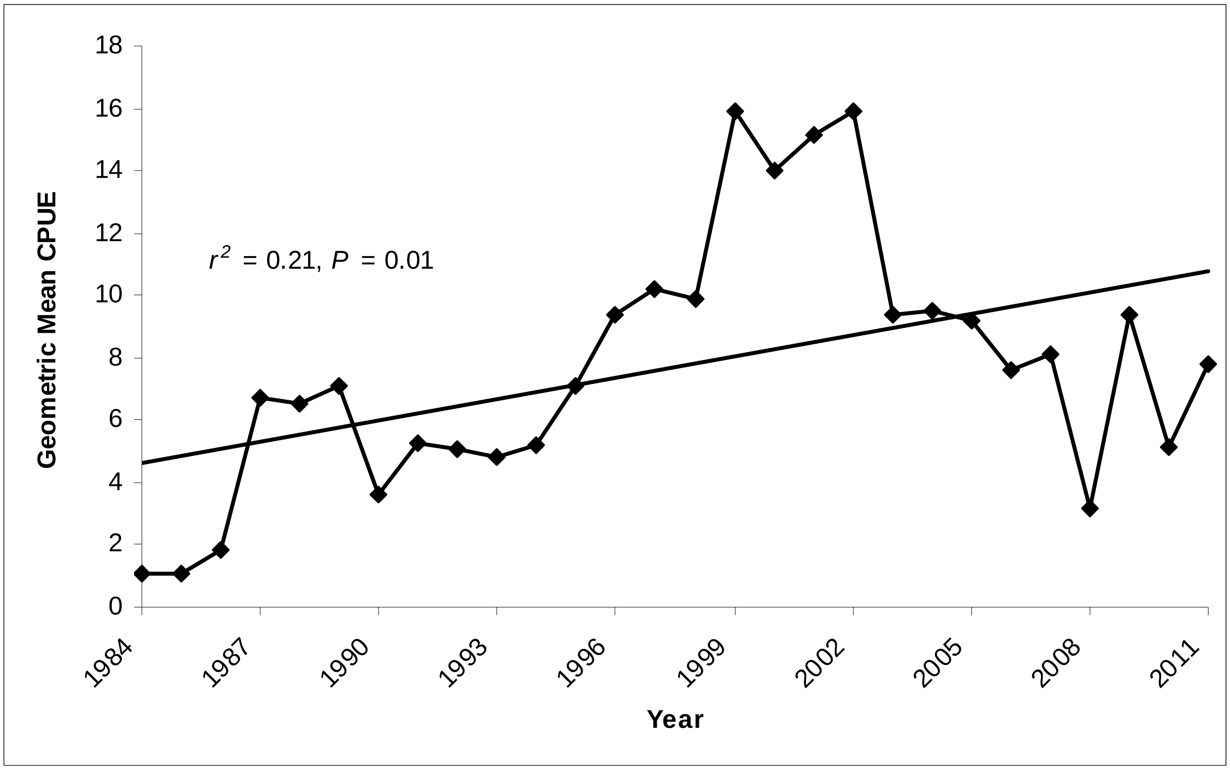


Figure 12. American shad geometric mean CPUE (fish per lift hour) from the East and West Fish Lifts at the Conowingo Dam, 1980-2011.

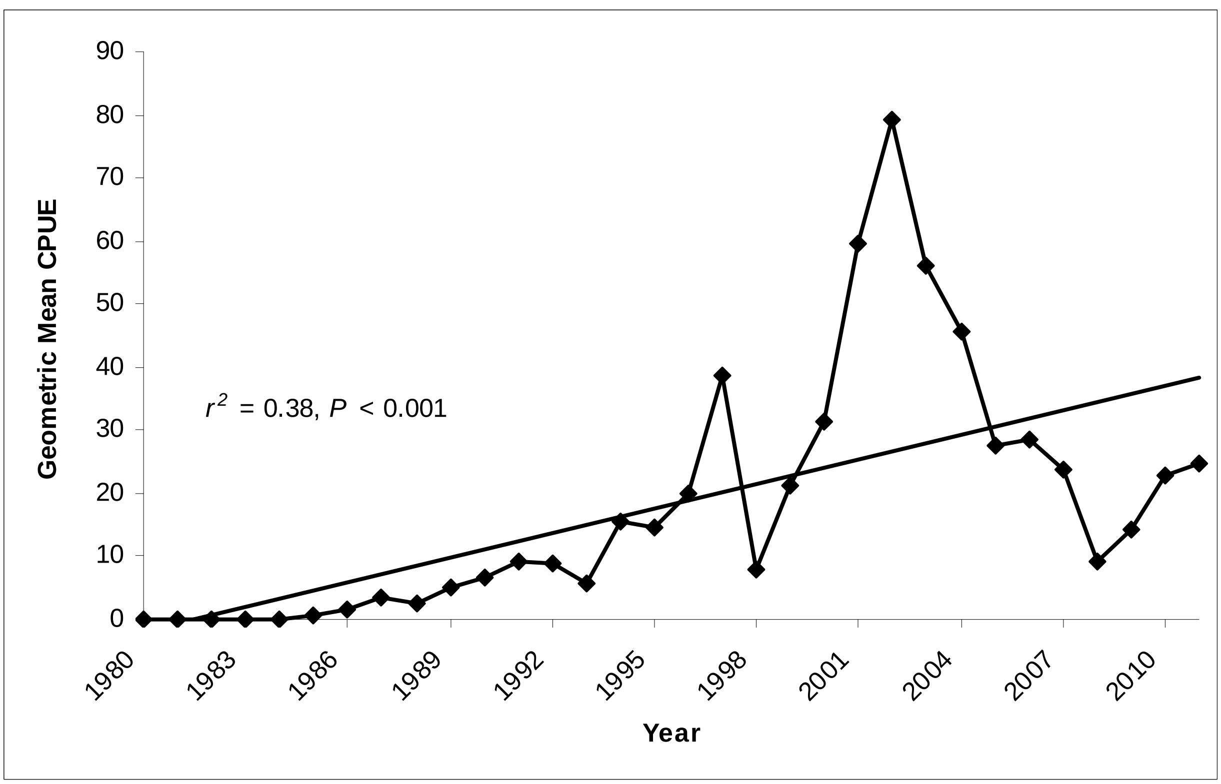


Figure 13. American shad geometric mean CPUE (fish per 1000 square yards of experimental drift gill net per hour fished) from the Potomac River, 1996-2011.

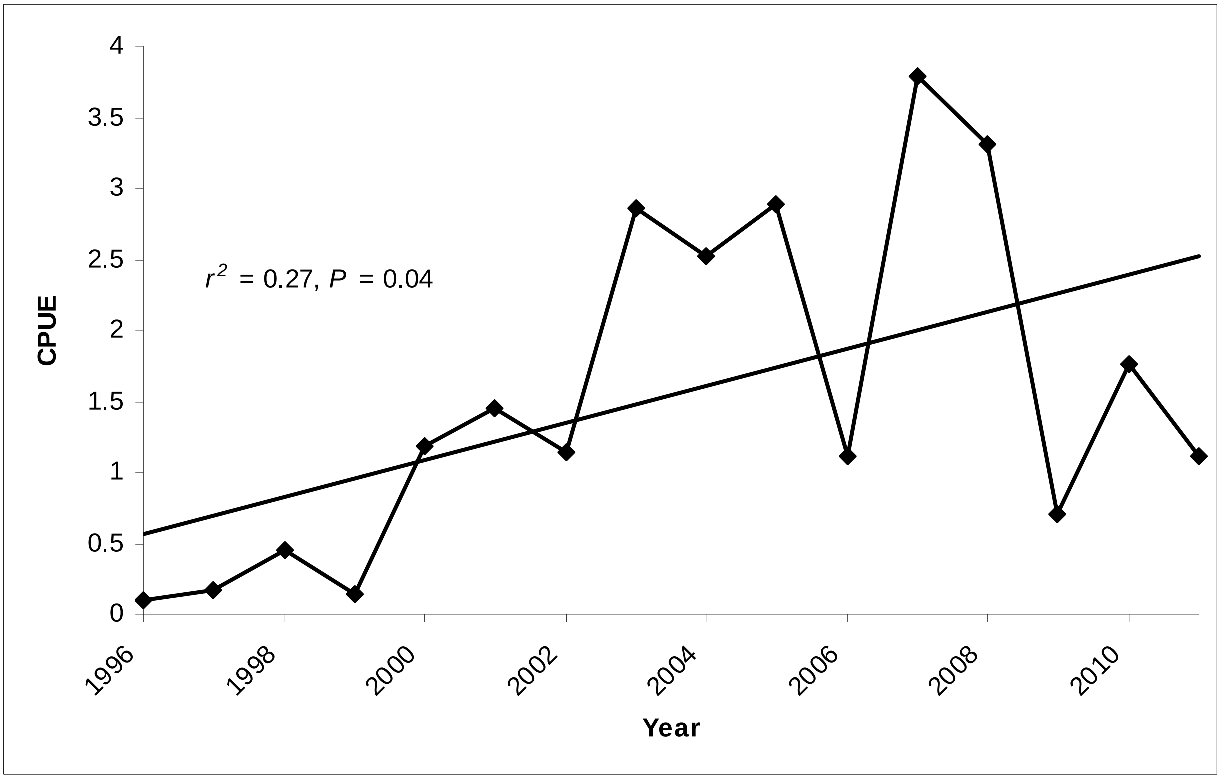


Figure 14. American shad geometric mean CPUE (fish per net day) from the Mill Creek pound net in the Nanticoke River, 1988-2011. No pound nets were fished in 2004.

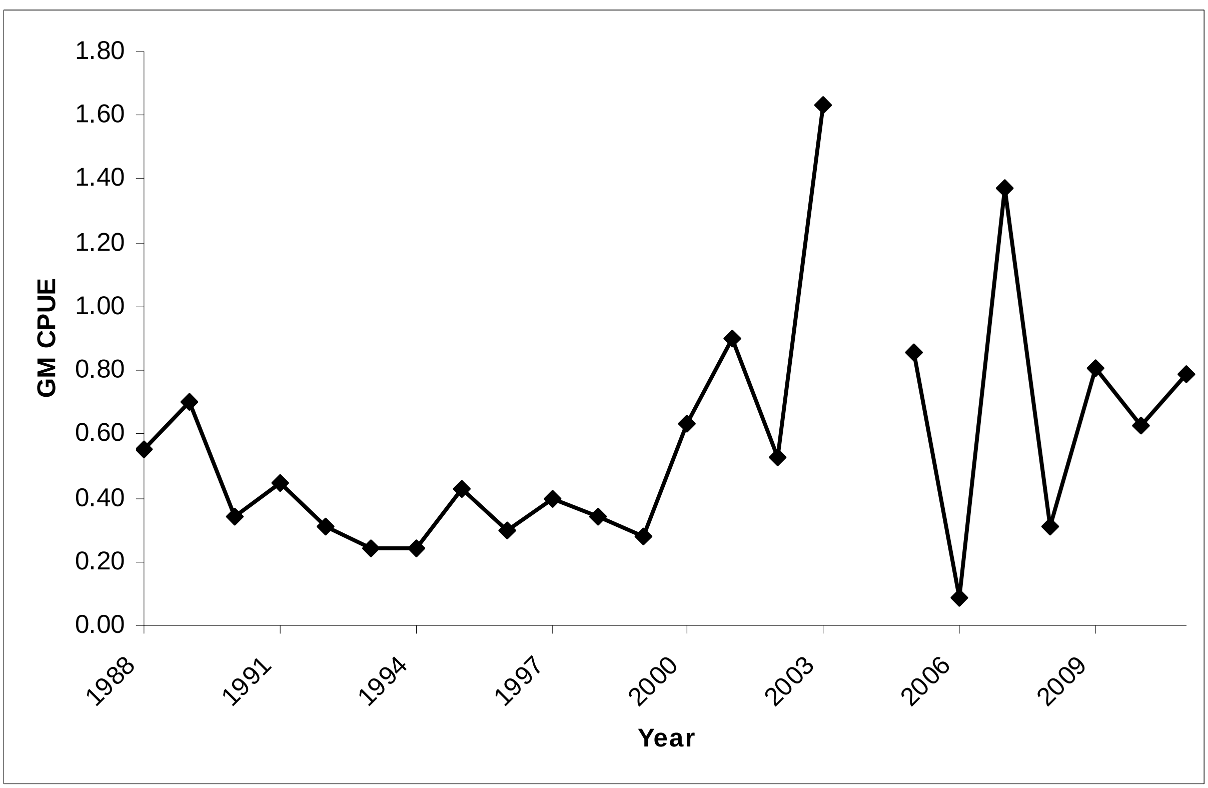


Figure 15. American shad geometric mean CPUE (fish per net day) from fyke nets in the Nanticoke River, 1988-2011.

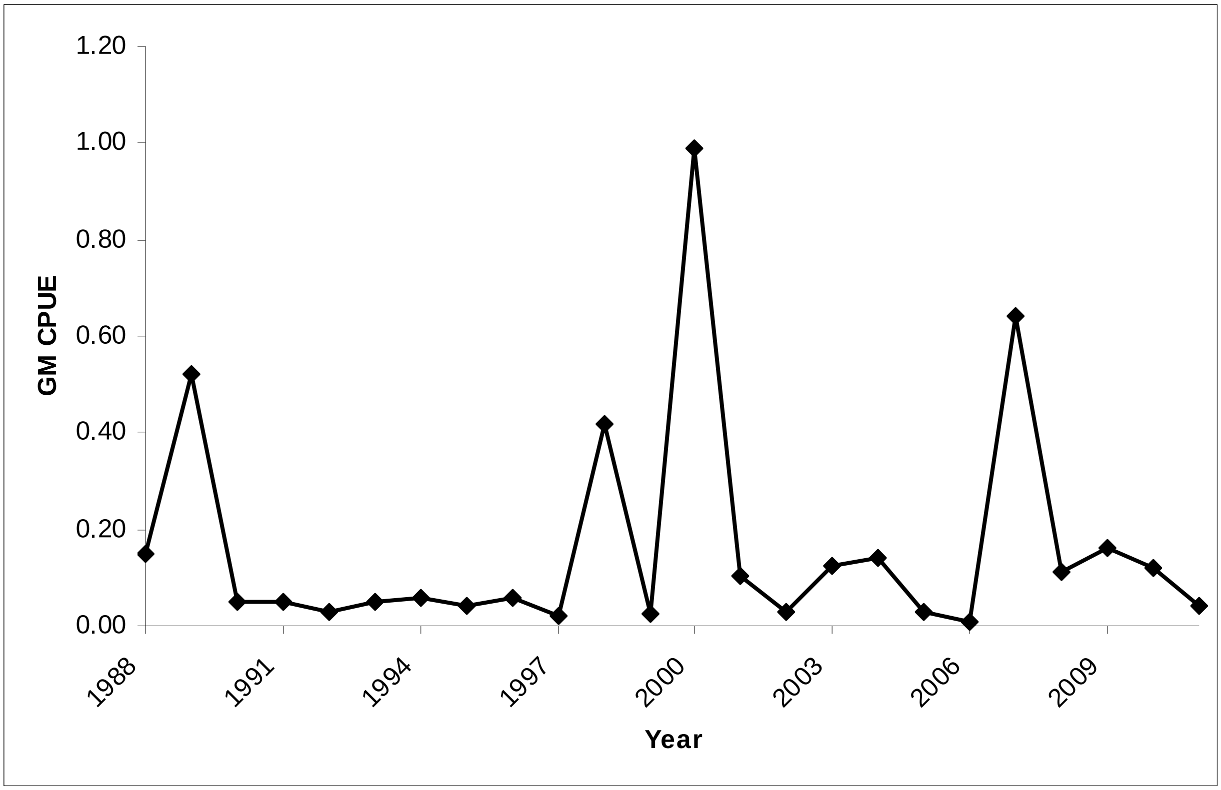


Figure 16. Baywide juvenile American shad geometric mean CPUE (catch per haul), 1959-2011.

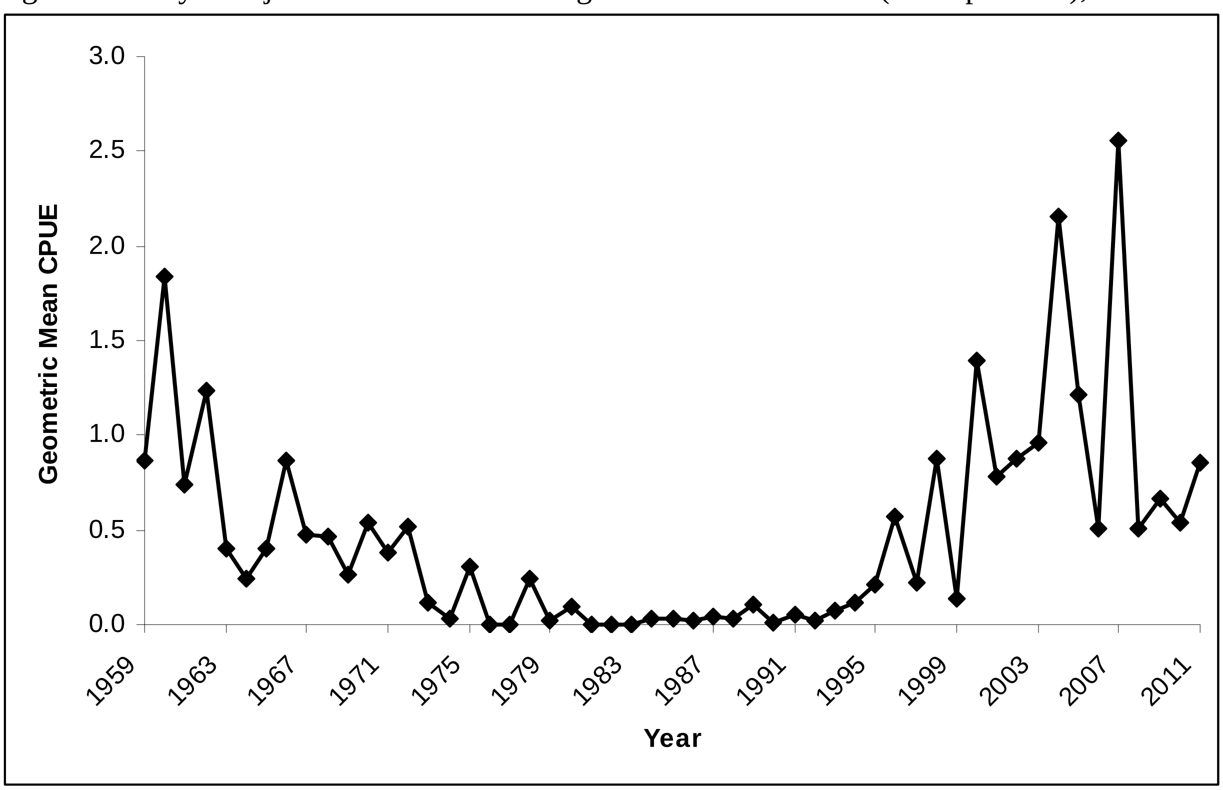


Figure 17. Upper Chesapeake Bay juvenile American shad geometric mean CPUE (catch per haul), 1959-2011.

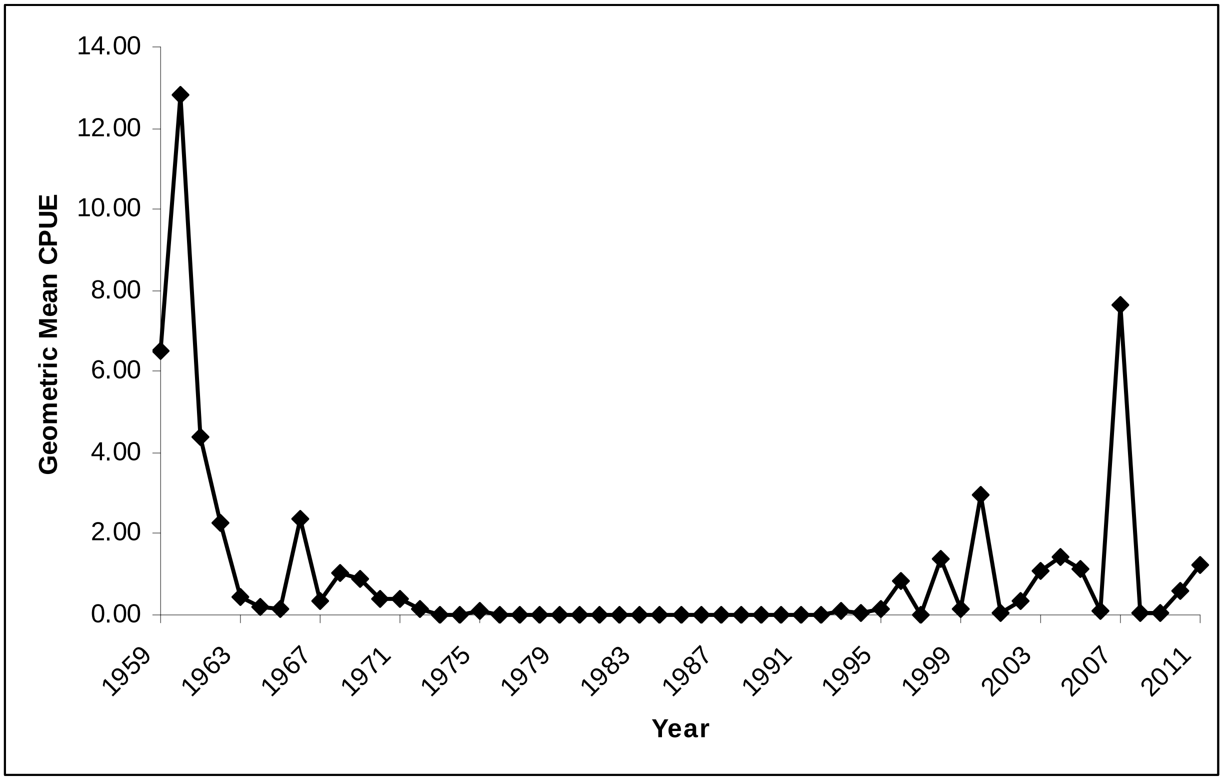


Figure 18. Nanticoke River juvenile American shad geometric mean CPUE (catch per haul), 1959-2011.

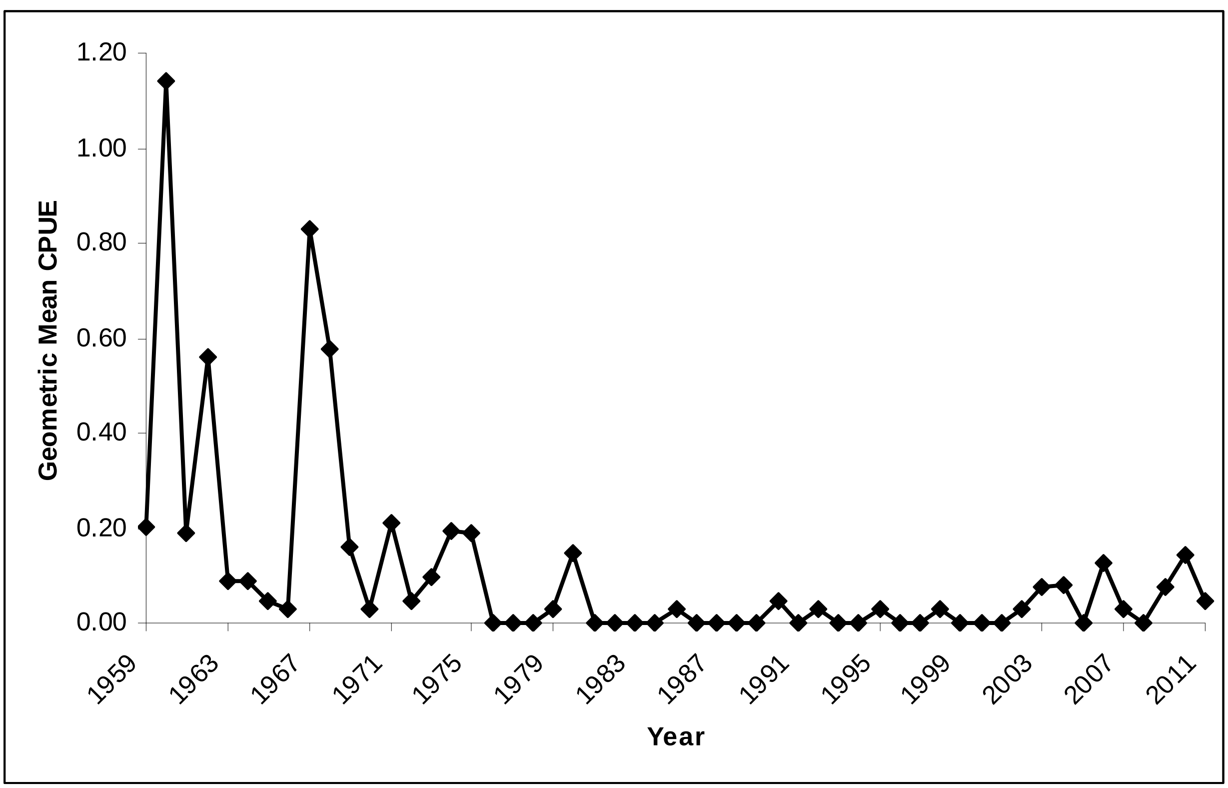


Figure 19. Potomac River juvenile American shad geometric mean CPUE (catch per haul), 1959-2011.

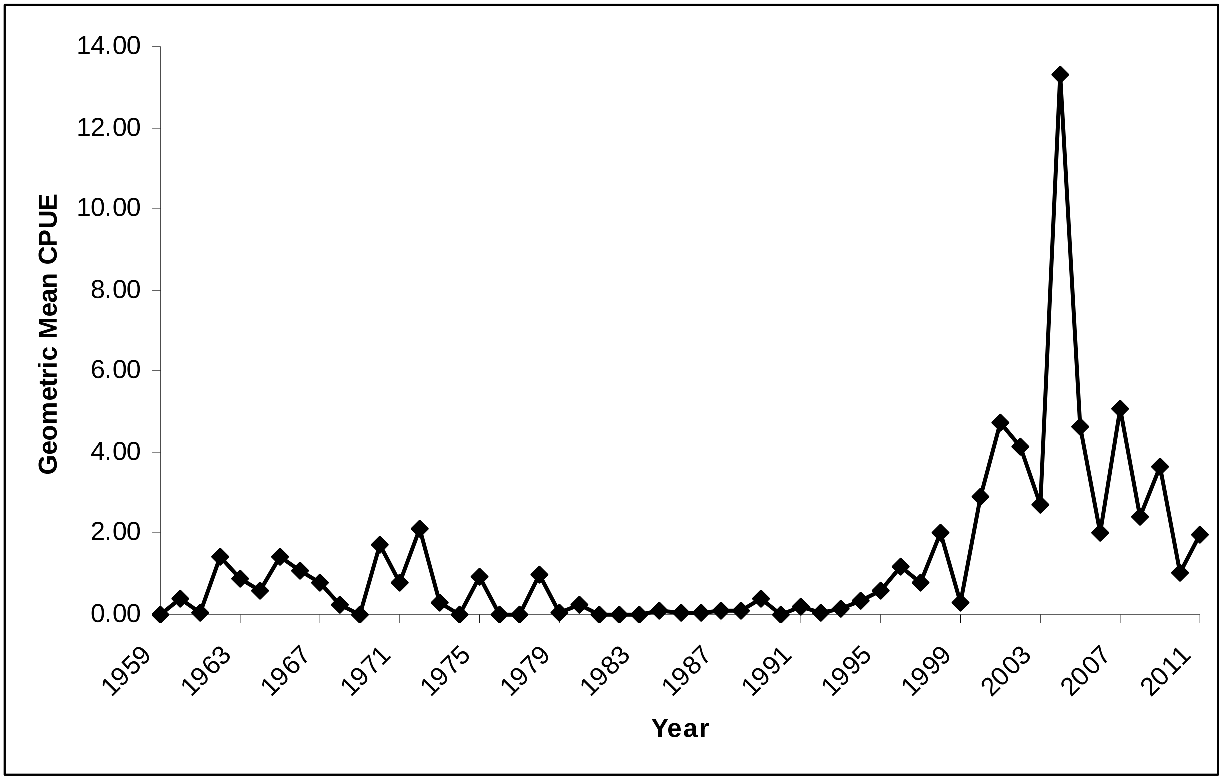


Figure 20. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from Deer Creek (Susquehanna River), 2004-2011.

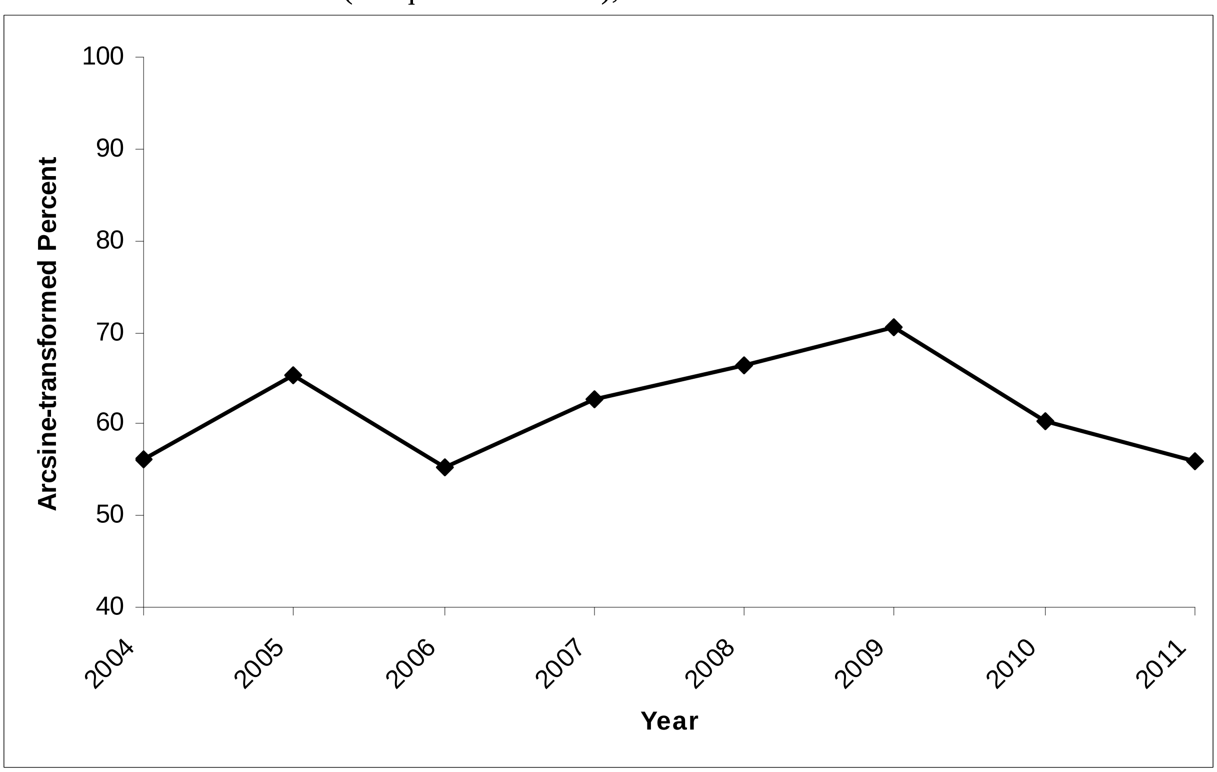


Figure 21. Arcsine-transformed percentages of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1989-2011.

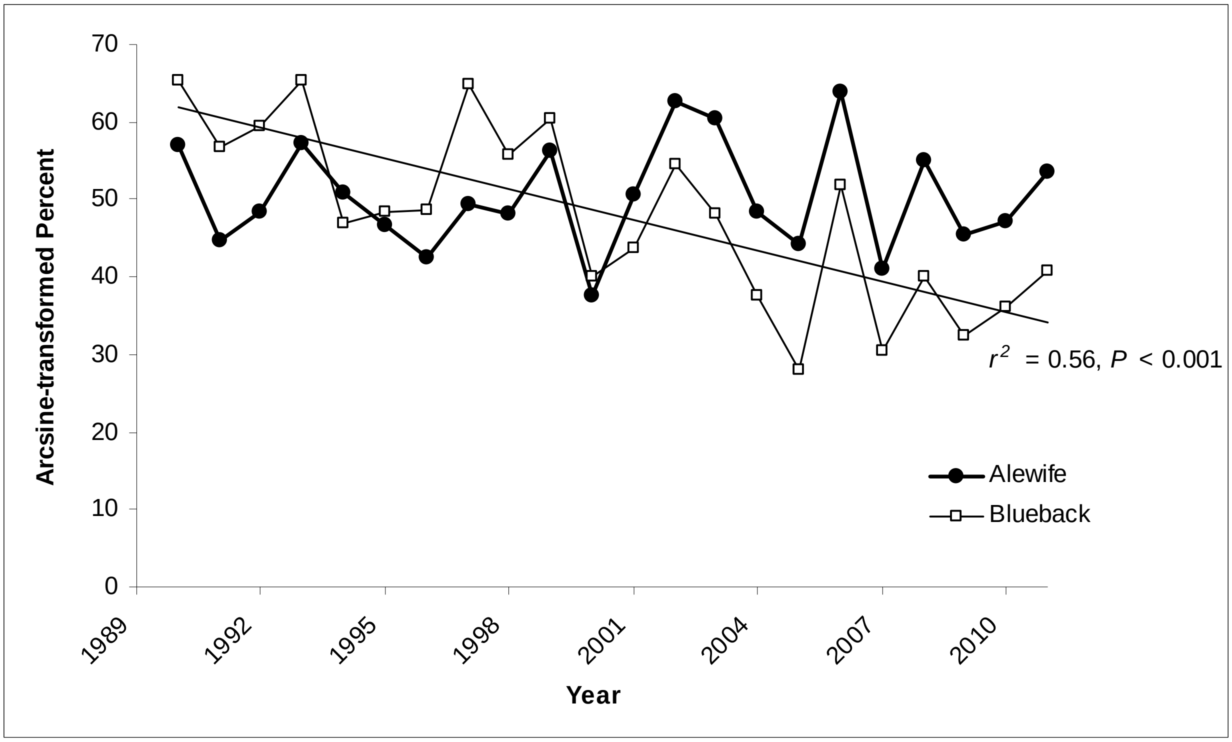


Figure 22. Mean length by age over time for male alewife herring sampled from the Nanticoke River, 1989-2011.

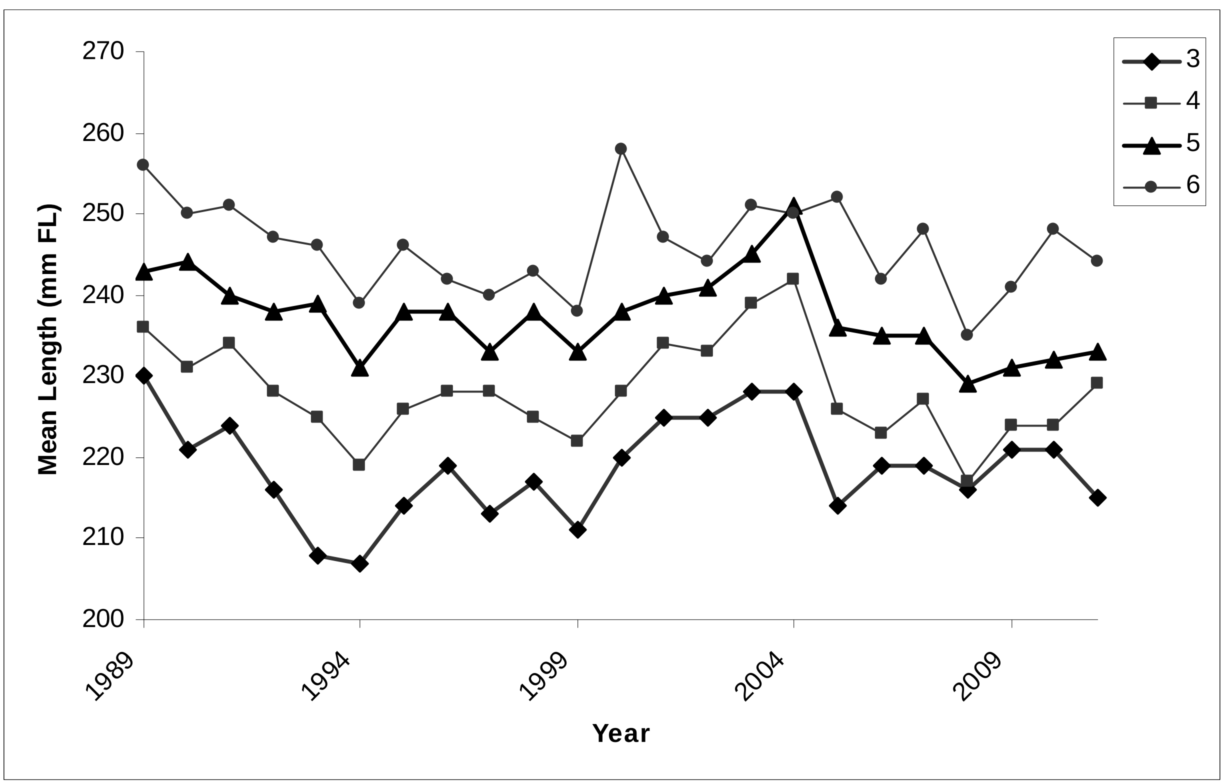


Figure 23. Mean length by age over time for female alewife herring sampled from the Nanticoke River, 1989-2011. Trend lines are included for ages where mean length varies significantly over time.

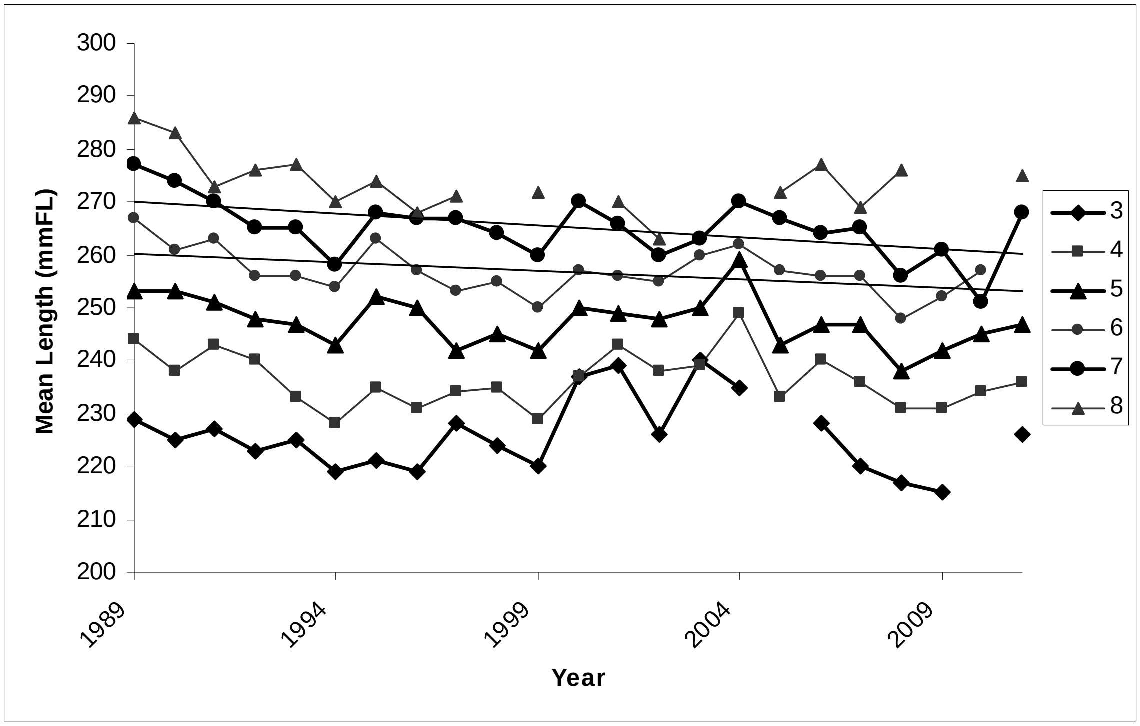


Figure 24. Mean length by age over time for male blueback herring sampled from the Nanticoke River, 1989-2011. Trend lines are included for ages where mean length varies significantly over time.

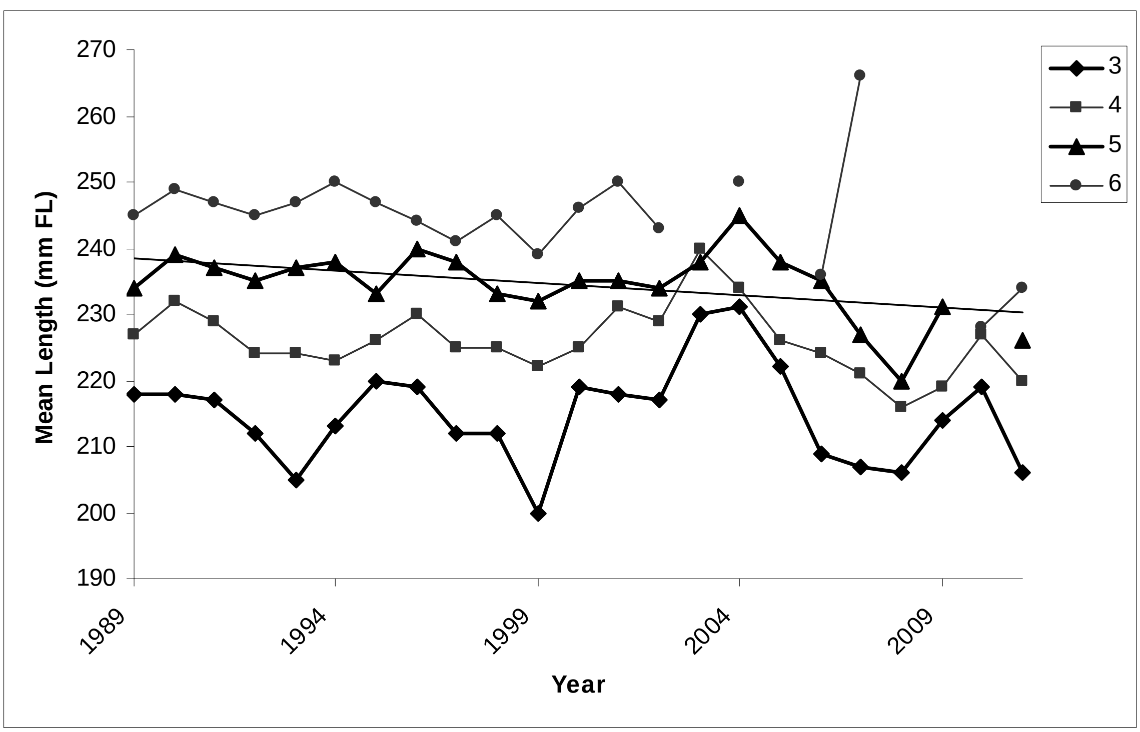


Figure 25. Mean length by age over time for female blueback herring sampled from the Nanticoke River, 1989-2011. Trend lines are included for ages where mean length varies significantly over time.

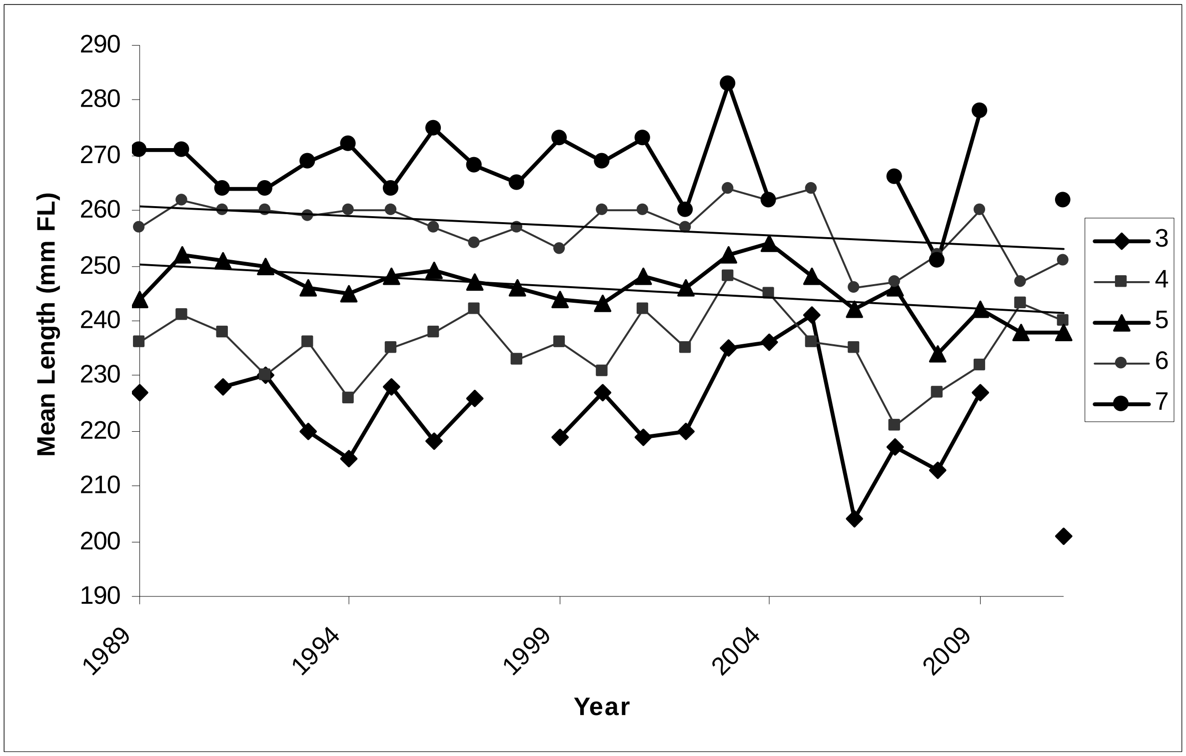


Figure 26. Geometric mean CPUE (catch per net day) of adult alewife herring from Nanticoke River fyke nets, 1989-2011.

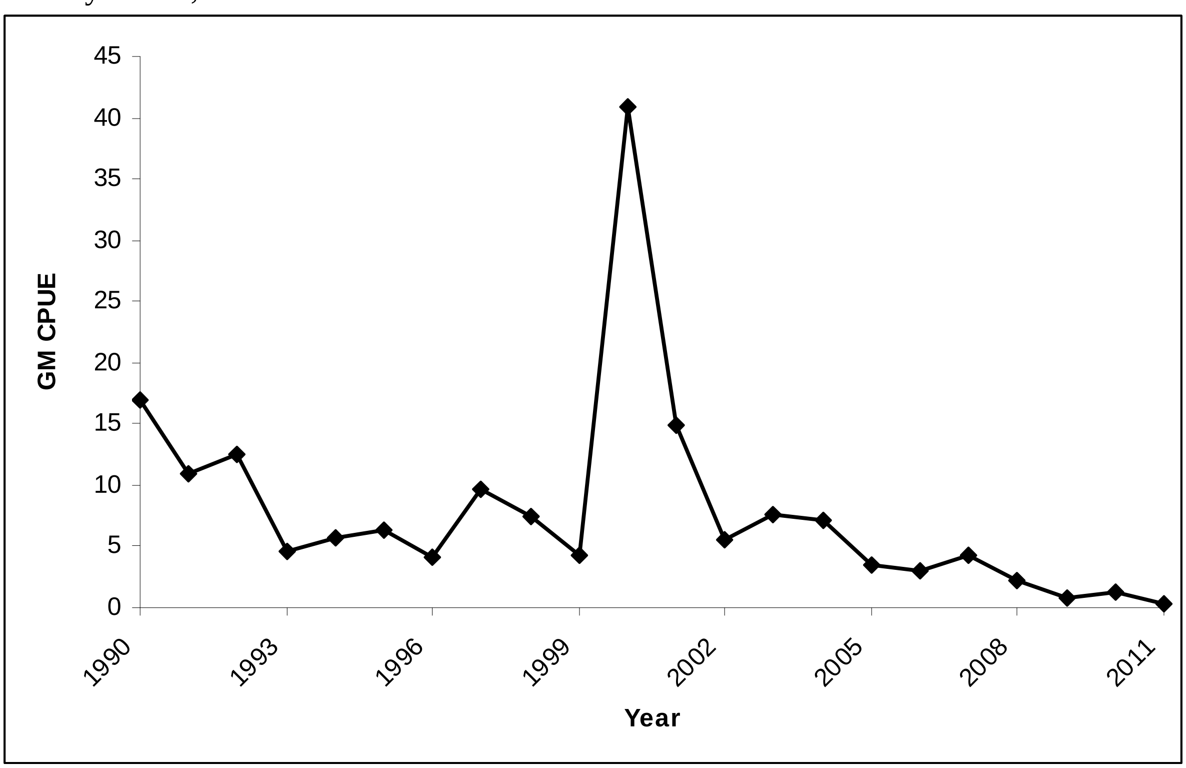


Figure 27. Geometric mean CPUE (catch per net day) of adult blueback herring from Nanticoke River fyke nets, 1989-2011.

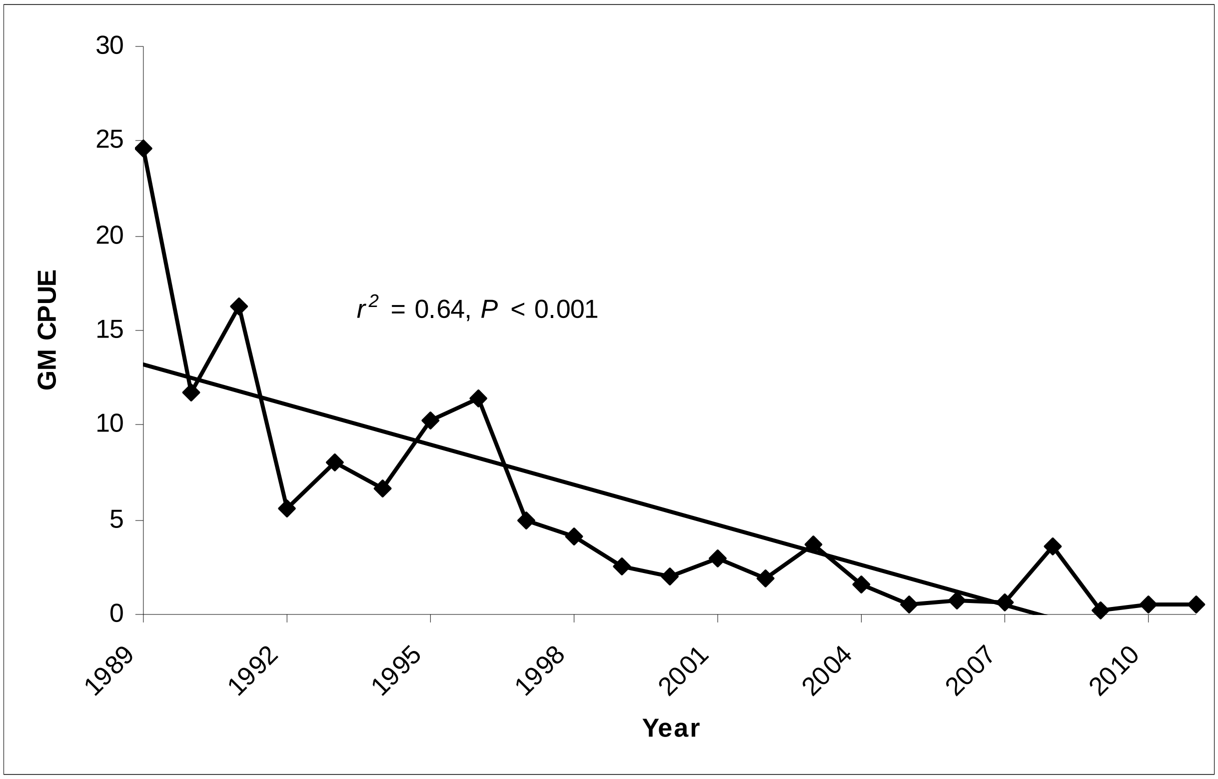


Figure 28. Total reported commercial river herring landings in pounds from the Nanticoke River, 1980-2011.

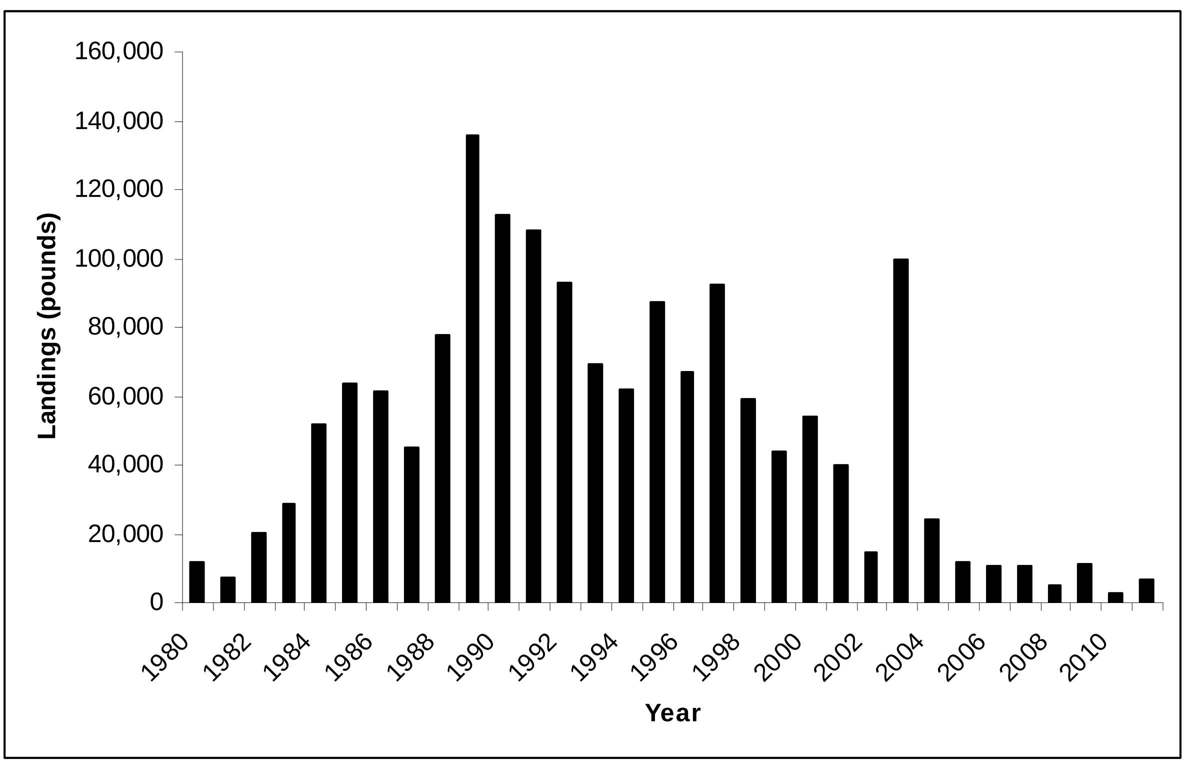


Figure 29. Maryland's commercial river herring landings, 1929-2011.

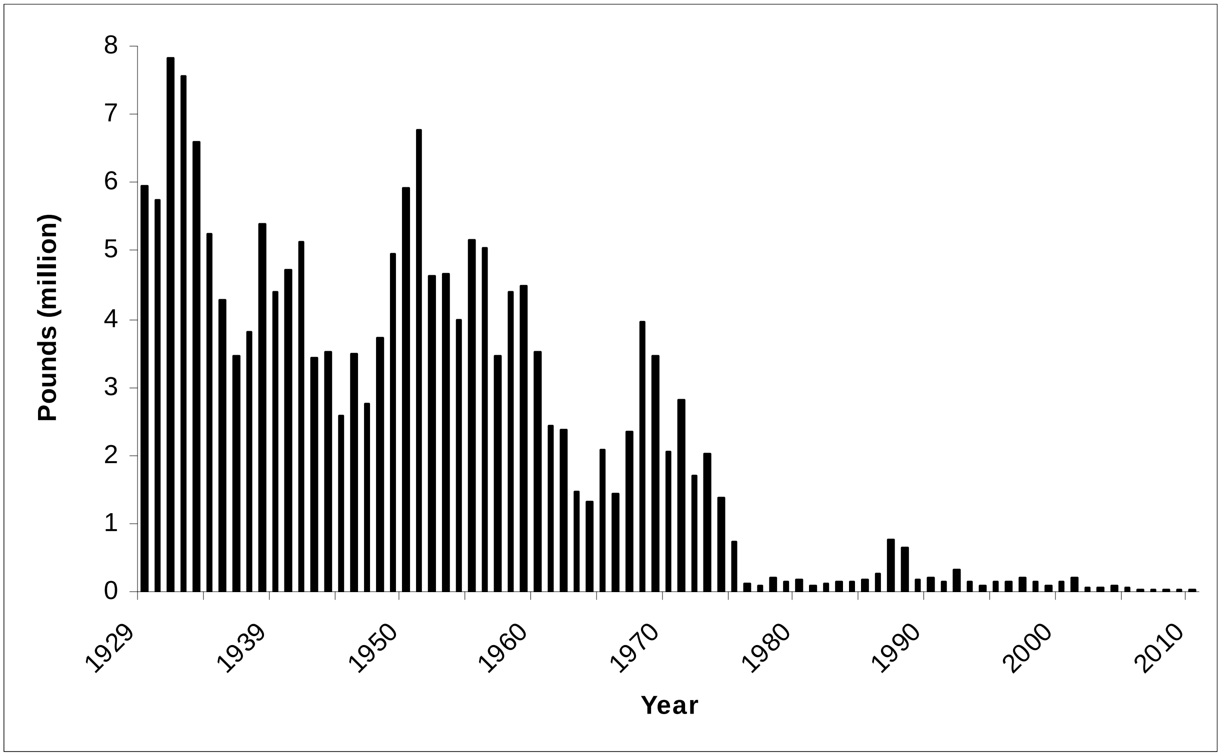


Figure 30. Nanticoke River juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2011.

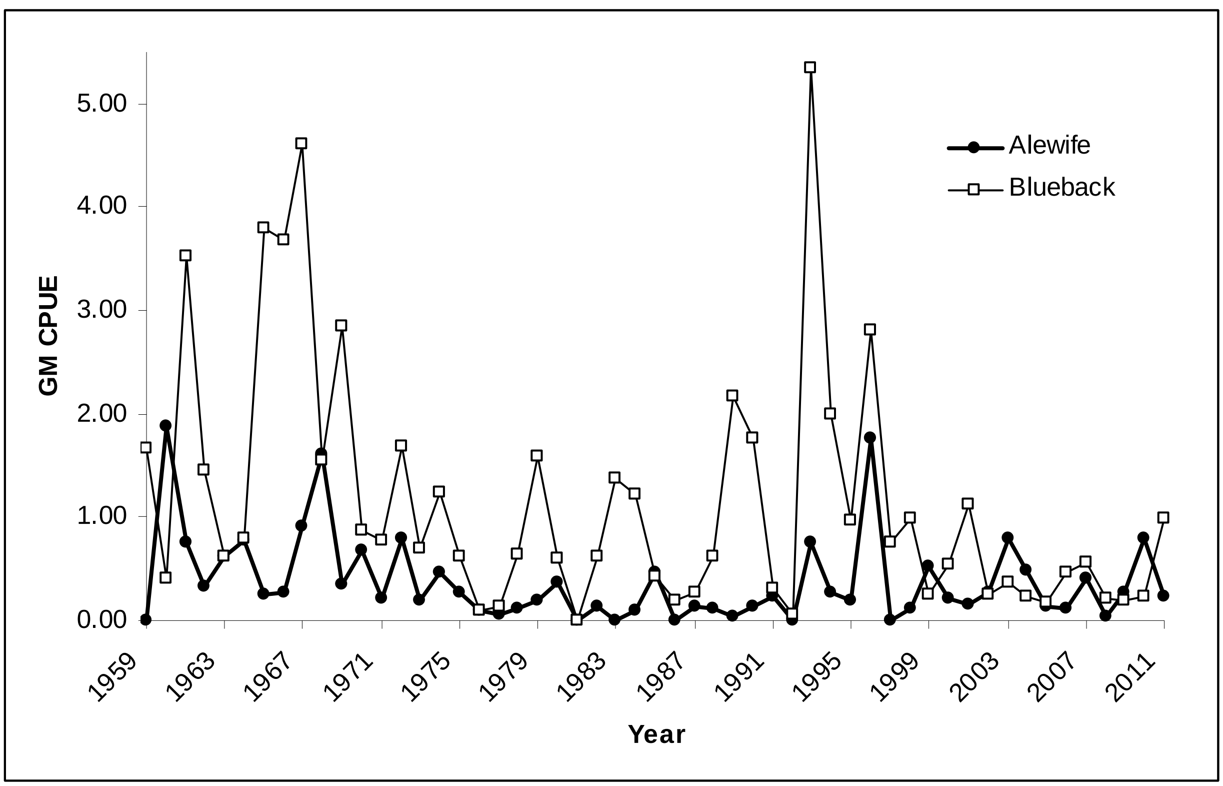
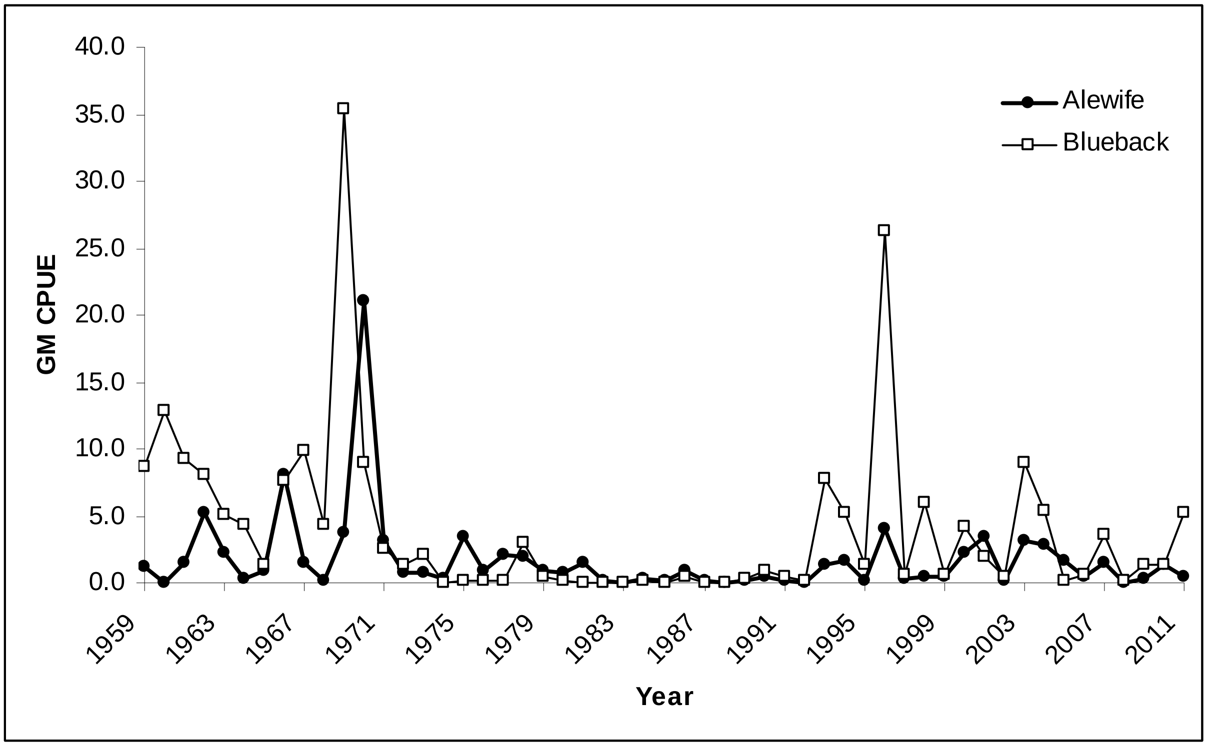


Figure 31. Baywide juvenile alewife and blueback herring geometric mean CPUE (catch per haul), 1959-2011.



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 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 19 years of this survey (1993-2011). However, since no cooperating fishermen could be located on the lower Potomac River, sampling was not conducted in this area for 2009, but did resume in 2010. Commercial pound nets were sampled at the mouth of the Nanticoke River, Potomac River and in Hooper Strait just outside of the mouth of Fishing Bay in 2011 (Figure 1). Each site was sampled once every two weeks, weather and fisherman's schedule permitting. The commercial fishermen set all nets sampled as part of their regular fishing routine. Net soak time and manner in which they were fished were consistent with the fisherman's day-to-day operations.

All targeted species were measured from each net when possible. In instances 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). At least 50 menhaden were measured to the nearest mm FL each day, when available, and scale samples were randomly taken from 25 of the measured fish. Water temperature (°C), salinity (ppt), GPS coordinates (NAD 83), date and hours fished were also recorded at each net.

Menhaden scales were aged by two MD DNR biologists. Otoliths, weight to the nearest gram, TL and sex were taken from a sub sample of weakfish, spot and Atlantic croaker. The Atlantic croaker and weakfish otoliths were processed and aged by the South Carolina Department of Natural Resources (SC DNR). Spot otoliths from 2007 through 2010 were stored for later processing and analysis by MD DNR staff. All stored otoliths and those from 2011 were processed and aged for this report. The right otolith from each specimen was mounted to a glass slide for sectioning. The otoliths were mounted in Crystalbond 509, with a melting point of 121˚C. Once mounted the otolith were sectioned using a Buehler IsoMet® Low Speed Saw using two blades with a 0.4 mm spacer in between. 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 right otolith was damaged, missing or miss cut the left otolith was substituted.

To supplement the pound net data and make up for the reduced number of pound nets sampled, seafood dealer sampling was added in 2009 and continued in 2010 and 2011. Only one seafood dealer agreed to participate in 2010 and 2011. The dealer purchased fish from pound netters in the Hooper's Island area and from a gill netter targeting Atlantic croaker. Seafood dealer sampling was conducted only once in 2011.

Random boxes of fish were selected for each of the target species of fish available. If all species were present, but time did not allow for sampling of all species, priority was given in the following order: weakfish, Atlantic croaker, spot, summer flounder, bluefish, Spanish mackerel and red drum. All measurements were to the nearest mm total length (TL) except for Spanish mackerel, which were measured to the nearest mm fork length (FL). All fish measured were also weighed. All measurements were taken to the nearest gram on an A&D SK-5001WP portable digital wash down scale with a 0.001 kg resolution.

Juvenile indices were calculated for weakfish, Atlantic croaker and spot from the MD DNR Blue Crab Trawl Survey data. This survey utilizes a 4.9 m semi-balloon otter trawl with a body and cod end of 25-mm-stretch-mesh and a 13-mm-stretch-mesh cod end liner towed for 6 min at 4.0-4.8 km/h. The systems sampled included the Chester River, Eastern Bay, Choptank River and Patuxent River (six fixed sampling stations each), Tangier Sound (five fixed stations) and Pocomoke Sound (eight fixed stations). Each station was sampled once a month from May - October. Juvenile croaker, spot and weakfish collected by this survey have been enumerated, and entered into a computer database since 1989 (Davis et al.1995).

<u>Analytical Procedures</u>

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 November 15, 2011, prior to MRIP changing to the new estimation procedures in 2012. Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2010. 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 2011 charter log book data had not been finalized, only data through 2010 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 = 1,296) determined from 2003-2008 Chesapeake Bay pound net survey data, and June through September 2003-2008 measurements of age zero croaker (n=156) 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 2003-2008 were L_∞ = 417.1 mm TL and K= 0.364, 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 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 and seafood dealer pound net length data divided into 20 mm length groups. In order to detect differences in pre-harvest (vessel) and post-harvest (dealer) samples, length frequency distributions were calculated separately. Length frequency distributions for weakfish, bluefish and Atlantic menhaden were constructed for onboard sampling only, because menhaden were not sampled at seafood dealers and sample sizes of the remaining species were very low.

Length-at-age keys were constructed for weakfish and Atlantic croaker using the 2009 age samples since SC DNR had not processed 2010 and 2011 samples. 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 2009 and weakfish from 2003 through 2009. Age length keys for spot were constructed for 2007 through 2011. 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 and 2011 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 abundance. Similarly the Atlantic croaker index was limited to Tangier Sound, Pocomoke Sound and the Patuxent River. All sites were used for the spot index. Indices and confidence intervals were derived using SAS® software (SAS 2006).

RESULTS and DISCUSSION

The Nanticoke River, Potomac River and Hooper Straight were sampled from May 24 through September 7, 2011 (Table 2). Nine of the ten target species, and sixteen non-target species (Table 3) were encountered during this time period. Spanish mackerel was the only target species not encountered during onboard sampling. One seafood dealer sampling trip in the Hooper's Island area was conducted on June 9, 2010, during which data was collected from two of the ten target species. Only Atlantic croaker and Summer Flounder were sampled from the seafood dealer in 2011. Since black drum cannot be commercially harvested in Maryland's portion of Chesapeake Bay, this species was not available for dealer sampling. No weakfish, spot, bluefish, spotted seatrout, Spanish mackerel or red drum were encountered, and Atlantic menhaden were not sampled from seafood dealers in 2011.

Weakfish

Twenty-six weakfish were sampled in the 2011 pound net survey, the second lowest catch of the 19 year time series. Weakfish mean length in 2011 was 236 mm TL, a decline from the 2010 mean length of 253 mm TL, and the shortest mean length of the 19 year time series (Table 4). No weakfish were encountered during the 2011 seafood dealer sampling, likely because weakfish are normally not available in the region until July and sampling was only conducted in June (Table 5). Weakfish RSD analysis for 2011 was limited to the RSD_{stock} category fish (Table 6). This was the third consecutive year no weakfish were recorded in the RSD_{pref} category. The 2011 onboard pound net survey length frequency distribution also indicated a slight shift to smaller sizes for the fourth consecutive year, with 50% of sampled weakfish in the 210 mm TL group (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).

In 2011, females accounted for 65% of fish sampled from the pound net survey (n=23). Female mean TL and mean weight were 242 mm TL and 147g, respectively, while males averaged 233 mm TL and 127g. In 2010, females averaged 256 mm TL and 268g and accounted for 68% of fish sampled (n=45), while male mean length and weight were 251 mm TL and 155g, respectively.

Total Maryland commercial weakfish harvest (Chesapeake Bay and Atlantic Ocean combined) in 2010 declined to 2,148 pounds, with the Chesapeake Bay portion decreasing from 1,355 pounds in 2009 to 40 pounds in 2010 (Figure 3). The 2010 total harvest was the lowest of the 81 year time series and was well below Maryland's average of 627,669 pounds per year. The 2010 commercial harvest for Chesapeake Bay was the lowest since 1969. Maryland recreational anglers harvested an estimated 2,833 (PSE = 68) weakfish during 2010, with an estimated weight of 1,810 (PSE = 70.1) pounds (Figure 4). The number of weakfish harvested by the recreational fishery in 2010 represented a 22% increase compared to the 2009 estimate (2,314), and was the forth lowest of the 1981-2010 time series. According to the MRIP estimates, Maryland anglers released 104,421 (PSE = 31) weakfish in 2010, a more than 14 fold increase from 2009 (6,700, PSE = 42.2). Estimated recreational harvest decreased steadily from 475,348 fish in 2000 to near zero in 2006, and recovered slightly in 2007 and 2010. Both the recreational harvest estimates and the reported commercial landings in 2010 may have been affected by a regulation change that took place in April 2010. The new regulation reduced the bag limit from 3 fish to 1 fish per 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 2,122 to 75,154 weakfish from 1993 to 2010 (Figure 5), with a dramatic decline occurring in 2003. The reported charter boat harvest had the same trend as the reported commercial harvest ($R^2 = 0.62$, $P < 0.001$) and the statewide MRIP estimate ($R^2 = 0.80$, $P < 0.001$), 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 2010 geometric mean of 0.63 weakfish per angler was the forth lowest mean of the time series (Figure 6). The CPA geometric mean has significantly declined from 1993 – 2010 ($R^2 = 0.81$, $P < 0.001$).

