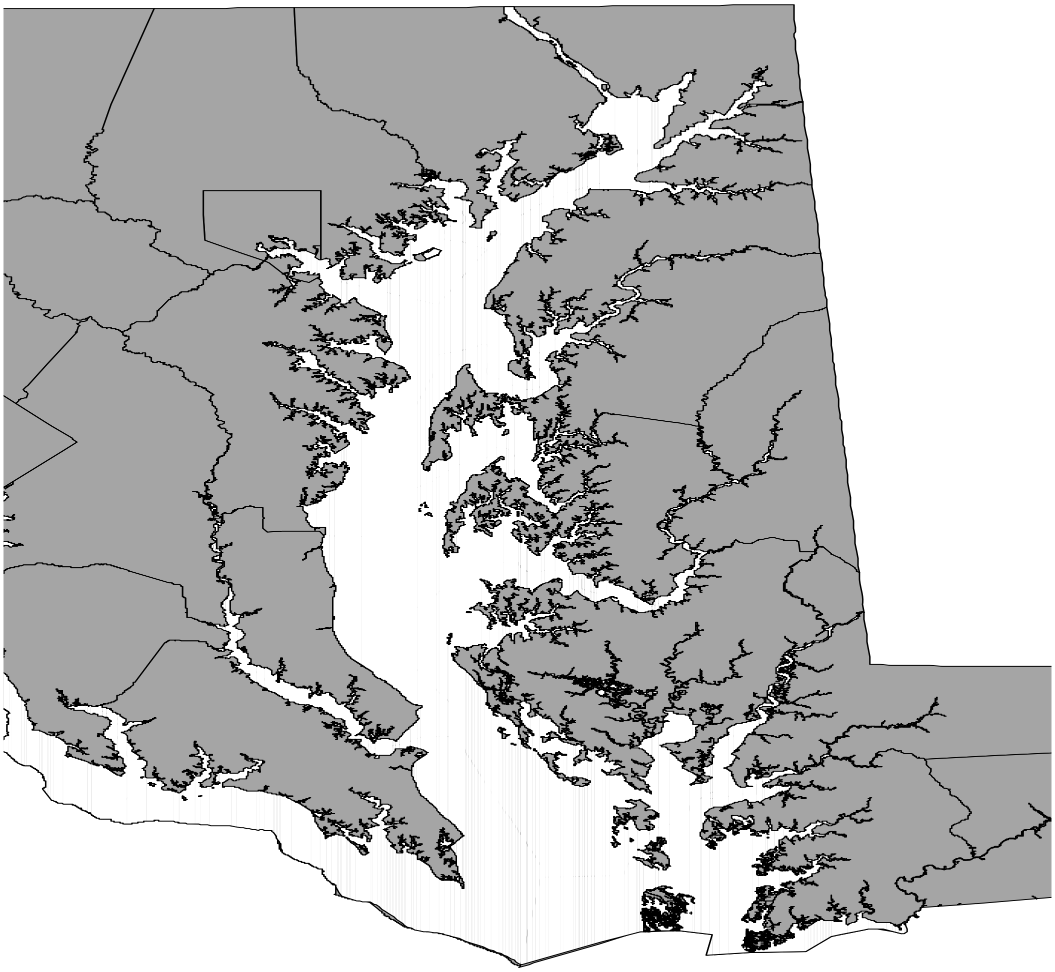


Chesapeake Bay Finfish / Habitat Investigations

US FWS FEDERAL AID PROJECT
F-61-R-5
2008 - 2009

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-5

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish / Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2008 through October 31, 2009

Executive Summary

The primary objective of the Chesapeake Bay Finfish / Habitat Investigations Survey was to monitor and biologically characterize resident and migratory finfish species in the Maryland portion of the Chesapeake Bay and examine fish-habitat interactions. This Survey provides information regarding recruitment, relative abundance, age and size structure, growth, mortality, migration patterns, and affects of habitat modifications on finfish populations in Maryland's Chesapeake Bay. The data generated are utilized in both intrastate and interstate management processes and provides a reference point for future fisheries management considerations.

Channel catfish population biomass and instantaneous fishing mortality (F) were determined using a surplus production model for the Head-of-Bay (HOB) stock. HOB biomass and fishing mortality estimates were compared to biological reference points derived from the model. Model results indicated steady population growth from 1980 – 1989. Biomass declined through 2002, and then increased through 2007. Biomass in the final year of the assessment (2008) was estimated at 8.4 million pounds, approximately 27% greater than B_{msy} , a parameter generated by the model that can be used as a biological reference point. Since biomass was greater than B_{msy}, HOB channel catfish stocks were not considered overfished. Instantaneous fishing mortality was generally low between 1980 and 1995 but increased to unsustainable levels from 1996 – 2002. Fishing mortality then declined to more reasonable rates from 2003 – 2008 with the time series low occurring in 2007. The 2008 F estimate was nearly 50% below the suggested biological reference point, indicating that overfishing was not occurring.

Channel catfish stocks in the Choptank and Potomac rivers were assessed qualitatively with available fishery dependent and independent data. The Choptank River relative abundance data indicated that this stock has been growing since 1990 and that young-of-year relative abundance has been generally high since 1997. Potomac River channel catfish relative abundance data indicated that the population is at a low and stable level as compared to the time period 1990 – 1996. Juvenile production has been low when compared to the early 1980's. Commensurate with theses declines has been an increase in blue catfish relative abundance. No cause and effect relationship can be definitively proven, but inter-specific competition between the two ictalurid species may provide one hypothesis as to why the Potomac River population has failed to increase or sustain biomass while the Choptank River and HOB stocks have increased.

American shad abundance in the lower Susquehanna River increased during 2009 from the previous year, but was still significantly below the highest abundance recorded in 2001 . Populations of American shad in Maryland continue to be impacted by predation, bycatch and turbine mortality. Juvenile American shad production also mirrored this trend with the 2009 baywide indices well below their historic average. Hickory shad stocks in the upper Chesapeake Bay continue to demonstrate stable population characteristics as indicated by their elevated abundance estimates, low mortality rates, and diverse age structure and spawning history. The decreases in catch per angler hour (CPAH) observed on Deer Creek may be related to reduced effort in April because of low stream flow conditions. River herring abundance indices for 2009 continued to be very low and populations throughout Maryland waters demonstrated characteristics of overfishing, including elevated mortality rates, truncated age structure, few repeat spawners and poor juvenile production. River herring stocks are also projected to remain low during the next several years.

Weakfish have experienced a sharp decline in abundance coast wide. Recreational catch estimates by the National Marine Fisheries Service (NMFS) for Maryland fell steadily from 475,348 fish in 2000 to 493 fish in 2006, and remained very low (2,590) in 2008. Maryland's commercial weakfish harvest declined to 5,815 pounds in 2008, the lowest catch on record. The 2009 mean length for weakfish from the onboard pound net survey was 262mm TL, also the lowest of the time series. The 2009 length frequency distribution and RSD analysis indicated that only smaller weakfish were available in Maryland waters. Fish aged from the 2008 pound net survey were all 3 years of age or younger.

Summer flounder mean length from the pound net survey was 368 mm TL in 2008, above the average for the 15 year time series. Relative stock densities in 2009 indicated a decrease in the stock category and an increase in the preferred category compared 2008. Charter boat catch per unit effort (CPUE) has significantly declined from 1993 - 2008, but has been relatively stable for the past five 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 2009 was 265 mm TL, the 3rd lowest recorded between 1993-2009. Length distribution and RSD analysis indicated a shift toward smaller bluefish in 2009. Both recreational and commercial bluefish harvests in Maryland declined in 2008, and were below the long term average. The latest coast wide stock assessment indicated the stock was not overfished and overfishing was not occurring.

The mean length of Atlantic croaker examined from the pound net survey in 2009 was 320 mm TL; the largest of the 17-year time series. RSDs for Atlantic croaker indicated an increase in $RSD_{preferred}$, $RSD_{memorable}$ and RSD_{trophy} fish. Individuals aged from the 2008 survey ranged from 1 – 11 years old. Maryland Atlantic croaker commercial harvest increased to 592,211 pounds while the estimated 2008 recreational harvest of 689,184 fish decreased compared to2007. In contrast, the 2008 charter boat CPUE was the highest of the 16 year time series.

Spot length frequency distribution in 2009 was truncated, and the mean length was below the average of the time series. Juvenile indexes have been lower in recent years with improvement detected in 2007 and 2008. However a drastic decline occurred 2009. Commercial and recreational harvests declined in 2008 from above average levels in 2007. The charter boat geometric mean catch per angler also decreased in 2008, but was still above the long term average.

Resident / premigratory striped bass harvested in the Chesapeake Bay during the summer – fall 2008 pound net and hook and line commercial fisheries ranged from 1 to 14 years of age. Four and five year old striped bass from the 2003 and 2004 year-classes dominated samples taken from pound nets, comprising 68% of the sample. Check station sampling determined that the majority of the pound net and hook-and-line fishery harvest was also composed of four and five year old individuals from the 2003 and 2004 year-classes.

The 2008-2009 commercial striped bass drift gill net fishery harvest was comprised primarily of fish between 4 and 6 years old from the 2003, 2004 and 2005 year-classes. Striped bass from the 2004 year-class comprised 46% of the total drift gill net harvest. The 2005 and 2003 (ages 4, and 6) cohorts accounted for an additional 51% of the total harvest while age 8 to 13 year-old fish contributed only 2% to the total. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 3 to 13 (1996 – 2006 year-classes).

The spring, 2009 spawning stock survey indicated that there were 15 age-classes of striped bass present on the Potomac River and upper Bay spawning grounds. These fish ranged in age from 2 to 15 years old. Age 6 striped bass from the 2003 year-class were the most abundant component of the male spawning stock. Age 13 (1996 year-class) and age 9 (2000 year-class) females were the major contributors to 2009 total female abundance and CPUE. Age 8 and older females comprised 88% of the female spawning stock in 2009. Females younger than age 7 have been uncommon in the spawning stock since 1996; however, several females ages 4, 5, and 6 were sampled on the spawning grounds in 2009. The Chesapeake Bay striped bass spawning stock remains healthy and is closely monitored by MD DNR biologists in partnership with other coastal states and the ASMFC.

During the 2009 spring trophy season, biologists intercepted 322 fishing trips, interviewed 747 anglers, and examined a total of 216 striped bass. The average total length of striped bass sampled was 913 mm TL (35.9 inches), and the average weight was 7.9 kg (17.4 lbs). Most fish sampled from the trophy fishery were between eight and thirteen years old. The 2000 year-class (age 9) was the most frequently observed year-class, constituting 29% of the sampled harvest. Average CPAH based on recreational angler interviews was 0.4 fish per hour.

The 2009 striped bass juvenile index, the annual measure of striped bass spawning success in Chesapeake Bay, was 7.9. This was slightly below the long-term average of 11.7, but more than twice the 2008 value. During this survey, which monitors the four major spawning systems in Maryland, biologists identified and counted more than 35,000 fish of 49 species, including over 1,000 young-of-year 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.

MD DNR biologists continued to tag and release striped bass in 2009 as part of ongoing, interstate and coastal studies. A total of 1,002 striped bass were tagged and released during the 2009 sampling season with USFWS internal anchor tags. Of this sample, 856 were tagged in the Chesapeake Bay during the spring spawning stock assessment survey. A total of 146 striped bass were tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise. Anglers encountering a tagged striped bass were asked to help management efforts by calling the phone number printed on the tag and providing catch information. Specialized coded wire tag (CWT) sampling was conducted on the Patuxent River during 2009. A total of 60 striped bass were scanned for the presence of CWT's but none were found to be CWT positive.

Tax map derived development indices appear to be the most reliable source for standardized, readily updated, and accessible development indicators in Maryland. Counts of structures per acre and square footage of structures per acre had a strong relationship with "new" Towson IS estimates for 2000 and predictions of IS developed from these indices were well within the "play" experienced when using other data sources to estimate IS.

Little change in anadromous fish stream spawning in Mattawoman Creek was indicated between 1971 and 1989-1991 but by 2008-2009 spawning site losses were evident for all three species groups. Stream spawning of anadromous fish nearly ceased in Piscataway, Swan, and Broad creeks, and Oxon Run between 1971 and 2008-2009. The most current urban cover estimate for Mattawoman Creek is similar to Piscataway Creek in 1973 while the current Piscataway Creek urban cover estimate is similar to that projected for the Mattawoman Creek development district. If planned development proceeds in the Mattawoman watershed, anadromous fish stream spawning is expected to cease. Elevated conductivity in non-tidal Mattawoman and Piscataway creeks indicated that urbanization has impacted both systems. Average conductivity was greater in the more urbanized Piscataway Creek than Mattawoman Creek while the conductivity gradient in the Mattawoman non-tidal mainstem changed from declining to increasing with distance from the estuary between 1991 and 2008-2009.

Regression analyses (multiple watersheds and years) indicated IS was negatively related to an index of yellow perch egg-larval survival (L_p, the proportion of standard estuarine plankton tows with larvae), but the relationships were different in fresh-tidal and brackish systems. On average, L_p was higher in fresh-tidal systems until high levels of IS (≈ 20%) were reached.

A total of 90,075 fish (trawl and seine combined) representing 55 species were captured from the ten subestuaries sampled during 2009. Of these 55 species, 8 comprised 90% of the catch, but only three (white perch, Atlantic menhaden, and blueback herring) were target species. White perch have been the most consistently captured species and is an ideal target species for examining habitat impacts because they are ubiquitous, effectively captured by both gears as adults and juveniles, have similar habitat requirements as other target anadromous species, and are important recreationally.

The Mattawoman Creek fish community has declined over the last two decades in spite of meeting Chesapeake Bay habitat goals related to water clarity, dissolved oxygen, nutrients and SAV. The summer trawl sampling species richness and relative abundance for this watershed ranked last in comparison with other watersheds monitored in 2009, including brackish tributaries with very high IS. It was the most highly ranked system in the early 1990s.

Structure counts for the Mattawoman Creek watershed steadily increased from nearly 11,000 to 21,000 between 1989-2008. Regression models described little or no effect of development on total catch or the number of species collected until a threshold of approximately18,000 structures was reached in 2002. Subsequent development beyond this threshold (10% IS) was followed by further declines.

Based on these results planned levels of development in the Charles County's portion of the Mattawoman Creek watershed should be considered in light of the extent of declines detected in the fish community at current levels of IS and that mitigation and restoration measures must be considered to offset damage already exhibited.

There was no indication that the Corsica River is experiencing changes in habitat quality based on current water quality and fish assemblages. A decline in the dissolved oxygen levels for the Wicomico River provided indication that a development threshold (tipping point) has been crossed in this watershed and that expanded monitoring efforts should be undertaken to clarify what changes and to what extent they have occurred.

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 Cope Hubbard and Rocky Graves. We also wish to thank Don Cosden, Mary Groves, Tim Groves, and Ross Williams of Inland Fisheries and Brian Richardson and Chuck Stence of the Hatchery Program for assisting with Patuxent River electrofishing for CWT tagged striped bass.

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

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

James Uphoff
Rudy Lukacovic
James P. Mower
Margaret S. McGinty
Keith A. Whiteford

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 2009, 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 30 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 2008 through February 2009.

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.

Choptank River Fishery Independent Sampling

In 2009, 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 24 February through 1 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.

Marshyhope River Fishery Independent Sampling

A fishery independent survey of the Marshyhope River was initiated in 2007. During 2009, four experimental fyke nets were set in this system from 26 February – 2 April. Locations ranged from the Maryland Route 392 bridge near Hurlock, Maryland to approximately 2 miles downstream of Federalsburg, Maryland (Figure 3). Sampling protocol mimicked that of the Choptank River in all respects. Since this was the third year of sampling the Marshyhope River, this effort should be viewed as a pilot study. Data were compiled into the Nanticoke River dataset for presentation.

Upper Chesapeake Bay Fishery Dependent Sampling

Commercial fyke net catches were sampled for yellow perch from 14 February 2009 through 11 March 2009 from Gunpowder River and Northeast River (Figures 4, 5). All yellow perch were measured and sexed (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River Fishery Dependent Sampling

From 17 February 2009 to 1 May 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 6). Net sites and dates fished were at the discretion of the commercial fishermen. All yellow perch caught were sexed, measured for total length and a non-random sample of otoliths removed for age determination. Thirty randomly selected white perch from the fyke nets were sexed and measured and a subsample was processed for age determination (otoliths). A bushel of unculled, mixed catfish species was randomly selected, identified as channel or white catfish and total lengths measured.

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 (Piavis and Webb, in publ.).

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 7-9
Yellow perch	Tables 11-14 and Figures 10-13
Channel catfish	Tables 15-17 and Figures 14-16
White catfish	Tables 18-20 and Figures 17-19

Growth

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

Mortality

White perch	Table 26
Yellow perch	Table 27

Recruitment

White perch	Figures 20-21
Yellow perch	Figures 22-23

Channel catfish	Figures 24-25

<u>Relative Abundance</u>

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

CITATIONS

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

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

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

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

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

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 2008 – February 2009. Different symbols indicate each of 6 different sampling rounds.

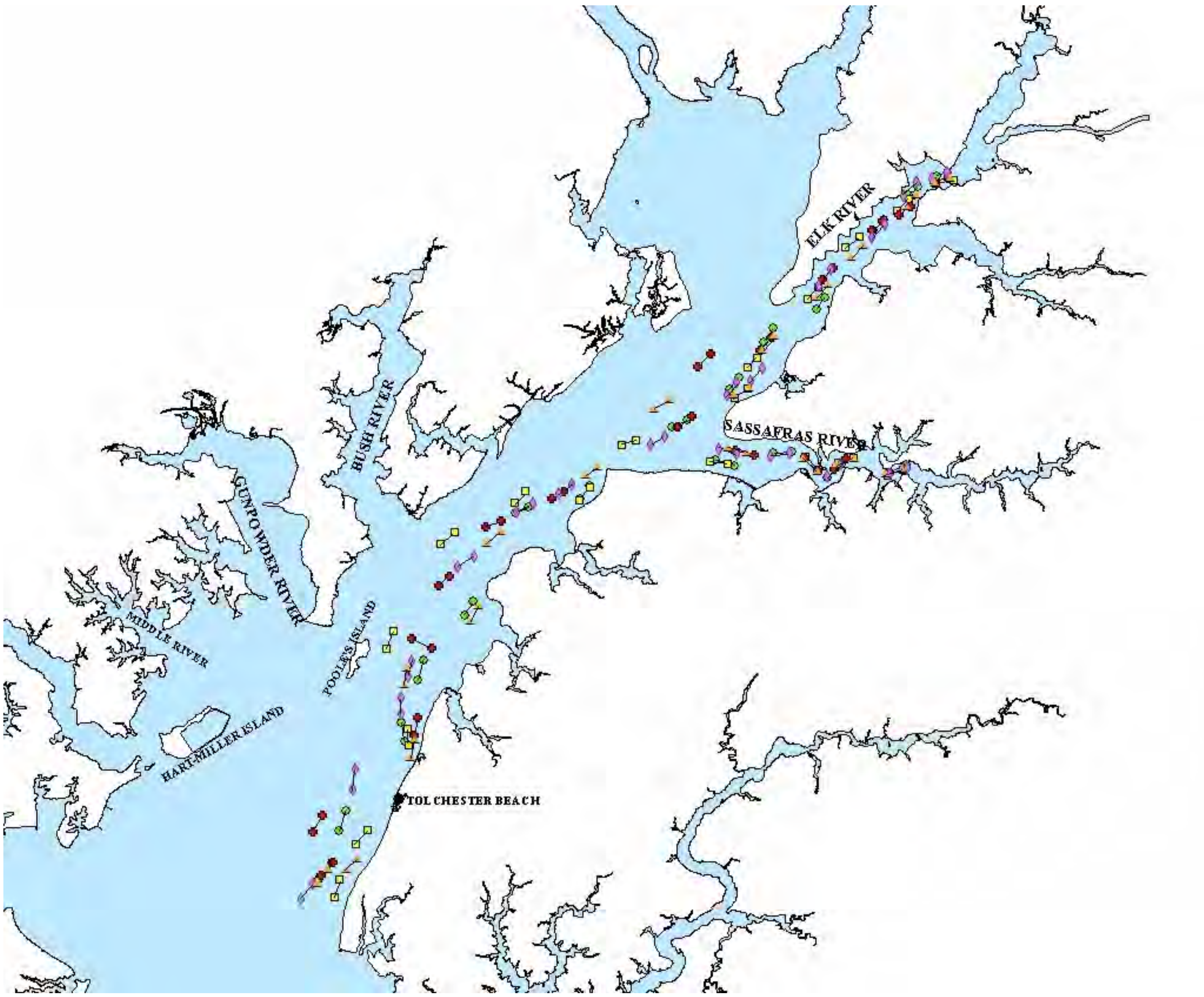


Figure 2. Choptank River fyke net locations, 2009. Circles indicate sites.

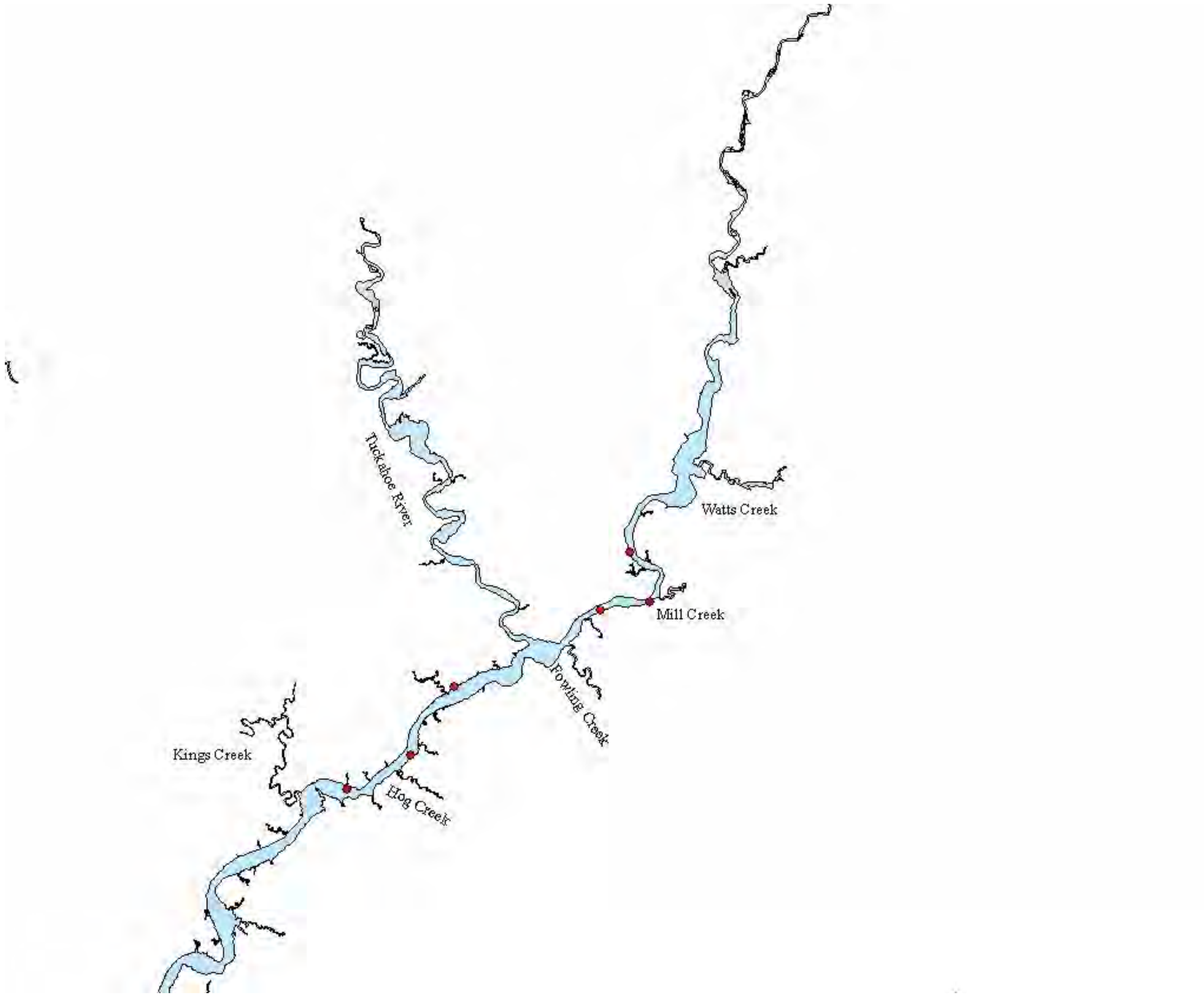


Figure 3. Marshyhope River fyke net locations, 2007, 2008 and 2009.

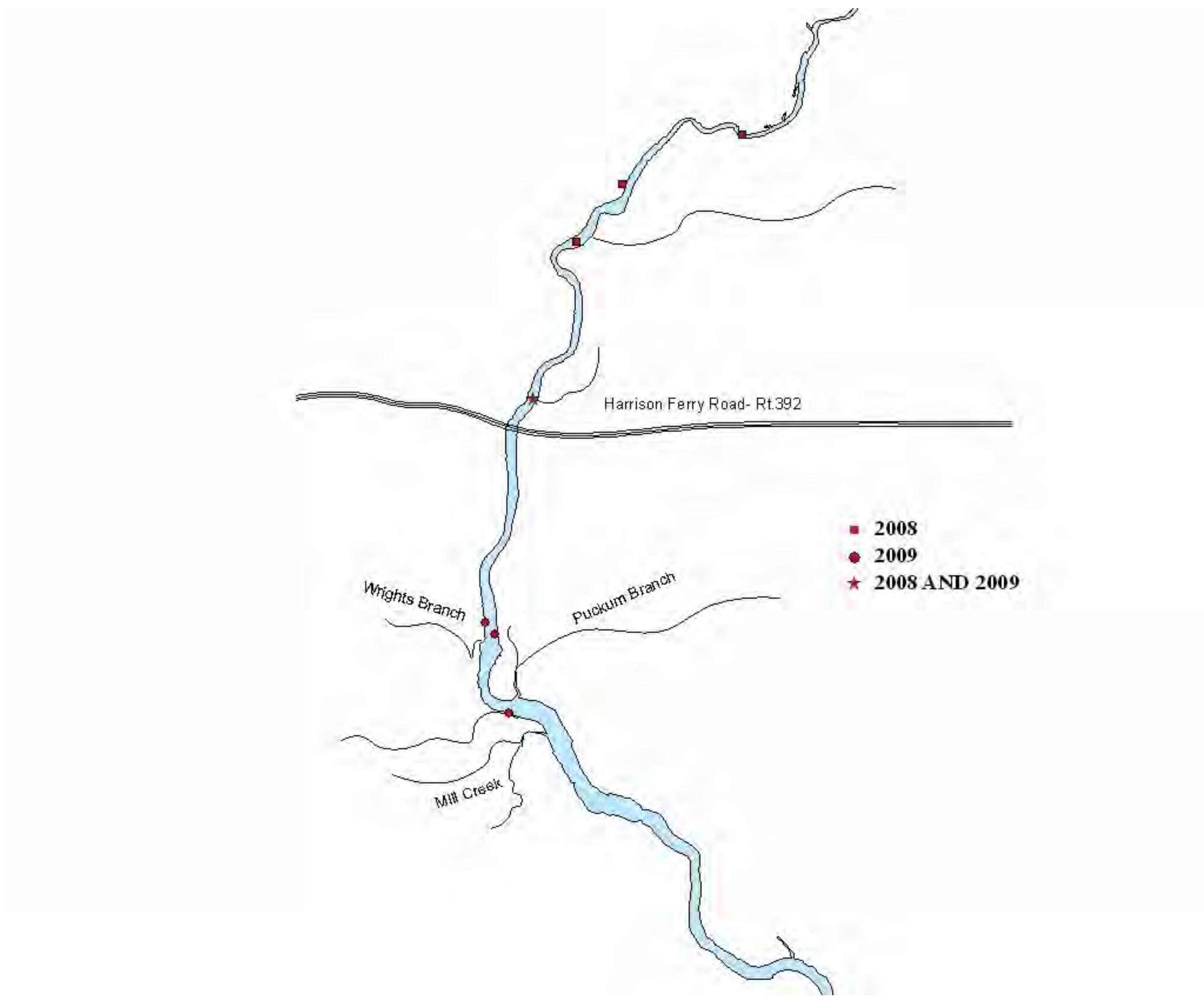


Figure 4. Commercial yellow perch fyke net sites sample during 2009 in the Gunpowder River.

Figure 5. Commercial yellow perch fyke net sites sample during 2009 in the Northeast River. Black lines indicate the geographic range of fyke net locations.

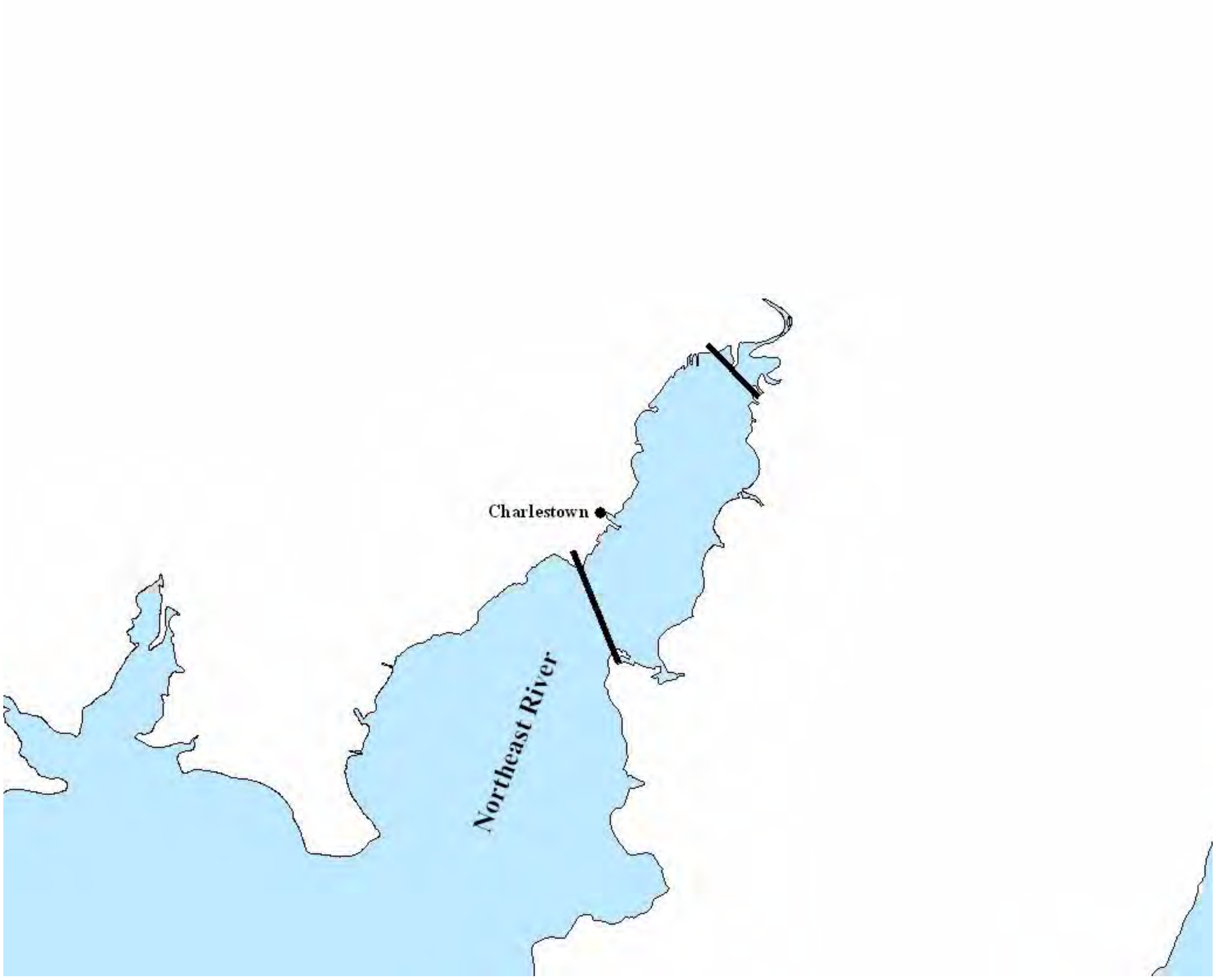


Figure 6. Commercial fyke net and pound net sites sample during 2009 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

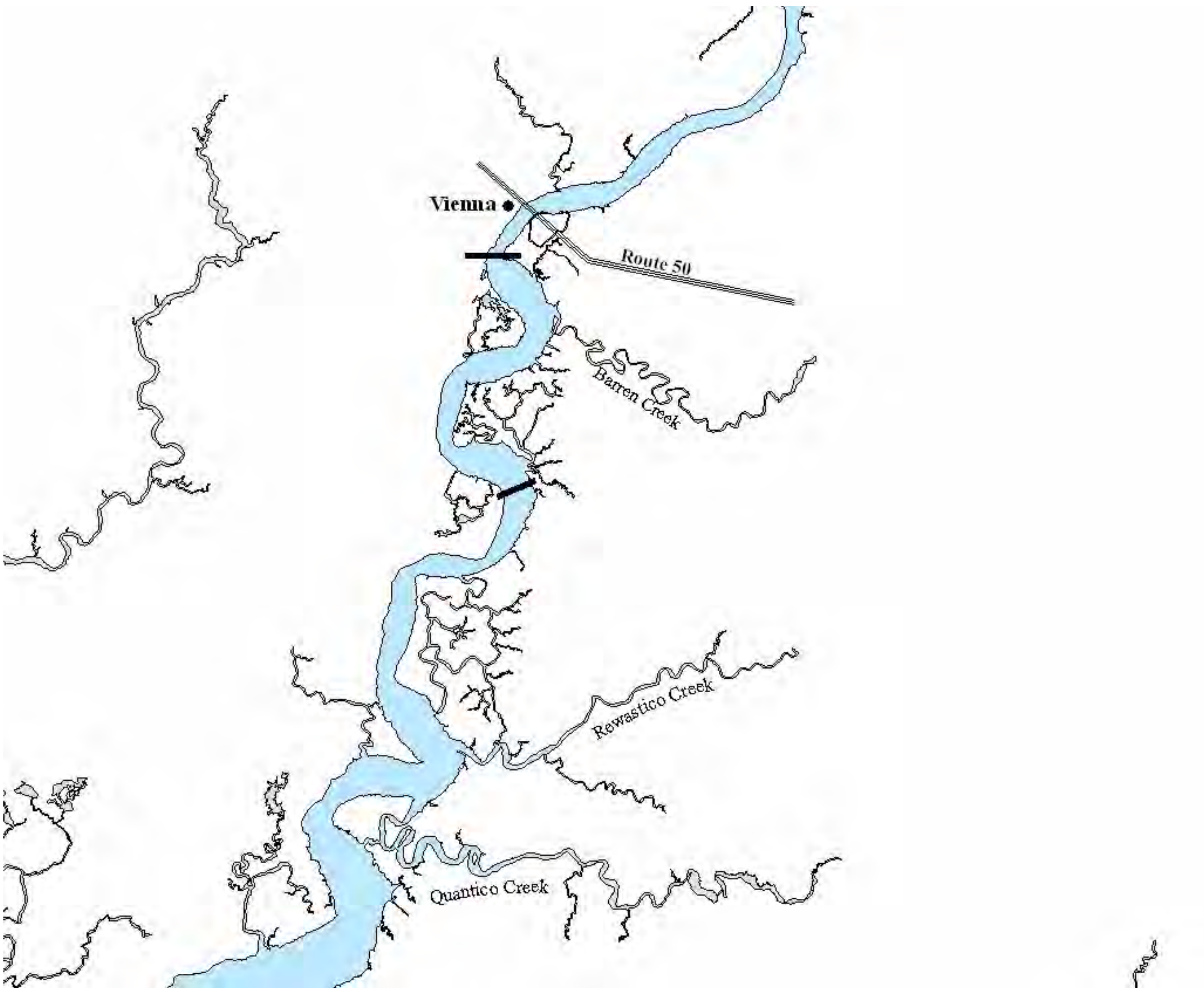


Table 1. White perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2009.

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

Table 2. White perch catch at age matrix from Choptank River fyke net survey, 2000 – 2009.

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

Table 3. White perch catch at age matrix from Nanticoke River fyke and pound net survey, 2000 – 2009. 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

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2009.

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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2009.

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

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2009.

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

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2009. 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

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2009. 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

Figure 7. White perch length-frequency from 2009 upper Chesapeake Bay winter trawl survey.

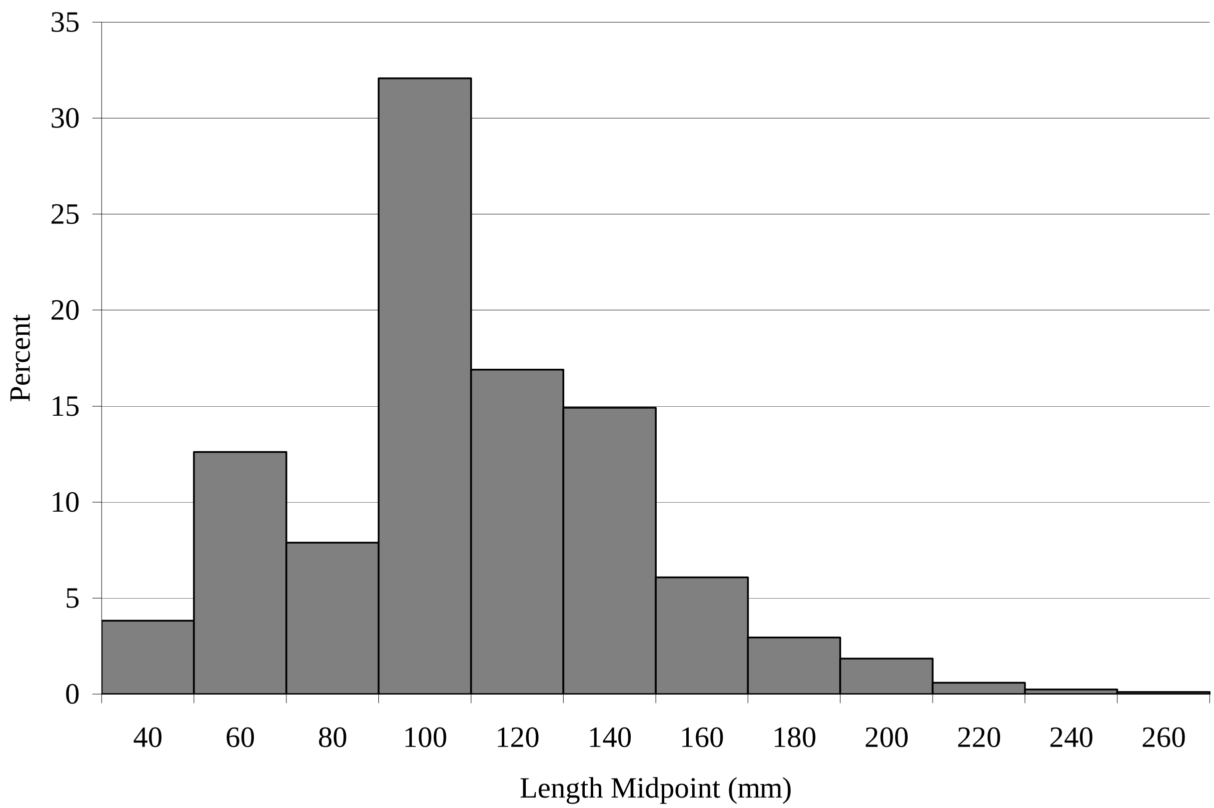


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2009. Minimum length cut-offs in parentheses.

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

Figure 8. White perch length-frequency from 2009 Choptank River fyke net survey.

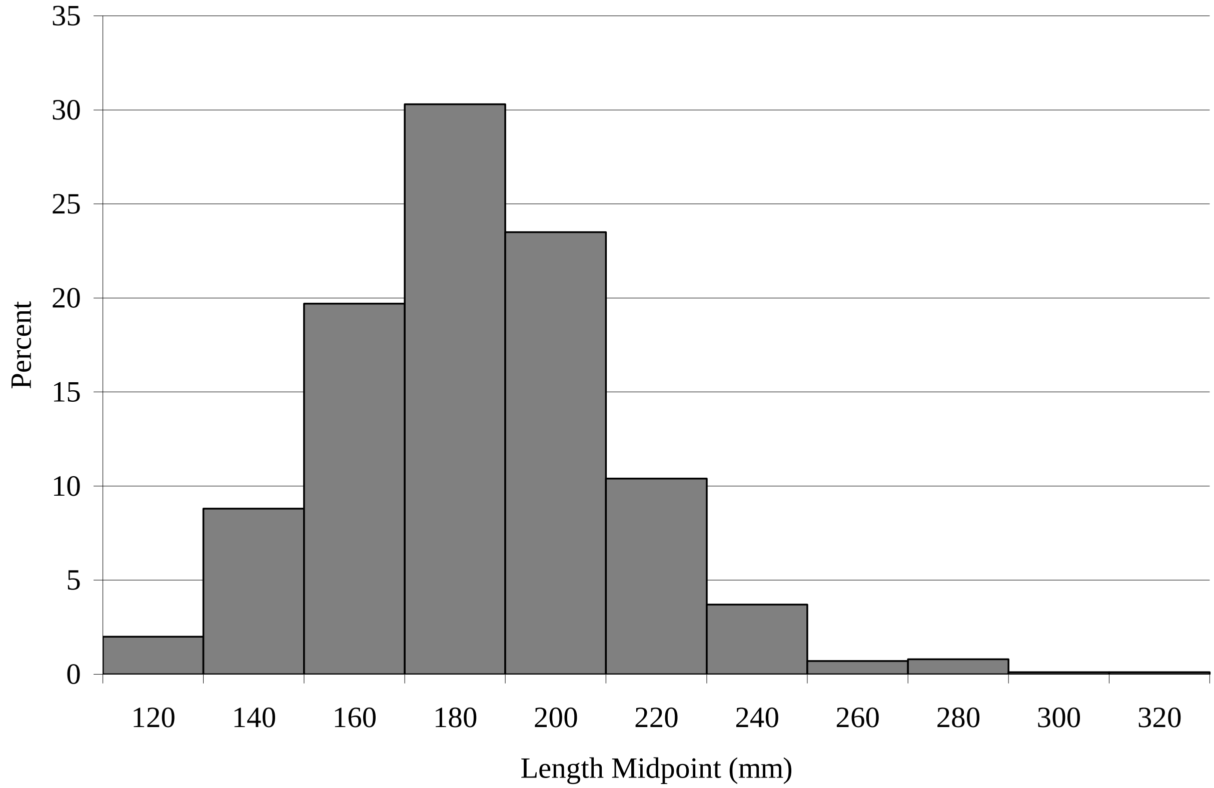


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2009. Minimum length cut-offs in parentheses. 2007 -- 2009 include Marshyhope River data.

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

Figure 9. White perch length-frequency from 2009 Nanticoke River fyke and pound net survey, including Marshyhope River data.

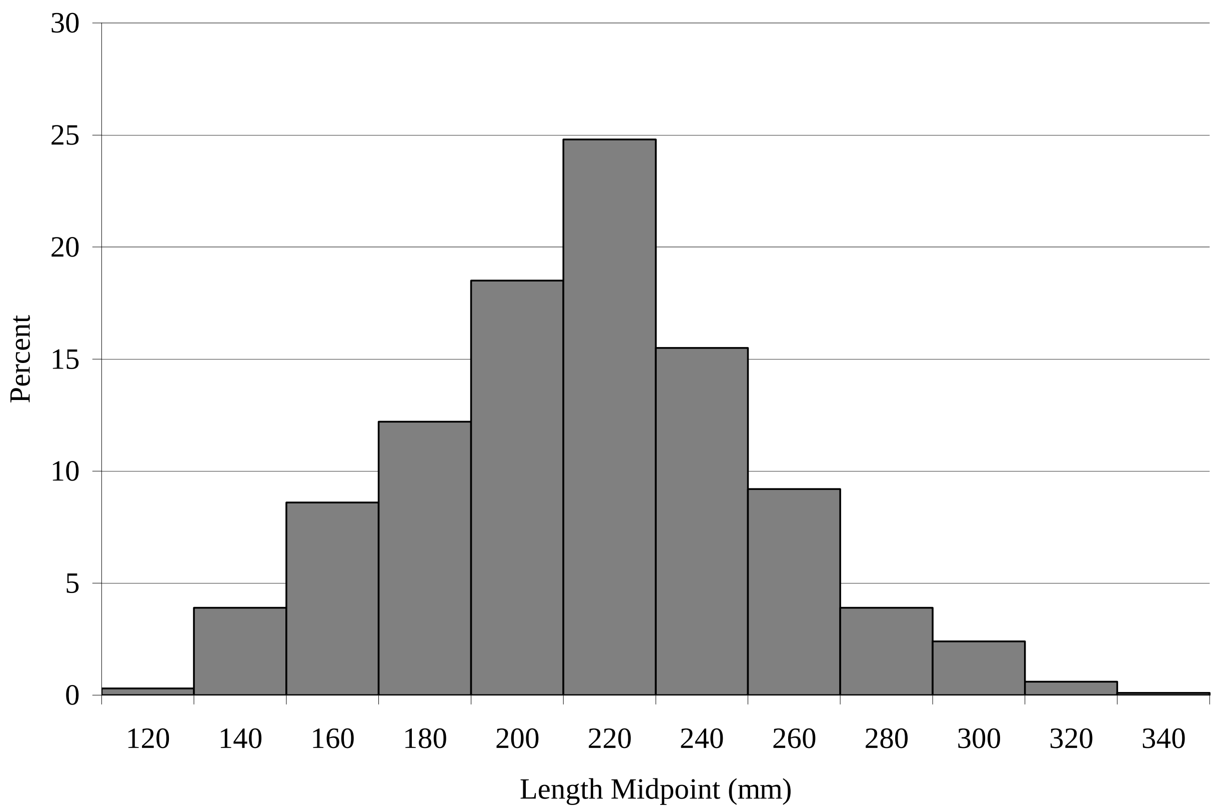


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2009. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length-frequency from the 2009 upper Chesapeake Bay winter trawl survey.

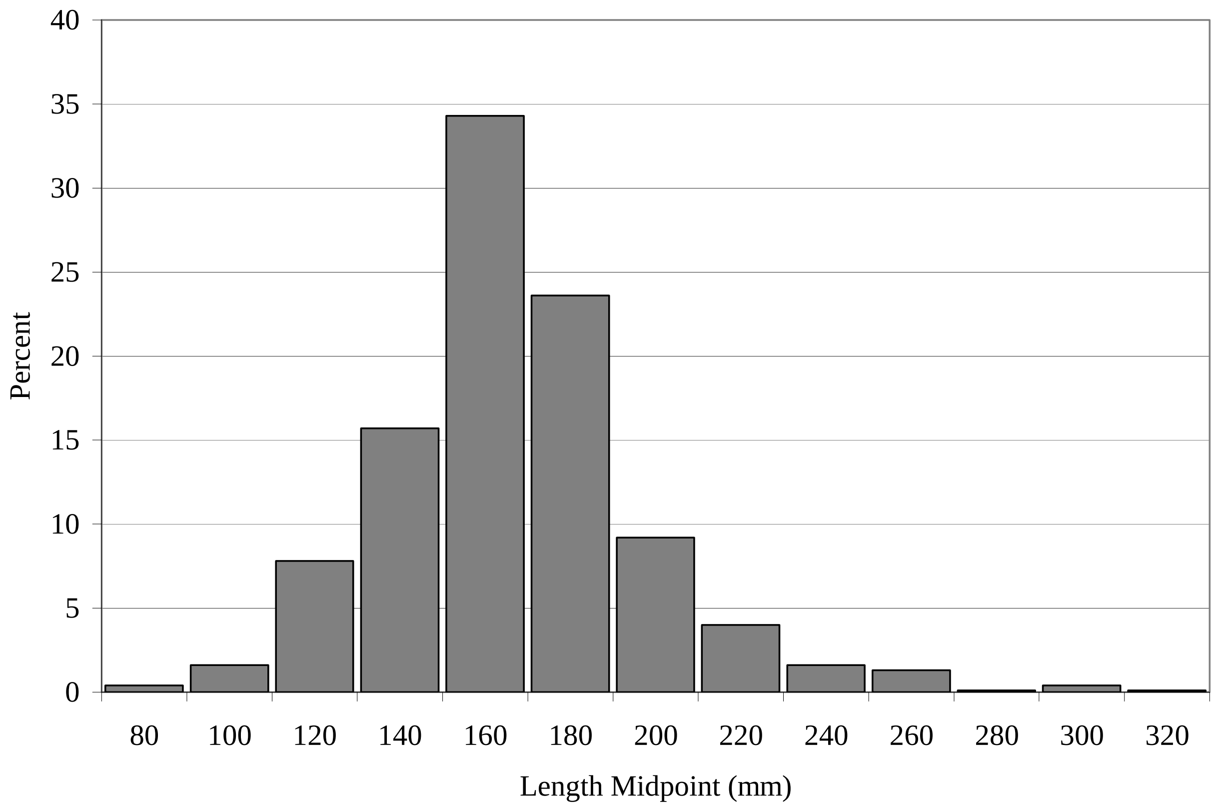


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2009. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length-frequency from the 2009 Choptank River fyke net survey.

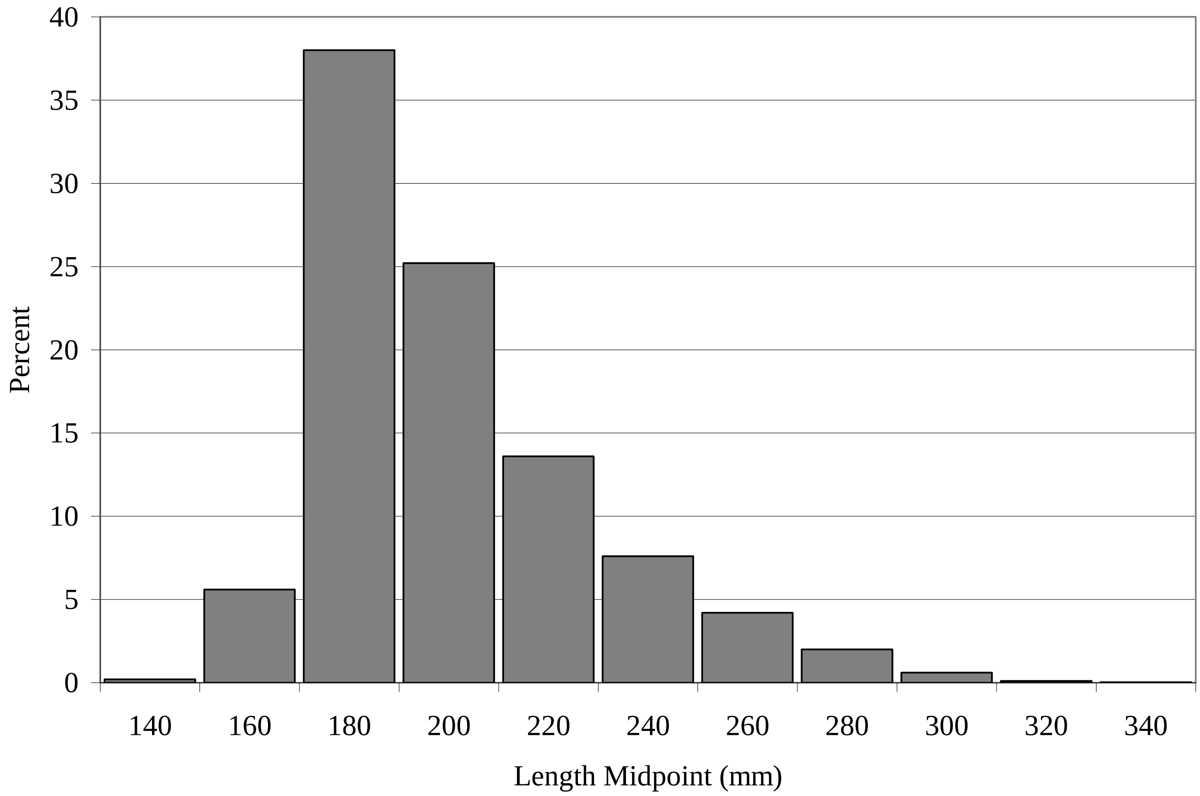


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2009. Minimum length cut-offs in parentheses.

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

Figure 12. Yellow perch length frequency from the 2009 upper Chesapeake commercial fyke net survey.

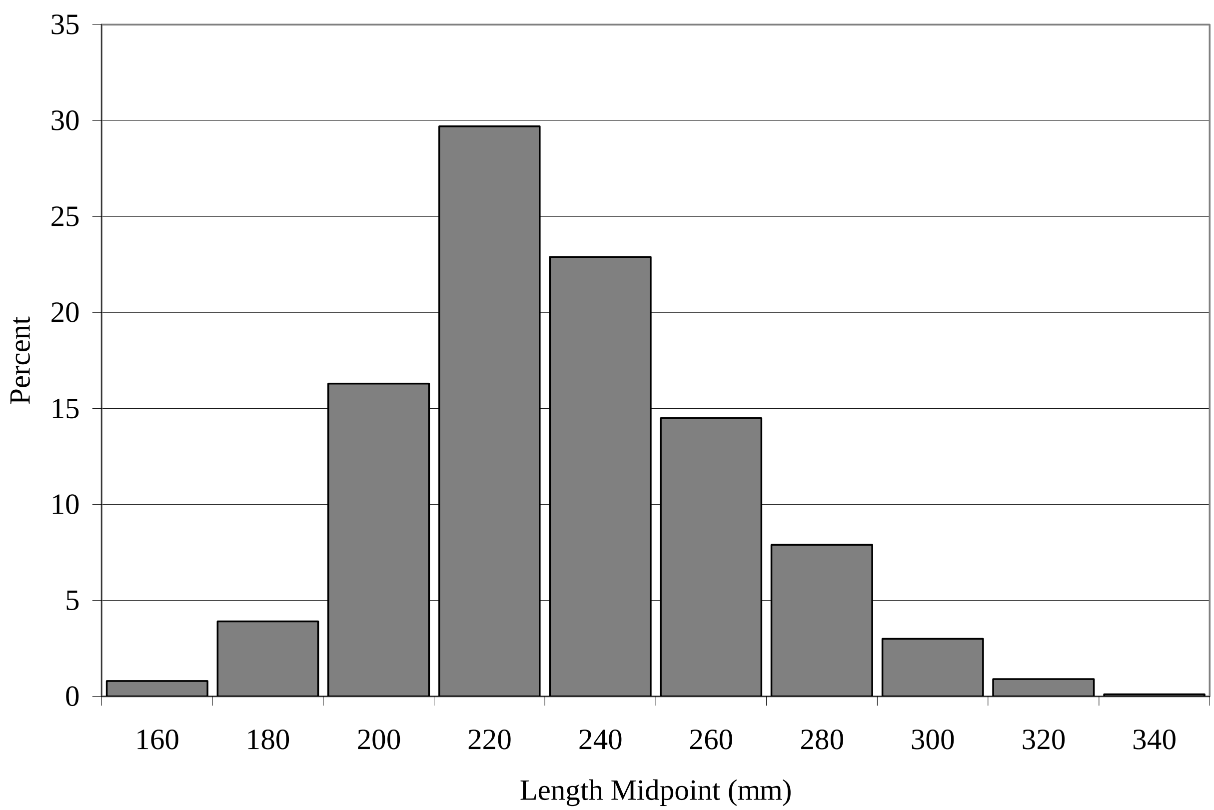


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2009. Minimum length cut-offs in parentheses; 2007-- 2009 includes Marshyhope River data.

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

Figure 13. Yellow perch length frequency from the 2009 Nanticoke River survey fyke and pound net survey. Includes Marshyhope River data.

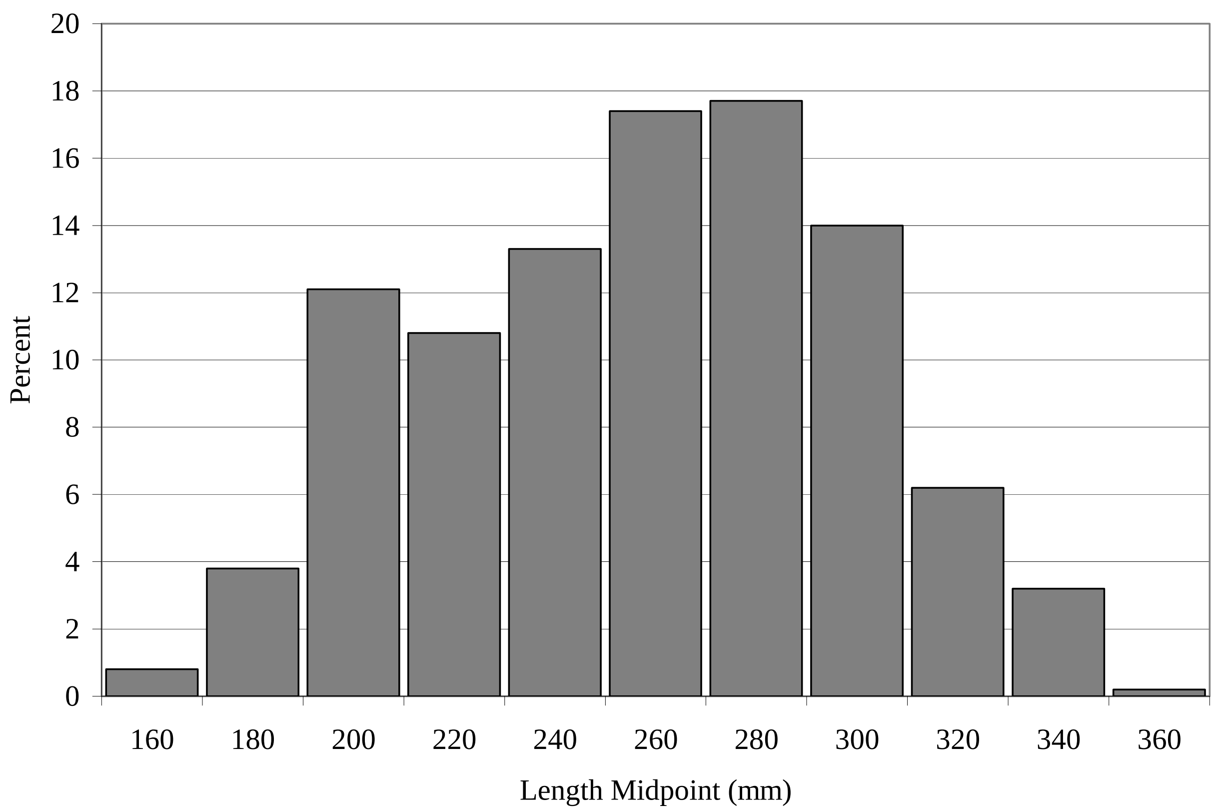


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2009. Minimum length cut-offs in parentheses.

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

Figure 14. Length frequency of channel catfish from the 2009 upper Chesapeake Bay winter trawl survey.

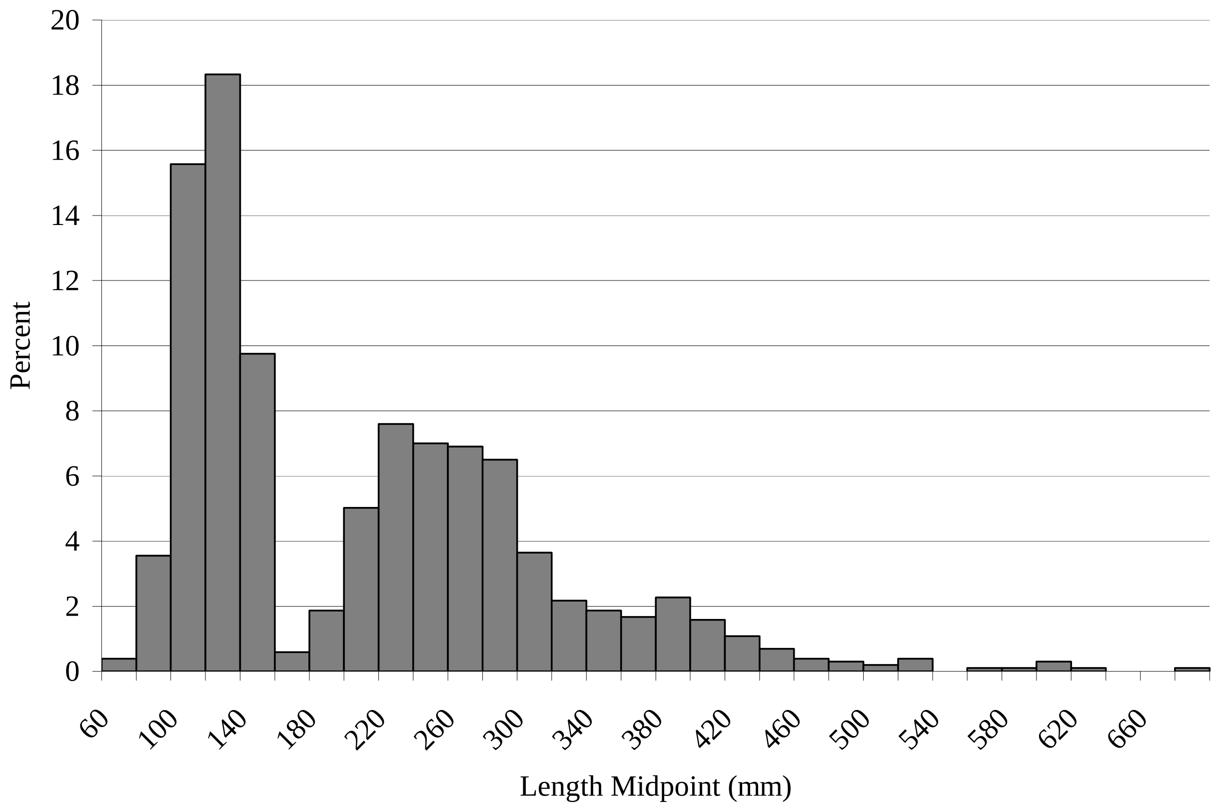


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2009. Minimum length cut-offs in parentheses.

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

Figure 15. Channel catfish length frequency from the 2009 Choptank River fyke net survey.

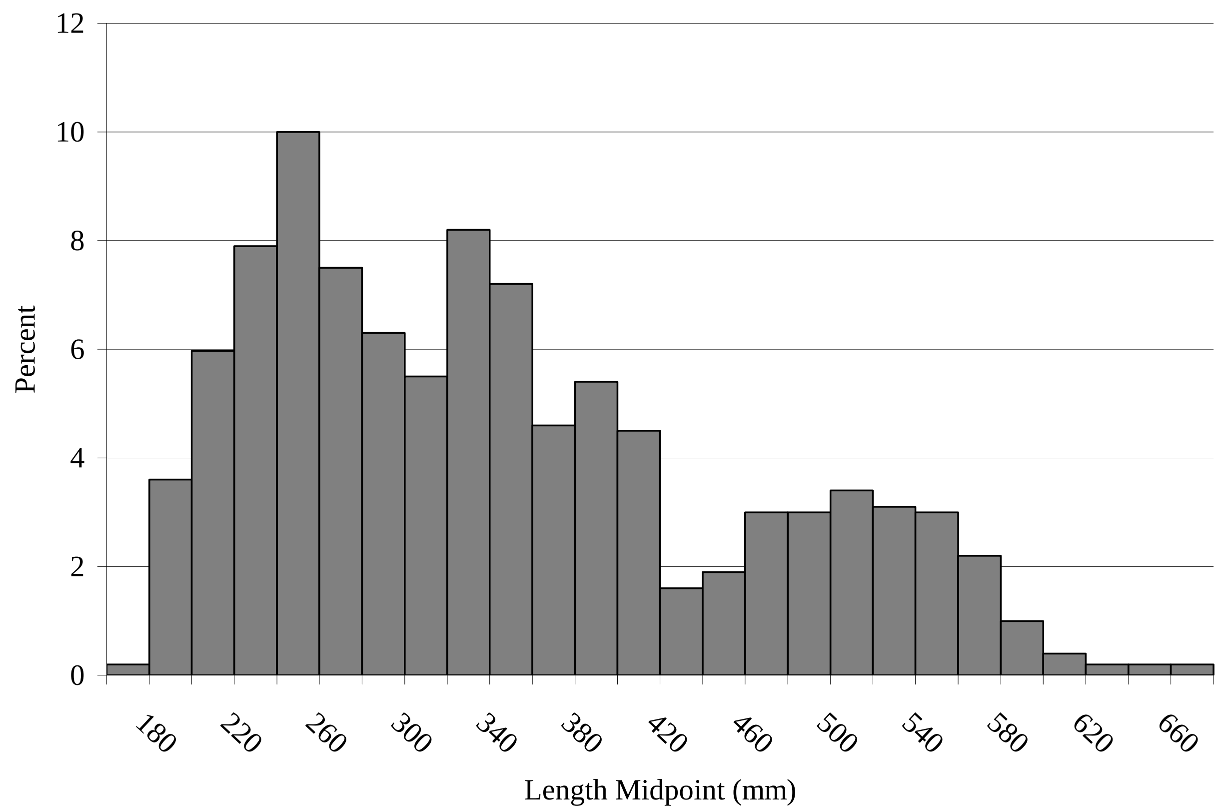


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2009. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 16. Channel catfish length frequency from the 2009 Nanticoke River fyke and pound net survey. Includes Marshyhope fyke net data.

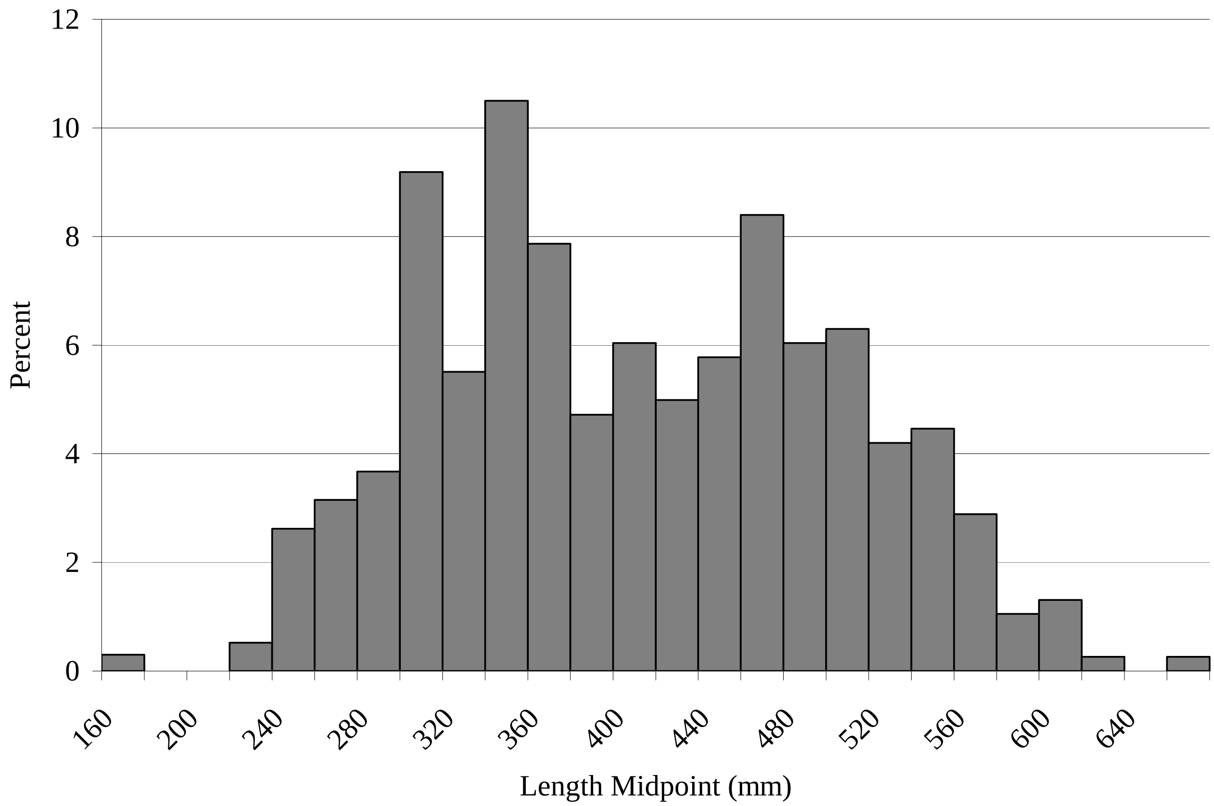


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2009. Minimum length cut-offs in parentheses.

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

Figure 17. White catfish length frequency from the 2009 upper Chesapeake Bay winter trawl survey.

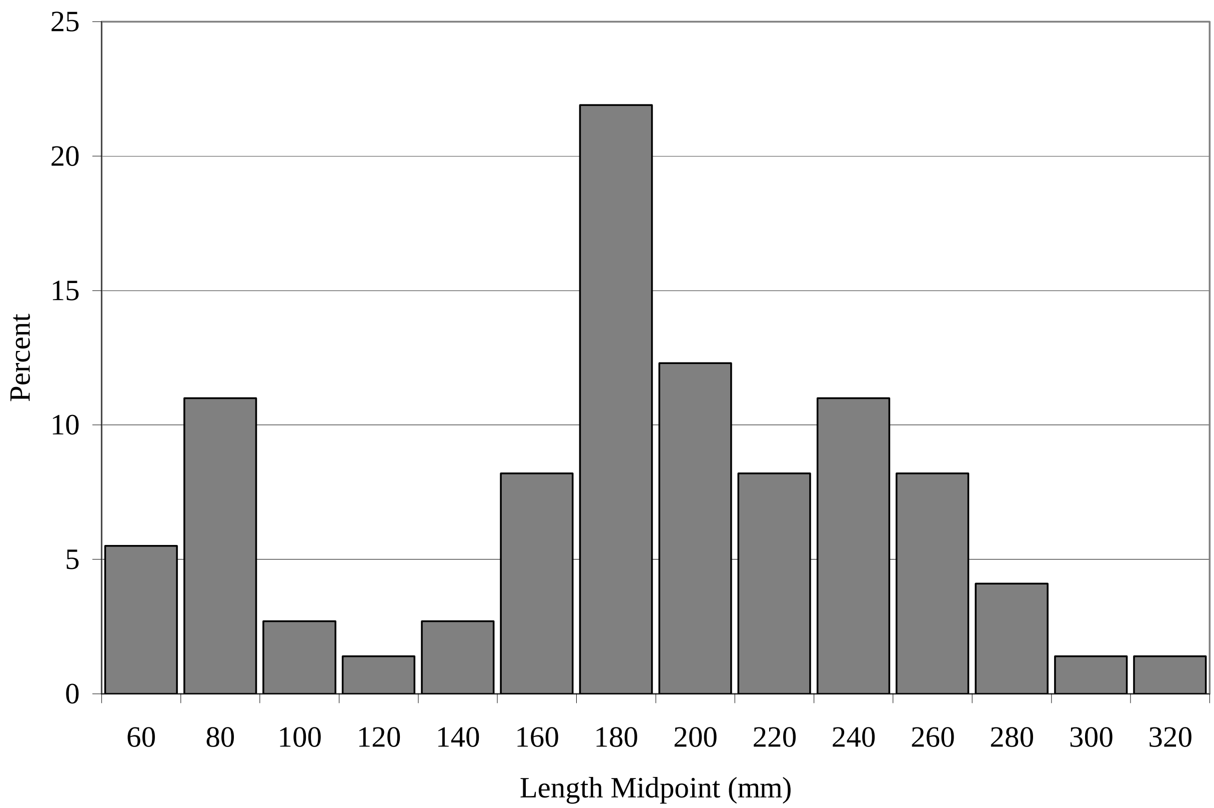


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2009. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2009 Choptank River fyke net survey.

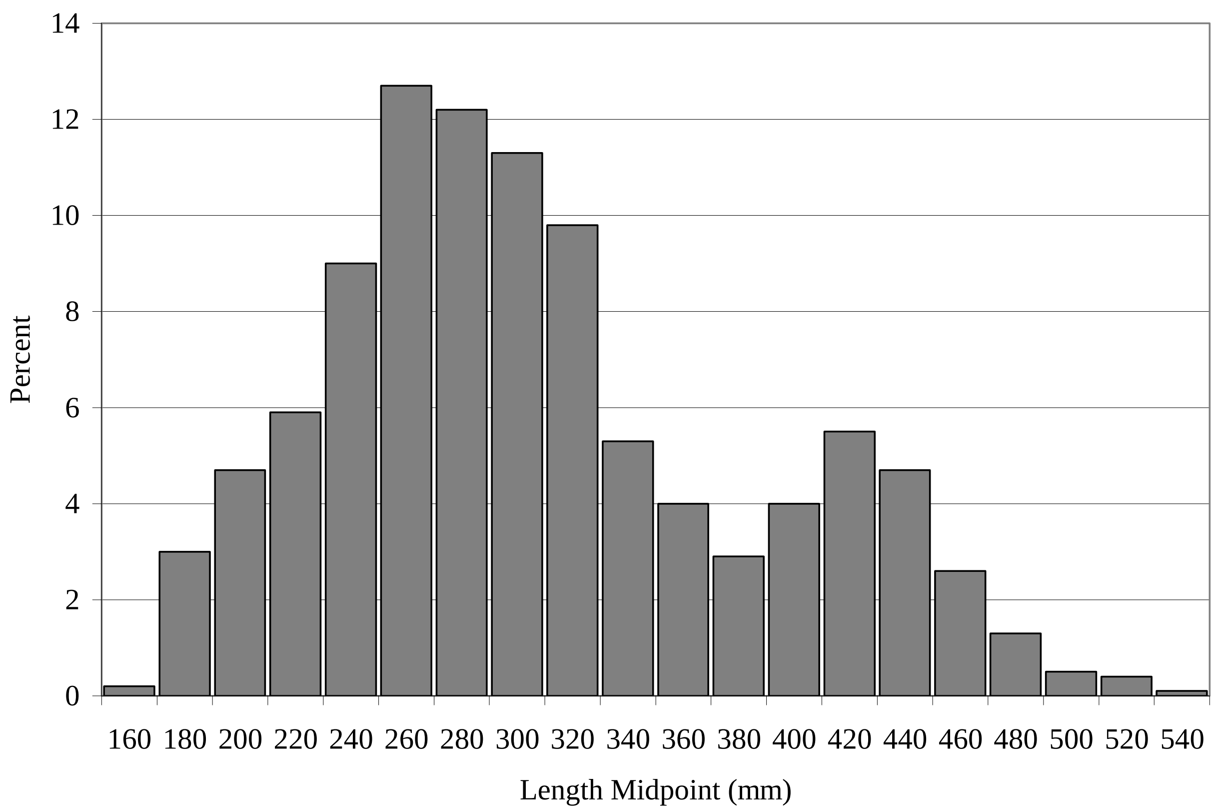


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2009. 2007 -- 2009 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 19. White catfish length frequency from the 2009 Nanticoke River fyke and pound net survey. Includes Marshyhope River fyke net data.

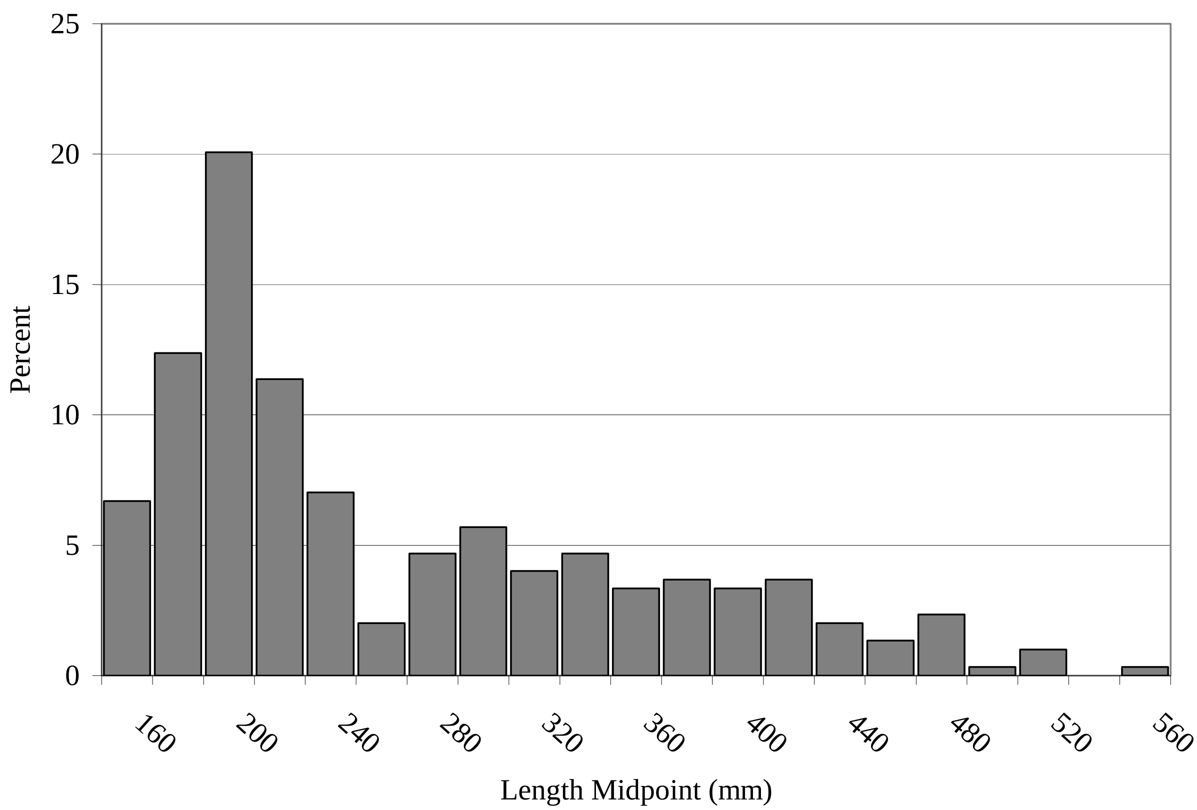


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

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	0.1	-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

2000 – 2009	F	5.7×10^{-6}	3.19	296	0.28	-1.14
	M	6.4×10^{-6}	3.15	245	0.33	-1.12
	Combined	4.0×10^{-6}	3.25	281	0.31	-0.80

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

Sample Year	Sex	(allometry)		(von Bertalanffy)		
		alpha	beta	L-inf	K	t_0
2000	F	2.0×10^{-4}	2.56	272	0.50	1.10
	M	1.4×10^{-4}	2.60	288	0.24	-0.60
	Combined	7.7×10^{-5}	2.72	280	0.36	0.51
2001	F			380	0.10	-2.80
	M	NA			NSF	
	Combined				NSF	
2002	F	1.3×10^{-6}	3.48	328	0.17	-2.50
	M	1.9×10^{-6}	3.40	286	0.22	-1.40
	Combined	1.1×10^{-6}	3.50	327	0.17	-2.20
2003	F			386	0.11	-2.90
	M	NA		263	0.30	-0.21
	Combined			329	0.16	-1.90
2004	F	5.3×10^{-6}	3.22	322	0.25	-0.30
	M	2.4×10^{-6}	3.35	288	0.21	-1.50
	Combined	2.6×10^{-6}	3.35	335	0.18	-1.20
2005	F	2.3×10^{-6}	3.36	313	0.23	-0.53
	M	NSF		313	0.14	-2.65
	Combined	1.50×10^{-6}	3.44	321	0.17	-1.60
2006	F			311	0.22	-1.41
	M	NA		279	0.19	-2.54
	Combined			321	0.16	-2.60
2007	F	6.2×10^{-6}	2.76	299	0.23	-0.81
	M	1.0×10^{-6}	3.08	282	0.24	-0.79
	Combined	3.4×10^{-6}	2.87	297	0.23	-0.70
2008	F	4.1×10^{-6}	3.25	295	0.35	0.23
	M	8.0×10^{-6}	3.12	254	0.38	-0.20
	Combined	3.6×10^{-6}	3.27	288	0.32	-0.16

2009	F	3.4×10^{-6}	3.28	285	0.33	0.47
	M	1.4×10^{-4}	2.58	273	0.18	-1.70
	Combined	5.9×10^{-6}	3.18	284	0.25	-0.33
2000 – 2009	F	7.6×10^{-6}	3.14	304	0.24	-0.71
	M	2.2×10^{-5}	2.94	270	0.23	-1.20
	Combined	5.7×10^{-6}	3.19	299	0.22	-0.99

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
2000 – 2009	F	7.3×10^{-6}	3.10	316	0.43	-0.80
	M	3.4×10^{-6}	3.22	279	0.31	-1.80
	Combined	4.0×10^{-6}	2.20	270	0.55	-0.48

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
1998 – 2009	F	3.21×10^{-6}	3.26	307	0.38	-1.31
	M	3.14×10^{-6}	3.24	243	0.42	-2.82
	Combined	1.54×10^{-6}	3.39	263	0.67	-0.45

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
2000 – 2009	F	4.9×10^{-6}	3.20	352	0.28	-1.42
	M	1.5×10^{-5}	2.97	295	0.32	-1.35
	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.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Choptank	0.34	0.48	0.25	0.46	0.1	0.58	0.58	0.40	minmal	0.35
Nanticoke	0.42	0.58	0.44	0.31	NR	NR	0.22	0.18	0.16	0.12
Upper Bay trawl	0.09	0.58	0.51	0.13	NA	0.5	0.12	0.19	0.26	0.54

Table 27. Estimated instantaneous fishing mortality rates (F) for yellow perch. NR= not reliable; NA=not available.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Choptank[1]	NR	minimal	0.03	0.05	NR	0.08	minimal	0	NR	0.17
Upper Bay fyke2	0.22	0.32	0.89	0.30	0.30	0.31	0.10	0.14	0.02	0.14

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

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

Figure 20. Baywide young-of-year relative abundance index for white perch, 1962 – 2009, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

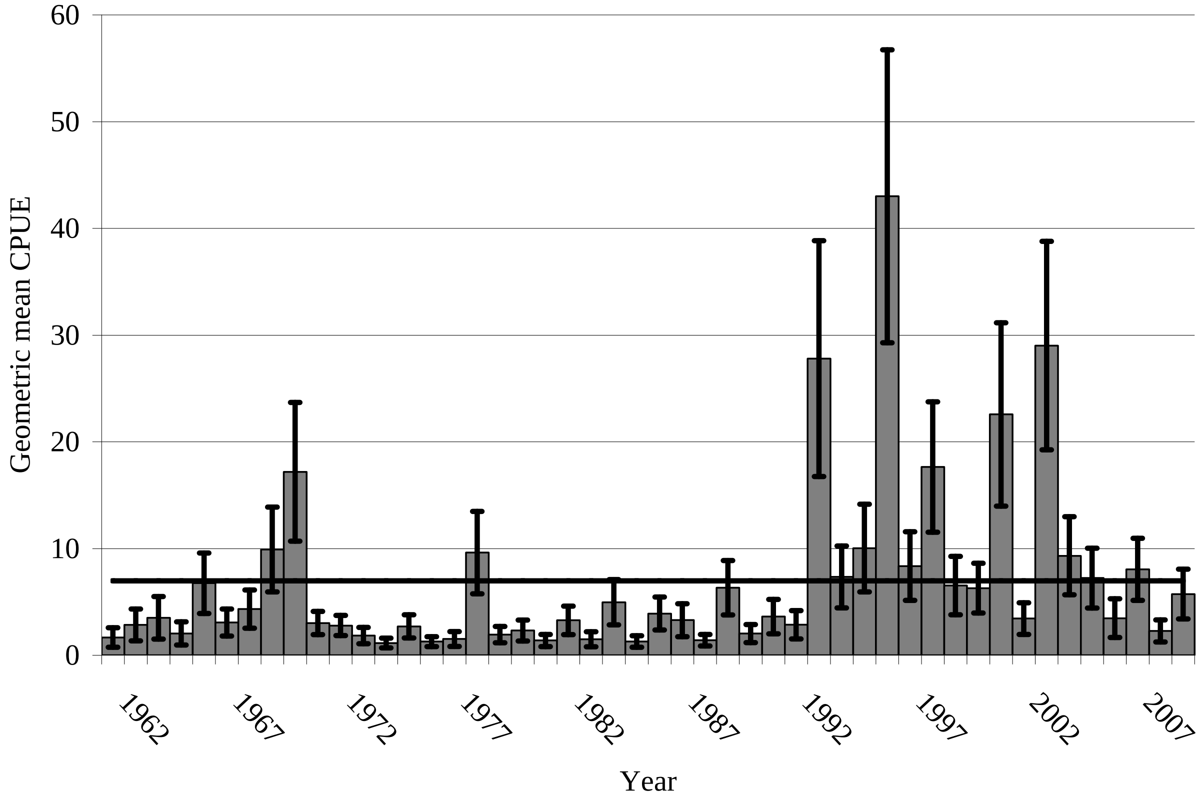


Figure 21. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

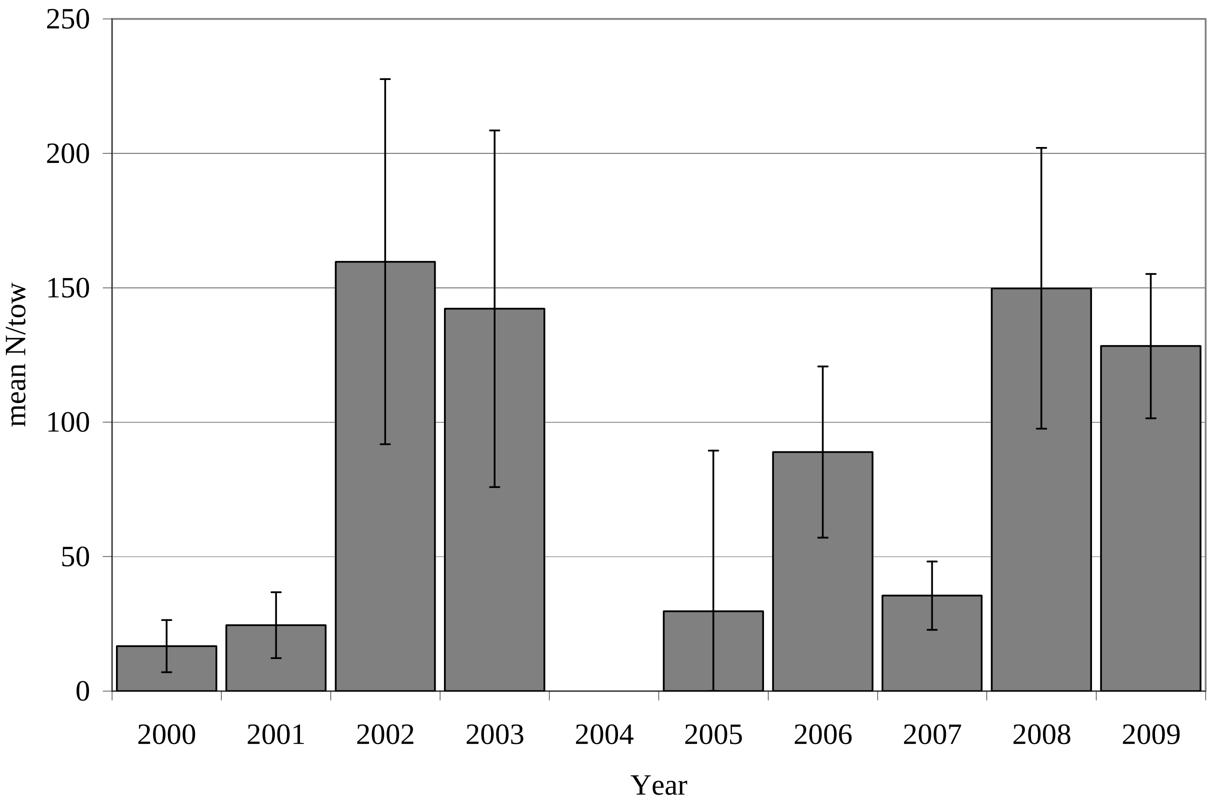


Figure 22. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2009, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

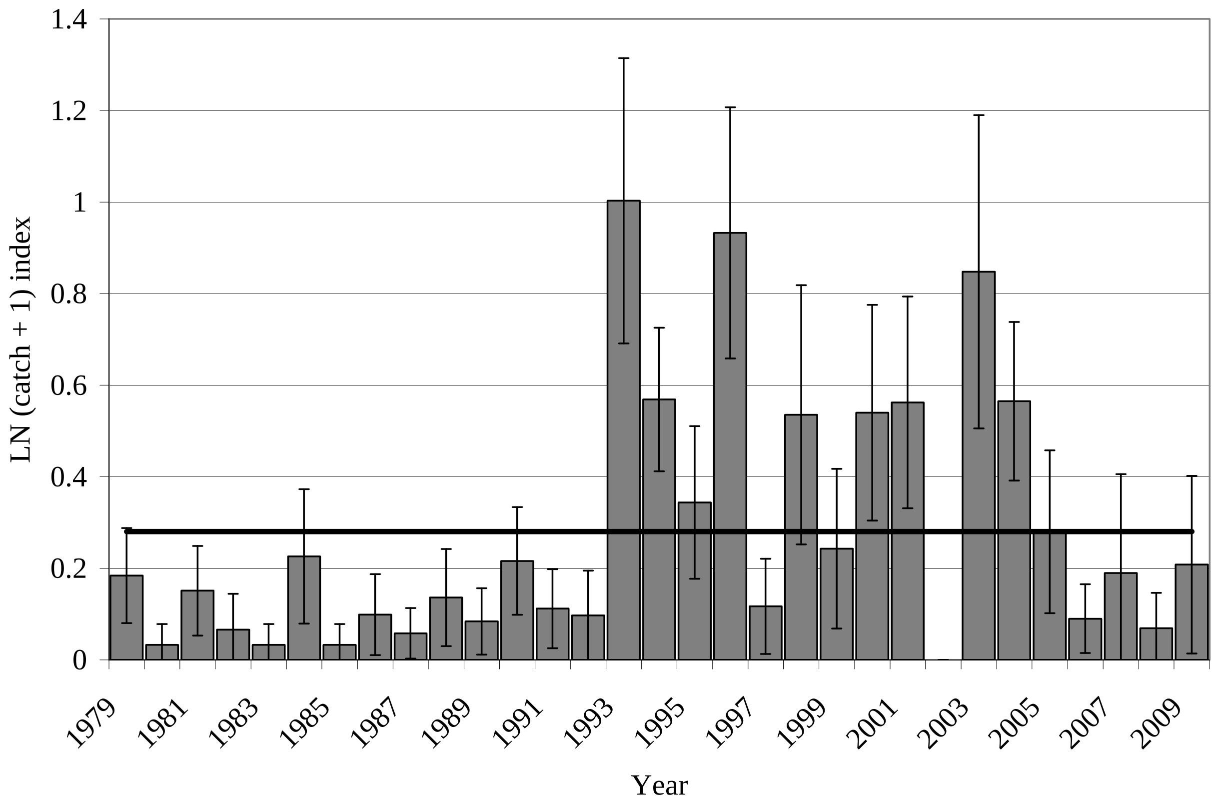


Figure 23. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

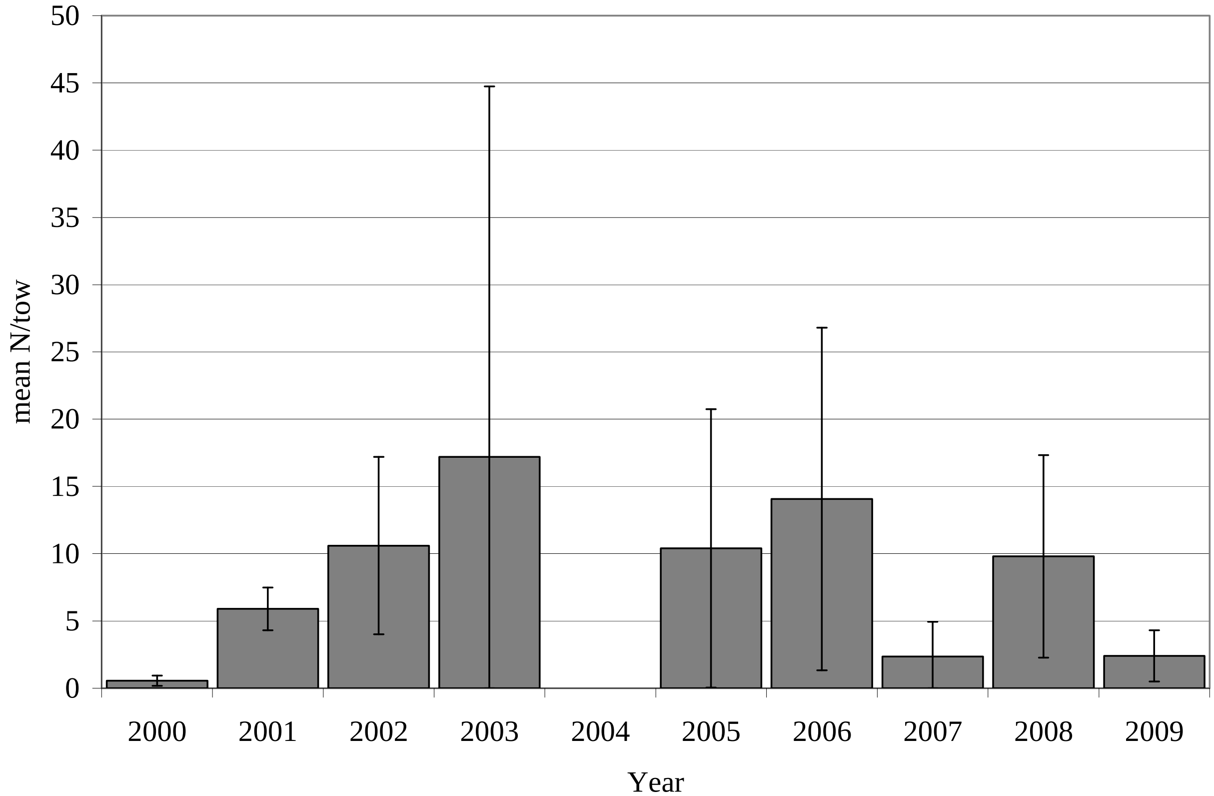


Figure 24. Bay-wide young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average. Error bars = 95% confidence intervals.

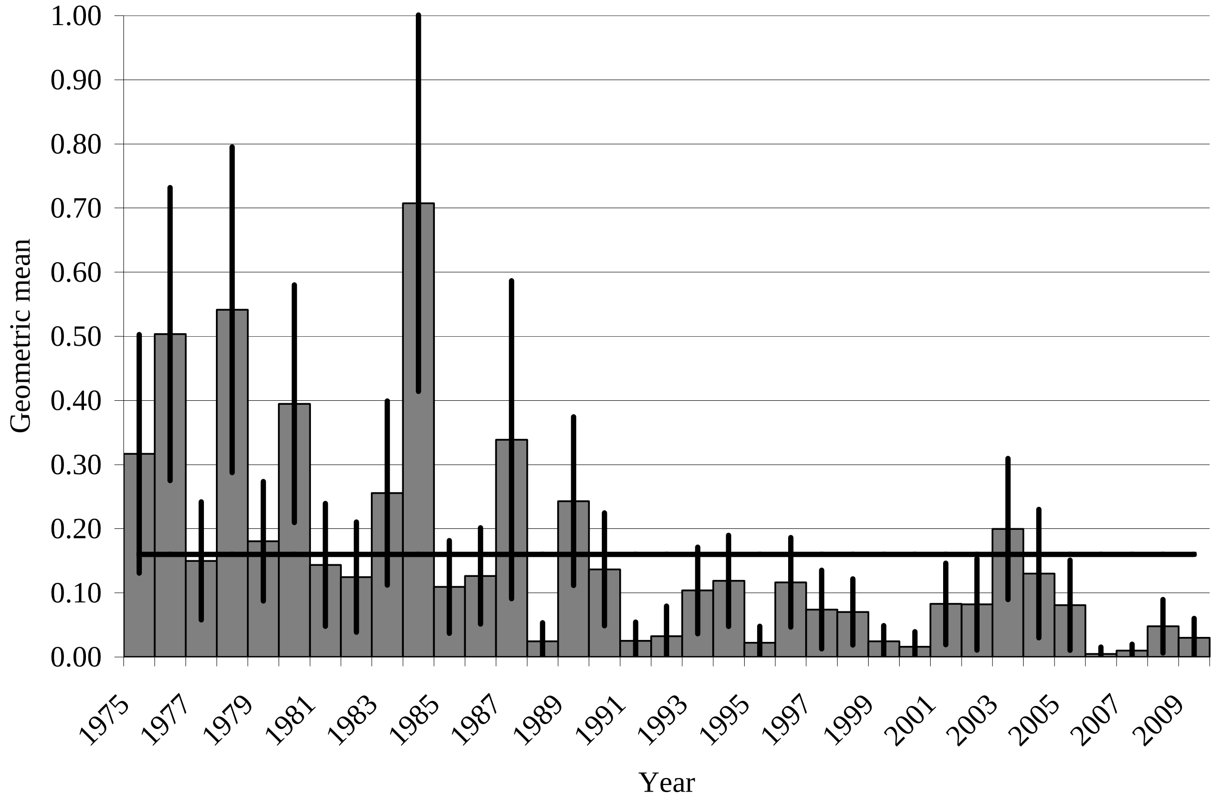


Figure 25. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and
2005.

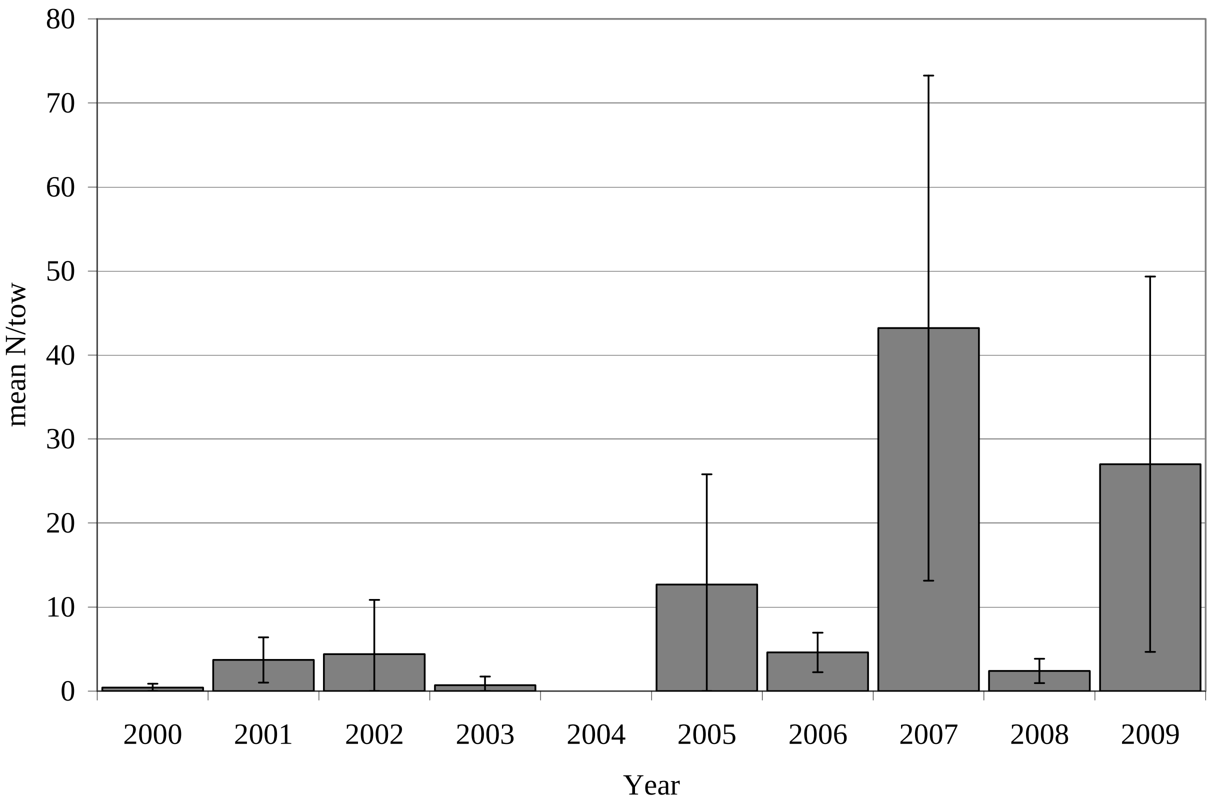


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2009.

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

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2009.

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

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2009.

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

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2009.

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

Figure 26. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2009. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

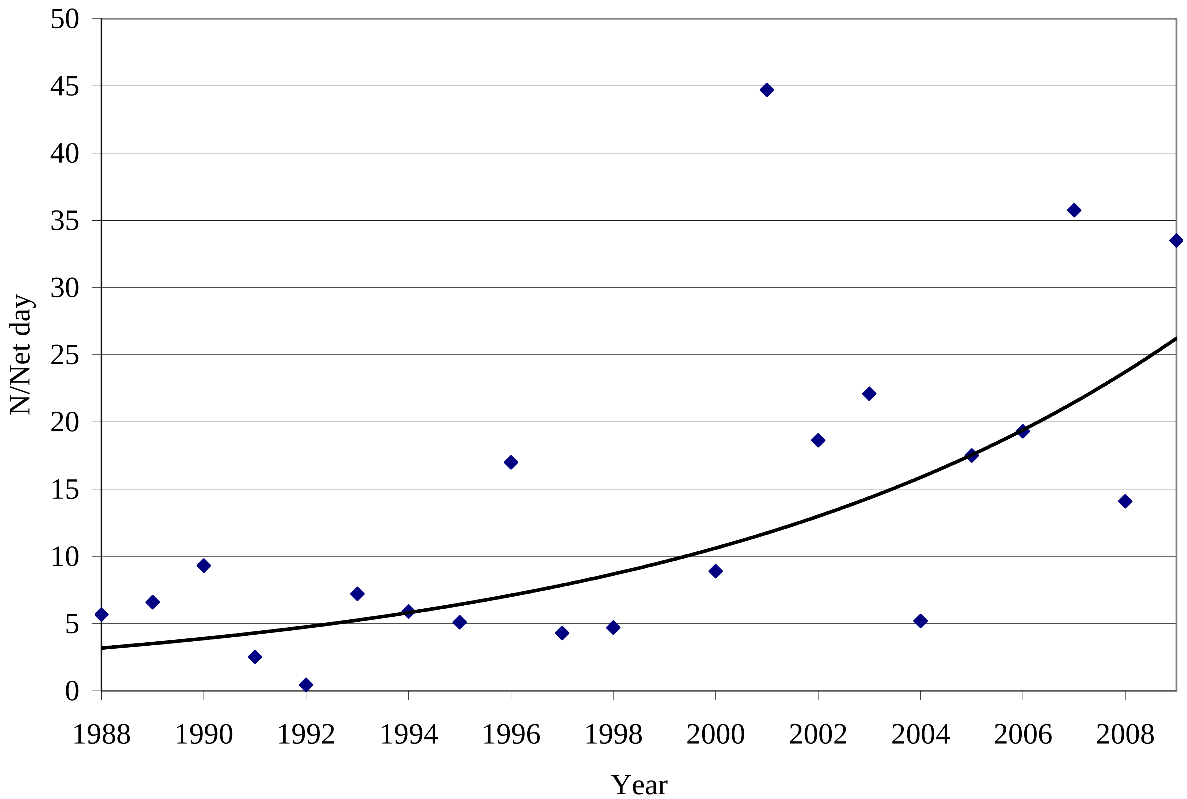


Figure 27. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2009. Not surveyed in 2004, small sample sizes in 2003 and 2005.

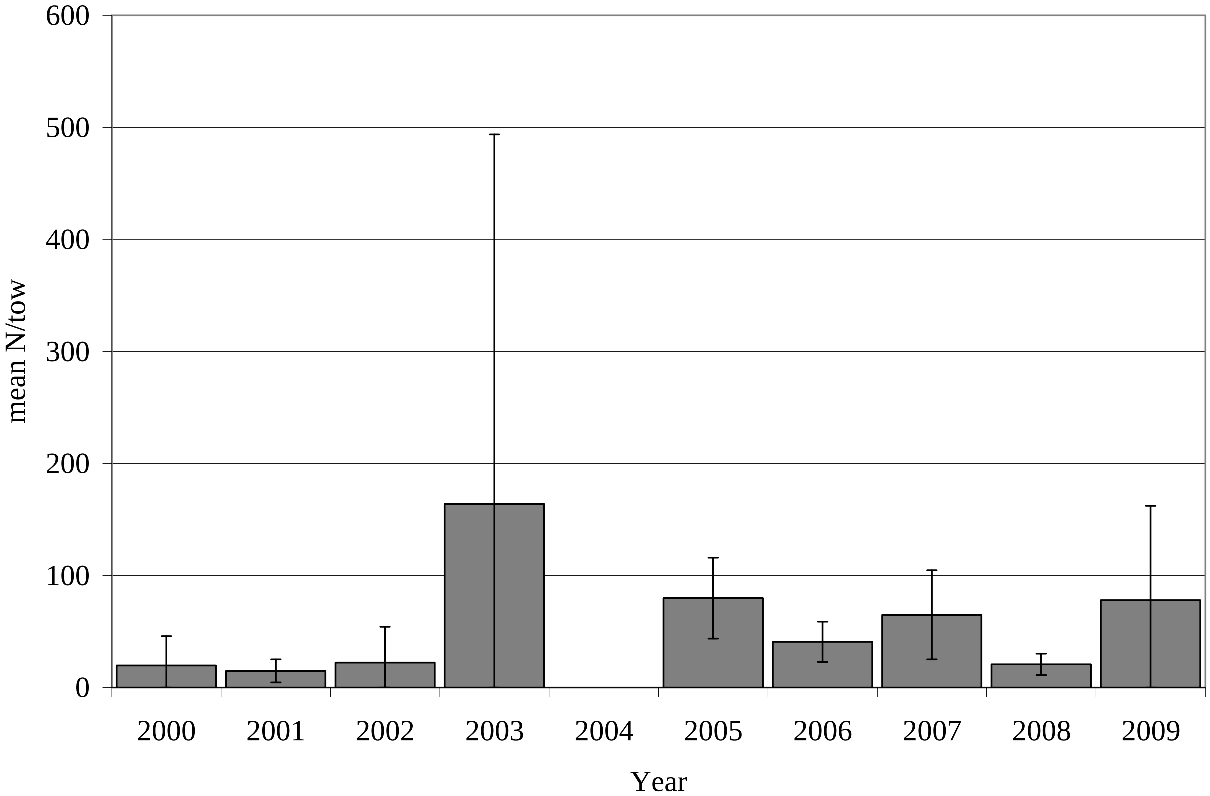


Figure 28. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2009. Horizontal line indicates time series average relative abundance.

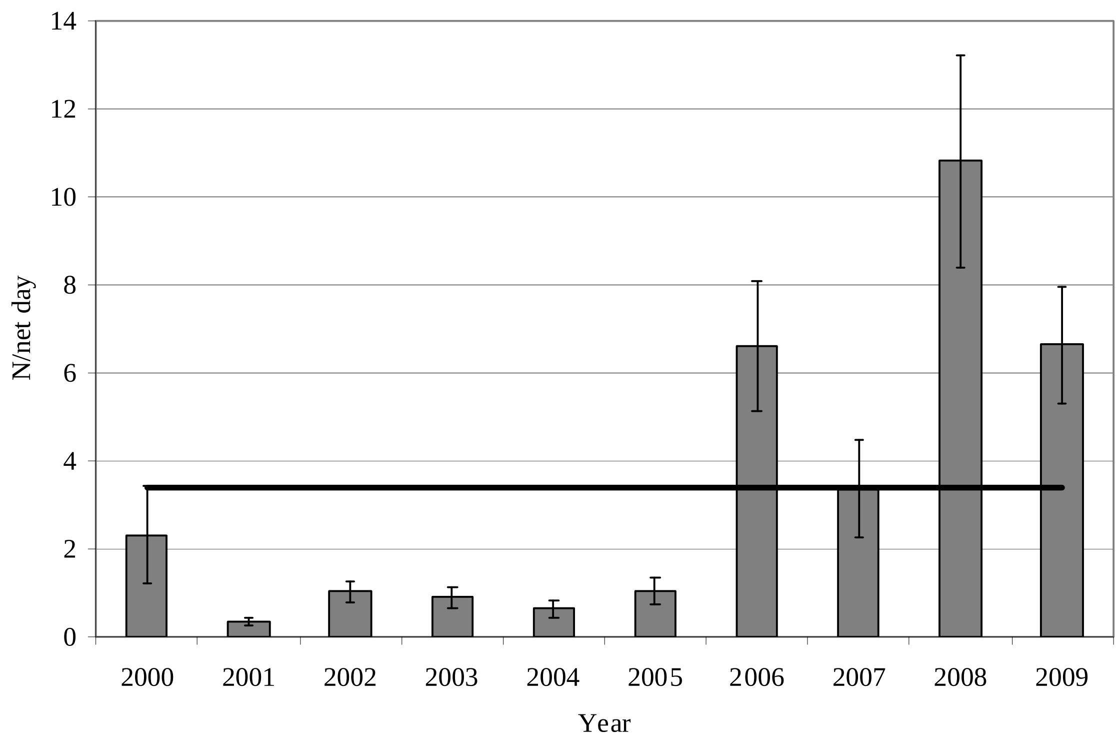
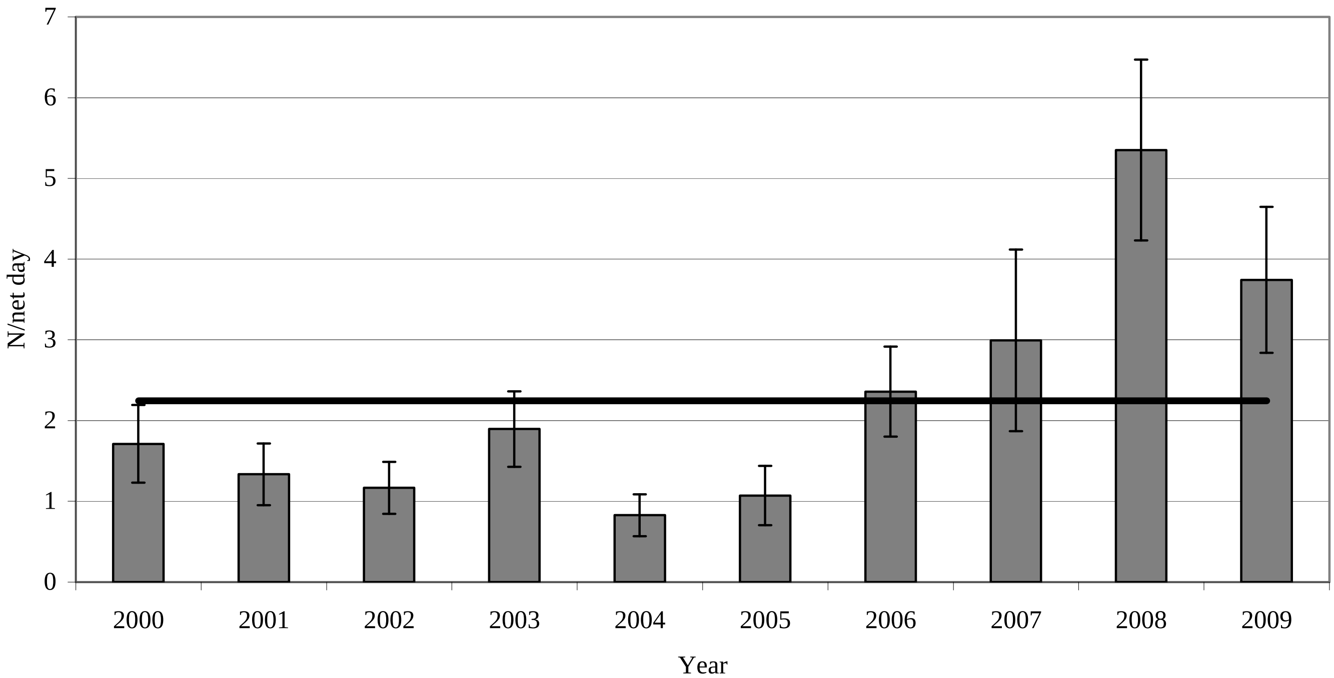


Figure 29. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2009. Horizontal line indicates time series average relative abundance.



PROJECT NO. 1
JOB NO. 2

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

Channel catfish inhabit fresh or brackish waters in the Chesapeake Bay and its tributaries. Current management includes a 254 mm (10 inches; TL) minimum size limit for the commercial and recreational fisheries, with no creel or catch limits, and no closed season. The Potomac River Fisheries Commission (PRFC) manages channel catfish in the Potomac River mainstem. The minimum size limit in the Potomac River is 203 mm (8 inches; TL) for commercial and recreational fisheries with no closed season or creel or catch limits.

Channel catfish are important to recreational and commercial fishers throughout Maryland's portion of the Chesapeake Bay. Recreational harvest is largely undocumented, but the Marine Recreational Fishery Statistic Survey (MRFSS) provides some harvest estimates (National Oceanic and Atmospheric Administration, personal communication). In addition, recreational harvest estimates are available from geographically and temporally limited surveys. A Maryland Department of Natural Resources (MD DNR) creel survey conducted during the spring of 1985 in the lower Susquehanna River estimated that recreational fishers harvested 25,894 channel catfish (Weinrich et al. 1986). The estimated Susquehanna recreational harvest in 1985 was four times higher than any other year of the survey (1980 – 1984). Commercial harvest in the Susquehanna River and upper Chesapeake Bay region mimicked the increased recreational harvest over that same period.

Commercial channel catfish harvest peaked in 1996 at 2.45 million pounds in 2004, and totaled 1.34 million pounds in 2008. At its peak in 1996, channel catfish were the 2nd largest commercial landings by weight of all finfish harvested in Maryland, behind only Atlantic menhaden (3.9 million pounds). In 2005, channel catfish harvests were the 5th largest of all commercially harvested finfish in Maryland. However, by 2008, channel catfish harvests rebounded to become the 3rd largest species of finfish harvest.

Channel catfish populations were last assessed in 2006 (Piavis and Webb 2007). This Job is an update of the 2006 assessment. The 2006 assessment attempted to describe population dynamics in 6 systems, the Head-of-Bay (HOB; areas north of the Preston Lane Memorial Bridges except the Chester River), the Chester River, the Choptank River, the Nanticoke River, the Potomac River, and the Patuxent River. In this assessment, the Chester River was combined into the HOB assessment, and the Nanticoke and the Patuxent River assessments were discontinued. Previous attempts to fit models to the Nanticoke River and the Patuxent River channel catfish populations were unsuccessful, and no fishery independent data exist to qualitatively describe population dynamics. For this report, channel catfish populations were modeled with a surplus production model for the HOB, the Choptank River, and the Potomac River (including tributaries). In cases where model fits were unreliable, indices of relative abundance were utilized to illustrate trends in population abundance.

METHODS

Landings

Maryland commercial fishery landings were available from the 1920's, but fishers were only required to report catch as general catfish landings (mixed species, predominately bullheads (*Ameiurus spp.*), channel catfish, and white catfish (*Ameiurus catus*)) until 1996. Beginning in 1996, commercial fishers were required to report catfish landings as general, channel, or white catfish. The amount of channel catfish reported in the general category for the years 1996 – 2008 was calculated by determining the proportion of channel catfish in the combined white and channel catfish landings. This proportion was then multiplied by the amount of general catfish landed. The estimated annual landings of channel catfish in the general category were then added to the declared channel catfish landings for an estimated total commercial removal. To determine commercial channel catfish landing prior to 1996, the general catfish landings were multiplied by the average proportion of channel catfish of the total declared catfish landings by species for the years 1996 – 2008. The Potomac River Fisheries Commission provided commercial landings from the Potomac River (personal communication, Potomac River Fisheries Commission).

Recreational landings, as estimated by the MRFSS were largely imprecise. However, several years contained estimates where the proportional standard error (PSE) was 30% or less. Estimated harvest from those years was compared to commercial landings to determine the average percentage of recreational landings to commercial landings. The average percentage was then applied to annual commercial harvest of years when PSE's of the recreational estimate exceeded 30%.

Fishery Dependent Relative Abundance Indices

Fishery dependent relative abundance estimates were determined for the fyke net, pot net, and pound net fisheries. Effort data for these gear types were available from 1980 – 1984, 1990, and 1992 – 2008. An index of effort was constructed to standardize landings because commercial catch reporting was completed monthly and not on a trip basis. The index was nominal fishing effort, or simply the total number of nets declared by fishers in any month. Only fishers that reported catfish harvest > 500 lbs were used for relative abundance estimates. This eliminated fishers that were not targeting channel catfish. Since recreational harvest estimates were imprecise, no relative abundance estimates for the recreational fishery were developed.

Fishery Independent Relative Abundance Indices

Several fishery independent relative abundance indices were used either qualitatively or included in the surplus production models. Available indices included spring drift gill net surveys in the HOB (1985 – 2008; Figure 1), the Choptank River (1984 – 1996; Figure 2), and the Potomac River (1984 – 2008; Figure 1), a MD DNR fyke net survey in the Choptank River (1993 – 2008; Figure 2), a HOB winter trawl survey (2000 – 2008; Figure 3), and a juvenile recruitment index for the HOB, the Choptank River, and the Potomac River (1975 – 2008; Figure 4).

Data from the drift gill net survey (Project 2, Job 3, Task 2) in the HOB, the Choptank River, and the Potomac River were included in the surplus production models for those river systems. Since the surplus production model is a weight-based model, indices based on number were transformed to weight-based indices. Channel catfish weight per gill net set was estimated by determining average channel catfish length per mesh size per gill net set and applying a length-weight formula from the Susquehanna Flats area of the HOB:

$$\log_{10}(\text{Wt g}) = 3.09684 \text{ X } \log_{10}(\text{TL cm}) - 2.1622$$ (Fewlass 1980).

The average weight per gill net set and mesh size was then multiplied by the total number captured per mesh size and net set. The final index was the geometric mean weight per net set standardized to 1000-gill net yards X hours.

A fyke net survey in the Choptank River (Project 1, Job 2) was used to formulate a river-specific index for channel catfish during 1993 – 2008. Average channel catfish length per net set was determined, and the same length weight equation used for the drift gill net survey was utilized to transform numbers caught per set to biomass caught per set. This geometric mean index was included in the surplus production model runs.

Channel catfish juvenile recruitment was determined from the Estuarine Juvenile Finfish Survey (EJFS; Project 2, Job 3, Task 3). The EJFS is designed to estimate young-of-year striped bass (*Morone saxatilis*) relative abundance, but it has proved valuable in determining year-class strength of other species as well. These data were used qualitatively, that is, they were not included in the model. Relative juvenile abundance indices were available for the HOB, the Choptank River, and the Potomac River.

The HOB winter trawl survey (Project 1, Job 1) provided channel catfish relative abundance for the HOB. Available data from this survey (2000-2008) were largely unusable because of limited sample size. The recent initiation of this survey and limited sampling during 2003 – 2005 precluded its use in the surplus production model.

General surplus production model formulation

Surplus production models fit biomass estimates to the equation

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

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

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

$$\text{index (I)} = q \{(B_{t+1} + B_t)/2\}\, e^{\varepsilon},$$

where q was catchability and e^{ε} was the lognormal residual error. This form simplified the solution by not having to solve for a catchability parameter for each index. In this closed form, average catchability for each index was $e^{(1/n)\,\Sigma \ln(I_t / B_t)}$. The log function to be maximized was simply the sum of all log-likelihoods multiplied by a weighting factor.

The log-likelihood function for an individual index is

$$LL = -n/2\, (\ln(2\pi) + 2\ln(\sigma) + 1)$$

where $\sigma = \sqrt{\Sigma(\ln I_t - \ln \hat{I}_t)^2/n}$, and n is the number of data points in the series.

All runs were performed in an Excel spreadsheet using the Evolver genetic tree algorithm (Palisades Corporation, 2003) to estimate biomass and solve for the 3 unknown parameters (B_0, r, K). Reference points and fishing mortality were estimated from standard relationships (Prager 1994; Haddon 2001):

Maximum Sustainable Yield = rK/4

$B_{msy} = K/2$

$F_{msy} = r/2$

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

Uncertainty

Bootstrapping, or resampling residuals and adding them to the natural logarithm of the observed indices, then re-exponentiating the values was used to quantify model uncertainty (n=500 trials). Mean, median, standard deviation and coefficient of variation were calculated for all fitted parameters and each estimate of annual biomass and F. Confidence intervals (80% CI) were determined from cumulative percent distributions of the bootstrapped parameter estimates.

Area-specific surplus production model runs

The HOB was defined as the area north of the Preston Lane Memorial Bridges. Other area model runs included those for the Choptank, and the Potomac Rivers. Total removals were area-specific commercial catches plus a constant percentage for recreational harvest.   All combinations of fishery dependent and fishery independent indices of relative abundance with equal weighting were used in model runs.

RESULTS

Landings

Baywide commercial landings generally varied between 400,000 pounds and 700,000 pounds from 1929 through the mid-1970's (Figure 5). Landings increased rapidly from 1976 through 1996. Since 1996, landings decreased to a recent low in 2007. Baywide recreational landings estimates have varied greatly over the period 1980 – 2008.

Area-specific commercial landings since 1980 were developed for use in the surplus production model. The HOB landings were approximately 600,000 pounds in the 1980's, but increased to over 2 million pounds in the 1990's (Figure 6). Since 1996, landings have deceased rather substantially. Choptank River commercial landings were below 50,000 pounds early in the time-series, but exceeded 100,000 pounds in 3 distinct time periods, 1989 – 1992, 1998 – 1999, and 2004 – 2008 (Figure 7). Potomac River landings declined through the time period 1985 – 2008 (Figure 8).

Fishery Dependent Relative Abundance Indices

Fishery dependent relative abundance indices from the commercial fishery were developed. The HOB fyke net index indicated higher catch-per-effort in the 1990's and mid 2000's as compared to the early 1980's and early 2000's (Figure 9). The HOB fish pot index showed no discernible trend, while the HOB pound net index indicated a rising relative abundance from the 1980's through the mid-1990's (Figure 10). Unlike the fyke net index, the pound net relative abundance values remained depressed between 2002 – 2008 (Figure 11).

Fishery dependent relative abundance indices for the Choptank River were also developed for the commercial fyke net fishery, the fish pot fishery, and the pound net fishery. The fyke net fishery has been stable since the mid 1990's, but indices for 2004, 2006, and 2008 were somewhat higher (Figure 12). Choptank River fish pot relative abundance has been steadily increasing since 2000, and the pound net index has had a U-shaped response since 1996 (Figures 13, 14).

The only informative commercial fishery index from the Potomac River was the fish pot index. Relative abundance values from this fishery indicated a decidedly declining trend since the 1980's (Figure 15).

Fishery Independent Relative Abundance Indices

The HOB fishery independent indices included a sprint drift gill net survey (1985 – 2008), a young-of-year (yoy) seine survey (1975 – 2009), and a shorter duration winter trawl survey (2000 – 2009). The drift gill net survey indicated low relative abundance during the mid 1980's and again during the early 2000's, with a fairly strong rebound since 2005 (Figure 16). The yoy survey indicated poor recruitment since 1990 (Figure 17). The HOB winter trawl survey indicated higher catch per effort values during 2006, 2007 and 2009 than the period 2000 – 2002 (Figure 18). The period 2003 – 2005 was either not sampled, or sampling effort was too low to be considered informative.

The Choptank River fishery independent indices included a fyke net survey (1993 – 2008) and a yoy seine survey (1975 – 2009). A spring drift gill net survey was conducted between 1984 – 1996, and although this survey provided no recent data, it was included in the surplus production run. The fyke net survey indicated higher relative abundance values in 2003, and 2006 – 2008 than at any other time since the mid 1990's (Figure 19). The drift gill net data were somewhat noisy, but a generally declining trend was evident over the time period (Figure 20). The yoy seine survey provided an estimate of relative reproductive success. Since 1978, some of the strongest reproduction occurred between 2001 – 2004, with relatively high values in 2008 and 2009 (Figure 21).

The fishery independent indices from the Potomac River included a spring drift gill net survey and a yoy seine survey. The biomass index from the drift gill net survey indicated stable relative abundance estimates throughout much of the time series, but high levels of production were evident between 1990 – 1996 (Figure 22). The yoy seine survey indicated markedly lower reproduction during the extended period 1986 – 2009 (Figure 23).

Surplus Production Model Runs

Employment of a surplus production model was attempted for all three systems, but could only be used for the HOB. The Choptank River biomass indices in the later portion of the time series were approaching previous high levels and made estimating K difficult. In contrast, the Potomac River data indicated a classic one-way trip (downward) that made fitting a production model improbable (Prager 1994; Magnusson and Hilborn 2007).

The HOB model was run with all combinations of indices (commercial fyke net CPUE, commercial fish pot CPUE, commercial pound net CPUE, and DNR experimental drift gill net CPUE). Generally, all runs fell into three classes, nonsensical or failed fits, runs that were at or near carrying capacity for long periods of time, and fits that indicated population building through the mid-1990's with a decrease until the early 2000's followed by an increase in recent years. Only model runs from the latter class were considered as representative of channel catfish population dynamics in the HOB. The final run contained the commercial fyke net CPUE and the DNR experimental drift gill net CPUE index. The final run was selected because it contained a fishery independent index that covered time periods of missing data from the commercial fishery indices.

Estimated parameters r, K, and B_0 were 0.52, 13.3 million pounds, and 3.6 million pounds, respectively. Biomass increased from 3.6 million pounds in 1980 to 10.1 million pounds in 1989. Channel catfish biomass then trended lower to 5.8 million pounds in 2000, but nearly doubled to 10.2 million pounds in 2007 (Figure 24).

Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ K or 6.6 million pounds. F_{msy} was estimated as ½ r or 0.26. Maximum sustainable yield was estimated rK/4 or 1.7 million pounds. Instantaneous fishing mortality (F) peaked from 1996 – 2000, but then fell to low levels in the late 2000's (Figure 25). Ratios of B:B_{msy} and F:F_{msy} indicated a period of increasing surplus biomass and moderate F between 1980 – 1988. Fishing mortality then rose to unsustainable levels from 1994 – 2001, that is, the F:F_{msy} ratio was greater than 1.0 (Figure 26). After 2001, however, the F:F_{MSY} ratio declined and the B:B_{MSY} ratio increased.

Bootstrapping provided estimates of uncertainty for this model. The intrinsic rate of increase (r) was precisely estimated (CV=23%). Estimates of K and B_0 were also precisely estimated with CV's equal to 24% and 22%, respectively. Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than r and K in model outputs and subsequent management advice. Coefficients of variation of annual biomass estimates ranged from 15% -- 29%. In the final year of the assessment (2008), there was only a 17% chance that channel catfish biomass was below B_{msy}, and a 0.8% chance that overfishing was occurring.

DISCUSSION

Channel catfish provide valuable recreational and commercial fisheries while occupying an important ecological niche among brackish-tidal fresh ecosystems in Maryland's portion of the Chesapeake Bay. The primary objective of this Job was to describe trends in channel catfish abundance throughout the Bay region. Since only one area (HOB) provided a successful model run,TChoptank River and Potomac River stocks were assessed through qualitative examination of available relative abundance data.

The HOB surplus production model indicated a period of population increase from 1980 – 1989 followed by a decline through 2000. Since 2000, population biomass increased to 8.4 million pounds by 2008. These results generally mimic the original model run (Piavis and Webb 2007). However, the population increase early in the time series was more pronounced and the population decline through 2000 was less severe in the updated assessment. Estimated parameters r, K, and B_0 were similar between the 2 assessments, with K and B_0 being higher in the latest assessment. This result is reasonable given that the current assessment included the Chester River. The addition of the Chester River should increase both the carrying capacity (K) and the initial biomass estimate (B_0).

Maximum sustainable yield (MSY) was identified as 1.7 million pounds. Total estimated removals were above MSY in only 2 years during the expansion/plateau phase of channel catfish abundance (14 years). Total estimated removals exceeded MSY in each year except 2000 during the period when the population contracted (1994 – 2000). Harvests at or above MSY have not been achieved since 1999 and population biomass has increased. The population biomass during 2008 was 27% higher than B_{MSY} (B_{MSY} = the population biomass that can sustain harvest at MSY), given that the $B:B_{MSY}$ ratio for 2008 was 1.27. A $B:B_{MSY}$ ratio greater than 1.0 indicates that the stock is not overfished. This metric has proven more robust than absolute biomass values from surplus production modeling (Prager 1994).

Inspection of the trajectories of F moved opposite that of biomass. The previous assessment indicated that population contraction occurred before F increased, indicating that fishing pressure was stable, and the F had little influence on biomass decline. This assessment indicated that no lag in fact existed. As F ramped up, the population biomass stabilized and then F increased beyond F_{MSY} and population biomass contracted. Regardless, the period beginning in 2000 had F rates below F_{MSY} and population biomass expanded. In the final year of the assessment, the $F:F_{MSY}$ ratio was 0.52. $F:F_{MSY}$ ratios less than 1.0 indicate that overfishing is not occurring. Similar to the $B:B_{MSY}$ ratio, the F ratio is a more robust estimate of the status of F than absolute values (Prager 1994).

The recent biomass increase is at odds with the seine survey recruitment indices from the HOB. The recruitment index has been low or zero since 1990. The EJFS seine survey is not directed at channel catfish and may not be suitable to describe channel catfish yoy abundance in the HOB. A winter trawl survey (Project 1 Job 1) may offer an alternative index, but the temporal coverage is minimal. The trawl survey results indicated strong year-classes for the 2004, 2006, and 2008 cohorts. In comparison, the seine survey did not collect channel catfish from the 2004 or 2006 cohort, and only a trivial amount of the 2008 cohort.

Lack of model fits necessitated utilization of relative abundance indices to describe population dynamics of channel catfish in the Choptank and Potomac rivers. In the Choptank River, all indices indicated an expanding population since the late 1990’s. Fishery dependent indices (commercial fyke net, pot net and pound net relative abundance) indicated a period of contraction from the early 1990’s to approximately 2000, followed by population expansion through 2008. The fishery independent fyke net survey (Project 1 Job 1) indicated a nearly identical trend, corroborating the signals from the fishery dependent surveys. In addition, the recruitment index from the EJFS seine survey is also in agreement with the observation of an expanding population. The Choptank River recruitment index showed generally high juvenile production from 1994 – 2004 and again in 2008. Site selection in the Choptank River seine survey may better sample preferred juvenile channel catfish habitats than in the HOB.

The Potomac River indices are quite different than either the Choptank River relative abundance trends or the HOB model results. The Potomac River fish pot index and the Fisheries Service drift gill net survey results indicated a decline in channel catfish biomass since the early 1990’s. The juvenile seine survey indicated that recruitment since 1986 has been very low. However there is a large degree of uncertainty in the validity of the seine survey for channel catfish, given that the HOB index may not effectively describe recruitment dynamics. Regardless, the available fishery dependent and independent surveys indicate that the channel catfish population in the Potomac River is low (relative to the mid 1990’s) and stable. Ecological changes in the Potomac

River may affect channel catfish population dynamics also. Blue catfish (*I. furcatus*) have become established in the river. The same drift gill net survey that was utilized to describe channel catfish relative abundance also samples blue catfish. The decline in channel catfish biomass in 1997 corresponds to the first appearance of blue catfish in the survey. Since that time, blue catfish biomass has increased and channel catfish population biomass has remained much lower than levels that were evident prior to the appearance of blue catfish (Figure 27). Inter-specific competition via blue catfish predation on channel catfish and competition for available prey may be negatively effecting channel catfish population recovery.

CITATIONS

Fewless, L. 1980. Life history and management of the channel catfish in the Susquehanna River. Maryland Department of Natural Resources, Federal Aid in Sport Fish Restoration, Project F-20-R, Annapolis, Maryland.

Haddon, M. 2001.Modelling and quantitative methods in fisheries. Chapman and Hall/CRC Publishing. New York.

Magnusson, A. and R. Hilborn. 2007. What makes fisheries data informative. Fish and Fisheries. 8:337-358.

Sauls, B. D. Dowling, J. Odenkirk, and E. Cosby. 1998. Catfish populations in Chesapeake Bay. Chesapeake Bay Program., U.S. Environmental Protection Agency, Annapolis, Maryland.

Piavis, P and E. Webb III. 2007. Population assessment of channel catfish in Maryland with special emphasis on Head-of-Bay stocks. *In* Chesapeake Bay finfish and habitat investigations. Maryland Department of Natural Resources. Report F-61-R Annapolis, Maryland.

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

Prager, M.H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fishery Bulletin. 92:374-389.

Weinrich, D., E. Franklin, S. Minkkinen, and A. Jarzynski. 1986. Investigation of American shad in the upper Chesapeake Bay. Maryland Department of Natural Resources. Tidewater Administration. Annapolis, Maryland.

LIST OF FIGURES

LIST OF FIGURES (continued)

Figure 1. Head-of-Bay fishery independent drift gill net sampling locations.

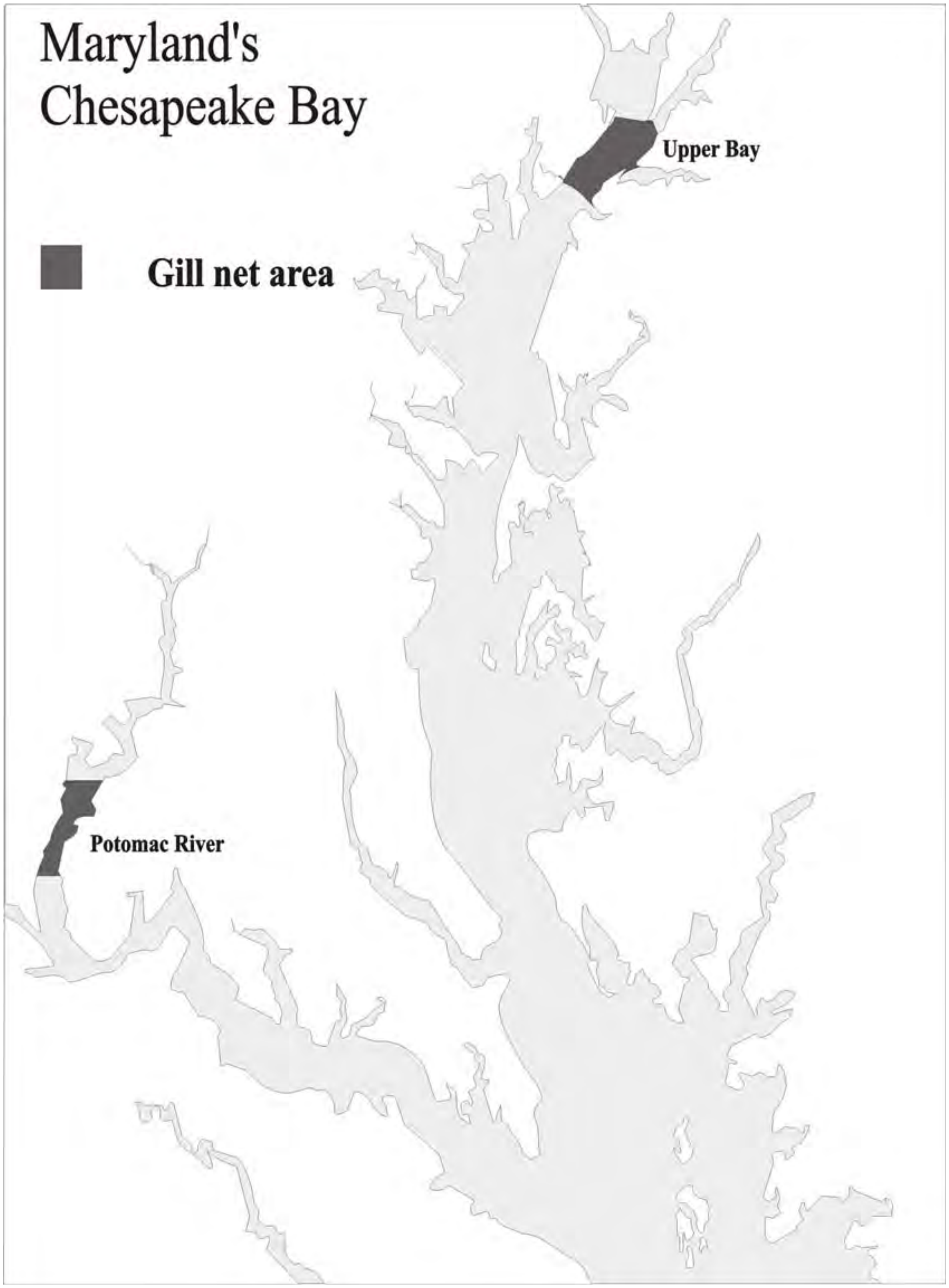


Figure 2. Choptank River fishery independent fyke net locations (triangles) and area of fishery independent drift gill net sets (double tailed arrow).

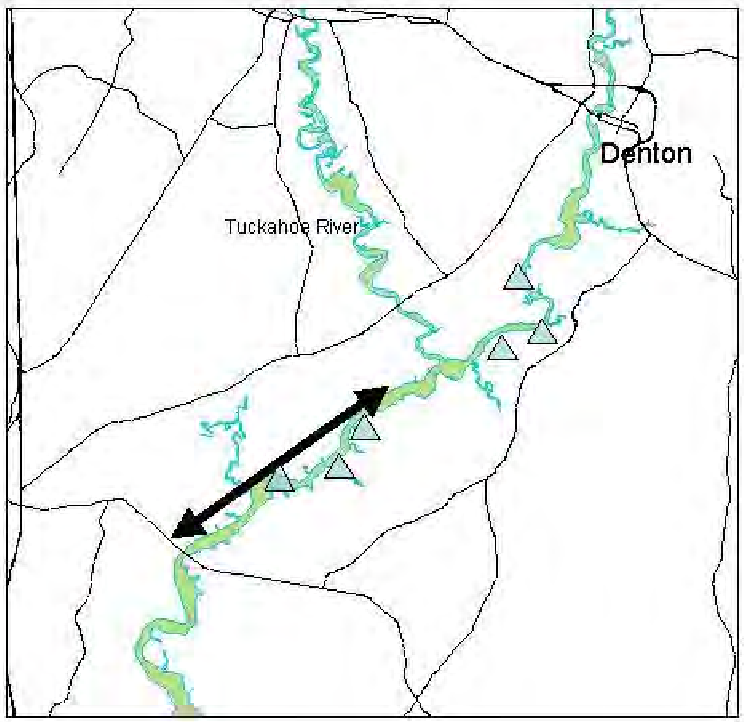


Figure 3. . Head-of-Bay winter trawl sites (triangles=main bay sites, squares=Elk River sites, circles=Sassafras River sites).

