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

STATE: Maryland

PROJECT NO.: F-61-R-3

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish / Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2006 through October 31, 2007

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.

Yellow perch in Maryland tidal waters support both commercial and recreational fisheries. Upper Chesapeake Bay yellow perch population dynamics were described with a statistical catch-at-age model for the time period 1998 – 2006. Yellow perch abundance (age 3 and older) peaked in 1999 at 1.64 million fish before declining to 712,000 fish in 2002. The yellow perch population rose during 2002 – 2006 with abundance in 2006 estimated at 1.55 million fish. Estimated instantaneous fishing mortality ranged from 0.25 to 0.48 during 1998 – 2001 before rising to 1.01 in 2002. Mortality decreased steadily from 1.01 in 2002 to 0.11 in 2006. Based on biological reference points, overfishing occurred in 2002 and possibly 2003, but overfishing did not occur 1998 – 2001 or 2004 – 2006.

Yellow perch population dynamics in the Choptank River were described by analyzing

relative abundance trends from agency fyke net surveys, (1988 – 2007). Analysis indicated a logarithmic increase of approximately 800% during this time period as the population doubled approximately every 5 - 6 years. Low mortality rates over the most recent years were also noted. No violations of F targets or limits were suspected.

Adult American shad indices in the Susquehanna River, including fish lift GM, hook and line GM and relative population estimates have continued to trend downward during the last six years. American shad relative abundance in the Nanticoke River also remained low. Age structures in both systems were unchanged indicating nonselective mortality. The Upper Chesapeake Bay American shad juvenile index for 2007 indicated near record spawning success and was likely related to ideal flow conditions. The low abundance of adult American shad, a coastwide phenomenon, indicates increased mortality on ocean migrant fish possibly through commercial exploitation, increased predation, or a combination of both parameters.

Adult hickory shad relative abundance indices in Deer Creek remained stable while those in the Nanticoke River decreased. Juvenile sampling caught few hickory shad due primarily to gear aversion.

Adult alewife herring repeat spawning indices and GM CPUEs in the Nanticoke River have shown no trend, but remain very low. Blueback herring repeat spawning indices and GM CPUEs have decreased significantly since 1989. Fishing mortality rates, age structure and sex ratios appeared stable for both species during the time series. In general, adult alewife and blueback herring stocks and corresponding juvenile indices for both species have been low for most of the years in the 19 year time series.

Weakfish have experienced a sharp decline in abundance coast wide. Recreational catch estimates by the NMFS for Maryland fell steadily from 475,348 fish in 2000 to 493 fish in 2006. Maryland’s commercial weakfish harvest rose slightly to 32,417 pounds in 2006, but was still the third lowest catch on record. The 2007 mean length for weakfish from pound net sampling was 275 mm TL, the second smallest of the time series. The 2007 length frequency distribution and RSD analysis indicate that only smaller weakfish were available in Maryland waters. Fish aged from 2006 pound net sampling were all 4 years of age or younger.

The mean length of summer flounder collected from pound nets was 341 mm TL in 2007, near average for the 15 time series. Relative stock densities in 2007 indicated a shift up from the RSD stock category to the quality category compared 2006. Both commercial and recreational harvest of summer flounder decreased in 2006. The NMFS 2006 coast wide stock assessment concluded that summer flounder stocks were not overfished, but overfishing was occurring.

Mean length of bluefish sampled from pound nets in 2007 was 318 mm TL, 6th highest during the 1993-2007 time period. Length distribution and RSD analysis indicated a modest

shift toward larger bluefish in 2007. Both recreational and commercial bluefish harvest's in Maryland were below average in 2006. The latest coast wide stock assessment indicated bluefish were not overfished and overfishing was not occurring.

The mean length of Atlantic croaker examined from pound net sampling in 2007 was 307 mm TL, the fifth largest mean length of the 15-year time series. RSD analysis for Atlantic croaker indicated a continued dominance of $RSD_{preferred}$ and $RSD_{memorable}$ fish and a time series high of RSD_{trophy} fish. Fish aged from 2006 pound net sampling ranged from 1 – 13 years of age. Maryland Atlantic croaker total commercial harvest for 2006 decreased to 344,318 pounds, while the corresponding recreational harvest estimate of 834,894 fish was similar to the previous two years.

Spot length frequency distributions in 2007 were somewhat truncated, but the mean length remained near the average of the time series. Juvenile indexes have been lower than the long-term average in recent years. Commercial harvest declined in 2006, while recreational catch estimates remained near the average. The percent of spot over 254 mm TL in the pound net samples was one percent, lower than the previous 4 years.

Resident / premigratory striped bass present in the Chesapeake Bay during the summer – fall 2006 pound net and hook and line commercial fisheries ranged from 1 to 14 years of age. Three year old striped bass from the 2003 year-class and 5 year old fish from the 2001 year-class dominated samples taken from pound nets, contributing 32% of the total sample in 2006. Check station sampling determined that five year old striped bass from the dominant 2001 year-class comprised 36% of the commercial hook & line harvest and 37% of the pound net harvest.

The 2006-2007 commercial drift gill net fishery harvest was comprised primarily of four, five and 6 year old striped bass from the 2001, 2002 and 2003 year-classes. Age groups 4, 5 and 6 contributed approximately 78% of the drift gill net harvest while age 7 to 14 year-old fish contributed 22%. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from 4 to 14 (1993 – 2003 year classes)

The spring, 2007 spawning stock survey indicated that there were 16 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 19 years old. Age 4 male striped bass from the 2003 year-class were the most abundant component of the male striped bass spawning stock. Age 11 (1996 year-class) and age 10 (1997 year-class) females were the major contributors to 2007 total female abundance. Age 8 and older females comprised 93% of the female spawning stock in 2007, a 9% increase from 2006.

The 2007 striped bass juvenile index, a measure of striped bass spawning success in Chesapeake Bay, was 13.4, slightly above the 54-year average of 12.0. During beach seine

sampling, 1,768 young-of-year (YOY) striped bass were collected. The Upper Bay and the Nanticoke River both produced above-average numbers of YOY striped bass. Reproduction in the Potomac and Choptank rivers was below average. The healthy level of reproduction in 2007 follows a low index in 2006. Striped bass populations are known for this variable spawning success in which several years of average reproduction are interspersed with occasional large and small year-classes.

During the 2007 recreational trophy season, biologists intercepted 542 fishing trips, interviewed 809 anglers, and examined a total of 301 striped bass. The average total length of striped bass sampled was 861 mm TL (33.8 inches), and the average weight was 6.8 kg (14.9 lbs). Most fish sampled from the trophy fishery were between seven and eleven years old. The 2000 year-class (7 years old) was the most frequently observed year-class, constituting 21% of the sampled harvest. Average catch rate based on angler interviews was 0.5 fish per hour, a drop from the catch rate of 2.6 fish per hour in 2006. New 2007 size limits resulted in considerable change in length frequencies, catch rates, and age structure of the trophy season harvest.

A total of 1,142 striped bass were tagged and released for growth and mortality studies during the spring, 2006 sampling season. Of this sample, 772 were tagged with USFWS internal anchor tags. A total of 370 striped bass were sampled and tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise. A high reward tag (HRT) study was also incorporated into the spring fishery-independent spawning stock study in order to obtain a current estimate of reporting rate. Results were not yet available for this report. Specialized coded wire tag (CWT) sampling was continued on the Patuxent River during 2007. A total of 48 striped bass were scanned for the presence of CWT's , but none were found to be CWT positive.

During 2007, L_p (proportion of estuarine tows containing larval yellow perch) fell within the historic range in the Bush, Corsica and Nanticoke Rivers, and Langford Creek, a tributary to the Chester River. The Severn River estimate was below the historic range. All four estimates of L_p from the Severn River (17% Impervious Surface – IS) during 1998-2007 were less than the historic minimum of $L_p = 0.4$ while only 5 of 16 estimates from remaining systems (IS < 13%) were below $L_p = 0.4$.

Based on presence-absence comparisons with the Bush River stream surveys conducted during the 1970's and recent surveys from the less developed Aberdeen Proving Ground watersheds, it appears that white perch and yellow perch use of historical stream spawning habitat has diminished. Yellow perch postlarvae were quite abundant in the Bush River estuary during the past two years, indicating that loss of stream spawning habitat may not be critical to the population. However, reduced stream spawning could be critical to recreational anglers because this is where and when yellow perch are accessible to the traditional shore-based fishery. Herring/shad presence in streams did not indicate marked changes in spawning activity with watershed development. Viability of eggs and larvae was unknown, but their presence might have represented losses to the population if habitat conditions have become detrimental and spawning behavior has not changed.

Impervious surface (IS) had a significant, positive influence on the odds of juvenile and adult white perch, juvenile spot and striped bass, and all stages of blue crabs (combined) being absent from trawl samples taken in mid-channel bottom habitat. This likely reflected the strong negative relationship between average DO in the bottom habitat and IS in brackish systems, and the strong, positive asymptotic response of presence-absence of these species with dissolved oxygen.

Plots of P_{wpj} or P_{wpa} (proportion of trawls with juvenile or ages 1+ white perch, respectively) against IS by salinity category (fresh or brackish) in Potomac River tributaries suggests that IS has a negative impact, but the impact appears more gradual in fresh-tidal areas than brackish. The difference in IS thresholds between fresh-tidal and brackish tributaries reflect substantial differences in dissolved oxygen (DO) levels in bottom waters. During 2003 – 2007, mean bottom DO in fresh-tidal tributaries (IS < 15%) averaged at saturation or slightly above saturation, regardless of IS. In brackish tributaries, however, bottom DO became increasingly depleted as IS increased and averaged in the hypoxic range past IS $\geq$15%.

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 for white perch, yellow perch, channel catfish and white catfish. In order to update finfish population assessments and management plans, data on population vital rates should be clearly defined and current. 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 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, and sampling depth was divided into two strata; shallow water (< 6m) and deep water (>6m). Each site visit was 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 was 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 2006 through February 2007.

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 of the R/V Laidly. Ice-cover prevented the final 2 rounds of the 2007 survey from being completed.

Choptank River Fishery Independent Sampling

Six experimental fyke nets were used 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 26 February 2007 through 4 April 2007 (Figure 2). These nets had a 64 mm stretch-mesh body and 76 mm stretch-mesh in the wings (7.6 m long) and leads (30.5 m long). Nets were set perpendicular to the shore with the wings at 45° angles.

Net hoops were brought aboard first to ensure that all fish were retained. Fish were then removed and placed into a tub and identified. All yellow perch and a subsample of up to 30 fish of each target species were sexed and measured. All non-target species were counted and released. Otoliths from a subsample of white and yellow perch were removed for age determination.

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 Maryland Route 392 Bridge near Hurlock, Maryland to approximately 2 miles downstream from Federalsburg, Maryland (Figure 3). Sampling protocol mimicked that of the Choptank River in all respects. Since this was the first year 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 during early March from the Bush River and Northeast River. 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 5 March 2007 to 27 April 2007, 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 3). Net sites and dates nets were fished 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. 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, minimum quality length is 36 - 41% of the world record length, minimum preferred length is 45 - 55% of the world record length, minimum memorable length is 59 - 64% of the world record length and minimum trophy length is 74 - 80% of the world record length. 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(mm TL)^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 the Ssentongo and Larkin (1973) length based method,

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

where lengths are converted such that $y = -\log_e (1-L/L_\infty)$, and $y_c = -\log_e (1-L_c/L_\infty)$, L is total length, L_c is the length of first recruitment to the fisheries and K and L_∞ are von Bertalanffy parameters. Von Bertalanffy parameters for yellow perch were from 2006 age at length samples for sexes combined (K=0.6 and L_∞ =244). Yellow perch L_c was 216 mm.

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 Estuarine Juvenile Finfish Survey 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 (Figure 1) were used to determine the yellow perch juvenile relative abundance 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 abundance from all baywide permanent sites.

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 (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 catch per effort at age matrix included all yellow perch encountered. Prior to 1993, all sampling began 1 March, but 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 used 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 5-7
Yellow perch	Tables 11-14 and Figures 8-11
Channel catfish	Tables 15-17 and Figures 12-14
White catfish	Tables 18-20 and Figures 15-17

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White perch	Tables 28-29
Yellow perch	Tables 30-31 and Figure 24
Channel catfish	Figures 25-26
White catfish	Figure 27

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

Figure 1. Upper Chesapeake Bay winter trawl survey locations, 2006. Dark triangles indicate mid-bay sites, light triangles indicate upper-bay sites, circles indicate Sassafras River site, and squares indicate Elk River sites.

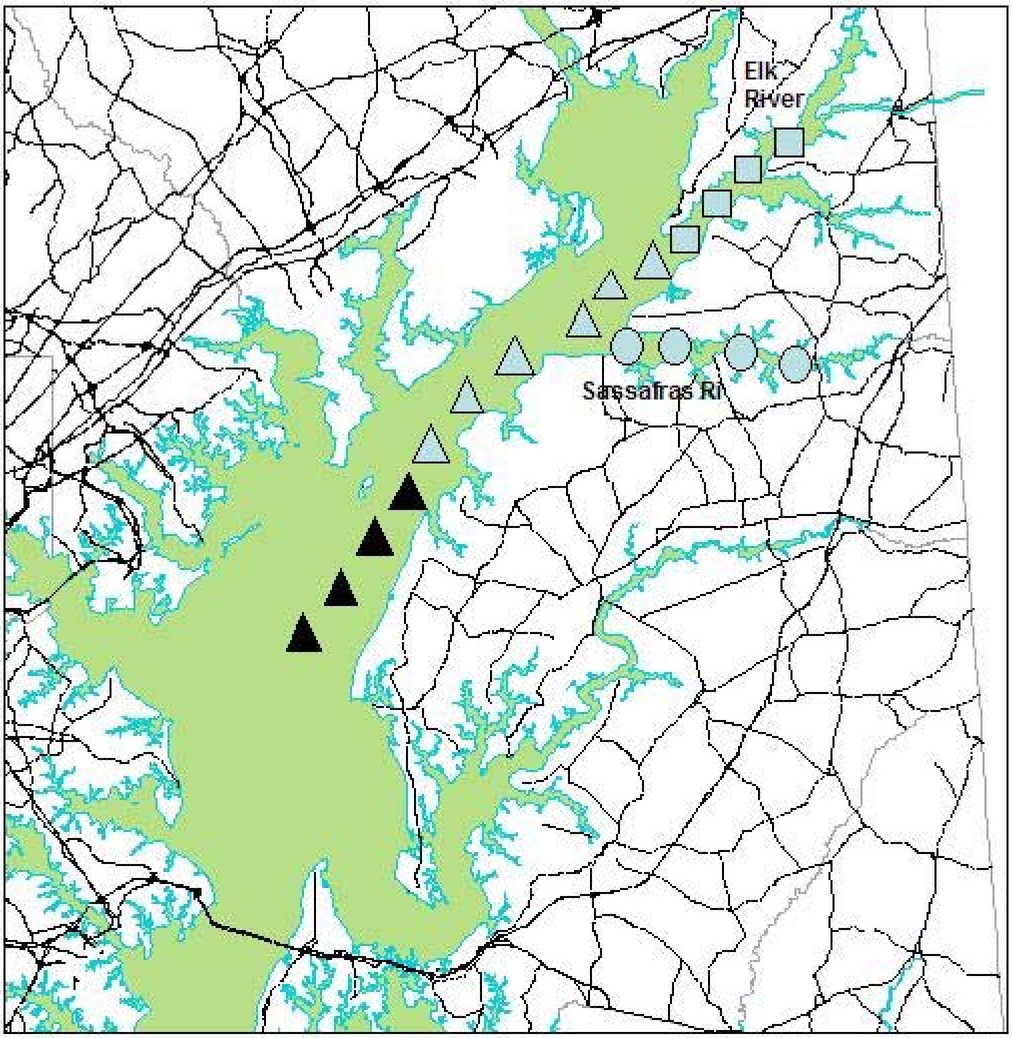


Figure 2. Choptank River fyke net locations, 2007. Triangles indicate sites.