The 2011 weakfish juvenile GM increased slightly for the third straight year, but was still the 10th lowest value in the 23 year time series (Figure 7). Weakfish juvenile abundance generally increased from 1989 to 1996 in Pocomoke and Tangier sounds, remaining at a relatively high level through 2001, but generally decreased from 2003 to 2008. 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 22 fish in 2010 and 25 fish in 2011, but aging of the samples has not been completed at this time. Age samples from 2003 – 2009 indicate a shift to younger fish, with age 1-4 fish present in 2006 and 2007, ages 1-3 present in 2008 and ages 1 and 2 present in 2009, although sample sizes have become extremely small (Table 7). Age one fish comprised over 75% of sampled fish in 2008 and 2009.

Mortality estimates for 2007 through 2011 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 8). 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 has been classified as depleted due to 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 2004-2011. 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 2011 mean length of 359 mm TL decreased slightly compared to 2010, but was still the third highest of the 19 year time series. The 2011 seafood dealer survey mean length and weight for summer flounder was 435 mm TL and 933 g, respectively (Table 5), nearly identical to the 2010 values of 434 mm TL and 933 g. Relative stock densities in the 2011 onboard pound net survey indicated a slight decrease in the stock and memorable categories with a corresponding increase in the quality category compared to 2010 (Table 9). The 2011 values were more similar to those of 2009 and 2010 than the trends from 2006 to 2008, which indicated fewer flounder in the preferred category and more in the stock category. The length frequency distribution from the onboard sampling in 2011 peaked at the 310 mm TL length group, with abundance steadily declining through the larger length groups (Figure 8). There was a reduction in the proportion of larger fish compared to 2010. The number of summer flounder sampled in 2011 was the second lowest of the 19 years surveyed (Table 4). The proportion of the 2011 catch greater than or equal to the 356 mm TL minimum commercial size limit (51%) was similar to the 2010 (54%). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches from 2007 - 2011 to the 2011 recreational size limit of 483 mm TL indicated a lower proportion of legal fish in the stock during 2011 (4%) compared to 2010 (13%). However, the 2011 percentage was the same as those from 2007 through 2009.

The seafood dealer length frequency distributions were truncated by the 356 mm TL minimum size limit, and only 13 fish were sampled in 2011. 2011 lengths peaked with the 370 mm size group, with 84% of the sampled fish in the 370 to 450 mm size groups (Figure 9). This was not similar to the 2009 or 2010 distributions, but the very low 2011 sample size makes any comparisons to previous years tenuous (Figure 9).

Maryland's commercial summer flounder harvest totaled 188,406 pounds in 2010, the 24th lowest in the 48 year time series (Figure 10). The long-term commercial harvest average (1962 – 2010) is 418,426 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 (Figure 10). The recreational harvest estimate of 39,243 (PSE = 28.5) fish caught in 2010 ranked 30th out of the 30 year time series, and declined 56% from the 2009 estimate of 89,660 (PSE = 18.3) fish (Figure 11). The 2010 MRIP recreational release estimate of 1,629,651 (PSE = 13.3) fish was the second highest of the 1981- 2010 time series, representing an increase back up to 2007 values (Figure 11). This is consistent with the RSD analysis and onboard length frequency distributions, which indicate a decrease in fish greater than the minimum recreational size limit.

Reported summer flounder charter boat harvest has been variable, but has generally increased to the time series high of 14,371 fish in 2010 from the 2003 low of 1,051 fish (Figure 12). 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 = 0.45, P = 0.002) over the entire time series (Figure 13), but has been relatively stable for the past seven years. The recreational fishery has been subject to increasingly restrictive regulations in the past several years, which most likely reduced harvest rates.

A stock assessment using the Age Structured Assessment Program (ASAP) was conducted in 2008 by the National Marine Fisheries Service (NMFS), and 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 2007 at 40 million fish, similar to the long term mean of 41.6 million fish (NFSC 2008). 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. The current level of F = 0.29 is below the threshold, but slightly above the level necessary to rebuild the stock to the target level by 2012. The NMFS assessment concluded that summer flounder stocks were not overfished, and overfishing was not occurring (NFSC 2008).

Bluefish

Bluefish sampled from the onboard pound net survey averaged 245 mm TL during 2011, a decrease from the 2010 mean of 297 mm TL (Table 4). The 2011 mean length was below the 19 year time series mean of 302 mm. Bluefish were not sampled in the 2011 seafood dealer survey. One hundred percent of sampled bluefish were in the RSD_{stock} category (Table 10). Indicating a decrease in larger bluefish compared to 2009. The pound net survey length frequency distribution shifted to smaller size bluefish in 2011, and was even more skewed to the smallest size groups than in 2008 and 2009 (Figure 14). Forty-four percent of sampled bluefish in 2011 were in the 210 mm TL group, while 80% of the sample was below 250 mm TL. Their were no recorded bluefish lengths in 2011 seafood dealer survey due to time of year and number of trips. The 2009 distribution peaked in the 370 mm TL length group compared to the 230 mm length group for pound net survey fish that year. Bluefish from the 230 mm TL length group were not encountered in the post harvest dealer survey in 2009, indicating a large portion of the smaller bluefish may have been discarded or sold as bait. Anecdotal information from cooperating fishermen confirms that some small bluefish are used for crab bait, especially when menhaden are not available.

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. 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 28% in 2010 to 105,731 pounds, and remained below the 1929-2010 average of 172,655 pounds (Figure 15). The 2010 catch was the median value of the 81 year time series. The total commercial landings have fluctuated without trend from 42,662 to 157,436 pounds from 1993 – 2011 (Figure 15). 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 16). The 2010 estimate of 301,279 (PSE = 15) fish harvested decreased slightly compared to 2009 (334,856 fish), and was well below the time series average of 875,000 fish. Estimated recreational releases also decreased by 68% in 2010 to 157,878 (PSE = 20.5) compared to 2009 (494,377 fish, PSE = 14.7), a continued decline from 2008 (1,855,033 fish) which was the highest release estimate of the time series (Figure 16).

Reported bluefish harvest from charter boat logs ranged from 27,667 – 134,828 fish per year from 1993 to 2010 (Figure 17). Harvest from charter boat logs did generally trend with state wide MRIP estimates, but was not significantly correlated 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 again in 2009 and 2010 (Figure 18).

A stock assessment update was produced in 2010 (Shepherd and Nieland 2010) of Atlantic coast bluefish utilizing the forward projecting catch at age (ASAP) model. The assessment indicated that F has remained 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, and the 2009 cohort which was well below average at 8.0 million fish (Shepherd and Nieland 2010). The model indicated that overfishing is not occurring and that the stock is not overfished.

<u>Atlantic croaker</u>

Atlantic croaker mean length from the onboard pound net survey decreased to 281 mm TL compared to 2010, and was the third lowest value of the 19 year time series (Table 4). Seafood dealer mean length and weight increased in 2011 to 310 mm TL and 370 g respectively, for pound net caught fish, compared to 2010 (269 mm TL and 257 g) (Table 5). Gill net caught fish were also measured during dealer sampling for the first time in 2011, with a mean length of 316 mm TL and a mean weight of 459 g (n = 244). Sixty-three percent of sampled pound net croaker from onboard sampling in 2011 were in the $RSD_{preferred}$ category, an increase over 2010. $RSD_{memorable}$ and RSD_{trophy} fish declined in 2011 while the $RSD_{quality}$ category increased (Table 11). The length frequency distribution for 2011 demonstrated a reduction in larger fish, with the primary peak occurring in the 250 and 270 mm size groups (Figure 19). A 229 mm TL commercial size limit in Maryland artificially truncates the seafood dealer survey length frequency distribution. No sub-legal fish were recorded in the 2011 seafood dealer survey. The 230 mm length group only accounted for 1.6% of the pound net caught Atlantic croaker seafood dealer samples, with generally inclining abundance through the 310 mm size group (Figure 20). The fish house length frequency distribution would indicate an increase in larger croaker in 2011, but is contradicted by the RSD analysis, mean length and length frequency distribution data from onboard sampling; which indicate a shift to smaller croaker in 2011. Gill net fish house length frequency peaked in the 290 and 310 mm length groups with catches dropping of 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).

In 2011 pound net catches, females averaged 303 mm TL and 395 g (n=136), while males averaged 288 mm TL and 321 g (n=109). This was a decrease for females while the males showed almost no change compared to 2010 values of 320 mm TL and 456 g for females, and 289 mm TL and 320 g for males. In 2011 females accounted for 56% of the pound net samples, slightly lower then in 2008 (64%), 2009 (69%) and 2010 (66%). 2011 gill net samples were slightly larger than those from pound nets, with mean lengths and weights of 311 mm TL and 441 g for females (n = 43) and 314 mm TL and 491 g for males (n = 9). Gill net samples were 79% female and 21% male, but sample size was low, so these percentages may not reflect the actual male to female composition of the gill net harvest.

During 2010, the Maryland Atlantic croaker total commercial harvest of 490,067 pounds (Chesapeake Bay and Atlantic Ocean combined) increased 8% compared to 2009 (Figure 22). The 2010 harvest was still well below the 1929-2010 average of 1,046,881 pounds. The 2010 recreational harvest was estimated at 813,573 fish (PSE = 12.9) a 22% decrease from 2009, and was above the 1981-2010 average of 754,474 fish (Figure 23).

The 2010 recreational releases increased 19% compared to 2009 (Figure 23), and was below the 1981-2010 average of 1,258,893 fish.

Reported Atlantic croaker harvest from charter boats ranged from 127,664 – 448,789 fish during the 18 year time period (Figure 24). The charter boat log book harvest did trend with the statewide MRIP estimates (R^2 = 0.36, P = 0.0078), 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 = 0.43, P = 0.004) from 1993 to 2010, with relatively stable values prior to 2004 and generally increased values since 2004 (Figure 25). The 2010 value of 6.03 fish per angler was the highest of the 18 year time series.

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 of the 20 year time series for 2008, but fell sharply in 2009 (Figure 26). The 2011 GM increased slightly to 1.15 fish per tow, and remained below the 23 year time series mean of 3.4 fish per tow. Atlantic croaker recruitment has been linked to environmental factors including winter temperature in nursery areas (Lankford and Targett 2001, Hare and Able 2007) and 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 2009 Atlantic croaker otoliths ranged from 0 to 8 (n=222), with at least three fish present in each age class (Table 12). The number of Atlantic croaker sampled in 2009 (n=1,381) was applied to an age-length key for 2009 (Table 12). This application indicated that 37% of the fish were age three, 31% were age one, 11% were age four, 9% were age two and 8% were age five. The remaining age groups each accounted for three percent or less of the fish sampled, and 2009 was the first year with no fish greater than age 8 (Table 12). Two hundred sixty-eight Atlantic croaker otoliths were collected in 2010, but aging has not been completed at this time. Instantaneous total mortality in 2011 was Z = 0.93, an increase from 2010, and the fifth year of increasing values since the 1999-2010 time series low of 0.33 in 2006 (Table 8).

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 values and rising SSB values since the late 1980's. Model estimated values of F, SSB and biological reference points are too uncertain to be used to determine stock status. However, the ratio of F to FMSY (the F needed to produce maximum sustainable yield) was deemed reliable and can be 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 2011 to 193 mm TL, below the 18 year time series mean of 206 mm TL (Table 4). The 2011 seafood dealer survey did not encounter any spot, likely due to the small number of trips and time of year (Table 5). The onboard sampling length frequency distribution in 2011 was similar to the 2010, and expanded slightly compared to the 2009 distribution (Figure 27). Both mean length and length frequency distribution are more reliable then the previous two years due to increased sample size in 2011 (n = 582). Two jumbo spot were present in the 2011 onboard sampling accounting for less than 1% of the sample. Jumbo spot in the survey have been declining for the past several years, with the pound net sample comprised of no spot >254 mm TL in 2009 and 2010, less than 1% in 2007 and 2008, <2% in 2006 and 3% in 2005. This followed good catches in the early part of the decade (10% in 2003, 13% in 2004).

Commercial harvest in 2010 increased slightly to 580,694 pounds (Figure 28), the 3rd highest catch of the 81 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, into the mid 1980's until rebounding to moderate levels through the present. 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, 2009, and 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) and 87% of the 2010 harvest (507,091), 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 2010 non-gill net harvest increased to 70,603 pounds. 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, and the overall increase in spot landings the past two years may indicate an increase in availability.

Maryland recreational harvest estimates from the MRIP indicated that spot catches since 1981 have been variable (Figure 29). Recreational harvest has varied 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 2010 recreational harvest estimate (995,390 fish; PSE = 20) decreased 54% compared to 2009, dropping well below the time series mean estimate of 1,707,159 fish, and marked the 8th lowest value of the 30 year time series. The release estimate of 1,022,820 fish (PSE = 14.6) increased 30% compared to 2009, and was very close to the long term mean of 1,094,194 fish (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 2010 reported harvest was the lowest of the time series. 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, generally increased from 2002 – 2007, declined slightly to 8.96 in 2008 and then increased slightly to 9.73 fish in 2009. In 2010 the geometric mean decreased to 5.82, the second lowest value in the 18 year time series, well below the mean of 7.97 fish per angler (Figure 31).

Spot juvenile trawl index values from 1989-2011 were quite variable (Figure 32). The 2010 GM value of 104.5 spot per tow was the highest value of the time series, but the 2011 value of 0.6 spot per tow was the second lowest value of the 23 year time series.

Age one dominated the pound net catch from 2007 to 2011, accounting for 75% to 99% of sampled fish (Table 13). Age zero and two fish were present every year, with age zero accounting for 0.4% to 24.3% of sampled spot and age two accounted for 0.2% to 3.3%. Two fish 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. However, recreational harvest and release estimates were high from 2005 to 2009, except the 2009 release estimate. Virginia and North Carolina recently voiced concern over decreasing spot harvests in their waters, and ASMFC's spot Plan Review Team is currently examining 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.

Red Drum

Red drum were rarely encountered in the onboard pound net or seafood dealer sampling, with only two being examined in 2011 survey. Red drum mean length from the 2011 onboard sampling was 678 mm TL, above the 18 year time series mean of 470 mm TL (Table 4). The number of red drum sampled from the onboard sampling peaked in 2002 (Table 4); however, none were measured from 1993 to 1998. Maryland is near the northern limit for red drum and catches would be expected to increase if the stock expands in response to the current Atlantic coast stock recovery plan (ASMFC 2002).

The Maryland commercial red drum harvest in 2010 totaled 19 pounds, compared to 12 pounds in 2009 (Figure 33). Average harvest from 2004 to 2010 was 31 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 any red drum in 2010, but did estimate 1,814 (PSE = 95.7) releases in 2010 (Figure 34). Recreational harvest estimates have been extremely variable ranging from zero (22 of the 30 years in the 1981 - 2010 time series) to 12,804 fish (in 2006). Peak number of red drum releases occurred in 2002 at 18,412 fish (Figure 34).

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 21 red drum per year (Figure 35). The low reported catch does indicate red drum are 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.

Black Drum

Black drum are only occasionally encountered during the MD DNR onboard pound net sampling, with three being sampled in 2011 (Table 4). Lengths throughout the time series have ranged from 244 to 1330 mm TL, and averaged 978 mm TL in 2011. 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 2009 have been variable, ranging from zero to over 13,000 fish in 1983 (Figure 37). In 2010, MRIP estimated 3,467 black drum were harvested and 2,619 were released by recreational anglers, with PSE values of 100 for both estimates. 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 reveled black drum were harvested in all years of the 1993-2010 time series, with a mean catch of 411 fish per year and ranging from 104 – 905 fish per year (Figure 38). The charter harvest had no significant trend to either the state wide or inland for hire only MRIP estimates. The geometric mean significantly declined ($R^2 = 0.72$, $P < 0.001$) throughout the time series, but did increase slightly in 2009 and 2010 (Figure 39). The CPA of 0.20 in 2010 was nearly identical to 2009, and was the highest value since 2001.

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. No Spanish mackerel were encountered in 2011, it was the second year of the survey that none were measured (Table 4). The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 (Table 4). Also, no Spanish mackerel were encountered during seafood dealer sampling in 2011 (Table 5). Spanish mackerel usually are more abundant in Maryland's portion of Chesapeake Bay in late summer, but no seafood dealer sampling was conducted at that time in 2011.

The 2010 commercial harvest of Spanish mackerel in Maryland was 3,806 pounds, 67% less than in 2009 (11,416 pounds; Figure 40), and below the 1965 to 2010 mean of 6,388 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 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 – 2010 were variable, ranging from 0 – 24,725 fish with an average of 9,024 fish taken. In 2010, an estimated 6,671 (PSE = 54.7) Spanish mackerel were harvested, a four fold decrease from the 2009 estimate of 24,725 fish (PSE = 43.0, Figure 41). 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 ($R^2 = 0.66$, $P < 0.01$) and the statewide MRIP estimates ($R^2 = 0.51$, $P < 0.01$), 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. Four were measured from the onboard sampling in 2011 with a mean length of 361 mm TL (Table 4), and none were encountered during seafood dealer sampling (Table 5). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 6,792 pounds from 1991-2010 (Figure 44). Reported 2010 harvest was 1,025 pounds, well below the 1991- 2010 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 by 85% to 1,725 (PSE = 71), but the high PSE values in 2009 and 2010 indicate the MRIP survey does not provide reliable estimates for this species in Maryland.

Spotted seatrout harvest from 2010 charter boats had the lowest fish per year in the 14 year time series, ranging from 224 – 20,030 fish per year and averaged 4,360 fish per year (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 trend (Figure 47). The recreational spotted seatrout fishery in Chesapeake Bay is persecuted by a small group of anglers that are unlikely 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 2011 was 213 mm FL, the lowest mean length of the 2004 to 2011 time series (Table 4). Menhaden samples were not collected from the seafood dealer survey in 2011. Menhaden length frequencies from onboard sampling for 2006 and 2007 were very similar and robust compared to 2005 (Figure 48). However, the 2008 length frequency distribution was more concentrated around the mean length, 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. The 2010 and 2011 length distribution indicated a shift to smaller fish, and a more even distribution of lengths.

Atlantic menhaden scale samples were taken from 425 fish in 2010 and 397 fish in 2011, but ages could only be assigned to 388 fish in 2010 and 384 fish in 2011 (Tables 14 and 15). In 2010 and 2011 over half of the menhaden aged were less than 2 years old. 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 16). Menhaden ages greater then 4 made up 2% to 4.5% of the population form 2005 to 2011.

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 1935-2008 was four million pounds. The 2010 commercial harvest decreased for the third straight year, but was still the 13^{th} highest of the 75 year time series (6.9 million pounds), with 97% of harvest from the Chesapeake Bay (Figure 49). The vast majority of Maryland's annual menhaden harvest consistently comes from the Chesapeake Bay.

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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, 2011.

Area	**Month**	**Number of Sampling Trips**	**Mean Water Temp. °C**	**Mean Salinity (ppt)**
Point Lookout	May	1	21.7	6.5
Point Lookout	June	2	24	7
Nanticoke	June	3	26.9	10.2
Hooper Strait	June	2	26.4	10
Point Lookout	July	2	27.0	9.8
Nanticoke	July	2	29.4	11.2
Hooper Strait	July	1	29.5	11.6
Point Lookout	August	3	26.6	13.2
Nanticoke	August	2	27.5	12.3
Hooper Strait	August	2	27.2	13.5
Nanticoke	September	1	24.2	9.6

Table 3. List of non-target species observed during the 2011 onboard pound net survey.

Common Name	*Scientific Name*
Butterfish	*Peprilus triacanthus*
Cobia	*Rachycentron canadum*
Common Carp	*Cyprinus carpio*
Cownose ray	*Rhinoptera bonasus*
Gizzard shad	*Dorosoma cepedianum*
Hogchoker	*Trinectes maculates*
Houndfish	*Tylosurus crocodilus*
Northern puffer	*Sphoeroides maculatus*
Northern searobin	*Prionotus carolinus*
Oyster toadfish	*Opsanus tau*
Southern stingray	*Dasyatis americana*
Striped bass	*Morone saxatilis*
Striped burrfish	*Chilomycterus schoepfi*
Threadfin herring	*Opisthonema oglinum*
White catfish	*Ameiurus catus*
White perch	*Morone americana*

T able 4. Mean length (mm TL), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993 - 2011.

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

Table 4. Continued.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Red Drum																			
mean length						302	332	648		316	506	647	353	366	658	361			678
std. dev.							71			44		468		21	40	57			18
n	0	0	0	0	0	1	16	1	0	177	1	2	1	16	2	21	0	0	2
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		
std. dev.			34	62				34	34	81	63	95	33	35	51	59	53		
n			44	27	1	1		49	19	20	11	8	373	445	158	18	7	0	0
Menhaden (Fork Length)																			
mean length												262	282	238	243	246	245	232	213
std. dev.												28	36	42	41	29	40	36	39
n												213	1052	826	854	826	366	836	773

Table 5. Mean length (mm TL), mean weight (g) and sample sizes of summer migrant fishes from Chesapeake Bay seafood dealer sampling, 2009- 2011.

	2009	2010	2011
Weakfish			
mean length	337		
mean weight	376		
n	6	0	0
Summer flounder			
mean length	419	434	434.7
mean weight	794	933	911.6
n	389	79	13
Bluefish			
mean length	391	438	
mean weight	640	844	
n	184	4	0
Atlantic croaker			
mean length	300	269	314
mean weight	370	257	429.5
n	1287	546	365
Spot			
mean length	211	211	
mean weight	141	115	
n	581	249	0
Spotted Seatrout			
mean length	419	511	
mean weight	682	1308	
n	2	4	0
Red Drum			
mean length	577		
mean weight	2137		
n	5	0	0
Spanish Mackerel (Fork Length)			
mean length	413	378	
mean weight	681	240	
n	176	1	0
Menhaden (Fork Length)			
mean length	258		
mean weight	247	Not	Not
n	146	Measured	Measured

Table 6. Relative stock density of weakfish from Chesapeake Bay summer onboard pound net survey, 1993 - 2011.

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				

Table 7. Weakfish proportion at age using pound net length and age data, number of age samples and number of length samples by year, 2003-2009.

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

Table 8. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2011.

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Weakfish	0.74	0.4	0.62	0.58	0.73	1.29	1.44	1.35	*	*	*	*	*
Atlantic croaker	0.52	0.53	0.41	0.42	0.60	0.48	0.40	0.33	0.42	0.43	0.59	0.78	0.93

* Insufficient data to calculate 2007 - 2011 weakfish estimates.

Table 9. Relative stock density of summer flounder from Chesapeake Bay summer onboard pound net survey, 1993 - 2011.

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	

Table 10. Relative stock density of bluefish from Chesapeake Bay summer onboard pound net survey, 1993 - 2011.

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				

Table 11. Relative stock density of Atlantic croaker from Chesapeake Bay summer onboard pound net survey, 1993 - 2011.

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

Table 12. Atlantic croaker proportion at age using pound net length and age data, number of age samples and number of length samples by year, 1999-2009.

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

Table 13. Spot proportion at age, number of samples aged and number of length samples by year using pound net length and age data, 2007-2011.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	# Aged	# Measured
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	1,201
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

Table 14. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2010.

Age	Mean Length (mm FL)	Number Aged
0		0
1	207	153
2	237	125
3	271	63
4	281	34
5	289	10
6	303	3

Table 15. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2011.

Age	Mean Length (mm FL)	Number Aged
0		0
1	189	197
2	236	106
3	260	59
4	293	20
5	298	2

Table 16. Atlantic menhaden proportion at age using pound net length and age data, number of age samples and number of length samples by year, 2005-2011.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	# 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

Figure 1. Summer pound net sampling area map for 2011.

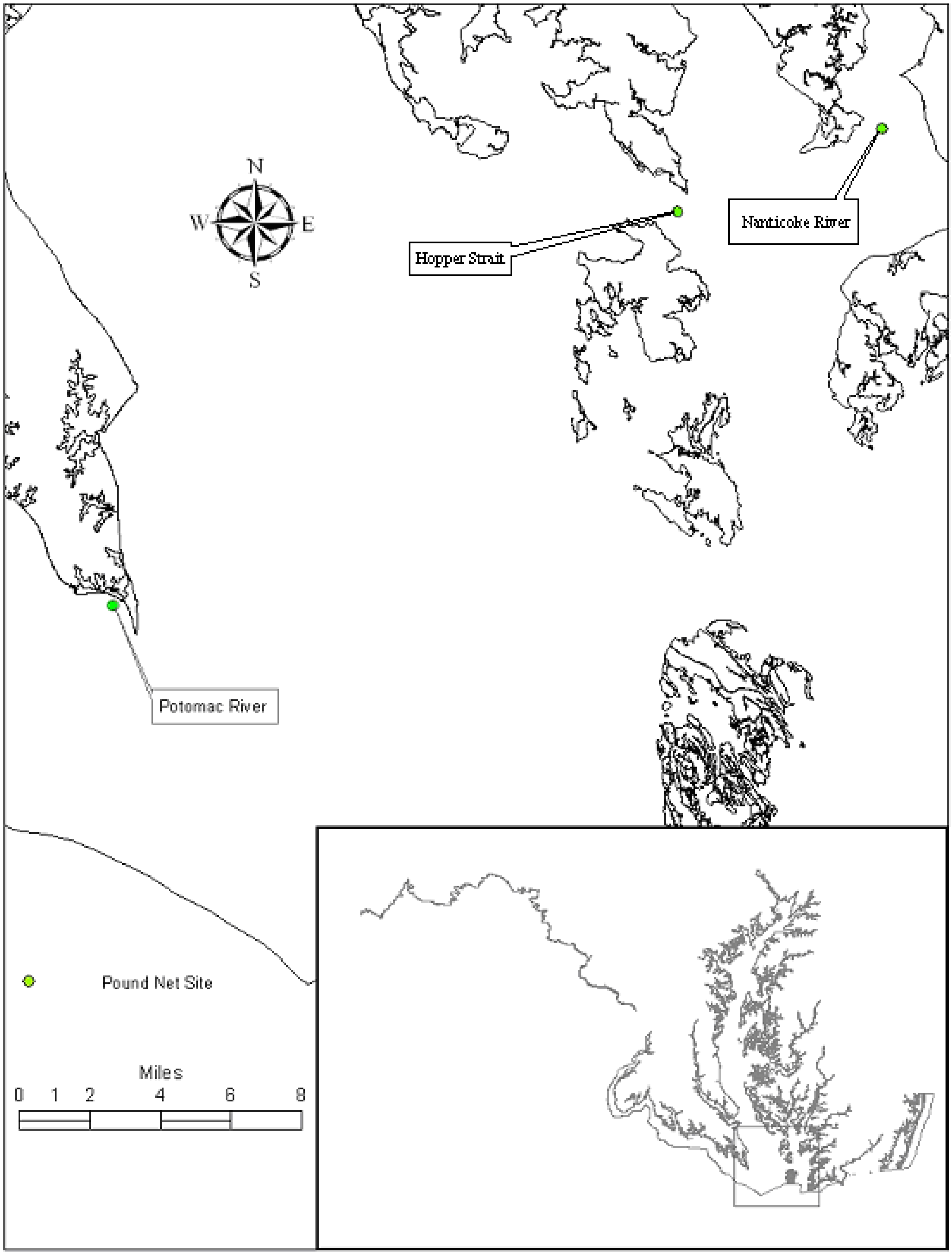


Figure 2. Weakfish length frequency distributions from onboard pound net sampling, 2008-2011.

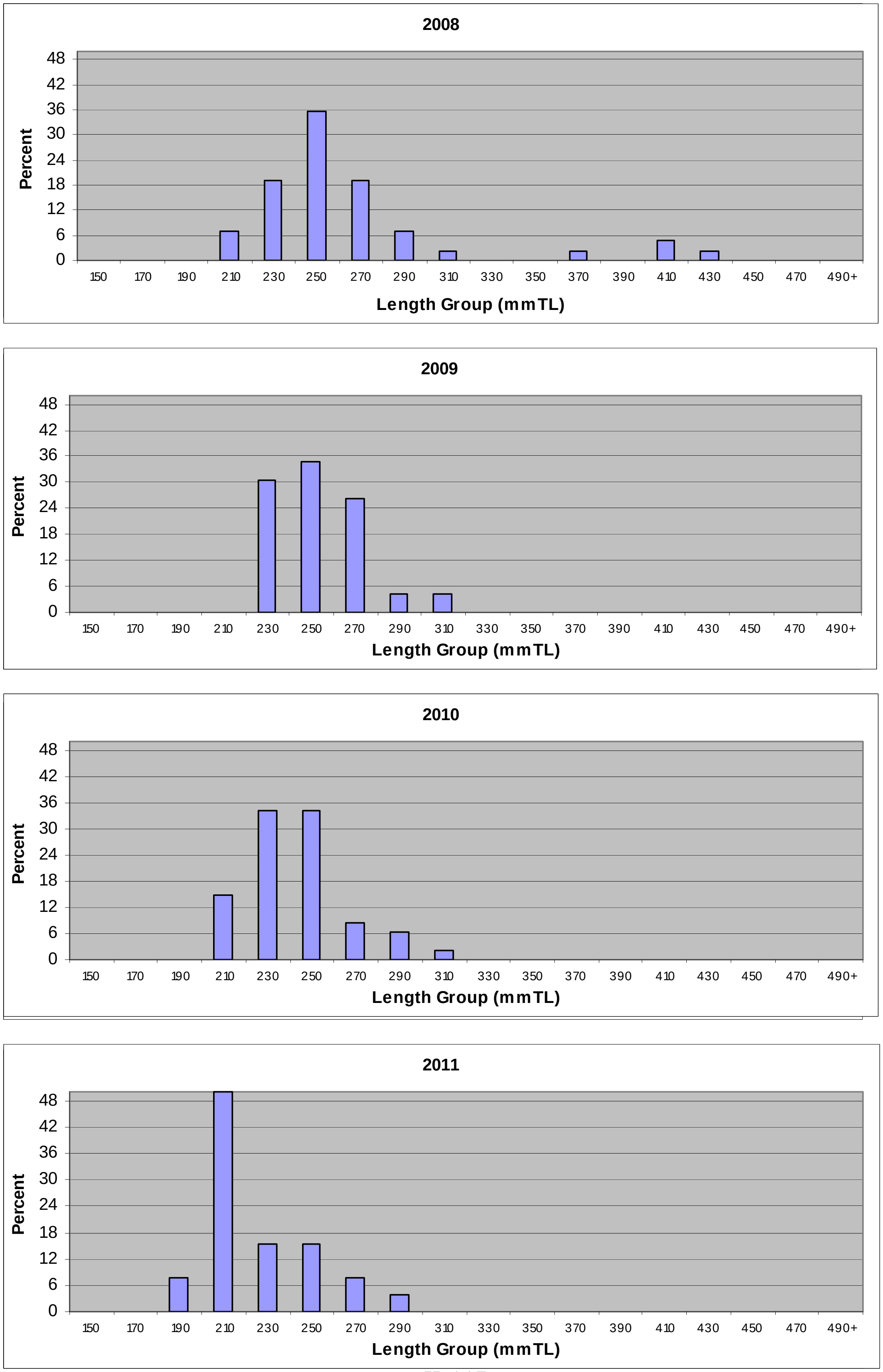


Figure 3. Maryland commercial weakfish harvest by area, 1929-2010.

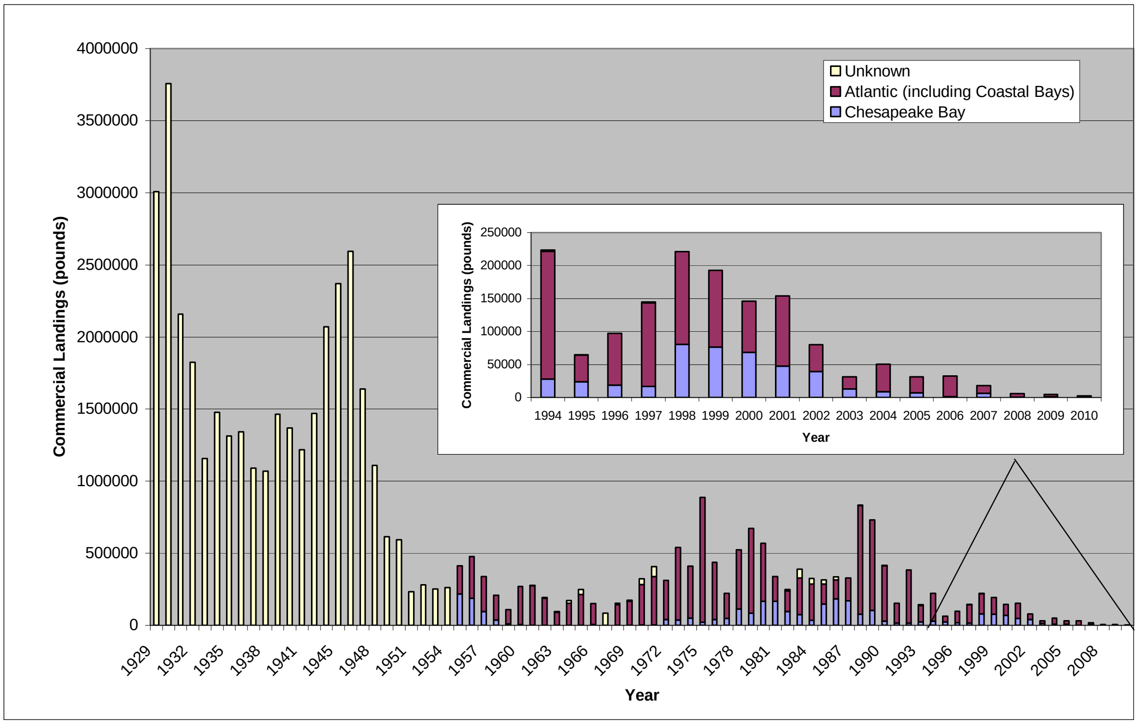


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2010 (Source: MRIP, 2011).

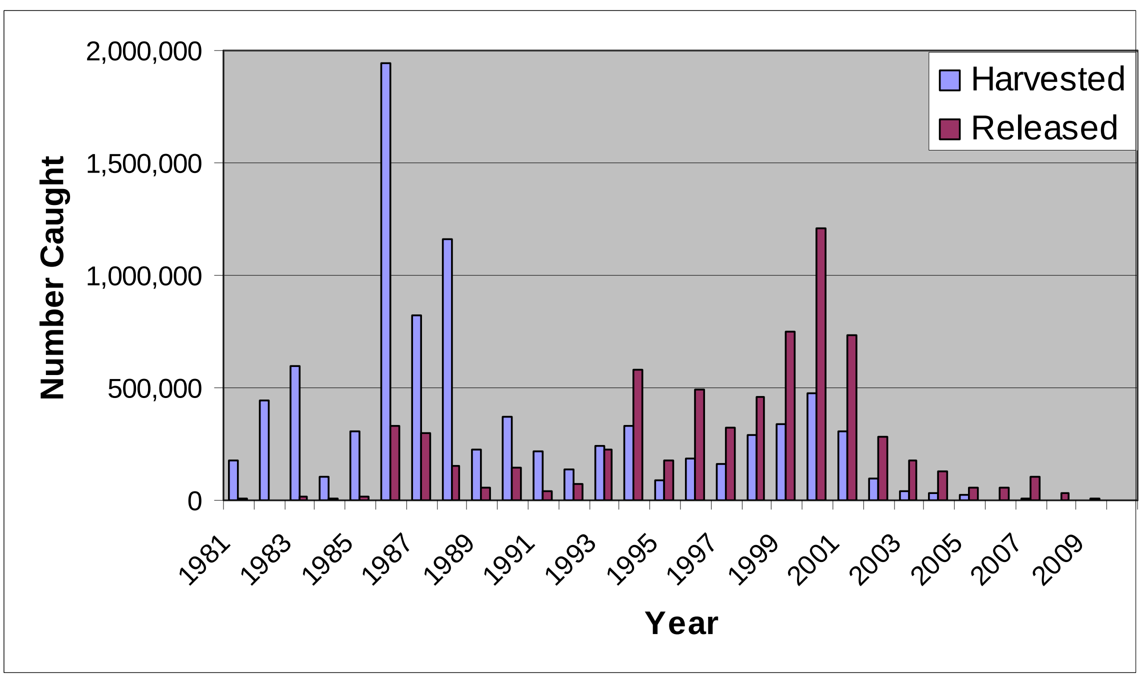


Figure 5. Weakfish statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2010.

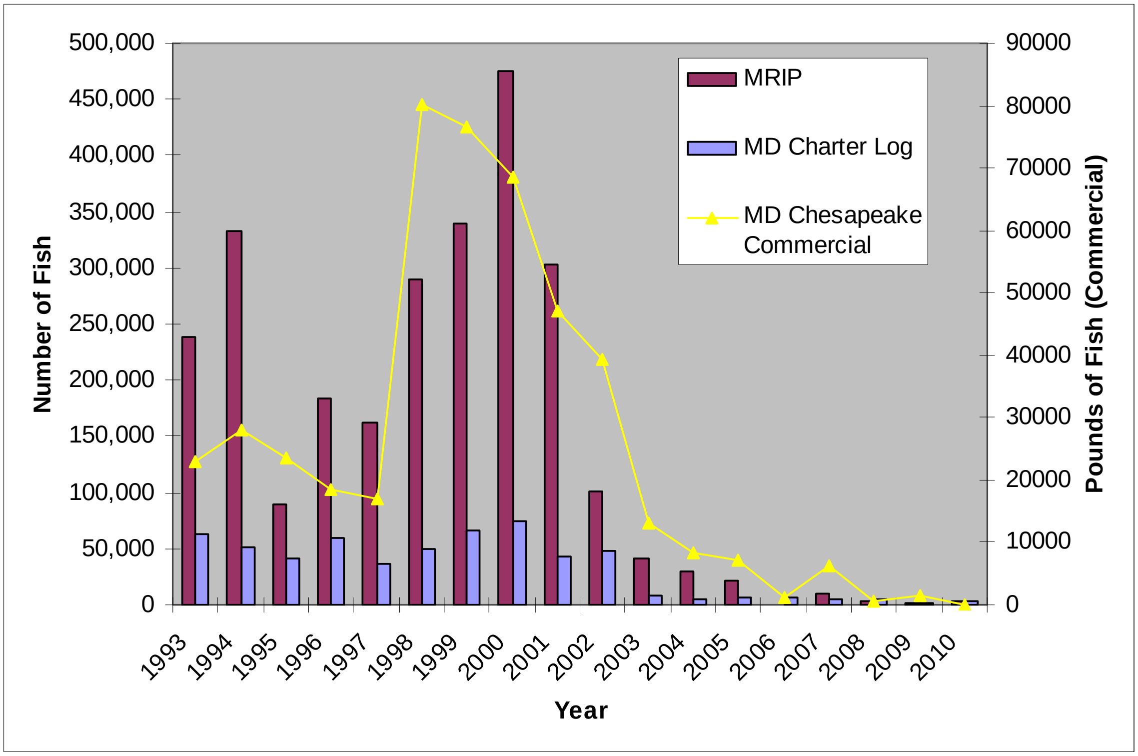


Figure 6. Weakfish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

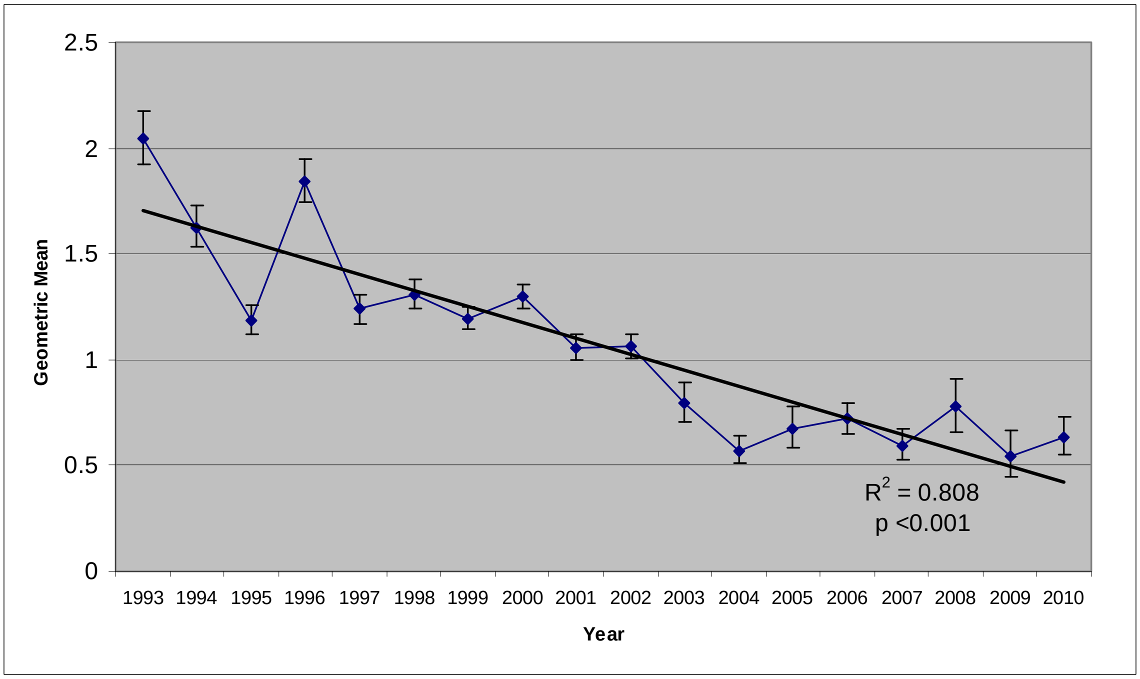


Figure 7. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2011.

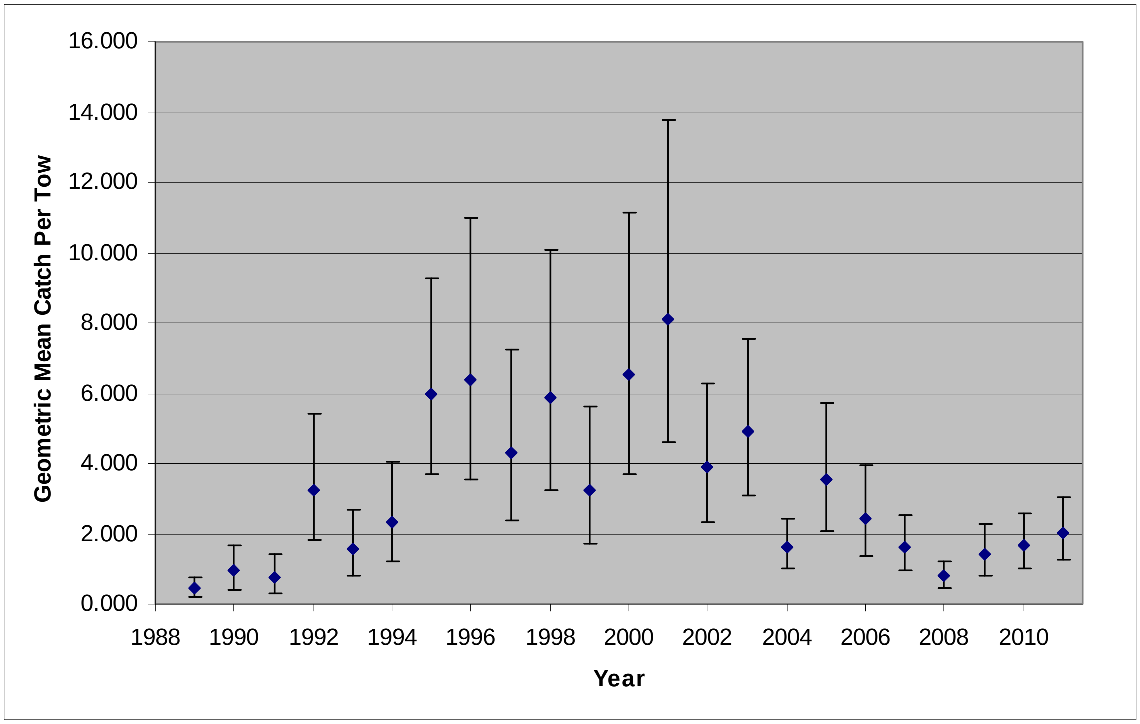


Figure 8. Summer flounder length frequency distributions from onboard pound net sampling, 2008-2011.

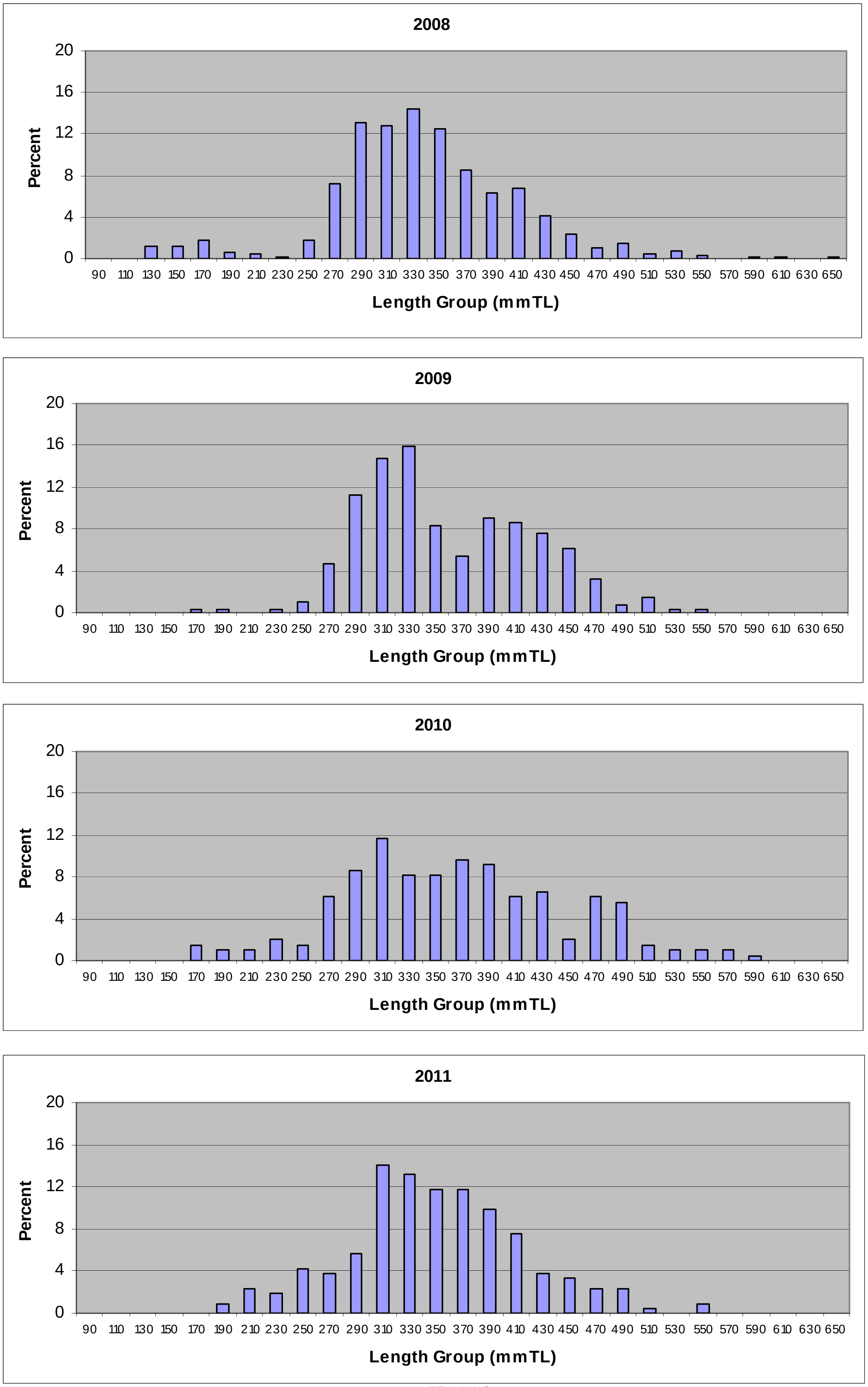


Figure 9. Summer flounder length frequency distributions from seafood dealer sampling, 2009-2011.

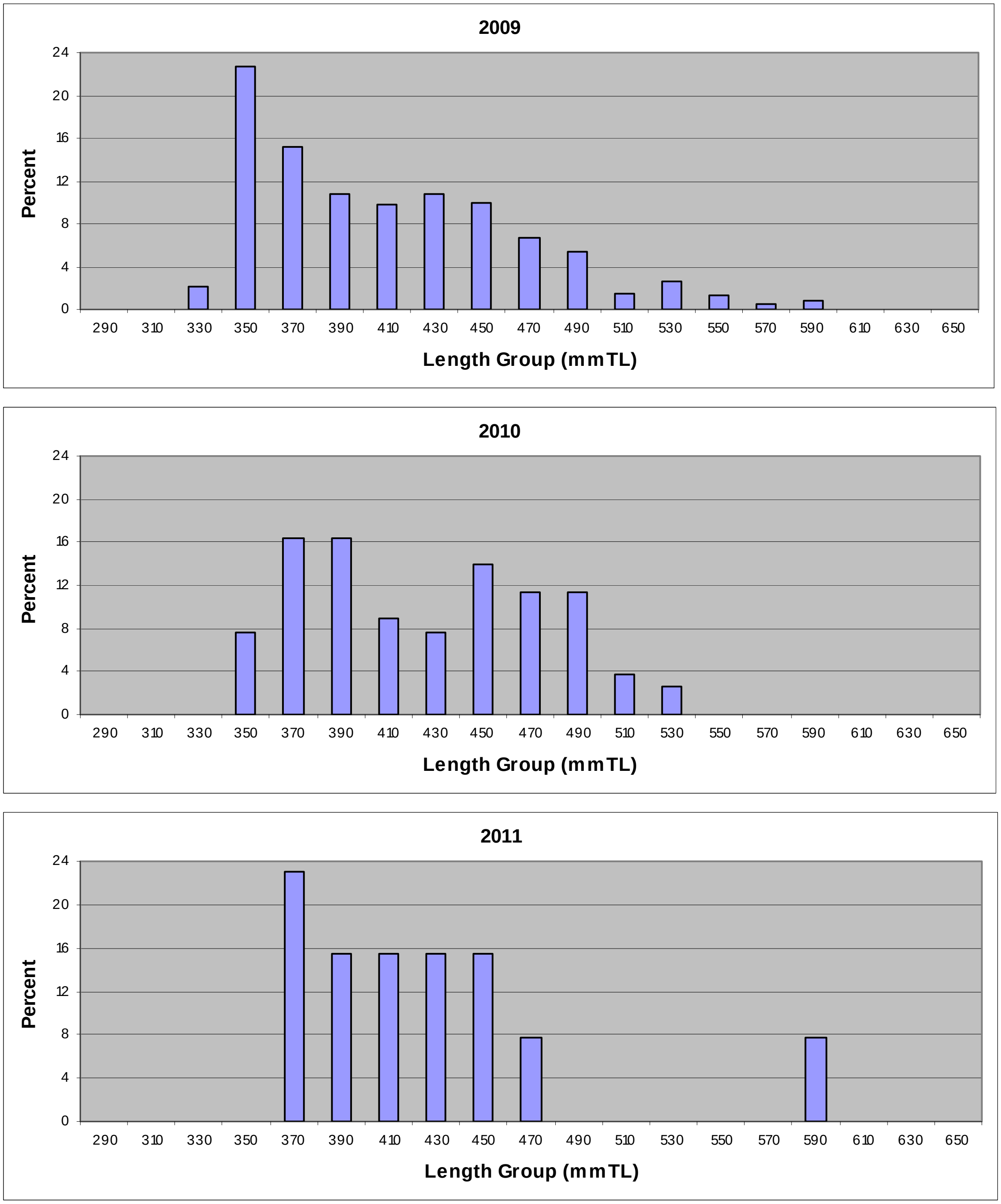


Figure 10. Maryland commercial summer flounder harvest by area, 1962-2010.

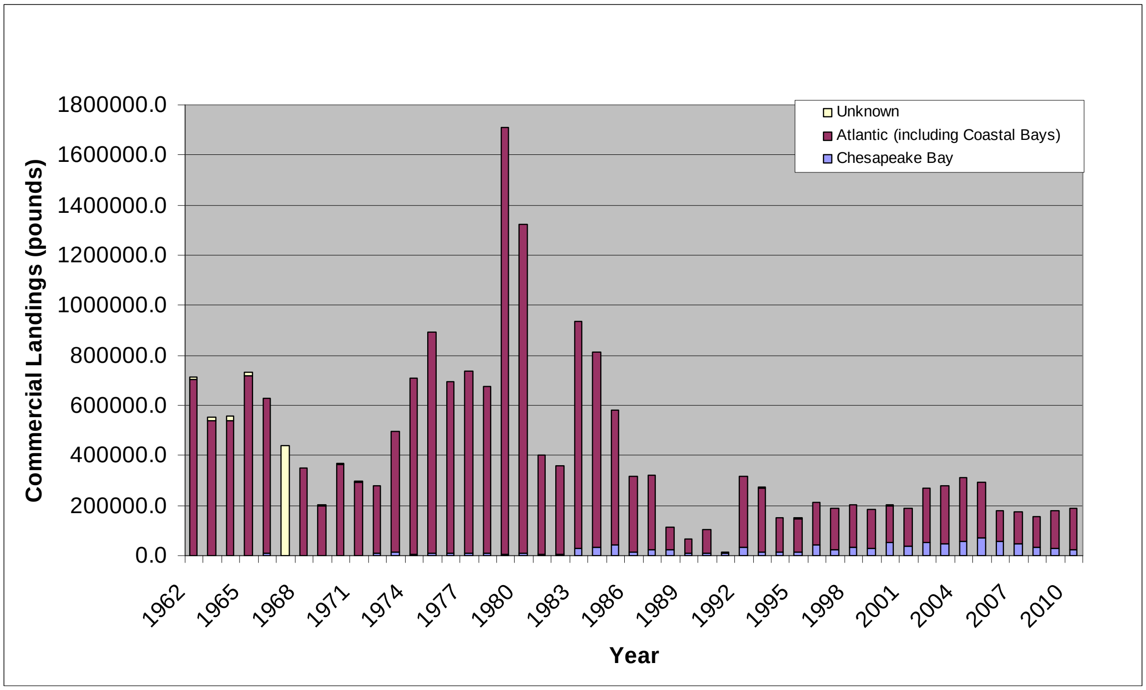


Figure 11. Estimated Maryland recreational summer flounder harvest and releases for 1981-2010 (Source: MRIP, 2011).

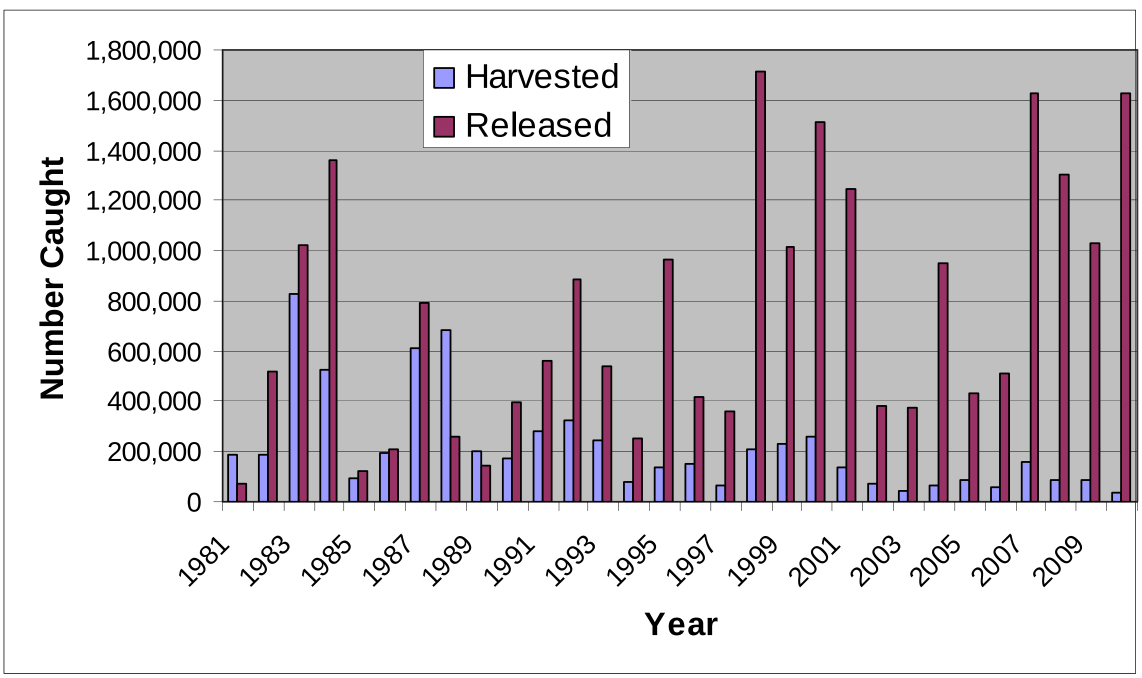


Figure 12. Summer Flounder statewide MRIP harvest and reported charter boat harvest from Maryland logbooks in numbers, 1993-2010.

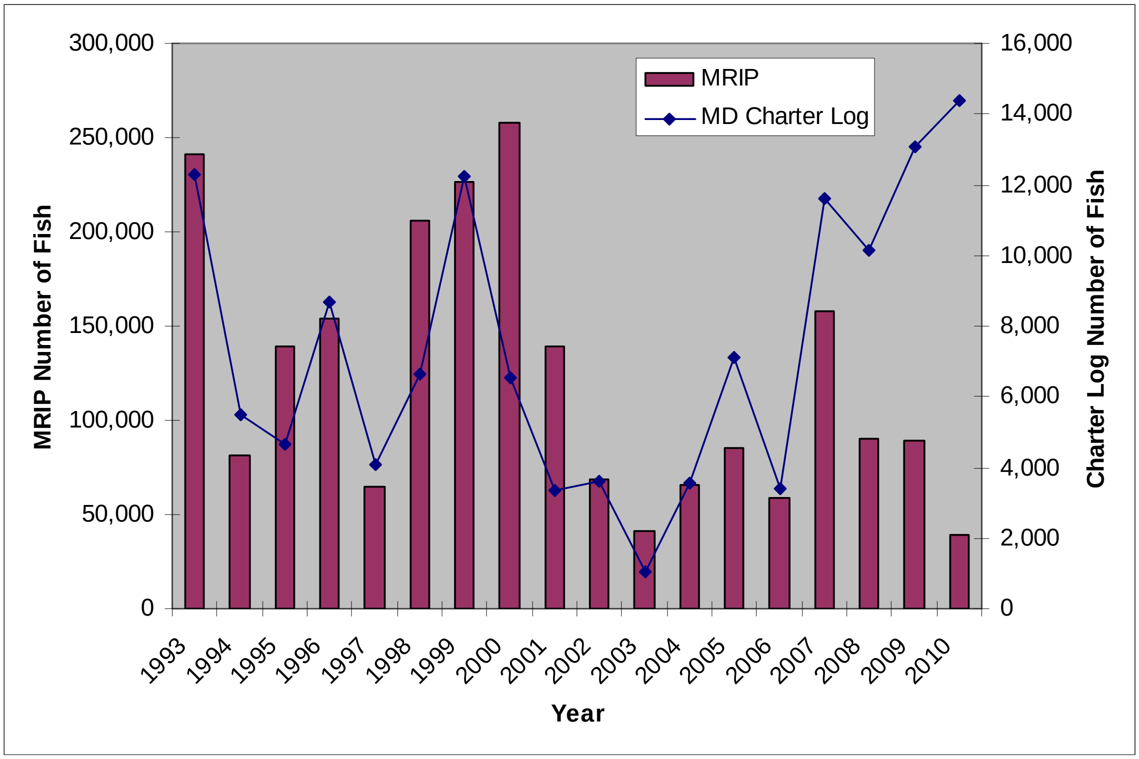


Figure 13. Summer flounder geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

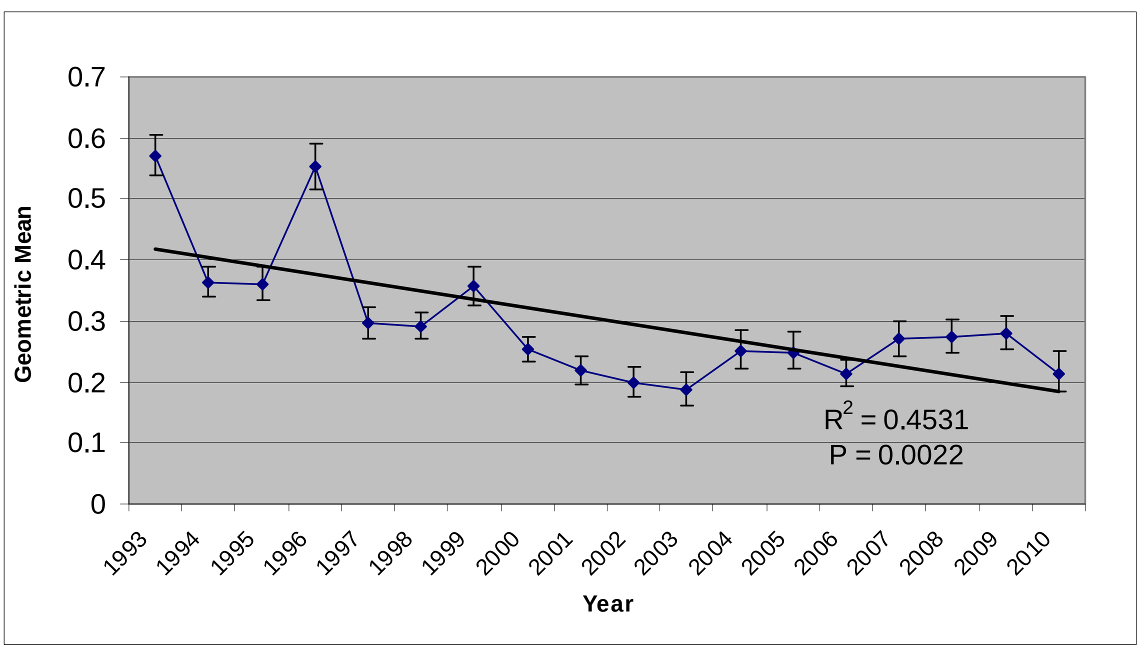
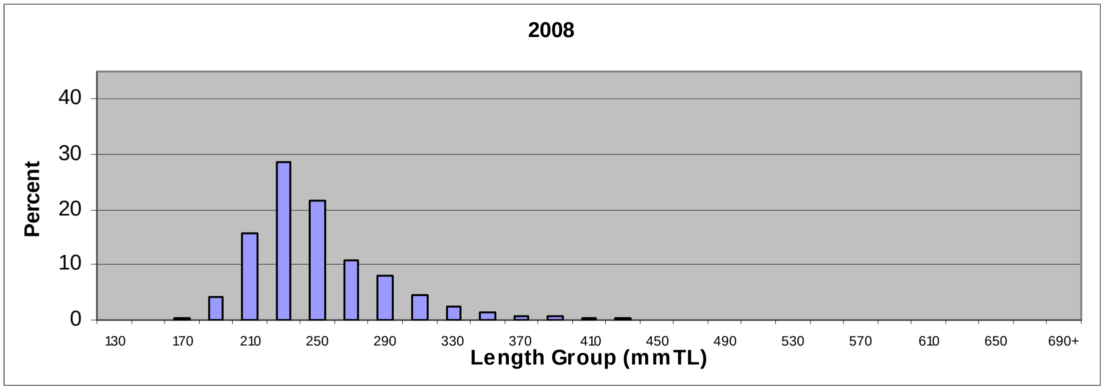
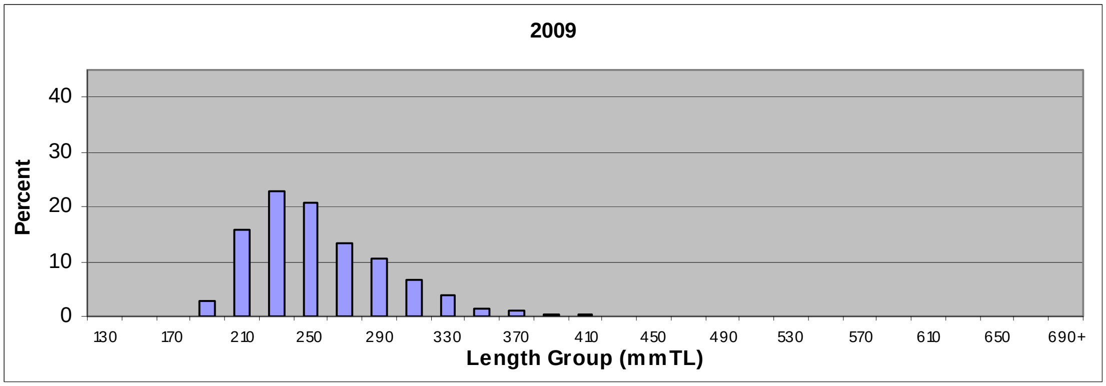
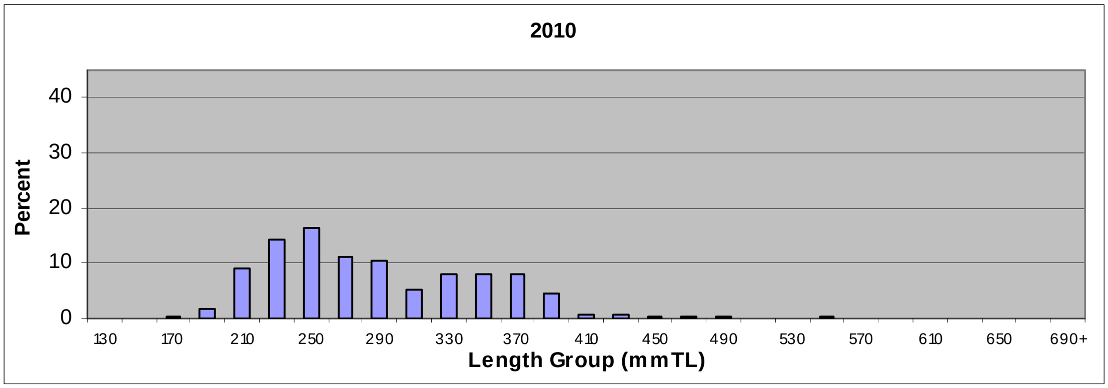


Figure 14. Bluefish length frequency distributions from onboard pound net sampling, 2008-2011.







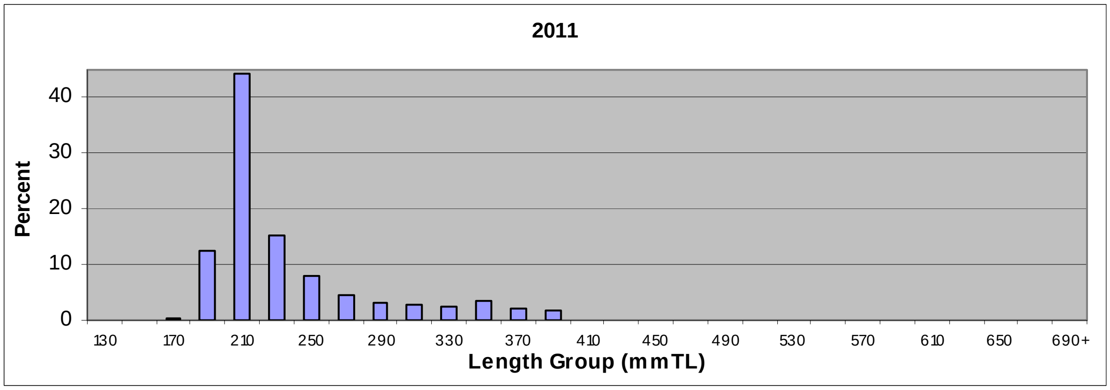


Figure 15. Maryland commercial bluefish harvest by area, 1929-2010.

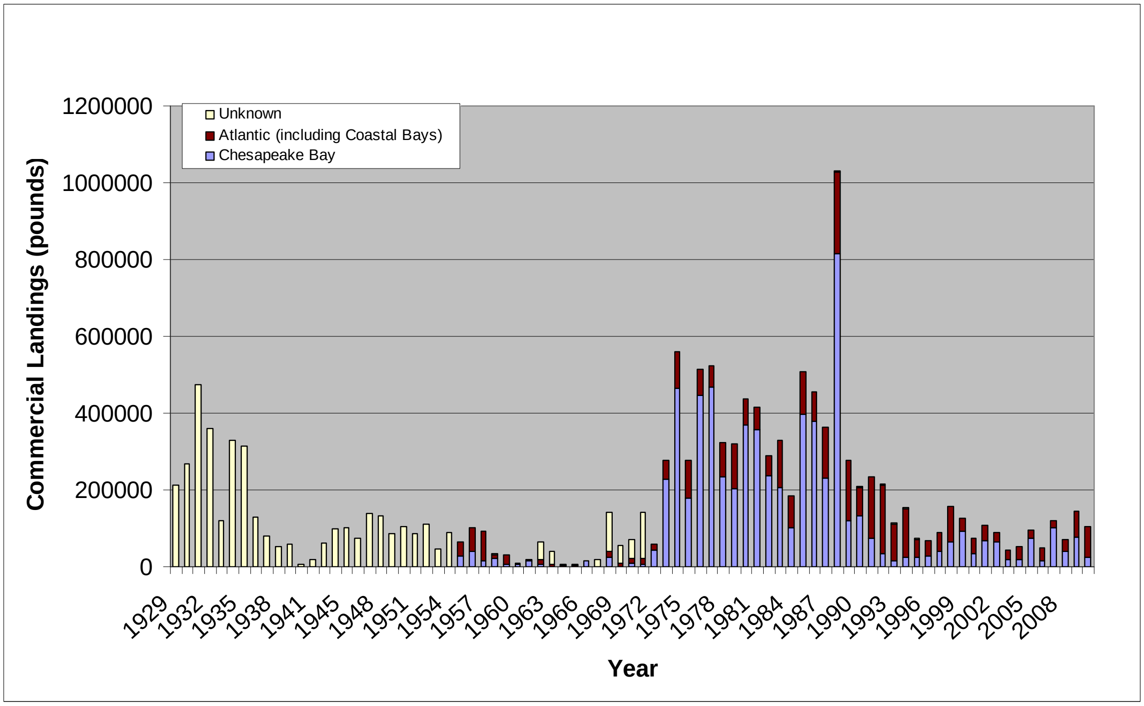


Figure 16. Estimated Maryland recreational bluefish harvest and releases for 1981-2010 (Source: MRIP, 2011).