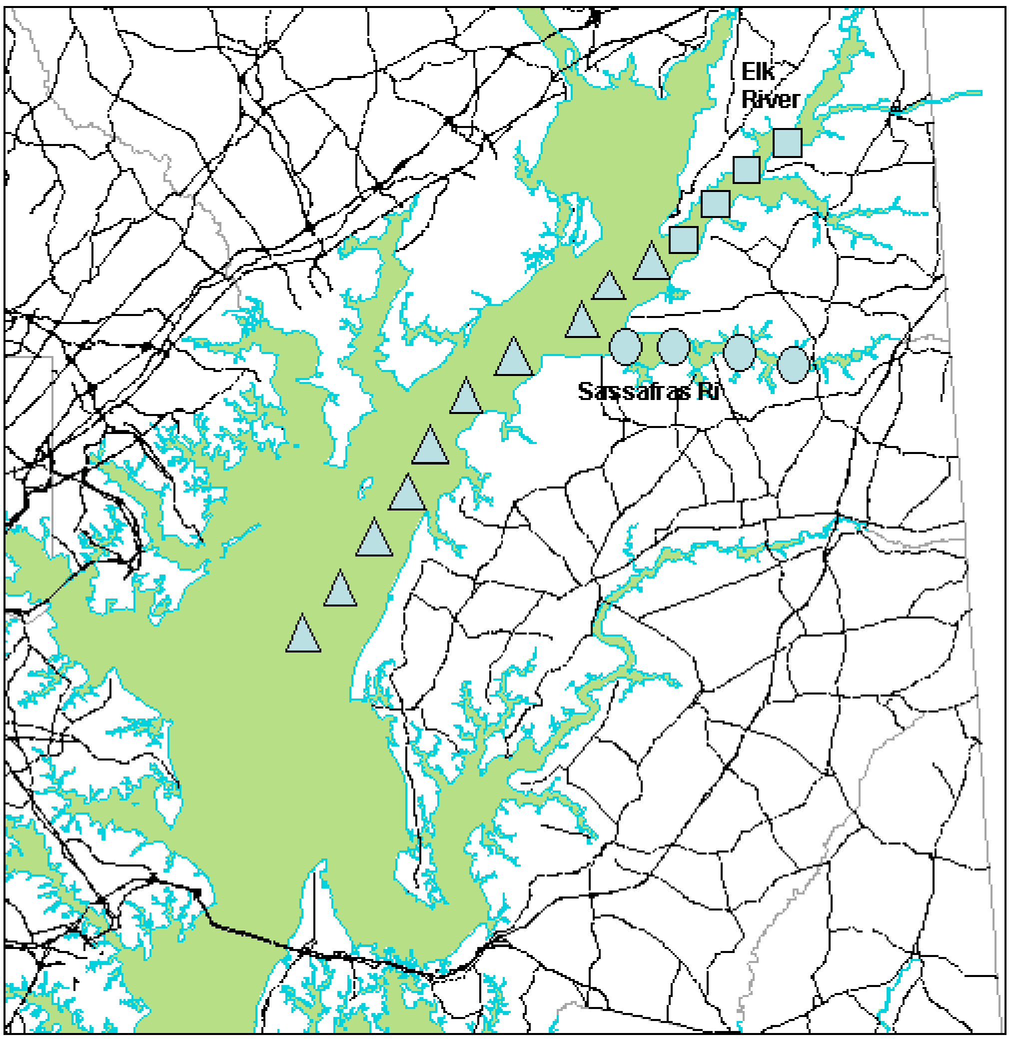


Figure 4. Estuarine Juvenile Finfish Survey seine site locations.

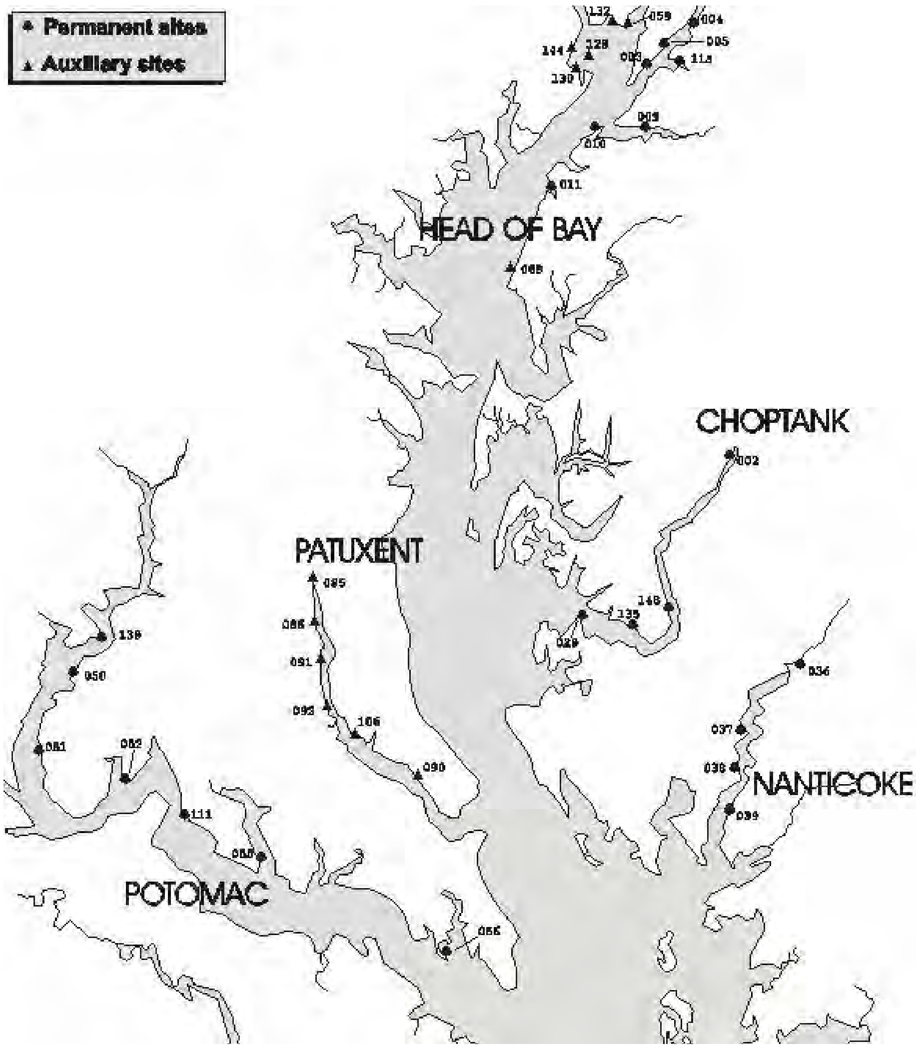


Figure 5. Chesapeake Bay channel catfish landings from the commercial and recreational fisheries, 1929 – 2008.

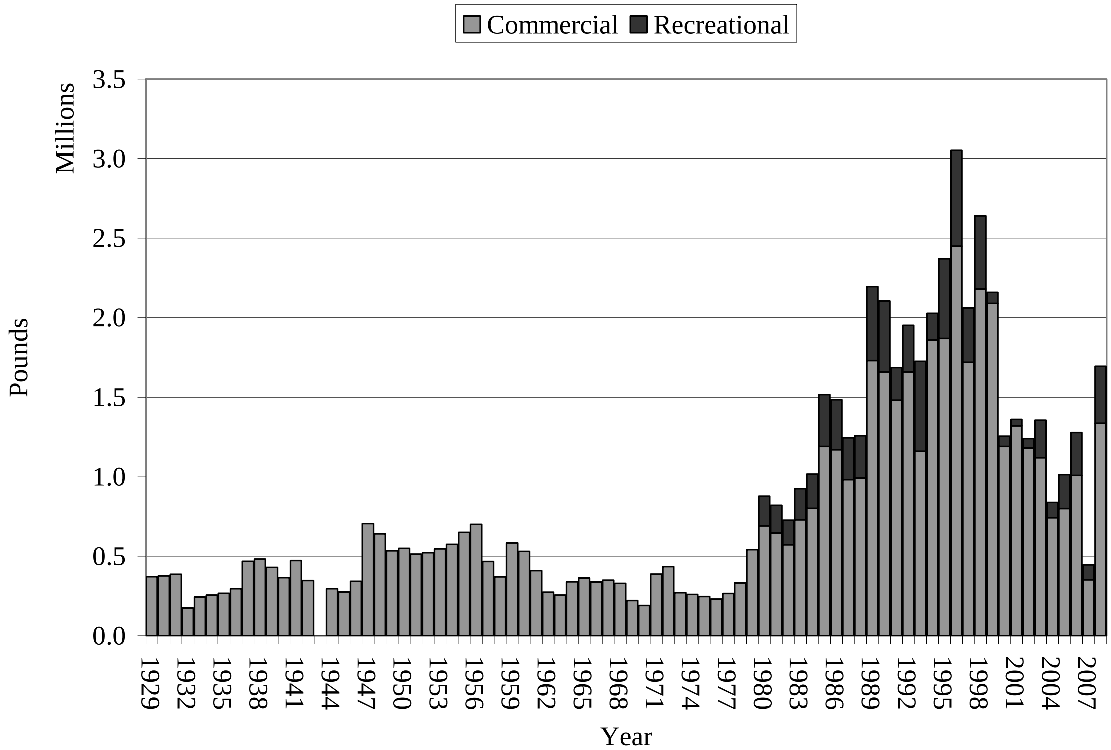


Figure 6. Head-of-Bay channel catfish landings from the commercial and recreational (estimated) fisheries, 1980 – 2008.

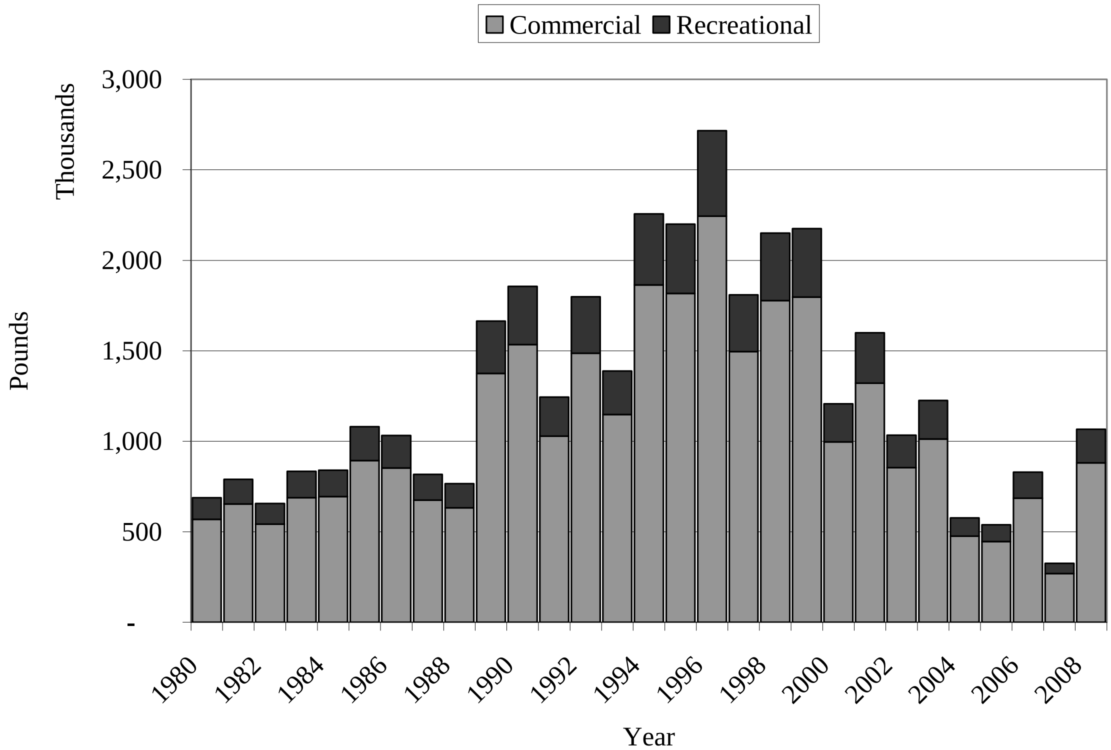


Figure 7. Choptank River channel catfish landings from the commercial and recreational (estimated) fisheries, 1980 – 2008.

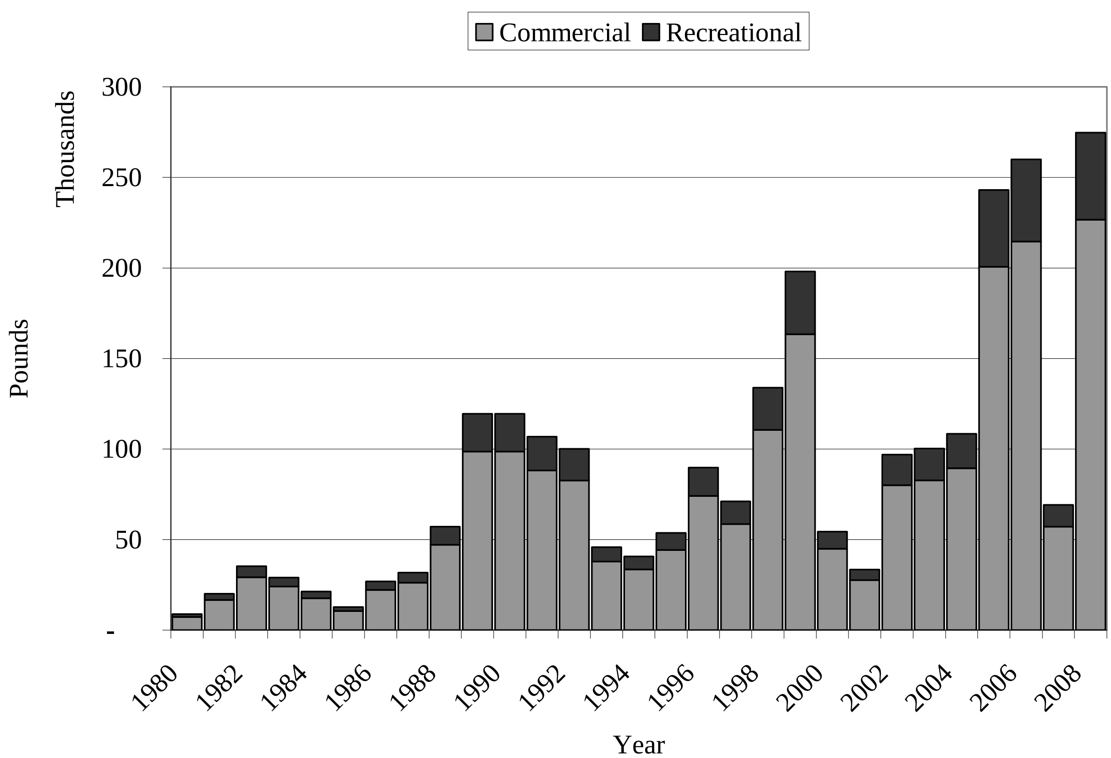


Figure 8. Potomac River channel catfish landings from the commercial and recreational (estimated) fisheries, 1985 – 2008.

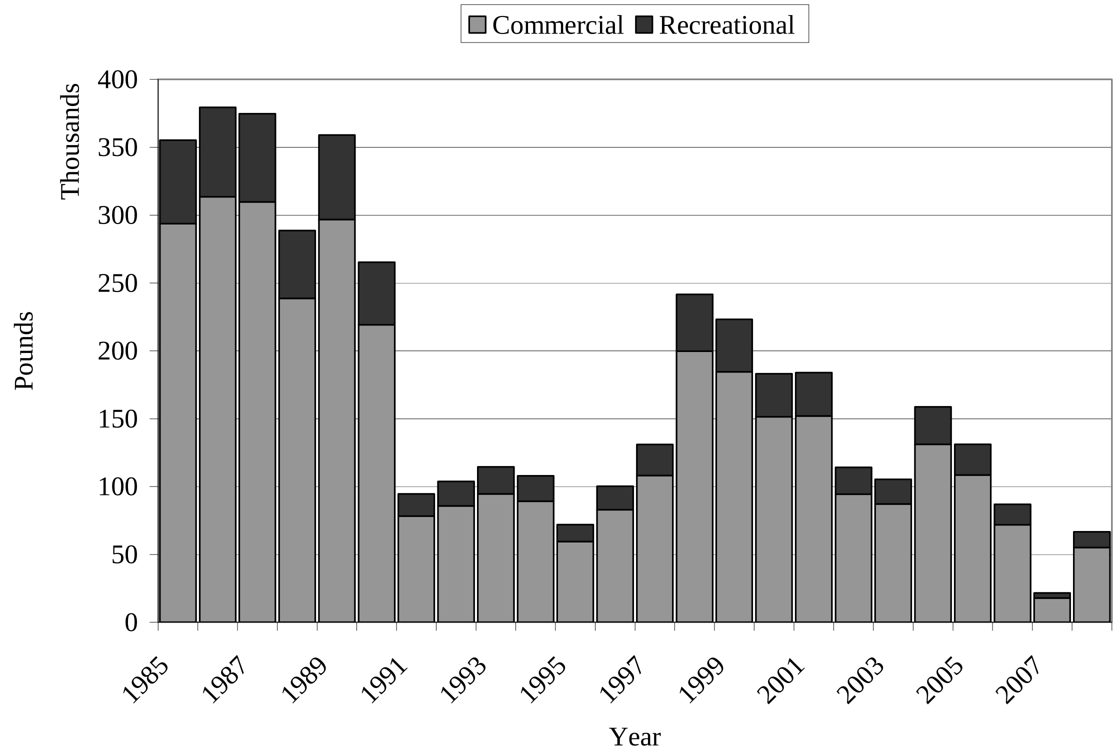


Figure 9. Head-of-Bay channel catfish fishery dependent fyke net index, 1980 – 2008.

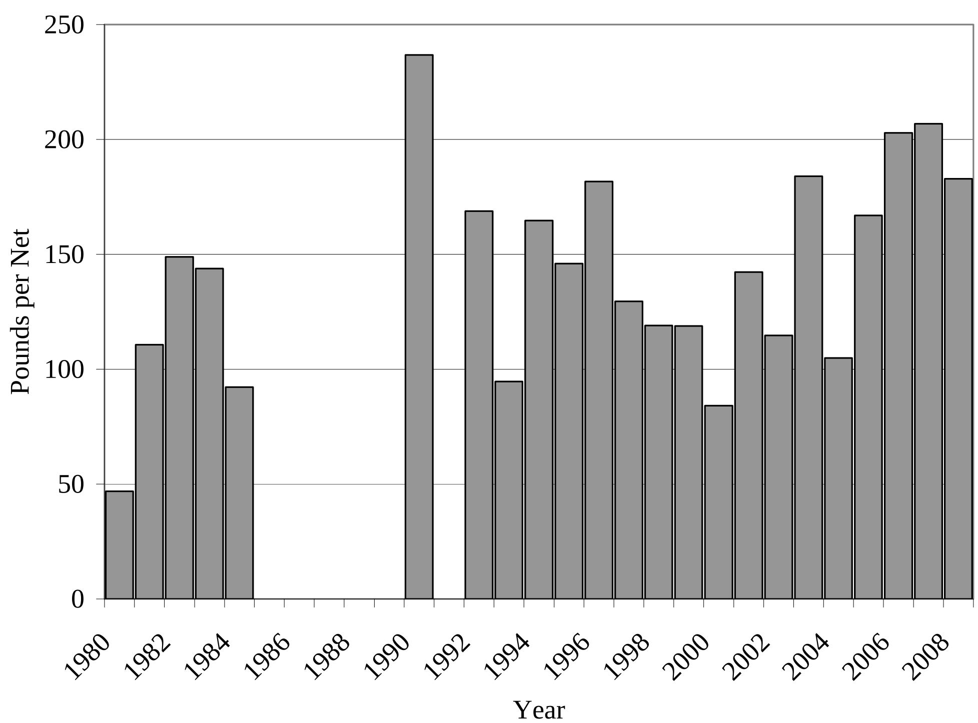


Figure 10. Head-of-Bay channel catfish fishery dependent fish pot index, 1980 – 2008.

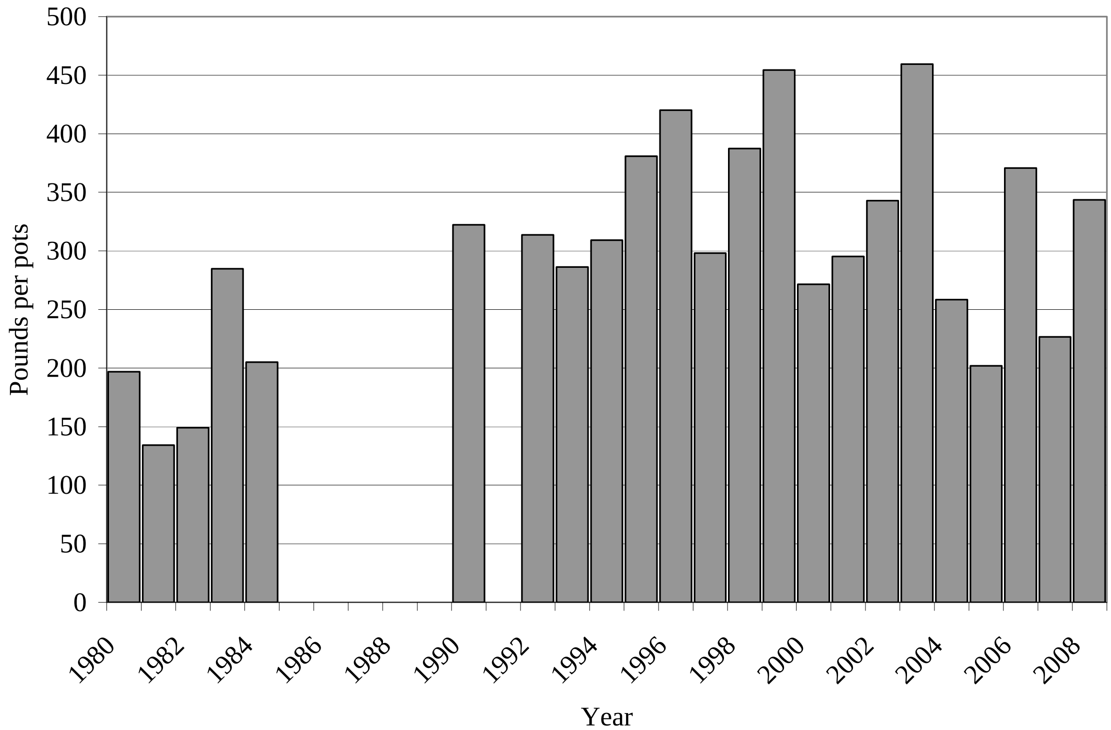


Figure 11. Head-of-Bay channel catfish fishery dependent pound net index, 1980 – 2008.

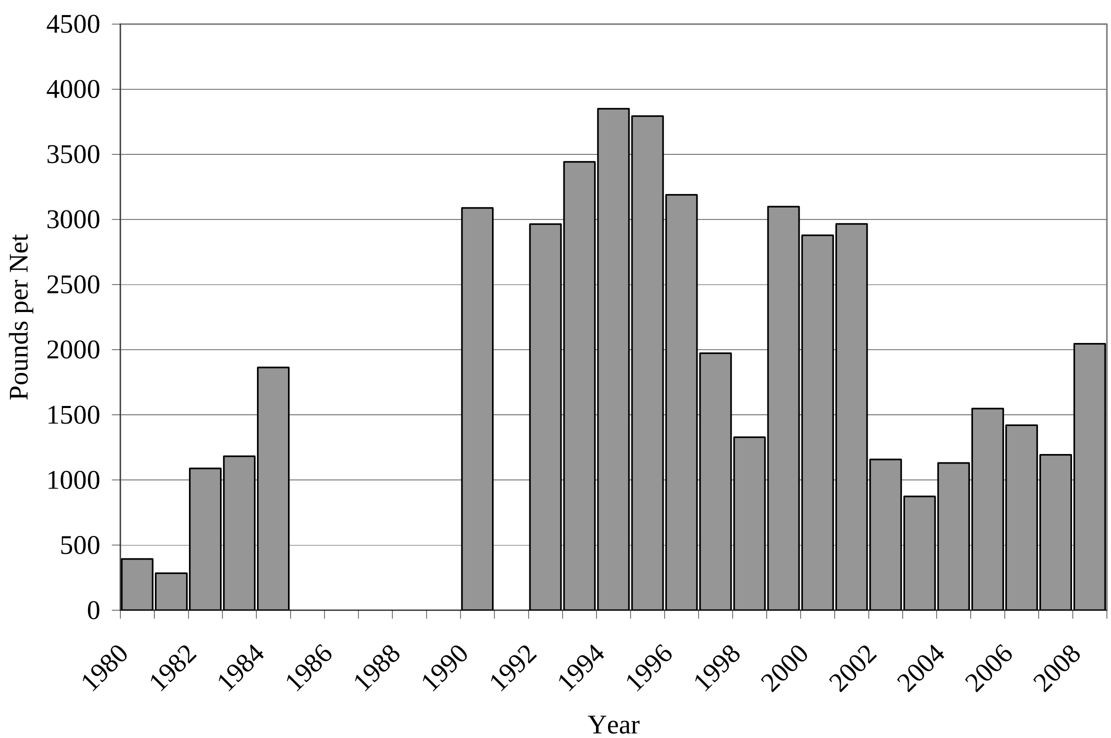


Figure 12. Choptank River channel catfish fishery dependent fyke net index, 1980 – 2008.

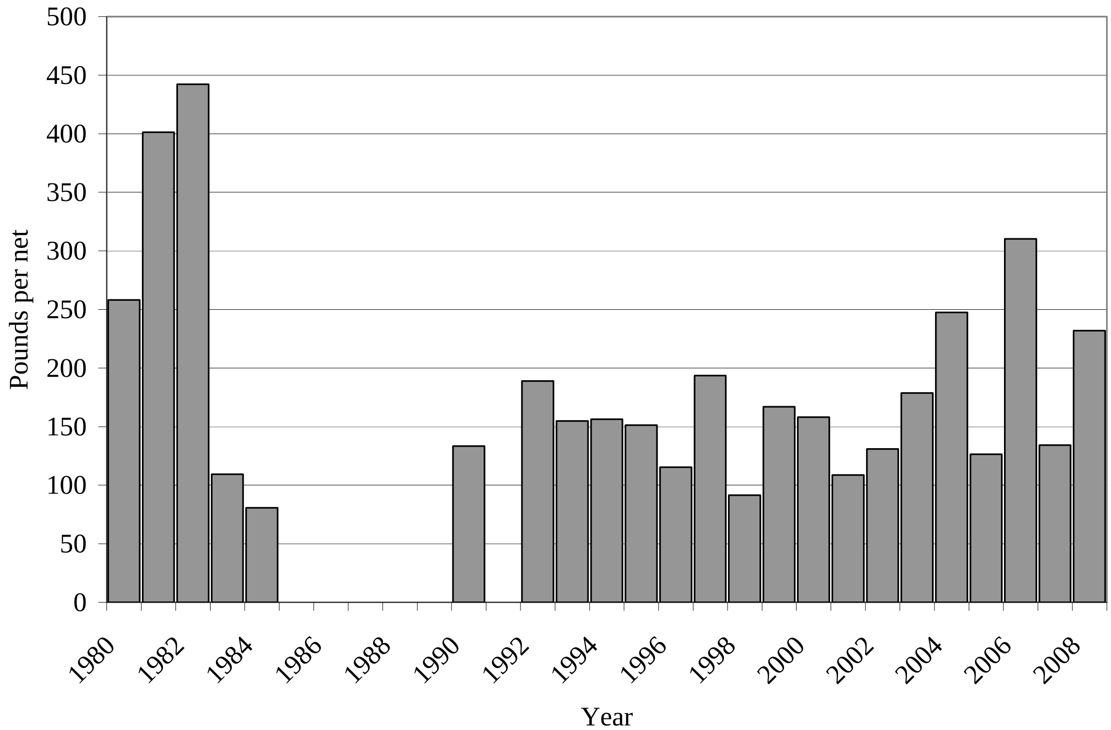


Figure 13. Choptank River channel catfish fishery dependent fish pot index, 1980 – 2008.

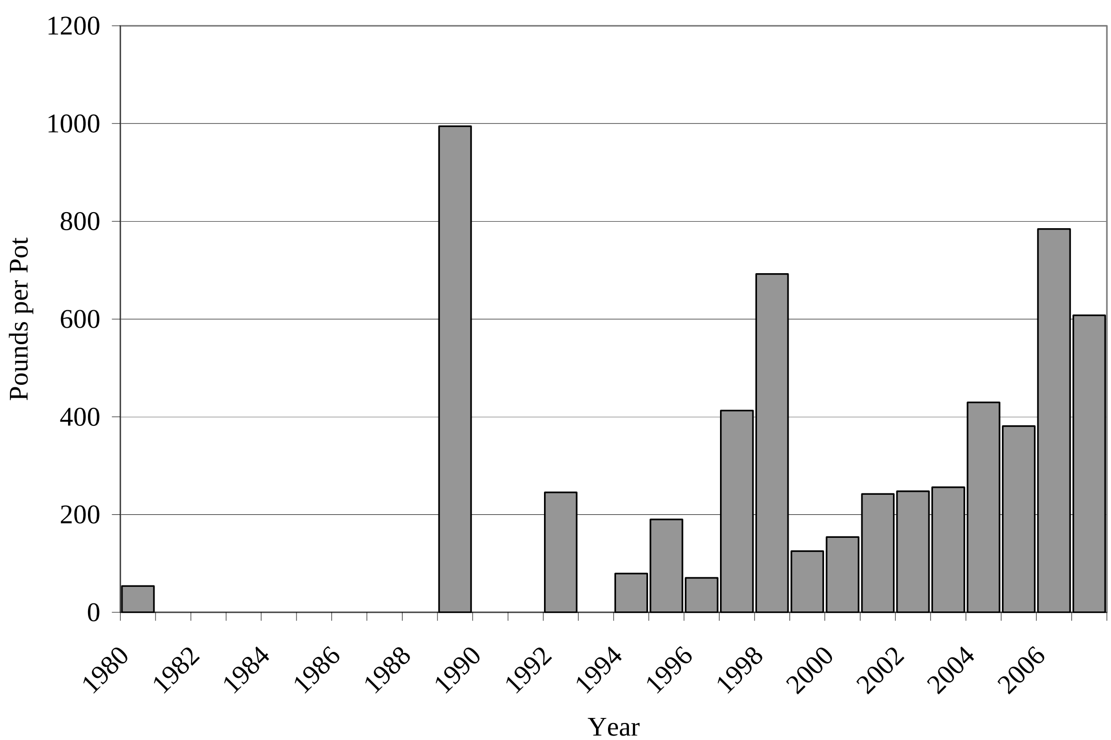


Figure 14. Choptank River channel catfish fishery dependent pound net index, 1980 – 2008.

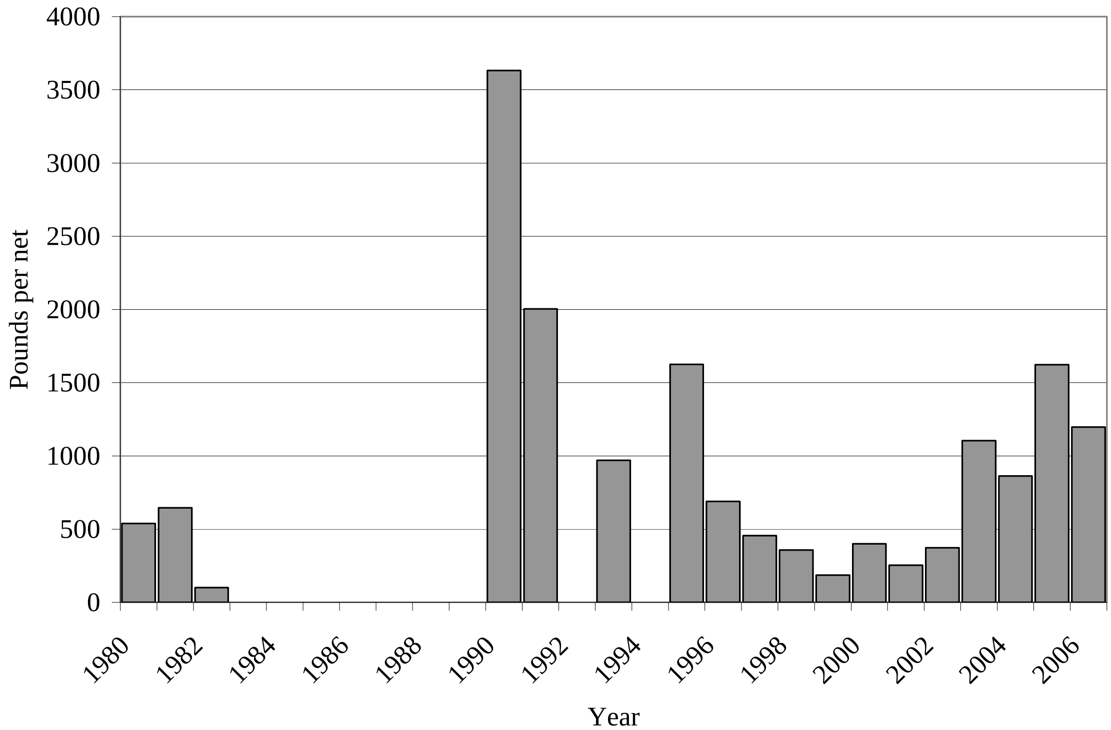


Figure 15. Potomac River channel catfish fishery dependent fish pot index, 1980 -- 2008.

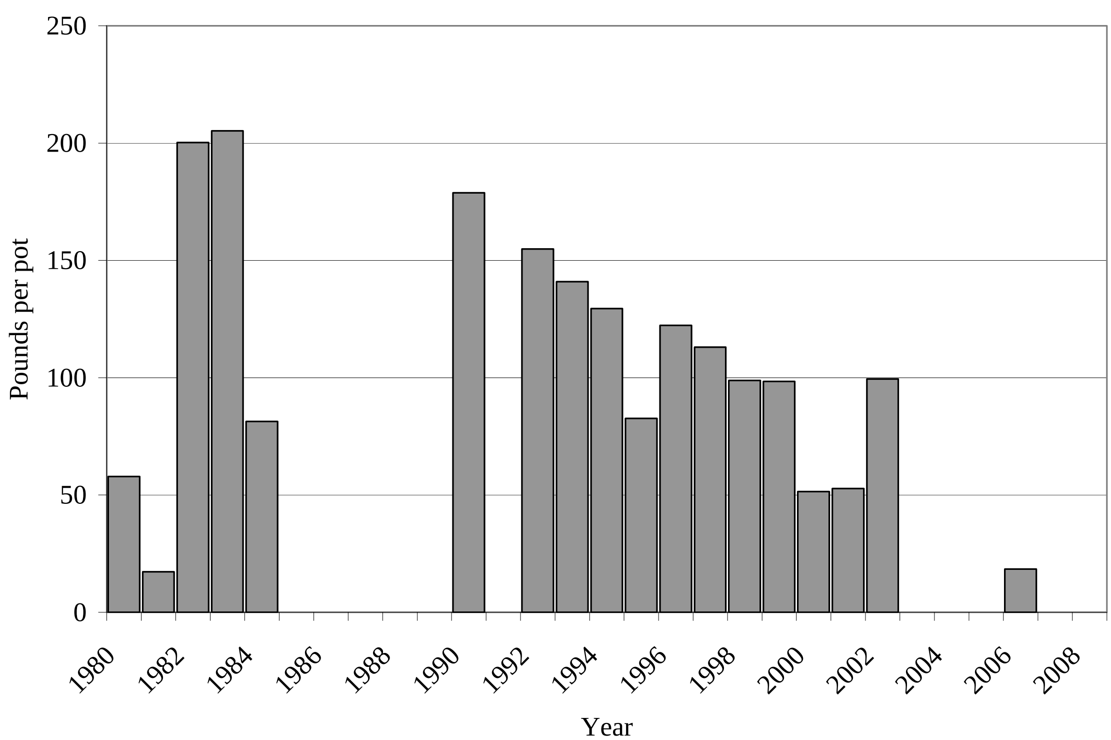


Figure 16. Head-of-Bay channel catfish fishery independent drift gill net biomass index, 1985 -- 2008.

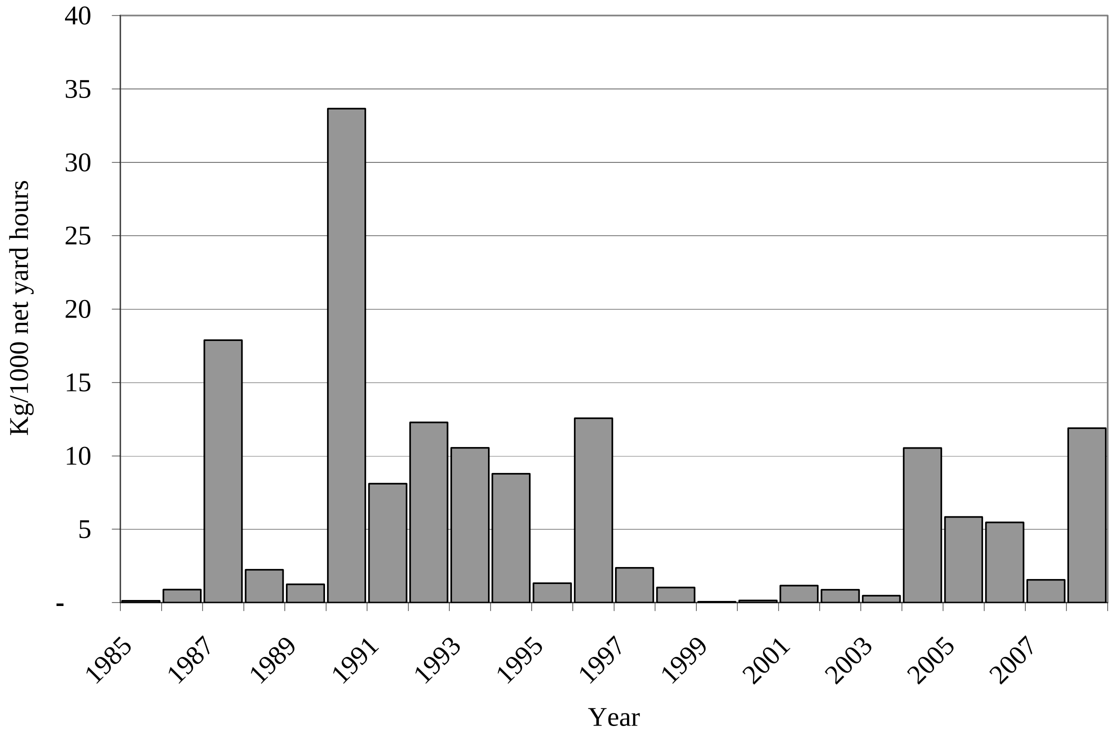


Figure 17. Head-of-Bay channel catfish fishery independent young-of-year seine index, 1975 – 2009.

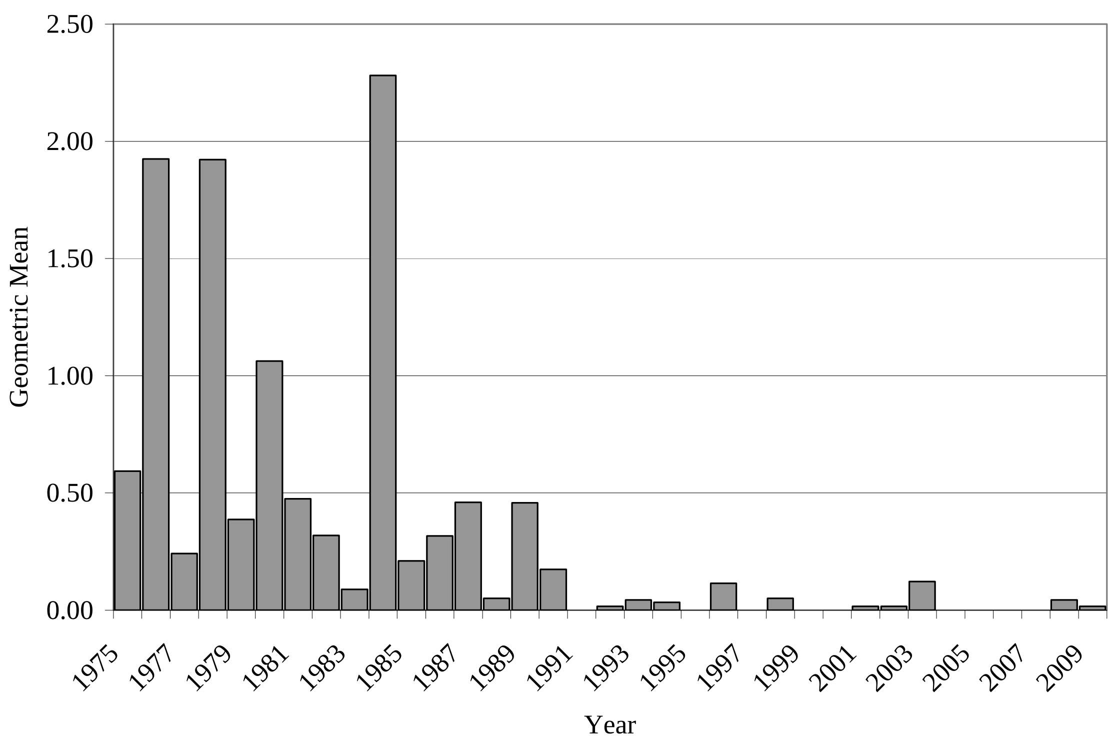


Figure 18. Head-of-Bay channel catfish fishery independent trawl survey index (n-based) with 80% confidence intervals, 2000 – 2009.

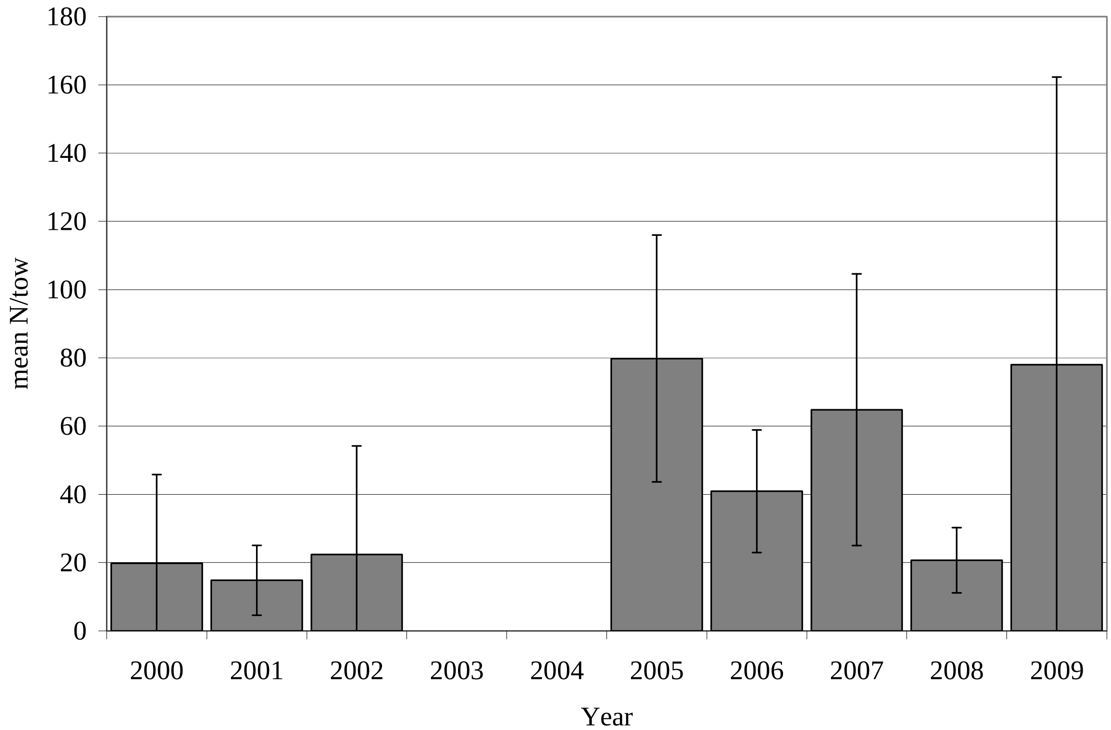


Figure 19. Choptank River channel catfish fishery independent fyke net biomass geometric mean index, 1993 – 2009.

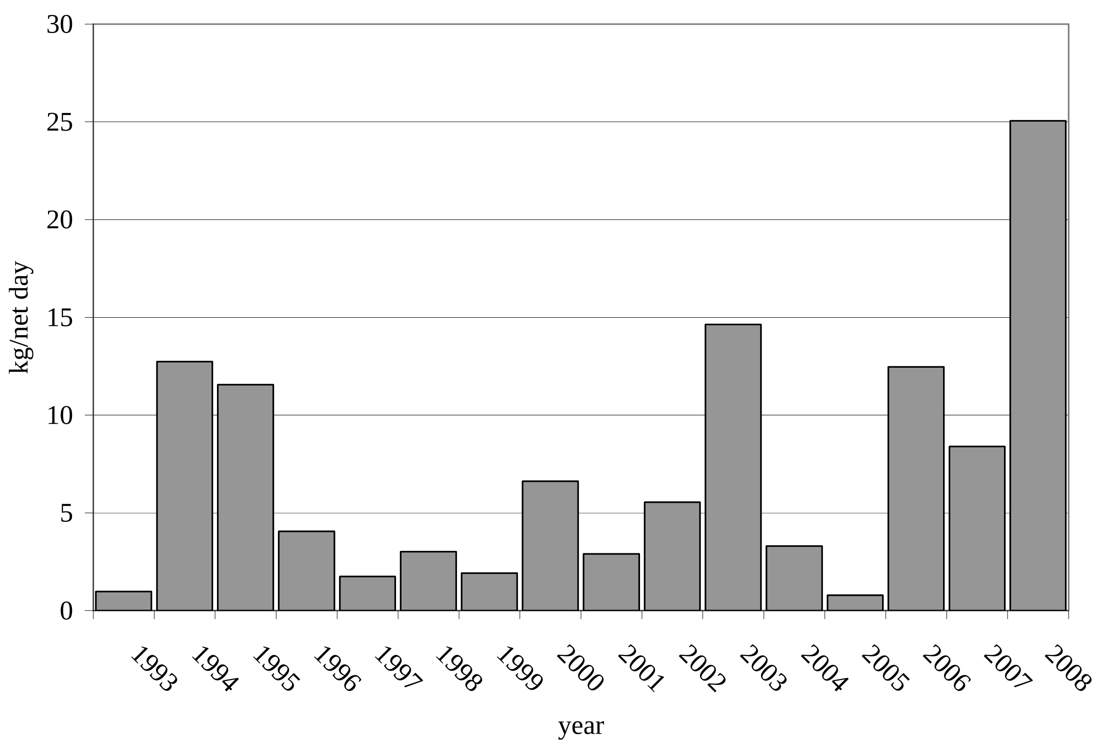


Figure 20. Choptank River channel catfish fishery independent drift gill net biomass index, 1983 -- 1996.

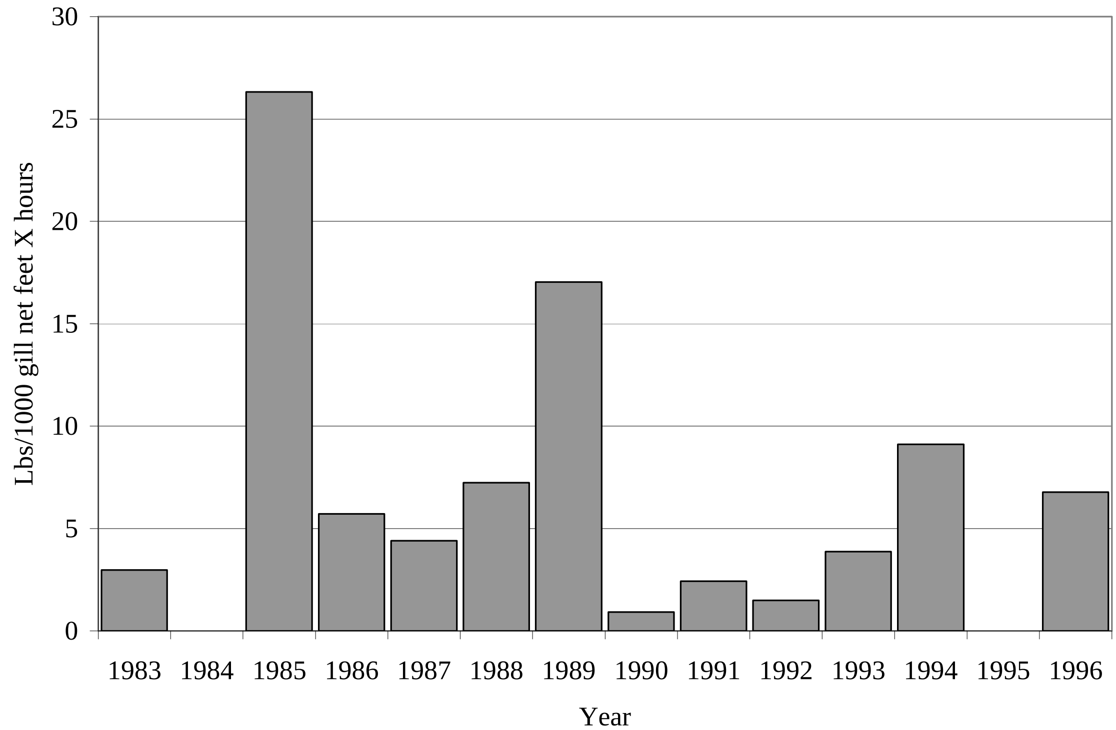


Figure 21. Choptank River channel catfish fishery independent young-of-year seine index, 1975 – 2009.

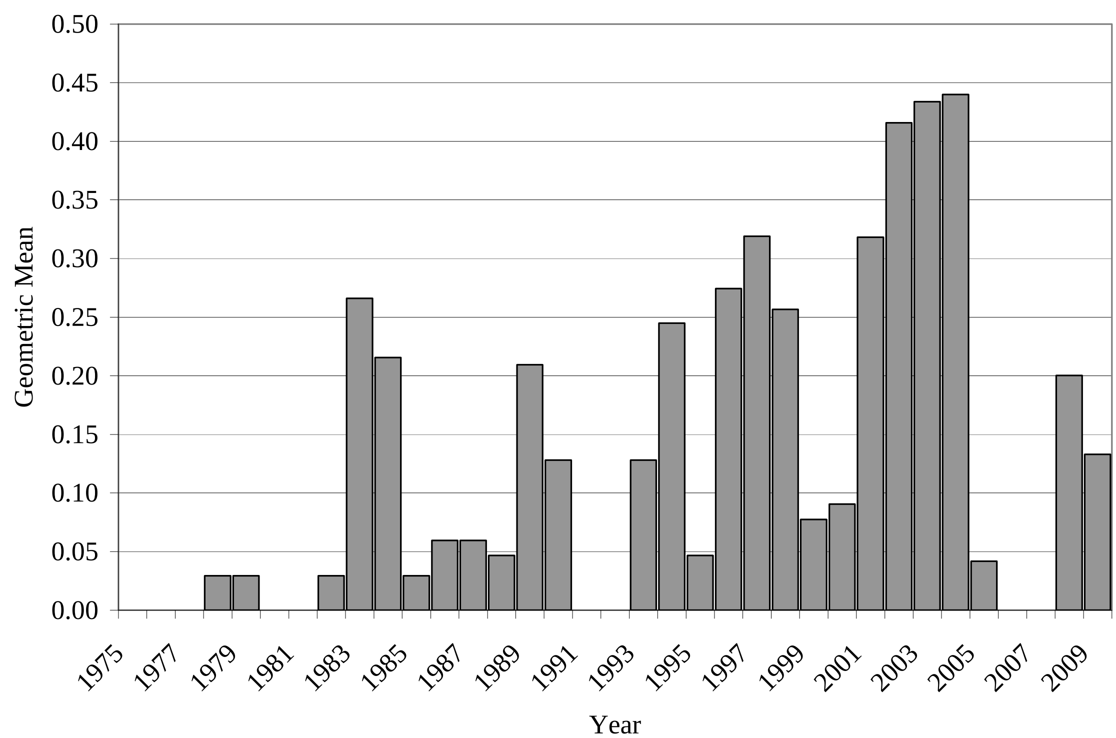


Figure 22. Potomac River channel catfish fishery independent drift gill net biomass index, 1984 – 2008.

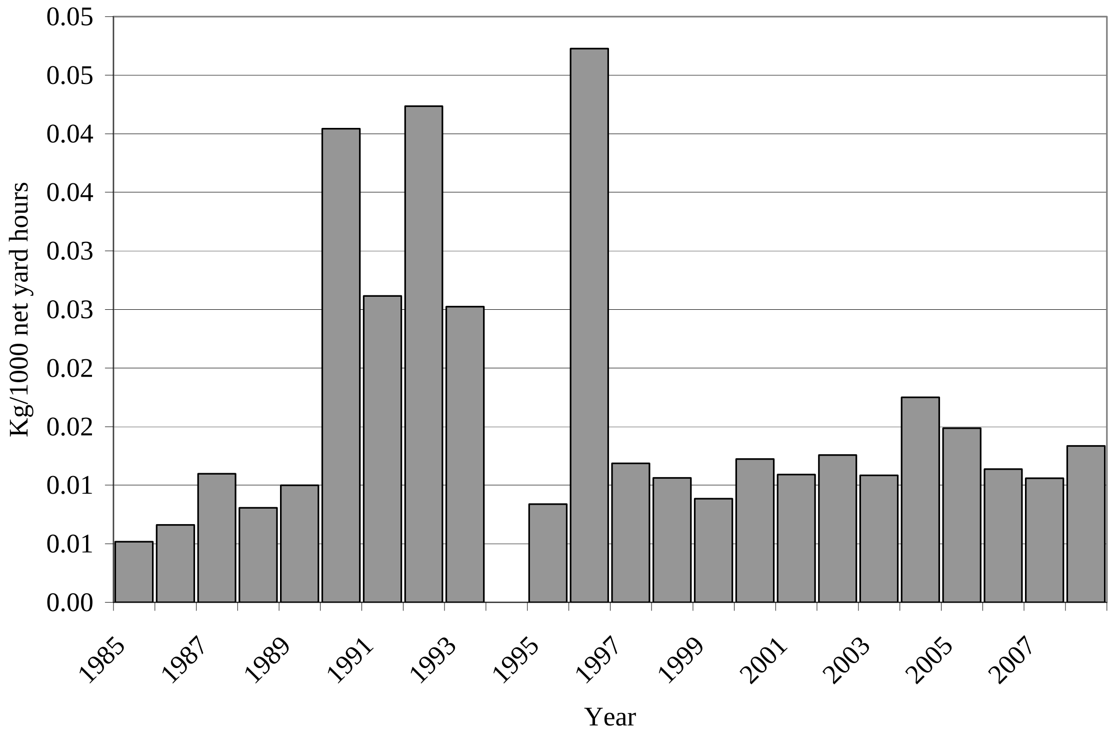


Figure 23. Potomac River channel catfish fishery independent young-of-year seine index, 1984 – 2008.

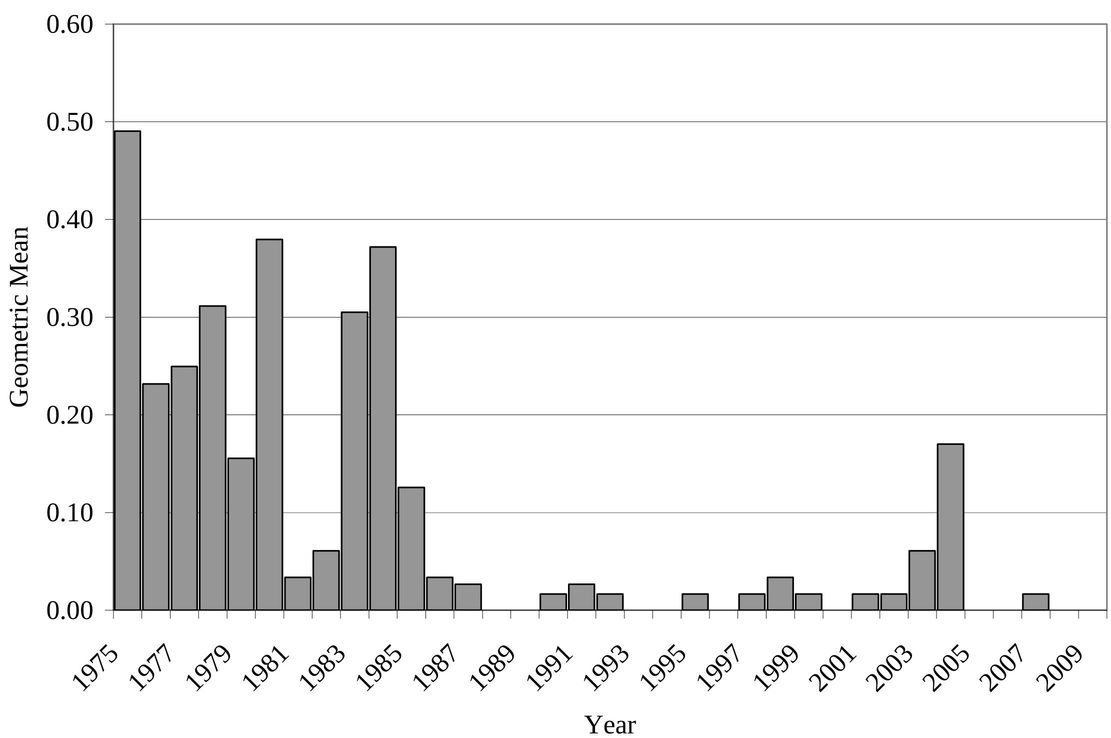


Figure 24. Biomass estimates of Head-of-Bay channel catfish from a surplus production model with 80 % confidence intervals, 1980 – 2008.

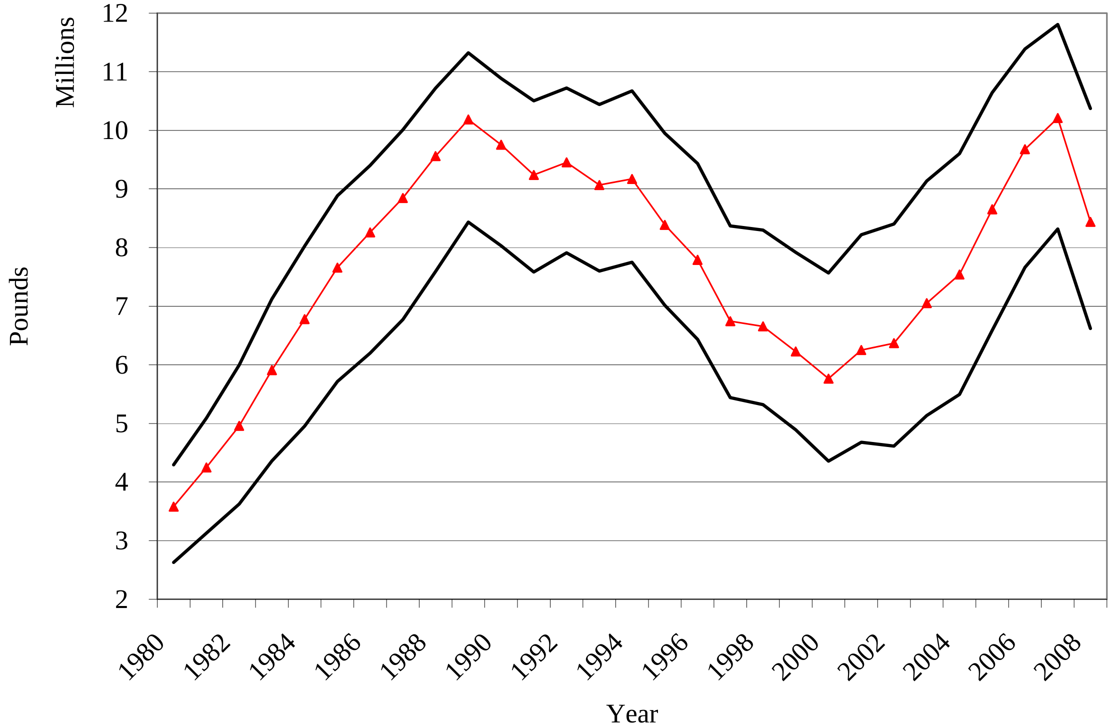


Figure 25. Instantaneous fishing mortality estimates of Head-of-Bay channel catfish from a surplus production model with 80% confidence intervals, 1980 – 2008.

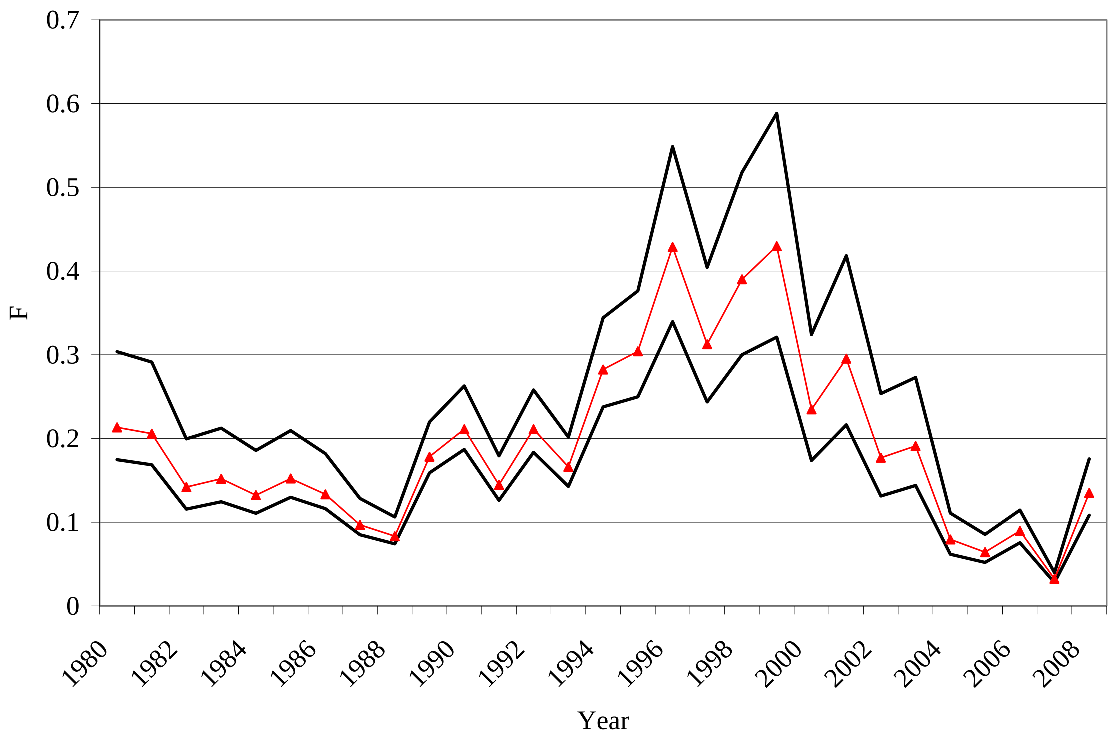


Figure 26. Biomass:Biomass at maximum sustainable yield (B:B_{MSY}) and F:F at maximum sustainable yield (F:F_{MSY}) ratios for Head-of-Bay channel catfish from a surplus production model, 1980 – 2008.

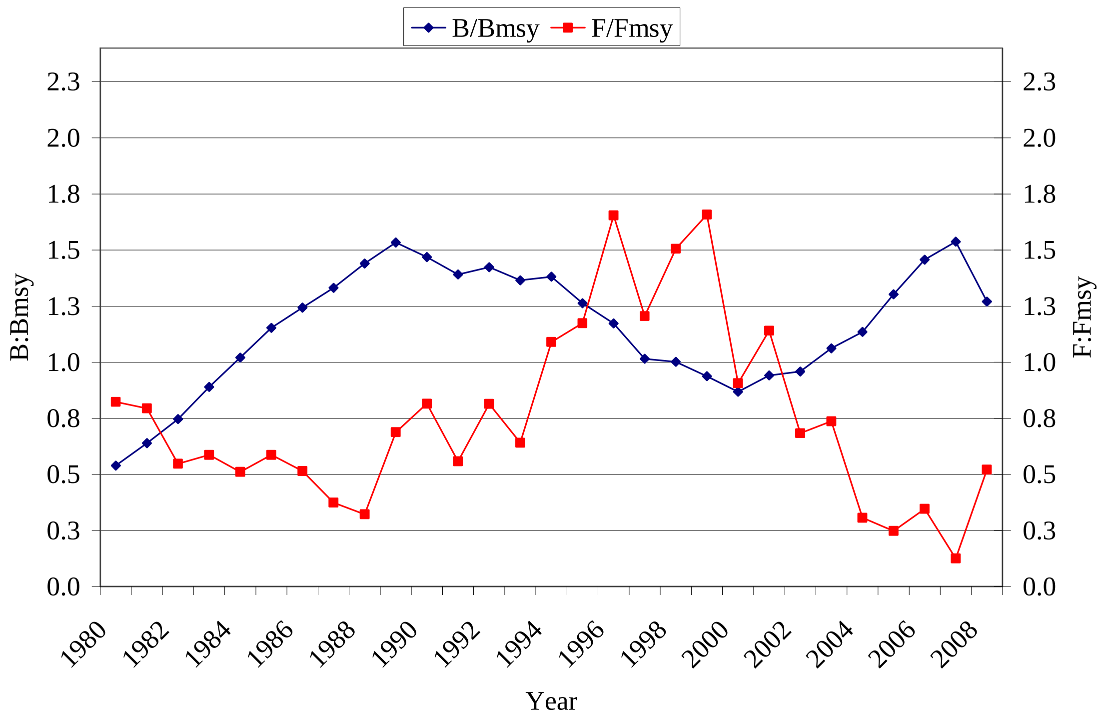
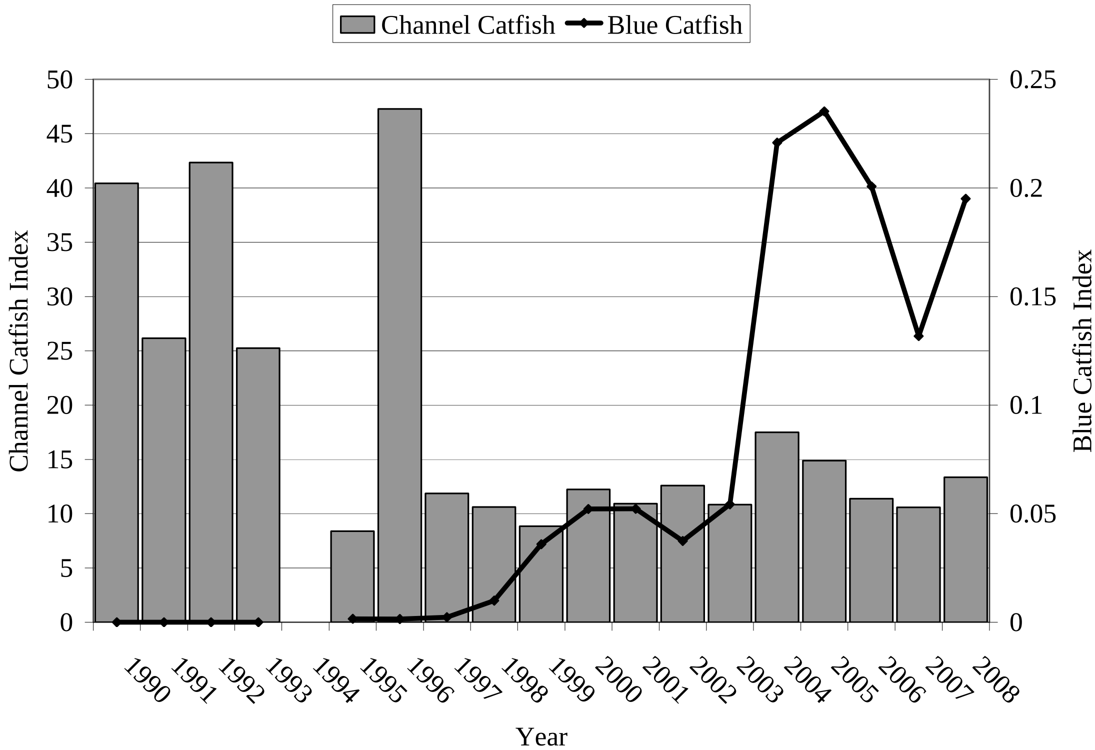


Figure 27. Fishery independent drift gill net biomass indices for channel catfish and blue catfish from the Potomac River, 1990 – 2008.



PROJECT NO. 2
JOB NO 1

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

Prepared by
A. Jarzynski and R. Sadzinski

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 and Pocomoke rivers.

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 2009 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 27 April through 29 May 2009. 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.

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 (7) between 17 February and 1 May 2009. 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) 30.4 and 35.7 (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 44-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 31 March to 1 May 2009. The ichthyoplankton net was constructed of 500 μm mesh net with a 500mm metal ring opening. The net was towed for six-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 2009 in the Chester and Pocomoke rivers 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) and five sites on the Pocomoke River (Figure 5). 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.

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 (1989-2009) 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 into 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. In addition to these assumptions 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 1984 and was estimated as $\log_e [1 - (C_t / N_t)]$ (Ricker 1975).

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 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 for tagging was calculated as the geometric mean of fish caught per boat hour.

In addition, spring recreational data for American and hickory shad was collected from anglers fishing the lower Susquehanna River. A roving creel was utilized to survey anglers fishing in the Conowingo Dam tailrace. This non-random survey interviewed stream bank anglers and generated a catch-per-angler-hour (CPAH) for American shad. A logbook was distributed to interested anglers who were asked to document their American and hickory shad catches during the spring season. Data collected from this voluntary effort included date and location fished, catch, and hours spent fishing. CPAH by location and species was subsequently 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 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 estimate.

2. Ichthyoplankton Samples

Successful clupeid reproduction in the lower Nanticoke River was determined by the presence of eggs through biweekly plankton net 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 2009 male-female ratio of adult American shad captured by hook and line from the Conowingo tailrace was 1.45:1. Of the 668 fish sampled by this gear, 622 were successfully scale-aged (Table 1). Those American shad not aged directly because of regenerated scales, were not assigned ages.

The 2009 male-female ratio for adult American shad captured in the Nanticoke River was 2.5:1. Of the ninety American shad collected from the Nanticoke pound and fyke nets in 2009, 86 were subsequently aged (Table 1).

The percentages of Conowingo tailrace repeat spawning American shad in 2009 was 20.3% for males and 18.2% for females (Table 1). The arcsine-transformed proportions of these upper Bay repeat spawners (sexes combined) has significantly increased for the time series ($r^2 = 0.51$ $p< 0.001$; Figure 6). The percentages of repeat spawners for the Nanticoke River in 2009 were 36.7% 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 ($r^2 = 0.49$ $p < 0.001$; Figure 7).

2. *Relative Abundance*

Of the 668 adult American shad sampled from the Conowingo tailrace in 2009 (Table 2), 635 (95%) were tagged and 104 (16.4%) subsequently recaptured from the east lift (Table 3). The east lift also recaptured three American shad tagged in 2008. In 2009, there were no reported tagged American shad recaptured from either commercial fishermen or recreational anglers.

In 2009, the east lift operated from 1 April through 5 June and technicians counted 29,272 American shad passing the viewing window during this 66 day period. Peak passage was on 4

May when 4,670 American shad were recorded. In 2009, the west lift at Conowingo Dam operated from 28 April to 29 May. The 6,534 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 17 May when 1,069 American shad were collected. All of the 44 marked American shad recaptured by the west lift in 2009 were fish marked this year (Table 3). Based on model estimates, the American shad tailrace population estimate in 2009 was 188,113 fish and has trended up for the time series (Figure 8; r^2=0.65, P< 0.001).

The angler-based roving creel in the Conowingo Dam's tailrace interviewed forty anglers in 2009. The American shad CPAH for these anglers was 1.41, a significant increase from 2008 when the CPAH was 0.74 (Table 4). CPAH from 2001-2009 has increased significantly (r^2=0.55, P=0.02). Logbook data indicated an increase in CPAH of American shad compared to 2008 (Table 5) but no significant was indicated trend for the time series (1999-2009, r^2=0.34, P=0.06).

Estimates of hook and line tagging and fish lift geometric mean (GM) CPUEs have increased significantly for the time series (r^2=0.31, P= 0.004; r^2=0.42, P<0.001, respectively, Figures 9 and 10). However, a significant decrease in the fish lift GM CPUE (r^2=0.88, P<0.001) has been noted since 2002 while hook and line tagging GM CPUE has declined in five of the previous seven years..

Nanticoke River pound and fyke net GM CPUEs have both shown no trend since 2001 (r^2=0.15, P= 0.09; Figure 11; (r^2=0.008, P=0.70; Figure 12). American shad catches for both gear types 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 Conowingo tailrace, mortality estimates from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 2.07. The average difference between the natural logs of the spawning group frequency produced a Z = 2.08. Nanticoke River mortality estimates from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 1.39. The average difference between the natural logs of the spawning group frequency produced a Z = 1.29.

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 116 readable adult American shad otoliths collected from the west lift at Conowingo Dam in 2009, 62% were classified as non-hatchery fish (M. Hendricks PA Fish and Boat Comm., Pers. Comm. 2010). Fifty-two adult American shad otoliths collected from the Nanticoke River were sent to Delaware Division of Fish and Wildlife for oxytetracycline (OTC) analysis. Results indicated that 75% were non-hatchery fish (M. Stangl pers. Comm.).

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 eight samples (n = 97). Salinity at plankton tow stations ranged from 0.1 to 4.0 ppm.

C. Juveniles

No juvenile American shad were caught by haul seine in either the Chester or Pocomoke rivers during the 2009 sampling season.

II. Hickory Shad

A. Adults

1. Sex and Age Composition

The male-female ratio of adult hickory shad collected from the Nanticoke River in 2009 was 0.5:1. However the low sample size (n = 6) makes this result quite tenuous and precluded further age analysis.

2. Relative Abundance

Hickory shad CPAH in Deer Creek ranged from 3.6 to 8.3 for the time series with the lowest value (3.6) estimated in 2009 (Table 7). There was also no significant tend for the time series (1998-2009, r^2=0.14, *P*=0.26).

Nanticoke River pound net GM CPUEs for adult hickory shad have decreased since 2002 (r^2=0.83, *P*=0.005; Figure 13) while those for fyke nets have indicated no trend (r^2=0.07, *P*=0.44; Figure 14) during this period.

3. *Mortality*

Hoenig's (1983) equation ($\ln (M_x) = 1.46 - 1.01\{\ln (t_{max})\}$) was utilized to estimate hickory shad mortality in the upper Bay. Since tmax = 9, M was calculated to equal 0.47**.** Estimated Z from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 0.59. The average difference between the natural logs of the spawning group frequency produced a Z = 0.54.

B. Juveniles

During the 2009 beach seine sampling five juvenile hickory shad were collected from the Pocomoke River and none from the Chester River.

III. Alewife and Blueback Herring

A. Adults

1. Sex and Age Composition

The 2009 male: female ratio for Nanticoke River alewife herring was 1:2.74. Of the 217 alewives sampled, 216 were subsequently aged. Age groups 3-7 were present with the 2005 year-class (age 4, sexes combined) the most abundant, accounting for 38.4% of the total catch. Females were most abundant at age 5 and males at age 4 (Table 8).

The 2009 male: female ratio for Nanticoke River blueback herring was 1:1.09. Of the 71 blueback herring sampled, 66 were subsequently aged. Blueback herring were present at ages 3-7 with the 2005 year-class (age 4, sexes combined) the most abundant accounting for 56.1% of the sample. Males and females were both most abundant at age 4 (Table 8).

The percentages of alewife and blueback herring repeat spawners (sexes combined) for the Nanticoke River during 2009 were 50.9% and 28.8%, respectively (Table 8). The arcsine-transformed proportion of alewife repeat spawners (sexes combined) indicated no trend (1989-2009; r^2=0.01 P=0.91), while that for blueback herring represented a decreasing trend (1989-2009; r^2=0.56, P<0.01; Figure 15).

Using Speir and Mowrer's (1987) maturity schedule calculation, 91.4% of male alewife and 81.5% of male blueback herring were mature by age 4. The percentages of female alewife and blueback herring mature by age 4 were 76.6% and 71.4%, respectively.

2. Length-at-Age

For 2009, Nanticoke River female alewife herring mean lengths-at-age were greater than the corresponding male mean lengths-at-age except for age 3 (Table 9). Female blueback herring mean lengths-at-age were greater than for all corresponding male lengths-at-age (Table 10). Mean length-at-age for alewife females ages 4 to 8 and males ages 4 to 7 have decreased significantly since 1989 (Table 10). Regressions of blueback herring lengths for females ages 3-7 and males at ages 3-7 and 9 have significantly decreased since 1989 (Table 11).

3. Relative Abundance

Nanticoke River alewife herring fyke net GM CPUEs have decreased significantly (1989-2009; r^2=0.3, P=0.01; Figure 16), as have those for blueback herring (1989-2009; r^2=0.64, P<0.01; Figure 17). While the combined GM CPUEs (species, sexes, gears) have shown no trend over time (1989-2009; r^2=0.06, P=0.3; Figure 18) reported Nanticoke River commercial river herring landings (species combined) have significantly decreased since 1989 (r^2=0.76, P<0.01)

4. ***Mortality***

In 2009, instantaneous mortality (Z) for Nanticoke River alewife herring (sexes combined) was Z = 1.31 (annual mortality {A} = 73.02%). Since maximum age (T_{max}) for alewife herring from the Nanticoke was 7, M = 0.43 and F = 0.88. Separate estimates of Z for males and females were 0.97 (annual mortality {A} = 62.09%), and 1.32 (annual mortality {A} = 73.29%;), respectively (Figure 19).

Instantaneous mortality (Z) for Nanticoke River blueback herring in 2009 (sexes combined) was Z = 0.97 (annual mortality {A} = 62.09%) and since the maximum age (T_{max}) for Nanticoke blueback herring was 7, M = 0.43 and F = 0.54. The estimated Z for blueback herring males in 2009 was 0.90 (annual mortality {A} = 59.34) and 0.75 for females (annual mortality {A} = 52.76%; Figure 20).

B. Juveniles

For 2009, juvenile seining in the Chester River produced 18 juvenile alewife herring (CPUE = 0.4) and 19 juvenile blueback herring (CPUE = 0.42). Two juvenile alewives (CPUE = 0.07) and three blueback herring (CPUE = 0.11) were captured from the Pocomoke River during 2009.

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 the Petersen estimates (Figure 21) likely underestimate the American shad population. Conowingo Dam lift efficiencies (defined as annual catch at Conowingo Dam divided by population estimate) have averaged 48% since 1986. Lift efficiency in 2001, the year of the highest lift catch, was calculated at 98%. However, even with the problems associated with each procedure, the overall population trends derived from each method are quite similar.

The declines noted for both estimates since 2001 have also been mirrored by other measures of relative abundance. 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 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 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 decline in most Chesapeake Bay tributaries. Increases in abundance had only occurred in Maryland river systems where significant restoration stocking has occurred over many years such as the Patuxent River. However, even in these systems, abundance has recently declined (B. Richardson, MD DNR pers comm.). 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 also sharply declined (Figure 22).

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.).

Total mortality rates (Z) for Chesapeake Bay stocks of American shad in 2009 averaged 1.33 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 appears to demonstrate 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 are fully recruited, and the marks easily detected and non-lethal.

During the early 1950s, historical data of heavily exploited American shad stocks in the Potomac River 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 (Durell, unpublished data) but have shown no significant trend over time (2005-2009; r^2=0.03, P=0.70; Figure 23). 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 18% indicating that the increased adult population in 2009 may be partly attributable 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 2009 decreased to very low levels for the time series (Figure 24). Although spawning conditions appeared favorable in the upper Chesapeake Bay in 2009, only two juvenile American shad were captured from the seven permanent seine sites and none from the six auxiliary stations. Juvenile American shad indices in the upper Chesapeake Bay (Figure 25) 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 in the face of substantial declines in the overall population. 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 for three of the past five years (Figure 26). This trend may be related to decreases in adult abundance as indicated by sharp declines in CPUE during DNR spring gill net sampling (M. Baldwin, pers. comm. Figure 22).

Quantitative habitat analysis investigated the relationship between submerged aquatic vegetation (SAV) and American shad juvenile indices in the upper Chesapeake Bay. Since SAV can substitute as 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). Since no correlation was found between upper Bay SAV density and American shad juvenile indices from 1990 through 2009 (r^2 = 0.16, p = 0.54) water quality may not be a limiting factor on juvenile production.

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. 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 this spring season.

Hickory shad age structure and repeat spawning has been consistent and ideal featuring 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 mostly 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 verses 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 18) and the entire Maryland portion of the Chesapeake Bay (Figure 27) have decreased significantly. Alewife and blueback herring CPUEs from the Nanticoke River pound and fyke nets mirror this trend. 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 = 37) and Pocomoke rivers (n = 5) 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 28, 29 and 30). 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.

ASMFC (Atlantic States Marine Fisheries Commission). 1998. American shad stock assessment peer review report. Washington, D. C. 217 pp.

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

Crecco, V. 1996. Further evidence of offshore displacement of Atlantic coast bluefish based on commercial landings and fishing effort. Report to the ASMFC Bluefish Technical Committee.

Diamond, S., L. Cowell, and L. Crowder. 2000. Population effects of shrimp trawl bycatch on Atlantic croaker. Canadian Journal of Fisheries and Aquatic Sciences. 57: 2010 - 2021.

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

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.

Hendricks, M.L. 2008. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 2007. *In* Restoration of American shad to the Susquehanna River, Annual Report, 2007. Susquehanna River Anadromous Restoration Committee.

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

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. 2002. Stock assessment of weakfish through 2000, including estimates of stock size on January 1, 2001. A report to the Atlantic States Marine Fisheries Commission. Washington, DC 25 pp.

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

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.

Lee, L.M. 2003. Population assessment and short-term stock projections of bluefish. A report to the Atlantic States Marine Fisheries Commission. Washington, DC 22 pp.

Lee, L., J. Hightower, and P. Rand. 2001. Population dynamics of Atlantic croaker occurring along the U.S. east coast, 1981 - 1998. A Report to Atlantic States Marine Fisheries Commission, Washington DC.

Leggett, W. C. 1976. The American shad *Alosa sapidissima* with special reference to its migration and population dynamics in the Connecticut River. American Fisheries Society Monograph 1:169-225.

Loesch, J. G. 1987. Overview of life history aspects of anadromous alewife and blueback herring in freshwater habitats. American Fisheries Society Symposium. 1:89-103.

Loesch, J. G. and W. H. Kriete, Jr. 1984. Study of *Alosa* stock composition and year-class strength in Virginia. Virginia Institute of Marine Science, Annual Report, Anadromous Fish Project, Gloucester Point, Virginia.

Lukacovic, R. 1998. Mortality of American shad caught and released by anglers below Conowingo Dam. Maryland Department of Natural Resources, Fisheries Service. Fisheries Technical Report Series, Number 21.

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.

Mowrer, J. 2000. Resident and migratory juvenile finfish recruitment survey. *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.

Nataf, D. 2002. An examination of Maryland's angler's perceptions, preferences and attitudes; 2001. Maryland Department of Natural Resources, Fisheries Service, Annapolis, MD

NMFS (National Marine Fisheries Service). 2003. Assessment of summer flounder, 2002: Report of the Stock Assessment Workshop, Southern Demersal Subcommittee. Woods Hole, MA.

Piavis P. G. and J. Uphoff. 1999. Status of yellow perch in Maryland's portion of Chesapeake Bay during 1998. Maryland Department of Natural Resources, Fisheries Service. Fisheries Technical Report Series, Number 24.

Piavis, P., R. Sadzinski, and T. Jarzynski. 2001. 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.

Poole, R.W. 1974. *An Introduction to Quantitative Ecology*. McGraw-Hill Book Company, New York.

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.

Sadzinski, R.A., J. H. Uphoff, Jr. and P.G. Piavis. 2002-. Evaluating recovery of American shad in the tidal Susquehanna River. Unpublished. Maryland Department of Natural Resources, Annapolis, Maryland

Sadzinski, R., A. Jarzynski,. 2006. Stock assessment of adult and juvenile anadromous species in the Chesapeake Bay. Pages II-1 to II-48 *in* Chesapeake Bay finfish / habitat investigations, 2006. Maryland Department of Natural Resources, Federal Aid Annual Report F-61-R-1, 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. Pages I.1 - I.96 *in* 2001 Stock assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay. Maryland Department of Natural Resources, Federal Aid Annual Report F-54-R, Annapolis, Maryland.

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.

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.

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

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.

Winslow, S. E. and K. B. Rawls. 1992. North Carolina alosid management program completion report for Project AFC-36, Segments 1-3. North Carolina Department of Environment, Health, and Natural Resources, Division of Marine Fisheries. Morehead City, North Carolina.

Younger, M. S. 1985. *A First Course in Linear Regression, 2nd edition*. Duxbury Press, Boston.

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 2009.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	1	0	0	--	1	0
3	20	0	0	--	20	0
4	244	11	120	0	364	11
5	93	55	91	15	184	70
6	11	9	36	25	47	34
7	0	--	5	5	5	5
8	0	--	1	1	1	1
9	0	--	0	--	0	--
Totals	369	75	253	46	622	121
Percent Repeats	20.3%		18.2%		19.4%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	7	0	0	--	7	0
4	30	4	6	0	36	4
5	21	16	10	6	31	22
6	2	2	2	2	4	4
7	0	--	2	2	2	2
8	0	--	0	--	0	--
9	0	--	0	--	0	--
Totals	60	22	20	10	80	32
Percent Repeats	36.7%		50.0%		40.0%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0	--	0	--	0	--
3	0	--	0	--	0	--
4	4	0	1	0	5	0
5	0	--	7	4	7	4
6	4	4	9	8	13	12
7	0	--	5	5	5	5
8	0	--	2	2	2	2
9	0	--	0	--	0	--
10	0	--	1	1	1	1
Totals	8	4	25	20	33	24
Percent Repeats	50.0%		80.0%		72.7%	

Table 2. Conowingo Dam tailrace hook and line data, 1982-2009.

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

Table 3. Recaptured American shad in 2009 at Conowingo Dam's east and west lifts by tag color and year.

East Lift		
Tag Color	Year Tagged	Number Recaptured
Green	2009	104
Pink	2008	3
West Lift		
Tag Color	Year Tagged	Number Recaptured
Green	2009	44
Pink	2008	0

Table 4. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2009.

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

Table 5. Summary of the spring American shad logbook data, 1999-2009.

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	18	750.0	1,035	1.38
2005	18	567.0	533	0.94
2006	19	227.3	305	1.34
2007	10	285.5	853	2.99
2008	16	568.0	1,269	2.23
2009	10	378	967	2.60

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]	Recreational Bycatch Mortality	Ocean Commercial Landings (in pounds) [3]	Minimum Total Losses (Numbers)	Conowingo Dam tailrace estimate
1997	0	43,790	2,274	4,200	Unknown	24,859 (99,435)	75,123	132,619
1998	0	16,152	1,300	4,200	Unknown	18,526 (74,105)	39,908	147,536
1999	0	43,455	3,136	4,200	Unknown	13,623 (54,491)	64,414	155,593
2000	0	60,452	3,102	4,200	Unknown	4,834 (19,337)	72,588	192,820
2001	0	130,876	2,607	4,200	Unknown	2,347 (9,386)	140,030	209,274
2002	0	40,142	2,837	4,200	Unknown	1,882 (7,529)	49,061	205,147
2003	0	50,224	2,160	4,200	Unknown	621 (2,485)	57,205	140,795
2004	0	29,911	1,218	4,200	Unknown	220 (879)	35,549	116,239
2005	0	42,873	1,412	4,200	Unknown	0	48,485	113,448
2006	0	41,201	1,696	4,200	Unknown	0	95,582	131,326
2007	0	14,120	1,737	4,200	Unknown	0	20,057	139,283
2008	0	7,075	1,477	4,200	Unknown	0	12,752	149,676
2009	0	15,490	173	4,200	Unknown	0	19,863	188,113

[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. Summary of the spring hickory shad log book data from Deer Creek, 1998-2009.

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	18	272.5	1,699	6.23
2006	19	762	4,905	6.43
2007	17	782.5	3,395	4.34
2008	22	995.25	5,469	5.50
2009	15	561.25	2,022	3.60

Table 8. Numbers of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2009.

Alewives

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	5	0	4	0	9	0
4	33	4	50	5	83	9
5	15	9	61	44	76	53
6	5	5	33	33	38	38
7			10	10	10	10
8						
9						
Totals	58	18	158	92	216	110
Percent Repeats	31.03%		58.23%		50.93%	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	9	0	5	0	14	0
4	17	4	20	1	37	5
5	5	5	8	7	13	12
6			1	1	1	1
7			1	1	1	1
8						
9						
Totals	31	9	35	10	66	19
Percent Repeats	29.03%		28.57%		28.79%	

Table 9. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2009.

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	226	228	239	245	251					
2004	215	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					

Table 9, continued

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

Table 10. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2009.

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1989		218	227	234	245	259	262	279		
1990		218	232	239	249	258	263	270		
1991		217	229	237	247	258	260	273		
1992		212	224	235	245	251	260	256		
1993		205	224	237	247	256	262	261		
1994		213	223	238	250	256				
1995		220	226	233	247	256				
1996	205	219	230	240	244	270	261			
1997		212	225	238	241	247	257			
1998		212	225	233	245	253				
1999		200	222	232	239	251				
2000		219	225	235	246	249				
2001		218	231	235	250					
2002		217	229	234	243					
2003	215	230	240	238						
2004	216	231	234	245	250					
2005		222	226	238						
2006		209	224	235	236	270				
2007		207	221	227	266					
2008		206	216	220						
2009		214	219	231						

Females

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1989		227	236	244	257	271	279	297		
1990			241	252	262	271	281	286	291	
1991		228	238	251	260	264	273	285		
1992		230	230	250	260	264	272	281		
1993		220	236	246	259	269	277	290	296	
1994		215	226	245	260	272	282	277		
1995		228	235	248	260	264	270			
1996		218	238	249	257	275	278			
1997		226	242	247	254	268	276	290		
1998			233	246	257	265	281			
1999		219	236	244	253	273				
2000		227	231	243	260	269	275			
2001		219	242	248	260	273				
2002		220	235	246	257	260				
2003	224	235	248	252	264	283				
2004		236	245	254	262	262				
2005		241	236	248	264					
2006		204	235	242	246					
2007		217	221	246	247	266				
2008		213	227	234	252	251	261			
2009		227	232	242	260	278				

Table 11. Regression statistics for alewife and blueback herring in 2009 based on cumulative data.

Alewife		**Male**				**Female**		
Age	**N**	**Slope**	r^2	**P**	**N**	**Slope**	r^2	**P**
3	371	-0.086	0.002	0.429	112	-0.216	0.0122	0.247
4	1334	-0.379	0.0454	<0.001	1208	-0.379	0.0487	<0.001
5	1097	-0.376	0.042	<0.001	1623	-0.363	0.0492	<0.001
6	449	-0.500	0.0739	<0.001	1007	-0.378	0.0519	<0.001
7	70	-0.937	0.178	<0.001	329	-0.456	0.0876	<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	192	-0.236	0.0277	0.021	50	-0.314	0.0627	0.079
4	837	-0.247	0.0212	<0.001	725	-0.264	0.0250	<0.001
5	934	-0.181	0.0085	0.005	898	-0.238	0.0167	<0.001
6	647	-0.509	0.039	<0.001	683	-0.436	0.0284	<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

Table 12. Age structure of hickory shad from the Susquehanna River based on scales, 1998-2009.

Year	Number per Age Group							
	II	III	IV	V	VI	VII	VIII	IX
1998	68	176	104	18	0	1	0	0
1999	45	351	98	4	2	0	0	0
2000	19	106	115	39	3	2	0	0
2001	11	121	72	31	4	0	0	0
2002	20	94	89	25	8	4	0	0
2003	1	22	30	21	4	1	1	0
2004	0	7	19	22	15	15	3	0
2005	0	5	14	23	27	9	1	1
2006	1	16	56	53	36	13	3	0
2007	0	33	47	29	17	3	1	0
2008	0	14	44	50	30	8	3	0
2009	0	9	20	53	23	12	1	0

Figure 1. Location of the 2009 hook and line sampling in Conowingo Dam tailrace.

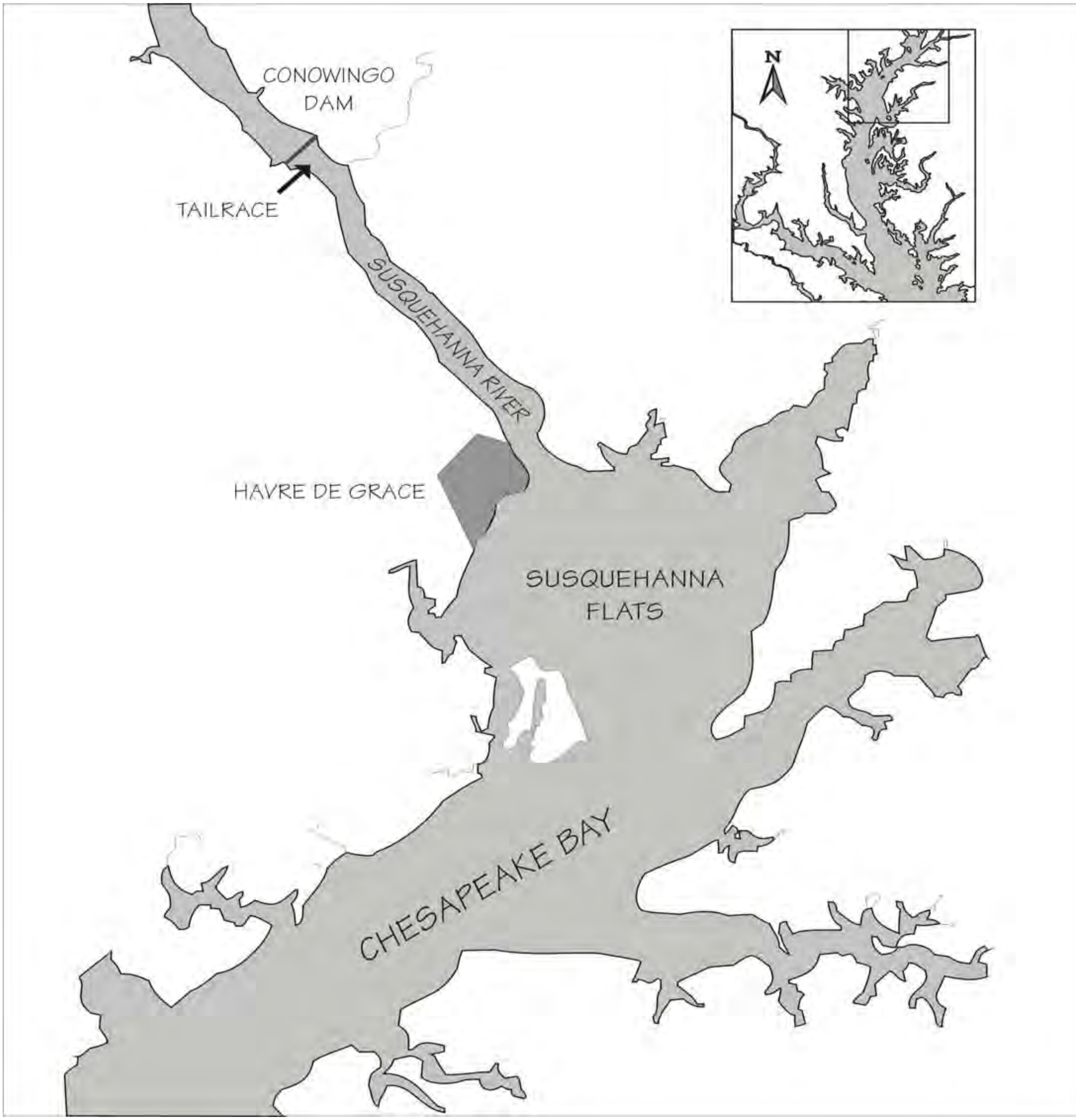


Figure 2. Distribution of the 2009 fyke and pound nets sampled on the Nanticoke River.

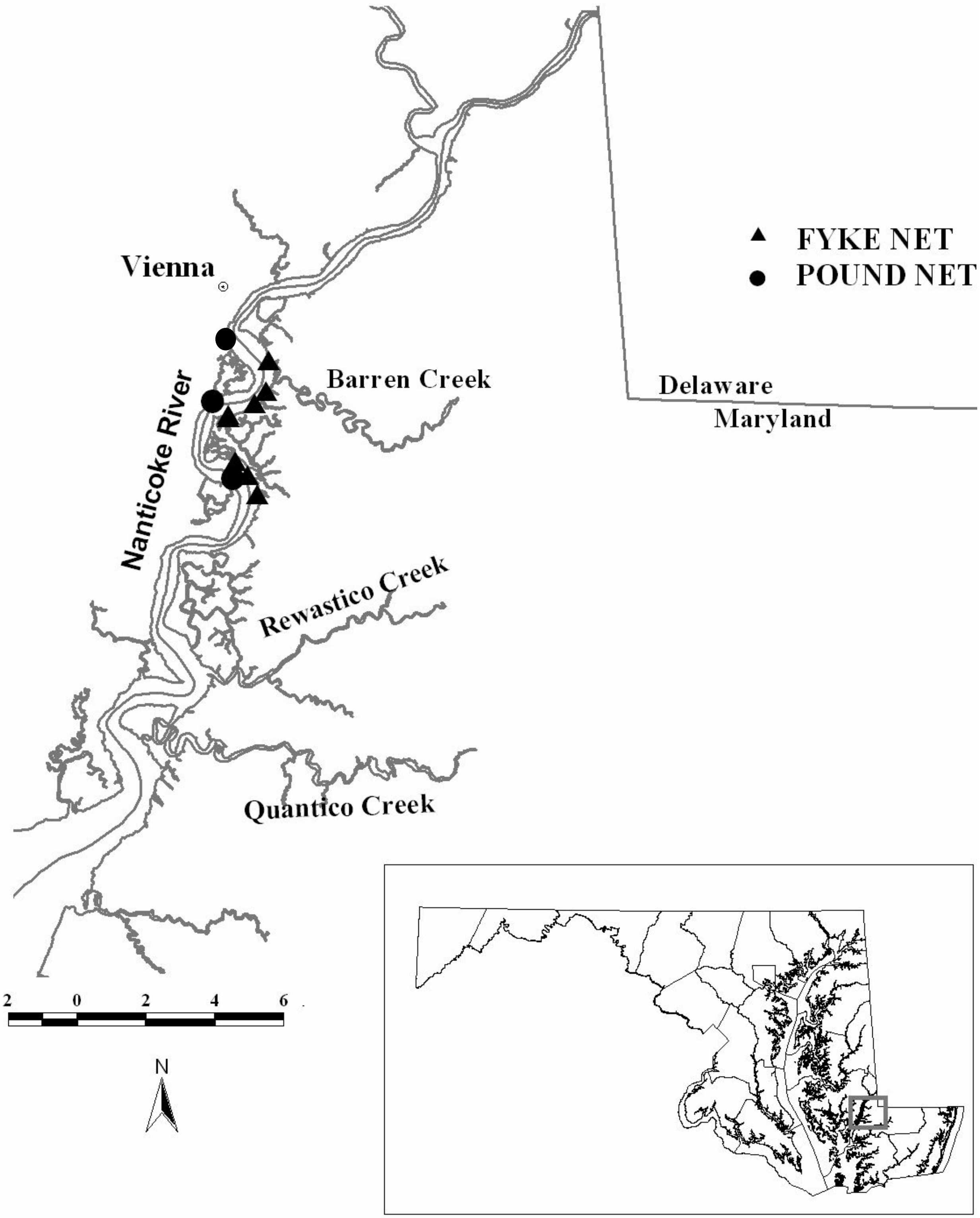


Figure 3. Distribution of the 2009 seine sites on the Chester River (black circles).

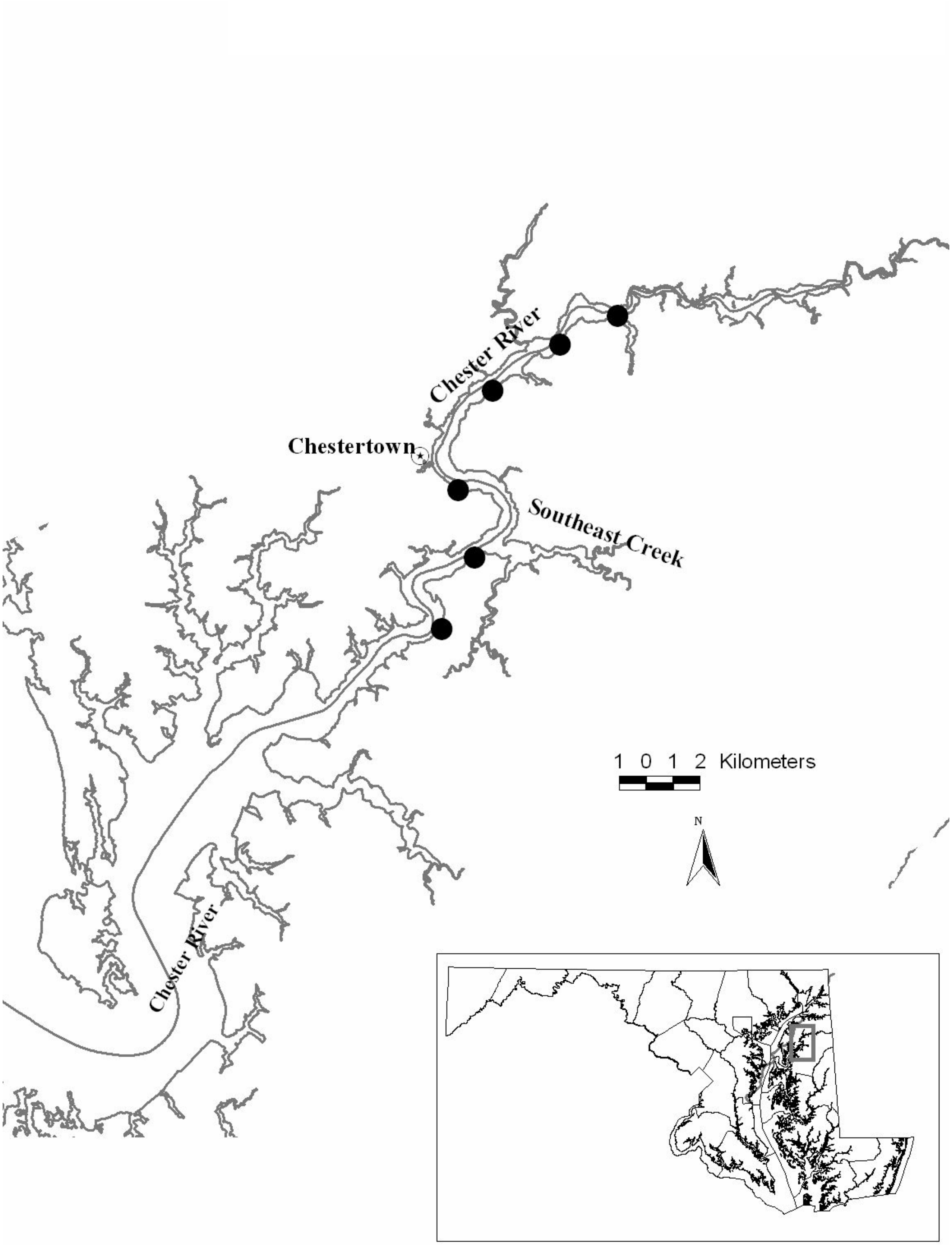


Figure 4. Distribution of the 2009 seine sites on the Pocomoke River (black circles).

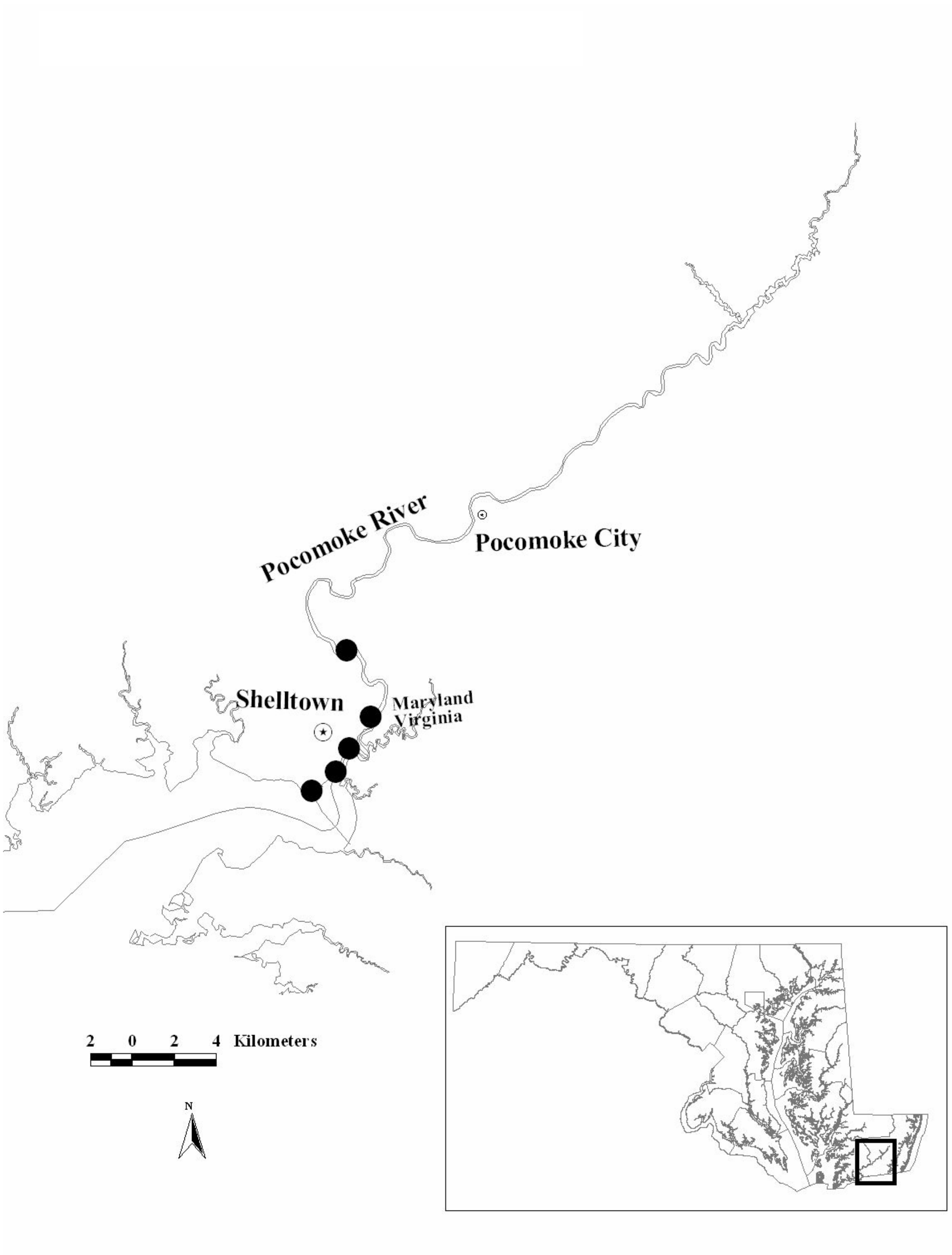


Figure 5. Distribution of the 2009 ichthyoplankton sampling sites on the Nanticoke River.

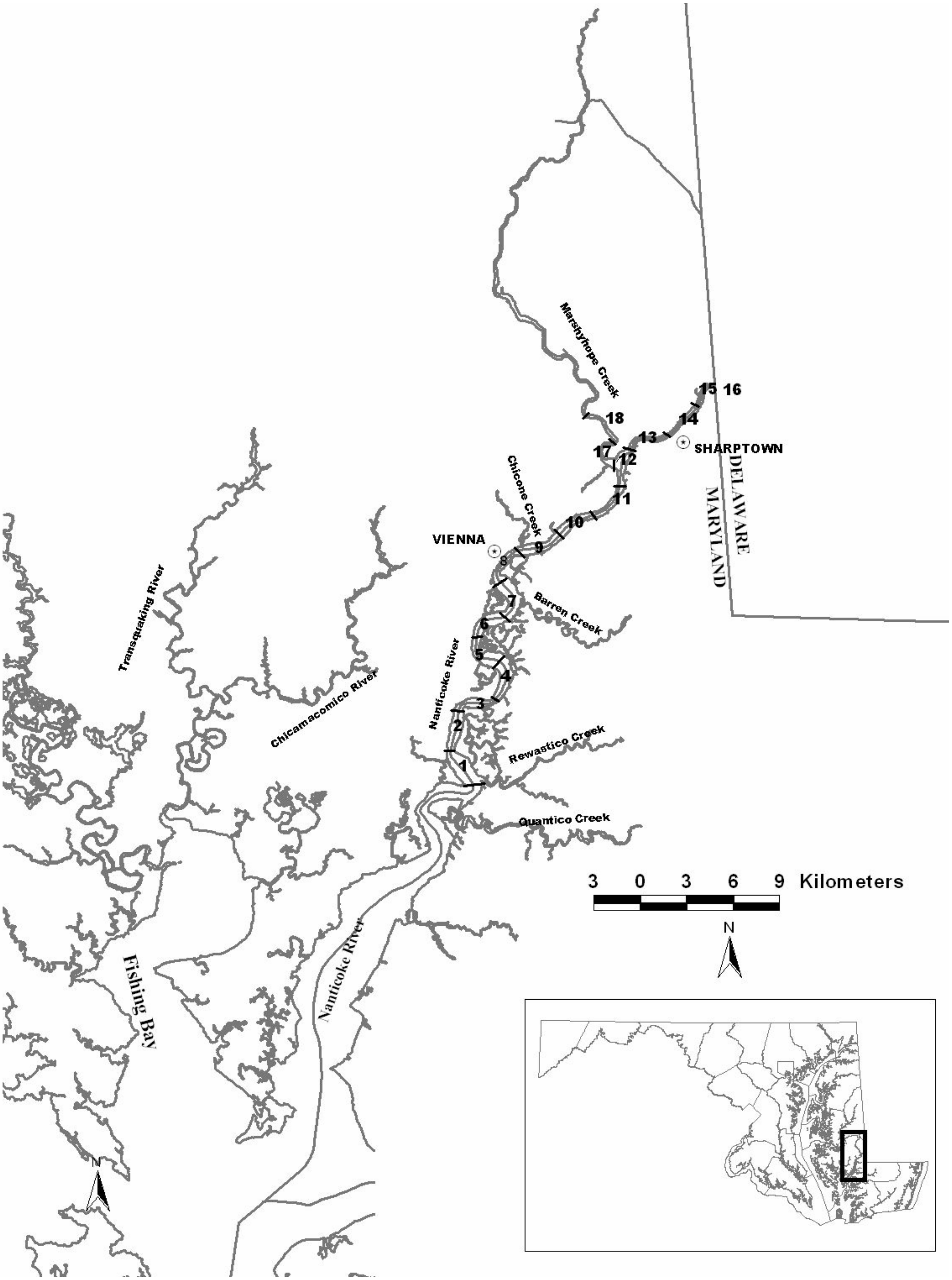


Figure 6. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2009).

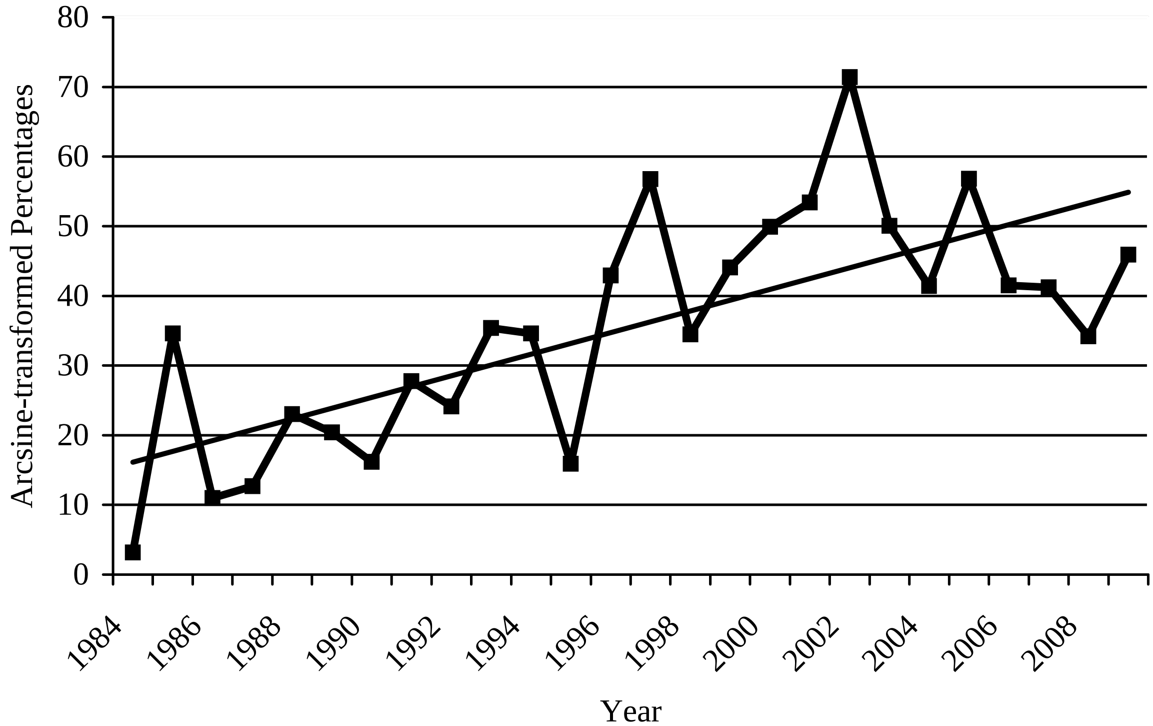


Figure 7. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River (1988-2009).

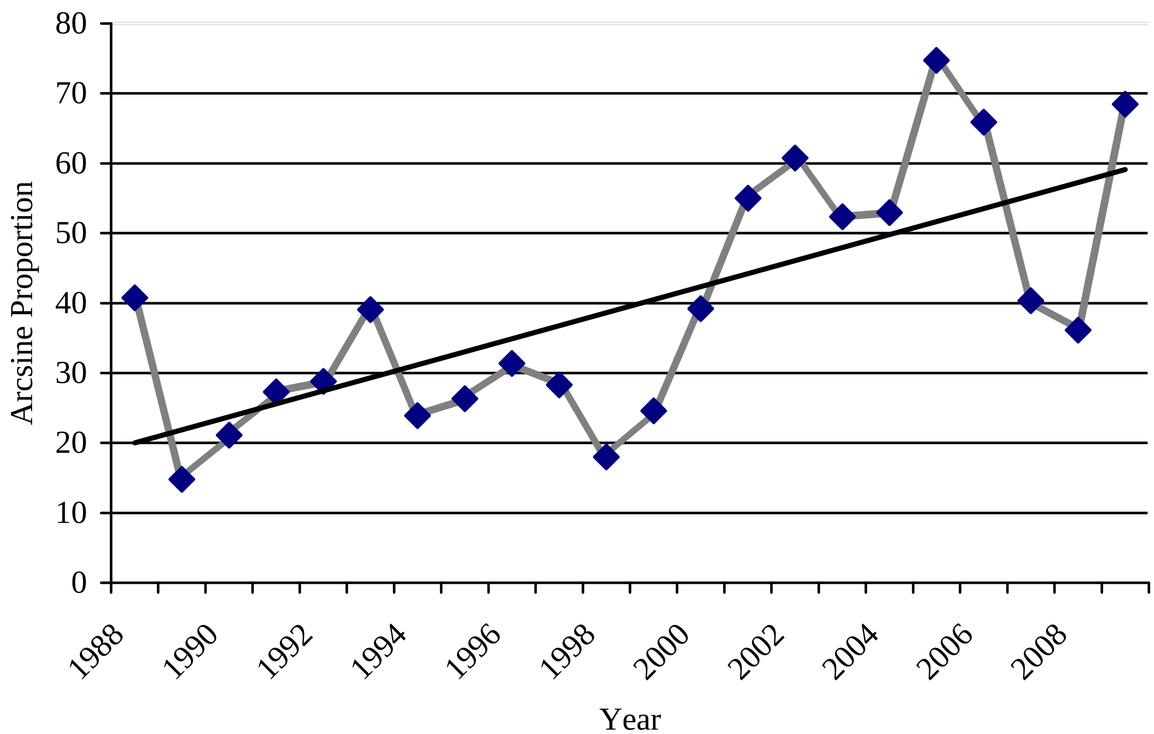


Figure 8. Conowingo Dam tailrace population estimates of American shad, 1986-2009.

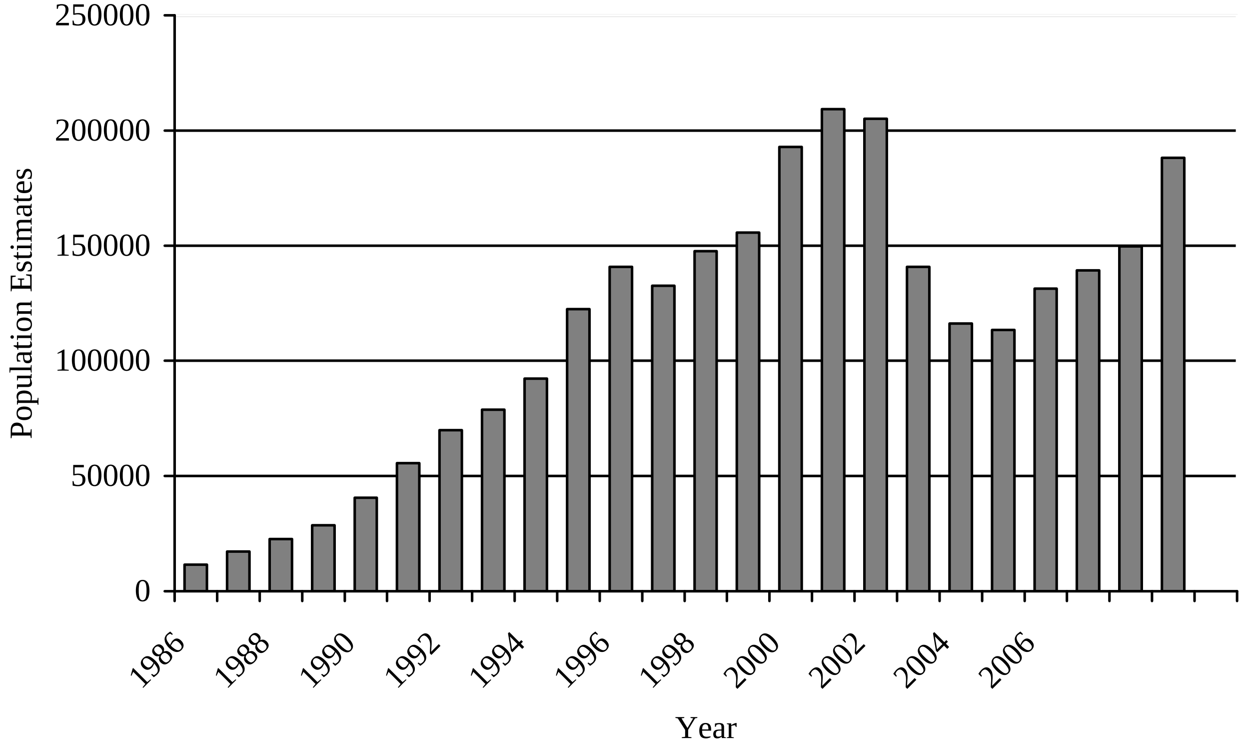


Figure 9. Geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2009.

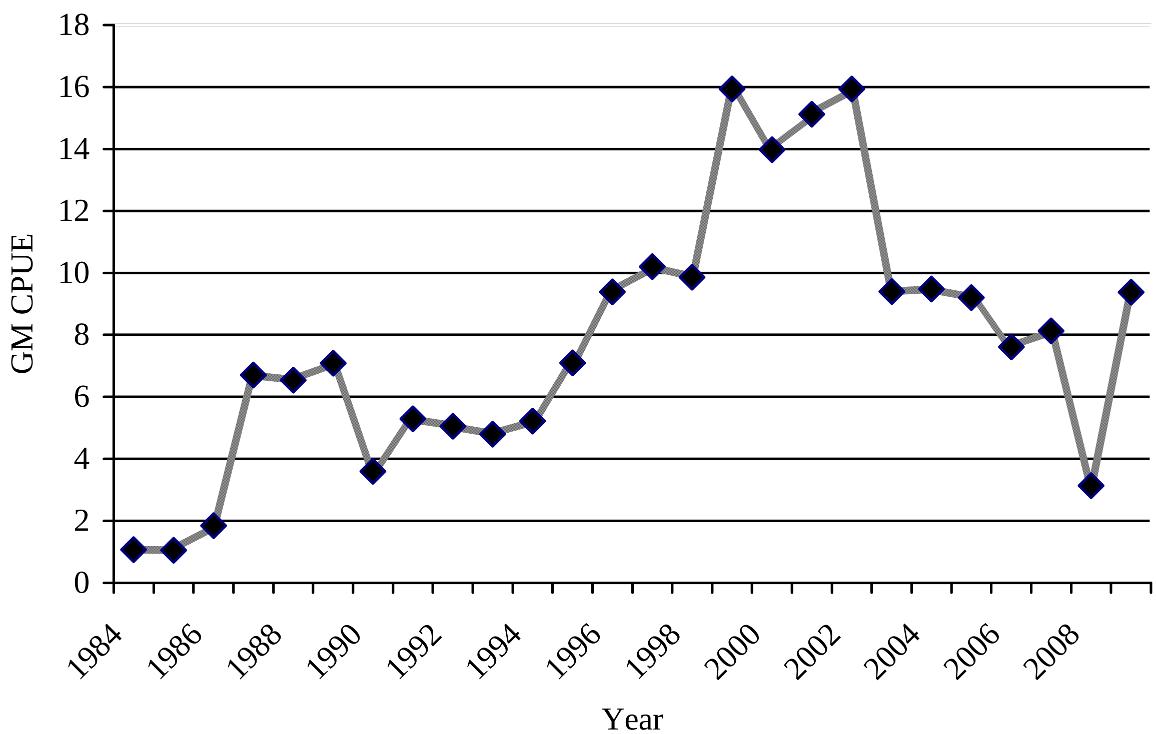


Figure 10. Geometric mean CPUE of American shad from the lifts at Conowingo Dam, 1980-2009.

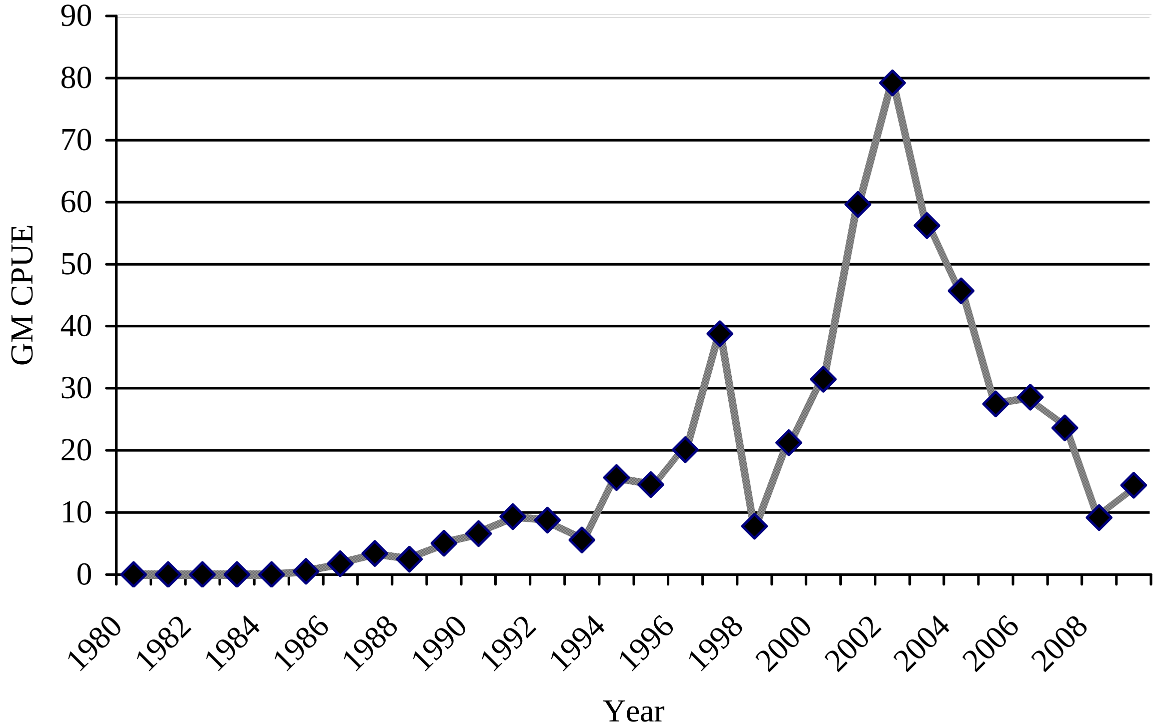
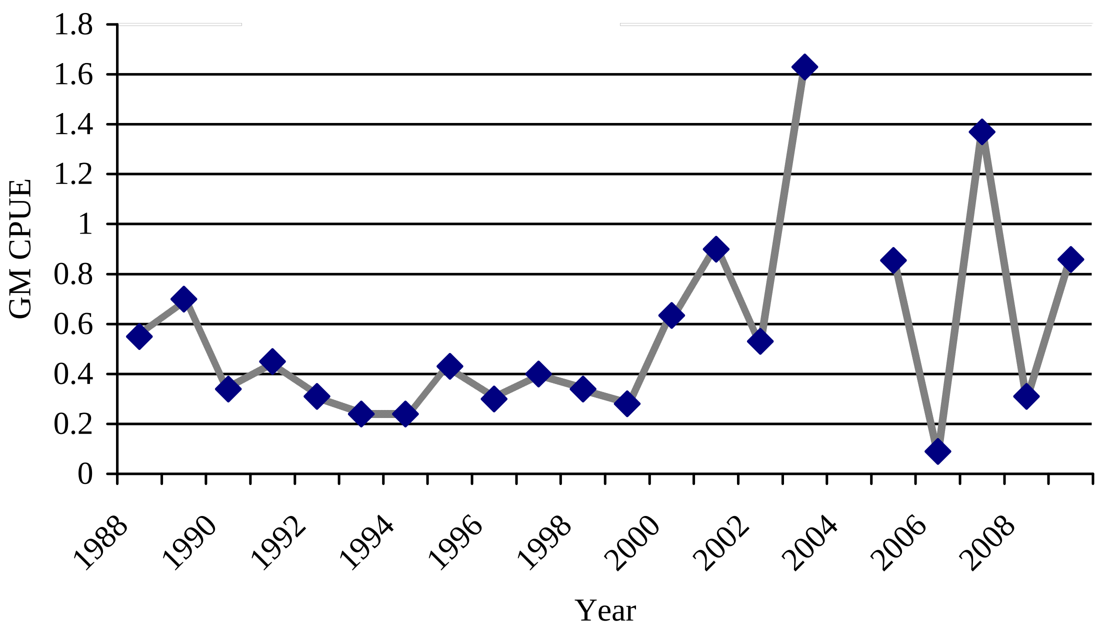


Figure 11. Pound net geometric mean CPUE for American shad from the Nanticoke River, 1988-2009. [4]



[4] No Pound nets were fished in 2004.

Figure 12. American shad geometric mean CPUE from fyke nets on the Nanticoke River, 1989-2009.

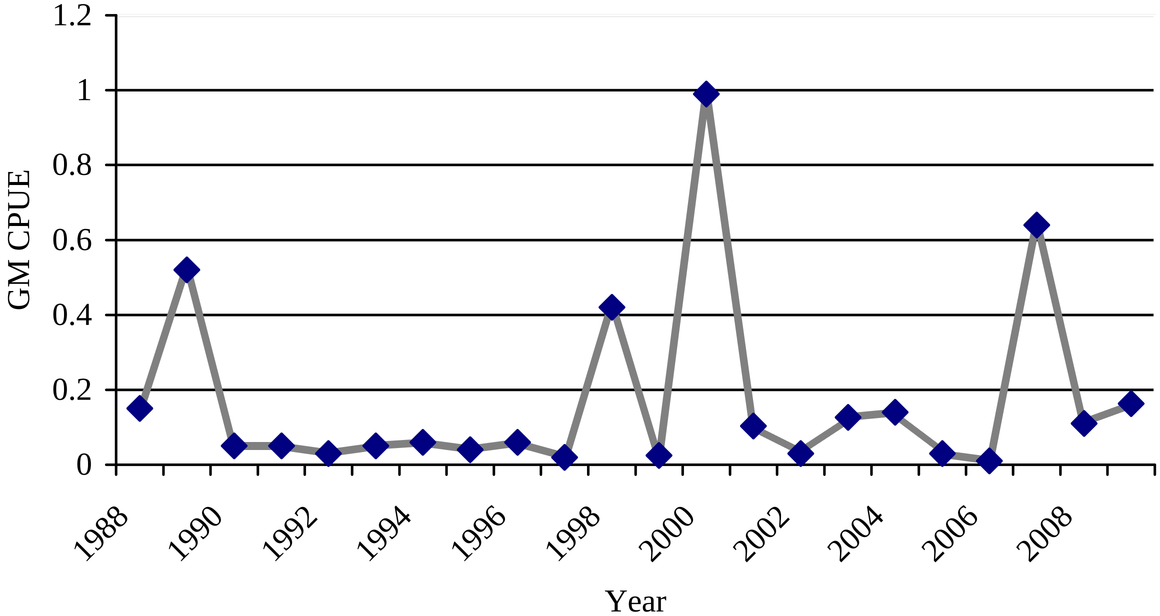
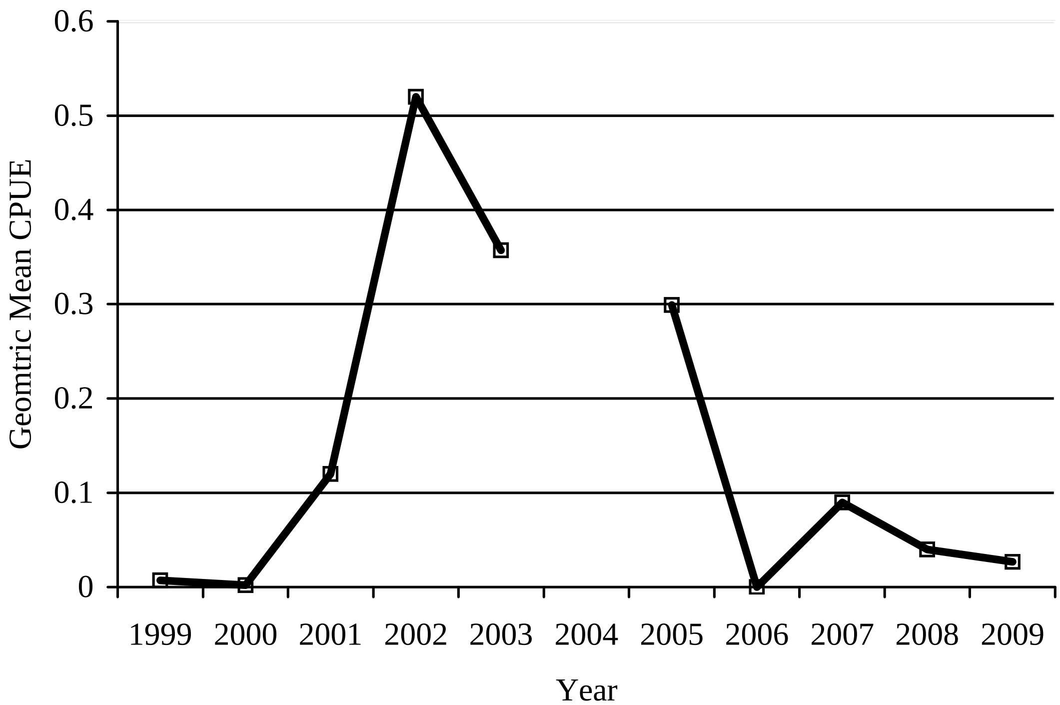


Figure 13. Adult hickory shad geometric mean CPUE from Nanticoke River pound nets, 1999-2009.[5]



[5] No pound nets were set in 2004.

Figure 14. Adult hickory shad CPUE from Nanticoke River fyke nets, 1999-2009.

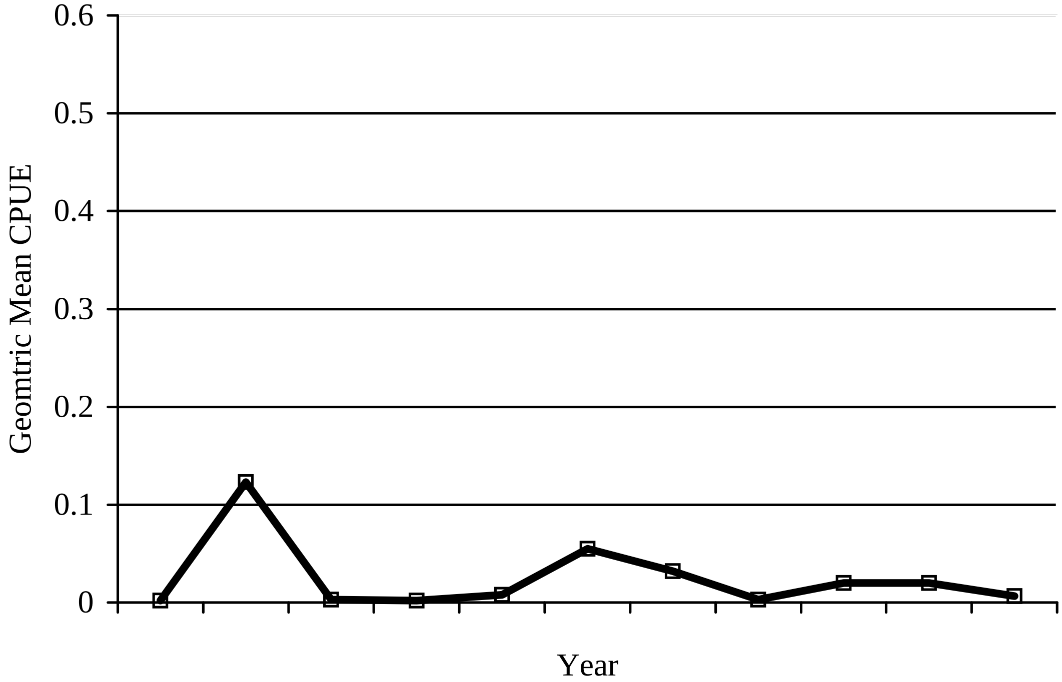


Figure 15. Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1989-2009.

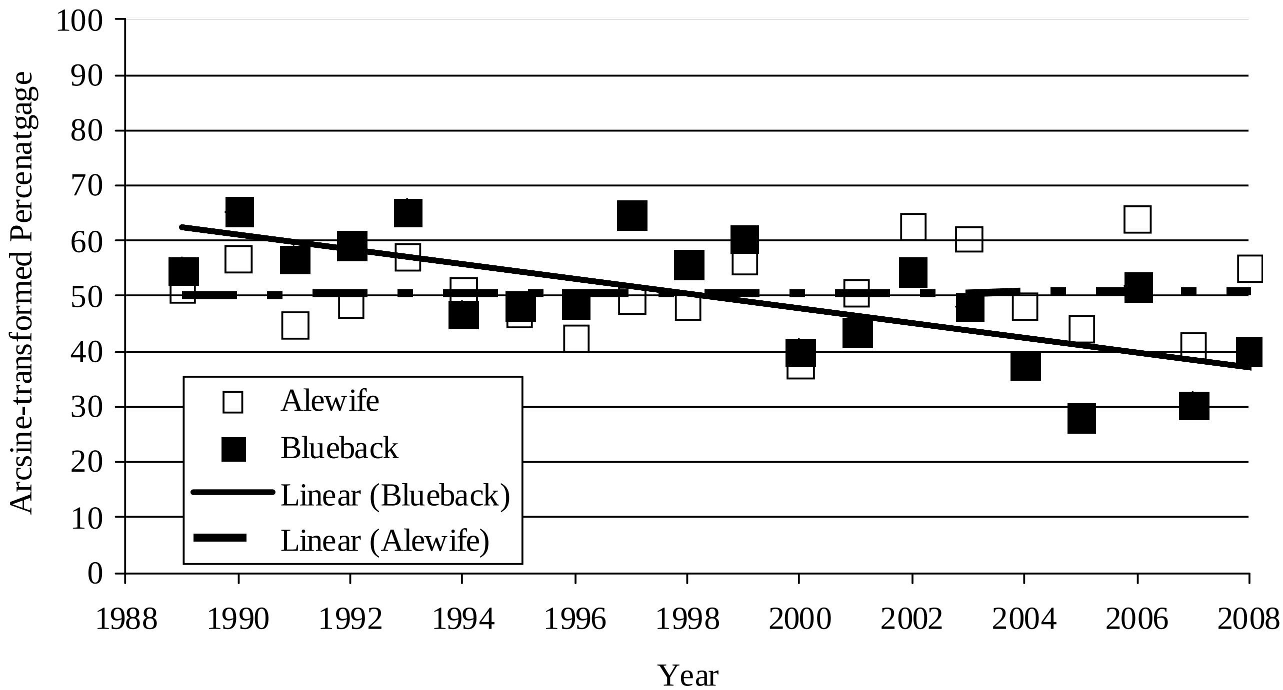


Figure 16. Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1989-2009.

