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

STATE: Maryland

PROJECT NO.: F-61-R-4

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish / Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2007 through October 31, 2008

Executive Summary

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

White perch population abundance, instantaneous fishing mortality (F), and recruitment trends were determined using a surplus production model. Bay-wide biomass and fishing mortality estimates were compared to biological reference points. Model results indicated steady population growth from 1980 – 1993. Biomass declined slightly through 2002, and was stable through 2007. Biomass was approximately 30% 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}, white perch stocks were not considered over-fished. Instantaneous fishing mortality was high in the early 1980's, and declined to a time series minimum in 1990. Fishing mortality then increased from 1990 through 2005. Fishing mortality declined in 2006 and 2007 to levels lower than any year since 1995. The 2007 F estimate was below the suggested biological reference point that indicates that over-fishing was not occurring. Bay-wide juvenile production was generally high during 1993 – 2008, but juvenile production was below average in 2006 and 2008. Choptank River white perch stocks were assessed with a catch survey analysis. The model indicated increasing population growth since 1989, and was estimated to be near 6 million fish in 2007. A suite of biological reference points were produced in a previous assessment and compared to F estimates generated for Choptank River white perch. Fishing mortality in the Choptank River exceed the proposed target from 1991 through

2002, but has been below the target F rate since 2002. These results indicated that over-fishing was not occurring in the Choptank River.

Adult American shad stocks in Maryland have declined precipitously since 2001 even though significant improvements have been accomplished in water quality and habitat. The complexity of the problem is both a localized issue involving Chesapeake Bay tributary by-catch and ocean by-catch, fish lift losses on the Susquehanna River and coastal and Chesapeake Bay predation. Bay wide juvenile American shad production decreased in 2008 and may be attributed to very low spawning stock biomass. The dramatic declines in American shad stocks are being addresses through the Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 and action by the Management Board should occur during 2010.

Adult hickory shad relative abundance indices in Deer Creek remained stable but Nanticoke River indices remained at low levels and may not accurately depict the status of adult stocks in this system. Juvenile sampling encountered few hickory shad and the low numbers appears directly related to sampling gear aversion. In general, hickory shad stocks are not significantly affected by ocean by-catch and predation as reflected in the low estimated total mortality rates. Consequently, Maryland Chesapeake Bay stocks of this species appears stable.

Adult alewife and blueback herring stocks in Maryland remained at very depressed levels. This is indicated by the low adult indices from the Nanticoke River, statewide landings being less than four percent of the high for the time series, and high estimated total mortality rates. Juvenile indices were also very low in 2008 and may be indicative of adult abundance below some critical threshold level necessary for stock stabilization and future growth. ASMFC's Management Board is also preparing to act on Amendment 2 which will likely reduce fishing mortality for both species and should include both coastal recommendations and in-state mandates.

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 low in 2007 (11,910 fish). Maryland's commercial weakfish harvest declined to 11,910 pounds in 2007, and was the lowest catch on record. The 2008 mean total length (TL) for weakfish from the pound net survey was 276 mm TL, the third lowest of the time series. The 2008 length frequency distribution and RSD analysis indicated that only smaller weakfish were available in Maryland waters. Fish aged from the 2007 pound net survey were all 4 years of age or younger.

Summer flounder mean length from the pound net survey was 347 mm TL in 2008, close to the 15 year survey average. Relative stock densities in 2008 indicated a shift up from the stock category to the quality and preferred category compared to 2007. Both commercial and recreational harvest of summer flounder increased in 2007. The NMFS 2006 coast wide stock assessment concluded that summer flounder stocks were not overfished, but that overfishing was occurring.

Mean length of bluefish from the 2008 pound net survey was 260 mm TL, 2nd lowest of the 1993-2007 survey. Length distribution and RSD analysis indicated a shift back to smaller bluefish in 2008. Both recreational and commercial bluefish harvest levels increased in 2007, but were still below average for Maryland. The latest coast wide stock assessment indicated the stock was not overfished and overfishing is not occurring.

The mean length of Atlantic croaker examined from the pound net survey in 2007 was 298 mm TL, average for the time series. Length frequency distribution and RSD analysis for Atlantic croaker indicated a broadening of the size structure in 2008. Fish aged from the 2007 pound net survey ranged in age from 1 – 12 years old. Maryland Atlantic croaker total commercial harvest increased in 2007 (474,338 pounds), as did the 2007 recreational harvest, estimated at 1,092,784 fish.

Spot length frequency distribution continued to truncate in 2008, and the mean length was the 6th lowest of the time series. Juvenile indices have been lower in recent years than the long-term average, but did increase in 2008. Commercial and recreational harvest increased sharply in 2007. The percent of spot over 254 mm TL in the 2008 pound net samples was less than one percent, which was lower than the previous 5 years.

Resident / premigratory striped bass present in the Chesapeake Bay during the summer – fall 2007 pound net and hook and line commercial fisheries ranged from 2 to14 years of age. Four year old striped bass from the 2003 year-class dominated samples taken from pound nets, composing 51% of the sample in 2007. Check station sampling determined that the majority of the pound net and hook-and-line fishery harvest was composed of four and five year old striped bass from the 2002 and 2003 year-classes.

The 2007-2008 commercial striped bass drift gill net fishery harvest was comprised primarily of fish between 4 and 7 years old from the 2001, 2002, 2003 and 2004 year-classes. Striped bass from the 2003 year-class comprised 51% of the total drift gill net harvest. Year-classes 2004, 2002, and 2001 (ages 4, 6, and 7) made up 35% of the total harvest while age 8 to 14 year-old fish contributed 13% to the total. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from age 3 to14 (1994 – 2005 year-classes).

The spring, 2008 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 18 years old. Age 4 (2004 year-class) and age 5 (2003 year-class) male striped bass were the most abundant component of the male striped bass spawning stock. Age 12 (1996 year-class) females were the major contributors to 2008 total female abundance. Age 8 and older females comprised 95% of the female spawning stock in 2008. The Chesapeake Bay striped bass spawning stock remains healthy and is closely monitored by MD DNR biologists in partnership with other coastal states through the Atlantic State's Marine Fisheries Commission.

The 2008 striped bass juvenile index, a measure of striped bass spawning success in Chesapeake Bay, was 3.2, below the long-term average of 11.7. During the survey DNR biologists collected 422 young-of-year (YOY) striped bass. Healthy striped bass populations are known for such highly variable spawning success. This is only the third time in the past decade that striped bass reproduction in Maryland's Chesapeake Bay has been below average. Two of the most successful spawning years ever documented (2001 and 2003) also occurred during this past decade. Typically, several years of average reproduction are interspersed with occasional large and small year-classes.

Poor reproduction was also observed for other spring-spawning species such as white perch and American shad, leading biologists to suspect that large-scale environmental factors were responsible. Heavy rains in early May resulted in decreased water temperatures on major striped bass spawning grounds. The spring water temperatures fell below levels known to be lethally cold to striped bass eggs and larvae, and survival of these sensitive life stages is a major determinant of spawning success.

During the 2008 trophy season, biologists intercepted 271 fishing trips, interviewed 329 anglers, and examined a total of 200 striped bass. The average total length of striped bass sampled was 920 mm TL (36.2 inches), and the average weight was 7.8 kg (17.2 lbs). Most fish sampled from the trophy fishery were between nine and twelve years old. The 1996 year-class (age 12) and 1997 year-class (age 11), were the most frequently observed year-classes, constituting 45.6% of the sampled harvest. Average catch rate based on angler interviews was 0.3 fish per hour a drop from the catch rate of 0.5 fish per hour in 2007.

A total of 1,161 striped bass were tagged and released for growth and mortality studies during the spring, 2008 sampling season with USFWS internal anchor tags. Of this sample, 628 were tagged in the Chesapeake Bay during spring spawning stock assessment activities. A total of 1,033 striped bass were tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise. Specialized coded wire tag (CWT) sampling was continued on the Patuxent River during 2008. A total of 82 striped bass were scanned for the presence of CWT's , but none were found to be CWT positive.

Stream icthyoplankton sampling was conducted in Mattawoman Creek, Piscataway Creek and Bush River watersheds in 2008. Mattawoman Creek and Piscataway Creek data were compared to historic data to determine if spawning habitat use had changed. Piscataway Creek samples showed a complete absence of eggs and larvae, indicating the habitat supported little, if any, anadromous fish spawning. Mattawoman Creek samples showed that anadromous fish continued to use the watershed to spawn, however, fewer stations showed presence of anadromous eggs and larvae, indicating that spawning habitat use has declined.

Data from 2005 to 2008 were compared from the Bush River and Aberdeen Proving Ground and evaluated to determine the status of spawning habitat. Yellow perch and white perch were rare in the Bush River, even though historically, the Bush River supported spawning for both species. Aberdeen Proving Ground historically supported yellow perch and white perch spawning and recent sampling showed continued spawning of both species. Percent presence of eggs and larvae of each species was compared to impervious cover estimates. Results suggest that land development is impacting the quality of habitat and reducing the amount of stream habitat available for their spawning. River herring were observed at numerous sites in both the Bush River and Aberdeen Proving Ground, indicating that habitat change is not impacting their use of these areas for spawning.

During 2008, L_p (proportion of estuarine tows containing yellow perch larvae) fell below the historic range in the Severn, South and Nanticoke Rivers. In the three tidal-fresh systems, Mattawoman Creek, Piscataway Creek and Bush River, L_p fell within the historic range. The risk of falling below the historic minimum was near 1 for brackish systems and near 0 for tidal-fresh systems. High salinity and high impervious surface in the watershed are attributed to the low L_p in the brackish habitats.

All systems sampled in 2007 were revisited in 2008, with the exception of Piscataway Creek as submerged vegetation was too dense to effectively operate gear. Nanjemoy Creek was substituted for Piscataway Creek. Water quality criteria violations were minimal in all rivers. Impervious cover did not appear to impact water quality or fish populations within the systems sampled. The threshold for impervious cover impacts may be higher in tidal-fresh systems than that previously established for brackish systems.

APPROVAL

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Striped bass were collected for portions of this study from commercial pound nets owned and operated by Danny Beck, Keith Collins, Tommy Crowder, John Dean, and Tommy Hallock. 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.

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SURVEY TITLE: CHESAPEAKE BAY FINFISH/HABITAT INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 1
JOB NO. 1

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

METHODS

I. Field Operations

Upper Chesapeake Bay Winter Trawl

The upper Chesapeake Bay winter bottom trawl survey is designed to collect fishery-independent data for the assessment of population trends of white and yellow perch and channel and white catfish. The 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 2007 through February 2008.

The 2003 survey was hampered by ice conditions such that only 1 of 6 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 6 rounds were completed in 2005 because of catastrophic engine failure. Ice-cover prevented the final 2 rounds of the 2007 survey from being completed. All rounds were completed in 2008.

Choptank River Fishery Independent Sampling

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 14 February 2008 through 28 March 2008 (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. Four experimental fyke nets were set in this system from 23 February 2007 – 27 March 2007. Locations ranged from the Maryland Route 392 bridge near Hurlock, Maryland to approximately 2 miles downstream of Federalsburg, Maryland. During 2008, net locations were re-assessed and relocated further downstream (Figure 3). Fyke nets were fished from 18 February 2008 through 1 April 2008. Sampling protocol mimicked that of the Choptank River in all respects. Since this was the second 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 2008 through 11 March 2008 from the Bush River, Gunpowder River, Northeast River, and Chester River (Figures 4, 5, 6). All yellow perch were measured and sexed (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River Fishery Dependent Sampling

From 4 February 2008 to 28 April 2008, 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 7). Net sites and dates fished were at the discretion of the commercial fishermen. All yellow perch caught were sexed, measured for total length and a non-random sample of otoliths removed for age determination. Thirty randomly selected white perch from the fyke nets were sexed and measured and a subsample was processed for age determination (otoliths). A bushel of unculled, mixed catfish species was randomly selected, identified as channel or white catfish and total lengths measured.

II. Data compilation

Population Age Structures

Population age structures were determined for yellow perch and white perch in 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) were constructed by determining the proportion-at-age per 20-mm length group and applying that proportion to the total number-at-length.

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. All indices were untransformed grand means.

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) 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, Figure 1). However, since the Ordinary Pt. seine site was lost because it was bulk-headed, 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 in either tables or figures organized by data type (age structure, length structure, etc.), species, and survey. Data summaries are provided in these locations:

Population Age Structures

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

Population Length Structures

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

Growth

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

Mortality

White perch	Table 26
Yellow perch	Table 27

Recruitment

White perch	Figures 21-22
Yellow perch	Figures 23-24
Channel catfish	Figures 25-26

Relative Abundance

White perch	Tables 28-29

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

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Figure 1. Upper Chesapeake Bay winter trawl survey locations, December 2007 – February 2008. Different symbols indicate each of 6 different sampling rounds.

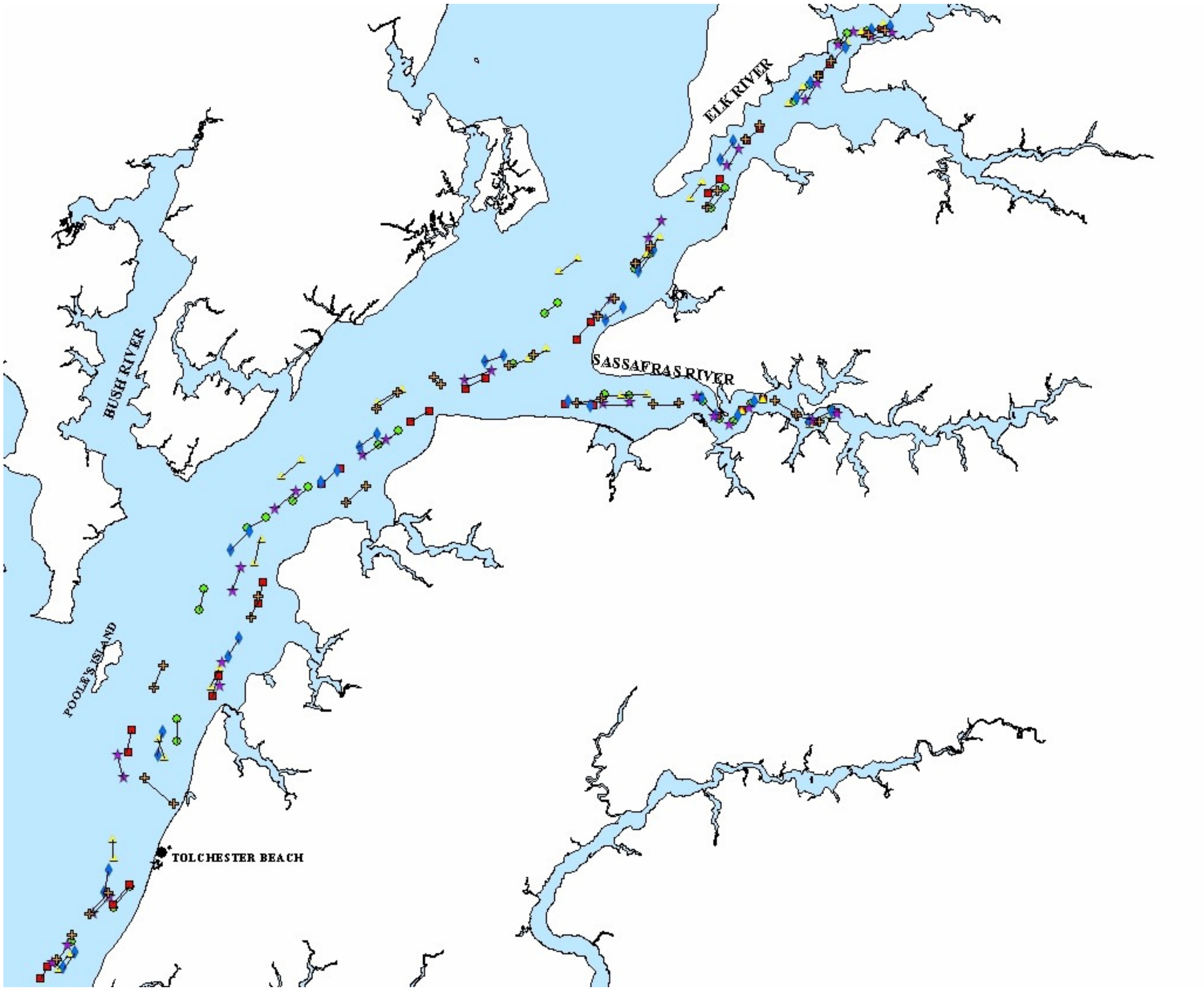


Figure 2. Choptank River fyke net locations, 2008. Circles indicate sites.

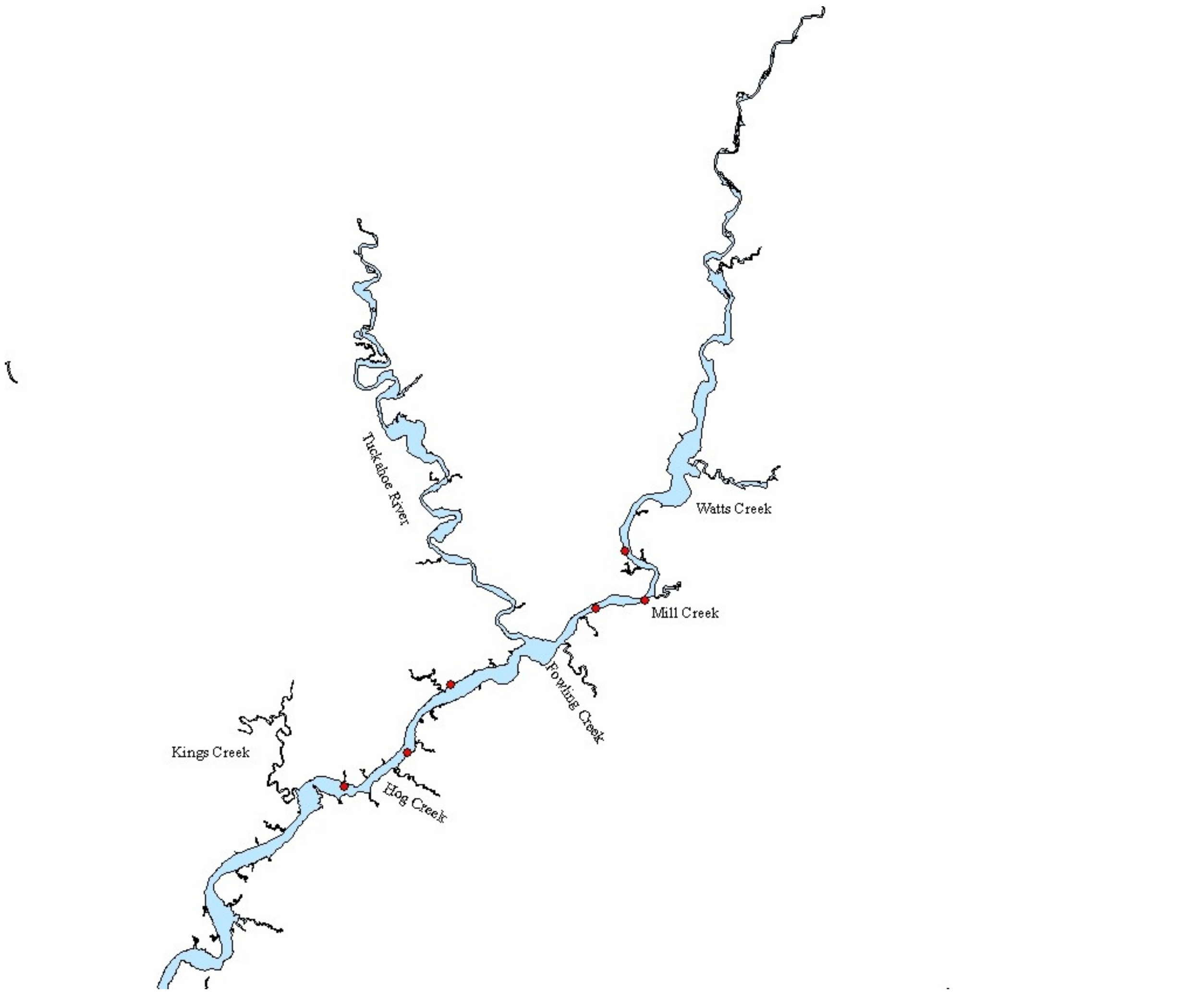


Figure 3. Marshyhope River fyke net locations, 2007, 2008 and 2009.

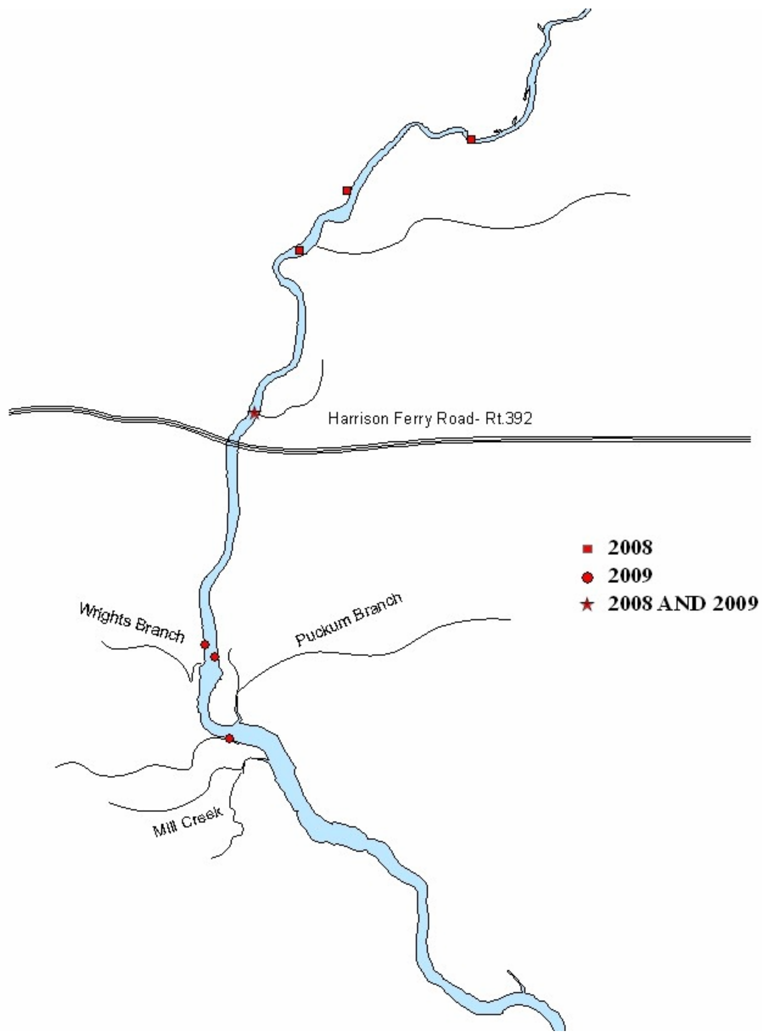


Figure 4. Commercial yellow perch fyke net sites sample during 2008 in the Bush River and the Gunpowder River.

Figure 5. Commercial yellow perch fyke net sites sample during 2008 in the Northeast River. Black lines indicate the geographic range of fyke net locations.

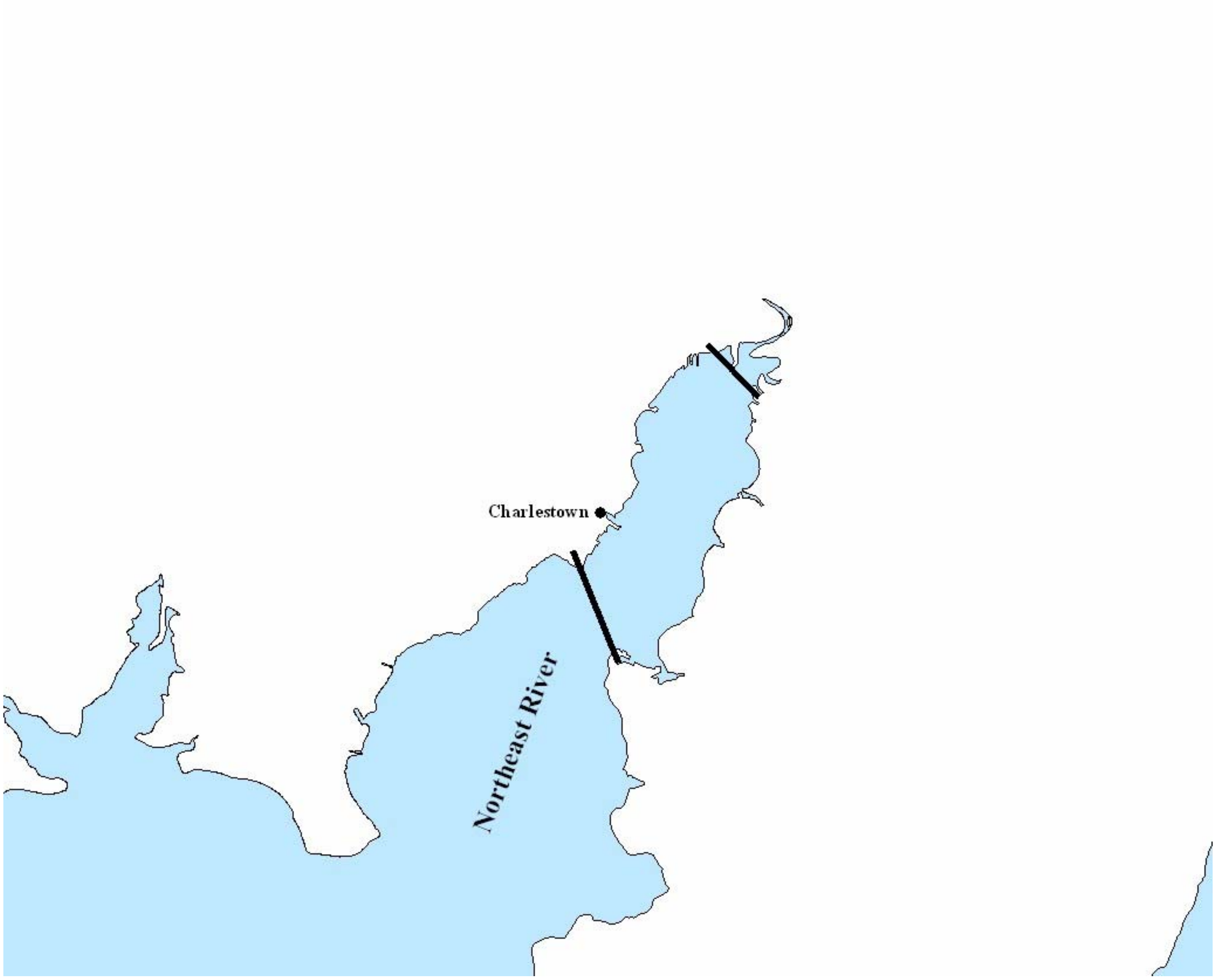


Figure 6. Commercial yellow perch fyke net sites sample during 2008 in the upper and lower portions of the Chester River.

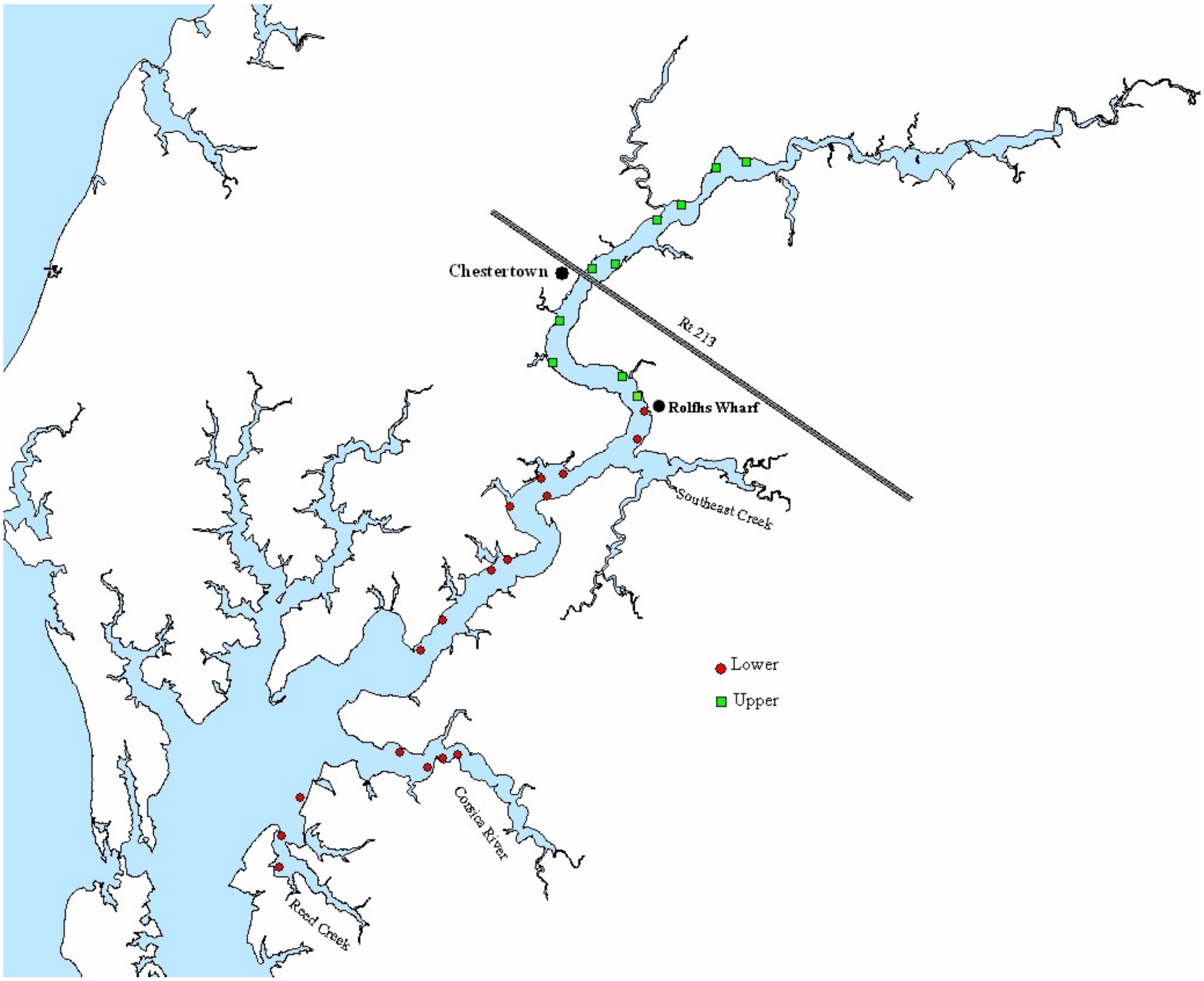


Figure 7. Commercial fyke net and pound net sites sample during 2008 in the Nanticoke River. Black lines indicate the geographic range of fyke net locations.

Table 1. White perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2008.

Year	AGE 1	2	3	4	5	6	7	8	9	10+	total
2000	1,730	4,972	2,551	3,160	1,992	2,011	3,011	244	450	236	20,356
2001	3,848	7,972	8,886	3,834	2,531	1,013	943	1,776	261	261	31,326
2002	19	2,470	1,588	2,675	1,141	2,236	1,395	308	656	115	12,603
2003	0	637	2,955	382	677	262	693	441	90	298	6,434
2004					NOT SAMPLED						
2005	1,072	1,882	313	332	177	322	278	67	107	11	4,561
2006	9,497	3,275	6,753	2,167	1,996	657	410	435	933	169	25,452
2007	2,521	2,011	3,657	881	621	158	94	137	22	47	10,149
2008	16,169	2,488	6,714	5,366	1,844	667	274	319	101	109	34,091

Table 2. White perch catch at age matrix from Choptank River fyke net survey, 2000 – 2008.

Year	AGE 1	2	3	4	5	6	7	8	9	10+	total
2000	0	36	1,908	11,021	10,946	2,074	7,199	1,010	540	0	34,734
2001	0	459	18,269	14,111	5,521	2,368	562	788	202	0	42,278
2002	0	339	11,286	6,602	3,108	3,133	681	920	566	69	26,703
2003	0	1,226	9,263	8,146	9,397	435	6,410	1,944	942	1,038	38,801
2004	0	0	9,374	3,023	3,619	4,272	351	2,265	776	649	24,329
2005	0	954	4,432	8,890	5,199	2,912	978	201	1,375	49	24,990
2006	0	270	17,964	704	7,765	3,760	442	487	271	3,877	35,538
2007	0	361	3,279	24,904	2,823	10,824	4,154	1,584	1,640	1,373	50,940
2008	0	0	6,366	4,504	13,082	1,102	4,252	2,594	556	1,107	33,474

Table 3. White perch catch at age matrix from Nanticoke River fyke and pound net survey, 2000 – 2008. 2007+2008 include Marshyhope River data.

Year	AGE 1	2	3	4	5	6	7	8	9	10+	total
2000	0	42	593	6,074	6,471	2,813	1,942	365	81	0	18,382
2001	0	0	681	796	3,262	1,822	689	785	94	38	8,167
2002	0	5	1,469	1,927	504	2,124	1,132	632	244	13.5	8,051
2003	0	97	318	2,559	1,567	446	994	652	180	175	6,989
2004	0	6,930	3,892	12,215	3,259	1,835	1,297	1,361	443	886	32,120
2005	0	826	1,302	5,847	3,903	5,288	2,400	1,237	1,497	2,582	24,882
2006	0	0	5,759	3,280	5,298	3,488	3,590	1,287	861	799	24,404
2007	0	497	1,948	12,876	727	6,236	2,260	2,716	977	1,573	29,891
2008	0	33	902	1,188	2,780	824	1,457	665	593	496	8,937

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2008.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	total
2000	15	74	13	93	3	6	3	0	0	0	207
2001	633	72	92	13	63	4	0	3	0	0	880
2002	1,197	38	867	87	182	31	82	19	5	0	2,508
2003	2,454	2,105	106	203	95	53	0	0	0	0	5,016
2004	NOT SAMPLED										
2005	451	1	369	7	13	1	2	1	0	0	845
2006	1,410	1,939	686	115	14	10	0	0	0	0	4,174
2007	86	473	287	0	60	6	0	2	0	0	914
2008	1,054	232	585	514	130	0	0	0	0	0	2,515

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2008.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	total
1988	0	9	268	9	2	21	19	1	1	5	335
1989	0	0	80	234	81	41	8	2	2	0	448
1990	0	22	179	82	273	53	10	8	5	1	633
1991	0	7	41	53	18	44	9	2	2	0	176
1992	0	1	8	14	15	7	6	0	0	0	51
1993	0	3	75	150	98	109	37	7	4	0	483
1994	0	42	158	25	81	87	78	64	5	18	558
1995	0	79	258	23	68	67	42	37	5	21	600
1996	0	857	343	267	35	81	47	27	43	9	1,709
1997	0	14	641	99	86	0	19	24	8	0	891
1998	0	142	77	583	26	31	0	8	3	17	887
1999	0	306	8,514	86	3,148	32	9	8	0	6	12,109
2000	0	329	92	1,378	27	140	0	7	0	0	1,973
2001	0	878	1,986	102	1,139	19	72	2	0	0	4,198
2002	0	334	1,336	1,169	38	430	104	51	3	0	3,465
2003	0	369	440	922	333	34	226	35	32	2	2,392
2004	0	60	504	177	120	103	0	61	0	7	1,032
2005	0	1,667	137	416	134	55	140	23	52	15	2,639
2006	0	173	1,858	176	395	64	66	42	0	7	2,781
2007	0	1,512	737	1,560	33	182	109	28	10	12	4,183
2008	0	39	1,303	130	326	13	49	20	0	0	1,880

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2008.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	total
1999	0	0	1,621	33	337	408	28	0	2	0	2,429
2000	0	35	138	2937	129	369	211	0	0	0	3,819
2001	0	0	83	90	432	17	9	17	0	0	648
2002	0	52	117	528	56	1,000	14	39	53	0	1,859
2003	0	27	565	78	361	45	418	6	15	25	1,540
2004	0	4	473	499	62	50	3	43	2	2	1,138
2005	0	18	27	1,320	414	73	37	0	26	5	1,920
2006	0	32	476	9	848	245	0	1	10	0	1,621
2007	0	2	290	1,400	23	548	168	3	0	14	2,448
2008	0	70	3,855	3,782	4,820	75	789	149	14	2	13,556

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2008. 2007 + 2008 include Marshyhope River data.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	Total
1999	0	10	1,072	323	295	22	0	4	14	22	1,762
2000	0	0	16	561	78	83	7	0	0	0	745
2001	0	2	36	114	737	48	36	3	0	0	976
2002	0	128	9	60	36	940	39	24	6	0	1,242
2003	0	17	123	2	49	2	45	1	2	0	241
2004	0	7	58	93	0	1	10	21	1	0	191
2005	0	59	6	34	35	0	1	0	4	0	139
2006	0	56	381	18	34	50	4	3	6	5	557
2007	0	38	244	291	37	32	16	0	0	2	660
2008	0	36	238	144	148	25	9	4	2	7	613

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2008. 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

Figure 8. White perch length-frequency from 2008 upper Chesapeake Bay winter trawl survey.

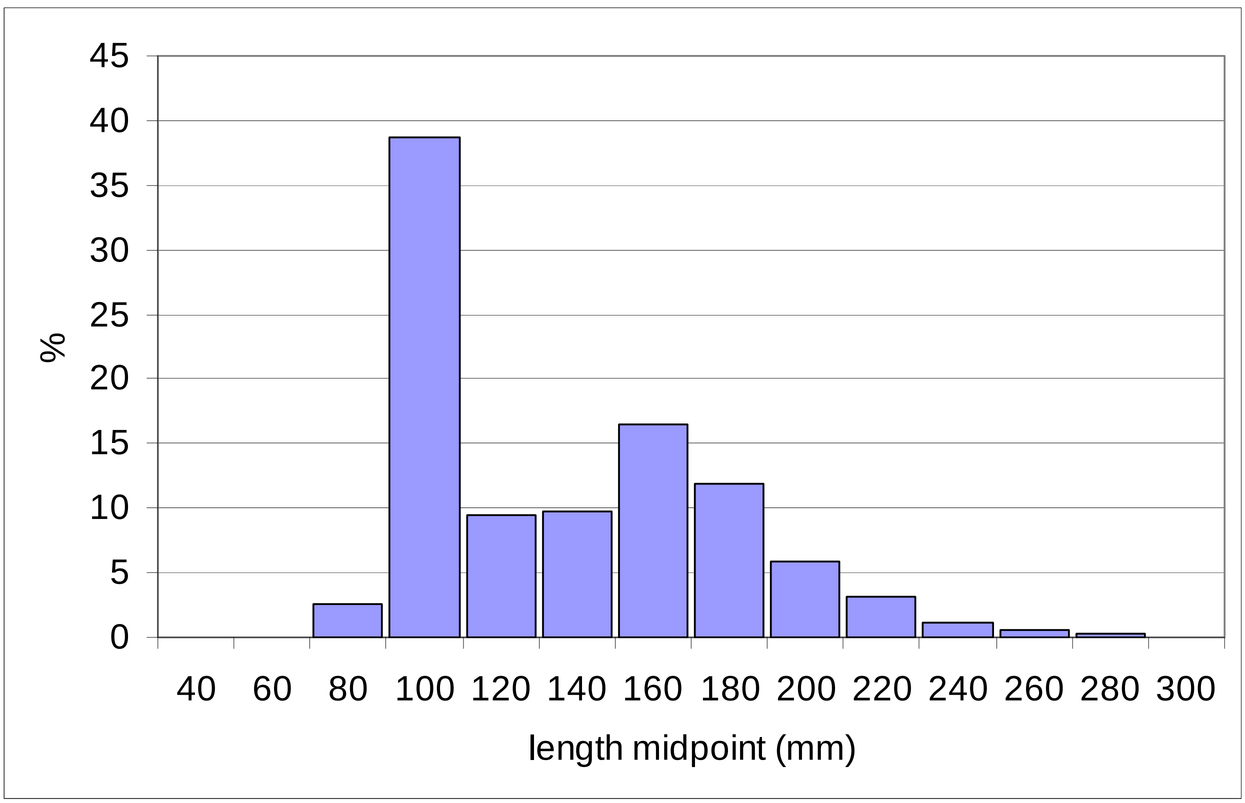


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2008. Minimum length cut-offs in parentheses.

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

Figure 9. White perch length-frequency from 2008 Choptank River fyke net survey.

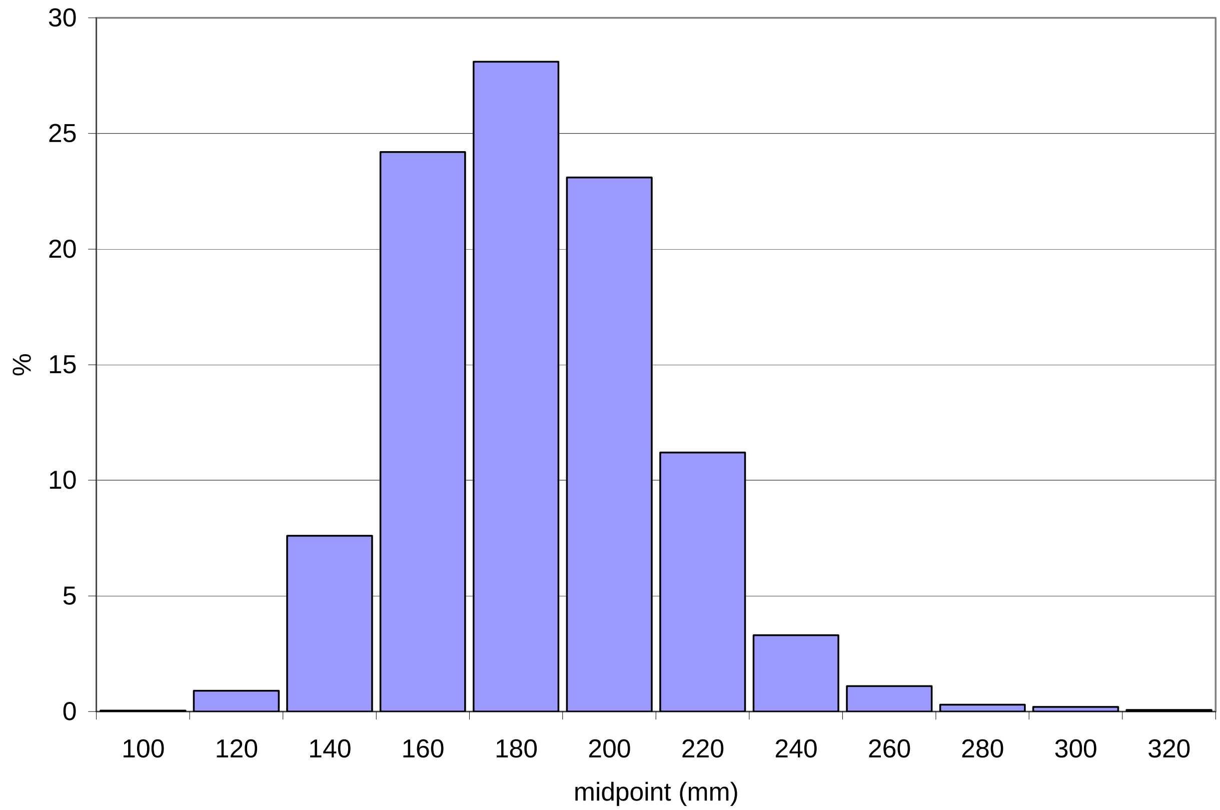


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2008. Minimum length cut-offs in parentheses. 2007 + 2008 include Marshyhope River data.

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

Figure 10. White perch length-frequency from 2008 Nanticoke River fyke and pound net survey, including Marshyhope River data.

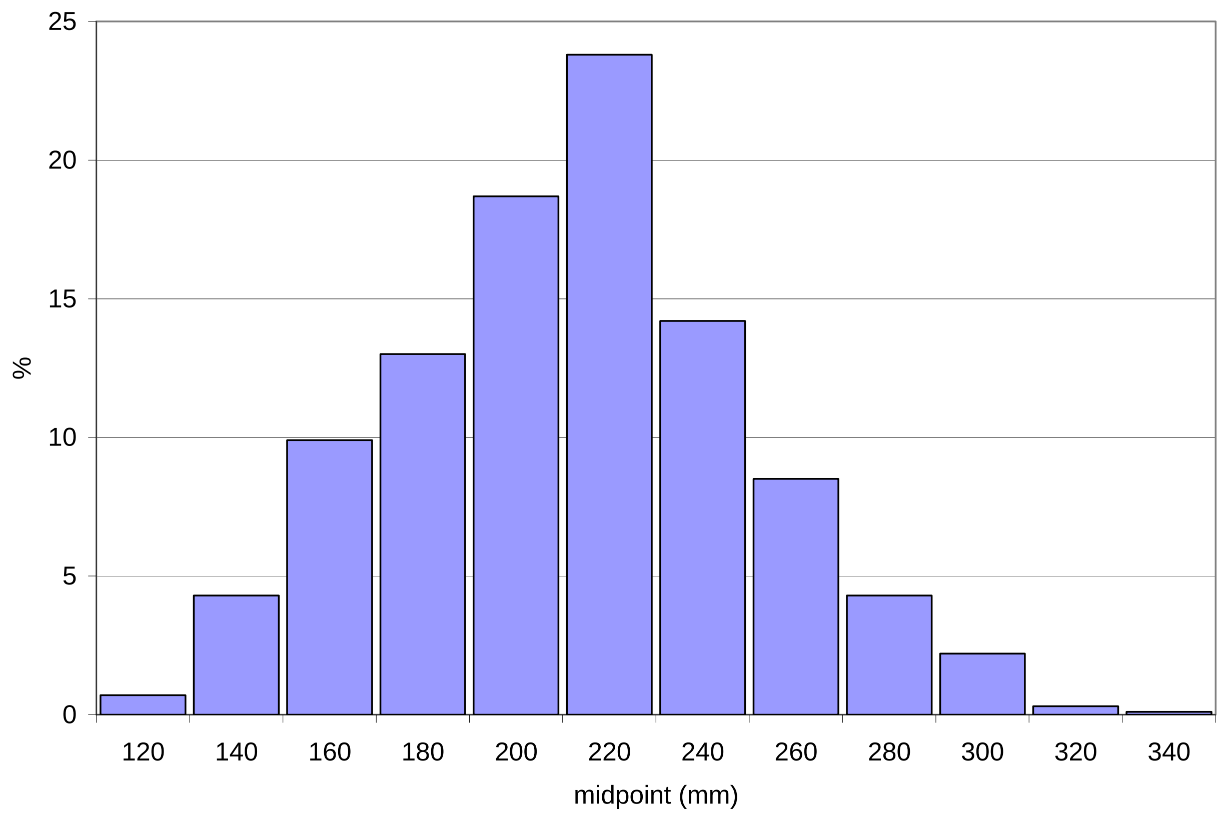


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2008. Minimum length cut-offs in parentheses.

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

Figure 11. Yellow perch length-frequency from the 2008 upper Chesapeake Bay winter trawl survey.

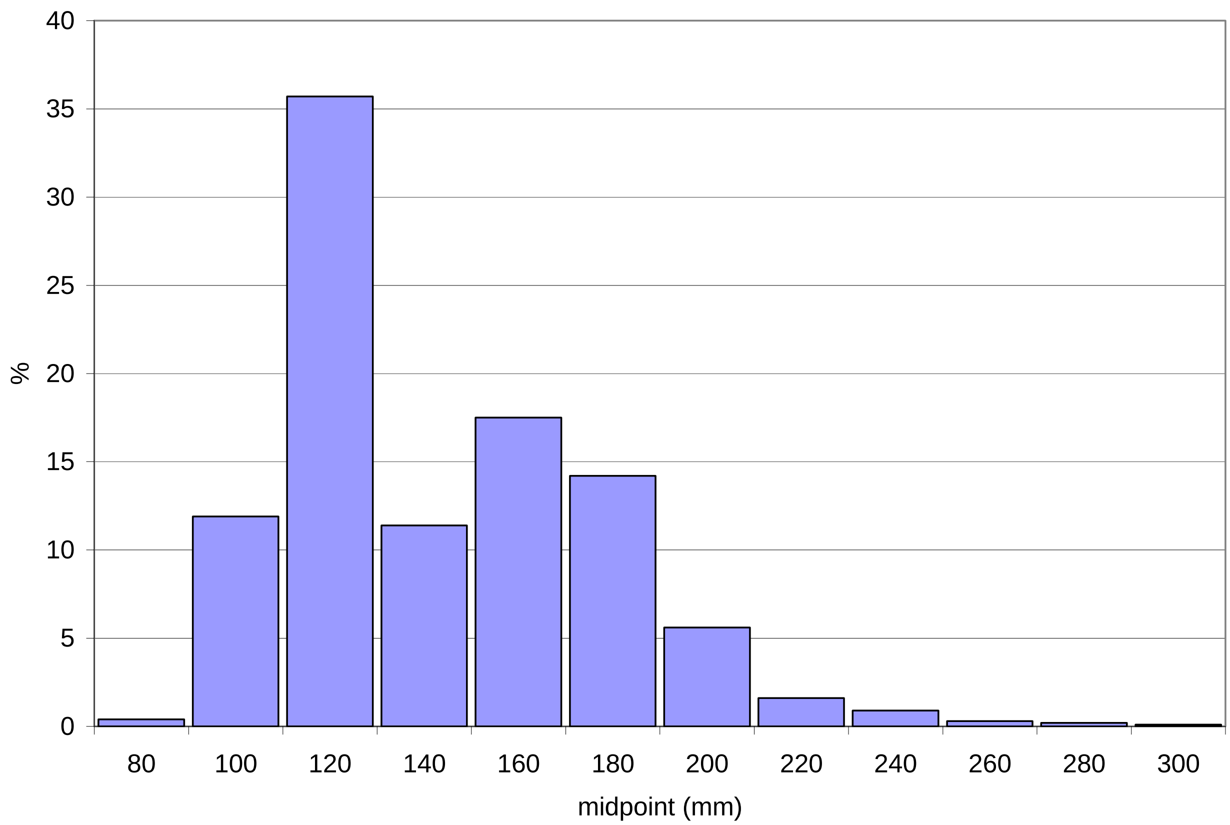


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2008. Minimum length cut-offs in parentheses.

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

Figure 12. Yellow perch length-frequency from the 2008 Choptank River fyke net survey.

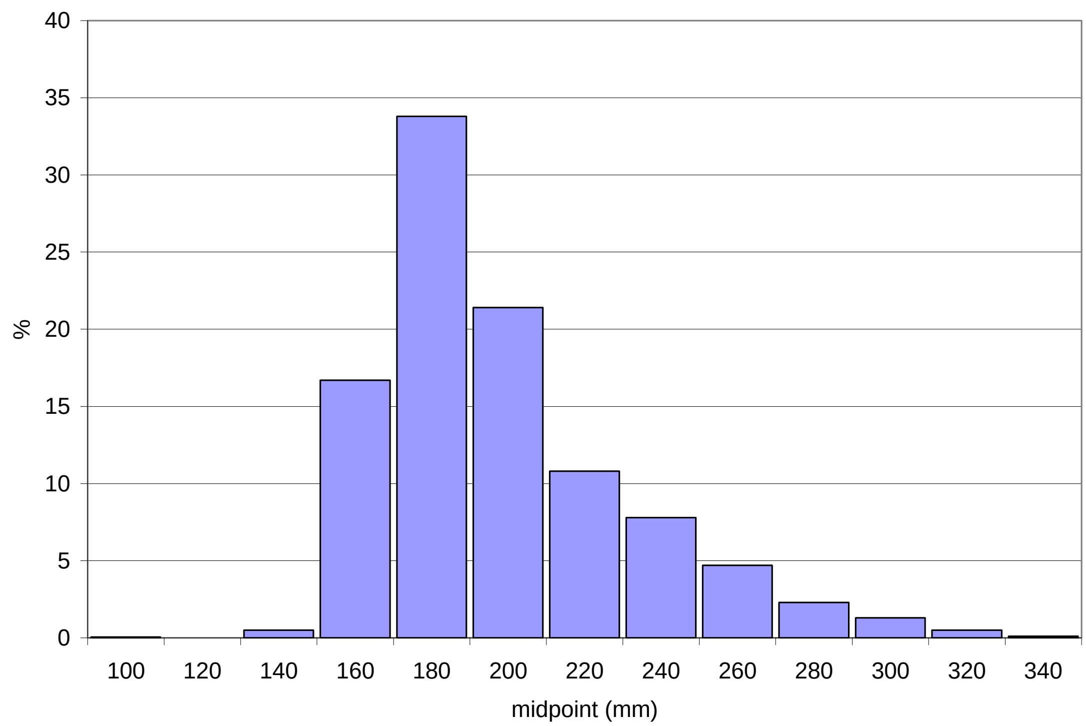


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2008. Minimum length cut-offs in parentheses.

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

Figure 13. Yellow perch length frequency from the 2008 upper Chesapeake commercial fyke net survey.

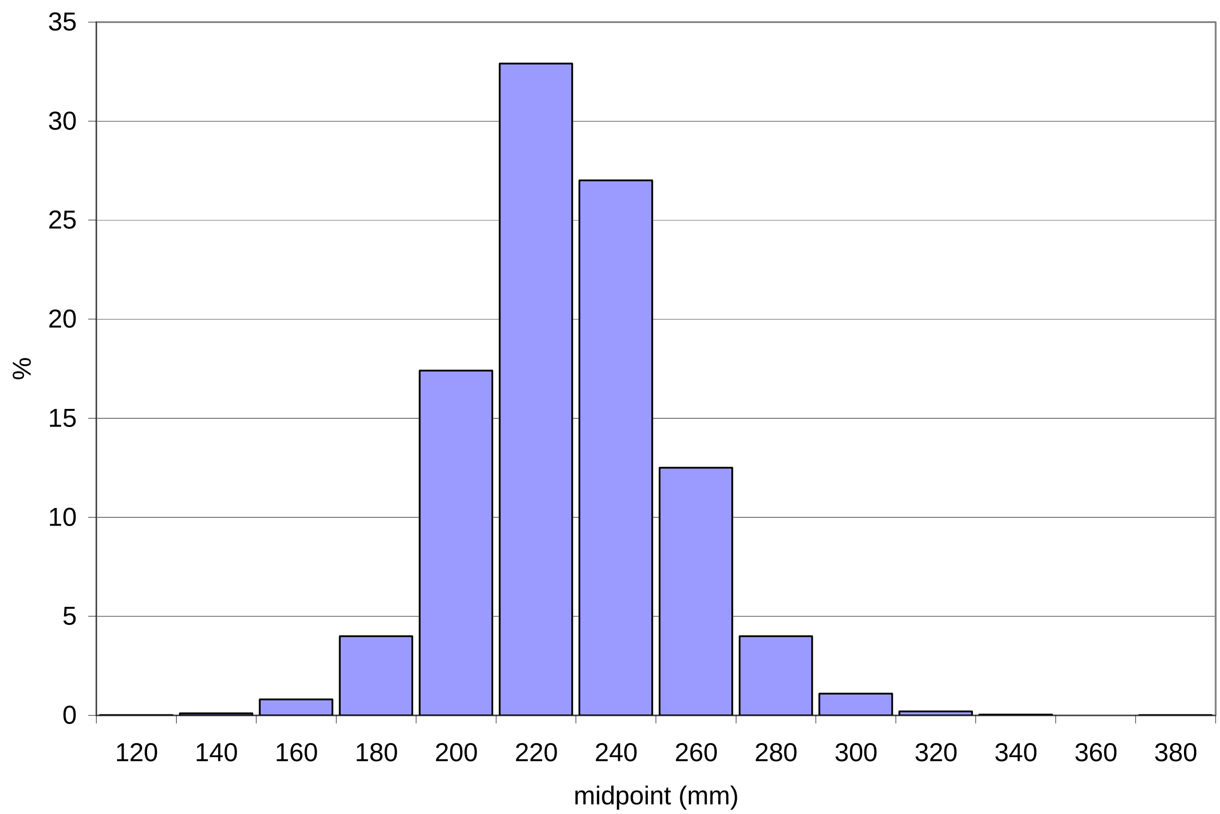


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2008. Minimum length cut-offs in parentheses; 2007 includes Marshyhope River data.

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

Figure 14. Yellow perch length frequency from the 2008 Nanticoke River survey fyke and pound net survey. Includes Marshyhope River data.

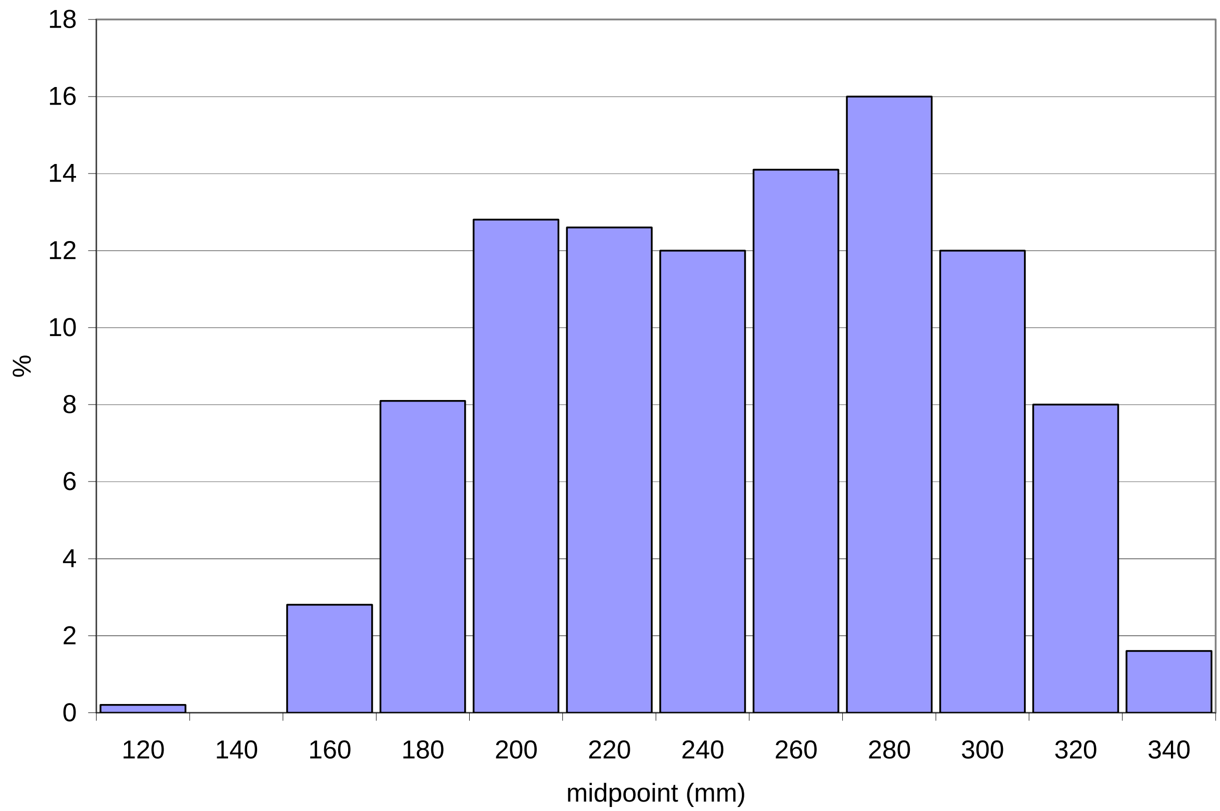


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2008. Minimum length cut-offs in parentheses.

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

Figure 15. Length frequency of channel catfish from the 2008 upper Chesapeake Bay winter trawl survey.

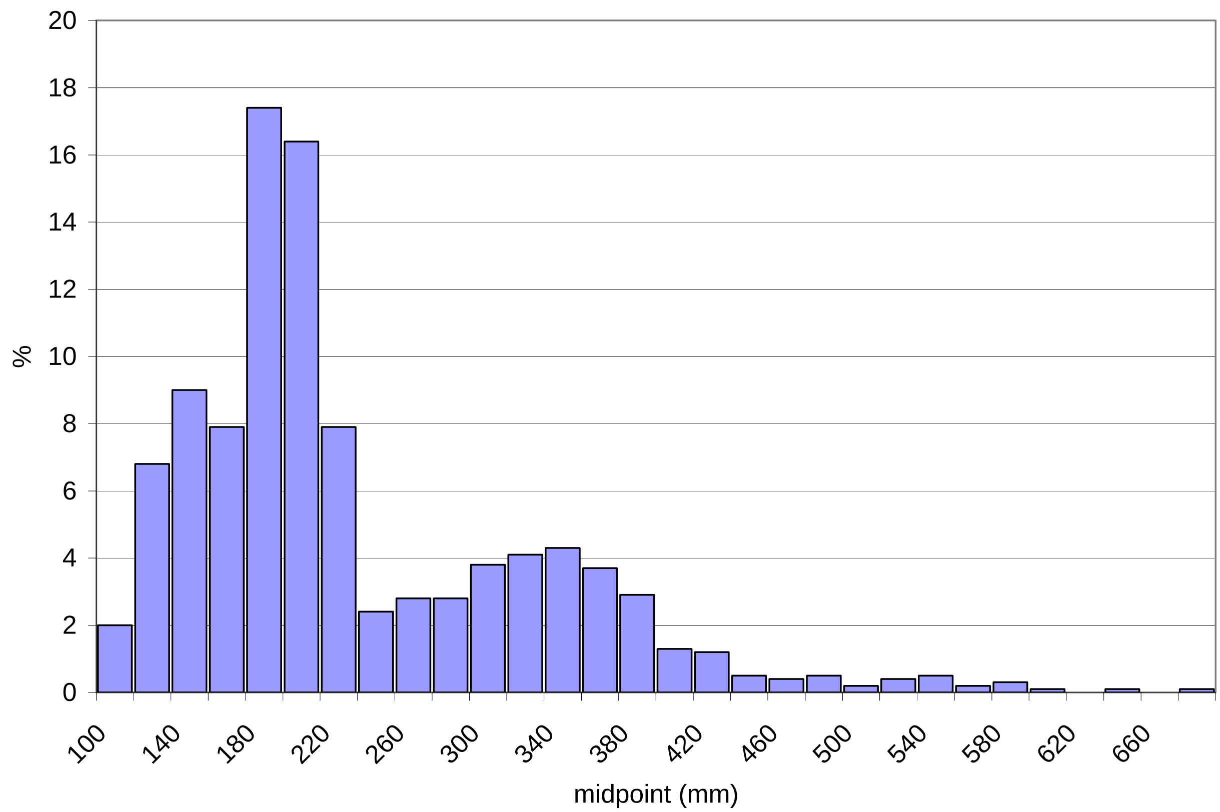


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2008. Minimum length cut-offs in parentheses.

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

Figure 16. Channel catfish length frequency from the 2008 Choptank River fyke net survey.

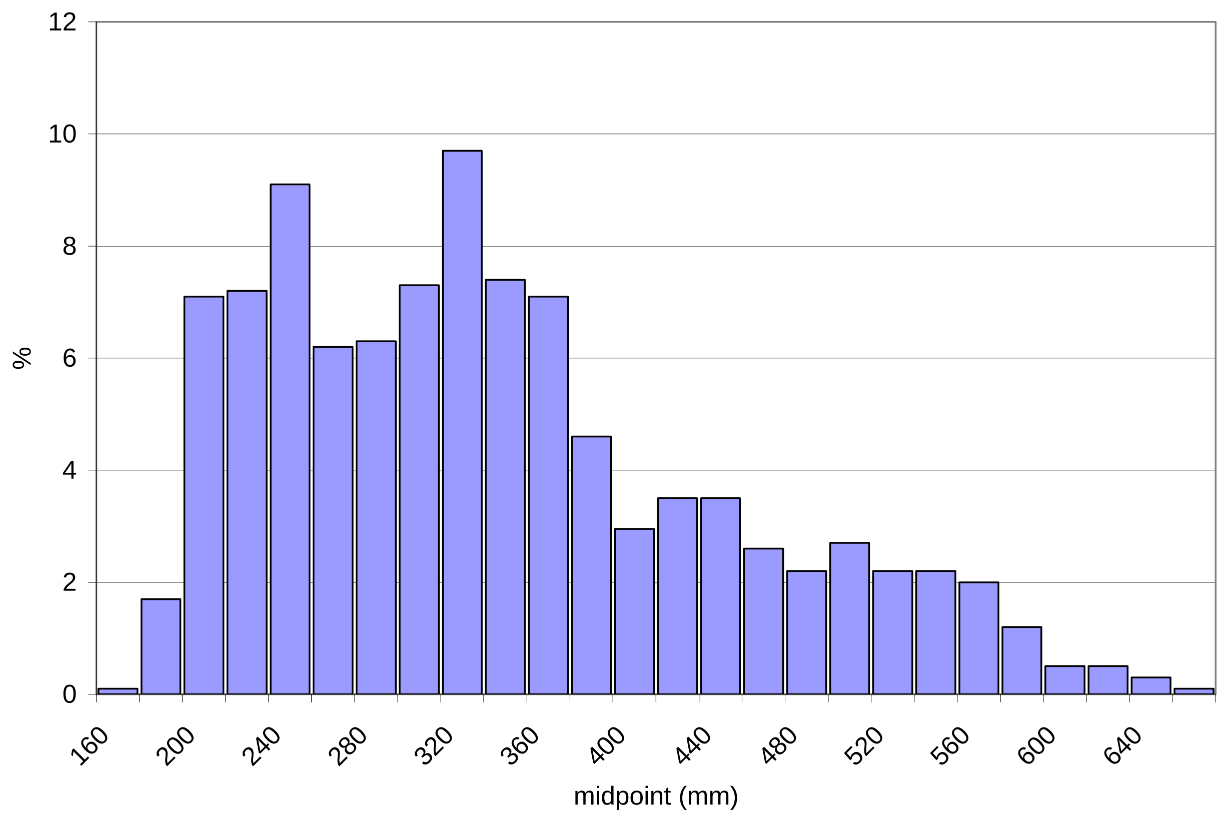


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2008. 2007 + 2008 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 17. Channel catfish length frequency from the 2008 Nanticoke River fyke and pound net survey. Includes Marshyhope fyke net data.

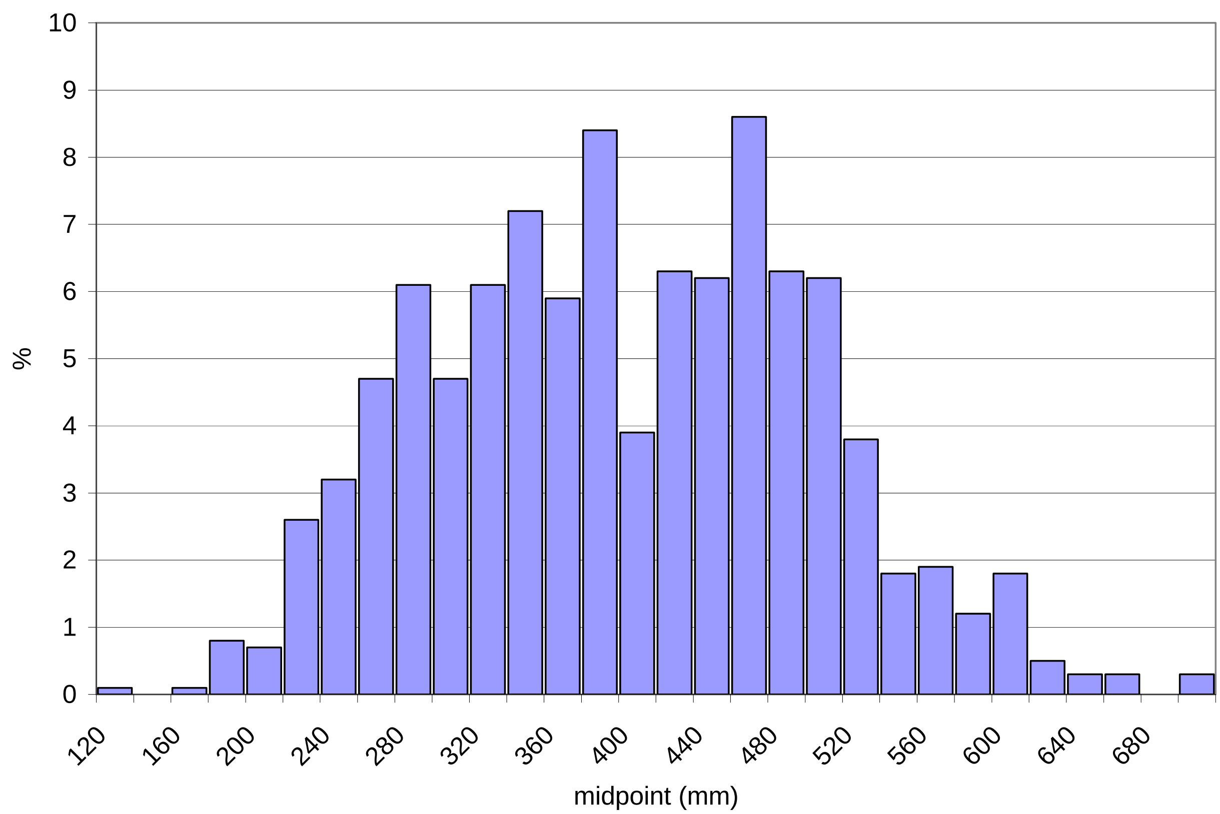


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2008. Minimum length cut-offs in parentheses.

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

Figure 18. White catfish length frequency from the 2008 upper Chesapeake Bay winter trawl survey.

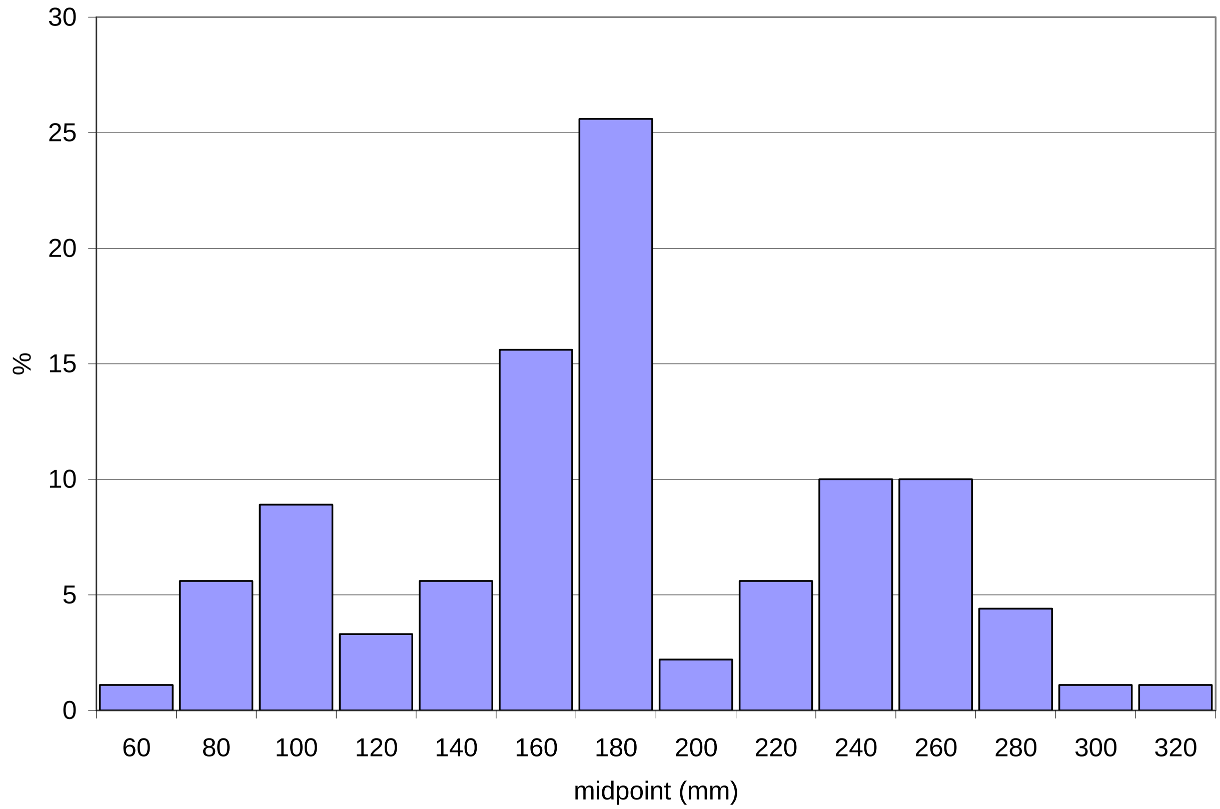


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2008. Minimum length cut-offs in parentheses.

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

Figure 19. White catfish length frequency from the 2008 Choptank River fyke net survey.

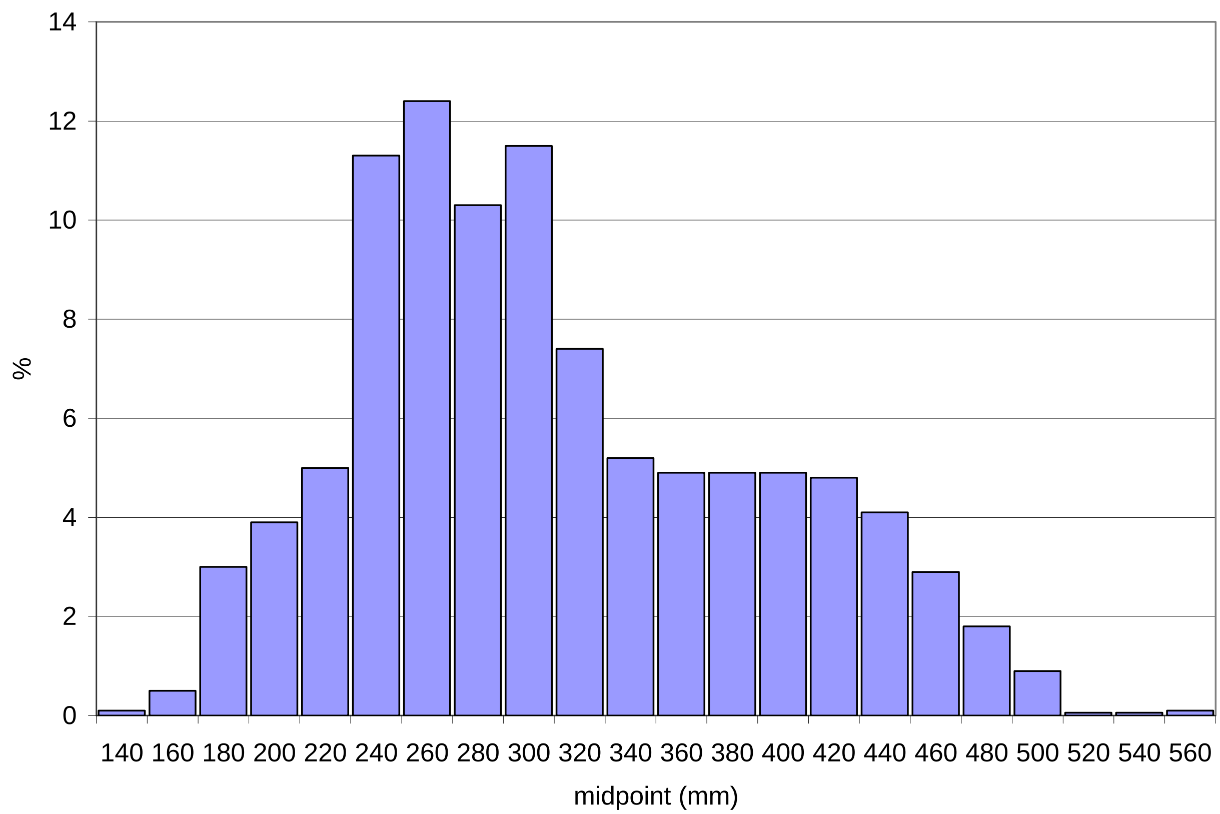


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2008. 2007 + 2008 include Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 20. White catfish length frequency from the 2008 Nanticoke River fyke and pound net survey. Includes Marshyhope River fyke net data.

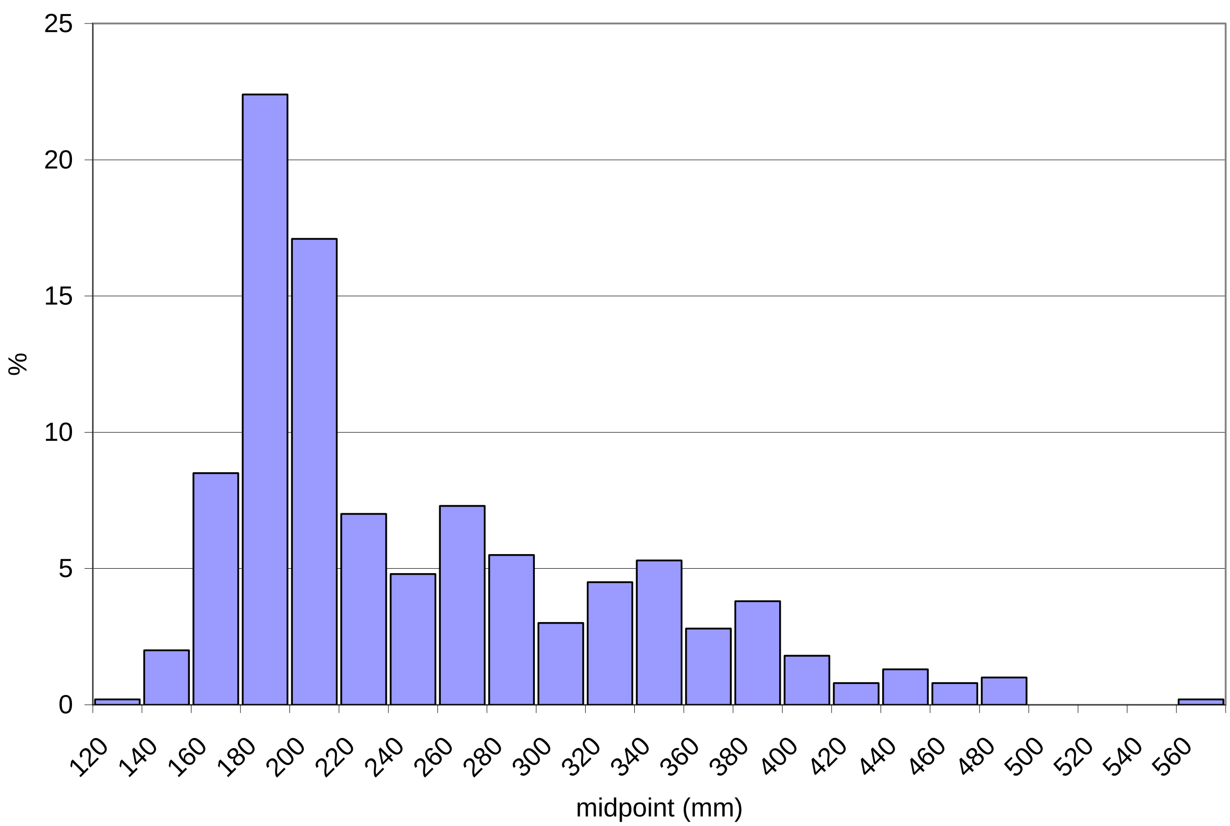


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

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
2000 – 2008	F	6.7×10^{-6}	3.16	288	0.32	-0.82
	M	8.4×10^{-6}	3.10	249	0.33	-1.08
	Combined	4.9×10^{-6}	3.22	280	0.32	-0.68

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
2000 – 2008	F	8.9×10^{-6}	3.12	309	0.28	-0.96
	M	1.1×10^{-5}	3.07	274	0.30	-1.13
	Combined	5.5×10^{-6}	3.20	304	0.27	-1.10

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
2000 – 2008	F	7.0×10^{-6}	3.10	314	0.46	-0.66
	M	3.5×10^{-6}	3.22	273	0.34	-1.57
	Combined	3.9×10^{-6}	3.21	267	0.60	-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

Table 24 Continued. 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 – 2008	F	3.71×10^{-6}	3.23	313	0.35	-1.57
	M	2.74×10^{-6}	3.27	252	0.32	-4.11
	Combined	1.74×10^{-6}	3.36	267	0.59	-0.80

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

Table 25 Continued. 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 Alpha	Allometry Beta	vonBertalanffy L-inf	vonBertalanffy K	vonBertalanffy t_0
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
2000 – 2008	F	2.36×10^{-6}	3.32	345	0.40	-1.25
	M	3.74×10^{-6}	3.22	292	0.44	-1.22
	Combined	9.44×10^{-7}	3.48	306	0.51	-0.95

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
Choptank	0.34	0.48	0.25	0.46	0.1	0.58	0.58	0.40	minmal
Nanticoke	0.42	0.58	0.44	0.31	NR	NR	0.22	0.18	0.16
Upper Bay trawl	0.09	0.58	0.51	0.13	NA	0.5	0.12	0.19	0.26

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
Choptank[1]	NR	minimal	0.03	0.05	NR	0.08	minimal	0	NR
Nanticoke[2]	0.1	0.05	0.06	NA	NA	NA	NA	NA	NA
Upper Bay fyke[3]	0.22	0.32	0.89	0.30	0.30	0.31	0.10	0.14	NA

[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.
[2]See Sadzinski et al. 2002
[3]N-weighted population F from Piavis and Webb in publ.

Figure 21. Baywide young-of-year relative abundance index for white perch, 1962 – 2008, based on EJFS data. Bold horizontal line=time series average. Error bars indicate 95% CI's.

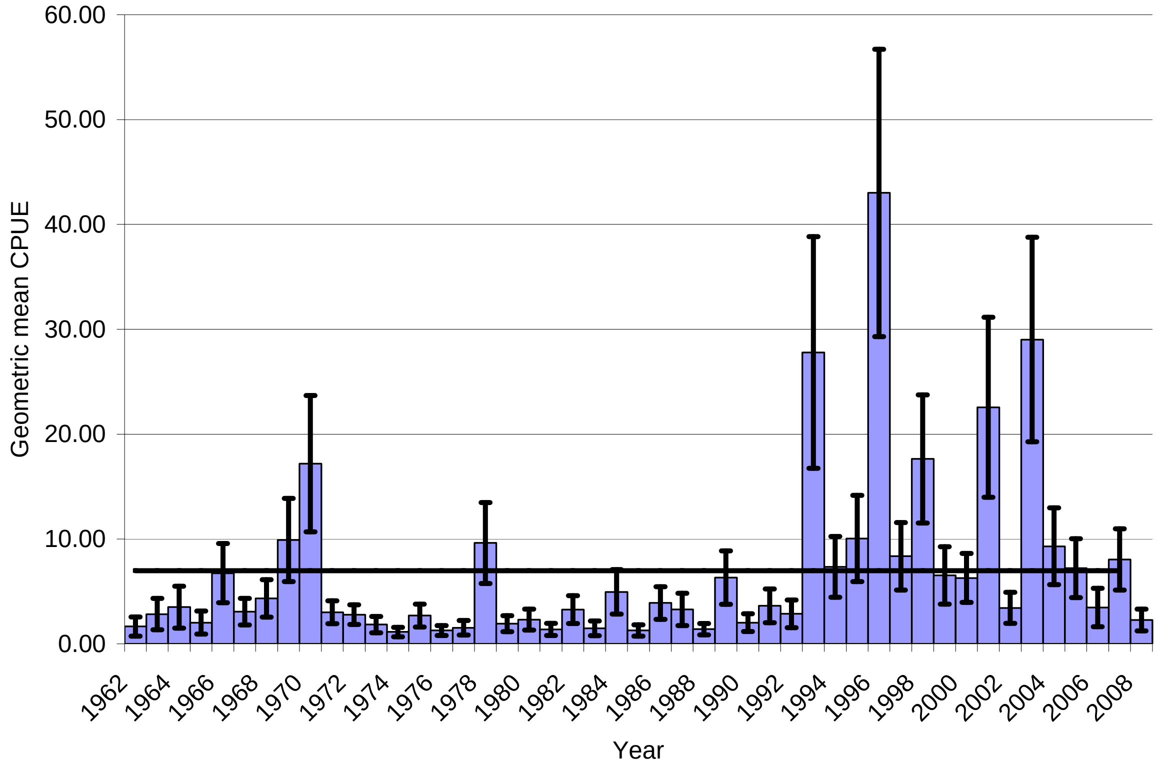


Figure 22. Age 1 white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Year-class indicated in parentheses.

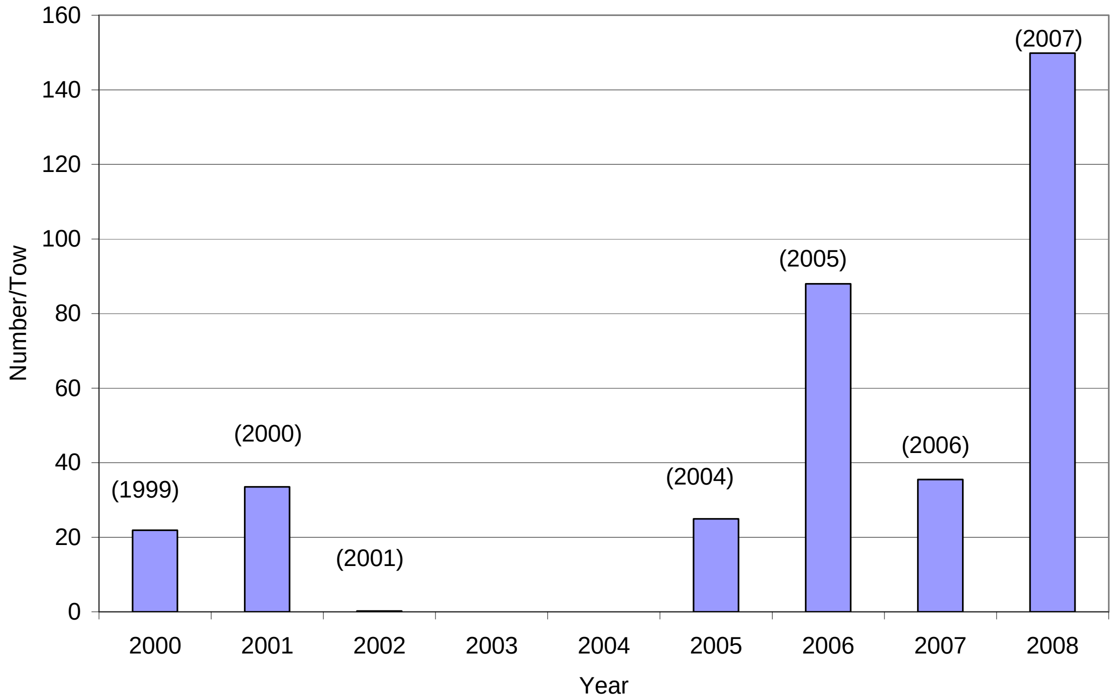


Figure 23. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2008, based on Estuarine Juvenile Finfish Survey data. Horizontal line=time series average. Error bars indicate 95% confidence interval.

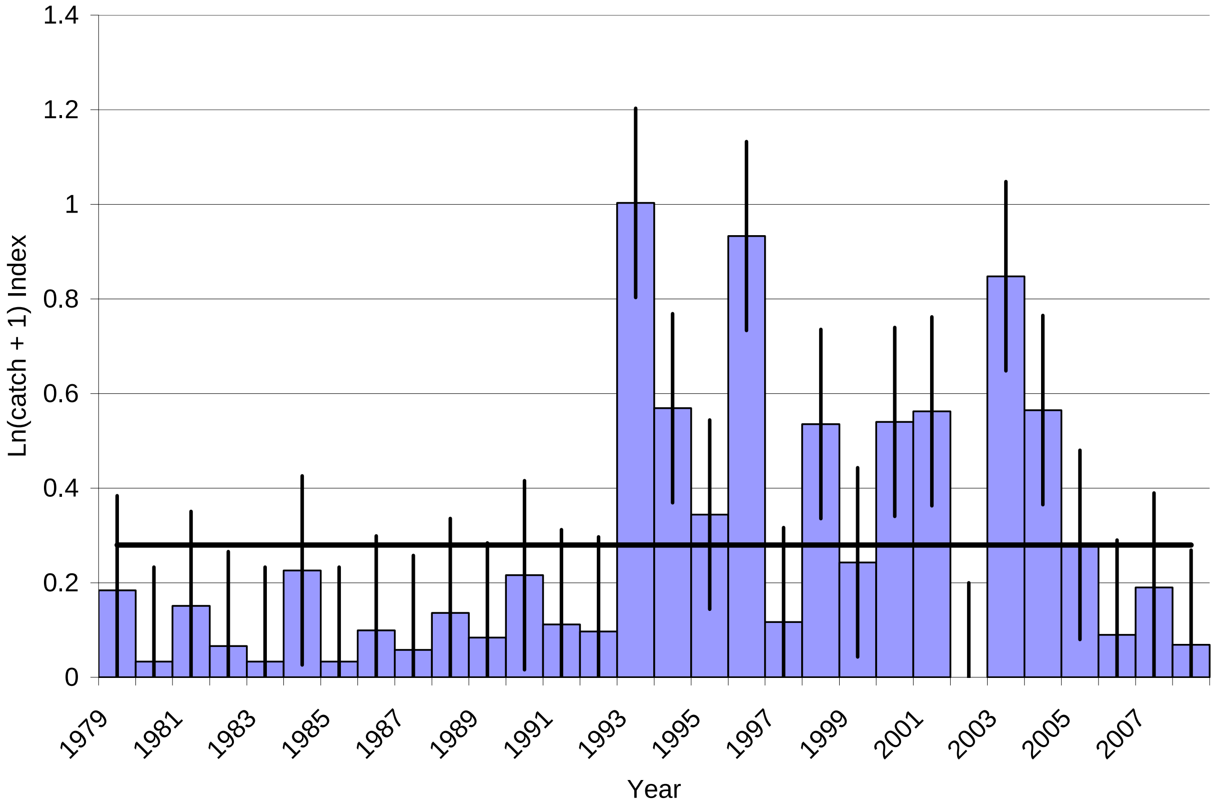


Figure 24. Age 1 yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Year-class indicated in parentheses.

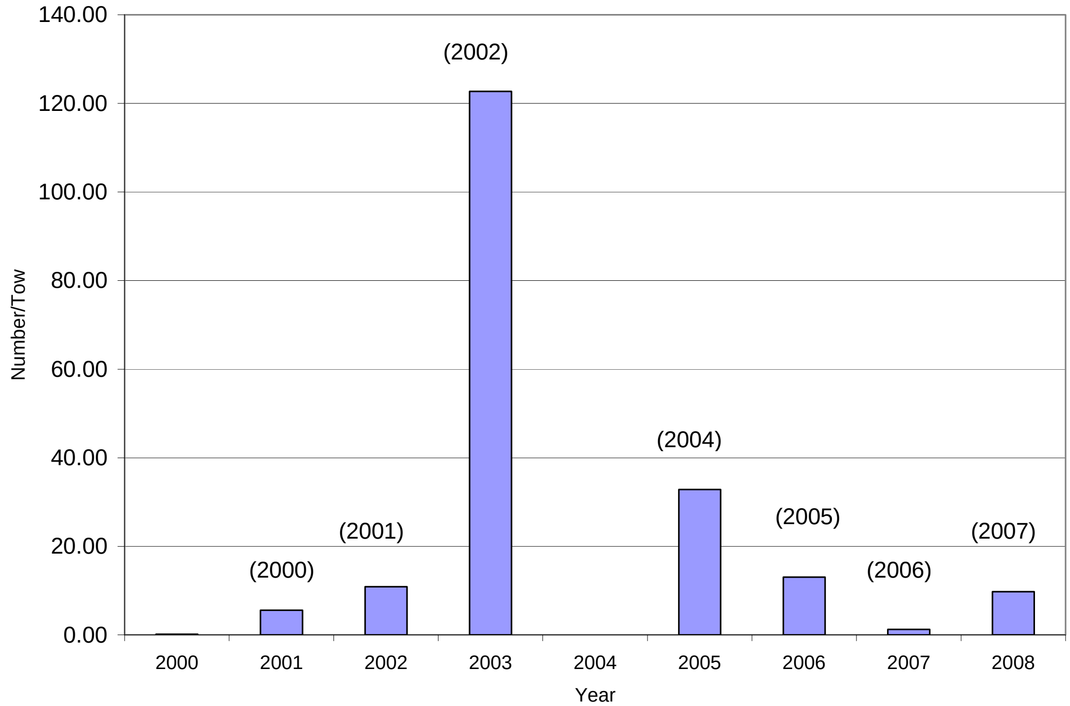


Figure 25. Bay-wide young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average. Error bars = 95% confidence intervals.

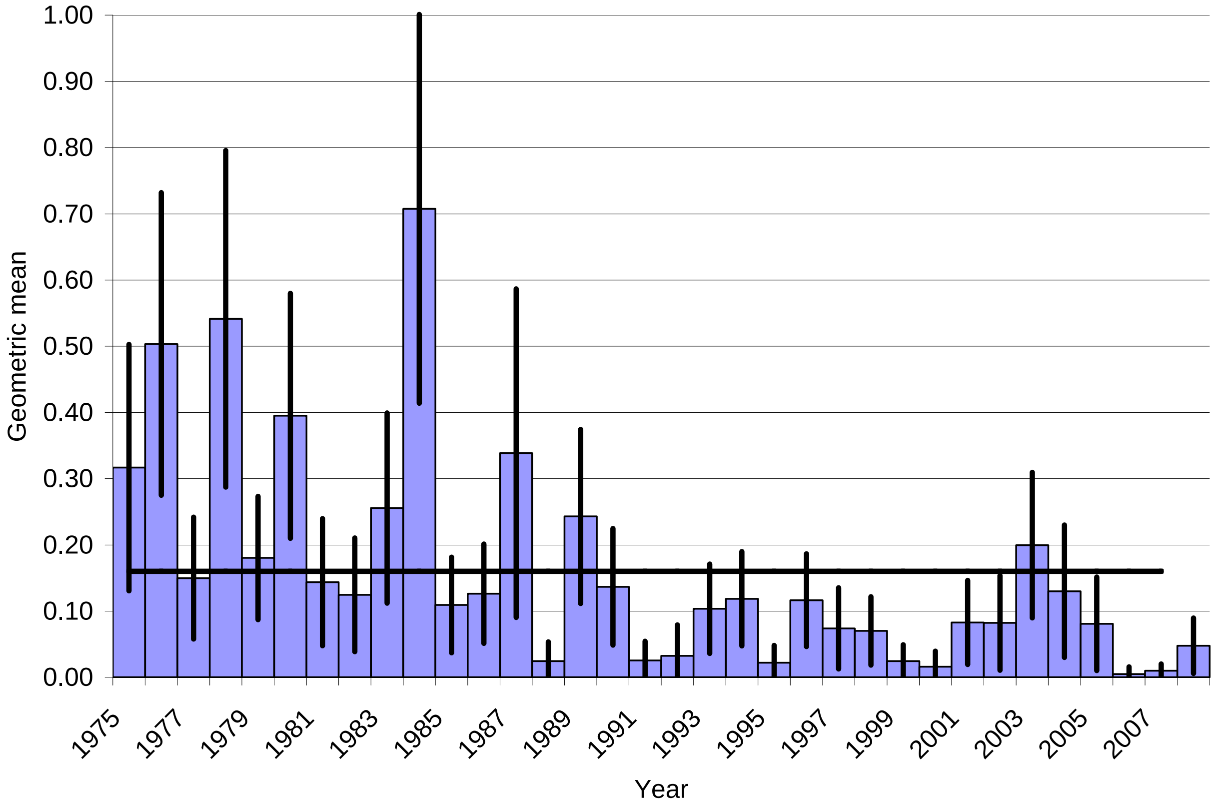


Figure 26. Age 1 channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Year-class indicated in parentheses.

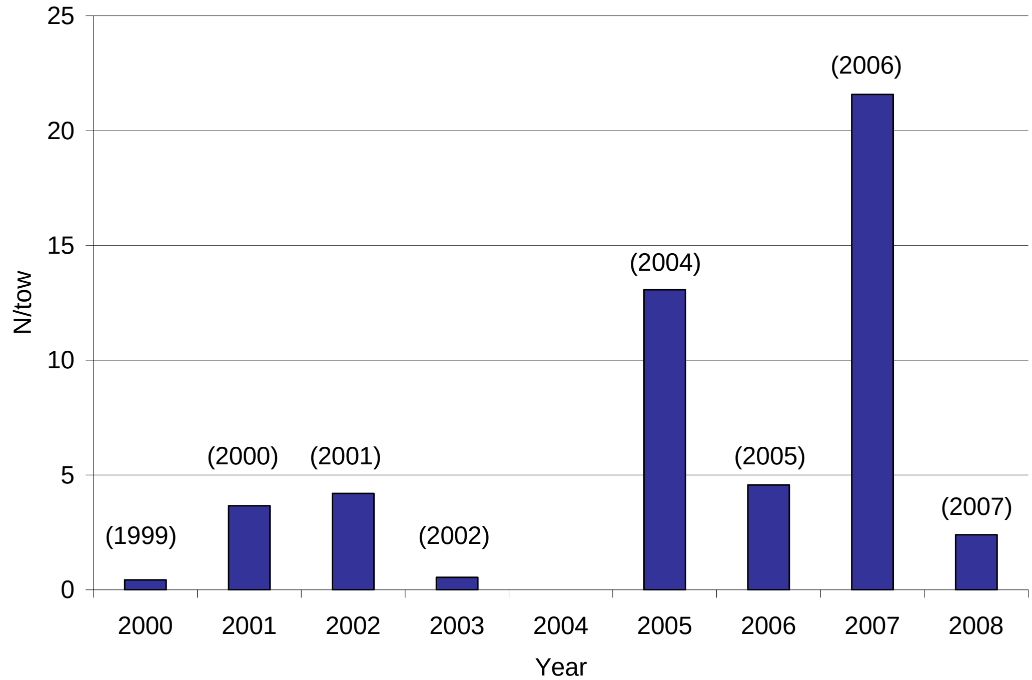


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2008.

	AGE											
Year	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2000	21.9	62.9	32.3	40	25.2	25.5	38.1	3.1	5.7	3	257.7	79
2001	33.5	69.3	77.3	33.3	22	8.8	8.2	15.4	2.3	2.3	272.4	115
2002	0.2	22.5	14.4	24.3	10.4	20.3	12.7	2.8	6	1	114.6	110
2003	0	63.7	295.5	38.2	67.7	26.2	69.3	44.1	9	29.8	643.4	20
2004					NOT SAMPLED							
2005	24.93	43.77	7.3	7.7	4.1	7.5	6.5	1.6	2.49	0.3	106.2	43
2006	87.94	30.3	62.5	20.1	18.5	6.1	3.8	4	0.9	1.6	235.7	108
2007	35.5	28.3	51.5	12.4	8.7	2.2	1.3	1.9	0.3	0.7	142.9	71
2008	149.8	23.0	62.2	49.7	17.1	6.2	2.5	3.0	0.9	1.0	315.3	108

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2008.

	AGE											
Year	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2000	0.0	0.1	6.2	35.6	35.3	6.7	23.2	3.3	1.7	0.0	112.0	310
2001	0.0	1.5	58.9	45.5	17.8	7.6	1.8	2.5	0.7	0.0	136.4	310
2002	0.0	1.1	36.9	21.6	10.2	10.2	2.2	3.0	1.8	0.2	87.3	306
2003	0.0	4.7	35.5	31.2	36.0	1.7	24.6	7.4	3.6	4.0	148.7	261
2004	0.0	0.0	37.3	12.0	14.4	17.0	1.4	9.0	3.1	2.6	96.9	251
2005	0.0	4.1	18.9	37.8	22.1	12.4	4.2	0.9	5.9	0.2	106.3	235
2006	0.0	1.1	76.1	3.0	32.9	15.9	1.9	2.1	1.1	16.4	150.6	236
2007	0.0	1.8	16.2	122.7	13.9	53.3	20.4	7.8	8.1	6.8	250.9	203
2008	0.0	0.0	25.7	18.2	52.8	4.4	17.1	10.5	2.2	4.5	135.3	248

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2008.

	AGE											
	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2000	0.19	0.94	0.16	1.18	0.04	0.08	0.04	0.00	0.00	0.00	2.62	79
2001	5.55	0.63	0.81	0.11	0.55	0.04	0.00	0.03	0.00	0.00	7.72	114
2002	10.88	0.35	7.88	0.79	1.65	0.28	0.75	0.17	0.05	0.00	22.80	110
2003	122.70	105.25	5.30	10.15	4.75	2.65	0.00	0.00	0.00	0.00	250.80	20
2004	NOT SAMPLED											
2005	32.79	45.10	15.96	2.67	0.32	0.22	0.00	0.00	0.00	0.00	97.06	43
2006	13.06	17.96	6.35	1.06	0.13	0.09	0.00	0.00	0.00	0.00	38.65	108
2007	1.21	6.66	4.04	0.00	0.84	0.08	0.00	0.03	0.00	0.00	12.87	71
2008	9.76	2.15	5.42	4.76	1.20	0.00	0.00	0.00	0.00	0.00	23.29	108

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2008.

	AGE											
	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
1988	0.00	0.15	4.54	0.15	0.03	0.36	0.32	0.02	0.02	0.08	5.68	59
1989	0.00	0.00	1.18	3.44	1.19	0.60	0.12	0.03	0.03	0.00	6.59	68
1990	0.00	0.32	2.63	1.21	4.01	0.78	0.15	0.12	0.07	0.01	9.31	68
1991	0.00	0.10	0.59	0.76	0.26	0.63	0.13	0.03	0.03	0.00	2.51	70
1992	0.00	0.01	0.07	0.12	0.13	0.06	0.05	0.00	0.00	0.00	0.45	113
1993	0.00	0.03	0.63	1.25	0.82	0.91	0.31	0.06	0.03	0.00	4.03	120
1994	0.00	0.37	1.39	0.22	0.71	0.76	0.68	0.56	0.04	0.16	4.89	114
1995	0.00	0.65	2.13	0.19	0.56	0.55	0.35	0.31	0.04	0.17	4.96	121
1996	0.00	6.12	2.45	1.91	0.25	0.58	0.34	0.19	0.31	0.06	12.21	140
1997	0.00	0.09	4.19	0.65	0.56	0.00	0.12	0.16	0.05	0.00	5.82	153
1998	0.00	0.92	0.50	3.79	0.17	0.20	0.00	0.05	0.02	0.11	5.76	154
1999	0.00	1.72	47.83	0.48	17.69	0.18	0.05	0.04	0.00	0.03	68.03	178
2000	0.00	2.01	0.56	8.40	0.16	0.85	0.00	0.04	0.00	0.00	12.03	164
2001	0.00	5.35	12.11	0.62	6.95	0.12	0.44	0.01	0.00	0.00	25.60	164
2002	0.00	1.88	7.51	6.57	0.21	2.42	0.58	0.29	0.02	0.00	19.47	178
2003	0.00	3.05	3.63	7.62	2.76	0.28	1.86	0.29	0.27	0.01	19.77	121
2004	0.00	0.38	3.23	1.13	0.77	0.66	0.00	0.39	0.00	0.04	6.62	156
2005	0.00	8.96	0.74	2.24	0.72	0.30	0.75	0.12	0.28	0.08	14.19	186
2006	0.00	1.09	11.76	1.11	2.50	0.41	0.42	0.27	0.00	0.04	17.56	158
2007	0.00	10.80	5.26	11.14	0.24	1.30	0.78	0.20	0.07	0.09	29.88	140
2008	0.00	0.23	7.85	0.78	1.96	0.08	0.30	0.12	0.00	0.00	11.33	166

Figure 27. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2008. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

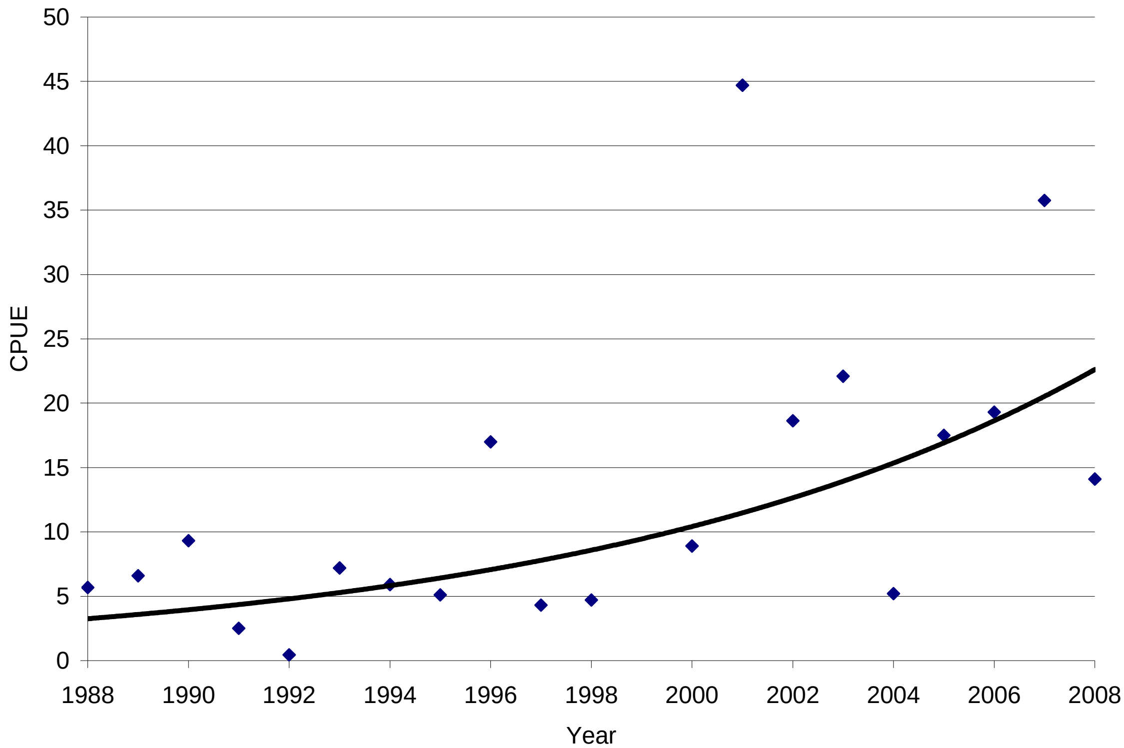


Figure 28. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2008. Not surveyed in 2004, small sample sizes in 2003 and 2005.

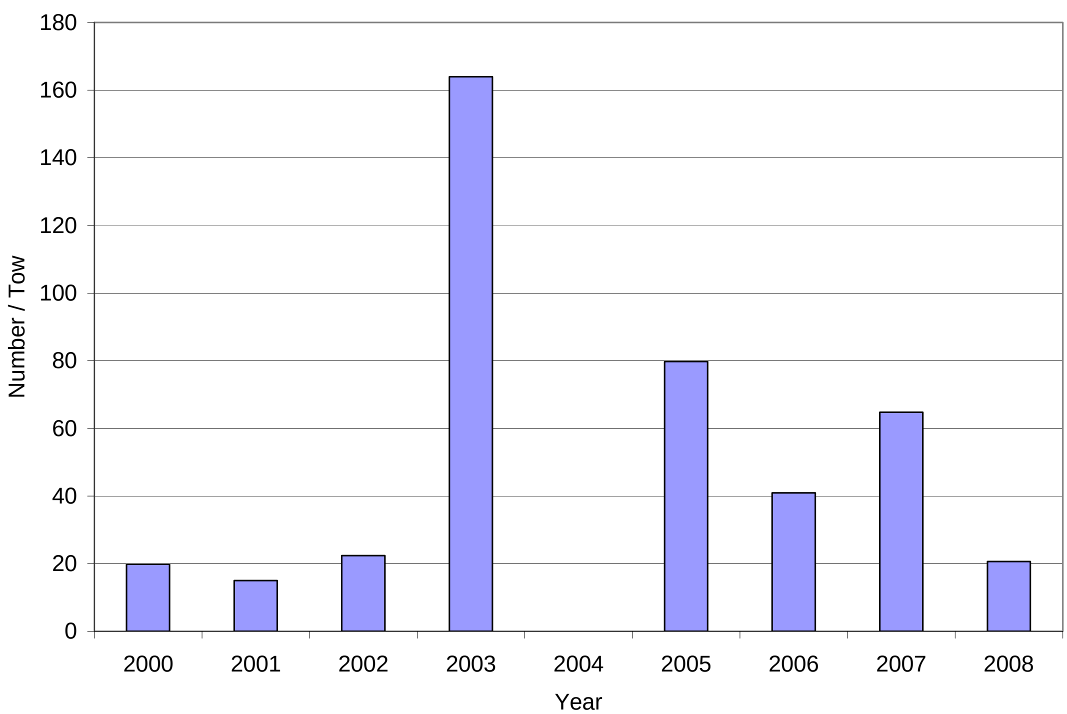


Figure 29. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2008.

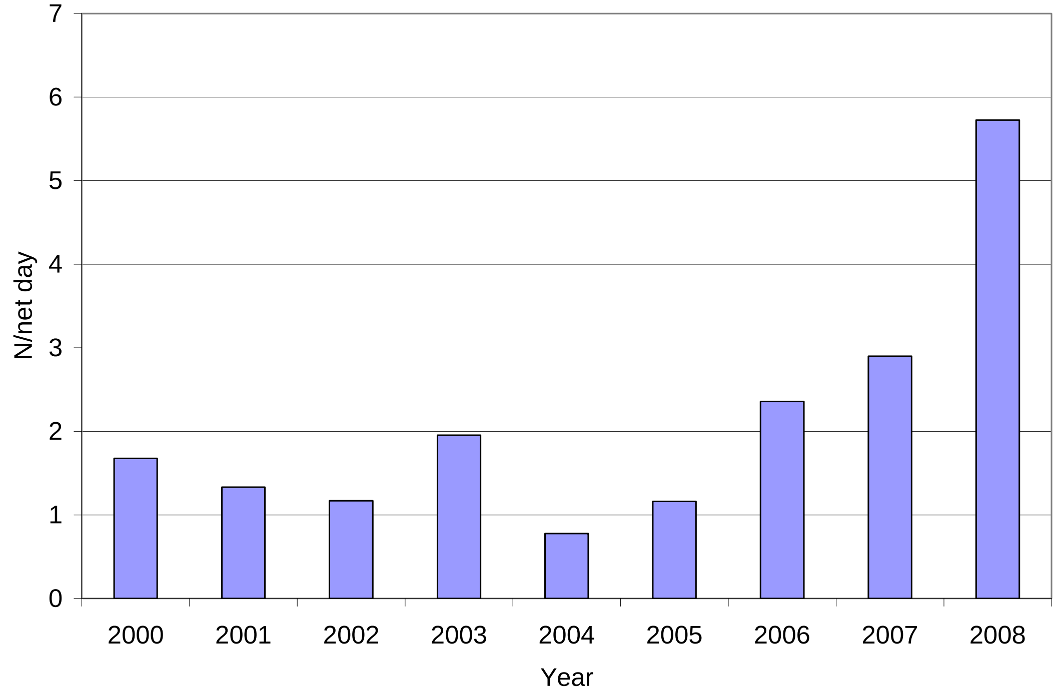
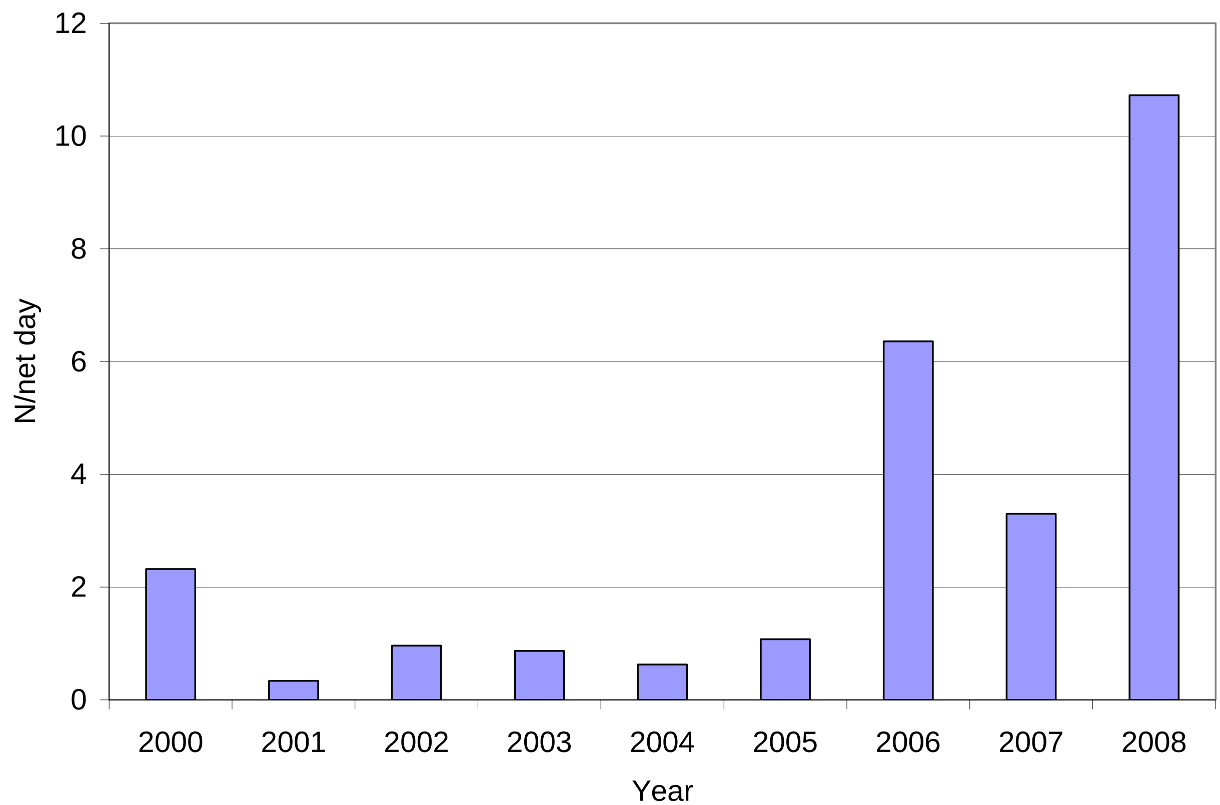


Figure 30. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2008.



PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF WHITE PERCH IN MARYLAND WITH SPECIAL EMPHASIS ON CHOPTANK RIVER STOCKS

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

White perch fisheries are important in the Chesapeake Bay region. Based on the Marine Recreational Fisheries Statistics Survey (MRFSS; National Marine Fisheries Service, personal communication), Maryland's 2007 recreational white perch landings were 1,145,000 pounds, and have averaged 887,000 pounds during the five-year period 2003 – 2007. The 2007 recreational white perch harvest was the highest in the time-series (1981 – 2007). White perch also support a robust commercial fishery in Maryland. Commercial white perch landings were 603,000 pounds in 2007, and averaged 1,135,000 pounds over the five-year period 2003 – 2007. Commercial landings in 2006 and 2007 were the lowest since 1991.

Maryland's white perch stocks were last assessed in 2006 (Piavis and Webb 2006). For that assessment, a surplus production model was used to assess baywide white perch stocks for the period 1980 - 2005, and a catch-survey analysis was used to describe white perch population dynamics in the Choptank River for the period 1989 - 2005. The 2008 assessment provides an update of those previous assessments and also investigates the suitability of including other data sources into the population models. Additional parameters investigated included abundance, mortality, recruitment/production, and catch-per-unit-of-effort. This updated assessment will provide important information regarding management of this species, particularly in the upcoming preparation of the Chesapeake Bay White Perch Fisheries Management Plan.

METHODS

Bay-wide surplus production modeling

Fishery Dependent Catch per Unit Effort Indices

Commercial landings and catch per unit effort (CPUE) indices were determined from DNR commercial catch records. Landings data exist prior to World War II, but associated effort data are only available for 1980 – 1984, 1990, and 1992 – 2007. Three primary white perch commercial fisheries were utilized to estimate relative abundance indices; fyke net, drift gill net, and pound net fisheries. For fyke and pound nets, effort can only reliably be ascribed as numbers of nets fished, while drift gill net effort was determined as pounds per 1,000 yard^2 X hours fished. A 1,000 pound monthly minimum landings criterion was used to filter out non-directed effort.

All recreational landings and CPUE indices were determined from the MRFSS during 1981 – 2007 (National Marine Fisheries Service, personal communication). Effort was defined as those trips targeting white perch or catching white perch. CPUE was defined as pounds per 1,000 angler trips.

Fishery Independent Catch per Unit Effort Indices

Fisheries Service has conducted a striped bass spawning survey since 1980. Drift gill nets with a range of mesh sizes are deployed in the upper Chesapeake Bay and Potomac River. In some years, the Choptank River and Elk River were also sampled. Detailed description of these methods may be found in Project 2, Job 3, Task 2 of this report. The survey is intended to index striped bass spawning stock biomass, but by-catch is also counted and measured. Analysis of by-catch trends have proved valuable for species other than striped bass such as white perch (*Morone americana*) and gizzard shad (*Dorosoma cepedianum*). All areas were used to formulate a fishery independent biomass index, but only mesh sizes of 3” – 4.5” stretch mesh were considered. Years with available data included 1982 – 1983 and 1985 – 2007.

The biomass index was derived by determining the annual average length per mesh size and substituting the average length into an allometric equation of length-weight. The Nanticoke River allometric equation (sexes and all years combined) was used (2000 – 2008; from Project 1, Job 1). Average weight per mesh size was multiplied by total caught per net set. Effort was determined as gear length*gear width*hours fished. Catch per effort was defined as pounds per 1,000 foot^2 hours.

White perch young-of-year (yoy) relative abundance has been estimated since 1962 from the Estuarine Juvenile Finfish Survey. This seine survey visits sites in several Chesapeake Bay systems in three rounds during July – September. Detailed methods can be found in Project 2, Job 3, Task 3 of this report. Geometric mean catch per haul from all permanent sites was used as the index of production.

Model formulation

Surplus production models fit biomass estimates to the equation:

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

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

The model took the form of the Haddon (2001) implementation where series of biomass estimates are generated to maximize a log-likelihood function by solving for initial biomass (B_0), r, and K. A correlation matrix was produced for all indices to determine their utility in the model. Commercial fyke net CPUE, drift gill net CPUE, pound net CPUE, recreational angler CPUE (all fishery dependent indices) and the biomass index from the striped bass spawning stock biomass survey (fishery independent index) were investigated for inclusion in the model. Negatively correlated indices will confound parameter estimation, and indices with low correlation coefficients were deemed too noisy for inclusion. An estimated index (I^) is derived from the equation

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

where q is average catchability and e^{ε} is the lognormal residual error. This form simplifies the solution by not having to solve for a catchability parameter for each index. In this closed form, average catchability (q) for each index is

$$q = e^{(1/n)\,\Sigma \ln(I_t / B)_t}. \qquad [3]$$

The log function to be maximized is simply the sum of all log-likelihoods multiplied by a weighting factor. For this assessment all indices were weighted equally. The log-likelihood function for an individual index is

$$LL = -n/2\ (\ln(2\pi) + 2\ln(\sigma) + 1) \qquad [4]$$

where $\sigma = \sqrt{\Sigma(\ln I_{t,a} - \ln I\hat{}_{t,a})^2/n}$, [5]

and n is the number of data points in the series, $I_{t,a}$ is the observed index in year a and $I\hat{}_{t,a}$ is the expected index in year a. 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 expected indices, then re-exponentiating the values, quantified model uncertainty (Number of bootstraps = 200). Mean, median, standard deviation and coefficient of variation were calculated for all fitted parameters and each estimate of annual biomass. Confidence intervals (80% CI) were determined from cumulative percent distributions of the biomass, F, $B:B_{msy}$ and $F:F_{msy}$, in addition to the fitted parameters (r, K, and B_0).

Choptank River White Perch Assessment

Site Description

The Choptank River is located on Maryland's eastern shore of the Chesapeake Bay. The watershed encompasses 370,896 acres and contains two predominant tributaries; Tuckahoe River and Hunting Creek. Agricultural acreage constitutes the majority of the watershed land use (62.5%; 1994), followed by forested acreage (28.3%). Historic wetland loss was estimated at 38%. Impervious surface accounted for 2% of the watershed, and 1990 census data estimated a population density of 0.14 people per acre.

Fisheries Service fyke nets were located from river km 65.4 to km 78.1 (Figure 1). The Choptank River is tidal and generally fresh at the five survey sites. However, during the severe drought of 2001 - 2002, salinity increased to 6 ppt, but has never exceeded white perch tolerance limits (18 ppt; Setzler-Hamilton 1991).

Field Operations

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

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

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

CSA Model Structure

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

$$R_{t+1} = (R_t + P_t)\, e^{-M t} - C_t\, e^{-M t (1-T t)} \qquad [6]$$

where R is the post-recruit abundance, P is the pre-recruit abundance, M is instantaneous natural mortality, C is harvest, and T is the fraction of time between the survey and the harvest.

