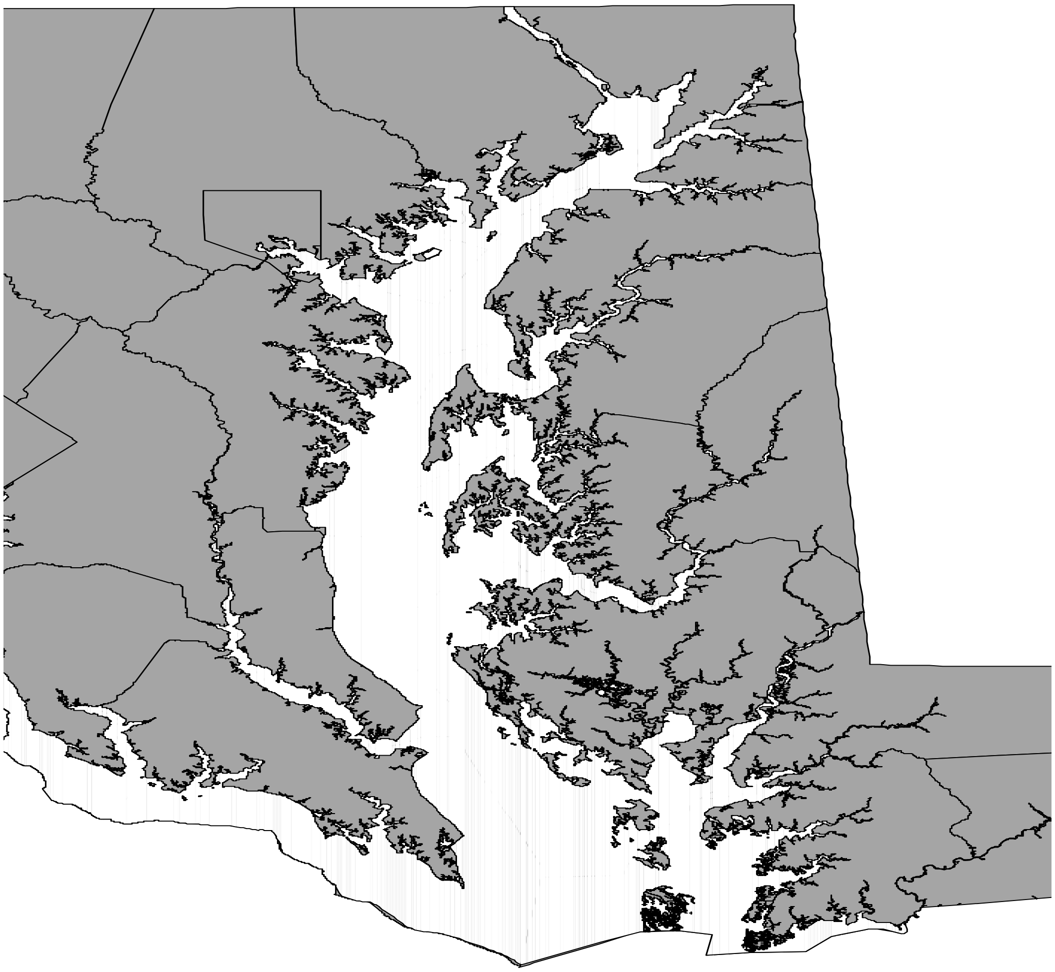


Chesapeake Bay Finfish Investigations

US FWS FEDERAL AID PROJECT
F-61-R-6
2009 - 2010

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley
Governor

Anthony G. Brown
Lt. Governor

Fisheries Service
Chesapeake Finfish Program
Tawes State Office Building
580 Taylor Avenue
Annapolis, Maryland 21401

John R. Griffin
Secretary

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

STATE: Maryland

PROJECT NO.: F-61-R-6

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2009 through October 31, 2010

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.

Yellow perch population abundance, biomass, instantaneous fishing mortality (F) and recruitment (N at age 3) were determined using a statistical catch at age model for Head-of-Bay (HOB) yellow perch. In addition, biological reference points were updated using a spawning stock biomass per recruit model. Target ($F_{35\%}$) and limit ($F_{25\%}$) F were defined as 0.53 and 0.82, respectively. Population abundance (age 3 and older) was generally stable, ranging from 828,000 fish to 972,000 yellow perch during 2005 – 2010. Maximum abundance occurred in 1999 (1.6 million yellow perch). Terminal year (2010) abundance was estimated as 972,000. Biomass was estimated at 187,000 kg in 2010. The time series low 102,000 kg in 2005. The recent abundance and biomass estimates indicated that the population has been fairly stable since 2006. Instantaneous fishing mortality ranged from 0.03 to 1.12 over the time period 1998 – 2010. Fishing mortality has generally been around 0.20 since 2006. Fishing mortality was below the target in 2010 and bootstrap analysis indicated a 0.07% chance that F exceeded the target. Therefore, overfishing was not occurring in the HOB. No biomass or abundance reference points have been determined. Recruitment has been near average since 2007, except for a poor recruiting year-class in 2009. Choptank River yellow perch were assessed with relative abundance indices from a fishery

independent fyke net survey (1988 – 2010). Time-series analysis showed an increasing trend, suggesting continual expansion of that yellow perch population. Exploitation was estimated to be at very low levels. Mortality was below target levels in the Choptank River, also.

American shad abundance estimates in the lower Susquehanna River increased in 2010, but was still below the time series mean, and well below the peak values from earlier in the decade. Populations of American shad in Maryland continue to be impacted by predation, bycatch and turbine mortality. The bay-wide juvenile American shad index has been near the long- term mean for the past three years.

Hickory shad stocks in the upper Chesapeake Bay continue to demonstrate stable population characteristics as indicated by their stable abundance estimates, low mortality rates, and diverse age structure and spawning history. River herring abundance indices for 2010 continue to be very low and populations throughout Maryland waters demonstrated characteristics of overfishing, including truncated age structure, few repeat spawner's and poor juvenile production. River herring and American shad stocks are projected to remain low for the next several years, until rebuilding can occur.

Weakfish have experienced a sharp decline in coast wide abundance. 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 (2,134 fish in 2009). Maryland's commercial weakfish harvest declined to 4,888 pounds in 2009, and was the lowest catch on record. The 2009 mean length for weakfish from the onboard pound net survey was 253mm TL, the lowest of the time series. The 2009 length frequency distribution and RSD analysis indicate that only smaller weakfish were available in Maryland waters. Fish aged from the 2009 pound net survey were all 2 years of age or younger.

Summer flounder mean length from the pound net survey was 374 mm TL in 2010, the highest mean value estimated for the 18 year survey. Relative stock densities in the 2010 fisheries dependent pound net survey indicated a slight increase in the stock and memorable categories with a corresponding decrease in the quality category compared to 2009. Charter boat CPUEs have declined from 1993 - 2003, but have been relatively stable for the past six 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 2010 was 297 mm TL, similar to the time series mean. Length distribution and RSD analysis indicated a continued dominance of smaller bluefish in 2010. Recreational bluefish harvest estimates declined in 2009, but commercial harvests increased, both were 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 2010 was 295 mm TL; this was equal to the time series mean length. For Atlantic croaker from the onboard pound net survey $RSD_{memorable}$ and RSD_{trophy} fish declined in 2010 while the $RSD_{quality}$ category increased. Croaker aged from the 2009 survey ranged from 0 – 8 years old. Maryland Atlantic croaker total commercial harvest decreased to 448,550 pounds; while the 2009 recreational harvest estimated of 689,184 fish increased compared to 2008. In contrast, the 2009 charter boat geometric catch per angler was the highest of the 17 year time series.

Spot length frequency distribution expanded slightly in 2010 after exhibiting truncated distributions the previous 2 years. The mean length for spot increased to near the average of the time series. Juvenile indices have been lower in recent years, but spiked to the time series high in 2010. Commercial harvests increased sharply in 2009, while the recreational estimate remained similar to 2008. The charter boat geometric mean catch per angler also increased in 2009, remaining above the long -term mean.

Resident / premigratory striped bass harvested in the Chesapeake Bay during the summer – fall 2009 pound net and hook and line commercial fisheries ranged from 1 to 16 years of age. Two year old (2007 year-class), four year old (2005 year-class), and five year old (2004 year-class) striped bass dominated samples taken from pound nets, comprising 79% 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 2003, 2004, and 2005 year-classes.

The 2009-2010 commercial striped bass drift gill net fishery harvest was comprised primarily of fish between 4 and 6 years old from the 2004, 2005 and 2006 year-classes. Striped bass from the 2005 year-class (five year old fish) comprised 29% of the total drift gill net harvest. The 2006 and 2004 (ages 4 and 6) cohorts accounted for 49% of the total harvest while age 8 to 12 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 3 to 12 (1998 – 2007 year-classes).

The spring, 2010 spawning stock survey indicated that there were 17 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 18 years old. Male striped bass ranged in age from 2 to 15 years old, with 3 year old and 5 year old males being the most abundant component of the male striped bass spawning stock. Age 14 (1996 year-class) females were the major contributors to the 2010 total female abundance. Age 8 and older females comprised 94% of the female spawning stock in 2010, a slight increase from 2009

The 2010 striped bass juvenile index, the annual measure of striped bass spawning success in Chesapeake Bay, was 5.6. This is below the average long-term average of 11.6. During the survey, biologists identified and counted more than 37,000 fish of 50 species, including 737 young-of-year

(YOY) striped bass. Variable reproductive success is a normal condition of striped bass populations. Typically, several years of average reproduction are interspersed with occasional large and small year-classes. Large year-classes in successful spawning years like 2001, 2003 and 2005 bolster the population by offsetting less successful years. The largest year-class ever measured occurred in 1996.

Other species present in higher than normal abundance during the 2010 juvenile striped bass survey were spot, yellow perch and river herring. YOY spot, a species important as forage and popular among recreational anglers, were abundant and widespread in the Bay. Spot reproduction was the highest documented since 2005. White perch reproduction was above average in the Upper Bay, and average (healthy) bay-wide. River herring reproduction rebounded slightly from consecutive years of below average reproduction to values similar to 2007. Any increase in herring reproduction is encouraging because adult river herring populations remain at low levels and face many challenges including blockages to upstream migration and degraded water quality.

During the 2010 trophy season, biologists intercepted 238 fishing trips, interviewed 601 anglers, and examined 263 striped bass. The average total length of striped bass sampled was 913 mm total length (mm TL) (35.9 inches), which was the same as in 2009. The average weight was 7.8 kg (17.1 lbs). Most fish sampled from the trophy fishery were between seven and fourteen years old. The 2000 year-class (age 10) was the most frequently observed year-class, constituting 23% of the sampled harvest. Average catch rate based on angler interviews was 0.5 fish per hour.

MD DNR biologists continued to tag and release striped bass in 2010 as part of an interstate, coastal population study for growth and mortality. A total of 1,388 striped bass were tagged and released with USFWS internal anchor tags. Of this sample, 821 were tagged in the Chesapeake Bay during the spring spawning stock assessment survey. A total of 567 striped bass were tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise.

APPROVAL

Lynn Waller Fegley, Assistant Director
Estuarine & Marine Fisheries Division
Maryland Fisheries Service
Maryland Department of Natural Resources

Dale Weinrich, Chief
Chesapeake Finfish Program
Estuarine & Marine Fisheries Division
Maryland Fisheries Service
Maryland Department of Natural Resources

ACKNOWLEDGEMENTS

The Maryland Department of Natural Resources (MD DNR) would like to thank the Maryland Watermen's Association commercial captains and their crews who allowed us to sample their commercial catches. We also wish to thank RMC Environmental Services personnel for their aid in acquiring tag returns and catch data from the fish lifts at Conowingo Dam. Appreciation is also extended to MD DNR Hatchery personnel, Brian Richardson and staff for otolith analysis of juvenile and adult American shad and to Connie Lewis, Fisheries Statistics, for providing commercial landings. We would also like to express appreciation to 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 Joseph Kennedy and Robert Boarman.

PROJECT STAFF

Dale Weinrich, Survey Leader

Harry T. Hornick
Eric Q. Durell
Beth A. Versak
Lisa D. Warner
Angela M. Giuliano
Jeffrey R. Horne
Amy L. Batdorf
Stephanie Grap
Katherine Skogen

Paul Piavis
Edward J. Webb, III
Bruce H. Pyle
Harry W. Rickabaugh
Robert A. Sadzinski
Anthony A. Jarzynski
Craig Weedon
Jim Mower

CONTENTS

SURVEY TITLE: CHESAPEAKE BAY FINFISH/HABITAT INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 1
JOB NO. 1

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

METHODS

I. Field Operations

Upper Chesapeake Bay Winter Trawl

The upper Chesapeake Bay winter bottom trawl survey is designed to collect fishery-independent data for the assessment of population trends of white and yellow perch and channel and white catfish. For 2010, 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 (< 6m) and deep water (>6m). 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 long 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 2009 through February 2010.

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 sample year. Only 56 of the scheduled 108 trawls were completed.

Choptank River Fishery Independent Sampling

In 2010, 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 25 February through 7 April (Figure

2). These nets contained a 64mm stretch-mesh body and 76mm 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 from 28 February 2010 through 3 March 2010 from Back River, Middle River, and Northeast 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 22 March 2010 to 30 April 2009, 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 2010 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.

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 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 (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 Maryland Juvenile Striped Bass Survey (Project 2, Job 2, Task 3) 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 (Project 2, Job 2, Task 3). However, since the Ordinary Pt. seine site was lost because of bulkhead construction, 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 catch per unit effort (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
Channel catfish	Tables 15-17 and Figures 13-15
White catfish	Tables 18-20 and Figures 16-18

Growth

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

Mortality

White perch	Table 26
Yellow perch	Table 27

Recruitment

White perch	Figures 19-20
Yellow perch	Figures 21-22
Channel catfish	Figures 23-24

Relative Abundance

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

CITATIONS

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

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

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

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

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

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

Figure 1. Upper Chesapeake Bay winter trawl survey locations, December 2009 – February 2010. Different symbols indicate each of 6 different sampling rounds.

Figure 2. Choptank River fyke net locations, 2010. Circles indicate sites.

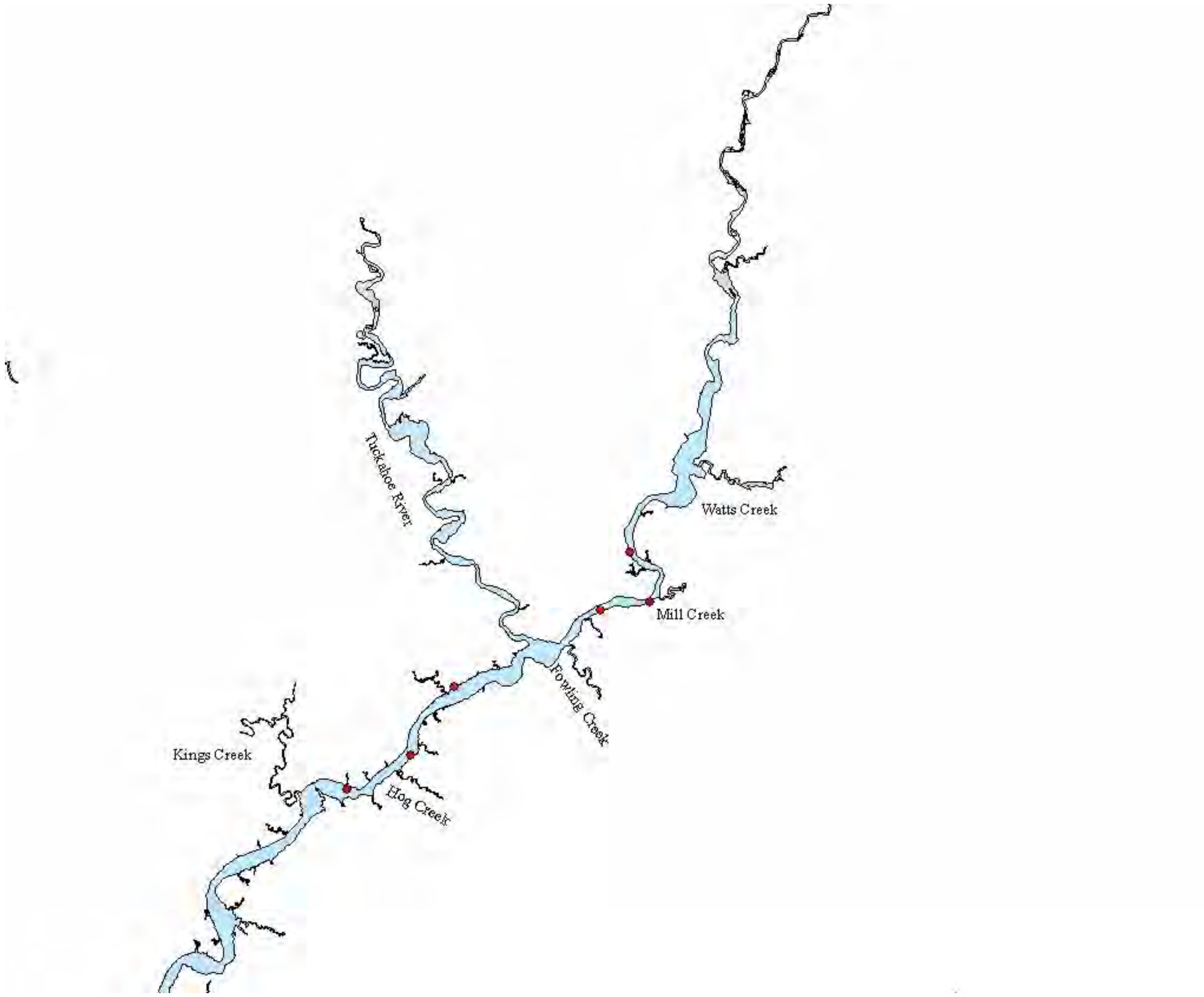


Figure 3. Commercial yellow perch fyke net sites sample during 2010 in Middle and Back rivers.

Figure 4. Commercial yellow perch fyke net sites sample during 2010 in the Northeast River. Black lines indicate the geographic range of fyke net locations.

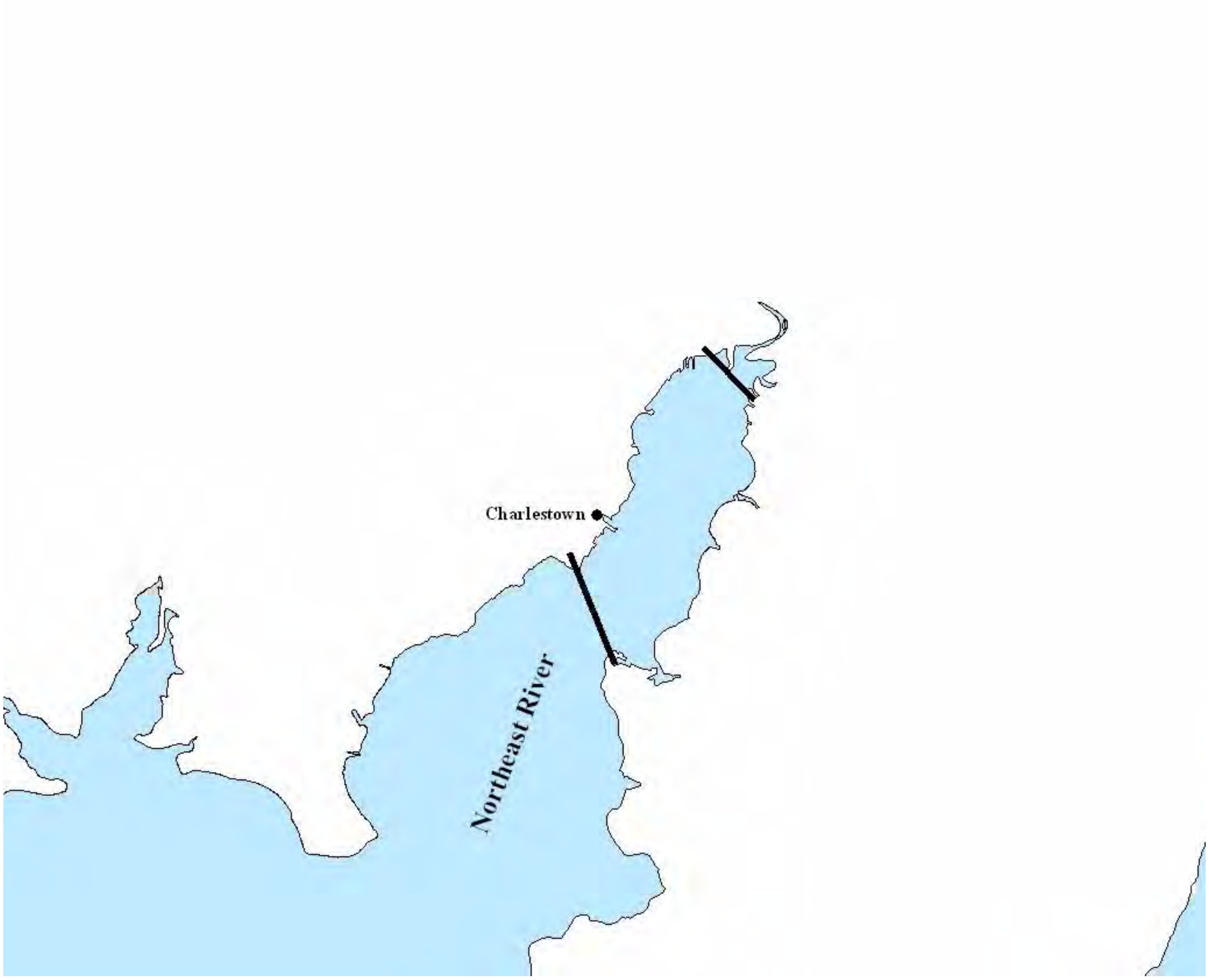


Figure 5. Commercial fyke net and pound net sites sample during 2010 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

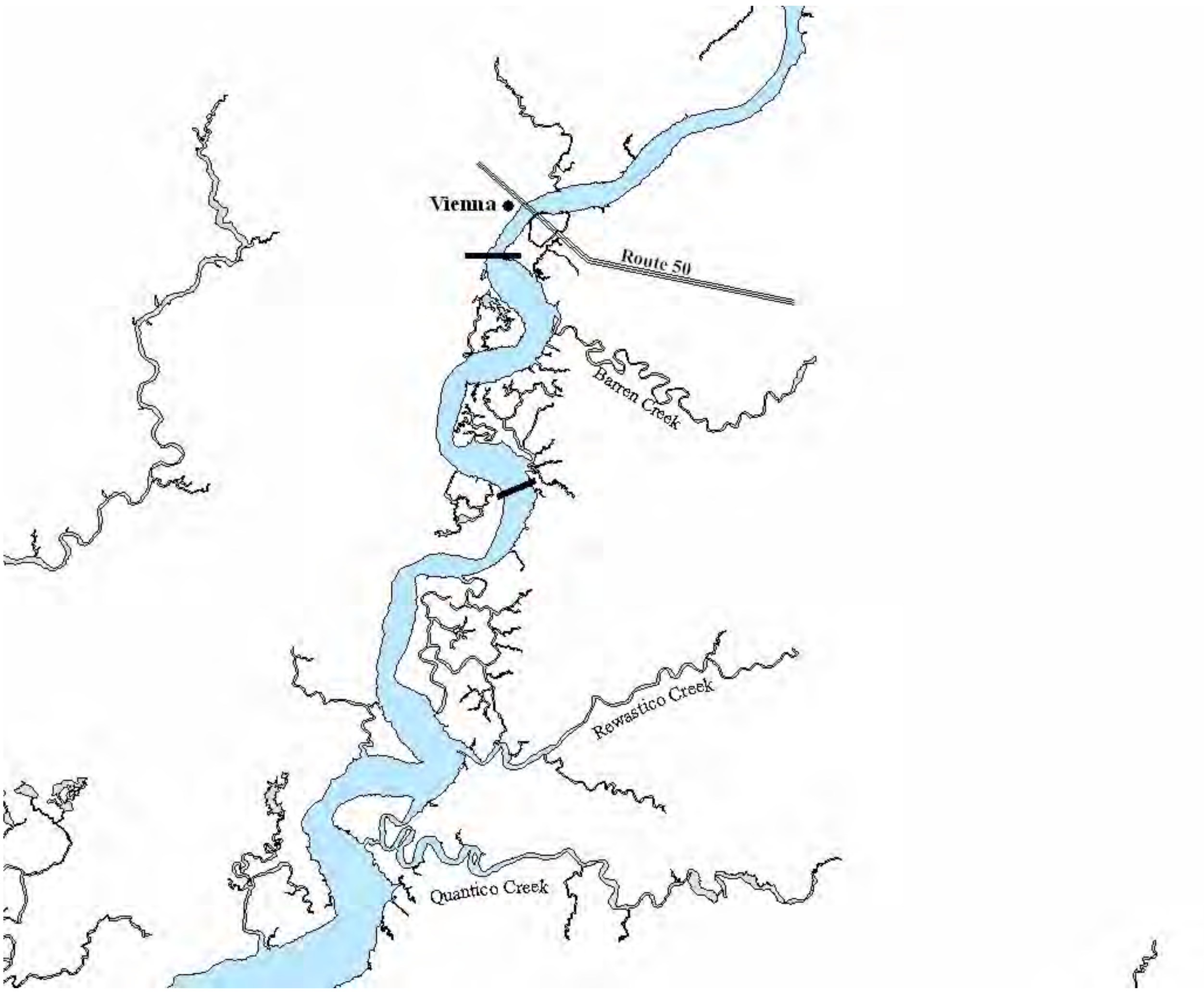


Table 1. White perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2010.

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

Table 2. White perch catch at age matrix from Choptank River fyke net survey, 2000 – 2010.

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

Table 3. White perch catch at age matrix from Nanticoke River fyke and pound net survey, 2000 – 2010. 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

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2010.

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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2010.

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

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2010.

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

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2010. 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

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2010. 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

Figure 6. White perch length-frequency from 2010 upper Chesapeake Bay winter trawl survey.

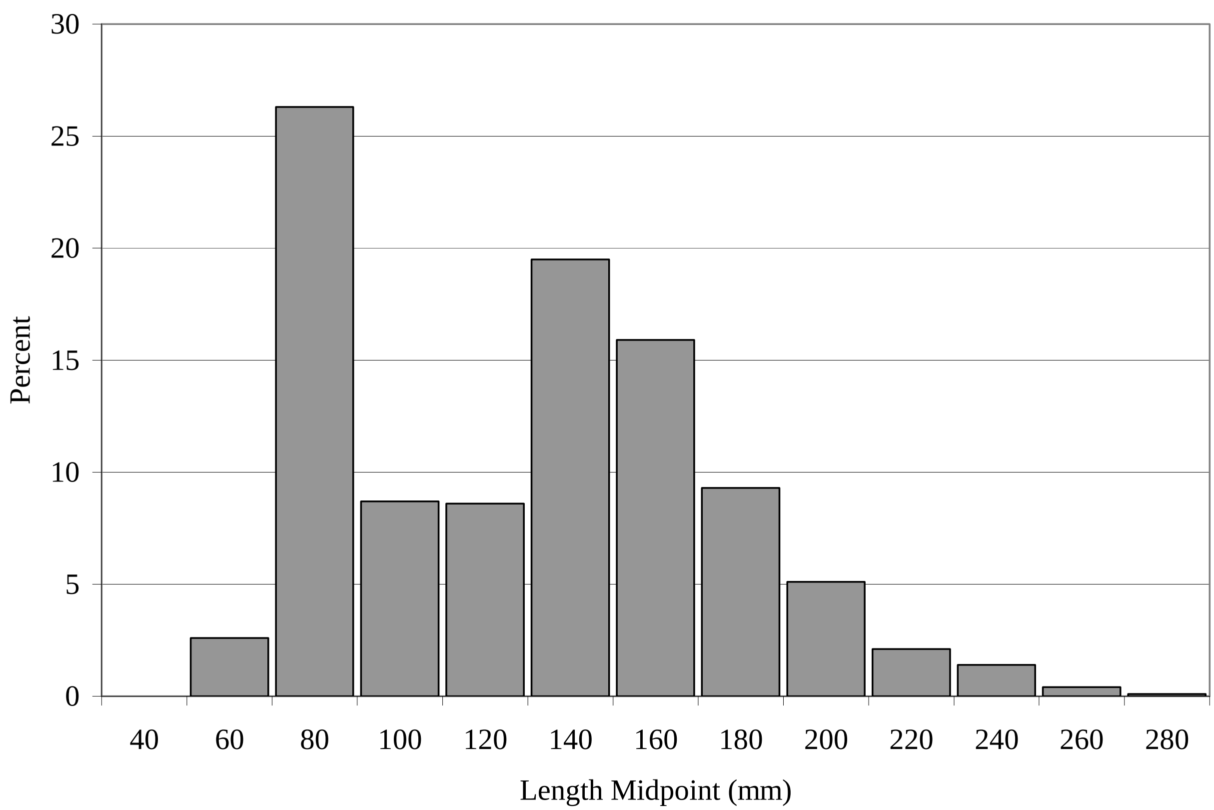


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2010. Minimum length cut-offs in parentheses.

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

Figure 7. White perch length-frequency from 2010 Choptank River fyke net survey.

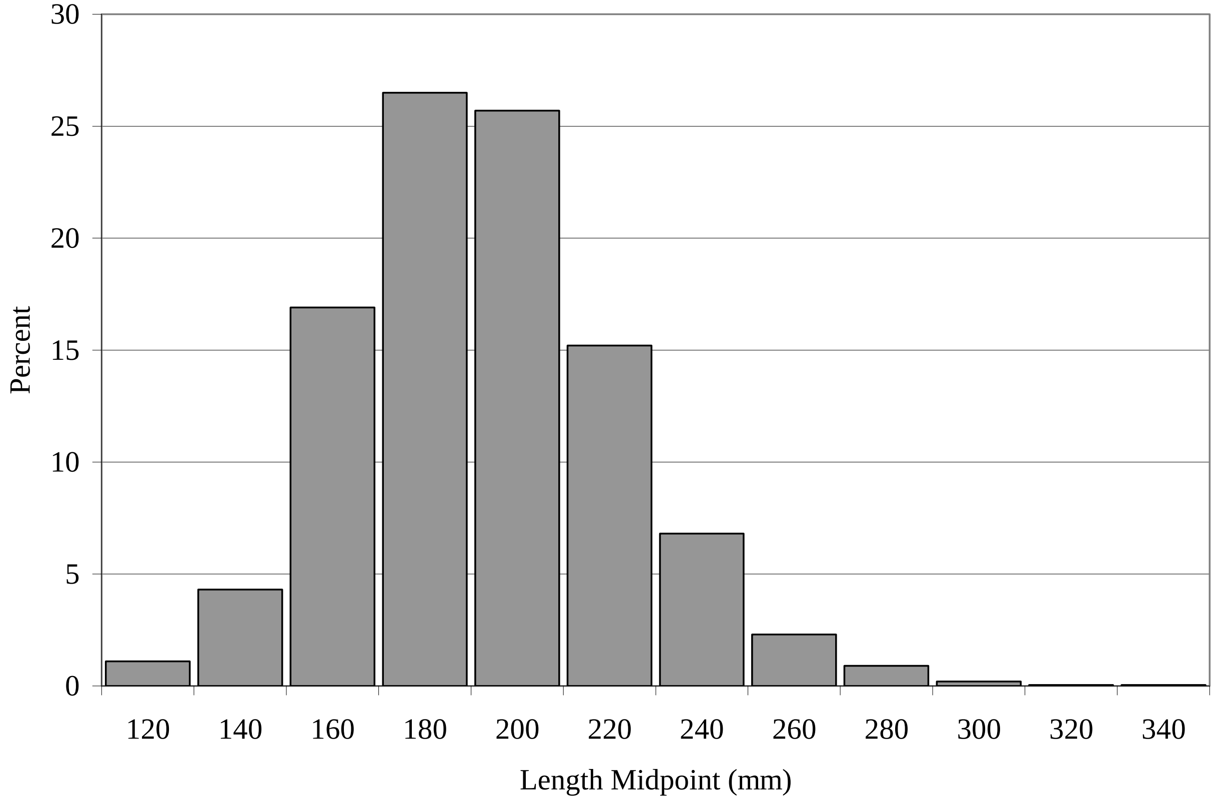


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2010. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

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

Figure 8. White perch length-frequency from 2010 Nanticoke River fyke and pound net survey, including Marshyhope River data.

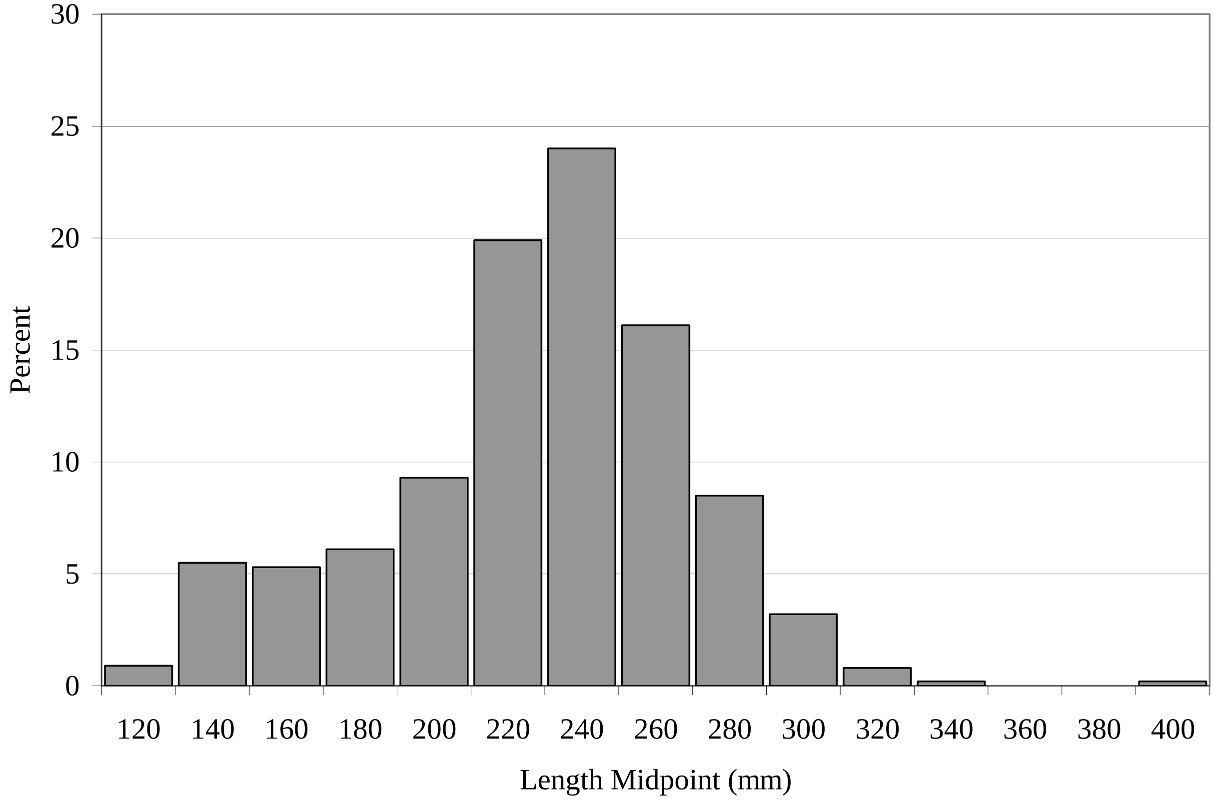


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2010. Minimum length cut-offs in parentheses.

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

Figure 9. Yellow perch length-frequency from the 2010 upper Chesapeake Bay winter trawl survey.

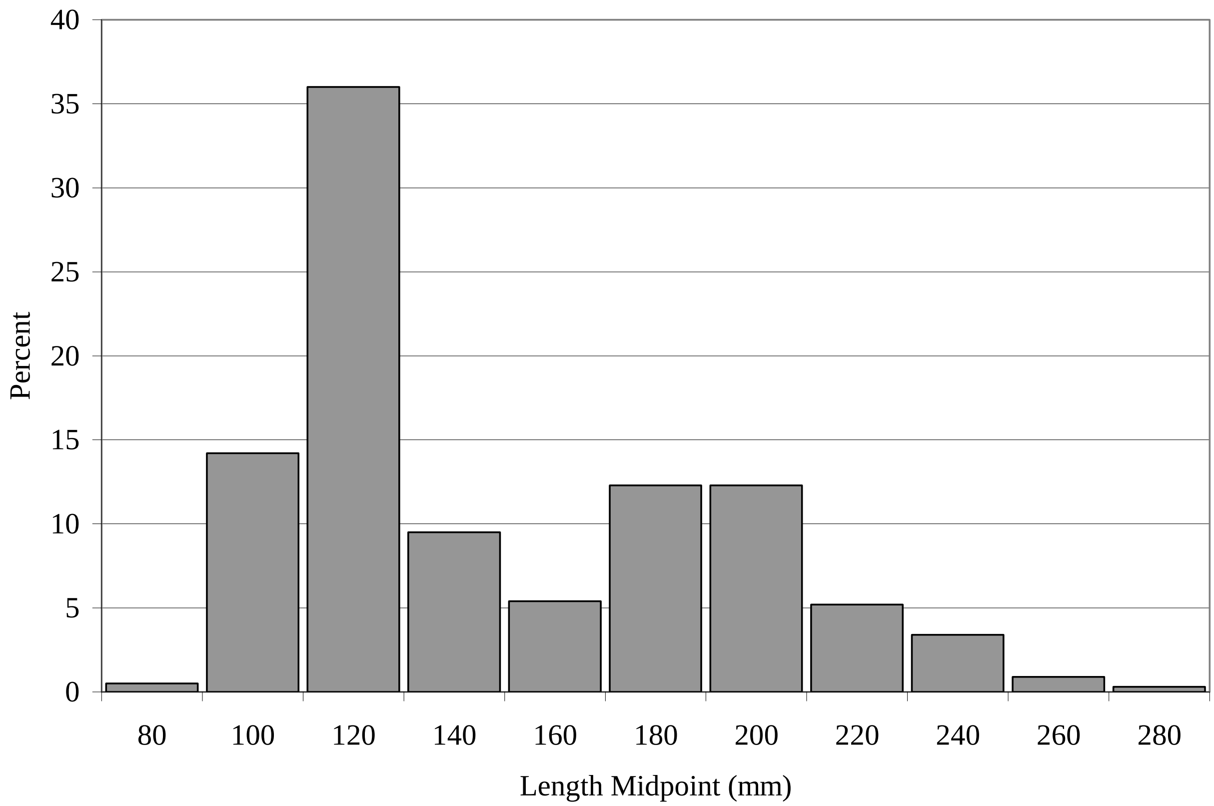


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2010. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length-frequency from the 2010 Choptank River fyke net survey.

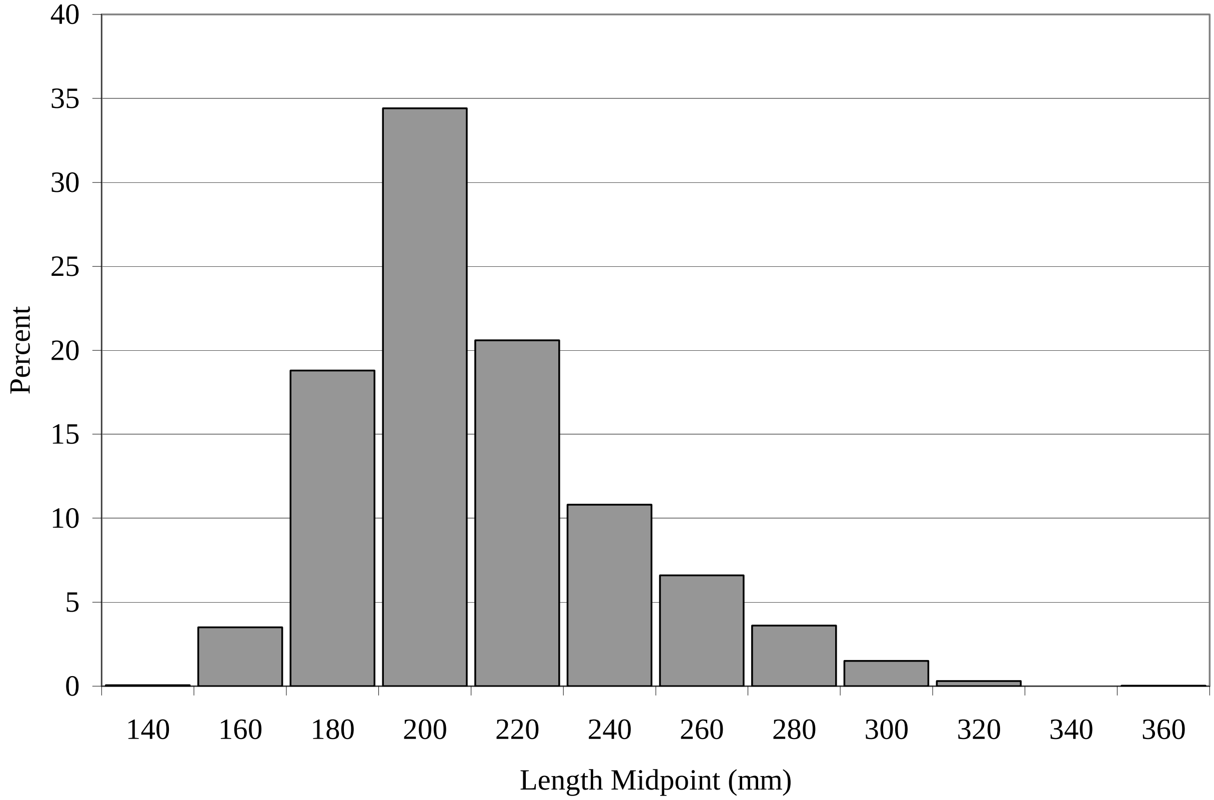


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2010. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length frequency from the 2010 upper Chesapeake commercial fyke net survey.

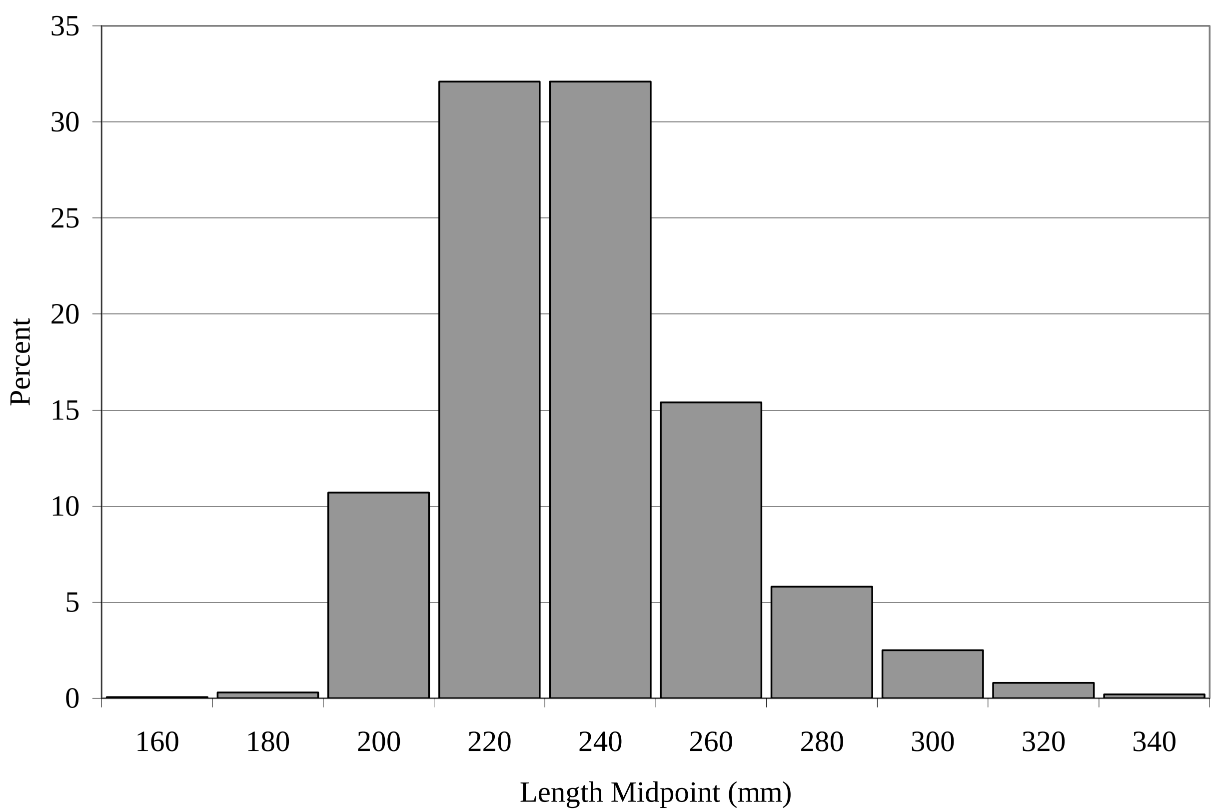


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2010. Minimum length cut-offs in parentheses; 2007-- 2009 includes Marshyhope River data.

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

Figure 12. Yellow perch length frequency from the 2010 Nanticoke River survey fyke and pound net survey.

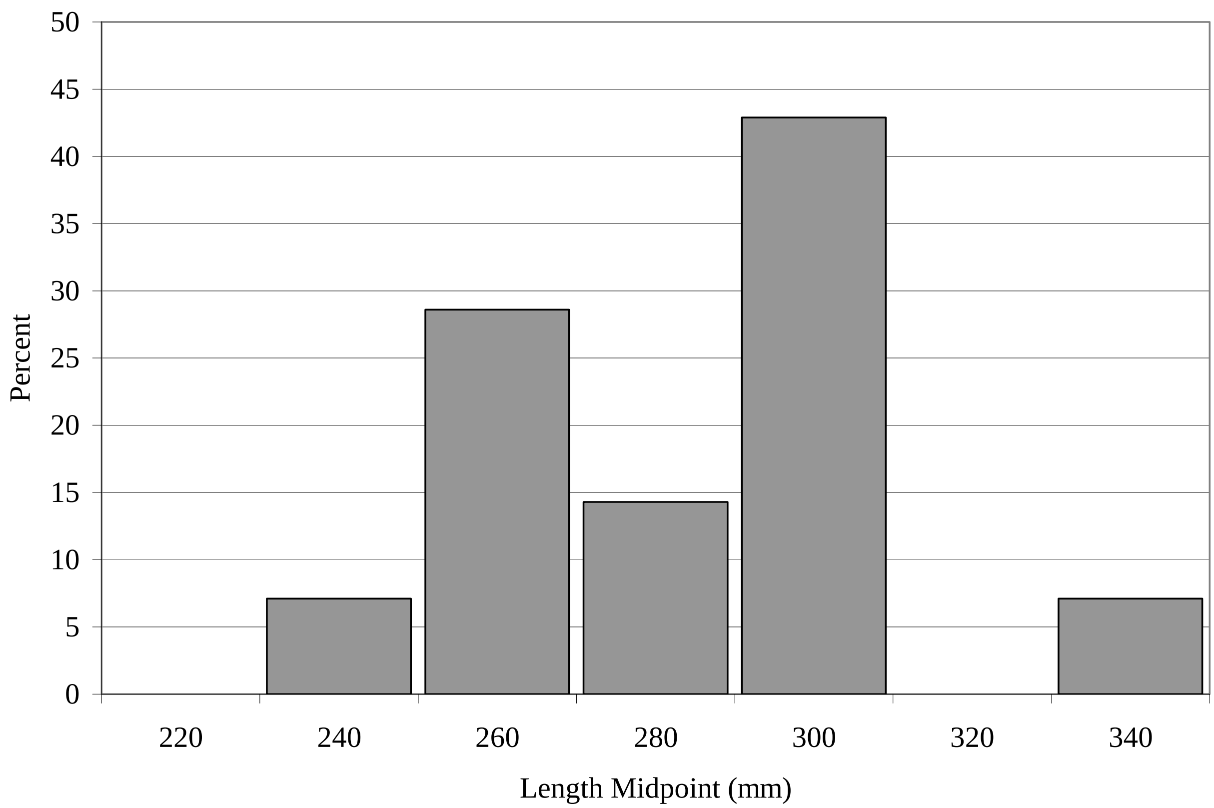


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2010. Minimum length cut-offs in parentheses.

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

Figure 13. Length frequency of channel catfish from the 2010 upper Chesapeake Bay winter trawl survey.

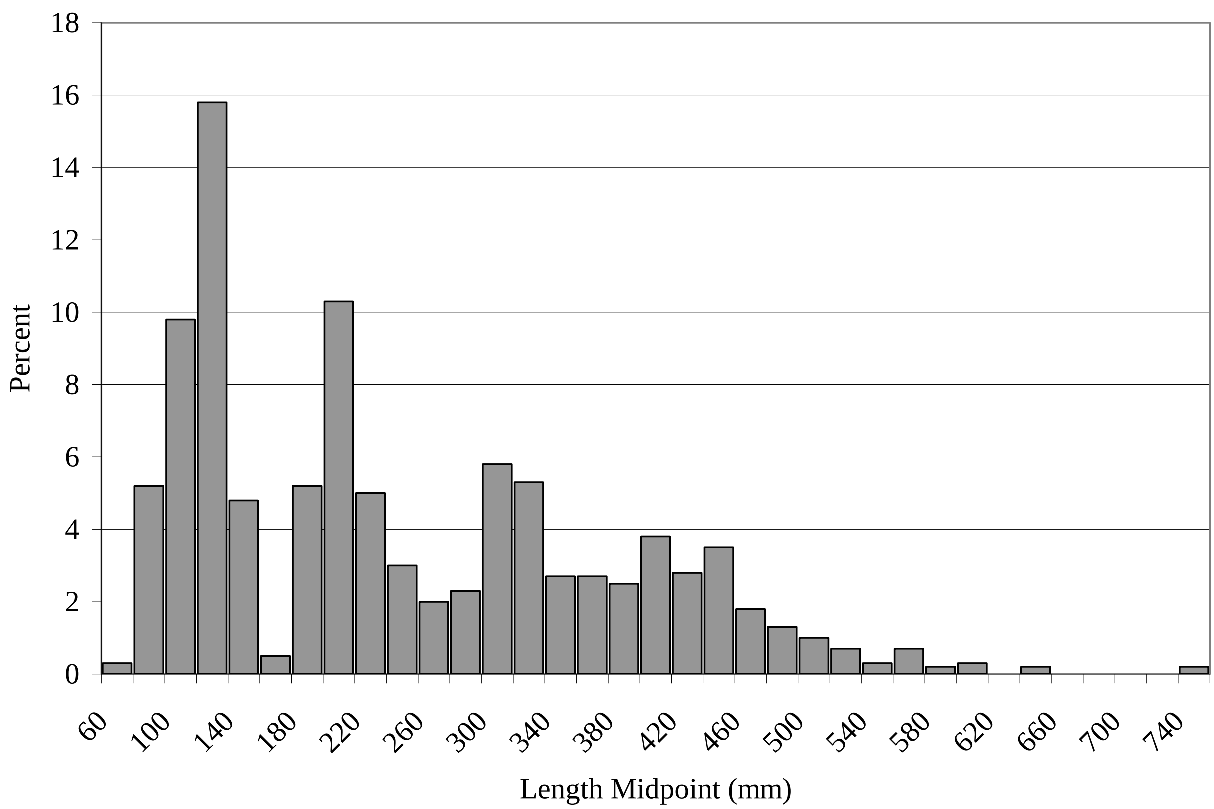


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2010. Minimum length cut-offs in parentheses.

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

Figure 14. Channel catfish length frequency from the 2010 Choptank River fyke net survey.

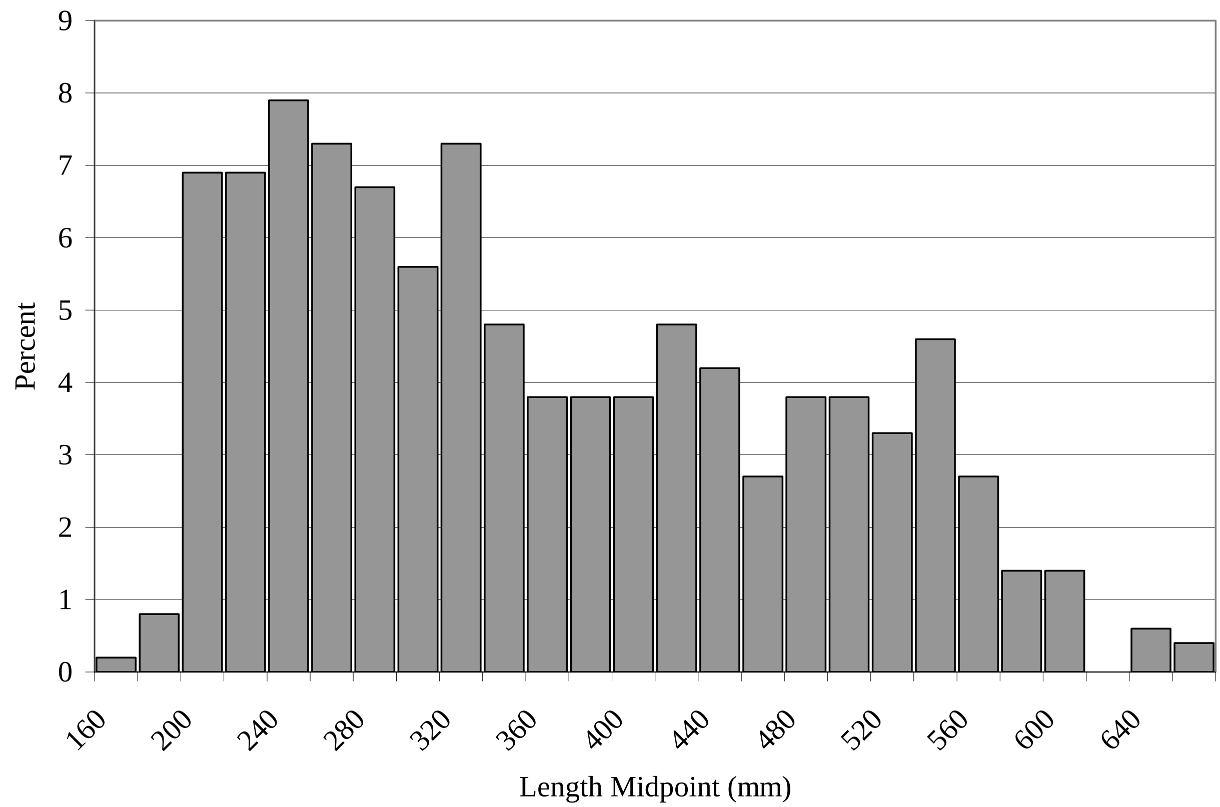


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2010. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 15. Channel catfish length frequency from the 2010 Nanticoke River fyke and pound net survey.

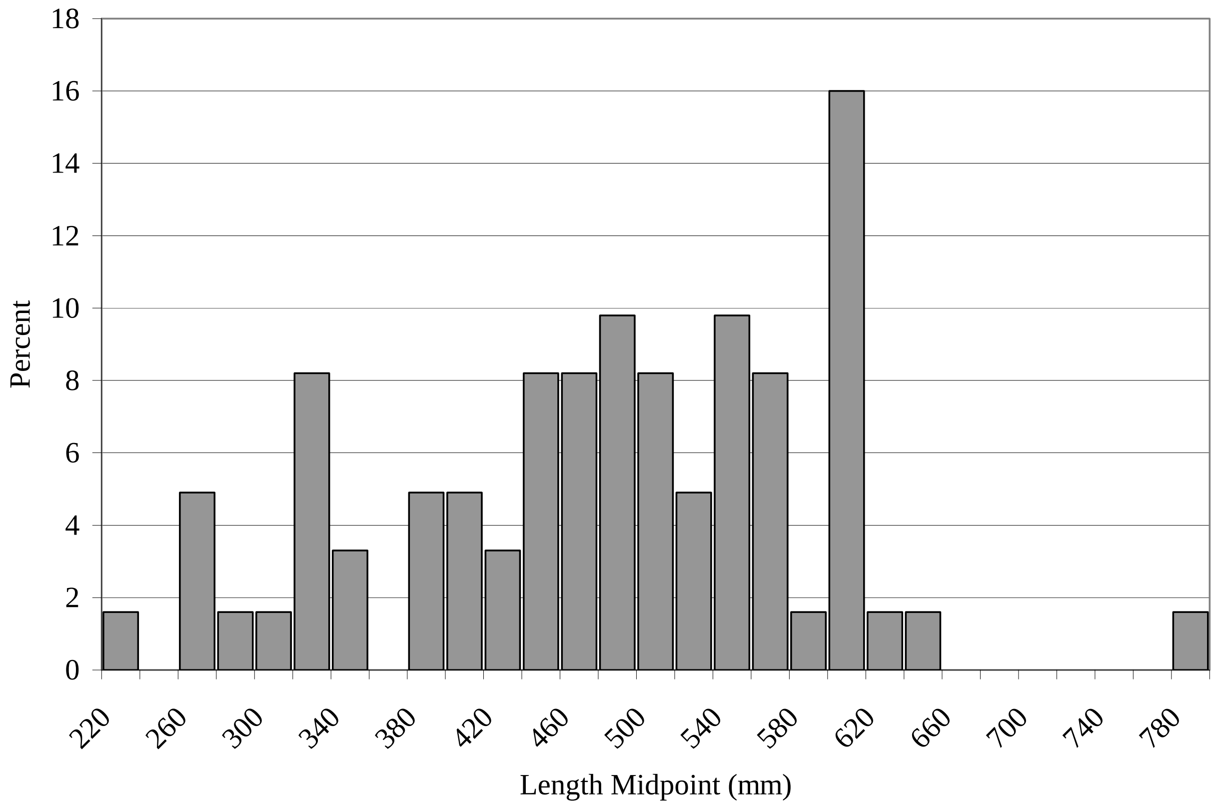


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2010. Minimum length cut-offs in parentheses.

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

Figure 16. White catfish length frequency from the 2010 upper Chesapeake Bay winter trawl survey.

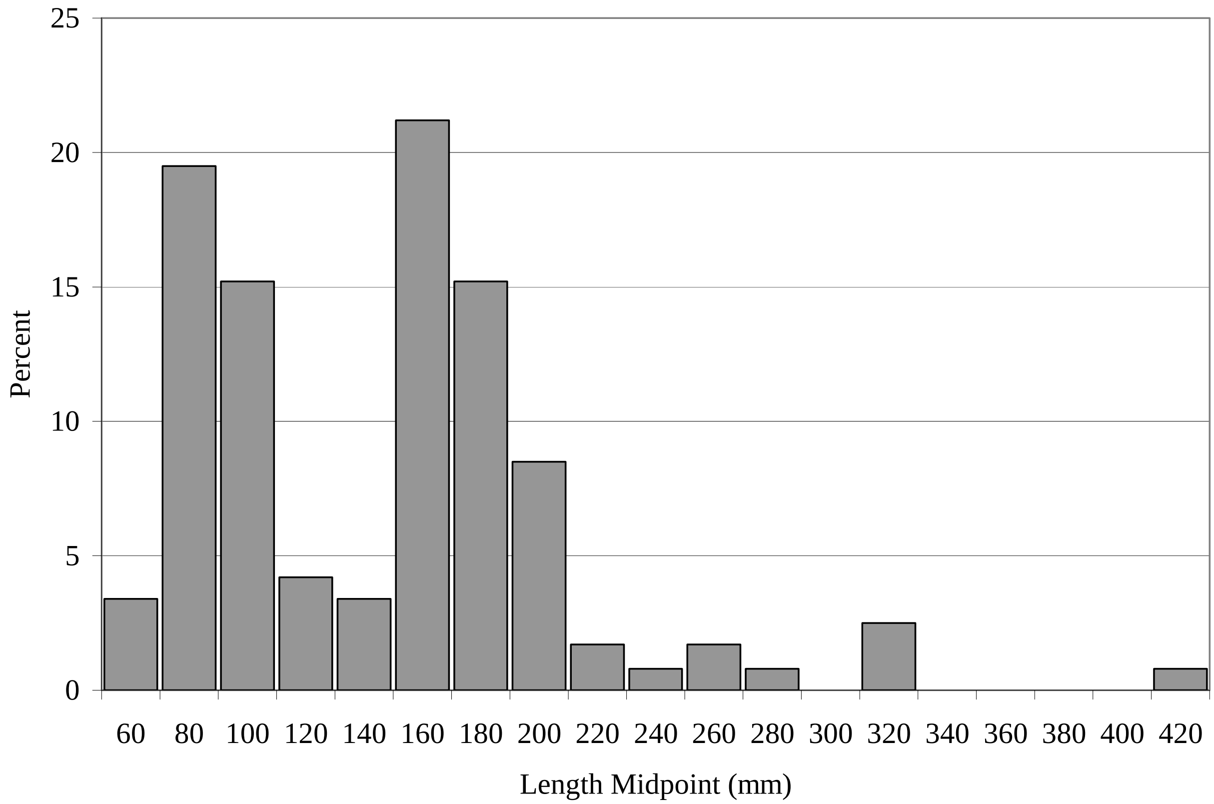


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2010. Minimum length cut-offs in parentheses.

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

Figure 17. White catfish length frequency from the 2010 Choptank River fyke net survey.

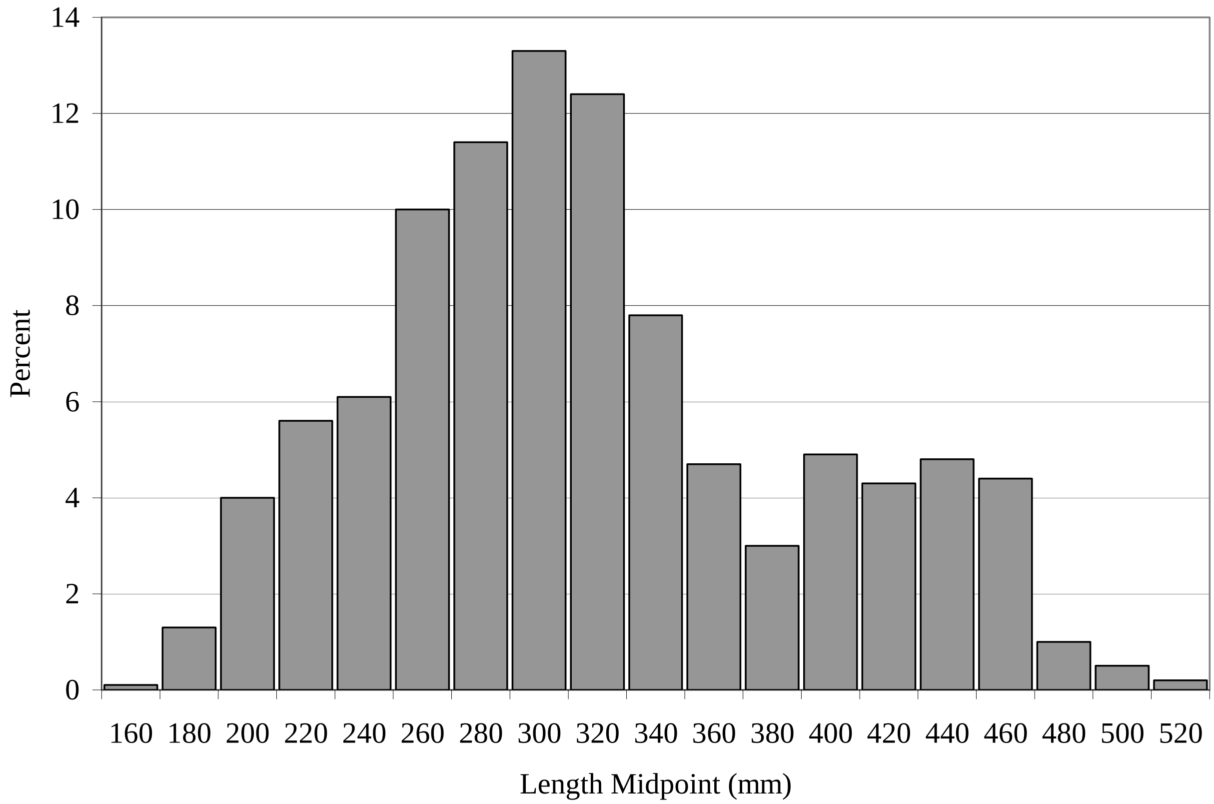


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2010. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2010 Nanticoke River fyke and pound net survey.

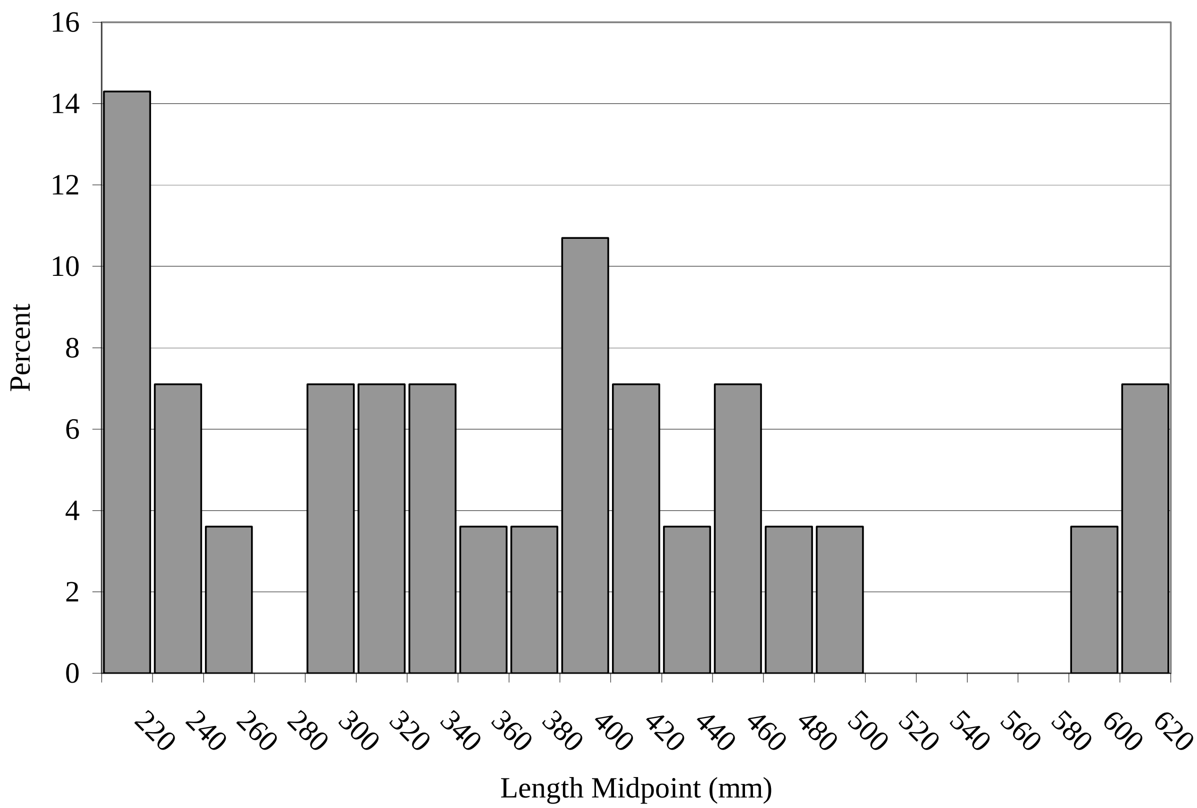


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

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
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	
2000 – 2010	F	4.9×10^{-6}	3.22	299	0.21	-1.29
	M	6.1×10^{-6}	3.16	243	0.25	-1.35
	Combined	3.4×10^{-6}	3.28	287	0.22	-1.17

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

Sample Year	Sex	alpha	beta	L-inf	K	t_0
2008	F	$4.1 X 10^{-6}$	3.25	295	0.35	0.23
	M	$8.0 X 10^{-6}$	3.12	254	0.38	-0.20
	Combined	$3.6 X 10^{-6}$	3.27	288	0.32	-0.16
2009	F	$3.4 X 10^{-6}$	3.28	285	0.33	0.47
	M	$1.4 X 10^{-4}$	2.58	273	0.18	-1.70
	Combined	$5.9 X 10^{-6}$	3.18	284	0.25	-0.33
2010	F	$1.7 X 10^{-6}$	3.41	345	0.16	-1.36
	M	$3.4 X 10^{-5}$	2.85	275	0.25	-0.46
	Combined	$2.7 X 10^{-6}$	3.32	318	0.18	-1.03
2000 – 2010	F	$X 10^{-6}$	3.16	306	0.23	-0.76
	M	$X 10^{-5}$	2.93	270	0.24	-1.08
	Combined	$X 10^{-6}$	3.20	300	0.21	-0.98

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
2007	F	2.3×10^{-5}	2.88	308	0.52	0.19
	M	1.3×10^{-5}	2.97	279	0.29	-1.40
	Combined	1.1×10^{-5}	3.02	277	0.54	-0.01
2008	F	5.8×10^{-6}	3.12	322	0.43	-0.12
	M	1.1×10^{-5}	3.00	253	0.26	-2.82
	Combined	8.1×10^{-6}	3.06	289	0.40	-0.59
2009	F	8.7×10^{-6}	3.06	315	0.40	-0.63
	M	2.8×10^{-6}	3.26	288	0.35	-0.24
	Combined	4.4×10^{-6}	2.18	308	0.29	-1.71
2010	F	1.3×10^{-5}	2.97		NSF	
	M	4.7×10^{-6}	3.16		NSF	
	Combined	9.9×10^{-6}	3.02		NSF	
2000 – 2010	F	9.9×10^{-6}	3.04	310	0.32	-1.00
	M	3.4×10^{-6}	3.22	302	0.16	-3.26
	Combined	5.1×10^{-6}	3.15	266	0.38	-1.14

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

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
1998 – 2010	F	4.83×10^{-6}	3.19	308	0.30	-1.31
	M	2.67×10^{-6}	3.27	244	0.35	-2.45
	Combined	2.20×10^{-6}	3.32	264	0.52	-0.46

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

2010	F	NSF			NSF	
	M	NSF			NSF	
	Combined	NSF			NSF	
2000 – 2010	F	4.9×10^{-6}	3.20	352	0.28	-1.41
	M	1.5×10^{-5}	2.97	294	0.32	-1.32
	Combined	1.9×10^{-6}	3.35	308	0.38	-1.06

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.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Choptank	0.48	0.25	0.46	0.1	0.58	0.58	0.40	MIN	0.35	0.99
Nanticoke	0.58	0.44	0.31	NR	NR	0.22	0.18	0.16	0.12	0.66
Upper Bay trawl	0.58	0.51	0.13	NA	0.5	0.12	0.19	0.26	0.54	0.76

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

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Choptank[1]	MIN	0.03	0.05	NR	0.08	MIN	0	NR	0.17	MIN
Upper Bay fyke[2]	0.32	0.89	0.30	0.30	0.31	0.10	0.14	0.02	0.14	0.19

[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 – 2010, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

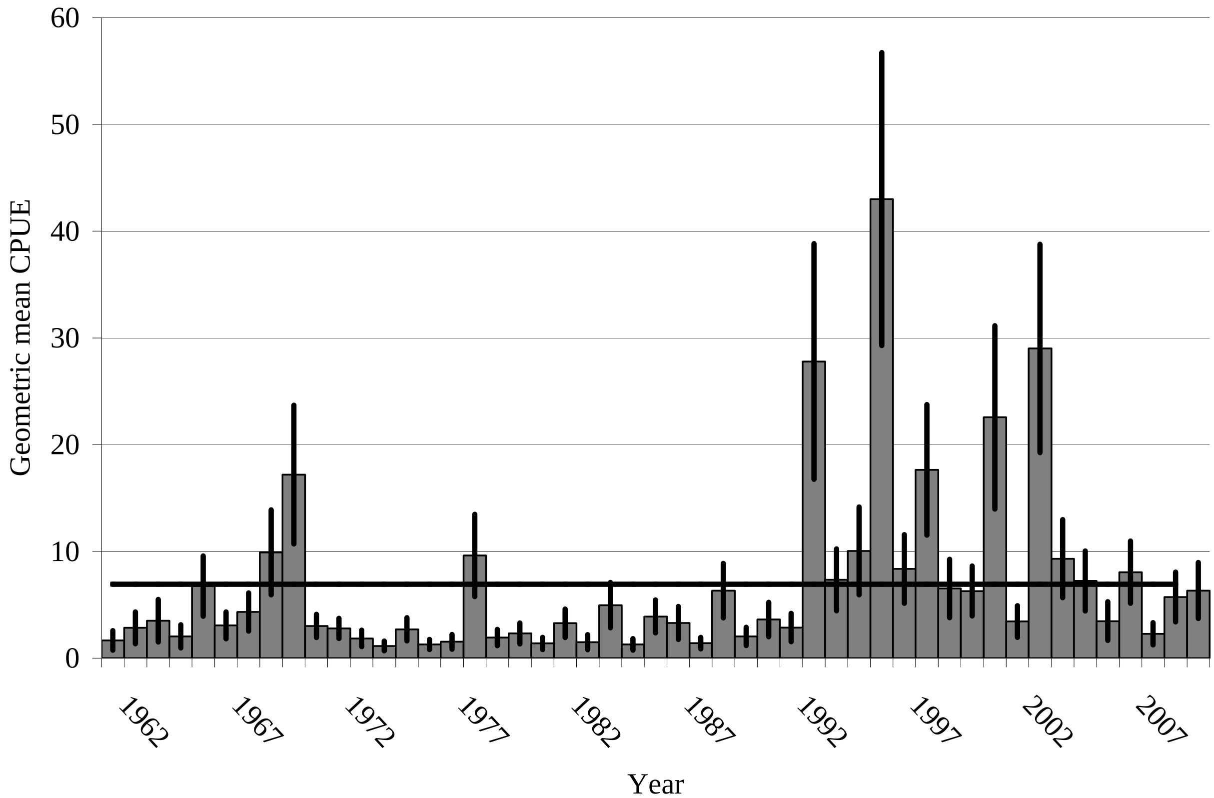


Figure 20. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

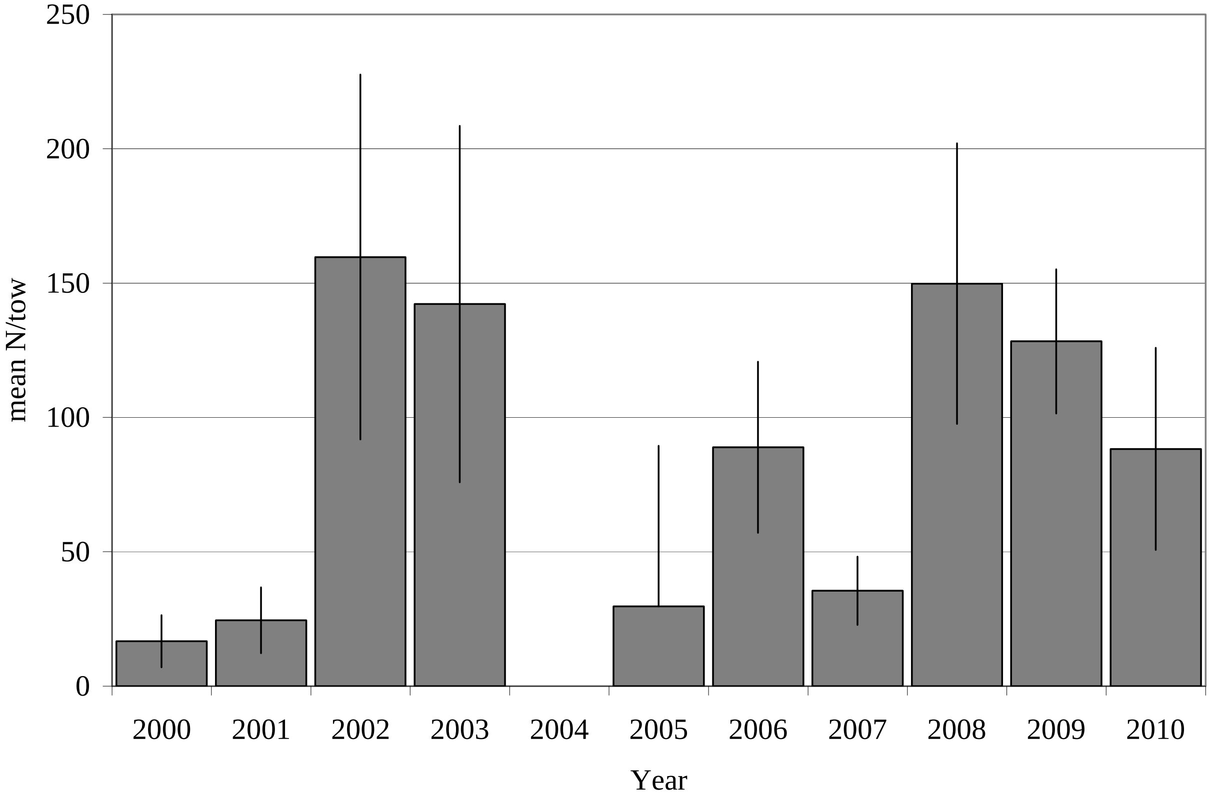


Figure 21. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2010, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

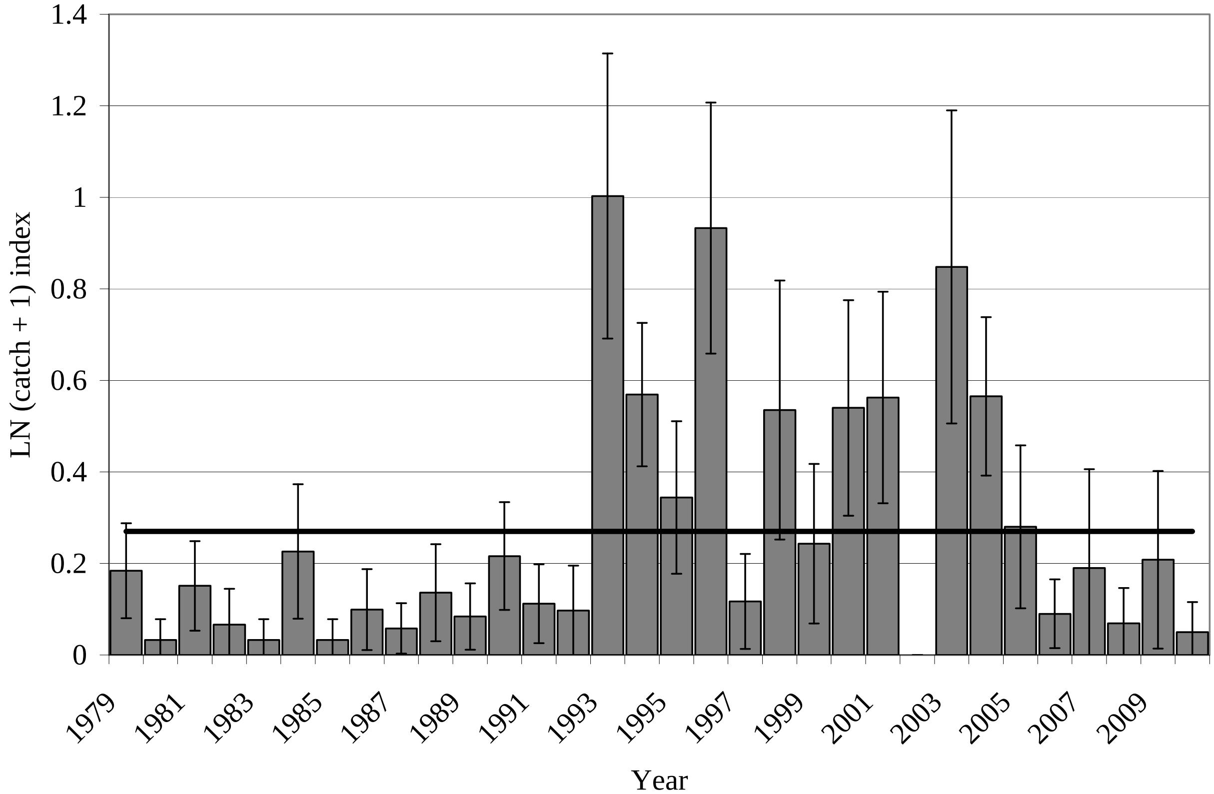


Figure 22. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

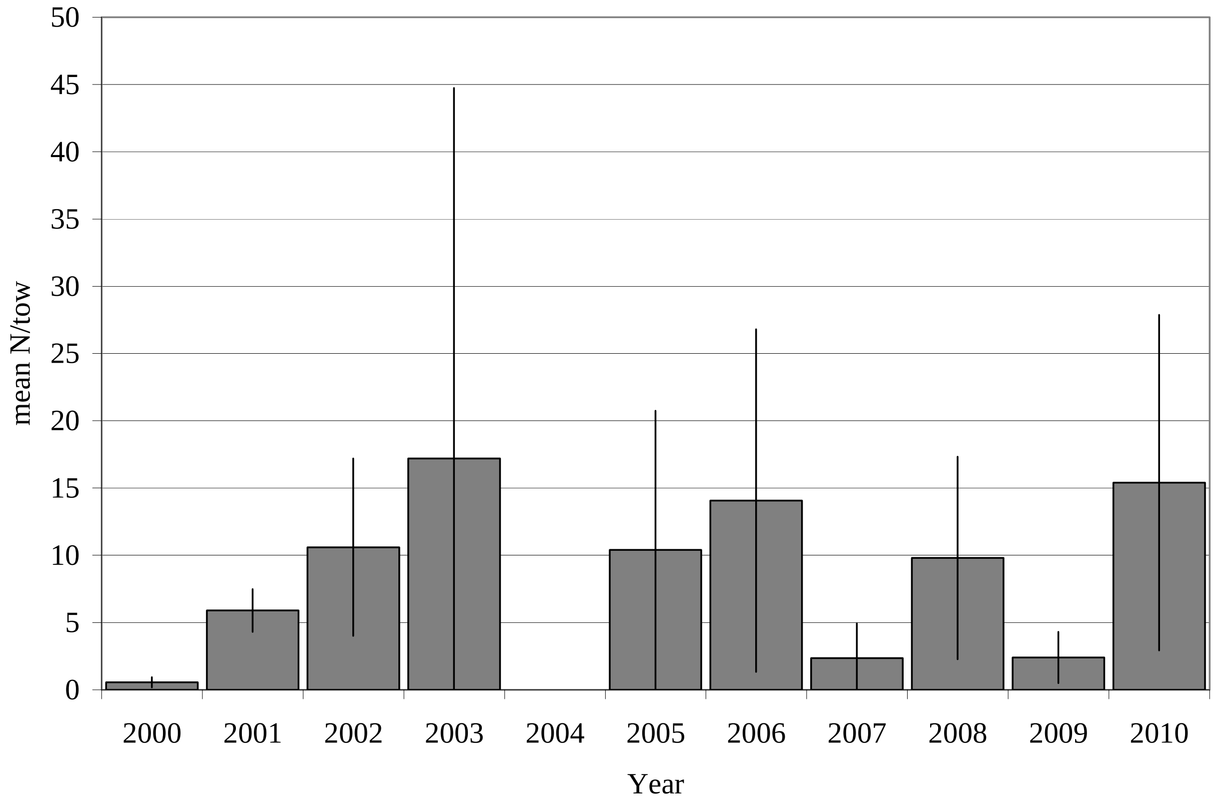


Figure 23. Bay-wide young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average. Error bars = 95% confidence intervals.

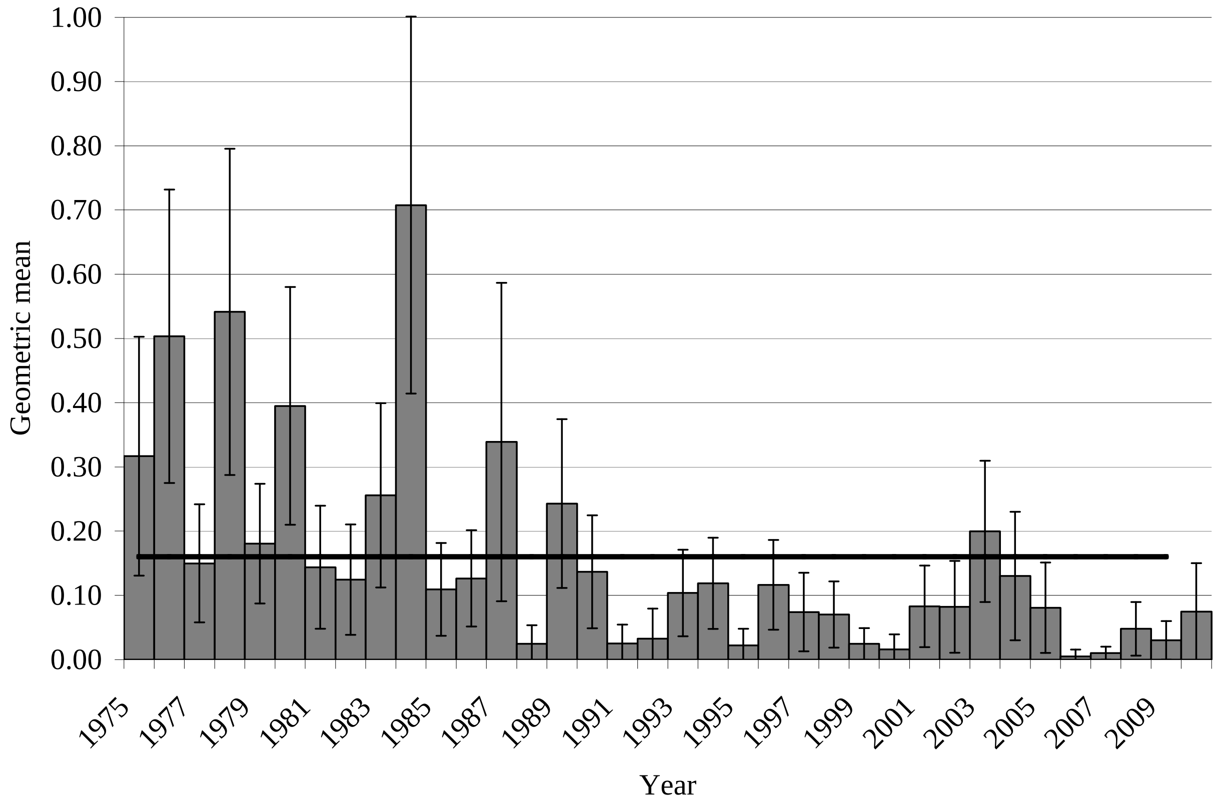


Figure 24. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

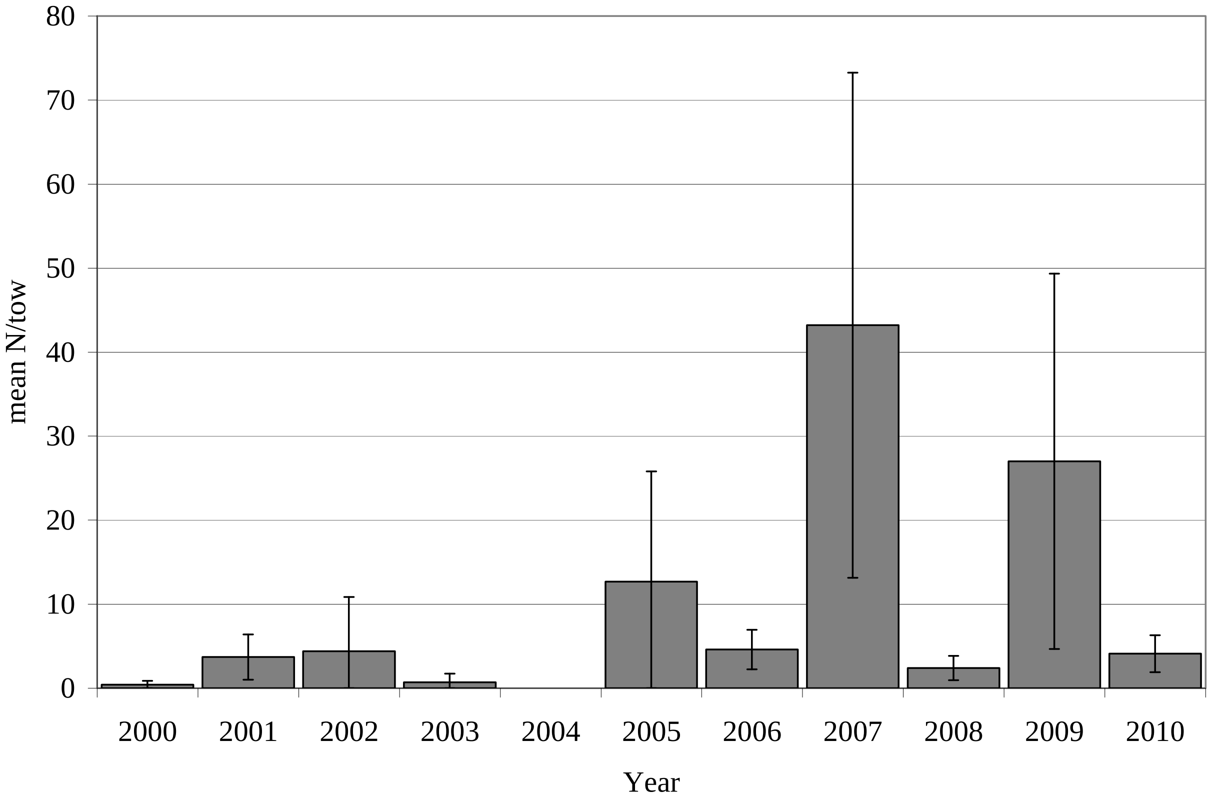


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2010.

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

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2010.

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

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2010.

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

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2010.

YEAR	AGE										sum	total
	1	2	3	4	5	6	7	8	9	10+	CPE	effort
1988	0.0	0.2	4.5	0.2	0.0	0.4	0.3	0.0	0.0	0.1	5.7	59
1989	0.0	0.0	1.2	3.4	1.2	0.6	0.1	0.0	0.0	0.0	6.6	68
1990	0.0	0.3	2.6	1.2	4.0	0.8	0.1	0.1	0.1	0.0	9.3	68
1991	0.0	0.1	0.6	0.8	0.3	0.6	0.1	0.0	0.0	0.0	2.5	70
1992	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.5	113
1993	0.0	0.0	0.6	1.3	0.8	0.9	0.3	0.1	0.0	0.0	4.0	120
1994	0.0	0.4	1.4	0.2	0.7	0.8	0.7	0.6	0.0	0.2	4.9	114
1995	0.0	0.7	2.1	0.2	0.6	0.6	0.3	0.3	0.0	0.2	5.0	121
1996	0.0	6.1	2.5	1.9	0.3	0.6	0.3	0.2	0.3	0.1	12.2	140
1997	0.0	0.1	4.2	0.6	0.6	0.0	0.1	0.2	0.1	0.0	5.8	153
1998	0.0	0.9	0.5	3.8	0.2	0.2	0.0	0.1	0.0	0.1	5.8	154
1999	0.0	1.7	47.8	0.5	17.7	0.2	0.1	0.0	0.0	0.0	68.0	178
2000	0.0	2.0	0.6	8.4	0.2	0.9	0.0	0.0	0.0	0.0	12.0	164
2001	0.0	5.3	11.9	0.6	6.8	0.1	0.4	0.0	0.0	0.0	25.1	167
2002	0.0	1.9	7.5	6.6	0.2	2.4	0.6	0.3	0.0	0.0	19.5	178
2003	0.0	3.1	3.6	7.6	2.8	0.3	1.9	0.3	0.3	0.0	19.8	121
2004	0.0	0.4	3.2	1.1	0.8	0.7	0.0	0.4	0.0	0.0	6.6	156
2005	0.0	9.0	0.7	2.2	0.7	0.3	0.8	0.1	0.3	0.1	14.2	186
2006	0.0	1.1	11.8	1.1	2.5	0.4	0.4	0.3	0.0	0.0	17.6	158
2007	0.0	10.8	5.3	11.1	0.2	1.3	0.8	0.2	0.1	0.1	29.9	140
2008	0.0	0.2	7.8	0.8	2.0	0.1	0.3	0.1	0.0	0.0	11.3	166
2009	0.0	0.0	6.1	14.8	1.0	0.9	0.2	0.0	0.0	0.0	23.0	143
2010	0.0	0.4	0.8	7.9	18.3	0.4	1.2	0.0	0.1	0.0	26.3	144

Figure 25. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2010. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

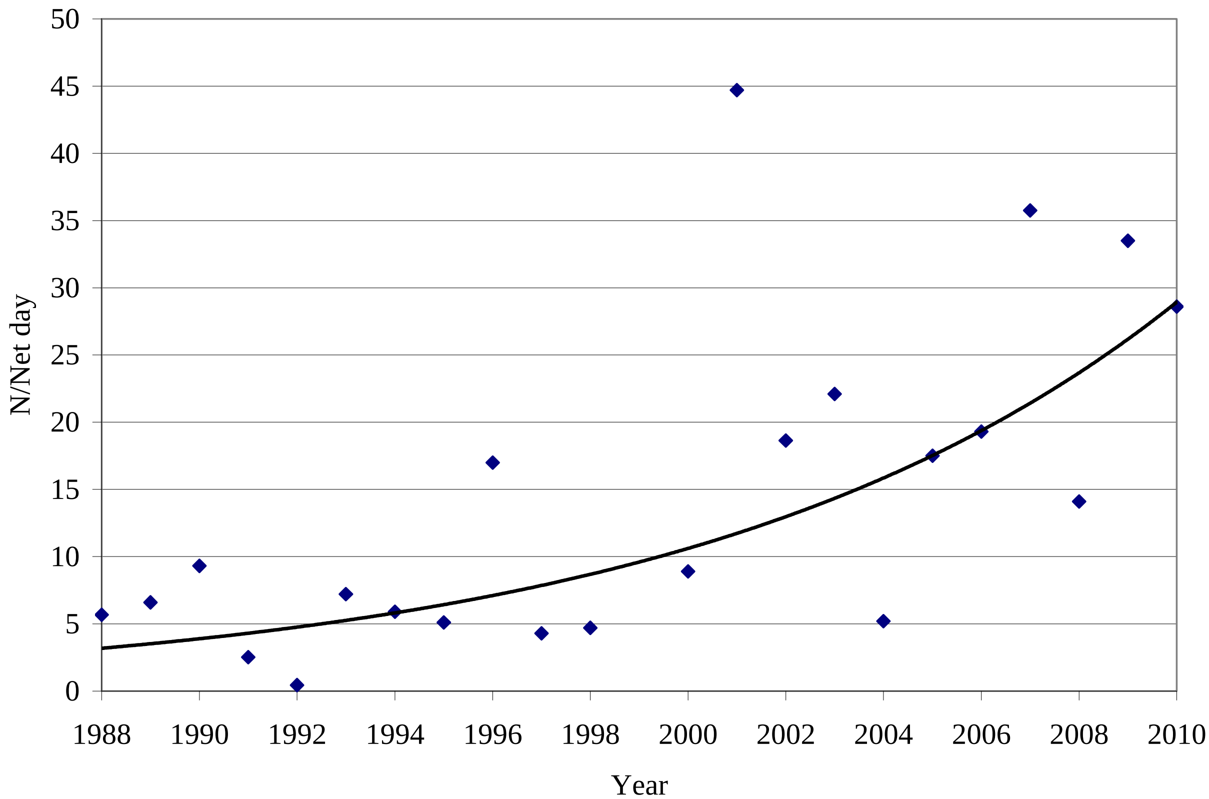


Figure 26. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2010. Not surveyed in 2004, small sample sizes in 2003 and 2005.

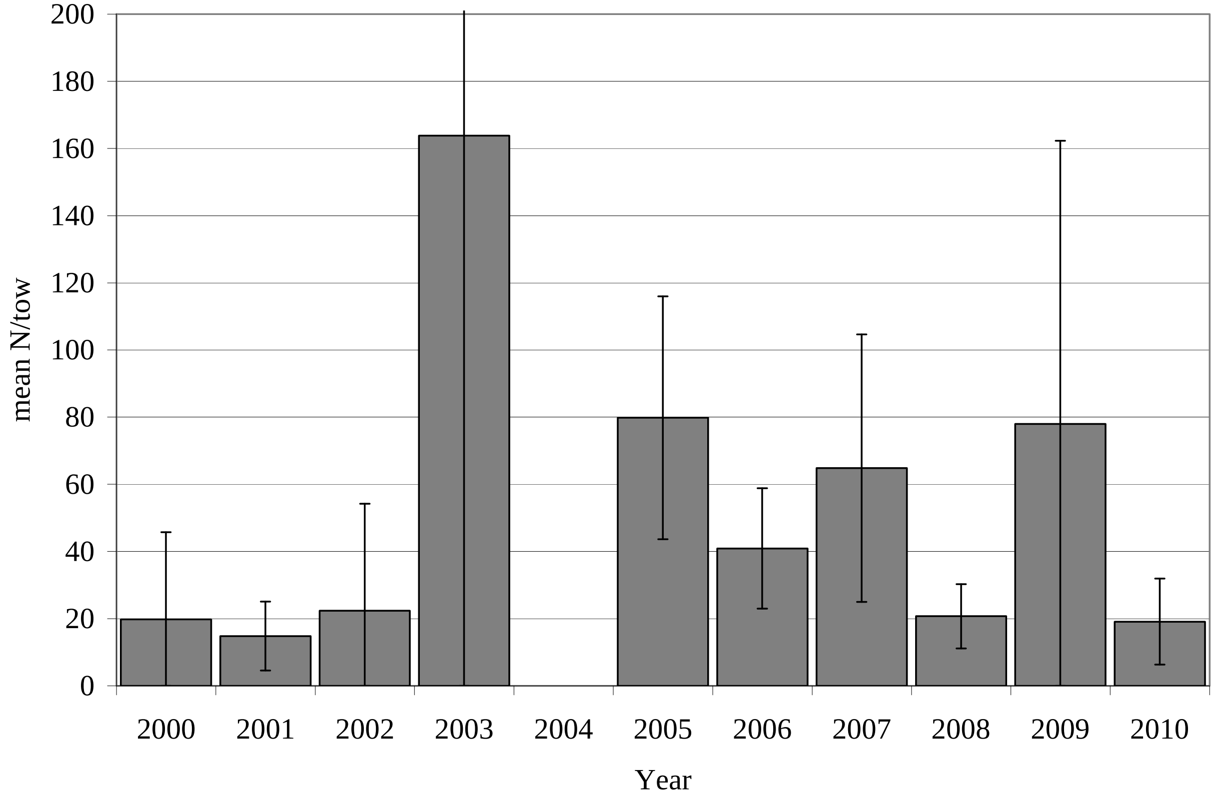


Figure 27. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2010. Horizontal line indicates time series average relative abundance.

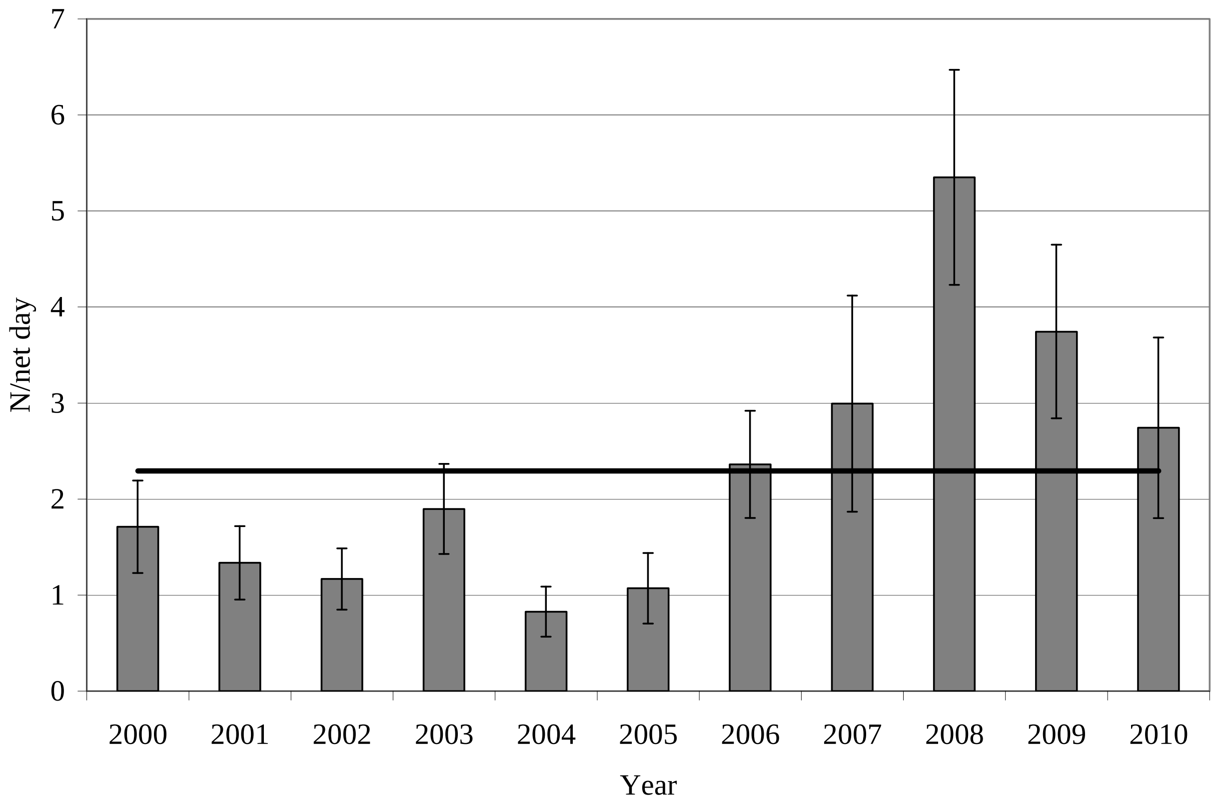
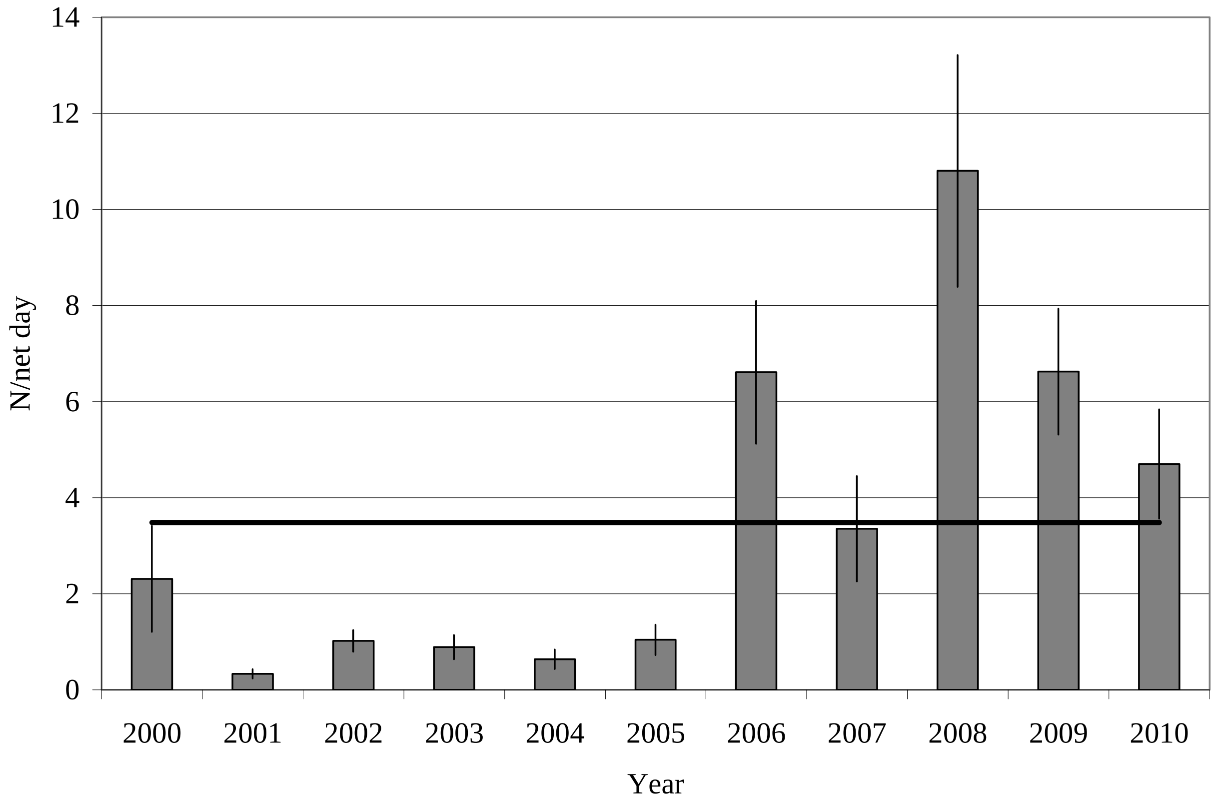


Figure 28. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2010. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF YELLOW PERCH IN MARYLAND WITH SPECIAL EMPHASIS ON HEAD-OF-BAY STOCKS

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

Yellow perch (*Perca flavescens)* are an important finfish resource in Maryland's tidewater region. The dense aggregation during the late February – March spawning period offers recreational anglers the earliest opportunity to fish. Yellow perch are similarly an important seasonal fishery for commercial fishers. The modest commercial fishery occurs during a slack season between striped bass (*Morone saxatilis)* and white perch *(M. americana)* gill netting and the white perch spawning run. Over the 10 year period 2001 -- 2010, annual commercial harvest in Maryland ranged from 77,200 kg in 2002 to 7,300 kg in 2008, and averaged 46,100 kg since 1929.