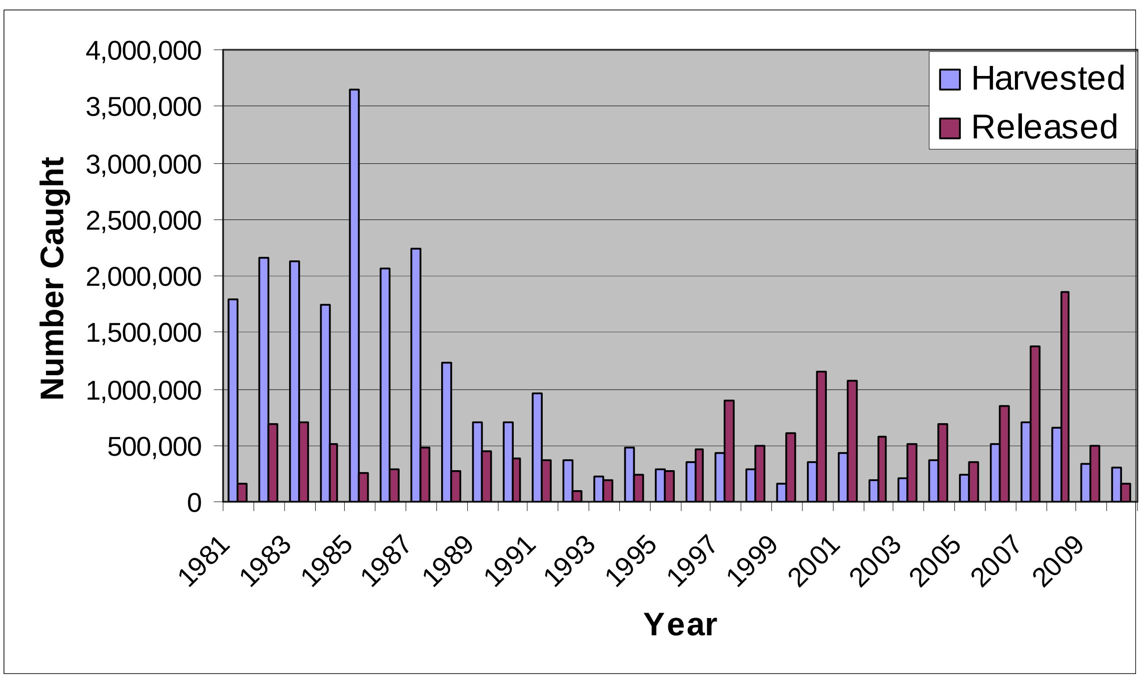


Figure 17. Bluefish statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2010.

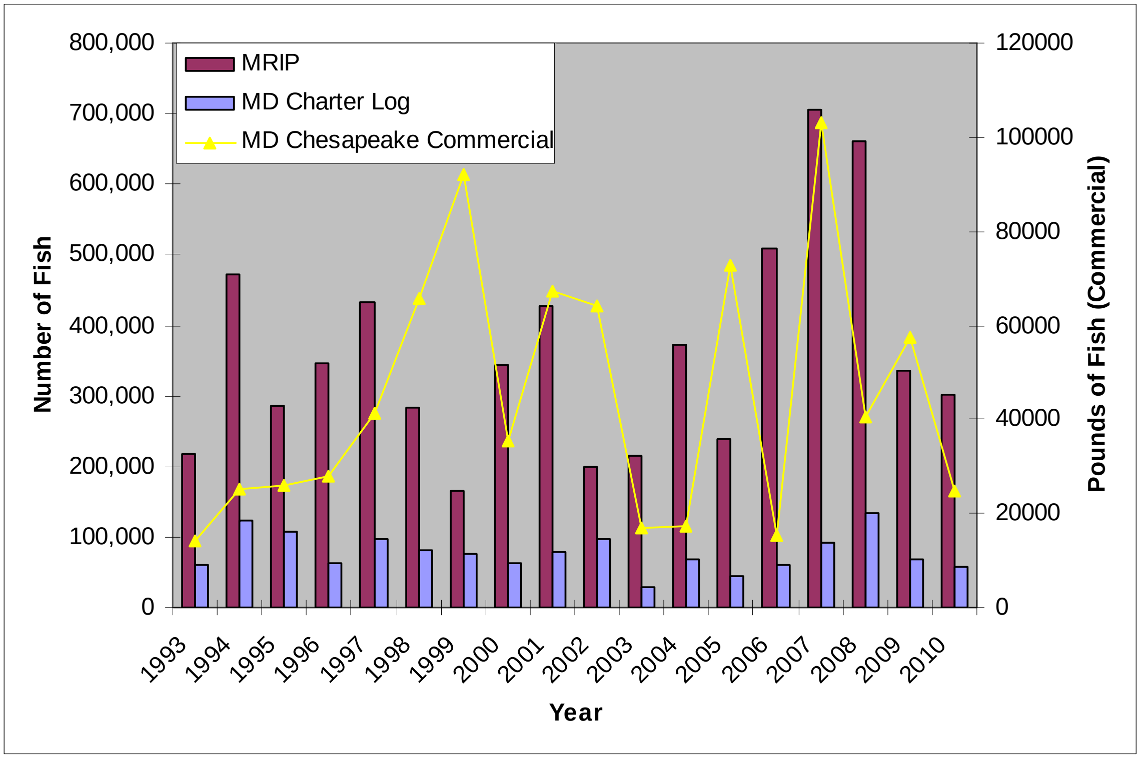


Figure 18. Bluefish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

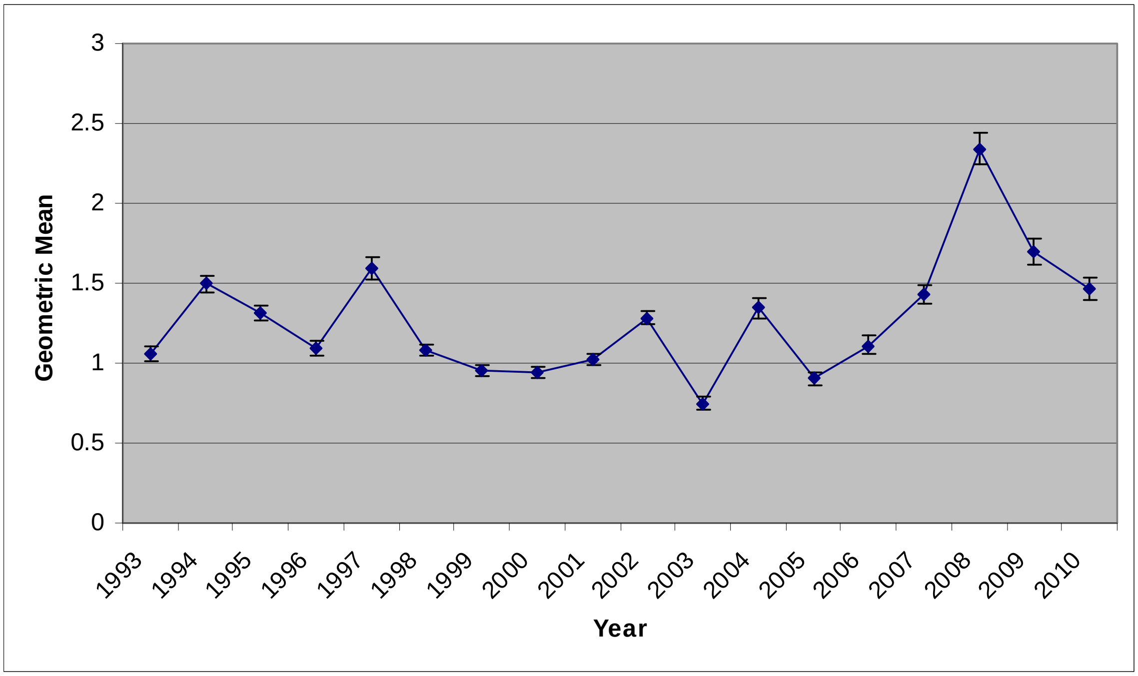


Figure 19. Atlantic croaker length frequency distributions from onboard pound net sampling, 2008-2011.

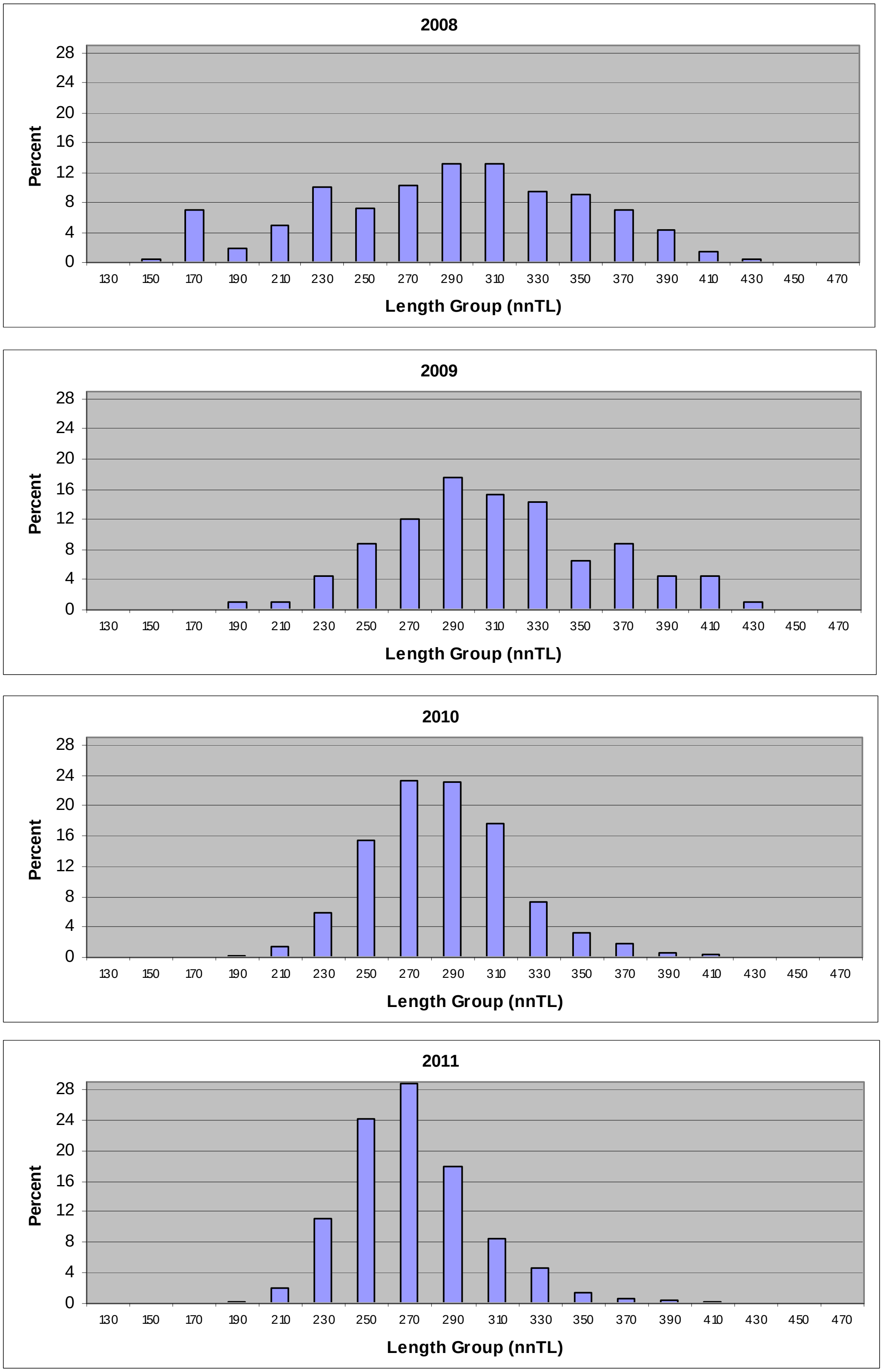


Figure 20. Atlantic croaker length frequency distributions from seafood dealer pound net sampling, 2009-2011.

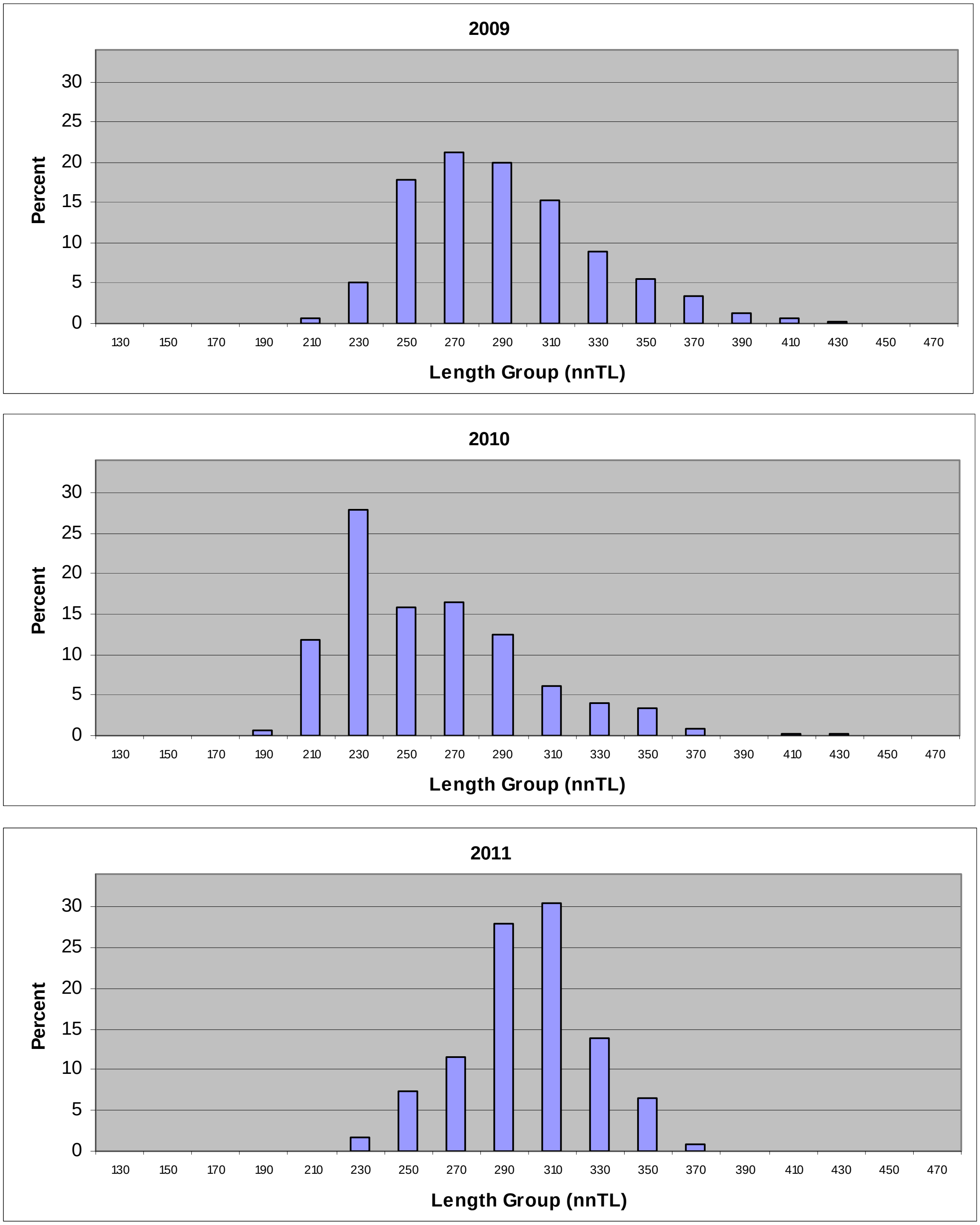


Figure 21. Atlantic croaker length frequency distributions from seafood dealer gill net sampling for 2011.

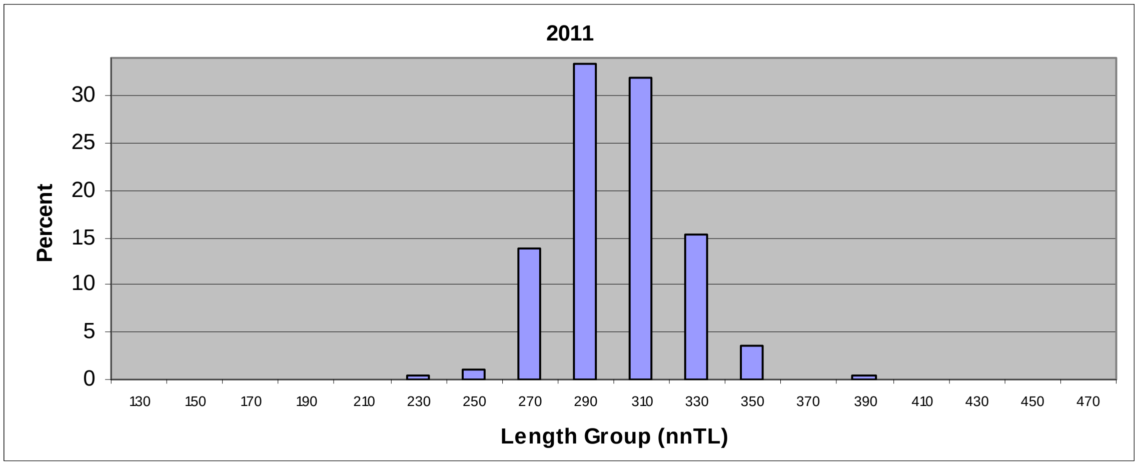


Figure 22. Maryland commercial Atlantic croaker harvest by area, 1929-2010.

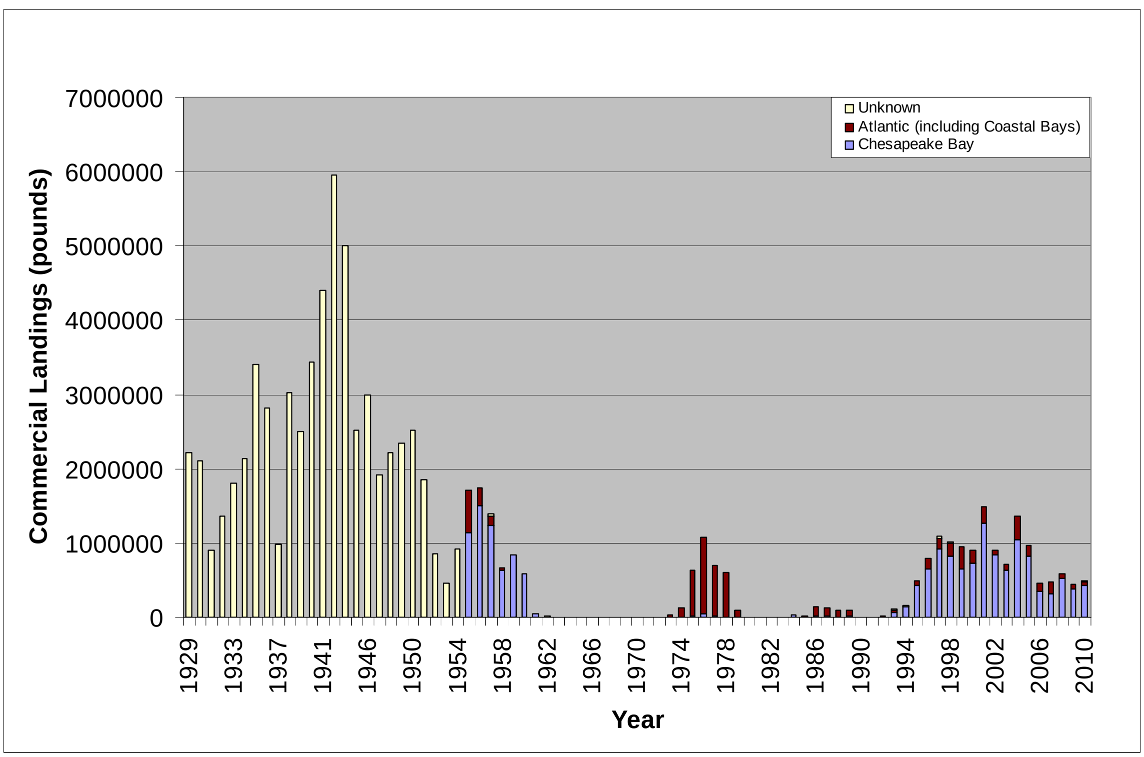


Figure 23. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2010 (Source: MRIP, 2011).

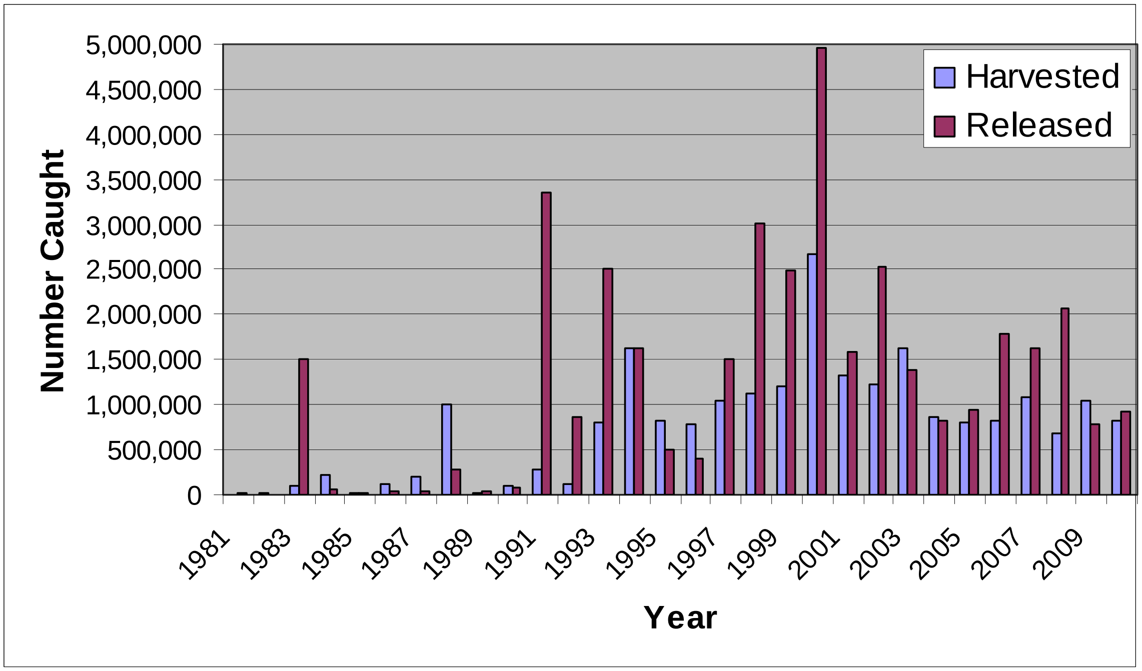


Figure 24. Atlantic croaker statewide MRIP harvest, MRIP for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2010.

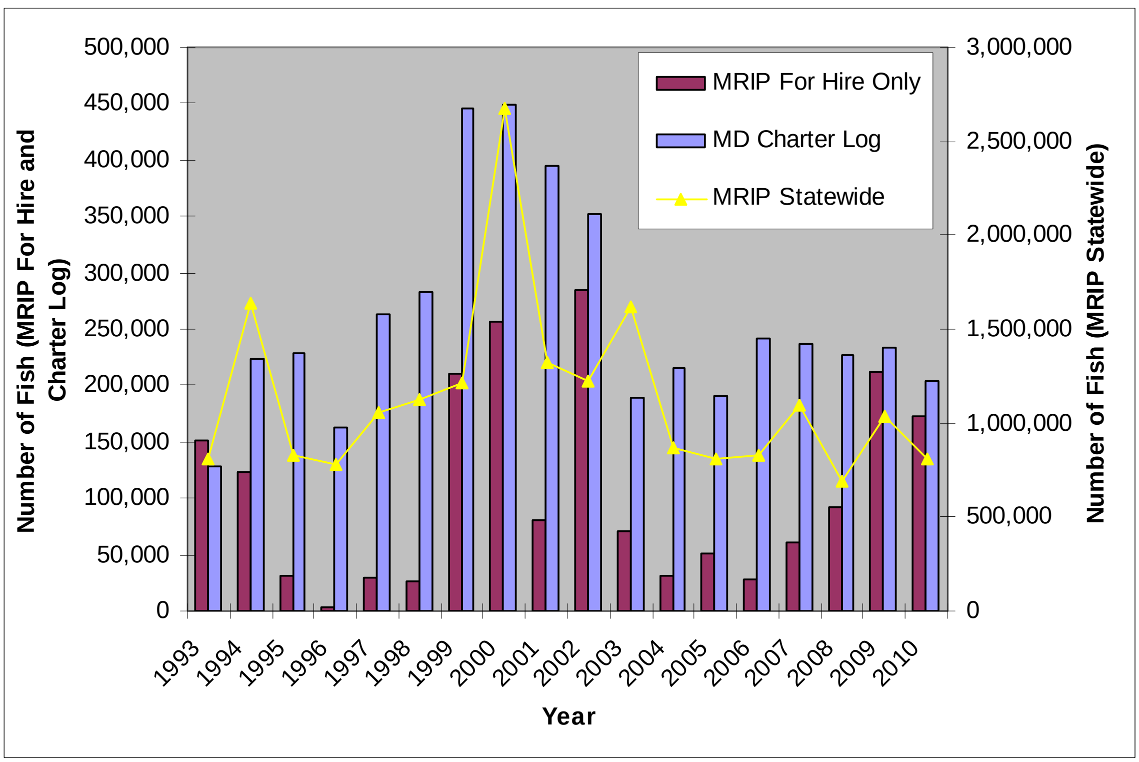


Figure 25. Atlantic croaker geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

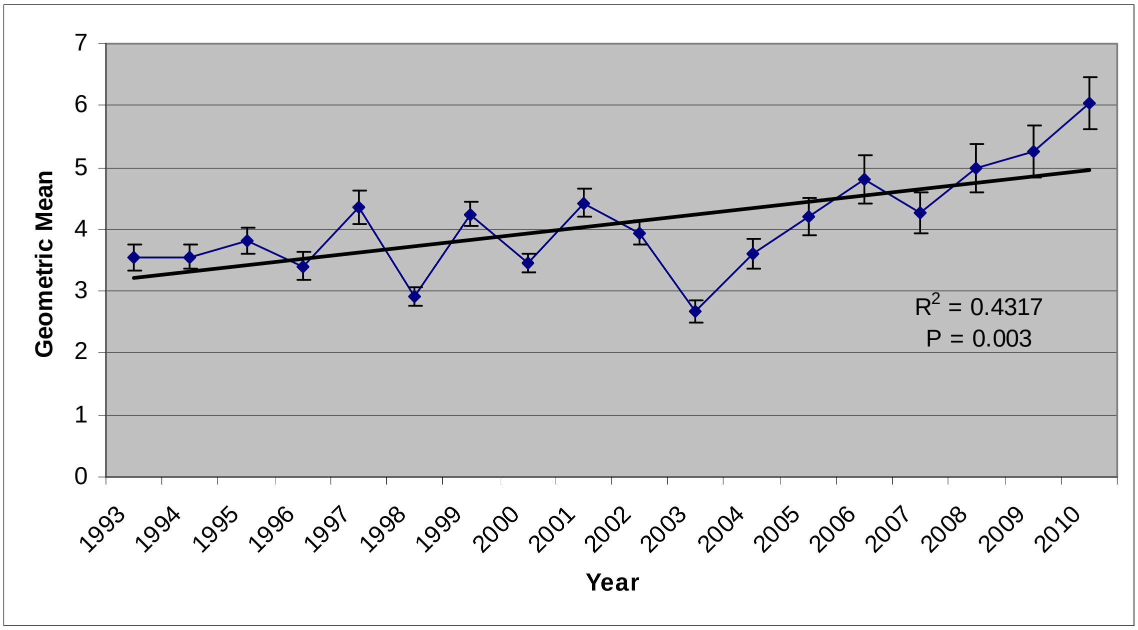


Figure 26. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2011.

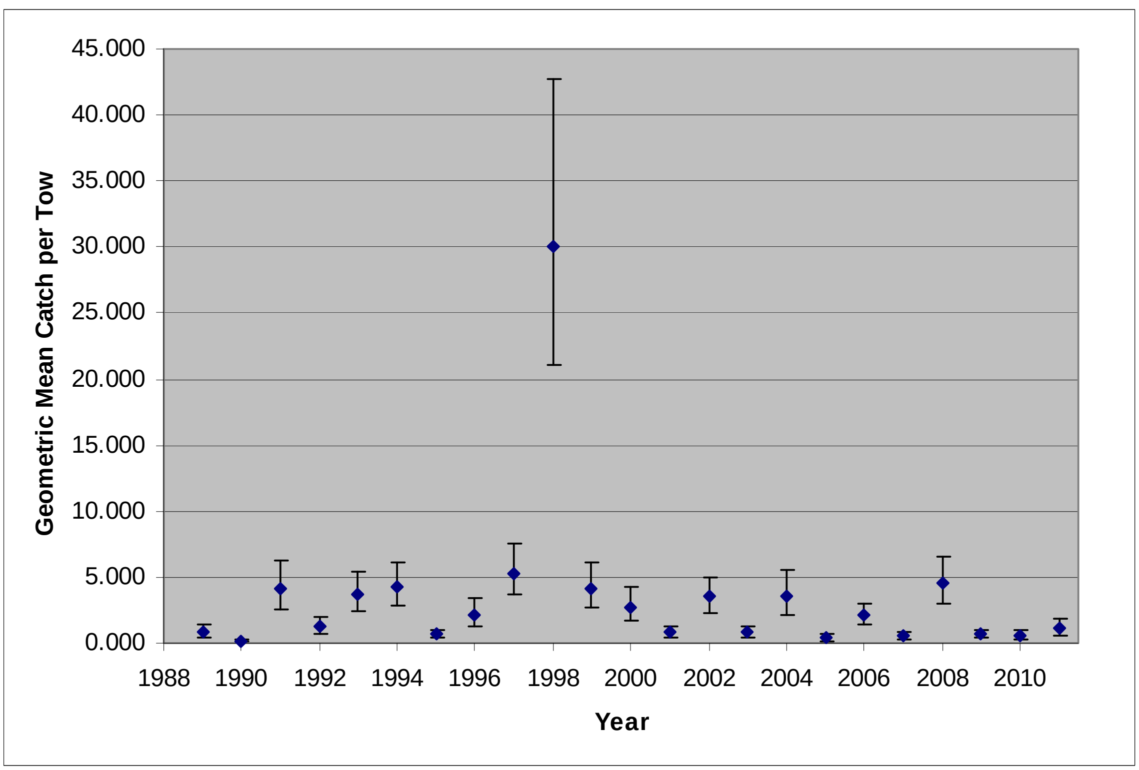


Figure 27. Spot length frequency distributions from onboard pound net sampling, 2008-2011.

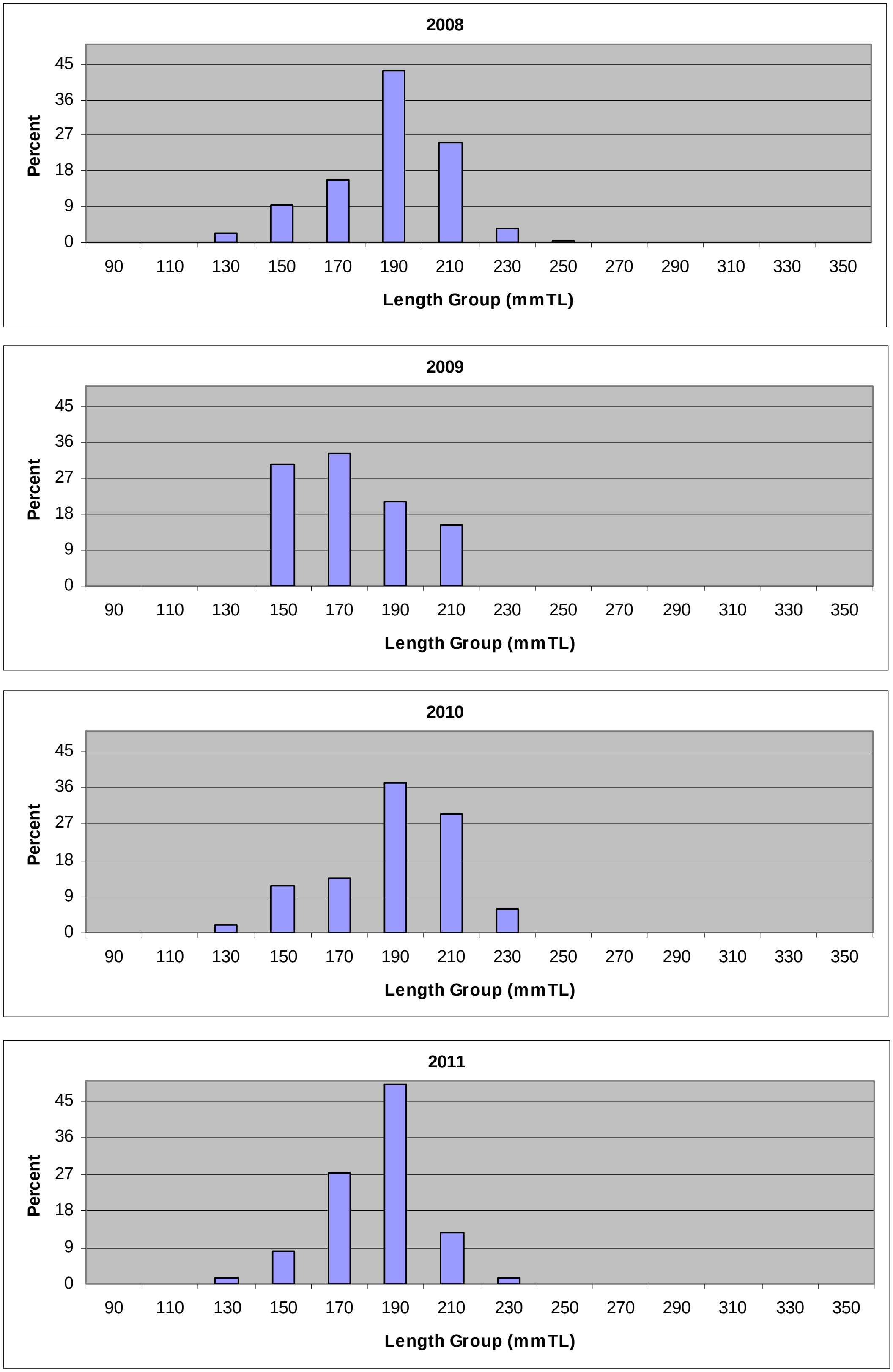


Figure 28. Maryland commercial spot harvest by area, 1929-2010.

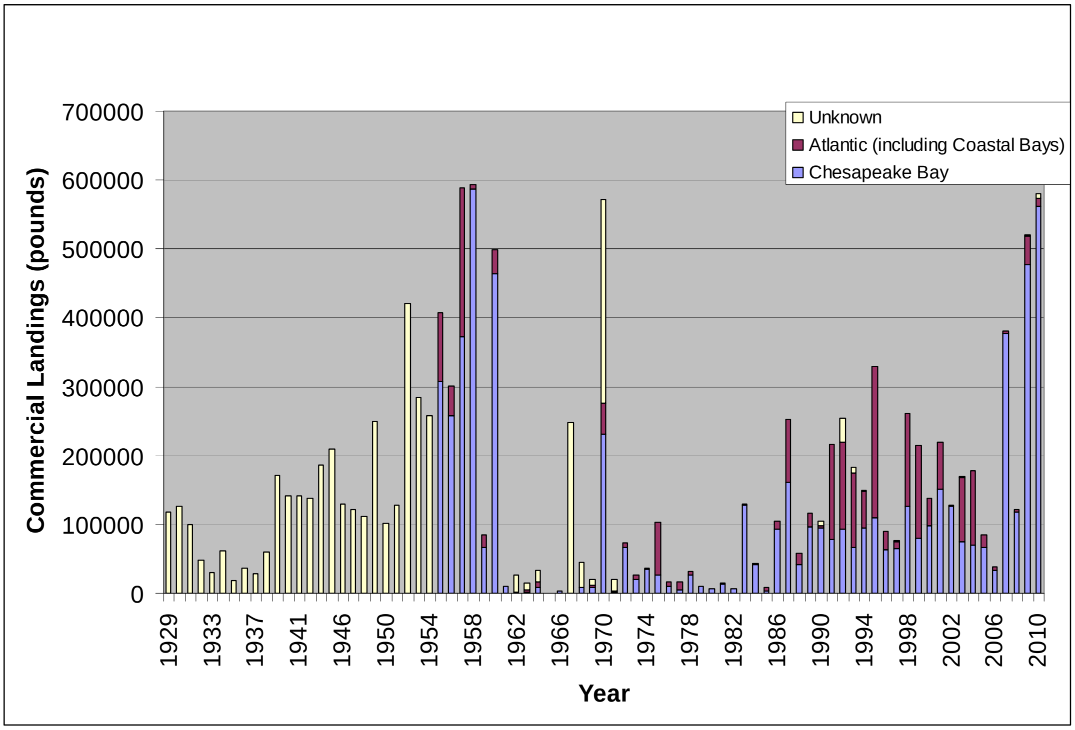


Figure 29. Estimated Maryland recreational spot harvest and releases for 1981-2010 (Source: MRIP, 2011).

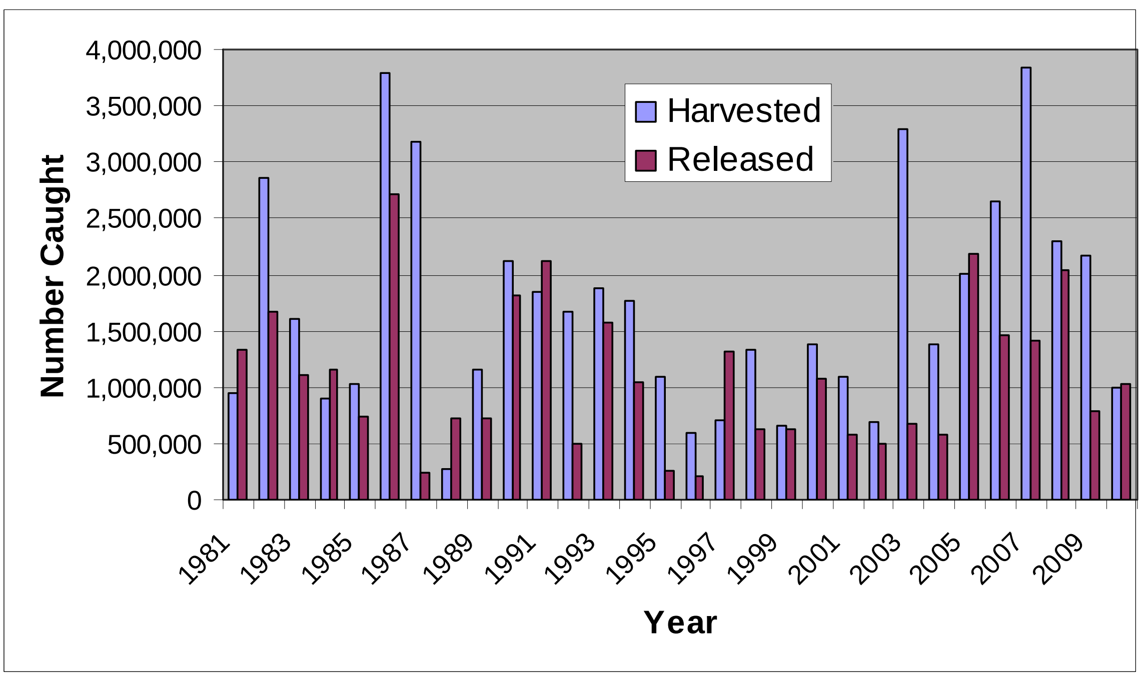


Figure 30. Spot statewide MRIP harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2010.

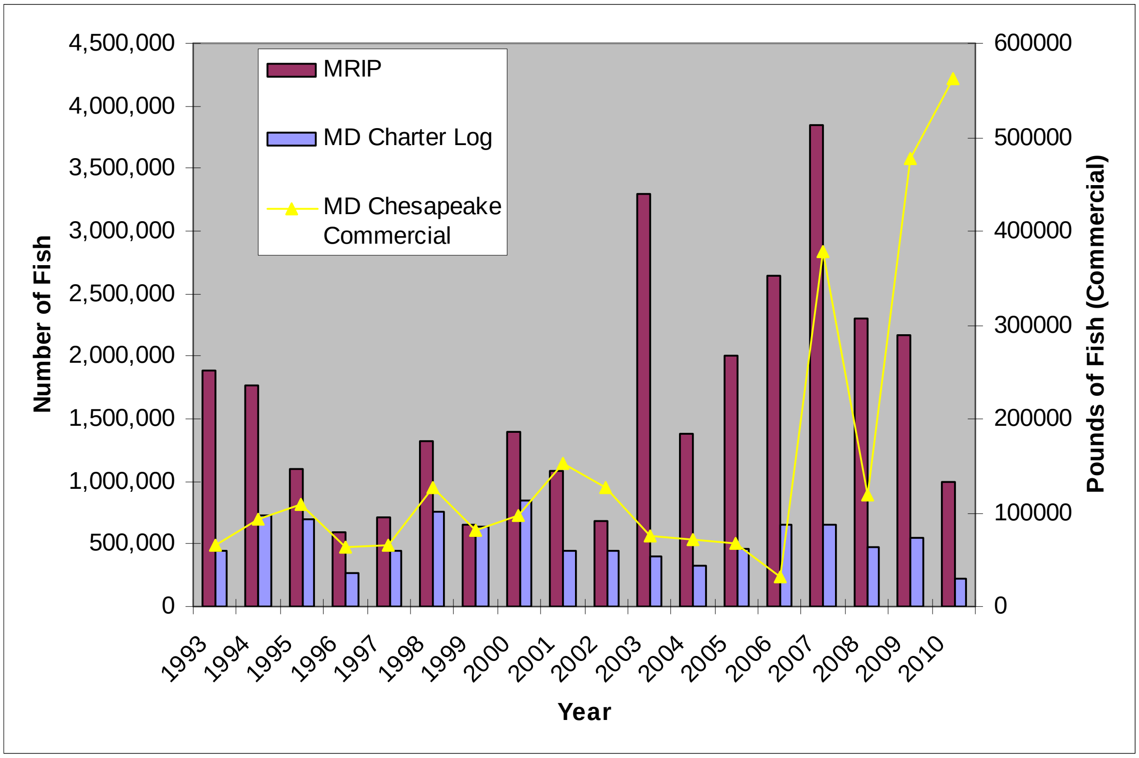


Figure 31. Spot geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

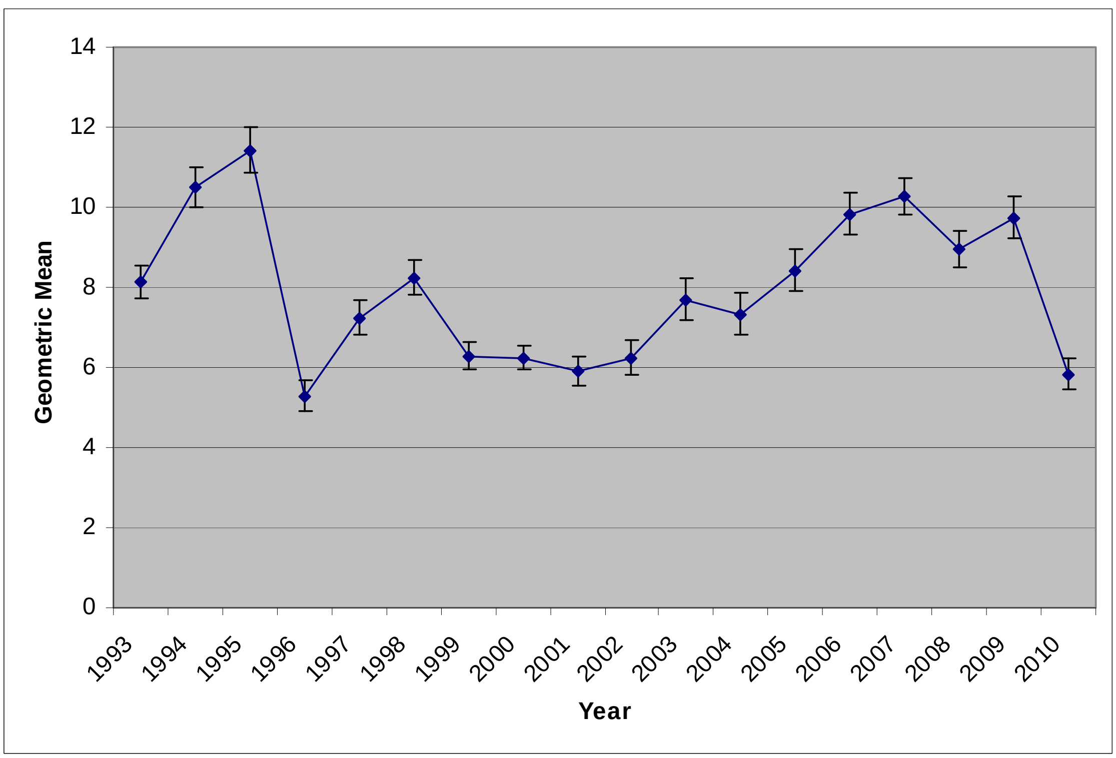


Figure 32. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2011.

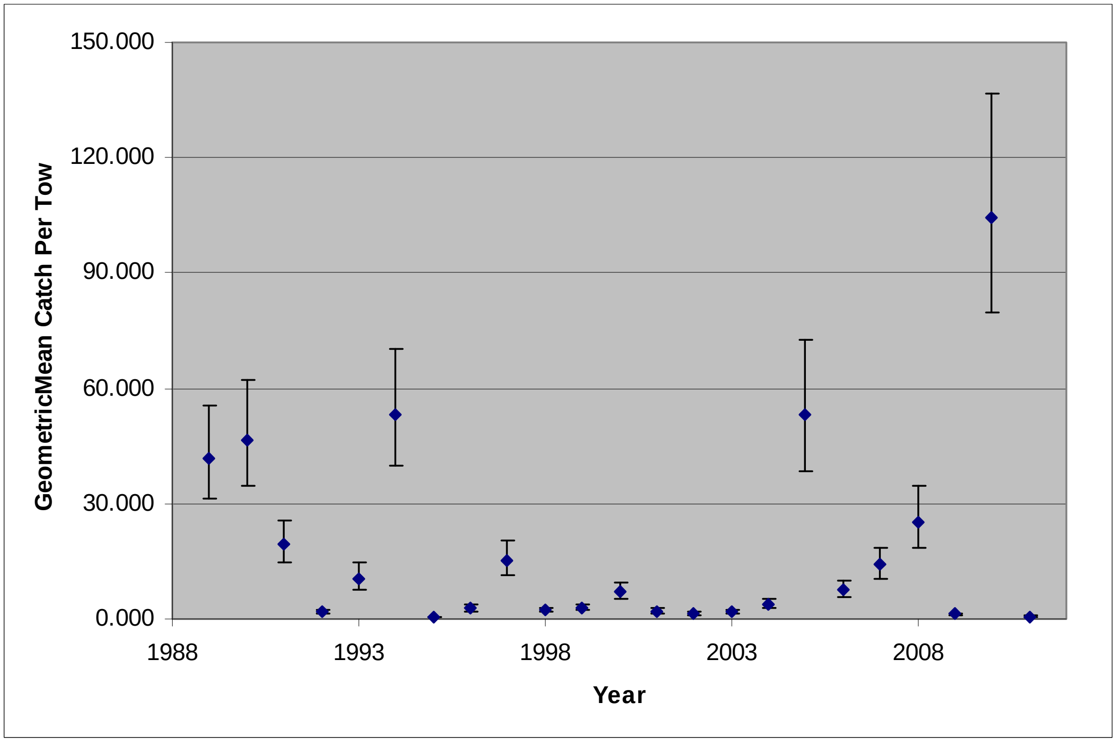


Figure 33. Maryland commercial red drum harvest by area, 1958-2010.

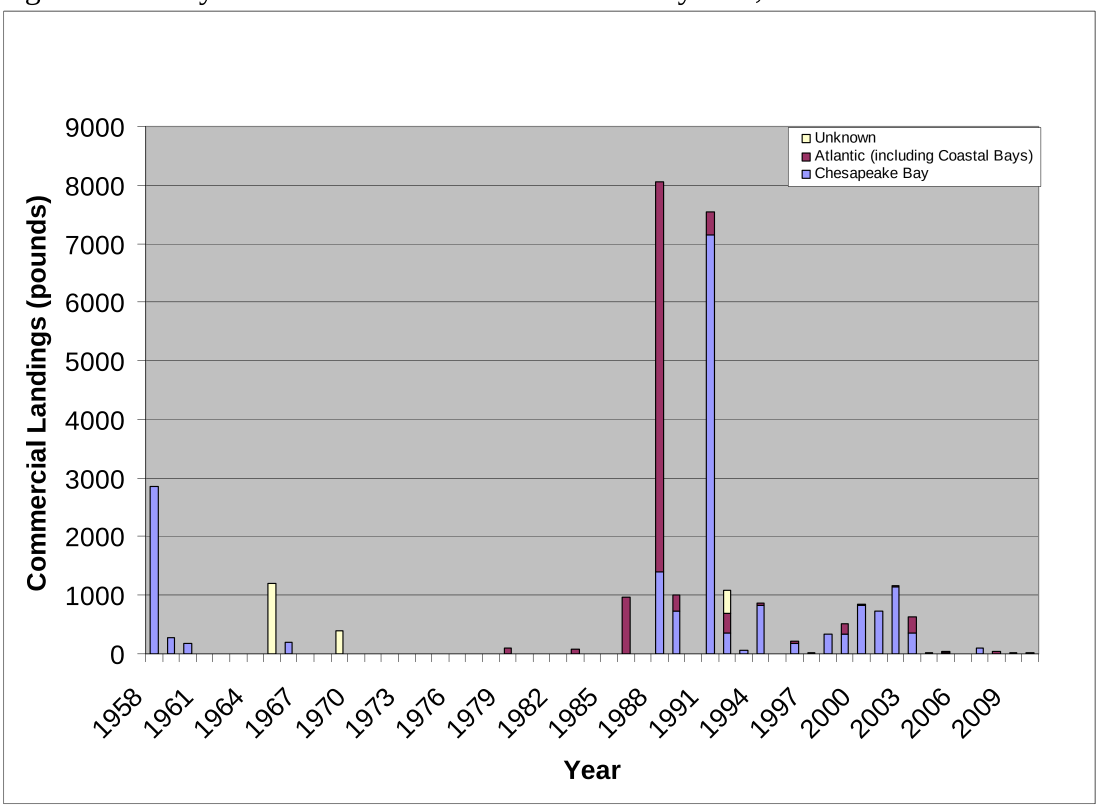


Figure 34. Estimated Maryland recreational red drum harvest and releases for 1981-2010 (Source: MRIP, 2011).

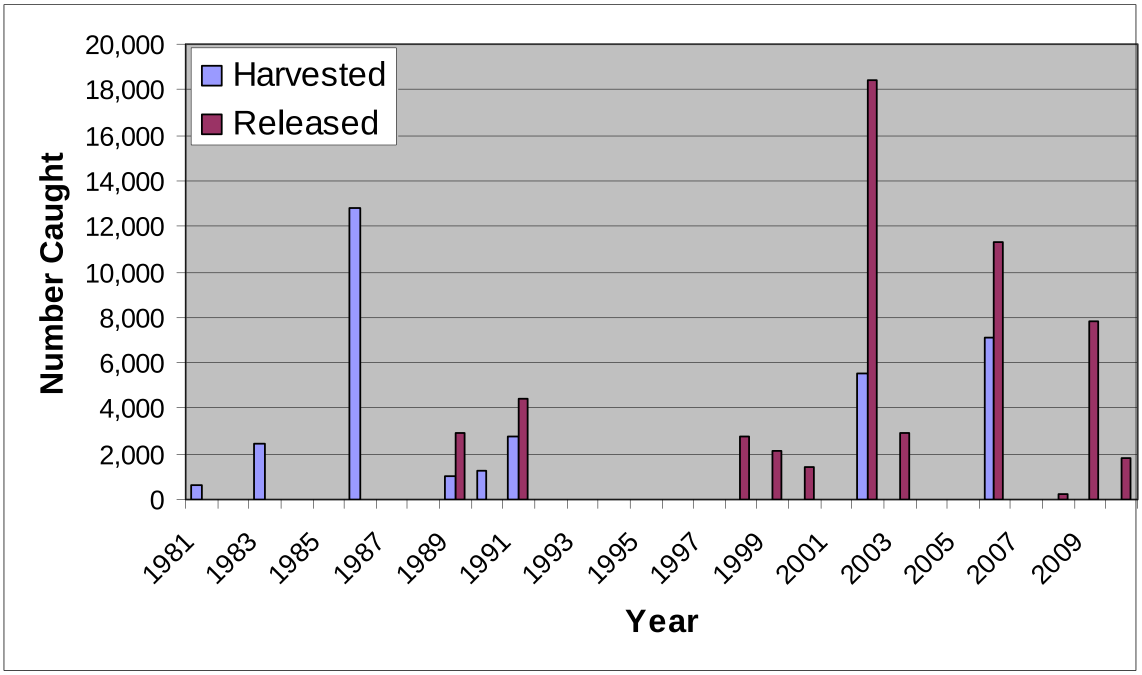


Figure 35. Number of red drum harvested and the number of anglers catching red drum from the Maryland Charter boat logs, 1993-2010.

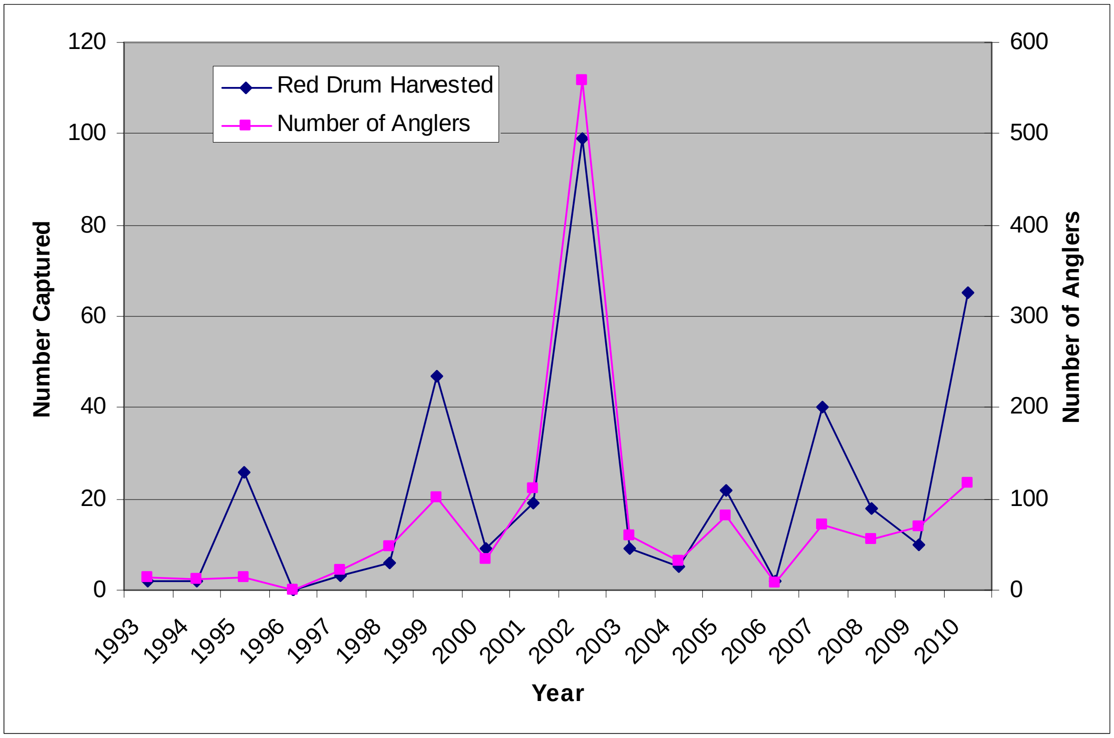


Figure 36. Maryland commercial black drum harvest by area, 1929-2010.

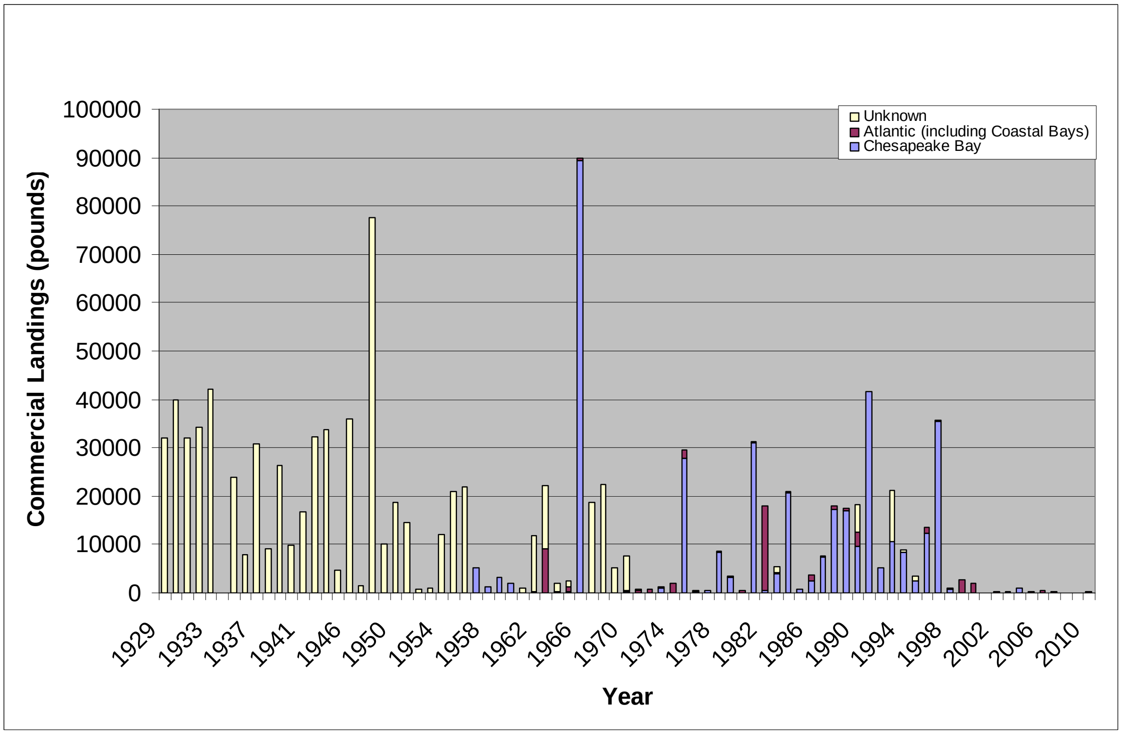


Figure 37. Estimated Maryland recreational black drum harvest and releases for 1981-2010 (Source: MRIP, 2011).

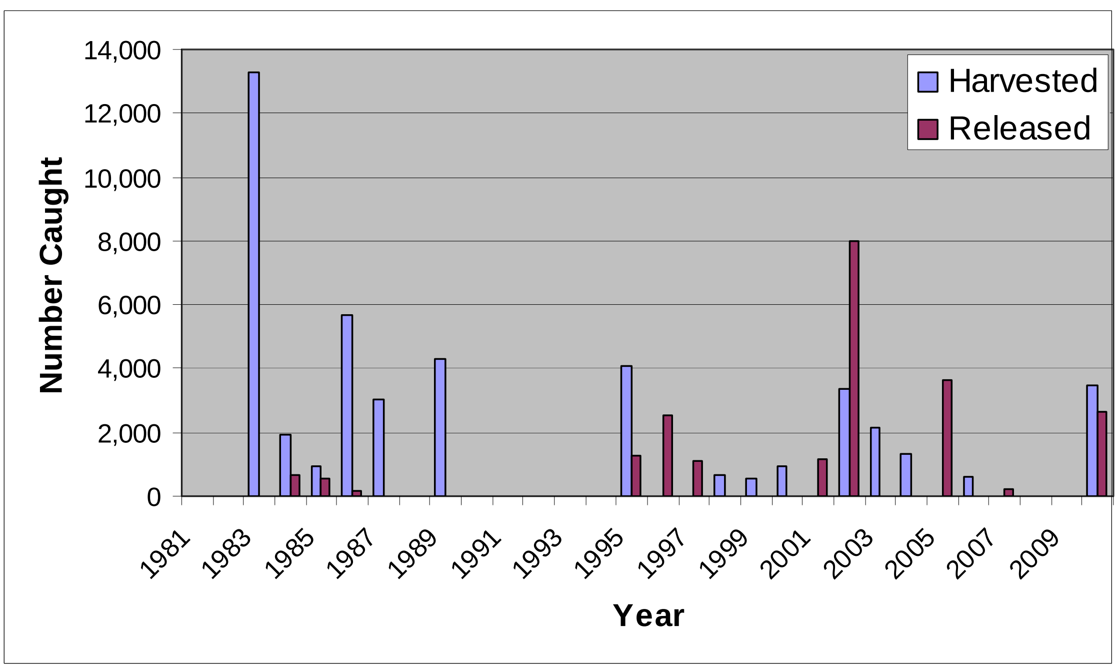


Figure 38. Reported Maryland charter boat harvest for black drum in numbers, 1993-2010.

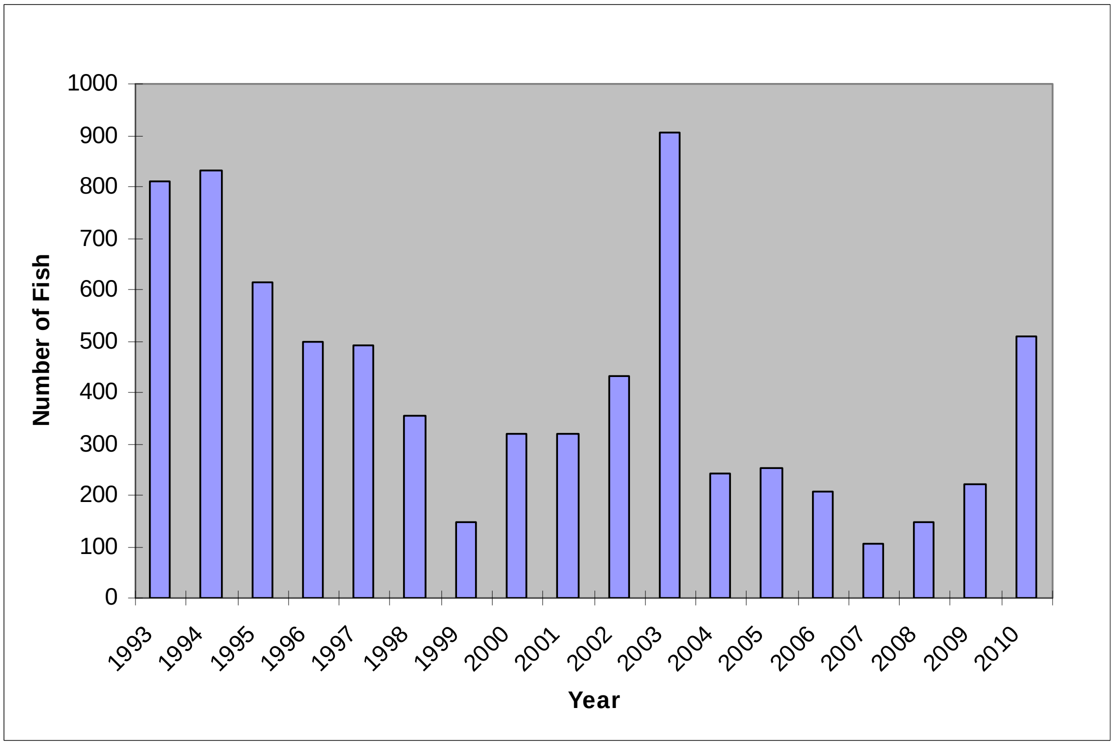


Figure 39. Black drum geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

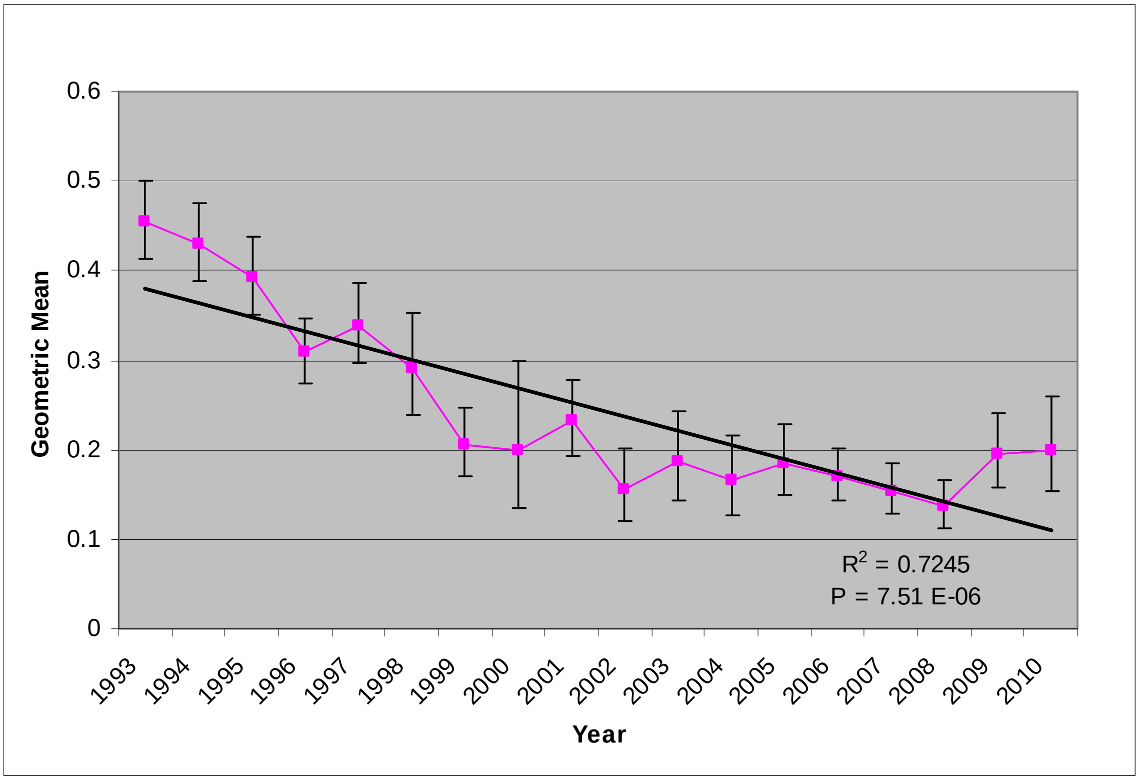


Figure 40. Maryland commercial Spanish mackerel harvest by area, 1965-2010.

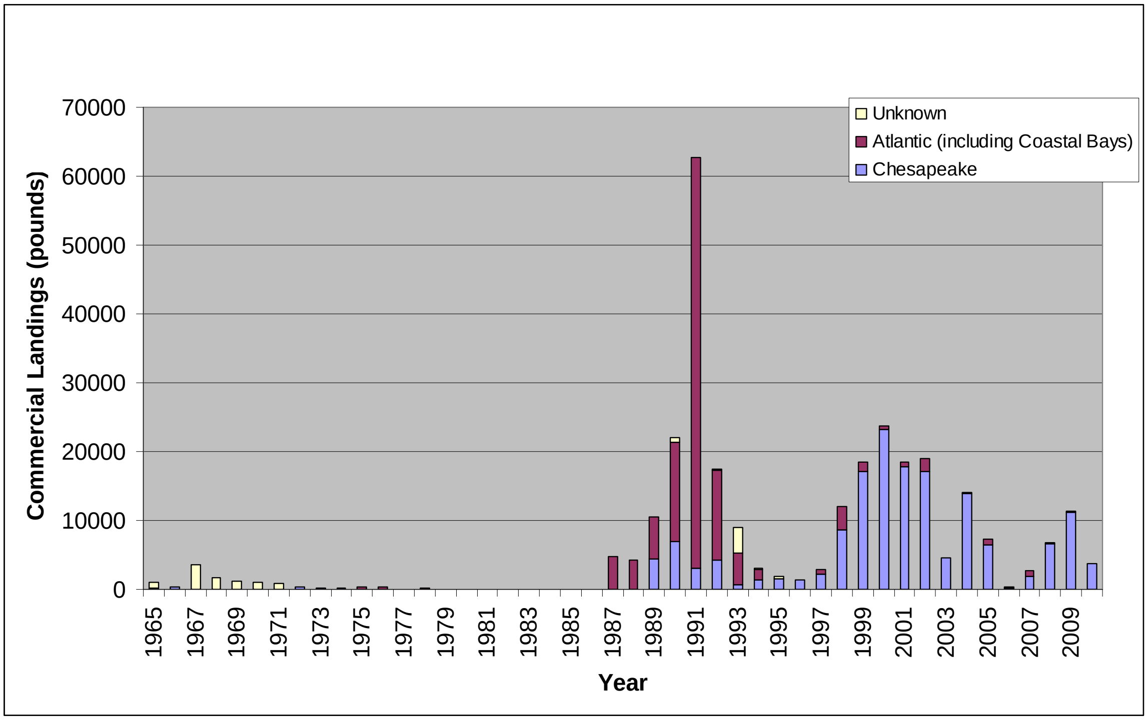


Figure 41. Estimated Maryland recreational Spanish mackerel harvest and releases for 1981-2010 (Source: MRIP, 2011).

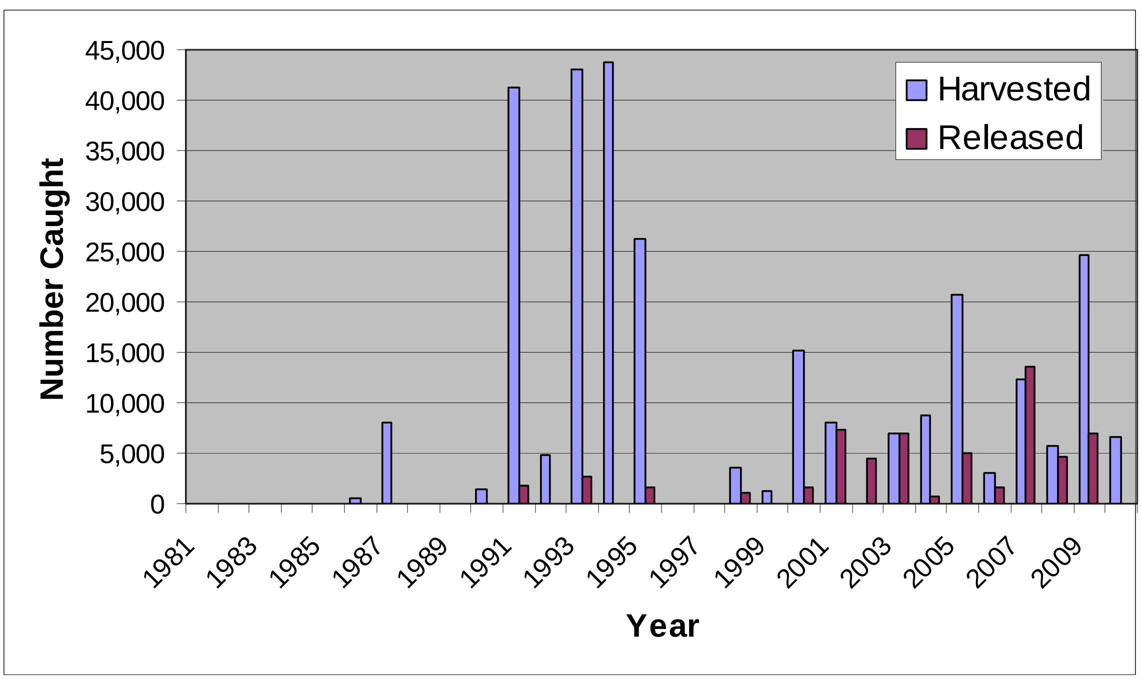


Figure 42. Spanish mackerel statewide MRIP harvest, MRIP for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2010.