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

$$r_t = R_t\, q \qquad [7]$$

and,

$$p_t = P_t\, q\, \Phi \qquad [8]$$

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

Substituting [7] and [8] into equation [6] yields

$$r_{t+1} = (r_t + p_t / \Phi)\, e^{-M} - q\, C_t\, e^{-Mt(1-Tt)} \qquad [9]$$

CSA Error Structure

Adding a process error term (ε) into [9] yields

$$r_{t+1} = (r_t + p_t / \Phi)\, e^{-M\,\varepsilon} - q\, C_t\, e^{-M(1-Tt)\varepsilon} \qquad [10]$$

Measurement error (η and δ) is similarly incorporated into [7] and [8]

$$p_t = P_t\, q\, e^{\eta} \qquad [11]$$

$$r_t = R_t\, q\, \Phi\, e^{\delta} \qquad [12]$$

The original CSA utilized a mixed error model structure (Collie and Sissenwine 1983), which yields the objective function to be minimized

$$SSQ = \lambda_{\varepsilon} \Sigma \varepsilon^2 + \Sigma \eta^2 + \lambda_{\delta} \Sigma \delta^2 \quad [13]$$

where λ_{ε}, λ_{δ}, and λ_{η} are weighting factors. Equation [13] yields 3*i*-2 residual errors and 2*i* parameters to be fitted (q, $r_{1...i}$, $p_{1...i-1}$; Collie and Sissenwine 1983).

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

$$SSQ = \lambda_{\eta} \Sigma \eta^2 + \lambda_{\delta} \Sigma \delta^2 \quad [14]$$

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

Abundance and Mortality Estimation

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

$$h_t = C_t /((P_t + R_t) * e^{-Mt*Tt}) \quad [15]$$

Total instantaneous fishing mortality (F) was

$$F_t = -\log_e (1-h_t) . \quad [16]$$

Inputs

Pre-recruit and post-recruit indices of abundance were determined from Fisheries Service fyke net catches. Pre-recruits were those white perch between 185 and 202 mm TL. Post-recruit white perch were those fish greater than 202 mm TL because the commercial fishery operates under a 203 mm TL minimum size limit. Numbers of pre-recruit and post-recruit white perch were determined for each fyke net visit by applying the proportion of pre-recruit and post-recruit white perch from the length subsample to the total catch. Those totals were then summed for the year and divided by total fyke net effort, defined as numbers of days the gear were in the water.

Harvest estimates were determined for the commercial and recreational fisheries. Commercial harvesters are required to submit monthly landings reports by river system, in pounds, to the Maryland Department of Natural Resources. Numbers of commercially harvested white perch were determined by dividing pounds harvested (by gear type) by estimated average weight of legal white perch. Average legal weight by gear type was determined from several sources. Average length of fyke net caught white perch was taken from Fisheries Service survey nets. An allometric equation was applied to the average length to determine average weight. Average length of white perch caught in the gill net fishery was determined from data collected between 1989 - 1994 and 1996 by the Fisheries Service striped bass spawning stock gill net survey in the Choptank River. Data from the Fisheries Service upper Bay striped bass spawning stock survey was used for the 1995 and 1997 – 2007 mean length estimates. An allometric equation was applied to average length to determine average weight.

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

Relative catchability of pre-recruits (Φ) was set at 1.0 because length-frequencies indicated that white perch were recruited to the survey gear below the lower cut-off for pre-recruits. Natural mortality (M) was 0.20. An initial catchability for the runs was set at 5.0 X 10 $^{-5.}$ Fraction of year that the survey preceded the fishery (T) was 0.5.

Uncertainty

The model was bootstrapped 500 times by resampling residuals and adding them to the natural logarithm of the expected index values, then re-exponentiating the values. Mean, median, standard deviation and CV's were calculated for q and each estimate of P_t and R_t, exclusive of the terminal year. Confidence intervals (80%) were determined from cumulative percent distributions of the bootstrapped parameter estimates.

RESULTS

Fishery dependent trends

White perch commercial landings exhibited two time periods of relatively high landings since 1929, one during the mid 1960's and early 1970's and the latest from the mid 1990's through 2004 (Figure 2). Two intermediate peaks occurred in the early 1950's and early 1980's. Recreational landings during 1981 – 2007, as estimated by MRFSS, indicated a linear increase from 1981 to 1998, followed by a decline through 2001 and another increase through 2007 (Figure 3). Commercial and recreational catches were somewhat similar through 2005, but landings diverged during 2006 and 2007 with recreational landings increasing while commercial landings decreased nearly in half.

Commercial fyke net CPUE suggested a near linearly increasing relative abundance from 1980 –2003 followed by a decline from 2004 – 2007 (Figure 4). Commercial drift gill net CPUE was stable throughout most of the time-series, but indicated higher relative abundance from 2002 – 2005 before declining during 2006 – 2007 (Figure 5). Commercial pound net CPUE reflected no clear trend (Figure 6). Recreational CPUE indicated increasing relative abundance from the early 1980's through 1992, followed by a decline. Relative abundance increased from 2002 through 2007 (Figure 7).

Fishery independent survey trends

A biomass index for white perch was formulated from the striped bass spring spawning stock biomass gill net survey. This fishery independent survey indicated that relative abundance was stable through 1994 then increased rapidly to a peak in 1997. A secondary biomass peak was evident during 2004 – 2006 (Figure 8).

White perch juvenile abundance has generally been above average since the mid 1990's (Figure 9). Since 1993, the index was at or above the time-series average (1962 – 2008) in 11 of 16 years. Previous to 1993, reproduction was near or above average in only 4 of 31 years.

Bay-wide surplus production model

Correlation analysis was used to determine which combinations of indices (recreational CPUE, fyke net CPUE, drift gill net CPUE, pound net CPUE, and the biomass index) would be appropriate for use in the white perch surplus production model.

Pound net CPUE was poorly correlated with other indices so it was excluded. The model was run with all combinations of the remaining indices. Generally, these runs fell into three classes; failed fits, runs that never produced biomass over B_{msy}, (an unlikely outcome), and one fit that indicated population building through the late 1990's with a decrease in 1999, followed by a stable population through 2007. The model run from the latter category was considered as representative of white perch population dynamics. The final run selected contained recreational CPUE and the fishery independent biomass index from the striped bass spawning stock gill net survey.

Estimated parameters, r, K, and B_0 were 0.45, 20.6 million pounds and 4.0 million pounds, respectively. Biomass increased from a low of 4.0 million pounds in 1980 to a high value of 16.3 million pounds during 1993 (Figure 10). Instantaneous fishing mortality (F) generally increased from 1990 – 2005 with a peak in 1997 (Figure 10). Fishing mortality decreased in 2006 and 2007 relative to 2005 due to the drop in commercial harvest.

Biomass at maximum sustainable yield (B_{msy}) was estimated as 1/2K or 10.3 million pounds. F_{msy} was estimated as 1/2r or 0.22. Maximum sustainable yield was estimated as rK/4 or 2.3 million pounds. Ratios of $B:B_{msy}$ and $F:F_{msy}$ were within acceptable ranges, that is, $B/B_{msy} > 1$ and $F/F_{msy} < 1$ for large portions of the time series (Figure 11).

In the final year of the assessment (2007) F was 39% below F_{msy} and biomass was 33% > B_{msy}. Similarly, total estimated removals averaged 2.0 million pounds during the most recent 5-year period, 2003 – 2007, below the 2.3 million pound MSY estimate. The 2007 harvest estimate (recreational and commercial) was 1.7 million pounds.

Residuals of observed error from the 2 indices showed no patterns. The recreational CPUE index had only one relatively large negative residual (Figure 12). The biomass index had an extended period of negative residuals (9 years) covering the time span where the population was increasing, yet the observed biomass index was flat to increasing (Figure 13).

Uncertainty

Parameter estimates for r, K, and B_0 were very precise. CV values were 8.6%, 8.5% and 9.7%, respectively, and median values were close to final estimates (Table 1). Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than r and K in model outputs. Annual biomass estimate CV's ranged from 9.4% – 14.8%. Annual F estimates were slightly less precisely estimated, but were still very precise given that CV's ranged from 11.4% to 16.5%. Confidence intervals (80%) of bootstrapped runs were relatively tight for biomass (Figure 14) and F (Figure 15). However, biomass may have been biased high whereas F was probably biased low.

Surplus production models may not estimate absolute biomass or F reliably, but the ratios of $B:B_{msy}$ and $F:F_{msy}$ are generally robust (Prager 1994). Confidence intervals of these population benchmarks were generally very tight (Figures 16 and 17). Bootstrap results indicated that it was highly unlikely that the white perch population was over-fished ($B:B_{msy} >1$) in the terminal year of the assessment (2007), and that it was highly unlikely that over-fishing was occurring ($F:F_{msy} < 1$) in 2007.

Choptank River White Perch Assessment

Total removals by the commercial and recreational fisheries on the Choptank River were below 500,000 white perch early in the time-series, but increased to a peak removal of over 2 million fish in 1997 (Figure 18). Landings exhibited a general decline from 1998 through 2007. Pre-recruit fishery independent CPUE values showed a generally increasing trend over the time-series (Figure 19). Post-recruit white perch CPUE was flat from 1989 – 1995, and then steadily increased through 2005 (Figure 20).

Choptank River white perch data fit the CSA model well. Total population abundance in numbers increased from 991,300 white perch during 1989 to 6.0 million fish in 2007 (Figure 21). Pre-recruit abundance (185 mm – 202 mm) ranged from 501,000 white perch in 1991 to 3.1 million in 2007. Post-recruit white perch abundance ranged from 460,000 white perch in 1989 to 2.9 million fish in 2007. Instantaneous fishing mortality (F) increased through 1997 followed by a general decline through 2007 (Figure 22). Final year F was 0.21.

Examination of pre-recruit residuals indicated a period of negative residuals for the first 5 years and positive residuals over the last 9 years (Figure 23). The years of negative residuals coincides with reduced sampling effort relative to subsequent years. Post-recruit residuals showed no discernible pattern (Figure 24).

A suite of biological reference points were determined for Chesapeake Bay white perch in a previous assessment (Piavis and Webb, 2006). Spawning stock biomass per recruit analysis determined maximum spawning potential reference points. Given the early time at first maturity, $F_{30\%}$ (target) and $F_{20\%}$ (limit) MSP reference points appear appropriate. Target F and limit F were 0.6 and 1.12, respectively. Target F was exceeded several years in the 1990's, and the limit was exceeded in 1997. However, F has been at or below the target since 2001 (Figure 22).

Uncertainty

Bootstrap evaluation of the model indicated precise results. Pre-recruit abundance fit very well with CV's, ranging from 11.5% to 28.1% (Table 2). CV's of fully recruited white perch ranged from 18.9% to 26.8%. CV's of F ranged from 14.2% to 20.4%. Catchability was very precisely estimated at 8.9% (CV). Confidence intervals (80%) of pre-recruit and post-recruit abundance were also determined from bootstrap samples (Figures 25, 26, and 27). Confidence intervals around F indicated that F is likely biased low (Figure 28). However, based on the distribution of bootstrapped F estimates, it is highly unlikely that F exceeded the proposed F_{target} in the final year of the assessment (2007).

DISCUSSION

Chesapeake Bay Assessment

The model utilized for the white perch Chesapeake Bay assessment was selected based on available data. Lack of long-term age data precluded age based assessments such as Virtual Population Analysis (VPA). The population data appeared to have completed a full population cycle, critical for model/data fit (Prager 1994, Magnusson and Hilborn 2007). The bay-wide assessment would not be sensitive to localized population declines, but juvenile abundance data provided by the Estuarine Juvenile Finfish Survey (Project 2, Job 2, Task 3) indicated healthy reproduction in all 8 regions surveyed. Adult population data such as age data and length distributions should be monitored on a watershed basis where practicable.

Chesapeake Bay white perch stocks are at relatively high levels with moderate fishing mortality. Stocks have declined since 1993, but remain above reasonable benchmarks. Incorporating model and data uncertainty into the assessment also indicates a high likelihood that population levels are above B_{msy}. Similarly, F levels are reasonable given model and data uncertainty. Fishing mortality estimates from the surplus production model are biomass based F's and, thus, not directly comparable to reference points derived from spawning stock biomass per recruit models. However, the surplus production estimates provide their own management benchmarks in the form of MSY. Long-term biomass should be above B_{msy} and F should be below F_{msy}. Based on those benchmarks, white perch populations are not over-fished and over-fishing is not occurring. The last time that F approached the over-fishing definition was 1998, and the last time that biomass approached an over-fished level was in 1987.

Harvest levels exceeded MSY in 1997, 2000, and 2005, but this occurred at high population levels causing a slight decline in abundance. Juvenile production has also been at high levels, which help mitigate any short-term violation of MSY. Harvest in 2007 was comfortably below MSY.

Choptank River Assessment

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

Intermediate-term monitoring of Choptank River resident species afforded a more in-depth statistical treatment of the data. CPUE analysis with a CSA indicated a growing population, both in pre-recruit and post-recruit white perch numbers. Uncertainty analysis indicated fairly precise results. Population levels have increased throughout the course of the study, consistent with Fisheries Service CPUE indicators and commercial CPUE.

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

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

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Table 1. Uncertainty parameters for Bay-wide white perch biomass dynamic model. (r=intrinsic rate of increase, Std Dev=standard deviation, and CV=coefficient of variation). K and biomass parameters are in pounds.

Parameter	Estimate	Mean	Median	Std Dev	CV
r	0.451	0.483	0.478	0.042	0.086
K	20,639,529	19,693,665	19,970,634	1,672,316	0.085
Bo	3,994,997	3,627,882	3,709,673	352,328	0.097
B 1981	4,353,649	3,954,503	3,954,503	423,171	0.107
B 1982	5,101,449	4,671,316	4,671,316	534,406	0.114
B 1983	5,943,999	5,494,329	5,494,329	689,217	0.125
B 1984	7,109,854	6,654,445	6,654,445	888,075	0.133
B 1985	8,210,396	7,765,543	7,765,543	1,114,220	0.143
B 1986	9,701,379	9,273,969	9,273,969	1,345,830	0.145
B 1987	11,202,930	10,788,521	10,788,521	1,537,689	0.143
B 1988	12,648,292	12,227,300	12,227,300	1,660,950	0.136
B 1989	13,653,901	13,199,962	13,199,962	1,710,021	0.130
B 1990	14,892,908	14,391,909	14,391,909	1,717,542	0.119
B 1991	15,462,752	14,899,410	14,899,410	1,685,856	0.113
B 1992	15,962,543	15,347,571	15,347,571	1,658,036	0.108
B 1993	16,310,286	15,653,903	15,653,903	1,635,196	0.104
B 1994	16,053,979	15,367,318	15,367,318	1,619,457	0.105
B 1995	15,809,432	15,113,673	15,113,673	1,617,671	0.107
B 1996	15,886,328	15,192,430	15,192,430	1,622,429	0.107
B 1997	15,245,824	14,553,617	14,553,617	1,625,211	0.112
B 1998	13,985,728	13,307,687	13,307,687	1,639,410	0.123
B 1999	14,075,517	13,424,212	13,424,212	1,680,668	0.125
B 2000	14,264,348	13,631,705	13,631,705	1,711,325	0.126
B 2001	13,762,356	13,140,785	13,140,785	1,729,873	0.132
B 2002	13,698,786	13,091,153	13,091,153	1,761,300	0.135
B 2003	13,698,446	13,101,085	13,101,085	1,789,387	0.137
B 2004	13,514,265	12,923,599	12,923,599	1,812,620	0.140
B 2005	13,538,401	12,953,812	12,953,812	1,839,481	0.142
B 2006	13,193,537	12,611,907	12,611,907	1,861,180	0.148
B 2007	13,755,408	13,178,295	13,178,295	1,895,235	0.144

Table 1. Continued.

Parameter	Estimate	Mean	Median	St Dev	CV
B:Bmsy 1980	0.387	0.369	0.368	0.026	0.072
B:Bmsy 1981	0.422	0.402	0.400	0.031	0.078
B:Bmsy 1982	0.494	0.475	0.473	0.041	0.086
B:Bmsy 1983	0.576	0.558	0.558	0.055	0.098
B:Bmsy 1984	0.689	0.676	0.674	0.073	0.108
B:Bmsy 1985	0.796	0.789	0.786	0.094	0.119
B:Bmsy 1986	0.940	0.942	0.936	0.114	0.121
B:Bmsy 1987	1.086	1.097	1.088	0.130	0.119
B:Bmsy 1988	1.226	1.243	1.239	0.137	0.110
B:Bmsy 1989	1.323	1.341	1.342	0.135	0.100
B:Bmsy 1990	1.443	1.462	1.468	0.127	0.087
B:Bmsy 1991	1.498	1.514	1.524	0.113	0.074
B:Bmsy 1992	1.547	1.559	1.567	0.099	0.063
B:Bmsy 1993	1.580	1.589	1.594	0.086	0.054
B:Bmsy 1994	1.556	1.560	1.561	0.075	0.048
B:Bmsy 1995	1.532	1.533	1.531	0.070	0.045
B:Bmsy 1996	1.539	1.541	1.540	0.066	0.043
B:Bmsy 1997	1.477	1.476	1.475	0.065	0.044
B:Bmsy 1998	1.355	1.348	1.347	0.072	0.053
B:Bmsy 1999	1.364	1.360	1.357	0.077	0.056
B:Bmsy 2000	1.382	1.381	1.378	0.080	0.058
B:Bmsy 2001	1.334	1.331	1.329	0.084	0.063
B:Bmsy 2002	1.327	1.325	1.323	0.089	0.067
B:Bmsy 2003	1.327	1.326	1.324	0.092	0.070
B:Bmsy 2004	1.310	1.308	1.307	0.096	0.074
B:Bmsy 2005	1.312	1.311	1.310	0.100	0.076
B:Bmsy 2006	1.278	1.276	1.276	0.104	0.082
B:Bmsy 2007	1.333	1.334	1.332	0.106	0.080
F 1980	0.320	0.365	0.349	0.050	0.137
F 1981	0.203	0.230	0.221	0.032	0.139
F 1982	0.191	0.215	0.208	0.031	0.144
F 1983	0.133	0.148	0.144	0.022	0.148
F 1984	0.152	0.167	0.163	0.026	0.155
F 1985	0.094	0.102	0.100	0.016	0.158
F 1986	0.088	0.094	0.093	0.015	0.157
F 1987	0.080	0.085	0.085	0.013	0.153
F 1988	0.100	0.106	0.105	0.016	0.147
F 1989	0.064	0.067	0.067	0.009	0.138
F 1990	0.091	0.096	0.096	0.012	0.129
F 1991	0.084	0.089	0.088	0.011	0.121
F 1992	0.084	0.088	0.088	0.010	0.115
F 1993	0.117	0.124	0.122	0.014	0.114
F 1994	0.123	0.130	0.129	0.015	0.115
F 1995	0.106	0.113	0.111	0.013	0.117
F 1996	0.156	0.166	0.163	0.020	0.120
F 1997	0.224	0.240	0.234	0.031	0.131
F 1998	0.150	0.161	0.157	0.022	0.140
F 1999	0.139	0.149	0.146	0.021	0.140

Table 1. Continued

Parameter	Estimate	Mean	Median	St Dev	CV
F 2000	0.192	0.206	0.201	0.030	0.145
F 2001	0.168	0.181	0.177	0.027	0.150
F 2002	0.164	0.177	0.173	0.027	0.153
F 2003	0.180	0.194	0.190	0.030	0.157
F 2004	0.167	0.180	0.176	0.029	0.160
F 2005	0.199	0.215	0.211	0.036	0.165
F 2006	0.128	0.138	0.135	0.023	0.165
F 2007	0.136	0.146	0.144	0.024	0.161
F:Fmsy 1980	1.419	1.511	1.496	0.153	0.102
F:Fmsy 1981	0.902	0.955	0.948	0.115	0.120
F:Fmsy 1982	0.849	0.894	0.894	0.125	0.140
F:Fmsy 1983	0.592	0.616	0.616	0.097	0.158
F:Fmsy 1984	0.673	0.695	0.700	0.122	0.176
F:Fmsy 1985	0.418	0.427	0.425	0.080	0.188
F:Fmsy 1986	0.390	0.395	0.389	0.077	0.195
F:Fmsy 1987	0.356	0.357	0.355	0.070	0.195
F:Fmsy 1988	0.443	0.442	0.442	0.085	0.192
F:Fmsy 1989	0.283	0.282	0.283	0.051	0.183
F:Fmsy 1990	0.405	0.402	0.404	0.069	0.171
F:Fmsy 1991	0.374	0.371	0.373	0.059	0.159
F:Fmsy 1992	0.372	0.369	0.370	0.055	0.148
F:Fmsy 1993	0.518	0.516	0.518	0.072	0.140
F:Fmsy 1994	0.544	0.542	0.543	0.073	0.135
F:Fmsy 1995	0.471	0.470	0.470	0.062	0.132
F:Fmsy 1996	0.691	0.690	0.693	0.091	0.132
F:Fmsy 1997	0.993	0.998	1.001	0.138	0.138
F:Fmsy 1998	0.664	0.669	0.668	0.096	0.144
F:Fmsy 1999	0.618	0.621	0.621	0.091	0.146
F:Fmsy 2000	0.850	0.856	0.854	0.130	0.151
F:Fmsy 2001	0.746	0.753	0.749	0.118	0.156
F:Fmsy 2002	0.729	0.736	0.732	0.118	0.160
F:Fmsy 2003	0.800	0.808	0.802	0.133	0.164
F:Fmsy 2004	0.741	0.749	0.743	0.126	0.168
F:Fmsy 2005	0.884	0.894	0.885	0.155	0.174
F:Fmsy 2006	0.567	0.574	0.568	0.100	0.175
F:Fmsy 2007	0.603	0.608	0.603	0.105	0.173

Table 2. Uncertainty estimates for Choptank River white perch assessment. (q= catchability)

Parameter	Estimate	Mean	Median	St Dev	CV
q	2.34E-05	2.51E-05	2.51E-05	2.24E-06	8.90E-02
Pre-recruit N 1989	525,571	529,174	530,521	118,797	0.224
Pre-recruit N 1990	1,011,673	978,590	984,367	184,275	0.188
Pre-recruit N 1991	510,653	523,687	529,333	147,067	0.281
Pre-recruit N 1992	1,110,125	1,108,795	1,100,416	172,683	0.156
Pre-recruit N 1993	1,121,822	1,103,896	1,102,416	179,197	0.162
Pre-recruit N 1994	1,124,080	1,155,066	1,167,453	206,752	0.179
Pre-recruit N 1995	1,361,300	1,320,422	1,321,510	224,274	0.170
Pre-recruit N 1996	1,832,925	1,781,878	1,798,259	257,016	0.144
Pre-recruit N 1997	2,149,894	2,117,489	2,120,670	243,238	0.115
Pre-recruit N 1998	1,280,561	1,293,910	1,294,565	275,078	0.213
Pre-recruit N 1999	2,049,413	2,045,933	2,055,599	294,050	0.144
Pre-recruit N 2000	1,361,807	1,345,537	1,350,871	264,631	0.197
Pre-recruit N 2001	1,740,196	1,697,221	1,689,057	289,694	0.171
Pre-recruit N 2002	1,375,002	1,368,154	1,378,700	308,175	0.225
Pre-recruit N 2003	1,872,965	1,846,566	1,858,731	370,209	0.200
Pre-recruit N 2004	1,883,478	1,853,558	1,841,533	359,595	0.194
Pre-recruit N 2005	1,955,323	1,928,833	1,925,610	421,621	0.219
Pre-recruit N 2006	2,006,493	1,935,016	1,937,116	457,088	0.236
Pre-recruit N 2007	3,126,974	3,035,976	3,039,857	592,625	0.195
Post-Recruit N 1989	463,377	413,591	942,765	129,321	0.313
Post-Recruit N 1990	493,936	456,124	1,434,713	181,469	0.398
Post-Recruit N 1991	761,175	703,130	1,226,817	154,790	0.220
Post-Recruit N 1992	564,487	527,635	1,636,430	149,141	0.283
Post-Recruit N 1993	508,138	476,877	1,580,773	154,852	0.325
Post-Recruit N 1994	513,631	473,360	1,628,426	193,749	0.409
Post-Recruit N 1995	645,906	638,305	1,958,727	194,411	0.305
Post-Recruit N 1996	673,647	633,956	2,415,834	253,743	0.400
Post-Recruit N 1997	907,118	832,828	2,950,316	188,471	0.226
Post-Recruit N 1998	673,415	586,060	1,879,970	277,896	0.474
Post-Recruit N 1999	972,214	911,623	2,957,556	261,187	0.287
Post-Recruit N 2000	988,853	936,396	2,281,933	263,290	0.281
Post-Recruit N 2001	992,204	935,935	2,633,156	298,323	0.319
Post-Recruit N 2002	1,197,794	1,116,541	2,484,694	347,852	0.312
Post-Recruit N 2003	1,391,893	1,319,761	3,166,327	402,555	0.305
Post-Recruit N 2004	1,710,699	1,630,030	3,483,587	432,876	0.266
Post-Recruit N 2005	1,758,005	1,667,462	3,596,295	529,032	0.317
Post-Recruit N 2006	2,219,423	2,123,604	4,058,620	660,340	0.311
Post-Recruit N 2007	2,923,817	2,786,847	5,822,823	865,207	0.310
Post-Recruit N 2008	3,926,471	3,739,826	6,736,875	999,827	0.267

Table 2. Continued.

Parameter	Estimate	Mean	Median	St Dev	CV
Total N 1989	988,949	942,765	929,109	129,321	0.137
Total N 1990	1,505,609	1,434,713	1,426,255	181,469	0.126
Total N 1991	1,271,829	1,226,817	1,217,457	154,790	0.126
Total N 1992	1,674,612	1,636,430	1,627,003	149,141	0.091
Total N 1993	1,629,960	1,580,773	1,565,432	154,852	0.098
Total N 1994	1,637,711	1,628,426	1,621,060	193,749	0.119
Total N 1995	2,007,207	1,958,727	1,953,906	194,411	0.099
Total N 1996	2,506,572	2,415,834	2,412,559	253,743	0.105
Total N 1997	3,057,012	2,950,316	2,929,845	188,471	0.064
Total N 1998	1,953,977	1,879,970	1,862,205	277,896	0.148
Total N 1999	3,021,627	2,957,556	2,944,459	261,187	0.088
Total N 2000	2,350,660	2,281,933	2,273,652	263,290	0.115
Total N 2001	2,732,400	2,633,156	2,626,070	298,323	0.113
Total N 2002	2,572,797	2,484,694	2,474,631	347,852	0.140
Total N 2003	3,264,858	3,166,327	3,138,637	402,555	0.127
Total N 2004	3,594,178	3,483,587	3,458,053	432,876	0.124
Total N 2005	3,713,329	3,596,295	3,573,833	529,032	0.147
Total N 2006	4,225,916	4,058,620	3,987,693	660,340	0.163
Total N 2007	6,050,791	5,822,823	5,775,811	865,207	0.149
F 1989	0.493	0.544	0.536	0.102	0.188
F 1990	0.478	0.528	0.517	0.092	0.174
F 1991	0.613	0.666	0.651	0.126	0.189
F 1992	0.995	1.062	1.044	0.172	0.162
F 1993	0.943	1.039	1.023	0.185	0.179
F 1994	0.704	0.763	0.742	0.147	0.193
F 1995	0.879	0.956	0.932	0.167	0.174
F 1996	0.819	0.893	0.867	0.165	0.185
F 1997	1.335	1.449	1.438	0.207	0.143
F 1998	0.496	0.545	0.530	0.111	0.205
F 1999	0.903	0.974	0.957	0.152	0.156
F 2000	0.657	0.713	0.695	0.129	0.182
F 2001	0.616	0.677	0.660	0.115	0.170
F 2002	0.409	0.447	0.435	0.083	0.186
F 2003	0.441	0.477	0.469	0.081	0.170
F 2004	0.510	0.552	0.542	0.093	0.169
F 2005	0.310	0.337	0.329	0.059	0.175
F 2006	0.167	0.182	0.179	0.034	0.185
F 2007	0.235	0.250	0.245	0.043	0.172

Figure 1. Choptank River fyke net locations, 2008. Circles indicate locations.

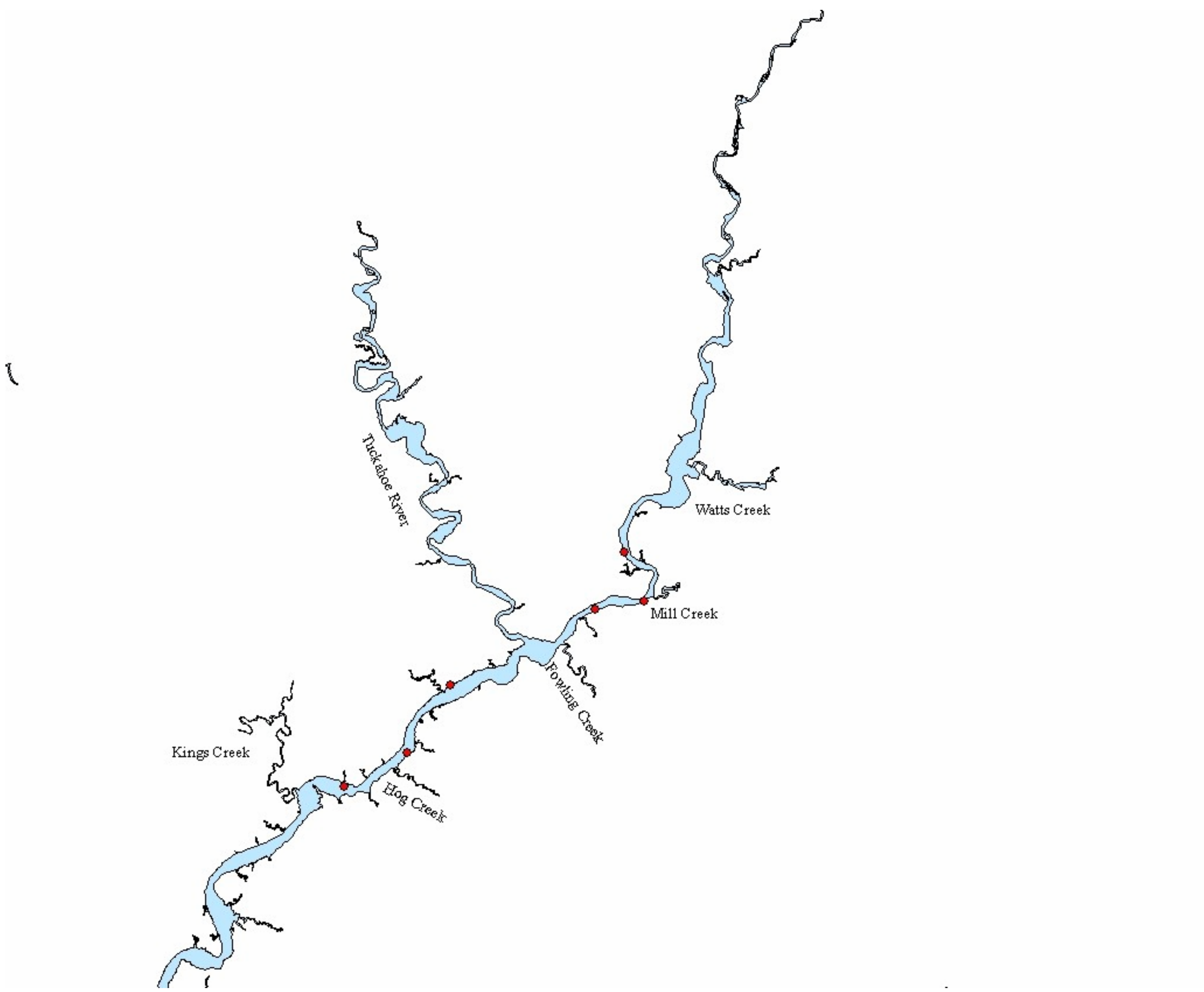


Figure 2. Commercial white perch landings in Maryland, 1929 - 2007.

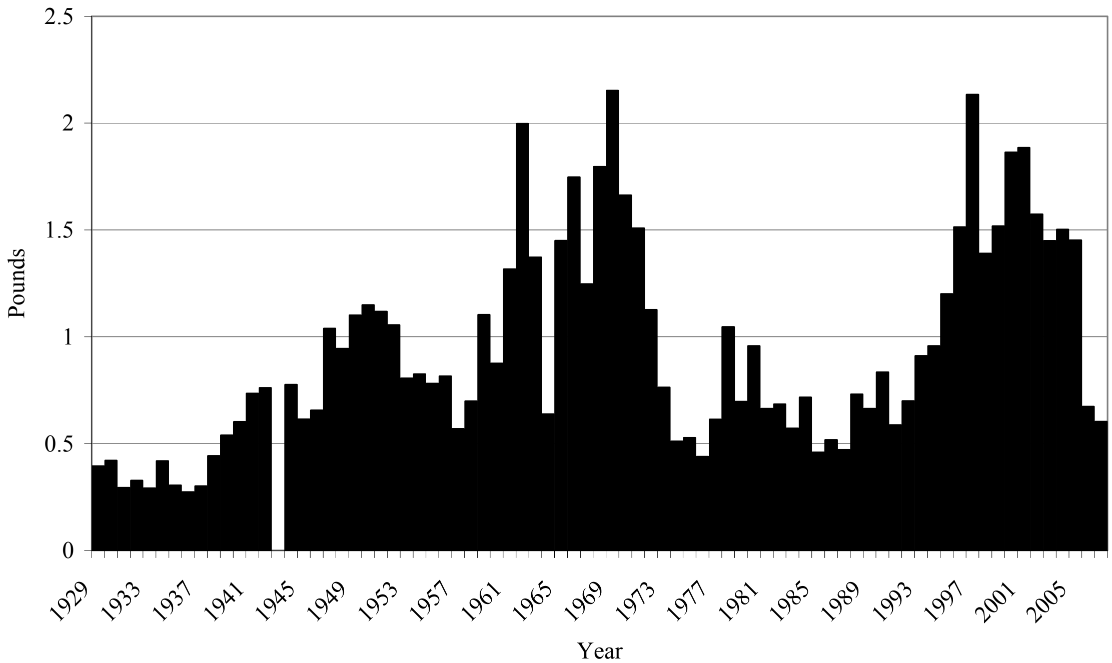


Figure 3. Recreational white perch landings in Maryland, 1981-2007.

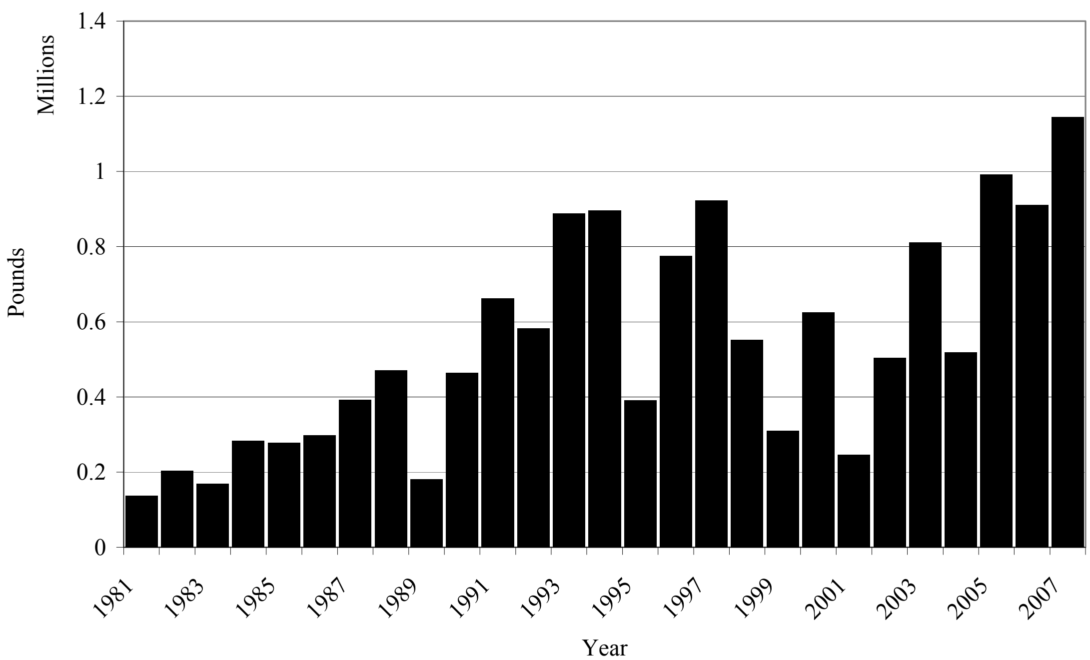


Figure 4. Commercial white perch fyke net catch per unit effort, 1980 - 2007.

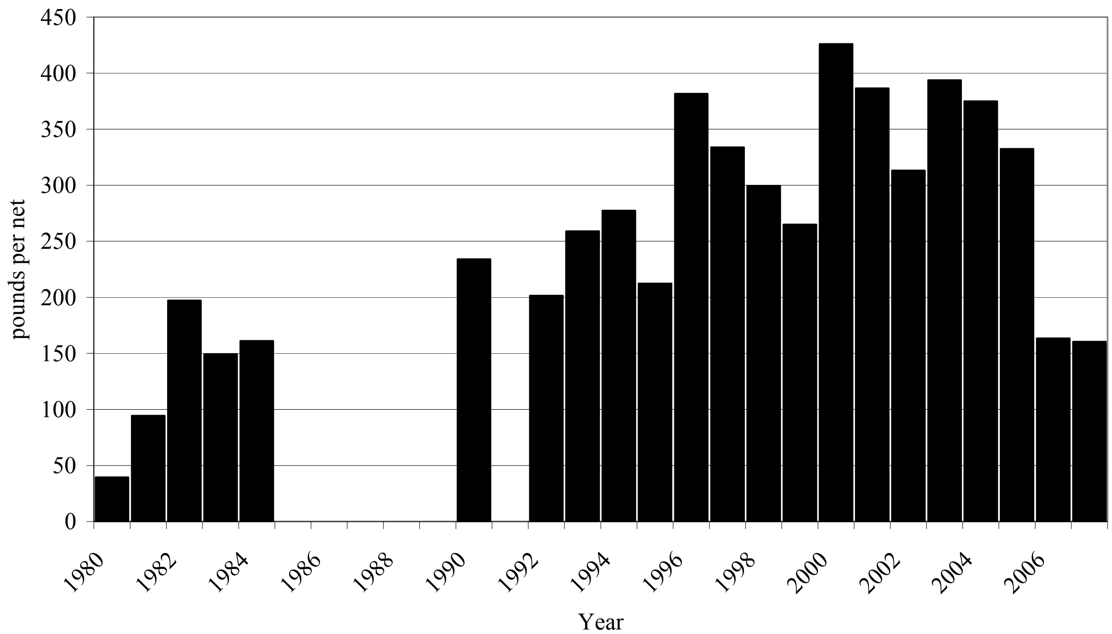


Figure 5. Commercial white perch drift gill net catch per unit effort, 1980 - 2007.

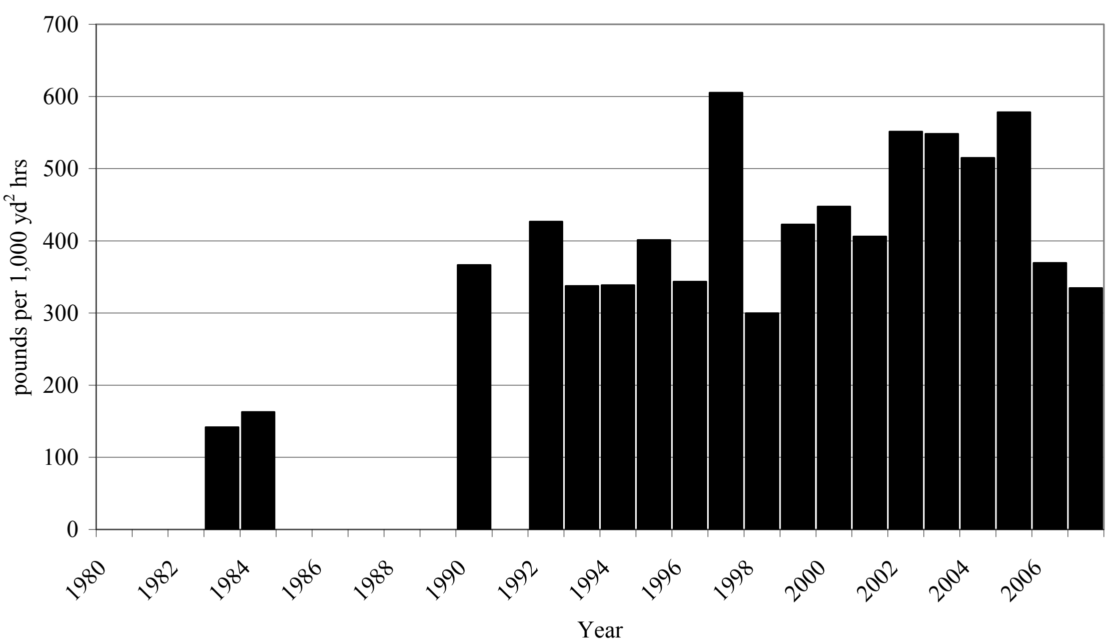


Figure 6. Commercial white perch pound net catch per unit effort, 1980 - 2007

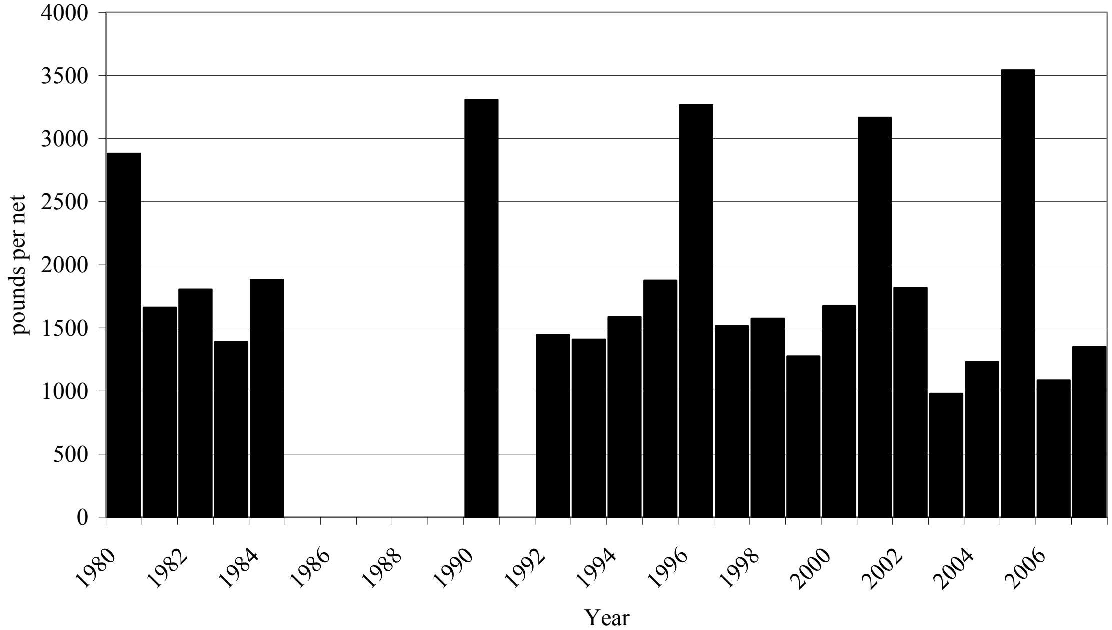


Figure 7. Recreational white perch catch per unit effort, 1981 - 2007.

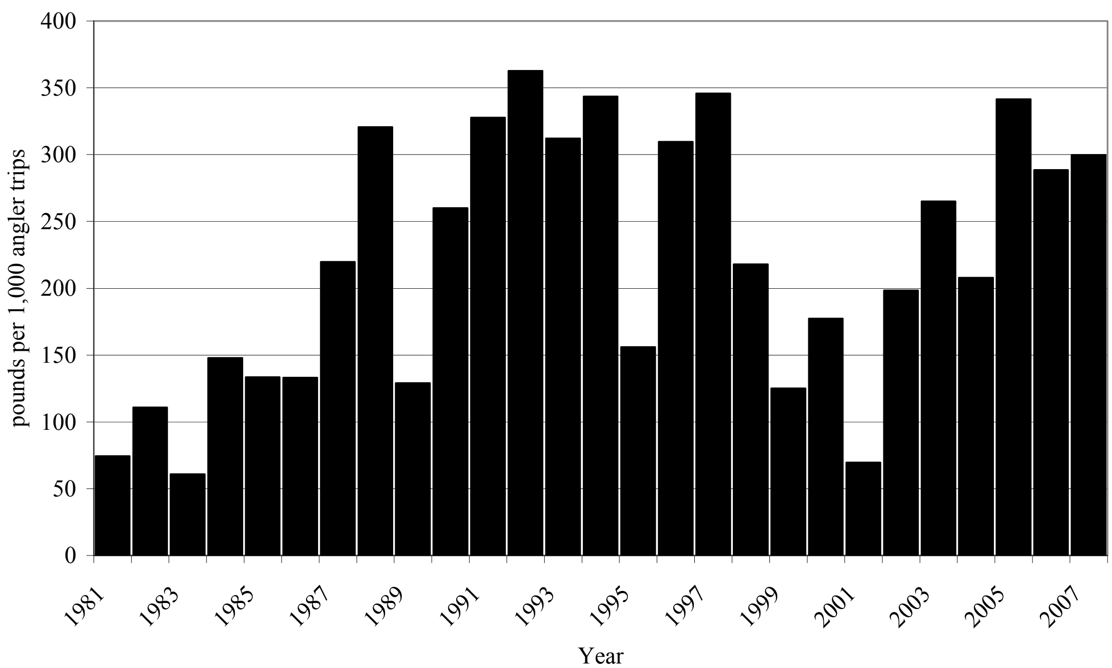


Figure 8. Maryland white perch fishery independent gill net biomass index, 1980 - 2007.

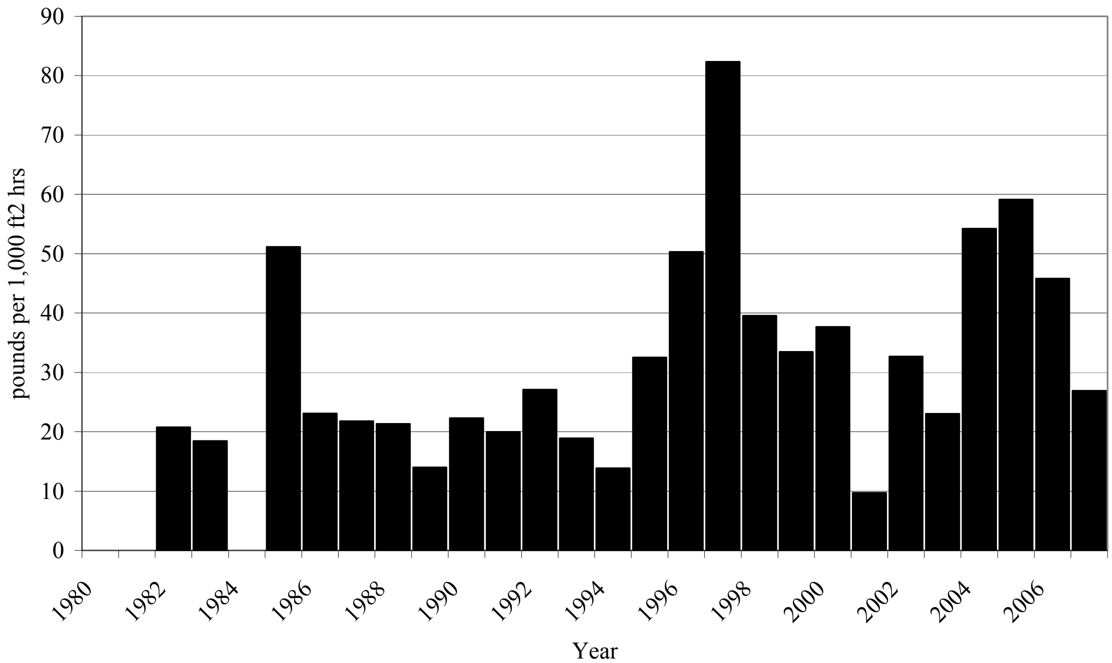


Figure 9. Baywide white perch young-of-year index, 1962 - 2008

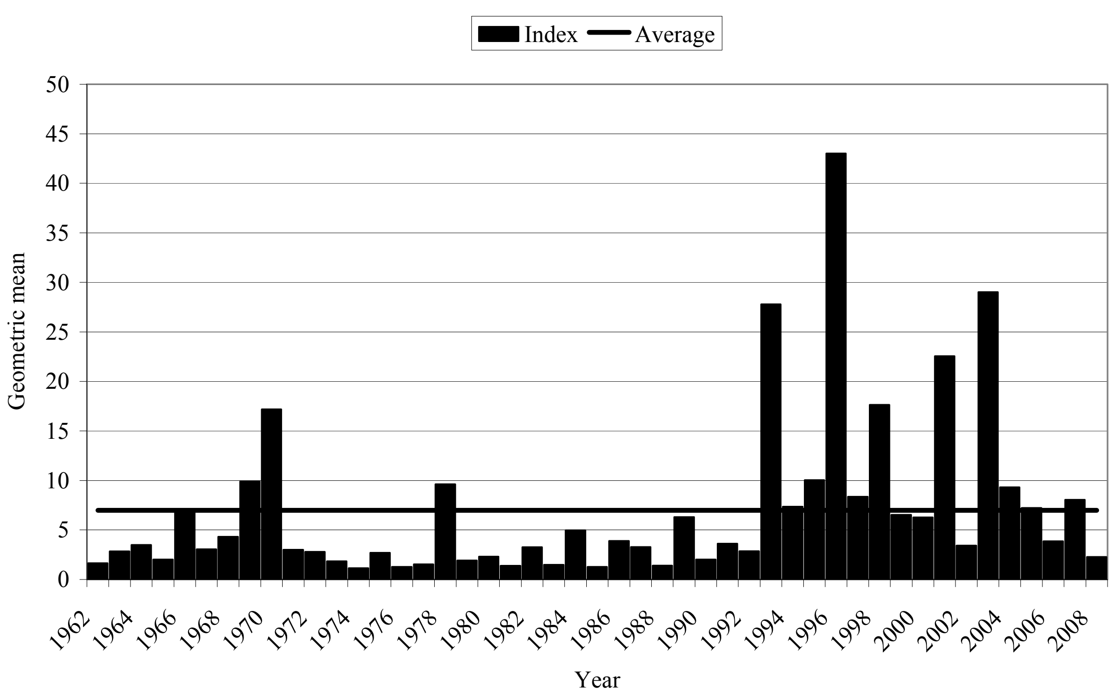


Figure 10. Chesapeake Bay white perch population biomass and F estimates, 1980 - 2007.

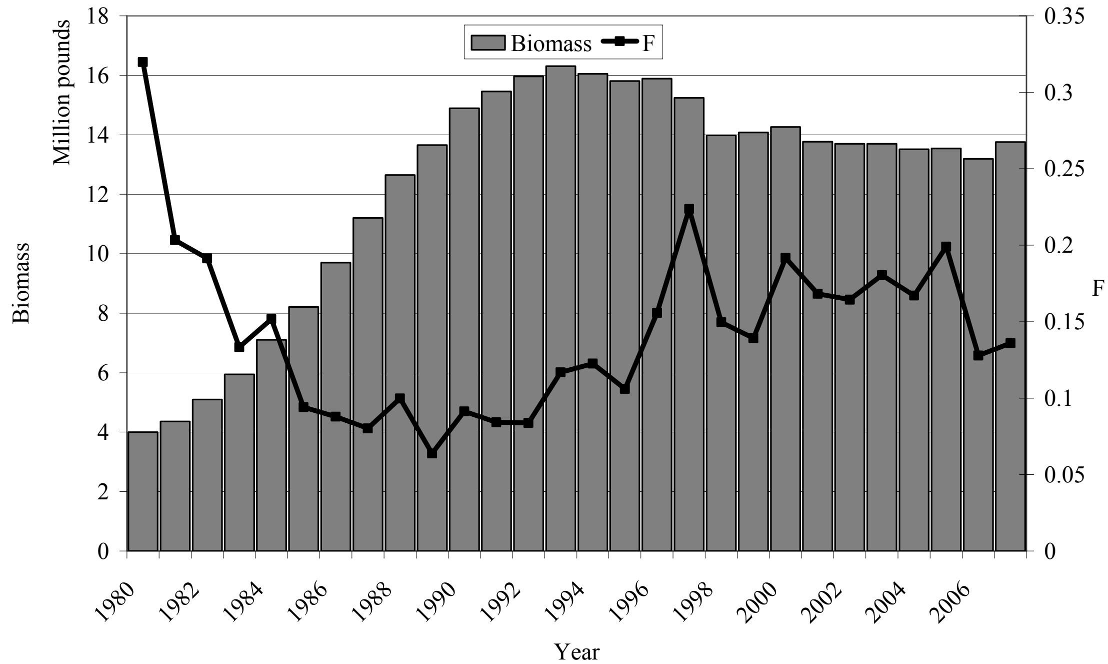


Figure 11. B/Bmsy and F/Fmsy ratios from baywide white perch surplus production model, 1980 - 2007.

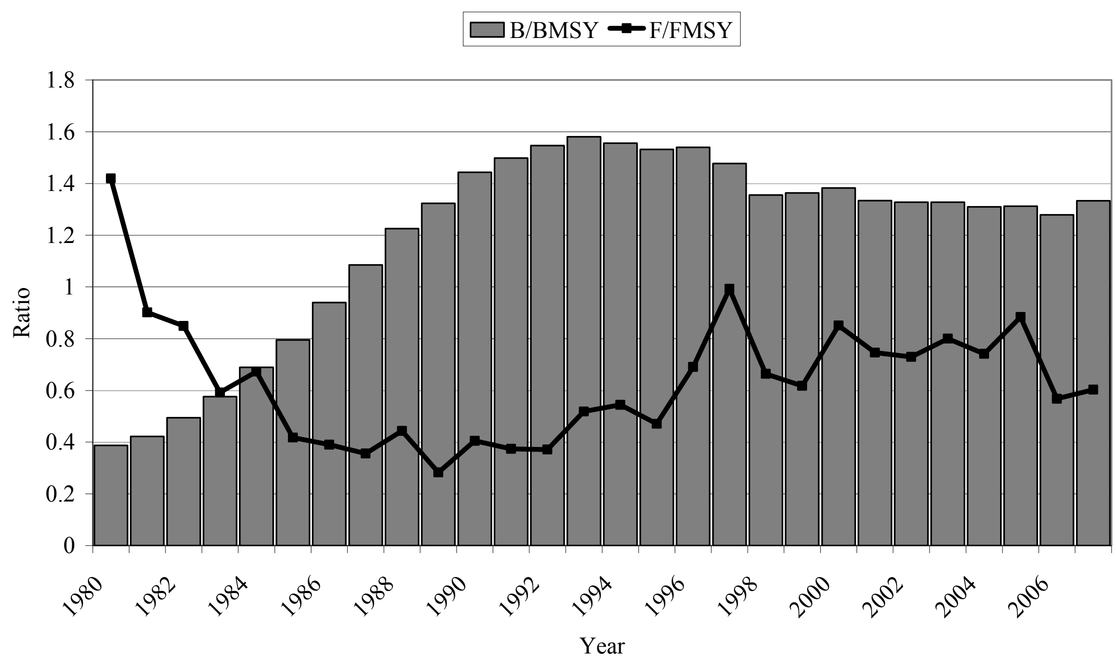


Figure 12. Recreational white perch CPUE residuals from the baywide surplus production model.

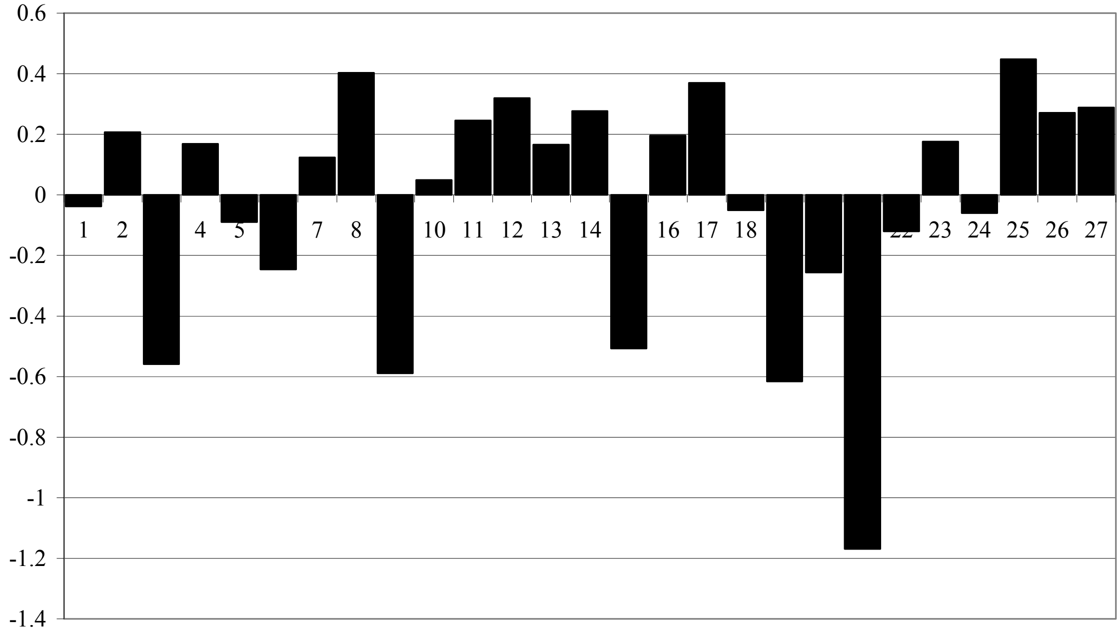


Figure 13. Fishery independent white perch biomass index residuals from the baywide surplus production model.

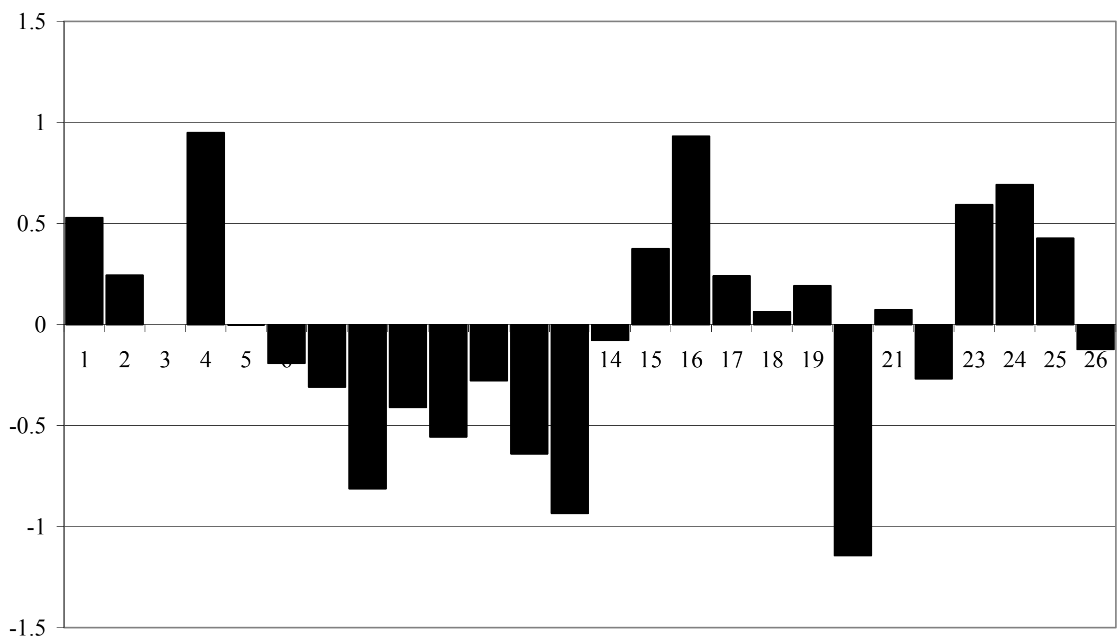


Figure 14. Biomass estimates and 80% confidence intervals for baywide white perch surplus production analysis.

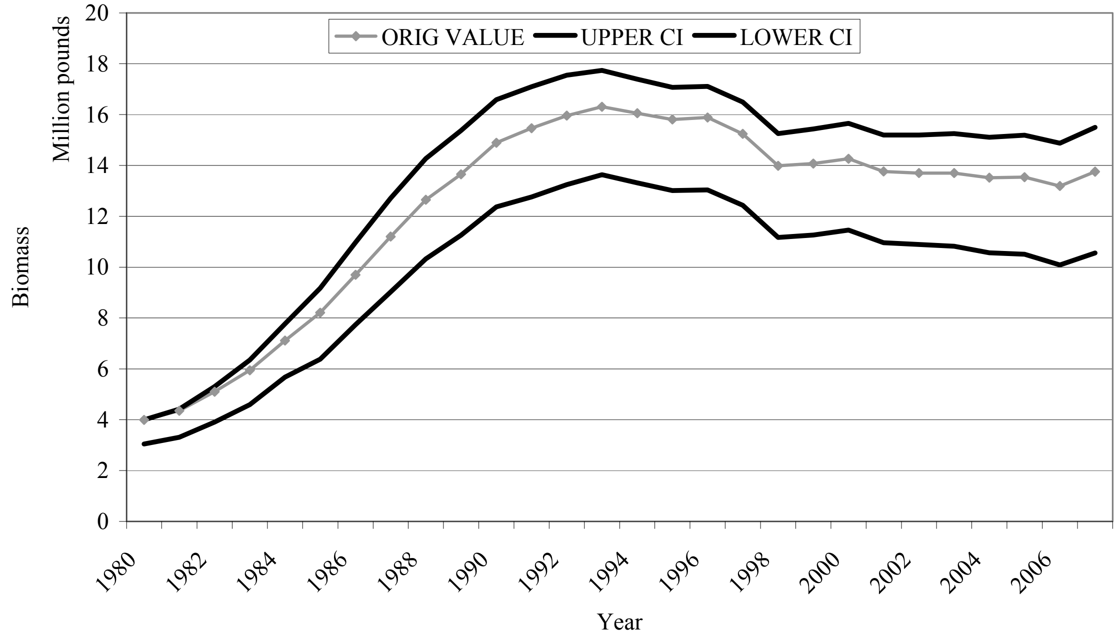


Figure 15. F estimate and 80% confidence intervals for baywide white perch surplus production analysis.

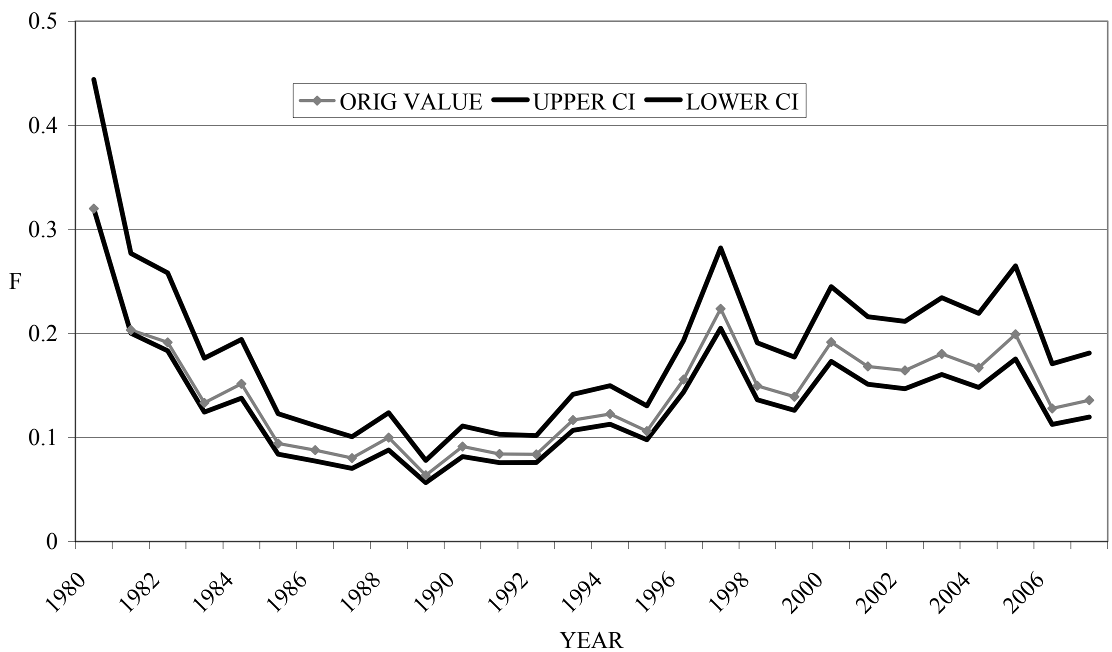


Figure 16. B/Bmsy ratio and 80% confidence intervals for baywide white perch surplus production analysis.

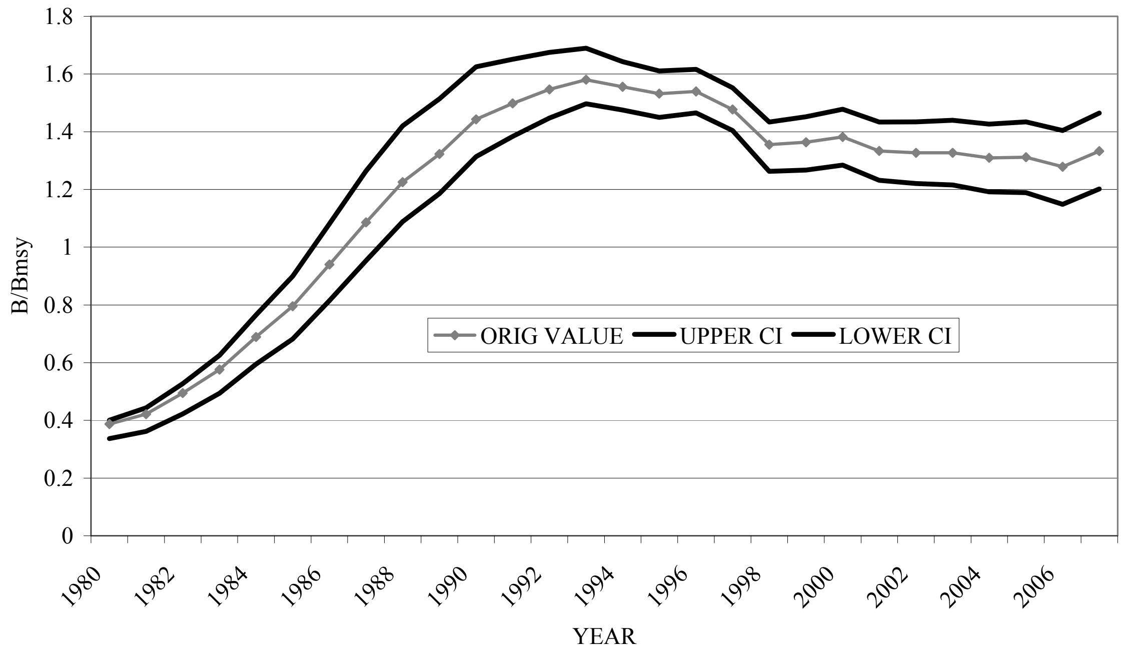


Figure 17. F/Fmsy and 80% confidence intervals for baywide white perch surplus production analysis.

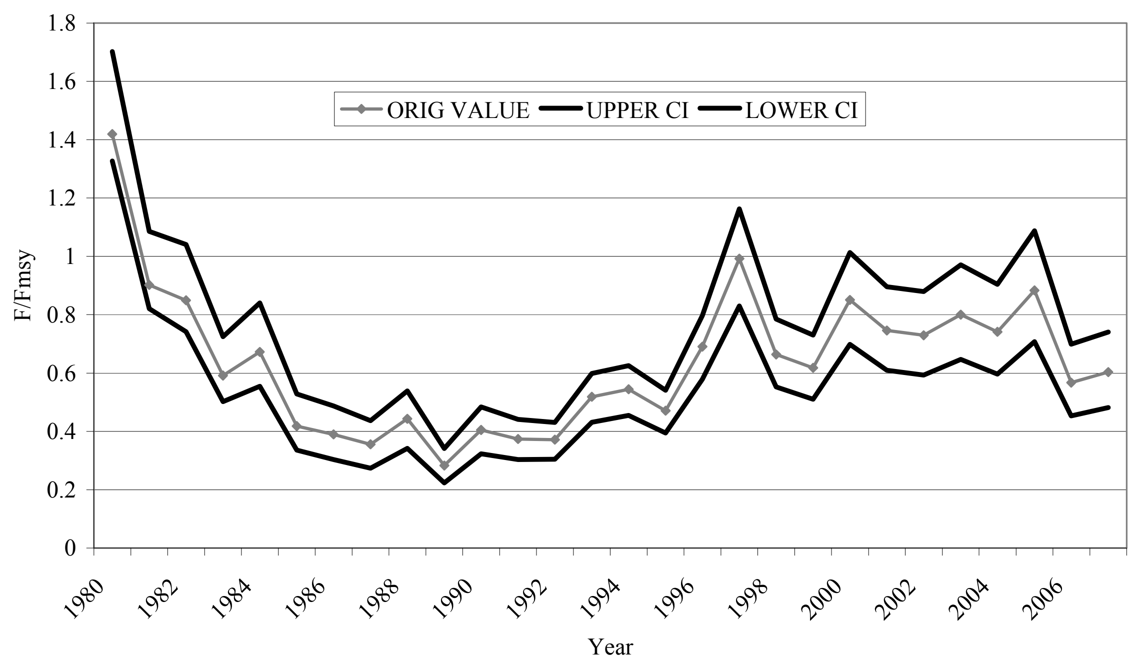


Figure 18. Estimated white perch removals by fishery for Choptank River white perch, 1989 - 2007.

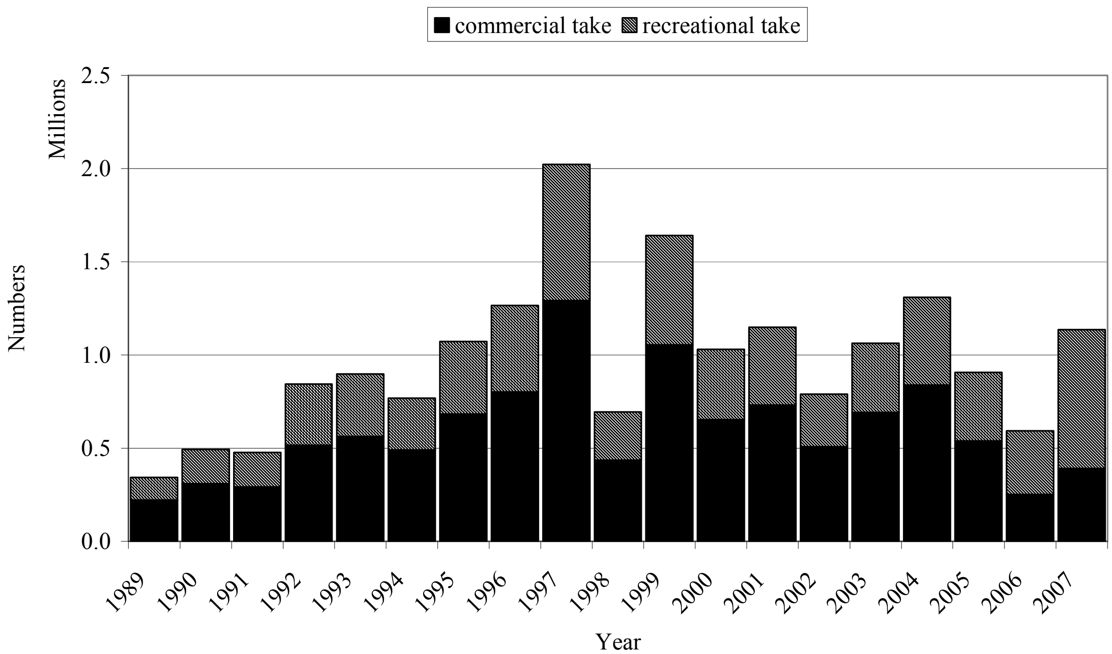


Figure 19. Observed pre-recruit white perch fyke net index, Choptank River, 1989 - 2008

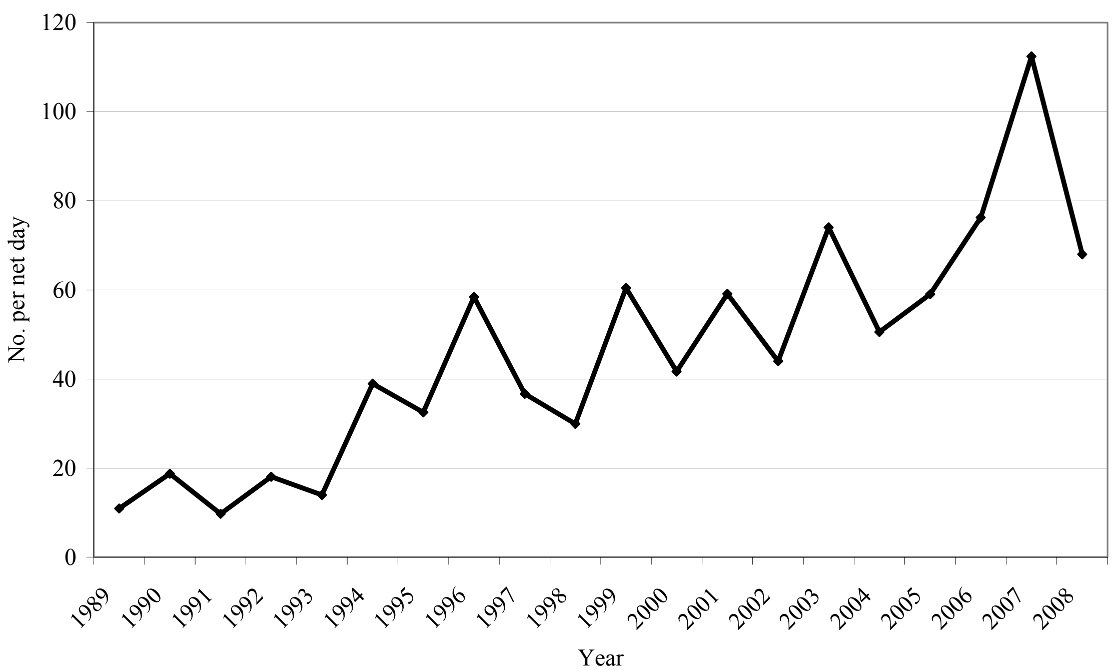


Figure 20. Observed post-recruit white perch index, Choptank River, 1989-2008.

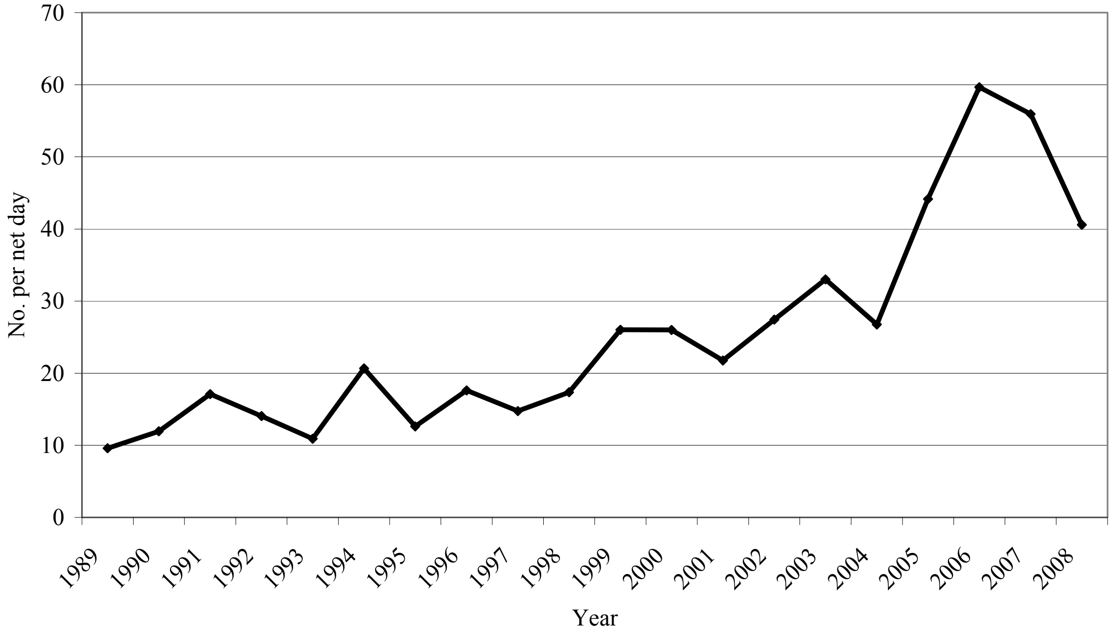


Figure 21. Estimated population abundance of pre-recruit and post-recruit white perch in the Choptank River, 1989 - 2007.

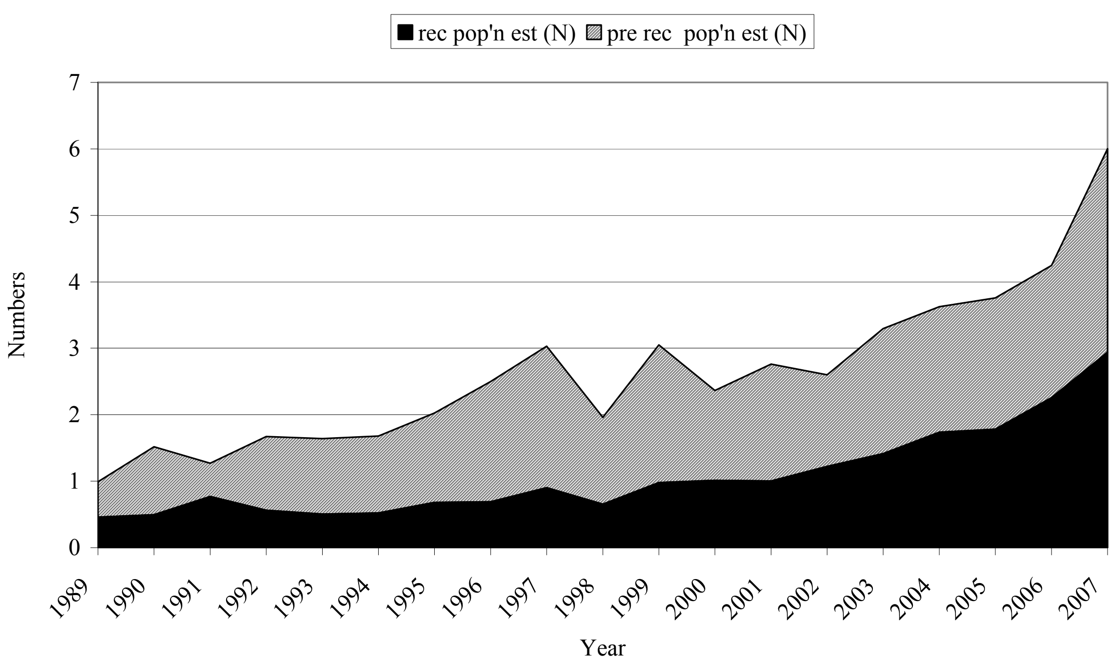


Figure 22. Estimated F for Choptank River white perch with proposed reference points, 1989-2007

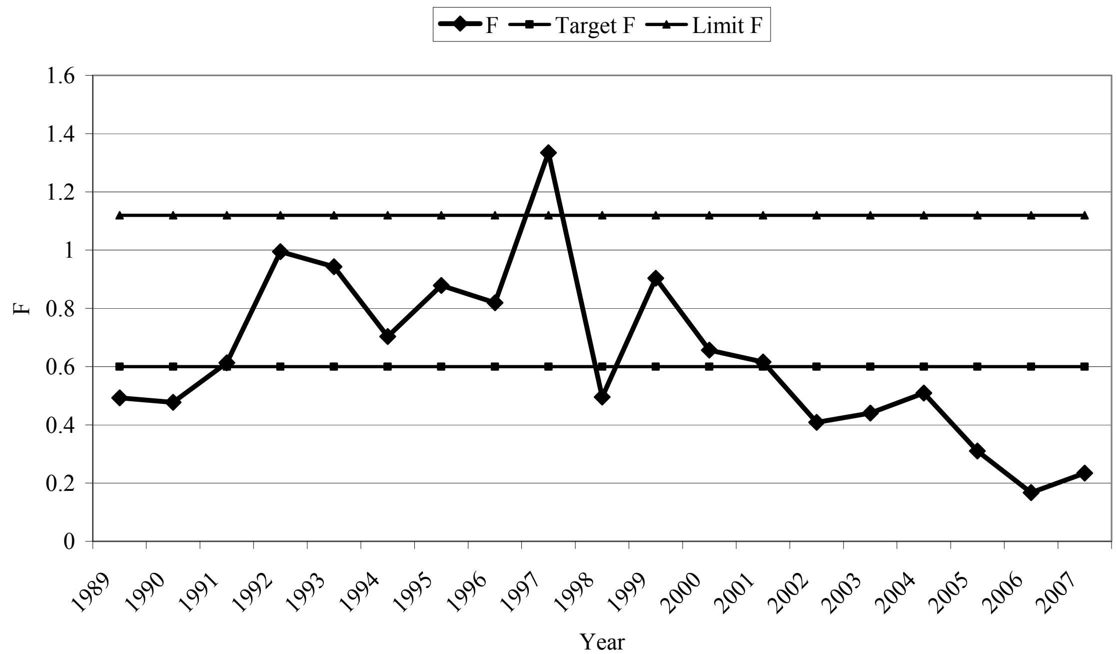


Figure 23. Pre-recruit residuals from catch-survey analysis of Choptank River white perch

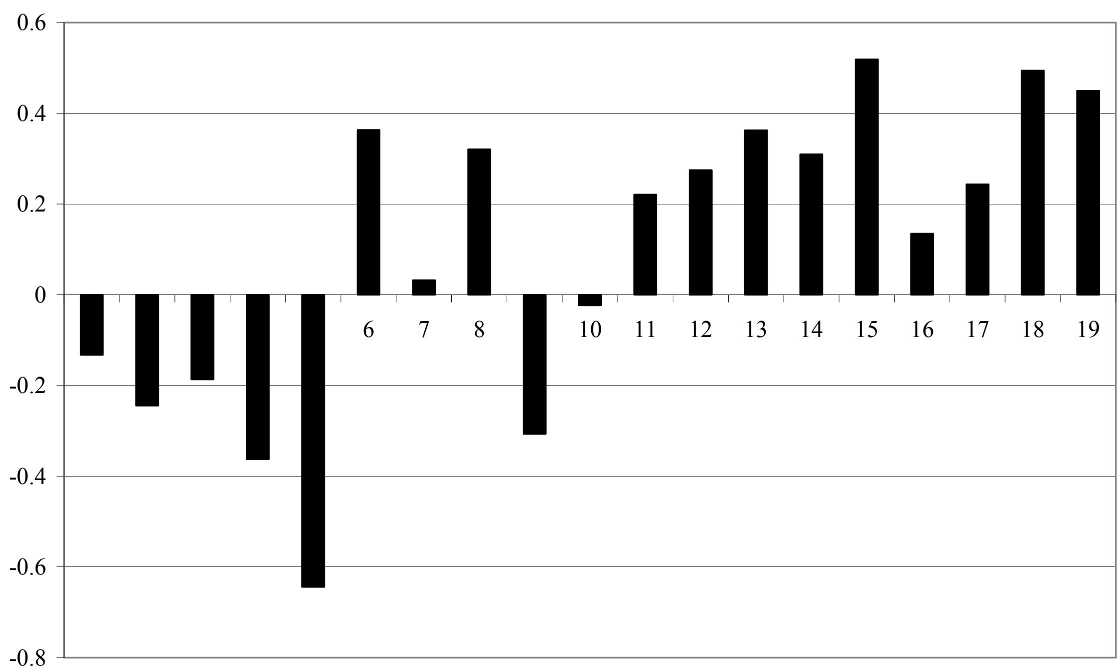


Figure 24. Post-recruit residuals from catch-survey analysis of Choptank River white perch

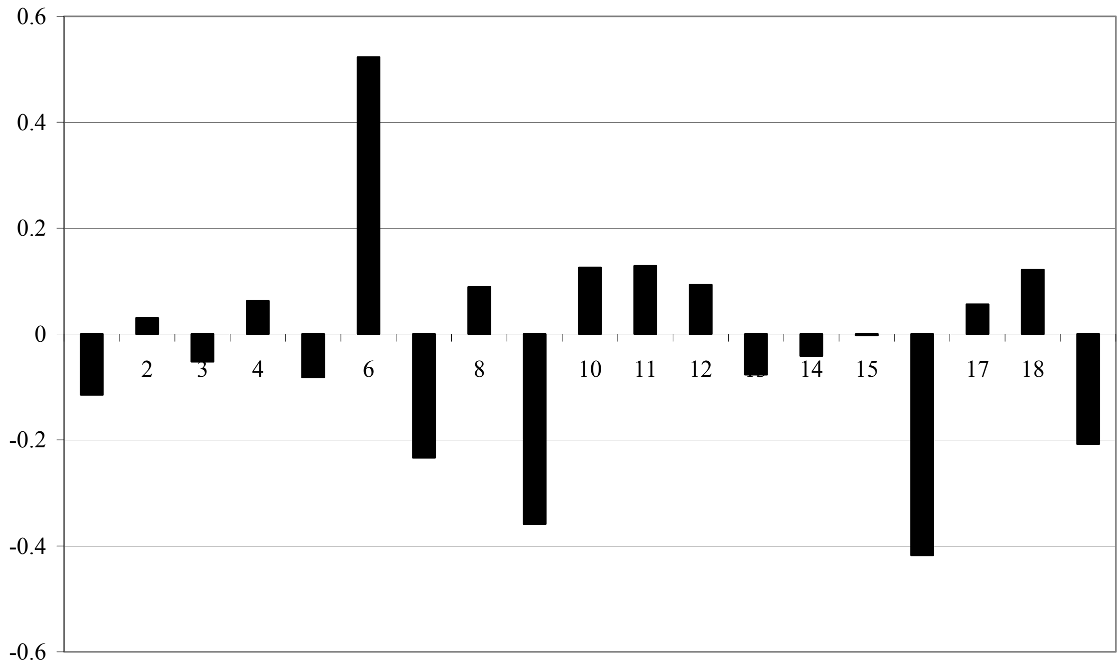


Figure 25. Estimated pre-recruit white perch abundance and 80% confidence intervals from a Choptank River catch survey analysis

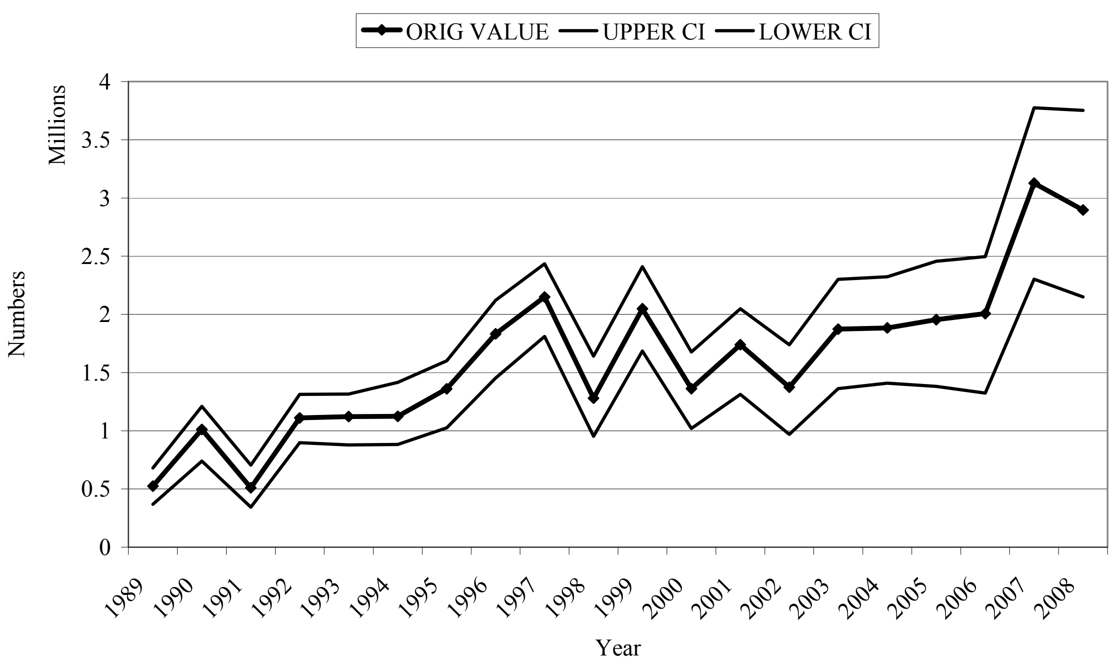


Figure 26. Post-recruit white perch abundance and 80% confidence intervals from a Choptank River catch survey analysis

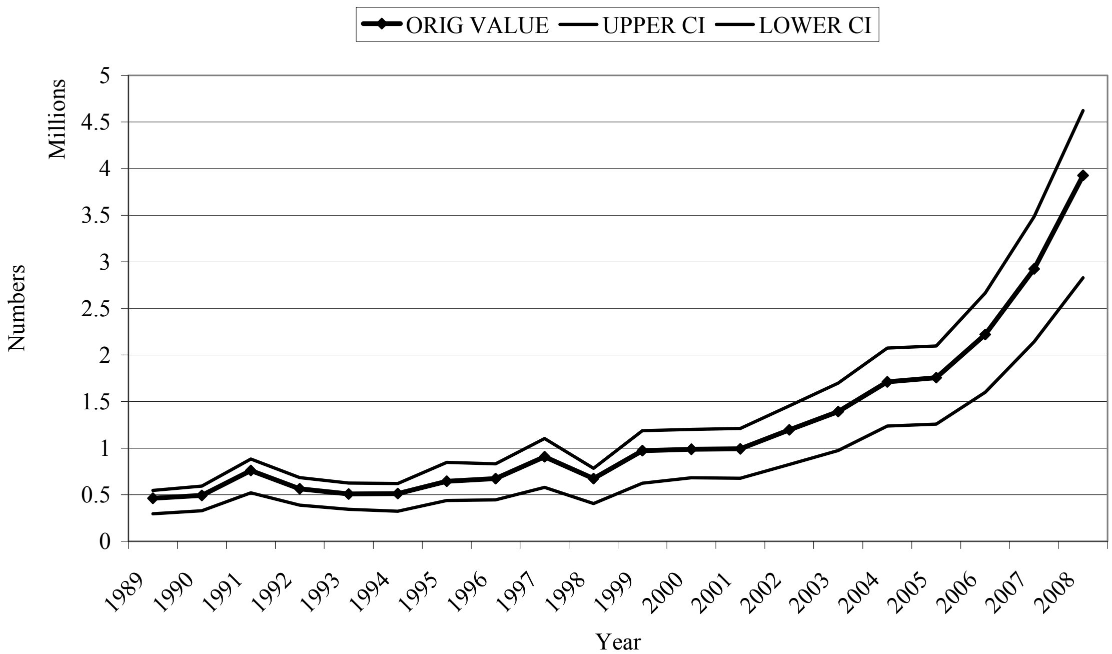


Figure 27. Estimated total population abundance and 80% confidence intervals for Choptank River white perch, 1989 - 2007.

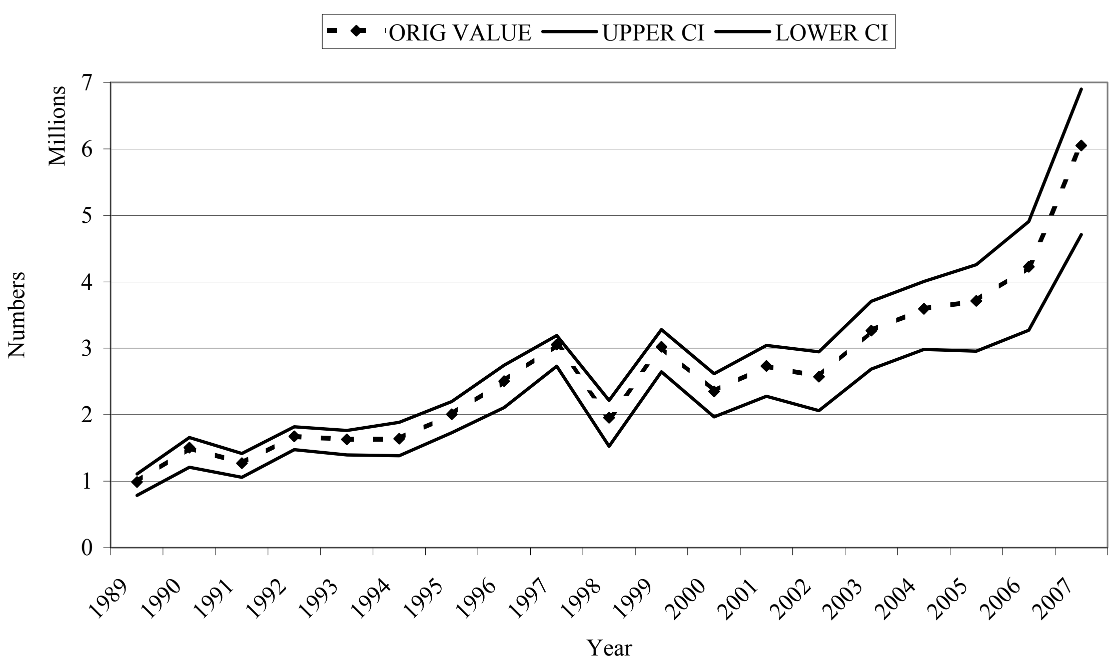
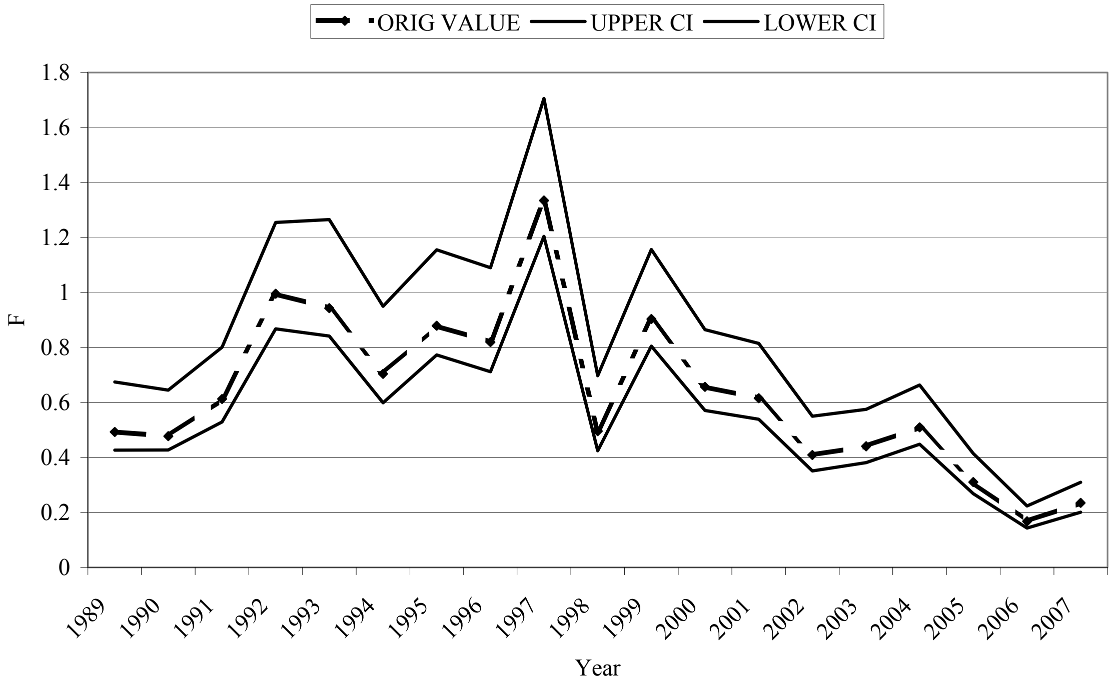


Figure 28. Choptank River white perch F estimates with 80% confidence intervals, 1989-2007.



PROJECT NO. 2
JOB NO 1

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

Prepared by Anthony Jarzynski and Robert Sadzinski

INTRODUCTION

The primary objective of Project 2 Job 1 was to assess trends in stock status of four anadromous alosine species in Maryland's portion of Chesapeake Bay and selected tributaries. Information for adult and juvenile American shad (*Alosa sapidissima*) and hickory shad (*Alosa mediocris*) and alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in Maryland tributaries was collected using both fishery independent and dependent sampling gear. Spring sampling targeted adult American and hickory shad and blueback and alewife herring. Survey biologists worked with commercial fishermen using fyke and pound nets in the Nanticoke River, in addition to sampling Fisheries Service fyke nets in the Choptank River. Long-term mark-recapture data of adult American shad was utilized to estimate relative abundance in the lower Susquehanna River below Conowingo Dam. Summer sampling targeted juvenile alosines in the Susquehanna, Chester and Pocomoke rivers using haul seines.

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 Chesapeake Bay, Atlantic States Marine Fisheries Commission (ASMFC), the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) and Chesapeake Bay Program's Living Resources Committee.

METHODS

A. Adults

I. Field Operations

Adult anadromous alosine species sampled in the spring of 2008 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. A minimum of four scales per fish 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.

Susquehanna River

American shad were angled from the Conowingo tailrace (Figure 1) on the lower Susquehanna River two to five times per week from 21 April through 04 June 2008. Two rods were fished simultaneously, with each rod rigged with two shad darts and a lead weight added, when necessary, to achieve proper depth. Fish in good physical condition and females not spent or running ripe were measured for fork and total length, had a scale sample removed and were quickly tagged and released. A Maryland Department of Natural Resources (MD DNR) Fisheries Service hat was given to fishers as reward for returned tags.

Nanticoke River

American and hickory shad and alewife and blueback herring in the Nanticoke River were collected from commercial pound nets (3) and fyke nets (6). Pound nets were located just below Vienna, Maryland and at the mouths of Mill and Dens Creek. These nets were sampled at least once per week from 14 March to 28 April 2008 while fyke nets were located between river kilometer (rkm) 30.4 and 35.7 (Figure 2). Targeted species captured from these nets were sorted according to species and transferred to the survey boat for processing.

All American and hickory shad along with a minimum of ten alewife and ten blueback herring selected at random from unculled catches were counted, sexed, fork length measured and scales removed for age analysis. The total number of herring harvested was estimated by multiplying the number of bushels harvested by the number of fish per bushel from sampled nets on that particular day or by direct counts.

Potomac River

American shad from the Potomac River were collected by MD DNR Striped Bass Stock Assessment personnel using multi-panel drift gill nets. Methods utilized in this study are presented in: Characterization of Striped Bass Spawning Stocks in Maryland, Project 2 Job 3, Task 2. American shad collected by this gear were counted, sexed, fork and total length measured and scales removed for age and spawning history analysis.

B. Juveniles

Summer Seining

Juvenile alosines were sampled biweekly from July to October in the Chester and Pocomoke rivers using 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 3) and five sites on the Pocomoke River, although the uppermost site cannot be seined because of debris in the water (Figure 4). Sites were chosen based on availability, seinable beaches, historical spawning importance and their proposed or existing restoration efforts. All fish were counted by species and fork length measurements were recorded for the four-alosine species. A juvenile catch-per-unit-effort (CPUE) was calculated for each species by dividing the total catch, by the number of sites, times the number of site visits resulting in catch-per-seine-per-day.

Presence/Absence of Eggs/Larvae

Successful alosine reproduction in the lower Nanticoke River was indicated by the presence/absence of eggs through bi-weekly ichthyoplankton sampling. These samples were collected twice per week from 24 March to 28 April 2008. 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. At the conclusion of the tow, the contents were rinsed into a masonry jar for presence/absence determination.

Sampling sites on the Nanticoke River repeated historic sampling (J. Mowrer, MD DNR, pers. comm., Figure 5). The river was divided into eighteen one-mile cells and during each sampling day, ten cells were randomly selected. Because of time constraints and the difficulty of determining species on the boat, presence of alosine (eggs or larvae) was only recorded.

II. Statistical Analyses

A. Adults

Age composition

Age-at-length keys were constructed by determining the proportion-at-age by sex for American shad per 20-mm length group and applying that proportion to the total number of fish in that increment. Since almost all American shad scale samples were read, age assignment was not necessary.

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

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

where AG_m is the percent of an age group that is mature

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

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

Length-frequency

Mean length-at-age was calculated by sex for alewife and blueback herring. Time series analysis using linear regression was used to examine trends in Nanticoke River alewife and blueback herring lengths (1989-2008) for ages 3 to 9. Males and females were analyzed separately.

American Shad Abundance

Chapman's modification of the Petersen statistic (Chapman 1951) was used to calculate relative abundance of adult American shad in the Conowingo tailrace. The equation was (Ricker 1975);

$$N = \frac{(C+1)\ (M+1)}{(R+1)}$$

where N = the relative population estimate

C = the number of fish examined for tags

M = the number of fish tagged

R = the number of tagged fish recaptured

The Conowingo tailrace estimate used American shad captured in the tailrace by hook and line and subsequently recaptured by the east fish lift. Fish caught in the east lift were placed 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. Daily catch logs by species were subsequently distributed to DNR personnel. Annual catch-per-unit-effort (CPUE) for American shad was calculated as the geometric mean of fish caught per operating hour.

The number of recaptured American shad at Conowingo Dam dropped to record low number in 2008 and therefore a biomass surplus production model was used to estimate population abundance (Macall 2002). However, numbers were used as its unit of measure rather than biomass. The model equation was:

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

where N_t was the population in year t;

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

r was the intrinsic rate of population increase;

K was the maximum population size; and

C_{t-1} was 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 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). This model assumed a proportional consumption of American shad by striped bass and that American shad were landed as proportional bycatch to the Atlantic herring fishery because population estimates without these assumptions fell below the fish lift catches at Conowingo Dam. Instantaneous annual fishing mortality rates associated with fish passage in year t (F_{tp}) during 1984-2008 were estimated as $\log_e[1- (C_t / N_t)]$ (Ricker 1975). Estimates of abundance were derived from model output.

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 (GM) (based on a $\log_e$-transformation; Sokal and Rohlf 1981) of fish caught per net day. Nanticoke River pound net CPUEs and commercial landings of alewife and blueback herring (species combined) were analyzed for trends using linear regression. Annual CPUE of upper Bay American shad captured by hook and line was calculated as the geometric mean of fish caught per boat hour

Mortality Estimates

Two methods based on the number of repeat spawning marks were utilized to estimate total instantaneous alosine mortalities. 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.

Quantitative Habitat Analysis

Quantitative habitat analysis investigated the relationship between submerged aquatic vegetation (SAV) and American shad juvenile indices in the upper Chesapeake Bay. Since SAV is an indirect measurement of water quality, American shad survival may increase as SAVs increase in density. Pearson product moment correlation ($P \leq 0.05$) was used to test for an association between juvenile American shad indices in the upper Chesapeake Bay and SAV density as measured by hectares of SAV.

RESULTS

1. American shad

a. Adult

Sex and Age Composition

The 2008 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.58:1. Of the 164 fish sampled by this gear, 161 were scale-aged (Table 1). Those American shad not aged directly because of regenerated scales, were not assigned ages.

A total of 58 American shad were captured from the Nanticoke River pound and fyke nets and 40 were subsequently aged (Table 1). The 2008 male-female ratio for adult American shad captured in the Nanticoke River was 1.4:1.

Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line in 2008 was 10.2% for males and 9.8% for females (Table 1). The arcsine-transformed proportions of these repeat spawners (sexes combined) had significantly increased for the time series (r^2 = 0.277 p = 0.007) but since 2005 have decreased drastically (Figure 6). The arcsine-transformed proportions of repeat spawning American shad from fyke and pound nets in the Nanticoke River showed no trend for the time series (Figure 7; r^2 = 0.08 p = 0.21). Potomac River repeat spawning American shad also had no trend for the time series (r^2 = 0.08 p = 0.21).

Relative Abundance

Of the 164 adult American shad sampled in Conowingo tailrace in 2008 (Table 2), 160 (98%) were tagged and 3 (2%) subsequently recaptured from the east lift (Table 3). The east lift also captured seven American shad tagged in 2007. In 2008, there were no reported recaptured American shad caught from either commercial or recreational fishermen.

In 2008, the east lift operated from 16 April through 6 June and technicians counted 19,914 American shad passing the viewing window. Peak passage was on 11 May when 1,943 American shad were recorded.

In 2008, the west lift at Conowingo Dam operated from 23 April to 2 June. The 2,627 American shad caught in the west lift were returned to the tailrace, used for experimentation or retained for hatchery operations. Peak capture from the west lift was on 18 May when 642 American shad were collected. Eight tagged American shad were recaptured in 2008 from the west lift; seven tagged in 2008 and one tagged in 2007 (Table 3). Based on model estimates, the Conowingo dam tailrace American shad population estimate in 2008 was 31,839 fish and has trended down since 2000 (Figure 8; r^2=0.65, P= 0.02).

Estimates of hook and line and fish lift geometric mean CPUEs have also decreased significantly since 2002 (hook and line: r^2=0.83, P= 0.002 and fish lifts: r^2=0.86, P<0.001; Figures 9 and 10). Nanticoke River pound net geometric mean CPUEs for American shad have been extremely variable since 2001 (r^2=0.07, P= 0.58; Figure 11). Nanticoke River fyke net geometric mean CPUEs for American shad have been very low most years and have exhibited no trend (r^2=0.01, P=0.67; Figure 12).

Mortality Estimates

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 = 1.66. The average difference between the natural logs of the spawning group frequency produced Z = 1.67. Nanticoke River mortality estimates from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 0.94. The average difference between the natural logs of the spawning group frequency produced Z = 0.94.

American shad mortalities (in numbers) from Maryland waters are presented in Table 4. In general, total annual mortalities appear proportional to the abundance of American shad in the Conowingo tailrace.

Otolith Examination

Of the 52 readable adult American shad otoliths collected from the west lift at Conowingo Dam in 2008, 57% were classified as non-hatchery fish (Hendricks 2008). Twenty-nine adult American shad otoliths collected from the Nanticoke River were sent to Delaware Division of Fish and Wildlife (DE DFW) for oxytetracycline (OTC) analysis. Results indicated that 83% were non-hatchery fish (M. Stangl, DE DFW, pers. comm.).

b. Juvenile

No juvenile American shad were caught by haul seine in the Chester and Pocomoke rivers during the 2008 sampling season.

c. Presence/Absence of Clupeid Eggs

Successful clupeid reproduction in the lower Nanticoke River was determined by the presence of eggs collected during biweekly plankton net tows. Fertilized clupeid eggs or larvae were found in six samples (n = 198). Salinity at plankton tow locations ranged from 0.1 to 5.8 ppm.

d. Quantitative Habitat Analysis

SAV estimates in the upper Chesapeake Bay were obtained from the Tidewater Ecosystem Assessment, Resource Assessment Service (L. Karrh, MD DNR pers. comm.) while upper

Chesapeake Bay American shad juvenile indices (geometric mean CPUEs) were obtained from the Maryland Fisheries Service, Juvenile Striped Bass Recruitment Assessment (Project 2 Job 3 Task 3). There was no correlation between SAV density and American shad juvenile indices (1990-2008; r^2=0.16, P=0.55).

2. Hickory Shad

a. Adults

Sex and Age Composition

Ten adult hickory shad were collected from the Nanticoke River and because of this low sample number, age analysis was negated. The 2008 male-female ratio for Nanticoke River adult hickory shad was 1.6:1.

Relative Abundance

Nanticoke River pound net geometric mean CPUEs for adult hickory shad have decreased since 2002 (r^2=0.84, P=0.01; Figure 13) while fyke net geometric mean CPUEs have showed no trend (r^2=0.04, P=0.57; Figure 14).

b. Juveniles

Two locations were selected to characterize juvenile hickory shad; the Chester and Pocomoke rivers. These locations were chosen because they duplicated sampling sites targeting American shad, during the summer sampling haul seine sampling, no juvenile hickory shad were collected from either system in 2008.

3. Alewife and Blueback Herring

a. Adults

Sex and Age Composition

The 2008 male: female ratio for Nanticoke River alewife was 1:1.8**.** Of the 187 alewives, sampled, 183 were aged. For 2008, alewife were present at ages 3-9 with the 2003 year-class (age 5, sexes combined) the most abundant, accounting for 44.8% of the total catch. Females and males were most abundant at age 5 (Table 5).

The 2008 male: female ratio for blueback herring from the Nanticoke River was 1:1.3. Of the 84 blueback herring sampled, 82 could be aged. Blueback herring were present at ages 3-8 with the 2004 year-class (age 4, sexes combined) the most abundant accounting for 51.2% of the sample. Males and females were both most abundant at age 4 (Table 5).

Repeat Spawning

The percentages of alewife and blueback herring repeat spawning (sexes combined) from the Nanticoke River during 2008 was 67.2% and 41.5%, respectively (Table 5). The arcsine-transformed proportion of alewife repeat spawners (sexes combined) indicated no trend (1989-2008; $r^2<0.03$ $P=0.49$), while blueback herring repeat spawning showed a decreasing trend (1989-2008; $r^2=0.47$, $P<0.01$; Figure 15).

Using Speir and Mowrer's (1987) maturity schedule calculation, 80.3% of male alewife and 100% of male blueback herring were mature by age 4. The percentages of female alewife and blueback herring mature by age 4 were 75.2% and 85.2%, respectively.

Length-at-Age

For 2008, Nanticoke River female alewife mean lengths-at-age were generally greater than corresponding male mean lengths-at-age except for age group 7 (Table 6). Blueback herring female mean lengths-at-age were greater for all age groups than corresponding male lengths-at-age (Table 7). Mean length-at-age for Nanticoke River alewife females ages 4 to 7 and males ages 4 to 7 have decreased significantly since 1989 (Table 8). Regressions of blueback herring lengths for females ages 3-7 and males at ages 3-7 and 9 have also significantly decreased since 1989 (Table 8).

Relative Abundance

Nanticoke River alewife herring geometric mean fyke net CPUEs have decreased significantly (1989-2008; r^2=<0.2 P=0.05; Figure 16), as have those for blueback herring (1989-2008; r^2=0.63 P<0.01; Figure 17). Nanticoke River commercial river herring landings (species combined) have significantly decreased since 1989 (r^2=0.74 P<0.01) while the combined CPUEs (sexes and gears combined) have shown no trend over time (1989-2008; r^2=0.03 P=0.5; Figure 18).

Mortality Estimates

Since maximum age (T_{max}) for alewife herring from the Nanticoke River samples was age 9, then M = 0.33 and F = 0.92. Consequently, the instantaneous mortality estimate (Z) in 2008 for Nanticoke River alewife herring (sexes combined) was Z = 1.25 (annual mortality {A} = 73.4%). Estimates of Z for Nanticoke River alewife herring males was 1.65 (annual mortality {A} = 80.8%), and for females Z = 1.08 (annual mortality {A} = 66.0%; Figure 19).

Instantaneous mortality (Z) in 2008 for Nanticoke River blueback herring (sexes combined) was Z = 0.84 (annual mortality {A} = 56.8%) and the maximum age (T_{max}) for blueback herring from the Nanticoke River samples in 2008 was age 8, thus M = 0.38 and F = 0.47. Estimates of Z for blueback herring males in 2008 was 1.3 (annual mortality {A} = 73.3) and for females Z = 0.7 (annual mortality {A} = 48.3%; Figure 20).

b. Juvenile

For 2008, juvenile seining in the Chester River produced one juvenile alewife herring (CPUE = 0.02) and 36 juvenile blueback herring (CPUE = 0.78). No juvenile alewife herring or blueback herring were captured from the Pocomoke River in 2008**.**

DISCUSSION

Anadromous Species

1. American shad

a. Adults

The modified Petersen statistic for estimating relative abundance of American shad in the Conowingo Dam tailrace had been utilized since inception of the project in 1984. However, in 2008 this application overestimated the population because of poor recapture rates. Therefore, modeling became necessary in order to obtain a more accurate American shad population estimate for 2008. Expected recapture rates (30%) at Conowingo Dam were compared to actual rates. In 2008, the east lift at Conowingo Dam only captured three 2008 tagged fish (2%) The best model estimates were derived when striped bass predation rate estimates and ocean bycatch losses were included in the model. Otherwise, model estimates went to zero in 2008. However, the most important conclusion of these modified 2008 estimates were not the point estimates but that the declining trend since 2001 continued. Data from two creel surveys targeting American shad in the Susquehanna River have generally shown significant decreases in catch-per-angler-hour during the last seven years (Tables 9 and 10) and track abundance decreases in the Conowingo Dam's tailrace.

Since closure of the American shad commercial fisheries in Atlantic Ocean waters on December 31, 2005, abundance indices have continued to decline in most Chesapeake Bay tributaries, including the tailrace population estimates and Conowingo Dam lift geometric means. Increases in abundance have only occurred in Maryland river systems where significant restoration stocking has occurred over many years, such as the Patuxent River (B. Richardson, MD DNR, pers. comm.).

The American shad stock assessment conducted by ASMFC (2007) indicated that stocks were also declining in most river systems along the east coast. This assessment indicated that total mortality rates (Z) in Maryland's targeted rivers (Susquehanna and Nanticoke rivers) exceeded the minimum benchmark Z estimates. Factors contributing to the increased mortality rates of American shad may include predation, and directed and non-directed ocean harvest, and Chesapeake Bay bycatch. American shad often appear as bait in various markets particularly in New England and southern Canada (K Hattala, NY DEC pers. comm.). This is most likely because of the difficulty in identifying and differentiating the four anadromous alosines, particularly subadults, caught in the ocean as bycatch.

Since aging techniques for American shad using scales has been shown to be somewhat tenuous (McBride et al 2006), freshwater spawning marks may hold the best means of non-lethal aging and the highest accuracy for an age-based assessment of survival and mortality. Mortality rates for Chesapeake Bay stocks of American shad averaged Z=1.33 and are within the range of reported Z estimates from other studies (ASMFC 2007). It should be noted that these mortality calculations are for previously spawned fish and these estimates are likely maximum rates.

Historical data on repeat spawning of heavily exploited American shad stocks in the Potomac River showed 17% repeat spawners (Walburg and Sykes 1957). Adult American shad captured from the Striped Bass Spawning Stock Survey (Project 2, Job 3, Task 2) indicated that repeat spawning American shad in the Potomac River have averaged 40% for the time series. In addition, MD DNR also targets American shad for strip spawning in the Potomac River since 2002 (Richardson 2008). Repeat spawning data from these fish have shown varying rates of repeat spawning (38% to 60%) since 2003 but no trend over the 7 year time period (r^2=0.38, P=0.14; Figure 21). During the early 1980's, repeat spawning was generally less than 10% in the upper Chesapeake Bay (Weinrich et al 1982) but since 2003 repeat spawning from the tailrace has averaged 19%.

Juveniles

Baywide juvenile American shad production in 2008 decreased from the high of 2007 (Figure 22). Although spawning conditions were ideal during both years, low adult indices in 2008 may be indicative of a low adult spawning threshold and thus be incapable of producing a strong year-class. Maryland juvenile American shad indices have been primarily driven by the upper Chesapeake Bay (Figure 23) and Potomac River (Figure 24). In the upper Chesapeake Bay during 2008, only two juvenile American shad were captured at seven permanent sites by the Juvenile Striped Bass Recruitment Survey (Project 2 Job 3 Task 3) in forty-two hauls and none were captured from the six auxiliary sites.

The poor juvenile recruitment in 2008 indicates that either environmental conditions were unsatisfactory for successful reproduction and/or adults were below a minimum threshold necessary to produce a strong year-class. Based on observed flow conditions, water temperature, and normal precipitation in the two watersheds, the level of spawning stock biomass may be responsible for the continued decline in juvenile American shad production.

2. Hickory shad

a. Adults

Deer Creek, a tributary to the Susquehanna River in Harford County, has the greatest densities of hickory shad in Maryland (Richardson et al 2004). Hickory shad catch-per-angler-hour (CPAH) in Deer Creek based on Fisheries Service logbook surveys ranged from 4.3 to 8.3 for the time series and has varied without trend since 1998 (r^2=0.14, P=0.26; Table 11).

Hickory shad age structure and repeat spawning history from this system has been consistent over the last three years, indicating a wide range of ages and a high percentage of repeat spawning fish. Richardson (et. al 2004) noted that ninety percent of these fish have spawned by age four and stocks generally consisted of few virgin fish. Since the oldest fish in these samples was age nine (Table 12), using Hoenig's (1983) estimation of natural mortality ($\ln(M_x) = 1.46$ –

1.01{ln (t_{max})}), M = 0.47. Estimated Z calculated from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 0.59 in 2006. The average difference between the natural logs of the spawning group frequency produced Z = 0.54.

In general, the resultant Z appears attributable to natural mortality since only a catch and release fishery for hickory shad exists in Maryland. These low mortality estimates indicate that bycatch mortality or predation on this species is minimum further substantiated by the high percentage of repeat spawning adult fish. Based on the low estimated total mortality rates for hickory shad, the factors effecting American shad appear not to have impacted hickory shad as indicated by their low total mortality rates and consistent hook and line catch rates. 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, sampling using haul seines during the mid summer and fall likely missed juvenile hickory shad. Since adults may spawn up to six weeks before American shad (late March to late April), juveniles reach a larger size earlier in the summer. Therefore, in order to accurately represent hickory shad juvenile production, sampling would need to be initiated earlier.

3. Alewife and blueback herring

a. Adults

The commercial river herring fishery on the Nanticoke River is a mixed fishery and fishers do not differentiate between alewife and blueback herring. River herring pound net CPUEs (species combined) from 1989-2008 in the Nanticoke River showed no obvious trend while the separate blueback herring and alewife herring CPUEs decreased during this time period. Depleted river herring stocks on the east coast have prompted Connecticut, Rhode Island, Massachusetts and North Carolina to close their recreational and commercial river herring fisheries. ASMFC is also preparing Amendment 2 to the Interstate Management Plan for Shad and River Herring which will attempt to reduce fishing mortality for both species. In 2008, river herring commercial landings in Maryland were 3.7% of their recorded high, adult stocks are projected to remain at low abundance levels for the near future.

The recently completed river herring stock status report by ASMFC indicated a sharp decline of older fish. Age-based mortality rates for both species indicated no trend but ranged from 1.00 to 1.40 while repeat spawner mortality rates varied between 0.8 and 1.3 (ASMFC 2008). Baywide commercial landings in Maryland have decreased significantly and likely reflect the low abundance of both species.

b. Juveniles

The low juvenile blueback and alewife herring catches by survey personnel from the Chester (n = 37) and Pocomoke rivers (n = 0) was low. Juvenile indices for alewife and blueback herring in the lower Nanticoke River obtained from the Juvenile Striped Bass Recruitment Survey (Figures 25 and 26, respectively) indicated low catches for both species and this same trend was observed baywide (Figure 27). This trend prevalent since the late 1990s may be indicative of adult abundance below some critical threshold level necessary for stock stabilization and future growth.

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Table 1. Numbers of adult American shad and repeat spawners by sex and age sampled from the Conowingo tailrace and Nanticoke River (gears combined) in 2008.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2			0			
3	6		0		6	
4	28		49		77	0
5	21	3	37	2	58	5
6	4	3	13	5	17	8
7	0		2	2	2	2
8	0		0		0	0
9	0		1	1	1	1
Totals	59	6	102	10	161	16
Percent Repeats	10.2%		9.8%		9.9%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	9	0	1	0	10	0
4	12	0	6	0	18	0
5	3	2	5	2	8	4
6	1	0	2	0	3	0
7	0		0		0	
8	0		0		0	
9	0		1	1	1	1
Totals	25	2	15	3	40	5
Percent Repeats	8.0%		20%		12.5%	

Potomac River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0		0		0	
3	0		0		0	
4	2	0	8	0	10	0
5	0		32	3	32	3
6	1	1	25	17	26	18
7	0		5	5	5	5
8	0		3	3	3	3
9	0		0		0	
10	0		1	1	1	1
Totals	3	1	74	29	77	30
Percent Repeats	33%		39%		43%	

Table 2. Conowingo Dam tailrace hook and line data, 1982-2008.

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

Table 3. Recaptured American shad in 2008 at Conowingo Dam's east and west lifts by tag color and year.

East Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Green	2008	3
Pink	2007	7
West Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Green	2008	7
Pink	2007	1

Table 4. 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	Recreational Bycatch Mortality	Ocean Commercial Landings (in pounds) [2]	Minimum Total Losses	Conowingo Dam tailrace estimate
1999	0	80,275	3,136	4,200	Unknown	13,623 (54,491)	101,234	176569
2000	0	85,215	3,102	4,200	Unknown	4,834 (19,337)	97,351	176604
2001	0	176,357	2,607	4,200	Unknown	2,347 (9,386)	185,511	171697
2002	0	71,357	2,837	4,200	Unknown	1,882 (7,529)	80,276	75827
2003	0	62,186	2,160	4,200	Unknown	621 (2,485)	69,167	60811
2004	0	34,550	1,218	4,200	Unknown	220 (879)	40,188	46422
2005	0	48,903	1,412	4,200	Unknown	0	54,515	50269
2006	0	53,632	1,696	4,200	Unknown	0	59,528	42392
2007	0	14,120	1,737	4,200	Unknown	0	20,057	24312
2008	0	7,075	1,477	4,200	Unknown	0	12,752	31840

[1] Includes east and west lift mortalities at Conowingo Dam
[2] Numbers in parenthesis is the reported pounds and were converted to numbers by dividing it by an estimated four pounds per fish.

Table 5. Numbers of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2008.