The commercial fishery is predominately a fyke net fishery located above the Preston Lane Memorial Bridges in the upper Chesapeake Bay region. Fyke net harvest accounted for 94% of the total yellow perch commercial harvest over the ten year period 2001 – 2010. From 1988 – 1999, commercial fishers in the upper Bay had a closed season in February, and an 8 ½" minimum size limit (no maximum size limit). During 2000 – 2007, the commercial fishery had a closed season in February, and an 8½" – 11" slot limit in order to preserve larger spawning females and to enhance population age structure (Uphoff and Piavis 1999). Regulations changed for the 2008 fishing season due to a legislative mandate that caused a closure of the commercial yellow perch fishery from 1 January 2008 through 15 March 2008. The January – mid March closure encompassed a significant part of the commercial yellow perch season. Completion of a suitable stock assessment in late 2008 prompted the establishment of a total allowable catch (TAC) for the commercial yellow perch fishery. Hard caps on the upper Chesapeake Bay commercial fishery were 17,272 kg in 2009 and 18,158 kg in 2010.

The recreational fishery is generally a bank-based bait fishery in upstream reaches of spawning tributaries. Recreational participation can vary among years due to inclement weather patterns, availability of public access and yellow perch population levels (personal observation). Recreational fishers had a 5 fish daily creel limit and a 9” minimum size limit (msl) with no closed season, 1988 -- 2008. Middle western shore tributaries and the Nanticoke River on the eastern shore remained closed to recreational harvest. Recreational yellow perch fishery restrictions were eased in 2009, whereby all areas were opened to harvest under a 9” msl and a 10 fish daily creel limit. Recreational creel surveys were conducted during the 2008 and 2009 spawning runs (Wilberg and Humphrey 2008, 2009). Results from the creel surveys indicated that recreational harvest was minor. Another survey indicated that yellow perch harvest in the uppermost reach of the Susquehanna River in Maryland ranged from 4,500 – 6,000 yellow perch during the late 1950’s and early 1960’s (McCauley et al. 2007).

Prior to 2009, tidal yellow perch management in Maryland focused on managing fishing mortality (F) to produce 35% maximum spawning potential (%MSP). Targets and limits were developed for yellow perch recreational and commercial fisheries using growth estimates, fishery selectivity, and partial recruitment estimates in a spawning stock biomass per recruit model (Piavis and Uphoff 1999; Yellow Perch Workgroup

2002). However, managing based solely on F was problematic because fishing mortality estimates were based on catch curves that capture a generational history of F, but not the true annual F. Over time, data sufficiently matured to assess of upper Chesapeake Bay yellow perch population dynamics with a statistical catch-at-age model with data through 2006 (Piavis and Webb 2008).

This report updated and refined the statistical catch-at-age model to estimate fishing mortality, abundance in both biomass and numbers, and recruitment of upper Bay yellow perch. The update included four more years of data (2007 -- 2010) and the model was refined by revisiting fishery independent indices and weightings, solving for fishery selectivity, and using a different algorithm to stabilize model runs.

In addition, we updated the spawning stock biomass per recruit model (SSB/R) that was used to set biological reference points contained in the current Fisheries Management Plan (Piavis and Uphoff 1999; Yellow Perch Workgroup 2002). The $F_{0.1}$ reference point from a yield per recruit model (YPR) was also determined. We incorporated the fishery selectivity vector produced from the current assessment along with updated growth parameters into the new SSB/R model.

Data from an on-going fishery independent fyke net survey in the Choptank River were also analyzed. The Choptank River is located in the mid-Bay region on Maryland's eastern shore. The watershed encompasses 371,000 acres. The Choptank River has an active recreational-only yellow perch fishery (9" minimum size limit, 10 fish creel limit). The fyke net survey provided a time-series of relative abundance estimates spanning 23 years. This survey provides the only relative abundance dataset of yellow perch outside of the upper Chesapeake Bay.

METHODS

Upper Chesapeake Bay statistical catch-at-age model

Data

Fishery dependent data

The area assessed included the Chesapeake Bay north of the Preston Lane Memorial Bridges and all tributaries except the Chester River (Figure 1). Data supported an assessment covering 1998 – 2010. Commercial landings and effort were needed for the assessment. Commercial fishermen are obligated to submit monthly catch reports and effort (number of nets) by gear and area fished (Lewis 2010). Effort was calculated as the number of fyke nets utilized by watermen that landed more than 100 pounds of yellow perch in any month, multiplied by the number of days in the month to get a total number of net days. The only exception was the month of April where 15 days were ascribed as the effort multiplier since the yellow perch spawning run and down-running activity is largely completed early in the month. The 2008 yellow perch season began on 15 March 2008, so the effort multiplier was 16 days for March and 15 days for April. The 2009 and 2010 commercial seasons were closed early due to the fishery attaining the TAC. The effort multipliers for March 2009 and 2010 were adjusted accordingly.

No estimates of recreational harvest prior to 2008 were available, but we assumed recreational harvest to be a minor component of the total removals. Creel surveys conducted in the upper Bay during 2008 and 2009 estimated that recreational harvest in the Bush River was only 242 yellow perch in 2008 and 234 in 2009, and 1,480 yellow perch in Northeast River in 2009 (Wilberg and Humphrey 2008, 2009) .

Biological samples were taken from cooperating commercial fyke net fishermen, from 1998 – 2010. Not all regions were sampled in every year, but biologists generally visited two areas per year. These included the Middle River, Back River, Bush River, Gunpowder River, and Northeast River. Random samples were taken from pre-culled catches (Table 1). Yellow perch were measured (mm TL) and sex was determined by examining external gonadal exudation. A non-random subsample was procured for otolith extraction and subsequent age determination. Ages were determined by counting annular rings on otoliths submersed in glycerin under a dissecting microscope with direct light. Weights and lengths were also taken for these specimens. Ages were mostly determined by one individual (experienced) reader. Percent agreement and precision were recently determined between the two age readers with percent agreement at 97% and mean CV of 0.56% (see Appendix A). These values compared favorably with estimates of precision from a yellow perch population in Pennsylvania (Niewinski and Ferreri 1999) and a population in Lake Erie (Vandergoot et al. 2008).

We formulated a commercial catch-at-age (CAA) matrix for each sample year by sex, for ages 3 – 8+. Length and weight data were disaggregated by sex into 20 mm length intervals. Average weight, by sex, in each interval was multiplied by the number of yellow perch (by sex) in each interval to get a total interval weight. Sample weights of all intervals were summed to get total sample weight by sex. Total landings by sex were calculated by multiplying reported commercial landings by the proportion of sex-specific sample weights. Total number of harvested yellow perch was determined by multiplying the sex-specific landings estimates by the number of sex-specific yellow perch in the sample divided by the total sex-specific sample weight. Total number harvested by sex and age-class was determined by formulating annual sex-specific age-length keys in 20 mm increments for legal sized fish only. The estimated total number harvested by sex was multiplied by the sex-specific proportion catch-at-age to get the number at age and sex harvested. Male and female CAA matrices were added together to arrive at a final annual CAA matrix. We substituted the lowest annual catch for an age-group if there was no representation of an age-class in any particular year (Table 2).

Fishery independent data

We also incorporated data from fishery-independent surveys into the model. The upper Bay winter trawl survey, initiated in December 1999, provided some data in spite of weather and mechanical problems (Piavis and Webb 2010). Trawling effort was sufficient to generate a relative abundance index of 3 year-old yellow perch and an aggregated age 4+ abundance index for the years 2000 – 2002 and 2006 – 2010.

The upper Chesapeake Bay winter bottom trawl survey is designed to collect fishery-independent data for the assessment of population trends of white perch and yellow perch and channel catfish (*Ictalururs puntatus*). Six sampling rounds were scheduled from December through February. The Chesapeake Bay 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; Figure 2). Sites were approximately 2.6 km in length and variable in width. Each sampling station was divided into west/north or east/south halves by drawing a line parallel to the shipping channel, and sampling depth was divided into two strata; shallow water (<6m) and deep water (>6 m). Each site visit was randomized for depth strata and the north/south or east/west directional components.

The trawl was a 7.6 m bottom trawl consisting of 7.6 cm stretch-mesh wings and body, 1.9 cm stretch-mesh cod end and a 1.3 cm stretch-mesh liner. Following the 10-minute tow at approximately 3 kts, the trawl was retrieved into the boat by winch and the catch was emptied into either a culling board or a large tub if catches were large. A minimum of 50 fish per species were sexed and measured. Non-random sub-samples of yellow perch were sacrificed for otolith extraction and subsequent age determination. An annual age-length key (10 mm intervals) was created and applied to the length structure of each individual haul. The age-length key was not sex-specific because male yellow perch were not routinely ripe, making sex determination difficult. The age 3 and age 4+ trawl indexes were geometric mean catch per tow.

Another age 3 index was developed from the Estuarine Juvenile Finfish Survey (EJFS; Durrell 2008). The EJFS is a seine survey in several areas of the Chesapeake Bay. Previous yellow perch assessments indicated that a suite of selected upper Bay seine sites provided a good index of age 0 abundance. Therefore, only the Howell Pt., Ordinary Pt., Tim’s Creek, Elk Neck State Park, Parlor Pt. and Welch Pt. permanent sites were used to index abundance. The index was the age 0 geometric mean catch per seine haul, lagged three years. So the 1995 survey indexed age 3 abundance in 1998, the 1996 survey indexed age 3 abundance in 1999, *et cetera*.

Model formulation

The statistical catch-at-age model used to assess yellow perch took the basic form of an Integrated Analysis (Haddon 2001). Minimum requirements include a CAA matrix, and either an independent estimate of population size or an index of effort, or both, in order to tune the catch to true population levels. The goal of determining abundance at age and year is accomplished through several steps occurring simultaneously, but essentially the model searches for the correct annual F (instantaneous fishing mortality), abundance starting values, and fishery selectivity and catchability that produce the most likely results seen in the data.

The model determines the most likely fit by solving an objective function. The objective function is solved by minimizing the sums of squared errors between observed and predicted values of the CAA, F, and fishery independent tuning indices. We assumed a log-normal error structure for all parameters.

The objective function to be minimized can be represented by the equation

$$SSR = \Sigma\lambda_F[\mathrm{Ln}(E_y \bullet q_{comm}) - \mathrm{Ln}(F_{y\ pred})]^2 + \Sigma\lambda_C[\mathrm{Ln}(C_{a,y\ obs}) - \mathrm{Ln}(C_{a,y\ pred})]^2 \quad [1]$$

$$+ \Sigma\lambda_S[\mathrm{Ln}(I_{seine\ 0,y\text{-}3\ obs}) - \mathrm{Ln}(I_{seine\ 0,y\text{-}3\ pred})]^2 + \Sigma\lambda_{T3}[\mathrm{Ln}(I_{trwl\ 3,y\ obs}) - \mathrm{Ln}(I_{trwl\ 3,y\ pred})]^2$$

$$+ \Sigma\lambda_{T4+}[\mathrm{Ln}(I_{trwl\ 4+,y\ obs}) - \mathrm{Ln}(I_{trwl\ 4+,y\ pred})]^2$$

where E_y is the commercial fishing effort index in year y, q_{comm} is catchability of the commercial fyke net fishery, F_y is instantaneous fishing mortality in year y, $C_{a,y}$ is the catch of age a yellow perch in year y, $I_{seine\ 0,\ y\text{-}3}$ is the seine index, $I_{trwl\ 3,y}$ and $I_{trwl\ 4+,y}$ are the trawl indexes of age 3 and 4+ yellow perch in year y, and λ_F, λ_C, λ_Y, $\lambda_{S,}$ λ_{T3} and λ_{T4+} are weighting factors. The fishery independent indexes were weighted by the inverse variance. The final weighting scheme was unity for the CAA and F, and weights of the fishery independent tuning indexes were 1.00 for the age 3 seine index, 2.44 for the age 3 trawl index, and 2.06 for the age 4+ trawl index.

All components of the objective function stem from estimating numbers-at-age for each year in the assessment. Numbers-at-age are determined from common fishery equations

$$N_{a+1,\,y+1} = N_{a,\,y}\, e^{-(M+s_a F)} \quad \text{for } a = 3 \text{ to } 7$$

$$N_{8+,\,y+1} = N_{a-1,y}\, e^{-(M+F_y \cdot s_a)} + N_{8+,y}\, e^{-(M+F_y \cdot s_{a-1})} \quad \text{for } a = 8+$$

where s_a is an age-specific selectivity factor. Biomass at age was estimated by multiplying the abundance-at-age matrix by the annual weight at age matrix from the fishery weights.

Once a matrix of abundance is computed, the predicted components of the objective function are constructed. The first step in forming the objective function is to determine a predicted CAA matrix from the equation

$$CAA_{pred} = (F_y/Z_y)*N_{a,y}*(1-S_{a,y})$$

where Z_y (instantaneous total mortality) is F_y + M (instantaneous natural mortality), and $S_{a,y}$ is age and year specific survivorship ($e^{-(M+s_a F_{a,y})}$).

The model needs information other than the CAA matrix to scale the abundance estimates to the correct level (Haddon 2001). Predicted F and fishery independent indexes were used. An F_{pred} vector was produced from the model runs, and F_{obs} was the q_{comm} multiplied by the annual commercial fishing effort index (E_y). In essence, this is a "semi-observed F" because the fitted parameter q_{comm} was used to calculate F_{obs} (Haddon 2001). Gear saturation may affect the tuning ability of the model. In order to assure that gear saturation was not an issue, landings were regressed against effort. The predicted age 3 trawl index was $N_{3,y}*q_{trawl,3,y}$. Similarly the predicted age 4+ trawl index was $N_{4+,y}*q_{trawl,4+,y}$. The predicted age 3 seine index was $N_{3,y} * q_{seine}$.

Model run

The model requires estimation of $N_{4\ldots8+,\,1998}$, $R_{1998\ldots2010}$ (where R is recruitment or abundance at age 3), F_y, q_{comm}, $q_{trawl,3}$, $q_{trawl,4+}$ and q_{seine}. To obtain initial estimates of abundance ($N_{4…8+, 1998}$), a Gulland style virtual population analysis (Megrey 1989) was performed on the CAA matrix. This analysis provided estimates for $N_{4…8+, 1998.}$ This model used a constant initial recruitment value of 50 yellow perch ($R_{1998…2010}$). Starting values of catchability were 0.1 for the commercial fishery and 0.0002 for seine and trawl surveys. Initial values of F were set at 0.2 for all years. In addition, selectivity was estimated for two time periods because commercial regulations changed over the course of the assessment. A 9" minimum size limit was enforced during 1998 – 1999, suggesting a flat-topped selectivity pattern. During 2000 – 2010, the commercial fishery had an 8 ½" – 11" slot limit which should produce a dome-shaped selectivity pattern. For the first time period, selectivity was constrained to a maximum of 1. For the second time period (slot limit), selectivity for each age-class was divided by the maximum selectivity to ensure that at least one age class was fully selected (Quinn and Deriso, 1999). Previous model runs indicated that the model fit was quite insensitive to starting values of R, *q*, and F (Piavis and Webb 2008), but we changed starting values of R to 300,000; 1,000,000; and 10,000,000 and used alternative starting values of F (0.5 and 2.0) to ensure that the model was stable. We assumed a constant instantaneous natural mortality (M) = 0.25.

The model was implemented in an Excel spreadsheet, and all fitting was done with the Microsoft Excel Solver algorithm. Uncertainty was quantified by bootstrapping. Residuals were randomized and added back to the predicted CAA matrix and fishery independent indexes, and the model was rerun. The model was bootstrapped 10,000 times and 80% confidence intervals were determined from the cumulative percent distribution for F, R, N, and biomass. In addition, coefficients of variation (CV) were produced for all parameters.

Spawning stock biomass per recruit and biological reference points

We used a Thompson-Bell Spawning Stock Biomass per Recruit analysis (SSB/R) following the procedures of Gabriel et al. (1989) to determine the percentage of SSB/R of an unfished stock that current harvest was producing and at what level of fishing intensity various reference points would have been met. The method uses the fishery selectivity pattern to scale F and the number mature at age to define SSB/R more precisely. The Thompson-Bell modification determines the number (N_{ts}) and weight (W_{ts}) available at spawning as

$$N_{ts} = N_t * e^{-((c * p_t * F) + d*M)}$$

$$\text{where } N_t = N_{t-1} * e^{-((p_{t-1} * F) + M)}$$

$$\text{and } W_{ts} = fr_{ts} * N_{ts} * W_t$$

where c is the fraction of F before spawning, p is the fraction vulnerable to harvest at age (selectivity), d is the fraction of M that occurs before spawning, fr_{ts} is the fraction mature at age t, and W_t is the mean weight at age (Table 3). We used an arbitrary initial cohort of 100,000 at age 0. The assessment was run for 12 age-classes. Female yellow perch growth rate was modeled with vonBertalanffy growth parameters (L_∞ = 308 mm K = 0.3 t_0 = -1.14) and an allometric length-weight relationship (α = 4.83 X 10^{-6} β = 3.19) from upper Bay yellow perch during 1998 -- 2010 (see Project 1 Job1). The fishery selectivity vector for a fishery with an 8 1/2” to 11” slot limit was taken from the current assessment. This models the SSB/R for a predominantly commercial fishery. For a predominantly recreational fishery (9” minimum size limit) selectivity was the same as previous assessments (Piavis and Uphoff 1999).

The Thompson-Bell SSB/R analysis was constructed as a Microsoft Excel spreadsheet. An initial run with F = 0 determined the unfished (virgin) spawning stock biomass. We selected $F_{35\%}$ and $F_{25\%}$ as target and limit reference points, consistent with the current Yellow Perch Fisheries Management Plan (Yellow Perch Workgroup 2002). These reference points are the level of F that produce the reproductive output of stock sizes that are 35% and 25% of virgin stock size, respectively.

The biomass corresponding to the various reference points were identified, and the Goal Seek option within a Microsoft Excel spreadsheet was used to determine what instantaneous fishing mortality rates produced $F_{25\%}$, and $F_{35\%}$. The model was also run with F values of 0 to 1.2 in increments of 0.1 to produce SSB/R curves.

The Thompson-Bell yield per recruit model was used to determine $F_{0.1}$ reference point. The yield per recruit model stated that

$$N_t = N_{t-1} * e^{-(p_{t-1} * F + M)}$$

$$\text{and yield} = W_t *((p_t*F)/(p_t*F+M))*(1-e^{-(p_t*F+M)})*N_t.$$

The fishery specific selectivity-at-age vectors (p_t) were the same as the SSB/R model. Yield was determined for F’s ranging from 0 - 1.2 in increments of 0.1, except the yield at F=0.01 was determined in order to find the slope of the line at the origin in order to assess $F_{0.1}$.

Choptank River relative abundance analysis

Relative abundance data were derived from fyke net sampling in the Choptank River (Project 1 Job 1). Data from 1988 were taken from a previous survey (Casey et al

1988). Catch per unit effort (CPUE) was determined as the number of yellow perch caught per net day. Over the years, the starting date of this survey has varied. In order to standardize the dataset as accurately as possible, a 1 March start date was used. The Choptank River survey is a multi-species survey, so fyke netting was generally extended well past the end of the yellow perch spawning run. An effort cut-off was determined for each year as the day when 95% of the total yellow perch catch from 1 March occurred.

Catch per unit effort since 1988 was modeled with SAS PROC NLIN procedure. An exponential increase was assumed, and therefore, a power function was used:

$$CPUE = a \bullet e^{(b \bullet yr)}$$

where yr is year from 1 to 23 (corresponding to 1988 – 2010) and a and b are fitted parameters. The nonlinear regression was analyzed for outliers by inspecting studentized residuals. Residuals that were outside of the range of -2.5 to 2.5 were omitted from analysis and the regression was rerun. The regression was considered significant at the $\alpha = 0.05$ level.

RESULTS

Upper Chesapeake Bay statistical catch-at-age model

Landings were regressed against effort to determine if gear saturations occurred, which would compromise the selection of effort as a tuning index. No gear saturation was evident ($R^2 = 0.56$ P=0.002; Figure 3). Selectivity at age was estimated for 2 time periods corresponding to different commercial regulations. The model fit the 1998 – 1999 time period with a flat-topped selectivity pattern with 5-year old yellow perch being fully recruited. Selectivity for age 3 yellow perch was 0.20. The model fit the 2000 –

2010 time period with a dome-shaped selectivity pattern, as was expected given the adoption of the slot limit during 2000. Yellow perch were fully recruited at age 6 and s_{8+} was 0.22 (Figure 4). Catchability for the commercial fyke net fishery was estimated as 2.48×10^{-5}, catchability of the trawl survey was 2.52×10^{-6} for age 3 yellow perch, 8.52×10^{-7} for aggregated age 4+ yellow perch, and catchability of the seine survey was 1.79×10^{-6}.

Abundance estimates increased from 764,000 yellow perch in 1998 to 1.6 million yellow perch in 1999 (Figure 5). Abundance then declined to 549,000 yellow perch by 2005. Since 2005, abundance estimates have ranged without trend from 828,000 fish to 972,000 fish. Terminal year abundance was estimated at 920,000 yellow perch. Biomass increased from the time series low of 102,000 kg (2005) to 187,000 kg in 2010 (Figure 6). Maximum biomass was 318,000 kg in 1999.

Instantaneous fishing mortality (fully selected F) ranged from 0.03 – 1.12 during 1998 – 2010. Fishing mortality peaked in 2002 to 1.12, and then declined to 0.16 during 2006. Since 2006, F has generally been around 0.20 except for 2008 when F was estimated at 0.03. The commercial fishery was closed from 1 January 2008 to 15 March 2008 which essentially closed the commercial fishery in 2008. Fully recruited F was 0.24 in the terminal year (Figure 7).

Estimated recruitment (abundance of age 3 yellow perch) ranged from 12,700 yellow perch in 2005 (2002 year-class) to 1,168,000 yellow perch in 1999 (1996 year-class) and averaged 311,000 yellow perch, 1998 – 2010 (Figure 8). Yellow perch recruitment was poor in 1998, 2000, and 2005 (1995, 1997, and 2002 year-classes, respectively). Strong recruitment occurred in 1999, 2004, and 2006 (1996, 2001, and 2003 year-classes, respectively).

Residual plots of the CAA matrix indicated reasonable fits for age 3 catch (Figure 9). The age 4 residual plot was influenced by one large negative residual (Figure 10). The model fit age 5 and age 6 catches well (Figures 11, 12). Residual plots for the age 7 catch at age was influenced by one large positive residual and the age 8+ residuals indicated a good fit (Figures 13, 14). Residuals of the fishery independent indexes were also plotted. The seine survey (3 year old index) was suitable with only one large positive residual in the first year and one large negative residual in the last year (Figure 15). The age 3 and aggregated age 4+ trawl survey indexes also fit well (Figures 16, 17).

Bootstrapping provided confidence intervals and quantified uncertainty. Analysis of 80% confidence intervals indicated that F and R were generally precisely estimated (Figures 18, 19). However, F may have been biased high during 2002 – 2005 and there was a larger amount of uncertainty in the 2010 estimate of R. Abundance estimates were generally biased low since 2003 (Figure 20). There was a much higher level of uncertainty in N estimates in the latter portion of the time series. Inspection of CV's of the N estimates indicated reliable fits, but they were greater than 20% since 2005 with the highest level (28%) in 2010 (Table 4). Coefficients of variation of all other parameters were similarly well estimated, except for the starting values of age 7 and 8+ abundance in 1998.

Spawning stock biomass per recruit and biological reference points

Spawning stock biomass per recruit modeling produced percent maximum spawning potential (%MSP) at F curves for a fishery with an 8 ½" – 11" slot limit (commercial fishery; Figure 21) and a fishery with a 9” minimum size limit (recreational fishery; Figure 22). For the upper Bay, which is a predominately commercial fishery, the target reference point ($F_{35\%}$) was 0.53 and the limit reference point ($F_{25\%}$) was 0.82 Yield per recruit modeling produced $F_{0.1}$ reference point of 0.13. Fully selected F in 2010 (0.24) produced a %MSP of 57%. For a predominately recreational fishery (9” minimum size limit), the target reference point ($F_{35\%}$) was 0.50 and the limit reference point ($F_{25\%}$) was 0.80. Yield per recruit modeling produced $F_{0.1}$ reference points of 0.15. The bootstrap distribution of F indicated that there was only a 0.07% chance that F exceeded $F_{35\%}$ in the upper Chesapeake Bay during 2010.

Choptank River relative abundance analysis

Non-linear regression of CPUE and year provided a statistically significant fit (P<0.0001). However, two data points were identified as possible outliers. Exclusion of the CPUE values for 1999 and 2001 greatly improved the fit and corrected a bias toward negative residuals. The final equation, $CPUE = 3.2661 \bullet e^{(0.097 \bullet yr)}$, was highly statistically significant (P<0.0001). The resultant curve indicated that CPUE increased from 3.6 fish/net day in 1988 to 30.4 fish/net day in 2010 (Figure 23).

DISCUSSION

Statistical catch-at-age models incorporate many advances in fisheries science into an analytical framework, often relaxing sometimes onerous assumptions associated with virtual population analysis. One major assumption that is relaxed is that the CAA matrix is measured without error. However, certain assumptions are common between the two families of population assessments. Common assumptions include that M is constant and accurately assigned; that there is no net immigration or emigration; and in the current model, that q does not vary over time. Severe violations of these assumptions may confound the model results.

The model assumed constant natural mortality (M) = 0.25. Total instantaneous mortality in areas closed to commercial and recreational fishing produced estimates of Z near 0.25 – 0.30, which in the absence of F would approximate M (Piavis et al. 1993; Piavis and Webb 2008). Over a 20 year period of monitoring yellow perch in Chesapeake Bay, 10 year old yellow perch were not rare, and the oldest captured yellow perch was 14 years old, consistent with a lower M (Yellow Perch Workgroup 2002). Regardless, an alternative model run using fixed M at 0.3 preserved the trends in F and N from the base run, but N estimates were approximately 10% higher and F estimates were approximately 10% lower than the base run.

Recently, research in the Laurentian Great Lakes assumed a higher M than our model. Wilberg et al. (2005) utilized M=0.37 for a Bayesian statistical catch at age model for Lake Michigan yellow perch. Ecosystem differences could cause lower natural mortality in Chesapeake Bay yellow perch relative to Great Lakes yellow perch.

Abundance of gizzard shad (*Dorosoma cepedianum*), white perch, alosids (*Alosa spp.*) and other forage fish likely reduce predation pressure on Chesapeake Bay yellow perch. Yellow perch over-winter mortality was negatively correlated with gizzard shad abundance in Oneida Lake, NY because gizzard shad provided a buffer against predation (Fitzgerald et al. 2006). Alternatively, large abundance of gizzard shad could cause increased mortality if interspecific competition for zooplankton is intense. However, Roseman et al. (1996) noted no overlap of yellow perch and gizzard shad diets. Generally, young-of-year yellow perch exhibited an ontogenetic shift to benthic prey items before annual decreases in *Daphnia* spp occurred.

A longer growing season in the Chesapeake Bay region may also significantly decrease predation risk, thus reducing M by increasing growth rates of juvenile yellow perch. Headley and Lauer (2008) determined an average length of about 75 mm for age 1 Southern Lake Michigan yellow perch. Age 1 yellow perch collected in the upper Bay trawl survey averaged 117 mm in 2006 and 115 mm in 2007.

The concept of a unit stock must also be established such that there is no net gain or loss from immigration or emigration. Two recent investigations have helped satisfy this assumption, one on the molecular level and one at the individual level. The assessment area is characterized by an increasing salinity gradient from north to south, ostensibly acting as a barrier to movement into or out of the study area. The assessment excluded the Chester River population which is the lowest eastern shore tributary above the Bay Bridges. The Chester River has historically been excluded from upper Bay assessments because of high salinities at the river mouth. Recent genetic analysis indicates that a salinity barrier exists that inhibits gene flow. Yellow perch genetics within the Chesapeake Bay exhibited genetic profiles such that yellow perch were separated into distinct lines among the Bush River (in the assessment area), Severn River, Choptank River, and Nanticoke River (Grzybowski et al. 2010). However, the Severn River yellow perch were most closely related to the Bush River samples, and the largest divergences were the Nanticoke River population and the Choptank River population from themselves and the upper Bay yellow perch. These results validate the hypothesis that gene flow from the upper Bay is limited.

In 2008, we conducted an *ad hoc* yellow perch tagging survey in the Chester, Bush, Gunpowder, and Northeast rivers. The latter three systems are within the assessment area. Tags from each particular system were a unique color. Tag returns indicated that yellow perch were at large for 2 – 383 days. Commercial and recreational tag returns indicated significant movement among rivers in the assessment area but not the Chester River. Out of system recaptures of yellow perch tagged in the Northeast River accounted for 86% of the tag returns, and none were from outside of the assessment area. Gunpowder River source yellow perch had 29% of the returns from outside of the tagging system, with none from outside of the assessment area. There were only three recaptures of yellow perch tagged in the Bush River and all were recaptured within the system. However, commercial fishermen reported catching Bush River fish (as verified by the unique tag color) in the Chesapeake Bay just outside of the Bush River. No recaptures were reported from outside of the assessment area. Yellow perch tagged in the Chester River showed very limited immigration to the upper Bay, with only one tag encountered outside of the system (79 reported recaptures or 1.3%). At least for 2008 and 2009, no movement out of the upper Bay was noted, and very minimal emigration from the Chester River to the upper Bay was evident.

The assessment assumed constant catchability for the commercial fishery and all of the fishery independent surveys. Recent fishery literature has explored the folly of assuming that catchability is constant among both fishery-dependent and fishery-independent data sources. Wilberg et al. (2010) identified several factors that may influence catchability, including density dependent changes in q, environmental variability, and changes in fisher behavior. Density dependent changes in catchability are possible, but at least for the time period encompassed by this assessment, large variations in q are unlikely. In addition, fisher behavior is unlikely to have caused large-scale variations in q over the assessment period because the largest harvesters have maintained relatively consistent sites, gear, and fishing techniques. Gear saturation could also have an effect on the ability of the model to accurately determine q. This is particularly important when a model is selected that uses effort to tune F to influence abundance estimates. A plot of landings and effort did not indicate that gear saturation occurred. Environmental variation in the upper Chesapeake Bay may be the most confounding of the three influences on q. Commercial fishers suggested that yellow perch migration differs in year with ice cover, in that larger fish will ascend to upper river stretches earlier in the season when ice cover is present. In addition, increased submerged aquatic vegetation could decrease q, which has been noted by at least one commercial yellow perch fisher. The relatively short time span of the assessment likely buffers against error in assuming a constant q, but future updates need to be inspected for any serial trends in q estimates. For example, a consistently significant decline or increase in q or an increase in CV's of q could indicate that the assumption of constancy was violated.

Given the available data, the model performed well and appears to have captured the population dynamics of yellow perch in the upper Chesapeake Bay. The only relatively imprecise estimates were the starting abundances estimates of age 7 and 8+ yellow perch in 1998. The imprecision would have little effect on total abundance estimates because the older age classes comprise a very small portion of the population and they pass from the population early in the time series. Yellow perch populations grew rapidly from 1998 to 1999 due to the recruitment of the dominant 1996 year-class. Recruitment was at or below average during 2000 – 2003. The lack of another large year-class combined with high mortalities in 2002 caused the population to decline but stabilize at a lower level, about 600,000 fish. Good recruitment in 2004 and 2006 and a decline in F contributed to a population expansion ranging from 828,000 – 976,000 yellow perch during 2007 -- 2010. Abundance was precisely estimated as evidenced by CV's of the bootstrap distributions less than 30%, but the highest CV's occurred in the most recent years. Estimates prior to 2005 had CV's less than 20%, but from 2005 – 2010, CV's were greater than 20% (Figure 24). The 2005 – 2010 time period encompasses cohorts that have not fully passed from the population, that is, there is at least one incomplete cohort in those years. The 2010 abundance estimate had the highest CV (28%). The tuning indices gave partially different signals. The 3 year old trawl survey index and the 3 year old commercial CPUE indicated a large recruitment event in 2010, but the 3 year old seine index produced a more muted signal. The data must mature so that a longer catch history of the 2007 year-class resolves the difference.

Recruitment was a prime contributor to population abundance, even when F varied from 0.03 – 1.12. Three year-old yellow perch contributed 32% on average to total population abundance. However, 3 year-old yellow perch comprised 63% of the population in years with the largest three year-classes, and only 5% in the 3 years with the smallest year-classes. Piavis et al. (1993) suggested that dominant year-classes were important for yellow perch populations in the Chesapeake Bay region. A strong 1985 year-class in the Choptank River sustained the population over a period of low recruitment from 1986 – 1992. Similarly, the strong 1984 year-class in the upper Chesapeake Bay was responsible for higher commercial landings during the late 1980's, followed by a period of low recruitment and declining commercial harvest.

Commercial yellow perch regulations changed from a minimum size limit only to a slot limit in 2000. Uphoff and Piavis (1999) simulated population responses for several management scenarios ranging from *status quo* to high minimum size limits and slot limits. Slot limits provided more diversity in the age composition of the spawning stock over a wider range of F. The statistical catch-at-age model produced annual survival estimates at age. During the period before the slot limit was enacted (1998 – 1999), survival of age 8+ yellow perch averaged 48%, but when the slot limit was in effect (2000 – 2010) average annual survival increased to 72%. Variation in fishing effort could confound the interpretation of the increased annual survival at age. From 1998 – 1999, fishing effort averaged approximately 20,000 fyke net days, compared to 12,585 for the period 2000 – 2010. Undoubtedly, both factors (decreased effort and establishment of a maximum size limit) caused the increased survival of age 8+ yellow perch.

Instantaneous fishing mortality estimates and variability of the estimates from bootstrapping determined the probability that yellow perch stocks in the upper Chesapeake Bay were overfished. Point estimates of F indicated that since biological reference points were adopted for management (2002), the F_{limit} was exceeded in 2002 (78% probability) and F_{target} was exceeded in 2004 (40% probability). In addition, there was a 24% probability that F_{target} was exceed in 2001 and 2003. There was no probability of F exceeding either target or the limit since 2005. Given the low probability of exceeding F-based biological reference points, we determined that overfishing was not occurring in the upper Chesapeake Bay. Currently, no biomass based targets or limits have been determined so assessment of over-fished status cannot be determined.

Choptank River yellow perch relative abundance has increased significantly over the past 10 years. Estimated fishing mortality has generally been below F=0.1 (Project 1 Job 1). In addition, recruitment, as defined by relative abundance of 3 year old yellow perch has been relatively high during 2006 – 2009 (Project 1 Job 1). Based on recent F estimates and results from the SSB/R analysis utilizing a 9” minimum size limit selectivity pattern, over 80% MSP can be achieved. The calculated MSP is considerably higher than the current target (35%MSP), and as such, over-fishing is not occurring.

<u>**LIST OF TABLES**</u>

LIST OF FIGURES

LITERATURE CITED

Casey, J.F., S. Minkkinen, J. Soldo. 1988. Characterization of Choptank River populations of white and yellow perch . Maryland Department of Natural Resources Tidewater Administration Report. Annapolis, Maryland.

Durrell, E. 2008. Maryland juvenile striped bass survey. Proect 2, Job 3, Task 3. In Chesapeake Bay Finfish and Habitat Investigations. Maryland Department Of Natural Resources Fisheries Service Report F-61-R-3. Annapolis, Maryland.

Fitzgerald, D., J. Forney, L. Rudstam, B. Irwin, and A. VanDeValk. 2006. Gizzard shad put a freeze on winter mortality of age-0 yellow perch but not white perch. Ecological Applications. 16:1487—1501.

Gabriel, W., M. Sissenwine, and W. Overholtz. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. North American Journal of Fisheries Management. 9:383—391.

Grzybowski, M., O. Sepulveda-Villet, C. Stepien, D. Rosauer, F. Binkowski, R. Klaper, B. Shepherd, and F. Goetz. 2010. Genetic variation of 17 wild yellow perch Populations from the Midwest and east coast analyzed via microsatellites. Transactions of the American Fisheries Society. 139:270 – 287.

Haddon, M. 2001. Modelling and Quantitative Methods in Fisheries. Chapman and Hall/CRC. Boca Raton.

Headley, H. and T. Lauer. 2008. Density-dependent growth of yellow perch in southern Lake Michigan, 1984 – 2004. North American Journal of Fisheries Management. 28:57—69.

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

McCauley, A., H. Speir, and D. Weinrich. A summary of Maryland tidewater, spring, upriver sportfishing surveys, 1958 – 1997. Maryland Department of Natural Resources Fisheries Service Fisheries. Technical Memorandum Number 34. Annapolis, Maryland.

Megrey, B. 1989. Review and comparison of age-structured stock assessment models from theoretical and applied points of view. American Fisheries Society Symposium, 6:8-48.

Niewinski, B.C. and C.P. Ferreri.1999. A comparison of three structures for estimating the age of yellow perch. North American Journal of Fisheries Management. 19:872-877.

Piavis, P. and J. Uphoff. 1999. Status of yellow perch in Maryland's portion of Chesapeake Bay during 1998. Fisheries Technical Report Series Number 25, Maryland Department of Natural Resources, Annapolis, Maryland.

Piavis, P. and E. Webb. 2010. Population vital rates of resident finfish in selected tidal areas of Maryland's Chesapeake Bay. Project1, Job 1. In Chesapeake Bay Finfish and Habitat Investigations. Maryland Department of Natural Resources Fisheries Service Report F-61-R-5. Annapolis, Maryland.

Piavis, P. and E. Webb. 2008. Population assessment of yellow perch in Maryland with special emphasis on head-of-Bay stocks. Project1, Job 2. In Chesapeake Bay Finfish and Habitat Investigations. Maryland Department of Natural Resources Fisheries Service Report F-61-R-3. Annapolis, Maryland.

Piavis, P., E. Webb, J. Uphoff, B. Pyle and W. Eaton. 1993. Investigation of yellow perch stocks in Maryland. Maryland Department of Natural Resources Tidewater Administration. Report F-46-R. Annapolis, Maryland.

Quinn, T. and R. Deriso.1999. Quantitative Fish Dynamics. Oxford University Press, New York.

Roseman, E., E. Mills, J. Forney, L. Rudstam. 1996. Evaluation of competition between age-0 yellow perch (*Perca flavescens*) and gizzard shad (*Dorosoma cepedianum*) in Oneida Lake, New York. Canadian Journal of Fisheries and Aquatic Sciences. 53:865—874.

Uphoff, J. and P. Piavis. 1999. Yellow perch management alternatives and spawning potential. Maryland Department of Natural Resources. Fisheries Service. Technical Report Number 28. Annapolis, Maryland.

Vandergoot, C.S., M.T. Bur, and K.A. Powell. 2008. Lake Erie yellow perch age estimation based on three structures: precision processing times, and management implications. North American Journal of Fisheries Management. 28:563-571.

Wilberg, M., J. Bence, B. Eggold, D. Makauskas, and D. Clapp. 2005. Yellow perch Dynamics in southwestern Lake Michigan during 1986 – 2002. North American Journal of Fisheries Management. 25:1130 – 1152.

Wilberg, M. and J. Humphrey. 2009. A creel survey for early spring fisheries of Maryland's Chesapeake Bay tributaries. Progress Report to Maryland Department of Natural Resources Fisheries Service. Annapolis, Maryland.

Wilberg, M. and J. Humphrey. 2008. A creel survey for early spring fisheries of Maryland's Chesapeake Bay tributaries. Progress Report to Maryland Department of Natural Resources Fisheries Service. CBL Report 08-059. Annapolis, Maryland.

Wilberg, M, J. Thornton, B. Linton, and J. Berkson. 2010. Incorporating time-varying catchability into population dynamic stock assessment models. Reviews in Fisheries Science. 18:7-24.

Yellow Perch Workgroup. 2002. Maryland Tidewater Yellow Perch Fishery Management Plan . Maryland Department of Natural Resources, Annapolis, Maryland.

Table 1. Sample sizes for lengths and ages and the years used in forming the catch-at-age matrix for upper Chesapeake Bay yellow perch.

Year	Length sample size	Age sample size Females	Males
1998	890	131	67
1999	1453	231	42
2000	1670	187	59
2001	445	79	19
2002	1440	79	43
2003	1078	69	35
2004	964	70	39
2005	973	56	45
2006	1015	56	44
2007	1386	53	34
2008	8927	272	89
2009	1321	69	42
2010	1322	56	49

Table 2 Catch-at age matrix, harvest (N), and landings (kg) for upper Chesapeake Bay yellow perch, 1998 –2010. Entries in bold were lowest value (1998 – 2006) to substitute for 0 estimated catch.

Year	**3**	**4**	**5**	**6**	**7**	**8+**	**Harvest**	**Landings**
1998	3,086	51,318	151,407	**3,068**	**1,437**	**580**	210,896	42,937
1999	224,304	7,503	65,241	79,448	6,984	794	384,274	69,960
2000	876	162,415	4,826	9,278	15,570	**580**	193,545	30,566
2001	27,708	11,273	169,957	3,936	4,546	7,441	224,860	30,680
2002	24,777	119,202	11,544	211,205	4,101	27,478	398,308	46,525
2003	45,646	1,400	34,692	4,621	37,693	3,612	127,665	20,448
2004	55,005	70,522	8,333	8,088	**1,437**	6,462	149,848	21,632
2005	377	99,246	24,017	3,068	1,437	4,127	132,272	18,841
2006	24,636	580	31,575	7,688	**1,437**	580	66,496	11,542
2007	5,604	54,280	1,564	20,722	6,972	1,173	90,315	15,902
2008	1,643	5,076	7,509	127	1,551	414	16,320	3,117
2009	1,746	34,940	27,300	29,895	1,681	3,194	100,351	19.558
2010	39,285	14,244	22,652	20,086	20,335	1,386	118,256	22,559

Table 3. Input variables for Thompson-Bell spawning stock biomass per recruit and yield per recruit models. f_{rs} = proportion mature, c=proportion of fishing mortality before spawning, d=proportion of natural mortality before spawning, and M=instantaneous natural mortality.

Age	f_{rs}	selectivity pattern (p)		c	d	M
		Slot limit	9"msl			
1	0.00	0.00	0.00	0.95	0.15	0.25
2	0.35	0.08	0.09	0.95	0.15	0.25
3	0.80	0.20	0.24	0.95	0.15	0.25
4	1.00	0.67	0.64	0.95	0.15	0.25
5	1.00	0.90	0.84	0.95	0.15	0.25
6	1.00	1.00	0.87	0.95	0.15	0.25
7	1.00	0.92	1.00	0.95	0.15	0.25
8	1.00	0.23	1.00	0.95	0.15	0.25
9	1.00	0.23	1.00	0.95	0.15	0.25
10	1.00	0.23	1.00	0.95	0.15	0.25
11	1.00	0.23	1.00	0.95	0.15	0.25
12	1.00	0.23	1.00	0.95	0.15	0.25

Table 4. Coefficient of variation of catchability (q), initial N in 1998, recruitment (R), instantaneaous fishing mortality (F), population abundance (N) and biomass (B) for upper Chesapeake Bay yellow perch statistical catch at age model.

Parameter	CV		Parameter	CV
q Comm	0.184		N 1998	0.142
q Trwl 3	0.220		N 1999	0.150
q Seine 3	0.204		N 2000	0.167
q Trwl 4+	0.222		N 2001	0.154
N_4 1998	0.221		N 2002	0.169
N_5 1998	0.203		N 2003	0.194
N_6 1998	0.322		N 2004	0.189
N_7 1998	0.439		N 2005	0.221
N_8+ 1998	0.457		N 2006	0.229
R 1998	0.208		N 2007	0.223
R 1999	0.188		N 2008	0.231
R 2000	0.191		N 2009	0.229
R 2001	0.194		N 2010	0.276
R 2002	0.195		B 1998	0.149
R 2003	0.225		B 1999	0.146
R 2004	0.229		B 2000	0.167
R 2005	0.265		B 2001	0.158
R 2006	0.257		B 2002	0.169
R 2007	0.278		B 2003	0.193
R 2008	0.314		B 2004	0.188
R 2009	0.384		B 2005	0.219
R 2010	0.472		B 2006	0.229
F 1998	0.218		B 2007	0.223
F 1999	0.215		B 2008	0.231
F 2000	0.220		B 2009	0.230
F 2001	0.205		B 2010	0.256
F 2002	0.190			
F 2003	0.251			
F 2004	0.274			
F 2005	0.287			
F 2006	0.287			
F 2007	0.282			
F 2008	0.276			
F 2009	0.262			
F 2010	0.279			

Figure 1. Upper Chesapeake Bay study area. Solid lines indicate areas not included in the assessment. Dotted lines indicate upper Bay watersheds that were closed to commercial yellow perch harvest in 2010.

Figure 2. Upper Chesapeake Bay winter trawl survey locations for the 2010 sampling season.

Figure 3. Commercial yellow perch landings v. fyke net effort for upper Chesapeake Bay yellow perch fishery with statistically significant linear trend line.

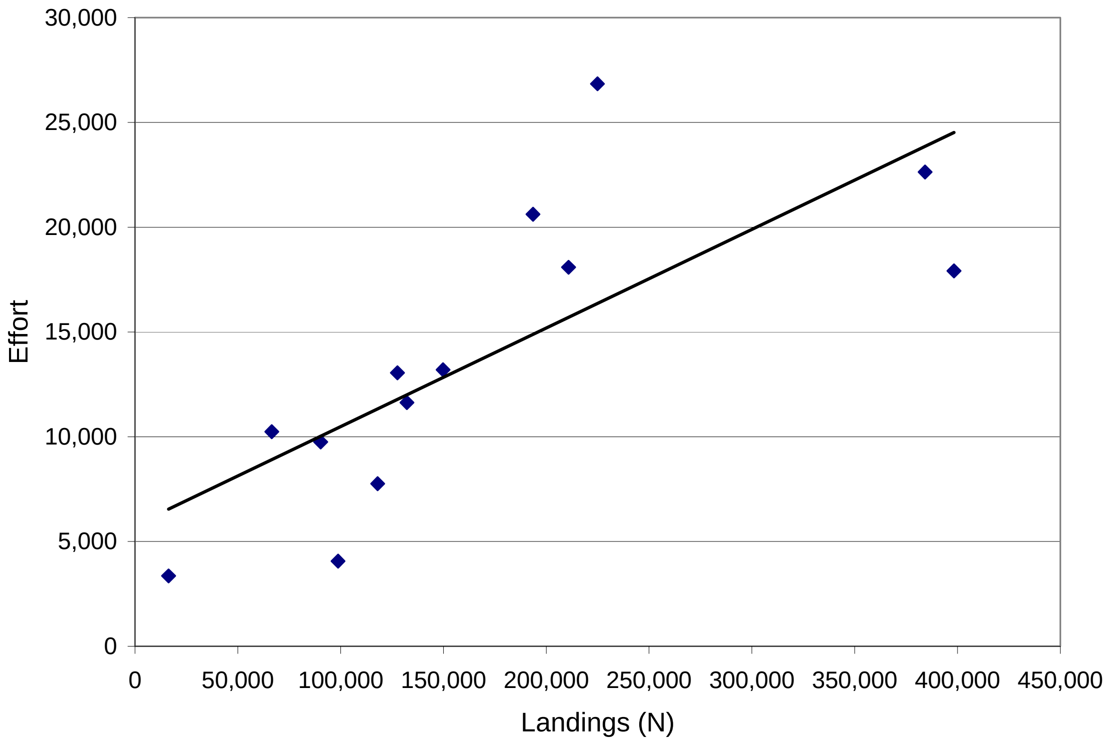


Figure 4. Yellow perch commercial fyke net selectivity ogives for 2 time periods, 1998-1999 and 2000-2010.

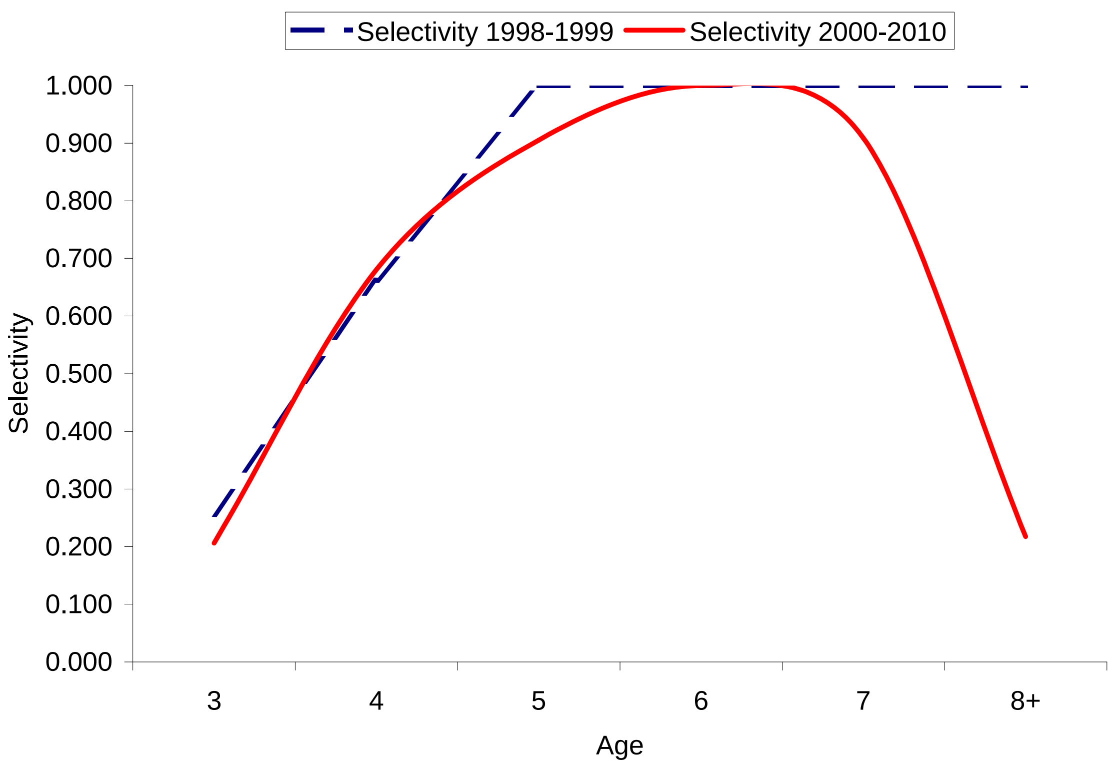


Figure 5. Upper Chesapeake Bay yellow perch abundance estimates (N, ages 3+), 1998 – 2010.

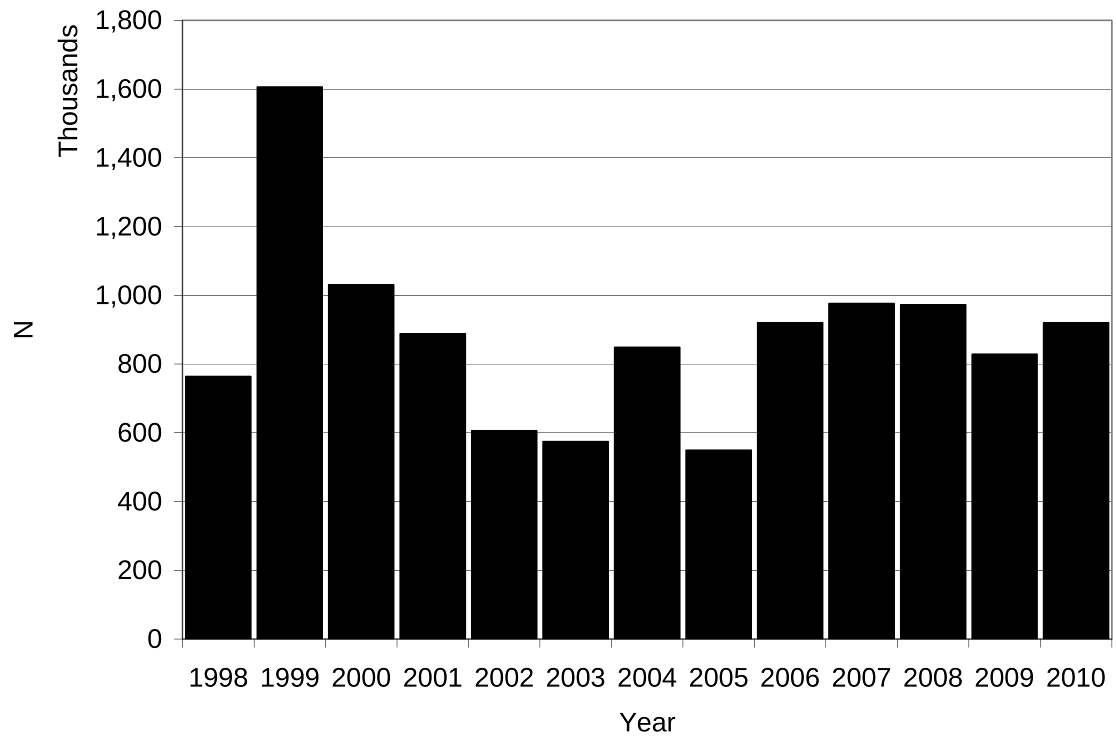


Figure 6. Upper Chesapeake Bay yellow perch biomass (kg, ages 3+) estimates, 1998 – 2010.

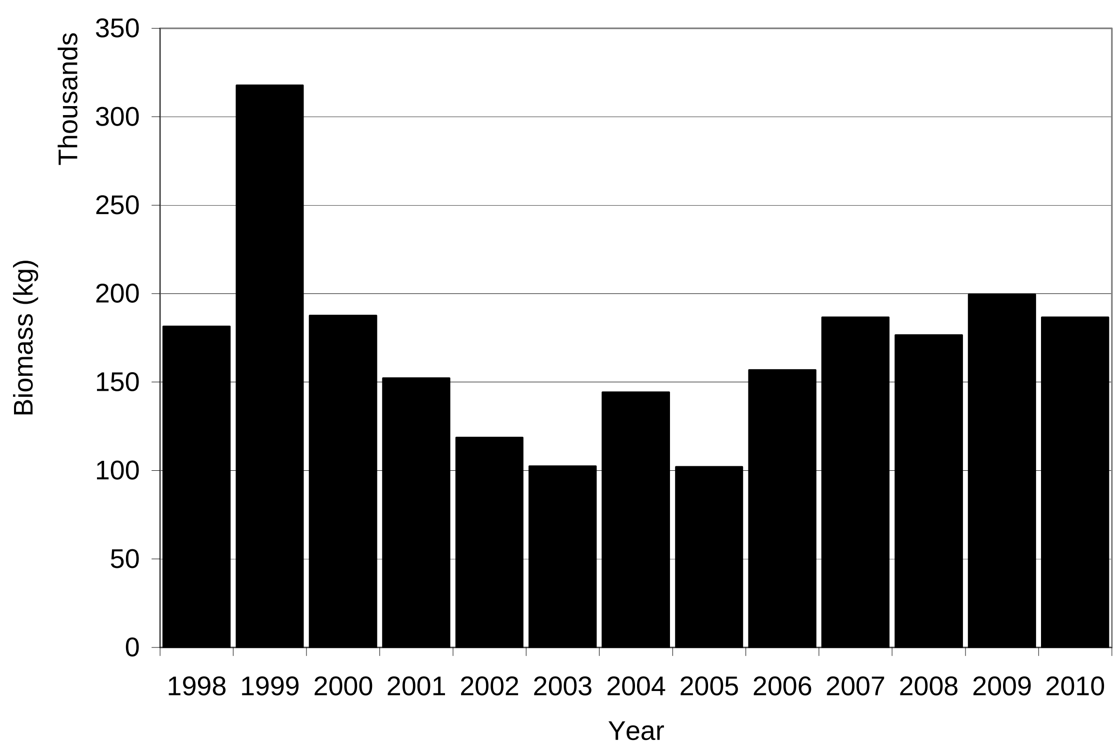


Figure 7. Upper Chesapeake Bay yellow perch fully recruited instantaneous fishing mortality (F) estimates, 1998 – 2010.

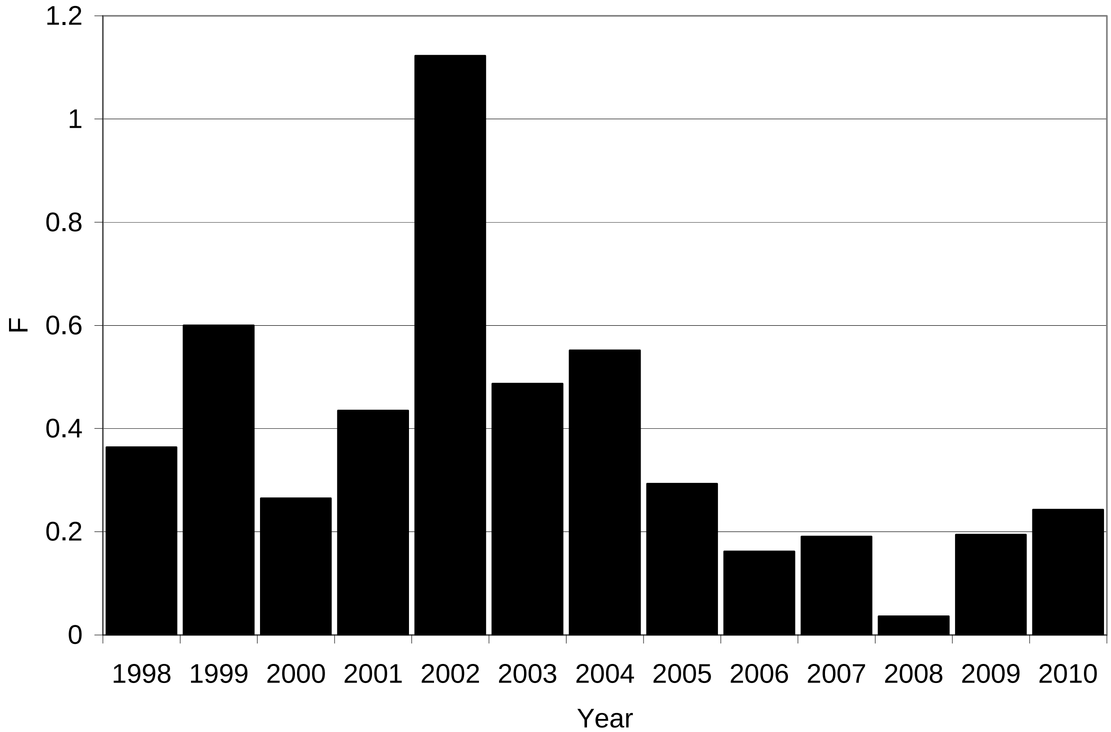


Figure 8. Upper Chesapeake Bay yellow perch recruitment (R, age 3) estimates, 1998 – 2010. Horizontal line indicates time series average.

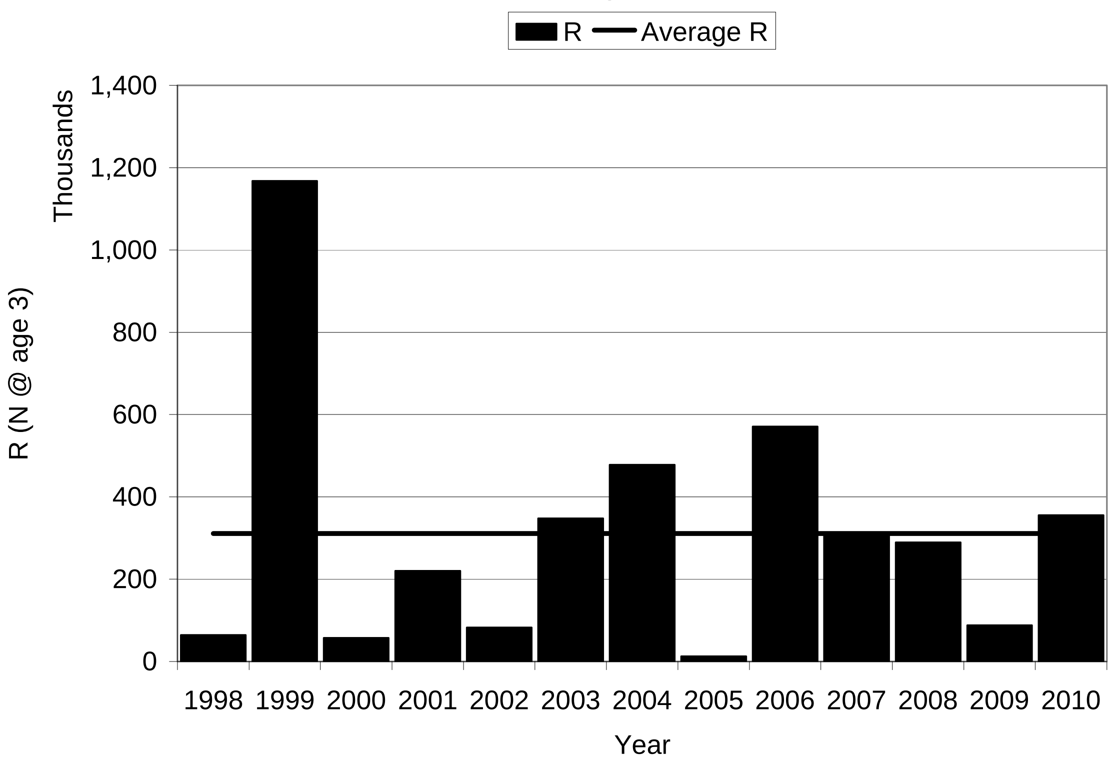


Figure 9. Age 3 residual pattern from upper Chesapeake Bay yellow perch population model.

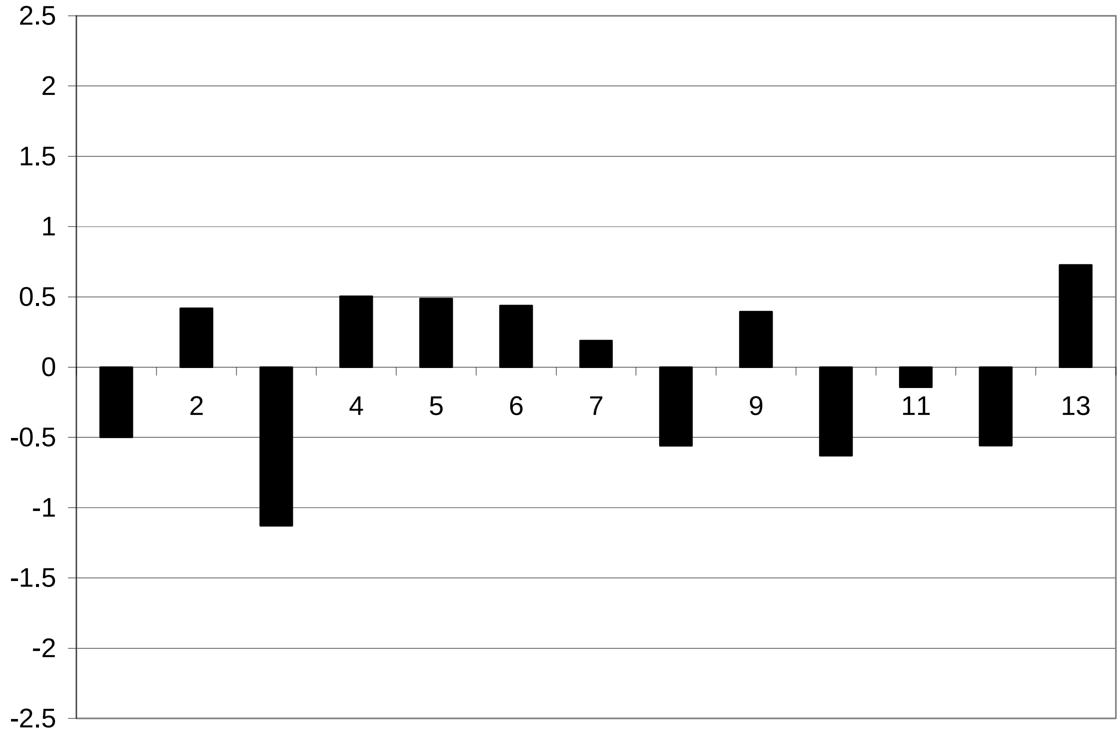


Figure 10. Age 4 residual pattern from upper Chesapeake Bay yellow perch population model.

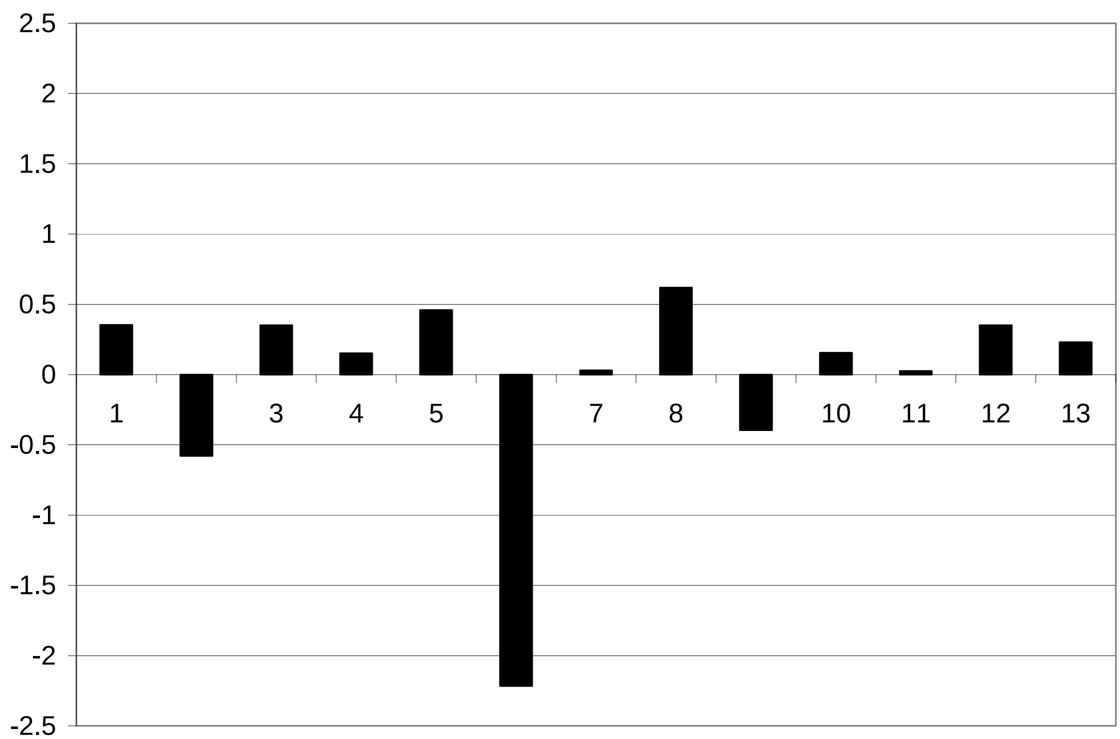


Figure 11. Age 5 residual pattern from upper Chesapeake Bay yellow perch population model.

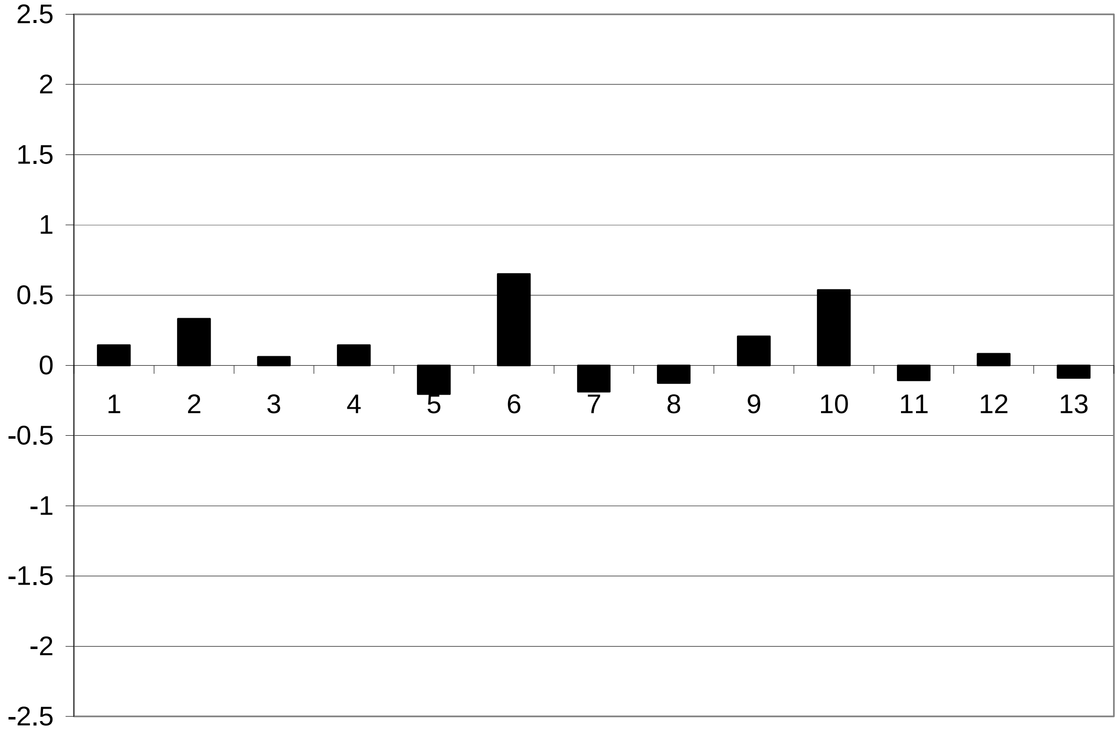


Figure 12. Age 6 residual pattern from upper Chesapeake Bay yellow perch population model.

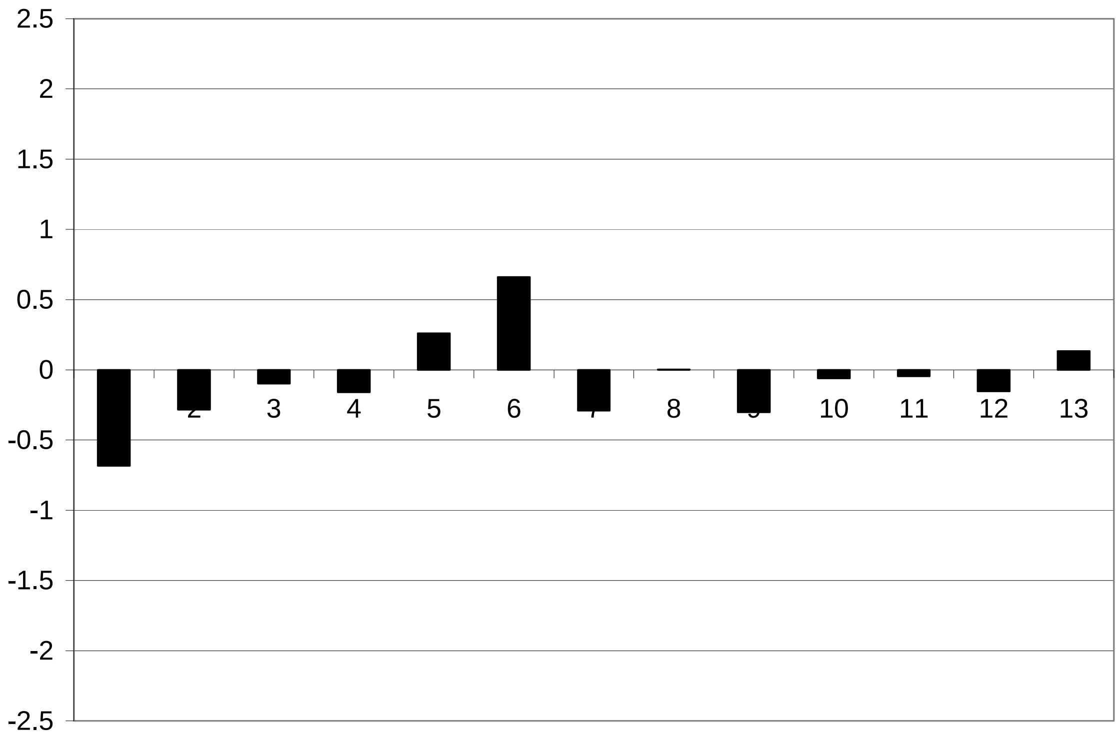


Figure 13. Age 7 residual pattern from upper Chesapeake Bay yellow perch population model.

Figure 14. Age 8+ residual pattern from upper Chesapeake Bay yellow perch population model.

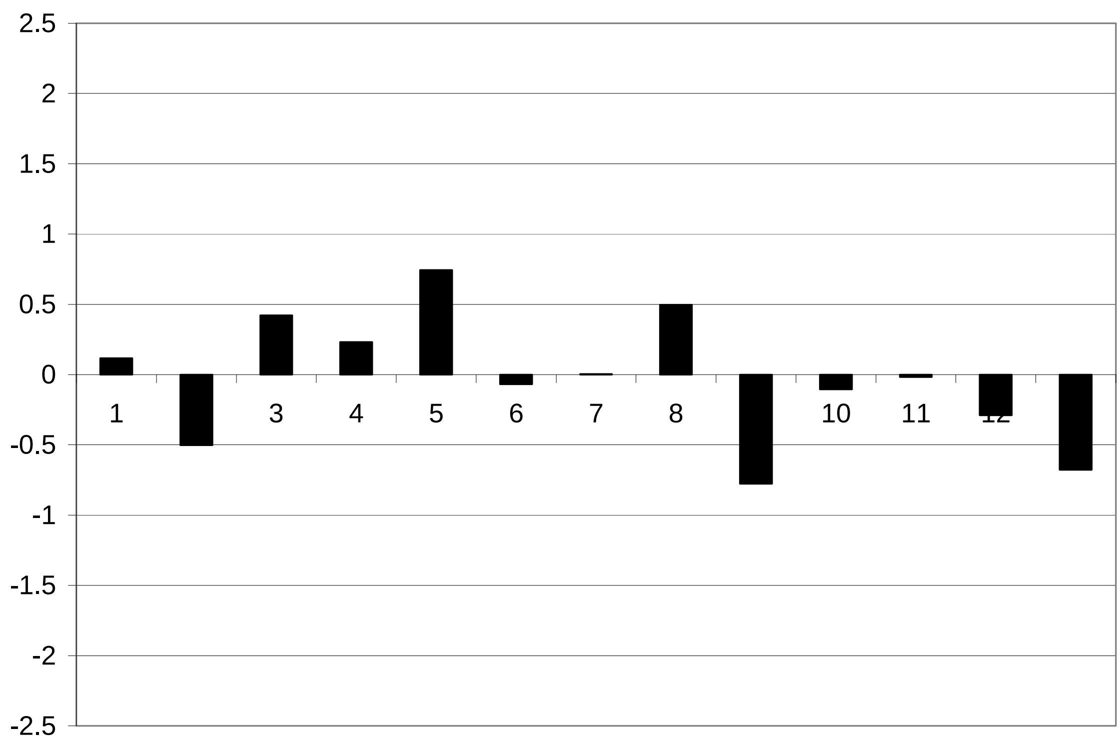


Figure 15. Residual pattern of fishery independent age 3 seine index from upper Chesapeake Bay yellow perch population model.

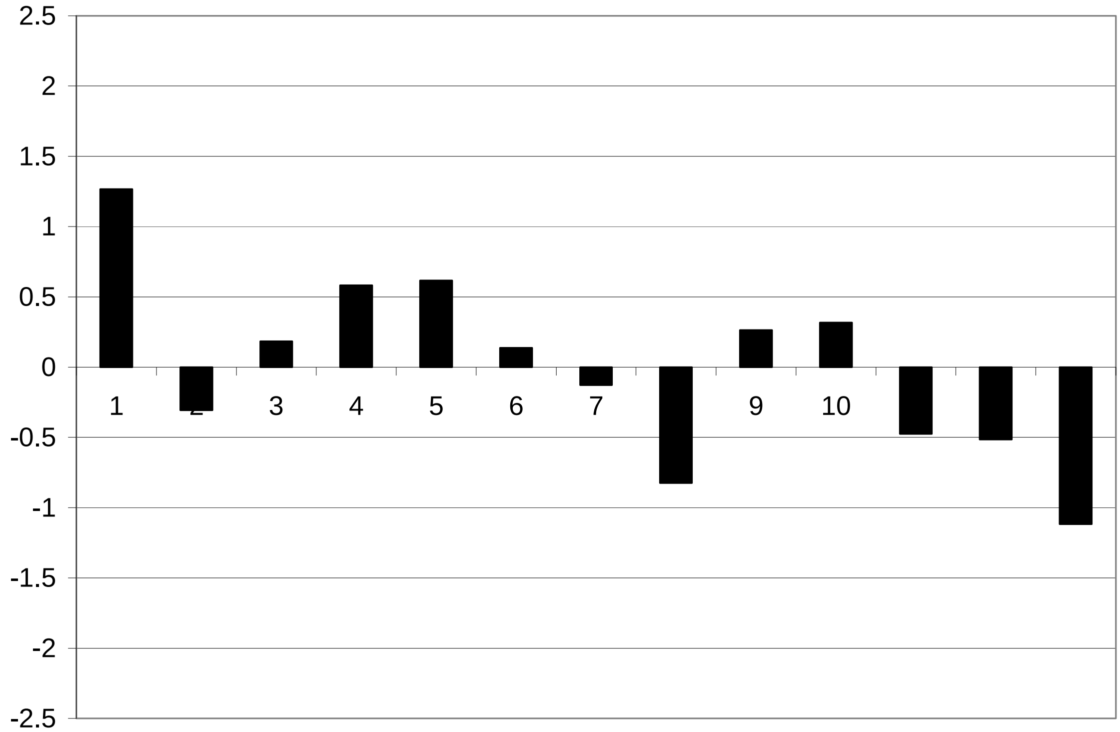


Figure 16. Residual pattern of fishery independent age 3 trawl index from upper Chesapeake Bay yellow perch population model.

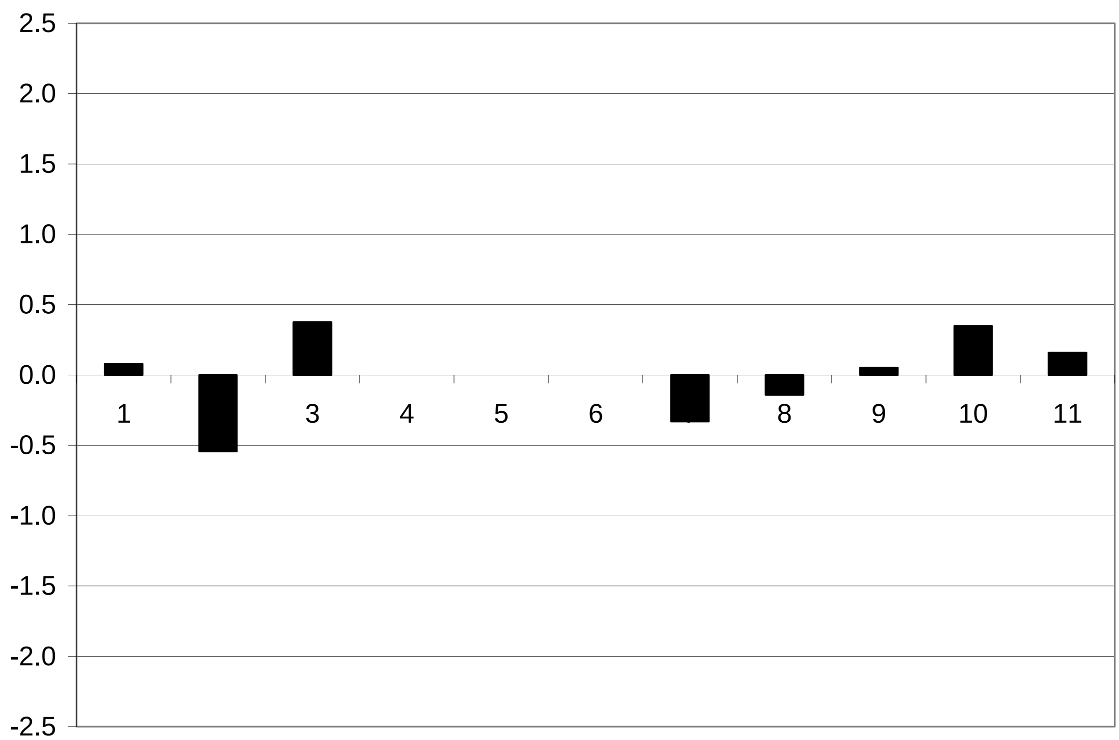


Figure 17. Residual pattern of fishery independent age 4+ trawl index from upper Chesapeake Bay yellow perch population model.

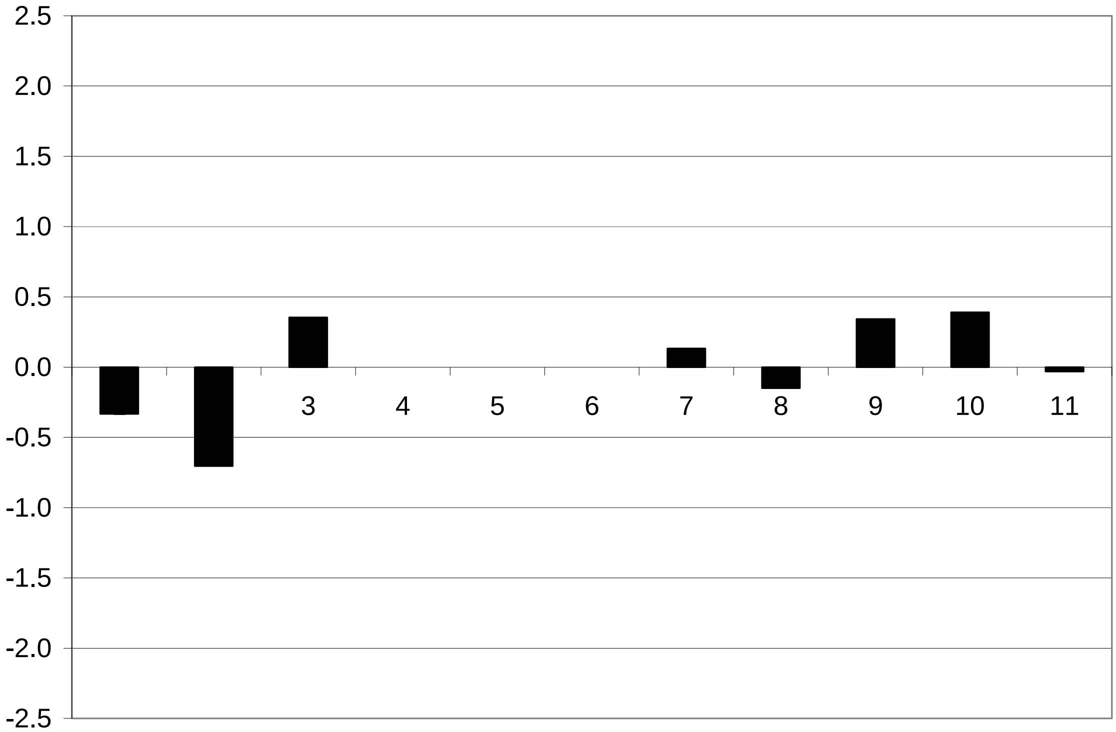


Figure 18. 80% confidence intervals of fully recruited F estimates from upper Chesapeake Bay yellow perch population model.

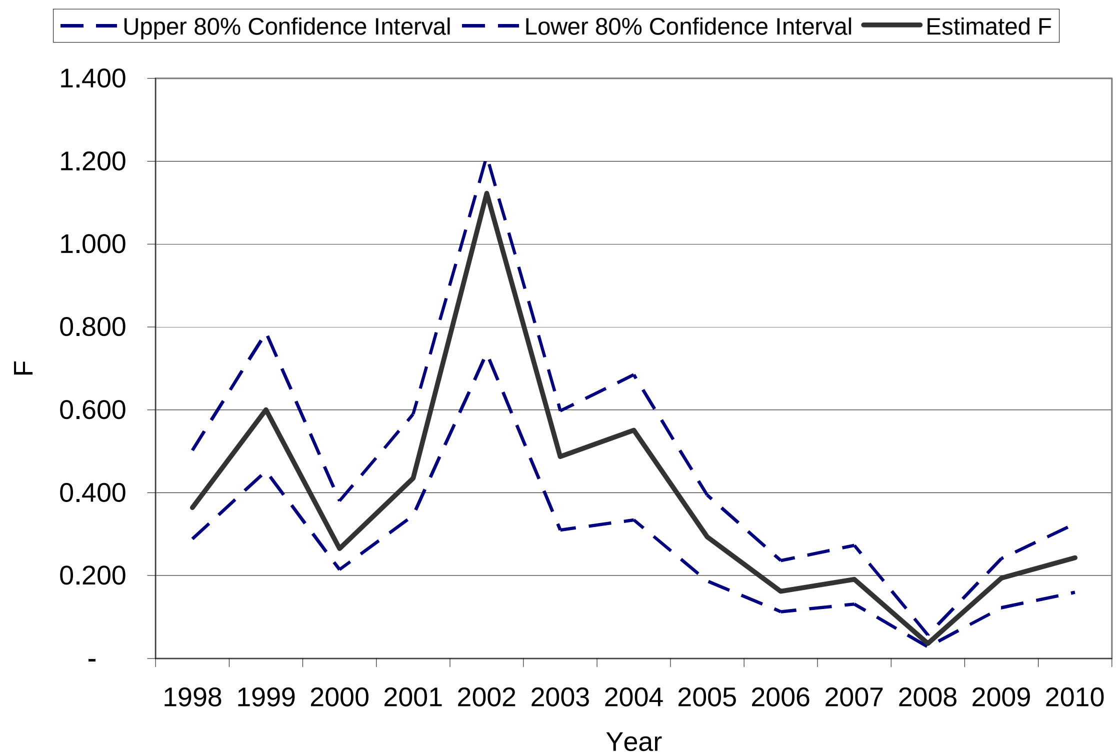


Figure 19. 80% confidence intervals of recruitment (age 3, R) estimates from upper Chesapeake Bay yellow perch population model.

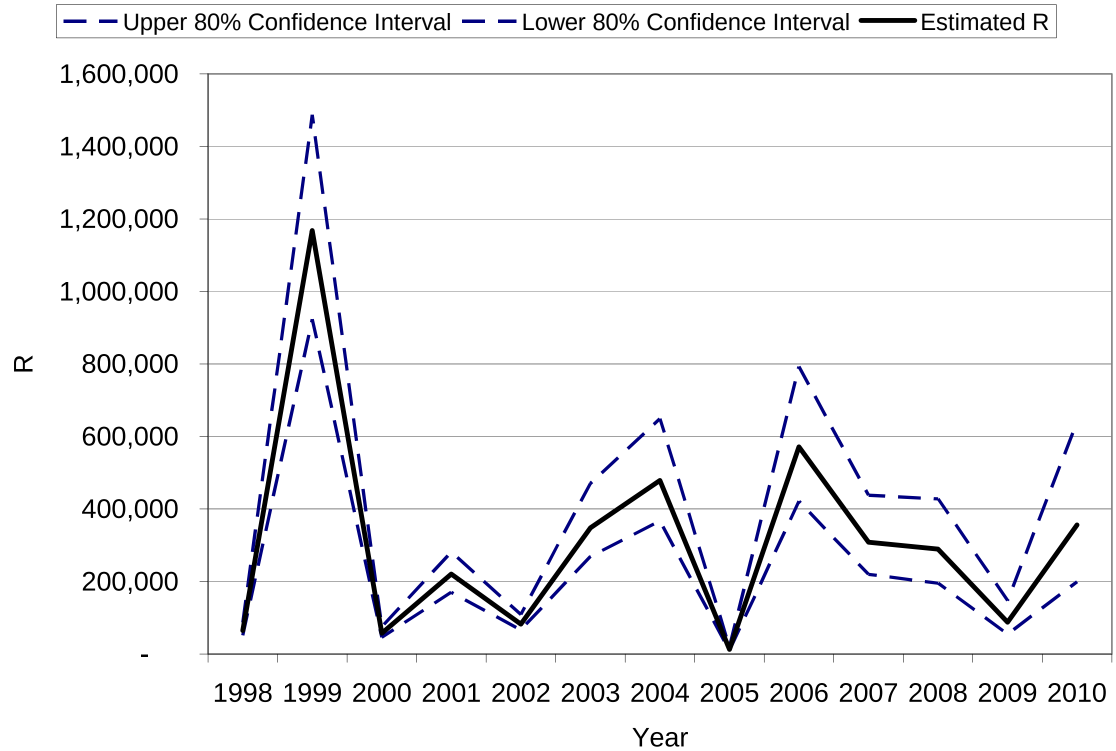


Figure 20. 80% confidence intervals of abundance (N, ages 3+) estimates from upper Chesapeake Bay yellow perch population model.

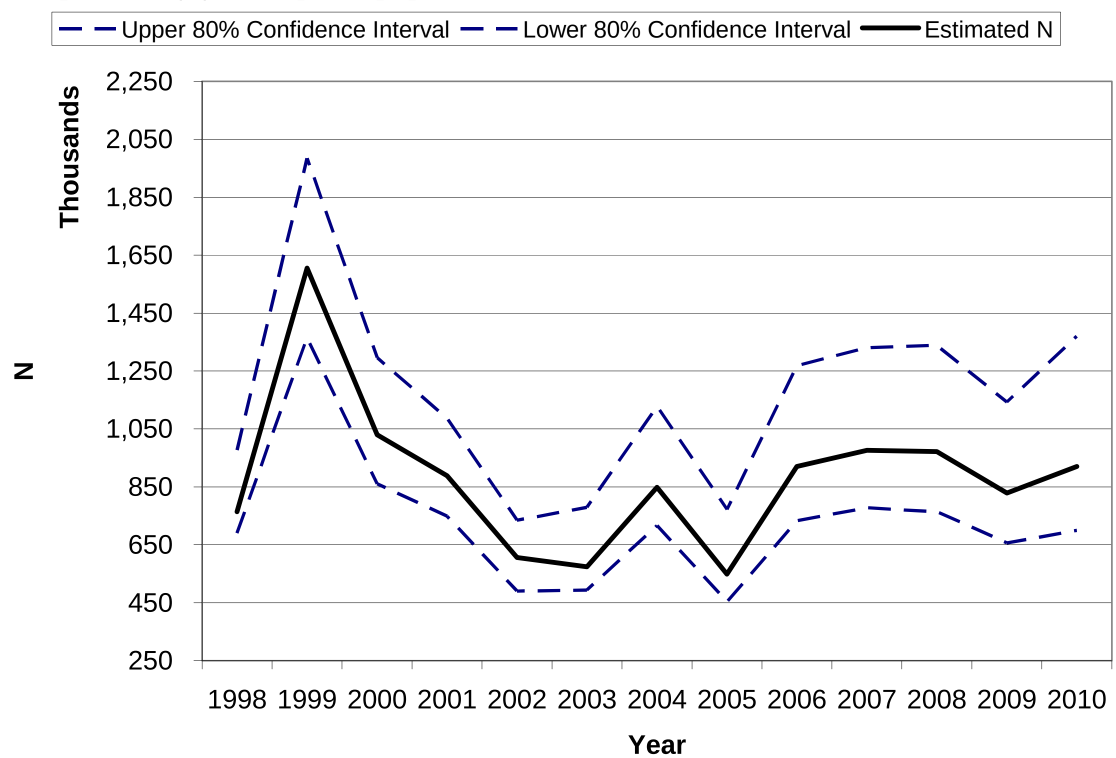


Figure 21. Percent maximum spawning potential (%MSP) versus F from Chesapeake Bay yellow perch spawning stock biomass/recruit model for 8 1/2" – 11" slot limit.

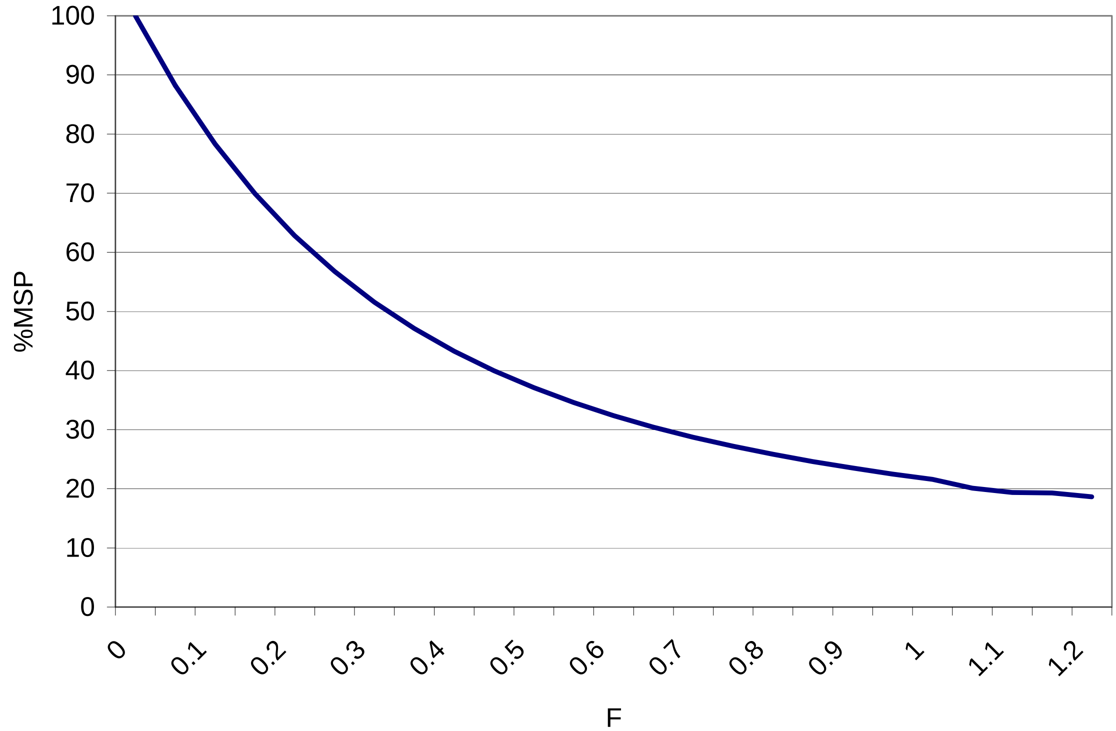


Figure 22. Percent maximum spawning potential (%MSP) versus F from Chesapeake Bay yellow perch spawning stock biomass/recruit model for 9" minimum size limit.

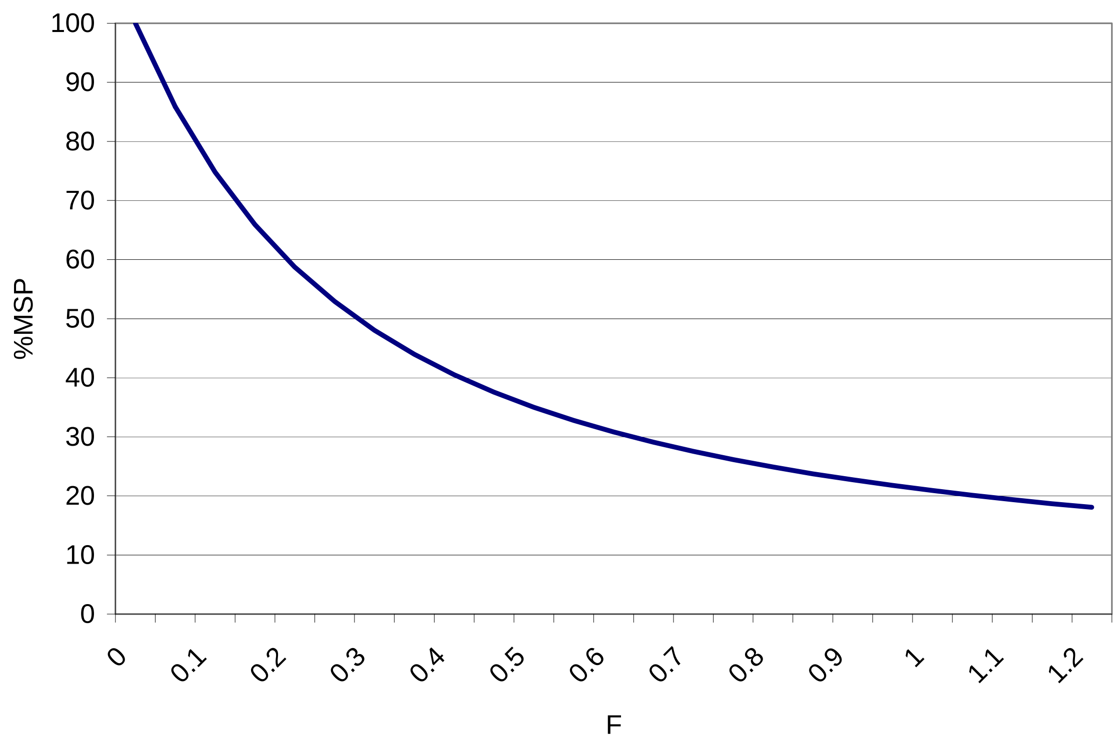


Figure 23. Yellow perch relative abundance (fish/net day) from Choptank River fishery independent fyke net survey, 1988 – 2010. Predicted CPUE curve is statistically significant at P < 0.0001.

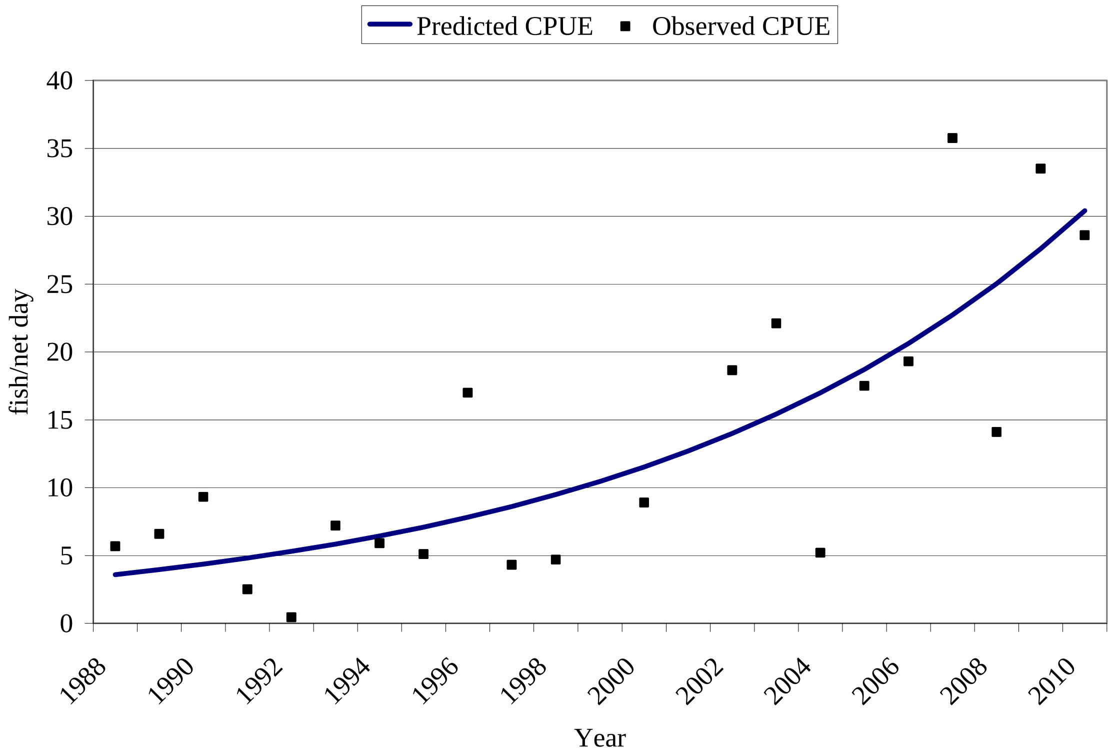
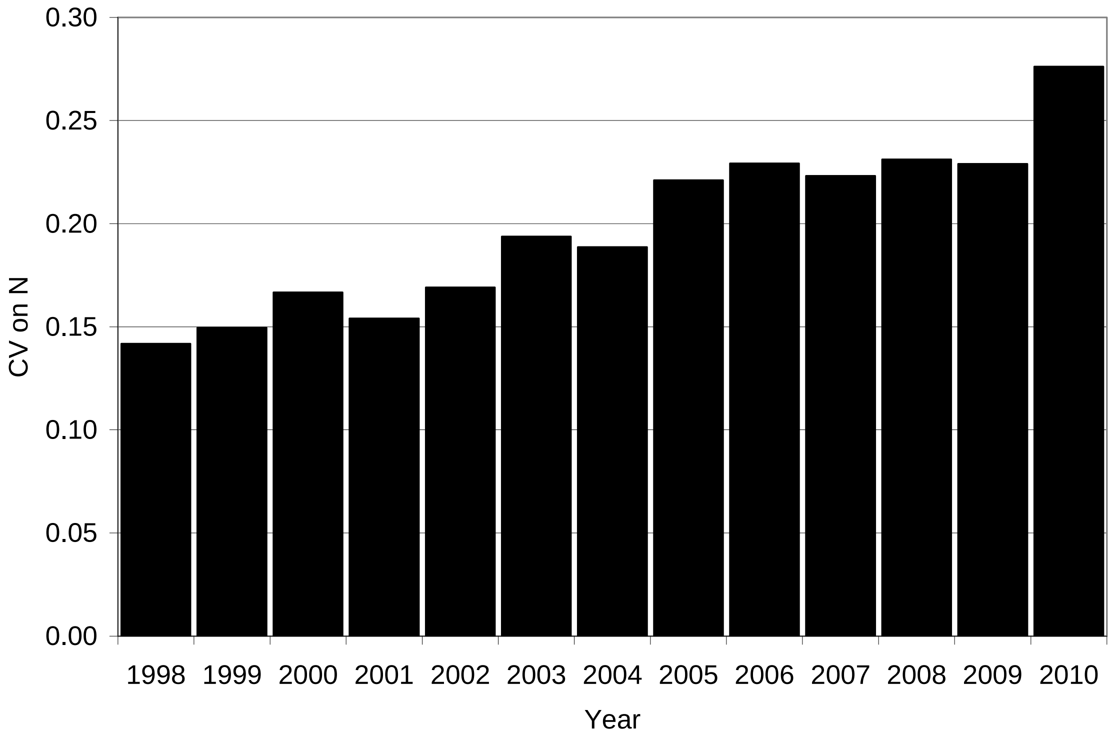


Figure 24. Coefficient of variation of abundance estimates of from upper Chesapeake Bay yellow perch population model.



APPENDIX A

BETWEEN READER PRECISION FOR UPPER CHESAPEAKE BAY YELLOW PERCH AGE DETERMINATION USING WHOLE OTOLITHS

INTRODUCTION

Age determination of a fish species is an important component of most biological assessments. In fact, many length-based variants of analytical fishery techniques still rely on at least some age derived information such as vonBertalanffy parameters. Biologists often rely on age determination to assess mortality rates, growth rates, and to construct age-length keys that are used to formulate catch-at-age matrices (CAA). The CAA matrices are inputs for population models such as virtual population analysis (VPA) or statistical catch at age models.

Fishery literature is replete with aging studies that compare different structures for age estimation (scales, spines, vertebrae, otoliths) or define the degree of bias in age determination within or among laboratories. Campana (2001) provided a useful review to guide researchers in all facets of the age estimation process that included validation, precision and quality control. Methods for describing precision and bias in age determination may include percent agreement or age-bias plots (Campana et al. 1995), mean coefficient of variation (Chang 1982), average percent error (Hoenig et al 1995) or pairwise statistical analysis.

The upper Chesapeake Bay yellow perch stock has been assessed annually since 2008 by using a statistical catch at age model. A reviewer of the assessment requested detailed information on the quality of the age data. In the early 1990's, an *ad hoc* age precision survey indicated 98% reader agreement. No further analysis was conducted, given the high degree of reproducibility. Since yellow perch are now assessed with a statistical catch at age model, it is important to document any potential source of error.

The goal of this study was to more formally assess the precision of our age determination methodology and relate the implications of potential otolith aging bias to the yellow perch stock assessment.