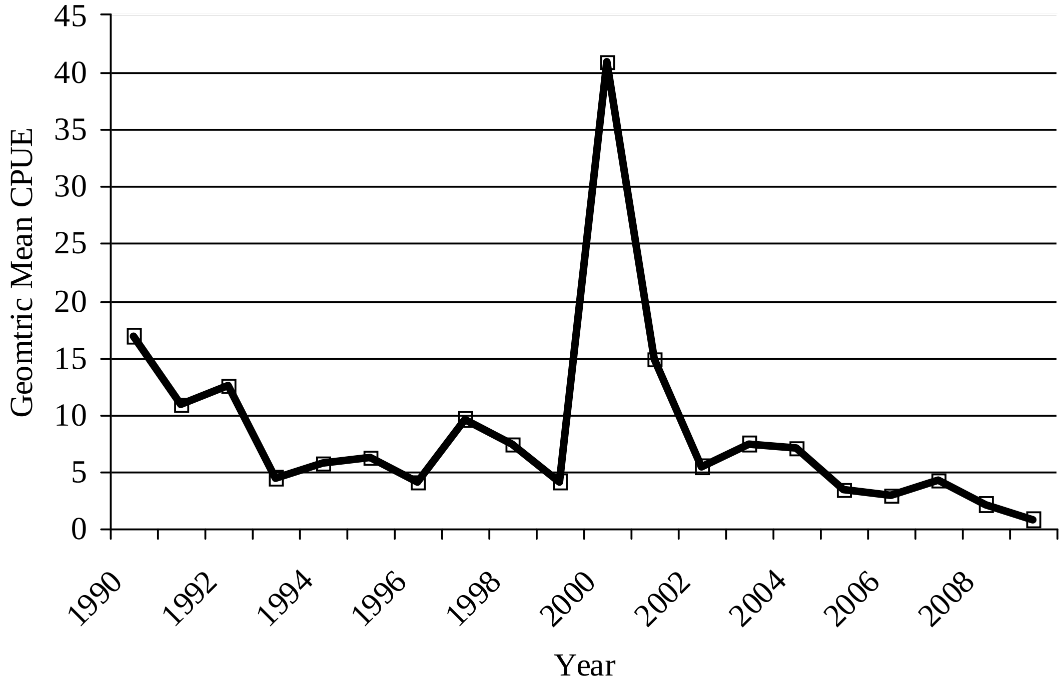


Figure 17. Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2009**.**

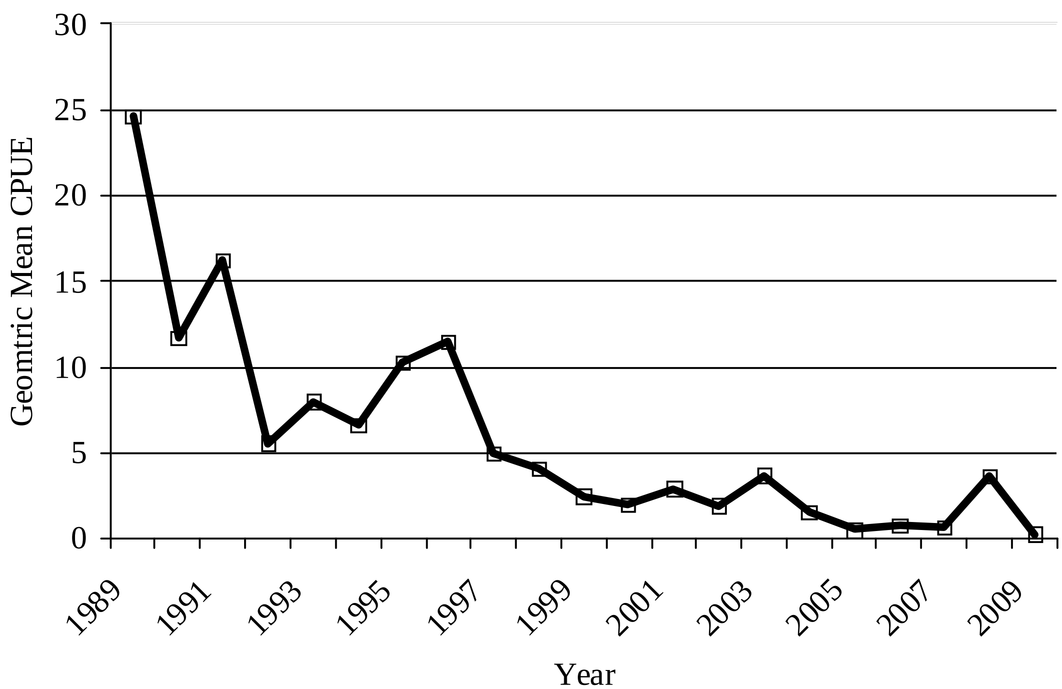


Figure 18. Regression analysis estimates of geometric mean CPUE (alewife and blueback herring combined, 1989-2009), and the total commercial river herring landings in pounds, 1980-2009 from the Nanticoke River.

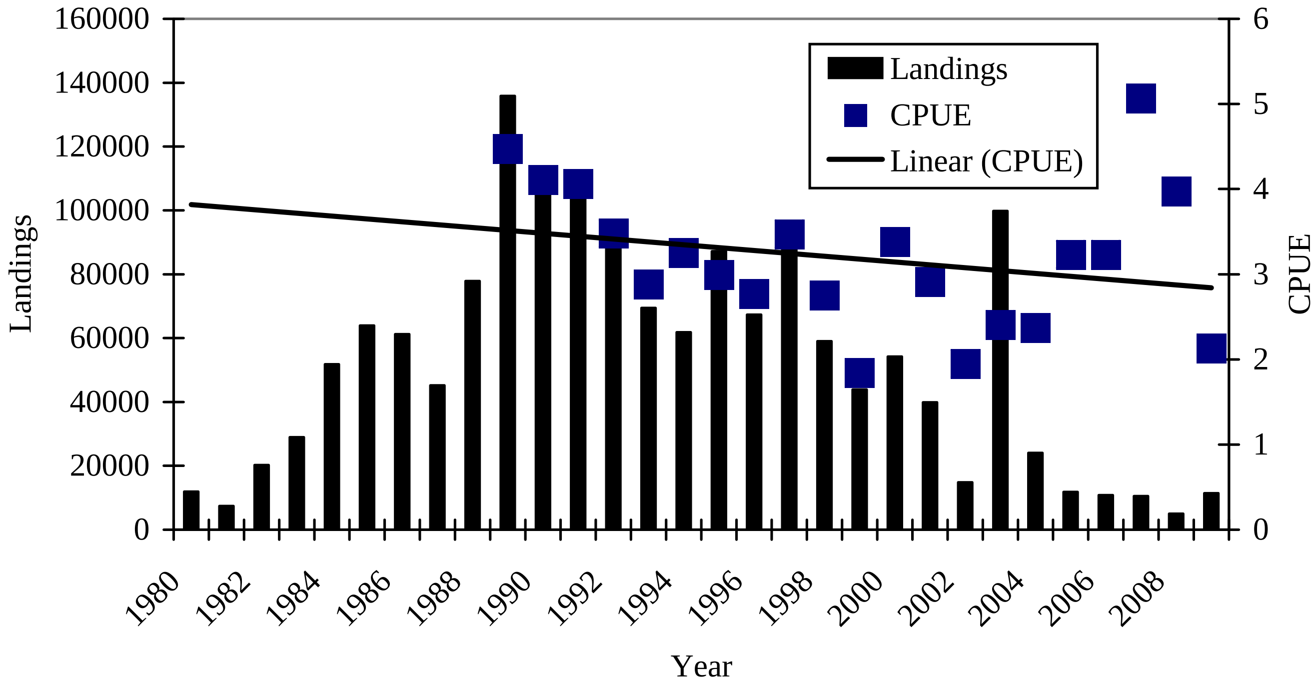


Figure 19. Instantaneous mortality (Z) of Nanticoke River alewife herring (1989-2009).

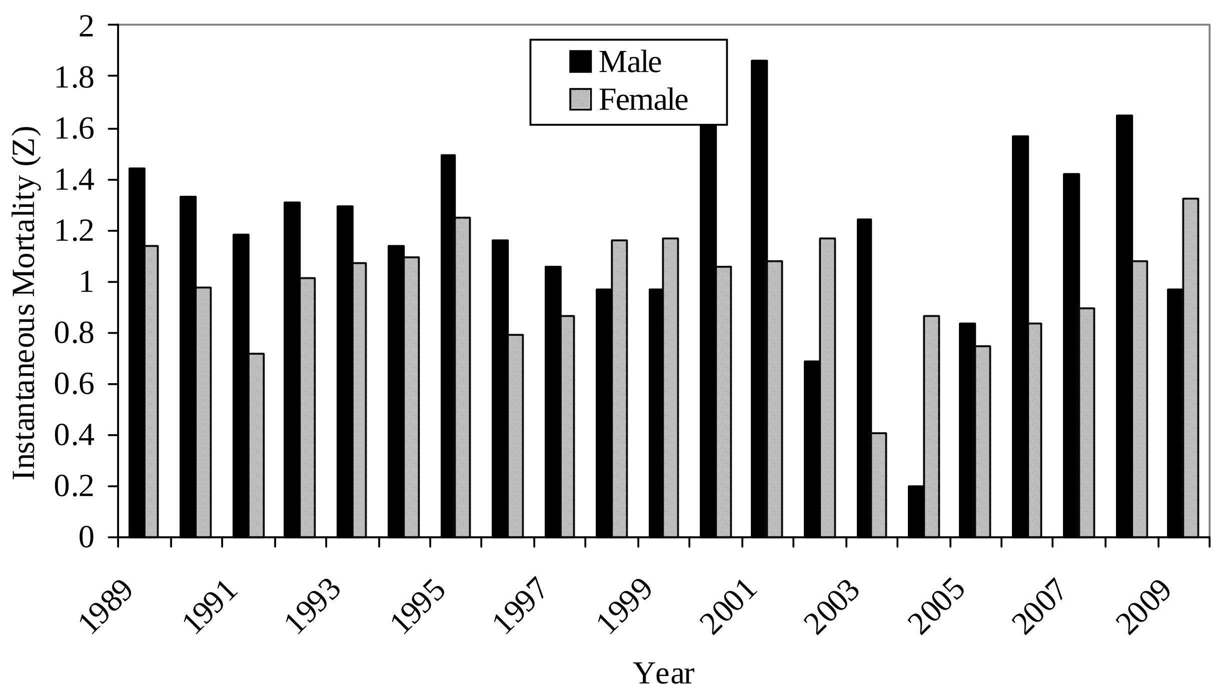


Figure 20. Instantaneous mortality (Z) of Nanticoke River blueback herring (1989-2009).

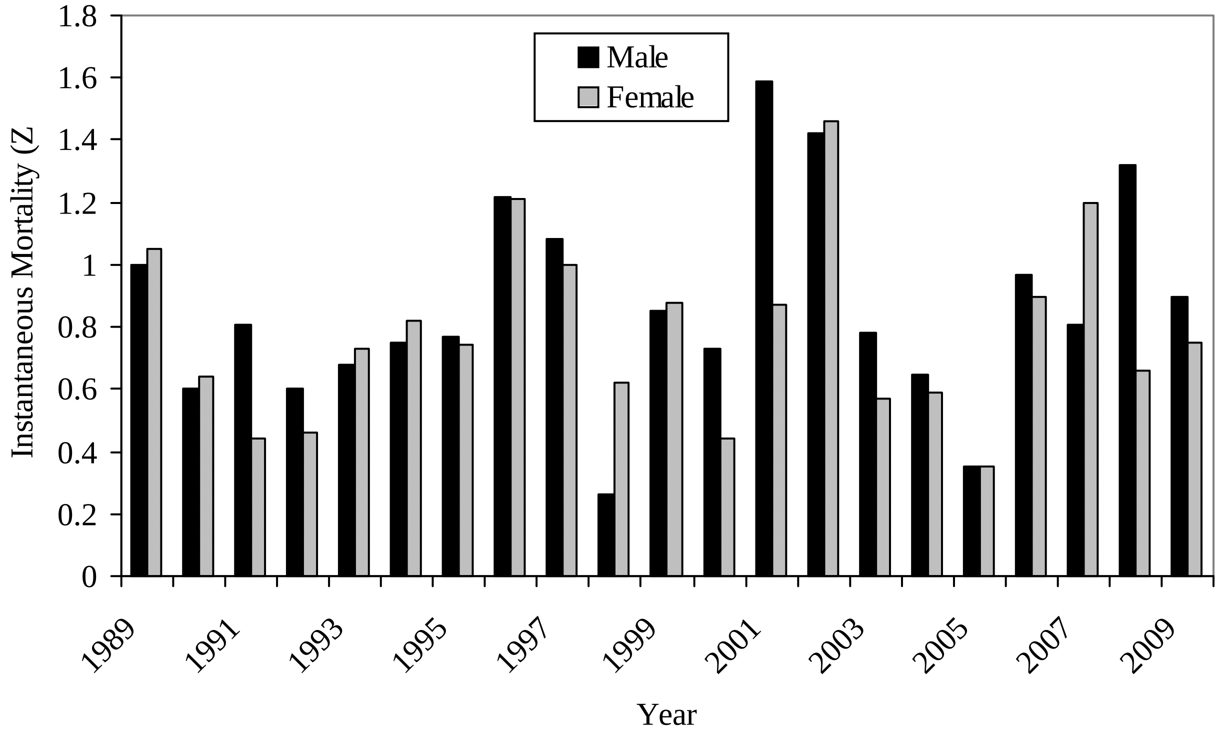


Figure 21. Conowingo Dam adult American shad tailrace Petersen population estimates compared to the SPM results, 1986-2009.

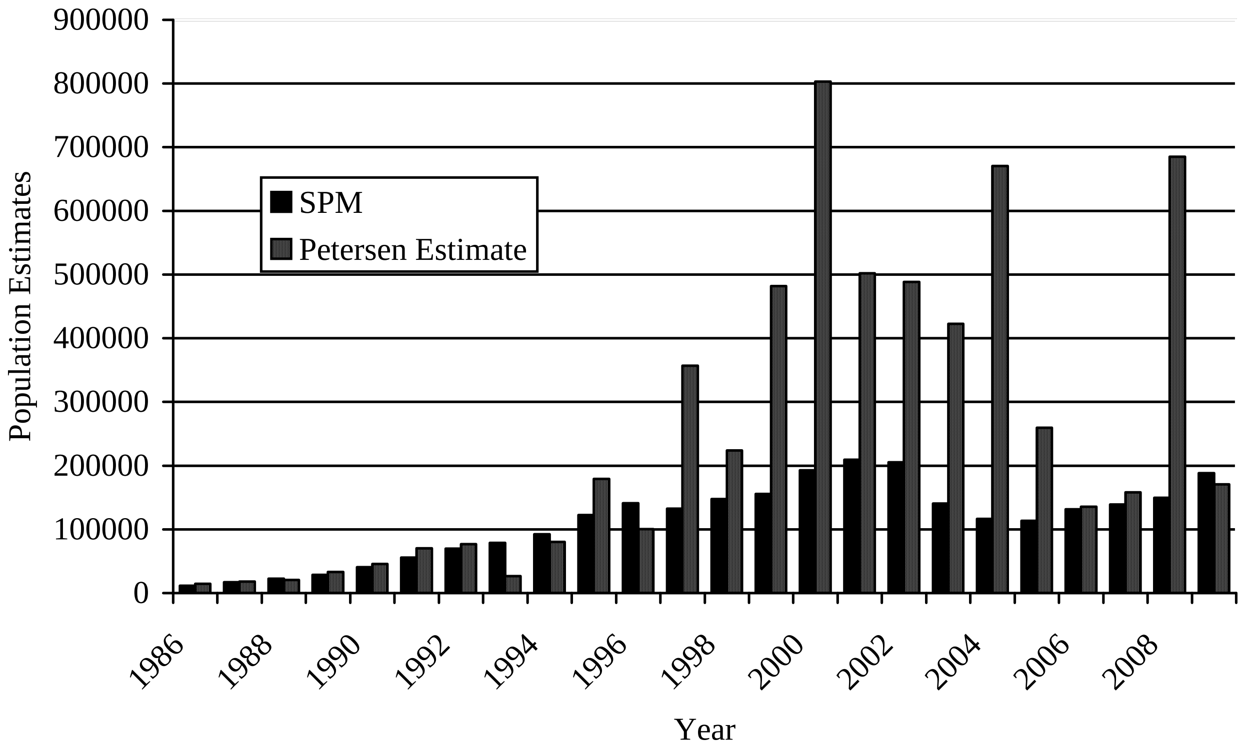


Figure 22. Potomac River adult American shad gill net CPUE from the SBSSS, 1996-2009.

Figure 23. Trends in percentages of repeat spawning American shad (sexes combined) collected from the Potomac River (2002-2009).

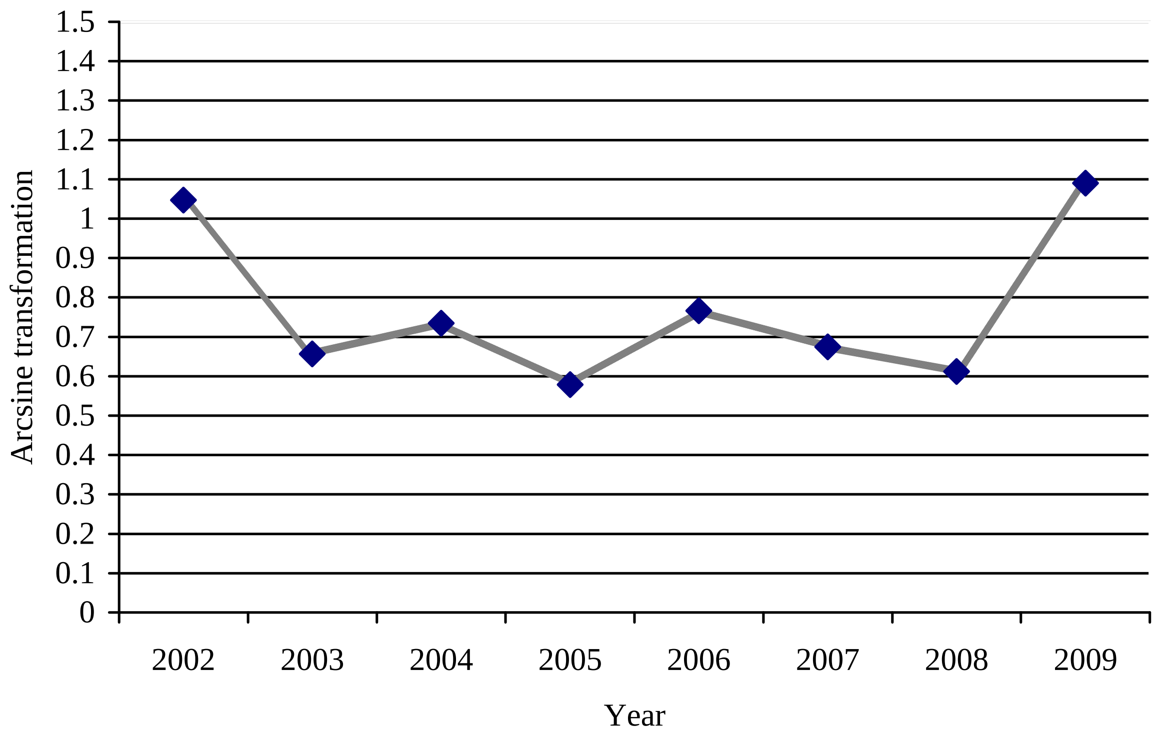


Figure 24. Baywide juvenile American shad geometric mean CPUEs, 1959-2009.

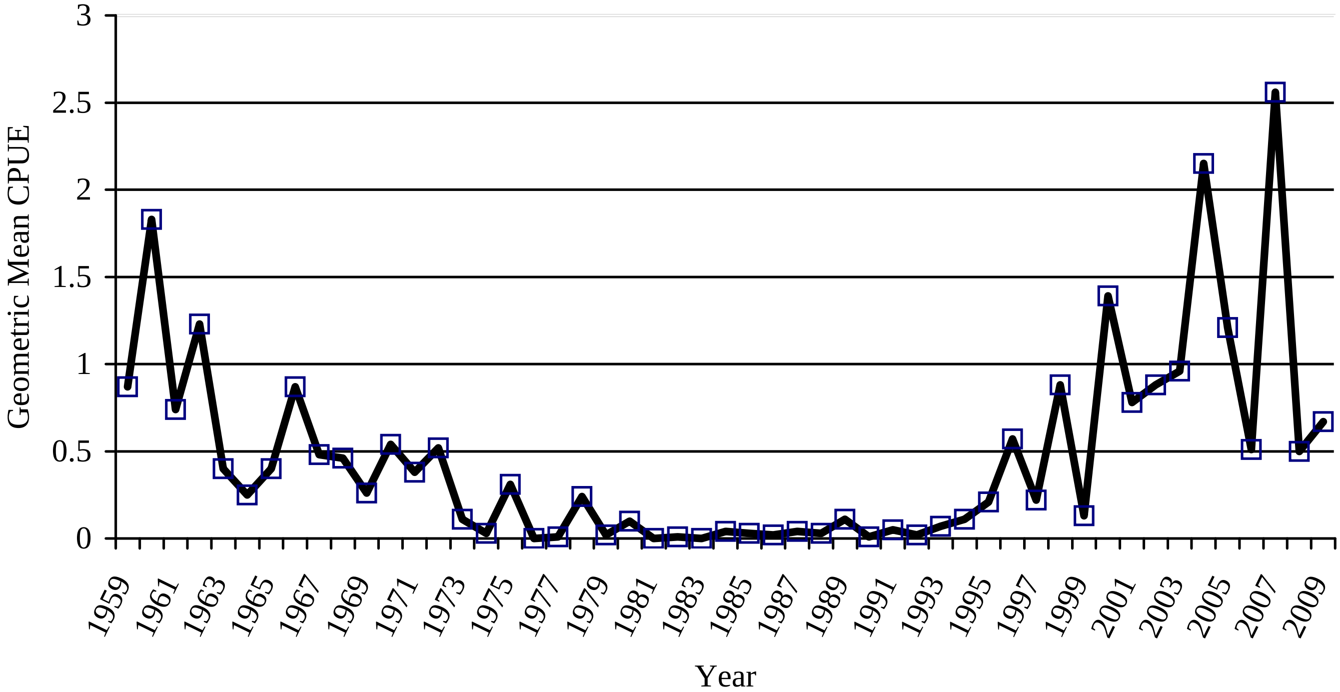


Figure 25. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1959-2009.

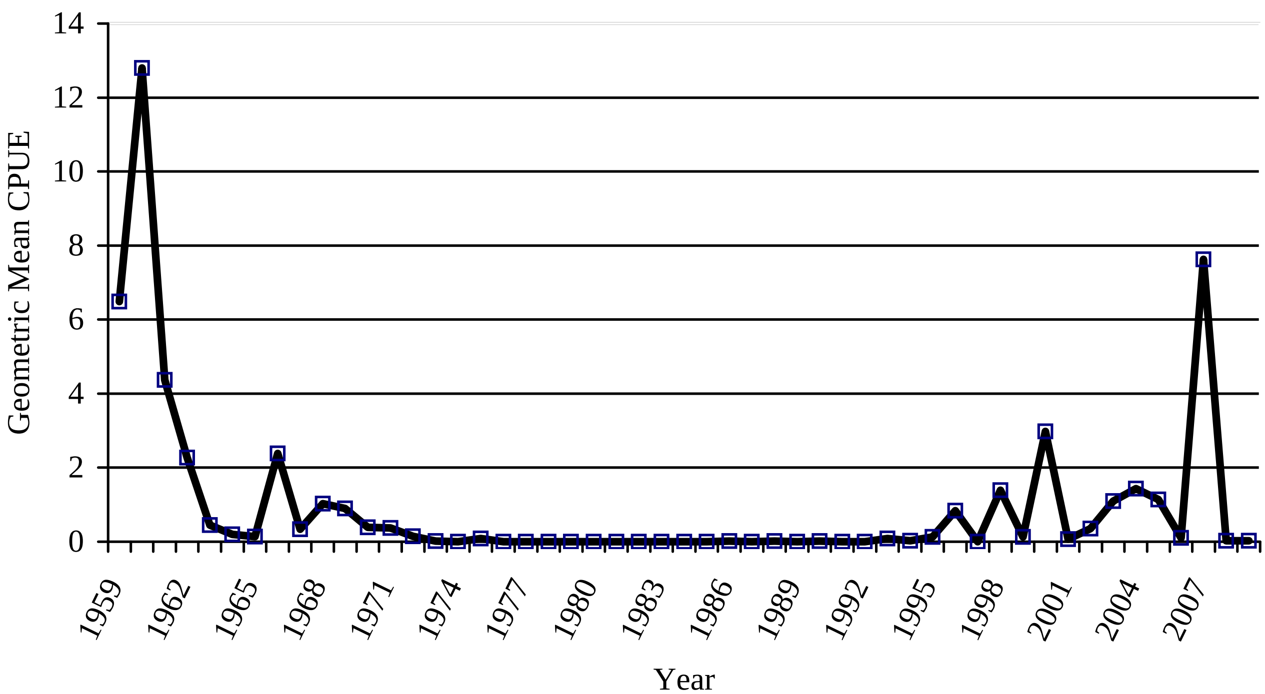


Figure 26. Potomac River geometric mean CPUEs for juvenile American shad, 1959-2009.

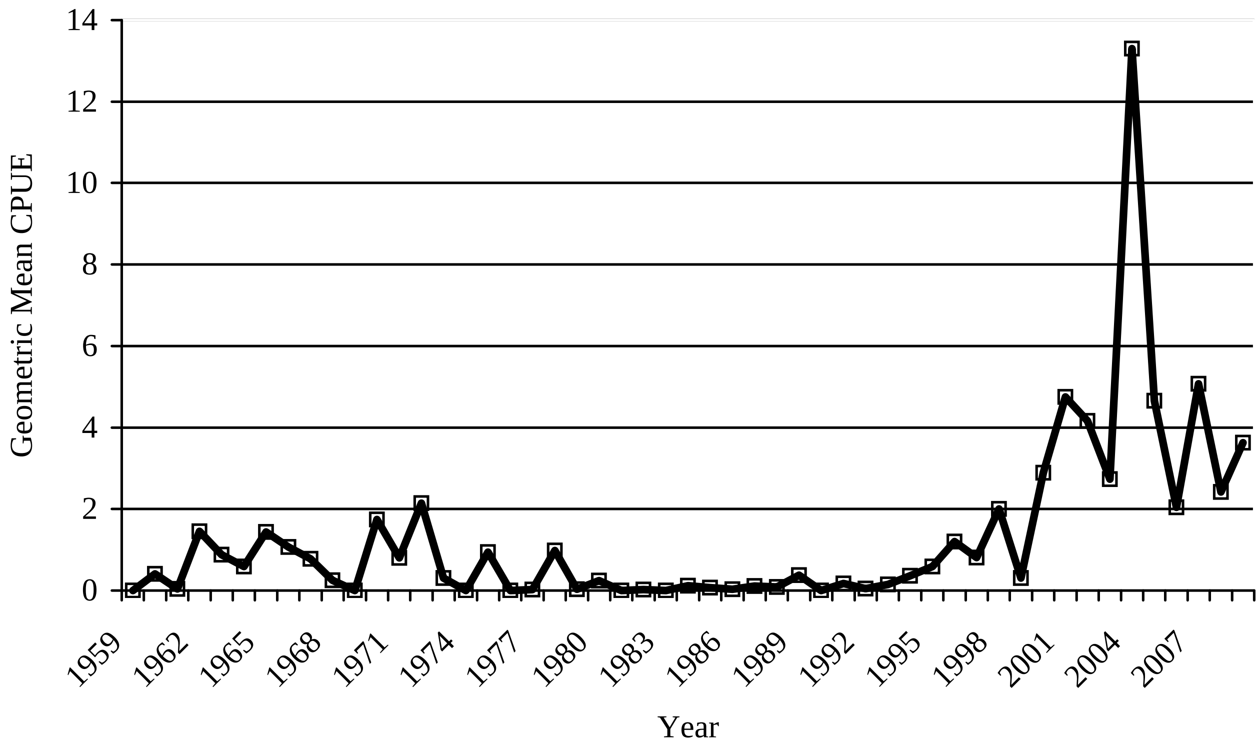


Figure 27. Maryland's commercial river herring landings, 1932-2009.

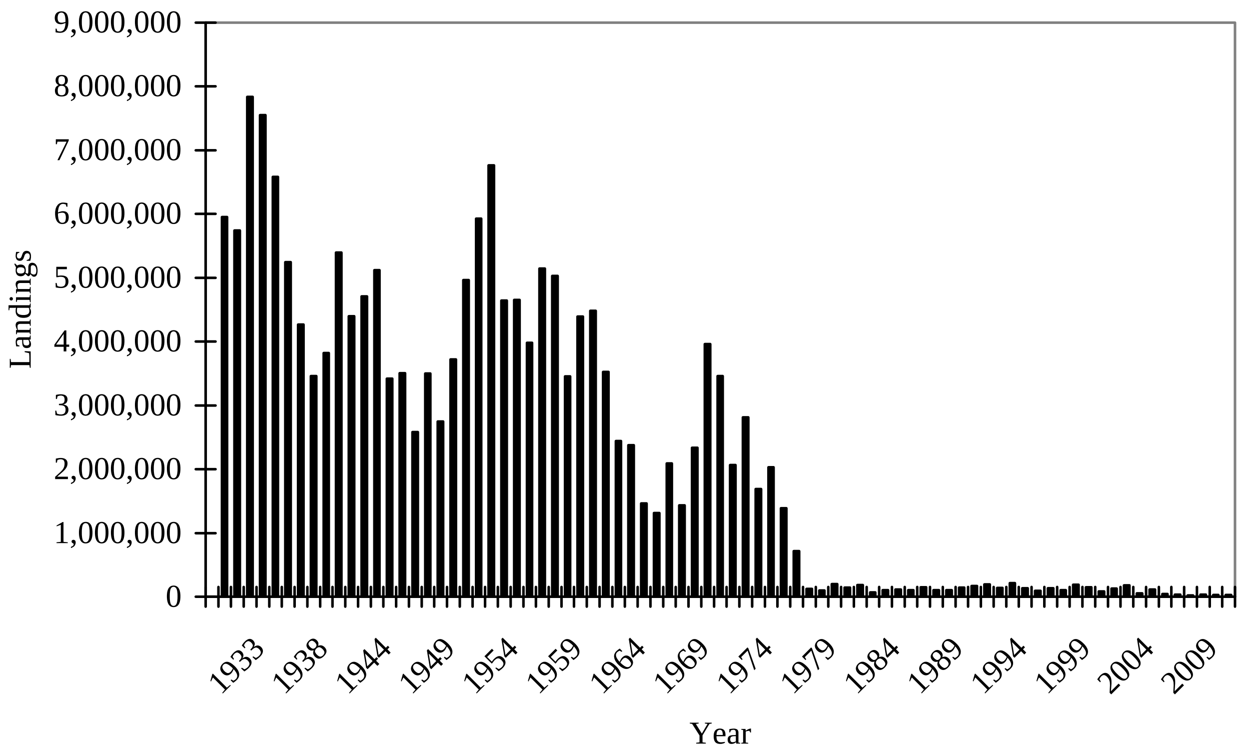


Figure 28. Nanticoke River juvenile alewife herring geometric mean CPUEs, 1959-2009.

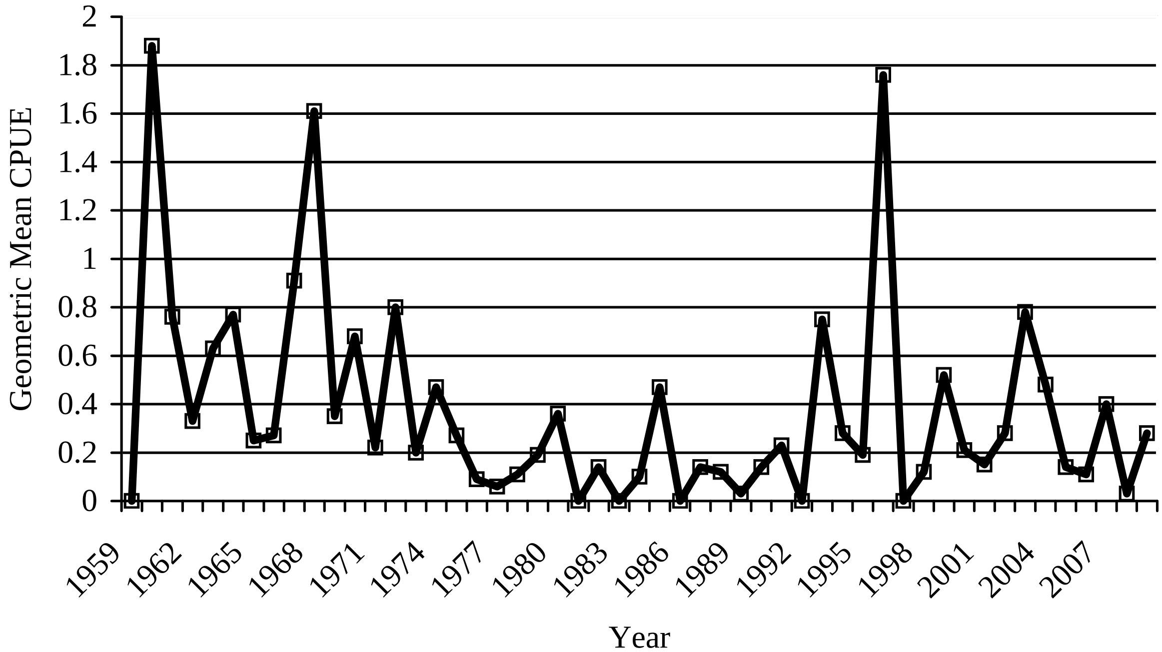


Figure 29. Nanticoke River juvenile blueback herring geometric mean CPUEs, 1959-2009.

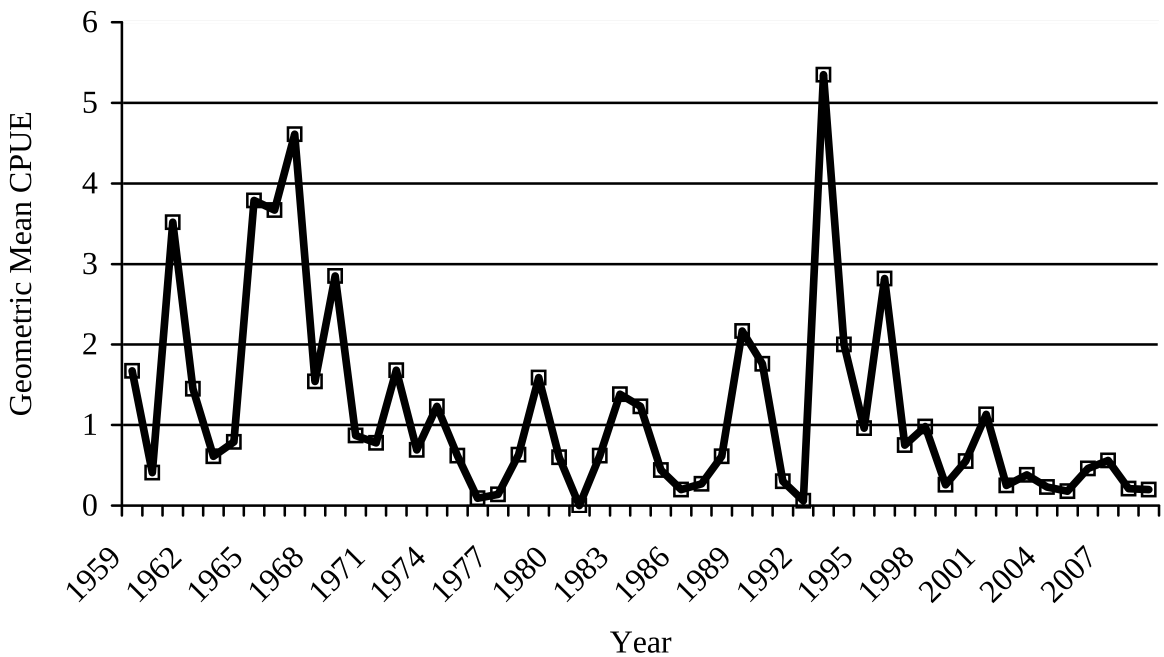
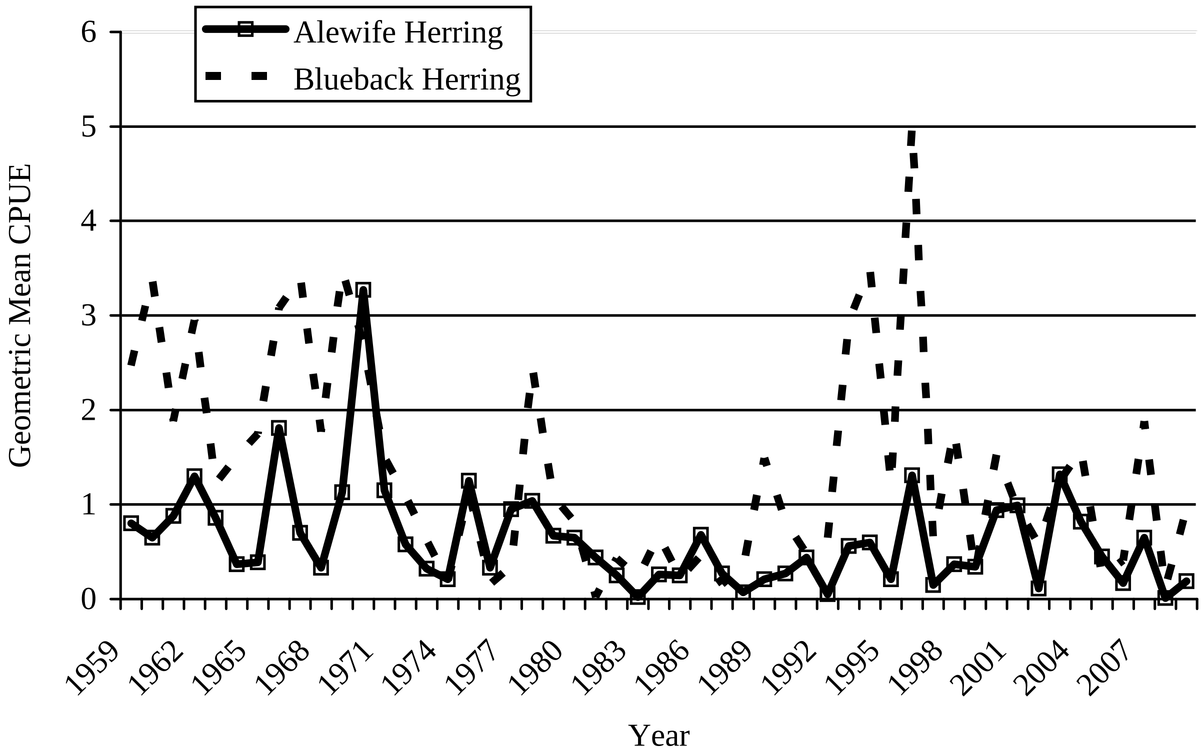


Figure 30. Baywide juvenile alewife and blueback herring geometric mean CPUEs, 1959-2009.



PROJECT NO. 2
JOB NO. 2

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

Prepared by Harry W. Rickabaugh Jr.

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, Dale Timmons personal communication 2005). 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 provides 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

Sampling Procedures

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 (1993-2008). However, since no cooperating fishermen could be located on the lower Potomac River, sampling was not conducted in this area for 2009. Commercial pound nets were sampled at the mouth of the Nanticoke River and Fishing Bay in 2009 (Figure 1). Each site was sampled once every two weeks, weather and fisherman's schedule permitting. The commercial fisherman 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 and Atlantic croaker. The otoliths were processed and aged by the South Carolina Department of Natural Resources (SC DNR).

Otoliths were also collected from a sub sample of spot for later processing and analysis as staff time permits. Non-target species were noted but generally not measured or enumerated. 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 also conducted. Only two seafood dealers, who handle a significant quantity of the target species, agreed to participate. One dealer purchased almost all of its fish from pound netters in the Hooper's Island area. The other was a large centralized dealer excepting fish from a verity of gears and areas. Only one sampling trip was made to the large dealer, due to the inability to determine what region or what gear the fish had come from. It was also difficult to measure some species that were already packaged for shipment and/ or were shipped before samples could be taken. For this reason, only Atlantic croaker were measured during the large dealer trip. The other seafood dealer was sampled 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, red drum and Atlantic menhaden. All measurements were to the nearest mm total length (TL) except for Spanish mackerel and Atlantic menhaden, which were measured to the nearest mm fork length (FL). At least 50 menhaden were measured each day, when available and time allowed, and scale samples were randomly taken from 25 of the measured fish. All fish measured were also weighed. All weights prior to July 1, 2009 were taken to the nearest 10 grams on a Yamato Accu-weigh portable digital wash down scale with a 0.01 kg resolution. All measurements after July 1, 2009 were taken to the nearest gram on an A&D SK-5001WP portable digital wash down scale with a 0.001 kg resolution.

Analytical Procedures

Commercial and recreational harvest for the target species were examined utilizing Maryland's mandatory commercial reporting system, and from the National Marine Fisheries Service's Marine Recreational Fisheries Statistics Survey (MRFSS). Since these data sets will not finalized until the spring of the following year, harvest data for this report are through 2008. 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 arithmetic and 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. Arithmetic and geometric mean CPA were compared using linear regression, and if significantly correlated ($P < 0.01$) the geometric mean catch was utilized. 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 linier regression, with P values of 0.01 or less considered significant. Since the 2009 charter log book data had not been finalized only data through 2008 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: $y = -\log_e (1\text{-}L/L_\infty)$, and $y_c = -\log_e (1\text{-}L_c/L_\infty)$, 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). This trawl data was 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 weakfish, summer flounder, bluefish, Atlantic croaker, Atlantic menhaden 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 distribution for Spanish mackerel was derived for the seafood dealer sampling only, as sample size for the onboard survey was very low for this species.

A length-at-age key was constructed for weakfish and Atlantic croaker using the 2008 age samples, since 2009 samples had not yet been processed by SC DNR. Age sample 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 2008.

A length-at-age key was also constructed for Atlantic menhaden using 2009 age and length data. Age sample and length data were assigned to 20mm FL groups beginning with the 130mm length group.

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).

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 have represented 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 DISCUSION

The Nanticoke River and Fishing Bay were sampled from May 26 through September 1, 2009 (Table 2). Except for red drum, all ten of the target species, and eleven non-target species (Table 3), were encountered during this time period. Seven seafood dealer sampling trips in the Hooper's Island area were conducted between June 2 and September 14, 2009 during which data was collected from nine 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.

Weakfish

Twenty-three weakfish were sampled in the 2009 pound net survey, the lowest catch of the 17 year time series. Weakfish mean length in 2009 was 262 mm TL, a decline from the 2008 mean length of 276 mm TL, and the shortest mean length of the 17 year time series (Table 4). Six weakfish were encountered during the 2009 seafood dealer sampling, with a mean length of 337 mm TL and a mean weight of 376 g (Table 5). Weakfish RSD analysis for 2009 was limited to the RSD_{stock} category fish (Table 6). This was the first year no weakfish were recorded in the RSD_{pref} category and only the second year RSD_{qual} weakfish were not sampled. This may reflect pound net sample size, since three preferred size weakfish were encountered during dealer sampling. The 2009 onboard pound net survey length frequency distribution also indicated a slight shift to smaller sizes for the third consecutive year, with over 91% of sampled weakfish between 230 and 289 mm TL (Figure 2). Since only 6 weakfish were collected from the 2009 dealer sampling, no frequency distribution was produced from this data.

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 between 2001 - 2009, with far fewer large weakfish being encountered. All of the weakfish sampled in the 2009 pound net survey were below the recreational size limit of 331 mm TL (13 inches), and 96 percent were below the commercial size limit of 305 mm TL (12 inches).

In 2009, females accounted for 81% of fish sampled from the pound net survey (n=13). Female mean TL and mean weight were 268 mm TL and 208g, respectively, while males averaged 241 mm TL and 143g. In 2008, females averaged 277 mm TL and 225g and accounted for 76% of fish sampled (n=32), while male mean length and weight were 270 mm TL and 203g, respectively. However, the decreases in mean lengths and weights for both sexes in 2009 compared to 2008 may be artifacts of small sample sizes.

Total commercial weakfish harvest (Chesapeake Bay and Atlantic Ocean combined) in 2008 declined to 5,815 pounds, with the Chesapeake Bay portion decreasing from 6,150 pounds in 2007 to 459 pounds in 2008 (Figure 3). Total 2008 harvest was the lowest of the 79 year time series and well below Maryland's average of 651,646 pounds per year. The 2008 commercial harvest for Chesapeake Bay was the second lowest since 1969. Maryland recreational anglers harvested an estimated 2,590 (PSE = 70.6) weakfish during 2008, with an estimated weight of 2,194 (PSE 84.7) pounds (MRFSS 2009; Figure 4). The number of weakfish harvested by the recreational fishery in 2008 represented a 75% decrease compared to the 2007 estimate (10,316), and was the second lowest of the 1981-2008 time series. According to the MRFSS Maryland anglers released 30,260 (PSE = 53.1) weakfish in 2008, a 72% decrease from 2007 (106,308, PSE = 46.7). Estimated recreational harvest had decreased steadily from 475,348 fish in 2000 to near zero in 2006 before recovering slightly in 2007.

Maryland charter boat captains reported harvesting between 5,271 and 75,154 weakfish between 1993 – 2008 (Figure 5), with a dramatic decline occurring in 2003. The reported charter boat harvest was significantly correlated to both the reported commercial harvest ($R^2 = 0.57$, $P < 0.001$) and the statewide MRFSS estimate ($R^2 = 0.78$, $P < 0.001$), but not the inland for hire only MRFSS estimate. The arithmetic and geometric mean harvest per angler from the charter boat logs were significantly correlated ($R^2 = 0.99$, $P < 0.001$). Of the 27,350 entries reported only one was not included in this analysis since the CPA exceeded 200. The geometric mean CPA has declined significantly from 1993 – 2008 (Figure 6).

The 2008 weakfish juvenile GM of 1.4 increased slightly, after decreasing three straight years, but was still the 5th lowest value in the 21-year time series (Figure 7). Weakfish juvenile abundance generally increased between 1989 - 1996 in Pocomoke and Tangier sounds, remaining at a relatively high level through 2001, but has generally decreased from 2003 to the present. 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 early1990's.

Otoliths from 41 weakfish were aged for 2008, with only ages 1 through 3 present (Table 7). Age composition was 86% age one, 7% age two and 7% age three. The 2008 age structure was similar to that of 2006 and 2007, skewed toward younger fish, but was further truncated with no age four fish present. Twenty-two weakfish were sampled for age in 2009, but ageing of the sample has not been completed at this time.

Mortality estimates for 2007 through 2009 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, while F was moderate and M 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 onboard and seafood dealer sampling surveys, is directly related to a coast wide stock decline.

Summer flounder

Summer flounder pound net survey mean lengths have varied widely from 2004-2009. Mean total lengths have ranged from the time series high of 374 mm TL in 2005 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 2009 seafood dealer survey mean length and weight for summer flounder was 419 mm TL and 794 g, respectively (Table 5). Relative stock densities in the 2009 onboard pound net survey indicated a decrease in the stock category with a corresponding increase in the preferred category compared to 2008 (Table 9). A similar trend in RSDs occurred between 2006 - 2008. The 2009 length frequency distribution indicated a shift to a more bimodal distribution with peaks at 330 and 390 mm TL (Figure 8). In 2007 a shift occurred away from a bimodal distribution, an increase in mean size and a decrease in the RSD_{stock} category suggesting the large 2006 year-class became a dominate component of the 2007 fishery. As these fish age, they would still contribute to the catch, but a return to a bimodal distribution in 2009 indicated younger fish were contributing more heavily to the stock. The proportion of the 2009 catch greater then the 356 mm TL minimum commercial size limit (47%) increased compared to the previous two years (42% in 2008, 31% in 2007). Recreational size limits have been adjusted annually, but comparing the onboard pound net survey catches from 2007 - 2009 to the 2009 recreational size limit of 420mm also indicated a greater proportion of legal fish in the stock during 2009 (24%) compared to 2008 and 2007 (14% and 12% respectively).

The 2009 seafood dealer length frequency distribution was truncated by the 356 mm TL minimum size limit. It peaked at the minimum size group of 350 mm, declined to the 410 mm length group, remained generally stable through the 450 mm length group and then followed a generally asymptotic decline through the remainder of the size range (Figure 9). This distribution would indicate a greater number of 350 – 369 mm TL summer flounder than the pound net survey distribution, but otherwise tracked very closely for the length groups available for harvest under the 2009 commercial size limit.

Maryland's commercial summer flounder harvest totaled 156,720 pounds in 2008, the 7th lowest in the 46-year time series (Figure 10). The long-term commercial harvest average (1962 – 2008) is 428,440 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 89,729 (PSE = 22.0) fish caught in 2008 ranked 21st out of the 28 year time series, a substantial decrease over the 2007 estimate of 157,360 (PSE = 20.6) fish (MRFSS 2009; Figure 11). The 2008 MRFSS recreational release estimate of 1,306,428 (PSE = 11.6) fish was the sixth highest of the 1981- 2008 time series, representing a slight decrease compared to 2007 (Figure 11).

Reported summer flounder charter boat harvest has varied without trend, and has ranged from 1,051 -12,308 fish (Figure 12). The charter boat catch was significantly correlated to the statewide MRFSS estimate ($R^2 = 0.42$, $P < 0.001$), but not the commercial landings or for the 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 arithmetic and geometric indices were significantly correlated ($R^2 = 0.87$, $P < 0.001$). The geometric mean index did decline significantly over the time period (Figure 13), but has been relatively stable for the past five years. The recreational fishery has been subject to increasingly restrictive regulations in the past several years, which most likely reduced catch 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 between 1982 - 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 265 mm TL during 2009, similar to the 2008 mean of 260 mm TL (Table 4). The 2009 mean length was the 3rd lowest for the 17 year time series. The mean length and weight of bluefish sampled in the 2009 seafood dealer survey were 391 mm TL and 640 g, respectively (Table 5). The bluefish RSD_{stock} value has increased the past three years (94 in 2007, 99 in 2008 and 100% in 2009), with a corresponding decrease in RSD_{qual} and $RSD_{memorable}$ and the disappearance of $RSD_{preferred}$ (Table 10). The pound net survey length frequency distribution indicated a dramatic shift to smaller sizes compared to the previous three years (Figure 14). Eighty-six percent of sampled bluefish in 2009 were less than 310 mm TL, while only 33% of the sample was below 310 mm TL in 2007. The seafood dealer survey bluefish length distribution peaked in the 370 mm TL length group (Figure 15) compared to the 230 mm length group for pound net survey fish. Bluefish from the 230 mm TL length group were not encountered in the post harvest dealer survey, indicating a large portion of the smaller bluefish may have been discarded or sold as bait.

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 and 2009 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 declined more than 42% in 2008 to 70,278 pounds, 60% below the 1929-2007 average of 173,841 pounds (Figure 16). The 2008 catch was the 55th highest of the 79-year time series. The total commercial landings have fluctuated without trend between 42,662 and 157,436 pounds from 1993 – 2008 (Figure 16). The majority of Maryland's commercial bluefish harvest from 1972 through 1988 came from the Chesapeake Bay. However, Chesapeake Bay catches declined after 1998 while Atlantic Ocean and coastal bay catches remained stable. Recreational harvests estimates for bluefish were high through most of the 1980's, but have since stabilized at a lower level (MRFSS 2009; Figure 17). The 2008 estimate of 659,968 (PSE = 14.7) fish harvested decreased slightly after increasing the previous two years, and remained below the time series average of 914,781 fish. Estimated recreational releases, however, increased in 2008 to 1,855,033 fish (PSE = 16.4), the highest release estimate of the time series (Figure 17). The decrease in harvested fish, and increase in released fish, supports the pound net findings of increased numbers of small bluefish and decreasing numbers of larger bluefish.

Reported bluefish harvest from charter boat logs ranged from 27,667 – 134,828 fish per year between 1993 – 2008 (Figure 18). The charter boat logs do generally trend with state wide MRFSS estimates, but were not significantly correlated with recreational estimates or commercial landings. The arithmetic and geometric mean CPA's were significantly correlated ($R^2 = 0.96$, $P < 0.001$). Two of the 65,078 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, and then increased to the time series high in 2008 (Figure 19).

The latest NMFS stock assessment of Atlantic coast bluefish utilizing a VPA model indicated that F has decreased since 1991 from a high of F=0.41 to F=0.15 in 2004 (NMFS 2005). Total stock biomass declined from 99,790 mt in 1982 to 29,483 mt in 1997, but increased to 47,235 mt in 2004 (NMFS 2005). The VPA indicated that overfishing is not occurring.

Atlantic croaker

Atlantic croaker mean length from the onboard pound net survey increased to the time series high in 2009 (320 mm TL) but this increase may be directly related to the small sample size (Table 4). Seafood dealer mean length and weight were 300 mm TL and 370 g, respectively (Table 5). Fifty-two percent of sampled pound net croaker in 2009 were in the $RSD_{memorable}$ category, an increase over 2008. RSD_{stock} and $RSD_{quality}$ fish declined in 2009 while the $RSD_{preferred}$ and RSD_{trophy} categories increased, with values similar to 2007 (Table 11). The length frequency distribution for 2009 demonstrated a reduction in smaller length groups, with the primary peak occurring in the 290 and 330 mm size groups (Figure 20). A 229 mm TL commercial size limit in Maryland artificially truncates the seafood dealer survey length frequency distribution. The 270 and 290 mm length groups accounted for 41.1% of the Atlantic croaker seafood dealer samples, with steadily declining abundance through the larger length groups (Figure 21).

In 2009 pound net catches, females averaged 325 mm TL and 509 g (n = 154), while males averaged 308 mm TL and 405 g (n=68). Mean length of males increased slightly in 2009, and mean weights for both sexes increased. In 2009, females accounted for 69% (n = 154) of the pound net catch, similar to that of 2008 (64%).

During 2008, the Maryland Atlantic croaker total commercial harvest (Chesapeake Bay and Atlantic Ocean combined) increased 24% over 2007 to 592,211 pounds (Figure 22). However, the 2008 harvest was still well below the 1929-2008 average of 1,061,503 pounds. Chesapeake Bay commercial harvest increased 65% in 2008. The 2008 recreational harvest was estimated at 689,184 fish (PSE = 17.8), a 37% decrease from 2007 and more comparable to estimates form 2004 to 2006 (MRFSS 2009; Figure 23). The 2008 estimate was also below the time series average of 742,222 fish. The 2008 recreational releases increased 27%, compared to 2007 (MRFSS 2009; Figure 23), and was above the 1981-2008 average of 1,287,933 fish.

Reported Atlantic croaker harvest from charter boats ranged from 127,664 – 448,789 fish during the 16 year time period (Figure 24). The charter boat log book harvest was weakly correlated (R^2 = 0.38, P = 0.0109) with the MRFSS for hire inland only estimates, but not with the Chesapeake Bay commercial landings or statewide MRFSS estimates. The MRFSS did, however, follow the same general trend. The arithmetic and geometric mean catch per angler were significantly correlated (R^2 = 0.79, P < 0.01). Three of the 47,357 entries were not used because of CPA values exceeding 200 fish. The geometric mean catch per angler has varied without trend (Figure 25), and the 2008 value of 4.98 was the highest of the 16 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 to the fourth lowest value in 2009 (Figure 26). 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 2008 Atlantic croaker otoliths ranged from 0 to 11 (n=289), with at least two fish present in each age class (Table 12). The number of Atlantic croaker sampled from pound nets in 2008 (n=1,532) was applied to an age-length key for 2008. This application indicated that 28% of the fish were age two, 19% were age four, 18% were age six, 14% were age three, 7% were age one and 6% were age zero. The remaining age groups each accounted for five percent or less of the fish sampled (Table 13). Two hundred twenty-two Atlantic croaker otoliths were collected in 2009, but ageing had not been completed at this time. Instantaneous total mortality in 2009 was Z = 0.59, an increase from 2008, and the third year of increasing values since the 1999-2009 time series low of 0.33 in 2006 (Table 8).

In 2004, the ASMFC Atlantic Croaker Technical Committee completed a stock assessment using an age structured production model (ASMFC 2005). The assessment indicated rising F values from F=0.17 in 1973 to the time series high of F=0.50 in 1979. A period of declining F values then followed, with the time series minimum of F=0.03 occurring in 1992. F rose gradually until 1997 were it remained stable, averaging F=0.10 from 1997 – 2002. SSB estimates from 1992 through 2002 were the highest of the 30-year time series. Since F was estimated to be below target and threshold values and SSB above target and threshold values, the conclusion drawn was that the north Atlantic component of the stock is not overfished. A coast wide stock assessment is in progress and is scheduled for review in March of 2010.

Spot

Spot mean length from the onboard sampling decreased in 2009 to 185 mm TL, the third lowest of the16 year time series (Table 4). Spot from seafood dealer sampling had a mean length and weight of 211 mm and 141 g, respectively (Table 5). The length frequency distribution in 2009 was further truncated, with fish between 150 and 199 mm TL accounting for 67% of the catch (Figure 27). Both mean length and length frequency distribution from the onboard sampling in 2009 may have been affected by the small sample size (n = 33). No jumbo spot were present in the 2009 onboard sampling. Jumbo spot in the survey have been declining for the past several years, with less than 1% of the pound net sample comprising spot >254 mm TL 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 length frequency distribution from the seafood dealer survey indicated the majority of commercially harvested spot were 190 mm or greater (Figure 28), with a more normal distribution. 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 bellow marketable size.

Commercial harvest in 2008 decreased 68% to 120,994 pounds, near the long-term average (1929 – 2008) of 142,720 pounds (Figure 29). 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 can be attributed to a large increase in gill net harvest, which accounted for 95% of the 2007 spot harvest (380,648 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). This would seem to indicate the 2007 spike in gill net landings was a one year event, likely triggered by market demand, availability 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 2009; Figure 30). 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 30). The 2008 recreational harvest estimate (2,296,888 fish; PSE = 12.5) decreased from the time series high in 2007, but was still above the mean estimate of 1,716,025 fish, and marked the 7th highest value of the 28 year time series. The release estimate of 2,040,388 fish (PSE = 12.7) was also relatively high, and above the long term mean of 1,107,822 fish (Figure 30).

Reported spot harvest from charter boats between 1993 - 2008 ranged from 265,473 – 848,492 fish per year (Figure 31). The charter boat log book harvest was not significantly correlated 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. The arithmetic and geometric mean CPA were significantly correlated ($R^2 = 0.83$, $P < 0.01$). Twenty-two of the 40,357 charter log book entries were not utilized because of greatly inflated CPA values (>300). The geometric mean CPA was highest in 1995, stable at a relatively low level from 1999 – 2002, generally increased from 2002 – 2007 and declined slightly to 9.0 in 2008 (Figure 32).

Spot juvenile trawl indices between 1989-2009 were quite variable, with generally higher values in the earlier part of the time series and low values from 2001-2004 Figure 33). Index values have been generally higher from 2004 to 2008, but the 2009 GM of 1.2 spot per tow was the second lowest value of the 21 year 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 four years. 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 sampling, with none being examined in 2009. The 2009 seafood dealer sampling encountered 5 red drum, which averaged 577 mm TL and 2137 g (Table 5). All sampled fish were within the legal slot limit (18 inches – 25 inches TL), and would have been legal if caught in the recreational fishery (18 inches – 27 inches TL). 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 2008 totaled 40 pounds, compared to 90 pounds in 2007 (Figure 34). Average harvest between 2004 – 2008 was 37 pounds per year. Lower harvest since 2003, however, 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 (2009) estimated that recreational fishermen did not harvest any red drum, but did estimate 258 (PSE = 67.8) releases in 2008 (Figure 35). Recreational harvest estimates have been extremely variable ranging from zero for 16 of the 28 years of the 1981 - 2008 time series, to 12,804 fish in 2006. Peak number of red drum releases occurred in 2002 at 18,412 fish (Figure 35).

Maryland charter boat captains reported harvesting red drum in every year from 1993 - 2008, except for 1996. Catches were low for all years, ranging from zero to 99 fish, with a mean of 19.3 red drum per year (Figure 36). 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 13 being sampled in 2009 (Table 4). Lengths throughout the time series have ranged from 244 to 1266 mm TL, and averaged 1147 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 37). Recreational harvest and release estimates between 1981-2008 have been variable, ranging from zero to over 13,000 fish in 1984 (MRFSS 2009; Figure 38). In 2008, 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 1993-2008 time series, with catches ranging from 104 – 905 fish per year (Figure 39). The charter harvest was not correlated to either the state wide, or the inland for hire only MRFSS estimates. The geometric and arithmetic means were not significantly correlated, likely related to the high variability in some years. Since the 95% confidence intervals were large for the arithmetic mean (Figure 40), the geometric mean was utilized for this analysis. The geometric mean has declined significantly through time (Figure 41) but it is unclear weather this trend is indicative of a decline in the abundance, or a decrease in the number of trips targeting black drum, since targeted species is not specified in the logs.

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. Mean length for 2009 was 418 mm FL, a decline from the previous three years, although sample size was very small (n = 7; Table 4). The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 (Table 4). Mean length and weight from the seafood dealer sampling in 2009 was 413 mm FL and 681g (Table 5; n=176). The length frequency distribution from the seafood dealer sampling approximated a normal distribution, with 64% of the mackerel between 370 and 429 mm FL (Figure 42). The bell shaped distribution would indicate that the entire size range of Spanish mackerel in Chesapeake Bay is available to the pound net fishery. This is not unexpected, since onboard sampling has rarely encountered a sub-legal Spanish mackerel.

The 2008 commercial harvest of Spanish mackerel in Maryland was 6,834 pounds, over 2.5 times greater then in 2007 (2,648 pounds; Figure 43). 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. The average harvest for the 44 year time series was 6,322 pounds. 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 2009; Figure 44). This followed a period of seven out of ten annual estimates with zero fish captured. Harvest estimates for 1998 – 2008 were variable, ranging from 0 – 20,792 fish with an average of 7,811 fish taken. In 2008, 5,777 (PSE = 78.3) Spanish mackerel were harvested, a decrease from the 2007 estimate of 12,360 fish (PSE = 52.4) (Figure 44). However, because of the high PSE values, the estimates are considered tenuous.

Spanish mackerel harvest from charter boats between 1993 and 2008 ranged from 563 – 10,653 fish per year (Figure 45). The charter boat log book harvest was significantly correlated with the MRFSS for hire inland only estimates ($R^2 = 0.65$, $P < 0.01$) and the statewide MRFSS estimates ($R^2 = 0.58$, $P < 0.01$), but not the Chesapeake Bay commercial landings. The arithmetic and geometric mean CPA were significantly correlated (R^2 = 0.92, $P < 0.01$) with the geometric mean CPA varying without trend (Figure 46). It would appear that Spanish mackerel are providing a small but somewhat consistent opportunity for recreational anglers in Chesapeake Bay.

Spotted Seatrout

Spotted seatrout were rarely encountered during sampling. For 2009, three were measured from the onboard sampling (mean length = 467 mm TL), and only two from seafood dealer sampling (mean length = 419 mm TL, mean weight = 682 g; Tables 4 and 5). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 7,480 pounds from 1991-2008 (Figure 47). Reported 2008 harvest was 269 pounds, well below the 1991- 2008 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 2009; Figure 48). Release estimates also declined to zero fish in 2008 (Figure 48).

Spotted seatrout harvest from charter boats ranged from 249 – 20,030 fish per year (Figure 49) and averaged 4,537 fish per year from 1997 - 2008. No harvest was reported between 1993-1996, but it is not clear if spotted seatrout were not reported at that time or none were captured. The charter boat log book harvest was not significantly correlated with the MRFSS for hire inland only estimates, the statewide MRFSS estimates. or the Chesapeake Bay commercial landings. The arithmetic and geometric mean CPA were significantly correlated (R^2 = 0.67, $P < 0.01$) with the geometric mean CPA varying without trend (Figure 50). The recreational spotted seatrout fishery in Chesapeake Bay is conducted by a small group of anglers that are unlikely represented in the MRFSS . This is supported by the 2007 and 2008 reported charter harvests 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 2009 was 245 mm FL, similar to the 2008 mean of 246 mm FL (Table 4). Samples from the seafood dealer survey averaged 258 mm FL and 247 g (Table 5). Menhaden length frequencies from onboard sampling for 2006 and 2007 were very similar and robust compared to 2005 (Figure 51). 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 length distribution from seafood dealer sampling in 2009 was more skewed toward larger fish than the onboard sampling distribution (Figure 52). This may be related to sample size for the seafood dealer sampling (n=146 fish) and not an accurate reflection of fishermen preference, since menhaden are usually landed regardless of size for use as bait.

Ages derived from 2007 and 2008 Atlantic menhaden scale analysis ranged from age 1 to age 6. Appling the length frequency distribution of Atlantic menhaden captured from pound nets to the age-length key for both years, indicated that ages one through three accounted for over 85 % of the catch. For 2009, ages were derived for 258 menhaden and ranged from zero to five years of age (Table 14). Applying the length frequency of Atlantic menhaden captured from both the onboard and seafood dealer sampling in 2009 (n=512) to the age-length key, indicated that 17% of the fish were age one, 25% were age two, 38% were age three, and 17% were age four, with the proportion of age groups five and zero accounting for less than 3% each (Table 15).

Atlantic menhaden commercial harvest in Maryland increased from 7,000 pounds in 1935 to over 8 million pounds in 1965 (Figure 53). 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 2008 commercial harvest decreased 28% compared to 2007, but was still the ninth highest on record (8.9 million pounds), with 98% of harvest from the Chesapeake Bay (Figure 53). 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. 2005. *Atlantic Croaker Stock Assessment and Peer Review report*. Atlantic States Marine Fisheries Commission. Washington, D.C. 361p.

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.

Northeast Fisheries Science Center (NFSC). 2009. 48th Northeast Regional Stock Assessment Workshop (48th SAW) Assessment Summary Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-10; 50 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.

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.

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

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, 2009.

Area	**Month**	**Number of Sampling Trips**	**Mean Water Temp. ©**	**Mean Salinity (ppt)**
Nanticoke	May	1	22.9	14
Fishing Bay	May	1	22.9	14.3
Nanticoke	June	2	23.8	13.9
Fishing Bay	June	2	24.1	14
Nanticoke	July	2	25.3	14.1
Fishing Bay	July	2	25.5	14.7
Nanticoke	August	2	27.7	13.1
Fishing Bay	August	2	27.8	14.3
Nanticoke	September	1	24.3	11.7
Fishing Bay	September	1	24.9	14.8

Table 3. List of non-target species observed during the 2009 onboard pound net survey.

Common Name	Scientific Name
Atlantic cutlassfish	*Trichiurus lepturus*
Butterfish	*Peprilus triacanthus*
Cownose ray	*Rhinoptera bonasus*
Crevalle jack	*Caranx hippos*
Gizzard shad	*Dorosoma cepedianum*
Harvestfish	*Peprilus alepidotus*
Hickory shad	*Alosa mediocris*
Hogchoker	*Trinectes maculates*
Southern stingray	*Dasyatis americana*
Striped bass	*Morone saxatilis*
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 - 2009.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Weakfish																	
mean length	276	291	306	293	297	337	334	361	334	325	324	273	278	290	275	276	262
std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42	52	22
n	435	642	565	1431	755	1234	851	333	76	196	129	326	304	62	61	42	23
Summer flounder																	
mean length	347	309	297	335	295	339	325	347	358	324	353	327	374	286	341	347	368
std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66	72	64
n	209	845	1669	930	818	1301	1285	1565	854	486	759	577	499	1274	1056	982	277
Bluefish																	
mean length	312	316	323	307	330	343	306	303	307	293	320	251	325	311	318	260	265
std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70	41	43
n	45	621	912	619	339	378	288	398	406	592	223	581	841	1422	1509	2676	1181
Atlantic croaker																	
mean length	233	259	286	294	301	310	296	302	317	279	287	311	317	304	307	298	320
std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54	62	50
n	471	1081	974	2190	1450	1057	1399	2209	733	771	3352	1653	2398	1295	2963	1532	91
Spot																	
mean length	184	207	206	235	190	230	213	230	239	184	216	208	197	191	208	198	185
std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23	21	21
n	309	451	158	275	924	60	572	510	126	681	1354	882	2818	2195	519	1195	33
Spotted Seatrout																	
mean length		448	452			541	460								414	464	467
std. dev.		86	42				134								43	72	167
n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3	10	3
Black Drum																	
mean length		1106	741	353		1074				435	475	780	1130	1031	1144	875	1147
std. dev.		175	454	20		182				190	20	212		228	95	238	84
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5	13

Table 4. Continued.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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
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
Menhaden (Fork Length)																	
mean length												262	282	238	243	246	245
std. dev.												28	36	42	41	29	40
n												213	1052	826	854	826	366

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

Species	n Length	Mean Length (mm)	STD Length	n Weight	Mean Weight (g)	STD Weight
Weakfish	6	337	64	6	376	118
Summer flounder	389	419	56	389	794	366
Bluefish	184	391	79	184	640	640
Atlantic croaker	1290	300	38	1287	370	158
Spot	581	211	22	572	141	50
Spotted Seatrout	2	419	64	2	682	336
Red Drum	5	577	22	5	2137	511
Spanish Mackerel	176	413	40	176	681	205
Menhaden	146	258	24	97	247	67

Table 6. Relative stock density of weakfish from Chesapeake Bay summer onboard pound net survey, 1993 - 2009.

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				

Table 7. Weakfish mean length (mm TL), mean weight and number sampled by age, and proportion at age, 2008.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged	Proportion at Age*
1	259	174	35	86
2	306	286	3	7
3	427	684	3	7

*All weakfish captured were measured and aged, n=41.

Table 8. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2009.

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

* Insufficient data to calculate 2007 - 2009 weakfish estimates.

Table 9. Relative stock density of summer flounder from Chesapeake Bay summer onboard pound net survey, 1993 - 2009.

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	

Table 10. Relative stock density of bluefish from Chesapeake Bay summer onboard pound net survey, 1993 - 2009.

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	

Table 11. Relative stock density of Atlantic croaker from Chesapeake Bay summer onboard pound net survey, 1993 - 2009.

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

Table 12. Atlantic croaker mean length (mm TL), mean weight and number sampled by age, 2008.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged
0	196	86	15
1	206	110	18
2	257	226	61
3	299	355	30
4	343	548	50
5	367	686	15
6	381	741	76
7	395	890	5
8	412	961	4
9	434	1019	6
10	381	783	7
11	391	785	2

Table 13. Atlantic croaker proportion at age using 2008 pound net length and age data (ages: n= 288 and lengths: n=1,532).

Age	0	1	2	3	4	5	6	7	8	9	10	11
n	84	111	433	214	292	69	269	15	7	7	26	5
Proportion at age	5.50	7.24	28.27	13.96	19.05	4.51	17.57	0.96	0.44	0.48	1.71	0.31

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 2009.

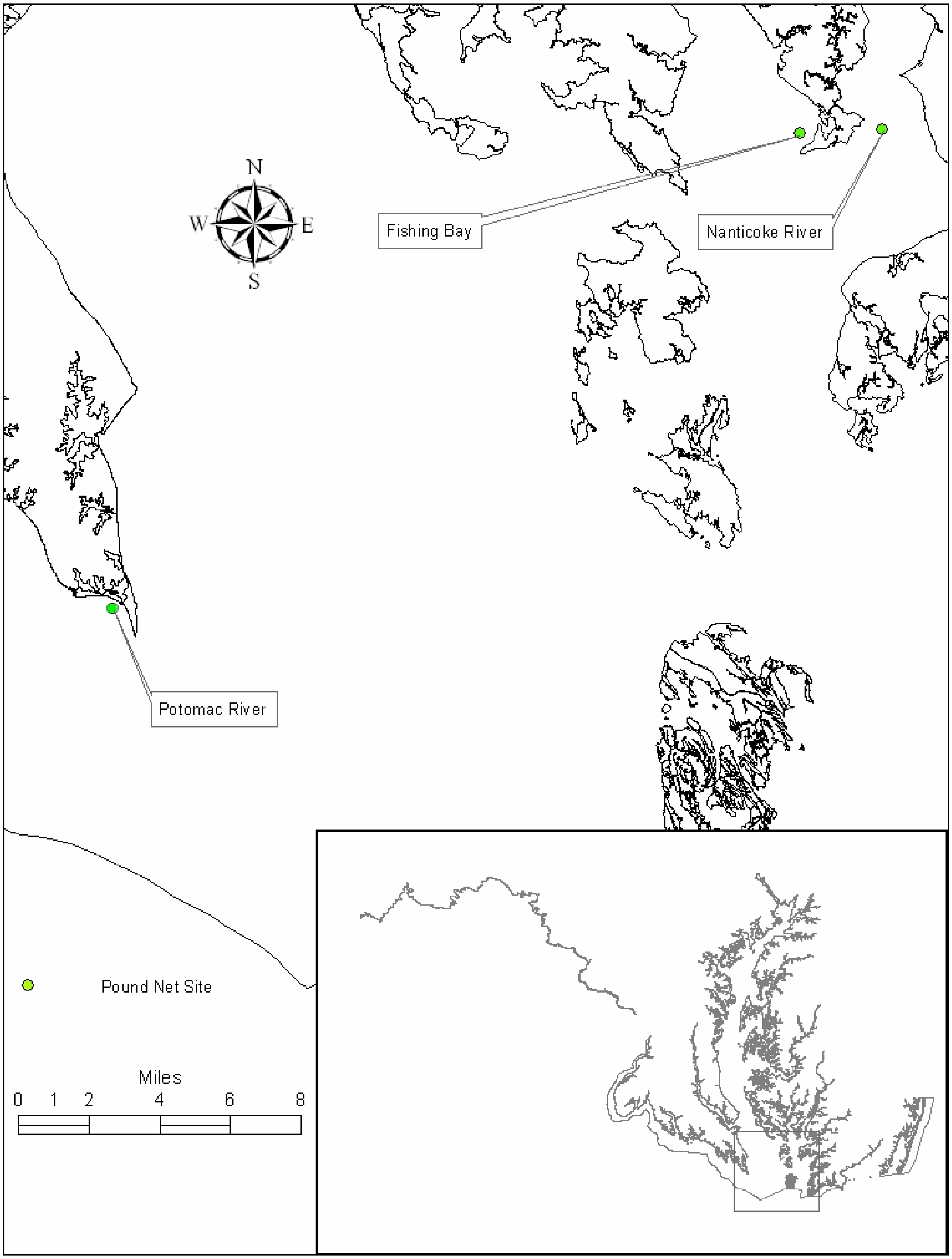


Figure 2. Weakfish length frequency distributions from onboard pound net sampling, 2006-2009.

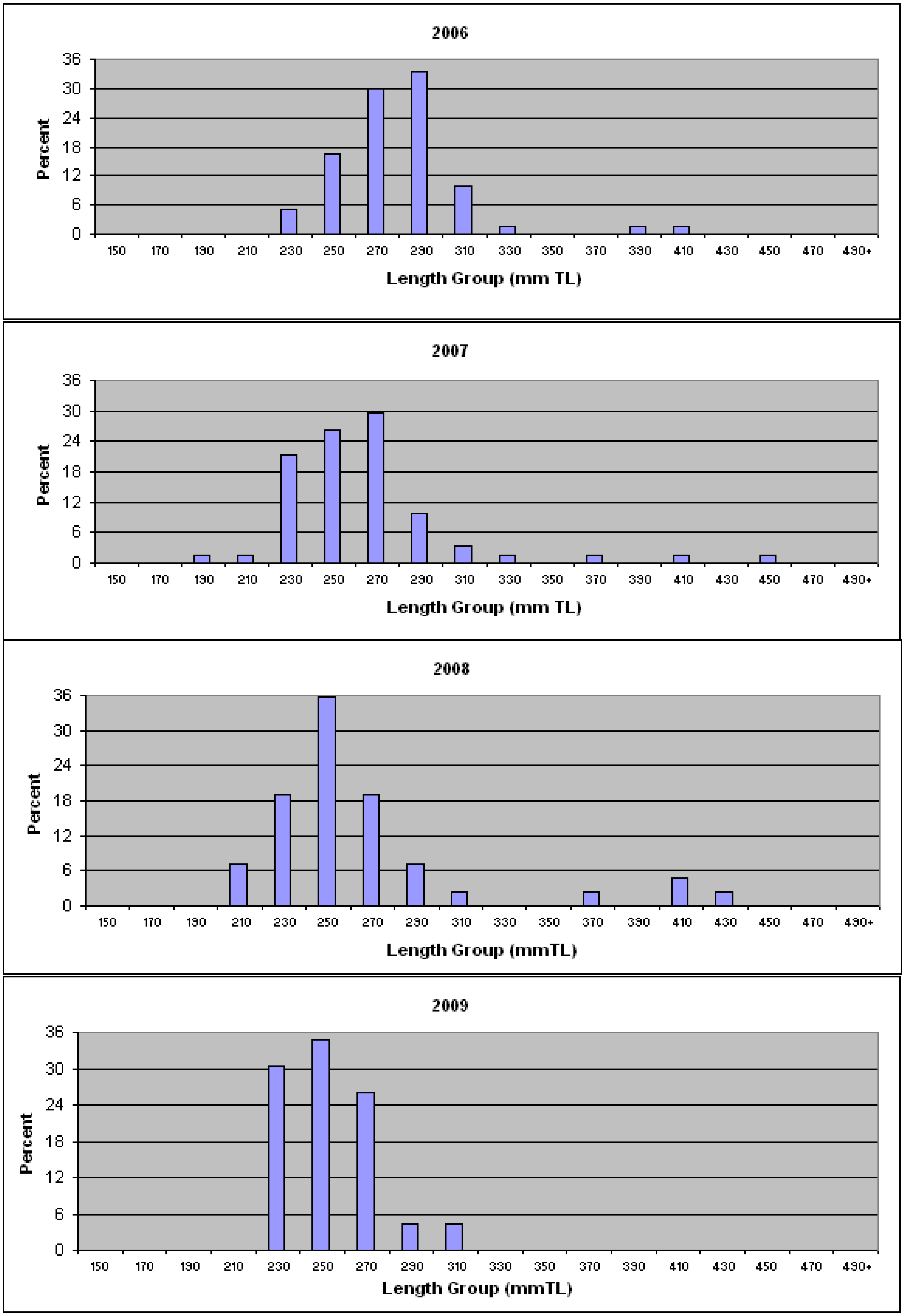


Figure 3. Maryland commercial weakfish harvest by area, 1929-2008.

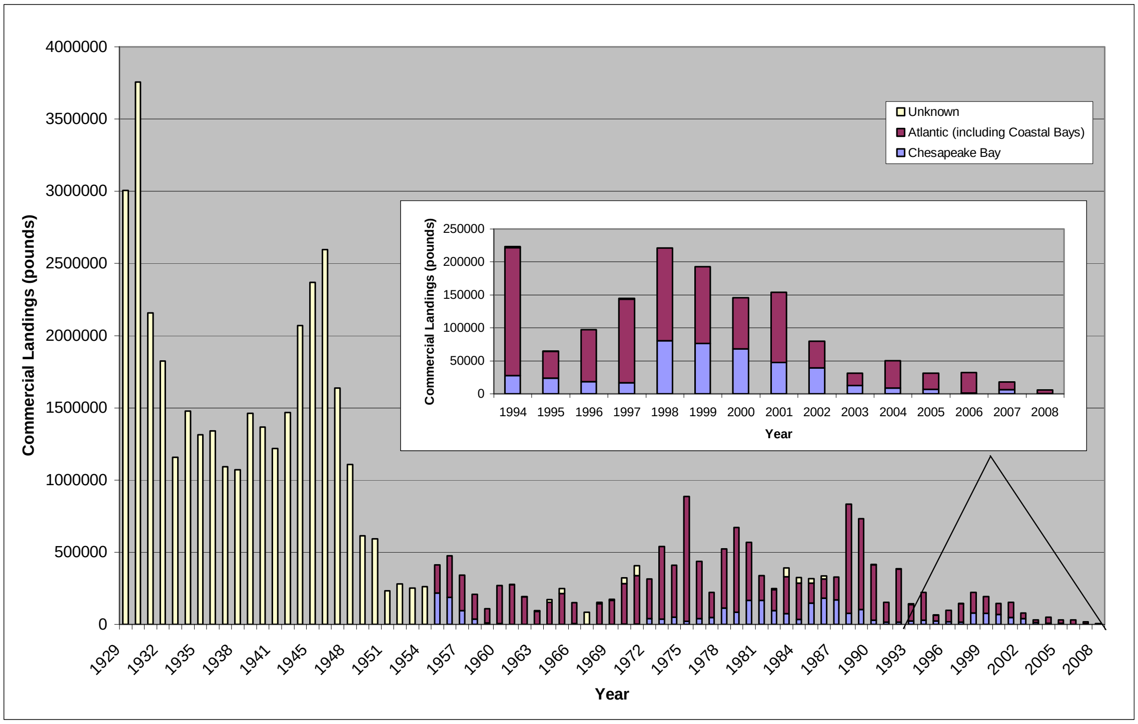


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2008 (Source: MRFSS, 2009).

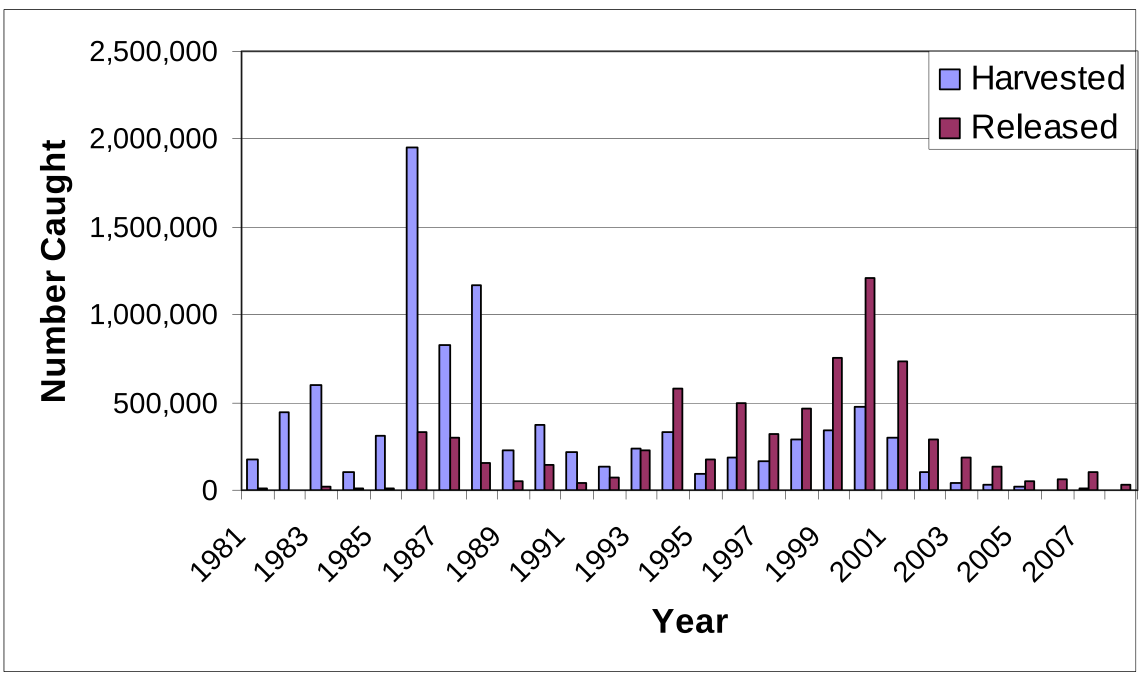


Figure 5. Weakfish statewide MRFSS harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2008.

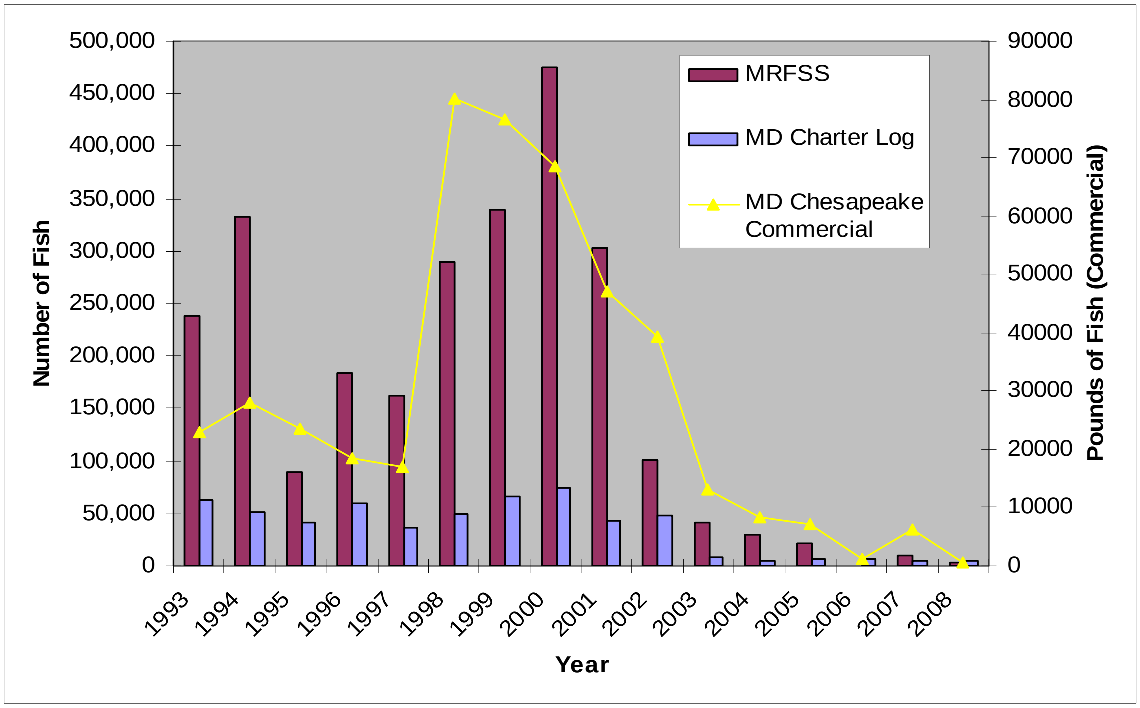


Figure 6. Weakfish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

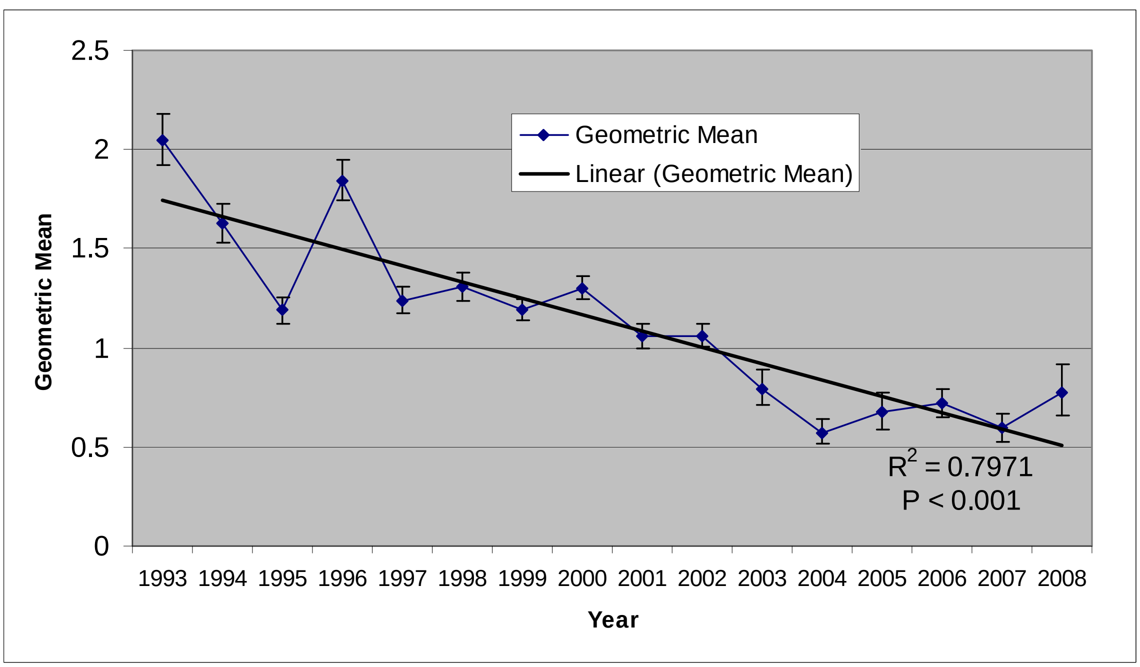
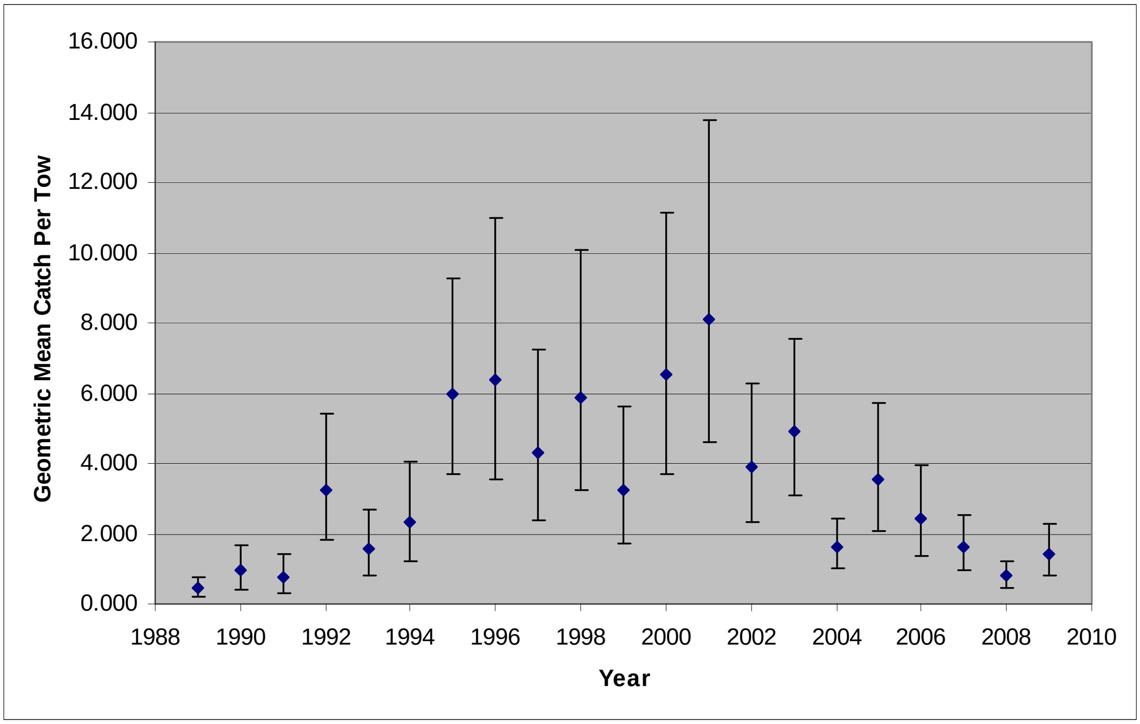


Figure 7. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2009.



(Note: Confidence intervals were generated by the MEANS Procedure in SAS.)

Figure 8. Summer flounder length frequency distributions from onboard pound net sampling, 2006-2009.

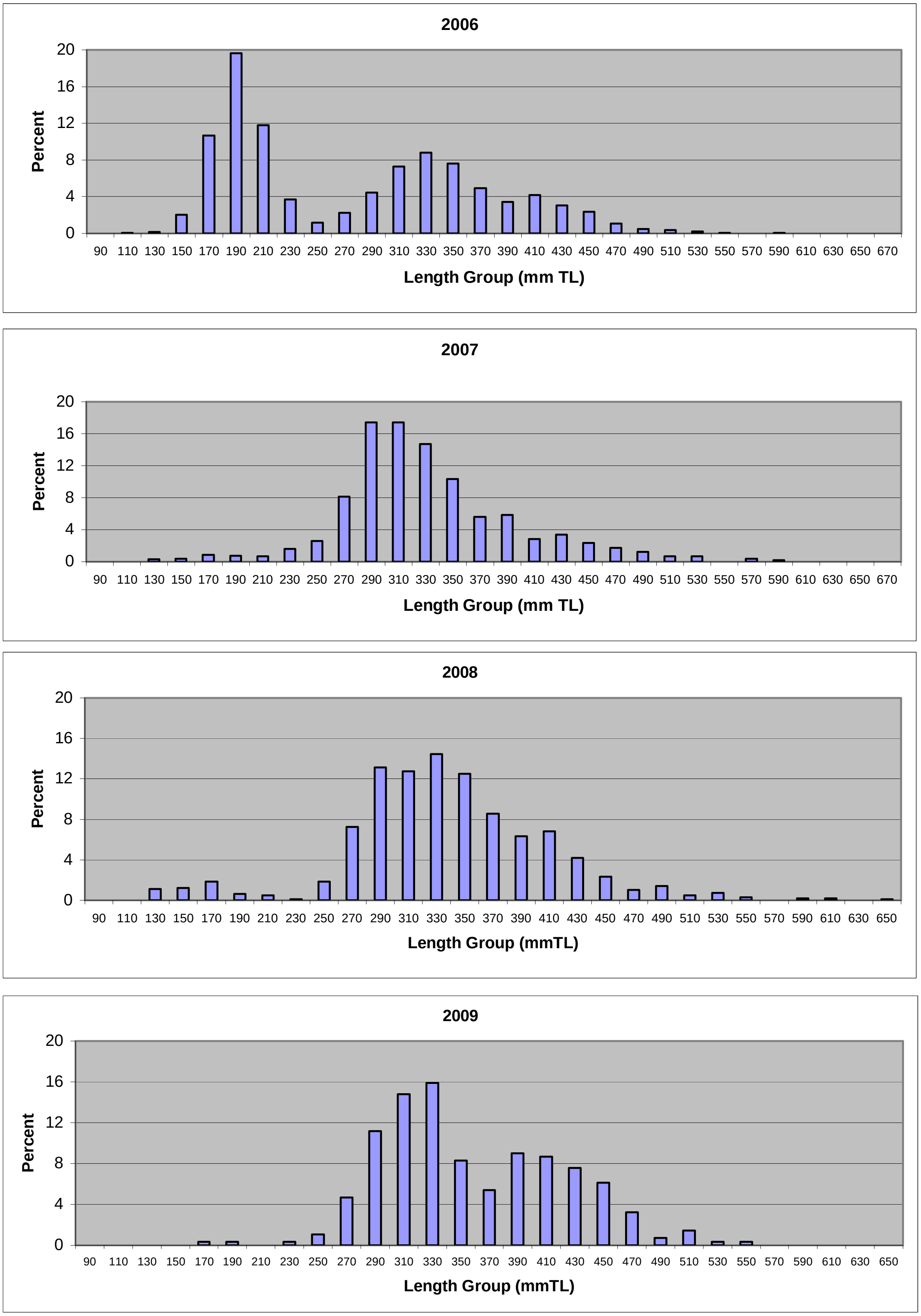


Figure 9. Summer flounder 2009length frequency distribution from seafood dealer sampling.

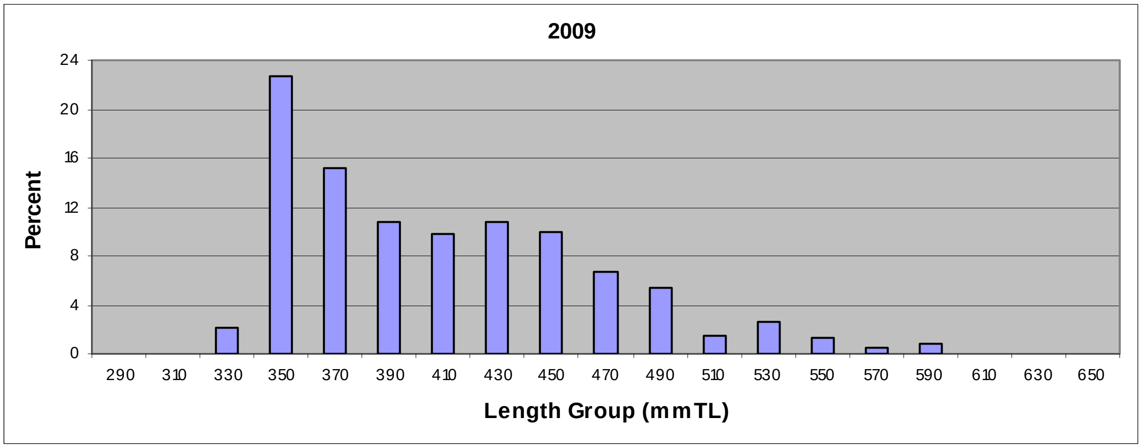


Figure 10. Maryland commercial summer flounder harvest by area, 1962-2008.

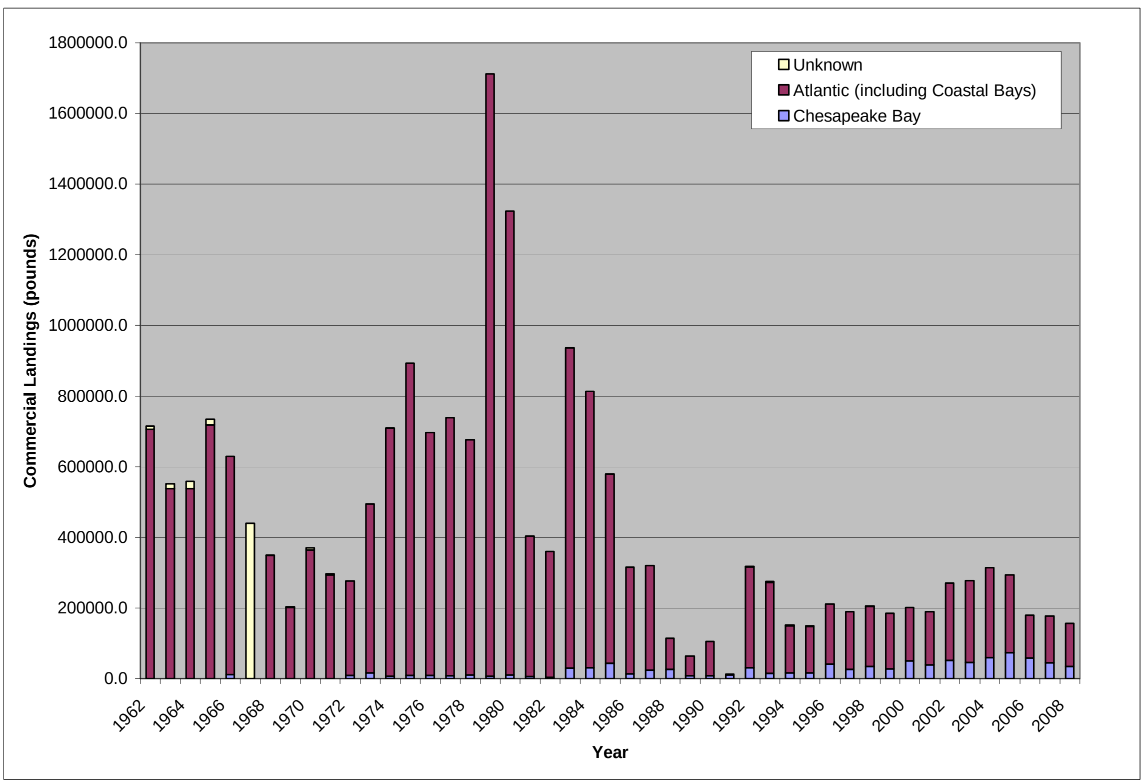


Figure 11. Estimated Maryland recreational summer flounder harvest and releases for 1981-2008 (Source: MRFSS, 2009).

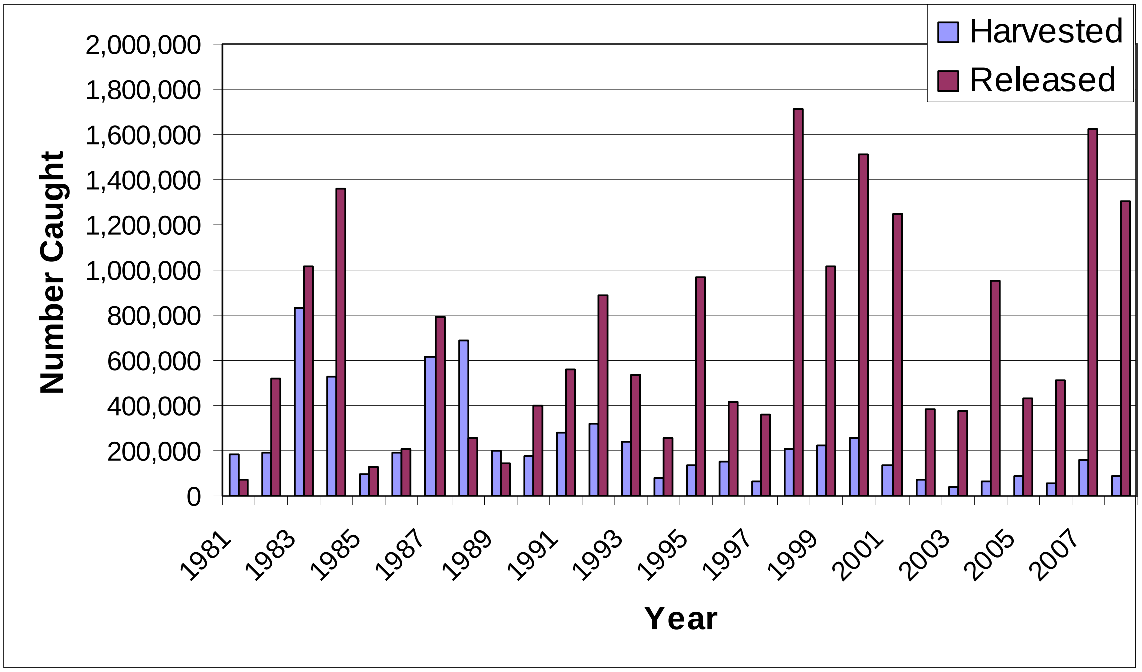


Figure 12. Summer Flounder statewide MRFSS harvest and Maryland reported charter boat harvest in numbers, 1993-2008.

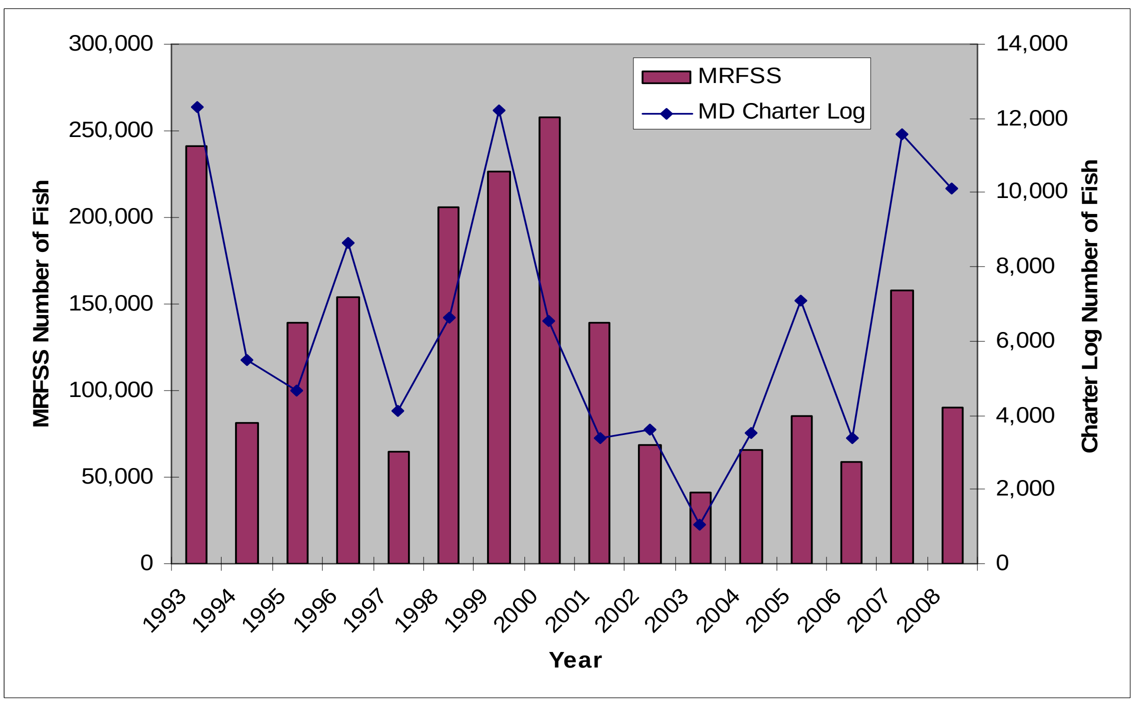


Figure 13. Summer flounder geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

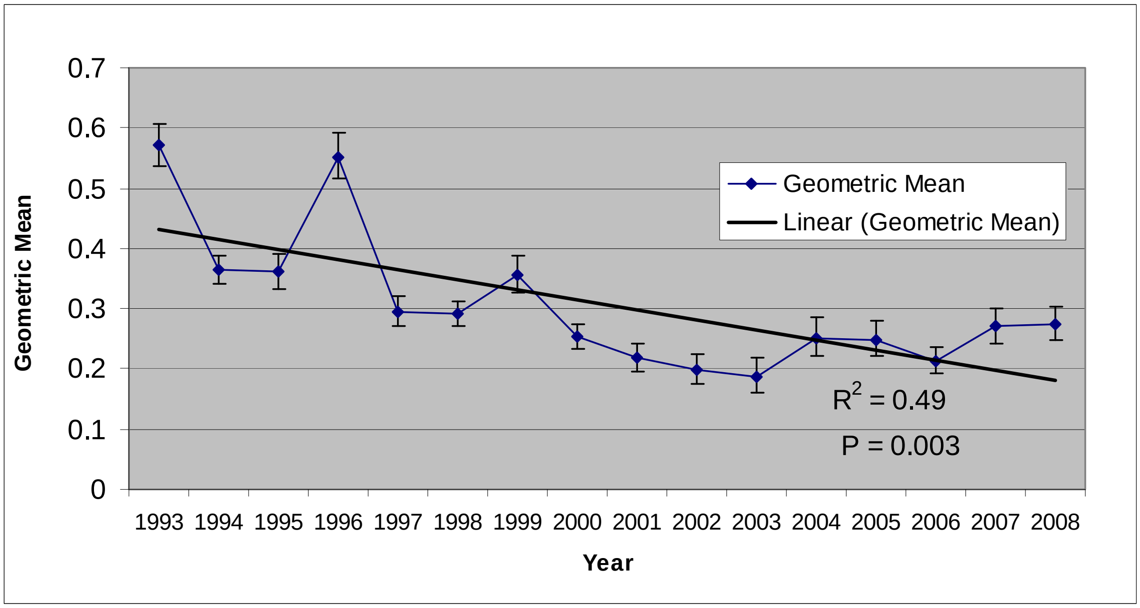


Figure 14. Bluefish length frequency distributions from onboard pound net sampling, 2006-2009.

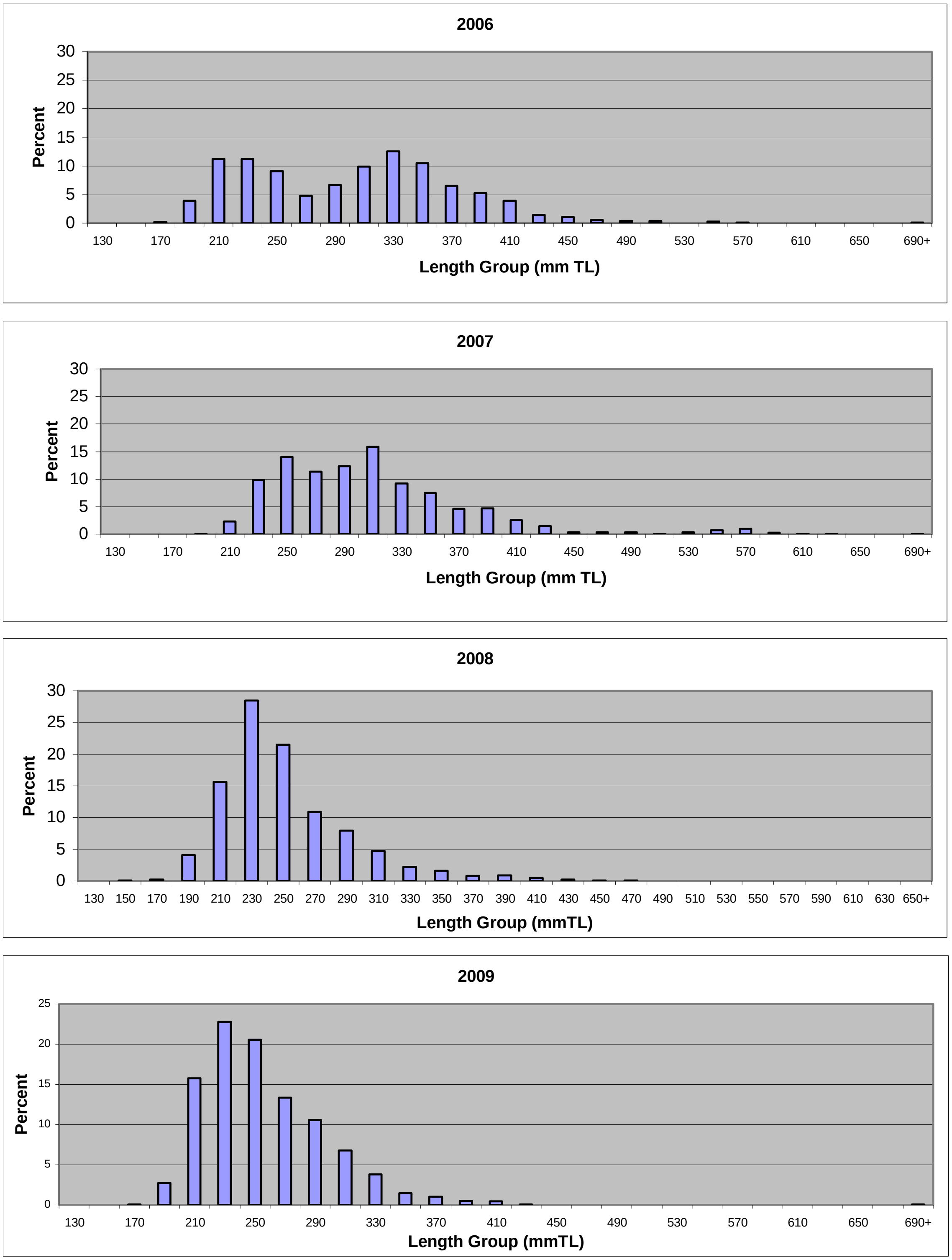


Figure 15. Bluefish 2009 length frequency distribution from seafood dealer sampling.

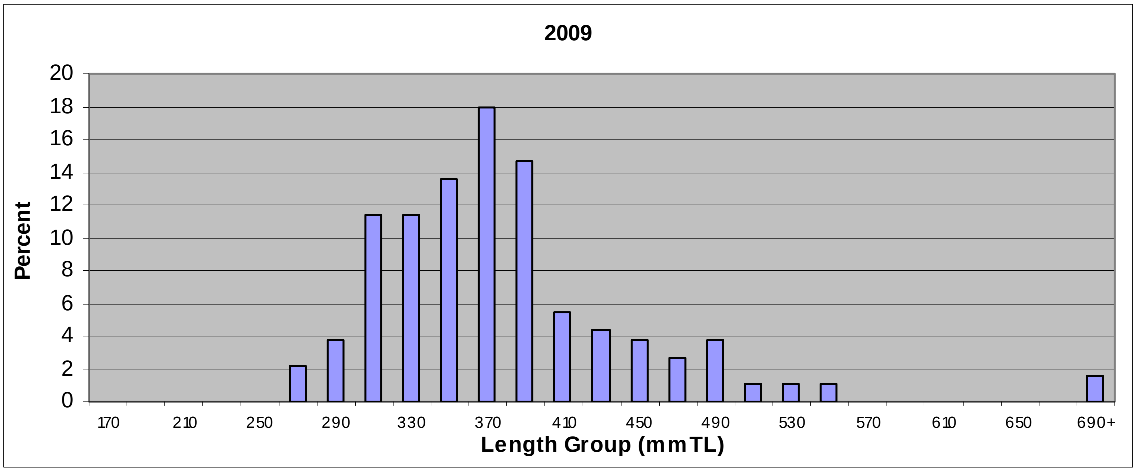


Figure 16. Maryland commercial bluefish harvest by area, 1929-2008.

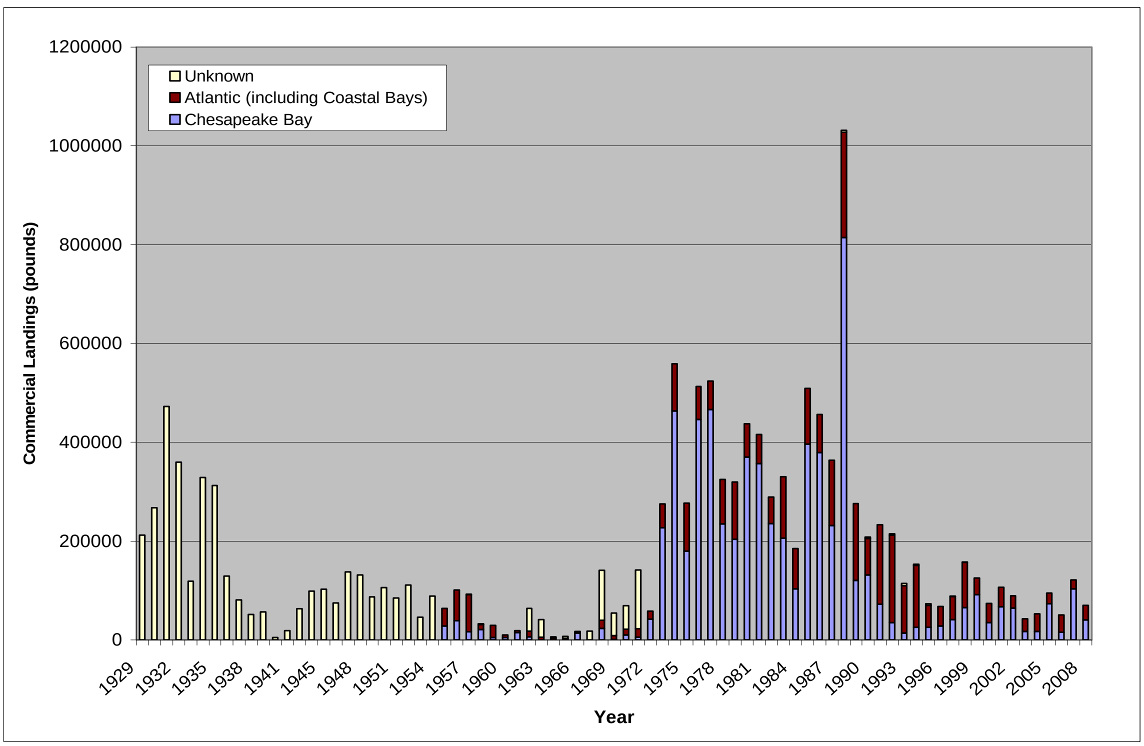


Figure 17. Estimated Maryland recreational bluefish harvest and releases for 1981-2008 (Source: MRFSS, 2009).

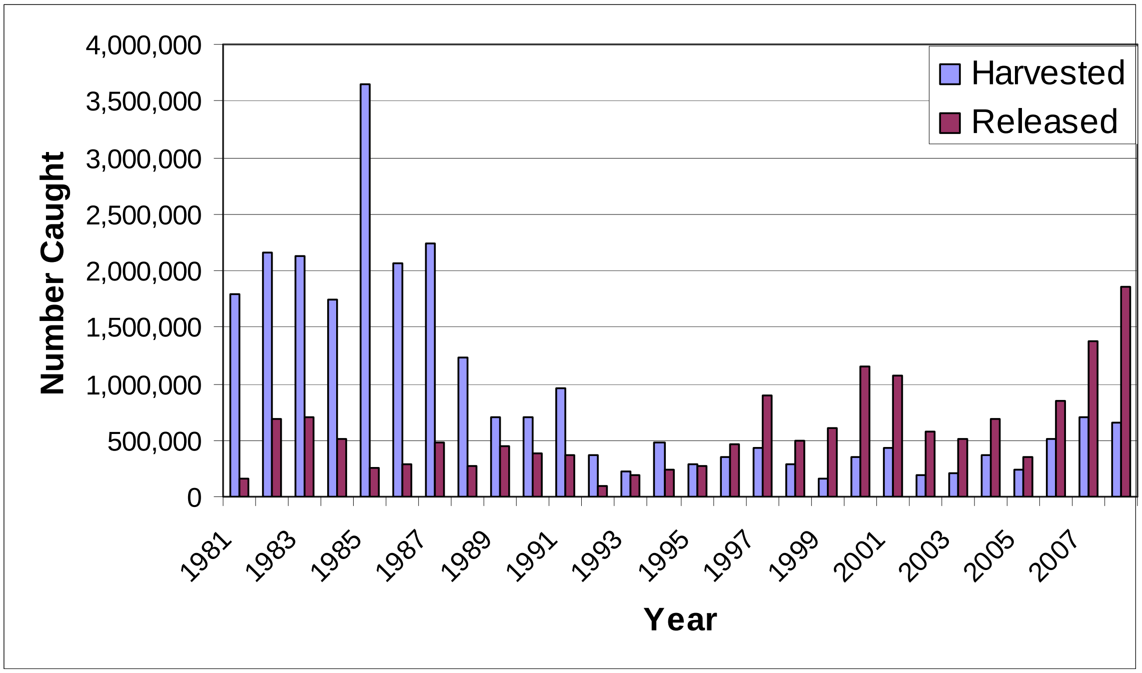


Figure 18. Bluefish statewide MRFSS harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2008.

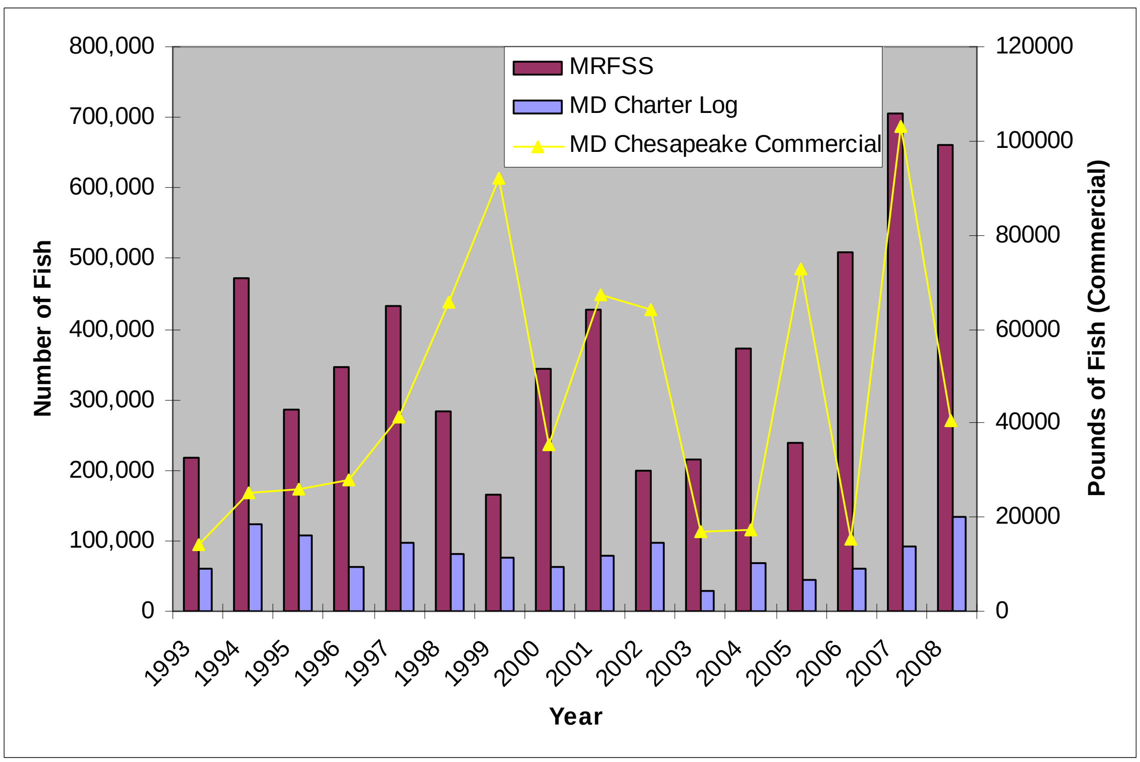


Figure 19. Bluefish geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

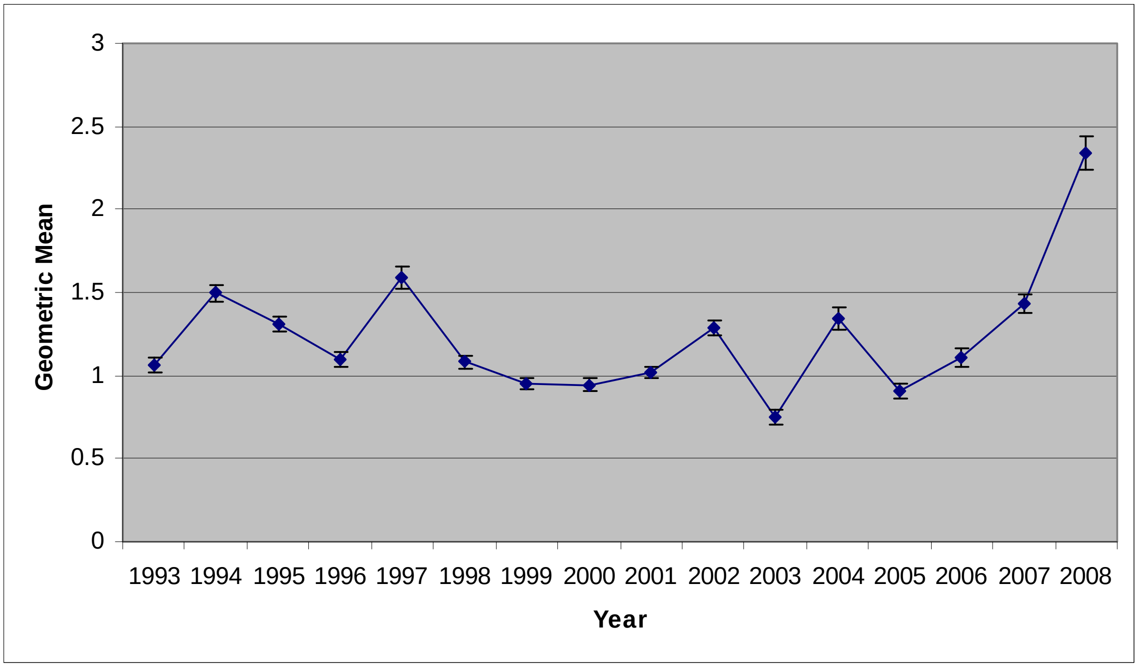


Figure 20. Atlantic croaker length frequency distributions from onboard pound net sampling, 2006-2009.

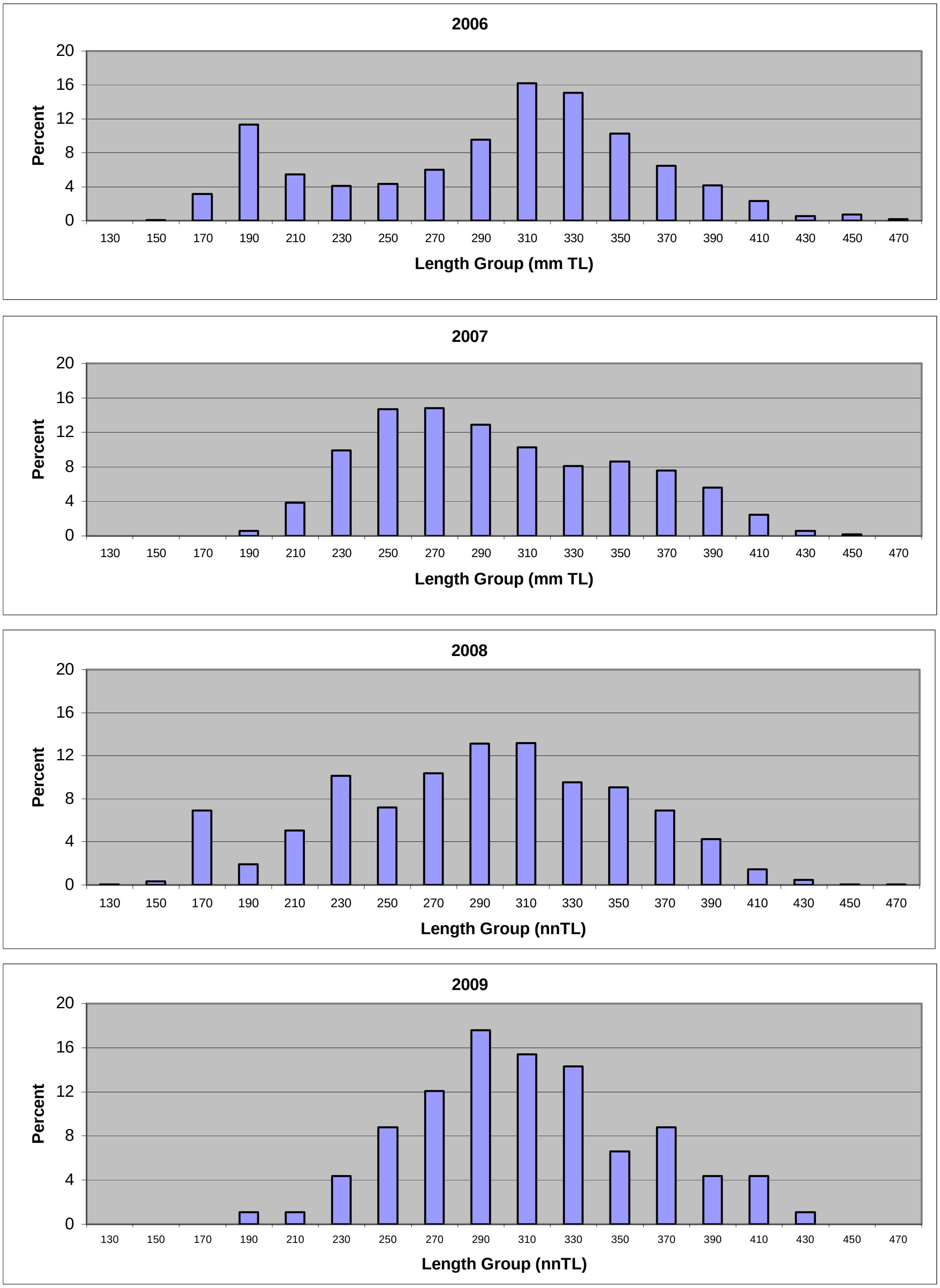


Figure 21. Atlantic croaker 2009 length frequency distribution from seafood dealer sampling.

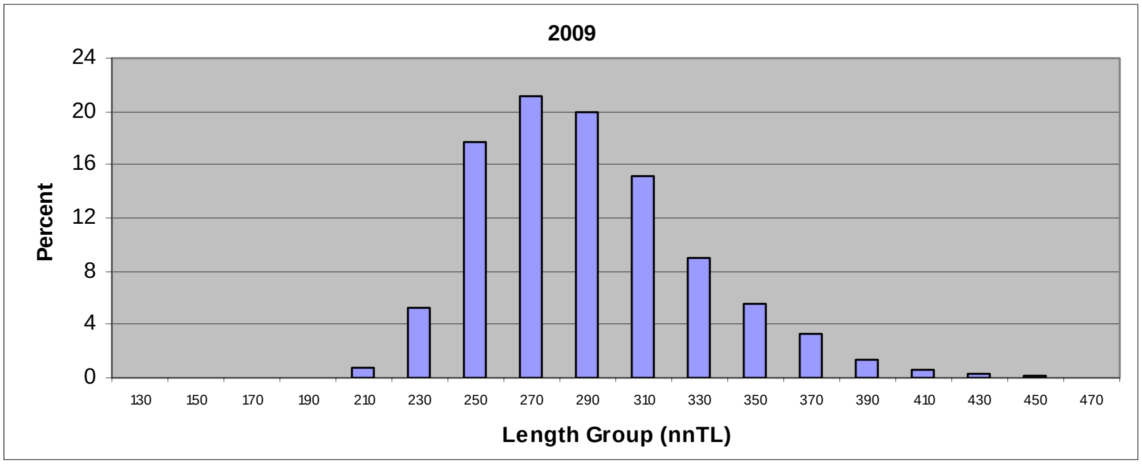


Figure 22. Maryland commercial Atlantic croaker harvest by area, 1929-2008.

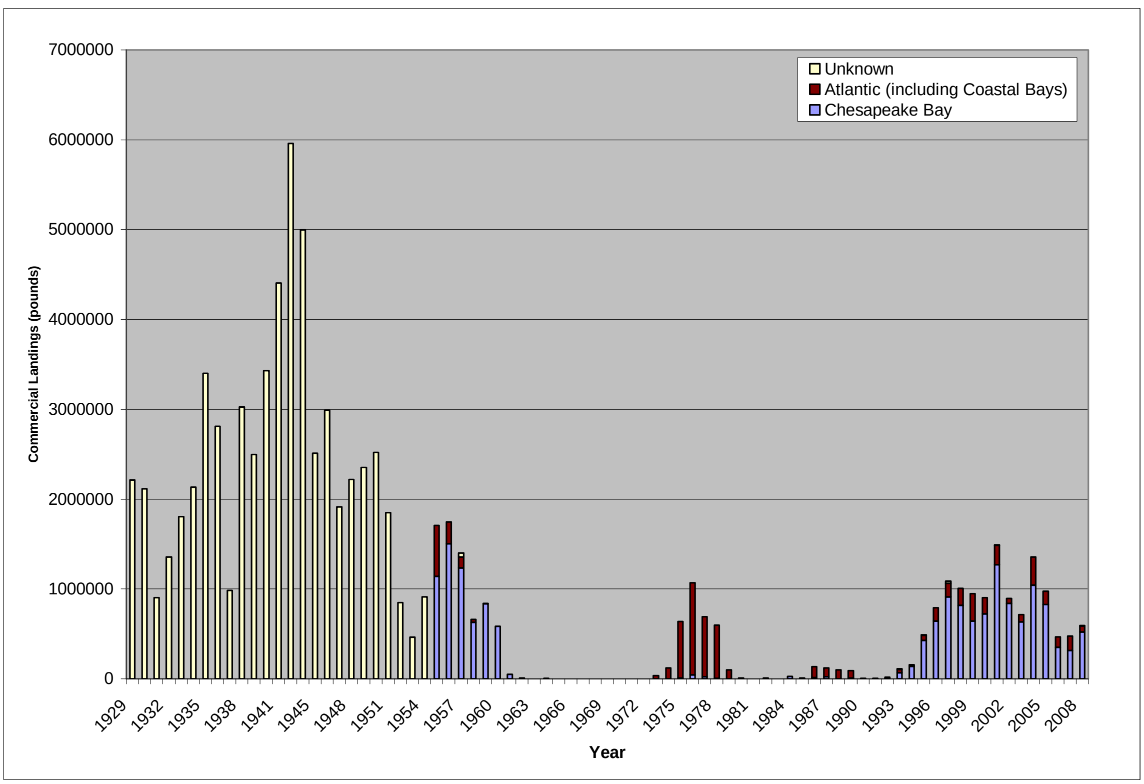


Figure 23. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2008 (Source: MRFSS, 2009).

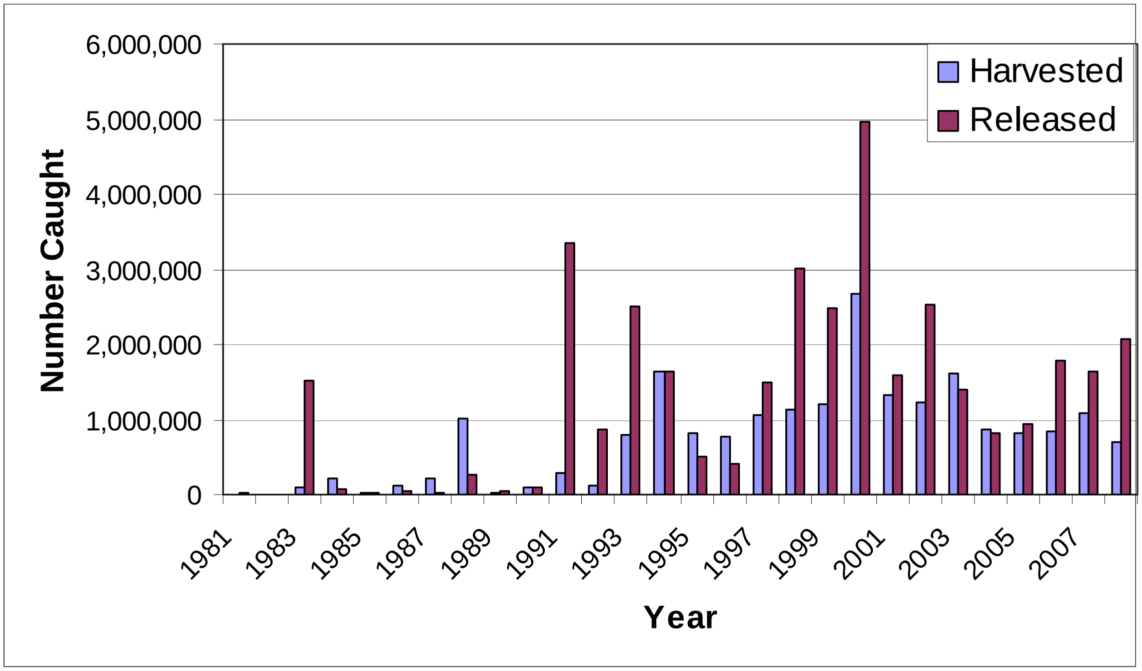


Figure 24. Atlantic croaker statewide MRFSS harvest, MRFSS for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2008.