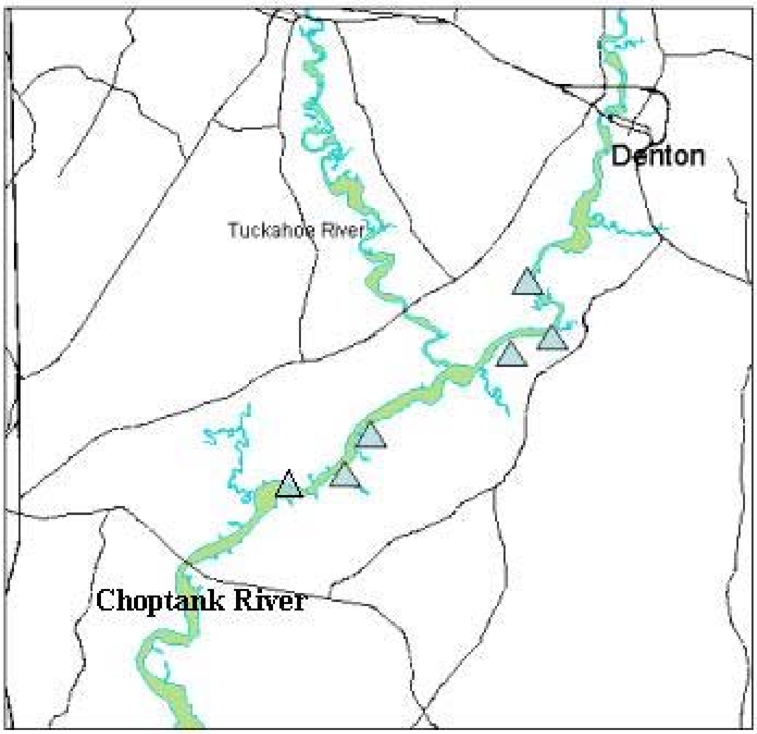


Figure 3. Marshyhope River fyke net locations, 2007. Triangles indicate sites.

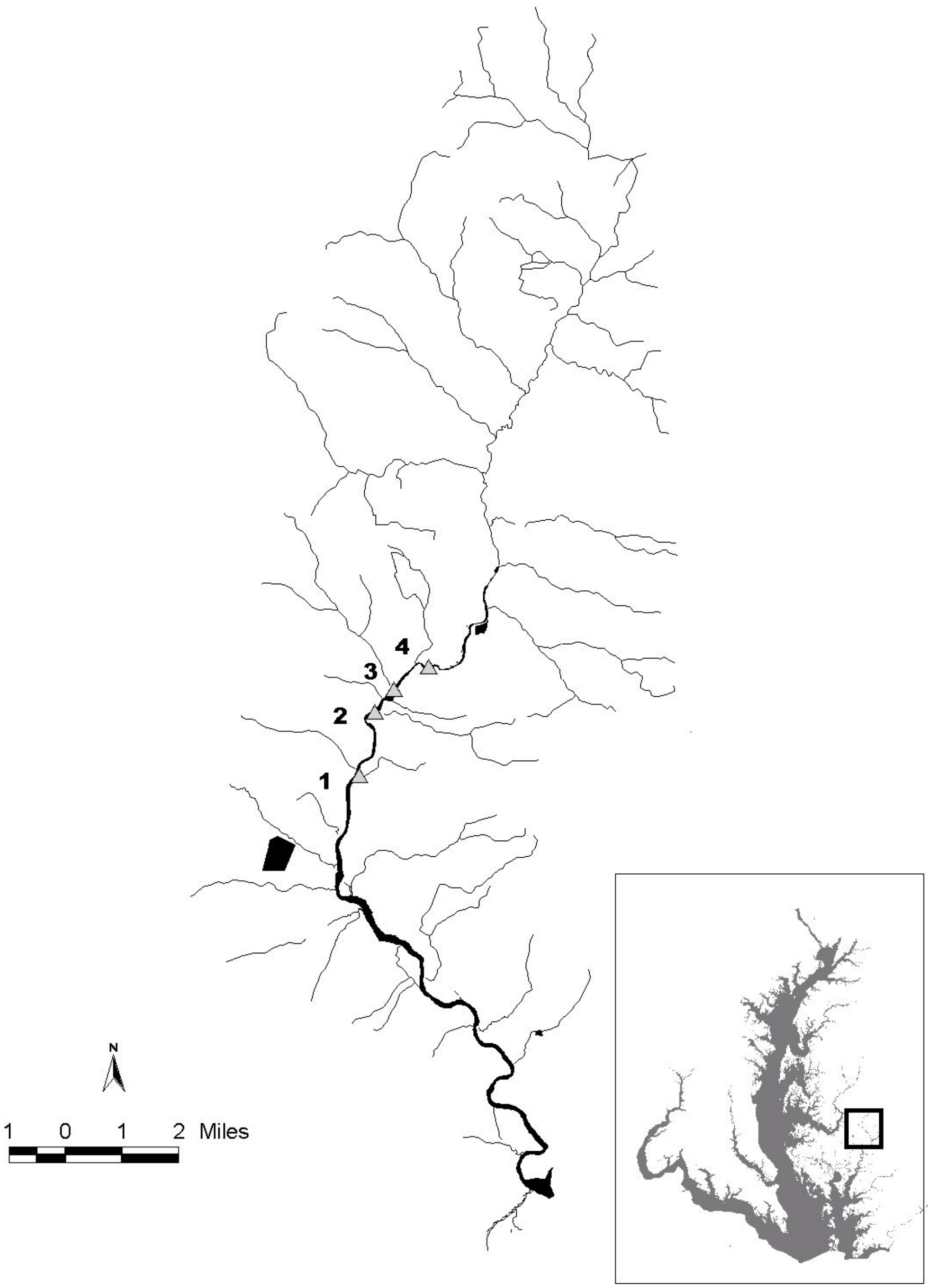


Figure 4. Nanticoke River survey site range, 2007. Circles indicate the range of net locations.

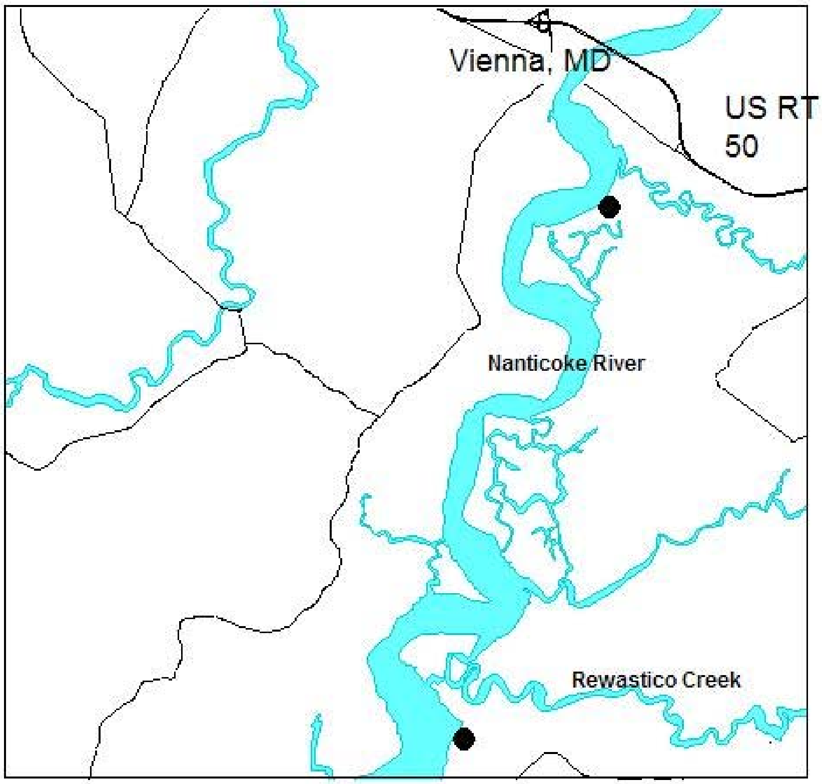


Table 1. White perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2007.

	AGE										
Year	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

Table 2. White perch catch at age matrix from Choptank River fyke net survey, 2000 – 2007.

	AGE										
Year	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

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

	AGE										
Year	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

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2007.

	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

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2007.

	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

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2007.

	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

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2007. 2007 includes 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

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2007. 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

Figure 5. White perch length-frequency from 2007 upper Chesapeake Bay winter trawl survey.

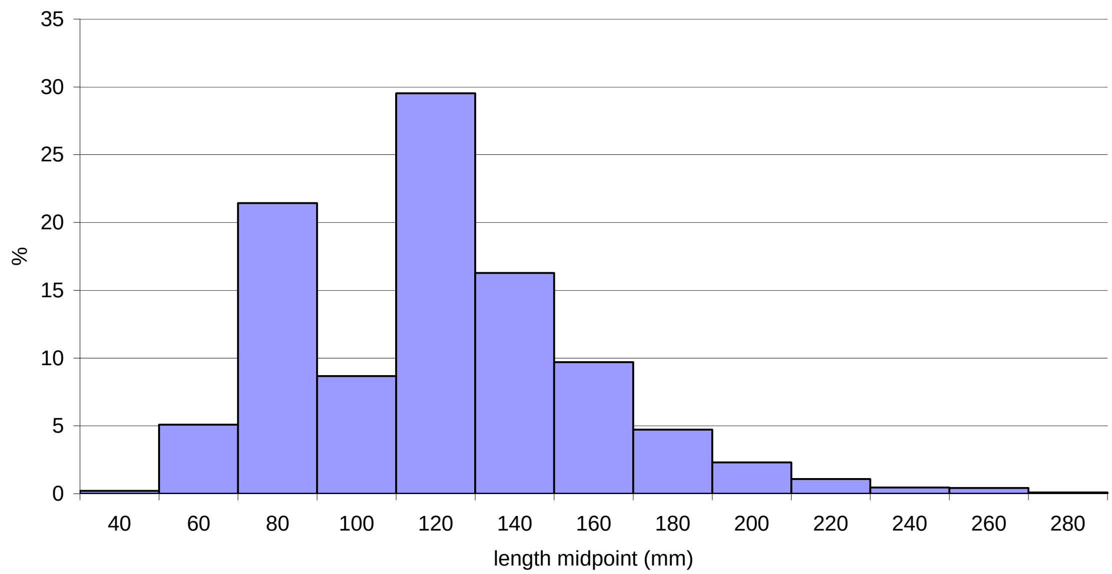


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2007. Minimum length cut-offs in parentheses.

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

Figure 6. White perch length-frequency from 2007 Choptank River fyke net survey.

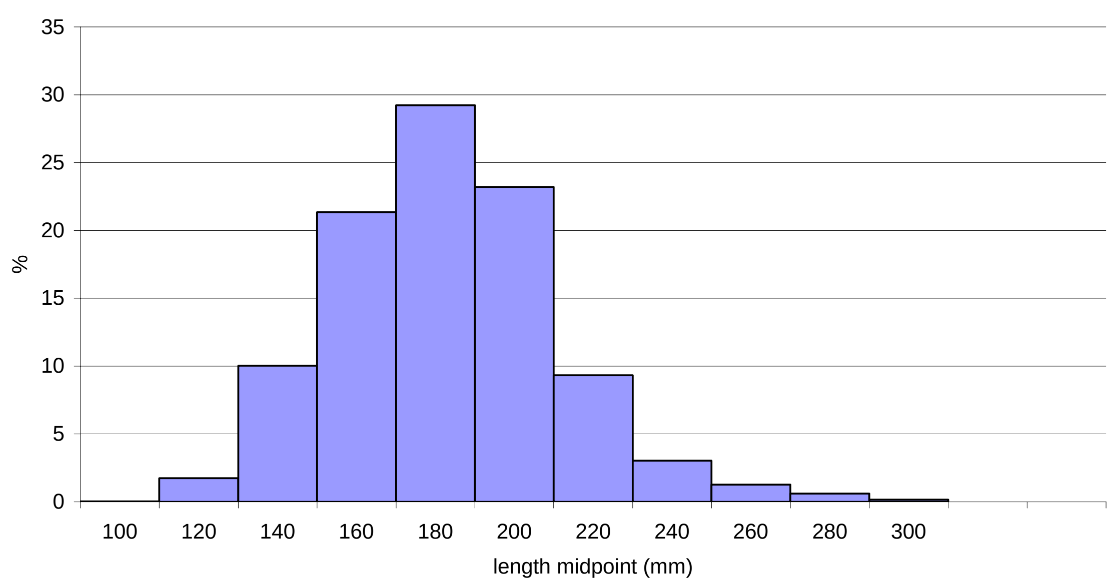


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2007. Minimum length cut-offs in parentheses. 2007 includes Marshyhope River data.

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

Figure 7. White perch length-frequency from 2007 Nanticoke River fyke and pound net survey, including Marshyhope River data.