METHODS

Yellow perch from the 2010 upper Chesapeake Bay commercial fishery monitoring effort were used to determine between reader variability. Yellow perch were measured (mm TL) and sex was determined by examining external gonadal exudation. A non-random subsample was procured for otolith extraction and subsequent age determination. Sex and weight were also determined for those specimen selected for otolith extraction.

Ages were determined by counting annular rings on whole otoliths submersed in glycerin under a dissecting microscope with direct light. We assumed a January 1 birth date and therefore counted the edge of the otolith as an annulus. Given previous *ad hoc* assessments of our aging procedures and the fact that both readers have 20 years of experience in reading yellow perch otoliths, side-by-side age determination was viewed as an unwarranted duplication of effort. The initial reader (reader 1) had all information available (length, weight, sex, etc). The second reader (reader 2) had no knowledge of any biological characteristics of the specimen and did not know the age estimation of reader 1.

Age data were analyzed on two levels. First, at the reader level to assess bias and precision, and secondly, at the assessment level by comparing CAA vectors produced by age determination from reader 1 and reader 2. At the reader level, percent agreement, coefficient of variation (CV; Chang 1982) and age bias plots provided a basis for comparison. In addition, a Kolmogorov-Smirnov test and Wilcoxon's sign-rank test were used to assess differences between readers (α= 0.05; Sokal and Rohlf 1981). At the assessment level, a CAA vector of the survey length sample was produced from age-length keys based on each reader's interpretation. The age-length keys were sex-specific and applied in 20 mm increments. The resultant CAA vectors were compared with a Kolmogorov-Smirnov test (α= 0.05; Sokal and Rohlf 1981).

RESULTS

Otolilths of 171 yellow perch (74 males and 97 females) were aged by two biologists. Ages represented in the sample ranged from 2 years old to 9 years old and total length ranged from 182 mm to 391 mm. Percent agreement between the 2 readers was 97% and the resultant CV was 0.56%. Age bias plots did not indicate any tremendous bias (Figure A-1). The null hypothesis that the cumulative age frequency distribution produced from reader 1 was the same as from reader 2 could not be rejected (Figure A-2; Kolmogorov-Smirnov D-statistic=0.11 critical value=0.15). Similarly, the null hypothesis that the median difference between reader 1 and reader 2 was 0 could not be rejected (Wilcoxon sign-rank test, p-Value=1.0). The CAA vector produced from the age-length key was similar between readers. The maximum difference between the CAA vectors was 10.4% (Table A-1). The null hypothesis that the cumulative age frequency distribution off the CAA vector produced from reader 1 was the same as from reader 2 could not be rejected (Figure A-3; Kolmogorov-Smirnov D-statistic=0.01 critical value=0.05).

DISCUSSION

This study indicated that using whole yellow perch otoliths for age estimation produced high reader agreement and very good precision. Previously, only *ad hoc* assessments were conducted to assure reliable age determination. In spite of relatively precise age determination, CAA vectors may become compromised when errors are magnified by the expansion of the age misspecification when applied to a sample or population length structure.

Our results compare favorably with other precision/age agreement surveys. Vandergoot et al (2008) estimated precision of three aging structures and three readers of otoliths from Lake Erie yellow perch. An estimate of reader agreement between an expert and an intermediate reader was 96% and age estimates had a CV of 1%. Another study for Pymatuning Reservoir, PA yellow perch found 96% reader agreement and CV of 0.8% (Niewinski and Ferreri 1999). Our results (97% reader agreement and 0.56 % CV) were remarkably similar. The Lake Erie and Pymatuning Reservoir studies employed sectioned otoliths. Although reader agreement may not be an appropriate metric to compare studies, CV's do provide a basis for comparison between the studies and methodologies (Campana et al 1995; Hoxmeier et al 2001). The increased time to section and prepare the otoliths is likely unwarranted, given the low CV of our aging program (whole otoliths).

In order to assess the effects of the 2 different age structures, we computed 2 age-length keys (sex-specific) and applied them separately to the sample length data. The 2

CAA vectors were generally similar, but the highest percent difference between readers occurred at age 4. All of the disputed age samples were from male yellow perch, and although the length range corresponding to age 4 comprises a large portion of the sample, male yellow perch were a smaller portion of the sample. Therefore, the error was not magnified when we expanded the age distribution to the sample length distribution. For example, the difference in age estimation of age 4 yellow perch was over 12% but the difference in the CAA vector was 10%. Regardless, all of the ages that did not agree were re-aged, and a consensus age was easily assigned. The error appears to be more likely measurement error as opposed to process error.

Currently, we assess upper Chesapeake Bay yellow perch stocks with a statistical catch at age model (Haddon 2001). One of the advancements of this type of analytical VPA is the relaxation of the assumption that the CAA is measured without error. The fact that the model internally estimates a predicted CAA matrix somewhat lessens the burden of biases involved with age estimation. In addition, the model employs a plus group for yellow perch 8 years old and greater. Any difficulty or bias in estimating these older yellow perch would not be a concern. In this study, there was 100% agreement of older yellow perch if an age 8 plus group was adopted. However, future age estimation may be enhanced by employing side-by-side age assessment and also by increasing sample sizes if the bias is random (observation error) and not systematic (process error). Given the high rate of agreement and low CV over the entire age structure of the sample, the former is more likely.

LITERATURE CITED

Campana, S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59:197-242.

Campana, S.E., M.C. Annand, and J.I. McMillan. 1995. Graphical and statistical methods for determining the consistency of age determination. Transactions of the American Fisheries Society 124:131-138.

Chang, W.Y.B. 1982. A statistical method for evaluating the reproducibility of age determination. Canadian Journal of Fisheries and Aquatic Sciences 39:1208-1210.

Haddon, M. 2001. Modelling and Quantitative Methods in Fisheries. Chapman and Hall/CRC Publishing. New York.

Hoenig, J.M., M.J. Morgan, and C.A. Brown. 1995. Analysing differences between two age determination methods by test of symmetry. Canadian Journal of Fisheries and Aquatic Sciences 52:364-368.

Hoxmeier, R.J., D.D. Aday, and D.H. Wahl. 2001. Factors influencing precision of age estimation from scales and otoliths of bluefills in Illinois reservoirs. North American Journal of Fisheries Management 21:374-380.

Niewinski, B.C. and C.P. Ferreri. 1999. A comparison of three structures for estimating the age of yellow perch. North American Journal of Fisheries Management 19:872-877.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. W.H. Freeman and Company. New York.

Vandergoot, C.S., M.T. Bur, and K.A. Powell. 2008. Lake Erie yellow perch age estimation based on three structures: precision, processing times, and management implications. North American Journal of Fisheries Management 28:563-571.

Table A-1. Sample catch at age vectors produced from 2 age-length keys from independent age readers for upper Chesapeake Bay yellow perch.

	AGE							
	2	3	4	5	6	7	8	9
READER 1	13	607	192	333	300	338	0	26
READER 2	12	606	172	345	316	330	1	24
% DIFFERENCE	7.7	0.2	10.4	-3.6	-5.3	2.4		7.7

Figure A-1. Age bias plot of upper Chesapeake Bay yellow perch. Data points indicate average age assigned by reader 2 of yellow perch of an age assigned by reader 1. Error bars indicate 95% confidence interval of the means of reader 2. Diagonal line indicates 1:1 relationship between readers.

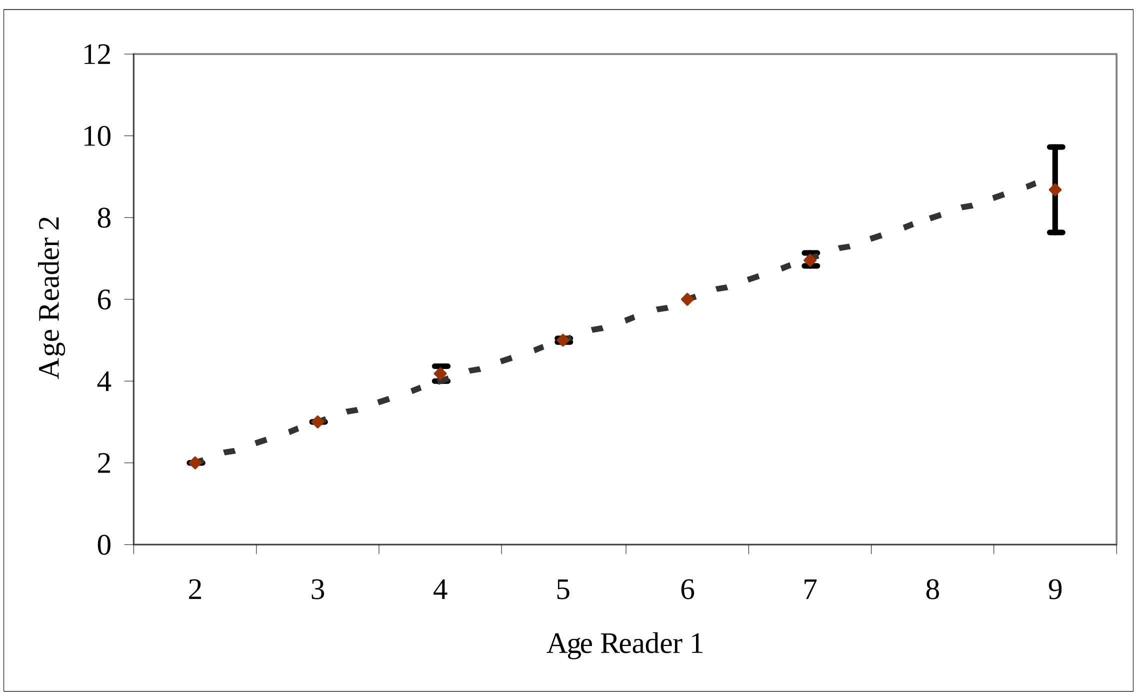
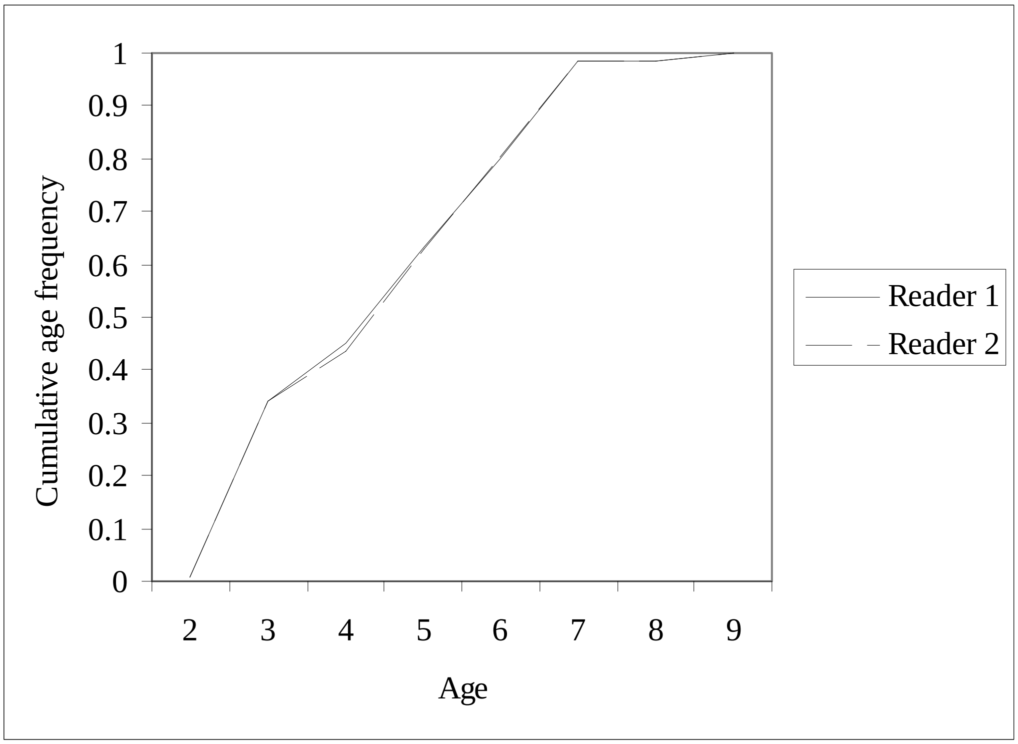


Figure A-2. Cumulative age frequency distributions of 2 readers of upper Chesapeake Bay yellow perch otoliths. There are 2 lines there, believe me.

Figure A-3. Cumulative age frequency distribution of the 2010 catch at age vector from 2 independent age readers for upper Chesapeake Bay yellow perch.



PROJECT NO. 2
JOB NO 1

STOCK ASSESSMENT OF ADULT AND JUVENILE ANADROMOUS ALOSA SPECIES IN THE CHESAPEAKE BAY AND SELECT TRIBUTARIES

Prepared by
Harry Rickabaugh Jr. and Anthony Jarzynski

INTRODUCTION

The primary objective of Project 2 Job 1 was to assess trends in the stock status of four anadromous alosine species present in Maryland's portion of the Chesapeake Bay and selected tributaries. Information regarding alosine spawning adults and their subsequent spawning success in Maryland tributaries was collected using both fishery dependent and independent sampling gear. Survey biologists worked with Nanticoke River commercial fishermen to sample adults followed by independent ichthyoplankton collections. Long-term estimates of abundance and physical characterization data was collected from adult American and hickory shad in the lower Susquehanna River below Conowingo Dam. Summer sampling targeted juvenile alosines in the Chester River.

The data collected during this study provided information from broad geographic ranges and was utilized 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 (EBFM).

METHODS

I. Field Operations

A. Adults

Adult alosine species sampled in the spring of 2010 were sexed (when possible) by expression of gonadal products and fork length (mm FL) measured. Scales from American shad, hickory shad, alewife herring and blueback herring were removed below the insertion of the dorsal fin for later age and spawning history analysis.

1. Susquehanna River

American shad were angled from the Conowingo tailrace (Figure 1) on the lower Susquehanna River two to five times per week from 15 April through 21 May 2010. Two rods were fished simultaneously, with each rod rigged with two shad darts and lead weight added, when necessary, to achieve proper depth. Fish in good physical condition and females not spent or running ripe were quickly tagged and released. A Maryland Department of Natural Resources (MDNR) Fisheries Service hat was given to fishers as reward for returned tags.

Hickory shad have been collected for hatchery brood stock by MD DNR Fisheries Service, Restoration and Enhancement Program and sub-sampled for age, repeat spawning marks, sex, length and weight since 2002. Scale reading technique was standardized and considered reliable from 2004 on. In 2004 and 2005 fish were collected using hook and line, and have been collected using electrofishing gear from 2006 to the present.

2. Nanticoke River

American and hickory shad and alewife and blueback herring in the Nanticoke River were collected from commercial pound nets (2) and fyke nets (2) between 22 March and 30 April 2010. The two pound nets were located just below Vienna and at the mouth of Mill Creek while fyke nets were located between river kilometer (rkm) 29.9 and 36.9 (Figure 2). Targeted fish captured from these nets were sorted according to species and transferred to the survey boat for processing. Depending on the daily catches, the total number of herring harvested was recorded by direct counts or estimated by multiplying the number of bushels harvested by the number of fish per bushel from sampled nets on that particular day. All nets were sampled one to two days per week during the 40-day survey period. Dead adult American shad from the Nanticoke River survey had otoliths removed and sent to Delaware Division of Fish and Wildlife for oxytetracycline (OTC) analysis.

B. Ichthyoplankton

Successful alosine reproduction in the lower Nanticoke River was indicated by the presence/absence of eggs or larvae through ichthyoplankton sampling. These samples were collected twice per week from 1 April to 30 April 2010. The ichthyoplankton net was constructed of 500 μm mesh net with a 500mm metal ring opening. The net was towed for two-minutes at approximately two knots and at the conclusion of the tow the contents were flushed down into a masonry jar for presence/absence determination. The river was divided into eighteen one-mile cells and during each sampling day, ten cells were randomly selected. This methodology repeated historic ichthyoplankton sampling (J. Mowrer pers. comm. MDNR; Figure 3) Because of time constraints and the difficulty of determining species on the boat, presence of alosine (eggs or larvae) was only recorded.

C. Juveniles

Juvenile alosines were sampled biweekly from late June to October of 2010 in the Chester River with a 30.5 x1.2m x 6.4mm mesh haul seine. Seine sites were located a minimum of 0.5

miles apart and consisted of six sites on the Chester River (Figure 4). Sites were selected based on the availability of seinable beaches and historical spawning importance. All fish collected were enumerated by species and fork length measurements recorded for the four alosine species.

II. Statistical Analyses

A. Adults

1. Age and sex composition

Age determination utilizing scales was attempted for all American shad and river herring samples collected from the upper Bay and Nanticoke River. 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 since it was assumed that each fish had completed a full year's growth at the time of capture. Hickory shad scales were aged by the Restoration and Enhancement Program.

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

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

Where AG_m = the percent of an age group that is mature

AG_r = the number of repeat spawners in the next oldest age group

AG_n = the total number of fish in the oldest age group.

2. Length-frequency

Mean length-at-age was calculated by sex only for alewife and blueback herring. Time series analysis using linear regression was utilized to examine trends in Nanticoke River alewife and blueback herring lengths (1989-2010) for ages 3 to 7. Males and females were analyzed separately.

3. Relative Abundance

A biomass surplus production model (SPM; Macall 2002) was employed to estimate adult American shad relative abundance in the tailrace below Conowingo Dam. This model, which utilized numbers as its unit of measure rather than biomass was:

$$N_t = N_{t-1} \bullet (r \cdot N_{t-1} \bullet (1-N_{t-1}) / K) - C_{t-1};$$

where N_t = the population in year t;

N_{t-1} = the population in the previous year;

r = the intrinsic rate of population increase;

K = the maximum population size; and

C_{t-1} = losses associated with upstream and downstream fish passage in the previous year (equivalent to catch in a surplus production model).

An observation error model was also employed that assumed all residual errors were in the population observations and the logistic equation used to describe the time-series was deterministic and without error (Haddon 2001). Assumptions included in this model were that a proportional consumption of American shad by striped bass occurred annually, that American shad were landed as proportional bycatch to the Atlantic herring fishery, and adult American shad turbine mortality estimates were correct. These assumptions and a minimum output constraint greater than the number lifted was also applied annually because without it, model estimates fell below the actual fish lift catches at Conowingo Dam. The SPM also required an initial population estimate in 1985 and was estimated as $\log_e [1- (C_t / N_t)]$ (Ricker 1975).

Adult American shad catch-per-unit-effort (CPUE) for the tailrace area was also calculated from the fish lifts. Fish collected in the east lift were deposited into a trough, directed past a 4'x10' counting window, identified to species and enumerated by experienced technicians. American shad possessing a tag were counted and the tag color noted. American shad recaptured from the west lift were counted and either utilized for experimental purposes (hatchery brood stock, sacrificed for otolith extraction) or returned to the tailrace. Daily catch logs for each lift by species were subsequently distributed to DNR personnel. Annual catch-per-unit-effort (CPUE) for American shad was subsequently calculated as the geometric mean of fish caught per operating hour for both lifts at Conowingo Dam. Annual CPUE of upper Bay American shad captured by hook and line was calculated as the geometric mean of fish caught per boat hour.

In addition, recreational data from a roving creel was collected from anglers in the Conowingo Dam tailrace during the spring. This non-random survey interviewed stream bank anglers and generated a catch-per-angler-hour (CPAH) for American shad. Spring upper Chesapeake Bay American shad and hickory shad logbooks have also been voluntary returned to the Department documenting location, catch and hours spent fishing. CPAH by location and species was generated from these data.

Relative abundance, measured as annual CPUE for alewife and blueback herring and American shad collected from fyke and pound nets in the Nanticoke River were calculated as the geometric mean (based on a $\log_e$-transformation; Sokal and Rohlf 1981) of fish caught per fyke per day. Nanticoke River pound net CPUEs and commercial landings of alewife and blueback herring (species combined) were also analyzed for trends using linear regression.

4. Mortality

Two methods based on the number of repeat spawning marks were utilized to estimate total instantaneous mortality for American and hickory shad and river herring. For the first method, total instantaneous mortalities (Z) were estimated by the $\log_e$-transformed spawning group frequency plotted against the corresponding number of times spawned, assuming that consecutive spawning occurred (ASMFC 1988);

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

where S_{fx} = number of fish with 1,2,...f spawning marks in year x;

a = y-intercept;

W_{fx} = frequency of spawning marks (1,2,...f) in year x.

The second method averaged the difference between the natural logs of the spawning group frequencies providing an overall Z between repeat spawning age groups. The Z calculated for these fish represents mortality associated with repeat spawning.

B. Juveniles

1. Relative Abundance

Juvenile alosine catch-per-unit-effort (CPUE) from the summer seine survey was calculated by dividing the total catch, by the number of sites, divided by the number of site visits resulting in catch-per-seine-per-day.

2. Ichthyoplankton Samples

Successful clupeid reproduction in the lower Nanticoke River was determined by the presence of eggs through biweekly tows. The percent of clupeid eggs (positive tows) was determined by the number of tows with eggs divided by the total number of tows.

RESULTS

I. American shad

A. Adults

1. *Sex and Age Composition*

The 2010 male-female ratio of adult American shad captured by hook and line from the Conowingo tailrace was 1.14:1. Of the 486 fish sampled by this gear, 437 were successfully scale-aged (Table 1). Those American shad not aged directly because of regenerated scales, were not assigned ages.

The 2010 male-female ratio for adult American shad captured in the Nanticoke River was 1.43:1. Of the 34 American shad collected from the Nanticoke pound and fyke nets in 2010, 33 were subsequently aged (Table 1).

The percentages of Conowingo tailrace repeat spawning American shad in 2010 was 31.8% for males and 27.4% for females (Table 1). The arcsine-transformed proportions of these upper Bay repeat spawners (sexes combined) has significantly increased for the time series (r^2 = 0.55 $p < 0.001$; Figure 5). The percentages of repeat spawners for the Nanticoke River in 2010 were 48.5% for males and 50.0% for females. The arcsine-transformed proportions of Nanticoke repeat spawning American shad has also significantly increased for the time series (r^2 = 0.55 $p < 0.001$; Figure 6).

Males were present in age groups 3-7 while females were found in age groups 4-8 (Table 1). The 2005 year-class of males (age V) was the most abundant age group sampled, accounting for 44.9% of the total catch. For females, the 2006 (age IV) was the most abundant age group, accounting for 44.3%, of the total catch.

2. Relative Abundance

Of the 486 adult American shad sampled from the Conowingo tailrace in 2010 (Table 2), 431 (89%) were tagged and 106 (24.6%) subsequently recaptured from the east lift (Table 3). The east lift also captured nine American shad tagged in 2009. In 2010, there were no reported tagged American shad recaptured from either commercial fishermen or recreational anglers.

In 2010, the east lift operated from 5 April through 6 June, with the exceptions of April 6th, 8th, 10th and 12th, and technicians counted 37,757 American shad passing the viewing window during this 59 day period. Peak passage was on 20 April when 2,272 American shad were recorded. In 2010, the west lift at Conowingo Dam operated on 27 days from 21 April to 25 May. The 5,605 American shad captured were retained for hatchery operations, sacrificed for characterization data collection, or returned alive to the tailrace. Peak capture from the west lift was on 6 May when 1,128 American shad were collected. Twenty-one of the 23 marked American shad recaptured by the west lift in 2010 were fish marked this year (Table 3), and there was one marked fish from both 2009 and 2008. Based on model estimates, the American shad tailrace population estimate in 2010 was 93,949 fish, and trended up from 1986 to 2001, declined from 2001 to 2007 and has increased from 2008 to 2010 (Figure 7).

The angler-based roving creel in the Conowingo Dam's tailrace interviewed thirty-six anglers in 2010 on only four days because of time constraints. Catch-per-angler-hour (CPAH) from these anglers was 1.78, an increase from 2009 when the CPAH was 1.41 (Table 4). CPAH from 2001-2010 has varied with no significant trend. American shad logbook data indicated a decrease in CPAH compared to 2009 (Table 5) but there was no significant trend for the time series (1999-2010; r^2=0.39, P=0.03).

Estimates of hook and line geometric mean (GM) CPUEs indicated no significant trend for the 1984-2010 time series, but did increase from 1984 to 2002, dropped sharply in 2003 and has been variable with a slight declining trend through 2010 (Figures 8). The Conowingo Dam fish lift GM significantly increased over the 1980-2010 time series (r^2 = 0.40, $p<0.001$; Figure 9). However, the GM decreased steadily from the time series high in 2002 through 2008 before increasing slightly in 2009 and 2010.

Nanticoke River pound and fyke net GM CPUEs have both shown no trend since 2001 (r^2=0.084, P= 0.19; Figure 10; r^2=0.004, P=0.79; Figure 11). American shad catches for both gear types declined in 2010, and remain quite low especially for fyke nets.

3. Mortality

Since American shad do not fully recruit until age seven to the Maryland portion of the Chesapeake Bay, repeat spawning marks were utilized to calculate total mortality rates. For the 2010 Conowingo tailrace, mortality estimate from the spawning group frequency plotted against the corresponding number of times spawned resulted in Z = 1.37. The average difference between the natural logs of the spawning group frequency also produced Z = 1.37. The 2010 Nanticoke River mortality estimate from the spawning group frequency plotted against the corresponding number of times spawned resulted in Z = 0.96. The average difference between the natural logs of the spawning group frequency produced Z = 0.99.

Estimated American shad mortalities (in numbers) from Maryland waters are presented in Table 6. In general, these estimates appear proportional to the abundance of American shad estimated for the Conowingo tailrace.

Otolith Examination

Of the 179 adult American shad otoliths collected from the west lift at Conowingo Dam in 2010, 65% were classified as non-hatchery fish (M. Hendricks PA Fish and Boat Comm., Pers. Comm. 2010). Fourteen adult American shad otoliths collected from the Nanticoke River were sent to Delaware Division of Fish and Wildlife for oxytetracycline (OTC) analysis. Eleven of the 14 were readable, and results indicated that 91% were non-hatchery fish (M. Stangl pers. Comm.), but very low sample size makes this percentage tenuous at best.

B. Ichthyoplankton

Successful alosine reproduction in the lower Nanticoke River was determined by the presence of eggs and/or larvae collected during the spring biweekly plankton net tows in this system. Fertilized alosine eggs and/or larvae were found in 30 samples (n = 70). Salinity at plankton tow stations ranged from 0.0 to 0.5 ppm.

C. Juveniles

No juvenile American shad were caught by haul seine in the Chester River during the 2010 sampling season.

II. Hickory Shad

A. Adults

1. Sex and Age Composition

Only one hickory shad was collected from the Nanticoke River in 2010. Sex was not determined and the single sample was not aged. Fish sampled from the brood stock collection survey in the Susquehanna River in 2010 had a male-female sex ratio of 1/1.09. Ages from 2004 through 2010 ranged from 2 to 9 years old, with age 3 to 8 fish being present every year and age 2 and 9 fish being rare (Table 7). Repeat spawning has ranged from 67.4% to 89.0% from 2004 to 2010, and all repeat spawners have been at least 4 years old (Table 8). Male and female repeat spawning percentage was nearly identical in 2010 with the majority of repeat spawners being age 4 or 5 (Table 9).

2. Relative Abundance

Hickory shad CPAH from angler logbooks ranged from 3.5 to 8.4 for the time series with the lowest value (3.5) estimated in 2010 (Table 10). There was also no significant trend for the time series (1998-2010; r^2=0.12, P=0.25). Nanticoke River pound net GM CPUEs for adult hickory shad decreased since 2002 (Figure 12) while those for fyke nets have indicated no trend during this period (Figure 13).

3. *Mortality*

Hoenig's (1983) equation ($\ln (M_x) = 1.46 - 1.01\{\ln (t_{max})\}$) was utilized to estimate hickory shad natural mortality in the upper Bay. Since t_{max} = 9, M was calculated to equal 0.47**.** Estimated Z from the spawning group frequency plotted against the corresponding number of times spawned for 2010 resulted in a Z = 0.74. The average difference between the natural logs of the spawning group frequency produced a Z = 0.57.

B. Juveniles

During the 2010 beach seine sampling five juvenile hickory shad were collected from the Chester River.

III. Alewife and Blueback Herring

A. Adults

1. Sex and Age Composition

The 2010 male: female ratio for Nanticoke River alewife herring was 1:1.8. Of the 70 alewives sampled, 69 were subsequently aged. Age groups 3-7 were present with the 2005 year-class (age 5, sexes combined) the most abundant, accounting for 33.3% of the total catch. Females were most abundant at age 5 and males at age 4 (Table 11).

The 2010 male: female ratio for Nanticoke River blueback herring was 1:1.36. Of the 27 blueback herring sampled, 26 were subsequently aged. Blueback herring were present at ages 3-6 with the 2006 year-class (age 4, sexes combined) the most abundant accounting for 57.7% of the sample. Males and females were both most abundant at age 4 (Table 11).

The percentages of alewife and blueback herring repeat spawners (sexes combined) for the Nanticoke River during 2010 were 53.6% and 34.6%, respectively (Table 11). The arcsine-transformed proportion of alewife repeat spawners (sexes combined) indicated no trend (1989-2010; r^2=0.01 P=0.95), while that for blueback herring represented a decreasing trend (1989-2010; r^2=0.56, P<0.01; Figure 14).

Using Speir and Mowrer's (1987) maturity schedule calculation, 84% of male alewife and 100% of male blueback herring were mature by age 4. The percentages of female alewife and blueback herring mature by age 4 were 65.9% and 93.3%, respectively.

2. Length-at-Age

For 2010, Nanticoke River female alewife herring mean lengths-at-age were greater than the corresponding male mean lengths-at-age (Table 12). Female blueback herring mean lengths-at-age were greater than for all corresponding male lengths-at-age (Table 13). Mean length-at-age for alewife females ages 4 to 7 and males ages 4 to 7 have decreased significantly since 1989 (Table 14). Regressions of blueback herring lengths for females ages 4-7 and males at ages 4-7 and 9 have significantly decreased since 1989 (Table 14).

3. Relative Abundance

Nanticoke River alewife herring fyke net GM CPUEs have decreased significantly (1989-2010; r^2=0.1, P=0.15; Figure 15), as have those for blueback herring (1989-2010; r^2=0.64, P<0.01; Figure 16). While the combined GM CPUEs (species, sexes, gears) have shown a decreasing trend over time (1989-2010; r^2=0.148, P=0.08; Figure 17) reported Nanticoke River commercial river herring landings (species combined) have significantly decreased since 1989 ($r^2$0.78, P<0.01)

4. *Mortality*

In 2010, instantaneous mortality (Z) for Nanticoke River alewife herring (sexes combined) was Z = 0.92 (annual mortality {A} = 60.15%). Since maximum age (T_{max}) for alewife herring from the Nanticoke was 7, M = 0.43 and F = 0.49. Separate estimates of Z for males and females were 0.81 (annual mortality {A} = 55.51%), and 0.81 (annual mortality {A} = 55.51%;), respectively (Figure 18).

Instantaneous mortality (Z) for Nanticoke River blueback herring in 2010 (sexes combined) was Z = 1.10 (annual mortality {A} = 66.71%) and since the maximum age (T_{max}) for

Nanticoke blueback herring was 6, M = 0.50 and F = 0.60. The estimated Z for blueback herring males in 2010 was 0.69 (annual mortality {A} = 49.84) and 0.90 for females (annual mortality {A} = 59.34%; Figure 19).

B. Juveniles

For 2010, juvenile seining in the Chester River produced two juvenile alewife herring (CPUE = 0.05) and 27 juvenile blueback herring (CPUE = 0.66).

DISCUSSION

I. American Shad

A. Adults

The modified Petersen statistic for estimating relative abundance of American shad in the Conowingo Dam tailrace had been utilized since 1980. However, in 2008 this application may have overestimated the population as only 2% (3) of the fish marked in 2008 were recaptured compared to historical recaptures rates of 15% to 30%. Subsequently a biomass production model (SPM) was developed in order to obtain more accurate American shad population estimates. The best model estimates were derived when estimated striped bass predation rates, ocean bycatch losses and estimated losses due to both upstream and downstream passage were included. Otherwise, without these inclusions, the model estimates went to zero. In addition to this problem, the SPM had to be constrained so that population estimates were greater than the total lift catches at Conowingo Dam. SPM results when compared to Petersen population estimates (Figure 20) likely underestimate the American shad population because results would indicate that Conowingo Dam lift efficiencies (defined as annual catch at Conowingo Dam divided by population estimate) averaged 42.7% but was as high as 98.7 % in 2004. However, the Petersen estimates are likely overestimates, especially in years of low recaptures from Conowingo Dam.

Comparison of estimates calculated utilizing the Petersen statistic to those generated from the model indicated that the Petersen statistic appeared to overestimate the relative abundance of American shad in the Conowingo tailrace. However, even with the differences in the yearly point estimates, the overall population trends derived from each method are significantly correlated using linear regression ($r^2 = 0.36$, $p = 0.002$).

The declines noted for both estimates from 2001 to 2007 have also been mirrored by other measures of relative abundance. Estimates have increased modestly the past two years. Data from the roving creel and logbook surveys targeting American shad in the Susquehanna River watershed have generally shown substantial decreases in catch-per-angler-hour (CPAH) during the last seven years, compared to the higher values of the early 2000s, as have the Department's CPAH rates in capturing adults by hook and line for tagging. Fish lift CPUE's have also sharply declined since 2001. It should be noted, however, that hook and line CPUEs are not necessarily highly sensitive to abundance changes in the tailrace since this gear can become saturated on select days. The population explosion of gizzard shad in the Susquehanna drainage may also be affecting fish lift CPUEs through overcrowding at the fish lift weir gates thereby excluding American shad from entering the lift.

Since closure of the American shad commercial fisheries in Atlantic Ocean waters in December 2005, abundance indices have continued to generally decline. The Potomac River stock of American shad had remained stable, based on the Striped Bass Spawning Stock Survey (SBSSS; Project 2, Job 3, and Task 2), but in 2009 gill net CPUE sharply declined before rebounding in 2010 (Figure 21).

The 2007 American shad stock assessment conducted by ASMFC (2007) indicated that stocks were declining in most river systems along the east coast. This assessment indicated that total mortality rates in Maryland's targeted rivers (Susquehanna and Nanticoke) exceeded the benchmark Zs. Factors contributing to the increased American shad mortality rates included predation, Chesapeake Bay bycatch, Conowingo Dam turbine mortality, and ocean harvest/discards.

Kritzer and Black (2007) demonstrated a significant bycatch of alosines in the developing Atlantic herring trawl fishery which likely included both American shad and river herring. A major difficulty in quantifying ocean bycatch is identifying and differentiating the four alosines, particularly subadults that appear as "bait" in various markets particularly in New England and southern Canada (K Hattala, NY DEC pers comm.).

In 2010, American shad abundance appears to have increased in the Susquehanna River as indicated by increased abundance estimates (total lift catch, lift CPUE and population estimates), but the DNR hook and line CPUE decreased in 2010. Factors contributing to this increase included increased adult recruitment from stronger year-classes and reduced fish lift efficiencies, decreasing the catchability of adult American shad at Conowingo Dam and reducing turbine mortality (SRAFRC. 2007).

Total mortality rates (Z) for Chesapeake Bay stocks of American shad in 2010 averaged 1.17 and are within the range of reported Z estimates from other studies (ASMFC 2007). It should be noted that these mortality estimates are for previously spawned fish and are likely maximum rates because estimates include mortality during the spawning runs. Based on age structure, percent repeat spawning, mortality rates and abundance in the Susquehanna River; the SPM has demonstrated that American shad turbine mortality is likely suppressing the population.

Since aging techniques for American shad utilizing scales has been shown to be tenuous (McBride et al 2006), freshwater spawning marks may provide a viable alternative in estimating survival and assessing mortality. Spawning marks have several advantages in that the fish analyzed were fully recruited, the mark was easily detected and the mark was non-lethal.

Historical data, of heavily exploited American shad stocks in the Potomac River during the early 1950s, averaged 17% repeat spawners (Walburg and Sykes 1957). Analysis of adult American shad captured during the Striped Bass Spawning Stock Survey (Project 2, Job 3, Task 2) indicated that numbers of repeat spawning American shad in the Potomac River have averaged 40% for the time series and in 2010 equaled 35% (Durell, unpublished data) and have shown no significant trend over time (2005-2010; r^2=0.02, P=0.72; Figure 22). During the early 1980's, repeat spawning was generally less than 10% in the upper Chesapeake Bay (Weinrich et al. 1982). However, since 2005 repeat spawning of adult American shad collected from the Conowingo tailrace averaged 20% indicating that the increased adult population in 2010 may be partly attributed to increases in the number of larger, older, non-virgin fish. The relatively stable adult abundance and high percentages of repeat spawners observed in the Potomac River stock would tend to support the possibility of a correlation between stock abundance and the number of repeat spawners.

B. Juveniles

Baywide juvenile American shad production in 2010 remained at a very low levels for the third year (Figure 23). Juvenile American shad indices in the upper Chesapeake Bay (Figure 24) have been primarily driven by wild production below Conowingo Dam as indicated by the continued absence of hatchery-marked fish collected by the Juvenile Striped Bass Recruitment Survey (Project 2 Job 3 Task 3). Another factor possibly affecting reproductive success, both above and below Conowingo Dam, is the lifting of a higher percentage of returning spawners during substantial population declines. Not only would this reduce the number of potential spawners utilizing the upper Bay spawning and nursery habitat but continued inefficiencies at upstream passage facilities precludes these spawners from utilizing the prime habitat above York Haven Dam. Predation by apex predators, particularly striped bass and the recently introduced flathead catfish could also be having a negative effect on spawning and subsequent juvenile survival. A decline in the reproductive success of American shad in the Potomac River has also occurred as noted by a decline in this system's juvenile index in recent years and the lowest value of the past 10 years occurring in 2010 (Figure 25).

Quantitative habitat analysis investigated the relationship between submerged aquatic vegetation (SAV) and American shad juvenile indices in the upper Chesapeake Bay. Since SAV is an indirect measurement of water quality, American shad survival may increase as SAVs increase in density. Pearson product moment correlation ($P \leq 0.05$) was used to test for an association between juvenile American shad indices in the upper Chesapeake Bay and SAV density as measured by hectares of SAV. SAV estimates for the upper Bay were obtained from the MDDNR Resource Assessment Service (L. Karrh, pers. comm.) while juvenile data was obtained from the MDDNR Fisheries Service Juvenile Striped Bass Recruitment Survey (Project 2, Job 3, Task 3). No correlation was found between upper Bay SAV density and American shad juvenile indices from 1990 through 2009 ($r = -0.1136$, $p = 0.6239$). This may indicate that water quality parameters that are favorable for SAV may not be favorable for increased juvenile American shad production, or that water quality may not be the limiting factor on juvenile production. In either case, the use of SAV density to predict American shad juvenile production in the upper bay does not appear to be appropriate, and this analysis will not be conducted in the future.

II. Hickory Shad

A. Adults

Because of their innate avoidance to fixed commercial fishing gears hickory shad abundance in the Nanticoke River, as measured by the pound and fyke catches, may be a tenuous indicator of abundance for this species. Extensive spring electrofishing conducted in the Nanticoke River watershed concluded that stocks have increased in this system for the time series 2002- 2009 (Richardson, 2009) a trend not evident in either pound or fyke net CPUE’s.

Deer Creek, a tributary to the Susquehanna River in Harford County, has the greatest densities of hickory shad in Maryland (Richardson et al 2004). Logbook data collected from Deer Creek anglers since 1998 has indicated catch rates exceeding four fish per hour for all years except 2009 and 2010. Hickory shad are quite 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 as observed by staff during that spring season. Catch rates have been quite variable, with the continued low catch rates the past two years preceded by the highest and 4th highest CPAH values of the 13 year time series in 2007 and 2008 respectively.

Hickory shad age structure and repeat spawning has been consistent and ideal; a wide range of ages and a high percentage of older fish. Richardson (et. al 2004) noted that ninety percent of these fish from the upper Chesapeake have spawned by age four and this stock generally consists of few virgin fish.

Since only a catch and release fishery exists for hickory shad in Maryland, the resultant estimates of Z appear attributable to natural mortality The high percentage of repeat spawners is also indicative of reduced bycatch mortality. Based on the low estimated total mortality rates and continued high angler catch rates for hickory shad, the factors affecting the declines in American shad and river herring stocks along the east coast do not appear to be impacting hickory shad. Since both mature adults and immature sub-adults migrate and overwinter closer to the coast, hickory shad ocean bycatch is minimized compared to the other alosines (ASMFC 2009). This is confirmed by the few hickory shad observed portside as bycatch in the ocean small-mesh fisheries (Matthew Cieri - Maine Dep. Marine Res., pers comm.).

B. Juveniles

Because of their large size, gear avoidance and preference for deeper water, haul seine sampling for juvenile hickory shad during mid-summer through fall has generally been unsuccessful. Since hickory shad adults may spawn up to six weeks before American shad (late March to late April versus late April to early June), juvenile hickory shad reach a larger size earlier in the summer. 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 seine. Consequently, in order to accurately assess hickory shad juvenile production, sampling would need to be initiated prior to 1 June.

III. River Herring

A. Adults

The commercial river herring fishery on the Nanticoke River is a mixed fishery and fishers do not differentiate between species. Reported commercial river herring landings for both the Nanticoke River (Figure 17) and the entire Maryland portion of the Chesapeake Bay (Figure 26) have decreased to, and remained at, historic lows. Alewife and blueback herring CPUEs from the Nanticoke River pound and fyke nets have also declined. Reported river herring landings along the east coast have also decreased significantly, prompting the states of Connecticut, Rhode Island, Massachusetts and North Carolina to close their recreational and commercial river herring fisheries. Amendment 2 recently passed by the ASMFC Interstate Management Plan for American Shad and River Herring requires states to develop and implement a sustainable fishery plan if jurisdictions have an open commercial or recreational fishery. The recently completed ASMFC river herring stock status report indicated that coastwide, and Maryland, adult river herring stocks are projected to remain at low abundance levels for the near future.

B. Juveniles

The low juvenile blueback and alewife herring catches by survey personnel from the Chester (n = 40) was also observed on other major Maryland river herring nursery areas by the Juvenile Striped Bass Recruitment Survey (Project 2, Job 3, Task 3) The conclusion from this survey was that juvenile alewife and blueback production specifically in the Nanticoke River and Bay-wide in general has been erratic; characterized by more declines than increases in the CPUE and low numbers of juveniles observed (Figures 27, 28 and 29). Significant declines in both juvenile production and adult abundance would strongly indicate that river herring stocks in Maryland may be in a density dependent relationship where the stock size is at or even below some critical threshold necessary for stabilization and future growth.

CITATIONS

ASMFC (Atlantic States Marine Fisheries Commission). 2009. Atlantic Coast Diadromous Fish Habitat: A Review of Utilization, Threats, Recommendations for Conservation, and Research Needs. Washington, D. C. 465 pp.

ASMFC (Atlantic States Marine Fisheries Commission). 2008. River Herring Stock Status Report. Washington, D. C. 639 pp.

ASMFC (Atlantic States Marine Fisheries Commission). 2007. American shad stock assessment Report for peer review. Volume III. Washington, D. C. 546 pp.

ASMFC (Atlantic States Marine Fisheries Commission). 1988. Supplement to the fishery management plan for the anadromous alosid stocks of the eastern United States: American shad, hickory shad, alewife, and blueback herring. Washington, D. C.

Haddon, M. 2001. Modeling and quantitative methods in fisheries. Chapman and Hall / CRC, Washington, D.C.

Hattala, K.A., A.W. Kahnle, D.R. Smith, R.V. Jesien and V. Whalon. 1998. Total mortality, population size, and exploitation rates of American shad in the Hudson River estuary, New York. Interim Report for the Atlantic States Marine Fisheries Commission.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82(1):898-903.

Kritzer J. and P. Black. 2007. Oceanic Distribution and Bycatch of River Herring. An analysis of federal fishery-independent and fishery-dependent data. Environmental Defense Fund. Progress Report, October 2007

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

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

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

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

Sokal, R. R. and J. E. Rohlf. 1981. *Biometry, 2nd edition*. Freeman, San Francisco.

Speir, H. and J. Mowrer. 1987. Anadromous Fish Research, Maryland. Federal Aid Report. Project No. AFC -14-3. United States Department of Commerce.

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

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

Table 1. Numbers of adult American shad and repeat spawners by sex and age sampled from the Conowingo tailrace, Nanticoke River (gears combined) and Potomac River (SBSSS) in 2010.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	14	0	0	--	14	0
4	97	3	89	0	186	3
5	106	57	82	26	188	83
6	17	17	27	26	44	43
7	2	2	2	2	4	4
8	0	--	1	1	1	1
Totals	236	75	201	55	437	134
Percent Repeats	31.8		27.4		30.7	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	2	0	0	--	2	0
4	6	0	2	0	8	0
5	7	5	8	3	15	8
6	4	4	4	4	8	8
7	0	--	0	--	0	--
8	0	--	0	--	0	--
9	0	--	0	--	0	--
Totals	19	9	14	7	33	16
Percent Repeats	47.4		50.0		48.5	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0	--	0	--	0	--
3	5	0	0	--	5	0
4	18	0	18	0	36	0
5	15	12	5	0	20	12
6	5	4	2	2	7	6
7	1	1	2	2	3	3
8	0	--	2	2	2	2
9	2	2	0	--	2	2
10	0	--	0	--	0	--
Totals	46	19	29	6	75	25
Percent Repeats	41.3%		20.7%		33.3%	

Table 2. Conowingo Dam tailrace hook and line data, 1982-2010.

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	5.00	3.6
1991	437	77	5.68	5.29
1992	383	62.75	6.10	5.05
1993	264	47.5	5.56	4.8
1994	498	88.5	5.63	5.22
1995	625	84.5	7.40	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	58.50	11.42	9.38
2010	485	62.00	7.82	5.11

Table 3. Recaptured American shad in 2010 at Conowingo Dam's east and west lifts by tag color and year.

East Lift		
Tag Color	Year Tagged	Number Recaptured
Pink	2010	106
Orange	2009	9
West Lift		
Tag Color	Year Tagged	Number Recaptured
Pink	2010	21
Orange	2009	1
Green	2008	1

Table 4. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2010.

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 5. Summary of the spring American shad logbook data, 1999-2010.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of American Shad Caught	Mean Number of American Shad Caught Per Hour
1999	7	160.5	463	2.88
2000	10	404.0	3,137	7.76
2001	8	272.5	1,647	6.04
2002	8	331.5	1,799	5.43
2003	9	530.0	1,222	2.31
2004	15	291.0	1,035	3.56
2005	12	258.5	533	2.06
2006	16	639.0	747	1.17
2007	10	242.0	873	3.61
2008	14	559.5	1,269	2.27
2009	10	378.0	967	2.56
2010	14	429.5	857	2.00

Table 6. Estimated adult American shad mortalities in Maryland waters.

Year	Total Pounds Landed in Maryland's Portion of the Chesapeake Bay	Mortality (in Numbers) at east Lift of Conowingo Dam[1]	Mortality (in Numbers) at the West Lift of Conowingo Dam	Estimated Commercial Chesapeake Bay Bycatch Mortality[2]	Recreat-ional Bycatch Mortality	Ocean Commercial Landings (in pounds)[3]	Minimum Total Losses (Numbers)	Cono-wingo Dam tailrace estimate
1997	0	43,790	2,274	4,200	Unknown	24,859 (99,435)	75,123	155,658
1998	0	16,152	1,300	4,200	Unknown	18,526 (74,105)	39,908	158,742
1999	0	43,455	3,136	4,200	Unknown	13,623 (54,491)	64,414	195,005
2000	0	60,452	3,102	4,200	Unknown	4,834 (19,337)	72,588	209,157
2001	0	130,876	2,607	4,200	Unknown	2,347 (9,386)	140,030	206,045
2002	0	40,142	2,837	4,200	Unknown	1,882 (7,529)	49,061	132,533
2003	0	50,224	2,160	4,200	Unknown	621 (2,485)	57,205	127,295
2004	0	29,911	1,218	4,200	Unknown	220 (879)	35,549	110,836
2005	0	42,873	1,412	4,200	Unknown	0	48,485	108,089
2006	0	41,201	1,696	4,200	Unknown	0	95,582	94,193
2007	0	14,120	1,737	4,200	Unknown	0	20,057	78,008
2008	0	7,075	1,477	4,200	Unknown	0	12,752	79,837
2009	0	15,490	173	4,200	Unknown	0	19,863	86,537
2010	0	21,793	1,298	4,200	Unknown	0	23,089	93,949

[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] Numbers in parenthesis is the reported pounds and were converted to numbers by dividing it by an estimated four pounds per fish.

Table 7. Percent of hickory shad by age and number sampled form brood stock collection in Deer Creek by year, 2004-2010.

Year	N	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9
2004	80		7.5%	23.8%	27.5%	18.8%	18.8%	3.8%	
2005	80		6.3%	17.5%	28.8%	33.8%	11.3%	1.3%	1.3%
2006	178	0.6%	9.0%	31.5%	29.8%	20.2%	7.3%	1.7%	
2007	139		6.5%	23.7%	33.8%	20.9%	12.2%	2.2%	0.7%
2008	149		9.4%	29.5%	33.6%	20.1%	5.4%	2.0%	
2009	118		7.6%	16.9%	44.9%	19.5%	10.2%	0.8%	
2010	240		12.5%	37.9%	31.3%	11.3%	6.7%	0.4%	

Table 8. Percent repeat spawning hickory shad, sexes combined, by year form brood stock collection in Deer Creek, 2004-2010.

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

Table 9. Numbers of adult hickory shad and repeat spawners by sex and age sampled from brood stock collection in Deer Creek in 2010.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	22	0	8	--	30	0
4	50	40	41	23	91	63
5	37	37	38	37	75	74
6	10	10	17	17	27	27
7	6	6	10	10	16	16
8	0	--	1	1	1	1
Totals	125	93	115	88	240	181
Percent Repeats	74.4		76.5		75.4	

Table 10. Summary of the spring hickory shad log book data, 1998-2010.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad Caught	Mean Number of Hickory Shad Caught per Hour
1998	19	600	4,980	8.30
1999	15	817	5,115	6.26
2000	14	655	3,171	4.84
2001	13	533	2,515	4.72
2002	11	476	2,433	5.11
2003	14	635	3,143	4.95
2004	18	750	3,225	4.30
2005	19	474	2,094	4.42
2006	20	766	4,902	6.40
2007	17	401	3,357	8.37
2008	22	942	5,465	5.80
2009	15	561	2,022	3.60
2010	16	552	1956	3.54

Table 11. Numbers of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2010.

Alewives

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	2	0	0	0	2	0
4	14	1	5	0	19	1
5	4	2	19	9	23	11
6	5	5	16	16	21	21
7			4	4	4	4
8						
9						
Totals	25	8	44	29	69	37
Percent Repeats	32.0%		65.9%		53.6%	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	2	0	0	0	2	0
4	8	2	7	0	15	2
5	0	0	6	4	6	4
6	1	1	2	2	3	3
7						
8						
9						
Totals	11	3	15	6	26	9
Percent Repeats	27.3%		40.0%		34.6%	

Table 12. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2010.

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					

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				

Table 13. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2010.

Male

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					

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				

Table 14. Regression statistics for alewife and blueback herring lengths from 1989 to 2010 based on cumulative data.

Alewife	Male				Female			
Age	N	Slope	r^2	P	N	Slope	r^2	P
3	373	-0.099	0.002	0.353	112	-0.216	0.0122	0.247
4	1348	-0.378	0.0474	<0.001	1213	-0.374	0.0484	<0.001
5	1101	-0.377	0.0432	<0.001	1642	-0.350	0.0485	<0.001
6	454	-0.454	0.0642	<0.001	1023	-0.352	0.0478	<0.001
7	70	-0.937	0.178	<0.001	333	-0.492	0.104	<0.001
8	6	-1.183	0.117	0.506	94	-0.594	0.0837	0.005
9					12	-0.625	0.0680	0.413

Blueback herring	Male				Female			
Age	N	Slope	r^2	P	N	Slope	r^2	P
3	194	-0.213	0.0233	0.034	50	-0.314	0.0627	0.079
4	845	-0.231	0.0197	<0.001	732	-0.220	0.0180	<0.001
5	934	-0.181	0.0085	0.005	904	-0.256	0.0202	<0.001
6	648	-0.526	0.0436	<0.001	685	-0.447	0.0309	<0.001
7	281	-0.602	0.030	0.004	337	-0.371	0.0241	0.004
8	90	-0.259	0.0025	0.641	111	-0.430	0.0198	0.141
9	21	-4.561	0.258	0.019	33	-0.005	<0.001	0.996
10					5	+1.667	0.357	0.287

Figure 1. Location of the 2010 hook and line sampling in Conowingo Dam tailrace.

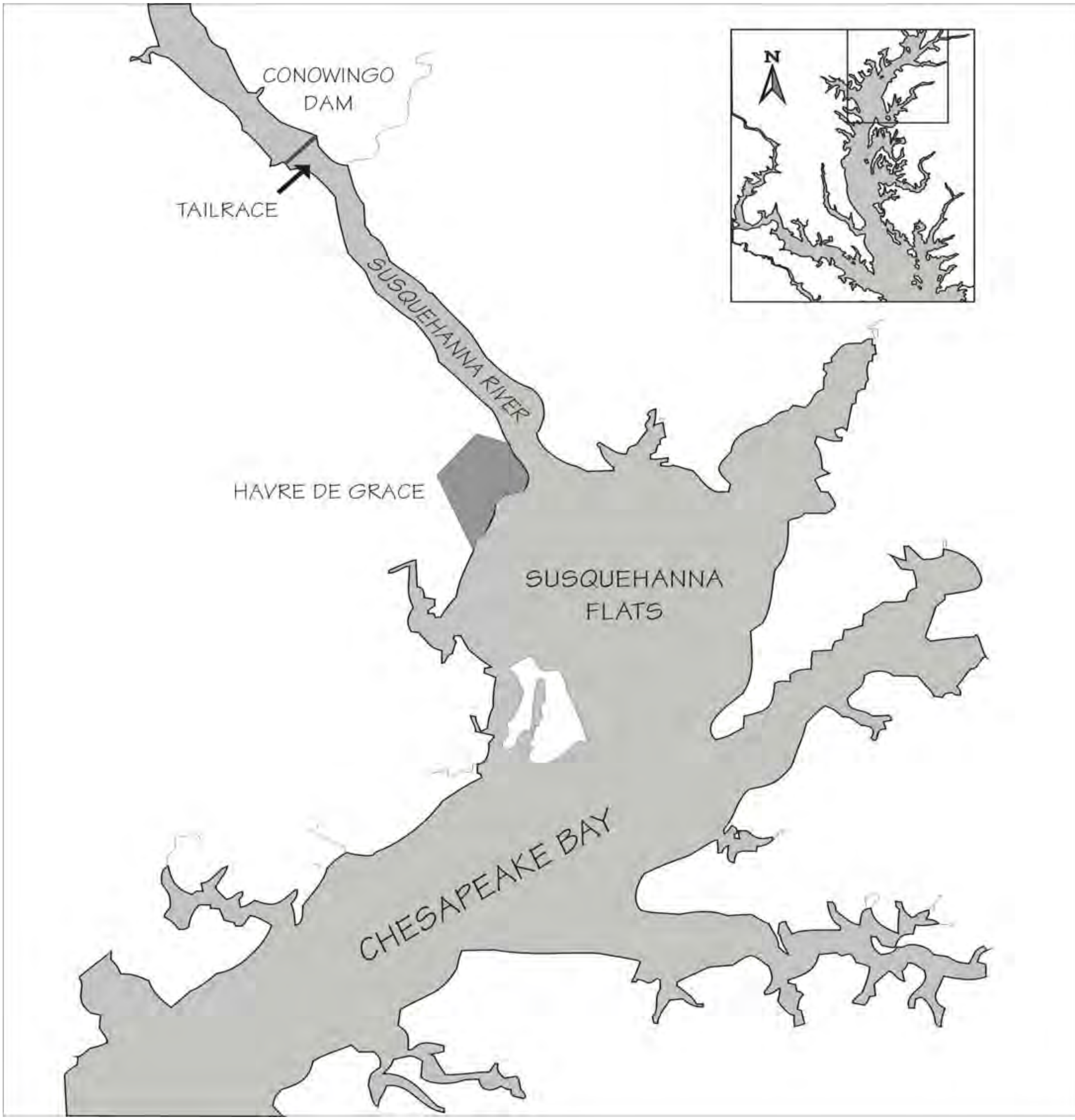


Figure 2. Distribution of the 2010 fyke and pound nets sampled on the Nanticoke River.

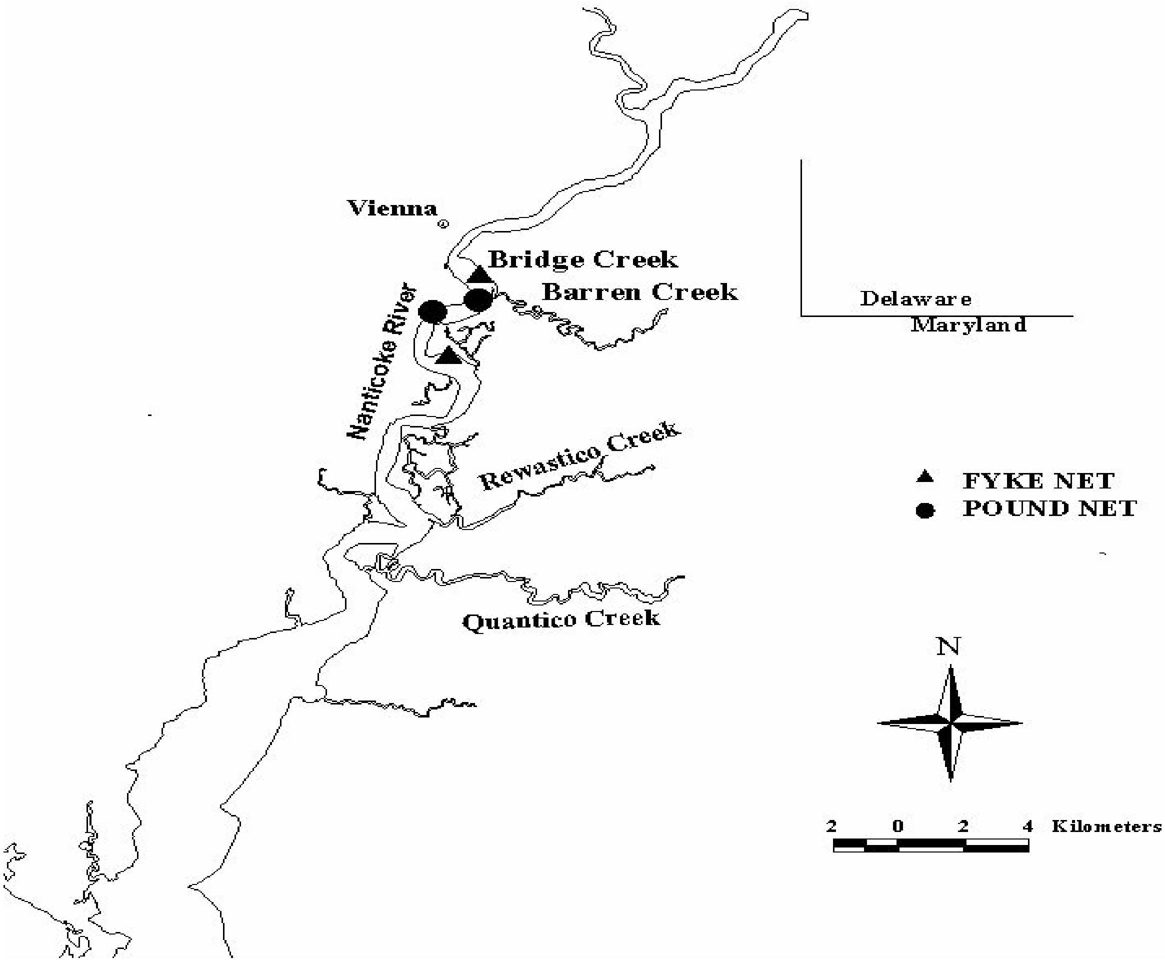


Figure 3. Distribution of the 2010 ichthyoplankton sampling sites on the Nanticoke River.

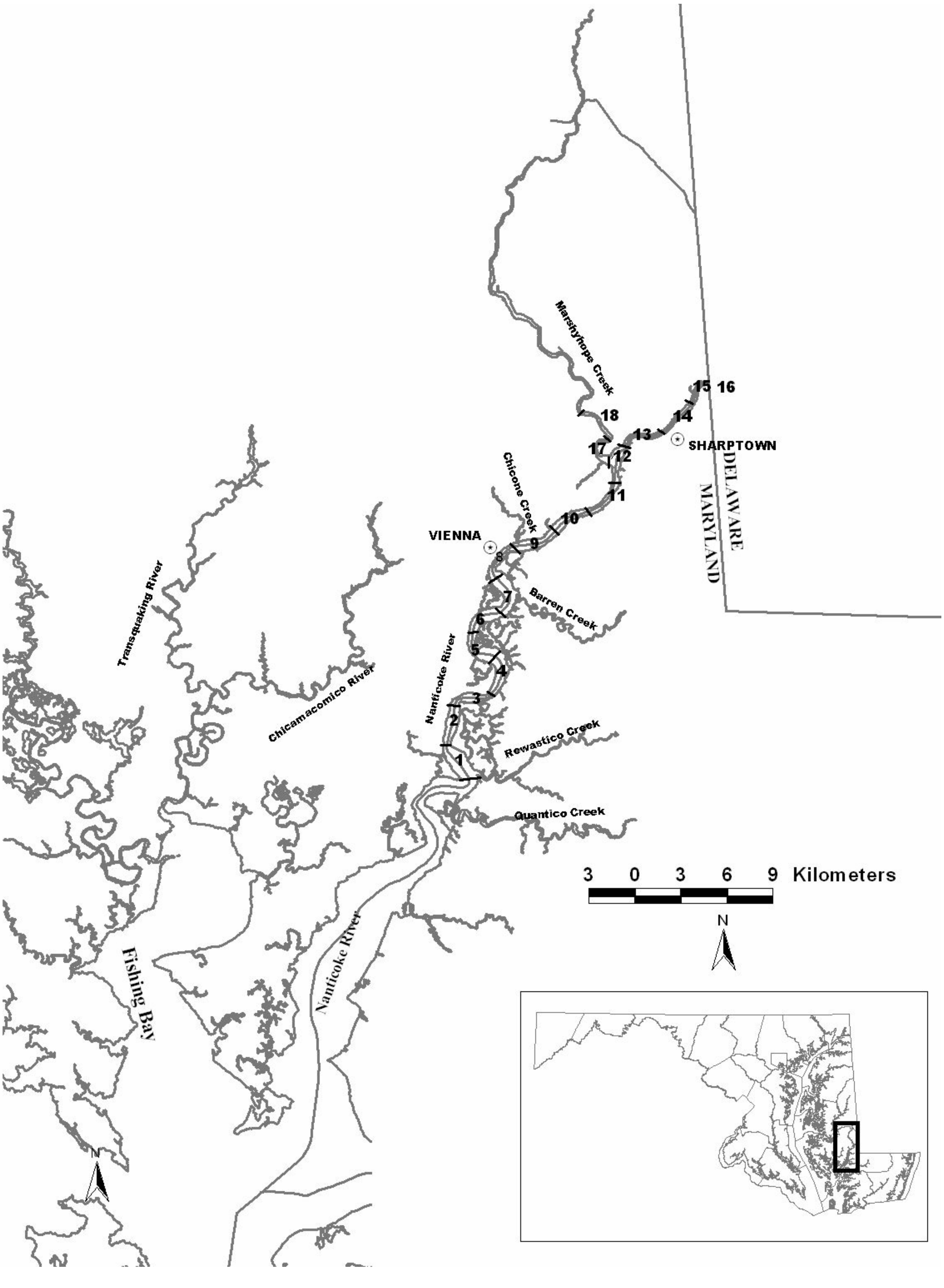


Figure 4. Distribution of the 2010 seine sites on the Chester River (black circles).

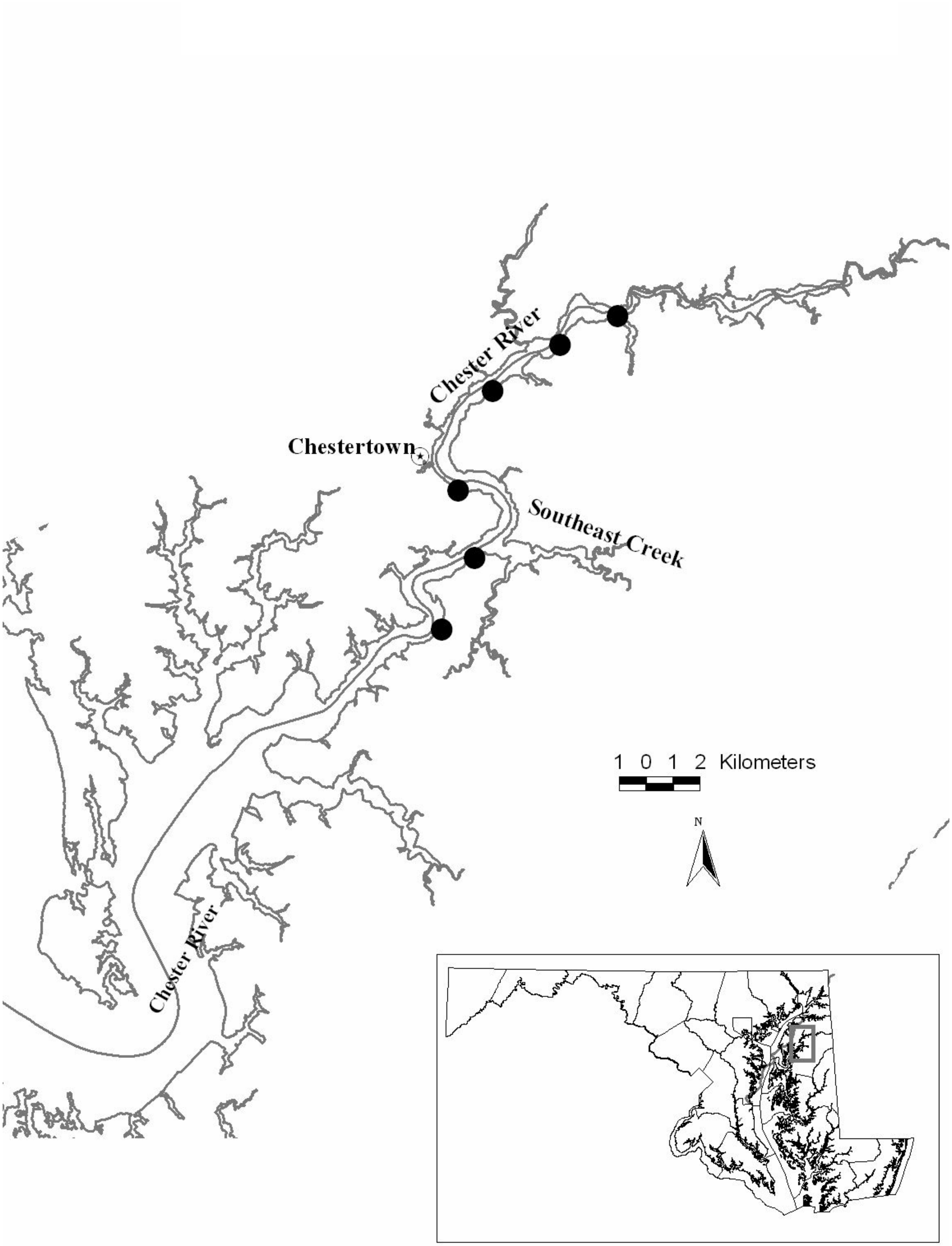


Figure 5. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2010).

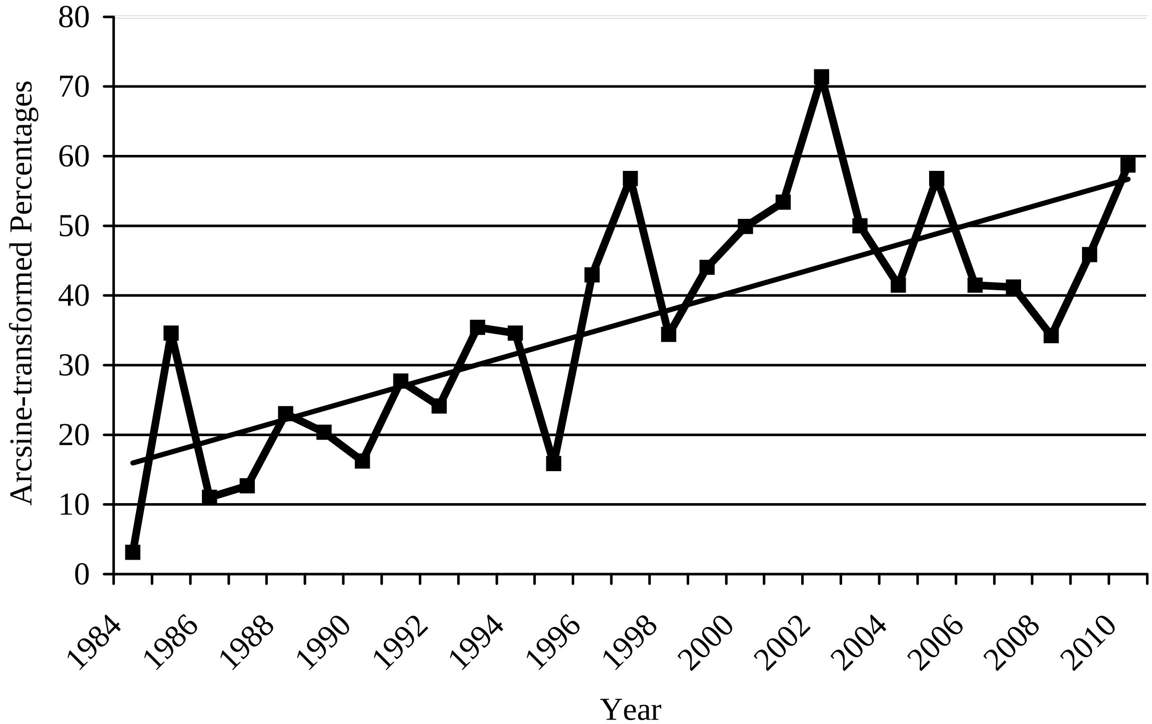


Figure 6. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River (1988-2010).

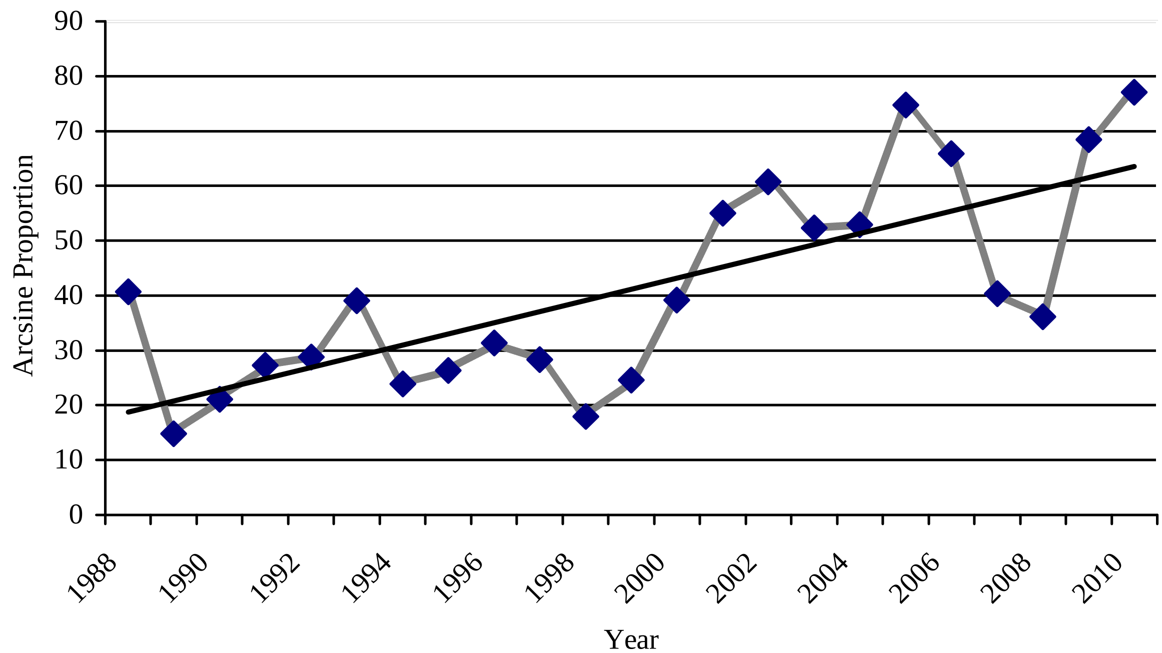


Figure 7. Conowingo Dam tailrace population estimates of American shad, 1986-2010.

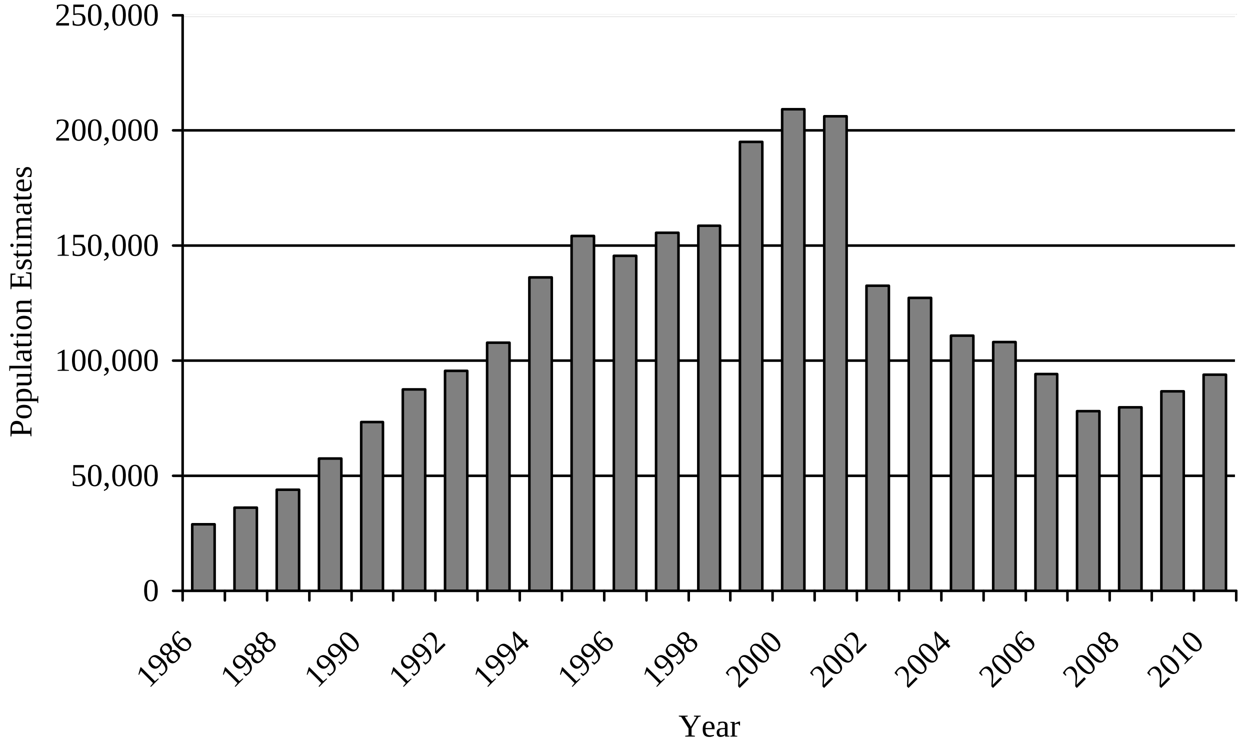


Figure 8. American shad geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2010.

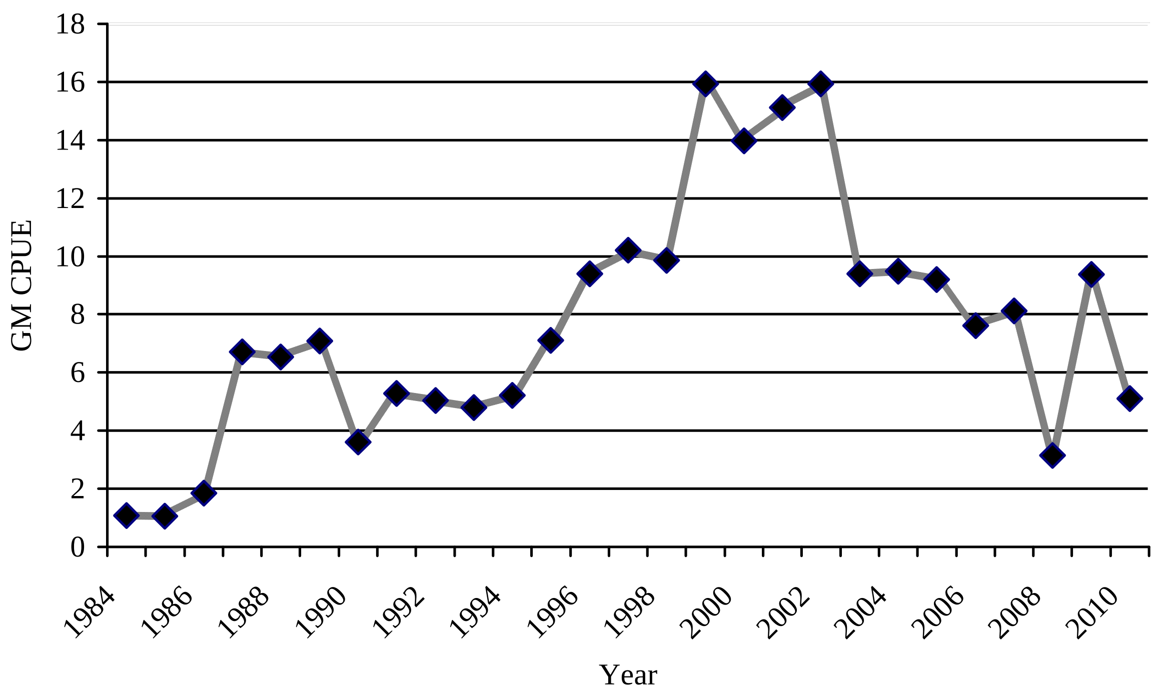


Figure 9. Geometric mean CPUE of adult American shad from the lifts at Conowingo Dam, 1980-2010.

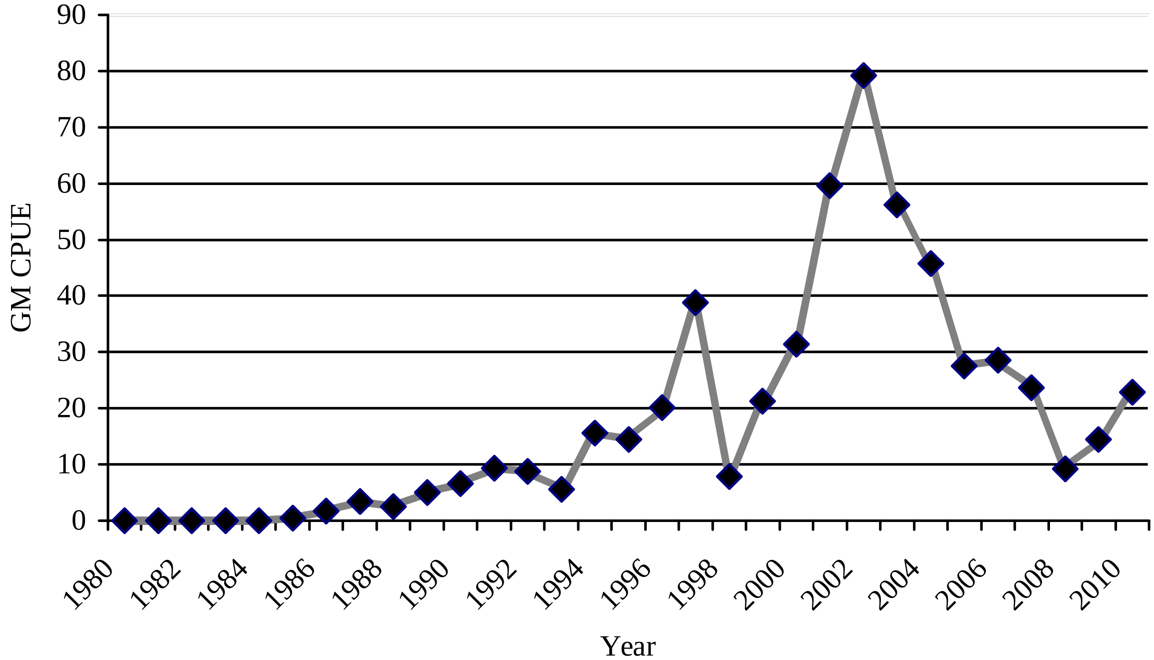
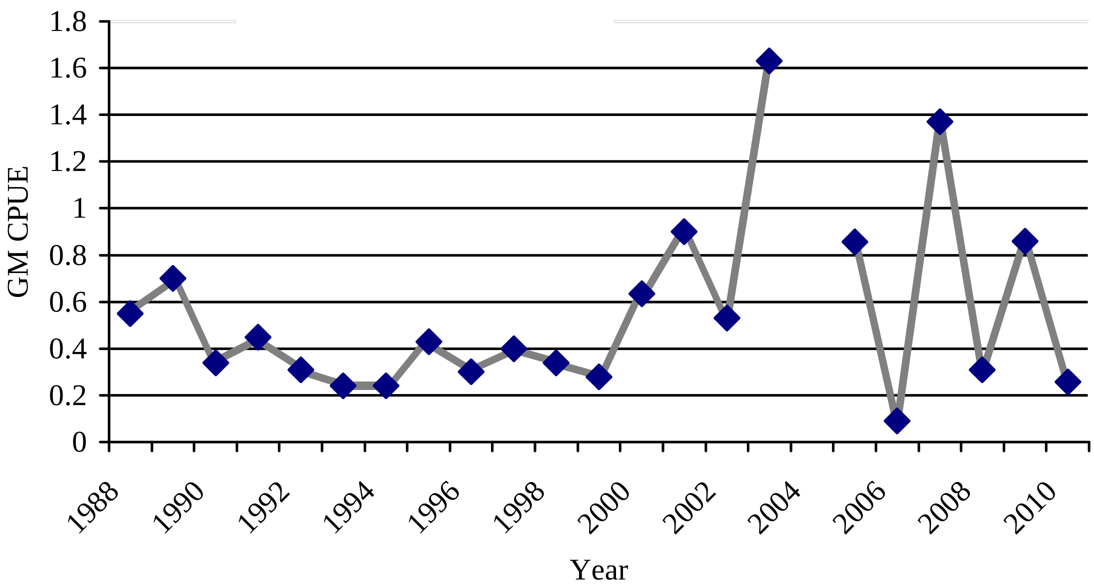


Figure 10. Pound net geometric mean CPUE for adult American shad from the Nanticoke River, 1988-2010. [4]



[4] No Pound nets were fished in 2004.

Figure 11. Adult American shad geometric mean CPUE from fyke nets on the Nanticoke River, 1989-2010.

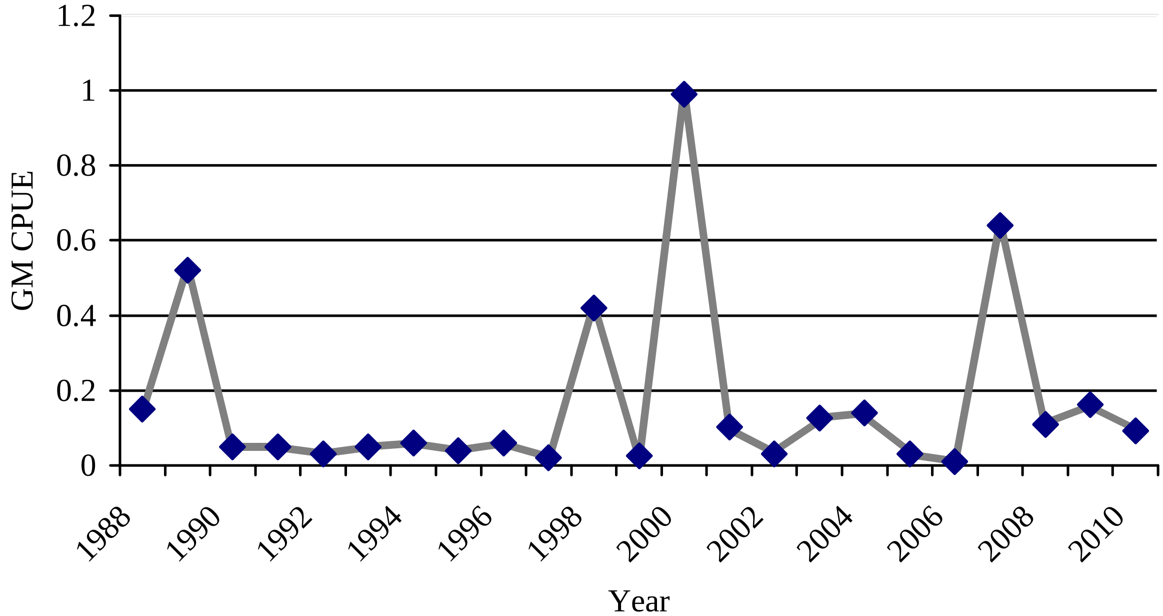
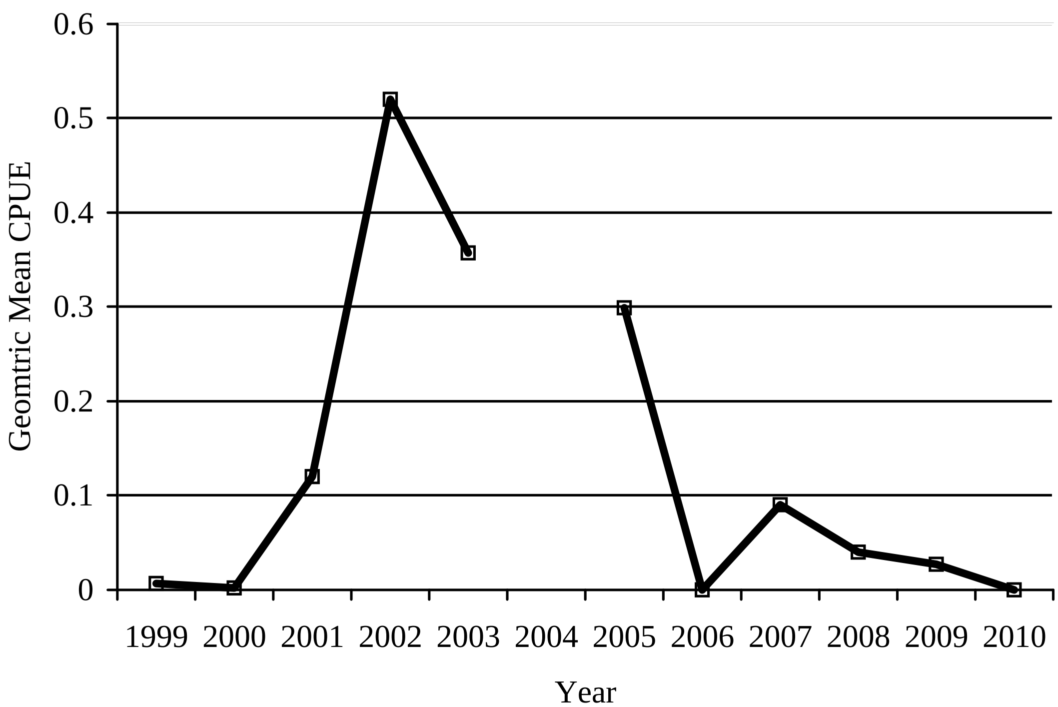


Figure 12. Adult hickory shad geometric mean CPUE from Nanticoke River pound nets, 1999-2010.[5]



[5] No pound nets were set in 2004.

Figure 13. Adult hickory shad CPUE from Nanticoke River fyke nets, 1999-2010.

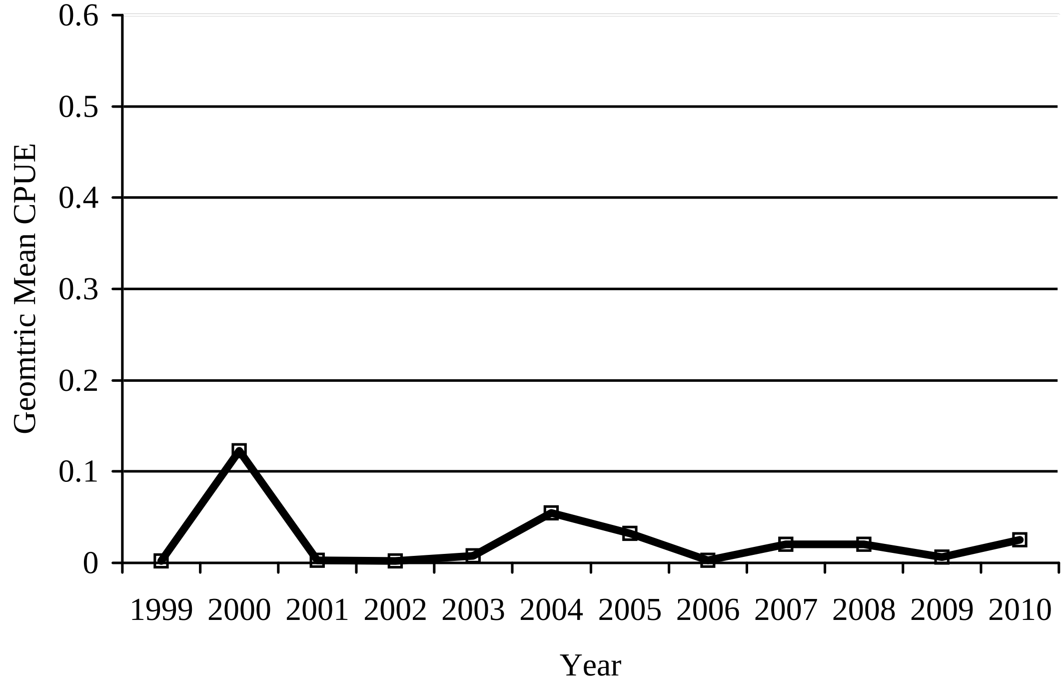


Figure 14. Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1989-2010.

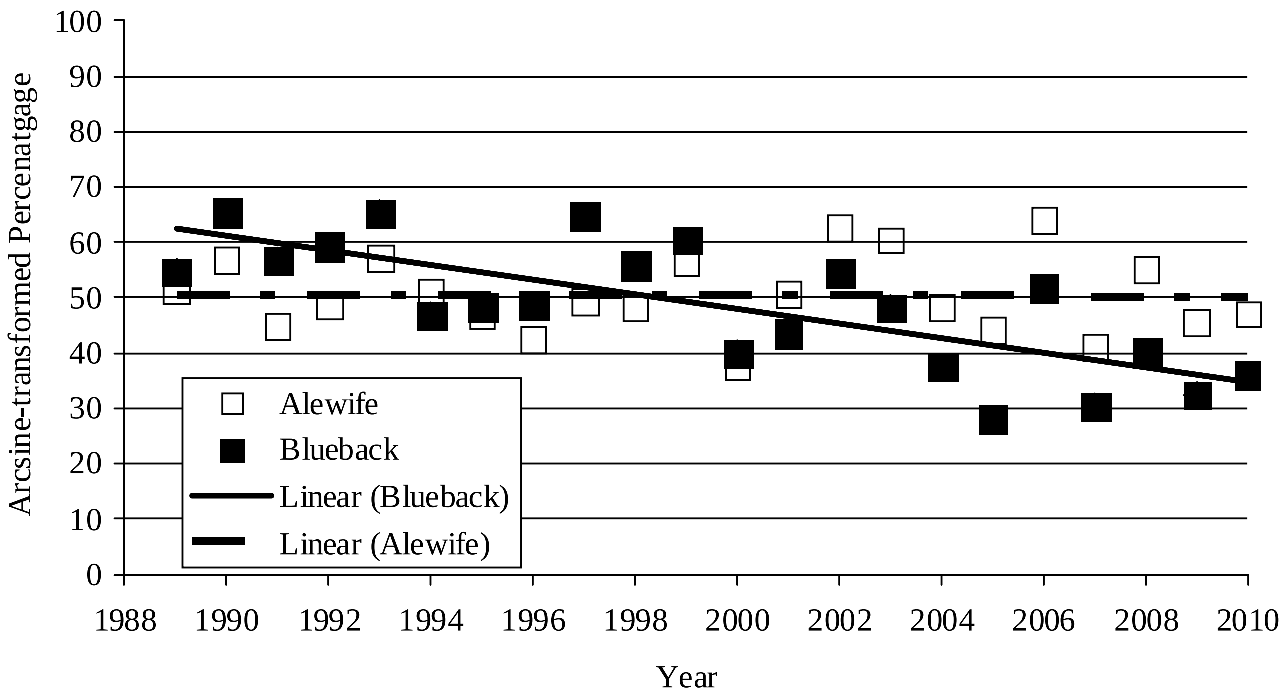


Figure 15. Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1989-2010.

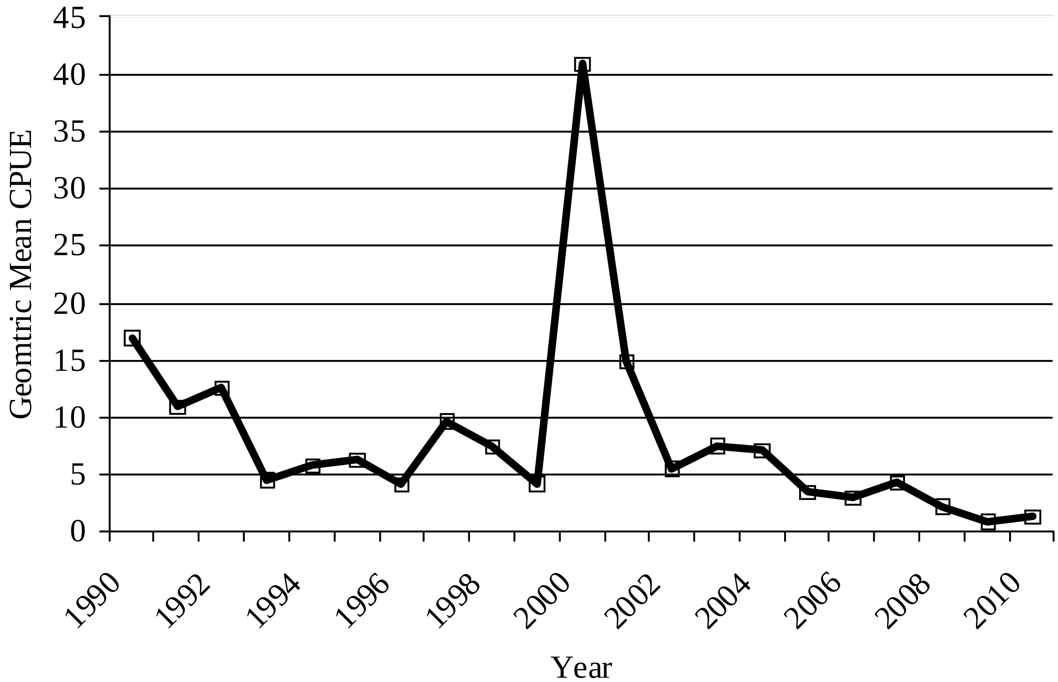


Figure 16. Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2010.

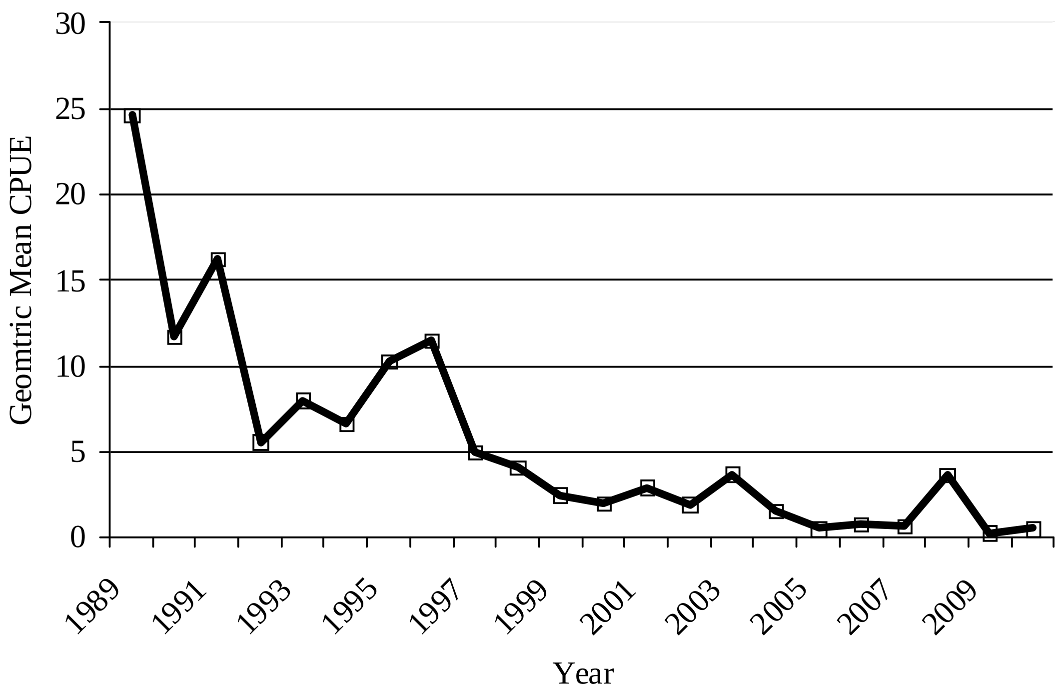


Figure 17. Regression analysis estimates of geometric mean CPUE (alewife and blueback herring combined, 1989-2010), and the total commercial river herring landings in pounds, 1980-2010 from the Nanticoke River.

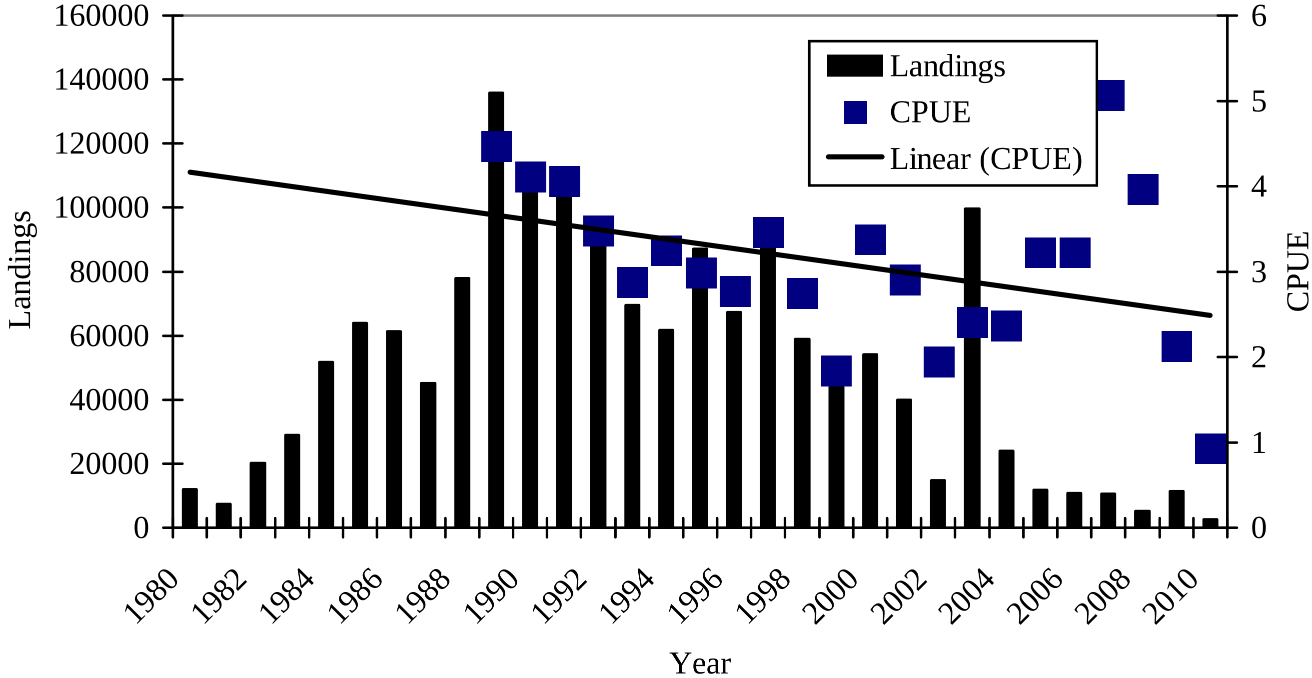


Figure 18. Instantaneous mortality (Z) of Nanticoke River alewife herring (1989-2010).

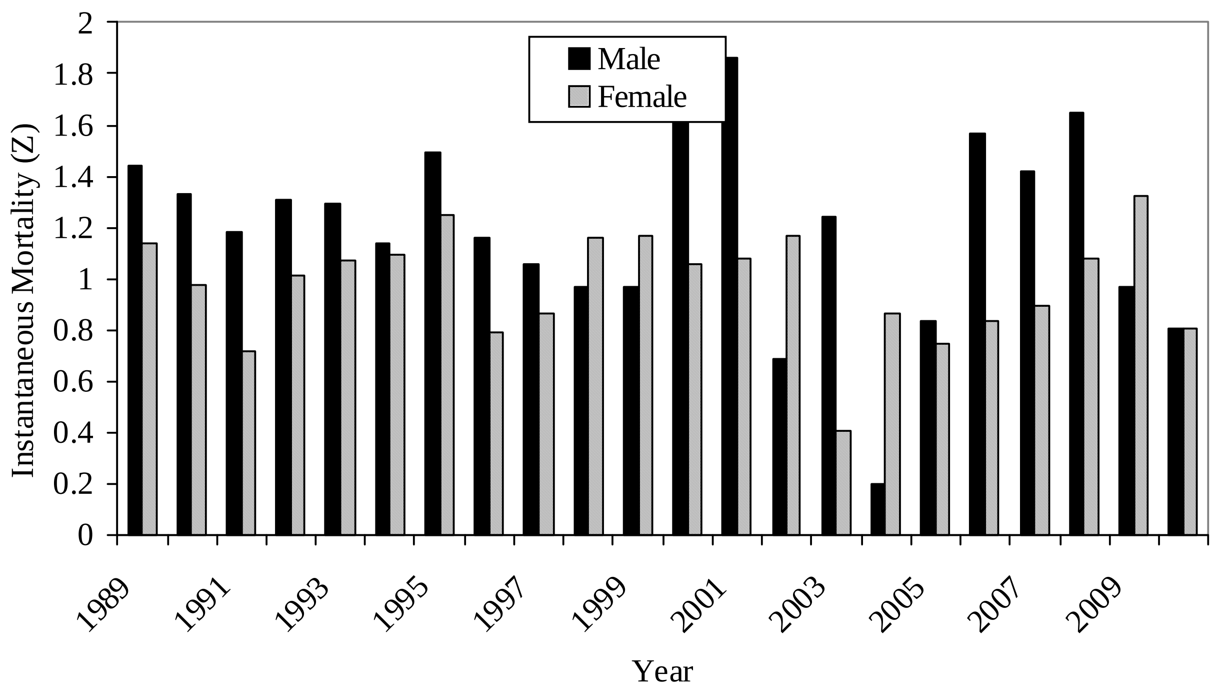


Figure 19. Instantaneous mortality (Z) of Nanticoke River blueback herring (1989-2010).