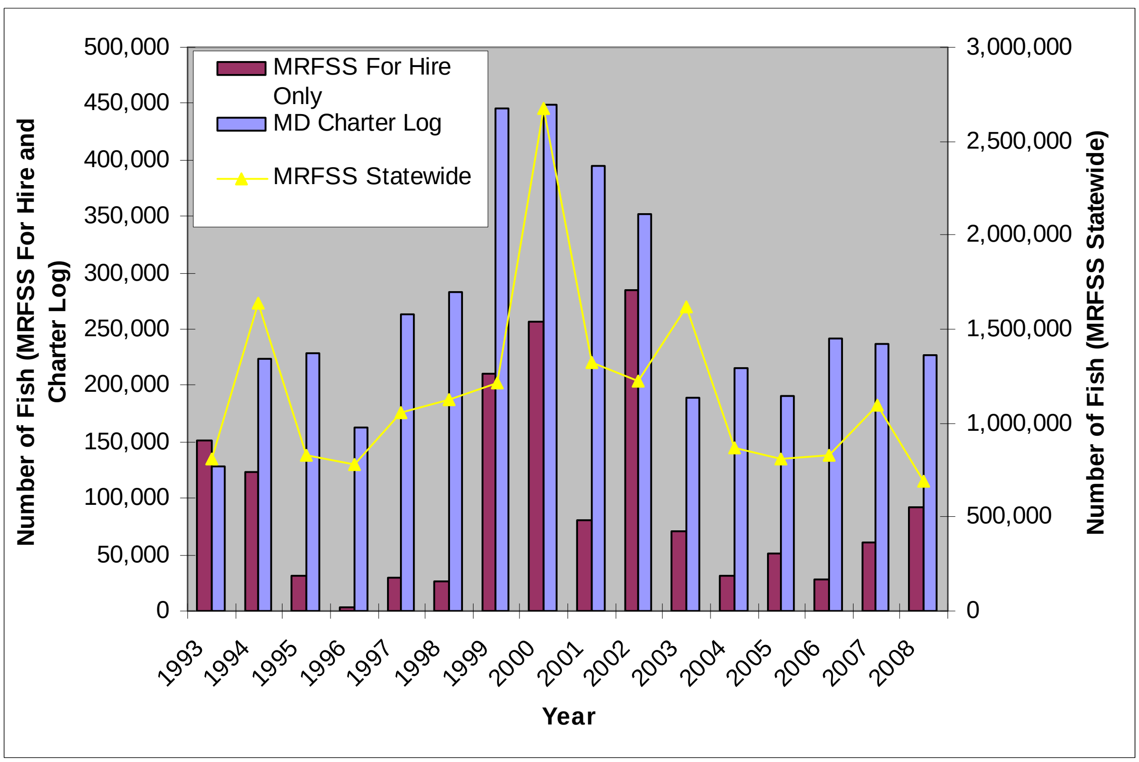


Figure 25. Atlantic croaker geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

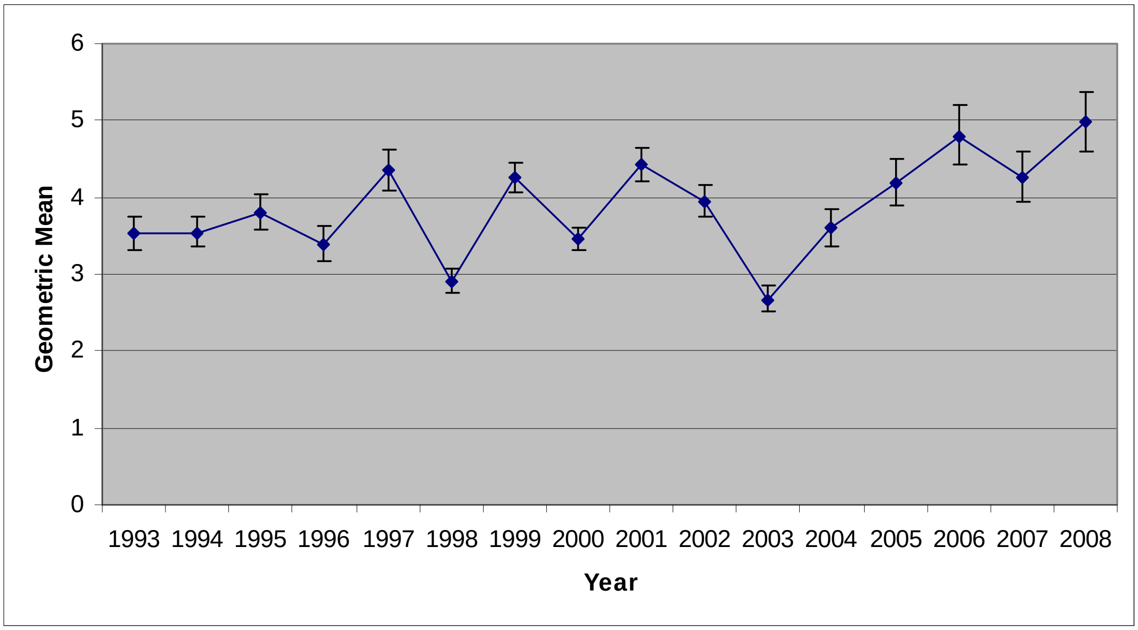
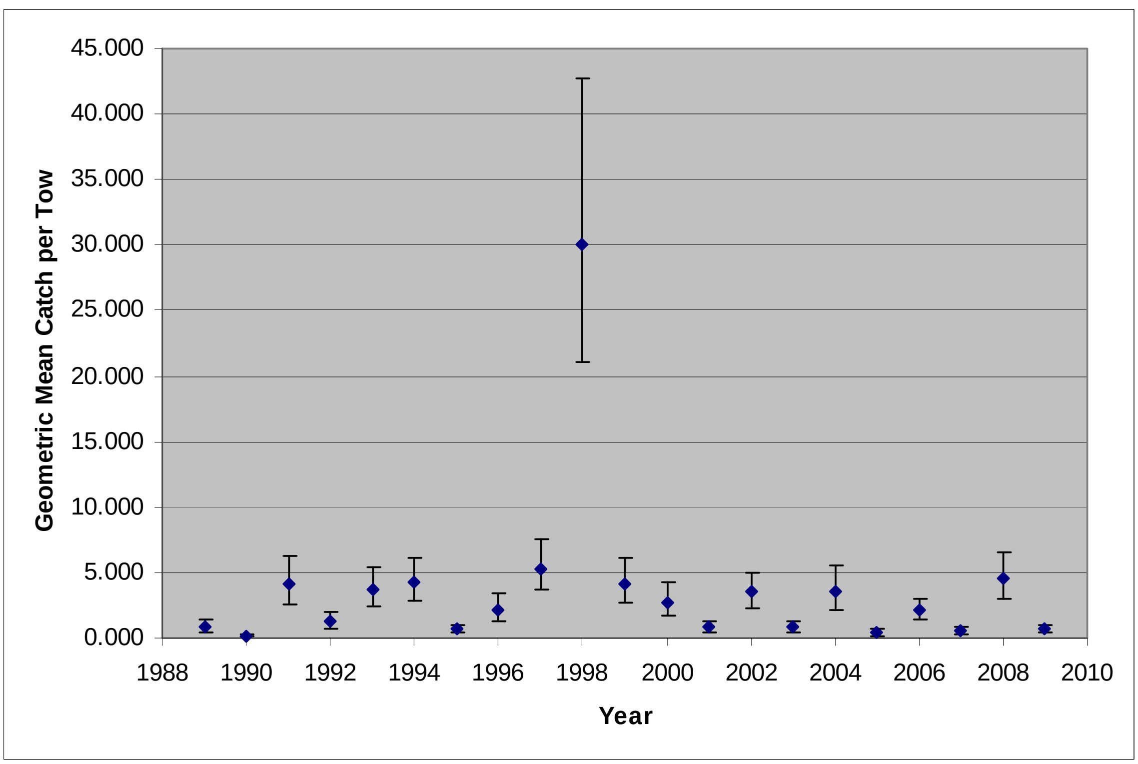


Figure 26. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2009.



(Note: Confidence intervals were generated by the MEANS Procedure in SAS.)

Figure 27. Spot length frequency distributions from onboard pound net sampling, 2006-2009.

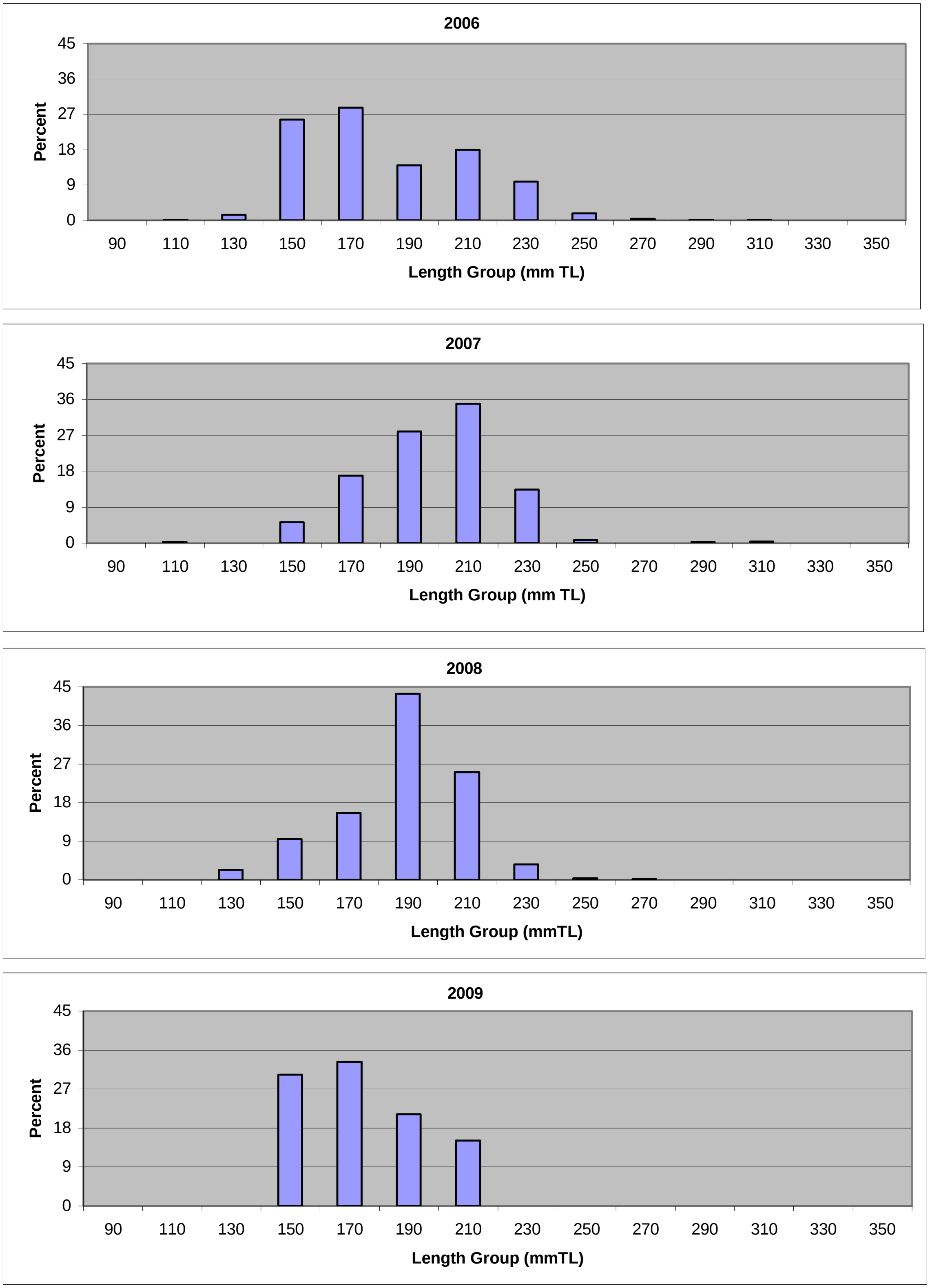


Figure 28. Spot 2009 length frequency distribution from seafood dealer sampling.

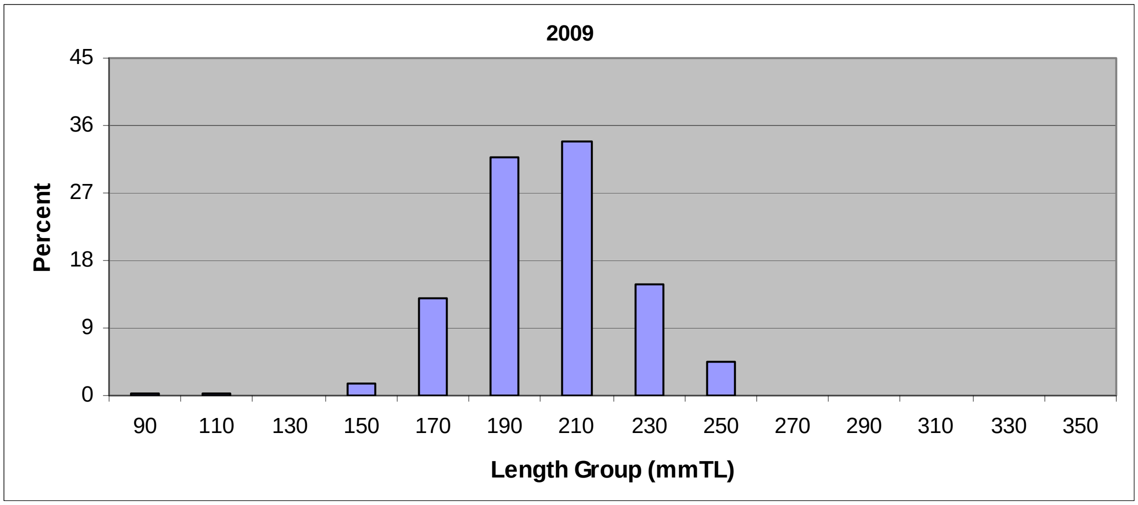


Figure 29. Maryland commercial spot harvest by area, 1929-2008.

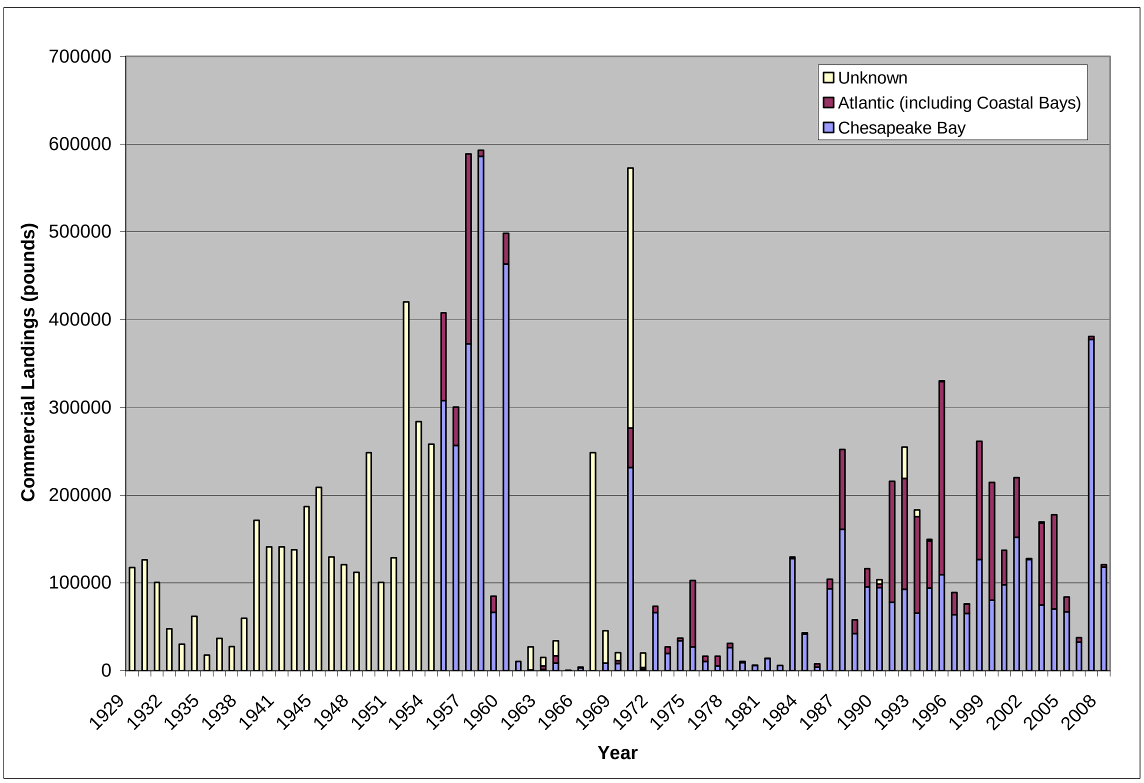


Figure 30. Estimated Maryland recreational spot harvest and releases for 1981-2008 (Source: MRFSS, 2009).

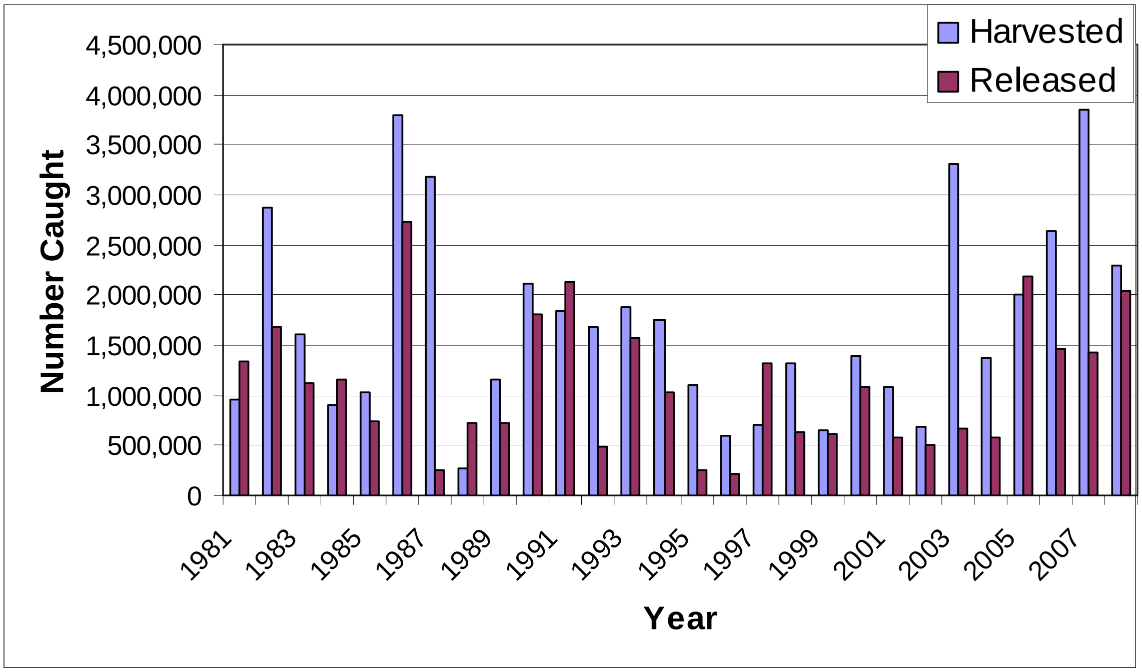


Figure 31. Spot statewide MRFSS harvest in numbers, Maryland reported charter boat harvest in numbers and Maryland commercial harvest in pounds, 1993-2008.

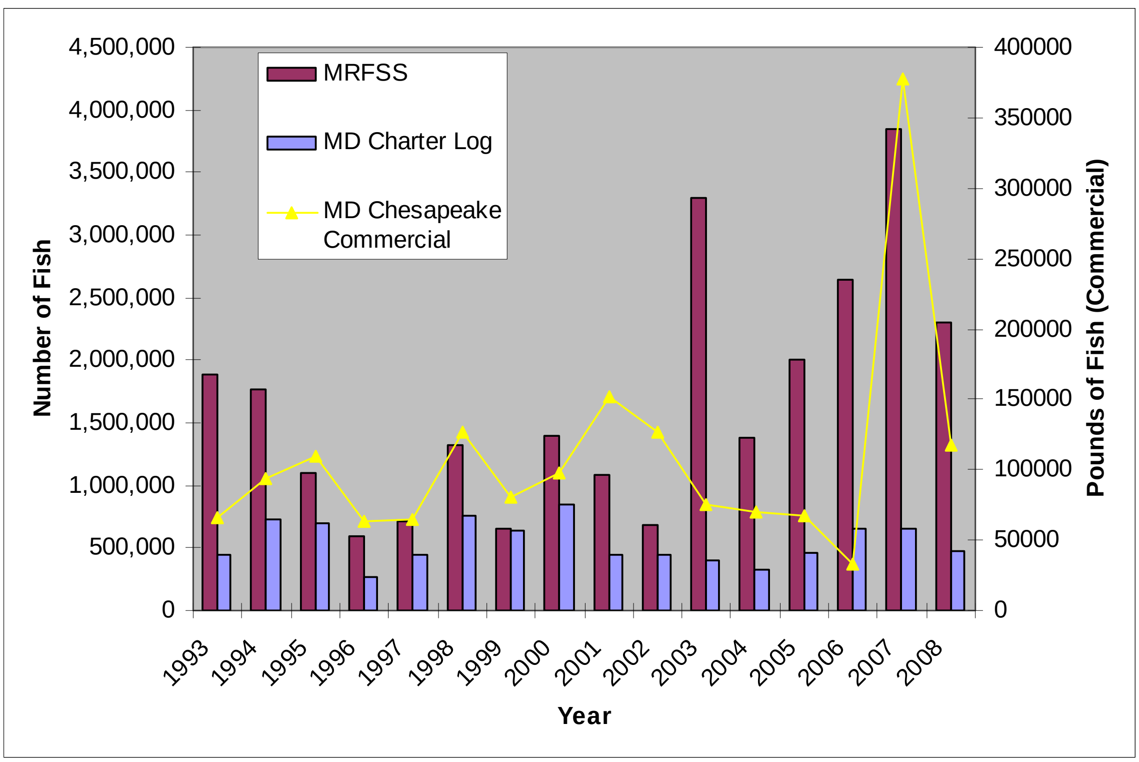


Figure 32. Spot geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

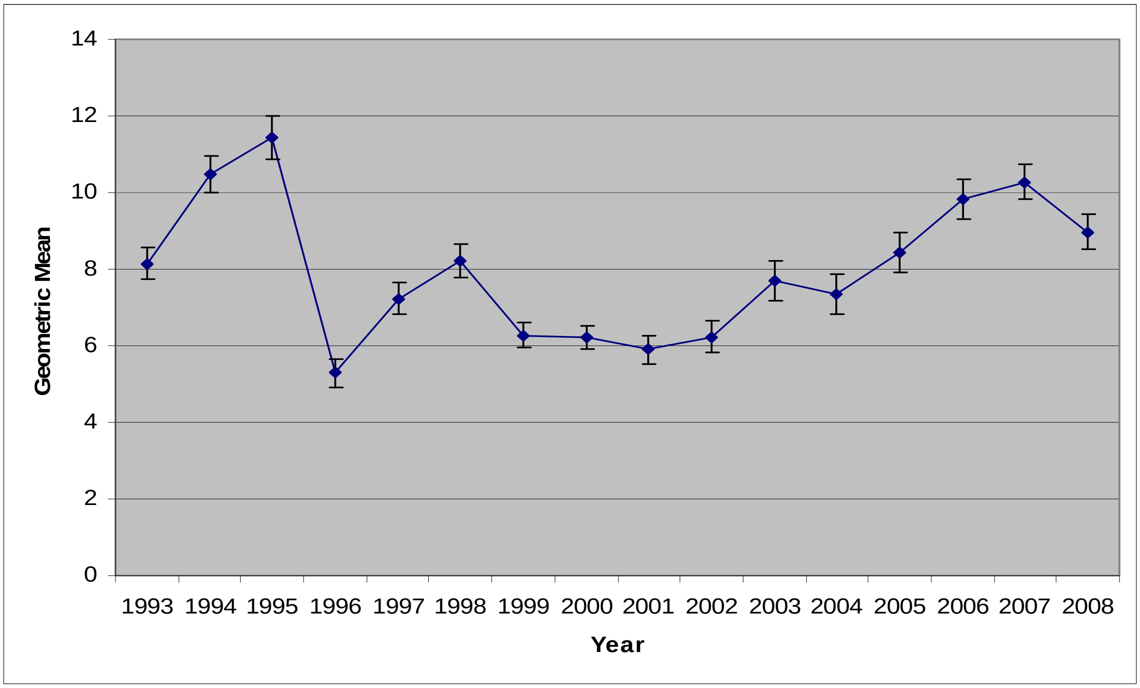
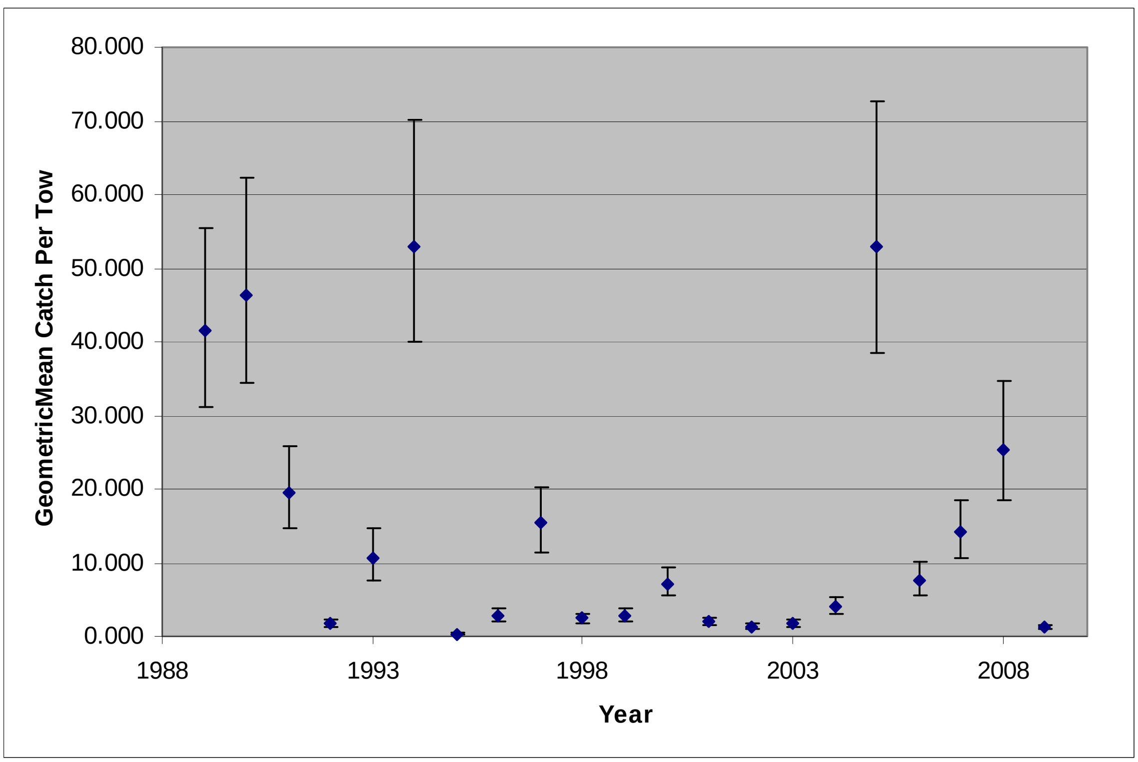


Figure 33. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2009.



(Note: Confidence intervals were generated by the MEANS Procedure in SAS.)

Figure 34. Maryland commercial red drum harvest by area, 1958-2008.

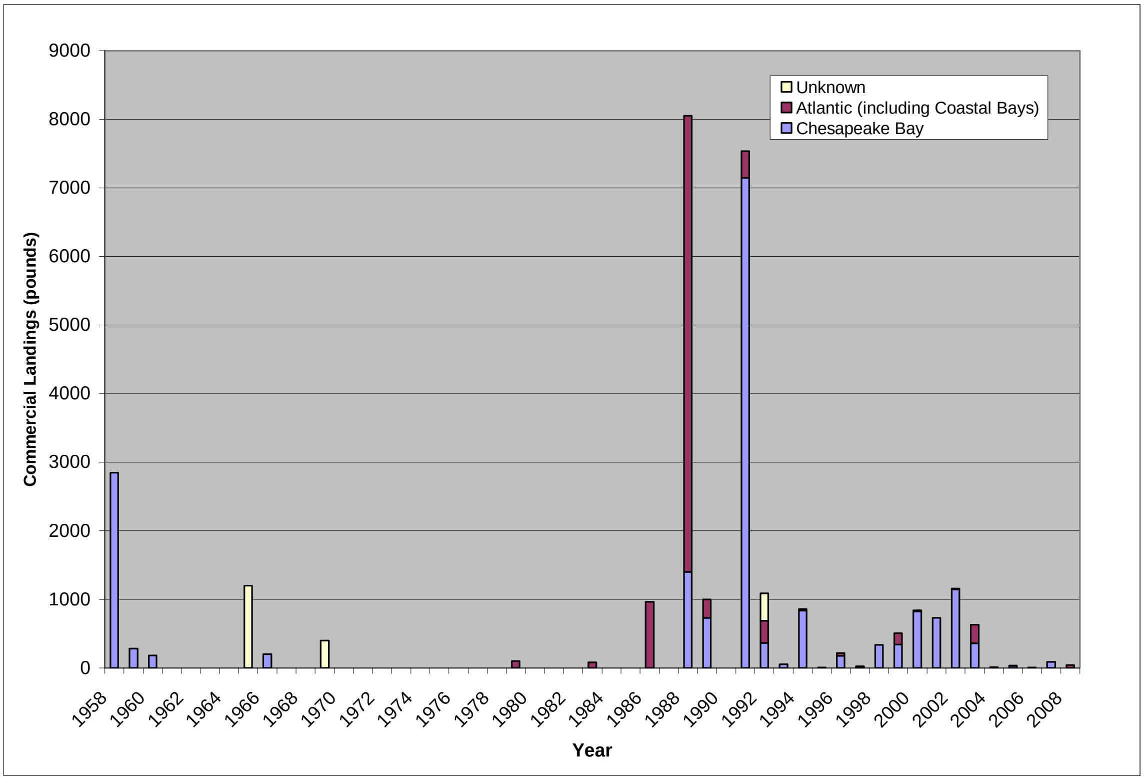


Figure 35. Estimated Maryland recreational red drum harvest and releases for 1981-2008 (Source: MRFSS, 2009).

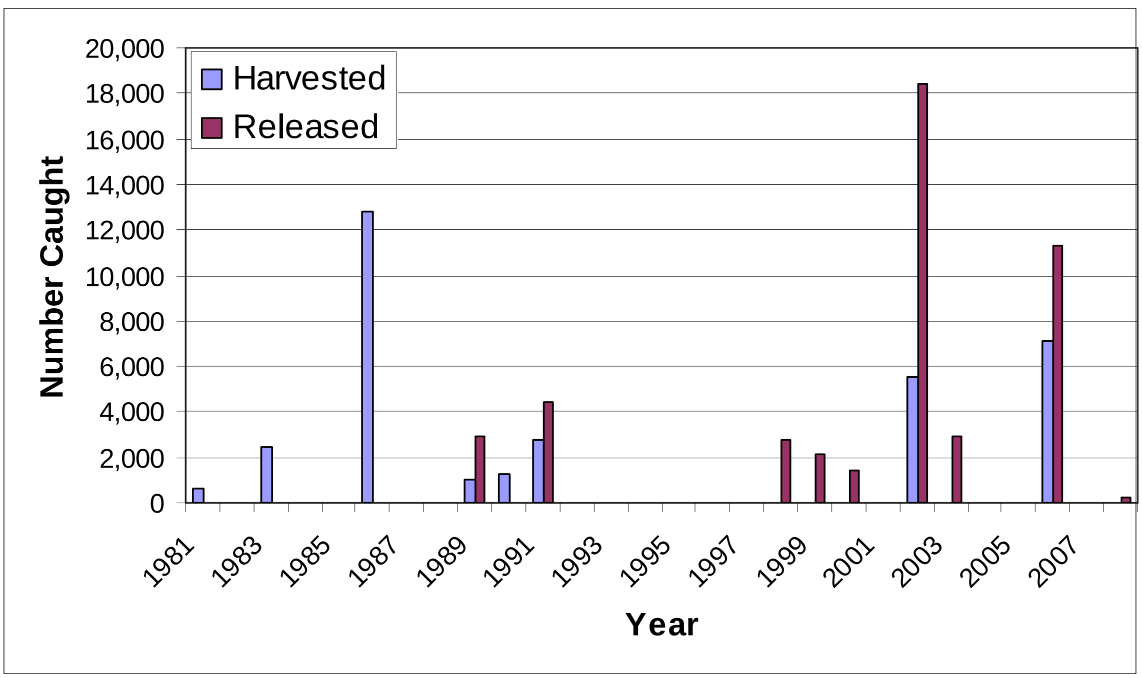


Figure 36. Number of red drum harvested and the number of anglers catching red drum from the Maryland Charter boat logs, 1993-2008.

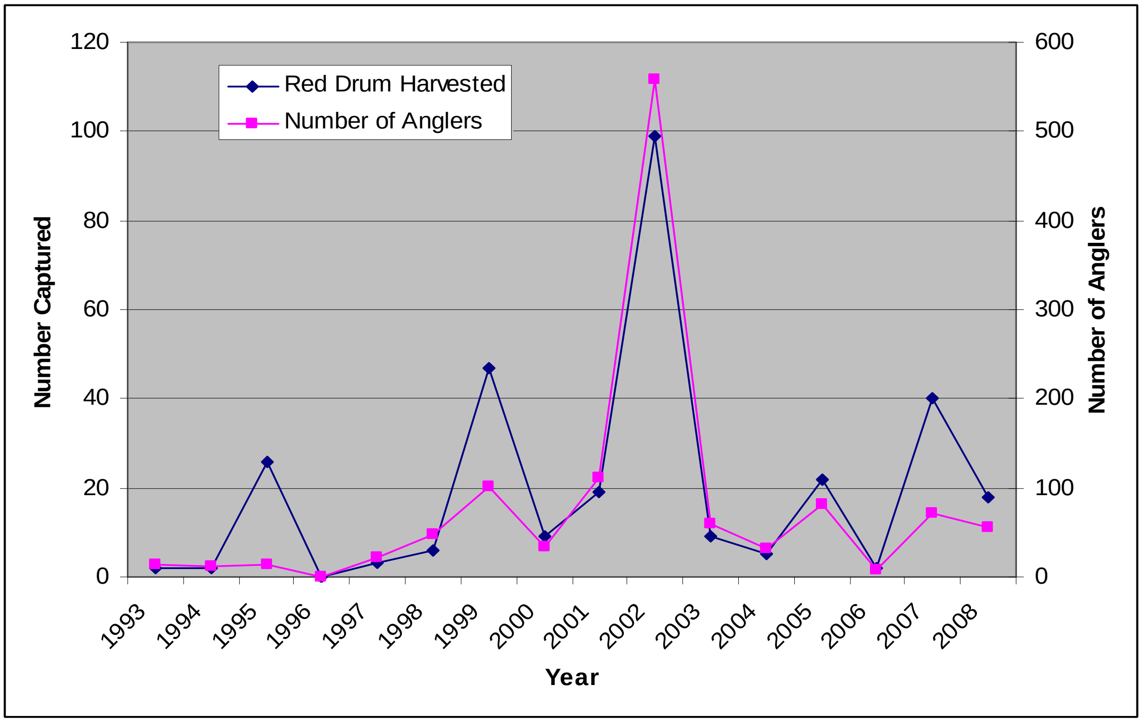


Figure 37. Maryland commercial black drum harvest by area, 1929-2008.

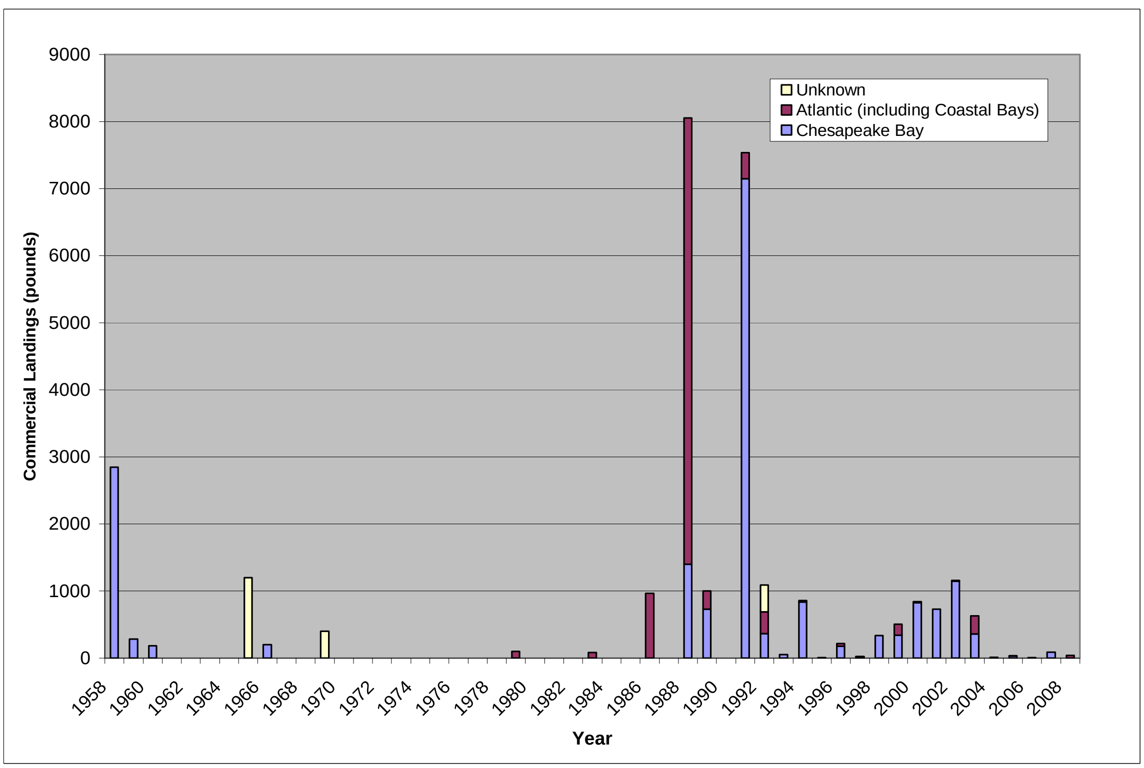


Figure 38. Estimated Maryland recreational black drum harvest and releases for 1981-2008 (Source: MRFSS, 2009).

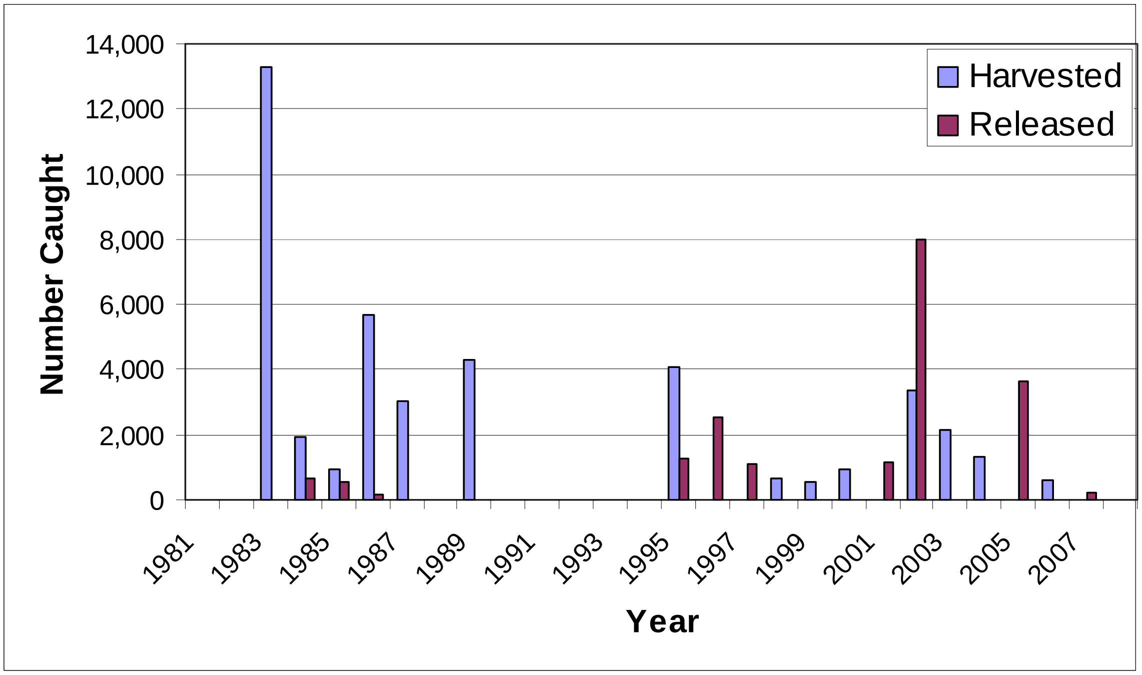


Figure 39. Reported Maryland charter boat harvest for black drum in numbers, 1993-2008.

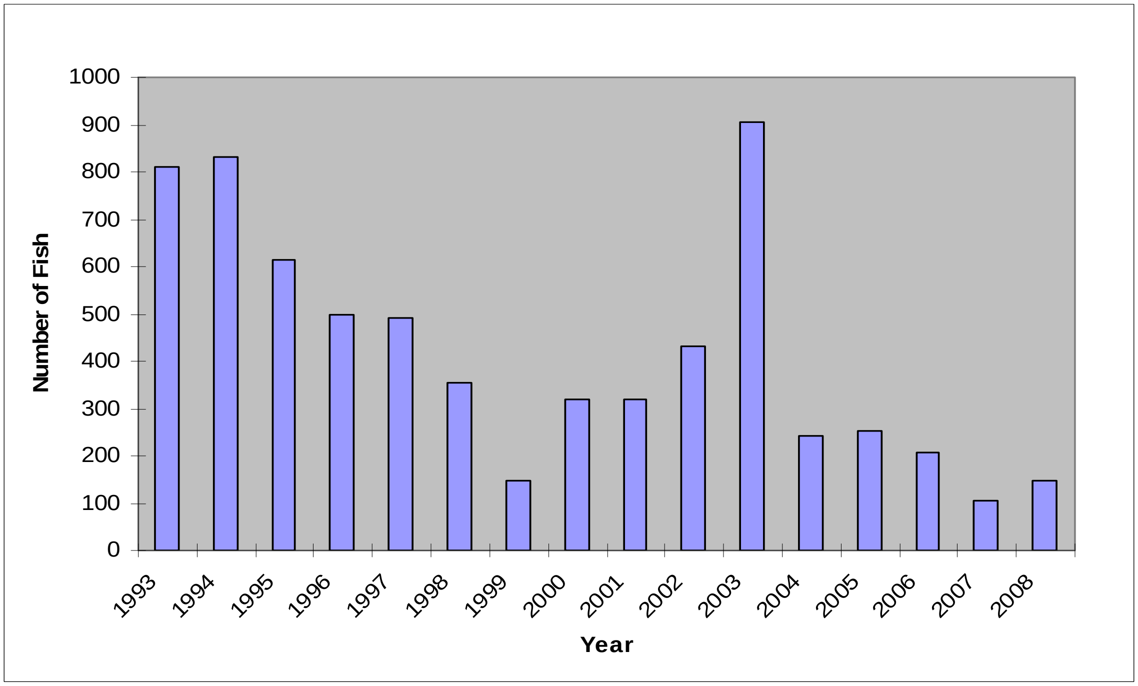


Figure 40. Black drum arithmetic mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

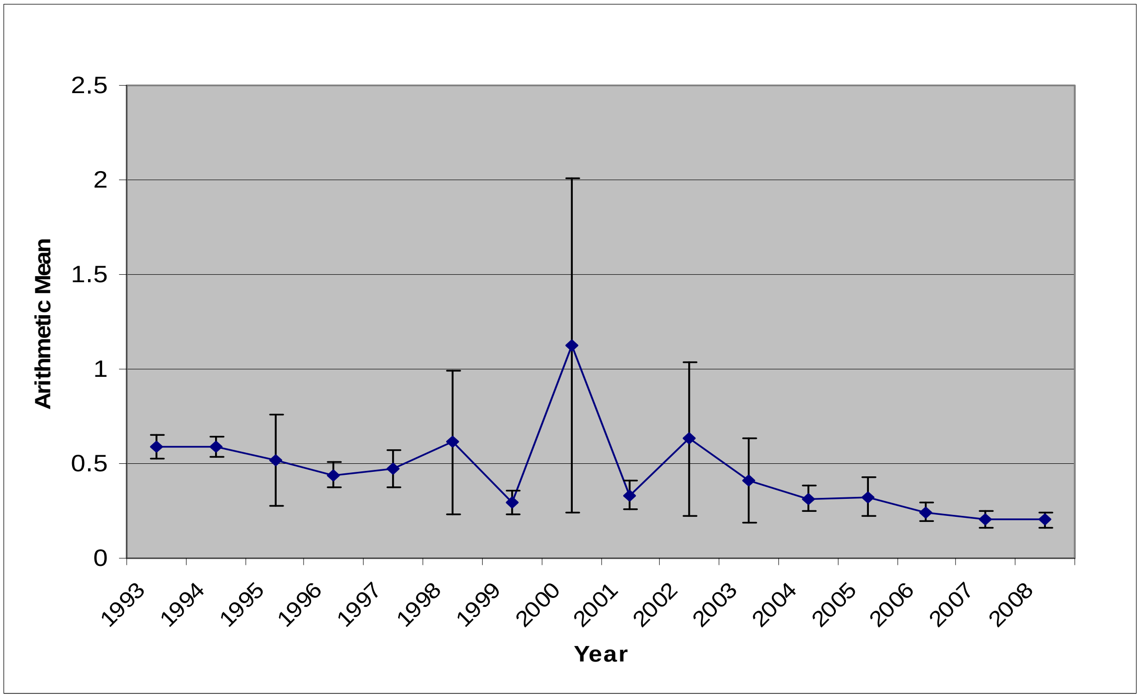


Figure 41. Black drum geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

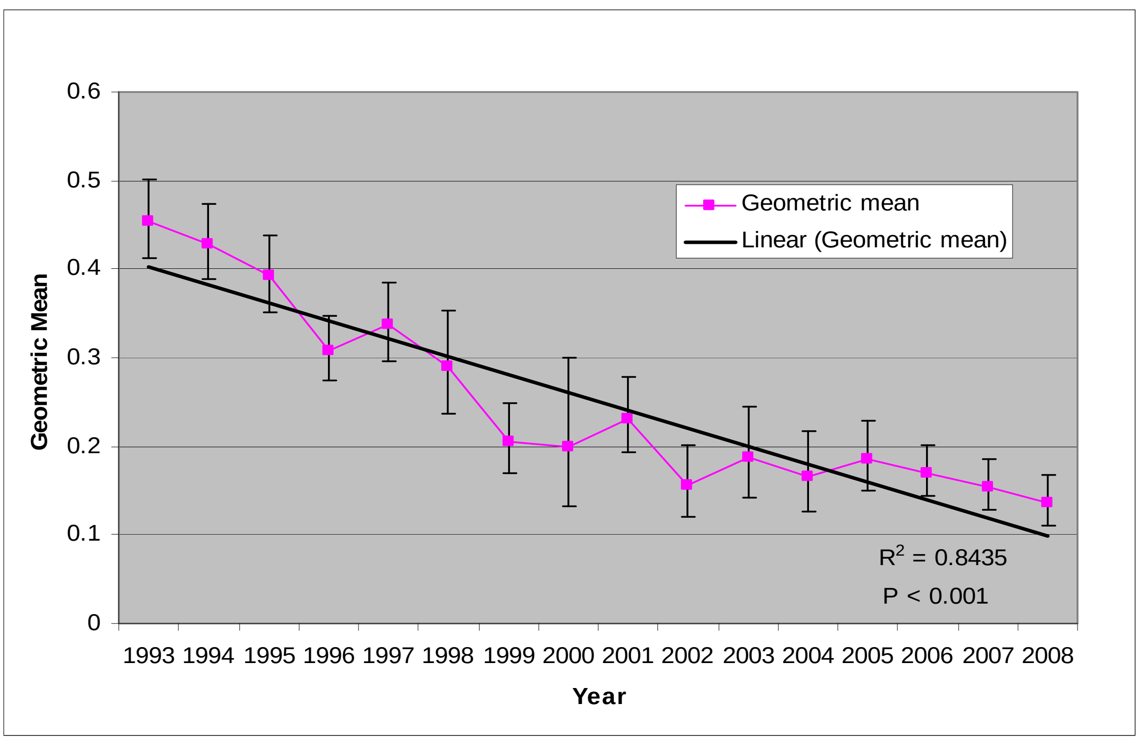


Figure 42. Spanish mackerel 2009 length frequency distribution from seafood dealer sampling.

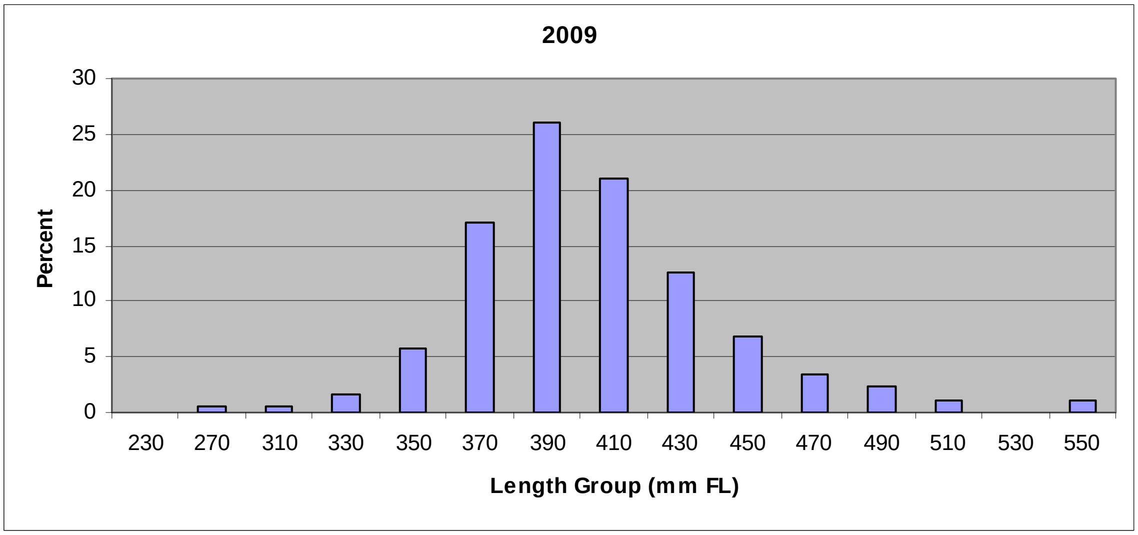


Figure 43. Maryland commercial Spanish mackerel harvest by area, 1965-2008.

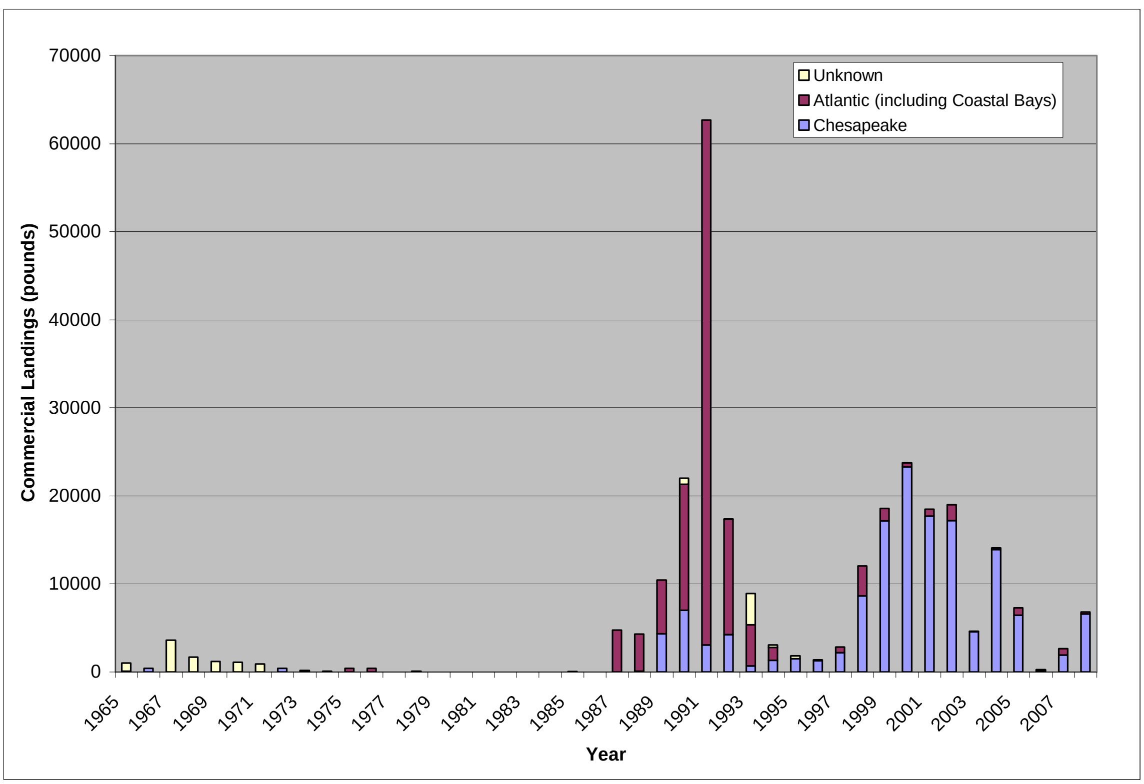


Figure 44. Estimated Maryland recreational Spanish mackerel harvest and releases for 1981-2008 (Source: MRFSS, 2009).

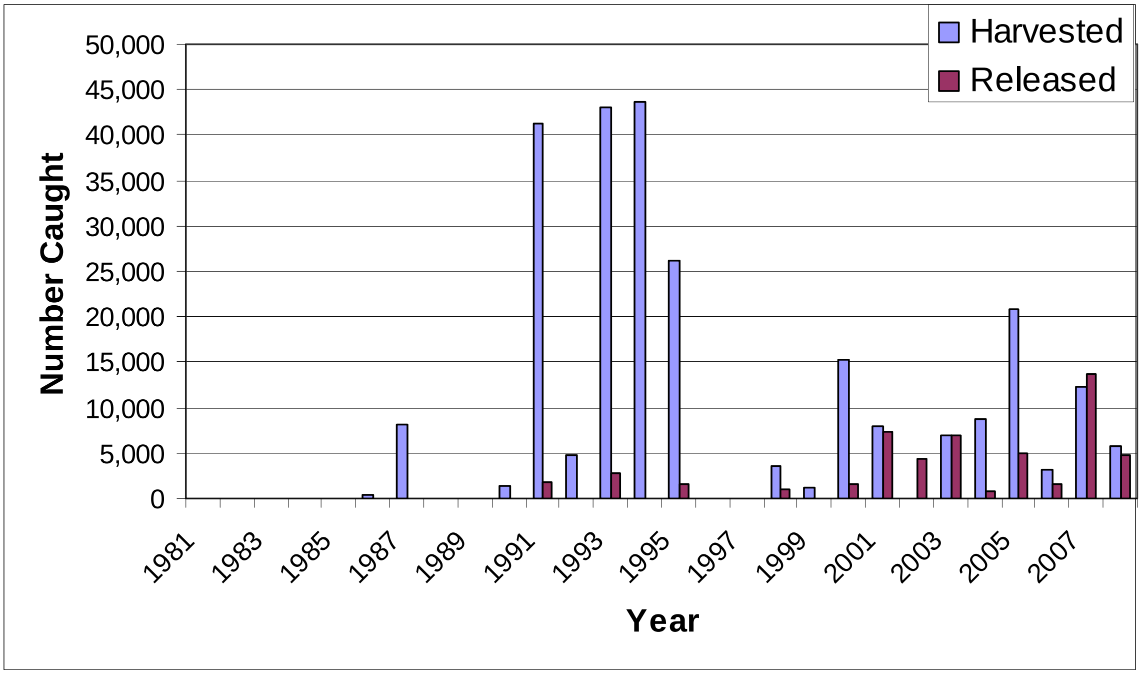


Figure 45. Spanish mackerel statewide MRFSS harvest, MRFSS for hire inland harvest and Maryland reported charter boat harvest in numbers, 1993-2008.

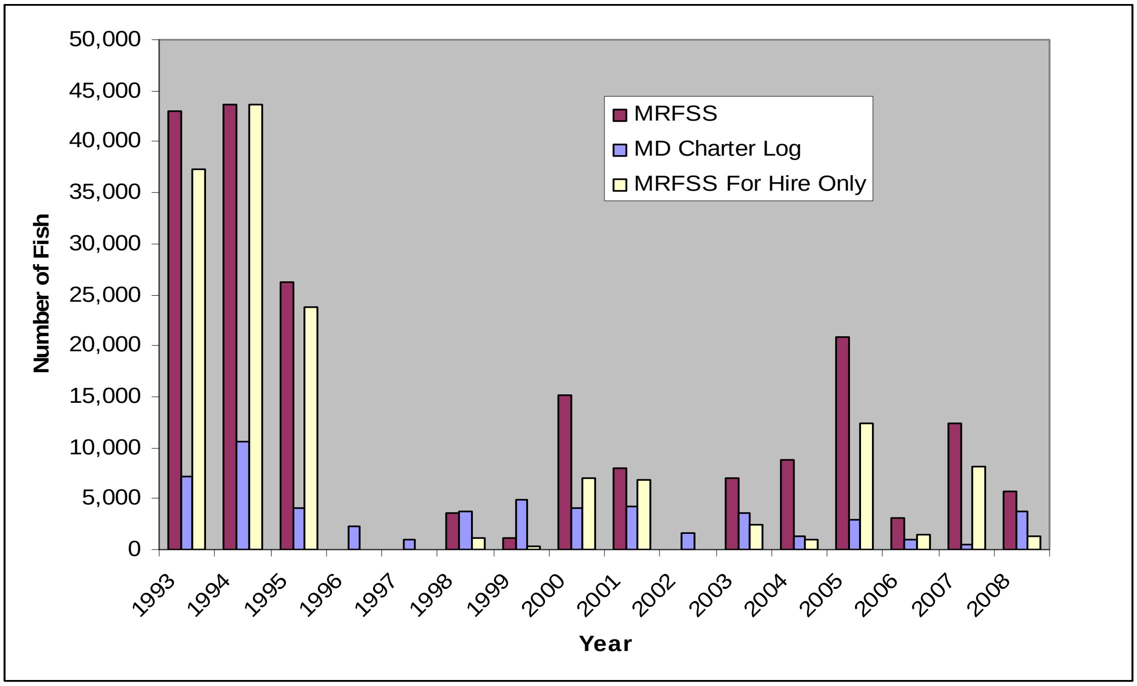


Figure 46. Spanish mackerel geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

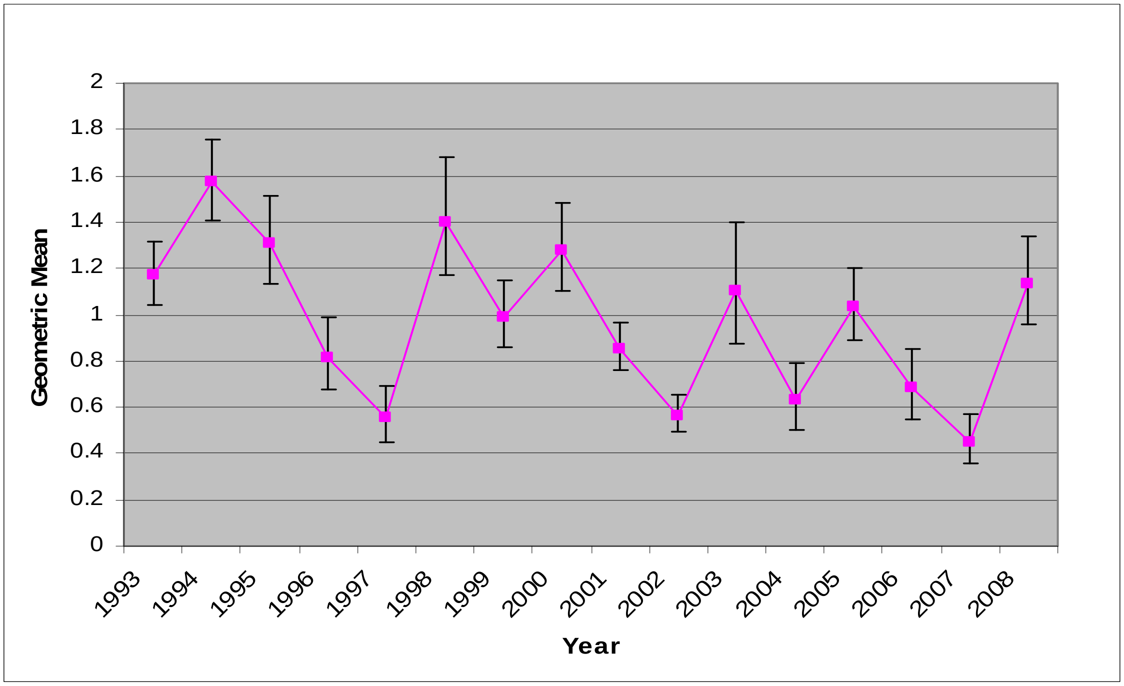


Figure 47. Maryland commercial spotted seatrout harvest by area, 1944-2008.

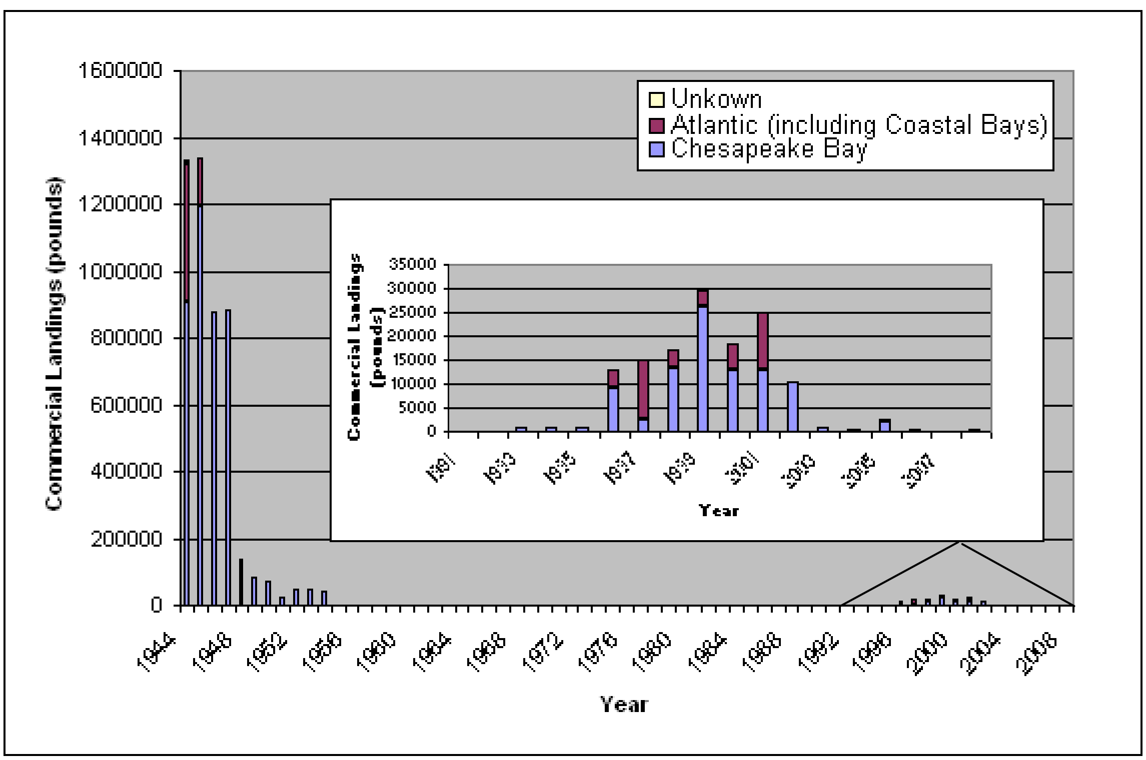


Figure 48. Estimated Maryland recreational spotted seatrout harvest and releases for 1981-2008 (Source: MRFSS, 2009).

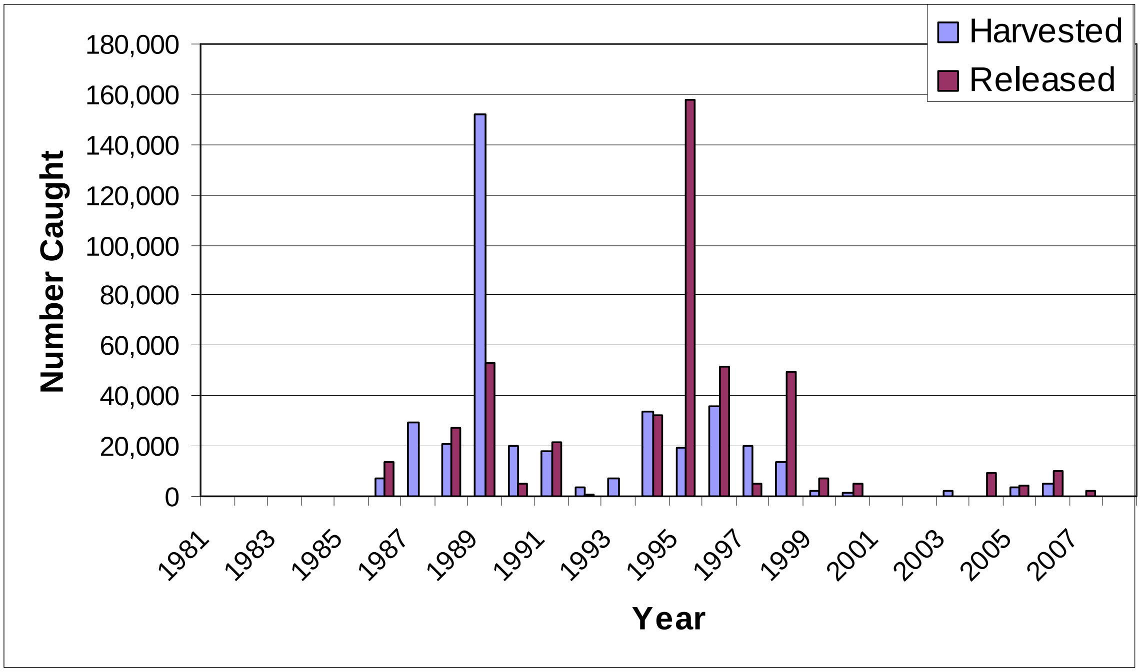


Figure 49. Reported Maryland charter boat harvest for spotted seatrout in numbers, 1993-2008.

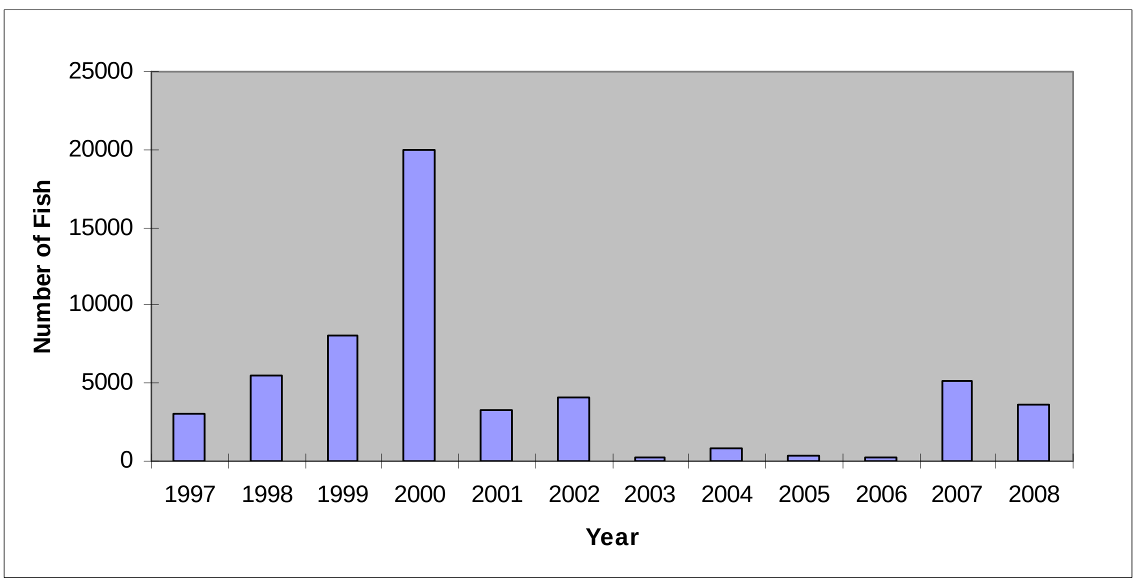


Figure 50. Spotted seatrout geometric mean catch per angler from Maryland charter boat logs, with 95% confidence intervals, 1993-2008.

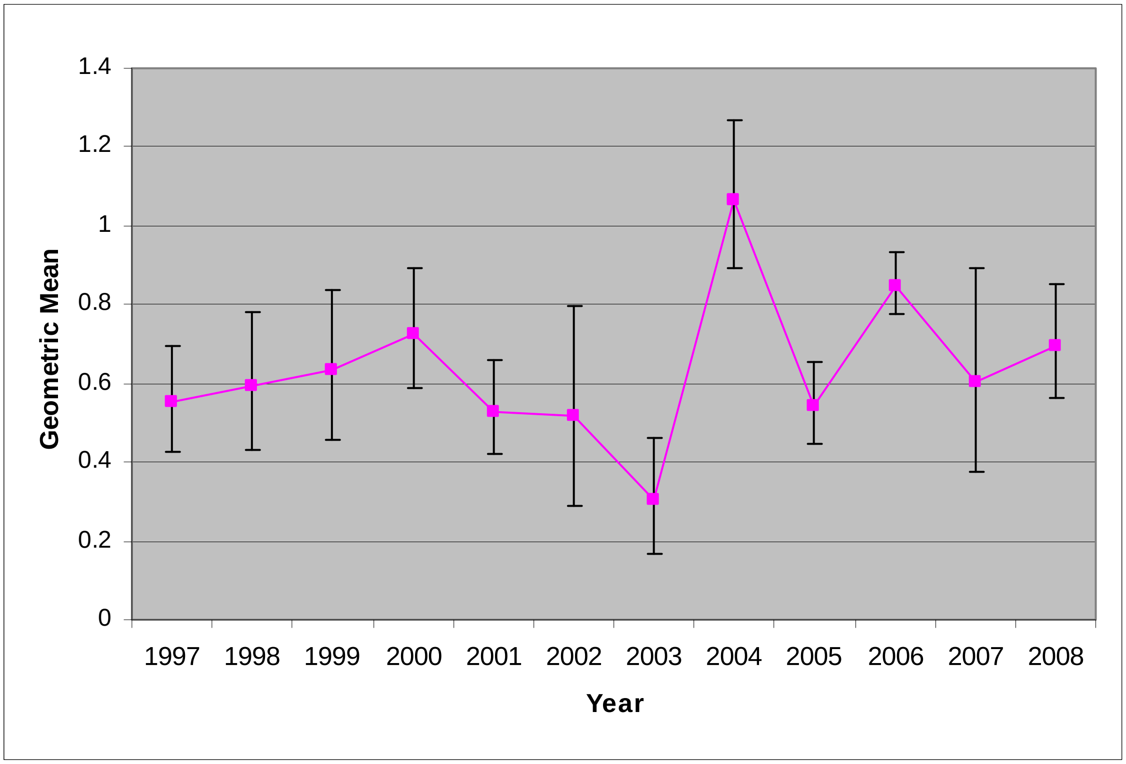


Figure 51. Menhaden length frequency distributions from onboard pound net sampling, 2006-2009.

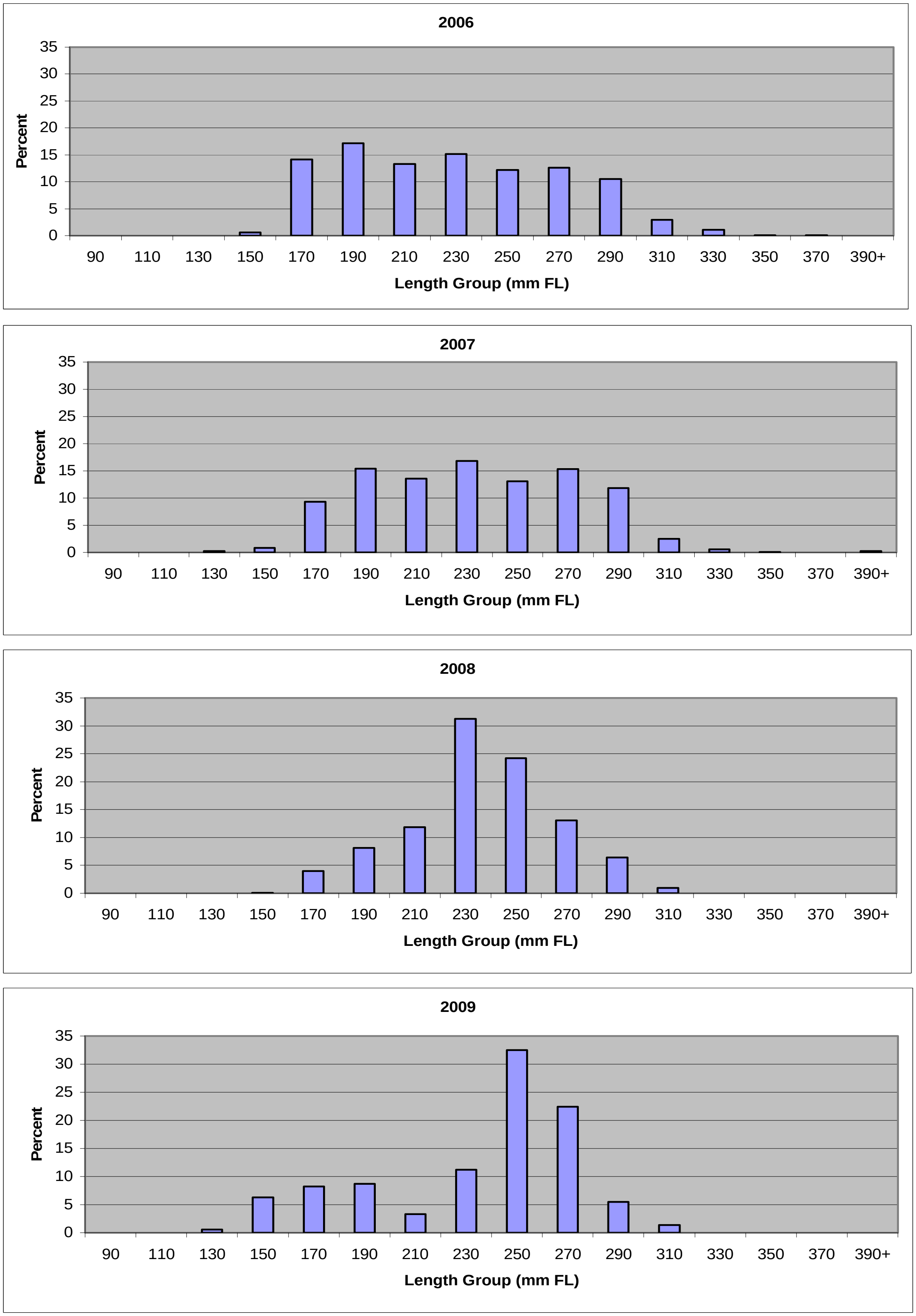


Figure 52. Atlantic menhaden 2009 length frequency distribution from seafood dealer sampling.

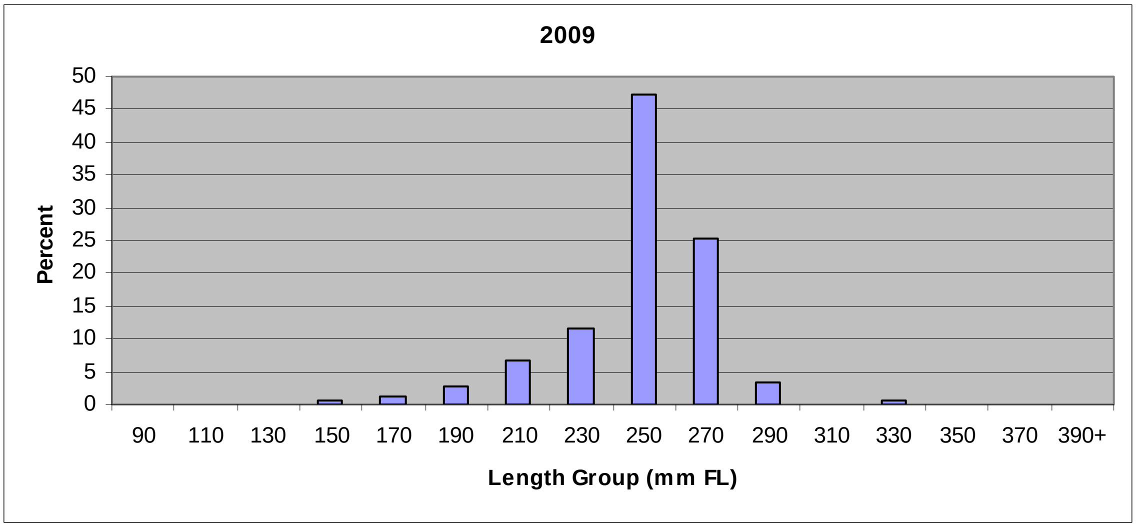
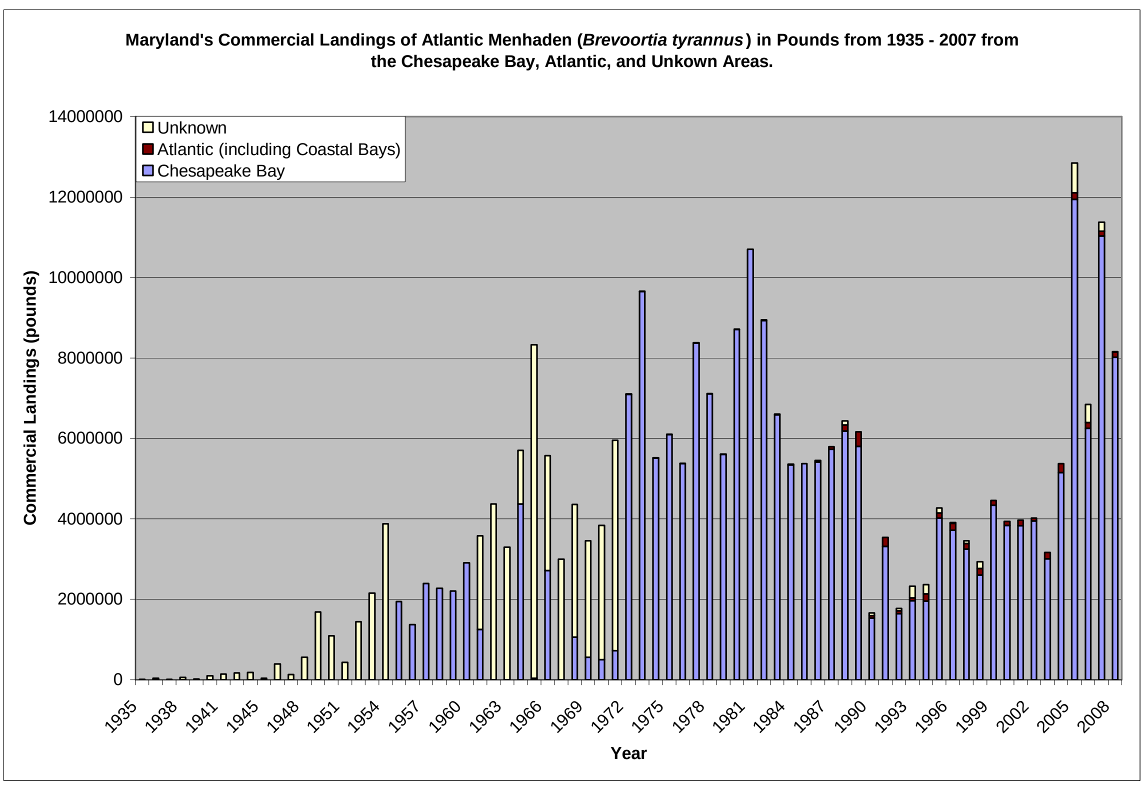


Figure 53. Maryland commercial Atlantic menhaden harvest by area, 1935-2008.



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 2008 Maryland striped bass (Morone saxatilis) commercial pound net and hook-and-line harvest. The 2008 pound net season ran from 2 June through 29 November while the commercial hook-and-line fishery was open from 16 June through 27 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 2008 commercial fisheries seasons were used to characterize the length and age structure of the entire 2008 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 was ascertained by adding a check station component to the commercial pound net monitoring (MDDNR 2002). This allowed for the direct comparison of the length distribution of striped bass sampled from pound nets to the length distribution of harvested striped bass sampled at check stations.

Pound net sampling occurred monthly from May through November 2008 (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 2008, striped bass were sampled from pound nets in the upper, middle, and lower Bay. Whenever possible, all striped bass in each pound net were measured in order to investigate by-catch. Full net sampling was not possible when pound nets contained too many fish to be transferred to FS boats. If a full net could not be sampled, a random sub-sample was taken.

At each net sampled, all striped bass were measured for total length (mm TL), and the presence and category of external anomalies were noted. Scales were removed from 3 fish per 10-millimeter length group per area, 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 fishery 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 2008 (Figure 1). For pound nets, sample targets of 100 fish per month from June through August and 200 fish per month were established for September through November. This monthly allocation reflects consistent historic pattern 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 the 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<300mm=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 2008 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 pound net and commercial 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, pound net, and hook-and-line check stations samples were examined.

RESULTS and DISCUSSION

Pound net monitoring

During the 2008 striped bass pound net study, 2,510 striped bass were sampled from two pound nets in the upper Bay, three pound nets in the middle Bay, and one pound net in the lower Bay. The six nets were sampled a total of 19 times during the study.

Striped bass sampled from pound nets ranged from 187-939 mm TL, with a mean length of 506 mm TL (Figure 2). In 2008, 74% of striped bass collected from full net samples were less than the minimum legal size of eighteen inches TL, while 21% 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 14 years of age (Table 3, Figure 2). Three year-old fish from the 2005 year-class contributed 13%, more age 3 fish than in 2007 (9%), but less than in 2006 (38%). Age 5 fish from the 2003 year-class occurred with the greatest frequency, composing 36% of the sample, more Age 5 fish than in 2007 (21%) (Figure 3, Table 3). Age 4 fish contributed 32% in 2008, which is less than the contribution in 2007 (51%). Striped bass age 6 and over were uncommon again in 2008, and accounted for 15.1% of the sample, slightly higher than their contribution in 2007 (11.7%). Fish age 8 and older composed 2.6% of the sample in 2008, which was double that of 2007 (1.2%). 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

Sixteen hundred and twenty six striped bass were sampled at hook-and-line check stations in 2008. The mean length of sampled striped bass was 504 mm TL. Striped bass sampled from the hook-and-line fishery ranged from 440 to 856 mm TL (Figure 4) and from 3 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 79% of the hook-and-line harvest, the same as in 2007 (79%; Figure 5). Fish greater than 650 mm TL contributed only 4% 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 primarily at the beginning of the season, and contributed just 1% to the overall harvest (Figure 6). Historically, these fish have not been available in large numbers during the summer (MDDNR 2002). Approximately 5% of the harvest was sub-legal (< 457 mm TL). Mean lengths-at-age and weights-at-age for the 2008 combined hook-and-line and pound net fisheries are shown in Tables 4 and 5.

The 2008 hook-and-line harvest accounted for 20%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2008 (see Project 2, Job 3, Task 5A). The estimated 2008 catch-at-age of the hook-and-line fishery is presented in Table 6. The majority of the harvest was composed of three to five year-old striped bass. Five year-old fish from the strong 2003 year-class accounted for 36% of the total, less than in 2007 (16%). Age 4 striped bass from the 2004 year-class contributed 42%, less than their contribution in 2007 (Figure 7). Age three fish from the 2005 year-class contributed 12% to the hook-and-line harvest, less than in 2007 (21%). Striped bass age 7 and older contributed very little to the overall harvest in 2008 (5%), but is more than in 2007 (3%).

Pound net check station sampling

Eight hundred and eighty four striped bass were sampled at pound net check stations in 2008. Striped bass sampled ranged from 447 to 884 mm TL (Figure 4). Legal-sized striped bass sampled from the pound net fishery ranged from 3 to 12 years of age. Striped bass in the 450 -530 mm TL length groups accounted for 65% of the 2008 pound net harvest, which is similar to 2007 (66%; Figure 5). The contribution of striped bass in the 570–630 mm TL length groups decreased from 21% in 2007 to 17% in 2008. Fish greater than 650 mm TL composed 9% of the sample, similar to 2007 (10%). In general, few large fish were available to the 2008 fishery (Figure 6). Mean lengths-at-age and weights-at-age from the 2008 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 2008 commercial harvest. The estimated 2008 catch-at-age for the pound net fishery is presented in Table 6. Fish age four to six contributed 84% of the 2008 total pound net harvest. Five year-old fish from the 2003 year-class dominated the pound net harvest in 2008, contributing 44% to the total harvest (Figure 7). Striped bass age 8 and over composed 4% of the 2008 harvest, double the contribution in 2007 (2%). Sub-legal striped bass (< 457 mm TL) comprised 1% of the total pound net harvest.

Monitoring summary

Striped bass ranging from 457 to 550 mm TL comprised 74% and 87%, respectively, of the 2008 pound net and hook and line fisheries, with few large fish being harvested from either fishery (Figure 5). In 2008, 124 fish from pound net monitoring and 69 fish from check station sampling were aged. Older fish were again scarce throughout the summer. Smaller fish, especially the 2003 year-class, were more abundant, accounting for the majority of the harvest (Figure 7). Length frequencies of fish sampled from pound nets and check stations were almost identical, except more 470 mm length group fish were caught in the hook and line fishery (Figure 4).

Bay-wide, the mean lengths of 4, 5, and 6 year-old legal-sized striped bass (≥457 mm TL) decreased during the period 1990 to 2000 (Figure 8). Since 2001, there was no apparent trend for mean lengths of striped bass aged 4 to 6. A Duncan's Test was performed to compare lengths and weights of striped bass harvested between fisheries and months. Striped bass were significantly longer 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 July and the smallest in August. 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 June and the smallest in October. Striped bass from July, September and November were all similar in length and weight. Striped bass from August were slightly smaller than fish harvested in June, but larger than fish harvested in July, September, 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. N. Am. J. Fish Manag. 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.

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 2008 Maryland Chesapeake Bay commercial pound net monitoring survey.

Month	**Area**	**Number of Nets Sampled**	**Mean Water Temp. °C**	**Mean Salinity (ppt)**	**Number of Fish Sampled**
May	Upper	-	-	-	-
	Middle	2	17.1	8.3	249
	Lower	2	17.1	9.7	271
June	Upper	-	-	-	-
	Middle	3	23.1	8.5	320
	Lower	-	-	-	-
July	Upper	1	25.3	6.8	61
	Middle	1	27.8	10.4	30
	Lower	1	25.4	10.6	28
September	Upper	-	-	-	-
	Middle	1	25.8	13.0	126
	Lower	2	22.7	15.6	359
October	Upper	-	-	-	-
	Middle	2	20.4	14.7	319
	Lower	3	20.1	16.8	705
November	Upper	1	11.3	9.2	42
	Middle	-	-	-	-
	Lower	-	-	-	-

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, May through November 2008.

Year-class	Age	n	Mean length (mm TL)	STD	STDERR	LCLM	UCLM
2007	1	17	270	64	16	237	303
2006	2	7	334	66	25	274	395
2005	3	20	383	41	9	364	403
2004	4	15	482	56	15	450	513
2003	5	18	570	78	18	532	610
2002	6	8	644	77	27	579	708
2001	7	14	678	82	22	631	726
2000	8	12	711	56	16	676	747
1999	9	3	745	25	14	684	806
1998	10	5	779	72	32	690	868
1997	11	2	879	33	24	-	-
1996	12	2	892	66	47	-	-
1994	14	1	910	-	-	-	-

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, May through November 2008.

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2007	1	82	2.42
2006	2	46	1.36
2005	3	448	13.20
2004	4	1,100	32.41
2003	5	1,207	35.56
2002	6	239	7.04
2001	7	185	5.45
2000	8	63	1.86
1999	9	5	0.15
1998	10	8	0.24
1997	11	5	0.15
1996	12	5	0.15
1994	14	1	0.03
Total		**3,394**	**100.00**

Table 4. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) for ages 3-12 sampled from commercial pound net and hook-and-line fisheries in Maryland's Chesapeake Bay, June through November 2008.

Year-class	Age	n	Mean Length (mm TL)	STD	STDERR	LCLM	UCLM
2005	3	2	473	10	7	390	555
2004	4	4	484	37	19	424	543
2003	5	22	591	60	13	564	618
2002	6	8	617	53	19	572	661
2001	7	17	698	53	13	671	726
2000	8	9	757	55	18	714	799
1999	9	0	-	-	-	-	-
1998	10	2	801	14	10	674	928
1997	11	2	752	42	30	-	-
1996	12	3	833	65	38	672	995

Table 5. Mean weights-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 2008. Mean weights are weighted by the sample n-at-length in each age.

Age	Year-class	n Aged	Weighted Mean weight* (kg)
3	2005	2	1.0
4	2004	4	1.1
5	2003	22	2.1
6	2002	8	2.5
7	2001	17	3.4
8	2000	9	4.4
9	1999	0	-
10	1998	2	6.0
11	1997	2	4.7
12	1996	3	6.6

* 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 2008.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Numbers of Fish*	**Percent of Total**	**Landings in Numbers of Fish***	**Percent of Total**
2005	3	50,978	11.8	31,648	5.7
2004	4	181,610	42.1	167,102	29.9
2003	5	155,324	36.0	245,589	43.9
2002	6	22,568	5.2	55,068	9.8
2001	7	14,072	3.3	39,877	7.1
2000	8	5,310	1.2	15,191	2.7
1999	9	266	0.1	1,266	0.2
1998	10	797	0.2	1,266	0.2
1997	11	531	0.1	1,266	0.2
1996	12	266	0.1	1,266	0.2
Total**		**431,721**	**100.0**	**559,537**	**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 2008.

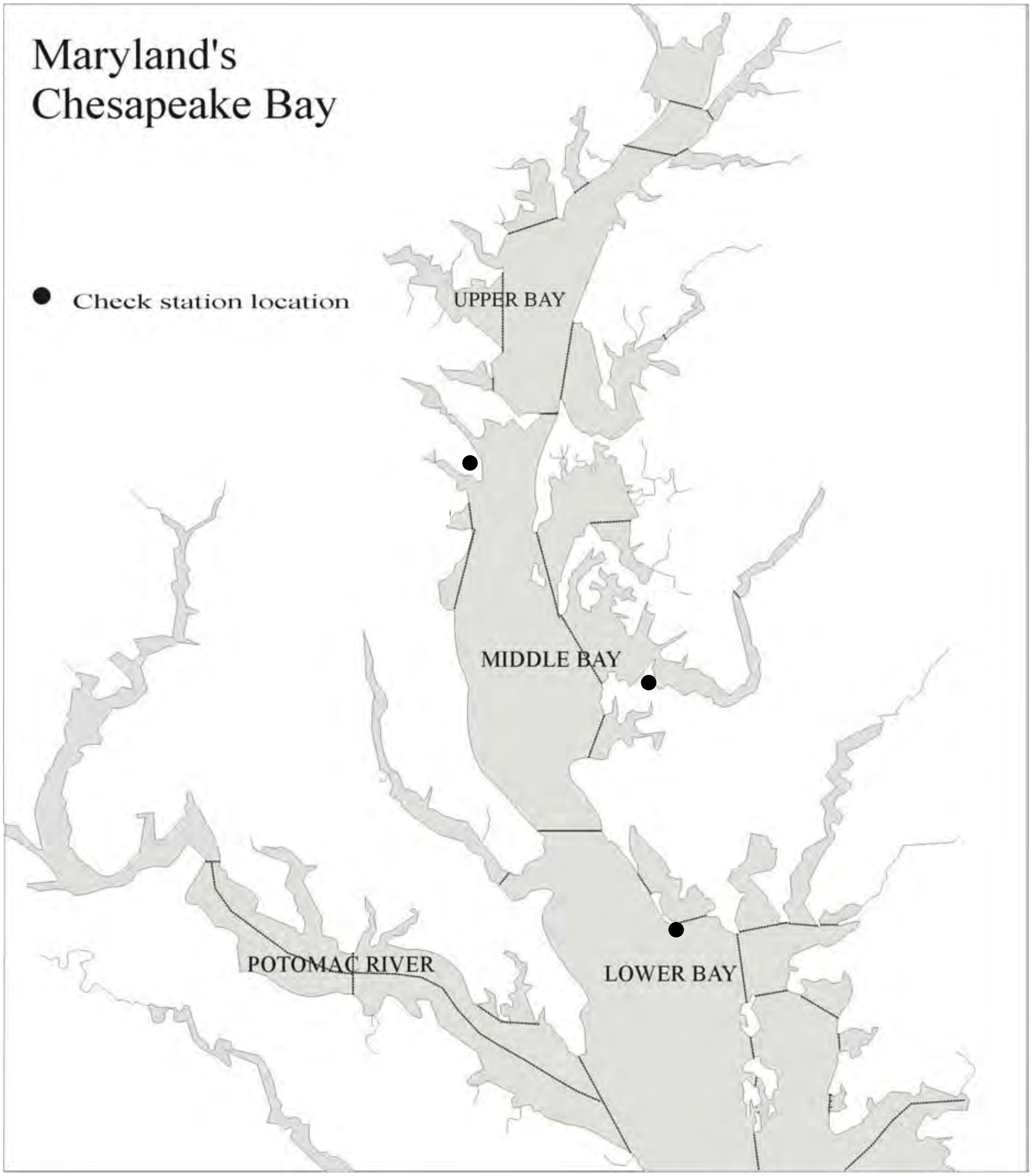
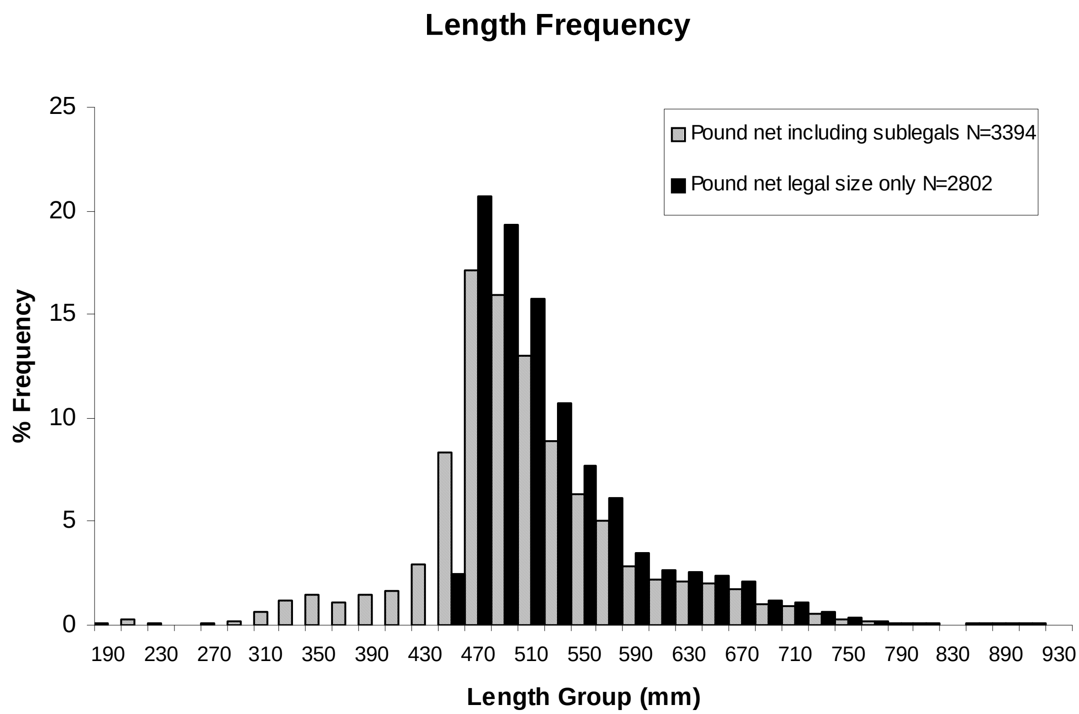


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, May through November 2008.



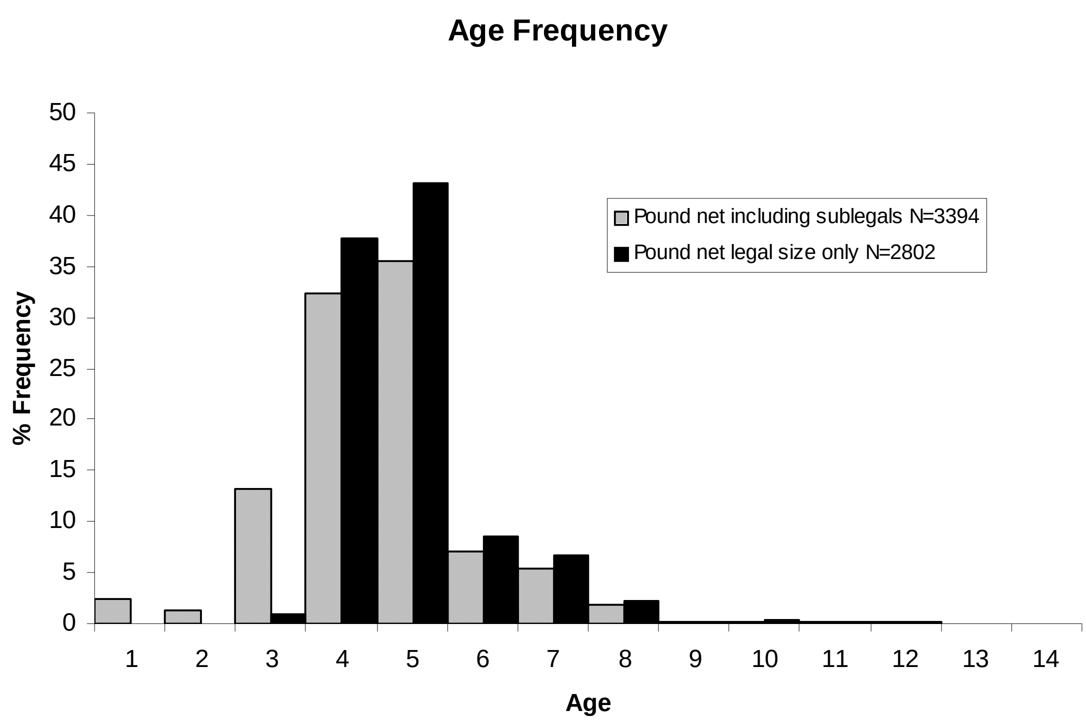


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2008.

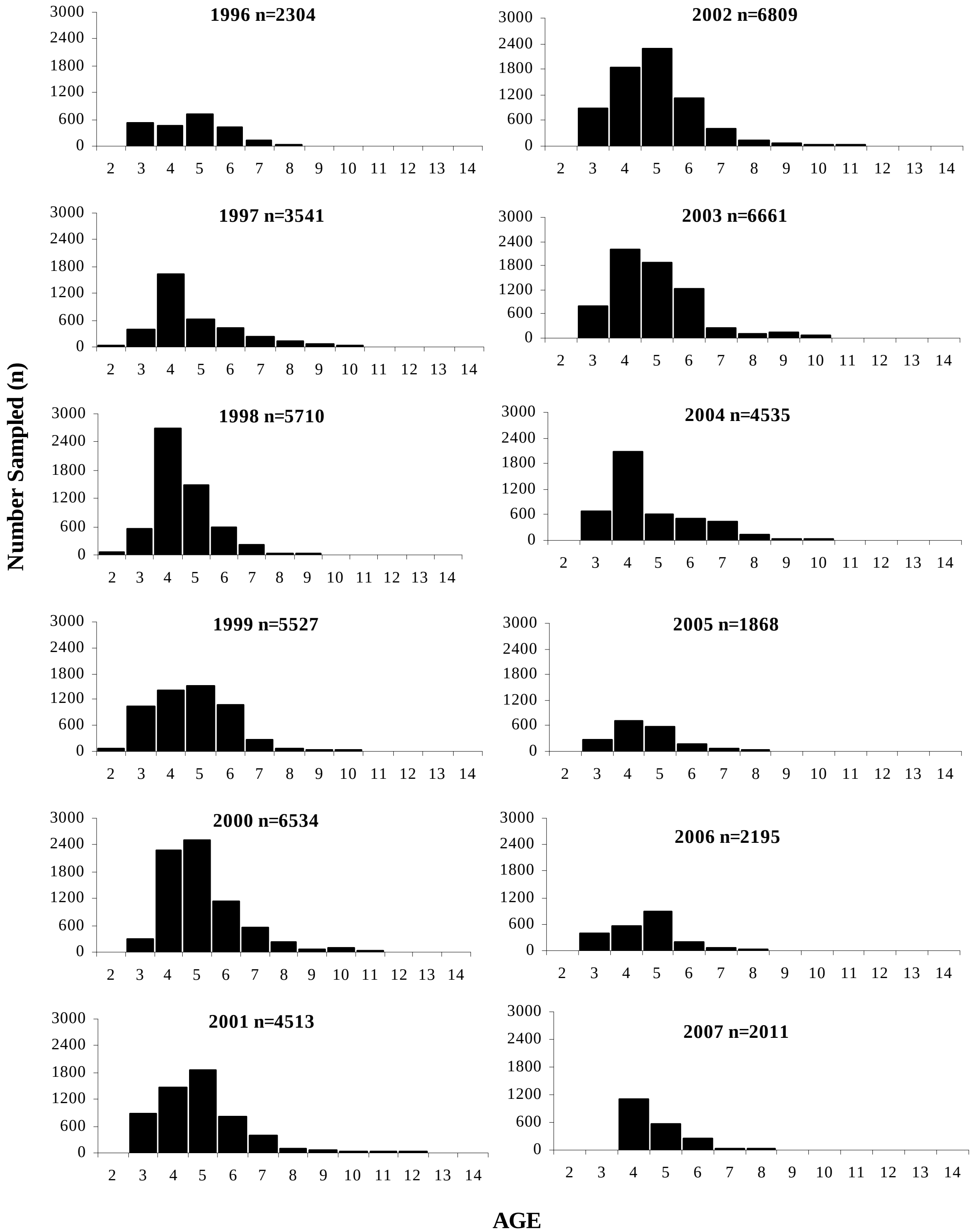


Figure 3 (continued).

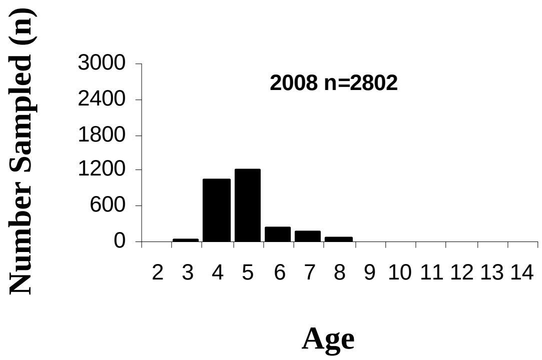


Figure 4. Length frequency of striped bass sampled during the 2008 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from May through November 2008. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

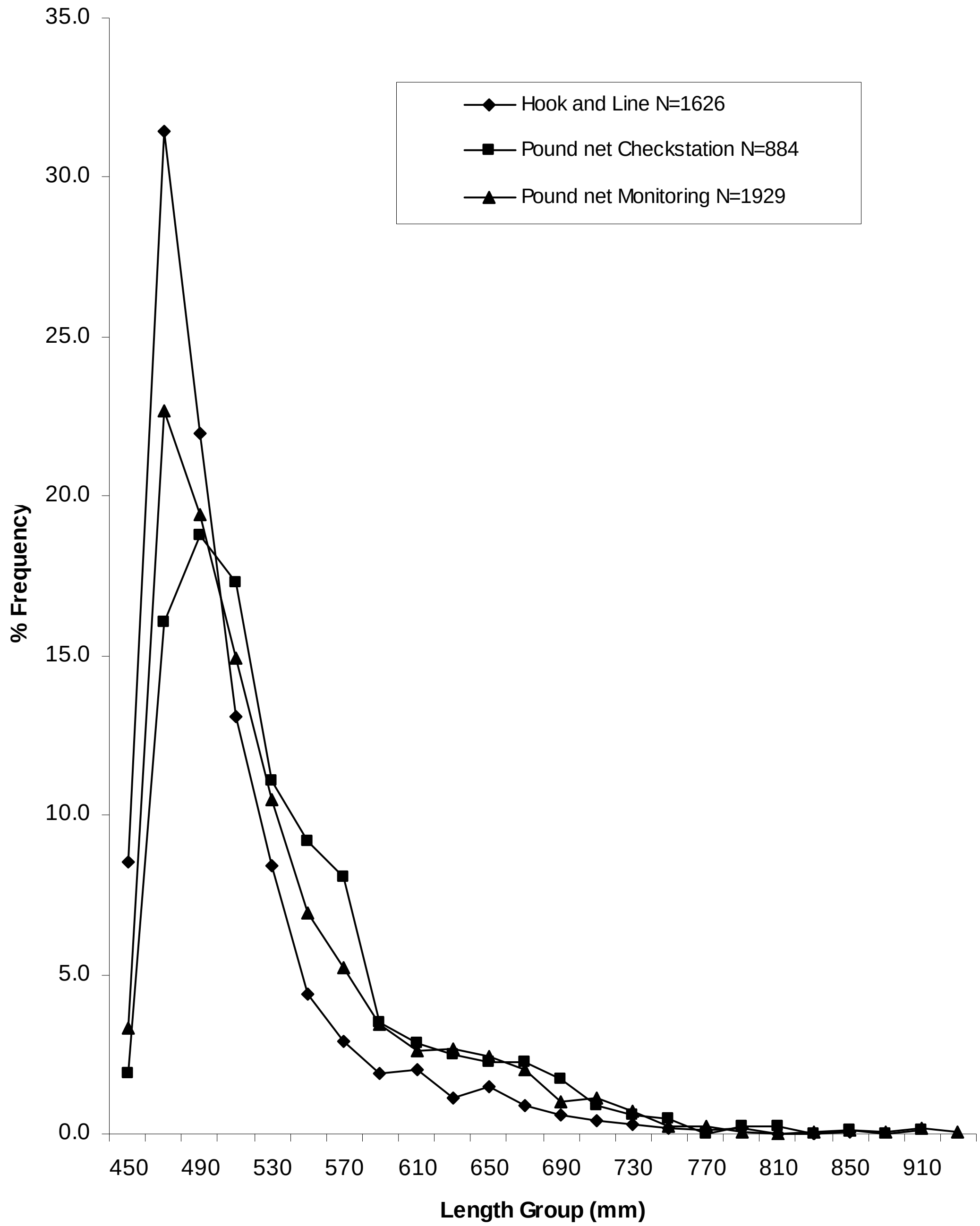
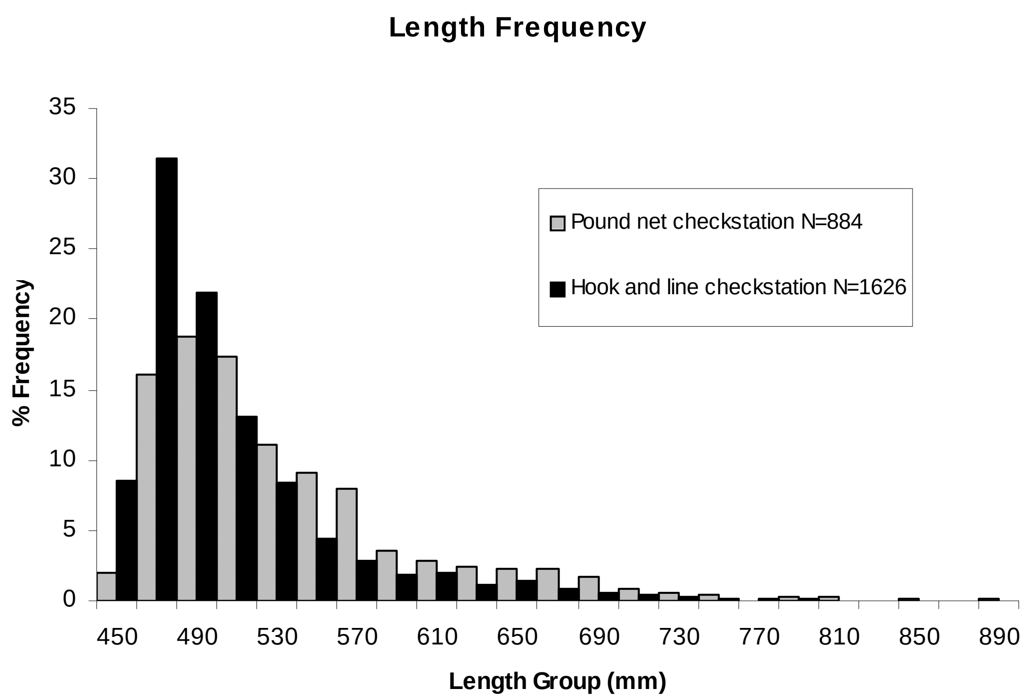


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2008.



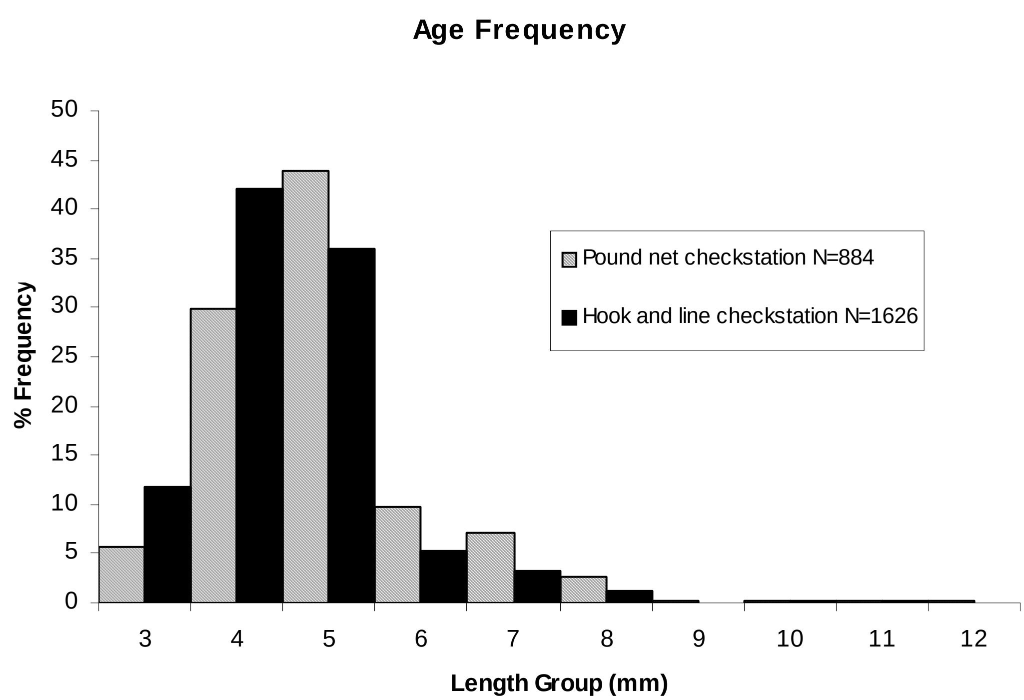


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2008. Note different scales.

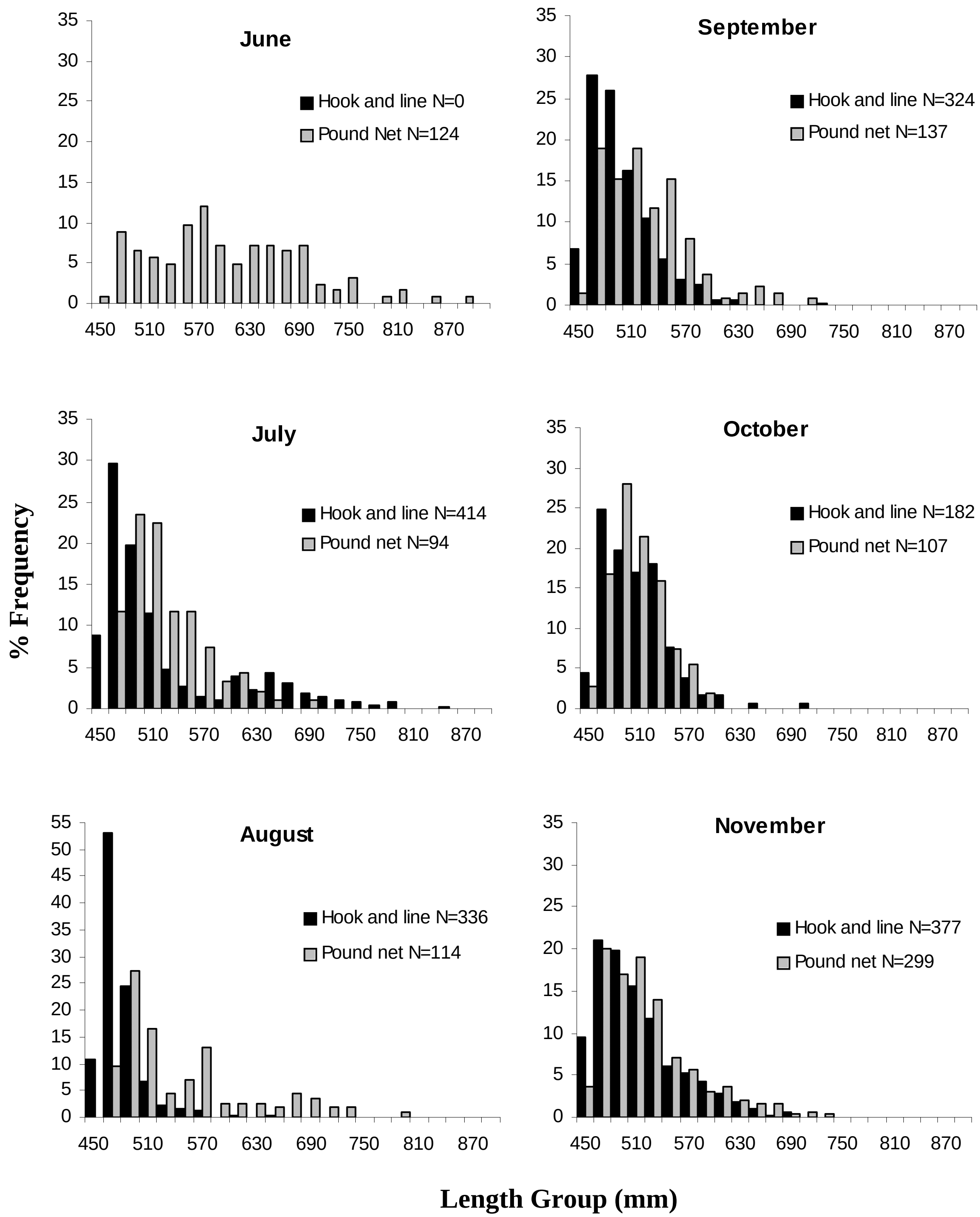


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2008. Note-pound net check station sampling began in 2000.

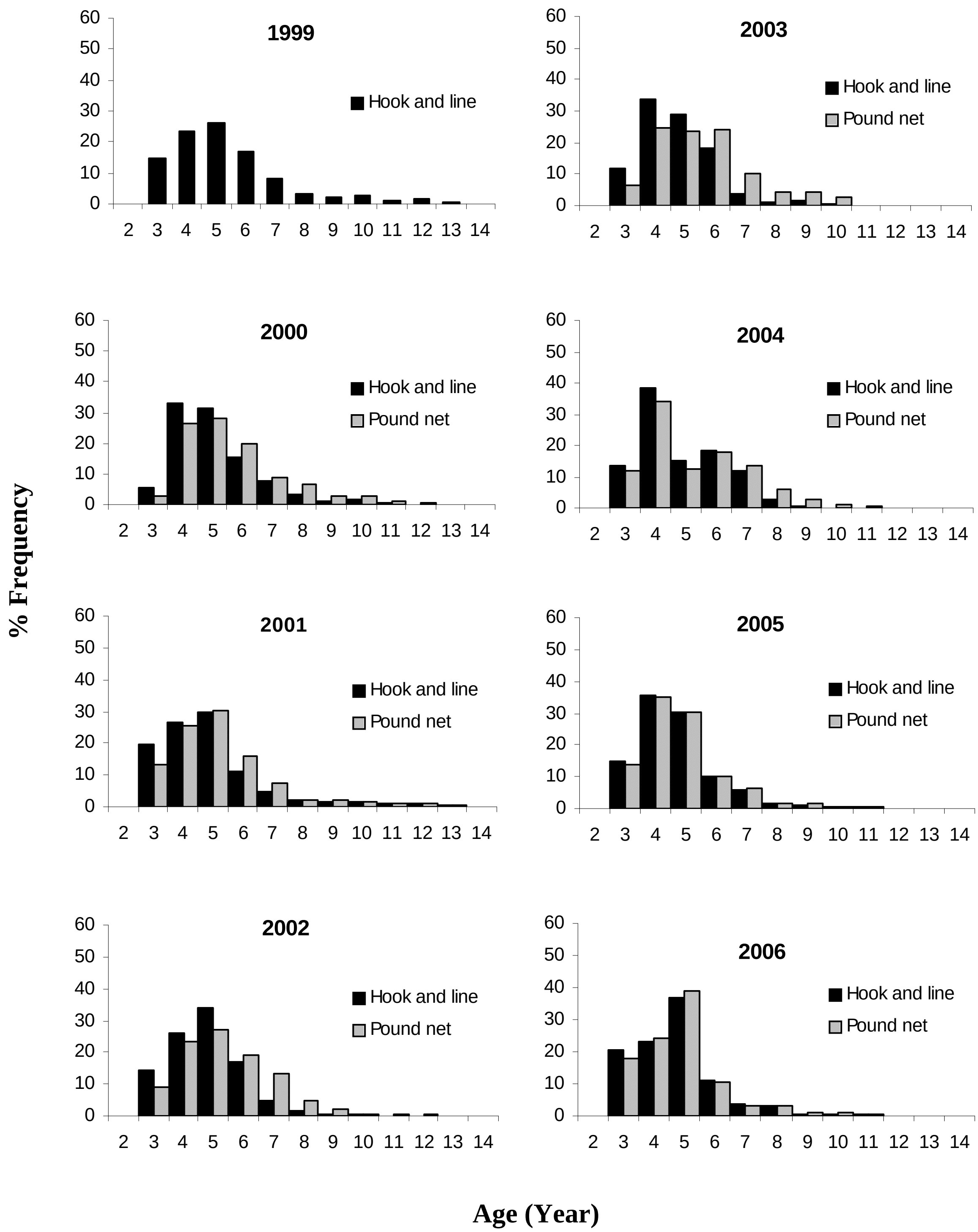


Figure 7 (cont.)

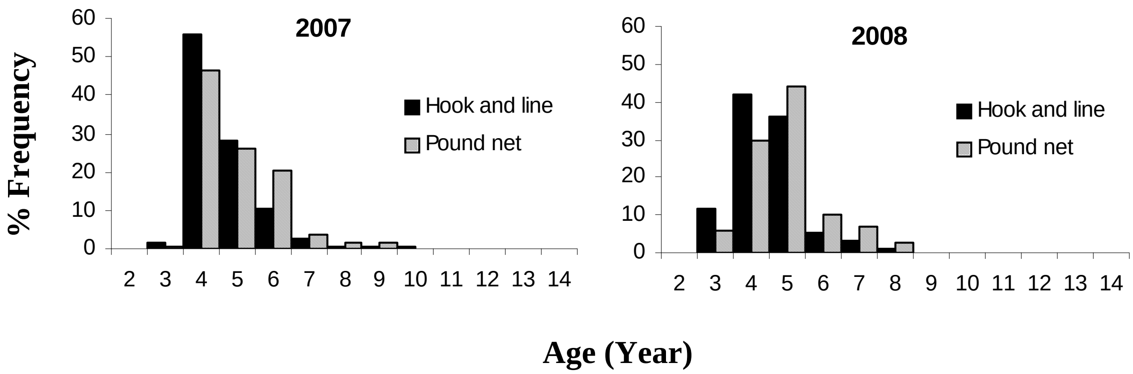
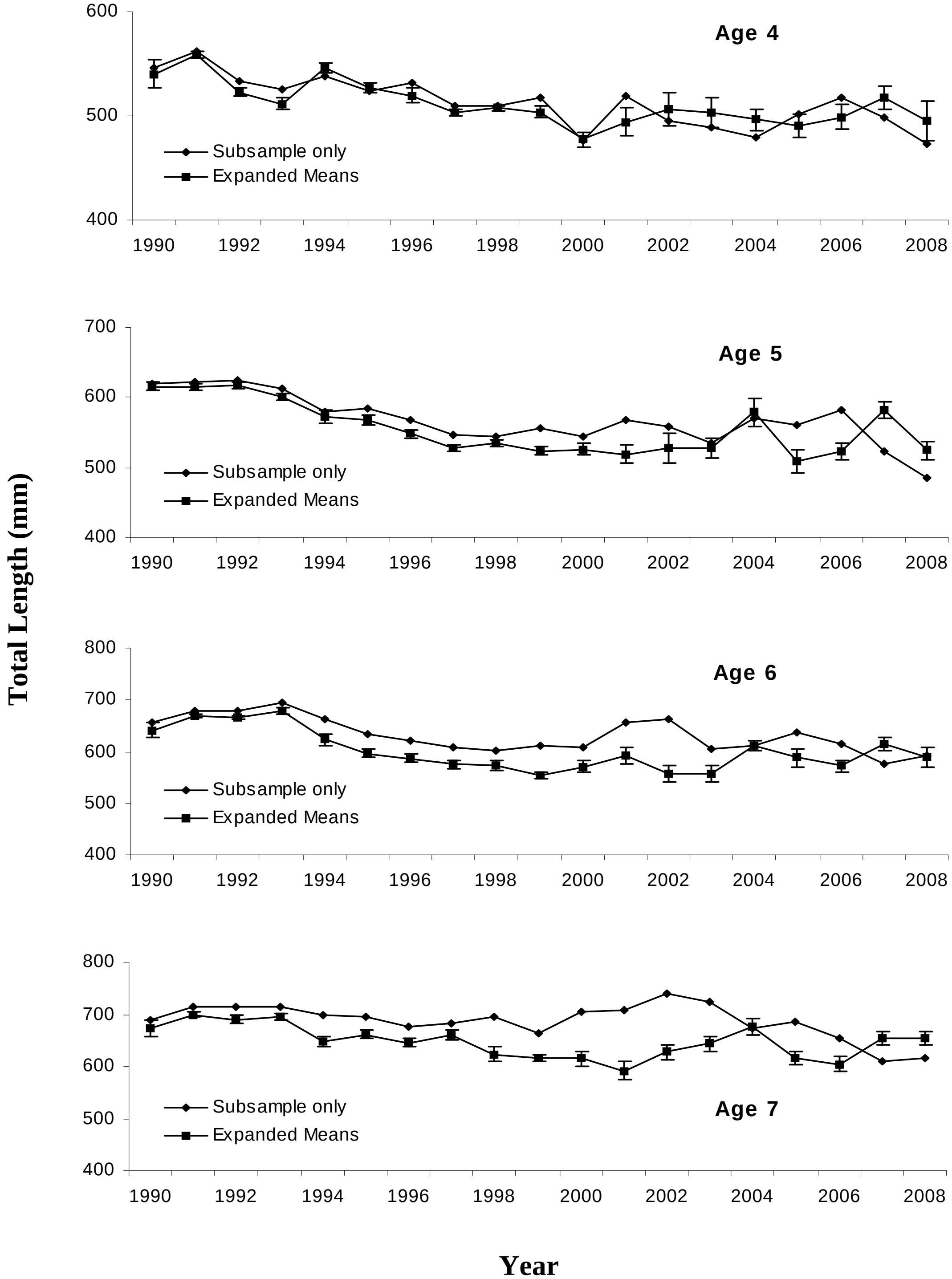


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations,1990 through 2008. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating means. The 95% confidence intervals are shown around points in the sub-sample data series.



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 structures of striped bass (*Morone saxatilis*) sampled from the December 1, 2008 - February 28, 2009 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. 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, 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. 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.

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 2008-2009 winter gill net harvest was estimated by applying the sample age distribution to the total 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 2008 – February 2009 gill net season, the year used for age calculations was 2009.

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). 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. 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. 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 2008-2009 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 55% of the total Maryland Chesapeake Bay commercial harvest, by weight, for 2008. A total of 3,842 were measured for total length, 3,841 were weighed, and 117 striped bass were aged from the December 2008 - February 2009 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 1994-1995 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 2008-2009 commercial drift gill net harvest consisted primarily of striped bass from the 2004 (age 5) year-class (Table 1), comprising 46% of the total harvest.

Year-classes 2005, and 2003 (ages 4 and 6) comprised an additional 51% of the total harvest, while age groups 8-13 contributed only 2% to the total. The contribution of fish greater than 8 years old was much lower than the 2007-2008 gill net harvest of 13% (Hoover 2008). The youngest fish observed in the 2008-2009 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 2008-2009 winter gill net fishery at age 3 (2006 year-class), with an expanded mean length and weight of 455 mm TL and 1.19 kg. The 2004 (age 5) year-class was most commonly observed in the sampled landings with an expanded mean length and weight of 517 mm TL and 1.69 kg, respectively. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 13, 1996 year-class) were 849 mm TL and 6.66 kg.

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 2% of the bay-wide sampled harvest.

Time series of sub-sampled and expanded mean lengths and weights for the period 1994-2009 are shown in Figures 4 and 5 for ages 4 through 9 (generally 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. Age 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.

Lai, H. L. 1987. Optimum allocation for estimating age composition using an age-length key. Fishery Bulletin. 85:179-183.

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 2008 - February 2009.

Year-Class	Age	Catch	Percentage of the Catch
2006	3	1,835	1
2005	4	104,669	33
2004	5	145,599	46
2003	6	54,743	17
2002	7	2,698	1
2001	8	2,309	1
2000	9	1,508	0
1999	10	726	0
1998	11	419	0
1997	12	91	0
1996	13	164	0
Total*		**314,761**	**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 2008-February 2009.

Year-Class	Age	n fish aged	Mean TL (mm) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean TL (mm)
2006	3	1	444	22	455
2005	4	12	481	1,278	486
2004	5	19	530	1,777	517
2003	6	34	636	668	572
2002	7	9	707	33	666
2001	8	16	765	28	714
2000	9	10	792	18	744
1999	10	8	860	9	857
1998	11	5	886	5	887
1997	12	1	817	1	811
1996	13	2	849	2	849
Total*		**117**		**3,842**	

Table 3. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2008-February 2009.

Year-Class	Age	n fish aged	Mean Weight (kg) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean weight (kg)
2006	3	1	1.03	22	1.19
2005	4	12	1.38	1,278	1.40
2004	5	19	1.88	1,777	1.69
2003	6	34	3.19	667	2.29
2002	7	9	4.17	33	3.53
2001	8	16	4.97	28	4.23
2000	9	10	5.65	18	4.92
1999	10	8	7.00	9	6.97
1998	11	5	7.56	5	7.43
1997	12	1	5.18	1	5.57
1996	13	2	6.47	2	6.66
Total*		**117**		**3,841**	

* 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 2008-February 2009.

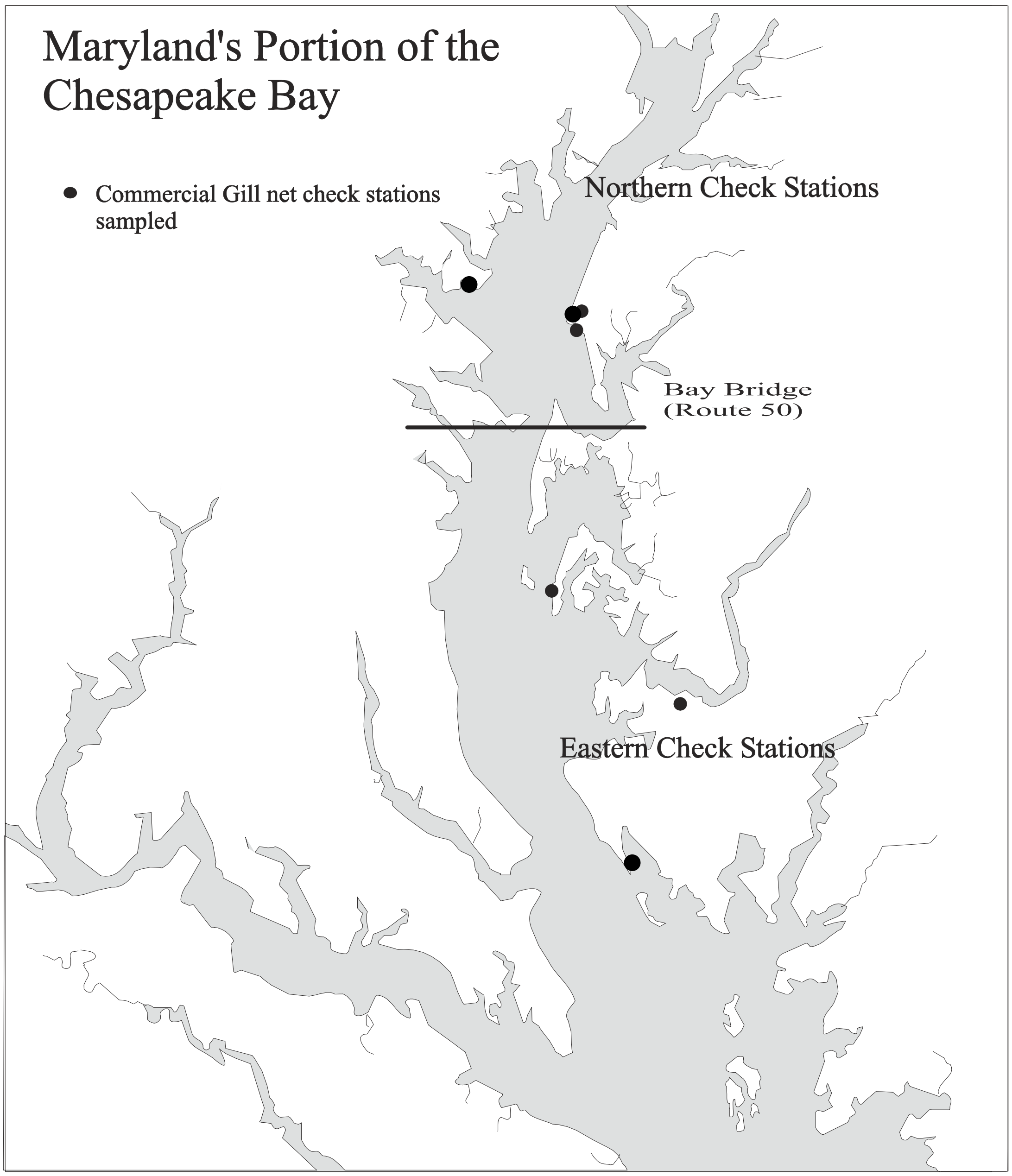


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2009.

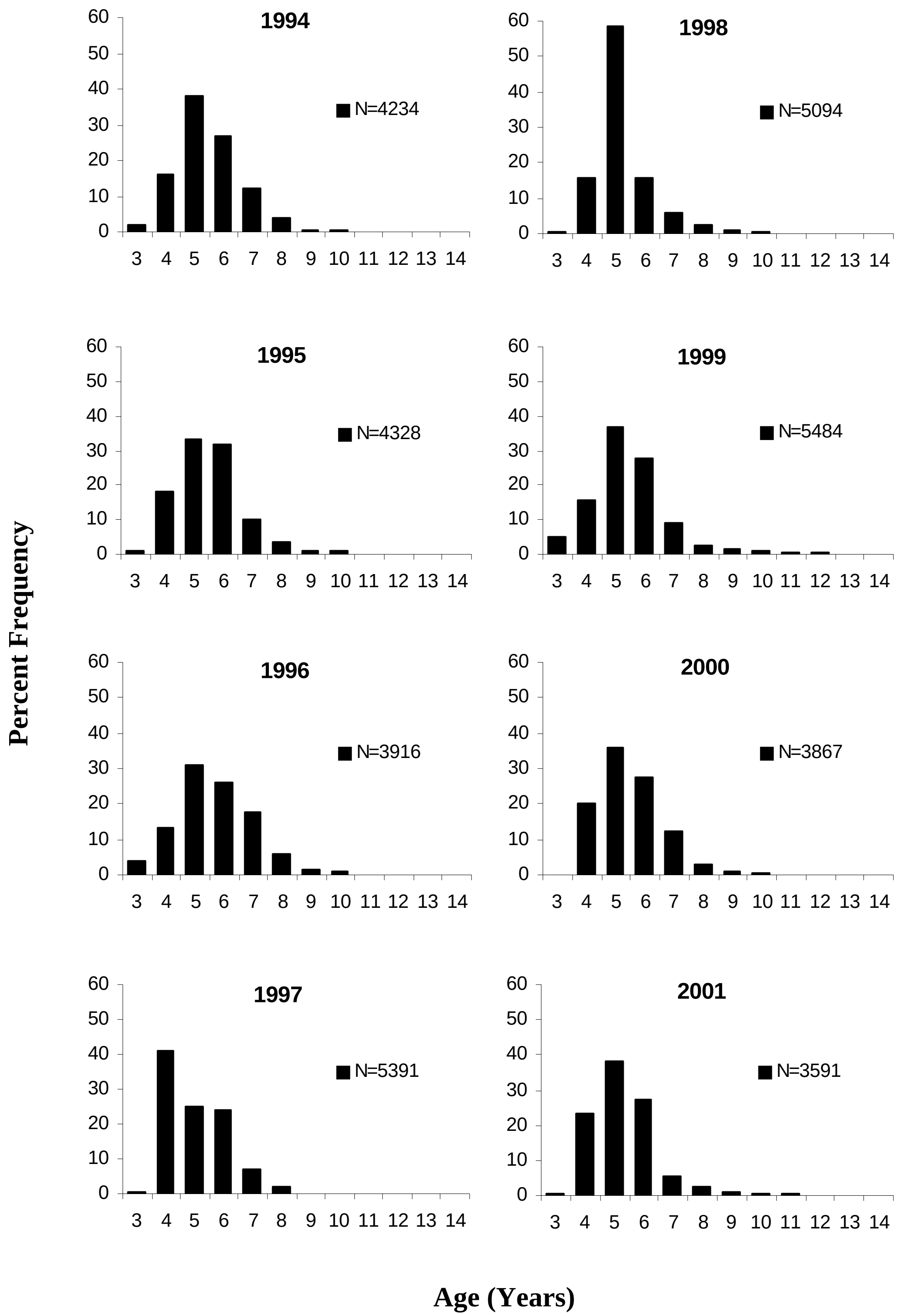


Figure 2. Cont.

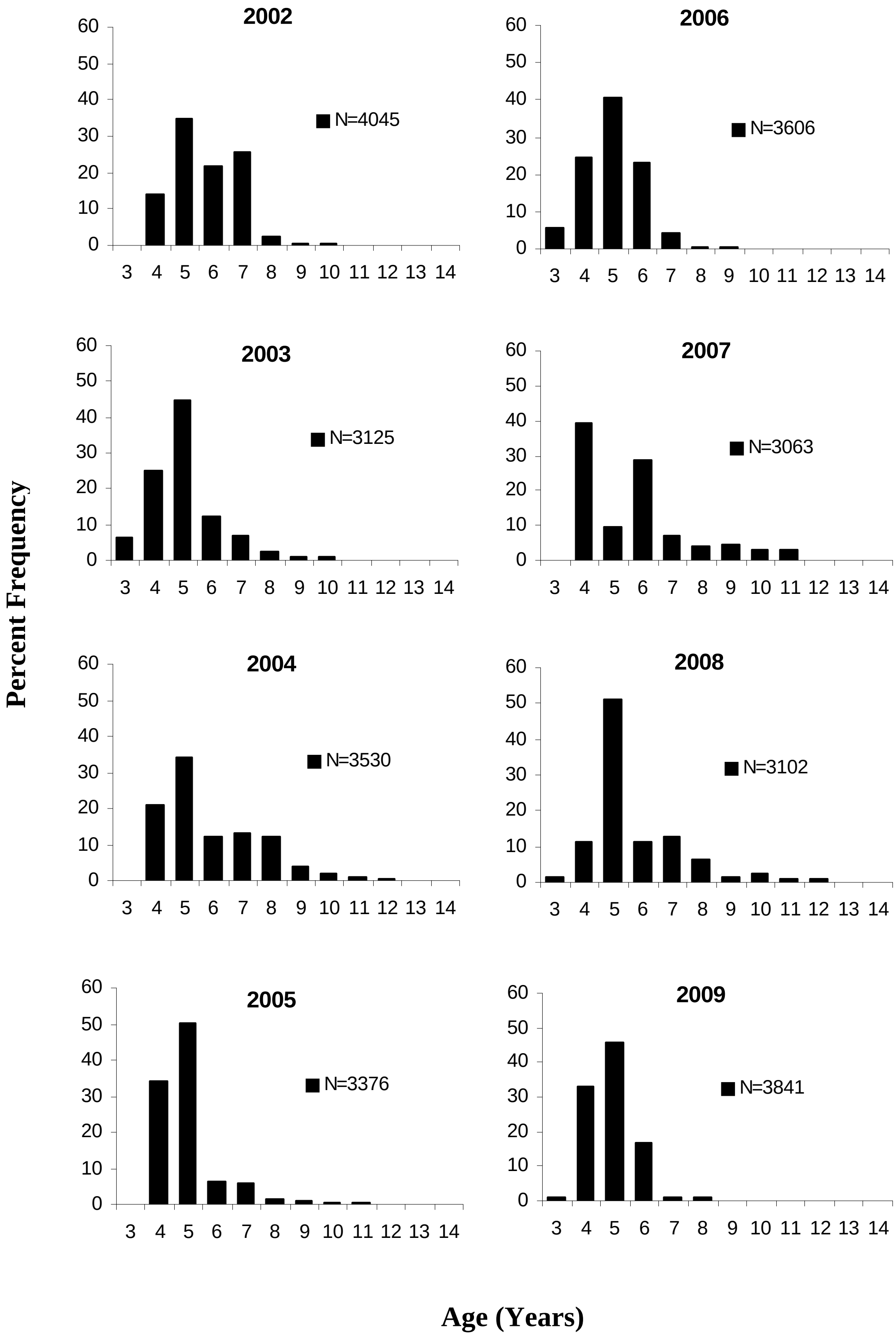


Figure 3. Length frequency distributions, by area and bay-wide, of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2008-February 2009. (Note: Scale for Frequency in Baywide is higher).

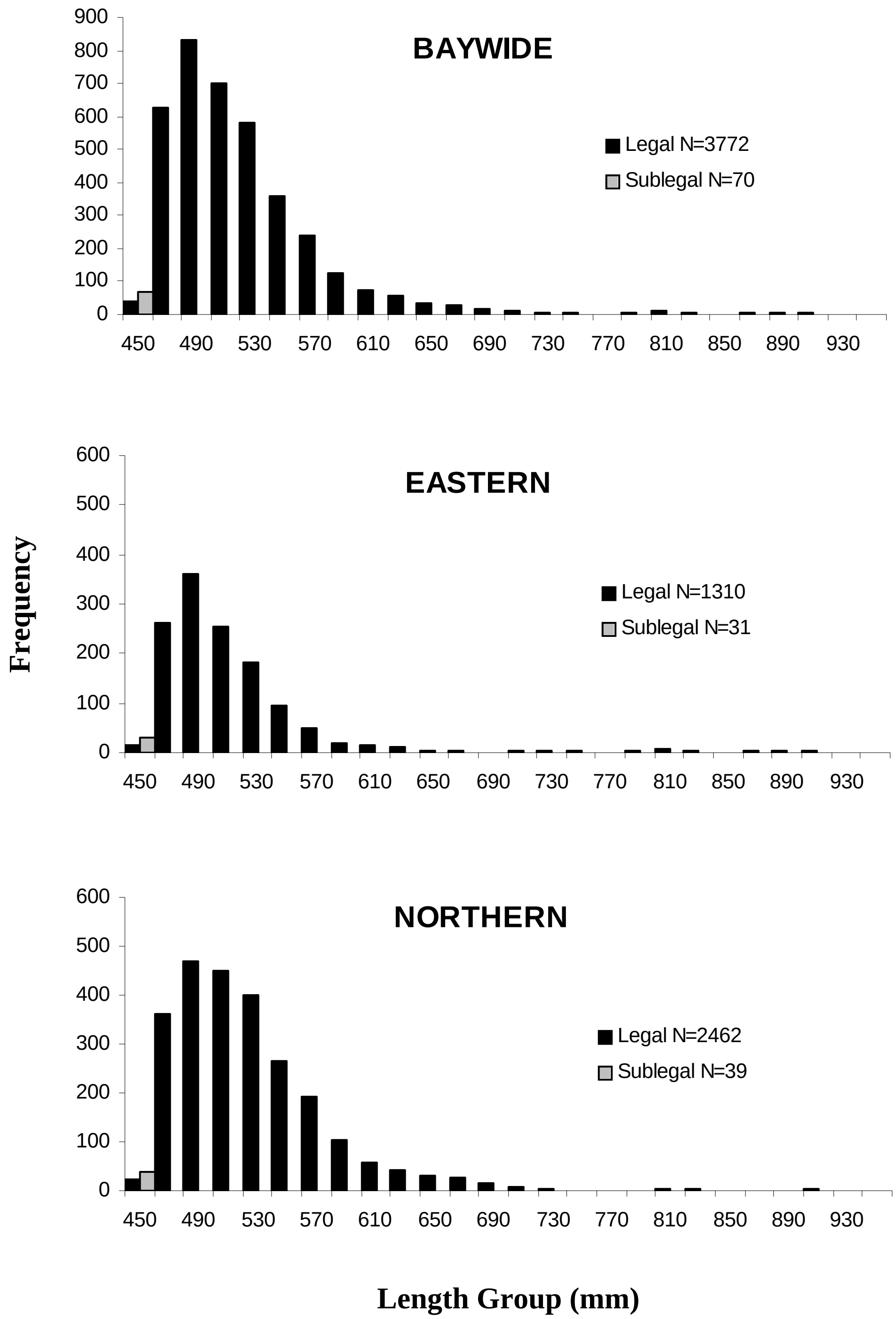


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2008 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. The year refers to the year in which the season ended.