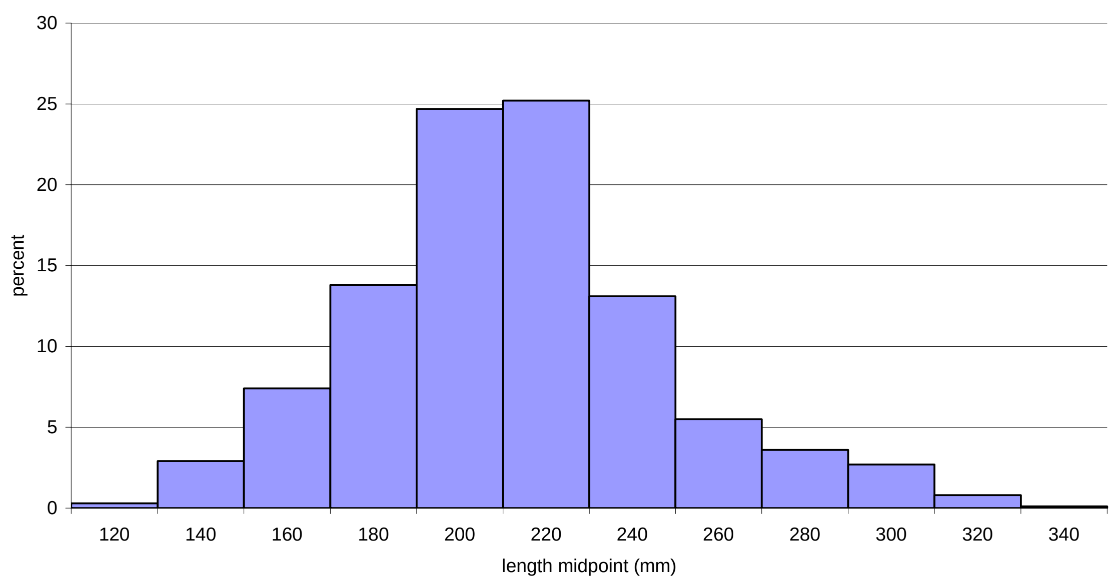


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2007. Minimum length cut-offs in parentheses.

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

Figure 8. Yellow perch length-frequency from the 2007 upper Chesapeake Bay winter trawl survey.

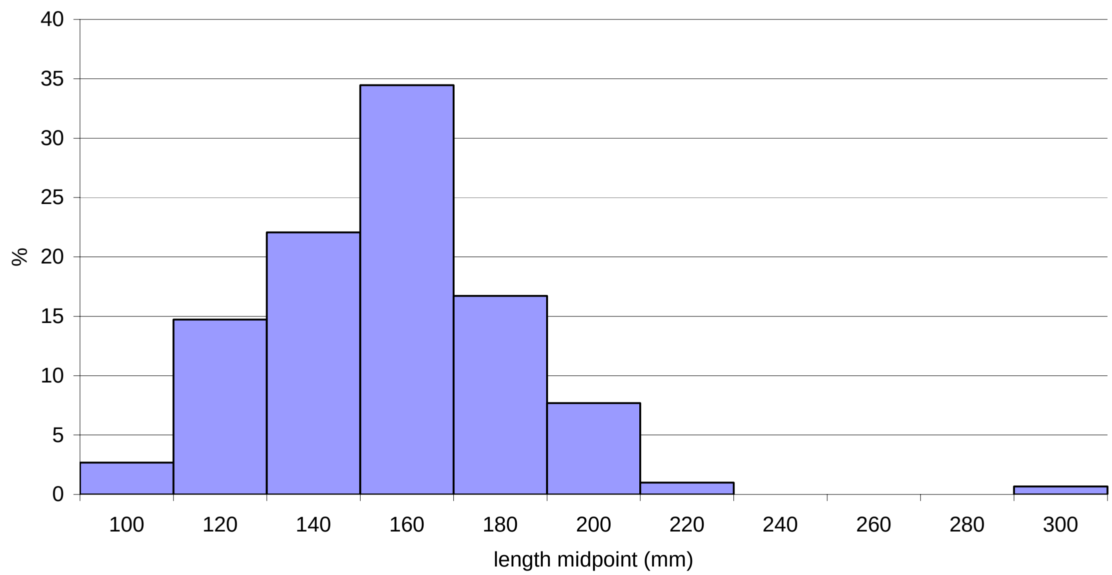


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2007. Minimum length cut-offs in parentheses.

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

Figure 9. Yellow perch length-frequency from the 2007 Choptank River fyke net survey.

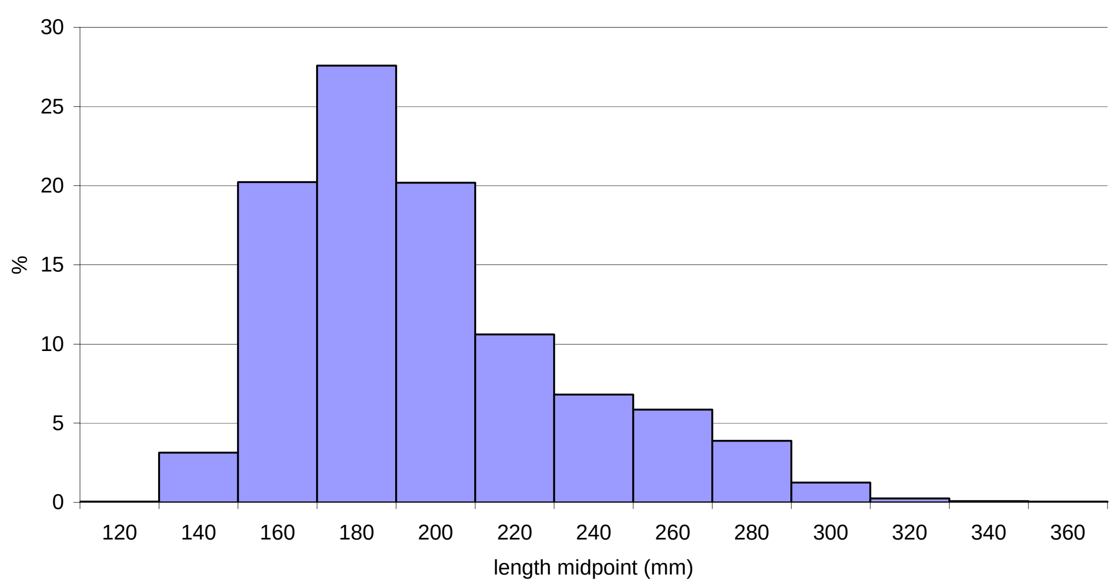


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2007. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length frequency from the 2007 upper Chesapeake commercial fyke net survey.

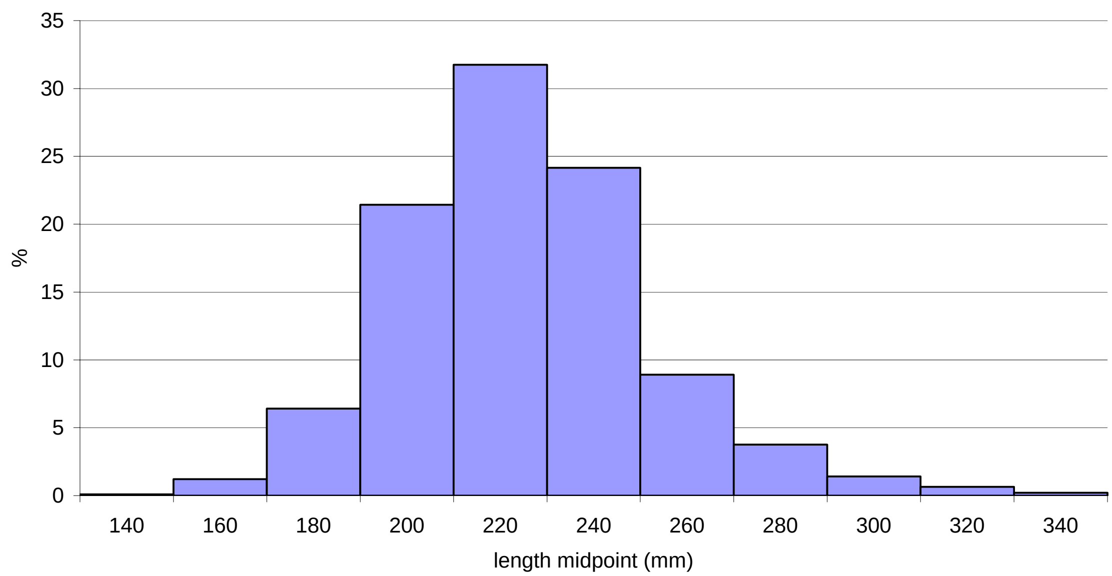


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2007. Minimum length cut-offs in parentheses; 2007 includes Marshyhope River data.

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

Figure 11. Yellow perch length frequency from the 2007 Nanticoke River survey fyke and pound net survey. Includes Marshyhope River data.

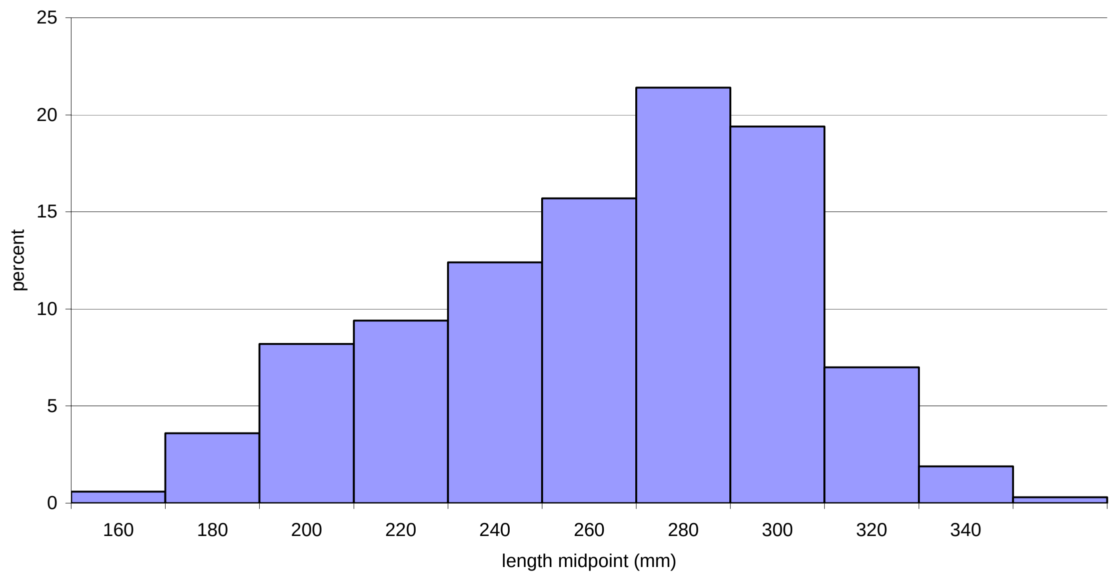


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2007. Minimum length cut-offs in parentheses.

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

Figure 12. Length frequency of channel catfish from the 2007 upper Chesapeake Bay winter trawl survey.

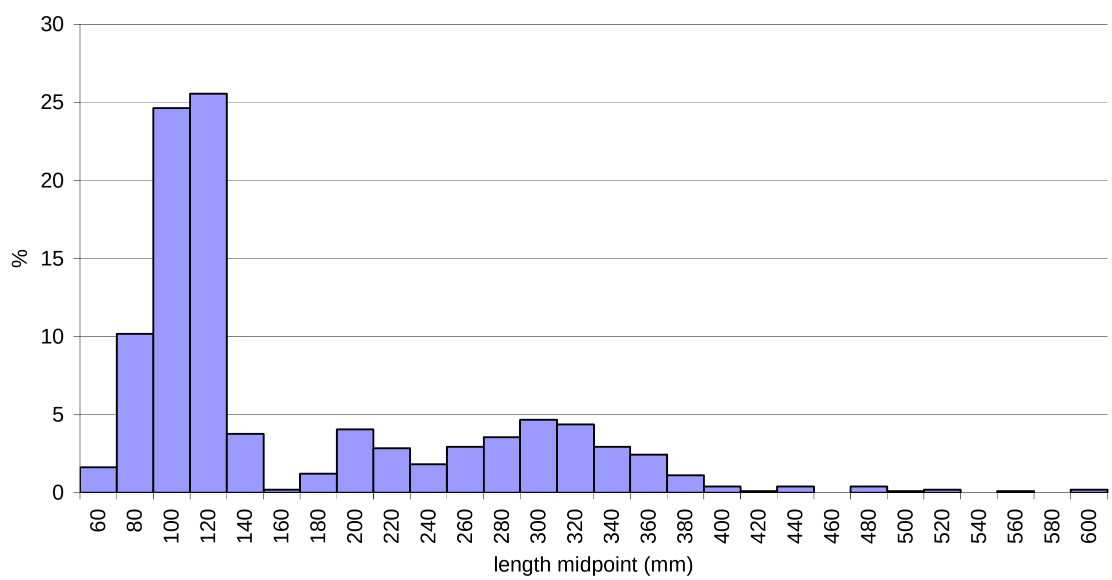


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2007. Minimum length cut-offs in parentheses.

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

Figure 13. Channel catfish length frequency from the 2007 Choptank River fyke net survey.

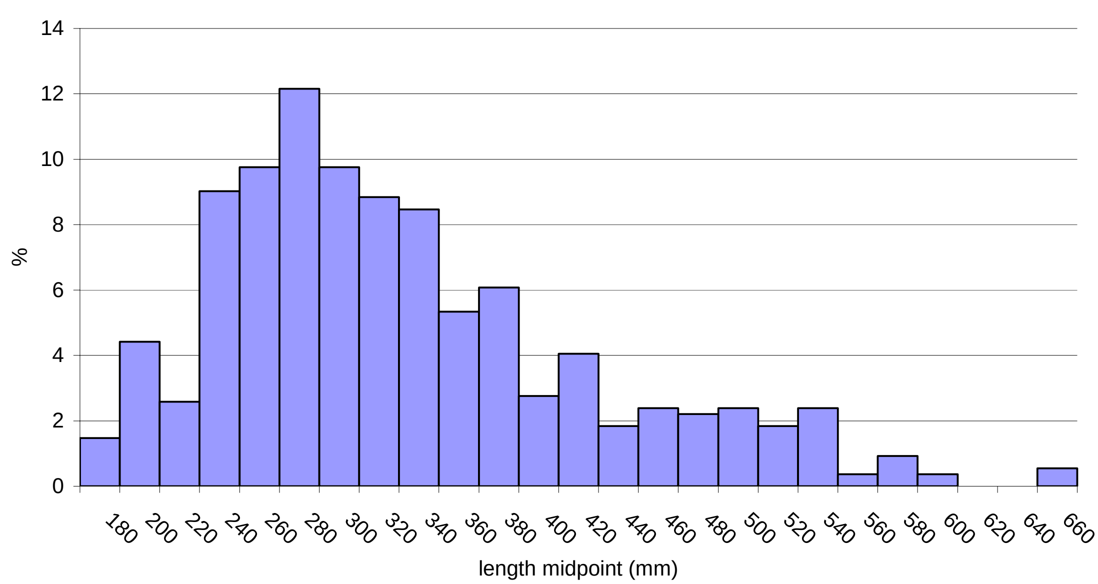


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2007. 2007 includes Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 14. Channel catfish length frequency from the 2007 Nanticoke River fyke and pound net survey. Includes Marshyhope fyke net data.