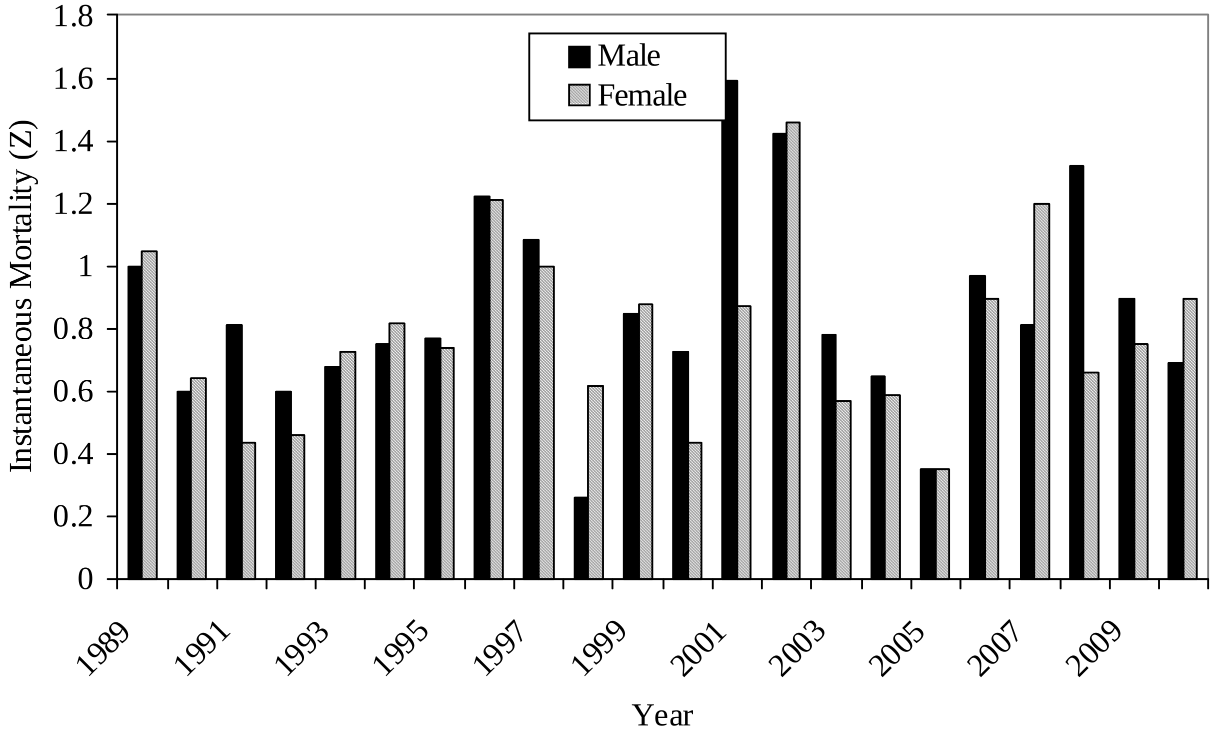


Figure 20. Conowingo Dam adult American shad tailrace Petersen population estimates compared to the SPM results, 1986-2010. Note: 2004 and 2008 have high levels of uncertainty due to low very low recapture rates.

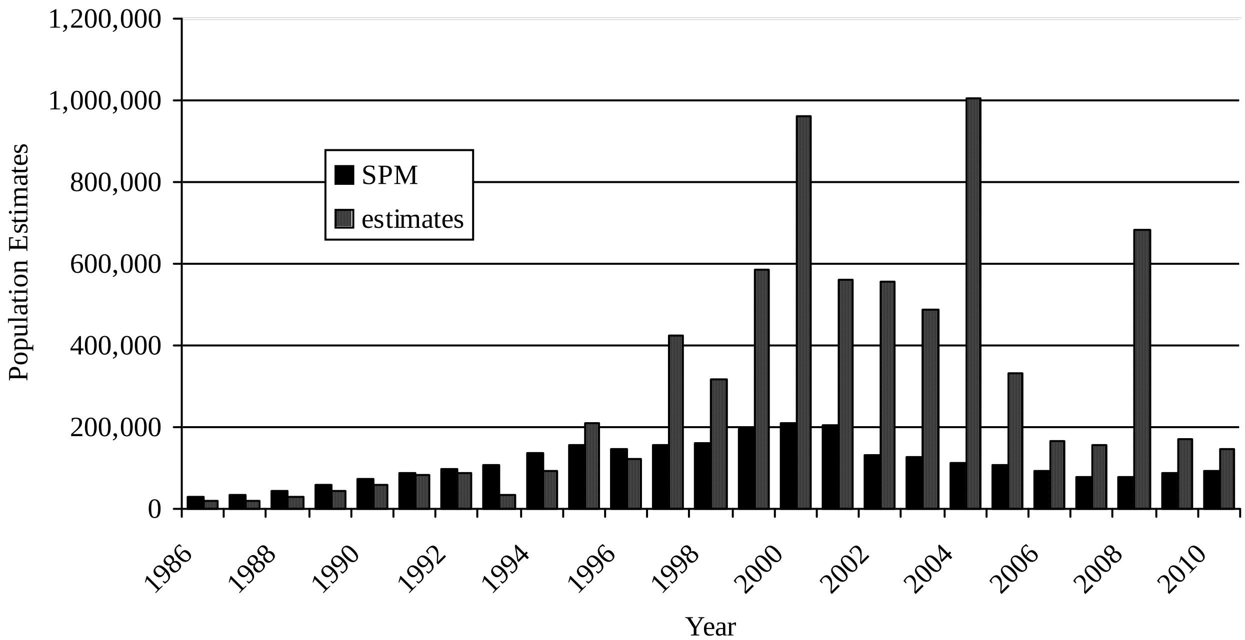


Figure 21. Potomac River adult American shad gill net CPUE from the SBSSS, 1996-2010.

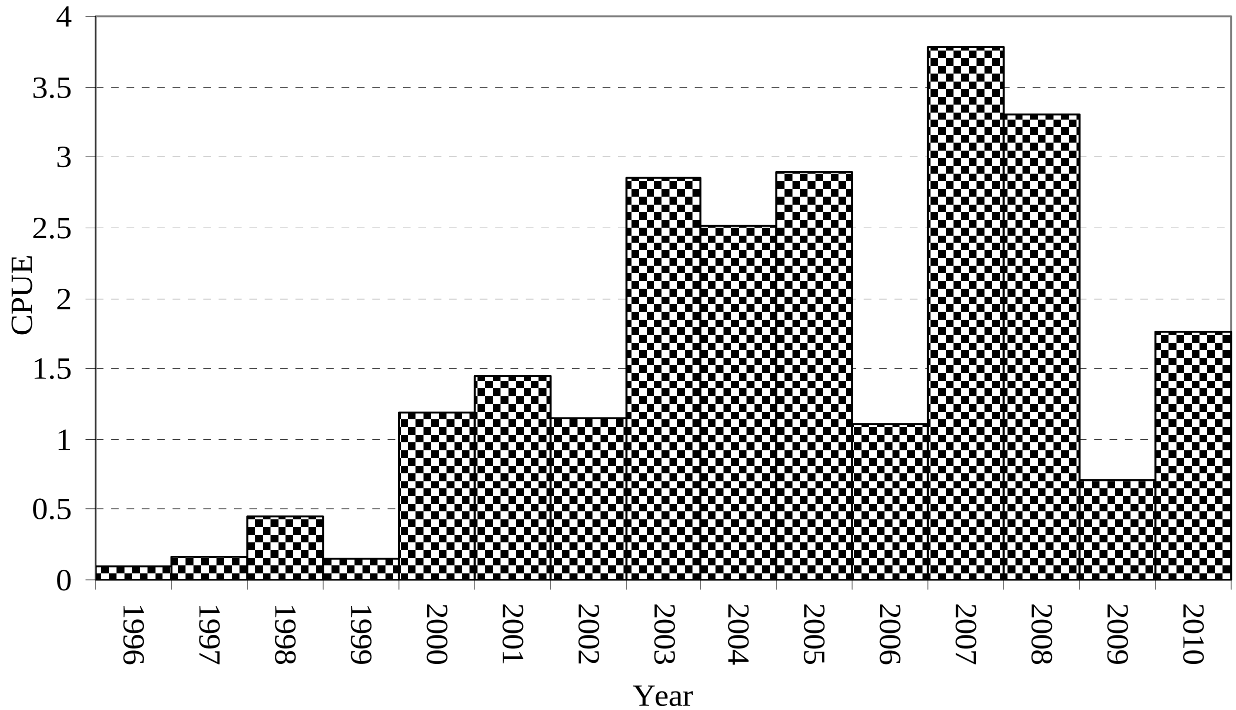


Figure 22. Trends in percentages of repeat spawning American shad (sexes combined) collected from the Potomac River (2002-2010).

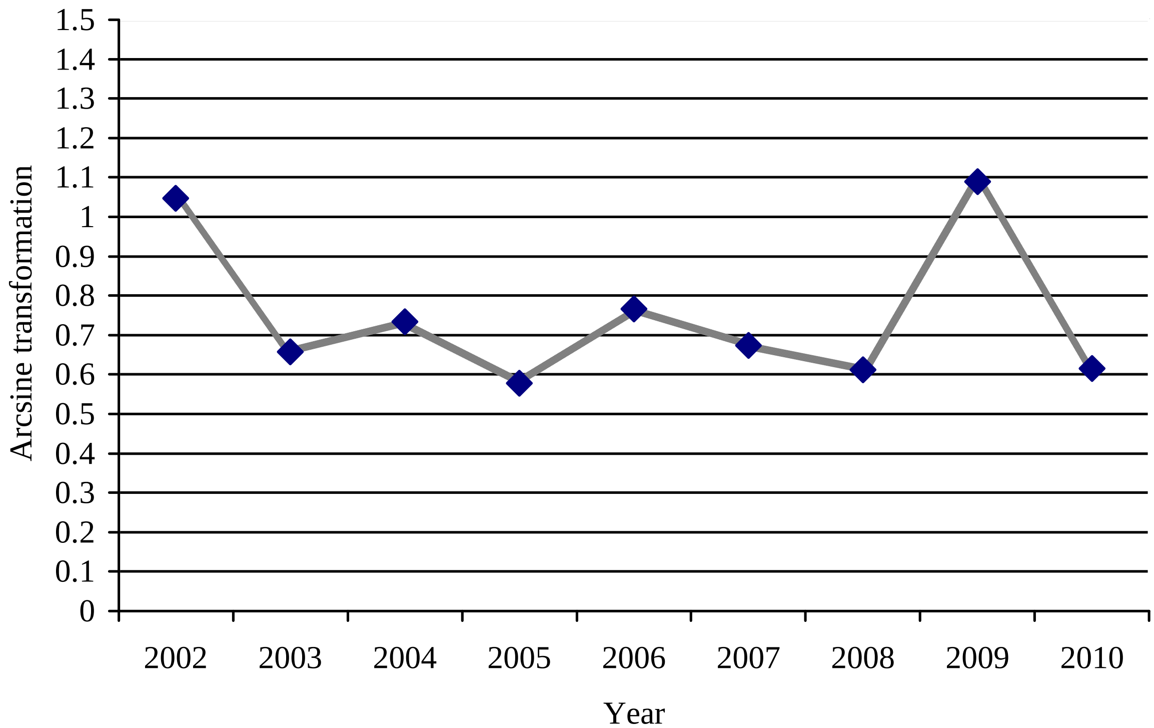


Figure 23. Baywide juvenile American shad geometric mean CPUEs, 1959-2010.

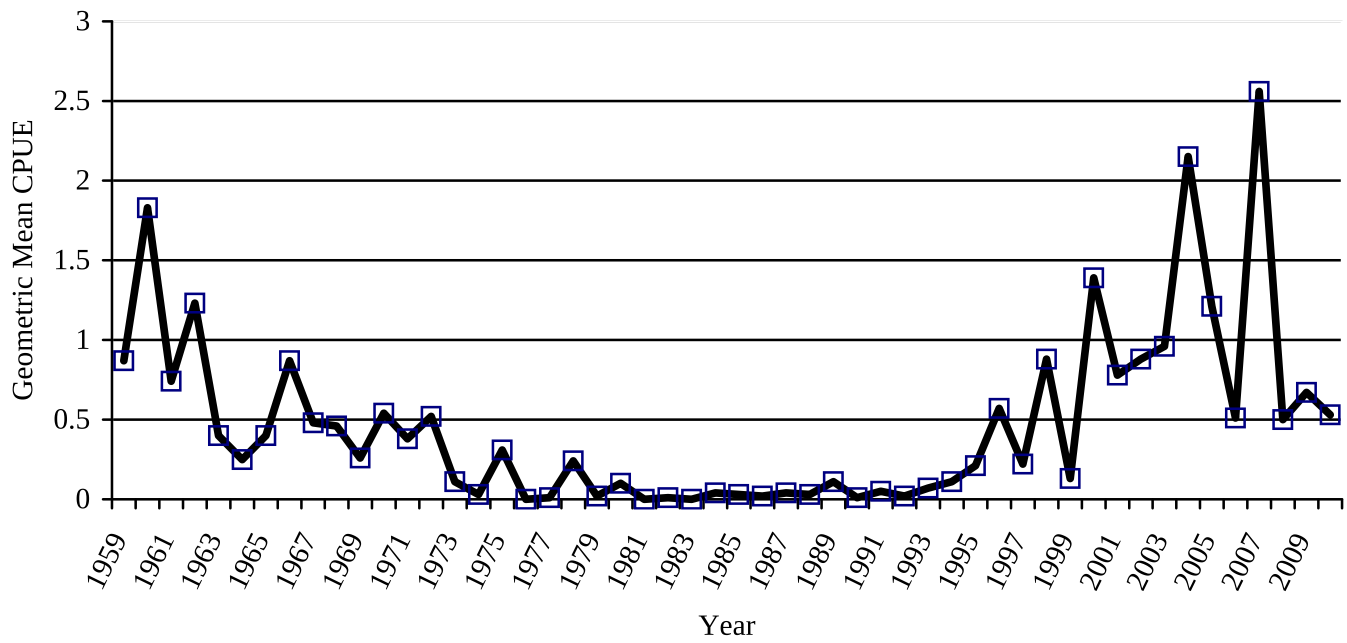


Figure 24.   Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1959-2010.

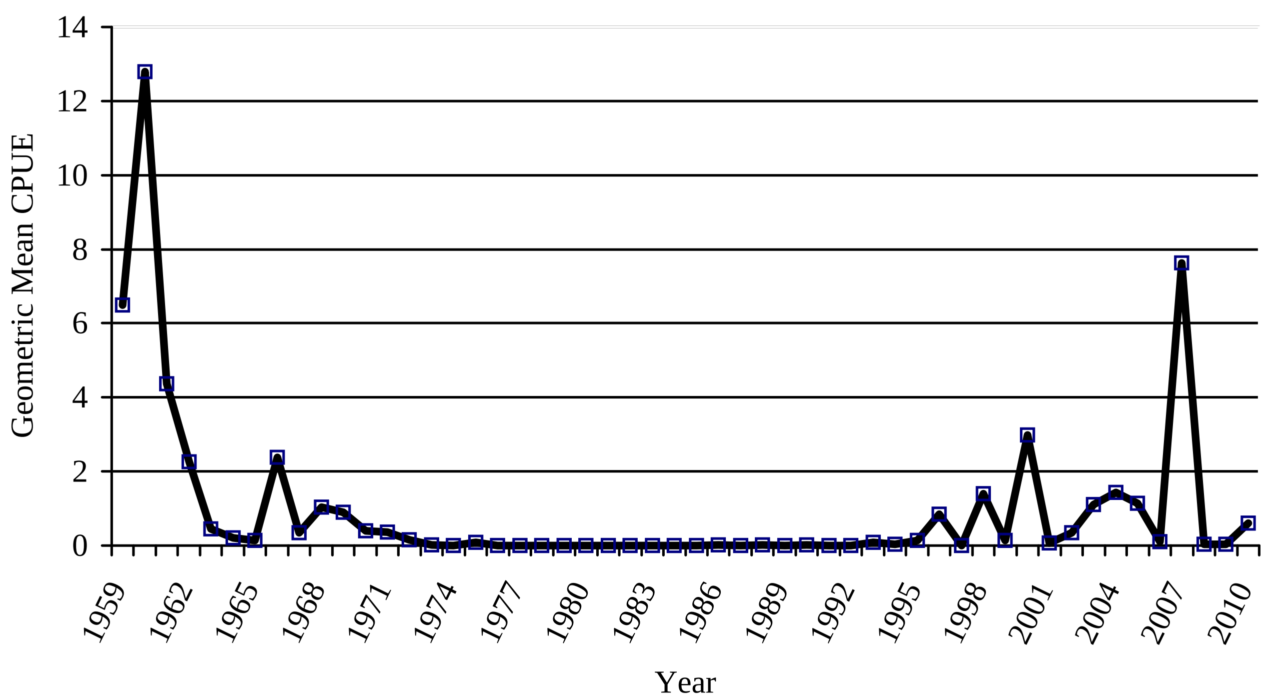


Figure 25. Potomac River geometric mean CPUEs for juvenile American shad, 1959-2010.

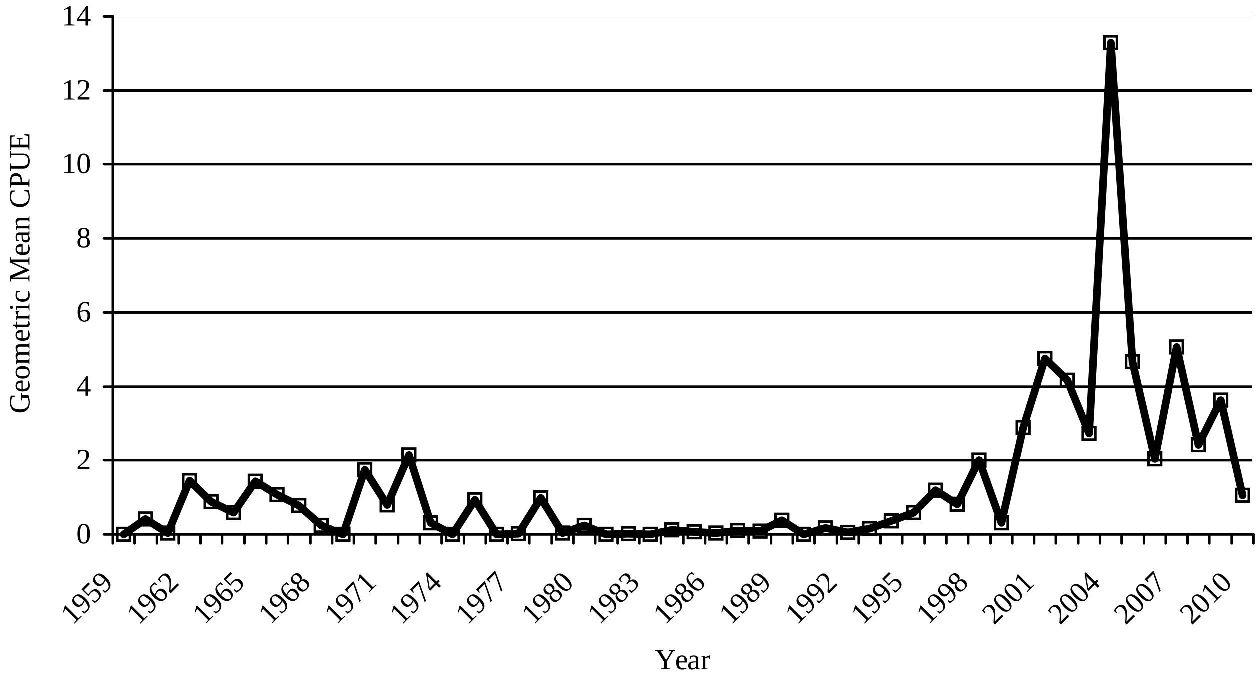


Figure 26. Maryland's commercial river herring landings, 1932-2010.

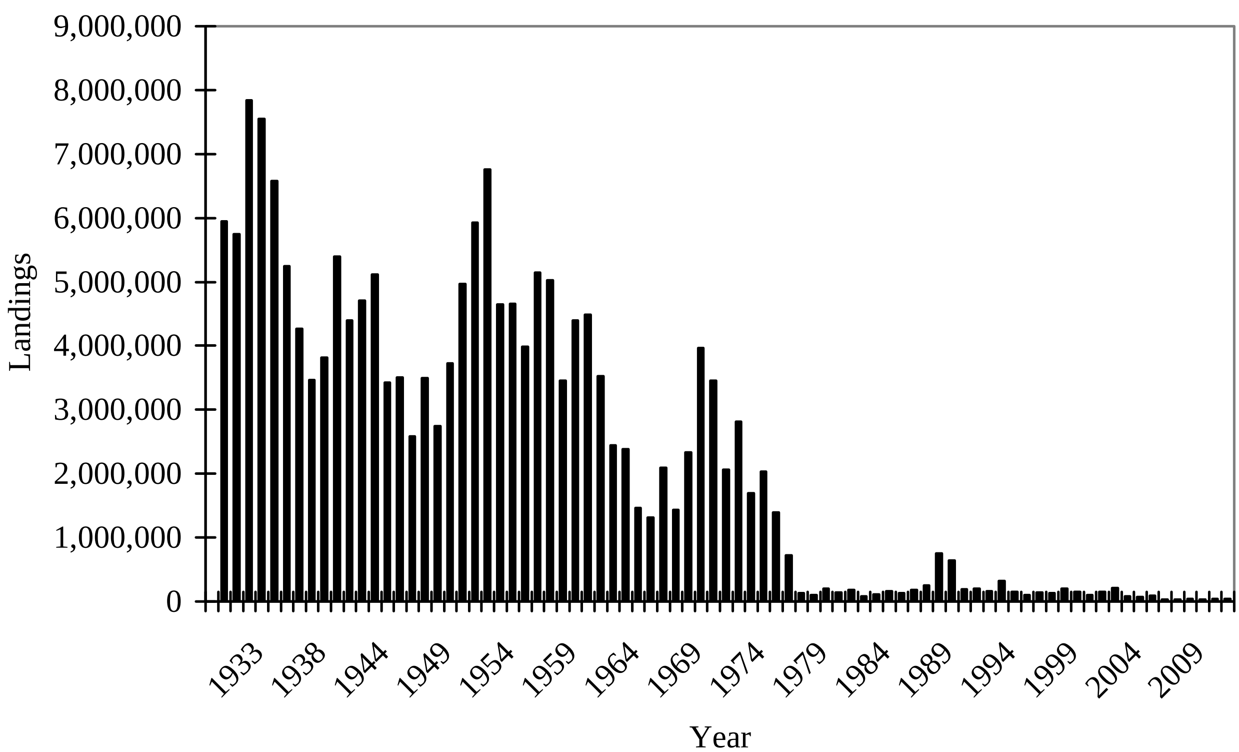


Figure 27. Nanticoke River juvenile alewife herring geometric mean CPUEs, 1959-2010.

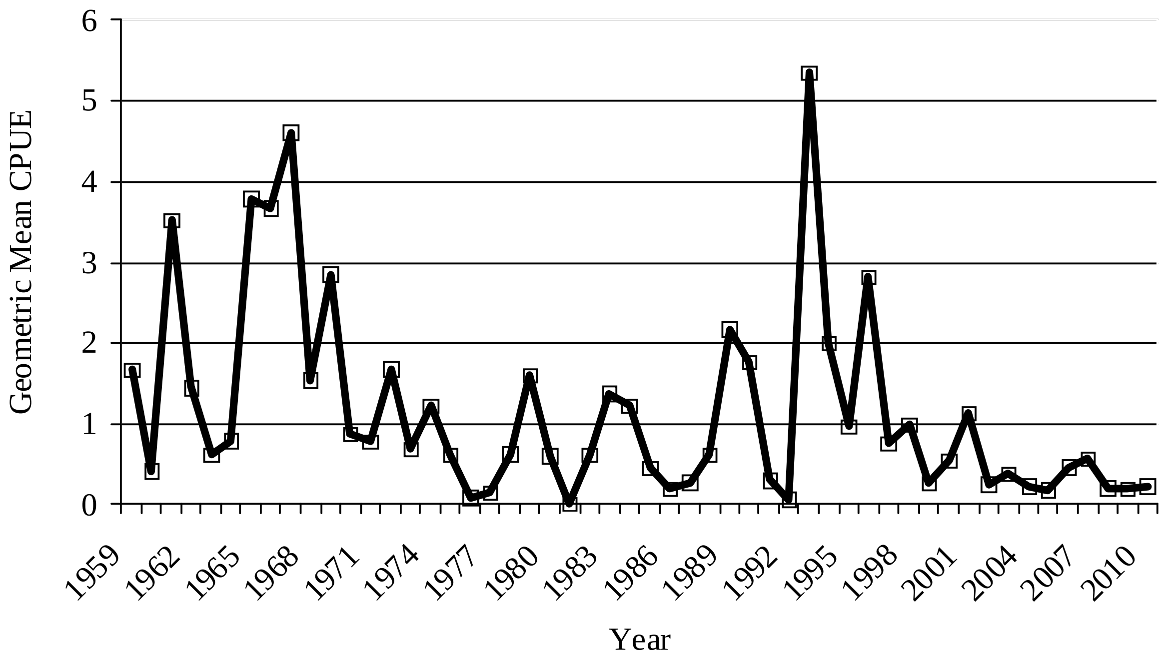


Figure 28. Nanticoke River juvenile blueback herring geometric mean CPUEs, 1959-2010.

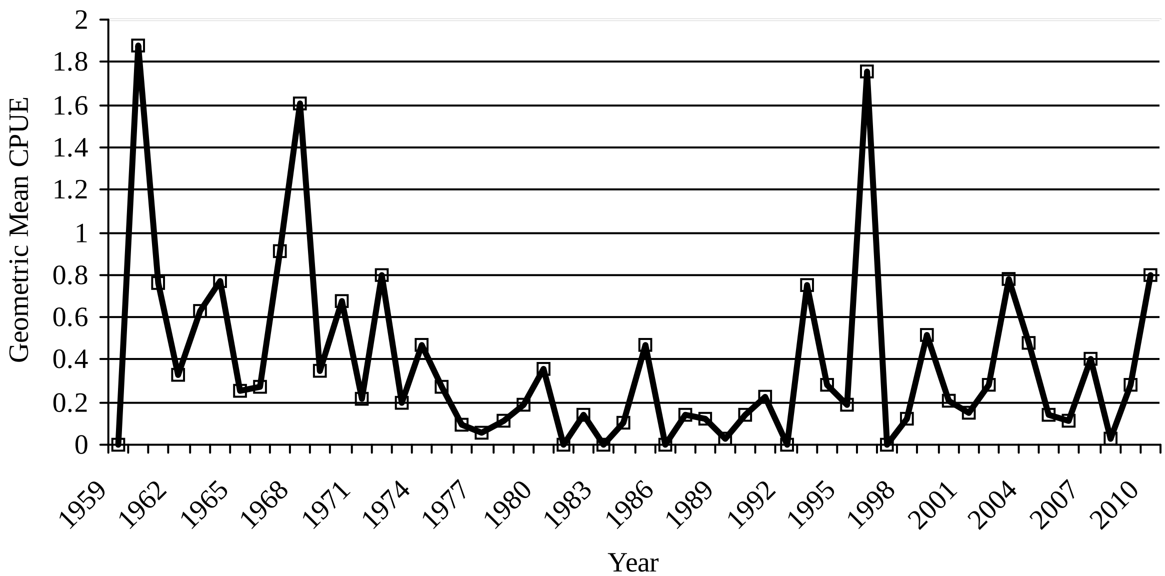
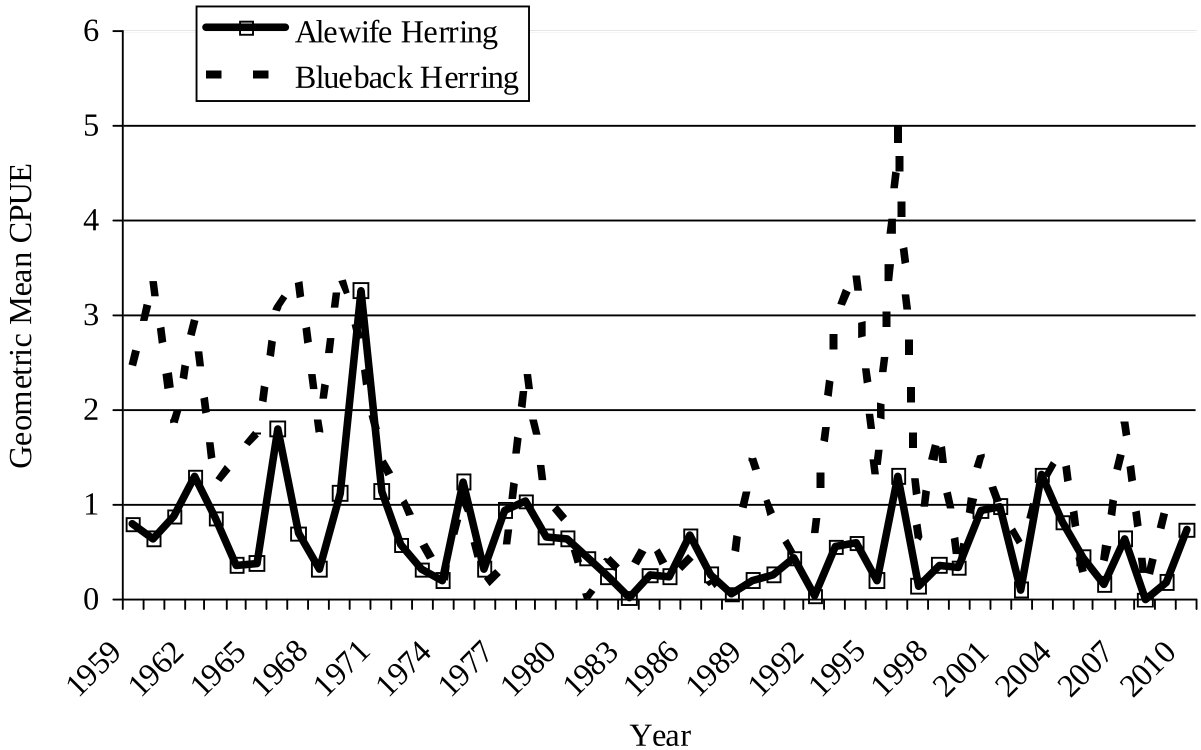


Figure 29. Baywide juvenile alewife and blueback herring geometric mean CPUEs, 1959-2010.



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 Stephanie Grap

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 15 years of this survey (1993-2010). 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, Fishing Bay and in Chesapeake Bay just north of the mouth of the Potomac River in 2010 (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. Menhaden scales were aged by a MD DNR biologist. 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 were stored for later processing and analysis by MD DNR staff when time permits. Water temperature (°C), salinity (ppt), GPS coordinates (NAD 83), date and hours fished were also recorded at each net.

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. Only one seafood dealer agreed to participate. The dealer purchased almost all of its fish from pound netters in the Hooper's Island area. Seafood dealer sampling was conducted every other week throughout the season, unless the dealer indicated catches were low. 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).

Analytical Procedures

Commercial and recreational harvest for the target species were examined utilizing Maryland's mandatory commercial reporting system and the National Marine Fisheries Service (NMFS) Marine Recreational Fisheries Statistics Survey (MRFSS). Since these data sets are not finalized until the spring of the following year, harvest data for this report are through 2009. Harvest from Maryland's commercial reporting system was divided by area into Chesapeake Bay, Atlantic Ocean (including coastal bays) and unknown area.

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. Linear regression of the log(catch / angler trip) compared to year was analyzed using linear regression to identify significant trends in relative abundance. The state wide MRFSS 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 MRFSS recreational catch estimates (numbers), MRFSS 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 2010 charter log book data had not been finalized only data through 2009 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, since 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 2010 samples had not yet been processed by SC DNR. Age and length data were assigned to 20mm TL groups for each species and then applied to the length-at-age key to determine the proportion at age for each species in 2009.

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 and Fishing Bay were sampled from May 25 through September 14, 2010 (Table 2). Seven of the ten target species, and twenty-one non-target species (Table 3) were encountered during this time period. No spotted seatrout, red drum or Spanish mackerel were encountered during onboard sampling. Two seafood dealer sampling trips in the Hooper's Island area were conducted on June 7 and June 21, 2010, during which data were collected from six of the ten target species. Since black drum cannot be commercially harvested in Maryland's portion of Chesapeake Bay, this species was not available for dealer sampling. No weakfish or red drum were encountered, and Atlantic menhaden were not sampled from seafood dealers in 2010.

Pound net catches were poor through the summer of 2010, especially in the mid bay region, so no sampling was conducted after June.

Weakfish

Forty-seven weakfish were sampled in the 2010 pound net survey, the third lowest catch of the 18 year time series. Weakfish mean length in 2010 was 253 mm TL, a decline from the 2009 mean length of 262 mm TL, and the shortest mean length of the 18 year time series (Table 4). No weakfish were encountered during the 2010 seafood dealer sampling, but weakfish usually are not available in the region until July and sampling was only conducted in June (Table 5). Weakfish RSD analysis for 2010 was limited to the RSD_{stock} category fish (Table 6). This was the second year no weakfish were recorded in the RSD_{pref} category and only the third year RSD_{qual} weakfish were not sampled. The 2010 onboard pound net survey length frequency distribution also indicated a slight shift to smaller sizes for the fourth consecutive year, with over 68% of sampled weakfish between 230 and 259 mm TL (Figure 2).

Chesapeake Bay weakfish length-frequencies were truncated from 1993 – 1998, while those for 1999 and 2000 contained considerably more weakfish greater than 380 mm TL. However, this trend reversed from 2001 to 2010, with far fewer large weakfish being encountered. All of the weakfish sampled in the 2010 pound net survey were below the recreational size limit of 331 mm TL (13 inches), and 94 percent were below the commercial size limit of 305 mm TL (12 inches).

In 2010, females accounted for 67% of fish sampled from the pound net survey (n=45). Female mean TL and mean weight were 256 mm TL and 268g, respectively, while males averaged 251 mm TL and 155g. In 2009, females averaged 268 mm TL and 208g and accounted for 81% of fish sampled (n=13), while male mean length and weight were 241 mm TL and 143g, respectively.

Total Maryland commercial weakfish harvest (Chesapeake Bay and Atlantic Ocean combined) in 2009 declined to 4,888 pounds, with the Chesapeake Bay portion increasing from 459 pounds in 2008 to 1,355 pounds in 2009 (Figure 3). Total 2009 harvest was the lowest of the 80 year time series and well below Maryland's average of 635,488 pounds per year. The 2009 commercial harvest for Chesapeake Bay was the fourth lowest since 1969. Maryland recreational anglers harvested an estimated 2,134 (PSE = 69.8) weakfish during 2009, with an estimated weight of 1,506 (PSE 65.5) pounds (MRFSS 2010; Figure 4). The number of weakfish harvested by the recreational fishery in 2009 represented an 18% decrease compared to the 2008 estimate (2,590), and was the second lowest of the 1981-2009 time series. According to the MRFSS, Maryland anglers released 6,700 (PSE = 42.2) weakfish in 2009, a 78% decrease from 2008 (30,260, PSE = 53.1). Estimated recreational harvest decreased steadily from 475,348 fish in 2000 to near zero in 2006, recovered slightly in 2007, but has decreased through 2009.

The reported harvest from Maryland charter boat captains has ranged from 2,122 to 75,154 weakfish from 1993 to 2009 (Figure 5), with a dramatic decline occurring in 2003. The reported charter boat harvest had the same trend as the reported commercial harvest ($R^2 = 0.60$, $P < 0.001$) and the statewide MRFSS estimate ($R^2 = 0.79$, $P < 0.001$), but not the inland for hire only MRFSS estimate. Of the 27,530 entries reported, only one was not included in this analysis since the CPA exceeded 200. The 2009 geometric mean of 0.55 weakfish per angler was the lowest of the time series (Figure 6). The CPA geometric mean has graphically declined from 1993 – 2009, but linear regression produced an R^2 of 0.034 ($p<0.001$) due to high catch variability within years.

The 2010 weakfish juvenile GM of 1.7 increased slightly for the second straight year, but was still the 9th lowest value in the 22 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.

Otoliths from 22 weakfish were aged for 2009, with only ages one and two present (Table 7). Age composition of the sample was 81% age one and 19% age two. The age structure continued to truncate, 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. Forty-five weakfish were sampled for age in 2010, but aging of the samples has not been completed at this time.

Mortality estimates for 2007 through 2010 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 confirms 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 2004-2010. 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 2008 mean length of 347 mm TL was similar to 2007, but the 2009 mean length increased to 368 mm TL, the second highest of the 17 year time series. The 2010 seafood dealer survey mean length and weight for summer flounder was 434 mm TL and 933 g, respectively (Table 5), an increase from the 2009 values of 419 mm TL and 794 g. Relative stock densities in the 2010 onboard pound net survey indicated a slight increase in the stock and memorable categories with a corresponding decrease in the quality category compared to 2009 (Table 9). The 2010 values were more similar to those of 2009 then the trends from 2006 to 2008, which indicated fewer flounder in the preferred category and more in the stock category. Length groups from the onboard sampling were more evenly distributed in 2010 compared to the more discernable bimodal distribution in 2009 (Figure 8). The number of summer flounder sampled in 2010 was the lowest of the 18 years surveyed (Table 4), despite regaining access to the Potomac River pound net which had been very productive for flounder in previous years. The proportion of the 2009 catch greater than or equal to the 356 mm TL minimum commercial size limit (54%) increased for the third year (47% in 2009, 42% in 2008 and 31% in 2007). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches from 2007 - 2010 to the 2010 recreational size limit of 483 mm TL also indicated a greater proportion of legal fish in the stock during 2010 (13% compared to 4% each year in 2007 through 2009).

The 2009 seafood dealer length frequency distribution was truncated by the 356 mm TL minimum size limit. It peaked at the 370 and 390 mm size groups, with a secondary peak at 450 mm and no fish above the 530 mm size group (Figure 9). This was not similar to the 2009 distribution that peaked at the minimum size and then followed a generally asymptotic decline through the 590 mm size group (Figure 9). The 2010 distribution indicated a greater number of summer flounder in the 450 mm size group and the lack of fish above the 430 mm size group compared to the onboard pound net survey distribution, but otherwise was similar for the length groups available for harvest under the 2010 commercial size limit.

Maryland's commercial summer flounder harvest totaled 299,227 pounds in 2009, the 23rd lowest in the 48 year time series (Figure 10). The long-term commercial harvest average (1962 – 2009) is 425,665 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 89,660 (PSE = 218.3) fish caught in 2009 ranked 22nd out of the 29 year time series, and was very similar to the 2007 estimate of 89,729 (PSE = 22.0) fish (MRFSS 2010; Figure 11). The 2009 MRFSS recreational release estimate of 1,028,759 (PSE = 14.1) fish was the seventh highest of the 1981- 2009 time series, representing a slight decrease compared to 2008 (Figure 11).

Reported summer flounder charter boat harvest has been variable, but has generally increased to the time series high of 13,067 fish in 2009 from the 2003 low of 1,051 fish (Figure 12). Linear regression indicated no significant trend between the charter boat catch and the statewide MRFSS estimate, the commercial landings or the for hire inland only MRFSS estimate. This is not surprising, since the majority of the commercial harvest occurs in the Atlantic Ocean, and the MRFSS 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 decline graphically from 1993 to 2003 (Figure 13), but has been relatively stable for the past six 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 297 mm TL during 2010, an increase from the 2009 mean of 267 mm TL (Table 4). The 2010 mean length was close to the 18 year time series mean of 305 mm. Only 4 bluefish were sampled in the 2010 seafood dealer survey with a mean length and weight of 438 mm TL and 844 g respectively (Table 5). The bluefish RSD_{stock} value (98%) decreased slightly, with a corresponding increase in RSD_{qual} and $RSD_{preferred}$ compared to 2009 (Table 10). The pound net survey length frequency distribution broadened somewhat in 2010 after a dramatic shift to smaller sizes in 2008 and 2009 (Figure 14). Eighty-six percent of sampled bluefish in 2009 were less than 310 mm TL, while only 63% of the sample was below 310 mm TL in 2010. A 2010 seafood dealer survey bluefish length distribution was not constructed due to low sample size (4 fish). 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 2010 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 increased more than 108% in 2009 to 145,862 pounds, slightly below the 1929-2009 average of 173,492 pounds (Figure 15). The 2009 catch was the 29th highest of the 80 year time series. The total commercial landings have fluctuated without trend from 42,662 to 157,436 pounds from 1993 – 2009 (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 since stabilized at a lower level (MRFSS 2010; Figure 16). The 2009 estimate of 334,856 (PSE = 18.7) fish harvested decreased nearly 50% compared to 2008 (659,968 fish), and was well below the time series average of 894,783 fish. Estimated recreational releases also decreased sharply in 2009 to 494,377 (PSE = 14.7) compared to 2008 (1,855,033 fish, PSE = 16.4), 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 2009 (Figure 17). Harvest from charter boat logs did generally trend with state wide MRFSS estimates, but was not significantly correlated with recreational estimates or commercial landings. Two of the 67,655 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 (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 model ASAP. 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.

Atlantic croaker

Atlantic croaker mean length from the onboard pound net survey decreased to 295 mm TL compared to 2009, and was similar to the 2008 value (Table 4). The 2009 value (320 mm TL) was the time series high, but may not represent a significant change due to the small sample size (Table 4). Seafood dealer mean length and weight decreased in 2010 to 269 mm TL and 257 g respectively compared to 2009 (300 mm TL and 370 g) (Table 5). Fifty-three percent of sampled pound net croaker in 2010 were in the $RSD_{preferred}$ category, an increase over 2009. $RSD_{memorable}$ and RSD_{trophy} fish declined in 2010 while the $RSD_{quality}$ category increased (Table 11). The length frequency distribution for 2010 demonstrated a reduction in larger fish, with the primary peak occurring in the 270 and 290 mm size groups (Figure 19). A 229 mm TL commercial size limit in Maryland artificially truncates the seafood dealer survey length frequency distribution, although some sub-legal fish were encountered on one day of sampling. The

230 mm length group accounted for 27.8% of the Atlantic croaker seafood dealer samples, with generally declining abundance through the larger length groups (Figure 20). RSD analysis and length frequency distribution indicate a shift to smaller croaker in 2010.

In 2010 pound net catches, females averaged 320 mm TL and 456 g (n=170), while males averaged 289 mm TL and 320 g (n=89). This was a decrease for both sexes compared to 2009 values, 325 mm TL and 509 g for females, and 308 mm TL and 405 g for males. In 2010 females accounted for 66% of the pound net samples, similar to that of 2008 (64%) and 2009 (69%).

During 2009, the Maryland Atlantic croaker total commercial harvest of 448,550 pounds (Chesapeake Bay and Atlantic Ocean combined) decreased 25% compared to 2008 (Figure 21). The 2009 harvest was well below the 1929-2009 average of 1,053,841 pounds. The 2009 recreational harvest was estimated at 1,038,428 fish (PSE = 16.4) a 51% increase from 2008, and was above the long term average of 752,436 fish (MRFSS 2010; Figure 22). The 2009 recreational releases decreased 62% compared to 2008 (MRFSS 2010; Figure 22), and was below the 1981-2009 average of 1,270,805 fish.

Reported Atlantic croaker harvest from charter boats ranged from 127,664 – 448,789 fish during the 17 year time period (Figure 23). The charter boat log book harvest did weakly trend with the statewide MRFSS estimates (R^2 = 0.35, P = 0.0118), but not with the Chesapeake Bay commercial landings or for hire inland only MRFSS estimates. The MRFSS for hire inland only did, however, follow the same general trend. Three of the 49,176 entries were not used because of CPA values exceeding 200 fish. The geometric mean catch per angler varied without trend from 1993 to 2003, but has generally increased since (Figure 24). The 2009 value of 5.25 fish per angler was the highest of the 17 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 25). The 2010 GM remained low at 0.10 fish per tow, and was the sixth lowest of the 22 year time series. Atlantic croaker recruitment has been linked to environmental factors including winter temperature in nursery areas (Lankford and Targett 2001, Hare and Able 2007) 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. 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 (Table 13). Two hundred sixty-eight Atlantic croaker otoliths were collected in 2010, but aging has not been completed at this time. Instantaneous total mortality in 2010 was Z = 0.78, an increase from 2009, and the fourth 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) is 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 increased in 2010 to 201 mm TL, just below the 17 year time series mean of 207 mm TL (Table 4). Spot from seafood dealer sampling in 2010 had a mean length and weight of 198 mm TL and 115 g, respectively (Table 5), both decreased compared to 2009 (211 mm and 141 g). The length frequency distribution in 2010 expanded slightly compared to 2009, and was similar to the 2008 distribution (Figure 26). Both mean length and length frequency distribution from the onboard sampling in 2010 may have been affected by the small sample size (n = 51). No jumbo spot were present in the 2010 onboard sampling. 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, 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). The 2010 length frequency distribution from the seafood dealer survey was truncated compared to the 2009 distribution; with the majority of commercially harvested spot being 190 mm or greater (Figure 27). There is no size limit for spot, but it is highly likely fishermen are discarding small spot, or selling them as bait, thus artificially deflating the number of fish below marketable size.

Commercial harvest in 2009 increased over four fold to 520,151 pounds (Figure 28), the 4th highest catch of the 80 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 and 2009 can be attributed to a large increase in gill net harvest, which accounted for 95% of the 2007 spot harvest (380,648 pounds) and 90% of the 2009 harvest (467,595 pounds), compared to 43% of the 2006 harvest (16,420 pounds). The reported spot harvest, excluding gill net landings, for 2007 (19,703 pounds) was similar to the 2006 non-gill net harvest of 21,354 pounds. In 2008 gill nets accounted for 48% of commercial harvest, with an increasing catch in non-gill net fisheries (62,934 pounds). The 2009 gill net harvest was similar to 2008 (52,556 pounds). This would seem to indicate the 2007 and 2009 spike in gill net landings were due to increased effort directed at spot, likely triggered by market demand and\or the decreased availability of other more desirable species.

Maryland recreational harvest data from the MRFSS indicated that spot catches since 1981 have been variable (MRFSS 2010; 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 2009 recreational harvest estimate (2,170,685 fish; PSE = 10.4) decreased slightly from 2008, but was still above the mean estimate of 1,731,702 fish, and marked the 8th highest value of the 29 year time series. The release estimate of 783,980 fish (PSE = 12.0) decreased 62% compared to 2008, and was below the long term mean of 1,096,655 fish (Figure 29).

Reported spot harvest for charter boat from 1993 to 2009 ranged from 265,473 to 848,492 fish per year (Figure 30). The charter boat log book harvest did not significantly trend with the MRFSS for hire inland only estimates, the Chesapeake Bay commercial landings or statewide MRFSS estimates. This is not surprising, since charter boat captains sometimes have clients catch spot to use as bait for larger predatory species. MRFSS surveys may not accurately account for spot used as bait, while the commercial harvest tends to be more incidental. Twenty-four of the 42,501 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 9.0 in 2008 and then increased slightly to 9.7 fish in 2009 (Figure 31).

Spot juvenile trawl indices from 1989-2010 were quite variable (Figure 32). The 2009 GM index was the second lowest value of the 22 year time series, but the 2010 value of 104.5 spot per tow was the highest value of the time series.

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 2008 could be indicative of growth overfishing. However, recreational harvest and release estimates have been high the past five years, 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 are rarely encountered in the onboard pound net or seafood dealer sampling, with none being examined in either survey in 2010. 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 2009 totaled 12 pounds, compared to 40 pounds in 2008 (Figure 33). Average harvest from 2004 to 2009 was 33 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 by weight.

The MRFSS (2010) estimated that recreational fishermen did not harvest any red drum in 2009, but did estimate 7,851 (PSE = 53.6) releases in 2009 (Figure 34). Recreational harvest estimates have been extremely variable ranging from zero (17 of the

29 years in the 1981 - 2009 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 - 2009, except for 1996. Catches were low for all years, ranging from zero to 99 fish, with a mean of 18.7 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 MRFSS 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 2010 (Table 4). Lengths throughout the time series have ranged from 244 to 1330 mm TL, and averaged 1061 mm TL in 2009. 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 1984 (MRFSS 2009; Figure 37). In 2009, MRFSS estimated no black drum were harvested or released by recreational anglers. However, it is highly unlikely no black drum were caught. The zero harvest estimates seem somewhat tenuous, since the MRFSS 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 1993-2009 time series, with catches 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 MRFSS estimates. The geometric mean has declined graphically through time (Figure 39), but inter year variability in catch is high, as indicated by the low R^2 value of 0.137. The 2009 CPA did increase to 0.20, 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 2010, the first year of the survey 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). Only one Spanish mackerel was encountered during seafood dealer sampling in 2010, the fish was 378 mm FL and 240g (Table 5). Spanish mackerel usually are more abundant in Maryland's portion of Chesapeake Bay in late summer, and no seafood dealer sampling was conducted at that time in 2010.

The 2009 commercial harvest of Spanish mackerel in Maryland was 11,416 pounds, 40% greater than in 2008 (6,834 pounds; Figure 40), and above the 1965 to 2009 mean of 6,445 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 (MRFSS 2010; Figure 41). This followed a period of seven out of ten annual estimates with zero fish captured. Harvest estimates for 1998 – 2009 were variable, ranging from 0 – 24,725 fish with an average of 9,220 fish taken. In 2009, 24,725 (PSE = 43.0) Spanish mackerel were harvested, a four fold increase from the 2008 estimate of 5,777 fish (PSE = 78.3), and the highest value since 1995 (Figure 41). However, because of the high PSE values, these estimates are considered tenuous.

Spanish mackerel charter boat harvest from 1993 to 2009 ranged from 563 – 10,653 fish per year (Figure 42). The charter boat log book harvest did trend significantly with the MRFSS for hire inland only estimates ($R^2 = 0.65$, $P < 0.01$) and the statewide MRFSS 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

Sampling for spotted seatrout rarely encounters this species. None were measured from the onboard sampling in 2010, and only four were encountered during seafood dealer sampling (mean length = 511 mm TL, mean weight = 1308 g; Tables 4 and 5). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from1955 – 1990 and 7,096 pounds from 1991-2009 (Figure 44). Reported 2009 harvest was 176 pounds, well below the 1991- 2009 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 (MRFSS 2010; Figure 45). The 2009 estimate of 11,680 (PSE = 100) was the highest since 1998, but the extremely high PSE value indicates the MRFSS survey does not provide reliable estimates for this species.

Spotted seatrout harvest from charter boats ranged from 249 – 20,030 fish per year (Figure 46) and averaged 4,678 fish per year from 1997 - 2009. 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 MRFSS for hire inland only estimates, the statewide MRFSS 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 limited to a small group of anglers that are unlikely represented in the MRFSS. This is supported by the 2007 and 2008 reported charter harvest values that approximated the time series mean and coincided with zero value estimates from the MRFSS.

Atlantic Menhaden

Mean FL for Atlantic menhaden sampled from commercial pound nets in 2010 was 232 mm FL, the lowest mean length of the 2004 to 2010 time series (Table 4). Menhaden samples were not collected from the seafood dealer survey in 2010. 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 length distribution indicated a shift to smaller fish, and a more even distribution of lengths.

Scale samples were taken from 425 Atlantic menhaden, but aging was not completed in time for inclusion in this report.

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 2009 commercial harvest decreased for the second straight year, but was still the tenth highest on record (7.8 million pounds), with 96% of harvest from the Chesapeake Bay (Figure 49). The vast majority of Maryland’s annual menhaden harvest consistently comes from the Chesapeake Bay.

CITATIONS

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

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

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

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

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

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

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

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

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

MRFSS. 2008. Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division.

Montane, M.M., and H.M. Austin. 2005. Effects of hurricanes on Atlantic croaker (*Micropogonias undulatus*) recruitment to Chesapeake Bay. Pp. 185-192. In Hurricane Isabel in Perspective. K. Sellner, ed. Chesapeake Research Consortium, CRC Publication 05-160, Edgewater, MD.

Norcross, B.L., and H.M. Austin. 1988. Middle Atlantic Bight meridional wind component effect on bottom water temperature and spawning distribution of Atlantic croaker. Continental Shelf Research 8(1):69–88.

Northeast Fisheries Science Center (NFSC). 2008. 47th Northeast Regional Stock Assessment Workshop (47th SAW) Assessment Summary Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 08-11; 22 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

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

SAS. 2006. SAS Enterprise Guide software, Version 4 of the SAS System for Windows. Copyright © 2006 SAS Institute Inc., Cary, NC, USA.

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

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

TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

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, 2010.

Area	**Month**	**Number of Sampling Trips**	**Mean Water Temp. ©**	**Mean Salinity (ppt)**
Nanticoke	May	1	20.1	11.8
Fishing Bay	June	2	28	13.4
Nanticoke	June	3	27.1	13
Point Lookout	June	2	25.4	12.7
Fishing Bay	July	1	29.4	14.6
Nanticoke	July	2	28.2	13.7
Point Lookout	July	2	27.4	14.1
Chesapeake	August	1	27.3	15.4
Fishing Bay	August	1	28	14.9
Nanticoke	August	1	28	14.4
Point Lookout	August	3	27.2	15.8
Chesapeake	September	1	23.6	17.8
Nanticoke	September	1	24.8	16.8
Point Lookout	September	1	24	17.9

Table 3. List of non-target species observed during the 2010 onboard pound net survey.

Common Name	Scientific Name
American shad	*Alosa sapidissima*
Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic herring	*Clupea harengus*
Atlantic thread herring	*Opisthonema oglinum*
Butterfish	*Peprilus triacanthus*
Common Carp	*Cyprinus carpio*
Cownose ray	*Rhinoptera bonasus*
Crevalle jack	*Caranx hippos*
Gizzard shad	*Dorosoma cepedianum*
Harvestfish	*Peprilus alepidotus*
Hickory shad	*Alosa mediocris*
Hogchoker	*Trinectes maculates*
Northern Puffer	*Sphoeroides maculatus*
Northern searobin	*Prionotus carolinus*
Oyster toadfish	*Opsanus tau*
Silver perch	*Bairdiella chrysoura*
Southern kingfish	*Menticirrhus americanus*
Southern stingray	*Dasyatis americana*
Striped bass	*Morone saxatilis*
White catfish	*Ameiurus catus*
White perch	*Morone americana*

Table 4. Mean length (mm TL), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay onboard pound net sampling, 1993 - 2010.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Weakfish																		
mean length	276	291	306	293	297	337	334	361	334	325	324	273	278	290	275	276	262	253
std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42	52	22	24
n	435	642	565	1431	755	1234	851	333	76	196	129	326	304	62	61	42	23	47
Summer flounder																		
mean length	347	309	297	335	295	339	325	347	358	324	353	327	374	286	341	347	368	374
std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66	72	64	84
n	209	845	1669	930	818	1301	1285	1565	854	486	759	577	499	1274	1056	982	277	197
Bluefish																		
mean length	312	316	323	307	330	343	306	303	307	293	320	251	325	311	318	260	265	297
std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70	41	43	60
n	45	621	912	619	339	378	288	398	406	592	223	581	841	1422	1509	2676	1181	488
Atlantic croaker																		
mean length	233	259	286	294	301	310	296	302	317	279	287	311	317	304	307	298	320	295
std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54	62	50	34
n	471	1081	974	2190	1450	1057	1399	2209	733	771	3352	1653	2398	1295	2963	1532	91	1968
Spot																		
mean length	184	207	206	235	190	230	213	230	239	184	216	208	197	191	208	198	185	201
std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23	21	21	22
n	309	451	158	275	924	60	572	510	126	681	1354	882	2818	2195	519	1195	33	51
Spotted Seatrout																		
mean length		448	452			541	460								414	464	262	
std. dev.		86	42				134								43	72	22	
n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3	10	23	0
Black Drum																		
mean length		1106	741	353		1074				435	475	780	1130	1031	1144	875	1147	1061
std. dev.		175	454	20		182				190	20	212		228	95	238	84	345
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5	13	3

Table 4. Continued.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Red Drum																		
mean length						302	332	648		316	506	647	353	366	658	361		
std. dev.							71			44		468		21	40	57		
n	0	0	0	0	0	1	16	1	0	177	1	2	1	16	2	21	0	0
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
Menhaden (Fork Length)																		
mean length												262	282	238	243	246	245	232
std. dev.												28	36	42	41	29	40	37
n												213	1052	826	854	826	366	811

Table 5. Mean length (mm TL), mean weight (g) and sample sizes of summer migrant fishes from Chesapeake Bay seafood dealer sampling, 2009- 2010.

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

Table 6. Relative stock density of weakfish from Chesapeake Bay summer onboard pound net survey, 1993 - 2010.

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				

Table 7. Weakfish mean length (mm TL), mean weight and number sampled by age, and proportion at age, 2009.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged	Percent of Age Sample
1	267	200	17	81
2	337	398	5	19

Table 8. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2010.

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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

* Insufficient data to calculate 2007 - 2010 weakfish estimates.

Table 9. Relative stock density of summer flounder from Chesapeake Bay summer onboard pound net survey, 1993 - 2010.

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	

Table 10. Relative stock density of bluefish from Chesapeake Bay summer onboard pound net survey, 1993 - 2010.

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		

Table 11. Relative stock density of Atlantic croaker from Chesapeake Bay summer onboard pound net survey, 1993 - 2010.

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		10	53	36	1

Table 12. Atlantic croaker mean length (mm TL), mean weight and number sampled by age, 2009.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged
0			0
1	256	237	24
2	294	360	13
3	317	458	93
4	327	498	33
5	334	534	27
6	355	612	11
7	379	750	18
8	375	646	3

Table 13. Atlantic croaker proportion at age using 2009 pound net length and age data (ages: n= 222 and lengths: n=1,381).

Age	0	1	2	3	4	5	6	7	8
n	0	426	118	517	154	108	25	30	4
Proportion at age	0.00	30.86	8.54	37.41	11.12	7.81	1.80	2.16	0.30

Table 14. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2009.

Age	Mean Length (mm FL)	Number Aged
0	156	1
1	186	42
2	246	61
3	266	101
4	278	45
5	289	8

Table 15. Atlantic menhaden proportion at age using 2009 pound net length and age data (ages: n=258 and lengths: n=512).

Age	0	1	2	3	4	5
n	2	86	128	195	88	14
Proportion at age	0.4	16.8	24.9	38.0	17.2	2.7

Figure 1. Summer pound net sampling area map for 2010.

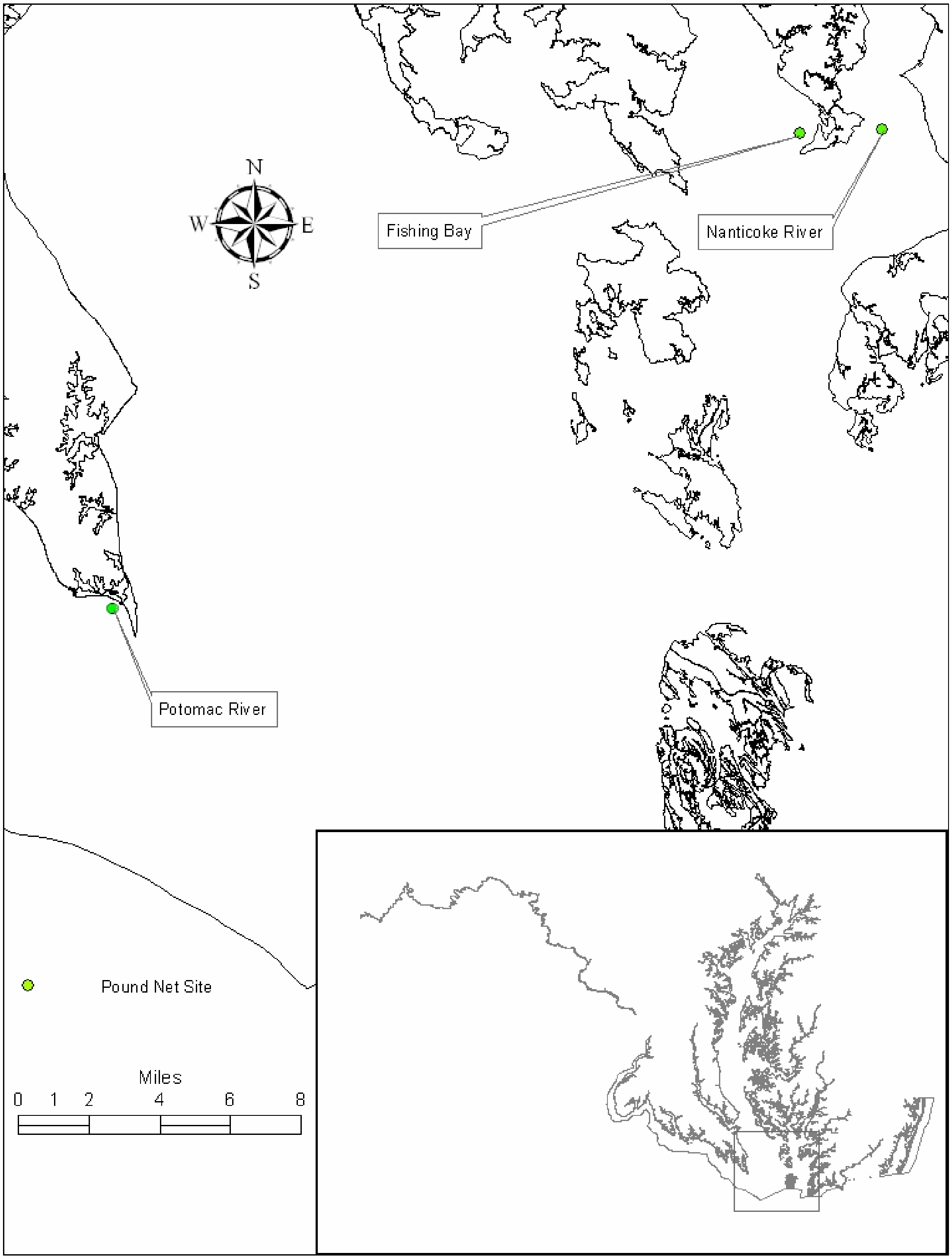


Figure 2. Weakfish length frequency distributions from onboard pound net sampling, 2007-2010.

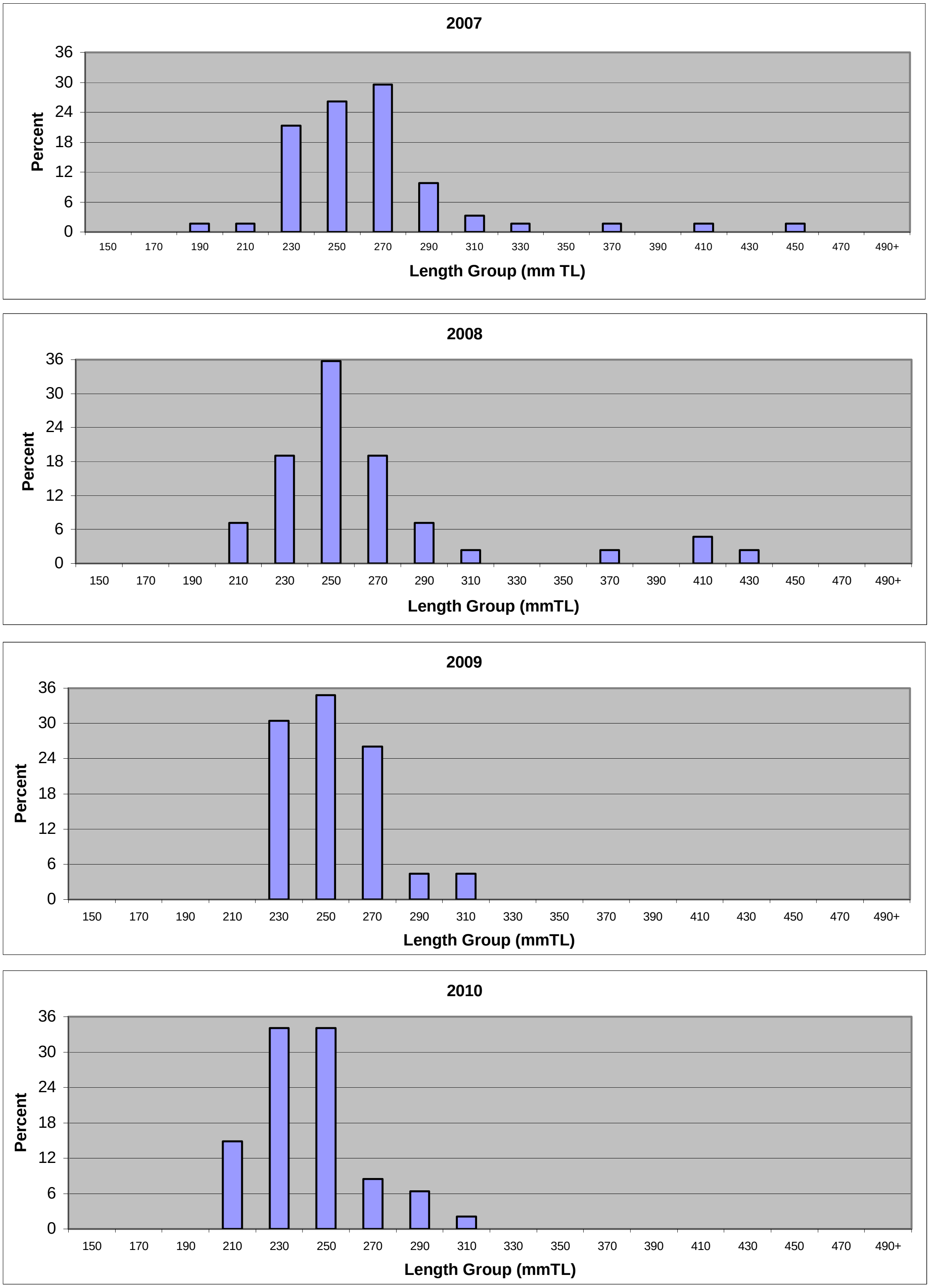


Figure 3. Maryland commercial weakfish harvest by area, 1929-2009.

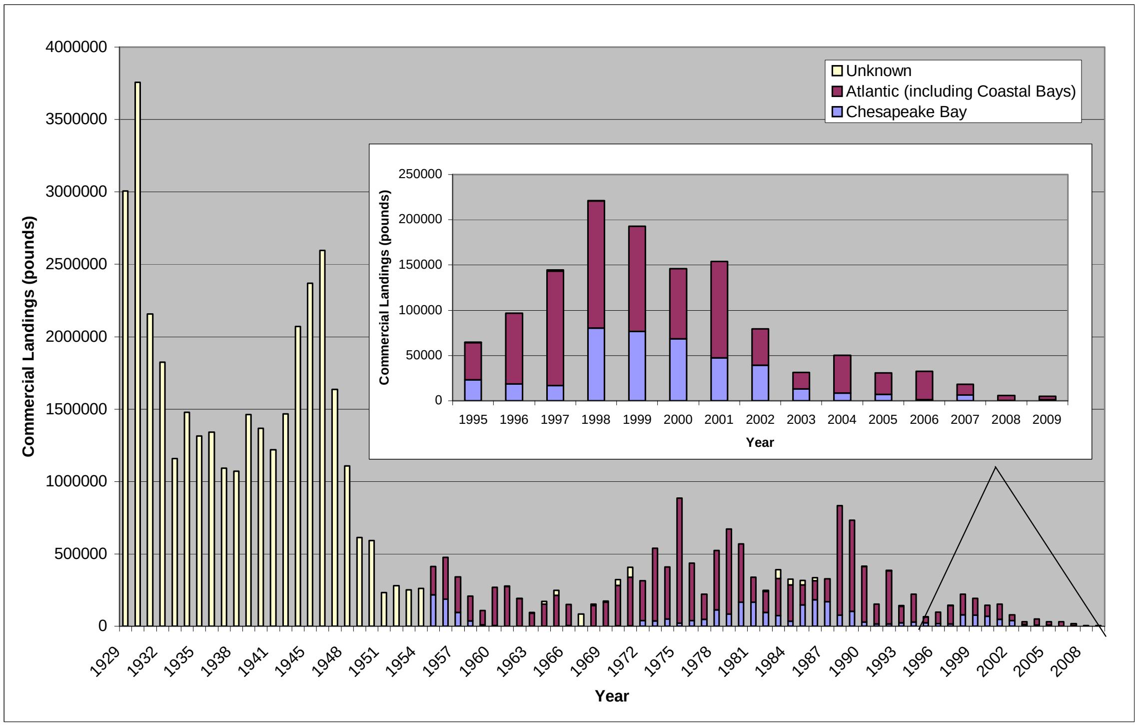


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2009 (Source: MRFSS, 2010).

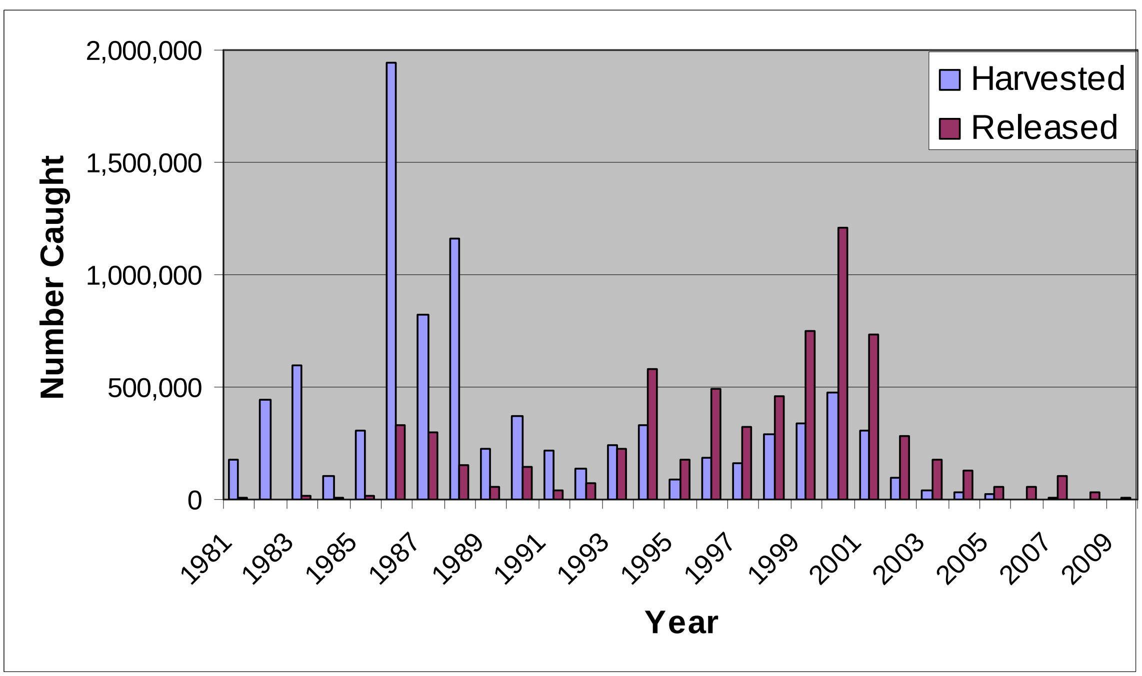


Figure 5. Weakfish statewide MRFSS harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2009.

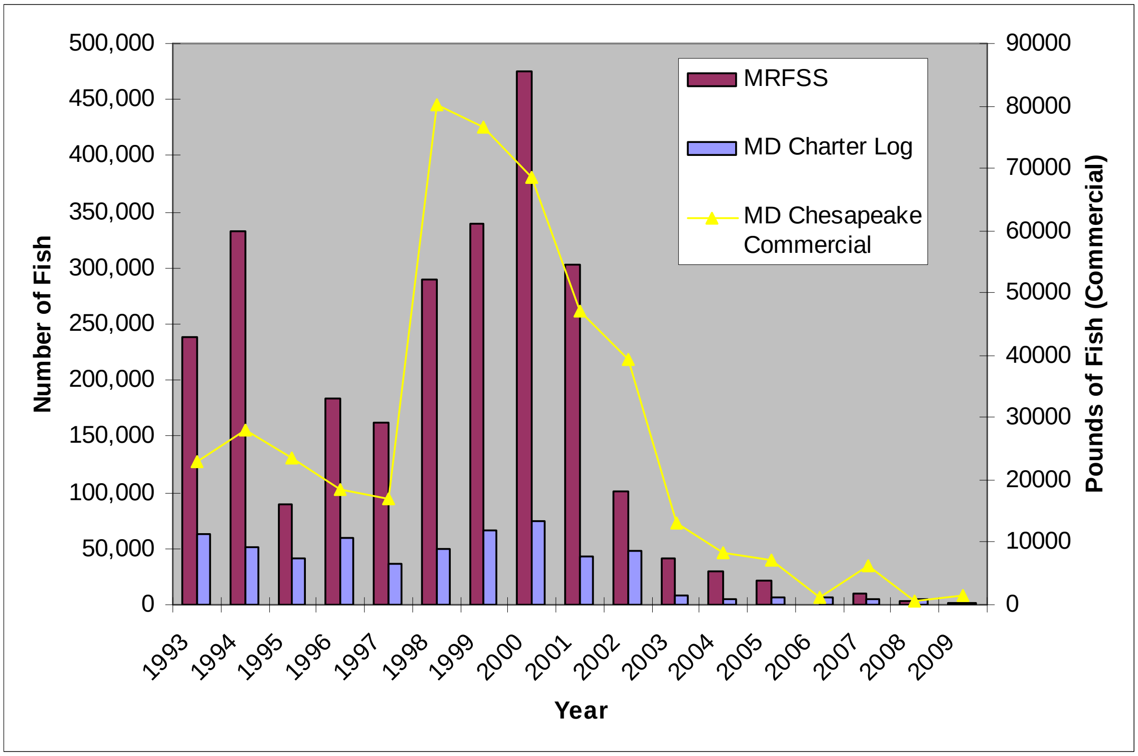


Figure 6. Weakfish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

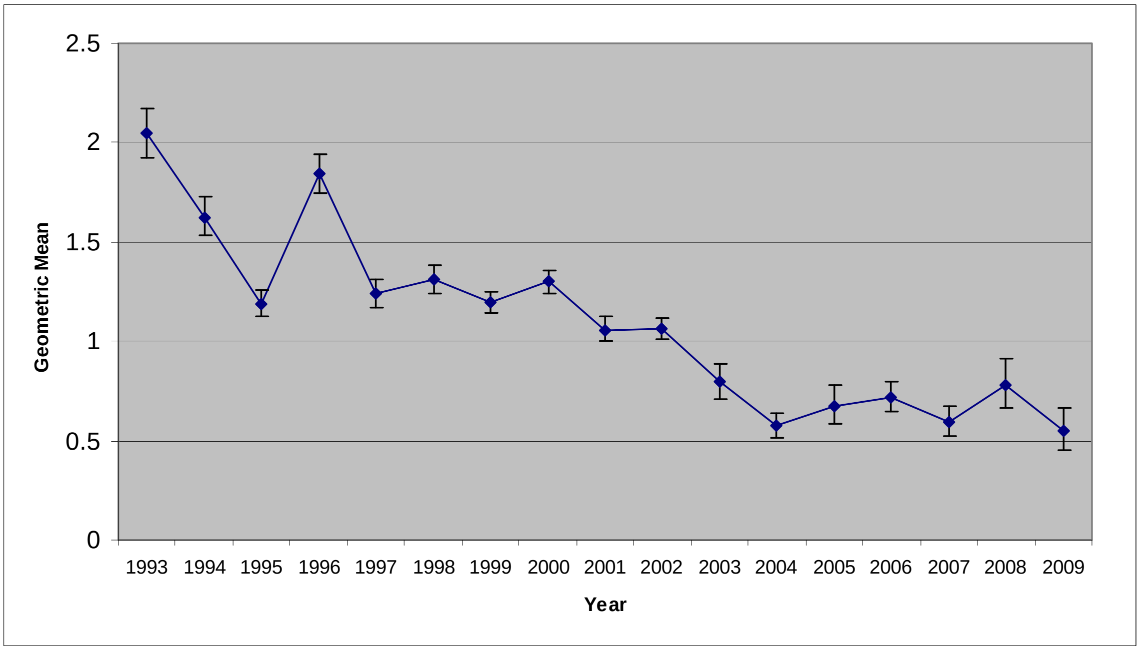


Figure 7. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2010.

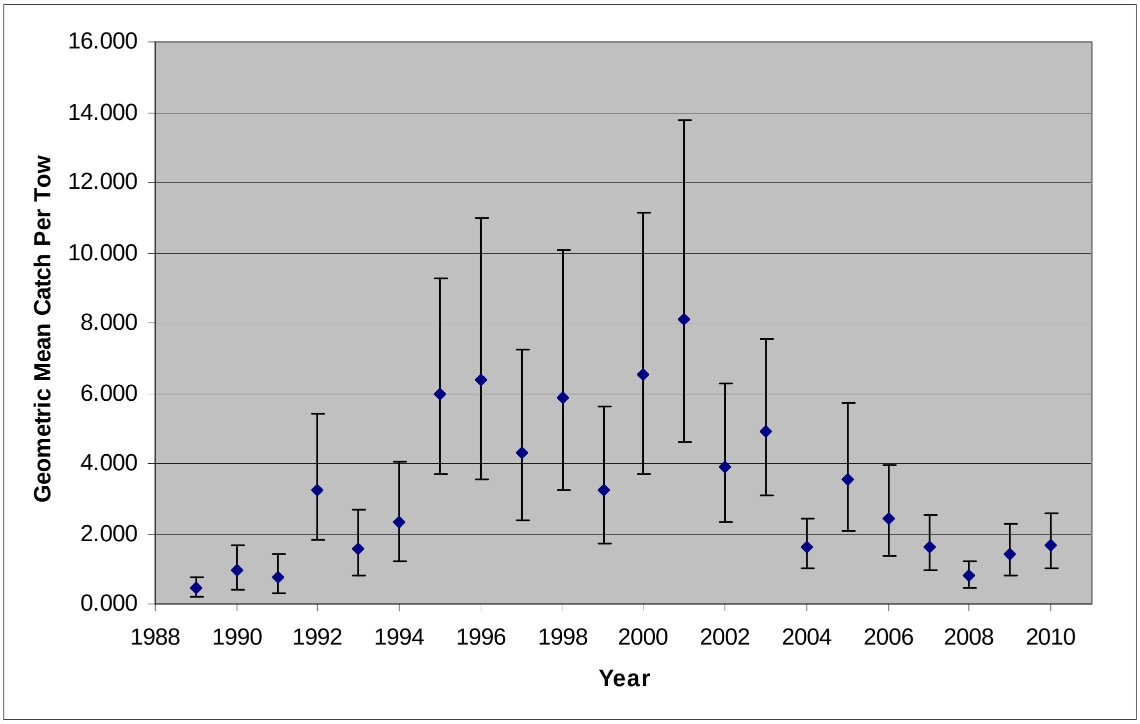


Figure 8. Summer flounder length frequency distributions from onboard pound net sampling, 2007-
2010.

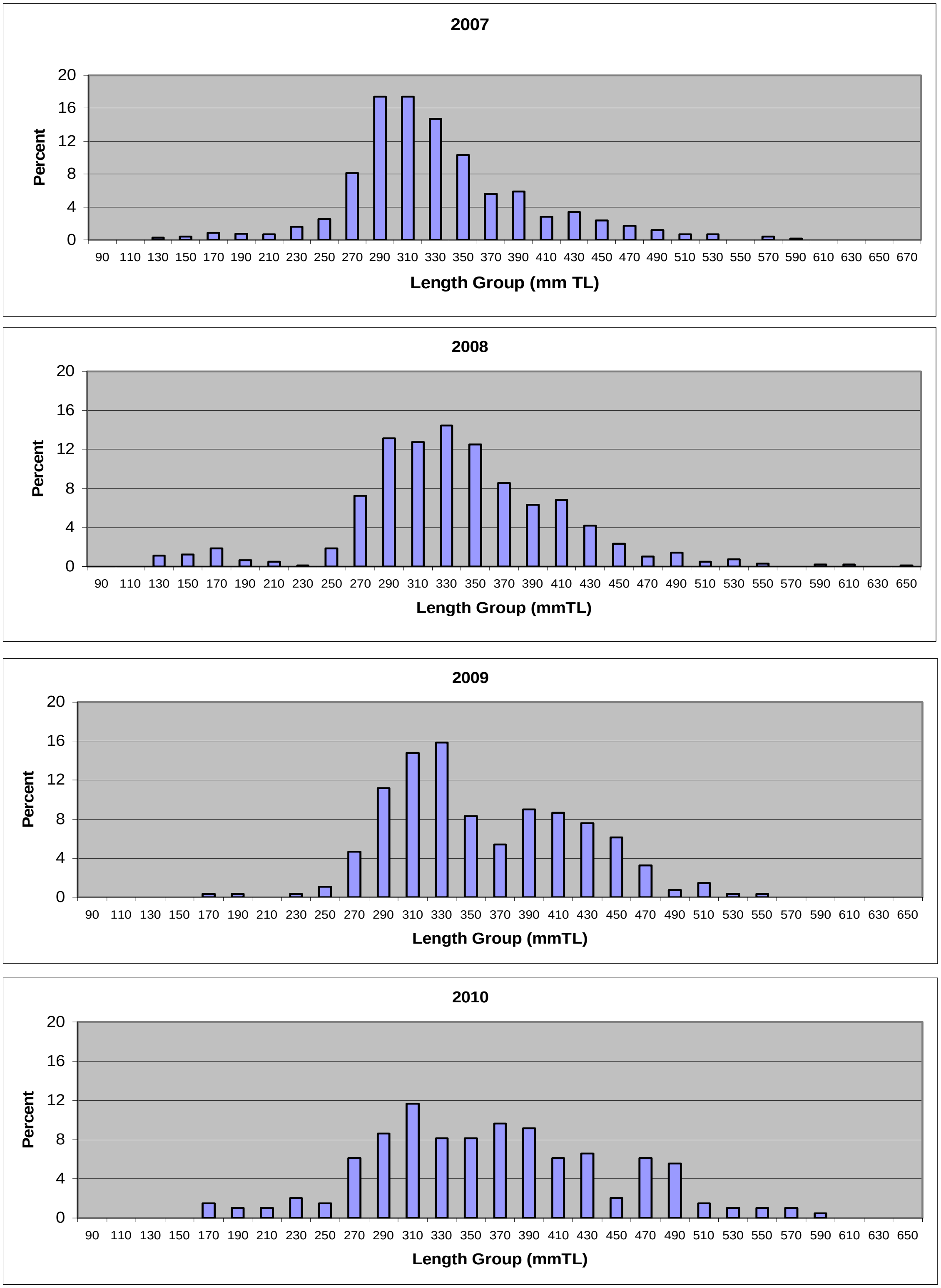
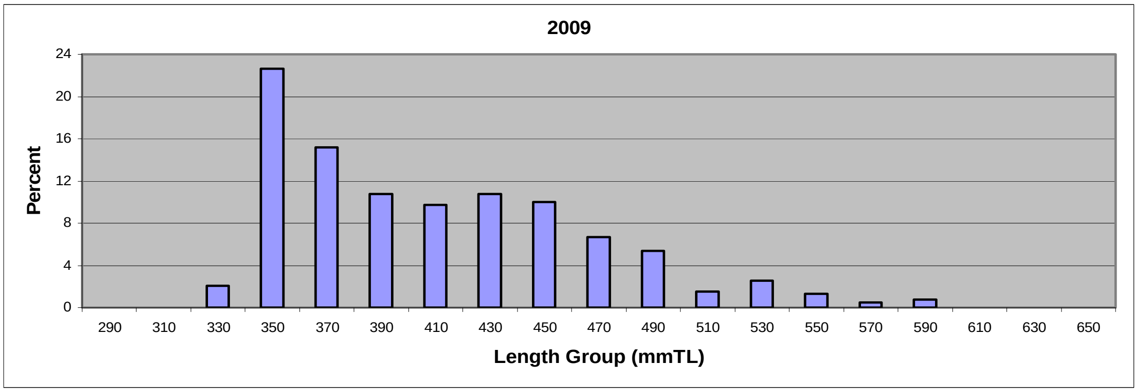


Figure 9. Summer flounder length frequency distributions from seafood dealer sampling, 2009 and 2010.



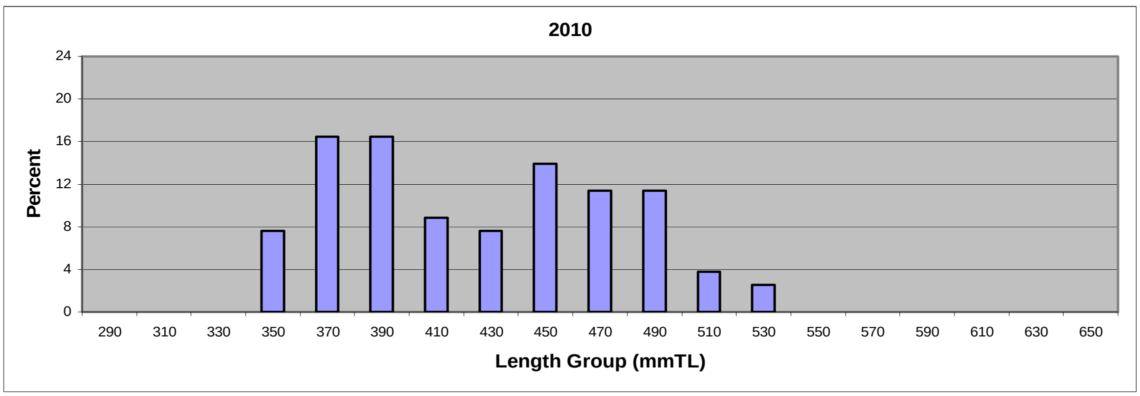


Figure 10. Maryland commercial summer flounder harvest by area, 1962-2009.

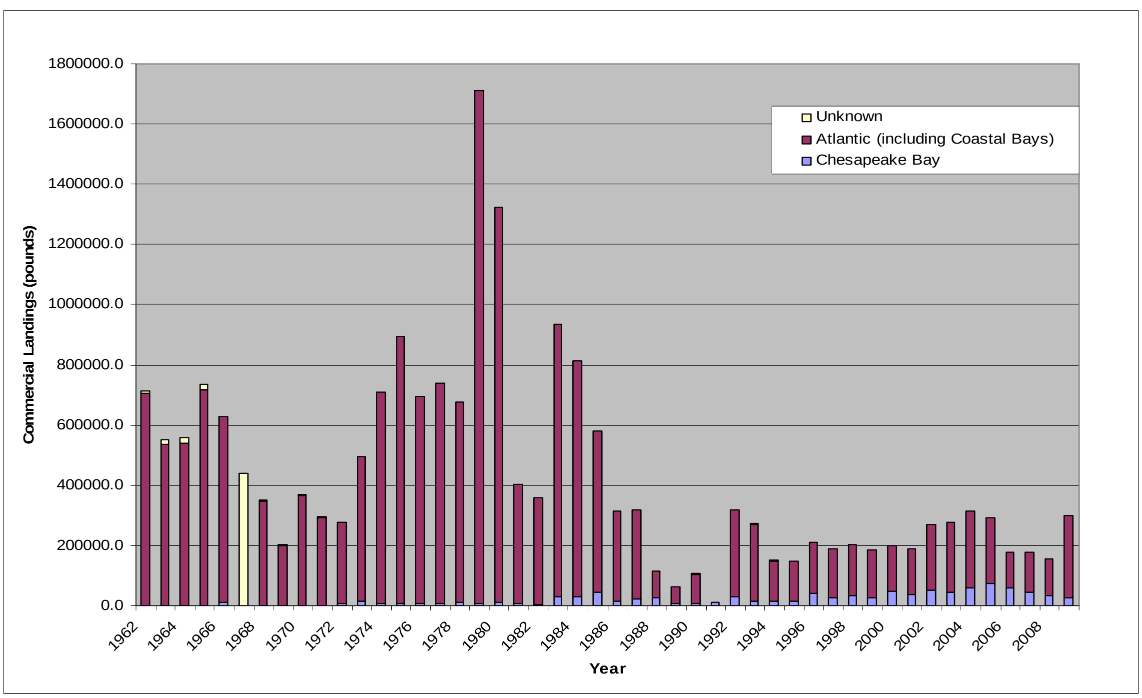


Figure 11. Estimated Maryland recreational summer flounder harvest and releases for 1981-2009 (Source: MRFSS, 2010).

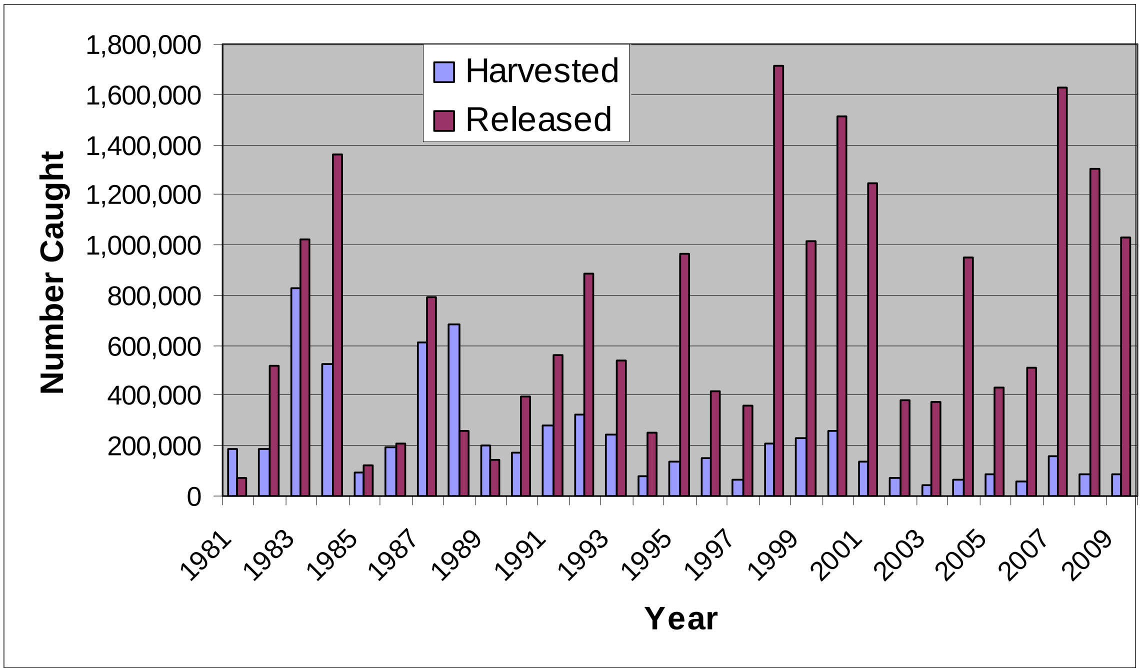


Figure 12. Summer Flounder statewide MRFSS harvest and reported charter boat harvest from Maryland logbooks in numbers, 1993-2009.

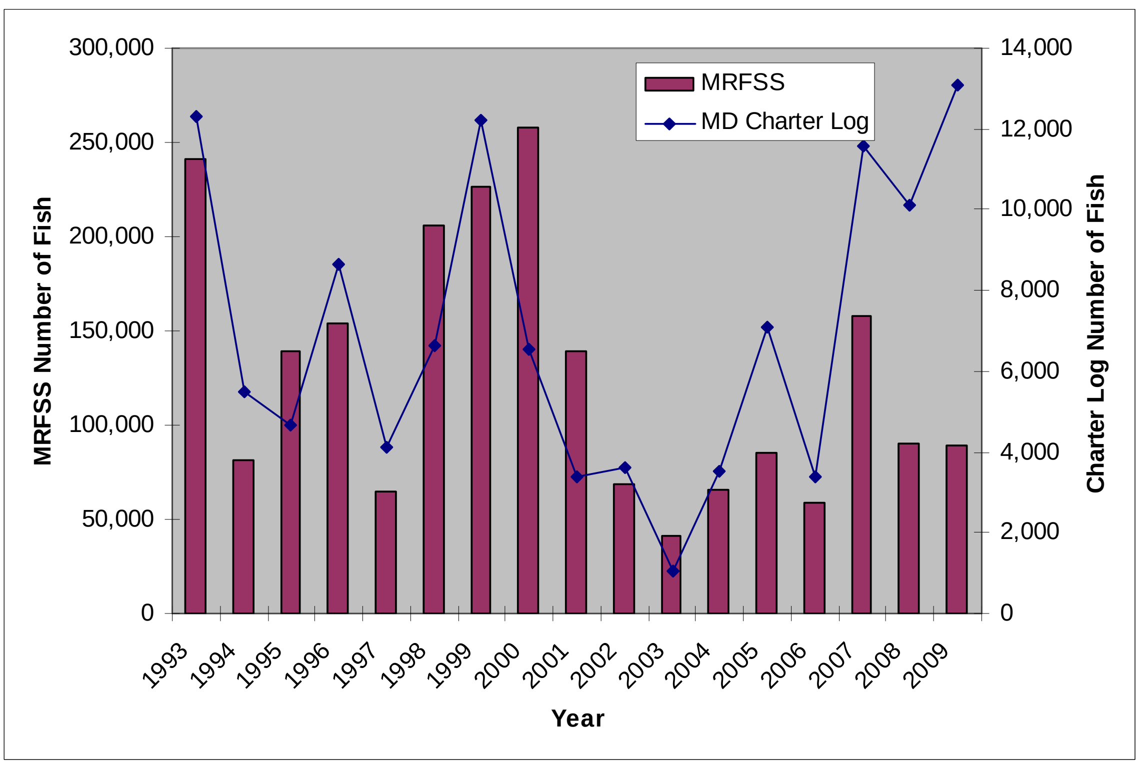


Figure 13. Summer flounder geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

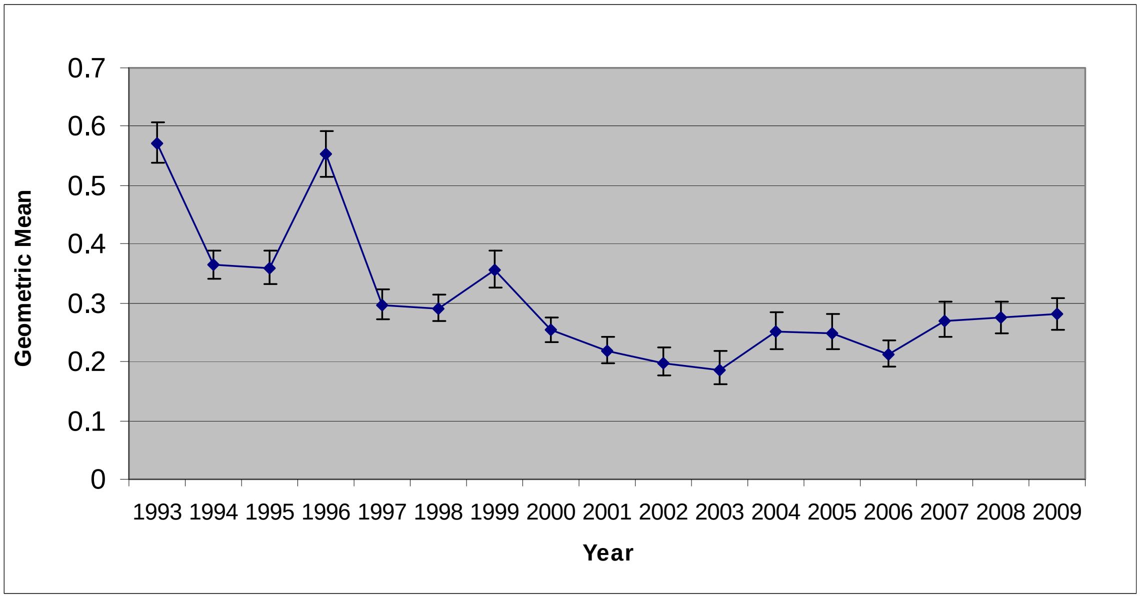


Figure 14. Bluefish length frequency distributions from onboard pound net sampling, 2007-2010.

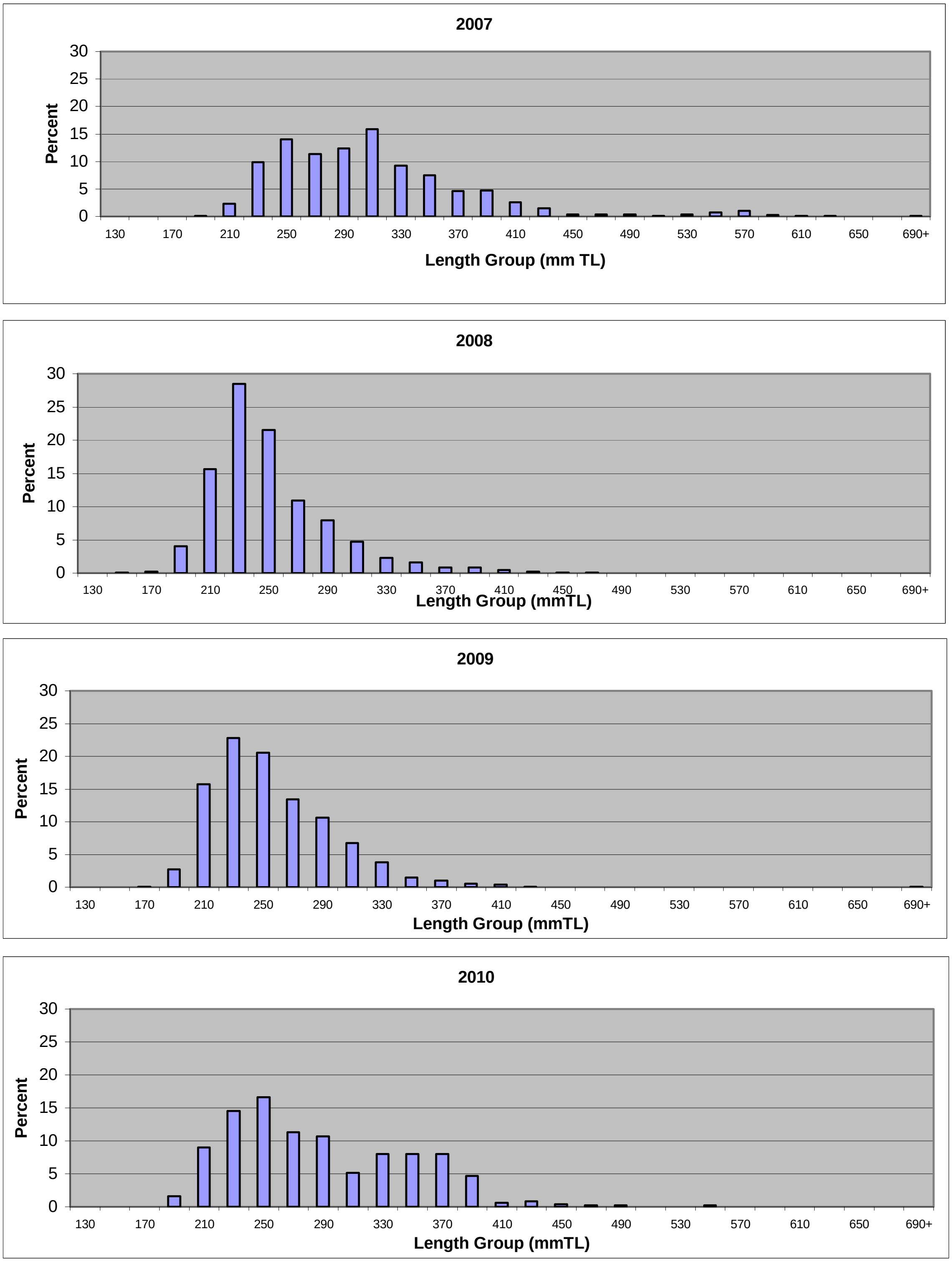


Figure 15. Maryland commercial bluefish harvest by area, 1929-2009.

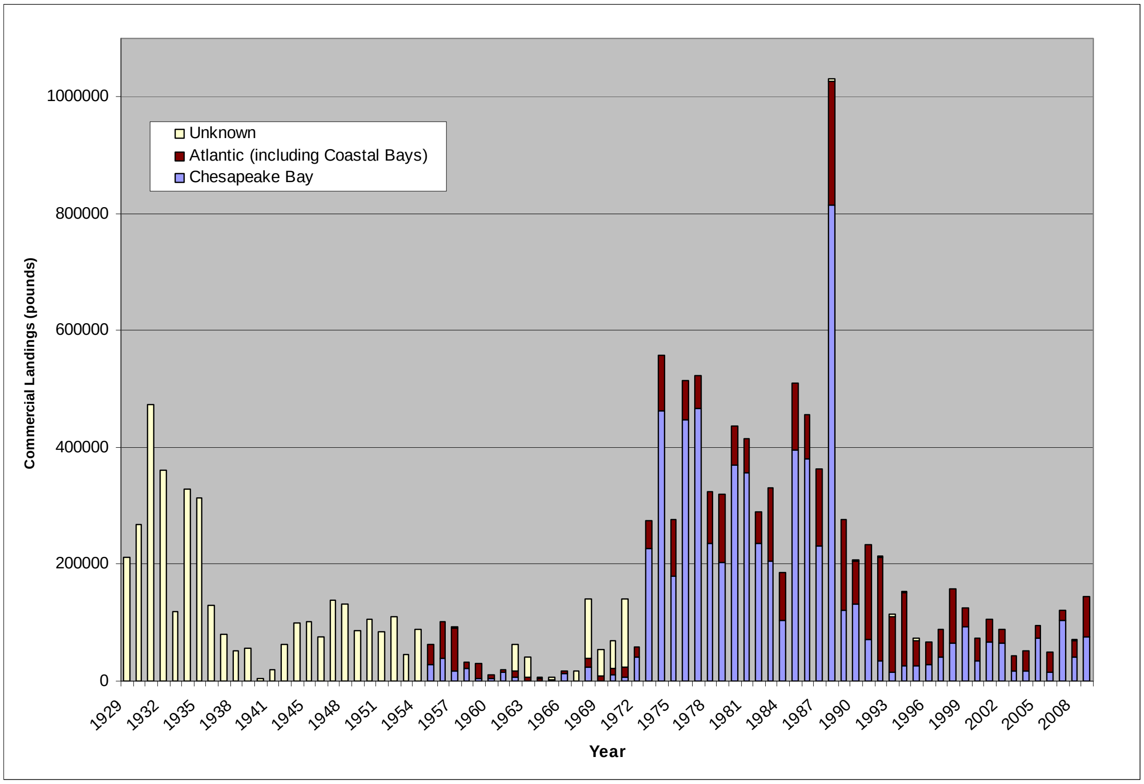


Figure 16. Estimated Maryland recreational bluefish harvest and releases for 1981-2009 (Source: MRFSS, 2010).

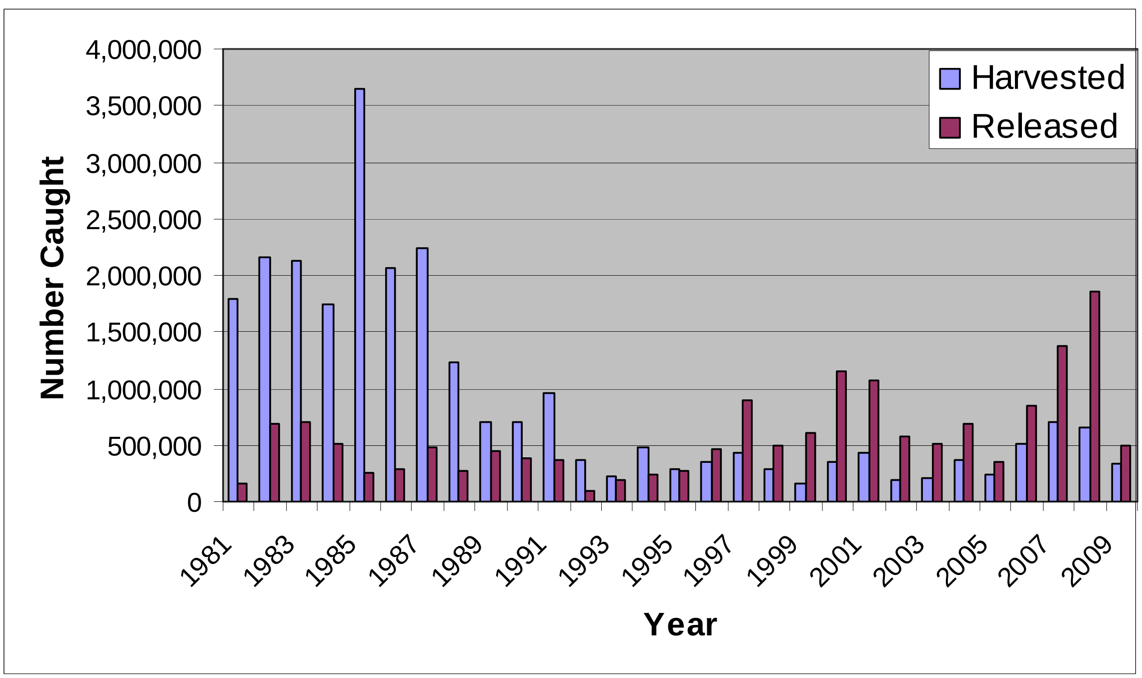


Figure 17. Bluefish statewide MRFSS harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2009.