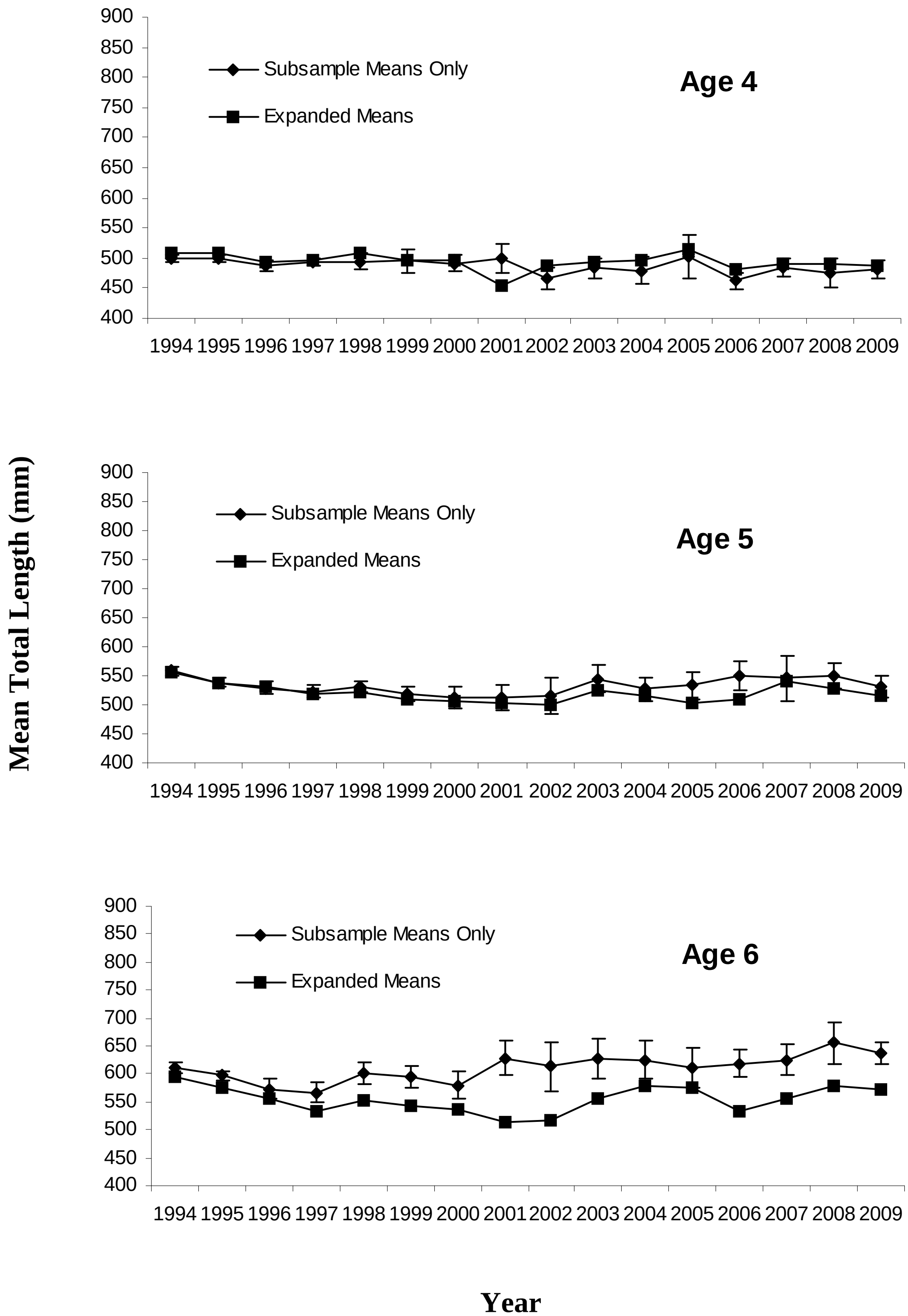


Figure 4. (Continued.)

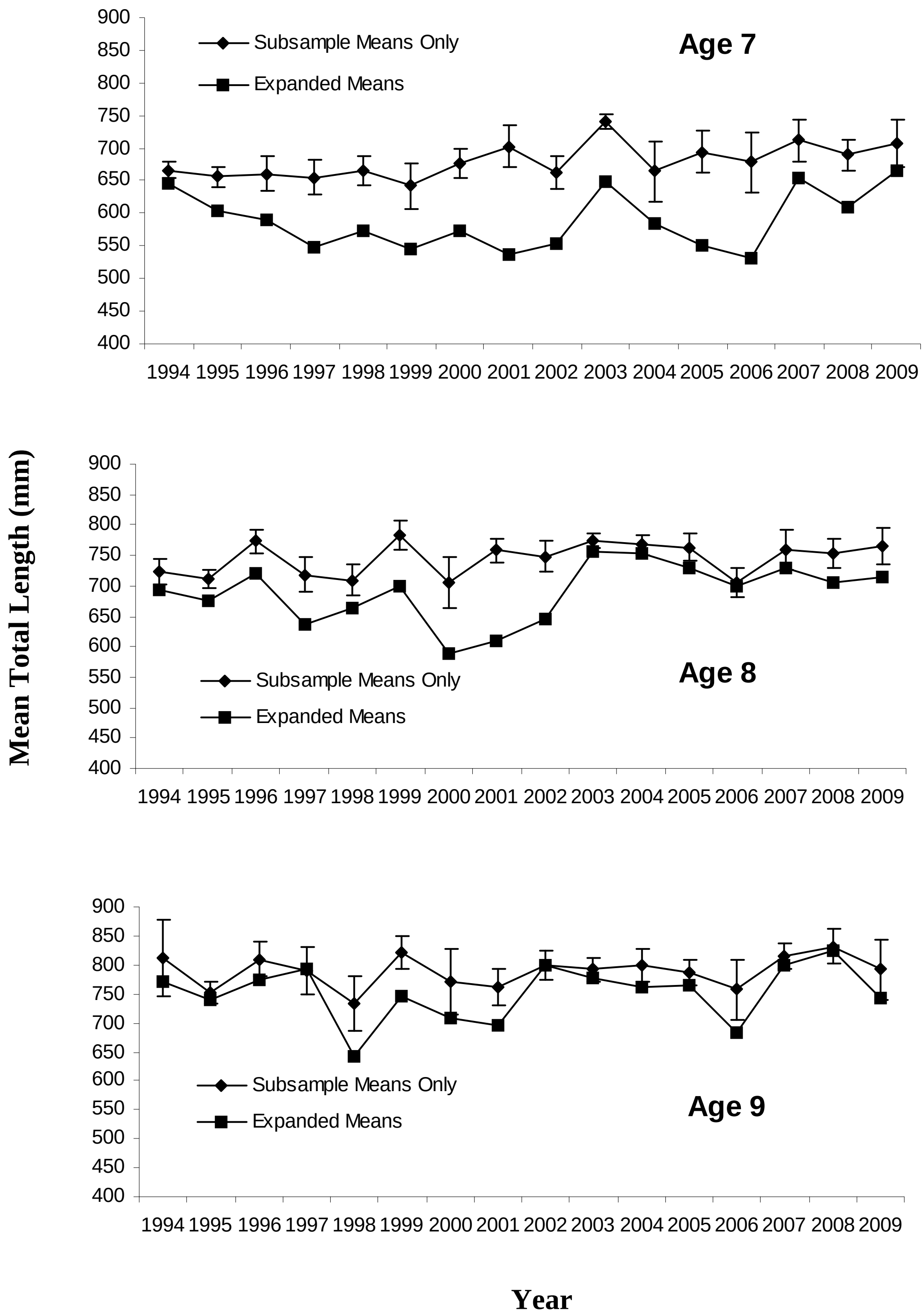


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2009 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. The year refers to the year in which the season ended.

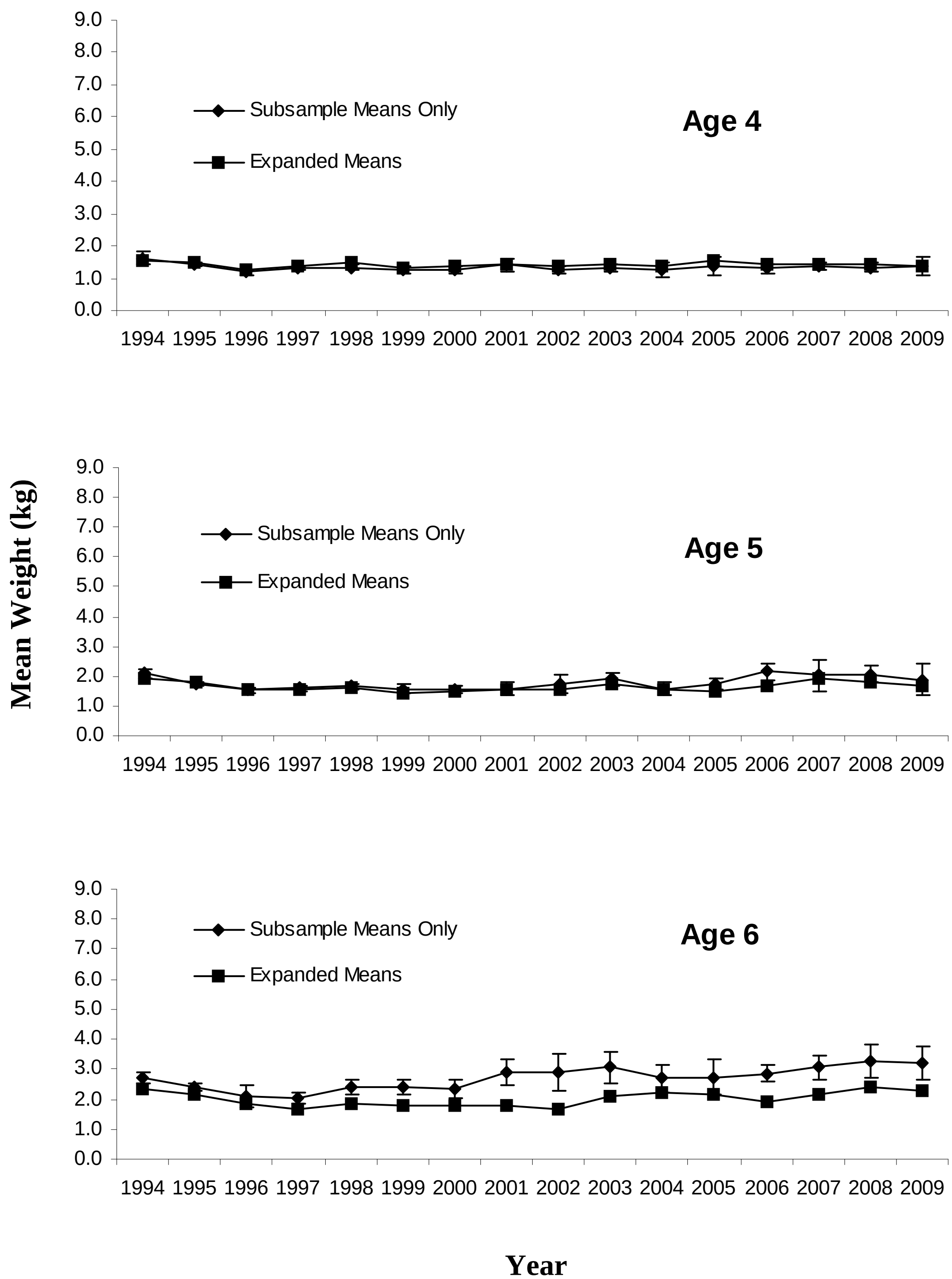
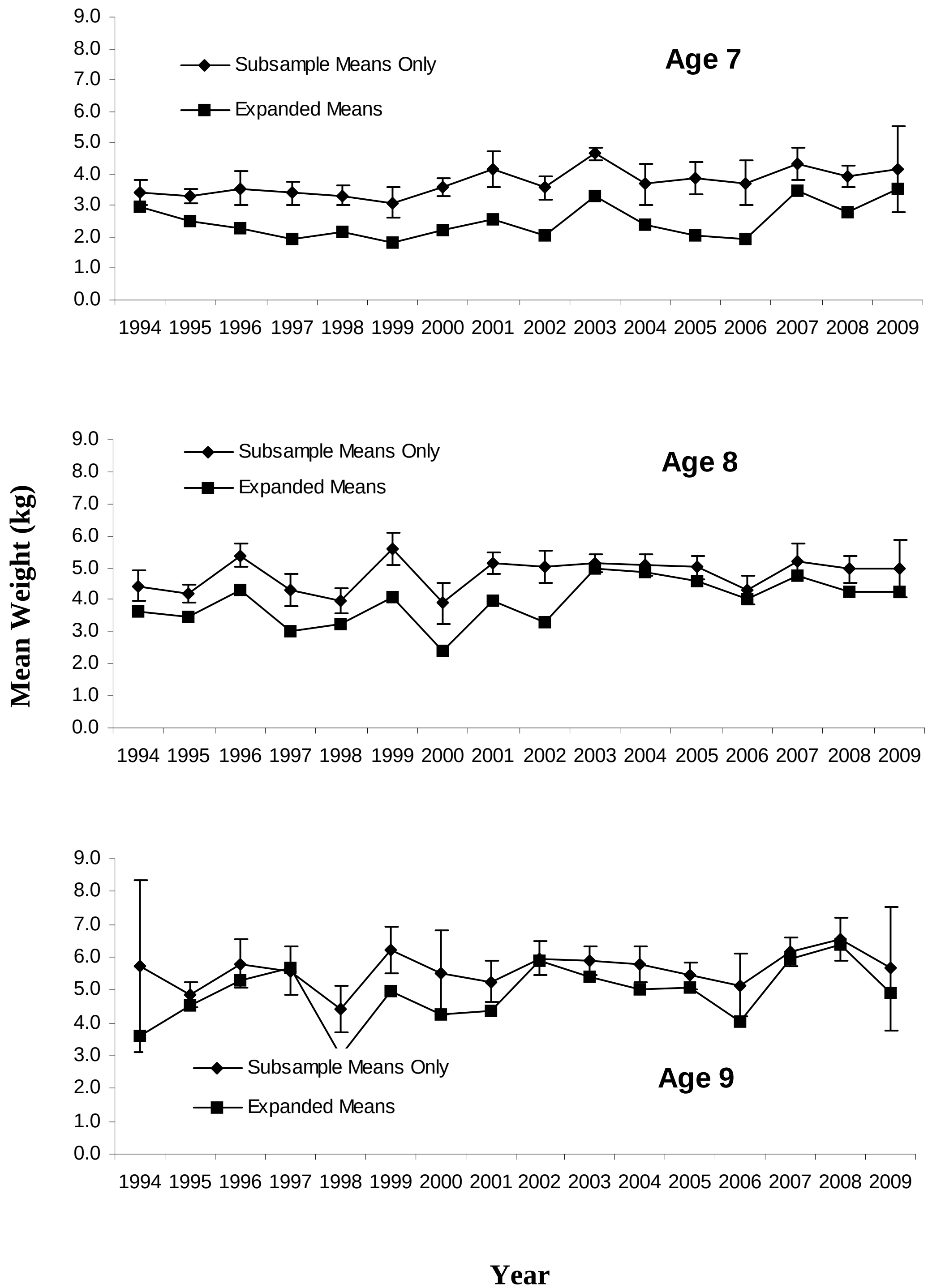


Figure 5. (Continued.)



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

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Angela Giuliano

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, 2008 and April 30, 2009. 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 2008-April 2009 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 historically the majority of the coastal harvest has been 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.

During the 2006-2007 and 2007-2008 seasons, fish were purchased for sex determination. Due to the consistency of sex ratios between years, these purchases were discontinued.

Analytical procedures

Age composition of the Atlantic commercial fisheries was estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). In the first stage of the survey, 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. The number of scales selected to be aged per length group reflected the variance of ages expected in that length group. The guideline was to read approximately twice as many scales as there were ages per length group, based on the method of Barker et al. 2004. Target sample sizes were: length groups<670 mm=6 scales per length group; 670-700=8 scales per length group; >710=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. 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 2008-April 2009 Atlantic fishery, the year used for age calculations was 2009. 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 2008 through April 2009 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 examined. 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 six days between November 2008 and January 2009. A total of 163 fish were measured and weighed and the ALK was developed from 104 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 2008-2009 Atlantic coast fishing season ranged from age four (2005 year-class) to age 14 (1995 year-class). Most striped bass harvested were ages six through eight (Table 1) and the median age was seven, identical to the 2007-2008 season. Striped bass were recruited into the Atlantic coast fishery as young as age four, but due to the 24 inch minimum size limit, few fish younger than age six were harvested.

The 2003 year-class was the most abundant year-class in the 2008-2009 fishing season followed by the 2001 year-class (Figure 1). Age six fish composed 37% of the aged sub-sample while age eight fish composed 21% of the aged sub-sample (Figure 1). The 2001 year-class had been the most abundant during the previous two Atlantic fishing seasons (28% of the aged sub-sample in 2006, 29% of the aged sub-sample in 2007-2008).

Based on the estimated catch-at-age, the three most common ages harvested during the 2008-2009 Atlantic coast fishery were ages 6, 8, and 7 (49%, 17%, and 16% respectively of the estimated catch-at-age). Though the 2003 year-class (age six) was the most abundant year-class this year, the 2001 year-class (age eight) was the most abundant the previous two years. The 2001 year-class comprised 38% of the estimated harvest in 2006 and 30% of the estimated harvest during the 2007-2008 season.

These data suggest that the 2003 and 2001 year-classes were strong, consistent with results from the juvenile index survey (Project 2, Job 3, Task 3) which showed that the 2001 and 2003 year classes were large while the 2002 year-class was below average. Fish caught on the Atlantic coast come from nursery grounds in many states. While the 2002 year-class was below average in the Chesapeake Bay and Delaware Bay, this cohort was average in the Hudson River (ASMFC Striped Bass Technical Committee 2003).

Striped bass sampled at Atlantic coast check stations during the 2008-2009 season had a mean length of 726 mm TL and mean weight of 4.0 kg. The mean length and weight were smaller during the 2007-2008 season (706 mm and 3.8 kg, respectively). Though the mean weights were not significantly different between the two seasons (t-test, α=0.05, P=0.28), the mean length harvested during the 2007-2008 season was significantly smaller than was harvested during the 2008-2009 season (t-test, α=0.05, P=0.02). The most common length groups in the sample were between 670 and 710 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). Expanded means were usually lower than the sub-sampled means. Most of the differences between sub-sampled and expanded means occurred between ages 6 and 8. The small differences observed between the sub-sampled and expanded means were due to the sub-sample and sample sizes being similar. In 2009, 104 fish were aged of 163 fish sampled, resulting in the aged sub-sample representing most of the overall sample. Recently recruited age 4 fish had an expanded mean length of 612 mm TL and expanded mean weight of 2.2 kg. Age 6 striped bass, the most abundant age harvested, had an expanded mean length of 683 mm TL and expanded mean weight of 3.1 kg. Age 8 striped bass, the next most abundant year-class harvested, had an expanded mean length of 751 mm TL and an expanded mean weight of 4.1 kg.

CITATIONS

ASMFC Striped Bass Technical Committee. 2003. 2003 Stock Assessment Report for Striped Bass: Catch-at-Age VPA & Tag Release/Recovery Based Survival Estimation. Report #SBTC-2003-3.

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. 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 2008-April 2009.

2008-2009			
Year-Class	**Age**	**Catch**	**Percent**
2005	4	114	0.8
2004	5	428	3.1
2003	6	6,873	49.2
2002	7	2,251	16.1
2001	8	2,401	17.2
2000	9	779	5.6
1999	10	171	1.2
1998	11	257	1.8
1997	12	514	3.7
1996	13	86	0.6
1995	14	86	0.6
	Total	**13,960**	**100**

*Total may not equal 100% 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 2008-April 2009. 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	4	1	617	---	---	1	612
2004	5	3	624	590	659	5	628
2003	6	38	687	674	700	80	683
2002	7	18	732	698	766	26	712
2001	8	22	770	745	796	28	751
2000	9	9	829	778	879	9	828
1999	10	2	897	821	973	2	897
1998	11	3	922	845	999	3	930
1997	12	6	961	938	983	6	958
1996	13	1	955	---	---	1	950
1995	14	1	1005	---	---	1	1003
Total	**---**	**104**	**---**	**---**	**---**	**162**	**---**

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2008-April 2009. 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	4	1	2.4	---	---	1	2.2
2004	5	3	2.6	1.4	3.7	5	2.4
2003	6	38	3.2	3.0	3.4	80	3.1
2002	7	18	4.1	3.5	4.6	26	3.6
2001	8	22	4.2	3.8	4.7	28	4.1
2000	9	9	6.1	4.7	7.4	9	5.9
1999	10	2	8.5	0.9	16.1	2	8.0
1998	11	3	7.5	6.1	8.9	3	8.4
1997	12	6	9.4	8.5	10.2	6	9.4
1996	13	1	9.6	---	---	1	8.7
1995	14	1	12.9	---	---	1	11.5
Total	**---**	**104**	**---**	**---**	**---**	**162**	**---**

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.

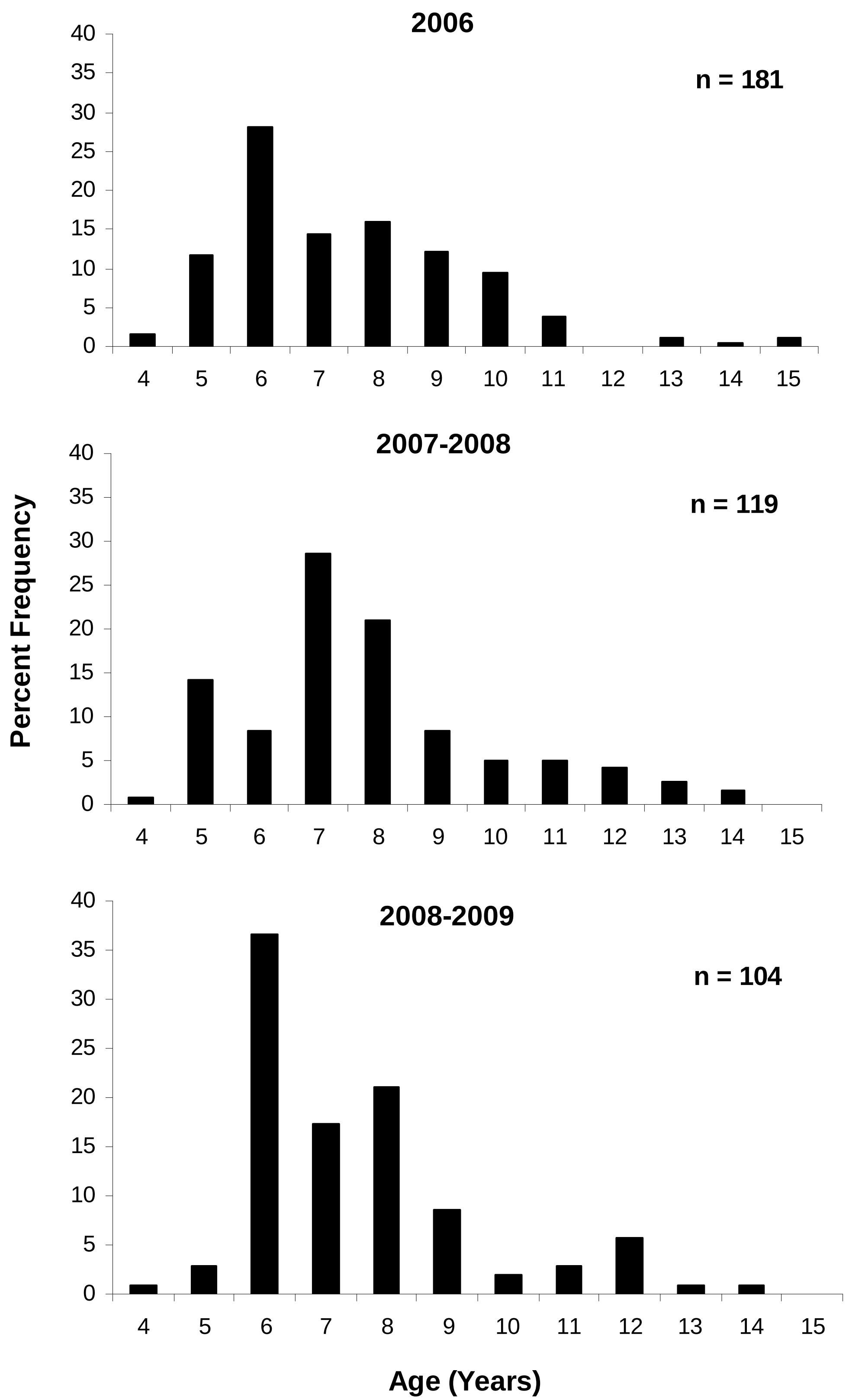


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, November 2006-April 2007, the November 2007-April 2008 fishing season, and the November 2008-April 2009 fishing season.

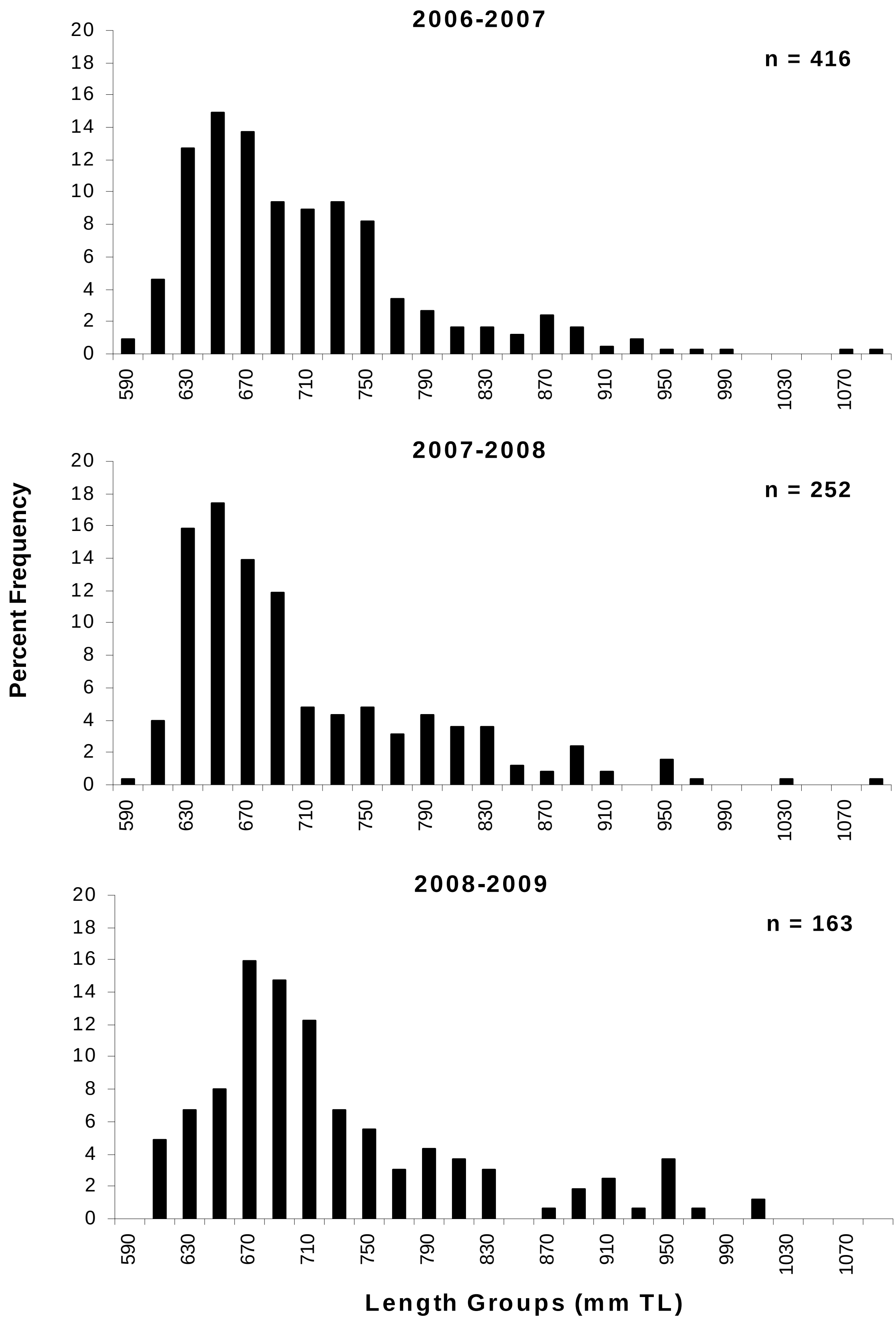


Figure 3. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2009 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences in scales on the y-axis.

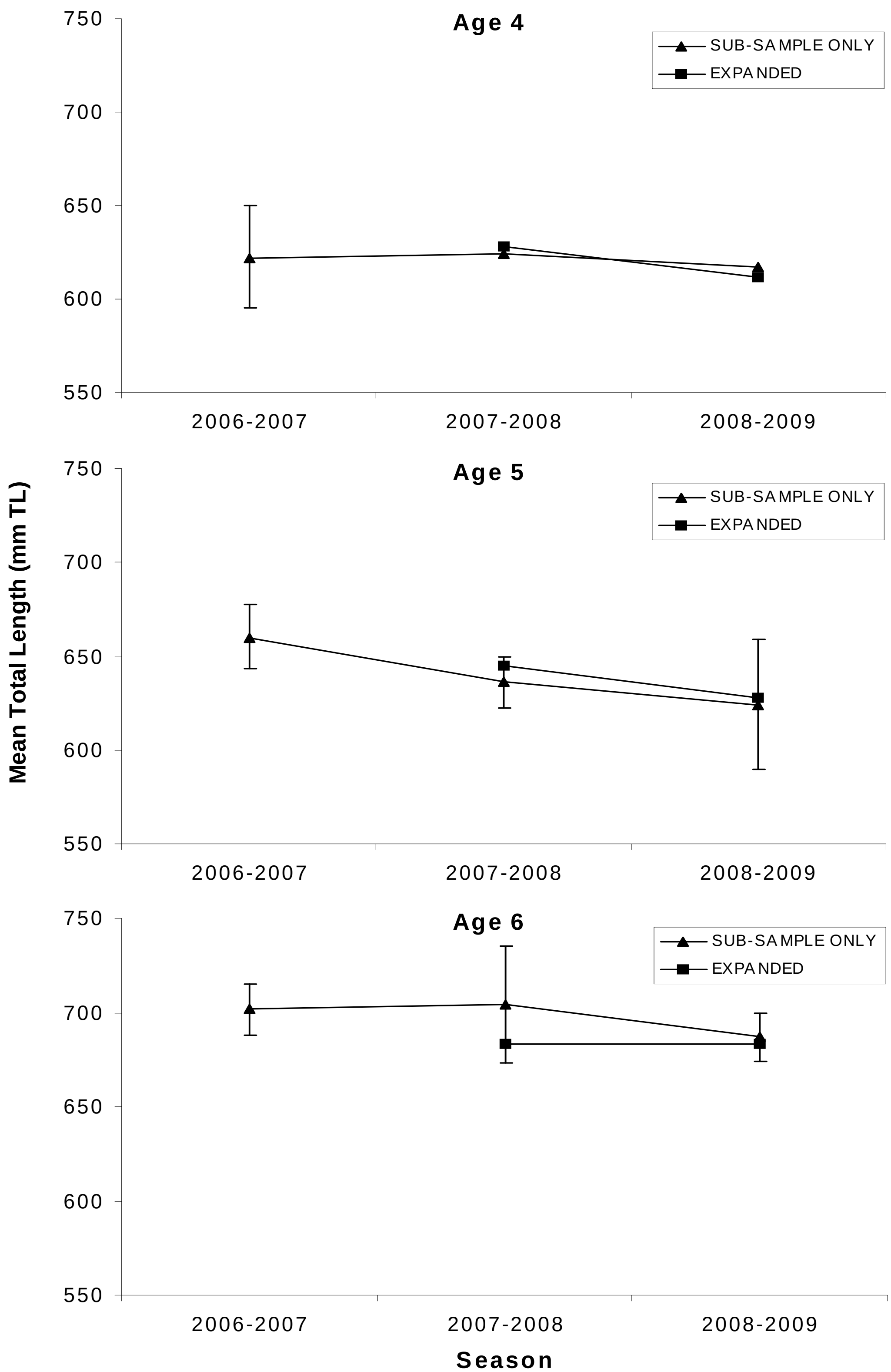


Figure 3. (Continued.)

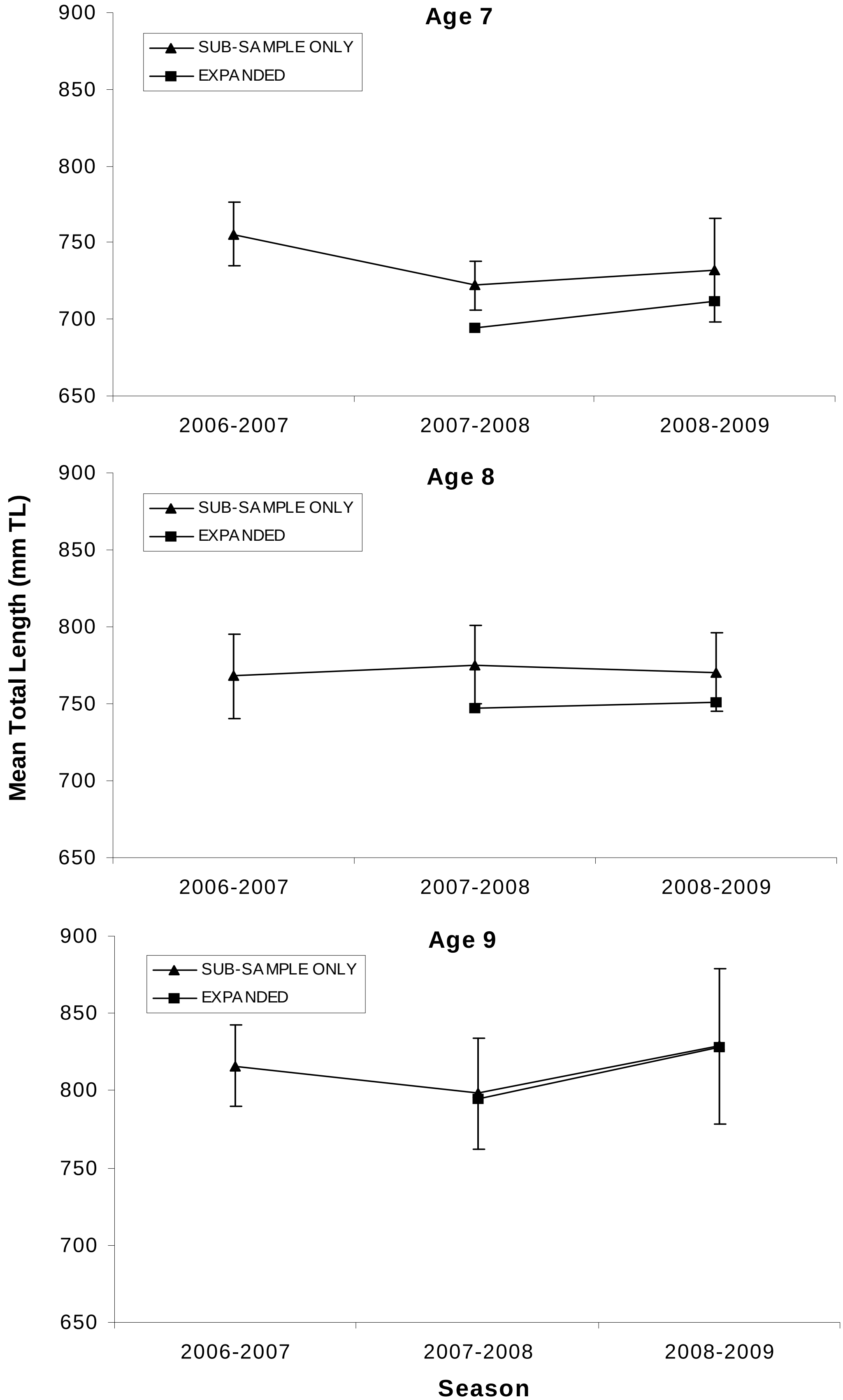


Figure 3. (Continued.)

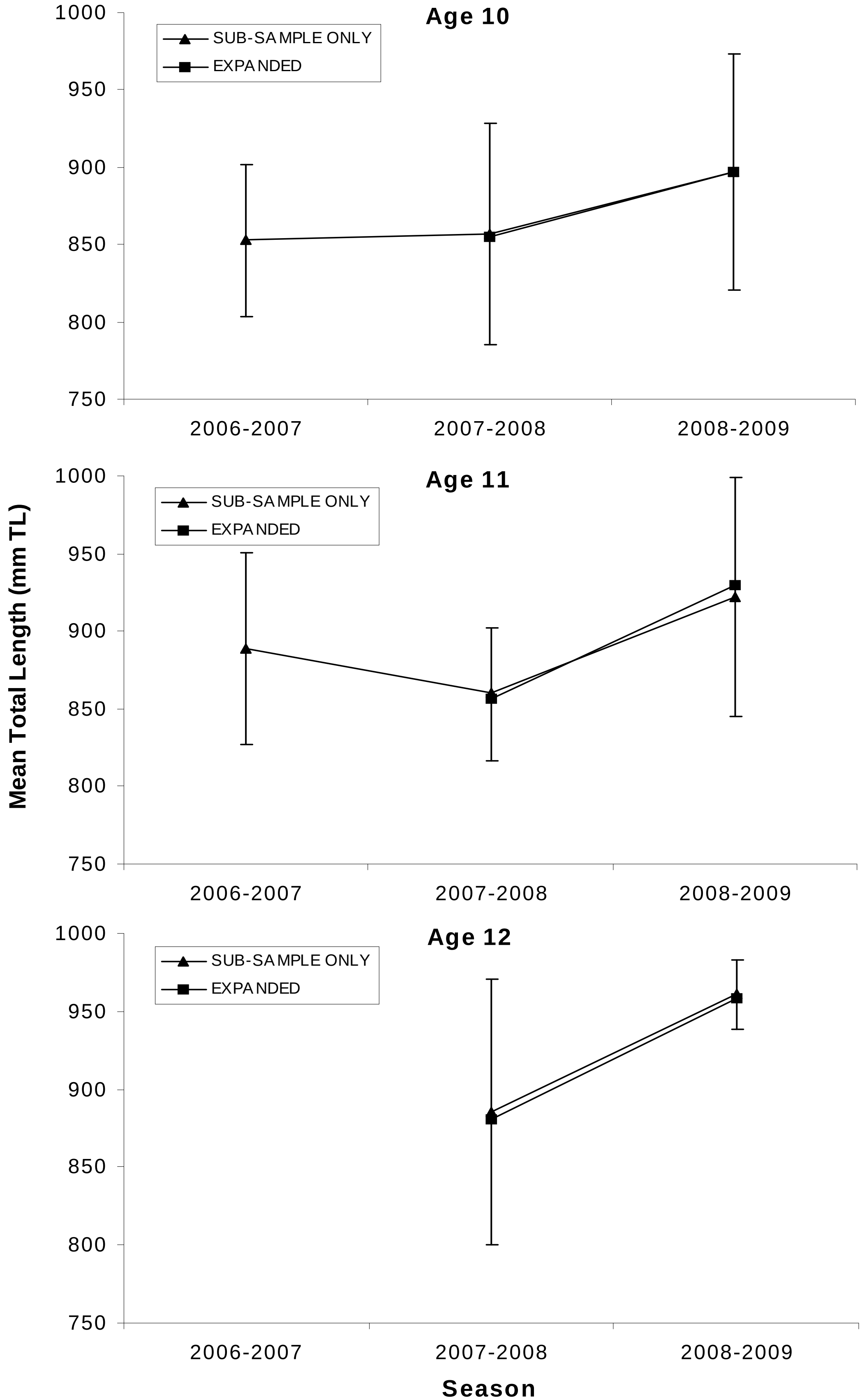


Figure 4. Mean weight (kg) of the aged sub-sample, by year, for individual age-classes of striped bass (through age 12) sampled from the Maryland Atlantic coast trawl and gill net landings, 2006-2009 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. *Note differences of scale on the y-axis.

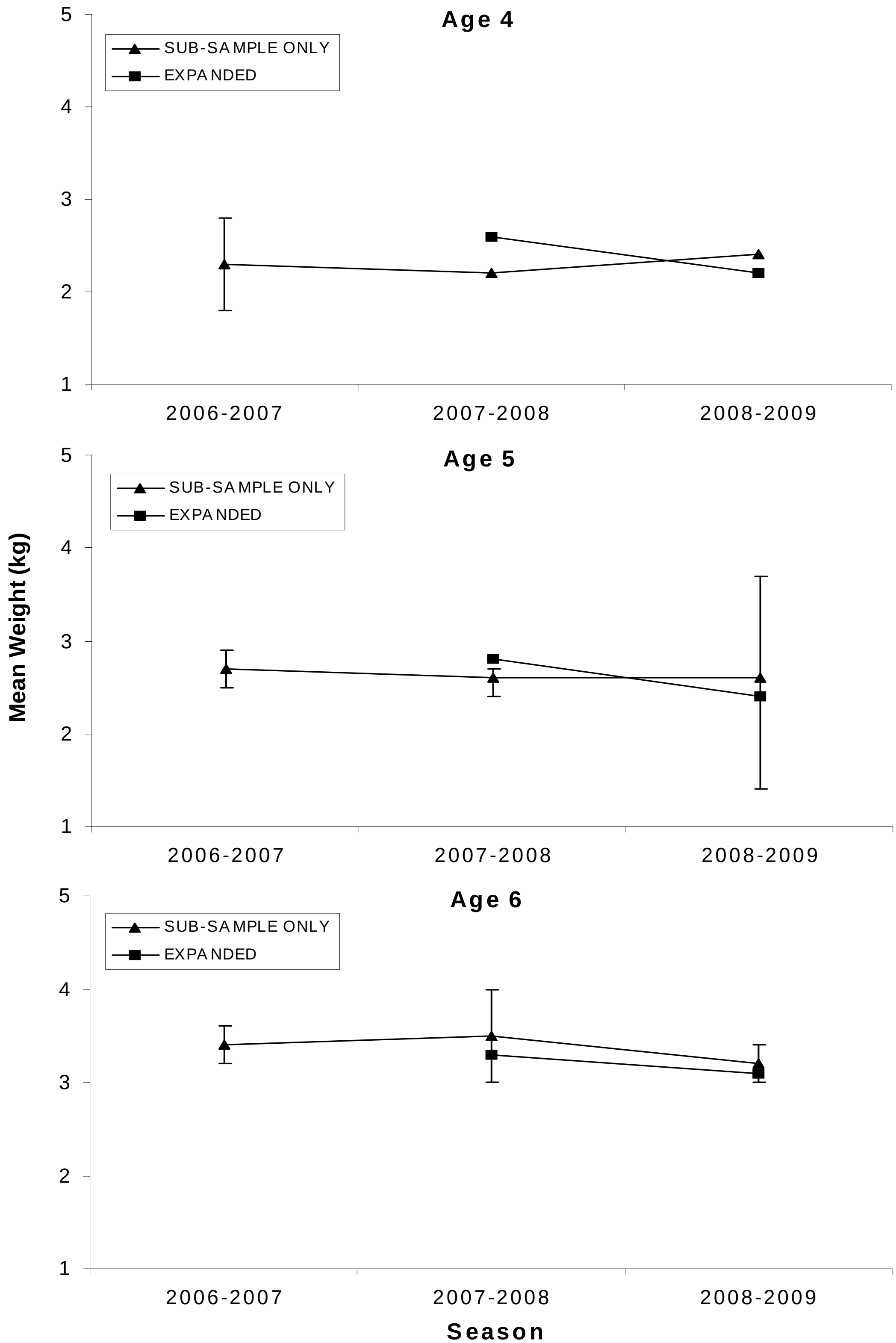


Figure 4. (Continued.)

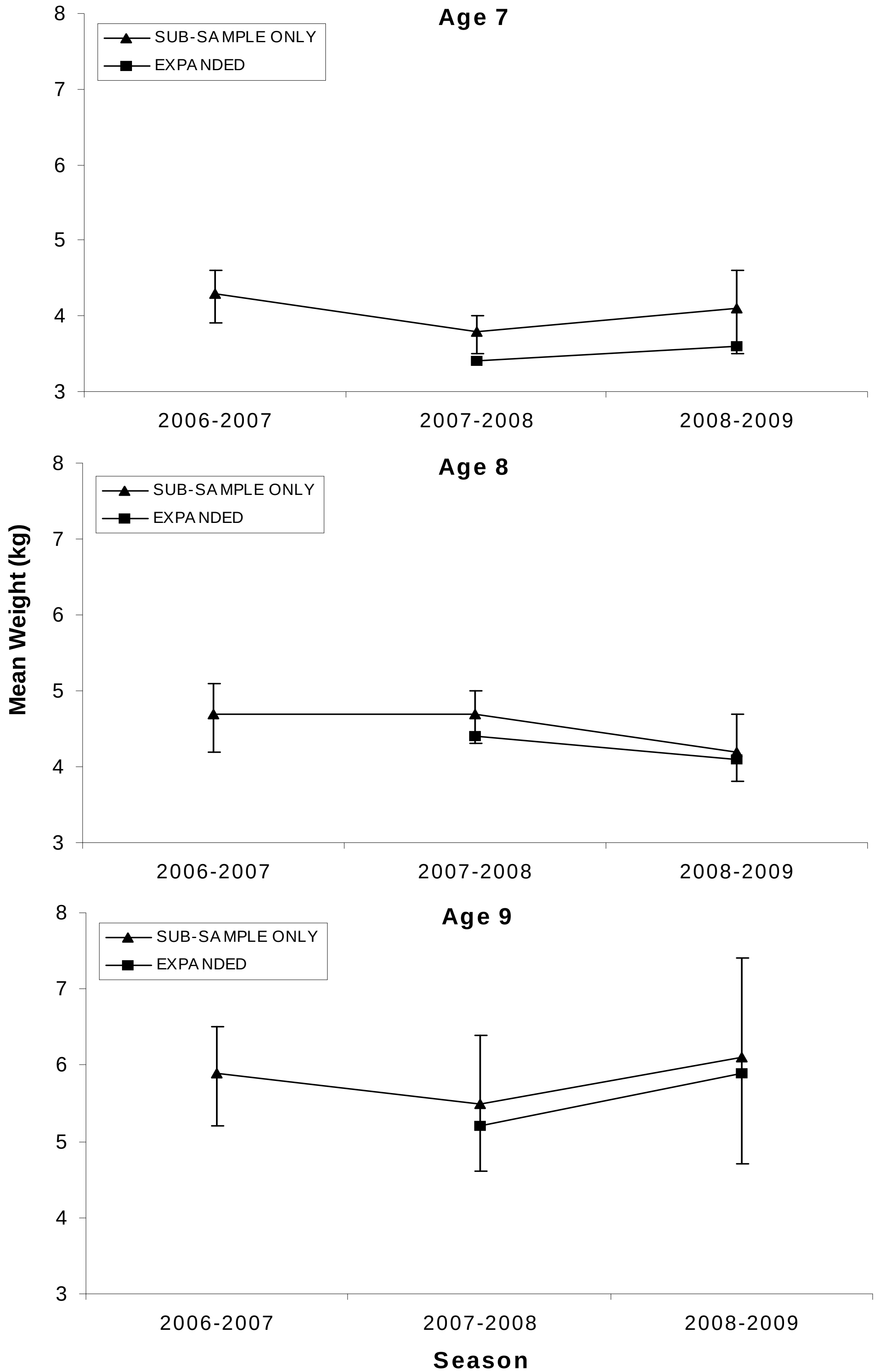
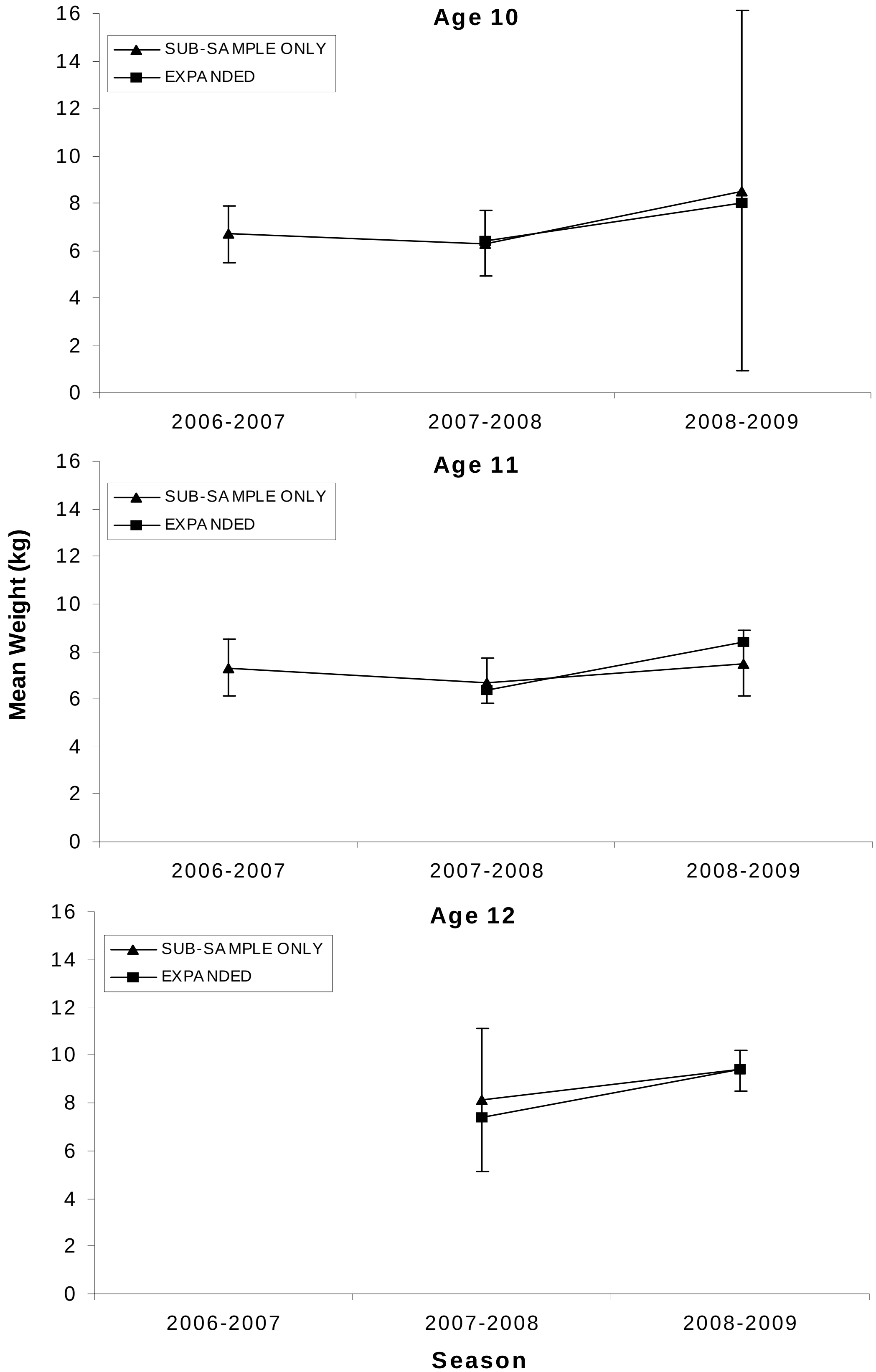


Figure 4. (Continued.)



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 2009 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 2009 (Figure 1). Gill nets were fished 6 days per week, weather permitting, from late March until mid-May. In the Potomac River, sampling was conducted from March 31 to May 14 for a total of 33 sample days. In the upper Bay, sampling was conducted from April 9 to May 20 for a total of 28 sample days.

Individual net panels were 150 feet long, and ranged from 8.0 to 11.5 feet deep depending on mesh size. The panels were constructed of multifilament nylon webbing in 3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0 and 10.0-inch stretch-mesh. In the upper Bay, all 10 panels were tied together, end to end, to fish the entire suite of meshes simultaneously. In the Potomac River, because of the design of the fishing boat, the gang of panels was split in half, with two suites of panels (5 meshes tied together) fished simultaneously end to end. In both systems, all 10 panels were fished twice daily unless weather prohibited a second set. The order of panels within the suite of nets was randomized with gaps of 5 to 10 feet between each panel. Overall soak times for each panel ranged from 6 to 188 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). Beginning in 2004, scales from the Patuxent River CWT survey (Project No. 2, Job No. 3, Task 6) were also used to fill gaps within larger length groups of the ALKs. Patuxent River fish were assumed to be similar in length-at-age to those sampled from the gill net and recreational creel surveys, but because of small sample sizes, this assumption could not be tested.

Development of selectivity-corrected CPUEs and variance estimates

CPUEs for individual mesh sizes and length groups were calculated for each spawning area in 2009. 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 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 528 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 2009 CPUE values indicated an increase over 2008 values.

The 2009 un-weighted CPUE for Potomac females (22) ranked fourteenth of 24 years in the time series, below the series average of 28 (Table 2). The un-weighted CPUE for Potomac males (314) ranked sixteenth in the time-series, a substantial increase from 2008, but still below the time series average of 452 (Table 3). The upper Bay female CPUE (52) ranked fourth highest in the time series. This was the highest value since 2003 and well above the time series average of 35 (Table 4). The un-weighted CPUE for upper Bay males was 671, the fifth highest CPUE in the time series, and above the time series average of 453 (Table 5). The Choptank River has not been sampled since 1996 (Tables 6 and 7).

Weighted CPUE values were pooled for use in the annual coast-wide striped bass stock assessment. These indices are presented in a time series for ages one through 15+ (Table 8). The 2009 selectivity-corrected total weighted CPUE (574) was the highest value since 2004 and above 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 2009 age-specific CPUEs were all below 0.10 and indicated a small variance in CPUE. Historically, 78% of the CV values were less than 0.10 and 87% 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 could likely be 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 (93%, Tables 12 and 13) pooled, total CPUEs. On the Potomac River, males from the 2005 year-class made up 37% of the un-weighted and weighted CPUEs. The next highest contributors to total CPUE were males from the 2003 year-class, making up18% of both the un-weighted and weighted CPUEs. In the upper Bay, males from the dominant 2003 year-class comprised 28% of the un-weighted and weighted CPUEs. The contribution of males from the 2005 year-class was similar, making up 26% of the un-weighted and weighted CPUEs.

Female CPUEs were distributed across many year-classes, with the 1996 year-class contributing approximately 21% of the weighted and un-weighted CPUEs in both systems. The next greatest contribution to female CPUE was from the 2000 year-class, which contributed 16% to the un-weighted and weighted CPUEs in the upper Bay and 20% in the Potomac.

As in previous years, upper Bay fish accounted for most of the total CPUE, contributing 68% to the total un-weighted and 78% to the weighted CPUEs. Overall, males from the 2003 and 2005 year-classes contributed substantially to the total un-weighted and weighted CPUEs in 2009, making up 51% of the total.

Temperature and catch patterns

Surface water temperatures on the Potomac River increased gradually over the duration of the 2009 survey. Daily water temperatures ranged from 10.5°C to 18.8°C. Daily female CPUEs on the Potomac suggested sporadic spawning activity throughout the survey with peaks around April 9, April 11, and April 29 (Figure 2). These peaks in female CPUE correspond with the high concentrations of males encountered on April 6, April 11, and April 26-27, suggesting possible spawning activity.

Surface water temperatures on the upper Bay increased during the spawning survey from 9.4 °C to 18.7 °C. Daily female CPUEs from the upper Bay were sporadic, with a distinct peak on April 9 at the start of the survey (Figure 3). Smaller peaks were also observed in mid to late April and the second week of May. The highest catches of male striped bass in the upper Bay occurred during the last two weeks of April, when water temperatures increased to 15 °C.

In both systems, air temperatures increased gradually over the length of the entire survey. Due to differences in daily sampling times, wide fluctuations in air temperatures were observed.

Length composition of the stock

In 2009, total length was measured for 890 male and 43 female striped bass sampled from the Potomac River and 969 males and 53 females collected 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 2009 ($P < 0.001$). Mean lengths are reported with 95% confidence intervals.

Mean lengths of male striped bass collected from the Potomac River (500 ± 8 mm TL) and upper Bay (535 ± 8 mm TL) were significantly different ($P<0.0001$) in 2009. Though a statistically significant difference in mean length was detected between the two sampling areas, the difference of 35 mm between the mean lengths is not biologically significant. This is supported by the length distributions which are statistically similar (χ^2=27.71, α=0.05, P=0.74).

Male striped bass on the Potomac ranged from 269 to 1034 mm TL. The length distribution was heavily influenced by the contribution of striped bass from the above average 2005 and 2003 year-classes. Male striped bass between 430 and 490 mm TL comprised 49% of the Potomac River male catch in 2009 (Figure 4). Potomac male CPUEs peaked between 410 and 470 mm TL, representing primarily the 2005 year-class (Figure 5).

Male striped bass on the upper Bay ranged from 303 to 1023 mm TL. Males between 430 and 510 mm TL contributed 48% 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 2003 year-classes. Application of the selectivity model to the data corrected the catch upward across the length distribution. The peak in corrected CPUE in the 490 mm length group represents the 2005 and 2003 year-classes (Figure 5). The 1996 year-class was mainly represented in the corrected CPUE peak at 990 mm. The peak at 910 mm was primarily composed of the 1998 year-class.

Mean lengths of female striped bass sampled from the Potomac River and upper Bay in 2009 were not significantly different (P=0.81). Female striped bass sampled from the Potomac ranged from 500 to 1107 mm TL (mean=952 ± 35), while females sampled in the upper Bay ranged from 600 to 1188 mm TL (mean=958 ± 34; Figure 4). The female length distributions could not be compared using a chi-square test because of the small sample sizes per length group.

Both the corrected and uncorrected CPUEs of Potomac River female striped bass were spread over a wide range of length groups. The highest un-corrected CPUE occurred in the 950 mm TL length group, which included females age nine to 12. The corrected CPUEs from 810 to 850 mm represent the 2000 and 2001 year-classes (Figure 6). The smaller peak at 1030 mm was primarily composed of the 1996 year-class.

Similarly in the upper Bay, female corrected and uncorrected CPUEs cover a very wide range of length groups, indicating return spawners through the 1993 year-class. The uncorrected and corrected CPUE peaks between 990 and 1090 mm TL reflect the continued contribution of the 1996 year-class. In both systems there was some contribution of females smaller than 700 mm TL, corresponding to the 2003-2005 year-classes.

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. Because of these issues, an analysis of covariance (ANCOVA) could not be performed to test for differences in LAA between areas.

Based on previous investigations, however, 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 2009 to produce separate male and female ALKs (Warner et al., 2006, Warner et al., 2008). Patuxent River CWT survey (Project 2, Job 3, Task 6B) fish were also included in the ALK, but the age by area interaction could not be tested, again, because of small sample sizes.

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 2008 and 2009 for all ages except for age three (t-test, α=0.05, P=0.003). Mean lengths of females were similar between 2008 and 2009 for all ages except age 11 (t-test, α=0.05, P=0.009).

Age composition of the stock

During the 2009 survey, fifteen age-classes, ranging from 2 to 16 were encountered (Tables 14 and 15). Male striped bass ranged from ages 2 to 15, with age 6 fish (2003 year-class) being the most abundant male cohort. The majority of females were ages 11 to 13, with one age 4 fish collected. Age 13 (1996 year-class) and age 9 (2000 year-class) females were 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 2009, a strong peak was indicated by the age six (2003 year-class) cohort. The contribution of males age 11 and older has increased in the later years of the time-series. Age 13 fish (1996 year-class) are still contributing to the spawning stock. Females younger than age 7 have been uncommon in the spawning stock since 1996 (Figure 9); however, several females age 4, 5 and 6 were sampled in 2009.

In 2009, age 8+ females constituted 88% of the female spawning stock (Figure 10), a slight decrease from the previous 2 years. With the exception of 1999, the contribution of females age eight and older fish to the spawning stock has been at or above 80% since 1996. The percentage of the overall sample (males and females combined) age 8 and older has varied without trend since 2001 (Figure 11). The 2009 value of 22% was a slight increase from 2008. 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). Maryland estimates indicated a decline for the period of 2006-2008; however, in 2009 there was an increase. The MD DNR estimate of ISP generated from the upper Bay in 2009 (483 kg) was the highest value since 2003 and well above the time-series average of 288 (Table 16, Figure 12). The 2009 Potomac River female ISP (190 kg) was only slightly above the 2008 value, and below the time series average of 241.

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 2009.

	MALES					FEMALES				
Length group (mm)	**Upper Bay**	**Potomac River**	**Creel**	**Patuxent**	**Total**	**Upper Bay**	**Potomac River**	**Creel**	**Patuxent**	**Total**
270	0	1	0	0	**1**	0	0	0	0	**0**
290	1	2	0	0	**3**	0	0	0	0	**0**
310	3	3	0	0	**6**	0	0	0	0	**0**
330	3	3	0	0	**6**	0	0	0	0	**0**
350	3	3	0	0	**6**	0	0	0	0	**0**
370	3	3	0	0	**6**	0	0	0	0	**0**
390	3	3	0	0	**6**	0	0	0	0	**0**
410	3	4	0	0	**7**	0	0	0	0	**0**
430	3	3	0	0	**6**	0	0	0	0	**0**
450	3	3	0	0	**6**	0	0	0	0	**0**
470	3	3	0	0	**6**	0	0	1	0	**1**
490	3	3	0	0	**6**	0	0	1	0	**1**
510	3	3	0	0	**6**	0	1	1	0	**2**
530	3	3	0	0	**6**	0	0	0	0	**0**
550	3	3	0	0	**6**	0	0	3	0	**3**
570	7	3	0	0	**10**	0	0	1	0	**1**
590	8	2	0	0	**10**	0	0	0	0	**0**
610	7	2	0	0	**9**	0	0	0	0	**0**
630	6	5	0	0	**11**	0	0	0	0	**0**
650	5	5	0	0	**10**	0	0	0	0	**0**
670	6	4	0	0	**10**	0	0	0	0	**0**
690	7	3	0	0	**10**	0	0	1	0	**1**
710	7	3	5	0	**15**	0	0	1	0	**1**
730	9	1	5	0	**15**	0	0	1	0	**1**
750	7	3	4	0	**14**	0	0	0	0	**0**
770	8	1	5	0	**14**	0	0	2	0	**2**
790	6	1	2	0	**9**	0	0	1	0	**1**
810	9	0	2	0	**11**	0	1	7	0	**8**
830	4	2	1	0	**7**	0	0	2	0	**2**
850	7	0	7	1	**15**	1	0	11	1	**13**
870	10	0	5	0	**15**	0	0	12	1	**13**
890	9	1	5	0	**15**	2	1	11	1	**15**
910	5	2	3	1	**11**	1	3	12	0	**16**
930	9	0	5	1	**15**	3	4	8	0	**15**
950	6	1	5	0	**12**	5	5	5	0	**15**
970	2	0	0	0	**2**	1	2	12	0	**15**
990	2	0	3	0	**5**	3	5	6	0	**14**
1010	1	1	0	0	**2**	2	6	7	0	**15**
1030	1	0	1	0	**2**	2	0	5	1	**8**
1050	1	0	0	0	**1**	3	1	1	2	**7**
1070	0	0	0	0	**0**	2	3	1	3	**9**
1090	0	0	0	0	**0**	0	0	4	3	**7**
1110	0	0	0	0	**0**	0	3	0	1	**4**
1130	0	0	0	0	**0**	0	0	1	0	**1**
1150	0	0	0	0	**0**	0	0	0	3	**3**
1170	0	0	0	0	**0**	0	0	0	0	**0**
1190	0	0	0	0	**0**	0	0	0	0	**0**
1210	0	0	0	0	**0**	0	0	0	1	**1**
1230	0	0	0	0	**0**	0	0	0	0	**0**
Total	**189**	**83**	**58**	**3**	**333**	**25**	**35**	**118**	**17**	**195**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2009 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Potomac River was not sampled in 1994.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	0.0	0.0	0.0	0.1	0.5	0.2	0.0	0.2	0.1	0.1	0.0	0.5	0.0	0.6	**2**
1986	0.0	0.0	1.0	7.3	0.7	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**10**
1987	0.0	0.0	0.0	2.9	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	**10**
1988	0.0	0.0	0.0	1.7	2.4	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	**10**
1989	0.0	0.0	0.0	0.0	6.9	4.7	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**16**
1990	0.0	0.0	0.0	0.0	1.6	3.7	3.5	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	**11**
1991	0.0	0.0	0.0	0.0	0.6	0.6	1.5	2.0	6.6	0.3	1.8	0.0	0.0	0.0	0.6	**14**
1992	0.0	0.0	0.0	2.6	6.4	6.7	8.7	11.4	8.2	8.7	0.0	0.0	0.0	0.0	0.0	**53**
1993	0.0	0.0	0.0	1.0	8.2	7.7	9.4	15.2	14.3	8.6	4.3	0.0	0.0	0.0	0.0	**69**
1994																
1995	0.0	0.0	0.0	0.0	0.0	3.1	4.6	4.8	4.6	6.6	5.5	5.0	0.7	0.0	0.0	**35**
1996	0.0	0.0	0.0	0.0	0.8	0.2	3.9	7.1	6.8	8.8	5.4	8.1	3.3	0.0	0.0	**45**
1997	0.0	0.0	0.0	0.0	0.0	4.2	2.4	5.7	10.2	10.8	5.1	5.1	1.5	1.7	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	3.4	2.8	3.2	5.0	2.2	6.5	2.0	0.3	0.0	0.3	**26**
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	0.0	0.0	0.0	2.4	3.8	8.9	5.0	5.6	2.0	3.8	0.0	0.0	**31**
2002	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	10.2	5.1	4.2	5.8	3.9	2.0	2.0	**37**
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.7	2.1	3.2	0.0	0.9	2.1	0.9	**11**
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.7	15.0	7.7	9.3	8.1	8.7	6.6	3.0	1.6	**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	9.3	4.2	5.2	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**
Average																**28**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2009 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Potomac River was not sampled in 1994.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	285.3	517.6	80.6	10.5	0.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**896**
1986	0.0	241.5	375.9	531.2	8.2	8.2	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1166**
1987	0.0	144.5	283.5	174.6	220.8	3.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	**829**
1988	0.0	18.2	107.4	63.8	75.9	81.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**347**
1989	0.0	51.9	240.9	134.5	39.1	55.2	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**543**
1990	0.0	114.2	351.8	172.8	73.8	28.3	33.8	26.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	**803**
1991	0.0	19.9	91.2	96.6	49.7	37.8	28.7	22.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0	**352**
1992	0.3	36.3	202.4	148.9	97.6	73.0	39.1	19.0	6.1	0.8	8.4	0.0	0.0	0.0	0.0	**632**
1993	0.0	30.4	141.7	133.9	101.4	83.7	62.6	43.6	21.9	1.8	0.0	0.0	0.0	0.0	0.0	**621**
1994																
1995	0.0	9.1	143.9	61.1	18.7	20.4	25.3	32.2	11.3	10.7	0.1	0.0	0.8	0.0	0.0	**334**
1996	0.0	0.0	230.6	172.9	24.8	26.8	17.7	22.7	19.3	3.6	0.6	0.8	0.0	0.0	0.0	**520**
1997	0.0	49.9	54.2	111.2	96.4	13.0	6.0	11.6	15.8	14.6	5.9	3.3	0.0	0.0	0.0	**382**
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	11.8	313.5	155.8	101.7	61.8	19.8	9.7	7.3	4.3	4.9	3.3	2.2	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	8.8	33.8	42.6	36.2	11.3	9.1	8.1	5.0	1.9	1.5	3.7	0.8	0.5	0.0	**163**
2002	0.0	19.3	78.6	47.4	58.7	25.1	20.2	11.2	2.7	3.0	2.0	3.2	2.1	0.0	0.4	**274**
2003	0.0	12.3	67.2	61.2	21.7	35.5	25.9	3.8	2.0	7.2	0.5	10.1	2.4	0.0	0.8	**251**
2004	0.0	8.4	113.9	69.5	46.9	27.7	31.7	25.6	5.8	7.3	12.4	6.0	8.7	9.3	2.2	**375**
2005	0.0	11.2	10.2	15.0	16.7	4.8	4.5	3.6	4.0	3.1	1.9	1.2	0.0	0.0	0.0	**76**
2006	0.0	8.6	139.8	23.4	36.3	15.4	6.5	7.0	8.3	9.3	7.5	4.8	0.6	0.4	0.0	**268**
2007	0.0	10.6	16.9	37.3	5.3	5.6	4.3	2.1	2.6	2.8	5.4	1.0	0.8	2.0	0.1	**97**
2008	0.0	6.2	36.7	20.4	12.0	1.7	1.8	2.3	1.1	1.2	1.3	2.4	0.4	0.0	0.2	**88**
2009	0.0	36.0	36.3	117.4	23.2	57.0	9.1	10.5	10.5	2.8	3.8	2.6	3.7	0.6	0.6	**314**
Average																**452**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the upper Bay during the 1985-2009 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	0.0	0.8	0.0	0.3	0.1	0.5	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.3	**2**
1986	0.0	0.0	0.3	24.3	0.0	0.0	0.5	0.5	3.8	0.0	0.0	0.0	0.0	0.0	0.3	**30**
1987	0.0	0.0	0.0	3.1	26.8	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	8.8	8.5	**50**
1988	0.0	0.0	4.2	8.8	6.5	31.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**52**
1989	0.0	0.0	1.2	1.8	6.2	3.9	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**22**
1990	0.0	0.0	0.0	0.3	0.0	0.3	1.8	5.3	0.0	0.0	0.0	0.9	0.6	0.0	0.0	**9**
1991	0.0	0.0	0.0	0.5	3.2	0.5	2.3	3.1	2.2	0.0	1.2	0.0	0.0	0.0	1.2	**14**
1992	0.0	0.0	0.2	4.4	3.5	5.6	4.4	4.9	4.3	4.2	0.3	0.0	0.5	1.1	0.4	**34**
1993	0.0	0.0	0.0	3.0	5.1	2.0	4.0	4.8	4.0	3.9	2.0	1.3	2.3	2.1	0.0	**35**
1994	0.0	0.0	0.0	0.4	0.8	3.0	1.3	2.9	1.5	2.9	1.1	0.0	0.0	0.0	0.0	**14**
1995	0.0	0.0	0.0	0.0	1.7	20.2	19.5	7.7	11.2	5.2	5.7	2.0	7.0	0.0	0.0	**80**
1996	0.0	0.0	0.0	0.0	0.0	1.3	11.2	10.2	6.4	5.4	7.0	1.8	0.0	0.0	0.0	**43**
1997	0.0	0.0	0.0	0.0	0.0	0.0	2.7	15.1	11.3	2.5	0.0	0.9	0.7	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	5.6	3.2	0.6	0.9	0.0	0.0	0.0	**15**
2000	0.0	0.0	0.0	0.0	0.0	2.3	4.5	0.8	1.8	4.4	2.1	1.0	0.2	0.3	0.0	**17**
2001	0.0	0.0	0.0	0.0	0.0	2.5	4.6	15.0	6.0	5.7	7.6	4.6	1.2	1.6	0.3	**49**
2002	0.0	0.0	0.0	0.0	0.0	2.0	1.6	1.8	10.6	2.7	1.5	2.4	1.1	0.5	0.0	**24**
2003	0.0	0.0	0.0	0.0	0.0	0.0	4.1	13.2	5.5	22.1	7.3	5.5	6.4	3.5	0.0	**68**
2004	0.0	0.0	0.0	0.0	0.0	0.0	2.7	7.3	12.0	7.0	11.3	3.2	1.6	0.5	0.0	**46**
2005	0.0	0.0	0.0	0.0	0.0	0.2	1.4	3.3	8.0	9.0	10.2	9.5	3.4	1.2	4.8	**51**
2006	0.0	0.0	0.0	0.0	3.2	5.3	3.2	0.3	4.3	5.9	3.5	4.9	6.8	2.3	6.6	**46**
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	1.4	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	7.9	2.1	0.8	1.7	**25**
2009	0.0	0.0	0.0	0.0	3.2	3.8	0.2	2.9	8.6	2.8	6.6	4.8	10.5	3.8	5.1	**52**
Average																**35**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the upper Bay during the 1985-2009 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15 +**	**Total**
1985	0.0	47.5	148.8	1.9	0.0	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**199**
1986	0.0	219.0	192.3	450.8	0.4	3.4	2.2	3.8	1.3	0.0	0.0	0.0	0.0	0.0	1.2	**874**
1987	0.0	131.7	231.0	68.1	138.8	0.0	2.1	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**576**
1988	0.0	52.1	38.0	61.6	37.8	36.8	0.6	0.0	0.0	7.2	0.0	0.0	0.0	0.0	0.0	**234**
1989	0.0	8.1	102.3	17.4	21.1	26.9	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**192**
1990	0.0	56.7	28.4	92.8	20.1	24.9	22.9	16.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**263**
1991	0.0	84.1	254.9	36.8	40.9	11.3	16.0	9.5	4.3	0.1	0.0	0.0	0.0	0.0	0.0	**458**
1992	0.0	22.5	193.9	150.1	19.4	52.9	27.7	19.1	7.5	0.5	0.0	0.0	0.0	0.0	0.0	**494**
1993	0.0	30.6	126.2	149.1	63.0	16.3	27.3	9.9	7.5	0.5	0.0	0.0	0.0	0.0	0.0	**430**
1994	0.0	25.4	54.5	96.3	101.8	43.2	14.5	26.8	6.4	2.1	0.3	0.0	0.0	0.0	0.0	**371**
1995	0.0	79.0	108.4	75.8	89.8	52.9	30.0	11.6	12.4	3.7	7.2	0.9	0.0	0.0	0.0	**471**
1996	0.0	6.2	433.5	57.6	23.3	86.2	59.2	34.1	29.0	11.8	12.0	0.0	0.6	0.0	0.0	**753**
1997	0.0	34.8	41.4	149.2	14.4	24.5	24.2	16.1	8.7	1.7	12.6	0.0	0.2	0.0	0.0	**328**
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	4.0	86.8	32.6	28.6	13.7	4.3	0.9	4.7	1.3	0.5	0.1	0.3	0.0	0.0	**178**
2000	0.0	15.5	56.0	89.3	51.5	81.1	30.5	11.3	7.0	7.0	5.6	3.8	2.3	0.4	0.8	**362**
2001	0.0	2.2	42.4	58.4	61.3	28.2	34.6	39.4	6.7	9.4	4.0	0.8	0.6	0.0	0.8	**289**
2002	0.0	144.7	18.3	32.8	98.7	37.5	33.5	41.2	18.3	4.3	1.2	0.7	2.0	0.0	0.0	**433**
2003	0.0	21.1	136.9	39.4	46.8	77.8	72.0	34.0	36.9	28.0	6.4	5.4	3.5	0.0	0.0	**508**
2004	0.0	45.7	220.0	154.5	37.3	36.1	48.4	42.9	40.1	25.7	20.3	0.8	2.3	1.1	0.0	**675**
2005	0.0	103.0	165.5	110.8	146.3	36.4	36.8	29.4	32.5	20.7	14.2	5.6	0.3	0.0	0.0	**702**
2006	0.0	8.9	345.1	52.6	53.7	34.4	17.0	15.6	16.7	17.4	11.0	6.3	1.3	1.0	0.0	**581**
2007	0.0	6.5	26.8	101.2	21.0	20.9	15.7	7.3	7.8	7.1	6.5	4.5	2.2	1.4	0.2	**229**
2008	0.0	1.5	120.9	166.8	178.4	26.8	35.4	29.0	14.9	13.6	10.5	10.4	18.8	3.8	3.3	**634**
2009	0.0	44.3	46.5	177.6	66.3	185.9	28.3	25.7	33.0	8.8	15.4	12.1	22.3	2.9	1.5	**671**
Average																**453**

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

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**
1985	0	0.0	0.0	0.0	2.2	0.8	2.9	0.8	1.0	0.4	0.0	0.6	1.3	0.5	1.0	**12**
1986	0	0.0	0.0	12.8	1.9	1.0	1.6	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	**18**
1987	0	0.0	0.0	6.8	20.7	3.3	0.6	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.5	**38**
1988	0	0.0	0.0	9.2	10.8	16.4	3.2	0.0	1.0	1.0	0.0	0.0	0.0	0.7	0.4	**43**
1989	0	0.0	0.0	17.0	31.8	22.7	39.1	3.0	0.5	0.6	0.0	0.0	0.5	0.0	0.0	**115**
1990	0	0.0	0.0	0.0	15.7	24.2	15.9	40.7	3.1	3.0	0.0	0.0	4.7	2.5	4.4	**114**
1991	0	0.0	0.0	1.3	0.8	22.9	23.1	15.5	32.9	4.8	3.4	0.0	14.1	14.1	5.1	**138**
1992	0	0.0	1.0	0.0	1.4	9.9	28.1	18.7	19.0	15.6	0.0	0.0	16.3	3.4	0.0	**113**
1993	0	0.0	0.0	3.0	0.0	5.4	15.2	30.1	23.5	19.0	8.2	1.6	2.8	5.6	2.8	**117**
1994	0	0.0	0.0	0.0	7.5	7.1	8.8	7.7	31.3	6.1	4.0	0.0	0.0	0.0	0.0	**73**
1995																
1996	0	0.0	0.0	0.0	6.9	26.4	38.3	37.0	36.5	37.5	21.6	8.7	1.1	0.0	0.0	**214**
Average																**90**

Table 7. Estimates of selectivity-corrected age-class CPE by year for male striped bass captured in the Choptank River during the 1985-1996 spawning stock surveys. CPUE is standardized as the number of fish captured in 1000 square yards of experimental drift gill net per hour. The Choptank River was not sampled in 1995, and has not been sampled since 1996.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**
1985	0.0	162.2	594.7	23.9	7.3	4.8	10.0	0.0	3.5	0.0	0.0	0.0	0.5	0.0	0	**807**
1986	0.0	290.2	172.6	393.9	12.0	6.1	1.6	1.2	0.0	0.0	0.0	0.0	0.6	0.0	0	**878**
1987	0.0	223.3	262.0	79.0	156.4	9.6	0.7	1.2	0.4	0.0	0.0	0.0	0.7	0.0	0	**733**
1988	0.0	27.0	223.3	114.6	53.5	111.5	4.7	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0	**536**
1989	0.0	228.5	58.1	466.1	278.6	191.9	173.9	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0	**1399**
1990	0.0	59.5	280.4	36.3	198.1	165.8	75.9	116.9	5.0	0.0	2.3	0.0	4.3	0.0	0	**944**
1991	0.0	410.4	174.9	112.2	62.1	115.6	79.8	55.5	18.2	0.6	0.0	0.0	0.0	0.0	0	**1029**
1992	0.0	16.2	733.0	135.2	168.4	141.9	136.4	81.2	23.6	10.1	0.0	0.0	0.0	11.3	0	**1457**
1993	0.0	291.3	128.8	1156.4	193.5	158.8	161.5	147.3	45.9	11.3	3.5	0.0	0.0	0.0	0	**2298**
1994	0.0	112.8	463.3	99.5	835.2	270.9	139.4	188.5	54.9	9.2	7.6	8.3	0.9	0.0	0	**2191**
1995																
1996	0.0	7.8	682.2	106.0	280.6	171.5	334.1	91.1	85.6	11.8	23.1	0.0	0.0	0.0	0	**1794**
Average																**1279**

Table 8. Mean values of the pooled, weighted, annual age-specific CPUEs (1985–2009) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Sum**
1985	0.0	140.5	305.5	31.9	4.8	1.3	2.2	0.0	0.4	0.1	0.0	0.4	0.3	0.0	0.7	**488**
1986	0.0	230.2	261.1	497.6	4.0	5.3	2.0	2.9	2.8	0.0	0.0	0.0	0.0	0.0	0.9	**1007**
1987	0.0	142.2	258.0	115.1	176.1	17.9	2.2	2.6	0.2	0.0	0.0	0.0	0.0	0.3	0.3	**715**
1988	0.0	40.8	77.6	71.3	57.0	74.6	1.3	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.3	**327**
1989	0.0	33.1	154.7	80.5	45.5	48.8	32.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	**396**
1990	0.0	78.1	158.1	120.4	48.3	34.3	32.0	29.8	0.9	0.1	0.1	0.5	0.7	0.1	0.2	**504**
1991	0.0	73.4	191.9	62.2	47.1	26.7	26.0	19.2	10.6	0.4	1.5	0.0	0.6	0.6	1.1	**461**
1992	0.1	27.4	221.1	153.5	58.6	69.9	42.9	29.1	13.7	7.0	3.3	0.0	0.9	1.2	0.2	**629**
1993	0.0	41.0	132.0	187.2	88.2	51.0	51.9	37.1	22.6	7.4	3.1	0.8	1.4	1.4	0.1	**625**
1994	0.0	26.8	103.5	98.0	117.9	59.5	34.0	42.9	17.6	8.6	3.1	1.3	0.3	0.0	0.0	**513**
1995	0.0	50.0	117.2	68.4	60.9	51.6	40.0	25.0	19.7	11.6	9.6	3.5	4.6	0.0	0.0	**462**
1996	0.0	4.0	368.3	102.2	34.7	69.5	64.4	42.3	35.4	16.7	15.2	4.7	1.6	0.0	0.0	**759**
1997	0.0	40.6	46.3	134.6	46.0	21.7	19.7	25.8	22.3	12.3	12.0	3.7	1.1	0.7	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	7.0	174.2	80.1	56.8	35.3	11.4	6.6	11.1	5.2	5.1	2.7	1.1	0.0	0.1	**397**
2000	0.0	10.2	50.7	107.6	50.3	58.2	27.2	14.1	8.1	7.9	7.8	4.9	2.1	2.6	0.8	**352**
2001	0.0	4.7	39.1	52.3	51.6	23.2	28.5	38.0	13.2	11.9	9.8	5.5	2.8	1.2	0.7	**283**
2002	0.0	96.3	41.5	38.5	83.3	34.0	29.9	31.6	22.8	7.4	4.1	5.4	4.2	1.1	0.2	**400**
2003	0.0	17.7	110.0	47.8	37.1	61.5	56.8	30.8	27.5	34.4	9.9	10.6	7.3	2.9	0.7	**455**
2004	0.0	31.3	179.1	121.7	41.0	32.9	43.9	46.5	37.2	26.4	27.3	8.1	8.3	5.7	1.5	**611**
2005	0.0	67.7	105.6	73.9	97.1	24.3	25.8	21.7	27.4	20.4	17.5	11.3	3.0	1.0	3.6	**500**
2006	0.0	8.8	266.0	41.3	49.0	30.3	15.0	12.8	18.5	21.5	13.4	10.7	8.9	3.0	6.6	**506**
2007	0.0	8.1	23.0	76.6	14.9	15.3	13.5	7.4	9.0	10.0	16.0	8.0	3.1	5.4	5.3	**216**
2008	0.0	3.3	88.4	110.5	114.4	17.1	23.1	19.8	11.3	12.1	10.1	14.1	13.4	3.3	3.6	**445**
2009	0.0	41.1	42.7	154.4	51.9	138.8	21.2	22.7	31.2	9.0	15.8	12.1	23.4	4.8	5.1	**574**
Average																**497**

Table 9. Lower confidence limits (95%) of the pooled, weighted, annual age-specific CPUEs (1985–2009) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0.0	127.3	277.1	28.8	4.2	1.0	0.9	*0.0*	*0.0*	*0.0*	0.0	*0.0*	*0.0*	*0.0*	*
1986	0.0	214.2	245.6	464.6	3.6	4.8	1.7	2.7	1.8	0.0	0.0	0.0	0.0	*0.0*	*
1987	0.0	130.4	245.1	110.6	167.8	12.1	*0.0*	2.3	*0.0*	0.0	0.0	0.0	0.0	0.1	*
1988	0.0	36.2	69.3	65.8	53.8	68.0	0.1	*0.0*	*0.0*	0.7	0.0	0.0	0.0	*0.0*	*
1989	0.0	24.7	148.0	66.1	35.5	41.5	24.8	*0.0*	0.0	*0.0*	0.0	0.0	*0.0*	0.0	*
1990	0.0	65.6	148.3	116.3	42.3	28.9	29.4	23.9	0.4	*0.0*	*0.0*	0.0	*0.0*	*0.0*	*
1991	0.0	57.0	182.6	58.6	44.8	22.6	22.4	16.5	5.4	*0.0*	0.6	0.0	*0.0*	*0.0*	*0.0*
1992	0.1	23.0	206.8	145.6	54.6	65.7	38.7	26.1	11.0	4.1	2.3	0.0	*0.0*	*0.0*	*
1993	0.0	30.5	125.3	159.4	83.6	47.7	47.1	31.7	18.1	3.8	1.7	*0.0*	0.0	*0.0*	*
1994	0.0	21.7	89.3	94.5	96.8	52.9	31.3	38.7	12.5	7.5	2.3	1.0	0.3	0.0	*
1995	0.0	45.8	114.5	66.4	59.3	49.6	38.5	24.1	18.7	11.0	9.2	3.2	1.9	0.0	*
1996	0.0	*0.0*	347.2	98.2	26.3	65.2	57.3	37.9	30.4	10.3	10.3	3.1	1.1	0.0	0.0
1997	0.0	39.0	44.7	132.5	44.3	20.8	18.8	23.8	20.1	11.2	8.0	3.3	1.0	0.5	0.0
1998	0.0	35.7	138.9	31.4	144.5	31.6	11.3	17.6	16.7	14.2	8.7	8.8	1.2	0.3	0.2
1999	0.0	5.9	169.4	77.5	54.9	34.0	10.9	6.3	10.2	4.8	4.6	2.3	1.1	0.0	0.1
2000	0.0	9.6	49.1	105.2	49.0	56.4	25.3	13.5	7.7	7.4	7.3	4.6	2.0	1.3	*
2001	0.0	4.2	37.6	51.1	50.4	20.4	27.6	36.7	12.6	11.2	9.2	4.7	2.3	0.8	*
2002	0.0	87.0	39.7	37.7	80.8	32.8	28.6	30.5	21.7	6.9	3.8	5.2	3.6	0.5	*
2003	0.0	17.1	106.1	46.5	35.9	59.2	54.9	27.5	26.4	31.5	8.8	8.2	6.7	1.3	0.4
2004	0.0	23.5	175.6	117.5	40.1	31.6	42.5	44.2	34.5	25.4	25.2	7.4	7.7	5.3	*
2005	0.0	64.5	100.7	71.4	93.2	23.3	24.9	21.0	26.4	19.2	16.4	10.2	2.6	0.8	*
2006	0.0	7.4	250.0	39.6	47.1	26.8	12.4	12.3	15.7	17.5	11.0	6.8	3.4	1.3	*
2007	0.0	7.1	21.9	74.5	14.5	14.9	12.6	6.2	8.0	9.3	13.2	7.0	2.8	3.9	*
2008	0.0	2.9	84.3	106.0	108.8	16.4	22.1	18.9	10.8	11.4	9.3	12.6	6.8	2.9	*
2009	0.0	39.5	41.2	149.8	50.0	133.7	20.5	21.9	29.4	8.5	15.0	10.8	20.6	4.3	*

* 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 (1985–2009) for the Maryland Chesapeake Bay striped bass spawning stock. CPUE is reported as the number of fish captured in 1000 square yards of net per hour.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0.0	153.6	334.0	35.1	5.4	1.6	3.4	0.2	2.6	0.2	0.1	0.8	0.6	0.1	*
1986	0.0	246.2	276.6	530.6	4.5	5.8	2.4	3.2	3.8	0.0	0.0	0.0	0.0	0.1	*
1987	0.0	154.0	270.9	119.6	184.5	23.7	5.4	2.8	2.3	0.0	0.0	0.0	0.0	0.5	*
1988	0.0	45.3	86.0	76.8	60.2	81.1	2.5	1.0	1.1	8.0	0.0	0.0	0.0	0.1	*
1989	0.0	41.6	161.4	95.0	55.5	56.0	41.0	0.6	0.1	0.2	0.0	0.0	0.1	0.0	*
1990	0.0	90.5	168.0	124.5	54.3	39.6	34.7	35.7	1.3	0.5	0.3	1.0	5.3	1.7	*
1991	0.0	89.8	201.2	65.8	49.4	30.8	29.6	21.8	15.8	1.2	2.3	0.0	6.3	5.4	2.9
1992	0.3	31.8	235.4	161.4	62.7	74.1	47.1	32.0	16.3	10.0	4.2	0.0	7.3	8.9	*
1993	0.0	51.4	138.7	215.1	92.9	54.2	56.7	42.5	27.1	11.0	4.5	1.7	2.8	7.6	*
1994	0.0	32.0	117.8	101.5	138.9	66.1	36.7	47.0	22.7	9.6	3.8	1.5	0.3	0.0	*
1995	0.0	54.2	120.0	70.3	62.5	53.5	41.5	25.9	20.6	12.1	10.1	3.8	7.2	0.0	*
1996	0.0	10.8	389.5	106.1	43.2	73.9	71.5	46.6	40.4	23.2	20.1	6.3	2.2	0.0	0.0
1997	0.0	42.2	47.9	139.2	47.7	22.3	20.6	27.6	24.0	12.9	15.8	3.9	1.2	0.7	0.0
1998	0.0	36.4	146.7	34.1	154.0	33.0	15.1	19.3	17.9	15.6	9.5	11.0	2.2	0.5	0.4
1999	0.0	8.2	179.0	82.7	58.7	36.6	11.8	6.9	12.0	5.7	5.6	3.0	1.1	0.0	0.1
2000	0.0	10.9	52.3	110.0	51.6	60.0	29.1	14.6	8.4	8.5	8.2	5.1	2.2	3.9	*
2001	0.0	5.2	40.6	53.6	52.8	26.1	29.3	39.3	13.7	12.6	10.4	6.4	3.3	1.6	*
2002	0.0	105.7	43.4	39.2	85.8	35.1	31.2	32.7	23.8	7.9	4.3	5.6	4.9	1.7	*
2003	0.0	18.3	113.9	49.1	38.3	63.8	58.7	34.0	28.5	37.3	10.9	12.9	8.0	4.6	0.9
2004	0.0	39.1	182.6	126.0	42.0	34.1	45.2	48.8	40.0	27.5	29.4	8.8	8.9	6.2	*
2005	0.0	70.8	110.5	76.4	101.0	25.3	26.8	22.5	28.5	21.5	18.5	12.5	3.3	1.2	*
2006	0.0	10.1	282.0	43.0	50.8	33.8	17.6	13.3	21.3	25.5	15.8	14.7	14.4	4.7	*
2007	0.0	9.1	24.1	78.7	15.4	15.8	14.4	8.5	10.1	10.8	18.8	8.9	3.3	7.0	*
2008	0.0	3.8	92.5	115.0	120.1	17.8	24.1	20.8	11.9	12.8	10.9	15.5	20.1	3.6	*
2009	0.0	42.7	44.2	159.0	53.7	143.9	21.9	23.4	33.1	9.4	16.7	13.5	26.2	5.3	*

* Note: Confidence intervals could not be calculated for age 15+ when more than one age class was present in the group.

Table 11. Coefficients of Variation of the pooled, weighted, annual age-specific CPUEs (1985–2009) for the Maryland Chesapeake Bay striped bass spawning stock.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0.00	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	0.00	0.03	0.03	0.03	0.06	0.05	0.09	0.05	0.18	0.00	0.00	0.00	0.28	2.62	*
1987	0.00	0.04	0.03	0.02	0.02	0.16	0.76	0.05	4.32	0.00	0.00	0.00	0.34	0.36	*
1988	0.00	0.06	0.05	0.04	0.03	0.04	0.45	0.00	13.03	0.42	0.00	0.00	0.00	1.10	*
1989	0.00	0.13	0.02	0.09	0.11	0.07	0.12	1.17	0.29	2.92	0.00	0.00	1.31	0.00	*
1990	0.00	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	0.00	0.11	0.02	0.03	0.02	0.08	0.07	0.07	0.25	0.96	0.29	0.00	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	0.00	3.38	3.16	*
1993	0.00	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	0.00	0.10	0.07	0.02	0.09	0.06	0.04	0.05	0.15	0.06	0.13	0.11	0.06	0.00	*
1995	0.00	0.04	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.29	0.00	*
1996	0.00	0.87	0.03	0.02	0.12	0.03	0.06	0.05	0.07	0.19	0.16	0.17	0.16	0.00	0.00
1997	0.00	0.02	0.02	0.01	0.02	0.02	0.02	0.04	0.04	0.04	0.16	0.04	0.06	0.07	0.00
1998	0.00	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	0.22
1999	0.00	0.08	0.01	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.05	0.07	0.02	0.00	0.17
2000	0.00	0.03	0.02	0.01	0.01	0.02	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.25	*
2001	0.00	0.05	0.02	0.01	0.01	0.06	0.02	0.02	0.02	0.03	0.03	0.08	0.09	0.18	*
2002	0.00	0.05	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.08	0.26	*
2003	0.00	0.02	0.02	0.01	0.02	0.02	0.02	0.05	0.02	0.04	0.06	0.11	0.04	0.28	0.21
2004	0.00	0.12	0.01	0.02	0.01	0.02	0.02	0.02	0.04	0.02	0.04	0.04	0.04	0.04	*
2005	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.05	0.06	0.09	*
2006	0.00	0.08	0.03	0.02	0.02	0.06	0.09	0.02	0.08	0.09	0.09	0.18	0.31	0.28	*
2007	0.00	0.06	0.02	0.01	0.01	0.01	0.03	0.08	0.06	0.04	0.09	0.06	0.04	0.15	*
2008	0.00	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	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.06	0.06	0.05	*

* Note: CV values >1.00 are noted by shadings. CVs could not be calculated for age 15+ when more than one age class was present in the group.

Table 12. Un-weighted striped bass catch per unit effort (CPUE) by year-class, late March through May 2009. 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**
2008	1	0.0	0.0	0.0	0.0	0.0	0.0
2007	2	80.3	7.6	0.0	0	36.0	44.3
2006	3	83.2	7.9	0.3	0.0	36.3	46.5
2005	4	295.0	27.9	0.0	0.0	117.4	177.6
2004	5	93.2	8.8	0.5	3.2	23.2	66.3
2003	6	247.2	23.3	0.5	3.8	57.0	185.9
2002	7	38.0	3.6	0.3	0.2	9.1	28.3
2001	8	41.8	3.9	2.6	2.9	10.5	25.7
2000	9	56.4	5.3	4.3	8.6	10.5	33.0
1999	10	16.3	1.5	1.9	2.8	2.8	8.8
1998	11	28.1	2.6	2.3	6.6	3.8	15.4
1997	12	21.4	2.0	1.9	4.8	2.6	12.1
1996	13	41.2	3.9	4.6	10.5	3.7	22.3
1995	14	8.5	0.8	1.2	3.8	0.6	2.9
≤1994	15+	8.5	0.8	1.4	5.1	0.6	1.5
Total		1059.2		22.0	52.5	314.1	670.7
% of Total				2	5	30	63
% of Sex				30	70	32	68
% of Potomac				7		93	
% of Upper Bay					7		93

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, late March through May 2009. 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
2008	1	0.0	0.0	0.0	0.0	0.0	0.0
2007	2	41.1	7.2	0.0	0.0	13.9	27.2
2006	3	42.7	7.4	0.1	0.0	14.0	28.6
2005	4	154.4	26.9	0.0	0.0	45.3	109.1
2004	5	51.9	9.0	0.2	2.0	8.9	40.7
2003	6	138.8	24.2	0.2	2.4	22.0	114.2
2002	7	21.2	3.7	0.1	0.1	3.5	17.4
2001	8	22.7	3.9	1.0	1.8	4.0	15.8
2000	9	31.2	5.4	1.7	5.3	4.1	20.3
1999	10	9.0	1.6	0.7	1.7	1.1	5.4
1998	11	15.8	2.8	0.9	4.1	1.5	9.5
1997	12	12.1	2.1	0.7	3.0	1.0	7.4
1996	13	23.4	4.1	1.8	6.5	1.4	13.7
1995	14	4.8	0.8	0.5	2.4	0.2	1.8
≤1994	15+	5.1	0.9	0.5	3.1	0.5	0.9
Total		574.3		8.5	32.2	121.4	412.2
% of Total				1	6	21	72
% of Sex				21	79	23	77
% of Potomac				7		93	
% of Upper Bay					7		93

* 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, late March through May 2009.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2007	2	POTOMAC	7	332	298	366	37	14
		UPPER	4	332	304	360	18	9
		COMBINED	11	332	312	352	30	9
2006	3	POTOMAC	7	383	344	422	42	16
		UPPER	5	375	349	402	21	10
		COMBINED	12	380	358	401	34	10
2005	4	POTOMAC	16	447	424	471	44	11
		UPPER	14	430	395	466	61	16
		COMBINED	30	439	420	459	53	10
2004	5	POTOMAC	8	568	520	615	57	20
		UPPER	9	577	502	653	98	33
		COMBINED	17	573	532	614	79	19
2003	6	POTOMAC	24	612	584	640	66	14
		UPPER	40	614	589	640	80	13
		COMBINED	64	614	595	632	75	9
2002	7	POTOMAC	17	680	652	707	53	13
		UPPER	9	713	646	780	87	29
		COMBINED	26	691	664	718	67	13
2001	8	POTOMAC	21	770	742	799	62	14
		UPPER	14	756	719	793	64	17
		COMBINED	35	765	743	786	63	11
2000	9	POTOMAC	16	826	794	859	61	15
		UPPER	25	808	776	839	76	15
		COMBINED	41	815	793	837	70	11
1999	10	POTOMAC	6	833	766	901	64	26
		UPPER	5	901	875	927	21	9
		COMBINED	11	864	825	904	59	18
1998	11	POTOMAC	4	896	744	1049	96	48
		UPPER	9	901	873	928	35	12
		COMBINED	13	899	866	933	56	16
1997	12	POTOMAC	3	951	874	1028	31	18
		UPPER	5	948	910	987	31	14
		COMBINED	8	949	925	973	29	10
1996	13	POTOMAC	4	944	927	961	11	5
		UPPER	7	942	861	1022	87	33
		COMBINED	11	943	897	988	68	20
1995	14	POTOMAC	1	1034	-	-	-	-
		UPPER	2	945	150	1739	88	63
		COMBINED	3	974	773	1176	81	47
1994	15	POTOMAC	1	1023	-	-	-	-
		UPPER	1	966	-	-	-	-
		COMBINED	2	995	632	1357	40	29

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, late March through May 2009.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2005	4	POTOMAC	1	500	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	500	-	-	-	-
2004	5	POTOMAC	1	699	-	-	-	-
		UPPER	2	620	372	867	28	20
		COMBINED	3	646	522	770	50	29
2003	6	POTOMAC	0	-	-	-	-	-
		UPPER	2	647	450	843	22	16
		COMBINED	2	647	450	843	22	16
2001	8	POTOMAC	4	817	783	850	21	11
		UPPER	1	821	-	-	-	-
		COMBINED	5	817	795	840	18	8
2000	9	POTOMAC	2	832	520	1143	35	25
		UPPER	6	908	874	941	32	13
		COMBINED	8	889	850	927	46	16
1999	10	POTOMAC	2	938	862	1014	8	6
		UPPER	2	973	852	1093	13	10
		COMBINED	4	955	920	990	22	11
1998	11	POTOMAC	7	949	924	973	26	10
		UPPER	13	923	896	949	43	12
		COMBINED	20	932	913	950	39	9
1997	12	POTOMAC	2	926	570	1282	40	28
		UPPER	10	1005	968	1042	52	16
		COMBINED	12	992	955	1028	58	17
1996	13	POTOMAC	13	1010	981	1039	48	13
		UPPER	8	1036	996	1076	48	17
		COMBINED	21	1020	998	1042	48	11
1995	14	POTOMAC	3	1070	993	1147	31	18
		UPPER	3	1047	933	1162	46	27
		COMBINED	6	1059	1020	1098	37	15
1994	15	POTOMAC	3	1060	908	1212	61	35
		UPPER	3	1140	977	1303	66	38
		COMBINED	6	1100	1025	1175	71	29
1993	16	POTOMAC	1	1066	-	-	-	-
		UPPER	2	1075	1017	1132	6	5
		COMBINED	3	1072	1055	1088	7	4

Table 16. Index of spawning biomass by year, for female striped bass ≥ 500 mm TL sampled from spawning areas of the Chesapeake Bay during March, April and May since 1985. The index is selectivity-corrected CPUE converted to biomass (kg) using parameters from a length-weight regression.

Year	Upper Bay	Potomac River
1985	64.93	25.90
1986	151.95	45.70
1987	400.49	88.84
1988	250.32	63.60
1989	120.29	80.54
1990	98.42	62.52
1991	109.38	138.65
1992	274.95	379.35
1993	278.52	420.88
1994	87.26	Not Sampled
1995	547.66	293.77
1996	347.87	391.57
1997	256.89	369.58
1998	157.41	216.98
1999	161.44	275.19
2000	169.91	301.76
2001	490.21	273.23
2002	266.39	380.74
2003	566.24	118.46
2004	389.76	578.78
2005	469.74	196.11
2006	407.50	461.58
2007	419.75	263.27
2008	230.19	163.08
2009	482.85	189.77
Average	**288.01**	**240.83**

Figure 1. Drift gill net sampling locations in spawning areas of the upper Chesapeake Bay and the Potomac River, late March - May 2009.

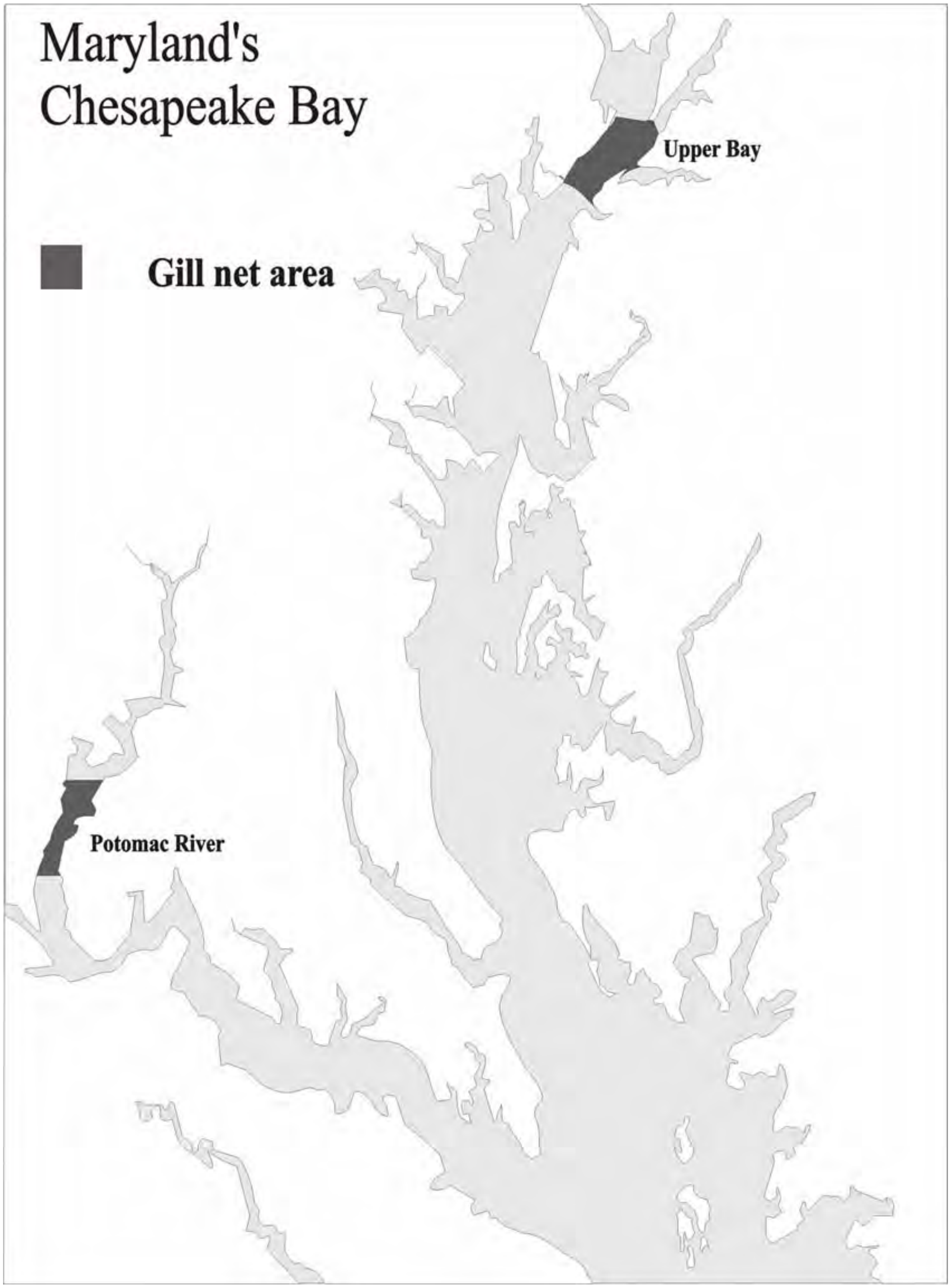


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, late March through May 2009. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

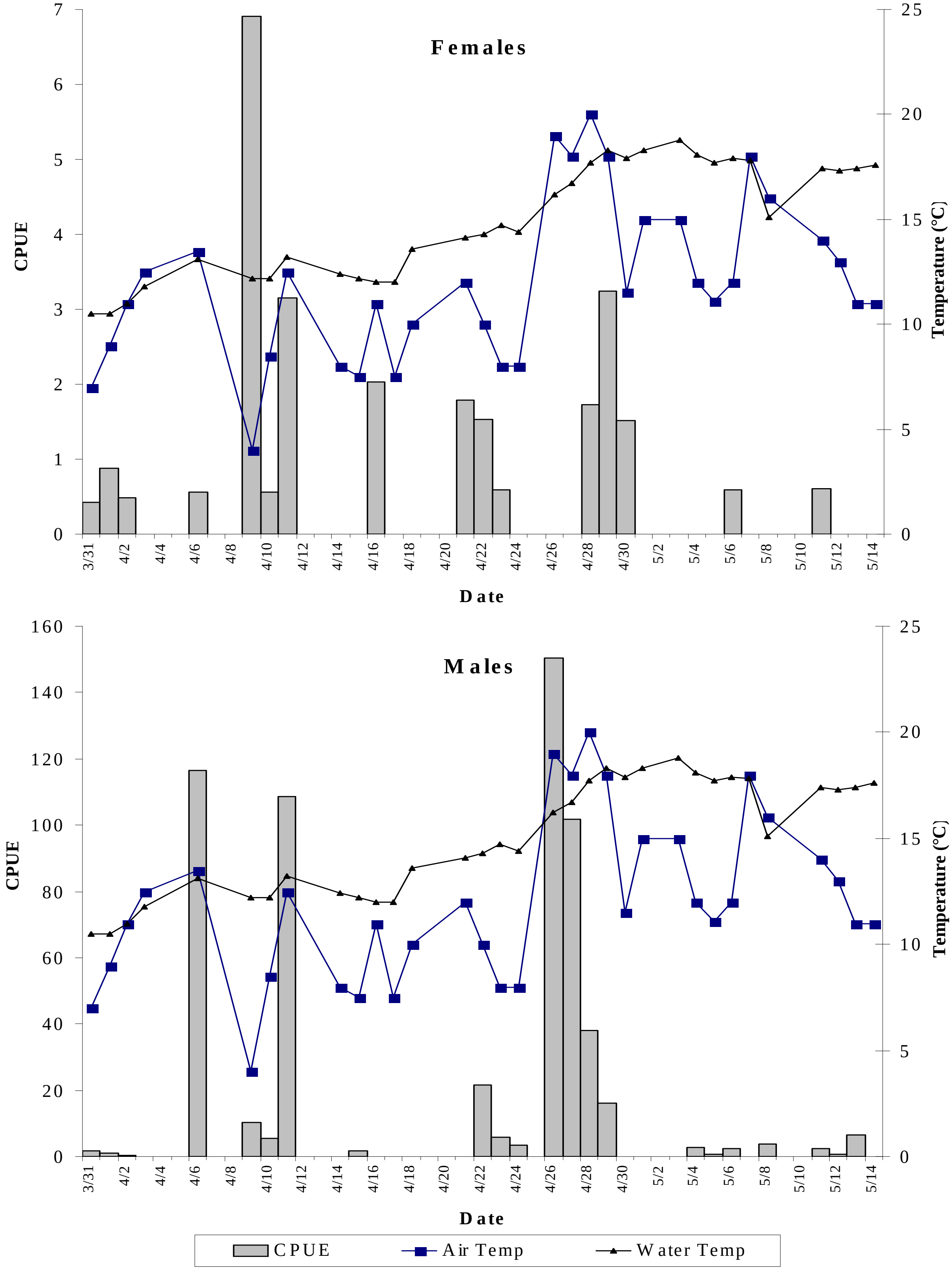


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the upper Chesapeake Bay, April through May 2009. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

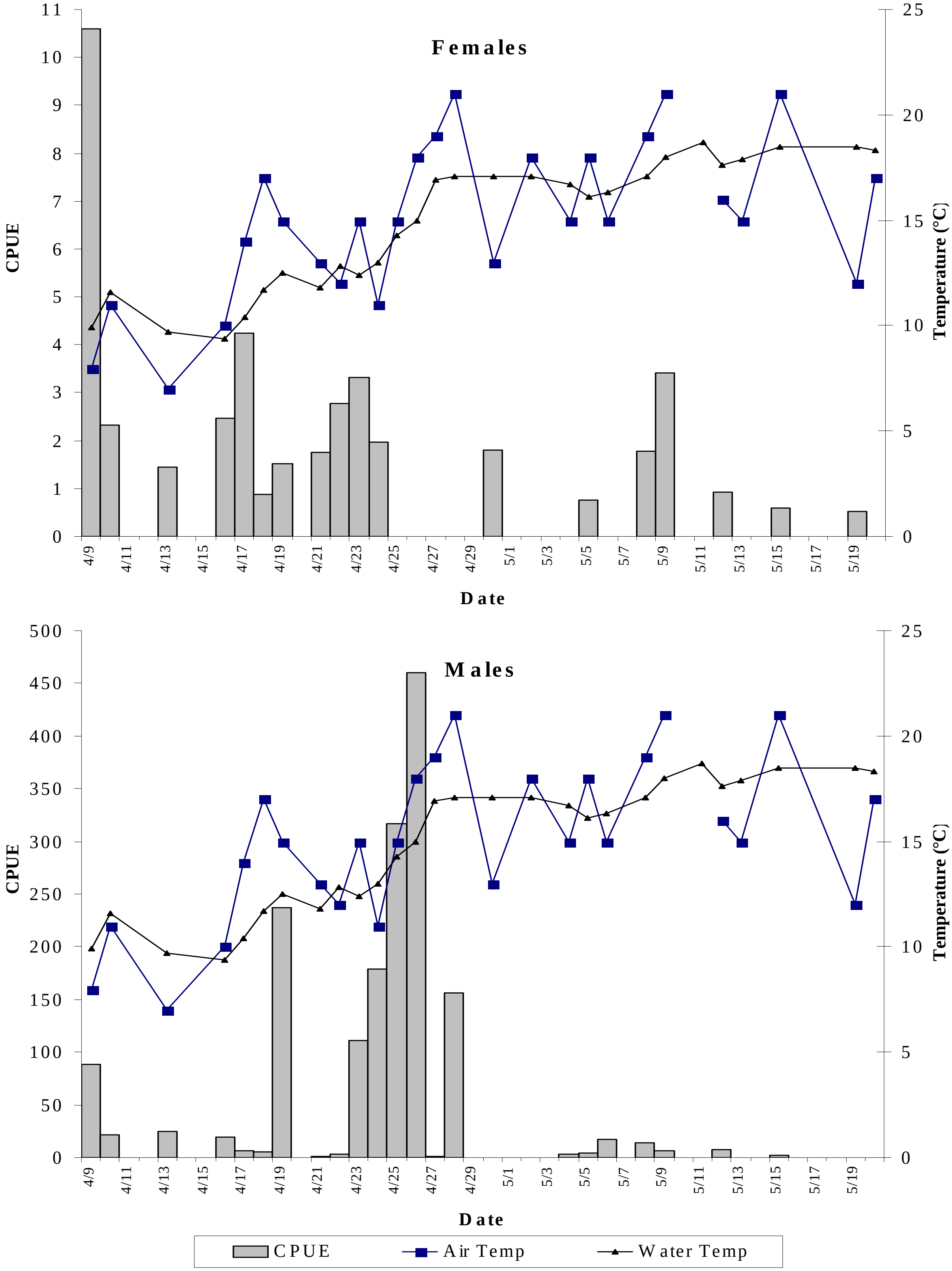


Figure 4. Length frequency of male and female striped bass from the spawning areas of the upper Chesapeake Bay and Potomac River, March through May 2009. Note different scales.

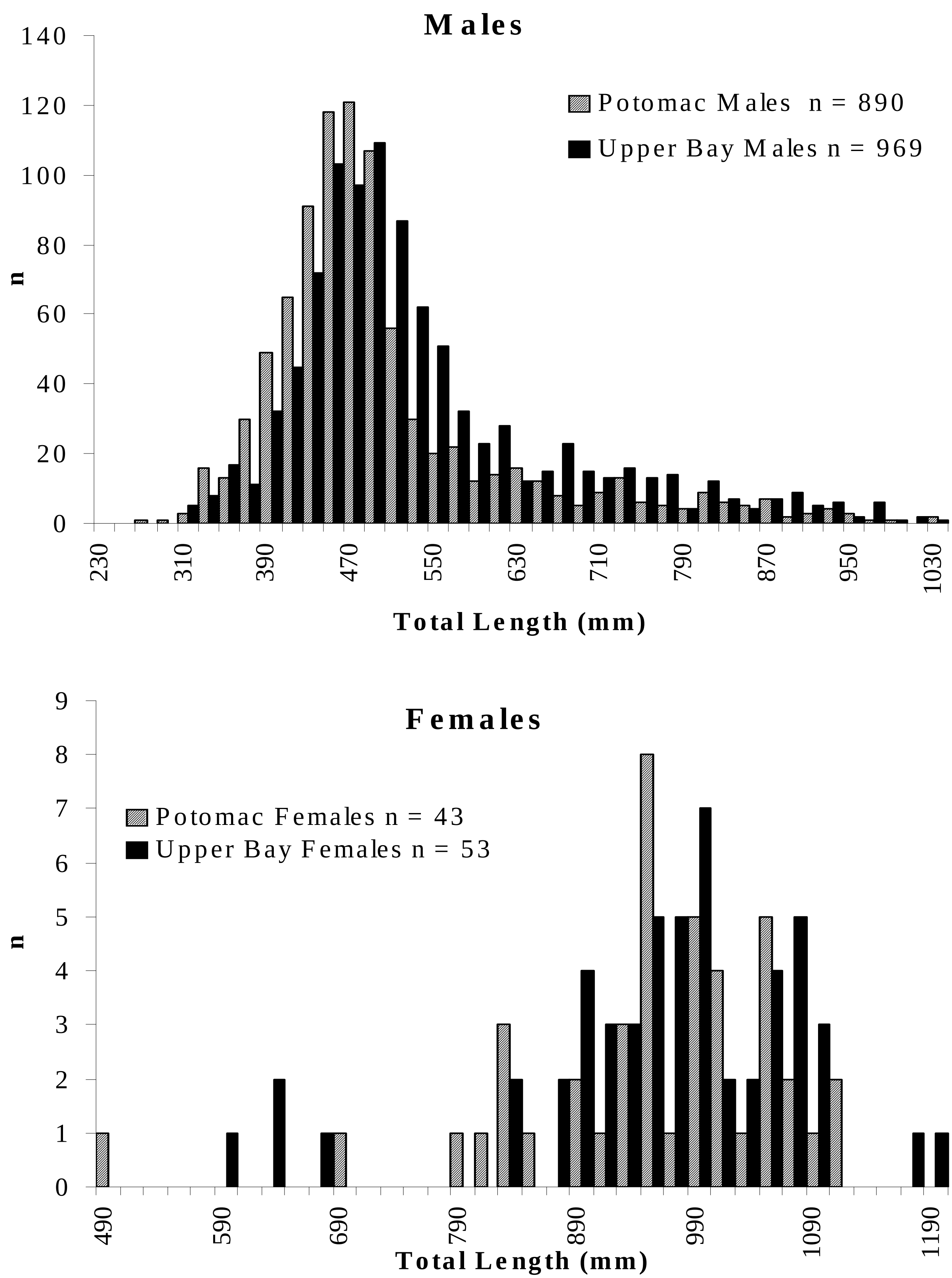
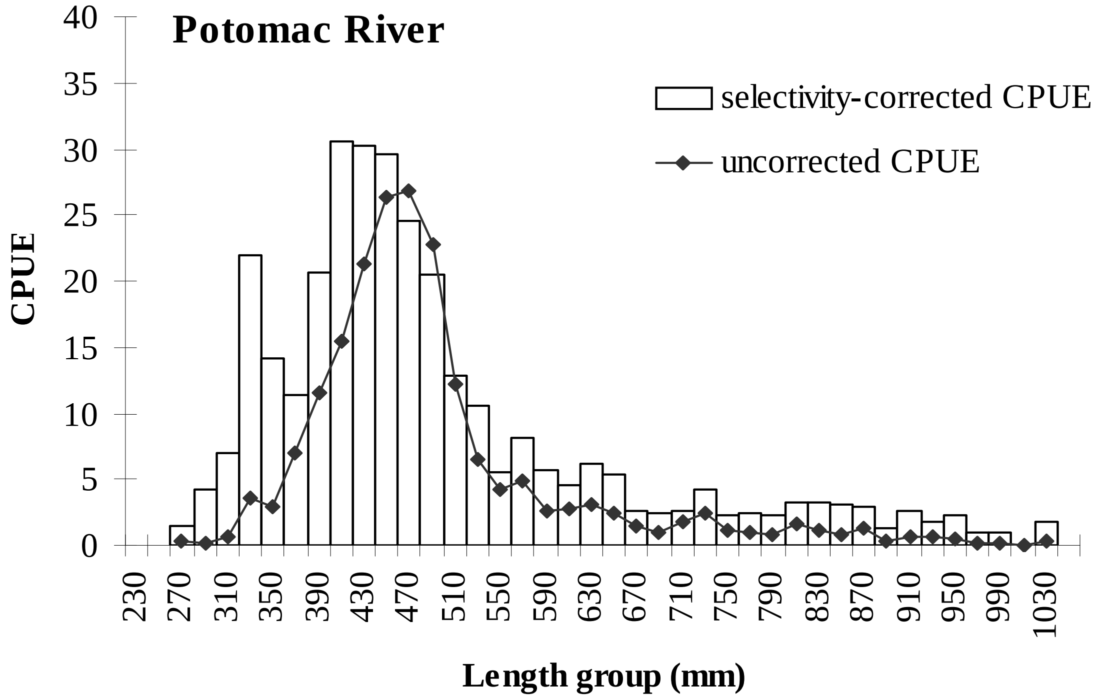


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the upper Bay and Potomac River, late March-May 2009. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net. Note different scales.



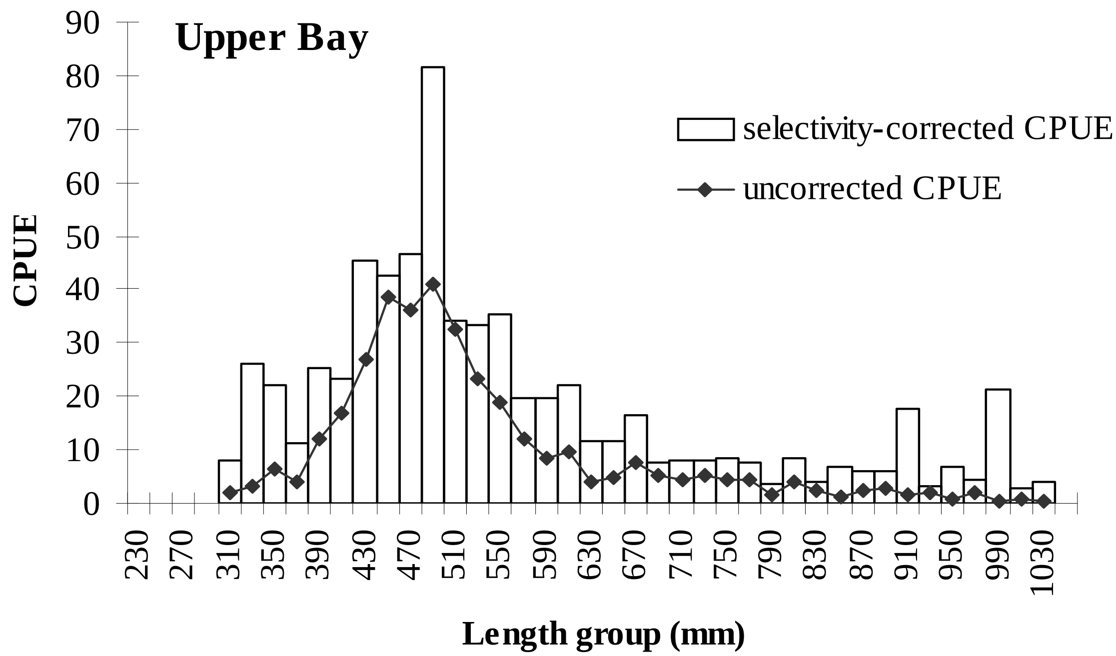
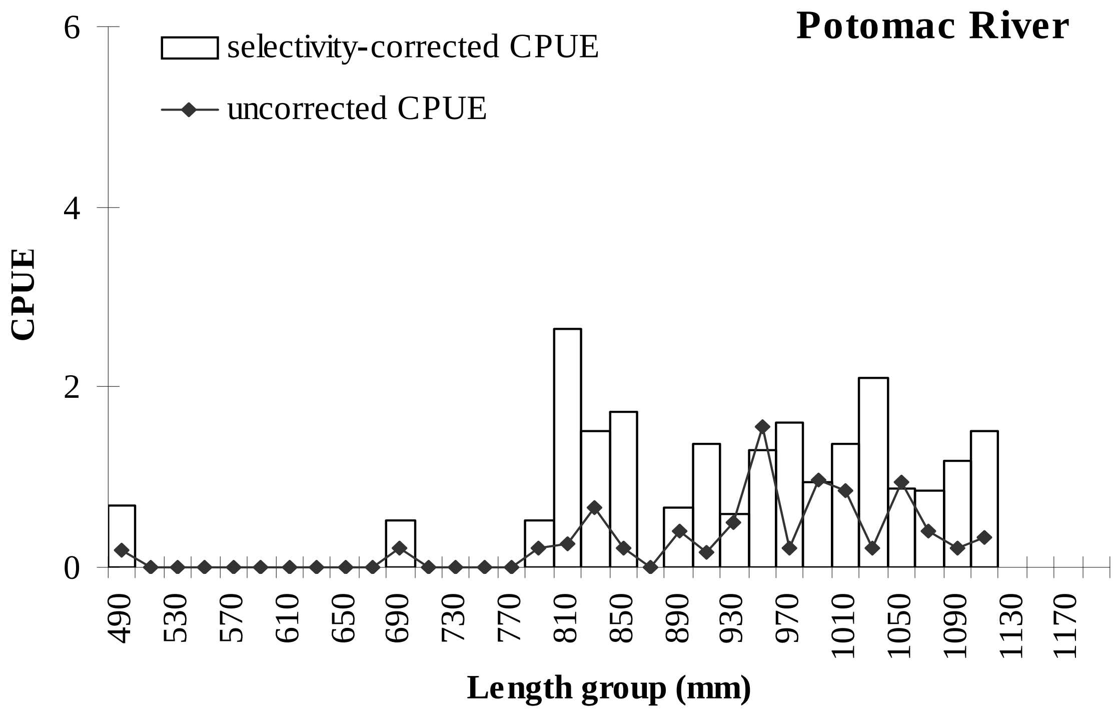


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the upper Bay and Potomac River, late March - May 2009. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



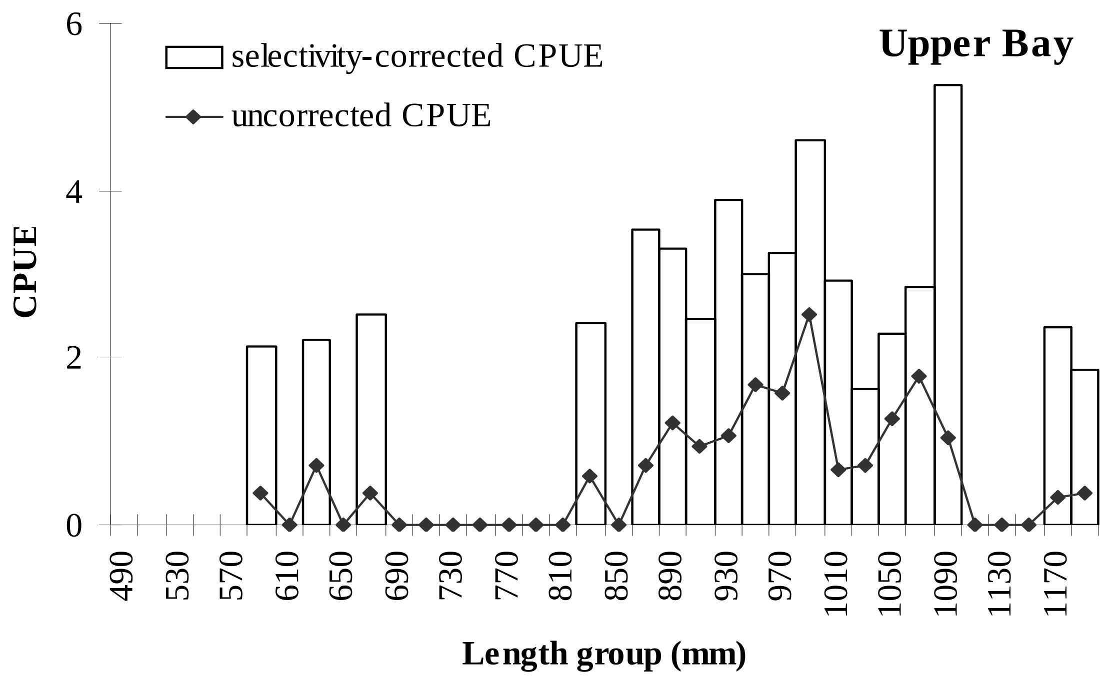


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985-2009. Error bars are ± 1 standard error (SE). The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

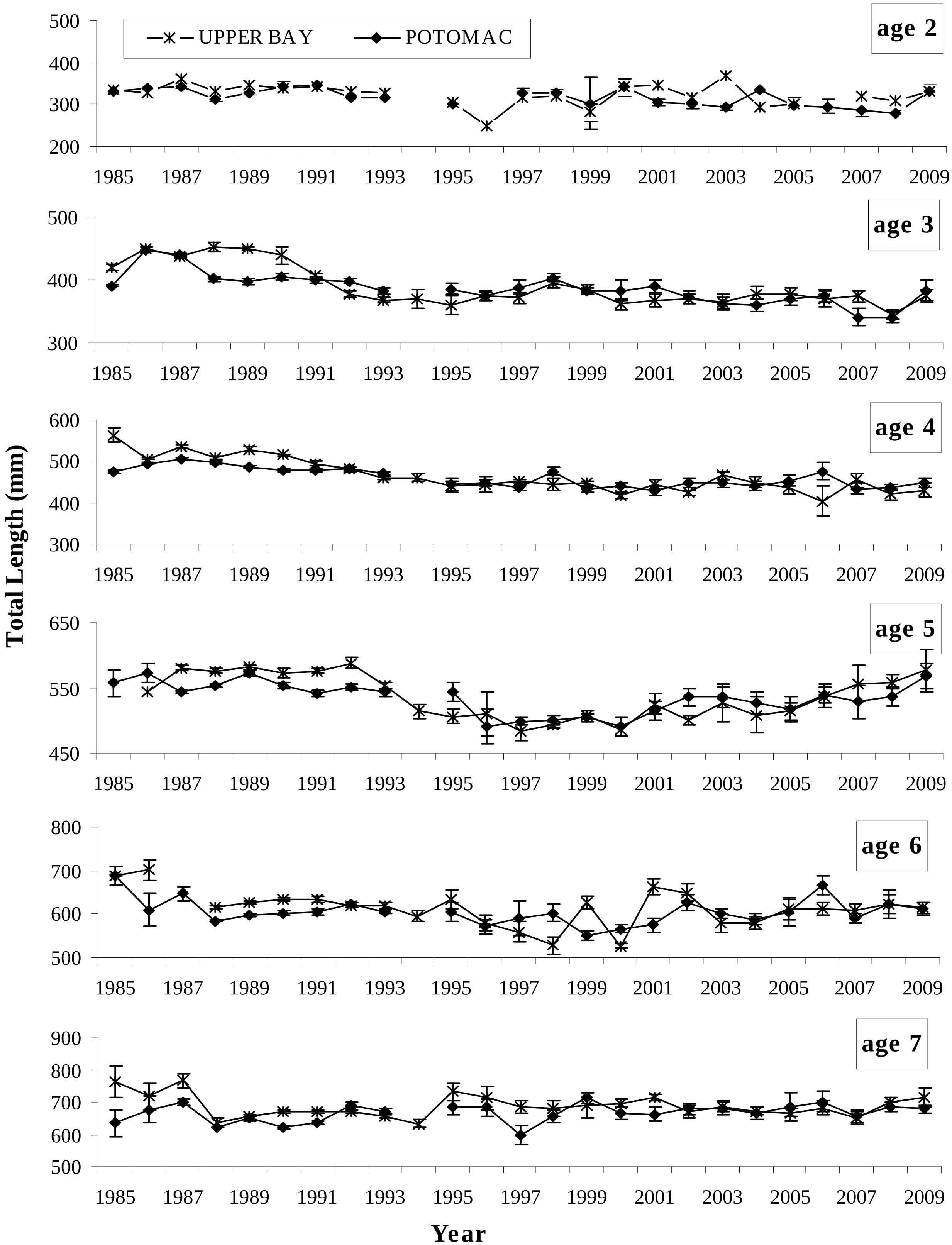


Figure 7. Continued.

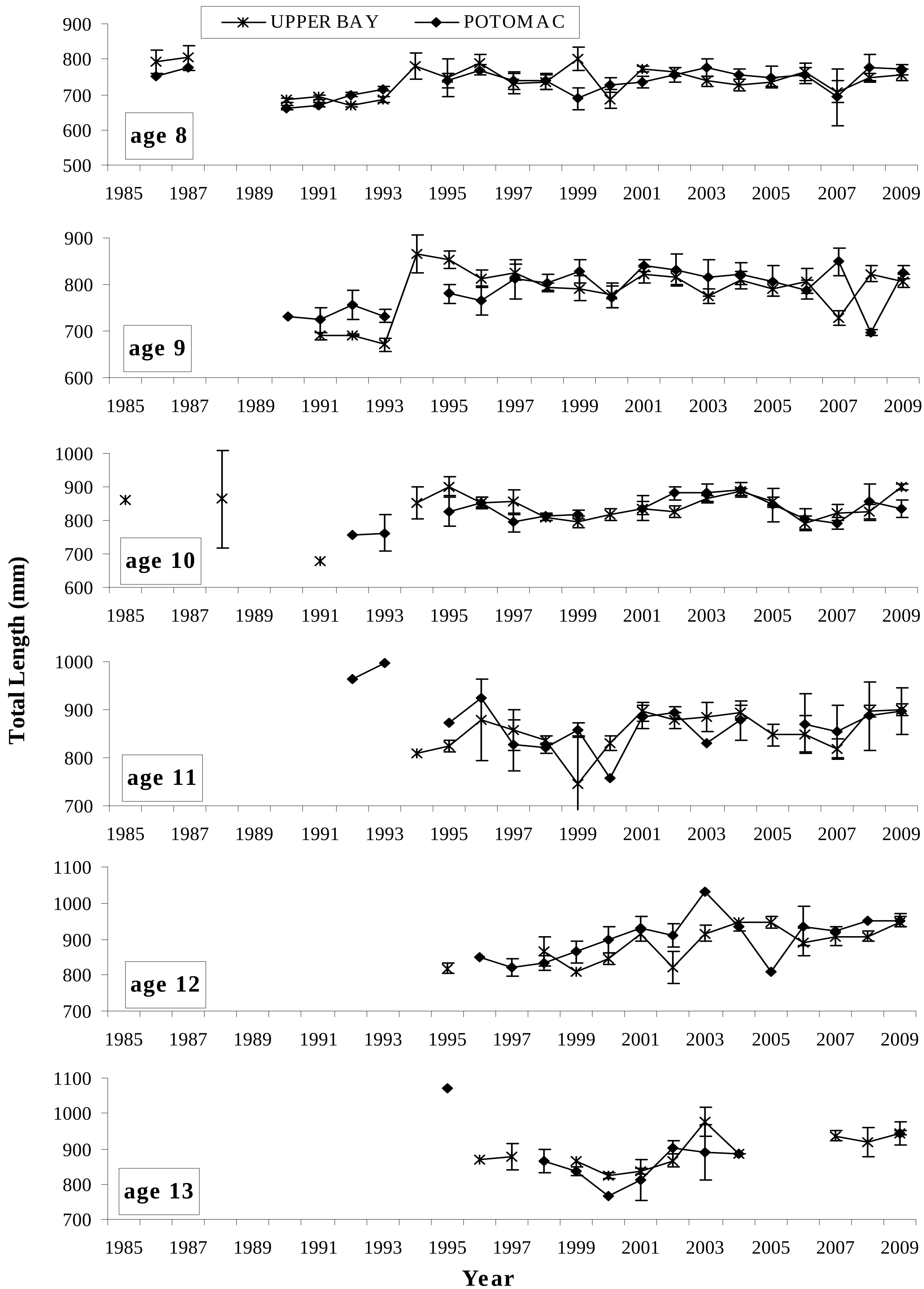


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from
spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985–2009. Error bars are ± 1 standard error (SE). Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

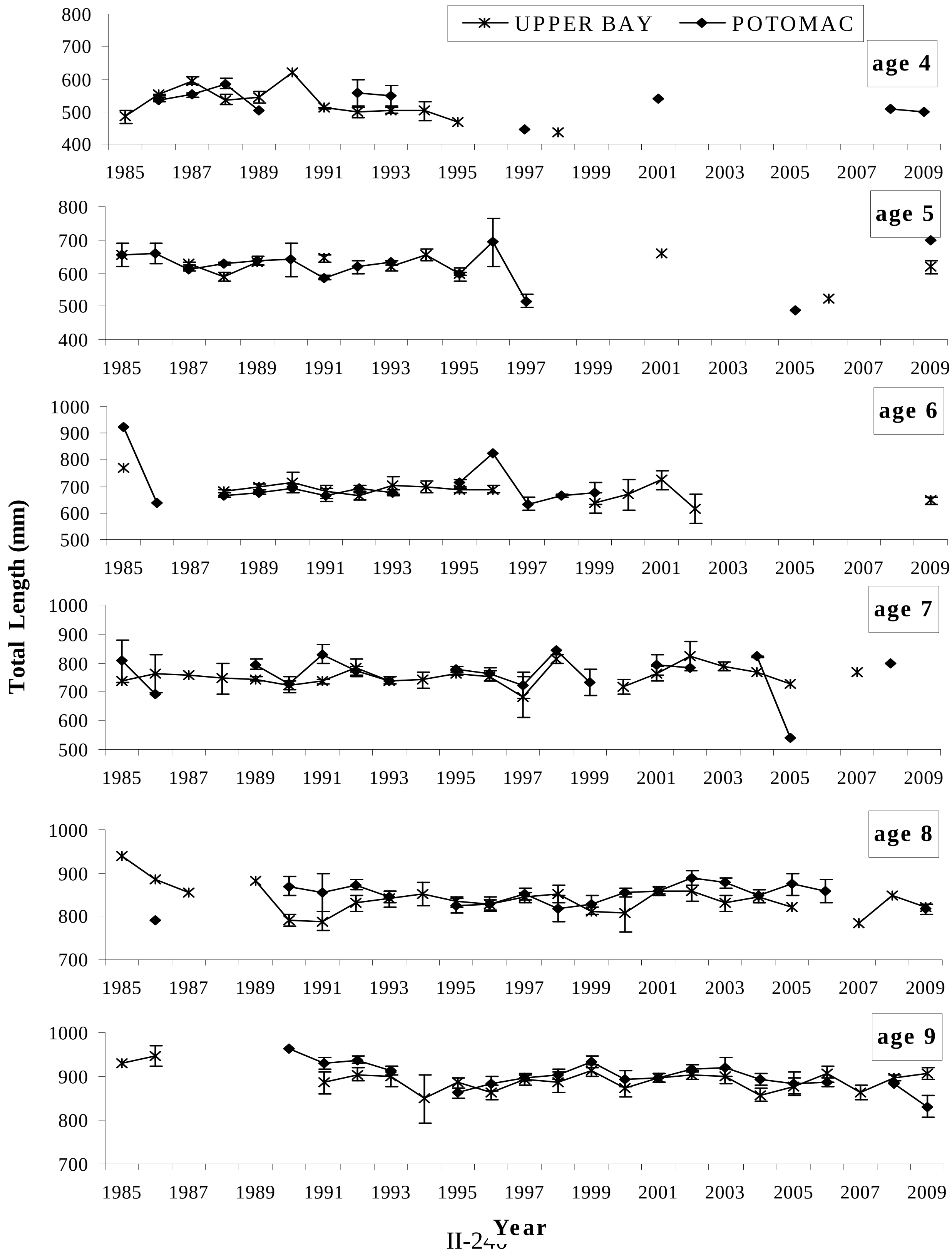


Figure 8. Continued.