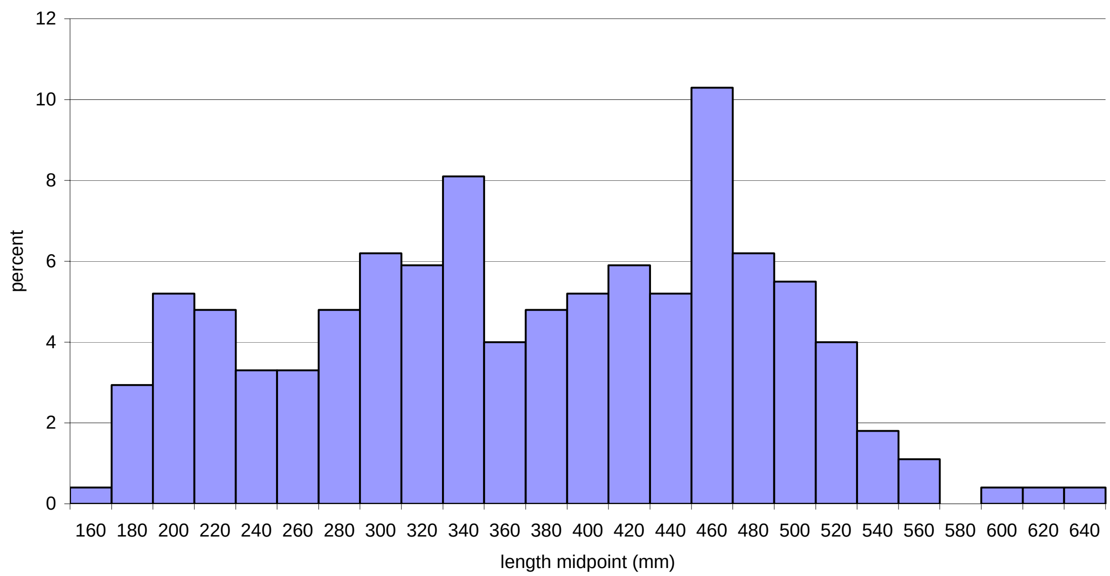


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2007. Minimum length cut-offs in parentheses.

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

Figure 15. White catfish length frequency from the 2007 upper Chesapeake Bay winter trawl survey.

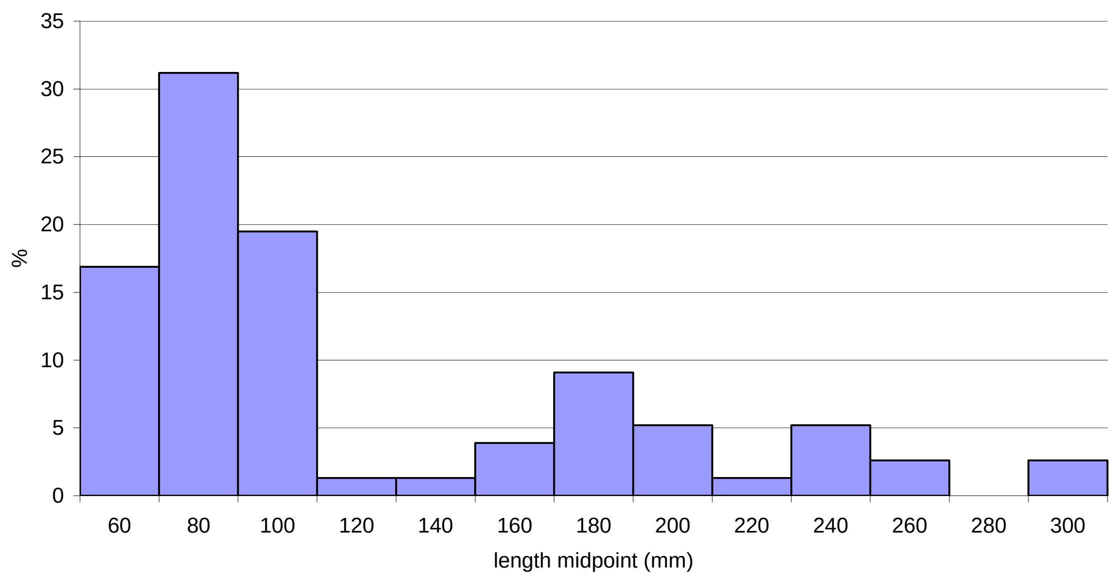


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2007. Minimum length cut-offs in parentheses.

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

Figure 16. White catfish length frequency from the 2007 Choptank River fyke net survey.

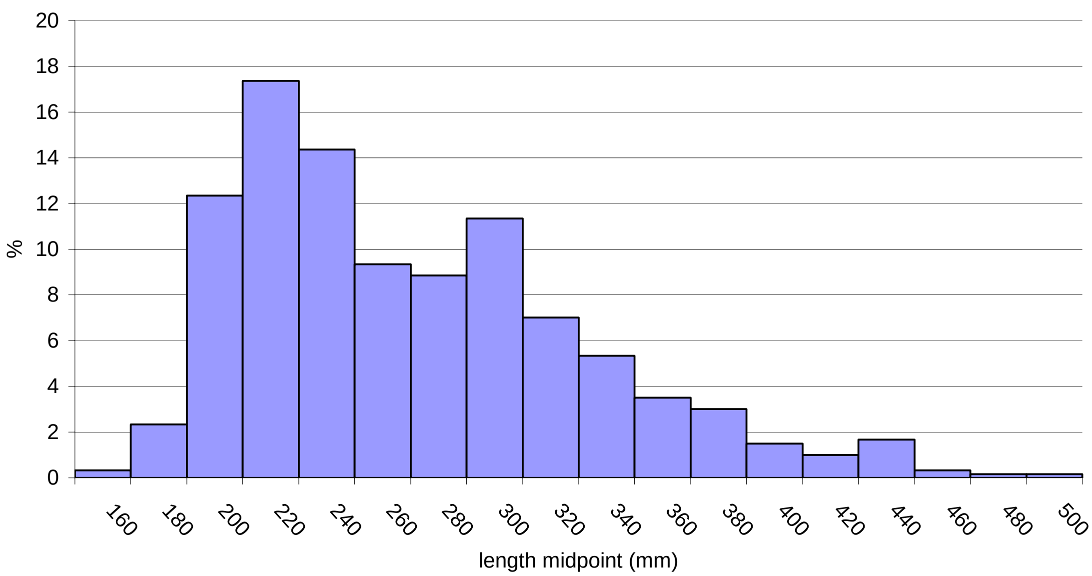


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2007. 2007 includes Marshyhope River fyke net data. Minimum length cut-offs in parentheses.

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

Figure 17. White catfish length frequency from the 2007 Nanticoke River fyke and pound net survey. Includes Marshyhope River fyke net data.

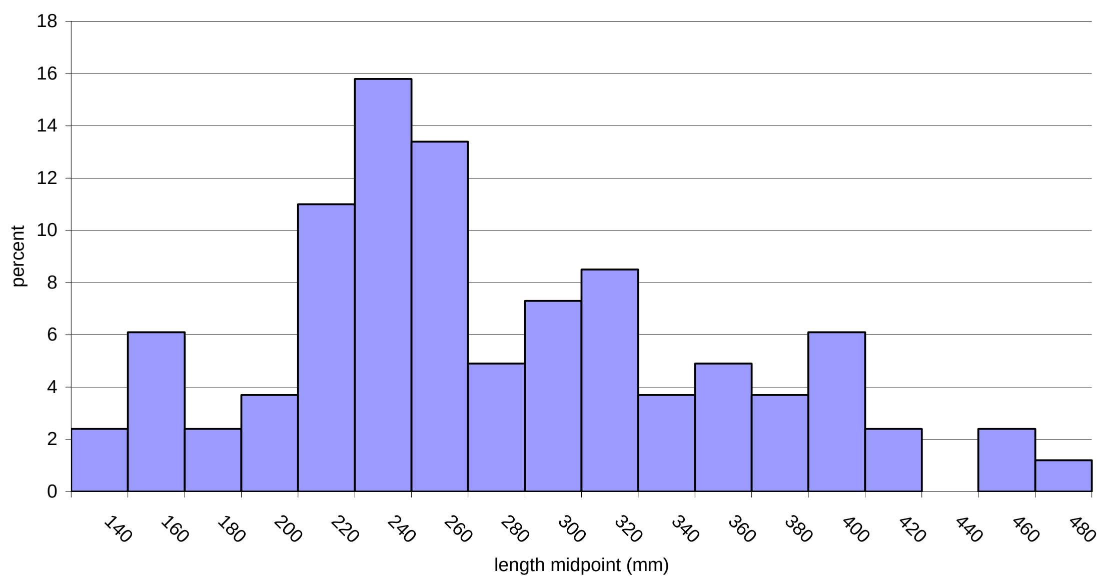


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

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}	3.20	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
2000 – 2007	F	7.7×10^{-6}	3.14	284	0.27	-0.62
	M	1.2×10^{-5}	3.04	255	0.24	-1.15
	Combined	6.0×10^{-6}	3.18	279	0.26	-0.63

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	1.97×10^{-4}	2.56	272	0.50	1.10
	M	1.40×10^{-4}	2.60	288	0.24	-0.60
	Combined	7.70×10^{-5}	2.72	280	0.36	0.51
2001	F			380	0.10	-2.80
	M	NA			NSF	
	Combined				NSF	
2002	F	1.29×10^{-6}	3.48	328	0.17	-2.50
	M	1.87×10^{-6}	3.40	286	0.22	-1.40
	Combined	1.11×10^{-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	5.34×10^{-6}	3.22	322	0.25	-0.30
	M	2.36×10^{-6}	3.35	288	0.21	-1.50
	Combined	2.59×10^{-6}	3.35	335	0.18	-1.20
2005	F	2.33×10^{-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
2000 – 2007	F	1.10×10^{-5}	3.08	316	0.20	-1.35
	M	1.20×10^{-5}	3.05	289	0.20	-1.62
	Combined	6.41×10^{-6}	3.18	314	0.19	-1.46

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	-0.20
	M	NA		268	0.26	-1.60
	Combined	NA		264	0.42	-0.90
2001	F	NA		329	0.32	-0.50
	M	NA		308	0.18	-2.20
	Combined	NA		278	0.40	-0.50
2002	F	NA		336	0.23	-2.20
	M	NA		270	0.30	-1.60
	Combined	NA		264	0.50	-0.80
2003	F	NA		264	0.82	0.36
	M	NA		263	0.35	-0.80
	Combined	NA		255	0.50	-0.70
2004	F	NA		306	0.41	-0.40
	M	NA		253	0.34	-1.20
	Combined	NA		259	0.51	-0.50
2005	F	NA		293	0.64	-0.50
	M	NA		244	0.63	0.10
	Combined	NA		258	0.45	-1.60
2006	F	NA		297	0.36	-1.05
	M	NA		291	0.24	-1.09
	Combined	NA		290	0.26	-2.00
2007	F	2.30×10^{-5}	2.88	308	0.52	0.19
	M	1.30×10^{-5}	2.97	279	0.29	-1.40
	Combined	1.1×10^{-5}	3.02	277	0.54	-0.01
2000 – 2007	F	1.2×10^{-5}	3.02	308	0.39	-0.51
	M	2.8×10^{-6}	3.26	270	0.28	-1.47
	Combined	4.1×10^{-6}	3.20	264	0.53	-0.30

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	-1.90
	M	6.7 X 10^{-6}	3.11	275	0.33	-2.00
	Combined	5.9 X 10^{-7}	3.57	286	0.38	-1.70
1999	F	4.1 X 10^{-6}	2.80	272	0.45	-0.90
	M	8.83 X 10^{-6}	3.06	226	1.47	1.17
	Combined	2.1X 10^{-5}	2.92	252	1.07	0.99
2000	F	NSF		272	0.62	0.62
	M	8.39 X 10^{-7}	3.48	246	0.39	-1.90
	Combined	NSF		254	0.82	0.86
2001	F	NSF		283	0.27	-2.70
	M	9.37 X 10^{-7}	3.45	230	0.50	-1.00
	Combined	NSF		240	1.14	0.85
2002	F	NA		329	0.21	-2.90
	M	NA		249	0.38	-1.10
	Combined	NA		266	0.48	-1.10
2003	F	6.68 X 10^{-7}	3.53	298	0.47	0.03
	M	NSF		246	0.44	-1.10
	Combined	4.14 X 10^{-7}	3.61	275	0.53	-0.10
2004	F	1.18 X 10^{-6}	3.43	297	0.75	1.14
	M	NSF		256	0.37	-2.50
	Combined	7.08 X 10^{-7}	3.52	273	1.04	1.35
2005	F	4.40 X 10^{-7}	3.62	358	0.25	-0.70
	M	5.61 X 10^{-7}	3.55	244	0.41	-0.50
	Combined	1.69 X 10^{-7}	3.79	256	0.64	0.32
2006	F	5.15 X 10^{-5}	2.75	288	0.34	-2.00
	M	4.75 X 10^{-5}	2.73	240	0.41	-2.00
	Combined	4.72 X 10^{-5}	2.75	244	0.60	-2.00
2007	F	1.96 X 10-6	3.35	325	0.34	-0.09
	M	4.38 X 10-6	3.18	240	0.61	0.61
	Combined	6.68 X 10-7	3.54	267	0.64	0.55
1998 – 2007	F	2.62 X 10-6	3.29	307	0.30	-1.40
	M	2.46 X 10-6	3.28	240	0.46	-1.26
	Combined	1.24 X 10-6	3.42	266	0.50	-0.55

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	0.10
	M	4.30×10^{-5}	2.71	373	0.16	-2.30
	Combined	8.53×10^{-7}	3.46	370	0.27	-0.40
2001	F			317	0.43	-0.40
	M	NA		276	0.34	-1.80
	Combined			290	0.38	-1.80
2002	F	1.22×10^{-6}	3.44	313	0.52	-0.60
	M	1.10×10^{-5}	3.03	278	0.49	-1.00
	Combined	2.69×10^{-7}	3.71	299	0.39	-1.70
2003	F			324	0.49	-0.30
	M	NA		273	0.38	-1.40
	Combined			298	0.56	-0.60
2004	F			326	0.43	-1.10
	M	NA		284	0.32	-3.40
	Combined			290	0.68	-0.50
2005	F	NSF		332	0.56	-0.10
	M	3.40×10^{-5}	2.84	286	0.68	0.10
	Combined	NSF		342	0.35	-1.10
2006	F	NA		313	0.73	0.30
	M			297	0.57	-0.10
	Combined			301	0.78	0.40
2007	F	1.80×10^{-6}	3.38	346	0.35	-0.80
	M	7.37×10^{-6}	3.10		NSF	
	Combined	1.18×10^{-6}	3.45	308	0.42	-0.80
2000 – 2007	F	2.34×10^{-6}	3.33	346	0.29	-1.50
	M	8.17×10^{-6}	3.09	298	0.31	-1.50
	Combined	1.26×10^{-6}	3.44	309	0.37	-1.20

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
Choptank	0.34	0.48	0.25	0.46	0.1	0.58	0.58	0.40
Nanticoke	0.42	0.58	0.44	0.31	NR	NR	0.22	0.18
Upper Bay trawl	0.09	0.58	0.51	0.13	NA	0.50	0.12	0.19

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
Choptank[1]	NR	minimal	0.03	0.05	NR	0.08	minimal	0
Nanticoke[2]	0.10	0.05	0.06	NA	NA	NA	NA	NA
Upper Bay fyke[3]	0.70	0.37	0.39	0.18	0.27	0.37	0.36	0.40

[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]Ssentongo and Larkin (1973) length based method

Figure 18. Baywide young-of-year relative abundance index for white perch, 1962 – 2007, based on Estuarine Juvenile Finfish Survey data. Bold horizontal line=time series average. Error bars indicate 95% confidence interval.