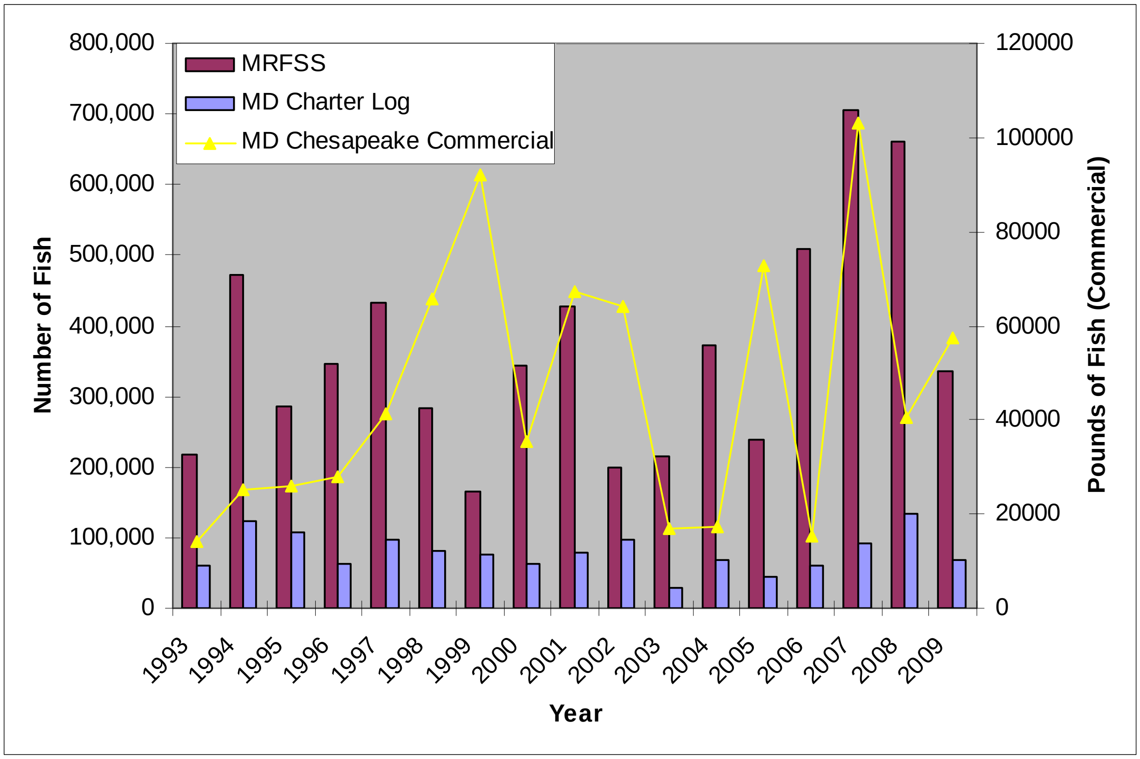


Figure 18. Bluefish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

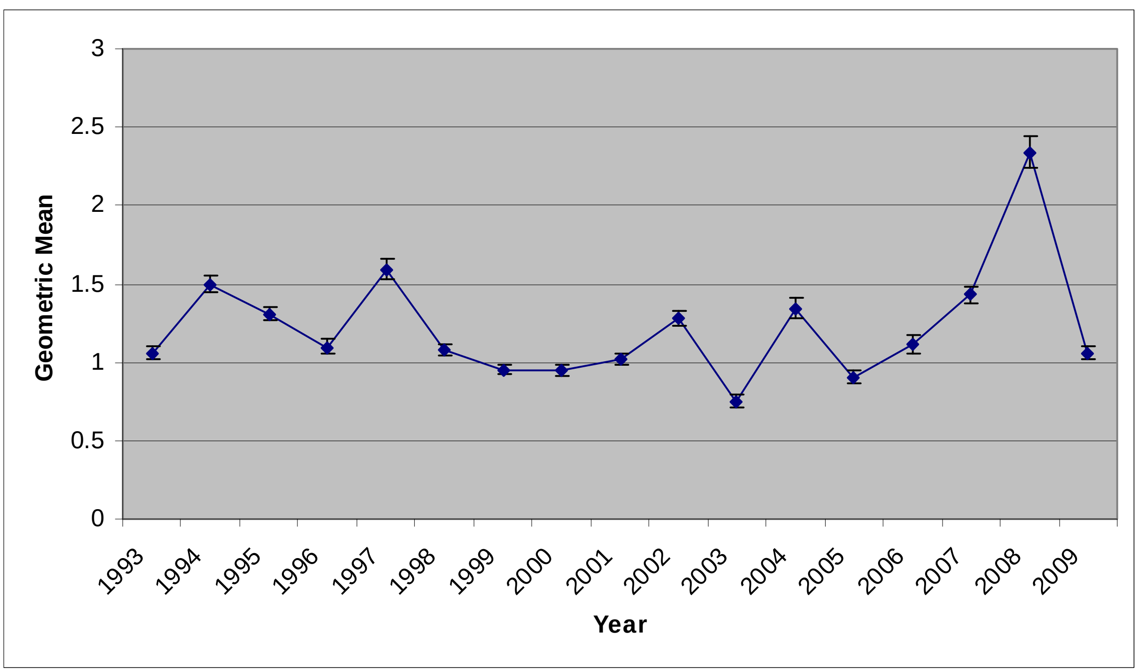


Figure 19. Atlantic croaker length frequency distributions from onboard pound net sampling, 2007-2010.

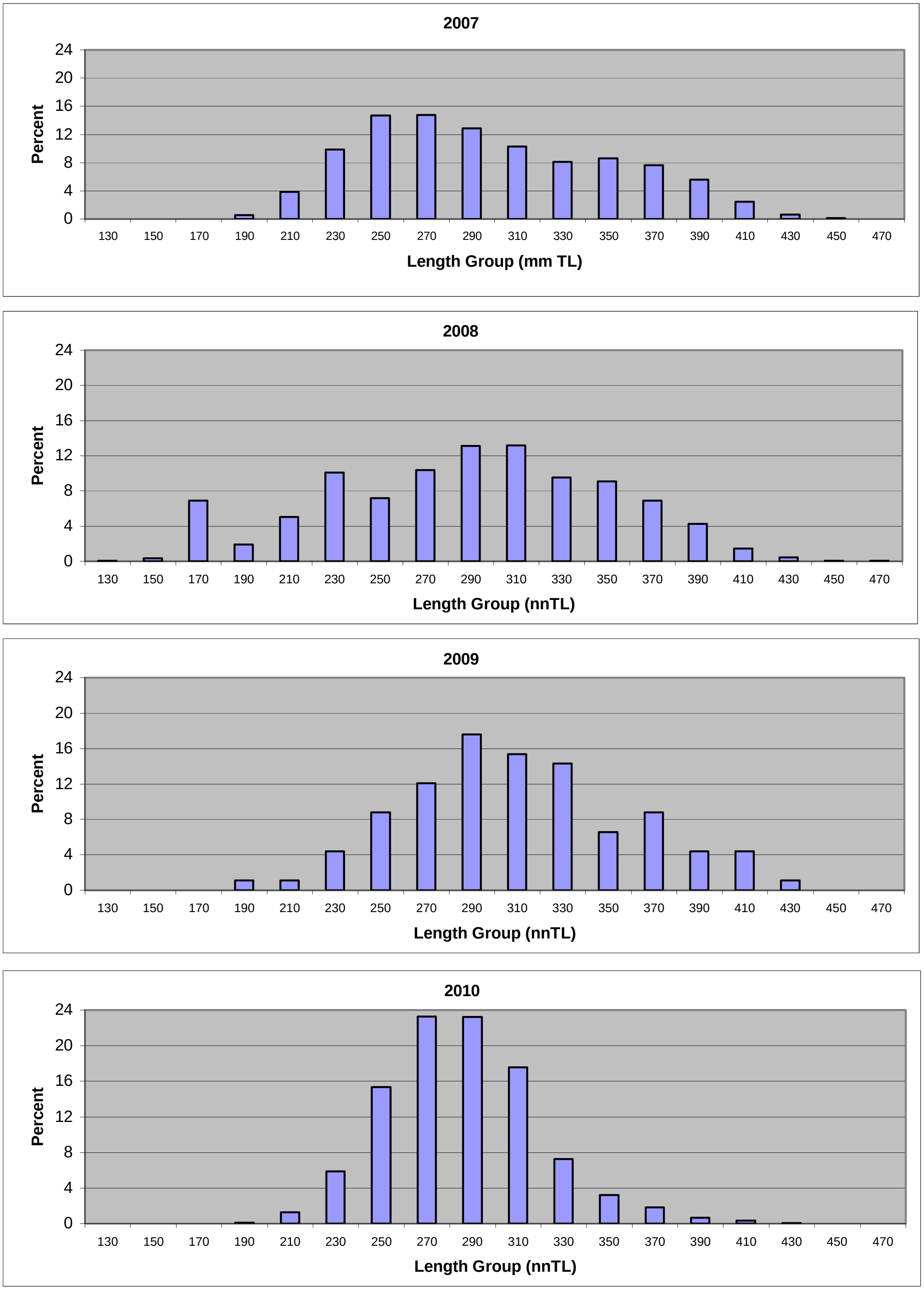


Figure 20. Atlantic croaker length frequency distributions from seafood dealer sampling, 2009 and 2010.

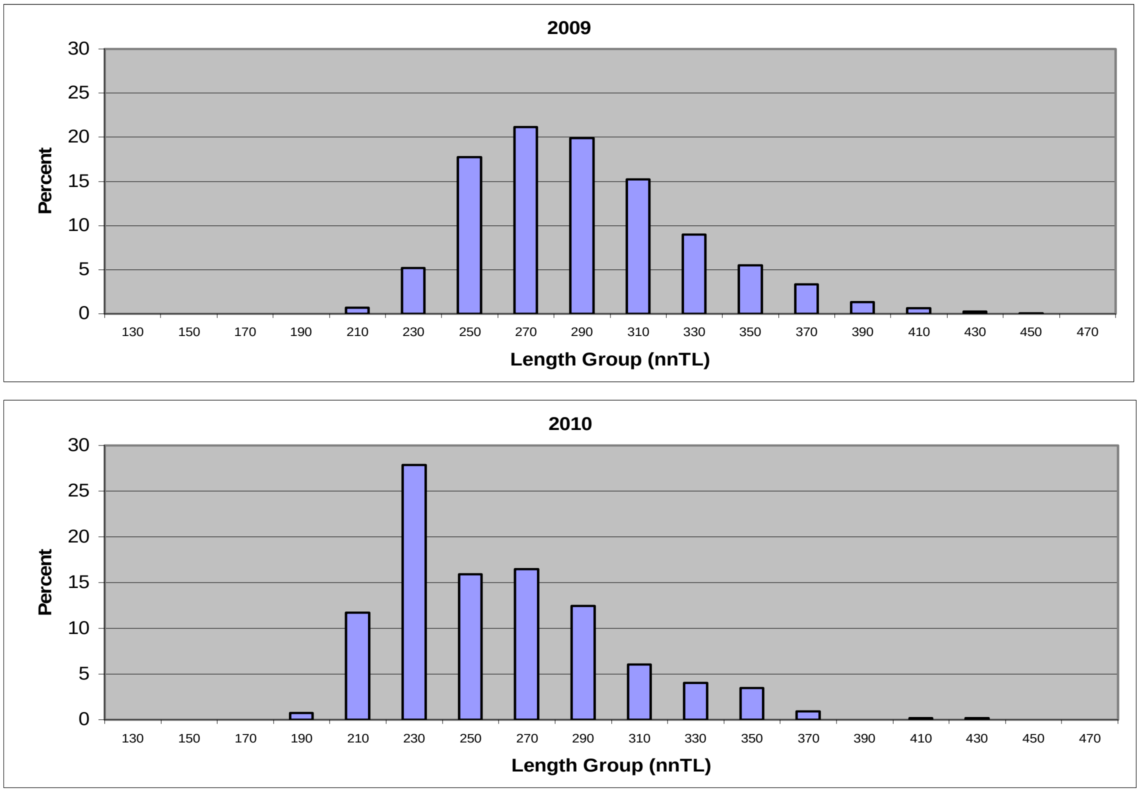


Figure 21. Maryland commercial Atlantic croaker harvest by area, 1929-2009.

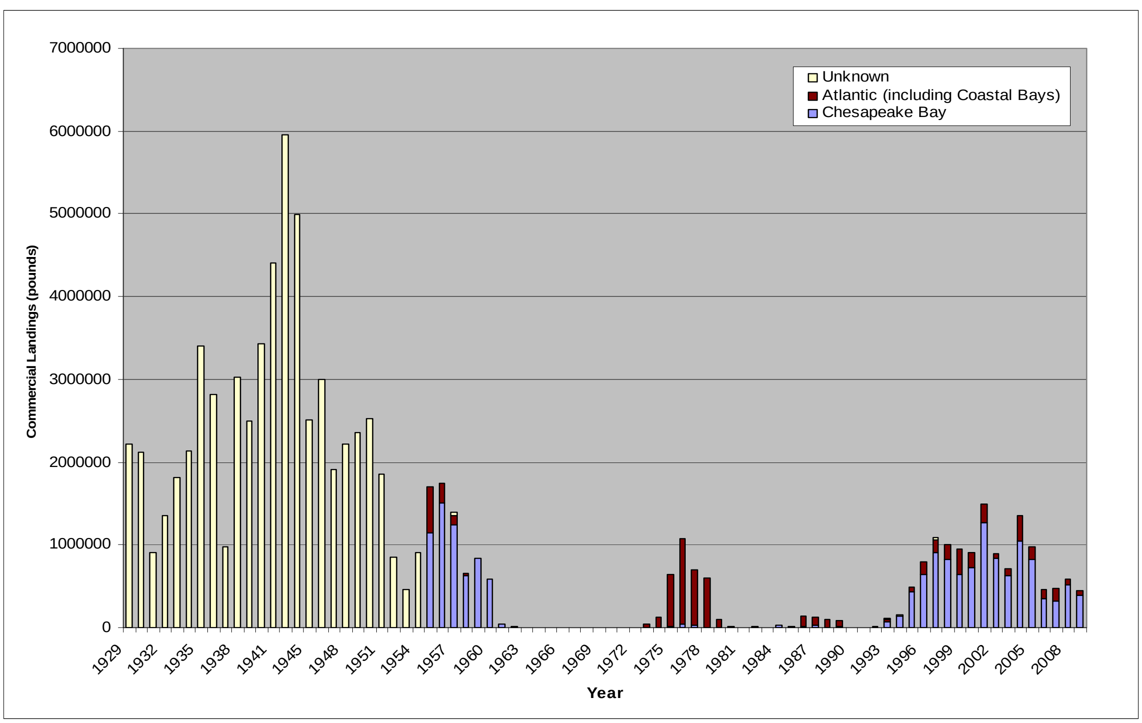


Figure 22. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2009 (Source: MRFSS, 2010).

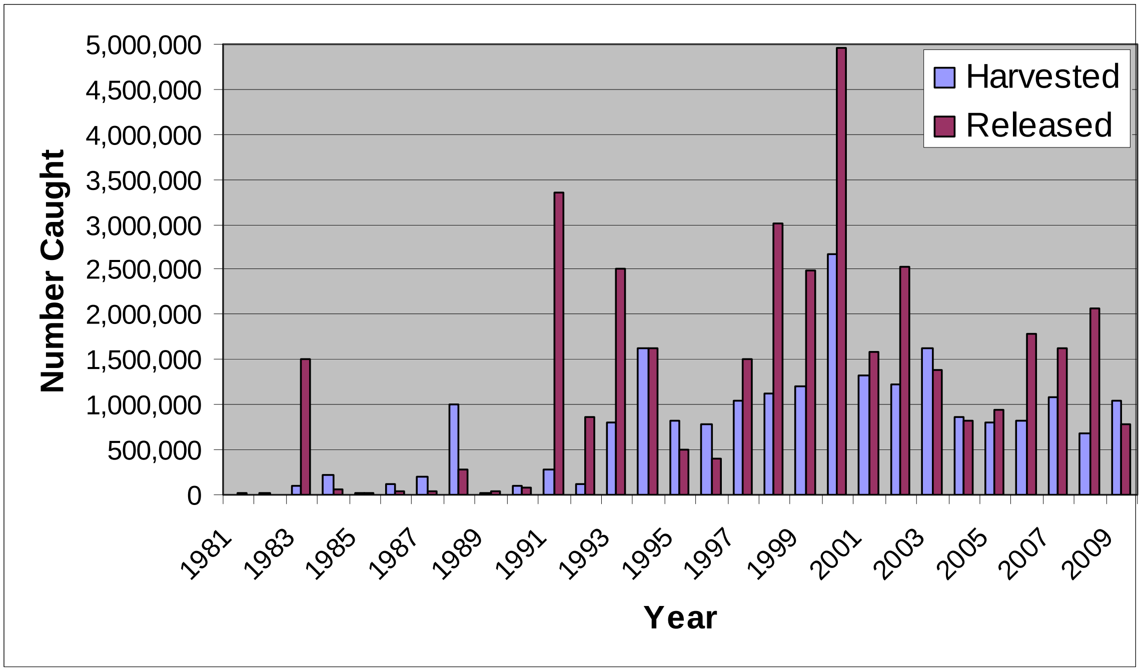


Figure 23. Atlantic croaker statewide MRFSS harvest, MRFSS for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2009.

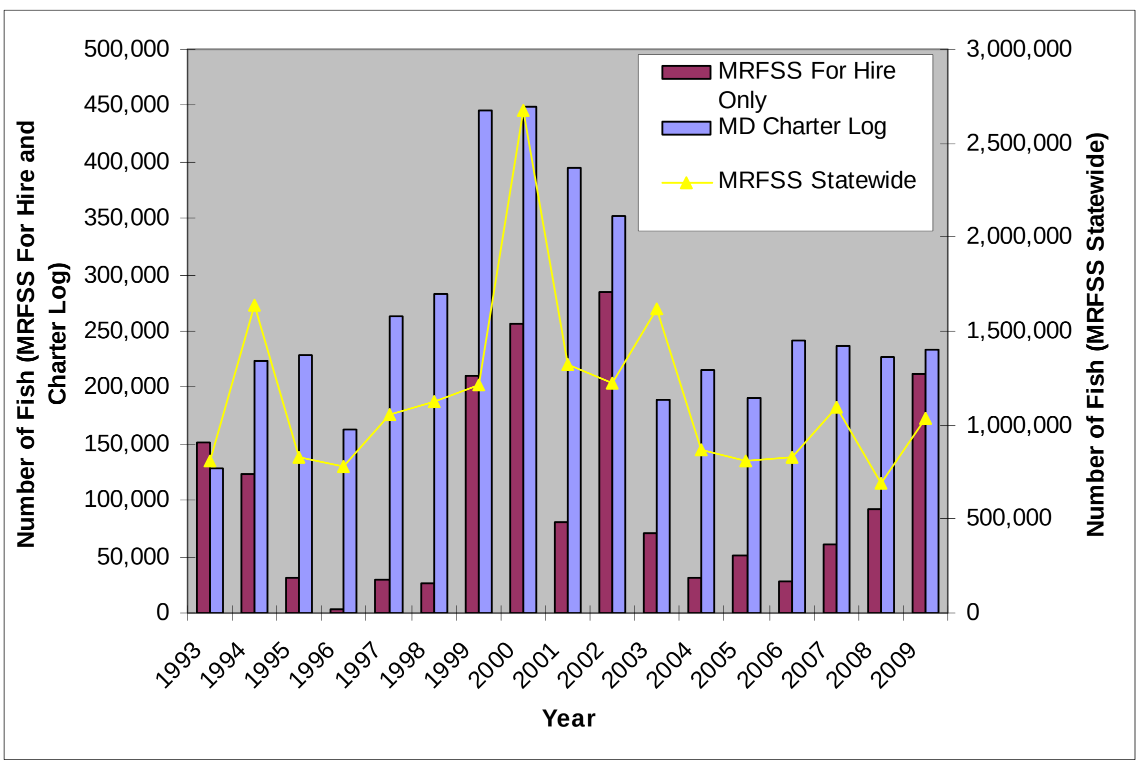


Figure 24. Atlantic croaker geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

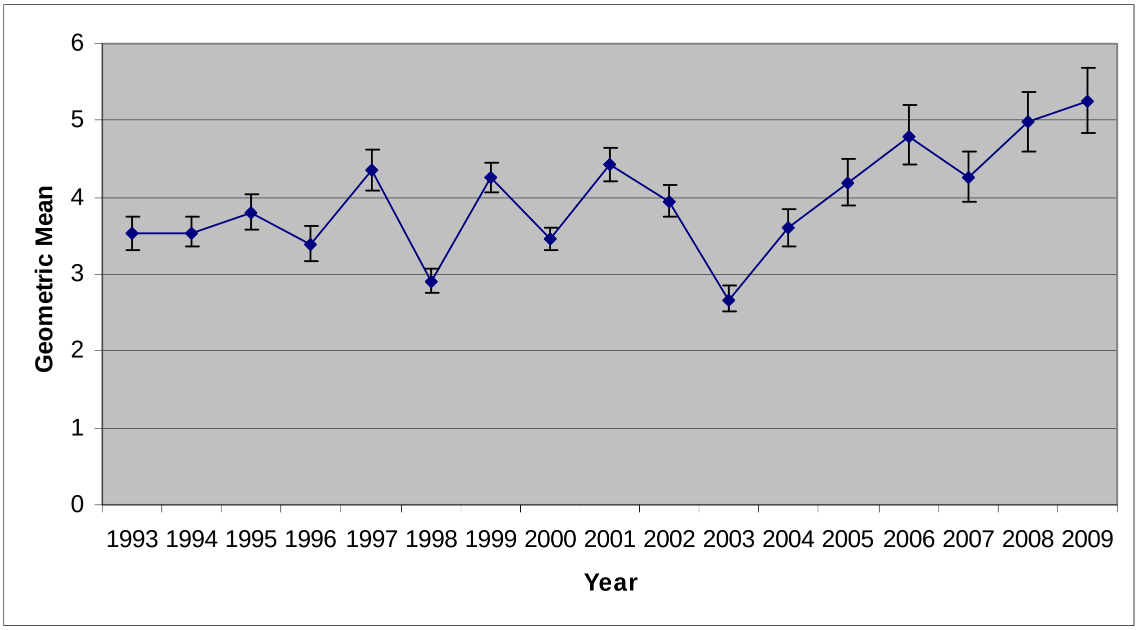


Figure 26. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2010.

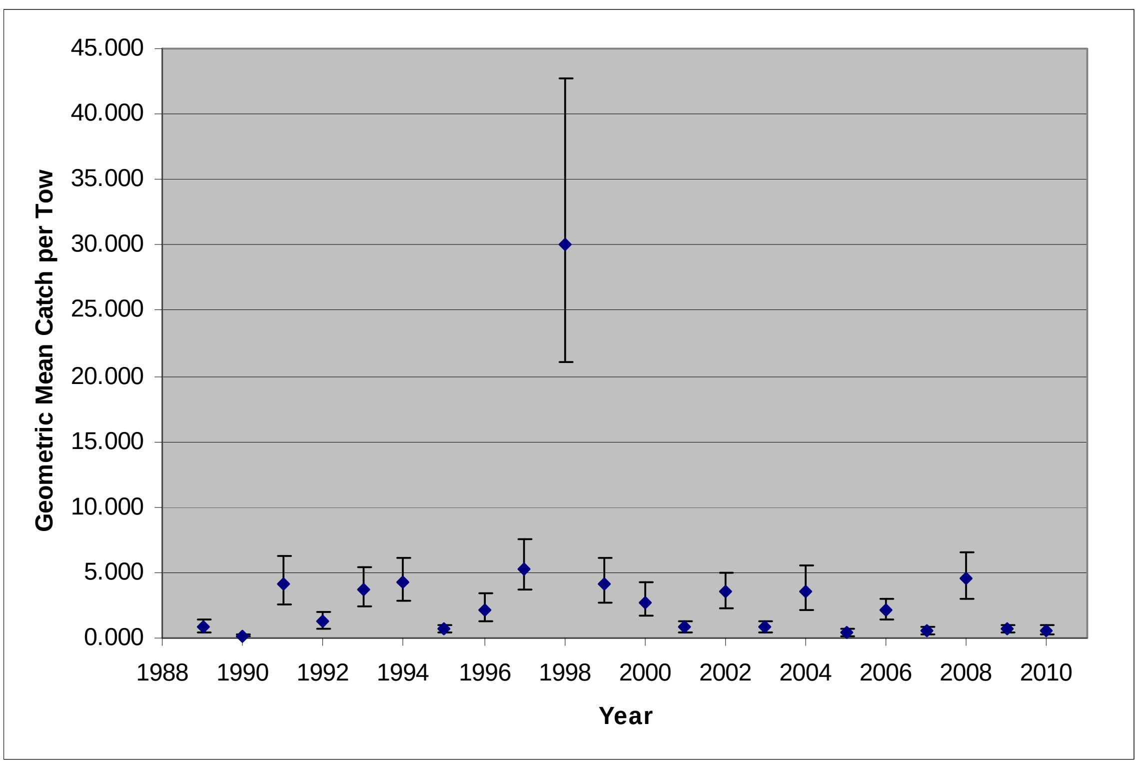


Figure 26. Spot length frequency distributions from onboard pound net sampling, 2007-2010.

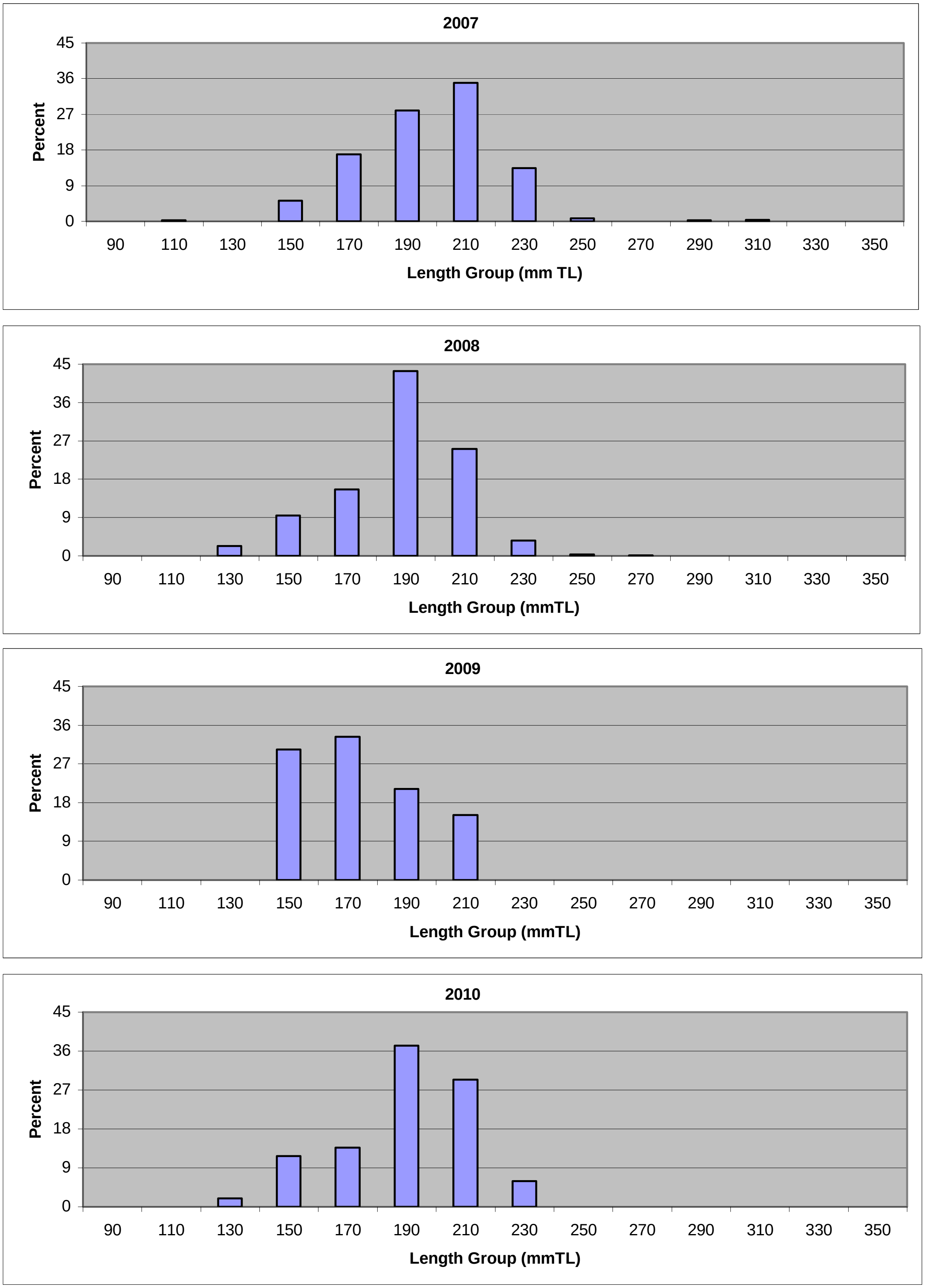
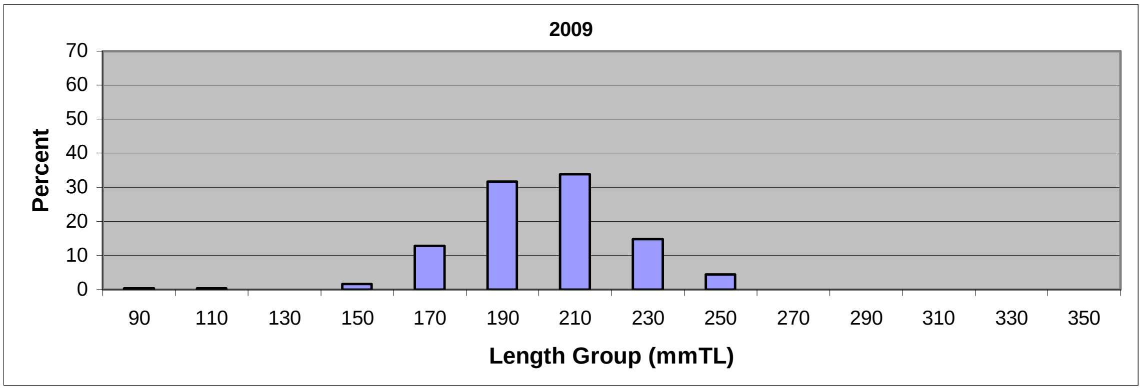


Figure 27. Spot length frequency distribution from seafood dealer sampling, 2009 and 2010.



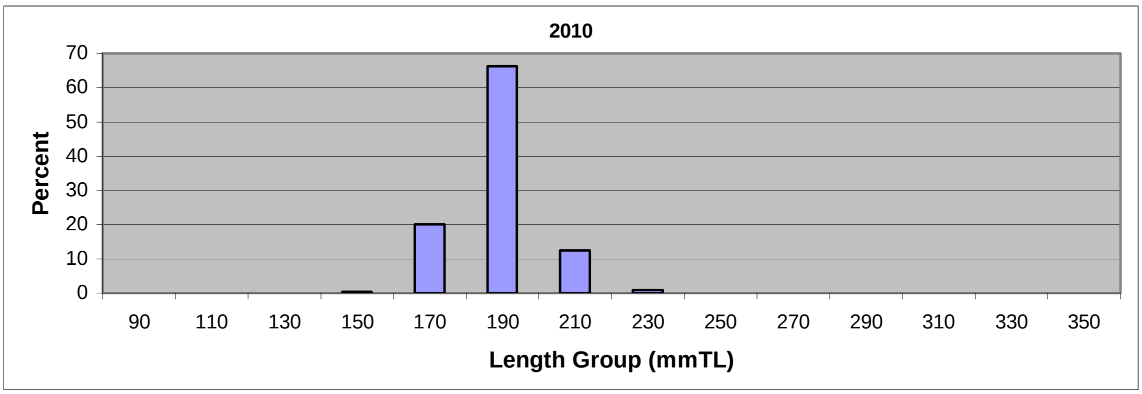


Figure 28. Maryland commercial spot harvest by area, 1929-2009.

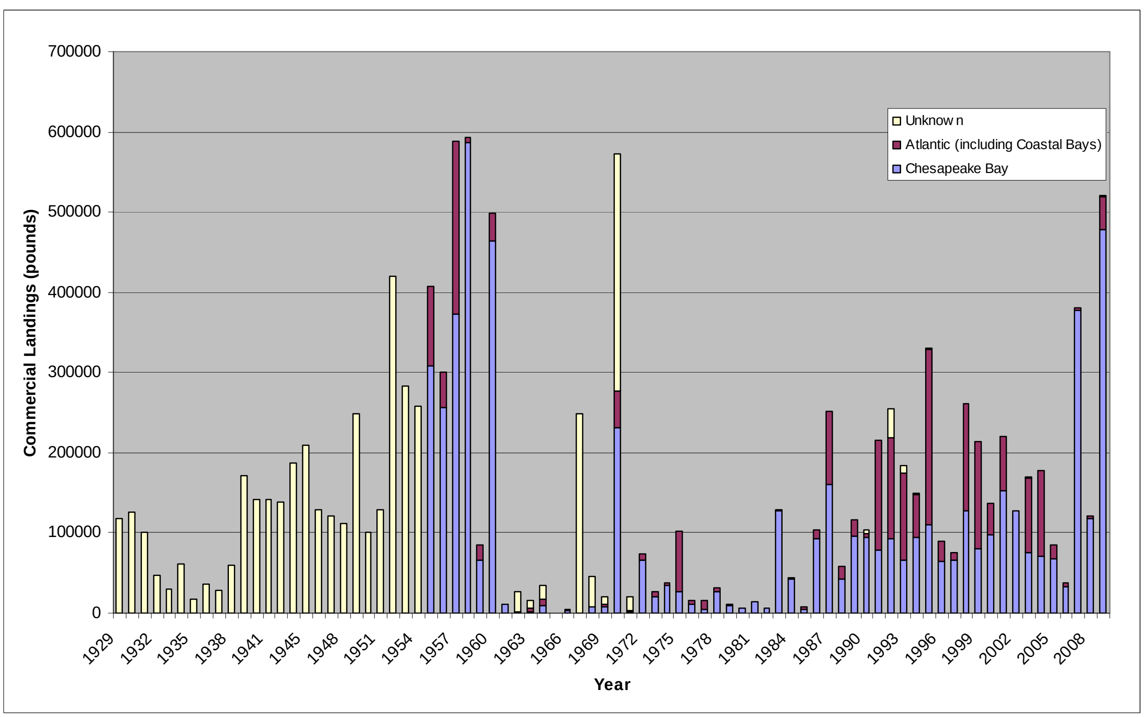


Figure 29. Estimated Maryland recreational spot harvest and releases for 1981-2009 (Source: MRFSS, 2010).

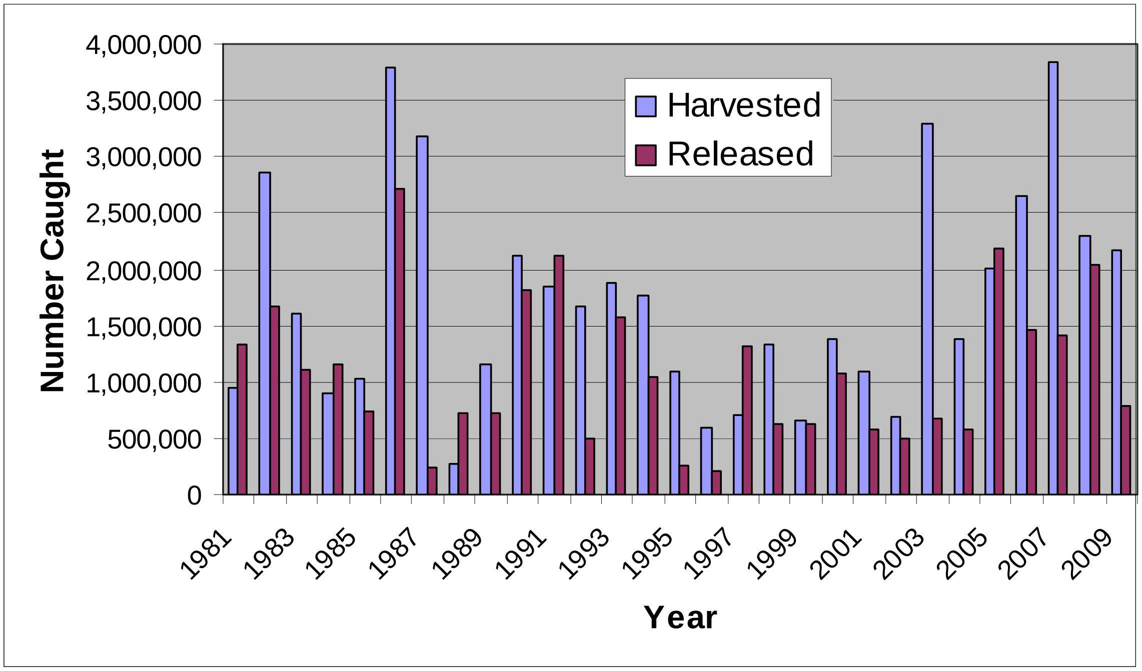


Figure 30. Spot statewide MRFSS harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2009.

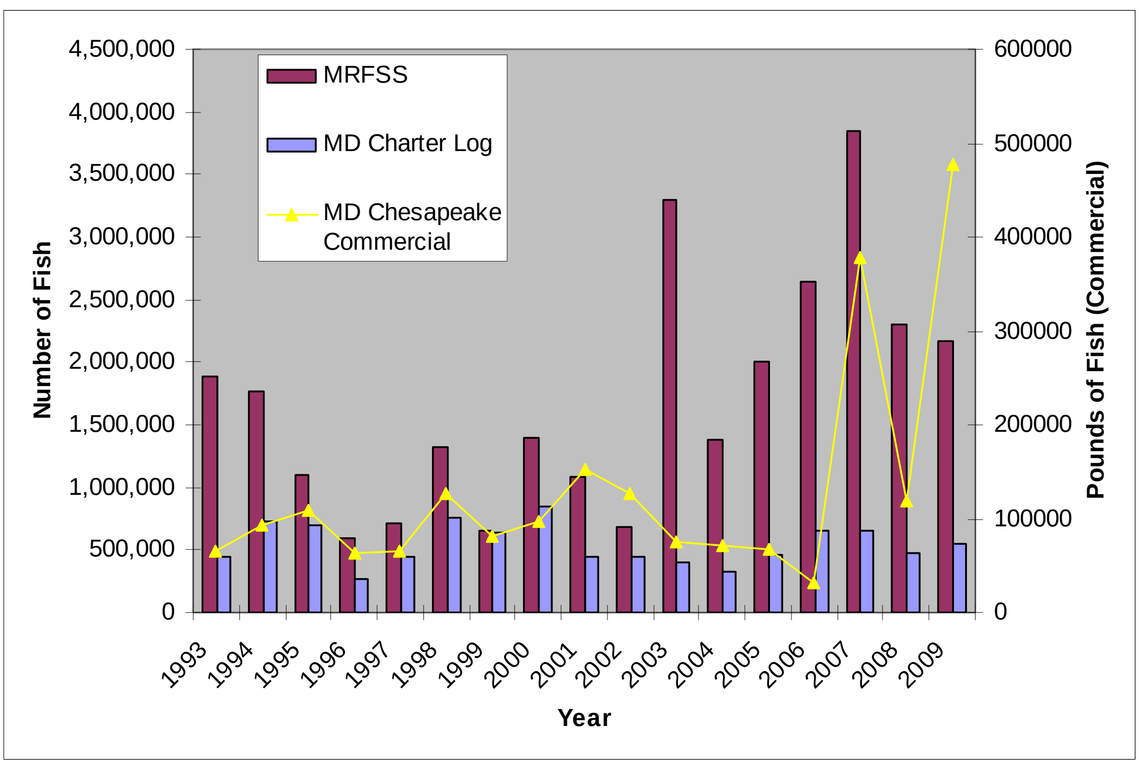


Figure 31. Spot geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

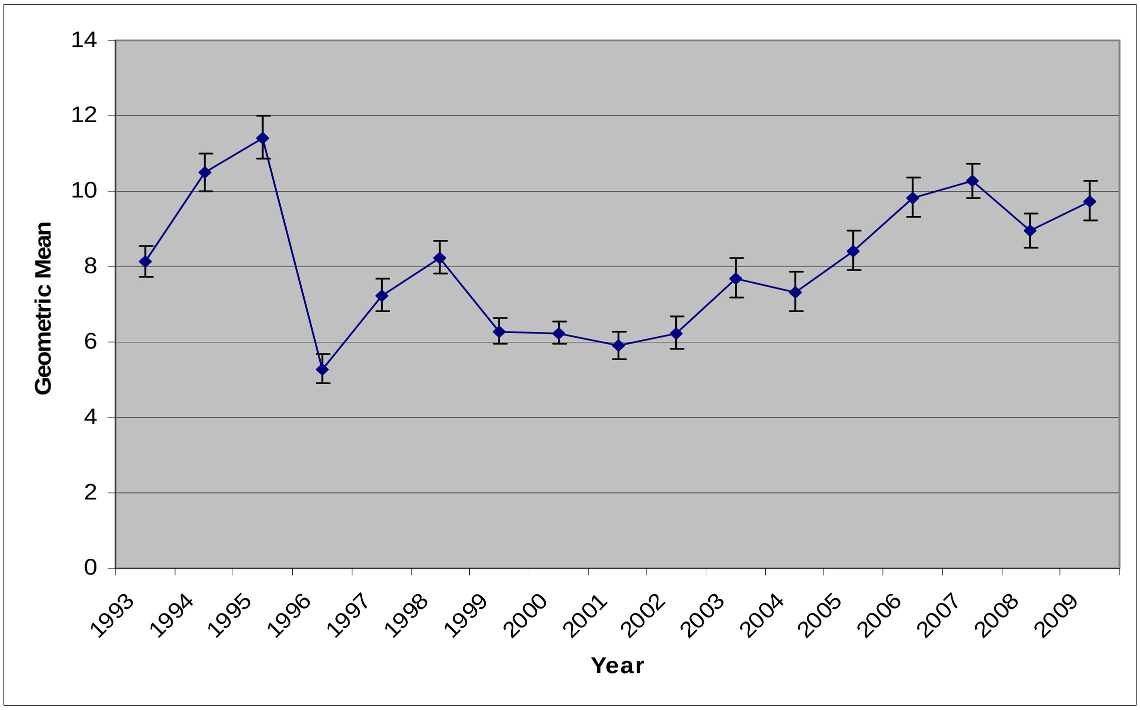


Figure 32. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2010.

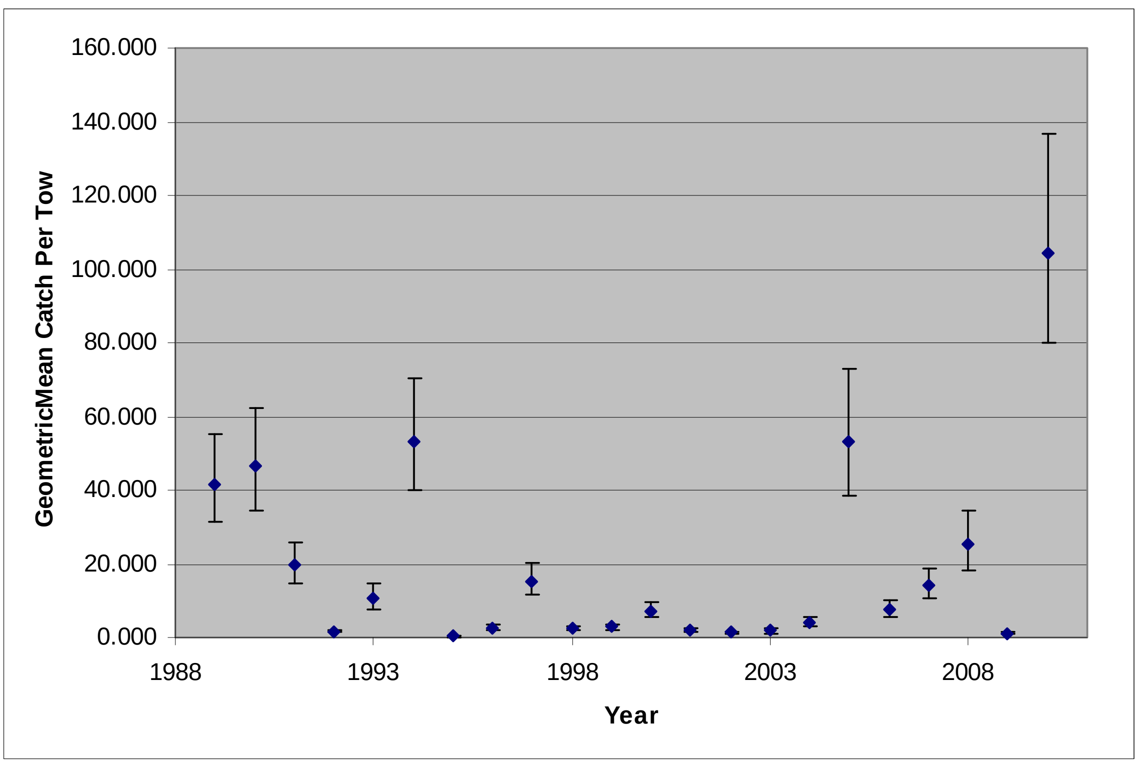


Figure 33. Maryland commercial red drum harvest by area, 1958-2009.

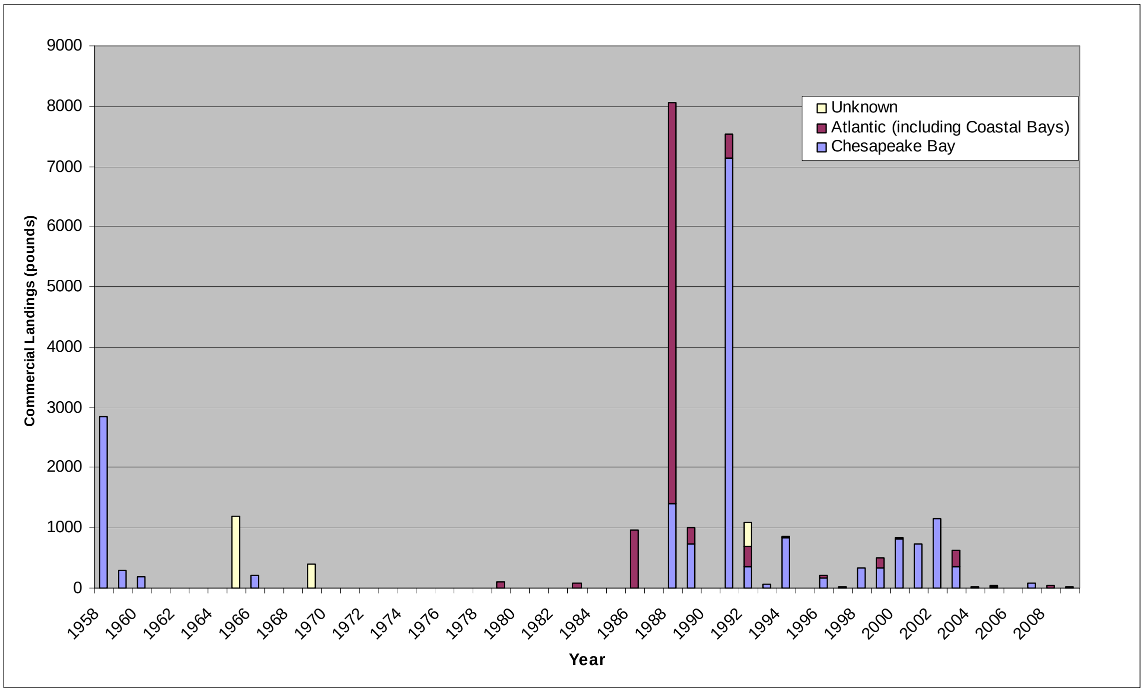


Figure 34. Estimated Maryland recreational red drum harvest and releases for 1981-2009 (Source: MRFSS, 2010).

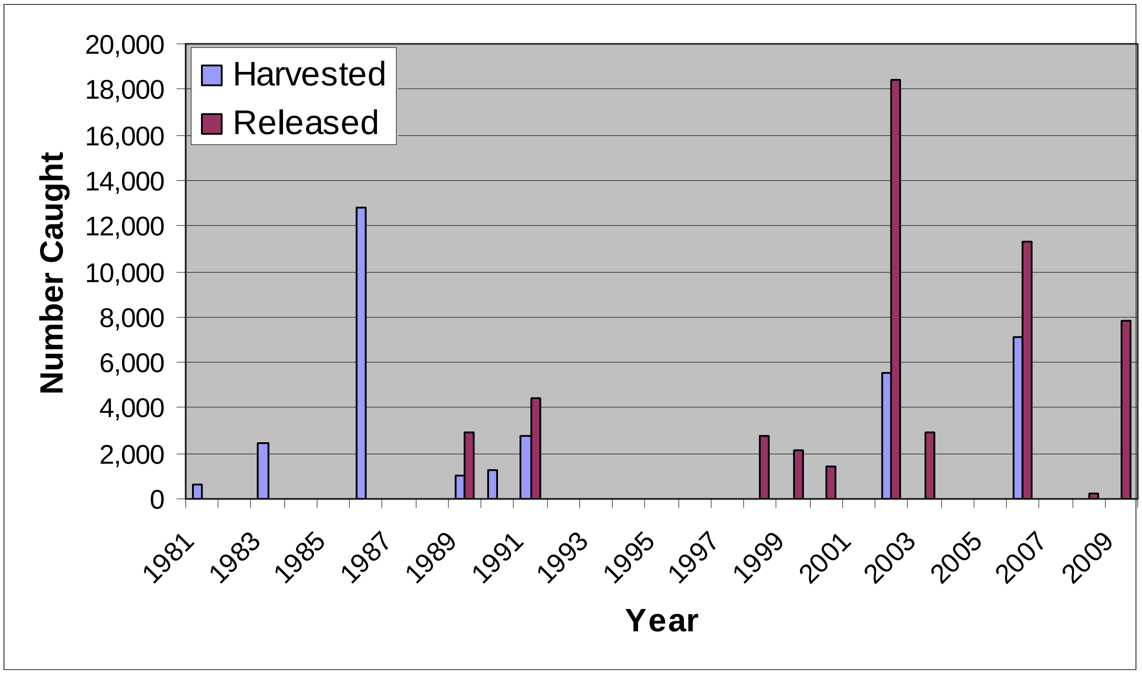


Figure 35. Number of red drum harvested and the number of anglers catching red drum from the Maryland Charter boat logs, 1993-2009.

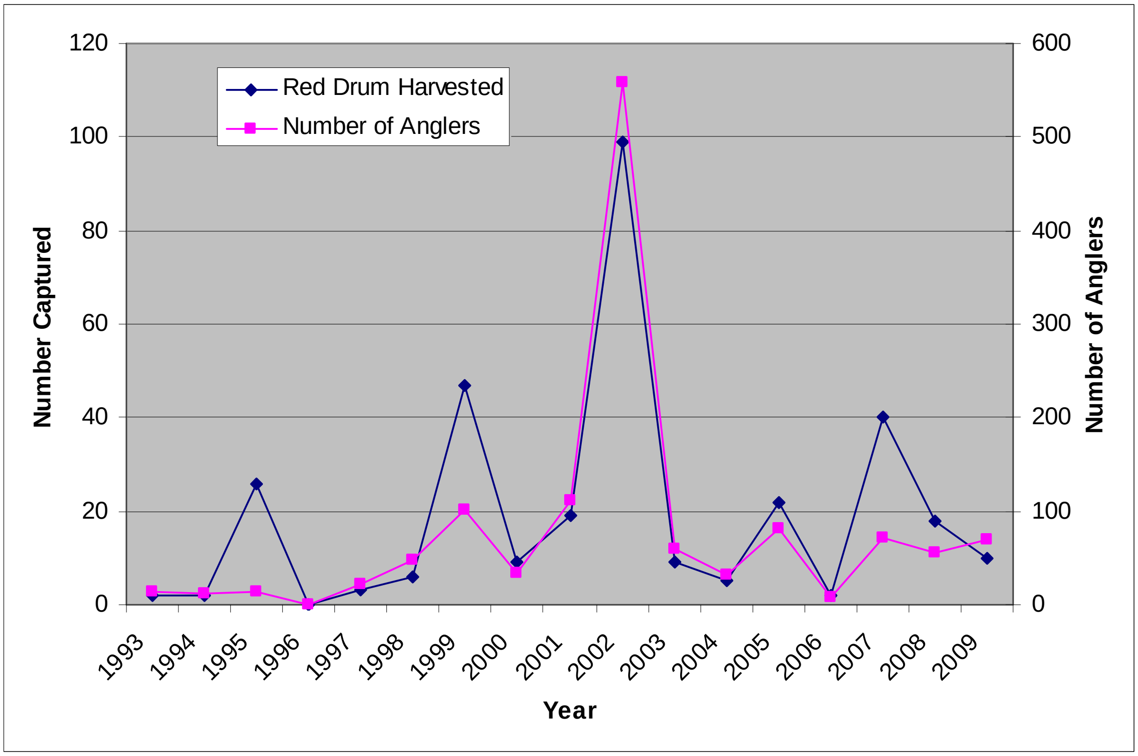


Figure 36. Maryland commercial black drum harvest by area, 1929-2009.

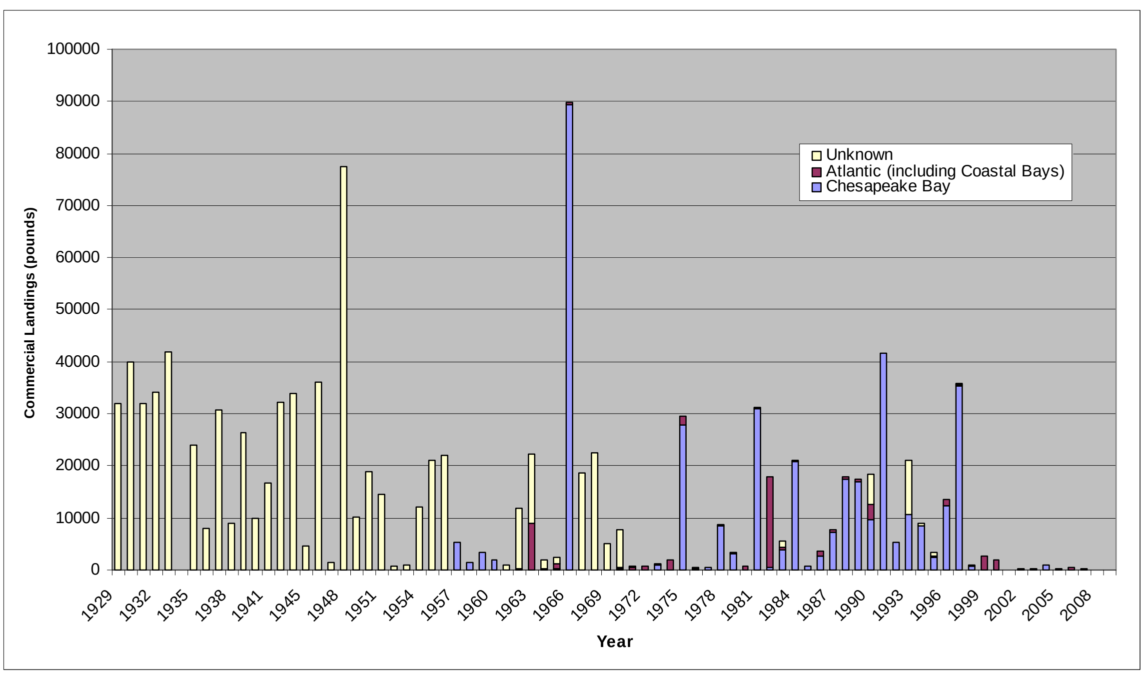


Figure 37. Estimated Maryland recreational black drum harvest and releases for 1981-2009 (Source: MRFSS, 2010).

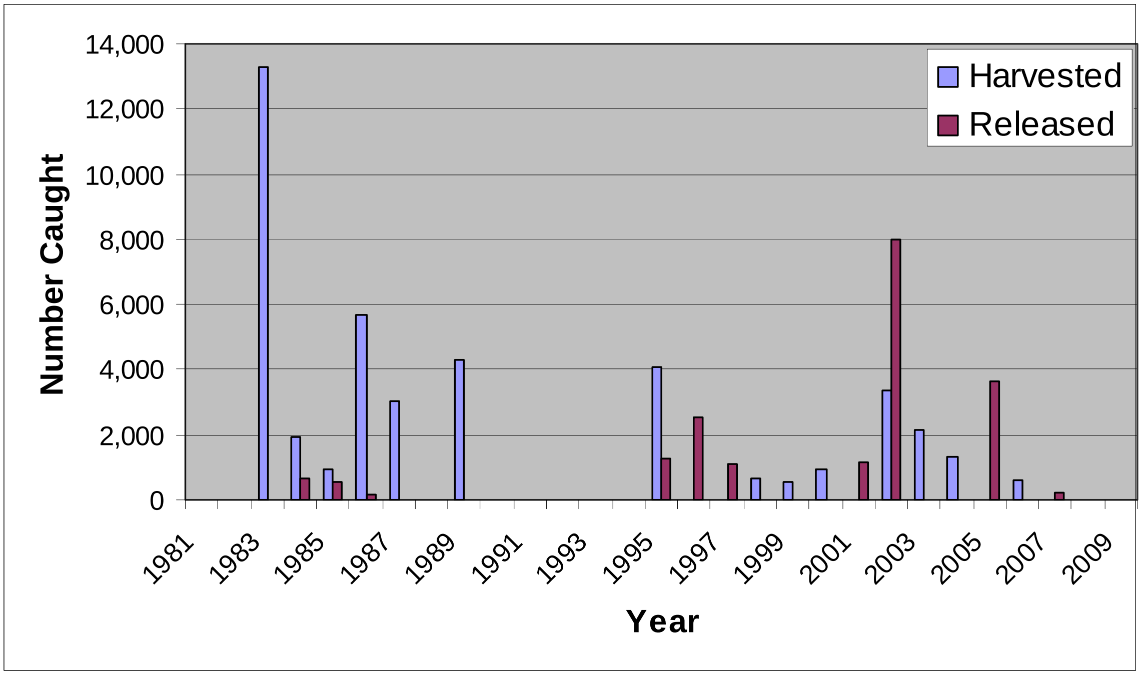


Figure 38. Reported Maryland charter boat harvest for black drum in numbers, 1993-2009.

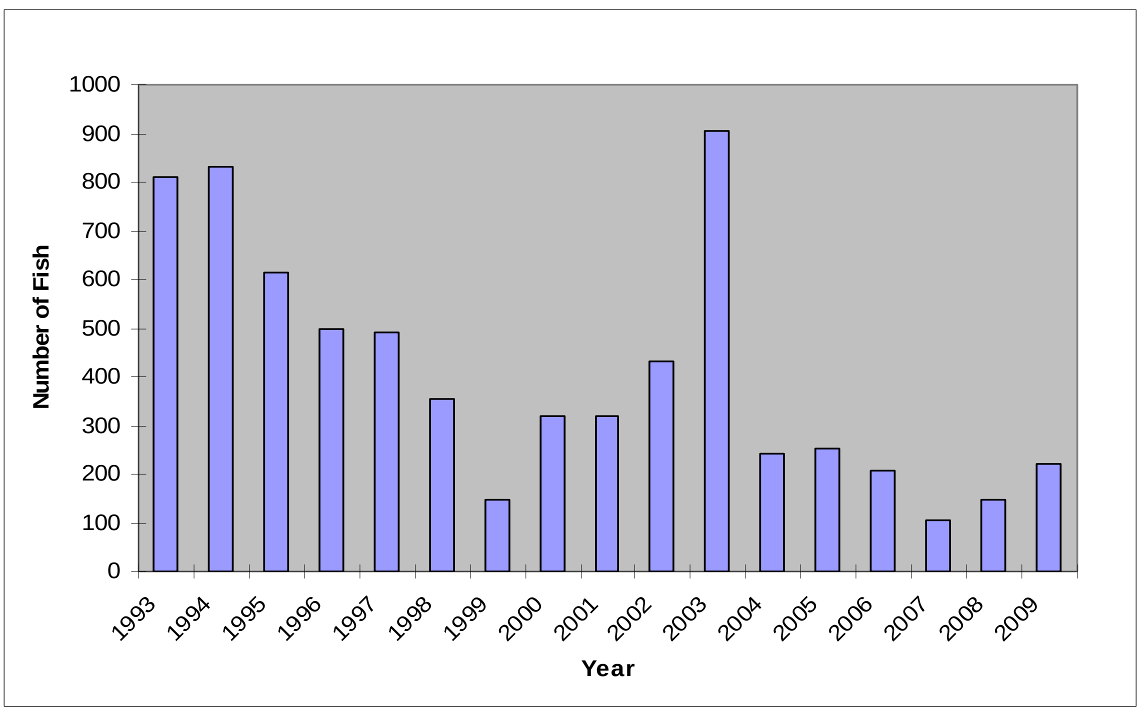


Figure 39. Black drum geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

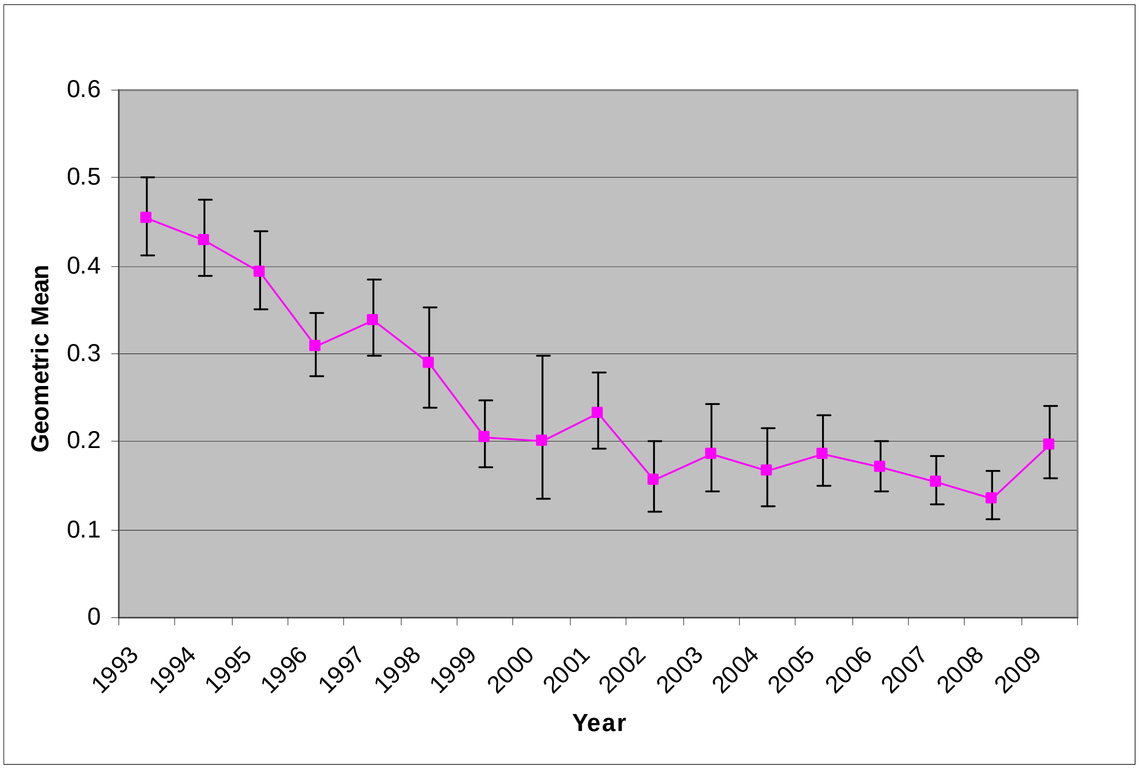


Figure 40. Maryland commercial Spanish mackerel harvest by area, 1965-2009.

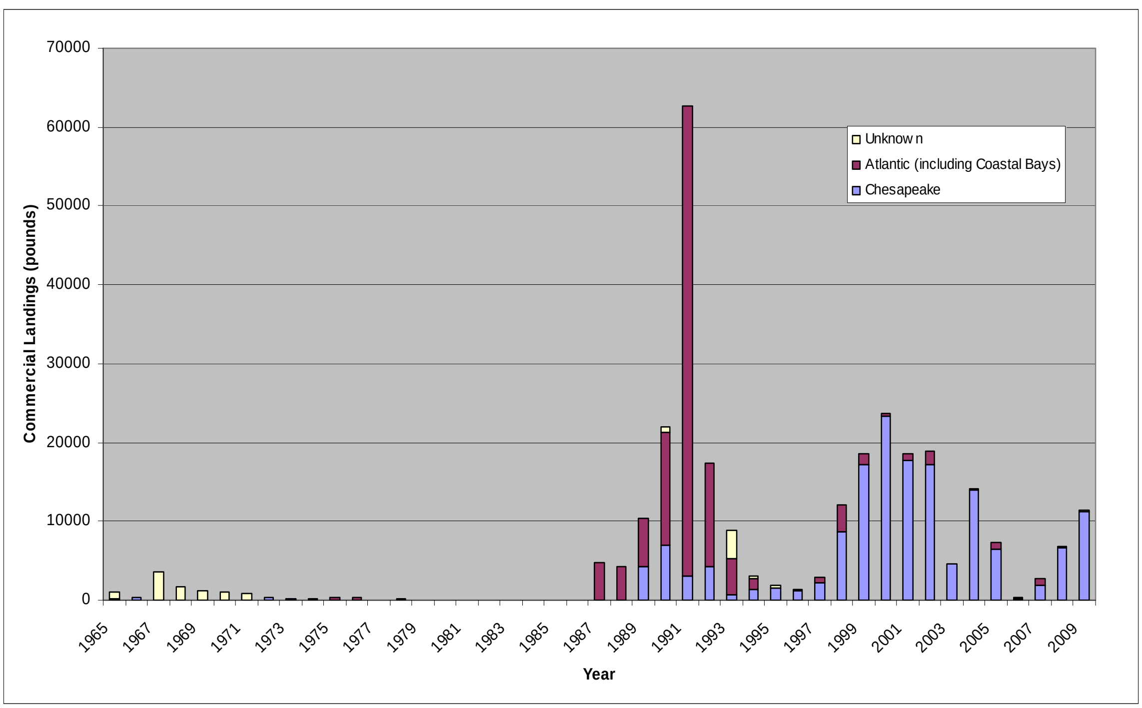


Figure 41. Estimated Maryland recreational Spanish mackerel harvest and releases for 1981-2009 (Source: MRFSS, 2010).

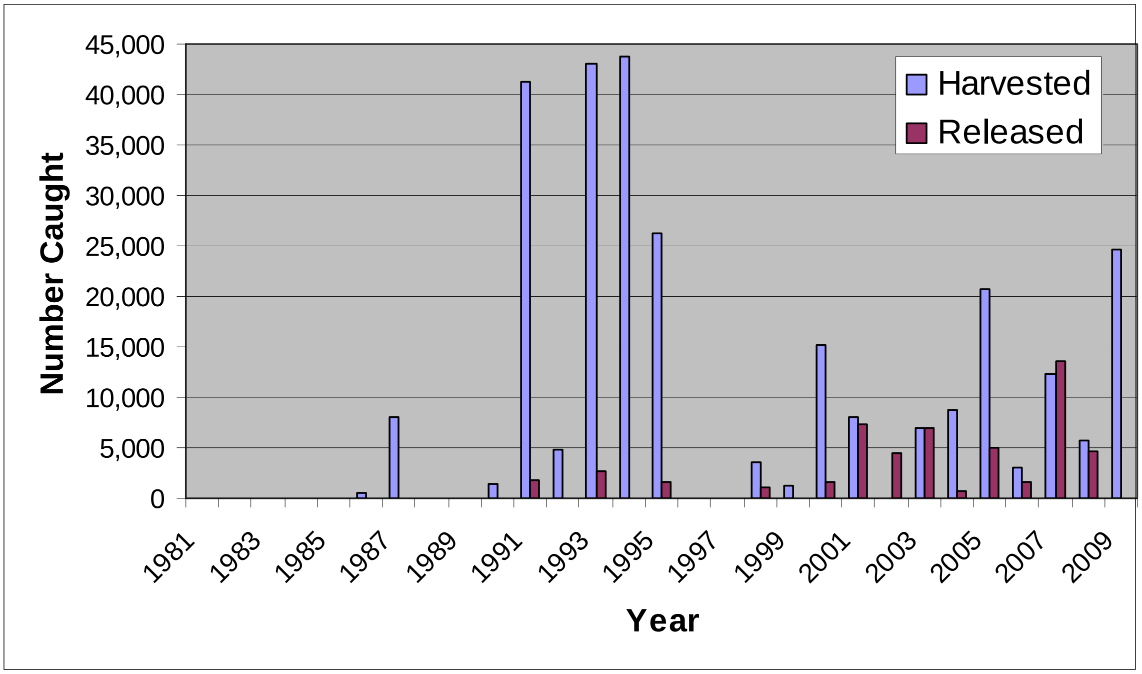


Figure 42. Spanish mackerel statewide MRFSS harvest, MRFSS for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2009.

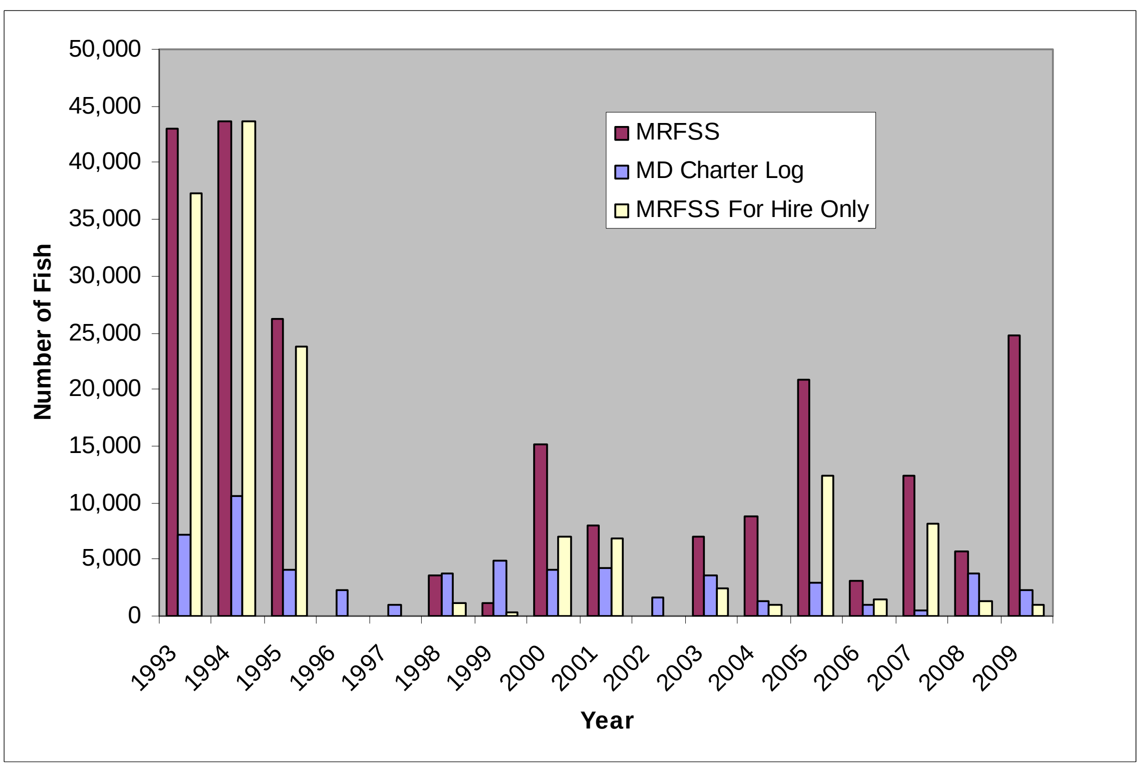


Figure 43. Spanish mackerel geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

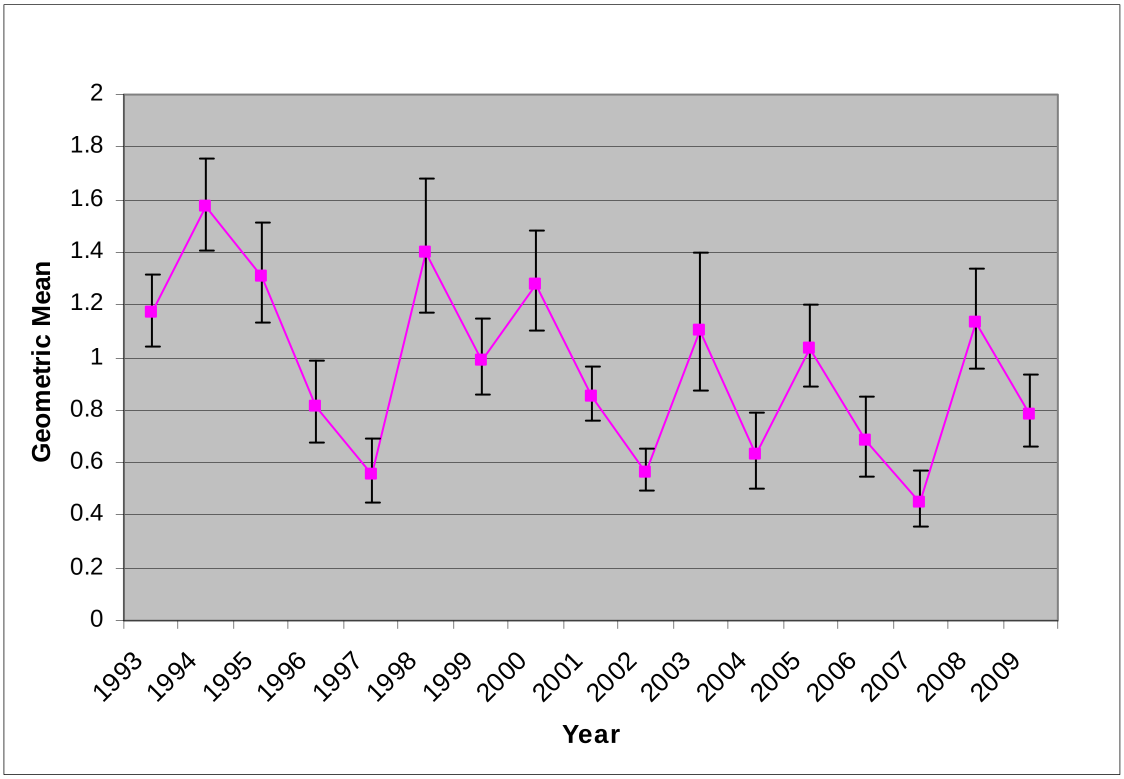


Figure 44. Maryland commercial spotted seatrout harvest by area, 1944-2009.

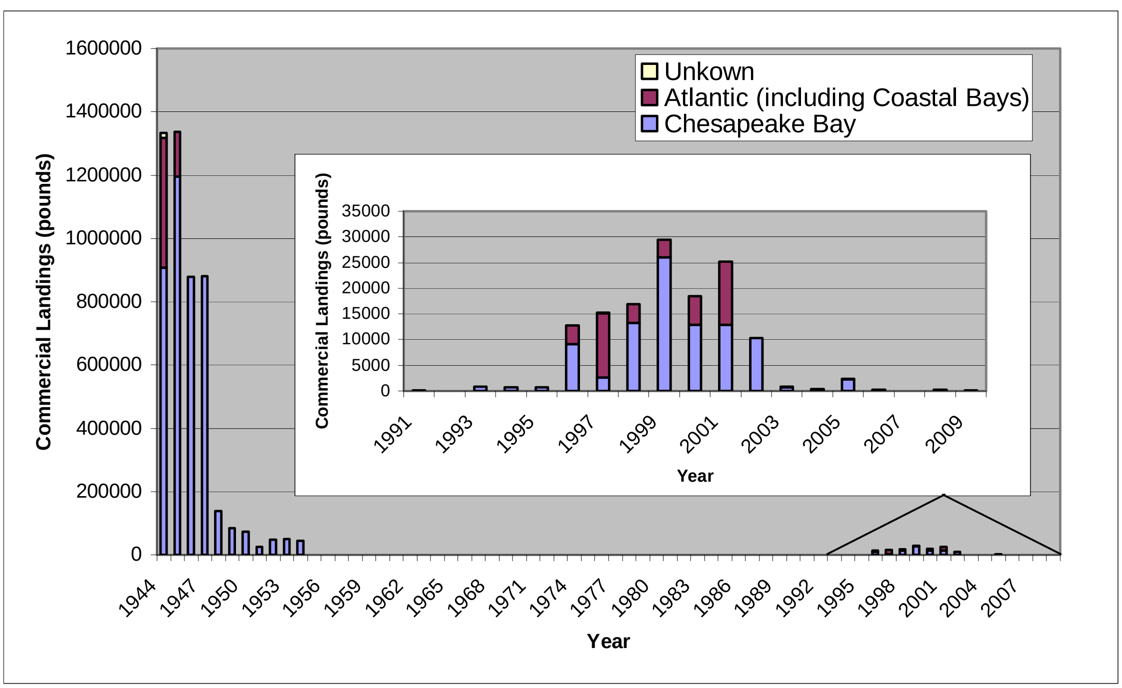


Figure 45. Estimated Maryland recreational spotted seatrout harvest and releases for 1981-2009 (Source: MRFSS, 2010).

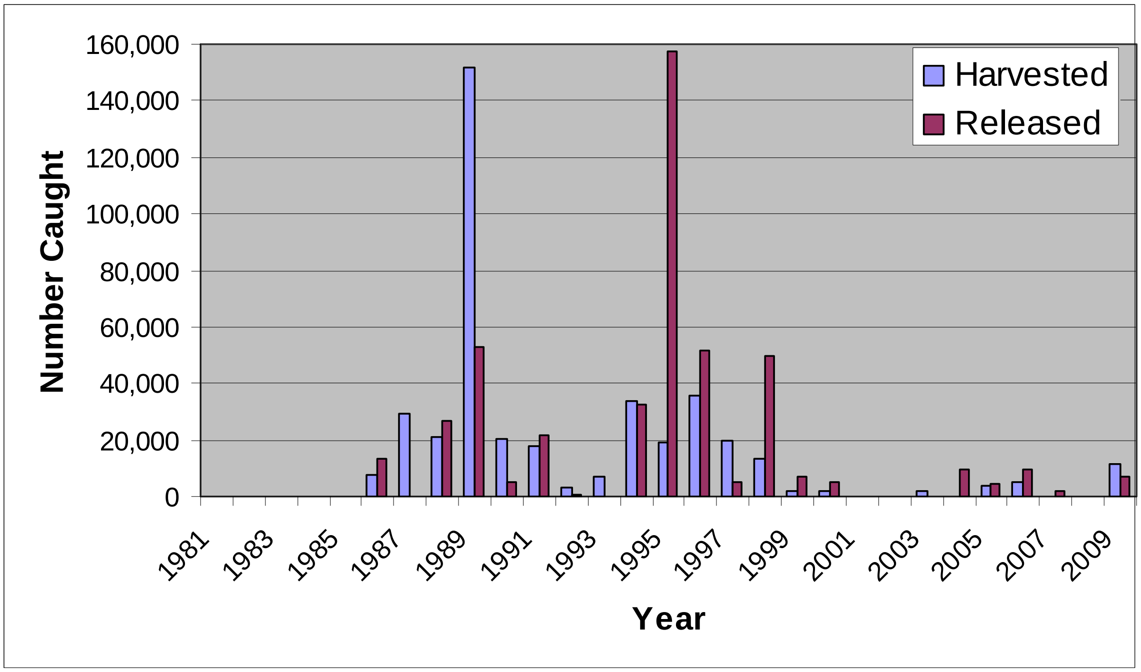


Figure 46. Reported Maryland charter boat harvest for spotted seatrout in numbers, 1993-2009.

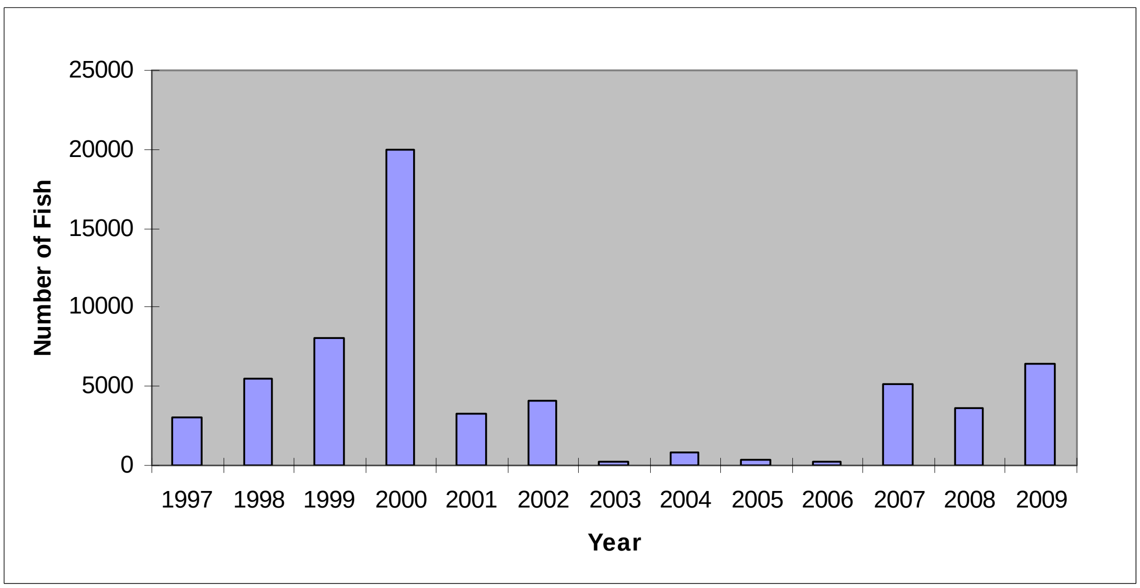


Figure 47. Spotted seatrout geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2009.

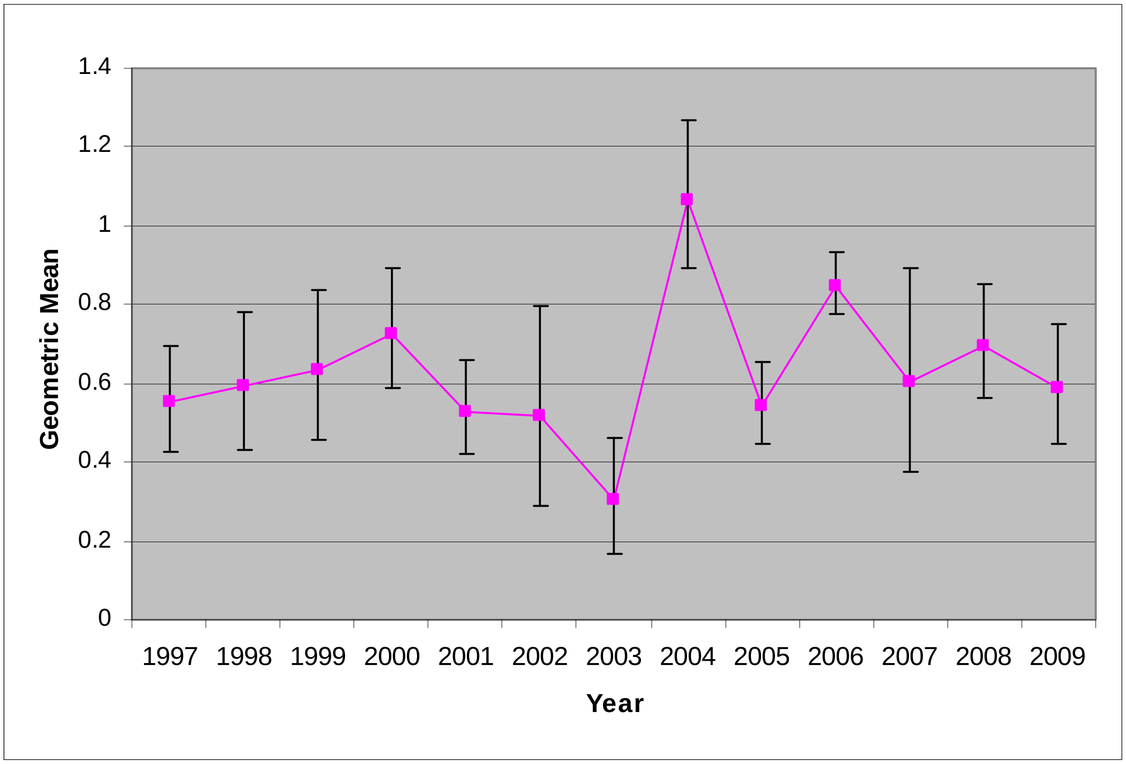


Figure 48. Menhaden length frequency distributions from onboard pound net sampling, 2007-2010.

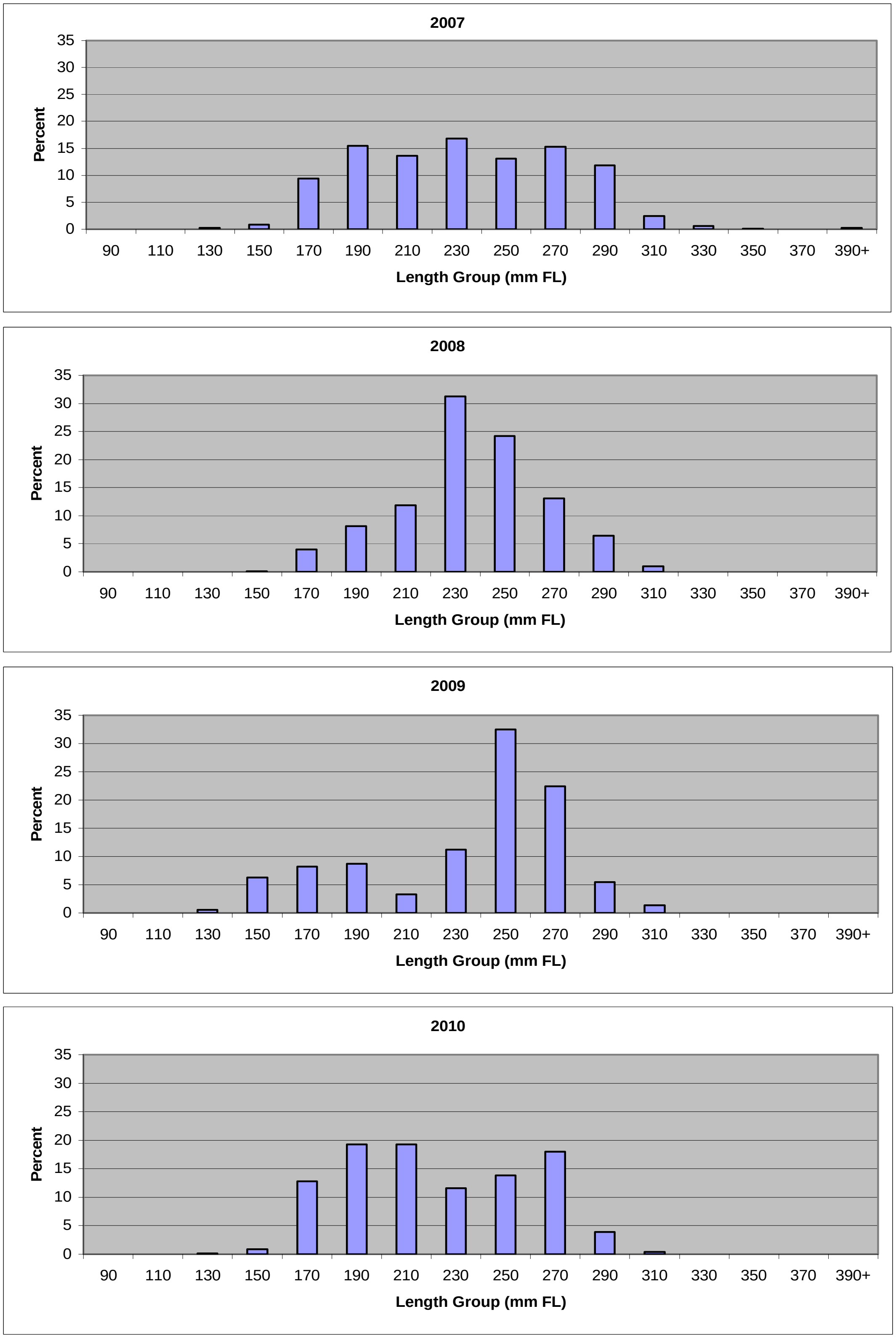
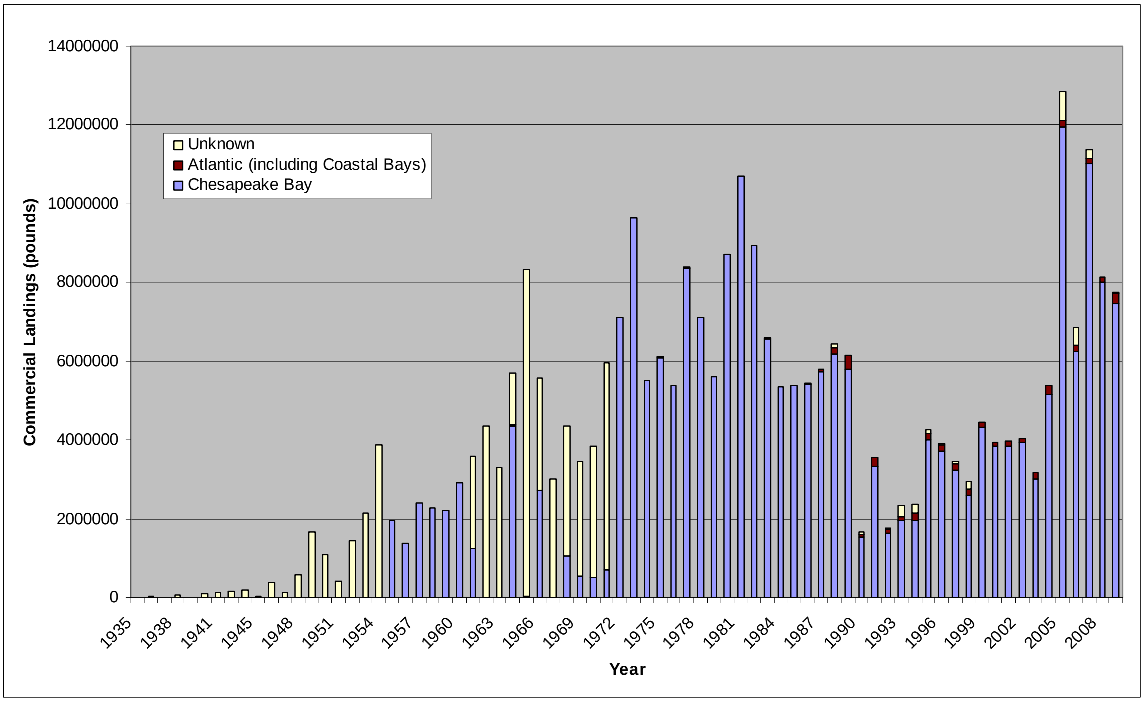


Figure 49. Maryland commercial Atlantic menhaden harvest by area, 1935-2009.



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 2009 Maryland striped bass (Morone saxatilis) commercial pound net and hook-and-line harvest. The 2009 pound net season ran from 1 June through 30 November while the commercial hook-and-line fishery was open from 15 June through 10 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 2009 commercial fisheries seasons were used to characterize the length and age structure of the entire 2009 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 August through November 2009 (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 2009, striped bass were sampled from pound nets in the upper and lower Bay. Whenever possible, all striped bass in each pound net were measured in order to investigate by-catch. Full net sampling was not possible when pound nets contained too many fish to be transferred to FS boats. If a full net could not be sampled, a random sub-sample was taken.

At each net sampled, all striped bass were measured for total length (mm TL), and the presence and category of external anomalies were noted. Scales were removed from 3 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 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 2009 (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 2 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 2009 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 2009 striped bass pound net study, 2,013 striped bass were sampled from two pound nets in the upper Bay and six pound nets in the lower Bay. The eight nets were sampled a total of 16 times during the study.

Striped bass sampled from pound nets ranged from 194-1173 mm TL, with a mean length of 469 mm TL (Figure 2). In 2009, 47% of striped bass collected from full net samples were less than the minimum legal size of 18 inches TL, while 30% 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 16 years of age (Table 3, Figure 2). Three year-old fish from the 2006 year-class contributed 11% in 2009; more age 3 fish than in 2007 (9%), but less than in 2006 (38%) and 2008 (13%). Age 4 fish from the above average 2005 year-class occurred with the greatest frequency, composing 31% of the sample, very similar to Age 4 fish in 2008 (32%) (Figure 3, Table 3). Age 5 fish contributed 18% in 2009, which is less than the contribution in 2008 (36%). Striped bass age 6 and over were uncommon again in 2009, and accounted for 9% of the sample; less than their contribution in 2008 (15%). Fish age 8 and older composed 1% of the sample in 2009, which was 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 2,260 striped bass were sampled at hook-and-line check stations in 2009. The mean length of sampled striped bass was 542 mm TL. Striped bass sampled from the hook-and-line fishery ranged from 443 to 860 mm TL (Figure 5) and from 2 to 12 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 66% of the hook-and-line harvest, less than in 2008 (79%; Figure 5). Fish greater than 650 mm TL contributed only 7% 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 4% 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 2009 combined hook-and-line and pound net fisheries are shown in Tables 4 and 5.

The 2009 hook-and-line harvest accounted for 29%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2009 (see Project 2, Job 3, Task 5A). The estimated 2009 catch-at-age of the hook-and-line fishery is presented in Table 6. The majority of the harvest was composed of four to six year-old striped bass. Fish from the strong 2003 year-class (age 6) accounted for 17% of the total, less than in 2008 (36%). Striped bass from the above average 2005 year-class (age 4) contributed 40%, which is much greater than their contribution in 2008 (Figure 7). Fish from the 2004 year-class (age 5) contributed 30% to the hook-and-line harvest, less than in 2008 (42%). Striped bass age 7 and older contributed just 5% to the overall harvest in 2009 (5%), similar to 2008.

Pound net check station sampling

A total of 1,087 striped bass were sampled at pound net check stations in 2009. Striped bass sampled ranged from 444 to 894 mm TL (Figure 5). Legal-sized striped bass sampled from the pound net fishery ranged from 2 to 12 years of age. Striped bass in the 450-530 mm TL length groups accounted for 56% of the 2009 pound net harvest, which is lower than 2008 (65%; Figure 5). The contribution of striped bass in the 570-630 mm TL length groups increased from 17% in 2008 to 22% in 2009. Fish greater than 650 mm TL composed 12% of the sample, slightly more than 2008 (9%). In general, few large fish were available to the 2009 pound net fishery (Figure 6). Mean lengths-at-age and weights-at-age from the 2009 hook-and-line and pound net fisheries combined, are shown in Tables 4 and 5, respectively.

The pound net fishery accounted for 25%, by weight, of the Maryland Chesapeake Bay 2009 commercial harvest. The estimated 2009 catch-at-age for the pound net fishery is presented in Table 6. Fish age four to six contributed 82% of the 2009 total pound net harvest. The contribution of six year-old fish from the 2003 year-class was lower in the pound net harvest in 2009 than in 2008, contributing 18% to the total harvest (Figure 7). Striped bass age 8 and over composed 5% of the 2009 harvest, similar to the contribution in 2008 (4%). Sub-legal striped bass (< 457 mm TL) composed 2% of the total pound net harvest.

Monitoring summary

Striped bass ranging from 457 to 550 mm TL composed 65% and 68%, respectively, of the 2009 pound net and hook and line fisheries. There were slightly more larger fish (>530 mm) harvested in 2009 compared to 2008 (74% and 87% respectively; Figure 5). In 2009, 97 fish from pound net monitoring and 95 fish from check station sampling were aged. Older fish were more scarce throughout the summer. Smaller fish (age 4 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 2009. Striped bass were significantly ($P<0.05$) longer and heavier from the pound net fishery than the hook-and-line fishery. For the hook-and-line fishery, the longest and heaviest fish were harvested in June and the smallest in September. Striped bass harvested in October and November were similar in length and weight. Fish from September and October were also similar in length and weight. For the pound net check station monitoring, the longest and heaviest fish were harvested in July and November and the smallest in September and October. Striped bass from August and October were similar in length and weight. Striped bass from June were slightly smaller than fish harvested in July and November.

CITATIONS

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

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

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

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

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

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

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

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

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

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 2009 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
August	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	1	27.8	12.7	33
September	Upper	2	23.1	4.6	26
	Middle	-	-	-	-
	Lower	2	20.7	15.4	302
October	Upper	1	14.3	2.4	5
	Middle	-	-	-	-
	Lower	7	17.0	16.0	775
November	Upper	-	-	-	-
	Middle	-	-	-	-
	Lower	4	13.4	12.3	872

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, August through November 2009.

Year-class	Age	n	Mean length (mm TL)	STD	STDERR	LCLM	UCLM
2008	1	7	241	27	10	221	261
2007	2	24	353	60	12	329	377
2006	3	5	420	49	22	377	463
2005	4	14	536	66	18	501	571
2004	5	16	581	60	15	552	610
2003	6	21	662	55	12	638	686
2002	7	2	703	7	5	693	713
2001	8	3	703	126	73	560	846
2000	9	2	768	68	48	674	862
1997	12	1	1042	-	-	-	-
1994	15	1	1125	-	-	-	-
1993	16	1	1173	-	-	-	-

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, August through November 2009.

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2008	1	11	0.55
2007	2	596	29.61
2006	3	230	11.43
2005	4	631	31.35
2004	5	371	18.43
2003	6	151	7.50
2002	7	2	0.10
2001	8	14	0.70
2000	9	2	0.10
1997	12	2	0.10
1994	15	2	0.10
1993	16	1	0.05
Total		**2,013**	**100.00**

Table 4. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) for ages 2-12 sampled from commercial pound net and hook-and-line fisheries in Maryland's Chesapeake Bay, June through November 2009.

Year-class	Age	n	Mean Length (mm TL)	STD	STDERR	LCLM	UCLM
2007	2	2	461	21	15	432	490
2006	3	2	486	9	7	403	568
2005	4	12	509	40	12	484	534
2004	5	12	572	58	17	535	608
2003	6	28	661	79	15	630	691
2002	7	7	731	40	15	694	768
2001	8	17	745	80	19	704	786
2000	9	8	789	40	14	756	823
1999	10	3	833	32	18	754	912
1998	11	2	821	28	20	573	1068
1997	12	4	825	11	5	808	842

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 2009. Mean weights are weighted by the sample n-at-length in each age.

Year-Class	Age	n Aged	Weighted Mean weight* (kg)
2007	2	2	1.1
2006	3	2	1.2
2005	4	12	1.3
2004	5	12	1.9
2003	6	28	3.0
2002	7	7	4.4
2001	8	17	4.4
2000	9	8	5.5
1999	10	3	6.6
1998	11	2	6.4
1997	12	4	6.1

* 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 2009.

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	2	14,961	2.3	17,732	3.1
2006	3	41,429	6.4	45,894	8.1
2005	4	258,932	39.8	209,132	36.9
2004	5	191,610	29.5	152,285	26.9
2003	6	112,492	17.3	102,740	18.1
2002	7	5,754	0.9	8,344	1.5
2001	8	18,125	2.8	20,339	3.6
2000	9	4,603	0.7	5,737	1.0
1999	10	863	0.1	1,565	0.3
1998	11	575	0.1	1,043	0.2
1997	12	863	0.1	2,086	0.4
Total**		**650,207**	**100.0**	**566,898**	**100.0**

* Landings (number of fish) are calculated as the pounds of fish reported to DNR by check station call-ins, divided by average weight per fish based on MD DNR check station monitoring surveys.

** 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 2009.

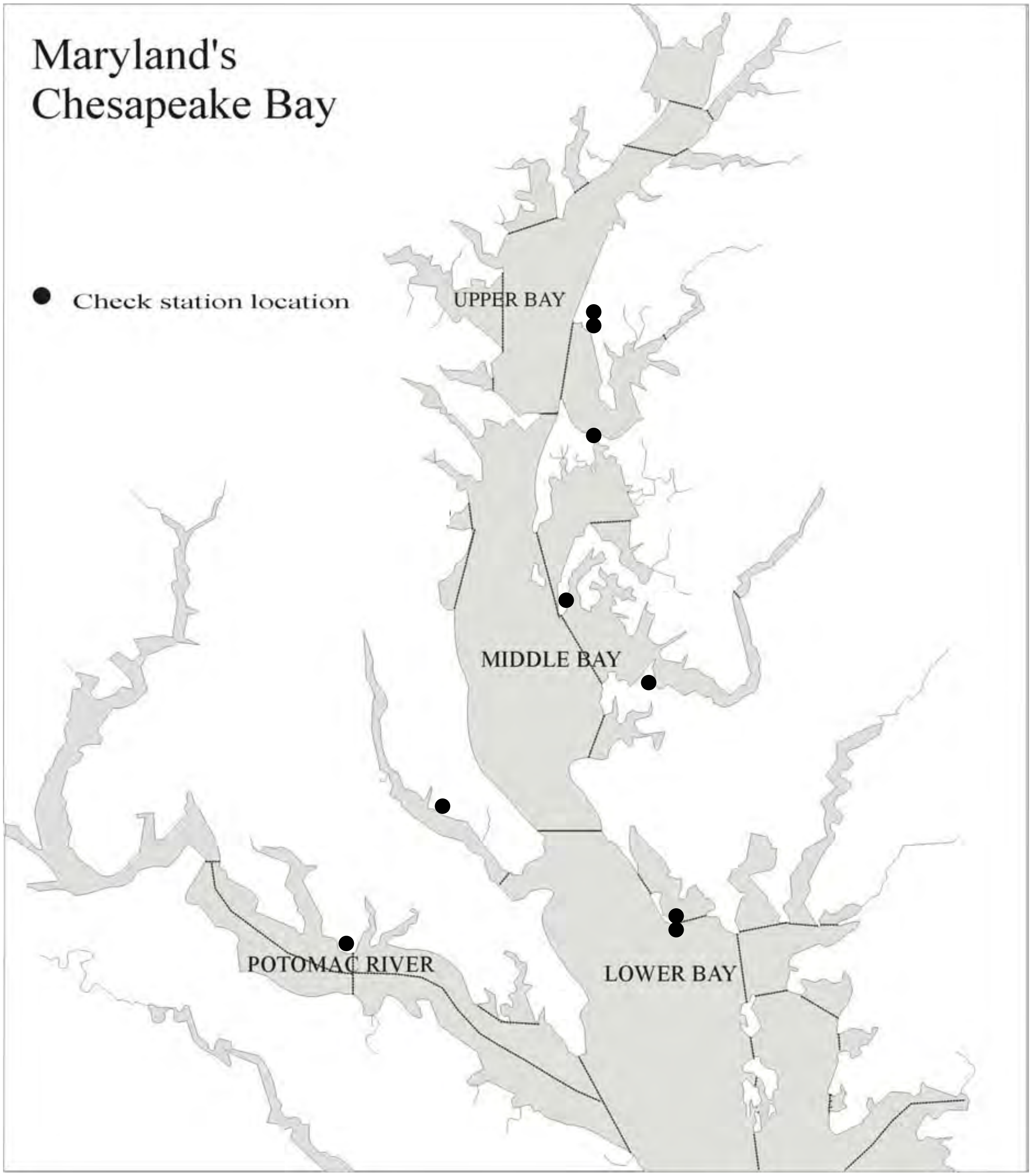
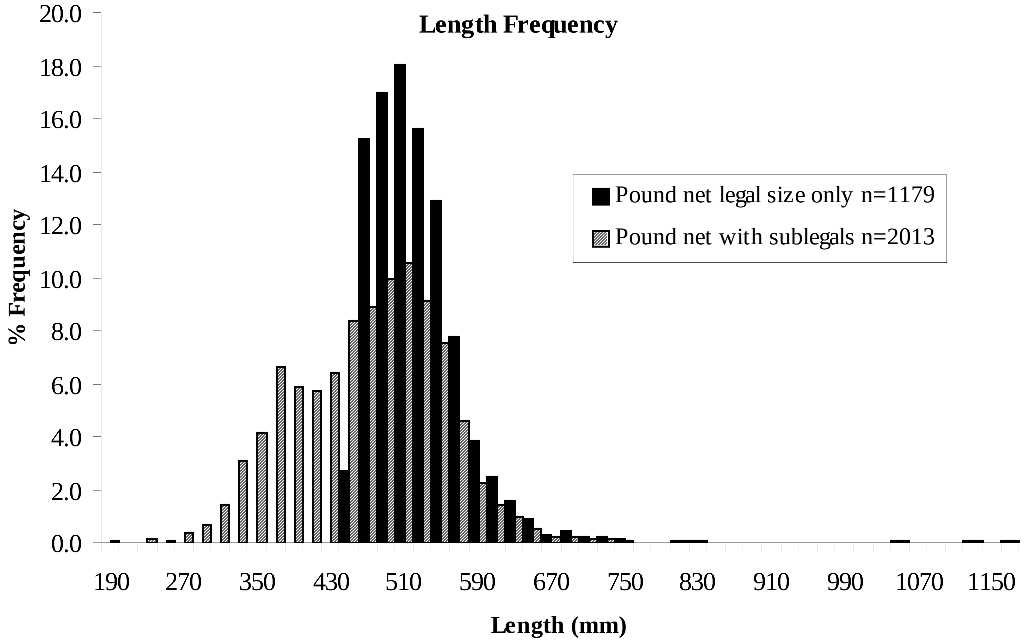


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, August through November 2009.