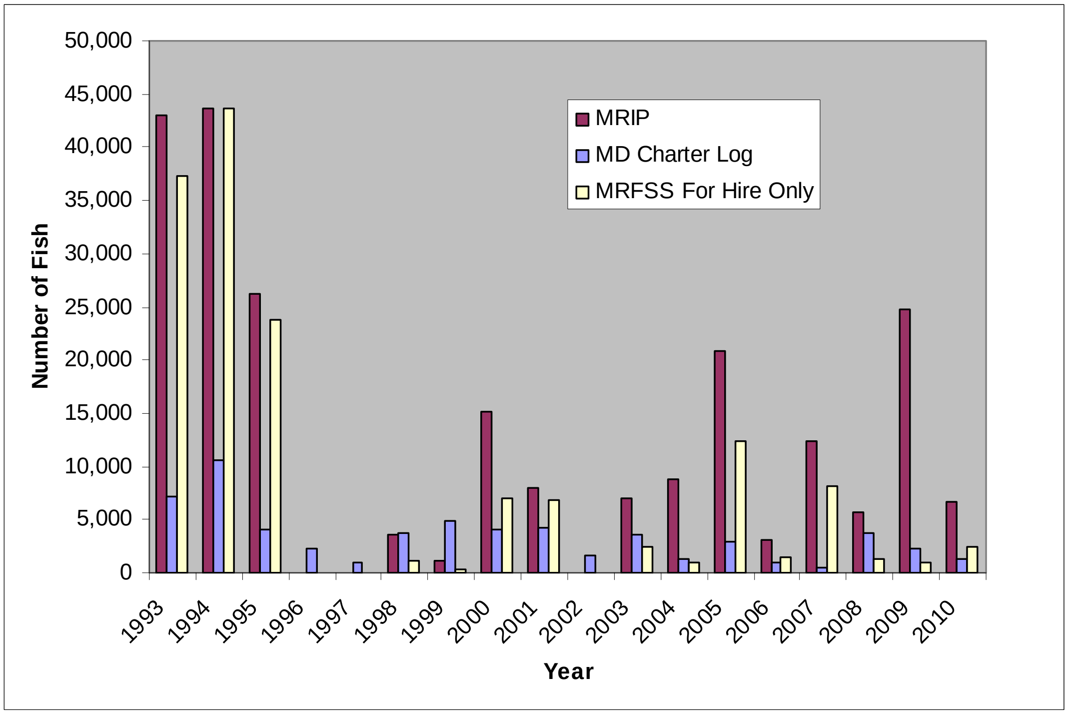


Figure 43. Spanish mackerel geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

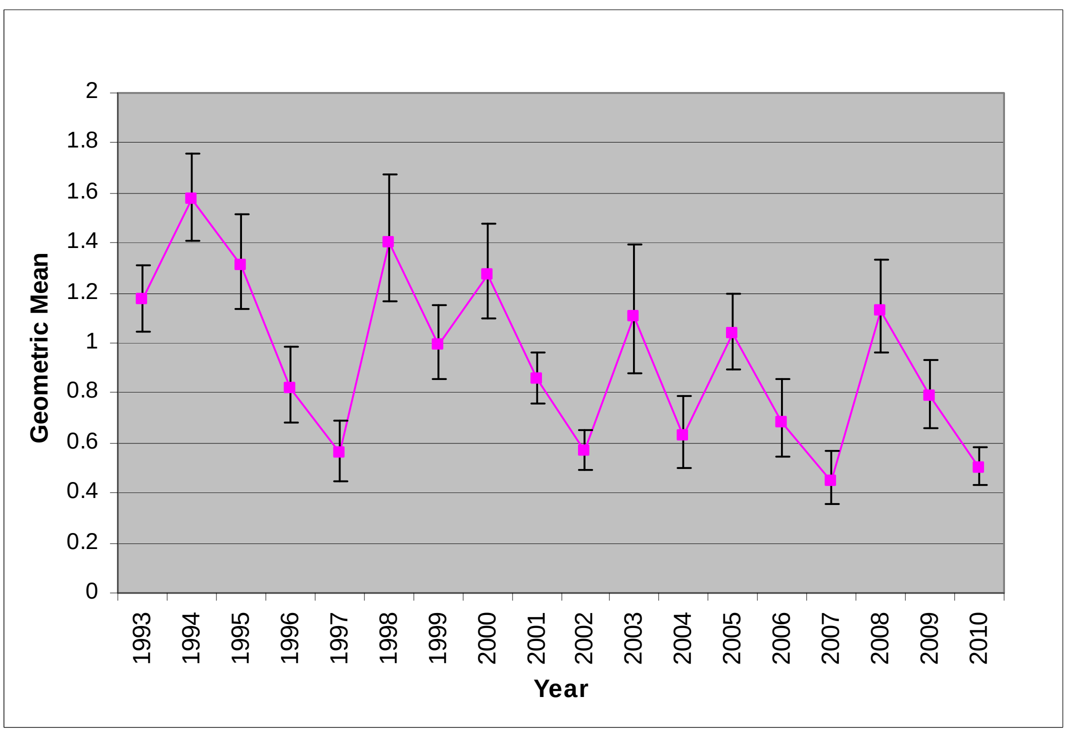


Figure 44. Maryland commercial spotted seatrout harvest by area, 1944-2010.

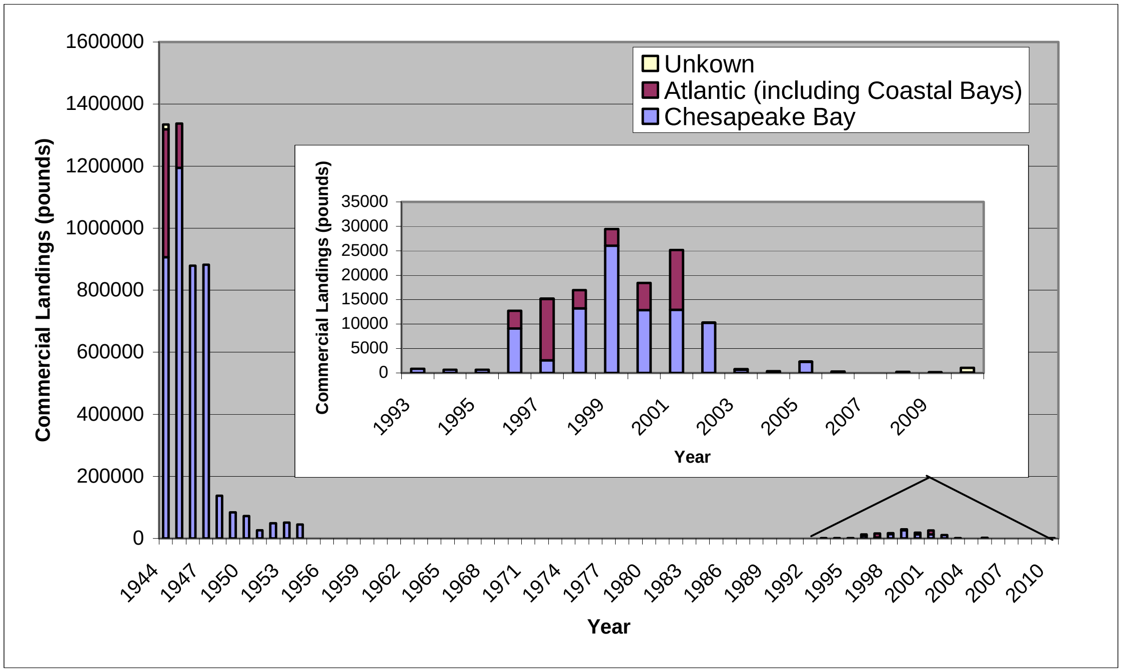


Figure 45. Estimated Maryland recreational spotted seatrout harvest and releases for 1981-2010 (Source: MRIP, 2011).

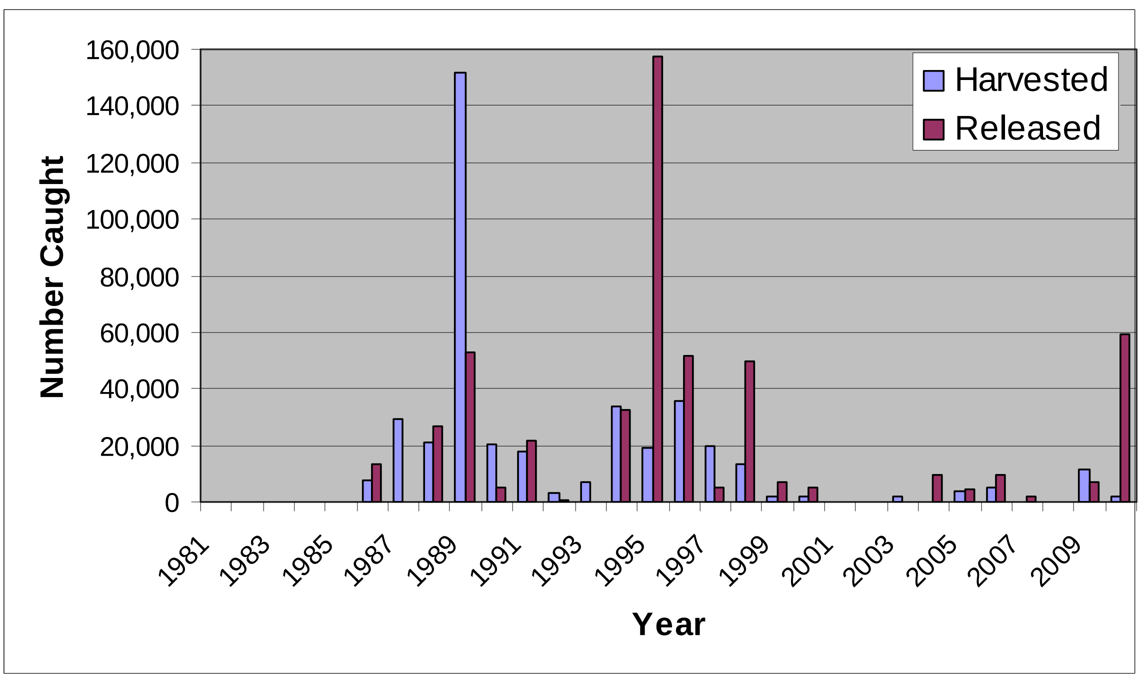


Figure 46. Reported Maryland charter boat harvest for spotted seatrout in numbers, 1993-2010.

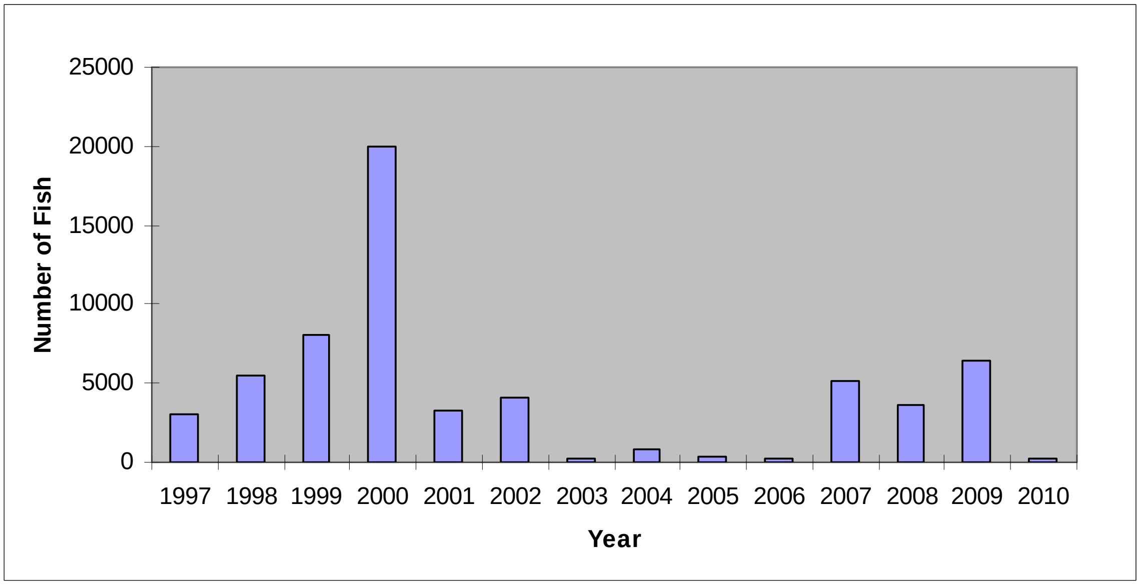


Figure 47. Spotted seatrout geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2010.

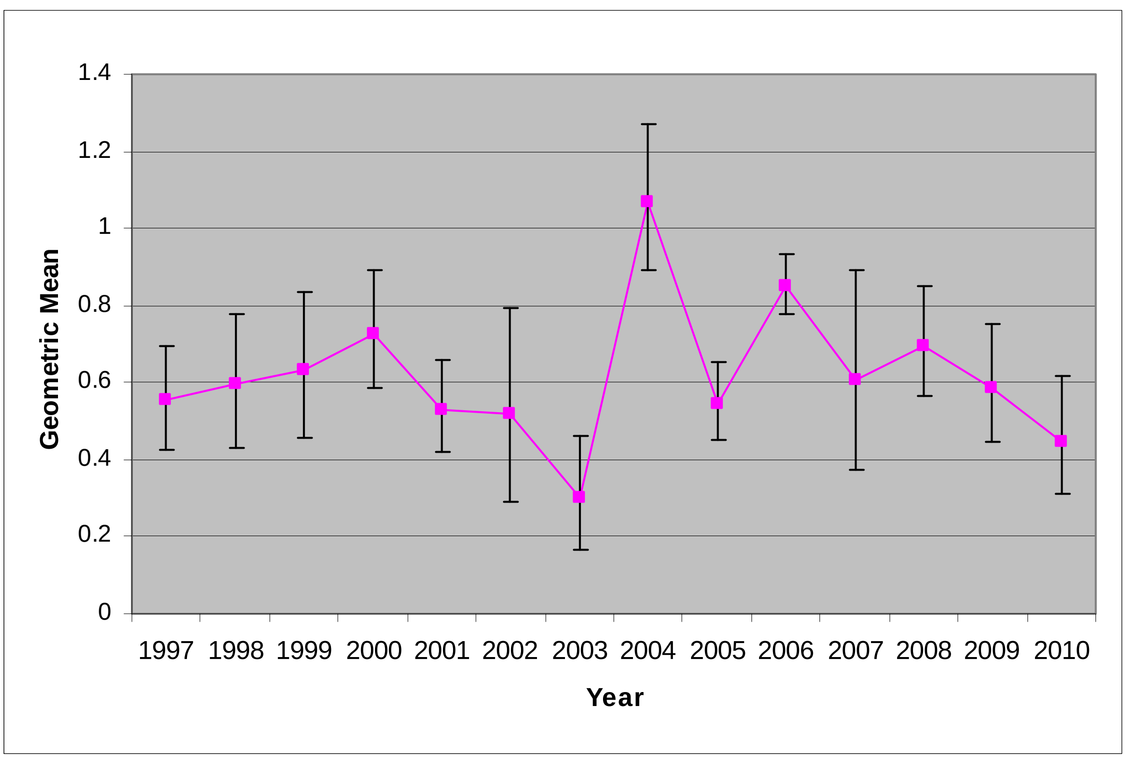


Figure 48. Menhaden length frequency distributions from onboard pound net sampling, 2008-2011.

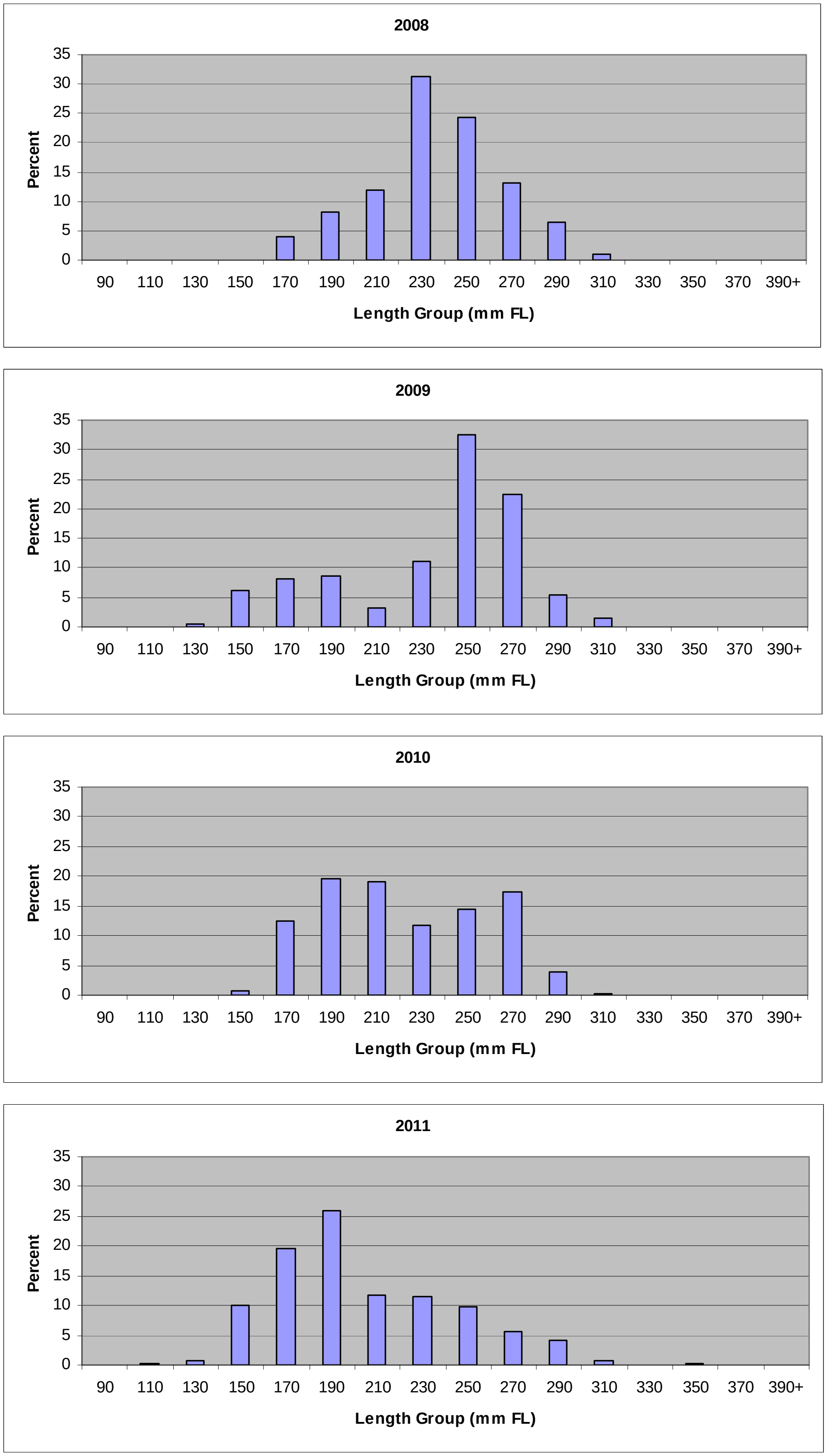
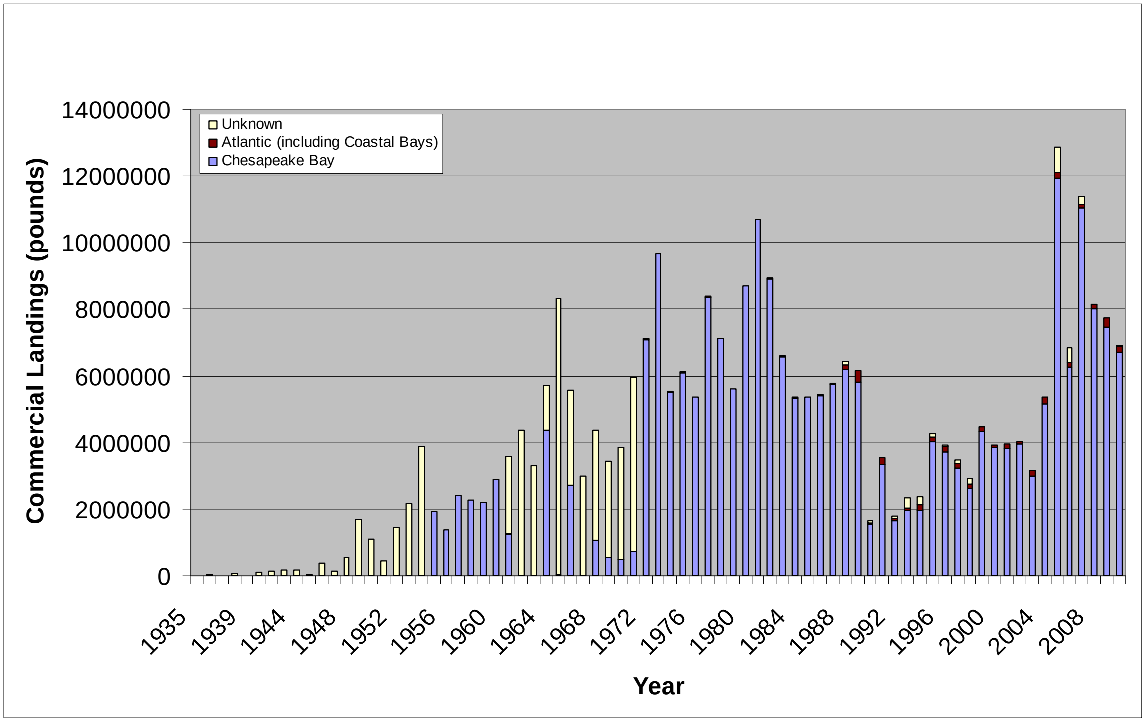


Figure 49. Maryland commercial Atlantic menhaden harvest by area, 1935-2010.



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 2010 Maryland striped bass (*Morone saxatilis)* commercial pound net and hook-and-line harvest. The 2010 pound net season ran from 1 June through 30 November while the commercial hook-and-line fishery was open from 7 June through 30 November. These fisheries targeted resident/pre-migratory striped bass. Harvested fish were sampled at commercial check stations and additional fish were sampled by visiting pound nets throughout the season.

In addition to characterizing the size and age structure of the commercial harvest, data from this survey were used to monitor temporal trends in size-at-age of the harvest. These data also provided the foundation for the construction of the Maryland catch-at-age matrix utilized by the Atlantic States Marine Fisheries Commission (ASMFC) in coastal striped bass stock assessment. Length and age distributions constructed from the 2010 commercial fisheries seasons were used to characterize the length and age structure of the entire 2010 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-size 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 structure of striped bass sampled at pound nets was representative of the size and age structure of striped bass landed by the commercial pound net fishery. The validity of this assumption was questioned in recent years 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 (MDDNR 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 May through November 2010 (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 2010, striped bass were sampled from pound nets in the upper, middle, 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 2010 (Figure 1). For pound nets, 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 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 2010 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 2010 striped bass pound net study, 2,641 striped bass were sampled from two pound nets in the upper Bay, one pound net in the middle Bay and three pound nets in the lower Bay. The six nets were sampled a total of 16 times during the study.

Striped bass sampled from pound nets ranged from 204-820 mm TL, with a mean length of 499 mm TL (Figure 2). In 2010, 40% of striped bass collected from full net samples were less than the minimum legal size of 18 inches TL, while 26% of fish from partially sampled nets were sub-legal. Mean total lengths of the aged sub-sample from pound nets are presented in Table 2.

Striped bass sampled from pound nets, ranged from 1 to 12 years of age (Table 3, Figure 2). Three year-old fish from the above average 2007 year-class contributed 33% in 2010; more age 3 fish than in 2007 (9%), 2008 (13%), and 2009 (11%). Age 4 fish from the below average 2006 year-class contributed 18% of the sample, lower than age 4 fish in 2009 (31%) (Figure 3, Table 3). Age 5 fish contributed 21% in 2010, which is similar to the contribution in 2009 (18%). Striped bass age 6 and over were more common in 2010, and accounted for 23% of the sample; more than their contribution in 2008 (15%) and 2009 (9%). Fish age 8 and older composed 1% of the sample in 2010, which was similar to 2009 (1%), but less than half that of 2008 (3%). Length frequencies of legal sized striped bass sampled at pound nets were almost identical to length distributions from the check stations, with slightly more smaller fish sampled from the hook and line survey (Figure 4).

Hook-and-line check station sampling

A total of 1,790 striped bass were sampled at hook-and-line check stations in 2010. The mean length of sampled striped bass was 544 mm TL. Striped bass sampled from the hook-and-line fishery ranged from 429 to 923 mm TL (Figure 5) and from 3 to 14 years of age (Figure 5).

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 69% of the hook-and-line harvest, similar to 2009 (66%; Figure 5). Fish greater than 650 mm TL contributed only 9% 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 6% 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 2010 combined hook-and-line and pound net fisheries are shown in Tables 4 and 5.

The 2010 hook-and-line harvest accounted for 25%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2010 (see Project 2, Job 3, Task 5A). The estimated 2010 catch-at-age of the hook-and-line fishery is presented in Table 6. The majority of the harvest was composed of three to six year-old striped bass. Striped bass from the 2007 and 2006 year-classes contributed 15% and 22%, respectively. Fish from the strong 2003 year-class (age 7) accounted for 11% of the total, less than in 2009 (17%). Striped bass from the above average 2005 year-class (age 5) contributed 27%, which is lower than their contribution in 2009 (Figure 7). Fish from the 2004 year-class (age 6) contributed 21% to the hook-and-line harvest, less than in 2009 (30%). Striped bass age 7 and older contributed 15% to the overall harvest in 2010, higher than 2009 (5%) due to the large 2003 year-class.

Pound net check station sampling

A total of 1,528 striped bass were sampled at pound net check stations in 2010. Striped bass sampled ranged from 439 to 905 mm TL (Figure 5). Striped bass sampled from the pound net fishery ranged from 3 to 12 years of age. Striped bass in the 450-530 mm TL length groups accounted for 66% of the 2010 pound net harvest, which is higher than 2009 (56%; Figure 5). The contribution of striped bass in the 570-630 mm TL length groups decreased from 22% in 2009 to 18% in 2010. Fish greater than 650 mm TL composed 5% of the sample, less than half that of 2009 (12%). In general, few large fish were available to the 2010 pound net fishery (Figure 6). Mean lengths-at-age and weights-at-age from the 2010 hook-and-line and pound net fisheries combined, are shown in Tables 4 and 5, respectively.

The pound net fishery accounted for 31%, by weight, of the Maryland Chesapeake Bay 2010 commercial harvest (see Proj. 2, Job 3, Task 5A). The estimated 2010 catch-at-age for the pound net fishery is presented in Table 6. Fish age three to six contributed 89% of the 2010 total pound net harvest. The contribution of seven year-old fish from the 2003 year-class was lower in the pound net harvest in 2010 than in 2009, contributing 9% to the total harvest (Figure 7). Striped bass age 8 and over composed 2% of the 2010 harvest, lower than the contribution in 2009 (5%). Sub-legal striped bass (< 457 mm TL) composed 0.5% of the total pound net harvest.

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 77% and 70%, respectively, of the 2010 pound net and hook-and-line fisheries. There were fewer large fish (>530 mm) harvested in 2010 compared to 2009 (50% and 56% respectively; Figure 5). In 2010, 65 fish from pound net monitoring and 116 fish from check station sampling were aged. Older fish were more scarce throughout the summer. Younger fish (age 3 to 6) were more 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 2010. Striped bass were significantly ($P<0.05$) longer and heavier from the hook-and-line fishery than the pound net fishery.

In the hook-and-line fishery, the longest and heaviest fish were harvested in September and the smallest in October/November. Striped bass harvested in every month, except September, were similar in length. Striped bass harvested in every month were similar in weight.

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

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LIST OF TABLES

LIST OF FIGURES

Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2010 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
May	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	2	18.6	11.0	252
June	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	2	24.9	11.2	254
July	Upper	-	-	-	-
	Middle	1	26.8	11.8	200
	Lower	-	-	-	-
August	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	1	21.7	15.3	266
September	Upper	1	23.2	13.8	201
	Middle	-	-	-	-
	Lower	2	23.9	17.0	257
October	Upper	2	13.2	14.6	273
	Middle	-	-	-	-
	Lower	4	16.6	15.1	729
November	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	1	13.1	16.4	209

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, May through November 2010.

Year-class	Age	n	Mean length (mm TL)	STD	STDERR	LCLM	UCLM
2009	1	13	286	52	14	255	318
2008	2	9	338	21	7	322	354
2007	3	17	425	58	14	395	454
2006	4	1	612	-	-	-	-
2005	5	5	552	61	27	476	628
2004	6	6	655	93	38	558	753
2003	7	5	699	43	19	646	753
2002	8	5	697	47	21	638	756
2001	9	2	780	57	40	272	1288
2000	10	0	-	-	-	-	-
1999	11	1	755	-	-	-	-
1998	12	1	819	-	-	-	-

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, May through November 2010.

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2009	1	53	2.00
2008	2	72	2.73
2007	3	875	33.14
2006	4	476	18.03
2005	5	553	20.94
2004	6	408	15.46
2003	7	170	6.44
2002	8	18	0.70
2001	9	11	0.43
2000	10	2	0.08
1999	11	1	0.05
1998	12	0	0.00
Total		**2,641**	**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 2010.

Year-class	Age	n	Mean Length (mm TL)	STD	STDERR	LCLM	UCLM
2007	3	8	475	18	6	460	490
2006	4	9	498	37	12	470	527
2005	5	9	570	55	18	528	612
2004	6	21	648	76	17	614	683
2003	7	24	709	83	17	674	744
2002	8	12	794	59	17	756	831
2001	9	21	791	56	12	766	816
2000	10	8	811	54	19	766	856
1999	11	1	830	-	-	-	-
1998	12	1	847	-	-	-	-
1997	13	1	887	-	-	-	-
1996	14	1	884	-	-	-	-

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 2010. Mean weights are weighted by the sample n-at-length in each age.

Year-Class	Age	n Aged	Weighted Mean weight* (kg)
2007	3	8	1.1
2006	4	9	1.2
2005	5	9	1.8
2004	6	21	2.7
2003	7	24	3.8
2002	8	12	5.1
2001	9	21	5.0
2000	10	8	5.6
1999	11	1	5.6
1998	12	1	5.8
1997	13	1	6.7
1996	14	1	7.1

* 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 2010.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Pounds of Fish	Percent of Total	Landings in Pounds of Fish	Percent of Total
2007	3	79,734	15.4	111,359	17.1
2006	4	112,497	21.7	153,385	23.5
2005	5	140,621	27.1	185,598	28.5
2004	6	109,598	21.1	127,325	19.5
2003	7	57,934	11.2	60,827	9.3
2002	8	8,620	1.7	6,095	0.9
2001	9	6,039	1.2	5,285	0.8
2000	10	2,092	0.4	1,789	0.3
1999	11	787	0.2	0	0.0
1998	12	435	0.1	405	0.1
1997	13	290	0.1	0	0.0
1996	14	290	0.1	0	0.0
Total*		**518,937**	**100.0**	**652,067**	**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 2010.

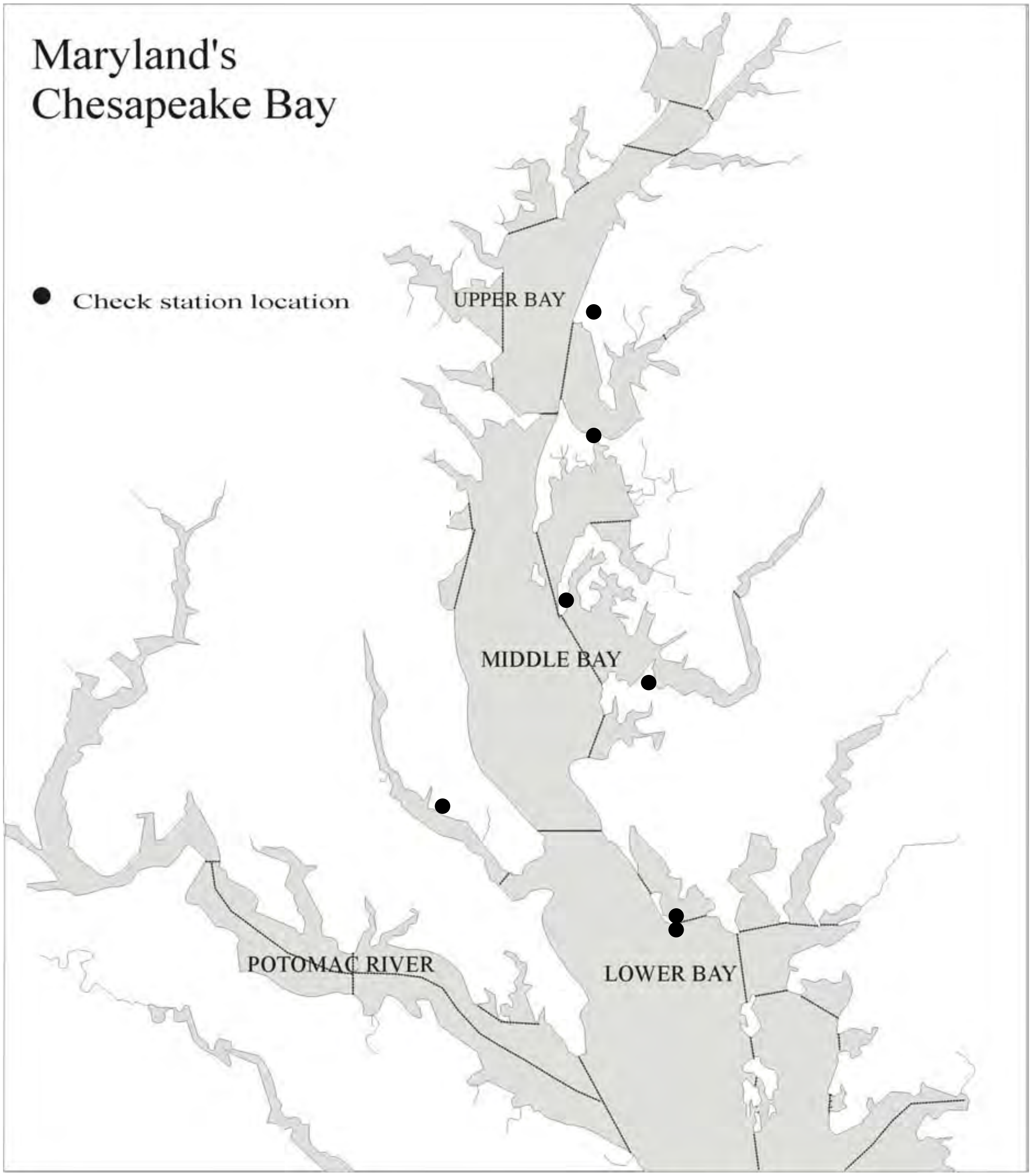
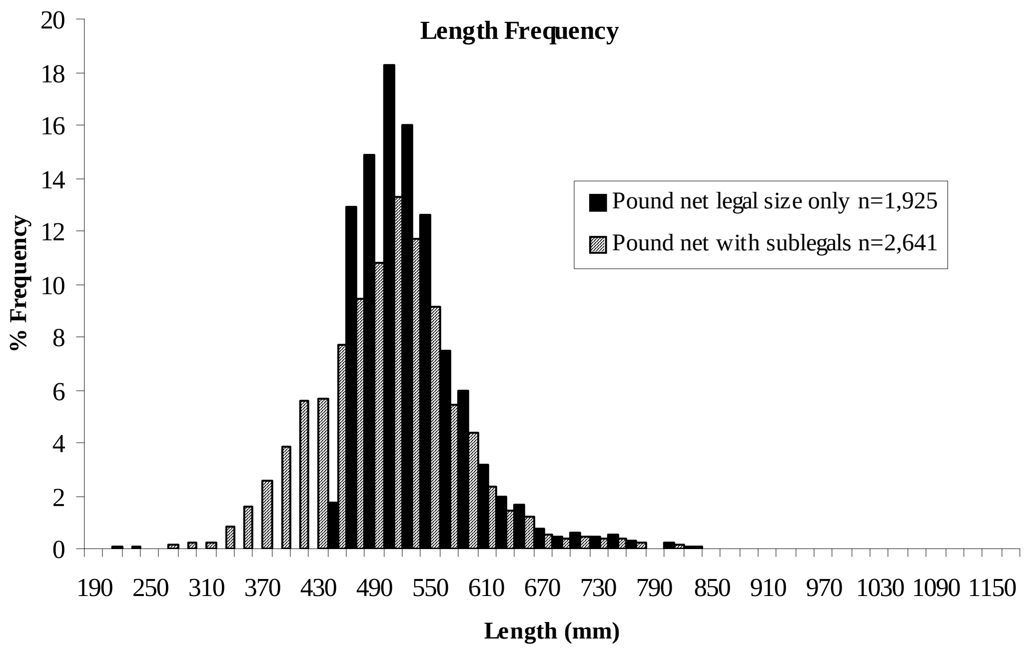


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, May through November 2010.



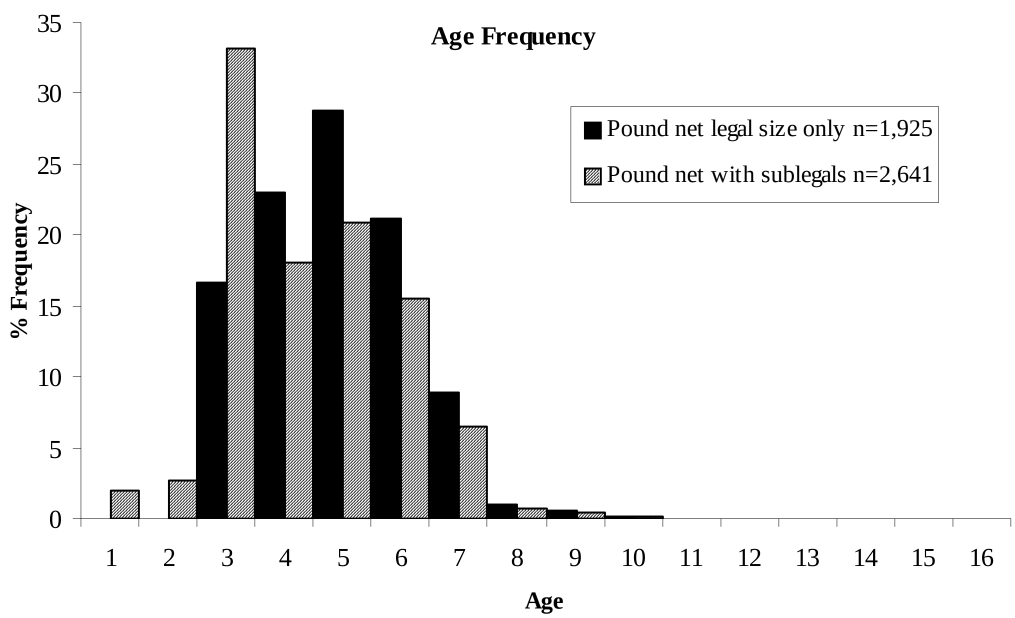


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2010.

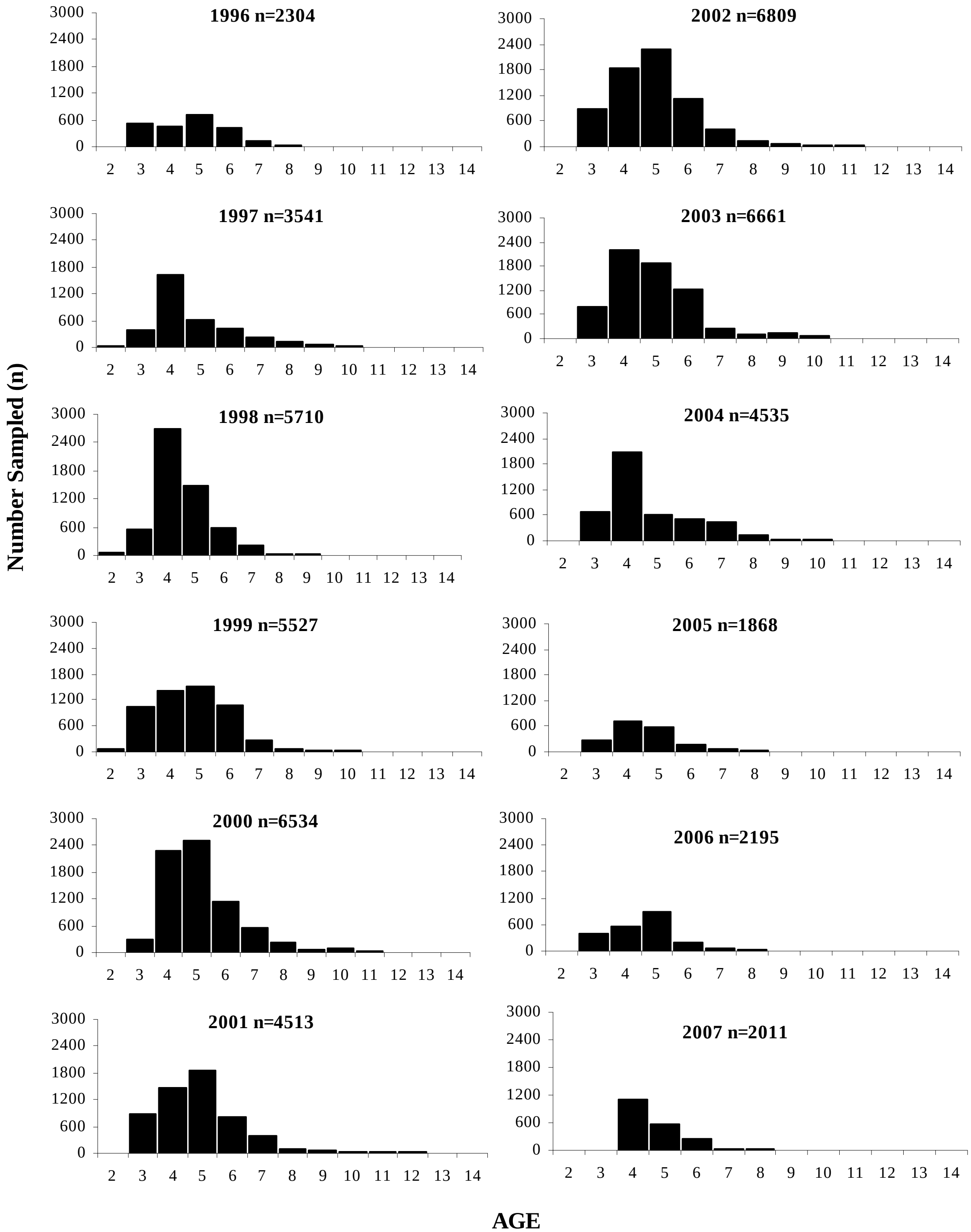


Figure 3. Continued.

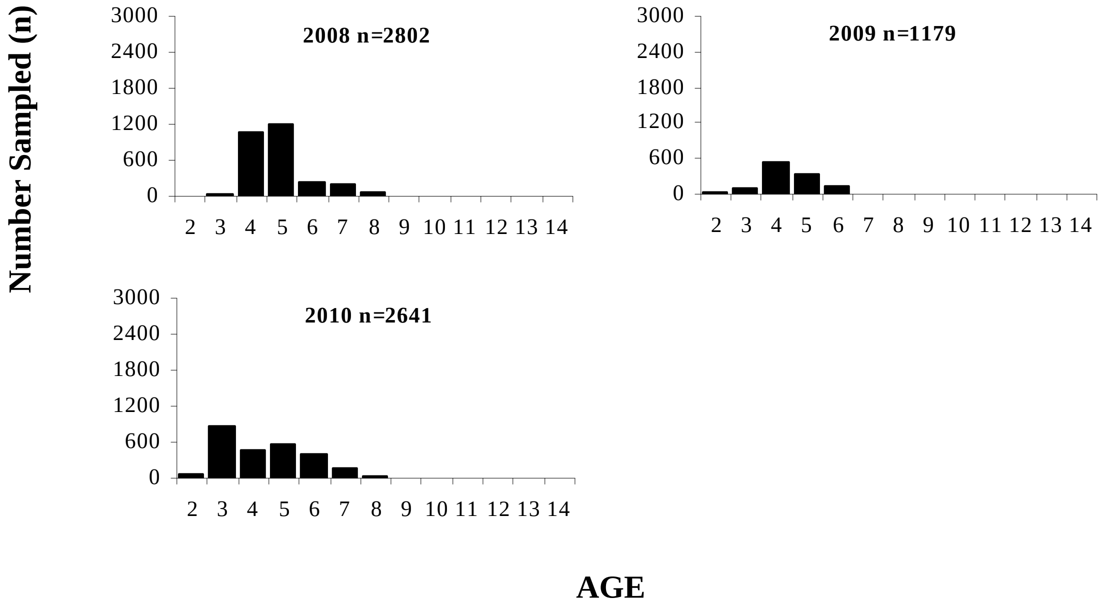


Figure 4. Length frequency of striped bass sampled during the 2010 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from May through November 2010. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

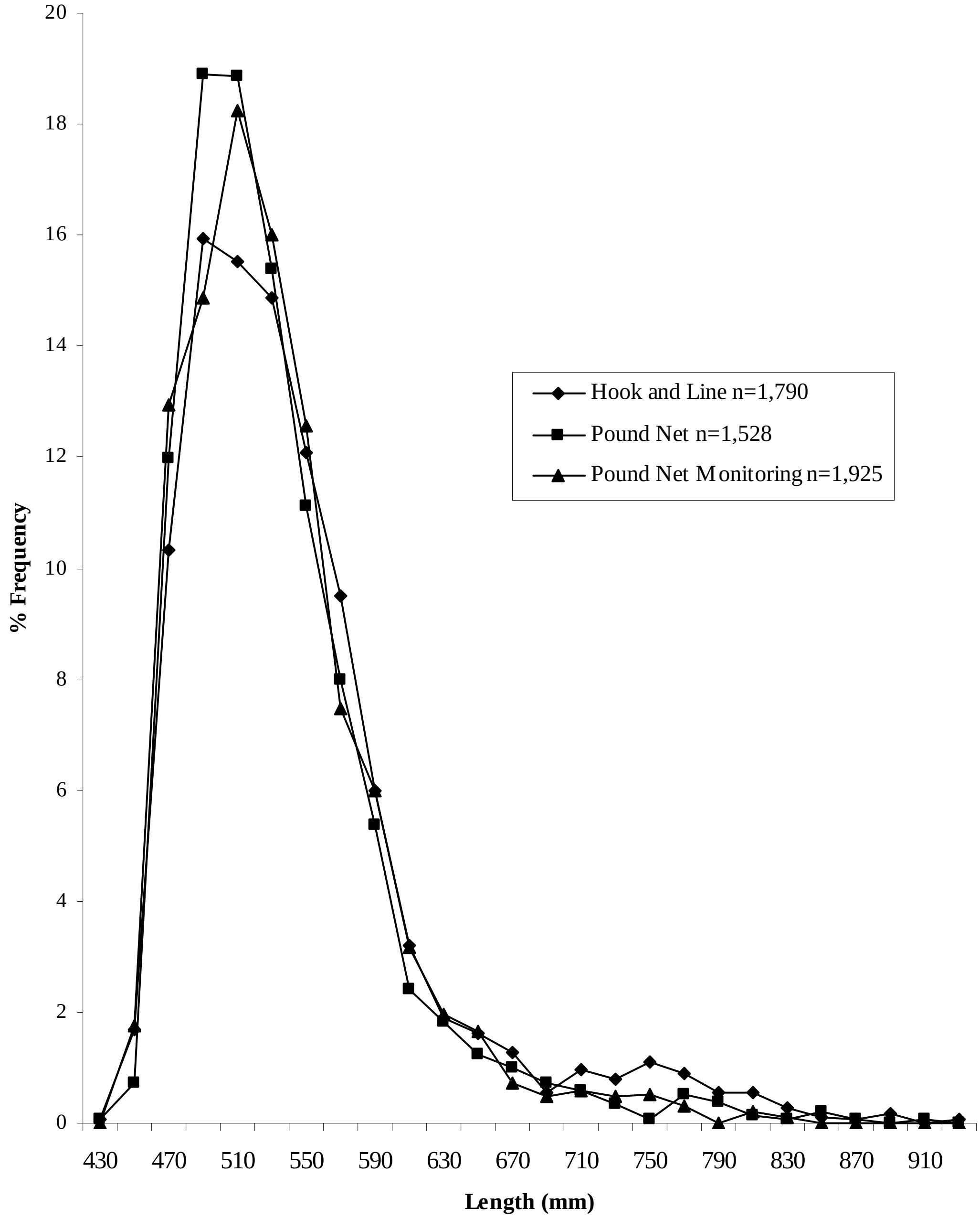
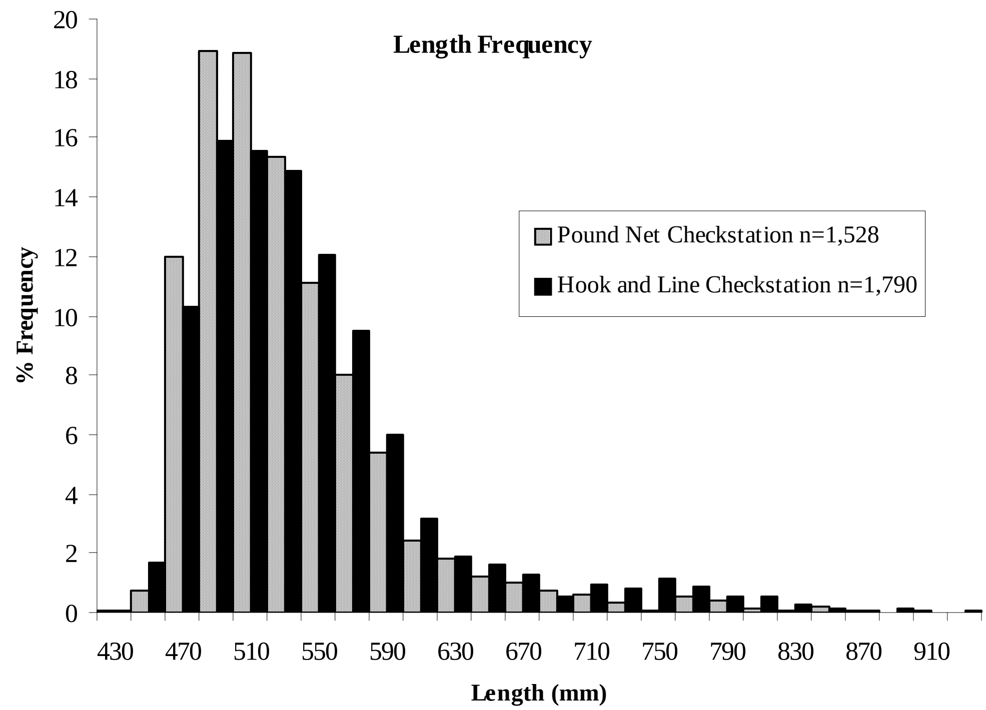


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2010.



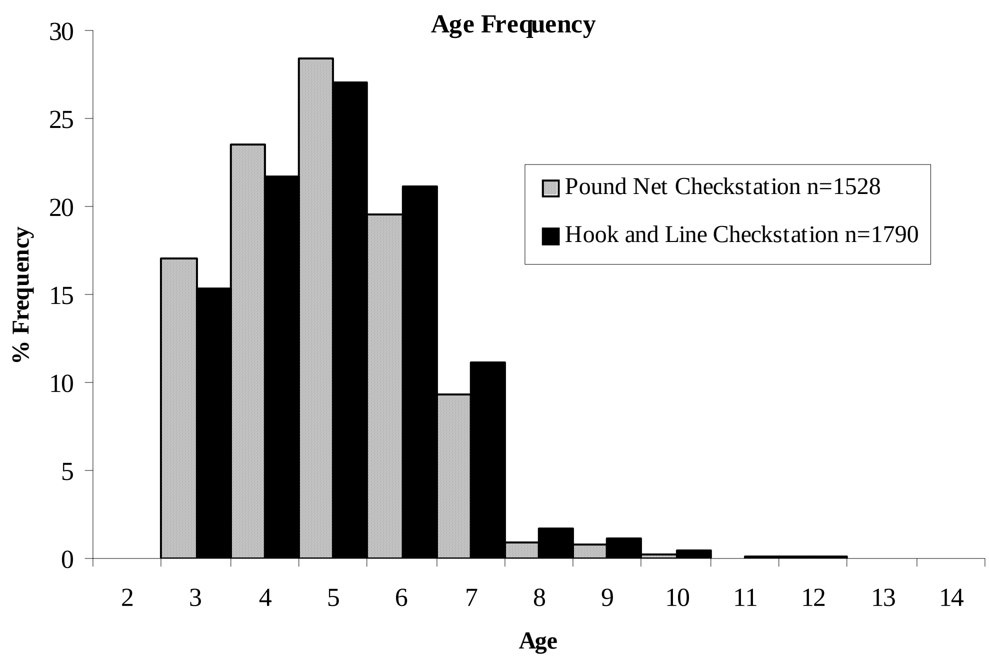


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2010.

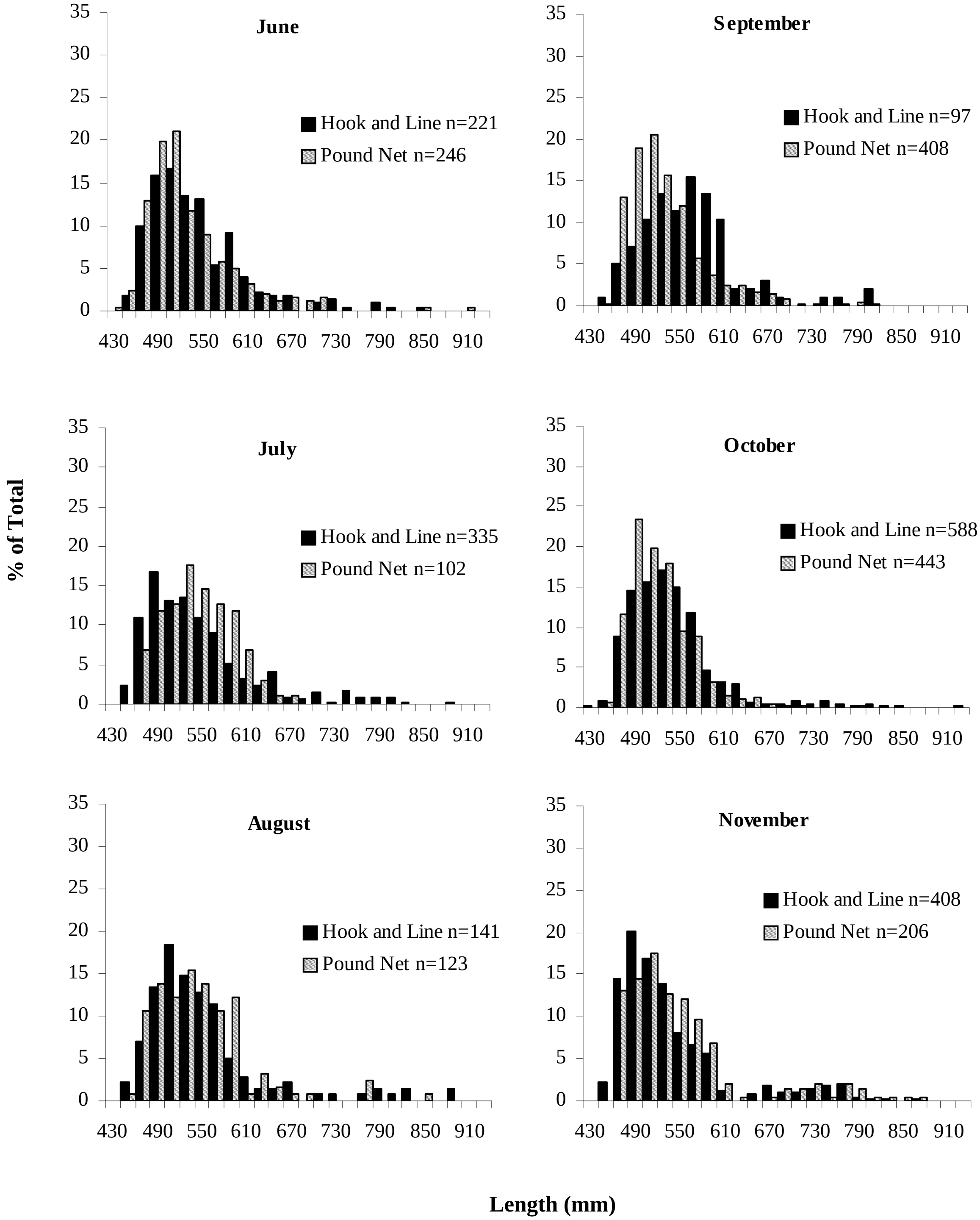
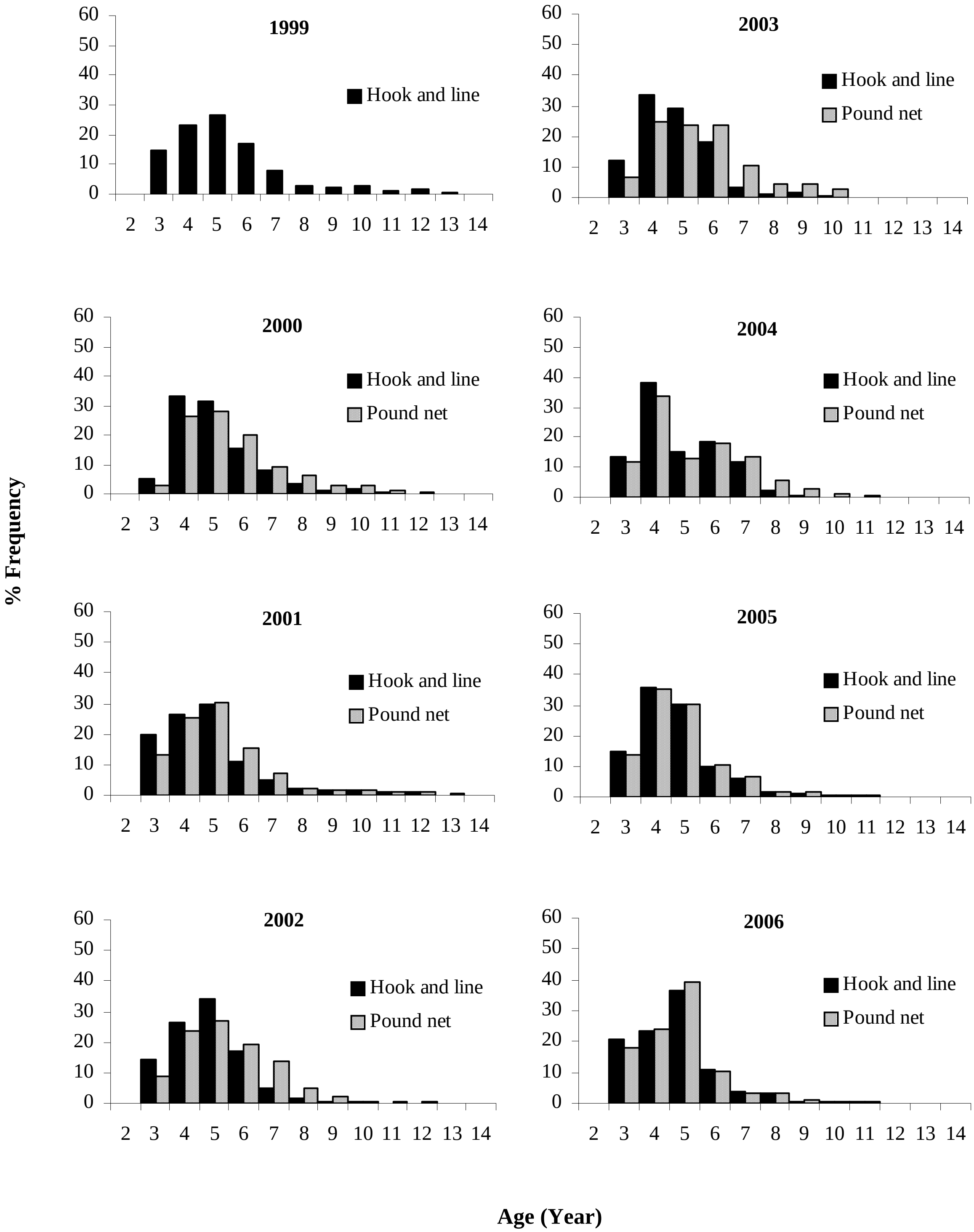


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2010. Note-pound net check station sampling began in 2000.


1999
Hook and line
2003
Hook and line
Pound net
2000
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2001
Hook and line
Pound net
2005
Hook and line
Pound net
2002
Hook and line
Pound net
2006
Hook and line
Pound net
% Frequency
Age (Year)

Figure 7. Continued.

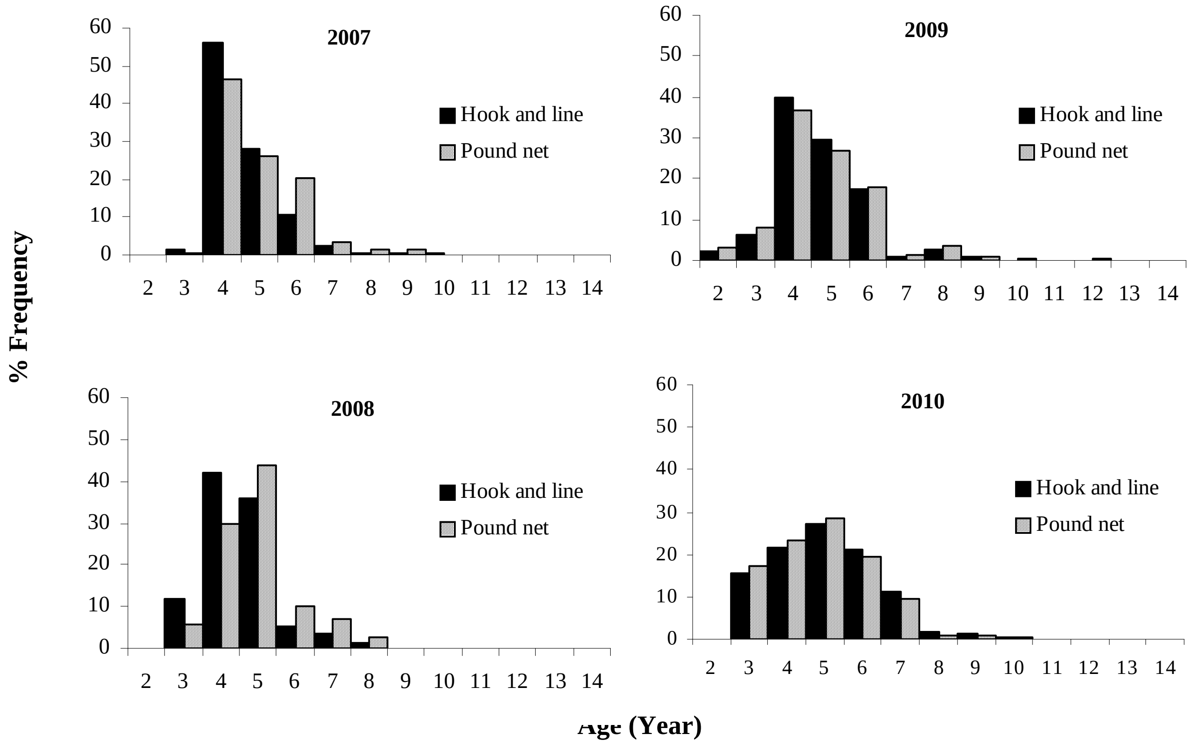
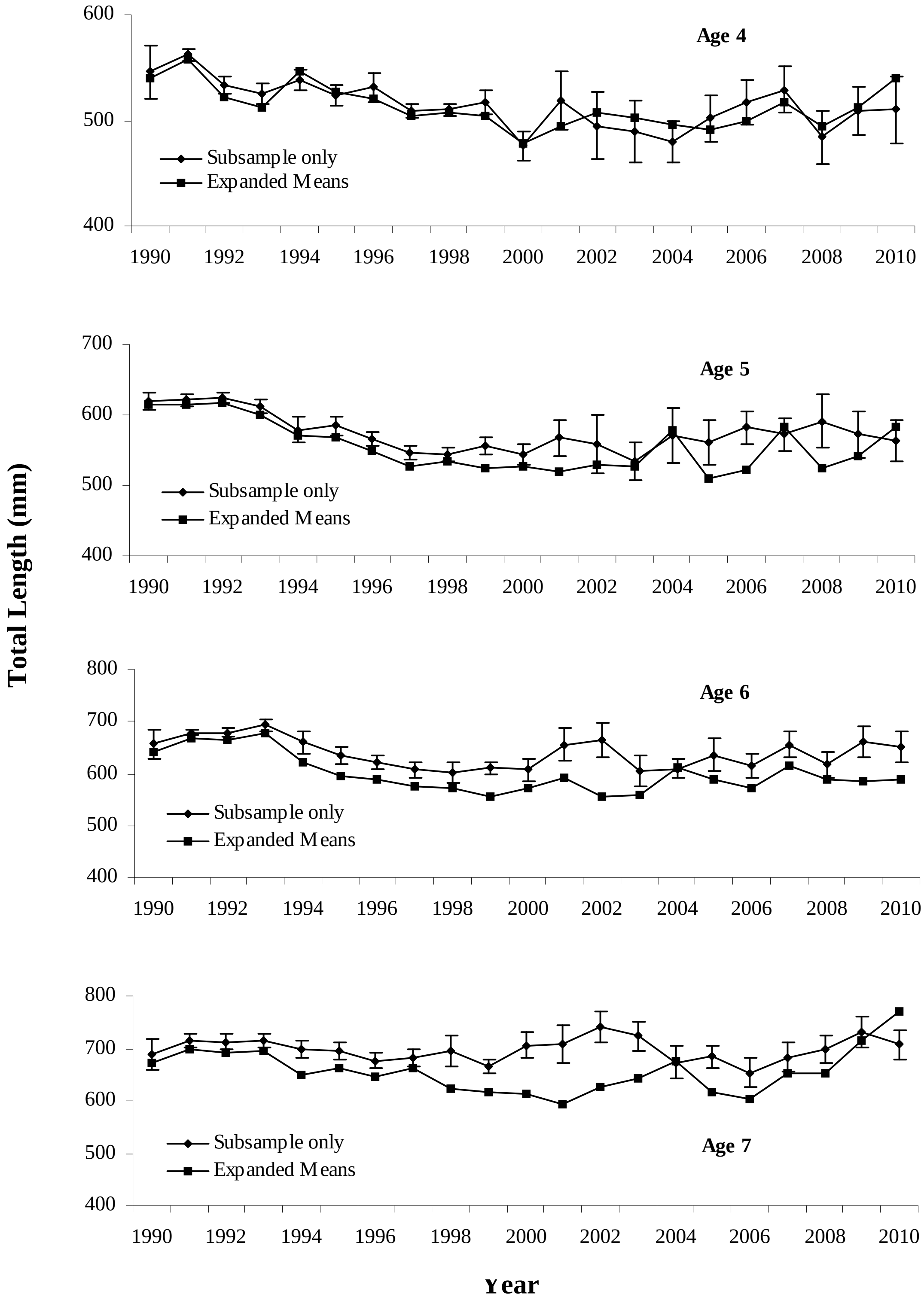


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-

old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations, 1990 through 2010. 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 1, 2010 - February 28, 2011 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 (multiple times per week when quota is 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 Area was defined as the region north of the Bay Bridge, while the Eastern Area was defined as the region south of the Bay Bridge on Maryland's Eastern Shore (Figure 1). The northern-most check station sampled in this survey was located in Baltimore, while the southern-most station was located on Tilghman Island.

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 variance of ages per length group (Barker et al. 2004). Target sample sizes were: length groups of 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.

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 2010-2011 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 2010 – February 2011 gill net season, the year used for age calculations was 2011.

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 2010-2011 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 39% of the total Maryland Chesapeake Bay commercial harvest, by weight. A total of 2,566 striped bass were sampled and 126 striped bass were aged from the harvest between December 2010 - February 2011. The sample size obtained was less than the established target due to season closures (season was open for 6 days each in December and January and 4 days in February).

Commercial gill nets have been limited to mesh sizes no less than 5 and no greater than 7 inches since the fishery reopened after the 1985-1990 moratorium. As a result, the range in ages of the commercial striped bass drift gill net landings has not fluctuated greatly since the inception of MD DNR check station monitoring during the 1993-1994 gill net season (Figure 2). 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. According to the estimated catch-at-age analysis, the 2010-2011 commercial drift gill net harvest consisted primarily of striped bass from the 2006 year-class (Age 5; Table 1), which composed 35% of the total harvest. The 2007 and 2005 year-classes (ages 4 and 6) composed an additional 45% of the total harvest, while age groups 8-13 contributed only 6% to the total. The contribution of fish greater than 8 years old was similar to the 2009-2010 harvest (6%) and higher than the 2008-2009 harvest (2%). The youngest fish observed in the 2010-2011 sampled harvest were age 4.

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 lower than sub-sample means. Striped bass were recruited into the 2010-2011 winter gill net fishery at age 4 (2007 year-class), with an expanded mean length and weight of 495 mm TL and 1.52 kg. The 2006 year-class (age 5) was most commonly observed in the sampled landings with an expanded mean length and weight of 547 mm TL and 2.03 kg, respectively. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 12, 1999 year-class) were 821 mm TL and 6.37 kg, respectively.

Length frequency distributions by check station area are presented in Figure 3. The length frequency distributions were dominated by fish in the 490-590 mm TL range. Distributions were similar when comparing the northern and eastern check stations. 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 1994-2011 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 in the age length key.

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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 2010 - February 2011.

Year-class	Age	Catch	Percentage of the catch
2007	4	35,069	21
2006	5	57,877	35
2005	6	39,558	24
2004	7	22,732	14
2003	8	6,685	4
2002	9	1,428	1
2001	10	1,338	1
2000	11	236	0
1999	12	129	0
Total*		**165,052**	**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 2010-February 2011.

Year-class	**Age**	**n fish aged**	**Mean TL (mm) of aged sub-sample**	**Estimated # at-age in sample**	**Expanded mean TL (mm)**
2007	4	16	477	545	495
2006	5	15	545	900	547
2005	6	14	598	615	548
2004	7	20	662	353	590
2003	8	24	732	104	624
2002	9	17	762	22	746
2001	10	15	811	21	765
2000	11	3	878	4	875
1999	12	2	823	2	822
Total*		**126**		**2,566**	

* 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 2010-February 2011.