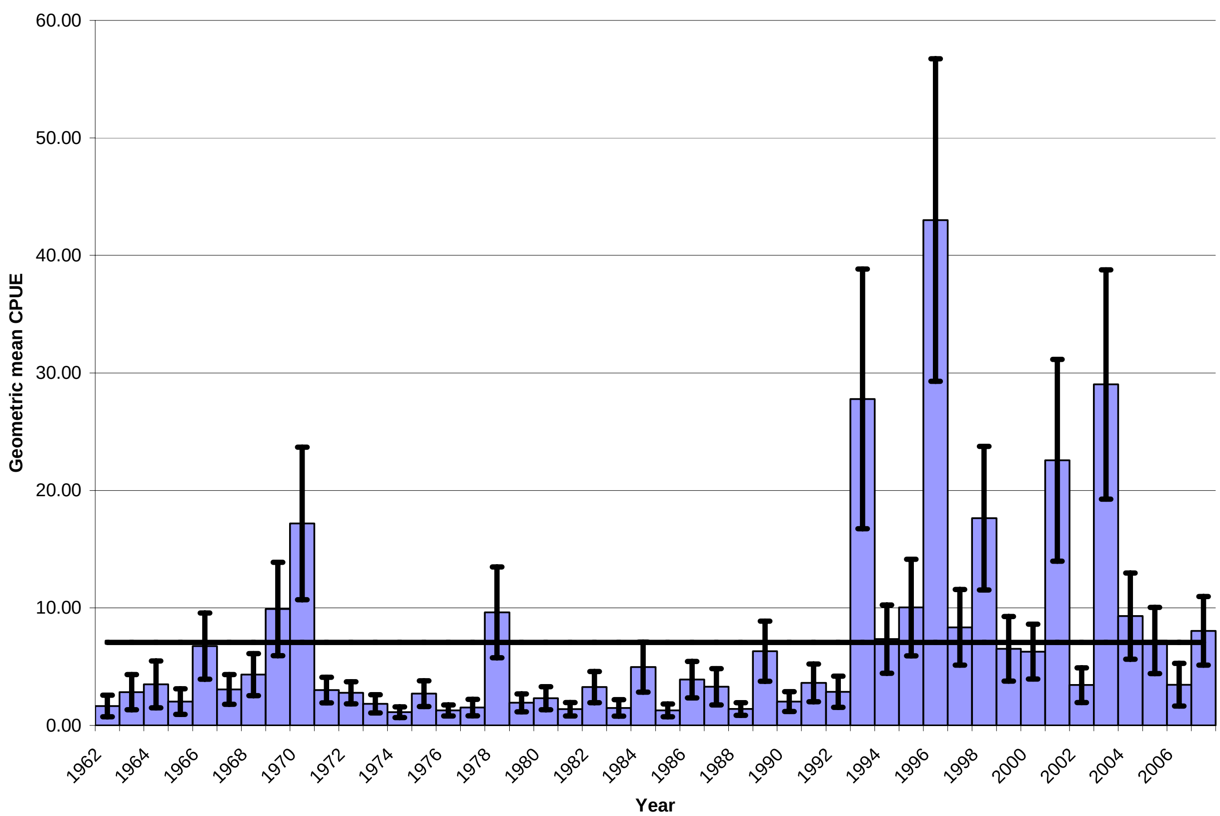


Figure 19. Age 1+ white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Year-class indicated in parentheses.

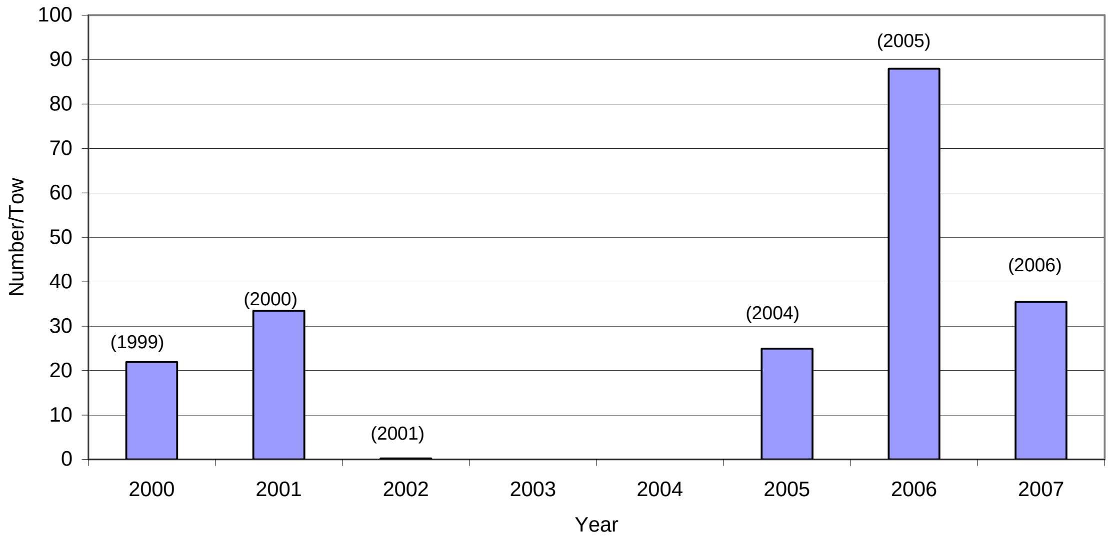


Figure 20. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2007, based on Estuarine Juvenile Finfish Survey data. Bold horizontal line=time series average. Error bars indicate 95% confidence interval.

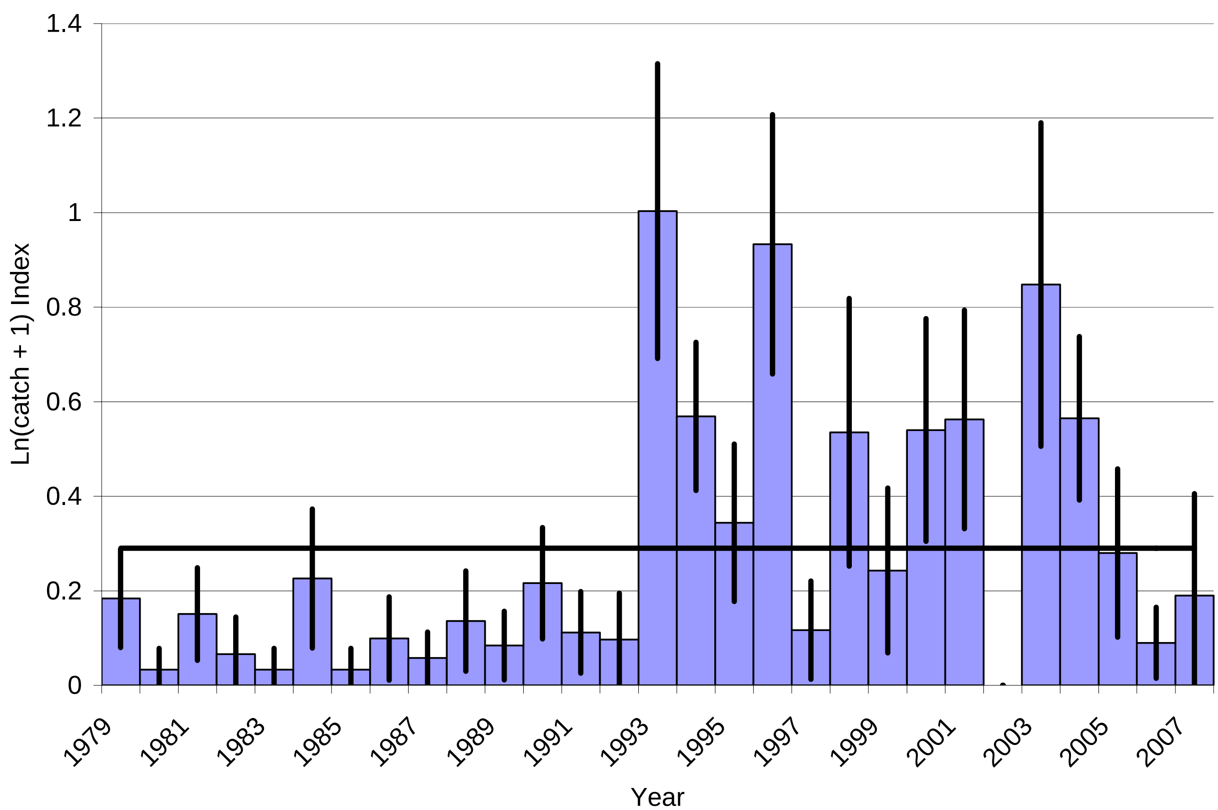


Figure 21. Age 1+ yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Year-class indicated in parentheses.

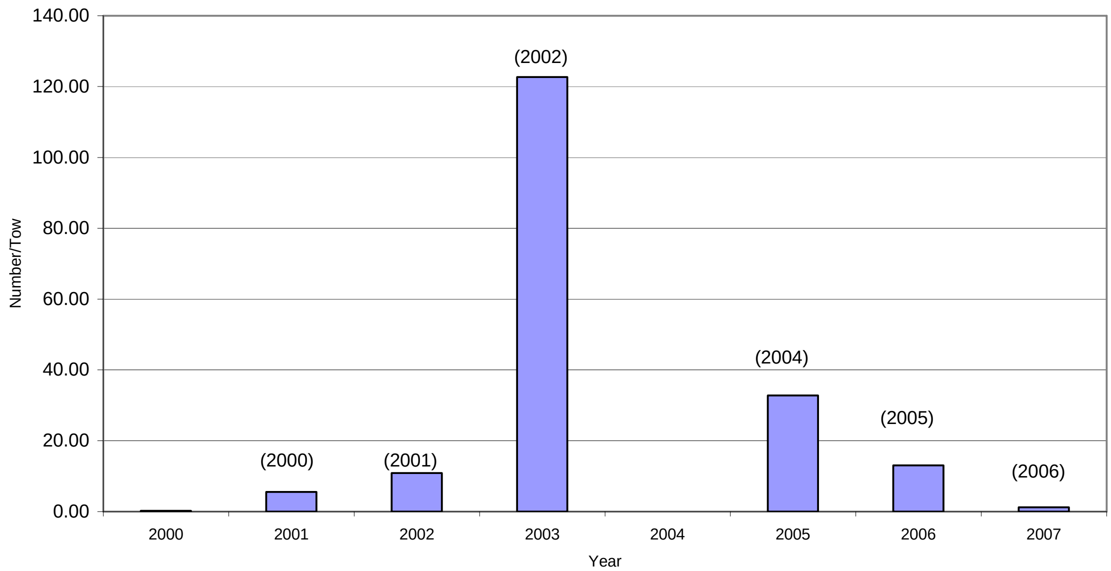


Figure 22. Bay-wide young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average. Error bars indicate 95% confidence intervals.

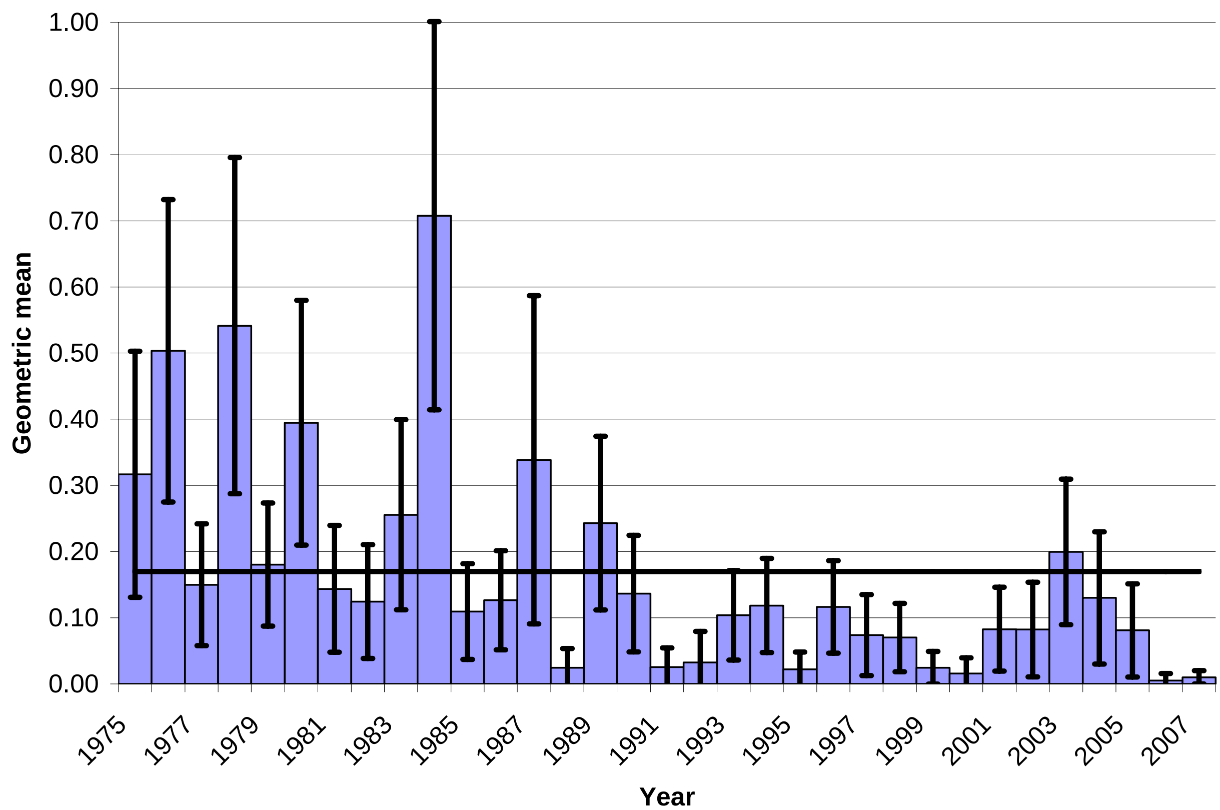


Figure 23. Age 1+ channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005. Year-class indicated in parentheses.