Alewives

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	5	0	2	0	7	0
4	24	4	26	3	50	7
5	26	24	56	48	82	72
6	10	10	17	17	27	27
7	1	1	13	13	14	14
8			2	2	2	2
9			1	1	1	1
Totals	66	39	117	84	183	123
Percent Repeats	59.1%		71.8%		67.2%	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	5	0	3	0	8	0
4	19	9	23	4	42	13
5	11	4	14	10	25	14
6			3	3	3	3
7			3	3	3	3
8			1	1	1	1
9						
Totals	35	13	47	21	82	34
Percent Repeats	37.1%		44.7%		41.5%	

Table 6. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2008.

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					

Table 6 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			

Table 7. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2008.

Males

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

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			

Table 8. Regression statistics for alewife and blueback herring in 2008 based on cumulative data.

Alewife		Male				Female		
Age	N	Slope	r^2	P	N	Slope	r^2	P
3	366	-0.122	0.003	0.286	108	-0.078	0.001	0.72
4	1301	-0.377	0.0398	<0.001	1158	-0.370	0.0378	<0.001
5	1082	-0.365	0.0367	0.001	1562	-0.343	0.0380	<0.001
6	444	-0.509	0.0717	<0.001	974	-0.372	0.0440	<0.001
7	70	-0.937	0.178	<0.001	319	-0.466	0.0824	<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	183	-0.276	0.0329	0.014	45	-0.518	0.147	0.009
4	820	-0.205	0.0131	0.001	705	-0.271	0.0231	<0.001
5	929	-0.172	0.0074	0.009	890	-0.232	0.0152	<0.001
6	647	-0.509	0.039	<0.001	682	-0.447	0.0292	<0.001
7	281	-0.602	0.030	0.004	336	-0.416	0.0291	0.002
8	90	-0.259	0.002	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 9. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2008.

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

Table 10. Summary of the spring American shad logbook data, 1999-2008.

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

Table 11. Summary of the spring hickory shad log book data from Deer Creek, 1998-2008.

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

Table 12. Age structure of hickory shad from the Susquehanna River based on scales, 1998-2008.

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

Figure 1. Location of the 2008 hook and line sampling in Conowingo Dam tailrace.

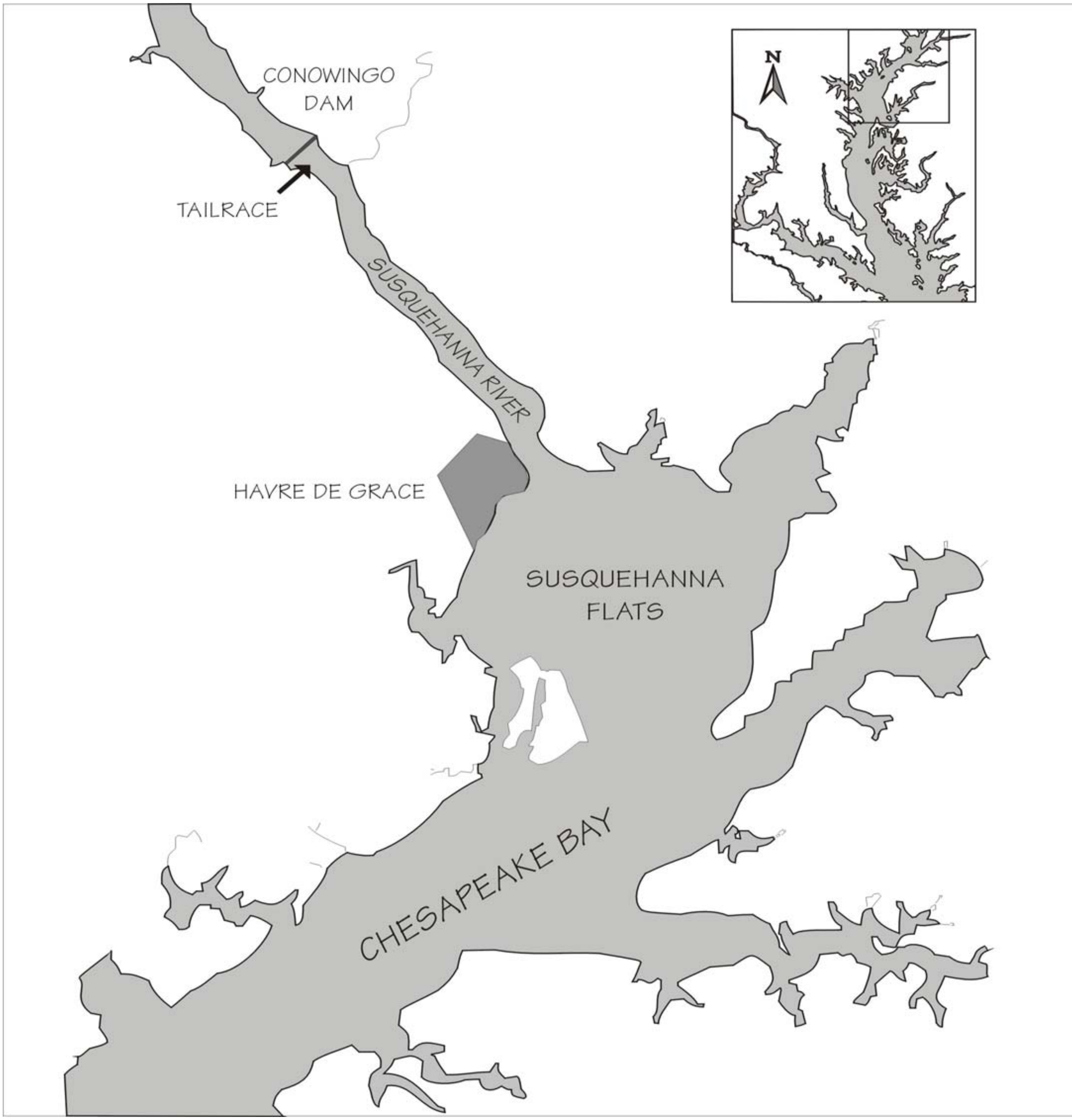


Figure 2. Distribution of the 2008 fyke and pound nets sampled on the Nanticoke River.

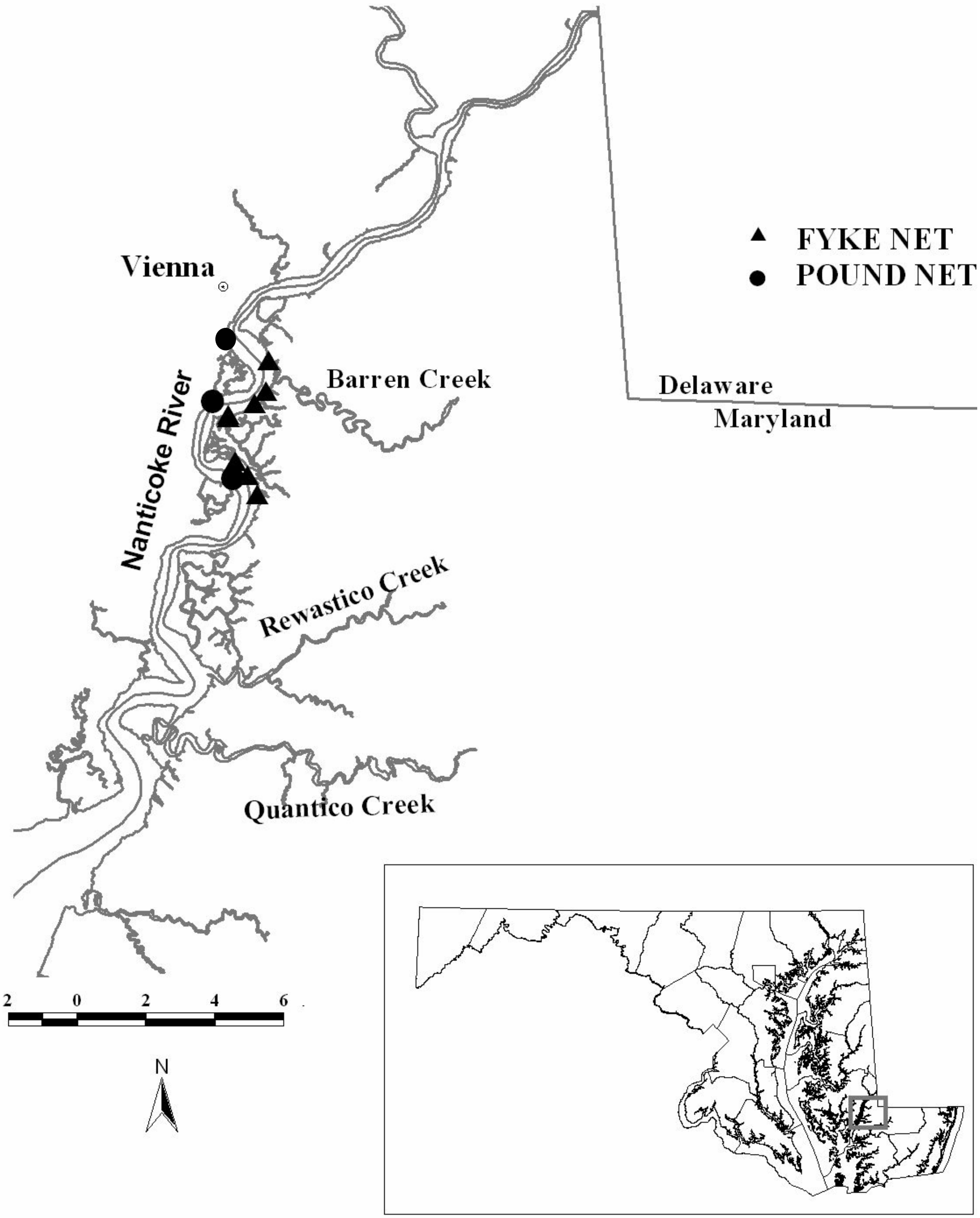


Figure 3. Distribution of the 2008 seine sites on the Chester River (black circles).

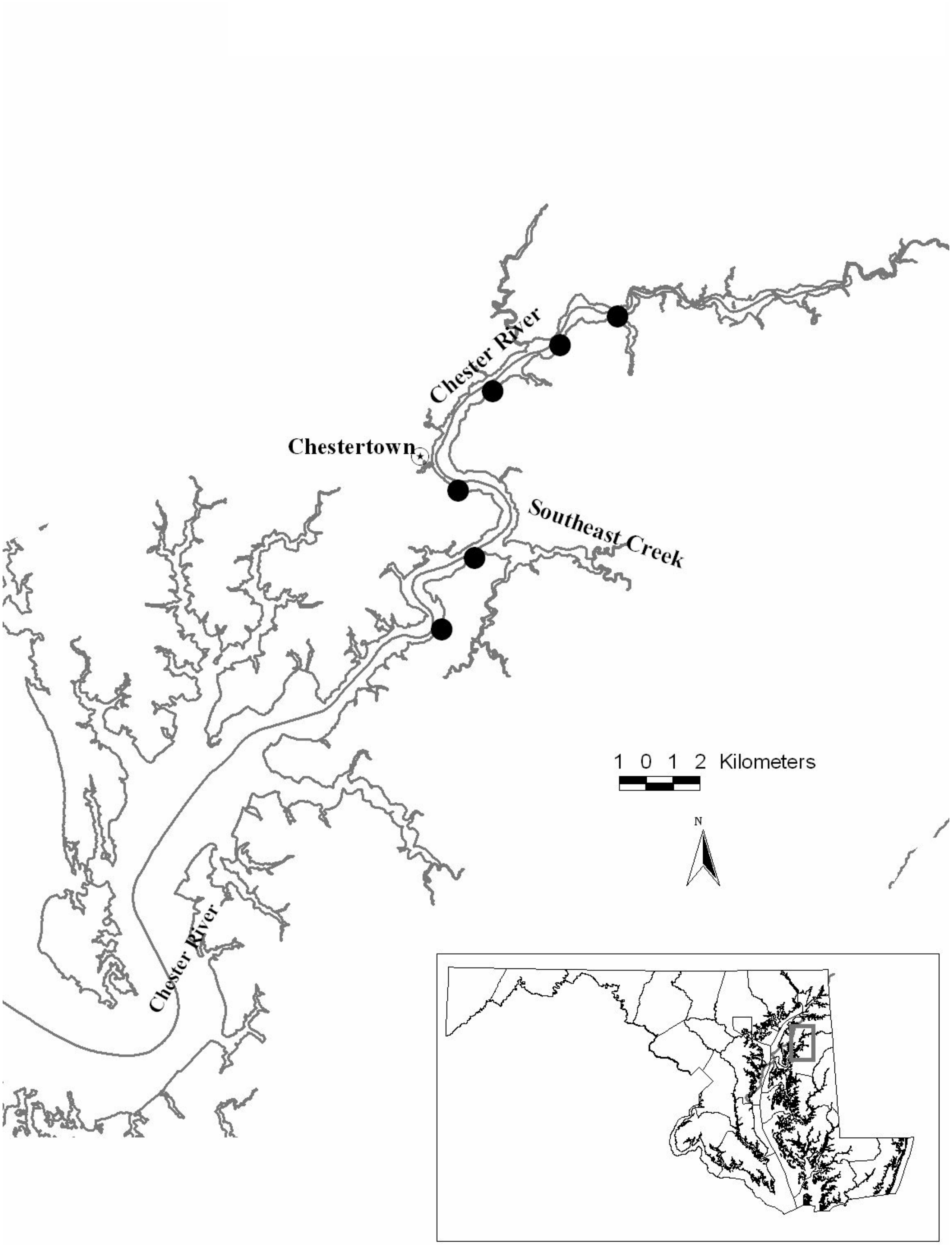


Figure 4. Distribution of the 2008 seine sites on the Pocomoke River (black circles).

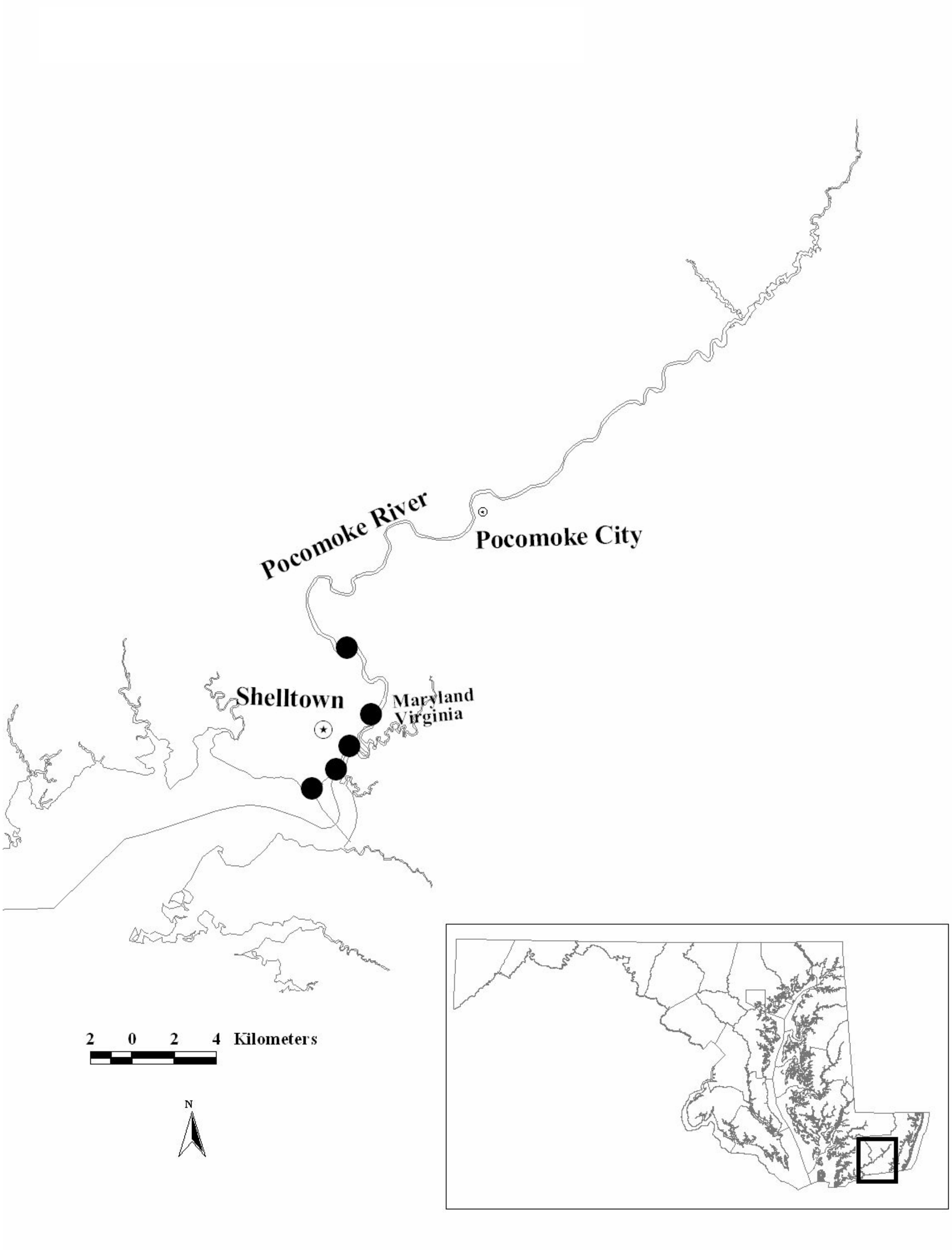


Figure 5. Distribution of the 2008 ichthyoplankton sampling sites on the Nanticoke River.

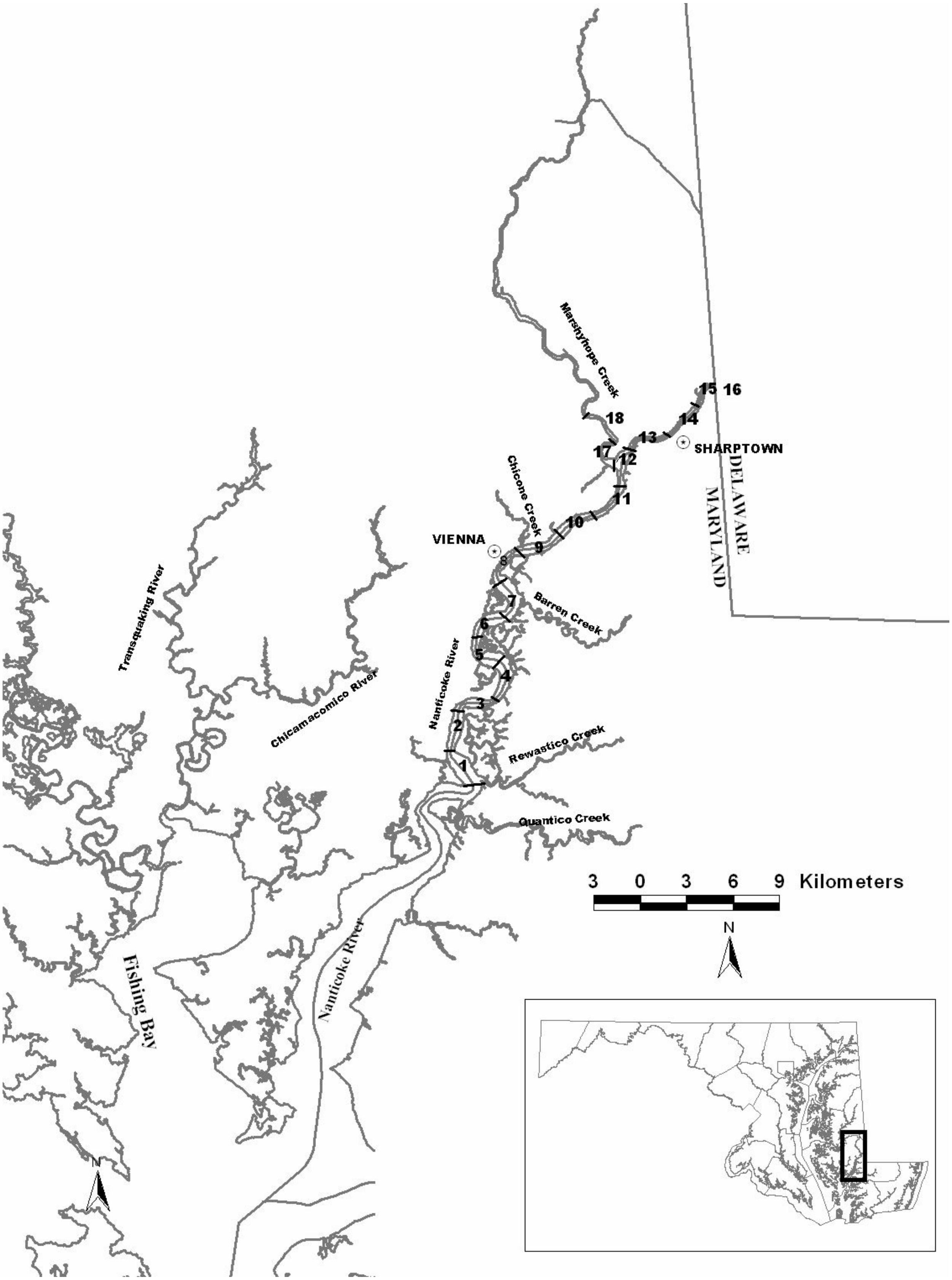


Figure 6. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2008).

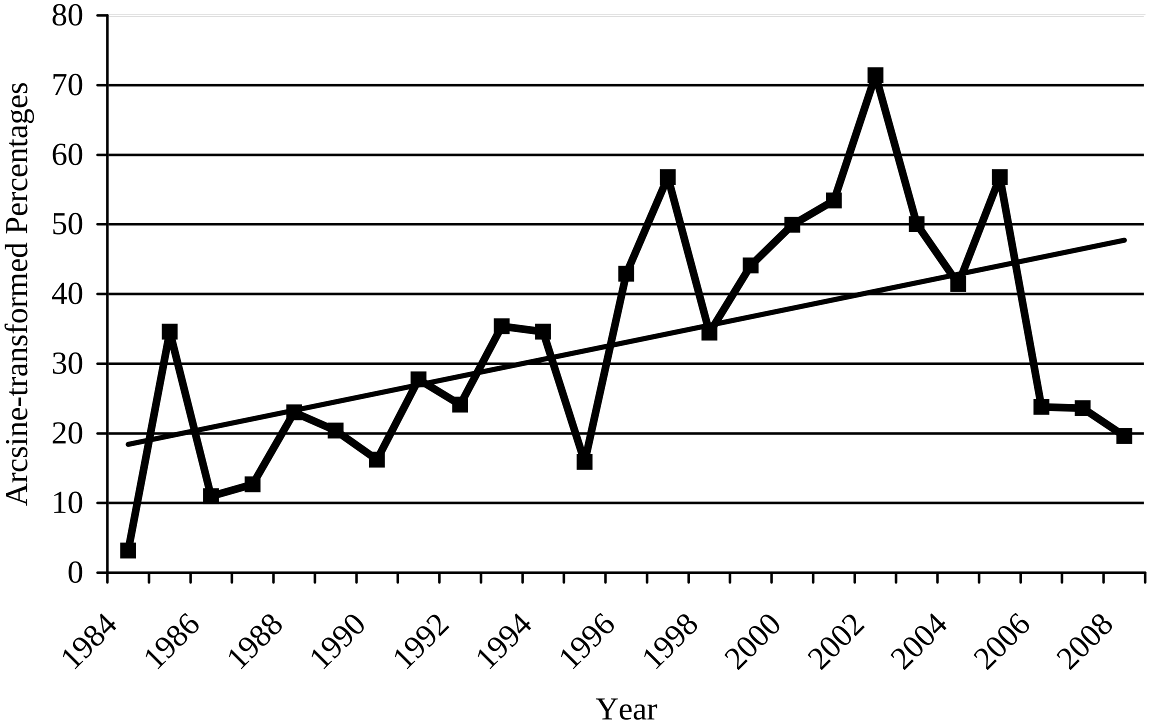


Figure 7. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River (1988-2008).

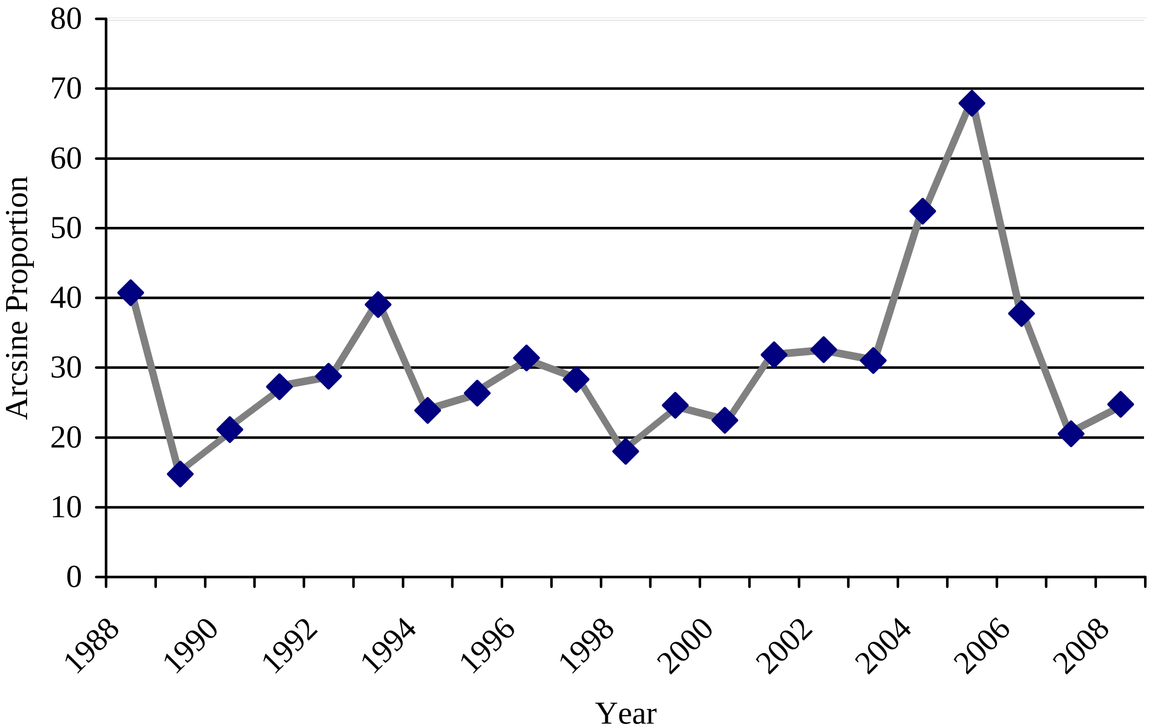


Figure 8. Conowingo Dam tailrace population estimates of American shad, 1985-2008.

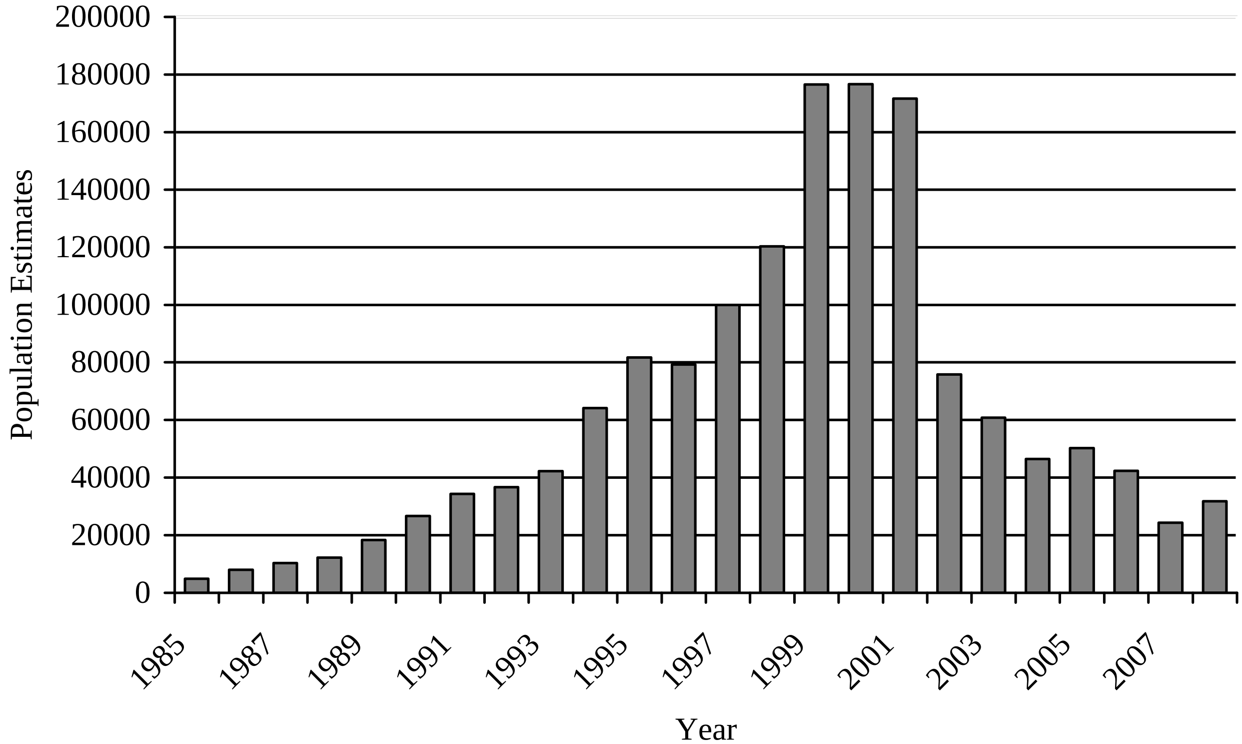


Figure 9. Geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2008.

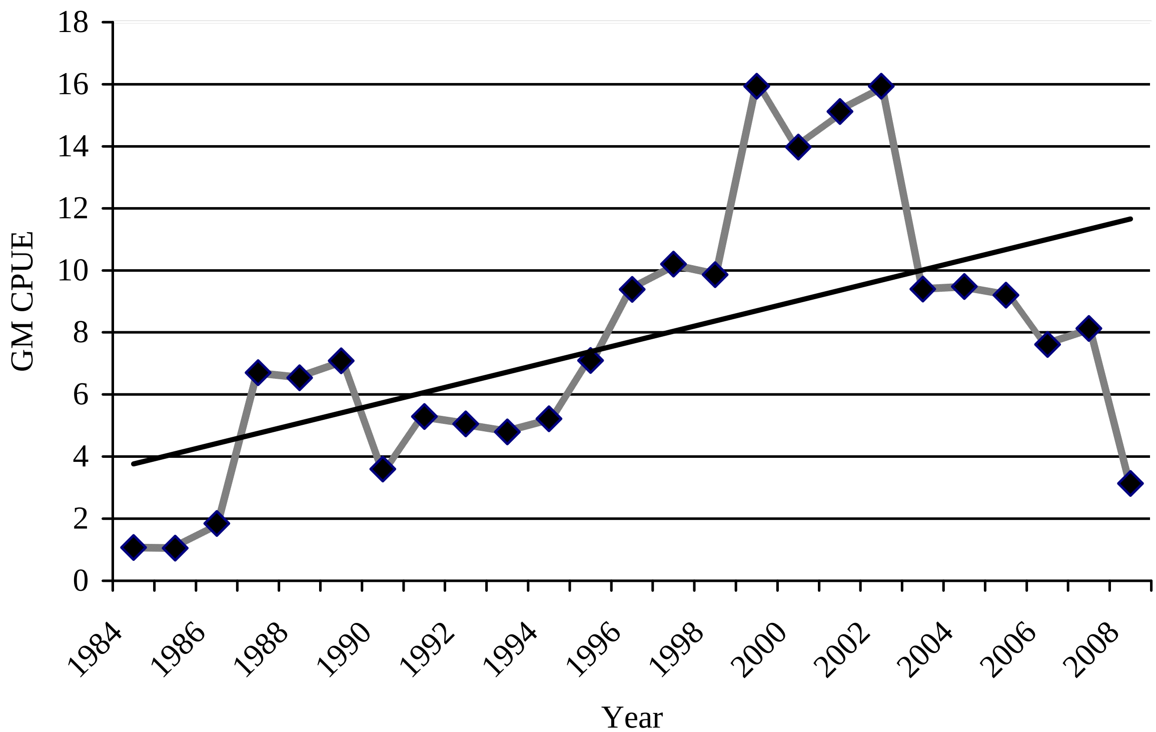


Figure 10. Geometric mean CPUE of American shad from the lifts at Conowingo Dam, 1980-2008.

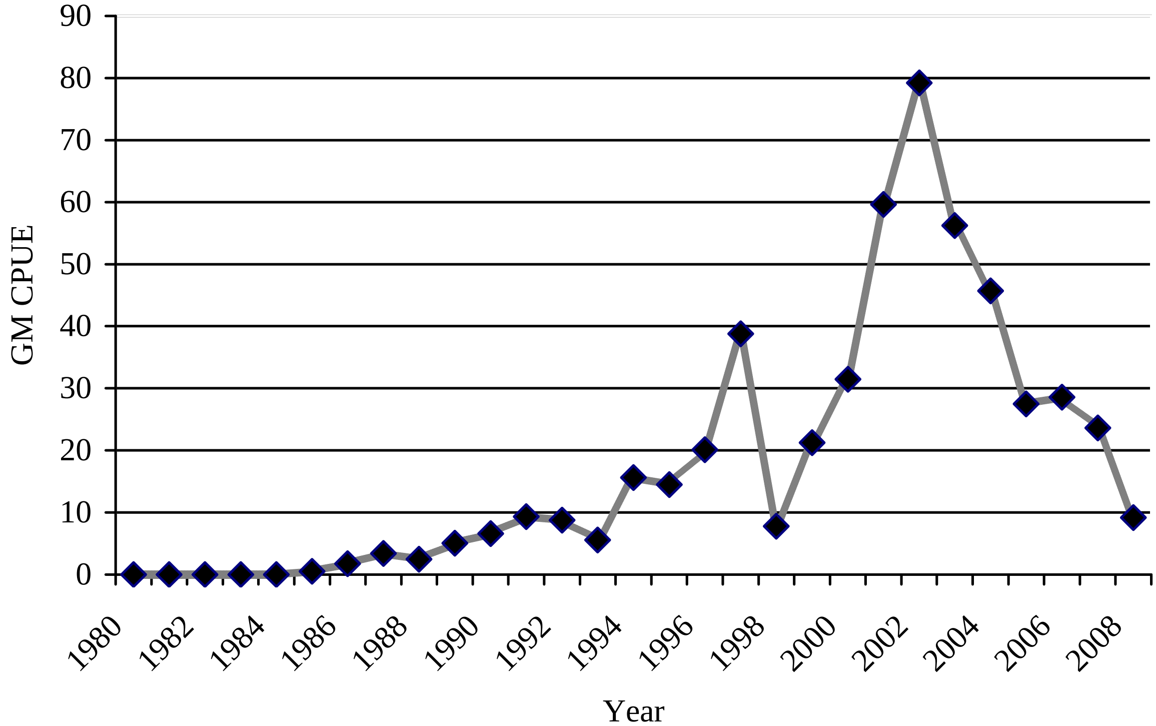
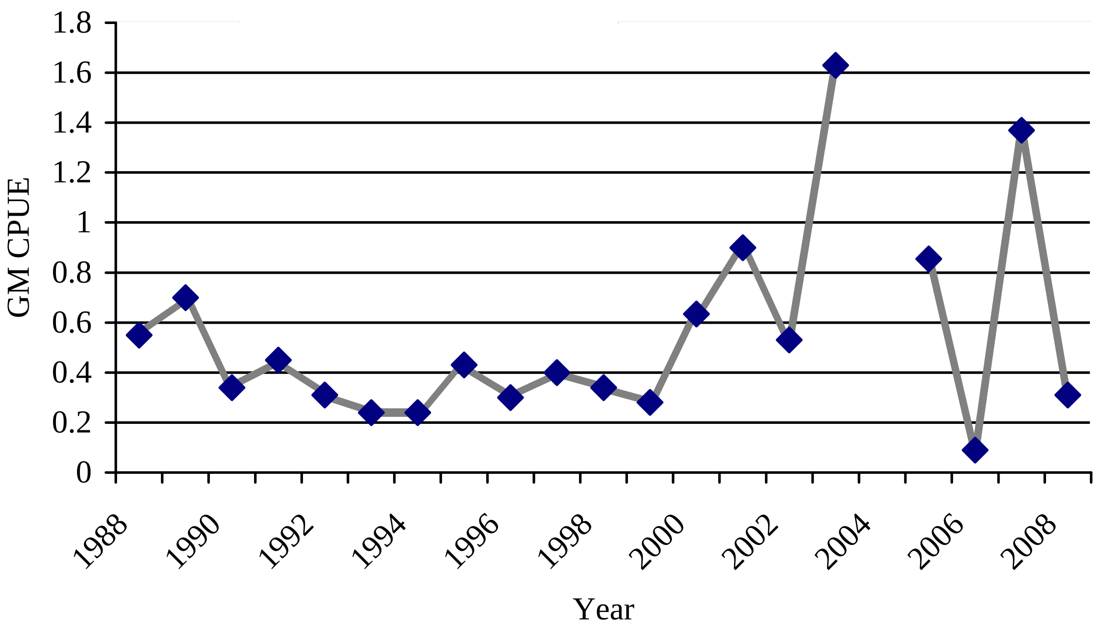


Figure 11. Pound net geometric mean CPUE for American shad from the Nanticoke River, 1988-2008. [3]



[3] No Pound nets were fished in 2004.

Figure 12. American shad geometric mean CPUE from fyke nets on the Nanticoke River, 1989-2008.

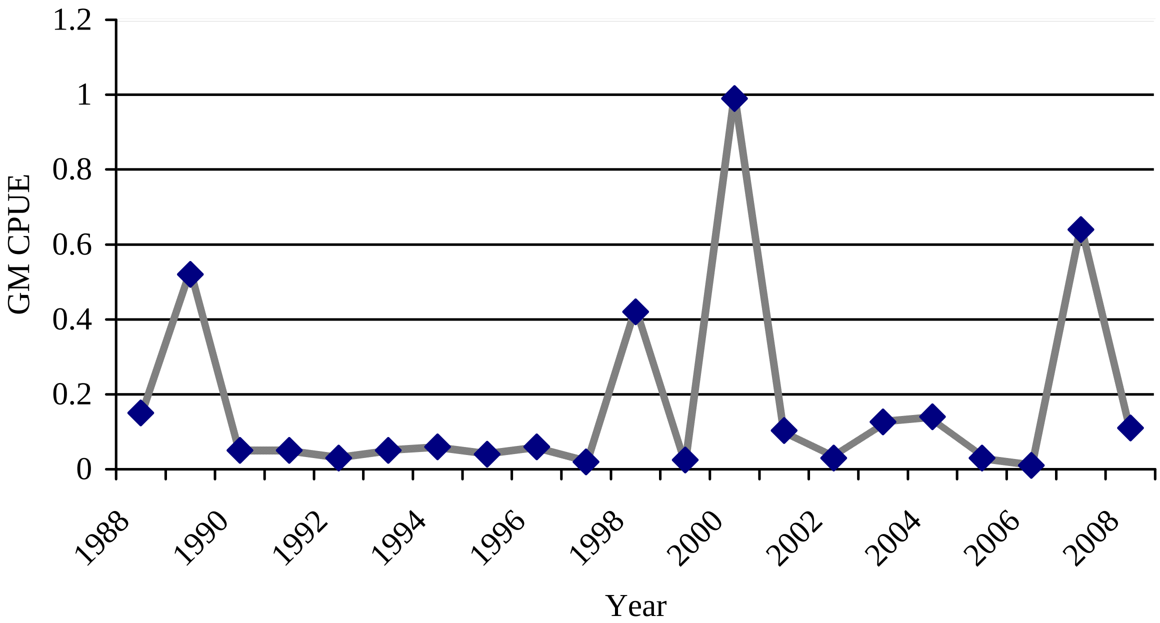
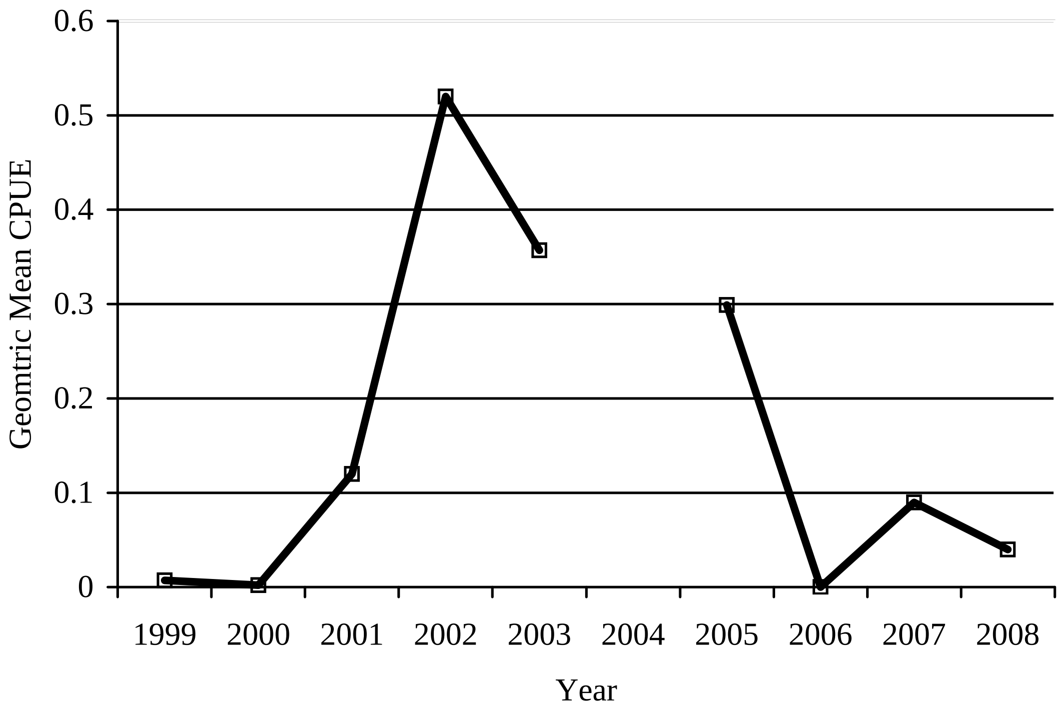


Figure 13. Adult hickory shad geometric mean CPUE from Nanticoke River pound nets, 1999-2008.[4]



[4] No pound nets were set in 2004.

Figure 14. Adult hickory shad CPUE from Nanticoke River fyke nets, 1999-2008.

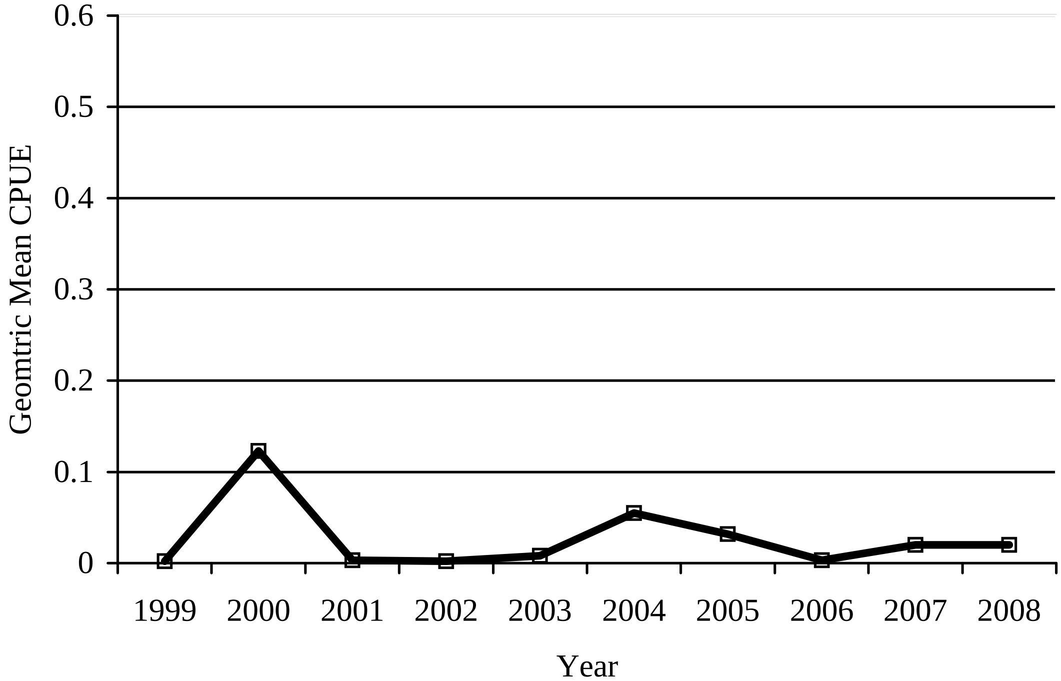


Figure 15. Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes and gears combined) from the Nanticoke River, 1989-2008.

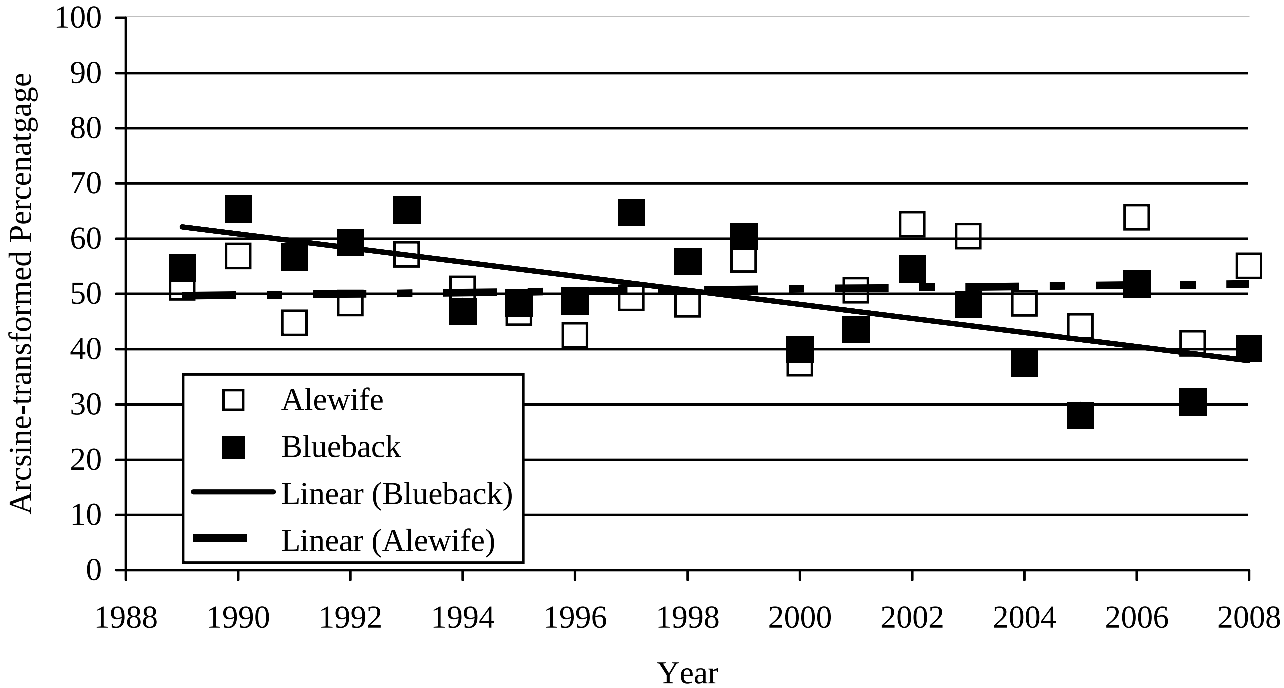


Figure 16. Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1989-2008.

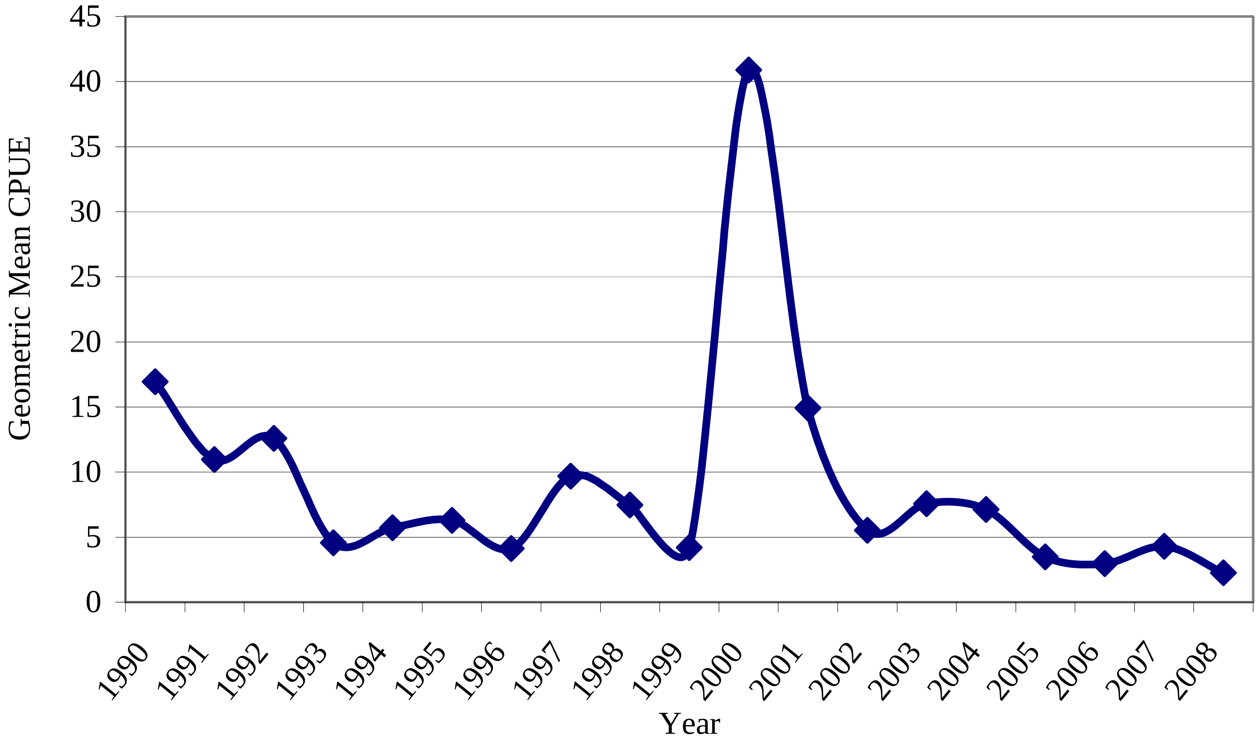


Figure 17. Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2008.

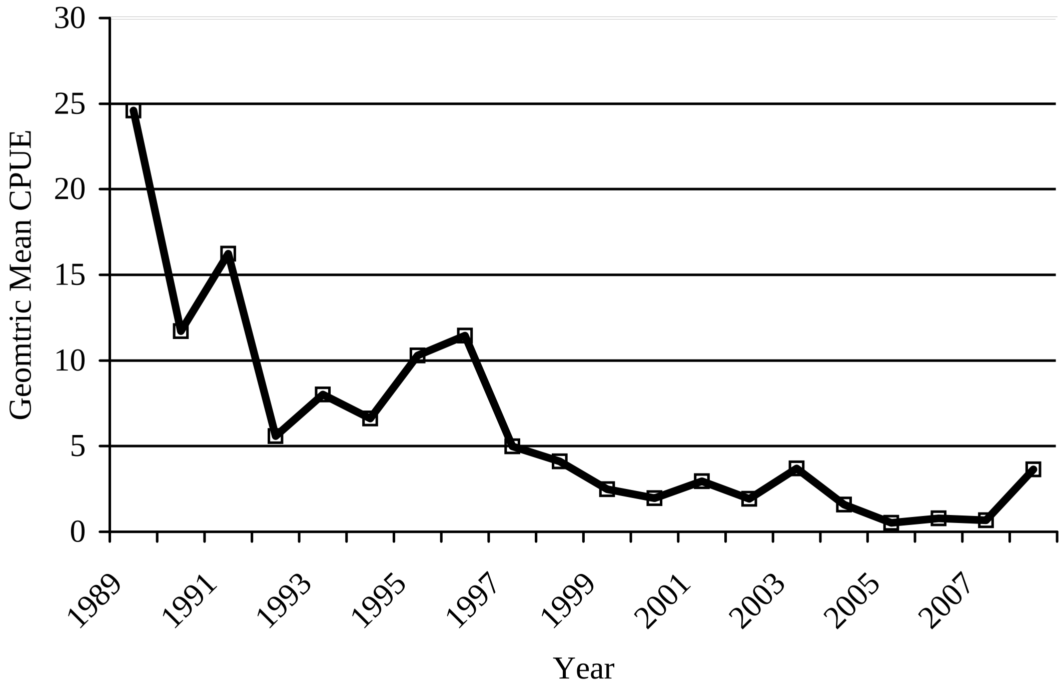


Figure 18. Regression analysis estimates of geometric mean CPUE (alewife and blueback herring combined, 1989-2008), and the total commercial river herring landings in pounds, 1980-2008 from the Nanticoke River.

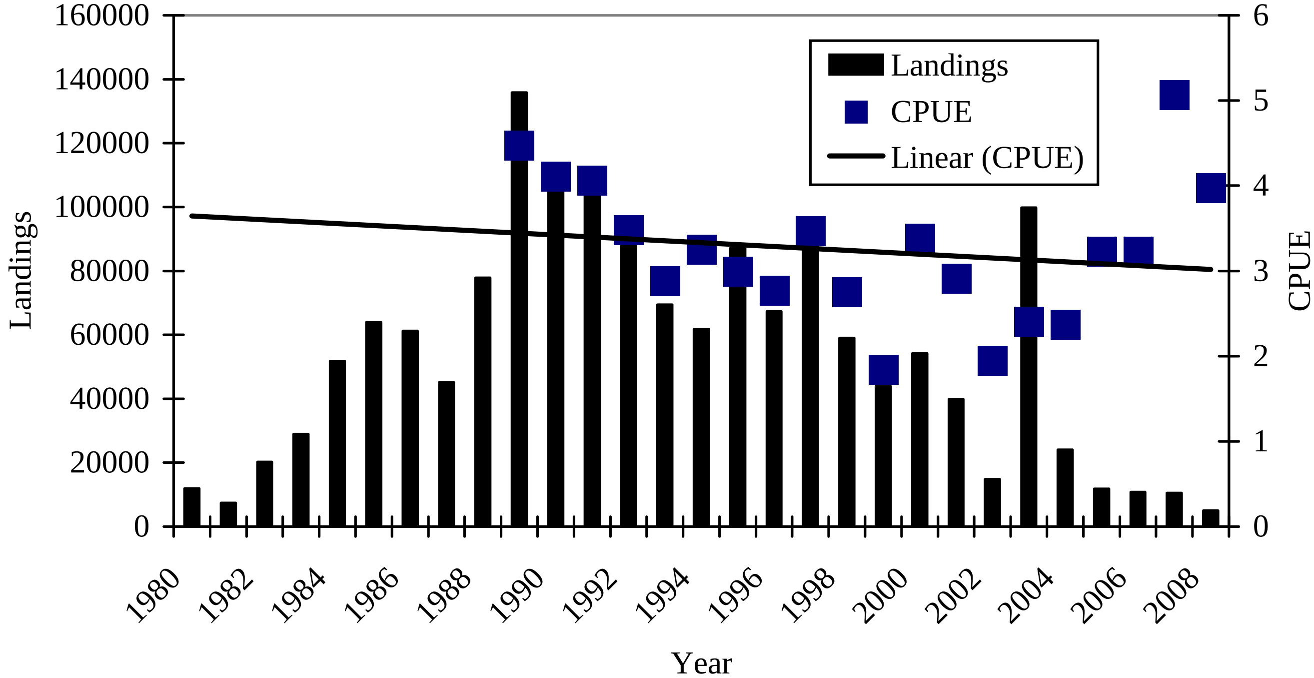


Figure 19. Instantaneous mortality (Z) of Nanticoke River alewife herring (1989-2008).

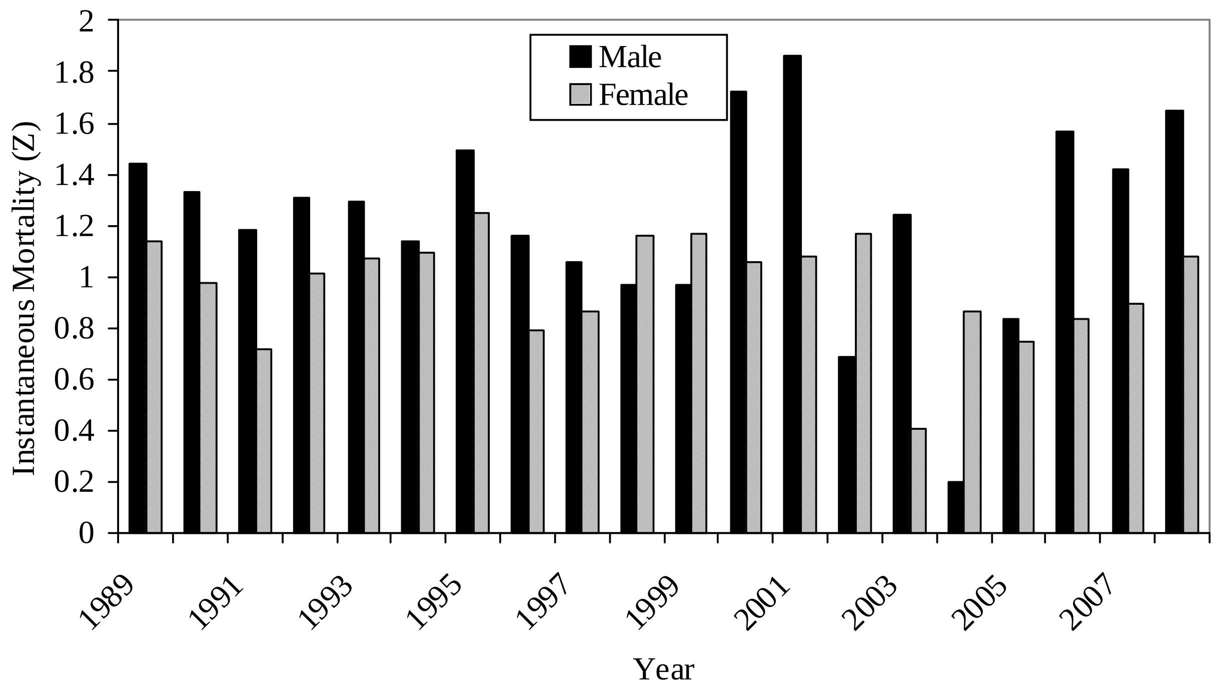


Figure 20. Instantaneous mortality (Z) of Nanticoke River blueback herring (1989-2008).

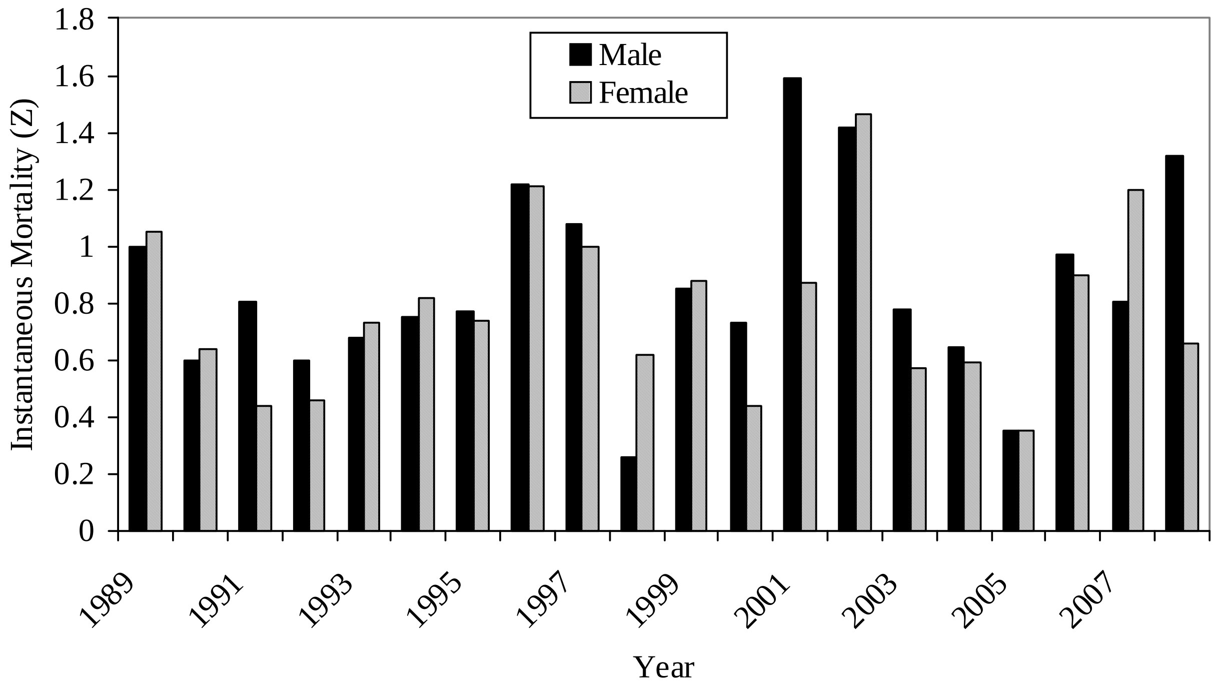


Figure 21. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Potomac River (2002-2008).

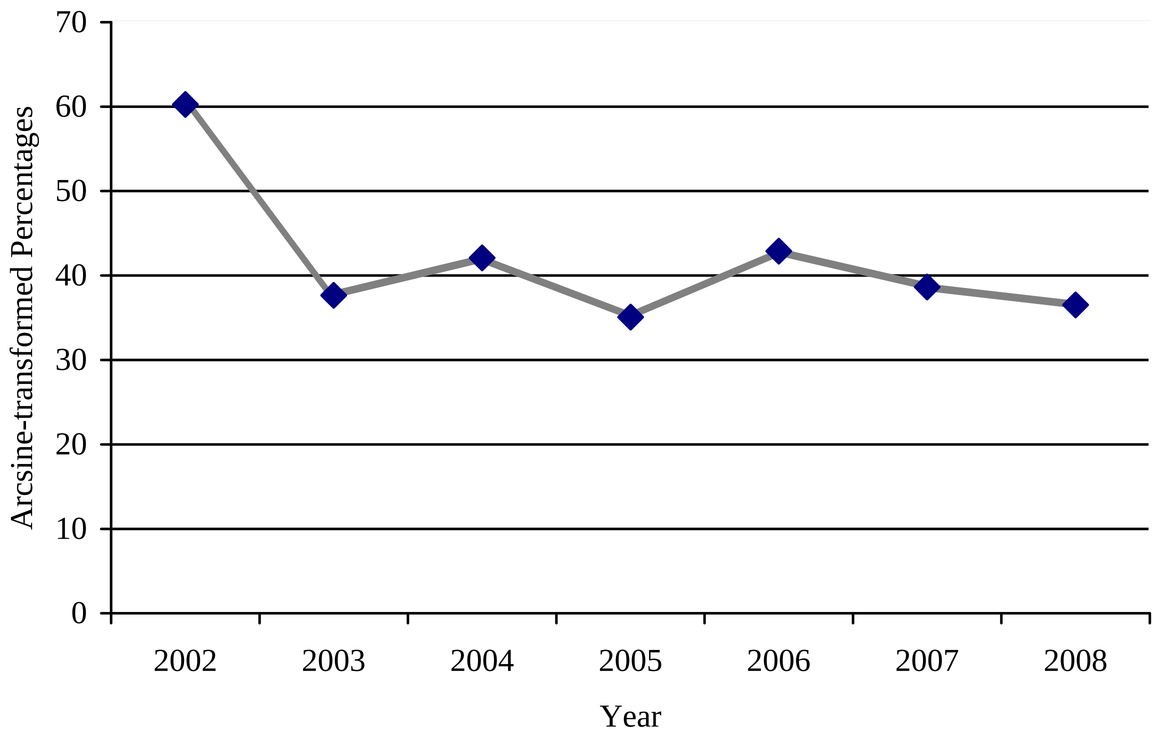


Figure 22. Baywide juvenile American shad geometric mean CPUEs, 1959-2008.

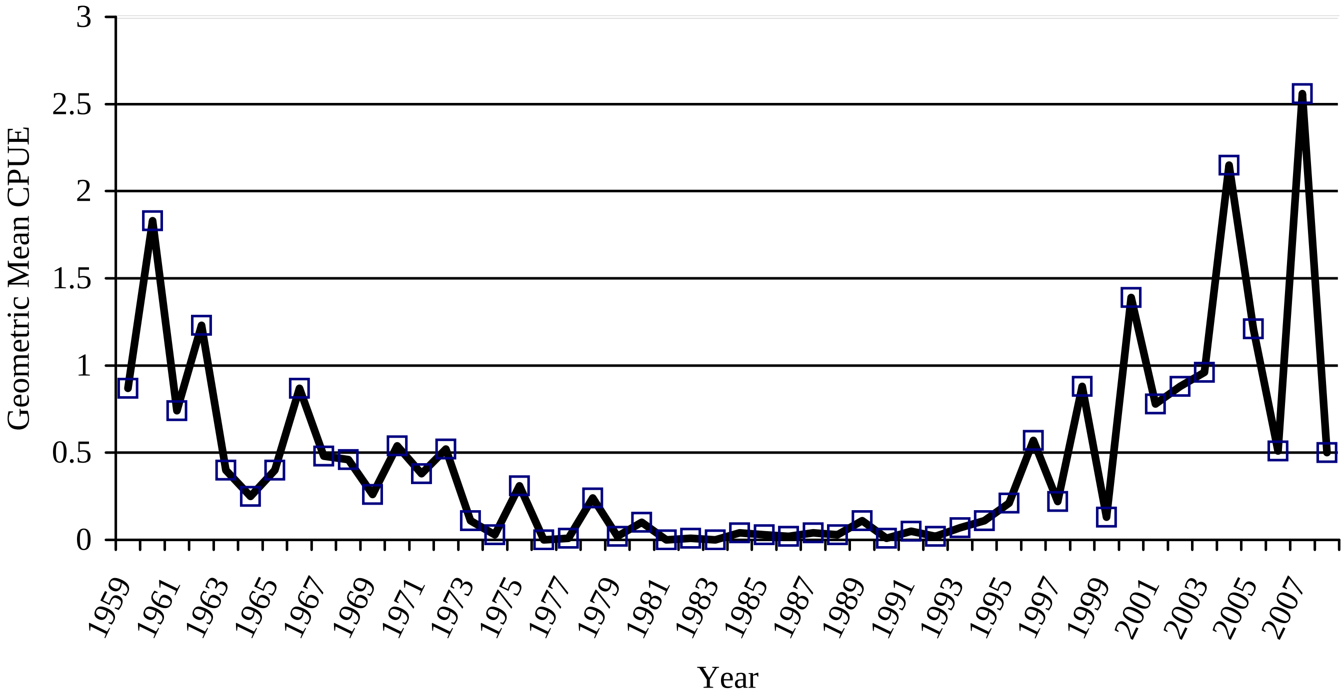


Figure 23. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1959-2008.

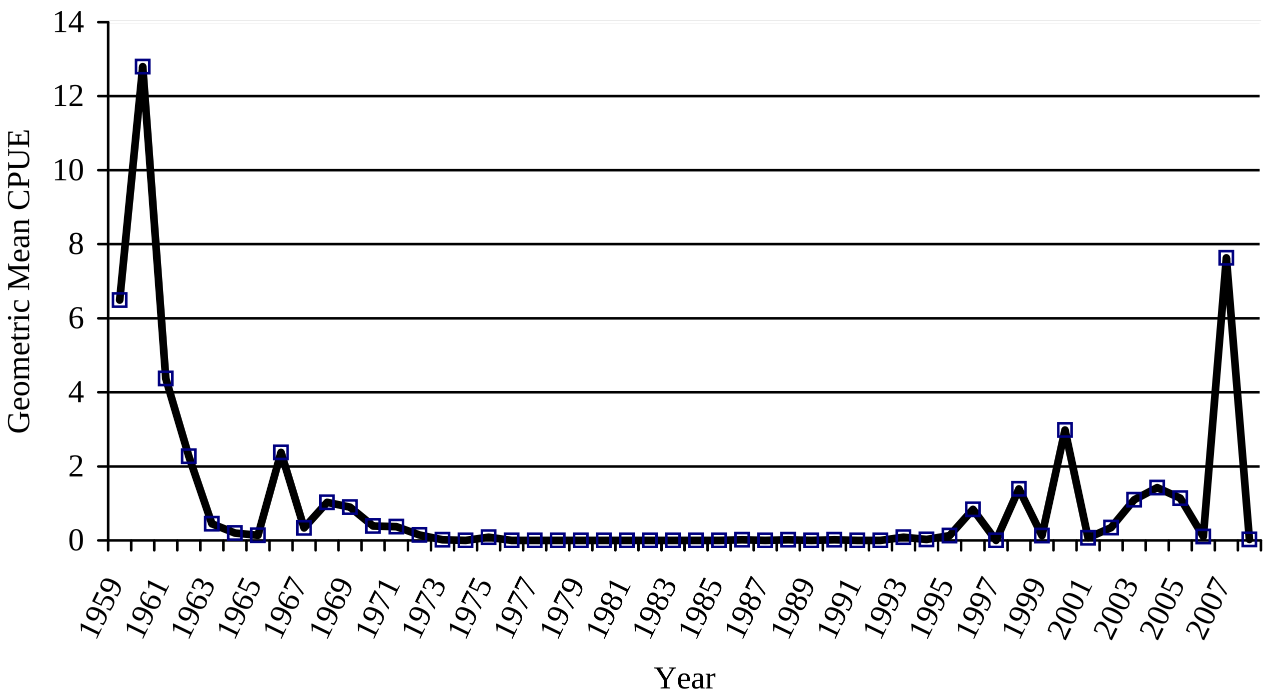


Figure 24. Potomac River geometric mean CPUEs for juvenile American shad, 1959-2008.

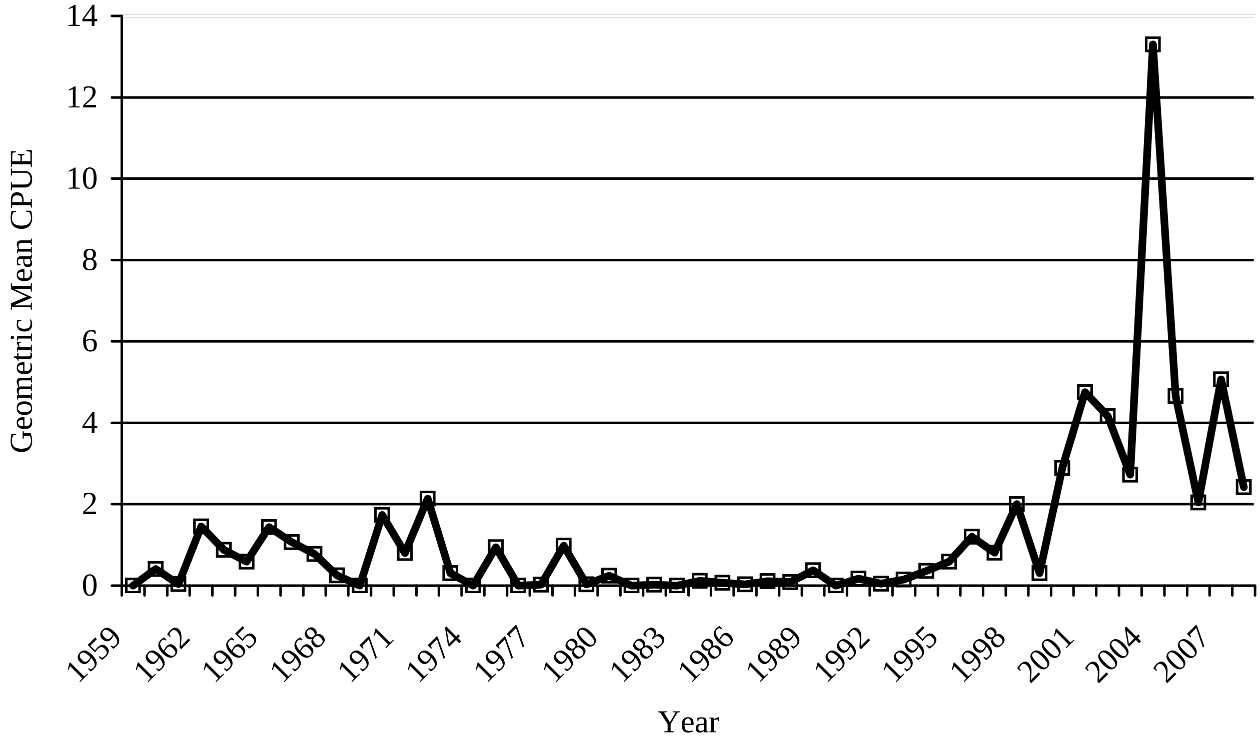


Figure 25. Nanticoke River juvenile alewife herring geometric mean CPUEs, 1959-2008.

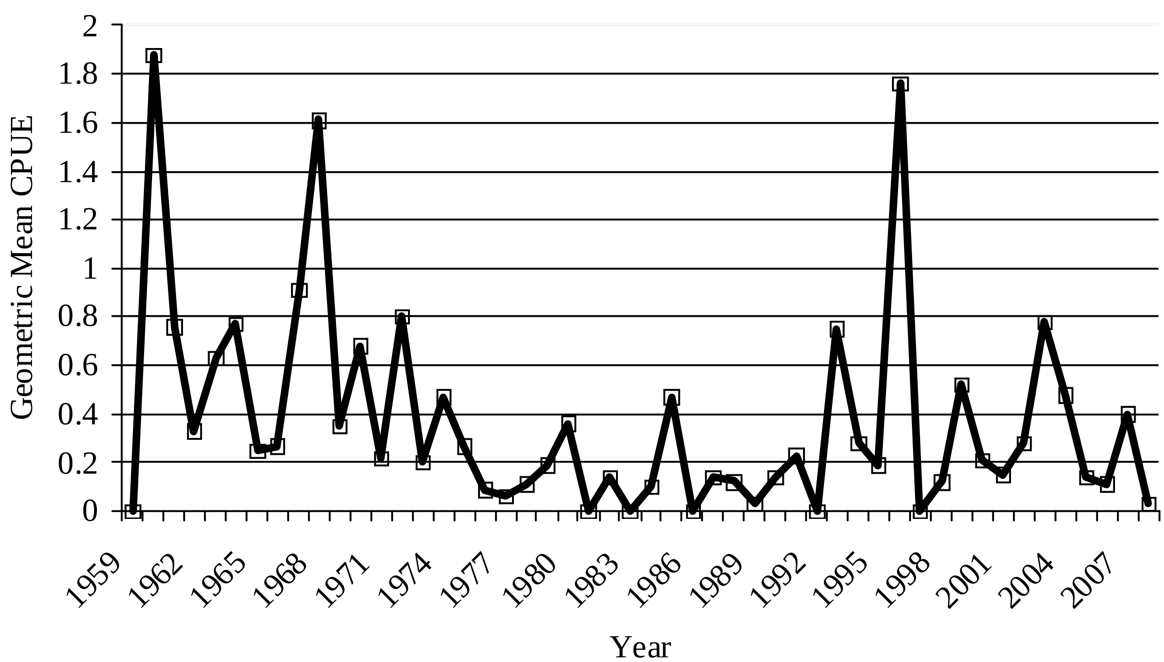


Figure 26. Nanticoke River juvenile blueback herring geometric mean CPUEs, 1959-2008.

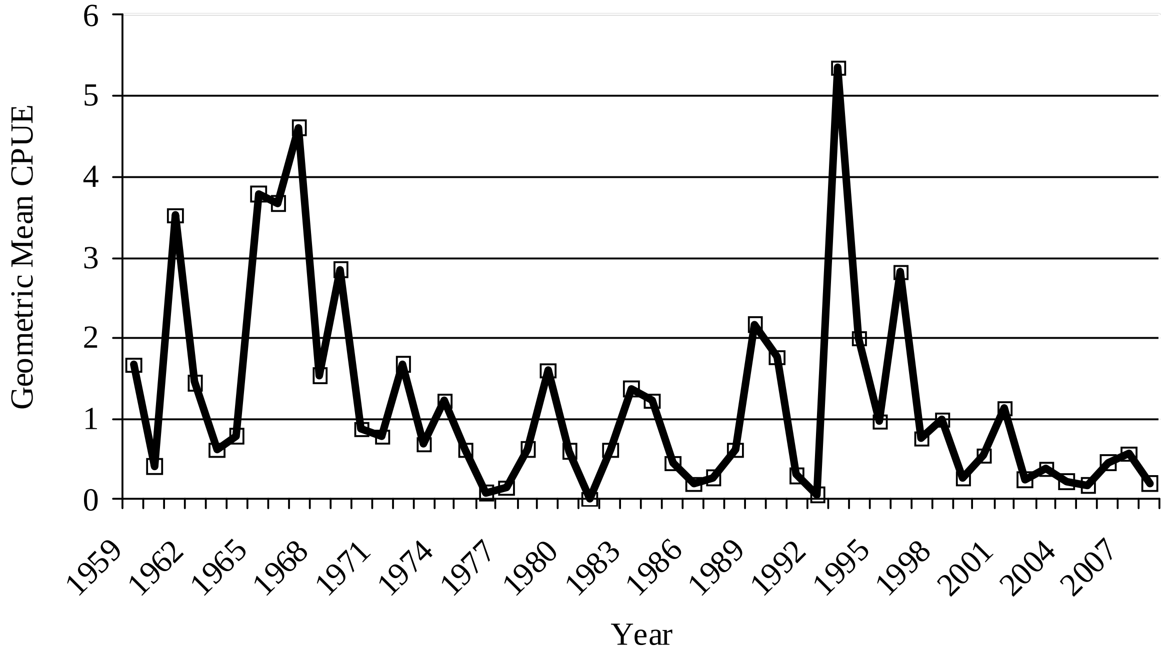
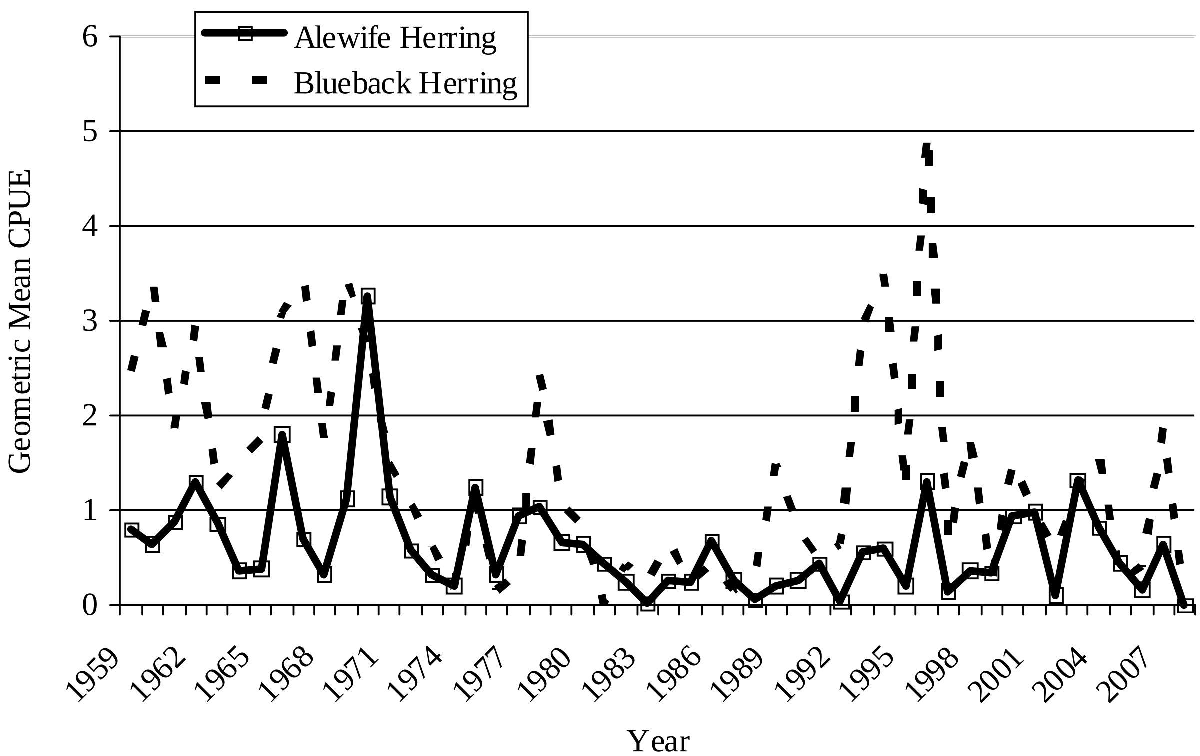


Figure 27. Baywide juvenile alewife and blueback herring geometric mean CPUEs, 1959-2008.



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. and Gerald A. Balmert

INTRODUCTION

The primary objective of 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 regalis*) and Spanish mackerel (*Scomberomorus maculates*) are less popular in Maryland because of lesser 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

During 2008, commercial pound nets were sampled at the mouth of the Potomac and Nanticoke rivers and Fishing Bay (Figure 1). The Potomac River sampling area has been consistently monitored throughout the survey, while the Nanticoke River and Fishing Bay sites were added this year to replace the Chesapeake Bay sampling area near Barren Island. Each site was sampled once every two weeks, weather and fisherman's schedule permitting. The commercial fishermen set all nets sampled as part of their regular fishing routine. Net soak time and manner in which they were fished were consistent with the fishermen'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 scale were aged by two MD DNR biologists, and only those in which agreement was reached were assigned final ages. 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 aging by MD. Aging was attempted using whole otoliths, but was unsuccessful. Spot otoliths will be archived until sectioning equipment is available to properly process these samples. 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.

Analytical Procedures

Commercial and recreational landings 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), respectively. Since these data sets are not finalized until the spring of the following year; landings data are through 2007 for this report. Landings from Maryland's commercial reporting system were divided by area into Chesapeake Bay, Atlantic (including Coastal bays) and unknown area.

Instantaneous total mortality rates for weakfish and Atlantic croaker were calculated using the Ssentongo and Larkin (1973) length based method,

$$Z = \{K/(y_{bar} - y_c)\}$$

where lengths are converted: $y = -\log_e (1-L/L_\infty)$, and $y_c = -\log_e (1-L_c/L_\infty)$, L = total length, L_c = length of first recruitment to the fisheries, K = growth coefficient and L_∞ = length that an average fish would achieve if it continued to grow, K and L_∞ are von Bertalanffy parameters. Von Bertalanffy parameters for weakfish for all years were estimated from otolith ages from 1999 Chesapeake Bay pound net survey data (Jarzynski *et al* 2000). Von Bertalanffy parameters for croaker mortality estimates were derived from pooled ages (otoliths; n = 733) determined from 2003-2006 Chesapeake Bay pound net survey data, and June through September 2004 measurements of age zero croaker from the MD DNR Blue Crab Trawl Survey from samples (Glenn Davis, MD DNR. personnel communication 2007). These trawl data were included to provide age zero fish that had not recruited to the pound net gear, and represented samples taken from the same time period 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 1999-2002 were L_∞ = 401.7 mm TL and K= 0.48. 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). 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, using pound net length data divided into 20 mm length groups for each.

A length-at-age key was constructed for weakfish and Atlantic croaker using the 2007 age samples, since 2008 samples had not yet been processed by SC DNR in time for inclusion in this report. Age sample and length data were assigned to 20 mm TL groups for each. The measurements were then applied to the length-at-age key to determine the proportion at age for each species in 2007.

A length-at-age key was also constructed for Atlantic menhaden using 2007 and 2008 age data. Age sample and length data were assigned to 20 mm FL groups beginning with the 180 mm length group.

Juvenile indices were calculated for weakfish, Atlantic croaker and spot from the MD DNR Blue Crab Trawl Survey. 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 include the Chester River, Eastern Bay, Choptank River and Patuxent River (six fixed sampling locations each), Tangier Sound (five stations) and Pocomoke Sound (eight stations). Each station was sampled once a month from May - October. Juvenile finfish collected by this survey have been enumerated 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 lower Potomac River was sampled from May 20, 2008 through September 9, 2008, while the Nanticoke River and Fishing Bay were sampled from June 9, 2008 to September 2, 2008 (Table 2). All eleven of the target species and 20 non-target species (Table 3) were encountered during the 2008 pound net survey.

Weakfish

Forty-two weakfish were sampled in the 2008 pound net survey, the lowest catch of the 16 year time series. Weakfish mean length in 2008 was 276 mm TL, nearly identical to the 2007 mean length of 275 mm TL (Table 4). RSDs for 2008 were similar to those of the past two years, indicating a continued dominance of RSD_{stock} fish (Table 5). However, a modest increase in 2008 RSD_{qual} and RSD_{pref} weakfish compared to the 2004 - 2007 time period was noted. The 2008 length frequency distribution also indicated a slight shift to smaller sizes for the second straight year, with over 81% of sampled weakfish between 210 and 289 mm TL (Figure 2).

Chesapeake Bay weakfish length-frequencies were truncated from 1993 – 1998, while those for 1999 and 2000 contained considerably more weakfish greater than 380 mm TL. However, this trend reversed during 2001 - 2008, with far fewer large weakfish encountered. Ninety percent of weakfish sampled in 2008 were below the recreational size limit of 331 mm TL (13 inches), and 86 percent were below the commercial size limit of 305 mm TL (12 inches).

In 2008, females accounted for 76% of fish sampled (n=32). Female mean TL and mean weight were 277 mm TL and 225g respectively, while males averaged 270 mm

TL and 203g. In 2007, females averaged 278 mm TL and 219g and accounted for 59% of fish sampled (n=36), while male mean length and weight was 270 mm TL and 190g, respectively. Mean lengths and weights were quite similar in 2007 and 2008, after decreasing from 2006 values, but these differences may be artifacts of small sample sizes.

Total commercial landings (Chesapeake Bay and Atlantic Ocean) in 2007 declined to 11,910 pounds, but the Chesapeake Bay portion increased from 1,131 pounds in 2006 to 6,150 pounds in 2007 (Figure 3). Total 2007 landings were the lowest of the 78 year time series and well below Maryland's average of 651,827 pounds per year. The 2007 commercial landings for Chesapeake Bay were the second lowest since 1969. Maryland recreational anglers harvested an estimated 11,910 weakfish during 2007, weighing 19,434 pounds (MRFSS 2008; Figure 4). The number of weakfish harvested by the recreational fishery in 2007 was 25 times greater than the 2006 estimate (470), but still the second lowest estimate of the 1981-2007 time series. Maryland anglers released 106,308 weakfish in 2007, an increase from 2006 (57,466). Estimated recreational harvest had decreased steadily from 475,348 fish in 2000 to near zero in 2006 before recovering slightly in 2007.

The 2008 weakfish juvenile GM of 0.8 decreased for the third straight year, and was the 3rd lowest value in the 20-year time series (Figure 5). Weakfish juvenile abundance generally increased from 1989 - 1996 in Pocomoke and Tangier sounds, remained at a relatively high level through 2001 but has generally decreased from 2001 to the present. This lack of recruitment may explain poor commercial and recreational landings in recent years. The relatively low abundance of juvenile weakfish since 2002 is similar to that of the early 1990's, but landings continue to be exceptionally low, unlike the higher landings in the early1990's.

Otoliths from 61 weakfish were aged for 2007, with only ages 1 through 4 present (Table 6). Age composition, based on the 2007 age length key, was 62% age one, 26% age two, 10% age three and 2% age 4. The 2007 age structure was similar to that of 2006, skewed toward younger fish. Forty-two weakfish were sampled for age in 2008, but ageing has not been completed at this time.

Mortality estimates for 2007 and 2008 could not be calculated because of extremely low sample size, instantaneous total mortality estimates calculated for 2004 and 2006 were Z=1.35 and Z=1.44, respectively (Table 7). Maryland's length-based estimates were similar to the coastal assessment of Z=1.4 for cohorts since 1995 (Kahn et al 2005).

The most recent weakfish Stock Assessment Workshop conducted by ASMFC in 2005 found neither the ADAPT model nor Gulland's cohort analysis provided usable estimates of fishing mortality (F) or stock biomass for recent years (Kahn et al 2005). Catch curve analysis of the catch-at-age matrix indicated total mortality has increased significantly in recent years (Kahn et al 2005). This analysis determined that relative F's were low and constant from 1994 -2001, and had increased in 2002 and 2003, but not to a level that would cause stock decline. The ASMFC Stock Assessment Committee believes an increase in natural mortality to be the primary causative factory in the recent weakfish stock decline. An updated coast wide stock assessment is currently being conducted.

Summer flounder

Summer flounder mean lengths varied widely from 2004-2007. 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 then increased to the 6th highest mean length (341 mm TL) in 2007 (Table 4). The 2008 mean length of 347 mm TL was similar to 2007. Relative stock densities in 2008 indicated a decrease in the stock category with corresponding increases in quality and preferred categories compared to 2007 (Table 8). This same trend was seen when comparing 2006 and 2007 RSDs. The 2008 length frequency distribution indicated an increase in flounder greater than 330 mm TL, fewer fish less than 270 mm TL (Figure 6). In 2007 a shift occurred away from a bimodal distribution, an increase in mean size, an increase in moderately sized fish and a decrease in the RSD_{stock} category, suggesting the large 2006 year-class became a dominate component of the 2007 pound net catch. It would appear these fish remain the primary contributor to the harvestable stock in 2008, with a greater proportion of the catch above the 356 mm TL minimum commercial size limit (42% in 2008 vs. 31% in 2007).

Maryland's commercial summer flounder harvest was 176,377 pounds in 2007, the 8th lowest in the 45-year time series (Figure 7). The long-term commercial harvest average, 1962 – 2007, is 434,094 pounds. In recent years the commercial flounder fishery has been managed by quota, with varying regulations and season closures to ensure the quota is not exceeded. From 2001 to 2004, Maryland harvested 91 to 100 percent of it's allotted quota, but only harvested 75% in 2005, 61% in 2006 and 87% in 2007. The majority of the Maryland commercial harvest comes from the Atlantic Ocean and coastal bays. The recreational harvest estimate of 157,360 fish caught in 2007 ranked

16th out of the 27 year time series, a substantial increase over the 2006 estimate of 58,386 fish (MRFSS 2008; Figure 8). The 2007 MRFSS recreational release estimate of 1,625,857 fish was the second highest of the 1981- 2007 time series, representing a three fold increase compared to 2006 (Figure 8).

Virtual population analysis (VPA), conducted in 2006 by the National Marine Fisheries Service (NMFS), indicated that summer flounder recruitment along the Atlantic coast declined from a peak in 1983 to the time series low in 1988 (Terceiro 2006). Recruitment since 1988 was generally higher, with estimates ranging between 25 and 35 million fish each year through 2004(long-term average = 35 million). Recruitment was below average at 25 million fish in 2003, average in 2004 at 35 million fish, and well below the average in 2005 at 15 million fish (Terceiro 2006). The VPA model estimated a rebound in recruitment for 2006 to 34 million fish. The NMFS coastal assessment found that F varied from F = 0.9 to F = 2.2 during 1982 - 1997, fell from approximately F=1.2 in 1997 to F=0.46 in 2003, then rose slightly to F=0.53 in 2005. The NMFS assessment concluded that summer flounder stocks were not overfished, but overfishing was occurring, with F_{2005} exceeding the threshold of F=0.276.

MD DNR survey data appeared to corroborate the NMFS VPA findings. The larger mean length observed during 2001 suggested decreased F and increased SSB, while the lower mean length in 2002 could be an indicator of increased juvenile survival in recent years. In addition, the increase in mean length in 2005 was likely a result of growth and survival of the 2002 year-class and the lower abundance of age 0 fish. The decline in mean length and increase in RSD_{stock} for summer flounder in 2006 supports an increase in age 0 fish in 2006 as well as the relatively low abundance of age 1 fish.

Bluefish

Bluefish averaged 260 mm TL during 2008, a decrease from the 2007 mean of 318 mm TL (Table 4). The 2008 mean length ranks 2^{nd} lowest for the 16 year time series. The 2008 bluefish RSD_{stock} value increased from 94 in 2007 to 99 in 2008, with a corresponding decrease in RSD_{qual} and the disappearance of $RSD_{preferred}$ and $RSD_{memorable}$ (Table 9). The decline in length frequency distribution in 2008 indicated a dramatic shift to smaller sizes compared to the previous three years (Figure 9). Eighty-one percent of sampled bluefish in 2008 were less than 310 mm TL, while only 33% of the sample was below 310 mm TL in 2007.

The 2005 through 2007 samples indicated a small shift to a larger grade of bluefish, although small bluefish still dominated the population. This trend reversed in 2008 when larger bluefish became scarce. Variable migration patterns into Chesapeake Bay may be responsible for these differences. Crecco (1996) reviewed sportfish catches and suggested that the bulk of the bluefish stock was displaced offshore. Lack of forage and inter-specific competition with striped bass were possible reasons for this displacement.

Maryland bluefish commercial harvest more than doubled in 2007 to 120,250 pounds, still below the 1929-2007 average of 175,462 pounds (Figure 10). The 2007 catch was the 35^{th} highest of the 78-year time series. 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 2008;

Figure 11). The 2007 estimate of 705,366 fish harvested increased for the second consecutive year, but was still below the time series average of 924,218 fish (Figure 11). Estimated recreational releases, however, increased in 2007 to 1,381,056 fish, the highest release estimate of the time series.

The latest NMFS stock assessment of Atlantic coast bluefish using the VPA 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 decreased slightly in 2008 to 298 mm TL compared to 2007 (307 mm TL) and was the 9th highest mean of the 16 year time series (Table 4). Forty-one percent of the sampled croaker in 2008 were in the $RSD_{memorable}$ category, an increase over 2007. $RSD_{preferred}$ and RSD_{trophy} fish declined while the RSD_{stock} and $RSD_{quality}$ categories increased, indicating a more diversified length structure in 2008 (Table 10). The length frequency distribution for 2008 demonstrated a broadening size structure, with the primary peak occurring in the 290 and 310 mm size groups (Figure 12). This would correspond to the continued presence of the 2005 year class, represented by the 250 and 270mm length group peak in the 2007 length frequency distribution. Two spikes, the 170 and 230 mm length groups, indicated an influx of younger fish into the population.

Mean lengths and weights, for croakers sub-sampled for age, in 2007 were 331 mm TL and 526g for females (n=213) and 319 mm TL and 433g for males (n=61). In

2008 pound net catches, females averaged 330 mm TL and 453g, while males averaged 298 mm TL and 390g (n=108). Mean length of males decreased slightly in 2008, while mean weights for both sexes decreased. The reason for the decrease in weight is not know, but sampled fish did not appear under nourished. In 2008 females accounted for 64% (n=193) of the pound net catch, similar to that of 2006 (65%), after a shift toward more females in 2007 (78%).

During 2007, Maryland Atlantic croaker total commercial harvest (Chesapeake Bay and Atlantic Ocean) increased 38% from 2006 to 474,338 pounds (Figure 13). However, the 2008 harvest was still well below the 1929-2007 average of 1,189,978 pounds. Chesapeake Bay commercial landings increased 41% in 2007. Recreational harvest in 2007 was estimated at 1,092,784 fish, a 30% increase compared to similar estimates for the previous three years (MRFSS 2008; Figure 14). The 2007 recreational releases decreased slightly compared to 2006 (MRFSS 2008; Figure 14), but both recreational harvest and release estimates were above the 1981-2007 averages. Estimated recreational harvest has averaged 695,616 pounds from 1981 – 2007, while commercial harvest during the same time period averaged 453,968 pounds.

The Atlantic croaker juvenile indices from 2003-2005 were lower than those of the late 1990s. However, this index increased to the third highest of the 20 year time series for 2008 (Figure 15). Atlantic croaker are very susceptible to winterkill events (Lankford and Targett 2001), but relatively mild winters during the late 1990's may have lessened natural mortality.

Ages derived from 2007 Atlantic croaker otoliths ranged from age 1 to 12 (n=275), with no age 11 fish present (Table 11). The number of Atlantic croaker sampled from pound nets in 2007 (n=2,963) was applied to an age-length key for 2007. This application indicated that 30% of the fish were age three, 27% were age five, 14% were age two, 11% were age one and 9 % were age four. The remaining age groups each accounted for three percent or less of the fish sampled (Table 12). Three hundred six Atlantic croaker otoliths were collected in 2008, but ageing had not been completed at this time. Instantaneous total mortality in 2008 was Z=0.36, a slight decrease from 2007 (Table 7).

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 scheduled for 2009.

Spot

Spot mean length decreased slightly in 2008 to 198 mm TL, ranking as the sixth lowest of the 15 year time series (Table 4). The length frequency distribution in 2008 was further truncated, with fish between 190 and 229 mm TL accounting for 69% of the catch (Figure 16). The availability of jumbo spot in 2008 continued to remain low, with less than 1% of the pound net sample comprised of spot >254 mm TL. The continued decline of jumbo spot in the pound net catches (3% in 2005, <2% in 2006), followed good catches in the early part of the decade (10% in 2003, 13% in 2004).

Commercial harvest in 2007 increased over 10 fold to 380,633 pounds, well above the long-term average (1929 – 2007) of 142,914 pounds (Figure 17). 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 harvest had been fairly steady from 2003-2005 ranging from 66,865 to 74,722 pounds before declining to 23,500 pounds in 2006. The unusually rapid increase in spot landings can be attributed to a large increase in gill net harvest, which accounted for 95% of the 2007 spot harvest (360,930 pounds) compared to 43% (16,420 pounds) of the 2006 harvest. The spot harvest excluding gill net for 2007 (19,703 pounds) was similar to the 2006 non-gill net harvest of 21,354 pounds.

Maryland recreational harvest data from MRFSS indicated that spot catches since 1981 has been variable (MRFSS 2008; Figure 18). 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 18). As with the commercial harvest, the 2007 recreational harvest estimate also increased sharply, with anglers harvesting 3,842,569 fish, the 26 year time series high. The release estimate of 1,421,513 fish was also relatively high, and above the long term mean of 1,073,282.

The spot juvenile trawl indices from 1989-2008 were quite variable, with generally higher values in the earlier part of the time series and low values from 2001-

2004 (Figure 19). The 2008 GM of 25.3 fish per tow was the 5th highest of the 20 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 % jumbo spot in 2005 through 2008, could be indicating growth overfishing of the stock. However, recreational harvest and release estimates have been high the past three 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 pound net sampling, with 21 fish being examined in 2008. All but one of the sampled fish were below the legal size limit (18 inches TL). The number of red drum sampled 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 2007 totaled 90 pounds, compared to 2 pounds in 2006 (Figure 20). Lower landings 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 landings by weight.

The MRFSS (2008) estimated that recreational fishermen did not harvest or release any red drum in 2007 (Figure 21). MRFSS estimates for 2006 were 7,118 fish harvested and 11,282 released in Maryland waters. Harvest estimates have been extremely variable ranging from zero, for 15 of the 27 years of the 1981 - 2007 time series, to 12,804 fish in 2006. Peak number of red drum releases occurred in 2002 at 18,412 fish (Figure 21).

Black Drum

Black drum are only occasionally encountered during MD DNR pound net sampling, with only five being sampled in 2008 (Table 4). Lengths throughout the time series ranged from 244 to 1260 mm TL. Commercial harvest of black drum was banned for Maryland's portion of Chesapeake Bay in 1999, but some fish are still harvested along the Atlantic coast (Figure 22). Recreational harvest and release estimates from 1981-2007 have been variable, ranging from zero to over 13,000 fish in 1984 (MRFSS 2008; Figure 23). In 2007, MRFSS estimated no black drum were harvested by recreational anglers but, 226 were caught and released. However, it is highly unlikely no black drum were harvested. The zero harvest estimate seems 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.

Spanish Mackerel

Spanish mackerel have been measured FL, TL or both in each year of the pound net sampling. Since 2001, only FL has been taken, to be consistent with data collected by other state and federal agencies. During this time period FL has ranged from 208 – 681 mm. Mean length for 2008 was 407 mm FL, a decline from the previous three years, although sample size was very small in 2008 (n = 18; Table 4). The number of mackerel measured has been low for most years with the largest samples occurring from 2005-2007 (Table 4).

The 2007 commercial harvest of Spanish mackerel in Maryland was 2,626 pounds, an increase from the very low 2006 landings of 278 pounds (Figure 24). 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 42 year time series was 7,345 pounds. Since 1996 the majority of mackerel harvest has come from Chesapeake Bay, but during the 1987 – 1995 time period the 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 2008; Figure 25). This followed a period of seven out of ten annual estimates with zero fish captured. Harvest estimates for 1998 – 2007 were variable, ranging from 0 – 20,792 fish with an average of 8,014 fish taken. In 2007, 12,360 fish were harvested, an increase from the 2006 estimate of 3,118 fish (Figure 25).

Spotted Seatrout

Pound net sampling rarely captures spotted seatrout. Only 10 were measured in 2008, the second year they were encountered after being absent from 1999 -2006 (Table 4). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 7,904 pounds from 1991-2007 (Figure 26). Reported 2007 harvest was 14 pounds, the second straight year of sharp decline. 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 (MRFSS 2008; Figure 27). The 1981-2007 average recreational harvest was 14,633 fish. Release estimates also declined to 2,231 pounds in 2007; well bellow the long term average of 16,839 fish (Figure 27).

Atlantic Menhaden

Mean FL for Atlantic menhaden sampled from commercial pound nets in 2008 was 246 mm FL, similar to the 2007 mean of 243 mm FL (Table 4). Menhaden length frequencies for 2006 and 2007 were very similar and robust compared to 2005 (Figure 28). 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. Ages derived from 2007 Atlantic menhaden scales ranged from age 1 to age 6 (n=379; Table 13). Applying the number of Atlantic menhaden captured from pound nets in 2007 (n=854) to the age-length key for 2007, indicated that 23% of the fish were age one, 37% were age two and 25% were age three, while the proportion of age groups four through six steadily decreased (Table 14). For 2008 ages were derived for 384 menhaden and, as observed in 2007, ranged from 1 to 6 years (Table 15). Applying the number of Atlantic menhaden captured from pound nets in 2008 (n=826) to the age-length key for 2008, indicated that 17% of the fish were age one, 45% were age two and 29% were age three, while the proportion of age groups four through six decreased steadily (Table 16).

Atlantic menhaden commercial harvest in Maryland increased from 7,000 pounds in 1935 to over 8 million pounds in 1965 (Figure 29). Commercial harvest remained above 3 million pounds until 1990 when landings 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 1935-2007 was 3.9 million pounds. The 2007 commercial harvest was the second highest on record at 11.3 million pounds, with 97% from the Chesapeake Bay. The vast majority of Maryland's annual menhaden landings consistently come from the Chesapeake Bay (Figure 29).

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

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

Table 2. Areas sampled, number of sampling trips, mean water temperature and mean salinity by month, 2008.

Area	**Month**	**Number of Sampling Trips**	**Mean Water Temp. ©**	**Mean Salinity (ppt)**
Point Lookout	May	1	16.7	8.25
Nanticoke	May	0	No data	No data
Fishing Bay	May	0	No data	No data
Point Lookout	June	2	22.3	10.6
Nanticoke	June	2	26.0	11.8
Fishing Bay	June	2	25.9	11.7
Point Lookout	July	3	26.2	12.7
Nanticoke	July	2	27.8	12.2
Fishing Bay	July	1	26.4	12.1
Point Lookout	August	2	25.8	14.5
Nanticoke	August	2	26.9	13.5
Fishing Bay	August	1	25.6	13.9
Point Lookout	September	1	25.6	15.8
Nanticoke	September	1	25	14.6
Fishing Bay	September	0	No data	No data

Table 3. List of non-target species observed during the 2008 pound net survey.

Common Name	Scientific Name
American eel	*Anguilla rostrata*
American Shad	*Alosa sapidissiama*
Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic herring	*Clupea harengus*
Atlantic spadefish	*Chaetodipterus faber*
Atlantic thread herring	*Opisthonema oglinum*
Blackcheek tonguefish	*Symphurus plagiusa*
Carp	*Cyprinus carpio*
Cownose ray	*Rhinoptera bonasus*
Gizzard shad	*Dorosoma cepedianum*
Harvestfish	*Peprilus alepidotus*
Hickory shad	*Alosa mediocris*
Hogchoker	*Trinectes maculates*
Northern puffer	*Sphoeroides maculatus*
Southern stingray	*Dasyatis americana*
Striped bass	*Morone saxatilis*
Striped mullet	*Mugil cephalus*
White catfish	*Ameiurus catus*
White perch	*Morone americana*
Windowpane flounder	*Scophthalamus aquosus*

Table 4. Mean length (mm TL), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay pound nets, 1993 - 2008.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Weakfish																
mean length	276	291	306	293	297	337	334	361	334	325	324	273	278	290	275	276
std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42	52
n	435	642	565	1431	755	1234	851	333	76	196	129	326	304	62	61	42
Summer flounder																
mean length	347	309	297	335	295	339	325	347	358	324	353	327	374	286	341	347
std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66	72
n	209	845	1669	930	818	1301	1285	1565	854	486	759	577	499	1274	1056	982
Bluefish																
mean length	312	316	323	307	330	343	306	303	307	293	320	251	325	311	318	260
std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70	41
n	45	621	912	619	339	378	288	398	406	592	223	581	841	1422	1509	2676
Atlantic croaker																
mean length	233	259	286	294	301	310	296	302	317	279	287	311	317	304	307	298
std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54	62
n	471	1081	974	2190	1450	1057	1399	2209	733	771	3352	1653	2398	1295	2963	1532
Spot																
mean length	184	207	206	235	190	230	213	230	239	184	216	208	197	191	208	198
std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23	21
n	309	451	158	275	924	60	572	510	126	681	1354	882	2818	2195	519	1195
Spotted Seatrout																
mean length		448	452			541	460								414	464
std. dev.		86	42				134								43	72
n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3	10
Black Drum																
mean length		1106	741	353		1074				435	475	780	1130	1031	1144	875
std. dev.		175	454	20		182				190	20	212		228	95	238
n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9	5
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
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
std. dev.			34	62				34	34	81	63	95	33	35	51	59
n			44	27	1	1		49	19	20	11	8	373	445	158	18
Menhaden (Fork Length)																
mean length												262	282	238	243	246
std. dev.												28	36	42	41	29
n												213	1052	826	854	826

Table 5. Relative stock density of weakfish from Chesapeake Bay summer pound net survey, 1993 - 2008.

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		

Table 6. Weakfish mean length (mm TL), mean weight and number sampled by age, and proportion at age, 2007.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged	Proportion at Age*
1	258	170	38	62
2	286	225	16	26
3	321	321	6	10
4	422	652	1	2

*All weakfish captured were measured and aged, n=61.

Table 7. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2008.

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Weakfish	0.74	0.4	0.62	0.58	0.73	1.29	1.44	1.35	*	*
Atlantic croaker	0.53	0.53	0.43	0.45	0.61	0.49	0.40	0.33	0.40	0.36

* Insufficient data to calculate 2007 and 2008 weakfish estimates.

Table 8. Relative stock density of summer flounder from Chesapeake Bay summer pound net survey, 1993 - 2008.

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	

Table 9. Relative stock density of bluefish from Chesapeake Bay summer pound net survey, 1993 - 2008.

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			

Table 10. Relative stock density of Atlantic croaker from Chesapeake Bay summer pound net survey, 1993 - 2008.

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

Table 11. Atlantic croaker mean length (mm TL), mean weight and number sampled by age, 2008.

Age	Mean Length (mm TL)	Mean Weigh (g)	Number Aged
1	233	146	32
2	255	201	29
3	291	309	56
4	322	445	20
5	373	686	93
6	381	778	5
7	408	879	6
8	402	855	9
9	404	869	17
10	407	875	7
11			
12	371	687	1

Table 12. Atlantic croaker proportion at age using 2007 pound net survey length and age data (ages: n= 275 and lengths: n=2963).

Age	1	2	3	4	5	6	7	8	9	10	11	12
n	332	425	890	261	800	38	32	48	97	30	0	10
Proportio	11.21	14.35	30.05	8.79	26.99	1.27	1.09	1.63	3.26	1.02	0.00	0.34

Table 13. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2007.

Age	Mean Length (mm FL)	Number Aged
1	194	71
2	236	142
3	272	101
4	289	45
5	295	17
6	317	2

Table 14. Atlantic menhaden proportion at age using 2007 pound net survey length and age data (ages: n=378 and lengths: n=854).

Age	1	2	3	4	5	6
n	193	320	211	91	34	5
Proportion at age	22.6	37.4	24.7	10.7	4	0.6

Table 15. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2008.

Age	Mean Length (mm FL)	Number Aged
1	204	58
2	243	172
3	265	115
4	283	30
5	297	8
6	270	1

Table 16. Atlantic menhaden proportion at age using 2008 pound net survey length and age data (ages: n=384 and lengths: n=826).

Age	1	2	3	4	5	6
n	137	368	243	60	16	2
Proportion at age	16.6	44.5	29.4	7.3	1.9	0.3

Figure 1. Summer pound net sampling area map for 2008.

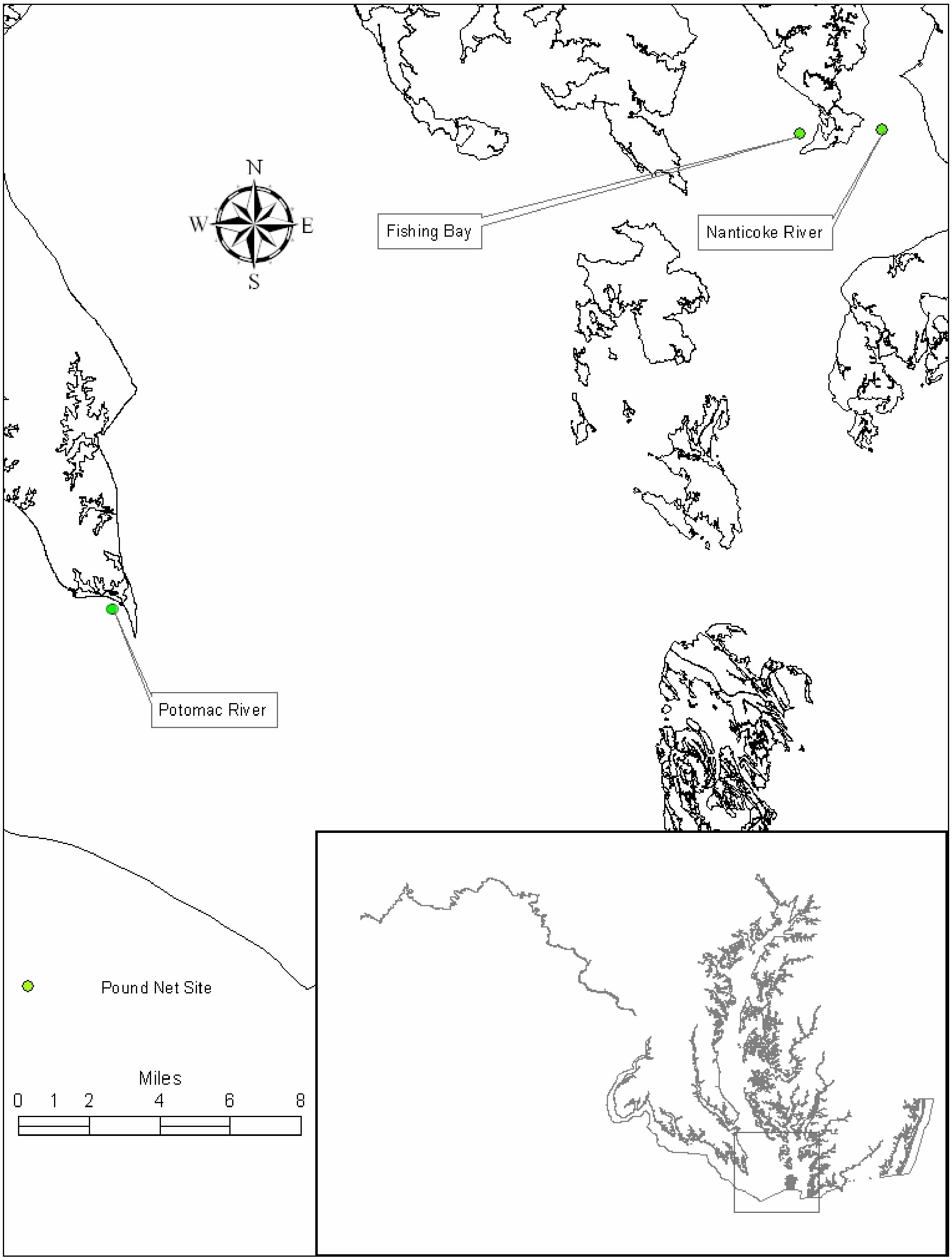


Figure 2. Weakfish length frequency distributions from pound nets, 2005-2008.

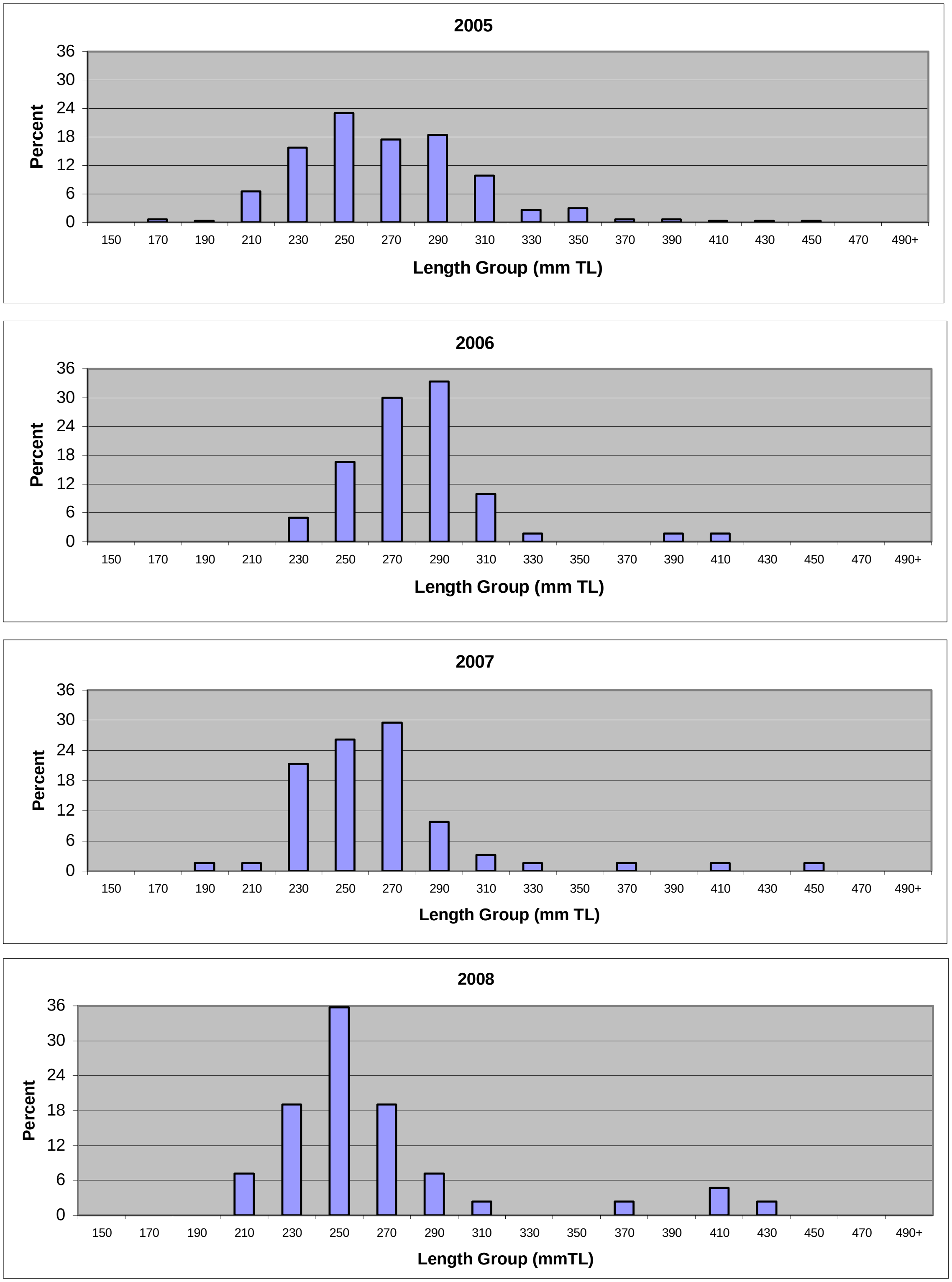


Figure 3. Maryland commercial weakfish landings by area, 1929-2007.

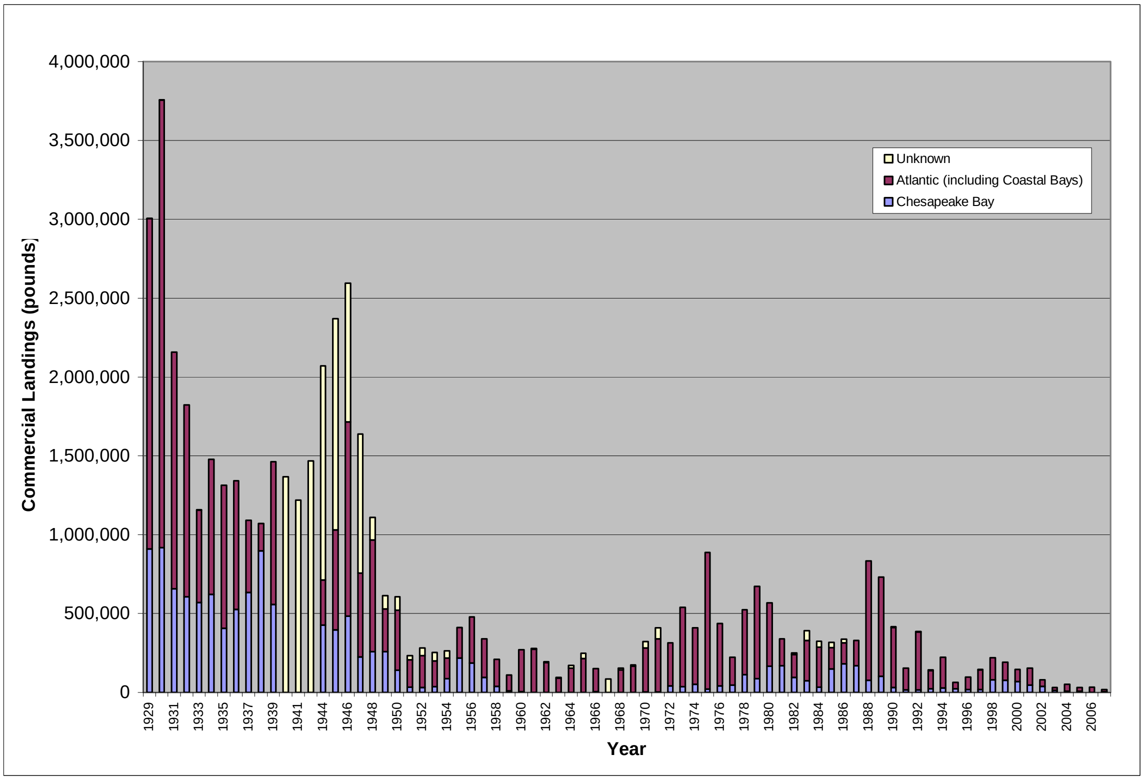


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2007 (Source: MRFSS, 2008).