Year-class	Age	n fish aged	Mean weight (kg) of aged sub-sample	Estimated # at-age in sample	Expanded mean weight (kg)
2007	4	16	1.37	545	1.52
2006	5	15	1.98	900	2.03
2005	6	14	2.74	615	2.06
2004	7	20	3.46	353	2.55
2003	8	24	4.90	104	3.08
2002	9	17	5.19	22	4.90
2001	10	15	6.39	21	5.41
2000	11	3	7.75	4	7.71
1999	12	2	6.77	2	6.37
Total*		**126**		**2,566**	

* 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 2010-February 2011.

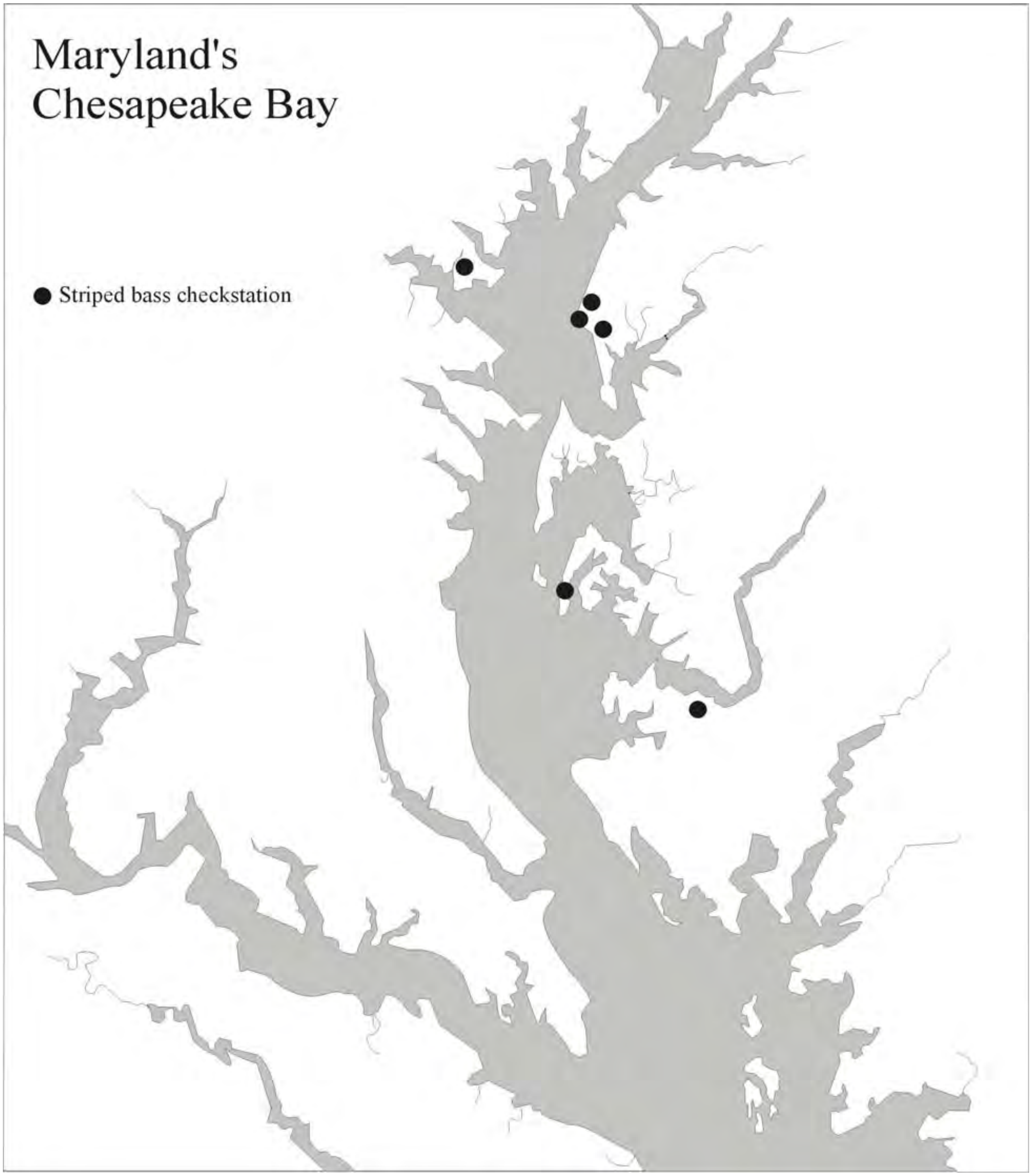
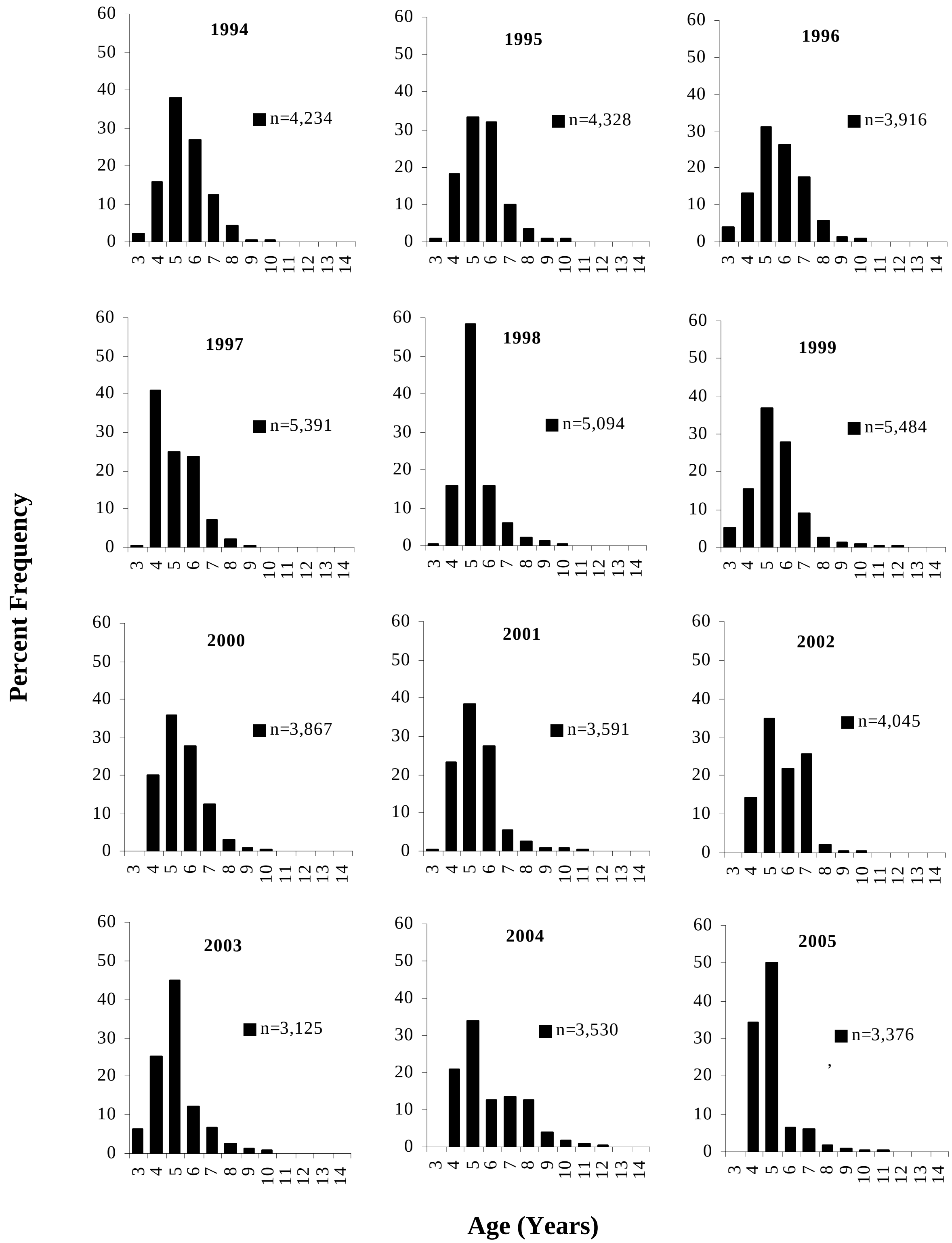


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2011.



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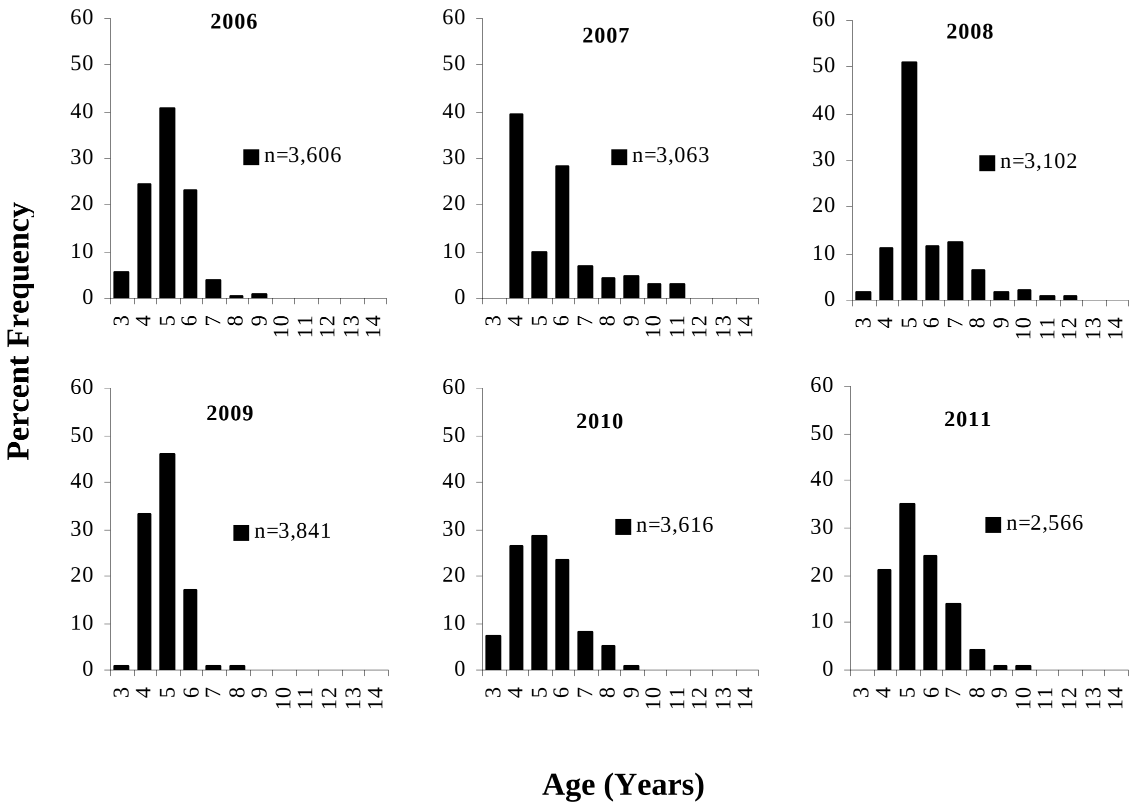


Figure 3. Length frequency distributions, by area and bay-wide, of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2010-February 2011.

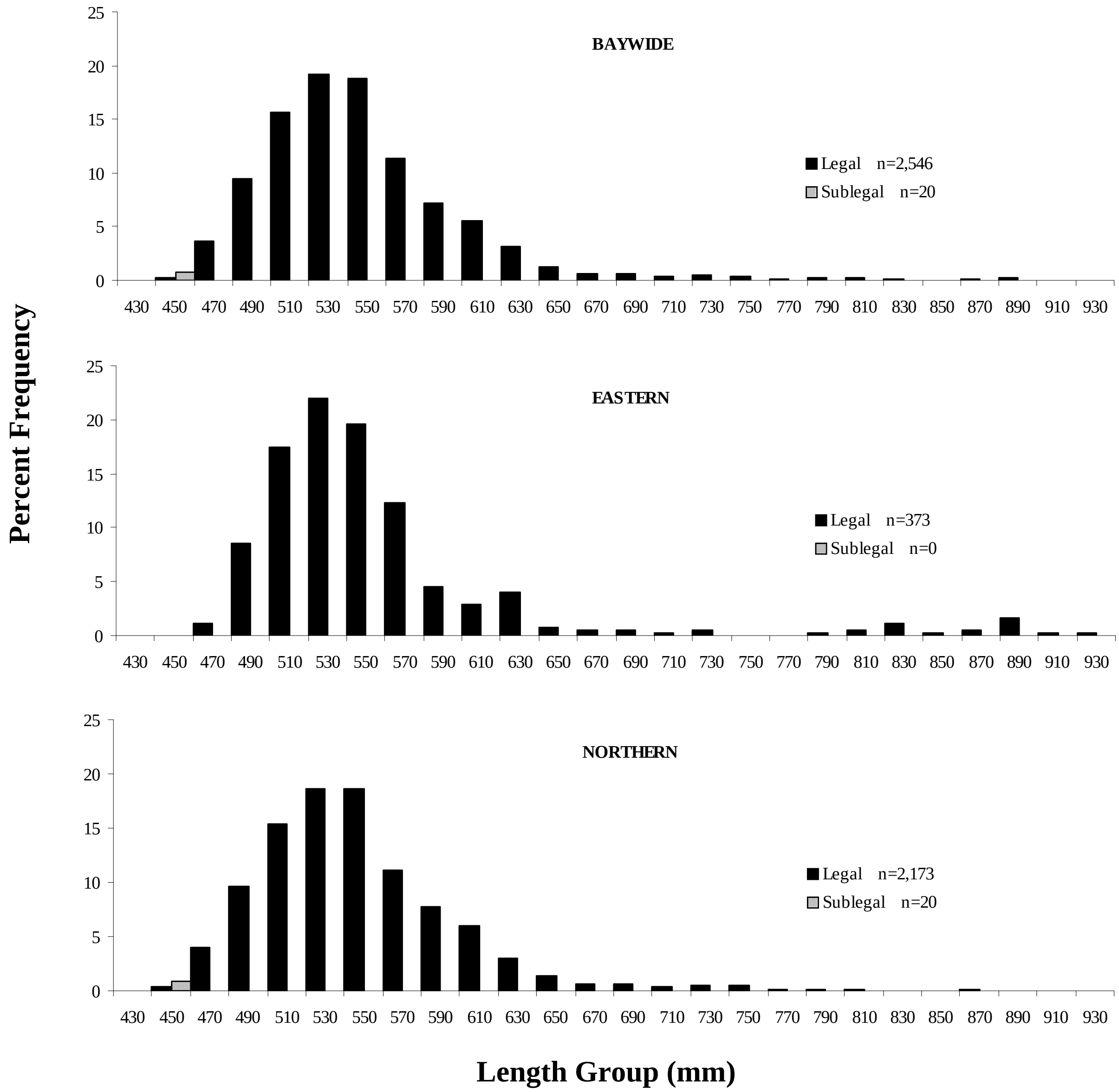
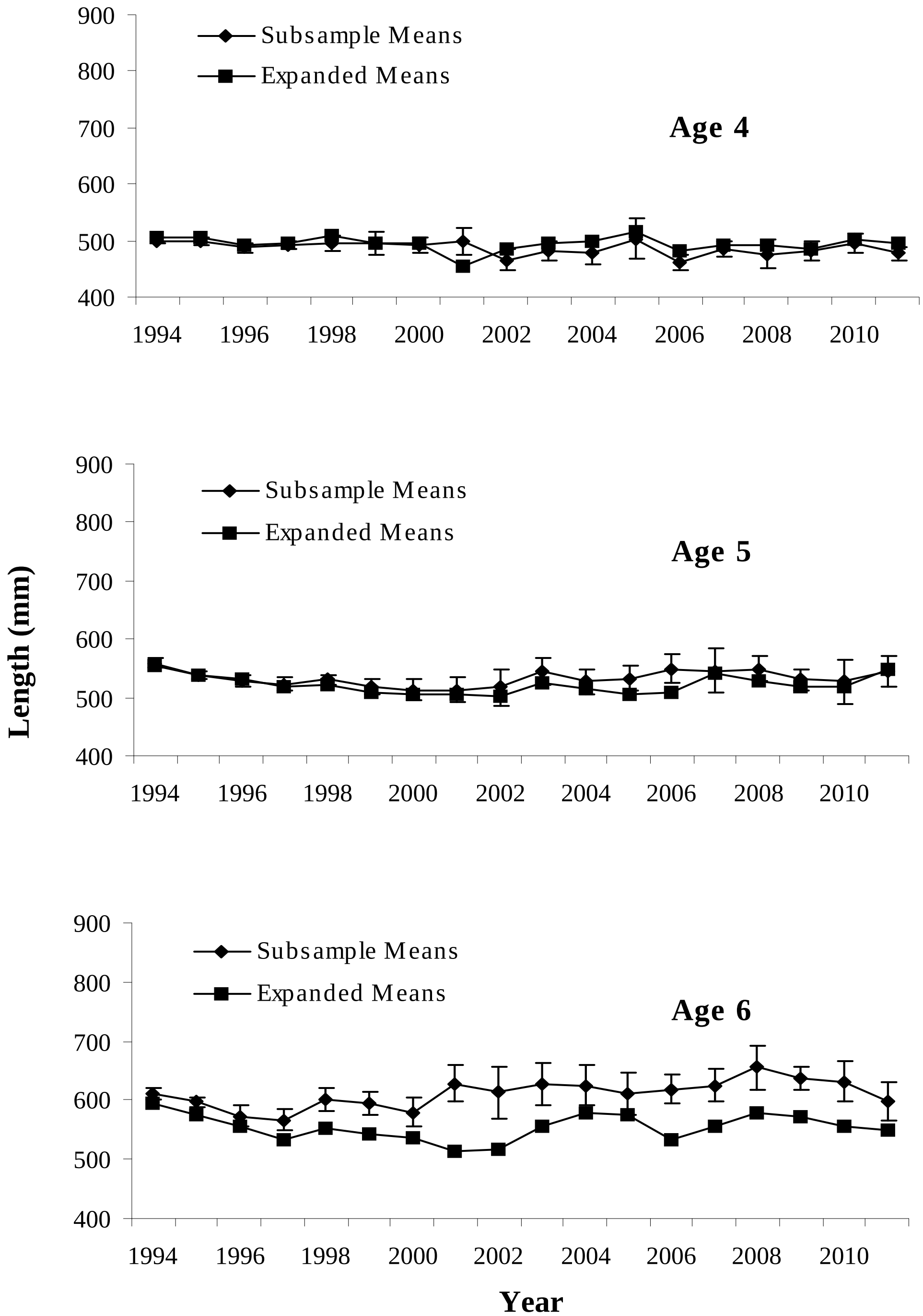


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2011 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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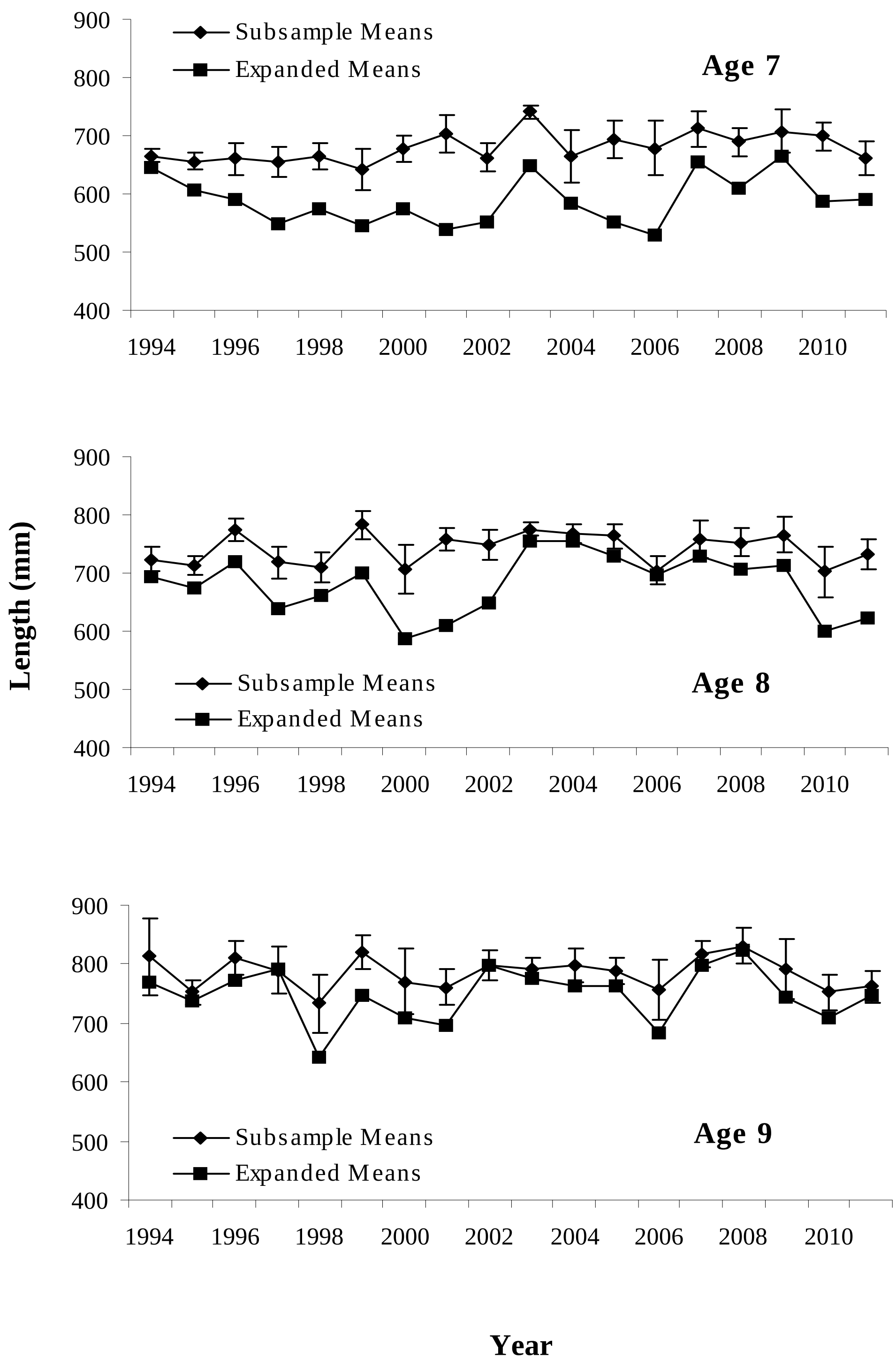
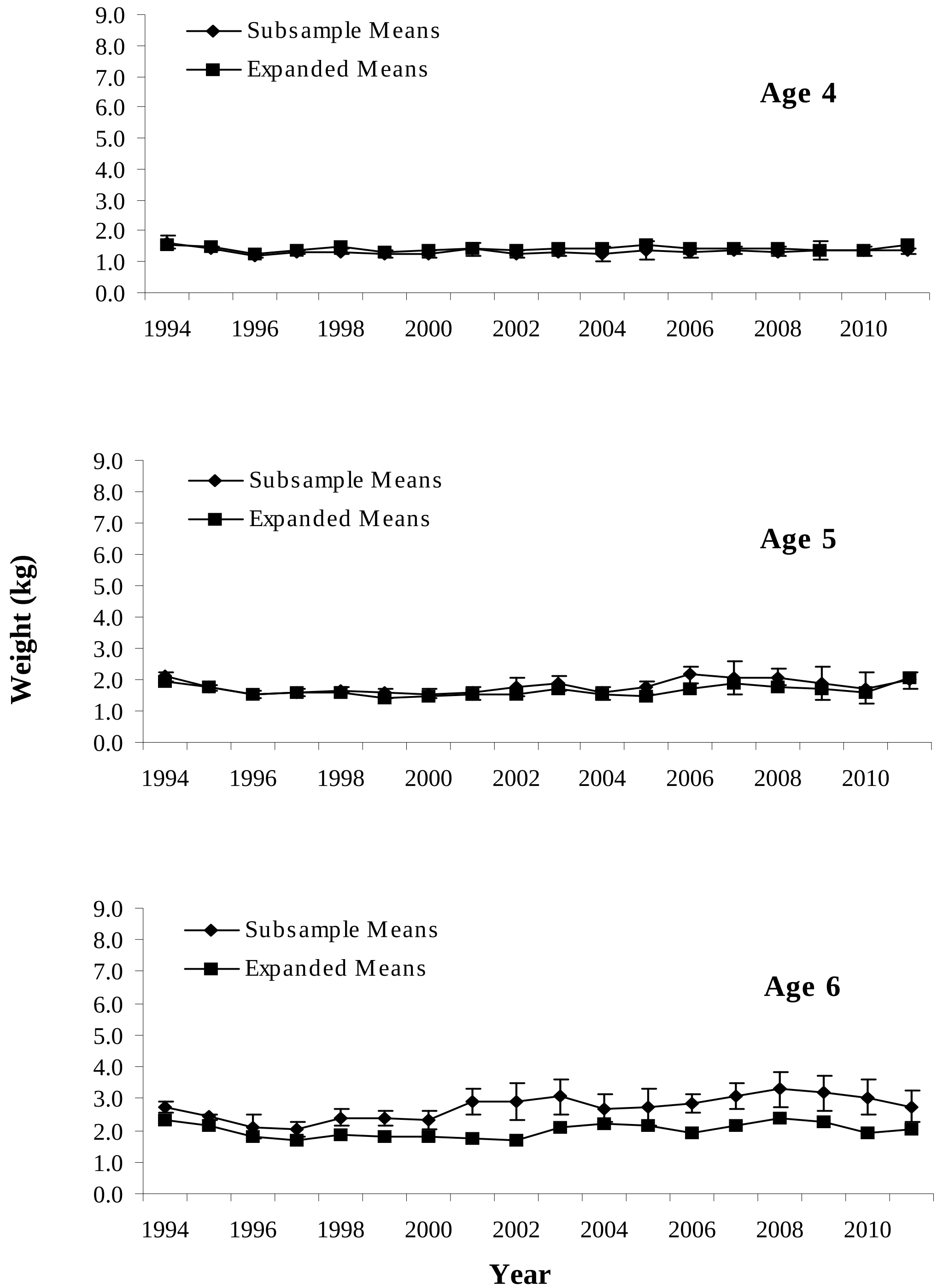


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2011 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.



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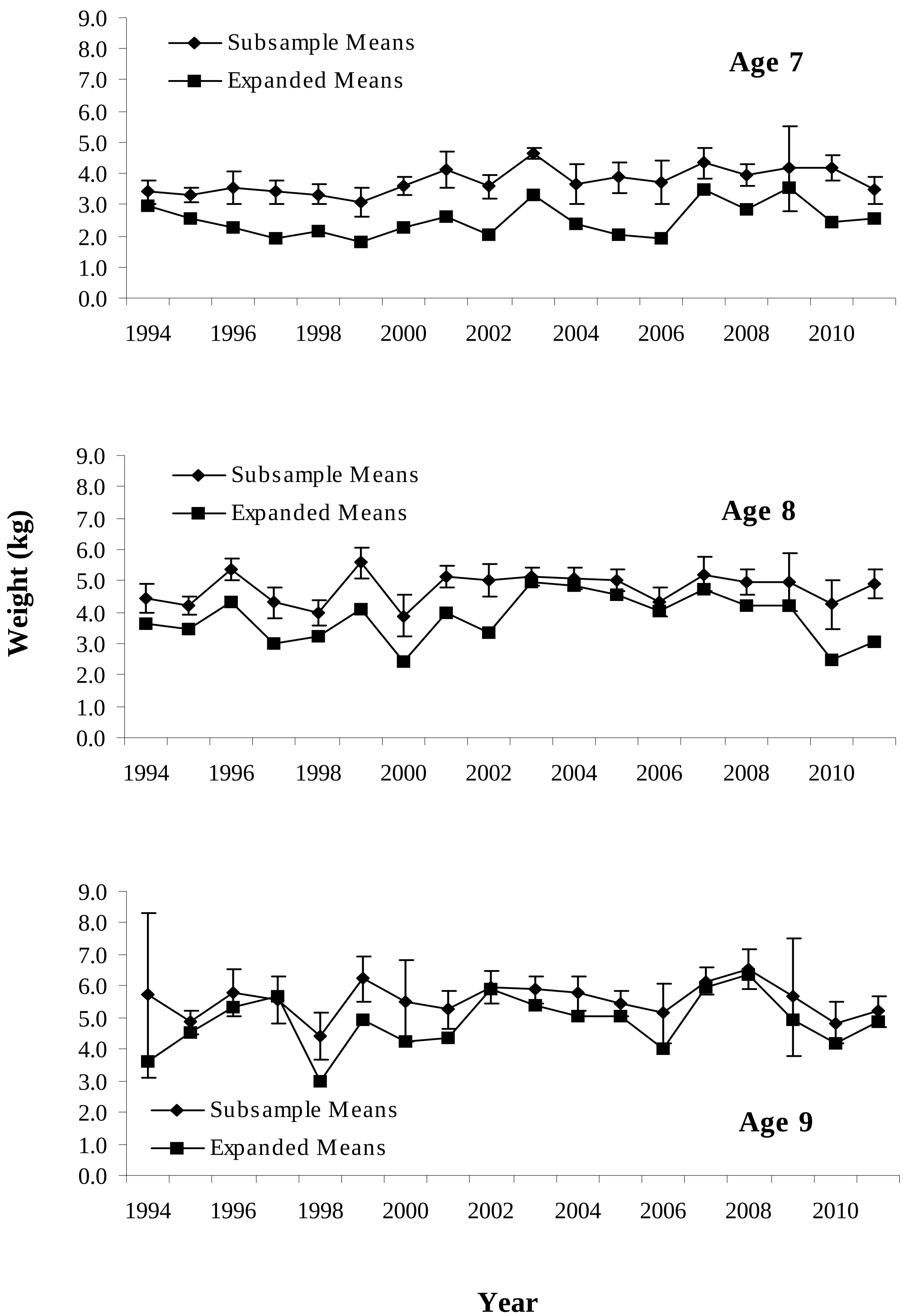

PROJECT NO. 2
JOB NO. 3
TASK NO. 1C

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by 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, 2010 and April 30, 2011. This fishery was managed with a 24 inch total length (TL) minimum size limit and an annual quota of 125,465 pounds. Although this report covers the November 2010-April 2011 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 intermittent and personnel sampled when fish were available. A monthly sample target of 150 fish was established for November, December, and January, because the majority of the coastal harvest was landed during these three months. Fish were measured (mm TL) and weighed (kg) and scales were randomly taken from five fish per 10 mm length group per day for age determination.

Analytical procedures

Age composition of the 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 2010 through April 2011. For stage two, a sub-sample of scales from Atlantic coast striped bass was aged. Due to the small sample size, the majority of scales are generally read and 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 2010-April 2011 Atlantic fishery, the year used for age calculations was 2011. These ages were then used to construct the ALK. The resulting ALK was applied to the sample length frequencies to generate a sample age distribution for all fish sampled at check stations. The age distribution of the total Atlantic coast harvest from November 2010 through April 2011 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 four days between November 2010 and April 2011. A total of 109 fish were measured and weighed and the ALK was developed from 99 scale samples. This is the smallest sample obtained from the Atlantic fishery in the time series. Because this fishery is largely a bycatch fishery, fish were harvested intermittently and difficult to intercept at the check stations.

Fish harvested during the 2010-2011 Atlantic coast fishing season ranged from age 5 (2006 year-class) to age 16 (1995 year-class) (Fig. 1). Most striped bass harvested were ages 6 through 10 (Table 1). Striped bass were recruited into the Atlantic coast fishery as young as age 5, but due to the 24 inch minimum size limit, few fish younger than age 6 were harvested.

Based on the estimated catch-at-age, the three most common ages harvested during the 2009-2010 Atlantic coast fishery were ages 7, 8, and 9 (20%, 19%, and 14% respectively). Age 10 (2001 year class) represented 14% of the fishery. The 2004 year-class (age 7) and 2003 year-class (age 8) are responsible for recruiting the majority of the fish into the fishery and are the most abundant.

Striped bass sampled at Atlantic coast check stations during the 2010-2011 season had a mean length of 778 mm TL and mean weight of 5.19 kg. The mean weight of fish in the 2010-2011 season was significantly different from fish in 2009-2010 (4.45 kg) (t-test, α=0.05, P=0.002). The mean length of fish harvested during the 2010-2011 season was significantly larger than that of the 2009-2010 (751 mm TL) harvest (t-test, α=0.05, P=0.032). The length distribution of fish harvested in the 2010-2011 season ranged from 620 to 1140 mm TL (Figure 2).

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). The small differences observed between the sub-sampled and expanded means were due to the sub-sample and sample sizes being similar. In 2011, 99 fish were aged of the 109 fish sampled, resulting in the aged sub-sample representing most of the overall sample. Recently recruited age 5 fish had an expanded mean length of 646 mm TL and expanded mean weight of 3.0 kg. Age 7 striped bass, the most abundant age harvested (Figure 1), had an expanded mean length of 696 mm TL and expanded mean weight of 3.7 kg. Age 8 striped bass, the next most abundant year-class harvested, had an expanded mean length of 759 mm TL and an expanded mean weight of 4.7 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 2010-April 2011.

2010-2011			
Year-Class	**Age**	**Catch**	**Percent**
2006	5	245	4.1
2005	6	774	12.8
2004	7	1,227	20.3
2003	8	1,159	19.2
2002	9	849	14.1
2001	10	831	13.8
2000	11	454	7.5
1999	12	111	1.8
1998	13	222	3.7
1997	14	55	0.9
1996	15	55	0.9
1995	16	55	0.9
	Total	**6,037**	**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 2010-April 2011. 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)
2006	5	3	650	596	703	4	646
2005	6	10	669	640	698	14	658
2004	7	19	705	674	736	22	696
2003	8	20	761	733	789	21	759
2002	9	15	802	762	843	15	801
2001	10	15	885	848	922	15	884
2000	11	8	882	800	964	8	878
1999	12	2	882	62	1701	2	879
1998	13	4	934	777	1091	4	934
1997	14	1	986	---	---	1	990
1996	15	1	1140	---	---	1	1140
1995	16	1	1032	---	---	1	1032
Total		**99**				**108**	

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2010-April 2011. 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)
2006	5	3	3.2	2.9	3.6	4	3.0
2005	6	10	3.2	2.7	3.6	14	3.1
2004	7	19	3.8	3.3	4.2	22	3.7
2003	8	20	4.6	4.2	5.0	21	4.7
2002	9	15	5.6	4.7	6.5	15	5.6
2001	10	15	6.9	6.2	7.6	15	6.9
2000	11	8	7.4	6.0	8.7	8	7.0
1999	12	2	7.3	---	---	2	7.0
1998	13	4	8.6	5.6	11.5	4	8.3
1997	14	1	9.0	---	---	1	9.1
1996	15	1	15.5	---	---	1	15.5
1995	16	1	10.9	---	---	1	10.9
Total		**99**				**108**	

Figure 1. Age distribution of striped bass sampled from the Atlantic coast fishery, 2006-2011 seasons.

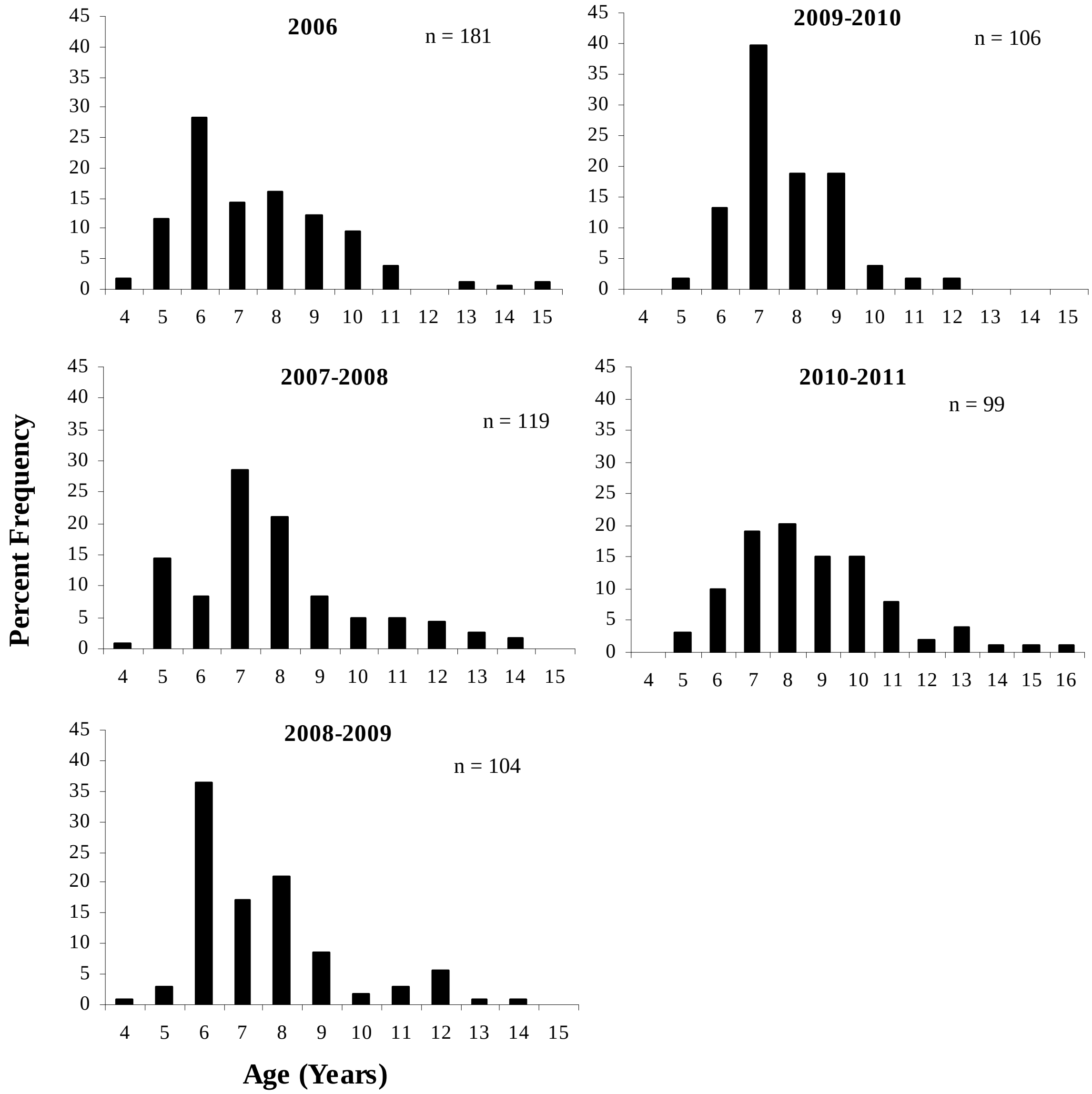


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, 2006-2011 seasons.

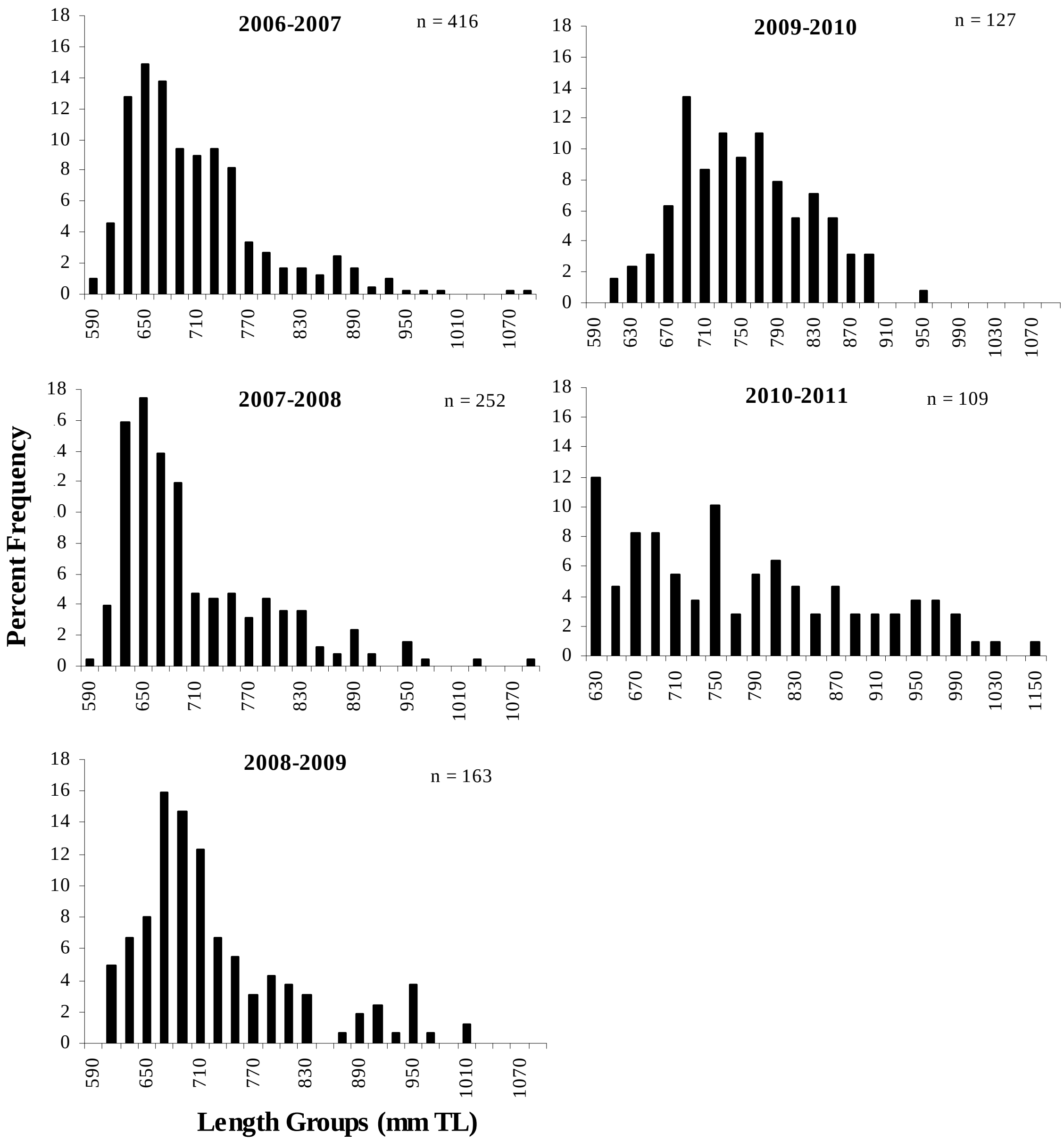
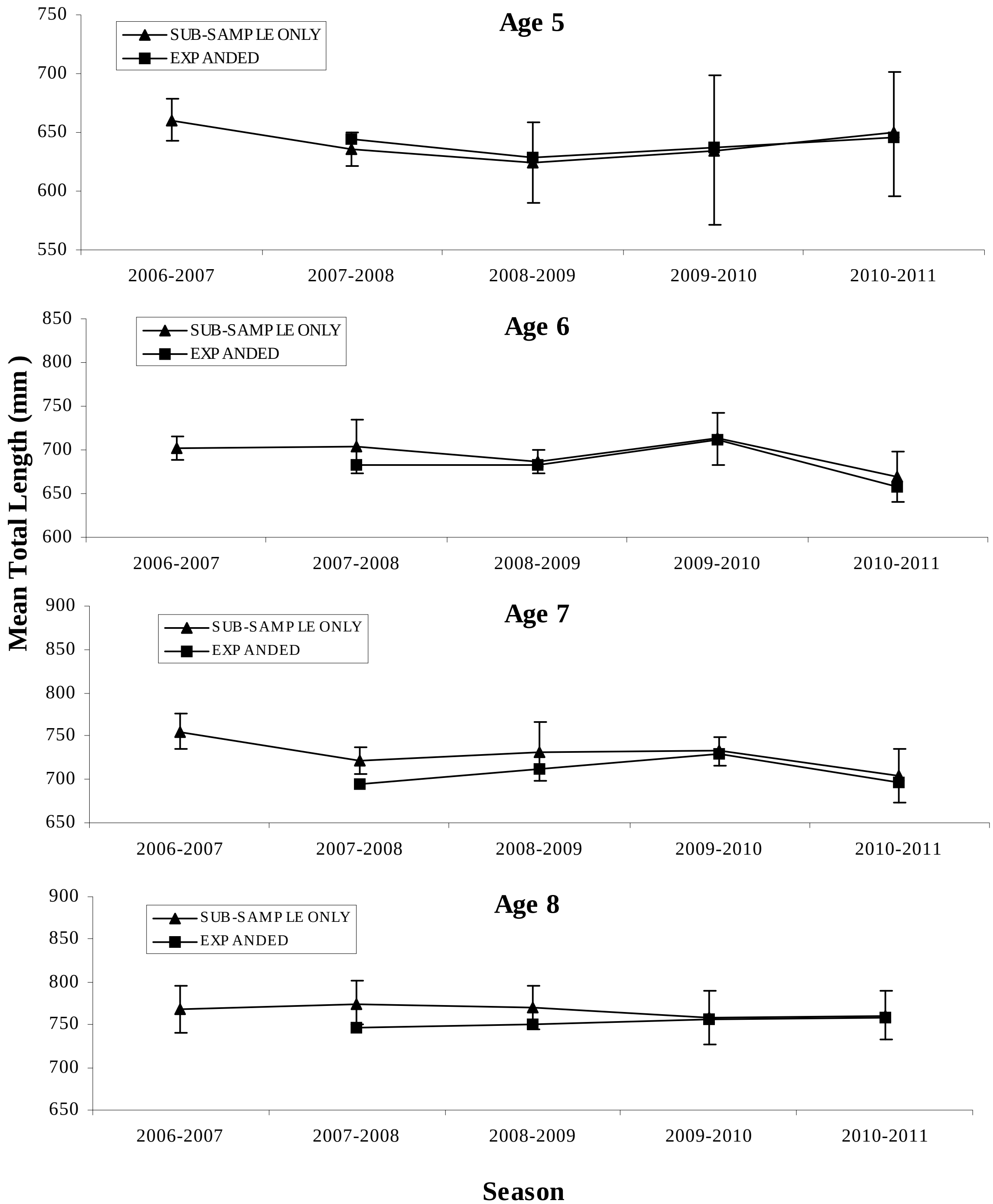


Figure 3. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2011 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences in scales on the y-axis.



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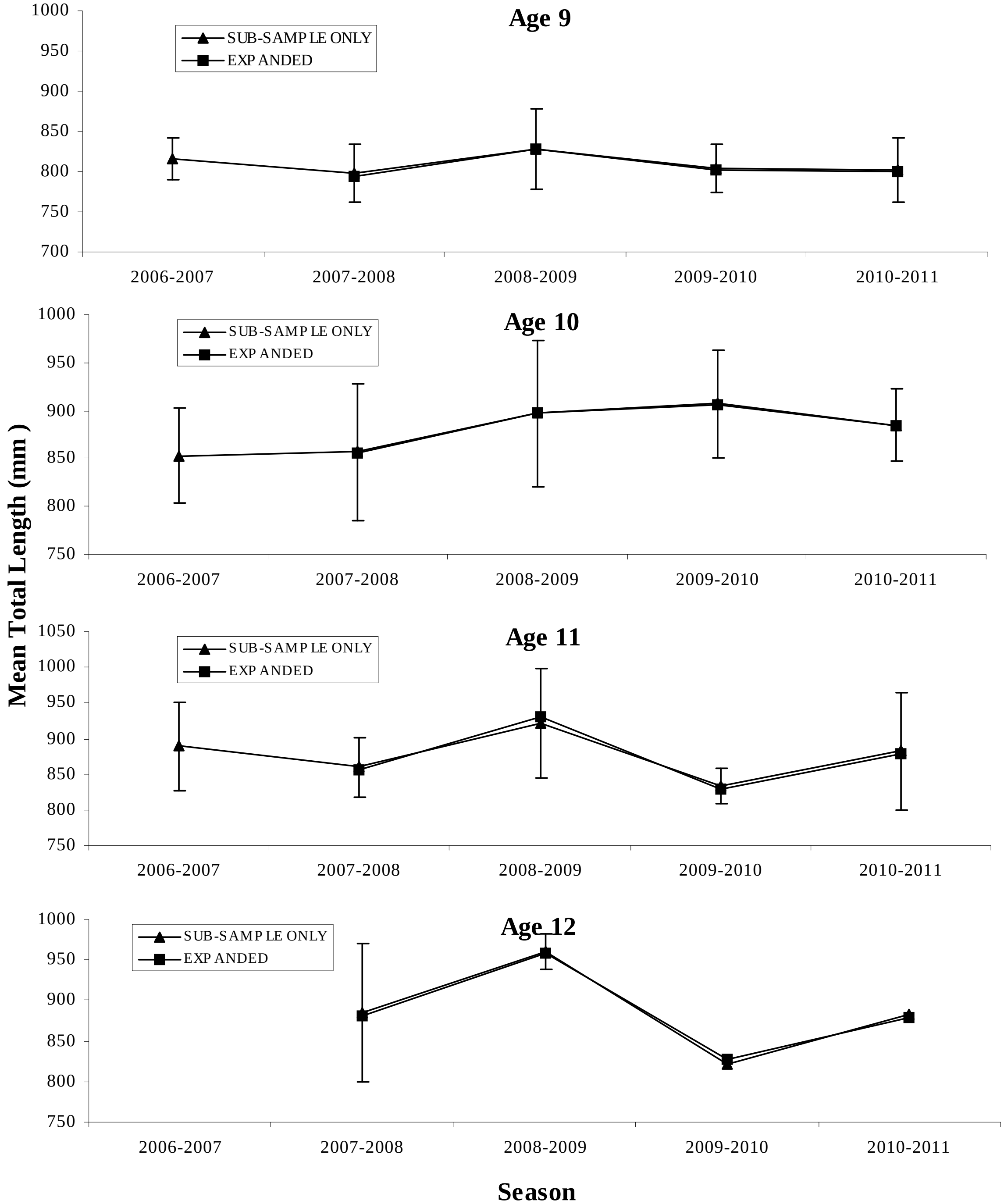
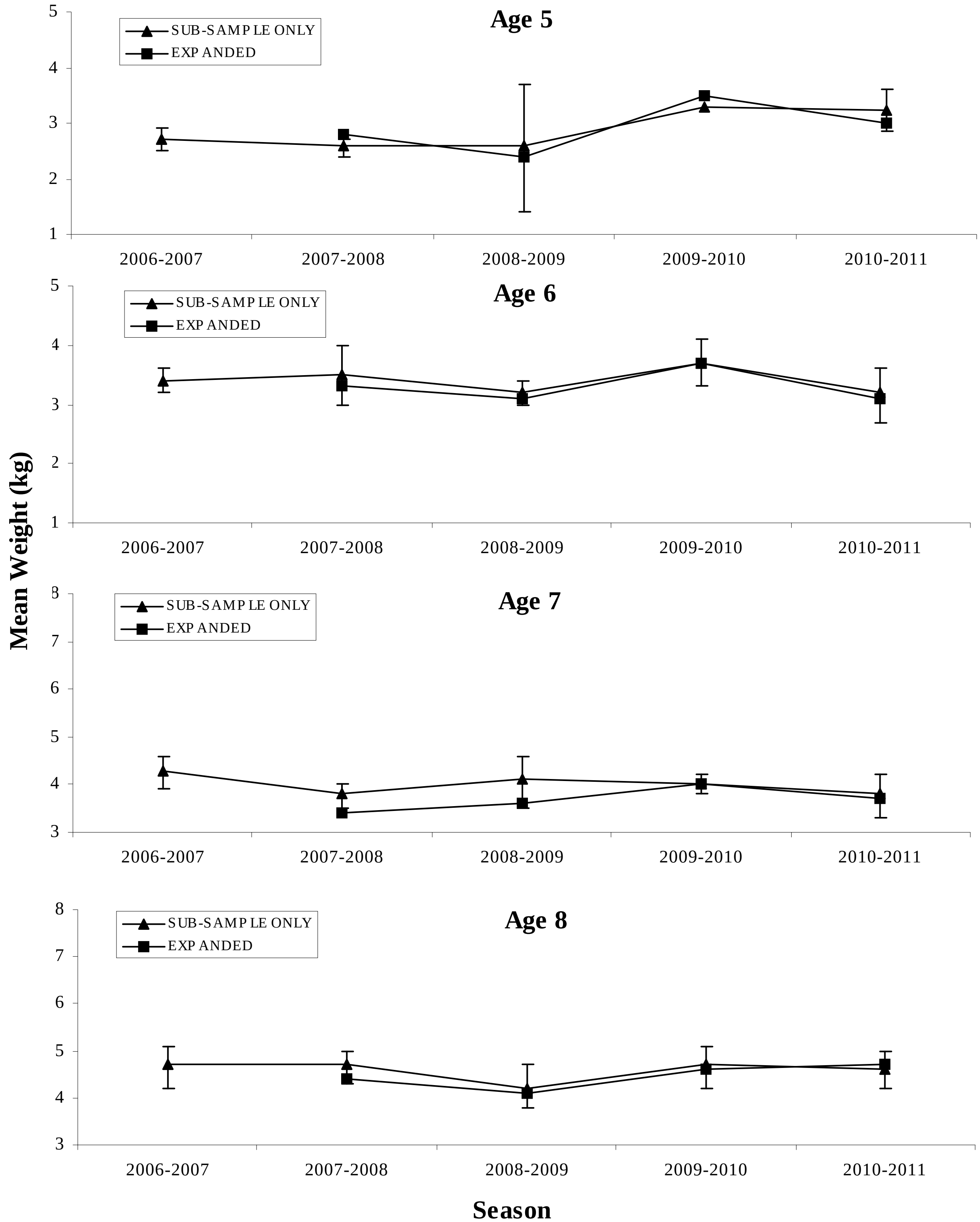


Figure 4. Mean weight (kg) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2011 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences of scale on the y-axis.



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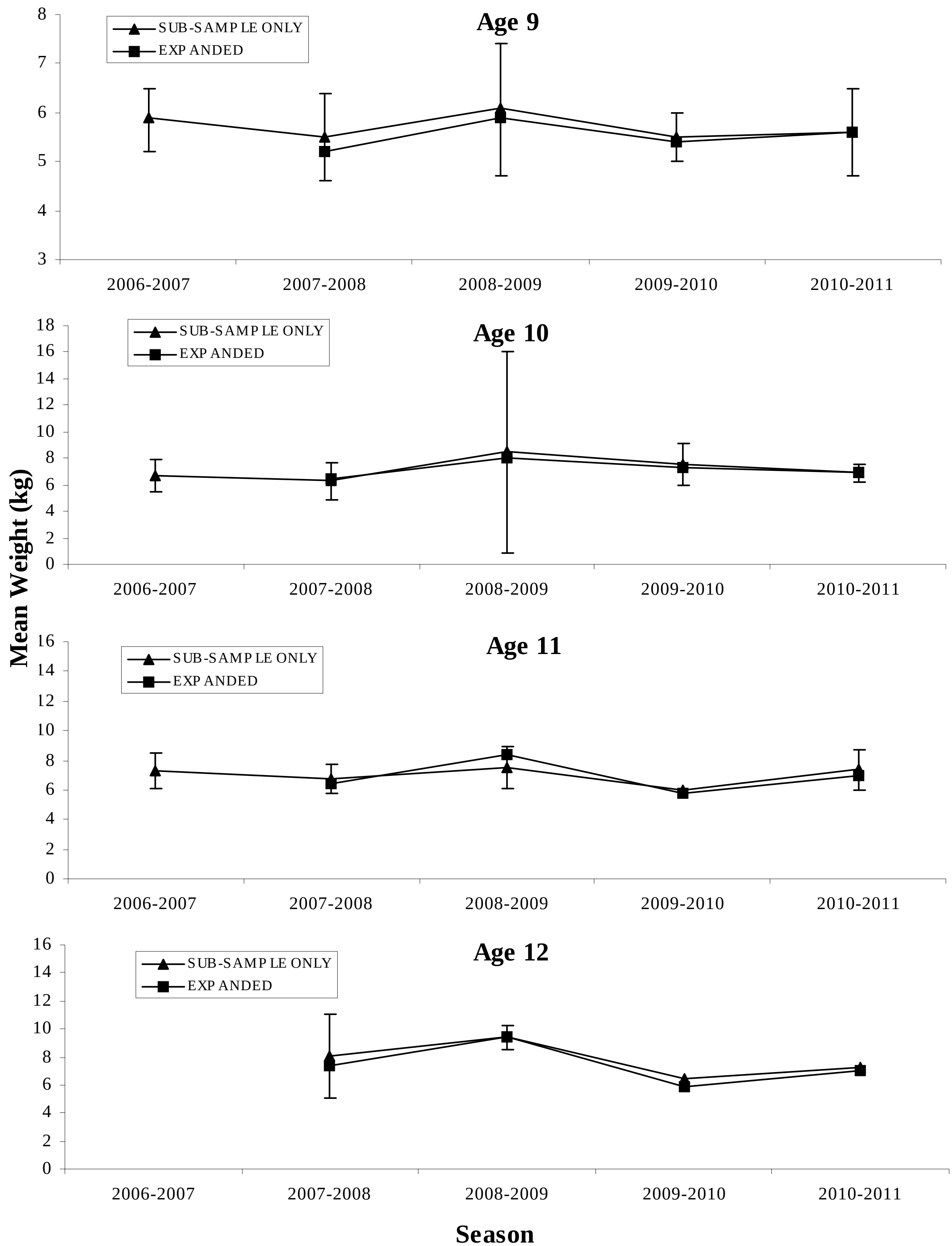

PROJECT NO. 2
JOB NO. 3
TASK NO. 2

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 2011 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 2011 (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 31 to May 11 for a total of 32 sample days. In the Upper Bay, sampling was also conducted from April 4 to May 21 with a total of 35 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 6 to 105 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 in 2011. 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):

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

RESULTS AND DISCUSSION

CPUEs and variance

A total of 601 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 2011 un-weighted CPUE for Potomac females (11) ranked twenty-first of 26 years in the time series, well below the series average of 27 (Table 2). This was the lowest value in the time series since 1990. The un-weighted CPUE for Potomac males (481) ranked eleventh in the time-series. This was the highest value seen since 1998 and was above the time series average of 445 (Table 3). The upper Bay female CPUE (27) ranked seventeenth in the 27 year time series. This was similar to 2010 and below the time series average of 35 (Table 4). The un-weighted CPUE for upper Bay males (410) was ranked seventeenth in the time series, a decrease from the last several years and below the time series average of 453 (Table 5). The Choptank River has not been sampled since 1996 (Tables 6 and 7).

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 2011 selectivity-corrected, total, weighted CPUE (458) was similar to the 2010 value (453) and below the time series average of 495.

Confidence limits were calculated for the pooled and weighted CPUEs (Tables 9 and 10). Confidence limits could not be calculated for the 15+ age group in years when these values are the sum of multiple age-class CPUEs. Coefficients of Variation (CV) of the 2011 age-specific CPUEs were all below 0.15 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 (98%, Tables 12 and 13), pooled, total CPUEs. Overall, young males from the 2008, 2007 and 2005 year-classes contributed substantially to the total un-weighted and weighted CPUEs in 2011, making up 56% of the total weighted CPUE and 55% of the un-weighted. In 2011 the contribution of Potomac fish to the total CPUE increased compared to previous years, contributing 53% to the total un-weighted and 41% to the weighted CPUEs.

The 2007 year-class continued to be the largest contributor to male CPUE for the second consecutive year, making up 23% of the un-weighted and weighted upper Bay male CPUEs and 34% of the un-weighted and weighted Potomac male CPUEs. The below average 2008 year-class was the second largest contributor to male CPUEs. In the Potomac River, these 3 year olds made up 20% of the un-weighted and weighted male CPUEs. This year-class contributed 14% to the total un-weighted and weighted upper Bay male CPUEs.

Female CPUEs were distributed across many year-classes in both systems. Four year old females from the 2007 year-class contributed to the CPUEs in both systems, comprising 7% in the Potomac River and 18% in the upper Bay. In the upper Bay, female fish age 7 and younger made up 34% of the un-weighted and weighted female CPUEs. Age 8 females from the large 2003 year-class made up 23% of the un-weighted and weighted female upper Bay CPUEs.

The 15+ age group, which now includes the record 1996 year-class, contributed 24% to the un-weighted and weighted female Potomac River CPUEs. In the Upper Bay, the contribution of the 15+ females to the un-weighted and weighted female CPUEs (8%) was lower. The next greatest contribution to female CPUE in the Potomac River was from the age 10 fish from the above average 2001 year-class, which contributed 18% to the un-weighted and weighted female CPUEs.

Temperature and catch patterns

Surface water temperatures on the Potomac River increased gradually throughout the survey. Daily water temperatures ranged from 9.9°C to 18.6°C. While water temperatures approached 15°C on April 17, they fell a couple degrees before surpassing 15°C on April 26. Female CPUE peaked on April 20 (Figure 2). This peak in female CPUE corresponds roughly with high concentrations of males encountered on April 13, suggesting possible spawning activity.

Surface water temperatures on the upper Bay during the spawning survey ranged from 7.1°C to 20°C. The upper Bay water temperatures were erratic through April and stayed below the 14°C needed to initiate spawning (Fay et al. 1983). Multiple gates were open for the entire month of April at Conowingo Dam, upstream of the survey sites, because of the heavy snowfalls and rain in the northern parts of the Susquehanna River watershed. Because Conowingo is a bottom draw dam, cold water was released, resulting in fluctuating water temperatures. Water temperatures finally reached 15°C on April 27. CPUEs for both sexes were relatively low during April, possibly due to the high water levels, high turbidity and large quantities of debris in the sample area. Peaks in female CPUE occurred on May 1 and May 5 (Figure 3). The highest CPUEs of male striped bass in the upper Bay occurred on April 19 and in the first week of May, but the majority of males were encountered throughout the month of May. These observations suggest a prolonged spawning period on the upper Bay beginning in early May, approximately two weeks after the peak on the Potomac River.

In both systems, wide fluctuations in air temperatures were observed, likely due to differences in sampling time. Both systems also showed general increasing trends in temperature, common for this time of year.

<u>Length composition of the stock</u>

In 2011, 2,224 male and 80 female striped bass were measured. On the Potomac River, 1,249 male and 30 female striped bass were sampled and 975 males and 50 females were sampled from the Upper Bay (Figure 4). The mean length of female striped bass in 2011 (912 ± 36 mm TL) was larger than the mean length of male striped bass (538 ± 5 mm TL, $P < 0.0001$). Mean lengths are reported with 2 standard errors. This is consistent with the known biology of the species.

Mean lengths of male striped bass collected from the Potomac River (503 ± 6 mm TL) and upper Bay (583 ± 9 mm TL) were significantly different ($P<0.0001$) in 2011. This is supported by the significant differences in length distributions ($\chi^2=103.97$, $\alpha=0.05$, $P<0.0001$) where the upper Bay observed more males in the 670-810 mm TL range than on the Potomac.

Male striped bass on the Potomac ranged from 268 to 1056 mm TL. The length distribution was heavily influenced by the contribution of striped bass from the above-average 2007 and 2005 year-classes. Male striped bass between 390 and 530 mm TL composed 69% of the Potomac River male catch in 2011 (Figure 4). Potomac male CPUEs (both uncorrected and selectivity-corrected) peaked between 390 and 530 mm TL, representing a combination of the 2006, 2007 and 2008 year-classes (Figure 5).

Male striped bass on the upper Bay ranged from 290 to 1106 mm TL. Males between 450 and 570 mm TL contributed 42% to the total catch of males in the upper Bay (Figure 4). The length distribution of male striped bass from the Upper Bay was also heavily influenced by the contribution of striped bass from the above average 2005 and 2007 year-classes, as well as the 2003 year-class. Male striped bass CPUE in the upper Bay was distributed across a wider range of sizes than in the Potomac River (Figure 5). The peaks in both corrected and uncorrected CPUEs represent the same year-classes as in the length distribution.

Female striped bass sampled from the Potomac River in 2011 were significantly larger than female striped bass sampled from the upper Bay (P=0.003). Female striped bass sampled from the Potomac ranged from 519 to 1209 mm TL (mean=980 ± 49 mm TL), while females sampled in the upper Bay ranged from 497 to 1164 mm TL (mean=872 ± 47 mm TL; Figure 4). The female length distributions could not be compared using a chi-square test because of the small sample sizes per length group.

The low number of females caught on the Potomac River in 2011 resulted in few discernable peaks in CPUE by length group. A single female fish from the 2007 year-class resulted in the peak in the 510 mm length group (Figure 6). The second peak in the 1070 mm length group was also from one fish from the 1995 year-class.

In the upper Bay, female corrected and uncorrected CPUEs cover 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. One fish in the 490 length group resulted in the highest female CPUE, due to being captured in a mesh size that was slightly larger than the optimum for fish of that length. While a range of mesh sizes are used to minimize bias, gill nets are very size selective and the selectivity correction attempts to estimate the relative abundance of fish at each length group in the population. When a single fish is caught in an unusual mesh size for its length, the selectivity correction adjusts the CPUE upward. This is most evident in the 490, 650 and 730 mm length groups. These fish were from the 2007, 2005 and 2003 year-classes, respectively.

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 2011 to produce separate male and female ALKs (Warner et al., 2006, Warner et al., 2008). This assumption was checked again following the protocol of Barker et al. (2004). This protocol compared the affect of area on mean LAA for the past five years using an ANCOVA. These assumptions generally held true using more recent data. There were no significant differences in the age*area interaction for female striped bass LAA for any year from 2007-2011. For male striped bass, significant age*area interactions were found for 2007-2009. However, since there was not a significant interaction effect for 2010 or 2011, it was determined that it was acceptable to continue to combine the surveys to produce separate male and female ALKs.

Age and sex-specific LAA relationships 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. For example, 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 2011 ($P > 0.05$) except for 6 and 10 year old males. Six year old males were significantly smaller on the upper Bay (567 mm TL) than the Potomac (614 mm TL, $P = 0.01$). Ten year old males were significantly larger on the upper Bay (868 mm TL) than the Potomac (757 mm TL, $P = 0.008$).

When comparing LAA between years, only gill net fish were used. Male and female LAA has been relatively stable since the mid 1990's (Figures 7 and 8). Mean lengths of males were similar in 2010 and 2011 for all ages except for age 2 (ANOVA, α=0.05, P=0.03). Mean lengths of females were similar in 2010 and 2011 for all ages that could be tested.

Age composition of the stock

During the 2011 survey, seventeen age-classes, ranging from 2 to 16 were encountered (Tables 14 and 15). Male striped bass ranged from ages 2 to 16, with age 8 fish (2003 year-class) being the most abundant male cohort. The majority of females were ages 8 to 13, with equal numbers of females collected at ages 8 (2003 year-class), 10 (2001 year-class), and 13 (1998 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 2011, the largest increase in age-specific CPUE was indicated by the age 8 (2003 year-class) cohort. The 1996 year-class has now moved into the 15+ age group, and while they still appear in the spawning stock, their contribution is declining (Figure 9).

In 2011, age 8+ females constituted 70% of the female spawning stock (Figure 10), the lowest value since 1996. The contribution of females age 8 and older fish to the spawning stock had been at or above 80% since 1996. Some decline is expected based on the results of the most recent coastwide stock assessment, which shows that female spawning stock biomass has been declining (ASMFC 2011). The abnormal spring water conditions during the survey likely contributed to the decline of this statistic as well.

The percentage of the overall sample (males and females combined) age 8 and older has been variable since 1997 (Figure 11). The 2011 value of 21% is an increase over 2010. The percentage of age 8+ fish is heavily influenced by strong year-classes and shows cyclical variations (Figure 9).

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 2011 the ISP (168) continued to decline and was well below the time-series average of 283 (Table 16, Figure 12). The 2011 Potomac River female ISP (105) also declined, and was well below the time series average of 234. In both systems, these were the lowest values since the 1990s.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2011.