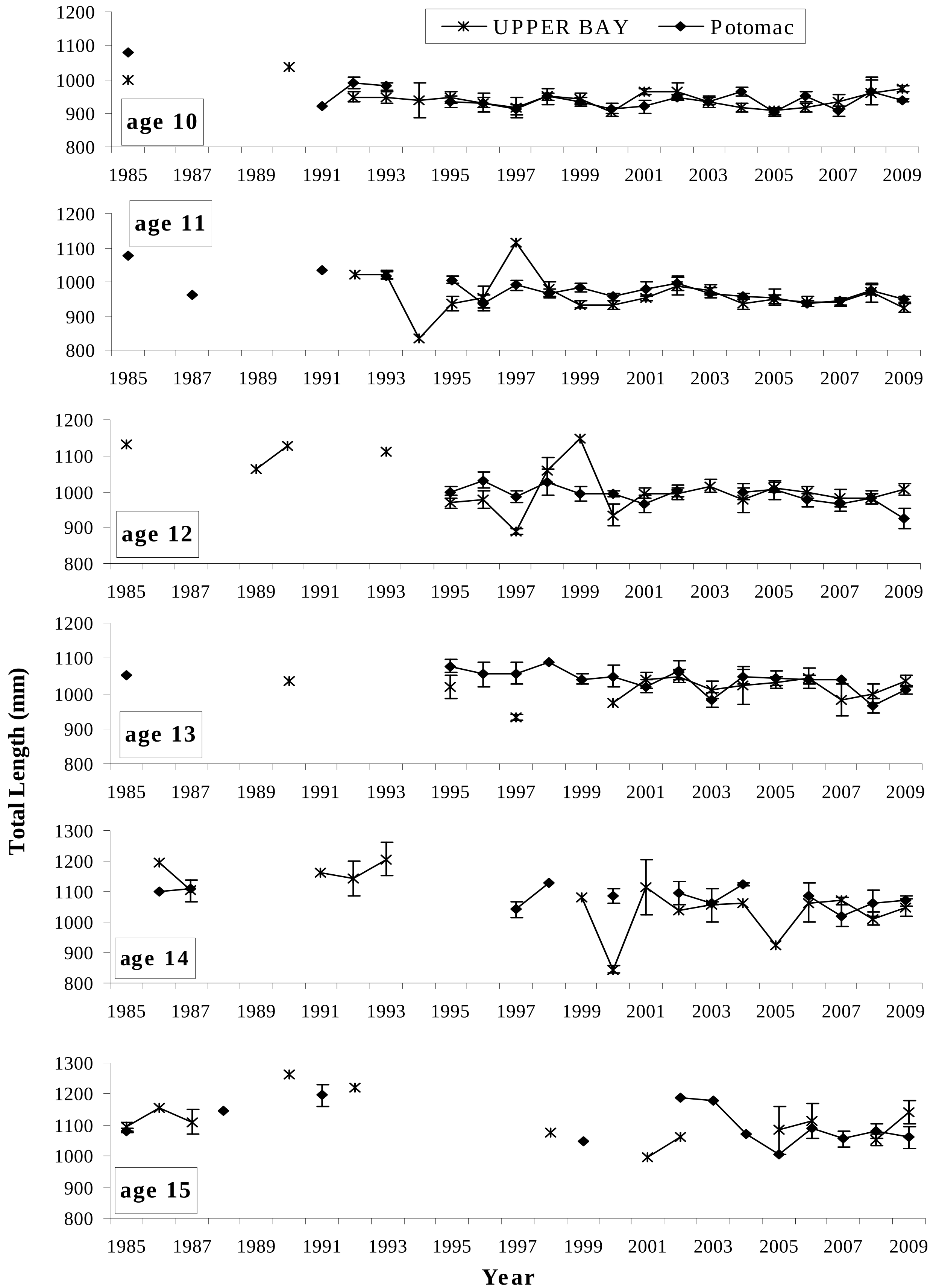


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the 2009 coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

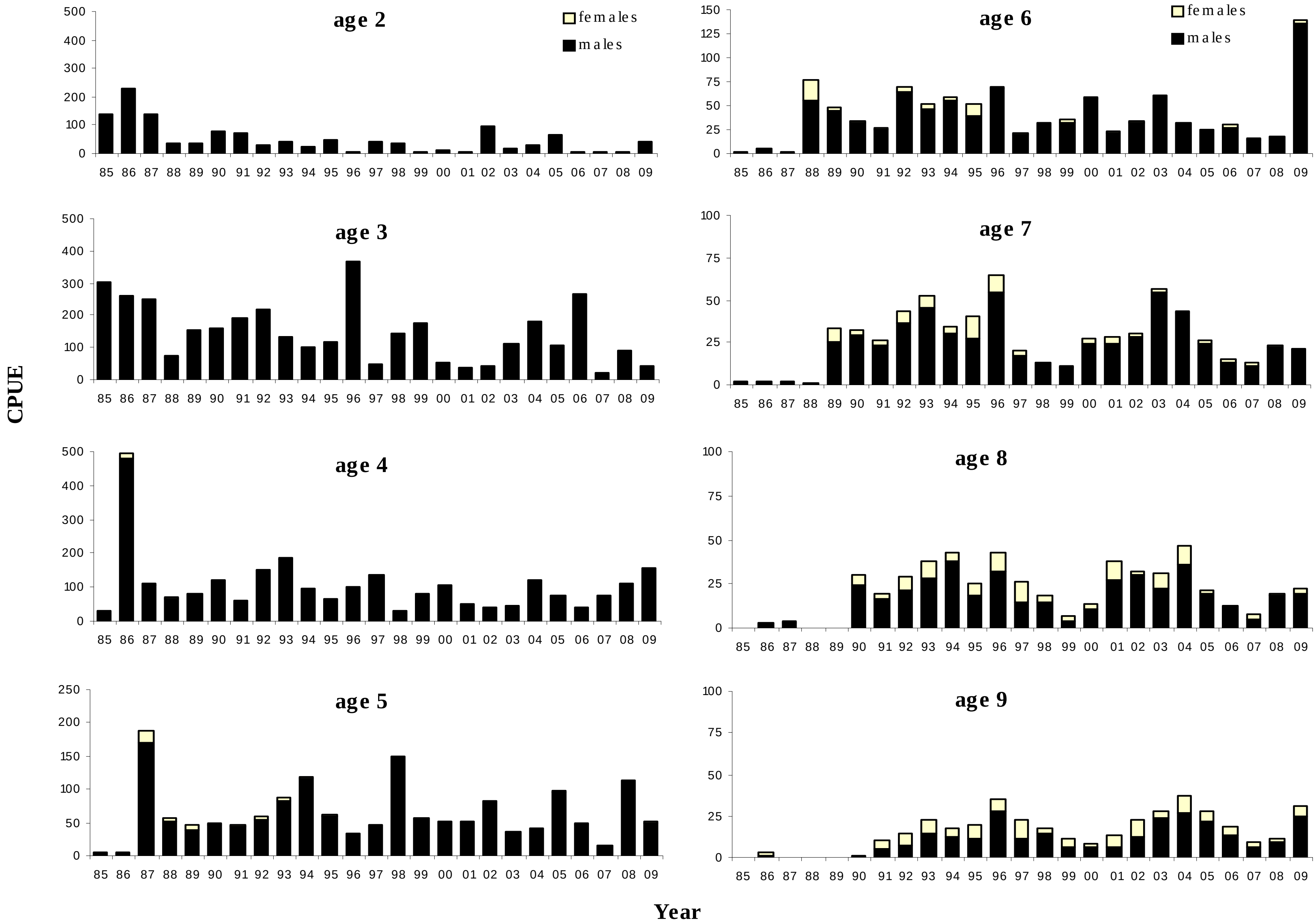


Figure 9. Continued.

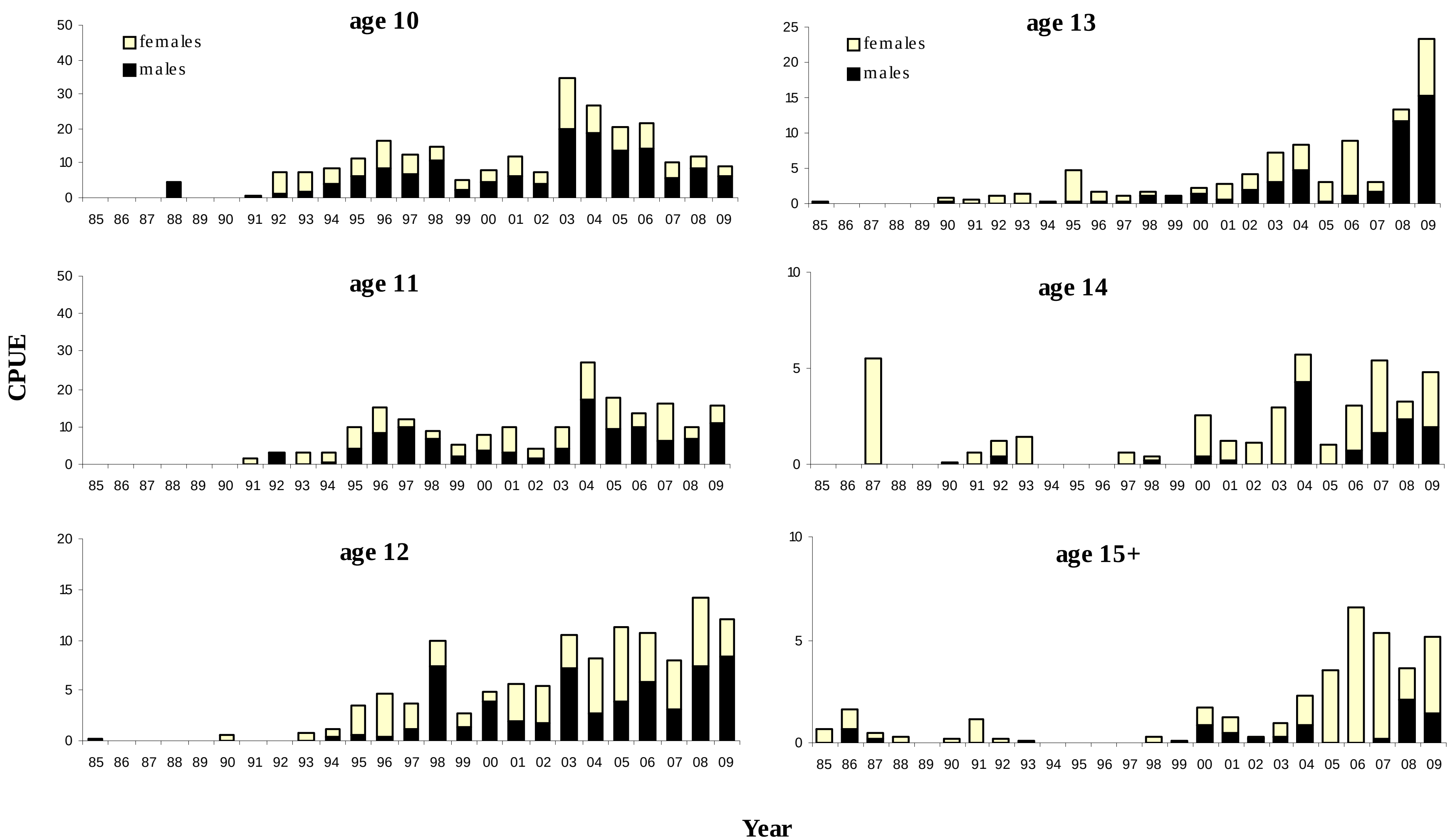
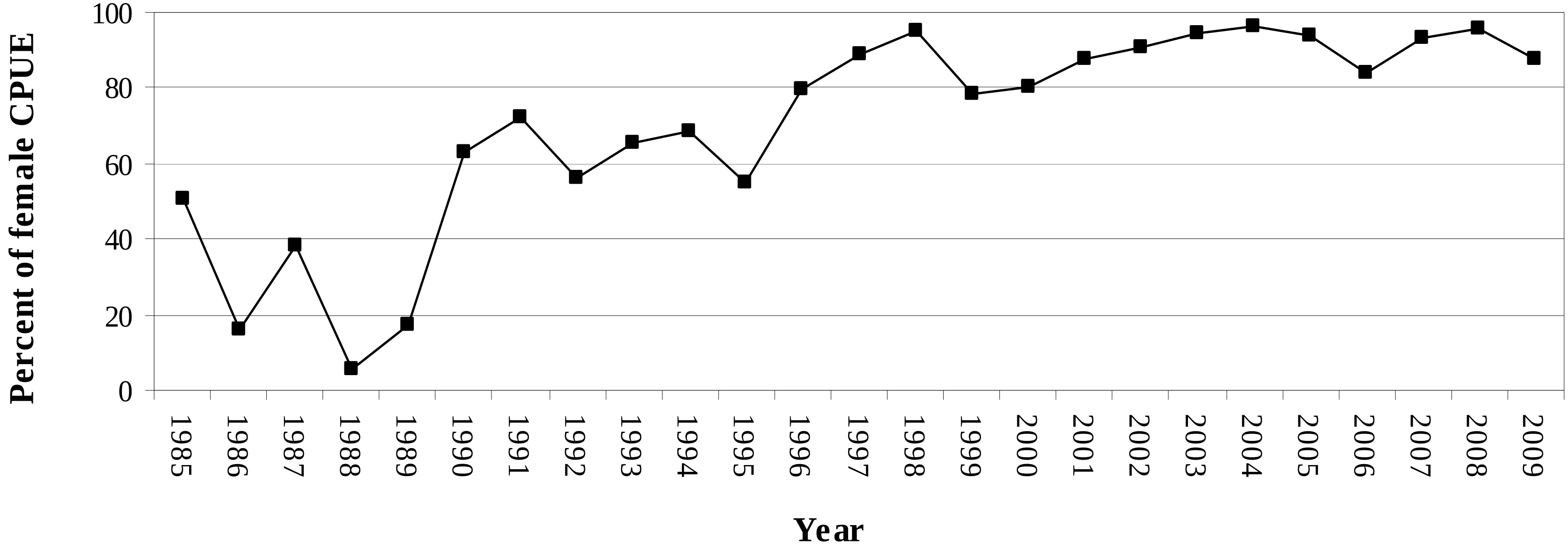
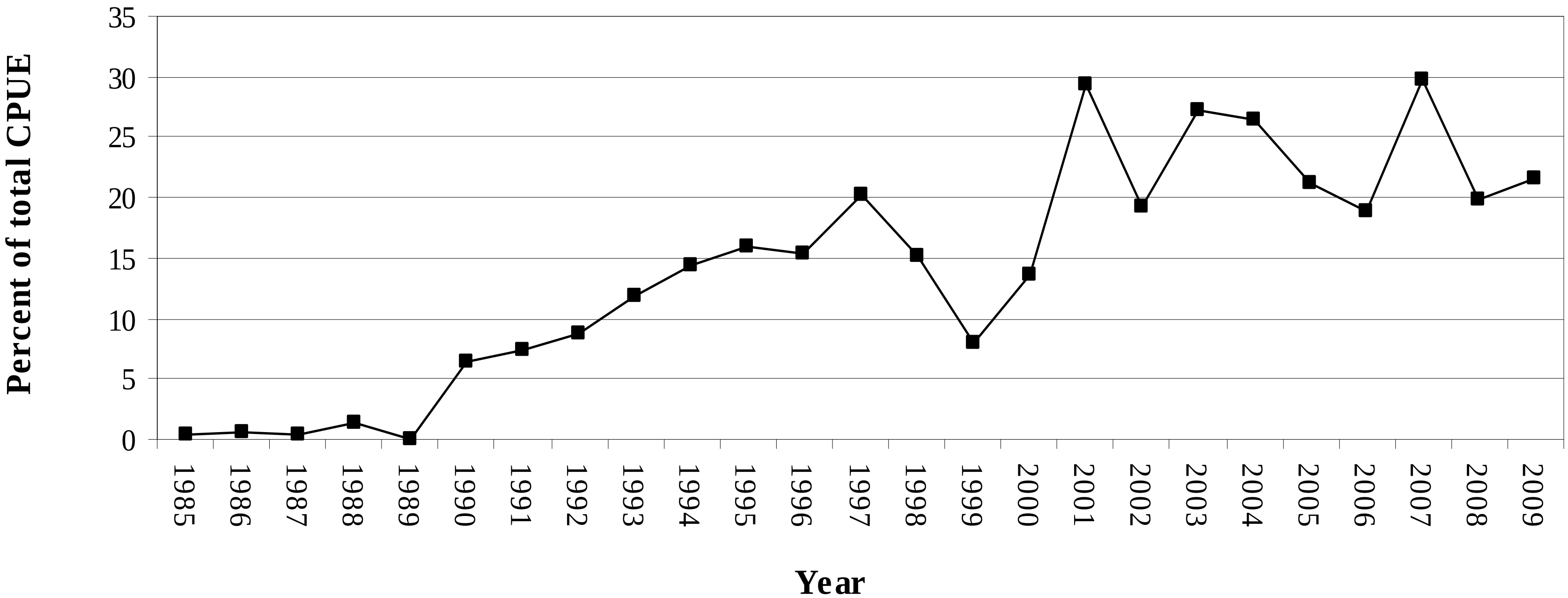


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the upper Chesapeake Bay, late March through May, 1985-2009 (Choptank River to 1996). Effort is standardized as 1000 square yards of net per hour. Area-specific indices were weighted based on the relative size of the spawning areas before area-specific indices were pooled.*



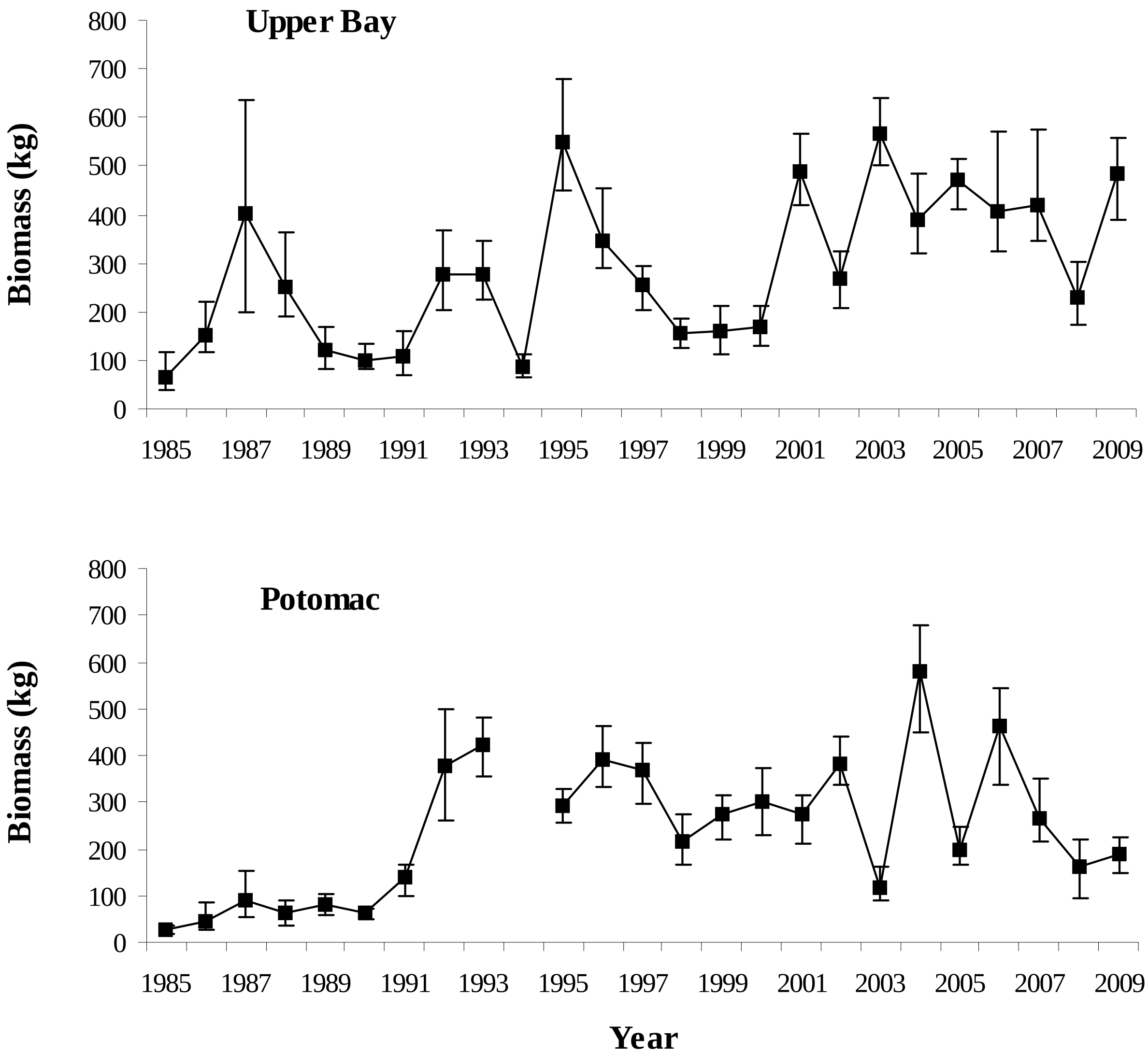
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385 (Hollis 1967).

Figure 11. Percentage (selectivity-corrected CPUE) of male and female striped bass age 8 and over sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the upper Chesapeake Bay, late March through May, 1985-2009 (Choptank River to 1996). Effort is standardized as 1000 square yards of net per hour. Area-specific indices were weighted based on the relative size of the spawning areas before area-specific indices were pooled.



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

Figure 12. Biomass (kg) of female striped bass greater than or equal to 500 mm TL collected from experimental drift gill nets fished in 3 spawning areas of the Maryland Chesapeake Bay during late March through May from 1985 until present. The index is corrected for gear selectivity, and bootstrap 95% confidence intervals are shown around each point. Note different scales.



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. Two site changes were made in 2009. The Choptank River auxiliary site at Dickinson Bay (#161) became the permanent replacement for site 135 (North shore opposite Hambrook Bar) after extensive stone rip-rap and shoreline changes made work there impossible. On the Potomac River, site 111, (Morgantown Steam Electric Station) became inaccessible due to new security restrictions at the facility. A replacement was established just downstream (Morgantown Power Plant Environmental Area, #162), but the area will be explored before 2010 to find a more suitable long-term replacement site.

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 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) has been adopted by the Atlantic States Marine Fisheries Commission (ASMFC) Striped Bass Technical Committee 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 the 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 analysis of variance (GLM; SAS 1990) on the $\log_e(x+1)$ transformed data. Means were considered significant at the p=0.05 level. Duncan's multiple range test was used to differentiate means.

RESULTS

Bay-wide Means

A total of 1,039 juvenile striped bass were collected at permanent stations in 2009. Individual samples yielded between 0 and 76 YOY striped bass. The AM of 7.9 was less than the time-series average (11.7) and the TPA (12.0) (Table 2, Figure 2). The GM of 3.92 (Table 3, Figure 3) was also less than the time-series average (4.23) and the TPA (4.32). The PPHL was 0.86, indicating that 86% 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 2009 $\log_e$-mean significantly greater than 23 years of the time-series. The 2009 $\log_e$-mean was significantly smaller than 12 years of the time-series, and was not discernible from 17 other years.

System Means

Head of Bay - In 42 samples, 287 juveniles were collected at the Head of Bay sites, resulting in an AM of 6.8, less than the time-series average (12.0) and the TPA of 17.3 (Table 2, Figure 5). The GM of 2.85 was also below the time-series average (5.69) 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 2009 $\log_e$-mean was significantly greater than only nine years of the time-series, and less than 19 years. The 2009 $\log_e$-mean was indiscernible from 24 year-classes of the time-series.

Potomac River - A total of 326 juveniles was collected in 42 samples. The AM of 7.8 was slightly less than the TPA (9.2) and the time-series average (8.4) (Table 2, Figure 5). The GM of 3.75 fell between the time-series average (3.63) 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 2009 Potomac River year-class significantly less than just seven years, and significantly greater than 22 years of the time-series. The 2009 $\log_e$-mean was not significantly different than the 23 other years of the time-series.

Choptank River - A total of 271 juveniles was collected in 24 Choptank River samples. The AM of 11.3 was less than the time-series average of 20.4, but greater than the TPA of 10.8 (Table 2, Figure 5). The GM of 6.61 also fell between its time-series average (8.04) 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 2009 Choptank River year-class smaller than nine years, and greater than 18 years of the time series. The 2009 year-class was not discernible from 25 other years of the time-series.

Nanticoke River - A total of 155 juveniles was collected in 24 samples on the Nanticoke River. The AM of 6.5 was less than the time-series average (8.3) and the TPA (8.6) (Table 2, Figure 5). The GM of 4.18 was above the time-series average (3.67) 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 2009 index significantly smaller than just the top four years of the time-series, and significantly larger than 19 years of the time-series. The 2009 index was statistically indiscernible from 29 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 32 juveniles were caught in 15 samples, resulting in an AM of 2.1 and a GM of 1.14. Both indices were less than their respective time-series averages and medians (Table 5).

On the **Patuxent River**, 54 YOY striped bass were caught in 18 samples for an AM of 3.0 and a GM of 1.87 (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 below their respective time-series median values.

DISCUSSION

Survey results indicate a below-average 2009 striped bass year-class for Maryland's portion of the Chesapeake Bay. Although the bay-wide AM and GM were substantially improved relative to 2008, both values are below their respective time-series averages and TPAs (Tables 2 and 3). However, YOY striped bass were present in 86% of samples (PPHL=0.86), a level often associated with average sized year-classes and higher than the time-series average of 70% (Table 4).

Recruitment in individual spawning areas was variable. In the Nanticoke and Potomac rivers, GM indices were greater than their respective long-term averages. The Nanticoke River GM was also above its TPA (Table 3). An analysis of variance offered further evidence of the strong recruitment in these two systems. Duncan's multiple range test (p=0.05) ranked recruitment in the Potomac River behind only the seven highest years of the time-series. Recruitment indices from just the four best years on the Nanticoke were significantly higher than 2009 (p=0.05). The Choptank

River GM was below its time-series average, but Duncan's multiple range test ($p=0.05$) found Choptank river recruitment to be significantly less than just nine other years of the time-series. Recruitment was less successful in the Head of Bay system, where the GM fell below the 50th percentile of the time-series and was less than half the TPA (Table 3).

Recruitment in auxiliary areas was uniformly low. Auxiliary Head of Bay sites, located primarily on the Susquehanna Flats, and in the Patuxent River produced indices below their respective time-series medians.

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 one fish from records prior to 1991. Since 1991, striped bass have been separated into 0, 1 and 2+ age groups in the recorded data. 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 62% of variability ($r^2 = 0.62$, $p \leq 0.001$) in the age 1 indices (Figure 10). The equation that best described this relationship was, $C_1 = (0.191739)(C_0) - 0.07084$, 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 index of age 1 striped bass (0.11) was nearly equal the predicted index of 0.08, as indicated by the small residual (Figure 11). 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.

<u>CITATIONS</u>

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. <u>Biometry</u>. 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.

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

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 yds. 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
162	Potomac River	Morgantown Power Plant Environmental Area
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
Average	12.0	8.4	20.4	8.3	11.7
TPA*	17.3	9.2	10.8	8.6	12.0

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

Table 3. Maryland juvenile striped bass survey geometric mean 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
Average	5.69	3.63	8.04	3.67	4.23
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
Average	11.8	206.3	1.45	93.44	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	104.3	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
Average	26.14	6.95		5.64	2.70	
Median	3.17	1.87		2.95	1.91	

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	NA

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

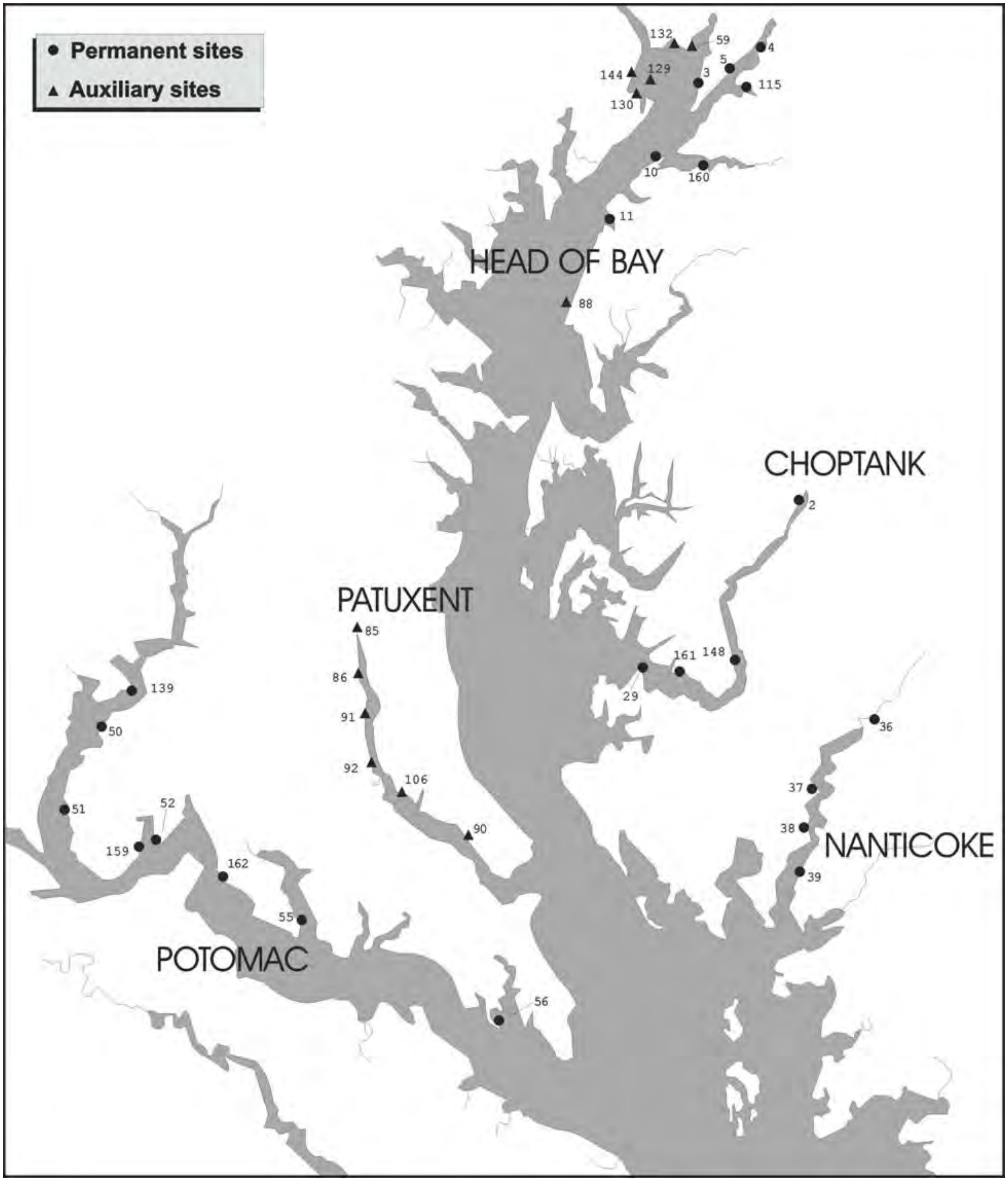


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

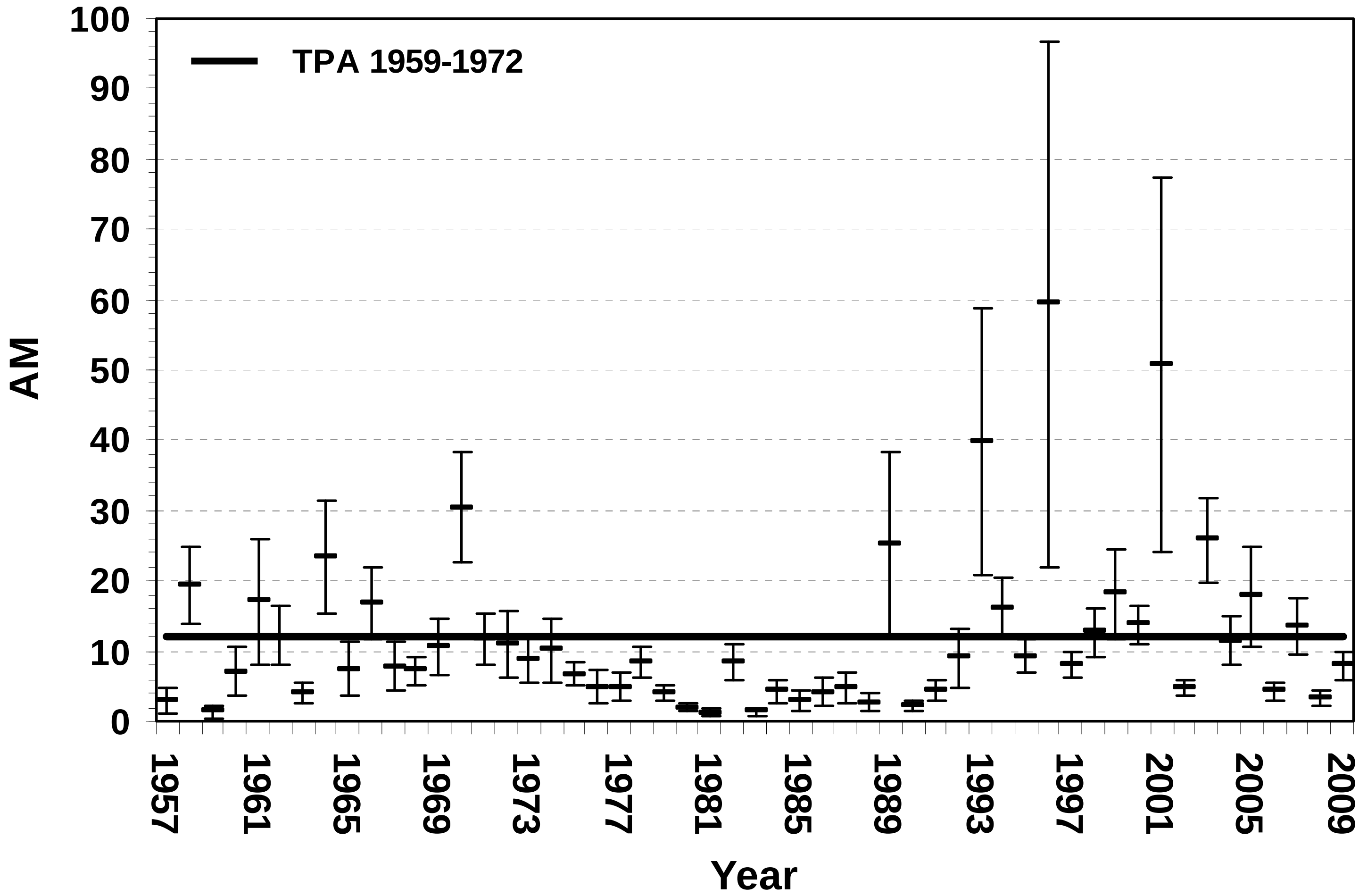


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

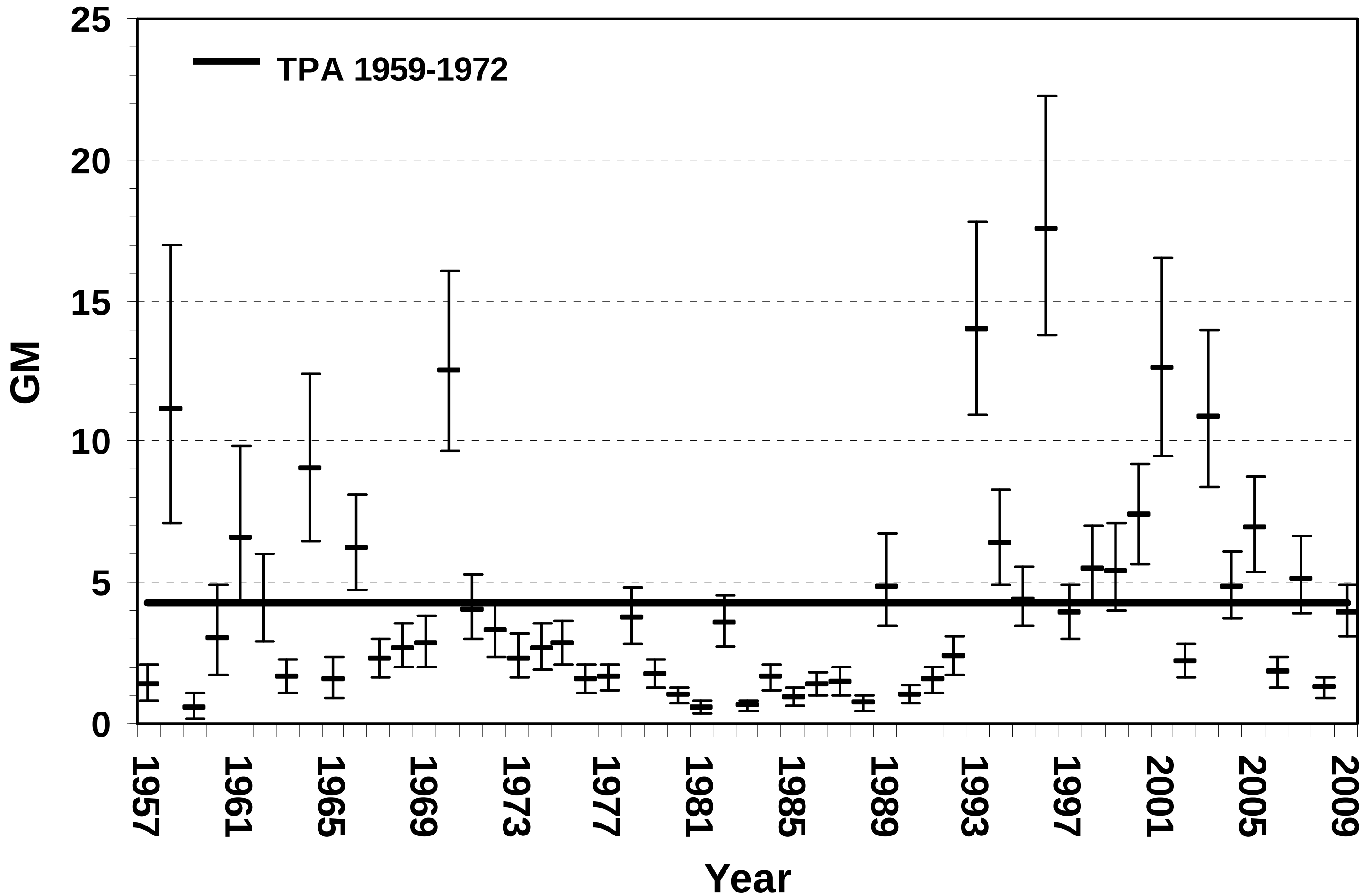


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL) as percent.

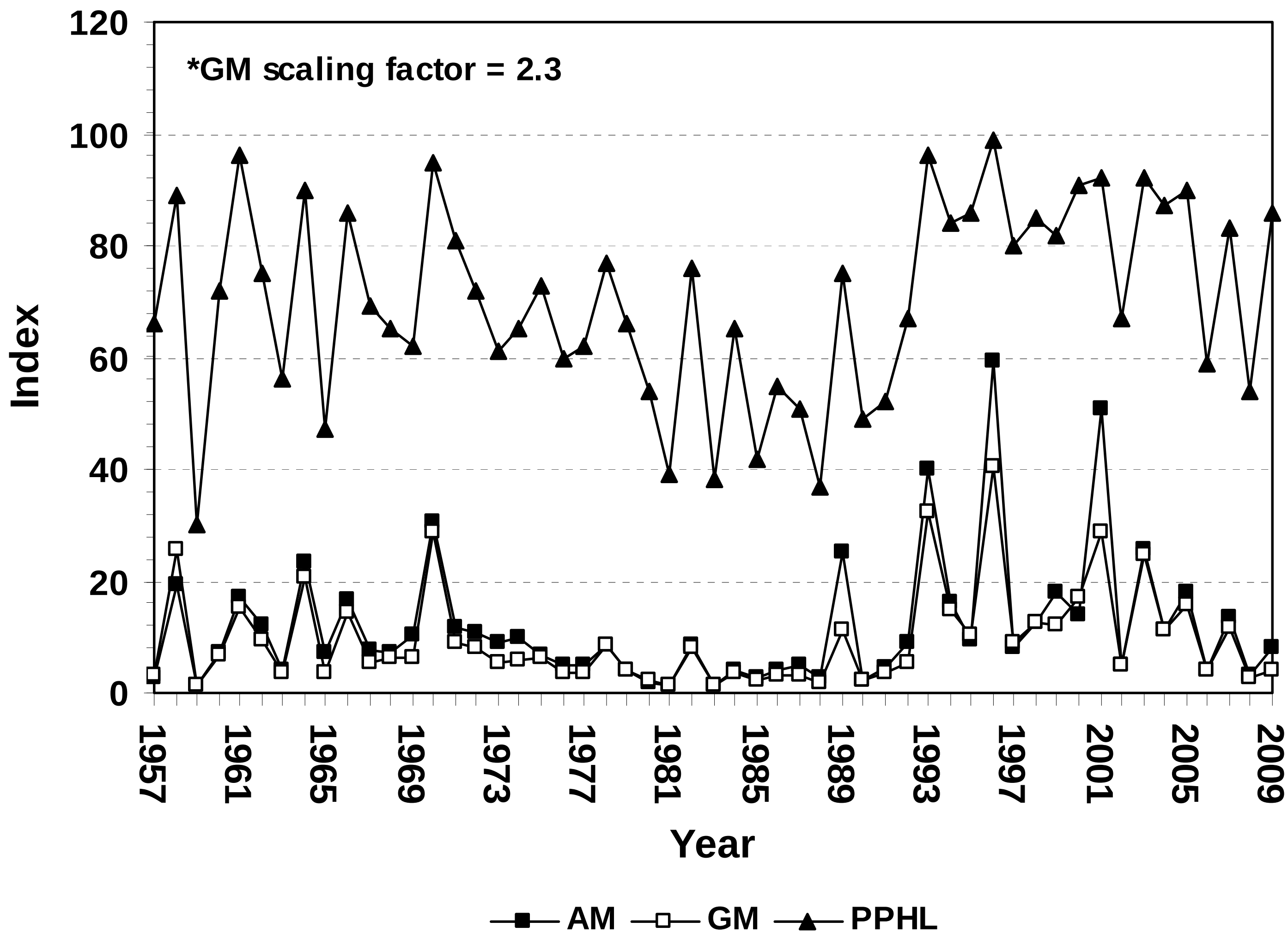


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

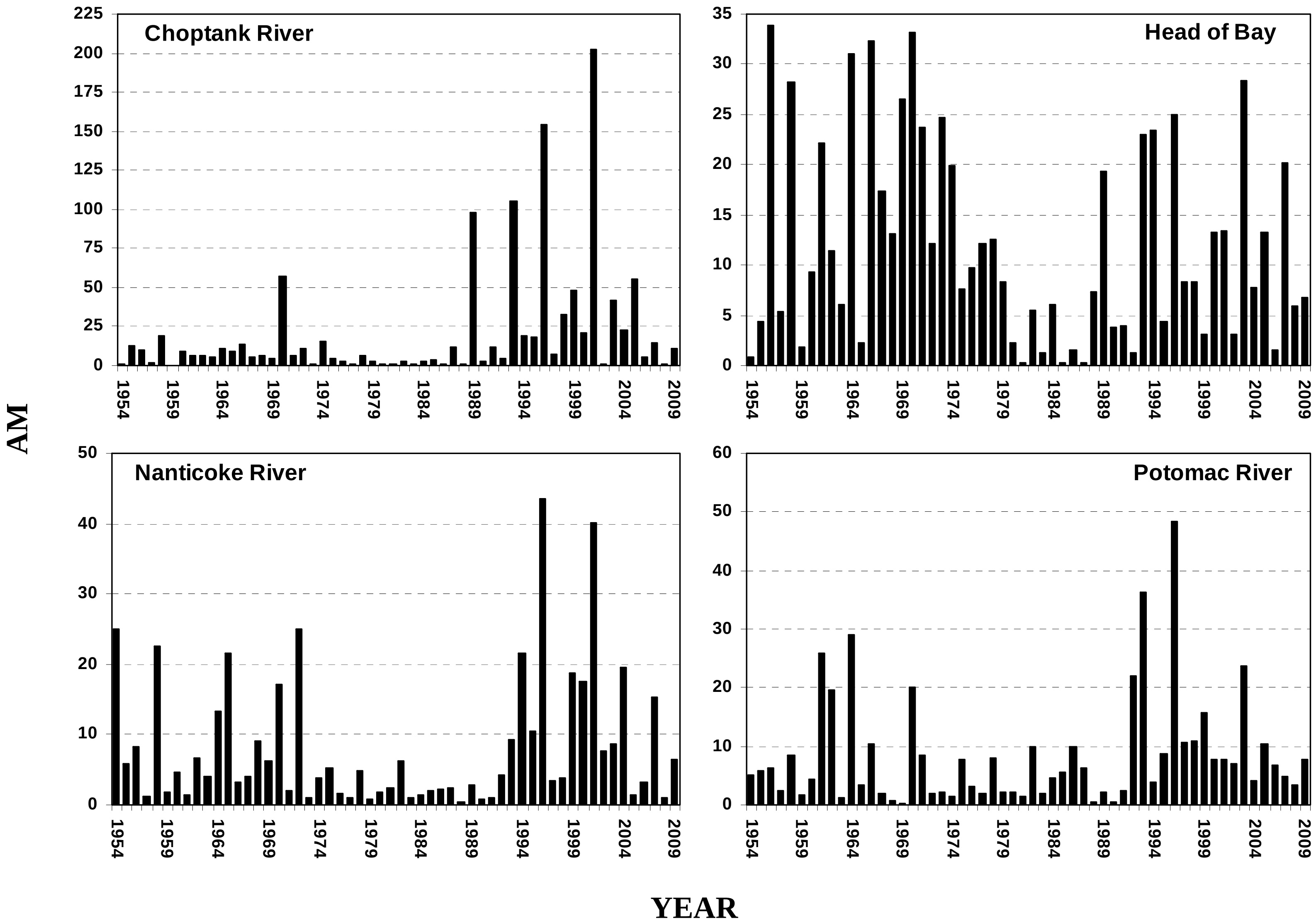


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

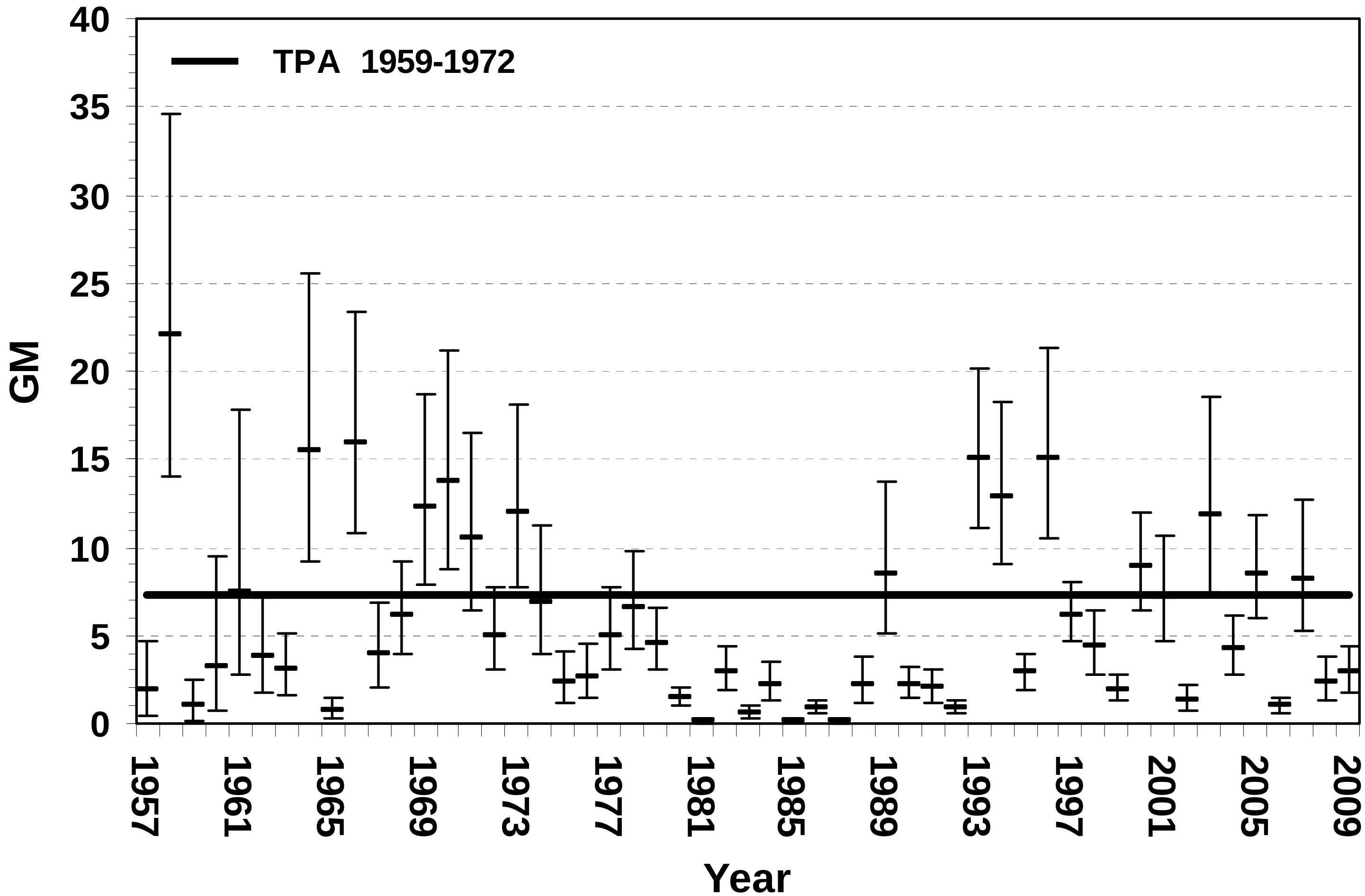


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

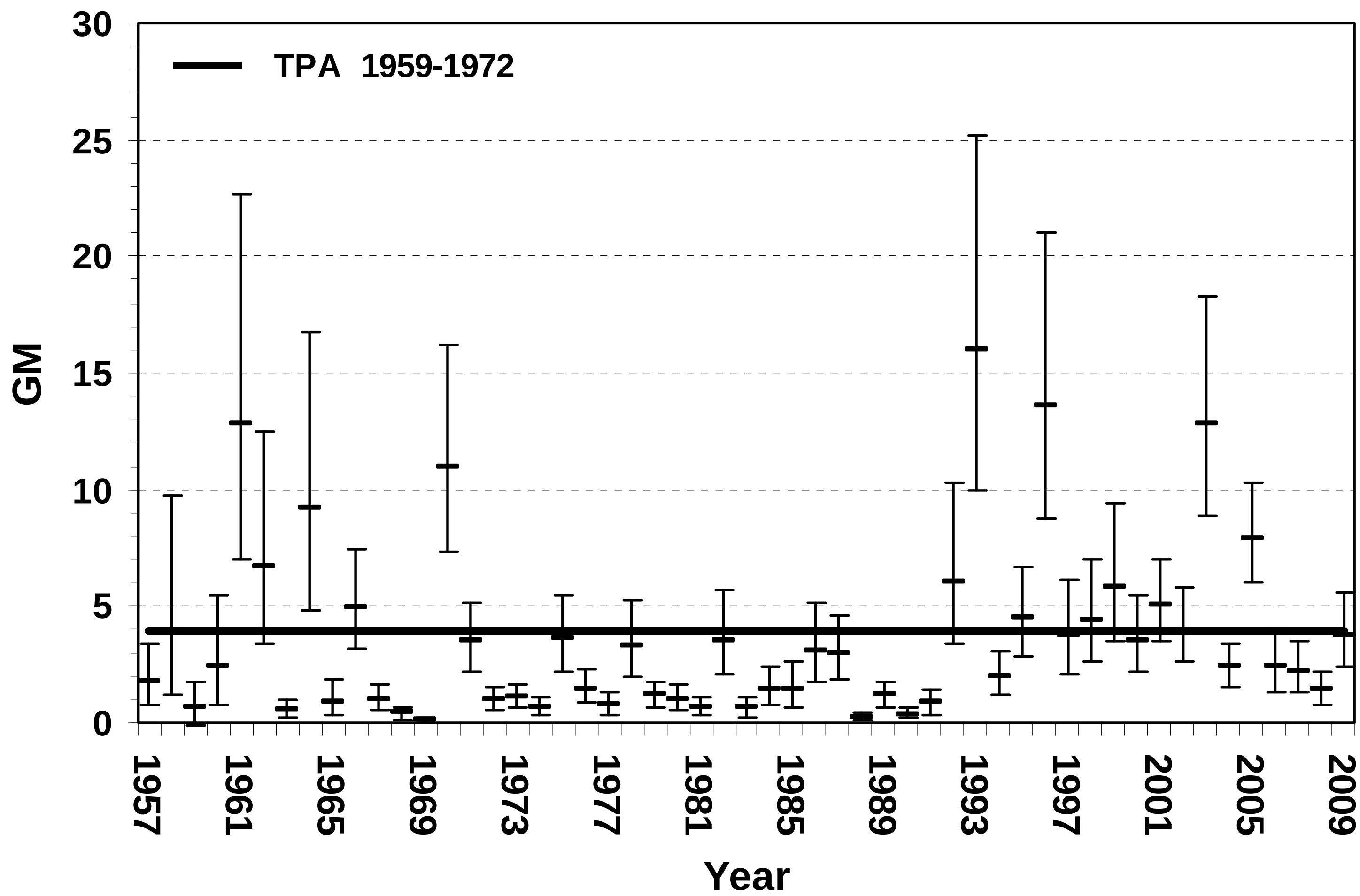


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

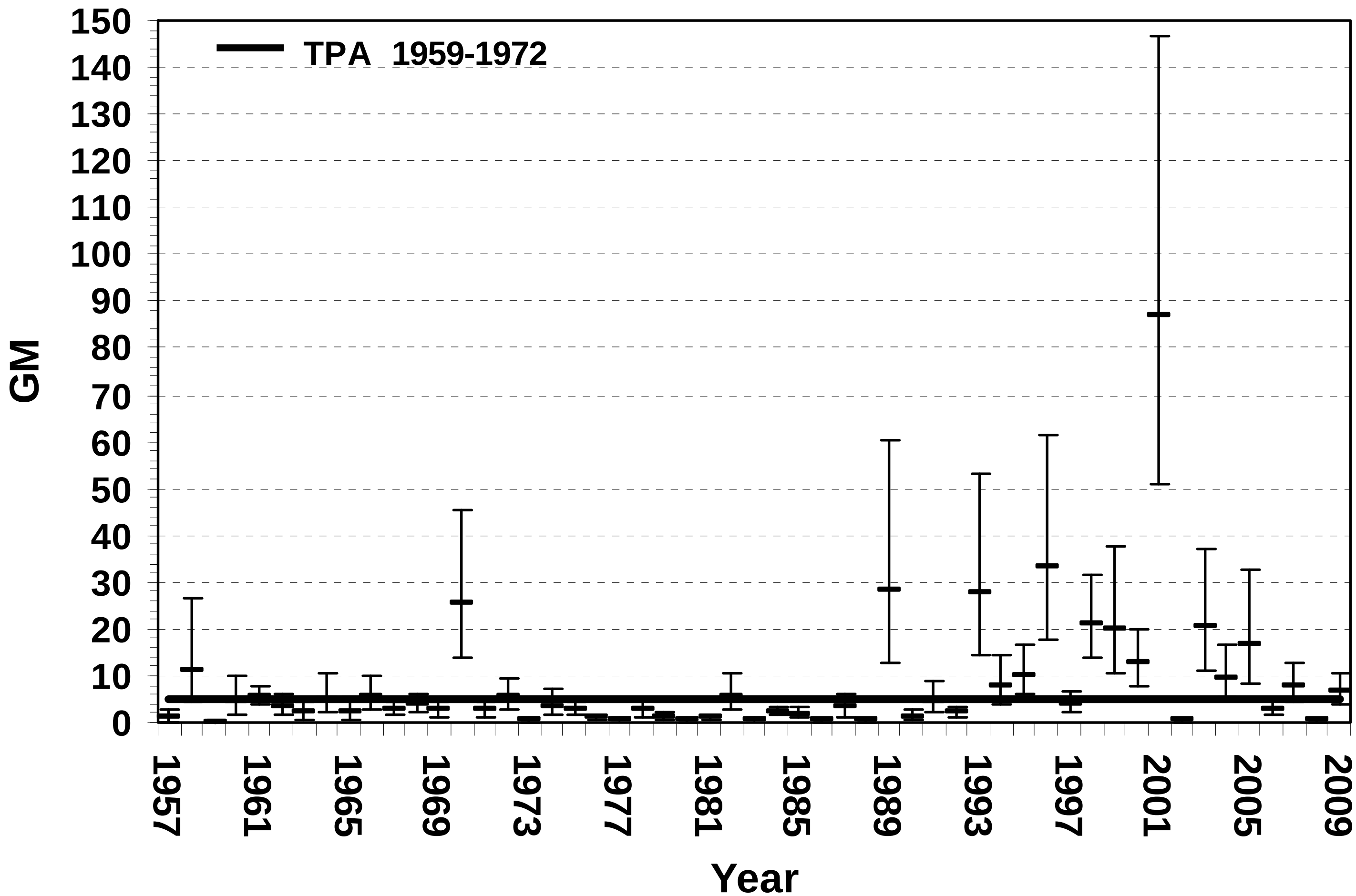


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (± 2 SE) for juvenile striped bass with target period average (TPA).

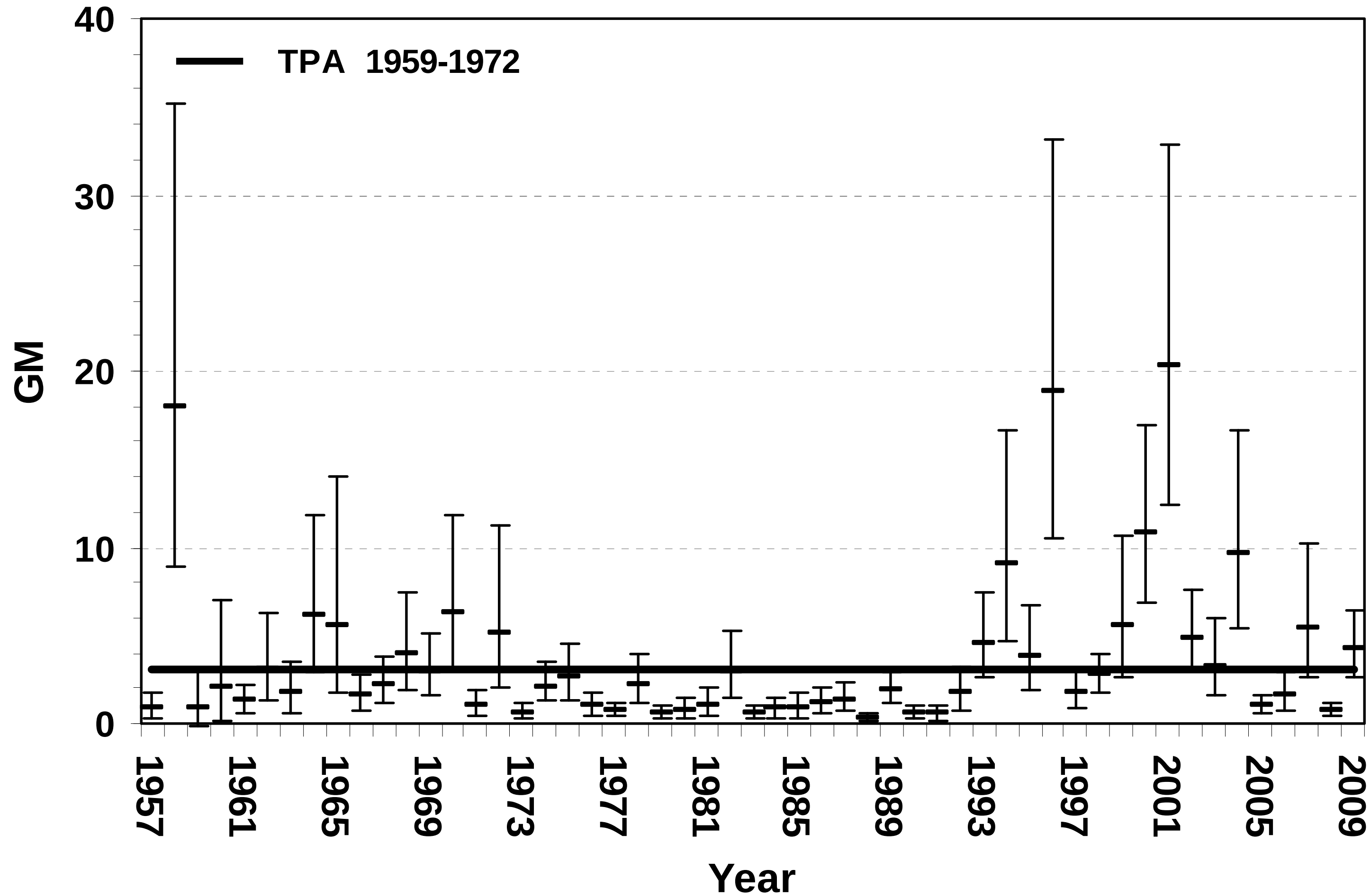


Figure 10. Relationship between age 0 and subsequent age1 striped bass indices.

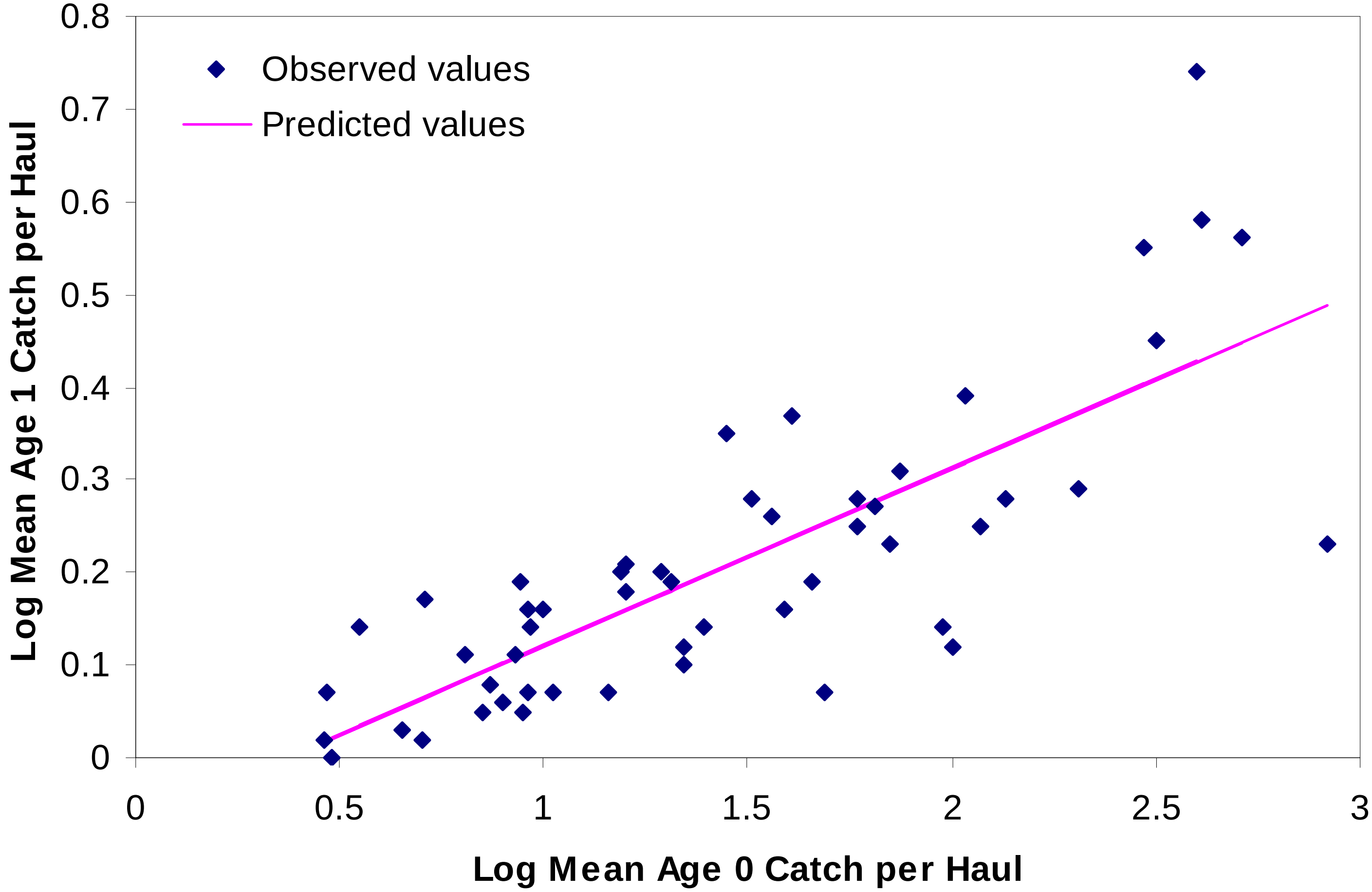
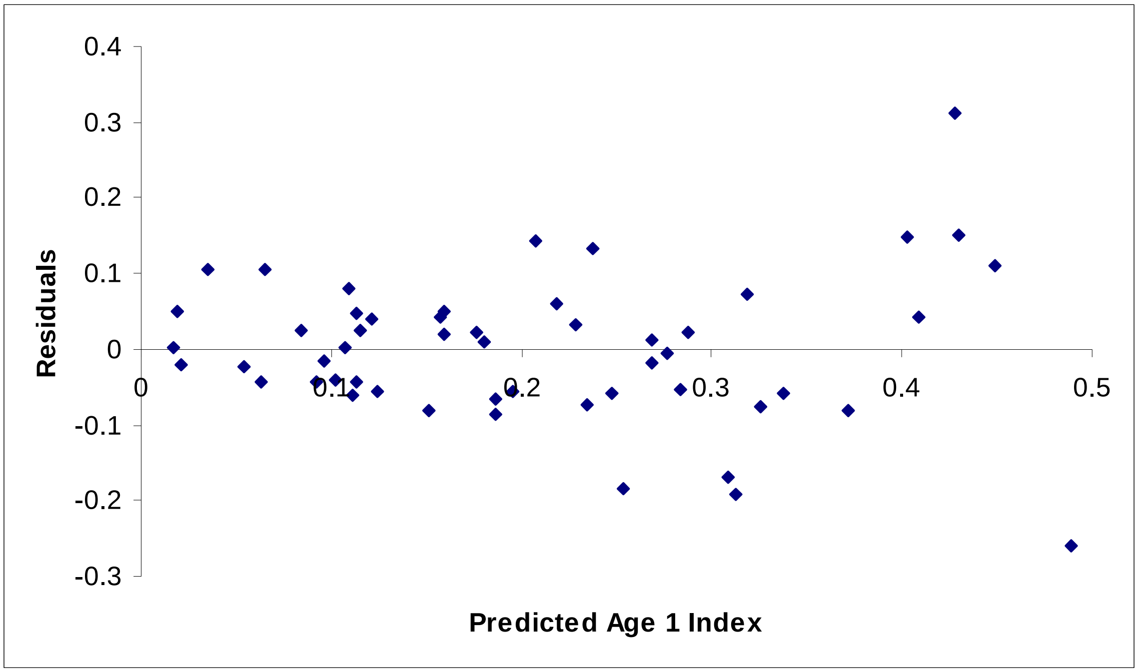
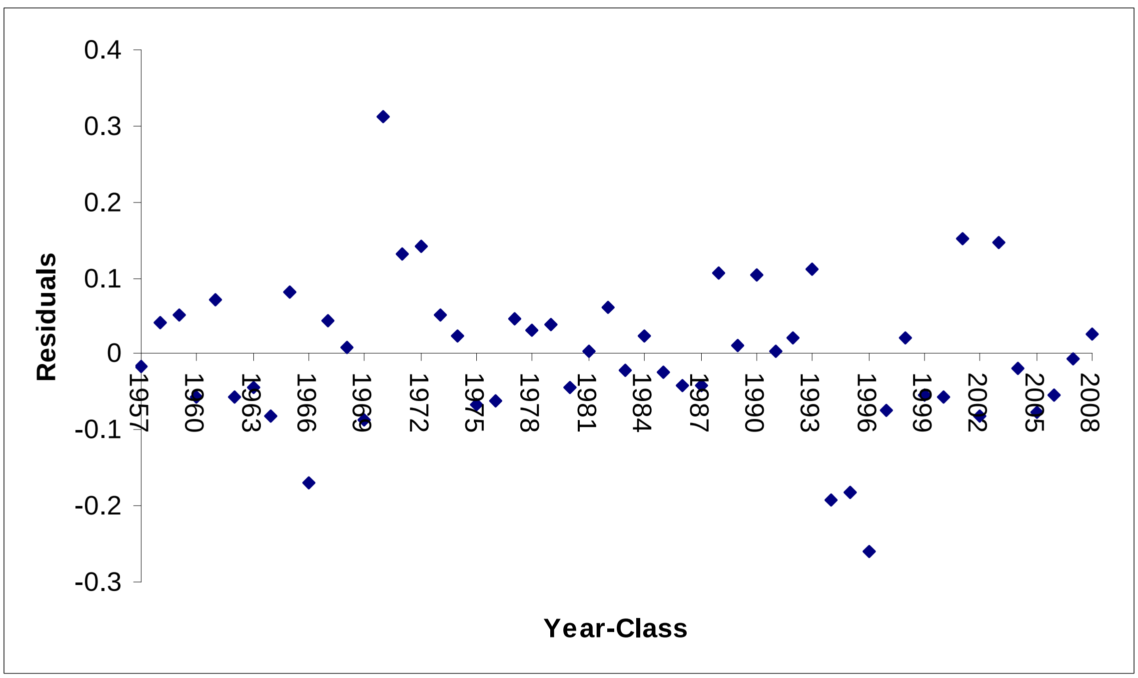


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 offshore cruise during the time period of summer 2008 through spring 2009. 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

From late March through May 2009, 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 female fish and all males over 700 mm TL. Tagging stopped when water temperatures exceeded 70^{o}F.

Additionally, from January 29 to February 7, 2009, 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 210 times at speeds ranging from 2.7 to 4.5 knots at depths of 18 to 85 feet (5.6 – 25.8 m) for 0.08 to 0.58 hours. 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 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 instantaneous rates – catch and release (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 2009 will not be completed until after March 27, 2010, 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 2008-2009 estimate of F for Chesapeake Bay (ASMFC 2009). Male fish 18 to 28 inches are generally accepted to comprise the Chesapeake Bay resident stock, while the 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 instantaneous rates model. Further details on these methodologies can be found in ASMFC 2009.

Estimates of survival, fishing mortality and recovery rates for the North Carolina tagging data were calculated using the same methods as Maryland's spring tagging data. Upon completion, these calculations will be analyzed by the USFWS.

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

RESULTS AND DISCUSSION

Spring tagging

The spring sampling component monitored the size and sex characteristics of striped bass spawning in the Potomac River and the upper Chesapeake Bay. Sampling occurred between March 31, 2009 and May 20, 2009. In 2009, 1,955 striped bass were sampled and 856 (44%) 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 of them were 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 2009 (625 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (540 mm TL) (Figure 2).

Tag releases and recaptures from both Maryland and Virginia's sampling (combined spring 2008 data) were used to estimate an instantaneous fishing mortality rate (F) for the 2008-2009 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. Specific methods and results are described in ASMFC 2009.

Estimates of survival and fishing mortality for the 2009 Chesapeake Bay spawning stock will be presented in the next report of the ASMFC Striped Bass Tagging Subcommittee. Stock assessments are currently being conducted every two years.

USFWS cooperative tagging cruise

The primary objective of the SEAMAP tagging cruise was to apply tags to as many striped bass as possible. In 2009, the fish were difficult to locate, with the majority encountered at, and north of the mouth of the Chesapeake Bay. The fish were also farther offshore and in deeper water than usual. This area was not typically sampled during past cruises. As a result, only 147 striped bass were captured during the 2009 cruise. Of those 147, 146 (99%) were tagged (Table 2). The mean total length of all fish captured on the 2009 cruise was 809 mm TL and of those tagged was 810 mm TL (Figure 2). These lengths were significantly lower than the mean total lengths for the 2008 cruise (854 mm TL – tagged and total sample; $P<0.0001$). The NC DMF is presently completing age determination for the 2009 cruise via scale analysis.

Estimates of survival and fishing mortality based on fish tagged in the 2009 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, March - May 2009.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	3/31/09 - 5/14/09	933	349	507670 – 508000 515001 – 515025
Upper Chesapeake Bay	4/9/09 - 5/20/09	1,022	507	490184 – 490500 490830 – 491000 507282 – 507307
Spring spawning survey totals:		1,955 [b]	856	

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

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2009 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)	1/29/09-2/7/09	147	146	556001 – 556146
Cooperative tagging cruise totals:		147	146	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, March - May 2009.

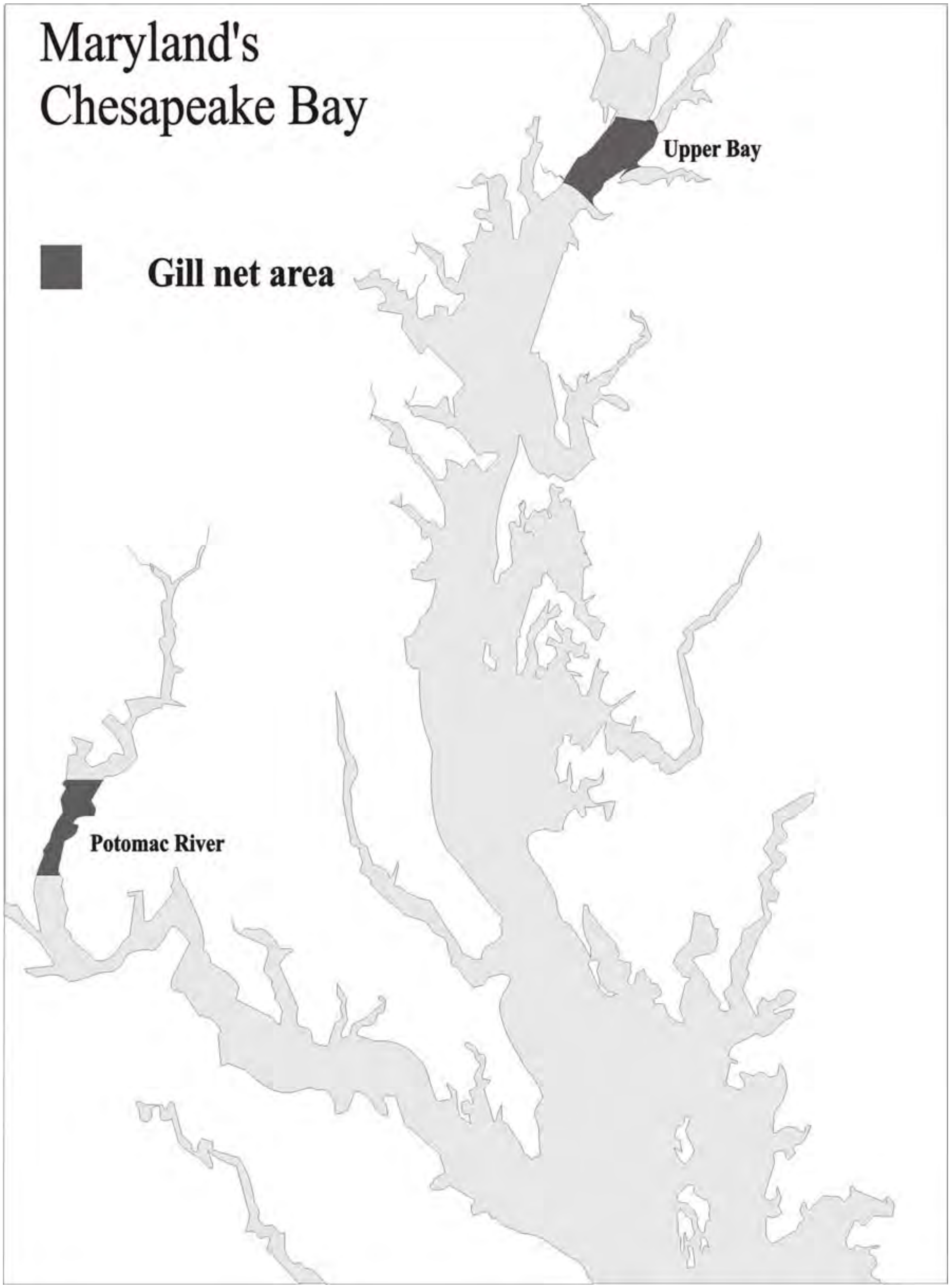
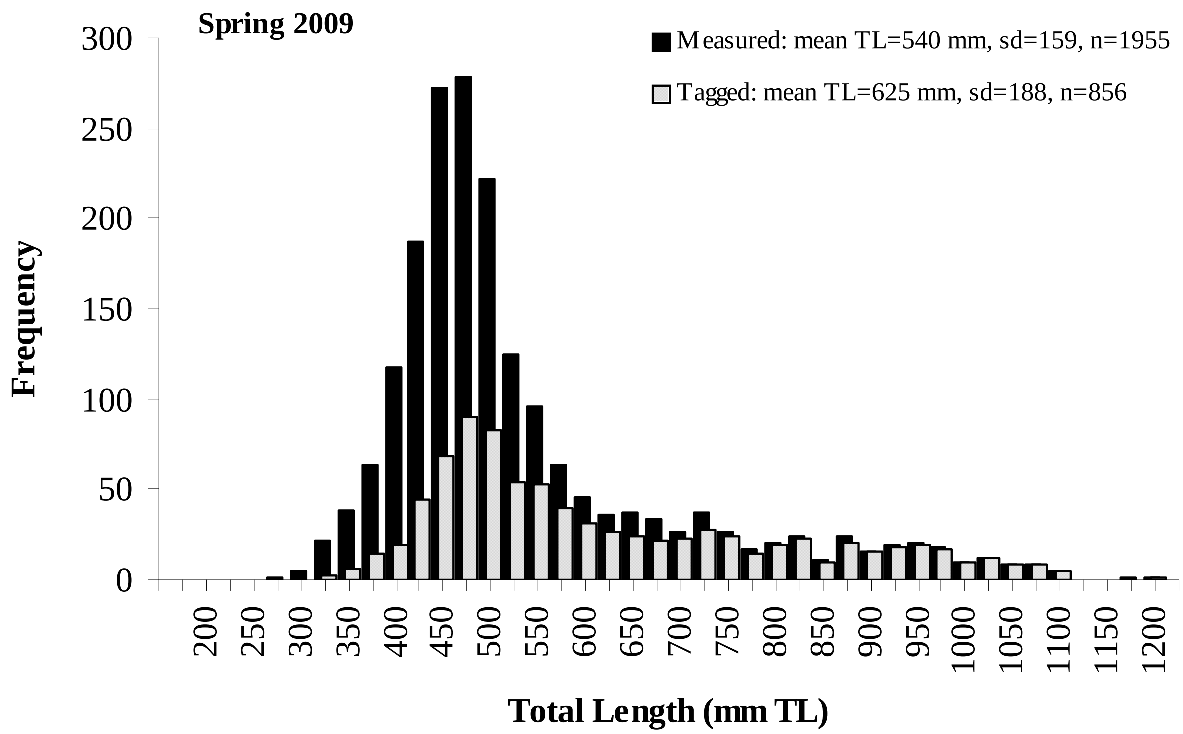
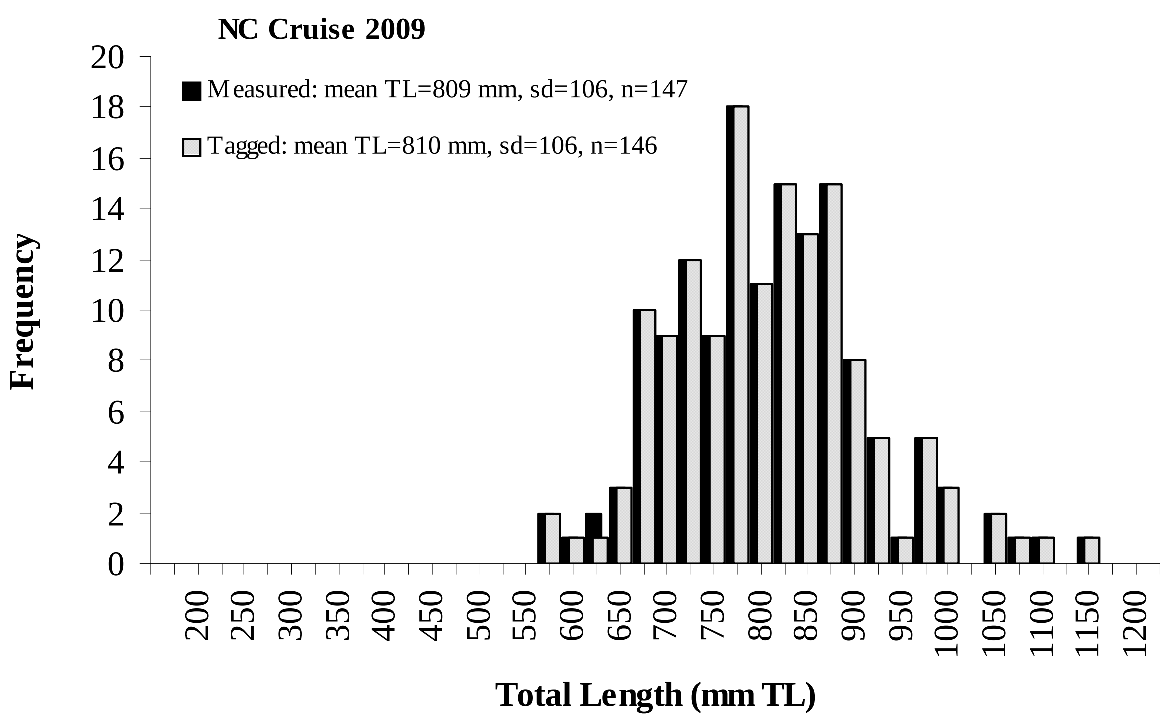


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay and offshore during the SEAMAP tagging cruise. Note different scales.





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 2008 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 nineteenth 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 2008 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 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 16 to November 27, 2008, Monday through Thursday. The pound net fishery was open from June 2 through November 29, 2008, Monday through Saturday. The haul seine fishery was open from June 9 to November 29, 2008, Monday through Friday. The Chesapeake Bay drift gill net season was split, with the first segment from January 1 through February 29, 2008 and the second segment from December 1 through December 31, 2008, 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, 2008 and November 3 through December 31, 2008.

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 2007, 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, 2007 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 Commercial Striped Bass Harvest 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. In order to avoid these issues and have more timely data, since 2001 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, 2,208,018 pounds of striped bass were harvested in 2008, representing 98% of the Chesapeake quota for the 2008 commercial fishing season. The estimated number of fish landed was 643,146 (Table 3). The Chesapeake drift gill net fishery landed 55% of the total landings followed by the pound net fishery at 25%. The hook-and-line fishery contributed 20% of the total landings.

Maryland's Atlantic Coast landings totaled 118,005 pounds (Table 3). This represented 93% of the Atlantic quota. The estimated number of fish landed was 14,079. The trawl fishery made up 69% 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 3.43 pounds when calculated from the check station log sheets and 4.09 pounds when measured by biologists (Table 4). Mean weights by specific gear type ranged from 3.02 to 3.84 pounds from check station log sheets and ranged from 2.81 to 4.81 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 3.71 pounds when calculated using the log sheet data and 4.81 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 8.39 pounds (Table 4). This is nearly identical to the average weight determined from the check station log sheets (8.38 pounds). Fish caught in the Atlantic gill net fishery averaged 9.64 pounds according to MD DNR estimates, and were larger on average than those caught in the trawl fishery (7.97 pounds). The average weights of fish from the Atlantic gill net and trawl fisheries, as calculated from check station log sheets, were 8.84 and 8.19 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 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 with an average around 600,000 pounds of striped bass harvested per year between 1998-2008.

Similar to the Chesapeake Bay fisheries, the Atlantic harvest has increased since the moratorium was lifted in 1990 and both fisheries harvest nearly 100% of their quota. In almost all years since 1990, the Atlantic trawl fishery has harvested more fish than the gill net fishery 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.

Commercial CPUE Trends

The pounds harvested by year and gear type were 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 303 pounds per trip. The Chesapeake Bay gill net fishery CPUE was 298 pounds per trip, a 17% decrease from the CPUE for 2007. (Table 6, Figure 6) and the hook-and-line fishery CPUE was 205 pounds per trip.

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 (321 lbs per trip), followed by the pound net fishery (269 lbs per trip) and the hook-and-line fishery (199 lbs per trip) (Table 6, Figure 6).

The Atlantic trawl fishery CPUE was 1,108 pounds per trip in 2008. The 2008 CPUE for the Atlantic gill net fishery was 383 pounds per trip, above the twelve year average of 234 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 2006 through 2008 trawl CPUEs. The increases in CPUE are consistent with increases in total stock abundance through 2004 as estimated by the Atlantic States Marine Fisheries Commission. (ASMFC 2008)

CITATIONS

Atlantic States Marine Fisheries Commission (ASMFC) 2008. 2008 Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic Striped Bass (Morone saxatilis): 2007 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 2008 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 2008 calendar year.

Area	Gear Type	Number Declared	Daily Allocation (pounds)	Seasonal Allocation (pounds)
Bay & Tributaries	Haul Seine	3	750	1,250
	Pound Net	151	200 [1]	1,050[1]
	Hook & Line	170	300	none
	Gill Net / Hook & Line	809	500	none
Atlantic Coast	Atlantic Trawl	31	none	1,950
	Atlantic Gill Net	39	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 2008 calendar year.

Area	Gear Type	Pounds[1]	Estimated[1] Number of Fish	Trips[2]
Chesapeake Bay[3]	Haul Seine	211	55	1
	Pound Net	559,087	172,525	1,845
	Hook & Line	432,139	142,868	2,111
	Gill Net	1,216,581	327,698	4,088
	Chesapeake Total Harvest	**2,208,018**	**643,146**	**8,045**
Atlantic Coast	Atlantic Trawl	80,888	9,879	73
	Atlantic Gill Net	37,117	4,200	97
	Atlantic Total Harvest	118,005	14,079	170
Maryland Totals		**2,326,023**	**657,225**	**8,215**

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 2008 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	3.84	N/A	N/A
	Pound Net	3.24	3.48 (3.37-3.59)	883
	Hook-and-Line	3.02	2.81 (2.74-2.87)	1,624
	Gill Net	3.71	4.81 (4.71-4.90)	3,628
	Chesapeake Total Harvest	**3.43**	**4.09 (4.02-4.15)**	**6,135**
Atlantic Coast	Trawl	8.19	7.97 (7.36-8.56)	183
	Gill Net	8.84	9.64 (9.02-10.27)	62
	Atlantic Total Harvest	**8.38**	**8.39 (7.90-8.88)**	**245**

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 gear type, 1990 to 2008.

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

Table 6. Striped bass average catch per trip (CPUE) in pounds by gear type, 1990 to 2008.

Year	Hook-and-Line	Pound Net	Drift Gill Net	Atlantic Gill Net	Atlantic Trawl
1990	25.0	80.7	76.0	20.8	161.4
1991	76.9	95.5	84.1	64.8	253.6
1992	69.5	129.7	113.5	84.4	271.1
1993	52.2	207.1	125.4	25.4	187.5
1994	108.2	247.8	139.0	128.5	284.3
1995	70.9	219.6	155.7	75.3	994.3
1996	85.4	209.8	187.9	151.2	407.2
1997	144.5	252.1	227.9	214.7	464.9
1998	163.7	272.5	218.0	216.7	381.1
1999	150.8	272.8	293.3	167.3	415.6
2000	159.9	225.4	275.5	281.4	485.3
2001	154.1	231.0	202.1	356.2	416.1
2002	178.1	207.7	251.7	248.1	381.6
2003	204.6	266.3	292.3	240.2	581.8
2004	169.9	162.4	285.2	148.1	635.9
2005	168.2	200.0	323.9	143.3	336.4
2006	251.2	359.5	339.5	315.2	872.8
2007	201.1	321.8	358.7	327.3	1,324.5
2008	204.7	303.0	297.6	382.6	1,108.1

Figure 1. Map of the 2008 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 2008.

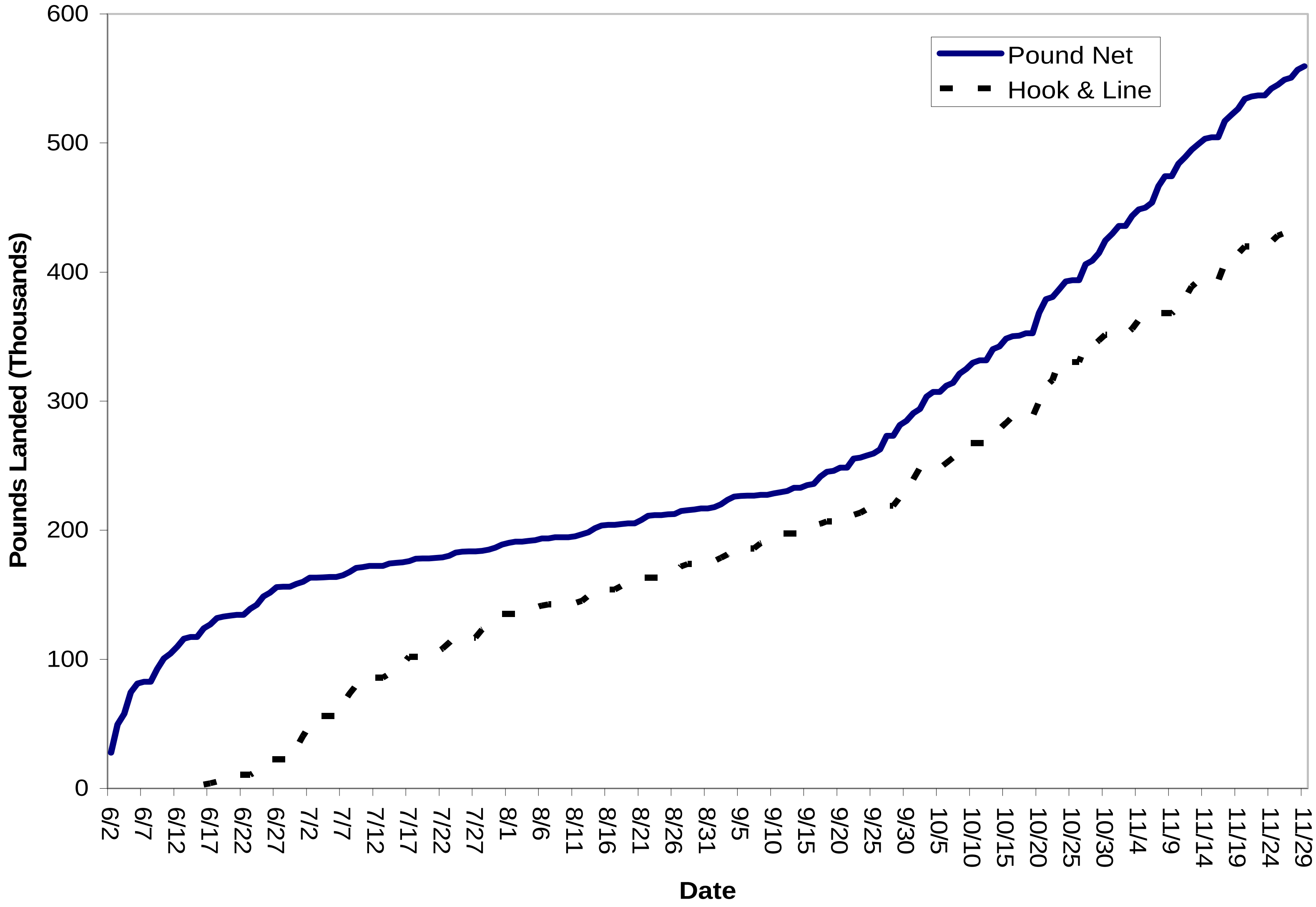
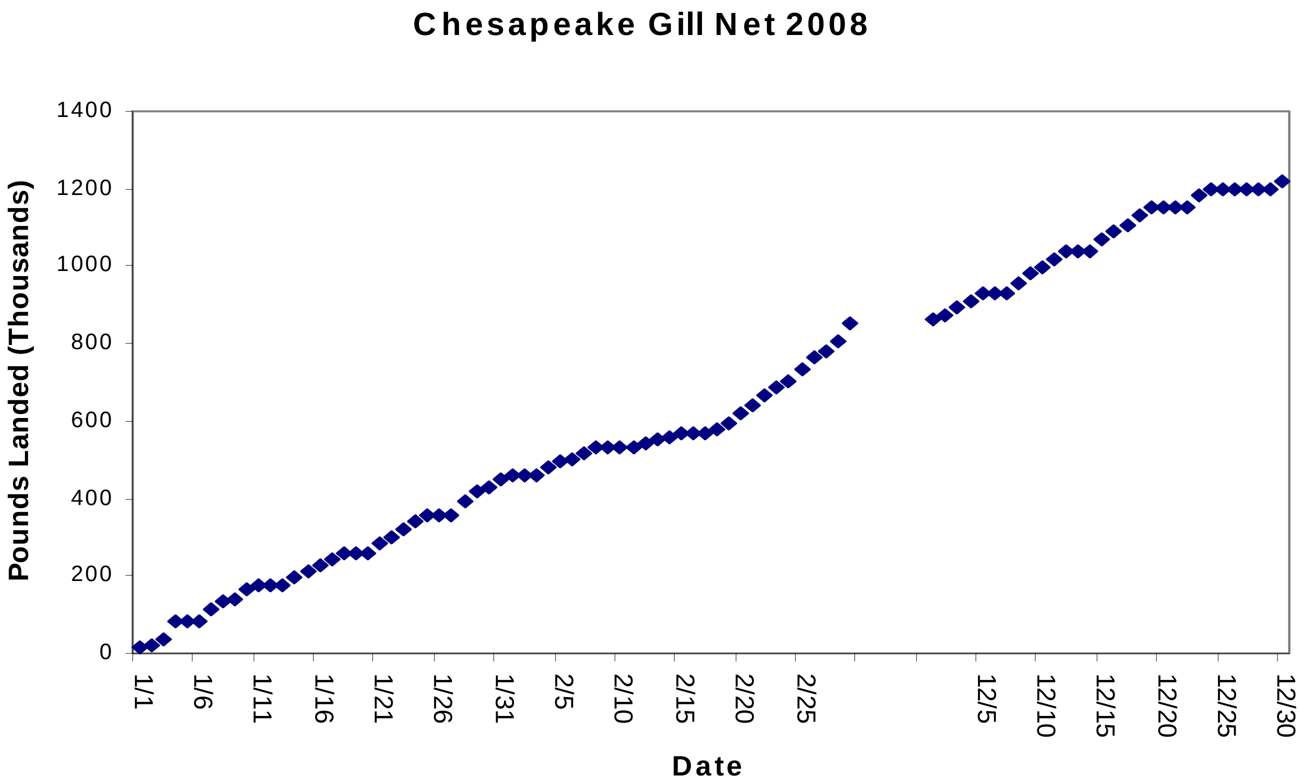


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fishery (combined) cumulative striped bass landings from check stations daily call-in reports, January- December 2008.



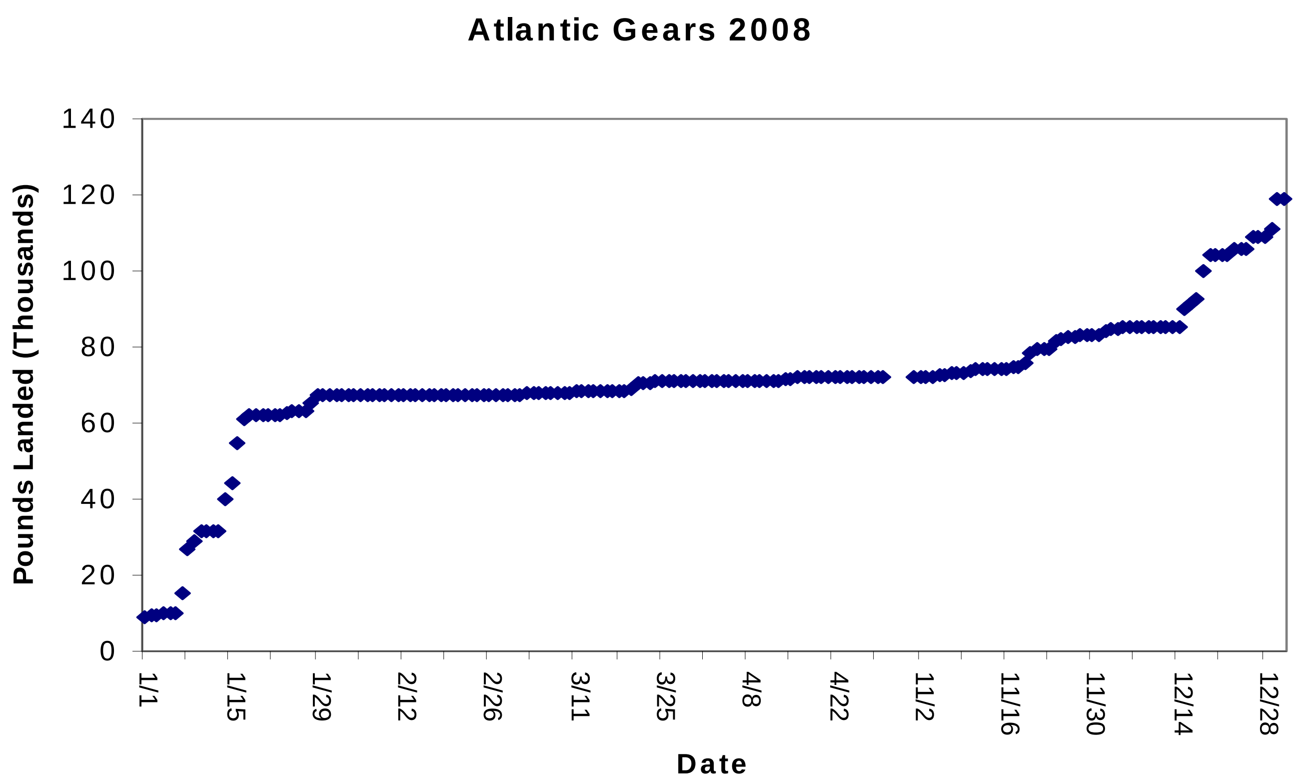


Figure 4. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by gear, 1990 – 2008.

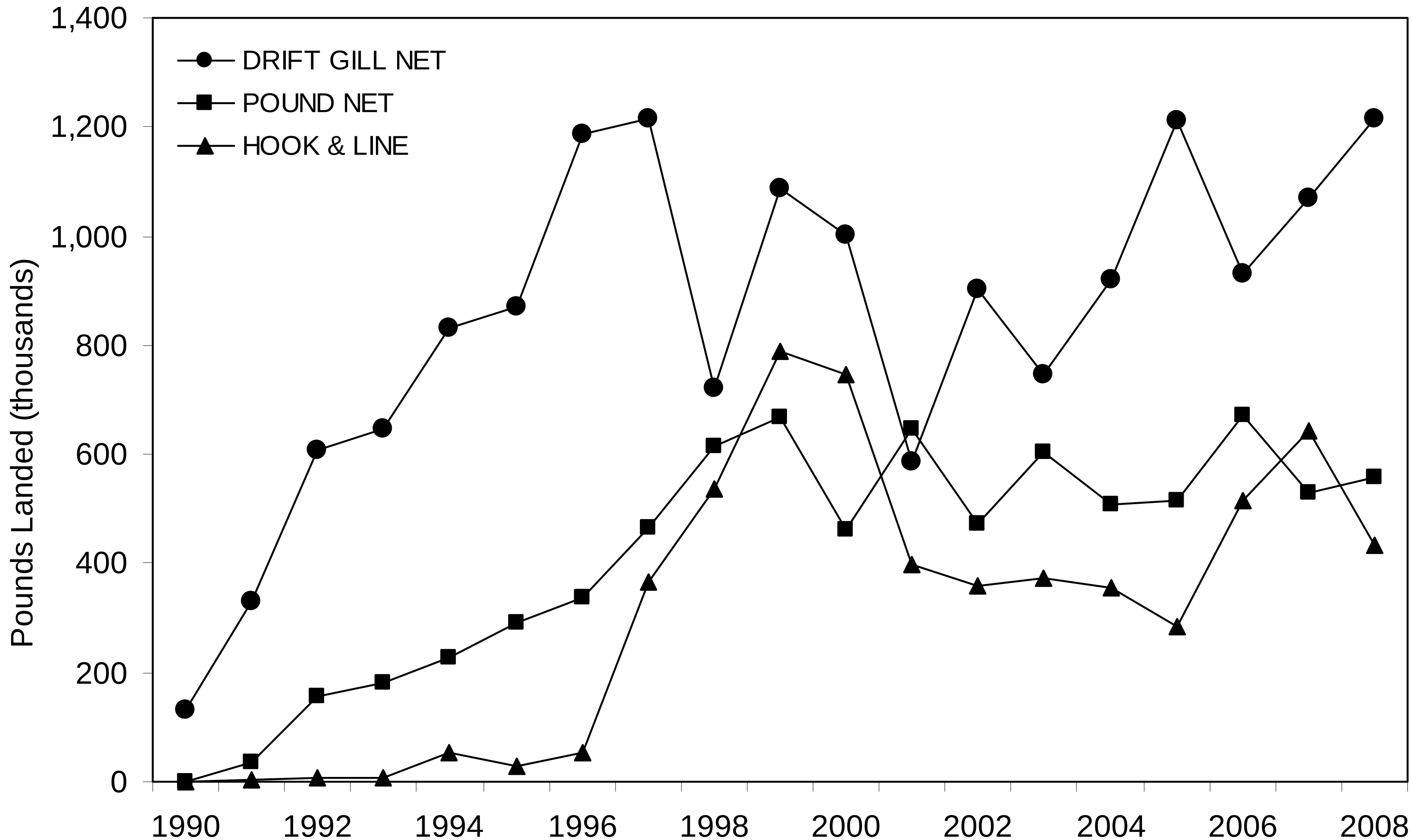


Figure 5. Maryland's Atlantic gill net and trawl fishery striped bass total harvest (thousands of pounds) per calendar year by gear type, 1990-2008.

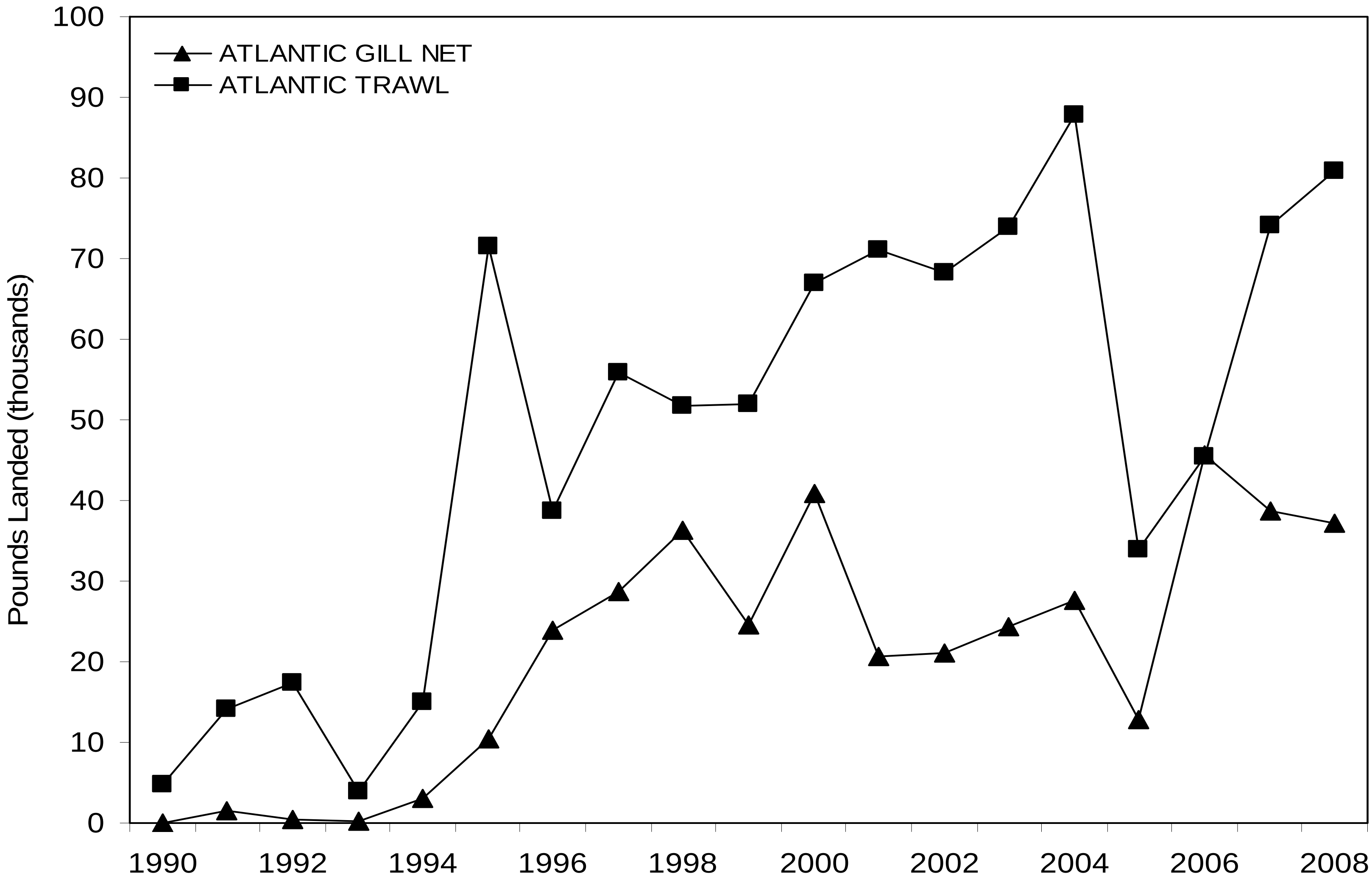


Figure 6. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by gear type, 1990- 2008. Trips were determined as days fished when striped bass catch was reported.

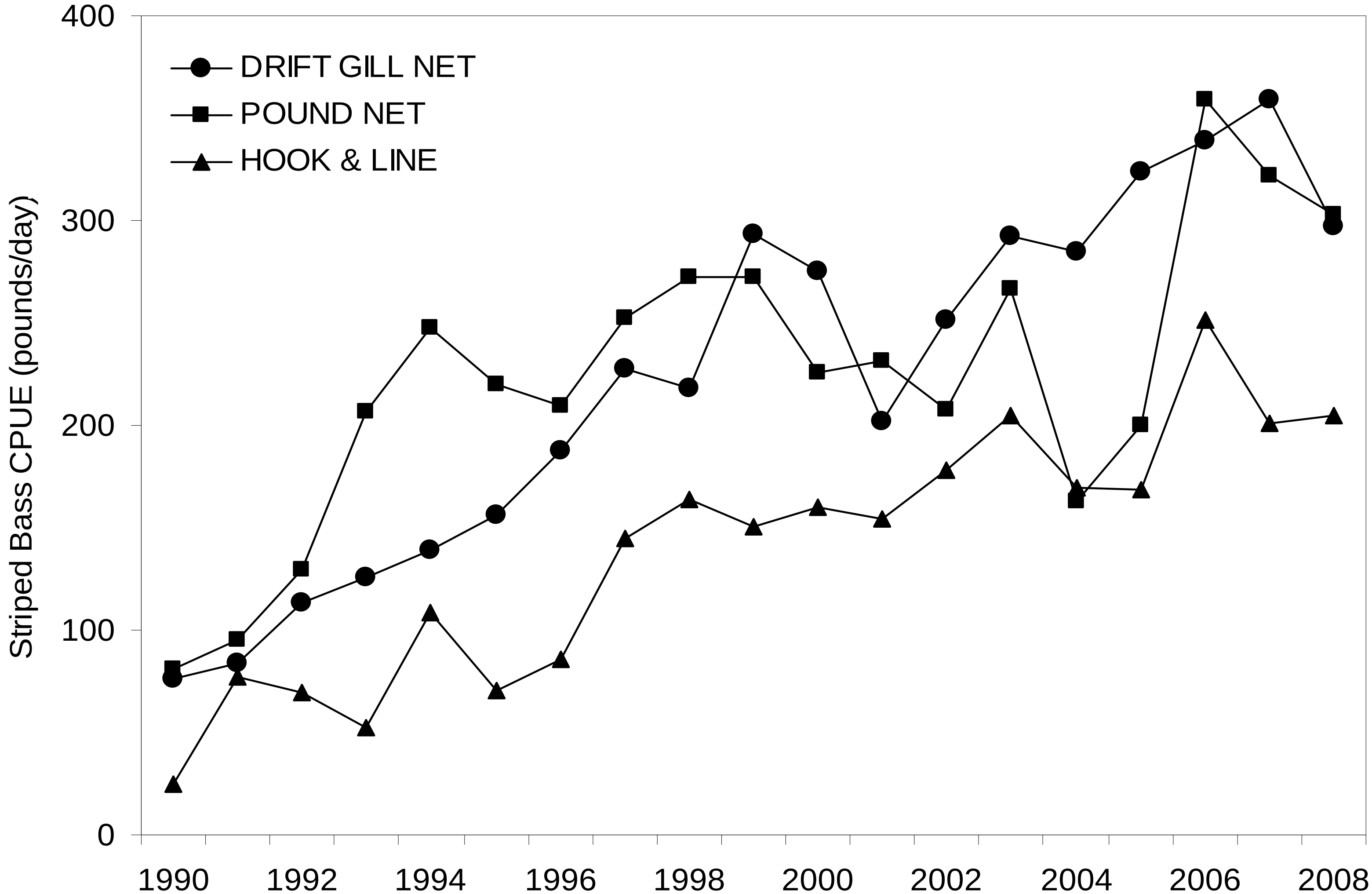
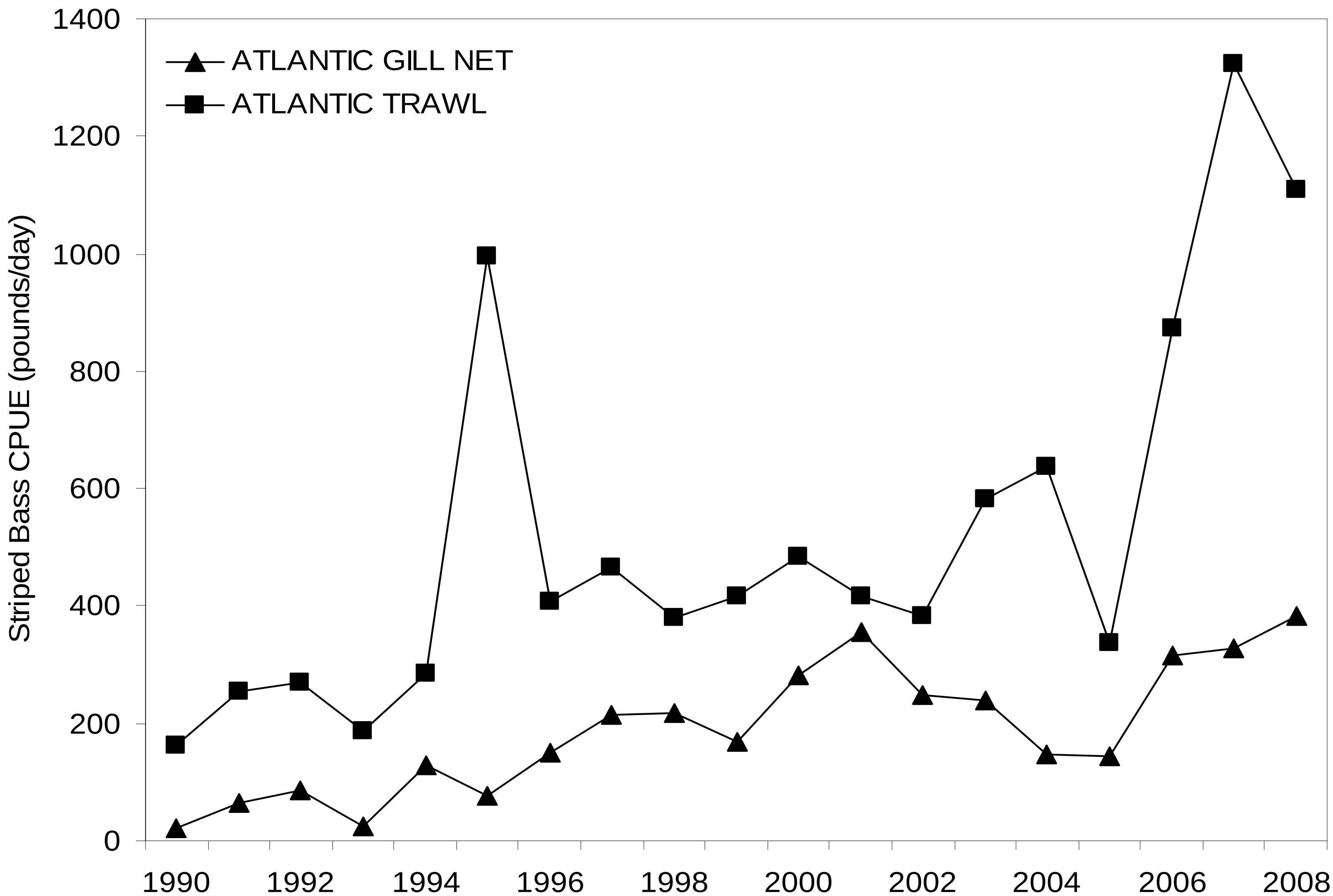


Figure 7. Maryland's Atlantic gill net and trawl fishery striped bass catch (pounds) per trip (CPUE), 1990-2008. Trips were determined as days fished when striped bass catch was reported.



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 2009 spring recreational season, which began on Saturday, April 18 and continued through May 15. In 2007, this survey was expanded to collect more data from private boat anglers for comparison with a concurrent telephone survey targeting private boat fishermen (Giuliano 2008). In 2009, the survey continued to emphasize the inclusion of data from private boat anglers even though the telephone survey was not conducted.

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-1970's, 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 restrictions have become progressively more liberal since 1991 as stock abundance increased (Table 1). The 2009 season was 28 days long (April 18 – 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 Stock Assessment Project initiated a dockside creel survey for the spring fishery in 2002. The survey was expanded in 2007 in order to better estimate catch per unit of effort (CPUE) for private boats, although the objectives remain the same:

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 2 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. 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 three major charter fishing ports in 2009: Solomons/Calvert Marina, Chesapeake Beach/Rod & Reel, and Deale/Happy Harbor (Table 2A). Preference was given to high-use sites to ensure the target of 60 fish per week would be sampled. Geographic coverage was spread out as much as possible between the middle and lower Bay. Though biological data were collected from charter boat harvest, interviews with anglers from charter boats were eliminated in 2008 to allow staff more time to survey private boat anglers. Charter boat 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 were not sampled in 2009. Public boat ramps were visited on one randomly selected weekday and one weekend day per week. Interviewers were stationed at two sites per selected day. They remained on-site from 10 AM-3 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 were used to supplement scales collected during the spring spawning stock gill net survey (Project No. 2, Job No. 3, Task No. 2) for the construction of a combined spring age-length key. The number of scales read from the trophy fishery has varied between years. In 2009, 189 scales were read. The age structure of fish sampled by the creel survey was estimated using the combined spring age-length key.

The season sampling target for otoliths was from 2 fish per 10 mm length group greater than or equal to 800 mm TL, for each sex. Otoliths were extracted by using a hacksaw to make a vertical cut from the top of the head above the margin of the pre-operculum down to a level above the eye socket. A second cut was made horizontally from the front of the head above the eye until it intersected the first cut, exposing the brain. The brain was removed carefully to expose the 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.

<u>Calculation of Harvest and Catch Rates</u>

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 1000 trips per year. In 2009, 23% 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 boats intercepted, number of anglers interviewed, and numbers of striped bass examined each year are presented in Table 5A. Both private and charter boat trips were intercepted; however, interviews in 2009 were from private boats and shore anglers while fish were only sampled from charter boats (Table 5B). Charter boat anglers were not interviewed as in previous years. Fishing activity during the spring season was highest in the middle Bay, specifically the region between the Chesapeake Bay Bridge and the mouth of the Patuxent River.

BIOLOGICAL DATA

Length and Weight

Length distribution

In 2009, the minimum size limit was 28 inches (711 mm) TL. Lengths ranged from 710 mm TL to 1220 mm TL. The catch was dominated by fish between 840 and 1020 mm TL (33 to 40 inches, Figure 2), similar to the length distribution observed in 2008..

Mean length

In 2009, the mean length for all sexes combined (913 mm TL) was slightly smaller than last year (Table 6A, Figure 3). The mean length of females (930 mm TL) was greater than the mean length of males (860 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. Based on 95% confidence intervals, the mean lengths of all fish combined and females increased significantly when compared to average lengths from all years except 2006 and 2008. Mean lengths in 2006 and 2008 for all fish and females are statistically similar to those observed in 2009. Mean lengths of males, based on 95% confidence intervals, are statistically similar to all other years of the survey.

Due to the limited number of observations, it was difficult to make definitive conclusions concerning the mean daily length of female striped bass harvested over the 2009 spring season (Figure 4). However, the data available indicate that the daily mean lengths were generally consistent throughout the 2009 season and similar to the patterns observed between 2005 and

2008. 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 2009 (7.9 kg) was similar to that observed in 2008 and was the second highest observed in all years (Table 6B). Based on 95% confidence intervals, the mean weight of females and all fish combined did not increase significantly from 2008 (Figure 5) and were not significantly higher than those observed in most other study years. The mean weight of males in 2009 was statistically similar to those observed in all other study years. The mean weight of females (8.3 kg) was greater than the mean weight of males (6.4 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).

<u>Age Structure</u>

The age distribution of striped bass from the sampled harvest in 2009 consisted of fish between 5 and 18 years of age (Figure 6). Most fish harvested were between 8 and 13 years old. The 2000 year-class (9 years old in 2009) was the most frequently observed cohort, constituting 29% of the sampled harvest. The 1998 year-class (11 years old in 2009) was the second most frequently observed, constituting 18% of the sampled harvest. The record-sized 1996 year-class (13 years old in 2009), which dominated catches in 2005, 2006, and 2008, constituted 12% of the sample harvest. The proportion of the harvest made up of the strong 2001 year-class (8 years old in 2009) has increased annually since 2007 and constituted 14% of the sampled harvest in 2009.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2009 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, 2) using only known-sex fish, and 3) assuming that the unknown fish were female (Table 7B).

Calculation method had little effect on the results. When the data were analyzed using all fish sampled, including unknown sex fish, females constituted 77% of the 2009 sampled harvest. When the data were analyzed using only known-sex fish, females constituted approximately 78% of the 2009 sampled harvest. Assuming the unknown sex fish were females, females would constitute approximately 78% of the harvest. These results were very similar to those from the 2008 sampled harvest but were slightly lower than the average proportion of females observed during the years 2002-2007, which ranged from 81-85%, depending on the calculation method chosen.

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 2009 spring survey season indicated that only 50% of the females caught between April 18 and May 15 were in pre-spawn condition (Table 8). This percentage is average based on the data from the past 7 years. This is in marked contrast to the 2008 spring season survey which indicated that 30% of females caught were in pre-spawn condition, the lowest percentage documented by the spring season creel survey.

Daily spawning condition of females

Because there were very few daily observations of female striped bass in pre-spawning condition in the 2009 survey, it was not possible to make any conclusions on trends observed in the data (Figure 7). The percent of pre-spawn females harvested ranged from 25% to 78% on any given day. The average daily percent of pre-spawn females in 2009 was 48%, higher than in 2008 (29%). Also, sample sizes of female striped bass were small, ranging from 8 to 29 fish on any given day (mean=24 fish, mode=29 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 2009 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.

Although no interviews of charter boat anglers were conducted, 2009 charter boat activity can be characterized from existing reporting methods. The mean HPT in 2009 according to charter boat logbooks was 5.0 fish per trip, similar to 2008 and consistent with other years (Table 9A). Mean HPT from private boat interviews (0.9) 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 logbook data in 2009 was 0.81 fish per person (Table 9B). HPA for private anglers, calculated from interview data, was 0.3 fish per person, similar to 2007 and 2008. (Table 9B).

Catch Per Unit Effort

In this report, catch is defined as the total number of fish harvested (kept) and released by each fishing party. Table 10A presents mean catch per trip (CPT) and mean catch per hour (CPH) calculated from all fishing modes combined. Since 2008, individuals from charter boat trips have not been interviewed and these numbers reflect private boat and shore angler interview data only. Mean CPT in 2009 (1.6) was the second lowest recorded in all years and significantly lower than the highest CPTs in the time series, 8.3 fish per trip in 2005 and 6.6 fish in 2006. Mean CPH was 0.4 fish per hour in 2009, statistically similar to 0.3 fish per hour in 2008. The decreases observed in CPT and CPH since 2006 are directly related to the reduction of charter boat interview data in 2007 and it's elimination after 2007 from the calculations. Because charter boat catch rates tend to be much higher than those from private boats, the removal of these data from the calculation have resulted in reduced catch rates.

Comparison of Catch Rates from Charter and Private Boats

In all years, charter boats caught more fish per trip than private boats (Tables 10B, 10C, and 10D). In 2009, private boats caught an average of 1.6 fish per trip, while charter boats caught 6 fish per trip. The private boat CPH was 0.4 fish per hour while charter boats had a CPH of 1.8 fish per hour, a value which has remained relatively constant since 2003. The lower private 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 2009 also varied without trend. However, CPH values in 2008 and 2009 were much lower than in previous years at least partially due to the lack of charter boat interview data.

Angler Characterization

States of residence

In 2009, 276 private boat/shore trips were intercepted for interviews and 747 anglers were interviewed during the period April 18-May 15 (Table 5A and Table 5B). Six states of residence were represented in 2009, fewer than any previous year (Table 11). Most anglers were from Maryland (87%), Virginia (6%), and Pennsylvania (6%), a similar residence distribution during previous years.

Number of Licensed Individuals

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 in order to estimate total fishing effort during the spring striped bass season. In 2008, there were on average 2.8 anglers per boat and of these 1.5 on average were license-exempt (Table 12). This question was retained for the 2009 survey, and even though the telephone survey was not conducted, the results were very consistent with last year. In 2009, there were on average 2.7 anglers per boat and of these anglers, 1.3 on average were license-exempt.

Fate of Tagged Fish

In 2009, a question was added to the survey in an attempt to determine whether an angler was more or less likely to keep a fish that had been tagged, assuming they were not at their creel limit and the fish was legal sized. This question was initiated after an Atlantic States Marine Fisheries Commission striped bass tagging subcommittee meeting amid concerns that anglers were more likely to throw back a fish that had been tagged and subsequently violate assumptions of the tagging models used in fisheries management. Though this question was asked hypothetically, and hence may not accurately represent what an angler would actually do if he caught a tagged fish, it would yield a greater number of responses than if the question was limited to just those anglers who had caught a tagged fish in the past. The question provided anglers with three options: keep the tagged fish, release the tagged fish with the tag still attached, or release the tagged fish without the tag.

Survey results for 2009 suggested that the majority of anglers (63%) would keep a tagged fish while 18.5% of anglers would release the fish with the tag still attached. The remainder of anglers would either release the fish without the tag (3%), were unsure of what they would do (13.5%), or would do a combination of two of the three choices depending on circumstances not adequately accounted for in the question (2%).

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)

Giuliano, A. 2008. Characterization of the striped bass spring recreational season and spawning stock in Maryland. In: MDDNR-Fisheries Service, Chesapeake Bay Finfish/Habitat Investigations, USFWS Federal Aid Project, F-61-R-4, 2007-2008, Project 2, Job 3, Task 5B, pp II-275-II-308.

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.

CITATIONS (Continued)

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

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

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

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, 1991-2009.

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

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2009. Sites are listed in a clockwise direction around Maryland's section of the Chesapeake Bay.

Region	**Site Name**	**Site Number**
Eastern Shore-Upper Bay	Rock Hall	01
Eastern Shore-Middle Bay	Matapeake Boat Ramp	02
Eastern Shore-Middle Bay	Kent Island Marina-Hemingway's	15
Eastern Shore-Middle Bay	Kentmorre Marina	03
Eastern Shore-Middle Bay	Queen Anne Marina	04
Eastern Shore-Middle Bay	Knapps Narrows Marina	13
Eastern Shore-Middle Bay	Tilghman Is./Harrison' s	05
Western Shore-Lower Bay	Pt. Lookout State Park	16
Western Shore-Lower Bay	Solomons Boat Ramp	17
Western Shore-Lower Bay	Solomons Island-Harbor Marina	18
Western Shore-Lower Bay	Solomons Island/Bunky's Charter Boats	06
Western Shore-Lower Bay	Solomons /Calvert Marina	07
Western Shore-Middle Bay	Breezy Point Fishing Center and Ramp	08
Western Shore-Middle Bay	Chesapeake Beach/Rod & Reel	09
Western Shore-Middle Bay	Herrington Harbor South	14
Western Shore-Middle Bay	Deale/Happy Harbor	10
Western Shore-Middle Bay	South River	12
Western Shore-Upper Bay	Sandy Pt. State Park Boat Ramp and Beach	11

Table 2B. Survey sites for the Maryland striped bass spring angler-intercept survey, 2009.

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

Table 3. Biological data collected by the Maryland striped bass spring season creel survey, 2009.

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, 2009.

Angler and Catch Data Collected
Number of hours fished
Fishing type: private boat or shore
Number of anglers on boat
Number of fish kept
Number of fish released
Number of anglers license exempt

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	330	329	200
2009	322	747	216

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	59	265	6	0	330
2009	46	275	1	0	322

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)

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)

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

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
Mean	**81**	**85**	**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*	83	50	81	49
Mean	**148**	**50**	**141**	**50**

*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	1424	**4.7** (4.6-4.8)	132	**4.9** (4.5-5.3)	44	**1.1** (0.6-1.4)
2003	1393	**5.7** (5.6-5.8)	101	**6.6** (5.8-7.3)	64	**1.1** (0.7-1.4)
2004	1591	**5.4** (5.3-5.5)	86	**5.6** (5.1-6.2)	42	**2.2** (1.7-2.8)
2005	1965	**5.5** (5.4-5.6)	49	**6.9** (6.3-7.5)	1	**0.0**
2006	1934	**5.3** (5.2-5.4)	92	**6.0** (5.3-6.7)	28	**1.4** (0.6-2.1)
2007	1607	**4.3** (4.2-4.4)	50	**4.9** (4.2-5.7)	483	**0.7** (0.6-0.8)
2008	1755	**4.9** (4.8-5.1)	0	N/A	260	**0.6** (0.5-0.7)
2009	1825	**5.0** (4.9-5.1)	0	N/A	275	**0.9** (0.7-1.0)

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

Year	Charter Logbook Trips (n)	Charter Logbook Mean HPA	Charter Creel Int. Trips (n)	Charter Creel Int. Mean HPA	Private Creel Int. Trips (n)	Private Creel Int. Mean HPA
2002	1424	**0.78** (0.76-0.79)	131	**0.8** (0.7-0.9)	43	**0.4** (0.3-0.6)
2003	1393	**0.93** (0.92-0.94)	101	**1.0** (0.9-1.2)	64	**0.4** (0.3-0.5)
2004	1591	**0.88** (0.86-0.89)	86	**0.9** (0.8-1.0)	42	**0.7** (0.5-0.8)
2005	1965	**0.88** (0.87-0.89)	49	**1.0** (0.9-1.1)	1	**0.0**
2006	1934	**0.86** (0.87-0.85)	90	**1.0** (0.8-1.1)	27	**0.5** (0.2-0.7)
2007	1607	**0.69** (0.68-0.71)	50	**0.8** (0.7-0.9)	483	**0.3** (0.2-0.3)
2008	1755	**0.79** (0.78-0.81)	0	N/A	260	**0.2** (0.2-0.3)
2009	1825	**0.81** (0.80-0.82)	0	N/A	275	**0.3** (0.3-0.4)

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)

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)

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

Table 10D. Charter boat mean catch, effort, and catch per hour, with 95% confidence limits, calculated from log book 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	1487	**5.5** (5.4-5.7)	**5.5** (5.3-5.7)	**1.0** (0.9-1.1)
2003	1420	**7.3** (7.0-7.6)	**4.0** (3.7-4.4)	**1.8** (1.7-1.9)
2004	1629	**7.4** (7.0-7.7)	**4.0** (3.6-4.4)	**1.8** (1.7-1.9)
2005	1994	**6.9** (6.6-7.1)	**3.1** (2.6-3.5)	**2.2** (2.1-2.3)
2006	1990	**8.0** (7.7-8.2)	**3.6** (3.2-3.9)	**2.2** (2.1-2.3)
2007	1793	**8.1** (7.8-8.4)	**4.6** (4.1-5.0)	**1.8** (1.7-1.8)
2008	1755	**6.4** (6.2-6.6)	N/A	N/A
2009	1825	**6.0** (5.9-6.2)	**3.4** (2.9-4.0)	**1.8** (1.7-1.8)

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

Table 12. The average number of anglers and average number of unlicensed anglers, per boat, with 95% confidence intervals, from the 2008 and 2009 Maryland striped bass spring season creel survey interview data.

Year	Number of Anglers Interviewed	Average Number of Anglers	Average Number of Unlicensed Anglers
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)

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 18-May 15, 2009.