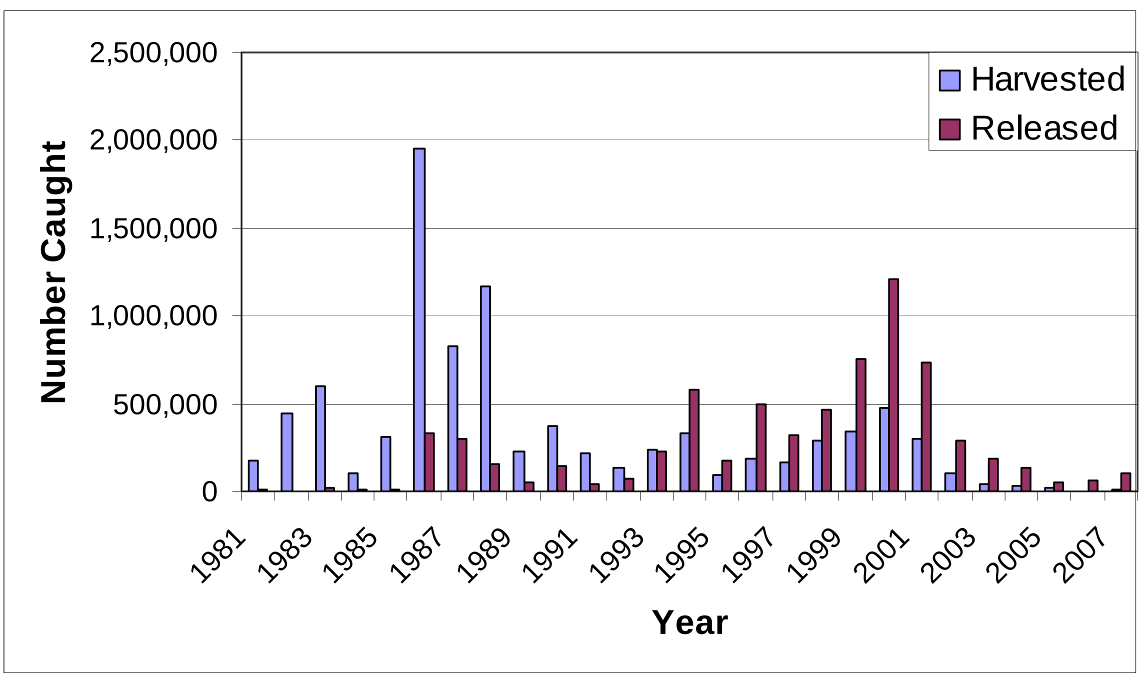
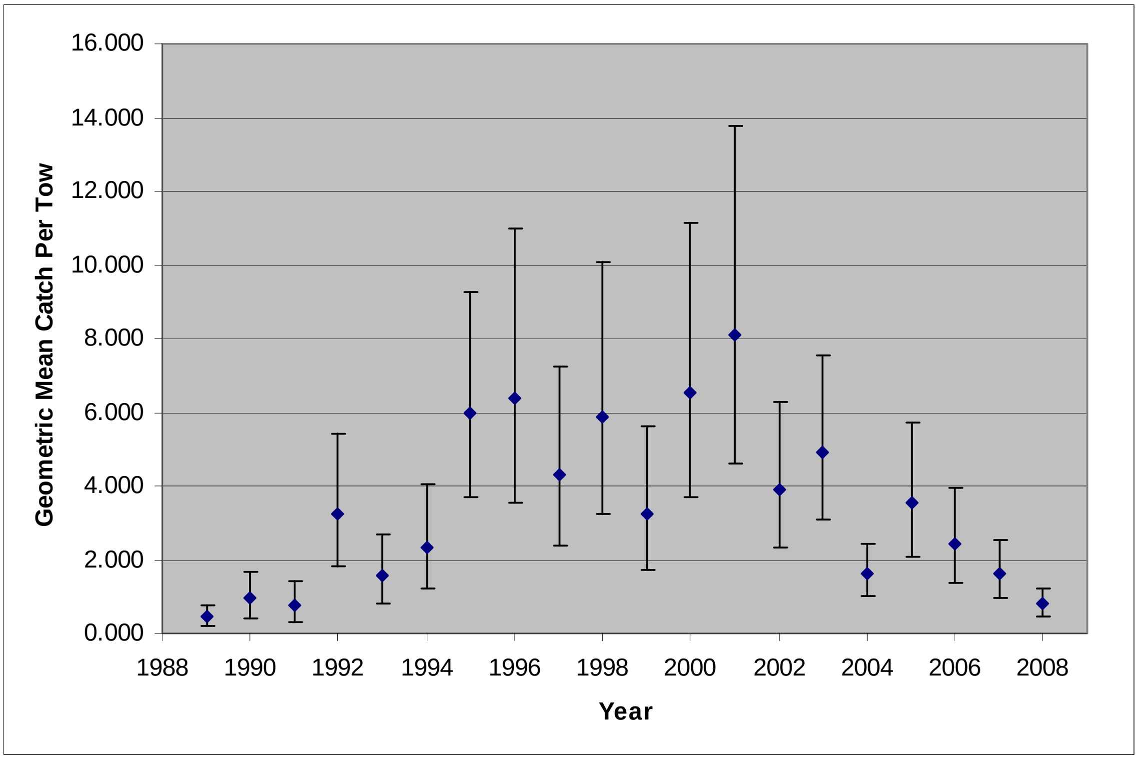


Figure 5. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2008.



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

Figure 6. Summer flounder length frequency distributions from pound nets, 2005-2008.

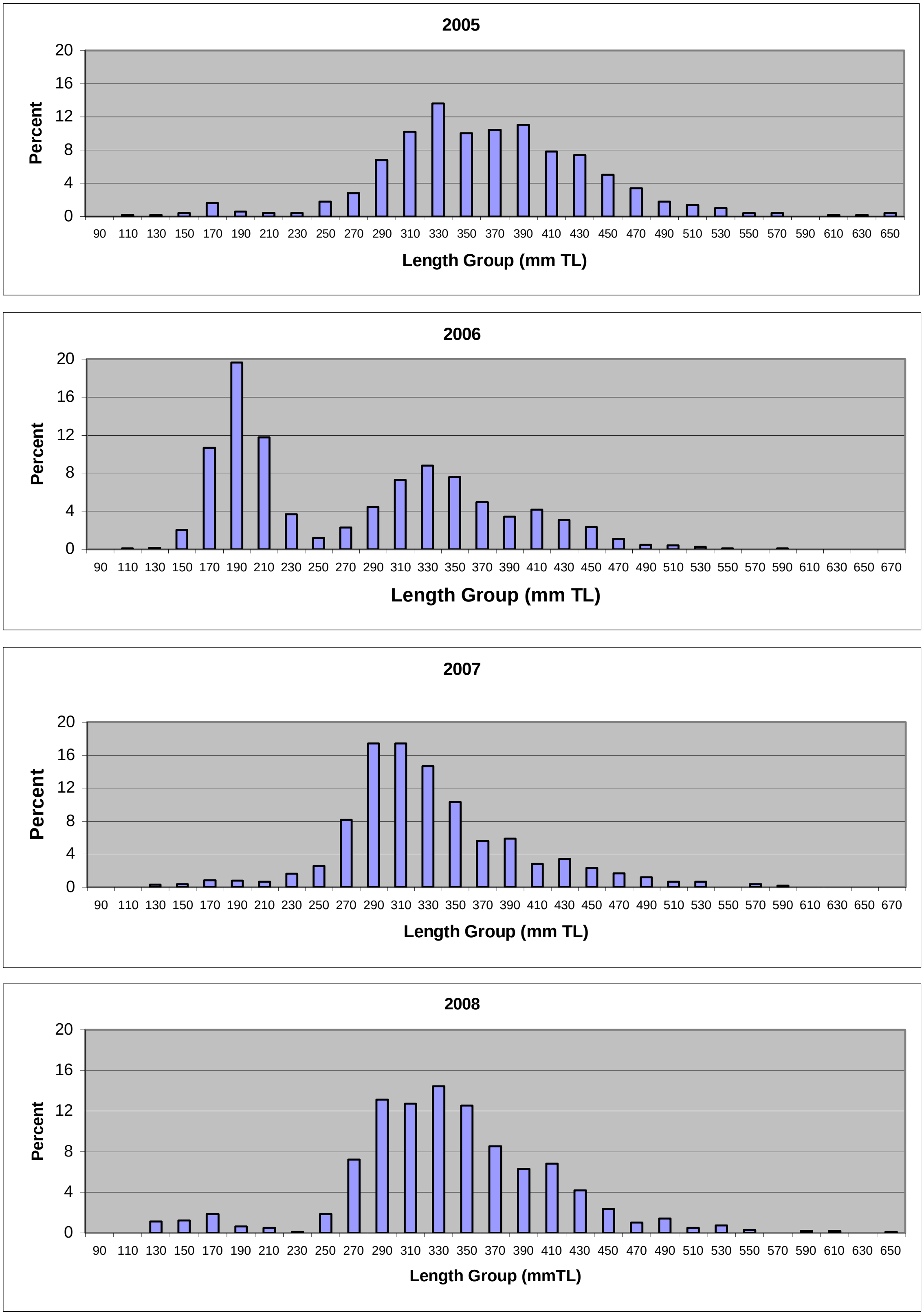


Figure 7. Maryland commercial summer flounder landings by area, 1962-2007.

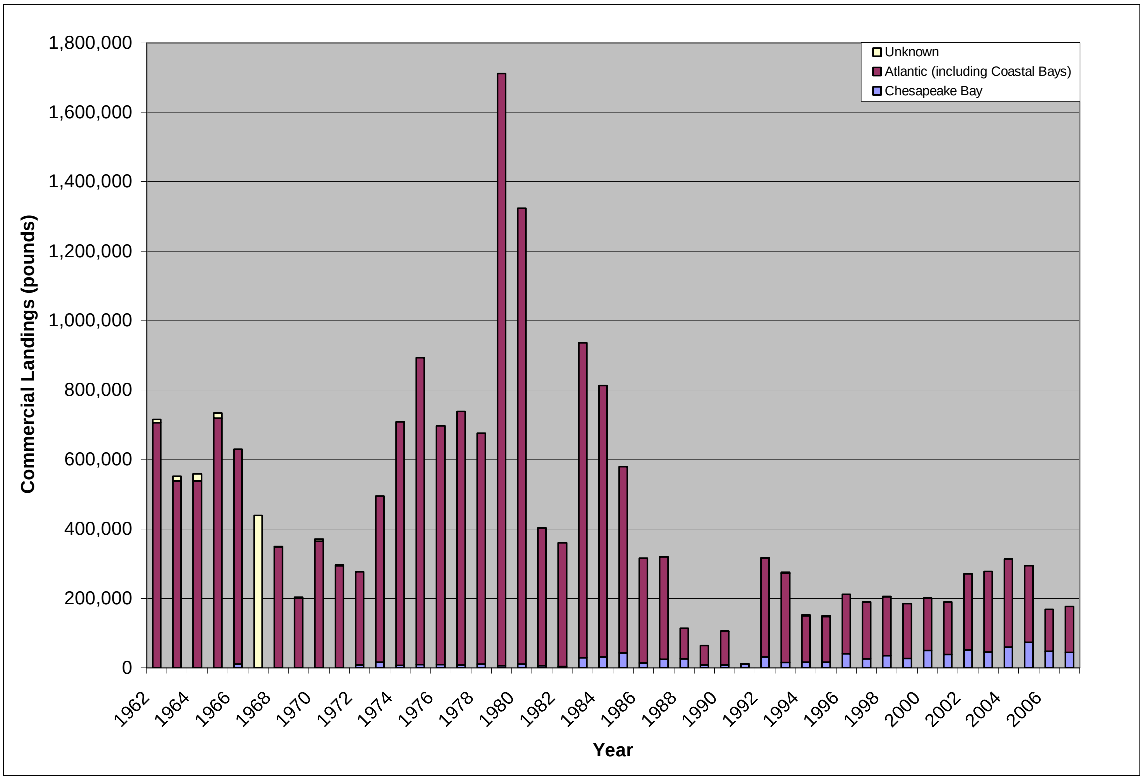
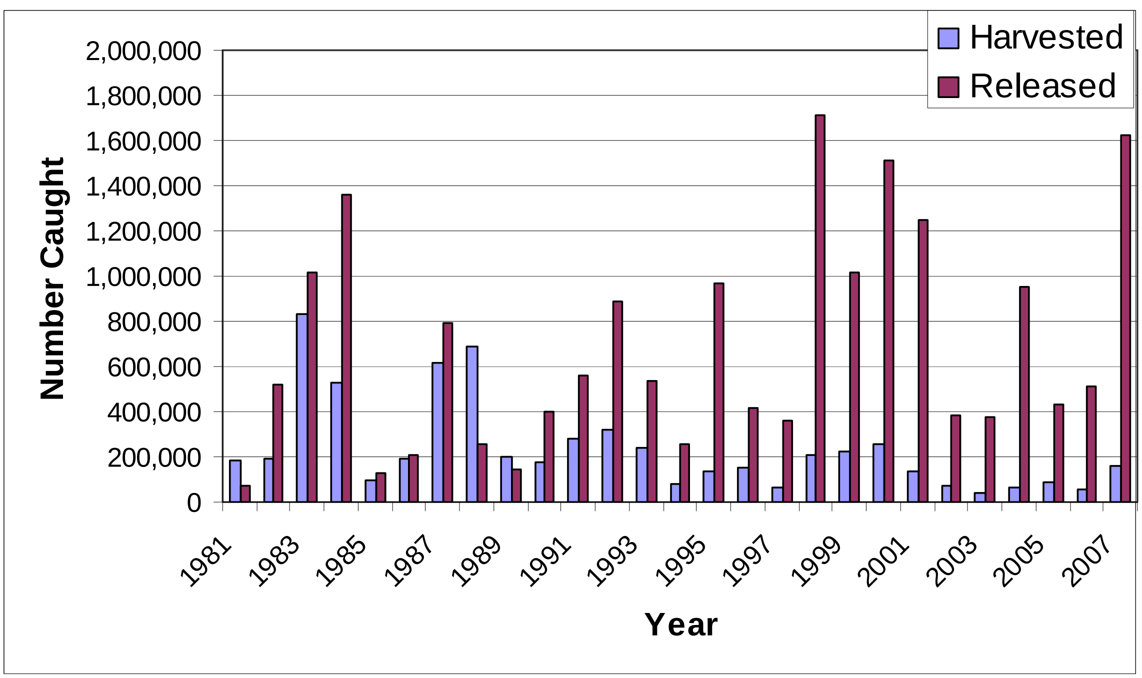


Figure 8. Estimated Maryland recreational summer flounder harvest and releases for 1981-2007 (Source: MRFSS, 2008).



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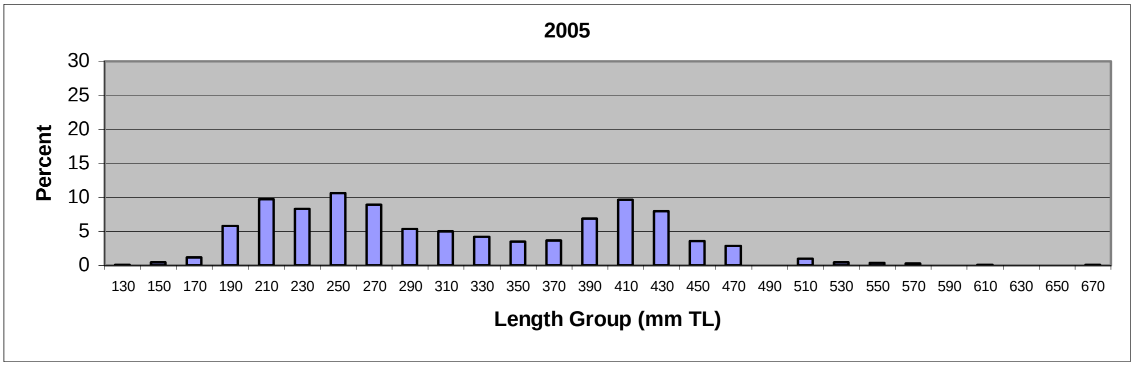

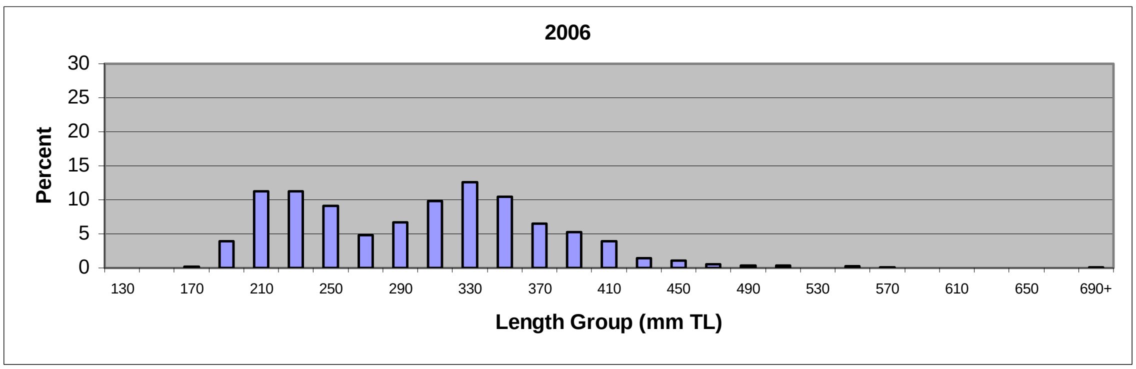

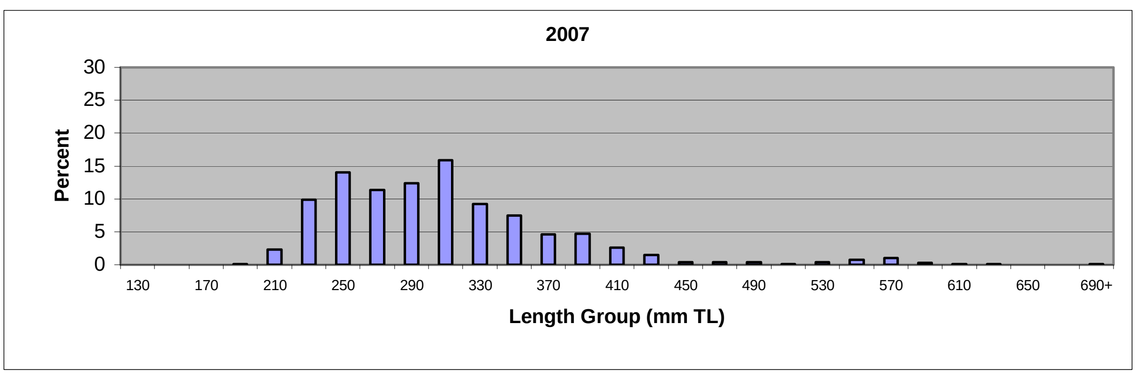

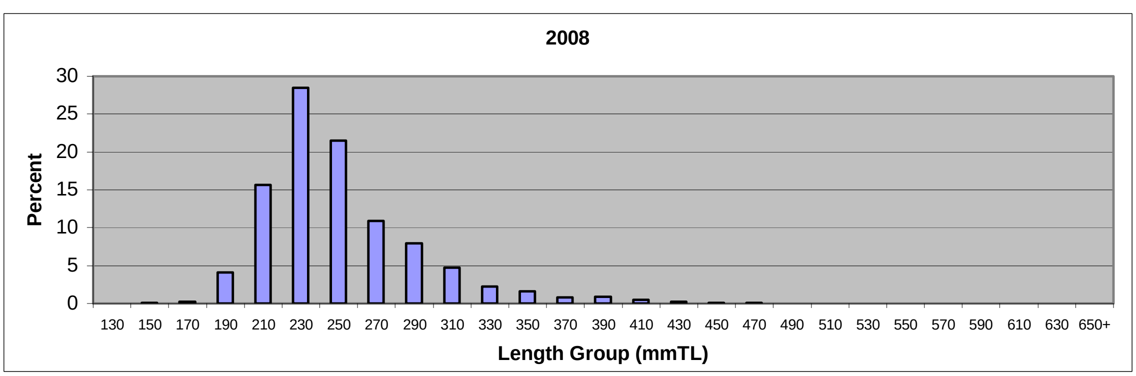

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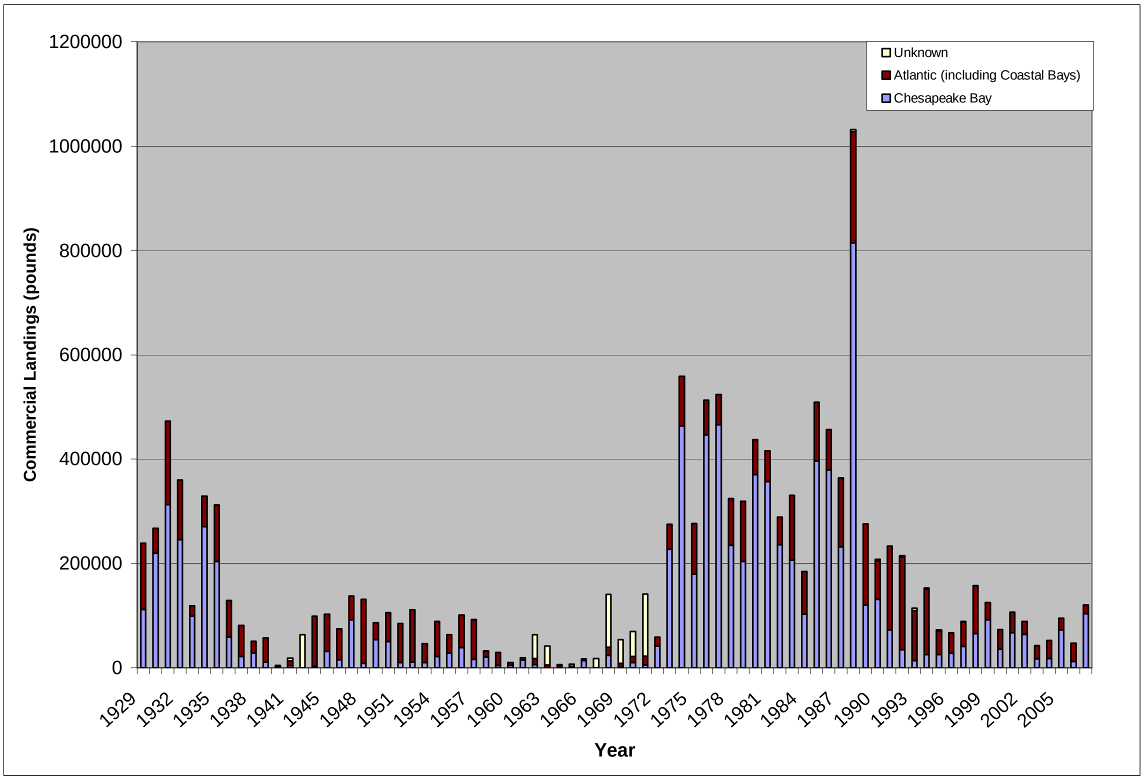

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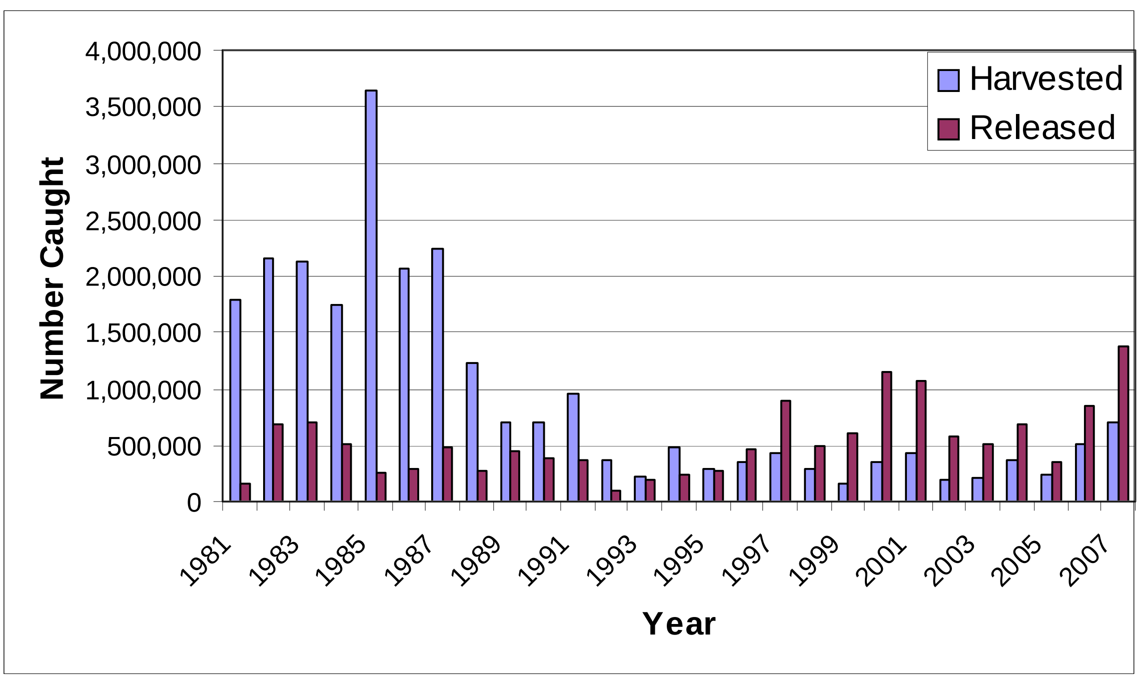

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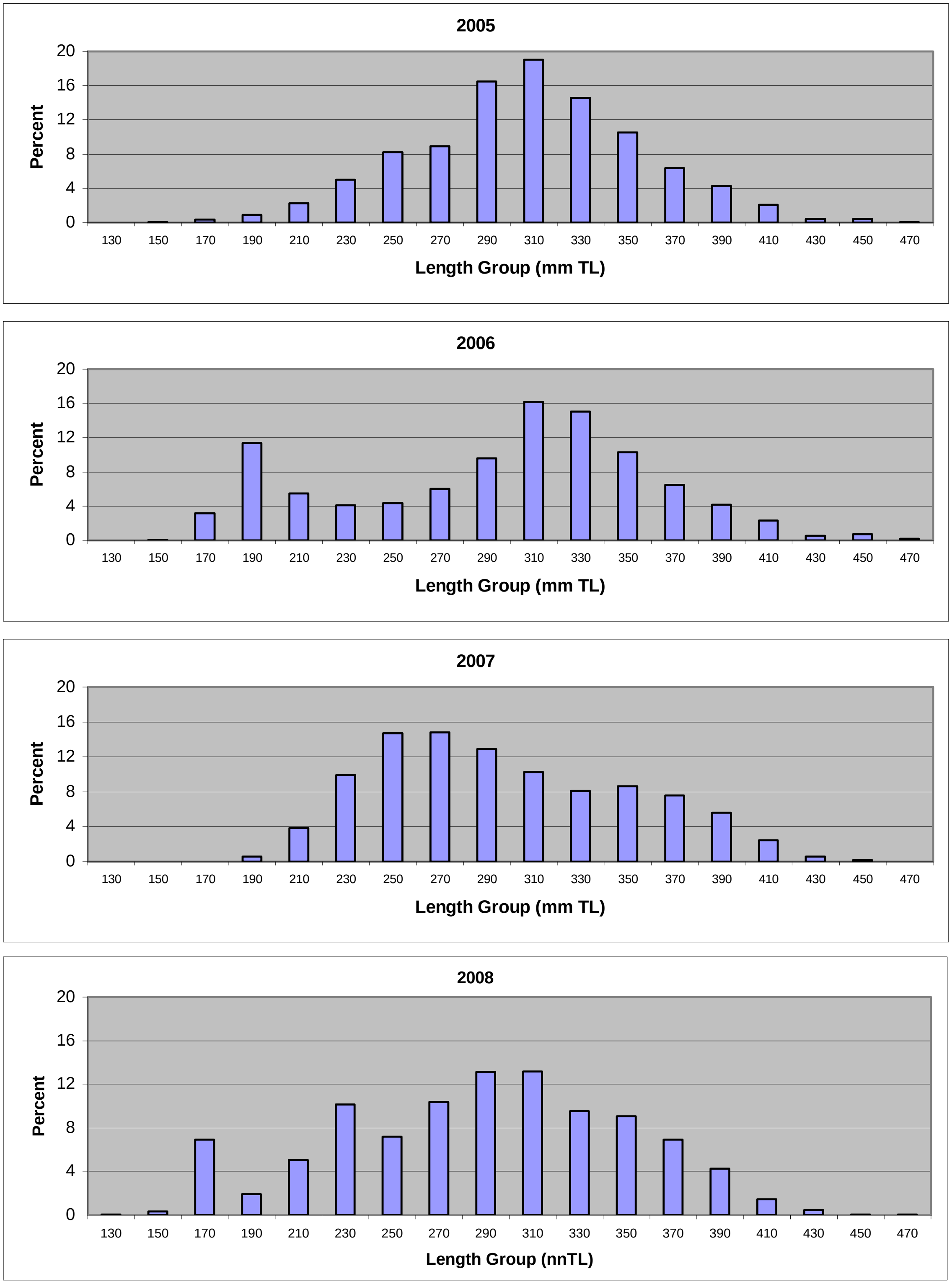


Figure 13. Maryland commercial Atlantic croaker landings by area, 1929-2007.

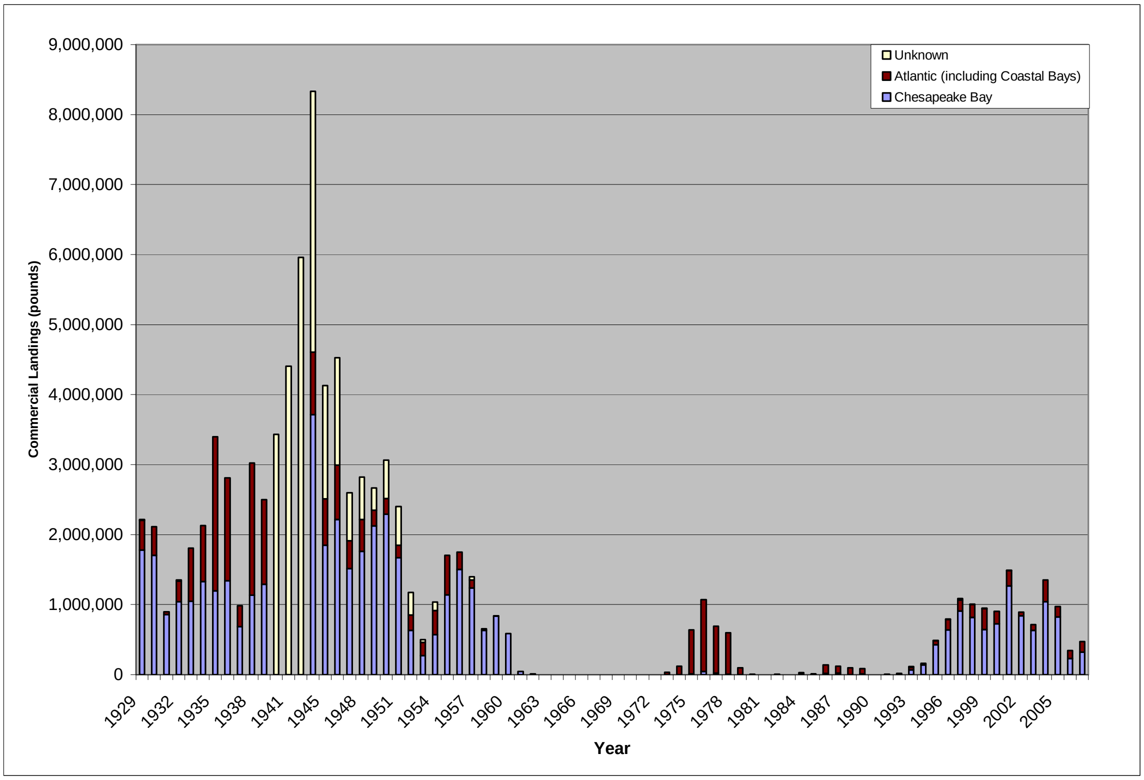


Figure 14. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2007 (Source: MRFSS, 2008).

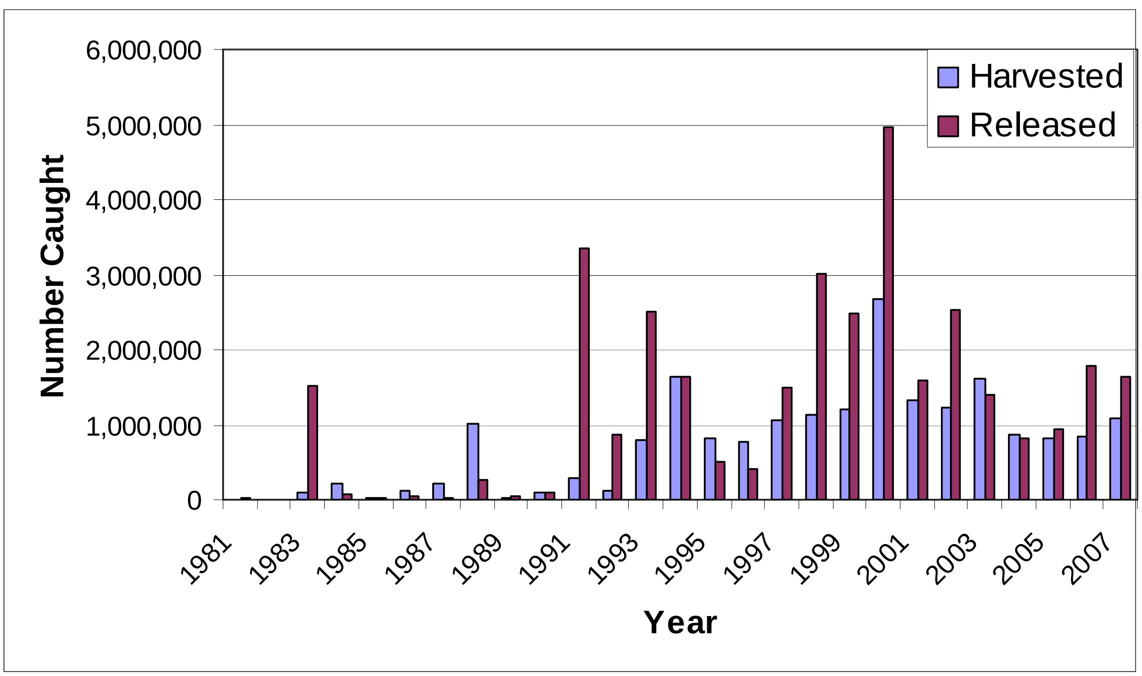
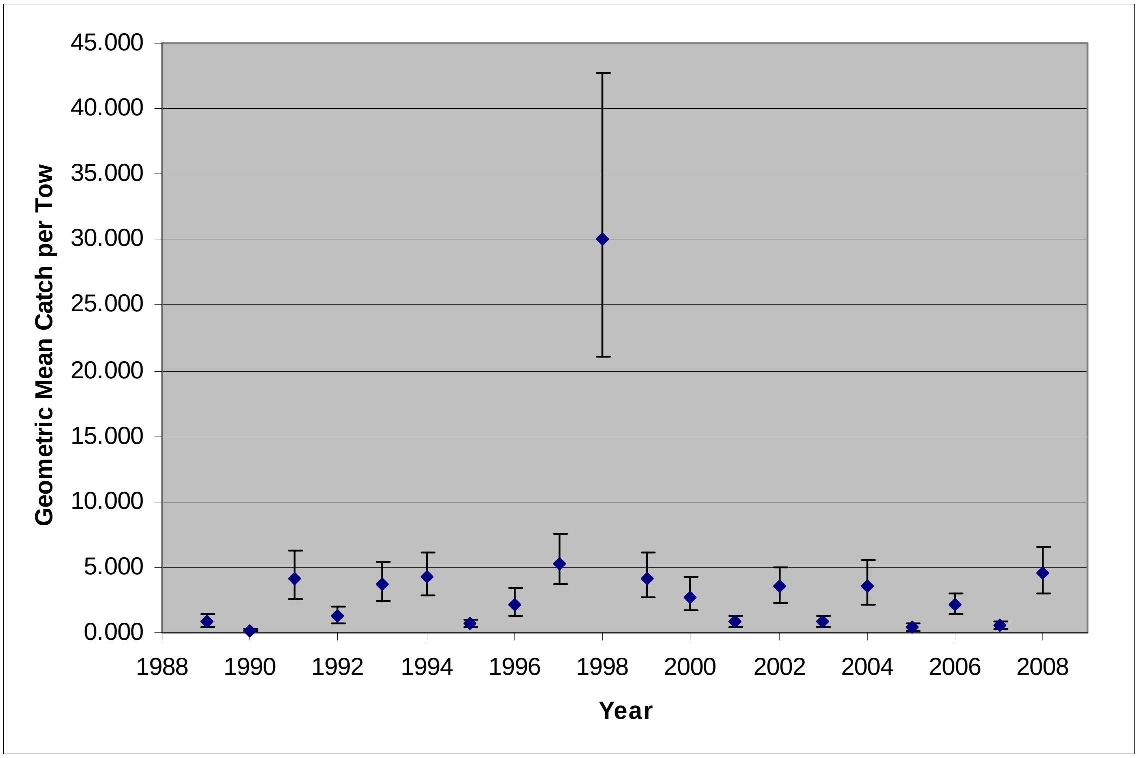


Figure 15. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2008.



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

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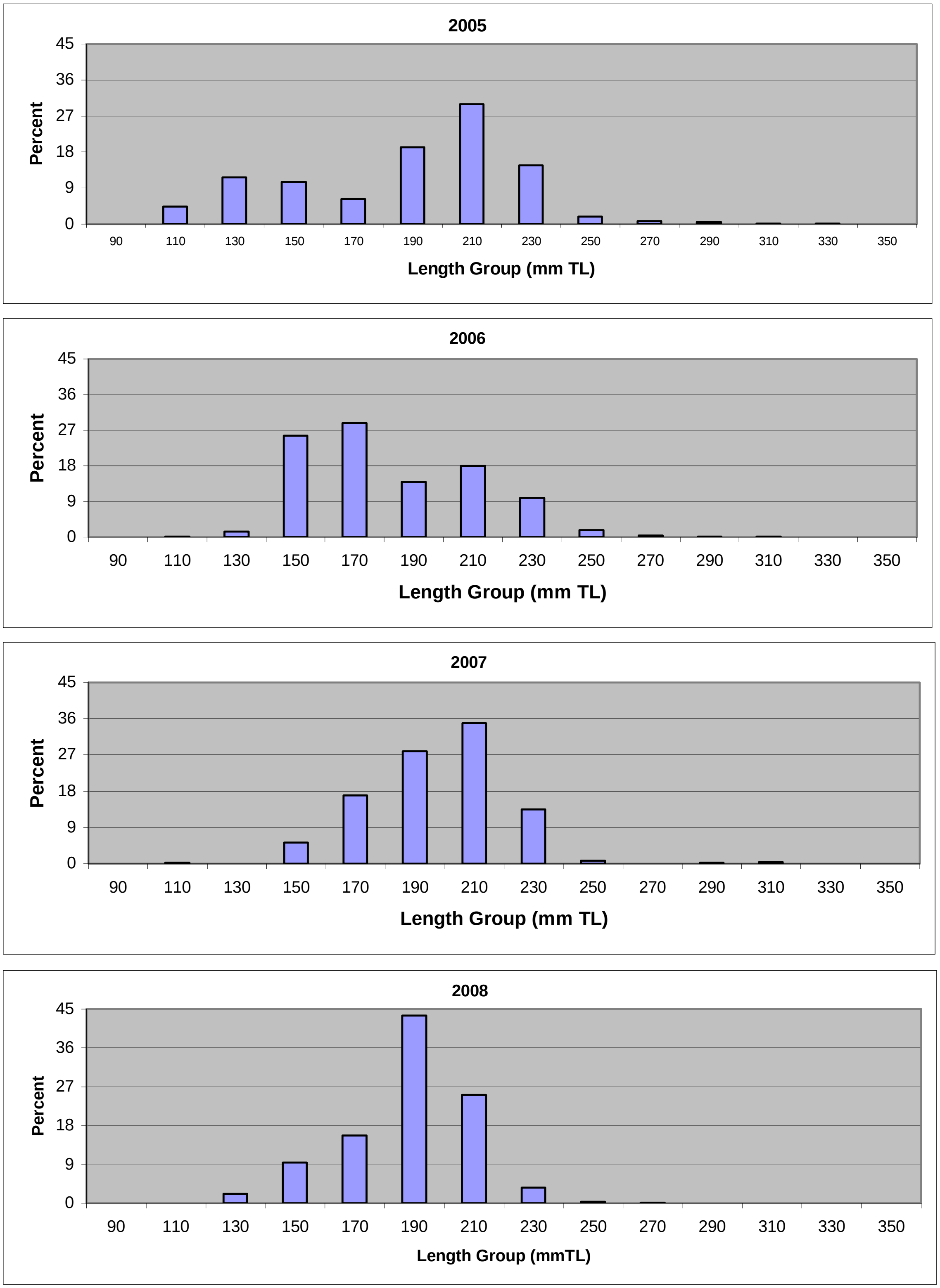

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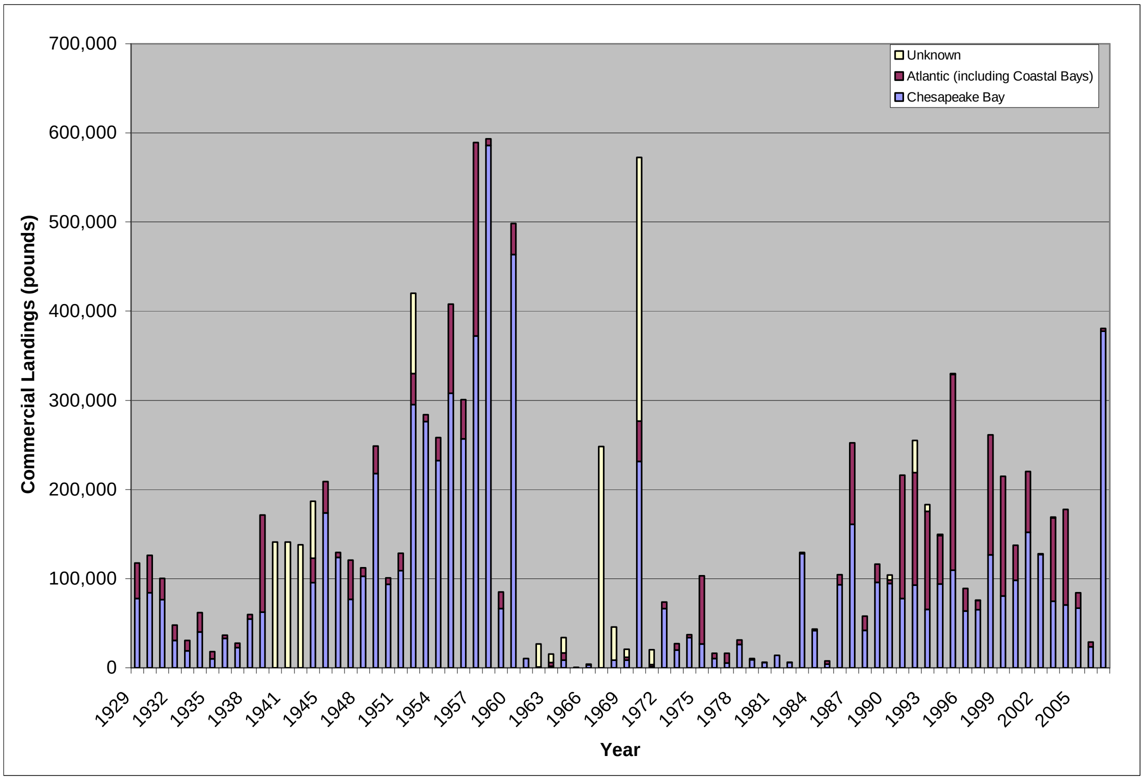

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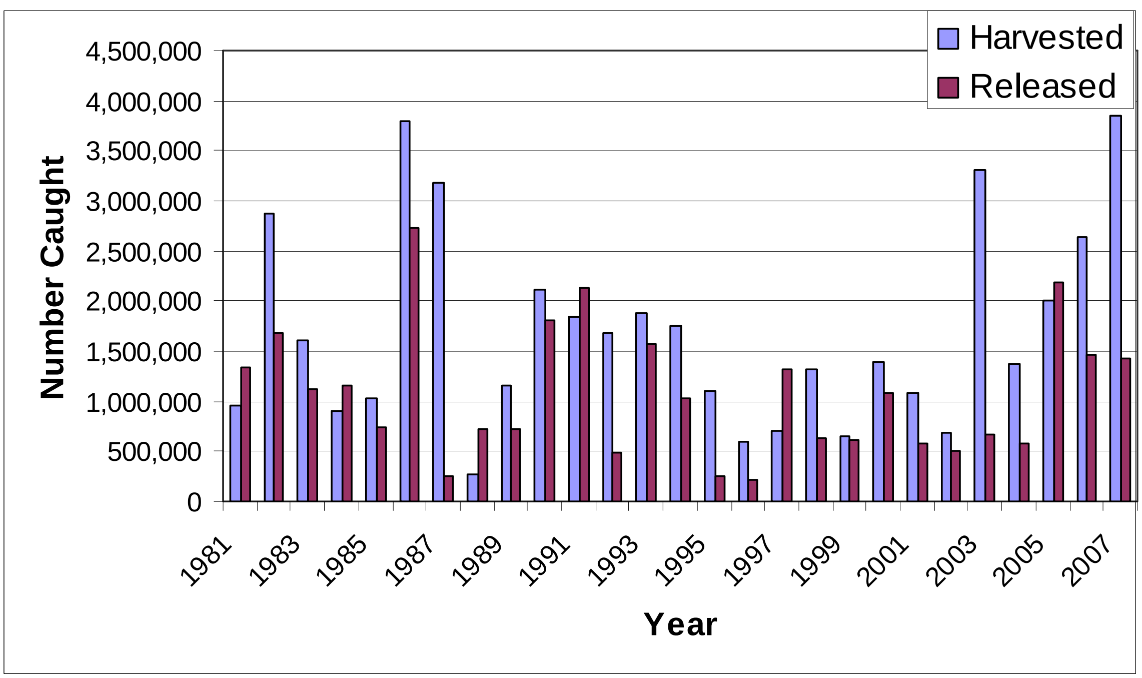

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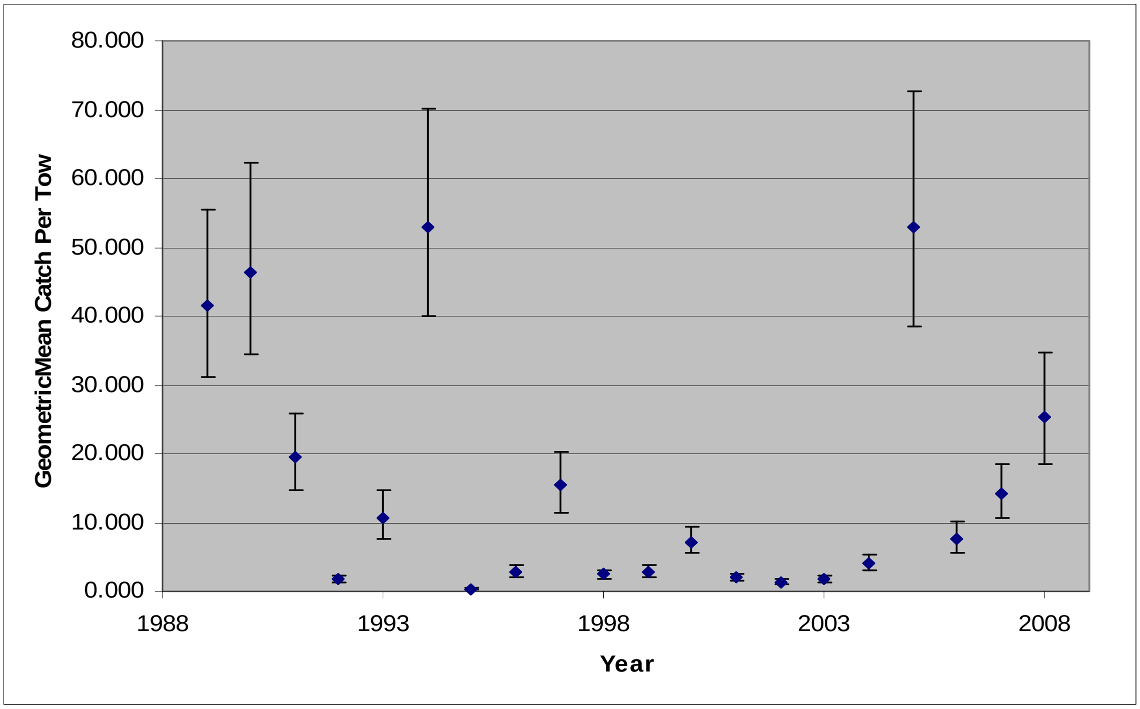

(Note: Confidence intervals were generated by the MEANS Procedure in SAS.)

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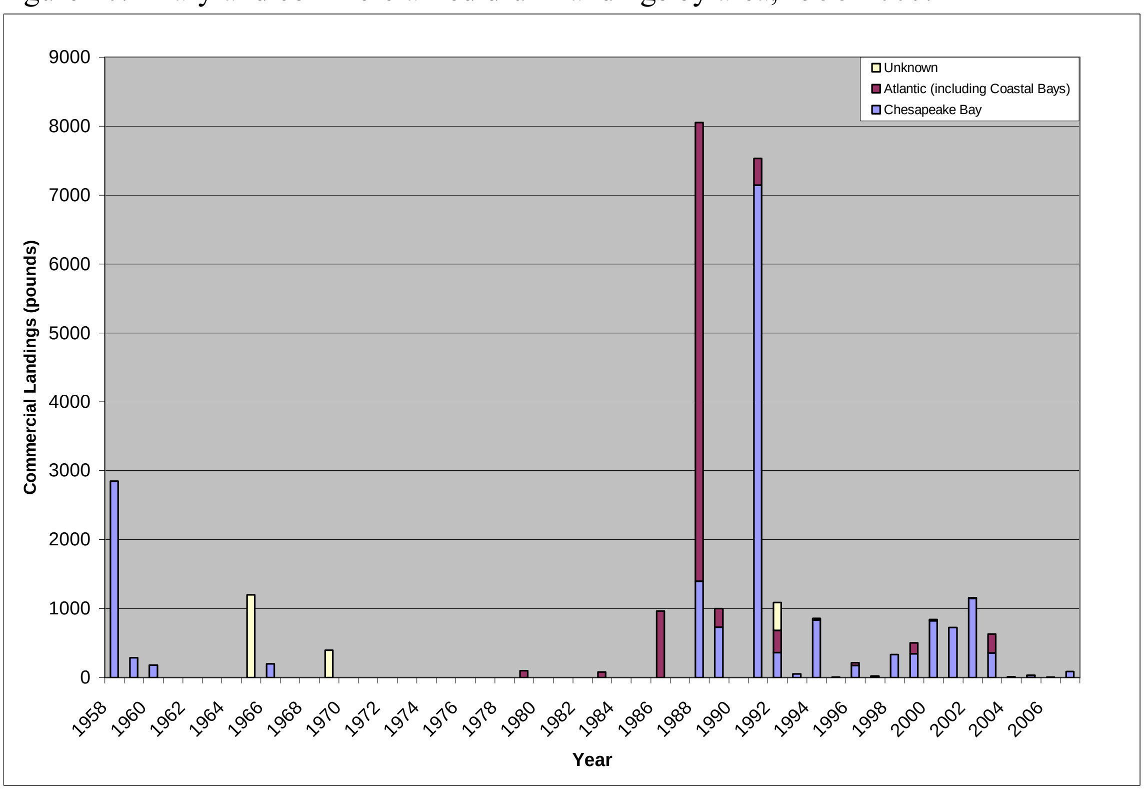
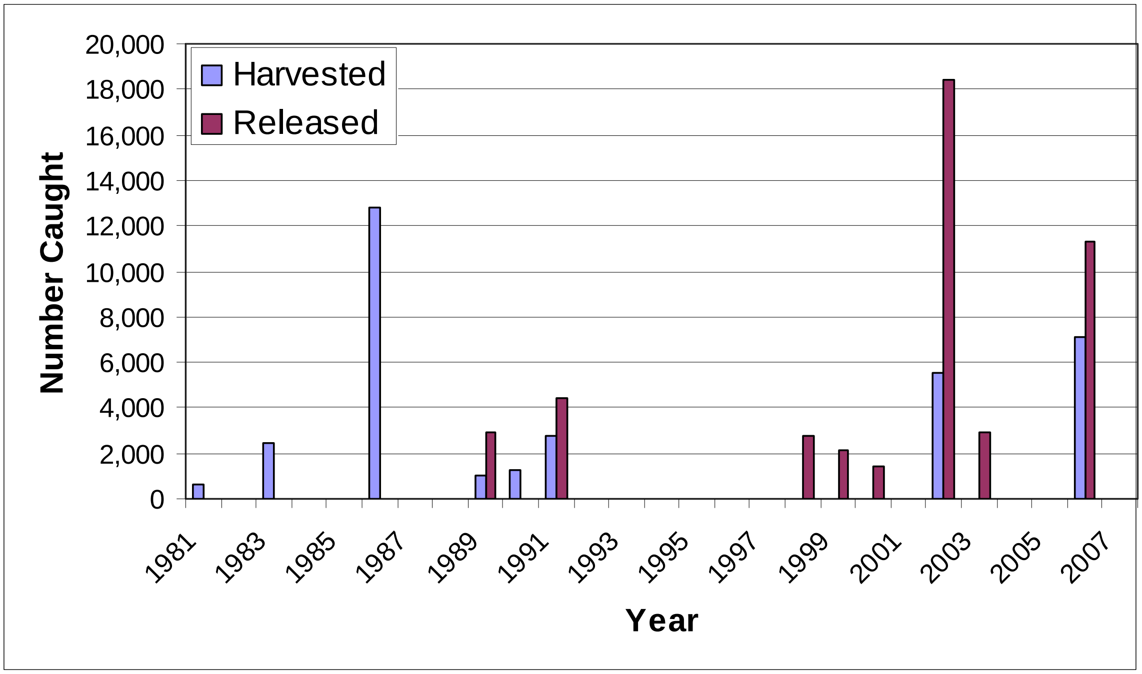


Figure 21. Estimated Maryland recreational red drum harvest and releases for 1981-2007 (Source: MRFSS, 2008).



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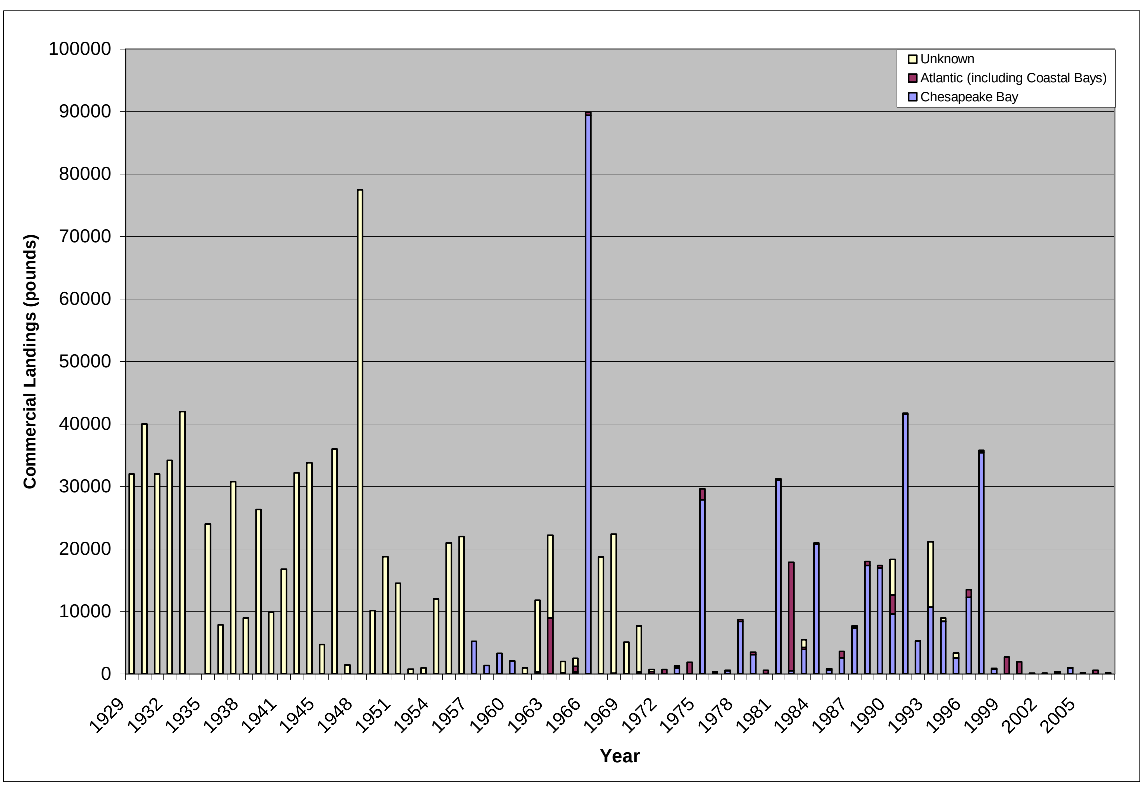

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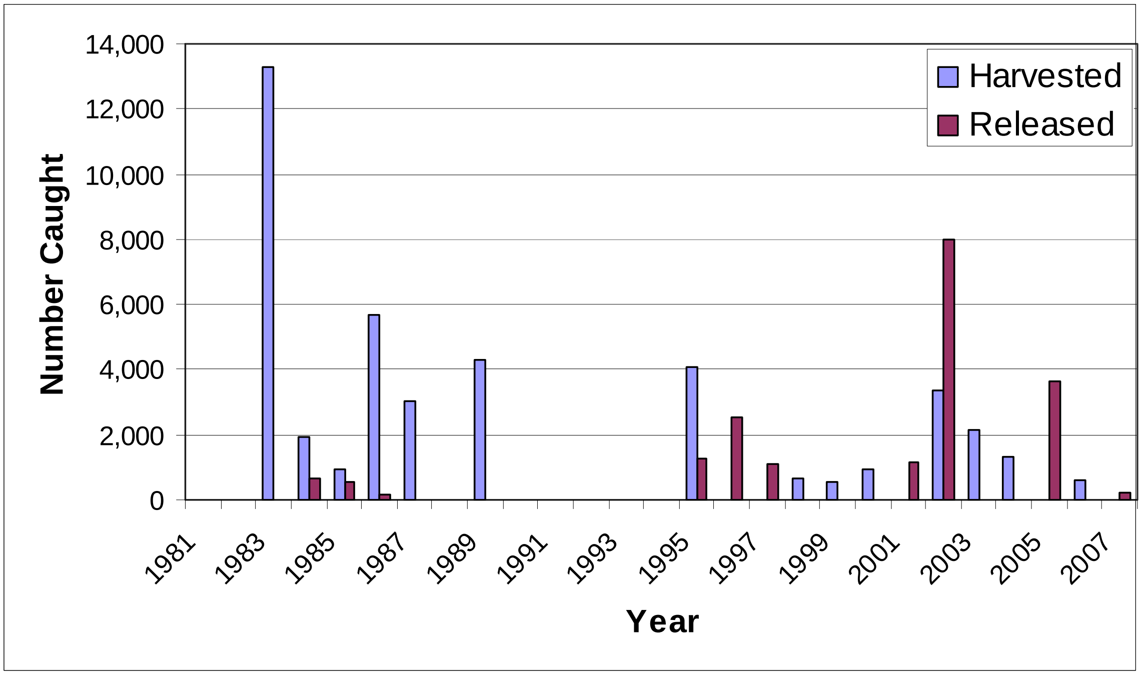

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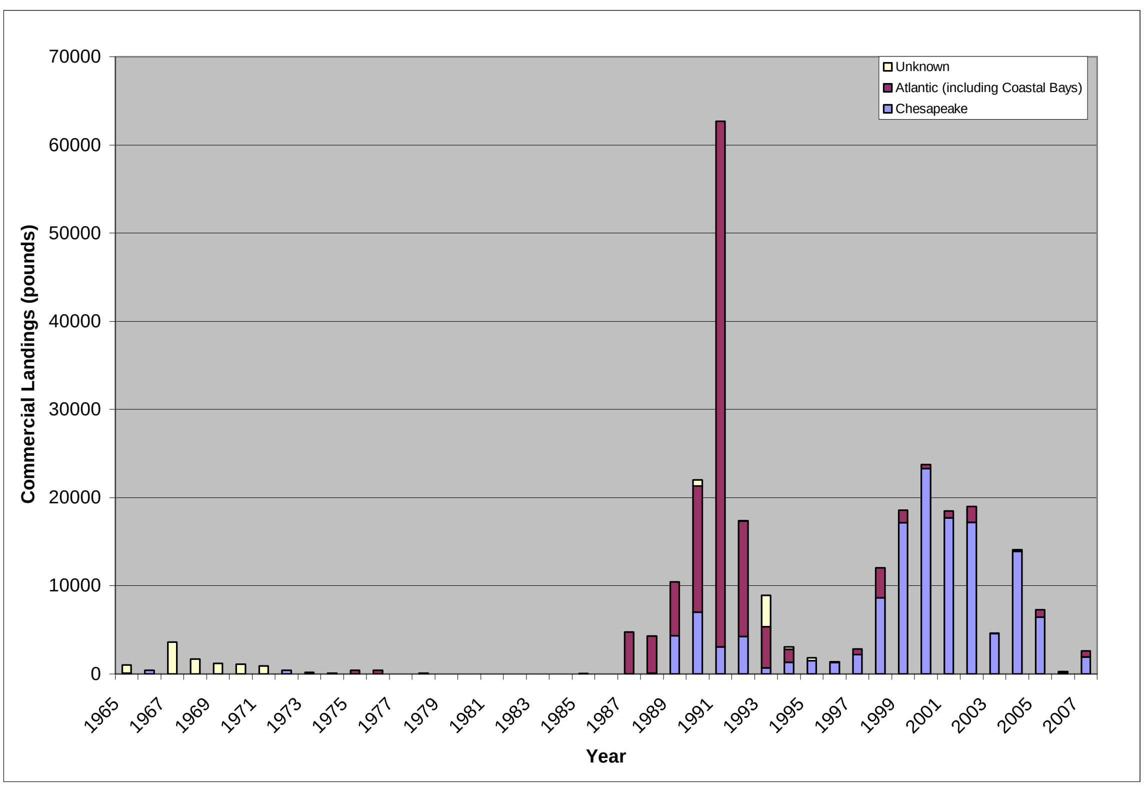

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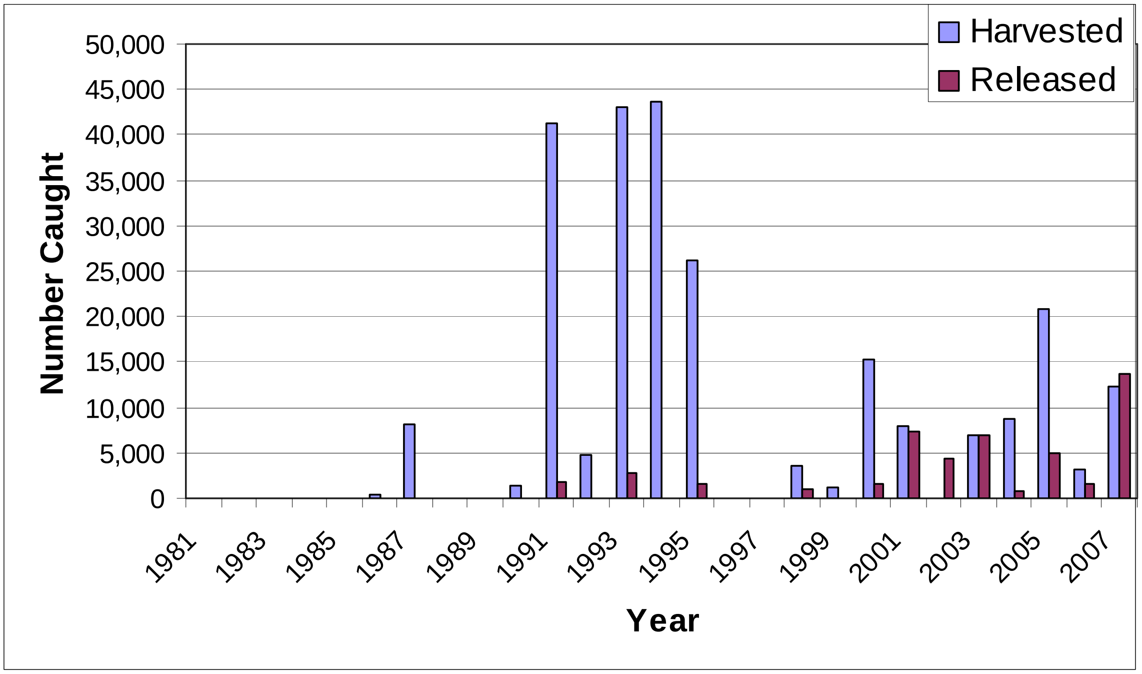

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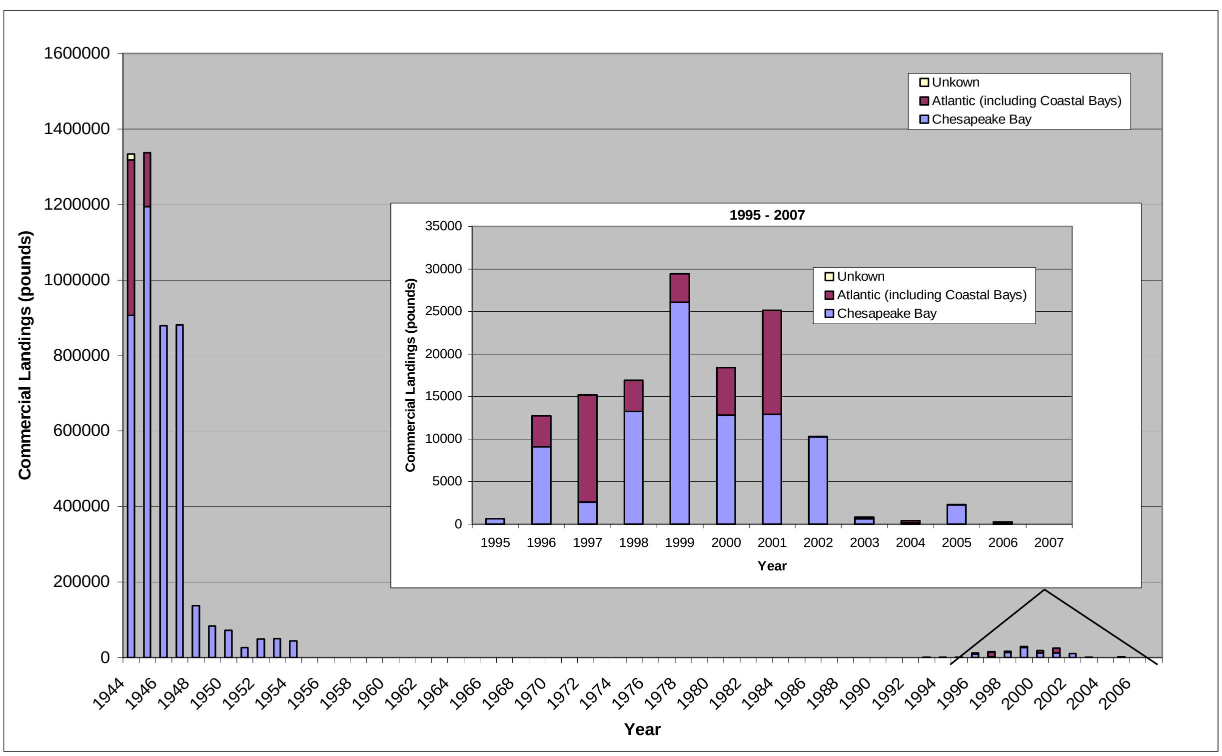

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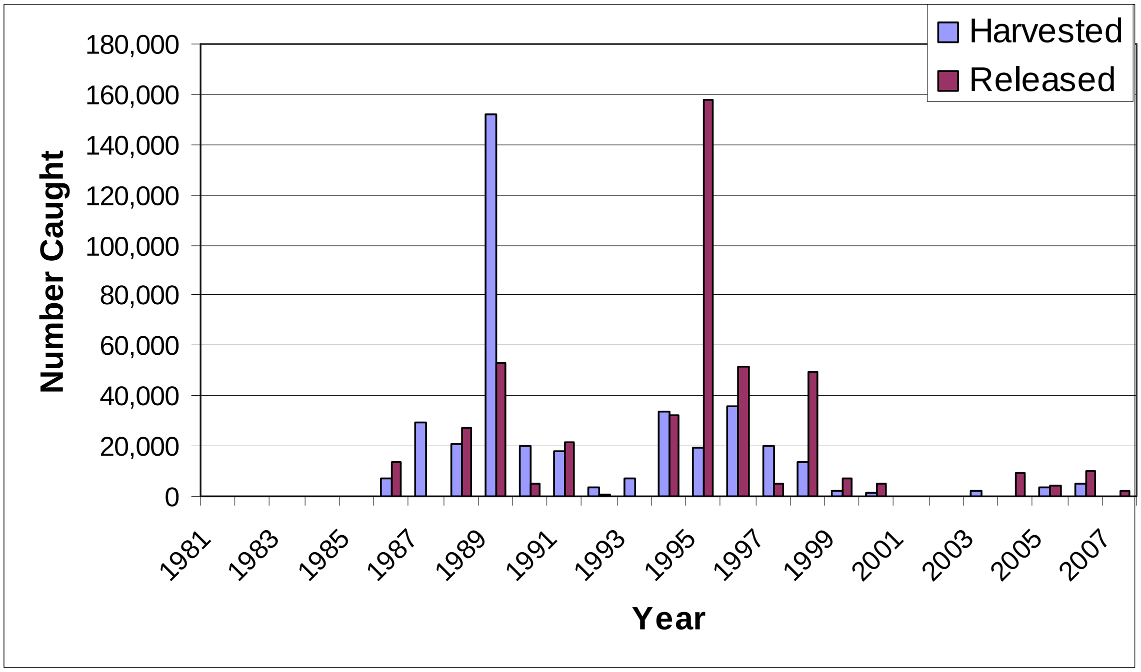

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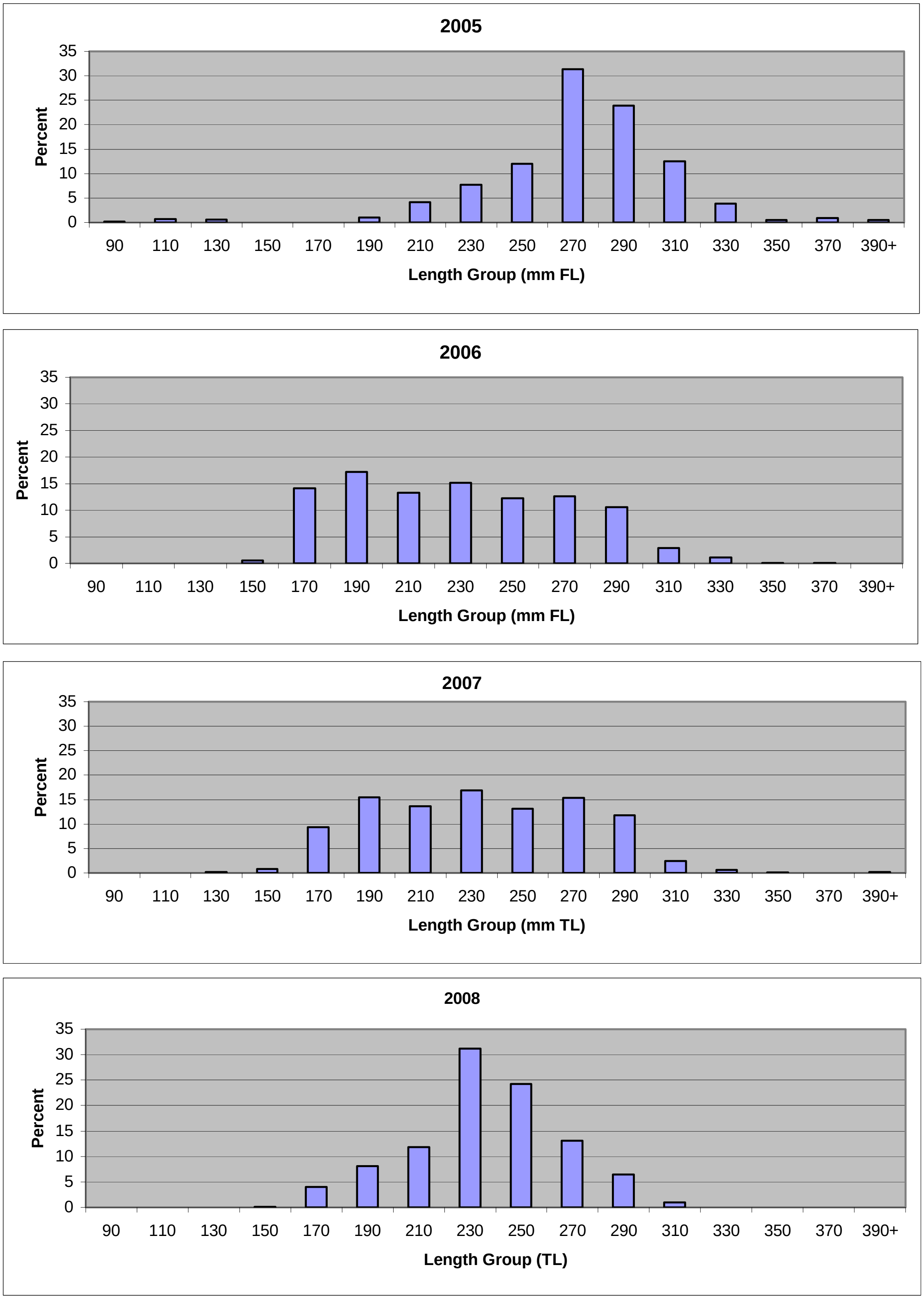

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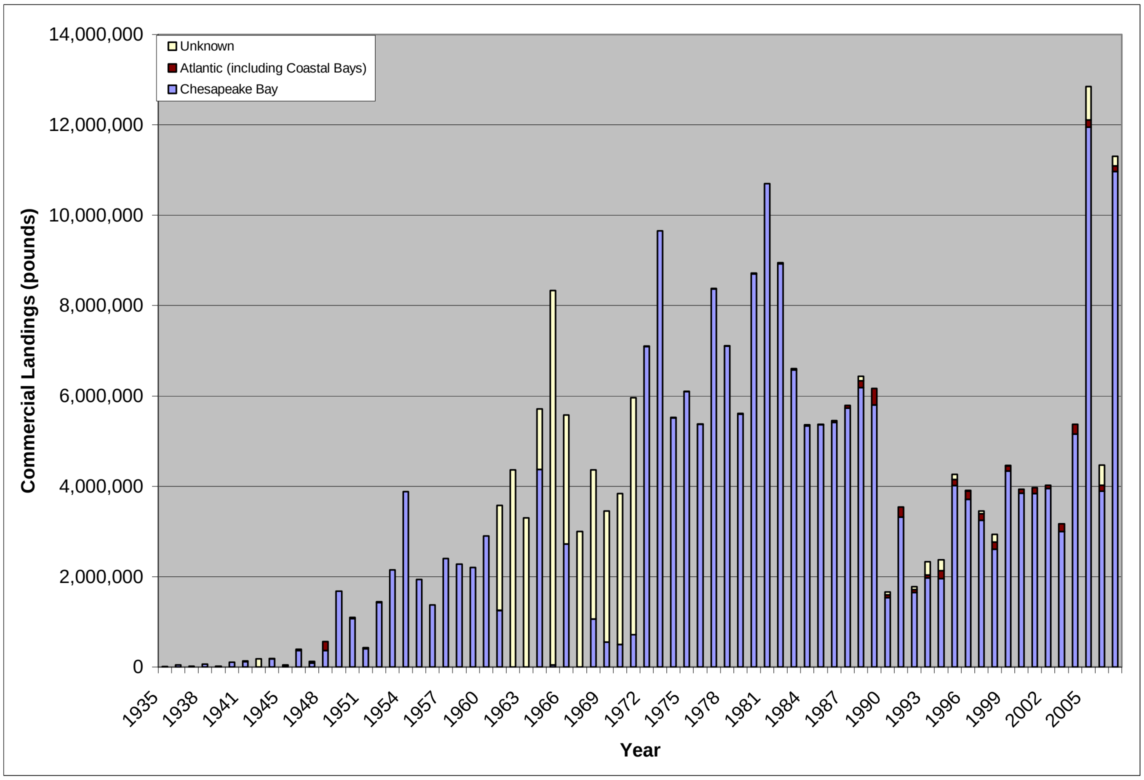

PROJECT NO. 2
JOB NO 3.
TASK NO. 1A

SUMMER – FALL STOCK ASSESSMENT AND COMMERCIAL FISHERY MONITORING

Prepared by Lisa Warner

INTRODUCTION

The primary objective of Project 2, Job 3, Task 1A was to characterize the size and age structures of the 2007 Maryland striped bass (Morone saxatilis) commercial pound net and hook-and-line harvest. The 2007 pound net season ran from 1 June through 30 November while the commercial hook-and-line fishery was open from 14 June through 30 November. These fisheries targeted resident/pre-migratory striped bass. Harvested fish were sampled at commercial check stations and additional fish were sampled by visiting pound nets throughout the season.

In addition to characterizing the size and age structure of the commercial harvest, data from this survey were used to monitor temporal trends in size-at-age of the harvest. These data also provided the foundation for the construction of the Maryland catch-at-age matrix utilized by the Atlantic States Marine Fisheries Commission (ASMFC) in coastal striped bass stock assessment. Length and age distributions constructed from the 2007 commercial fisheries seasons were used to characterize the length and age structure of the entire 2007 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 June through November 2007 (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 2007, 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.

<u>Commercial pound net/hook-and-line monitoring (check station)</u>

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 2007 (Figure 1). For pound nets, sample targets of 200 fish per month were established for June, and September through November and 100 fish per month from July and August. This monthly allocation reflects consistent historic pattern of harvest levels, which normally increase in the fall to twice summer harvest 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). The first stage refers to total length samples taken during the surveys, which was assumed to be a random sample of the commercial harvest. In this case, the length frequencies from hook-and-line and pound net check stations were combined with the pound net monitoring length frequency. In stage 2, a random sub-sample of scales was aged. These scales were selected in proportion to the length frequency of the initial sample. The total number of scales to be aged was determined using a Vartot analysis which is a derived index measuring the precision of an age-length key (Kimura 1977, Lai 1987). Regardless of the sample size indicated by the Vartot analysis, 10 fish in each length category over 700 mm TL were aged.

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 2007 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 2007 striped bass pound net study, 2,958 striped bass were sampled from one pound net in the upper Bay, six pound nets in the middle Bay, and two pound nets in the lower Bay. The nine nets were sampled a total of 19 times during the study.

Striped bass sampled from pound nets ranged from 241-930 mm TL, with a mean length of 482 mm TL (Figure 2). In 2007, 35% of striped bass collected from full net samples were less than minimum legal size of eighteen inches TL, while 25% of fish from partially sampled nets were sub-legal. Mean total lengths of the aged sub-sample from pound nets are presented in Table 2.

Striped bass sampled from pound nets, ranged from 2 to 14 years of age (Table 3, Figure 2). Three year-old fish from the 2004 year-class contributed only 9%, less than in 2006 (38%). Age 4 fish from the 2003 year-class occurred with the greatest frequency, composing 51% of the sample, more than in 2006 (18%) (Figure 3, Table 3). Age 5 fish contributed 21% in 2007, similar to the contribution in 2006 (22%). Striped bass aged 6 and over were uncommon again in 2007, and accounted for only 11.2% of the sample, slightly higher than their contribution in 2006 (5.2%). Fish aged 8 and older composed only 1.2% of the sample in 2007, which was less than in 2006 (3.1%).

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 pound net survey (Figure 4).

<u>Hook-and-line check station sampling</u>

Sixteen hundred and eighty striped bass were sampled at hook-and-line check stations in 2007. The mean length of sampled striped bass was 511 mm TL. Striped bass sampled from the hook-and-line fishery ranged from 439 to 922 mm TL (Figure 4) and from 3 to 14 years of age (Figure 5).

Length frequency and ages of the sampled fish were applied to the total harvest. Striped bass in the 470-550 mm length groups accounted for 79% of the hook-and-line harvest, slightly more than in 2006 (70%) (Figure 5). Fish greater than 650 mm TL contributed only 3% 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 3% of the harvest was sub-legal (< 457 mm TL). Mean lengths-at-age and weights-at-age for the 2007 combined hook-and-line and pound net fisheries are shown in Tables 4 and 5.

The 2007 hook-and-line harvest accounted for 29%, by weight, of the Maryland Chesapeake Bay total commercial harvest in 2007 (see Project 2, Job 3, Task 5A). The estimated 2007 catch-at-age of the hook-and-line fishery is presented in Table 6. The majority of the harvest was composed of four to six year-old striped bass. Four year-old fish from the strong 2003 year class accounted for 56% of the total, 35% more than in 2006. Age 5 striped bass from the 2002 year class contributed

29%, slightly more than their contribution in 2006 (Figure 7). Age six fish from the dominant 2001 year-class contributed 11% to the hook-and-line harvest, substantially less than in 2006 (37%). Striped bass aged 7 and older contributed very little to the overall harvest in 2007 (3%).

Pound net check station sampling

Eleven hundred and eighty seven striped bass were sampled at pound net check stations in 2007. Striped bass sampled ranged from 444 to 978 mm TL (Figure 4). Legal-sized striped bass sampled from the pound net fishery ranged from 3 to 14 years of age. Striped bass in the 450 -530 mm TL length groups accounted for 66% of the 2007 pound net harvest (Figure 5). The contribution of striped bass in the 570–630 mm TL length groups increased from 15% in 2006 to 21% in 2007. Fish greater than 650 mm TL composed 10% of the sample. In general, few large fish were available to the 2007 fishery (Figure 6). Mean lengths-at-age and weights-at-age from the 2007 hook-and-line and pound net fisheries combined, are shown in Tables 4 and 5, respectively.

The pound net fishery accounted for 24%, by weight, of the Maryland Chesapeake Bay 2007 commercial harvest. The estimated 2007 catch-at-age for the pound net fishery is presented in Table 6. Sub-legal striped bass (< 457 mm TL) made up less than 1% of the total pound net harvest. Fish aged four to six contributed 92% of the 2007 total pound net harvest. Four year-old fish from the 2003 year-class dominated the pound net harvest again in 2007, contributing 56% to the total harvest, more than in 2006 (Figure 7). Striped bass aged 8 and over composed only 2% of the 2007 harvest, less than in 2006 (5%).

Monitoring summary

Striped bass ranging from 457 to 550 mm TL comprised 69% and 86%, respectively, of the pound net and hook and line fisheries, with few large fish being harvested from either fishery

(Figure 5). In 2007, 75 fish from pound nets and 108 fish from check stations surveys were aged. Older fish were again scarce throughout the summer and 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 (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 striped bass aged 4 to 6. A Duncan's multiple range test (p=0.05) conducted on mean length-at-age showed no significant differences from 2001 to 2007, for three, four, and five year-old striped bass. The mean length of six year-old striped bass from 2007 was not different than fish sampled in all years except 2003 and 2004. Age 7 striped bass were significantly smaller than age 7 fish in 2002 and 2003. Eight year-old striped bass from the 1999 year-class were significantly shorter than all previous years except 2006. Nine year-old striped bass were no different than 9 year-old striped bass sampled in 2003 and 2006. Aged 10 striped bass from 1997 were similar to fish aged 10 in all years except 2002, and eleven year-old striped bass were similar to age 11 fish in all years. Age sample sizes were too small for ages greater than 11 to be analyzed by the Duncan's test.

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Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2007 Maryland Chesapeake Bay commercial pound net monitoring survey.

Month	**Area**	**Number of Nets Sampled**	**Mean Water Temp. °C**	**Mean Salinity (ppt)**	**Number of Fish Sampled**
June	Upper	-	-	-	-
	Middle	4	23.4	12.0	409
	Lower	2	23.2	15.5	305
July	Upper	-	-	-	-
	Middle	2	26.1	8.22	248
	Lower	-	-	-	-
August	Upper	-	-	-	-
	Middle	1	25.4	11.8	63
	Lower	1	29.1	13.1	351
September	Upper	1	20.5	4.0	563
	Middle	1	23.4	11.7	209
	Lower	1	22.9	10.3	396
October	Upper	1	18.3	3.8	358
	Middle	1	-	-	210
	Lower	1	21.4	15.0	206
November	Upper	-	-	-	-
	Middle	1	11.7	7.3	300
	Lower	1	13.4	15.9	196

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2007.

Year-class	Age	n	Mean length (mm TL)	STD	STDERR	LCLM	UCLM
2005	2	23	318	46	10	298	338
2004	3	11	391	44	13	362	421
2003	4	35	499	61	10	478	519
2002	5	20	566	75	17	531	601
2001	6	43	656	64	10	636	675
2000	7	9	683	67	22	632	734
1999	8	10	699	51	16	662	735
1998	9	13	743	65	18	704	783
1997	10	6	796	73	30	719	873
1996	11	3	823	88	51	606	1041
1995	12	3	860	99	57	615	1104
1994	13	2	858	28	20	610	1105
1993	14	5	902	57	25	832	973

Table 3. Number of striped bass, by age, sampled from pound nets, in Maryland's Chesapeake Bay, June through November 2007.

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2005	2	224	7.58
2004	3	278	9.41
2003	4	1,516	51.24
2002	5	610	20.61
2001	6	253	8.55
2000	7	43	1.44
1999	8	17	0.57
1998	9	14	0.47
1997	10	1	0.05
1996	11	1	0.02
1995	12	1	0.02
1994	13	0	0.00
1993	14	1	0.03
Total		**2,958**	**100.00**

Table 4. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) for ages 3-14 sampled from commercial pound net and hook-and-line fisheries in Maryland's Chesapeake Bay, June through November 2007.

Year-class	Age	n	Mean Length (mm TL)	STD	STDERR	LCLM	UCLM
2004	3	1	459	-	-	-	-
2003	4	24	529	46	9	548	511
2002	5	19	572	72	17	605	540
2001	6	43	656	64	10	675	636
2000	7	9	683	67	22	726	639
1999	8	10	699	51	16	730	667
1998	9	13	743	65	18	779	708
1997	10	6	796	73	30	855	738
1996	11	3	823	88	51	922	724
1995	12	3	860	99	57	971	748
1994	13	2	858	28	20	896	819
1993	14	5	902	57	25	952	853

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 2007. Mean weights are weighted by the sample n-at-length in each age.

Age	Year-class	n Aged	Weighted Mean weight (kg)
3	2004	1	0.9
4	2003	24	1.2
5	2002	19	1.3
6	2001	43	2.1
7	2000	9	2.1
8	1999	10	2.9
9	1998	13	3.5
10	1997	6	4.6
11	1996	3	6.0
12	1995	3	6.0
13	1994	2	6.7
14	1993	5	7.7

* 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 2007.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Numbers of Fish*	**Percent of Total**	**Landings in Numbers of Fish***	**Percent of Total**
2004	3	2,581	1.2	597	0.4
2003	4	135,461	56.9	67,770	46.3
2002	5	68,889	28.8	36,982	25.2
2001	6	23,772	10.2	29,623	20.2
2000	7	3,897	1.6	5,067	3.5
1999	8	1,365	0.5	3,015	2.1
1998	9	973	0.3	2,181	1.5
1997	10	203	0.1	566	0.4
1996	11	187	0.1	222	0.2
1995	12	148	0.1	203	0.1
1994	13	129	0.1	62	0
1993	14	194	0.1	206	0.1
Total		**237,800**	**100.0**	**146,493**	**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 2007.

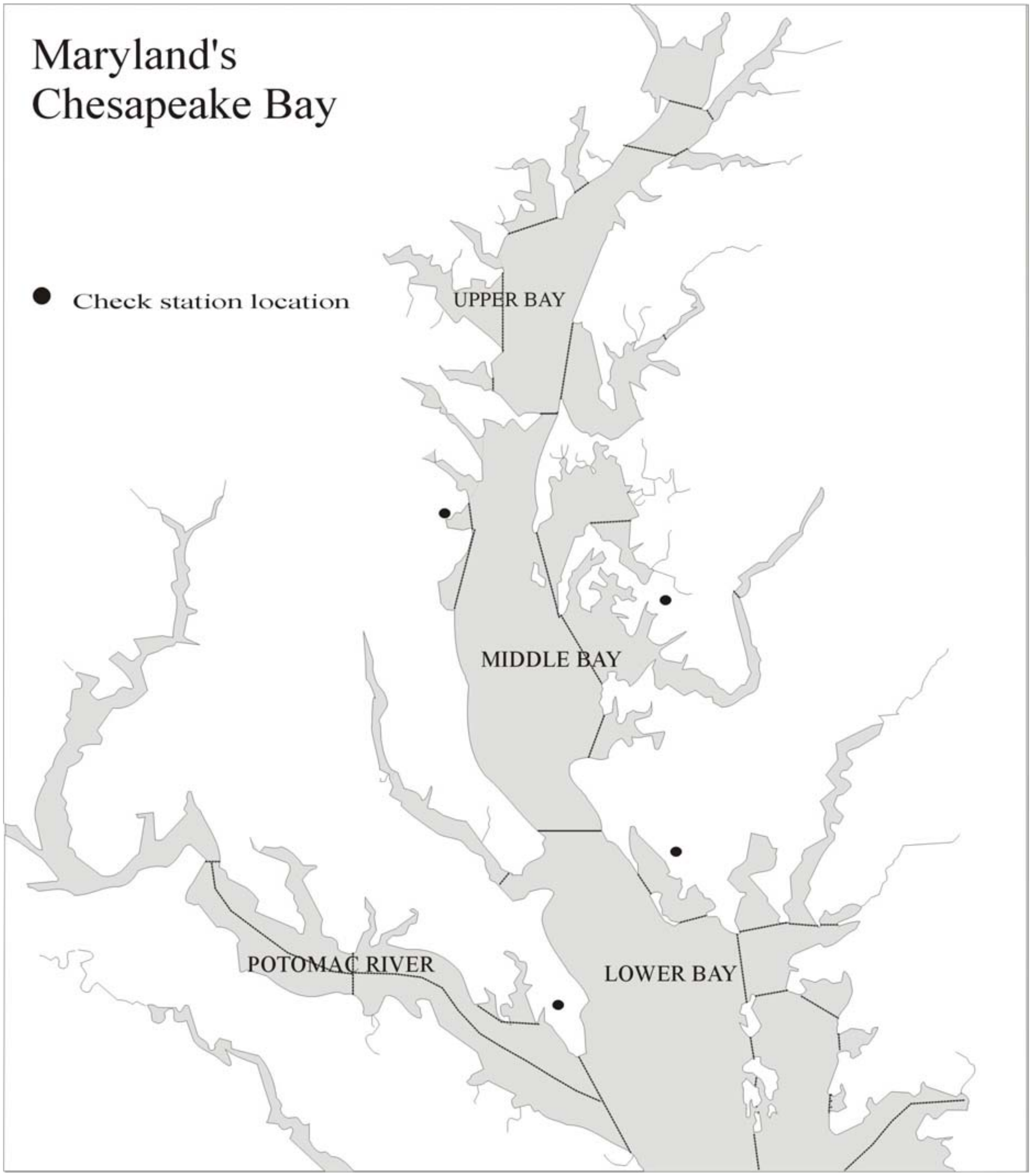


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study, June through November 2007.

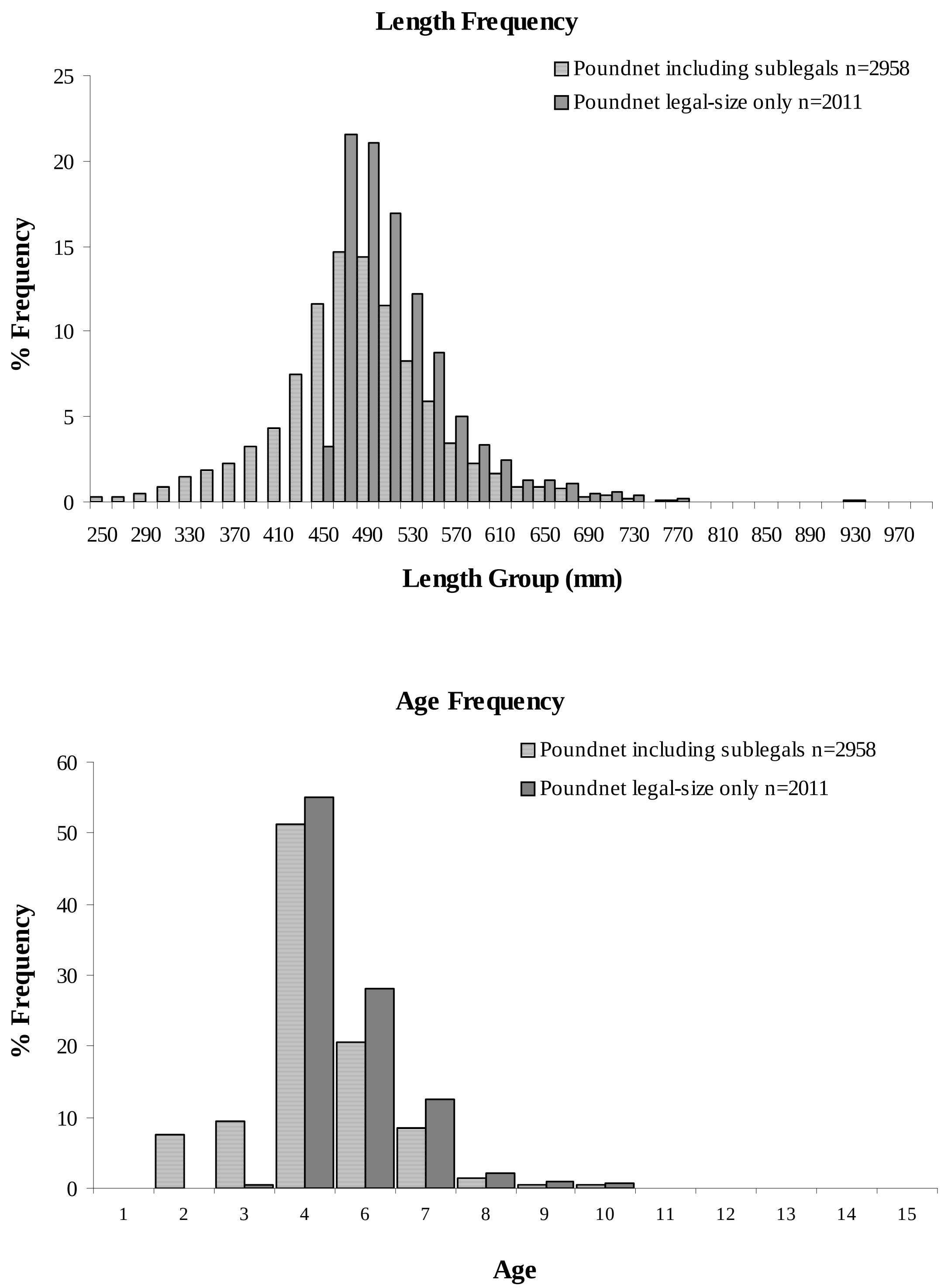


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2007.

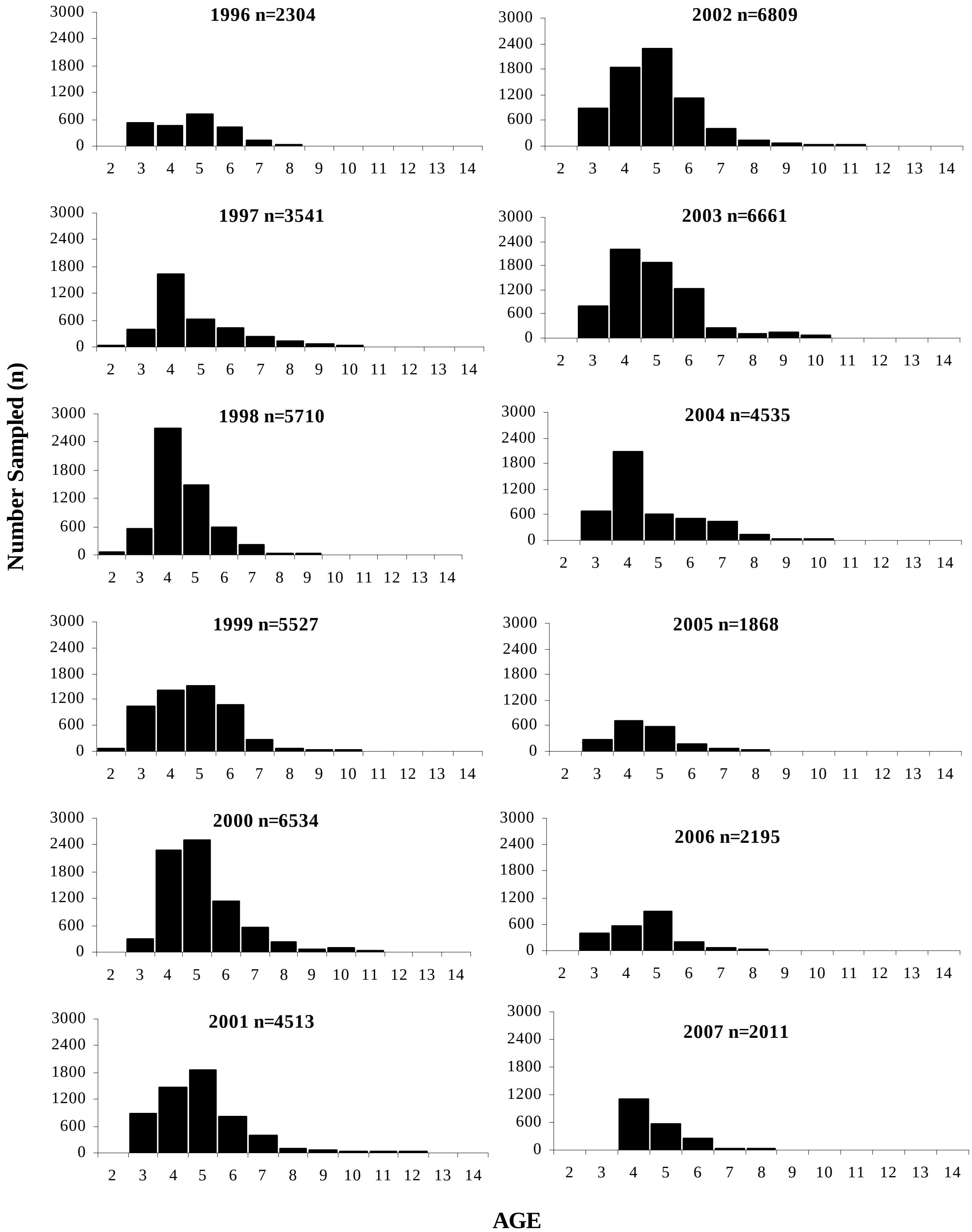


Figure 4. Length frequency of striped bass sampled during the 2007 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2007. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

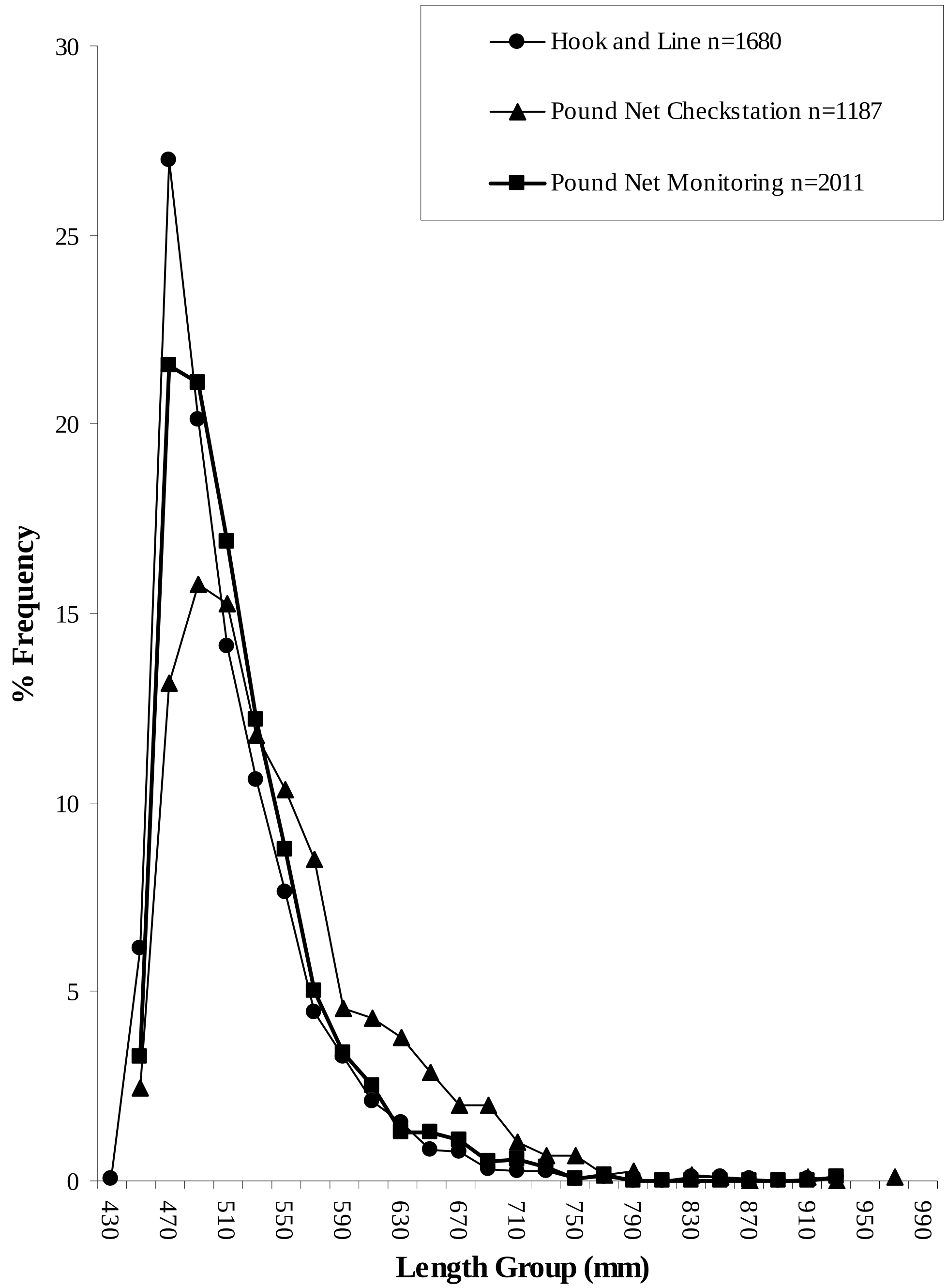
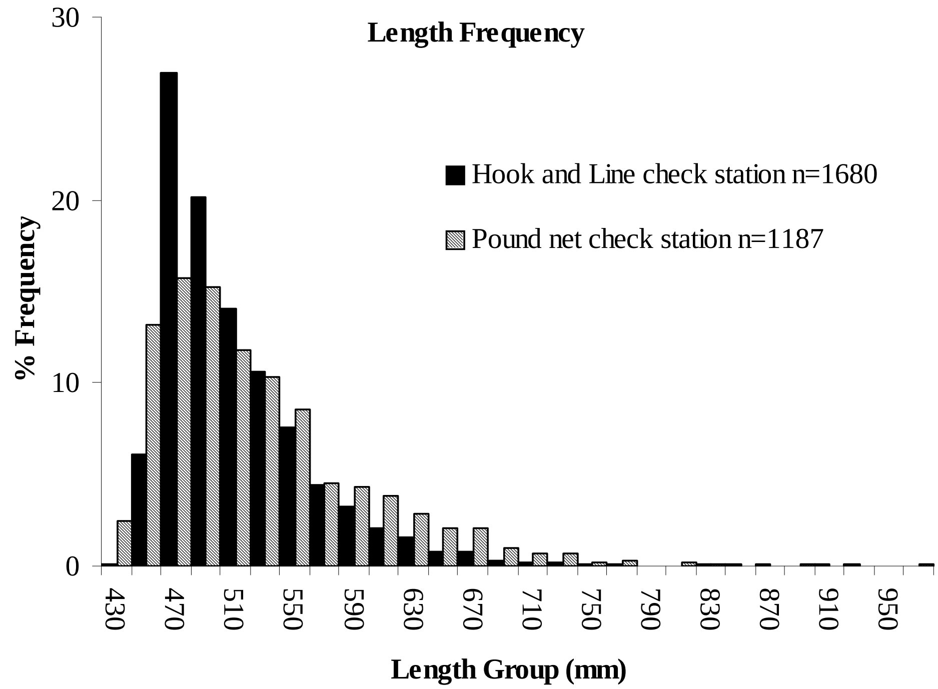


Figure 5. Age and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2007.



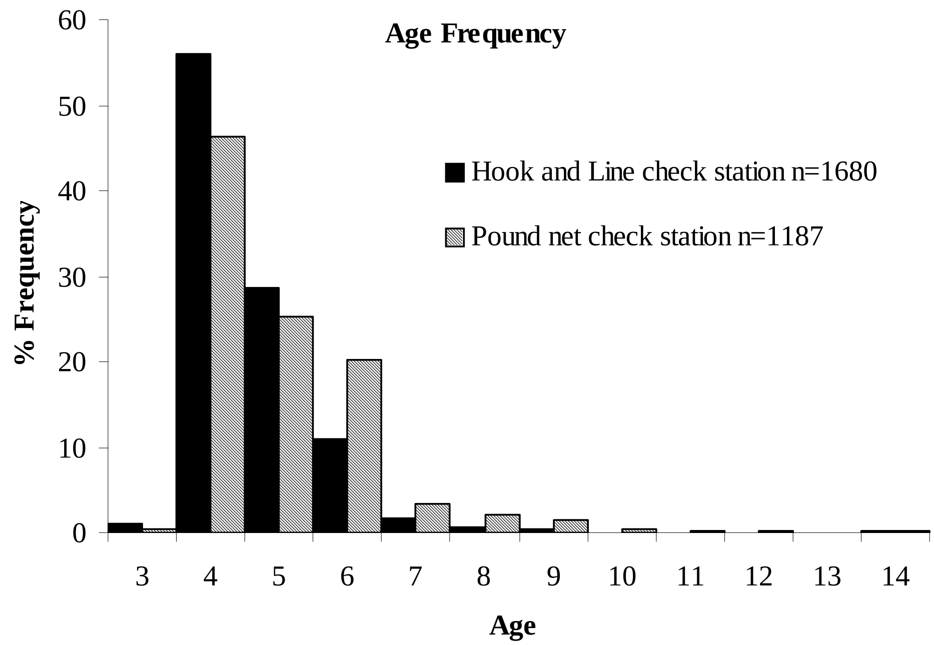


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2007.

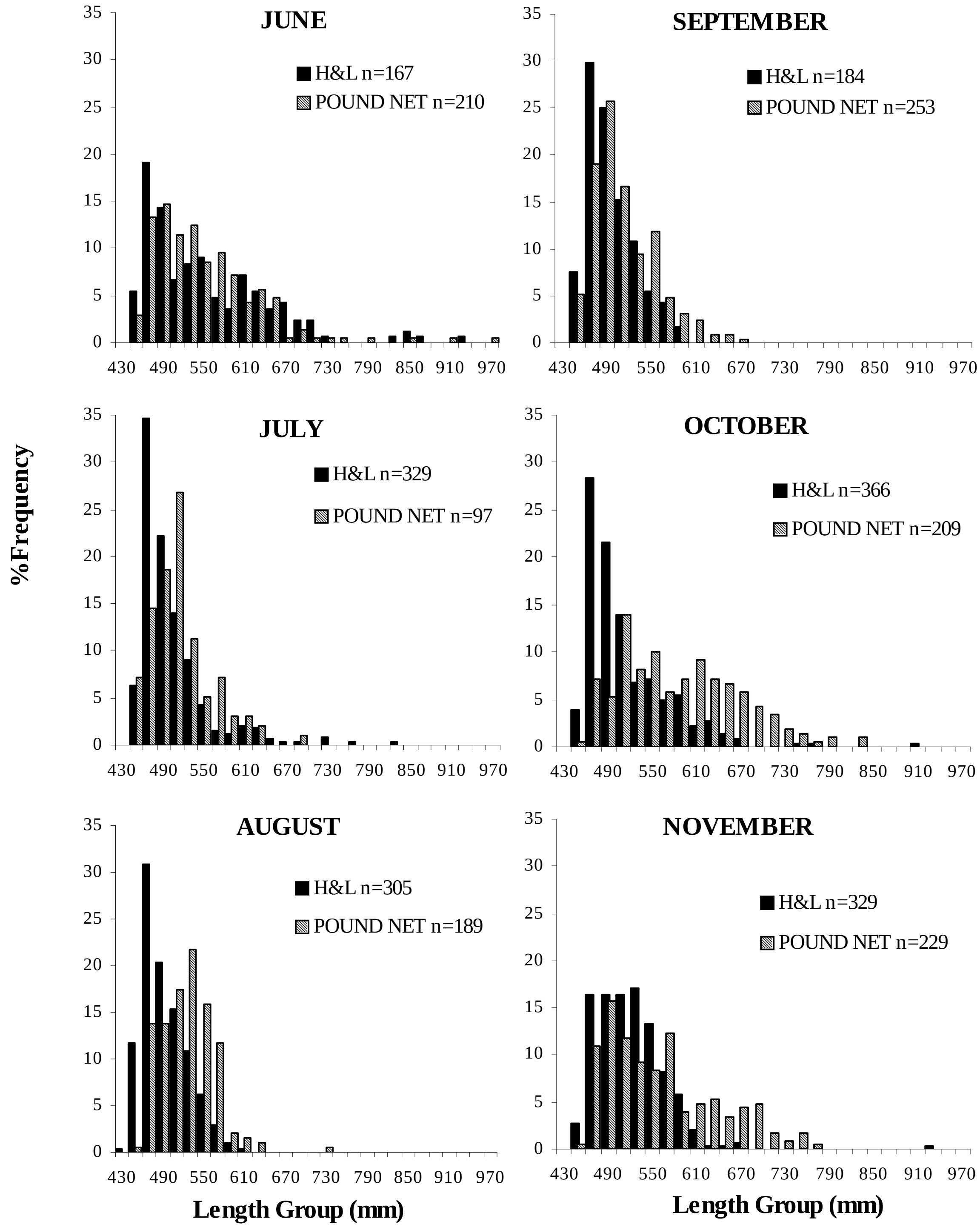


Figure 7. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2007. Note-pound net check station sampling began in 2000.

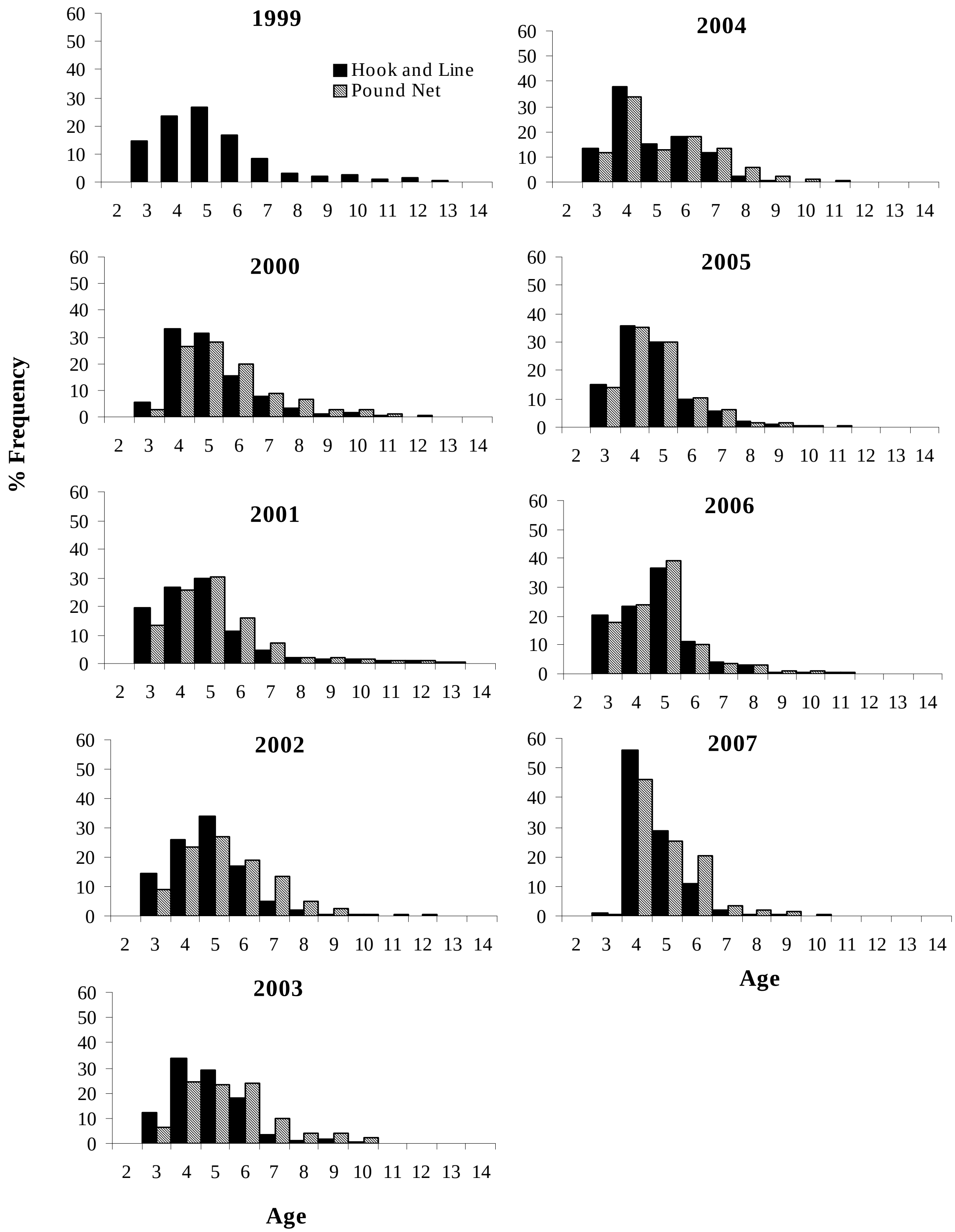
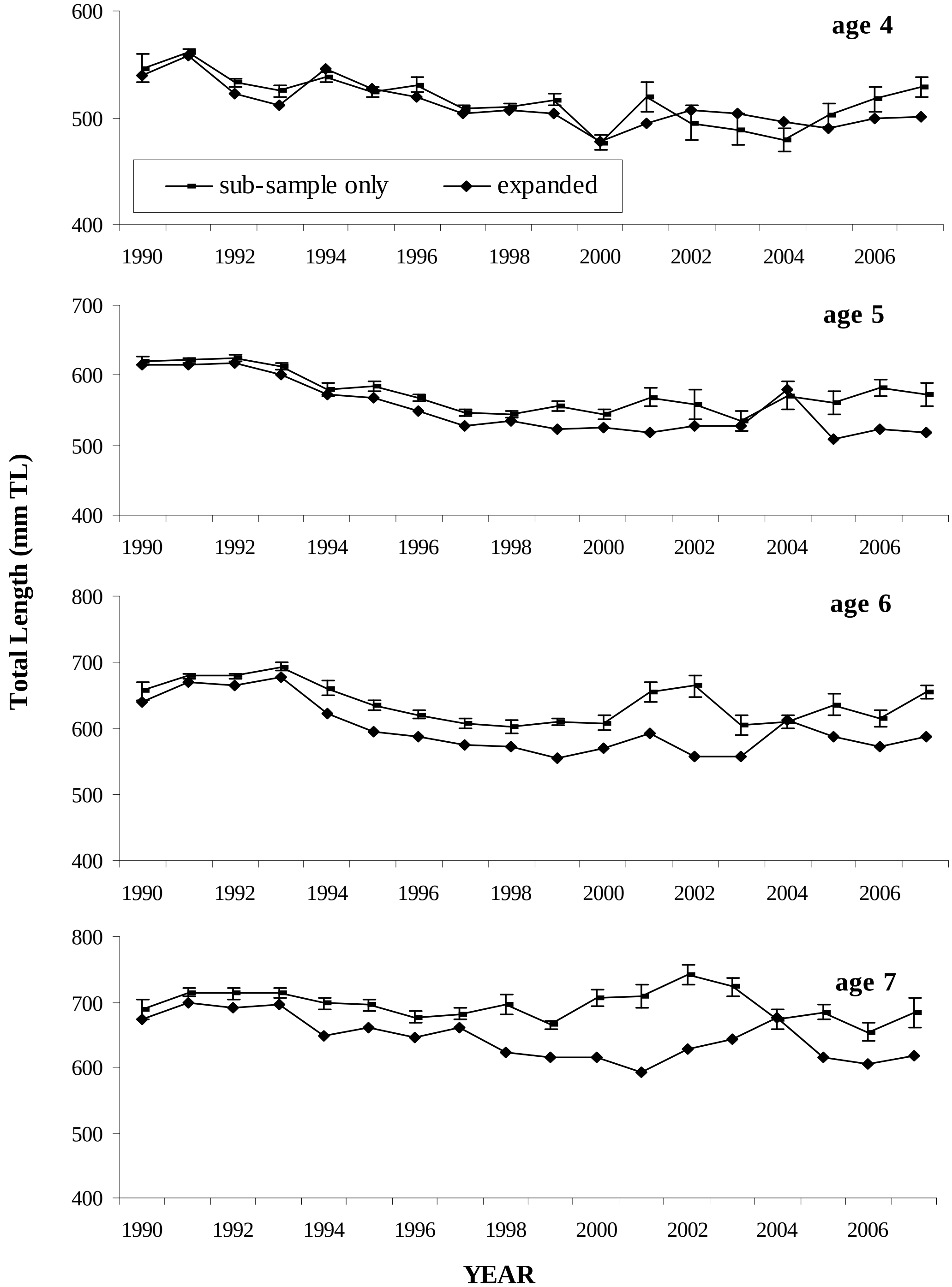


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations,1990 through 2007. Mean lengths were calculated by using sub-sampled ages only and 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 Andrea K. Hoover

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, 2007 - February 29, 2008 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 used 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 or medium-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 due to low landings in recent years. 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 southern 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 in Cambridge.

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 stage one, a random sample of lengths was taken from the total catch. In stage two, a sub-sample of scales was aged. Scales for aging were selected in proportion to the length frequency of the initial sample. The total number of scales to be aged was determined using a Vartot analysis which is a derived index measuring the precision of an age-length key (Kimura 1977, Lai 1987). Regardless of the sample size indicated by the Vartot analysis, 10 fish in each length category over 700 mm TL were aged, if available. 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 2007-2008 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 2007 – February 2008 gill net season, the year used for age calculations was 2008.

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. 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 2007-2008 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 50% of the total Maryland Chesapeake Bay commercial harvest, by weight, during the 2007 calendar year. A total of 3,113 striped bass were encountered; 3,012 were measured for total length (11 fish with no total length), 3,109 were weighed, and 211 striped bass were aged from the December 2007 - February 2008 harvest. The sample size obtained was only slightly less 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 2007-2008 commercial drift gill net harvest consisted primarily of striped bass from the 2003 (age 5) year-class (Table 1), comprising 51% of the total harvest.

Year-classes 2004, 2002, and 2001 (ages 4, 6, and 7) comprised an additional 35% of the total harvest, while age groups 8-14 contributed only 13% to the total. The contribution of fish greater than 8 years old was much lower than the 2006-2007 gill net harvest of 22% (Hoover 2008). The youngest fish observed in the 2007-2008 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-sampled means. Striped bass were recruited into the 2007-2008 winter gill net fishery at age 3 (2005 year-class), with an expanded mean length and weight of 470 mm TL and 1.28 kg. The 2003 (age 5) year-class was most commonly observed in the sampled landings, comprising 51% of the harvest with an expanded mean length and weight of 529 mm TL and 1.79 kg. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 14, 1994 year-class) were 782 mm TL and 5.71 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 composed 1% of the bay-wide sampled harvest.

Time series of sub-sampled and expanded mean lengths and weights for the period 1994-2008 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 have been variable over time, with no apparent trends over the 15 year time period.

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Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2007 - February 2008.

Year-Class	Age	Catch	Percentage of the Catch
2005	3	3,108	2
2004	4	23,085	11
2003	5	104,876	51
2002	6	23,477	11
2001	7	25,855	13
2000	8	13,505	7
1999	9	3,317	2
1998	10	4,618	2
1997	11	1,646	1
1996	12	1,876	1
1995	13	166	0
1994	14	345	0
	Total	**205,876**	**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 2007-February 2008.

Year-Class	Age	n fish aged	Mean TL (mm) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean TL (mm)
2005	3	1	463	47	470
2004	4	9	476	348	492
2003	5	42	550	1,580	529
2002	6	22	655	354	580
2001	7	37	690	390	610
2000	8	40	752	203	706
1999	9	16	831	50	825
1998	10	22	857	70	857
1997	11	8	872	25	871
1996	12	11	891	28	881
1995	13	1	776	3	767
1994	14	2	838	5	782
Total		**211**		**3,102**	

Table 3. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2007-February 2008.

Year-Class	Age	n fish aged	Mean Weight (kg) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean weight (kg)
2005	3	1	1.07	47	1.28
2004	4	9	1.32	348	1.46
2003	5	42	2.07	1,580	1.79
2002	6	22	3.28	354	2.40
2001	7	37	3.93	390	2.82
2000	8	40	4.97	203	4.23
1999	9	16	6.54	50	6.36
1998	10	22	7.19	70	6.99
1997	11	8	7.51	25	7.24
1996	12	11	8.17	28	7.56
1995	13	1	5.43	3	5.13
1994	14	2	6.66	5	5.71
Total		**211**		**3,102**	

* 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 2007-February 2008.