	MALES				FEMALES			
Length group (mm)	**Upper Bay**	**Potomac River**	**Creel**	**Total**	**Upper Bay**	**Potomac River**	**Creel**	**Total**
270	0	0	0	**0**	0	0	0	**0**
290	3	1	0	**4**	0	0	0	**0**
310	3	3	0	**6**	0	0	0	**0**
330	3	3	0	**6**	0	0	0	**0**
350	3	3	0	**6**	0	0	0	**0**
370	3	3	0	**6**	0	0	0	**0**
390	3	3	0	**6**	0	0	0	**0**
410	3	3	0	**6**	0	0	0	**0**
430	3	3	0	**6**	0	0	0	**0**
450	3	3	0	**6**	0	0	3	**3**
470	3	3	0	**6**	0	0	10	**10**
490	3	3	0	**6**	1	0	8	**9**
510	3	3	0	**6**	0	1	9	**10**
530	3	3	0	**6**	0	0	8	**8**
550	3	3	0	**6**	2	0	6	**8**
570	5	5	0	**10**	1	0	5	**6**
590	5	5	0	**10**	0	0	6	**6**
610	5	5	0	**10**	1	0	0	**1**
630	5	5	0	**10**	0	0	0	**0**
650	5	5	0	**10**	2	0	3	**5**
670	5	5	0	**10**	0	0	1	**1**
690	5	5	0	**10**	2	0	0	**2**
710	6	5	4	**15**	1	0	0	**1**
730	7	5	3	**15**	0	0	1	**1**
750	5	5	5	**15**	1	0	2	**3**
770	5	5	5	**15**	3	0	3	**6**
790	5	5	5	**15**	2	1	8	**11**
810	5	5	5	**15**	3	0	10	**13**
830	7	3	5	**15**	0	1	11	**12**
850	8	2	5	**15**	3	0	12	**15**
870	6	2	1	**9**	1	1	13	**15**
890	6	3	2	**11**	1	3	11	**15**
910	2	1	2	**5**	2	1	12	**15**
930	1	3	2	**6**	4	2	9	**15**
950	2	1	2	**5**	3	3	9	**15**
970	3	1	1	**5**	2	1	10	**13**
990	4	2	0	**6**	5	5	5	**15**
1010	2	1	1	**4**	2	1	5	**8**
1030	1	0	0	**1**	1	1	2	**4**
1050	0	1	1	**2**	1	0	4	**5**
1070	0	0	0	**0**	1	1	2	**4**
1090	0	0	0	**0**	1	2	4	**7**
1110	1	0	0	**1**	2	3	0	**5**
1130	0	0	0	**0**	0	0	2	**2**
1150	0	0	0	**0**	1	1	0	**2**
1170	0	0	0	**0**	1	1	0	**2**
1190	0	0	0	**0**	0	0	0	**0**
1210	0	0	0	**0**	0	1	0	**1**
Total	**153**	**125**	**49**	**327**	**50**	**30**	**194**	**274**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2011 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**
Average																**27**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2011 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Potomac River was not sampled in 1994.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	285.3	517.6	80.6	10.5	0.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**896**
1986	0.0	241.5	375.9	531.2	8.2	8.2	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1166**
1987	0.0	144.5	283.5	174.6	220.8	3.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	**829**
1988	0.0	18.2	107.4	63.8	75.9	81.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**347**
1989	0.0	51.9	240.9	134.5	39.1	55.2	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**543**
1990	0.0	114.2	351.8	172.8	73.8	28.3	33.8	26.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	**803**
1991	0.0	19.9	91.2	96.6	49.7	37.8	28.7	22.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0	**352**
1992	0.3	36.3	202.4	148.9	97.6	73.0	39.1	19.0	6.1	0.8	8.4	0.0	0.0	0.0	0.0	**632**
1993	0.0	30.4	141.7	133.9	101.4	83.7	62.6	43.6	21.9	1.8	0.0	0.0	0.0	0.0	0.0	**621**
1994																
1995	0.0	9.1	143.9	61.1	18.7	20.4	25.3	32.2	11.3	10.7	0.1	0.0	0.8	0.0	0.0	**334**
1996	0.0	0.0	230.6	172.9	24.8	26.8	17.7	22.7	19.3	3.6	0.6	0.8	0.0	0.0	0.0	**520**
1997	0.0	49.5	54.3	112.9	95.7	12.2	5.7	10.8	17.2	13.6	2.2	2.6	0.0	0.0	0.0	**377**
1998	0.0	72.9	200.7	29.8	128.9	49.8	16.9	11.7	4.3	9.0	8.6	5.0	2.9	0.5	0.0	**541**
1999	0.0	9.9	316.9	151.2	103.6	65.4	19.1	10.3	6.9	3.8	4.4	3.1	1.9	0.0	0.0	**696**
2000	0.0	1.9	42.2	136.8	48.5	18.1	14.8	9.8	5.5	0.0	0.1	3.7	0.1	0.4	0.9	**283**
2001	0.0	10.6	36.1	43.5	33.8	12.6	8.9	7.8	4.8	1.7	2.2	4.0	0.8	0.6	0.0	**167**
2002	0.0	27.2	75.4	48.7	52.4	23.0	20.9	7.9	2.3	3.4	2.2	1.6	2.0	0.0	0.6	**268**
2003	0.0	12.6	79.0	39.6	24.5	31.6	22.5	10.0	7.0	9.5	3.2	3.7	5.8	0.2	0.2	**249**
2004	0.0	10.5	148.8	90.4	25.9	17.6	19.5	17.2	8.4	8.1	11.5	1.8	1.1	1.6	1.6	**364**
2005	0.0	10.9	11.0	14.9	16.3	4.7	4.5	3.6	4.1	3.1	1.9	1.2	0.0	0.0	0.0	**76**
2006	0.0	8.3	127.1	20.7	33.5	14.5	6.3	6.9	8.2	9.1	7.4	4.7	0.6	0.4	0.0	**248**
2007	0.0	10.4	16.6	37.1	5.3	5.6	4.3	2.1	2.6	2.8	5.4	1.0	0.8	2.0	0.1	**96**
2008	0.0	6.1	35.8	20.1	12.0	1.7	1.8	2.3	1.1	1.2	1.3	2.5	0.4	0.0	0.2	**86**
2009	0.0	35.2	35.9	116.5	23.1	56.9	9.1	10.5	10.5	2.8	3.8	2.6	3.7	0.6	0.6	**312**
2010	0.0	3.2	104.9	58.0	49.2	29.7	23.9	1.7	6.8	3.6	0.9	1.2	1.3	0.6	0.4	**285**
2011	0.0	27.6	95.7	164.4	51.2	54.4	29.6	24.7	6.2	5.2	6.1	4.1	4.9	2.1	5.3	**481**
Average																**445**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the upper Bay during the 1985-2011 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**
Average																**35**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the upper Bay during the 1985-2011 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**
Average																**453**

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 (1985–2011) 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**
Average																**495**

Table 9. Lower confidence limits (95%) of the annual, pooled, weighted, age-specific CPUEs (1985–2011) 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	*

* 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 (1985–2011) 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	*

* 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 (1985–2011) 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	*

* 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 2011. 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
2010	1	0.0	0.0	0.0	0.0	0.0	0.0
2009	2	47.7	5.1	0.0	0.0	27.6	20.1
2008	3	155.1	16.7	0.1	0.0	95.7	59.2
2007	4	262.9	28.3	0.8	4.9	164.4	92.8
2006	5	93.1	10.0	0.4	2.0	51.2	39.5
2005	6	113.5	12.2	0.0	1.2	54.4	57.9
2004	7	72.9	7.8	0.0	1.3	29.6	42.0
2003	8	82.7	8.9	0.9	6.4	24.7	50.7
2002	9	18.8	2.0	0.4	1.3	6.2	10.9
2001	10	17.6	1.9	2.0	2.5	5.2	7.9
2000	11	15.4	1.7	1.1	1.2	6.1	7.0
1999	12	14.7	1.6	1.1	1.0	4.1	8.5
1998	13	8.8	0.9	1.1	2.1	4.9	0.7
1997	14	7.9	0.9	0.4	1.2	2.1	4.2
≤1996	15+	18.6	2.0	2.6	2.2	5.3	8.3
Total		929.7		11.0	27.4	481.4	409.9
% of Total				1	3	52	44
% of Sex				29	71	54	46
% of Potomac				2		98	
% of Upper Bay					6		94

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, late March through May 2011. 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**
2010	1	0.0	0.0	0.0	0.0	0.0	0.0
2009	2	23.0	5.0	0.0	0.0	10.6	12.4
2008	3	73.3	16.0	0.1	0.0	36.9	36.4
2007	4	123.7	27.0	0.3	3.0	63.4	57.0
2006	5	45.4	9.9	0.2	1.2	19.7	24.3
2005	6	57.3	12.5	0.0	0.7	21.0	35.6
2004	7	38.0	8.3	0.0	0.8	11.4	25.8
2003	8	44.9	9.8	0.4	3.9	9.5	31.1
2002	9	10.1	2.2	0.1	0.8	2.4	6.7
2001	10	9.1	2.0	0.8	1.5	2.0	4.8
2000	11	7.9	1.7	0.4	0.8	2.4	4.3
1999	12	7.8	1.7	0.4	0.6	1.6	5.2
1998	13	4.0	0.9	0.4	1.3	1.9	0.4
1997	14	4.3	0.9	0.2	0.7	0.8	2.6
≤1996	15+	9.5	2.1	1.0	1.4	2.1	5.0
Total		458.4		4.2	16.8	185.6	251.8
% of Total				1	4	40	55
% of Sex				20	80	42	58
% of Potomac				2		98	
% of Upper Bay					6		94

* 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 2011.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2009	2	POTOMAC	5	345	295	395	40	18
		UPPER	5	311	277	344	27	12
		COMBINED	10	328	301	354	37	12
2008	3	POTOMAC	11	359	334	384	37	11
		UPPER	15	376	349	403	49	13
		COMBINED	26	369	351	387	44	9
2007	4	POTOMAC	17	457	426	488	60	15
		UPPER	13	444	411	478	56	15
		COMBINED	30	451	430	473	58	11
2006	5	POTOMAC	11	555	524	586	46	14
		UPPER	6	561	501	620	56	23
		COMBINED	17	557	532	582	48	12
2005	6	POTOMAC	17	614	592	637	43	10
		UPPER	13	567	536	599	52	14
		COMBINED	30	594	575	613	52	9
2004	7	POTOMAC	18	696	660	732	73	17
		UPPER	17	683	642	724	80	19
		COMBINED	35	689	664	715	76	13
2003	8	POTOMAC	15	756	720	793	66	17
		UPPER	47	743	719	768	84	12
		COMBINED	62	747	726	767	80	10
2002	9	POTOMAC	11	790	746	834	66	20
		UPPER	9	801	735	867	86	29
		COMBINED	20	795	760	829	74	16
2001	10	POTOMAC	4	757	696	817	38	19
		UPPER	6	868	810	925	55	22
		COMBINED	10	823	770	876	74	23
2000	11	POTOMAC	7	877	790	964	94	36
		UPPER	11	899	862	936	55	17
		COMBINED	18	891	855	926	71	17
1999	12	POTOMAC	4	946	866	1027	51	25
		UPPER	5	932	851	1013	65	29
		COMBINED	9	939	895	982	56	19
1998	13	POTOMAC	2	887	455	1319	48	34
		UPPER	1	995	-	-	-	-
		COMBINED	3	923	747	1099	71	41
1997	14	POTOMAC	2	946	501	1391	49	35
		UPPER	3	993	922	1065	29	17
		COMBINED	5	974	923	1026	41	18
1996	15	POTOMAC	0	-	-	-	-	-
		UPPER	1	1106	-	-	-	-
		COMBINED	1	1106	-	-	-	-

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 2011.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2007	4	POTOMAC	1	519	-	-	-	-
		UPPER	2	550	-118	1217	74	53
		COMBINED	3	539	402	677	55	32
2006	5	POTOMAC	0	-	-	-	-	-
		UPPER	1	568	-	-	-	-
		COMBINED	1	568	-	-	-	-
2005	6	POTOMAC	0	-	-	-	-	-
		UPPER	4	600	519	682	51	26
		COMBINED	4	600	519	682	51	26
2004	7	POTOMAC	0	-	-	-	-	-
		UPPER	1	685	-	-	-	-
		COMBINED	1	685	-	-	-	-
2003	8	POTOMAC	4	869	728	1011	89	44
		UPPER	10	791	761	821	42	13
		COMBINED	14	813	775	852	66	18
2002	9	POTOMAC	2	891	815	967	8	6
		UPPER	3	830	531	1130	121	70
		COMBINED	5	855	741	968	92	41
2001	10	POTOMAC	6	932	896	967	34	14
		UPPER	7	915	858	973	62	23
		COMBINED	13	923	893	953	50	14
2000	11	POTOMAC	1	958	-	-	-	-
		UPPER	5	921	781	1061	113	50
		COMBINED	6	927	820	1034	102	42
1999	12	POTOMAC	2	1051	638	1463	46	33
		UPPER	7	965	934	996	33	13
		COMBINED	9	984	945	1022	50	17
1998	13	POTOMAC	8	1017	970	1064	56	20
		UPPER	5	1050	988	1112	50	22
		COMBINED	13	1029	997	1062	54	15
1997	14	POTOMAC	3	1125	1093	1157	13	8
		UPPER	1	971	-	-	-	-
		COMBINED	4	1087	963	1210	78	39
1996	15	POTOMAC	1	1209	-	-	-	-
		UPPER	2	1059	468	1649	66	47
		COMBINED	3	1109	864	1353	99	57
1995	16	POTOMAC	2	1127	498	1755	70	50
		UPPER	2	1161	1116	1205	5	4
		COMBINED	4	1144	1072	1215	45	23

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
Average	**282.87**	**234.41**

Figure 1. Drift gill net sampling locations in spawning areas of the upper Chesapeake Bay and the Potomac River, late March - May 2011.

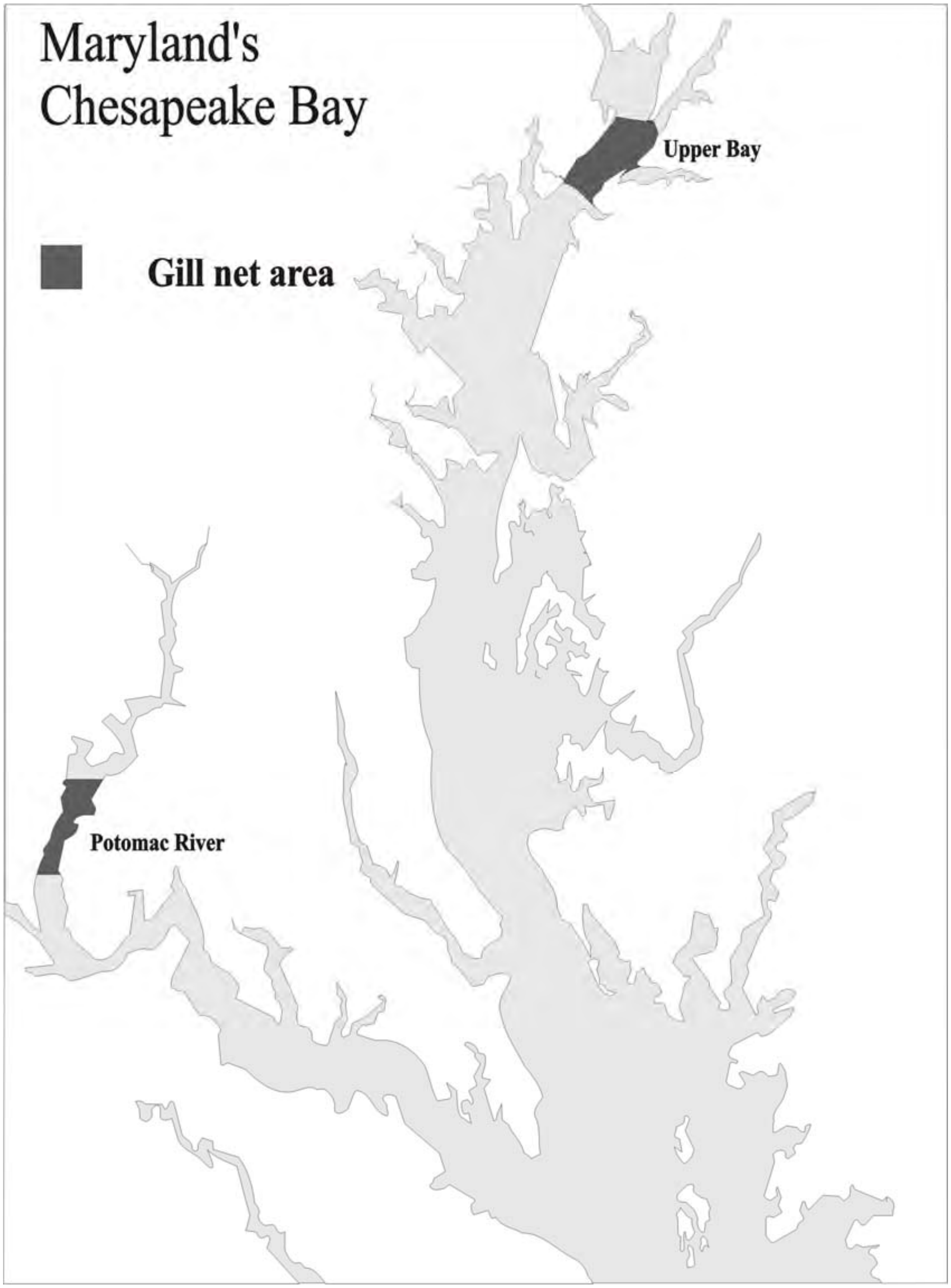


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, late March through May 2011. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

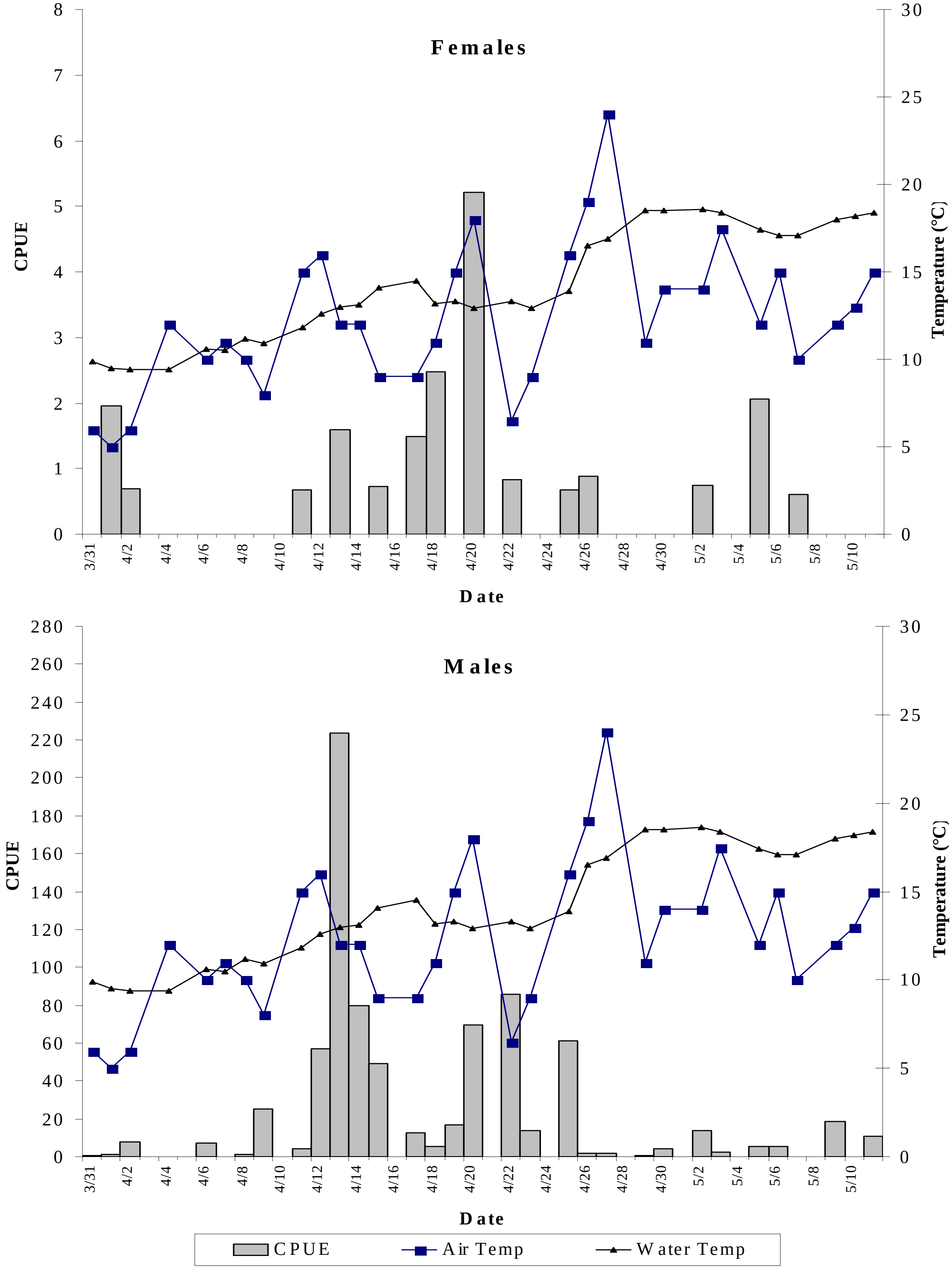


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the upper Chesapeake Bay, late March through May 2011. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

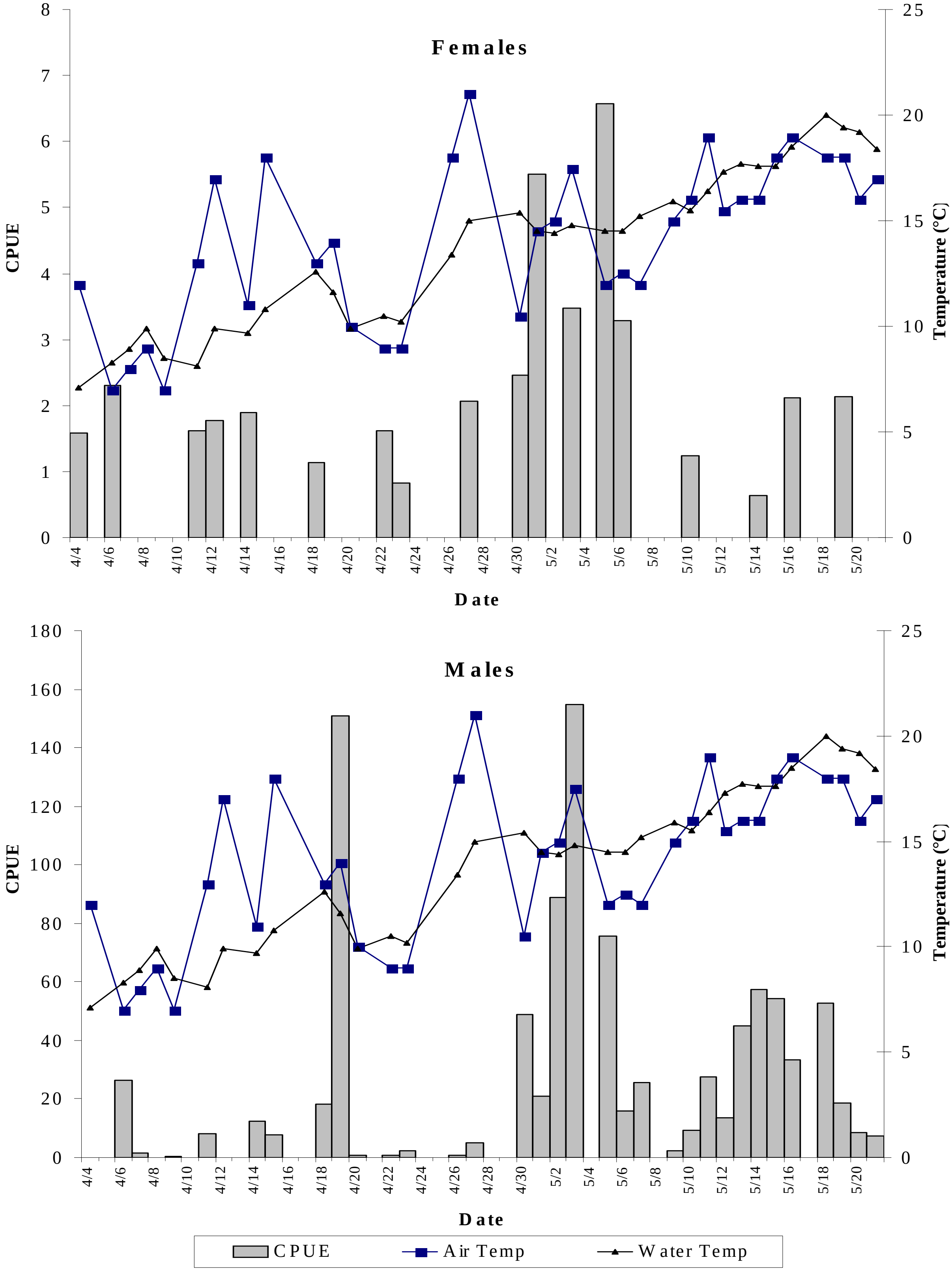
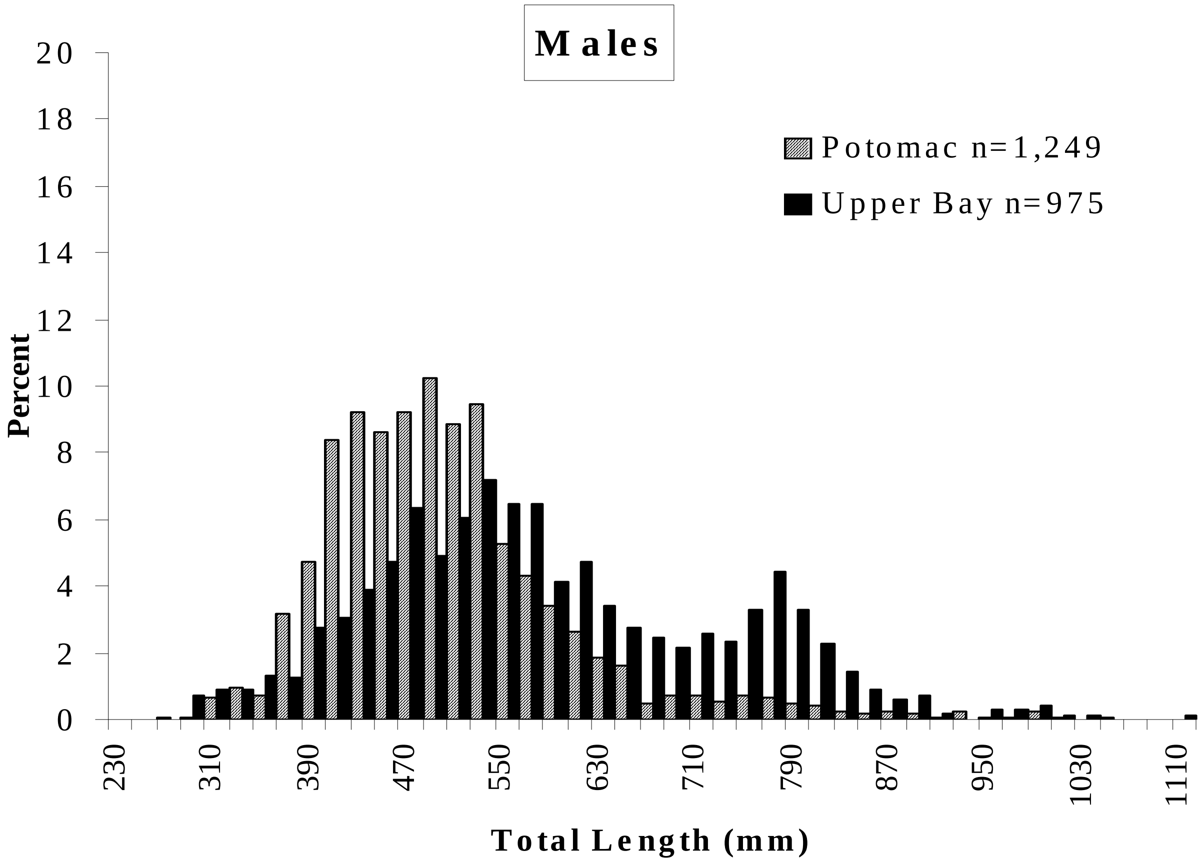


Figure 4. Length frequency of male and female striped bass from the spawning areas of the upper Chesapeake Bay and Potomac River, late March through May 2011. Note different scales.



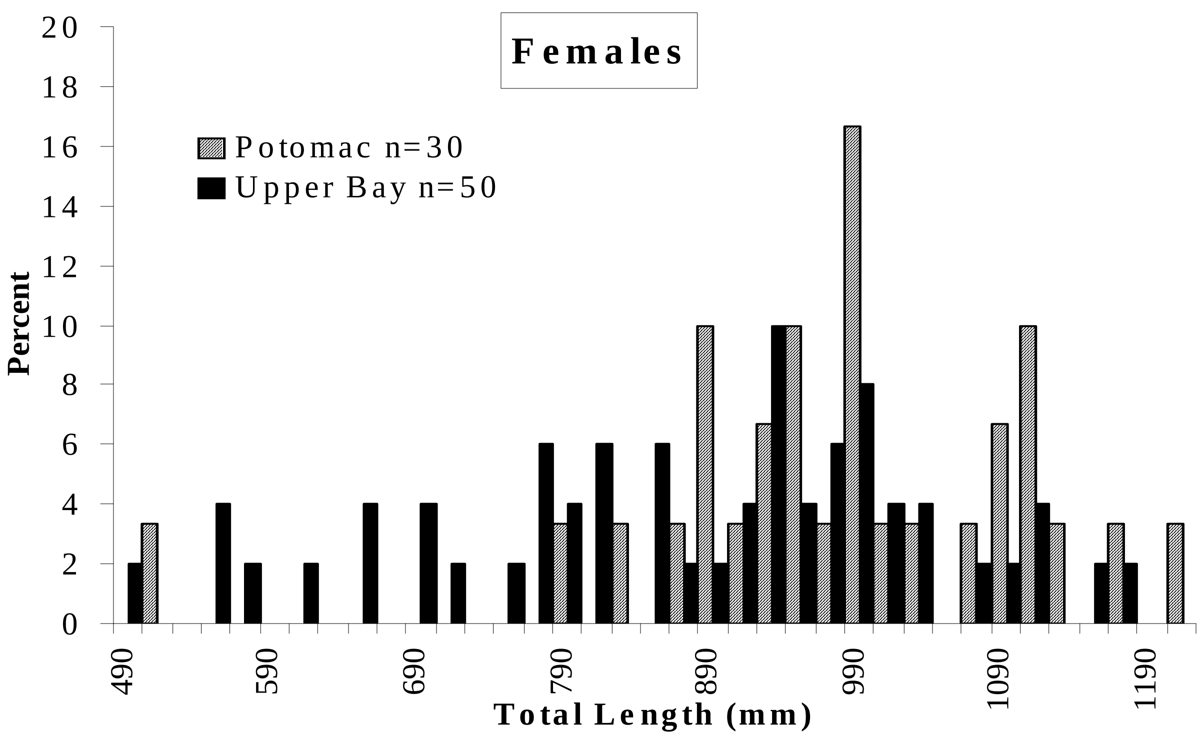
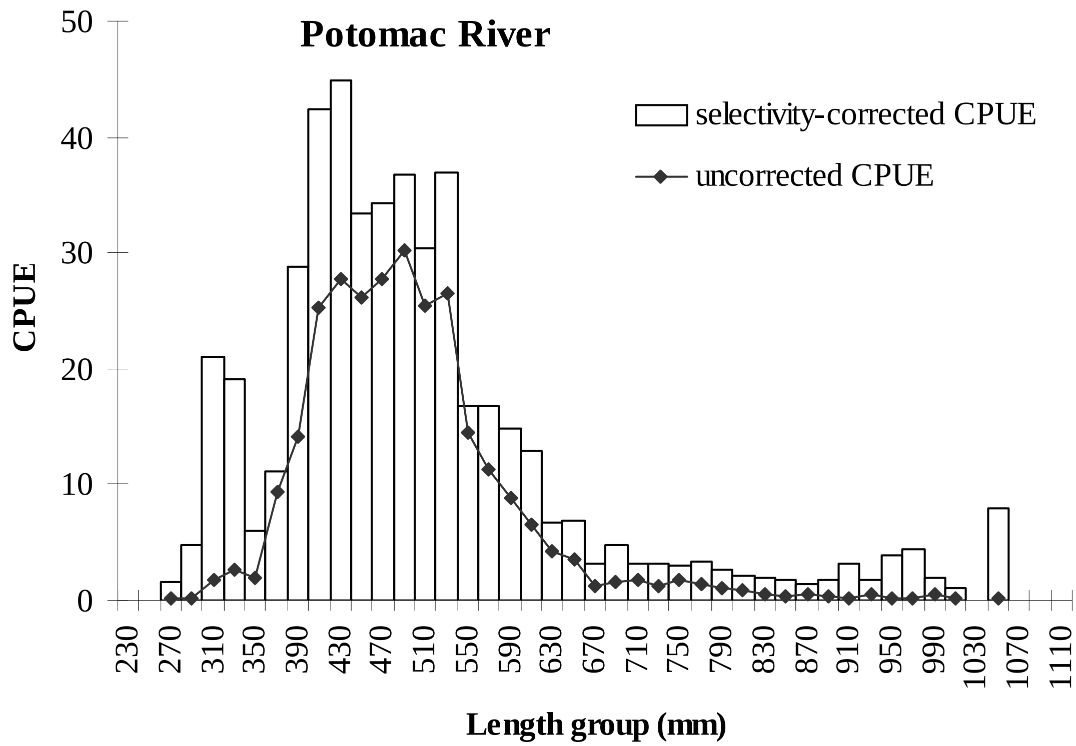


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the upper Bay and Potomac River, late March - May 2011. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



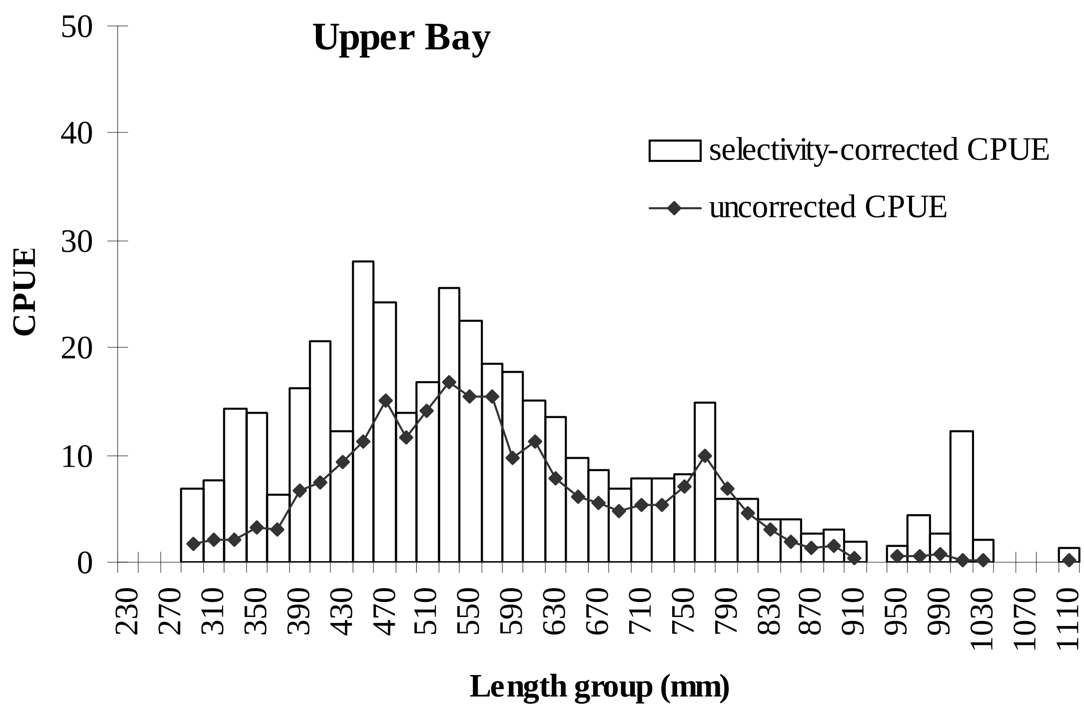
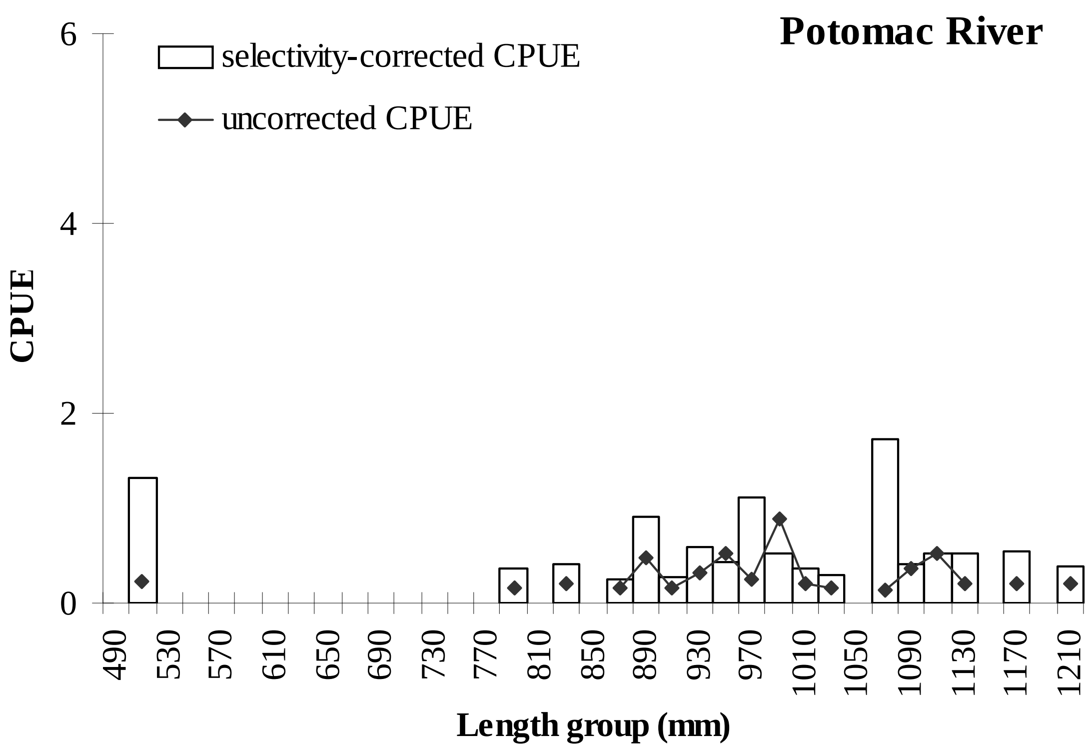


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the upper Bay and Potomac River, late March - May 2011. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



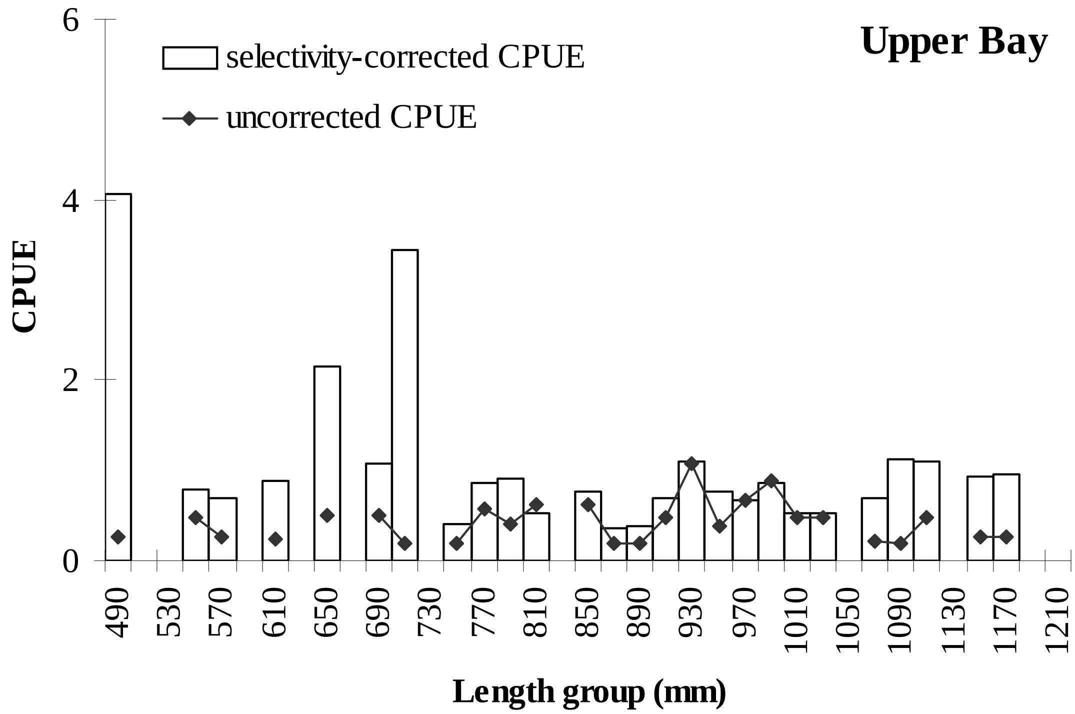


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985-2011. Error bars are ± 2 standard errors (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

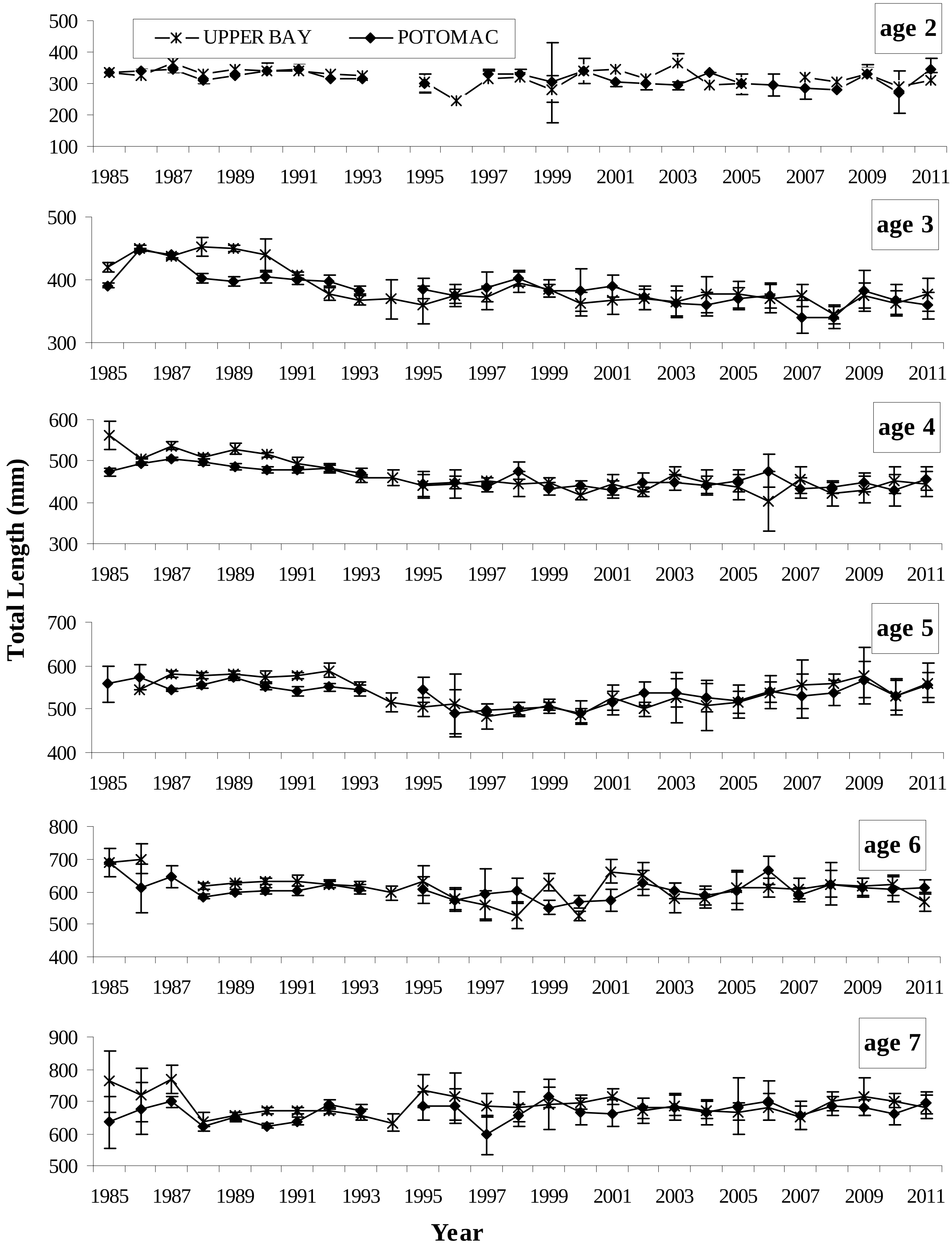


Figure 7. Continued.

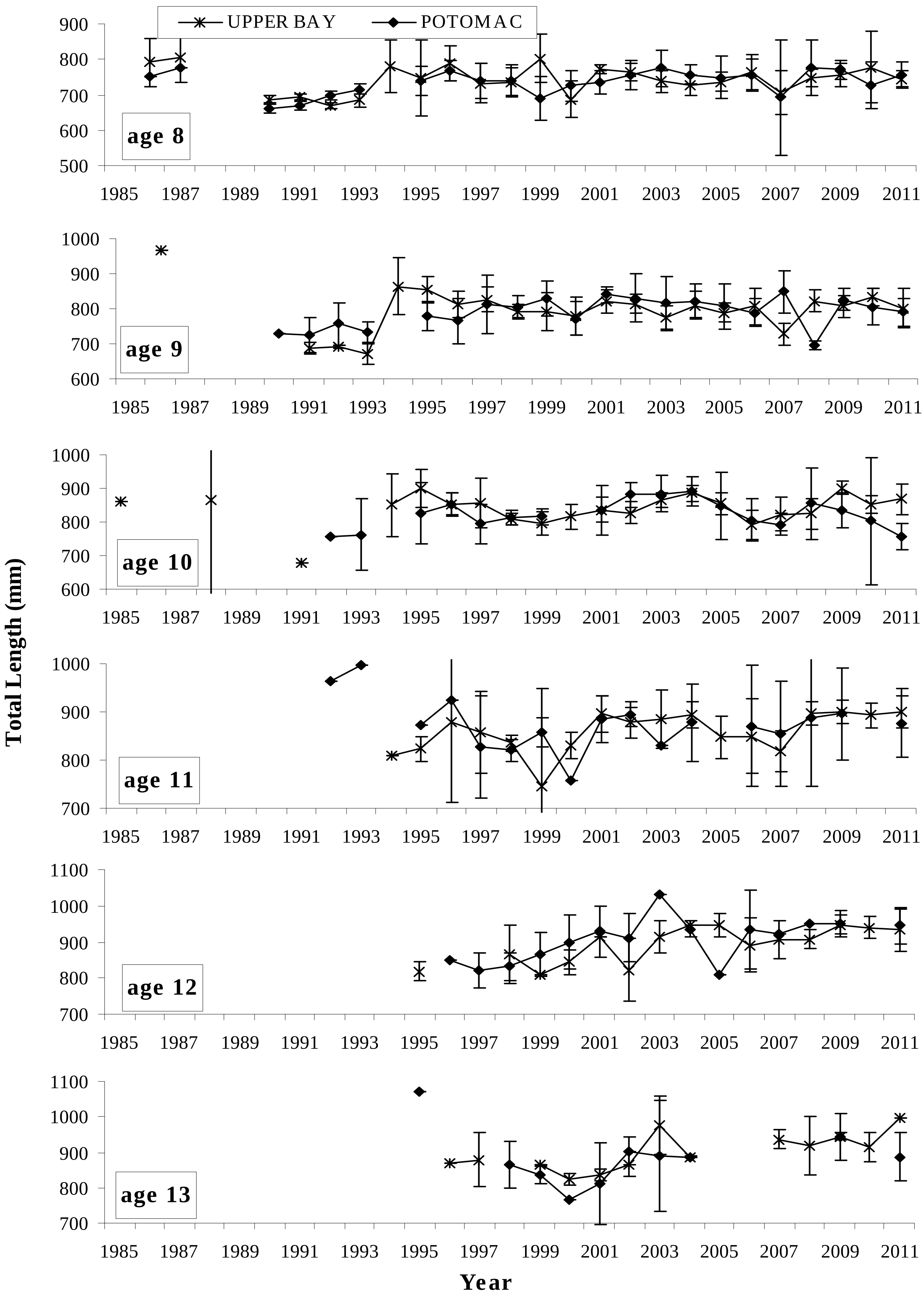


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from
spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985–2011. Error bars are ± 2 standard errors (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

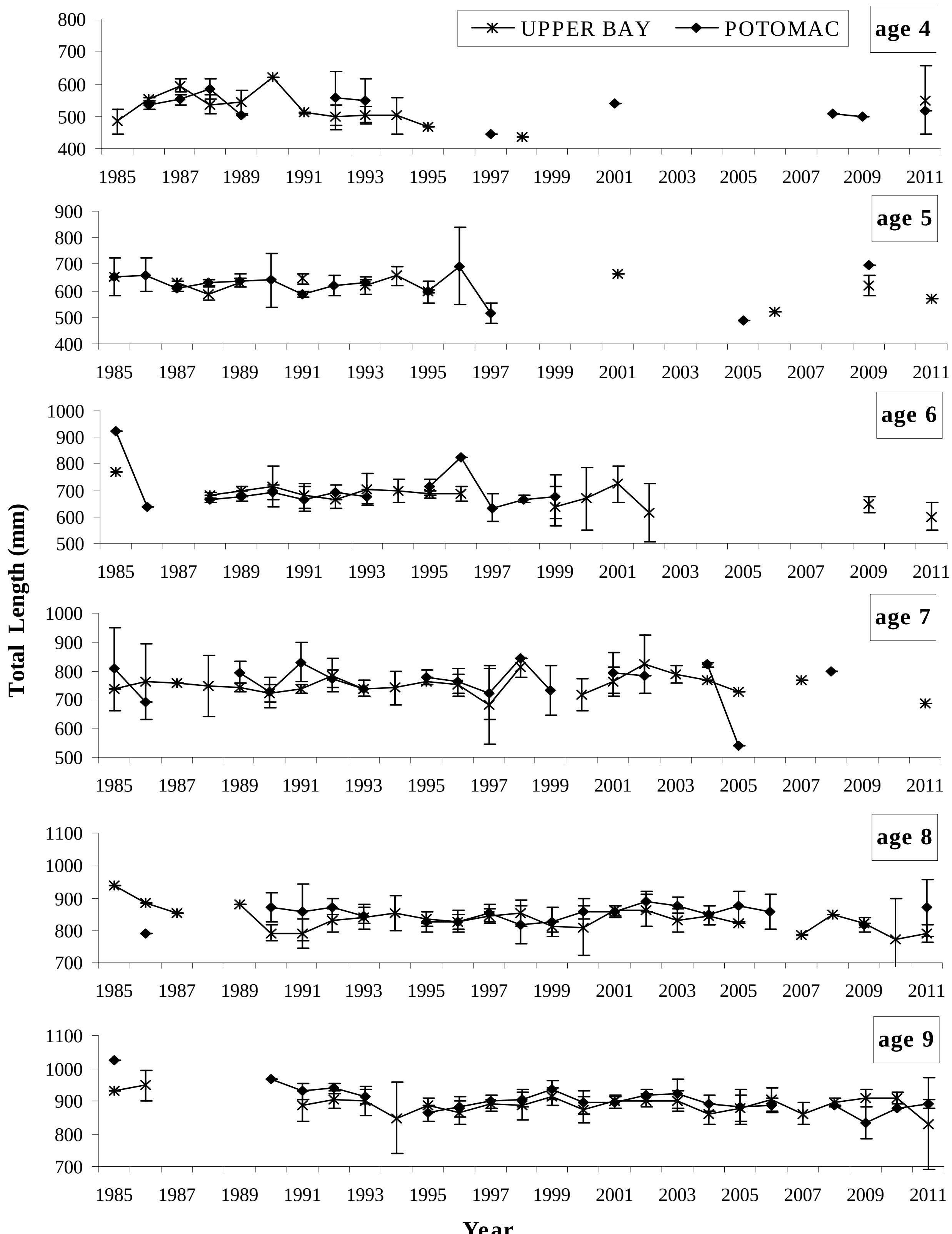


Figure 8. Continued.

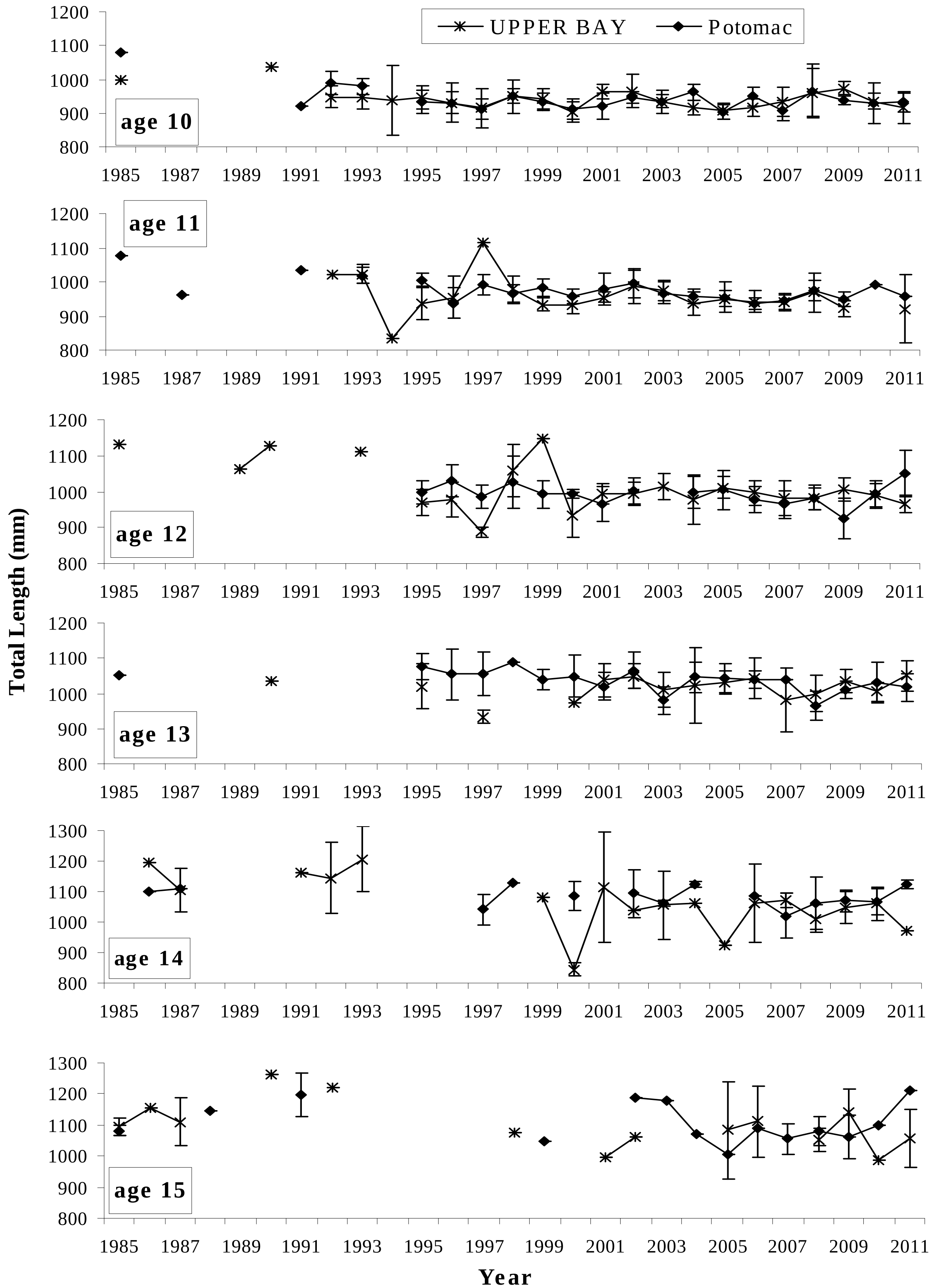


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

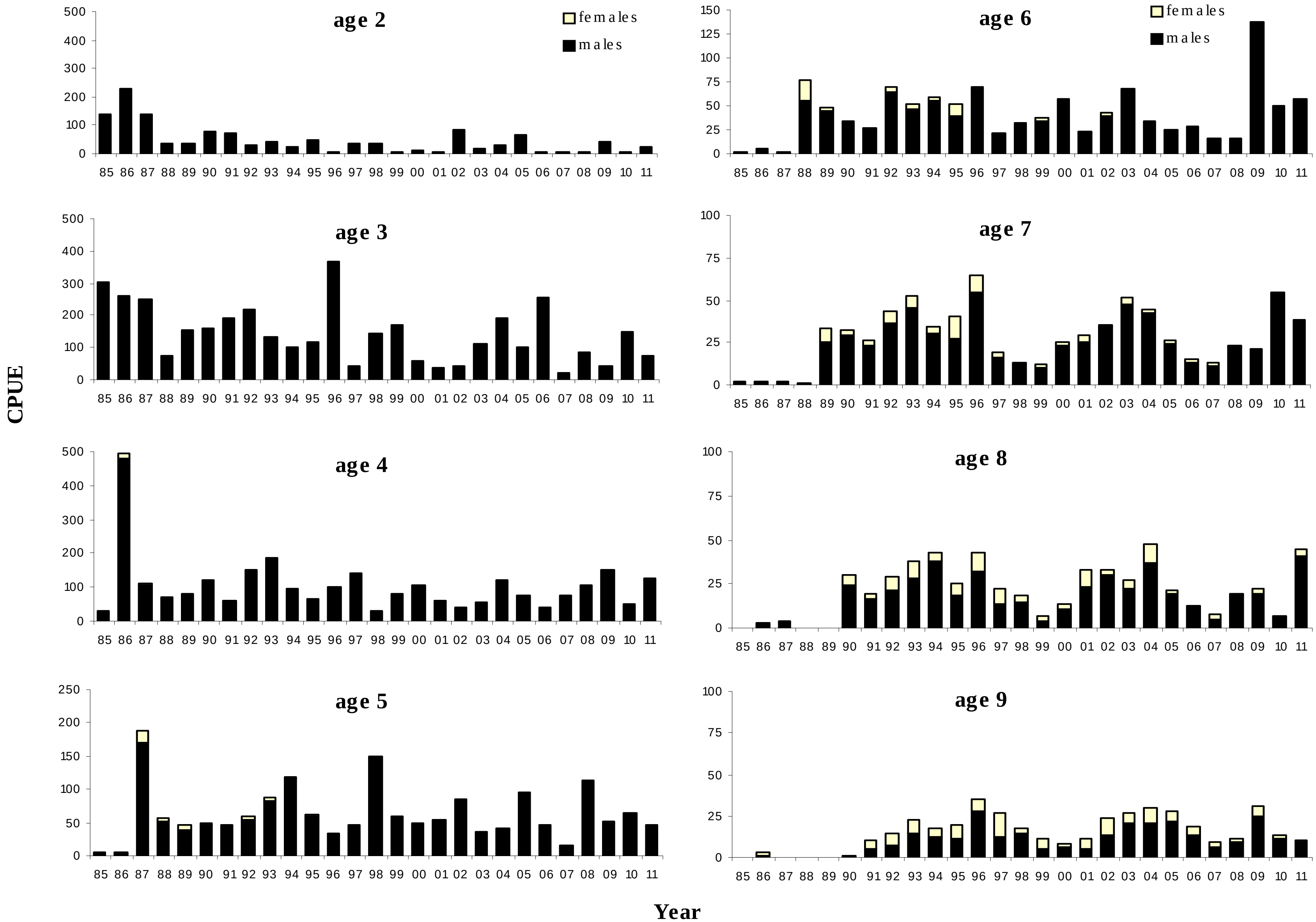


Figure 9. Continued.

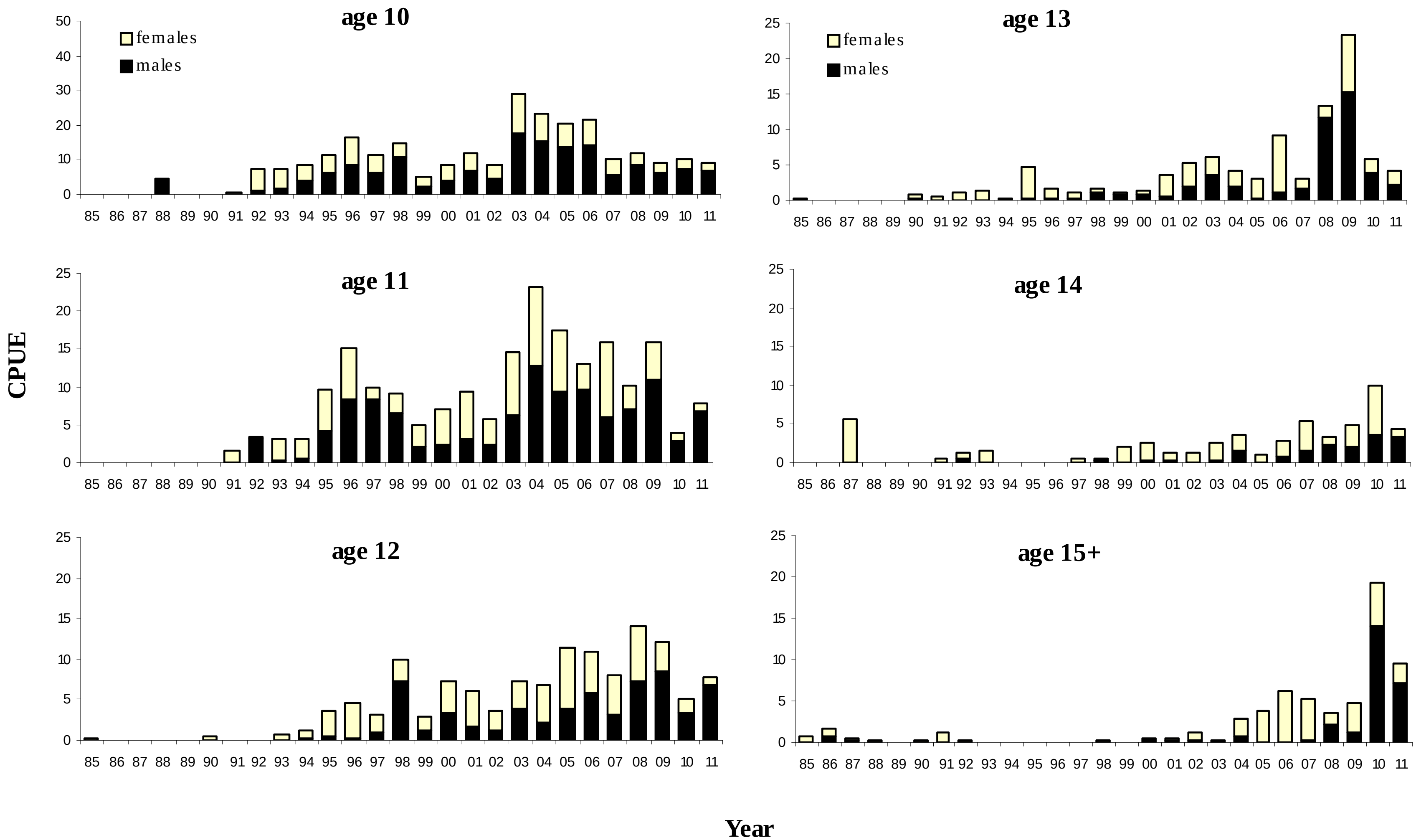
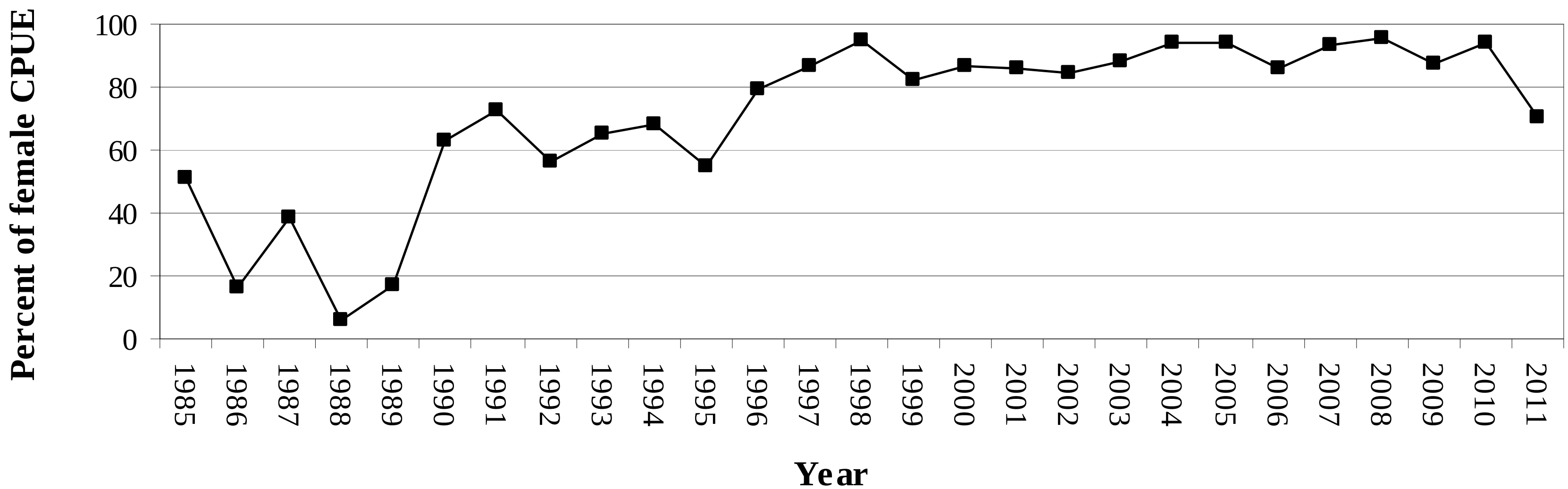
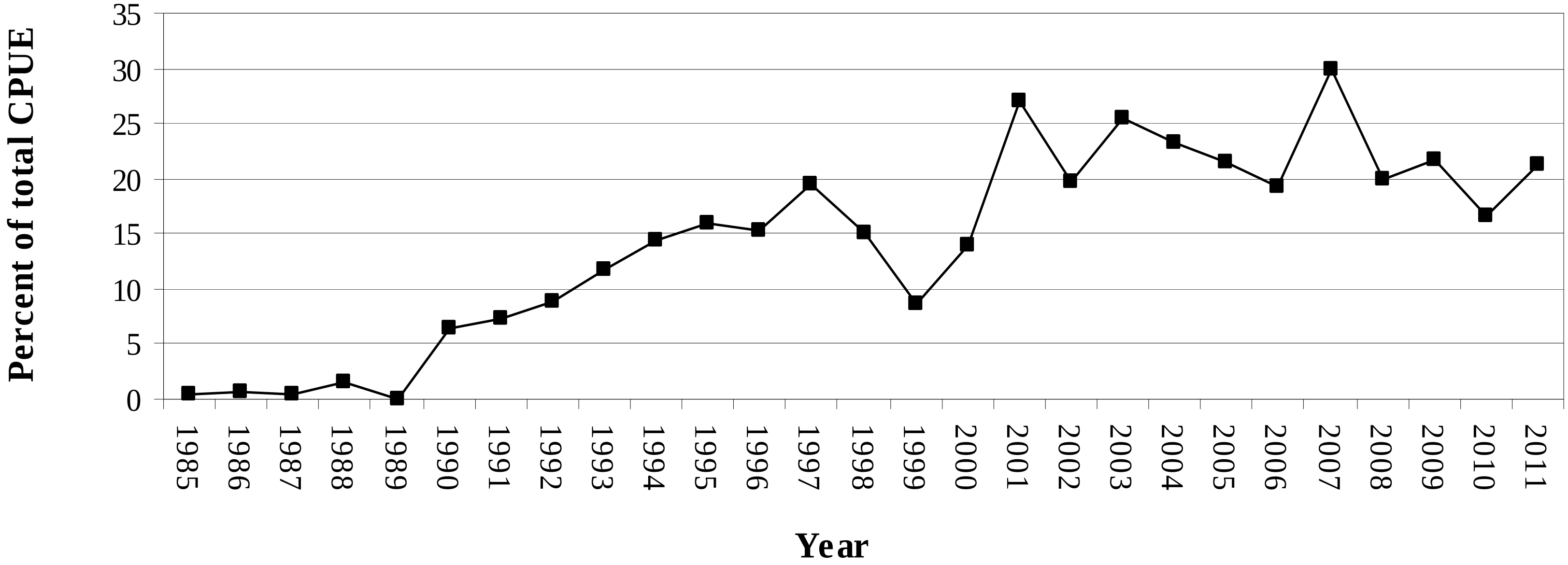


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the upper Chesapeake Bay, late March through May, 1985-2011 (Choptank River to 1996). Effort is 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.*



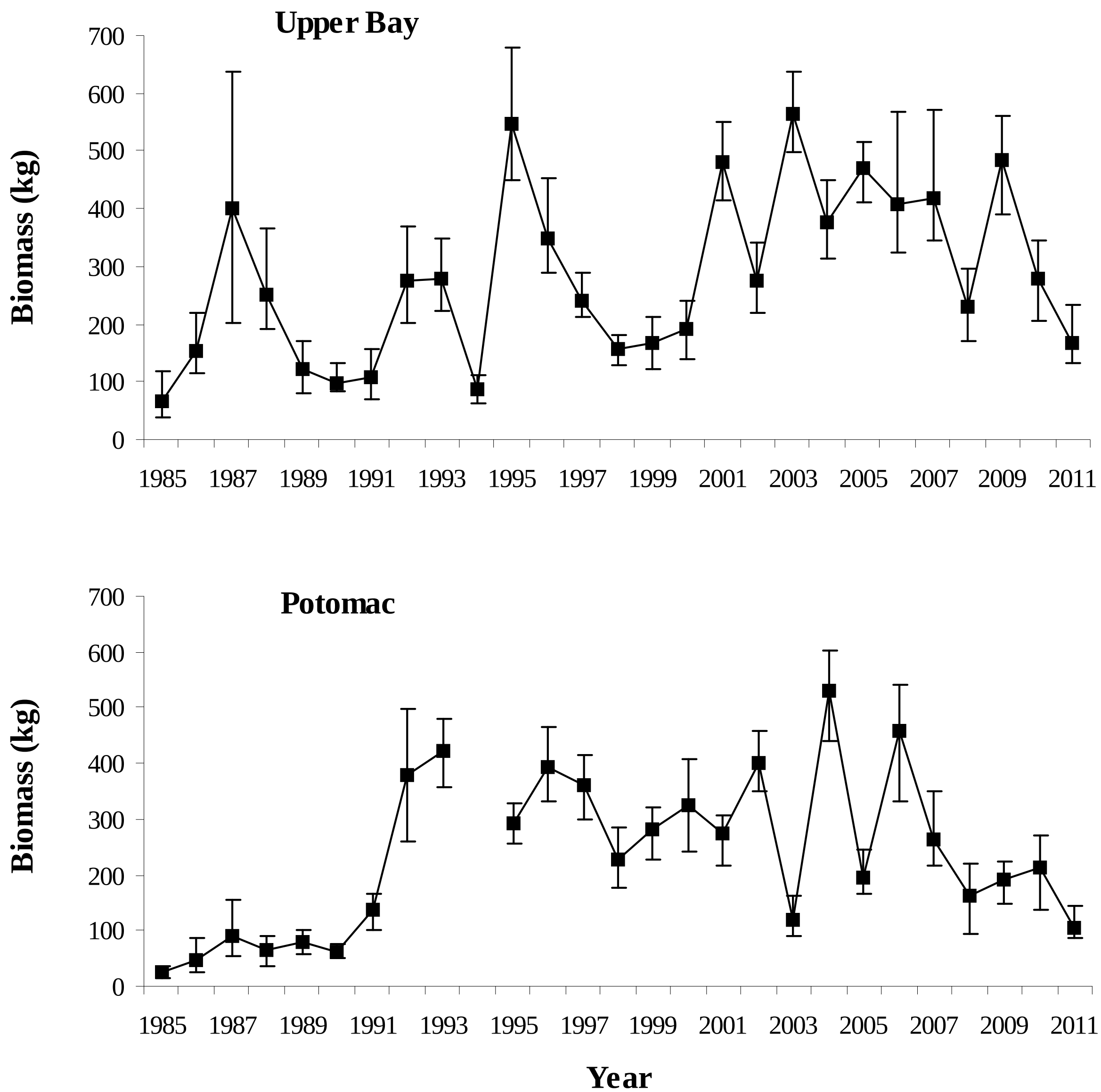
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385 (Hollis 1967).

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, 1985-2011 (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 3 spawning areas of the Maryland Chesapeake Bay during late March through May, 1985-2011. 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. Diminishing shoreline area at Castle Haven (site #29) on the Choptank River prompted the establishment of an auxiliary site nearby named Mouth of LeCompte Bay (site #165). The Mouth of LeCompte Bay site later proved unsuitable for sampling and will be replaced next year.

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 (^{o}C), tide stage, surface salinity (ppt), primary and secondary bottom substrates, and submerged aquatic vegetation within the sample area (ranked by quartiles). Dissolved oxygen (DO), pH, and turbidity (Secchi disk) were added in 1997. All data were entered and archived in Statistical Analysis System (SAS) databases (SAS 1990).

Estimators

The most commonly referenced striped bass ‘juvenile index’ is the arithmetic mean (AM). The AM has been used to predict harvest in New York waters (Schaefer 1972). Goodyear (1985) validated this index as a predictor of harvest in the Chesapeake Bay. The AM is an unbiased estimator of the mean regardless of the underlying frequency distribution (McConnaughey and Conquest 1992). The AM, however, is sensitive to high sample values (Sokol and Rolhf 1981).

Additionally, detection of significant differences between annual arithmetic means is often not possible due to high variances (Heimbuch et al. 1983; Wilson and Wiesburg 1991).

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

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

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

Bay-wide annual indices are compared to the target period average (TPA). The TPA is the average of indices from 1959 through 1972. These years have been suggested as a period of stable biomass and general stock health (ASMFC 1989) and "an appropriate stock rebuilding target"

(Gibson 1993). The TPA provides a fixed reference representing an average index produced by a healthy population. A fixed reference is an advantage over a time-series average that is revised annually and may be significantly biased by long-term trends in annual indices.