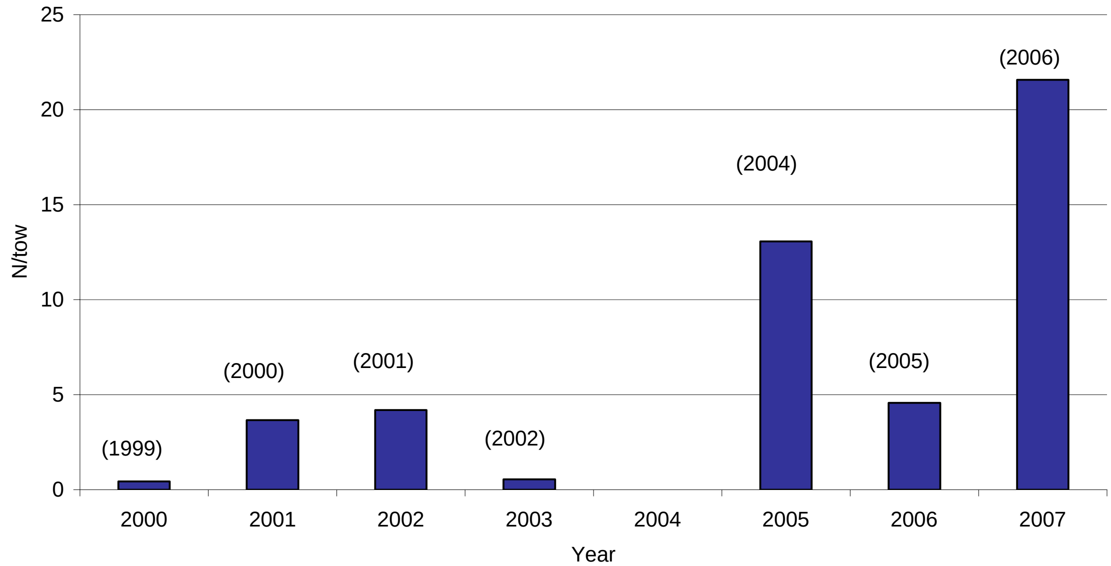


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2007.

					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	24.9	43.77	7.3	7.7	4.1	7.5	6.5	1.6	2.49	0.3	106.2	43
2006	87.9	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

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2007.

	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

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2007.

	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

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2007.

	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

Figure 24. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2007. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

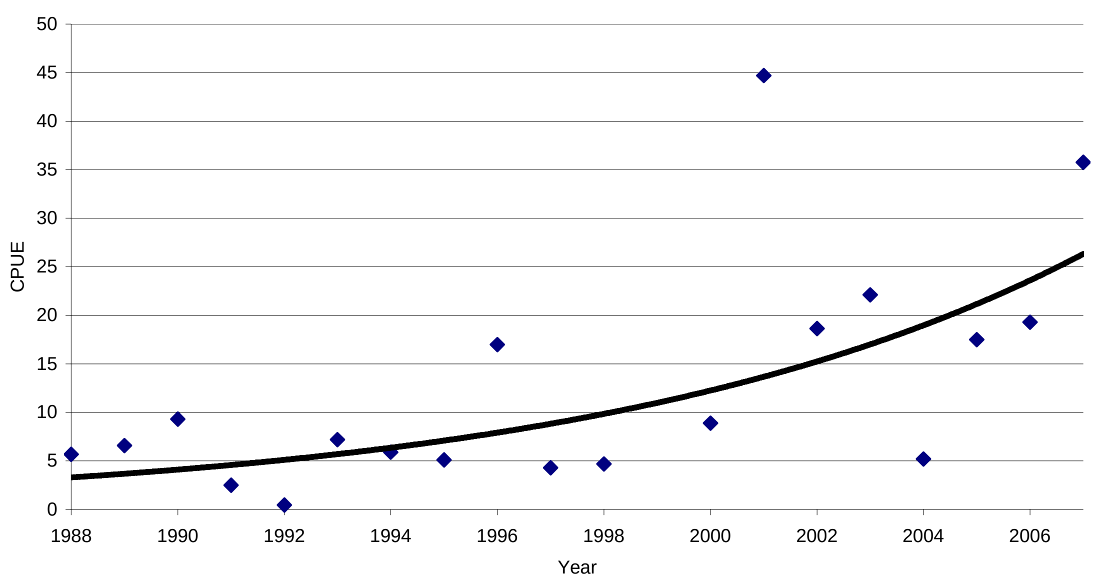


Figure 25. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2007. Not surveyed in 2004, small sample sizes in 2003 and 2005.

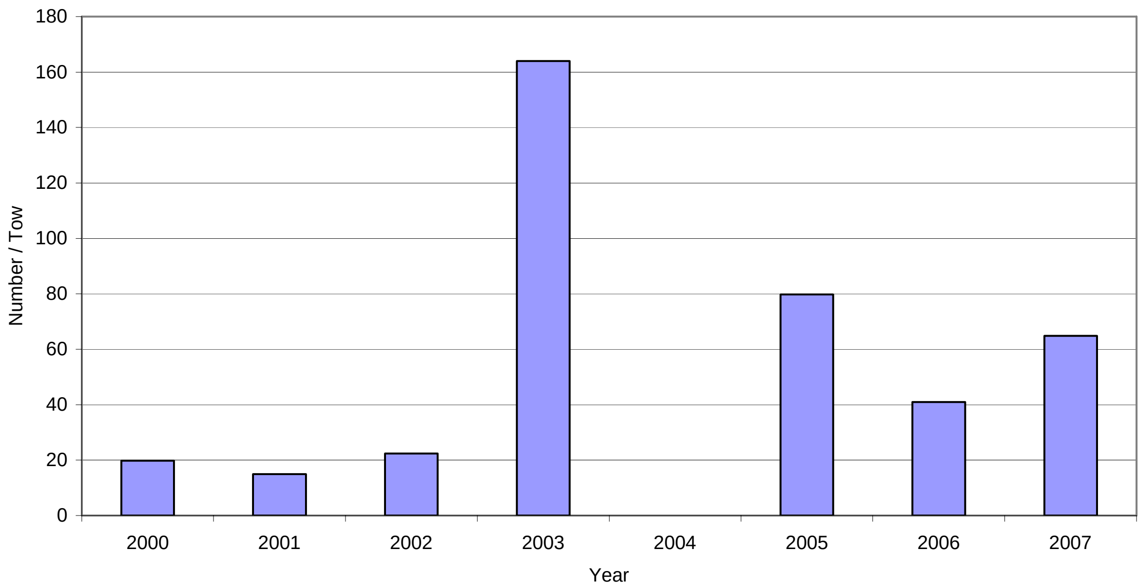


Figure 26. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2007.

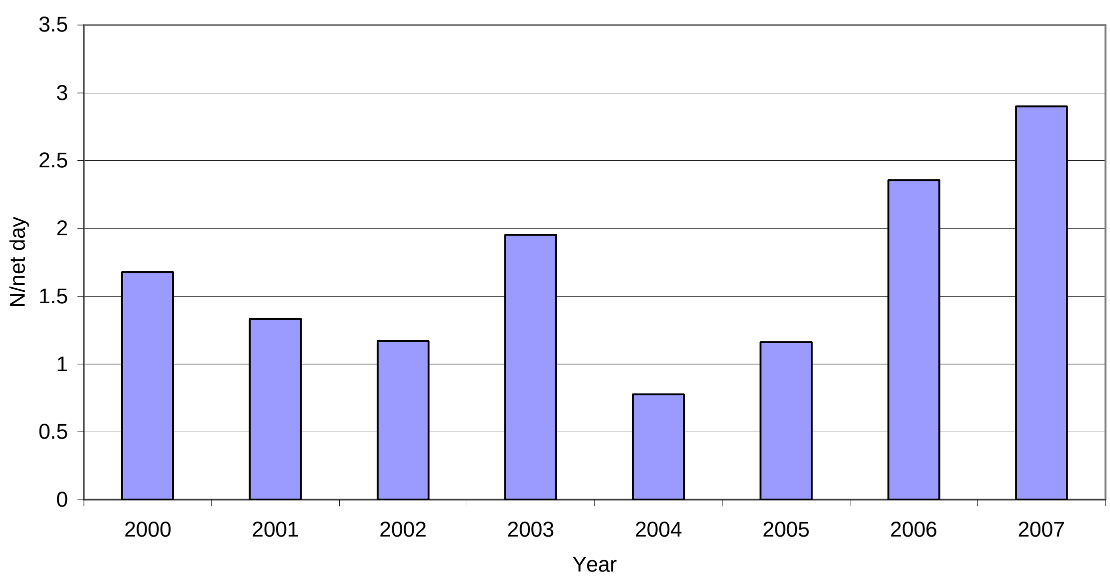
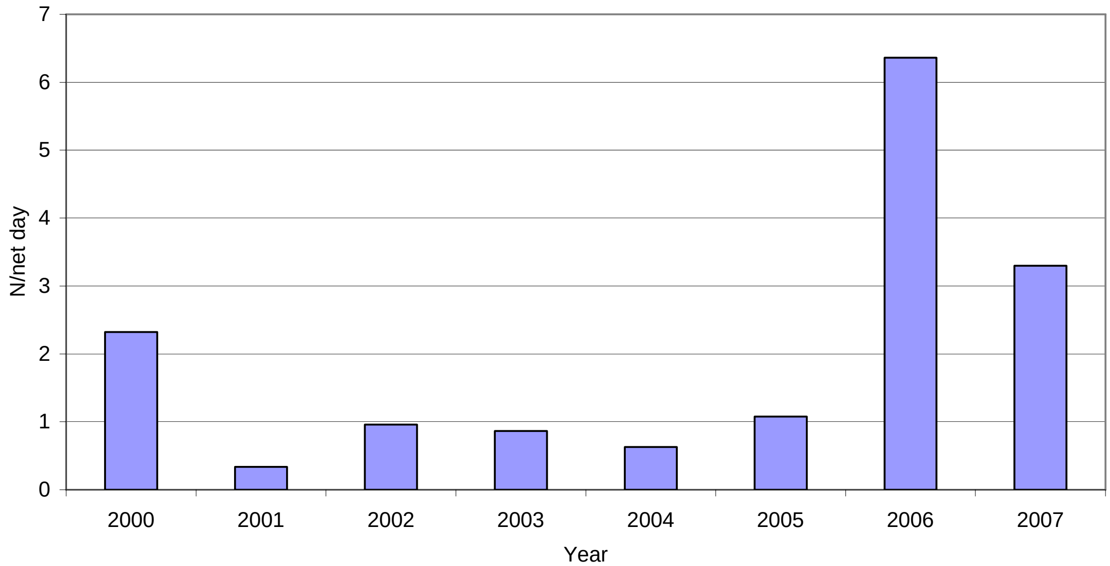


Figure 27. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2007.



PROJECT NO. 1
JOB NO. 2

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The objective of Project 1, Job 2 was to assess yellow perch (*Perca flavescens*) stock size, describe trends in recruitment, and to relate the assessment to previously defined biological reference points (Piavis and Uphoff 1998). In North America, yellow perch range from Nova Scotia to South Carolina on the east coast, west to the Mississippi drainage, then north to Saskatchewan. In Maryland, yellow perch have historically been reported from every major Chesapeake Bay tributary (Piavis 1991).

Yellow perch in Maryland tidal waters migrate from downstream stretches to less saline upstream areas during late winter. Preferred salinity level for spawning and larval development is approximately 2.0 ppt, with a marked decrease in larval survivorship when salinities approach 9.0 ppt (Victoria et al 1992). Spawning takes place generally in mid-March when water temperatures reach 8ºC (Hokanson 1977). Yellow perch deposit eggs in gelatinous strands, and multiple males fertilize the eggs (Tsai and Gibson 1971). The fisheries (commercial and recreational) are at their peak during this spawning run because fish are aggregated. After spawning, yellow perch quickly disaggregate. The commercial fishery is essentially a fyke net fishery located in the upper Chesapeake Bay region, above the Preston Lane Memorial Bridges. During 2007, the commercial fishery had a closed season in February, and operated under an 8 ½" – 11" slot limit in order to preserve larger spawning females. Several river systems remained closed to commercial harvest. Recreational fishers had a 5 fish daily creel limit and a 9” minimum size limit with no closed season. Several river systems also remained closed to recreational harvest.

Yellow perch are an important finfish resource in Maryland’s tidewater region. Because of the early spawning and often dense aggregation during spawning, yellow perch offer recreational anglers the earliest opportunity to fish. Yellow perch similarly are an important seasonal fishery for commercial fishers. The modest commercial fishery occurs during a slack season between striped bass (*Morone saxatilis)* and white perch (*M. americana*) gill netting and the white perch spawning run. Since 1987, commercial harvest in Maryland has ranged from 190,057 pounds in 1999 to 39,225 pounds in 2006, and averaged 103,578 pounds, annually since 1929.

Yellow perch management has, over the last several years, focused on managing fishing mortality to produce 35% maximum spawning potential (%MSP). Using growth estimates, fishery selectivity, and partial recruitment estimates, targets and limits were developed for yellow perch recreational and commercial fisheries (Piavis and Uphoff 1998). Heretofore, data has been temporally or geographically disparate. However, sufficient fishery dependent data are now available for the upper Bay stock to be assessed. In addition, ongoing monitoring in the Choptank River has provided a relative abundance time series sufficient for analysis.