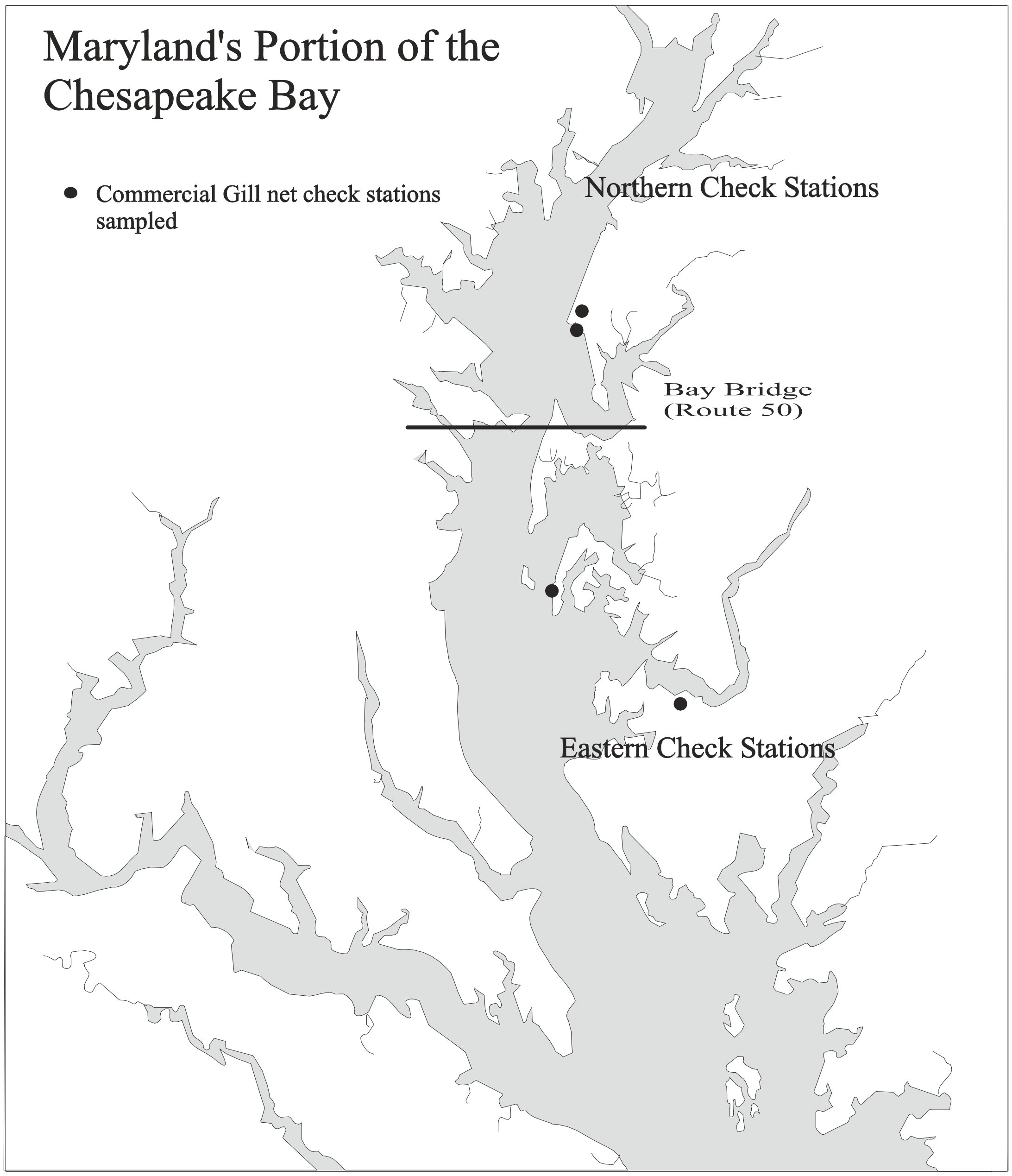


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2008.

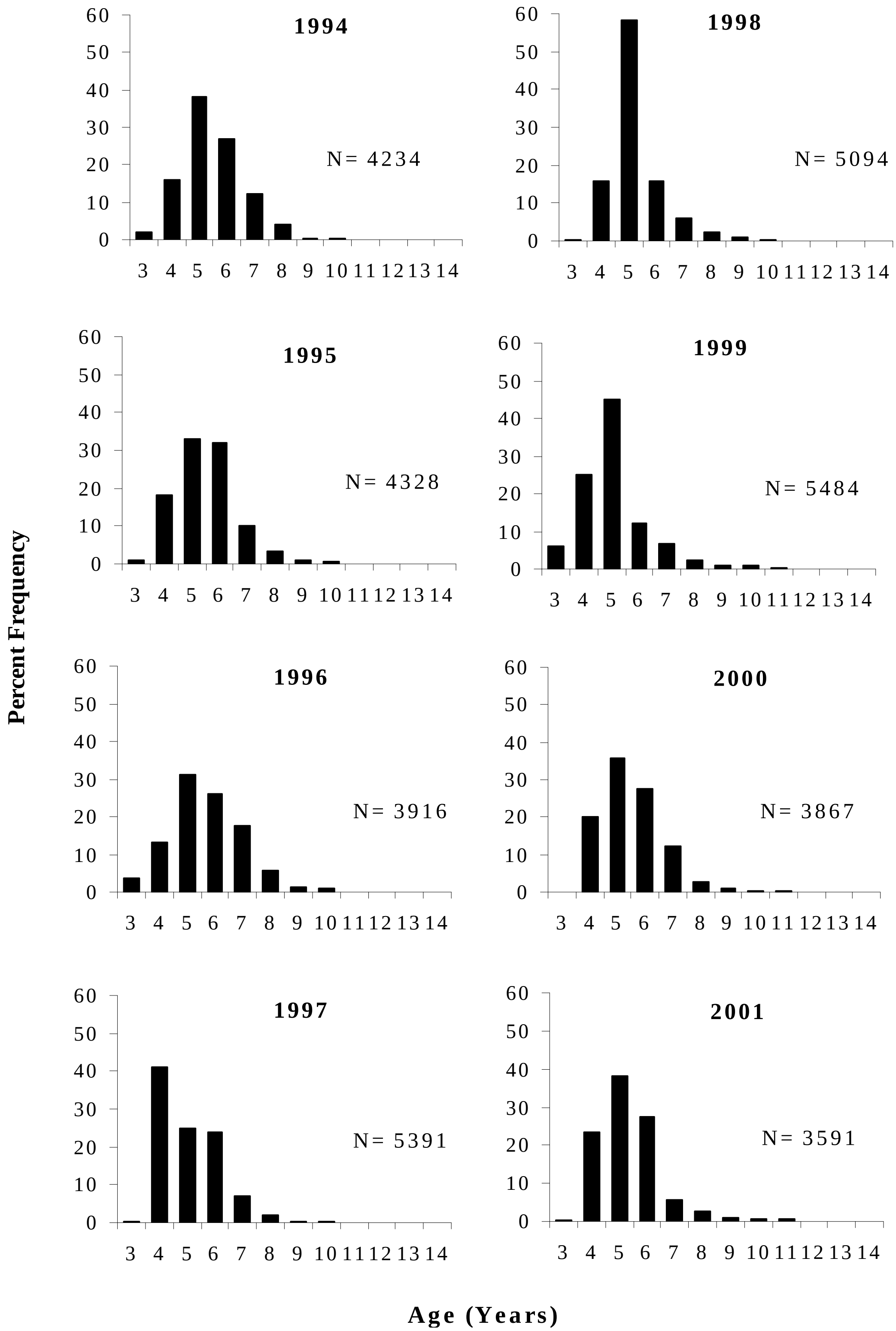


Figure 2. (Continued).

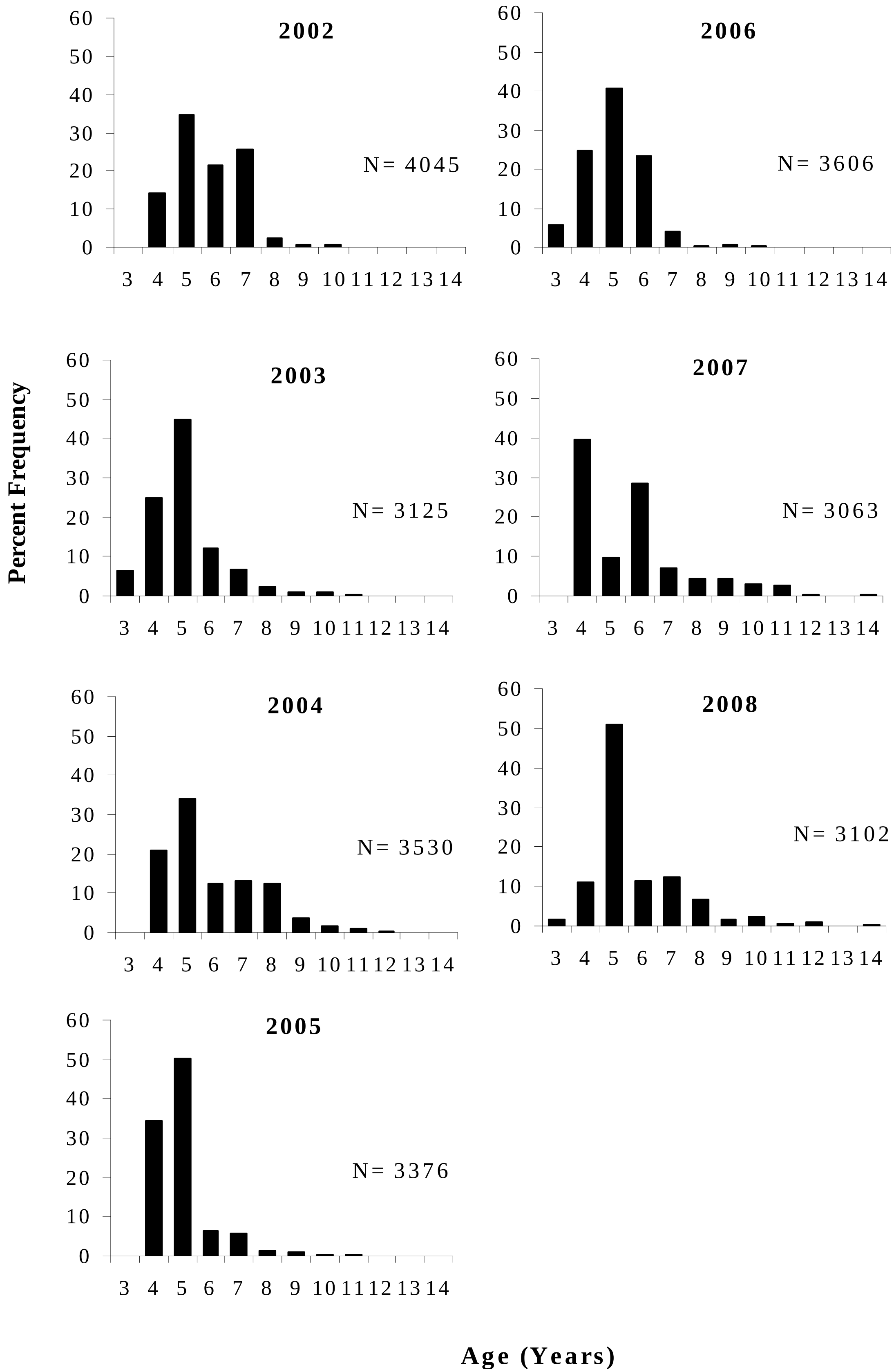


Figure 3. Length frequency distributions, by area and bay-wide, of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2007-February 2008.

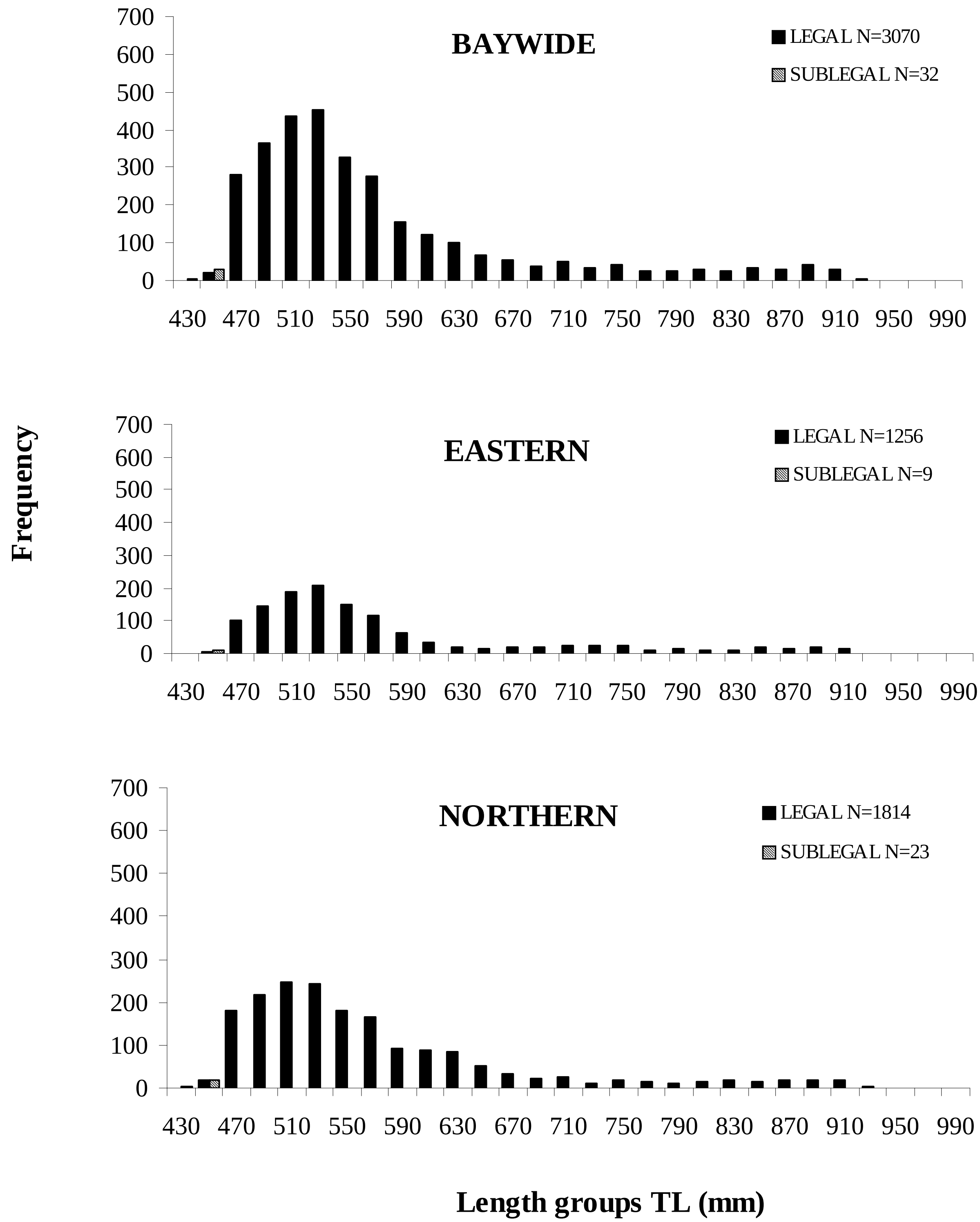
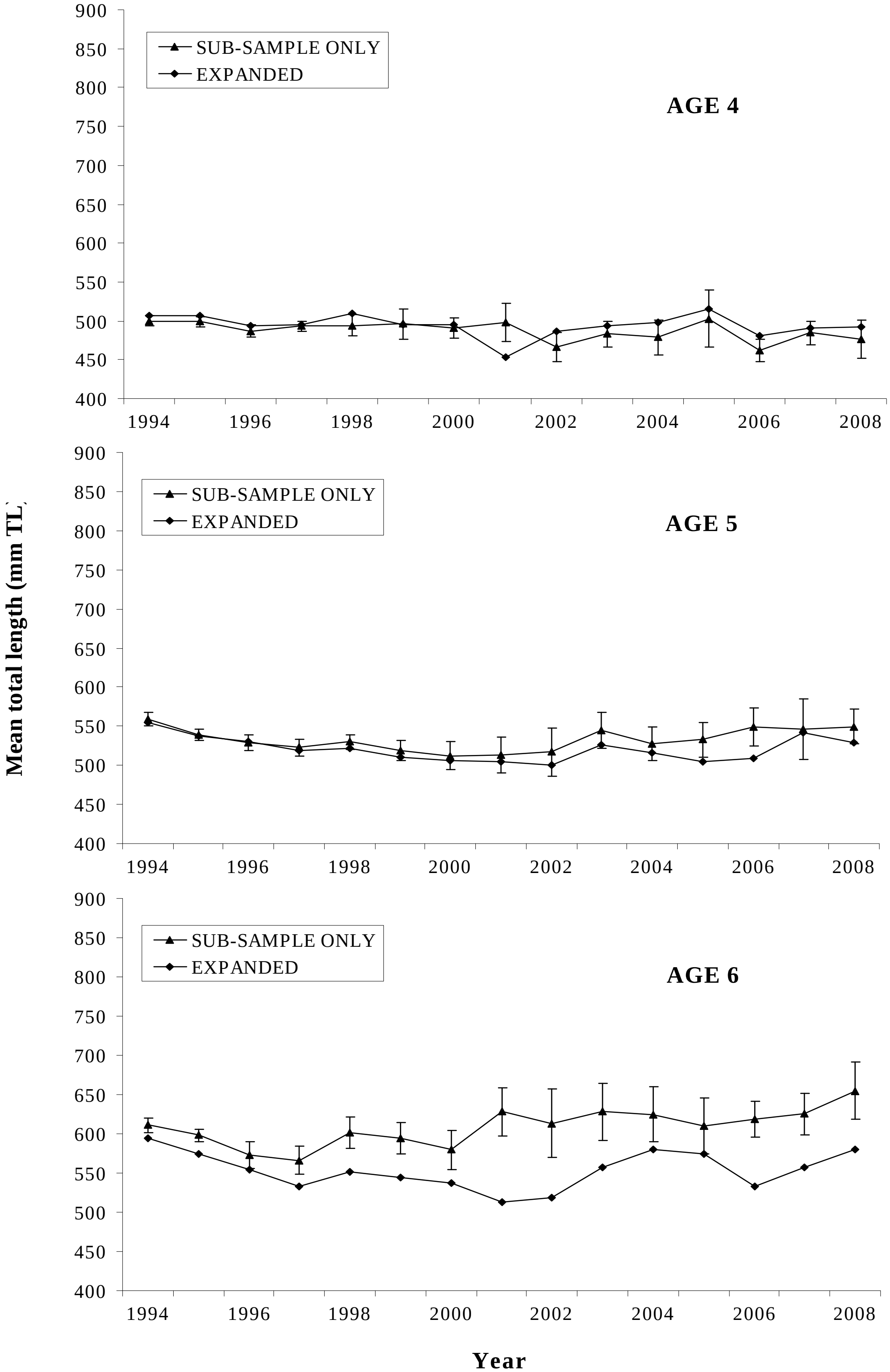


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2008 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample)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



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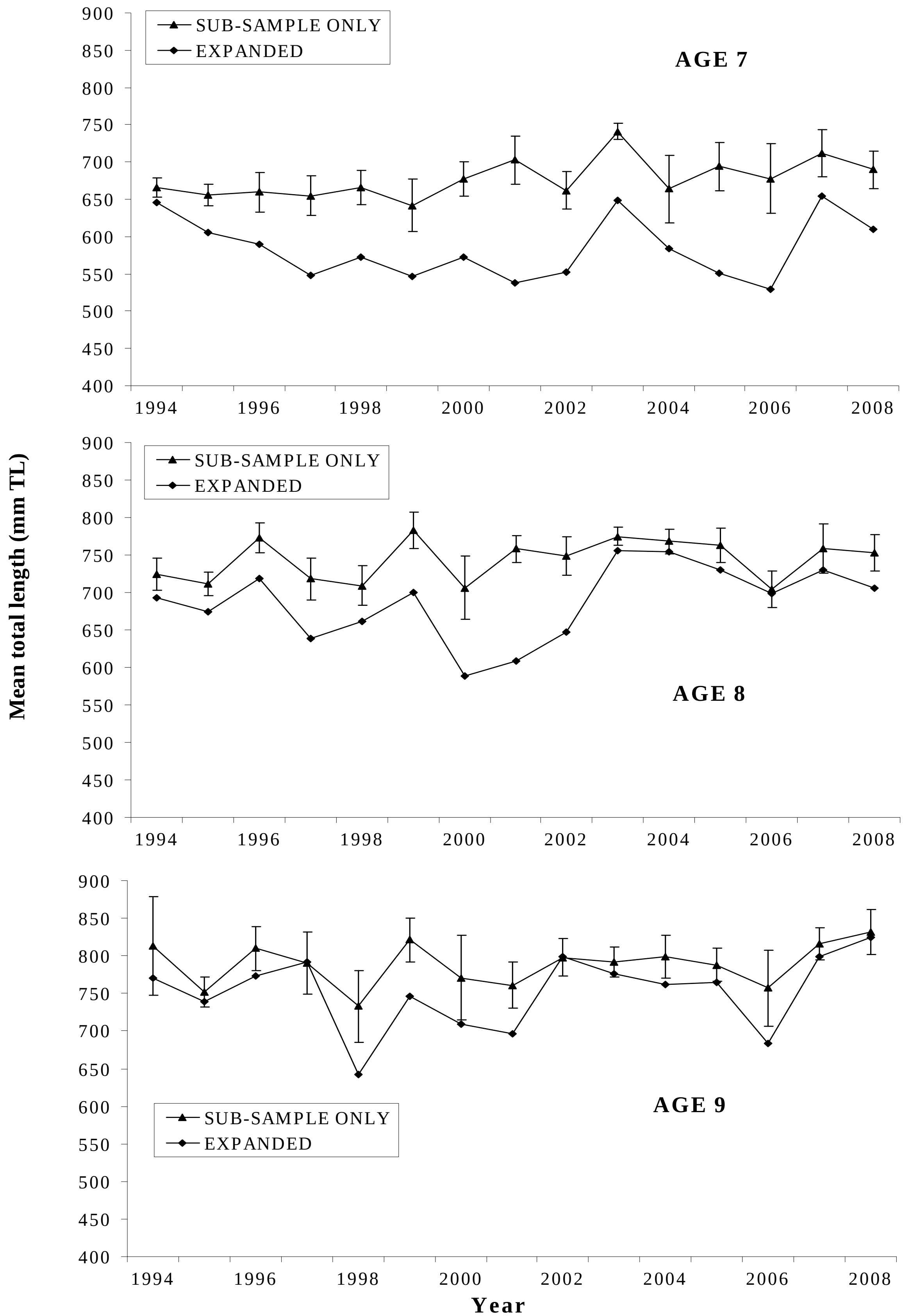


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2008 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. The year refers to the year in which the season ended.

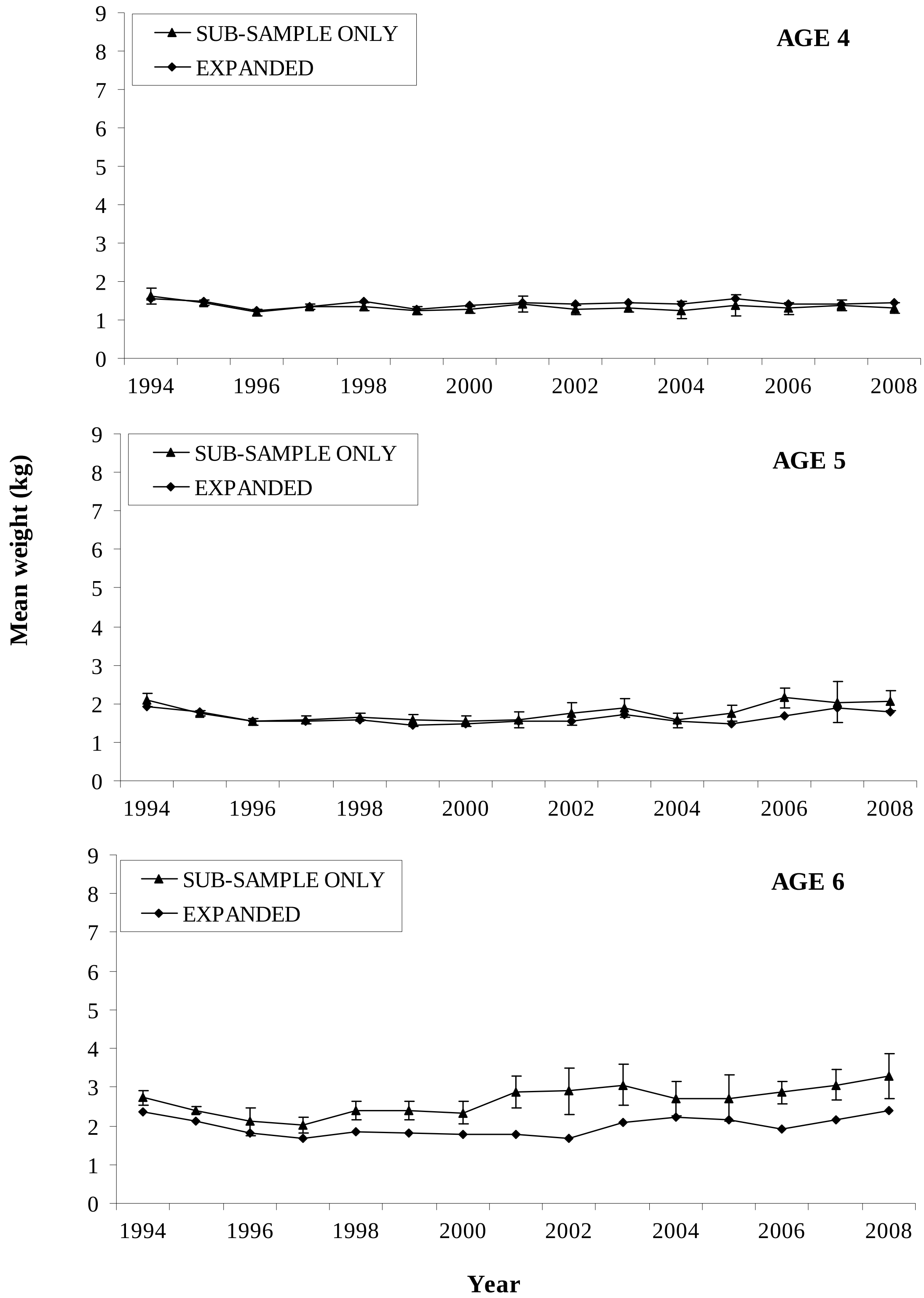
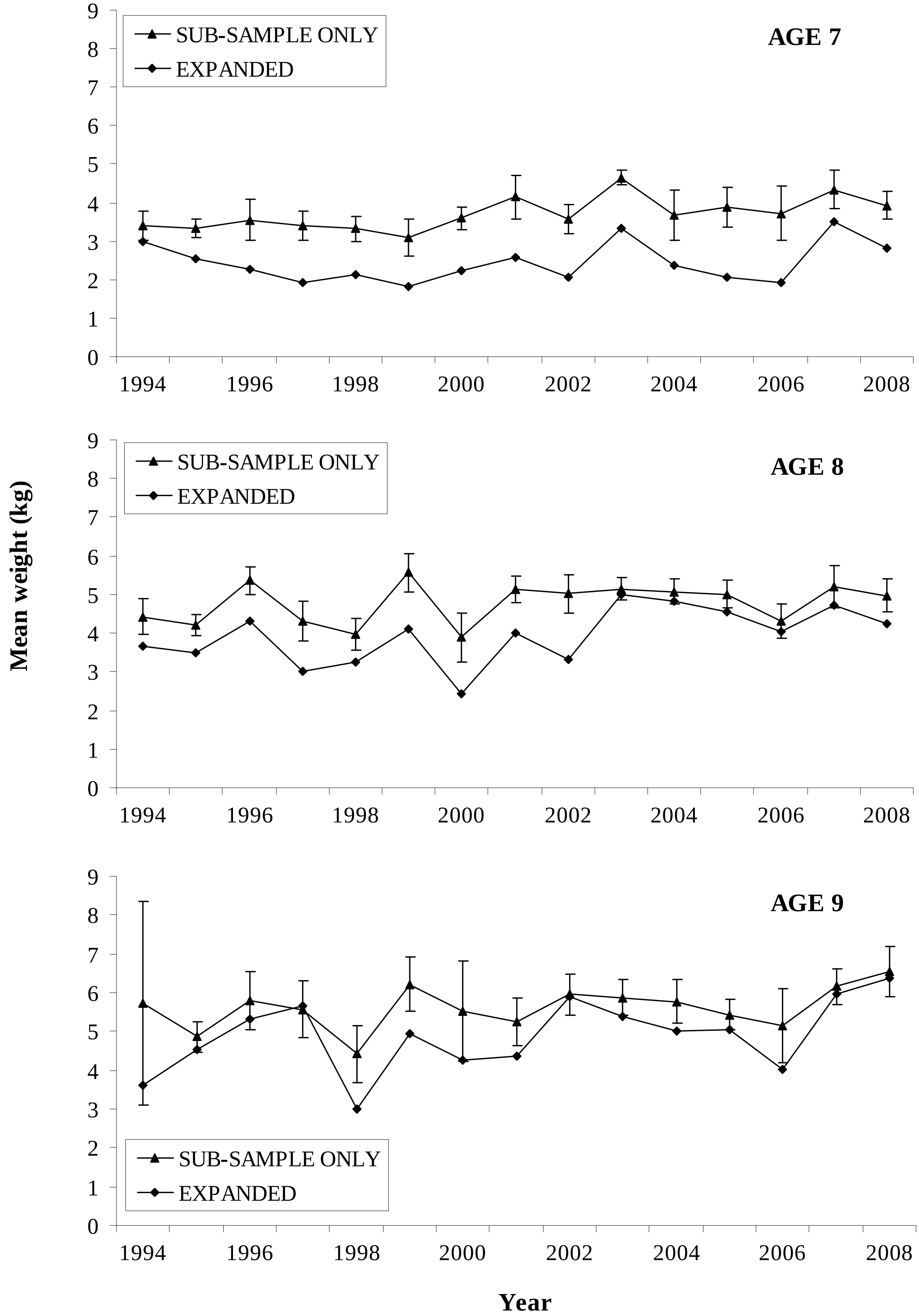


Figure 5. (Continued.)



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 Job 3, Task 1C was to characterize the size and age structure of commercially harvested striped bass (*Morone saxitilis*) from Maryland's Atlantic coast. Trawls and gill nets were permitted during the Atlantic season, which occurred between November 1, 2007 and April 30, 2008. 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 2007-April 2008 fishing season, the quota is managed by calendar year. Maryland's Atlantic coast fishery is not as large as the Chesapeake Bay commercial fishery and its annual quota comprises only 6% of Maryland's total commercial harvest quota. Monitoring of the coastal fishery began in 2006 to improve Maryland's catch-at-age and weight-at-age estimates used in the annual compliance report to the Atlantic States Marine Fisheries Commission as well as the coast-wide stock assessment.

METHODS

Data collection procedures

All striped bass commercially harvested in Maryland are required to pass through a Maryland Department of Natural Resources (MD DNR) approved check station. Check stations are typically cooperating fish dealers who report daily landings to MD DNR. A review of 2004 check station activity indicated that 85% of striped bass harvested along

Maryland's Atlantic coast passed through two check stations in Ocean City, Maryland. Consequently, sampling alternated between these two check stations as fish came in during the season. Catches were intermittent and personnel sampled when fish were available. A monthly sample target of 150 fish was established for November, December, and January, because the majority of the coastal harvest was landed during these three months. Fish were measured (mm TL) and weighed (kg) and scales were randomly taken from five fish per 10 mm length group per day for age determination.

Approximately 15 fish per month were purchased for sex determination. An incision was made in the abdomen of each fish to examine the gonads directly and determine the sex.

Analytical procedures

Age composition of the sample was estimated via two-stage sampling (Kimura 1977, Quinn and Desiro 1999). In stage one, a random sample of lengths was taken from the total catch from November 2007 through April 2008. For stage two, a sub-sample of scales from Atlantic coast striped bass was aged. The total number of scales to be aged was determined using a Vartot analysis, which is a derived index measuring the precision of an age-length key (ALK) (Kimura 1977, Lai 1987).

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 2007-April 2008 Atlantic fishery, the year used for age calculations was 2008. 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 2007 through April 2008 was estimated by applying the sample age distribution to the total landings.

Mean lengths-at-age and weights-at-age were calculated by year-class for the sub-sample of fish. Mean lengths-at-age and mean weights-at-age were also estimated for each year class using an expansion method. Bettoli and Miranda (2001) suggested that age-specific length distributions based on an aged sub-sample are often different than the age-specific length distribution based on the entire length sample. The two calculation methods (sub-sample means and expanded means) would result in equal means only if the length distributions for each age-class were normal, which rarely occurs in these data. Therefore, expanded means were calculated with an ALK and a probability table that applied ages from the sub-sample of aged fish to all sampled fish.

RESULTS and DISCUSSION

Sampling at coastal check stations was conducted on 11 days between November 2007 and January 2008. A total of 252 fish were measured and weighed and the ALK was developed from 119 scale samples.

Fish harvested during the 2007-2008 Atlantic coast fishing season ranged from age 4 to age 14. Most striped bass harvested were ages five through eight which is similar to the age range of striped bass harvested during the 2006-2007 fishing season (Table 1). Some striped bass were recruited into the Atlantic coast fishery at age 4, but due to the 24 inch minimum size limit, few younger fish were caught. The two most common ages harvested during the 2007-2008 Atlantic coast fishery were ages 7 and 5 (30% and 29% respectively of the estimated catch-at-age). Age 7 fish composed 29% of the aged sub-sample while age 5 fish composed only 14% of the aged sub-sample (Figure 1). The 2001 year-class (age 6 in 2006-2007) was also most abundant during the previous Atlantic fishing season (38% of the estimated harvest and 28% of the aged sample) suggesting that the 2001 year-class was strong. These data are consistent with results from the juvenile index survey which showed that the 2001 and 2003 year classes (ages 7 and 5, respectively) were large while the 2002 year-class (age 6 fish) was below average.

Striped bass sampled at Atlantic coast check stations during the 2007-2008 season had a mean length of 706 mm TL and mean weight of 3.8 kg. The most common length groups in the sample were between 630 and 690 mm TL which is similar to the length distribution of the 2006-2007 sample (Figure 2). The sample means-at-age and the expanded means-at-age for both length and weight also tended to be very similar (Tables 2 and 3). Most of the differences between sub-sampled and expanded means occurred between ages 5 and 8. The expanded means tended to be lower than the sub-sampled means. Recently recruited age 4 fish had an expanded mean length of 628 mm TL and expanded mean weight of 2.6 kg. Age 7 striped bass, the most abundant age harvested, had an expanded mean length of 694 mm TL and expanded mean weight of 3.4 kg. Age 5 striped bass, the next most abundant year-class harvested, had an expanded mean length of 645 mm TL and an expanded mean weight of 2.8 kg.

All of the 43 fish sampled for sex were accurately identified as male or female. Female striped bass composed 70% of the sampled harvest while males accounted for the remaining 30%. This is very similar to the 2006 – 2007 sample when female striped bass made up 74% of the sampled Atlantic coast harvest and males made up 26% (Durell et al. 2008). In contrast, the most recent sex ratio data from the Chesapeake Bay winter gill net fishery (2004-2005 season) indicated 85% of sampled fish were males and 15% females (Durell et al. 2006).

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Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Atlantic coast commercial fishery, November 2006-April 2007 and November 2007-April 2008.

2006-2007*			
Year-Class	**Age**	**Catch**	**Percent**
2002	4	432	2.4
2001	5	3,731	20.6
2000	6	6,954	38.3
1999	7	2,134	11.8
1998	8	2,487	13.7
1997	9	1,107	6.1
1996	10	890	4.9
1995	11	239	1.3
1994	12	28	0.2
1993	13	92	0.5
1992	14	17	0.0
1991	15	28	0.2
1990	16	6	0.0
	Total	**18,145**	**100**

2007-2008			
Year-Class	**Age**	**Catch**	**Percent**
2004	4	321	2.6
2003	5	3,530	29.0
2002	6	1,412	11.6
2001	7	3,631	29.9
2000	8	1,637	13.5
1999	9	506	4.2
1998	10	300	2.5
1997	11	301	2.5
1996	12	270	2.2
1995	13	145	1.2
1994	14	97	0.8
	Total	**12,150**	**100**

*This is the corrected catch-at-age table from last year's report.

Table 2. Sub-sample and expanded mean total lengths (mm TL) by year-class of striped bass sampled from Atlantic coast fishery, November 2007-April 2008. 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)
2004	4	1	624	---	---	7	628
2003	5	17	636	622	650	73	645
2002	6	10	704	673	735	29	683
2001	7	34	722	706	738	75	694
2000	8	25	775	750	801	34	747
1999	9	10	798	762	834	11	795
1998	10	6	857	785	928	6	855
1997	11	6	860	817	902	6	856
1996	12	5	885	800	971	6	881
1995	13	3	941	868	1013	3	939
1994	14	2	1055	737	1373	2	1055
Total	**---**	**119**	**---**	**---**	**---**	**252**	**---**

Table 3. Sub-sample and expanded mean weights (kg) by year-class of striped bass sampled from Atlantic coast fishery, November 2007-April 2008. 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)
2004	4	1	2.2	---	---	7	2.6
2003	5	17	2.6	2.4	2.7	73	2.8
2002	6	10	3.5	3.0	4.0	29	3.3
2001	7	34	3.8	3.5	4.0	75	3.4
2000	8	25	4.7	4.3	5.0	34	4.4
1999	9	10	5.5	4.6	6.4	11	5.2
1998	10	6	6.3	4.9	7.7	6	6.4
1997	11	6	6.7	5.8	7.7	6	6.4
1996	12	5	8.1	5.1	11.1	6	7.4
1995	13	3	8.2	4.1	12.3	3	8.5
1994	14	2	14.1	-15.8	43.9	2	14.1
Total	**---**	**119**	**---**	**---**	**---**	**252**	**---**

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

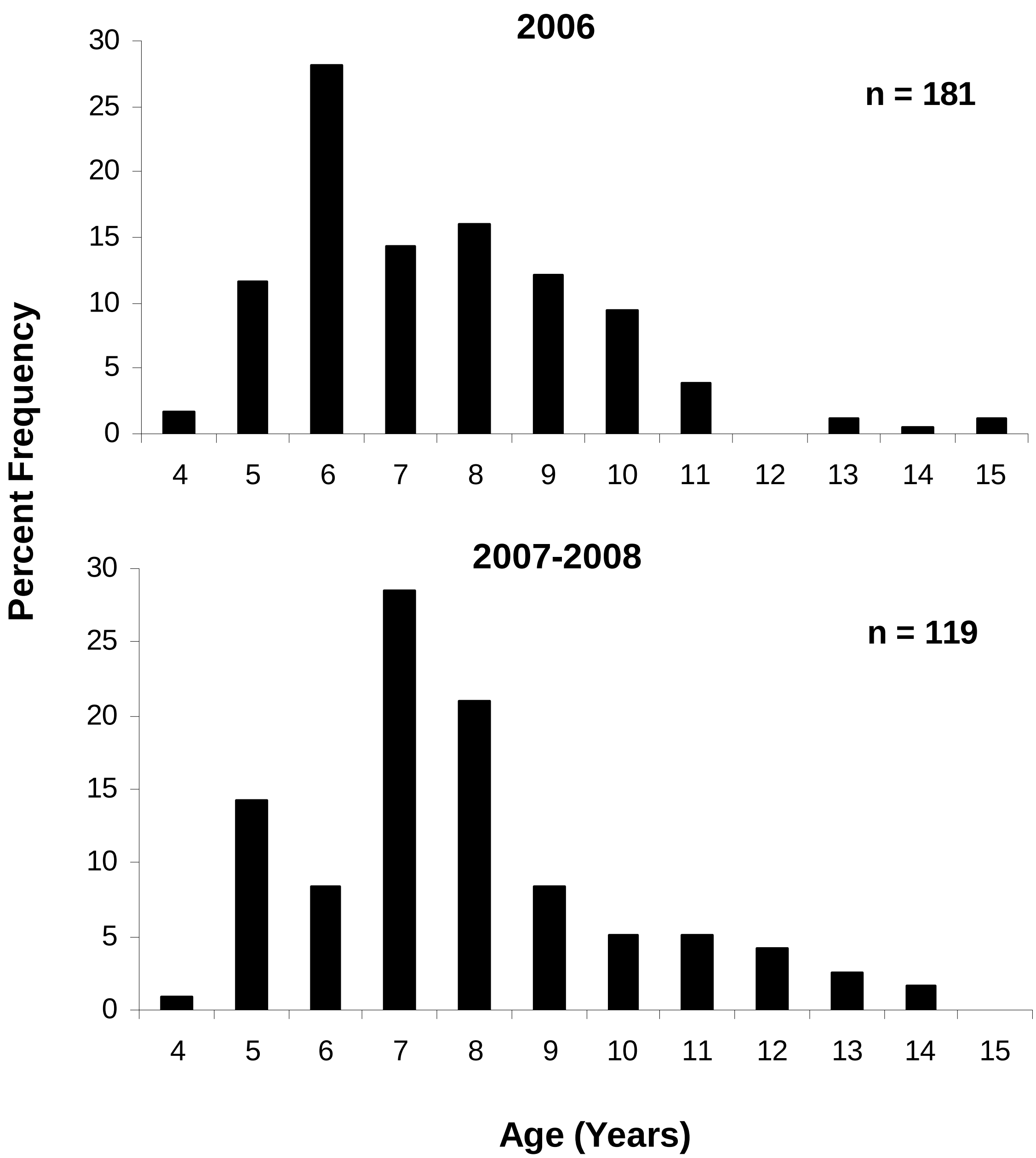
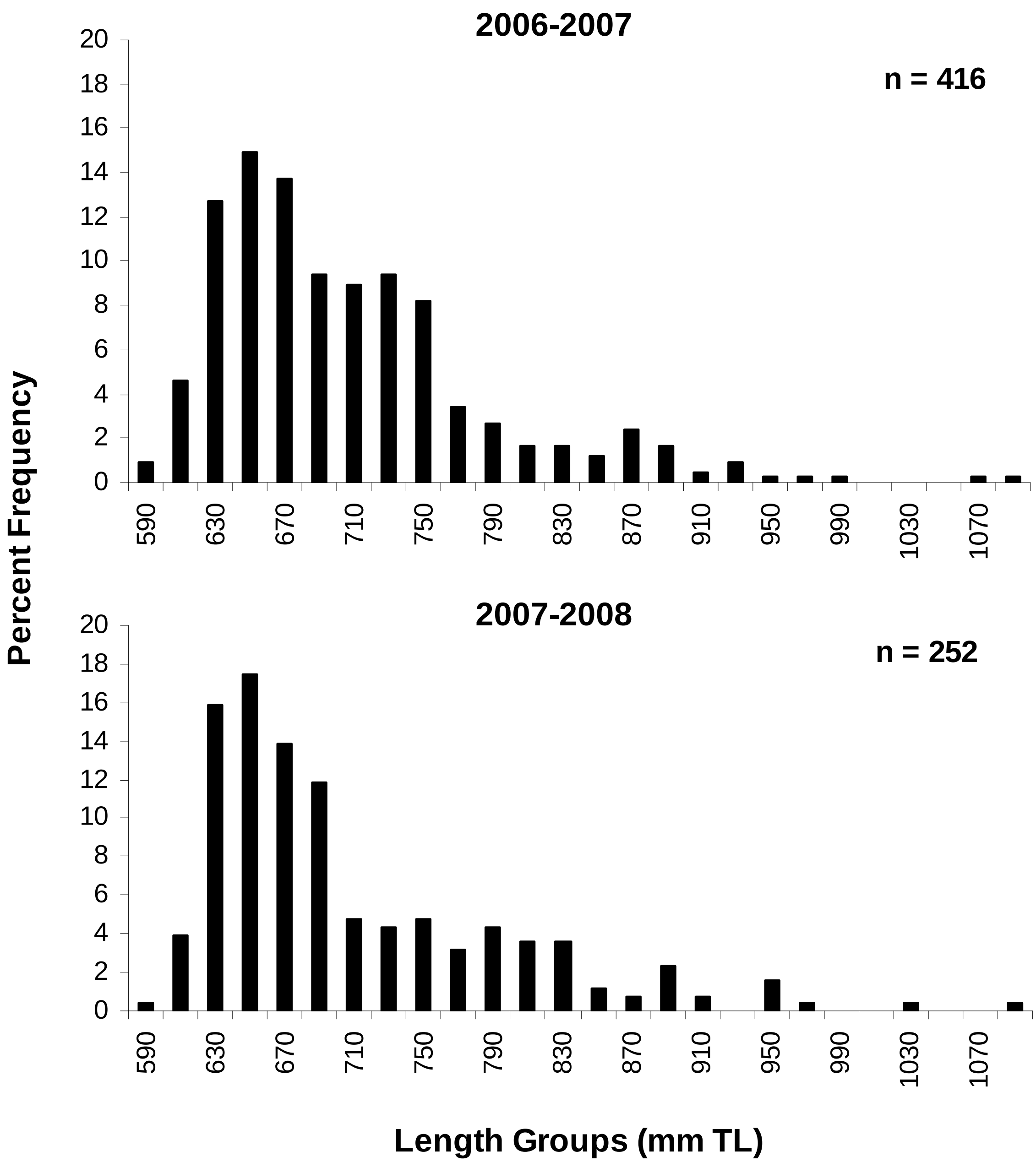


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, November 2006-April 2007 and November 2007-April 2008.



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Lisa Warner 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 (*Morone saxatilis*) in Chesapeake Bay. 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 2008 (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 15 for a total of 33 sample days. In the upper Bay, sampling was conducted from April 3 to May 16 for a total of 22 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 3.00, 3.75, 4.50, 5.25, 6.00, 6.50, 7.00, 8.00, 9.00 and 10.00-inch stretch-mesh. In the upper Bay, all 10 panels were tied together, end to end, so that the entire suite of meshes was fished 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 158 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 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. Finally, when time and fish condition permitted, U.S. Fish and Wildlife Service internal anchor tags were applied (see Project No. 2, Job No. 3, Task 4). Because of minimal results in recent years, and a shortage of coded wire tag (CWT) detection wands, fish were not checked for binary CWTs.

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 sampling (Project No. 2, Job No. 3, Task 5C) (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 in the ALKs in larger length groups. Patuxent River fish were assumed to be similar to striped bass 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 2008. 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 sets 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 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 male and female striped bass possessed unique physical selectivity characteristics, but no differences were evident for fish of the same sex in the upper Bay and the Potomac River. 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 1997-2008 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.

While calculation of the selectivity-corrected CPUEs has always produced confidence limits for the individual sex- and area-specific CPUEs, confidence limits for the pooled age-specific CPUE estimates are now reported as well. This method followed the procedure given 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:

- Time-series of daily water and air temperature and catch patterns were developed to examine patterns and relationships;
- The length-at-age (LAA) structure of the stock was examined among areas and over time, and confidence intervals for sex- and area-specific length-at-age were calculated (α=0.05);
- Trends in the age composition of the Bay spawning stock were examined. The percentage of the female spawning stock older than age 8, and the total stock older than age 8 were calculated;

- An index of spawning potential (ISP) was produced by converting the selectivity-corrected length group CPUE of female striped bass over 500 mm TL to biomass using 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. Scales aged from the various surveys used to create the sex-specific ALKs are presented in Table 1. The un-weighted time series data are presented by area in Tables 2-7.

The 2008 un-weighted CPUE for Potomac females (15) ranked sixteenth of 23 years in the time series, well below the series average of 28 (Table 2). The un-weighted CPUE for Potomac males (88) was the second lowest in the time-series, less than 2007 (97) and 81% below the time series average of 458 (Table 3). The upper Bay female CPUE (25) ranked fifteenth lowest in the time series, and below the time series average of 34 (Table 4). The un-weighted CPUE for upper Bay males was 634, the fifth highest CPUE in the time series, and above the time series average of 444 (Table 5). The Choptank River has not been sampled since 1996 (Tables 6 and 7).

Weighted CPUE values are 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 2008 selectivity-corrected total weighted CPUE (445) was over twice the 2007 value of 216 but slightly below the time series average of 497.

Confidence limits were calculated for the pooled and weighted CPUEs (Tables 9 and 10). Confidence limits could not be calculated for the 15+ age group in years when these values are the sum of multiple age-class CPUEs. Coefficients of Variation (CV) indicated a small variance in CPUE, as 77% of the CV values were less than 0.10 and 86% 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 (95%, Table 12) and weighted (96%, Table 13) pooled total CPUEs. Upper Bay males contributed 83% to the un-weighted and 88% to the weighted total CPUEs. Upper Bay males from the 2003 and 2004 year-classes contributed 54% to both the un-weighted and the weighted total upper Bay male CPUE, while males from the 2004 and 2005 year-classes comprised 65% of the Potomac weighted and un-weighted male CPUE.

Weighted CPUEs for Potomac River females were distributed across many year-classes, with the 1996 year-class contributing 32% of the weighted and 33% of the Potomac River female un-weighted CPUE. In the upper Bay, females from the 1996 year-class were more prevalent than any other year-class, contributing 32% to the upper Bay female un-weighted CPUE and 30% to the weighted CPUE. The next greatest contribution was from the 1998 year-class, which contributed 17% to the un-weighted and 16% to the weighted CPUEs.

As in previous years, upper Bay fish accounted for most of the total CPUE, contributing 87% to the total un-weighted and 91% to the weighted CPUEs. Overall, males from the 2003, 2004 and 2005 year-classes contributed almost equally to the total weighted CPUE in 2008, making up 70% of the total. Female striped bass from the 1996 year-class made up nearly one-third of the total weighted and un-weighted female CPUEs. Females from the 15+ age group contributed 7% to the weighted and 8% to the un-weighted female CPUE in 2008.

Temperature and catch patterns

Surface water temperatures on the Potomac River increased gradually over the duration of the 2008 survey. However, a sharp decline occurred as the survey ended. This dramatic decrease followed heavy rains from a storm system on May 10. Daily water temperatures ranged from 10.5 °C to 19.3 °C. Daily female CPUEs on the Potomac suggested sporadic spawning activity throughout the survey (Figure 2). The more consistent catches of females in early and mid-April correspond with the peaks in male CPUE on April 9th and April 19th, suggesting possible spawning activity.

Surface water temperatures on the upper Bay increased during the spawning survey from 8.4 °C to 18.6 °C. Daily female CPUEs from the upper Bay were sporadic, with a distinct peak on May 7 as water temperature neared 17 °C (Figure 3). The highest catches of male striped bass in the upper Bay occurred during the third week of April as water temperatures rose to 15 °C, with another smaller peak in early May.

In both systems, air temperatures increased gradually over the length of the entire survey with a cold spell occurring in the second week of May, prior to the end of the survey.

Length composition of the stock

In 2008, 298 male striped bass and 36 females were measured in the Potomac River, while 1,157 males and 26 females were sampled in the upper Bay (Figure 4). The length of one male striped bass in the upper Bay was not recorded.

Mean lengths of male striped bass collected from the Potomac River (447 mm TL ± 7 SE) and upper Bay (517 mm TL ± 4 SE) were significantly different (p = 0.0001) in 2008. Examination of the length distributions from each system showed that the mean size was affected by the higher catch in the upper Bay.

Male striped bass on the Potomac ranged from 279 to 1014 mm TL. The length distribution was influenced by the contribution of striped bass from the 2005 and 2004 year-classes. Male striped bass between 310 and 470 mm TL comprised 71% of the Potomac River male catch in 2008. The peak at 310 mm TL, representing the 2005 year-class, was most evident in the corrected CPUE values (Figure 5). The small peak at 790 mm TL, comprised of the 2000 year-class, was only evident in the corrected CPUE values.

Male striped bass on the upper Bay ranged from 296 to 1041 mm TL. Males between 410 and 510 mm TL contributed 62% to the total catch of males in the upper Bay. The 2005 year-class was represented by the high CPUEs in the 350 mm length group. The length distribution of male striped bass from the upper Bay was dominated by fish from the 2003 year-class. The uncorrected and corrected CPUE values reflected the influence of this large year-class over a wide spread of length groups. The 1994 year-class was represented in the corrected CPUE peak at 1050 mm.

Mean lengths of female striped bass sampled from the Potomac River and upper Bay in 2008 were not significantly different (p = 0.91). Female striped bass sampled from the Potomac ranged from 510 to 1193 mm TL (mean = 975, ± 18 SE), while females sampled in the upper Bay ranged from 849 to 1070 mm TL (mean = 973 ± 12 SE) (Figure 6).

Female striped bass between 910 and 1010 mm TL constituted 69% of the total female uncorrected CPUE, and 50% of the corrected CPUE in the Potomac River. The highest uncorrected CPUEs occurred in the 1010 mm length group. Application of the selectivity model to the data corrected the catch upward across the length distribution. The length distribution of female striped bass from the Potomac River showed the highest corrected CPUEs occurred in the 1110 mm length group which was comprised of striped bass from the 1992 through 1996 year-classes (Figure 6). In the upper Bay, 35% of the female corrected CPUE and 49% of the uncorrected CPUE was comprised of fish between 930 and 990 mm TL. The uncorrected CPUE peak value at 930 mm TL reflects the contribution of the 1996-1998 year-classes, while the corrected peak at 850 mm reflects the contributions of return spawners from all year-classes from 1996-2001 except 1997.

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 prohibited testing for differences in LAA relationships in some cases. Information from the area-specific length-at-age (LAA) relationships reflected known biology of the species, as there was a significant difference between LAA for the male and female spawning stocks encountered in the Potomac and Upper Bay in 2008 ($P>F < 0.001$).

Results of an analysis of covariance showed a significant age by area interaction for males ($p = 0.0001$) and no interaction for female ($p = 0.20$) striped bass. The difference in males stems from differences in sample sizes. Based on previous investigations which showed 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 2008 to produce separate male and female ALKs (Warner et al., 2008, Warner et al., 2006). 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 due to small sample sizes.

When comparing LAA between years, only gill net fish were used. Male and female LAA have been relatively stable since the mid 1990's (Figures 7 and 8). Mean lengths-at-age of male striped bass sampled in 2008 showed significant differences (t-tests, $\alpha = 0.05$) from those in 2007, for ages nine ($p = 0.02$) and eleven ($p = 0.0002$). Mean lengths-at-age of female striped bass sampled in 2008 showed a significant difference from those in 2007 for age nine only ($p = 0.03$) due to small sample sizes.

Age composition of the stock

Fifteen age-classes were sampled, ranging from ages 2 to 18 (Tables 14 and 15). Male striped bass ranged from ages 2 to 15, with age 5 fish (2003 year-class) being the most abundant male cohort. The majority of females were ages 7 to 15, with one age 4 and one age 18 also encountered. Age 12 females (1996 year-class) 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). The contribution of males age 11 and older has shown an increase in the later years of the time-series. Females younger than age 7 have been uncommon in the spawning stock since 1996 (Figure 9). However, one age 4 female was sampled on the Potomac River in 2008, the first since 1994.

In 2008, age 8+ females composed 95% of the female spawning stock (Figure 10), a slight increase from 2007. The percentage of the overall sample (males and females combined) age 8 and older has varied without trend since 1996 (Figure 11). The 2008 value of 20% was a 34% drop from the contribution in 2007, but was similar to that of 2006. The percentage of age 8+ fish among males and females is heavily influenced by strong year-classes and shows cyclical variations (Figure 9). Although the relative number of older fish declined between 1997 and 2000 as a result of the dilution of the spawning stock by young males from the strong 1993 and 1996 year-classes, more have been encountered in recent years (Figure 11).

The most recent estimate of spawning stock biomass (SSB) for coastal females was approximately 55 million pounds in 2006, well above the SSB target of 38.6 million pounds and the threshold of 30.9 million pounds (NOAA 2008). The MD DNR estimate of female SSB generated from the upper Bay in 2008 (230) dropped below the time-series average of 280 for the first time since 2002 (Table 16, Figure 12). The 2008 Potomac River female SSB (163) was also below the time series average of 243. Estimates from both areas have varied without trend in recent years.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2008.

	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 1985-2008 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**
Average																**28**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2008 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**
Average																**458**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the upper Bay during the 1985-2008 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**
Average																**34**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the upper Bay during the 1985-2008 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**
Average																**444**

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 (1985–2008) 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**
Average																**497**

Table 9. Lower confidence limits (95%) of the pooled, weighted, annual age-specific CPUEs (1985–2008) 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	*

* 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 (1985–2008) 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	*

* 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 (1985–2008) for the Maryland Chesapeake Bay striped bass spawning stock.

	Age														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
1985	0	0.05	0.05	0.05	0.06	0.11	0.28	2.16	2.50	1.04	0.29	0.58	0.64	2.14	*
1986	0	0.03	0.03	0.03	0.06	0.05	0.09	0.05	0.18	0	0	0	0.28	2.62	*
1987	0	0.04	0.03	0.02	0.02	0.16	0.76	0.05	4.32	0	0	0	0.34	0.36	*
1988	0	0.06	0.05	0.04	0.03	0.04	0.45	0.00	13.03	0.42	0	0	0	1.10	*
1989	0	0.13	0.02	0.09	0.11	0.07	0.12	1.17	0.29	2.92	0	0	1.31	0	*
1990	0	0.08	0.03	0.02	0.06	0.08	0.04	0.10	0.28	1.51	1.07	0.49	3.18	7.85	*
1991	0	0.11	0.02	0.03	0.02	0.08	0.07	0.07	0.25	0.96	0.29	0	5.10	4.29	0.82
1992	0.79	0.08	0.03	0.03	0.03	0.03	0.05	0.05	0.10	0.21	0.14	0	3.38	3.16	*
1993	0	0.13	0.03	0.07	0.03	0.03	0.05	0.07	0.10	0.24	0.23	0.54	0.49	2.19	*
1994	0	0.10	0.07	0.02	0.09	0.06	0.04	0.05	0.15	0.06	0.13	0.11	0.06	0.0	*
1995	0	0.04	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.29	0.0	*
1996	0	0.87	0.03	0.02	0.12	0.03	0.06	0.05	0.07	0.19	0.16	0.17	0.16	0.0	0
1997	0	0.02	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
1998	0	0.00	0.01	0.02	0.02	0.01	0.07	0.02	0.02	0.02	0.02	0.05	0.15	0.11	0.22
1999	0	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	0.17
2000	0	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	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	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	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	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	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	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	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	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	*

* 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 2008. 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
2007	1	0.0	0.0	0.0	0.0	0.0	0.0
2006	2	7.8	1.0	0.0	0.0	6.2	1.5
2005	3	157.5	20.7	0.0	0.0	36.7	120.9
2004	4	187.5	24.6	0.4	0.0	20.4	166.8
2003	5	190.8	25.0	0.4	0.0	12.0	178.4
2002	6	28.5	3.7	0.0	0.0	1.7	26.8
2001	7	38.6	5.1	0.9	0.5	1.8	35.4
2000	8	33.2	4.4	0.1	1.8	2.3	29.0
1999	9	19.0	2.5	0.4	2.6	1.1	14.9
1998	10	20.7	2.7	1.8	4.2	1.2	13.6
1997	11	17.9	2.3	2.4	3.6	1.3	10.5
1996	12	25.7	3.4	4.9	7.9	2.4	10.4
1995	13	22.5	3.0	1.2	2.1	0.4	18.8
1994	14	5.8	0.8	1.2	0.8	0.0	3.8
≤1993	15+	6.5	0.9	1.4	1.7	0.2	3.3
Total		762.0		15.0	25.3	87.6	634.1
% of Total				2	3	12	83
% of Sex				37	63	12	88
% of Potomac				15		85	
% of Upper Bay					4		96

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, late March through May 2008. 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
2007	1	0.0	0.0	0.0	0.0	0.0	0.0
2006	2	3.3	0.8	0.0	0.0	2.4	0.9
2005	3	88.4	19.9	0.0	0.0	14.1	74.3
2004	4	110.5	24.8	0.2	0.0	7.9	102.5
2003	5	114.4	25.7	0.2	0.0	4.6	109.7
2002	6	17.1	3.9	0.0	0.0	0.7	16.5
2001	7	23.1	5.2	0.4	0.3	0.7	21.8
2000	8	19.8	4.5	0.0	1.1	0.9	17.8
1999	9	11.3	2.6	0.1	1.6	0.4	9.2
1998	10	12.1	2.7	0.7	2.6	0.4	8.3
1997	11	10.1	2.3	0.9	2.2	0.5	6.5
1996	12	14.1	3.2	1.9	4.8	0.9	6.4
1995	13	13.4	3.0	0.5	1.3	0.1	11.5
1994	14	3.3	0.7	0.4	0.5	0.0	2.3
≤1993	15+	3.6	0.8	0.5	1.0	0.1	2.0
Total		444.8		5.8	15.5	33.8	389.7
% of Total				1	3	8	88
% of Sex				27	73	8	92
% of Potomac				15		85	
% of Upper Bay					4		96

* 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 2008.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2006	2	POTOMAC	1	279	-	-	-	-
		UPPER	1	307	-	-	-	-
		COMBINED	2	293	115	471	19.8	14.0
2005	3	POTOMAC	16	341	322	360	36.3	9.1
		UPPER	10	344	328	360	22.7	7.2
		COMBINED	26	342	330	355	31.3	6.1
2004	4	POTOMAC	10	435	418	452	24.1	7.6
		UPPER	15	420	389	451	55.2	14.3
		COMBINED	25	426	407	445	45.3	9.1
2003	5	POTOMAC	24	537	508	567	70.0	14.3
		UPPER	32	559	538	581	60.4	10.7
		COMBINED	56	550	533	567	65.0	8.7
2002	6	POTOMAC	6	624	542	705	78.0	32.0
		UPPER	10	623	576	670	66.1	20.9
		COMBINED	16	623	587	660	68.1	17.0
2001	7	POTOMAC	14	685	652	717	56.0	15.0
		UPPER	18	700	671	729	58.6	13.8
		COMBINED	32	693	673	714	57.1	10.1
2000	8	POTOMAC	3	776	612	941	66.0	38.3
		UPPER	35	747	723	771	69.8	11.8
		COMBINED	38	749	727	772	69.1	11.2
1999	9	POTOMAC	2	697	621	773	8.5	6.0
		UPPER	17	823	788	858	68.3	16.6
		COMBINED	19	810	773	846	75.7	17.4
1998	10	POTOMAC	3	856	627	1085	92.0	53.1
		UPPER	12	824	775	874	78.0	22.5
		COMBINED	15	831	787	874	78.5	20.3
1997	11	POTOMAC	3	888	581	1195	123.6	71.3
		UPPER	12	896	870	922	41.1	11.9
		COMBINED	15	894	862	927	59.3	15.3
1996	12	POTOMAC	1	950	-	-	-	-
		UPPER	17	908	880	936	54.4	13.2
		COMBINED	18	910	883	937	53.8	12.7
1995	13	POTOMAC	0	-	-	-	-	-
		UPPER	5	918	807	1030	90.1	40.3
		COMBINED	5	918	807	1030	90.1	40.3
1994	14	POTOMAC	0	-	-	-	-	-
		UPPER	2	1010	787	1232	24.7	17.5
		COMBINED	2	1010	787	1232	24.7	17.5
1993	15	POTOMAC	0	-	-	-	-	-
		UPPER	3	965	891	1038	29.7	17.1
		COMBINED	3	965	891	1038	29.7	17.1

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 males combined, late March through May 2008.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2004	4	POTOMAC	1	510	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	510	-	-	-	-
2001	7	POTOMAC	1	800	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	800	-	-	-	-
2000	8	POTOMAC	0	-	-	-	-	-
		UPPER	1	849	-	-	-	-
		COMBINED	1	849	-	-	-	-
1999	9	POTOMAC	1	885	-	-	-	-
		UPPER	2	896	820	972	8.5	6.0
		COMBINED	3	892	871	914	8.7	5.0
1998	10	POTOMAC	2	966	464	1467	55.9	39.5
		UPPER	4	960	847	1073	71.0	35.5
		COMBINED	6	962	899	1025	60.5	24.7
1997	11	POTOMAC	9	976	941	1011	45.1	15.0
		UPPER	2	969	606	1331	40.3	28.5
		COMBINED	11	975	946	1003	42.4	12.8
1996	12	POTOMAC	12	983	946	1021	58.9	17.0
		UPPER	8	980	944	1016	43.1	15.3
		COMBINED	20	982	958	1006	51.9	11.6
1995	13	POTOMAC	4	965	898	1031	41.9	21.0
		UPPER	3	1000	888	1112	45.1	26.0
		COMBINED	7	980	939	1020	43.7	16.5
1994	14	POTOMAC	2	1062	516	1608	60.8	43.0
		UPPER	3	1011	912	1111	40.0	23.1
		COMBINED	5	1032	970	1094	49.9	22.3
1993	15	POTOMAC	2	1080	775	1385	33.9	24.0
		UPPER	2	1052	823	1281	25.5	18.0
		COMBINED	4	1066	1019	1113	29.3	14.7
1990	18	POTOMAC	1	1071	-	-	-	-
		UPPER	0	-	-	-	-	-
		COMBINED	1	1071	-	-	-	-

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	Choptank River	Potomac River
1985	64.93	290.97	25.90
1986	151.95	129.67	45.70
1987	400.49	195.89	88.84
1988	250.32	309.27	63.60
1989	120.29	597.86	80.54
1990	98.42	899.29	62.52
1991	109.38	1010.60	138.65
1992	274.95	689.89	379.35
1993	278.52	1014.32	420.88
1994	87.26	449.78	Not Sampled
1995	547.66	Not Sampled	293.77
1996	347.87	1225.66	391.57
1997	256.89	Not Sampled	369.58
1998	157.41	Not Sampled	216.98
1999	161.44	Not Sampled	275.19
2000	169.91	Not Sampled	301.76
2001	490.21	Not Sampled	273.23
2002	266.39	Not Sampled	380.74
2003	566.24	Not Sampled	118.46
2004	389.76	Not Sampled	578.78
2005	469.74	Not Sampled	196.11
2006	407.50	Not Sampled	461.58
2007	419.75	Not Sampled	263.27
2008	230.19	Not Sampled	163.08
Average	**279.89**	**619.38**	**243.05**

Figure 1. Drift gill net sampling locations in spawning areas of the upper Chesapeake Bay and the Potomac River, late March - May 2008.

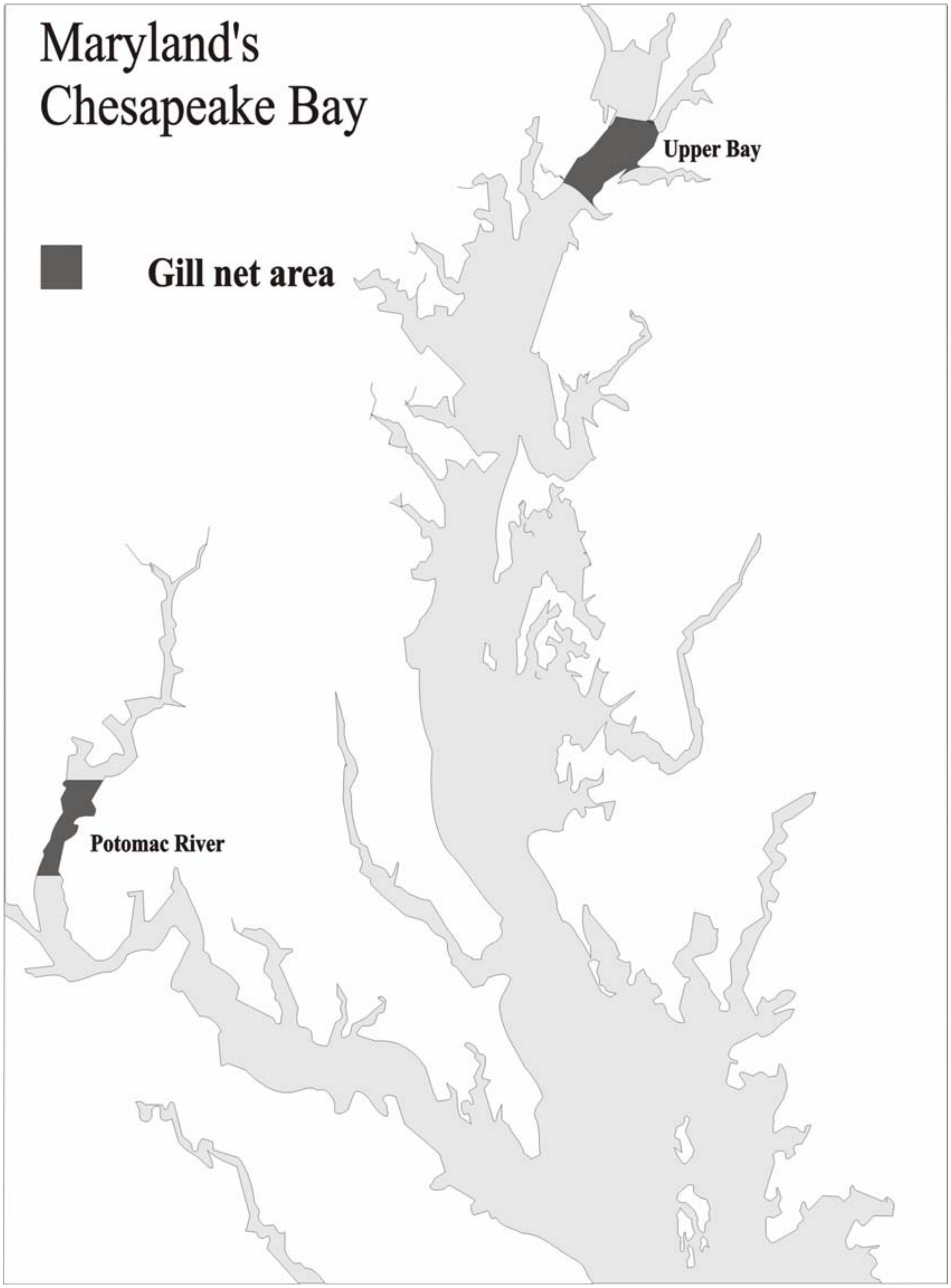


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, late March through May 2008. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

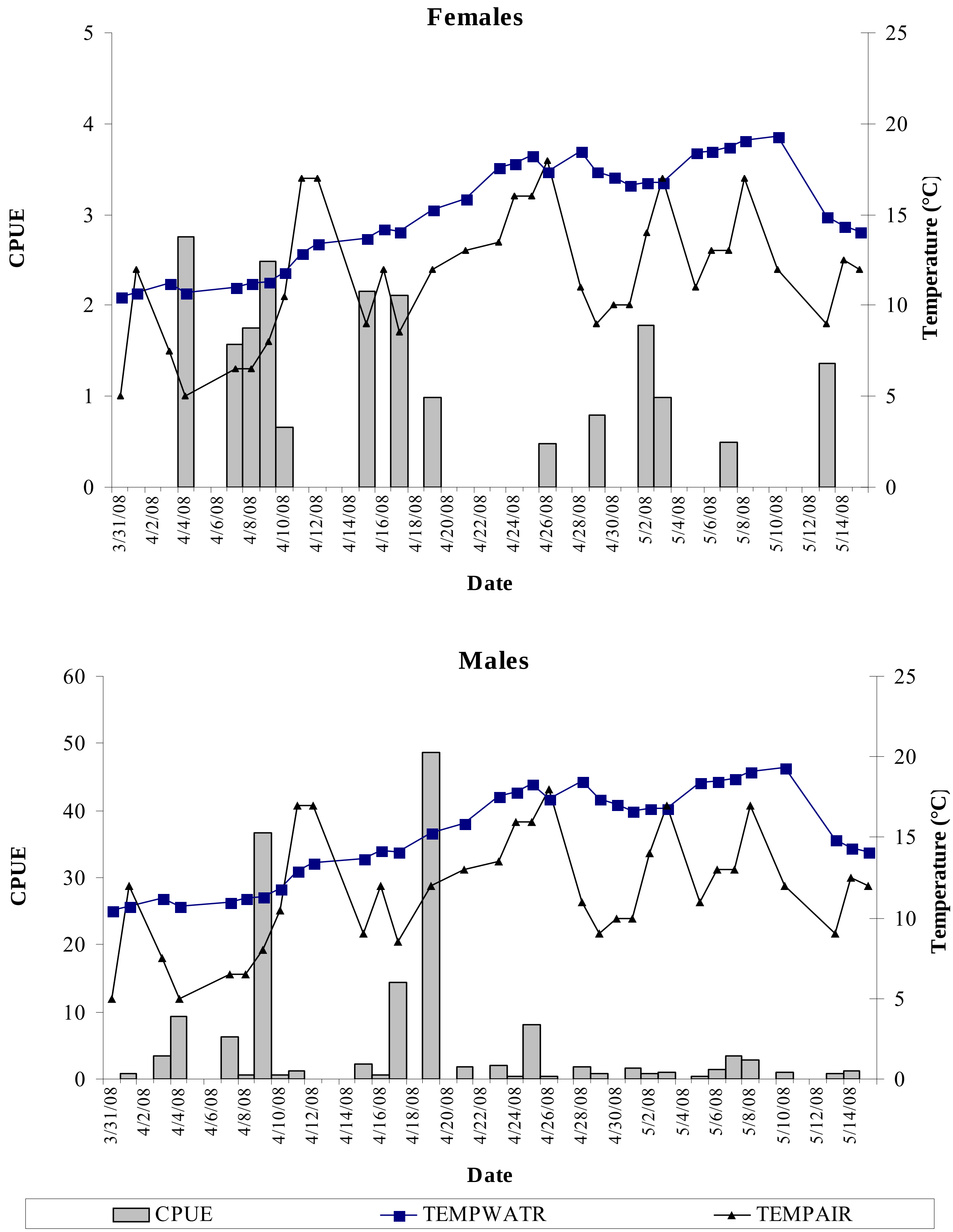
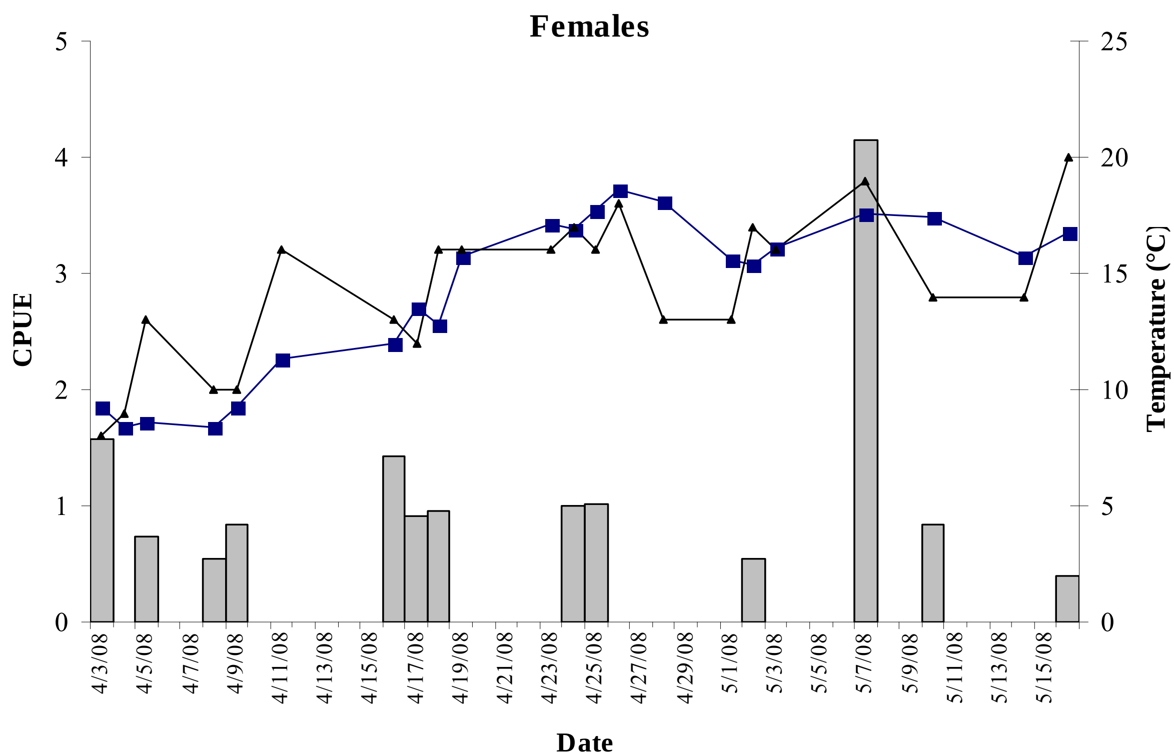


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the upper Chesapeake Bay, April through May 2008. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.



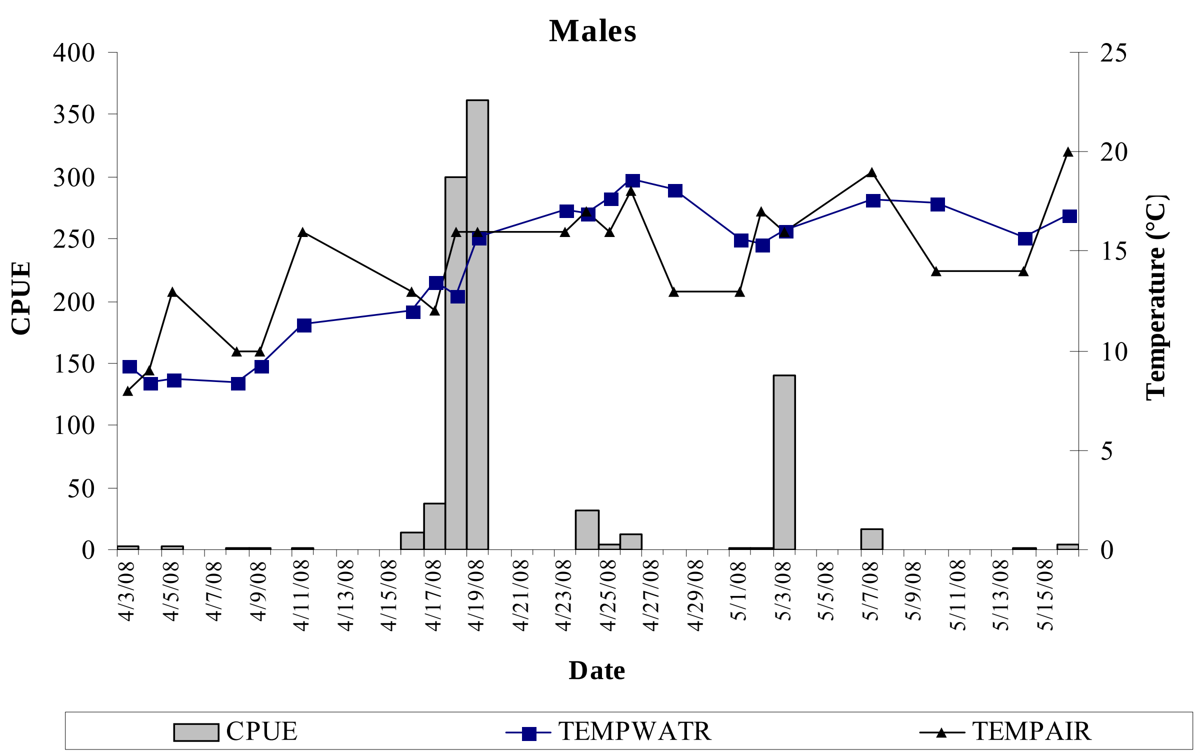
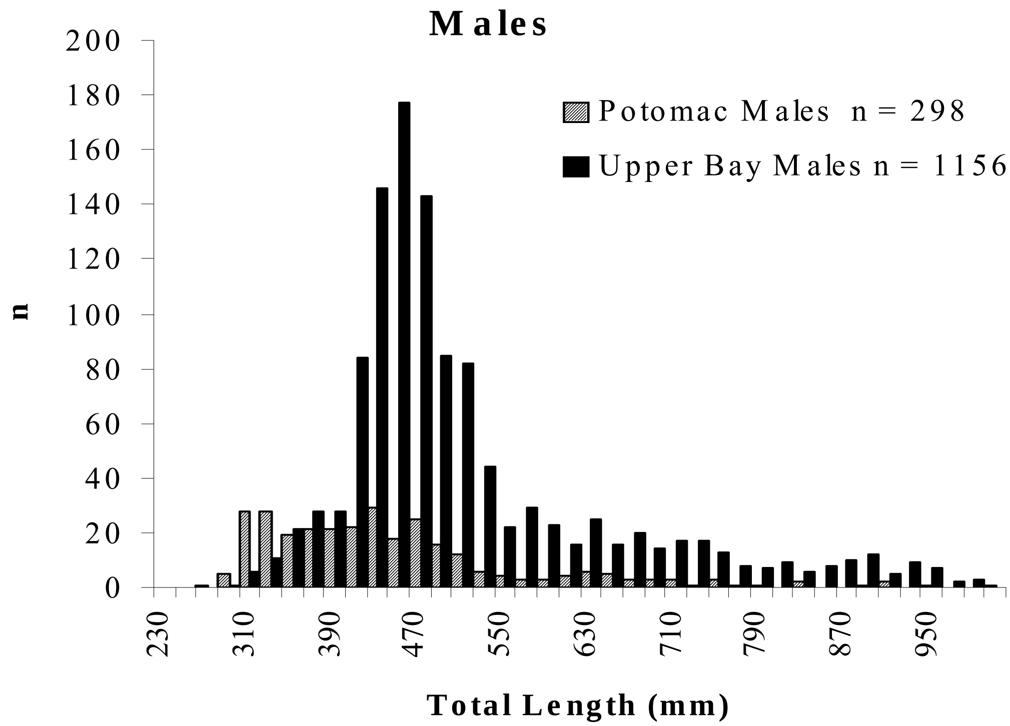
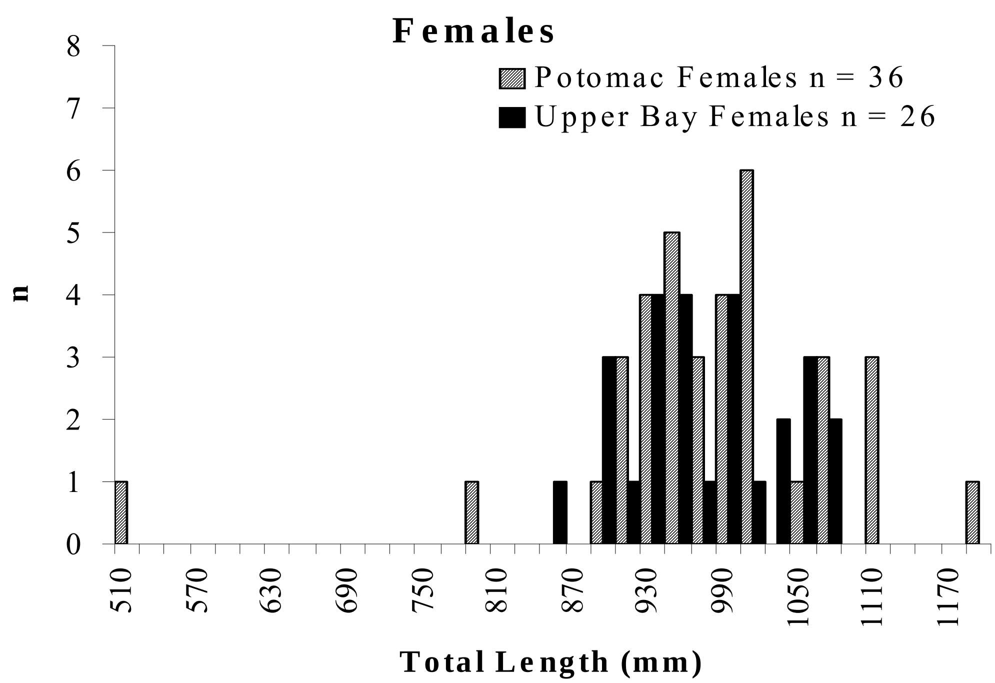


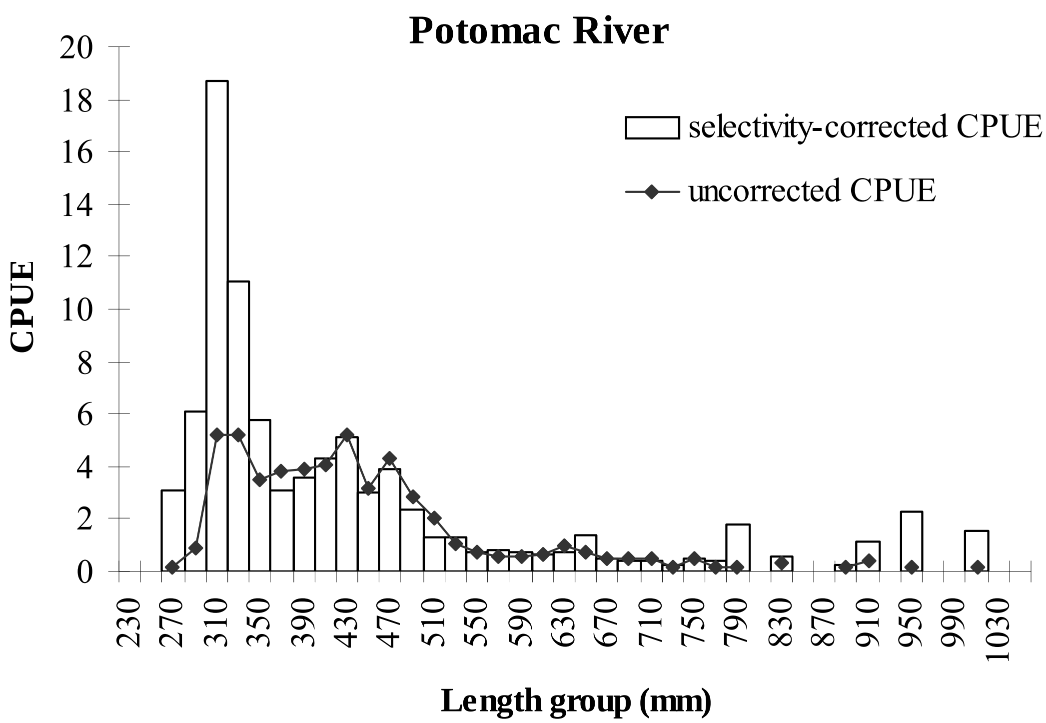
Figure 4. Length frequency of male and female striped bass from the spawning areas of the upper Chesapeake Bay and Potomac River, March through May 2008. Note different scales.





* Note the length of one male striped bass on the upper Bay was not recorded.

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 2008. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net. Note different scales.



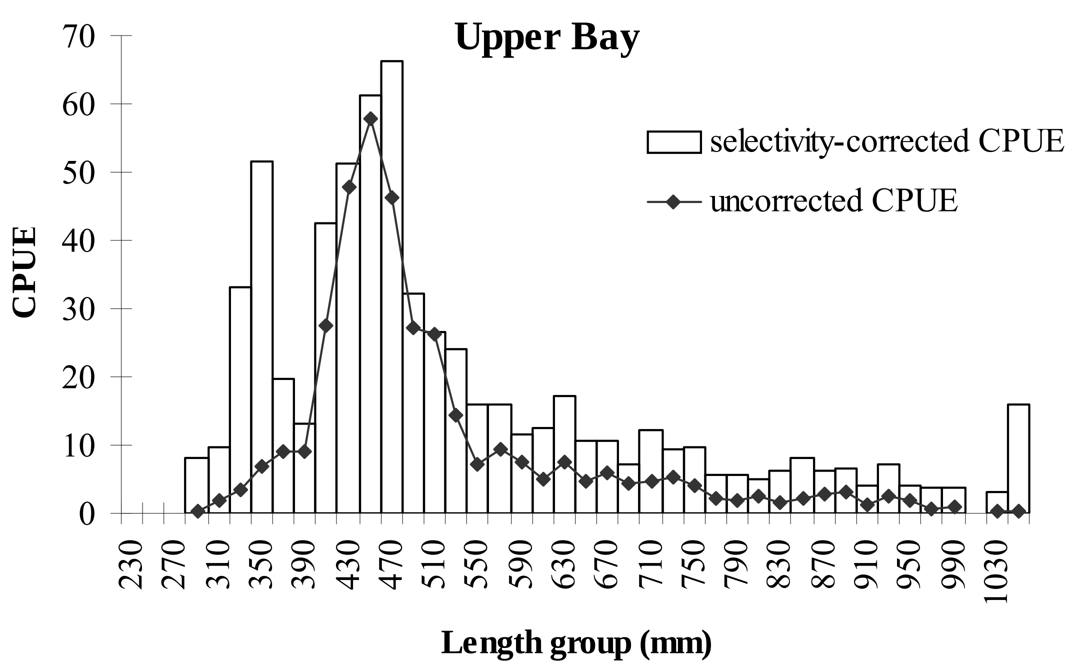
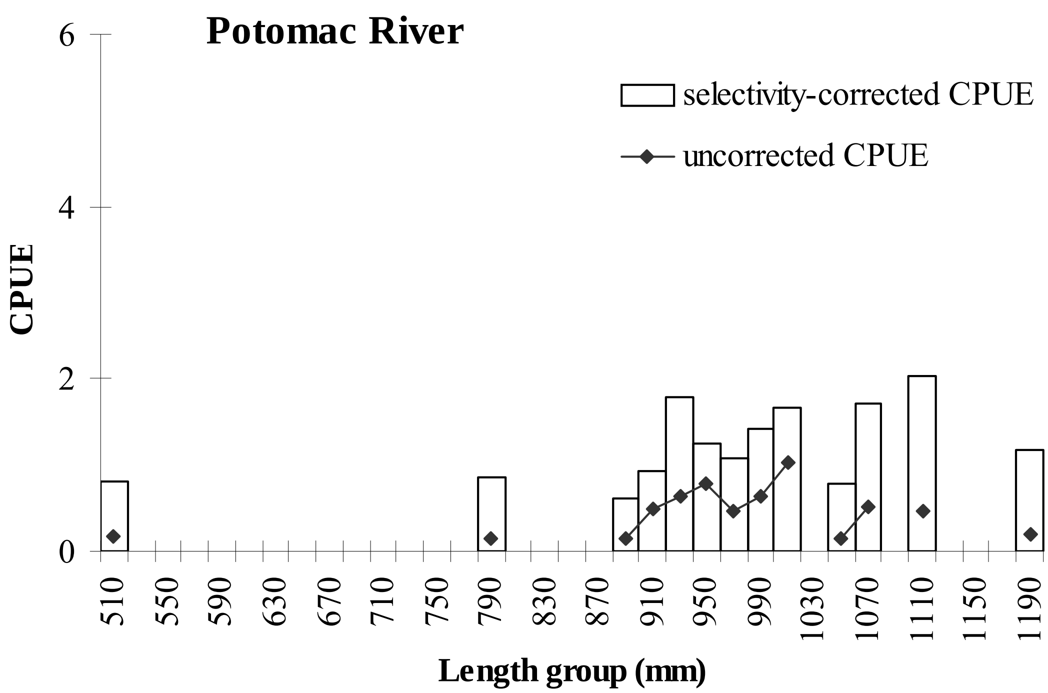


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the upper Bay and Potomac River, late March - May 2008. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



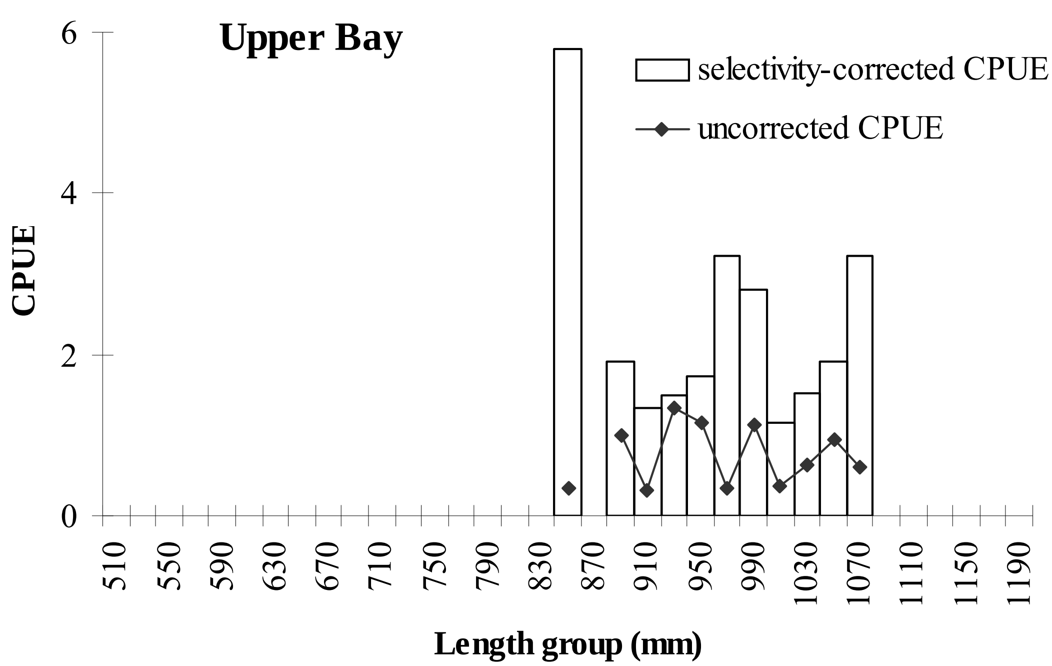


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985-2008. Error bars are 95% confidence intervals. The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

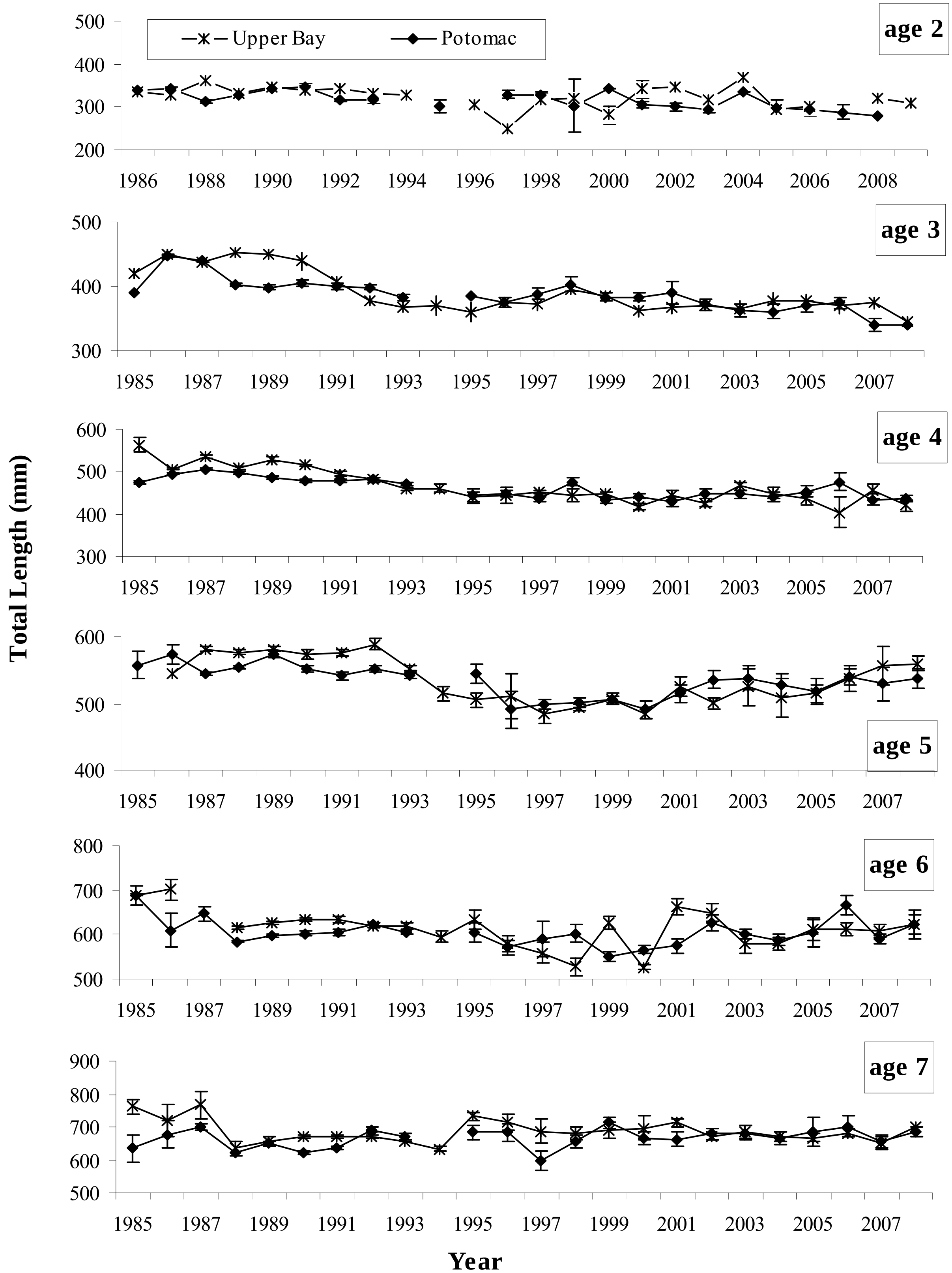


Figure 7. Continued.

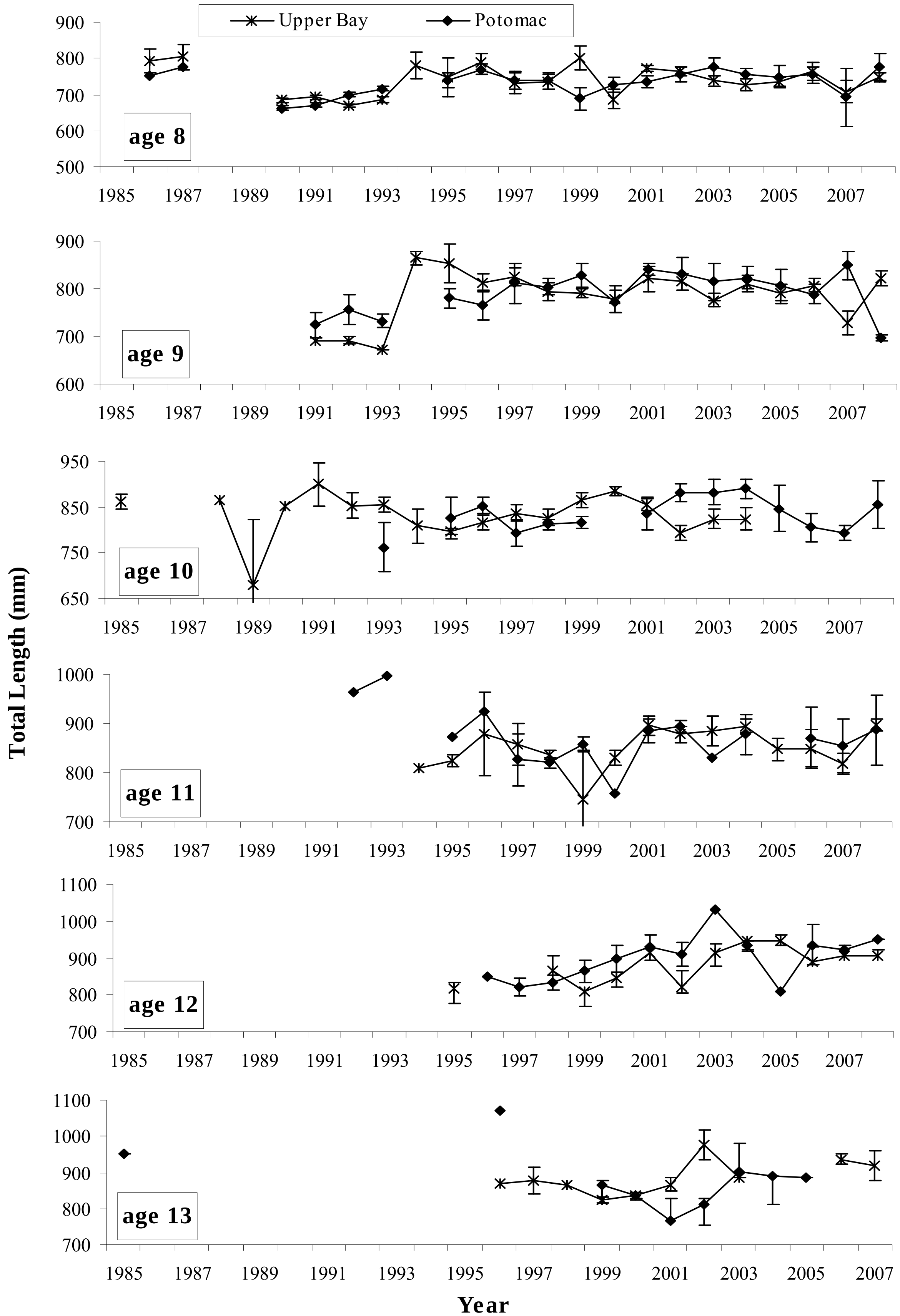


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from
spawning areas of the Potomac River and upper Chesapeake Bay during late March through May, 1985–2008. Error bars are 95% confidence intervals. Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

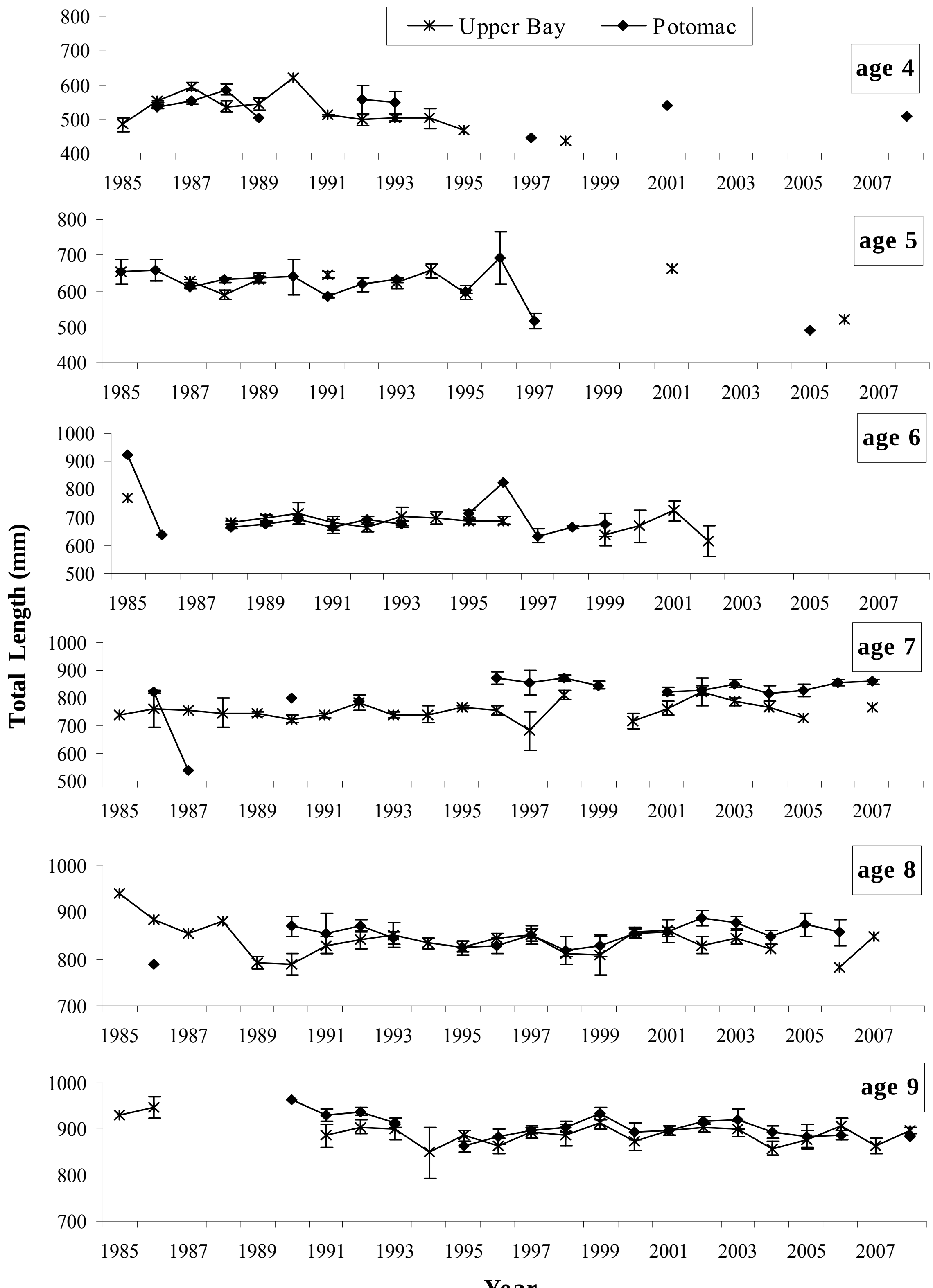


Figure 8. Continued.

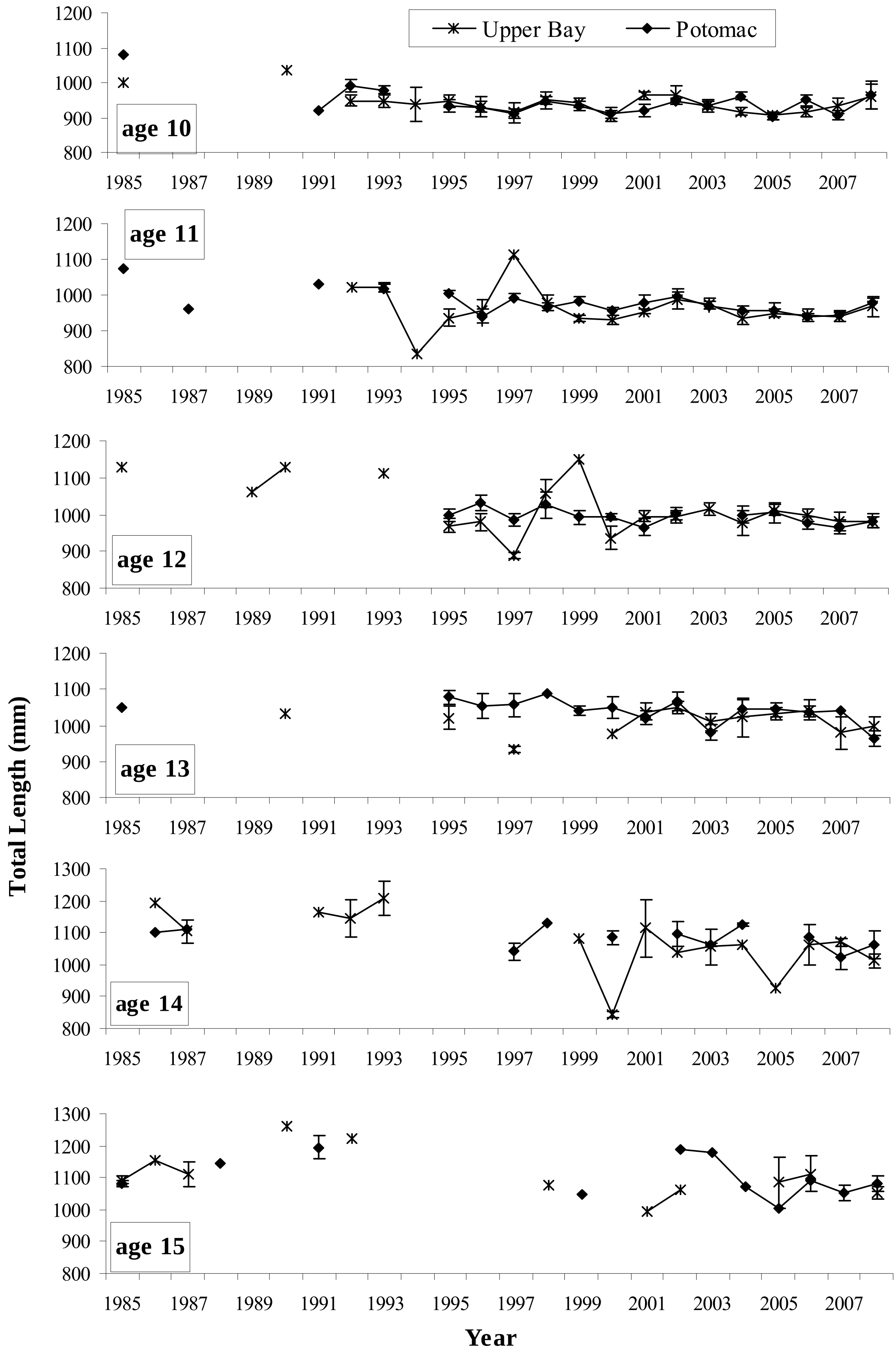


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the 2008 coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

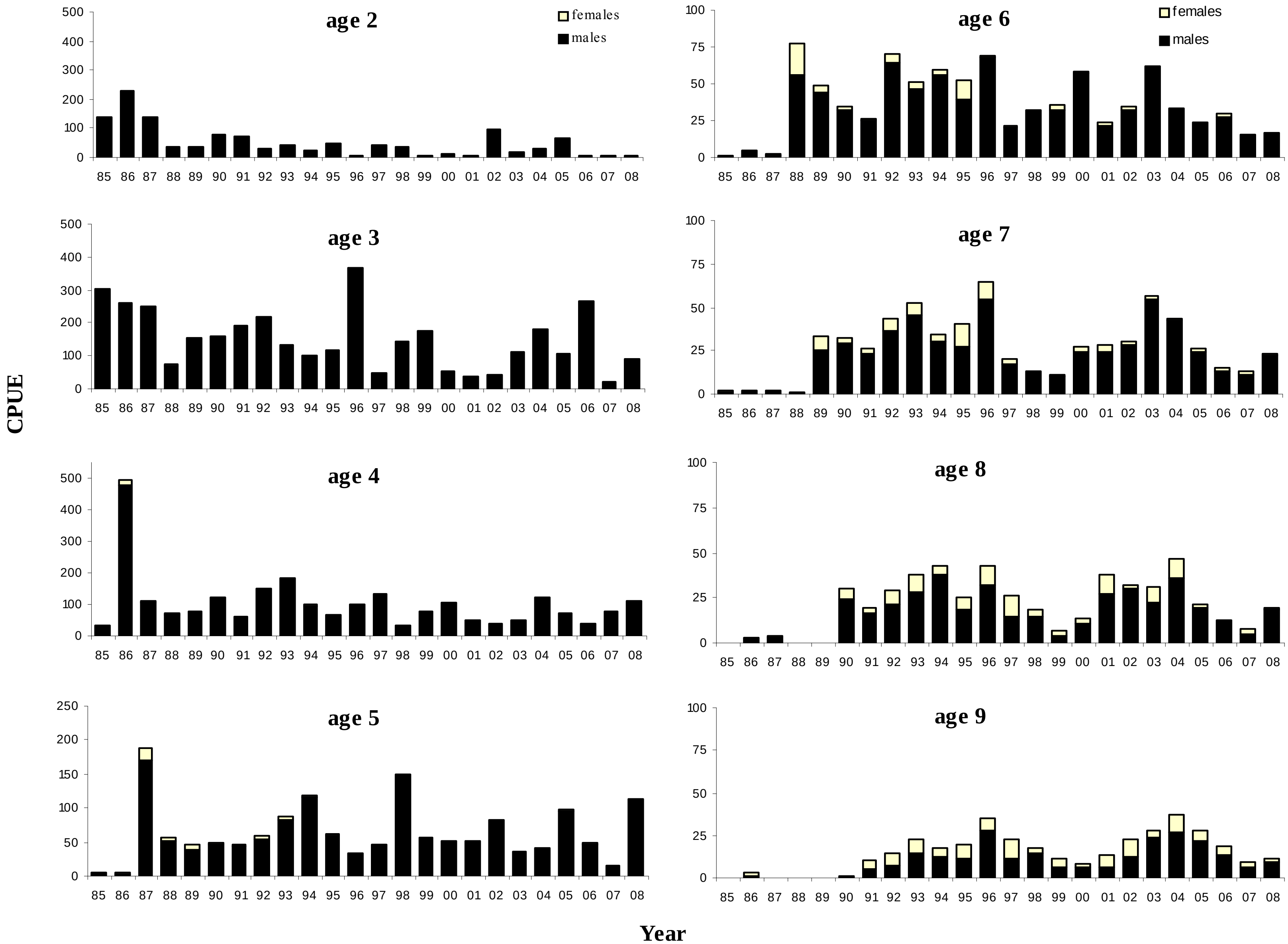


Figure 9. Continued.

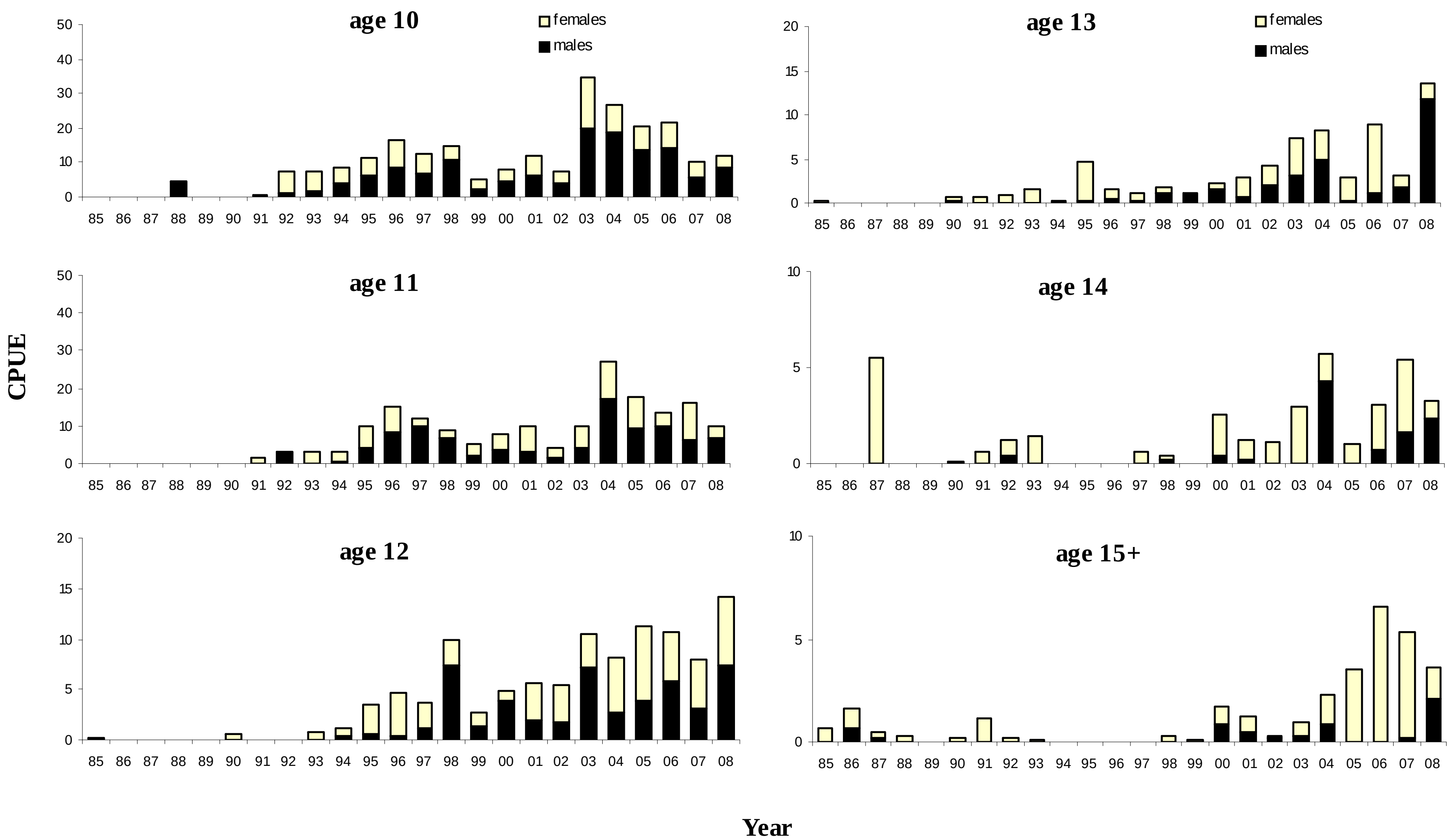
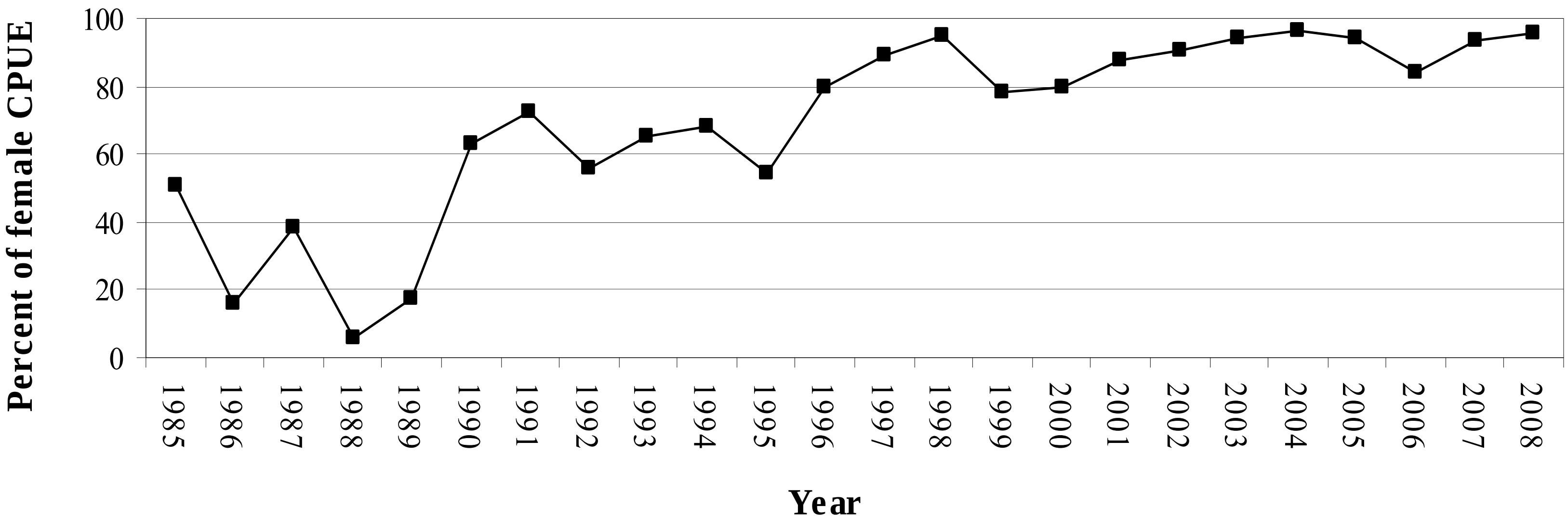
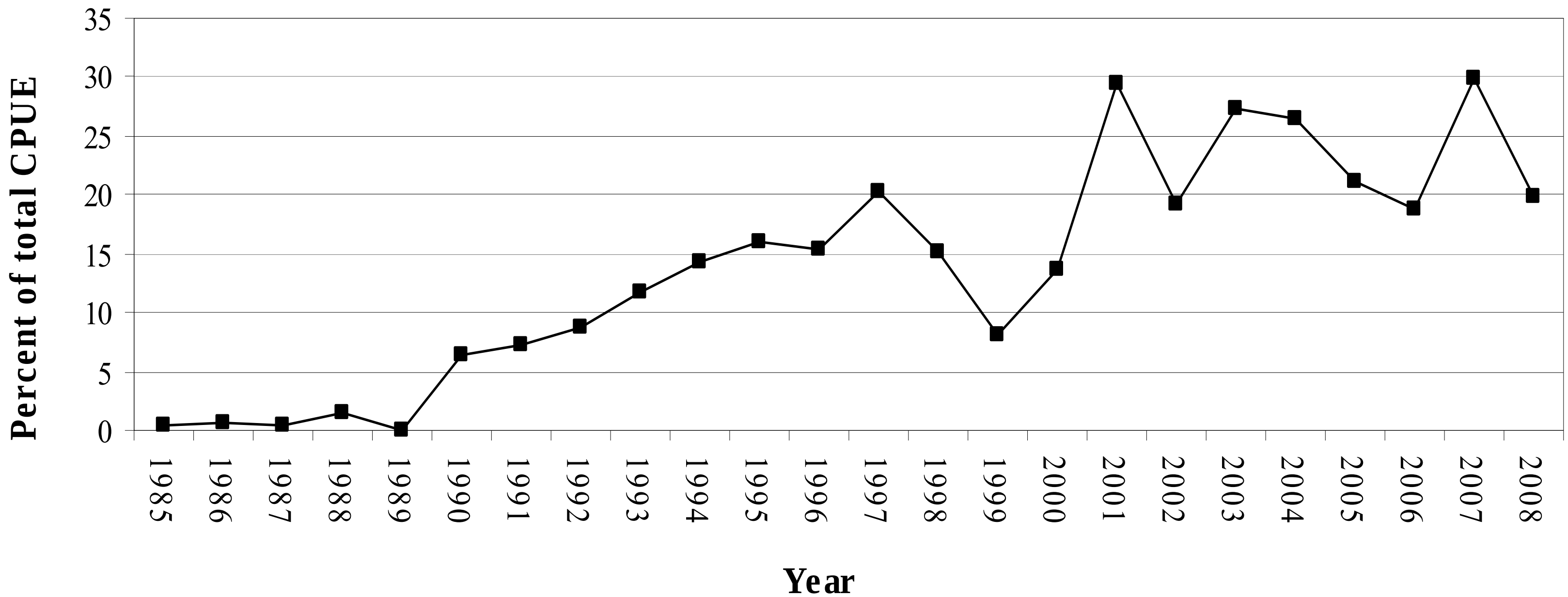


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the upper Chesapeake Bay, late March through May, 1985-2008 (Choptank River to 1996). Effort is 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.*



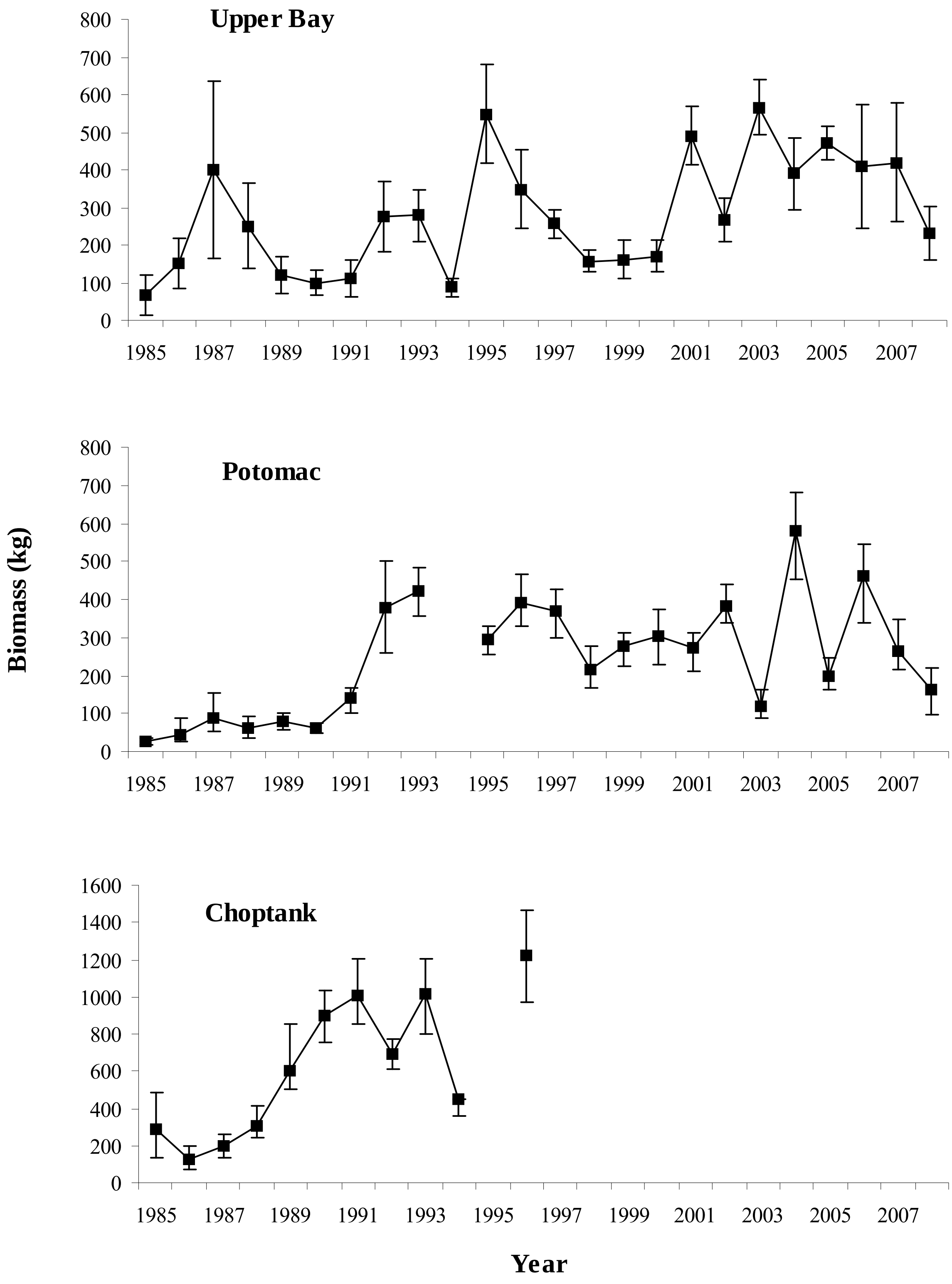
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385 (Hollis 1967).