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

RESULTS

Bay-wide Means

A total of 4,565 juvenile striped bass were collected at permanent stations in 2011. The AM (34.6) and GM (9.57) both exceeded their respective time-series averages and TPAs (Table 2 and 3, Figures 2 and 3). The PPHL was 0.93, indicating that 93% 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 2011 $\log_e$-mean was significantly smaller than just one year of the time-series (1996), and significantly greater than 43 other years.

System Means

Head of Bay - In 42 samples, 431 juveniles were collected at the Head of Bay sites for an AM of 10.3, less than the time-series average (11.9) and the TPA of 17.3 (Table 2, Figure 5). The GM of 5.79 was above the time-series average (5.64) but below the TPA (7.27) (Table 3, Figure 6). Differences in annual $\log_e$-means were significant (ANOVA: $P<0.0001$). Duncan's multiple range test (p=0.05) found the 2011 Head of Bay $\log_e$-mean significantly less than only six years of the time-series, and greater than 19 years. The 2011 $\log_e$-mean was indiscernible from 27 year-classes of the time-series.

Potomac River - A total of 536 juveniles was collected in 42 samples. The AM of 12.8 was greater than the TPA (9.2) and the time-series average (8.4) (Table 2, Figure 5). The GM of 7.18 was also greater than the time-series average (3.67) 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 2011 Potomac River year-class significantly less than just one years (1993), and significantly greater than 31 years of the time-series. The 2011 $\log_e$-mean was not significantly different than the 22 other years of the time-series.

Choptank River - A total of 3,016 juveniles was collected in 24 Choptank River samples. The AM of 125.7 was greater than the time-series average of 21.9 and the TPA of 10.8 (Table 2, Figure 5). The GM of 26.14 was also greater than its time-series average (8.26) 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 2011 Choptank River year-class smaller than just one year (2001), and greater than 44 years of the time series. The 2011 year-class was not discernible from nine other years of the time-series.

Nanticoke River - A total of 582 juveniles was collected in 24 samples on the Nanticoke River. The AM of 24.3 was greater than the time-series average (8.5) and TPA (8.6) (Table 2, Figure 5). The GM of 12.99 was also greater than its time-series average (3.82) 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 2011 index significantly greater than 46 years of the time-series. The 2011 index was statistically indiscernible from the top eight years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 258 juveniles were caught in 21 samples, resulting in an AM of 12.3, which was greater than the time-series average. The GM of 5.75 was also greater than the time-series average and median (Table 5).

On the **Patuxent River**, 765 YOY striped bass were caught in 18 samples for an AM of 42.5 and a GM of 13.41 (Table 5). Both Patuxent River indices exceeded their time-series averages.

DISCUSSION

Multiple indicators demonstrated that the 2011 striped bass recruitment in Maryland's Chesapeake Bay was very successful. The bay-wide AM and GM indices were both well above their respective time-series averages and TPAs (Tables 2 and 3). The AM ranked in the 95th percentile of the time-series, and the GM ranked in the 89th percentile of its time-series. Duncan's multiple range test (p=0.05) found the 2011 $\log_e$-mean was significantly smaller than only the record 1996 year-class. YOY striped bass occurred in 93% of the samples (PPHL=0.93), another indicator of a strong year-class and the highest observed since 1996 (Table 4, Figure 4).

The Bay-wide AM was influenced by one large sample from site #29 in September that contained 2,310 YOY striped bass, or 51% of the total YOY striped bass catch of the year. The GM was specifically adopted because the $\log_e$ data transformation mutes the effect of a single large sample value on the index. For example, if the large sample from site #29 is excluded from the analysis, the 2011 bay-wide GM of 9.57 (n=132) drops only slightly to 9.15 (n=131) and its rank of seventh in the GM time-series remains unchanged. Similarly, the analysis of variance on the $\log_e$-means remains unaffected by a single large sample value due to the data transformation.

Recruitment was well above average in all systems except the Head of Bay, where it was approximately average. Recruitment in the auxiliary Patuxent River and Head of Bay sites was also above average. The 2011 striped bass year-class was among the largest ever recorded in the Nanticoke (95th percentile), Choptank (93rd percentile), and Potomac (88th percentile) rivers.

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 ($r^2 = 0.608$, $p \leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was, $C_1=(0.192498)(C_0)- 0.07602$, 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 (0.02) was less than the index of 0.17 predicted by the regression analysis. Examination of residuals (Figure 11) shows that this regression equation can be used to predict subsequent yearling striped bass abundance with reasonable certainty in the case of small and average sized year-classes. Estimates of future abundance of age 1 striped bass are less reliable for dominant year-classes. Lower than expected abundance of age 1 striped bass may be an indication of density-dependent processes operating at high levels of abundance, such as cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

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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
* 165	Choptank River	Mouth of LeCompte Bay, northwest 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	43.6	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
Average	11.9	8.4	21.9	8.5	11.9
TPA*	17.3	9.2	10.8	8.6	12.0

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

Table 3. Maryland juvenile striped bass survey geometric mean 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	14.92	13.45	33.29	18.80	17.46
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
Average	5.64	3.67	8.26	3.82	4.29
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	0.33	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	0.58	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
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
2010	3.33	2.49	18	3.67	1.45	15
2011	42.5	13.41	18	12.29	5.75	21
Average	25.91	7.02		5.80	2.76	
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	N/A

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

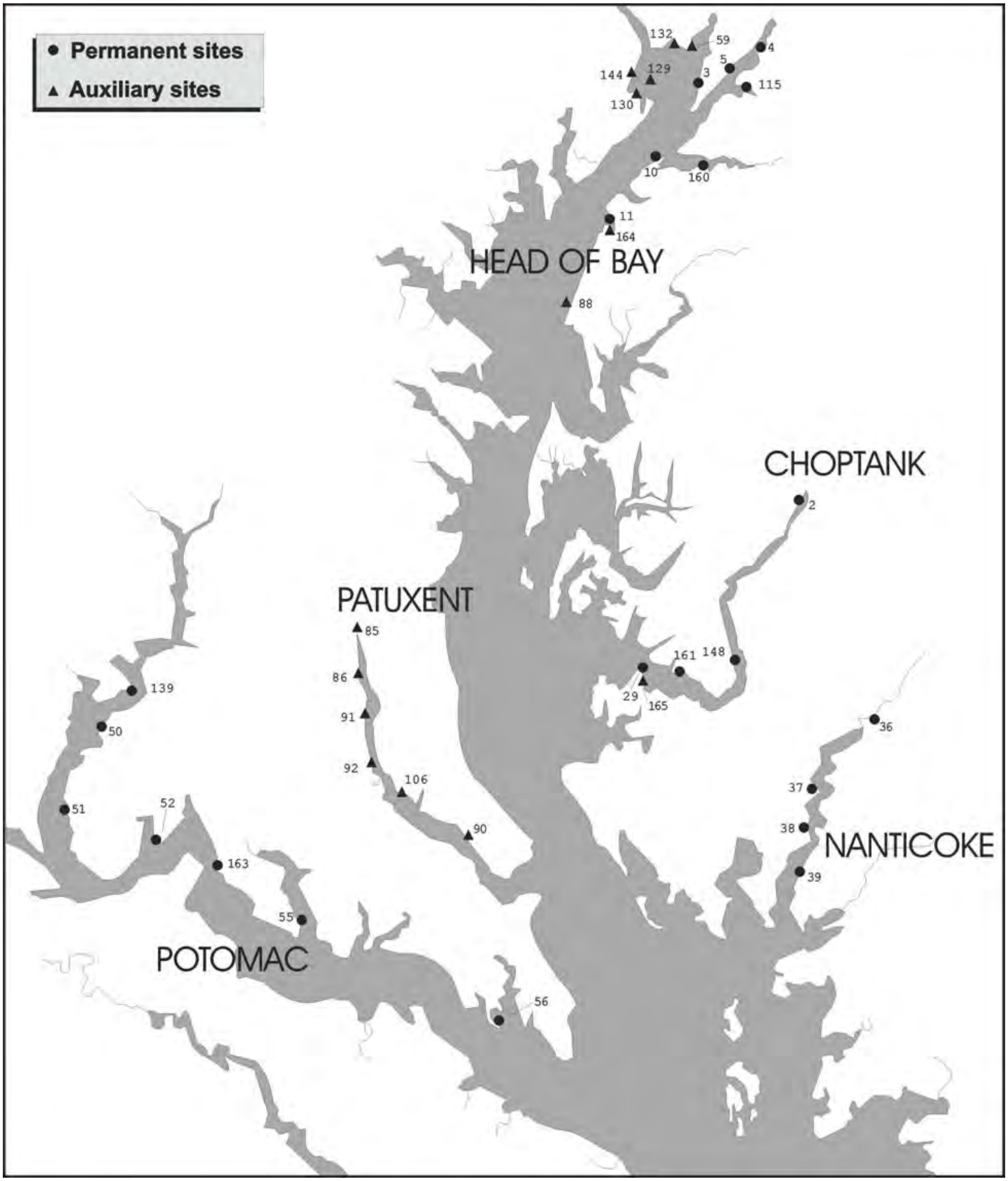


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

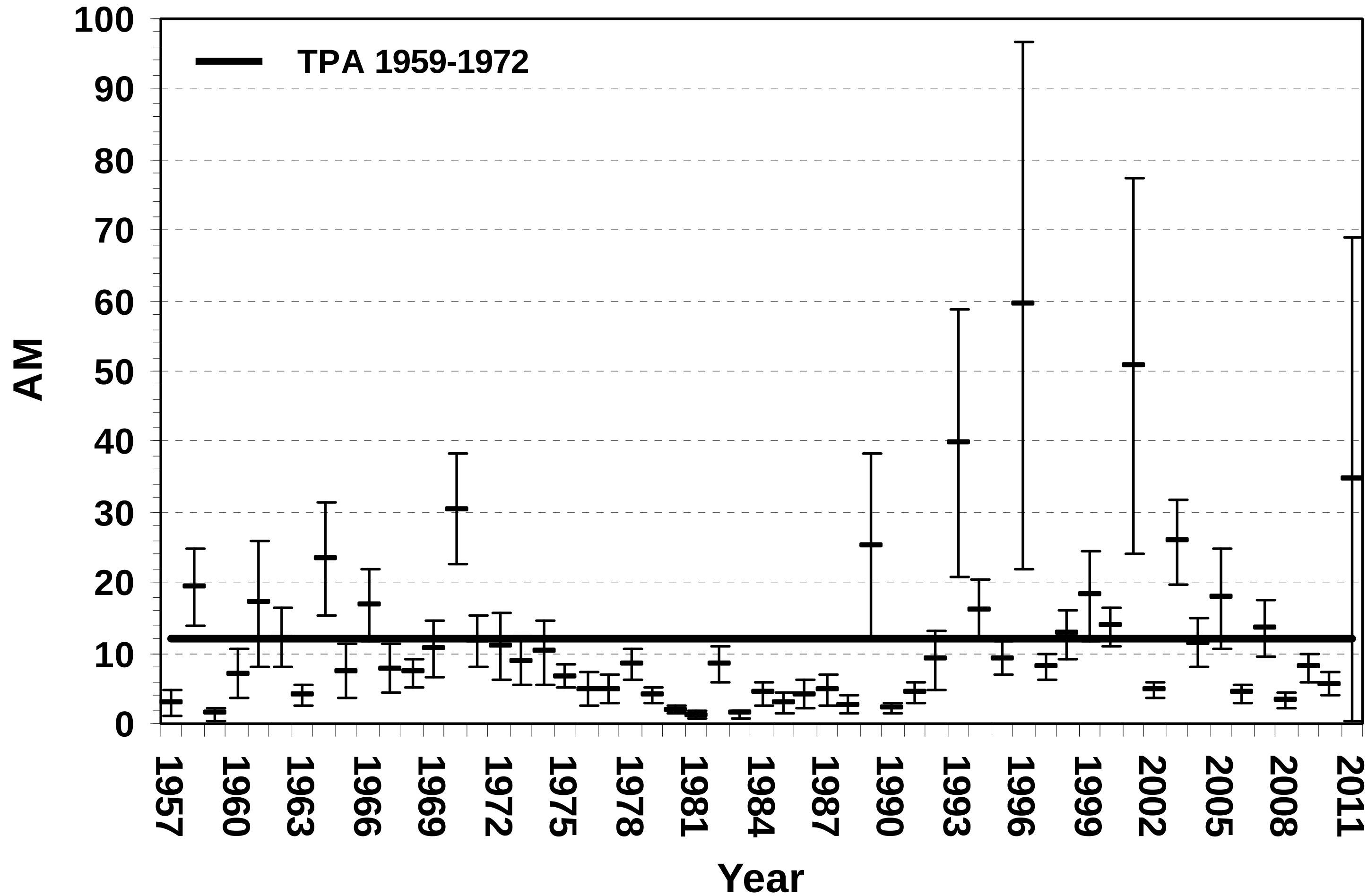


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

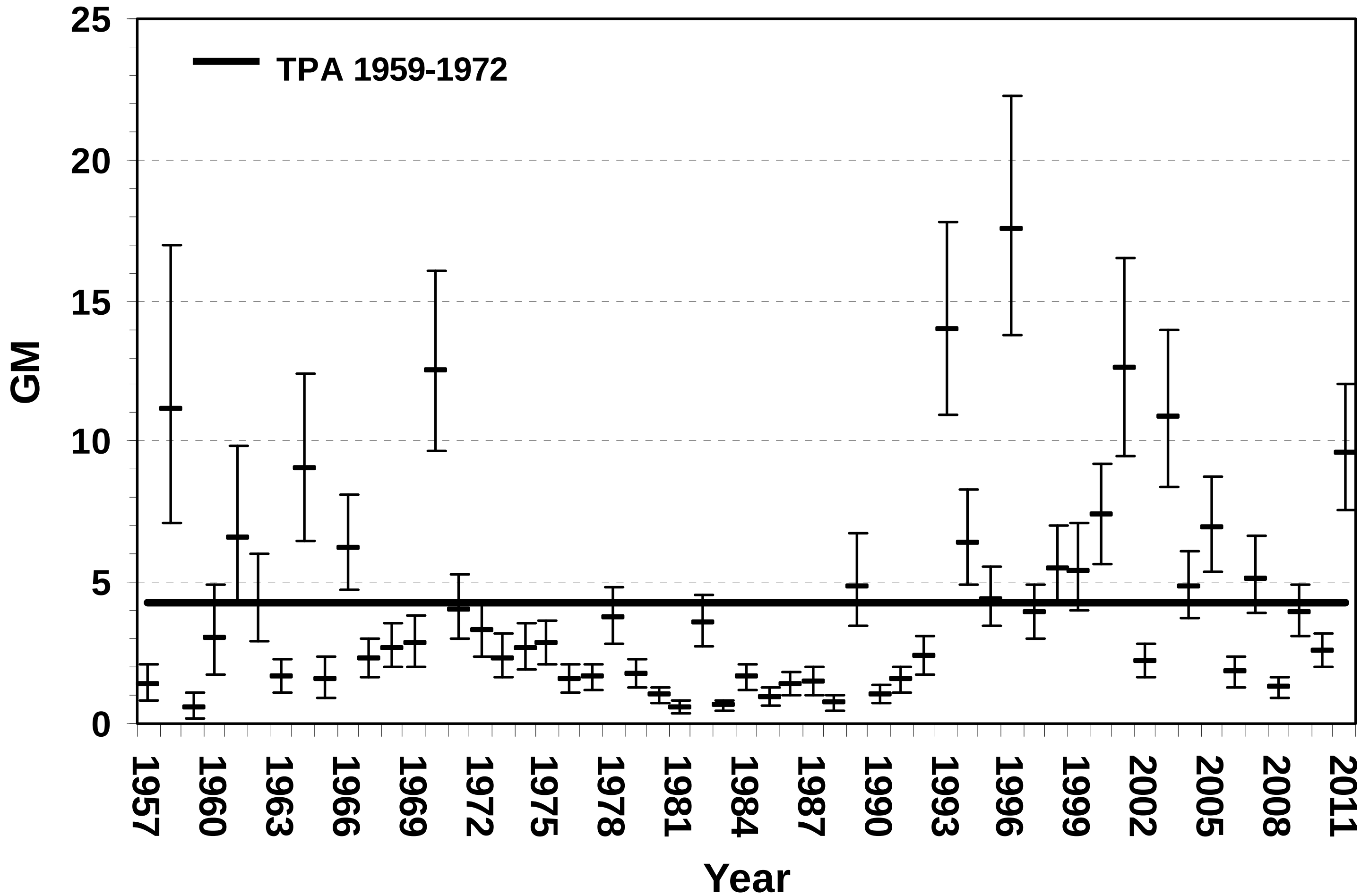


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

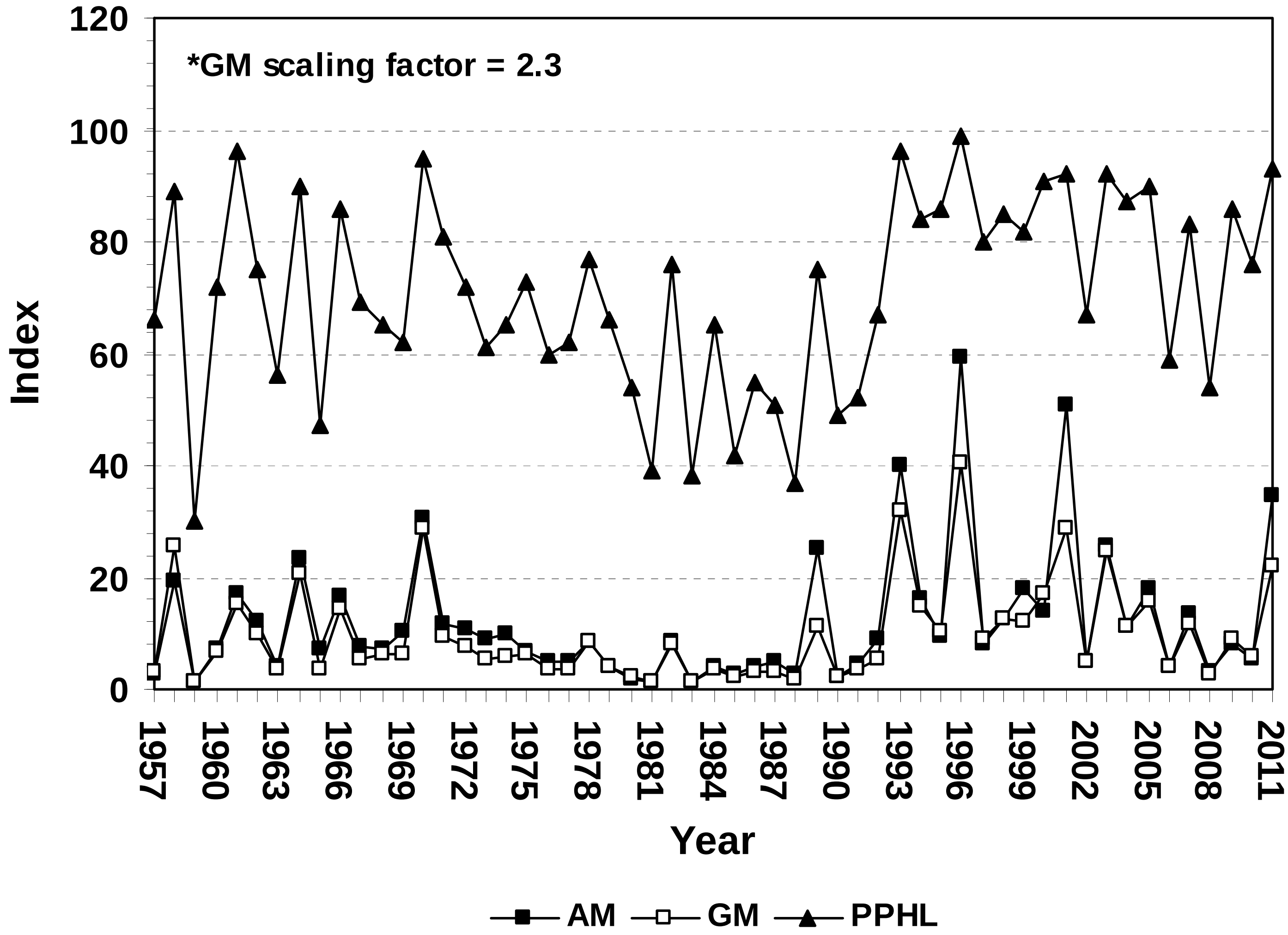


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

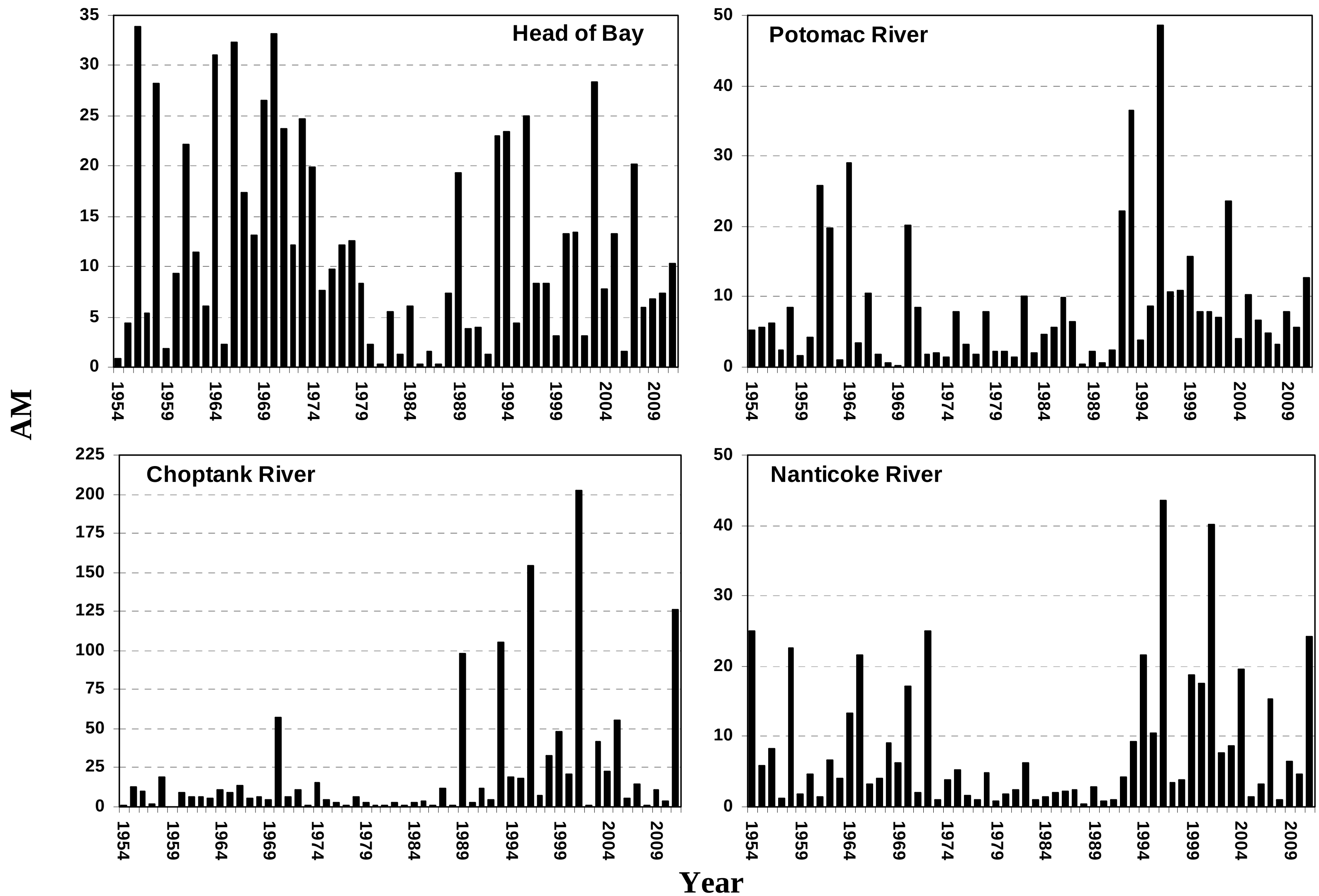


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

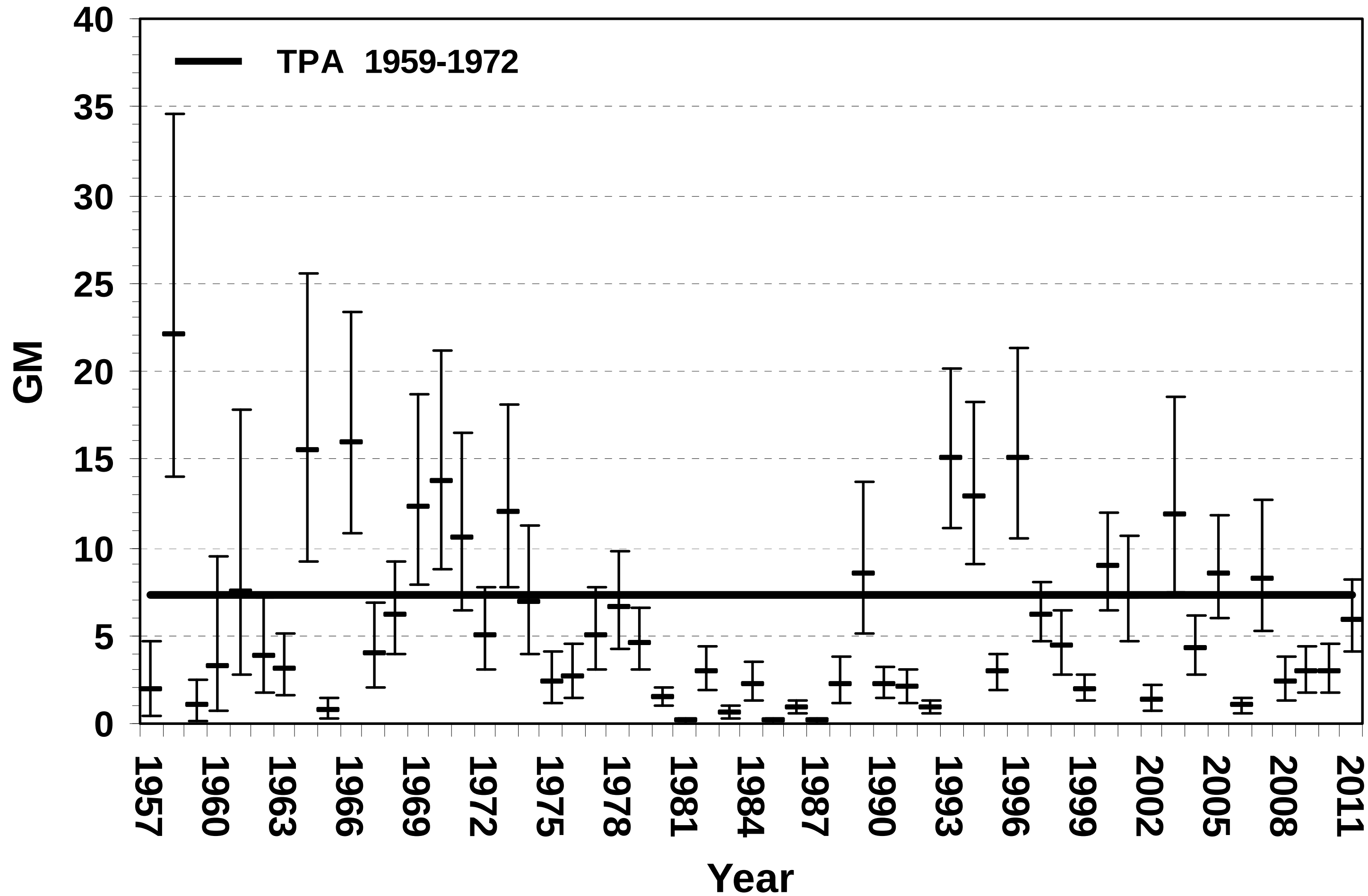


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

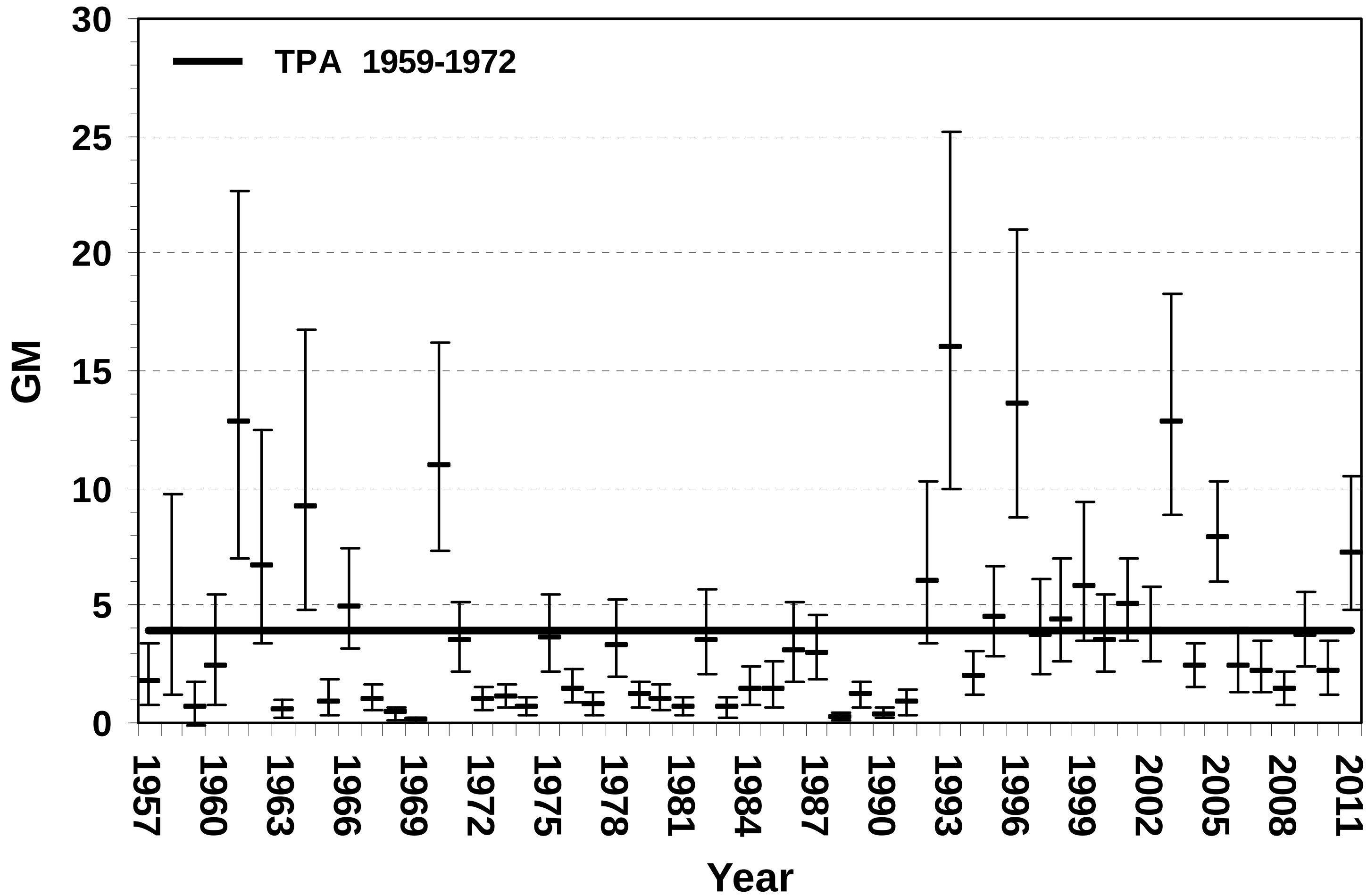


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

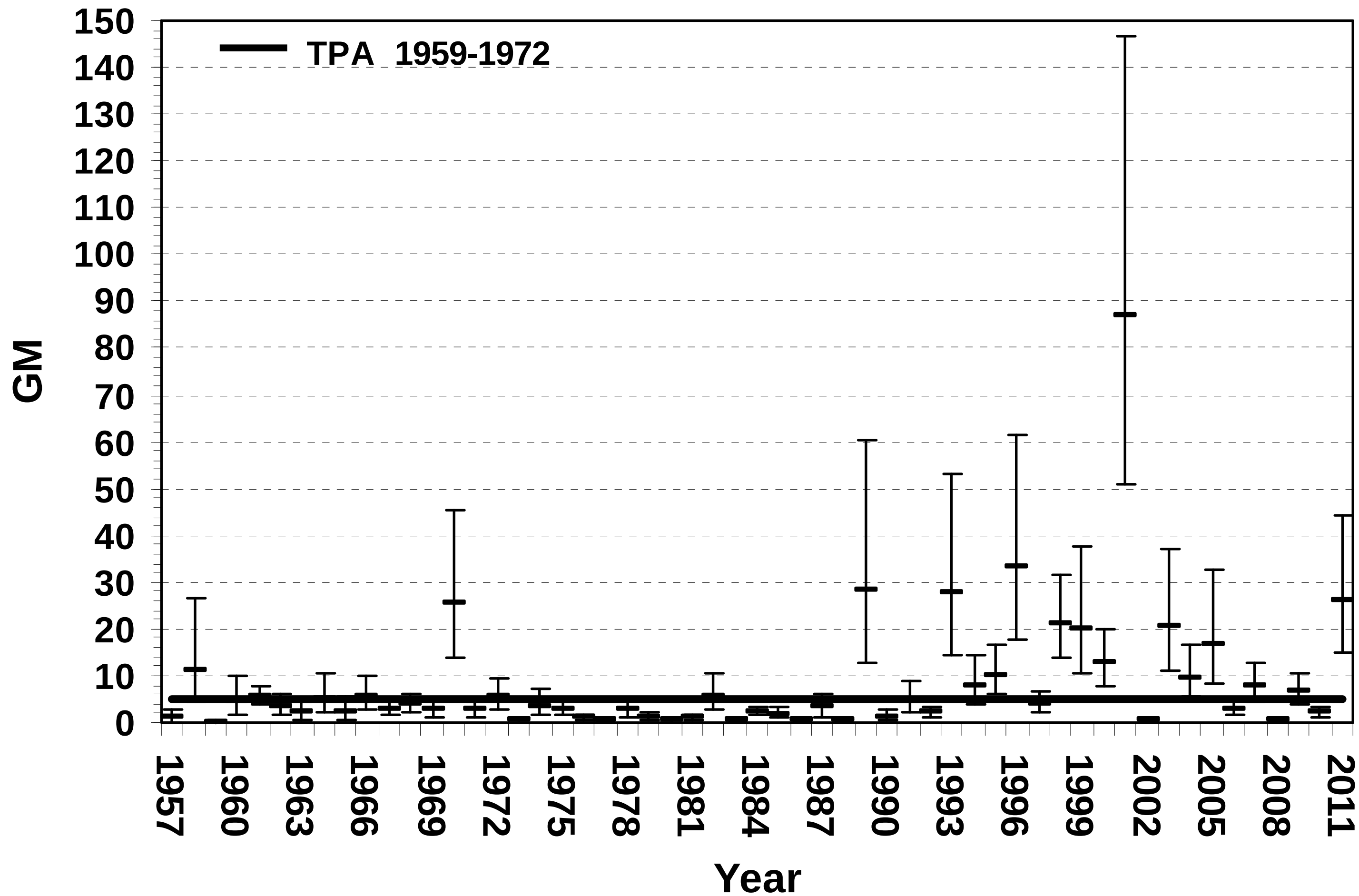


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

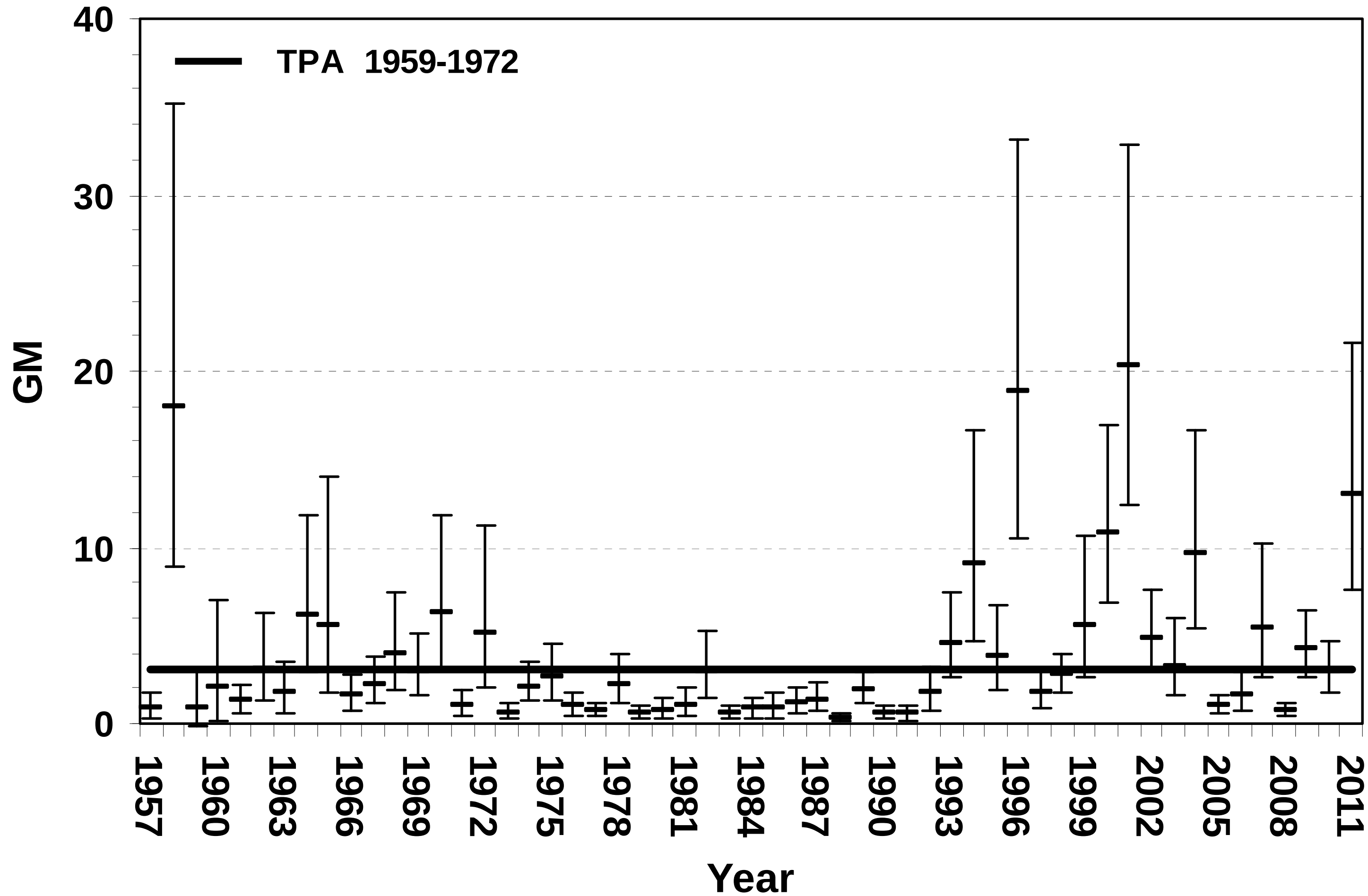


Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

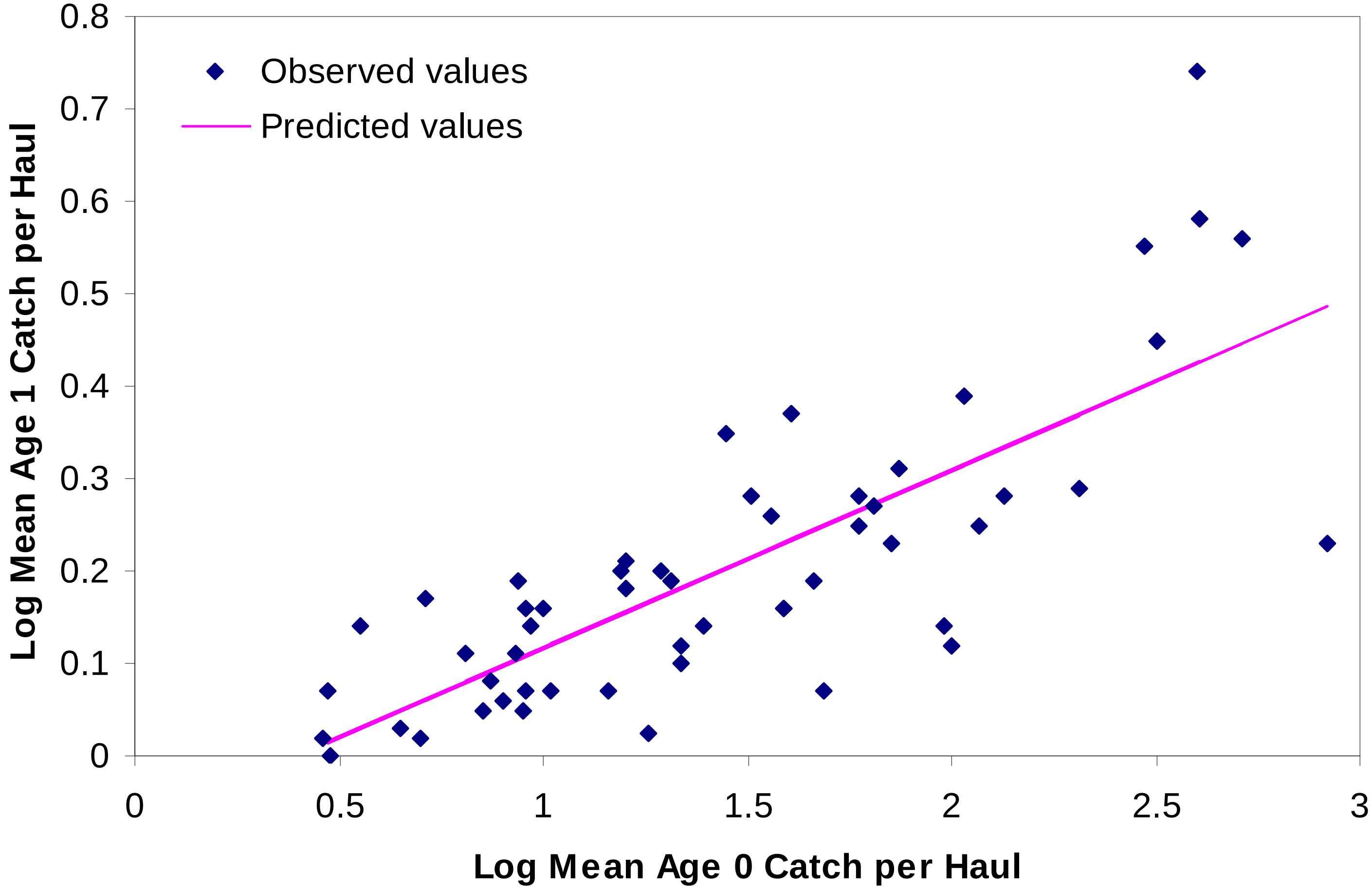
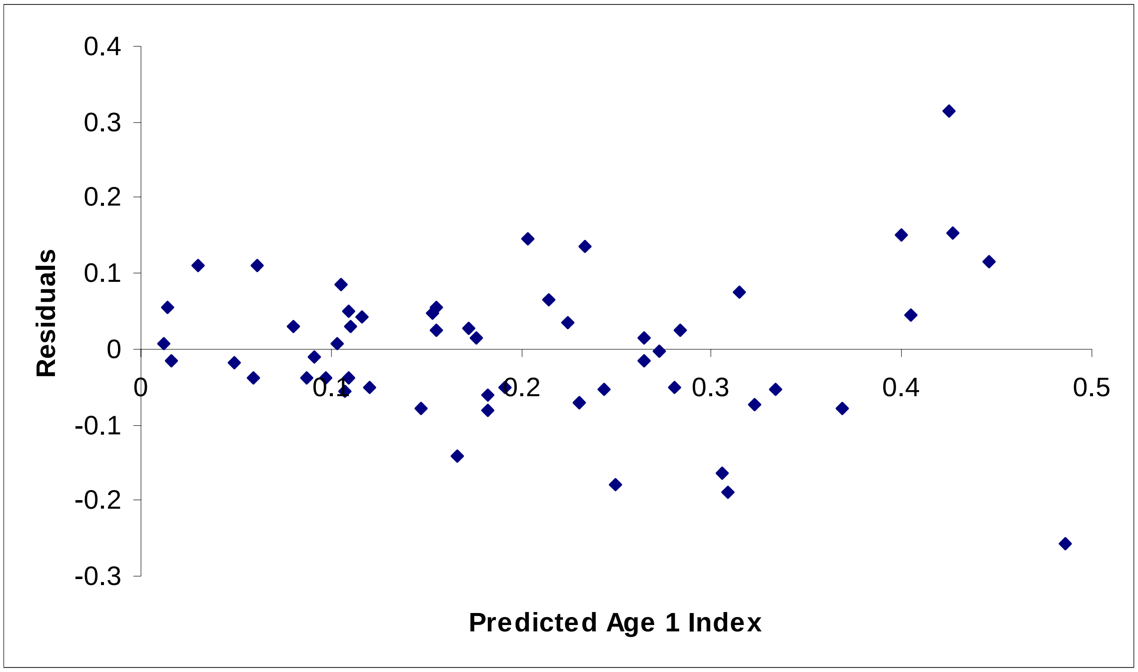
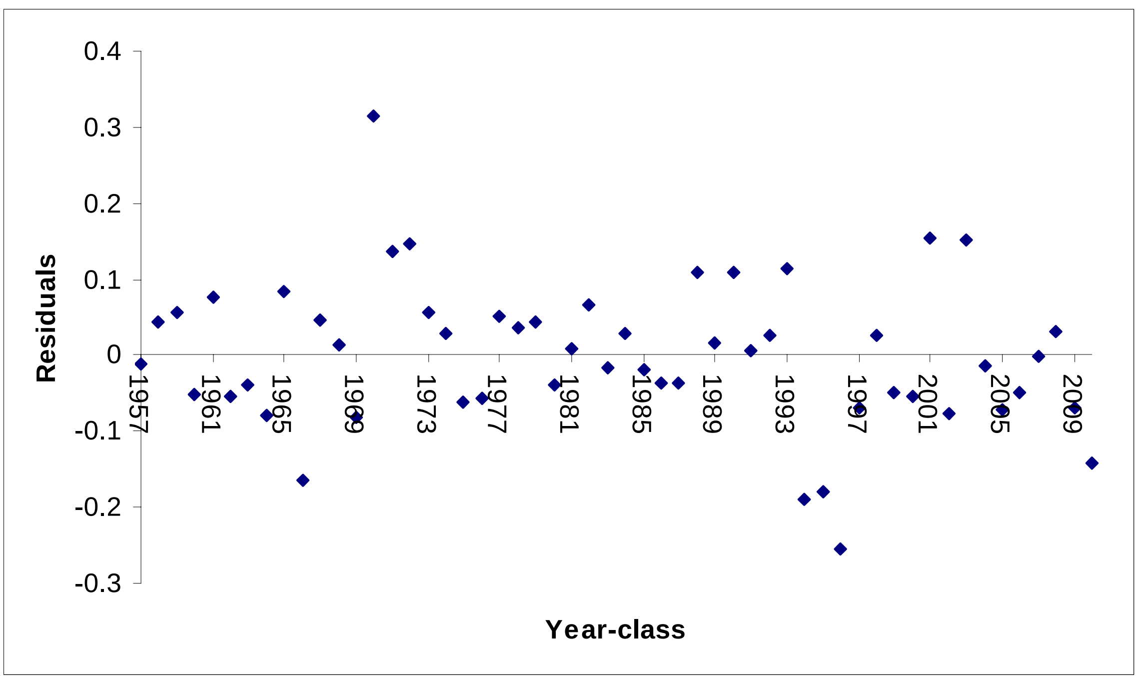


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 2010 through spring 2011. The Maryland Department of Natural Resources (MD DNR) 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 2011, 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 all 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^{o}F.

The 2011 cooperative tagging cruise was not conducted on a research vessel using trawls as in previous years, due to budget constraints. In order to maintain the time series of tagging data, a sportfishing vessel was chartered and fish were captured via hook and line. Sampling was conducted on one day, March 2, 2011, 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 still to tag coastal migratory striped bass wintering in the Atlantic Ocean off northeastern North Carolina and/or southeastern Virginia (state and federal waters). One to three lines containing parachute rigs using single 10/0 hooks in shad bodies were trolled from the 50 foot sportfishing vessel, *Midnight Sun*, at 2.5 knots, in depths of 70 to 75 feet (21 – 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.

<u>Tagging procedures</u>

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.

<u>Analytical Procedures</u>

Survival rates from fish tagged during the spring in Maryland were estimated using several approaches, all based on historic release and recovery data. 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.

Therefore during the most recent ASMFC stock assessment, the catch equation method and the instantaneous rates–catch and release (IRCR) model were utilized. The former uses total mortality, obtained from the previous MARK method, along with exploitation rate, as inputs to Baranov's catch equation to compute F and M (ASMFC 2011). The second method employs an age-independent form of the IRCR model developed in Jiang et al. (2007). The candidate models run in the IRCR model are similar in structure to the models used in MARK, but estimate instantaneous mortality rates instead of survival.

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 2011 will not be completed until after March 27, 2012, 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 2010-2011 estimate of F for Chesapeake Bay (ASMFC 2011). 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 (conducted by Virginia Institute of Marine Science) were combined to produce a Baywide estimate of F. Similar to the coastwide methods, two analytical methods were utilized to calculate the Chesapeake Bay F; Baranov's catch equation and the IRCR model. Further details on these 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. It has yet to be decided if the 2011 data will be used in the upcoming assessment. Upon completion, these calculations will be conducted by the USFWS.

For each study, t-tests were used to test for significant differences between the mean lengths of striped bass that were tagged and all striped bass measured for total length (SAS 1990). This was done to determine if the tagged fish were representative of the entire sample. Lengths were considered different at $P<0.05$.

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 31, 2011 and May 21, 2011. A total of 2,306 striped bass were sampled and 1,339 (58%) were tagged as part of this long-term survey (Table 1). In 2011, catches were spread more evenly throughout the survey, 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 2011 (587 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (551 mm TL) (Figure 2).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2010 data) were used to estimate an instantaneous fishing mortality rate (F) for the 2010-2011 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Fishing mortality estimates from the two methods were below the target F=0.27 set by ASMFC (ASMFC 2011).

Estimates of survival and fishing mortality for the 2011 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 2011, a total of 108 striped bass were captured and 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 2011 cruise was 810 mm TL (Figure 2). These lengths were significantly larger than the mean total lengths for the 2010 cruise (774 mm TL total sampled and tagged; $P<0.0001$). It is impossible to say if the difference in mean length is due to gear change, as no concurrent gear comparison study was conducted, however it is not uncommon for the mean lengths to vary from year to year. If funding becomes available in the future, the proper gear comparisons will be done.

Estimates of survival and fishing mortality based on fish tagged in the 2011 North Carolina study will be presented in the next report of the ASMFC Striped Bass Tagging Subcommittee.

CITATIONS

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

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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 2011.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	3/31/11 - 5/11/11	1,280	655	521144 – 521805
Upper Chesapeake Bay	4/4/11 - 5/21/11	1,026	684	515517 – 516000 524001 – 524210
Spring spawning survey totals:		2,306 [b]	1,339	

[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.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2011 SEAMAP cooperative tagging cruise.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Nearshore Atlantic Ocean (Near VA-NC line)	3/2/11	108	108	567001 – 567109
Cooperative tagging cruise totals:		108 [b]	108	

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

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, late March - May 2011.

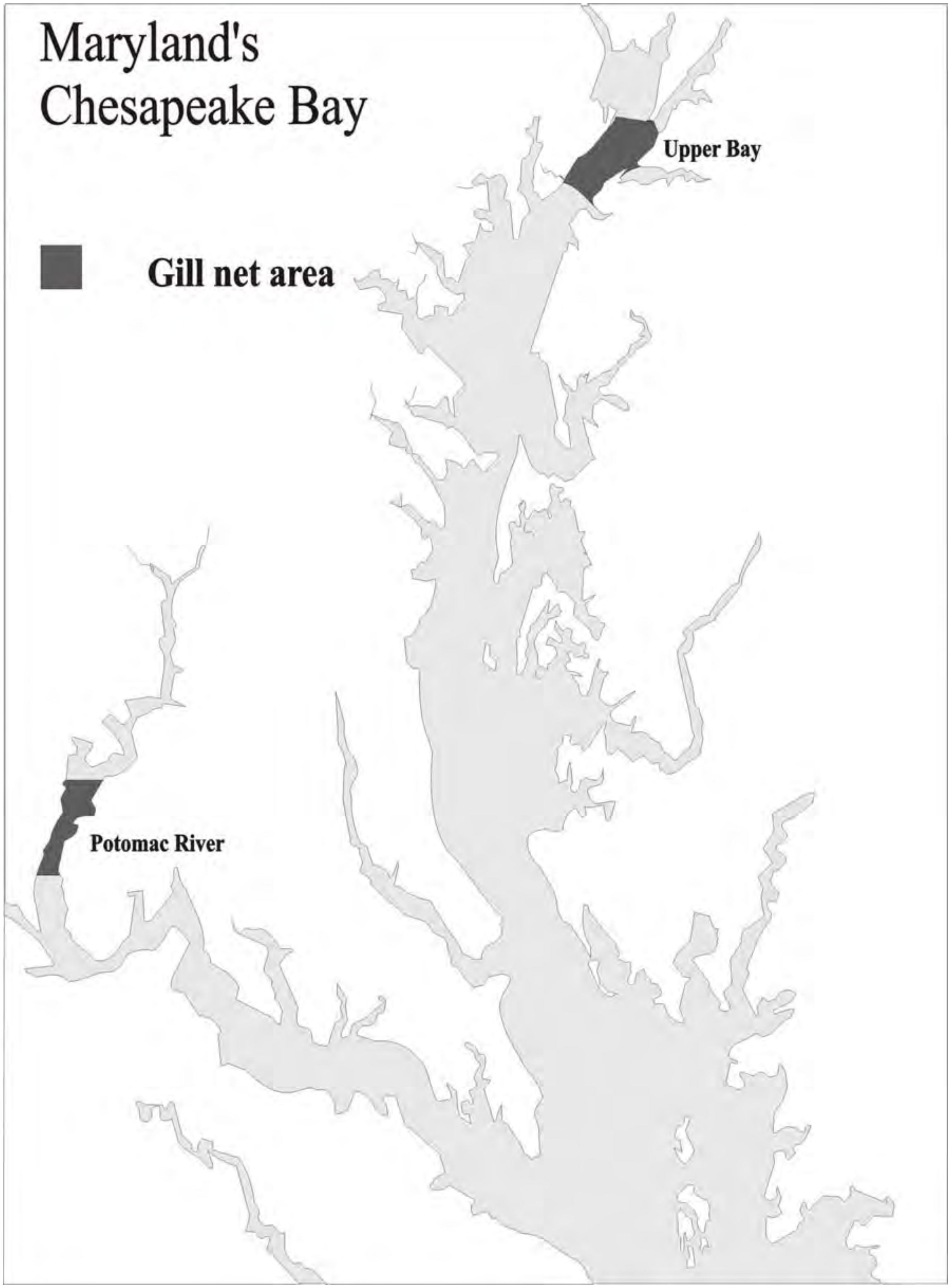
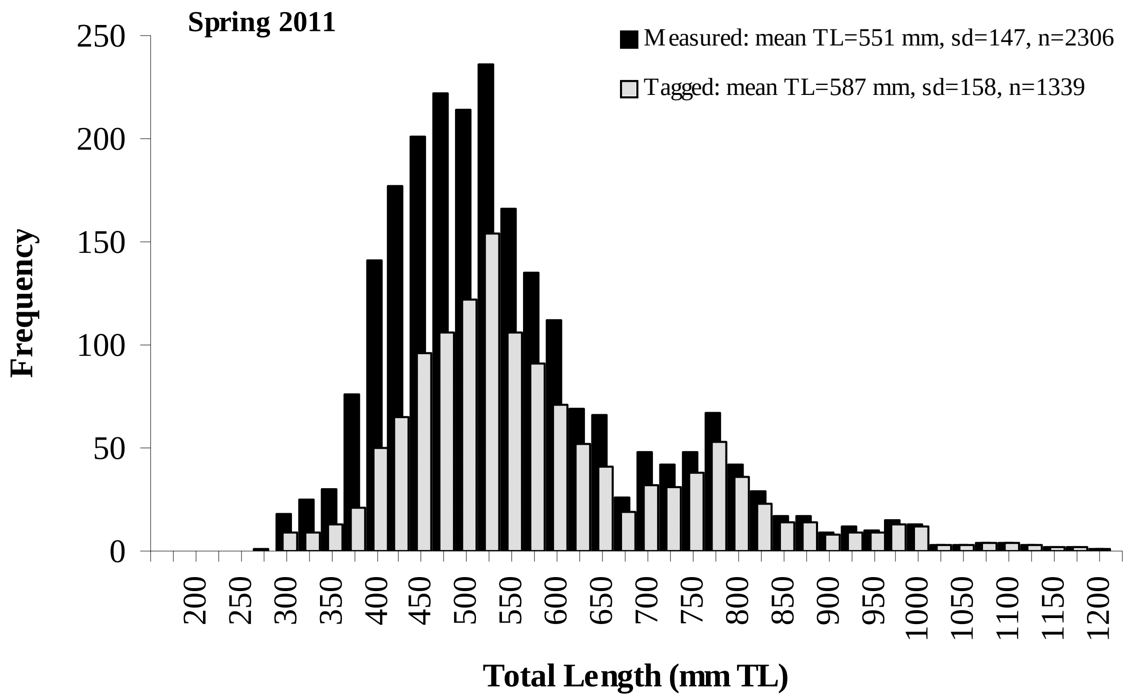
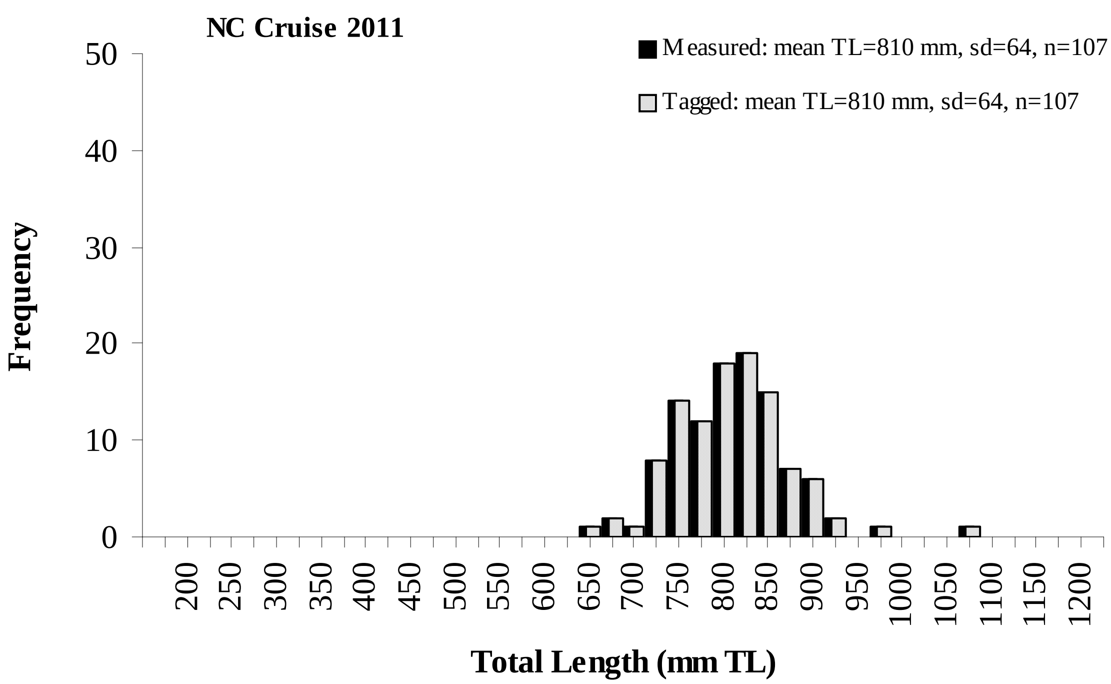


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay and offshore during the SEAMAP tagging cruise. Note different scales.





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 2010 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-first 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 2010 commercial quota for the Chesapeake Bay and its tributaries was 2,098,863 pounds with an 18 to 36 inch total length (TL) slot limit. There was a separate quota of 125,465 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. 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 (Table 1).

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, 2010, Monday through Thursday only. The pound net fishery was open from June 1 through November 30, 2010, Monday through Saturday. The haul seine fishery was open from June 7 through November 30, 2010, Monday through Friday. The Chesapeake Bay drift gill net season was split, with the first segment from January 1 through February 28, 2010 and the second segment from December 1 through December 31, 2010, Monday through Friday. The Atlantic

Coast fishery consisted of two gear types, gill net and trawl. Both gear types were permitted during the Atlantic season, which occurred in two segments: January 1 through April 30, 2010 and November 2 through December 31, 2010, 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, 2008 was established for receipt of declaration. MD DNR charged a fee to participants based upon the type of license held. Participants who held a Tidal Fishing License were required to pay $100. Participants who held an Unlimited Finfish Harvester License or Hook-and-Line License were required to pay $200. Individual-based seasonal allocations were determined for haul seine and pound net by dividing the gear-specific harvest allocations by the number of persons declaring their intent to fish with that gear. Daily allocations were established to distribute harvest over as many days as was practical, in an effort to avoid flooding the market (Table 2). 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 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 fishery's 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 on a monthly basis, regardless of fishing activity. Fishermen who did not return a MFR were sent a postal reminder within one month. 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 harvested in this report were supplied by the Permits 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, 2,105,775 pounds of striped bass were harvested in 2010, 6,912 pounds over the 2010 quota. The estimated number of fish landed was 600,737 (Table 3). The Chesapeake drift gill net fishery landed 44% of the total landings by weight, followed by the pound net fishery at 31%. The hook-and-line fishery contributed 25% of the total landings and less than 1% of fish were harvested by the haul seine fishery.

Maryland's Atlantic Coast landings totaled 44,802 pounds (Table 3), 80,663 pounds under the 2010 quota. The estimated number of fish landed was 5,369. The gill net fishery made up 64% 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 3.54 pounds when calculated from the check station log sheets and 3.69 pounds when measured by biologists (Table 4). Mean weights by specific gear type ranged from 3.34 to 3.65 pounds from check station log sheets and mean weights were 3.25 to 3.94 pounds when measured by biologists. The largest striped bass landed in the Chesapeake Bay were taken by gill net and haul seine fisheries. The average weight of fish harvested by gill net was 3.64 pounds when calculated using the log sheet data and 3.94 pounds when calculated using the MD DNR measurements.

Striped bass were also sampled at Atlantic Coast check stations to characterize coastal harvest (Project 2, Job 3, Task 1C, this report). Striped bass sampled from the Atlantic Coast fisheries by MD DNR biologists averaged 11.33 pounds (Table 4). The average weight calculated from the check station log sheets was 8.34 pounds. Fish caught in the Atlantic gill net fishery averaged 15.51 pounds according to MD DNR estimates, and were larger on average than those caught in the trawl fishery (10.60 pounds). The average weights of fish from the Atlantic gill net and trawl fisheries, as calculated from check station log sheets, were 7.88 and 9.31 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 5, 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 had stabilized around 600,000 pounds, on average, of striped bass harvested per year between 1998-2010.

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 except for the 2010 season where only 35% of the quota was harvested. In almost all years since 1990, the Atlantic trawl fishery harvest has been greater that the Atlantic gill net harvest with the exception of 2006 where the harvest of each gear was nearly equal and 2010 where the gill net harvest was significantly larger than the trawl harvest (Table 5, Figure 5). Though the Atlantic 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 (Table 3). The number of fishing trips in which striped bass were landed was determined from the MFRs. The pounds landed were divided by the number of trips to calculate an estimate of CPUE. The pound net fishery CPUE was 391 pounds per trip, an 11% increase from 2009. The Chesapeake Bay gill net fishery CPUE was 448 pounds per trip, a 38% increase from 2009 CPUE. The hook-and-line fishery CPUE was 193 pounds per trip, a 6% decrease from the previous 2 years (Table 6, 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 (353 lbs per trip), followed closely by the pound net fishery (345 lbs per trip) and the hook-and-line fishery (211 lbs per trip) (Table 6, Figure 6). The Atlantic trawl fishery CPUE was 511 pounds per trip in 2009, a 62% drop from 2009 CPUE and slightly below the twenty-one year average of 563 pounds per trip. The 2010 CPUE for the Atlantic gill net fishery was 235 pounds per trip, above the twenty-one year average of 198 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 gill net fishery has varied without trend since 1996. The Atlantic Trawl fishery has also been variable, with several spikes in harvest in 1995 and 1996-2009.

CITATIONS

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Table 1. Striped bass commercial harvest quotas (lbs) by gear type for the 2010 calendar year.

Gear Type	Total Adjusted Harvest Quota
Haul Seine, Pound Net	611,922
Hook-and-Line	599,907
Drift Gill Net	887,034
Chesapeake Total	**2,098,863**
Atlantic: Trawl, Gill Net	125,465
Maryland Total	**2,224,328**

Table 2. Individual season and daily harvest allocations (lbs) and the number of declared striped bass fishermen for the 2010 calendar year.

Area	Gear Type	Number Declared	Daily Allocation (pounds)	Seasonal Allocation (pounds)
Bay & Tributaries	Haul Seine	4	750	1,250
	Pound Net	193	200[1]	1,600[1]
	Hook & Line	144	500	none
	Gill Net / Hook & Line	809	500	none
Atlantic Coast	Atlantic Trawl	39	none	1,950
	Atlantic Gill Net	48	none	1,950

1. Pound net daily and season allocations were based on: 200 pounds daily per net, 1,600 pounds seasonal per net, maximum of four nets. Most fishermen declared four nets.

Table 3. Summary striped bass commercial harvest statistics by gear type for the 2010 calendar year.

Area	Gear Type	Pounds[1]	Estimated[1] Number of Fish	Trips[2]
Chesapeake Bay[3]	Haul Seine	1,288	353	4
	Pound Net	650,628	182,511	1,664
	Hook and Line	519,117	155,651	2,692
	Gill Net	934,742	256,853	2,089
	Chesapeake Total Harvest	**2,105,775**	**595,368**	**6,449**
Atlantic Coast	Atlantic Trawl	16,335	1,755	32
	Atlantic Gill Net	28,467	3,614	121
	Atlantic Total Harvest	**44,802**	**5,369**	**153**
Maryland Totals		**2,150,577**	**600,737**	**6,602**

1. Data from check station log sheets.

2. Trips were determined as days fished when striped bass catch was reported.

3. Includes all Maryland Chesapeake Bay and tributaries, except main stem Potomac River.

Table 4. Striped bass average weight (lbs) by gear type for the 2010 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	3.65	N/A	N/A
	Pound Net	3.56	3.25 (3.18-3.33)	1,528
	Hook-and-Line	3.34	3.64 (3.55-3.73)	1,789
	Gill Net	3.64	3.94 (3.88-3.99)	3,104
	Chesapeake Total Harvest	**3.54**	**3.69 (3.65-3.73)**	**6,421**
Atlantic Coast	Trawl	9.31	10.60 (9.72-11.47)	91
	Gill Net	7.88	15.51 (11.37-19.65)	16
	Atlantic Total Harvest	**8.34**	**11.33 (10.34-12.32)**	**107**

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 5. Pounds of striped bass harvested by commercial gear type, 1990 to 2010.

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

Table 6. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2010.

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

Figure 1. Map of the 2010 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 2010.

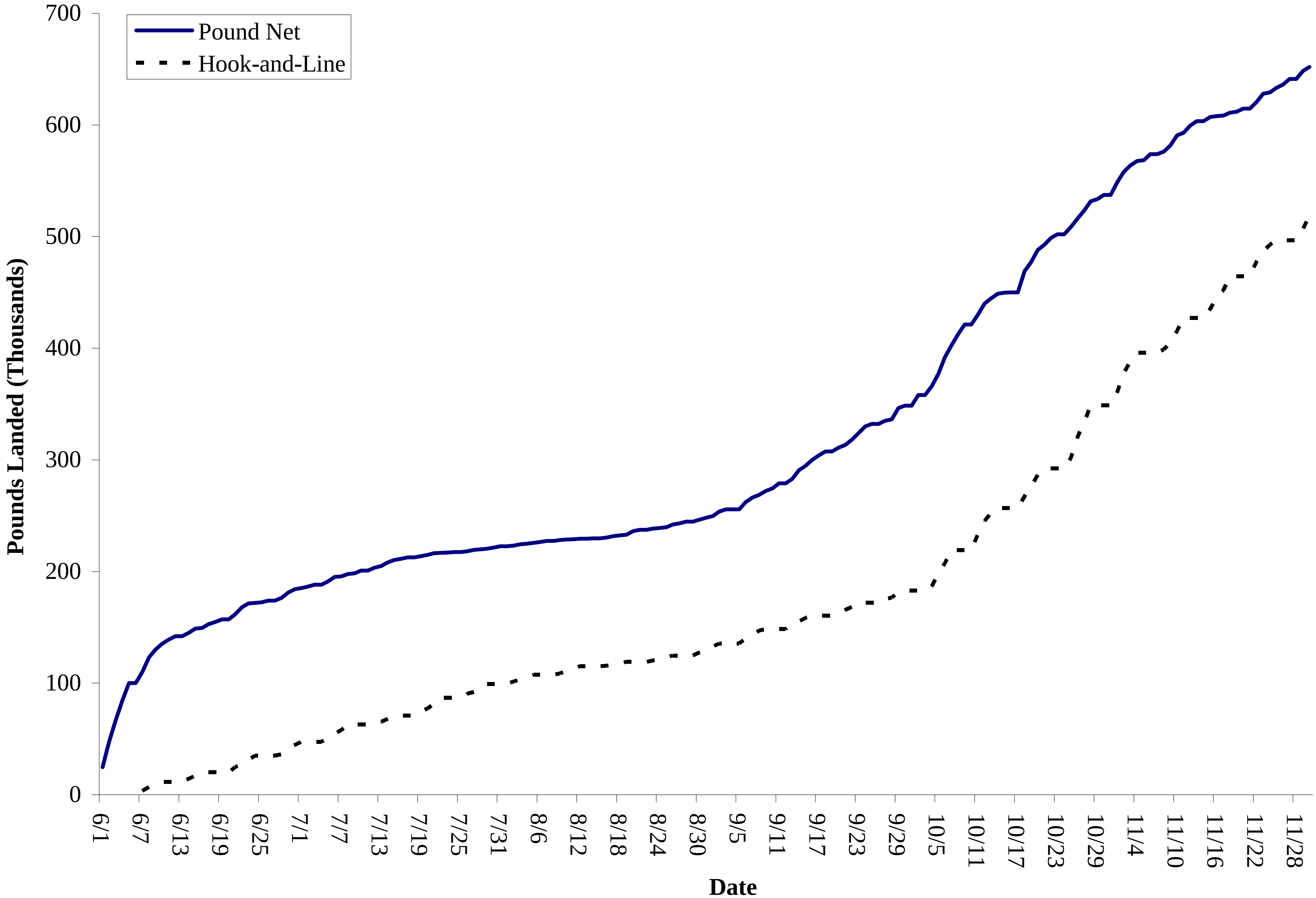
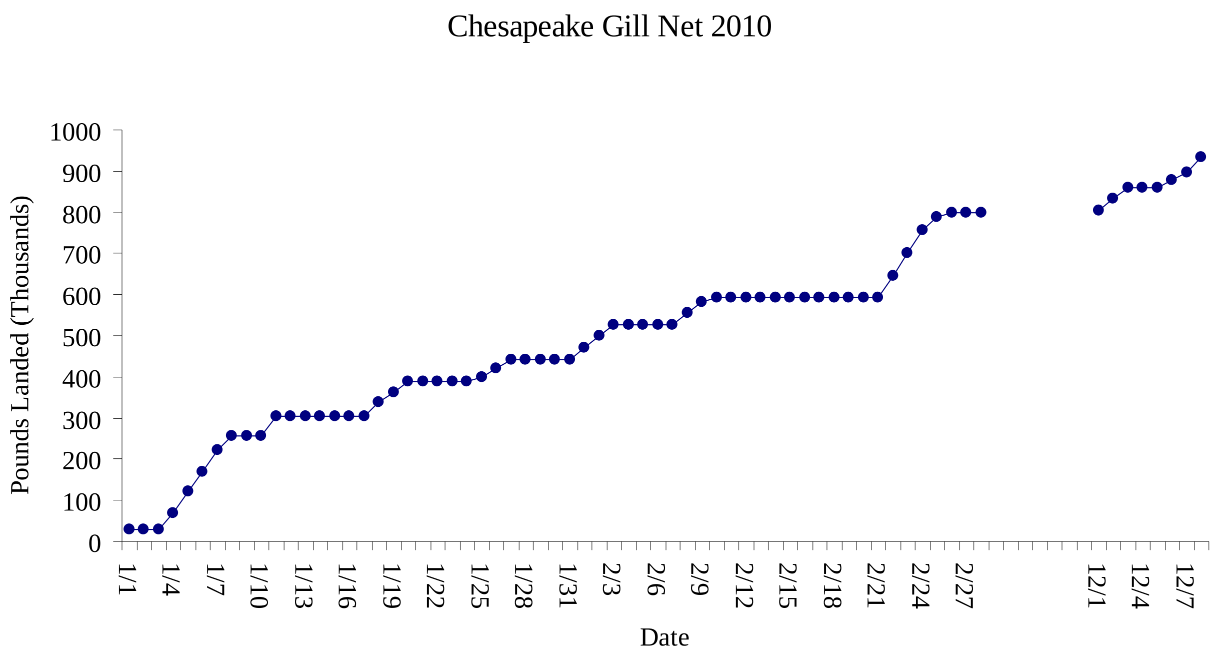


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fisheries (combined) cumulative striped bass landings from check stations' daily call-in reports, January-December 2010.