METHODS

Upper Chesapeake Bay statistical catch-at-age model

Data

The area assessed included the Chesapeake Bay north of the Preston Lane Memorial Bridges and all tributaries except the Chester River. Data supported an assessment covering 1998 – 2006. The assessment did not include data from 2007 because analysis of 2007 commercial catch data was not completed at this time. Commercial landings and effort were needed for the assessment. Landings were taken from catch reports that commercial fishermen are obligated to submit monthly. The number of nets, along with harvest, was also reported. Since the days the nets actually soaked are not reported, the number of nets was treated as an index of commercial activity. No estimates of recreational harvest were available.

Biological samples were taken from cooperating commercial fyke net fishermen, from 1998 – 2006. Not all regions were sampled in every year, but generally two areas per year were visited. These included the Bush River, Gunpowder River, and Northeast River. Random samples were taken from pre-culled catches. Yellow perch were measured (mm TL) and sex was determined by examining external gonadal exudation. A non-random subsample was procured for otolith extraction and subsequent age determination. Ages were determined by counting annular rings on otoliths, submersed in glycerin, under a dissecting microscope with direct light. Weights and lengths were also taken for these specimens. Length-weight and length-age relationships were reported in Job 1.

A commercial catch-at-age (CAA) matrix was determined for each sample year by sex, for ages 3 – 8+. Total sample weight of males and females for harvested yellow perch was determined by assigning a weight to each legal fish measured with the appropriate, sex-specific annual allometric equation (Job 1). Percent of landings ascribed to each sex was determined by dividing sex-specific sample weight by the total sample weight. Total weight of landings by sex was determined by multiplying the respective percentage from the sample by the total landing reported for that year. In order to determine the number of yellow perch harvested, by sex annually, the mean length of legal male and female yellow perch was determined from the length samples, placed into the appropriate allometric equation, and divided into the sex-specific landings. Total number harvested by age-class was determined by formulating annual age-length keys in 20 mm increments for legal sized fish only. The estimated total number harvested was multiplied by the percent catch-at-age to get the number at age and sex harvested. Male and female CAA were added together to arrive at a final annual CAA.

Data from fisheries independent surveys were also used for the assessment. The upper Bay winter trawl survey, initiated in December 1999 has provided some data in spite of weather and mechanical problems documented in Project 1 Job 1. Methods and site locations are also found in Job 1. In addition, estimates of relative yellow perch recruitment for the upper Bay were determined from the Estuarine Juvenile Finfish Survey (see Project 1, Job 1 and Project 2, Job 3, Task 3).

Model formulation

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

The model determines the most likely fit by solving an objective function. In this model framework, the objective function is to minimize the sum of squared errors. The computer algorithm searches for the best combination of parameter estimates that minimize the error between observed and predicted values of the CAA, yield, F, and fishery independent tuning indices. A log-normal error structure is assumed for all parameters.

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

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

where F_y is instantaneous fishing mortality in year y, q_{comm} is catchability of the commercial fyke net fishery, E_y is the commercial fishing effort index in year y, $C_{a,y}$ is the catch of age a yellow perch in year y, and $I_{a,y}$ is the trawl index of age a yellow perch in y.

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

$$N_{a+1,\, y+1} = N_{a,\, y}\, e^{-(M+sF)} \qquad [2]$$

where the superscript *s* is an age-specific selectivity factor. Therefore, population abundance estimates are needed for each age-class in the first sample year ($N_{4\ldots8+,\,1998}$) and for the age at first recruitment for every year in the assessment ($N_{3,1998\ldots2006}$), along with F_y and *q* (catchability) for the commercial fyke net fishery and the fishery independent trawl survey. These need only be rough estimates in order to seed the program as the iterative process adjusts those estimates to find the most reasonable fit.

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

$$CAA_{pred} = (F_y/Z_y)*N_{a,y}*(1-S_{a,y}) \qquad [3]$$

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

The model needs information other than the CAA matrix to scale the abundance estimates to the correct level (Haddon 2001). Predicted yield, F and fishery independent indices were used. A vector of F_{pred} is produced from the model fits, and F_{obs} is the combination of the estimated commercial *q* multiplied by the annual commercial fishing effort index (E_y). In essence, this is a "semi-observed F" because the fitted parameter *q* is used to calculate F_{obs} (Haddon 2001). Yield $_{pred}$ was determined as the sum product of the CAA_{pred} and mean weight at age, and Yield $_{obs}$ was the reported commercial harvest from the fyke net fishery. The final component of the objective function was the fishery independent trawl survey. In this segment, the predicted index (I_{pred}) was $N_{a,y}*q_{trawl}$ and I_{obs} was the mean catch per standardized trawl tow.

Model run data

The model run required several parameters or data points that needed to be derived. Selectivity was determined for two time periods because commercial regulations have changed over the course of the assessment. The first time period, 1998 –1999, employed a 9" minimum size limit. Proportion of catch at age (averaged for all years) at or above 9" was determined and the points were graphed in Excel software and a logarithmic trendline and equation were determined. During 2000 – 2006 the commercial yellow perch fishery had an 8 ½" – 11" slot limit which produced a dome-shaped selectivity pattern. Selectivity was determined in the same manner as the 1998 – 1999 period, but the data for the curve was the proportion of yellow perch at age that were greater than or equal to 8 ½" and equal to or less than 11". A 2^{nd} order polynomial equation was then fit to the data. In order to formulate a predicted yield, a weight at age vector was needed. Average weight at age was determined from all years, pooled.

The fishery independent trawl survey in the upper Bay was used as a tuning index. Only years where sufficient tows occurred were used. This limited the data to 2000 – 2002 and 2006. After pilot runs, it was apparent that only age classes 3, 4, 6 and 8+ were informative, so other age-classes were not included. The model needed to estimate *q* for the trawl survey. It was decided that catchability of the younger age-classes may be greater than older age-classes, so 2 q parameters were fitted, one corresponding to ages 3 and 4, and one corresponding to ages 6 and 8+.

The model also required that $N_{4\ldots8+,\,1998}$, $N_{3,1998\ldots2006}$, F_y , q_{comm} , $q_{trawl\,3,4}$, and $q_{trawl\,6,8+}$ be estimated to start the model run. To obtain estimates of starting abundance, a Gulland style virtual population analysis (Megrey 1989) was performed on the CAA. This analysis provided estimates for $N_{4\ldots8+,\,1998}$, and $N_{3,1998.2002.}$ Estimates for $N_{3,2003\ldots2006}$ were not able to be determined from the VPA because the cohorts were incomplete. The juvenile yellow perch index from the Estuarine Juvenile Finfish Survey (Project 2, Job 3, Task 3 and Project 1 Job 1) and results from the completed cohorts of the VPA were used to estimate abundance of 3 year-old yellow perch. The appropriately lagged juvenile index was regressed against 3 year-old abundance from the completed cohorts of the VPA. Juvenile indices from the later years were substituted into the equation to solve for N at age 3.

The model was implemented in an Excel spreadsheet, and all fitting was done with Evolver genetic tree algorithm (Palisades Corporation 2003). Uncertainty was quantified by bootstrapping. Residuals of the CAA matrix were randomized and added back to the original CAA matrix, and the model was rerun. The model was bootstrapped 300 times and median and 80% confidence intervals were determined from the cumulative percent distribution for F and N. Coefficients of variation of q_{comm}, F_y, and N_y were also determined.

Choptank River relative abundance analysis

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

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

$$CPUE = a \bullet e^{(b \bullet yr)} \qquad [4]$$

where yr is year from 1 to 20 (corresponding to 1988 – 2007) and a and b are fitted parameters. The nonlinear regression was analyzed for outliers by inspecting studentized residuals. Each residual that was outside of the range of -2.0 to 2.0 were omitted from analysis and the regression was rerun. The regression was considered significant at the $\alpha = 0.05$ level.

RESULTS

Upper Chesapeake Bay statistical catch-at-age model

Selectivity at age was estimated for 2 time periods corresponding to different commercial regulations. The first corresponded to the time period 1998 -1999, and the data were fit with a logarithmic curve (Figure 1). The second time period (2000 – 2006) was modeled with a 2nd order polynomial function in order to capture the dome shaped response of the selectivity vector to the slot limit. The fits were considered very good, given the high r^2 values (0.88 and 0.86 for the first and second time periods, respectively).

Initial abundance of yellow perch in 1988 for ages 4 – 8+ were estimated from a Gulland style VPA (cohort analysis). Starting values of abundance ranged from approximately 360,000 fish for 5 year old yellow perch to 3,000 fish for the 8+ year-classes (Table 1). The abundance of 3 year old fish was also determined from the cohort analysis for years 1998 – 2002. Recruitment to age 3 varied from 1.350 million fish in 1999 (strong 1996 year-class) to 136,000 fish in 2000 (1997 year-class). For the period 2003 – 2006, N_3 was estimated from the regression equation of the Estuarine Juvenile Finfish Survey juvenile yellow perch index (lagged 3 years) and N_3 from 1998 – 2002 that were derived from the cohort analysis. The regression was statistically significant (Figure 2; $r^2 = 0.91$, $p = 0.04$). Substituting the lagged juvenile indices into the equation for the 2003 – 2006 time period resulted in a range of recruitment from 130,000 fish in 2005 (2002 year-class) to 950,000 fish in 2006 (2003 year-class). The initial estimates of q_{comm} were derived as the average q from the cohort analysis. A starting F_y value of 0.5 was used for all years. Initially, F_y was taken from the cohort analysis also, but pilot runs showed that the model runs were extremely insensitive to initial estimates of F.

The final model run appeared to fit the data well. Several pilot run were made, and it became apparent that the model was either relatively insensitive to starting values, or that the starting values were very close to reality. Manipulation of the starting values up or down caused few problems as the model estimates were very close to the initial estimates. Population abundance rose from 850,000 fish in 1998 to 1.635 million fish in 1999. As the strong 1996 year-class moved through the population, abundance fell to 750,000 fish in 2002 (Figure 3). Abundance estimates increased thereafter to 1.5 million fish in 2006. The F trajectory indicated a period of moderate fishing mortality through 2001, after which fishing mortality increased greatly to 1.01 in 2002. Since 2002, fishing mortality has decreased steadily (Figure 4).

Uncertainty analysis indicated that the model fit the data very well, but the population estimates were biased low earlier in the time series (Figure 5). As a consequence, F was biased high during the same time period (Figure 6). Coefficients of variation (CV) for all of the estimates were very good. Coefficient of variation for the N estimates averaged 18.9% and ranged from 14.5% in 2002 to 27.1% in 2005 (Table 2). Coefficient of variation for the F estimates averaged 23.8% and ranged from 19.7% in 2002 to 26.9% in 1998. Coefficient of variation for q_{comm} was 15.3%.

Predetermined F target (0.48) and limit (0.63) values from spawning stock biomass per recruit modeling for the upper Chesapeake Bay were not exceeded in 2006. Uncertainty indicated that there was no chance that fishing mortality exceeded either the target or limit in 2006, only a 2% chance that the target was exceeded in 2005, and no chance that the limit was exceeded in 2005. Conversely, there was a 99.7% and a 97.7% probability that the target and limit was exceeded in 2002, respectively (Figure 7).

Choptank River relative abundance analysis

Non-linear regression of CPUE and year provided a statistically significant fit (P=0.002). However, there was an extreme negative bias in the residuals. Three data points were identified as possible outliers. Exclusion of the CPUE values for 1999, 2001, and 2004 greatly improved the fit and corrected a bias toward negative residuals. The final equation, $CPUE = 2.6788 \bullet e^{(0.1184 \bullet yr)}$, was highly statistically significant ($P<0.0001$). The resultant curve indicated that CPUE increased from 3.01 fish/net day in 1988 to 28.6 fish/net day in 2007 (Figure 8).

DISCUSSION

Upper Chesapeake Bay assessment

This assessment is the first attempt at applying a statistical catch at age model, or integrated analysis, to the upper Chesapeake Bay yellow perch population. Abundance estimates in this model are for yellow perch age 3 and older. The model fit the data well, although uncertainty analysis indicated that some of the population abundance estimates were biased low. The model appeared insensitive to starting estimates, but no formal investigation was performed.

Model results could have been affected by several issues. No long-term suitable recreational harvest data were available. However, some estimates exist from the Marine Recreational Fishery Statistics Survey (MRFSS) that suggest that the recreational harvest is approximately 18% of the commercial harvest (personal communication, National Oceanic and Atmospheric Administration). The period when the MRFSS is conducted, along with the fact that it is not intended to intercept upstream fishing sites populated by traditional yellow perch fishermen, produces results with generally imprecise estimates. Exploratory model runs were conducted using recreational yield equal to 18% of the commercial harvest as part of the objective function, but model results were unaffected. Commercial F and abundance trends were remarkably robust to the addition of the recreational kill component.

The derivation of the starting estimates was also a potential source of error. Many statistical catch at age models use a stock—recruitment relationship to seed the initial population abundance estimates. The current assessment used estimates derived from a

Gulland cohort analysis. The model proved robust to changes in the starting estimates indicating the model was fitting the data very well using the Gulland estimates.

The objective function errors were equal-weighted. This had the effect of giving errors in the CAA matrix the most influence on the model fit. Exploratory runs where F, yield, and the trawl index were up-weighted did not affect the population trajectory or the F estimates. Since there was no *a priori* reason for allocating more weighting to the F, yield or trawl index, an equal weighting scheme was retained for the final run.

Yellow perch populations fluctuated over the period 1998 – 2006. Model results, especially for abundance, were intuitive when other information such as the upper Chesapeake Bay juvenile index and commercial harvest are considered. Early in the time series, abundance almost doubled in one year from 0.853 million yellow perch in 1998 to over 1.6 million yellow perch in 1999. The juvenile index indicated a very strong year-class in 1996 with those fish recruiting to the population as 3 year olds in 1999. Commercial harvest in the upper Bay was high in 1999 (operating with only an 8 1/2" minimum size limit) which prompted a population decline to approximately 1 million yellow perch in 2000. Harvest fell in 2000, but increased in 2001. As a result of the increased harvest, and especially a weak 1999 year-class, populations declined to about 0.700 million yellow perch in 2002. During this period, commercial regulations were changed to incorporate an 11" maximum size limit. Good year-classes in 2000 and 2001, along with declining yellow perch fishing effort and the change in commercial regulations, caused population abundance to increase greatly by 2004. The increase in 2006 can be similarly attributed to the very strong 2003 year-class being recruited to the population. The abundance decline in 2005 is somewhat perplexing. Uncertainty analysis does not indicate a low bias in the estimate, F was on the decline, and commercial harvest was relatively low. The 2002 year-class was virtually non-existent in the juvenile index and the commercial catch at age matrix verified that the 2002 year-class was nearly a complete failure. Estimated abundance of 3 year-old yellow perch averaged 445,000 individuals, but the abundance of 2002 year-class fish in 2005 was estimated at only 25,000 individuals. These results, both the doubling of population size in 1999 and 2004, and the declines of nearly 60% and 40% in 2000 and 2005, respectively, indicate that yellow perch populations are reliant on dominant year-classes, even when recruitment has been fairly high and stable.