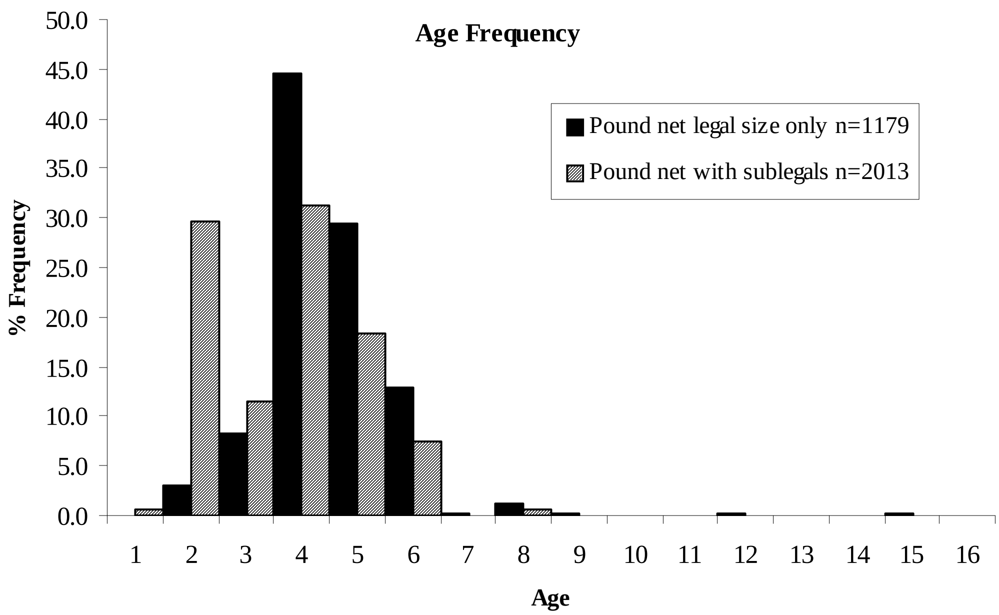


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2009.

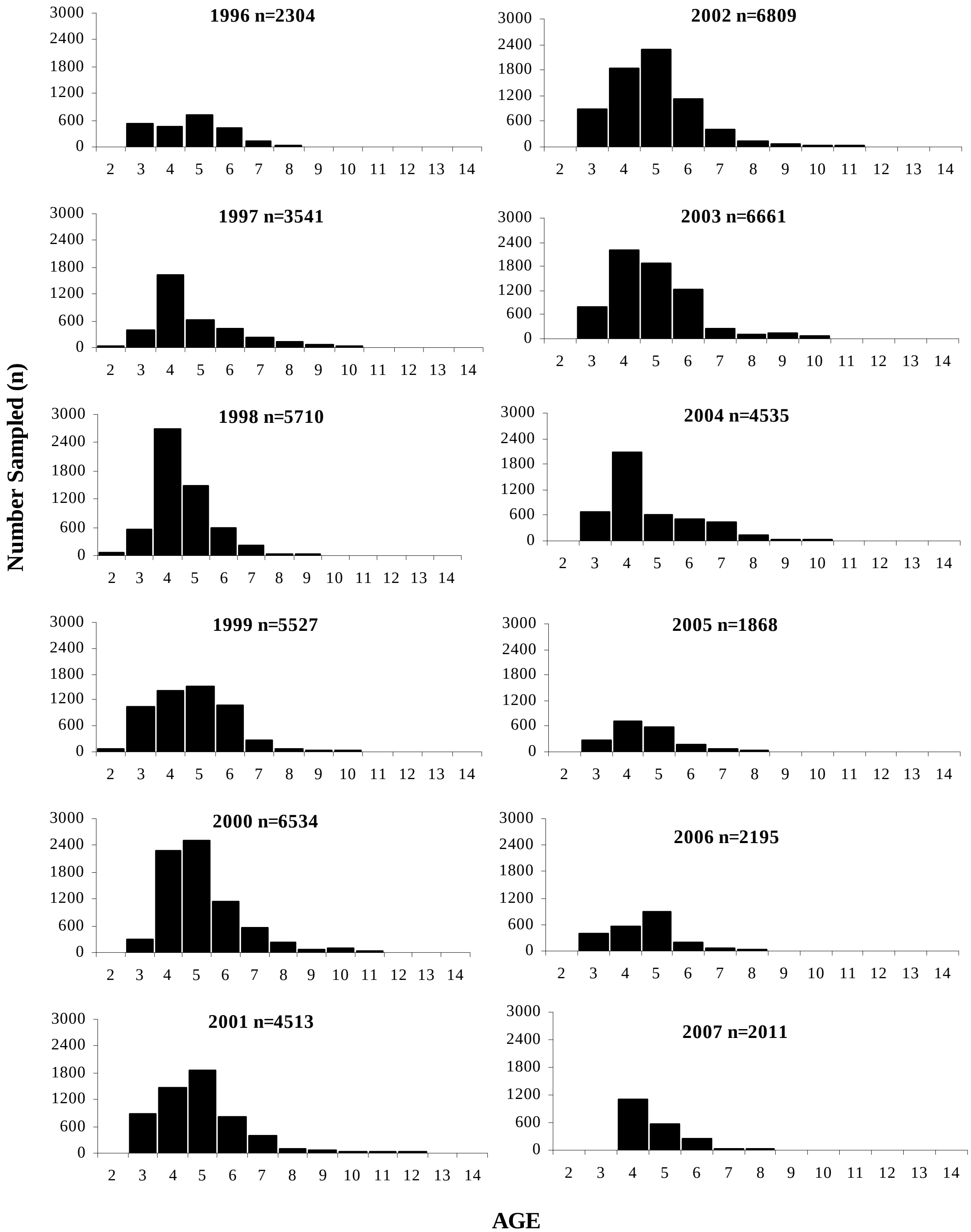


Figure 3. Continued.

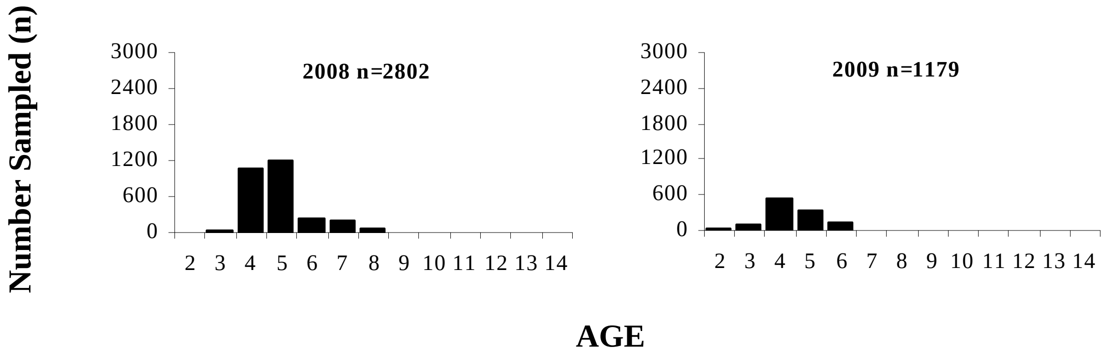


Figure 4. Length frequency of striped bass sampled during the 2009 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2009. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

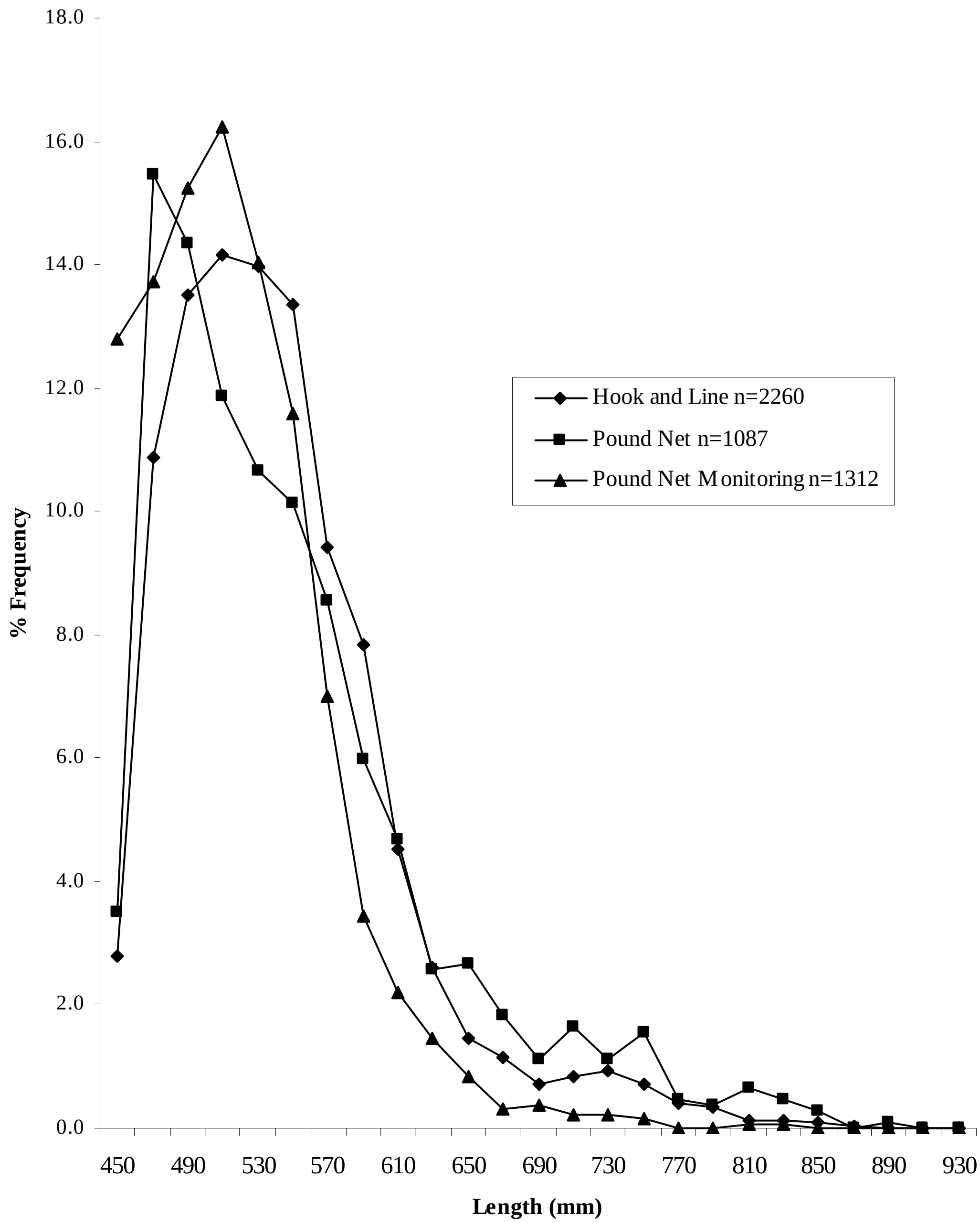
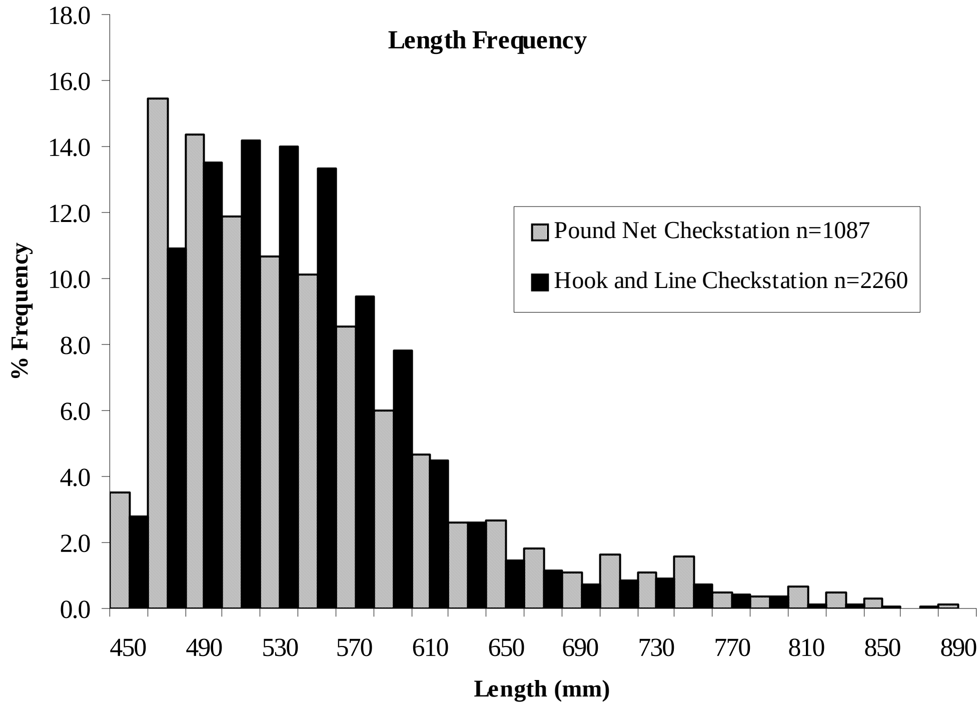


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2009.



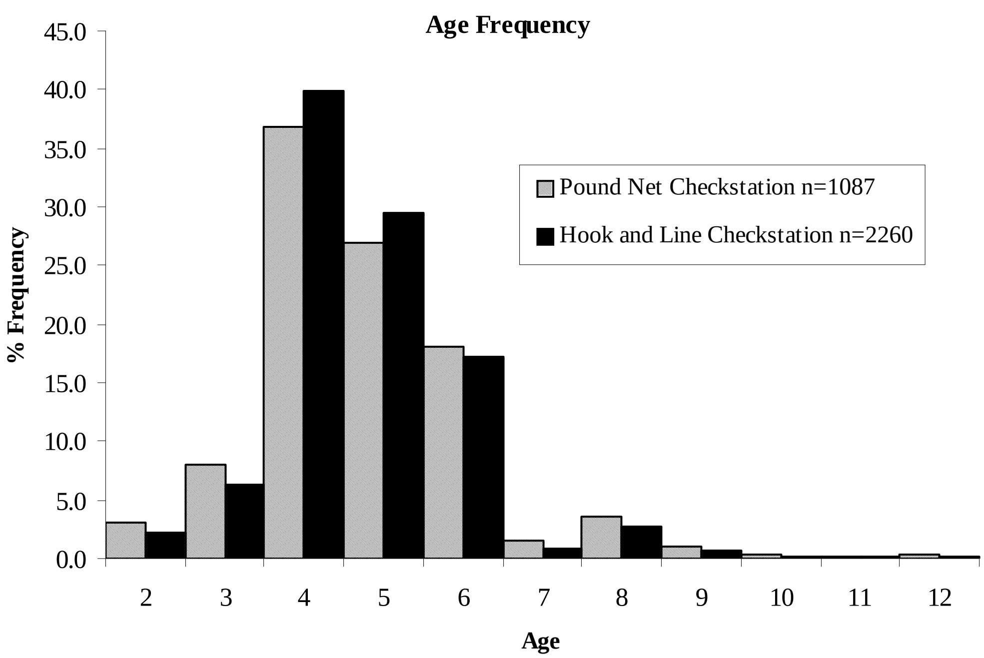


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2009.

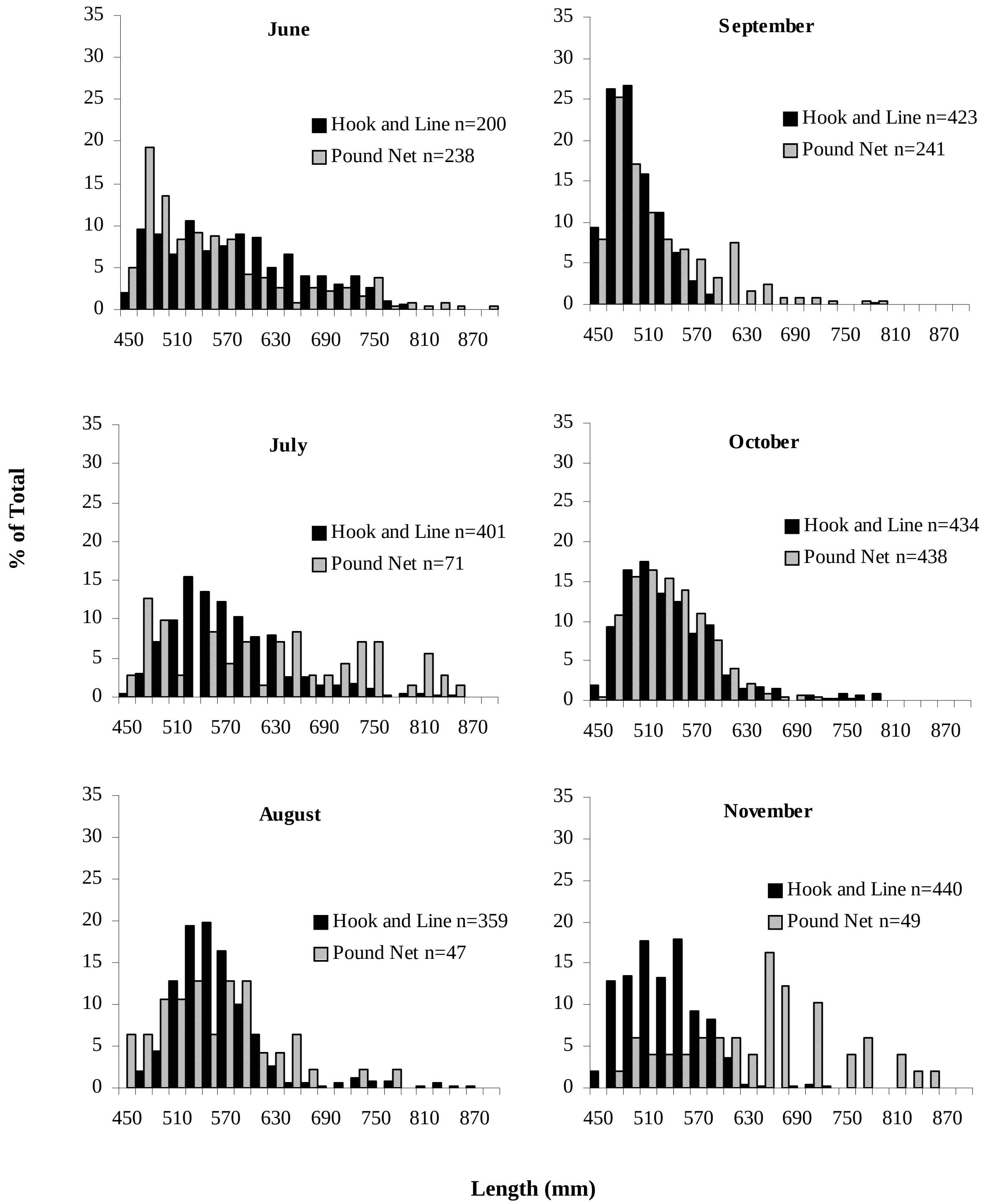


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2009. Note-pound net check station sampling began in 2000.

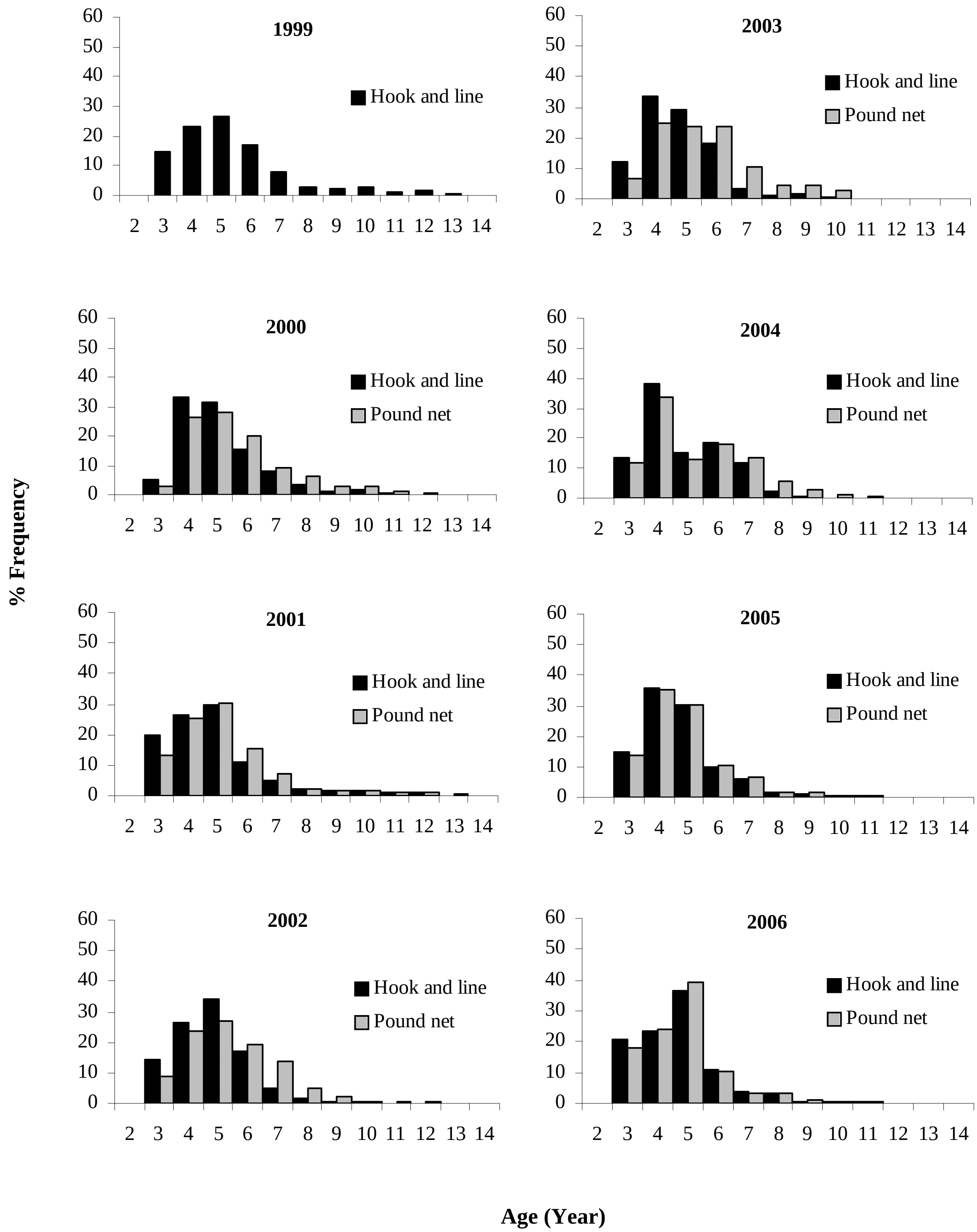


Figure 7. Continued.

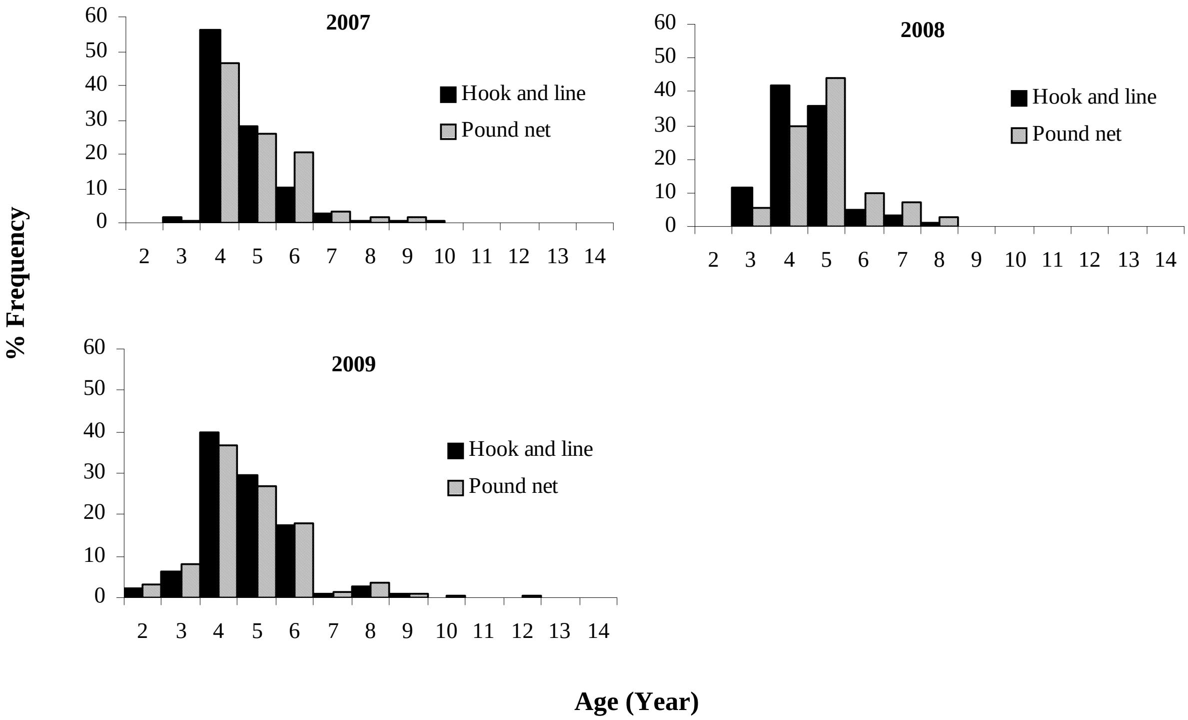
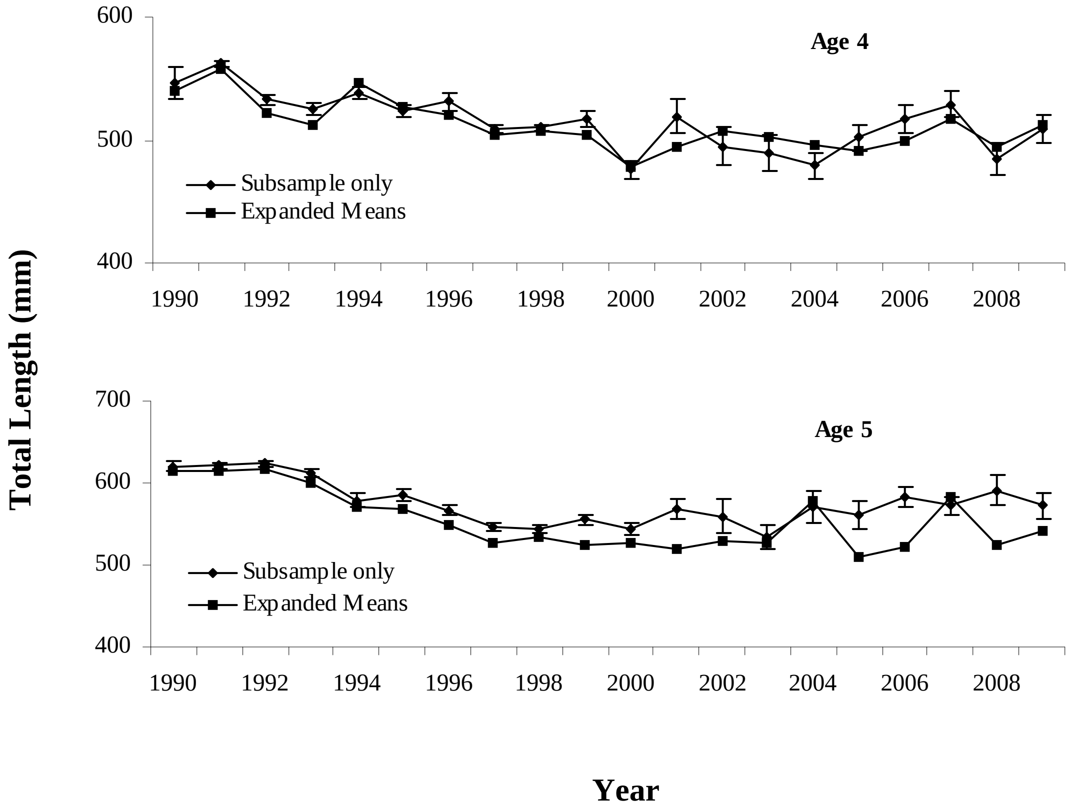
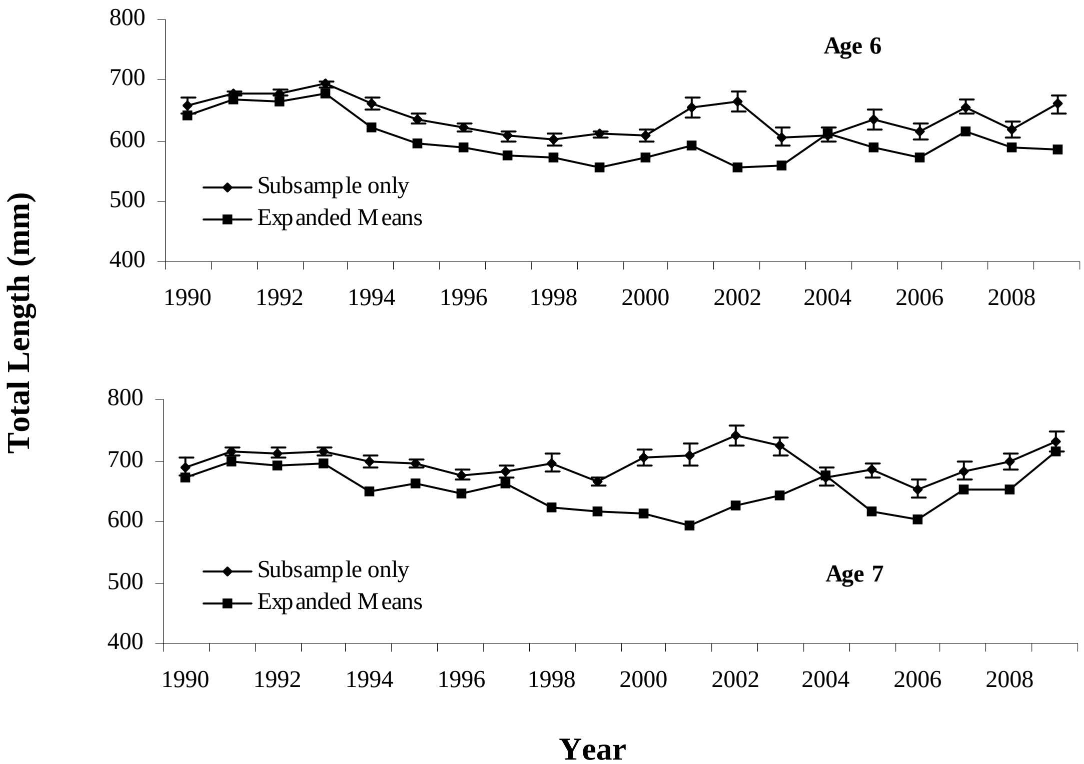


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations, 1990 through 2009. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating means. The 95% confidence intervals are shown around points in the sub-sample data series. Note different scales.



*Note-2007 and 2008 lengths at age edited from last year's report.

Figure 8. Continued.



*Note-2007 and 2008 lengths at age edited from last year's report.

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, 2009 - February 26, 2010 commercial drift gill net fishery. This fishery targets resident/pre-migratory Chesapeake Bay striped bass and accounts for a large portion 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. 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 stations sampled in this survey were located in Rock Hall, while the southern-most station was located on Hooper's 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, total length 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 2009-2010 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 2009 – February 2010 gill net season, the year used for age calculations was 2010.

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 2009-2010 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 46% of the total 2009 Maryland Chesapeake Bay commercial harvest, by weight. A total of 3,616 striped bass were sampled and 119 striped bass were aged from the December 2009 - February 2010 harvest. The sample size obtained was slightly more than the established target.

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 2009-2010 commercial drift gill net harvest consisted primarily of striped bass from the 2005 (age 5) year-class (Table 1), which composed 29% of the total harvest. The 2006 and 2004 year-classes (ages 4 and 6) composed an additional 49% 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 half the 2007-2008 harvest (13%), but higher than the 2008-2009 harvest (2%; Hoover 2008). The youngest fish observed in the 2009-2010 sampled harvest were age 3, similar to most other years.

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 2009-2010 winter gill net fishery at age 3 (2007 year-class), with an expanded mean length and weight of 506 mm TL and 1.44 kg. The 2005 (age 5) year-class was most commonly observed in the sampled landings with an expanded mean length and weight of 520 mm TL and 1.58 kg, respectively. The mean length and weight of the oldest fish in the aged sub-sample (age 12, 1998 year-class) were 839 mm TL and 6.53 kg, respectively.

Length frequency distributions by check station area are presented in Figure 3. The length frequency distributions were dominated by fish in the 470-570 mm TL range. Distributions were similar when comparing the northern and eastern area 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 1994-2010 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.

CITATIONS

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

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

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

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

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

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

LIST OF TABLES

LIST OF FIGURES

Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2009 - February 2010.

Year-Class	**Age**	**Catch**	**Percentage of the Catch**
2007	3	18,916	7
2006	4	69,023	26
2005	5	74,727	29
2004	6	60,648	23
2003	7	21,010	8
2002	8	13,357	5
2001	9	2,744	1
2000	10	361	0
1999	11	217	0
1998	12	72	0
Total*		**261,075**	**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 2009-February 2010.

Year-Class	Age	n fish aged	Mean TL (mm) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean TL (mm)
2007	3	4	478	263	506
2006	4	11	494	955	501
2005	5	15	527	1,034	520
2004	6	21	631	839	555
2003	7	32	699	292	588
2002	8	14	702	187	599
2001	9	16	753	37	709
2000	10	3	754	5	749
1999	11	2	900	3	898
1998	12	1	839	1	839
Total*		**119**		**3,616**	

* 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 2009-February 2010.

Year-Class	Age	n fish aged	Mean Weight (kg) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean weight (kg)
2007	3	4	1.32	263	1.44
2006	4	11	1.35	955	1.40
2005	5	15	1.73	1,033	1.58
2004	6	21	3.04	839	1.91
2003	7	32	4.18	292	2.44
2002	8	14	4.25	187	2.46
2001	9	16	4.83	37	4.21
2000	10	3	4.75	5	4.96
1999	11	2	8.48	3	8.01
1998	12	1	6.53	1	6.53
Total*		**119**		**3,616**	

* 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 2009-February 2010.

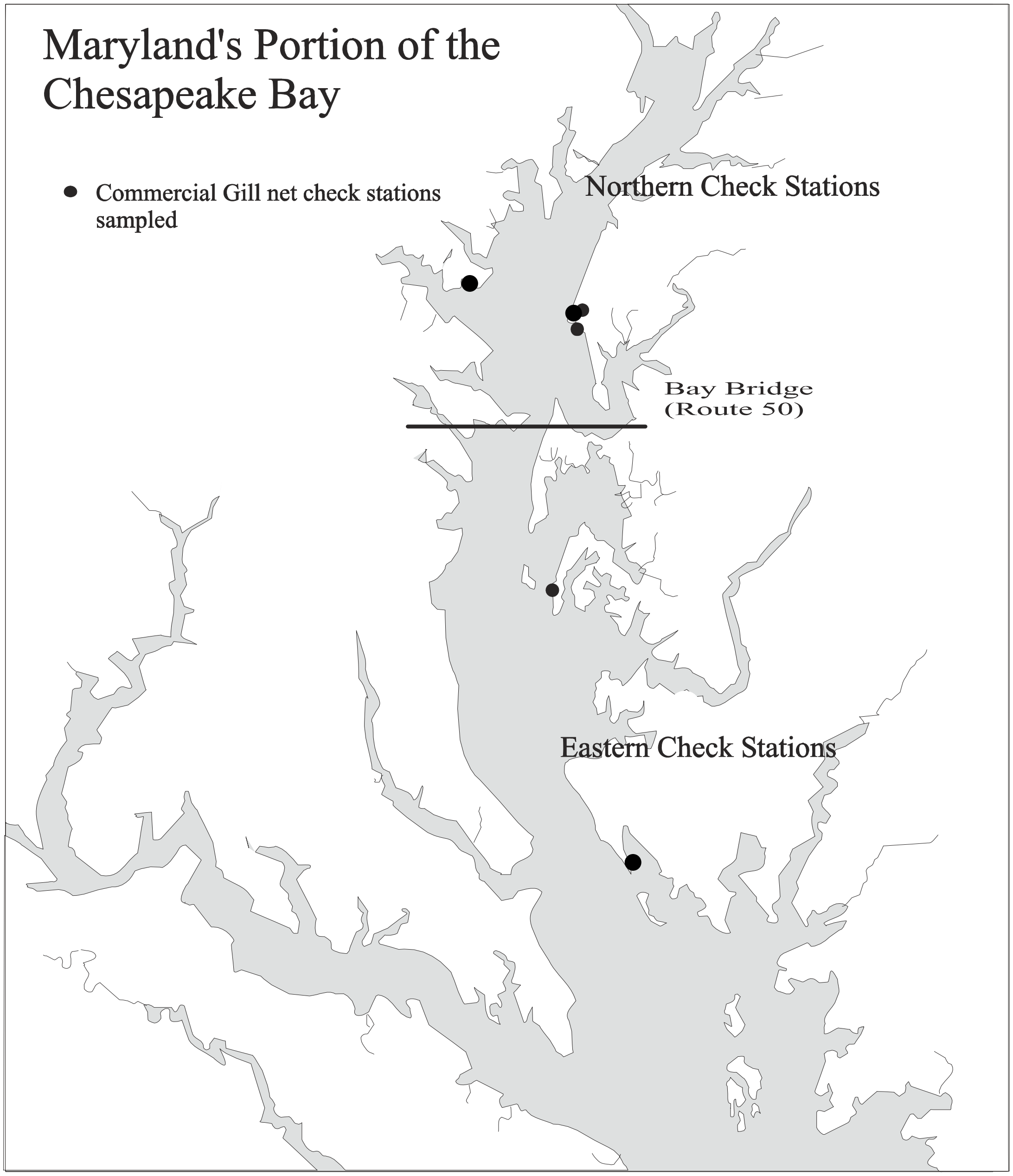


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2010.

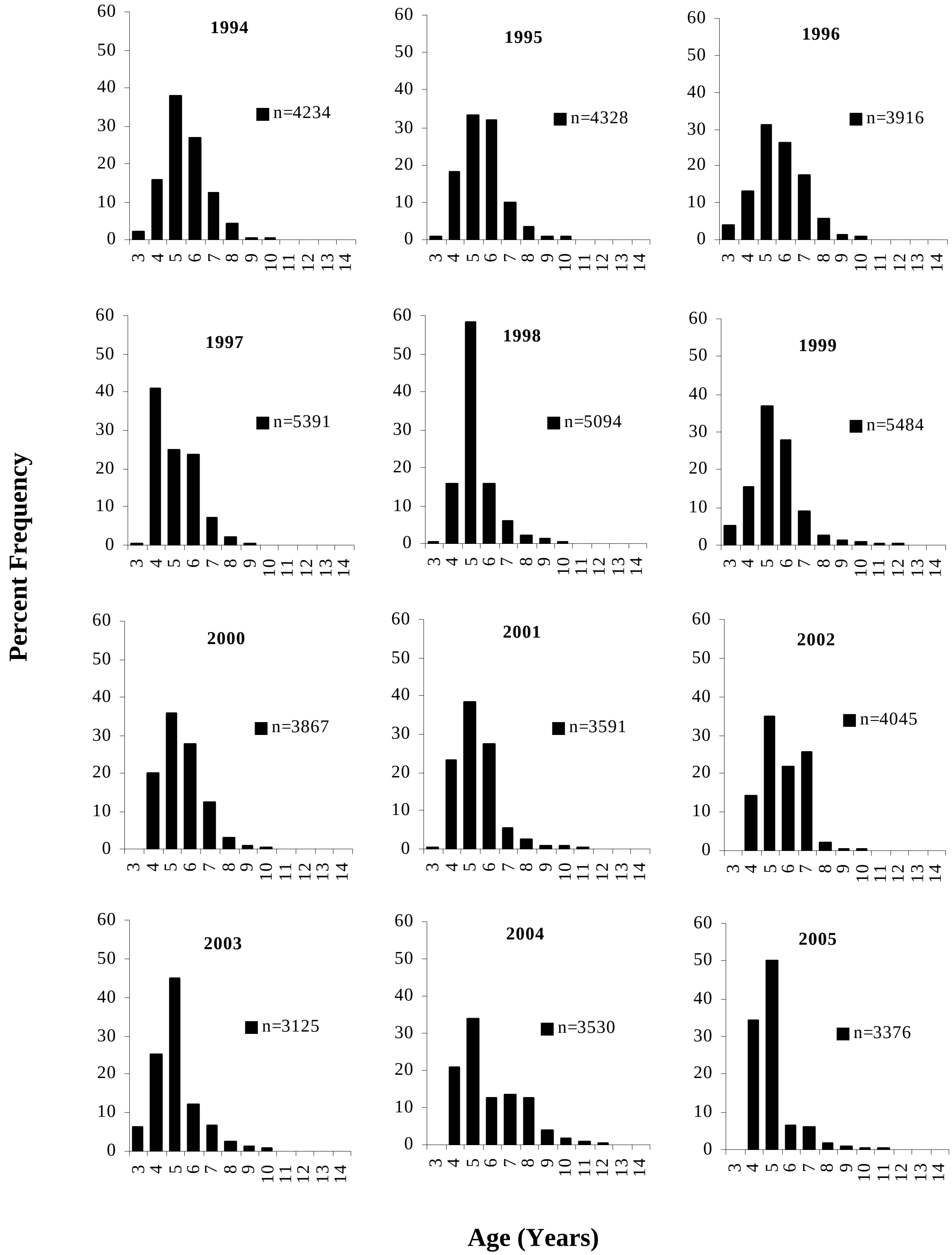


Figure 2. Continued.

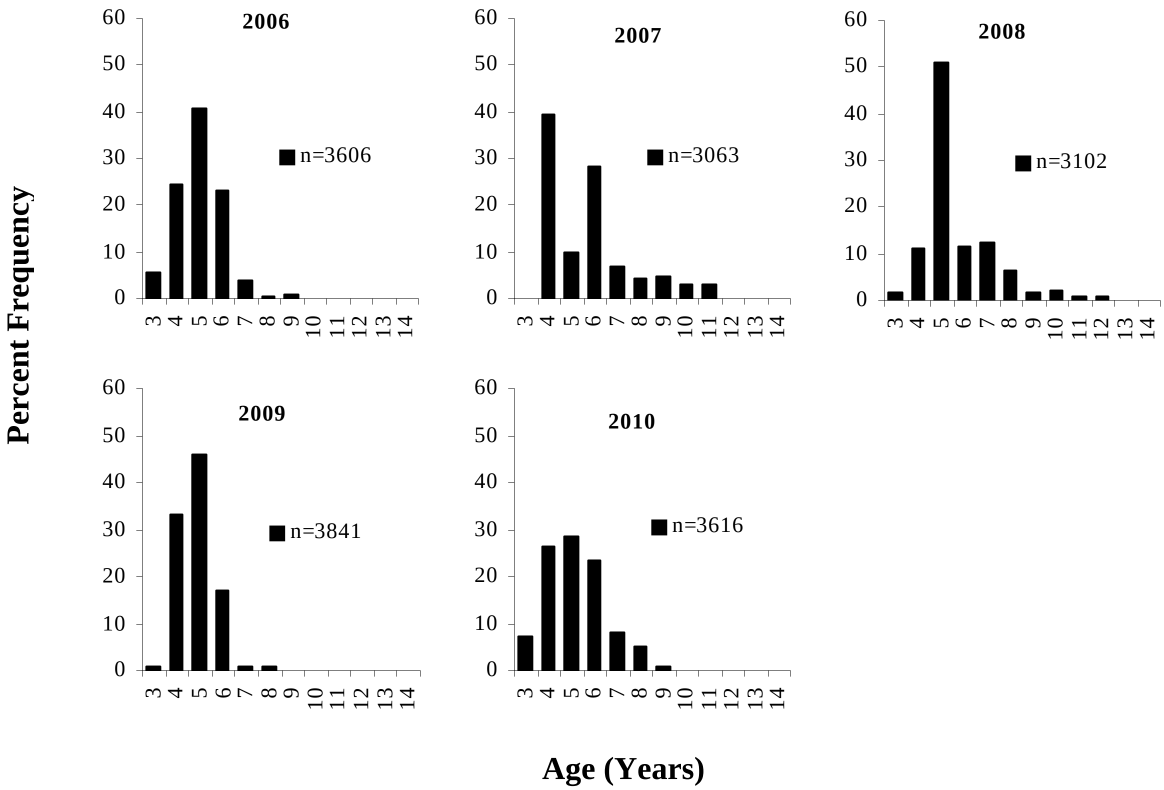


Figure 3. Length frequency distributions, by area and bay-wide, of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2009-February 2010.

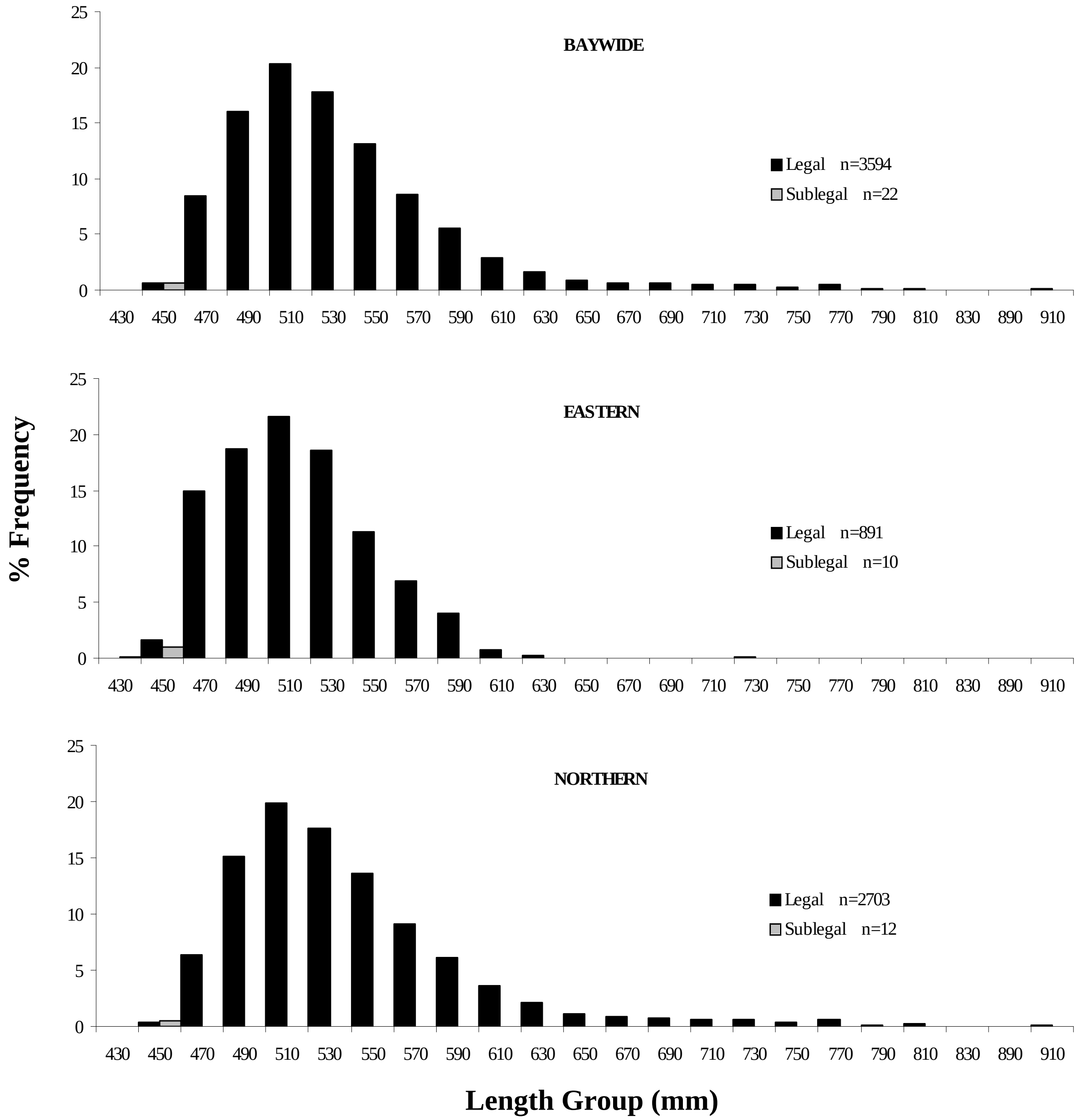


Figure 4. Mean total lengths (mm) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2010 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.

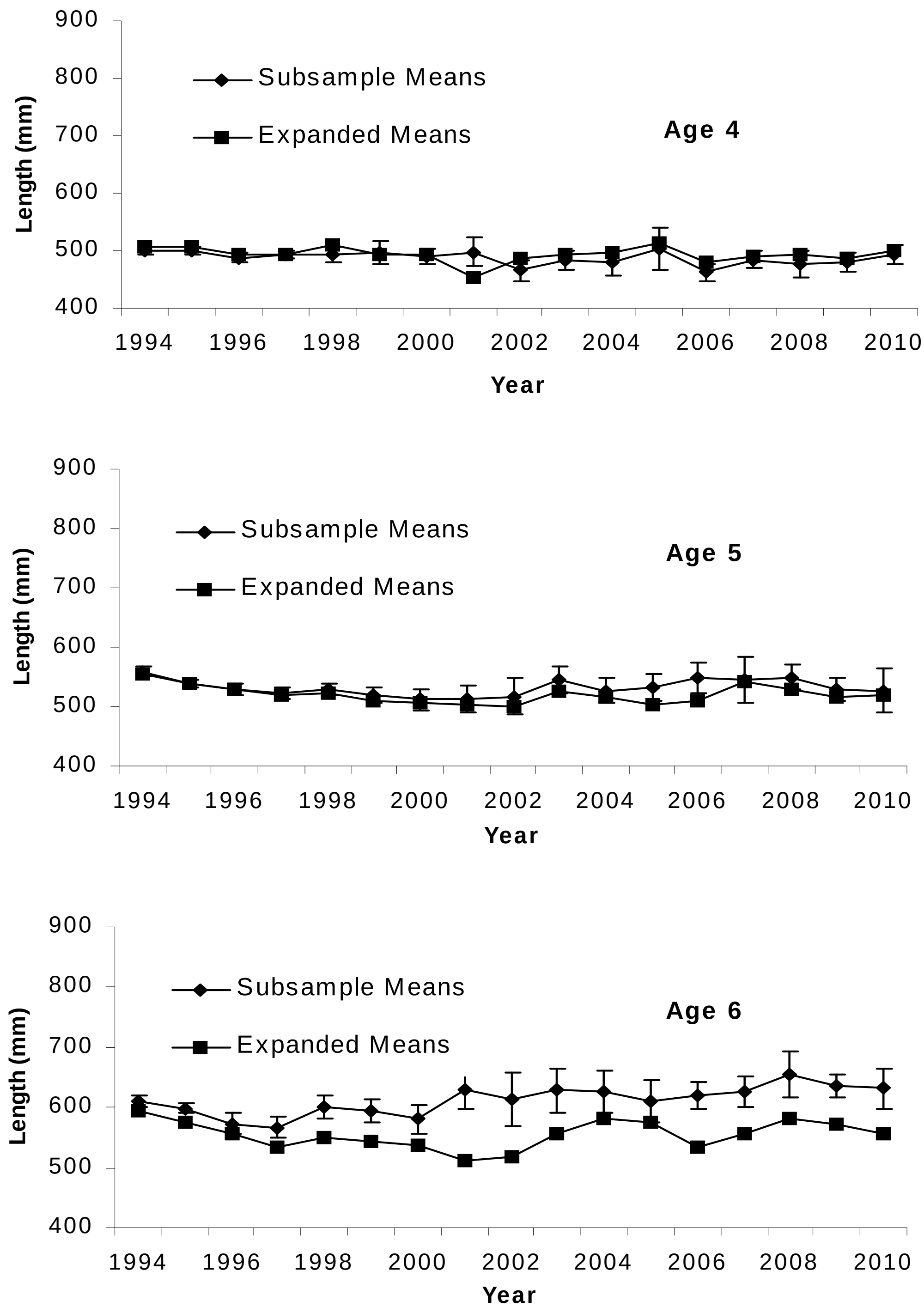
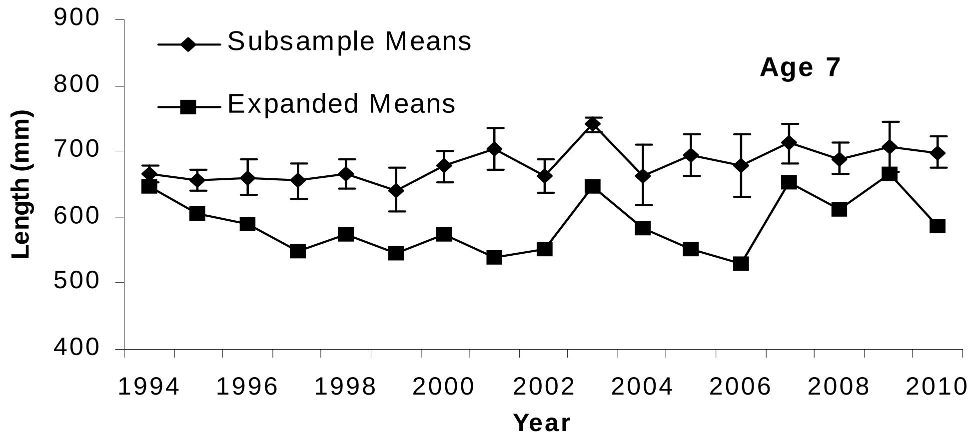
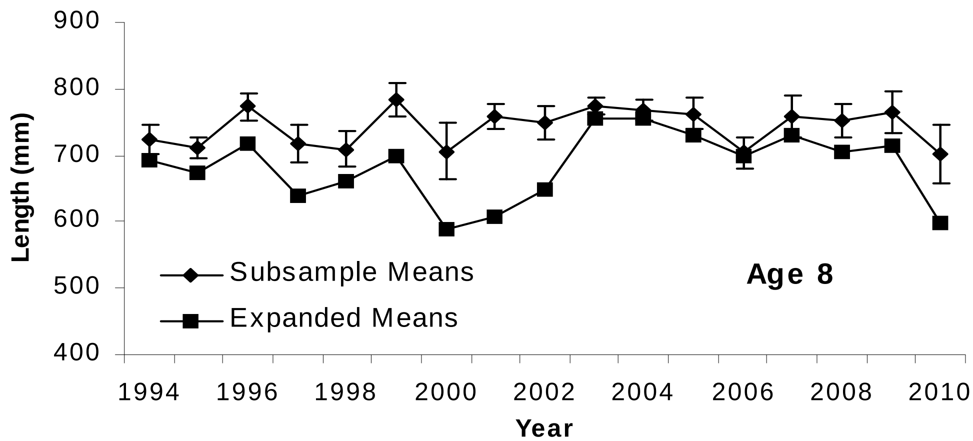


Figure 4. Continued.





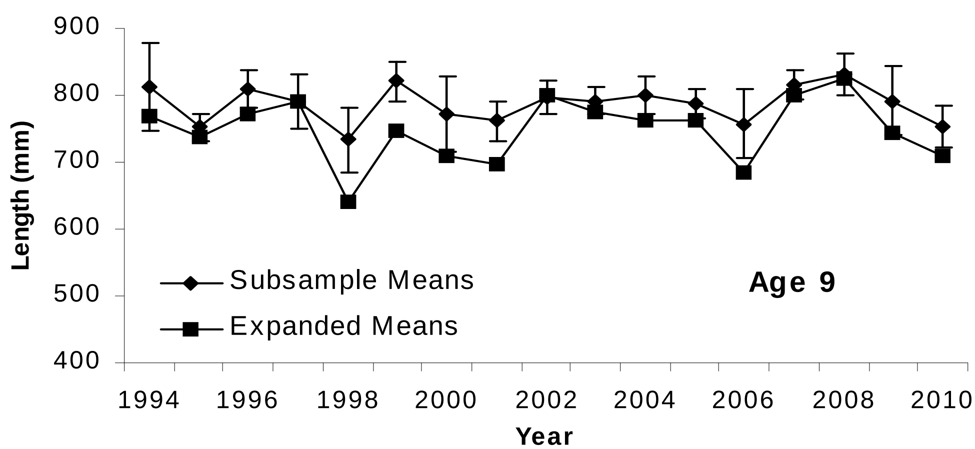
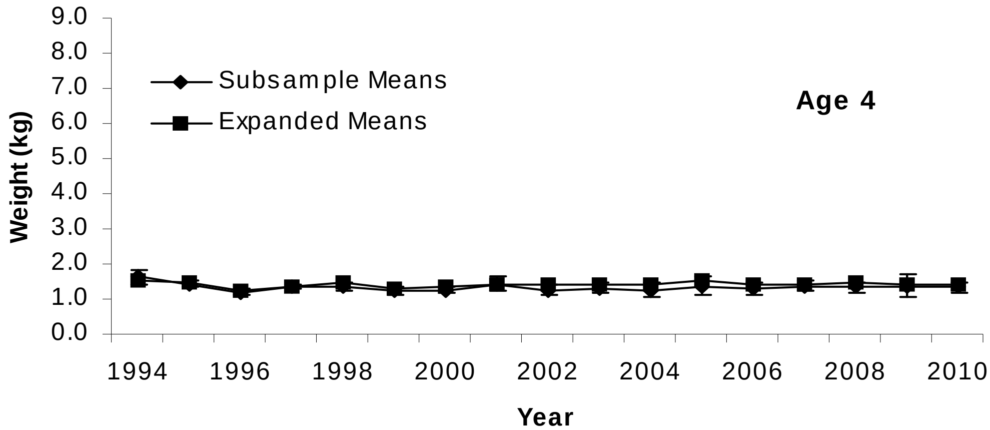
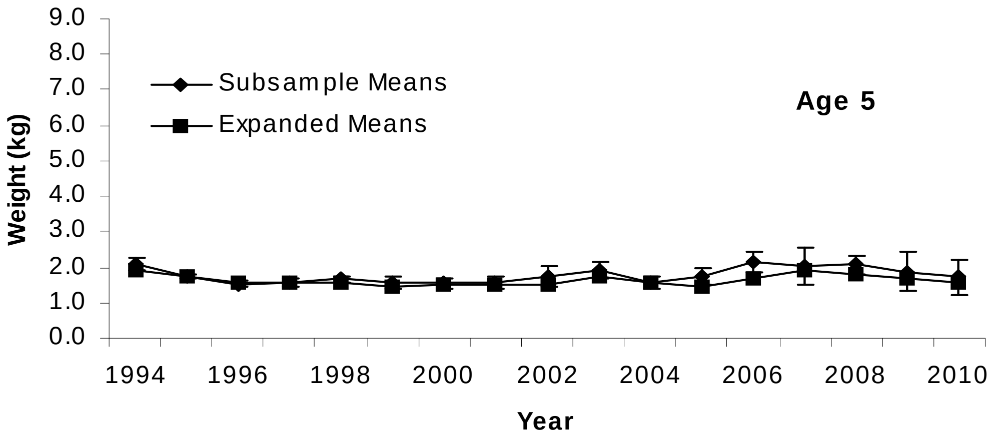


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2010 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. Year refers to the year in which the season ended.





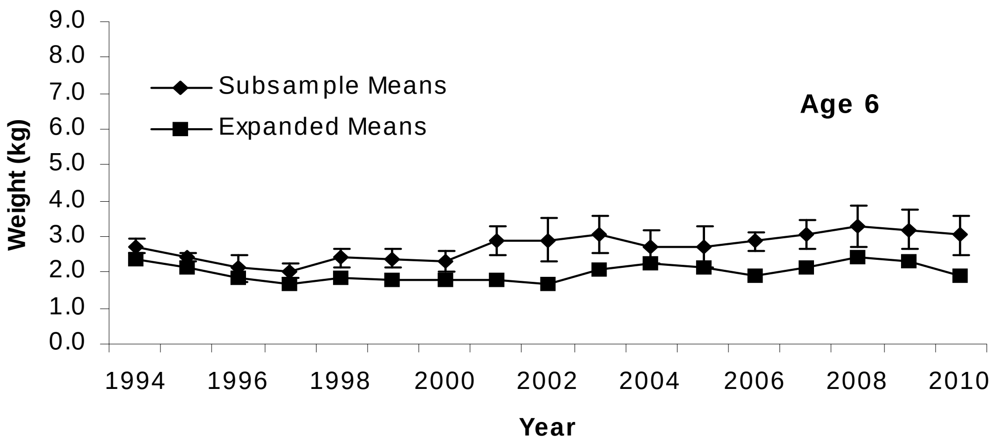
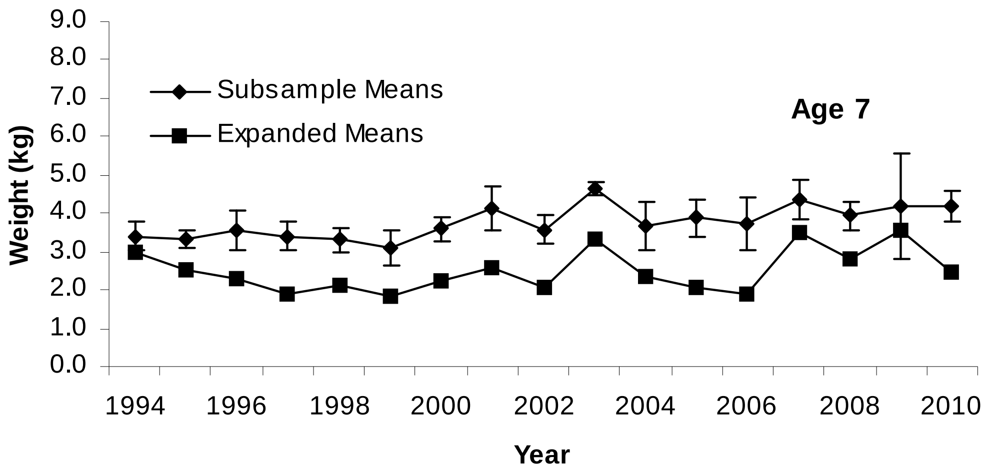
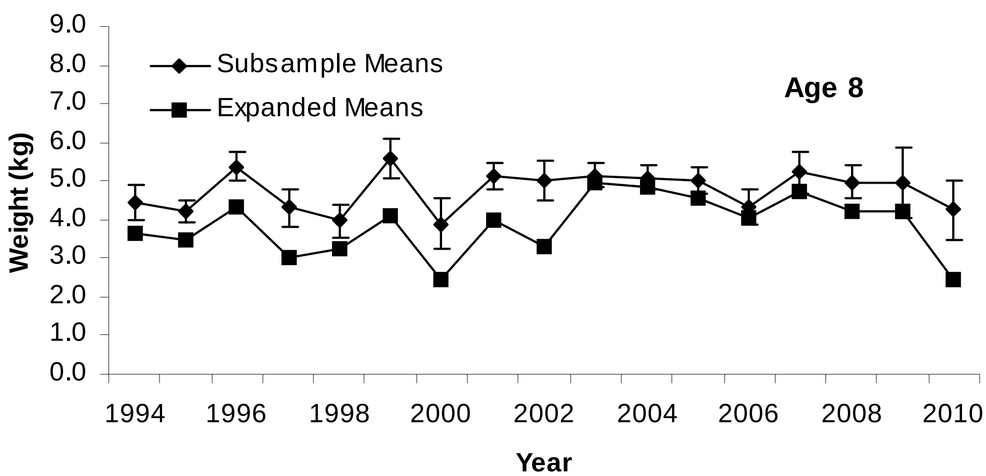
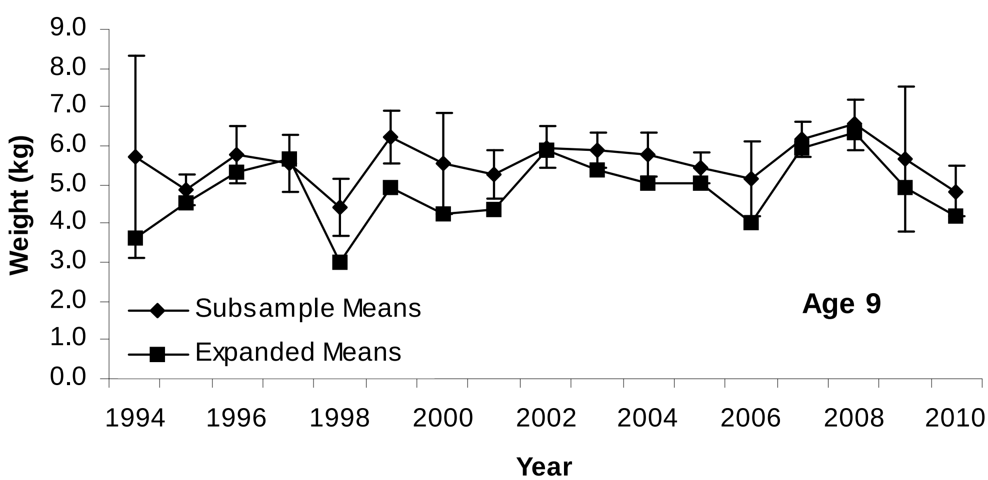


Figure 5. Continued.







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

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Amy Batdorf

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1C was to characterize the size and age structure of commercially harvested striped bass from Maryland's Atlantic coast. Trawls and gill nets were permitted during the Atlantic season, which occurred between November 1, 2009 and April 30, 2010. This fishery was managed with a 24 inch total length (TL) minimum size limit and an annual quota of 126,396 pounds. Although this report covers the November 2009-April 2010 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 2004 check station activity indicated that 85% 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 2009 through April 2010. For stage two, a sub-sample of scales from Atlantic coast striped bass was aged. Due to the sample size, the majority of scales are 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 2009-April 2010 Atlantic fishery, the year used for age calculations was 2010. 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 2009 through April 2010 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 seven days between November 2009 and April 2010. A total of 127 fish were measured and weighed and the ALK was developed from 106 scale samples. This is the smallest sample obtained from this 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 2009-2010 Atlantic coast fishing season ranged from age 5 (2005 year-class) to age 12 (1998 year-class) (Fig. 1). Most striped bass harvested were ages 6 through 9 (Table 1). Striped bass were recruited into the Atlantic coast fishery as young as age five, but due to the 24 inch minimum size limit, few fish younger than age six 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 (44%, 17%, and 17% respectively). With Age 6 (2004 year class) represented 15% of the fishery. The 2003 year-class (age 7) is now recruiting into the fishery and it has replaced the 2001 year class (age 9) as the most abundant.

Striped bass sampled at Atlantic coast check stations during the 2009-2010 season had a mean length of 751 mm TL and mean weight of 4.5 kg. The mean weight of fish in the 2009-2010 season was not significantly different from fish in 2008-2009 (4.0 kg) (t-test, α=0.05, P=0.28). The mean length of fish harvested during the 2009-2010 season

(726 mm TL) was significantly smaller than that of the 2009-2010 harvest (t-test, α=0.05, P=0.00001). The length distribution of fish harvested in the 2009-2010 season ranged from 610 to 950 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 2010, 106 fish were aged of the 127 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 637 mm TL and expanded mean weight of 3.5 kg. Age 7 striped bass, the most abundant age harvested (Figure 1), had an expanded mean length of 730 mm TL and expanded mean weight of 4.0 kg. Age 8 striped bass, the next most abundant year-class harvested, had an expanded mean length of 756 mm TL and an expanded mean weight of 4.6 kg.

CITATIONS

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

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

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

LIST OF TABLES

LIST OF FIGURES

Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Atlantic coast commercial fishery, November 2009-April 2010.

2009-2010			
Year-Class	**Age**	**Catch**	**Percent**
2005	5	106	1.6
2004	6	985	14.7
2003	7	2948	44.0
2002	8	1119	16.7
2001	9	1125	16.8
2000	10	211	3.1
1999	11	106	1.6
1998	12	106	1.6
	Total	**6,705**	**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 2009-April 2010. 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)**
2005	5	2	635	571	698	2	637
2004	6	14	713	682	743	19	712
2003	7	42	733	716	749	56	730
2002	8	20	758	726	789	21	756
2001	9	20	804	774	835	21	803
2000	10	4	907	851	963	4	906
1999	11	2	833	808	858	2	829
1998	12	2	821	---	---	2	827
Total		**106**				**127**	

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2009-April 2010. 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)**
2005	5	2	3.3	---	---	2	3.5
2004	6	14	3.7	3.3	4.1	19	3.7
2003	7	42	4.0	3.8	4.3	56	4.0
2002	8	20	4.7	4.2	5.1	21	4.6
2001	9	20	5.5	5.0	6.0	21	5.4
2000	10	4	7.5	6.0	9.1	4	7.3
1999	11	2	6.0	---	---	2	5.8
1998	12	2	6.4	---	---	2	5.9
Total		**106**				**127**	

Figure 1. Age distribution of striped bass sampled from the Atlantic coast fishery during the calendar year 2006, the November 2007-April 2008 fishing season, and the November 2008-April 2009 fishing season.

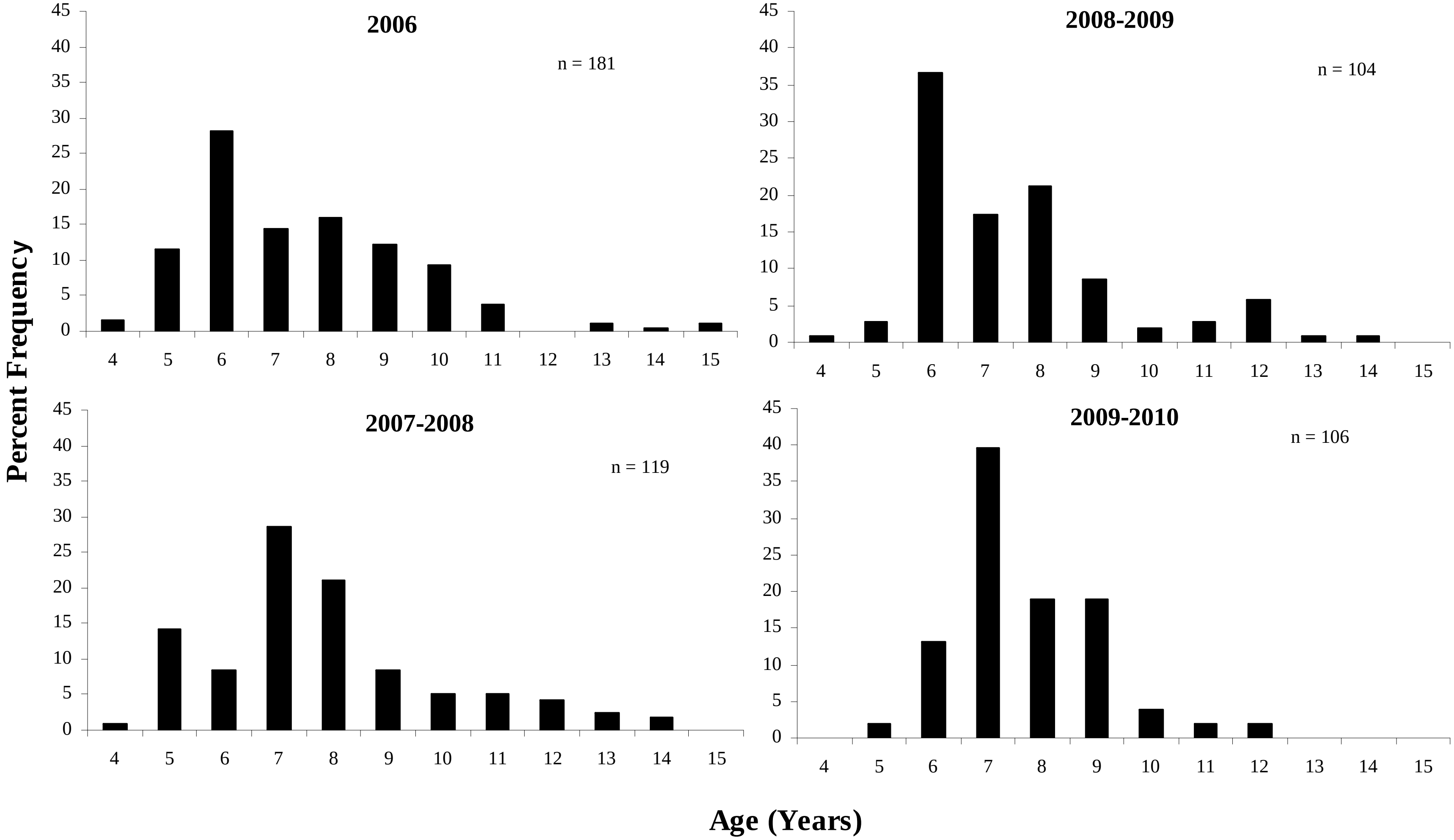


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, November 2006-April 2007, the November 2007-April 2008 fishing season, the November 2008-April 2009 fishing season, and the November 2009-April 2010 fishing season.

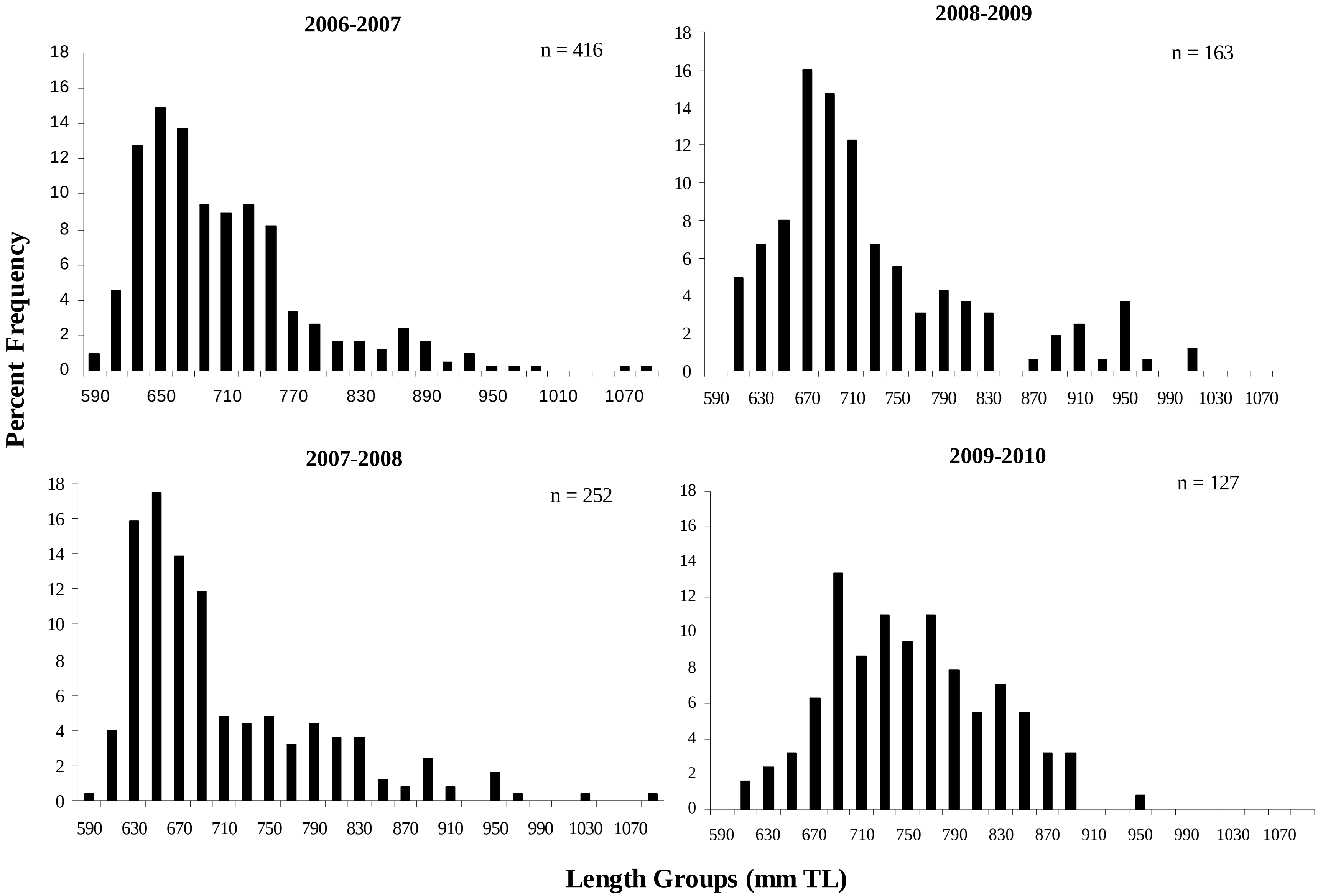


Figure 3. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2010 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences in scales on the y-axis.

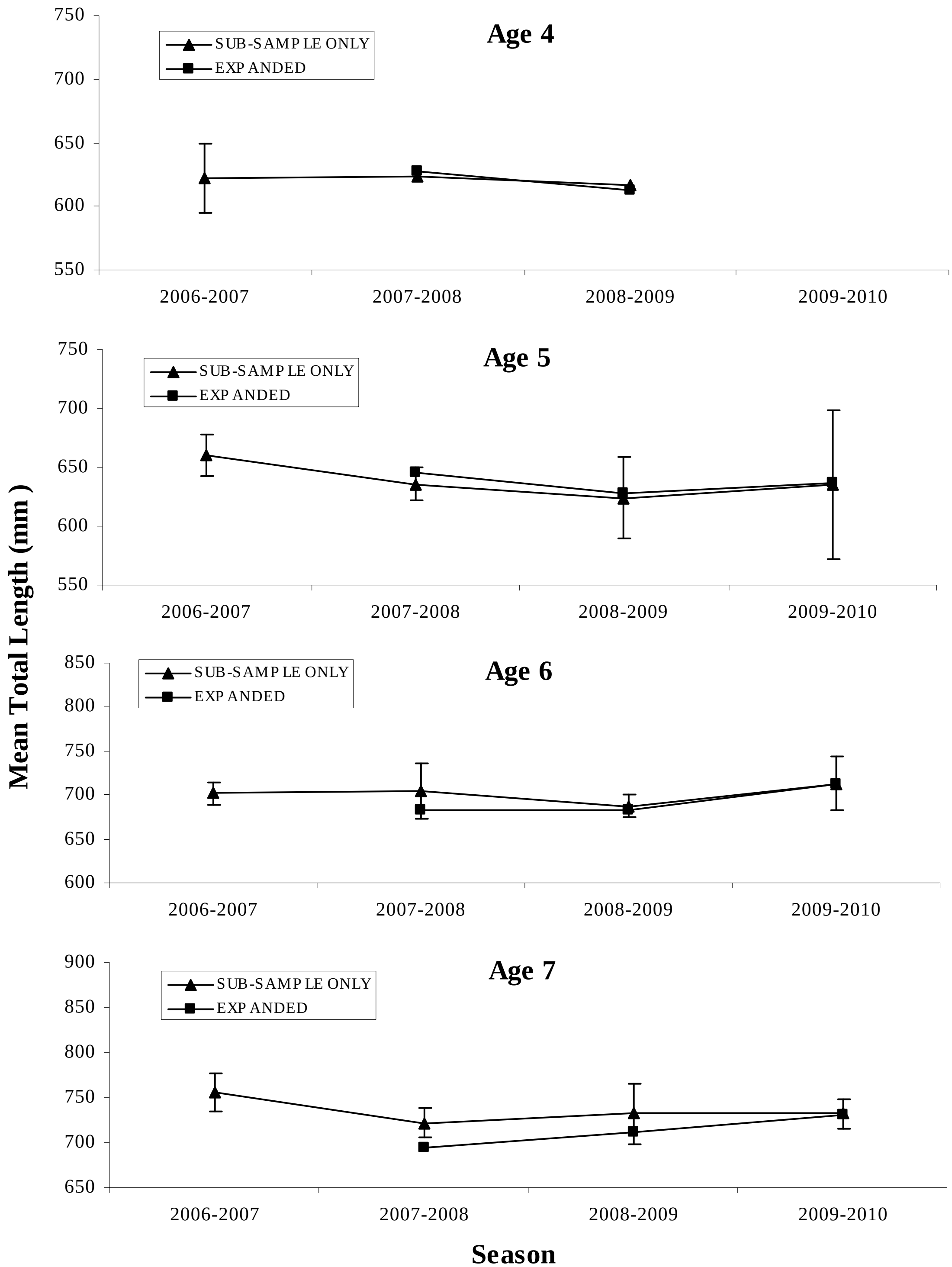


Figure 3. Continued

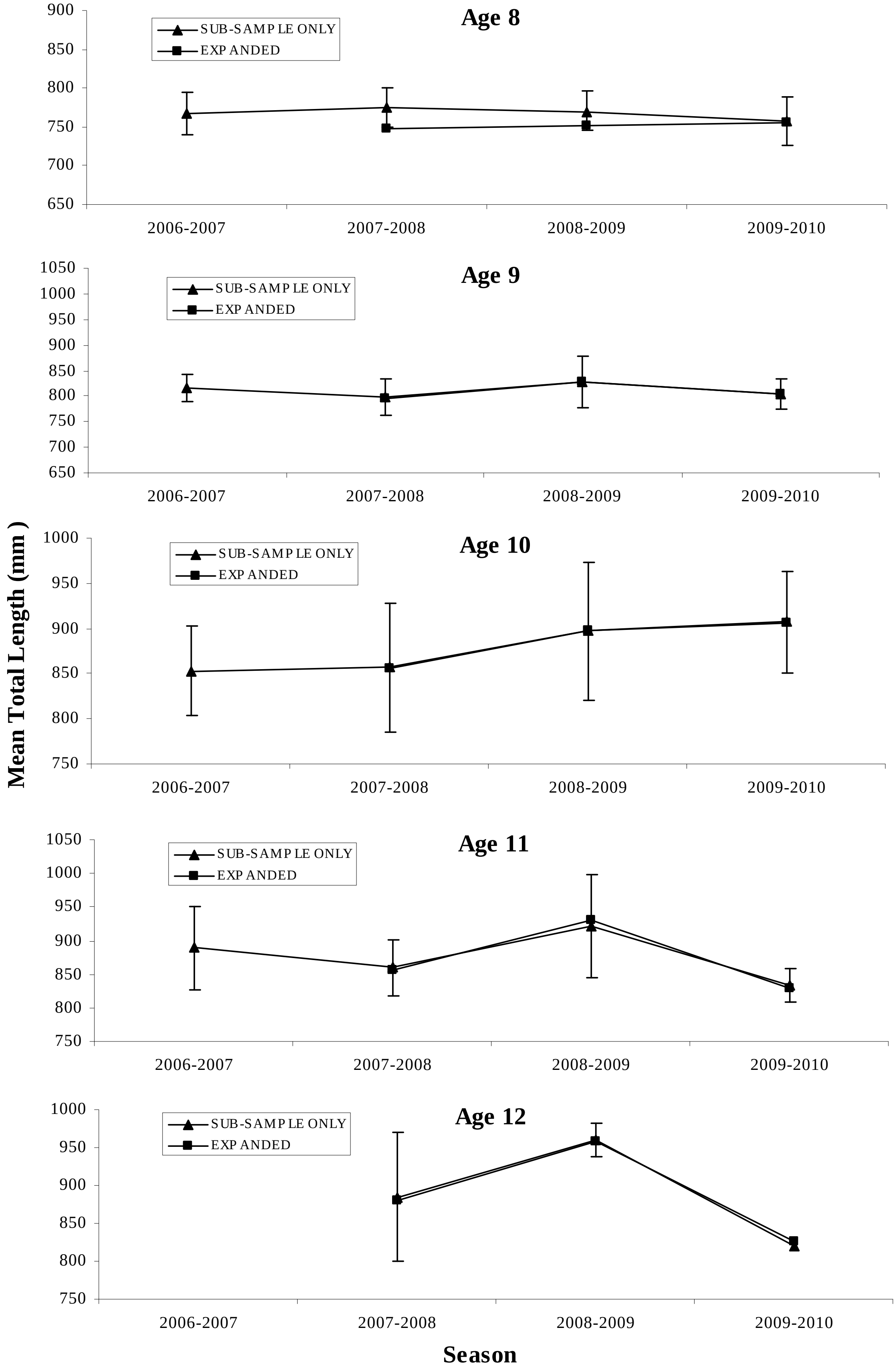


Figure 4. Mean weight (kg) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2010 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences of scale on the y-axis.

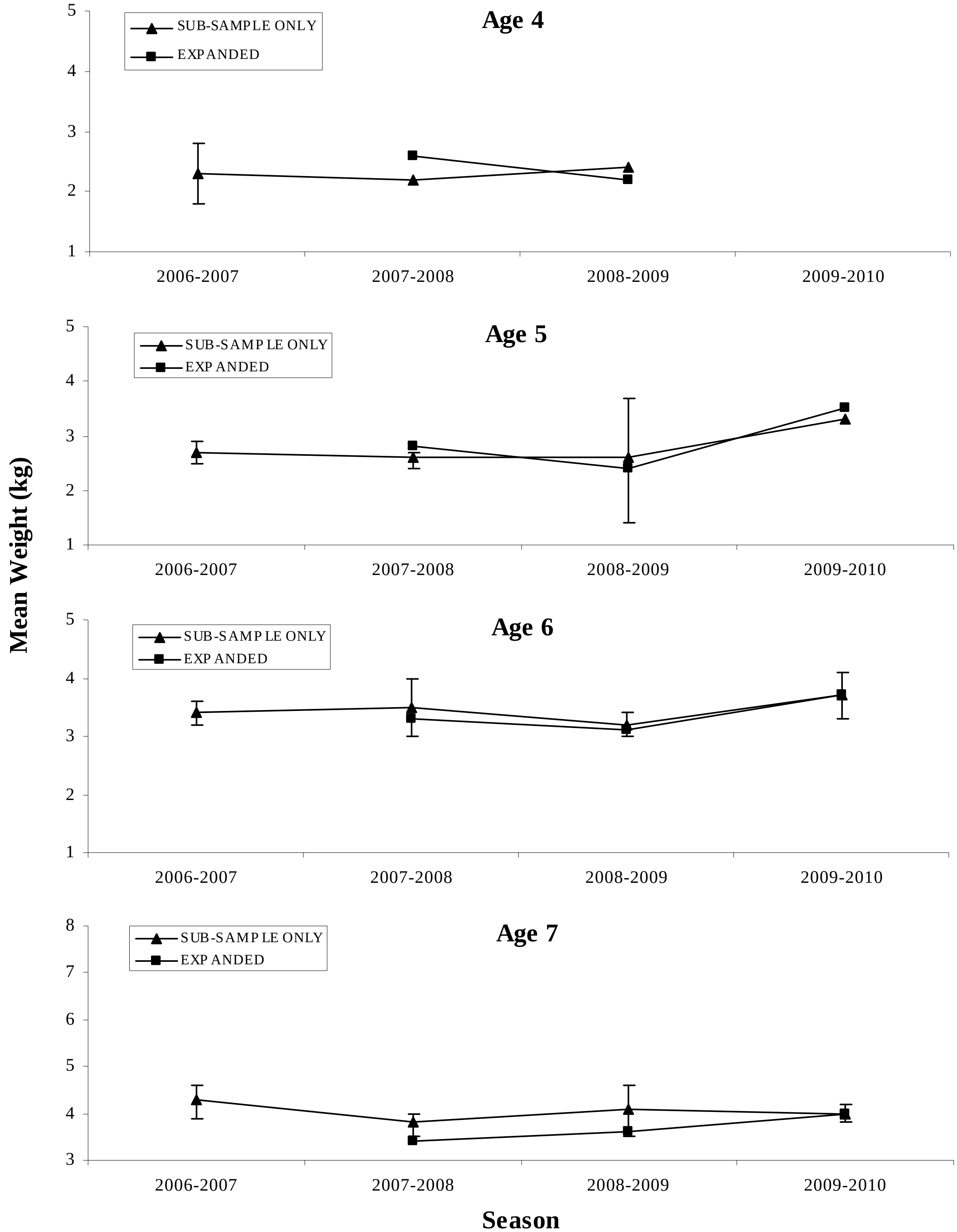
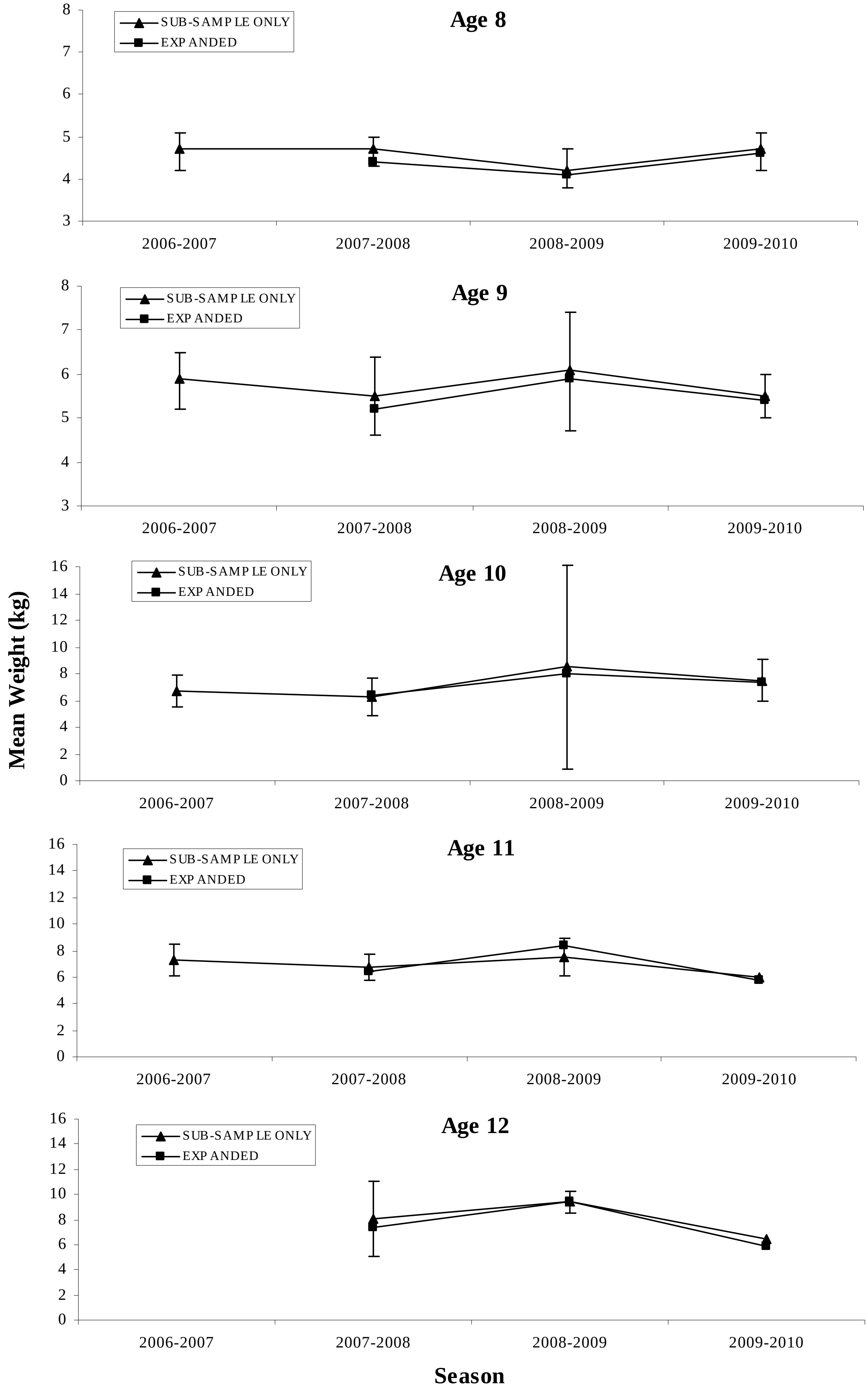


Figure 4. Continued



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Angela Giuliano and Beth A. Versak

INTRODUCTION

The primary objective of Project 2, Job 3, Task 2 was to generate estimates of relative abundance-at-age for striped bass in Chesapeake Bay during the 2010 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 2010 (Figure 1). Gill nets were fished 6 days per week, weather permitting, during April and May. In the Potomac River, sampling was conducted from April 1 to May 13 for a total of 30 sample days. In the Upper Bay, sampling was also conducted from April 1 to May 13 with a total of 32 sample days.

Individual net panels were 150 feet long, and ranged from 8.0 to 11.5 feet deep depending on mesh size. The panels were constructed of multifilament nylon webbing in 3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0 and 10.0-inch stretch-mesh. In the Upper Bay, all 10 panels were tied together, end to end, to fish the entire suite of meshes simultaneously. In the Potomac River, because of the design of the fishing boat, the gang of panels was split in half, with two suites of panels (5 meshes tied together) fished simultaneously end to end. In both systems, all 10 panels were fished twice daily unless weather prohibited a second set. 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 8 to 204 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). The Patuxent River CWT survey was not conducted in 2010, so those extra scales were not available to fill gaps within larger length groups of the ALKs.

Development of selectivity-corrected CPUEs and variance estimates

CPUEs for individual mesh sizes and length groups were calculated for each spawning area in 2010. 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 performed in 2000 determined that unique physical selectivity characteristics were evident by sex, but not by area (Waller, 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 1997-2009 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) 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):

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

This index was calculated for each spawning area individually, and then pooled using the same weights described above. Because of its relatively small weight, the contribution of the Choptank River ISP estimate to the Bay-wide estimate was negligible. When sampling of the Choptank ceased in 1997, previous years were not recalculated to exclude it.

RESULTS AND DISCUSSION

CPUEs and variance

Annual CPUE calculations produced four vectors of selectivity-corrected sex- and age-specific CPUE values. A total of 595 scales were aged from the various surveys to create the sex-specific ALKs (Table 1). The un-weighted time series data are presented by area in Tables 2-7. All 2010 CPUE values indicated a decrease over 2009 values.

The 2010 un-weighted CPUE for Potomac females (19) ranked sixteenth of 25 years in the time series, below the series average of 28 (Table 2). The un-weighted CPUE for Potomac males (285) ranked seventeenth in the time-series, a slight decrease from 2009, and still below the time series average of 445 (Table 3). The upper Bay female CPUE (27) ranked seventeenth in the time series. This was a large decrease from 2009 and below the time series average of 35 (Table 4). The un-weighted CPUE for upper Bay males was 520, the ninth highest CPUE in the time series, and above the time series average of 454 (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 coast-wide striped bass stock assessment. These indices are presented in a time series for ages one through 15+ (Table 8). The 2010 selectivity-corrected total weighted CPUE (453) was much lower than the 2009 value and below the time series average of 497.

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 2010 age-specific CPUEs were all below 0.10 and indicated a small variance in CPUE. Historically, 79% of the CV values were less than 0.10 and 88% 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 (95%, Tables 12 and 13), pooled, total CPUEs. Overall, young males from the 2007 and 2005 year-classes contributed substantially to the total un-weighted and weighted CPUEs in 2010, making up 47% of the totals. As in previous years, Upper Bay fish accounted for most of the total CPUE, contributing 64% to the total un-weighted and 74% to the weighted CPUEs.

The 2007 year-class made up 34% of the un-weighted and weighted Upper Bay male CPUEs. The three year olds made up 37% of the un-weighted and weighted Potomac male CPUEs. In 2010, Upper Bay males in the 15+ age group had an unusually high CPUE, making up 4% of the un-weighted and weighted male CPUE in that system. Typically, this age group is less than 1% of the total CPUE. The high 15+ age group CPUE was driven by two large male fish caught in the 6.5 inch mesh on the Upper Bay. Because the selectivity for large fish is low in that mesh size, the model tends to over-inflate the selectivity-corrected CPUE and increases the variance around the mean.

Female CPUEs were distributed across many year-classes, with the 1996 year-class contributing approximately 31% of the un-weighted and weighted female Potomac River

CPUEs. In the Upper Bay, the 1996 year-class contributed 25% to the un-weighted and weighted female CPUEs. The next greatest contribution to female CPUE was from the 15+ age group, which contributed 24% to the un-weighted and weighted female CPUEs in the Upper Bay and 22% in the Potomac.

Temperature and catch patterns

Surface water temperatures on the Potomac River increased between April 4 and April 8, reaching 15°C on April 6. Surface water temperatures stayed stable until a second temperature rise over April 29-May 7. Daily water temperatures ranged from 11.5°C to 21.7°C. The first peak in female CPUE on April 6 corresponded with water temperatures rising quickly from 11.9°C to 17.2°C. Daily female CPUEs on the Potomac suggested early spawning activity with additional peaks on April 10 and April 15 (Figure 2). These peaks in female CPUE correspond with high concentrations of males encountered on April 3 and April 10, suggesting possible spawning activity.

Surface water temperatures on the upper Bay during the spawning survey ranged from 9.3°C to 20.6°C. Daily female CPUEs from the upper Bay were sporadic with large peaks on April 9, following the rapid rise in water temperature to 17.5°C, and again on April 16 (Figure 3). Smaller peaks were also observed in late April and early May. The highest catches of male striped bass in the upper Bay occurred between April 6-9, corresponding with a rapid rise in water temperatures to 17.5°C. Another peak occurred on May 1, prior to the second large increase in water temperature. The highest peaks for both sexes occurred in the first two weeks of April, suggesting an early spawn. These observations were supported by the spring season creel survey (Project No. 2, Job No. 3, Task 5B) which showed 71% of females harvested during the trophy season (April 17-May 15) to be post-spawn. This was the highest percentage of post-spawn females harvested since the survey began in 2002.

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

Length composition of the stock

In 2010, 1,873 male and 71 female striped bass were measured. On the Potomac River, 616 male and 25 female striped bass were sampled and 1,257 males and 46 females were sampled from the Upper Bay (Figure 4). Mean lengths of each sex reflected known biology of the species, as there was a significant difference in mean length between the male and female spawning stocks encountered (both areas combined) in 2010 ($P < 0.001$). Mean lengths are reported with 95% confidence intervals.

Mean lengths of male striped bass collected from the Potomac River (467 ± 4 mm TL) and upper Bay (566 ± 4 mm TL) were significantly different ($P<0.0001$) in 2010. This is supported by the significant differences in length distributions (χ^2=96.23, α=0.05, $P<0.0001$).

Male striped bass on the Potomac ranged from 238 to 1032 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 510 mm TL composed 69% of the Potomac River male catch in 2010 (Figure 4). Potomac male CPUEs (both uncorrected and selectivity-corrected) peaked between 390 and 510 mm TL, representing a combination of the 2005, 2006 and 2007 year-classes (Figure 5). The peak at 830 mm was primarily composed of the 2001 year-class.

Male striped bass on the upper Bay ranged from 273 to 1086 mm TL. Males between 470 and 550 mm TL contributed 39% 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. Application of the selectivity model to the data corrected the catch upward across the length distribution. This was particularly evident in the selectivity-corrected CPUE peak between 310 and 370 mm length groups, representing the 2007 year-class. The second peak in both corrected and uncorrected CPUEs from the 470 to 550 mm length group represents the 2005 year-class (Figure 5). The 1995 and 1996 year-classes were represented in the corrected CPUE peak at 1050 mm.

Mean lengths of female striped bass sampled from the Potomac River and upper Bay in 2010 were not significantly different (P=0.09). Female striped bass sampled from the Potomac ranged from 879 to 1130 mm TL (mean=1029 ± 15), while females sampled in the upper Bay ranged from 707 to 1176 mm TL (mean=992 ± 14; 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 2010 resulted in few discernable peaks in CPUE. The highest corrected CPUE occurred in the 1110 mm TL length group, which was primarily composed of the 1996 year-class (Figure 6).

In the upper Bay, female corrected and uncorrected CPUEs cover a slightly wider range of length groups. The corrected CPUE peak at 710 mm TL was composed of the 2002 and 2003 year-classes. The 2000 year-class is evident in the corrected CPUE peak at 910 mm TL. The corrected CPUE peaks between 1050 and 1090 mm TL reflect the continued contribution of the 1996 year-class.

Length at age (LAA)

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 at those particular ages 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 between years (2009 and 2010), differences between areas (Upper Bay and Potomac), and an interaction effect. No differences between sample areas were detected in LAA for either sex in 2010 ($p>0.05$)

Based on this year's analysis and 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 2010 to produce separate male and female ALKs (Warner et al., 2006, Warner et al., 2008). Patuxent River CWT survey fish were not available as that survey was discontinued this year.

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 between 2009 and 2010 for all ages except for age 2 (ANOVA, $\alpha=0.05$, $P=0.01$). Mean lengths of females were similar between 2009 and 2010 for all ages except age 9 (ANOVA, $\alpha=0.05$, $P=0.02$).

Age composition of the stock

During the 2010 survey, seventeen age-classes, ranging from 2 to 18 were encountered (Tables 14 and 15). Male striped bass ranged from ages 2 to 15, with age 7 fish (2003 year-class) being the most abundant male cohort. The majority of females were ages 10 to 14, with two age 8 and two age 18 fish collected. Age 14 (1996 year-class) females were still the major contributors to the total female CPUE (Tables 12 and 13). 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 2010, the largest increases in age-specific CPUEs were indicated by the age 7 (2003 year-class) and age 15+ cohorts. Age 14 fish (1996 year-class) are still contributing to the spawning stock. Females younger than age 7 continued to be uncommon in the spawning stock since 1996 (Figure 9).

In 2010, age 8+ females constituted 94% of the female spawning stock (Figure 10), a slight increase from the previous year. The contribution of females age 8 and older fish to the spawning stock has been at or above 80% since 1997. The percentage of the overall sample (males and females combined) age 8 and older has been variable since 1997 (Figure 11). The 2010 value of 17%, however, is the lowest value since 2000. The percentage of age 8+ fish among males and females 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 been stable from 2006 to 2008 (ASMFC 2009). Trends in ISP in Maryland have differed by system over the past few years. The MD DNR estimate of ISP generated from the upper Bay has varied without trend and in 2010, the ISP (280) was slightly below the time-series average of 287 (Table 16, Figure 12). The 2010 Potomac River female ISP (213) was only slightly above the 2009 value, but still below the time series average of 240. These low values are consistent with the downward trend in ISP over the past few years on the Potomac River.

CITATIONS

ASMFC. 2009. 2009 Stock Assessment Report for Atlantic Striped Bass. A report prepared by the Atlantic Striped Bass Technical Committee. November 2009. 281 pp.

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

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

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

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

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

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

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

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

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

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

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2010.

	MALES				FEMALES			
Length group (mm)	**Upper Bay**	**Potomac River**	**Creel**	**Total**	**Upper Bay**	**Potomac River**	**Creel**	**Total**
230	0	1	0	**1**	0	0	0	**0**
250	0	0	0	**0**	0	0	0	**0**
270	1	0	0	**1**	0	0	0	**0**
290	5	1	0	**6**	0	0	0	**0**
310	3	3	0	**6**	0	0	0	**0**
330	3	3	0	**6**	0	0	0	**0**
350	3	3	0	**6**	0	0	0	**0**
370	3	3	0	**6**	0	0	0	**0**
390	3	3	0	**6**	0	0	0	**0**
410	3	3	0	**6**	0	0	0	**0**
430	3	3	0	**6**	0	0	0	**0**
450	3	3	0	**6**	0	0	2	**2**
470	3	3	0	**6**	0	0	2	**2**
490	3	3	0	**6**	0	0	6	**6**
510	3	3	0	**6**	0	0	2	**2**
530	3	4	0	**7**	0	0	3	**3**
550	3	3	0	**6**	0	0	3	**3**
570	7	3	0	**10**	0	0	1	**1**
590	6	4	0	**10**	0	0	2	**2**
610	8	2	0	**10**	0	0	0	**0**
630	6	4	0	**10**	0	0	0	**0**
650	6	4	0	**10**	0	0	0	**0**
670	5	5	0	**10**	0	0	0	**0**
690	7	3	0	**10**	0	0	1	**1**
710	7	3	2	**12**	1	0	2	**3**
730	7	3	5	**15**	0	0	2	**2**
750	7	3	5	**15**	0	0	3	**3**
770	8	2	5	**15**	0	0	3	**3**
790	10	0	4	**14**	0	0	3	**3**
810	9	1	5	**15**	0	0	4	**4**
830	9	1	2	**12**	1	0	8	**9**
850	9	1	5	**15**	0	0	14	**14**
870	9	1	2	**12**	0	1	14	**15**
890	8	2	4	**14**	5	1	9	**15**
910	9	1	3	**13**	2	1	12	**15**
930	9	0	3	**12**	4	1	10	**15**
950	2	0	3	**5**	6	0	9	**15**
970	7	0	2	**9**	3	2	10	**15**
990	7	0	0	**7**	3	3	9	**15**
1010	5	0	0	**5**	5	0	10	**15**
1030	1	1	0	**2**	4	3	6	**13**
1050	1	0	0	**1**	2	4	5	**11**
1070	1	0	0	**1**	1	0	9	**10**
1090	1	0	0	**1**	2	4	2	**8**
1110	0	0	0	**0**	2	3	4	**9**
1130	0	0	0	**0**	1	2	1	**4**
1150	0	0	0	**0**	1	0	0	**1**
1170	0	0	0	**0**	3	0	1	**4**
Total	**216**	**86**	**50**	**352**	**46**	**25**	**172**	**243**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2010 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. Revised estimates are shown for 1999 and 2001-2010.