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, 1985-2008 (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.

From 1954 to 1961, 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, are 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). A new auxiliary site was added in the Choptank River at Dickinson Bay which will eventually serve as the replacement for permanent site 148 (north shore opposite Hambrook Bar). Extensive rip-rap was installed at site 148 several years ago and shoreline changes have made sampling there difficult.

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) measurements were added in 1997. All data were entered and archived in Statistical Analysis System (SAS) databases (SAS 1990).

Estimators

The most widely used 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 ± 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 were 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 422 juvenile striped bass were collected at permanent stations in 2008. Individual samples yielded between 0 and 42 YOY striped bass. The AM of 3.2 was less than the time-series average (11.7) and the TPA (12.0) (Table 2, Figure 2). The GM of 1.26 (Table 3, Figure 3) was also less than the time-series average (4.23) and the TPA (4.32). The PPHL was 0.54, indicating that 54% 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 2008 $\log_e$-mean significantly greater than just two years of the time-series. The 2008 $\log_e$-mean was significantly smaller than 29 years of the time-series, and was not discernible from 20 other years.

System Means

Head of Bay - In 42 samples, 247 juveniles were collected at the Head of Bay sites, resulting in an AM of 5.9, less than the time-series average (12.1) and the TPA of 17.3 (Table 2, Figure 5). The GM of 2.33 was also below the time-series average (5.74) 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 2008 $\log_e$-mean was significantly greater than only four years of the time-series, and less than 21 years. The 2008 $\log_e$-mean was indiscernible from 26 year-classes of the time-series.

Potomac River - A total of 139 juveniles was collected in 42 samples. The AM of 3.3 was less than the TPA (9.2) and the time-series average (8.4) (Table 2, Figure 5). The GM of 1.40 was also less than 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 2008 Potomac River year-class significantly greater than just two years, and significantly less than 17 years of the time-series. The 2008 $\log_e$-mean was not significantly different than the 32 other years of the time-series.

Choptank River - A total of 13 juveniles was collected in 24 Choptank River samples. The AM of 0.5 was less than the time-series average of 20.6 and the TPA of 10.8 (Table 2, Figure 5). The GM of 0.34 was also less than its time-series average (8.07) 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 2008 Choptank River year-class smaller than 33 years, and not significantly different than the lowest 18 years of the time-series.

Nanticoke River - A total of 23 juveniles was collected in 24 samples on the Nanticoke River. The AM of 1.0 was less than the time-series average (8.3) and the TPA (8.6) (Table 2, Figure 5). The GM of 0.73 was also below the time-series average (3.66) 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 2008 index significantly smaller than the top 19 years of the time-series. The 2008 index was statistically indiscernible from 32 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 52 juveniles were caught in 15 samples, resulting in an AM of 3.5 and a GM of 2.02. Both indices were less than their respective time-series averages (Table 5).

On the **Patuxent River**, 18 samples yielded 6 juveniles for an AM of 0.3 and a GM of 0.24 (Table 5). Both indices were below their respective 26-year median values. Time-series averages for the Patuxent River are inflated by the unusually large year-classes of 1993 and 1996.

DISCUSSION

Survey results indicate a below-average 2008 striped bass year-class for Maryland's portion of the Chesapeake Bay. The bay-wide AM and GM fell in the bottom 25^{th} percentile of their respective time-series (Tables 2 and 3). Furthermore, YOY striped bass were captured in only 54% of samples (PPHL=0.54). An average sized year-class will typically result in a PPHL between 0.8 and 0.9 (Table 4). This agreement among indices creates more certainty that they represent actual changes in YOY striped bass abundance.

Recruitment in individual spawning areas was uniformly low. In the Head of Bay system and the Potomac River, AM and GM indices were below the 50^{th} percentile of their respective time-series. Recruitment indices in the Nanticoke and Choptank rivers fell below the 25^{th} percentile of their respective time-series. The Choptank River yielded the lowest PPHL of all spawning areas surveyed in 2008, with YOY striped bass present in only 29% of the samples taken.

Results at auxiliary sites were similar to those at permanent sites. Auxiliary Head of Bay sites, located primarily on the Susquehanna Flats, were below average. In the Patuxent River, recruitment indices were the third lowest ever recorded.

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 ($r^2 = 0.62$, $p \leq 0.001$)(Figure 10). The equation that best described this relationship was, $C_1 = 0.192541 \times C_0 - 0.07251$, 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.

The 2008 index of age 1 striped bass (0.27) was nearly equal to the predicted index of 0.28, 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.

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Table 1. Maryland juvenile striped bass survey sample sites.

Site Number	River or Creek	Area or Nearest Land Mark
		HEAD-OF-CHESAPEAKE BAY SYSTEM
* 58	Susquehanna Flats	North side Spoil Island, 1.9 miles south of Tyding's Park
* 130	Susquehanna Flats	North side of Plum Point
* 144	Susquehanna Flats	Tyding's Estate, west shore of flats
* 132	Susquehanna Flats	0.2 miles east of Poplar Point
* 59	Northeast River	Carpenter Point, K.O.A. Campground beach
3	Northeast River	Elk Neck State Park beach
4	Elk River	Welch Point, Elk River side
5	Elk River	Hyland Point Light
115	Bohemia River	Parlor Point
160	Sassafras River	Sassafras N.R.M.A, opposite Ordinary Point
10	Sassafras River	Howell Point, 500 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
111	Potomac River	Morgantown, Steam Electric Station
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
135	Choptank River	North shore opposite Hambrook Bar
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
Average	12.1	8.4	20.6	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
Average	5.74	3.63	8.07	3.66	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
Average	11.9	207.3	1.44	93.95	0.70	0.62	0.77	
TPA*	12.0	194.8	1.52	93.18	0.71	0.62	0.80	

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

Table 5. Maryland juvenile striped bass survey arithmetic (AM) and geometric (GM) mean catch per haul and number of seine hauls per year (n) for auxiliary sample sites.

	Patuxent River			Head of Bay		
Year	**AM**	**GM**	**n**	**AM**	**GM**	**n**
1983	0.06	0.04	18	0.58	0.33	12
1984	0.61	0.39	18	0.92	0.43	12
1985	3.17	1.95	18	1.00	0.24	12
1986	2.44	1.17	18	0.92	0.54	12
1987	2.94	0.94	17	0.33	0.26	9
1988	0.59	0.40	17	1.62	1.07	21
1989	1.39	0.92	18	10.43	1.91	21
1990	0.28	0.17	18	4.95	2.24	21
1991	0.94	0.53	18	2.15	0.98	20
1992	9.50	1.85	18	0.50	0.26	20
1993	104.30	47.18	18	28.00	11.11	21
1994	4.10	2.82	18	6.30	2.31	21
1995	7.28	3.46	18	2.95	1.15	21
1996	420.39	58.11	18	12.40	4.69	20
1997	7.33	2.72	18	2.70	2.18	20
1998	13.22	7.58	18	2.94	1.51	16
1999	7.28	5.39	18	3.62	2.13	13
2000	9.67	5.03	18	8.60	5.68	15
2001	17.28	10.01	18	19.47	6.62	15
2002	1.22	0.69	18	1.00	0.42	15
2003	61.11	22.17	18	16.06	11.79	16
2004	2.11	1.29	18	7.73	4.40	15
2005	8.94	3.91	18	5.53	4.35	15
2006	1.00	0.66	18	0.67	0.31	15
2007	15.22	6.07	18	5.33	2.72	15
2008	0.33	0.24	18	3.47	2.02	15
Average	27.03	7.14		5.78	2.76	
Median	3.64	1.90		3.21	1.97	

Table 6. Log mean catch per haul of age 0 and age 1 striped bass by year-class.

Year-class	Age 0	Age 1
1957	0.87	0.08
1958	2.50	0.45
1959	0.47	0.07
1960	1.39	0.14
1961	2.03	0.39
1962	1.66	0.19
1963	0.96	0.07
1964	2.31	0.29
1965	0.94	0.19
1966	1.98	0.14
1967	1.19	0.20
1968	1.31	0.19
1969	1.34	0.10
1970	2.60	0.74
1971	1.61	0.37
1972	1.45	0.35
1973	1.20	0.21
1974	1.29	0.20
1975	1.32	0.12
1976	0.95	0.05
1977	0.96	0.16
1978	1.56	0.26
1979	1.00	0.16
1980	0.70	0.02
1981	0.46	0.02
1982	1.51	0.28
1983	0.48	0.00
1984	0.97	0.14
1985	0.65	0.03
1986	0.85	0.05
1987	0.90	0.06
1988	0.55	0.14
1989	1.77	0.28
1990	0.71	0.17
1991	0.93	0.11
1992	1.20	0.18
1993	2.71	0.56

Table 6. Continued.

Year-class	**Age 0**	**Age 1**
1994	2.00	0.12
1995	1.69	0.07
1996	2.92	0.23
1997	1.59	0.16
1998	1.87	0.31
1999	1.85	0.23
2000	2.13	0.28
2001	2.61	0.58
2002	1.16	0.07
2003	2.47	0.55
2004	1.77	0.25
2005	2.07	0.25
2006	1.02	0.07
2007	1.81	0.27
2008	0.81	NA

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

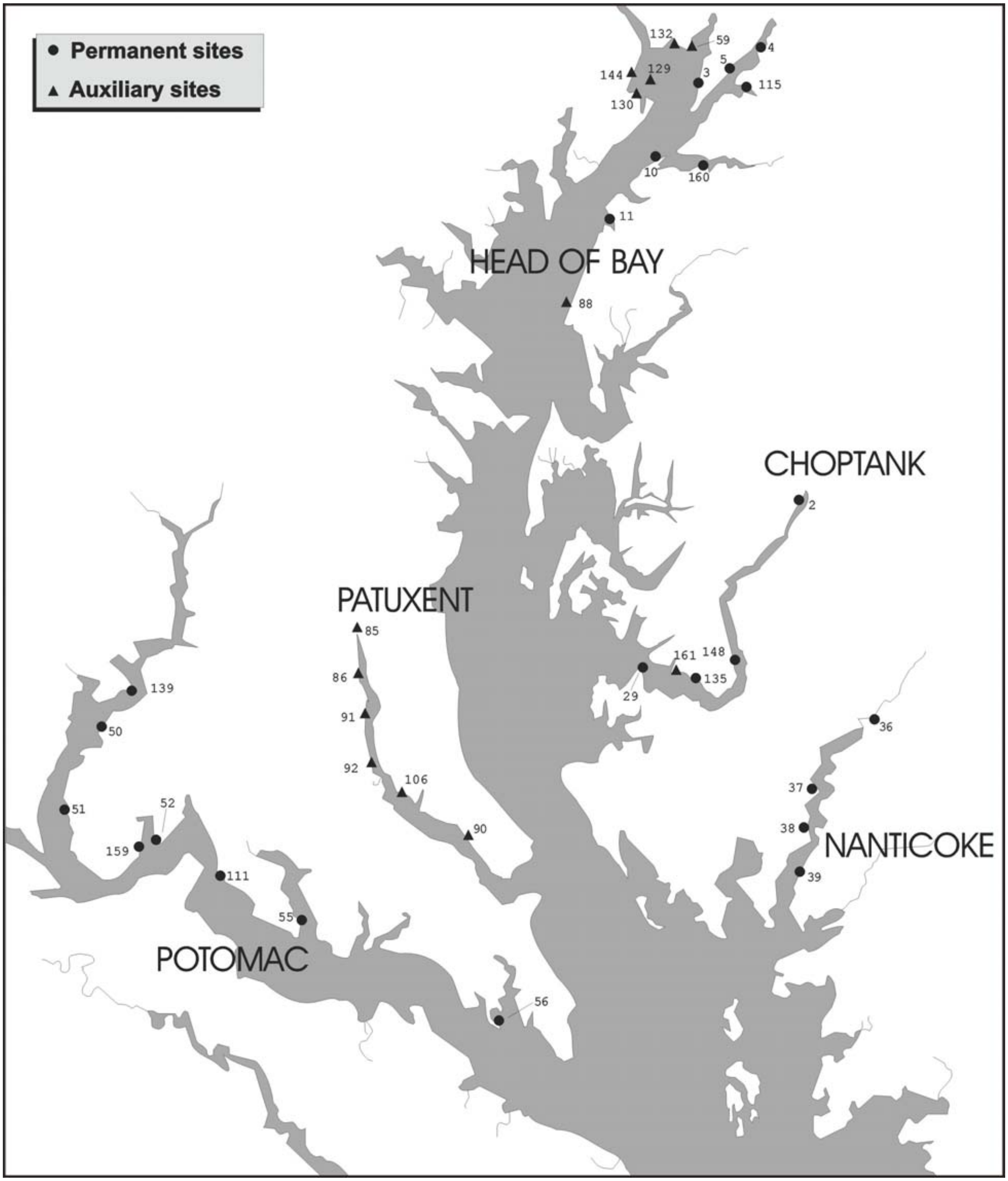


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

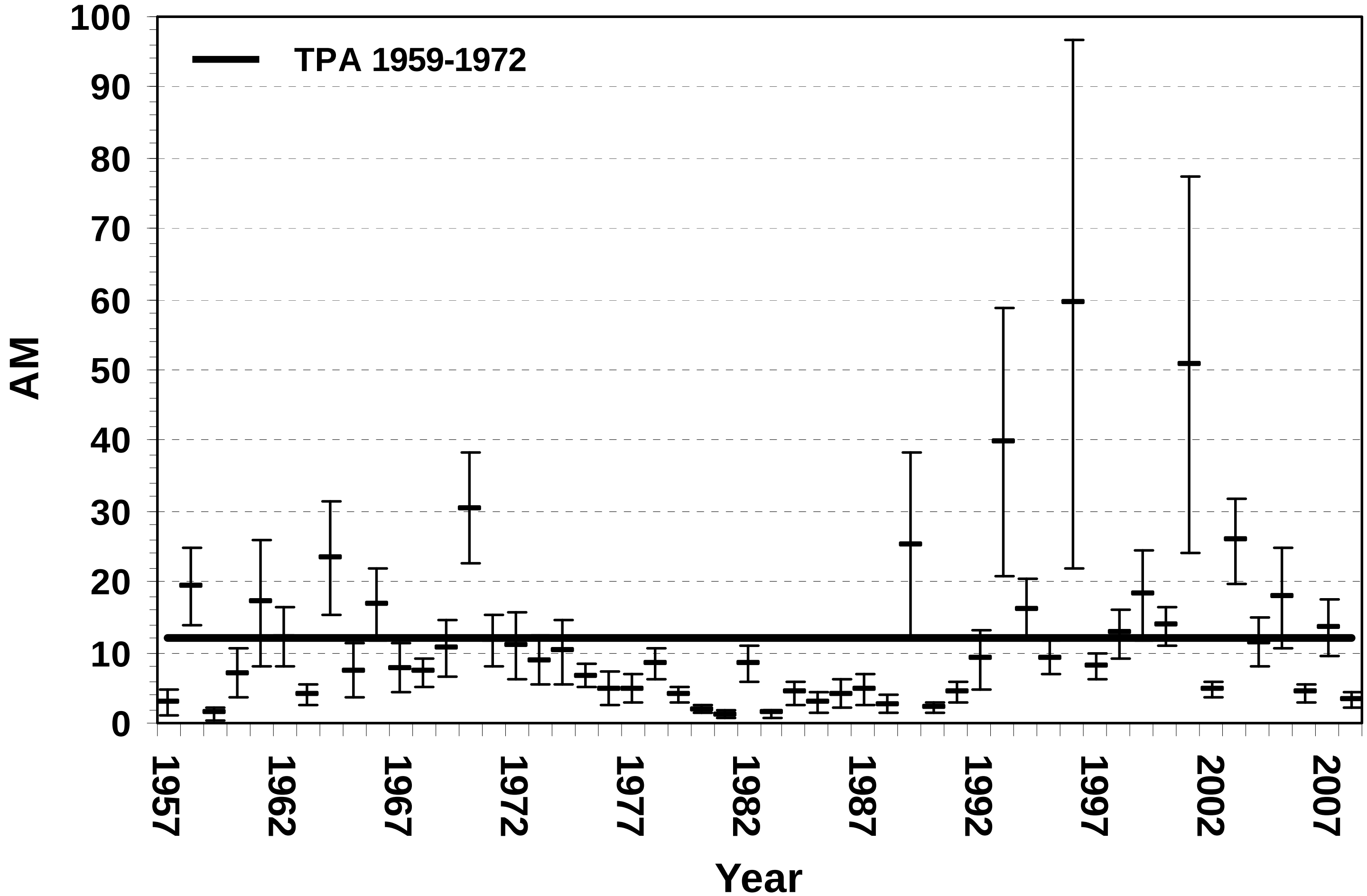


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

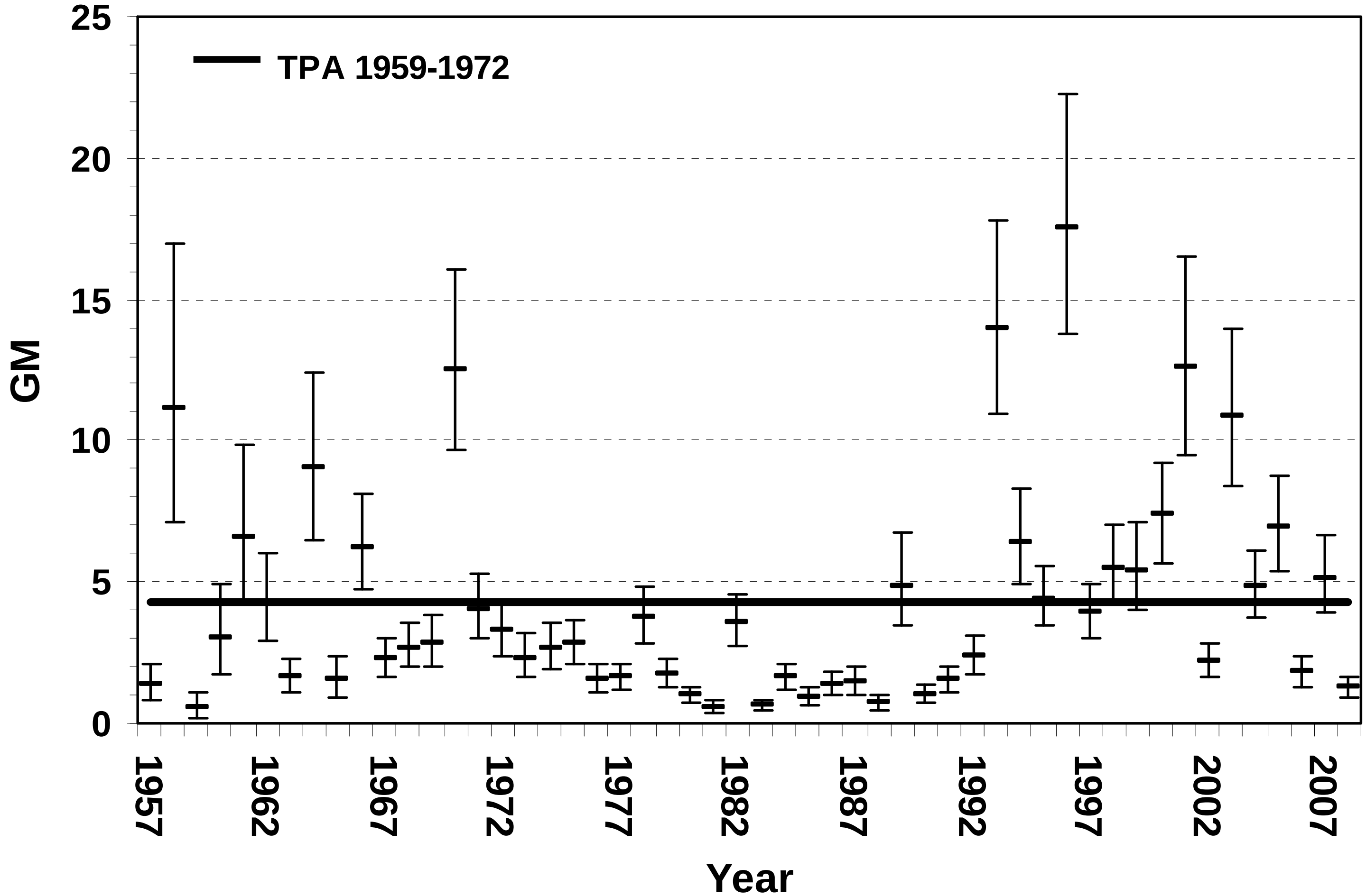


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL).

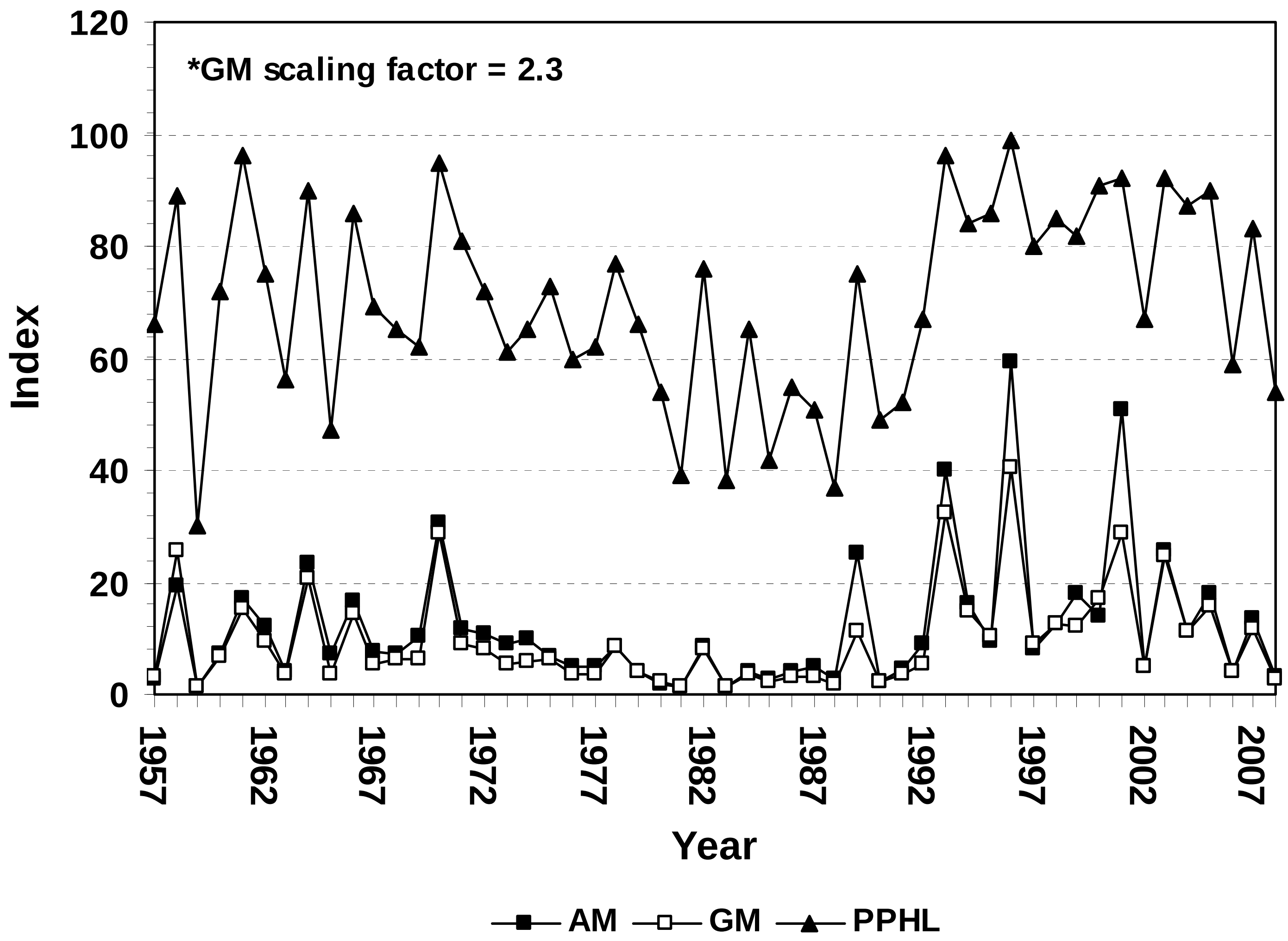


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

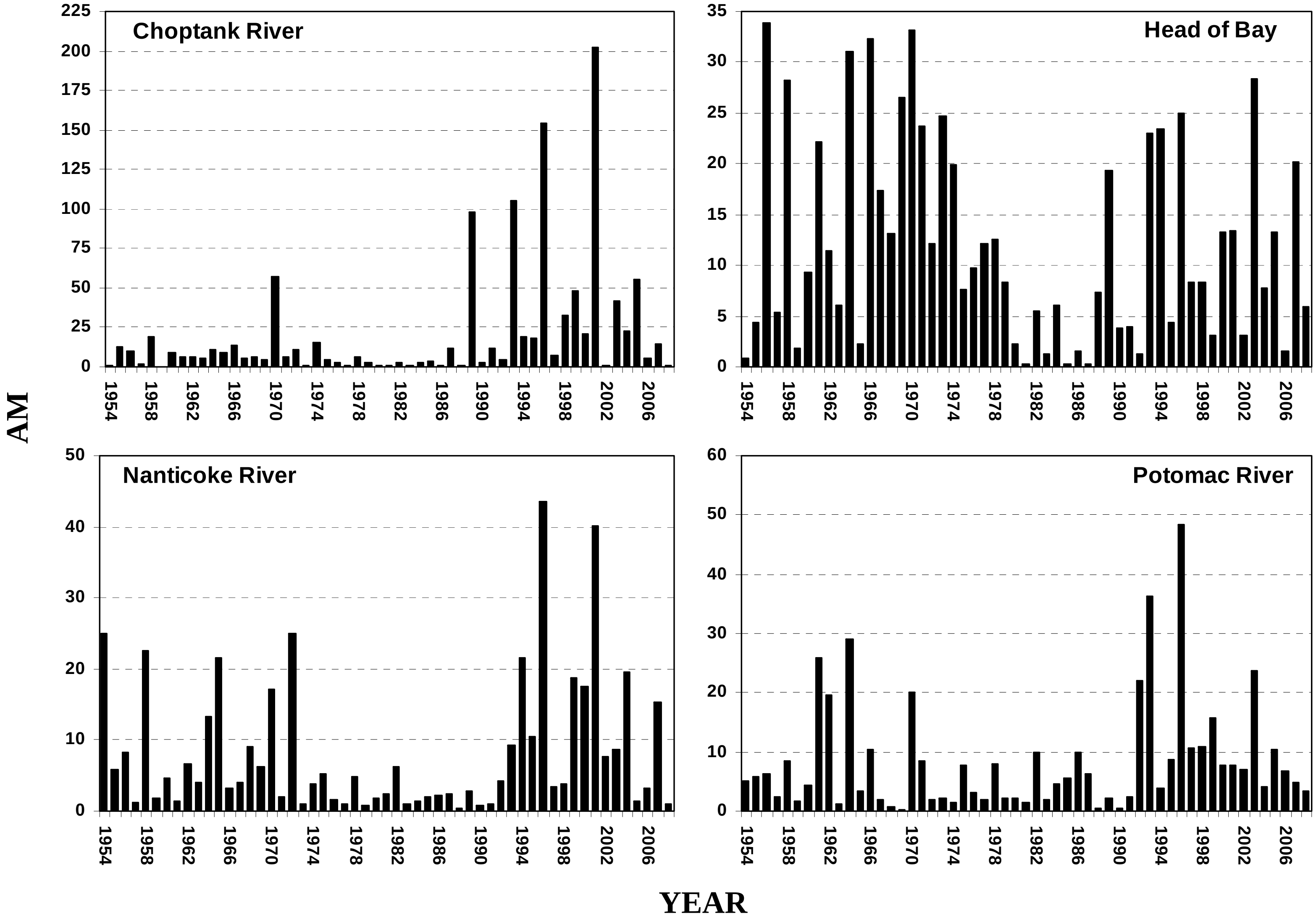


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

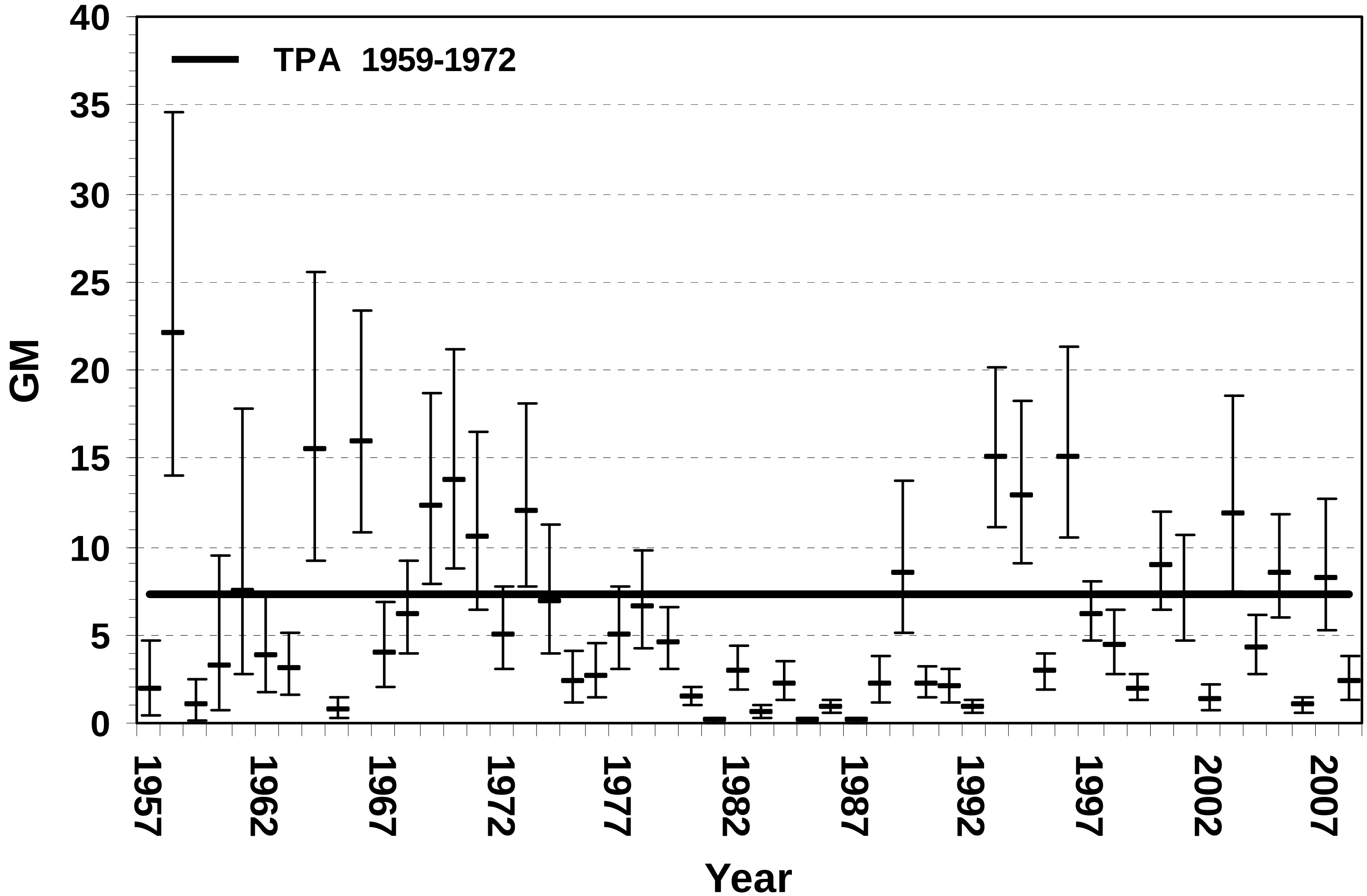


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

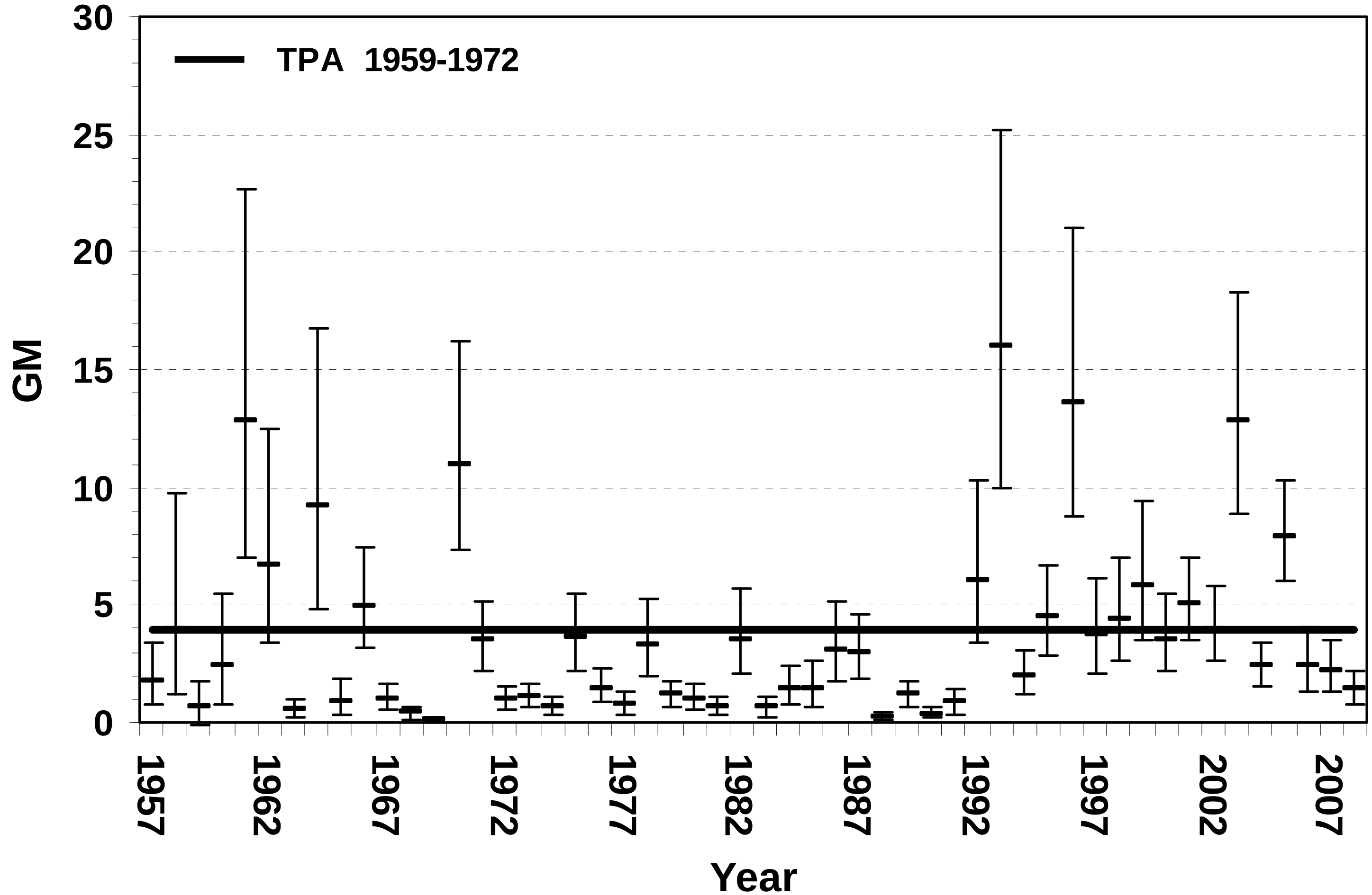


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

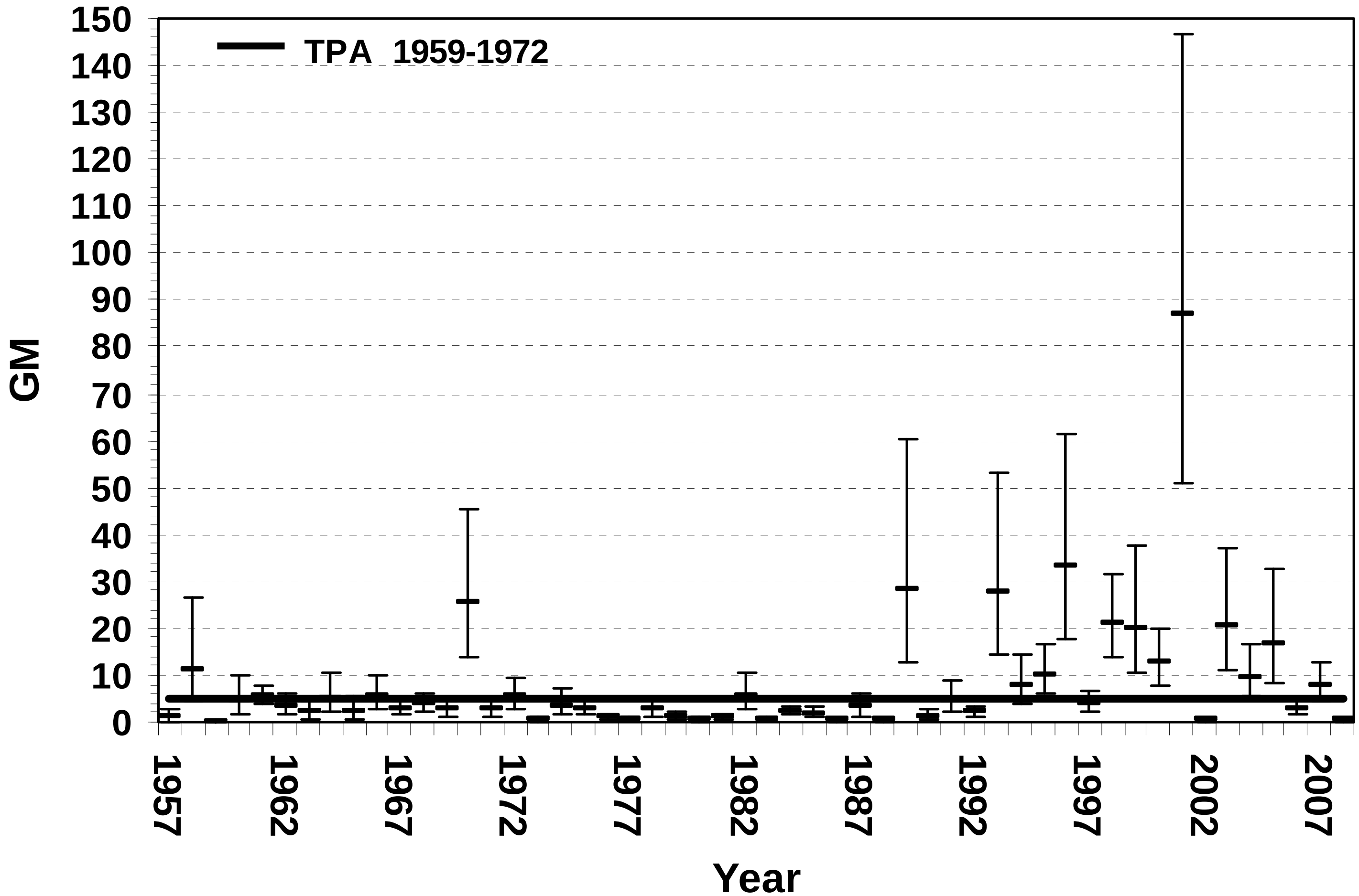


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

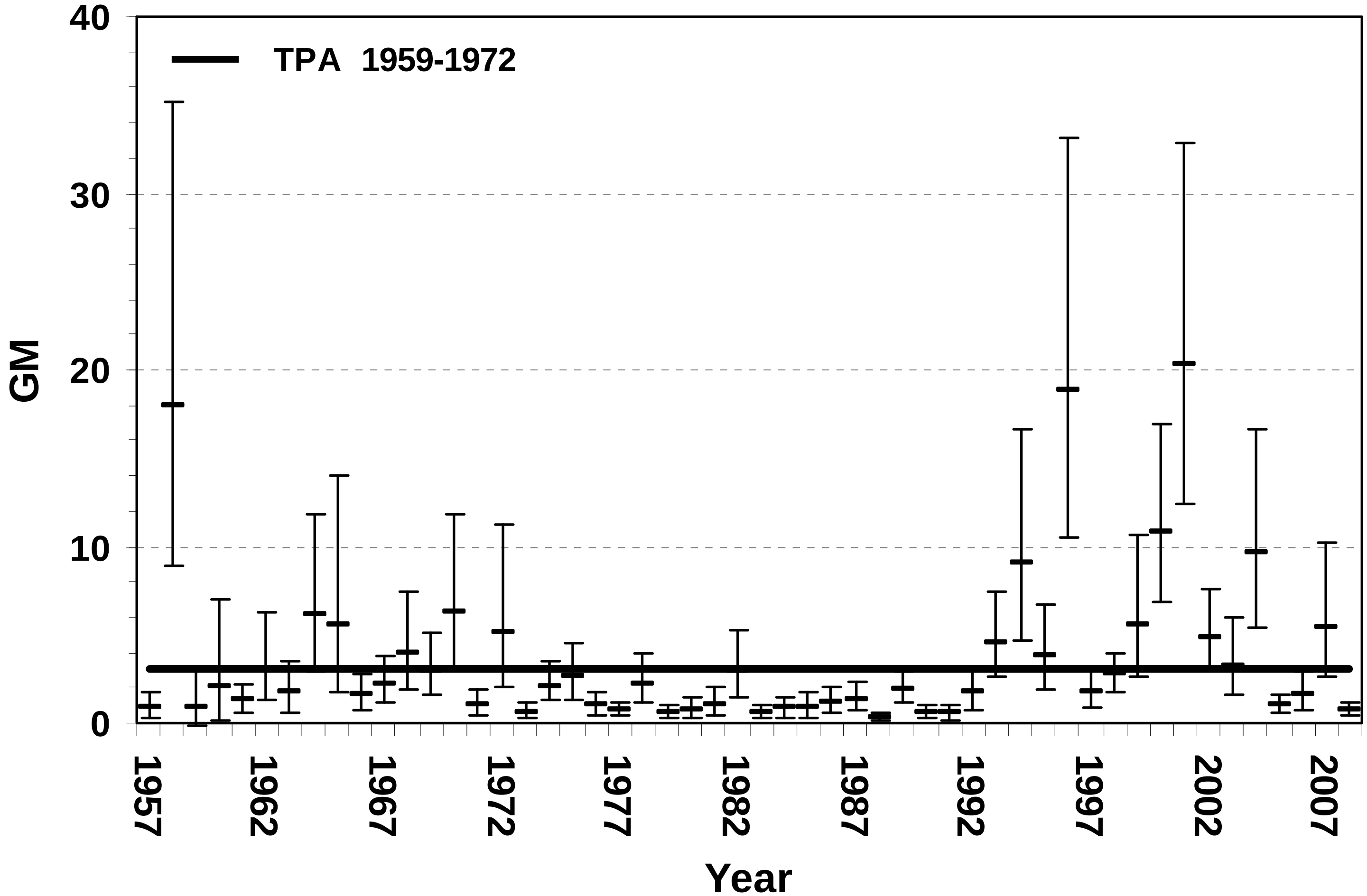


Figure 10. Regression of age 1 on age 0 striped bass.

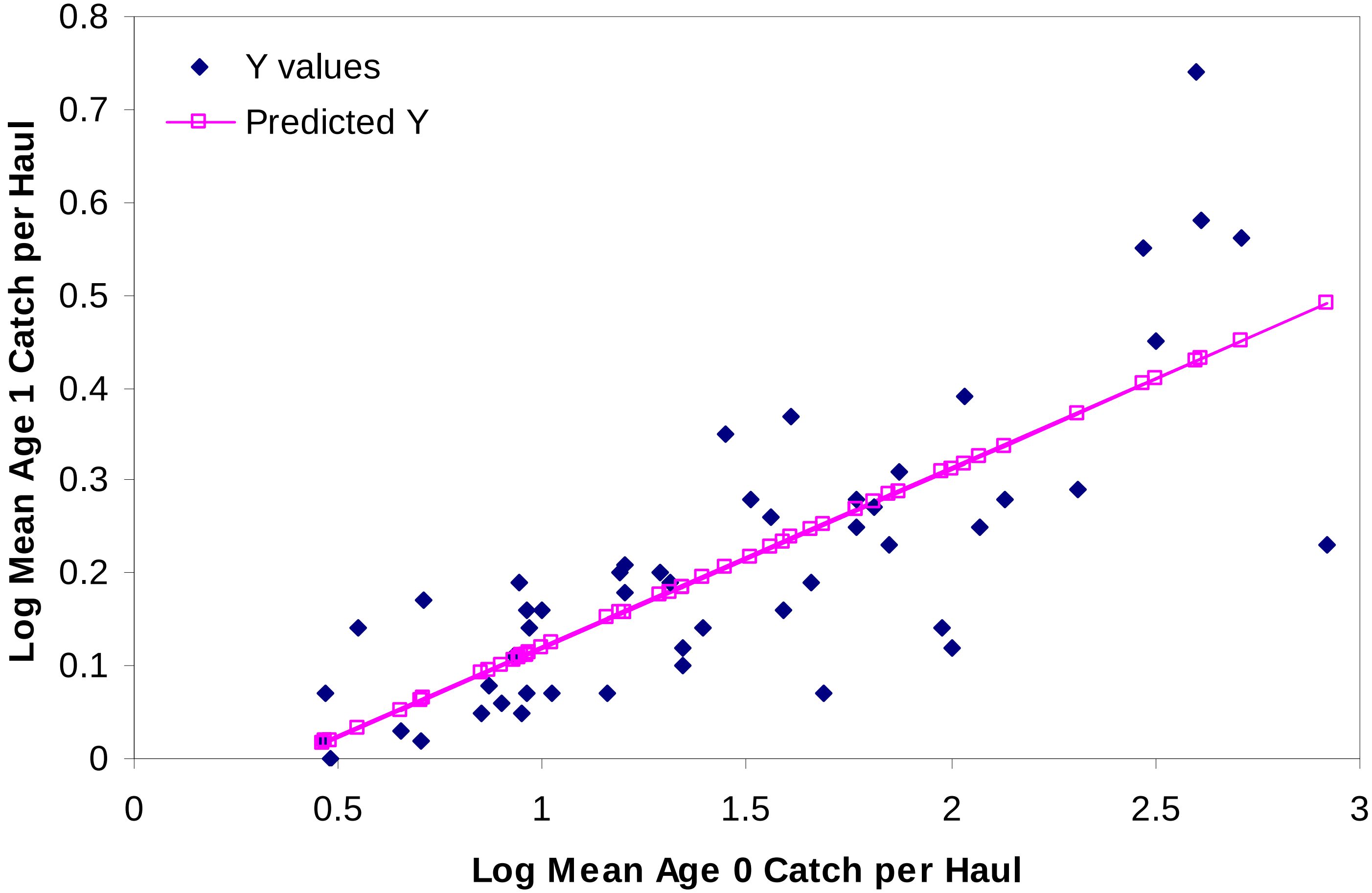
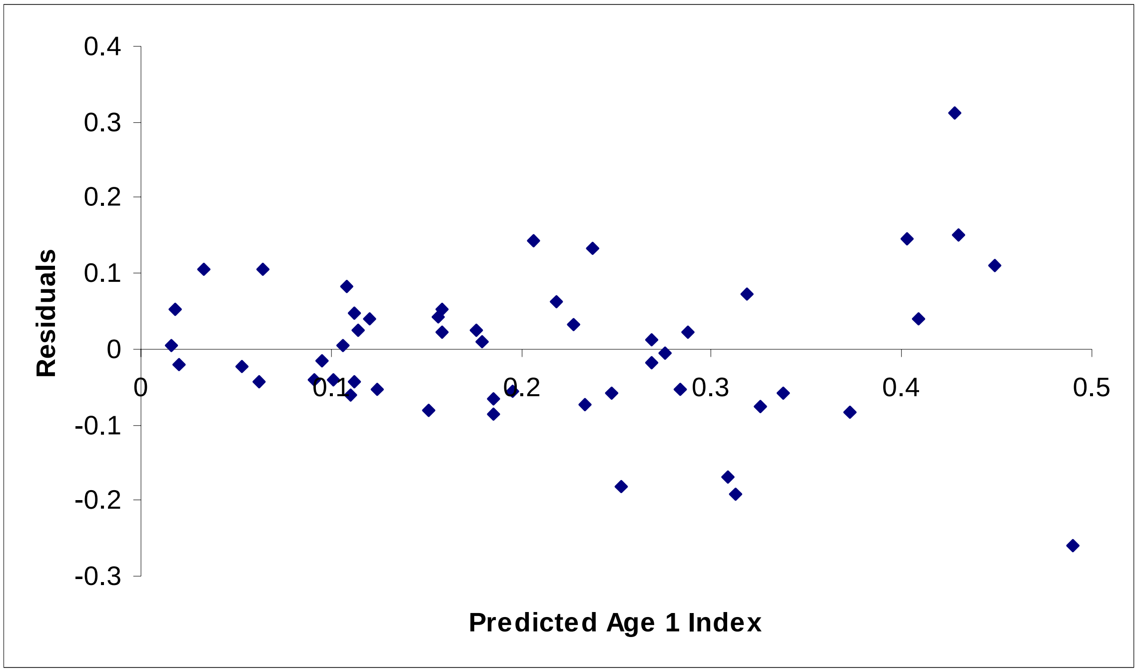
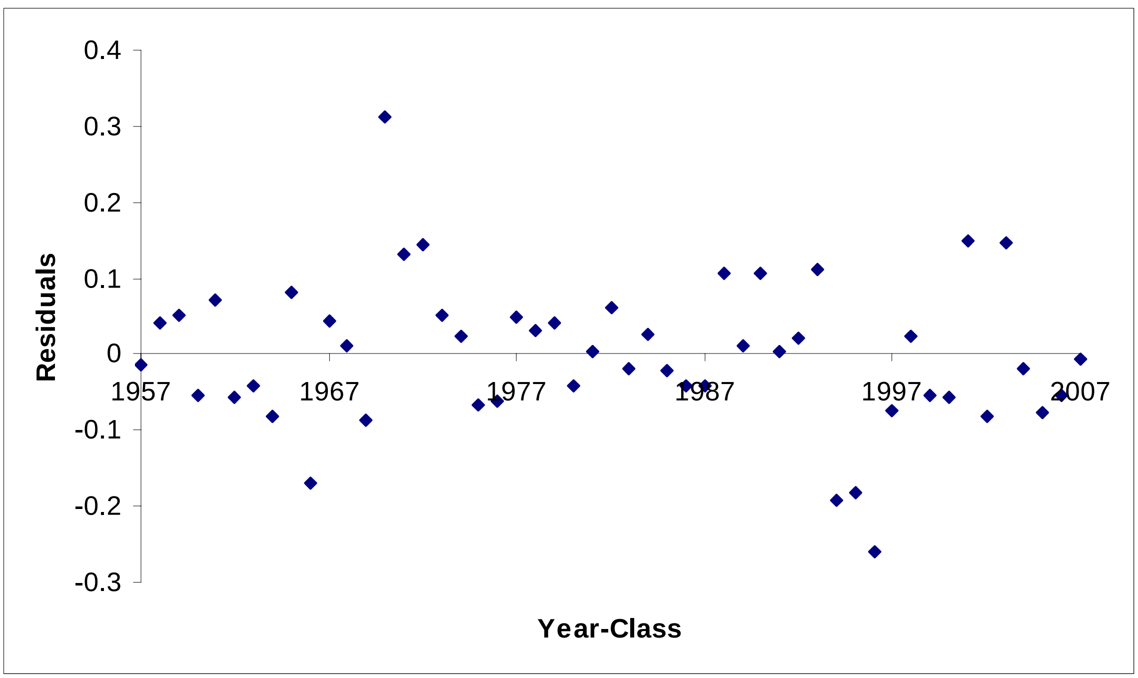


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 (*Morone saxatilis*) tagging activities in Maryland's portion of the Chesapeake Bay and the North Carolina offshore cruise during the time period of summer 2007 through spring 2008. 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. The high reward tagging study, designed to obtain a coast-wide estimate of tag reporting rate, continued in 2008.

METHODS

Sampling procedures

From late March through May 2008, 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 study. Scale samples were taken from all female fish and all males over 700 mm TL. Tagging stopped when water temperatures exceeded 70°F.

Along with the standard USFWS tags, high reward tags worth $125 were applied to every fifth, healthy fish ≥457 mm TL in order to randomly assign these tags to the sample. Data obtained from the recaptures of these tagged fish are utilized to obtain a current, annual estimate of reporting rate, which is vital in the estimation of fishing mortality (Hoenig et al. 2006).

Additionally, from January 15 to January 24, 2008, 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 to Cape Hatteras, North Carolina. Sampling was conducted 24 hours per day aboard the National Oceanic and Atmospheric Administration (NOAA) Research Vessel Oregon II. Two 65-foot (19.7 m) head-rope Mongoose trawls were towed 329 times at speeds ranging from 2.3 to 3.2 knots at depths of 30 to 109 feet (9.1 – 33.2 m) for 0.25 to 0.42 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 in the fish 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, only 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. There is concern that natural mortality in Chesapeake Bay striped bass has been increasing, and the use of a constant value for M is a weakness of the MARK method. The second method employed to calculate survival rates utilized total mortality, obtained from the previous method, along with exploitation, as inputs to Baranov's catch equation to compute F and M (NOAA 2008).

Finally, additional models were run using 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. At the 46th Northeast Regional Stock Assessment Workshop, the peer review panel concluded that the tag-based models should be investigated further in order to refine estimates of fishing and natural mortality (NOAA 2008).

For all methods, the recovery year began on the first day of tagging in the time series (March 28) and ran until March 27 of the following year. Since survival and F estimates for fish released in spring 2008 will not be completed until after March 27, 2009, 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 produced 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 2007-2008 estimate of F for Chesapeake Bay (Sharov, in preparation). 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 were utilized to produce a Baywide estimate of F. Three separate analytical methods were utilized to calculate the Chesapeake Bay F: exploitation rate, Baranov's catch equation and the instantaneous rates model. Further details on these methodologies can be found in Sharov (in preparation).

Reporting rate is estimated using the ratio of standard-reward recoveries to high-reward recoveries from the spring tagging. As in 2007, the 2008 study was conducted in the three major producer areas; Chesapeake Bay and the Delaware and Hudson rivers. A coastwide estimate of reporting rate, as well as area-specific estimates will be calculated. This approach is presented in Hoenig et al. (2006) and is similar to the methodologies used in previous high reward tagging studies conducted in Chesapeake Bay (Rugolo et al. 1994; Hornick et al. 2000; Hoover and Versak 2007). Results will be provided in a separate report to the ASMFC because the 2008 recovery year for these tags was not complete at the time of report submission.

Estimates of survival, fishing mortality and recovery rates for the North Carolina tagging data are calculated using the same methods as Maryland's spring tagging data. These calculations are also not complete, and will be analyzed by the USFWS.

For each study, t-tests were used to test for significant differences between the mean lengths of tagged striped bass 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, 2008 and May 16, 2008. In 2008, 1,517 striped bass were sampled and 628 (41%)

were tagged as part of this long-term survey (Table 1). Of those 628 tags, 83 were high reward tags. 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 2008 (594 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (522 mm TL) (Figure 2). In the upper Chesapeake Bay sampling area, the majority of fish sampled were captured in a two day period.

Tag releases and recaptures from both Maryland and Virginia's sampling were used to estimate a combined Bay-wide instantaneous fishing mortality rate (F) for the 2007-2008 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Fishing mortality estimates from the three methods were all below the target F=0.27 set by ASMFC. Specific methods and results are described in Sharov (in preparation).

Estimates of survival and fishing mortality for the Chesapeake Bay spawning stock will be presented in the 2009 report of the ASMFC Striped Bass Tagging Subcommittee.

<u>USFWS cooperative tagging cruise</u>

The primary objective of the SEAMAP tagging cruise was to apply tags to as many striped bass as possible. As a result, 1,033 (99%) of the 1,040 striped bass sampled on the cruise were tagged (Table 2). Similar to 2007, the majority of fish encountered in 2008 were located at the mouth of the Chesapeake Bay and north. This area was not typically sampled during previous cruises. The mean total length of fish captured and tagged on the 2008 cruise was 853 mm TL (Figure 2), significantly greater than the mean total lengths of the 2007 cruise (825 mm TL – tagged and total sample; P<0.0001). The NC DMF is presently completing age determination for the 2008 cruise via scale analysis.

Estimates of survival and fishing mortality based on fish tagged in the 2008 North Carolina study will be presented in the next report of the ASMFC Striped Bass Tagging Subcommittee.

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Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, March - May 2008.

System	Inclusive Release Dates	Total Fish Sampled	Total Fish Tagged	Approximate Tag Sequences [a]
Potomac River	3/31/08-5/15/08	334	190	507501 - 507669 576376 - 576396 [c]
Upper Chesapeake Bay	4/3/08-5/15/08	1,183	438	489410 – 489500 489888 – 490183 575035 – 575075 [c] 575133 – 575150 [c] 576351 – 576353 [c]
Spring spawning survey totals:		1,517 [b]	628	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes one fish with a missing length and one USFWS recapture.
[c] These sequences are high reward tags.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2008 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)	1/15/08-1/24/08	1,040	1,033	550001 – 551033
Cooperative tagging cruise totals:		1,040 [b]	1,033	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes 7 USFWS recaptures.

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, March - May 2008.

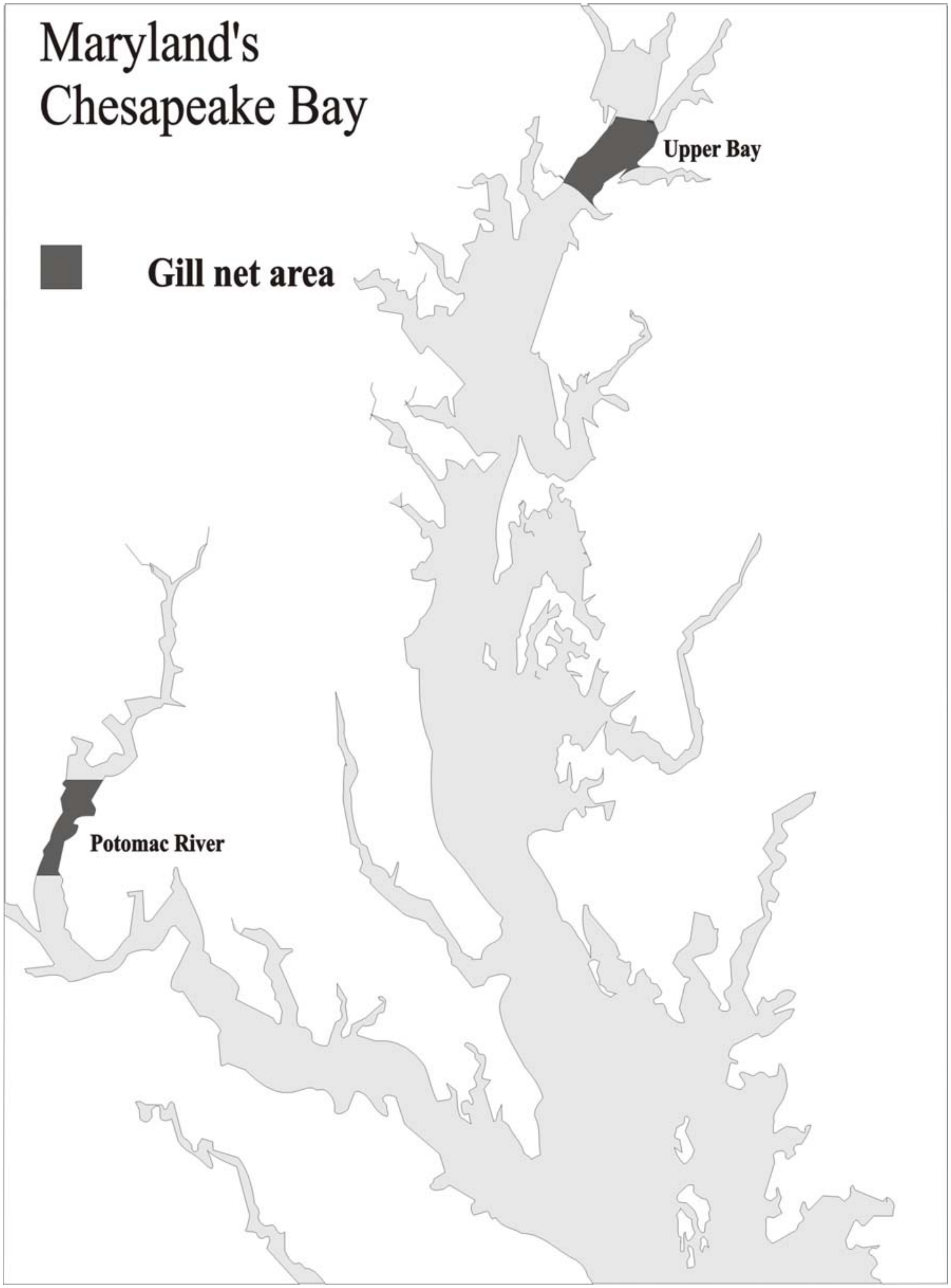
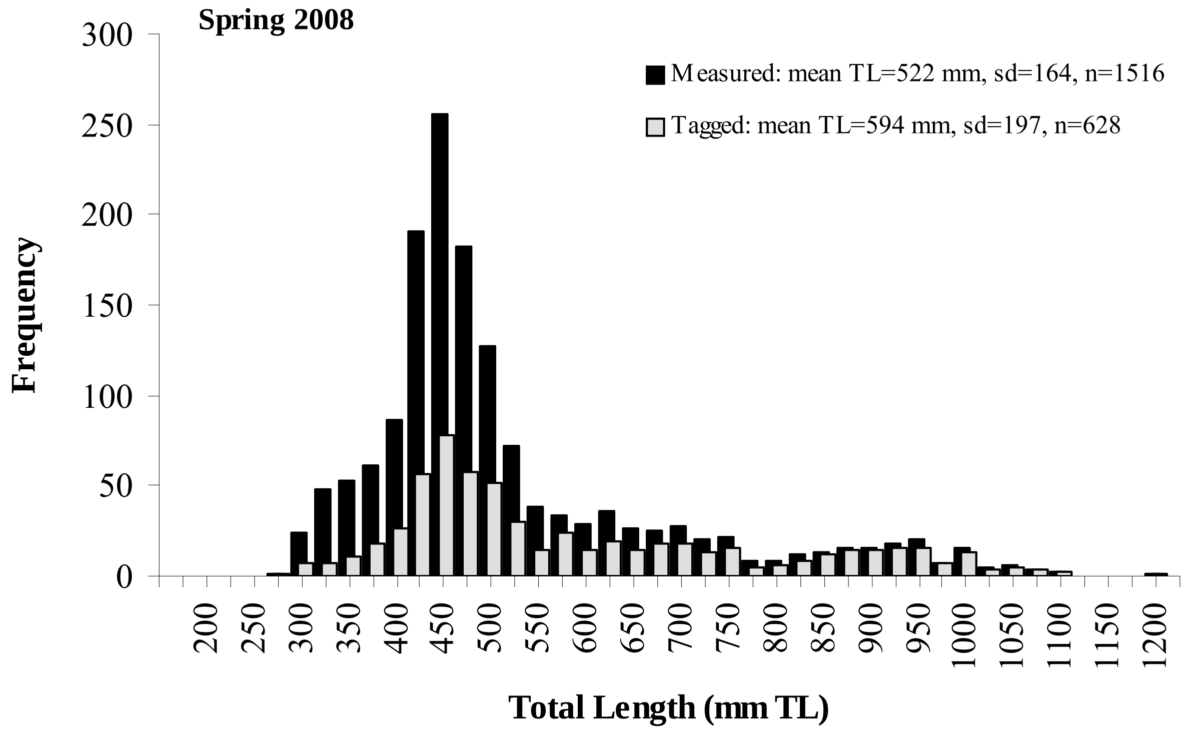
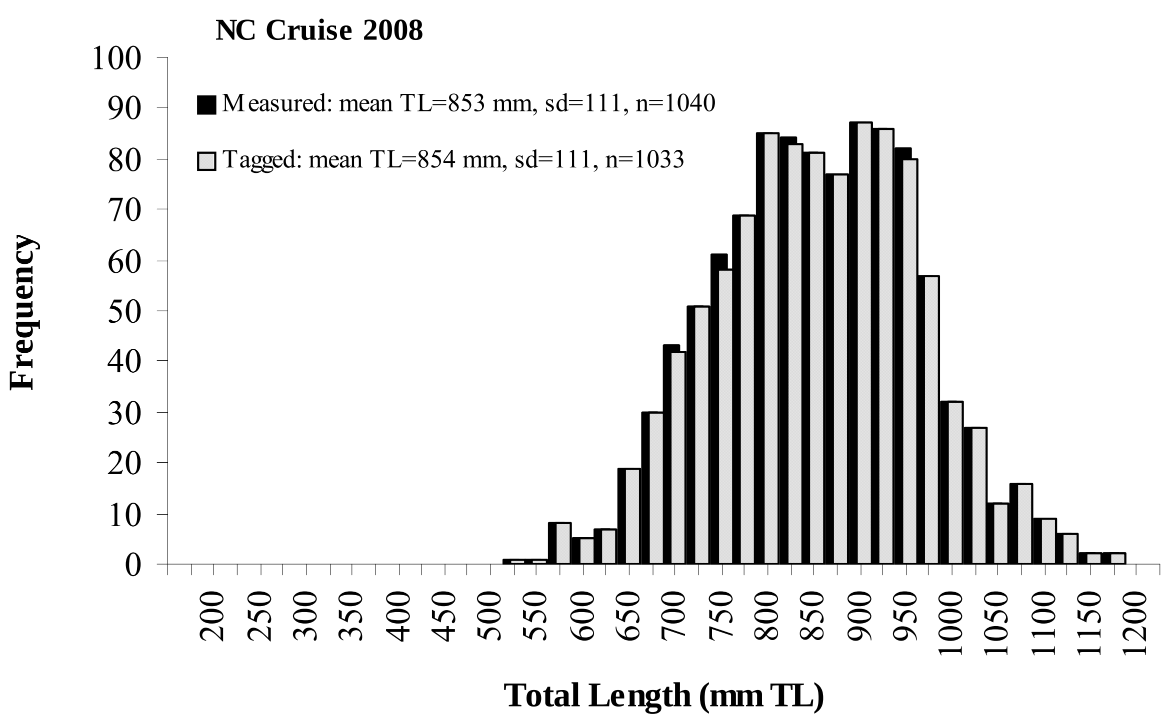


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay and offshore during the SEAMAP tagging cruise. Note different scales.





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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Angela Giuliano

INTRODUCTION

The primary objectives of Project 2, Job 3, Task 5A were to quantify the commercial striped bass harvest in 2007 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 eighteenth 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 2007 commercial quota for the Chesapeake Bay and its tributaries was 2,134,116 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. The hook-and-line fishery was open on selected days from June 14 to November 30, 2007. The pound net fishery was open from June 1 through November 30, 2007. The haul seine fishery was open from June 7 to November 30, 2007. The Chesapeake Bay drift gill net season was split, with the first segment from January 2 through February 28, 2007 and the second segment from December 3 through December 31, 2007. 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, 2007 and November 1 through December 31, 2007.

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 2006, 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, 2006 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 $100.00. Participants who held an Unlimited Finfish Harvester License or Hook-and-Line License were required to pay $200.00. 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 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 were considered to have no appreciable effect on the results and conclusions.

RESULTS AND DISCUSSION

On the Chesapeake Bay and its tributaries, 2,240,585 pounds of striped bass were harvested in 2007, representing 105% of the Chesapeake quota for the 2007 commercial fishing season. The estimated number of fish landed was 788,064 (Table 3). The Chesapeake drift gill net fishery contributed 48% (pounds) of the total landings and the pound net fishery contributed 29% (pounds). The hook-and-line fishery harvested the remaining 23% by weight. The haul seine fishery did not harvest any fish in 2007 despite a small number of fish being harvested for the first time in four years in 2006.

Maryland's Atlantic Coast landings totaled 112,791 pounds (Table 3). This represented 89% of the Atlantic quota. The estimated number of fish landed was 13,349. The trawl fishery made up 66% 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 harvest landed by the number of fish reported as harvested in the weekly check station log sheets. The second method involved direct sampling of striped bass at Chesapeake Bay check stations by MD DNR biologists to characterize the harvest of commercial striped bass fisheries by measuring and weighing a sub-sample of harvested fish (Project 2, Job 3, Tasks 1A and 1B, this report).

The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 2.84 pounds when calculated from the check station log sheets and 4.51 pounds when measured by biologists (Table 4). Mean weights by specific gear type ranged from 2.53 to 3.30

pounds from check station log sheets and ranged from 2.80 to 5.71 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 3.30 pounds when calculated using the log sheet data and 5.71 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 7.19 pounds (Table 4). This is lower than the average weight determined from the check station log sheets (8.45 pounds). Fish caught in the Atlantic gill net fishery averaged 6.61 pounds according to MD DNR estimates, and were smaller on average than those caught in the trawl fishery (8.17 pounds). The average weights of fish from the Atlantic gill net and trawl fisheries, as calculated from check station log sheets, were 7.98 and 8.72 pounds, respectively.

When comparing the average weights calculated from check station log sheets and the average weights calculated by MD DNR biologists, there are often discrepancies. Thousands of individual fish are weighed by MD DNR biologists each year resulting in precise estimates of average weight with narrow confidence intervals. Assuming the total pounds of fish landed were reported accurately by the check stations, the comparisons suggest that the actual number of fish harvested by the Chesapeake Bay commercial fisheries was lower than reported by the check stations. Conversely, the actual number of fish harvested in the Atlantic Coast fishery was likely higher than reported.

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 Chesapeake Bay gears. Harvest in the hook-and-line fishery peaked in 1999 and though it fell between 2001-2005, the harvest in 2006 and 2007 has shown an increasing trend. The pound net fishery harvest increased through the early 1990s and by 1998 had stabilized with an average of 568,657 pounds of striped bass harvested per year between 1998-2007. While the hook-and-line fishery tends to land the fewest number of pounds, in 2007 this fishery landed more pounds of fish than the pound net fishery.

The Atlantic coast fishery harvests far fewer pounds of striped bass compared to the Chesapeake Bay fisheries (Table 5, Figure 5). For example, in 2007, the Atlantic coast fishery harvested 112,791 pounds compared to 2.24 million pounds harvested from Chesapeake Bay. However, similar to the Chesapeake Bay fisheries, the pounds landed has increased since the moratorium was lifted in 1990. 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 number of pounds harvested by year and gear type was taken from check station log sheets (Table 3). The number of fishing trips in which striped bass were landed was estimated from the MFRs. The total of pounds landed was divided by the number of trips to calculate an estimate of CPUE. In 2007, the hook-and-line fishery CPUE was 201 pounds per trip, which was a 20% decrease from 2006, the highest CPUE in the time-series. The pound net fishery CPUE for 2007 was 322 pounds per trip, a large increase from 2005 but a small decrease from 2006. The CPUE for the 2007 Chesapeake Bay gill net fishery was 359 pounds per trip, the highest level since the fishery re-opened in 1990 (Table 5, Figure 4).

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 (316 lbs per trip), followed by the pound net fishery (262 lbs per trip) and the hook-and-line fishery (198 lbs per trip) (Table 6, Figure 6).

The Atlantic trawl fishery CPUE was 1,325 pounds per trip in 2007. This value is larger than the peak seen in 1995 (994 lbs per trip) when the Atlantic quota was increased. Overall, the trawl catch has been stable since 1996, averaging 451 pounds per trip between 1996-2005 with drastic increases in CPUE in 2006 and 2007. The 2007 CPUE for the Atlantic gill net fishery was 327 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 and 2007 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. However, the total stock abundance estimate for January 1, 2007 was approximately 3.2 million fish below the 10 year average (ASMFC 2008) signaling that total stock abundance has leveled off.

CITATIONS

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Table 1. Striped bass commercial harvest quotas (lbs) by gear type for the 2007 calendar year.

Gear Type	Total Adjusted Harvest Quota
Haul Seine, Pound Net	533,529
Hook-and-Line	640,235
Drift Gill Net	960,352
Chesapeake Total	**2,134,116**
Atlantic: Trawl, Gill Net	126,396
Maryland Total	**2,260,512**

Table 2. Individual season and daily harvest allocations (lbs) and the number of declared striped bass fishermen for the 2007 calendar year.

Area	Gear Type	Number Declared	Daily Allocation (pounds)	Seasonal Allocation (pounds)
Bay & Tributaries	Haul Seine	5	750	1,250
	Pound Net	147	200 [1]	1,050[1]
	Hook & Line	152	300	none
	Gill Net / Hook & Line	852	500	none
Atlantic Coast	Atlantic Trawl	29	none	1,950
	Atlantic Gill Net	41	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 2007 calendar year.

Area	Gear Type	Pounds[1]	Estimated[1] Number of Fish	Trips[2]
Chesapeake Bay[3]	Haul Seine	0	0	0
	Pound Net	528,683	209,132	1,643
	Hook & Line	643,598	255,199	3,200
	Gill Net	1,068,304	323,733	2,978
	Chesapeake Total Harvest	2,240,585	788,064	7,821
Atlantic Coast	Atlantic Trawl	74,172	8,510	56
	Atlantic Gill Net	38,619	4,839	118
	Atlantic Total Harvest	112,791	13,349	174
Maryland Totals		2,353,376	801,413	7,995

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 2007 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	N/A	N/A	N/A
	Pound Net	2.53	3.58 (3.46-3.69)	1,103
	Hook-and-Line	2.52	2.80 (2.73-2.87)	1,675
	Gill Net	3.30	5.71 (5.58-5.85)	3,268
	Chesapeake Total Harvest	2.84	4.51 (4.43-4.60)	6,046
Atlantic Coast	Trawl	8.72	8.17 (7.48-8.85)	110
	Gill Net	7.98	6.61 (6.40-6.83)	183
	Atlantic Total Harvest	8.45	7.19 (6.90-7.50)	293

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 2007.

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

Table 6. Striped bass average catch per trip (CPUE) in pounds by gear type, 1990 to 2007.

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

Figure 1. Map of the 2007 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 2007.

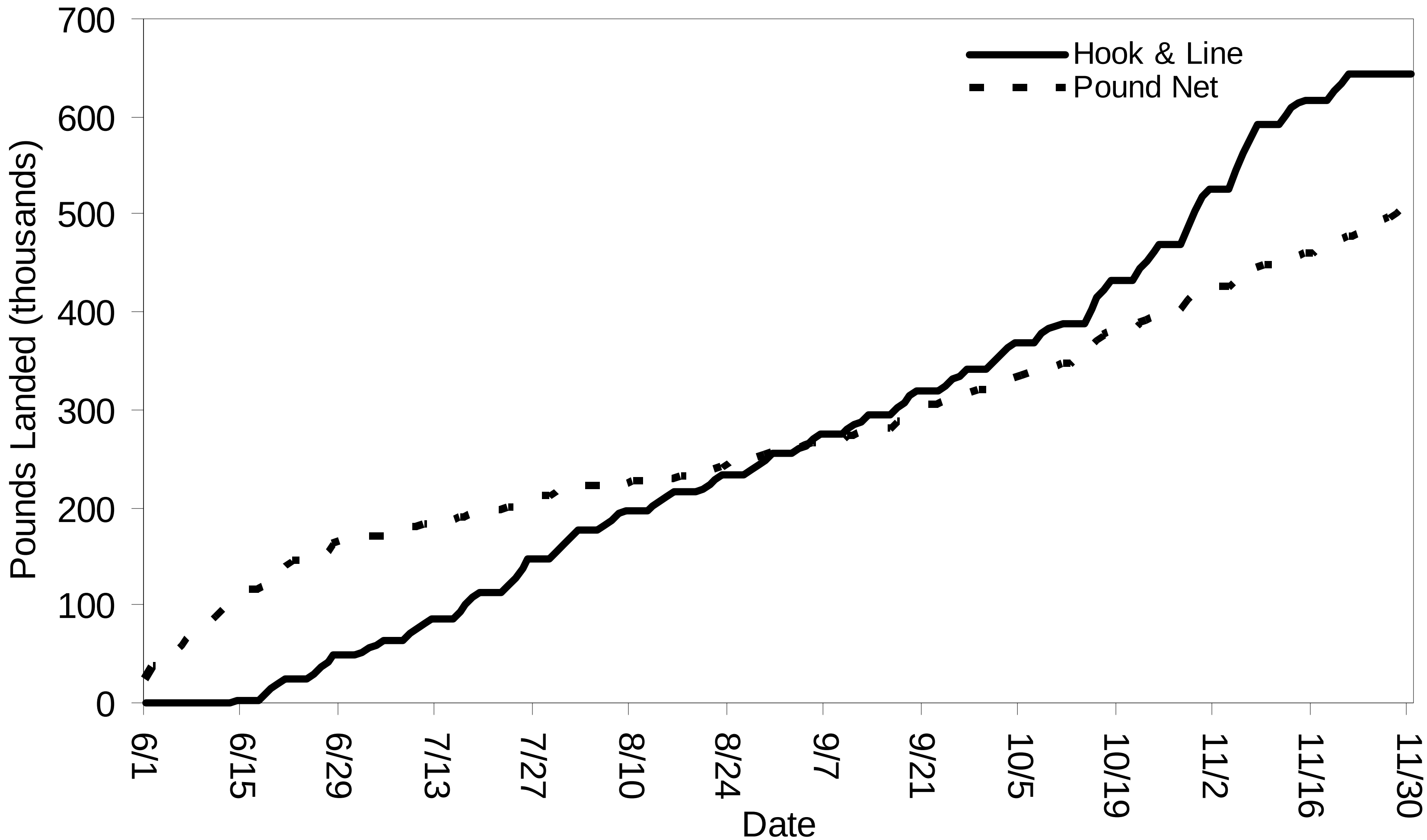
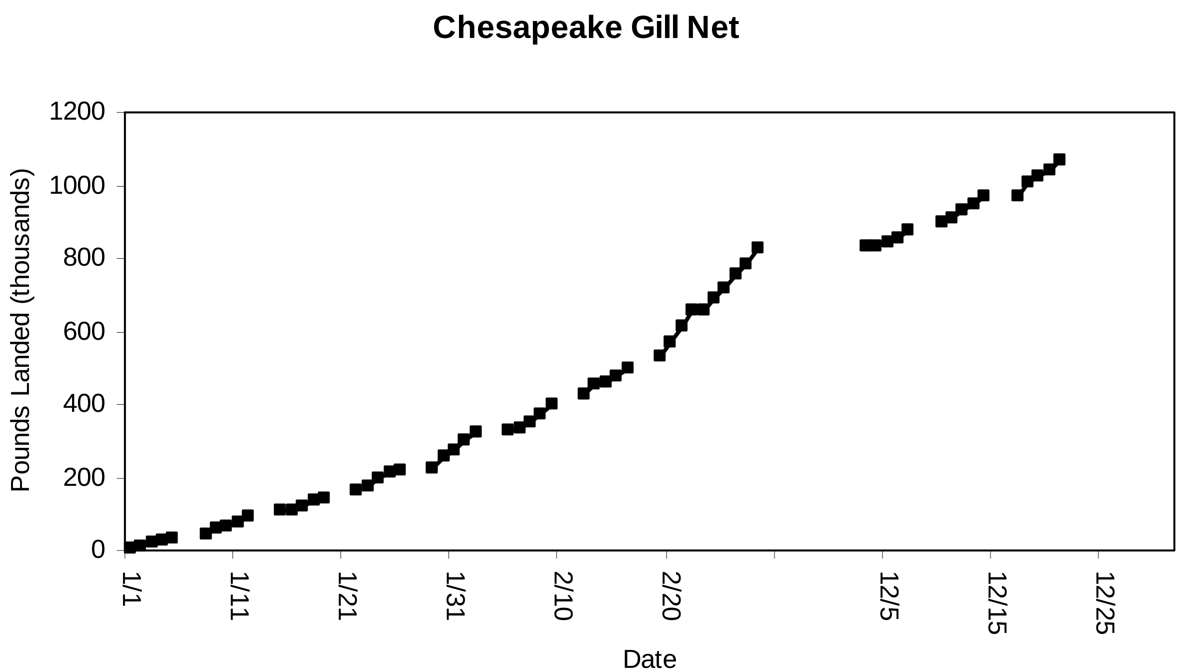


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fishery (combined) cumulative striped bass landings from check stations daily call-in reports, January- December 2007.



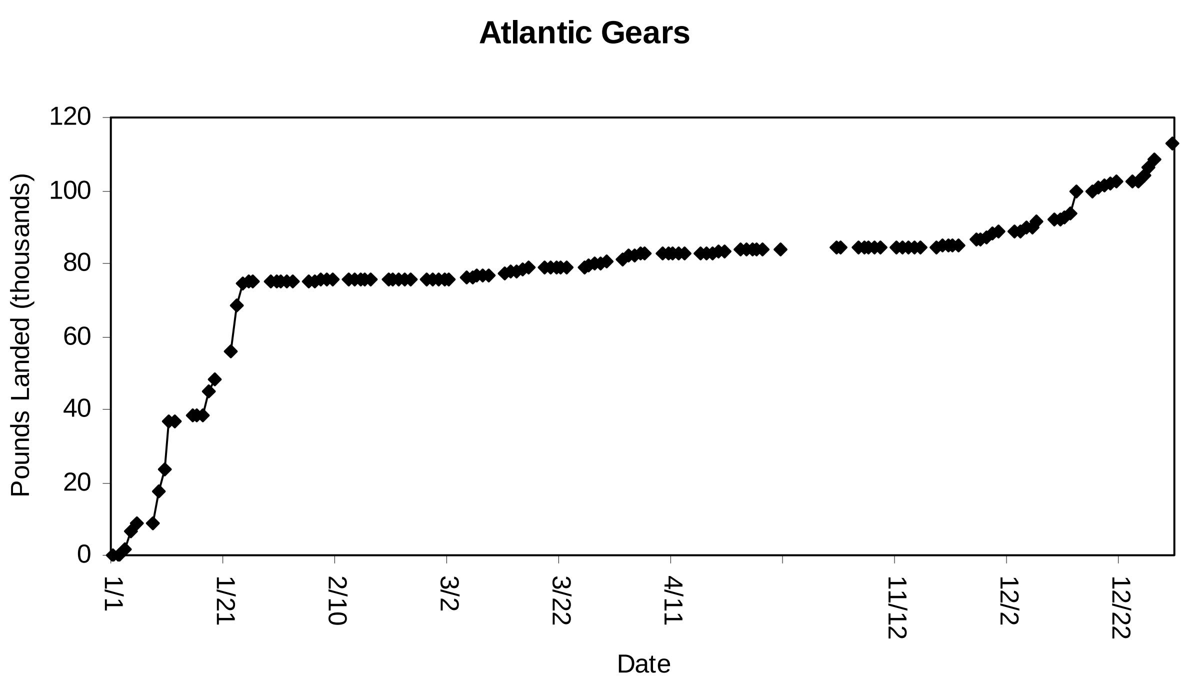


Figure 4. Maryland's Chesapeake Bay striped bass total harvest (thousands of pounds) per calendar year by gear, 1990 – 2007.

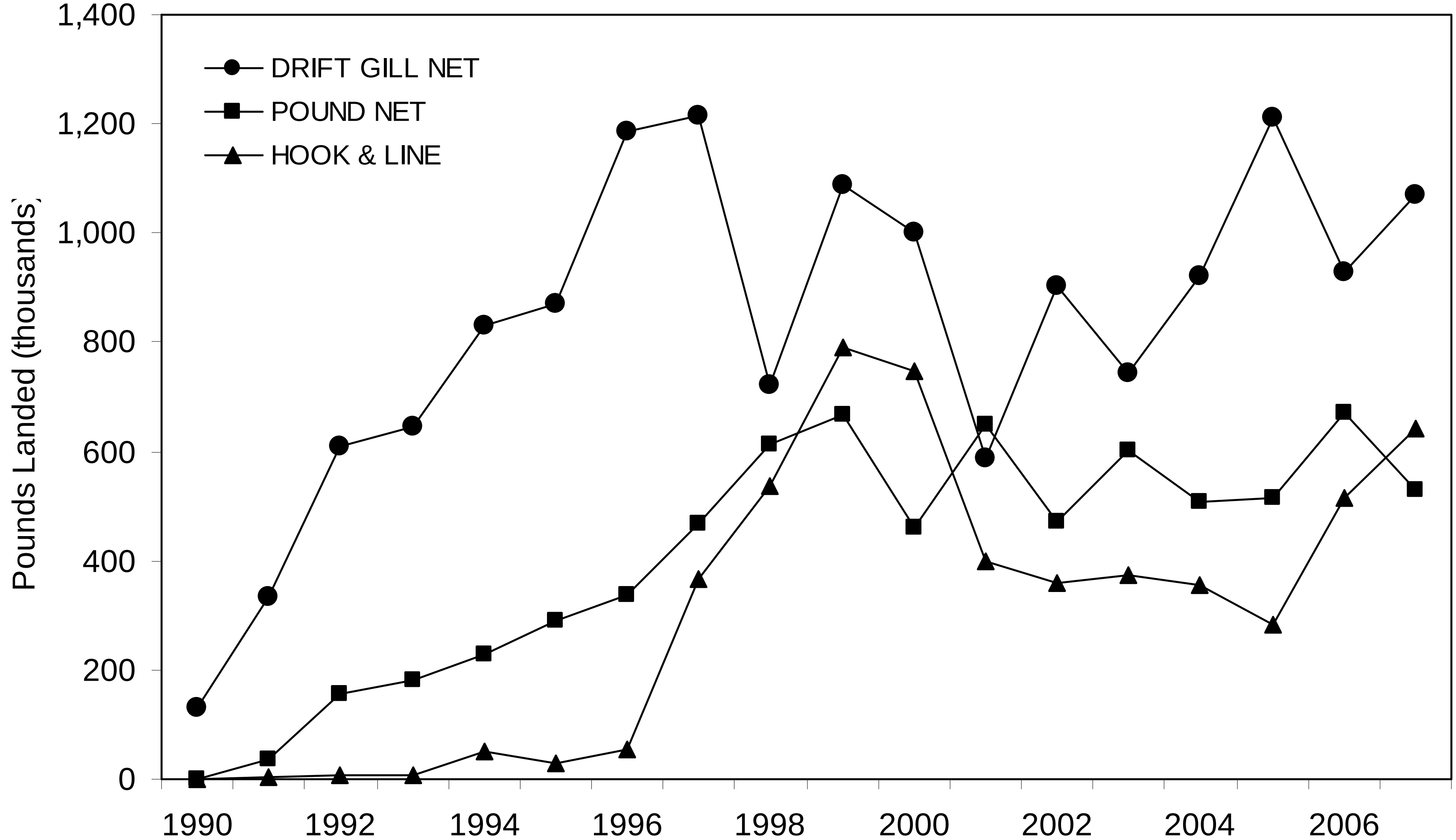


Figure 5. Maryland's Atlantic gill net and trawl fishery striped bass total harvest (thousands of pounds pounds) per calendar year by gear type, 1990-2007.

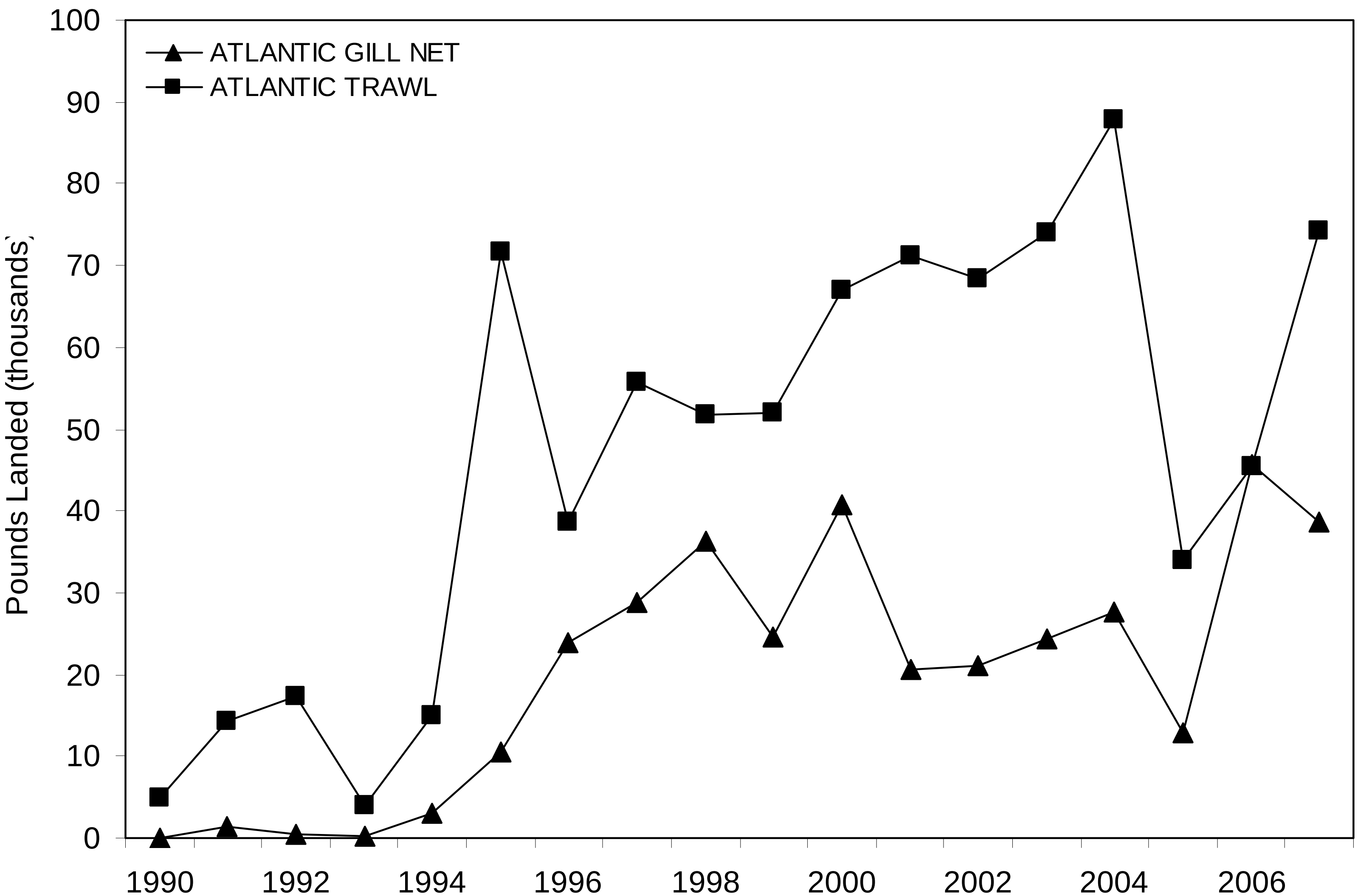


Figure 6. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by gear type, 1990- 2007. Trips were determined as days fished when striped bass catch was reported.

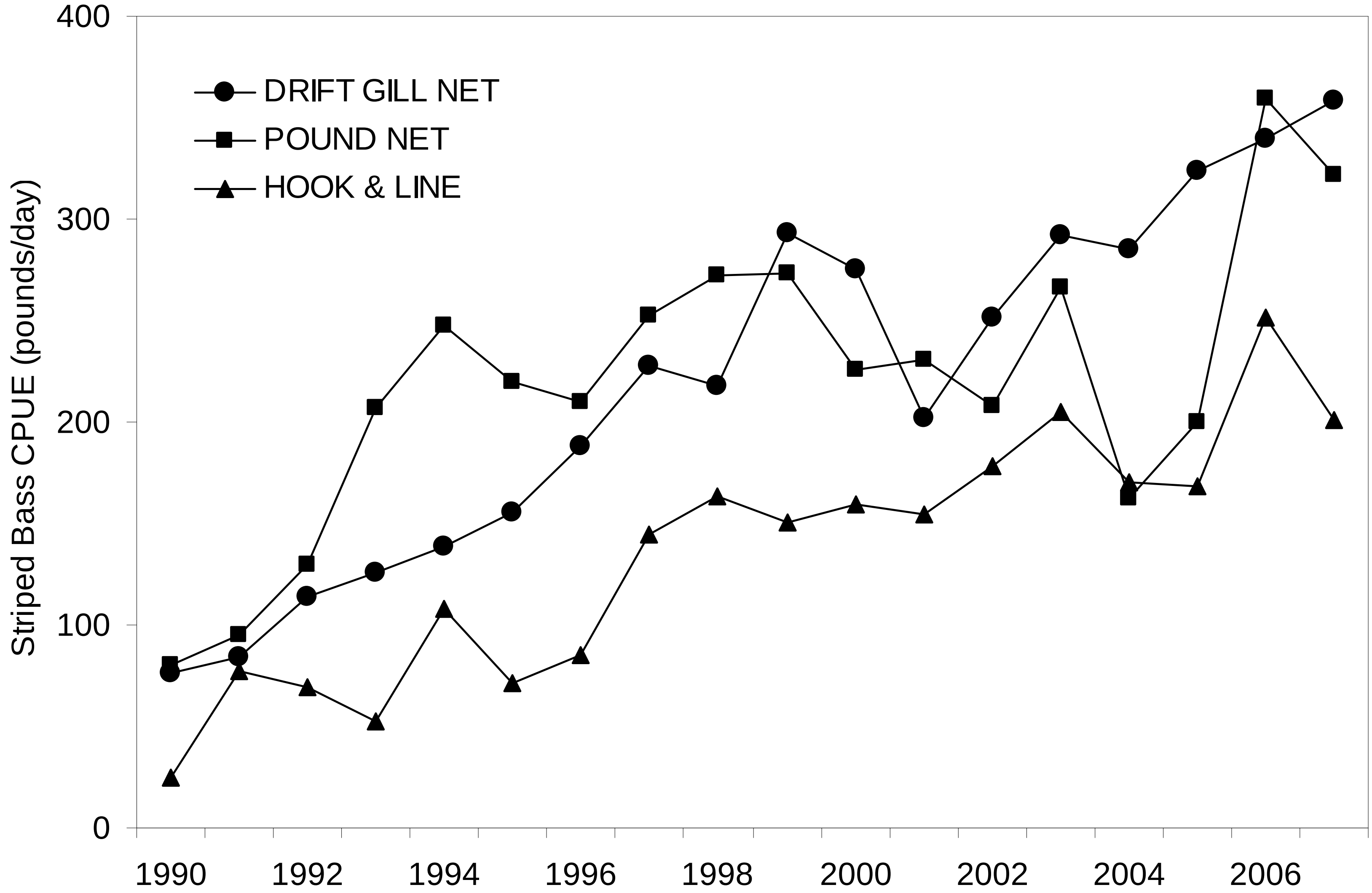
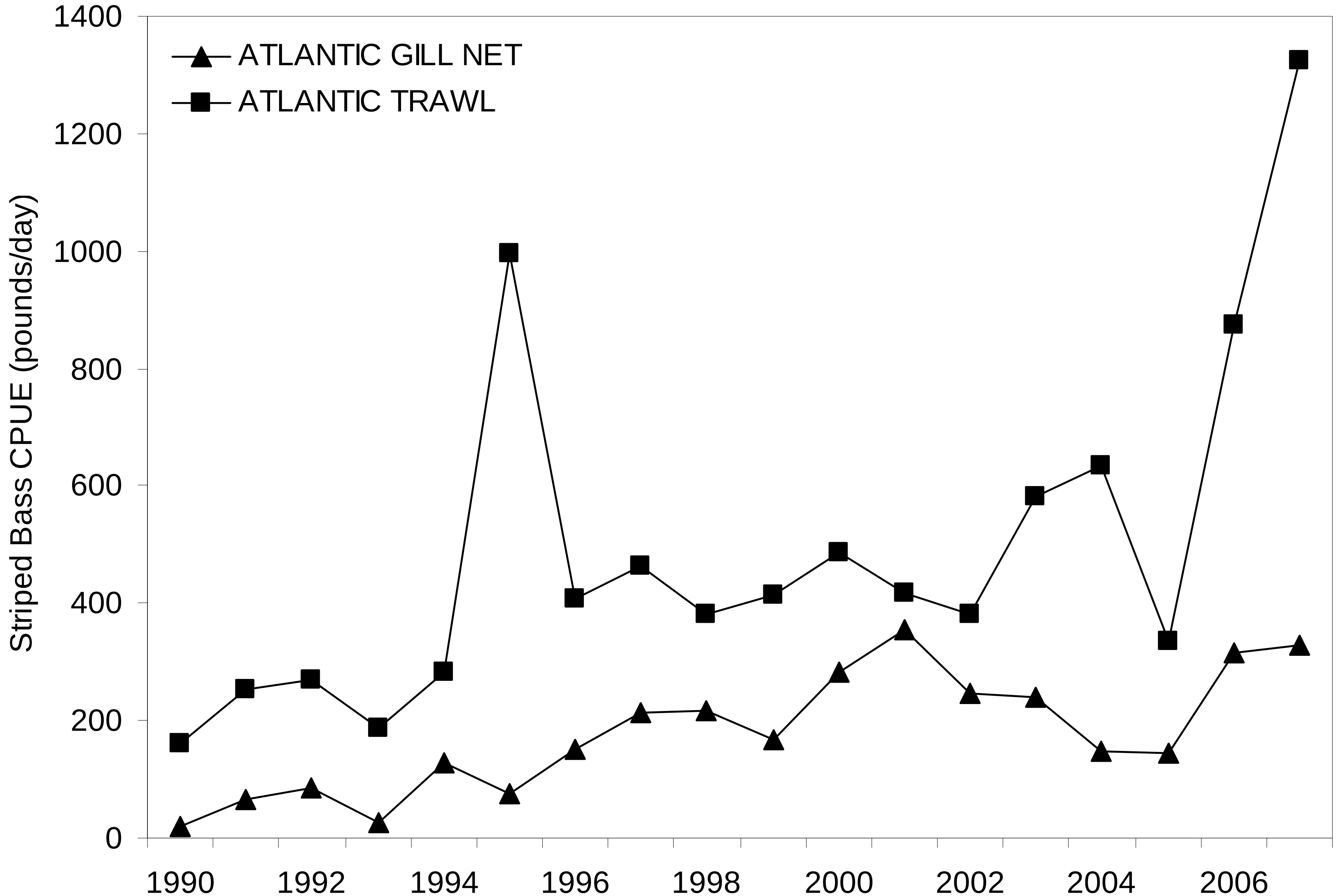


Figure 7. Maryland's Atlantic gill net and trawl fishery striped bass catch (pounds) per trip (CPUE), 1990-2007. Trips were determined as days fished when striped bass catch was reported.



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 2008 recreational spring season, which began on Saturday April 19 and continued through May 13. In 2007, the survey was expanded to collect more data from private boat anglers for comparison with a concurrent telephone survey targeting private boat fishermen. In 2008, the survey continued to emphasize the inclusion of data from private boat anglers.

A portion of the Atlantic migratory striped bass stock returns to Chesapeake Bay annually to spawn in the various tributaries during spring (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 area has a significant effect on subsequent striped bass catches and stock sizes 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 2008 season was 25 days long (April 19 – May 13), 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 and 2008 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 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. Due to 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. Biologists arrived at the 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. Sites were not chosen by a true random draw. Biologists alternated between four major charter fishing ports in 2008: Solomons/Calvert Marina, Chesapeake Beach/Rod & Reel, Deale/Happy Harbor, Tilghman Island/Harrison's (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 and eastern and western shores. Though biological data was collected from charter boat harvest, interviews with anglers from charter boats were eliminated in 2008 to allow staff more time to survey private boats and anglers. Charter boat activity is adequately characterized through the charter logbook data.

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 7 public boat ramps (Table 2B). Sites were categorized as high, medium, or low use based on the experiences of creel interviewers in previous years. High, medium, and low use sites were given relative weights of 3:2:1 for a probability-based random draw. Public boat ramps were visited on one randomly selected weekday and weekend day per week. Interviewers were stationed at four sites per selected day and remained on-site from 10 AM-3 PM. 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. Boat anglers were only interviewed after their trip was completed while shore-based anglers were interviewed as encountered.

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 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 spawning stock gillnet survey (Project No. 2, Job No. 3, Task No. 2, this report) for the construction of a combined spring age-length key. The number of scales read from the trophy fishery has varied between years. In 2008, 176 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 transverse cut from the top of the head down along the margin of the operculum. This cut continued to the top of the eye socket. A second cut was made horizontally from the front of the head above the eye until it meets with 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. These samples will be processed at a later date.

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, and an incision was made in the abdomen for internal inspection. Those fish yielding large amounts of milt were determined to be pre-spawn. Male fish with flaccid abdomens or that produced only a small amount of milt were considered post-spawn.

Calculation of Harvest and Catch Rates

Survey personnel interviewed private boat and shore anglers to obtain information from which to develop estimates of Harvest Per Trip (HPT), Harvest Per Angler (HPA), Catch Per Trip (CPT), and Catch Per Hour (CPH) (Table 4). The interview questions are provided in Appendix I. 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. 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 2008, 21% of the logbook data were excluded.

The analysis of catch rates from charter boat logs used a subset of data to include only fishing that occurred in areas specified in the MD DNR regulations during the spring season (see Figure 1). Data from the fisheries in the Susquehanna Flats area were excluded.

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. Trips sampled and interviews conducted in 2008 were from private boats and shore anglers while fish were sampled from charter boats. Anglers from charter boats were not interviewed as in previous years (Table 5B). Fishing activity during the spring season was highest in the middle and lower Bay, in the region between the Chesapeake Bay Bridge and the mouth of the Patuxent River.

BIOLOGICAL DATA

Length and Weight

Length distribution

In 2008, the minimum size limit was reverted to 28 inches TL, as in 2005. Consequently, the length distribution reflected this regulation change. The catch was dominated by fish between 840 and 1020 mm TL (33 to 40 inches) (Figure 2). This distribution is similar in shape to those observed from 2002-2005 when the minimum size limit was the same. However, the distribution in 2008 shifted slightly more to the right indicating a greater proportion of larger fish were caught compared to previous years.

Mean length

In 2008, the mean length for all sexes combined (920 mm TL) was the second highest compared with those observed in the 2002-2007 surveys (Table 6A, Figure 3). The mean length of females (933 mm TL) was greater than the mean length of males (877 mm TL), which is typical of the biology of the species. However, the mean total length of females was the highest observed across all survey years. Based on 95% confidence intervals, the mean lengths of all sexes combined and females increased significantly when compared to average lengths from all years except 2006. Mean lengths in 2006 are statistically similar to those observed in 2008.

Due to the limited number of observations, it was difficult to make definitive conclusions about the mean daily length of female striped bass harvested over the 2008 spring trophy season (Figure 4). However, the data available do indicate that the daily mean lengths were likely consistent across time within 2008 and similar to the pattern observed in 2007. This is in contrast to mean daily length data in 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 2008 fish (7.8 kg) increased compared to the mean weight observed in 2007 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 increased significantly from 2007 (Figure 5). However, these mean weights were not significantly higher than those observed in most other study years. The mean weight of males in 2008 was statistically similar to those observed in 2007. The mean weight of females (8.2 kg) was greater than the mean weight of males (6.7 kg), which is consistent with data from previous years. Females tend to grow larger than males, and most striped bass over 13.6 kg (30.0 lb) are females (Bigelow and Schroeder 1953).

Age Structure

The age distribution of striped bass from the sampled harvest in 2008 consisted of fish between 5 and 18 years of age (Figure 6). As with the length distribution, the age distribution was affected by the change in regulations on the spring fishery. Because the no take slot limit utilized in 2007 was removed in 2008, a greater proportion of older fish were allowed to be harvested. Most fish harvested were between 9 and 12 years old. The 1996 year-class (12 years old in 2008) was most frequently observed, constituting 27% of the sampled harvest. The 1997 year-class was the second most frequently observed, constituting 19% of the sampled harvest.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2008 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).

When the data were analyzed using only known-sex fish, females constituted approximately 78% of the 2008 sampled harvest. Because all fish sampled in 2008 were of known sex, the percentage of females in the harvest was the same regardless of calculation method. These results were slightly lower than the average proportion of females observed during the years 2002-2007, which ranged from 81-86% when the three methods of calculation were used.

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 2008 spring survey season indicated that only 30% of the females caught between April 19 and May 13 were in pre-spawn condition (Table 8), the lowest percentage documented by the spring season creel survey. This is in marked contrast to the 2007 spring season survey which showed that 59% of females caught were in pre-spawn condition, the highest 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 2008 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 11% to 52% on any given day. Also, sample sizes of female striped bass were small, ranging from 19 to 31 fish on any given day.

CATCH RATES AND FISHING EFFORT

Harvest Per Trip

Because of increased focus on improving our understanding of private boat fishing effort, all of the trips intercepted in 2008 were private boat trips (Table 5B). Creel survey interview data was 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, charter boat activity can be characterized from existing reporting methods. The mean HPT in 2008 from charter boat logbooks was 4.9 fish per trip, higher than that of 2007 but consistent with other years (Table 9A). Mean HPT from private boat interviews (0.6) was much lower than HPT from charter boats and lower than the private boat HPT in past years with the exceptions of 2005-2006.

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 2008 was 0.79 fish per person (Table 9B). HPA for private anglers, calculated from interview data, was 0.2 fish per person, lower than the HPA in past years (Table 9B).

Catch Per Unit Effort

In this report, catch is defined as the total 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 private boat and shore angler interview data. Mean CPT in 2008 was much lower than all other years. Mean CPT was 1.0 fish per trip in 2008, compared with 2.1 fish per trip in 2007 and 6.6 fish per trip in 2006. Mean CPH was 0.3 fish per hour in 2008 compared with 0.5 fish per hour in 2007 and 2.6 fish per hour in 2006. Confidence intervals indicate that there was a significant decrease in catch rates between 2007 and 2008. The decreases observed in CPT and CPH are the result of the elimination of charter boat interview data from the calculations as charter boat catch rates tend to be much higher than those from private boats.

Comparison of Catch Rates from Charter and Private Boats

In all years, charter boats caught more fish per trip than private boats (Tables 10B and 10D). The lower catch rate of private boats is probably influenced by the lower number of lines trolled on smaller private boats during the spring season. Charter boats typically troll with 10-20 lines, and may fish up to 7 days per week. Also, charter captain experience and constant communication with other captains enables them to track daily movements 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 2008 also generally varied without trend. However, the CPH in 2008 was much lower than in previous years at least partially due to the lack of charter boat interview data.

Angler Characterization

States of residence

In 2008, 271 trips were intercepted and 329 anglers were interviewed during the period April 19-May 13 (Table 5A). Ten states of residence were represented in 2008 (Table 11). Most anglers were from Maryland (83%), Virginia (9%), and Pennsylvania (5%), similar to the distribution of states of residence observed 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 (Project No. 2, Job 3, Task 5C, this report). In 2008, a question was added to the dockside creel survey 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 2.75 anglers per boat (Table 12). Of these anglers, 1.43 on average were license-exempt (Table 12).

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Table 1. History of MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2008.

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

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2008. 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, 2008.

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
Low	Pt. Lookout State Park
	Rock Hall

Table 3. Biological data collected by the Maryland striped bass spring season creel survey, 2008.

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, 2008.

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

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	271	329	200

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	0	265	6	0	271

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** (853-890)

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)

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

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
Mean	**81**	**85**	**86**

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

* Values for 2007 are corrected from last year's report.

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)

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)

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)

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)

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

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.

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

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

Number of Anglers Interviewed	Average Number of Anglers	Average Number of Unlicensed Anglers
267	**2.75** (2.62-2.89)	**1.43** (1.28-1.58)

Figure 1. MD DNR map showing legal open and closed striped bass fishing areas in Chesapeake Bay during the spring season, April 19-May 13, 2008.