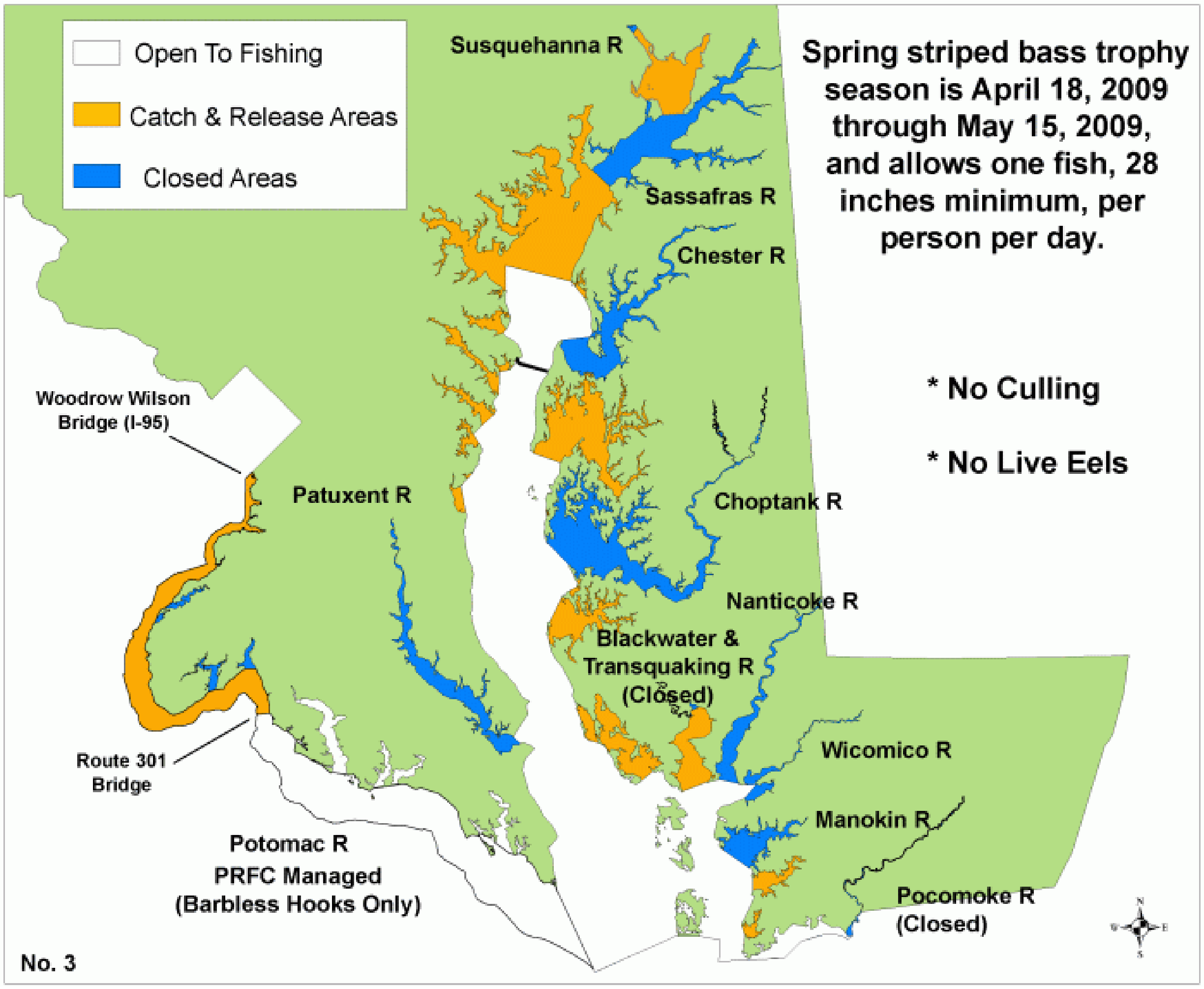


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

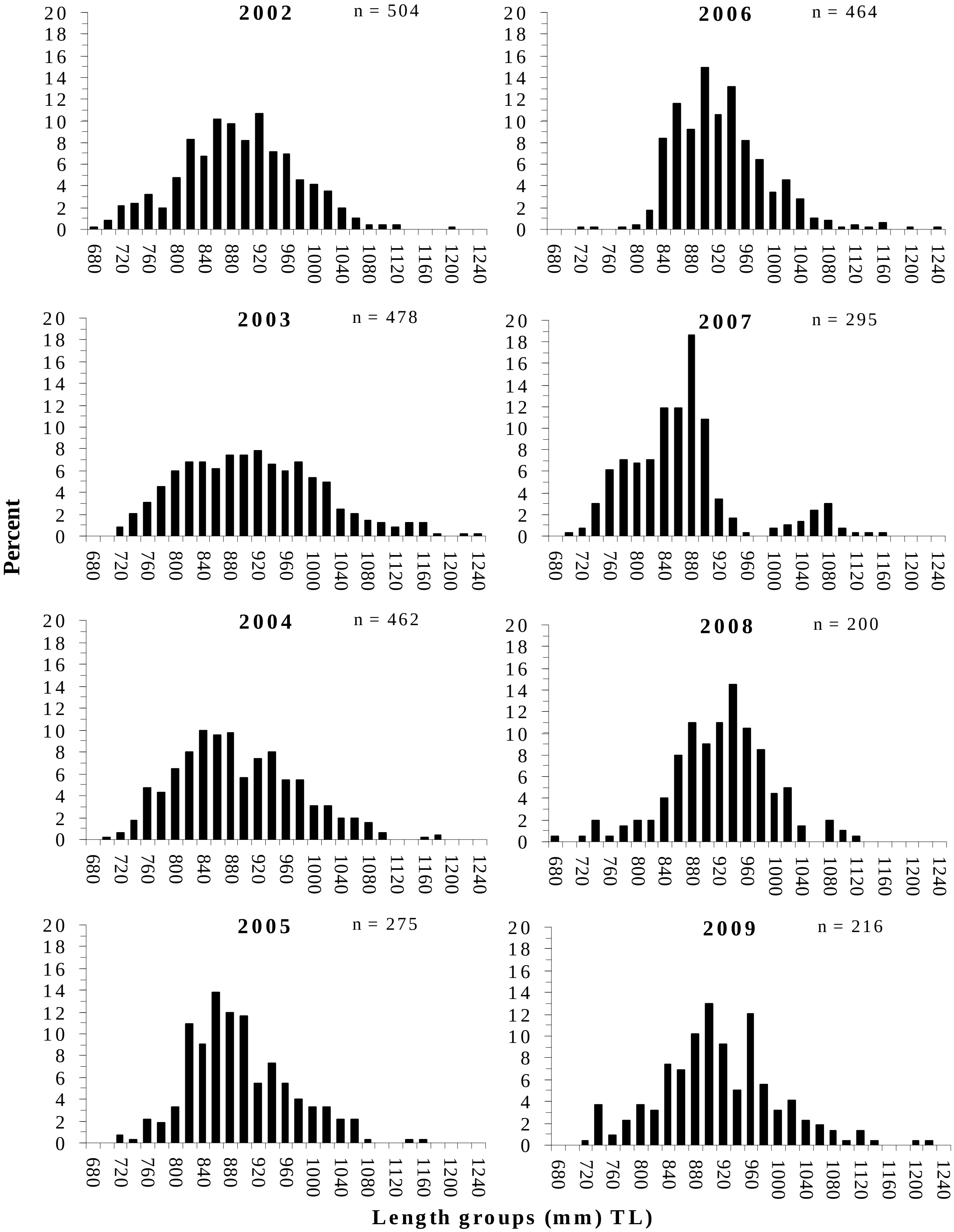


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

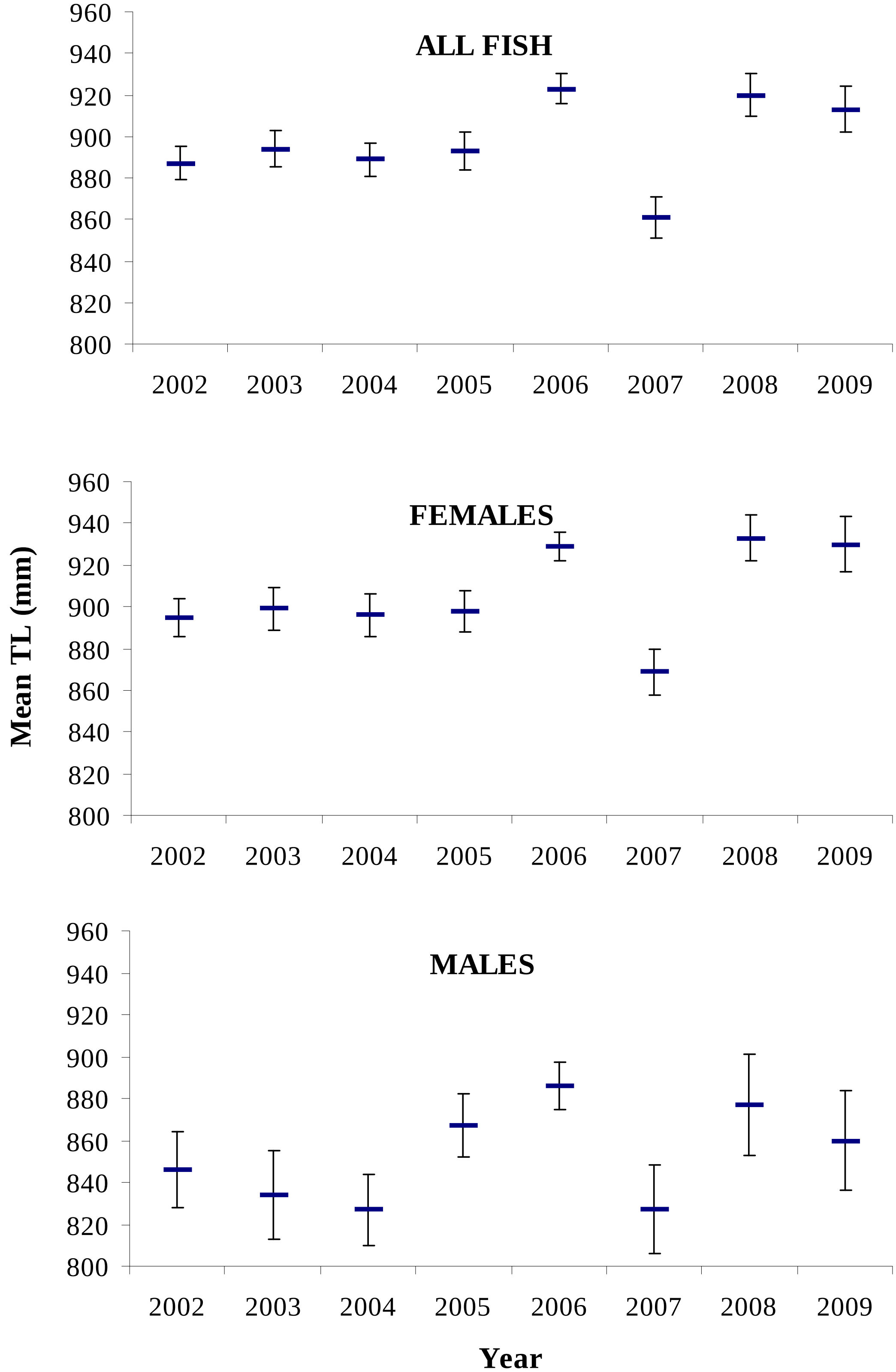


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

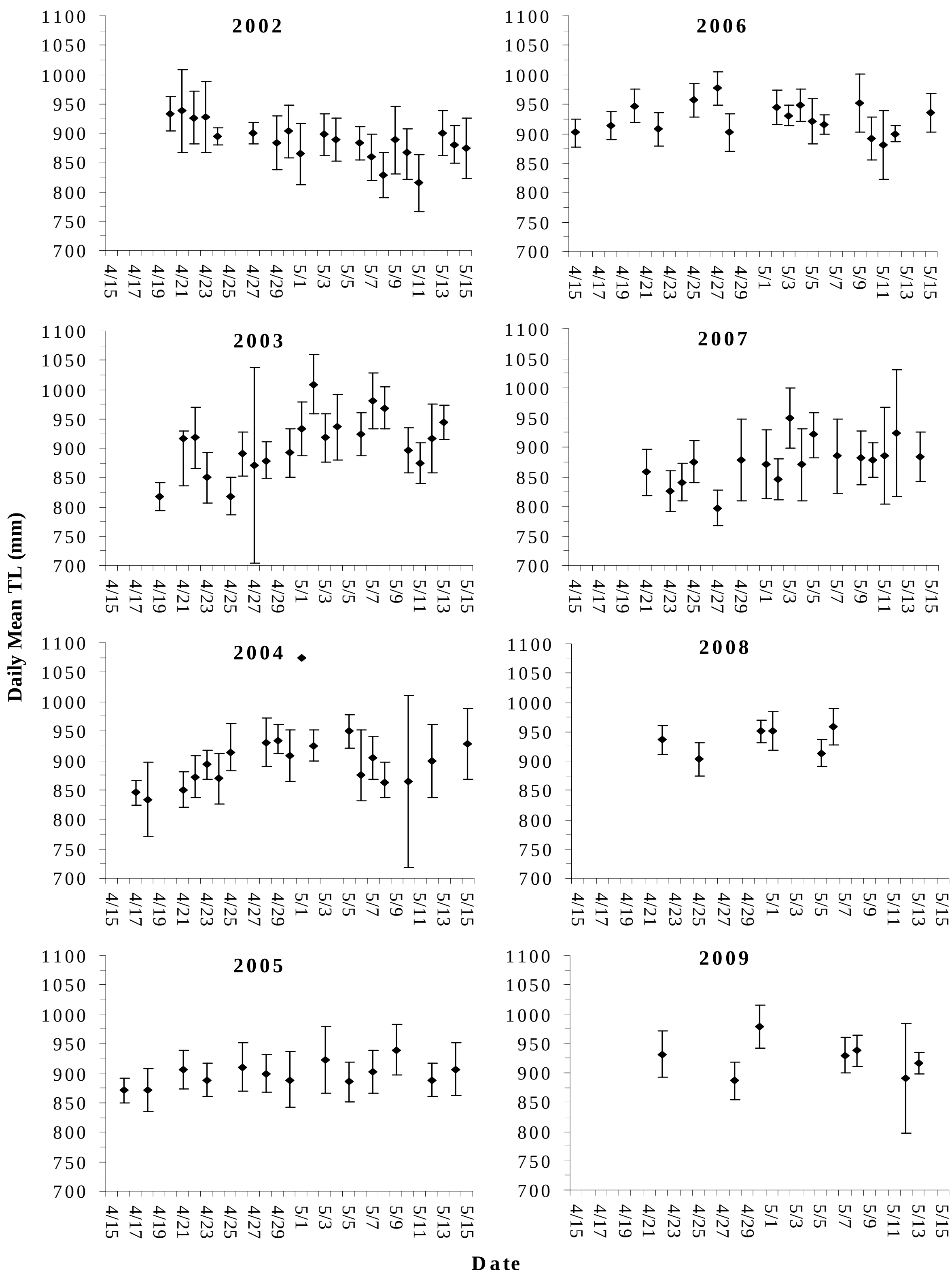


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

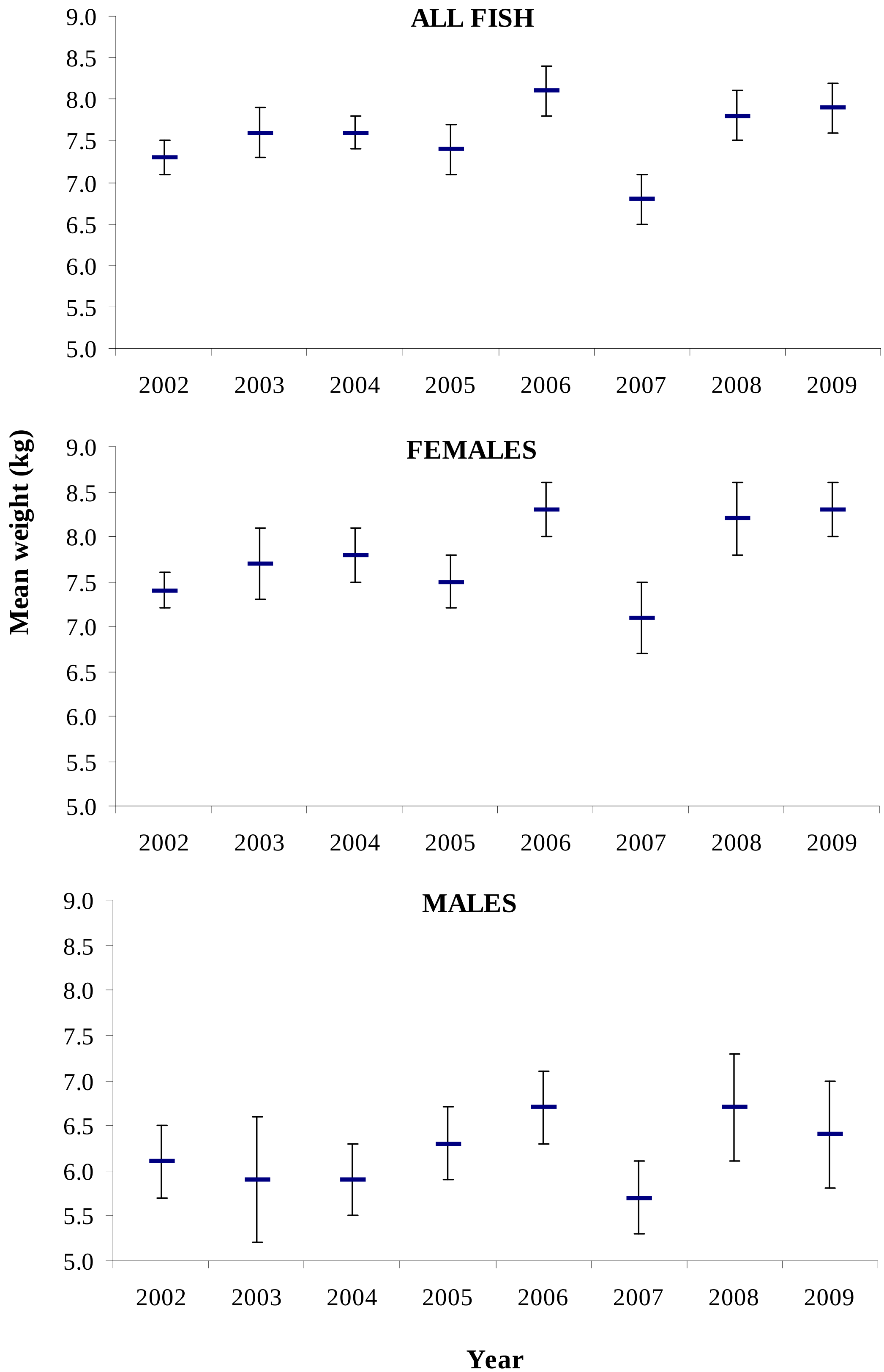


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

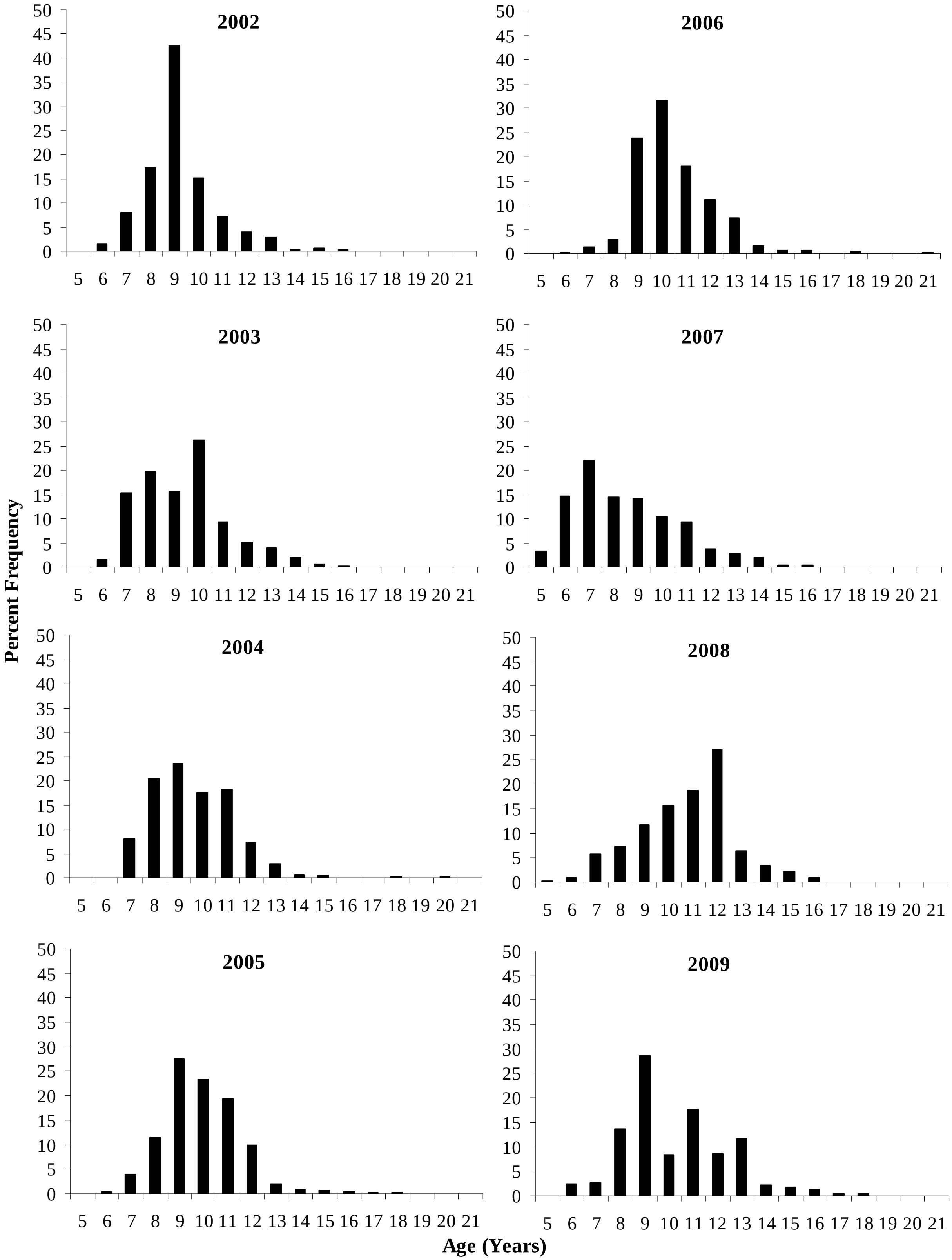


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

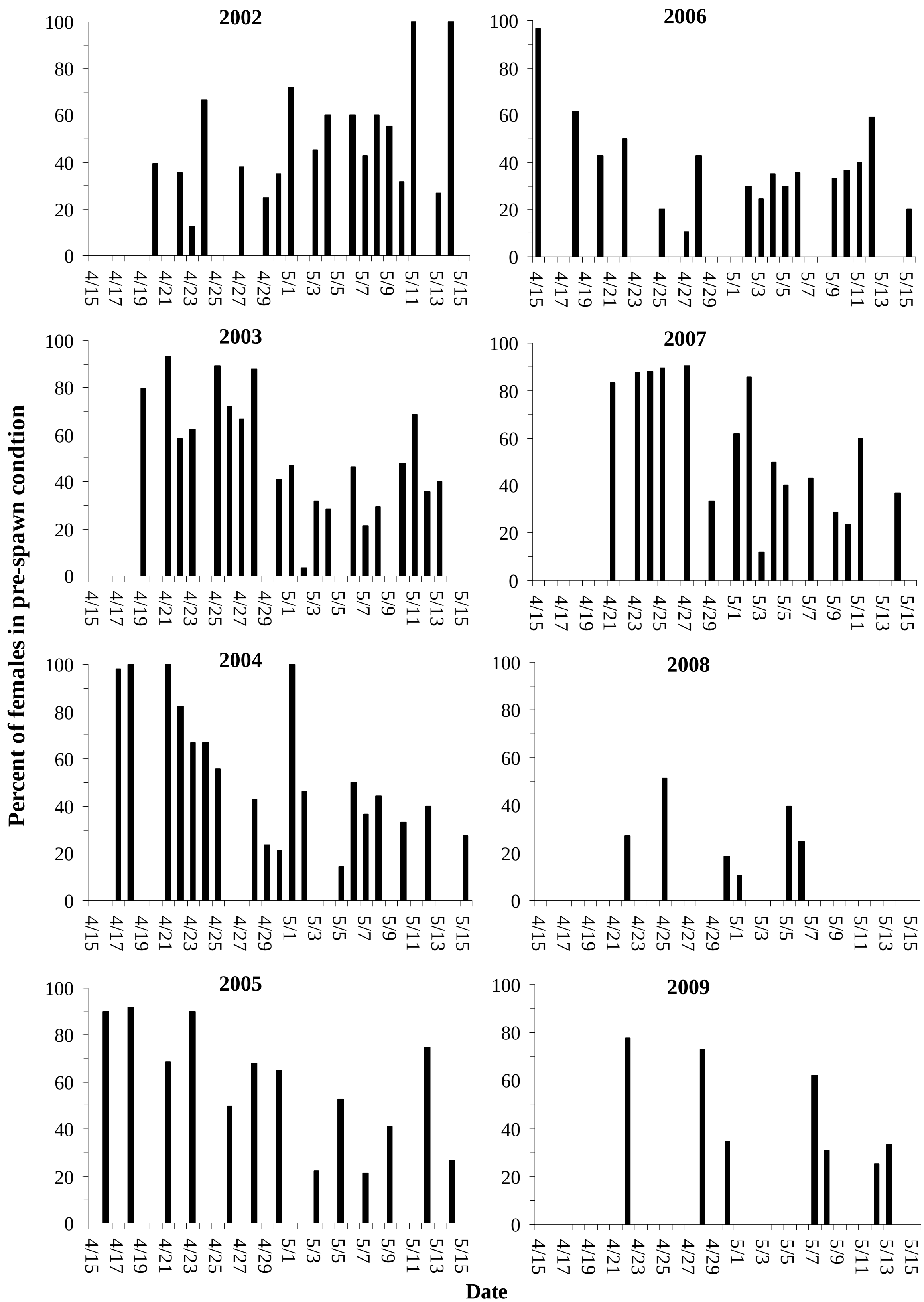
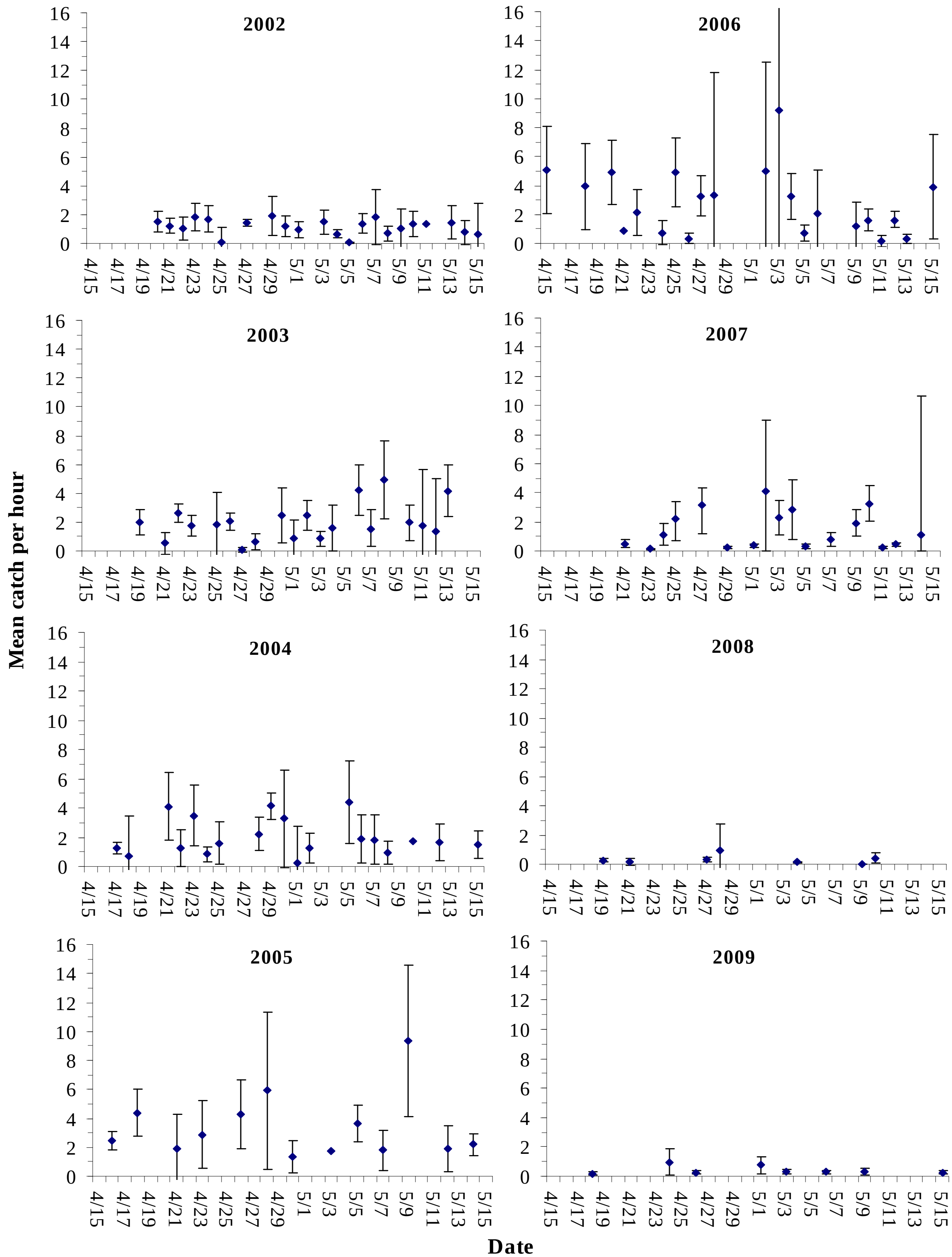


Figure 8. Daily mean catch per hour (CPH) of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15.



APPENDIX I

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

Part A. Trip Description-Effort and Catch Data (Private Boat Only)

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.) 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.

6.) What is your state of residence?

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

8.) If you caught a fish with a tag in it, it was legal size, and you were not at your creel limit, would you keep the fish, release the fish with the tag, or release the fish without the tag?

Part B. Data Form for Landed Catch (Charter Boat Only)

Boat # & Name	Fish #	TL	Weight	Sex	Spawn Cond.	Anomaly	Scale	Oto

PROJECT NO. 2
JOB NO. 3
TASK NO. 6

ELECTROFISHING SURVEY TO TARGET HATCHERY-REARED STRIPED BASS ON THE PATUXENT RIVER

Prepared by Amy Batdorf

INTRODUCTION

The primary objective of Project 2, Job 3, Task 6 was to collect hatchery-reared, known-age striped bass (*Morone saxatilis*) from the Patuxent River. These fish were marked with coded wire tags (CWTs) as fingerlings and released in Maryland waters between 1985 and 1995. When encountered, they provide a valuable data source for validating ageing techniques by direct comparison of known hatchery release data to scale and otolith ages. Since 1986, the search for these fish was conducted annually during routine monitoring surveys, but in recent years very few have been encountered (Versak 2006). Because striped bass may return to their natal rivers to spawn, sampling efforts have been focused on the spawning reaches of the Patuxent River where the majority of the CWT marked fish were released. By concentrating sampling in this system, the chances of encountering these fish would be increased.

METHODS

Sampling effort was focused on the freshwater portion of the upper Patuxent River in the area between Nottingham and Whites Landing (Figure 1) in early April 2009. The sampling design was based on reports of historical abundance of spawning striped bass in this area (D.

Cosden, personal communication, MD DNR Inland Fisheries Division) and on catches from past surveys (Zlokovitz and Versak 2003, Versak and Zlokovitz 2004, Zlokovitz and Versak 2006). These sources indicated that striped bass staged for spawning in the shallow mud flats opposite Hall Creek when water temperatures reached 10.0-11.0 ºC in late March or early April. This area, with depths ranging from 2-6 feet, tends to warm faster than the deeper channel areas, thus attracting pre-spawn adults. Due to the limited number of sampling days available in 2009, efforts were concentrated in this area.

Electrofishing was conducted with a Smith-Root SR-18 electrofishing boat with a 5,000 watt generator, and a pulsed, fully adjustable, DC current. The control setting was high, pulsed at 60 - 120 pps, with 60-80% power. Output range was 50-1000 volts and amps were generally set between 8-12. The pulsed DC current was less stressful to the fish than an alternating current (AC). Fish were collected by applying an electrical charge to the water through an anode (front booms with cable droppers), to the cathode (side droppers, or the boat itself). The size and effectiveness of the electrofishing field depended on control settings and water conductivity. Fish within this field, or nearby, were temporarily stunned and either floated to the surface or swam toward the anode. The lethargic state of the fish allowed the person positioned on the bow of the boat to easily net and handle the fish for sampling. (M. Groves, personal communication, MD DNR, Inland Fisheries Division).

Since hatchery stocking ended in 1995, only fish which were approximately 800 mm TL or larger were netted, measured, scanned for CWTs and sexed by expression of gonadal products. The left cheek area was tested for the presence of a CWT using a Northwest Marine Technologies CWT detector wand. Striped bass that did not test positive for CWTs were released after being revived in an onboard live well. CWT positive fish were sacrificed and scales and otoliths collected for age validation purposes. The CWTs were extracted by MDDNR biologists and read by U.S. Fish and Wildlife Service (USFWS) personnel for hatchery identification and year of release. Depth (feet), water temperature (°C), conductivity (µs) and shocking time (seconds) were recorded at each site.

RESULTS and DISCUSSION

In 2009, sampling was limited to two days, April 9 and April 17. Sixty striped bass were scanned for the presence of CWTs and none were found to be positive. A total effort of 4 hours and 33 minutes of actual shocking time was recorded on the electrofishing boats (Table 1). The mean total length (TL) of the 60 striped bass measured was 970 mm (minimum=493 mm, maximum=1,240 mm, median=958 mm). Of those 60 fish sampled, 43 (72%) were females.

The comparison of scale and tag ages in recent years supports the assumption that scales become less reliable for ageing fish older than 12 years (Secor et al. 1995). A current study utilizing Maryland's known age fish indicates that the accuracy of striped bass ageing may be increased significantly by reading otoliths rather than scales (H. Liao, personal communication, Old Dominion University). The additional scale and otolith samples from known-age striped bass help refine scale and otolith ageing techniques in support of recent Atlantic States Marine Fisheries Commission recommendations.

This survey will be terminated in the 2010 season since CWT positive fish have not been encountered since 2006. The time and effort required to collect hatchery fish does not justify the continuation of this study. Large striped bass encountered during the conduct of other surveys on the Patuxent River in the spring will be checked for CWTs whenever possible.

ACKNOWLEDGEMENTS

This electrofishing study was conducted with the assistance of Don Cosden, Mary Groves, Tim Groves, Brian Richardson, Chuck Stence, and Ross Williams of the Inland Fisheries Division.

CITATIONS

Secor, D. H., T. M. Trice and H. T. Hornick. 1995. Validation of Otolith-Based Ageing and a Comparison of Otolith and Scale-Based Ageing in Mark-Recaptured Chesapeake Bay Striped Bass, *Morone saxatilis*. Fish. Bull. 93: 186-190.

Versak, B. and E. Zlokovitz. 2004. Electrofishing Survey to Target Hatchery-Reared Striped Bass on the Patuxent River. In: Investigation of Striped Bass in Chesapeake Bay. USFWS Federal Aid Project, F-42-R-17, 2003-2004, Maryland Department of Natural Resources, Fisheries Service. Job No. 6B, pp 191-197.

Versak, B. 2006. Hatchery Stocking Contribution to Wild Stock Striped Bass in Maryland Chesapeake Bay and Tributaries. In: Chesapeake Bay Finfish and Habitat Investigations. USFWS Federal Aid Project, F-61-R-1, Period covered: 2004-2005, Maryland Department of Natural Resources, Fisheries Service. Project No. 2, Job No. 3, Task 6A, pp 271-280.

Zlokovitz, E. and B. Versak. 2003. Electrofishing Survey to Target Hatchery-Reared Striped Bass on the Patuxent River. In: Investigation of Striped Bass in Chesapeake Bay. USFWS Federal Aid Project, F-42-R-16, 2002-2003, Maryland Department of Natural Resources, Fisheries Service. Job No. 6B, pp 217-223.

Zlokovitz, E. and B. Versak 2006. Electrofishing Survey to Target Hatchery-Reared Striped Bass on the Patuxent River. In: Chesapeake Bay Finfish and Habitat Investigations. USFWS Federal Aid Project, F-61-R-1, Period covered: 2004-2005, Maryland Department of Natural Resources, Fisheries Service. Project No. 2, Job No. 3, Task 6B, pp 281-287.

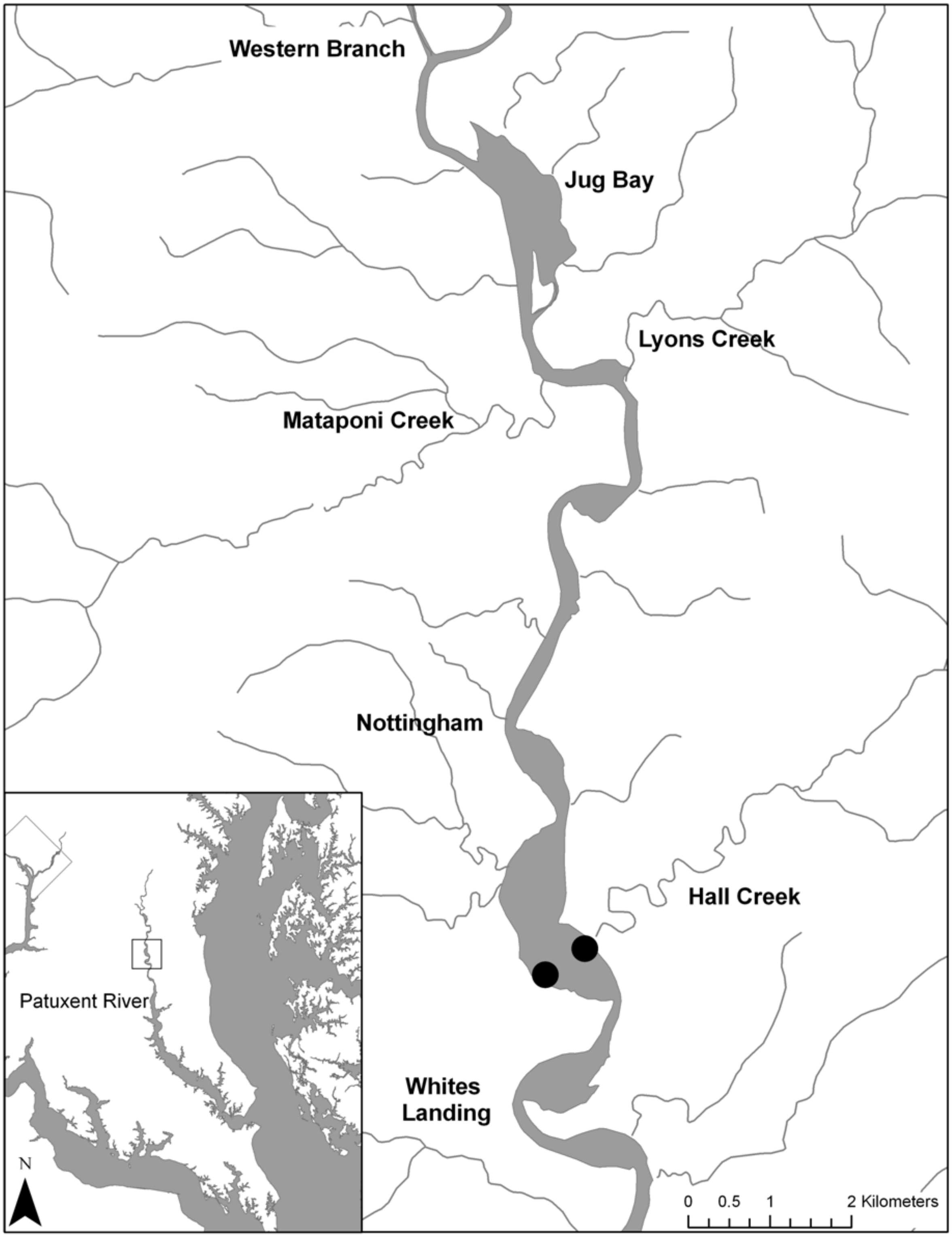
LIST OF TABLES

LIST OF FIGURES

Table 1. Electrofishing survey targeting hatchery-reared striped bass on the Patuxent River, 2009. Data summary by date, for all sites combined.

Date	# Fish Scanned	# CWT Positive	Total Effort (sec)	Mean Length (mm TL)	% Female	% Male	Mean Water Temp (°C)
4/09/09	32	0	10,146	965	66	34	11.7
4/17/08	28	0	6,264	975	79	21	12.1

Figure 1. Location of Patuxent River electrofishing sites, April 2009.



PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDNATION

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.

Participated in development of Ecosystem Based Fishery Management Plan for alosines in Chesapeake Bay. Efforts coordinated with the Maryland Sea Grant.

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, 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 Status Compliance Report.

Project staff also provided Maryland striped bass data and biological 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, New York and Virginia. For the past contract year, (October 1, 2008 through October 31, 2009) 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.

-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.

-Mr. Sherman Baynard, CCA.
Provision of striped bass fishery regulations, striped bass recreational, and charter boat harvest data.

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

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

-Dr. 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.

-Dr. Doug Vaughn, NMFS-NOAA.
Provision of juvenile Atlantic menhaden abundance indices.

-University of Maryland (U MD - CEES).
Provided five (7) 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 forty three (43) additional scientists, students and concerned stakeholders.

PROJECT NO. 3
JOB NO. 1

FISHERIES AND HABITAT INTERACTIONS PROJECT: DEVELOPMENT OF HABITAT-BASED REFERENCE POINTS FOR CHESAPEAKE BAY FISHES OF SPECIAL CONCERN: IMPERVIOUS SURFACE AS A TEST CASE - 2009

Prepared by Jim Uphoff, Margaret McGinty,
Rudy Lukacovic, Jim Mowrer, Bruce Pyle and Marek Topolski.

INTRODUCTION

Fisheries management uses biological reference points (BRPs) to determine how many fish can be safely harvested from a stock (Sissenwine and Shepherd 1987). The primary objective of Project 3 was to evaluate the concept of impervious surface reference points (ISRPs) as a similar tool for fish habitat management. The development of ISRPs involves determining functional relationships between a watershed's area covered in impervious cover (or IS; paved surfaces, buildings, and compacted soils) and habitat quality (water quality, physical structure, etc) or a species response (habitat occupation, abundance, distribution, mortality, recruitment success, growth, etc). Quantitative, habitat-based reference points based on impervious surface for estuarine watersheds are envisioned as a basis for strategies for managing fisheries in increasingly urbanizing coastal watersheds and for communicating the limits of fisheries resources to withstand development-related habitat changes to stakeholders and agencies involved in land-use planning.

Project activities in 2009 included investigating land-use indicators, spring stream anadromous fish icthyoplankton collections, spring yellow perch larval presence-absence sampling, and summer sampling of estuarine fish communities. These efforts were collectively aimed at defining the impact of impervious surface on target fish species populations and habitats.

INDICATORS OF LAND-USE

Introduction

Measures of urbanization are varied (National Research Council or NRC 2009). A recurring problem affecting our ability to relate urbanization to fisheries metrics is the lack of a standardized, readily updated, and accessible land-use data set. We have, by necessity, used several indicators of impervious surface (IS). The purpose of this section is to describe the indictors we have used, indicators that could be developed, and the associations among them. Measuring the strength of associations indicates how coherent these indicators are for describing trends in watershed urbanization.

Impervious Surface Estimates - We have primarily used IS estimates made by Towson University from Landsat, 30-meter pixel resolution satellite imagery (Eastern Shore of Chesapeake Bay in 1999 and western shore in 2001) for each watershed (Barnes et al. 2002) to develop IS reference points for brackish Chesapeake Bay tributaries (Uphoff et al. 2009). These "old" estimates have proven difficult to verify after we obtained them and additional ones could not be obtained for additional watersheds. IS estimates can be derived from Maryland Department of Planning (MDP) landcover estimates (available through Maryland's Surf Your Watershed http://www.dnr.state.md.us/watersheds/surf/) and have been used occasionally; 1994 land cover types (urban, forest, wetland, agriculture, etc) were assigned a coefficients for IS by MDP and summing the products of watershed cover type and IS coefficients would result in an estimate of IS (http://www.dnr.state.md.us/watersheds/surf/indic/metadata/pctimp_amet.pdf).

These methodologies were not identical, but estimates were generally close when both techniques were applied.

The Chesapeake Bay Chesapeake Bay Program (CBP) placed watershed profiles with estimates of IS, watershed area, and census-based estimates of human population (1970-2000 and projections for 2010 and 2020) for each watershed on their website until 2008. Unfortunately, these estimates are no longer supported or available online. While they were available, we created a spreadsheet with these data for tributaries that we were monitoring. Towson and MDP methodologies produced noticeably higher estimates for the same watersheds than CBP Regional Earth Science Applications Center (RESAC; http://www.geog.umd.edu/resac/lc2.html) based analysis of satellite imagery. RESAC based estimates of IS were about half of those estimated by Towson University, but trends were very similar (Uphoff 2008).

These data sets are becoming dated. Significant amounts of development can occur in 10-15 years and continued monitoring of fish and habitat conditions need to be matched with more concurrent measures of development. It is unknown when updated estimates of impervious surface may become available.

Tax Maps -The Maryland Department of Planning (MDP) annually updates the more than 2,800 property maps, or tax maps, for Maryland's 23 counties − Baltimore City maintains its own property maps (MDP 2010). Maryland's tax maps are updated and maintained electronically as part of MDP's Geographic Information System's (GIS) database. The tax maps are maintained in a Computer Aided Design (CAD) environment and updated on an annual cycle using new property plats and deed changes obtained from the State Department of Assessments and Taxation (Maryland Department of Planning 2010). Tax maps, also known as assessment maps, property maps or parcel maps, are a graphic representation of real property showing and defining individual property boundaries in relationship to contiguous real property. The primary purpose of the maps is to help State tax assessors locate properties for assessments and taxation purposes. Tax maps are also used by federal, State and local government agencies as well as private sector firms for a variety of analyses and decision making processes (Maryland Department of Planning 2010).

Tax map data appear to meet our requirements for a standardized, readily updated, and accessible data base. We estimated of number of structures and square footage of structures that existed during 2000 for comparison with the "new" Towson IS estimates.

Methods

New estimates of Impervious Surface - In December, 2009, we obtained land use area estimates for each watershed from D. Sides (Towson University) and calculated "new" Towson IS estimates of percent IS as Σ IA / Σ TA; where IA = impervious surface area estimated in the watershed and TA is the estimate of total area of the watershed. We used linear regression to determine the relationship of "old" and "new estimates".

Tax Map Indicators of Development – Two indicators of development were estimated, a count of structures and total building square footage. Count of structures could be obtained directly from the tax map data base. Total building square footage estimates for each watershed studied required multiple geoprocessing tools. Most files were managed using a file geodatabase in ArcCatalog 9.3.1 and geoprocessed using ArcMap 9.3.1 from Environmental Systems Research Institute (ESRI 2009). All feature datasets, feature classes, and shapefiles were spatially referenced using the NAD_1983_StatePlane_Maryland_FIPS_1900 projection to ensure accurate feature overlays and data extraction. North American Datum of 1983 (NAD 1983) describes earth's curvature and is used to position coordinates in North America. To reduce geographic distortion caused by mapping a three-dimensional surface in two dimensions, each state has a unique coordinate projection (Wade and Sommer 2006). Maryland's coordinate projection is StatePlane_Maryland_FIPS_1900.) Maryland 8-digit watersheds were extracted from a statewide shapefile provided by MD DNR and exported as separate feature classes (Figure 1).

All tax data were organized by county. Since watersheds straddle political boundaries, one statewide tax map was created for each year (1999 – 2008) digital tax maps were available by appending the county shapefiles into one feature class. Inconsistencies in the projection of 1998 and 1997 tax maps prevented their use. Statewide tax maps were generated for 1970 - 1998 from the 2008 tax map. A small portion of parcels had no coordinates and were omitted (Table 1).

Process models were developed using Model Builder in ArcMap to automate assembly of statewide tax maps, query tax map data, and assemble summary data. Each year's statewide tax map was clipped using the MD 8-digit watershed boundaries of interest (Bohemia River, Breton Bay, Bush River, Corsica River, Gunpowder River, Langford Creek, Magothy River, Mattawoman Creek, Middle River/Browns Creek, Miles River, Nanjemoy Creek, Northeast River, Piscataway Creek, Severn River, South River, St. Clements Bay, Tred Avon River, West River/Rhode River, Wicomico River/Gilbert Swamp/Zekiah Swamp, and Wye River) to create watershed tax maps (Figure 1). These watershed tax maps were queried for all parcels having foundation square feet greater than zero. A large portion of parcels did not have any record of foundation square feet or year built (Table 2) and all square feet and number of structure calculations are likely underestimates. The total foundation square feet in each watershed was calculated and appended into one file for each year.

Comparisons of Impervious Surface and Tax Map Indices of Development - “New” Towson IS, counts of structures, and square footage of structures were available for the 19 Chesapeake Bay subestuary watersheds we have studied. All comparisons were based on year 2000 estimates (Table 3). Counts of structures and square footage of structures in a watershed were standardized on a per area basis by dividing them by estimates of watershed acreage (available in the land use spreadsheet provided by D. Sides of Towson University). Linear and non-linear regression (Freund and Littel 2000) were used to determine the relationships of tax map indicators of development and IS. Nonlinear power functions were estimated with SAS Proc NLIN (Freund and Little 2000) as

$$IS = a*I^b;$$

where I = count of structures per area or square footage of structures per area, and a and b are coefficients for each indictor. Residuals were inspected for indications of bias or need for additional terms.

Results

The fit of the regression of old versus new IS estimates for systems studied since 2003 was very good ($r^2 = 0.99$, $P < 0.001$), but new estimates were slightly higher (slope = 1.14, SE = 0.04; intercept was not significantly different than 0). These “new” estimates were used in this report.

Linear regression analysis indicated that IS was positively and significantly ($P < 0.0001$) related to count of structures per acre of watershed ($r^2 = 0.93$) and square footage of structures per acre of watershed ($r^2 = 0.96$). In spite of these good fits, use of these linear equations for converting either indicator of development was limited at low IS because both counts and square footage became negative at IS lower than 3.5% and 2.6%, respectively.

Nonlinear power functions described these relationships better than linear regressions (count of structures per area $r^2 = 0.95$ and square footage per area $r^2 = 0.98$; $P < 0.0001$ in both cases) and became asymptotically low at low IS (Figure 2). The relationship of IS to count of structures per area (C) was described by the equation $0.0071C^{1.65}$ and the relationship of IS to square footage of structures per area (F) was described by $35.16F^{1.33}$. Plots of residuals versus predictions did not indicate bias or need for additional terms.

Discussion

We consider these tax map derived development indices as the best source for standardized, readily updated, and accessible development indicators in Maryland. Either index, counts of structures per acre or square footage of structures per acre, had a strong relationship with "new" Towson IS estimates for 2000 and predictions of IS developed from these indices are well within the "play" experienced when using other data sources to estimate IS. In the future, tax map data will be used as the basis for estimating target and threshold levels of development.

STREAM ICHTHYOPLANKTON SAMPLING

Introduction

A survey to identify anadromous spawning habitat in Maryland was conducted from 1970 to 1986 (O'Dell et al. 1970; 1975; 1980; Mowrer and McGinty 2002) with subsequent development of statewide maps detailing spawning habitat. Recreating these surveys provides an opportunity to explore whether spawning habitat has declined in response to urbanization. During 2009, stream sites in Piscataway and Mattawoman creeks (Figure 3) were sampled for eggs and larvae of herring, white perch, and yellow perch (hereafter "anadromous species") by citizen volunteers coordinated by program biologists. These two creeks were also sampled by volunteers during 2008. Methods of O'Dell et al. (1975) were used and sites that historically supported at least one of the three anadromous species were sampled.

Methods

In 2008-2009 ichthyoplankton samples were collected from Mattawoman and Piscataway creeks during March-May by citizen volunteers. These volunteers were trained and their subsequent collection activities monitored by Project staff. Of the 17 Mattawoman Creek stations sampled by O'Dell et al. (1975) in 1971 six were positive for the presence of one or more anadromous species. Consequently these six stations, plus three additional sites (based on volunteer interest) were sampled in 2008-2009 (Figure 4; Table 4). Thirty stations were sampled in Piscataway, Broad, and Swan creeks, and Oxon Run) in 1971 (O'Dell et al. 1975). Twelve stations were positive for anadromous fish presence in 1971 and nine were resampled by volunteers in 2008-2009 (Figure 5; Table 4).

Ichthyoplankton samples were collected at each site using stream drift nets constructed of 360-micron mesh material, attached to a square frame with a 300 X 460 mm opening. The frame was connected to a wooden handle so that the net could be held stationary in the stream. A threaded collar was placed on the end of the net where a mason jar was connected to collect the sample. Nets were placed in the stream with the opening facing upstream for five minutes. The nets were then retrieved and rinsed in the stream by repeatedly dipping the lower part of the net and splashing water on the outside of the net to avoid sample contamination. The stream drift nets and techniques were the same as those used by O'Dell et al. (1975). The jar was then removed from the net and an identification label describing site, date, time and collectors was placed in the jar. The jar was sealed and placed in a cooler for transport. Water temperature (°C), conductivity (µmho/cm) and dissolved oxygen (mg/L) were recorded at each site using a hand held YSI model 85 meter. Meters were calibrated for DO each day prior to use. All data were recorded on standard field data forms and verified at the site by a volunteer and signed off by a project biologist.

After a team finished sampling for the day, the samples were preserved with 10% buffered formalin by the biologist coordinating the day's collections. Two ml of rose bengal was added in order to stain the organisms red to aid sorting.

Ichthyoplankton samples were sorted in the laboratory by project personnel. All samples were rinsed with water to remove formalin and placed into a white sorting pan. Samples were sorted systematically (from one end of the pan to another) under a 10x bench magnifier. All eggs and larvae were removed and identified under a microscope. Eggs and larvae were retained in small vials and fixed with formaldehyde for verification.

Presence of white perch, yellow perch and herring eggs or larvae at each station in 2008-2009 was compared to their presence in 1971 to determine which sites still supported spawning. O'Dell et al. (1975) summarized spawning activity as the presence of any egg, larva, or adult (from wire trap sampling) at a site and we used this criterion (spawning detected at a site or not) as well in 2008-2009. Raw data of O'Dell et al. (1975) were not available to formulate other indicators of spawning.

Four mainstem stations previously sampled by O'Dell et al. (1975) in 1971, were sampled by Hall et al. (1992) during 1989-1991 for water quality and ichthyoplankton. Comparisons of spawning activity of the four targeted species and water quality were made among the current study, Odell et al. (1975) and Hall et al. (1992) to detect changes. Hall et al. (1992) collected ichthyoplankton with 0.5 m diameter plankton nets (3:1 length to opening ratio and 363µ mesh set for 2 minutes) suspended in the stream channel between two posts instead of stream drift nets.

Changes in spawning sites were compared to land-use changes in both watersheds. Percent urban land use measured by the Maryland Department of Planning was available for 1973 MDP (2004a) and 2000 (MDP 2004b). Urban land consists of high and low density residential, commercial, and institutional acreages and is not a direct measure of IS.

Conductivity measurements collected for each date and stream site during 2008-2009 were plotted and mainstem measurements summarized for each year. Unnamed tributaries were excluded from calculation of summary statistics to capture conditions in the largest portion of habitat, but were included in plots. Conductivity distributions in both streams and years were compared to breakpoint conductivity (<171 µS / cm) needed for a "good" fish index of biotic integrity based on Morgan et al's (2007) analysis of Maryland Biological Stream Survey fish data. Comparisons were then made to conductivity ranges previously reported for Mattawoman Creek (Hall et al. 1992), and Mattawoman and Piscataway creeks (O'Dell 1975).

A water quality database maintained by DNR's Tidewater Ecosystem Assessment Division (S. Garrison, MD DNR, personal communication) provided historic conductivity measurements for Mattawoman Creek between 1970 and 1989. These historic measurements, along with those collected in 2008-2009, were used to examine changes in conductivity over time. Monitoring was irregular for many of the historic stations and Table 5 provides a summary of site location, month sampled, total measurements at a site, and what years were sampled. Historic stations and those sampled in 2008-2009 were assigned river kilometers (RKM) using a GIS ruler tool that measured a transect approximating the center of the creek from the mouth to each station location. Stations were categorized as tidal or non-tidal. Conductivity measurements from eight non-tidal and four tidal sites sampled during 1970-1989 were summarized as monthly medians. These sites bounded Mattawoman Creek from its mouth to the city of Waldorf (Route 301 crossing), the major urban influence on the watershed (Figure 6). Median monthly conductivities during the historic period at each site were regressed against distance from the mouth to examine the pattern present at that time and linear and quadratic regressions were developed to describe the relationship of distance and historic median monthly conductivity. Sites within 4.5 km of the mouth were not included in this analysis in order to eliminate large effects of Potomac River salinity intrusion during some years.

Historic monthly median conductivities at each site and their trend were plotted and 2008 and 2009 spawning season median conductivities from each non-tidal site were added to these plots. Continuous estuarine conductivity samples during March and April 2008-2009, were collected by a DNR continuous monitor located at Sweden Point Marina. (M. Trice, MD DNR, personal communication; site information available at http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm).These results were summarized as monthly means and added to the plot of historic and 2008-2009 median conductivities.

Results and Discussion

In general, little change in anadromous fish stream spawning in Mattawoman Creek was indicated between 1971 and 1989-1991. Presence of spawning at these sites was stable (Table 6). However, by 2008-2009 spawning site losses were evident for all three species groups. Herring spawning was reduced from six sites in Mattawoman Creek in 1971 to three during 2008 and two by 2009. White perch stream spawning was detected at 1-2 sites in 1971 and 1989-1991, one in 2008, and none during 2009. Yellow perch stream spawning was detected at the most downstream stream site until 2009 (Table 6).

Stream spawning of anadromous fish nearly ceased in Piscataway, Swan, and Broad creeks, and Oxon Run between 1971 and 2008-2009. Spawning was not detected at any site in the Piscataway Creek drainage during 2008 and herring spawning was only detected on one date and location (one herring larvae on April 28 at PC2) in 2009 (Table 7). Spawning was not detected during 2008 or 2009 in the Oxon Run, Broad Creek and Swan Creek tributaries except for a single instance of herring eggs collected from Oxon Run on May 4, 2009.

Mattawoman and Piscataway creeks are adjacent watersheds that represent a continuum of response along an urban gradient (Limburg and Schmidt 1990) emanating from Washington, DC. In 1973, two years after O’Dell et al. (1975) surveyed these watersheds, the estimated percent urban cover for the Piscataway watershed was 23.6% and 12.2% for the Mattawoman. By 2000, urban land use in the Piscataway Creeks’ watershed had increased to 39.9% (16.5% IS) and 25.9% (9.0% IS) in the Mattawoman Creek's watershed. Increases in urban land use between 1971 and 2008-2009 were subsequently followed by loss of over half of the herring stream spawning sites in Mattawoman Creek and the possibility that white and yellow perch no longer spawn in this system at all. Stream spawning of anadromous fish has largely ceased in Piscataway Creek, a watershed both smaller and closer to Washington, DC, than Mattawoman Creek. These changes in anadromous spawning patterns were similar to those described for Hudson River tributaries by Limburg and Schmidt (1990). Urbanization of the Hudson watershed became greater as the New York metropolitan area expanded and the smaller tributaries (< 40 km^2) became more susceptible to capture by urban sprawl. As a consequence, alewife herring and white perch egg and larval densities exhibited a strong negative threshold response to this urbanization (Limburg and Schmidt 1990). Development leads to altered hydrologic features (Konrad and Booth 2005) and altered water quality (Morgan et al. 2007) needed for anadromous fish spawning habitat.

Projected growth in the Mattawoman Creek watershed at build-out (all buildable land developed) will result in IS that is, at best, equal to that of Piscataway Creek at present (16.5% IS), and is likely to approximate 22% IS (USACOE 2003; Beall 2008). If the status of anadromous fish spawning in Piscataway Creek is an indicator, stream spawning will disappear from Mattawoman Creek at projected levels of development.

Prior to the late 1980's much of the development across the U.S. occurred with little or no stormwater management and current management is still hampered by incomplete understanding, and contradictory and/or ineffective approaches (NRC 2009).
Development proponents for the Mattawoman Creek watershed have stated that "newly created impervious surfaces [in Mattawoman Creek] will be subject to offsetting controls not used in the

past…" that would disconnect impervious surface effects from the watershed (i.e., new development will have little effect; Beall 2008). However, techniques for minimizing this impact on fish habitat or restoring biotic integrity in streams are poorly developed (Wheeler et al. 2005; Palmer 2009). A recent review of stormwater management in the U.S. (NRC 2009) recommended considering impervious cover as a proxy for stormwater pollutant loading and provides further indication that impervious surface is unlikely to be decoupled from stormwater effects.

Conductivity levels for 2008 and 2009 were elevated in Piscataway Creek when compared to Mattawoman Creek, with lower levels recorded in 2008 for both systems (Table 8). Summary statistics indicated highly variable distributions by system and year. Based on comparisons with the 171 µmho / cm critical value for the MBSS fish IBI (FIBI; Morgan et al. 2007), Piscataway Creek was often (>90% of measurements) in excess of this criterion during the 2008-2009 anadromous fish spawning seasons. Mattawoman creek did not display values higher than the FIBI threshold in 2008, but 63% of the measurements were in excess of the FIBI conductivity criterion in 2009 (Table 8). Although not directly related to egg and larval survival, it provides a benchmark for good or bad conditions for fish diversity in Maryland streams (Morgan et al. 2007).

Plots of conductivity by system, year, and site indicated lower measurements in unnamed tributaries that were generally more isolated from roads (Figures 7-10). Conductivity declined as the surveys progressed from March into May in both watersheds during both years. Patterns of decline were different for each year, but similar between the two within a year. During 2008, conductivities in mainstem stations (Mattwoman Creek range = 47-148 µmho / cm; Piscataway Creek range = 163-301 µmho / cm, including TCM1) were stable during March and remained stable until mid-April before falling to a lower level for the remainder of the surveys. During 2009 (Mattwoman Creek's range = 97-737 µmho / cm; Piscataway Creek's range = 115-610 µmho / cm), conductivity was highly elevated in early March in both creeks (≈ 390-620 µmho / cm) following a significant snowfall at the beginning of March before steadily declining through May.

Conductivities had increased in a manner consistent with urbanization in both watersheds, with Mattawoman Creek during 2008 exhibiting measurements closer to historic, presumably more rural, conditions than Piscataway Creek. Conductivities measured in Mattawoman Creek during 2008 fell near or within ranges reported in 1971(O'Dell 1975) and 1989-1991 (Hall et al. 1992) but were mostly in excess of these two studies in 2009. O'Dell (1975) reported conductivity ranges of 50-200 µmho / cm in Mattawoman Creek and 60-220 µmho / cm in samples drawn from Piscataway Creek. Minimum conductivities for Piscataway Creek in 2008-2009 were lower than the maximum of the May 1971 range reported by O'Dell (1975), but were 2-3 times higher than the 1971 minimum. Most mainstem stream conductivity measurements in Mattawoman Creek during 2008 fell slightly above the range reported for March-April 1991 by Hall et al. (1992; 61-114 µmho / cm), but measurements were often well above this range during 2009. Conductivities fell into the 1991 range by late April 2008 and were slightly during the same time frame for 2009 (Figures 7-10).

The trend in median conductivity with distance from the mouth of Mattawoman Creek during 1970-1989 (hereafter, "historic" measurements) was best described by a quadratic regression ($R^2 = 0.37$, $P < 0.001$; Figure 11). Median conductivities were elevated nearest the mouth of the creek (≈ 190 µmho / cm at RKM 5), fell steadily to approximately 80 µmho / cm between RKMs 18 and 27, and then increased to 120-160 µmho / cm in the vicinity of Waldorf.

Conductivity measurements were as variable at the upstream station nearest Waldorf (RKM 35) during 1970-1989 as they were near the mouth of the creek where salinity intrusion from the Potomac River was possible (Figure 11).

Conductivity measurements during 2008-2009 monitoring indicated that the impact of urbanization had spread throughout the non-tidal portion of Mattawoman Creek. Conductivities were elevated beyond predicted medians during both years (particularly in 2009) and increased with upstream distance from the confluence of the stream and estuary (Figure 11). Mean conductivities measured at the Sweden Point Marina (RKM 4.7) were similar to historic values, higher than non-tidal medians in 2008, and lower than non-tidal medians in 2009.

Under pristine conditions, rainfall and snowmelt should dilute streamwater and lower conductivity (State Water Resources Control Board 2004). However, elevated conductivity, related primarily to increased chloride concentrations, has emerged as an indicator of impervious surfaces and urbanization (Wenner et al. 2003; Kaushal 2005; Morgan et al. 2007). In many areas, chloride concentrations in urban streams have increased (Kaushal *et al.* 2005) and specific conductance is both a good indicator of chloride levels and watershed urbanization (Morgan et al. 2007). Most inorganic acids, bases, and salts are relatively good conductors, while organic compounds that do not dissociate in aqueous solution conduct current poorly (APHA 1979). Wenner et al. (2003) concluded that routinely measured conductivity was a good way to assess the impact of urban pollution in streams in the Georgia (USA) piedmont.

In addition to conductivity serving as an indicator of multiple effects on habitat related to urbanization leading to chronic and permanent degradation, two additional hypotheses can be proposed for temporary loss of spawning sites in Mattawoman Creek in 2009. These hypotheses are directly related to road salt use after a 140 mm (or 5.5 inches, approximately) snowfall during the first week of March that drastically elevated conductivity.

For the first hypothesis, eggs and larvae may have died in direct response to sudden changes in salinity and potentially toxic amounts of associated contaminants and additives. Use of salt as a deicer could lead to both “shock loads” of salt that may be acutely toxic to freshwater biota and elevated chloride baselines (increased average concentrations) that have been associated with decreased fish and benthic diversity (Kaushal 2005; Wheeler et al. 2005; Morgan et al. 2007). Rapid salinity increases can result in osmotic stress and lower survival since higher salinity represents osmotic cost for fish eggs and larvae (Research Council of Norway 2009). Commonly used anti-clumping agents (ferro- and ferricyanide) mixed in with the road salt are not thought to be directly toxic, but are of concern because they can break down into toxic cyanide under exposure to ultraviolet light. The degree of breakdown into cyanide in nature is unclear, but these compounds have been implicated in fish kills (Burdick and Lipschuetz 1950; Pablo et al. 1996; Transportation Research Board 2007).

A Transportation Review Board (1991) review of salt use policies 20 years ago indicated that Maryland had been applying some of the highest loads per mile in the US. However, the state has recently indicated that a possible change to a low molecular-weight carbohydrate product (Ice B’Gone; www.seaco.com) as a road de-icer is under consideration.

Concerning the second hypothesis, changing stream chemistry may have caused disorientation that disrupted upstream migration of anadromous fish. Elevated conductivity and a trend of increasing values with distance would be indicative of changes in the chemical composition of Mattawoman Creek, especially during 2009. These changes from prevailing historic conditions could prevent anadromous fish from recognizing and ascending spawning areas. Alewife and blueback herring are thought to home to natal rivers to spawn (ASMFC 2009; ASMFC 2009b), while yellow and white perch populations are generally tributary-specific (Setzler-Hamilton 1991; Yellow Perch Workgroup 2002). Physiological details of spawning migrations are not well described for these target species, but homing migration in anadromous American shad and salmon has been attributed to chemical composition, smell, and pH of natal streams (Royce-Malmgren and Watson 1987; Dittman and Quinn 1996; Carruth et al. 2002; Leggett 2004). Conductivity is related to total dissolved solids in water (Cole 1975) and it was markedly higher during the beginning of the 2009 spawning season than reported ranges in 1971 (O'Dell et al. 1975), 1989-1991 (Hall et al. 1992), and 2008 (Table 4) or historic medians estimated from monitoring data.

Continued stream monitoring in Mattawoman Creek may provide insight into whether spawning site loss between 2008 and 2009 was a chronic response to urbanization or an acute response to road salt. A chronic loss would be indicated by continued low site use or complete site loss, while reoccupation of sites would support an acute response.

Elevated conductivity baselines associated with urbanization were indicated by several phenomena. First, conductivities at mainstem sites were higher than those from unnamed tributaries that were more remote from road networks. Second, most Mattawoman Creek measurements during 2008-2009 did not fall within the conductivity range measured during the same period in 1991. Third, average conductivity during the sampling periods was greater in the more urbanized Piscataway Creek than Mattawoman Creek. Fourth, the conductivity gradient for non-tidal stream waters has changed from declining with distance from the confluence with the estuary during 1970-1989 to increasing with distance during 2008-2009. Finally, median conductivities during 2008-2009 were generally higher than those measured during 1970-1989.

Low site occupation could also have reflected low population sizes; however, species surveyed during 2008-2009 were not at similar relative stock levels. Stock assessments have identified that many populations of river herring (alewife and blueback herring) along the Atlantic coast including those in Maryland are in decline or are at depressed stable levels (ASMFC 2009; 2009b; Limburg and Waldman 2009; Jarzynski and Sadzinski 2009). However, white perch abundance has been at relatively high levels throughout the Maryland portion of the Chesapeake Bay (Piavis and Webb 2009), while yellow perch abundance has varied from moderate to high for systems where assessments were conducted (Piavis 2009).

Volunteer-based sampling of Piscataway and Mattawoman creeks in 2008-2009 used only stream drift nets, while O'Dell et al. (1975) and Hall et al. (1992) determined spawning activity with ichthyoplankton nets and adult wire traps. Tabular summaries of egg, larval, and adult catches in Hall et al. (1992) allowed for a comparison of how conclusions of site use in Mattawoman Creek might have varied in 1991 with and without adult wire trap sampling. Sites estimated when eggs or larvae were present in one or more samples were identical to those when adults present in wire traps were included with the ichthyoplankton data (Hall et al. 1992). Similar results were obtained from the Bush River during 2006 at sites where ichthyoplankton drift nets and wire traps were used; adults were captured by traps at one site and eggs/larvae at nine sites with ichthyoplankton nets (Uphoff et al. 2007). Wire traps set in the Bush River during 2007 did not indicate different results than ichthyoplankton sampling for herring and yellow perch, but white perch adults were observed in two trap samples and not in plankton drift nets (Uphoff et al. 2008). These comparisons of trap and ichthyoplankton sampling indicated it was unlikely that an absence of adult wire trap sampling would impact interpretation of 2008-2009 spawning sites.

Absence of detectable stream spawning does not necessarily indicate an absence of spawning in the estuarine portion of these systems. Estuarine yellow perch presence-absence results for Mattawoman and Piscataway creeks did not indicate that lack of detectable stream spawning of this species in 2009 corresponded to their elimination from these subestuaries. Although the proportion of standard estuarine plankton tows (see following section) was lower in Piscataway Creek than in Mattawoman Creek (Figure 13), yellow perch larvae were present in both. Yellow perch larvae were highly abundant in the upstream tidal regions of these two subestuaries and much less abundant downstream. This would indicate that spawning occurred primarily in the upper tidal creek reaches and that large numbers of larvae were not drifting or swimming in from the Potomac River. Similar results have been noted in the Bush River, where stream spawning of yellow perch has largely ceased while estuarine spawning activity was high (McGinty et al. 2009). Yellow perch do not appear to be dependent on non-tidal stream spawning, but their use may confer benefit to the population through expanded spawning habitat diversity. Stream spawning is also very important to yellow perch anglers since it provides access for shore fisherman and most recreational harvest probably occurs during spawning season (Yellow Perch Workgroup 2002). The effect of lost stream spawning on the other anadromous species may be different as both blueback and alewife herring ascend streams much further than yellow or white perch.

ESTUARINE YELLOW PERCH LARVAL PRESENCE-ABSENCE SAMPLING

Introduction

Yellow perch larval presence-absence sampling during 2009 was conducted in the upper tidal reaches of the Nanticoke, Bush, Magothy, and Severn rivers and Mattawoman, Nanjemoy, and Piscataway creeks during late March through April (Figure 12). Annual L_p (proportion of tows with yellow perch larvae during a standard time period and where larvae would be expected) provides an easily collected measure of the product of egg production and egg through early postlarval survival. Yellow perch larvae can be readily identified in the field because they are larger and more developed than *Morone* larvae that could be confused with them (Lippson and Moran 1974).

Methods

A conical plankton net towed from a boat to collect yellow perch larvae at 10 sites (7 in Piscataway Creek) per system on 2-3 days each week in the upper portion of the estuaries sampled (Figure 12). Nets were 0.5-m in diameter, 1.0-m long, and constructed of 0.5 mm mesh. The nets were towed for two minutes at approximately 2.8 km per hour. Larval sampling occurred during late March through late April to early May, 2009.

Sites in all rivers except the Nanticoke were sampled with little spacing between tows because larval nurseries areas or the systems themselves were small. Piscataway Creek was only large enough for 7 stations and up to 3 upstream sites could not be sampled at very low tides. Extent of the area to be sampled was determined from bounds of larval presence in surveys conducted during the 1970s and 1980s (O’Dell 1987).

The Nanticoke River was divided into 18, 1.61-km (1-mile) segments that spanned the striped bass spawning ground where historic surveys were conducted (Uphoff 1997; Uphoff et al. 2005). The striped bass spawning area on the mainstem Nanticoke River was divided into upriver, mid-river, and lower river subareas, each containing 5-6 segments and Marshyhope Creek, a tributary, which contained 2 additional segments (Uphoff 1997). Maps detailing segment locations can be found in Uphoff (1997). Ten distinct segments were sampled with a single tow once a trip. Sample trips were made two times per week. Sampling segments were selected randomly in proportion to subarea size. Nanticoke River sampling was piggybacked onto multispecies sampling conducted by the ISSA Project (Project 2, Job 1).

Each sample was emptied into a glass jar and checked for larvae. If a jar contained enough detritus to obscure examination, it was emptied into a pan with a dark background and observed through a magnifying lens. Detritus was moved with a probe or forceps to free larvae for observation. If detritus loads or wave action prevented thorough examination, samples were preserved and brought back to the lab for sorting.

The proportion of tows with yellow perch larvae (L_p) was determined annually for dates spanning the first catch through the last date that larvae were consistently present. Uphoff et al. (2005) reviewed presence-absence of yellow perch larvae in past Choptank and Nanticoke river collections and found that starting dates during the first or early in the second week of April were typical and end dates occurred during the last week of April through the first week of May. Sampling during 2009 began during the last week of March and ended after larvae were absent (or nearly so) for two consecutive sampling rounds. In years where larvae disappeared quickly, sampling rounds into the third week of April were included in analysis even if larvae were not collected. Confidence intervals (95%) were constructed using the normal distribution to approximate the binomial distribution (Ott 1977; Uphoff 1997).

Yellow perch larval presence-absence during 2009 was compared to a record of L_p developed from collections in the tidal Nanticoke (1965-1971 and 2004-2008) and Choptank rivers (1986-1990 and 1998-2003), Mattawoman Creek (1990 and 2008), Severn River (2004-2008), Bush River (2006-2008), Corsica River (2006-2007), Langford Creek (2007), South River (2008), and Piscataway Creek (2008).

Trained volunteers from the Arlington Echo Outdoor Education Center conducted Severn River collections and volunteers from Anita Leight Estuarine Research Center conducted Bush River collections based on the sampling design described above. These volunteers had been instructed by project biologists on collection techniques and larval identification.

Historic collections in the Choptank and Nanticoke rivers targeted striped bass eggs and larvae (Uphoff 1997), but yellow perch were also common (J. Uphoff, MD DNR, personal observation). Larval presence-absence was calculated from data sheets (reflecting lab sorting) through 1990. After 1998, L_p in the Choptank River was determined directly in the field and recorded on data sheets (P. Piavis, MD DNR, personal communication). All tows were made for two minutes. Standard 0.5 m diameter nets were used in the Nanticoke River during 1965-1971 (1.0 * 0.5 mm mesh) and after 1998 in the Choptank River (0.5 mm mesh). Trawls with 0.5 m nets (0.5 mm mesh) mounted in the cod-end were used in the Choptank River between 1986-1990 (Uphoff et al. 2005). Survey designs for the Choptank and Nanticoke rivers are described in Uphoff (1997).

Choptank River and Nanticoke River collections made prior to 1991 were considered an historic reference and their mean L_p (0.66) was used as an estimate of central tendency. Nine of

11 reference estimates of L_p fell between 0.4-0.8 and this was used as the range of the “typical” minimum and maximum. The 95% CI’s of L_p of rivers sampled during 2009 were compared to the mean and “typical” range of historic values. Risk of L_p during 2009 falling below a criterion indicating potential poor reproduction was estimated as one minus the cumulative proportion (expressed as a percentage) of the L_p distribution function equaling or exceeding the “typical” minimum (0.4). This general technique of judging relative status of L_p was patterned after a similar application for striped bass eggs (Uphoff 1997).

Associations of mean salinity, IS, and L_p were tested with correlation analysis. Mean salinity of dates and sites used to calculate L_p were estimated for each system sampled during 2009. Past data with salinity measurements were available for Choptank River collections from 1998, 2000, and 2001; Nanticoke River between 2006-2008; Severn River between 2004-2008; Bush and Corsica rivers between 2006-2008, Langford Creek for 2007, and South River, Mattawoman Creek, and Piscataway Creek in 2008

Linear regression was used to further test whether L_p between 1998-2009 was influenced by IS and salinity. High salinities have been implicated in contributing to low L_p (Uphoff et al. 2005; 2007). The association of mean salinity and IS can be significant and as strong or stronger than those of IS or salinity with L_p (see Results). Ricker (1975) warned against using well correlated variables in multiple regressions, so separate regressions of IS against L_p were developed for fresh-tidal (< 2‰) and brackish tributaries ($\geq$ 2‰) to minimize confounding salinity with IS. Data from additional systems were included in the linear regressions by classifying systems as fresh-tidal or brackish. The Choptank River (1998-2004: IS = 3.0%), Nanticoke River (2004-2009; IS = 2.0%), Severn River (2004-2009; IS = 19.5%), , Corsica River (2006-2007; IS = 4.1%), Langford Creek (2007; IS = 3.1%), South River (2008; IS = 10.9%), Nanjemoy Creek (2009; IS = 0.9%), and Magothy River (2009; IS = 20.2%) were classified as brackish systems. The Bush River (2006-2008; IS = 11.3%), Mattawoman Creek (2008-2009; IS = 9.0%), and Piscataway Creek (2008-2009; IS = 16.5%) were classified as fresh-tidal. Residuals were inspected for non-normality and need for additional terms.

Results and Discussion

Proportions of tows with larval yellow perch in brackish systems with high IS, Severn River (L_p = 0.15, SD = 0.05, N = 60; 19.5 % IS) and Magothy River (L_p = 0.17, SD = 0.08, N = 24; 20.2 % IS), during 2009 were significantly lower than the historic reference range of L_p (Figure 13) based on 95% confidence interval overlap. Confidence intervals of L_p in Piscataway Creek (L_p = 0.39, SD = 0.08, N = 33; 16.5% IS), and the Nanticoke River (L_p = 0.41, SD = 0.07, N = 46; 2.0 % IS) overlapped the lower bound of the historic reference range. Mattawoman Creek (L_p = 0.92, SD = 0.04, N = 60; 9.0% IS) fell above the historic reference upper limit, while Nanjemoy Creek (L_p = 0.83, SD = 0.05, N = 60; 0.9% IS) and Bush River (L_p = 0.86, SD = 0.08, N = 33; 11.3% IS) overlapped the upper reference level (Figure 13).

Risk of falling below the “typical” historic minimum of L_p = 0.4 during 2009 was near 100% in high IS brackish systems (Magothy and Severn rivers). Moderate risk was present in the high IS fresh-tidal Piscataway Creek and the low IS Nanticoke River (45% and 37%, respectively). Risk of being below the historic minimum was near zero in Mattawoman and Nanjemoy creeks and the Bush River

Brackish systems with small watersheds and high IS (South, Severn, and Magothy rivers) have exhibited a persistent depression in $L_{p,}$ below the reference minimum, while remaining systems have exhibited extensive variation (Figure 14). Interpretation of L_p in recent years has been based on comparisons with previous collections from rural systems (Choptank and

Nanticoke) located on the Eastern Shore. These reference rivers have larger watersheds and more extensive regions of fresh-tidal water than some brackish tributaries sampled. However, L_p estimates from tributaries other than the Nanticoke or Choptank rivers (and excluding high IS brackish systems) during 2006-2009 have fallen within or above the historic reference range and the range that the reference rivers exhibited after the1965-1990 reference period (Figure 14).

Mean salinity was negatively associated with L_p ($r = -0.45$, $P < 0.02$). The association of IS and L_p ($r = -0.36$, $P < 0.07$) was marginal. Correlation analysis indicated a significant association between IS and mean salinity as well ($r = 0.52$, $P < 0.006$).

Linear regressions of L_p against IS by salinity category were significant ($P < 0.05$). The relationship of L_p and IS in fresh-tidal tributaries was described by the equation:

$L_p = (-0.052 \bullet IS) + 1.31$ ($r^2 = 0.51$, $P = 0.048$, $N = 8$; Figure A-4);

where IS = impervious surface percentage. Standard errors for the IS and intercept were 0.021 and 0.26, respectively. In brackish systems, the relationship of L_p and IS was described by the equation:

$L_p = (-0.018 \bullet IS) + 0.55$ ($r^2 = 0.35$, $P = 0.002$, $N = 25$; Figure A-4).

Standard errors for the slope and intercept were 0.005 and 0.05, respectively.

Residuals of both regressions appeared normally distributed with a mean very near zero and inspection of plots of residuals against predicted L_p did not indicate a need for additional terms.

These regressions indicated IS was negatively related to L_p, but the relationships were different in fresh-tidal and brackish systems. On average, L_p would be higher in fresh-tidal systems until high levels of IS (≈ 20%) were reached (Figure 15). No estimates of L_p from fresh-tidal systems with low IS (5% or less) are available; however, predicted L_p approaches 1.0 at the lowest estimate of IS (9%). The fresh-tidal relationship suggests an asymptotic relationship with an IS threshold of approximately 10%; L_p would remain high and steady (on average) below the threshold (since L_p cannot be higher than 1) and then decline rapidly beyond it. The dichotomous nature of the distribution of IS in brackish systems (a large, variable cluster of points at < 5% IS, a tightly grouped cluster of low values at 20% IS, and one low point at 11% IS) makes detection of a threshold difficult (Figure 15). Both relationships converge just beyond 20% IS at low L_p (< 0.2) when the fresh-tidal relationship was projected. This convergence may represent the lowest level of L_p likely to be observed for systems where yellow perch have not been extirpated.

The frequency distribution of L_p values since 1965 in areas other than high IS brackish systems (Severn, South, and Magothy rivers) exhibits a bimodal distribution (Figure 16). Values of L_p range from 0.19 to 1.0 and modes of L_p appear at 0.5 and 0.9, with a nadir at 0.7 (Figure 16). Qualitatively, L_p is either good or bad. Low L_p such as that consistently exhibited in the Severn, South, and Magothy rivers is rare in the other systems studied and occurs less than 10% of the time. Modes were not composed exclusively of fresh-tidal or brackish systems. Assuming catchability does not change greatly from year to year, egg production and egg through larval survival would need to be high to produce strong L_p, but only one needs to be low to result in low L_p.

L_p is not a measure of year-class success. Significant processes may exist that limit year-class success after larvae become too large to be sampled effectively by plankton nets. If survival of each life stage is independent of the other, a log-normal distribution of L_p might be expected (Hilborn and Walters 1992), i.e., high estimates of L_p would be uncommon and would represent the upper tail of the distribution. The bimodal frequency distribution of L_p suggests a lack of independence of processes influencing L_p. Year-class success of yellow perch has been reliably measured in the Head-of-Bay region by the Maryland Juvenile Striped Bass Survey (Yellow Perch Workgroup 2002; Durell and Weedon 2010) and the frequency distribution of these indices (1966-2009) can be described by a log-normal distribution (J. Uphoff, unpublished analysis). Given the caveat that the Head-of-Bay and the regions where L_p has been estimated are different, the log-normal frequency distribution of Head-of-Bay YOY and bimodal L_p distribution indicate that additional independent and important periods of larval survival occur at larval stages beyond those sampled effectively by 0.5 m nets used to estimate L_p.

SUMMER ESTUARINE SEINING AND TRAWLING

Methods

Impervious surface (IS) was estimated from Towson University interpretation of Landsat, 30-meter pixel resolution satellite imagery (Eastern Shore of Chesapeake Bay in 1999 and western shore in 2001) for each watershed (Barnes et al. 2002; See Indicators of Land-Use section). General land-use for all watersheds (i.e., percent urban, forest, etc.; all non-water acreages) was based on MDP data (http://www.dnr.state.md.us/watersheds/surf/)). Urban land-use consisted of low through high-density residential and industrial designations. Water surface area, in acres, was estimated with the planimeter function on MDMerlin satellite photographs and maps (www.mdmerlin.net). Shorelines were traced five times for each water body and an average acreage was calculated. The lower limit of each water body was arbitrarily determined by drawing a straight line between the lowest downriver points on opposite shores.

Ten watersheds were sampled in 2009, three in the upper Bay, three in mid-Bay and four in the Potomac drainage (Figure 17; Table 9). Tidal-fresh tributaries (median salinity < 2‰;

Table 9) sampled in 2009 included Mattawoman Creek, Piscataway Creek, Bush River, Gunpowder River and Northeast River (Figure 17). IS was estimated to cover approximately 1-16.5% of these watersheds. Nanjemoy Creek (0.9% IS) and Middle River (39% IS) were originally selected as fresh-tidal tributaries, but 2009 was abnormally dry through approximately mid-year (http://www.drought.gov/portal/server.pt/community/drought.gov/202/area_drought_information?mode=2&state=MD) and salinities were elevated. The Corsica River (4.1% IS), Tred Avon River (5.6% IS), and Wicomcio River (4.3%) were considered brackish (> 5‰) tributaries.

Four evenly spaced haul seine and bottom trawl sample sites were located in the upper two-thirds of each tributary (Figures 18-27). Sites were not located near the tributary mouth to reduce influence of the mainstem Bay or Potomac River waters on water quality measurements.

Bi-weekly sampling occurred from July through September with each site being sampled once per visit. All sites on one river were sampled on the same day. Sites were numbered from upstream (site 1) to downstream. The crew leader flipped a coin each day to determine whether to start upstream or downstream. This coin-flip somewhat randomized potential effects of location and time of day on catches and dissolved oxygen concentrations. However, sites located in the middle would likely not be influenced by the random start location as much as sites on the extremes because of the bus-route nature of the sampling design. If certain sites needed to be sampled on a given tide then the crew leader deviated from the sample route to accommodate this need. Trawl sites were generally in the channel, adjacent to seine sites. At some sites, seine hauls could not be made because of permanent obstructions, thick SAV beds, or lack of beaches. The latitude and longitude of the trawl sites was taken in the middle of the trawl area, while seine latitude and longitude were taken at the exact seining location.

Water quality parameters were recorded at all sites. Temperature (ºC), DO (mg/L), conductivity (μmho), salinity (‰) and pH were recorded for the surface, middle and bottom of the water column at the trawl sites and at the surface of the seine site. While a suite of water quality parameters were measured, DO was considered the estuarine habitat indicator for IS effects. Mid-depth measurements were omitted at shallow sites with less than 1.0 m difference between surface and bottom. Secchi depth was measured to the nearest 0.1 m at each trawl site. Weather, tide state (flood, ebb, high or low slack), date and start time were recorded for all sites.

Trawls and seines were used to sample fish. Target species were striped bass, yellow perch, white perch, alewife, blueback herring, American shad, spot, Atlantic croaker, and Atlantic menhaden. Gear specifications and techniques were selected to be compatible with other Fisheries Service surveys.

A 4.9 m semi-balloon otter trawl was used to sample fish in the mid-channel bottom habitat. The trawl was constructed of treated nylon mesh netting measuring 38.1 mm stretch in the body and 33 mm stretch mesh in the codend, with an untreated 12 mm stretch knotless mesh liner. The headrope was equipped with floats and the footrope was equipped with a 3.2 mm chain. The net was 0.61 m long by 0.30 m high with the trawl doors attached to a 6.1 m bridle leading to a 24.4 m towrope. Trawling was in the same direction as the tide. The trawl was set up tide to pass the site halfway through the tow thus allowing the same general area to be sampled regardless of tide direction. A single tow was made for six minutes at 3.2 km/hr (2.0 miles/hr) per site on each visit. Upon completion, the contents of the trawl were emptied into a tub for processing.

An untreated 30.5 m • 1.2 m bagless knotted 6.4 mm stretch mesh beach seine, the standard gear for Chesapeake Bay inshore fish surveys (Durell and Weedon 2010), was used to sample inshore habitat. The float-line was rigged with 38.1 mm • 66 mm floats spaced at 0.61 m (24 inch) intervals and the lead-line rigged with 57 gm (2 ounce) lead weights spaced evenly at 0.55 m (18 inch) intervals. One end of the seine was held on shore, while the other was stretched perpendicular to shore as far as depth permitted and then pulled with the tide in a quarter-arc. The open end of the net was moved towards shore once the net was stretched to its maximum. When both ends of the net were on shore, the net was retrieved by hand in a diminishing arc until the net was entirely pursed. The section of the net containing the fish was then placed in a washtub for processing. The distance the net was stretched from shore, maximum depth of the seine haul, primary and secondary bottom type, and percent of seine area containing aquatic vegetation were recorded.

All fish captured were identified to species and counted. Striped bass and yellow perch were separated into juveniles and adults. White perch were separated into three categories (juvenile, small, and harvestable size) based on size. The small white perch category consisted of age 1+ white perch smaller than 200 mm. White perch greater than or equal to 200 mm were considered to be of harvestable size and all captured were measured to the nearest millimeter.

Water quality data were compared to fish habitat criteria (Table 10) and reported as deviations from a target or limit (McGinty et al. 2006). Dissolved oxygen and temperature measurements were examined by watershed to determine habitat suitability for the target species. Percent of measurements that did not meet these requirements (violations) were calculated by river.

Presence-absence of targeted finfish species and life stages was used to examine changes in populations of various species, because it was robust to errors and biases in sampling, and reduced statistical concerns regarding contagious distributions and high frequency of zeros;

(Green 1979; Mangel and Smith 1990; Uphoff 1997). Presence-absence was calculated as the proportion of samples containing a target species and life stage for species separated into juveniles and adults. Confidence intervals (95%) were estimated by using the normal distribution to approximate the binomial probability distribution (Ott 1977). This approximation can be used when the sample size is greater than or equal to 5 divided by the smaller of the proportion of positive or zero tows (Ott 1977). Interpreting absence can pose interpretation problems (Green 1979) and sampling and analyses were generally designed to confine presence-absence to areas and times where species and life stages in question had been documented.

Relative abundance of all finfish combined was summarized as catch per unit effort (CPUE). General summaries of total catches were based on an arithmetic mean, but means of $\log_{10}$-transformed catches were used in some analyses. Typically, natural logarithms are used on ecological data to induce normality and reduce variability (Green 1979). The $\log_{10}$ transformation can be similarly applied and is easier to convert into a numeric scale on inspection (i.e, $2 = 10^2$ or 100; $3 = 10^3$ or 1,000). Species diversity was summarized as number of species captured (richness; Kwak and Peterson 2007). General comparisons among watersheds sampled during 2009 and exploratory analyses of hypotheses have been conducted that examined the role of development on the target species and fish communities for several established time-series. Details of these analyses are described in the sections that follow.

Results and Discussion

2009 Water Quality

Water quality data were examined to determine if habitat requirements were met for target species (Table 11). The Bush and Northeast rivers were the only rivers where temperature exceeded the criteria of 31°C (1.2%, Table 11). Among the tidal-fresh rivers three systems (Northeast River, and Mattawoman and Piscataway creeks) did not have DO violations (below the 5.0 mg/L living resources criterion; USEPA 2003; McGinty et al. 2009) for all habitats and depths. The Bush, Gunpowder and Northeast rivers had a very low percentage of DO violations with none greater than 5.6% (Table 11). In contrast, all brackish (mesohaline) tributaries had violations of the 5.0 m/L criteria, and all but Tred Avon River had violations of 3.0 mg/L. Nanjemoy Creek, the least developed brackish system surveyed, had the lowest level of DO violations (5.6%). The Corsica River had the greatest percentage of violations for both the 5.0 and 3.0 mg/L criteria. The Wicomico River had the second highest violation for both criteria (60.0% - 5.0 mg/L, 30.0% - 3.0 mg/L) (Table 11). Middle River, the most heavily developed sub-estuary, had frequencies of DO violations that were similar to less developed Tred Avon River and far less than Wicomico and Corsica rivers (Table 11).

Generally, tidal fresh subestuaries experienced few DO criteria violations than mesohaline subestuaries. Uphoff et al. (2009) reported frequent violations of DO criteria in mesohaline habitats associated with suburban landscapes. Salinity is a major source of differences in water density that impedes mixing and promotes stratification which influences oxygen depletion (Reid and Wood 1976; Eby and Crowder 2002; Kemp et al. 2005). Stratification of these mesohaline habitats has the potential to reduce flushing rates and contribute to lower oxygen concentrations because the exchange between oxygen poor and oxygen rich water is limited (Kemp et al, 2005). In tidal-fresh habitats, there is limited stratification (temperature related density differences) of the water column, so mixing is more likely. This does not mean these regions are immune to impacts of urbanization, and other habitat stress indicators associated with development in fresh-tidal systems need to be developed.

2009 Fish Sampling

A total of 90,075 fish (trawl and seine) were captured representing 55 species in 2009. Of these species, 8 comprised 90% of the catch. These species, in descending order, included white perch, bay anchovy, gizzard shad, blueback herring, Atlantic menhaden, spottail shiner, Atlantic silverside, and pumpkinseed. Only three of these species, white perch, Atlantic menhaden, and blueback herring were target species.

Seining was conducted in all systems except Mattawoman and Piscataway creeks because of thick SAV beds. Seining in Middle River ceased after the first month of sampling because SAV had extensively populated the sampling areas. Seining at station 4 in the Gunpowder River was also discontinued after the first round of sampling for the same reason. A total of 32,377 fish representing 47 species were captured in the seine. Nine species comprised 90% of the catch. They were, in descending order, white perch, gizzard shad, blueback herring, Atlantic menhaden, Atlantic silverside, spottail shiner, pumpkinseed and striped killifish. The greatest number of species in the seine was observed in the Gunpowder River, while CPUE was greatest in the Bush River (Table 12).

Trawl sampling was conducted in all systems (Table 13). A total of 57,698 fish were captured, representing 46 species. Three species comprised 90% of the total trawl catch; white perch, bay anchovy, and pumpkinseed. The number of species was highest in the Gunpowder River while CPUE was greatest in Nanjemoy Creek (Table 13).

Proportion of positive tows was calculated by river for all target species in trawls and seines (Table 14). White perch were the most prevalent species captured in both gears in all watersheds. The only exception was in Mattawoman Creek where juvenile striped bass were present more frequently than white perch juveniles or adults.

White perch percent presence (Wp or proportion of trawls with white perch present) in 2009, examined by river for trawls only, was high in seven systems and low in three (Table 15). The systems with high Wp had a mix of IS estimates, ranging from 0.9-39.1%, and were fresh-tidal to brackish. The low Wp systems had low to near threshold IS, 4.3-9.0% and consisted of two brackish and one fresh-tidal subestuary. Low Wp in the brackish Wicomico and Tred Avon rivers reflected low abundance of juveniles, while both adults and juveniles were poorly represented in fresh-tidal Mattawoman Creek. Low juvenile Wp in Wicomico and Tred Avon rivers would not be unusual because of their high salinities and low to modest year-class success in their main spawning rivers in 2009 (Durrell and Weedon 2010; Uphoff et al. 2009). Changes in Wp for both juveniles and adults in Mattawoman Creek (2009 Wp = 0.33 and 0.46 for juveniles and adults, respectively) represent a major change from past distributions (Wp = 0.88-1.0 during 2003-2007 for juveniles and adults). Tributaries upstream (Piscataway Creek) and downstream (Nanjemoy Creek) of Mattawoman Creek did not exhibit low Wp (Table 14).

EXAMINATION OF LONG-TERM DATA

Mattawoman Creek

Mattawoman Creek has been sampled continuously since 1989 (Carmichael et al. 1992). Until 2003, sampling was conducted monthly during July-September. Seining and trawling was conducted at five stations spaced evenly along the subestuary. Water quality measurements were taken at surface, mid-water and bottom depths in the trawl area using a Hydrolab (Carmichael et al. 1992). Trawl specifications changed in 2003. Those used during 1989-2002 were smaller (10 foot headrope and smaller mesh; Carmichael et al. 1992) than the 16 foot headrope trawl employed since 2003. The 10 foot trawl was towed for five minutes and the 16 foot trawl was towed for six minutes in the channel with the tide. Both gears were used in 2009 in Mattawoman Creek with the tow durations described above to analyze how this gear change may have affected habitat evaluation. Unfortunately, most of the 2009 small trawl samples did not catch any fish and species specific adjustments were not possible. However, comparisons of the small trawl catch of all species of fish and species richness in 2009 could be made with historic (1989-2002) samples. The last seven years of data from the large trawl were also evaluated.

A decline in number of species collected was noted with both gear types (Figure 28). Mean number of species collected in the small trawl during 1989-2002 was 28.7. In 2009, only 11 species were observed in the small trawl even though bimonthly sampling nearly doubled the effort employed annually during 1989-2002. Species richness estimates are positively influenced by sample size (Kwak and Anderson 2007). Thirteen species were identified in the large trawl in 2009 - seven less than 2008 (Figure 28). Sampling effort was biweekly for this entire time-series.

Mean number of species captured in small trawls was calculated by station for the historic period (1989-2002) and compared to richness in the small trawl by station for 2009 (Table 16). Species richness declined at all stations: Station 1 by half; Station 2 by one species; no catch at Station 3 (from a mean of 8.5 species); and Station 4 declined by nearly one third (Table 16).

Changes in richness in the small trawls were also examined by month (Table 16). Little change in richness was indicated in July, 2009. August had the most drastic decline in richness, going from an average of 10.5 species during 1989-2002 to 1 in 2009. Richness recovered somewhat by September, 2009 (Table 16)

Mean log_{10}-transformed catch of all species + 1 (log_{10} N) declined for both trawls (Figure 28). Examination of log_{10} N at each station indicated that declines began upstream and progressed downstream over time (Figure 29). Small trawl log_{10} N at Stations 1 and 2 had begun to decline in the early 2000s and 2002 was not visually different than 2009. Station 3 small trawl log_{10} N did not noticeably decline until 2002, but the decline between 2002 and 2009 was more pronounced. Station 4, nearest the junction with the Potomac River, underwent the least decline. Large trawl log_{10} N (2003-2009) had declined considerably at Stations 1-3 and may have declined to a lesser extent at Station 4 (Figure 29).

Potomac River seining data (Durrell and Weedon 2010) were examined to determine if these declining trends were unique to Mattawoman Creek or were more widespread. Species richness, abundance, and presence of dominant species over the last 20 years at four seining sites (representing nearshore habitat) on the upper Potomac River (below and above Mattawoman Creek) were examined (Figure 30). These nearshore fish community samples were then compared to Mattawoman trawl data from channel habitat. We assumed that nearshore community changes could occur if changes observed in Mattawoman Creek were occurring on a larger scale (ie. Potomac River). Species richness fluctuated in the seining data over time at each station (Figure 31). However, the Indianhead station (just outside of Mattawoman Creek) did decline from 14 species in 2007 to 10 species in 2008 and 2009. This represents two species less than the lowest count (1990; Figure 31), but is difficult to judge whether this decline was different from natural variation. Like species richness, log_{10} N fluctuated but did not change significantly at any of the four stations sampled (figure 31). None of the seven species comprising 90% of the catch changed in terms of presence-absence when all stations were examined collectively (Figure 32). These seining data did not support the hypothesis of a more widespread decline in community richness or abundance in the upper tidal Potomac River. Therefore, declines observed in Mattawoman Creek over the twenty year record were unique to Mattawoman Creek.

Number of species (S) collected annually and $\log_{10}$ N were used as dependent variables to investigate their relationship with development in the Mattawoman Creek watershed during 1989-2009. These dependent variables were chosen because they were basic, easily understood, and robust indicators of fish diversity and abundance (Kwak and Peterson 2007). Log_{10} N was not impacted by large amounts of zero catches as most single species indicators were.

Plots of the S and $\log_{10}$ N time-series indicated that both were stable (with some variation) into the early to mid-2000s (Figure 28). A large drop in $\log_{10}$ N in the 10 ft trawl occurred in 2002 and $\log_{10}$ N was even lower by 2009 when the gear was used along with the 16 ft trawl. A change to a 16 ft trawl in 2003 was made and the time-series plot suggested that S and $\log_{10}$ N had increased with the gear change, but both declined substantially by 2009. Surveys during 1989-2002 using the 10 ft trawl were conducted monthly, while surveys using a 16 ft trawl occurred twice a month as did the concurrent 10ft trawl survey in 2009. Number of species collected, particularly the collection of uncommon species, was very likely affected by sample size and size of gear employed (Kwak and Peterson 2007). Size of gear would affect $\log_{10}$ N, but the number of samples would likely affect estimation of variability much more than average total catch. In general, changes in S and $\log_{10}$ N suggested a negative threshold was crossed in 2002.

Linear regressions with indicator variables and slope shift coefficients (Freund and Littel 2000) were used to analyze S and $\log_{10}$ N for threshold responses to counts of structures built in the watershed (C). Structure counts were not available for 2009 and 1989-2008 data were analyzed (Table 17). Number of structures was considered an index of IS (see *Indicators of Land Use* section). Both gear (G) and years where a threshold (Y) was crossed or not crossed were coded as binary variables. Years where a 10 ft trawl was used were coded as 0 (1989-2002) and years where a 16 ft trawl was used (2003-2008) were coded as 1. Based on the beginning of a decline in $\log_{10}$ N (Figure 28), 2002 was designated as the year threshold effects began; years during 1989-2001 were coded 0 and years during 2002-2008 were coded as 1. A slope shift coefficient was estimated to detect the threshold effect of C on S and $\log_{10}$ N. The slope shift coefficient was estimated by including a variable equal to the product of C multiplied by Y (Freund and Littel 2000; Table 17). The equation for the multiple regression was

$$S \text{ or } \log_{10} N = a \bullet H + b \bullet G + c \bullet Y + d \bullet (C \bullet Y) + I;$$

where a, b, c, and d are coefficients and I is the intercept. If the slope shift coefficient (d) was significantly different ($P < 0.05$) from zero, the analysis would be considered complete (Freund and Littel 2000). The coefficient for the lower order terms (single terms with no interaction) would not be evaluated in the presence of higher order terms (Freund and Littel 2000). Residuals were examined for normality and trends with time or predicted S and $\log_{10}$ N.

Regressions for S ($R^2 = 0.78$) or $\log_{10}$ N ($R^2 = 0.72$) were highly significant ($P < 0.0005$; Tables 18 and 19). Importantly, the time by structure terms, d•(C•Y), which tested for change in slopes following the crossing of a development threshold in 2002, were significant for both S ($P = 0.05$; Table 18) and $\log_{10}$ N ($P = 0.001$; Table 19). Trends in residuals with time or with predicted S or $\log_{10}$ N were not indicated. Residuals of the $\log_{10}$ N regression appeared normally distributed. Residuals of the S regression were somewhat positively skewed with a positive secondary mode and it was difficult to judge whether these residuals were normally distributed or not.

While structure counts steadily increased from 10,943 to 21,290 between 1989-2008, both models described little or no effect of development until a threshold of approximately 18,000 structures was reached (Figure 33). Development beyond this threshold was followed by declines of S and $\log_{10}$ N (Figure 33).

We have some concern that these regression models of structures versus S or $\log_{10}$ N may have been overfitted (too many terms for the amount of observations; Babyak 2004). Overfitted models will fail to replicate in future samples. As a rule of thumb, a minimum of 10-15 observations per predictor will generally allow for good estimates from multiple regression models (Babyak 2004). The models utilized had 20 observations and 4 variables, or five observations per variable. Gear changes required an additional variable and, unfortunately, the gear change is nearly concurrent with the threshold year which may result in confounding the estimates. These problems do not preclude usefulness of these regressions, but this note of caution is necessary (Babyak 2004). Adjusted R^2's provide some indication of how overoptimistic the estimated relationships may be by accounting for the number of variables in calculating model fit (Freund and Littel 2000; Babyak 2004). Adjusted R^2's were 0.72 and 0.65 for S and $\log_{10}$ N, respectively, indicating fit would be nearly as good. The addition of 2009 structure data for future analysis may aid interpretation of whether overfitting is a problem since it will allow for inclusion of a year where both type of trawls were used. Collecting more data is a strategy for overcoming overfitting (Babyak 2004) and sampling with both trawls in this system will take place next year.

In the *Indicators of Land Use* section, an equation was developed to convert structures per acre to an estimate of "new" Towson IS which was subsequently applied to estimated IS associated with the threshold response in the Mattawoman Creek watershed. The equation describing the relationship of IS to structure count per area (C), $IS = 0.0071C^{1.65}$, can be solved for IS. The level of IS corresponding to the 2002 structures per acre threshold, (18,456 structures / 56771.5 acres or 0.324) was predicted by this equation to be 10.2% IS. This estimate is close to the 10% threshold level of IS developed from brackish subestuaries (Uphoff et al. 2009). Impervious surface was estimated from the equation above to occupy 11.1% of the Mattawoman Creek watershed in 2008.

Mattawoman Creek water quality data collected during fish sampling were also examined. Annual distribution of DO was examined to determine if oxygen dynamics changed over the twenty-year record (Figure 34). Prior to 2006, there was just one DO measurement (in 2001) violating the 5.0 mg/L criterion. In 2006, 16.7% of DO measurements were less than the 5.0 mg/L criterion and 4.2% were less than the 3.0 mg/L criteria. This was the only year the 3.0 mg/L criterion was violated. In 2007, 5.0 mg/L was violated 16.7% of the time and 4.5% of the time in 2008. There were no violations of these criteria in 2009. By and large, DO levels recorded in the daytime monitoring of channel conditions have been acceptable and do not indicate extensive depletion observed in brackish western shore tributaries such as the South and Severn rivers (Uphoff et al. 2005; 2009). However, these changes could indicate significant shifts in ecological processes that are concurrent with changes in the finfish community.

To further evaluate habitat conditions in Mattawoman Creek, 2009 continuous monitoring data from DNR's Resource Assessment Service monitoring station at the Sweden Point Marina was examined (http://mddnr.chesapeakebay.net/newmontech/contmon/eotb_results_graphs.cfm?station=mattawoman). This site was located near-shore in a dense SAV bed and continuous DO measurements from this site indicated frequent violations of the 5.0 mg/L criteria (Table 20). The most frequent violations were observed during August where the 5.0 mg/L criterion was violated 42% of the time (Table 18). Violations of the 3.0 mg/L criterion also increased over time with the greatest percentage of violations occurring in August of 2009 (Table 20). Declining DO at this continuous monitoring site may also be attributable to dense SAV beds in the area. The invasive, *Hydrilla verticillata*, appears to be the dominant species in Mattawoman Creek (McGinty, personal observation). Miranda et al. (2000) observed localized hypoxia in dense SAV beds in a reservoir. Caraco and Cole (2002) reported that beds of nonnative SAV (water chestnut *Trapa natans*) in the Hudson River were more likely to contribute to localized hypoxia than beds dominated by native species. Given these results, it is possible that the dense vegetation in Mattawoman Creek contributes to localized hypoxia. Despite documenting localized hypoxic conditions in SAV beds, Miranda et al. (2000) did not observe declines in fish densities, suggesting that these hypoxic microhabitats may exist without having a significant impact on fish densities.

Tidal-fresh systems have been more resilient in terms of DO responses to IS than brackish systems described by Uphoff et al. (2009). Lack of salinity-driven stratification, coupled with phosphorus (P) reductions may explain the different DO dynamics in tidal-fresh systems (Kemp et al. 2005). Limitation of P in the Potomac River point sources was followed by decreased algal biomass, reduced organic loading, higher DO, increased water clarity and recolonization of shoals with submerged aquatic vegetation (SAV; Kemp et al. 2005). Recent DNR water quality monitoring of the mid-Potomac River region indicates phosphorus and chlorophyll a concentrations are “good”, with concentrations of phosphorus and chlorophyll a declining between 1995 and 2006 (http://www.dnr.state.md.us/bay/tribstrat/mid_pot/mp_status_trends.html).

DNR water quality monitoring stations in Mattawoman Creek indicate similar changes in P, DO, water clarity, and SAV as described for the tidal-fresh mainstem Potomac River. In Mattawoman Creek, chlorophyll a has been steady and in the “good” range at the upper station and “fair” and declining at the lower station. Total P was “good” at both stations and declining (http://www.dnr.state.md.us/bay/tribstrat/low_pot/lp_statu_trends.html). These declines in phosphorus with attendant declines in chlorophyll a are likely contributing to improved water clarity and increased SAV growth in Mattawoman Creek. SAV coverage in Mattawoman Creek increased from 96 acres in 1989 to approximately 800 acres during 2005-2008 (http://web.vims.edu/bio/sav/SegmentAreaChart.htm). These SAV affect biogeochemical processes by enhancing deposition of suspended particles, thereby increasing water clarity, benthic photosynthesis, and nutrient assimilation (Kemp et al. 2005).

Nonlinear ecological feedback may yield poorer conditions than those expected at low levels of P (Kemp et al. 2005) and recent increases in DO violations may indicate Mattawoman Creek has undergone a negative change even though P trends have been favorable. Over the past two decades, the number of structures built in the watershed nearly doubled and attendant infrastructure (roads, sewers, schools, shopping centers, etc) would have increased concurrently. Multiple stressors besides nutrients (detrimental flow conditions, sediment, contaminants, invasive species, and elevated water temperature) are associated with development and IS (NRC 2009). Fish community richness and abundance has drastically declined recently and recent DO trends may be an additional signal of a negative habitat shift. Changes in the fish community may not be linked directly to changes in DO and these data may be symptoms of factors not captured directly by these indicators. Though it is not conclusive that increased urbanization has caused these declines, there is considerable literature that implicates development as a factor degrading Mattawoman Creek's estuarine fish habitat (Beach 2002; Capiella and Brown, 2001; Holland et al. 2004; Uphoff et al. 2005; Uphoff et al. 2009).

An alternate hypothesis of more widespread changes was not supported by other Potomac River monitoring (MD DNR seine survey and water quality monitoring) nor do comparisons with other systems sampled in 2009 support this hypothesis. Mattawoman Creek's species richness and CPUE rank last in comparison with other watersheds monitored in 2009.

Mattawoman Creek was characterized in the early 1990s as "near to the ideal conditions as can be found in the northern Chesapeake Bay, perhaps unattainable in the other systems, and should be protected from overdevelopment." (Carmichael et al. 1992). Mattawoman Creek watershed sits within a large portion of the growth district of Charles County (Charles County Government, 2006) and, as development increased beyond this watershed's threshold, substantial declines in the fish community followed. By 2009, the creek has become seriously degraded as fish habitat. Planned levels of development in Mattawoman Creek's Watershed to 22% IS should be reconsidered in light of the extent of declines detected in the fish community at current IS (11%). Without effective mitigation and restoration, further increases in impervious surface will result in irreversible ecological changes.

Corsica River

The Corsica River watershed was selected as a targeted watershed by MDDNR in 2005 to demonstrate the effectiveness of restoration practices (Rettig and Rochez 2009). This watershed is predominately in agriculture and much of the restoration focus has centered on reducing nutrient loads. Extensive monitoring is being conducted to track changes in both habitat and biota. The tidal fish community has been monitored since 2003 as part of this project.

Evaluation of water quality data show that the river has had violations of the 3.0 mg/L and 5.0 mg/L criteria each year since 2003 (Figure 35). Though the percentage of violations changed from year to year, they appear to have varied without trend. The temperature criterion of 31°C was exceeded in two years (2005 and 2006; Figure 36).

Species richness in the Corsica River remained fairly steady and rose slightly in the seine samples collected in 2009 (Figure 37). CPUE initially declined in the trawl samples and then recovered, while those for the seine showed a slight decline the first three years but stabilized thereafter (Table 21).

At this point, there is no indication that the Corsica River is either exhibiting improvements or declines in habitat quality based on water quality and fish assemblages. At present, the community appears to reflect what is expected of a low IS (4.1%) mesohaline habitat in the Chesapeake Bay. McGinty et al (2009) compared Corsica River to Langford Creek (IS = 3.1%), a similar sized watershed across the Chester River from the Corsica and found that the fish communities were similar in richness and abundance.

Wicomico River

The Wicomico River, a tributary to the Potomac River, was monitored annually from 1989 to 2003. It was considered a reference tributary for other mesohaline tributaries because of its rural watershed (Carmichael et al. 1992). The Wicomico was revisited in 2008 and 2009 by the ISSA Alosine Investigation (Project 2, Job 1), and the data were evaluated to determine the status of the habitat and fish community. The Wicomico watershed boundaries lie within two Maryland counties; Charles and St Mary's. According to the U.S. Census Bureau (2009), both counties experienced significant growth between 2000 and 2008. Charles County population grew by 16.8% and St. Mary's County by 17.8%. Since the mean travel time to work is between 30 and 40 minutes, this growth is probably spill over from Washington, DC. Growth projections provided by the Maryland State Archives suggest both counties will continue to grow, with population increasing by another 25.9% in Charles County and 28.1% in St. Mary's County by 2020 While growth will be directed within approved growth districts that are generally outside of the Wicomico River watershed in both counties, variances can be approved to develop outside of the growth envelope (St. Mary's County Planning Commission, 2003). Increased road density to accommodate growing transportation needs may impact the watershed. Because strong growth has occurred in the county since 2000, the Wicomico River Estuary was revisited to determine if the fish community and supporting habitat had changed in response to the population increase.

From 1989 to 2002, five equally spaced stations were sampled monthly in the Wicomico River. Water quality was recorded at these stations and DO dynamics were evaluated. Historically, bottom DO in the Wicomico River declined from upstream to downstream. Table 22 presents proportion of concentrations below the 5.0 and 3.0 mg/L living resources criteria (U.S. EPA 2003) and the mean and range of values observed over the 1989 to 2002 time frame.

These represent three samples annually over thirteen years of sampling. There were numerous DO violations of both the 5.0 and 3.0 mg/L criteria. The greatest number of violations was observed near the mouth of the river and fewest in the two upstream stations (Table 22) during 1989-2002. Minimum bottom DO also declined with distance from the mouth of the river, suggesting the source of low DO was from mainstem Potomac waters. In 2003, sampling effort increased from one to two samples a month and the number of sites decreased to four sites per river. In the Wicomico River, sampling at station 5, the station nearest the confluence with the Potomac River, was discontinued while the four remaining stations were sampled in 2003, 2008, and 2009. Data from 2003 followed the pattern where DO improved in the upriver direction (Table 23). However, during 2008 and 2009, upstream stations were in violation of the DO criteria most of the time, representing a significant change from the prior decade (Table 24 and 25). This changed pattern in DO is similar to that observed in suburban mesohaline tributaries by Uphoff et al. (2009) - bottom DO was lowest in the shallow uppermost tidal region and improved downstream. It is possible that the Wicomico River is showing signs of stress in response to changes in the watershed as indicated by the low DO measurements in upriver sites. Consequently, these early signs of degradation may warrant additional investigation into identifying the stressor.

Fish data for the same time period were examined to determine what effect these habitat changes were having on the fish community. Species richness remained similar in the seine samples, and increased for those in the trawl (Figures 38 and 39). However, a larger trawl was introduced and substituted for a smaller trawl when the study shifted focus in 2003. The seine methodology remained the same and no increase in species richness was detected for this habitat. However, seine sampling has not proven to be sensitive to changes in target species presence-absence in brackish tributaries (Uphoff et al. 2009). It was assumed that increased richness in the trawl samples was related to increasing the gear size, tow time, and sampling frequency.

Proportion of white perch collected in the seine increased slightly from a high of 0.8 during the period prior to 2002 to 1.0 in 2008 and 2009. The increase in white perch presence was more pronounced in the trawl, likely due to the change to larger gear.

In previous studies, systems undergoing change associated with development as they happened have not been observed and the inferences presented have been based on spatial differences in IS levels and not a time-series from a single watershed. However, the time-series data from the Wicomico River may be indicating declines in water quality that could be associated with the watershed crossing a threshold (tipping point) related to development. Monitoring of water quality should, therefore, be bolstered to provide better resolution of these changes.. The Wicomico River was once identified as a reference system in the Bay and, like Mattawoman Creek, it may be at an early stage of degradation. If so, it could become an ideal watershed for restrained growth, and application and evaluation of restoration and mitigation measures.

SUMMARY

1) Tax map derived development indices are the best source for standardized, readily updated, and accessible development indicators in Maryland. Counts of structures per acre and square footage of structures per acre had a strong relationship with “new” Towson IS estimates for 2000 and predictions of IS developed from these indices are well within the “play” experienced when using other data sources to estimate IS.

2) Little change in anadromous fish stream spawning in Mattawoman Creek was indicated between 1971 and 1989-1991; however, by 2008-2009 spawning site losses were evident for all three species groups. Stream spawning of anadromous fish nearly ceased in Piscataway, Swan, and Broad creeks, and Oxon Run between 1971 and 2008-2009. The most current urban cover estimate for Mattawoman Creek is similar to Piscataway Creek in 1973 and current Piscataway Creek urban cover is similar to that projected for Mattawoman Creek's development district. If planned development proceeds in Mattawoman Creek's watershed, anadromous fish stream spawning is expected to cease.

3) Elevated conductivity in non-tidal Mattawoman and Piscataway creeks indicated that urbanization has impacted both spawning streams. Average conductivity was greater in more urbanized Piscataway Creek than Mattawoman Creek. Mattawoman Creek's conductivity gradient in the non-tidal mainstem changed from declining to increasing with distance from the estuary between 1991 and 2008-2009.

4) Regression analyses (multiple watersheds and years) indicated IS was negatively related to an index of yellow perch egg-larval survival (L_p, the proportion of standard estuarine plankton tows with larvae), but the relationships were different in fresh-tidal and brackish systems. On average, L_p would be higher in fresh-tidal systems until high levels of IS (≈ 20%) were reached

5) Generally, tidal fresh subestuaries experienced few DO criteria violations than mesohaline subestuaries. A total of 90,075 fish (trawl and seine) were captured representing 55 species in ten subestuaries sampled during 2009. Of these species, 8 comprised 90% of the catch, but only three (white perch, Atlantic menhaden, and blueback herring) were target species. White perch have been the most consistently

6) Mattawoman Creek's summer trawl sampling species richness and relative abundance ranked last in comparison with other watersheds monitored in 2009, including brackish tributaries with very high IS. It was the most highly ranked system in the early 1990s.
7) Mattawoman Creek fish community has declined over the last two decades in spite of the achievement of meeting Chesapeake Bay habitat goals related to water clarity, dissolved oxygen, nutrients and SAV.
8) Counts of structures in Mattawoman Creek's watershed steadily increased from about 11,000 to 21,000 during 1989-2008. Regression models described little or no effect of development on number of species collected or catch of all species until a threshold of about 18,000 structures was reached in 2002. Development beyond this threshold was followed by declines. The number of structures per acre threshold corresponds to 10% IS.
9) Planned levels of development in Charles County's portion of Mattawoman Creek Watershed should be reconsidered in light of the extent of declines detected in the fish community at current levels of IS. Mitigation and restoration must be considered to offset damage already exhibited.
10) There is no indication that the Corsica River is experiencing changes in habitat quality based on water quality and fish assemblages.

11) A decline in Wicomico River dissolved oxygen could indicate a development threshold (tipping point) was crossed. Greater monitoring effort should be expended here to clarify whether changes have occurred.

Acknowledgements

We extend gratitude to Dr. Jim Long and Norma and Wheldon Merritt for their efforts in coordinating and participating in the collection of spring ichthyoplankton on Mattawoman Creek and Piscataway Creek respectively. Dr. Fred Pinkney (USWFS) is to be thanked for his assistance in obtaining Towson University impervious surface data.

CITATIONS

APHA (American Public Health Association). 1975. Standard Methods for the examination of water and wastewater. Washington, D.C.

ASMFC. 2009. Alewife. Available: http://www.asmfc.org/speciesDocuments/shad/alewifeHabitatFactsheet.pdf (December 2009).

ASMFC. 2009b. Blueback herring. Available: http://www.asmfc.org/speciesDocuments/shad/bluebackHabitatFactsheet.pdf (December 2009).

Babyak, M. A. 2002. What you see may not be what you get: A brief, nontechnical introduction to overfitting in regression-type models. Psychosomatic Medicine 66:411-421.

Barnes, K. B., J. M. Morgan III, M. C. Roberge, and Shannon Lowe Center for Geographic Information Sciences. 2002. Sprawl development: its patterns, consequences, and measurement. Towson University. Available: http://chesapeake.towson.edu/landscape/urbansprawl/download/Sprawl_white_paper.pdf (April 2008).

Beach, D. 2002. Coastal sprawl: the effects of urban design on aquatic ecosystems in the United States. Pew Oceans Commission, Arlington, Virginia.

Beall, M. C. 2008. Response to Letter, dated June 27, 2005. Supporting information to the U. S. Army Corps of Engineers to accompany Charles County Planning & Growth/Cross County Connector?RD XING) 04-63344-19 application. Charles County Government, Planning and Growth Management, La Plata, Maryland.

Burdick, G. E., and M. Lipschuetz. 1950. Toxicity of ferro- and ferricyanide solutions to fish, and determination of the cause of mortality. Transactions of the American Fisheries Society 78:192-202.

Cappiella, K., and K. Brown. 2001. Impervious cover and land use in the Chesapeake Bay watershed. Center for Watershed Protection, Ellicott City, MD.

Caraco, N. R. and J. J. Cole. 2002. Contrasting impacts of a native and alien macrophyte on dissolved oxygen in a large river. Ecological Applications. 12:1496-1509.

Carmichael, J., M. Roberts, B. Richardson, and S. J. Jordan. 1992. Fish sampling in eight Chesapeake Bay tributaries. CBRM-HI-92-2, Maryland Department of Natural Resources, Annapolis.

Carruth, L. L., R. E. Jones, and D. O. Norris. 2002. Cortisol and Pacific salmon: a new look at the role of stress hormones in olfaction and home-stream migration. Integrative and Comparative Biology 42:574-581.

Charles County Government, 2006. 2006 Charles County Comprehensive Plan. Charles County Government, Department of Planning and Growth Management. http://www.charelscoutny.org/pgm/planning/compplan/index.html.

Cole, G. A. 1975. Textbook of Limnology. The C. V. Mosby Company, St. Louis.

Dittman, A. H., and T. P. Quinn. 1996. Homing in Pacific salmon: mechanisms and ecological basis. The Journal of Experimental Biology 199:83-91.

Durell, E. Q., and C. Weedon. 2010. Striped bass seine survey juvenile index web page. Maryland Department of Natural Resources, Fisheries Service. Available: http://www.dnr.state.md.us/fisheries/juvindex/index.html (February 2010).

Eby, L. A., and L. B. Crowder. 2002. Hypoxia-based habitat compression in the Neuse River Estuary: context dependent shifts in behavioral avoidance thresholds. Canadian Journal of Fisheries and Aquatic Sciences 59:952-965.

ESRI. 2009. ArcView 9.3.1. Redlands, CA.

Freund, R. J., and R. C. Littel. 2000. SAS system for regression, third edition. SAS Institute, Cary, NC.

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

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York, New York.

Holland, A. F., D. M. Sanger, C. P. Gawle, S. B. Lerberg, M. S. Santiago, G. H. M. Riekerk, L. E. Zimmerman, and G. I. Scott. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298:151-178.

Jarzynski, A., and R. Sadzinski. 2009. Stock assessment of adult and juvenile anadromous species in the Chesapeake Bay and select tributaries. Chesapeake Bay Finfish/Habitat Investigations 2008, Project 2. Maryland Department of Natural Resources, Annapolis, Maryland.

Kaushal, S. S., P. M. Groffman, G. E. Likens, K. T. Belt, W. P. Stack, V. B. Kelly, L. E. Band, and G. T. Fisher. 2005. Increased salinization of fresh water in the northeastern United States. Proceedings of the National Academy of Sciences 102:13517-13520.

Kemp, W. M., and 17 coauthors. 2005. Eutrophication of Chesapeake Bay: historical trends and ecological interactions. Marine Ecology Progress Series 303:1-29.

Klauda, R. J., S. J. Fischer, L. W. Hall, and J. A. Sullivan. 1991. Alewife and blueback herring *Alosa pseudoharengus* and *Alosa aestivalis*. *In* Funderburk, S. L., J. A. Mihursky, S. J. Jordan and D. Riley, editors. 1991. Habitat requirements for Chesapeake Bay living resources. Second Edition. Living Resources Subcommittee, Chesapeake Bay Program. Annapolis, Maryland.

Konrad, C. P., and D. B. Booth. 2005. Hydrologic changes in urban streams and their ecological significance. Pages 157-177 *in* L. R. Brown, R. H. Gray, R. H. Hughes, and M. R. Meador, editors. Effects of urbanization on stream ecosystems. American Fisheries Society Symposium 47, Bethesda, Maryland.

Kwak, T. J., and J. T. Peterson. 2007. Community indices, parameters, and comparisons. Pages 677-763 in C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Leggett, W. C. 2004. The American shad, with special reference to its migration and population dynamics in the Connecticut River. American Fisheries Society Monograph 9:181-238.

Limburg, K.E. and R. E. Schmidt. 1990. Patterns of fish spawning in Hudson River tributaries: response to an urban gradient? Ecology 71:1238-1245.

Limburg and Waldman. 2009. Dramatic declines in north Atlantic diadromous fishes. BioScience 59: 955–965.

Lippson, A. J., and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Maryland Department of Natural Resources, PPSP-MP-13, Annapolis, Maryland.

Mangel, M. and P.E. Smith. 1990. Presence-absence sampling for fisheries management. Canadian Journal of Fisheries and Aquatic Science 47:1875-1887.

Maryland Department of Planning. 2010. Welcome to MDP's Property Map and Data Products. Available http://planning.maryland.gov/OurProducts/PropertyMapProducts/PropertyMapProducts.shtml. (January 2010).

Miranda, L.E., M. P. Driscoll, and M. S. Allen. 2000. Transient physicochemical microhabitats facilitate fish survival in inhospitable aquatic plant stands. Freshwater Biology 44:617-628

McGinty, M. 2006. Larval Fish Sampling in the Bush River, 2006. Final Report to Chesapeake Bay National Estuarine Research Reserve. Maryland Department of Natural Resources. Annapolis, Maryland.

McGinty, M., J. Uphoff, R. Lukacovic, J. Mowrer, and B. Pyle. 2006. Development of habitat based reference points for Chesapeake Bay fishes of special concern: impervious surface as a test case. Chesapeake Bay Finfish/Habitat Investigations 2006, Project 3. Maryland Department of Natural Resources, Annapolis, Maryland.

McGinty, M., J. Uphoff, R. Lukacovic, J. Mowrer, and B. Pyle. 2009b. Development of habitat based reference points for Chesapeake Bay fishes of special concern: impervious surface as a test case. Chesapeake Bay Finfish/Habitat Investigations 2008, Project 3. Maryland Department of Natural Resources, Annapolis, Maryland.

Morgan, R. P., K. M. Kline, and S. F. Cushman. 2007. Relationships among nutrients, chloride and biological indices in urban Maryland streams. Urban Ecosystems 10:153-166.

Mowrer and McGinty 2002. Anadromous and estuarine finfish spawning locations in Maryland. Fisheries Service Technical Report Number 42. Maryland Department of Natural Resources, Annapolis.

National Research Council or NRC. 2009. Urban stormwater management in the United States. National Academies Press, Washington, D.C.

O'Dell, C. J., J. P. Gabor, J. P. Mowrer, K. Tutwiler, R. Klien, and F. Ryan. 1970. Stream improvement program for anadromous fish management. NMFS Completion Report AFC-3. Maryland Department of Game and Inland Fish, Annapolis.

O'Dell, C. J., J. Gabor, and R. Dintamin. 1975. Survey of anadromous fish spawning areas: Potomac River and upper Chesapeake Bay drainage. Completion Report, Project AFC-8, Maryland Department of Natural Resources, Annapolis.

O'Dell, C. J., J. Mowrer, and J. Gabor. 1980. Survey and inventory of anadromous fish spawning areas: Chester River and west Chesapeake Bay drainage. Completion Report, Project AFC-9, Maryland Department of Natural Resources, Annapolis.

O'Dell, C.J. 1987. Status of yellow perch (*Perca flavescens*) in Maryland, 1987: a situation paper on the biology, distribution, stocks, and fisheries of yellow perch with suggested study needs and management actions. Maryland Department of Natural Resources, Annapolis, Maryland.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxbury Press. North Scituate, Massachusetts

Pablo, F., R. T. Buckney, and R. P. Lim. 1996. Toxicity of cyanide and iron-cyanide complexes to Australian bass *Macquaria novemaculeata* and black bream *Acanthopagrus butcheri*. Australasian Journal of Ecotoxicology 2:75-84.

Palmer, M. A. 2009. Reforming watershed restoration: science in need of application and applications in need of science. Estuaries and Coasts 32:1-17.

Piavis, P.G. 1991. Yellow perch *Perca flavescens*. Pages 14.1 – 14.15 *in* S.L. Funderburk, S.J. Jordan, J.A. Mihursky, and D. Riley, editors. Habitat requirements for Chesapeake Bay living resources, 2nd edition. Chesapeake Bay Program, Living Resources Subcommittee, Annapolis, Maryland.

Piavis, P. G., and E. Webb. 2009. Population vital rates of resident finfish in selected tidal areas of Maryland's Chesapeake Bay. Chesapeake Bay Finfish/Habitat Investigations 2008, Project 1. Maryland Department of Natural Resources, Annapolis, Maryland.

Piavis, P. G. 2009. Yellow perch assessment update 2009. Maryland Department of Natural Reosurces, Annapolis.

Reid, G. K., and R. D. Wood. 1976. Ecology of inland waters and estuaries. D. Van Norstrand Company, New York.

Research Council of Norway. 2009. The fish larva: a transitional life form, the foundation for aquaculture and fisheries. Oslo, Norway.

Rettig, A., and R. Rochez. 2009. The Corsica River: A Comprehensive Approach to Watershed Restoration. Maryland Department of Environment. Available: http://textonly.mde.state.md.us/ResearchCenter/Publications/General/eMDE/vol3no8/corsicariver.asp (February 2010).

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

Royce-Malmgren, C. H., and W. H. Watson III. 1987. Modification of olafactory-related behavior in juvenile Atlantic salmon by changes in pH. Journal of Chemical Ecology 13:533-546.

Setzler-Hamilton 1991. White perch *Morone americana*. Pages 12.1 – 12.20 *in* S.L. Funderburk, S.J. Jordan, J.A. Mihursky, and D. Riley, editors. Habitat requirements for Chesapeake Bay living resources, 2nd edition. Chesapeake Bay Program, Living Resources Subcommittee, Annapolis, Maryland.

Sisenwine, M.P., and J. G. Shepherd. 1987. An alternative perspective on recruitment overfishing and biological reference points. Canadian Journal of Fisheries and Aquatic Sciences 44:913-918.

St. Mary's County Planning Commission, 2003. Quality of life in St. Mary's County, a strategy for the 21st century. St. Mary's County, MD.

State Water Resources Control Board (California) 2004. Electrical Conductivity / Salinity Fact Sheet. Available: http://www.swrcb.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/3130fs.pdf (December 2009)

Transportation Research Board of the National Research Council. 1991. Road Salt Use in the US Available: http://onlinepubs.trb.org/onlinepubs/sr/sr235/017-030.pdf (December 2009)

Transportation Research Board of the National Research Council. 2007. Guidelines for the selection of snow and ice control materials to mitigate environmental impacts. National Cooperative Highway Research Program Report 577. Washington D.C.

U.S. Environmental Protection Agency (EPA). 2003. Ambient water quality criteria for dissolved oxygen, water clarity, and chlorophyll a for the Chesapeake Bay and its tidal tributaries. Chesapeake Bay Program Office, Annapolis, Maryland.

Uphoff, J. H. 1997. Using egg presence-absence to derive probability based management criteria for upper Chesapeake Bay striped bass. North American Journal of Fisheries Management 17:663-676.

Uphoff, J., M. McGinty, B. Richardson, P. Piavis, H. Speir, and M.F. Topolski. 2005. Interim assessment of yellow perch *Perca flavescens* habitat and population dynamics in Severn River, a suburbanized Chesapeake Bay sub-estuary. Fisheries Tech. Rep. Series, Number 46. Maryland Department of Natural Resources, Fisheries Service, Stevensville, MD.

Uphoff, J., M. McGinty, R. Lukacovic, J. Mowrer, and B. Pyle. 2007. Development of habitat based reference points for Chesapeake Bay fishes of special concern: impervious surface as a test case. Chesapeake Bay Finfish/Habitat Investigations 2006, F-61-R-1, Project 3. Maryland Department of Natural Resources, Annapolis, Maryland.

Uphoff, J., M. McGinty, R. Lukacovic, J. Mowrer, and B. Pyle. 2008. Development of habitat based reference points for Chesapeake Bay fishes of special concern: impervious surface as a test case. Chesapeake Bay Finfish/Habitat Investigations 2007, Project 3. Maryland Department of Natural Resources, Annapolis, Maryland.

Uphoff, J. H. 2008. Identifying priority areas for protection and restoration: Chesapeake Bay striped bass spawning and larval nursery areas as a model. A report to the Living Resources Subcommittee of the Chesapeake Bay Program. Fisheries Technical Report Series Number 52. Maryland Department of Natural Resources, Stevensville.

Uphoff, J. H., M. McGinty, R. Lukacovic, J. Mowrer, and B.Pyle. 2009. Impervious Surface Target and Limit Reference Points for Chesapeake Bay Subestuaries Based on Summer Dissolved Oxygen and Fish Distribution. Fisheries Service Technical Report Number 55. Maryland Department of Natural Resources, Annapolis.

U.S. Army Corps of Engineers. 2003. Mattawoman Creek Watershed Management Plan. Baltimore District, Maryland.

U.S. Environmental Protection Agency (EPA). 2003. Ambient water quality criteria for dissolved oxygen, water clarity, and chlorophyll a for the Chesapeake Bay and its tidal tributaries. Chesapeake Bay Program Office, Annapolis, Maryland.

Wade, T. and S. Sommer (Eds.). 2006. A to Z GIS. Redlands, CA: ESRI Press.

Wenner, D. B., M. Ruhlman, and S. Eggert. 2003. The importance of specific conductivity for assessing environmentally impacted streams. In K.J. Hatcher, editor. Proceedings of the 2003 Georgia Water Resources Conference. Athens.

Westin, D.T., C.E. Olney, and B.A. Rodgers. 1985. Effects of parental and dietary organochlorines on survival and body burdens of striped bass larvae. Transactions of the American Fisheries Society 114:125-136.

Wheeler, A. P., P. L. Angermeier, and A. E. Rosenberger. 2005. Impacts of new highways and subsequent landscape urbanization on stream habitat and biota. Reviews in Fisheries Science 13:141-164.

Yellow perch workgroup. 2002. Maryland tidewater yellow perch fishery management plan. Maryland Department of Natural Resources, Annapolis, Maryland.

Table 1. Percent of county parcels in the 2000 tax maps without coordinates.

County	Percent Parcels Without x,y coordinates
Allegheny	3.9
Anne Arundel	0.9
Baltimore City	1.8
Baltimore	2.2
Calvert	1.1
Caroline	0.4
Carroll	1.4
Cecil	1.2
Charles	1.6
Dorchester	0.7
Frederick	3.8
Garret	1.6
Harford	1.3
Howard	1.2
Kent	1.1
Montgomery	0.7
Prince George	0.8
Queen Anne	3.2
Somerset	0.2
St. Mary’s	1.7
Talbot	1.2
Washington	2.4
Wicomico	0.6
Worcester	1.4

Table 2. Percent of parcels in the 2000 watershed tax maps that did not have foundation square feet or structure year built data.

Watershed	Percent Zero Square Feet	Percent Zero Year Built
Bohemia River	40	40
Breton Bay	78	7
Bush River	20	20
Corsica River	78	7
Gunpowder River	16	16
Langford Creek	31	31
Magothy River	11	12
Mattawoman Creek	15	16
Middle River/Browns Creek	19	19
Miles River	78	7
Nanjemoy Creek	33	33
Northeast River	28	26
Piscataway Creek	13	13
Severn River	15	19
South River	17	19
St. Clements Bay	79	7
Tred Avon River	78	7
West River/Rhode River	26	27
Wicomico River/Gilbert Swamp/Zekiah Swamp	31	35
Wye River	78	7

Table 3. Estimates of impervious surface (IS) and data used to develop development indices based on Maryland tax maps. Count / area = count of structures per watershed acre. Square ft / acre = square footage of structures per watershed acre.

Watershed	Acres	Structure Count	Structure Square ft	IS	Count / acre	Square ft / acre
Nanjemoy Creek	45461	1460	2461976	0.9	0.03	54.2
Bohemia River	26395	1081	2091164	1.2	0.04	79.2
Langford Creek	23087	610	1170650	3.1	0.03	50.7
Wye River	49321	1640	4216329	3.4	0.03	85.5
Miles River	26707	2507	5851713	3.4	0.09	219.1
Corsica River	23065	1277	3450678	4.1	0.06	149.6
Wicomico River	141378	16521	34089324	4.3	0.12	241.1
Northeast River	39280	5743	11620433	4.4	0.15	295.8
Gunpowder River	533122	5908	9375949	4.4	0.01	17.6
St Clements Bay	28554	2203	3931610	4.4	0.08	137.7
West River Rhode River	15616	3476	6325844	5	0.22	405.1
Breton Bay	33889	3408	8969424	5.3	0.1	264.7
Mattawoman Creek	56772	16228	37764636	9	0.29	665.2
South River	33994	16986	38036360	10.9	0.5	1118.9
Bush River	31677	7613	24321156	11.3	0.24	767.8
Piscataway Creek	39236	21261	37149837	16.5	0.54	946.8
Severn River	39760	34382	75886550	19.5	0.86	1908.6
Magothy River	19565	23803	45611641	20.2	1.22	2331.3
Middle River	2744	8202	12329893	39.1	2.99	4493.7

Table 4. Summary of sites and dates, and sample sizes for anadromous fish egg and larvae sampling by volunteers in Mattawoman and Piscataway Creeks during 2008-2009.

System	Year	Number sites	1st date	Last date	Number visits	N
Piscataway	2008	5	17-Mar	4-May	8	39
Piscataway	2009	6	9-Mar	14-May	11	60
Mattawoman	2008	9	8-Mar	9-May	10	90
Mattawoman	2009	9	8-Mar	11-May	10	70

Table 5. Summary of historic conductivity sampling summarized to examine historic conditions in Mattawoman Creek. RKM = site location in river km from mouth; months – months when samples were drawn; N = sum of samples for all years. Type designates sites as tidal (T) or non-tidal (N).

RKM	1	1.8	2.4	2.8	3.9	4.8	6.3	8	10.5	12.4	18.1	27	30	34.9	38.8
Months	4 to 9	5 to 10	5,7,9	1 to 12	5,7,9	4 to 9	5,7,9	7,9	5,7.9	1 to 12	4 to 9	4 to 9	8,9	4 to 9	8,9
N	21	28	3	246	3	19	4	2	3	218	8	9	2	9	2
Type	T	T	T	T	T	T	T	T	T	N	N	N	N	N	N
	Years sampled														
1970									70			70	70	70	70
1971	71	71	71	71	71	71	71	71	71	71					
1974	74			74		74				74	74	74		74	
1975										75					
1976										76					
1977										77					
1978										78					
1979										79					
1980										80					
1981										81					
1982										82					
1983										83					
1984				84						84					
1985		85		85						85					
1986				86						86					
1987				87						87					
1988				88						88					
1989				89						89					
2008															
2009															

Table 6. Presence-absence of herring (blueback herring and alewife) and white perch stream spawning in Mattawoman Creek during 1971 and 2008-2009. 0 = site sampled, but spawning not detected; 1 = site sampled, spawning detected; and blank indicates no sample. Station locations are identified on Figure 4.

STATION	1971	1989	1990	1991	2008	2009
Herring						
MC1	1	1	1	1	1	1
MC2	1	1	1	1	0	0
MC3	1			1	1	1
MC4	1			1	0	0
MUT3	1				0	0
MUT5	1				1	0
White Perch						
MC1	1	1	1	1	1	0
MC2	0	0	1	0	0	0
MC3	1			0	0	0
Yellow Perch						
MC1	1	1	1	1	1	0

Table 7. Presence-absence of herring (blueback herring and alewife), white perch, and yellow perch stream spawning in Piscataway Creek during 1971, 1989-1991, and 2008-2009. 0 = site sampled, but spawning not detected; 1 = site sampled, spawning detected; and blank indicates no sample. Station locations are identified on Figure 5.

	Year		
STATION	1971	2008	2009
Herring			
PC1	1	0	0
PC2	1	0	1
PC3	1	0	0
PTC4	1	0	0
PUT4	1		0
White Perch			
PC1	1	0	0
PC2	1	0	0

Table 8. Summary statistics of conductivity (µmho / cm) for mainstem stations in Piscatatway and Mattawoman creeks during 2008-2009. Unnamed tributaries were excluded from analysis. Tinkers Creek was included with mainstem stations in Piscataway Creek.

Creek	Piscataway	Piscataway	Mattawoman	Mattawoman
Year	2008	2009	2008	2009
Mean	218.4	305.4	120.1	244.5
Standard Error	7.4	19.4	3.8	19.2
Median	210.4	260.6	124.6	211
Kurtosis	-0.38	1.85	2.1	1.41
Skewness	0.75	1.32	-1.41	1.37
Range	138	641	102	495
Minimum	163	97	47	115
Maximum	301	737	148.2	610
Count	29	50	39	40
Count > 171	28	46	0	25

Table 9. Characterization of watersheds monitored during July-October, 2009. Area = Mid refers to mid-Chesapeake Bay; Potomac indicates sub-estuary located on the tidal Potomac River; and Upper indicates upper Chesapeake Bay. Median salinity is based on 2009 measurements. IS = impervious surface estimates from Towson University based on 1999-2000 satellite imagery. Other land-uses are based on 1994 MDP estimates. Figure refers to map that has station locations and land-use distribution in a watershed.

Area	Watershed	Median Salinity	IS (%)	Total acres	Water acres	% Urban	% Forest	% Agriculture	% Wetland	Figure
Mid	Corsica R.	8.6	4.1	23,924	1,256	6	28	65	1	18
Mid	Middle R.	6.0	39.1	6,759	2,132	62	29	6	3	19
Mid	Tred Avon R.	10.6	7.5	23,518	4,338	22	38	39	>1	20
Potomac	Mattawoman Cr.	0.2	9.0	60,300	1,848	22	63	14	1	21
Potomac	Nanjemoy Cr.	6.0	0.9	46,604	2,345	6	74	16	4	22
Potomac	Piscataway Cr.	0.2	16.5	43,579	858	34	49	16	1	23
Potomac	Wicomico R.	11.2	4.3	49,364	1,398	7	51	37	4	24
Upper	Bush R.	0.4	11.3	36,964	7,966	24	48	22	6	25
Upper	Gunpowder R.	1.4	4.4	43,466	10,013	35	36	24	5	26
Upper	Northeast	0.1	4.4	40,377	3,884	6	36	65	1	27

Table 10. Water temperature and dissovled oxygen requirements for juvenile (J) and adult (A) target species.

Water Quality Criteria Requirements	Striped Bass	Yellow Perch	White Perch	Alewife	Blueback Herring	American Shad	Spot	Atlantic Croaker	Atlantic Menhaden
TEMPERATURE (^{o}C)	14.0-26.0 J	19.0 -24.0 J	15.2 - 31.0 J	17.0 - 23.0 J	11.5 - 28.0 J	15.6 - 23.90 J	6.0 - 25.0 J	17.5 - 28.2 J	16.9 - 28.2 J
	20.0 – 22.0 A Preferred	12.0 – 22.0 A	21.5 – 22.8 A preferred	16.0 – 22.0 A	8.0-22.8 A	8.0-30.0 A	12.0 - 24.0 A	14.9 - 31.4 A	6.0 - 25.0 A
DISSOLVED OXYGEN (mg/l)	>5.0 J, A	minimum of 5.0 J A	minimum of 5.0 – 7.0 J/A	minimum of 3.6 J A	minimum of 3.6 J	4.0 – 5.0 J A	2 - >5.0 J A		> 4.5 J, A
				> 5.0 preferred	> 5.0 preferred	>5.0 preferred	>5.0 preferred		

Table 11. Percentage of time overall habitat conditions (all depths in the channel and near shore) did not support the highest maximum temperature, threshold and target D.O. and the lowest maximum salinity for the target species during July-September, 2009 and percentage of time bottom dissolved oxygen in the channel was below 5.0 mg/L and 3.0 mg/L.