	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**
Average																**27**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2010 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. Revised estimates are shown for 1999 and 2001-2010.

	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**
Average																**444**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the upper Bay during the 1985-2010 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. Revised estimates are shown for 1997 and 1999-2010.

	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**
Average																**35**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the upper Bay during the 1985-2010 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. Revised estimates are shown for 1997 and 1999-2010.

	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**
Average																**454**

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 pooled, weighted, annual age-specific CPUEs (1985–2010) 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. Revised estimates are shown for 1997 and 1999-2010.

	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**
Average																**497**

Table 9. Lower confidence limits (95%) of the pooled, weighted, annual age-specific CPUEs (1985–2010) 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. Revised estimates are shown for 1997 and 1999-2010.

	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	*

* 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 pooled, weighted, annual age-specific CPUEs (1985–2010) 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. Revised estimates are shown for 1997 and 1999-2010.

	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	*

* 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 pooled, weighted, annual age-specific CPUEs (1985–2010) for the Maryland Chesapeake Bay striped bass spawning stock. Revised estimates are shown for 1997 and 1999-2010.

	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	0.0	*
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	0.0	*
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	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	*

* 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, April through May 2010. 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
2009	1	0.0	0.0	0.0	0.0	0.0	0.0
2008	2	13.4	1.6	0.0	0.0	3.2	10.2
2007	3	282.7	33.2	0.0	0.0	104.9	177.8
2006	4	103.6	12.2	0.0	0.0	58.0	45.6
2005	5	124.1	14.6	0.0	0.0	49.2	74.8
2004	6	93.3	11.0	0.0	0.0	29.7	63.6
2003	7	98.3	11.6	0.0	2.3	23.9	72.1
2002	8	11.5	1.4	0.1	1.3	1.7	8.4
2001	9	25.9	3.0	2.1	2.2	6.8	14.8
2000	10	18.8	2.2	2.3	2.7	3.6	10.1
1999	11	7.0	0.8	0.7	1.4	0.9	4.1
1998	12	9.3	1.1	1.5	2.0	1.2	4.7
1997	13	10.9	1.3	2.2	2.1	1.3	5.4
1996	14	18.6	2.2	5.9	6.6	0.6	5.4
≤1995	15+	33.3	3.9	4.1	6.3	0.4	22.5
Total		850.8		18.9	26.9	285.4	519.6
% of Total				2	3	34	61
% of Sex				41	59	35	65
% of Potomac				6		94	
% of Upper Bay					5		95

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, April through May 2010. 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
2009	1	0.0	0.0	0.0	0.0	0.0	0.0
2008	2	7.5	1.7	0.0	0.0	1.2	6.3
2007	3	149.7	33.0	0.0	0.0	40.4	109.3
2006	4	50.4	11.1	0.0	0.0	22.4	28.0
2005	5	65.0	14.3	0.0	0.0	19.0	46.0
2004	6	50.5	11.2	0.0	0.0	11.4	39.1
2003	7	54.9	12.1	0.0	1.4	9.2	44.3
2002	8	6.7	1.5	0.0	0.8	0.6	5.2
2001	9	13.9	3.1	0.8	1.4	2.6	9.1
2000	10	10.2	2.2	0.9	1.7	1.4	6.2
1999	11	4.0	0.9	0.3	0.8	0.3	2.5
1998	12	5.1	1.1	0.6	1.2	0.5	2.9
1997	13	5.9	1.3	0.8	1.3	0.5	3.3
1996	14	9.9	2.2	2.3	4.1	0.2	3.3
≤1995	15+	19.4	4.3	1.6	3.9	0.2	13.8
Total		453.1		7.3	16.5	110.0	319.3
% of Total				2	4	24	70
% of Sex				31	69	26	74
% of Potomac				6		94	
% of Upper Bay					5		95

* 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, as well as all males combined, April through May 2010.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2008	2	POTOMAC	2	273	-166	711	49	35
		UPPER	3	288	256	320	13	7
		COMBINED	5	282	248	316	27	12
2007	3	POTOMAC	17	368	343	393	49	12
		UPPER	24	363	342	384	50	10
		COMBINED	41	365	349	380	49	8
2006	4	POTOMAC	8	429	384	473	53	19
		UPPER	5	453	409	498	36	16
		COMBINED	13	438	410	466	47	13
2005	5	POTOMAC	16	530	494	567	69	17
		UPPER	7	529	478	580	55	21
		COMBINED	23	530	502	558	64	13
2004	6	POTOMAC	10	607	565	649	59	19
		UPPER	29	620	589	652	83	15
		COMBINED	39	617	592	642	77	12
2003	7	POTOMAC	16	663	626	700	70	18
		UPPER	57	702	680	725	84	11
		COMBINED	73	694	674	713	83	10
2002	8	POTOMAC	7	727	648	806	85	32
		UPPER	4	778	616	940	102	51
		COMBINED	11	746	685	806	90	27
2001	9	POTOMAC	6	805	737	872	64	26
		UPPER	21	833	805	860	60	13
		COMBINED	27	827	802	851	61	12
2000	10	POTOMAC	2	804	-397	2004	134	95
		UPPER	20	853	824	881	62	14
		COMBINED	22	848	818	878	67	14
1999	11	POTOMAC	0	-	-	-	-	-
		UPPER	9	892	863	922	38	13
		COMBINED	9	892	863	922	38	13
1998	12	POTOMAC	0	-	-	-	-	-
		UPPER	11	939	905	972	50	15
		COMBINED	11	939	905	972	50	15
1997	13	POTOMAC	0	-	-	-	-	-
		UPPER	11	913	867	959	69	21
		COMBINED	11	913	867	959	69	21
1996	14	POTOMAC	0	-	-	-	-	-
		UPPER	11	979	944	1014	52	16
		COMBINED	11	979	944	1014	52	16
1995	15	POTOMAC	1	1032	-	-	-	-
		UPPER	3	1045	942	1148	42	24
		COMBINED	4	1042	987	1097	35	17

Table 15. Mean length-at-age (mm TL) statistics for female striped bass collected in the Potomac River and the upper Bay, as well as all females combined, April through May 2010.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2003	7	POTOMAC	0	-	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	0	-	-	-	-	-
2002	8	POTOMAC	0	-	-	-	-	-
		UPPER	2	770	-30	1570	89	63
		COMBINED	2	770	-30	1570	89	63
2001	9	POTOMAC	1	879	-	-	-	-
		UPPER	5	907	882	933	20	9
		COMBINED	6	903	880	925	22	9
2000	10	POTOMAC	3	928	797	1059	53	30
		UPPER	10	935	907	963	39	12
		COMBINED	13	934	909	958	40	11
1999	11	POTOMAC	1	992	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	992	-	-	-	-
1998	12	POTOMAC	3	993	910	1075	33	19
		UPPER	8	991	952	1030	47	17
		COMBINED	11	991	963	1020	42	13
1997	13	POTOMAC	4	1030	937	1122	58	29
		UPPER	5	1004	966	1043	31	14
		COMBINED	9	1015	982	1049	44	15
1996	14	POTOMAC	8	1067	1016	1117	60	21
		UPPER	6	1060	987	1132	69	28
		COMBINED	14	1064	1028	1099	62	17
1995	15	POTOMAC	1	1099	-	-	-	-
		UPPER	1	986	-	-	-	-
		COMBINED	2	1043	325	1760	80	57
1994	16	POTOMAC	2	1083	657	1508	47	34
		UPPER	5	1093	1061	1126	26	12
		COMBINED	7	1090	1063	1117	29	11
1993	17	POTOMAC	1	1053	-	-	-	-
		UPPER	1	1176	-	-	-	-
		COMBINED	2	1115	333	1896	87	62
1992	18	POTOMAC	1	1130	-	-	-	-
		UPPER	1	1160	-	-	-	-
		COMBINED	2	1145	954	1336	21	15

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. Revised estimates are shown for 1997-2010.

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
Average	**287.31**	**239.57**

Figure 1. Drift gill net sampling locations in spawning areas of the upper Chesapeake Bay and the Potomac River, April - May 2010.

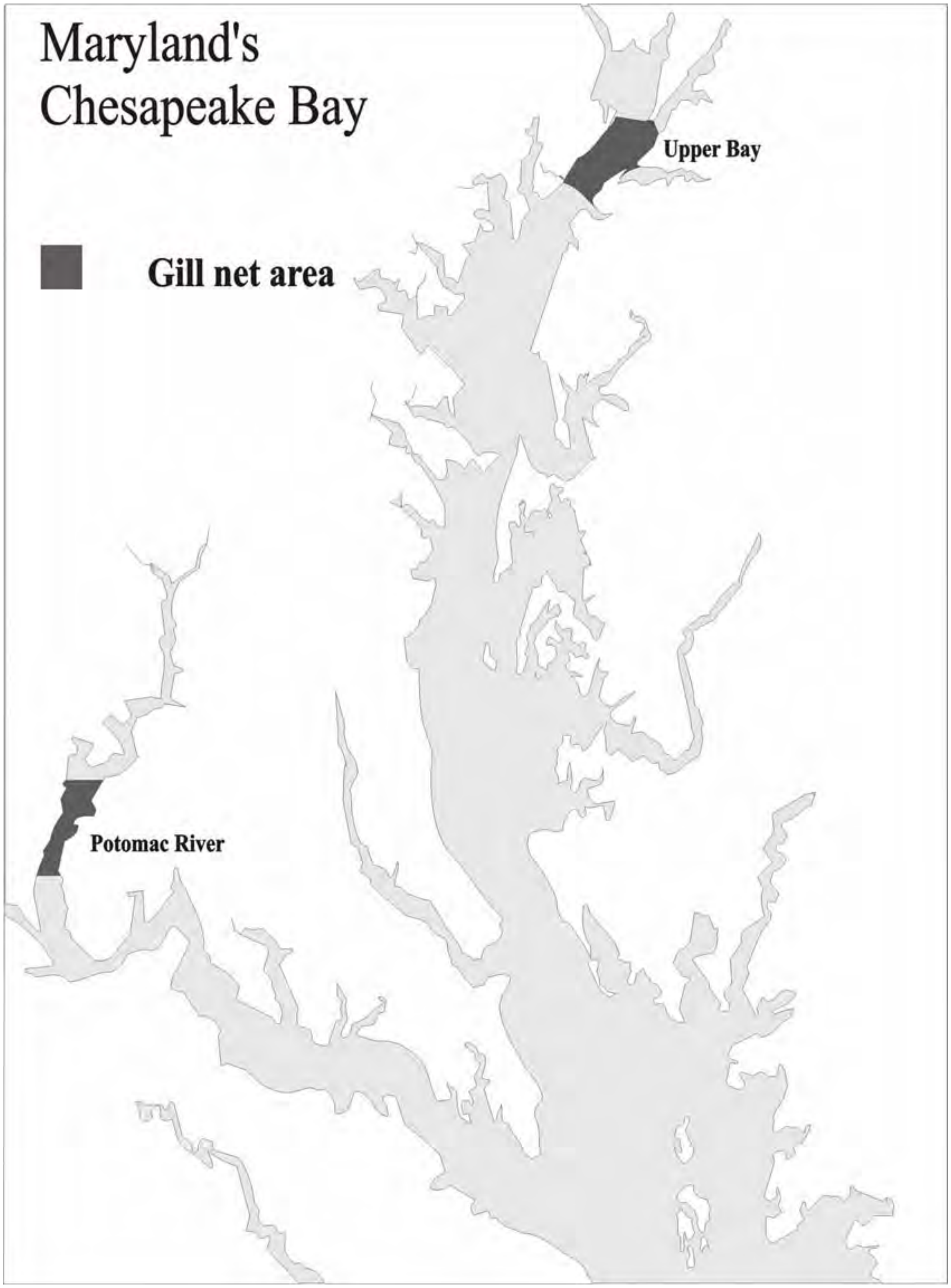


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, April through May 2010. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

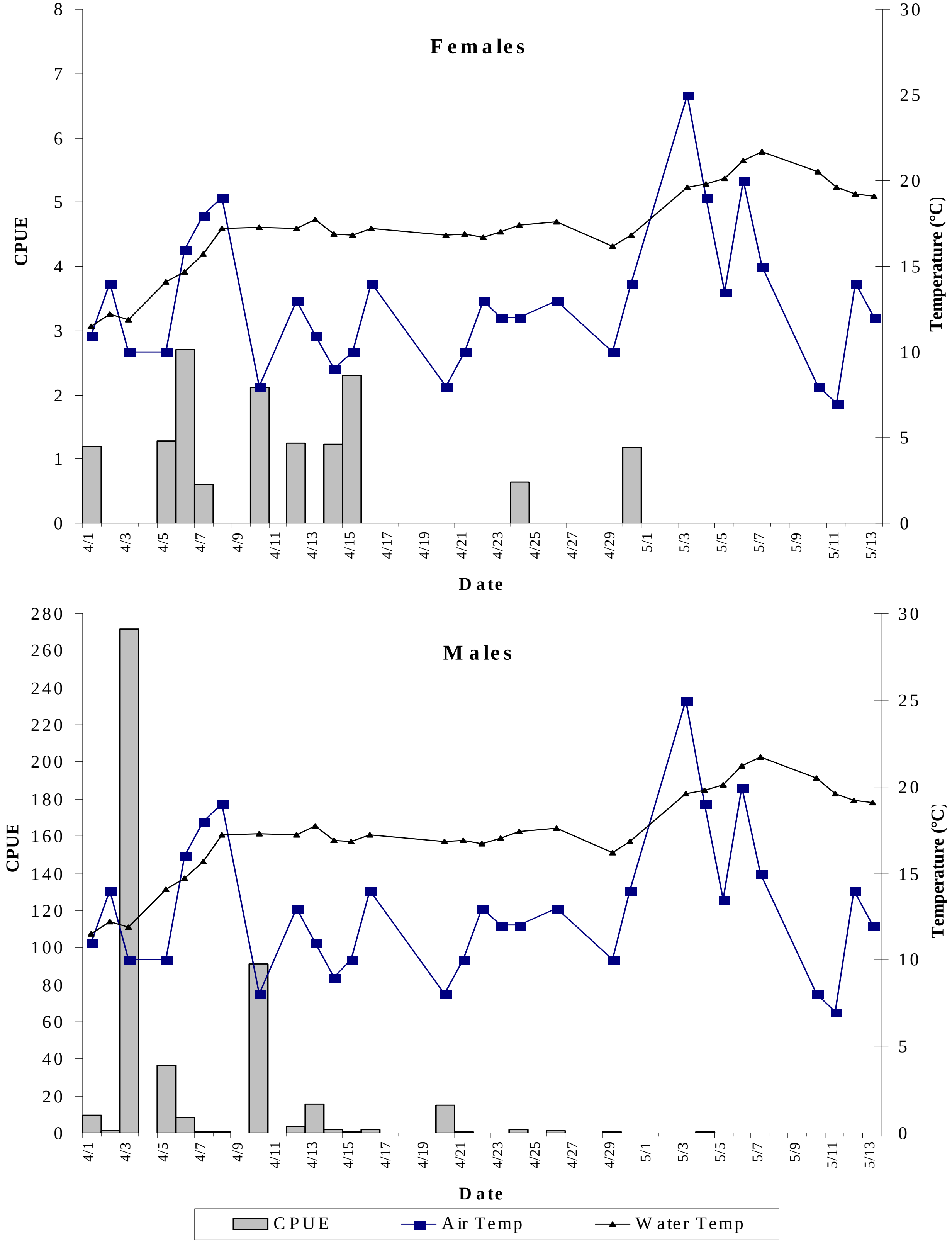


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the upper Chesapeake Bay, April through May 2010. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

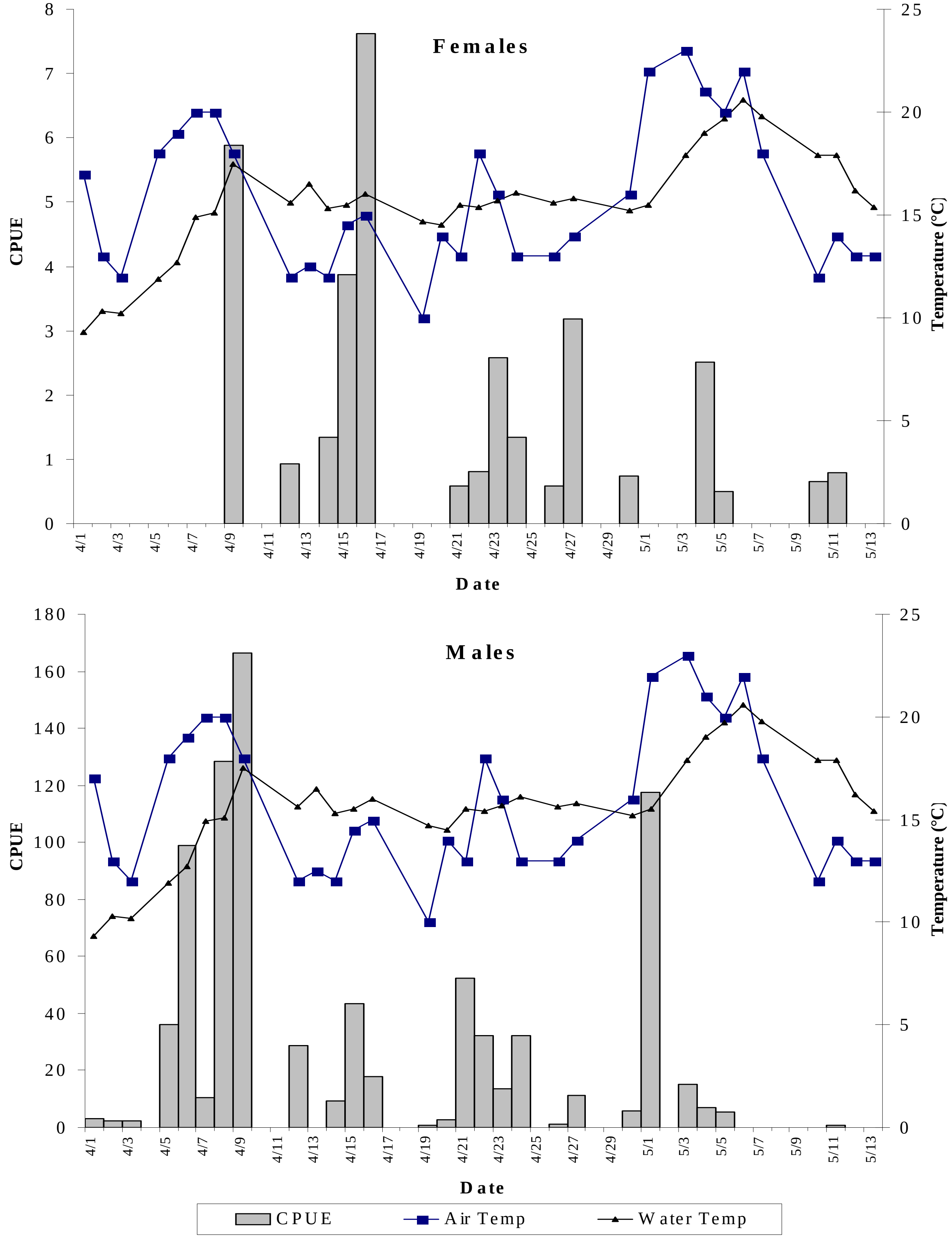
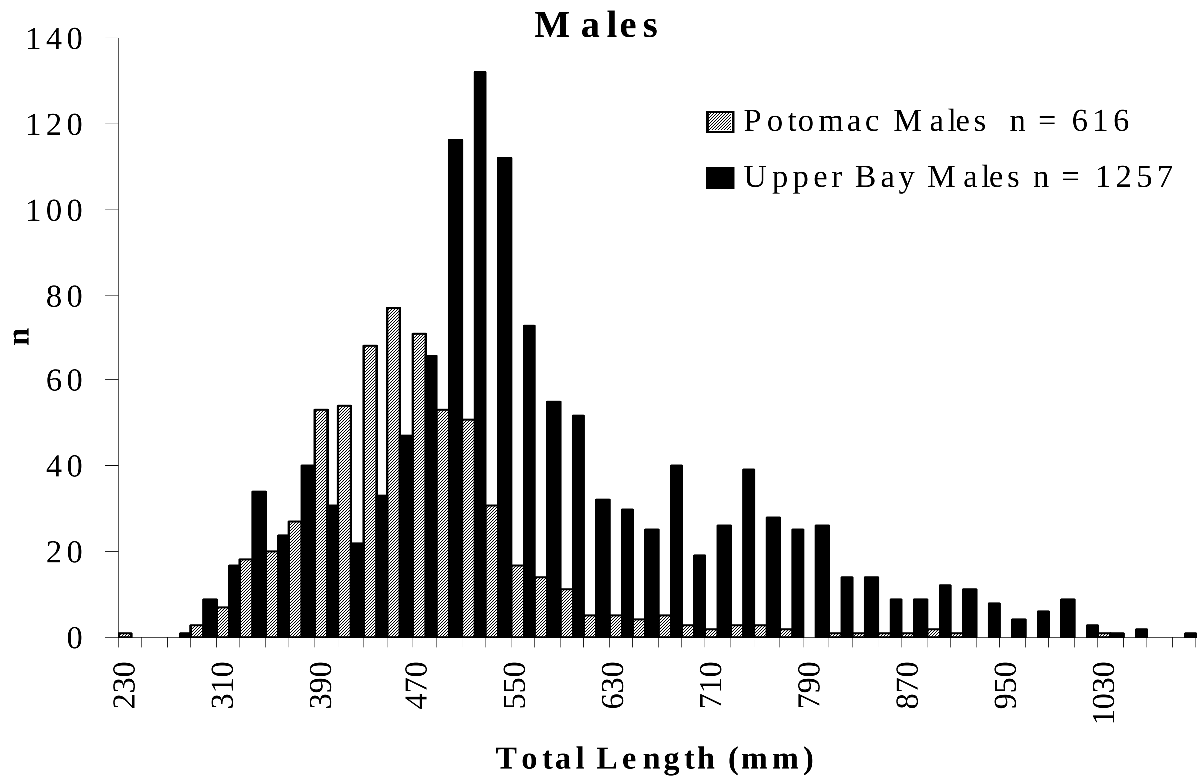


Figure 4. Length frequency of male and female striped bass from the spawning areas of the upper Chesapeake Bay and Potomac River, April through May 2010. Note different scales.



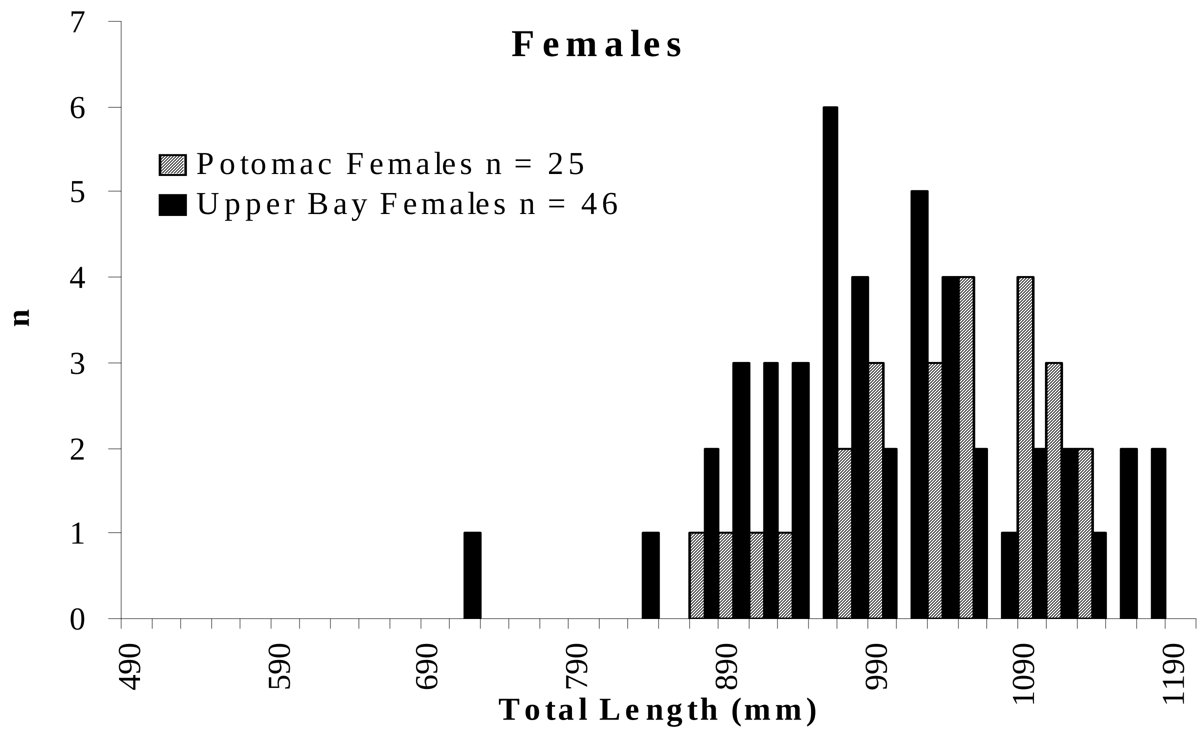
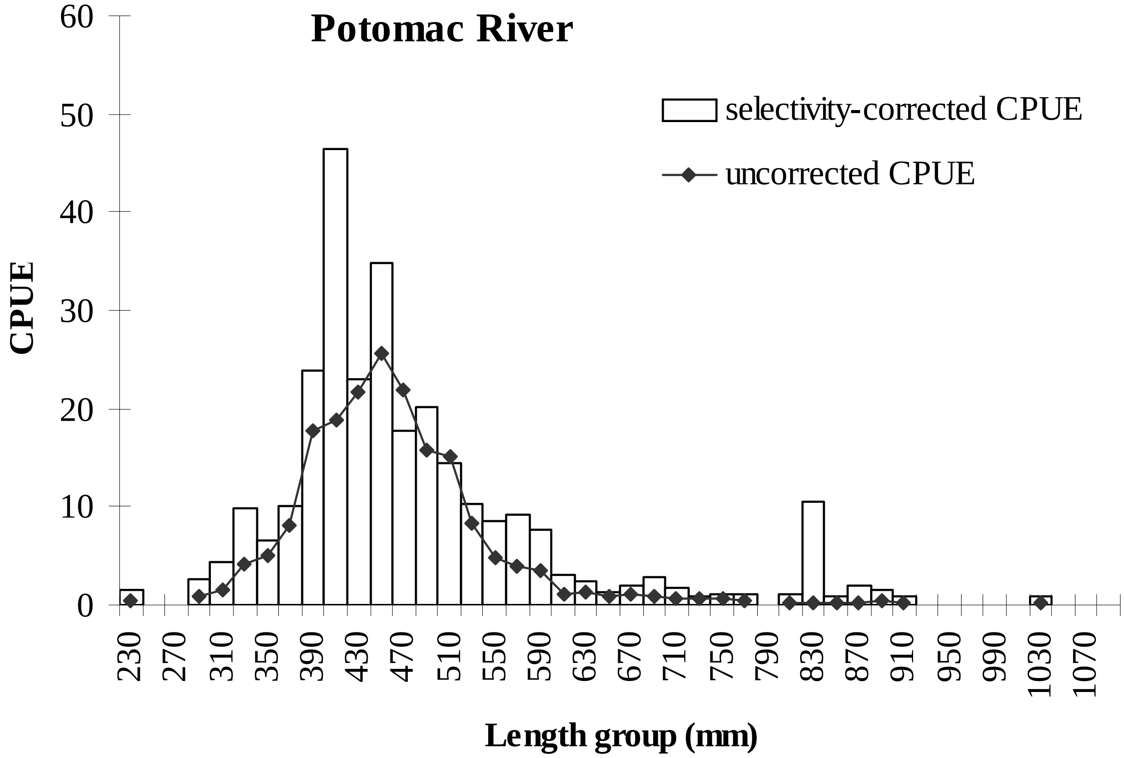


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the upper Bay and Potomac River, April - May 2010. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



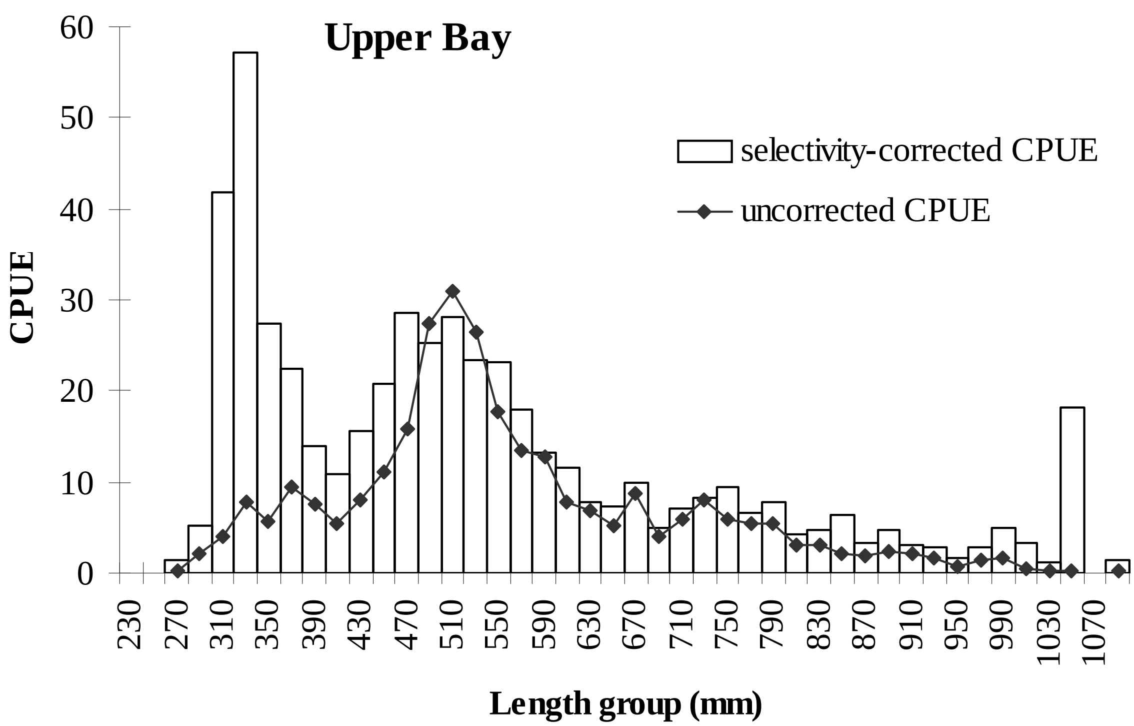
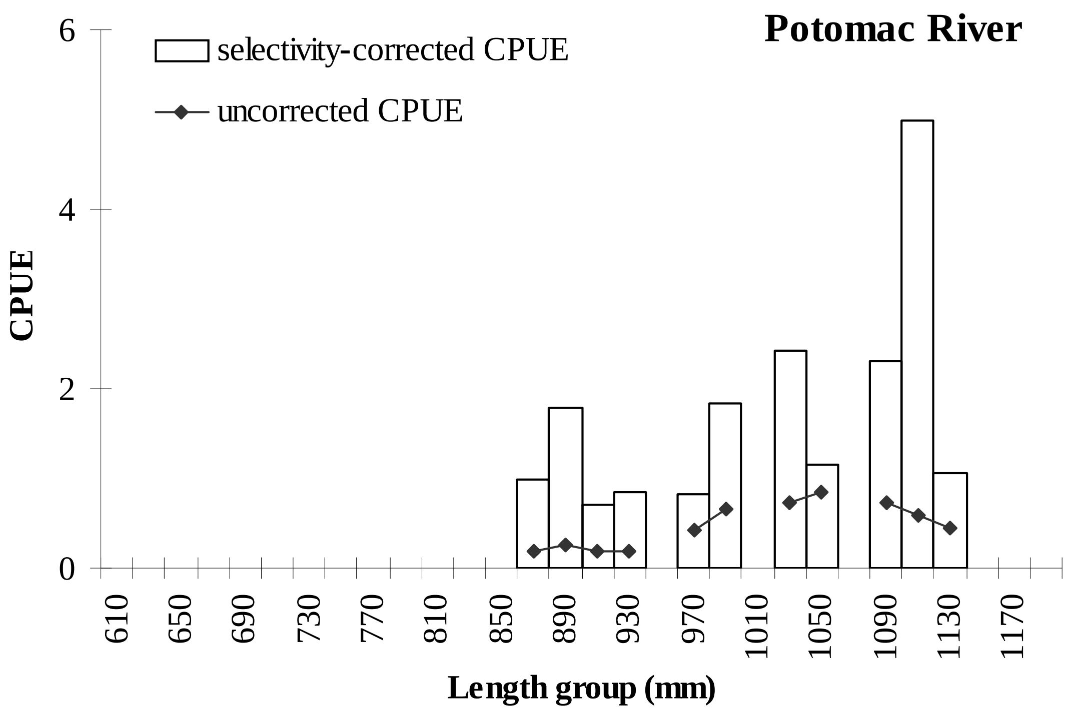


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the upper Bay and Potomac River, April - May 2010. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



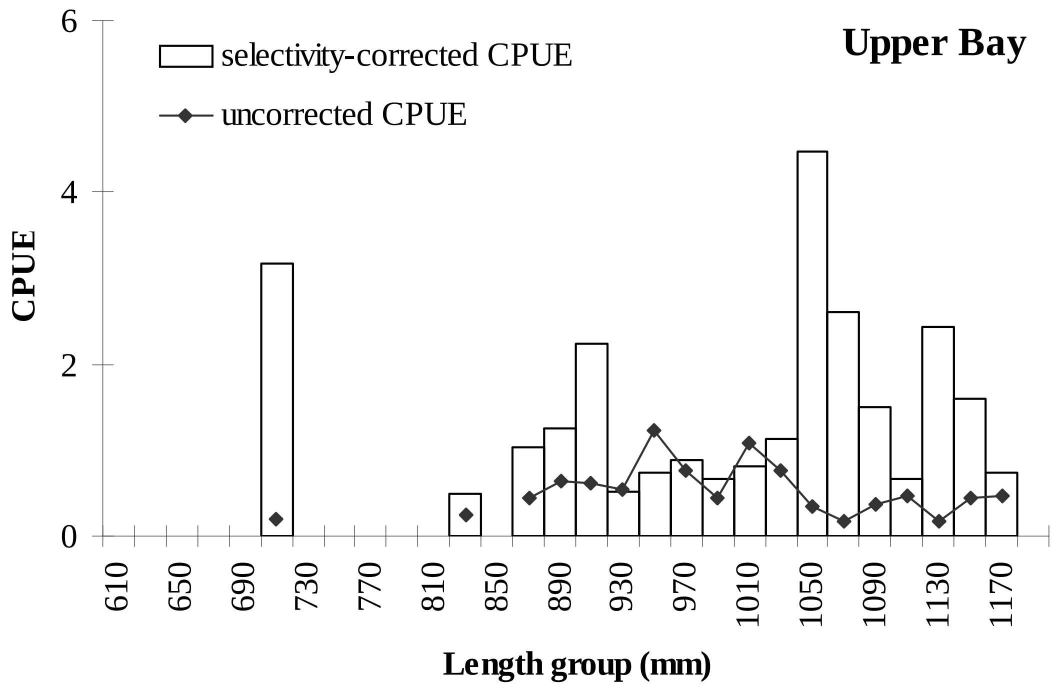


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985-2010. Error bars are ± 1 standard error (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

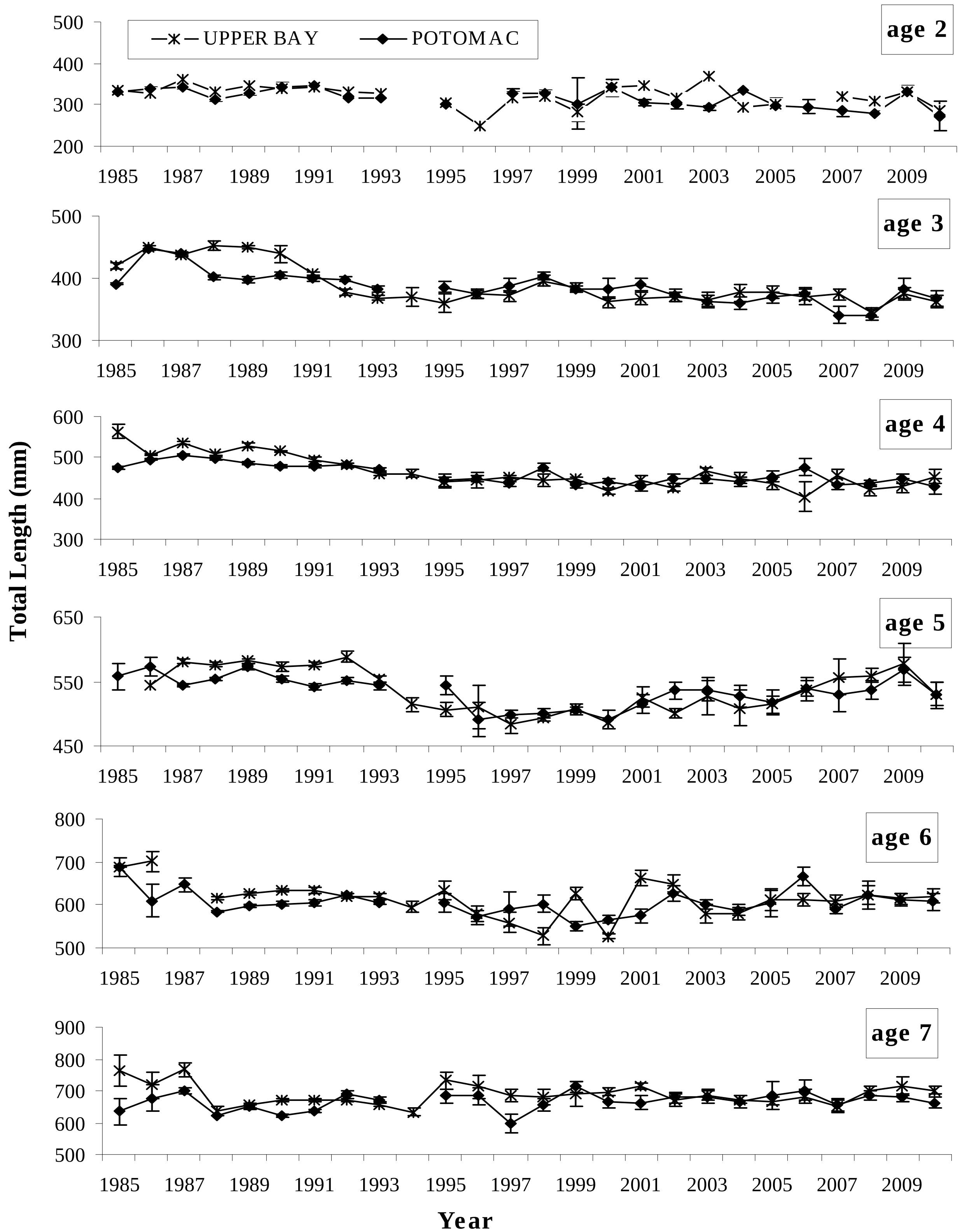


Figure 7. Continued.

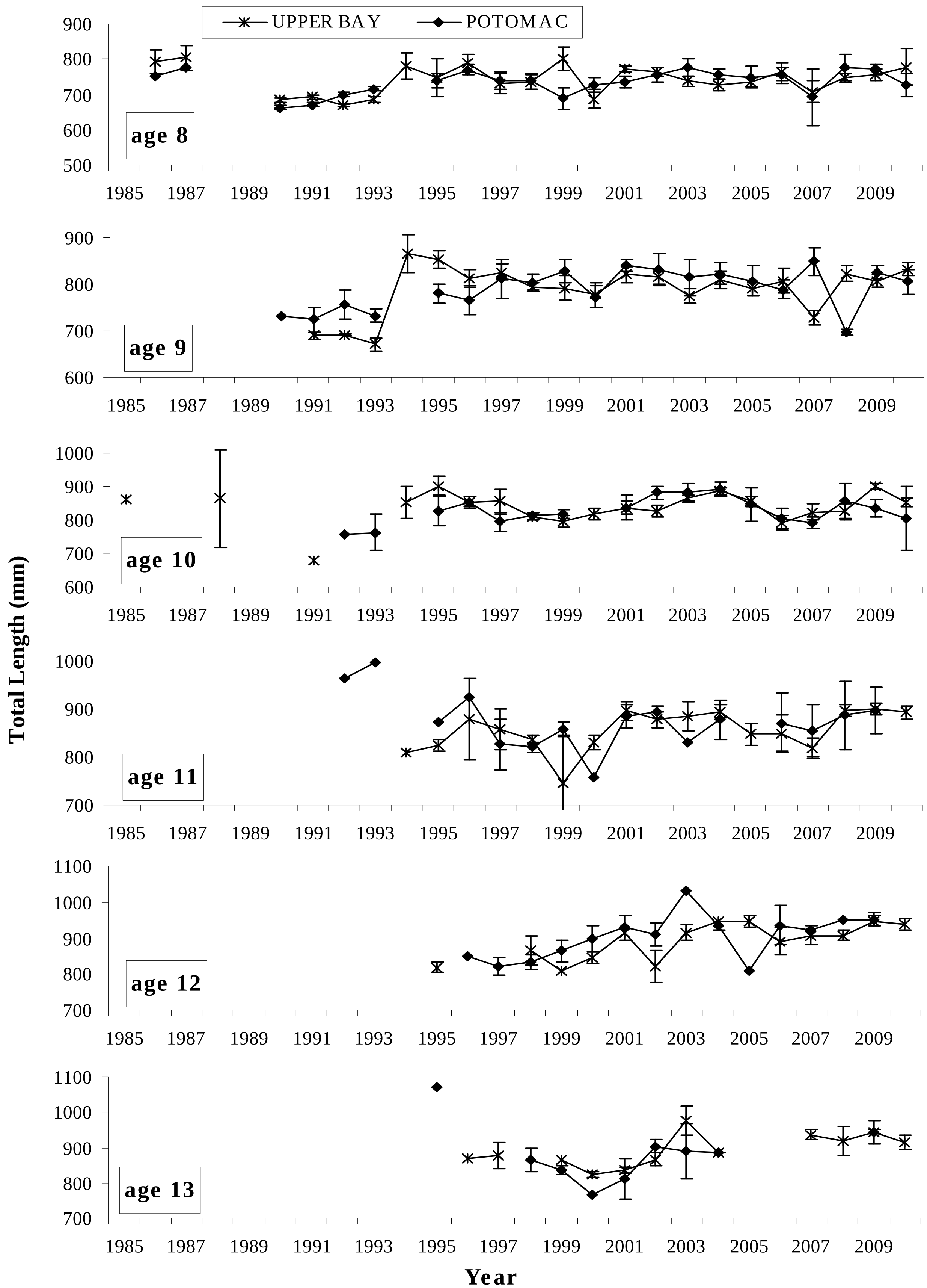


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from
spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985–2010. Error bars are ± 1 standard error (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

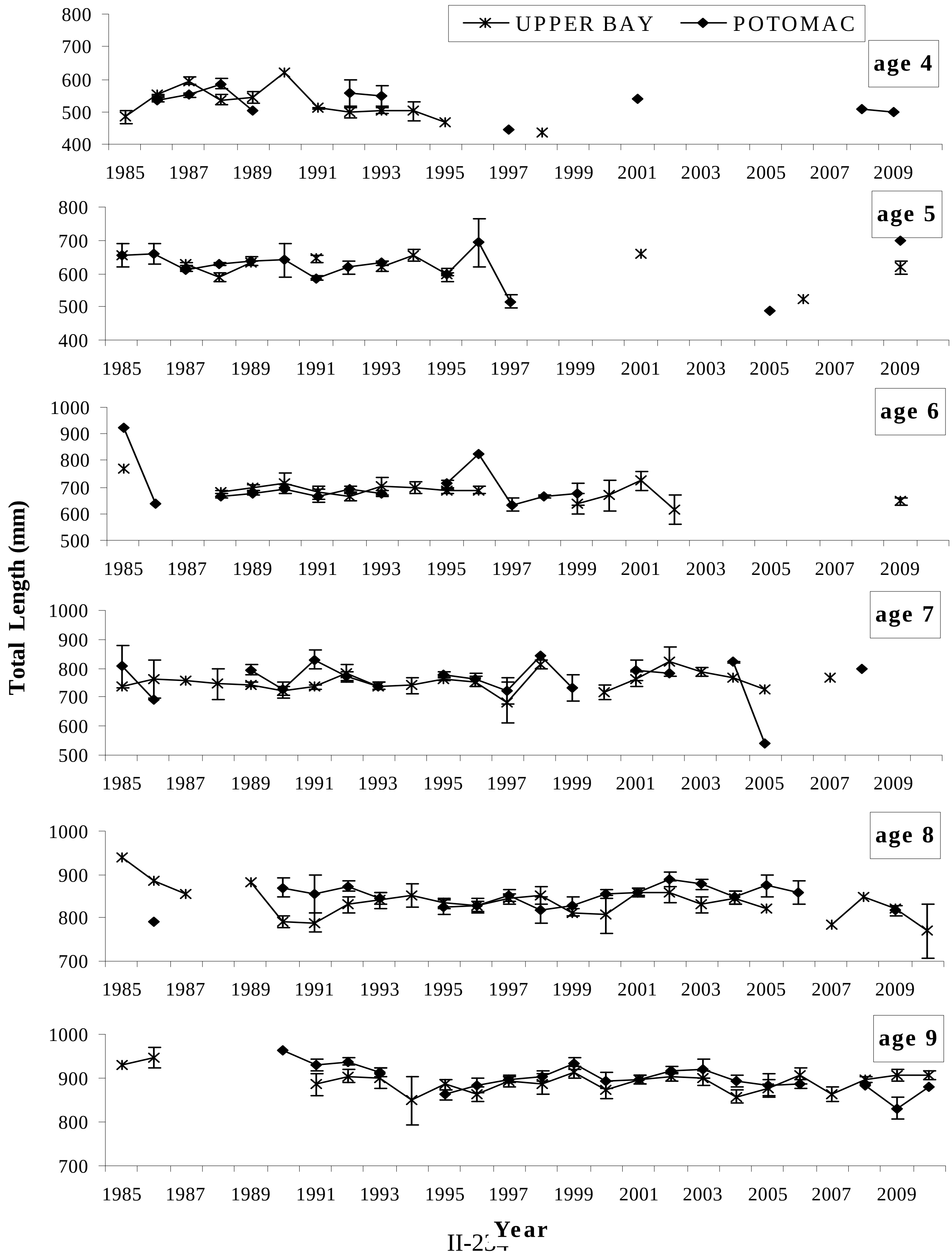


Figure 8. Continued.

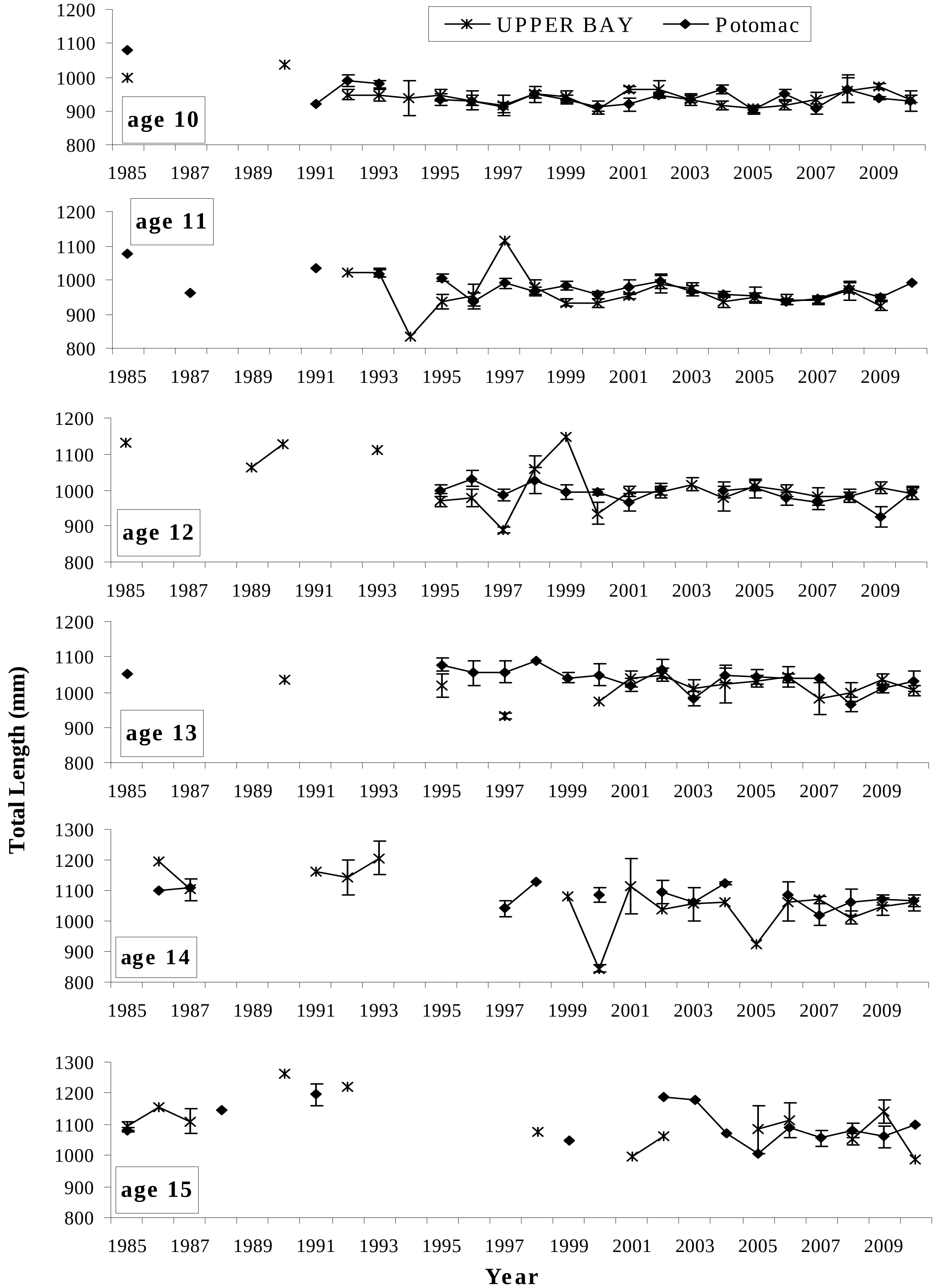


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales. Revised estimates are shown for 1997 and 1999-2010.

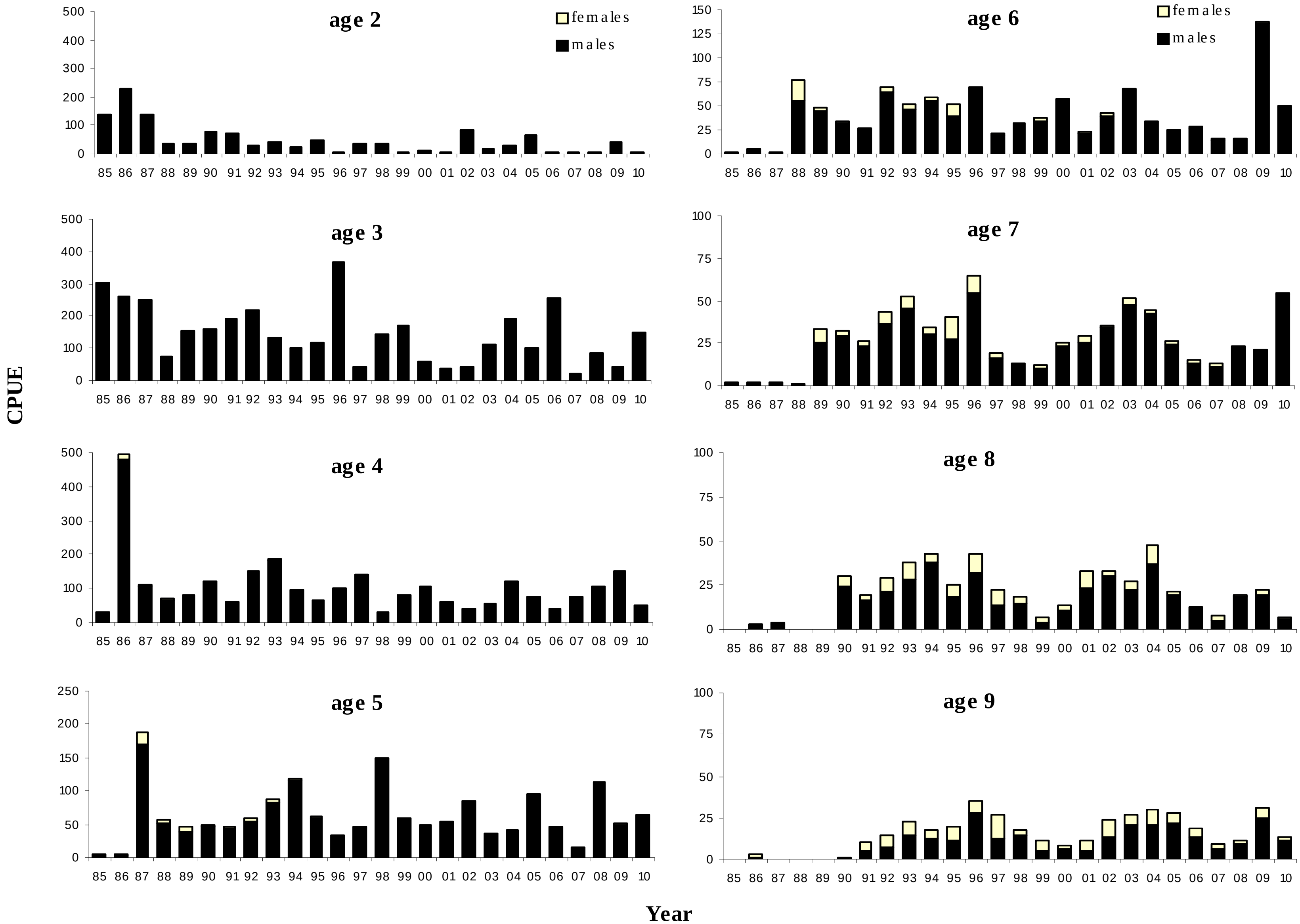


Figure 9. Continued.

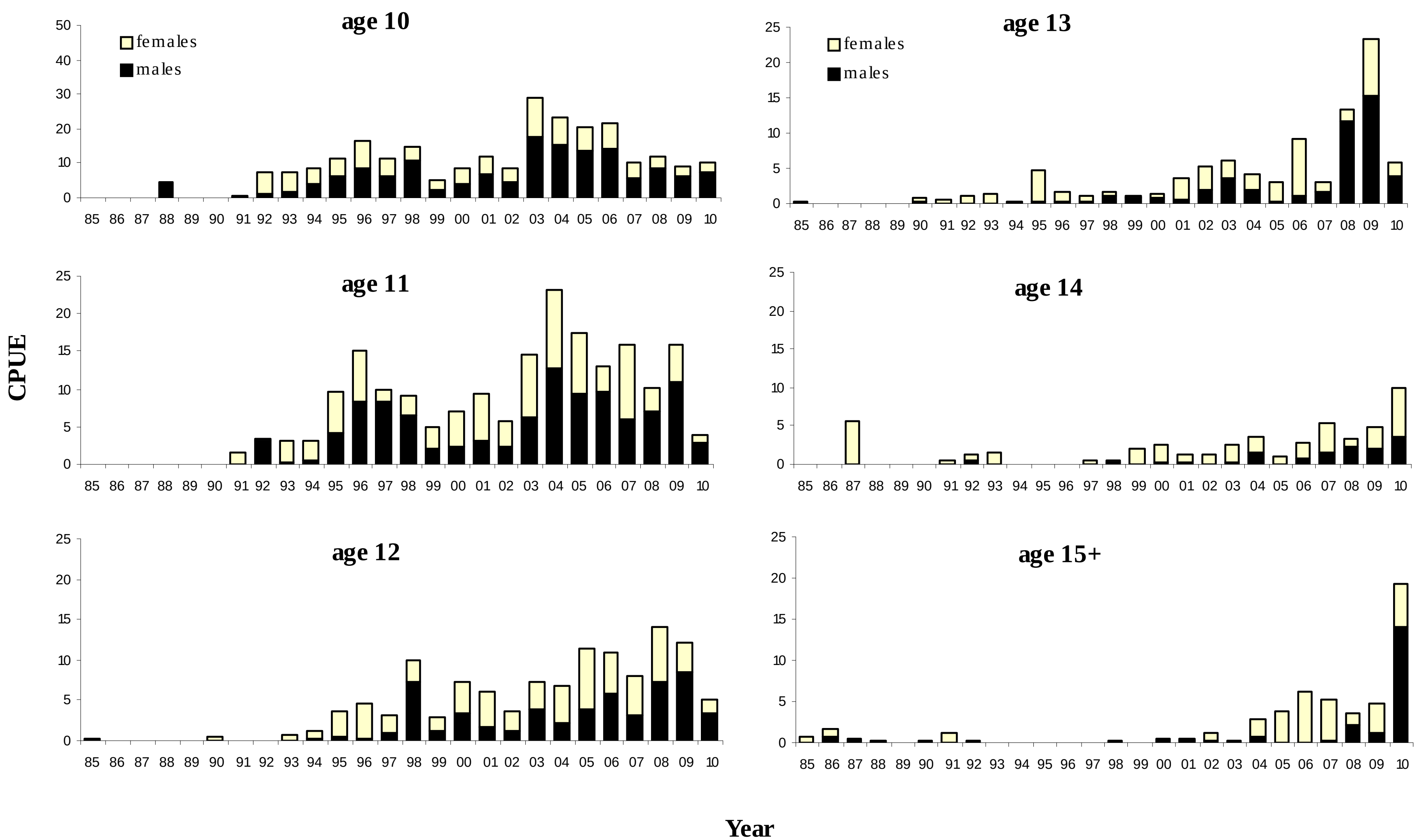
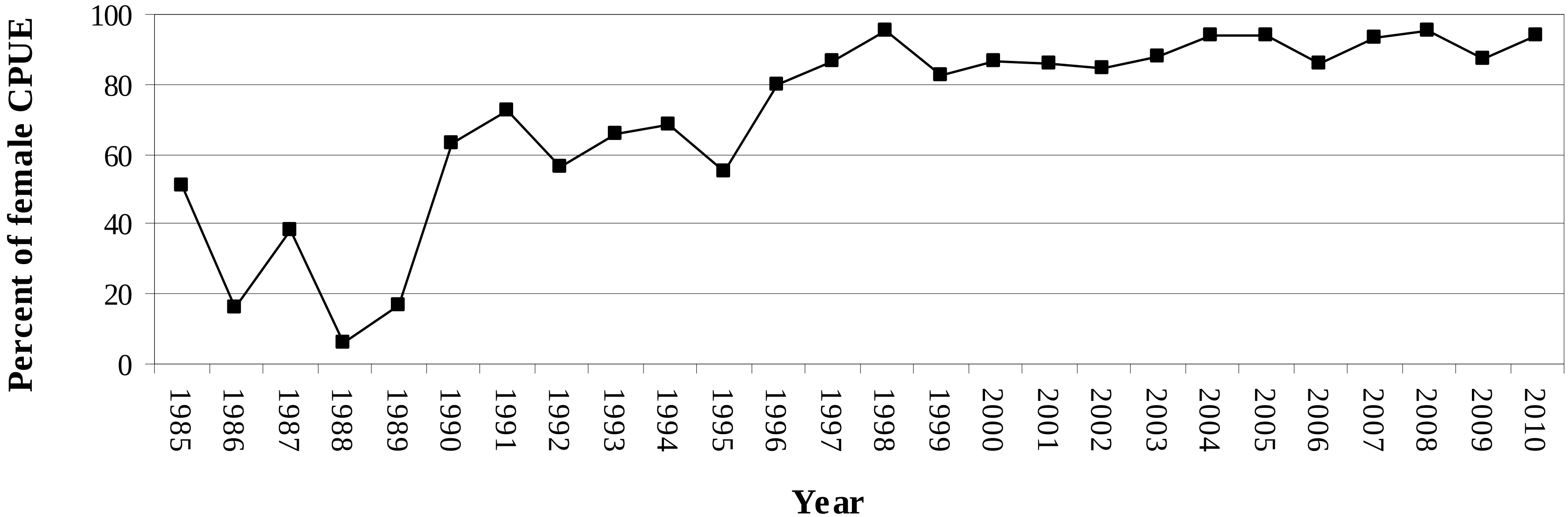
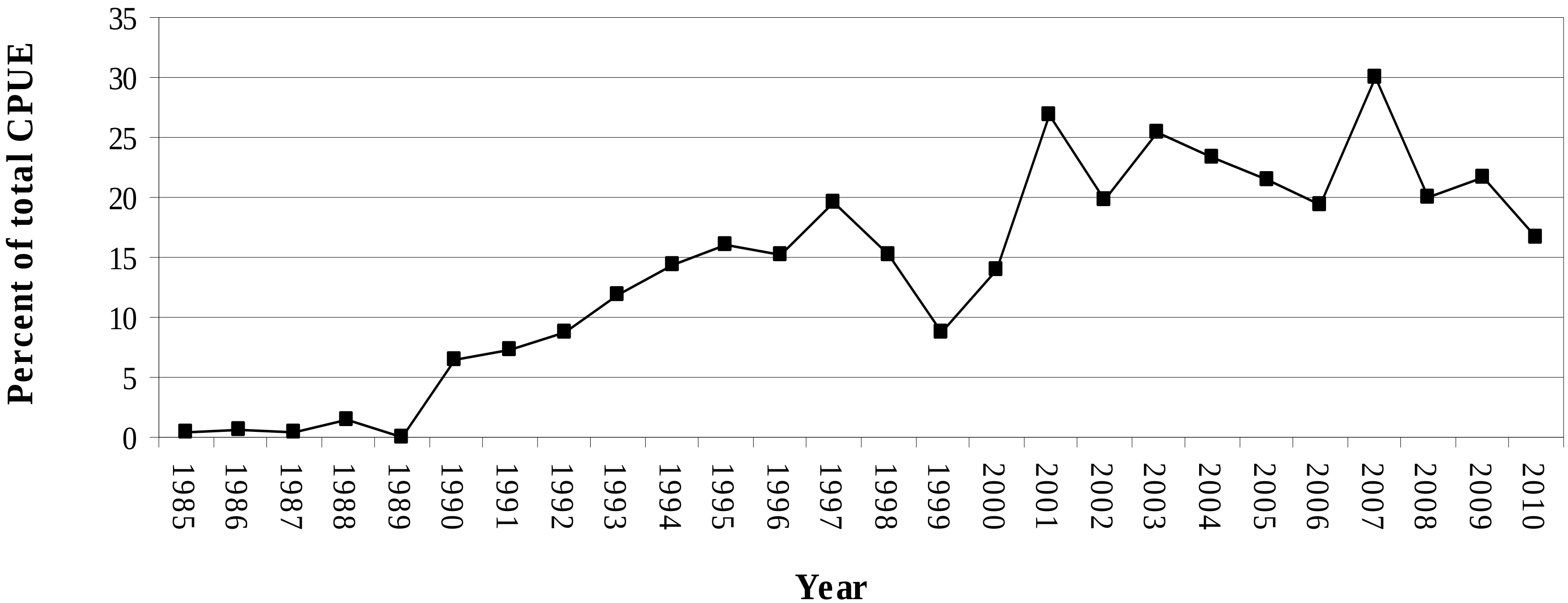


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the upper Chesapeake Bay, late March through May, 1985-2010 (Choptank River to 1996). Effort is 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.* Revised estimates are shown for 1997 and 1999-2010.



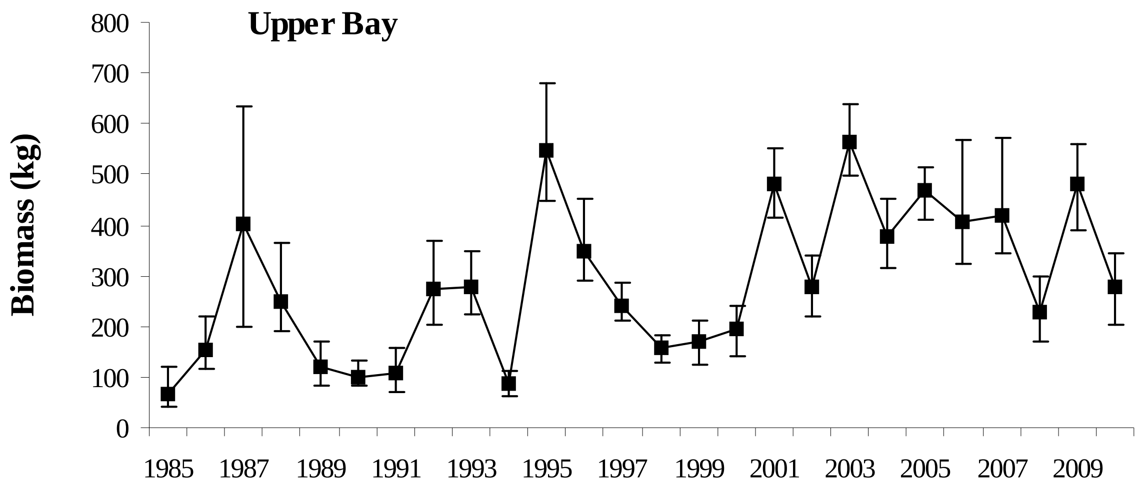
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385 (Hollis 1967).

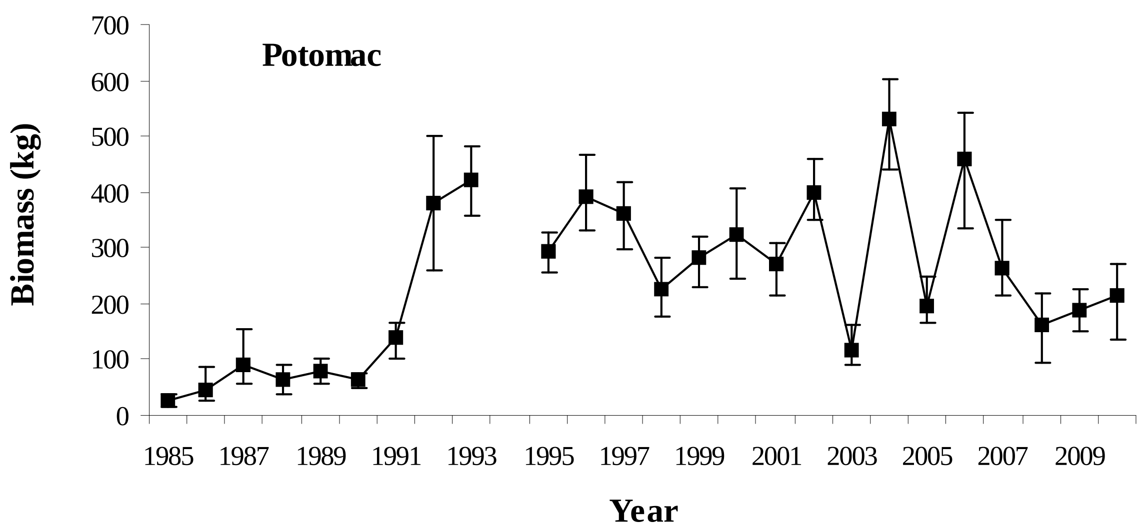
Figure 11. Percentage (selectivity-corrected CPUE) of male and female striped bass age 8 and over sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the upper Chesapeake Bay, late March through May, 1985-2010 (Choptank River to 1996). Effort is 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.* Revised estimates are shown for 1997 and 1999-2010.



*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 from 1985 until present. The index is corrected for gear selectivity, and bootstrap 95% confidence intervals are shown around each point. Note different scales. Revised estimates are shown for 1997-2010.





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. One site change was made in 2010. In 2009, the Morgantown Steam Electric Station site suddenly became inaccessible due to new security restrictions at the facility. A temporary replacement (Morgantown Power Plant Environmental Area, #162) was established just downstream but access was still difficult. In 2010, a permanent replacement site was established just upstream at the privately owned Aqualand Marina.

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 737 juvenile striped bass were collected at permanent stations in 2010. Individual samples yielded between 0 and 67 YOY striped bass. The AM of 5.6 was less than the time-series average (11.6) and the TPA (12.0) (Table 2, Figure 2). The GM of 2.54 (Table 3, Figure 3) was also less than the time-series average (4.20) and the TPA (4.32). The PPHL was 0.77, indicating that 77% 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 the 2010 $\log_e$-mean significantly greater than nine years of the time-series. The 2010 $\log_e$-mean was significantly smaller than 19 years of the time-series, and was not discernible from 25 other years.

System Means

Head of Bay - In 42 samples, 306 juveniles were collected at the Head of Bay sites, resulting in an AM of 7.3, less than the time-series average (11.9) and the TPA of 17.3 (Table 2, Figure 5). The GM of 2.90 was also below the time-series average (5.64) and the TPA (7.27) (Table 3, Figure

6). Differences in annual $\log_e$-means were significant (ANOVA: P<0.0001). Duncan's multiple range test (p=0.05) found the 2010 Head of Bay $\log_e$-mean was significantly greater than only eight years of the time-series, and less than 18 years. The 2010 $\log_e$-mean was indiscernible from 26 year-classes of the time-series.

Potomac River - A total of 241 juveniles was collected in 42 samples. The AM of 5.7 was less than the TPA (9.2) and the time-series average (8.4) (Table 2, Figure 5). The GM of 2.17 was also below the time-series average (3.60) and the 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 2010 Potomac River year-class significantly less than just 10 years, and significantly greater than seven years of the time-series. The 2010 $\log_e$-mean was not significantly different than the 36 other years of the time-series.

Choptank River - A total of 80 juveniles was collected in 24 Choptank River samples. The AM of 3.3 was less than the time-series average of 20.1 and the TPA of 10.8 (Table 2, Figure 5). The GM of 2.23 also fell below its time-series average (7.94) 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 2010 Choptank River year-class smaller than 15 years, and greater than just three years of the time series. The 2010 year-class was not discernible from 35 other years of the time-series.

Nanticoke River - A total of 110 juveniles was collected in 24 samples on the Nanticoke River. The AM of 4.6 was less than the time-series average (8.2) and the TPA (8.6) (Table 2, Figure 5). The GM of 2.96 was less than the time-series average (3.65) and the 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 2010 index significantly smaller than just the top six years of the time-series, and significantly larger than eight years of the time-series. The 2010 index was statistically indiscernible from 39 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 55 juveniles were caught in 15 samples, resulting in an AM of 3.7, which was between its time-series median and average. The GM of 1.45 was less than its time-series average and median (Table 5).

On the **Patuxent River**, 60 YOY striped bass were caught in 18 samples for an AM of 3.3 and a GM of 2.49 (Table 5). Time-series averages for the Patuxent River are inflated by the unusually large year-classes of 1993 and 1996, making the median a better benchmark for comparing the relative strength of year-classes. Both indices were above their respective time-series median values.

DISCUSSION

Survey results indicated a below-average 2010 striped bass year-class in Maryland's Chesapeake Bay. This was the third consecutive year of below average recruitment. The bay-wide AM and GM indices were both below their respective time-series averages and TPAs (Tables 2 and 3). The PPHL (0.77) was the only estimator that exceeds the time-series and target period averages, indicating that YOY striped bass were widely distributed though not abundant (Table 4, Figure 4).

Recruitment was below average in each of the four major spawning areas surveyed. In the Head of Bay system, and the Potomac and Choptank rivers, GM indices were less than their respective time-series and target period averages. GM indices from these three systems ranked in the second quartile of their respective time-series. The Nanticoke River GM was also below its TPA (Table 3), but was the only system in which confidence intervals around the GM bracketed the target period average (Figure 9). The Nanticoke River GM ranked in the third quartile of its time series.

RELATIONSHIP OF AGE 0 TO AGE 1 INDICES

INTRODUCTION

Indices of age 1 (yearling) striped bass (Table 6) developed from the Maryland juvenile striped bass survey 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 ($r^2=0.614$, $p\leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was, $C_1=(0.191233)(C_0)- 0.07151$, 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 (0.16) was less than the index of 0.23 predicted by the regression analysis. Examination of residuals (Figure 11) shows that this regression equation can be used to predict subsequent yearling striped bass abundance with reasonable certainty in the case of small and average sized year-classes. Estimates of future abundance of age 1 striped bass are less reliable for dominant year-classes. Lower than expected abundance of age 1 striped bass may be an indication of density-dependent processes operating at high levels of abundance, such as cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

CITATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

LIST OF TABLES

LIST OF FIGURES

Table 1. Maryland juvenile striped bass survey sample sites.

Site Number	River or Creek	Area or Nearest Land Mark
	HEAD-OF-CHESAPEAKE BAY SYSTEM	
* 58	Susquehanna Flats	North side Spoil Island, 1.9 miles south of Tyding's Park
* 130	Susquehanna Flats	North side of Plum Point
* 144	Susquehanna Flats	Tyding's Estate, west shore of flats
* 132	Susquehanna Flats	0.2 miles east of Poplar Point
* 59	Northeast River	Carpenter Point, K.O.A. Campground beach
3	Northeast River	Elk Neck State Park beach
4	Elk River	Welch Point, Elk River side
5	Elk River	Hyland Point Light
115	Bohemia River	Parlor Point
160	Sassafras River	Sassafras N.R.M.A., opposite Ordinary Point
10	Sassafras River	Howell Point, 500 yards east of point
11	Worton Creek	Mouth of Tim’s Creek, west shore
* 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 sites

Table 1. Continued.

Site Number	River or Creek	Area or Nearest Land Mark
	CHOPTANK RIVER SYSTEM	
2	Tuckahoe Creek	Northeast side near mouth
29	Choptank River	Castle Haven, northeast side
148	Choptank River	North side of Jamaica Point
161	Choptank River	Dickinson Bay, 0.5 miles from Howell Point
	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 sites

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
Average	11.9	8.4	20.1	8.2	11.6
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
Average	5.64	3.60	7.94	3.65	4.20
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
Average	11.7	205.8	1.44	93.23	0.70	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
Average	25.32	6.79		5.57	2.65	
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	NA

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

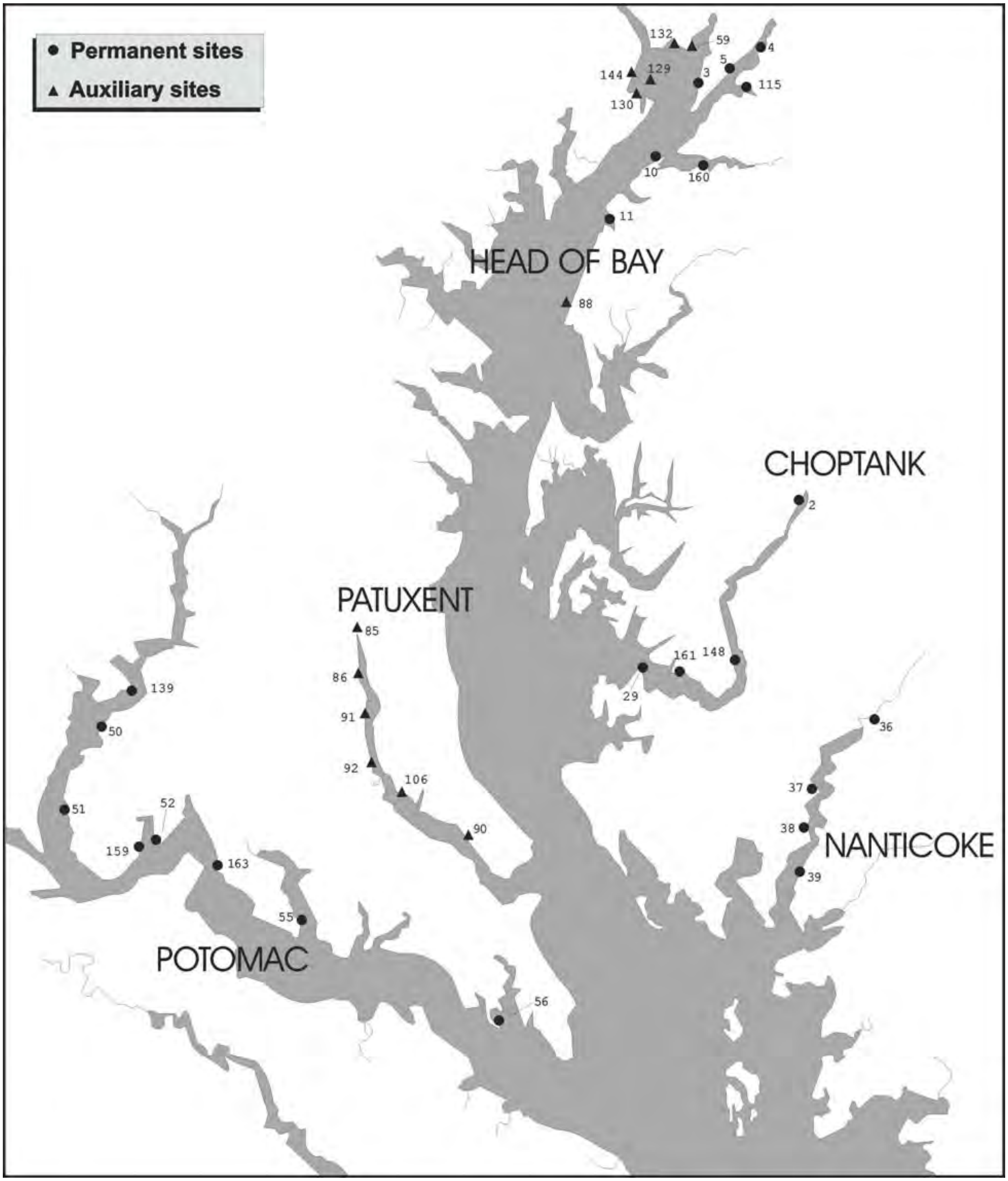


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

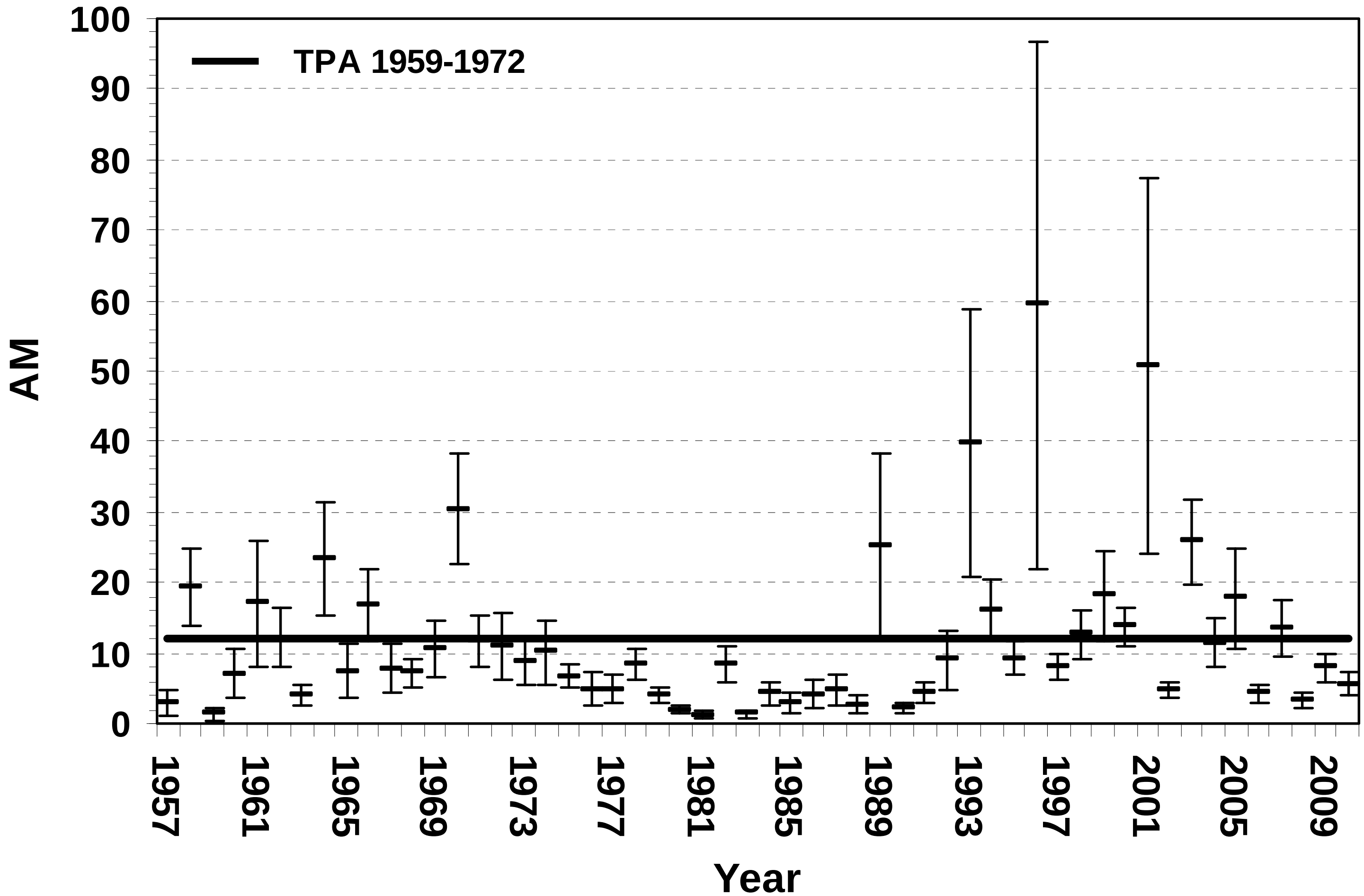


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

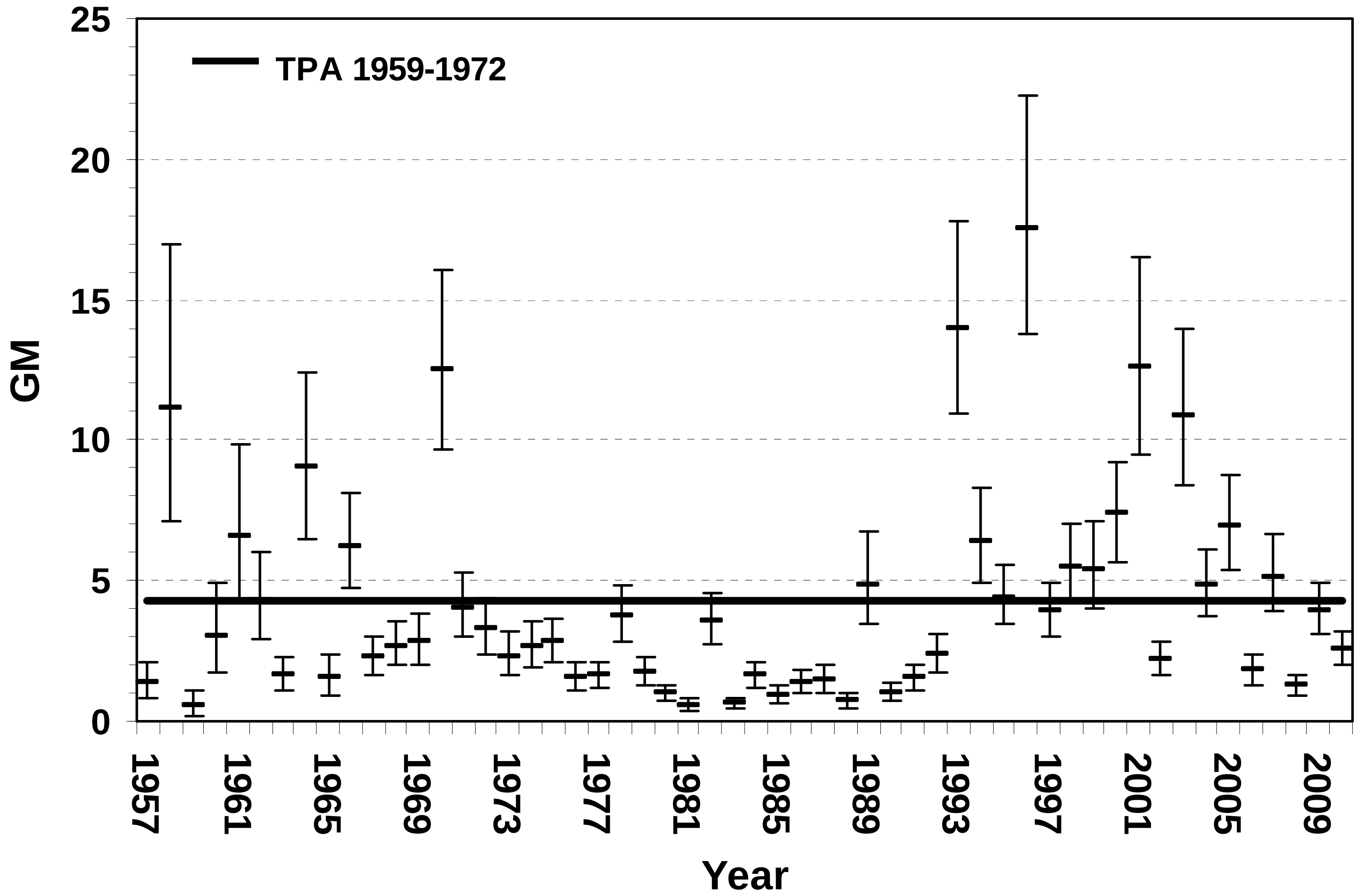


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

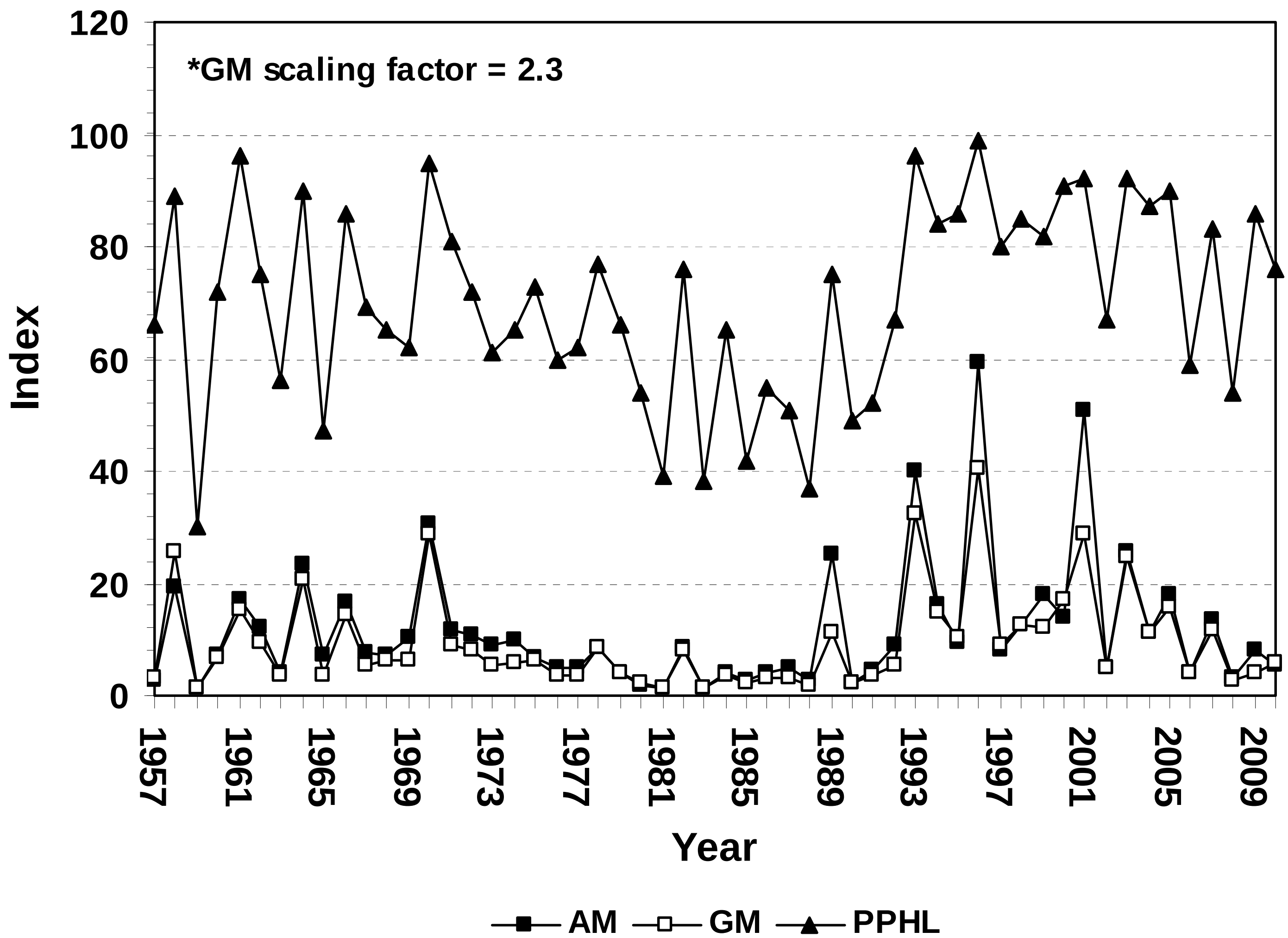


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

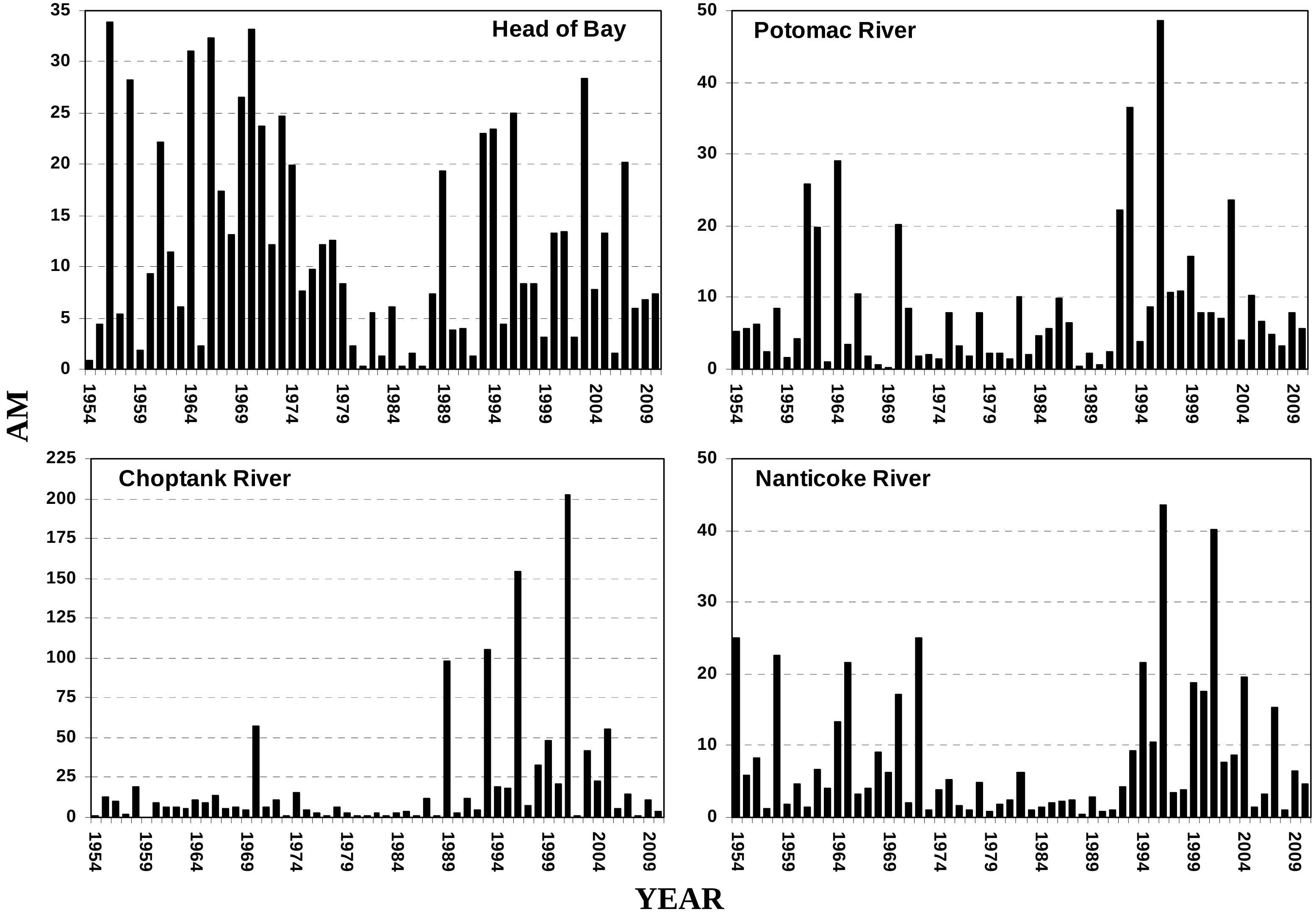


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

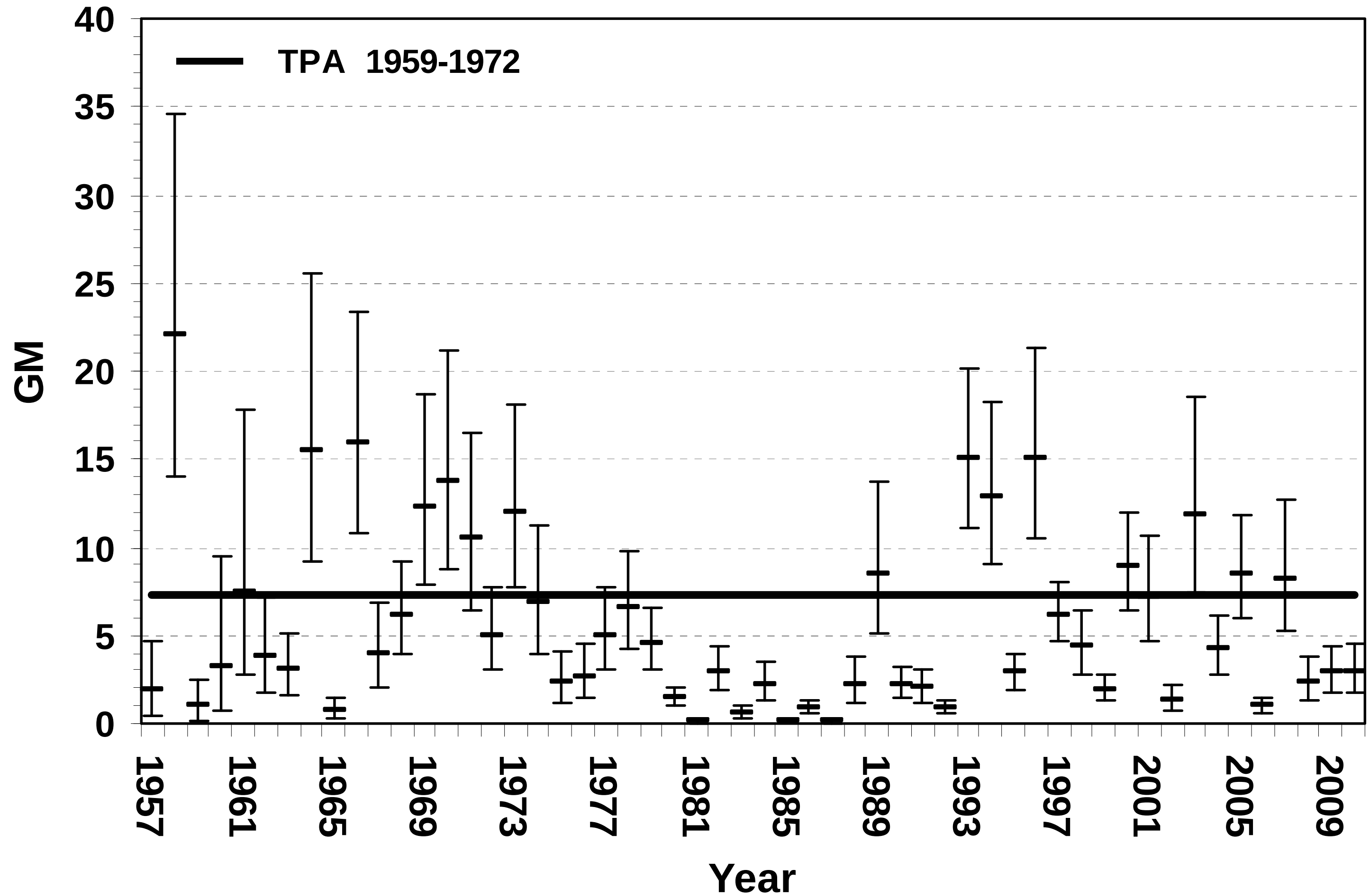


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

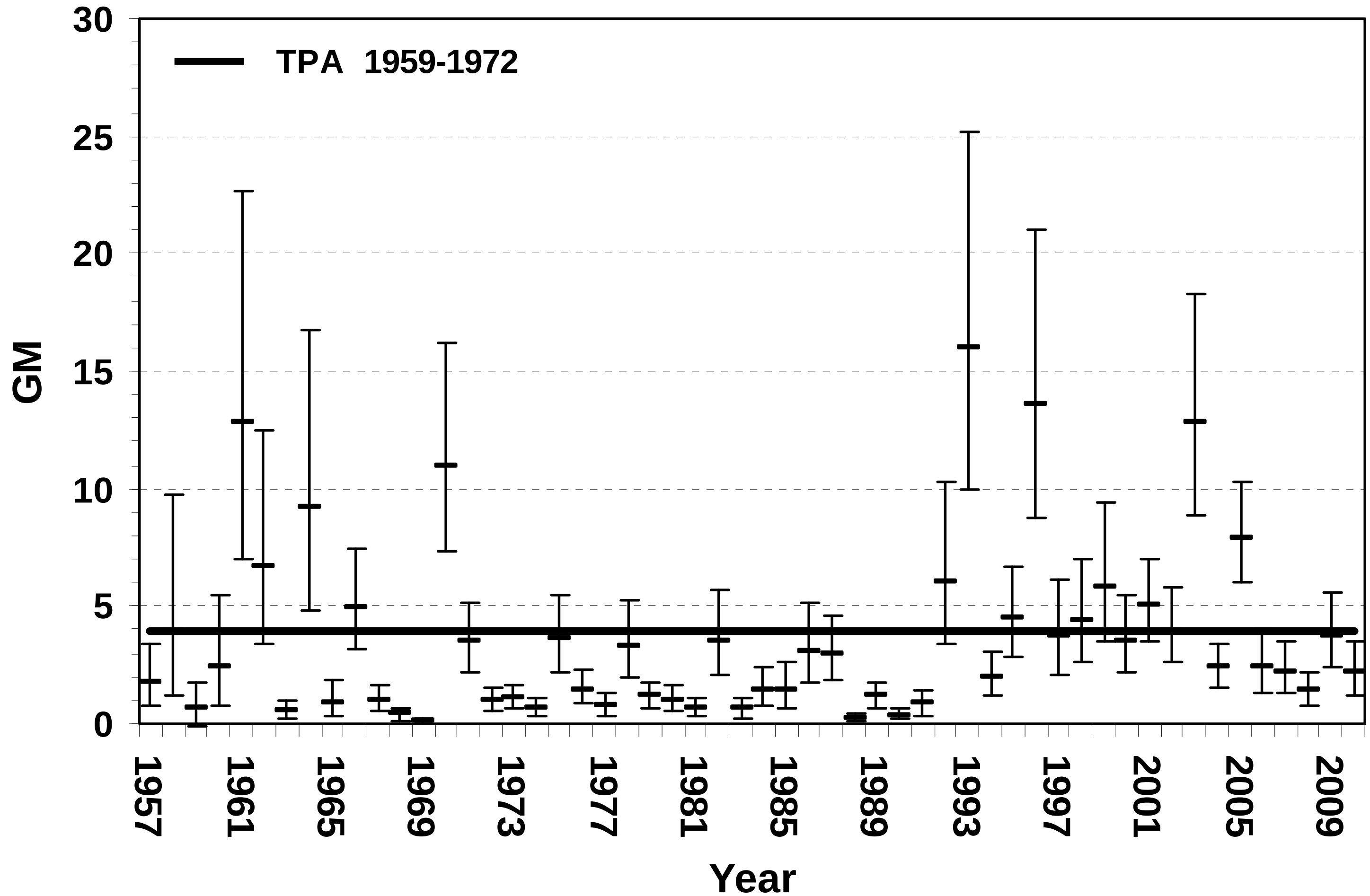


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

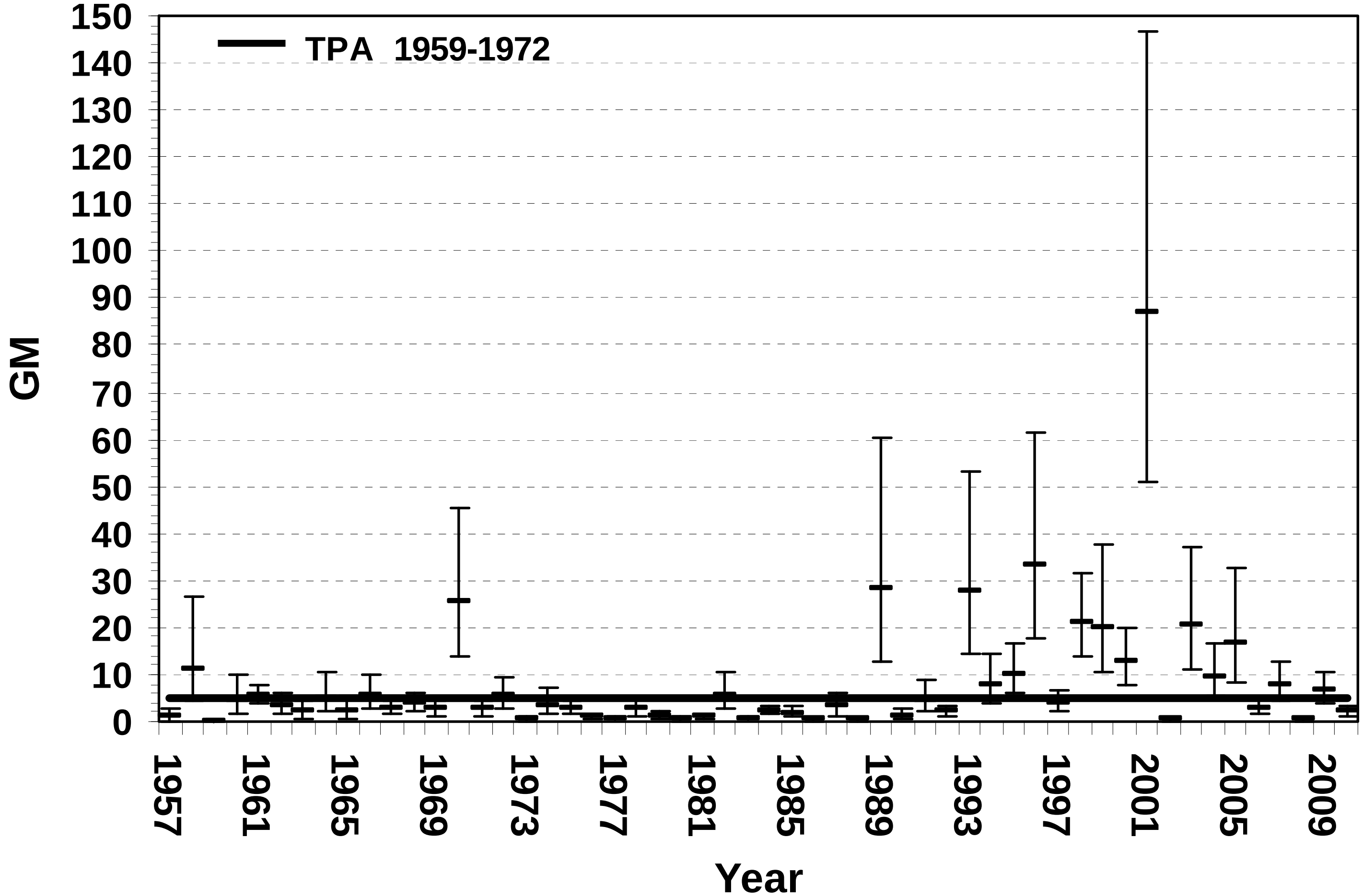


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

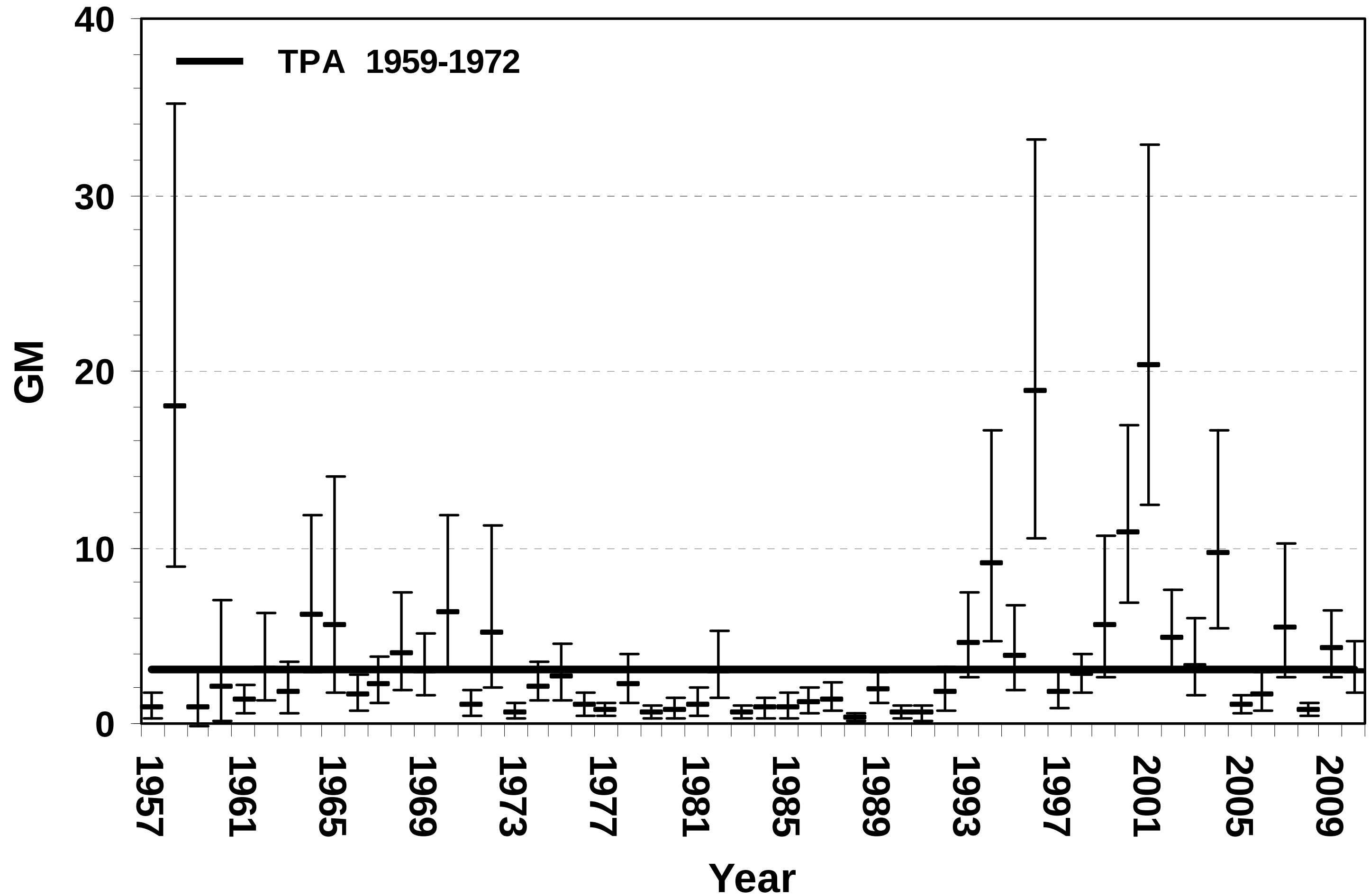


Figure 10. Relationship between age 0 and subsequent age 1 striped bass indices.