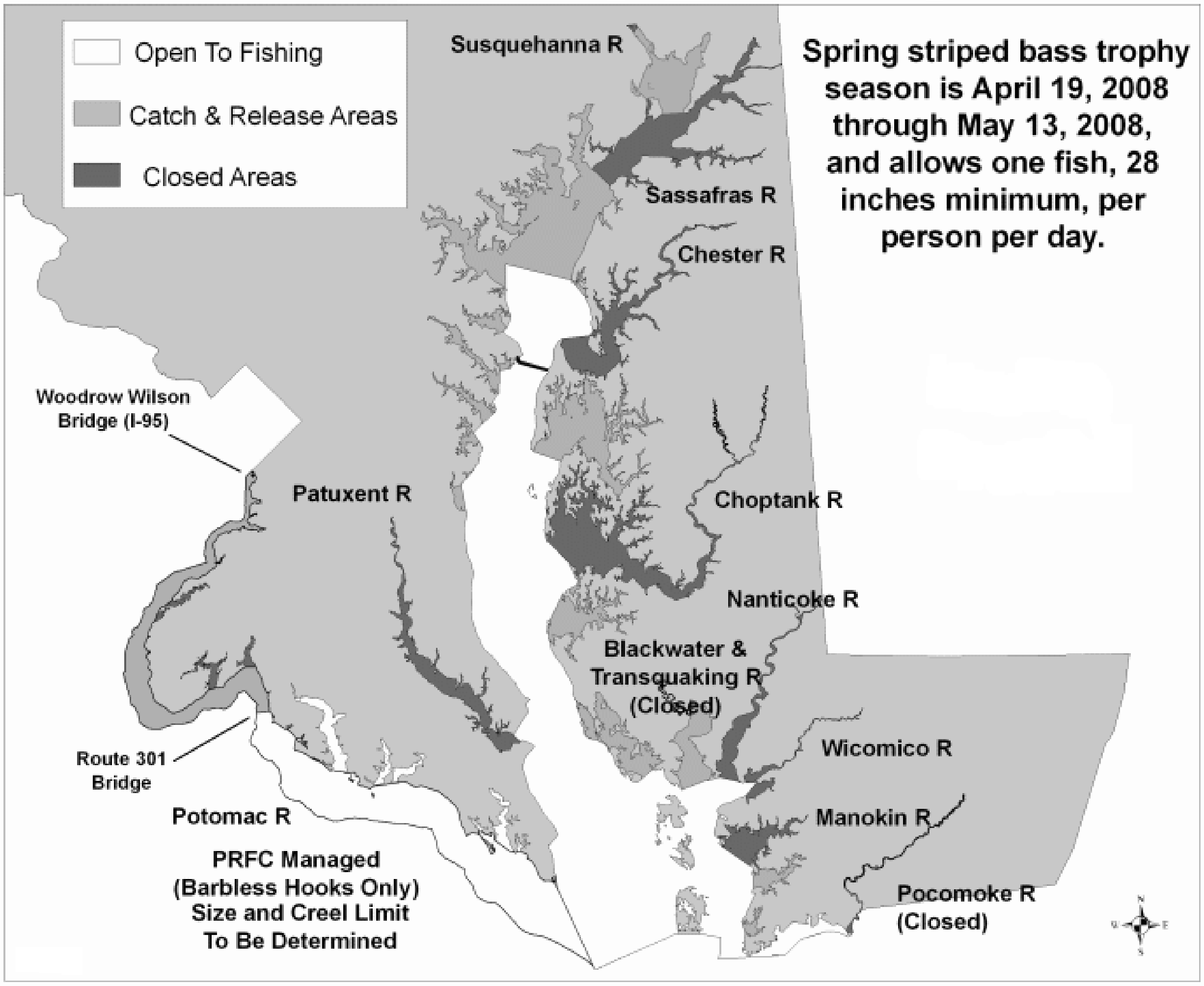


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

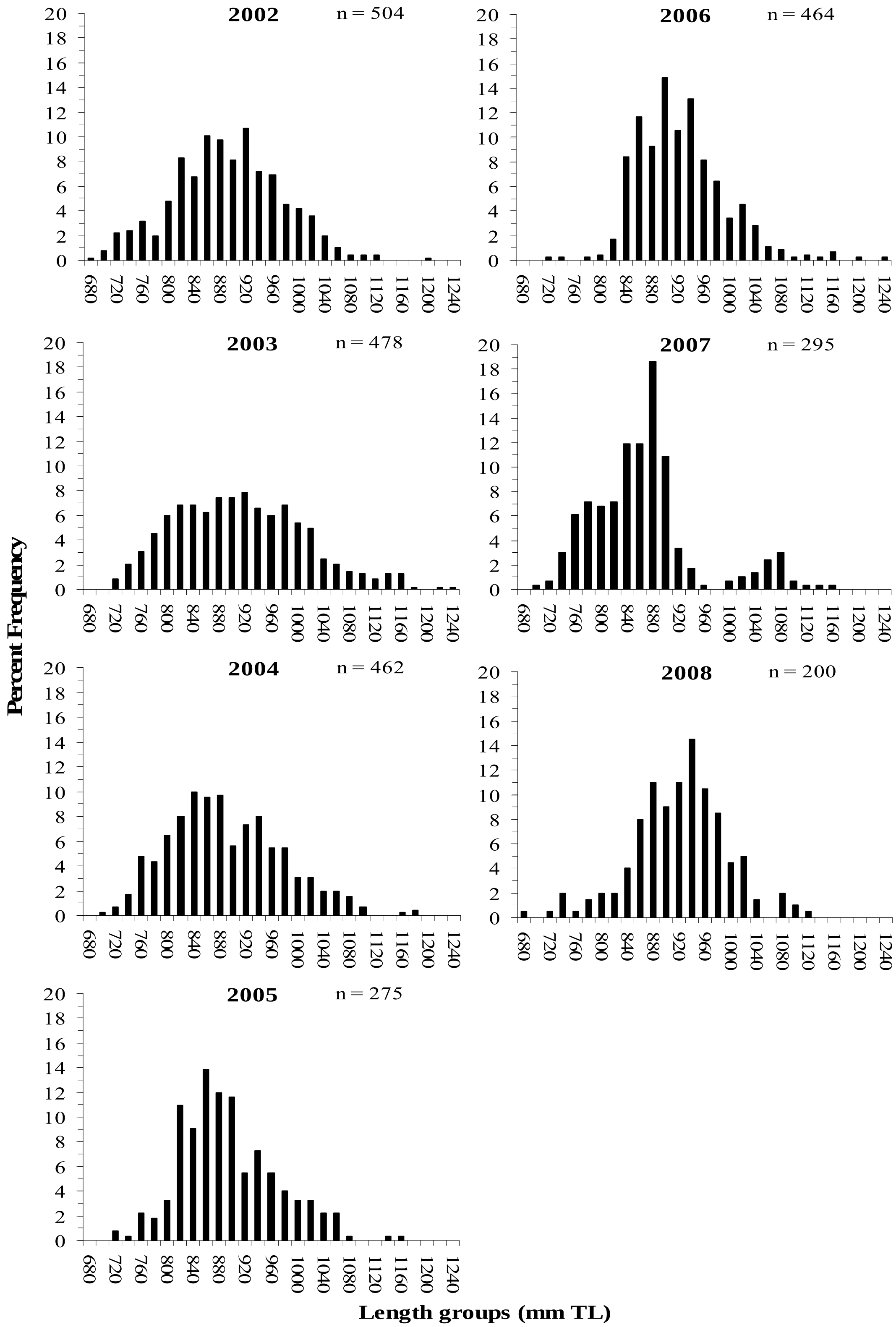


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

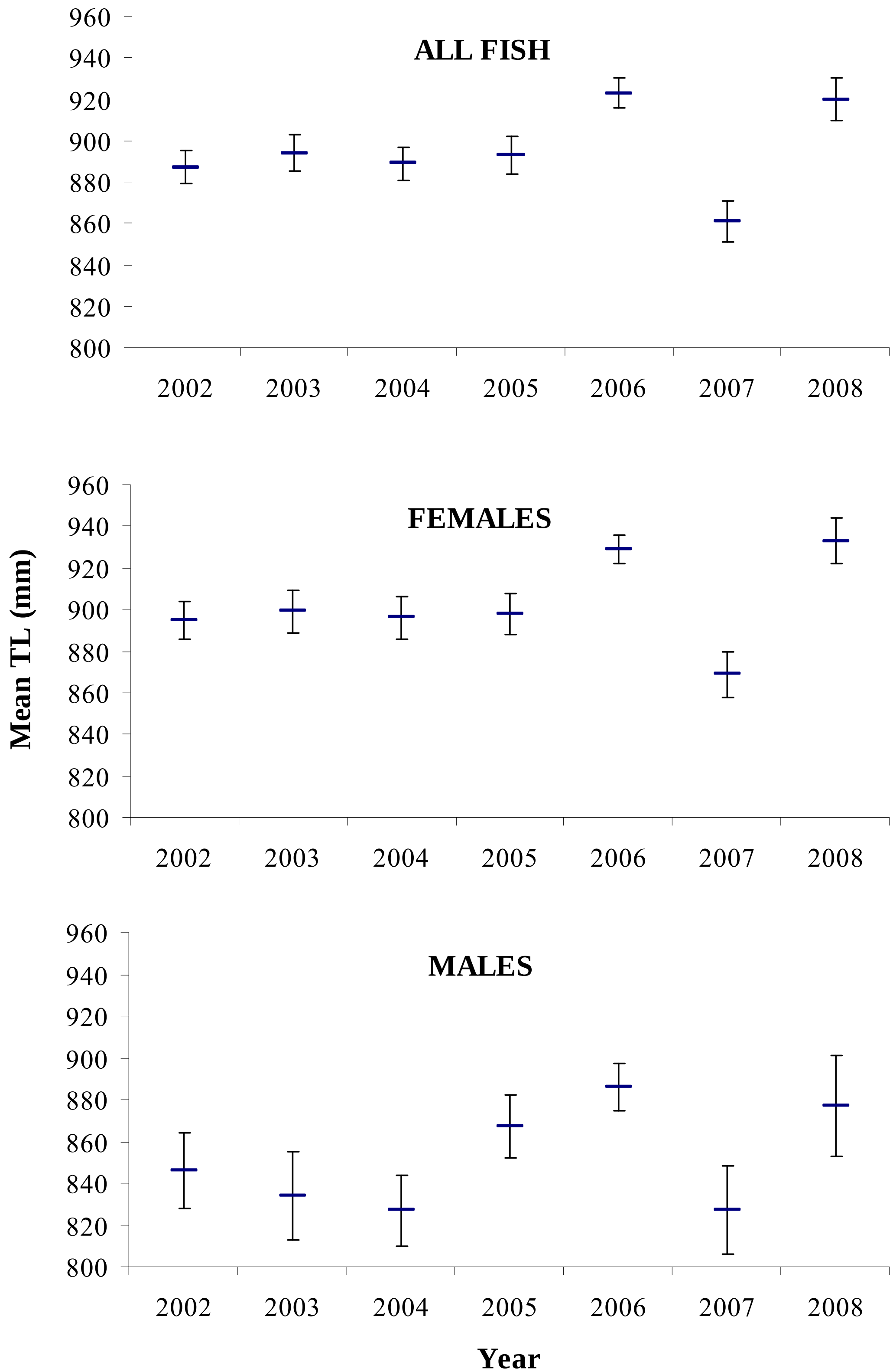


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

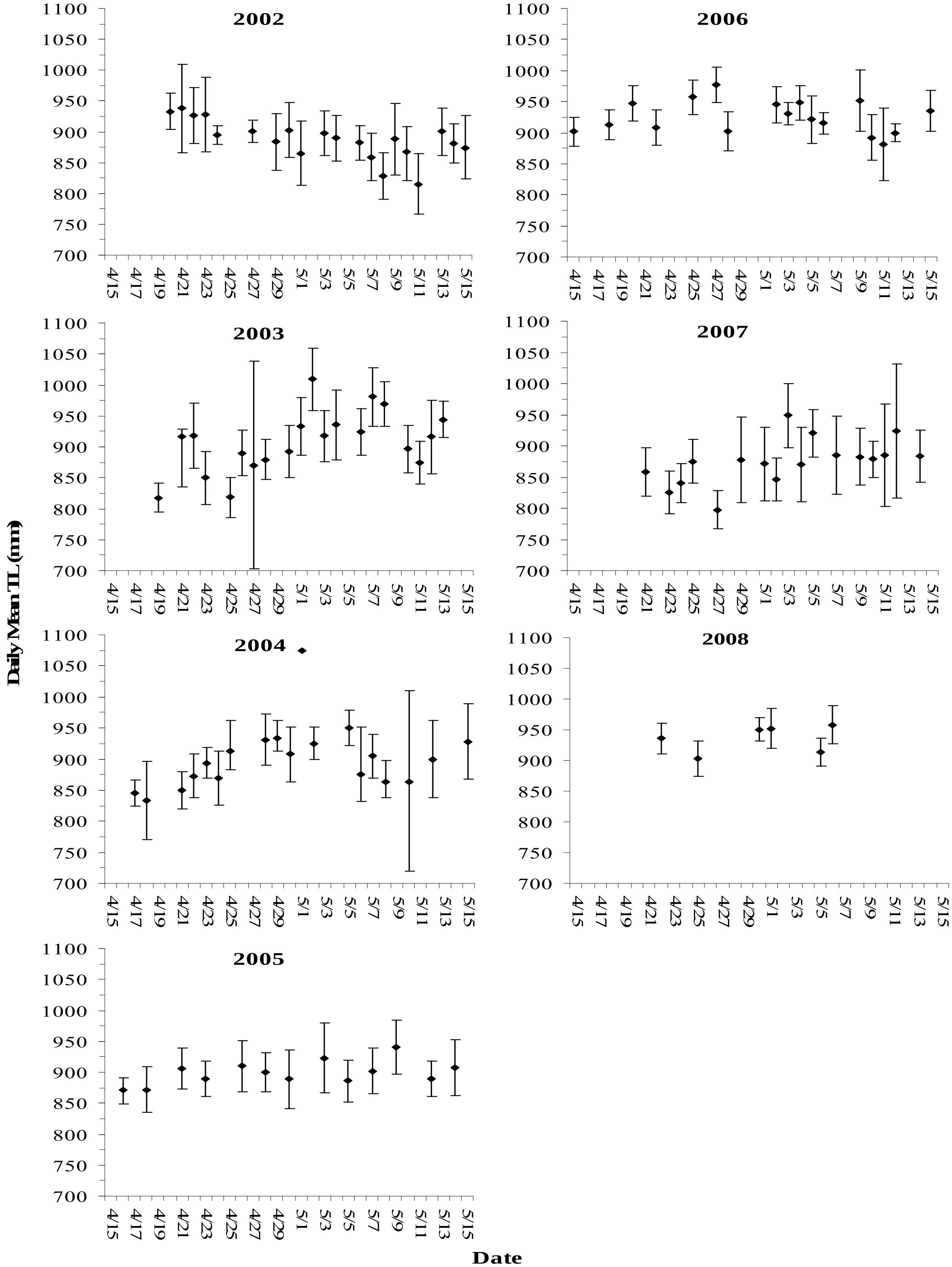


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

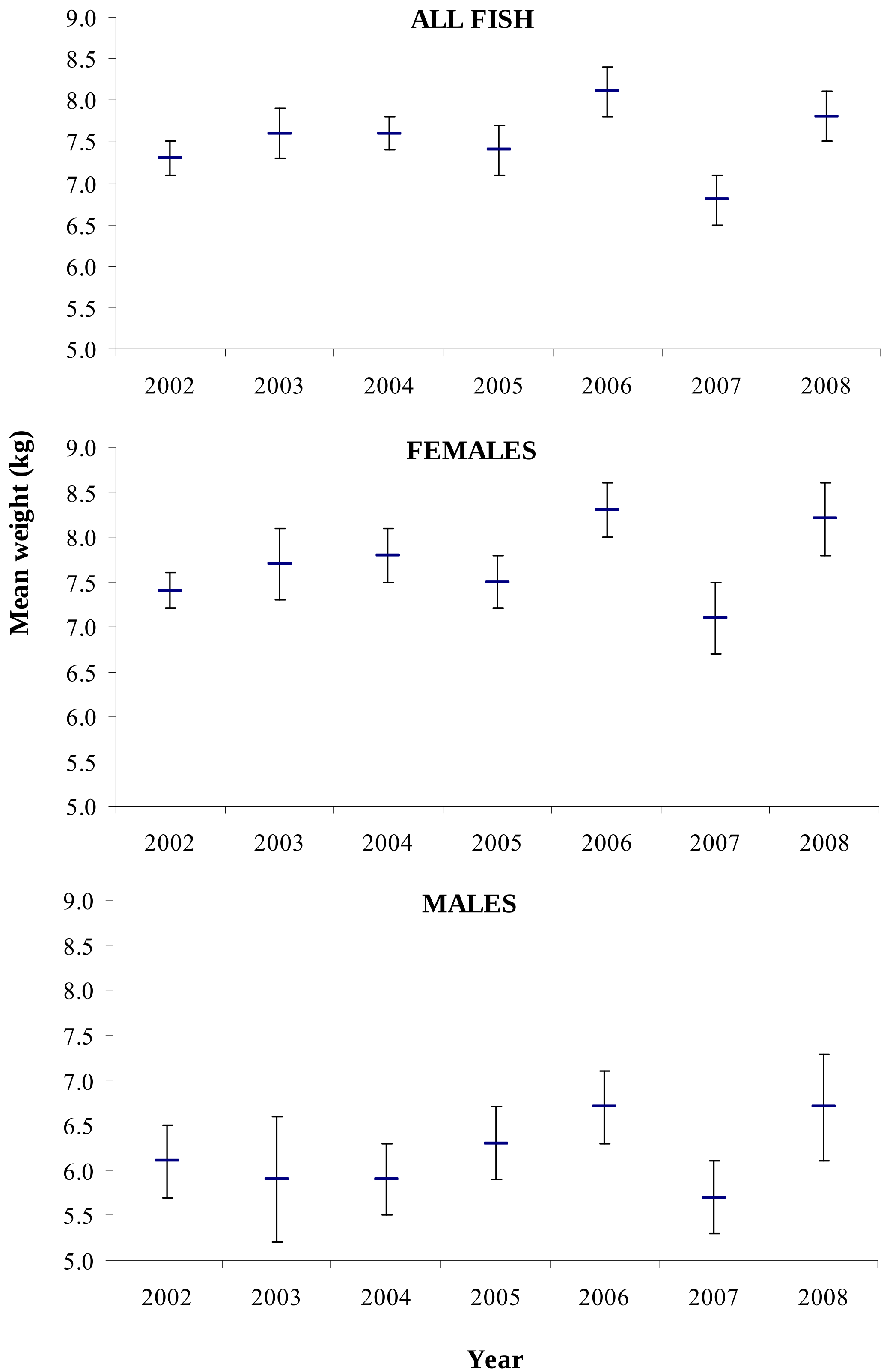


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

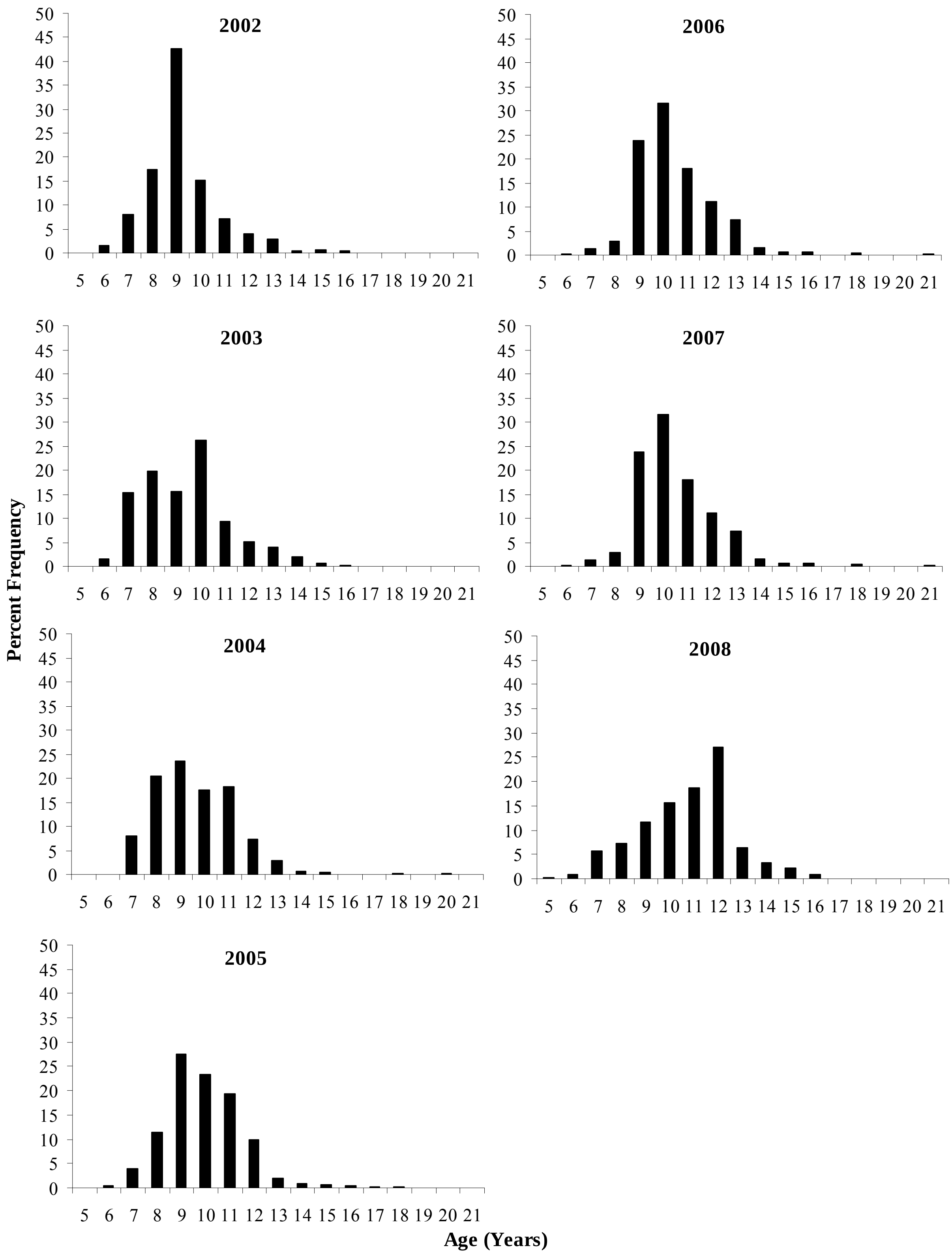


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

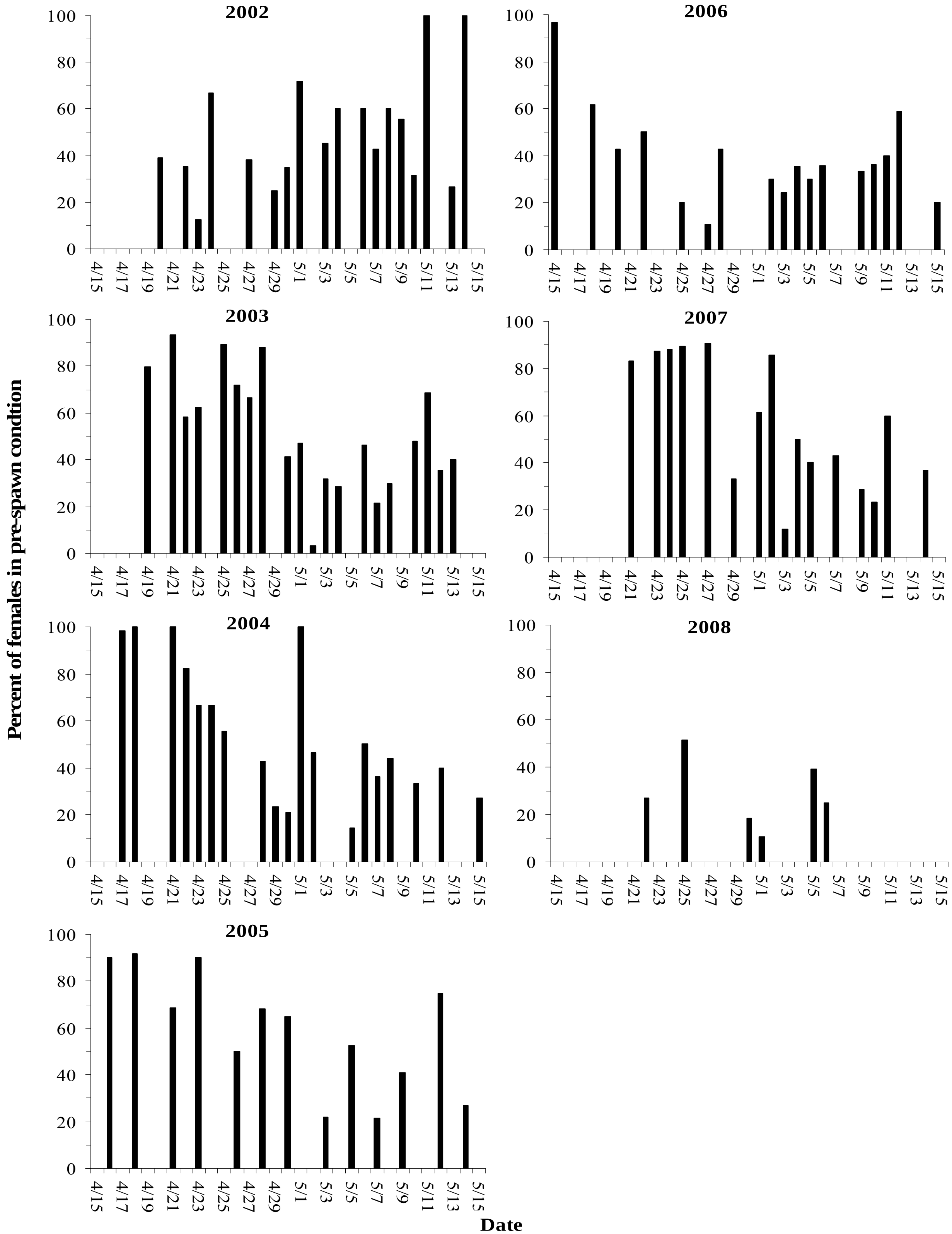
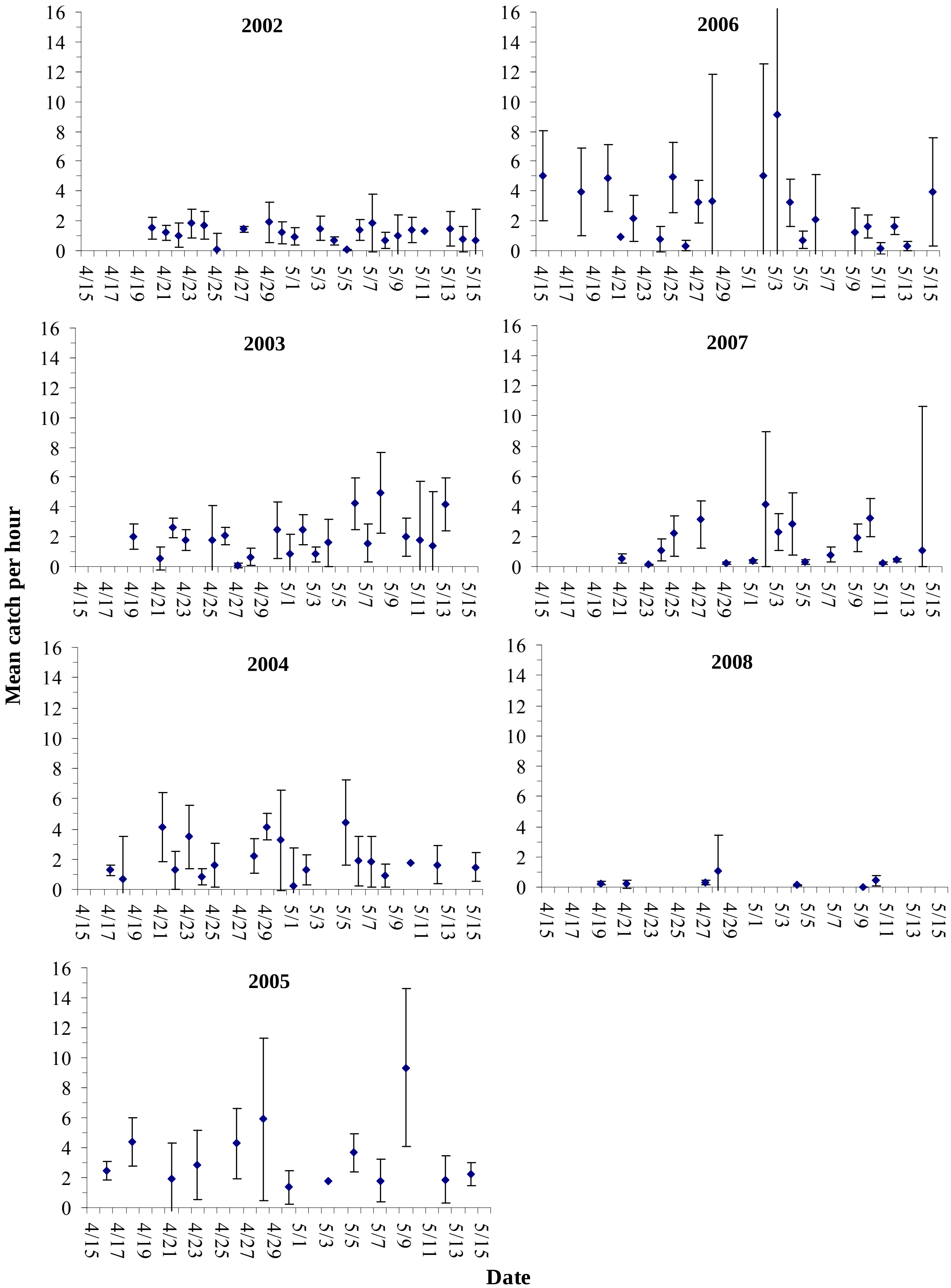


Figure 8. Daily mean catch per hour (CPH) of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15.



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?)

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. 5C

DEVELOPMENT OF SPRING SEASON RECREATIONAL STRIPED BASS HARVEST ESTIMATE THROUGH THE USE OF A TELEPHONE SURVEY

Prepared By Eric Q. Durell and Lisa Warner

INTRODUCTION

The primary objective of Project 2, Job 3, Task 5C was to develop an improved estimate of the spring season striped bass (*Morone saxatilis*) recreational harvest and fishing effort in Maryland's portion of the Chesapeake Bay. This survey began as a pilot study in 2007.

Management of the spring fishery has come under increasing scrutiny as recent estimates of migratory fish harvest derived from the Marine Recreational Fisheries Statistics Survey (MRFSS) have exceeded quotas assigned by the Atlantic States Marine Fisheries Commission (ASMFC).

Recreational spring seasons have targeted large, migratory striped bass in Maryland since 1991. Since 2001, season dates have been fairly consistent, beginning approximately the third Saturday in April and ending in mid-May. By regulation, the 2008 spring season was open from April 19 to May 13 with a creel limit of one fish per person, per day, and a minimum size of 28 inches. The season re-opened May 16 with a creel limit of two fish per person, per day, at 18-28 inches, or one fish at 18-28 inches and one greater than 28 inches.

Migratory striped bass may remain in the Chesapeake Bay through June because the timing and length of spawning seasons are heavily influenced by water temperatures

(Vladykov and Wallace 1952). Therefore, the estimation of migratory harvest was based on an analysis period of April 19 to June 13.

Some stakeholders have questioned the ability of the coast-wide MRFSS to accurately characterize a fishery of such small spatial and temporal scale. To address these concerns, MD DNR Fisheries Service implemented a telephone survey of licensed anglers to characterize fishing effort and harvest during this period. A concurrent access-intercept survey was also conducted to collect biological data from the harvest and interview anglers in person to identify potential biases of each survey type (Project 2, Job 3, Task 5B). The telephone survey focused on the effort of recreational anglers on private boats because charter boat effort is adequately characterized through existing methods.

METHODS

Telephone Survey

To develop an estimate of recreational fishing effort, Fisheries Service contracted QuanTech, Inc. of Arlington, Virginia to conduct a telephone survey of licensed anglers. To reduce recall bias, the telephone survey was designed to collect data on a weekly basis, inquiring about an interviewees' fishing activity only in the previous week, resulting in a recall period of 3-13 days (Table 1). Trained interviewers conducted the survey using a questionnaire developed by Fisheries Service staff in consultation with the contractor (Appendix 1).

Fisheries Service supplied the contractor with two licensing data sets: a data set of 2008 Bay Sport licenses sold up to April 18, and a data set of commercial licensees who are exempt from recreational licensing requirements by law. These data sets were combined to create a sample frame from which licensees were randomly selected for calling. Telephone numbers were not always collected on license applications, so the contractor was required to generate matching telephone numbers for the names and addresses supplied after a licensee was selected from the sample frame. Licensees were selected without replacement in a week, but with replacement over the course of the survey.

Calculation of Effort and Catch

To estimate how many licensees participated in the fishery during the analysis period, license sales were examined up to the beginning of the spring season, and weekly thereafter through June 13. Four types of licenses were considered: short-term 5 day Bay Sport licenses, Bay Sport boat licenses, individual Bay Sport annual licenses, and commercial fishing licenses (Table 2). Short-term licenses were later excluded from the telephone calling data frame because the behavior of this group was thought to be different from anglers who fish year-round, and would be difficult to capture through telephone interviews which inquire about fishing activity in only the previous week. Short-term licenses were included in the harvest analysis. Commercial license holders were included because they are permitted to participate in all recreational seasons without purchasing an additional recreational license. All other license types (e.g., non-tidal, crabbing) were excluded.

Weekly angler participation rates in the fishery were determined by dividing the number of interviewees who fished recreationally by the number of total respondents. Non-responses were excluded. The weekly rate of fishing activity was then multiplied by the total number of license sales to estimate the total number of anglers participating in the fishery in that week. To further characterize effort, the average weekly number of fishing trips taken by interviewed anglers was calculated and expanded to the total number of participating licensed anglers.

Mean harvest per angler trip (HPT) was determined from two different data sources: telephone interview results and the access-intercept survey (Job 3, Task 5B). Anglers interviewed by each survey were asked how many fish they caught and kept. Weekly estimates of fishing effort and harvest for the sampled population were expanded to the entire population of participating licensed anglers during the sample period to calculate total harvest.

Calculation of Migratory Harvest

ASMFC spring harvest limits pertain only to the number of migratory fish harvested in Maryland, so the total harvest was broken up into migratory and pre-migratory components. The general method used to estimate the migratory harvest in Maryland is presented in Jones (1993). The estimate is based on the Dorazio et al. (1994) size-specific probability of tagged fish in the Maryland spawning stock migrating to the Atlantic Ocean in their first year at large after tagging.

Length frequencies of harvested fish were developed in approximate two-week time intervals consistent with migratory harvest estimates reported in previous years (Barker et al. 2006, 2007). The 2008 Maryland Volunteer Charter Boat Survey was used to develop length frequencies of harvested fish because sample sizes from the internet-based Maryland Volunteer Striped Bass Angler Survey were inadequate in some time intervals. An expanded length frequency was developed for a given two-week interval by multiplying the ratio of fish in each length group by the total harvest in that interval. The number of fish harvested in each length group was then multiplied by the probability of migration for that length group. Numbers of migratory fish were then summed over length groups and time intervals to arrive at a total. This methodology was applied to total harvest estimates based on access-intercept data and telephone survey data for comparison.

RESULTS AND DISCUSSION

License Frame and Telephone Calls

Because of the time necessary to prepare the license frame for use (i.e. deleting records with incomplete or missing addresses, and producing matching telephone numbers), only license sales up to the beginning of the season were used for the telephone survey. After deleting problematic records and short-term 5 day licenses, the two datasets supplied to the contractor were combined to create a sampling frame of 42,568 license records. The use of a targeted database is more efficient than a random-digit-dial survey because it greatly reduces the number of phone calls necessary to characterize fishing effort. Approximately 800 licensees were called each calling week with an average of 52% of those calls resulting in completed interviews (Table 3).

Estimation of Licensed Effort

Telephone interviews showed that licensed participation in the fishery ranged from a high of 20% in the first week of the season to 6% in Week 7, with a general pattern of decline through the course of the seven week period (Table 4). Over 59,000 licensed anglers participated in the 2008 fishery during the study period (Table 5), a decrease of nearly 19,000 licensed anglers since last year.

Telephone survey interview data revealed that the average angler made approximately 1.4 fishing trips during the study period. When expanded to the estimated number of participating licensed anglers, this resulted in 83,506 licensed recreational fishing trips taken during the study period (Table 6).

Estimation of Harvest per Trip (HPT)

During the access-intercept survey, a total of 329 recreational anglers (323 boat-based; 6 shore-based) were interviewed following completion of their fishing trips to determine mean HPT. Similar questions were also asked of interviewees in the telephone survey.

HPT derived from the access-intercept survey (0.29) was slightly less than HPT derived from the telephone survey (0.35). A one-way analysis of variance (ANOVA) showed a slight, although significant, difference in overall mean HPT between the two surveys ($p=0.04$). Overall HPT values from the 2008 access-intercept and telephone surveys were nearly equal to their respective 2007 values of 0.29 and 0.32.

Weekly mean HPT results were similar for both surveys, with overlapping confidence intervals in all weeks (Table 7, Figure 1) except Week 3. The greatest divergence in HPT between the two data sources occurred in Week 3. Analysis of covariance (ANCOVA) showed no significant interaction between survey type and survey week ($p>0.05$), but did show differences among weeks ($p=0.001$).

The regulatory change on May 16 increased the creel limit and decreased the minimum size limit. HPT results from the access-intercept survey increased significantly

(ANOVA, p=0.0001) after the regulatory change. Telephone survey HPT results did not show any significant change by regulatory period (p>0.05).

Estimation of Licensed and Total Harvest

Weekly HPT estimates were multiplied by estimates of licensed trips to determine weekly harvest (Table 7). The overall licensed harvest using access-intercept catch rates was 23,438 fish. Overall licensed harvest using catch rates derived from the telephone survey was 30,046 fish, a difference of 6,608 fish (22%).

Maryland offers a boat license which allows otherwise unlicensed anglers to fish legally as a guest on a boat displaying the proper documentation. The 2008 access-intercept survey inquired about the number of anglers in a party that did not own individual fishing licenses. This question was not asked during the phone interviews because it often confused anglers and required further explanation which was better done in person. The overall rate of license-exempt effort was 42%. Weekly estimates of licensed harvest were multiplied by weekly proportions of license-exempt effort to arrive at estimates of total harvest. Total (licensed and unlicensed) harvest estimates using the access-intercept and telephone survey catch rates were 33,415 fish, and 42,895 fish, respectively (Table 8).

Estimation of Migratory Harvest

Cooperating charter boat captains submitted length data for 7,748 harvested striped bass during the 2008 analysis period. These data were used to develop length frequencies by approximate two-week time intervals (Table 9, Figure 2). Ninety fish less than 28 inches appear in the May 3-May 16 interval because minimum size limits decreased from 28 inches to 18 inches during this period. Expansion of the sample length frequency to the total harvest and the development of migratory harvest estimates using access-intercept source data are presented in Tables 10-13. The same procedures using telephone survey data are presented in Tables 14-17. The estimate of migratory harvest using the access-intercept HPT was 11,874 fish, while the estimate using the telephone survey HPT was 18,462 fish, a difference of 6,588 fish (36%; Table 18).

The trend of decreasing migratory harvest over the study period was evident with both methods of calculation. The contribution of migratory fish to the harvest declined from a high of 80% in the April 19-May 2 time increment to less than 3% in the May 31-June 13 increment (Figure 3).

Comparison of Results to Previous Reporting Method

Using MRFSS and Volunteer Charter Boat Survey data, Hoover et al. (2008) estimated the total Maryland harvest from April 19 to June 15, 2008 by private recreational anglers at 57,388 fish with a migrant harvest of 22,785 fish. The 2008 telephone survey estimate of migratory harvest (18,462 fish) is approximately 19% lower than the MRFSS-based method of Hoover et al. Harvest estimates from both methods are presented in Table 19 for comparison.

Two-Year Summary

The MRFSS was designed to survey fisheries on a much larger temporal and spatial scale than the Maryland spring striped bass fishery. However, the telephone survey addressed three major criticisms of the MRFSS-based harvest estimate by using a database of licensed anglers rather than random digit dial for phone calls, shortening the recall period to approximately one week instead of two months, and conducting an intense, concurrent access-intercept survey to enhance and verify data collected by phone.

The 2007 pilot study estimate did not measure license-exempt effort, but calculated a theoretical upper limit of migratory harvest (32,536 fish) which assumed that every guest on every boat was license-exempt by virtue of a boat license (Durell and Warner 2007). Retrospective application of the 42% rate of unlicensed effort measured in 2008 provides a more realistic estimate of Maryland's spring 2007 harvest of migratory striped bass (Table 20). The revised 2007 estimate of total (licensed and unlicensed) migratory striped bass harvest is 16,725 fish, 36% below the MRFSS-based estimation of 26,229 fish.

Methods were refined and improved in the second year of this study. License sales were examined and analyzed in greater detail, allowing for more precise estimates of angler participation in the fishery. The survey questionnaire was simplified, resulting in a shorter and less intrusive interview. Finally, license-exempt effort was measured by modifying the access-intercept survey questionnaire.

Angler behavior was remarkably similar in both years (Table 21). Just over half of all telephone calls yielded successful interviews in both years. Although the licensed population was smaller in 2008, approximately 12% of interviewees fished recreationally for striped bass in both years. On average, anglers took approximately 1.5 trips during both years. HPT estimates from the telephone survey were slightly higher than those from the access-intercept survey, but a weak significant difference (p=0.04) was evident only in 2008.

Telephone survey migrant harvest estimates were below MRFSS-based estimates in 2007 and 2008 by 36% and 19%, respectively (Table 22). The MRFSS-based estimate may be high, but not wildly so as some critics had suggested. The telephone survey and MRFSS-based estimates in both years are below the 30,000 fish cap imposed by ASMFC (although this cap was lifted in 2008). Therefore, Maryland is likely managing this fishery more conservatively than first thought.

CITATIONS

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Table 1. QuanTech, Inc. telephone survey calling schedule. Interviews inquired about recreational striped bass fishing activity in only the previous week to reduce recall bias.

Fishing Week	Calling Week
April 19-April 25	April 28-May 2
April 26-May 2	May 5- May 9
May 3- May 9	May 12- May 16
May 10- May 16	May 18- May 23
May 17- May 23	May 26- May 31
May 24- May 30	June 2- June 6
May 31-June 6	June 9- June 13
June 7- June 13	June 16-June 20

Table 2. License sales and time-increments considered in analysis of spring striped bass harvest estimates.

Fishing Week	Commercial Licenses	Boat Licenses	Individual Licenses	Short-Term Licenses	TOTAL	CUMULATIVE TOTAL
1	6,606	15,942	27,743	271	50,562	50,562
2		1,133	2,547	127	3,807	54,369
3		934	2,486	123	3,543	57,912
4		520	1,394	115	2,029	59,941
5		1,241	2,938	186	4,365	64,306
6		1,779	7,604	633	10,016	74,322
7		1,208	4,413	249	5,870	80,192
8		1,694	6,467	549	8,710	88,902

Table 3. Schedule of QuanTech calling activity and success rate of interviews.

Calling Week	# of Calls Made	# of Interviews	Success Rate
1	800	408	0.51
2	800	402	0.50
3	800	421	0.53
4	800	408	0.51
5	700	376	0.54
6	800	438	0.55
7	800	411	0.51
8	820	402	0.49
TOTAL	**6,320**	**3,266**	**0.52**

Table 4. Telephone interview results used to determine weekly licensed angler participation rate in the fishery.

Week	# Interviewed that Fished	# Interviewed that Did Not Fish	Total # Interviewed	Fishery Participation Rate
1	79	315	394	0.20
2	58	342	400	0.15
3	68	343	411	0.17
4	28	376	404	0.07
5	37	334	371	0.10
6	33	404	437	0.08
7	26	382	408	0.06
8	47	352	399	0.12
TOTAL	**376**	**2,848**	**3,224**	**0.12**

Table 5. Expansion of weekly fishery participation rates in the sampled population to the total licensed population.

Week	Fishery Participation Rate	License Frame	Total Licensed Angler Participation
1	0.20	50,562	10,138
2	0.15	54,369	7,884
3	0.17	57,912	9,582
4	0.07	59,941	4,154
5	0.10	64,306	6,413
6	0.08	74,322	5,612
7	0.06	80,192	5,110
8	0.12	88,902	10,472
TOTAL			**59,366**

* Sum of columns may not equal totals due to rounding

Table 6. Estimate of weekly trips per interviewed angler and expansion to total weekly licensed trips taken.

Week	# Interviewed that Fished	Total # Trips	Trips per Interviewed Angler	Total Licensed Angler Participation	Total Licensed Trips
1	79	114	1.44	10,138	14,630
2	58	92	1.59	7,884	12,505
3	68	105	1.54	9,582	14,795
4	28	41	1.46	4,154	6,083
5	37	45	1.22	6,413	7,800
6	33	38	1.15	5,612	6,463
7	26	40	1.54	5,110	7,862
8	47	60	1.28	10,472	13,369
TOTAL	**376**	**535**		**59,366**	**83,506**

Table 7. Comparison of two estimates of weekly licensed harvest in numbers of fish. Total licensed trips were multiplied by harvest per trip (HPT) derived from telephone interviews and access-intercept surveys.

Week	Total Licensed Trips	HPT (access-intercept)	Licensed Harvest (access-intercept) # of fish	HPT (telephone survey)	Licensed Harvest (telephone survey) # of fish
1	14,630	0.22	3,179	0.27	3,984
2	12,505	0.27	3,320	0.42	5,245
3	14,795	0.12	1,800	0.31	4,643
4	6,083	0.27	1,645	0.35	2,106
5	7,800	0.30	2,340	0.35	2,726
6	6,463	0.45	2,900	0.44	2,853
7	7,862	0.38	2,994	0.40	3,164
8	13,369	0.39	5,261	0.40	5,325
TOTAL	**83,506**		**23,438**		**30,046**

* Sum of columns may not equal totals due to rounding

Table 8. Comparison of two estimates of total harvest in numbers of fish. Licensed harvest derived from two survey methods was multiplied by the weekly proportion of unlicensed effort derived from access-intercept surveys.

Week	**Licensed Harvest (access-intercept) # of fish**	**Licensed Harvest (telephone survey) # of fish**	**Weekly Proportion of Unlicensed Effort**	**Total Harvest (access-intercept) # of fish**	**Total Harvest (telephone survey) # of fish**
1	3,179	3,984	0.48	4,699	5,889
2	3,320	5,245	0.53	5,080	8,027
3	1,800	4,643	0.39	2,494	6,434
4	1,645	2,106	0.34	2,201	2,819
5	2,340	2,726	0.41	3,306	3,851
6	2,900	2,853	0.45	4,195	4,127
7	2,994	3,164	0.27	3,801	4,017
8	5,261	5,325	0.45	7,639	7,732
TOTAL	**23,438**	**30,046**		**33,415**	**42,895**

* Sum of columns may not equal totals due to rounding

Table 9. Length frequencies developed from the 2008 Volunteer Charter Boat Survey used in the calculation of migratory striped bass harvest.

	Analysis Interval				
Length Group (inches)	**April 19-May 2**	**May 3-May 16**	**May 17-May 30**	**May 31-June 13**	**TOTAL**
18		1	117	67	185
19		15	319	162	496
20		15	267	109	391
21		8	184	104	296
22		12	151	68	231
23		7	104	48	159
24		11	102	46	159
25		8	65	17	90
26		6	64	13	83
27		7	43	12	62
28	27	23	37	20	107
29	77	45	29	9	160
30	108	41	26	10	185
31	138	44	10	2	194
32	264	90	17	5	376
33	315	115	6	2	438
34	399	115	7	3	524
35	383	123	9	1	516
36	500	147	9	1	657
37	447	126	3	2	578
38	436	126	7		569
39	383	95	1		479
40	230	49	1		280
41	191	36	5		232
42	99	26	1		126
43	64	11	1		76
44	42	9			51
45	15	1			16
46	14	2			16
47	5				5
48	5	1			6
49	3				3
50					0
51	1				1
52	1				1
TOTAL	**4,147**	**1,315**	**1,585**	**701**	**7,748**

Table 10. Probability-based estimate of migratory striped bass harvest from April 19-May 2, 2008 using harvest per trip value derived from the access-intercept survey.

April 19-May 2					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
28	0.1283	0.01	64	8	55
29	0.1930	0.02	182	35	147
30	0.2797	0.03	255	71	183
31	0.3868	0.03	325	126	200
32	0.5061	0.06	623	315	307
33	0.6247	0.08	743	464	279
34	0.7300	0.10	941	687	254
35	0.8146	0.09	903	736	167
36	0.8771	0.12	1,179	1,034	145
37	0.9206	0.11	1,054	970	84
38	0.9496	0.11	1,028	976	52
39	0.9683	0.09	903	875	29
40	0.9803	0.06	542	532	11
41	0.9878	0.05	450	445	5
42	0.9924	0.02	233	232	2
43	0.9953	0.02	151	150	1
44	0.9971	0.01	99	99	0
45	1.0000	0.00	35	35	0
46	1.0000	0.00	33	33	0
47	1.0000	0.00	12	12	0
48	1.0000	0.00	12	12	0
49	1.0000	0.00	7	7	0
50	1.0000	0.00	0	0	0
51	1.0000	0.00	2	2	0
52	1.0000	0.00	2	2	0
TOTAL		**1.00**	**9,779**	**7,858**	**1,921**

Table 11. Probability-based estimate of migratory striped bass harvest from May 3-16, 2008 using harvest per trip value derived from the access-intercept survey.

May 3-May 16					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.00	4	0	4
19		0.01	54	0	54
20		0.01	54	0	54
21		0.01	29	0	29
22		0.01	43	0	43
23		0.01	25	0	25
24		0.01	39	0	39
25		0.01	29	0	29
26	0.0528	0.00	21	1	20
27	0.0831	0.01	25	2	23
28	0.1283	0.02	82	11	72
29	0.1930	0.03	161	31	130
30	0.2797	0.03	146	41	105
31	0.3868	0.03	157	61	96
32	0.5061	0.07	321	163	159
33	0.6247	0.09	411	256	154
34	0.7300	0.09	411	300	111
35	0.8146	0.09	439	358	81
36	0.8771	0.11	525	460	65
37	0.9206	0.10	450	414	36
38	0.9496	0.10	450	427	23
39	0.9683	0.07	339	328	11
40	0.9803	0.04	175	172	3
41	0.9878	0.03	129	127	2
42	0.9924	0.02	93	92	1
43	0.9953	0.01	39	39	0
44	0.9971	0.01	32	32	0
45	1.0000	0.00	4	4	0
46	1.0000	0.00	7	7	0
47	1.0000	0.00	0	0	0
48	1.0000	0.00	4	4	0
TOTAL		**1.00**	**4,695**	**3,329**	**1,366**

Table 12. Probability-based estimate of migratory striped bass harvest from May 17-30, 2008 using harvest per trip value derived from the access-intercept survey.

May 17-May 30					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.07	554	0	554
19		0.20	1,510	0	1,510
20		0.17	1,264	0	1,264
21		0.12	871	0	871
22		0.10	715	0	715
23		0.07	492	0	492
24		0.06	483	0	483
25		0.04	308	0	308
26	0.0528	0.04	303	16	287
27	0.0831	0.03	203	17	187
28	0.1283	0.02	175	22	153
29	0.1930	0.02	137	26	111
30	0.2797	0.02	123	34	89
31	0.3868	0.01	47	18	29
32	0.5061	0.01	80	41	40
33	0.6247	0.00	28	18	11
34	0.7300	0.00	33	24	9
35	0.8146	0.01	43	35	8
36	0.8771	0.01	43	37	5
37	0.9206	0.00	14	13	1
38	0.9496	0.00	33	31	2
39	0.9683	0.00	5	5	0
40	0.9803	0.00	5	5	0
41	0.9878	0.00	24	23	0
42	0.9924	0.00	5	5	0
43	0.9953	0.00	5	5	0
TOTAL		**1.00**	**7,501**	**376**	**7,125**

* Sum of columns may not equal totals due to rounding

Table 13. Probability-based estimate of migratory striped bass harvest from May 31-June 13, 2008 using harvest per trip value derived from the access-intercept survey.

May 31-June 13					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.10	1,093	0	1,093
19		0.23	2,644	0	2,644
20		0.16	1,779	0	1,779
21		0.15	1,697	0	1,697
22		0.10	1,110	0	1,110
23		0.07	783	0	783
24		0.07	751	0	751
25		0.02	277	0	277
26	0.0528	0.02	212	11	201
27	0.0831	0.02	196	16	180
28	0.1283	0.03	326	42	285
29	0.1930	0.01	147	28	119
30	0.2797	0.01	163	46	118
31	0.3868	0.00	33	13	20
32	0.5061	0.01	82	41	40
33	0.6247	0.00	33	20	12
34	0.7300	0.00	49	36	13
35	0.8146	0.00	16	13	3
36	0.8771	0.00	16	14	2
37	0.9206	0.00	33	30	3
TOTAL		**1.00**	**11,440**	**311**	**11,129**

Table 14. Probability-based estimate of migratory striped bass harvest from April 19-May 2, 2008 using harvest per trip (HPT) value derived from the telephone survey.

April 19-May 2					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
28	0.1283	0.01	91	12	79
29	0.1930	0.02	258	50	209
30	0.2797	0.03	362	101	261
31	0.3868	0.03	463	179	284
32	0.5061	0.06	886	448	438
33	0.6247	0.08	1,057	660	397
34	0.7300	0.10	1,339	977	362
35	0.8146	0.09	1,285	1,047	238
36	0.8771	0.12	1,678	1,472	206
37	0.9206	0.11	1,500	1,381	119
38	0.9496	0.11	1,463	1,389	74
39	0.9683	0.09	1,285	1,244	41
40	0.9803	0.06	772	757	15
41	0.9878	0.05	641	633	8
42	0.9924	0.02	332	330	3
43	0.9953	0.02	215	214	1
44	0.9971	0.01	141	141	0
45	1.0000	0.00	50	50	0
46	1.0000	0.00	47	47	0
47	1.0000	0.00	17	17	0
48	1.0000	0.00	17	17	0
49	1.0000	0.00	10	10	0
50	1.0000	0.00	0	0	0
51	1.0000	0.00	3	3	0
52	1.0000	0.00	3	3	0
TOTAL		**1.00**	**13,915**	**11,182**	**2,733**

Table 15. Probability-based estimate of migratory striped bass harvest from May 3-16, 2008 using harvest per trip (HPT) value derived from the telephone survey.

May 3-May 16					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.00	7	0	7
19		0.01	106	0	106
20		0.01	106	0	106
21		0.01	56	0	56
22		0.01	84	0	84
23		0.01	49	0	49
24		0.01	77	0	77
25		0.01	56	0	56
26	0.0528	0.00	42	2	40
27	0.0831	0.01	49	4	45
28	0.1283	0.02	162	21	141
29	0.1930	0.03	317	61	256
30	0.2797	0.03	288	81	208
31	0.3868	0.03	310	120	190
32	0.5061	0.07	633	321	313
33	0.6247	0.09	809	506	304
34	0.7300	0.09	809	591	218
35	0.8146	0.09	865	705	160
36	0.8771	0.11	1,034	907	127
37	0.9206	0.10	887	816	70
38	0.9496	0.10	887	842	45
39	0.9683	0.07	668	647	21
40	0.9803	0.04	345	338	7
41	0.9878	0.03	253	250	3
42	0.9924	0.02	183	182	1
43	0.9953	0.01	77	77	0
44	0.9971	0.01	63	63	0
45	1.0000	0.00	7	7	0
46	1.0000	0.00	14	14	0
47	1.0000	0.00	0	0	0
48	1.0000	0.00	7	7	0
TOTAL		**1.00**	**9,253**	**6,561**	**2,692**

Table 16. Probability-based estimate of migratory striped bass harvest from May 17-30, 2008 using harvest per trip (HPT) value derived from the telephone survey.

May 17-May 30					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.07	589	0	589
19		0.20	1,606	0	1,606
20		0.17	1,344	0	1,344
21		0.12	926	0	926
22		0.10	760	0	760
23		0.07	523	0	523
24		0.06	513	0	513
25		0.04	327	0	327
26	0.0528	0.04	322	17	305
27	0.0831	0.03	216	18	198
28	0.1283	0.02	186	24	162
29	0.1930	0.02	146	28	118
30	0.2797	0.02	131	37	94
31	0.3868	0.01	50	19	31
32	0.5061	0.01	86	43	42
33	0.6247	0.00	30	19	11
34	0.7300	0.00	35	26	10
35	0.8146	0.01	45	37	8
36	0.8771	0.01	45	40	6
37	0.9206	0.00	15	14	1
38	0.9496	0.00	35	33	2
39	0.9683	0.00	5	5	0
40	0.9803	0.00	5	5	0
41	0.9878	0.00	25	25	0
42	0.9924	0.00	5	5	0
43	0.9953	0.00	5	5	0
TOTAL		**1.00**	**7,978**	**400**	**7,578**

Table 17. Probability-based estimate of migratory striped bass harvest from May 31-June 13, 2008 using harvest per trip (HPT) value derived from the telephone survey.

May 31-June 13					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.10	1,123	0	1,123
19		0.23	2,715	0	2,715
20		0.16	1,827	0	1,827
21		0.15	1,743	0	1,743
22		0.10	1,140	0	1,140
23		0.07	804	0	804
24		0.07	771	0	771
25		0.02	285	0	285
26	0.0528	0.02	218	12	206
27	0.0831	0.02	201	17	184
28	0.1283	0.03	335	43	292
29	0.1930	0.01	151	29	122
30	0.2797	0.01	168	47	121
31	0.3868	0.00	34	13	21
32	0.5061	0.01	84	42	41
33	0.6247	0.00	34	21	13
34	0.7300	0.00	50	37	14
35	0.8146	0.00	17	14	3
36	0.8771	0.00	17	15	2
37	0.9206	0.00	34	31	3
TOTAL		**1.00**	**11,749**	**319**	**11,430**

Table 18. Comparison of migratory and resident striped bass harvest estimates derived from telephone and access-intercept surveys from April 19-June 13, 2008.

Interval	Harvest with Access-intercept HPT			Harvest with Telephone Survey HPT		
	Migrant	Resident	TOTAL	Migrant	Resident	TOTAL
April 19-May 2	7,858	1,921	9,779	11,182	2,733	13,915
May 3-May 16	3,329	1,366	4,695	6,561	2,692	9,253
May 17-May 30	376	7,125	7,501	400	7,578	7,978
May 31-June 13	311	11,129	11,440	319	11,430	11,749
TOTAL	**11,874**	**21,541**	**33,415**	**18,462**	**24,433**	**42,895**

Table 19. Comparison of recreational harvest estimates derived from telephone survey and MRFSS data (Hoover et. al. 2008) from April 19-June 13, 2008.

Interval	Harvest Estimates from Telephone Survey			Harvest Estimates from MRFSS Data		
	Migrant	Resident	TOTAL	Migrant	Resident	TOTAL
April 19-May 2	11,182	2,733	13,915	11,567	2,419	13,986
May 3-May 16	6,561	2,692	9,253	9,926	1,890	11,816
May 17-May 30	400	7,578	7,978	949	15,596	16,545
May 31-June 13	319	11,430	11,749	343	14,698	15,041
TOTAL	**18,462**	**24,433**	**42,895**	**22,785**	**34,603**	**57,388**

Table 20. Telephone survey harvest estimates for spring 2007 adjusted retrospectively to include 42% unlicensed effort. 2007 MRFSS-based harvest estimates are included for comparison.

Interval	Adjusted 2007 Harvest Estimates from Telephone Survey			2007 Harvest Estimate from MRFSS Data		
	Migrant	Resident	TOTAL	Migrant	Resident	TOTAL
Apr 21-30	3,263	2,323	5,586	8,627	6,139	14,766
May 1-15	9,060	4,303	13,362	12,622	6,211	18,833
May 16-31	3,319	21,950	25,269	3,190	21,096	24,286
June 1-15	1,083	14,247	15,330	1,790	25,237	27,027
TOTAL	**16,725**	**42,823**	**59,548**	**26,229**	**58,683**	**84,912**

* Sum of columns may not equal totals due to rounding

Table 21. Summary results of angler behavior from two years of telephone and access-intercept surveys.

Year	Rate of Successful Calls	% of Licensed Anglers that Fished	Trips per Angler	HPT (Access-Intercept)	HPT (Telephone Survey)
2007	0.53	12	1.57	0.29	0.32
2008	0.52	12	1.42	0.29	0.35

Table 22. Telephone survey and MRFSS-based estimates of Maryland spring migratory striped bass harvest, 2007-2008.

Year	Telephone Survey Migrant Harvest Estimate	MRFSS-based Migrant Harvest Estimate	% Difference between Estimates
2007	16,725	26,229	36
2008	18,462	22,785	19

Figure 1. Comparison of weekly harvest per trip (HPT) estimates derived from 2008 access-intercept and telephone surveys.

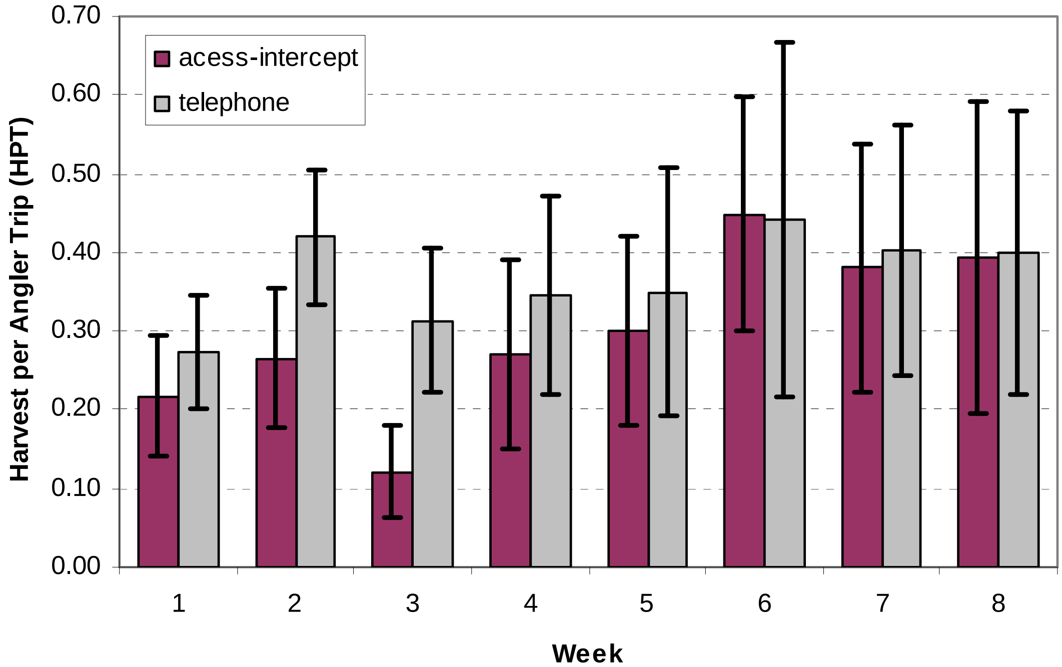


Figure 2. Length frequencies developed from the 2008 Volunteer Charter Boat Survey used in calculations of migratory striped bass harvest.

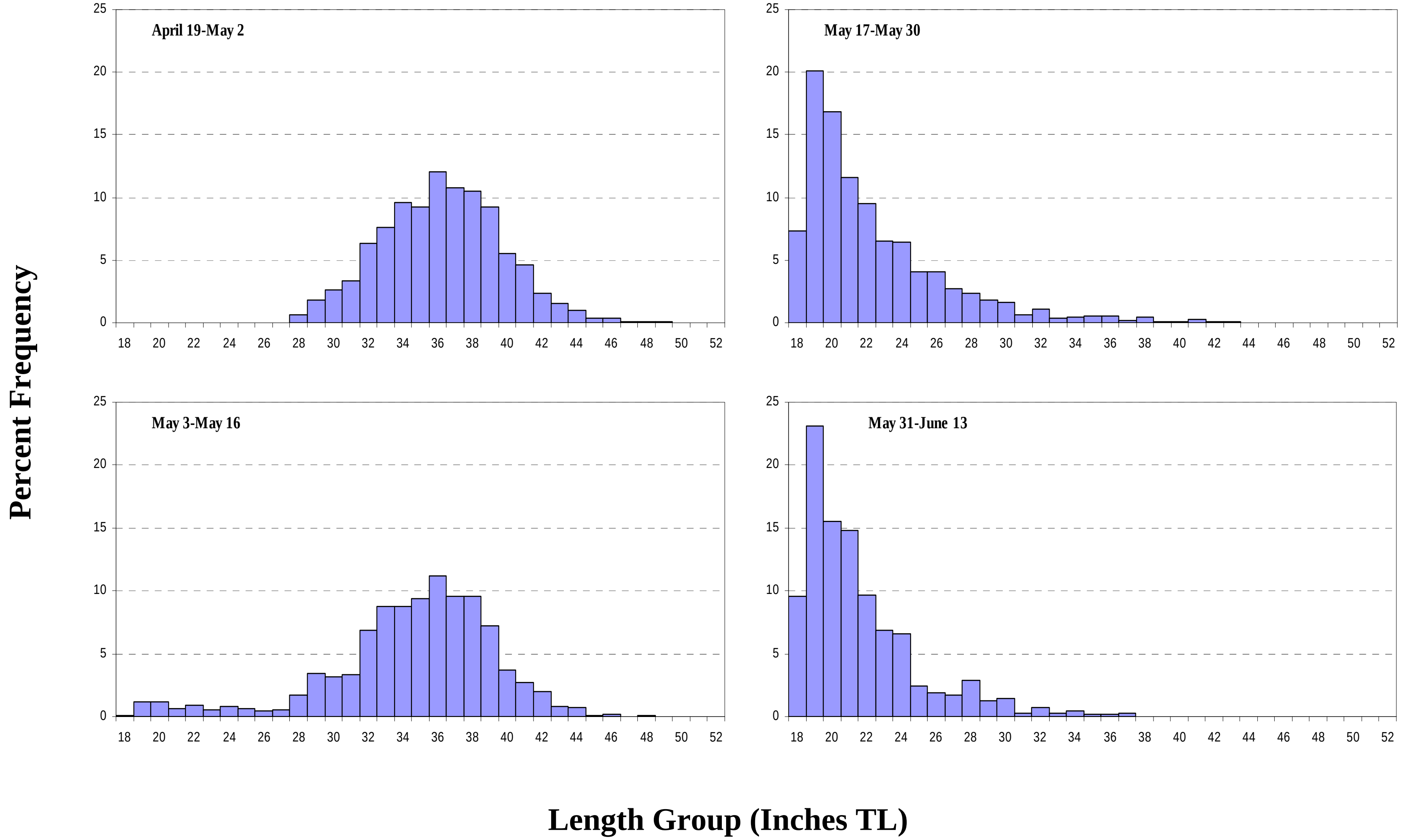
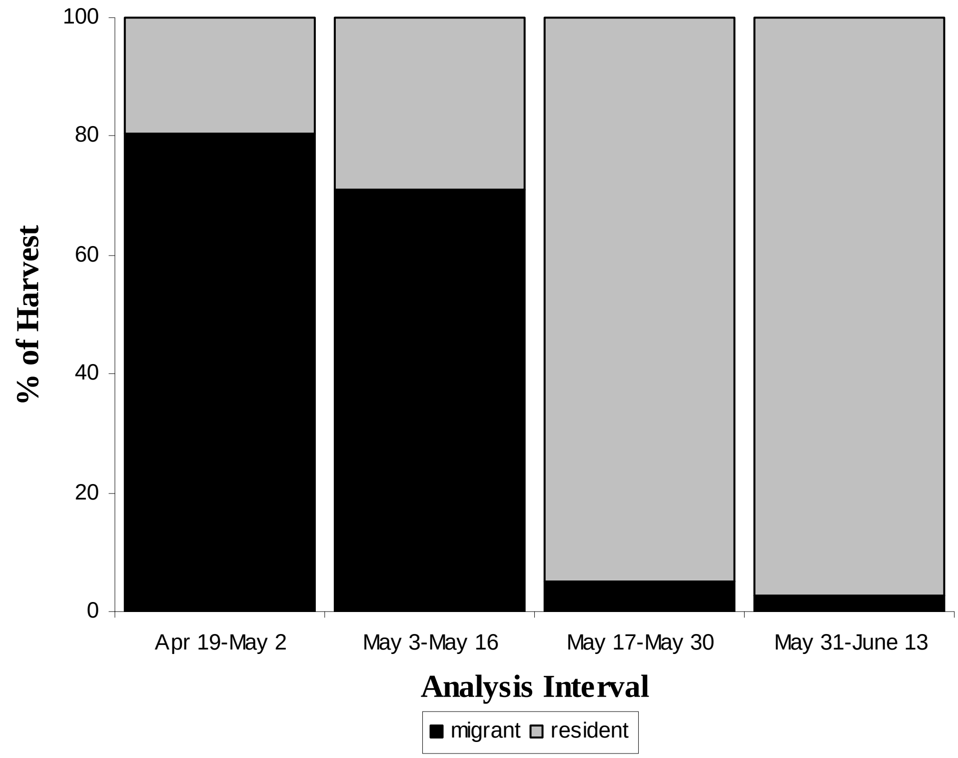


Figure 3. Estimated contribution of migratory and resident/pre-migratory striped bass harvested from April 19-June 13, 2008.



Appendix 1. Questionnaire used for 2008 telephone survey.

2008 Striped Bass Season Telephone Questionnaire

1. How many times did you fish for striped bass in Maryland during the period ___________?

Weeks defined as: April 19-25
Apr 26-May 2
May 3-9
May 10-16 (FISHERY CLOSED MAY 14, 15)
May 17-23* (FLATS FISHERY BEGINS MAY 16)
May 24-May 30
May 31-June 6
June 7-June 13

> From this point on, interview will pertain to most recent trip only. If more than one trip during this week, interview should begin again at number 2 for each trip.

2. On this trip, did you fish from a charter boat?

If YES, interview is over
If NO, go to 3.

3. On what day of the week did you fish?

4. Did you fish from a private boat or shore/pier/jetty?

5. How many people were in your party?

6. How many striped bass did your party keep?

7. In what area of the Bay did most of your fishing take place?

Upper Bay (north of Bay Bridge), Middle Bay (Bay Bridge to Cove Pt. at mouth of Patuxent), Lower Bay (Cove Pt. to Virginia state line)

***MAY 16-31 ONLY: If UPPER BAY or DON'T KNOW/REFUSED, go to 7B**

7B. Did you fish on the Susquehanna Flats as part of the new May 16-31 season?

8. At what time did you begin fishing (lines in the water)?

9. At what time did you stop fishing (lines out of the water)?

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

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

Prepared by Beth Versak

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 2008. 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 2008, 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 DC current (fully adjustable). 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 & DISCUSSION

In 2008, sampling was limited to two days, April 9 and April 10. Eighty-two striped bass were scanned for the presence of CWTs and none were found to be positive. A total effort of approximately two hours and 45 minutes of actual shocking time was recorded on the electrofishing boats (Table 1).

The mean total length (TL) of the 82 striped bass measured was 964 mm TL (minimum=814 mm TL, maximum=1,206 mm TL, median=944 mm TL). Of those 82 fish sampled, 72 (88%) were females.

Although no hatchery fish were encountered in 2008, this study remains pertinent. 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). Additional scale and otolith samples from known-age striped bass will help refine scale and otolith ageing techniques in support of recent Atlantic States Marine Fisheries Commission recommendations.

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

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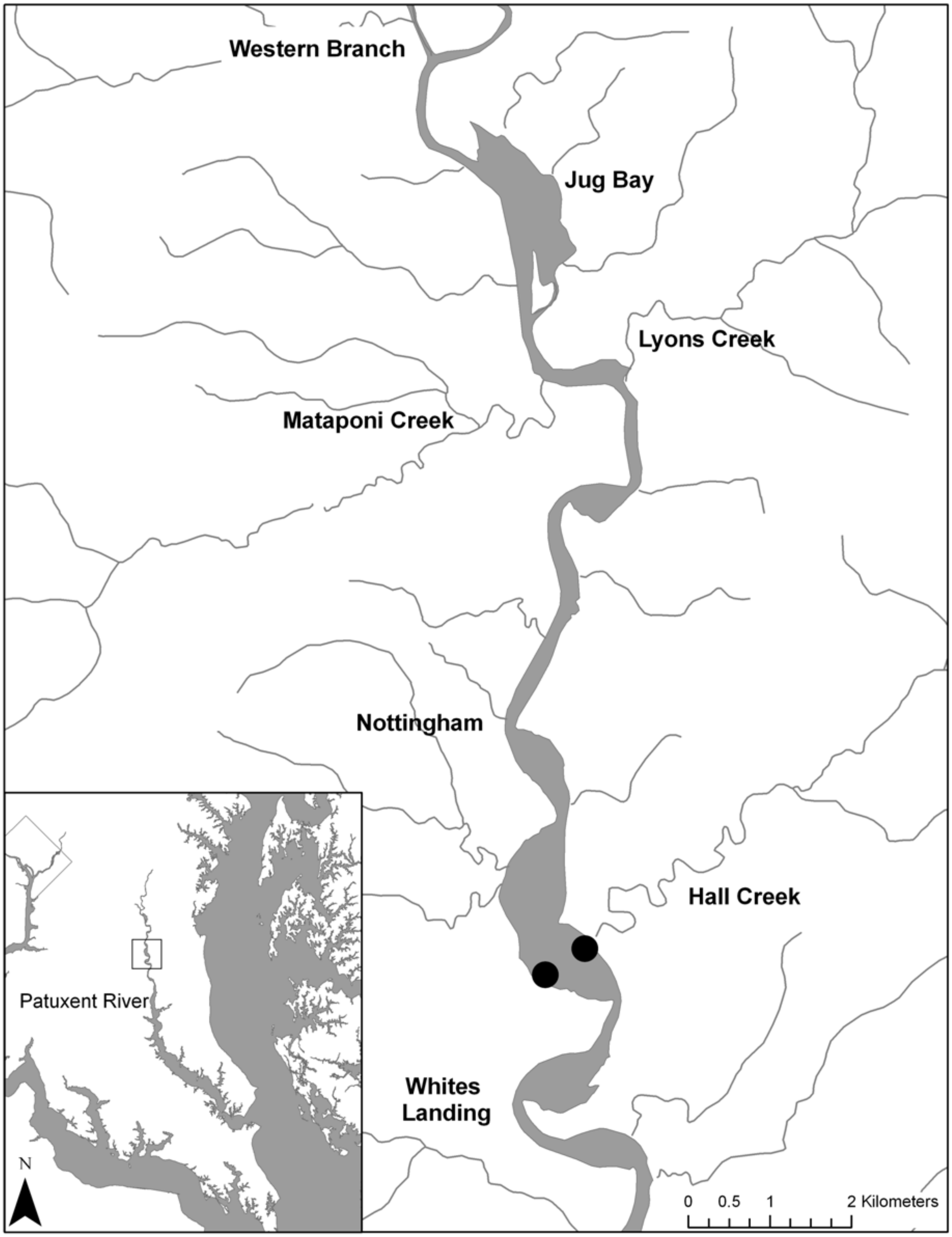
Table 1. Electrofishing survey targeting hatchery-reared striped bass on the Patuxent River, 2008. Data summary by date, for all sites combined.

Date	# Fish Scanned	# CWT Positive	Total Effort (secs)	Mean Length (mm TL)	% Female	% Male	Mean Water Temp (°C)
4/09/08	28	0	5,116	959	71	29	13.1
4/10/08	54	0	4,585	966	96	4	15.5

Figure 1. Location of Patuxent River electrofishing sites, April, 2008.



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 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:

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.

Project staff attended SRAFRC meetings as Maryland representatives to discuss American shad and river herring stock status and restoration in the Susquehanna River.

Atlantic croaker:

ASMFC Technical Committee representative attended the annual Atlantic croaker Technical Committee meeting to approve annual state status reports.

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.

Striped Bass Data Sharing and Web Page Development

To augment data sharing efforts, SBSA project staff in 2002 developed a web page within the MD DNR web site presenting historic Juvenile Striped Bass Survey (Job 3) results. This effort has enabled the public to access SBSA project data directly. The web page, http://www.dnr.state.md.us/fisheries/juvindex/index.html, is updated annually in October. Monthly visits to the web page for the period December 2007 to December 2008 are presented in Table 1. Increased traffic on the web page in October and November coincided with publication of survey results in the media and advertisement on the main Fisheries Service page. Although many large or complex data requests are still handled directly, the web page has saved staff a considerable amount of time answering basic and redundant data requests.

Table 1. Monthly visits to the Juvenile Striped Bass Survey web page, December 2007 to December 2008.

Month	Visits
December 2007	2,419
January 2008	2,531
February	2,570
March	4,949
April	1,693
May	3,274
June	2,836
July	3,091
August	2,788
September	3,224
October	11,562
November	14,594
December	3,983

Project staff 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, 2007 through October 31, 2008) the following specific requests for information have been accommodated:

-Atlantic States Marine Fisheries Commission (ASMFC).
Provision of striped bass juvenile index data; 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.

-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.

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

- Dr. Jonathan Casey, Salisbury University.
Provision of striped bass Voluntary Angler 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. Jason Schaffler, Old Dominion University.
Provision of juvenile Atlantic menhaden samples and Atlantic menhaden juvenile seine

survey data.

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

-Dr. Xingsheng Zhang, Oxford Laboratory - NMFS-NOAA.
Provision of juvenile Atlantic menhaden and striped bass seine survey data.

-University of Maryland (U MD - CEES).
Provided five (6) staff and students with current striped bass juvenile index data, American shad juvenile index data, recreational and commercial landings data, spring trophy season data and biological samples.

-The Interjurisdictional Project also provided related biological information and reports to thirty seven (37) 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 - 2008

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

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 using impervious surface reference points (ISRPs) as a similar tool for fish habitat management. 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 2008 included spring stream anadromous fish icthyoplankton collections, spring yellow perch larval presence-absence sampling, summer sampling of estuarine fish communities, and evaluation of data collected in previous years. These efforts were collectively aimed at defining the impact of impervious surface on target fish species populations and habitats. Each aspect of the project will be presented separately with report conclusions describing the collective understanding of the effects of habitat degradation on fish communities.

Stream Ichthyoplankton Sampling

Background

An effort to identify anadromous spawning habitat in Maryland was conducted from 1970 to 1986 (O'Dell et al, 1970, 1975, 1980). As a result, statewide maps of spawning habitat were developed to identify areas in need of restoration and protection. These data have since become the sole source of information utilized by planners for permitting decisions. Recreating these surveys provides an opportunity to explore whether spawning habitat is declining in response to landuse changes in targeted watersheds. To date, three watersheds have been sampled using citizen volunteers; the Bush River, Piscataway Creek and Mattawoman Creek (Figure 1).

METHODS

The same methods used in the historic O'Dell surveys were employed in the current study, and sites that historically supported at least one of the three target species, or target families (in the case of herring and shad) were sampled.

The Bush River was sampled from 2005-2008 in partnership with the Harford County Department of Public Works, Harford County Parks and Recreation, Aberdeen Proving Ground (APG), and Maryland Department of Natural Resources Chesapeake Bay National Estuarine Research Reserve. Historically, 26 sites were sampled in the Bush River watershed (Figure 2). Effort varied among the years to develop a better understanding of how spawning habitat use has changed over the 36 years that have elapsed since the historic survey was conducted. In 2005, 15 stations were sampled in non-tidal areas. These stations did not support spawning of white perch and yellow perch at the same capacity historically observed. One limitation of the 2005 sampling was that it did not include adult sampling by wire traps. In 2006, this gear was utilized at the most downstream station on each stream to verify plankton results. Additionally, collaboration with APG staff to sample four historic stations that supported spawning was also initiated. During 2006, stations on APG continued to support spawning habitat, while Bush River results were consistent with 2005. To better understand if observed differences among sites were driven by changes in land use, sampling was expanded in the Bush River, adding tidal sites to the sampling design. The intent was to compare tidal sites in the Bush River with tidal sites on APG. However, sampling was not conducted on APG in 2007, because of staff shortages. The full sampling design was conducted in 2008. This sampling was intended to finalize these comparisons and to assess if the observed differences between present and historic data were being driven by ongoing land use changes in the Bush River watershed.

Data for four years of sampling were evaluated by examining the proportion of samples with fish present, based on the estimated amount of impervious surface in the watershed. Impervious surface estimates were obtained from the Bush River Watershed Management Plan (WRAS; Center for Watershed Protection, 2003). Estimates for APG were calculated from 2002 land cover data by applying impervious surface coefficients. A difference was noted in percent impervious cover when water area was included in estimates of total watershed area (4% with vs 32% without). Based on general landuse patterns, the 4% estimate was applied because it better reflected the actual ground cover. However, two limitations to using these estimates were relevant: 1) they were derived from different sources and, therefore, may reflect different methods in developing the estimates; and 2) because the estimates were from different sources, the scale used in their calculation differed. For APG, since it was not possible to segregate individual watersheds for each stream, the estimate for impervious cover includes all APG property. Additionally, the WRAS did not provide estimates for all streams individually, so reported estimates, along with visual assessment of the land cover data were utilized to estimate if impervious cover was high or low. Because exact measurements for each individual stream were not available, all current data were utilized to estimate if the stream was above or below a 5% impervious surface threshold. The 5% threshold was established because of a dichotomous distribution of impervious surface, (i.e., watersheds were grouped at less than 5% impervious or exceeded 10%.) Data estimates that could not be clearly discerned were excluded. Table 1 presents the estimates that were utilized to assign impervious cover values to the streams sampled. Ideally, we would like to obtain estimates by stream to refine our analysis, however, staff resources do not permit that at this point.

In Piscataway and Mattawoman creeks, volunteers were trained to collect samples from sites that showed presence of one or more anadromous species in the original historic collections made by O'Dell, et al, (1972).

Historically, 17 stations were sampled in Mattawoman Creek and six stations were positive for presence of one or more anadromous species. These six stations plus three additional stations were sampled in 2008.

Thirty stations were sampled in Piscataway Creek and the surrounding watersheds in 1971. Twelve of these stations were positive for anadromous fish presence. Of these twelve stations, nine were selected to resample for presence of anadromous fish eggs and larvae in 2008.

Ichthyoplankton samples were collected in the Bush River, and the Piscataway and Mattawoman creeks from March through May. Samples were evaluated to determine the presence of six target species: white perch, yellow perch, alewife and blueback herring and hickory and American shad. Citizen volunteers were trained to collect samples in the Bush River with oversight by a volunteer coordinator provided by Harford County. DNR staff trained and oversaw volunteer efforts in Piscataway and Mattawoman creeks. Samples were collected using stream drift nets constructed of 360-micron mesh netting, attached to a square frame with a 300 X 460 mm opening. The frame was connected to a wood handle to hold the net stationary. A threaded collar located on the end of the net permitted attachment of a mason jar for sample collection. 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 jar was then removed from the net and a sample label noting site, date, time and collectors was placed in the jar. Finally, the jar was sealed and placed in a cooler for transport. After a team finished sampling for the day, the samples were returned to the coordinator, who then fixed them with 10% buffered formalin and 2 ml Rose Bengal to stain protein. Water temperature, pH, conductivity and dissolved oxygen 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 the volunteer and signed off by the volunteer coordinator.

Ichthyoplankton samples were sorted in the laboratory. All samples were rinsed with water to remove formalin and then placed into a white sorting pan. Samples were sorted systematically from one end of the pan to another under a 10x bench magnifier. All larvae and eggs were identified under a microscope and subsequently retained in small vials containing formaldehyde. Ten percent of the samples were sorted twice in order to assess sorting efficiency.

Presence of white perch, yellow perch and herring and/or shad eggs or larvae at each station was compared to historical presence to determine which streams still supported spawning. Presence of any of these life stages was used as evidence of spawning activity for comparisons with historical designations in O'Dell (1975). The proportions of samples with eggs or larvae of individual target species present and their 95% CI's were calculated for all data from the Bush River. These data were then compared with impervious cover classifications to examine its impact on fish spawning habitat.

RESULTS AND DISCUSSION

Bush River

A total of twenty-six stations were historically sampled in the Bush River and surrounding watersheds: Bush River proper: 15 sites, APG: 6 sites and Swan and Gashey's creeks: 5 sites (O'Dell et al, 1975). Of the fifteen historic stations in the Bush River, all but two were sampled over the study period, Bush Creek (BBS1) and the station on Unnamed Tributary 1 (BUN1). In addition to the historic stations in the Bush River, three stations where added in 2007. These stations were located in downstream tidal areas that were considered wadeable, including Winters Run (BWRT), Haha Branch (BHHT) and Grays Run (BGRT). Four of the six stations on APG were sampled. APG stations Bridge Creek and Delph Creek were not sampled because anadromous fish spawning was not collected when these sites were historically sampled. Figure 2 presents all historical and current stations sampled.

Bush River watershed land cover data for 1973 was compared to the most recent land cover data available (2002). Figure 3 presents this comparison for the two years with dominant land use types identified. Figure 3 provides strong evidence that the overall Bush River watershed has undergone significant land use changes, except for the APG, which has remained unchanged over the thirty year period. This information provides the opportunity to compare historic presence to contemporary presence and examine land use change (specifically impervious cover) as an explanatory variable that could be associated with changes in presence or absence of the finfish species observed.

Herring/Shad

Of the twenty-six historic stations sampled in the Bush River, APG and Swan Creek in 1973, thirteen supported herring spawning in 1973 (Figure 4). In 2005, fifteen of the original twenty-six stations were resampled. Twelve stations were located predominately in the nontidal reaches of the Bush River watershed and three stations in Swan Creek (Figure 5). Herring were historically observed at seven of the twelve stations in the Bush River and one of three Swan Creek sites (Figure 4). In the Bush

River, herring were observed at two stations where they were historically present and five stations where they were not. In Swan Creek, herring were observed at one station that historically showed presence and one that did not. Herring presence in 2006 was compared to historic presence in Figure 6. The same fifteen stations sampled in 2005 were resampled in 2006 along with four additional APG sites. Herring were observed at eight stations, four in the Bush River, three in APG and one in Swan Creek. Only one station in the Bush River historically had herring present. For 2007 eleven stations in the Bush River and three stations on Swan Creek were sampled (Figure 7). Three stations in the Bush River were new stations added to the downstream tidal areas. All stations sampled in 2007 were positive for herring presence. The sampling conducted in 2007 was slightly modified for 2008 with the addition of the four stations in APG. Herring were observed at four of the nine stations in the Bush River, one of two on Swan Creek and four of four on APG (Figure 8). When river herring presence over the last four years was compared to the historic presence, it appeared that herring had expanded their spawning habitat (Figure 9). Eight stations supported river herring spawning in 1973, opposed to eleven for the contemporary sampling program. Additionally, Swan Creek herring presence expanded from one station historically, to all three stations. However, since herring were stocked in Swan Creek in 2005 to test the effect of notching a weir, believed to preclude upstream migration of anadromous species, this expansion may be somewhat tenuous. APG did not show changes in habitat occupied; stations that historically supported spawning still indicated presence of eggs and/or larvae. When river herring distribution in the Bush River proper was evaluated, it did not appear that either species was migrating as far upstream to spawn as historically documented.

Yellow perch and white perch

Historic sampling for white perch indicated their presence at nine stations in the Bush River, four in APG, none in Swan Creek and one in Gashey's Creek. Figure 10 compares historic presence to results from 2005 to 2008. No white perch eggs or larvae were observed at any stream stations in the Bush River during the most recent sampling. Wire fish traps were set in the Bush River in 2006 and 2007 to determine if adults were present at sites where no eggs or larvae were observed. Ripe adult males were observed at one station (BOP1) in 2007, but the complete absence of eggs or larvae during the 2006-2008 sampling period provided strong indication that no successful spawning had occurred at this station. Three of four stations on APG continued to support white perch spawning between 2006 and 2008, but no white perch spawning activity was observed in Swan Creek. Since Gashey's Creek was not sampled, no conclusions could be drawn regarding white perch spawning activity in this tributary.

Yellow perch were historically present at five stations in the Bush River, four on APG, but none in Swan or Gashey's creeks. Present sampling indicated yellow perch presence at three stations in the Bush River, three in APG and none in Swan Creek (Figure 11). The loss of yellow perch and white perch spawning habitat appears to have directly impacted the spawning potential for both species.

To test if these changes could be attributed to land use changes, the 2005-2008 data were pooled and an impervious surface estimate assigned to each site. (Table 2) Stations were assigned to one of two impervious surface categories, >5% or <5% impervious surface, based on the estimated impervious surface for that stream. The proportion of stations with fish present was then calculated (with the 95% confidence intervals) by impervious category. Figure 12 presents results of this application. For river herring there appeared to be no effect of impervious surface on their presence as the distributions for each impervious category overlapped. However, yellow perch were present in samples more often in watersheds where impervious surface was below the 5% threshold while white perch were not observed at stations where the watershed exceeded 5% impervious surface.

Mattawoman and Piscataway Creek:

Stations in Mattawoman Creek were sampled in 2008 to determine the extent of spawning habitat still being occupied in comparison with the 1971 study. Serious concerns have arisen over land use changes in the Mattawoman watershed, based on the documented importance as nursery habitat. (Carmichael et al, 1992). Changes in land cover between 1973 and 2000 indicated an increase in urban coverage over the twenty-seven year period (Figure 13). Most of Mattawoman's watershed falls within the Charles County designated development district (U.S. Army Corps of Engineers 2003). The County has evaluated various growth scenarios for Mattawoman Creek. Chief among these is the conservative approach which caps impervious surface within the watershed at 15% (U. S. Army Corps of Engineers 2003). Considering the documented threats of impervious surface to aquatic resources, recent data from Mattawoman Creek is vital to establishing the current status of spawning fish populations and to determine if changes have occurred since the 1971 study.

Of the seventeen stations sampled in 1971, six showed evidence of herring spawning (Figure 14). Nine stations were sampled in 2008, but only three showed evidence of herring spawning (Figure 14).

Yellow perch were historically observed at only one station, but spawning was still documented at this site in 2008 (Figure 15). White perch were historically present at two stations, but were observed at just one station (the lowest in the watershed) in 2008 (Figure 16). These data suggest that a decline in river herring and white perch spawning habitat may have transpired between 1971 and 2008. However, the declines in the number of sites occupied and shifts in spawning locations, particularly for river herring, may also be a function of declines in spawning stock densities.

Table 3 documents the percent presence of each species by station. Only the lowest station on Mattawoman Creek had more than one sample with a given species present. The two stations that documented herring presence, had only one sample where eggs or larvae were observed. Although only eggs or larvae presence was noted, personal experience in this watershed indicated a decline in eggs and larvae abundance (M. McGinty, pers. obs.). Mattawoman Creek sampling in 2009 will seek to determine if these patterns continue and attempt to explain if changes in land use are directly affecting changes in spawning habitat occupation.

During 2008 sampling also occurred in Piscataway, Henson and Oxen creeks (referred to from this point forward as the Greater Piscataway area). As noted in Figure 17, land cover for this watershed has dramatically changed since 1973. Because these watersheds are adjacent to Washington, DC, they have experienced significant urban growth over the past thirty years.

Historically, a total of twenty-nine stations were sampled. Of these, twelve supported herring (Figure 18), none supported yellow perch (Figure 19) and six supported white perch (Figure 20). Nine of these stations were sampled again in 2008. No target species were observed at any site sampled in 2008 (Table 4). Volunteers are scheduled to sample these stations again in 2009.

Mattawoman Creek and the Greater Piscataway area are adjacent watersheds. As previously noted Mattawoman Creek is subject to increasing growth pressures, whereas the Greater Piscataway area has undergone significant development. Both watersheds have shown declines in spawning habitat use, with the Greater Piscataway area suffering a total loss. In order to determine if landscape alterations could be a factor in spawning habitat changes, the percentage of each land cover category between 1973 and 2000 (the most recent land cover data available) were compared (Tables 5 and 6). In 1973, two years after the initial survey, Piscataway's watershed was 23.6% urban (Note - percent urban and impervious surface were measured differently and are not interchangeable for comparisons). In spite of the large amount of urban coverage, the greater Piscataway area still supported spawning habitat for herring and white perch. By 2000, however, the landscape had increased to almost 40% urban and by 2008 no indication of spawning activity was detected. Mattawoman Creek with only 12.2% urban coverage in 1973, supported river herring, white perch and yellow perch spawning. By 2000, urban coverage in this watershed had almost doubled, and by 2008 a definite decline in spawning habitat use was found. Of importance is the fact that the present percent of urban cover in Mattawoman Creek (25.9%, Table 5) is similar to the percent urban cover calculated for Piscataway Creek in 1973 (23.6%, Table 6). Comparison of results from these two Potomac River tributaries with those from the Bush River, suggests that changes in urban coverage (ie, increased IS) are contributing to declines in spawning habitat occupation by several important finfish species

The exact mechanism(s) in the urbanizing landscape process that contribute to the observed losses in spawning habitat have not been identified. Until these mechanisms have been identified, limiting development in watersheds that continue to support spawning habitat is paramount and may provide the most effective means to protect and ultimately restore these habitats.

Spawning habitat in Nanjemoy Creek where urban cover is still well below 10%, will be evaluated in 2009 (Table 7). This watershed may provide a "minimally disturbed" reference system to which comparisons to Mattawoman and Piscataway creeks can be made.

Estuarine Yellow Perch Larval Presence-Absence Sampling

Background

Yellow perch larval presence-absence sampling during 2008 was conducted in the upper tidal reaches of the Nanticoke, Bush, South, and Severn rivers and Mattawoman and Piscataway creeks during late March through April (Figure 21). 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 collected larvae at 10 sites (7 in Piscataway Creek) per system on 2-3 days each week in the upper portion of the six watersheds sampled (Figure 21). Nets measured 0.5-m in diameter by 1.0-m long, and were constructed of 0.5 mm mesh material. Plankton 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 of 2008.

Sites in all rivers except the Nanticoke were sampled with little spacing between tows because larval nurseries or the systems themselves were small. Piscataway Creek was only large enough for 7 stations. Extent of the area 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 historic striped bass spawning grounds (Uphoff 1997; Uphoff et al. 2005). The striped bass spawning area on the mainstem Nanticoke was divided into upriver, midriver, and lower river subareas containing 5-6 segments while Marshyhope Creek, a major tributary, 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 per 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 the ISSA Alosine Investigation (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 returned 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 from previous Choptank and Nanticoke river collections and determined that starting dates during the first or early in the second week of April were typical while end dates normally occurred during the last week of April through the first week of May. Sampling during 2008 began during the last week of March and ended after larvae were absent (or nearly so) for two consecutive sampling rounds. In years when larvae disappeared quickly, sampling rounds continued into the third week of April even if larvae were not collected. Confidence intervals (95%) were constructed using the normal distribution to approximate the binomial distribution (Uphoff 1997).

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

Volunteers from the Arlington Echo Outdoor Education Center conducted Severn River plankton sampling, while volunteers from the Anita Leight Estuarine Research Center conducted the Bush River sampling. Bush River sampling was interrupted between April 10 and 22 because of boat breakdown. Trained volunteers were utilized for field sampling and ichthyoplankton identification.

Historic collections in the Choptank and Nanticoke rivers targeted striped bass eggs and larvae (Uphoff 1997), but yellow perch eggs and larvae were also noted (J. Uphoff, MD DNR, personal observation). Larval presence-absence was calculated from data sheets prior to 1998. After 1998, L_p in the Choptank River was determined directly in the field. Plankton 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 a 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 for rivers sampled during 2008 were compared to the mean and "typical" range of historic values. For 2008, the risk of L_p 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).

Regression was used to test whether L_p during 1998-2008 was linearly influenced by IS. Estimates were available for the Choptank River (1998-2004: IS = 2.1%), Nanticoke River (2004-2008; IS = 1.2%), Severn River (2004-2008; IS = 17.0%), Bush River (2006-2008; IS = 12.8%), Corsica River (2006-2007; IS = 4.0%), Langford Creek (2007; IS = 0.9%), South River (IS = 10.0%), Mattawoman Creek (IS = 8.5%), and

Piscataway Creek (IS = 14.9%). Separate regression analyses of L_p versus IS were conducted for fresh-tidal (< 1‰) and brackish tributaries. Uphoff et al. (2008) reported that differences in IS thresholds for white perch juveniles and adults existed between fresh-tidal and brackish tributaries that reflected substantial differences in bottom DO levels. Water column stratification is more likely when salinity is present and is a major influence on oxygen depletion (Kemp et al. 2005).

Mean salinity for dates and sites used to calculate L_p were estimated for each system. Data were available for the Choptank River collections during 1998, 2000, and 2001; Nanticoke River (2006-2008), Severn River (2004-2008), Bush and Corsica rivers (2006-2008), Langford Creek (2007) and South River, Mattawoman Creek, and Piscataway Creek ((2008). Uphoff et al. (2007) compared salinity (‰) and temperature data (°C) from 1998-2006 larval surveys to yellow perch larvae, water temperature (> 20 °C) and salinity (> 2 $^{o}/_{oo}$) requirements (Piavis 1991) to determine the extent and duration of suitable habitat in previous years. There was little indication that temperature influenced L_p (Uphoff et al. 2005; 2007) and comparisons with temperature were discontinued. However, high salinities have been implicated in contributing to low L_p (Uphoff et al. 2005; 2007). Mean salinities were plotted and linearly regressed against L_p to examine this relationship and to evaluate whether salinity > 2 $^{o}/_{oo}$ was detrimental.

RESULTS AND DISCUSSION

The proportion of tows with larval yellow perch present from three brackish systems, Severn River (L_p = 0.14, SD = 0.05, N = 50; 17.5 % IS), South River (L_p = 0.08, SD = 0.04, N = 50; 10.0 % IS), and Nanticoke River (L_p = 0.19, SD = 0.05, N = 58; 1.2

% IS) during 2008 was significantly lower than the historic L_p reference range (Figure 22) based on 95% confidence interval overlap. Confidence intervals of L_p from the three fresh-tidal systems, Mattawoman Creek (L_p = 0.67, SD = 0.06, N = 70; 8.5% IS), Piscataway Creek (L_p = 0.47, SD = 0.07, N = 47; 14.9% IS), and Bush River (L_p = 0.49, SD = 0.05, N = 90; 12.8% IS) fell within the historic range. Risk of falling below the "typical" historic minimum of L_p = 0.4 during 2008 was near one in brackish systems and near zero in fresh-tidal systems.

The linear regression of IS (%) and L_p (proportion) in brackish systems during 1998-2008 was significant (r^2 = 0.25, P = 0.02, N = 20; Figure 23) and was described by the equation

L_p = (-0.017*IS) + 0.52.

A significant relationship could not be detected with the five points from fresh-tidal systems (Figure 23).

Mean salinity was not linearly related to L_p at $P < 0.05$, but examination of the scatter plot indicated a possible threshold level of salinity (≈ 4‰) above which L_p was consistently below the historic median and near the historic minimum (Figure 24). The suggested mean salinity threshold of 4‰ was considerably greater than the 2‰ habitat requirement used previously (Piavis 1991). Below 4‰, there was wide variation in L_p (Figure 24).

Interpretation of the influence of salinity on L_p may be clouded by watersheds with higher impervious surface (ie Severn and South rivers). One observation for the Severn River was at a mean salinity that resulted in a higher L_p elsewhere (Langford Creek in 2007; L_p = 0.83 at 3.5 ‰). Other factors related to impervious surface could be suppressing L_p in both the Severn and South rivers where high salinity is coincidental or constitutes a minor contribution Uphoff et. al. 2005) The Severn River generally fell into the highest mortality group regardless of salinity treatment in experiments with yellow perch prolarvae from several Maryland tributaries (Victoria et al. 1992).

Mortality related to salinity offers a partial explanation of variation in L_p among tributaries. Mortality of yellow perch eggs and prolarvae in experiments generally increased with salinity and was complete by 12‰ (Sanderson 1950; Victoria et al. 1992). Eggs hatched successfully (< 30% mortality) at 6.7-8.8‰. The range of suitable salinities for prolarvae was lower than that for eggs and survival was highest at 2-9‰. In addition, abnormal behavior of larvae held for approximately one week at 8‰ suggesting that delayed mortality would occur (Victoria et al. 1992).

Two observations of note emerged after reviewing the 2008 collections. The first is the possibility of different relationships of L_p and IS in fresh-tidal and brackish tributaries. Fresh-tidal systems have only been sampled in four years (1990 and 2006-2008) and have exhibited the highest L_p in each of these years in spite of being collected from systems with 8.5-14.9% IS. Mattawoman Creek L_p in 1990 was represented by a point estimate because of low sample size (N = 10). In 2006-2007, confidence intervals of the "best" L_p overlapped among fresh-tidal (Bush River, 12.8% IS) and some low IS brackish systems sampled (Corsica River and Langford Creeks, ≈ 4% IS).

The second observation stems from the observation that poor years for L_p below the reference minimum are not just a feature of brackish high IS systems. Since 2004 the Nanticoke River, considered a brackish, low IS system has been in the historic Lp range 3 of five years and below it for two. The Choptank River, a second low IS reference system, also exhibited variation of L_p within and below the historic range between 1998 - 2004 (Figure 25).

Interpretation of annual L_p is not straightforward because it integrates the product of egg production, and the number of eggs that successfully hatch and survive to the larval stage. All of these factors would need to be moderate to high to produce an average to strong L_p, but only one needs to be low to result in low L_p. 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. However, distribution of L_p since 1965 in areas other than the Severn and South rivers does not appear to conform to a lognormal distribution and may adhere to a uniform or dome-shaped distribution (Figure 26). This suggests survival may not be independent across egg through postlarval stages.

Judgment of *Lp* estimates in recent years was based upon comparisons with rural Eastern Shore systems in the past because long time-series did not exist for non-reference systems. These reference rivers have larger watersheds and more extensive regions of fresh-tidal water than some brackish tributaries sampled. Uphoff et al. (2005) cautioned that comparability of smaller brackish tributaries with rural Eastern Shore reference systems could be biased. However, L_p estimates from tributaries other than the Nanticoke, and Choptank during 2006-2007 have compared favorably with historic reference (Figure 25).

Summer Estuarine Seining and Trawling

Sampling Areas

Impervious Surface Estimates

Table 8 summarizes percent impervious surface cover, non-water watershed area, and tidal water surface area estimates for the eight watersheds sampled in 2008. Estimates for the Bush River, Corsica River, Piscataway Creek, and Mattawoman Creek were from the Towson University, March 2001, Landsat 7, 30 meter pixel resolution for the western shore and October 1999 data for the Eastern Shore (estimates used in McGinty et al. 2006). The impervious surface estimate for the Tred Avon River was from King et al. (2004) because an estimate for this watershed was not available elsewhere. Remaining estimates were based on Maryland Department of Planning (or MDDOP 1994a) data available from: http://mddnr.chesapeakebay.net/wsprofiles/surf/prof/prof.html.

Water surface area, in acres, was estimated using 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.

General land-use for all watersheds (i.e., percent urban, forest, etc.; all non-water acreages) was based on MDDOP data (1994a). Urban land-use consisted of low through high density residential and industrial designations.

Eight watersheds were sampled in 2008, two in the Upper Bay, four mid-Bay and two in the Potomac drainage (Figure 27). Nanjemoy Creek was substituted for Piscataway Creek in 2008 because Piscataway Creek contained too much SAV to be effectively sampled. Nanjemoy Creek was sampled previously in 2003.

Upper-Bay Sampling Areas

The Bush River (36,964 watershed and 7,966 tidal water acres) is located on the western shore north of Baltimore. It had the second highest level of impervious surface (12.8%) of all rivers sampled in 2008 (Table 8). It is predominately forested (48%) with urban areas comprising 24%, agriculture 22% and wetlands 6% (Figure 28).

The Northeast River is a moderately urbanized watershed in Cecil County, Maryland. It covers 40,377 acres, containing 3,908 acres of tidal water, and 6.1% impervious cover (Table 8). It is 15.9% urban, 39.1% agriculture, 45.2% forest 0.1% wetland and 0.4% barren (Figure 29).

Mid-Bay Sampling Areas

The Corsica River, a tributary of the Chester River, has a watershed of 23,924 acres of which 4.0% is impervious surface (Figure 30; Table 8). Tidal water comprised 1,256 acres. Approximately 65% of the watershed is in crops, 28% is forested; urbanized areas account for 6%, and 1% is wetland. The Corsica River watershed has been selected to receive nearly $19 million to implement comprehensive watershed management measures. More information on this restoration effort is available at:

http://www.mde.state.md.us/ResearchCenter/Publications/General/eMDE/vol2no3/corsica.asp.

Langford Creek, a tributary of the Chester River, is located on Maryland's Eastern Shore. Its confluence with the Chester River lies directly across from the mouth of the Corsica River (Figure 31). This watershed (0.9% IS) is very similar in size (23,871 acres with 2,905 acres of tidal water) and land-use to the Corsica River (Table 8). Agriculture occupies 69% of the watershed, forests occupy 26%, urban areas comprise 4%; and wetlands, 1%.

The Tred Avon River is a tributary of the Choptank River (Figure 32). This watershed comprises 23,518 acres with tidal waters occupying 4,338 acres. Urban land comprises 22% of the watershed, agriculture 39%, forest 38%, and wetlands less than 1%. Impervious surface covers 5.6% of the watershed (Table 8).

The Wye River, also on Maryland's Eastern Shore, drains land in both Talbot and Queen Anne's County. The watershed covers 50,460 acres, with tidal water accounting for 6,142 acres, and IS 1.2% (Table 8). It is dominated by agriculture which comprises 69.9% of the watershed. Forest accounts for 25.9%, urban land 3.9%, wetlands 0.7 and barren land 0.1% (Figure 33).

Potomac Sampling Areas

Two tributaries of the Potomac River were sampled in 2008. The Mattawoman Creek watershed totals 60,300 acres with 1,799 acres of tidal water and 8.5% IS (Table 8). Forest occupies 63% of the watershed, agriculture covers 14%, urban areas 22%, and wetlands 1 % (Figure 34). Mattawoman Creek contains extensive military holdings within the watershed. The fluvial and tidal portion in Charles County has been slated for development to 15% IS. A significant fraction of the stream is located in Prince Georges County and is zoned for low IS development.

Nanjemoy Creek is located in Charles County, Maryland. The watershed totals 40,377 acres with forestland comprising 74%, agriculture 16%, urban 6%, and wetlands 4%. Impervious surface covers 1.8% of the watershed (Figure 35, Table 8).

General Statistical Considerations: Presence-Absence Sampling

Presence-absence sampling for targeted adult finfish species was used to address important management questions because it reduced expensive sample processing, 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 and its 95% confidence interval containing a target species and life stage 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.

Most of the areas sampled in 2007 were re-sampled in 2008. Sampling in Piscataway Creek was discontinued because the SAV beds were too dense to allow for efficient sampling. Nanjemoy Creek, another Potomac River tributary, was substituted. These changes were made to better meet study objectives to: (1) better define the relationship of IS, fish habitat, and fish relative abundance in tidal freshwater and (2) test the relationship developed from brackish water tributaries exhibiting different levels of development (where spatial differences were assumed to represent change in a watershed over time) on tributaries likely to undergo a change from rural to suburban (temporal change in the same watershed).

Tidal fresh tributaries (2‰ or less salinity) sampled in 2008 were Mattawoman Creek, the Bush River, and the Northeast River (Figure 27); IS was estimated to cover approximately 1-10% of these watersheds. Nanjemoy Creek is a low oligohaline tributary to the Potomac, just south of Mattawoman Creek. The impervious cover of this watershed is less than 2%. The Corsica River, Tred Avon River, Langford Creek, and Wye River are brackish water (greater than 5‰) tributaries located on Maryland's Eastern Shore that were estimated to have less than 6% impervious surface (Table 8). The Corsica , Tred Avon , and Wye rivers are located near towns that are undergoing development (Centerville, Easton, and Wye Mills, respectively). Langford Creek was selected as a control system (predominately for the Corsica River) because it is not located near towns that are the foci of local development on the Eastern Shore.

Four evenly spaced haul seine and bottom trawl sample sites were located in the upper two-thirds of each tributary. 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, 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), dissolved oxygen (mg/L), conductivity (μmho), salinity (ppt) 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. 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 used 0.61 m long by 0.30 m high trawl doors attached to a 6.1 m bridle leading to a 24.4 m towrope. 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. 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 Bay inshore fish surveys (Carmichael et al. 1992; Durell 2007), 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. Once 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 and life stage. 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 9) and reported as deviations from a target or limit (McGinty et al. 2006). These were examined by watershed to determine habitat suitability for the target species. Percent of violations of these requirements were calculated by river. Presence-absence was used as an index of relative abundance for each target species in near-shore (seine) or bottom (trawl) waters because their catch distributions were not normally distributed, nor could normality be induced by transformation (McGinty et al. 2006).

RESULTS AND DISCUSSION

2008 Data summary

Water quality data were examined to determine if habitat requirements were met for the target species (Table 9). For the most part, temperature remained below the 31°C criteria (Figure 36). The Northeast River exceeded the criteria 7.5% of the time and Wye River, 2.9% of the time (Table 10). All rivers had dissolved oxygen concentrations that fell below the 5.0 mg/L criteria (Figure 37). The Wye River had the greatest percent occurrence (42.2%) and the Bush River the least (2.2%) (Table 10). Figure 38 presents salinity distribution by watershed. The only station that had salinities greater than 13 ppt was the Tred Avon (4.3% of measurements; Table 10). Figure 39 presents the distribution of bottom dissolved oxygen by river sampled in 2008. Violations of the 5.0mg/L criteria were found in all rivers with the greatest number occurring in the Wye (42.2%) and the least in the Bush River (2.2%), (Table 10). Additionally, a 3.0 mg/L threshold for bottom DO levels was established by Uphoff et al, (2008). who found that fish presence was greatly reduced in habitats with less than 3.0 mg/L. The Bush and Northeast rivers did not have any oxygen concentrations below 3.0 mg/L. Langford Creek had the greatest at 8.2%, followed by Mattawoman Creek (7.9%), the Tred Avon River (7.5%), the Corsica River (6.1%), the Wye River (5.6%) and Nanjemoy Creek (2.5%), (Table 10). General assessment of these data suggests that while these watersheds are not completely free from habitat criteria violations, they appear adequate to support fish communities as evidenced by the numbers and species collected.

A total of 54,756 fish (29,580 trawl and 25,176 seine) were captured representing 48 species in 2008. Of these species, nine comprised 90% of the catch. These species, in descending order included, white perch, Atlantic menhaden, bay anchovy, spot, gizzard shad, brown bullhead, pumpkinseed, blueback herring and striped killifish. The following nine species comprised 90% of the 2008 haul seine catch: Atlantic menhaden, white perch, gizzard shad, blueback herring, striped killifish, pumpkinseed, Atlantic silverside, mummichog and spot (in descending order). Catch in the bottom trawl in 2008, were dominated (90%) by white perch, bay anchovy, spot and brown bullhead.

Seining was conducted in all rivers except Mattawoman Creek, as seining was precluded in this tributary because of the extensive SAV beds present. The highest number of species collect by this gear occurred in the Bush River (27) and Nanjemoy Creek (18), while cpue was greatest in the Bush River (Table 11).

Bottom trawl sampling was conducted in all 8 systems (Table 12). Species richness was highest in the Northeast River (22), and closely followed by the Bush River (21). Species comprising 90% of the trawl catch varied from 3 to 5 with white perch dominating in the lower salinity areas and bay anchovy in the higher salinity locations. Trawl CPUE was highest in Nanjemoy Creek and the Bush River.

Patterns of species richness and CPUE, in 2008, did not appear to be associated with impervious cover. The Bush River had the highest percent. impervious cover of all rivers sampled. However, this system had the greatest species richness and CPUE by seine and the second greatest species richness and CPUE by trawl. The water to land ratio for each watershed sampled was highest in the Bush River at 0.22 followed by the Tred Avon River (0.18), Wye River and Langford Creek (0.12) the Northeast River (0.10) the Corsica River and Nanjemoy Creek (0.05) and Mattawoman Creek (0.02). The large water acreage of the Bush River combined with the fact that the area is tidal-fresh may work together to allow for greater flushing of this tributary. A dilution factor may also be present in the Bush River as the fewest water quality violations were reported from this system in 2008 (Table 10). Additionally, 6% of the Bush River watershed is comprised of wetlands, another factor that would help mitigate water quality problems.

Exploring Tidal Fresh habitats

Uphoff et al. (2008) reported conflicting results concerning the relationship between dissolved oxygen and % impervious surface (Figure 40). They noted that in brackish tributaries a negative relationship existed between dissolved oxygen and % IS but for tidal fresh tributaries the opposite was found. Figure 41 presents the distribution of bottom DO concentrations in tidal fresh tributaries sampled during 2006-2008 by impervious surface level. Watersheds with the highest impervious surface contained the fewest bottom DO concentrations below 5.0 mg/L. It is possible that tidal fresh areas with greater impervious surface have different flushing dynamics because low salinity waters undergo little, if any stratification. Salinity is a major contributor to differences in water density, which subsequently impedes mixing and promotes stratification in brackish systems. Further, water column stratification is a major factor influencing oxygen depletion in Chesapeake Bay (Kemp et al. 2005). A second factor to consider is nutrient management efforts; particularly those dealing with phosphorus. Phosphorus is the major limiting nutrient in tidal fresh systems and extensive management efforts have resulted in significant reduction in phosphate loads. Consequently, phosphorus load reductions in tidal fresh areas could account for the healthy production observed in these areas. However, this also implies that excess nitrogen entering the system is not sequestered by phytoplankton and is thus passed through to downstream habitats where nitrogen is limiting.

Another difference noted in tidal fresh tributaries was an extensive abundance of SAV beds compared to the brackish systems. As previously noted, because of this extensive coverage in various watersheds, seine and trawl sampling had to be altered. Specifically neither gear could be employed on Piscataway Creek, and seining could no longer be done in Mattawoman Creek. However a possible by-product of these extensive SAV beds was a marked increase in water clarity. Figure 42 presents box and whisker plots of secchi depth by impervious cover. The two stations with highest water clarity were Mattawoman Creek (8.5% impervious) and Piscataway Creek (16.7% impervious). These two tributaries are located in the Upper Potomac River where SAV coverage has been widespread and increasing over the past few years. During 2006, estimates of SAV coverage in Mattawoman and Pscataway creeks were 45% and 80%, respectively, a substantial increase in the estimated 23% for both systems in 2003 (www.vims.edu/bio/sav/index.html).

The percent presence of target species collected by trawls and seines in tidal fresh areas in relation to impervious surface was evaluated (Figures 43a &b, 44a & b). Because of changes in sampling areas which resulted in unequal sampling effort among years, the data were pooled for all years. Aside from white perch juveniles and adults, all other target species showed somewhat random presence when compared with impervious surface. However, white perch juveniles and adults captured by bottom trawl showed a marked decline in those tidal-fresh tributary with the highest impervious surface..

The long term data set for Mattawoman Creek was analyzed to determine if changes in water quality or fish presence were responding to changes in watershed land use. Figures 45 and 46 present bottom dissolved oxygen concentrations (mg/L and saturation) for Mattawoman Creek since 1989. There appears to be a decline in DO concentrations over time, with more recent years showing some violations of the 5.0mg/L criteria. When first observed, the possibility was considered that this may have been a natural response by this system to transition from dominance by algal species to SAV dominance. However, when dissolved oxygen saturation was plotted, saturation began to fall below 75% with a few concentrations of less than 50% saturation in recent years. These declines in bottom DO and percent saturation may be indicative of Mattawoman Creek's early response to habitat changes directly related to development.

The presence of the key target species in Mattawoman Creek was also examined. Both blueback and alewife herring appear to be declining, with the other target species showing random or stable distributions (Figure 47). The decline in both river herring species may be their behavioral response to increased impervious cover in the watershed. However, herring populations have been declining coast-wide and the declines observed in Mattawoman Creek may be more driven by coastal stock abundance rather than local habitat variations.

Conclusions

Project 3 results have provided an understanding of the impacts of impervious surface on fish habitats and communities in brackish tributaries to the Chesapeake Bay (Uphoff et al. submitted). This understanding has been utilized in developing a management framework of impervious surface reference points that can help guide fisheries managers in better management and allocation of resources (Uphoff et al. submitted).

It would appear that fresh-tidal tributaries do not exhibit impervious surface-DO related conditions that are detrimental to fish habitat as readily as brackish tributaries, but other impervious surface related problems remain in fresh-tidal tributaries. Anadromous fish stream spawning habitat appears to be negatively influenced by impervious cover. Impervious surfaces increase runoff volume and intensity in streams, leading to physical instability, increased erosion, sedimentation, and thermal pollution (Beach 2002). Toxic metals and organic compounds may also be found in this runoff (Beach 2002). Siltation, impoundment, substrate removal, physical alterations, toxic or organic pollution, and increased acidification were cited as possible mechanisms that would depress anadromous fish spawning as urbanization of the Hudson River watershed progressed (Limburg and Schmidt 1990). Because spawning habitat losses have been linked to increased impervious cover, limiting development in important nursery habitats in order to preserve their function is vital. Additionally, because the tidal fresh habitats reflect better water quality conditions and serve as nursery habitats for many important aquatic species, extreme caution in planning for future development in these watersheds is also paramount.

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Table 12. Catch statistics and impervious cover in trawl by river in 2008.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Trawl
Langford	24	15	White perch adult Bay anchovy Spot	0.9	5143	214
Corsica	24	13	White perch adult Bay anchovy Spot	4	3549	148
Mattawoman	24	19	White perch adult White perch juvenile Bluegill Spottail shiner Pumpkinseed	8.5	989	41
Bush	18	21	White perch adult White perch juvenile Gizzard shad Brown bullhead Bay anchovy	12.8	4385	244
Nanjemoy	17	19	White perch juvenile Bay anchovy Brown bullhead White perch adult	1.8	4425	260
Wye	24	13	Bay anchovy Spot White perch adult	1.2	2964	124
Tred Avon	24	15	Bay anchovy Spot Hogchoker Weakfish	5.6	4065	169
Northeast	24	22	White perch juvenile White perch adult Gizzard shad Brown bullhead Bay anchovy	6.1	4060	169

Figure 1. Stream ichthyoplankton sampling areas.

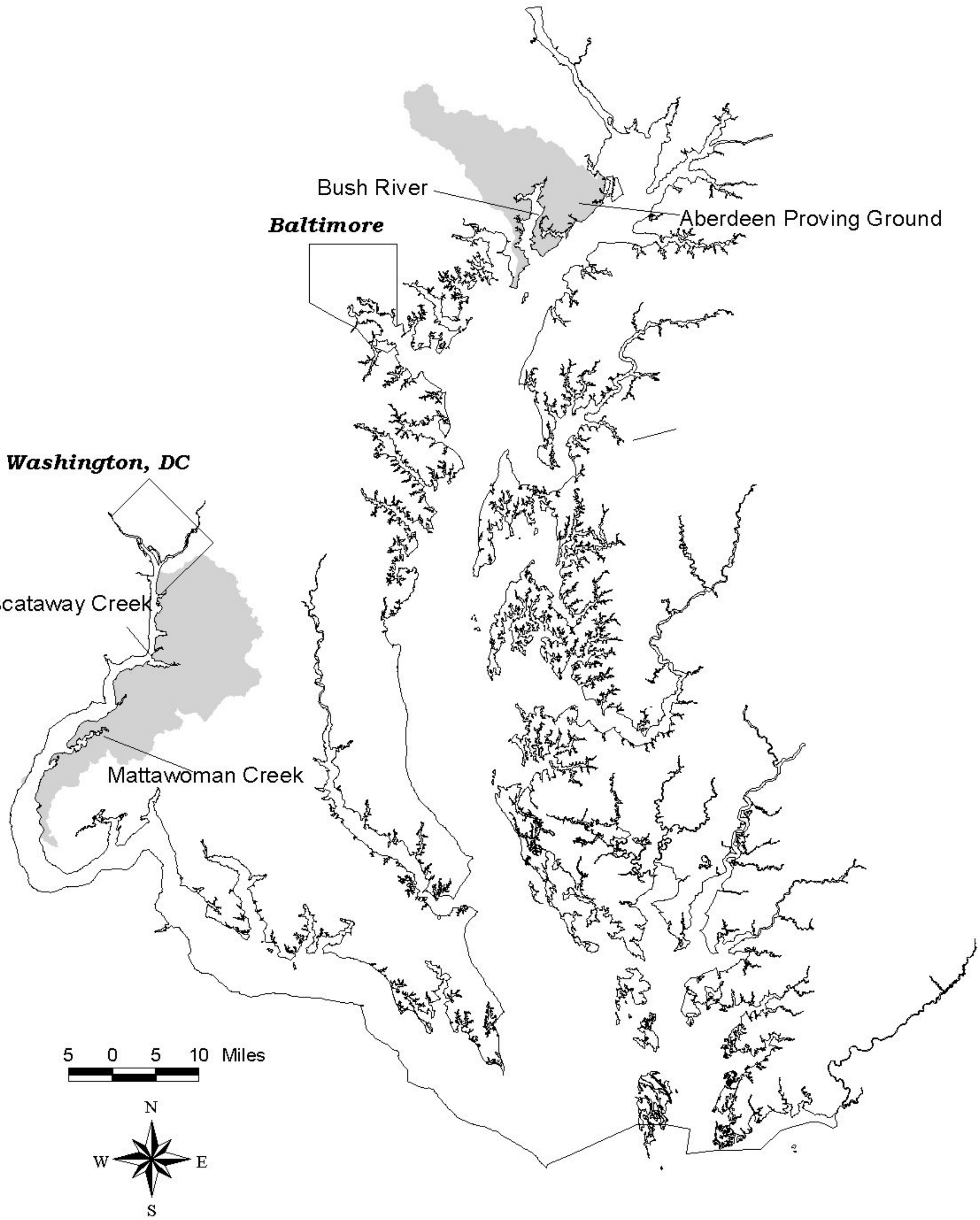


Figure 2. Historic and present sampling stations in the Bush River.

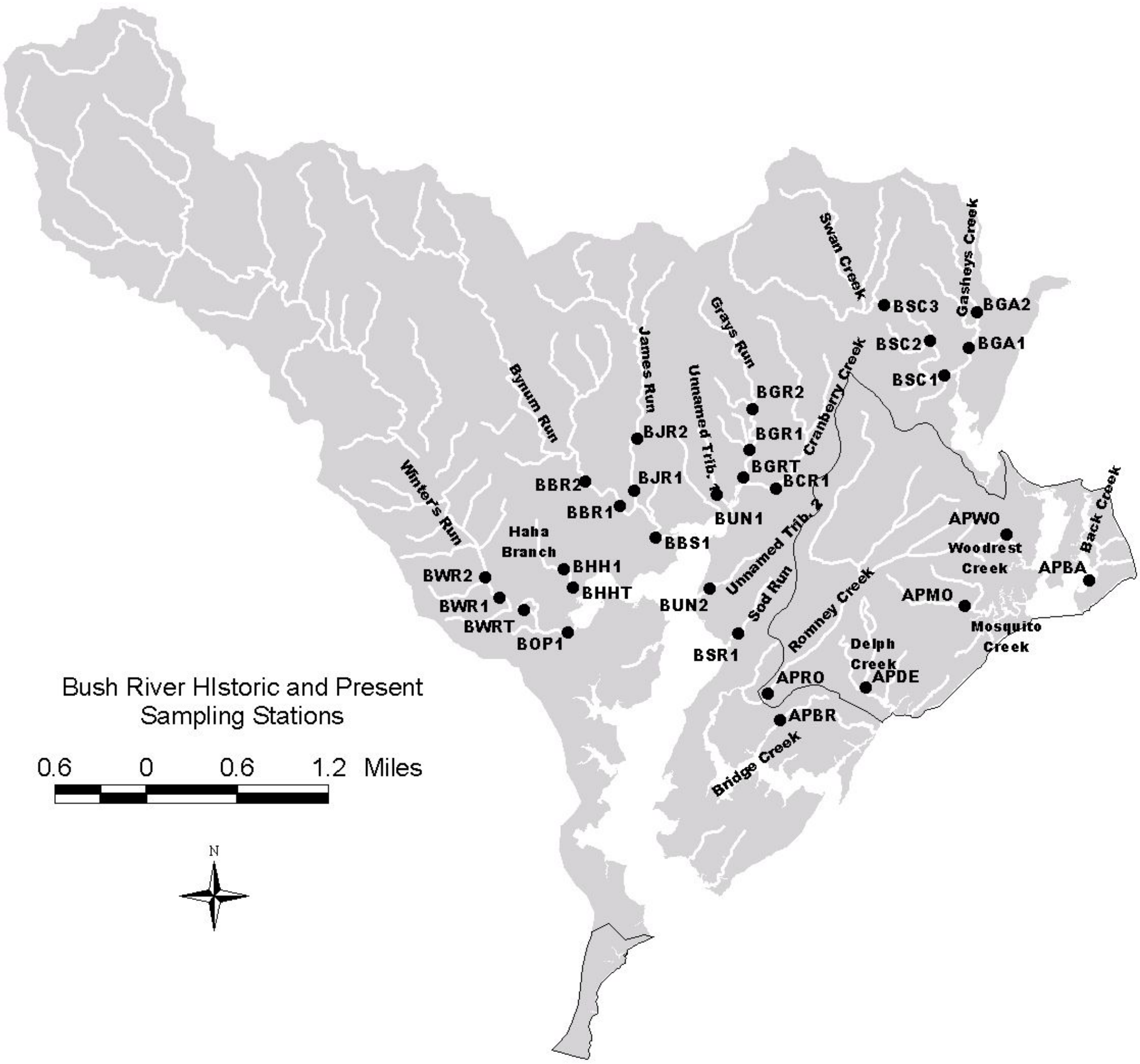
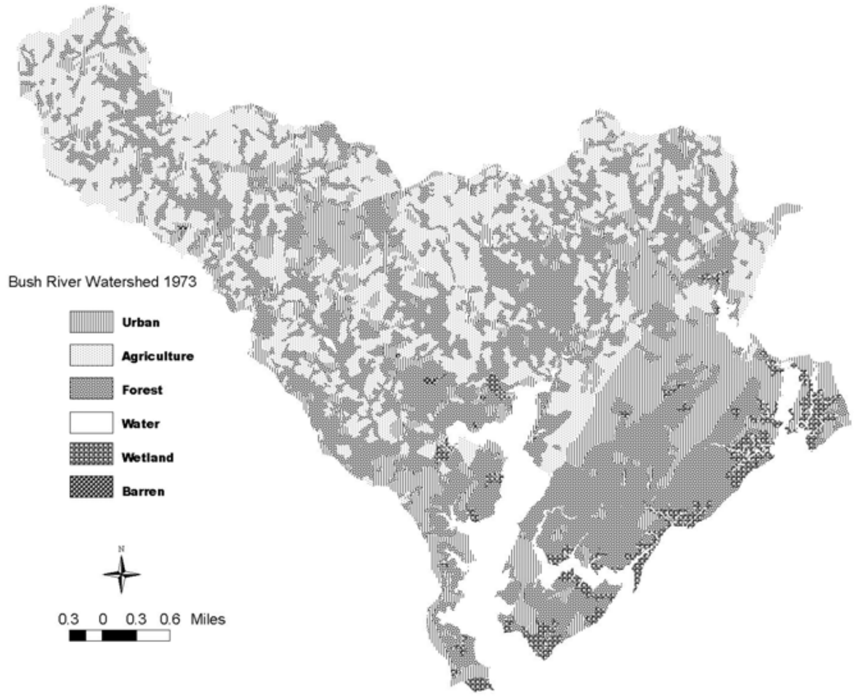


Figure 3. Land cover in the Bush River watershed, 1973 and 2002.



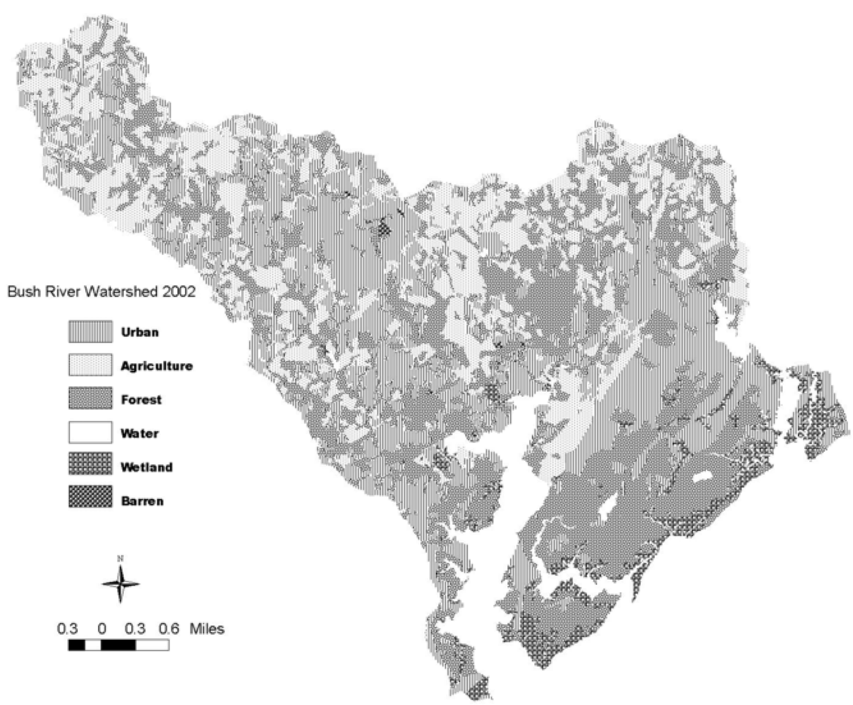


Figure 4. Stations sampled and herring presence in 1973.

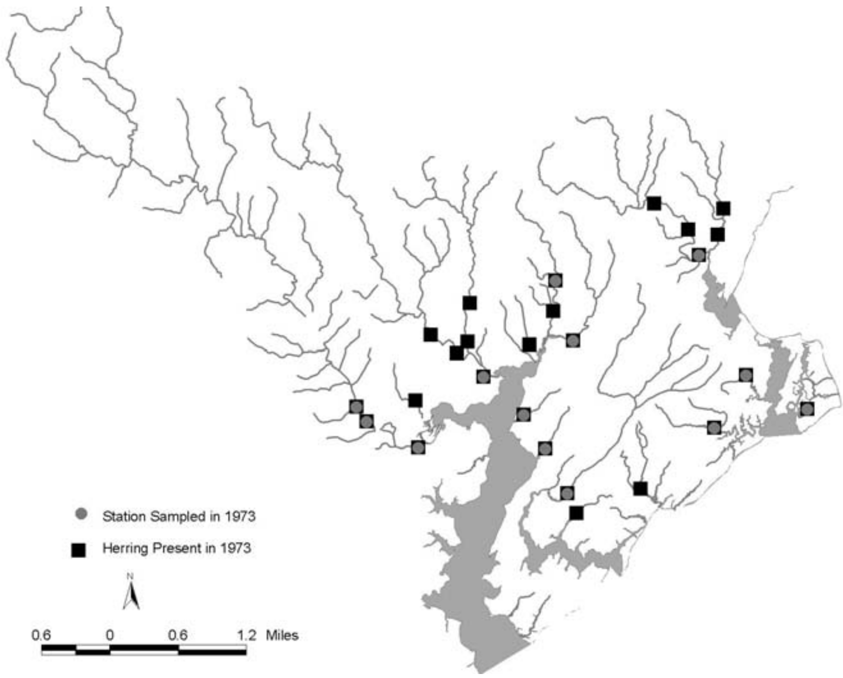


Figure 5. Stations sampled in 2005 and 2005 herring presence compared to presence in 1973.