Salinity Calssification	Watershed	Percentage Impervious	Temperature > 31°C	DO < 5.0 mg/L	Bottom DO < 5.0 mg/L	BottomDO < 3.0 mg/L
Fresh-tidal	Bush River	11.3	2.4	2.4	5.6	0.0
Fresh-tidal	Gunpowder River	4.4	0.0	2.3	0.0	0.0
Fresh-tidal	Mattawoman Creek	9.0	0.0	0.0	0.0	0.0
Fresh-tidal	Northeast	4.4	2.1	2.1	4.2	0.0
Fresh-tidal	Piscataway	16.5	0.0	0.0	0.0	0.0
Mesohaline	Corsica	4.1	0.0	45.7	65.6	43.7
Mesohaline	Tred Avon River	7.5	0.0	8.3	12.5	0.0
Mesohaline	Middle River	39.1	0.0	18.5	18.2	4.5
Mesohaline	Nanjemoy	0.9	0.0	5.6	5.6	5.6
Mesohaline	Wicomico	4.3	0.0	34.5	60.0	30.0

Table 12. Seine catch statistics and impervious cover by river for 2009.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Seine
Bush	24	31	gizzard shad white perch juvenile white perch adult spottail shiner pumpkinseed blueback herring channel catfish	11.29	9781	407.5
Corsica	20	24	white perch juvenile striped killifish white perch adult pumpkinseed striped bass Atlantic silverside spottail shiner mummichog alewife channel catfish banded killifish yellow perch juvenile striped anchovy	4.13	2257	112.8
Gunpowder	19	37	white perch juvenile spottail shiner gizzard shad Atlantic menhaden white perch adult banded killifish Atlantic silverside Bay anchovy pumpkinseed channel catfish	4.38	5026	264.5
Mattawoman	1	6	bluegill	8.99	67	67.0
Middle	5	18	white perch juvenile banded killifish pumpkinseed white perch adult Atlantic silverside inland silverside	39.12	1009	201.8
Nanjemoy	18	31	white perch juvenile white perch adult Atlantic menhaden Atlantic silverside Bay anchovy	0.94	3441	191.2

Table 12 (continued). Seine catch statistics and impervious cover by river for 2009.

Northeast	24	28	gizzard shad blueback herring white perch juvenile white perch adult Atlantic menhaden	4.35	7261	302.5
Piscataway	0			16.51		
Tred Avon	24	23	Atlantic silverside Atlantic menhaden striped killifish striped bass white perch adult	7.45	3535	147.3
Wicomico	32	20	Atlantic silverside white perch adult striped bass juvenile striped killifish mummichog	4.29	3620	113.1

Table 13. Trawl (16 ft headrope) catch statistics and impervious cover by river for 2009.
.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Trawl
Bush	18	19	white perch juvenile white perch adult bay anchovy gizzard shad	11.29	6237	346.5
Corsica	32	15	white perch adult white perch juvenile bay anchovy	4.13	8582	268.2
Gunpowder	24	23	white perch juvenile bay anchovy white perch adult gizzard shad	4.38	8022	334.3
Mattawoman	24	13	white perch juvenile white perch adult bluegill striped bass juvenile	8.99	427	17.8
Middle	24	17	white perch juvenile white perch adult bay anchovy	39.12	7493	312.2
Nanjemoy	18	17	white perch juvenile bay anchovy white perch adult	0.94	10033	557.4
Northeast	24	18	white perch adult white perch juvenile bay anchovy	4.35	5911	246.3
Piscataway	18	20	white perch juvenile spottail shiner white perch adult pumpkinseed	16.51	3590	199.4
Tred Avon	24	16	bay anchovy blue crab striped bass juvenile weakfish white perch adult	7.45	2158	89.9
Wicomico	32	20	bay anchovy white perch adult spot striped bass juvenile hogchoker Atlantic silverside	4.29	2211	69.1

Table 14. Proportion (pt = trawl, ps = seine) of positive tows and standard deviation (sd) for target species by river and gear for 2009.

	Bush		Gunpowder		Mattawoman		Middle		Nanjemoy		Northeast		Piscataway		Tred Avon	
Species in the Trawl	p_t	sd	p_t	sd	p_t	sd	p_t	sd	p_t	sd	p_t	sd	p_t	sd	p_t	sd
Alewife	0.11	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.17	0.08	0.00	0.00	0.00	0.00
Blueback	0.17	0.09	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.09	0.00	0.00
Atlantic menhaden	0.06	0.05	0.04	0.04	0.00	0.00	0.08	0.06	0.08	0.06	0.25	0.09	0.00	0.00	0.00	0.00
American shad	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.11	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Atlantic croaker	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spot	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.06	0.39	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Striped bass (adult)	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.04	0.06	0.05	0.08	0.06	0.00	0.00	0.04	0.04
Striped bass (juvenile)	0.11	0.07	0.33	0.10	0.62	0.11	0.54	0.10	0.72	0.11	0.17	0.08	0.06	0.05	0.83	0.08
White perch (adult)	0.89	0.07	0.92	0.06	0.52	0.11	0.96	0.04	1.00	0.00	0.96	0.04	0.78	0.10	0.63	0.10
White perch (juvenile)	1.00	0.00	0.96	0.04	0.52	0.11	1.00	0.00	0.94	0.05	1.00	0.00	1.00	0.00	0.00	0.00
Yellow perch (adult)	0.33	0.11	0.08	0.06	0.05	0.05	0.00	0.00	0.00	0.00	0.08	0.06	0.11	0.07	0.00	0.00
Yellow perch (juvenile)	0.17	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.00	0.00

	Bush		Gunpowder		Middle		Nanjemoy		Northeast		Tred Avon	
Species in the Seine	p_s	sd	p_s	sd	p_s	sd	p_s	sd	p_s	sd	p_s	sd
Alewife	29.00	0.09	0.32	0.11	0.00	0.00	0.00		0.11	0.07	0.33	0.10
Blueback	0.33	0.10	0.26	0.10	0.00	0.00	0.44	0.12	0.63	0.10	0.04	0.04
Atlantic menhaden	0.25	0.09	0.47	0.11	0.00	0.00	0.44	0.12	0.29	0.09	0.17	0.08
American shad	0.00	0.00	0.05	0.05	0.00	0.00	0.11	0.07	0.33	0.10	0.00	0.00
Atlantic croaker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spot	0.00	0.00	0.16	0.08	0.00	0.00	0.50	0.12	0.00	0.00	0.29	0.09
Striped bass (adult)	0.25	0.09	0.05	0.05	0.00	0.00	0.06	0.05	0.17	0.08	0.04	0.04
Striped bass (juvenile)	0.67	0.10	0.47	0.11	0.60	0.22	0.72	0.11	0.42	0.10	0.83	0.08
White perch (adult)	0.83	0.08	0.84	0.08	0.60	0.22	0.94	0.05	0.79	0.08	0.67	0.10
White perch (juvenile)	1.00	0.00	1.00	0.00	1.00	0.00	0.94	0.05	0.79	0.08	0.21	0.08
Yellow perch (adult)	0.17	0.08	0.05	0.05	0.40	0.22	0.06	0.05	0.08	0.06	0.00	0.00
Yellow perch (juvenile)	0.46	0.10	0.16	0.08	0.40	0.22	0.00	0.00	0.29	0.09	0.00	0.00

Table 15. Proportion of trawl samples withjuvenile and adult white perch during 2009.

RIVER	Proportion of white perch juveniles	Proportion white perch adults	% Impervious
BUSH	1.00	0.89	11.3
CORSICA	1.00	0.97	4.1
GUNPOWDER	0.96	0.92	4.4
MATTAWOMAN	0.33	0.46	9.0
MIDDLE	1.00	0.96	39.1
NANJEMOY	0.94	1.00	0.9
NORTH	1.00	0.96	4.4
PISCATAWAY	1.00	0.78	7.5
TRED AVON	0.00	0.63	7.5
WICOMICO	0.22	0.66	4.3

Table 16. Comparisons of mean species richness (count of species) collected by 10 ft trawl during 1989-2002 and 2009. Comparisons were made by station and month. Collections in 2009 represent approximately twice the level of effort as annual collections during 1989-2002.

Comparison	1989-2002 mean richness	2009 richness
Station		
Station 1	10.3	5
Station 2	8.1	7
Station 3	8.5	0
Station 4	8.2	3
Month		
July	10.1	9
August	10.5	1
September	7.7	4

Table 17. Summary of data and abbreviations used in the multiple regression to describe threshold effects of Mattawoman Creek Watershed development on annual (July-early October) number of species or mean log10 trawl catch (+1).

Year	Structures	Gear	Time	Time*house	Number Species	Log_{10} catch
Abbreviation	H	G	Y	H*Y	S	Log_{10} N
1989	10,943	0	0	0	15	3.02
1990	11,584	0	0	0	19	2.94
1991	11,966	0	0	0	14	3.14
1992	12,388	0	0	0	14	2.62
1993	12,791	0	0	0	13	2.96
1994	13,319	0	0	0	17	2.76
1995	13,906	0	0	0	8	3.19
1996	14,470	0	0	0	14	3.02
1997	15,135	0	0	0	11	2.86
1998	15,869	0	0	0	11	3.07
1999	16,564	0	0	0	15	3.14
2000	17,193	0	0	0	11	2.93
2001	17,863	0	0	0	14	2.9
2002	18,456	0	1	18,456	14	2.29
2003	18,988	1	1	18,988	24	3.34
2004	19,475	1	1	19,475	25	3.43
2005	19,931	1	1	19,931	26	3.35
2006	20,486	1	1	20,486	19	2.97
2007	20,968	1	1	20,968	19	2.93
2008	21,290	1	1	21,290	18	2.59

Table 18. ANOVA tables and coefficient estimates for the regression model investigating threshold effects of development on number of species encountered annually during 1989-2008 monitoring of Mattawoman Creek's estuary. Model R^2 = 0.77.

ANOVA for number of species

	df	*SS*	*MS*	*F*
Regression	4	346.7733852	86.69335	12.98108
Residual	15	100.1766148	6.678441	
Total	19	446.95		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	20.70765	4.76659	4.34	0.0006
Structures	-0.00050654	0.00033296	-1.52	0.1490
Gear	66.40383	27.18364	2.44	0.0274
Time	2.64112	3.04051	0.87	0.3987
Time*Structures	-0.00286	0.00135	-2.12	0.0508

Table 19. ANOVA tables and coefficient estimates for the regression model investigating threshold effects of development on annual mean $\log_{10}$–transformed catch (+1) of all fish during 1989-2008 monitoring of Mattawoman Creek's estuary. Model R^2 = 0.72.

ANOVA for mean $\log_{10}$ transformed catch (+1)

	df	*SS*	*MS*	*F*
Regression	4	1.014	0.253	9.69
Residual	15	0.392	0.0261	
Total	19	1.406		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	2.875	0.298	9.64	8.07E-08
Structures	6.36E-06	2.083E-05	0.30	0.764497
Gear	7.752	1.701	4.55	0.000378
Time	-0.701	0.190	-3.68	0.002194
Time*structures	-0.00034	8.424E-05	-4.08	0.000968

Table 20. Percentage of dissolved oxygen concentrations below the 5.0and 3.0 mg/L criteria. Data are from Tidewater Ecosystem Assessment's Continuous Monitoring data base, provided by Bill Romano.

Dissolved Oxygen less than 5.0 mg/L (%)						
Month	2004	2005	2006	2007	2008	2009
3		0	0	0	0	
4	0	0	0	0	0.28	0
5	0	0	0	0	1.18	5.58
6	0.03	0	9.72	0	3.58	28.4
7	1.48	0.44	4.94	0.37	1.75	11.2
8	2.15	39.8	4.6	14.78	7.29	42.52
9	0.24	21.67	7.78	17.17	2.09	5.24
10	0	12.34	0	9.18	0	0
Dissolved Oxygen less than 3.0 mg/L (%)						
Month	2004	2005	2006	2007	2008	2009
3		0	0	0	0	
4	0	0	0	0	0	0
5	0	0	0	0	0.07	0
6	0	0	2.67	0	0	2.36
7	0.27	0	0.13	0	0	0.88
8	0.74	7.09	0.03	0.84	0.15	16.15
9	0	2.26	0.49	0.49	0	0.08
10	0	3.39	0	0.11	0	0
11	0					

Table 21. Corsica River $\log_{10}$ catch per effort by year and gear type.

Year	Trawl	Seine
2003	2.78	3.08
2004	2.43	2.83
2005	2.22	2.68
2006	2.42	2.17
2007	2.28	2.24
2008	2.19	2.36
2009	2.46	2.07

Table 22. Proportion of dissolved oxygen (DO) measurements below living resources criteria and mean, min and max in the Wicomico River, 1989-2002.

Station	Bottom DO < 5.0 mg/L	BottomDO < 3.0 mg/L	Mean DO	Minimum DO	Maximum DO
1	0.15	0.00	6.36	4.35	9.87
2	0.08	0.00	6.65	3.82	9.86
3	0.29	0.05	5.77	2.22	8.88
4	0.51	0.27	4.50	0.46	8.24
5	0.005	0.25	4.77	0.15	8.86

Table 23. Proportion of dissolved oxygen (DO) measurements below living resources criteria and mean, min and max in the Wicomico River, 2003.

Station	Bottom DO < 5.0 mg/L	BottomDO < 3.0 mg/L	Mean DO	Minimum DO	Maximum DO
1	0.25	0.00	6.4	4.8	8.4
2	0.25	0.00	5.875	4.9	8.4
3	0.00	0.00	6.975	5.9	9.6
4	0.50	0.25	5.05	1.4	8.7

Table 24. Proportion of dissolved oxygen (DO) measurements below living resources criteria and mean, min and max in the Wicomico River, 2008.

Station	Bottom DO < 5.0 mg/L	BottomDO < 3.0 mg/L	Mean DO	Minimum DO	Maximum DO
1	1.00	0.25	3.44	0.18	4.96
2	0.50	0.25	3.9325	0.06	5.97
3	0.75	0.25	3.825	1.49	6.47
4	0.75	0.50	2.77	0.13	6.22

Table 25. Proportion of dissolved oxygen (DO) measurements below living resources criteria and mean, min and max in the Wicomico River, 2009.

Station	Bottom DO < 5.0 mg/L	BottomDO < 3.0 mg/L	Mean DO	Minimum DO	Maximum DO
1	1.00	0.75	1.633333	0.05	4.63
2	0.50	0.25	4.4025	0.24	7.88
3	0.25	0	5.12	4.17	5.57
4	0.50	0	5.19	4.66	5.93

Figure 1. Watersheds selected for comparisons of tax map based development indicators and impervious surface estimates.

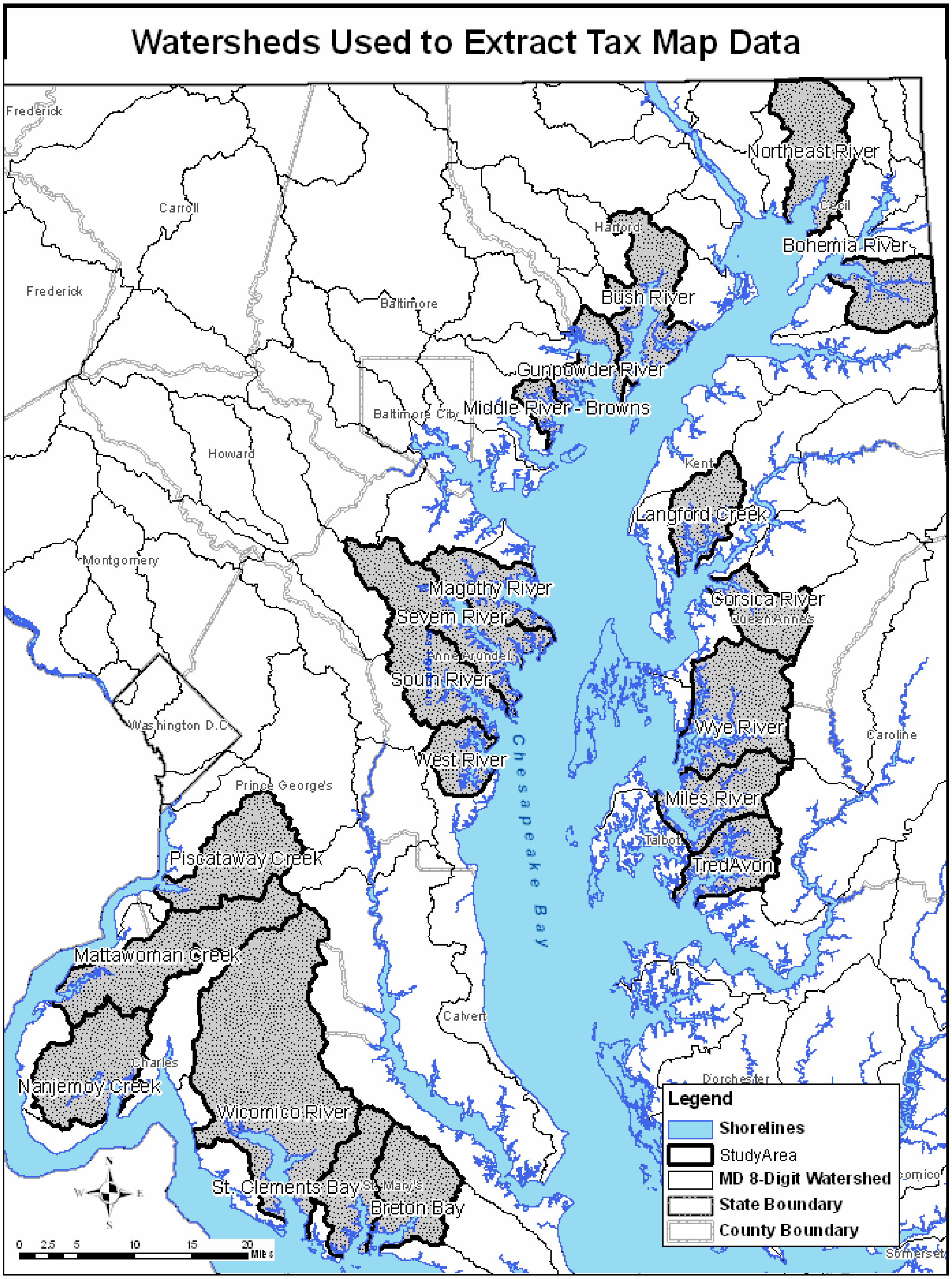

Watersheds Used to Extract Tax Map Data
Frederick
Carroll
Frederick
Baltimore
Harford
Cecil
Northeast River
Bohemia River
Bush River
Gunpowder River
Middle River - Browns
Baltimore City
Howard
Kent
Langford Creek
Montgomery
Magothy River
Severn River
Anne Arundel
South River
Corsica River
Queen Annes
Washington D.C.
Wye River
Caroline
West River
Chesapeake Bay
Prince George's
Miles River
Talbot
TredAvon
Piscataway Creek
Mattawoman Creek
Calvert
Charles
Nanjemoy Creek
Dorchester
Wicomico River
St. Clements Bay
St. Mary's
Breton Bay
Somerset
Legend
Shorelines
StudyArea
MD 8-Digit Watershed
State Boundary
County Boundary
0 2.5 5 10 15 20 Miles

Figure 2. Relationships of percent impervious surface with (A) count of structures per watershed acre and (B) square footage of structures per watershed acre. Observed data are indicated by open symbols and lines represent predictions from a non-linear power function.

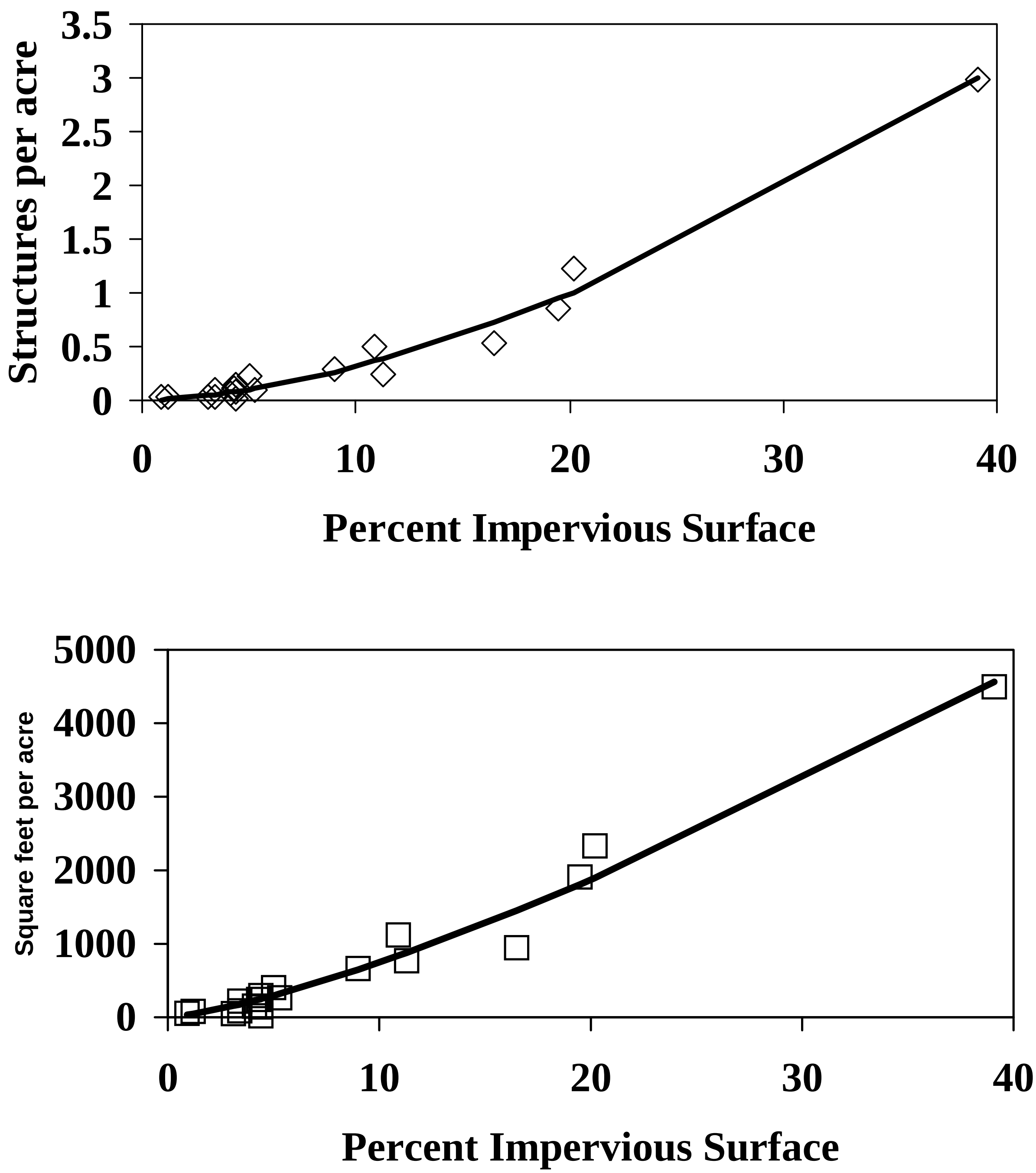


Figure 3.Watersheds sampled for stream spawning anadromous fish eggs and larvae in 2009.

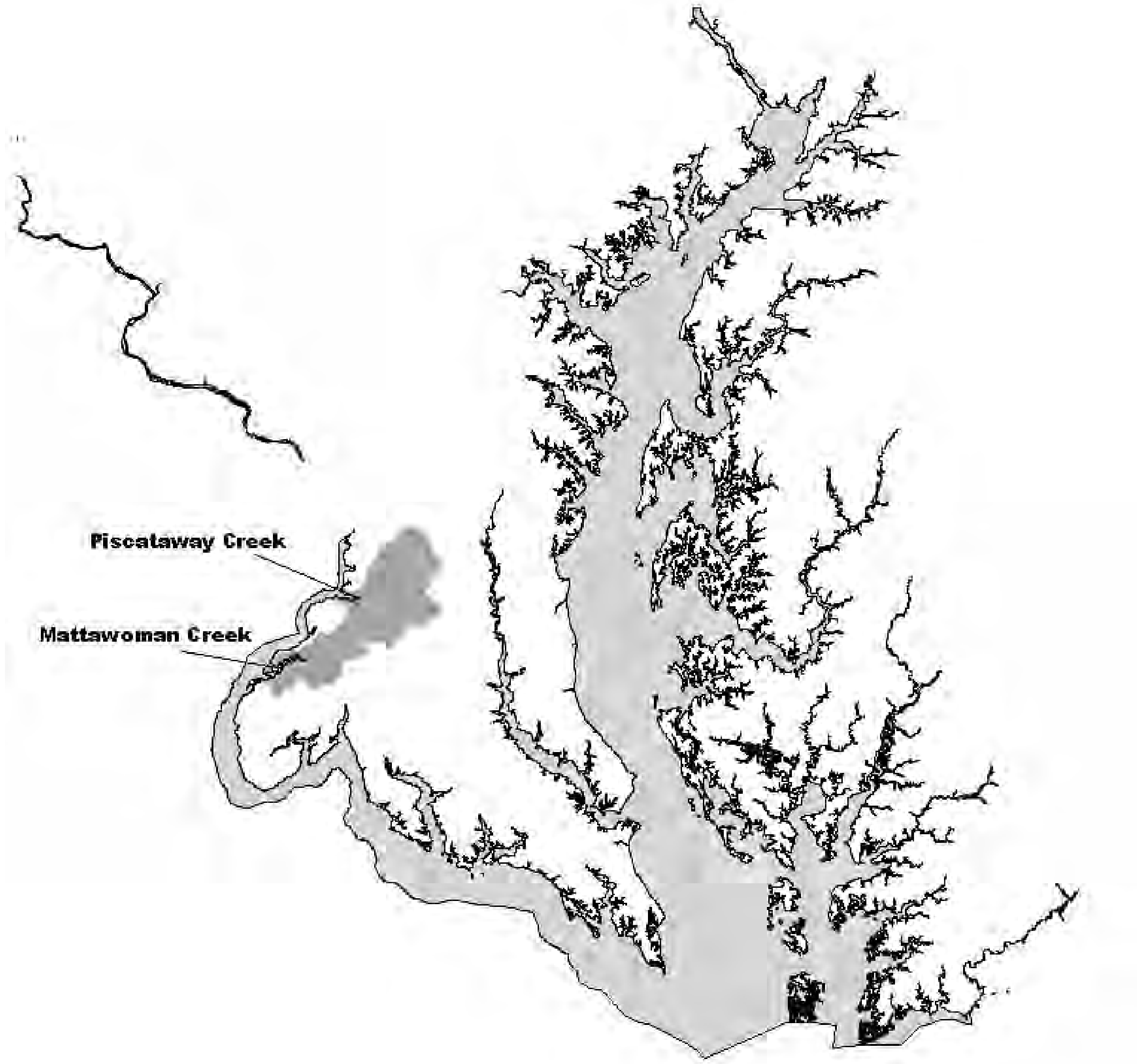


Figure 4. Mattawoman Creek historic and 2008-2009 sampling stations.

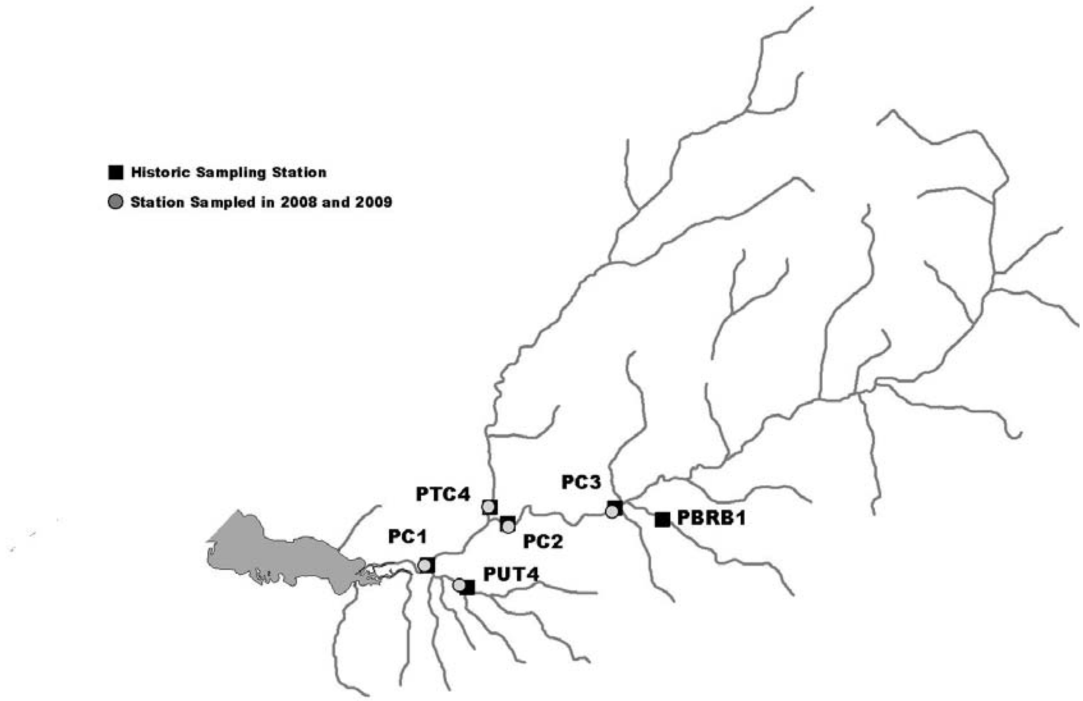


Figure 5. Piscataway Creek historic and 2008-2009 sampling stations.

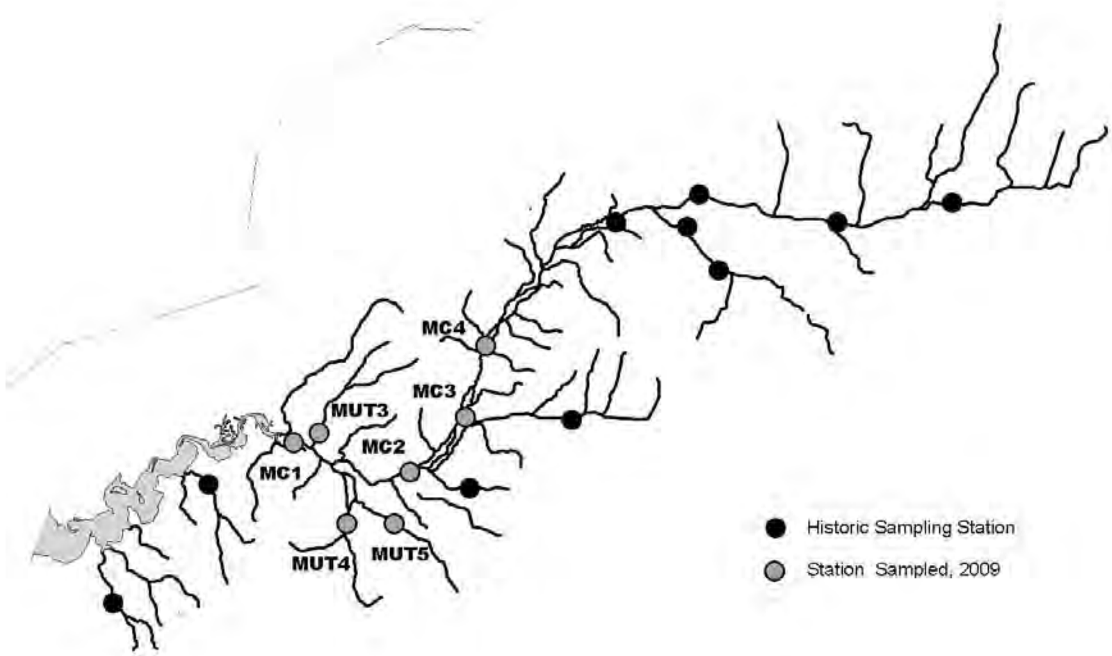


Figure 6. Mattawoman Creek stations with conductivity measurements used in analysis.

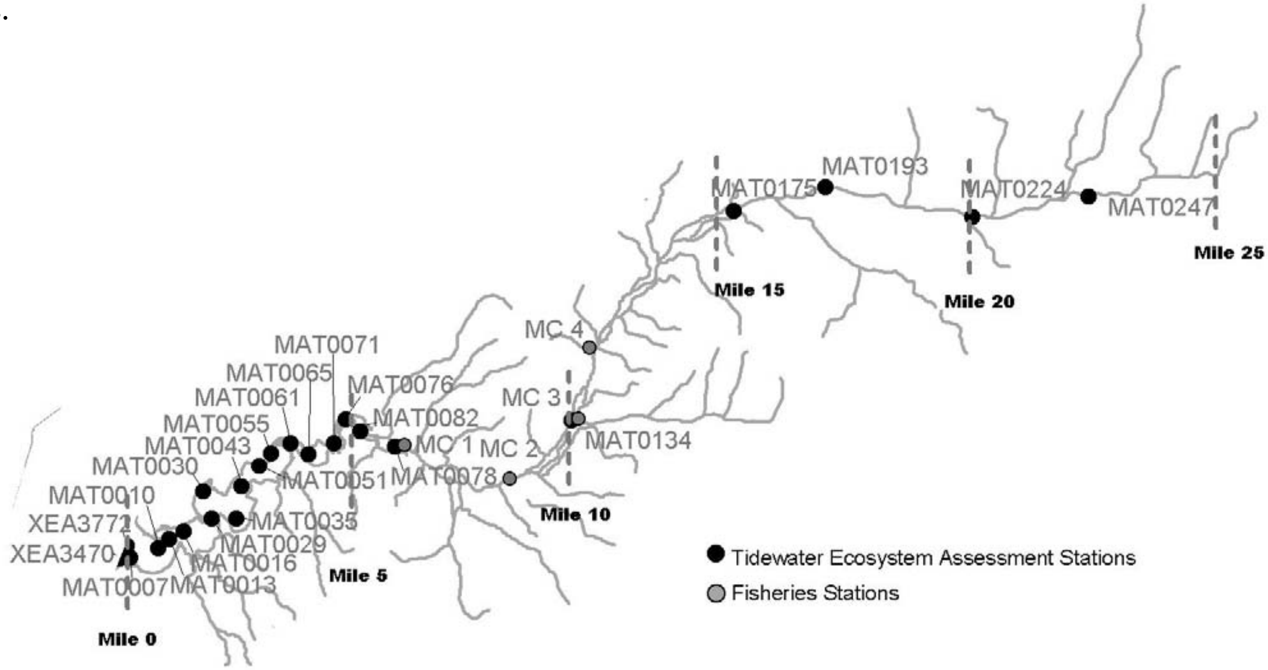


Figure 7. Conductivity during the 2008 anadromous fish stream spawning survey in Mattawoman Creek for mainstem stations (open symbols) and tributaies. Lines represent the minimum and maximum conductivities reported at MC2 and MC4 during March and April, 1991 (Hall et al. 1992). Stations labeled as MCx are mainstem stations, while stations labeled as MUTx are unnamed tributaries.

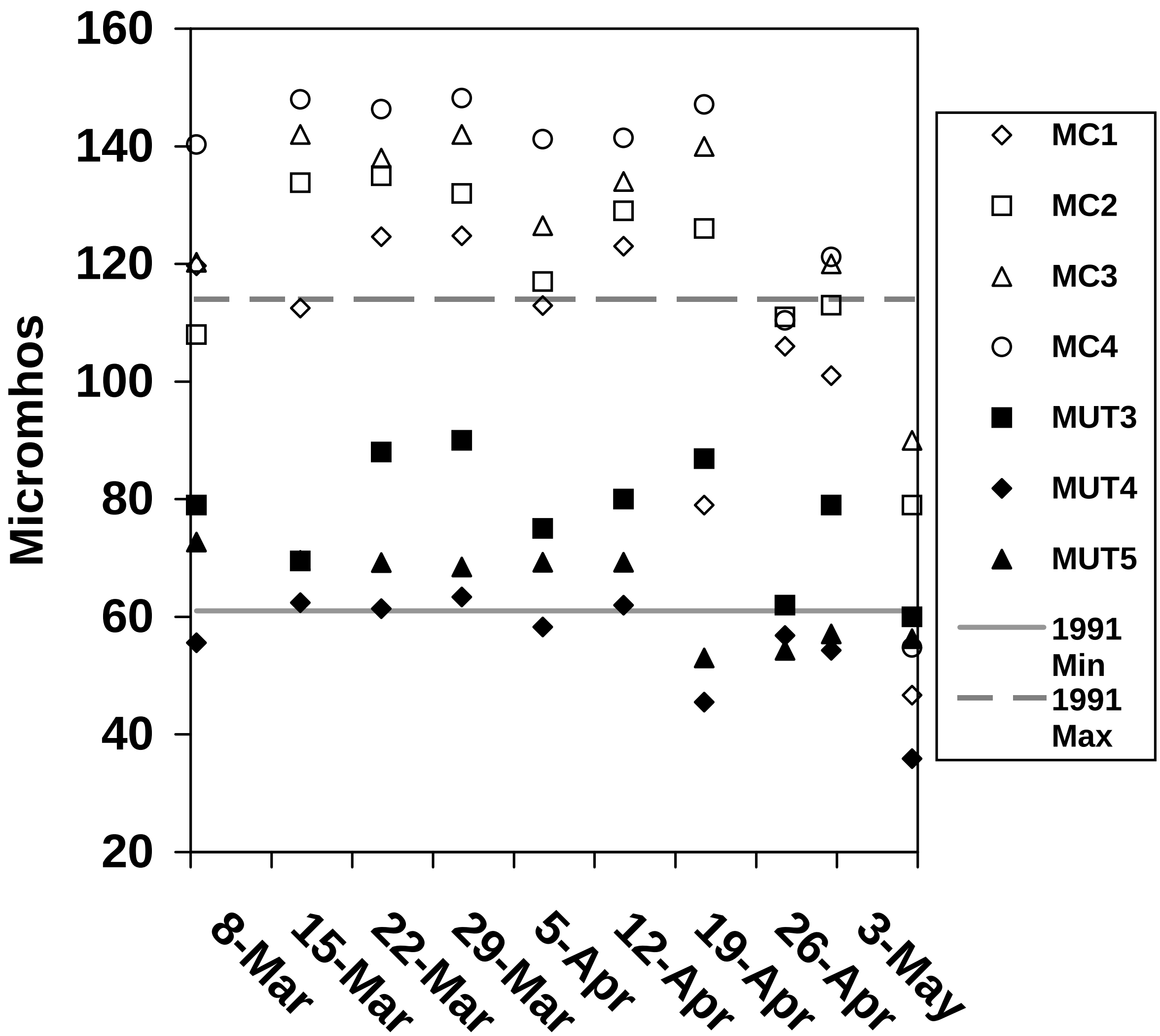


Figure 8. Conductivity during the 2009 anadromous fish stream spawning survey in Mattawoman Creek for mainstem stations (open symbols) and tributaies. Lines represent the minimum and maximum conductivities reported at MC2 and MC4 during March and April, 1991 (Hall et al. 1992). Stations labeled as MCx are mainstem stations, while stations labeled as MUTx are unnamed tributaries.

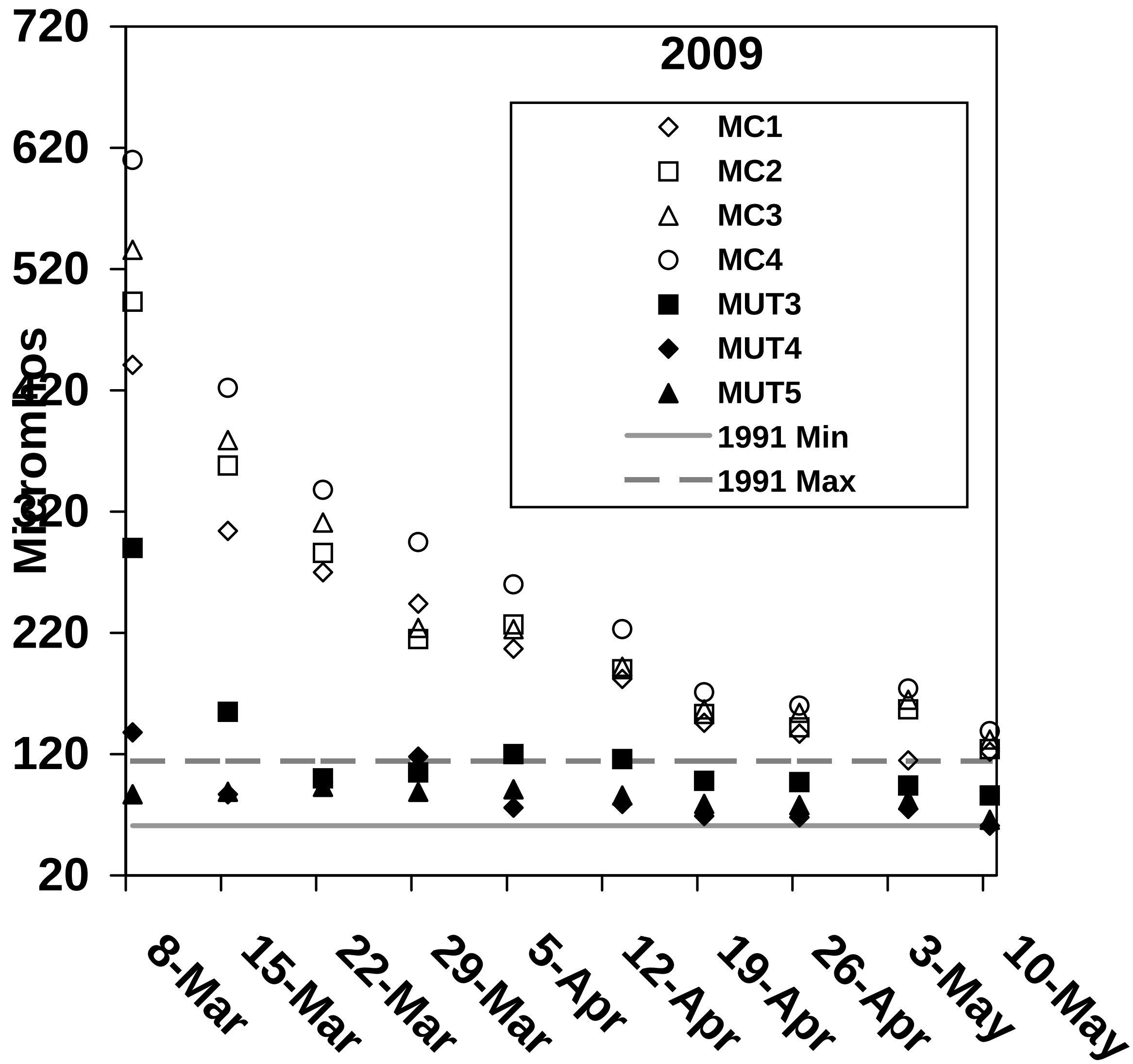


Figure 9. Conductivity during the 2008 anadromous fish stream spawning survey in Piscataway Creek for mainstem stations (open symbols) and tributaries. Stations PCx and PTC are mainstem stations, while PUT4 is a tributary.

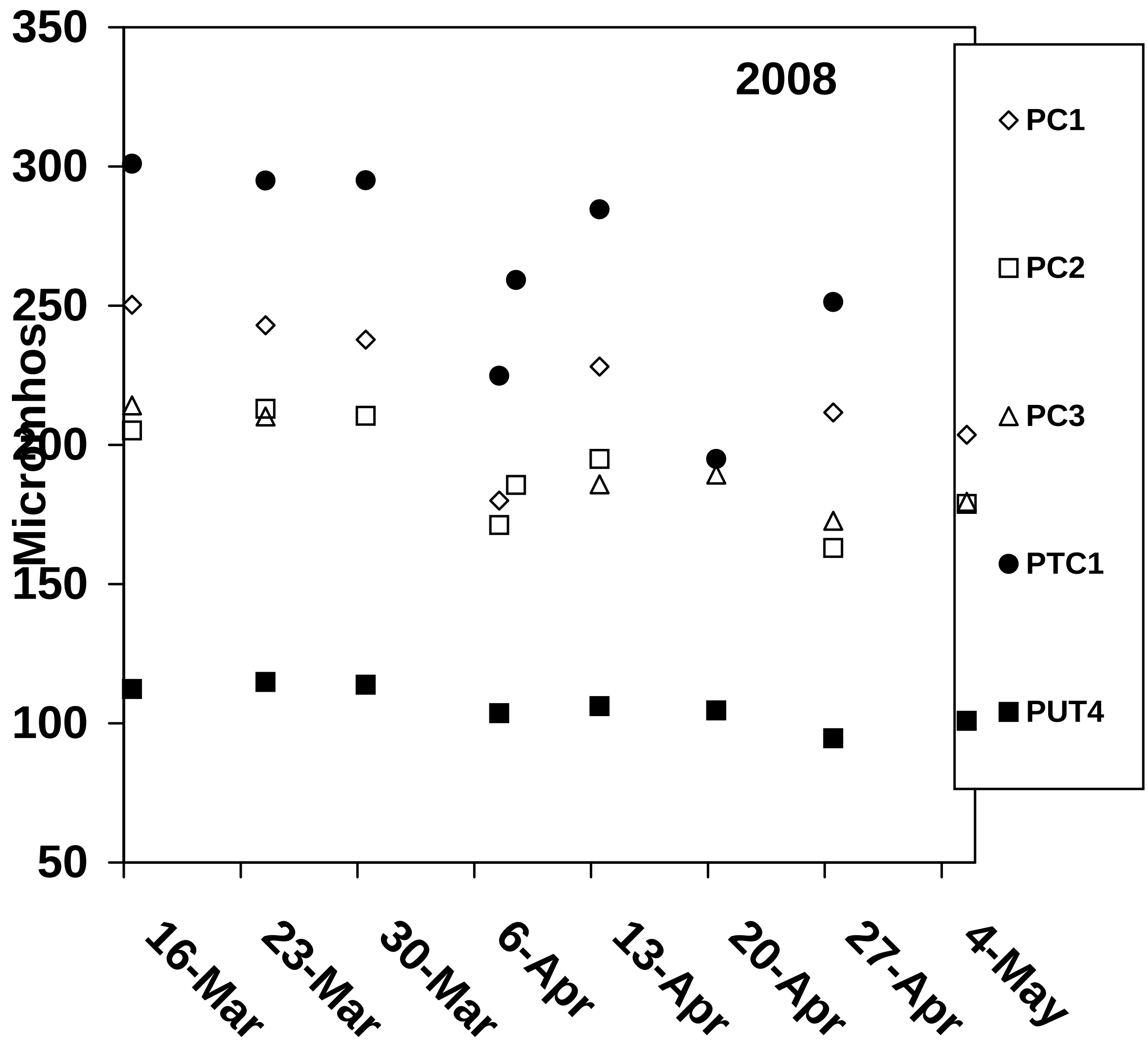


Figure 10. Conductivity during the 2009 anadromous fish stream spawning survey in Piscataway Creek for mainstem stations (open symbols) and tributaries. Stations PCx and PTC are mainstem stations, while PUT4 is a tributary.

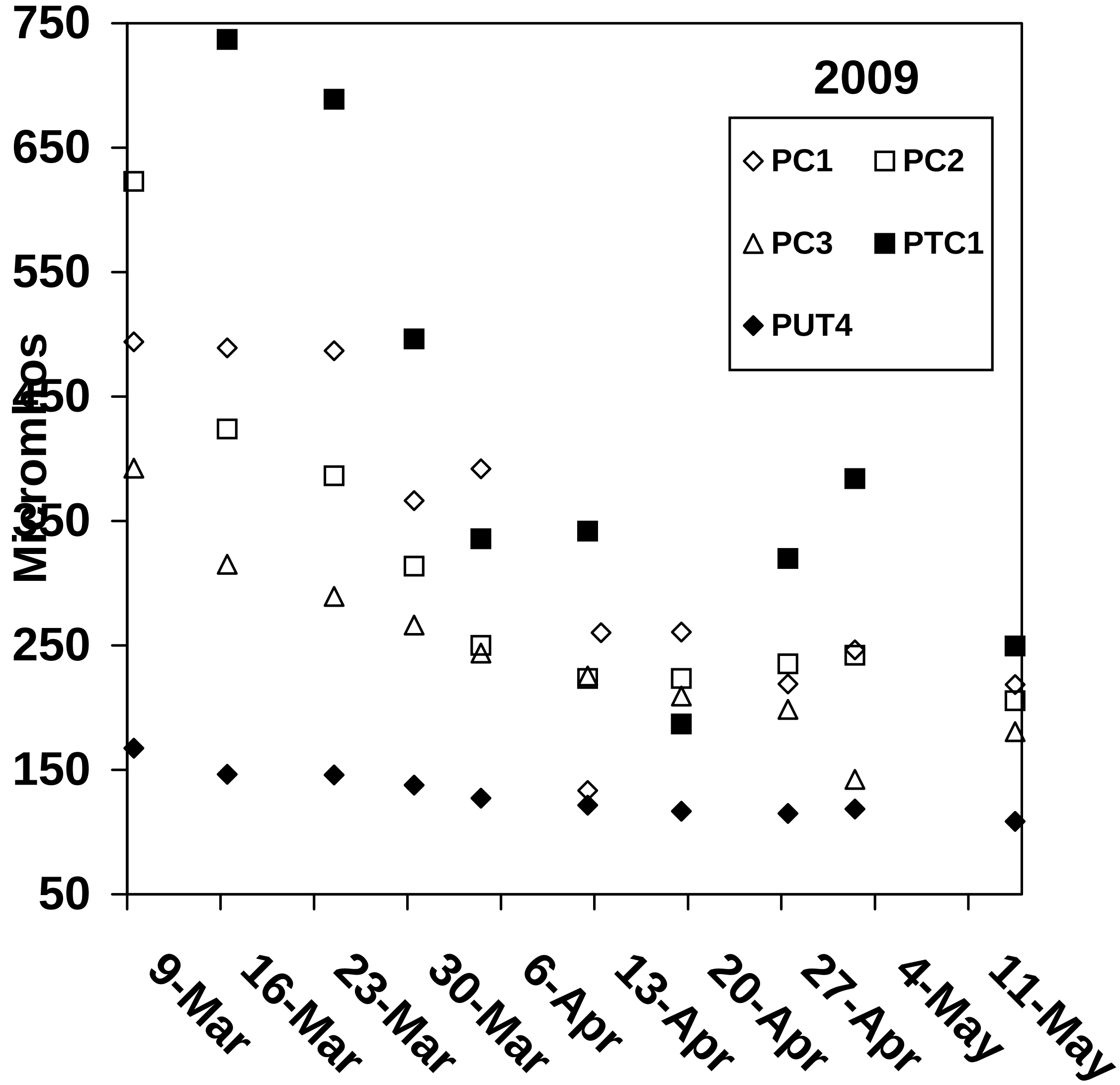


Figure 11. Historic (1970-1989; see Table 1) monthly median conductivity measurements in Mattawoman Creek (between the mouth and Waldorf,) plotted against distance from the mouth of the creek. Tidal (open squares) and non-tidal stations (open triangles) are designated. Predicted historic station medians are indicated by the line. Measurements from 2008 and 2009 stream spawning surveys and a continuous monitor at the Sweden Point Marina (March and April means) are superimposed on the plot and were not used to estimate the predicted line. The two stations furthest upstream are nearest Waldorf.

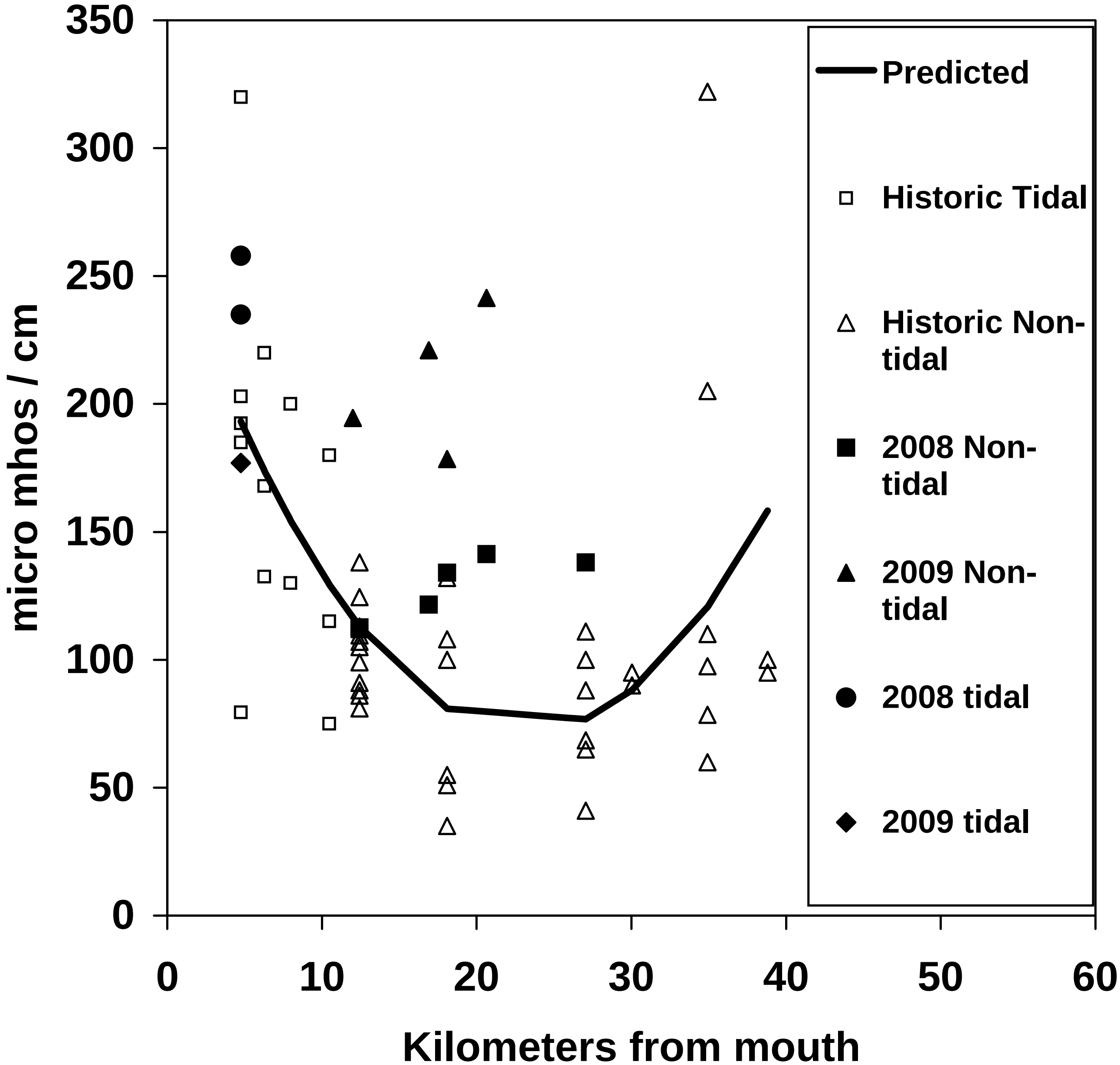


Figure 12. Sampling areas and stations for the spring yellow perch larval presence absence study.

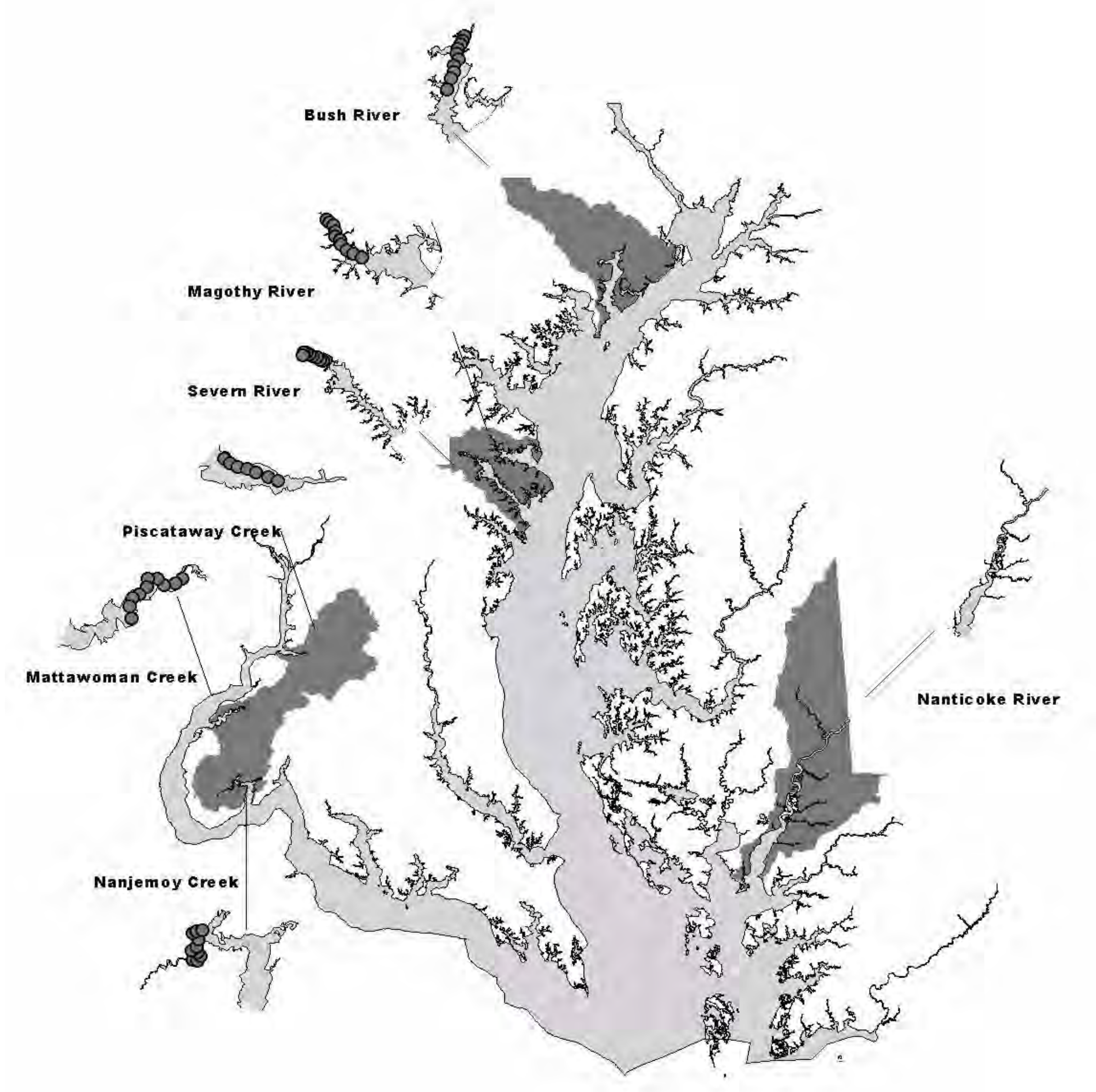


Figure 13. Proportion of tows with larval yellow perch and its 95% confidence interval in systems studied during 2009. Mean of brackish tributaries indicated by diamond and fresh-tidal mean indicated by dash. High and low points of “Historic” data indicate spread of 9 of 11 points and midpoint is the mean of historic period.

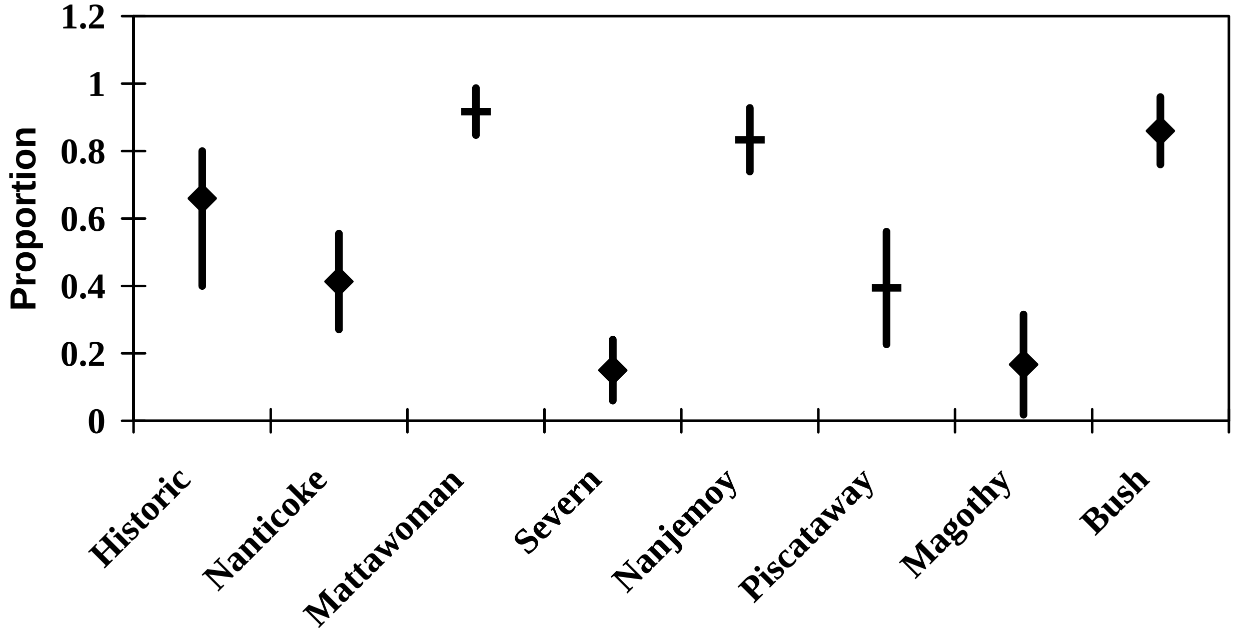


Figure 14. Proportion of tows with yellow perch larvae, by river, during 1965-2009. Dotted lines indicates reference system (Nanticoke and Choptank rivers) and period (prior to 1991) “typical” range..

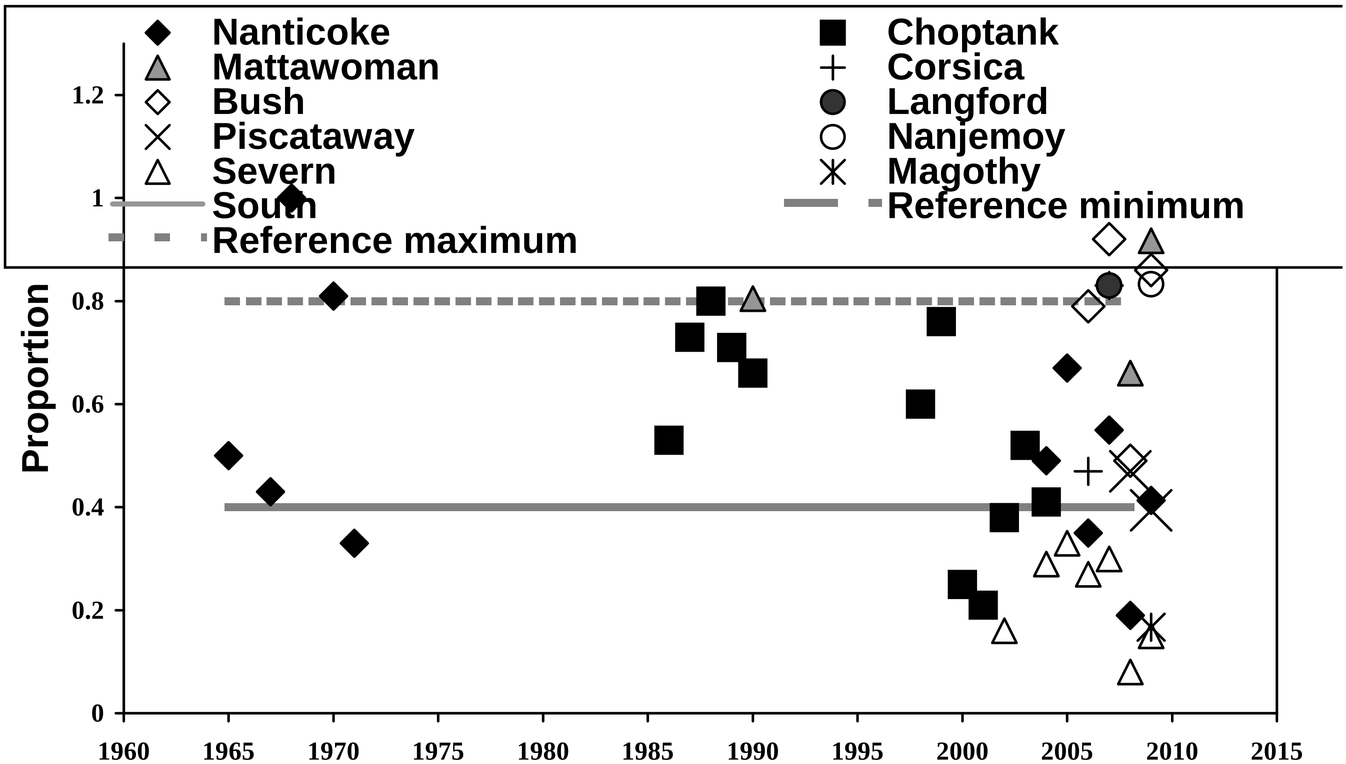


Figure 15. Impervious surface versus estuarine yellow perch larval presence-absence in towed nets 1998-2009. Salinity is treated as a categorical variable.

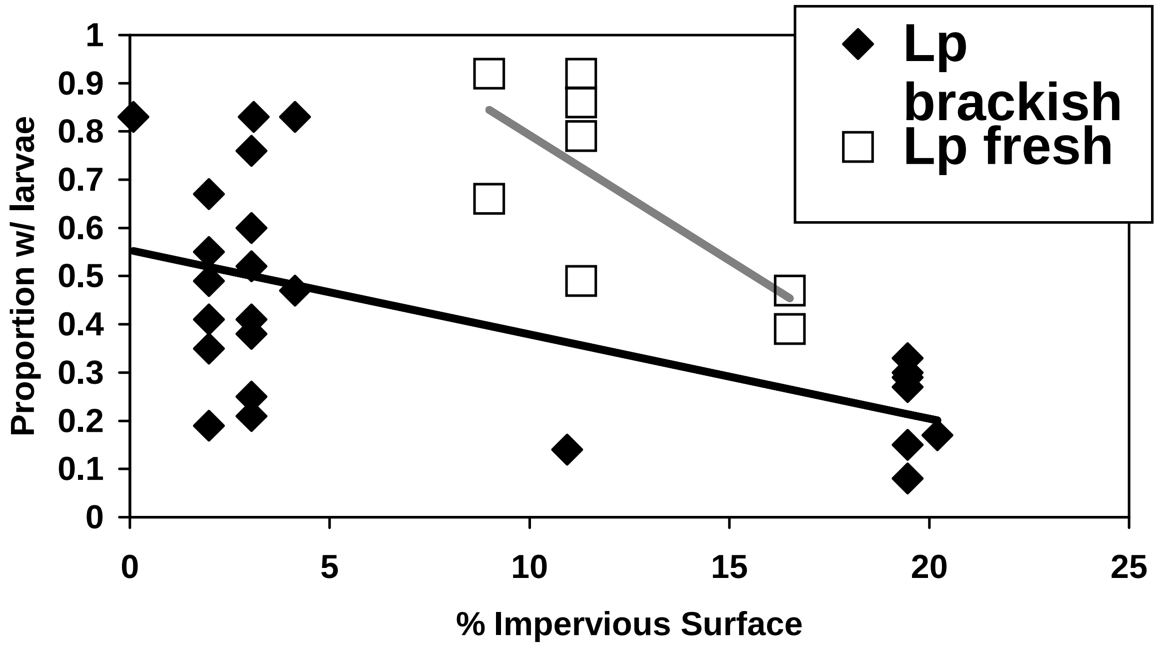


Figure 16. Number (N) of estimates of proportion of plankton tows with yellow perch larvae (Lp) falling within a category during 1965-2009. Severn, South, and Magothy rivers omitted due to suppression of Lp by factors related to impervious surface.

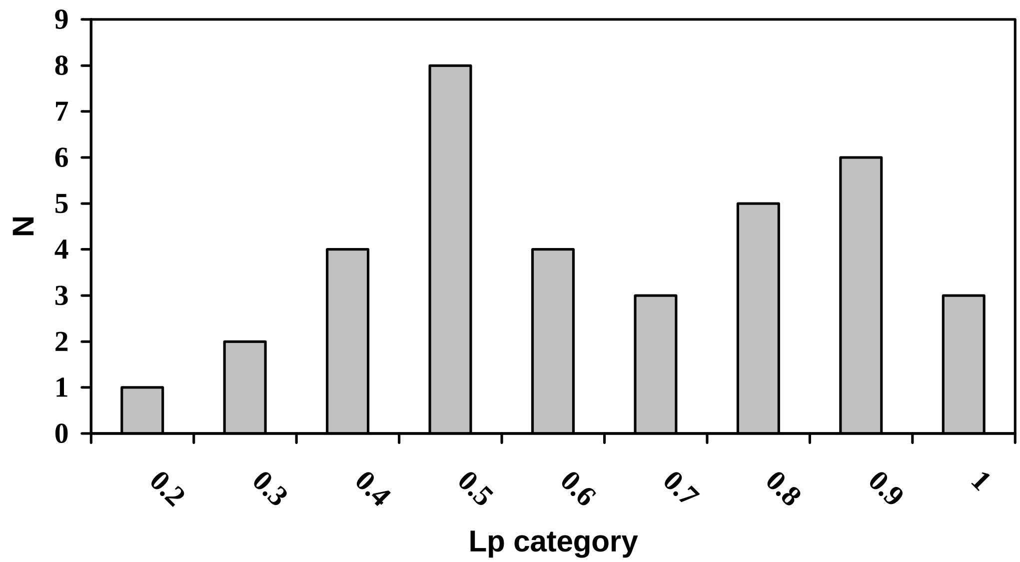


Figure 17. Rivers where seining and trawling was conducted in summer 2009. Watershed areas in Maryland indicated by dark gray shading.

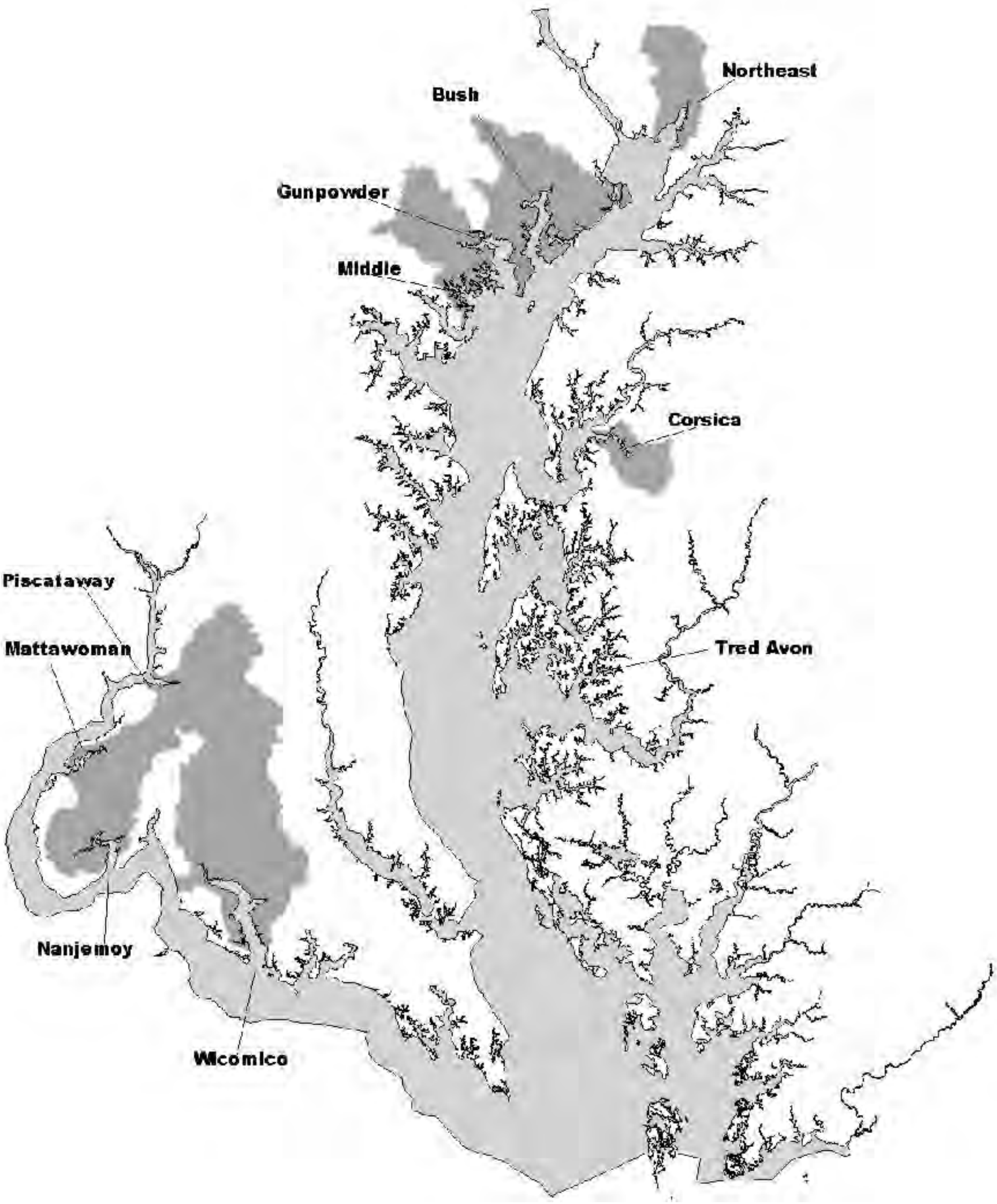


Figure 18. Land use and sampling stations in the Corsica River watershed.

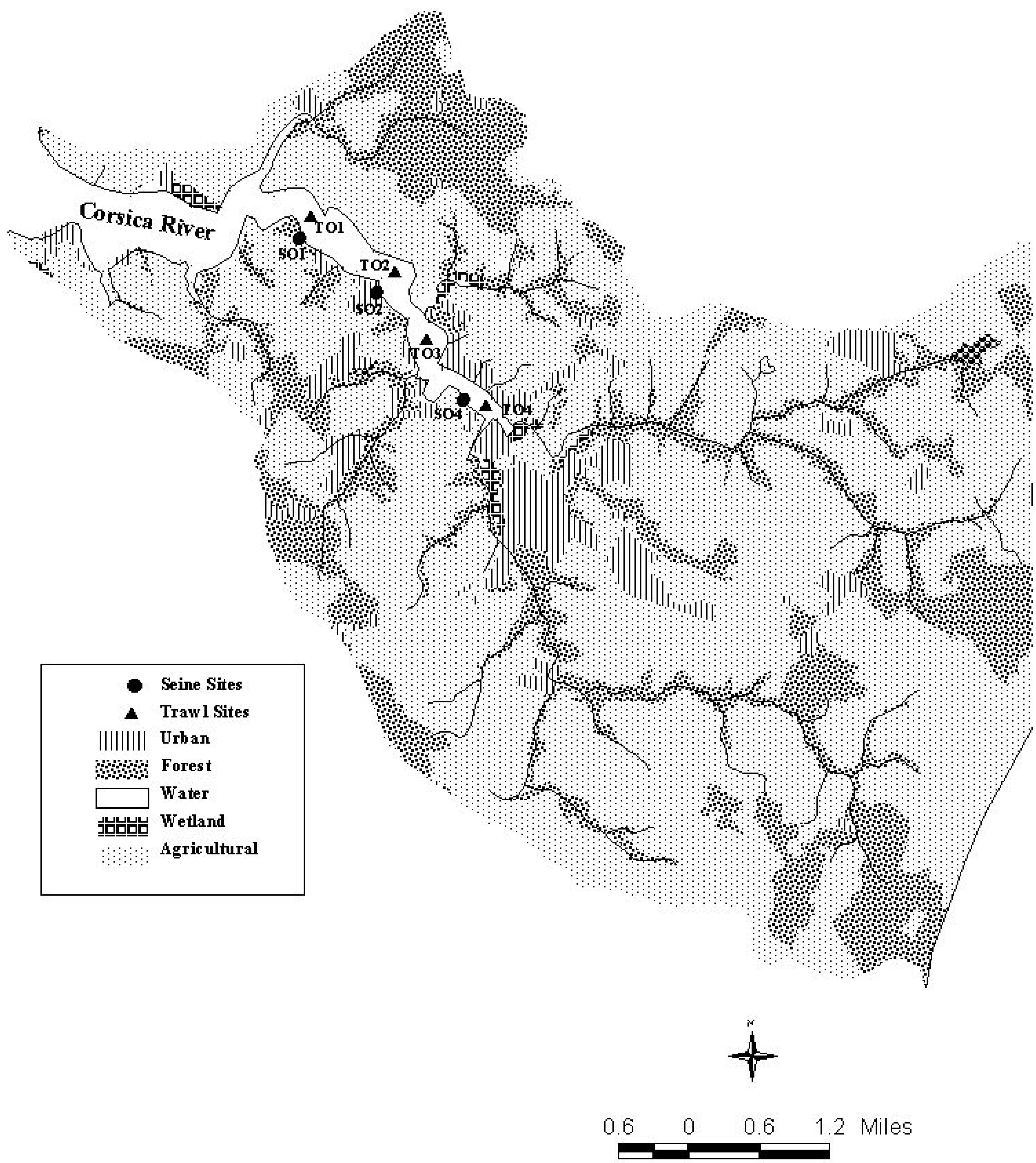


Figure 19. Land use and sampling stations in the Middle River watershed.

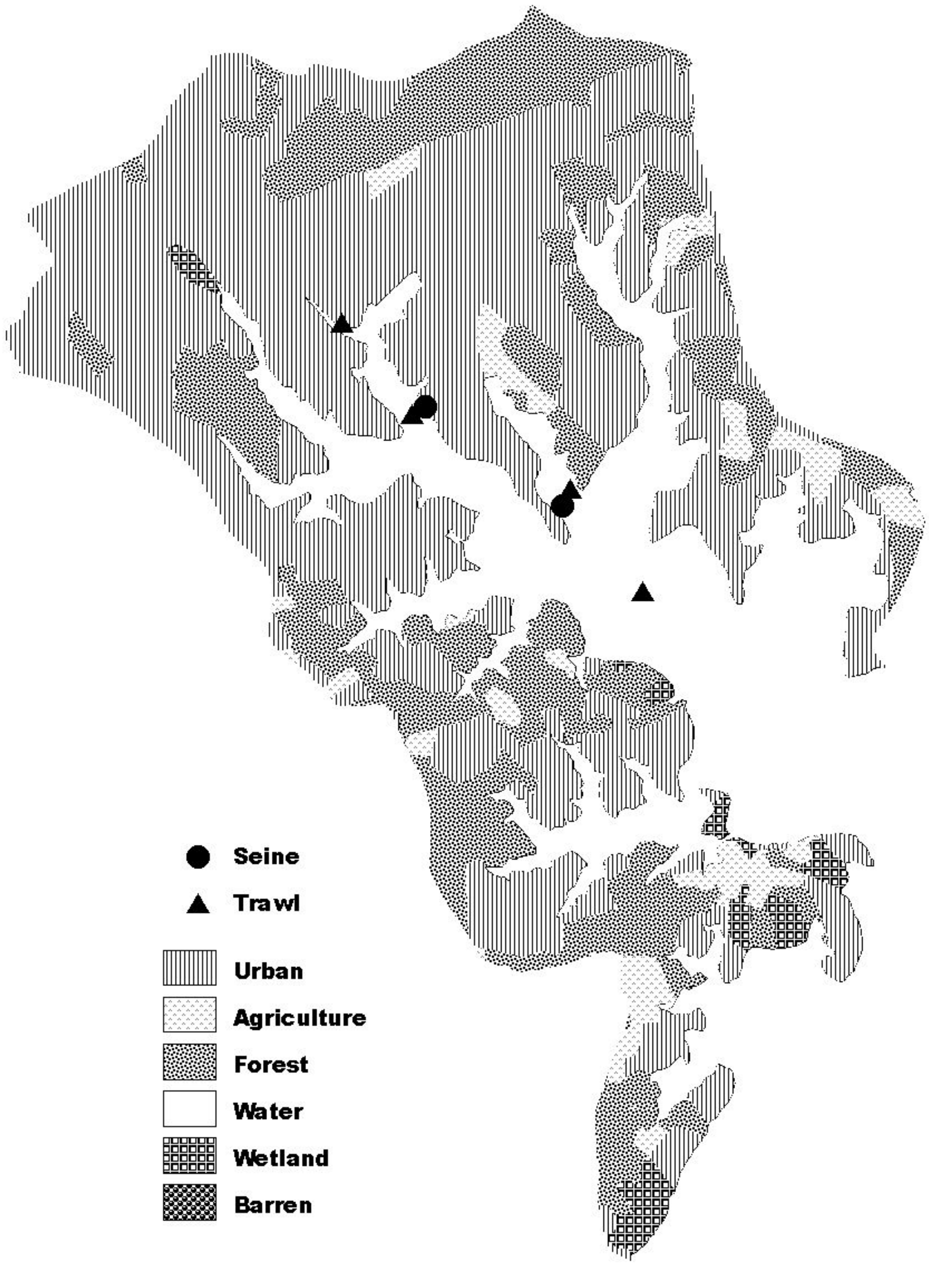


Figure 20. Land use and sampling stations in the Tred Avon watershed.

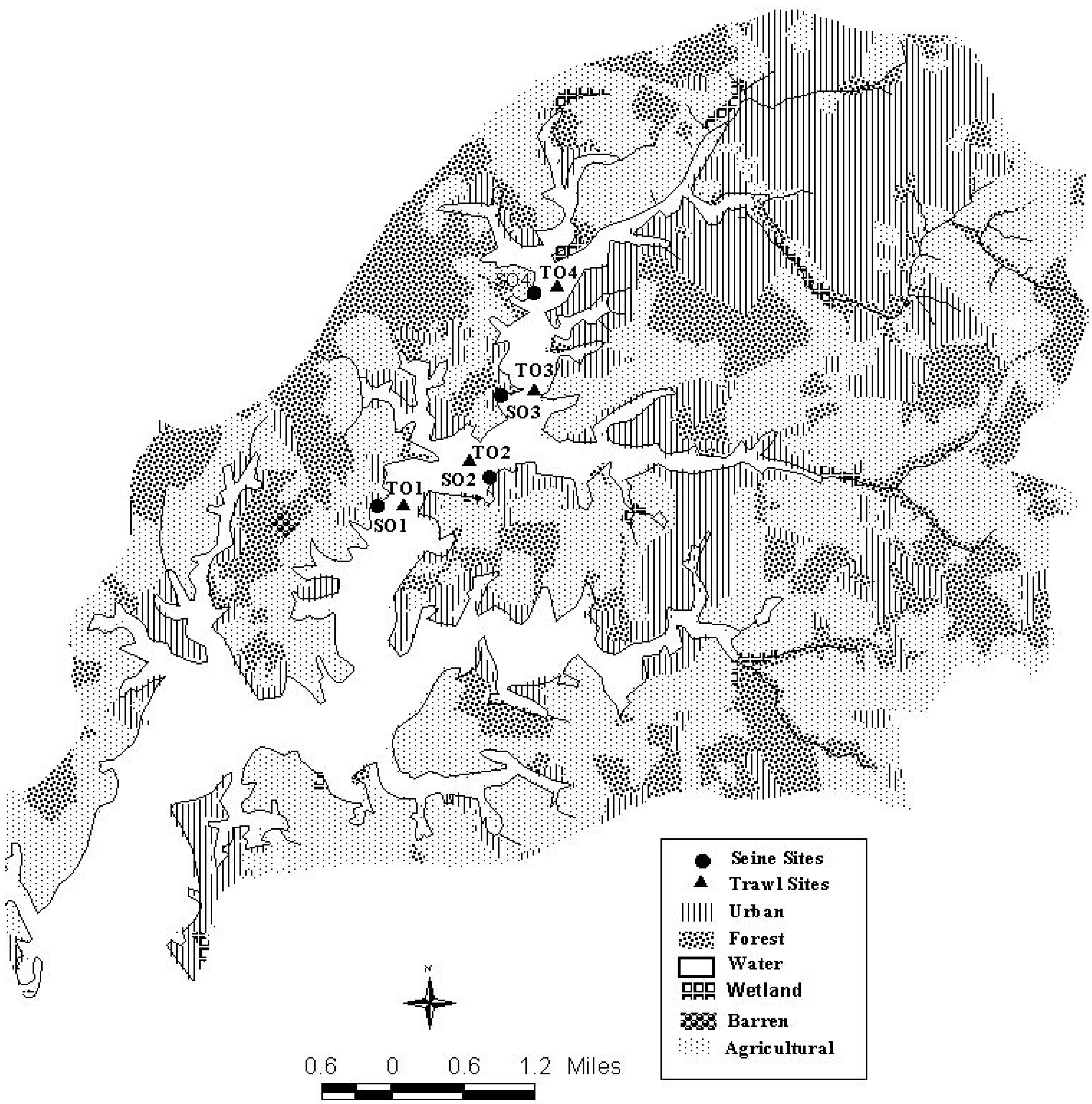


Figure 21. Land use and sampling stations in the Mattawoman Creek watershed.

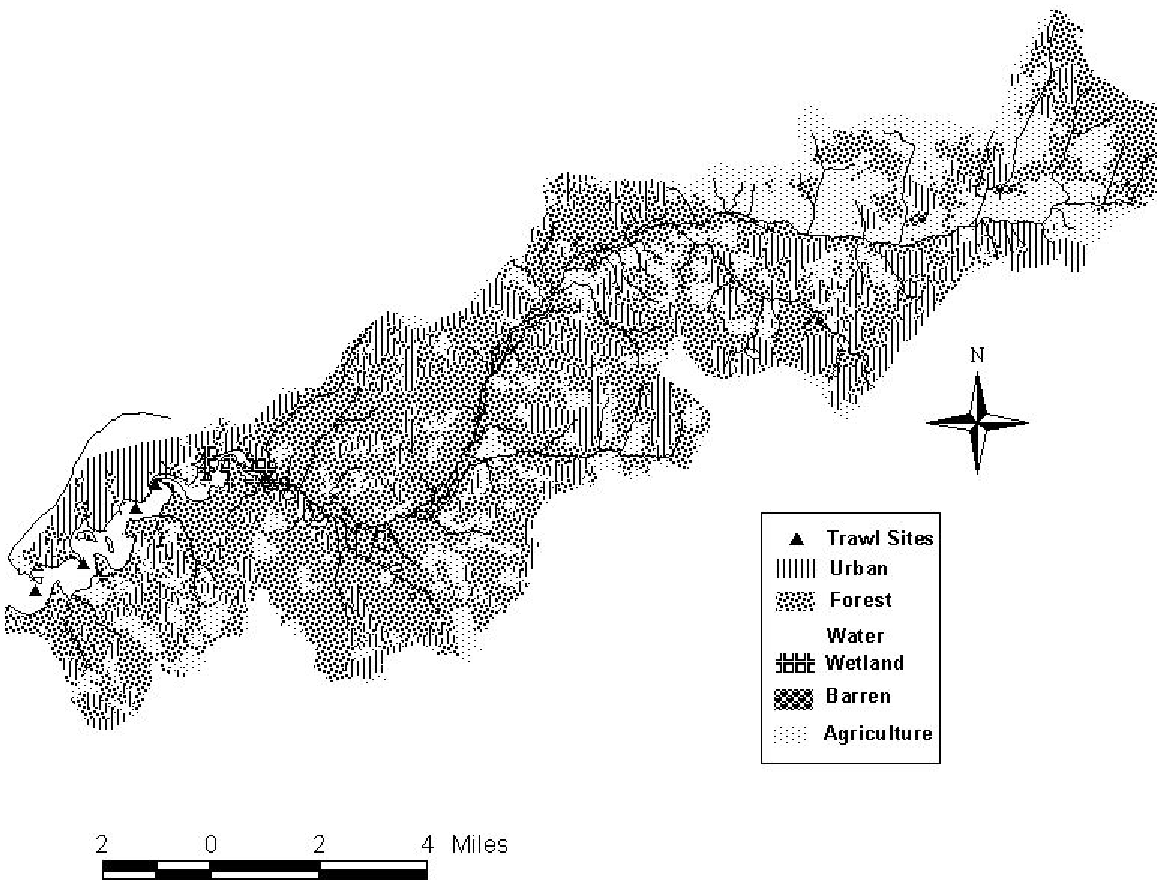


Figure 22. Land use and sampling stations in the Nanjemoy Creek watershed.

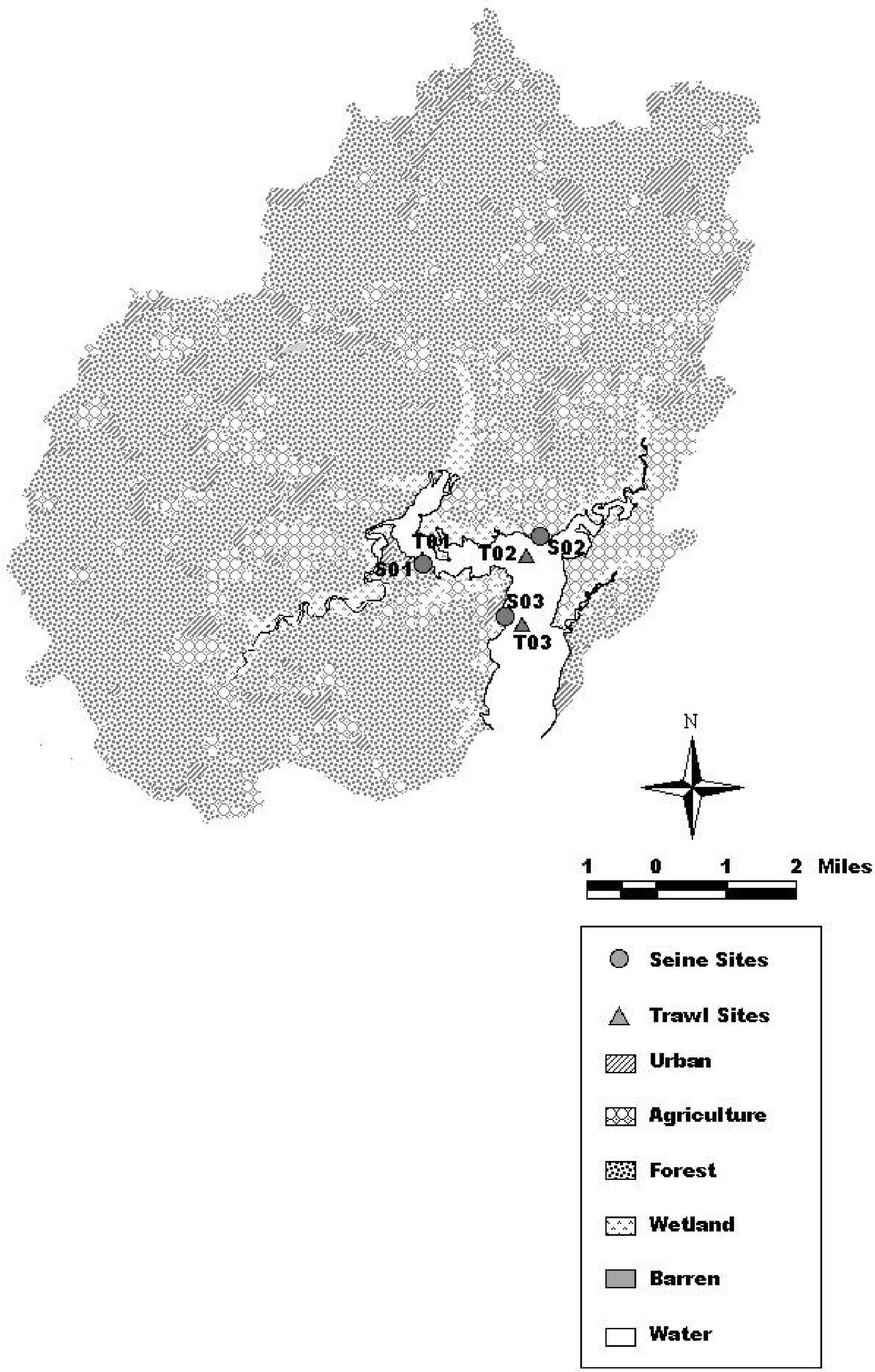


Figure 23. Land use and sampling stations in the Piscataway Creek watershed.

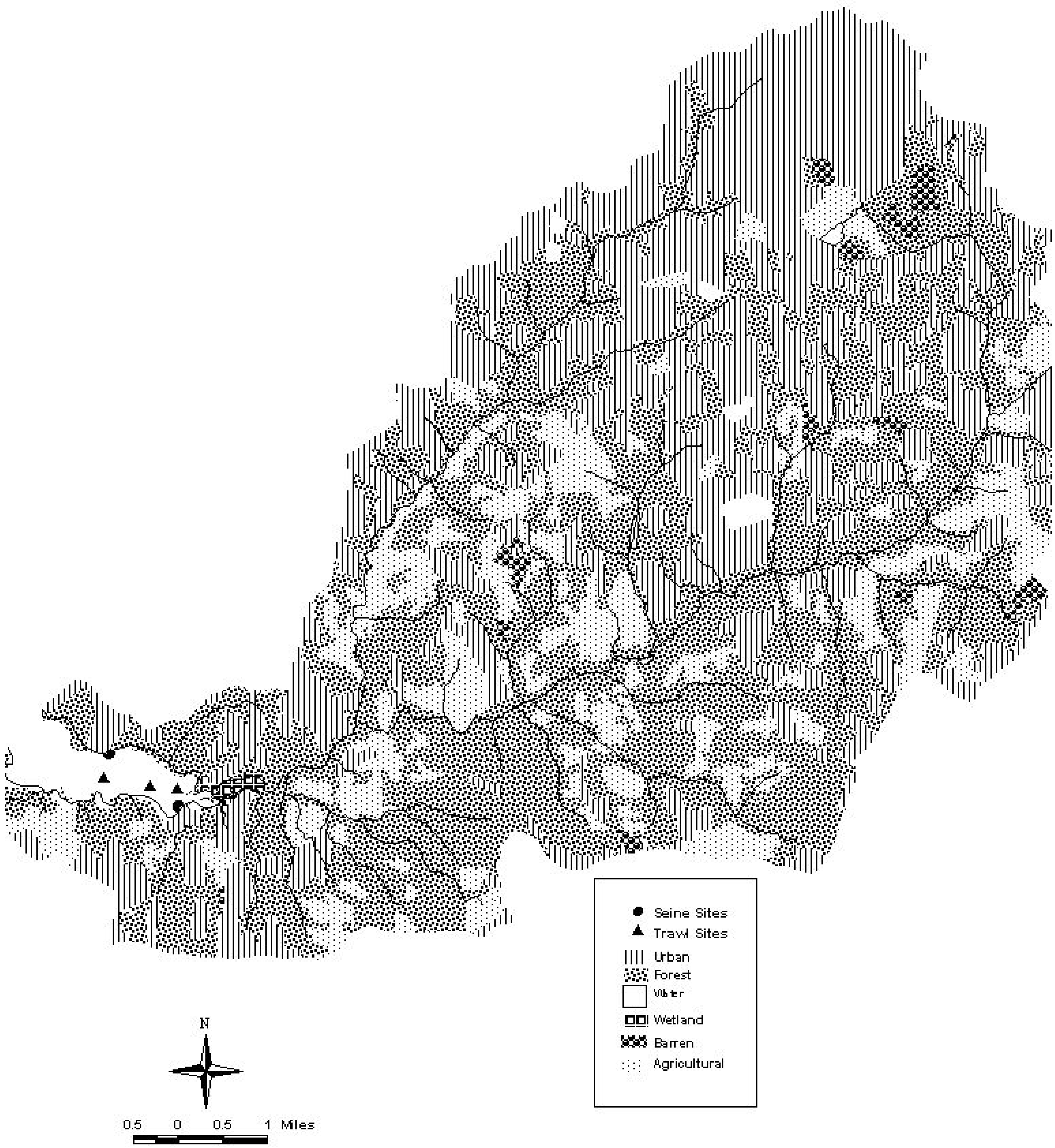


Figure 24. Land use and sampling stations in the Wicomico River watershed.

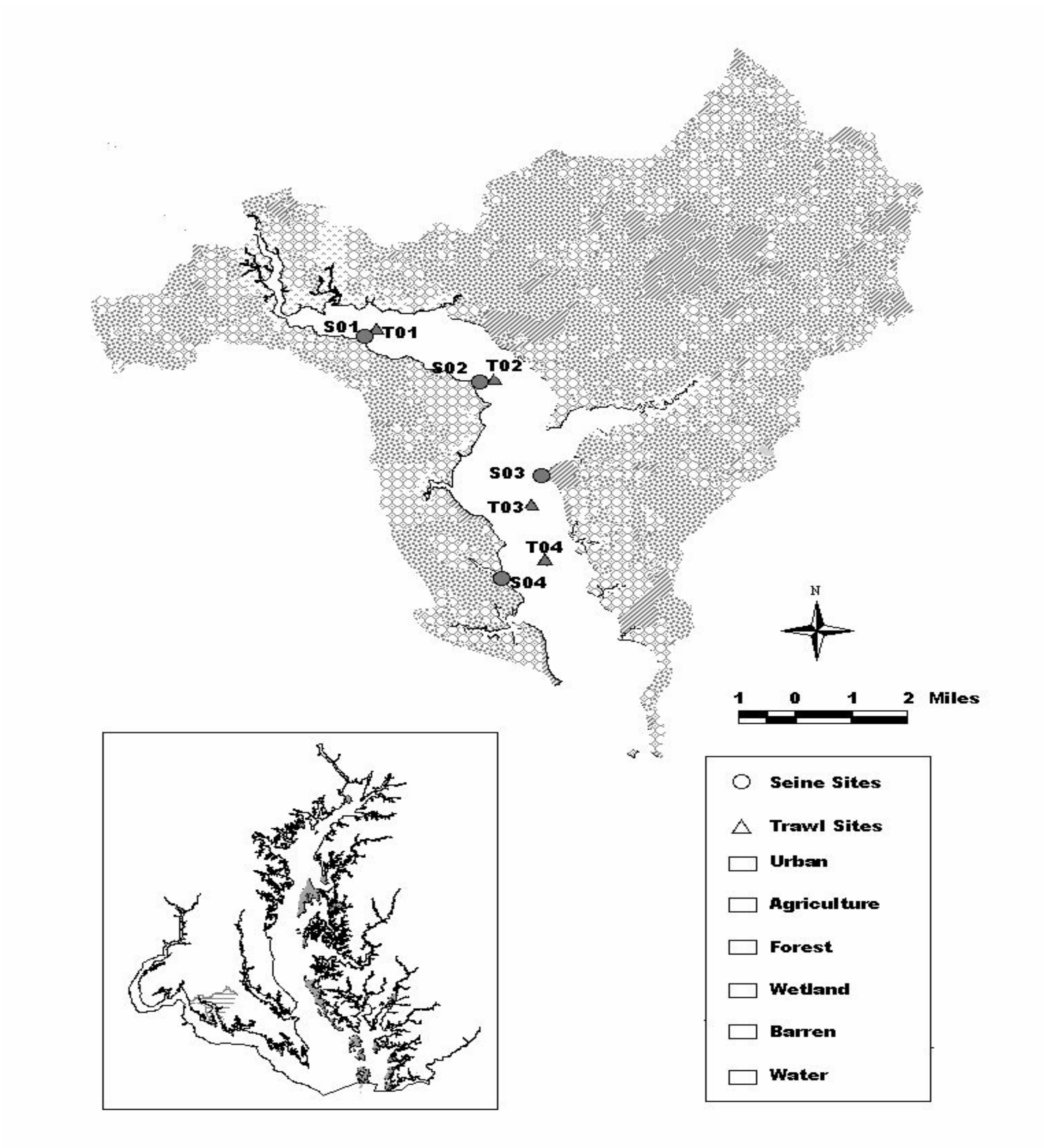


Figure 24. Land use and sampling stations in the Wicomico River watershed.

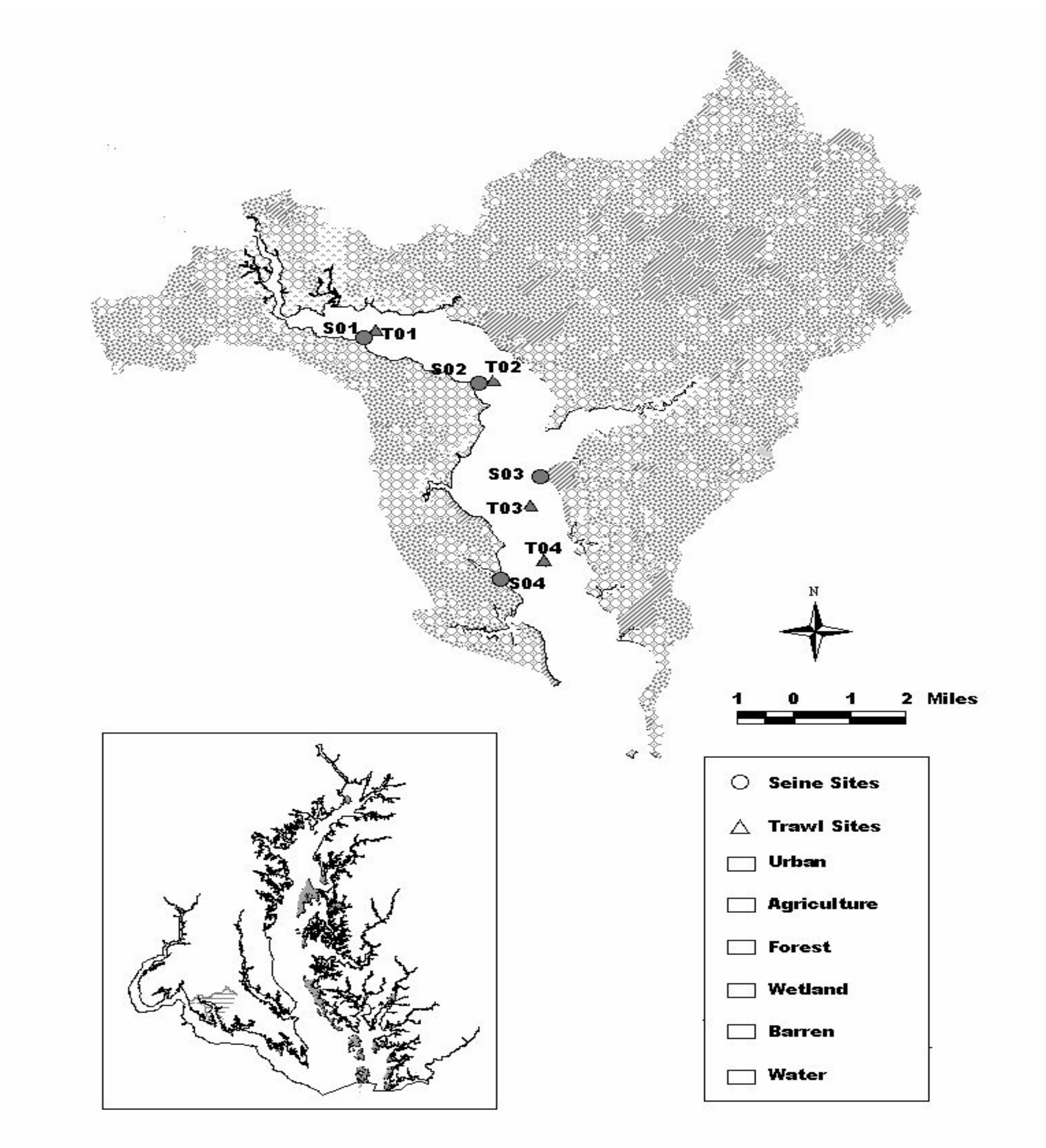


Figure 26. Land use and sampling stations in the Gunpowder River watershed.

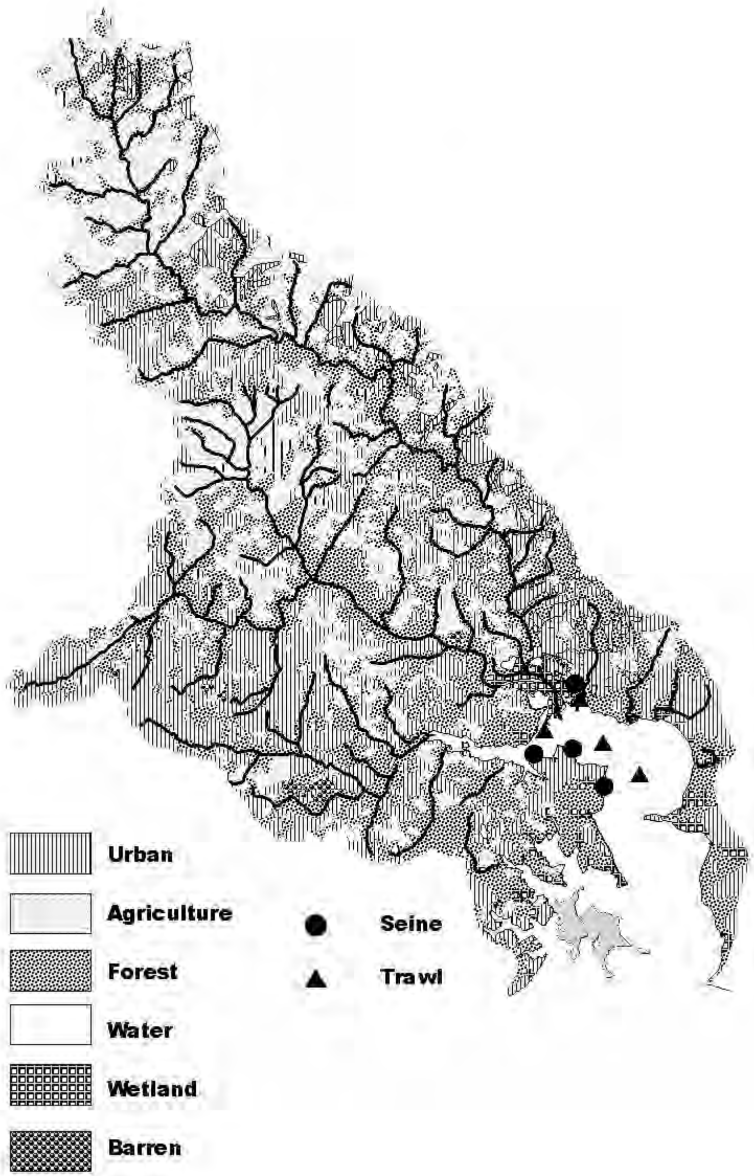


Figure 27. Land use and sampling stations in the Northeast River watershed.

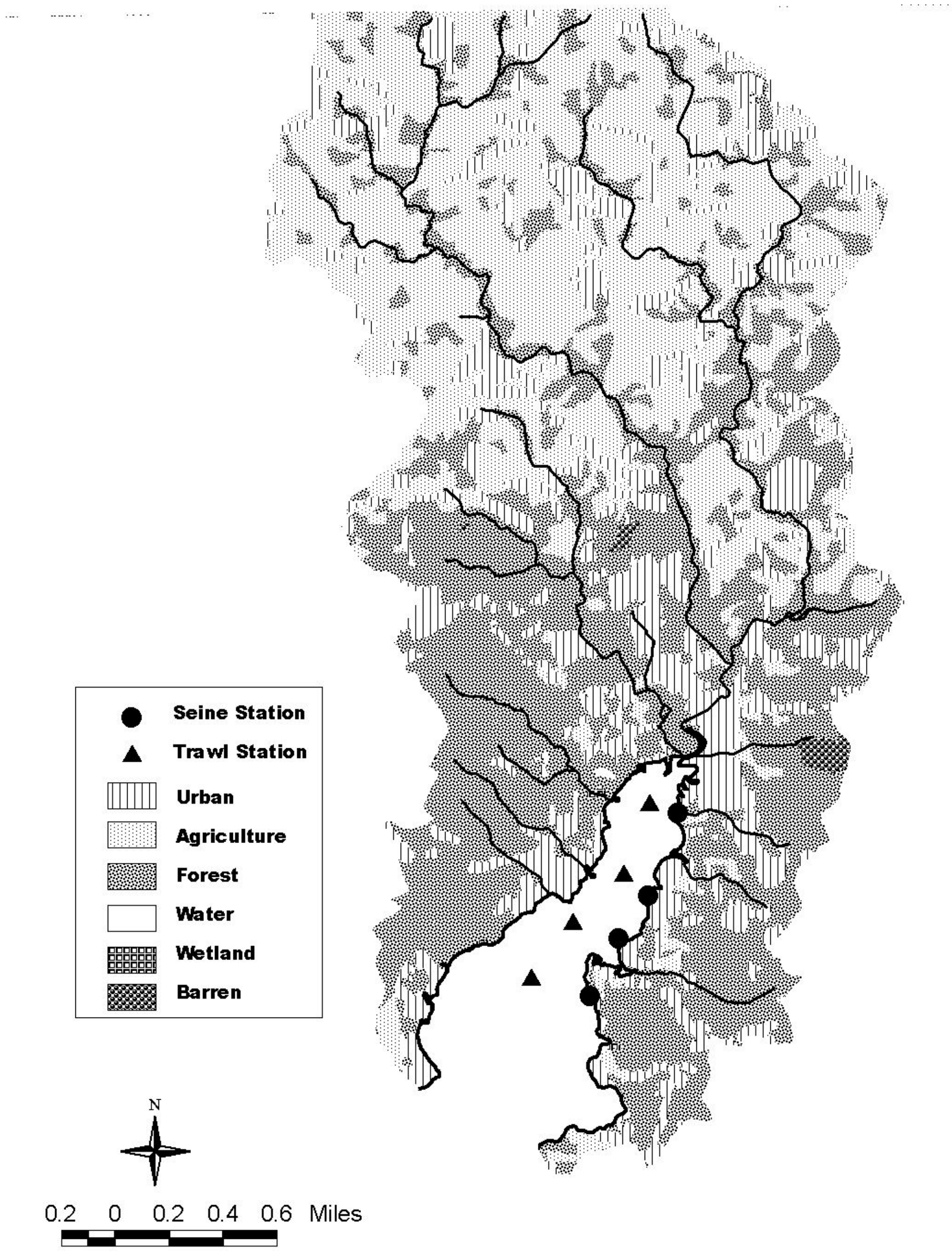


Figure 28. Trends in number of species annually captured (left Y-axis) and average $\log_{10}$ transformed catch of all species of fish (+1; right Y-axis) in Mattawoman Creek during 1989-2009. 10 ft = trawl with 10 foot headrope and 16 ft = trawl with 16 ft headrope.

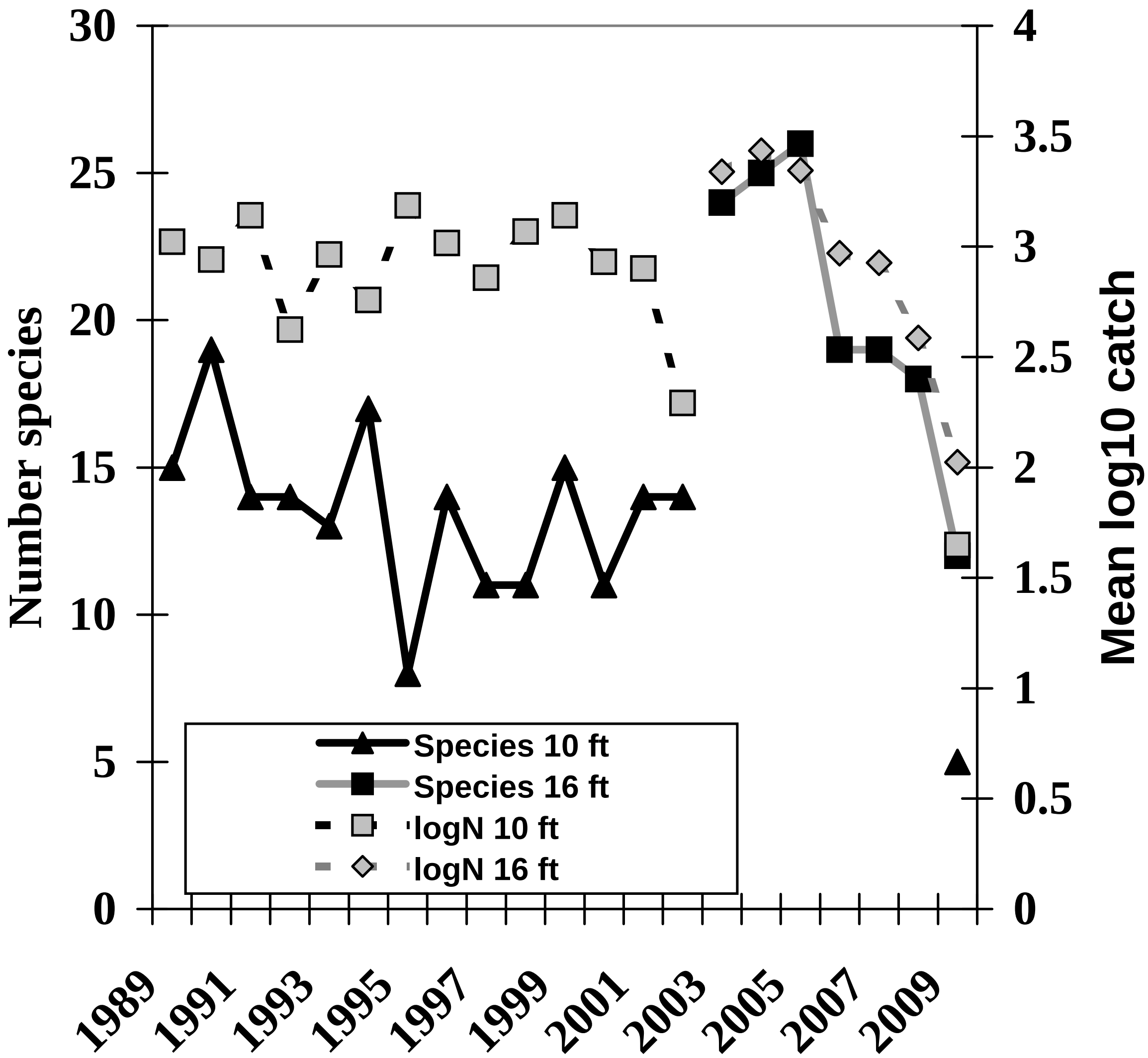
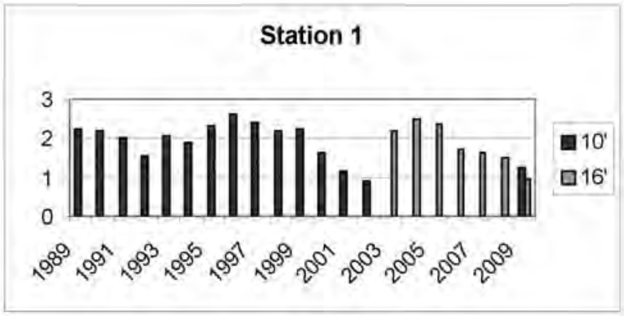
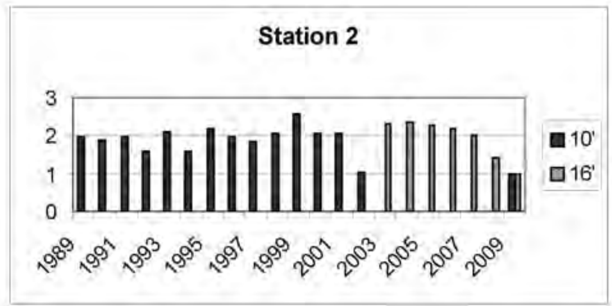
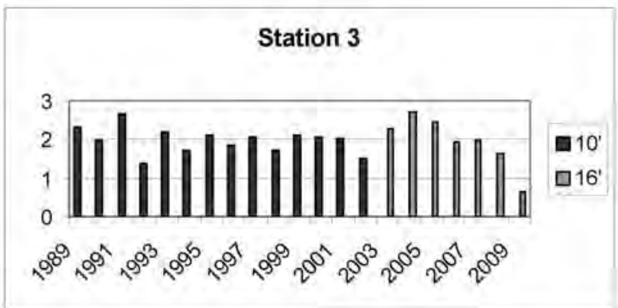


Figure 29. Log_{10} catch per effort by station and trawl type in Mattawoman Creek, 1989 to 2009; 10 ft and 16ft trawls were used at all stations.







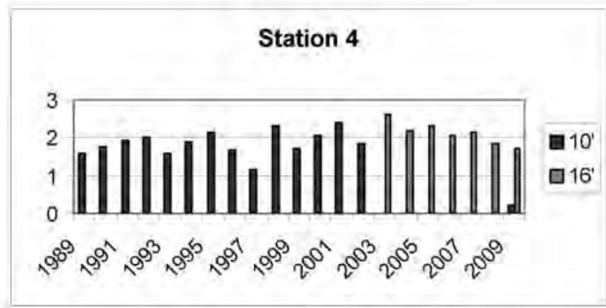


Figure 30. Striped bass sampling stations on the Upper Potomac River.

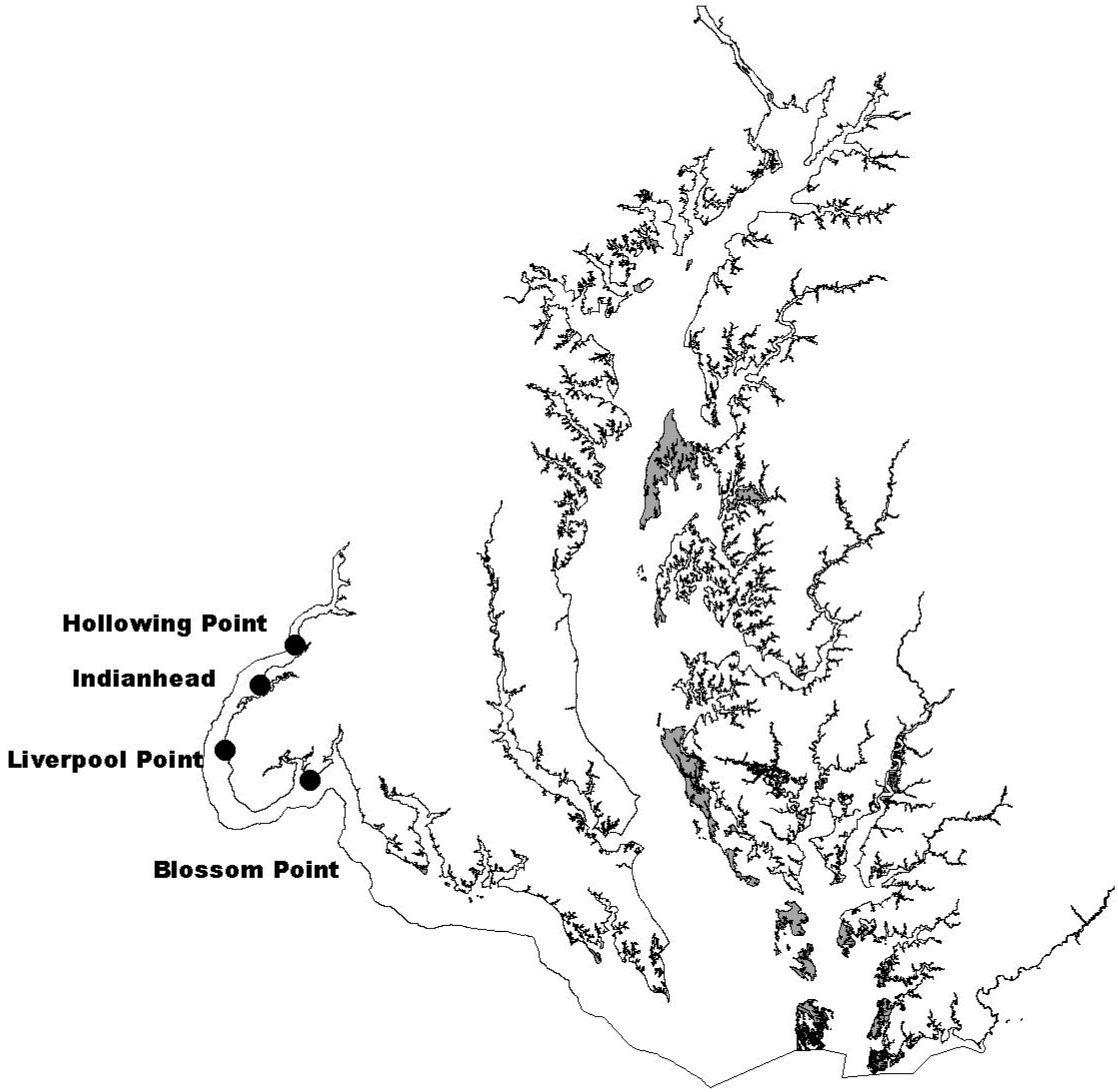


Figure 31. Species richness (number of species) by striped bass seining sites by year from 1989 to 2009. (Data provided by Eric Durell.)

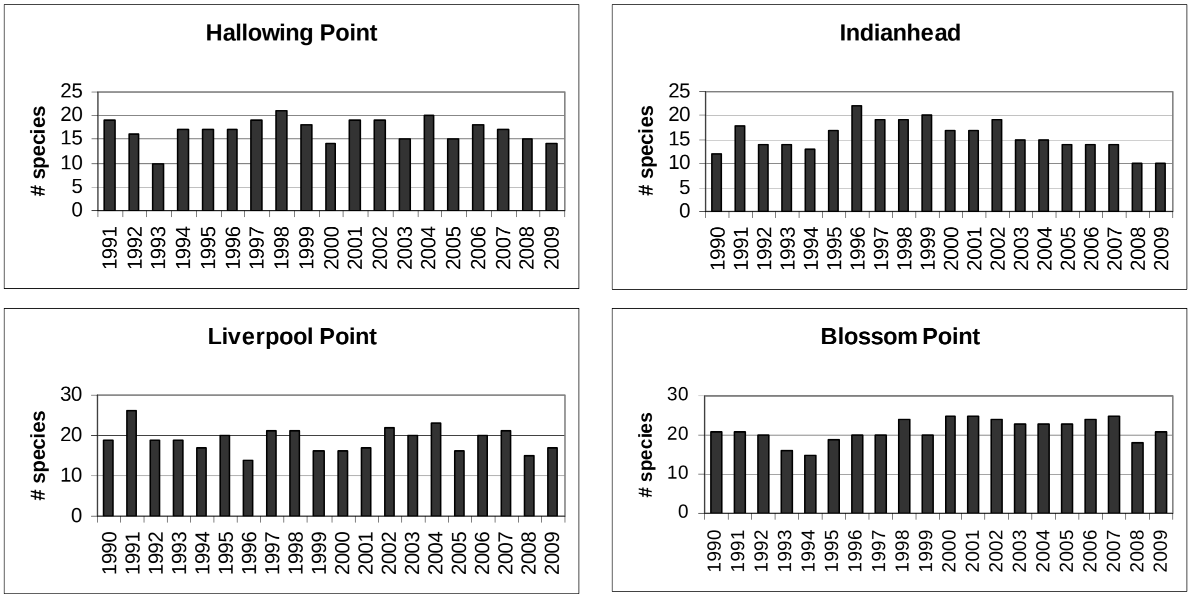


Figure 32. Species comprising 90% of the catch at striped bass seining sites from 1989 to 2009. (Data provided by Eric Durell.)

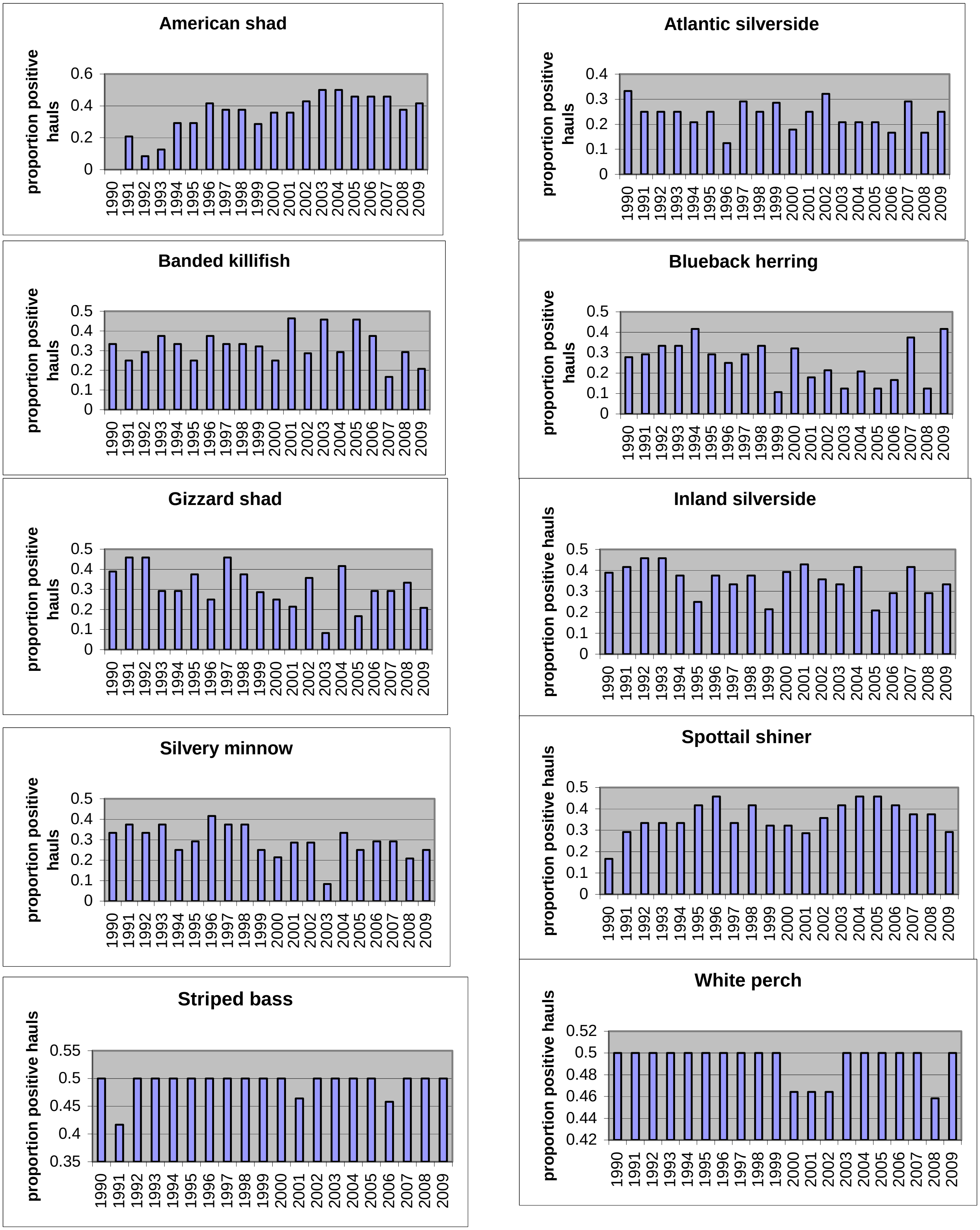


Figure 33. Observed and predicted number of species and mean log10-transformed catch (+1) plotted against number of structures built in Mattawoman Creek's watershed from 1989-2008. A 10 ft trawl (squares) was used to sample during 1989-2002 and a 16 ft trawl (diamonds) was used from 2003-2008. Species = number of species and P Species = predicted number of species. Log10 N = mean log10-transformed catch (+1). P Log10 N = predicted mean log10-transformed catch (+1).

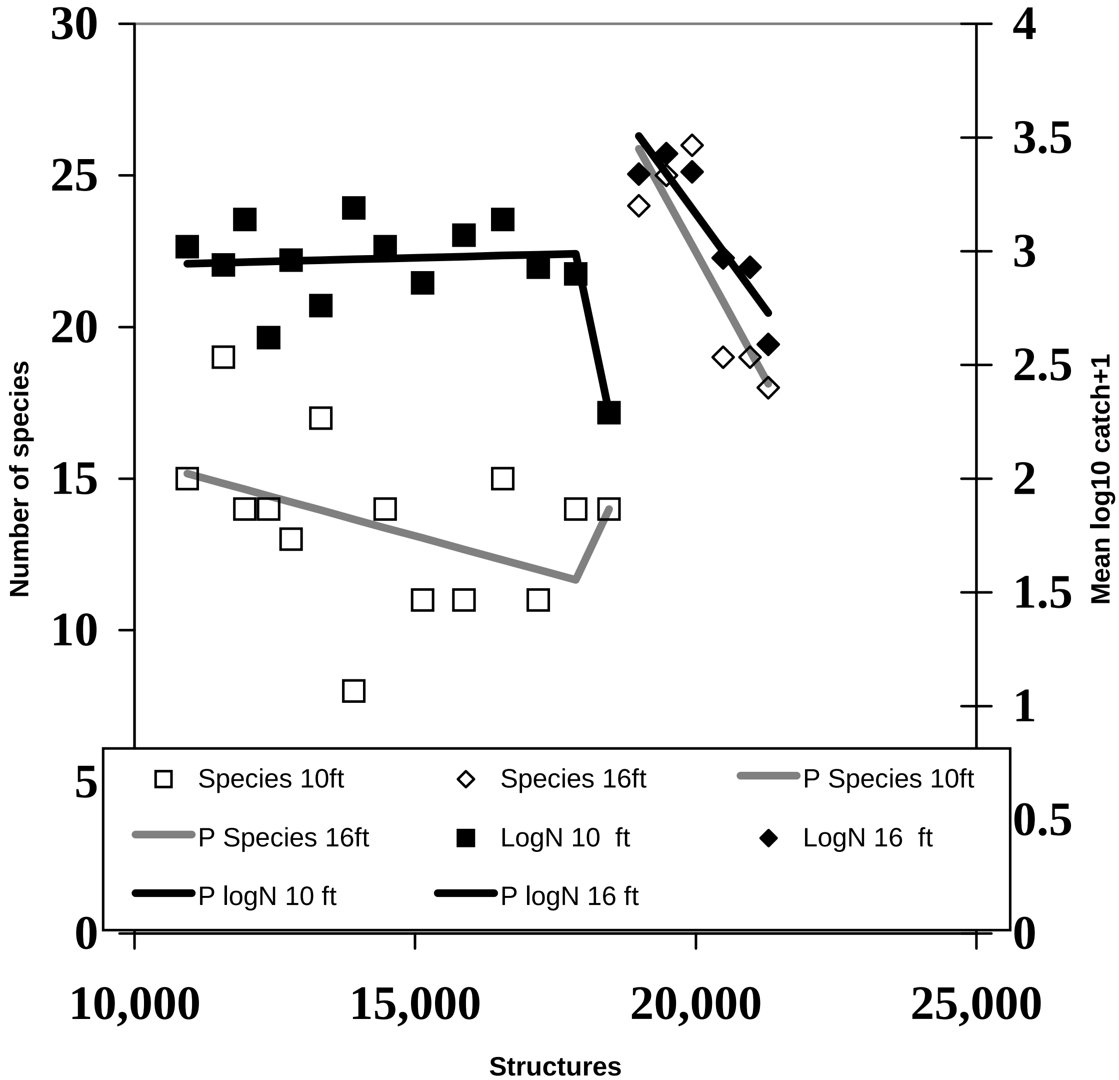


Figure 34. Box and whisker plot of bottom dissolved oxygen in Mattawoman Creek from 1989 to 2009. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

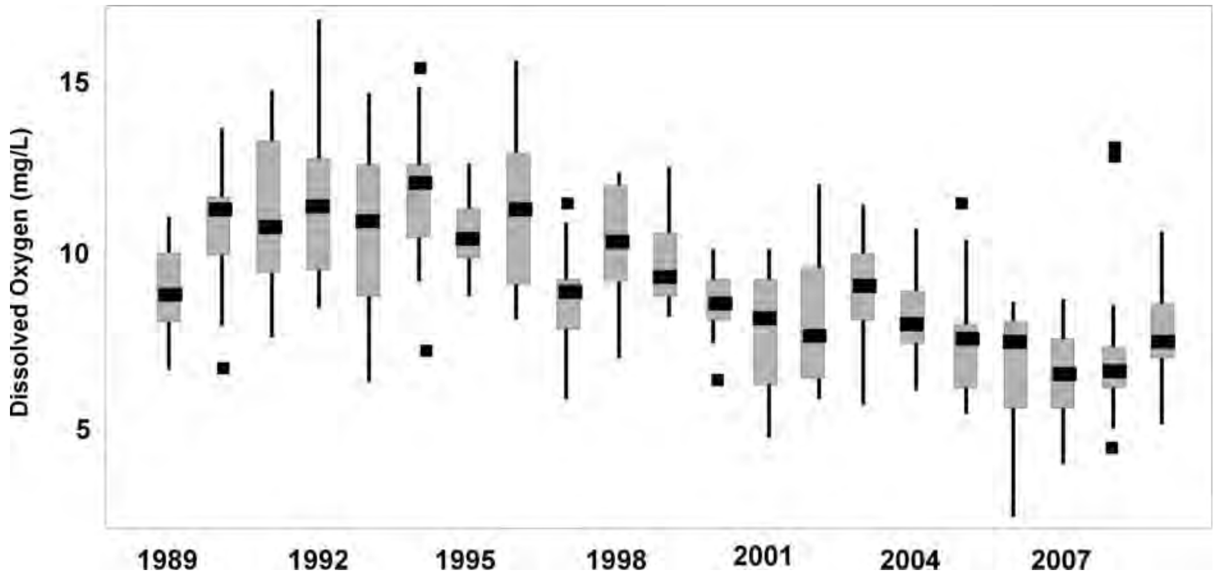


Figure 35. Proportion of violations of 3.0 and 5.0 mg/L criteria in the Corsica River.

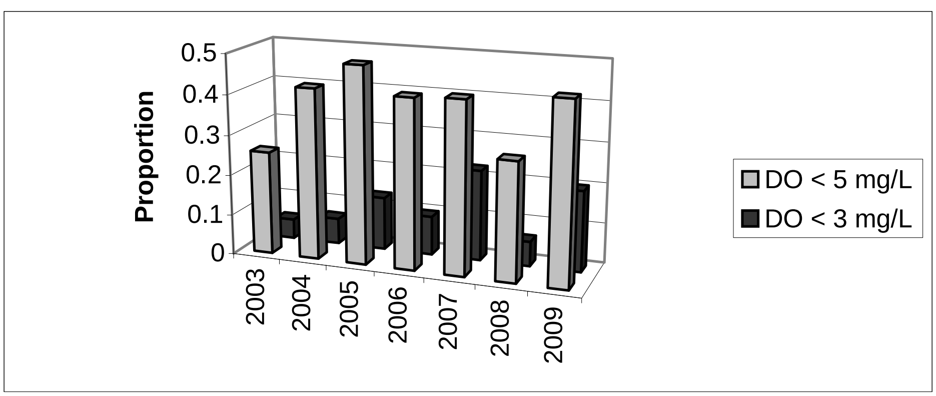


Figure 36. Proportion of temperature violations in Corsica River.

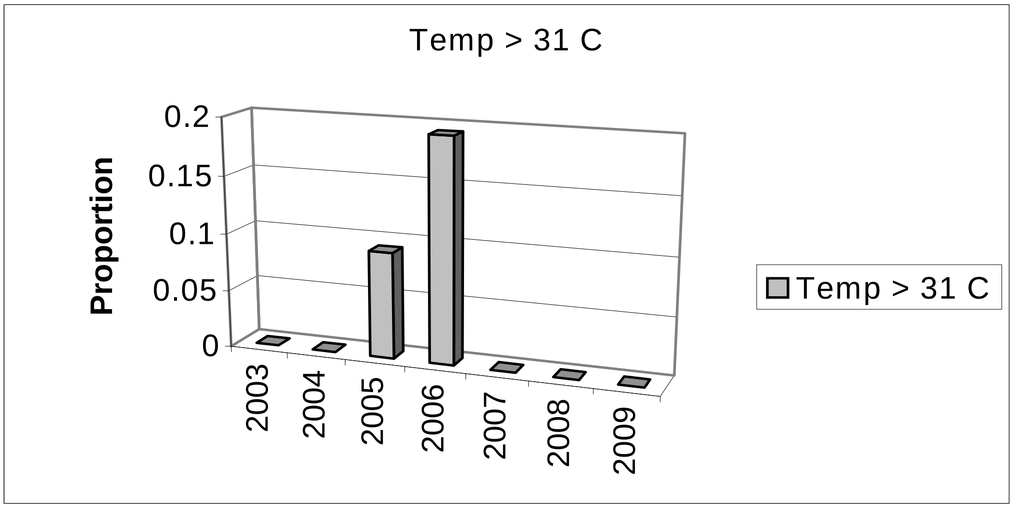


Figure 37. Number of species by year and gear type in the Corsica River.

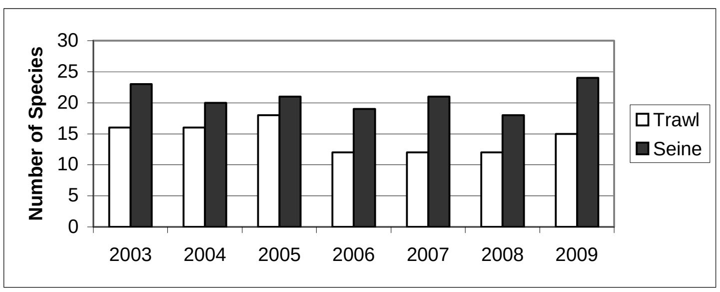


Figure 38. Number of species in the seine in Wicomico River, 1989-2009.

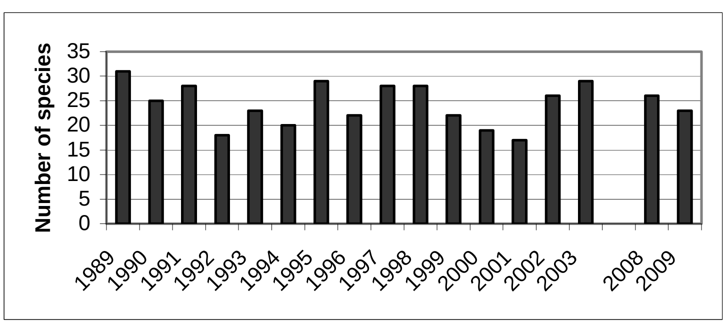


Figure 39. Number of species in the trawl in Wicomico River, 1989-2009. Note: We shifted from a small (10’ trawl) to a large (16’ trawl) in 2003.