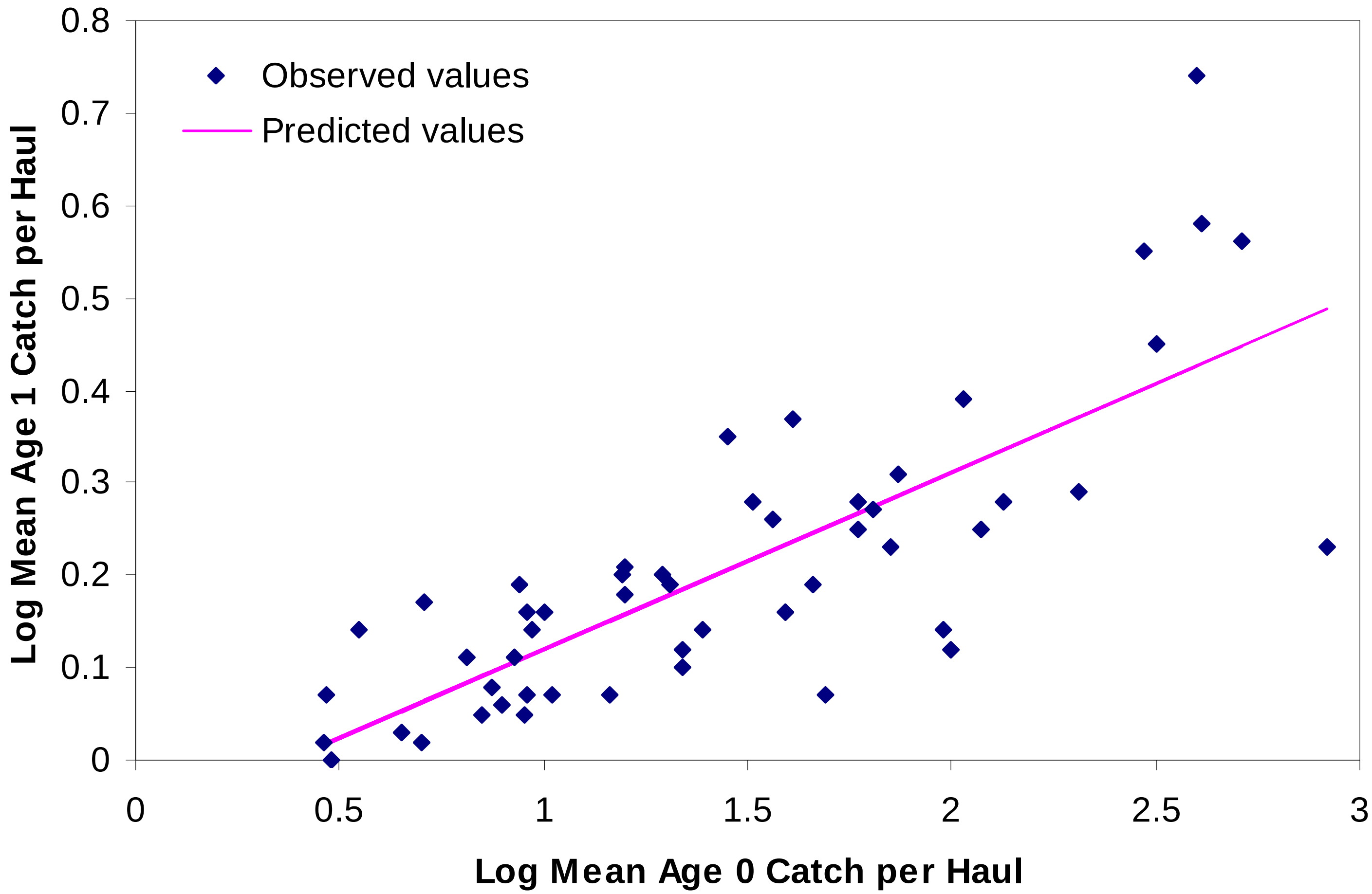
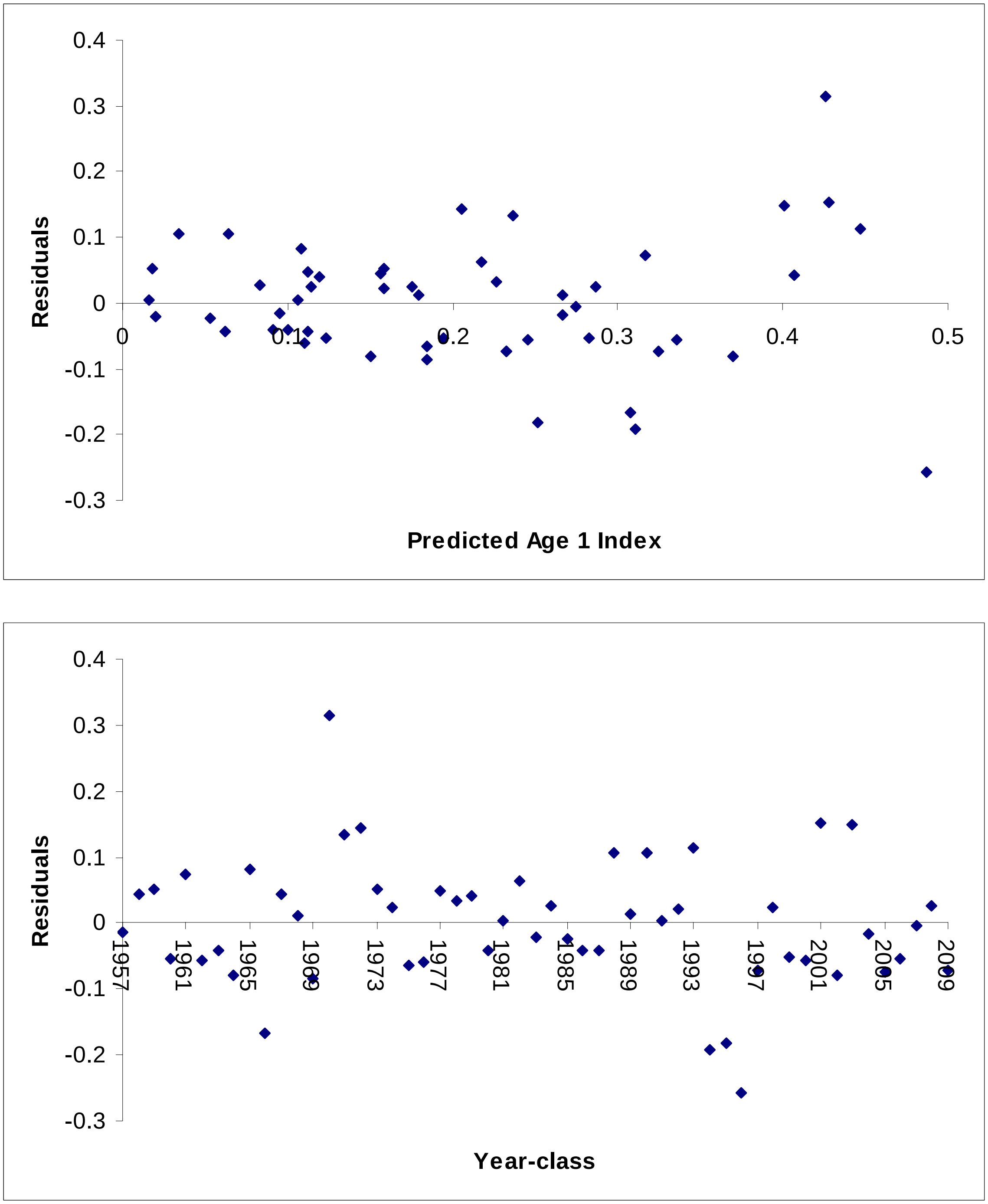


Figure 11. Residuals of age 1 and age 0 striped bass regression.



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 2009 through spring 2010. 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

In April and May 2010, 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.

Additionally, from February 18 to February 24, 2010, MD DNR staff joined the USFWS, National Marine Fisheries Service (NMFS), Atlantic States Marine Fisheries Commission (ASMFC), and North Carolina Division of Marine Fisheries (NC DMF) for the Southeast Area Monitoring and Assessment Program (SEAMAP) cooperative tagging cruise. The goal of the cruise was to tag coastal migratory striped bass wintering in the Atlantic Ocean from the Maryland-Virginia line south to Cape Hatteras, North Carolina. Sampling was conducted 24 hours per day aboard the Duke University Research Vessel Cape Hatteras. One 65-foot (19.7 m) head-rope Mongoose trawl was towed 200 times at speeds ranging from 2.5 to 4.5 knots at depths of 30 to 103 feet (9 – 31 m) for 0.07 to 0.5 hours per tow. Captured fish were placed in holding tanks equipped with an ambient water flow-through system for observation prior to tagging. 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. Vigorous fish with no external anomalies were subsequently measured, tagged, and released.

Tagging procedures

For all surveys, internal anchor tags, supplied by the USFWS, were inserted through an incision made in the left ventral side of healthy fish, slightly behind and below the tip of the pectoral fin. This small, shallow incision was made with a #12 curved scalpel after removing a few scales from the tag area. The incision was angled anteriorly through the musculature, encouraging the incision to fold together and the tag streamer to lie back along the fish's side. The tag anchor was then pushed through the remaining muscle tissue and peritoneum into the body cavity and checked for retention.

Analytical Procedures

Survival rates from fish tagged during the spring in Maryland were estimated using 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. Since it is believed that natural mortality in Chesapeake Bay is increasing, the use of a constant value for M became a weakness of the MARK method. In 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 2009).

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 2010 will not be completed until after March 27, 2011, these estimates will not appear in this report.

A comparative analysis of the 1993-2002 spring and fall tagging data showed that the spring data would produce similar estimates of fishing mortality (F) for Chesapeake Bay. Consequently the summer-fall directed fishing mortality effort was discontinued in 2005 (Sharov and Jones 2003). 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 2009-2010 estimate of F for Chesapeake Bay (unpublished data). Male fish 18 to 28 inches are generally accepted to compose the Chesapeake Bay resident stock, while larger fish are predominantly coastal migrants. Release and recapture data from Maryland and Virginia (tagging 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. Stock assessments are currently being conducted every two years, so results from these analyses will be published following the 2011 assessment. Further details on these methodologies can be found in the report of the last assessment (ASMFC 2009).

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. 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 April 1, 2010 and May 13, 2010. A total of 1,949 striped bass were sampled and 821 (42%) were tagged as part of this long-term survey (Table 1). Large samples caught in a short period of time required that fish 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 2010 (599 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (550 mm TL) (Figure 2).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2009 data) were used to estimate an instantaneous fishing mortality rate (F) for the 2009-2010 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 (unpublished data).

Estimates of survival and fishing mortality for the 2010 Chesapeake Bay spawning stock, as well as the resident stock, will be presented in the next report of the ASMFC Striped Bass Tagging

Subcommittee. Stock assessments are currently being conducted every two years.

North Carolina cooperative tagging cruise

The primary objective of the cooperative tagging cruise was to apply tags to as many striped bass as possible. In 2010, the fish were again far offshore in deep water, similar to 2009, making them difficult to locate. A total of 572 striped bass were captured during the cruise. Of those 572, biologists tagged 567 (99%) (Table 2). The mean total length of all fish captured on the 2010 cruise, and of those tagged was 774 mm TL (Figure 2). These lengths were significantly smaller than the mean total lengths for the 2009 cruise (809 mm TL total sampled and 810 mm TL tagged; $P<0.0001$). The NC DMF is presently completing age determination for the 2010 cruise via scale analysis.

Estimates of survival and fishing mortality based on fish tagged in the 2010 North Carolina study will be presented in the next report of the ASMFC Striped Bass Tagging Subcommittee.

CITATIONS

ASMFC. 2009. 2009 Stock Assessment Report for Atlantic Striped Bass. A report prepared by the Atlantic Striped Bass Technical Committee. November 2009. 281 pp.

Brownie, C., D. R. Anderson, K. P. Burnham, and D. S. Robson. 1985. Statistical Inference from Band Recovery Data - A Handbook. United States Department of the Interior, Fish and Wildlife Service, Resource Publication No. 156, Washington, D.C. 305 pp.

Burnham, K. P., G. C. White, and D. R. Anderson. 1995. Model selection strategy in the analysis of capture-recapture data. Biometrics 51:888-898.

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

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

Sharov, A. and P. Jones. 2003. Estimation of the fishing mortality rate of resident striped bass in Chesapeake Bay using spring tagging data. Maryland Department of Natural Resources. Annapolis, Maryland. 9 pp.

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

LIST OF TABLES

LIST OF FIGURES

Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, April - May 2010.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	4/1/10 - 5/13/10	643	142	521001 – 521143
Upper Chesapeake Bay	4/1/10 - 5/13/10	1,306	679	507308 – 507500 515026 – 515516
Spring spawning survey totals:		1,949 [b]	821	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes one USFWS recapture and one American Littoral Society recapture.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2010 SEAMAP cooperative tagging cruise.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Nearshore Atlantic Ocean (MD-VA line to Cape Hatteras, NC)	2/18/10-2/24/10	572	567	560501 – 561035 561051 – 561082
Cooperative tagging cruise totals:		572 [b]	567	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes one USFWS recapture and one American Littoral Society recapture.

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, April - May 2010.

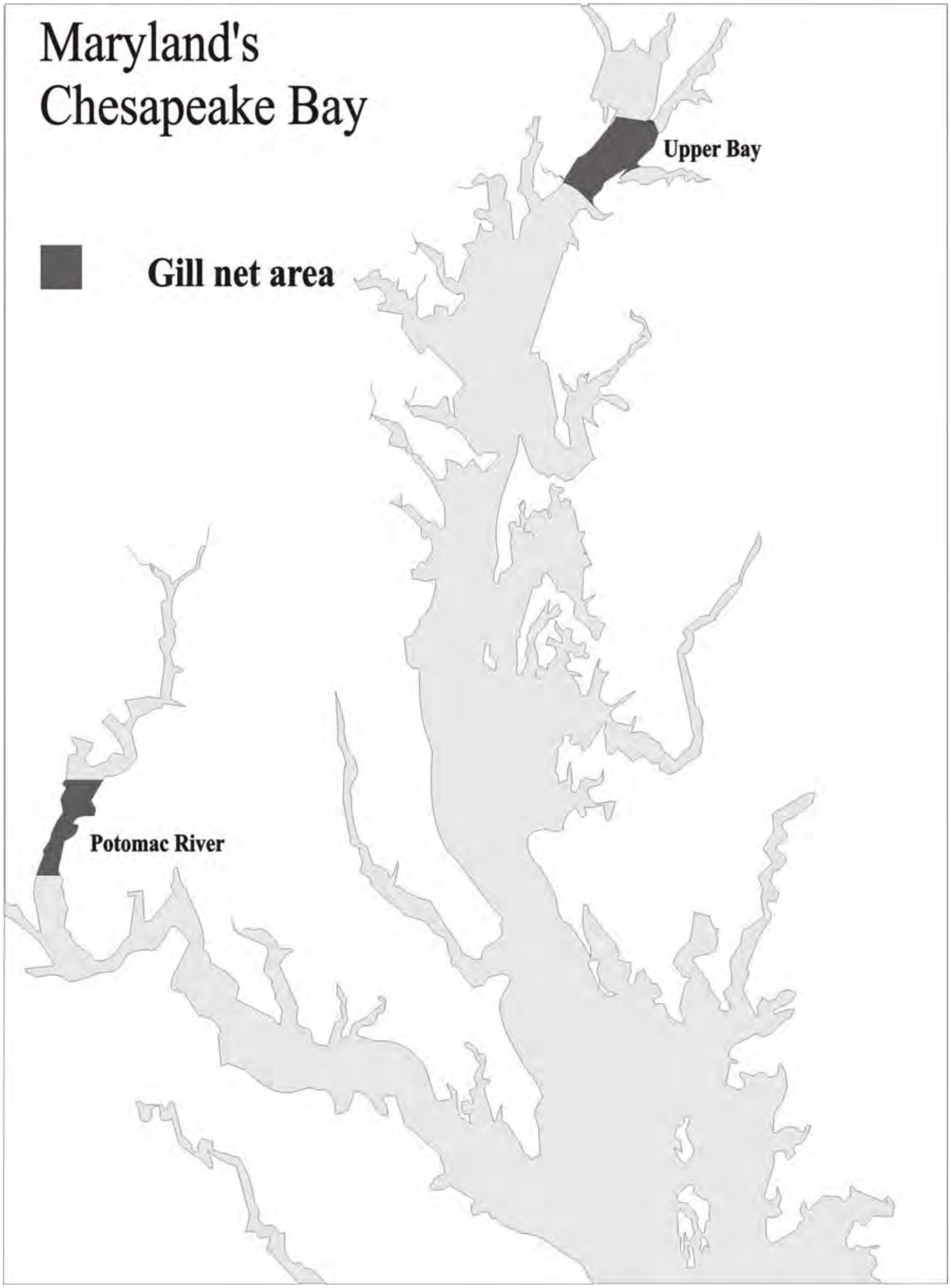
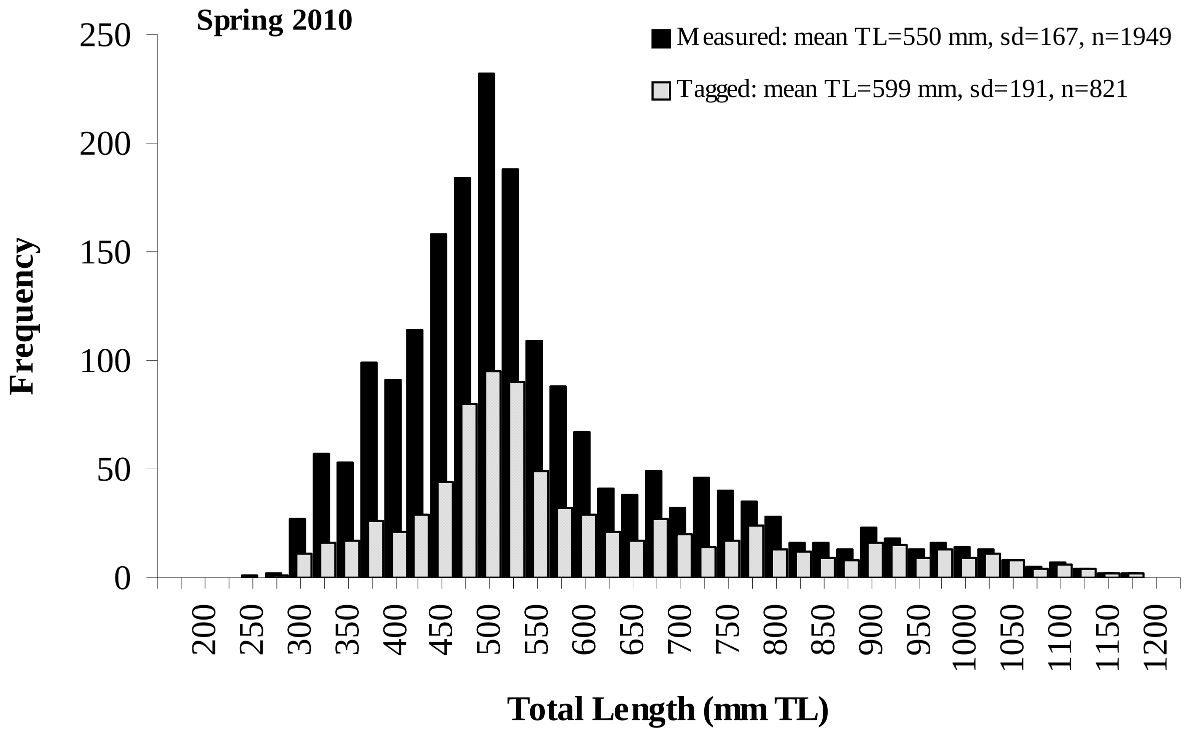
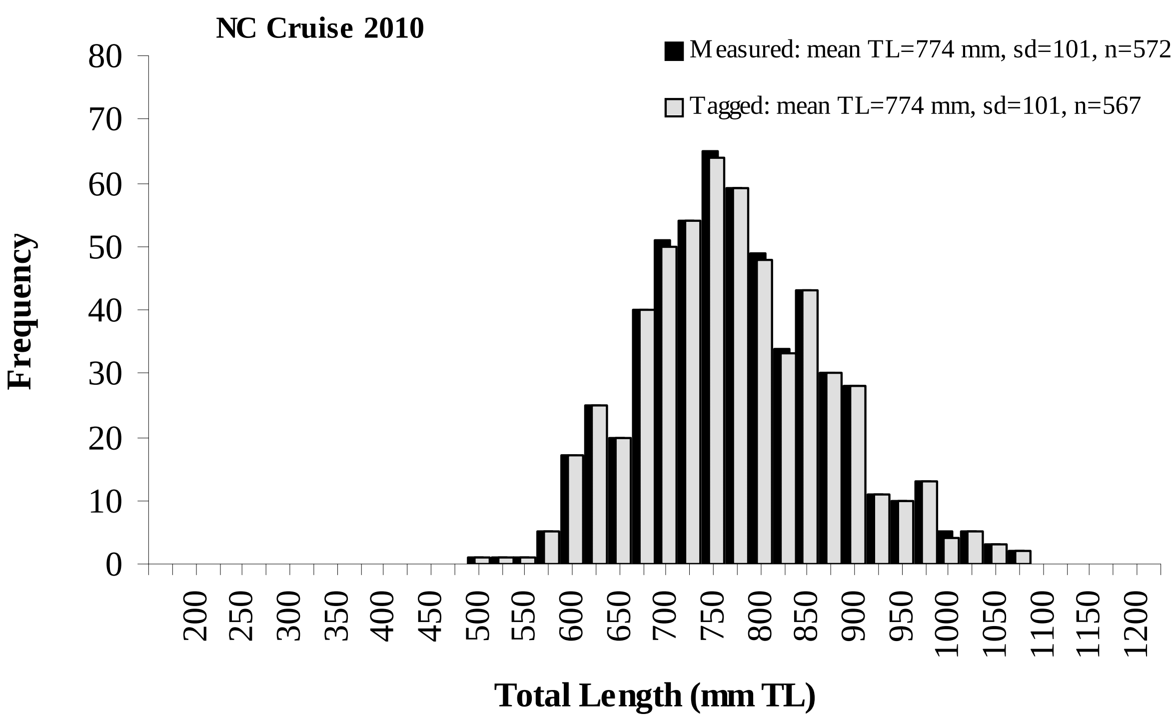


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay and offshore during the SEAMAP tagging cruise. Note different scales.





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 2009 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 twentieth 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 2009 commercial quota for the Chesapeake Bay and its tributaries was 2,254,831 pounds with an 18 to 36 inch total length (TL) slot limit. There was a separate quota of 126,396 pounds, with a 24-inch (TL) minimum size for the state's jurisdictional waters off the Atlantic Coast.

The Chesapeake Bay commercial quota was further divided by gear type. 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% (Table 1). When the allotted quota for a fishery (gear type) was not landed, it was transferred to another commercial fishery.

Each fishery was managed with specific seasons that can be modified by MD DNR as necessary. The hook-and-line fishery was open from June 15 to November 30, 2009, Monday through Thursday. The pound net fishery was open from June 1 through November 30, 2009, Monday through Saturday. The haul seine fishery was open from June 8 to November 30, 2009, Monday through Friday. The Chesapeake Bay drift gill net season was split, with the first segment from January 1 through February 28, 2009 and the second segment from December 1 through December 31, 2009, 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, 2009 and November 2 through December 31, 2009.

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 the 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 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, 2,267,293 pounds of striped bass were harvested in 2009, exceeding the quota by 12,462 pounds or 0.6%. The estimated number of fish landed was 649,062 (Table 3). The Chesapeake drift gill net fishery landed 46% of the total landings followed by the pound net fishery at 25%. The hook-and-line fishery contributed 29% of the total landings. No fish were landed by the haul seine fishery.

Maryland's Atlantic Coast landings totaled 127,327 pounds (Table 3), exceeding the Atlantic Coast quota by 931 pounds or 0.7%. The estimated number of fish landed was 13,409. The trawl fishery made up 74% of the Atlantic harvest, by weight, with the remainder from the gill net fishery.

Comparisons of Average Weight

The average weight of fish harvested was calculated using two methods. The first was by dividing the total weight of landings by the number of fish reported in the weekly check station log sheets. The second method involved direct sampling of striped bass at check stations by MD DNR biologists to characterize the harvest of commercial fisheries by measuring and weighing a sub-sample of fish (Project 2, Job 3, Tasks 1A, 1B, and 1C, in this report).

The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 3.49 pounds when calculated from the check station log sheets and 3.76 pounds when measured by biologists (Table 4). Mean weights by specific gear type ranged from 3.33 to 3.66 pounds from check station log sheets and ranged from 3.49 to 3.93 pounds when measured by biologists. The largest striped bass landed in the Chesapeake Bay, regardless of data source, were taken by gill net. The average weight of fish harvested by gill net was 3.66 pounds when calculated using the log sheet data and 3.93 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 10.17 pounds (Table 4). The average weight calculated from the check station log sheets is 9.50 pounds. Fish caught in the Atlantic trawl fishery averaged 10.44 pounds according to MD DNR estimates, and were larger on average than those caught in the gill net fishery (8.85 pounds). The average weights of fish from the Atlantic trawl and gill net fisheries, as calculated from check station log sheets, were 9.71 and 8.92 pounds, respectively.

Commercial Harvest Trends

Since the moratorium was lifted in 1990, striped bass harvests and quotas have increased 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 1998-2009.

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. 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 (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 351 pounds per trip, a 16% increase from 2008. The Chesapeake Bay gill net fishery CPUE was 324 pounds per trip, a slight increase from the CPUE for 2008.The hook-and-line fishery CPUE was 206 pounds per trip, similar to the previous two 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 (322 lbs per trip), followed by the pound net fishery (283 lbs per trip) and the hook-and-line fishery (200 lbs per trip) (Table 6, Figure 6). The Atlantic trawl fishery CPUE was 1,348 pounds per trip in 2009. The 2009 CPUE for the Atlantic gill net fishery was 326 pounds per trip, above the fourteen year average of 251 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. The Atlantic Ocean commercial fisheries for striped bass have demonstrated relatively stable CPUE trends since 1996 with large increases in the trawl CPUEs between 2006 and 2009. The increases in CPUE are consistent with increases in total stock abundance through 2004 as estimated by the Atlantic States Marine Fisheries Commission. (ASMFC 2010)

CITATIONS

Atlantic States Marine Fisheries Commission (ASMFC) 2010. 2010 Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic Striped Bass (Morone saxatilis): 2009 Fishing Year. A report by the ASMFC Atlantic Striped Bass Plan Review Team.

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

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

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

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

LIST OF TABLES

LIST OF FIGURES

Table 1. Striped bass commercial harvest quotas (lbs) by gear type for the 2009 calendar year.

Gear Type	Total Adjusted Harvest Quota
Haul Seine, Pound Net	563,708
Hook-and-Line	676,449
Drift Gill Net	1,014,674
Chesapeake Total	**2,254,831**
Atlantic: Trawl, Gill Net	126,396
Maryland Total	**2,381,227**

Table 2. Individual season and daily harvest allocations (lbs) and the number of declared striped bass fishermen for the 2009 calendar year.

Area	Gear Type	Number Declared	Daily Allocation (pounds)	Seasonal Allocation (pounds)
Bay & Tributaries	Haul Seine	4	750	1,250
	Pound Net	178	200[1]	1,600[1]
	Hook & Line	147	500	none
	Gill Net / Hook & Line	816	500	none
Atlantic Coast	Atlantic Trawl	39	none	1,950
	Atlantic Gill Net	43	none	1,950

1. Pound net daily and season allocations were based on: 200 pounds daily per net, 1,000 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 2009 calendar year.

Area	Gear Type	Pounds[1]	Estimated[1] Number of Fish	Trips[2]
Chesapeake Bay[3]	Haul Seine	0	0	0
	Pound Net	566,898	170,291	1,614
	Hook & Line	650,207	191,789	3,157
	Gill Net	1,050,188	286,982	3,242
	Chesapeake Total Harvest	**2,267,293**	**649,062**	**8,013**
Atlantic Coast	Atlantic Trawl	94,390	9,718	70
	Atlantic Gill Net	32,937	3,691	101
	Atlantic Total Harvest	**127,327**	**13,409**	**171**
Maryland Totals		**2,394,620**	**662,471**	**8,184**

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 2009 calendar year. Average weights calculated by MD DNR biologists include the 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	0	N/A	N/A
	Pound Net	3.33	3.73 (3.60-3.86)	1,087
	Hook-and-Line	3.39	3.49 (3.41-3.55)	2,259
	Gill Net	3.66	3.93 (3.87-3.99)	3,733
	Chesapeake Total Harvest	**3.49**	**3.76 (3.72-3.80)**	**7,079**
Atlantic Coast	Trawl	9.71	10.44 (10.12-11.87)	183
	Gill Net	8.92	8.85 (8.39-9.31)	68
	Atlantic Total Harvest	**9.50**	**10.17 (9.58-10.75)**	**176**

1. Data from check station log sheets, pounds divided by the number of fish reported.

2. Data from check station sampling by MDDNR biologists, all months combined.

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

Table 5. Pounds of striped bass landed by commercial gear type, 1990 to 2009.

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

Table 6. Striped bass average catch per trip (CPUE) in pounds by commercial gear type, 1990 to 2009.

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

Figure 1. Map of the 2009 Maryland authorized commercial striped bass check stations.

Figure 2. Maryland's Chesapeake Bay pound net and hook-and-line fishery cumulative striped bass landings from check stations daily call-in reports, June-November 2009.

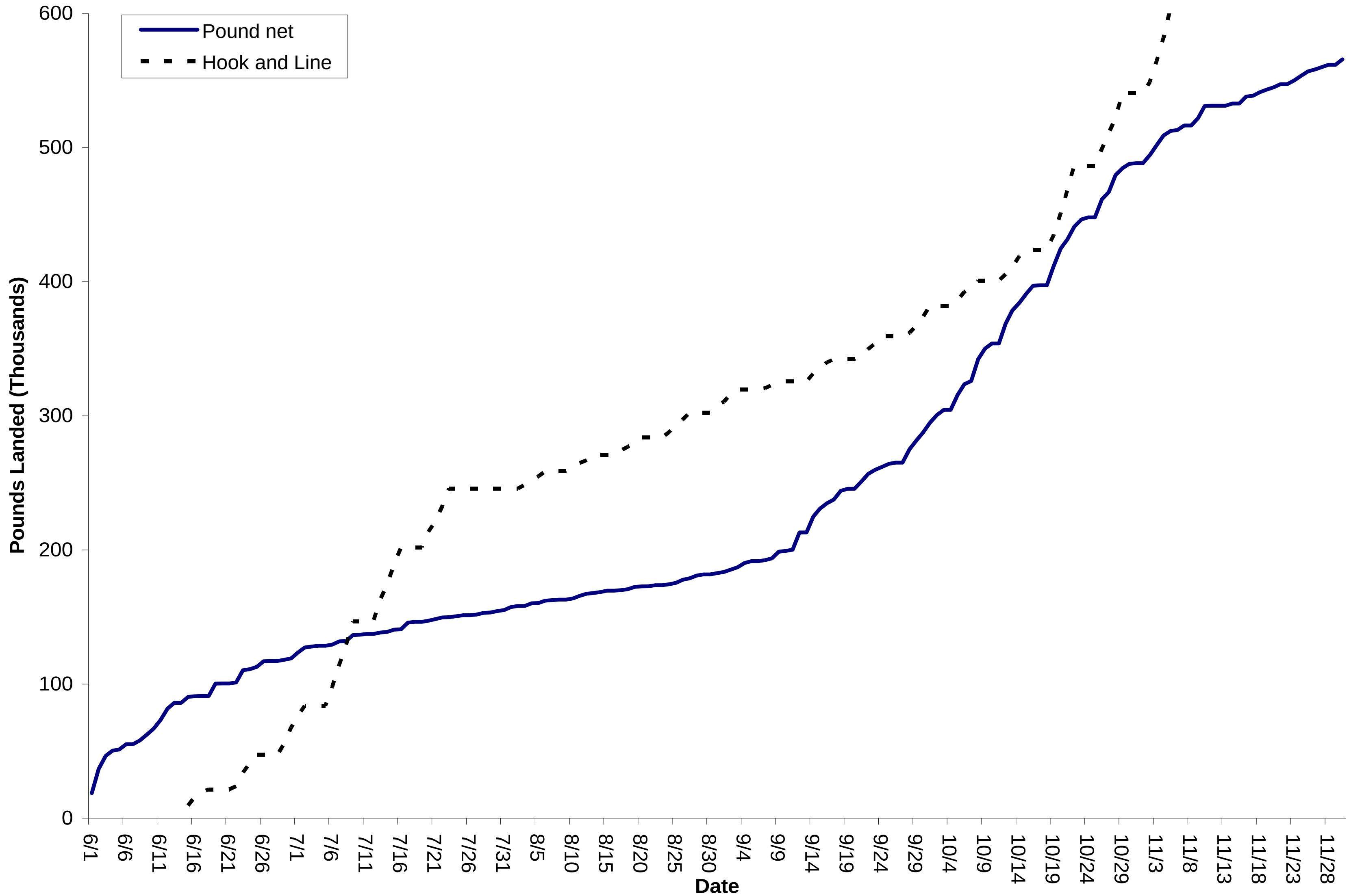
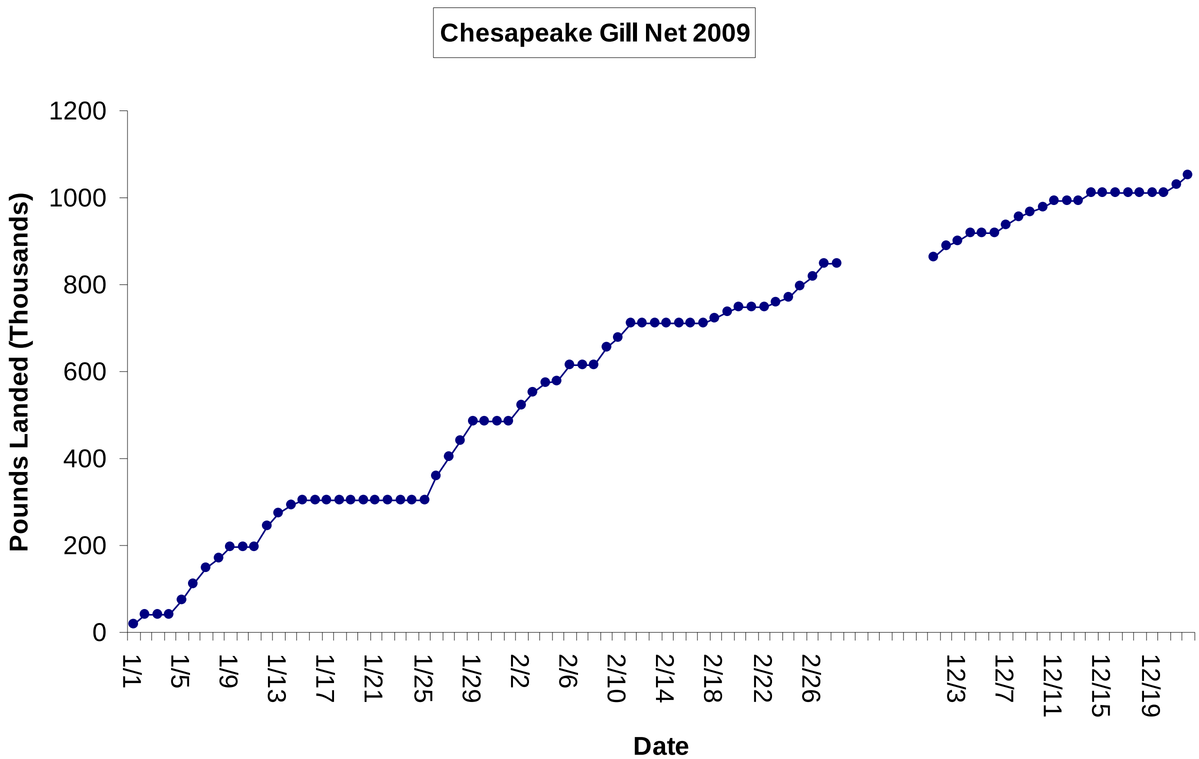


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fishery (combined) cumulative striped bass landings from check stations daily call-in reports, January- December 2009.



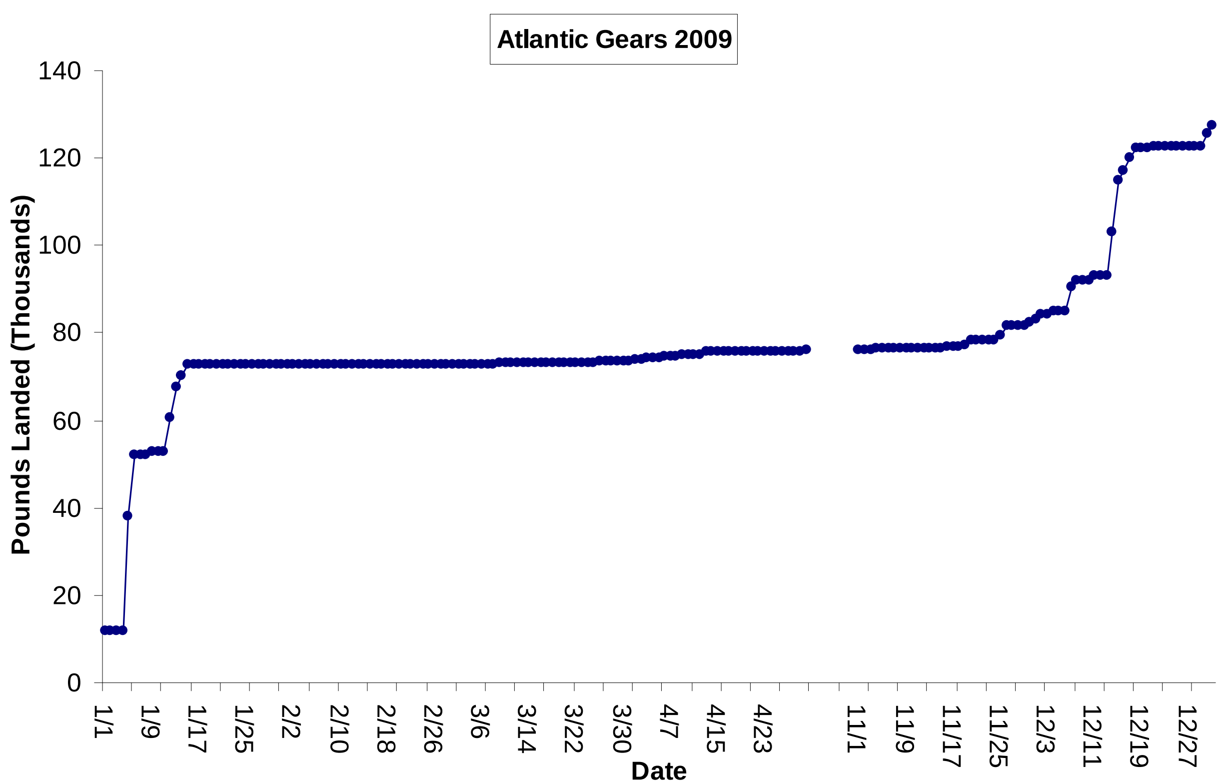


Figure 4. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990–2009.

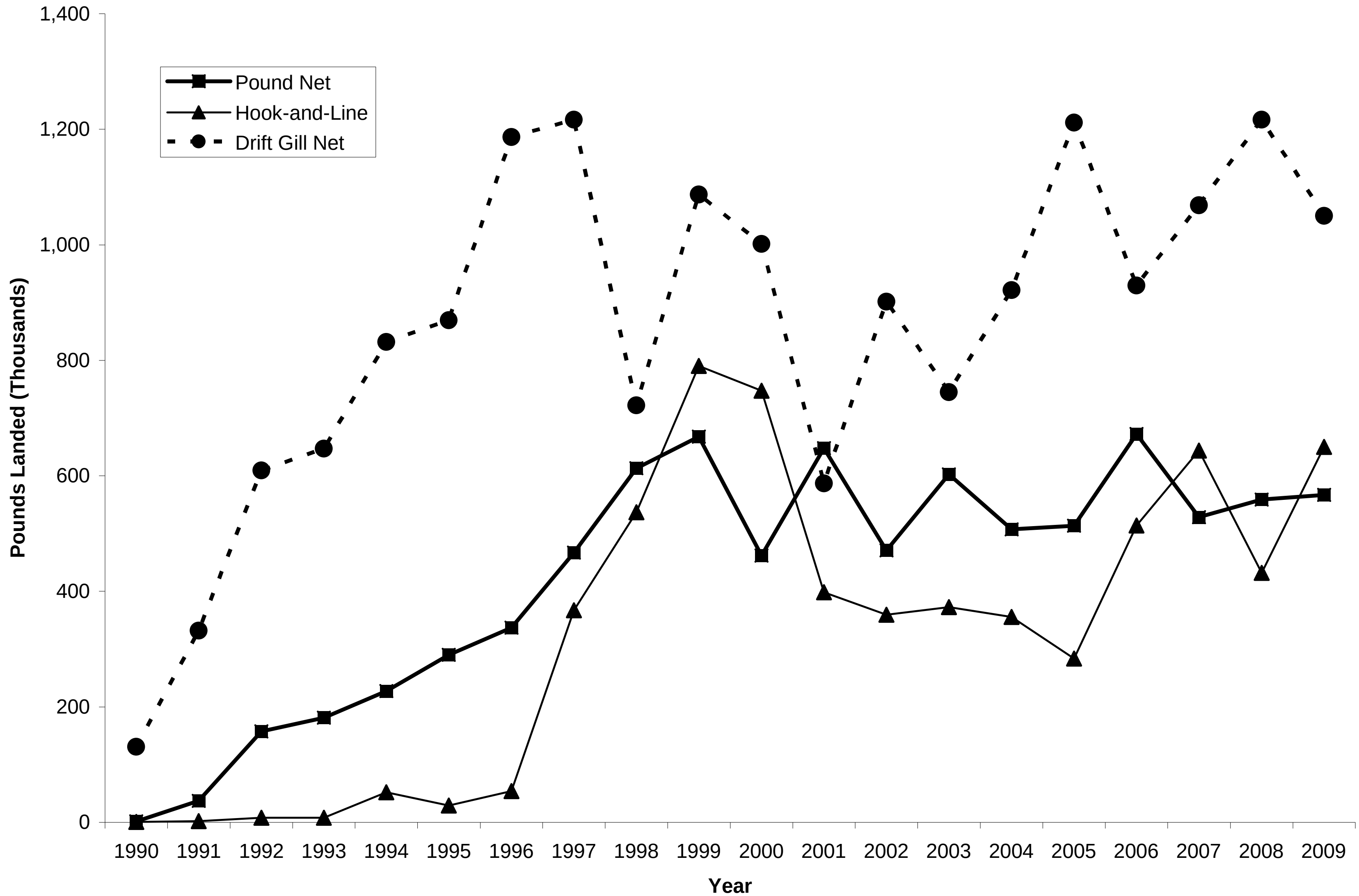


Figure 5. Maryland's Atlantic gill net and trawl fishery striped bass total harvest (thousands of pounds) per calendar year by commercial gear type, 1990-2009.

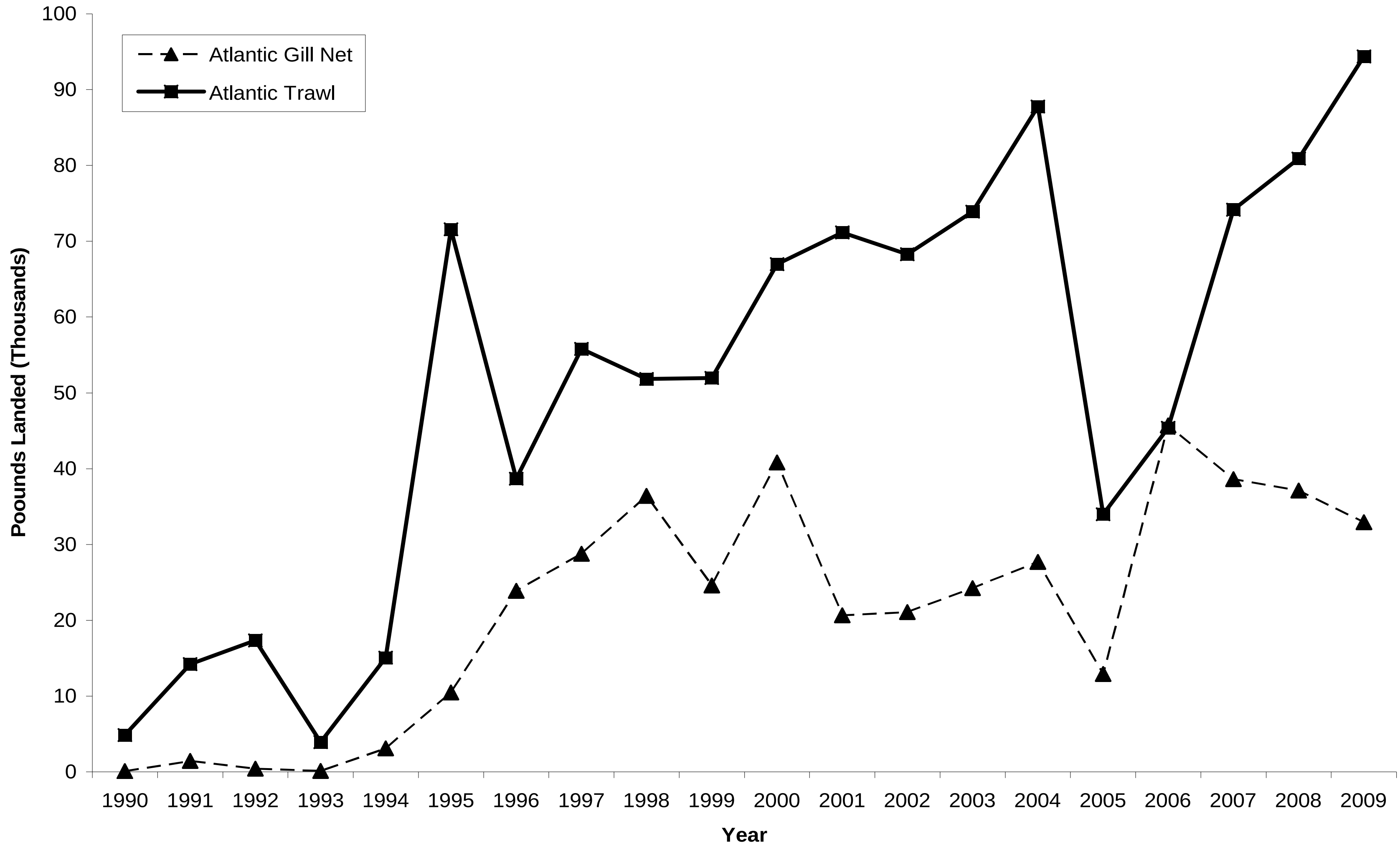


Figure 6. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by commercial gear type, 1990- 2009. Trips were determined as days fished when striped bass catch was reported.

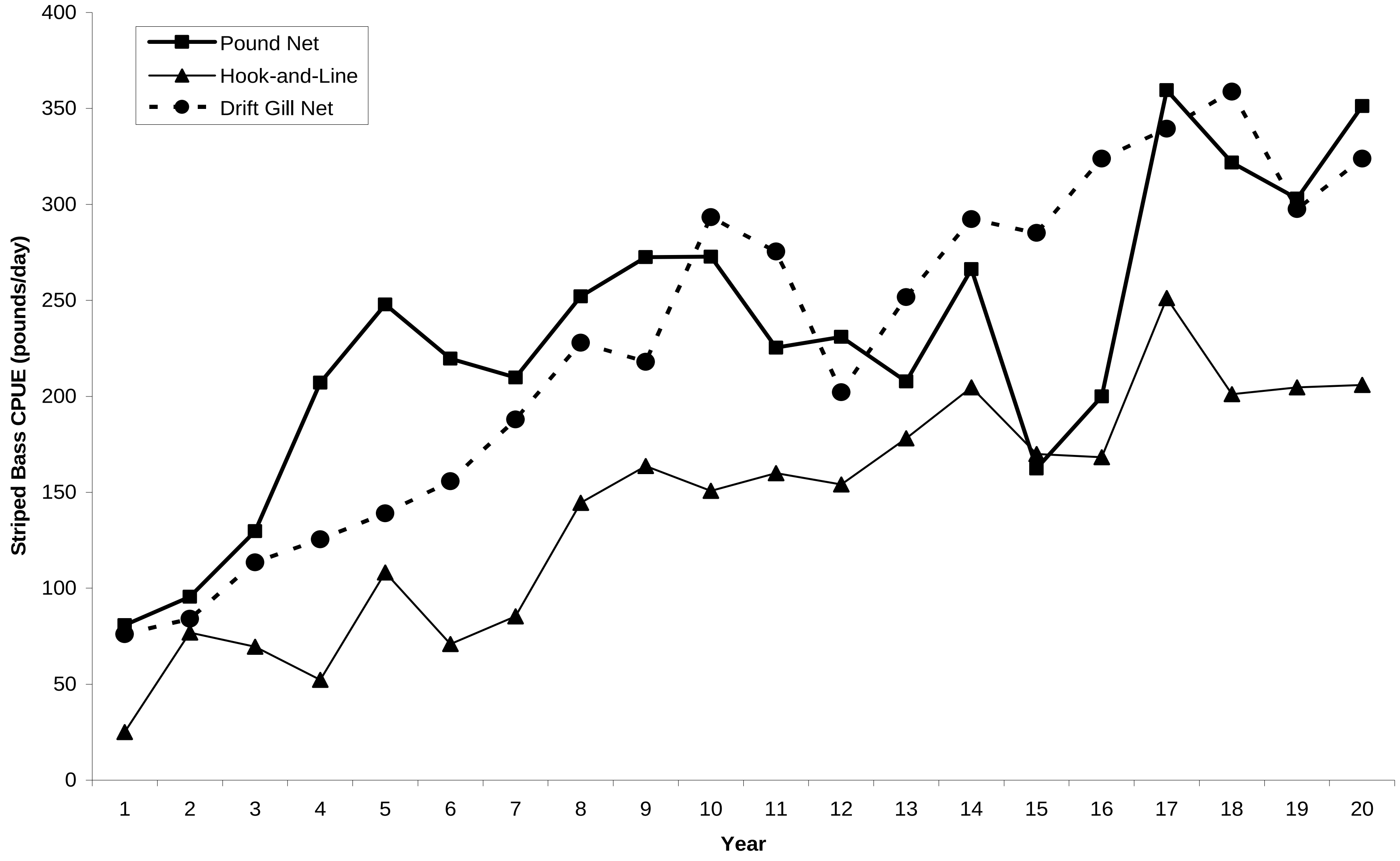
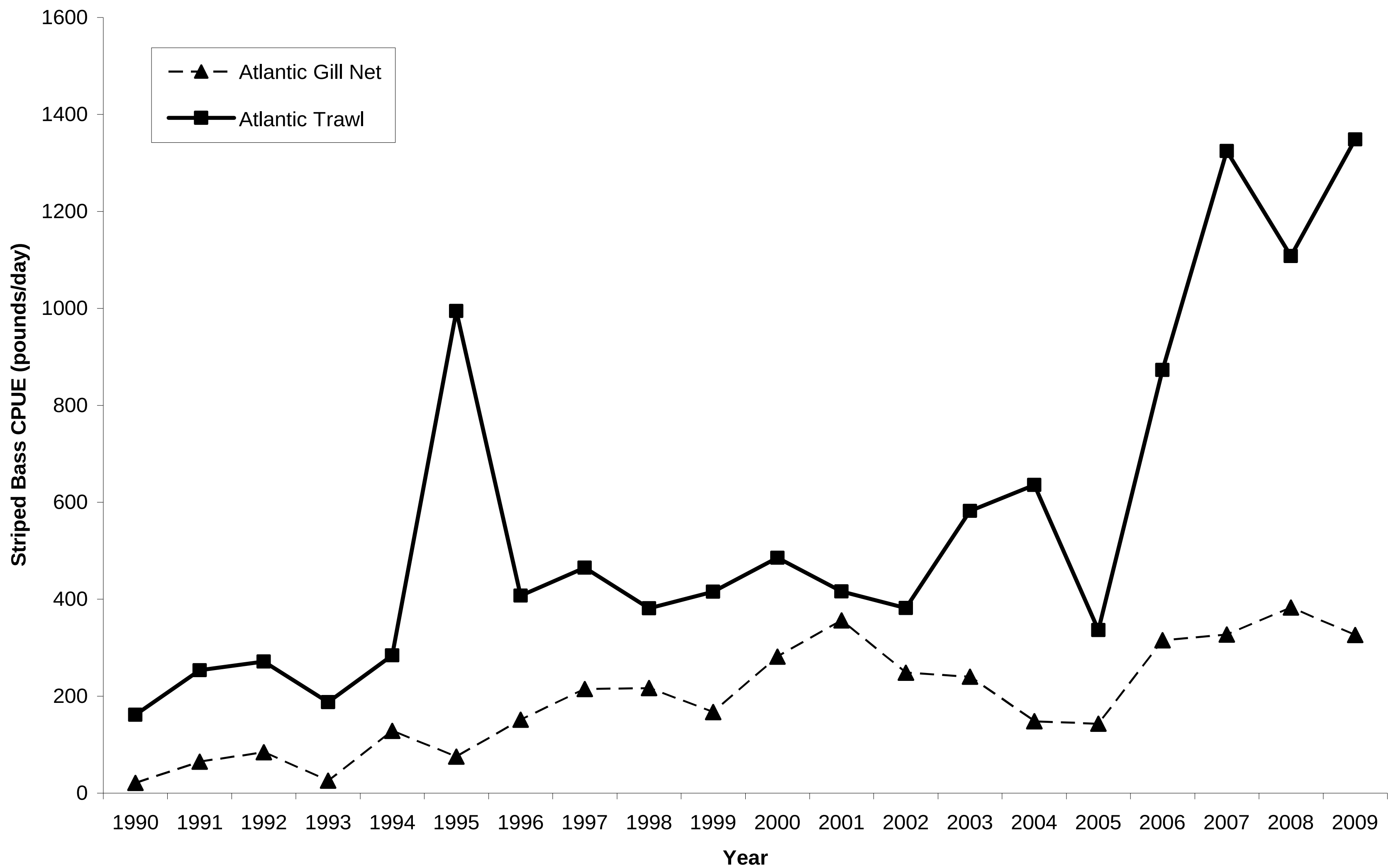


Figure 7. Maryland's Atlantic gill net and trawl fishery striped bass catch (pounds) per trip (CPUE), 1990-2009. Trips were determined as days fished when striped bass catch was reported.



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 2010 spring recreational season, which began on Saturday, April 17 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 2010 season was 27 days long (April 17 – 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 9:00 AM. In 2010, some trips did not return until as late as 1:00 PM. 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 2010: Solomons/Calvert Marina, Solomons/Beacon 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. Limited charter interviews were reinstated in 2010 to allow for equitable comparisons with socioeconomic data from previous years. Though few charter boat angler interviews were conducted, 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 5 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 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 saggital 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 2010, 20% 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 boats intercepted, number of anglers interviewed, and numbers of striped bass examined each year are presented in Table 5A. Only six charter boat anglers were interviewed in 2010 resulting in the majority of the angler interview data coming from private boat anglers. However, fish were sampled from 45 intercepted charter trips (Table 5B). No shore anglers with completed trips were intercepted during the spring trophy season. Fishing activity during the spring season was highest in the middle Bay, specifically the region between the Chesapeake Bay Bridge and the mouth of the Patuxent River.

BIOLOGICAL DATA

Length and Weight

Length distribution

The minimum size limit for the 2010 spring striped bass season was 28 inches (711 mm) TL. Lengths ranged from 702 mm TL to 1221 mm TL. The catch was dominated by fish between 860 and 980 mm TL (33 to 38 inches, Figure 2), similar to the length distribution observed in 2009.

Mean length

In 2010, the mean length for all fish (913 mm TL) was the same as 2009 and slightly smaller than 2008 (Table 6A, Figure 3). The mean length of females (932 mm TL) was greater than the mean length of males (833 mm TL), which is typical of the biology of the species. The mean total length of the females was the second highest observed across all survey years. Mean lengths in 2006, 2008, and 2009 for all fish and females are statistically similar to those observed in 2010 and larger than all other years. Mean length of males in 2010 was statistically similar to all other years of the survey except for 2006.

The mean daily lengths of female striped bass harvested in 2010 varied without trend, similar to patterns observed between 2005 and 2009 (Figure 4). This is in contrast 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 2010 (7.8 kg) was similar to that observed in 2009 and was the third highest observed in all years (Table 6B). Based on 95% confidence intervals, the mean weight of females and the mean weight of all fish did not change significantly from 2009 (Figure 5). The mean weight of males in 2010 was one of the lowest in the time series but was statistically similar to those observed in all other study years, except in 2006 and 2008. The mean weight of females (8.3 kg) was greater than the mean weight of males (5.7 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

In 2010, 222 scale samples were read. The age distribution of striped bass from the sampled harvest in 2010 ranged from 6 to 18 years old (Figure 6). Most fish harvested were between 7 and 14 years old. The 2000 year-class (10 years old in 2010) was the most frequently observed cohort, constituting 23% of the sampled harvest. The 2001 year-class (9 years old in 2010) was the second most frequently observed, constituting 20% of the sampled harvest. This strong year-class has increased annually in the harvest since 2007. The record-sized 1996 year-class (14 years old in 2010), which dominated catches in 2005, 2006, and 2008, constituted just 8% of the sample harvest. The next strong year-class entering the fishery is the 2003 year-class (7 years old in 2010). Though they made up just 2% of the sample harvest in 2009, they now constitute 10% of the sample harvest and were the third most frequently observed year-class.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2010 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. When the data were analyzed using all fish sampled, including unknown sex fish, females constituted 81% of the 2010 sampled harvest. The proportion of females in the sampled harvest was higher in 2010 than in 2009 but was consistent with the average of the time series.

Spawning Condition

Percent pre-spawn females

The need to understand spawning condition of the female portion of the catch helped initiate this study in 2002. Goshorn et al. (1992) studied the spawning condition of large female striped bass in the upper Chesapeake Bay spawning area during the 1982-1991 spawning seasons. Their results suggested that most large females spawn before mid-May in the upper Chesapeake Bay spawning area, indicating a high potential to harvest gravid females in the spring fishery during the first two weeks of May. Data from the 2010 spring season survey indicated that only 29% of the females caught between April 17 and May 15 were in pre-spawn condition, the lowest percentage documented by the spring creel survey (Table 8). This percentage is below the average of the past nine years but is similar to the results from 2008. The low number of pre-spawn female striped bass encountered suggests that the spawn was early. This is corroborated by the spring spawning stock survey (Project 2, Job 3, Task 2) which documented peaks in striped bass catch per unit effort in early April, prior to the opening of the spring trophy season.

Daily spawning condition of females

The majority of pre-spawn female striped bass were caught at the start of the trophy season and a second, smaller wave of pre-spawn females was encountered in early May (Figure 7). The percent of pre-spawn females harvested ranged from 7% to 75% on any given day. Sample sizes of female striped bass ranged from 8 to 44 fish daily (mean=24 fish, median=17 fish).

CATCH RATES AND FISHING EFFORT

Harvest Per Trip Unit Effort

Because of increased focus on improving our understanding of private boat fishing effort, all trips intercepted in 2010 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 2010. The HPT from six charter boat angler interviews was 11, which while very high was not significantly different from the other years of the survey based on 95% confidence intervals. The mean HPT in 2010 according to charter boat logbooks was 4.8 fish per trip, similar to 2008 and 2009 (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 (1.1) was much lower than HPT from charter boats but higher than the private boat HPT in the past two 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 1.0, similar to previous years. However, HPA from charter boat logbook data in 2010 was 0.76 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 0.4 fish per person, similar to past years (Table 9B).

<u>Catch Per Unit Effort</u>

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 2010 so these numbers reflect primarily private boat angler interview data. Mean CPT in 2010 (2.0) was the third lowest recorded in all years and consistent with the previous three years of the survey. Mean CPH was 0.5 fish per hour in 2010, statistically similar to 2007, 2008, and 2009. The decreases observed in CPT and CPH since 2006 are directly related to the reduction of charter boat interview data in 2007 and 2010 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.

<u>Comparison of Catch Rates from Charter and Private Boats</u>

In all years, charter boats caught more fish per trip than private boats (Tables 10B, 10C, and 10D). Though the charter boat creel interviews show a much higher catch per trip than in previous years (Table 10C), the sample size is too small for accurate conclusions and the charter boat logbook data (Table 10D) is likely more representative. In 2010, private boats caught an average of 1.6 fish per trip, while charter boats caught 5.7 fish per trip. The private boat CPH was 0.4 fish per hour while charter boats had a CPH of 1.3 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 2010 declined after the opening weekend but subsequently varied without trend. CPH values have decreased since 2007 due to the lack of charter boat interview data.

Angler Characterization

States of residence

In 2010, 199 trips (193 private boats and 6 charter boat trips) were intercepted for interviews and 601 anglers were interviewed during the period April 17-May 15 (Table 5A and

Table 5B). Thirteen states of residence were represented in 2010 (Table 11). Most anglers were from Maryland (87%), Virginia (6%), and Pennsylvania (6%), 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 and 2010 surveys, even though the telephone survey was not conducted. In 2010, there were on average 2.8 anglers per boat and of these anglers, 1.4 were license-exempt (Table 12). These results are remarkably consistent with previous years.

Angler Gender

In 2010, 95% of anglers interviewed by the creel survey were male and 5% were female (Table 13). These values are the same as the long term average for all years surveyed. The highest proportion of female anglers was encountered in 2006 (8%) while the lowest was encountered in 2005 (3%).

Number of Lines Fished

In 2006, six lines were fished on average per private boat and the maximum number encountered on a boat was 15. In 2010, the average number of lines fished per private boat was eight and ranged from one to 19 lines (Table 14). This was more lines, on average, than in 2006 (6 lines). In addition, the range of the number of lines fishes was smaller (3-15 lines) in 2006.

Dollars Spent per Day

Anglers spent an average of $89 per trip in 2010 (Table 15) in contrast to $148 per trip in 2005. The decrease in dollars spent since 2006 is due in part to the fact that fewer charter boat anglers were interviewed. Private boat anglers would mainly be paying for gas, food, bait, etc. while charter boat fees are generally higher per person.

Anglers' Years of Experience Fishing and Trips per Year

Anglers interviewed during the 2010 creel survey had been fishing for striped bass in Chesapeake Bay an average of 24 years and a median of 20 years (Table 16). This average is the highest on the time series but was similar to results in 2007 and 2005. The range of anglers' fishing experience for striped bass during the trophy season ranged from one year to 60 years.

For the first time during the angler intercept survey, anglers were asked approximately how many fishing trips they take per year (Table 17). Answers ranged from one trip to 100 trips per year with a mean of 22 trips per year.

Angler Satisfaction with Regulations

Anglers were also asked if they were satisfied with the current regulations. In 2010, 75% of the respondents said they were satisfied with the current striped bass regulations (Table 18). Of those that were dissatisfied (49 responses), most people wanted to increase the creel limit (37%). Ten respondents were against any pre-season catch and release of striped bass (20%). Other comments included limiting commercial fishing for striped bass, starting the spring trophy season earlier, and dissatisfaction with the implementation of the NOAA Federal Angler Registry.

CITATIONS

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

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

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

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

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

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

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

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

Durell, E. and L. Warner. 2007. Development of spring season recreational striped bass harvest estimate through the use of a telephone survey. In: MDDNR-Fisheries Service, Chesapeake Bay Finfish/Habitat Investigations, USFWS Federal Aid Project, F-61-R-3, 2006-2007, Project 2, Job 3, Task 5C, pp II-303-II-334.

Durell, E. and L. Warner. 2008. Development of spring season recreational striped bass harvest estimate through the use of a telephone survey. In: MDDNR-Fisheries Service, Chesapeake Bay Finfish/Habitat Investigations, USFWS Federal Aid Project, F-61-R-4, 2007-2008, Project 2, Job 3, Task 5C, pp II-309-II-341.

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

CITATIONS (Continued)

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

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

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

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

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

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

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

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

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

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

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

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

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

CITATIONS (Continued)

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

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

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

Table 1. History of MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2010.

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

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2010. 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 Island/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	29
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 Point State Park Boat Ramp and Beach	11

Table 2B. Survey sites for the Maryland striped bass spring angler-intercept survey, 2010.

Relative Use	**Access Intercept Site**
High	Sandy Point 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, 2010.

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, 2010.

Angler and Catch Data Collected
Number of hours fished
Fishing type: private boat or shore
Number of anglers on boat
Number of lines fished
Number of fish kept
Number of fish released
Number of anglers license exempt
State residence
Gender of anglers
Money spent on fishing trip
Years experience fishing & number trips per year
Satisfaction with regulations

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

* Charter boat numbers were corrected from last year to include only trips from the spring trophy season.

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

* Charter boat numbers were corrected from last year to include only trips from the spring trophy season.

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)

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)

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

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
Mean	**81**	**84**	**85**

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
Mean	**138**	**48**	**143**	**52**

*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)

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)

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)

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)

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)

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)

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
AL	0	0	0	0	1	0	0	0	0
CA	1	0	1	0	0	2	0	0	0
CO	0	0	1	0	1	1	0	0	1
DC	6	1	1	0	1	2	1	0	6
DE	6	7	3	0	9	8	1	0	3
FL	0	0	1	1	2	0	1	0	3
GA	1	1	0	2	2	0	0	0	0
IL	0	0	0	0	1	0	0	0	0
KY	0	1	0	0	0	0	0	0	1
KS	0	0	1	0	0	0	0	0	0
MA	0	1	1	0	0	0	0	1	1
MD	353	260	107	66	227	679	266	651	482
MI	1	0	0	0	1	1	0	0	0
MN	0	0	1	0	0	0	0	0	0
MT	0	0	0	0	0	0	0	1	2
NC	0	2	0	1	0	1	1	0	0
NJ	2	2	6	0	3	2	4	0	0
NY	4	0	0	1	1	0	0	0	1
OH	0	0	0	0	0	3	1	0	1
PA	27	19	17	4	22	32	16	46	18
RI	2	0	1	0	0	0	0	0	0
SC	0	0	1	0	0	1	0	0	0
TX	0	1	0	0	0	0	0	0	0
VA	48	31	30	13	56	71	29	44	42
WA	0	0	1	0	0	0	0	0	0
WI	0	0	0	1	0	0	0	0	0
WV	0	1	0	2	6	3	2	4	4
Outside U.S.	0	0	1	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	0	0	36
TOTAL	**451**	**327**	**174**	**91**	**333**	**806**	**322**	**747**	**601**

Table 12. The average number of anglers and average number of unlicensed anglers, per boat, with 95% confidence intervals, from the 2008-2010 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)

Table 13. Percent of male and female anglers interviewed by the Maryland striped bass spring season creel survey.

Year	% Male	% Female
2002	95	5
2003	96	4
2004	96	4
2005	97	3
2006	92	8
2007	93	7
2010	95	5

Table 14. Number of lines fished by private boats.

Year	Minimum	Maximum	Mean
2006	3	15	6
2010	1	19	8

Table 15. Dollars spent (per day) by anglers on striped bass fishing trips during the Maryland spring striped bass season.

Year	Minimum	Maximum	Median	Mean
2002	$0	$500	$100	$104
2003	$0	$1,300	$80	$90
2004	$0	$1,000	$100	$114
2005	$0	$1,200	$100	$148
2006	$0	$1,000	$100	$111
2007	$0	$3,000	$50	$63
2010	$0	$500	$76	$89

Table 16. Interviewed anglers' experience (years) fishing for striped bass in Chesapeake Bay.

Year	Minimum	Maximum	Median	Mean
2002	0	60	10	13
2003	0	75	20	20
2004	0	68	12	16
2005	0	64	20	23
2006	0	60	15	18
2007	0	70	21	23
2010	1	60	20	24

Table 17. Average number of fishing trips anglers take per year in Chesapeake Bay.

Year	Minimum	Maximum	Median	Mean
2010	1	100	15	22

Table 18. Percent of interviewed anglers expressing satisfaction with Maryland Chesapeake Bay striped bass fishing regulations.

Year	Satisfied (%)	Not Satisfied (%)
2002	68	32
2003	84	16
2004	70	30
2005	59	41
2006	70	30
2007	64	36
2010	75	25

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 17-May 15, 2010.

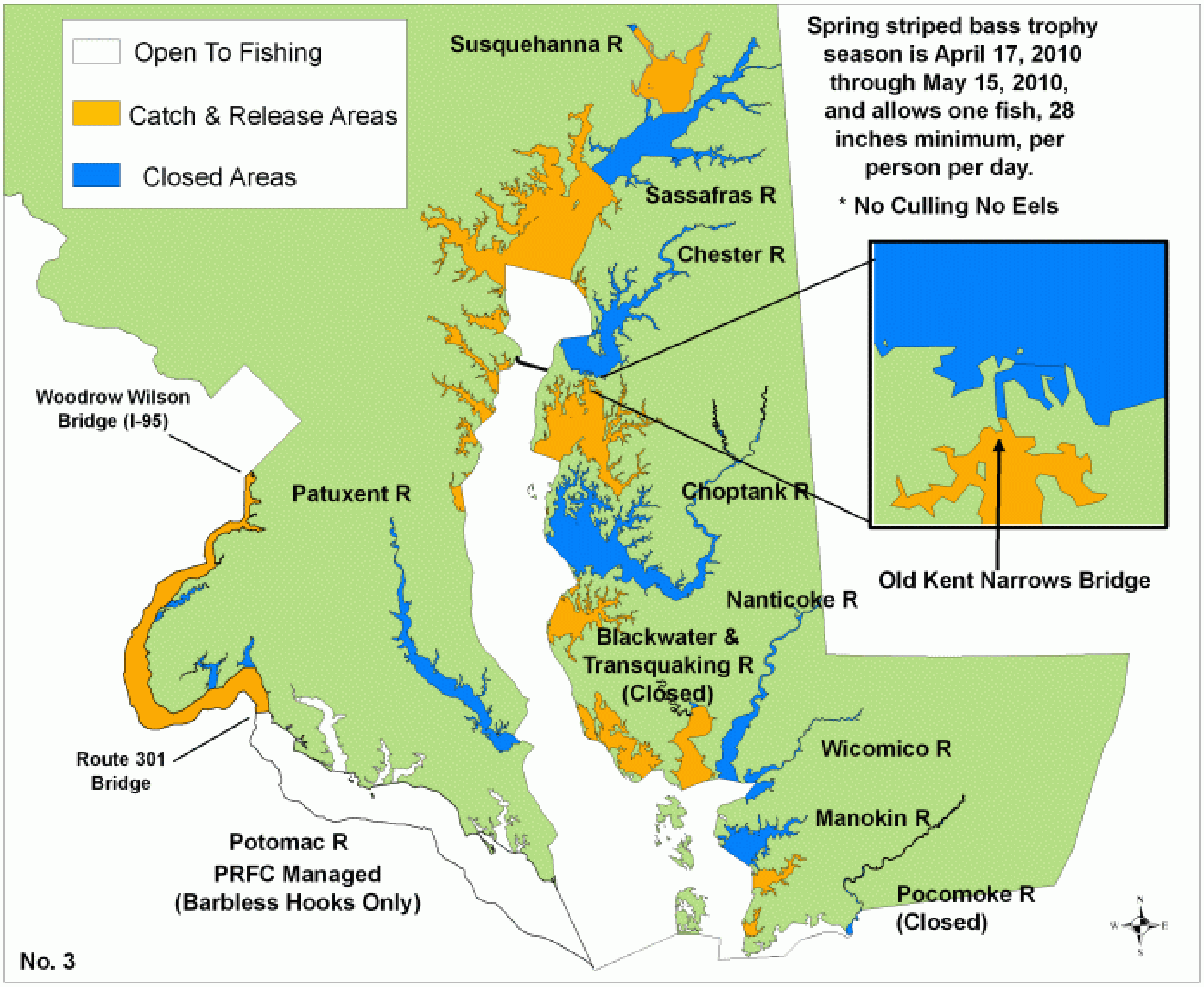


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

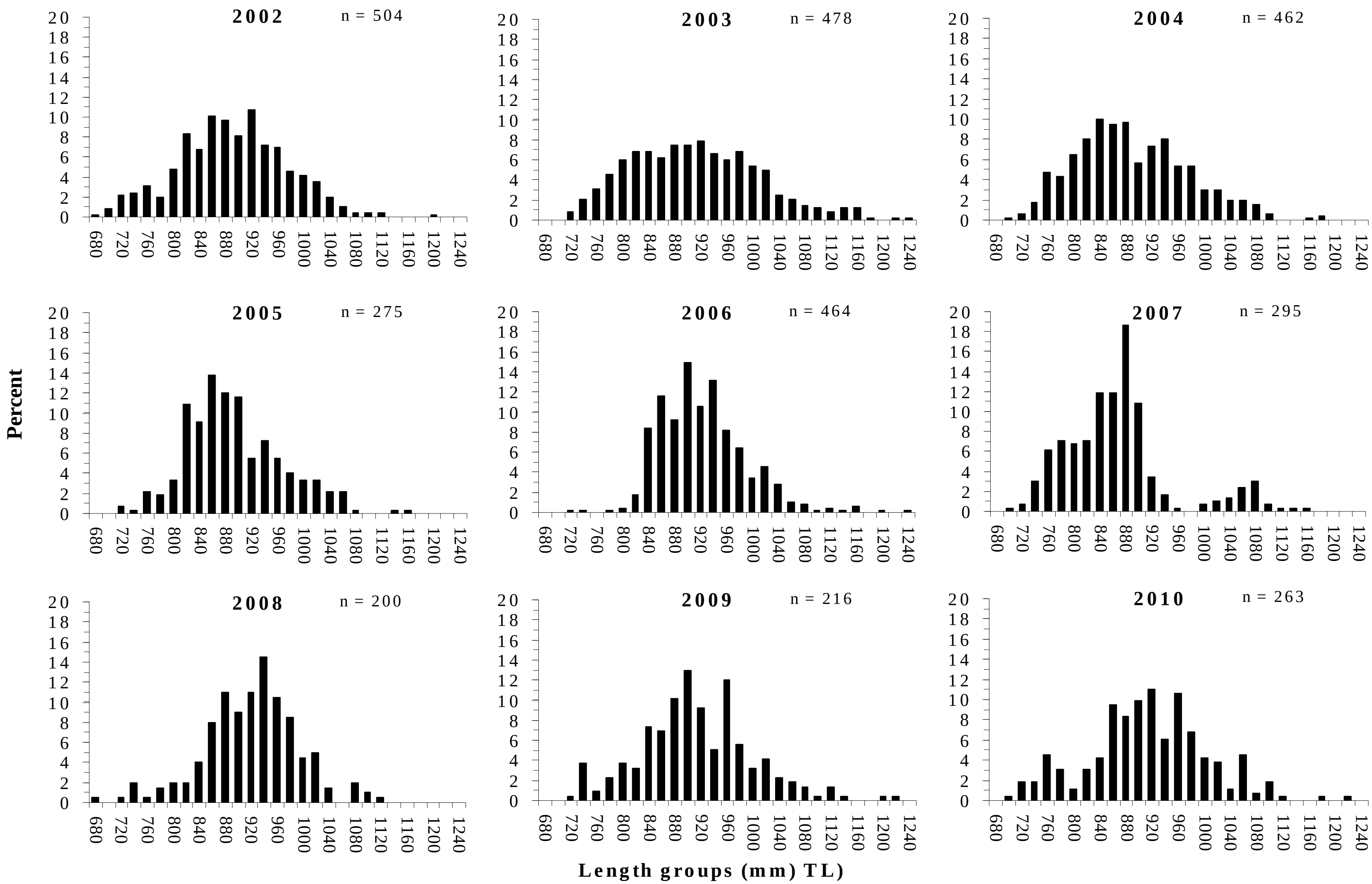


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

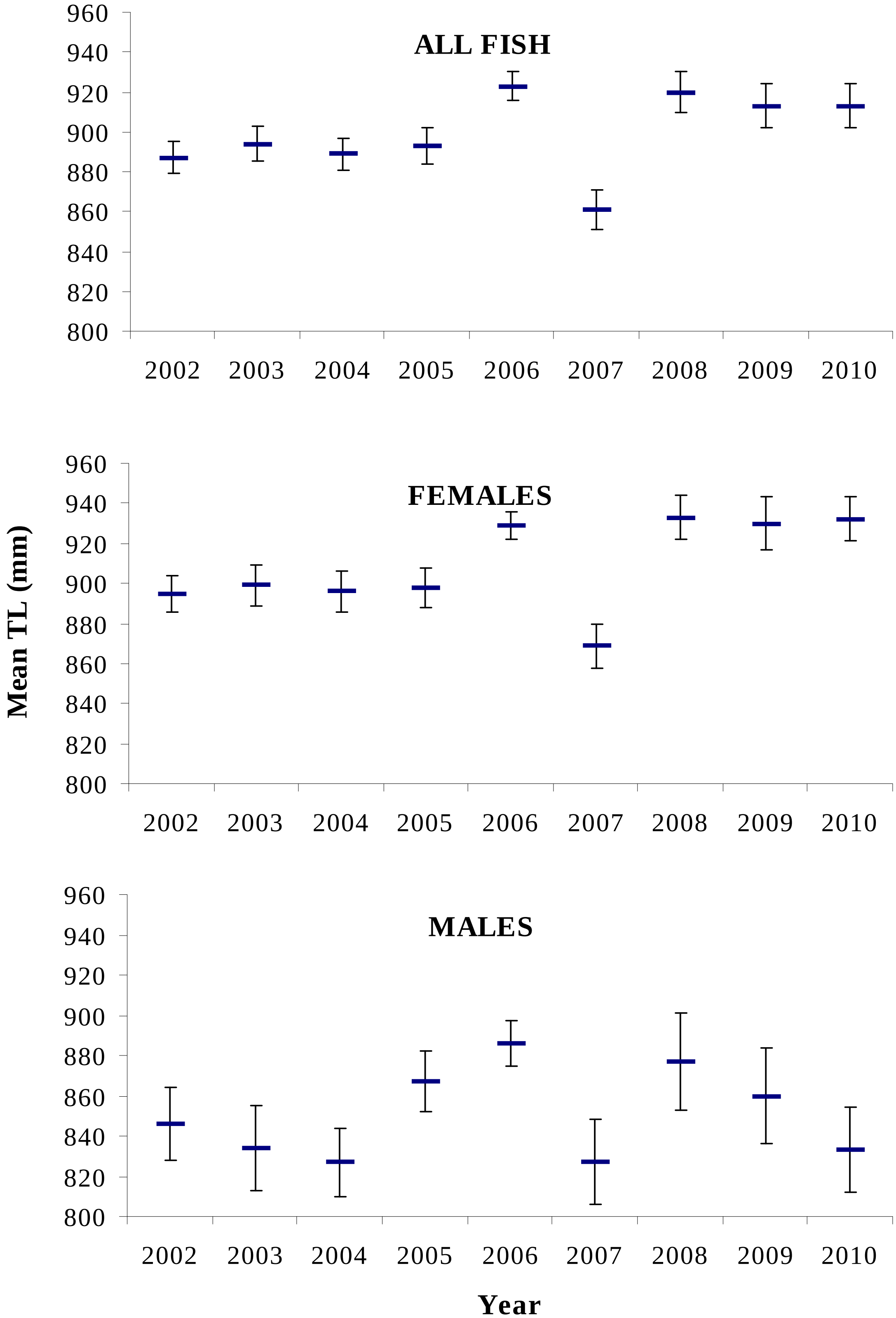


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

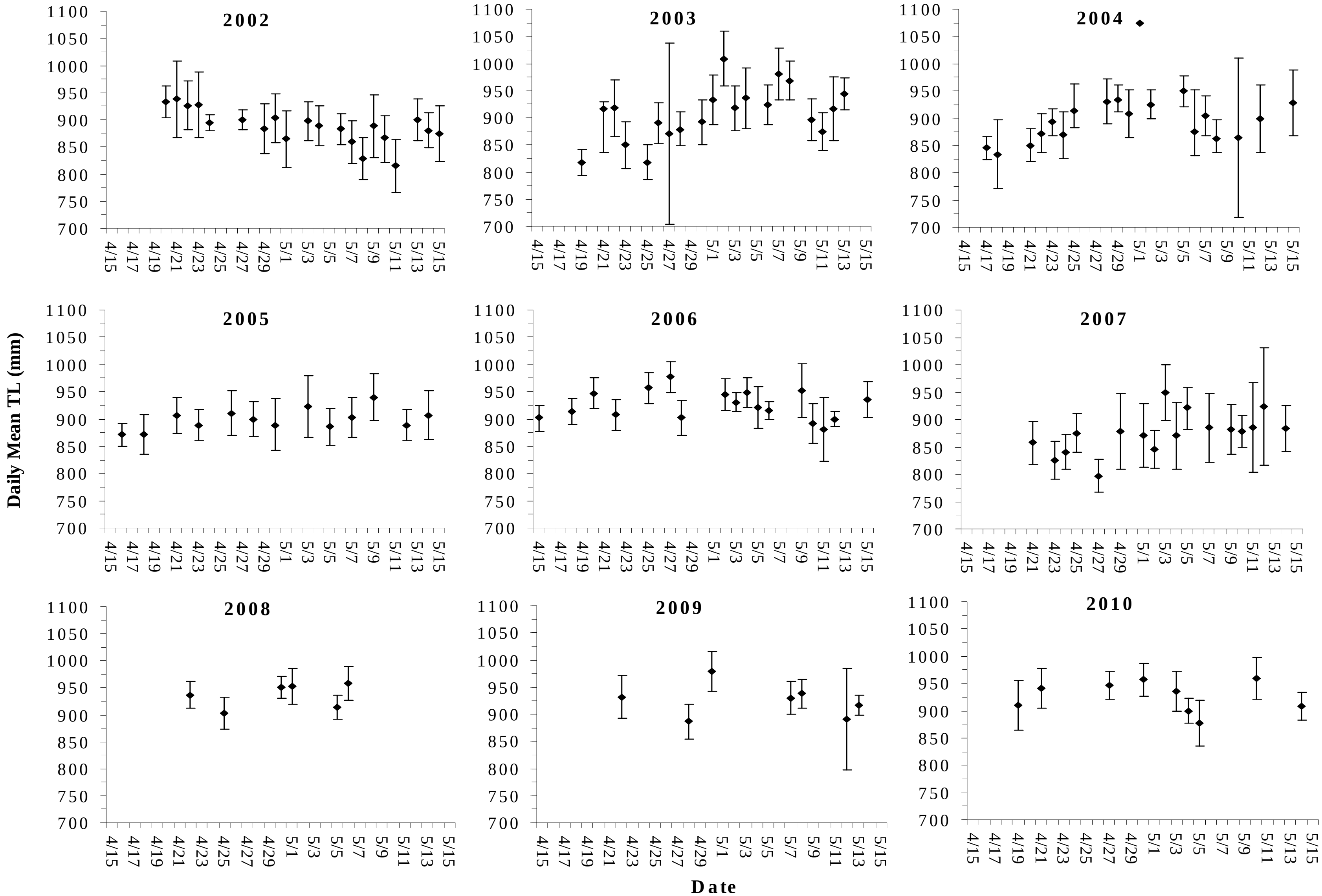


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

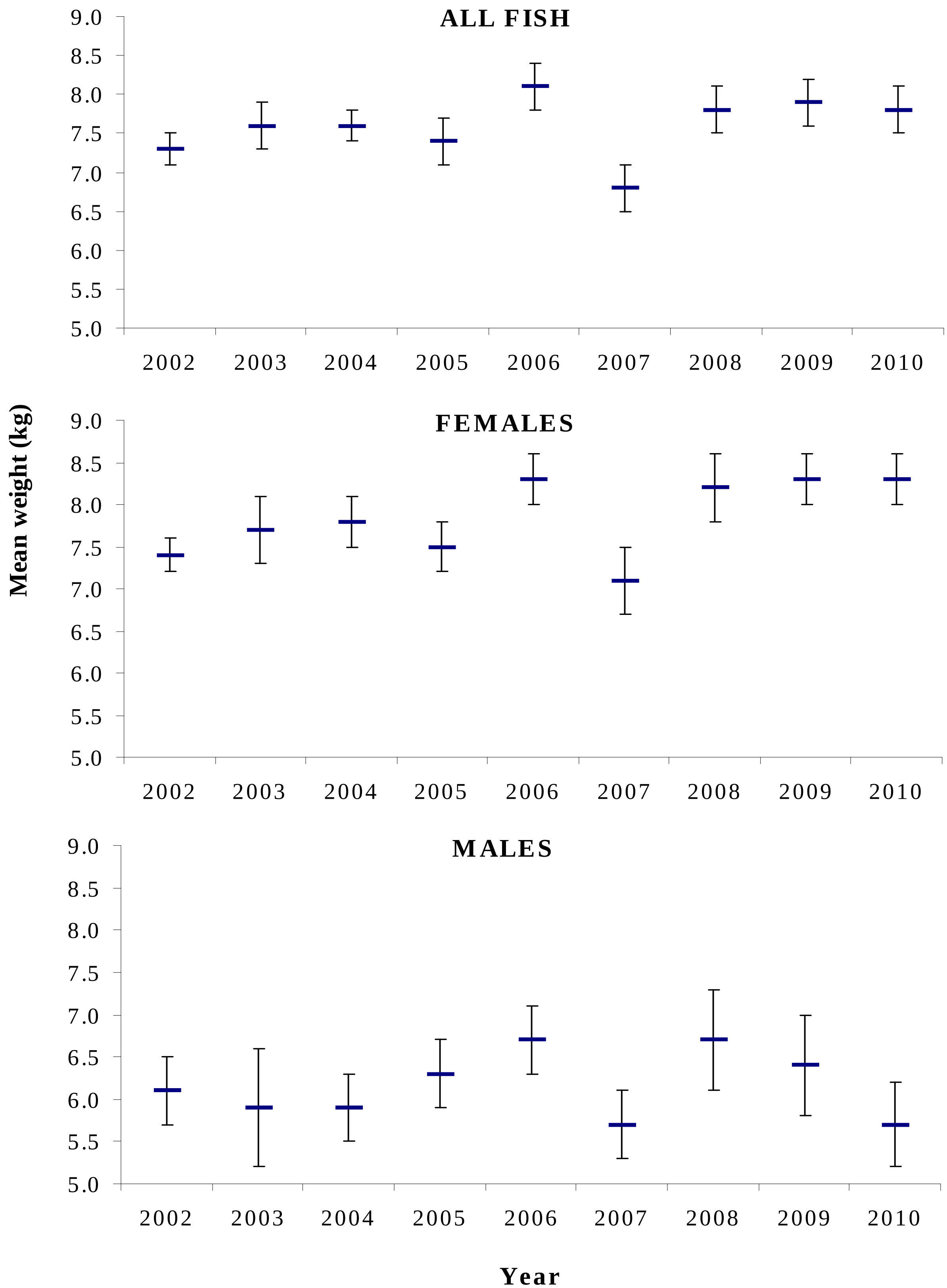


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

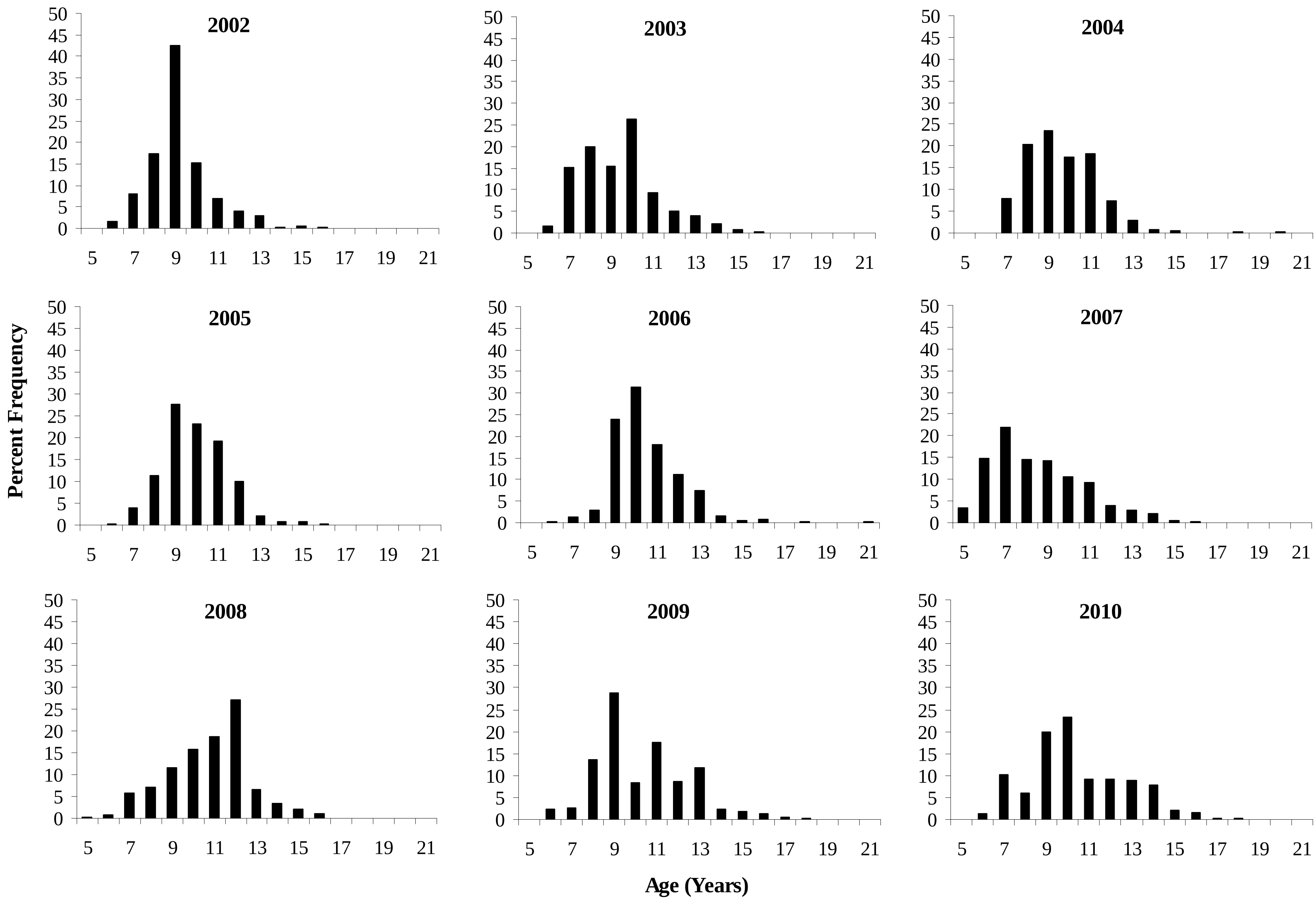


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

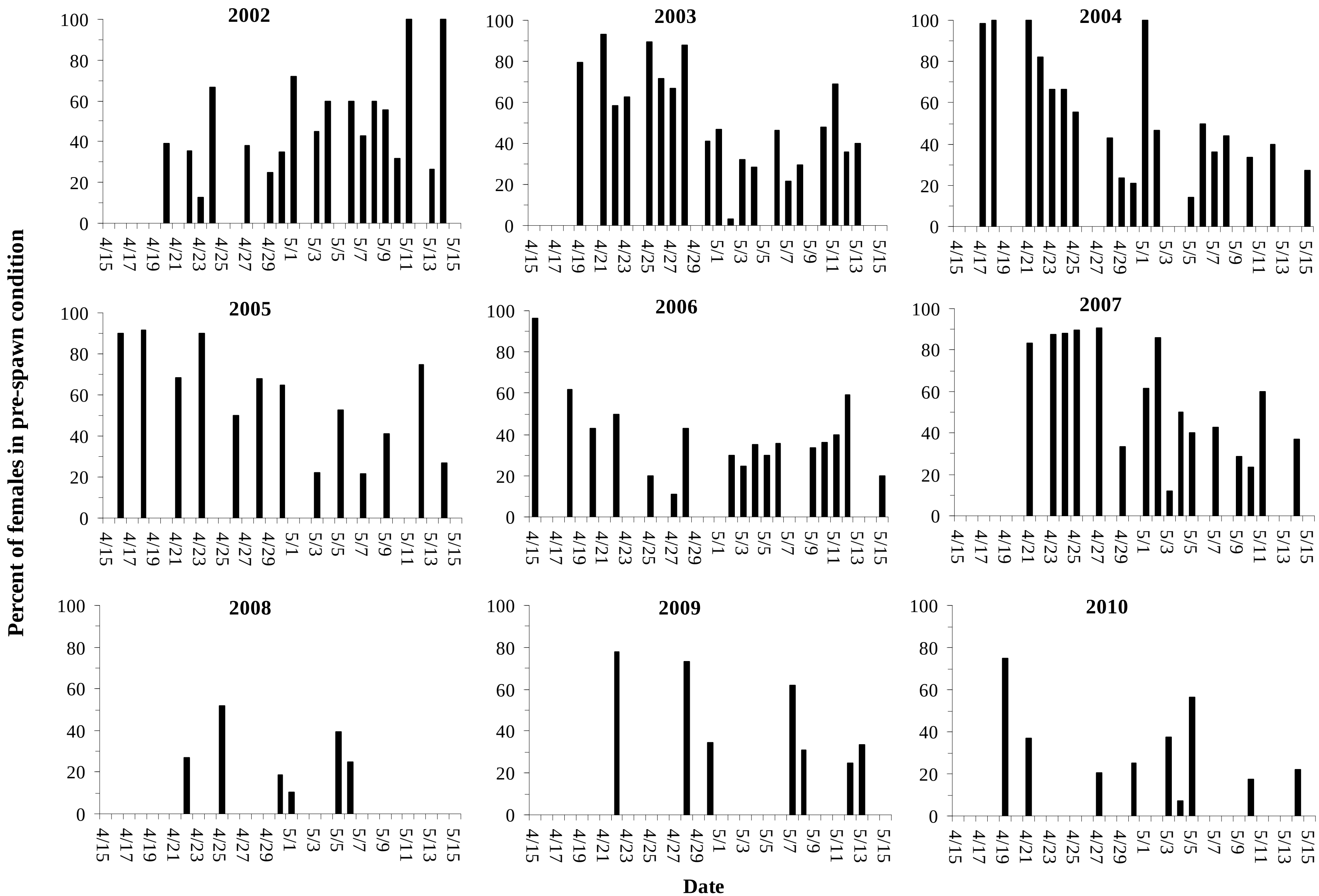
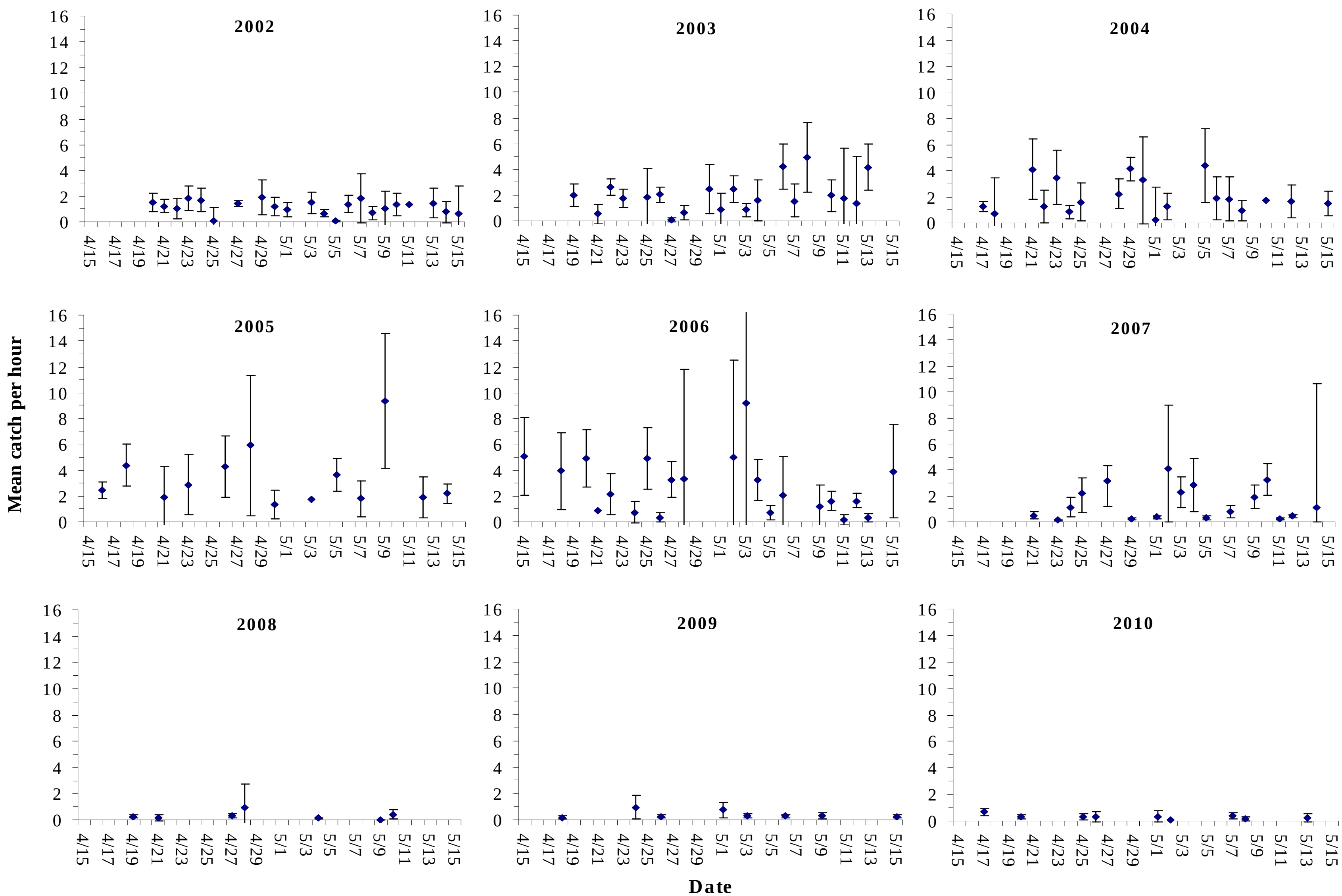


Figure 8. Daily mean catch per hour (CPH) of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15.



APPENDIX I

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

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

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

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

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

5.) How many lines were you fishing?

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

7.) Gender of anglers

8.) What is your state of residence?

9.) Approximately how much money did you spend today to go fishing? (Gas, food, tackle, fare, tip; **excluding the cost of the license**)

10.) How many years have you been fishing for striped bass?

11.) Approximately how many fishing trips do you take per year?

12.) 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?)

13.) Are you happy with the current MD Bay striped bass regulations? If not, what changes would you like to see?

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 annual American shad Technical Committee meeting to approve 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 and the PRFC Blue Crab Advisory Board.

Project staff participated in the USGS/NOAA Meetings to coordinate research activities conducted on Mycobacteriosis in Chesapeake Bay striped bass.

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 2009 to December 2010 are presented in Table 1. Increased traffic on the web page in October and November coincided with publication of 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 2009 to December 2010.

Date	Visits
Dec 31, 2009-Jan 28, 2010	4,809
Jan 29-Feb 25	3,595
Feb 26-Mar 25	3,424
Mar 26-Apr 22	3,880
Apr 23-May 20	3,123
May 21-June 17	3,683
June 18-July 15	3,396
July 16-Aug 12	4,189
Aug 13-Sept 9	3,385
Sept 10-Oct 7	3,889
Oct 8-Nov 4	5,054
Nov 5-Dec 2	3,009

Dec 3-Dec 30	2,156
TOTAL	47,592

Project staff also provided Maryland striped bass data and biological samples such as scale 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, 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, 2009 through October 31, 2010) 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.

-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.

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

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

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

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

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

-Mr. Jason Schaffler, Old Dominion University.

Provision of juvenile Atlantic menhaden biological samples and abundance indices.

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

-The Interjurisdictional Project also provided related biological information and reports to thirty five (35) additional scientists, students and concerned stakeholders.