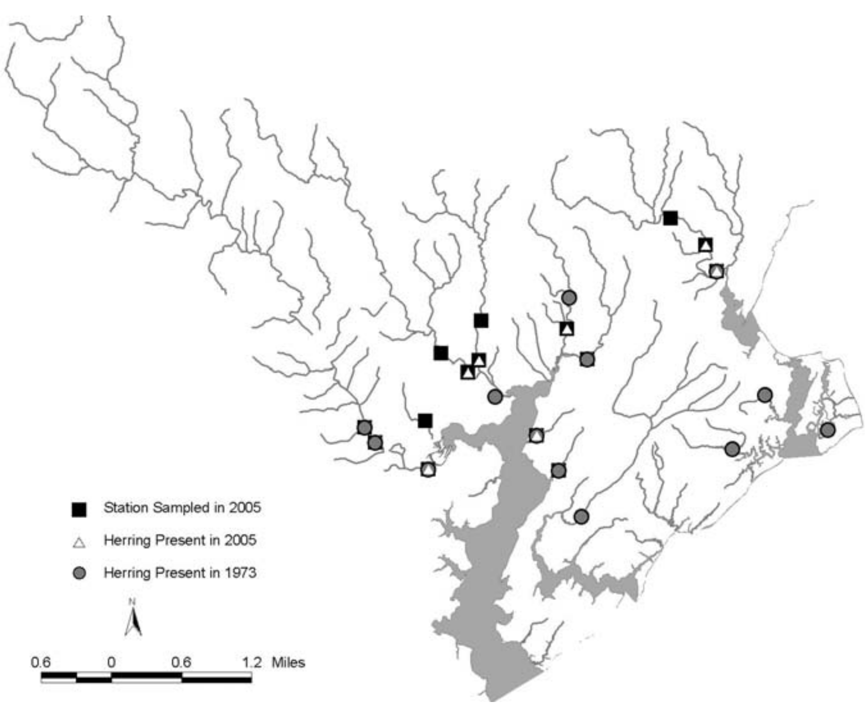


Figure 6. Stations sampled in 2006 and 2006 herring presence compared to presence in 1973.

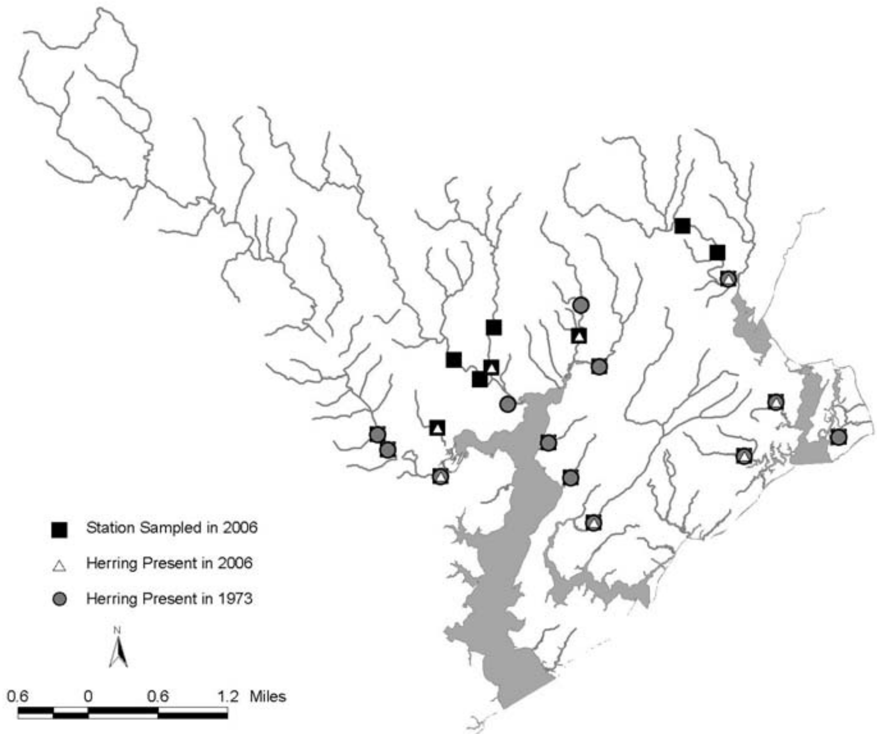


Figure 7. Stations sampled in 2007 and 2007 herring presence compared to presence in 1973.

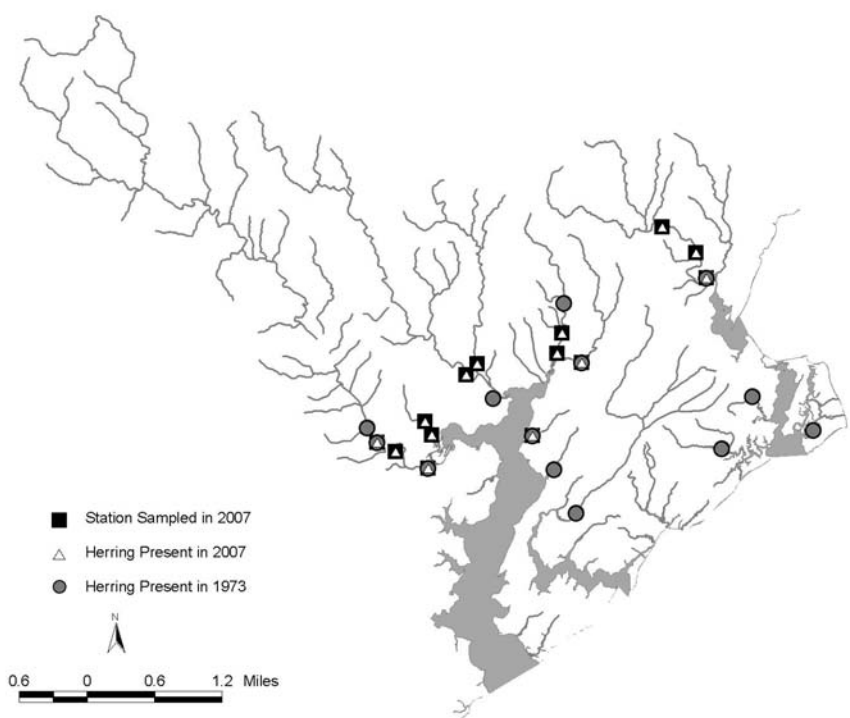


Figure 8. Stations sampled in 2008 and 2008 herring presence compared to presence in 1973.

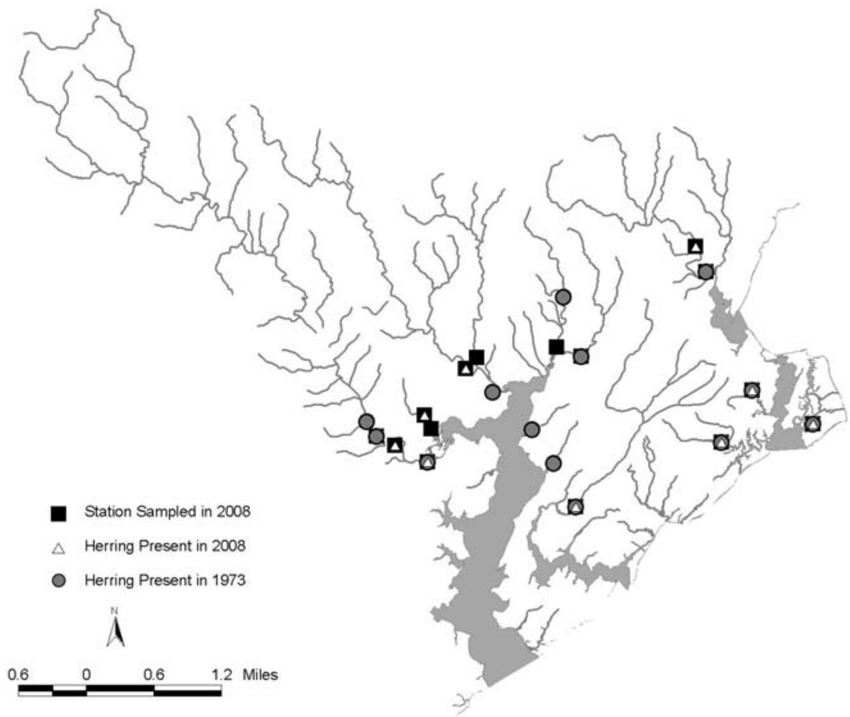


Figure 9. Historic stations sampled with comparisons between historic and present (2005-2008) presence of herring in the Bush River.

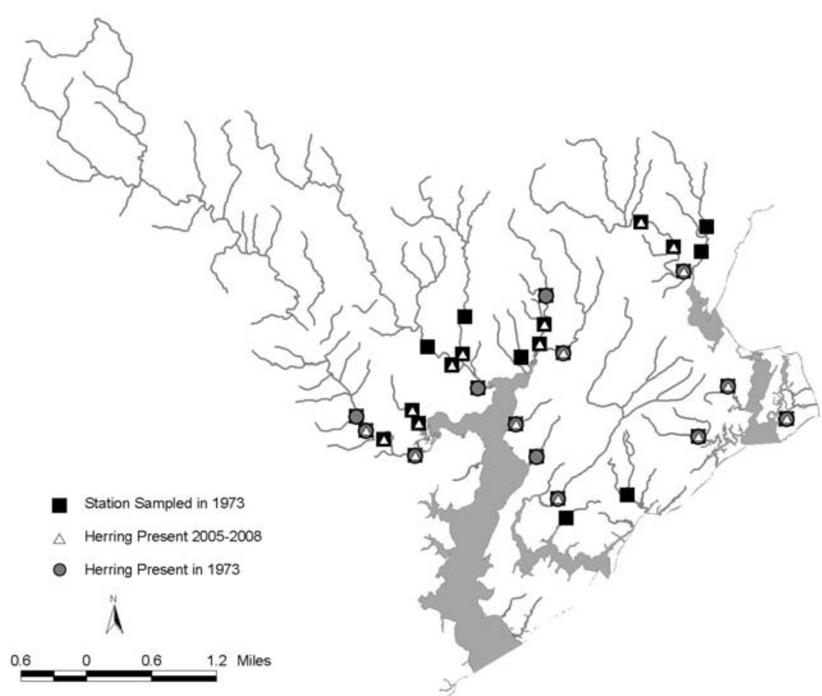


Figure 10. Historic stations sampled with comparisons between historic and present (2005-2008) presence of white perch in the Bush River.

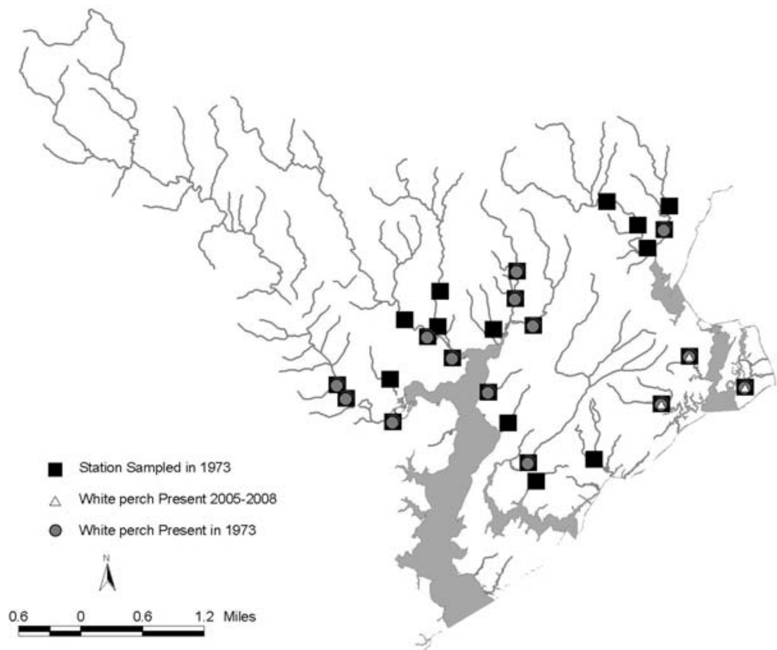


Figure 11. Historic stations sampled with comparisons between historic and present (2005-2008) presence of yellow perch in the Bush River.

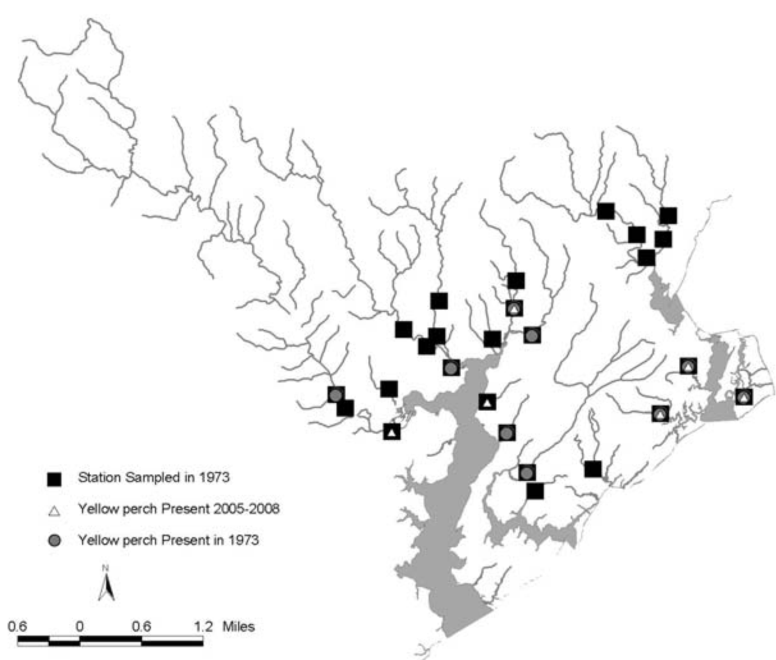


Figure 12. Proportion of herring, yellow perch and white perch present (with 95% confidence intervals) in Bush River, 2005-2008 by impervious cover groupings, with the

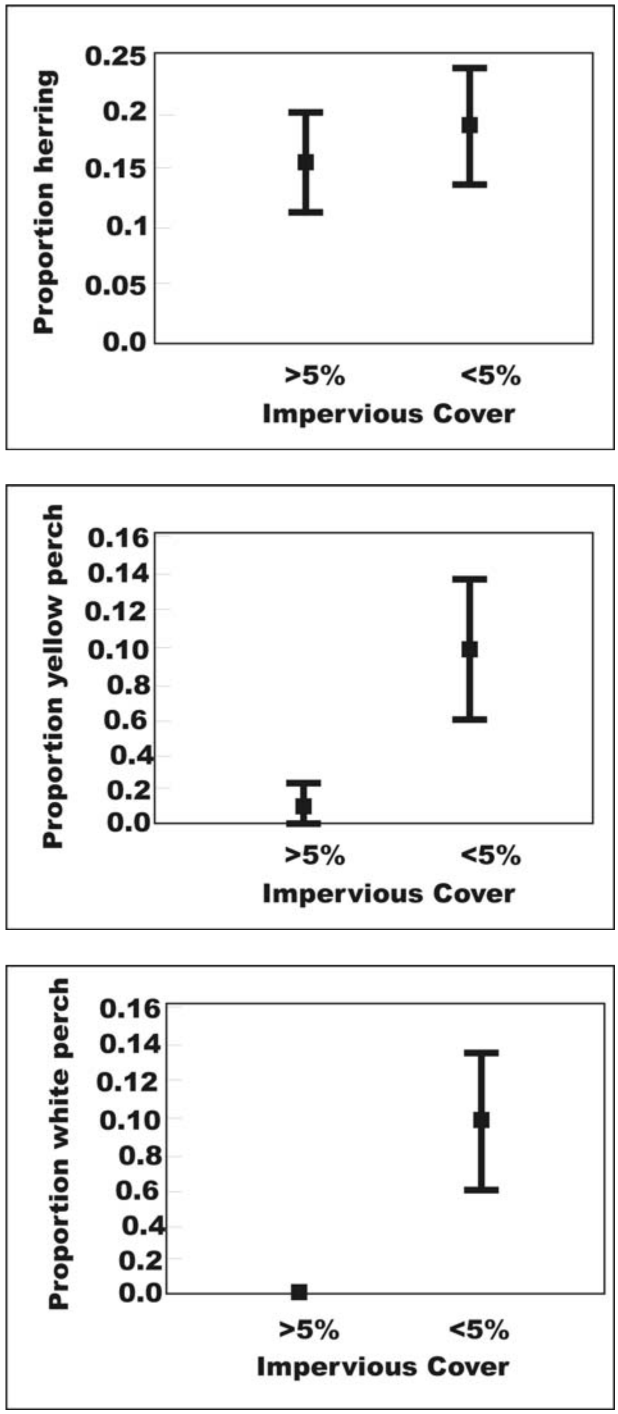
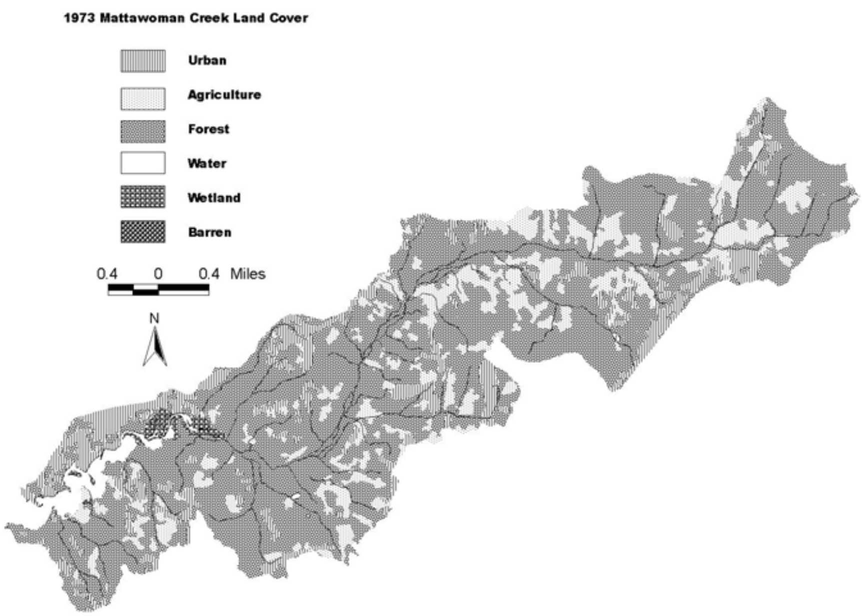


Figure 13. Land cover in the Mattawoman Creek watershed, 1973 and 2000.



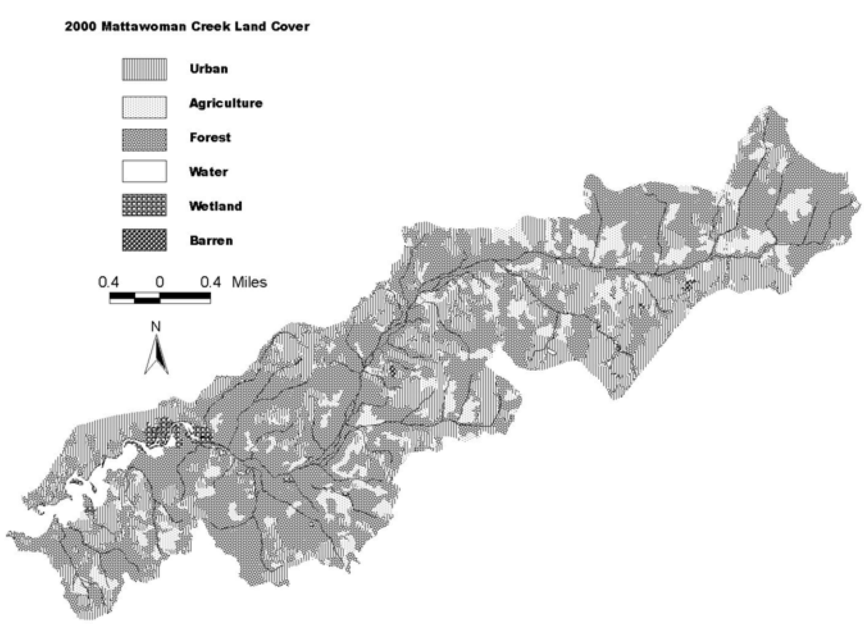


Figure 14. Historic stations sampled with comparisons between historic and present (2005-2008) presence of herring in Mattawoman Creek.

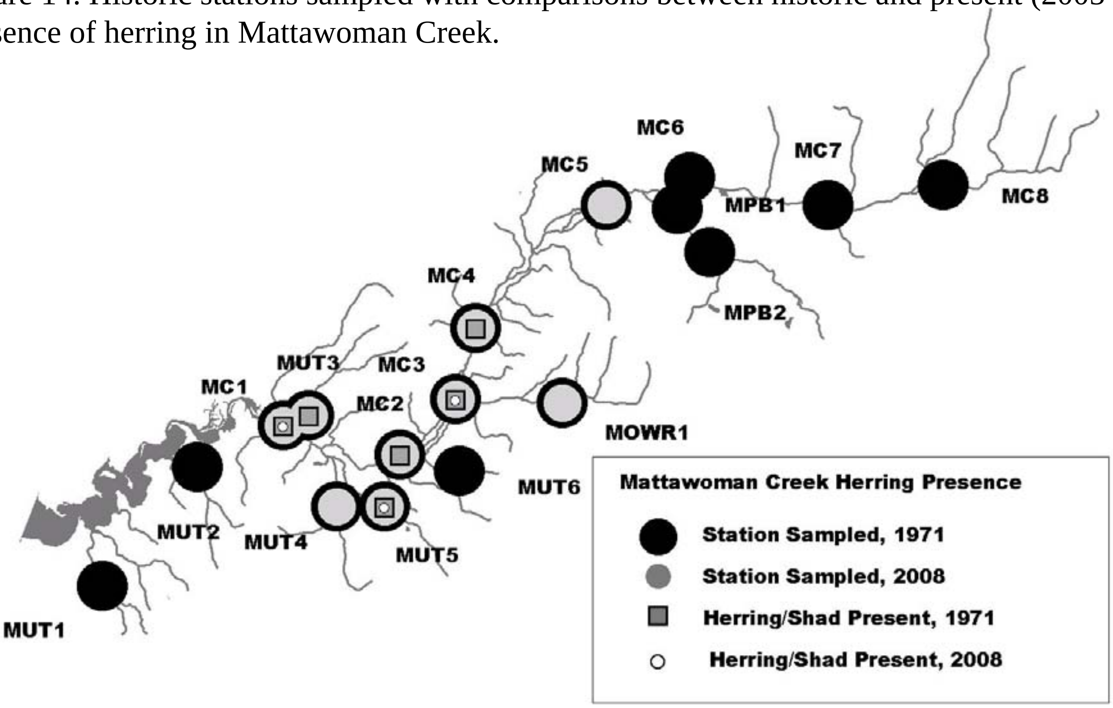


Figure 15. Historic stations sampled with comparisons between historic and present (2005-2008) presence of yellow perch in Mattawoman Creek.

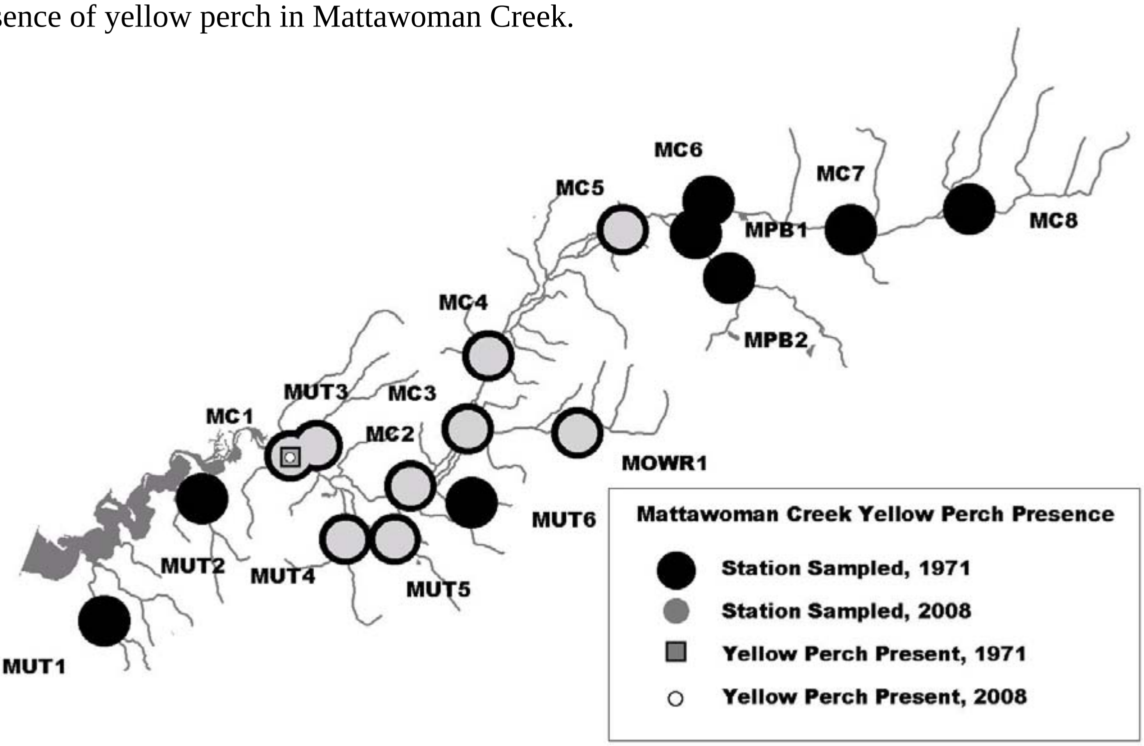


Figure 16. Historic stations sampled with comparisons between historic and present (2005-2008) presence of white perch in Mattawoman Creek.

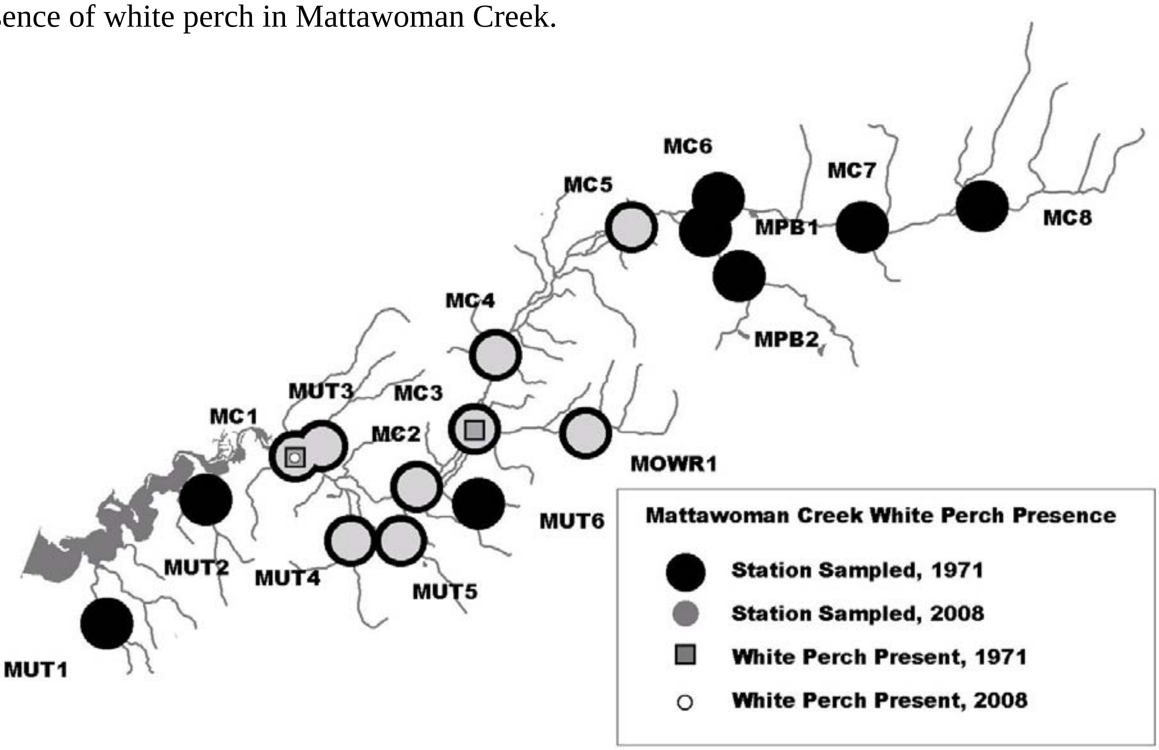


Figure 17. Land cover in the Piscataway and surrounding watersheds, 1973 and 2000.

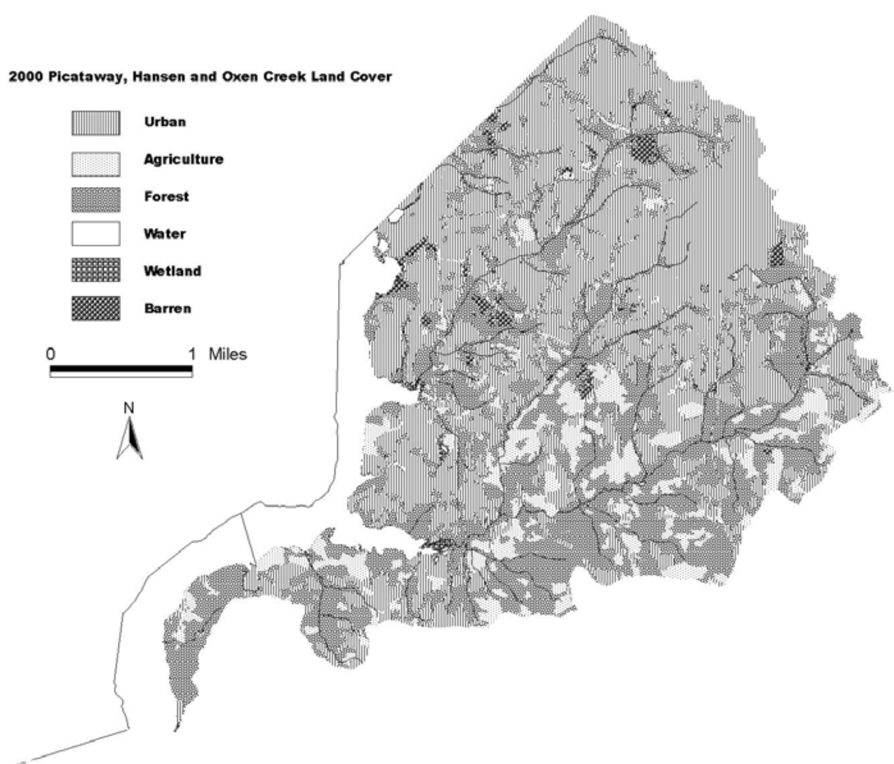


Figure 18. Historic stations sampled with comparisons between historic and present (2005-2008) presence of herring in Piscataway and surrounding watersheds.

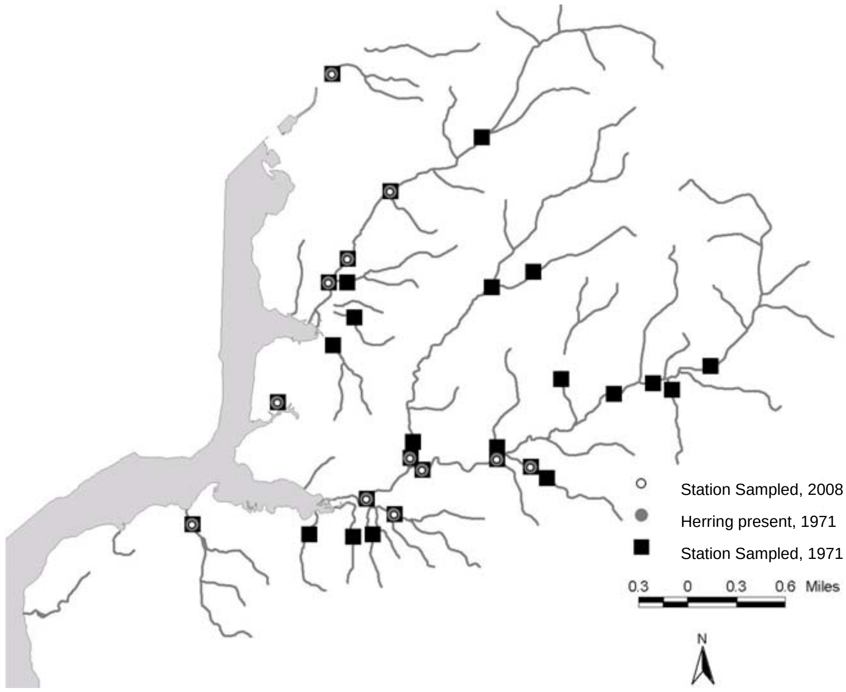


Figure 19. Historic stations sampled with comparisons between historic and present (2005-2008) presence of yellow perch in Piscataway and surrounding watersheds.

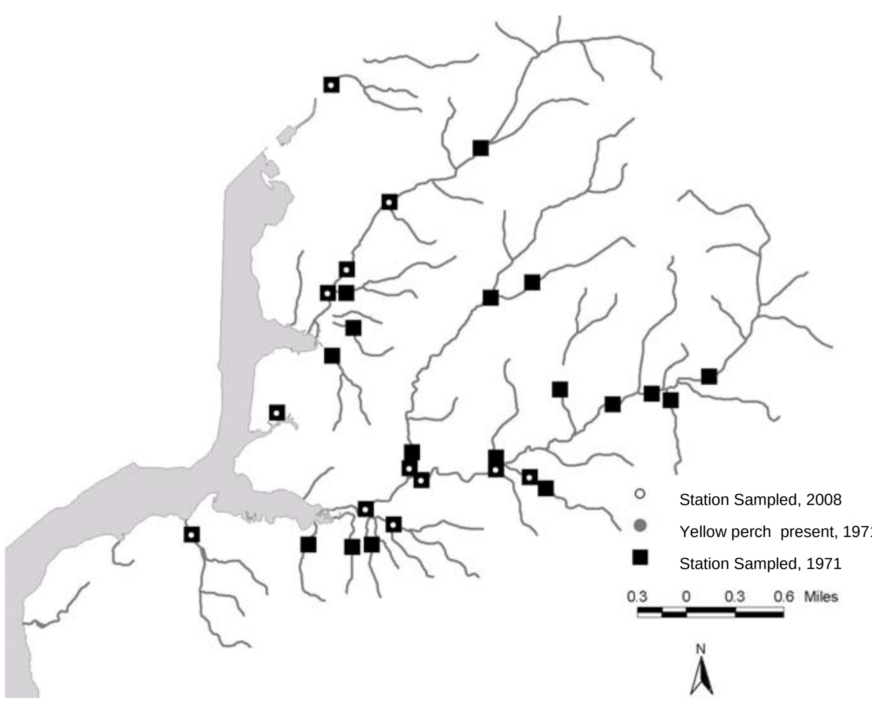


Figure 20. Historic stations sampled with comparisons between historic and present (2005-2008) presence of white perch in Piscataway and surrounding watersheds.

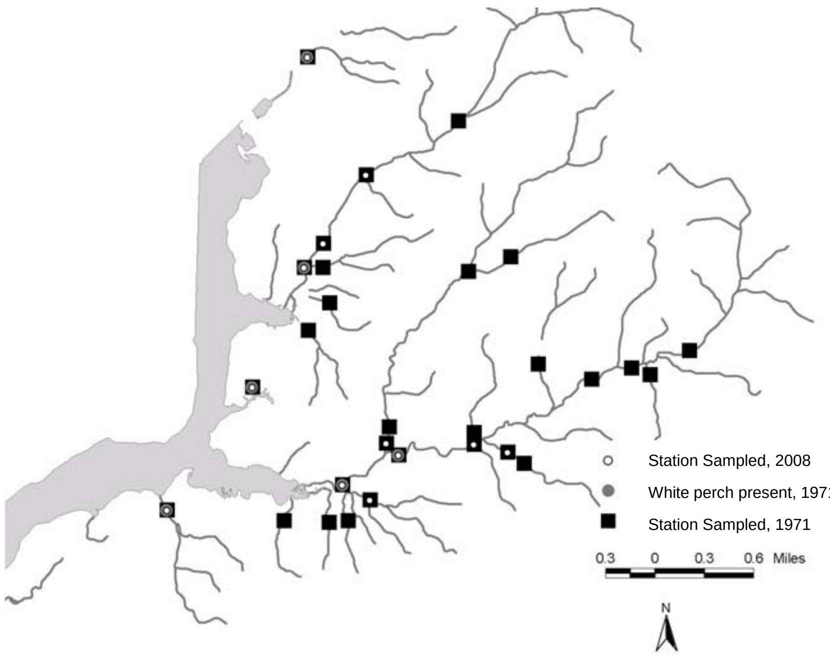


Figure 21. Tidal rivers sampled for yellow perch presence in 2008.

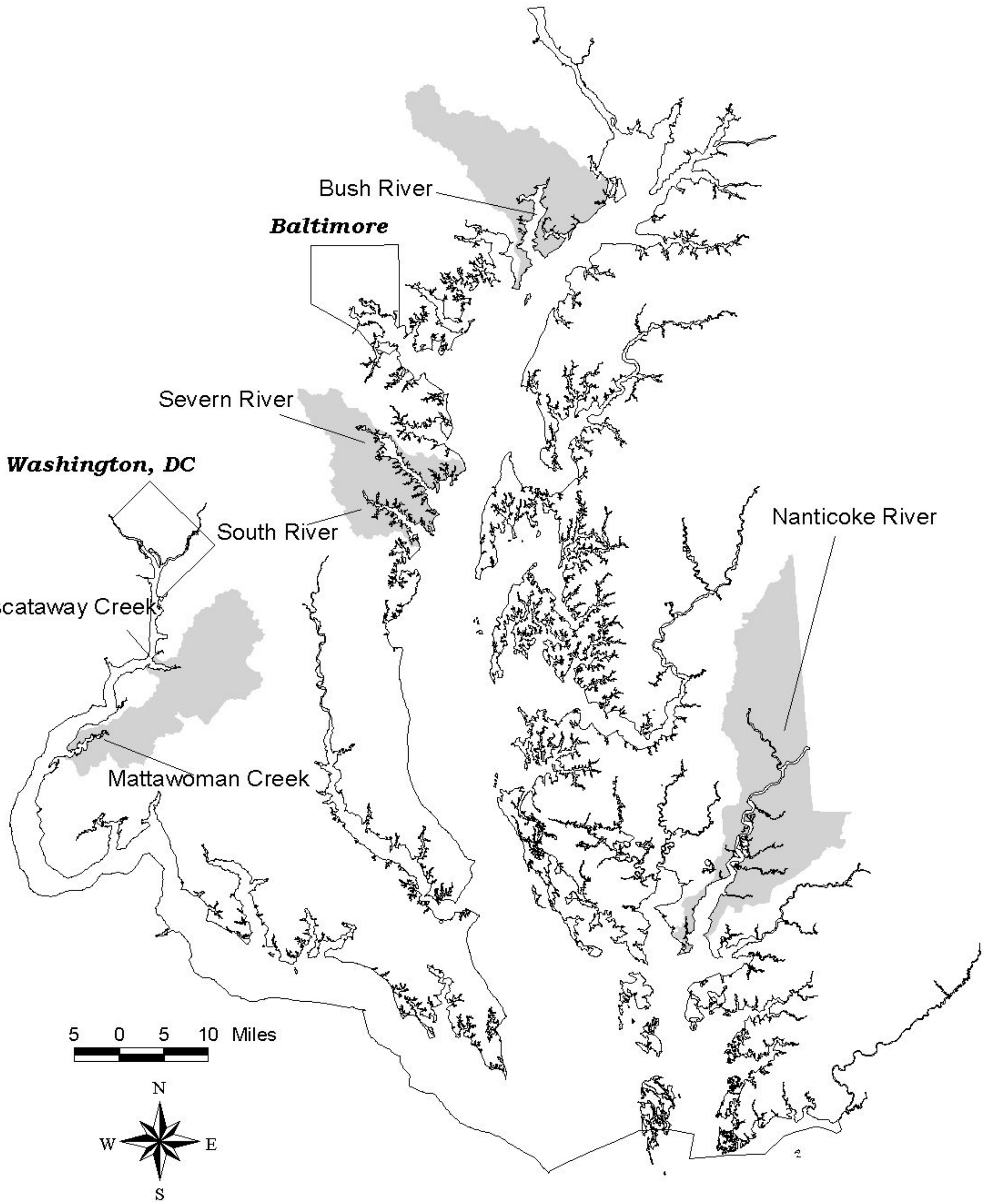


Figure 22. Proportion of tows with larval yellow perch and its 95% confidence interval in systems studied during 2008. Mean of brackish tributaries indicated by diamond and fresh-tidal mean indicated by dash. High and low points of "Historic" data indicate spread of 9 of 11 points and midpoint is the mean of historic period.

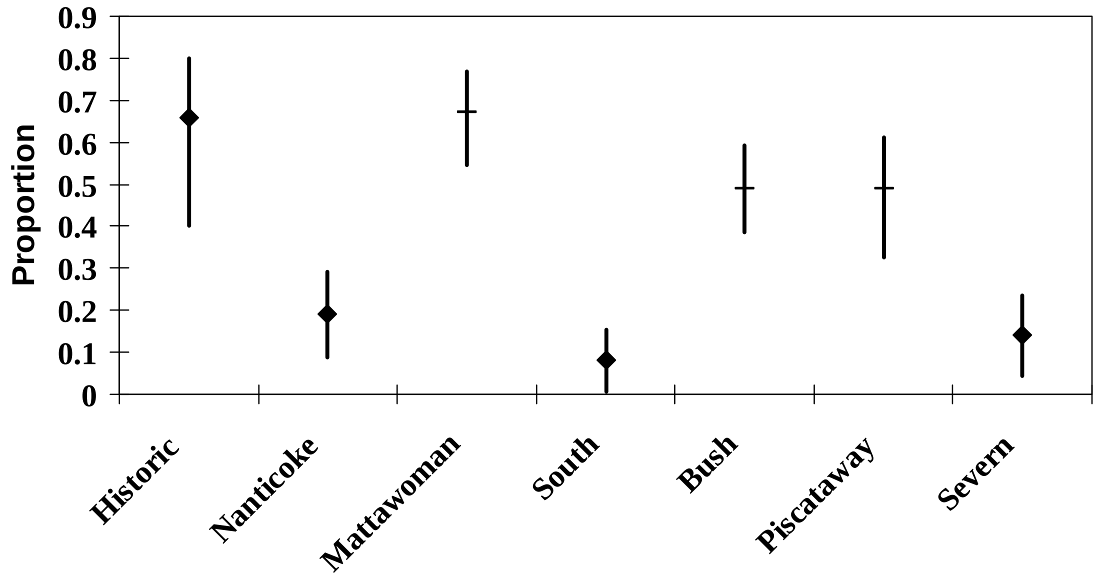


Figure 23. Plot of impervious surface (% of watershed) versus proportion of plankton tows with yellow perch larvae (Lp).

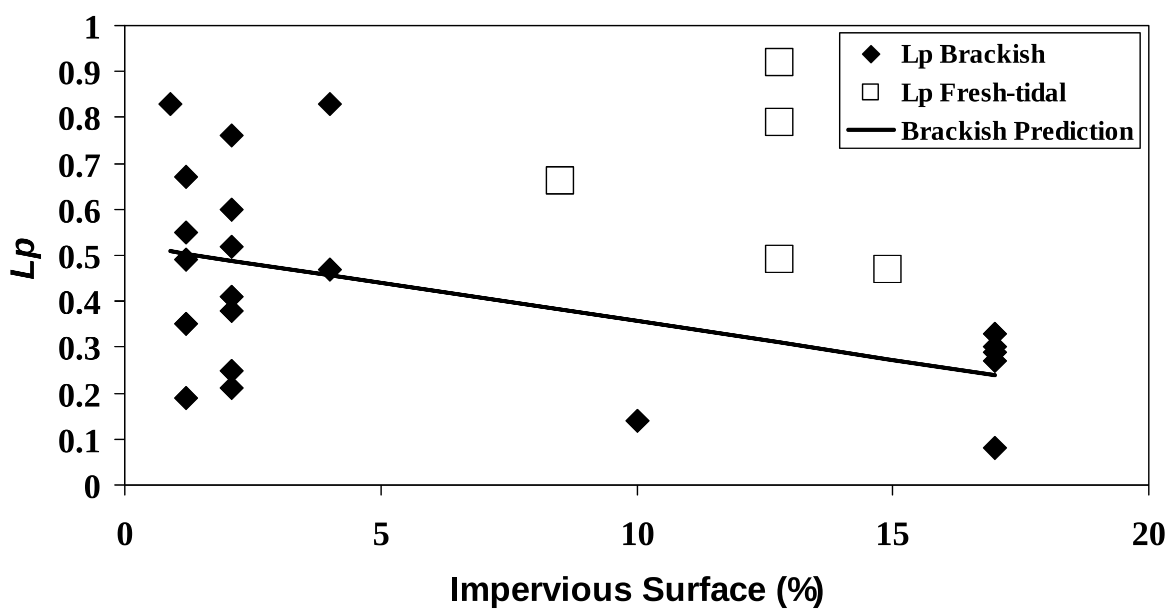


Figure 24. Plot of mean salinity in nursery area versus proportion of plankton tows with yellow perch larvae (*Lp*). Empty squares indicate Severn River and solid diamonds indicate remaining systems.

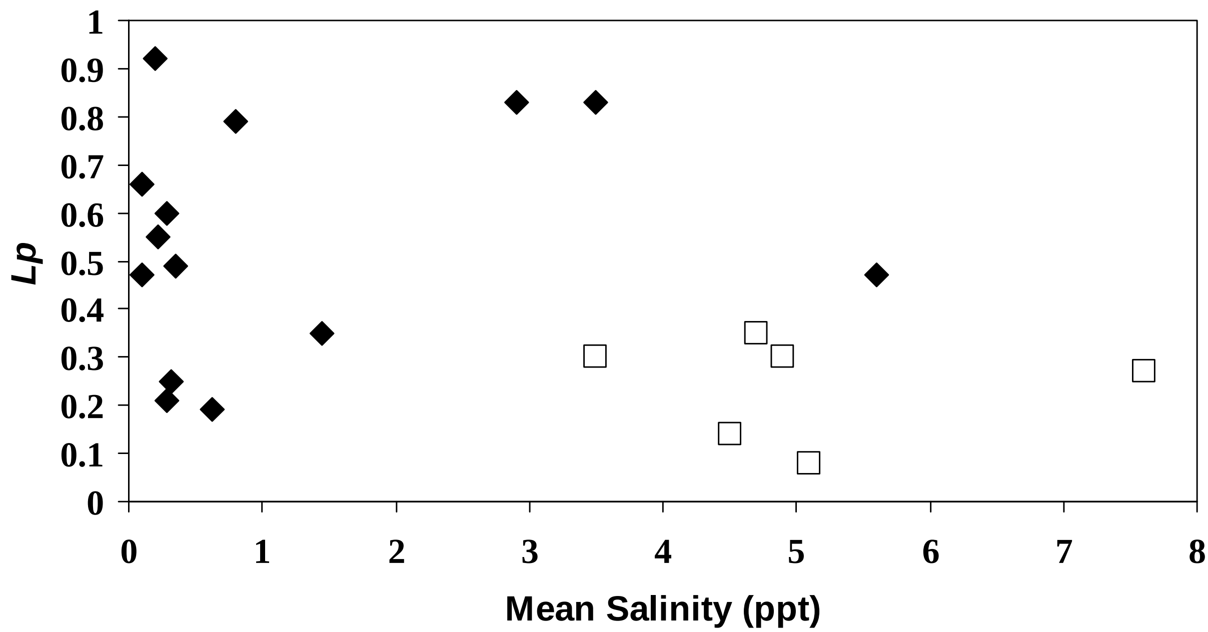


Figure 25. Proportion of tows with yellow perch larvae, by river, during 1965-2008. Dotted lines indicates reference system (Nanticoke and Choptank rivers) and period (prior to 1991) "typical" range.

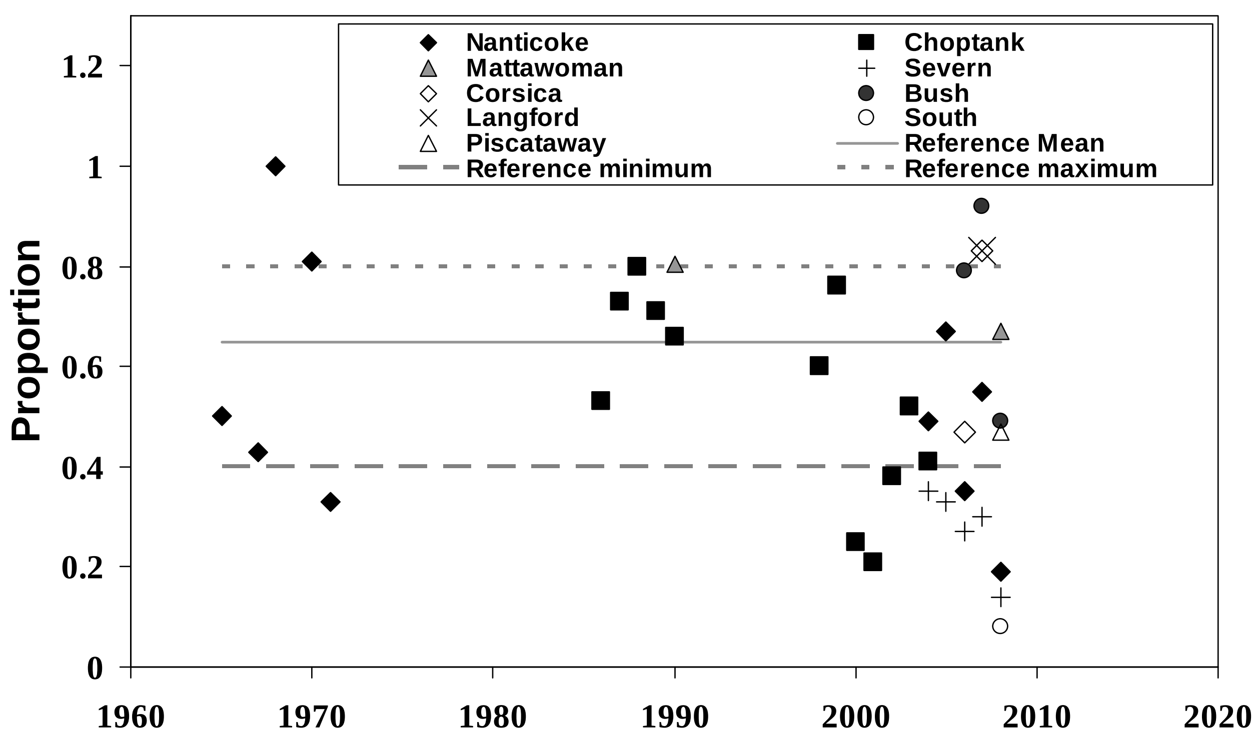


Figure 26. Number (N) of estimates of proportion of plankton tows with yellow perch larvae (Lp) falling within a category during 1965-2008. Severn and South rivers are omitted due to possible suppression of Lp due to factors related to impervious surface.

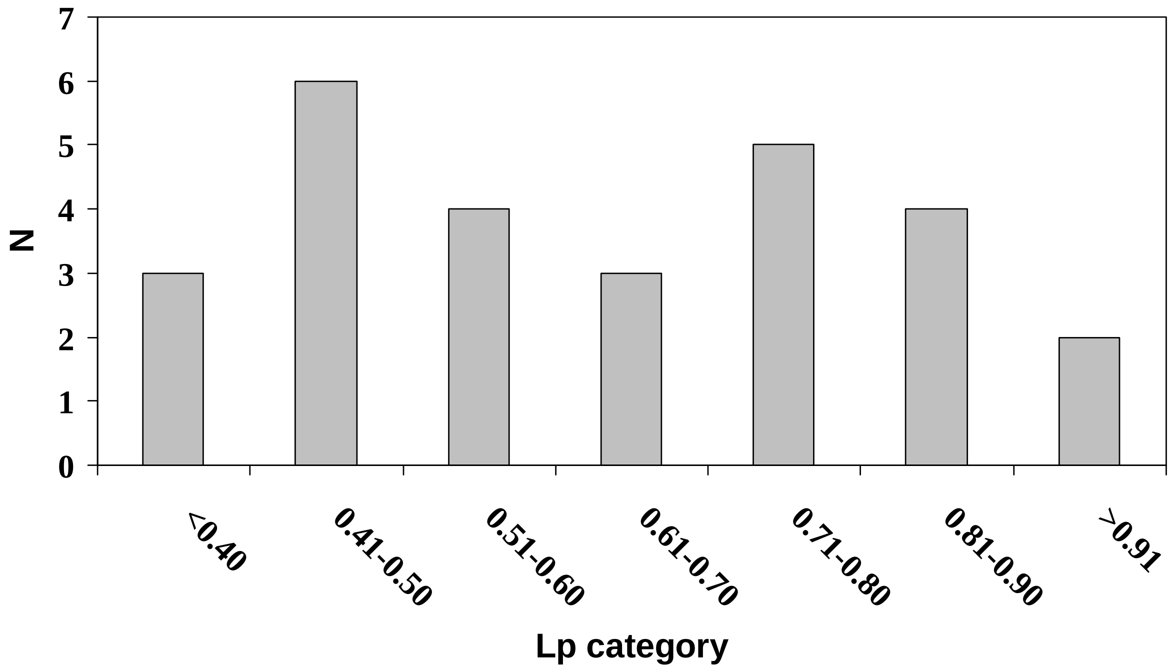


Figure 27. Watersheds sampled for juvenile and adult target species relative abundance and habitat conditions in 2008.

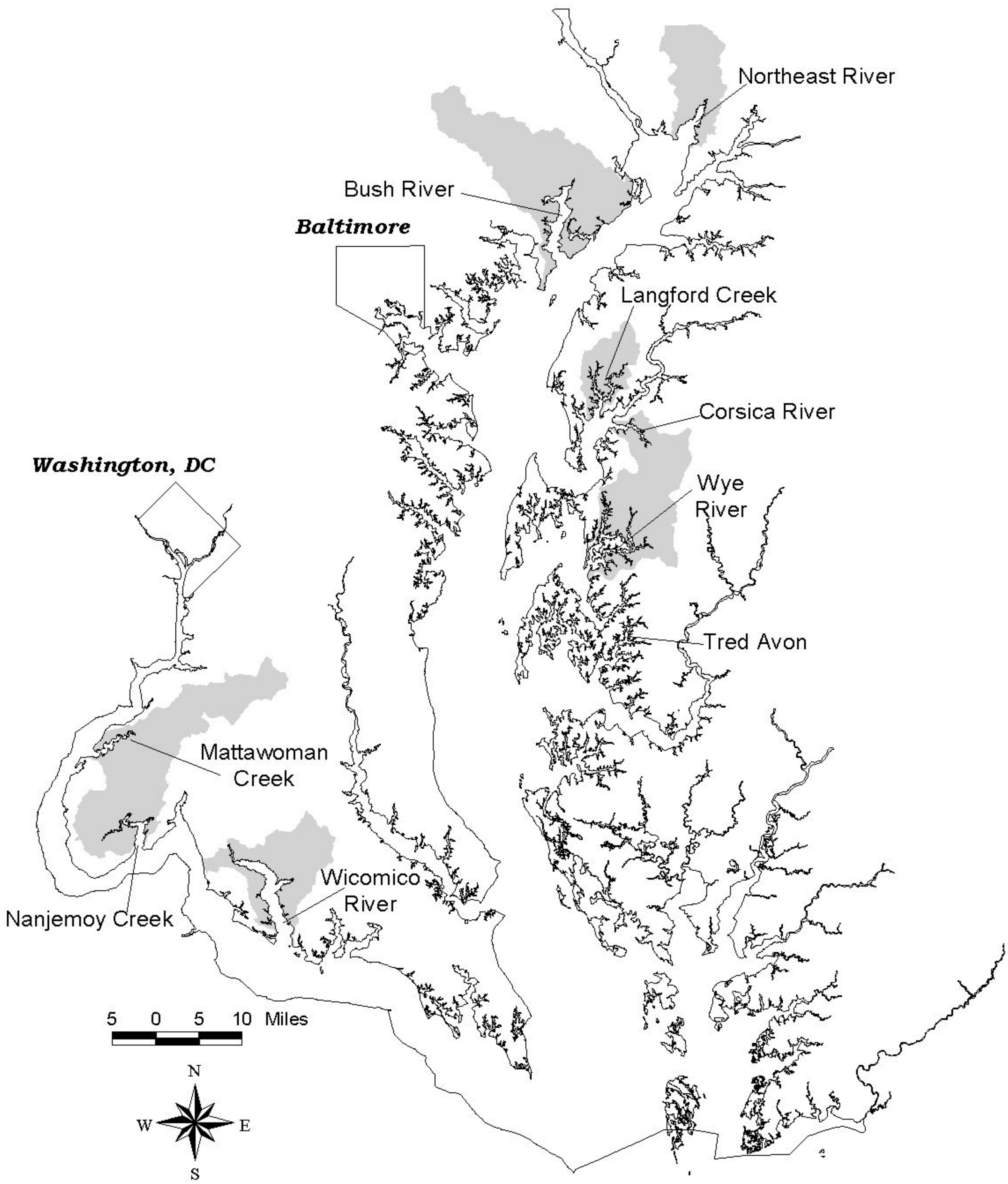


Figure 28. Land use and sampling stations n the Bush River watershed.

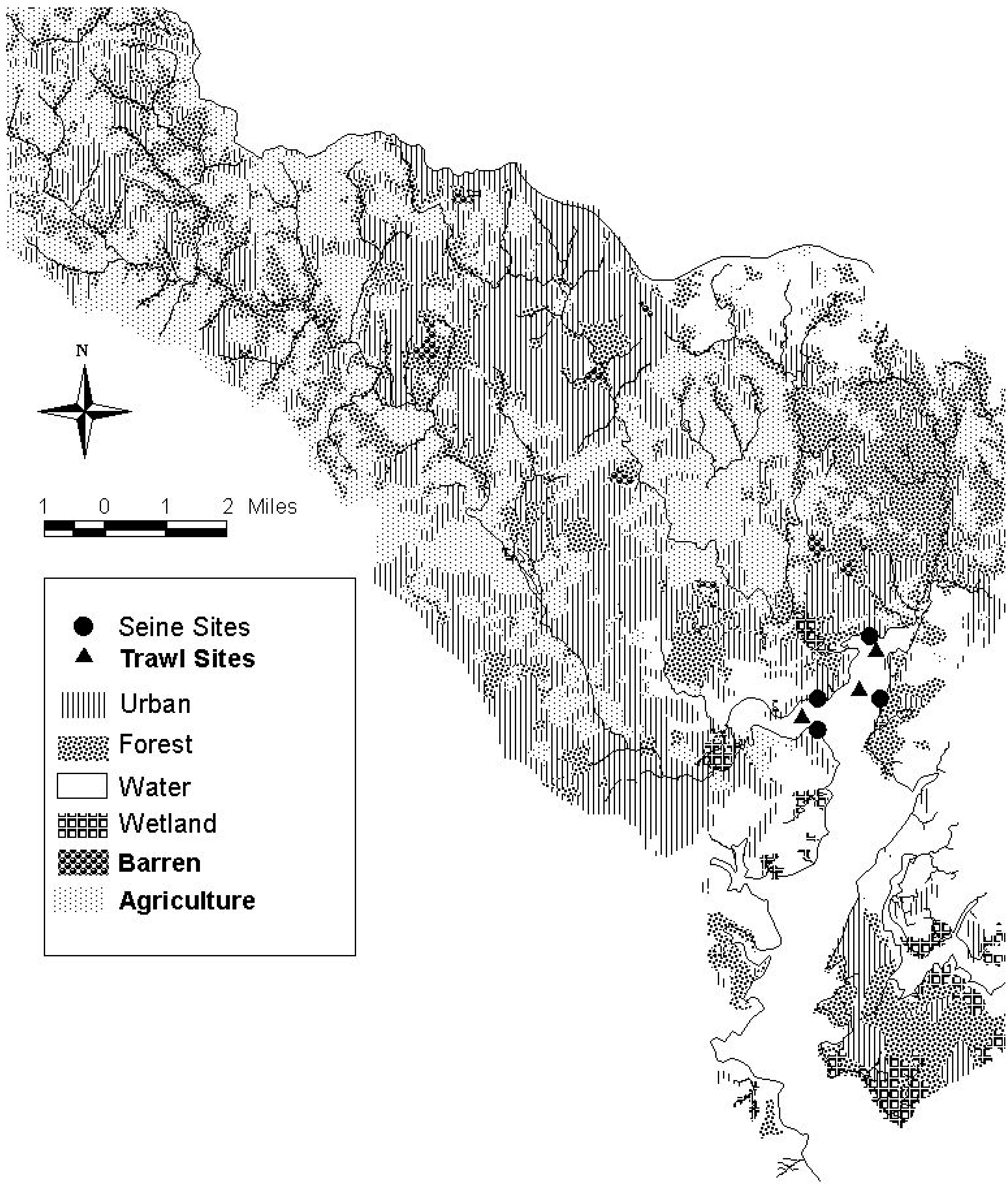


Figure 29. Land use and sampling stations in the Northeast River watershed.

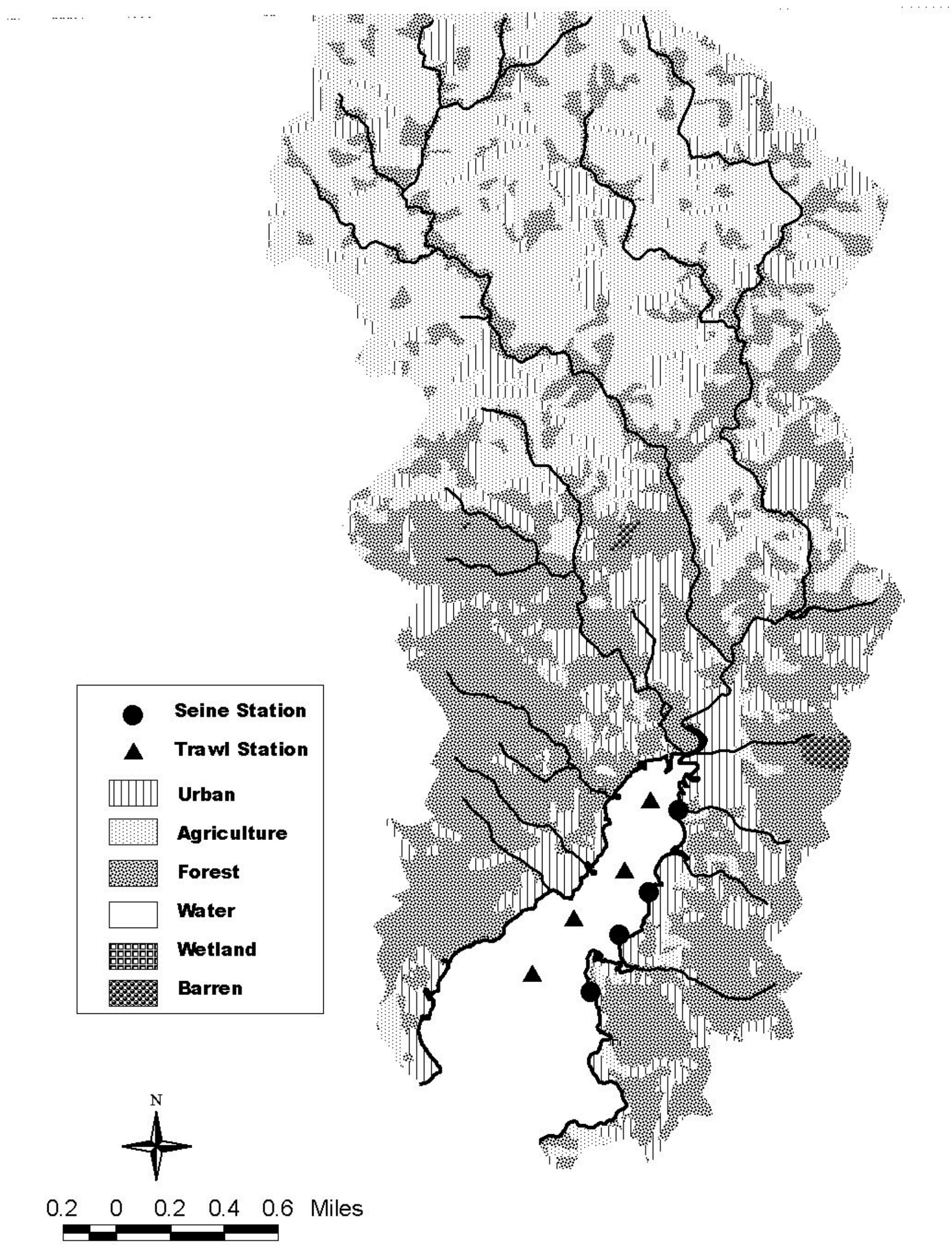


Figure 30. Land use and sampling stations in the Corsica River watershed.

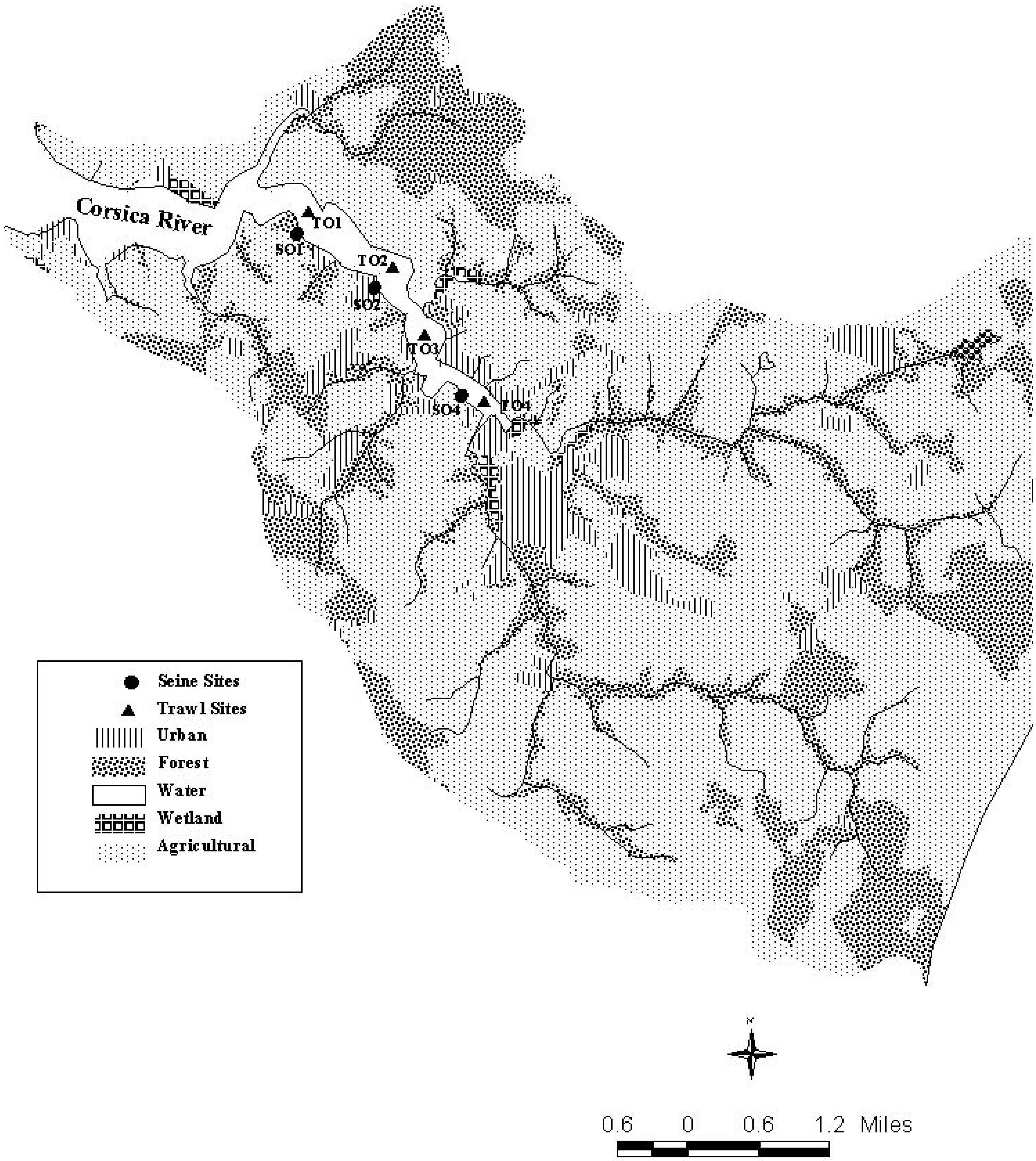


Figure 31. Land use and sampling stations in the Langford Creek watershed.

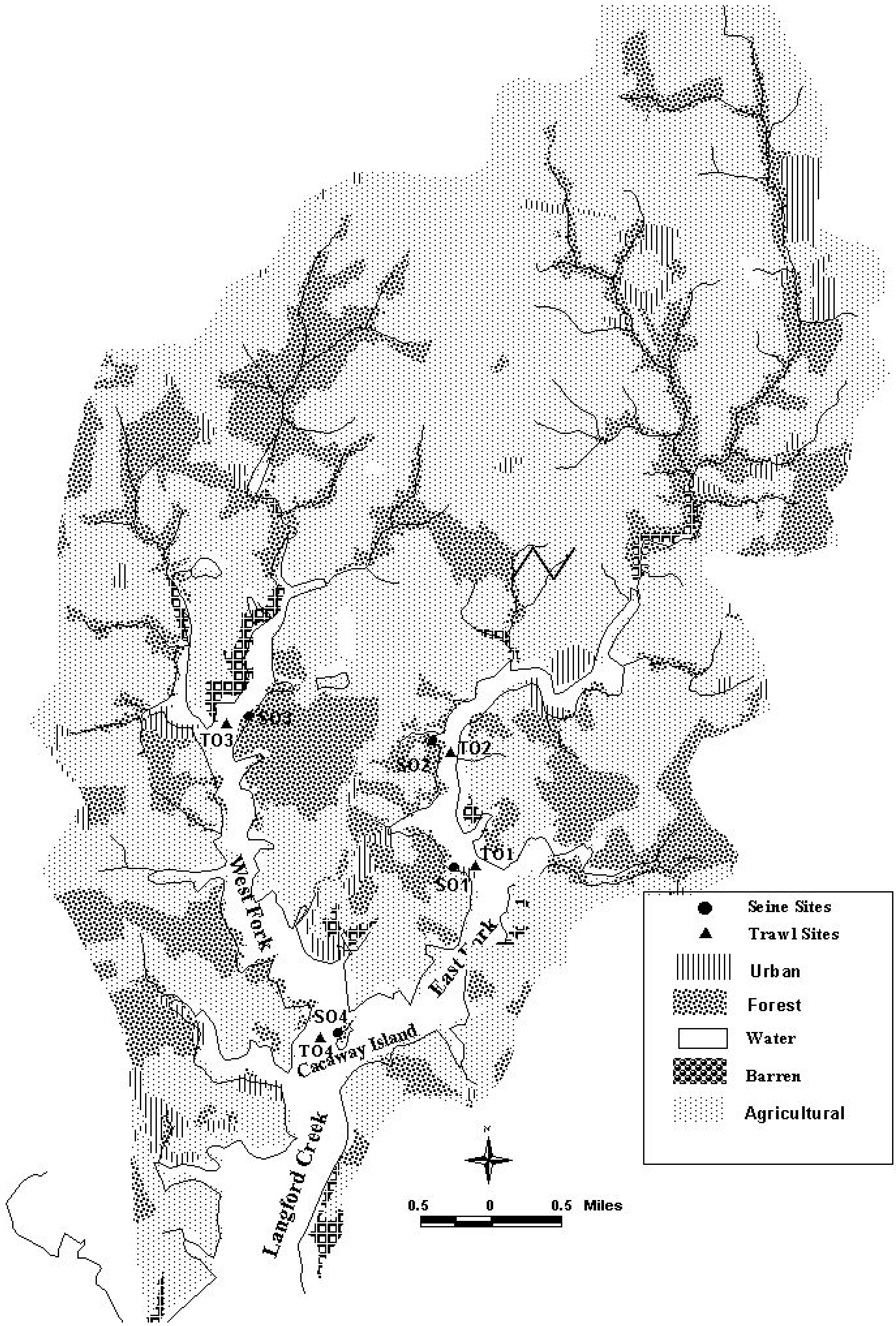


Figure 32. Land use and sampling stations in the Tred Avon watershed.

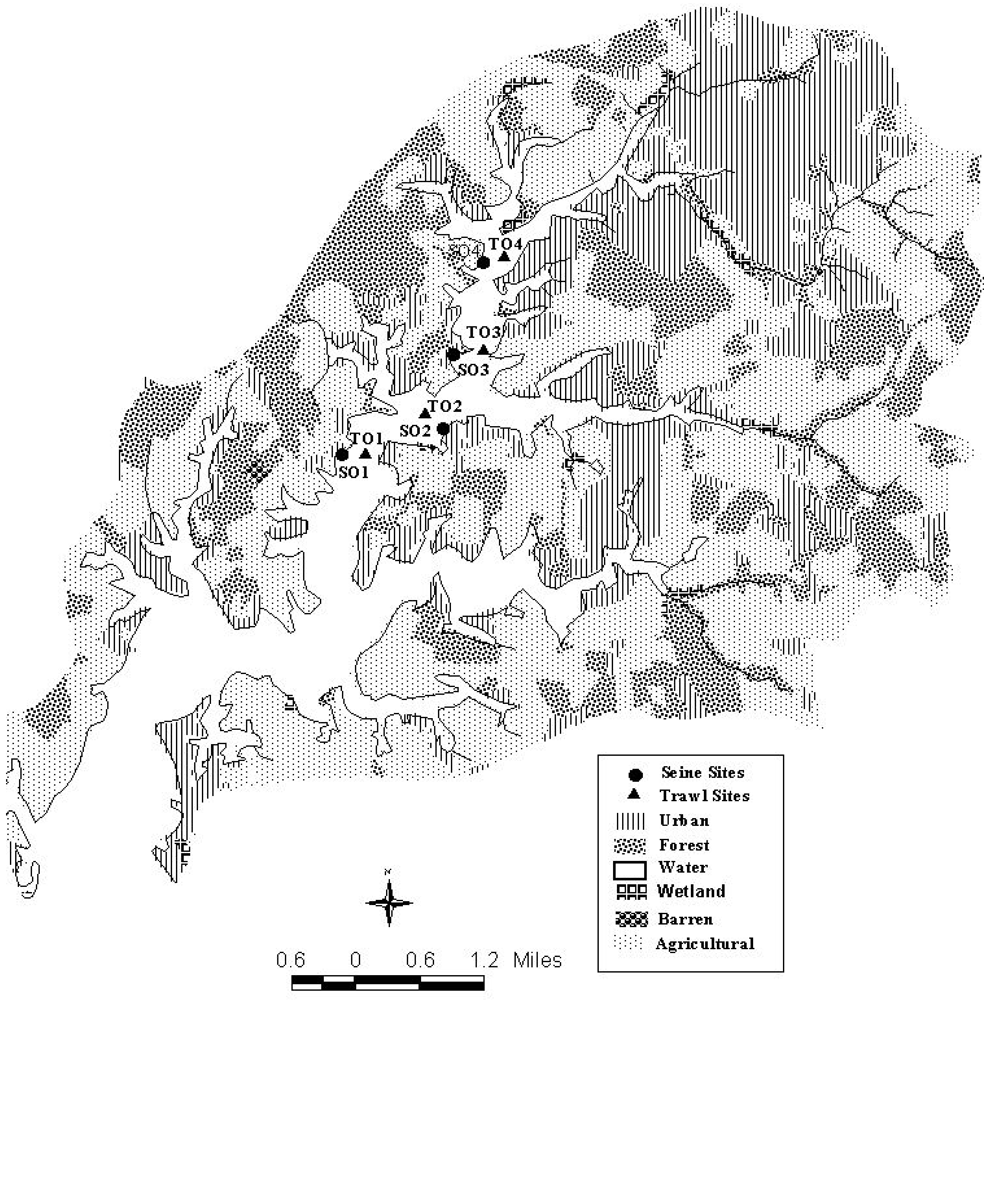


Figure 33. Land use and sampling stations in the Wye River watershed.

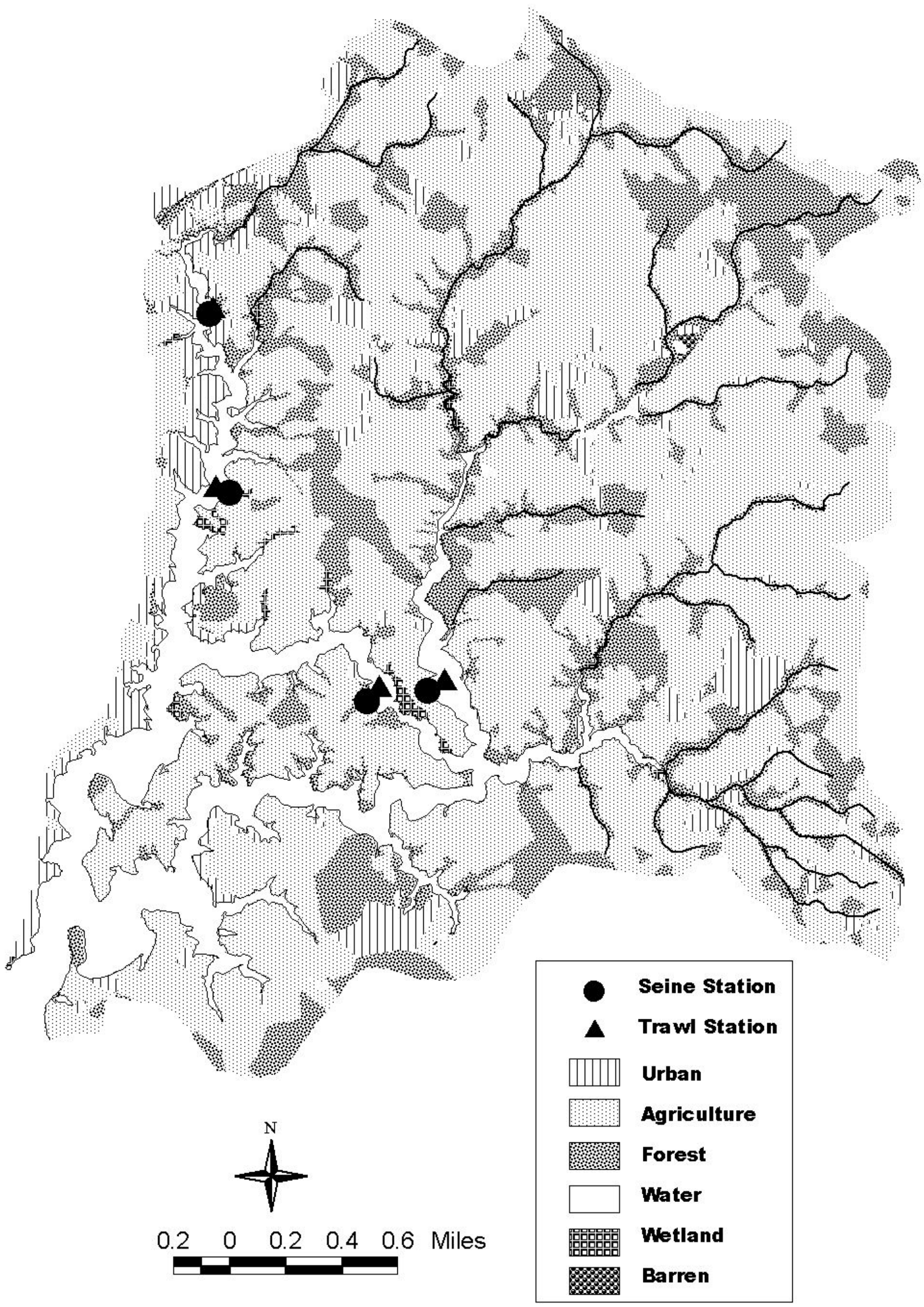


Figure 34. Land use and sampling stations in the Mattawoman Creek watershed.

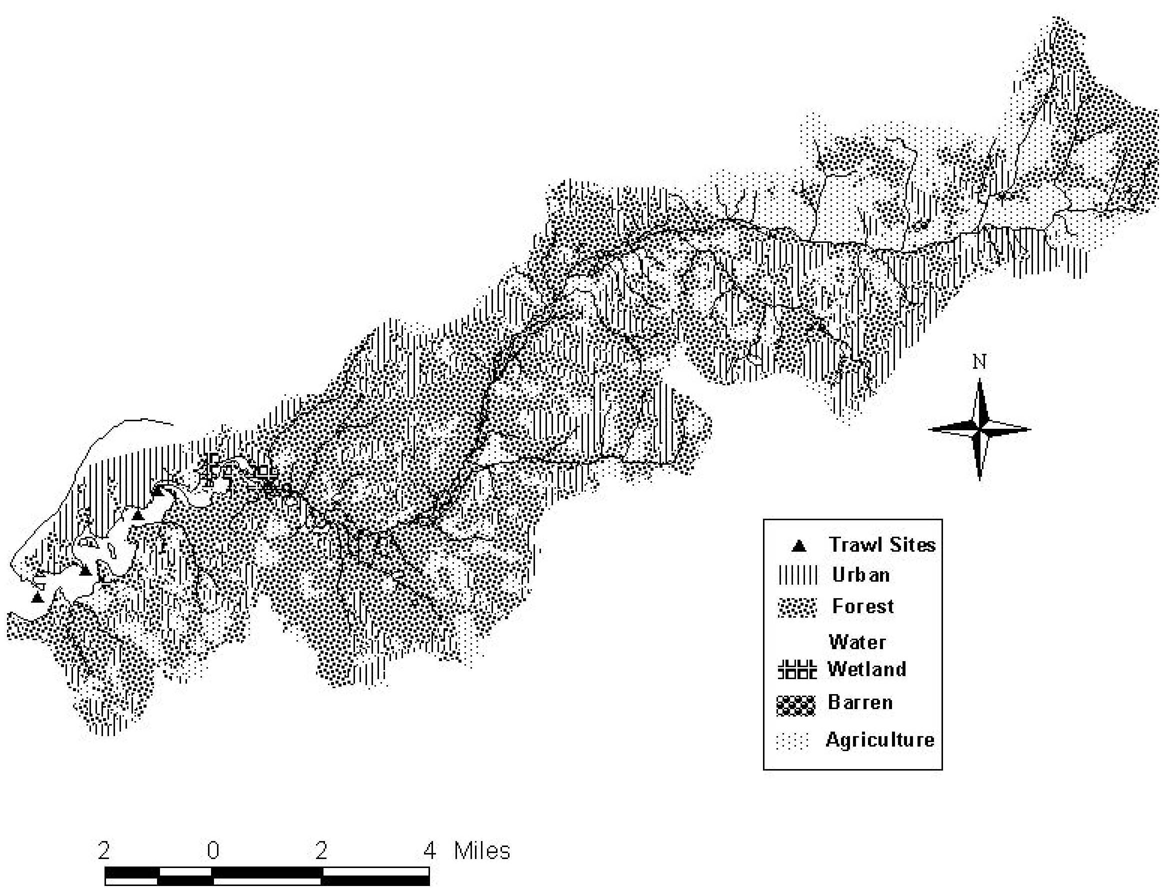


Figure 35. Land use and sampling stations in the Nanjemoy Creek watershed.

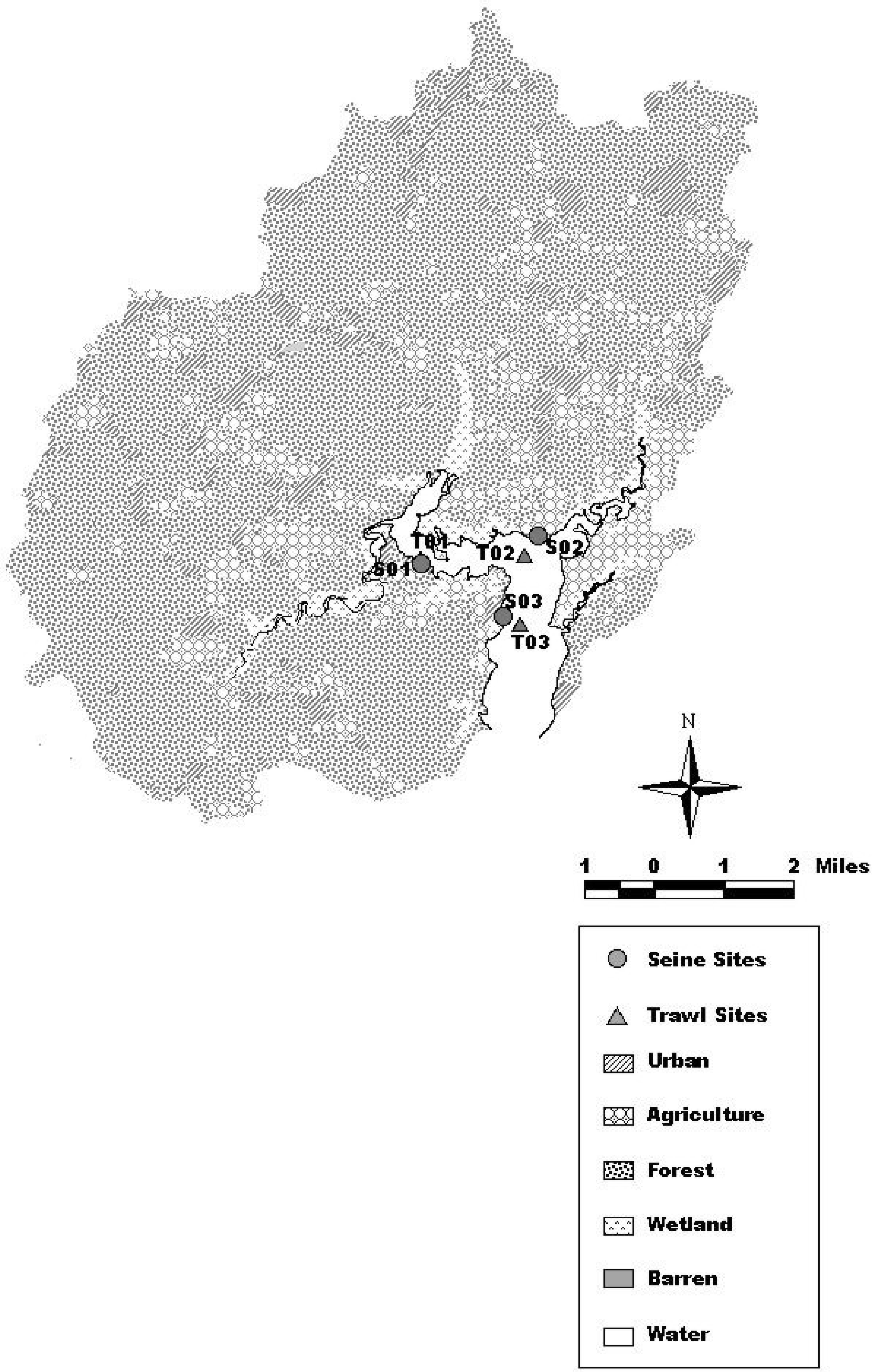


Figure 36. Distribution of temperature data for rivers sampled in 2008. Data include nearshore and offshore water column integrated data. The highlighted area indicates temperatures that are outside of the mean highest acceptable temperature for all target species combined. (Dark bar is the median, gray 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.)

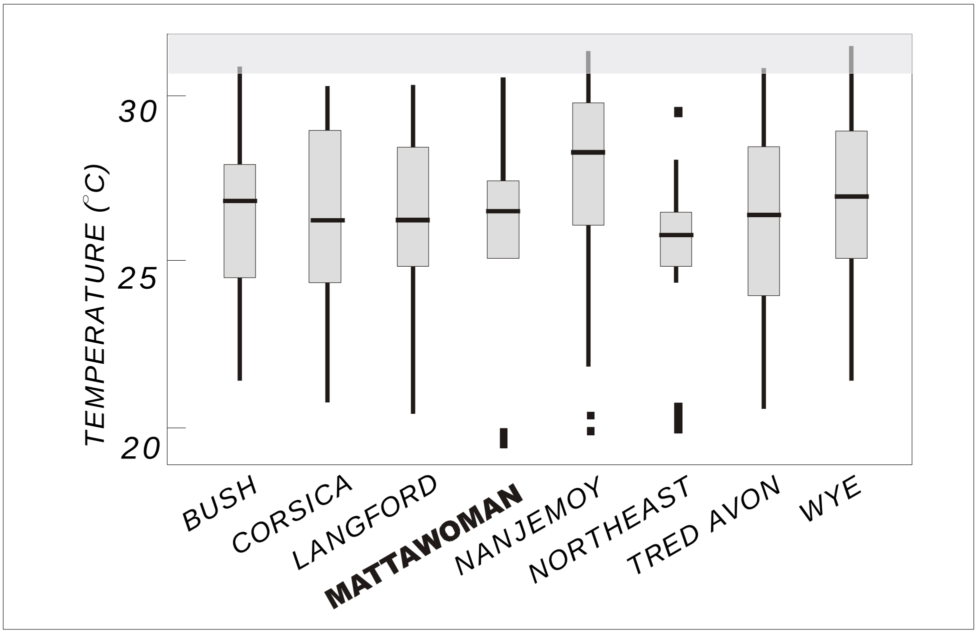


Figure 37. Distribution of dissolved oxygen data for rivers sampled in 2008. Data include nearshore and offshore water column integrated data. The highlighted area indicate dissolved oxygen concentrations below the 5.0 mg/L threshold. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

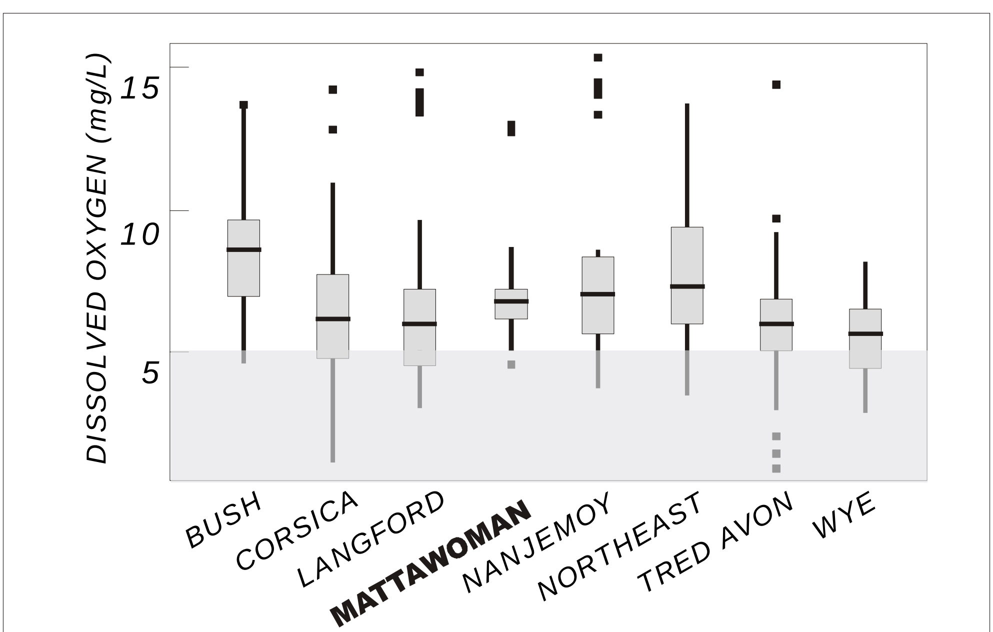


Figure 38. Distribution of salinity data for rivers sampled in 2008. Data include nearshore and offshore water column integrated data. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.) Horizontal line indicates salinity maximum for non-marine target species.

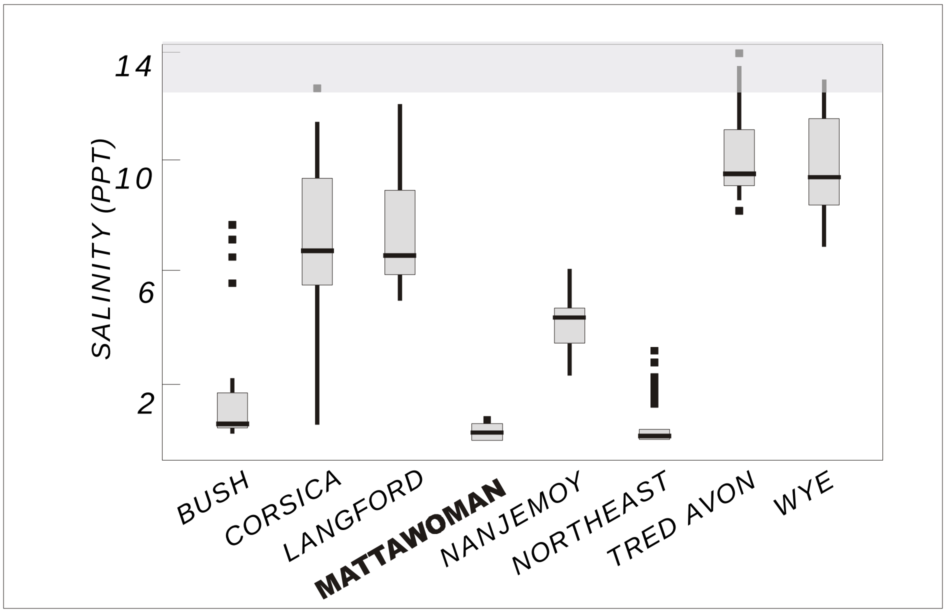


Figure 39. Distribution of bottom dissolved oxygen for rivers sampled in 2008. The gray shaded area represents concentrations below the 5.0 mg/l criteria. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

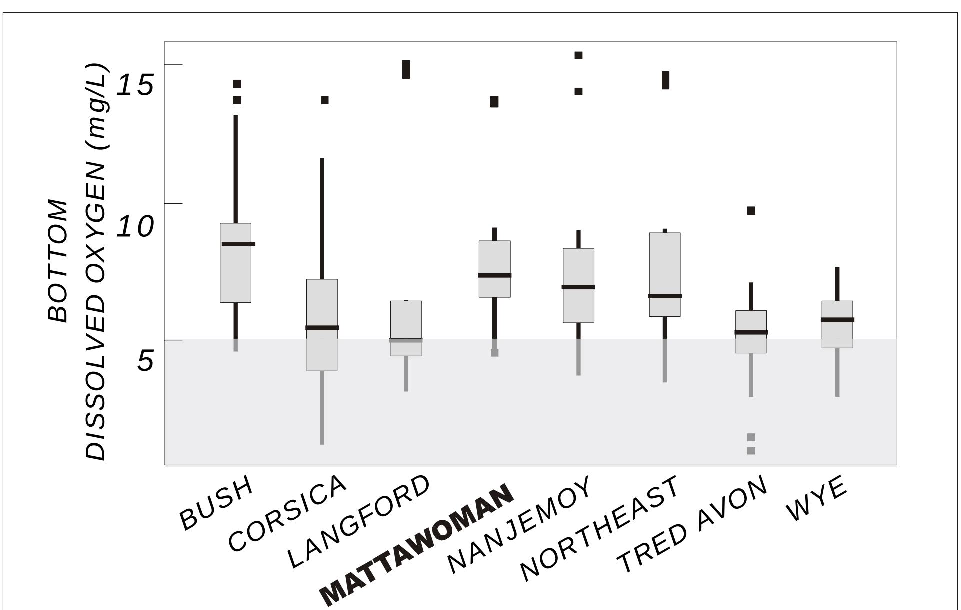


Figure 40. Mean bottom dissolved oxygen versus impervious surface for all brackish and tidal fresh systems during 2003-2008.

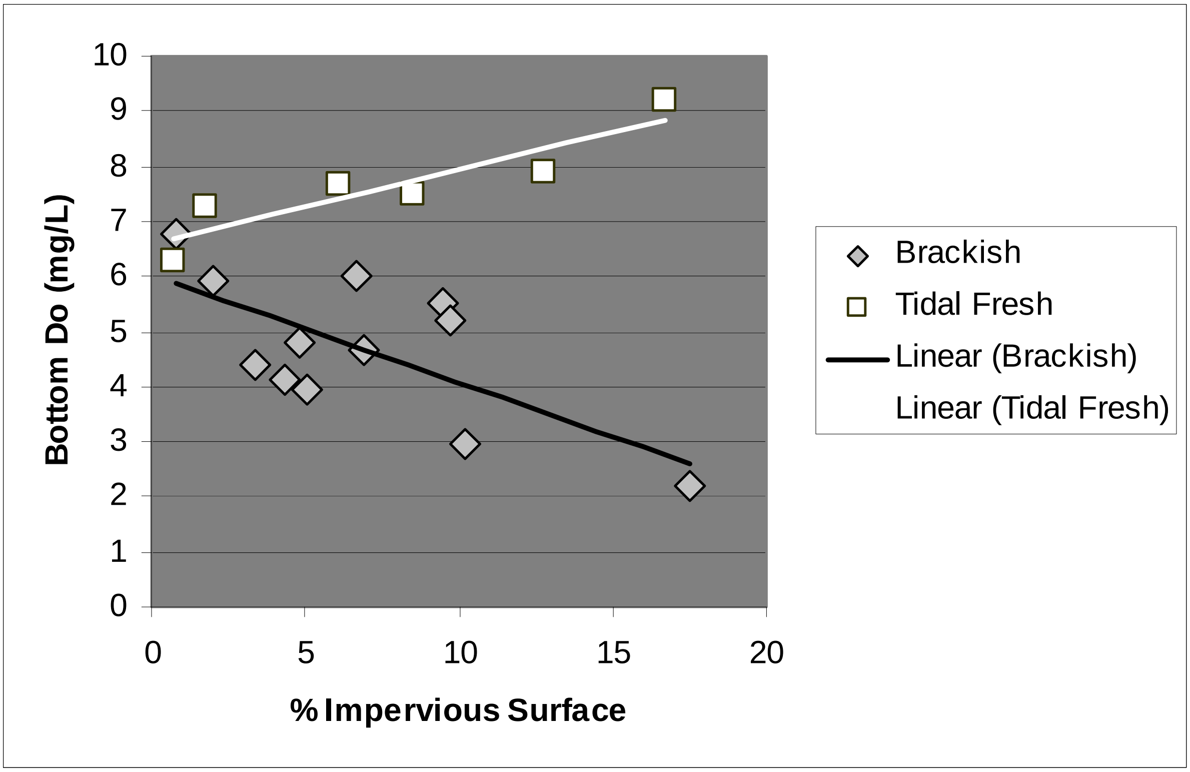


Figure 41. Distribution of bottom dissolved by percent impervious cover for tidal fresh rivers sampled during 2006-2008. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.) The shaded area indicates the 5.0 mg/L habitat criteria is not achieved.

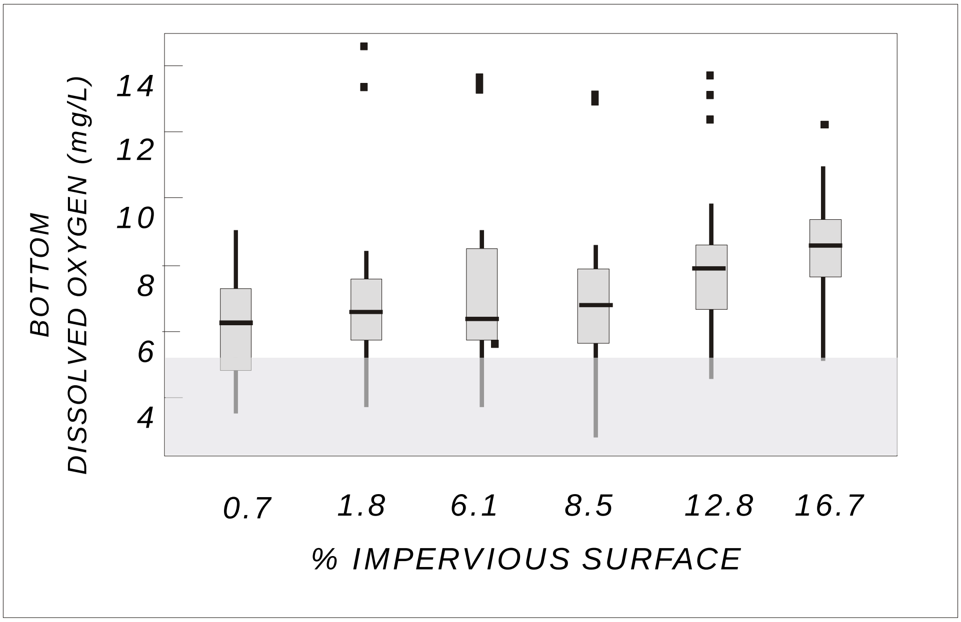


Figure 42. Distribution of secchi depth by impervious surface in tidal fresh rivers sampled in 2006-2008. The gray shaded area represents concentrations below the 5.0 mg/l criteria. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

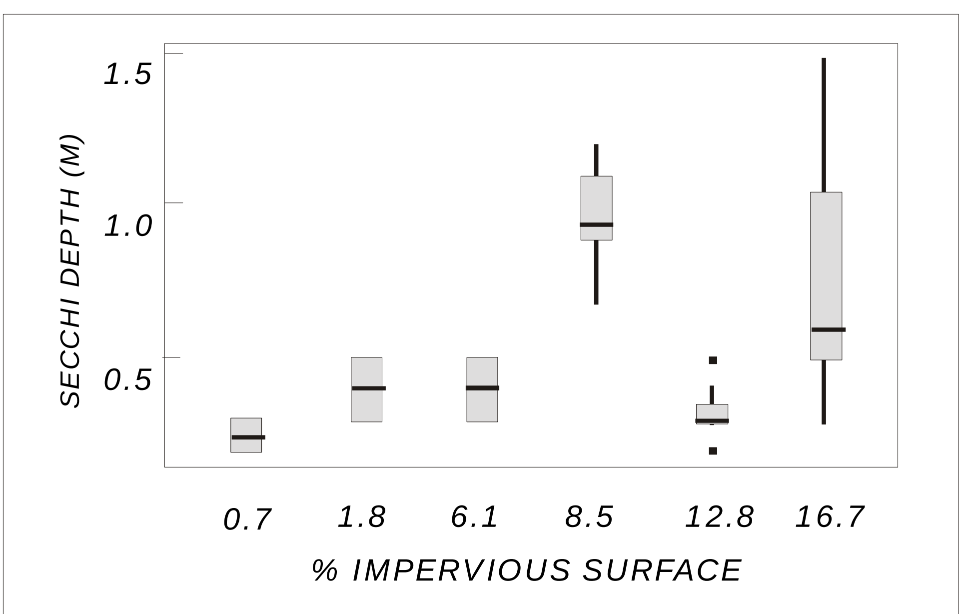


Figure 43a. Proportion of target species present in the trawl, in tidal fresh tributaries versus percentage of impervious surface.

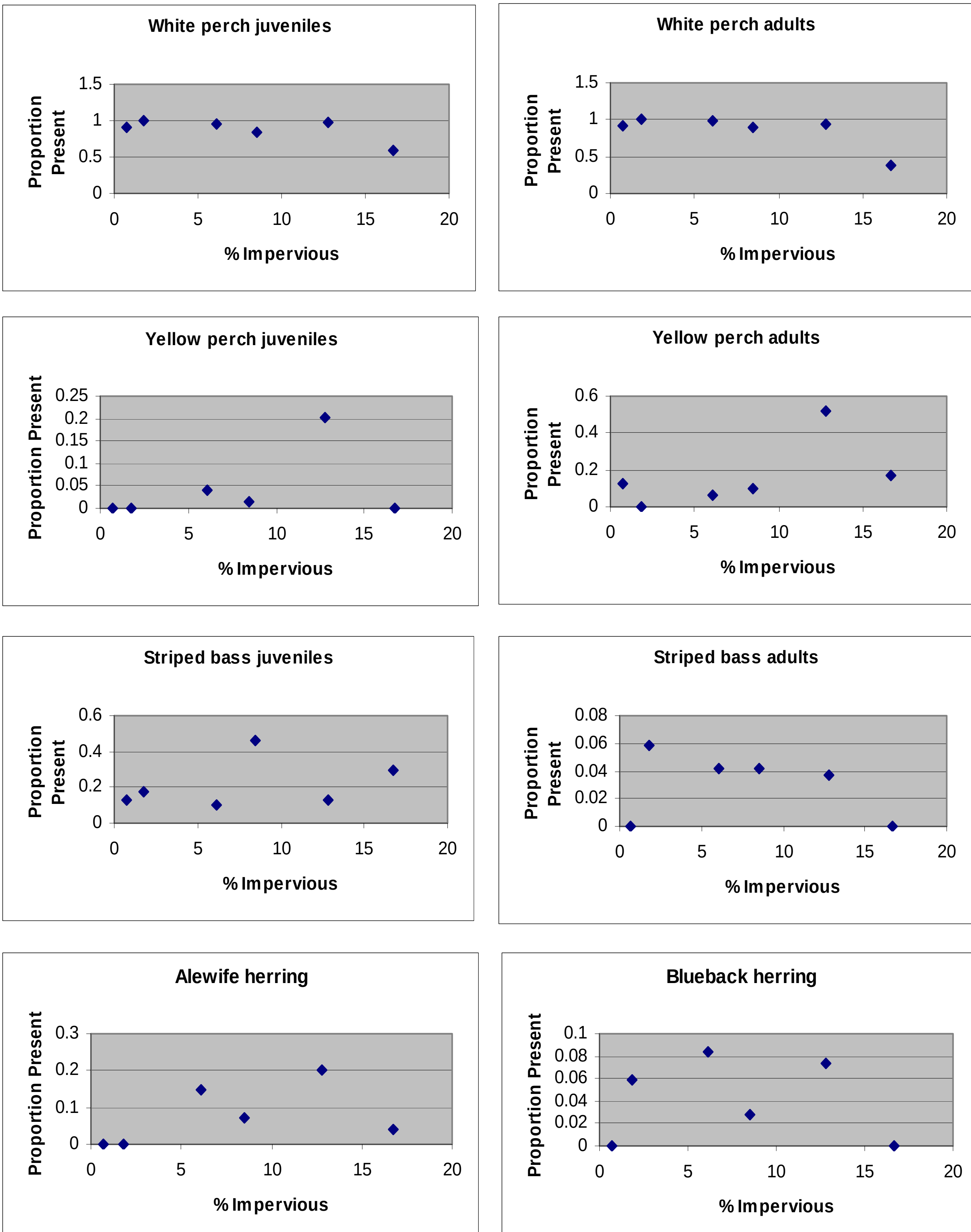


Figure 43b. Proportion of target species present in tidal fresh tributaries, in the trawl versus percentage of impervious surface.

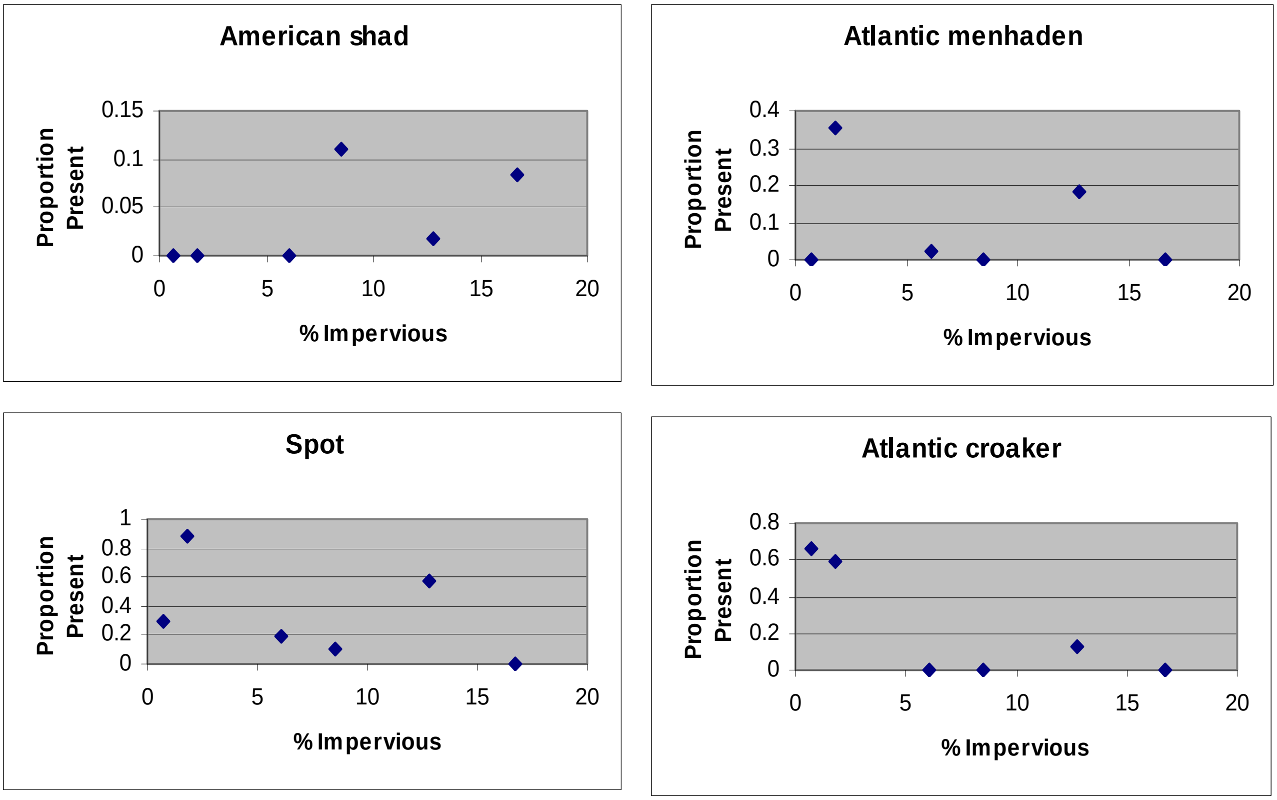


Figure 44a. Proportion of target species present in tidal fresh tributaries, in the seine versus percentage of impervious surface.

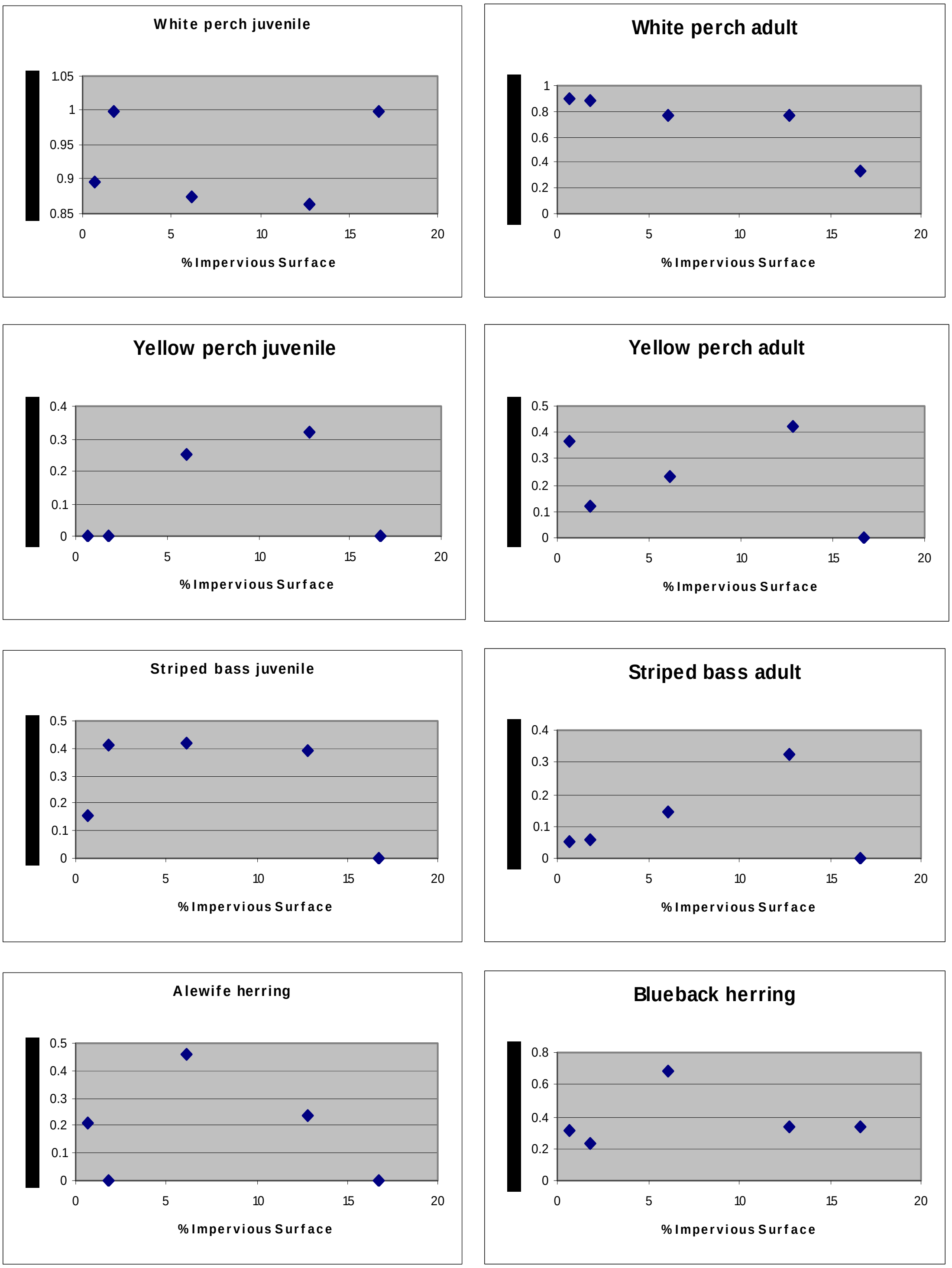


Figure 44b. Proportion of target species present in tidal fresh tributaries, in the seine versus percentage of impervious surface.

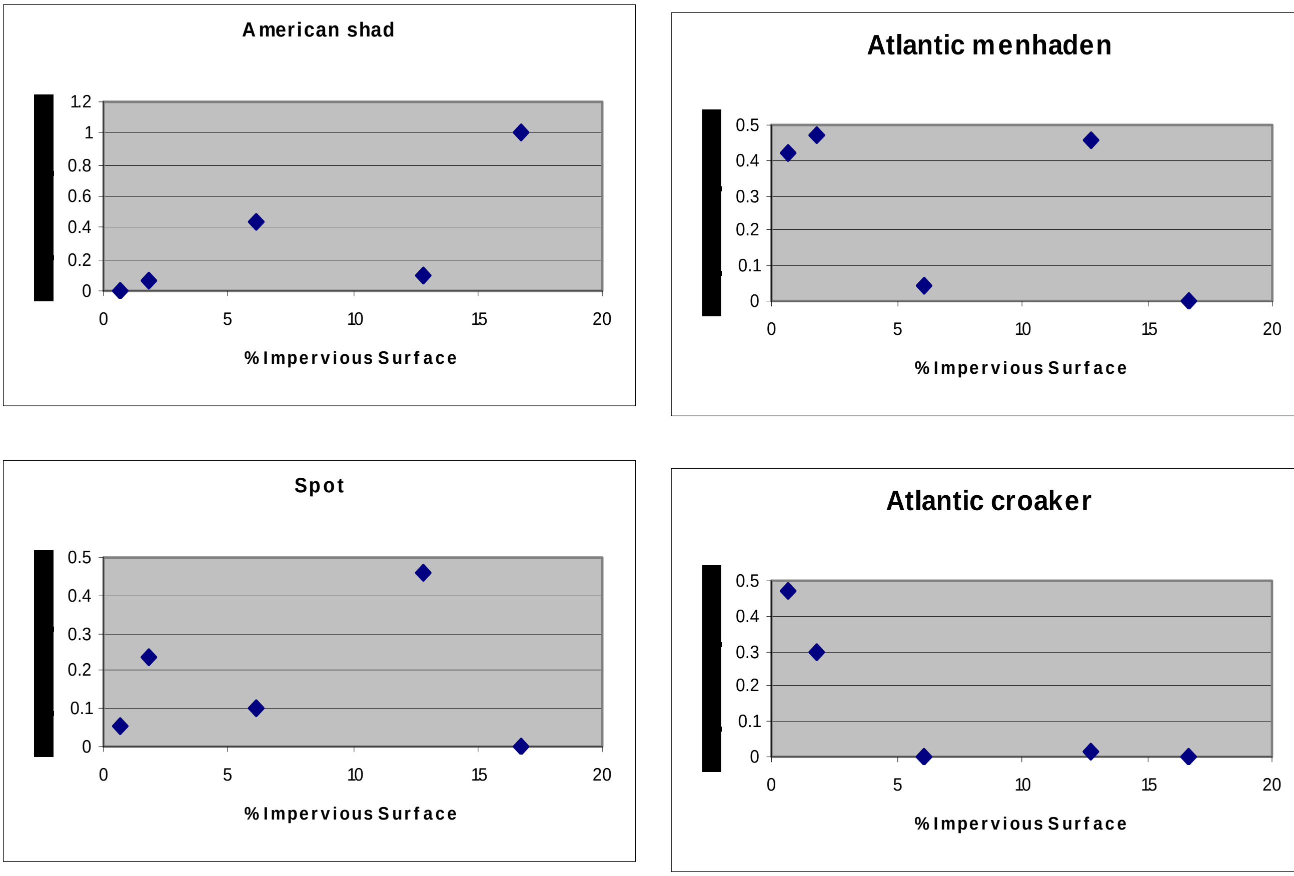


Figure 45. Distribution of bottom dissolved oxygen concentrations in Mattawoman Creek from 1989 to present. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

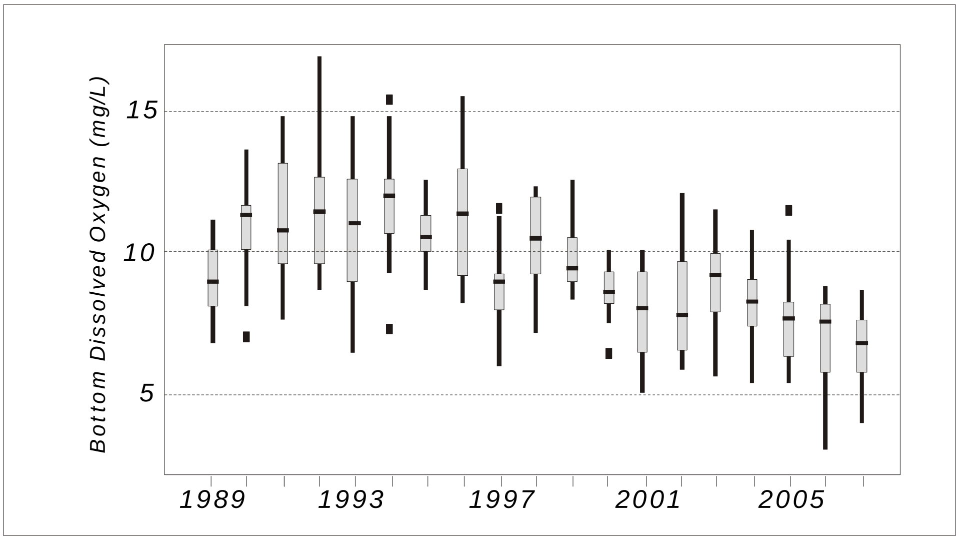


Figure 46. Distribution of bottom oxygen saturation in Mattawoman Creek, 1989 to present. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

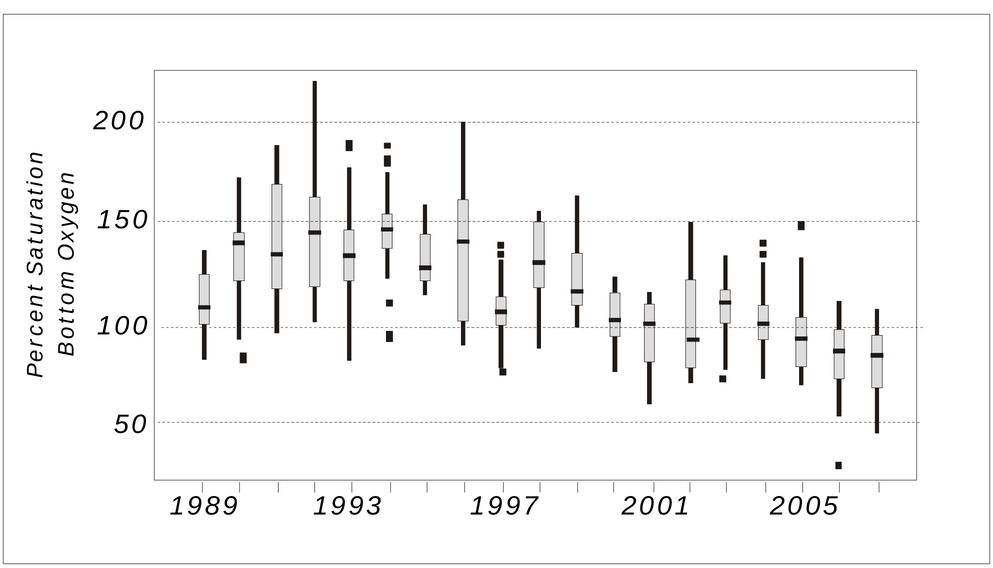


Figure 47. Percent presence of target species frequently captured in the trawl in Mattawoman Creek, from 1989 to present.