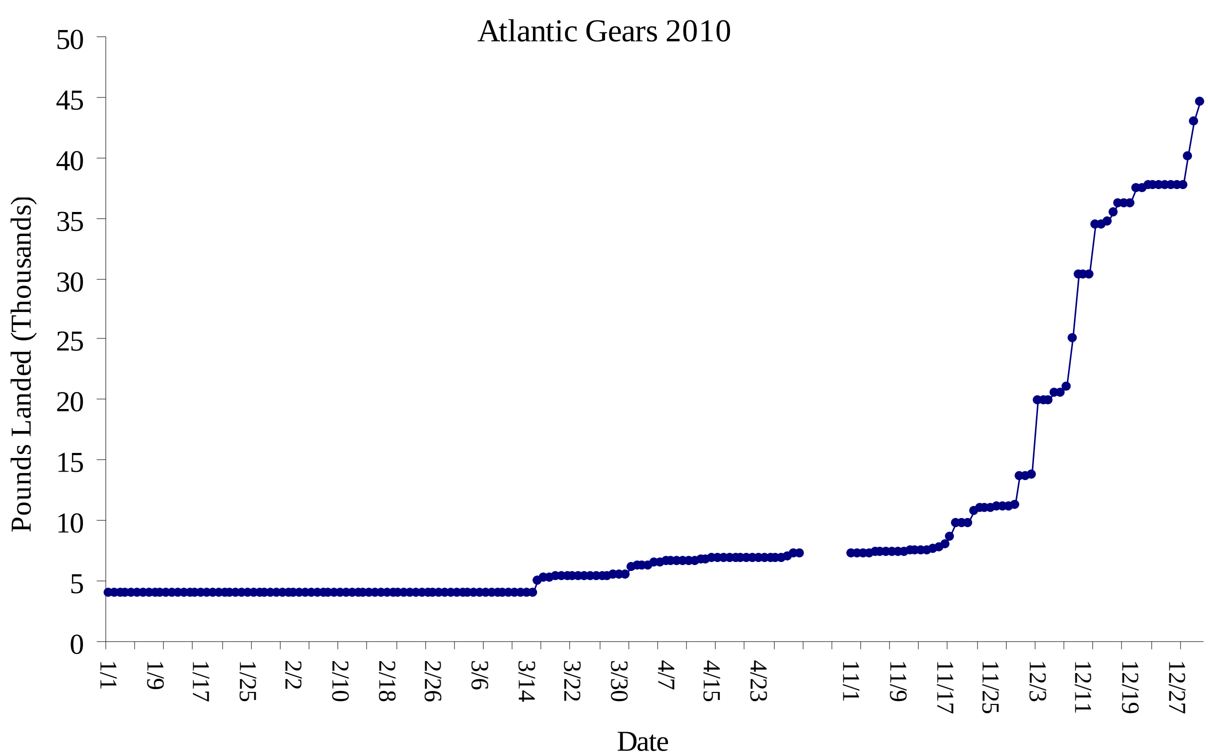


Figure 4. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990–2010.

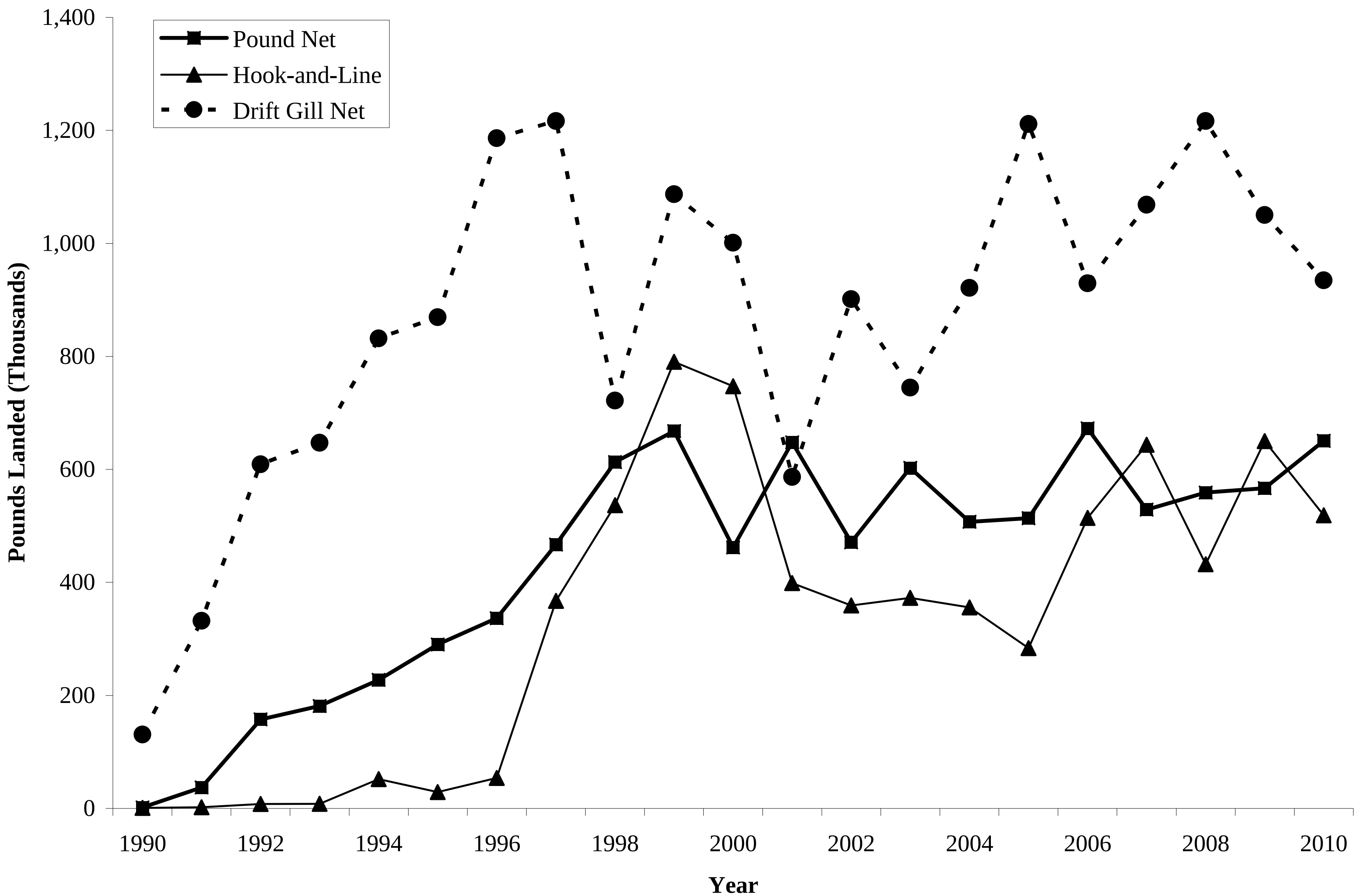


Figure 5. Maryland's Atlantic gill net and trawl fisheries total striped bass harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2010.

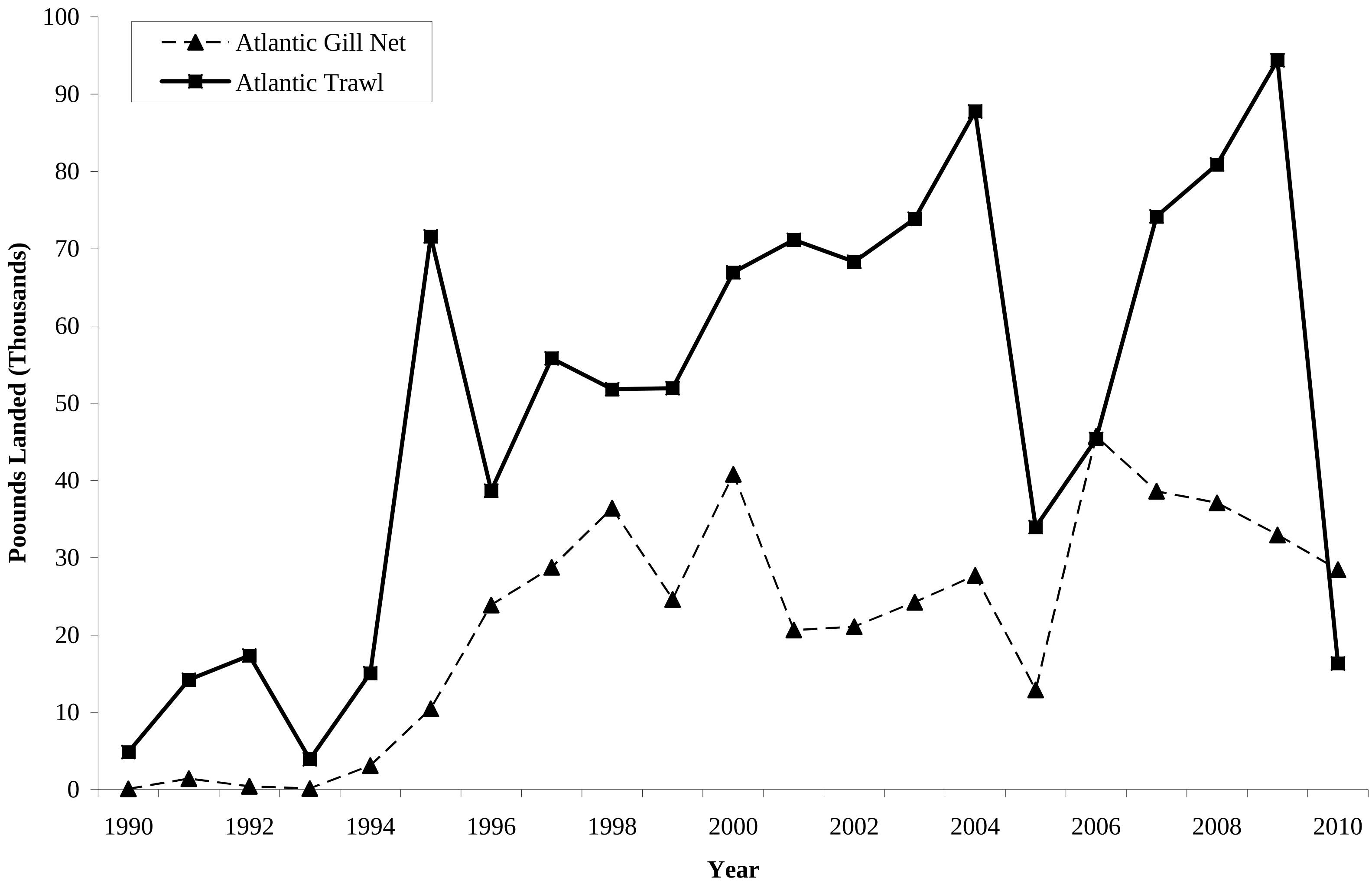


Figure 6. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990- 2010. Trips were determined as days fished when striped bass catch was reported.

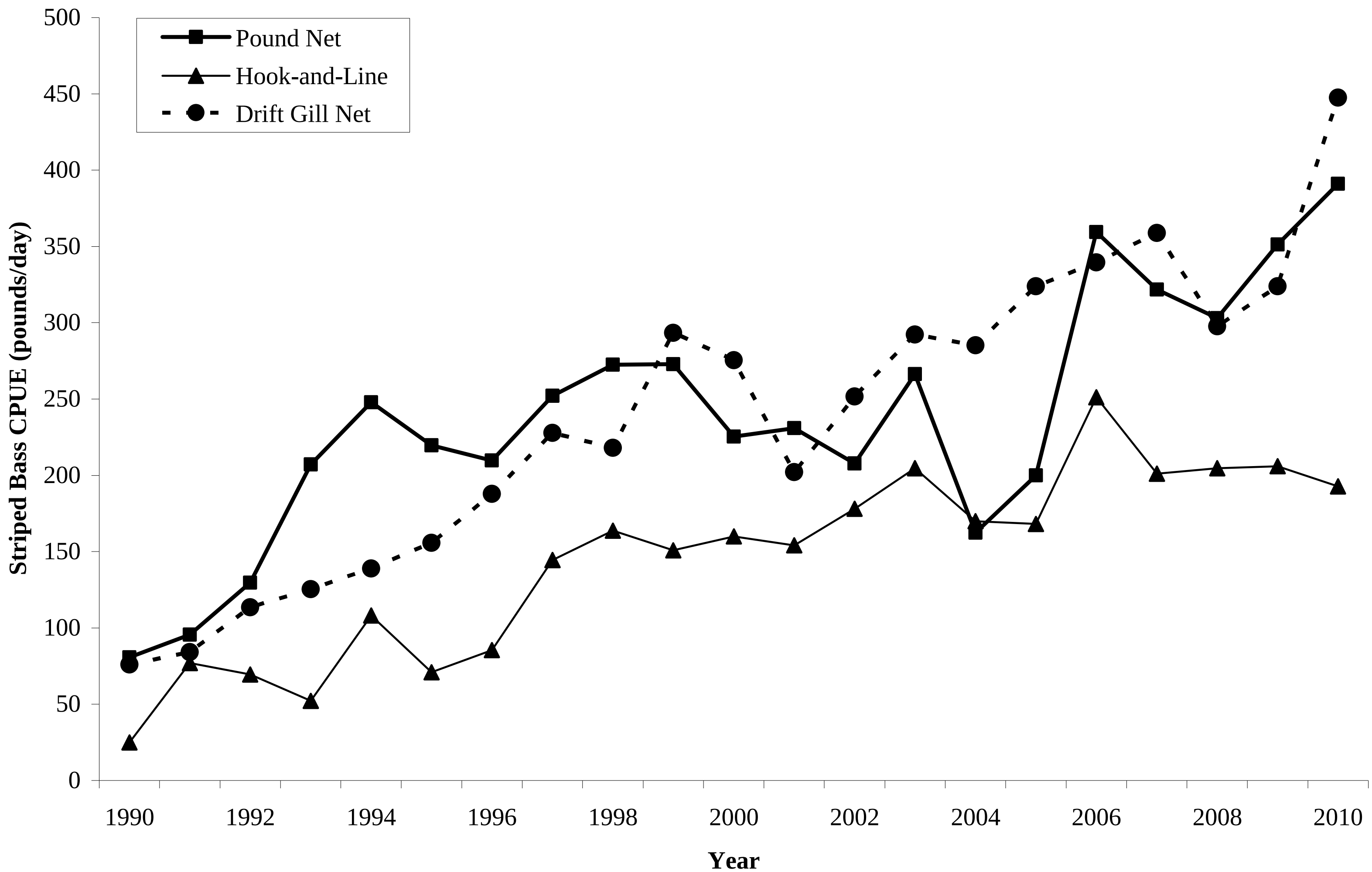
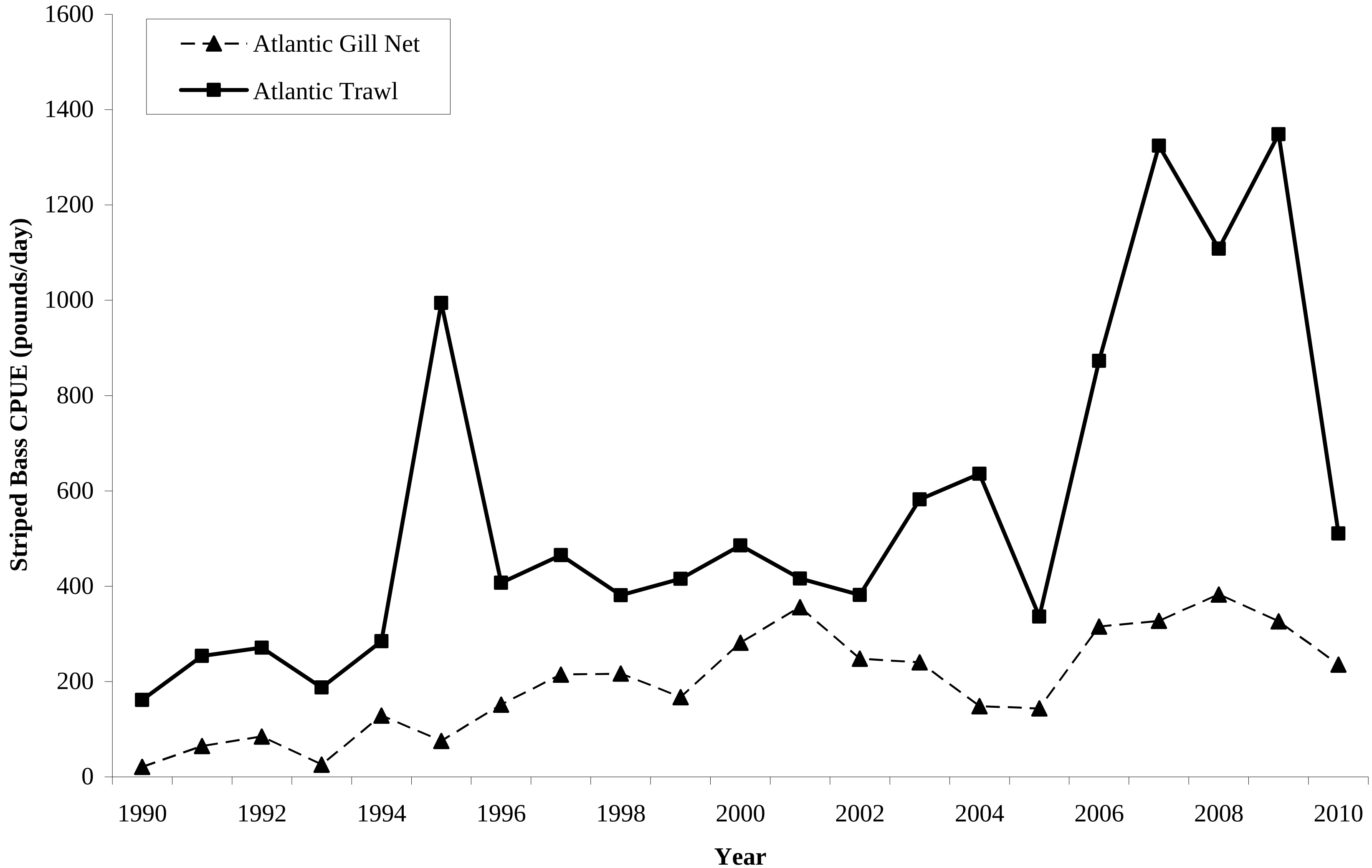


Figure 7. Maryland's Atlantic gill net and trawl fisheries striped bass catch (pounds) per trip (CPUE), 1990-2010. Trips were determined as days fished when striped bass catch was reported.



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 2011 spring recreational season, which began on Saturday, April 16 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 2011 season was 28 days long (April 16 – 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 2011, some trips did not return until as late as noon. 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 2011: Solomons/Calvert Marina, Tilghman Island/Harrison's, 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 or 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 2011, 243 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 from 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 2011, 22% 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 2011, 298 private boats and one charter trip were intercepted for interviews. Fish were sampled from 62 intercepted charter trips and one private boat trip (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 2011 spring striped bass season was 28 inches (711 mm) TL. Lengths ranged from 716 mm TL to 1137 mm TL. The catch was dominated by fish between 860 and 940 mm TL (34 to 37 inches, Figure 2), similar to the length distribution observed in 2010.

Mean length

In 2011, the mean length for all fish (890 mm TL) was significantly smaller than that observed from 2008-2010 but was similar to 2002-2005 (Table 6A, Figure 3). The mean length of females (906 mm TL) was greater than the mean length of males (829 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 but similar to other years. Mean length of males in 2011 was statistically similar to all other years of the survey except for 2005, 2006, and 2008.

The mean daily lengths of female striped bass harvested in 2011 showed a decrease in size as the season progressed (Figure 4). This is similar to mean daily length data for 2002 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 2011 (7.3 kg) was less than that observed in 2010, but not statistically different (Table 6B). Based on 95% confidence intervals, the mean weight of females (7.7 kg) was less than 2010 but not significantly (Figure 5). The mean weight of males in 2011 was the lowest in the time series but was statistically similar to those observed in all other study years, except in 2006. The mean weight of females (7.7 kg) was greater than the mean weight of males (5.6 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 2011 ranged from 6 to 16 years old (Figure 6). Most fish harvested were between 8 and 11 years old. The 2003 (8 years old in 2011) and 2001 (10 years old) year-classes were the most frequently observed cohorts, each constituting 29% of the sampled harvest. The strong 2003 year-class has increased annually in the harvest since 2008. The record-sized 1996 year-class (15 years old in 2011), which dominated catches in 2005, 2006, and 2008, constituted just 3% of the sample harvest.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2011 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 unknown sex fish in 2011. Females constituted 79% 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 2011 spring survey indicated that 42% of the females caught between April 16 and May 15 were in pre-spawn condition (Table 8). This percentage is similar to the average of the past nine years.

Daily spawning condition of females

The percentage of pre-spawn female striped bass stayed relatively consistent throughout the survey with one peak at the end of April (Figure 7). The percent of pre-spawn females harvested ranged from 16% to 74% on any given day. Sample sizes of female striped bass ranged from 8 to 52 fish daily (mean=23 fish, median=20 fish). The consistent percentage of pre-spawn female striped bass encountered suggests that spawning occurred throughout the sample period. This is corroborated by the juvenile seine survey (Project 2, Job 3, Task 3) which caught young-of-year striped bass across a wide range of lengths, indicating a prolonged spawning period.

CATCH RATES AND FISHING EFFORT

Harvest Per Trip Unit Effort

Because of increased focus on improving our understanding of private boat fishing effort, the majority of trips intercepted in 2011 for interviews were private boat trips (Table 5B). 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.

Charter boat activity can be accurately characterized from existing reporting methods so very few interviews of charter boat anglers were conducted in 2011. The HPT from the one charter boat angler interview was 4.0, which while less than 2010, was similar to previous 2002 and 2007. The mean HPT in 2011 according to charter boat logbooks was 4.8 fish per trip, similar to 2008-2009 and the same as 2010 (Table 9A). While this number is consistent with other years, it is significantly higher than 2007 and lower than HPT estimates from 2003-2006. Mean HPT from private boat interviews (0.9) was much lower than HPT from charter boats but consistent with previous 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 creel interviews was 0.8, similar to previous years. HPA from charter boat logbook data in 2011 was 0.8 fish per person, significantly lower than all other years except for 2002 and 2007 (Table 9B). HPA for private anglers, calculated from interview data, was 0.3 fish per person, similar to past years (Table 9B).

Catch Per Unit Effort

In this report, catch is defined as the total number of fish harvested (kept) and released by each fishing party. Table 10A presents mean catch per trip (CPT) and mean catch per hour (CPH) calculated from all fishing modes combined. Very few individuals from charter boat trips were interviewed in 2011 so these numbers reflect primarily private boat angler interview data.

Mean CPT in 2011 (1.2) was the second lowest recorded in all years and consistent with the previous four years of the survey. Mean CPH was 0.3 fish per hour in 2011, statistically similar to 2008-2010. The decreases observed in CPT and CPH since 2006 are directly related to the reduction of charter boat interview data in 2007 and 2010-2011 and it's elimination in 2008, and 2009 from the calculations. Because charter boat catch rates tend to be much higher than those from private boats, the removal of these data from the calculation have resulted in reduced catch rates.

Comparison of Catch Rates from Charter and Private Boats

In all years, charter boats caught more fish per trip than private boats (Tables 10B, 10C, and 10D). Though the mean CPH from charter boat creel interviews was 2.5 fish caught per hour (Table 10C), the sample size is too small for accurate conclusions and the charter boat logbook data (Table 10D) is more representative. In 2011, private boats caught an average of 1.2 fish per trip, while charter boats caught 5.7 fish per trip. The private boat CPH was 0.3 fish per hour while charter boats had a CPH of 1.4 fish per hour. 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.

Mean Daily Catch Per Hour

Anecdotal information from anglers and charter boat captains in most years indicated a decrease in catch rates during the latter portion of the spring season. Interview data showed that mean daily CPH declined slightly over time in some years, but has generally varied without trend since 2002 (Figure 8). Though there were not enough observations to make a definitive conclusion, it appears that daily CPH in 2011 varied without trend. CPH values have decreased since 2007 due to the lack of charter boat interview data.

Angler Characterization

States of residence

In 2011, 299 private boat trips were intercepted for interviews and 824 anglers were interviewed during the period April 16-May 15 (Table 5A and Table 5B). One interviewer's state residency data were removed due to inconsistencies in recording the states of residence for non-resident anglers, but residence information was still available for 544 anglers. Ten states of residence were represented in 2011 and one from the U.S. Virgin Islands (Table 11). Most anglers were from Maryland (90%), Virginia (4%), and Pennsylvania (3%), 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 which would not be captured with the license-based phone survey that was performed in 2007 and 2008 (Durell and Warner 2007; Durell and Warner 2008). 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 estimate total fishing effort during the spring striped bass season. This question was retained for the 2009-2011 surveys, even though the telephone survey was not conducted. In 2011, there were on average 2.7 anglers per boat and of these anglers, 1.5 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, 2010, and 2011. In 2006, six lines were fished on average per private boat and the maximum number encountered on a boat was 15. In 2011, the average number of lines fished per private boat was eight and ranged from two to 22 lines (Table 13). This was more lines, on average, than in 2006 (6 lines) but similar to 2010. 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, 1991-2011.

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

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2011. 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	Kentmorre 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 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, 2011.

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, 2011.

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, 2011.

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 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

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

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)

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)

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

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
Mean	**81**	**84**	**84**

Table 8. Spawning condition of the female portion of catch, sampled by the Maryland striped bass spring season creel survey, through May 15. Females of unknown spawning condition are excluded.

	Pre-spawn Females		Post-spawn Females	
Year	**n**	**%**	**n**	**%**
2002	150	45	181	55
2003	231	58	168	42
2004	222	55	180	45
2005	144	63	85	37
2006	162	41	231	59
2007	142	59	97	41
2008	47	30	108	70
2009*	81	49	83	50
2010	62	29	150	71
2011	79	42	107	58
Mean	**132**	**47**	**139**	**53**

*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	Charter Creel Int. Trips (n)	Charter Creel Int. Mean HPT	Private Creel Int. Trips (n)	Private Creel Int. Mean HPT
2002	1,424	**4.7** (4.6-4.8)	132	**4.9** (4.5-5.3)	44	**1.1** (0.6-1.4)
2003	1,393	**5.7** (5.6-5.8)	101	**6.6** (5.8-7.3)	64	**1.1** (0.7-1.4)
2004	1,591	**5.4** (5.3-5.5)	86	**5.6** (5.1-6.2)	42	**2.2** (1.7-2.8)
2005	1,965	**5.5** (5.4-5.6)	49	**6.9** (6.3-7.5)	1	**0.0**
2006	1,934	**5.3** (5.2-5.4)	92	**6.0** (5.3-6.7)	28	**1.4** (0.6-2.1)
2007	1,607	**4.3** (4.2-4.4)	50	**4.9** (4.2-5.7)	483	**0.7** (0.6-0.8)
2008	1,755	**4.9** (4.8-5.1)	0	N/A	260	**0.6** (0.5-0.7)
2009	1,849	**5.0** (4.9-5.1)	0	N/A	275	**0.9** (0.7-1.0)
2010	1,986	**4.8** (4.7-4.9)	6	**11.0** (5.1-16.9)	193	**1.1** (0.9-1.3)
2011	1,660	**4.8** (4.7-4.9)	1	**4.0**	298	**0.9** (0.7-1.0)

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	Charter Creel Int. Trips (n)	Charter Creel Int. Mean HPA	Private Creel Int. Trips (n)	Private Creel Int. Mean HPA
2002	1,424	**0.78** (0.76-0.79)	131	**0.8** (0.7-0.9)	43	**0.4** (0.3-0.6)
2003	1,393	**0.93** (0.92-0.94)	101	**1.0** (0.9-1.2)	64	**0.4** (0.3-0.5)
2004	1,591	**0.88** (0.86-0.89)	86	**0.9** (0.8-1.0)	42	**0.7** (0.5-0.8)
2005	1,965	**0.88** (0.87-0.89)	49	**1.0** (0.9-1.1)	1	**0.0**
2006	1,934	**0.86** (0.87-0.85)	90	**1.0** (0.8-1.1)	27	**0.5** (0.2-0.7)
2007	1,607	**0.69** (0.68-0.71)	50	**0.8** (0.7-0.9)	483	**0.3** (0.2-0.3)
2008	1,755	**0.79** (0.78-0.81)	0	N/A	260	**0.2** (0.2-0.3)
2009	1,849	**0.81** (0.80-0.82)	0	N/A	275	**0.3** (0.3-0.4)
2010	1,986	**0.76** (0.75-0.77)	6	**1.0**	193	**0.4** (0.3-0.5)
2011	1,660	**0.78** (0.77-0.80)	1	**0.8**	298	**0.3** (0.3-0.3)

Table 10A. Mean catch, effort, and catch per hour, with 95% confidence limits, calculated from the Maryland striped bass spring season creel survey interview data, through May 15. All trips and fishing modes are combined. 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	171	**5.8** (5.2-6.5)	**5.4** (5.1-5.6)	**1.2** (1.0-1.3)
2003	163	**6.6** (5.4-7.8)	**4.5** (4.2-4.9)	**1.9** (1.6-2.2)
2004	129	**6.0** (5.2-6.8)	**4.2** (3.8-4.5)	**1.9** (1.6-2.2)
2005	52	**8.3** (7.5-9.1)	**3.1** (2.6-3.5)	**3.5** (2.8-4.3)
2006	134	**6.6** (5.8-7.7)	**3.8** (3.5-4.1)	**2.6** (2.0-3.2)
2007	542	**2.1** (1.7-2.5)	**5.0** (5.1-4.9)	**0.5** (0.4-0.6)
2008	263	**1.0** (0.7-1.3)	**4.5** (4.3-4.7)	**0.3** (0.2-0.4)
2009	276	**1.6** (1.0-2.1)	**4.6** (4.5-4.8)	**0.4** (0.3-0.5)
2010	199	**2.0** (1.5-2.5)	**4.7** (4.5-4.9)	**0.5** (0.4-0.6)
2011	299	**1.2** (1.0-1.5)	**4.4** (4.2-4.6)	**0.3** (0.3-0.4)

Table 10B. 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)

Table 10C. Charter 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	130	**7.2** (6.6-7.9)	**5.5** (5.3-5.7)	**1.5** (1.3-1.6)
2003	100	**9.6** (8.0-11.2)	**4.0** (3.7-4.4)	**2.8** (2.4-3.2)
2004	86	**7.3** (6.5-8.1)	**4.0** (3.6-4.4)	**2.4** (2.0-2.8)
2005	51	**8.2** (7.7-9.2)	**3.1** (2.6-3.5)	**3.5** (2.9-4.3)
2006	92	**8.7** (7.7-9.7)	**3.6** (3.2-3.9)	**3.4** (2.7-4.2)
2007	50	**8.3** (6.9-9.5)	**4.6** (4.1-5.0)	**2.1** (1.6-2.6)
2008	0	N/A	N/A	N/A
2009	0	N/A	N/A	N/A
2010	6	**14.5** (6.7-22.2)	**3.3** (2.5-4.0)	**4.7** (2.6-6.4)
2011	1	**10.0**	**4.0**	**2.5**

Table 10D. 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)	**4.1** (3.8-4.4)	**1.4** (1.3-1.4)

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

Table 12. The average number of anglers and average number of unlicensed anglers, per boat, with 95% confidence intervals, from the 2008-2011 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)

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

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 16-May 15, 2011.

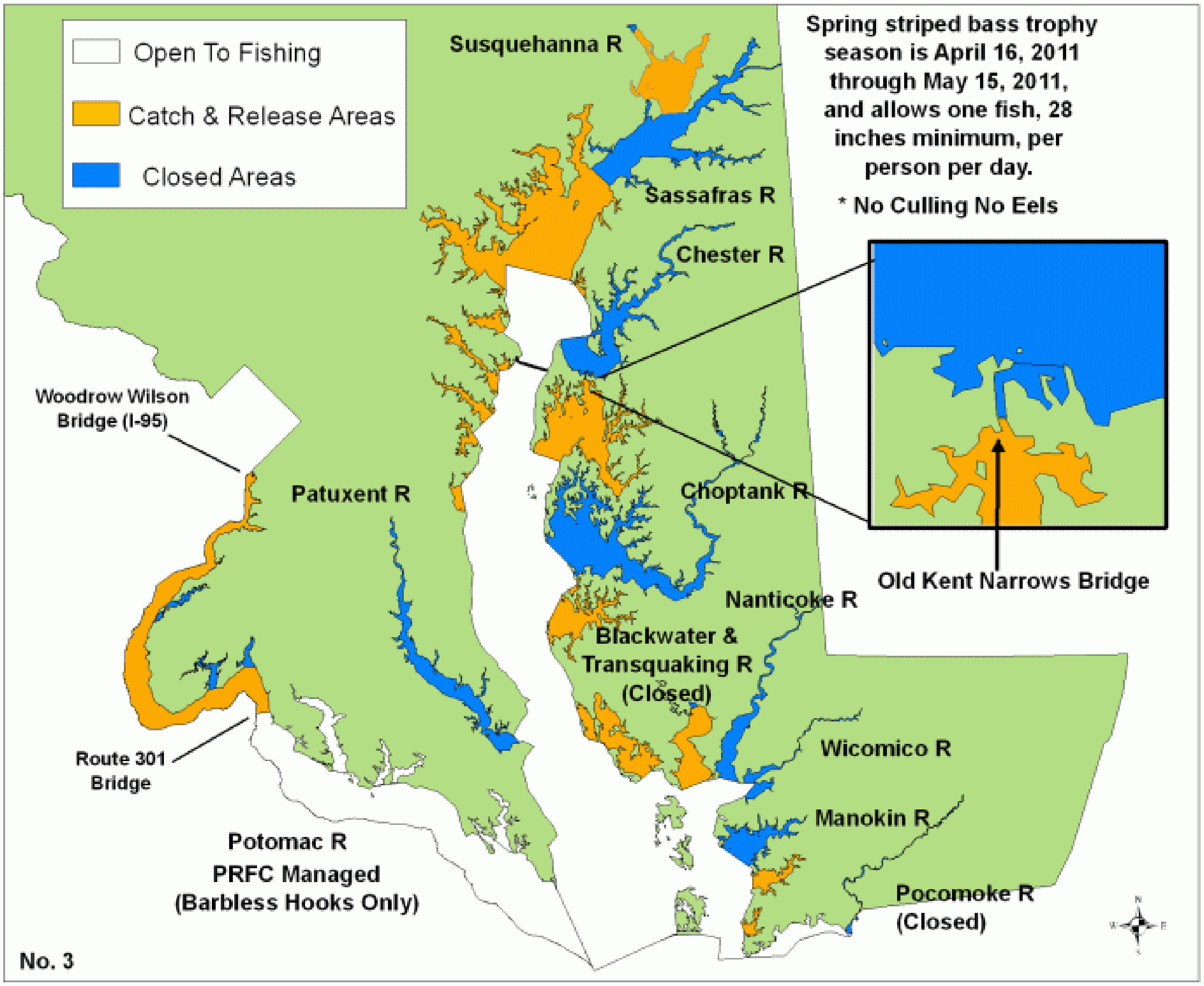


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

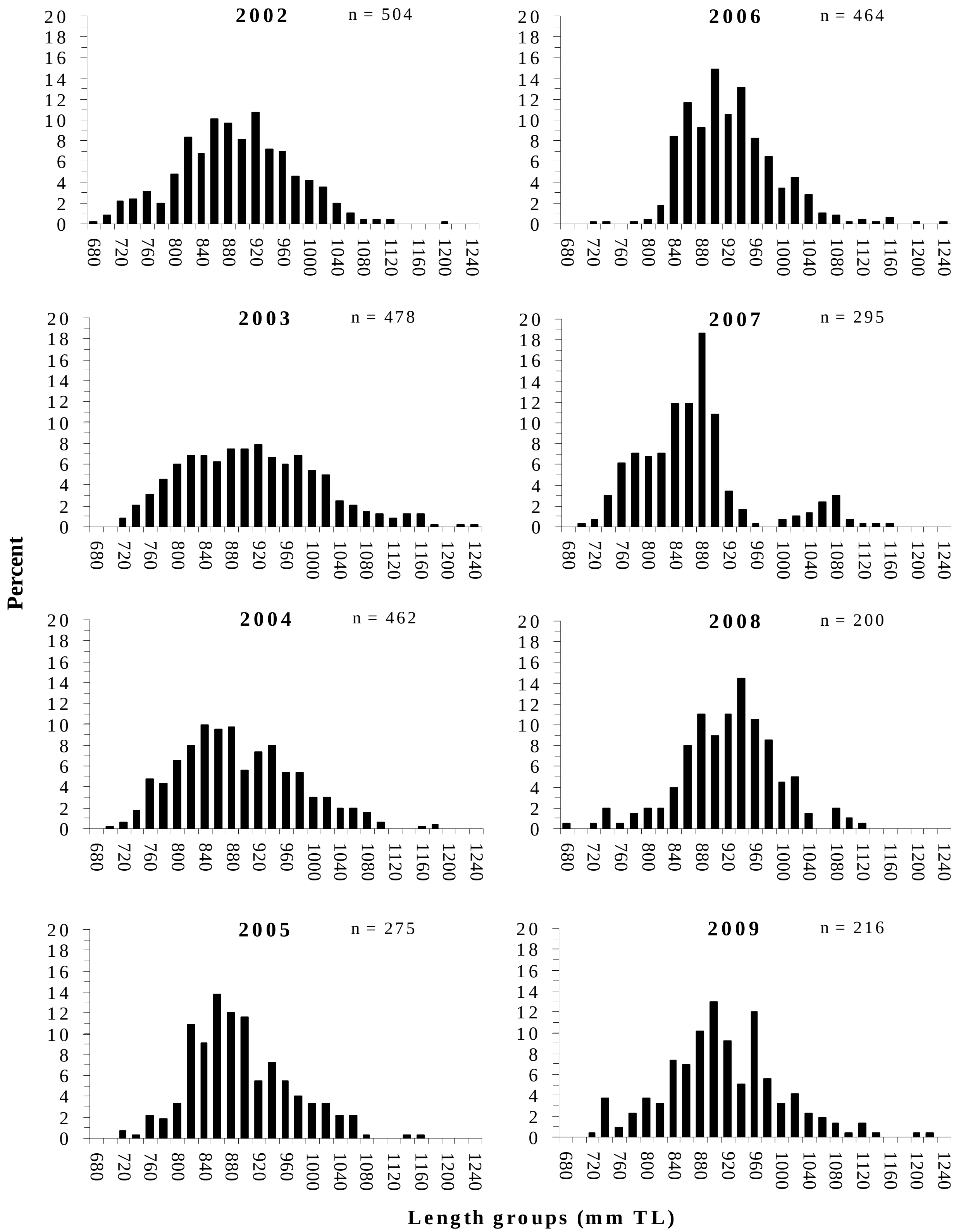


Figure 2. Continued.

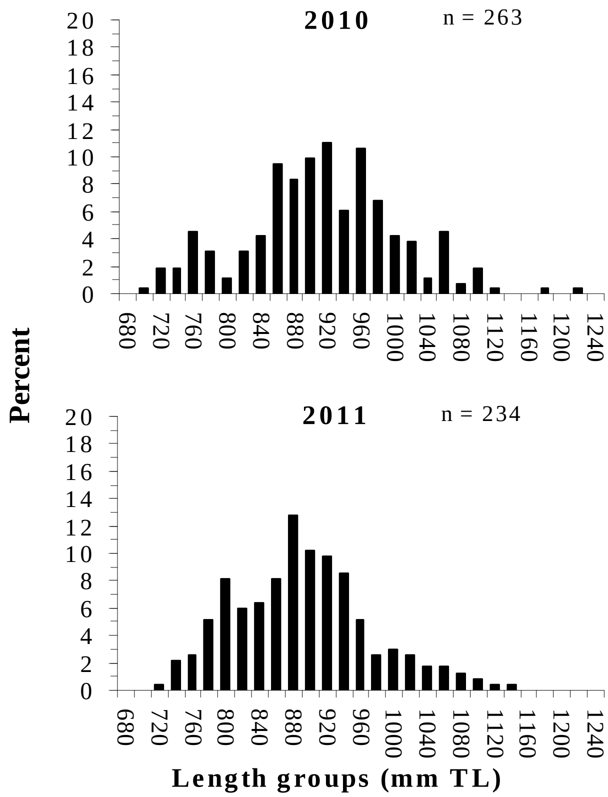


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

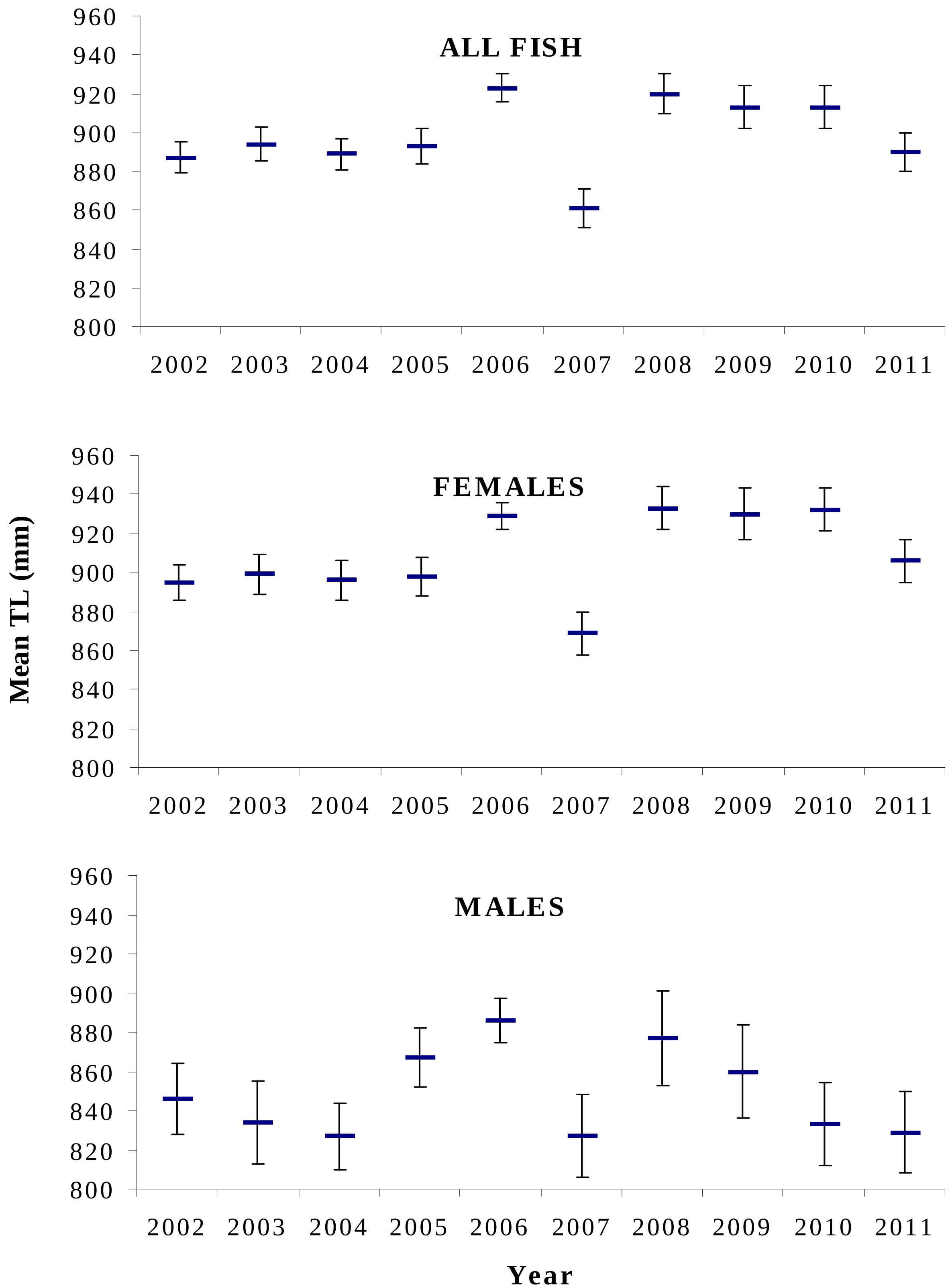


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

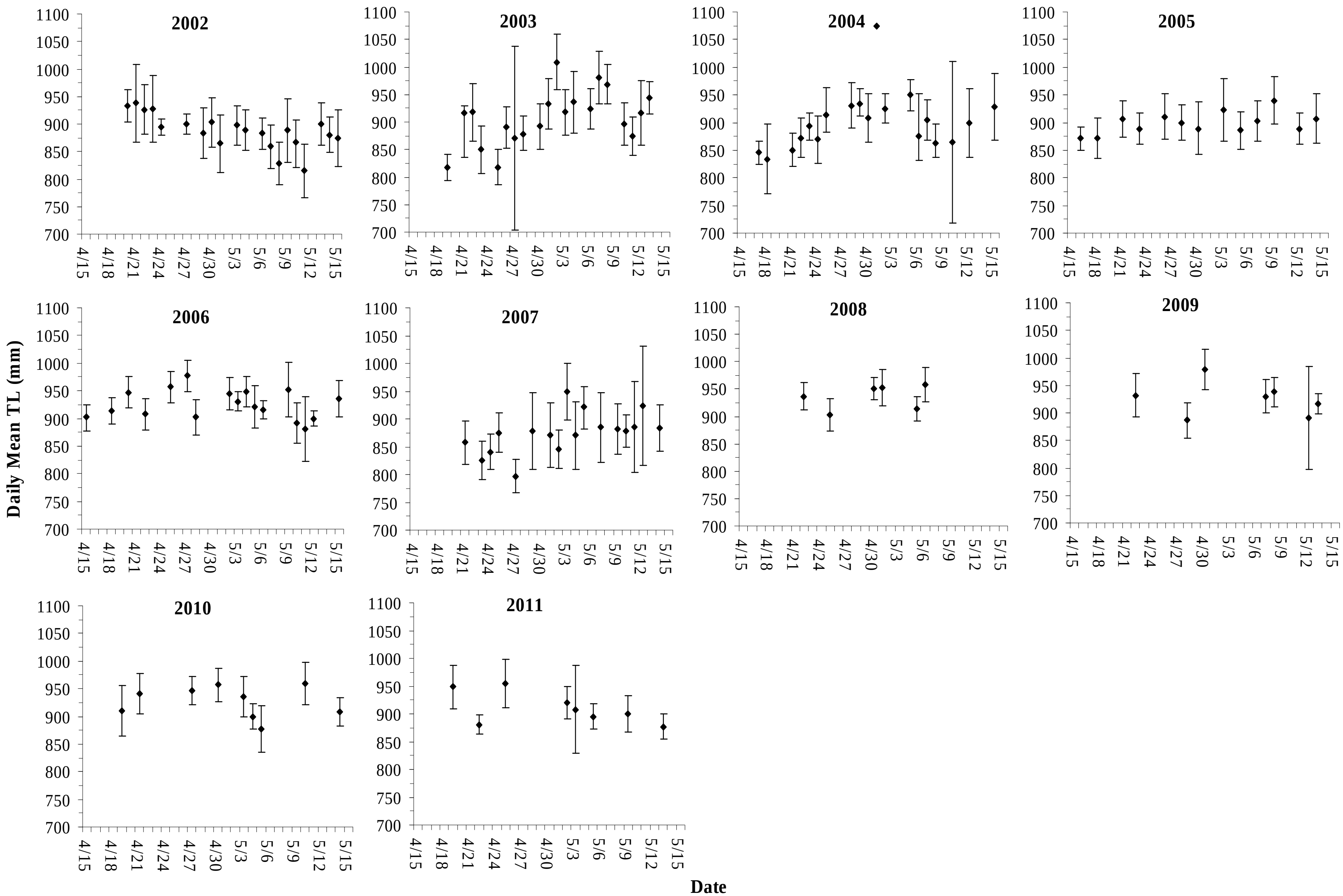


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

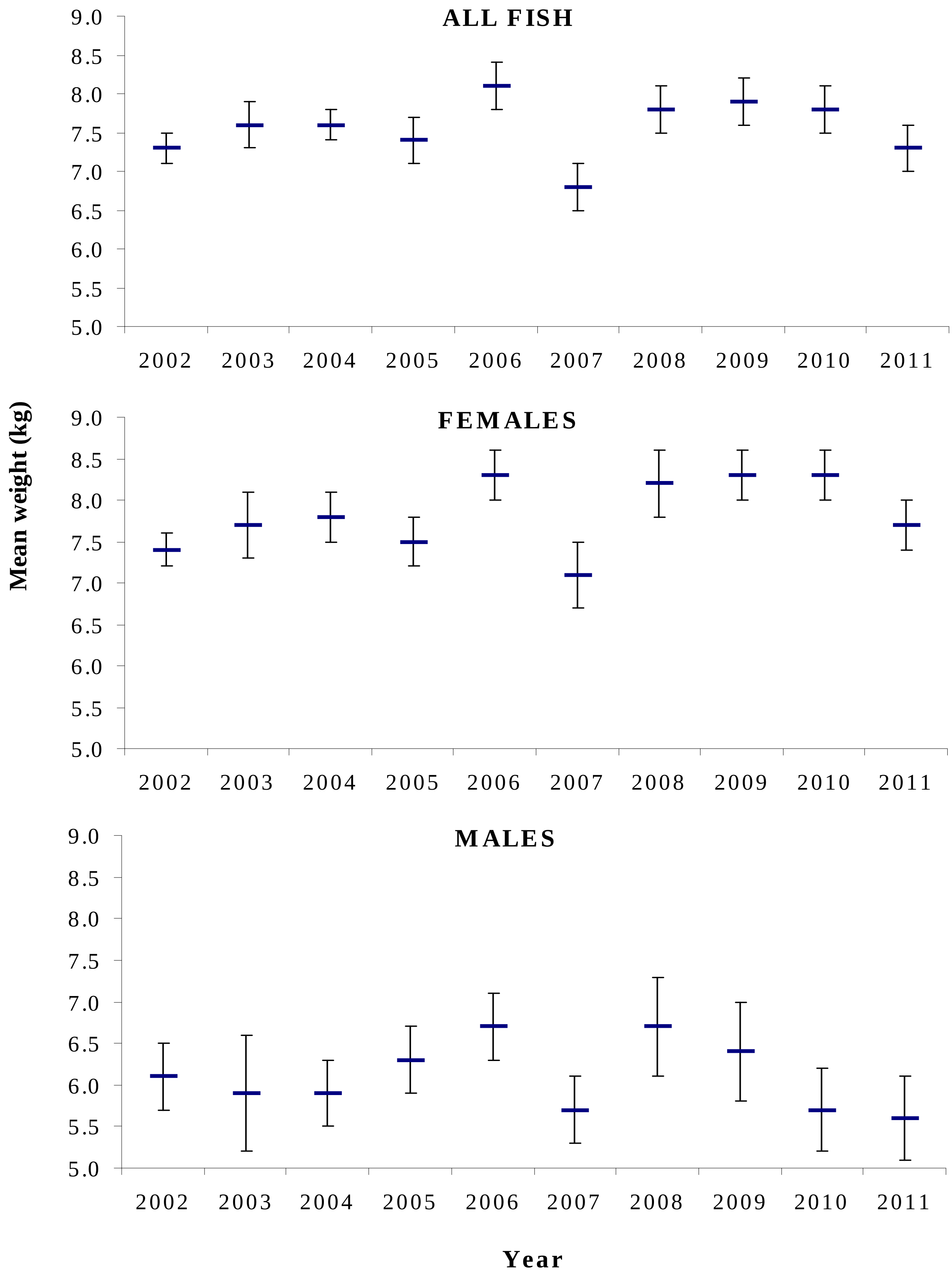


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

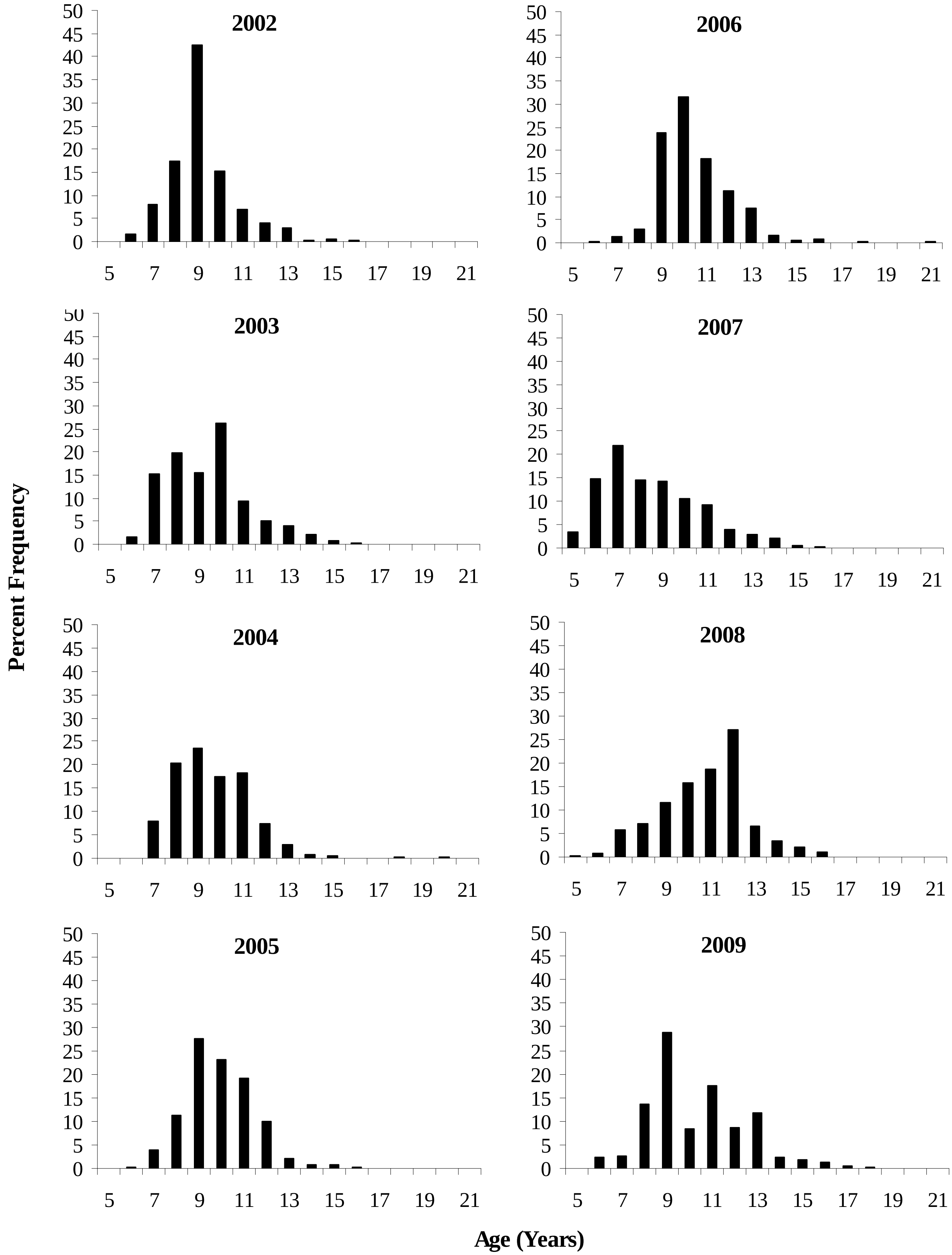


Figure 6. Continued.

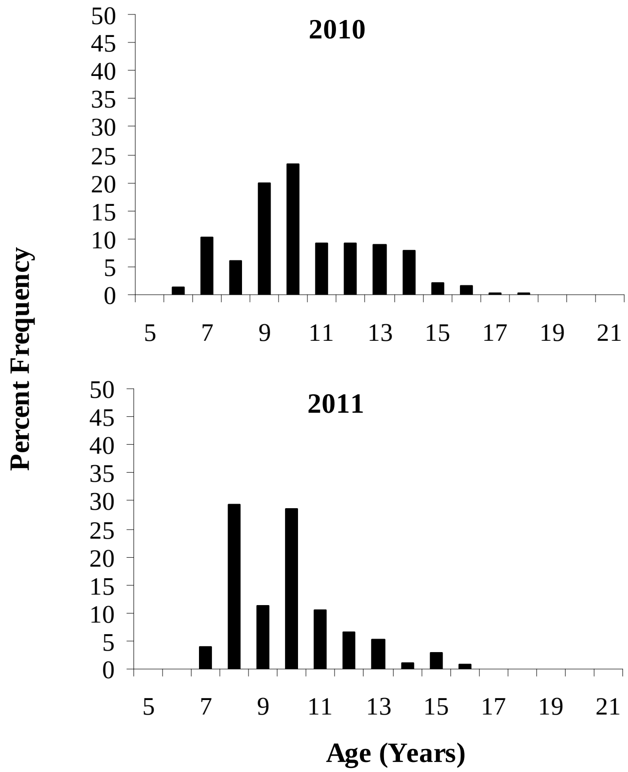


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

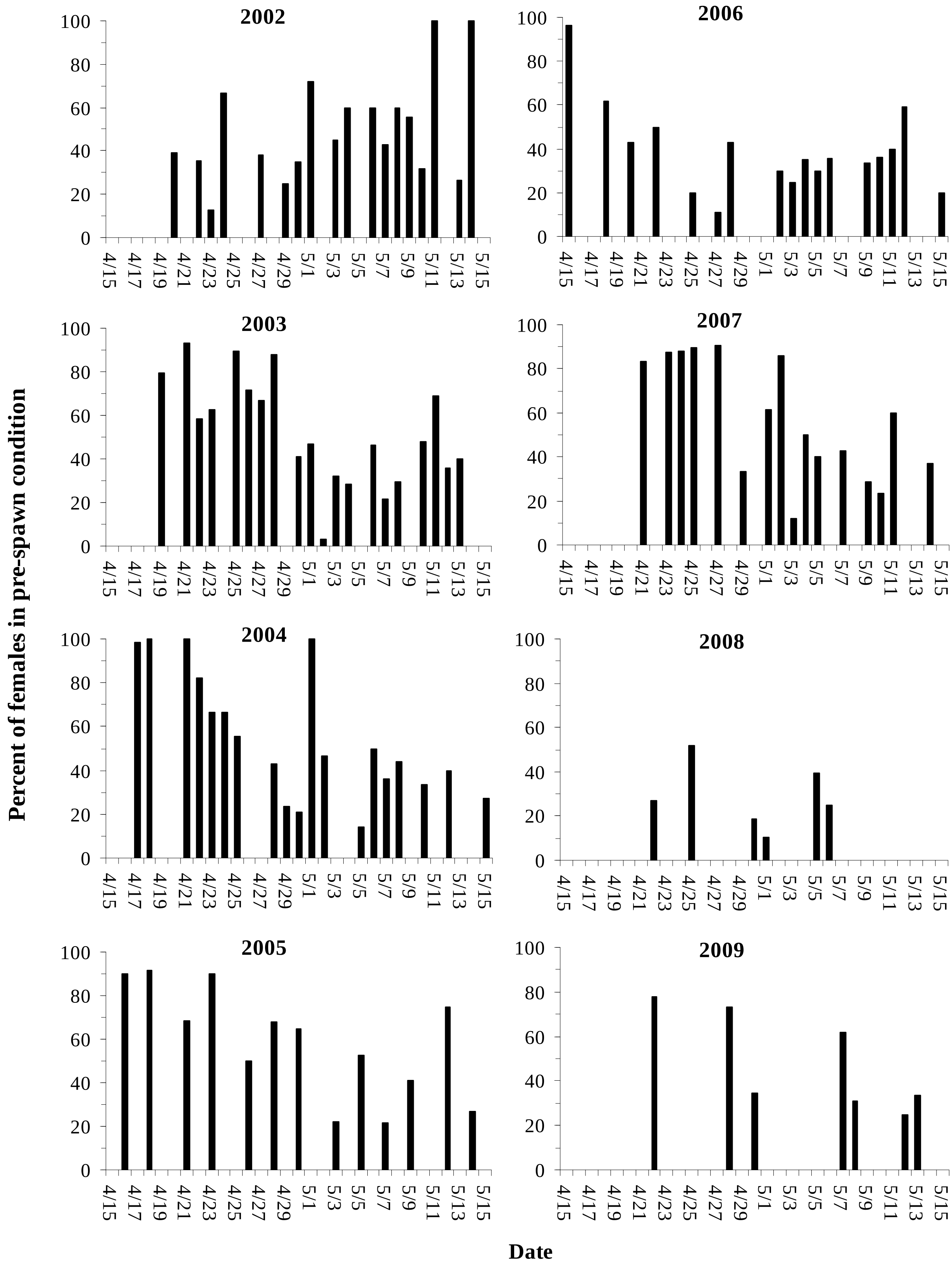


Figure 7. Continued.

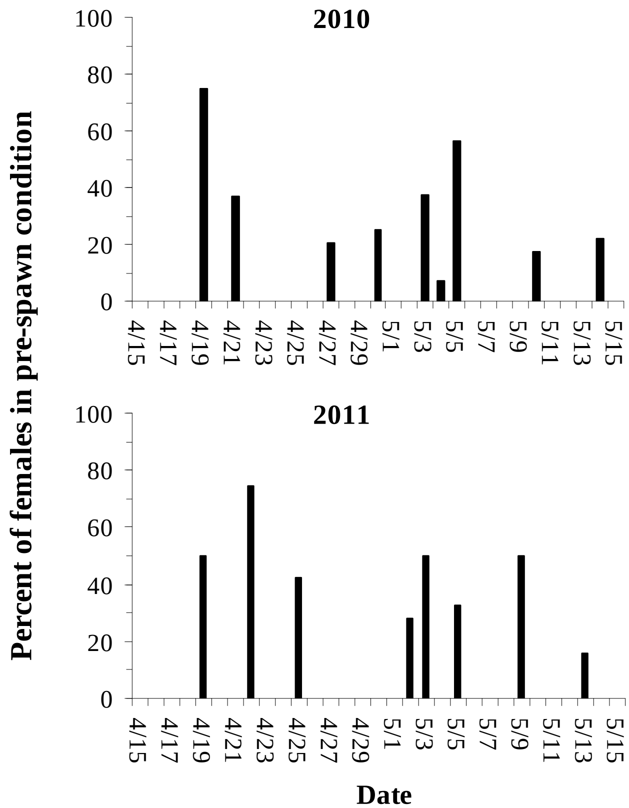
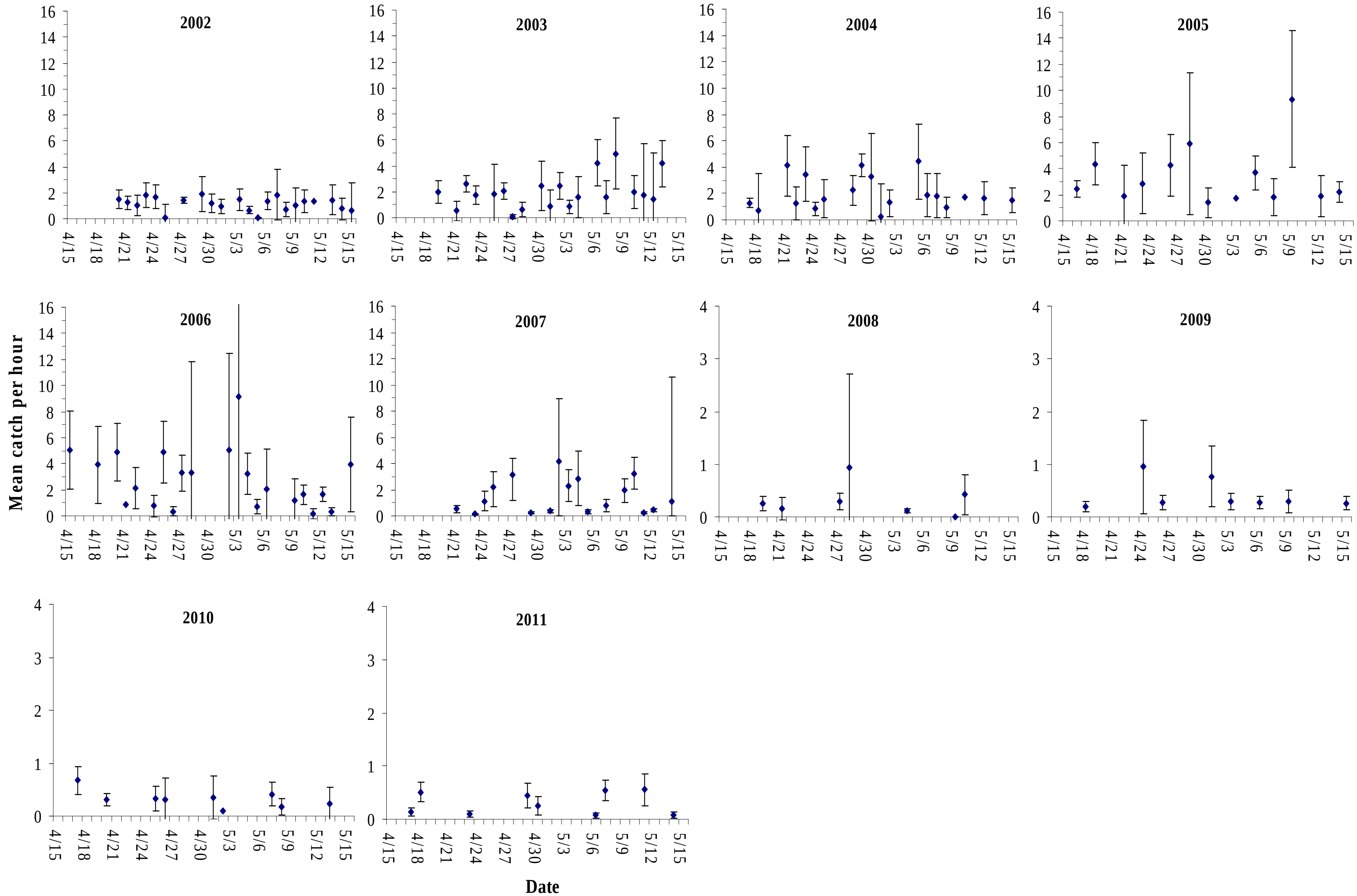


Figure 8. Daily mean catch per hour (CPH) of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15. Note different scale since 2008.



<u>APPENDIX I</u>

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

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

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

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

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

5.) How many lines were you fishing?

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

7.) What is your state of residence?

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

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

PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDINATION

Prepared by 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 Chesapeake Bay Living Resources Subcommittee (CBLRS), the Mid-Atlantic Migratory Fish Council (MAMFC), 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, SBSA project 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 project data directly. The web page, http://www.dnr.state.md.us/fisheries/juvindex/index.html, is updated annually in October. Monthly visits to the web page for the period December 2010 to January 2012 are presented in Table 1. Increased traffic on the web page in March and April coincided with the opening of the spring striped bass season and public interest in the status of the striped bass stock. An additional increase in volume in October 2011 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 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, December 2010 to January 2012

Date	Visits
Dec 31, 2010-Jan 28, 2011	2,125
Jan 29-Feb 25	196
Feb 26-Mar 25	18,237
Mar 26-Apr 22	43,253
Apr 23-May 20	18,386
May 21-June 17	2,674
June 18-July 15	2,577
July 16-Aug 12	3,048
Aug 13-Sept 9	2,388
Sept 10-Oct 7	2,689
Oct 8-Nov 4	4,317
Nov 5-Dec 2	2,686
Dec 3-Dec 30	2,511
Dec 31, 2011-Jan 27, 2012	2,443
TOTAL	107,530

Project staff also provided Maryland striped bass data and biological samples such as scale and finfish samples, to other state, federal, private and academic researchers. These included the National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), University of Maryland, University of Massachusetts, Virginia Institute of Marine Sciences, Georgetown University, the Pennsylvania State University, Stony Brook University, the Hudson River Foundation, and the states of Delaware, Massachusetts, New York and Virginia. For the past contract year, (October 1, 2010 through October 31, 2011) 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, American shad and river herring CPUE data.

-Dr. Robert Aguilar, Smithsonian Environmental Research Center (SERC).
Provided striped bass juvenile index data,

-Ms. Robin Arnetta. U.S. Army Corp. of Engineers.
Provided finfish community data from the Choptank River.

-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

- 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 recreational survey data, results of fishery dependent monitoring programs and ASMFC Striped Bass Compliance Report information.

- 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.

-University of Maryland (U MD - CEES), Chesapeake Biological Laboratory and Horn Point Environmental Laboratory.
Provided five (5) staff and students with current striped bass juvenile index data, American shad juvenile index data, recreational and commercial landings data, and biological samples.

-The Interjurisdictional Project also provided related biological information and reports to thirty five (37) additional scientists, students and concerned stakeholders.