Boom and bust population dynamics are not new in fisheries management. Percids have exhibited large population fluctuations throughout their known ranges. This assessment suggests that even a population that has had relatively successful reproduction can be influenced greatly by one strong or weak year-class. Juvenile relative abundance has been at or above average in six of the last nine years. However, one year-class failure (2002) with relatively low harvest rates caused a population decline of nearly 40%.

Tidal yellow perch populations have been managed by a %MSP approach since the adoption of the fishery management plan in 2002 (Yellow Perch Workgroup, 2002). Targets and limits were set for Chesapeake Bay yellow perch based on a spawning biomass per recruit analysis (Piavis and Uphoff 1998). A fishery with an 8 ½" to 11" slot limit has a target F of 0.48 and a limit F of 0.63. Model results and uncertainty analysis indicated that there was no chance that the limit was exceeded in 2000, 2001, 2005 or 2006, and a very slight chance that the limit was exceeded in 2003 and 2004. However, there was a greater than 97% chance that the limit was exceeded in 2002. There was a relatively high probability that the target was exceeded in 2003 (57%). In no other year was the probability that F exceeded the target greater than 4%.

<u>Choptank River relative abundance analysis</u>

Choptank River yellow perch fyke netting indicated that the population has increased substantially since 1988. Catch per unit effort increased over 800% during 1988 – 2007. Based on the relative abundance analysis, the yellow perch population in the Choptank River has doubled every 5 – 6 years. This population doubling time is slightly longer than the theoretical population doubling times (based on growth and natural mortality parameters) that ranged from 1.4 – 4.4 years (Froese and Pauly, 2007). The population increase is intuitive given that fishing mortality (F) has been very low, ranging from below detectable levels to 0.08 since 2000 (Project 1, Job 1).

There are no reliable juvenile indices for Choptank River yellow perch, but relative abundance-at-age indicated that there were strong year-classes recently. The 2005 year-class appeared strong, and as in other systems, the 2003 year-class was extremely strong, only surpassed by the dominant 1996 and 1998 year-classes. Additionally as in other systems, the 2002 year-class was weak. Low fishing mortality rates and growing spawning stock suggests that the population growth seen over the last 15 years should continue in the Choptank River.

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Table 1. Starting parameter estimates for the upper Chesapeake Bay yellow perch statistical catch-at-age model. q=catchability; N=abundance; F=instantaneous fishing mortality.

Parameter	Starting value
q_comm	0.1
q_trawl 3-4	0.0002
q_trawl 6-8	0.0002
N 1998 age 4	205,000
N 1998 age 5	362,000
N 1998 age 6	17,500
N 1998 age 7	4,000
N 1998 age 8+	3,000
N 1998 age 3	320,000
N 1999 age 3	1,350,000
N 2000 age 3	136,000
N 2001 age 3	278,000
N 2002 age 3	190,000
N 2003 age 3	416,000
N 2004 age 3	442,000
N 2005 age 3	130,000
N 2006 age 3	950,000
F 1998	0.5
F 1999	0.5
F 2000	0.5
F 2001	0.5
F 2002	0.5
F 2003	0.5
F 2004	0.5
F 2005	0.5
F 2006	0.5

Table 2. Final estimates, medians, and coefficients of variation (CV) of parameters from the upper Chesapeake Bay yellow perch statistical catch-at-age model.

Parameter	Estimate	Median	CV
N_1998	853,089	982,275	0.165
N_1999	1,635,533	1,835,308	0.152
N_2000	1,002,441	1,192,535	0.168
N_2001	865,132	1,021,983	0.152
N_2002	712,493	804,277	0.145
N_2003	750,002	832,764	0.180
N_2004	1,556,112	1,630,607	0.250
N_2005	1,048,973	1,102,021	0.271
N_2006	1,552,769	1,452,213	0.223
F_1998	0.269	0.229	0.269
F_1999	0.482	0.387	0.230
F_2000	0.253	0.231	0.231
F_2001	0.343	0.315	0.225
F_2002	1.007	1.001	0.197
F_2003	0.571	0.501	0.220
F_2004	0.341	0.315	0.264
F_2005	0.261	0.261	0.253
F_2006	0.114	0.114	0.251
q_comm	2.34356E-05	1.91979E-05	0.153

Figure 1. Fitted selectivity curves for the commercial yellow perch fishery from 2 time periods, 1998-1999 and 2000-2006.

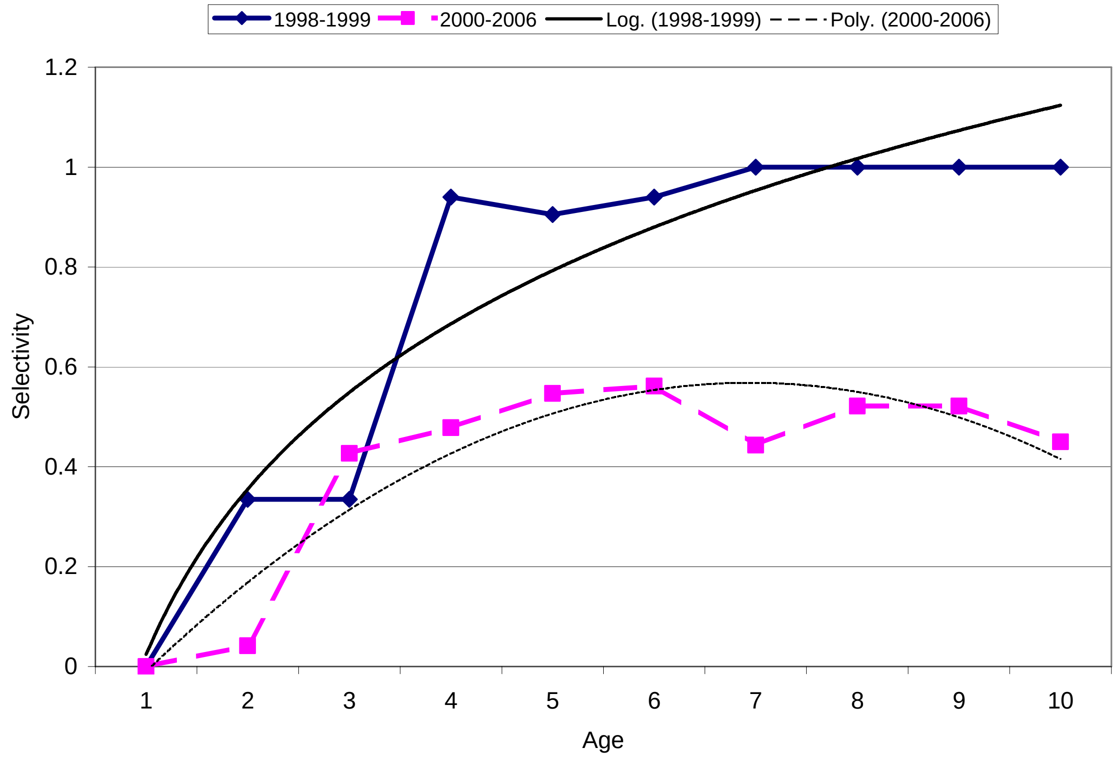


Figure 2. Regression line of upper Chesapeake Bay yellow perch juvenile index, lagged 3 years, and Gulland VPA estimates of abundance of age 3 yellow perch (Ln(N at age 3).

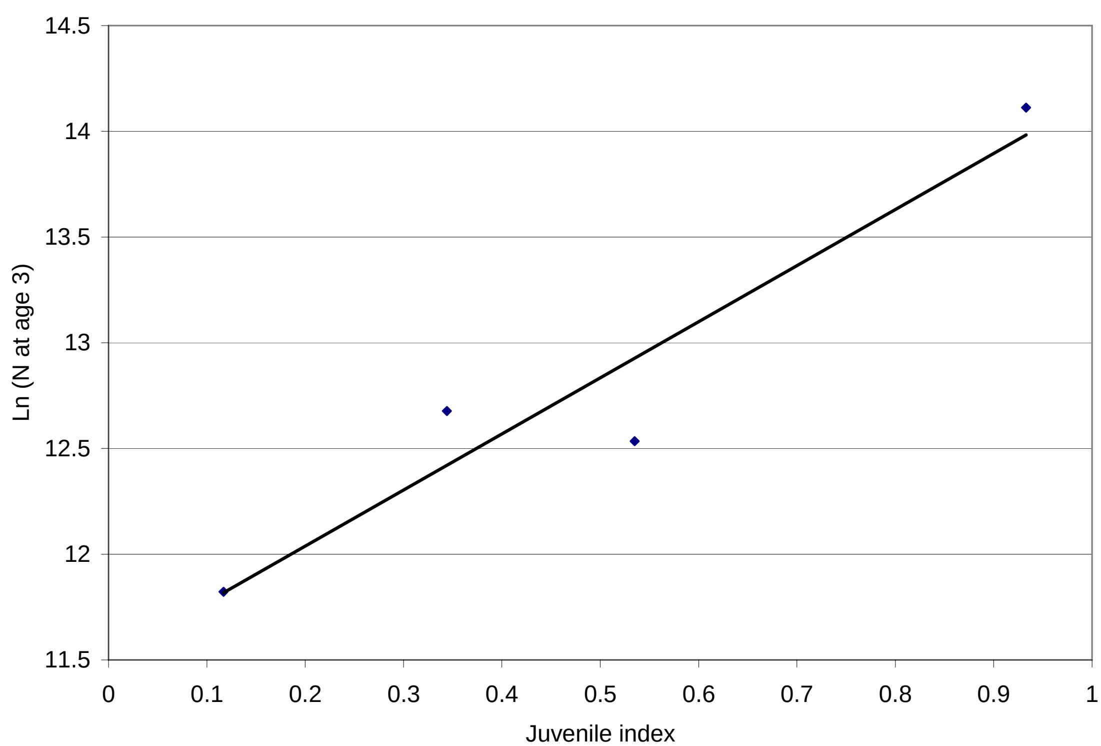


Figure 3. Upper Chesapeake Bay yellow perch abundance estimates from the statistical catch-at-age model, 1998—2006.

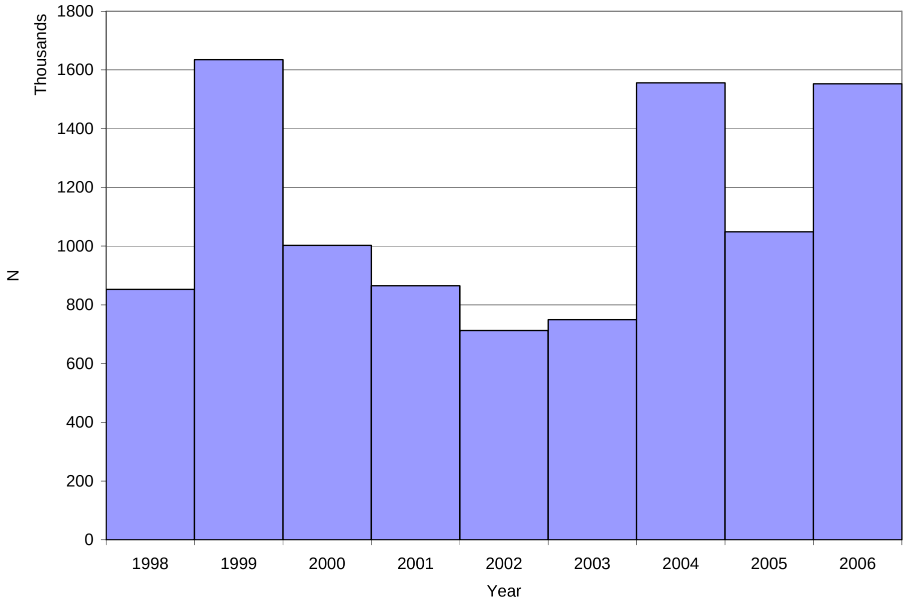


Figure 4. Upper Chesapeake Bay instantaneous fishing mortality of yellow perch from the statistical catch-at-age model, 1998—2006

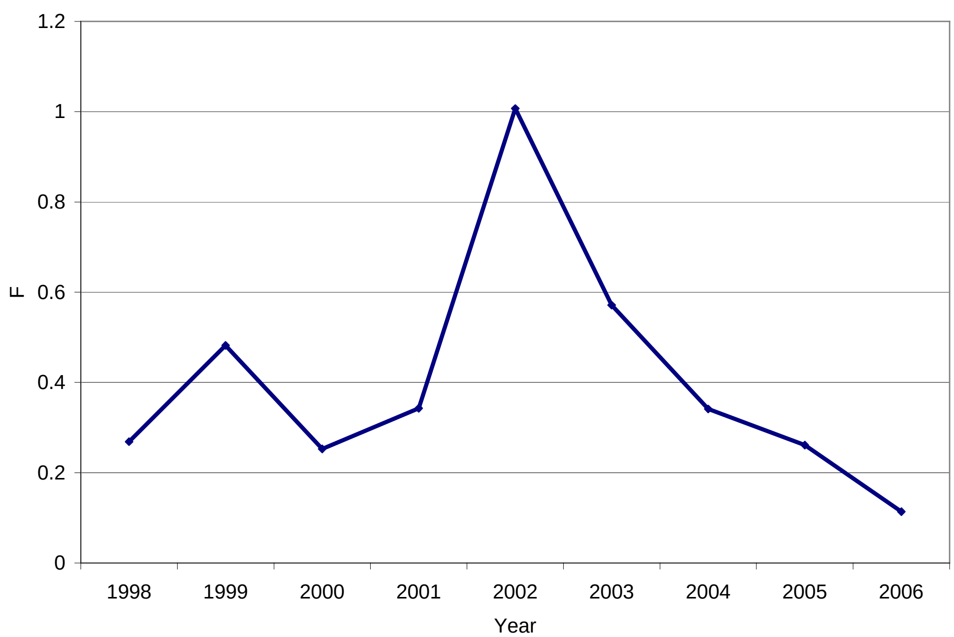


Figure 5. Upper Chesapeake Bay yellow perch abundance and 80% confidence intervals from the statistical catch-at-age model. (300 bootstrap runs).

Figure 6. Upper Chesapeake Bay yellow perch instantaneous fishing mortality and 80% confidence intervals from the statistical catch-at-age model.

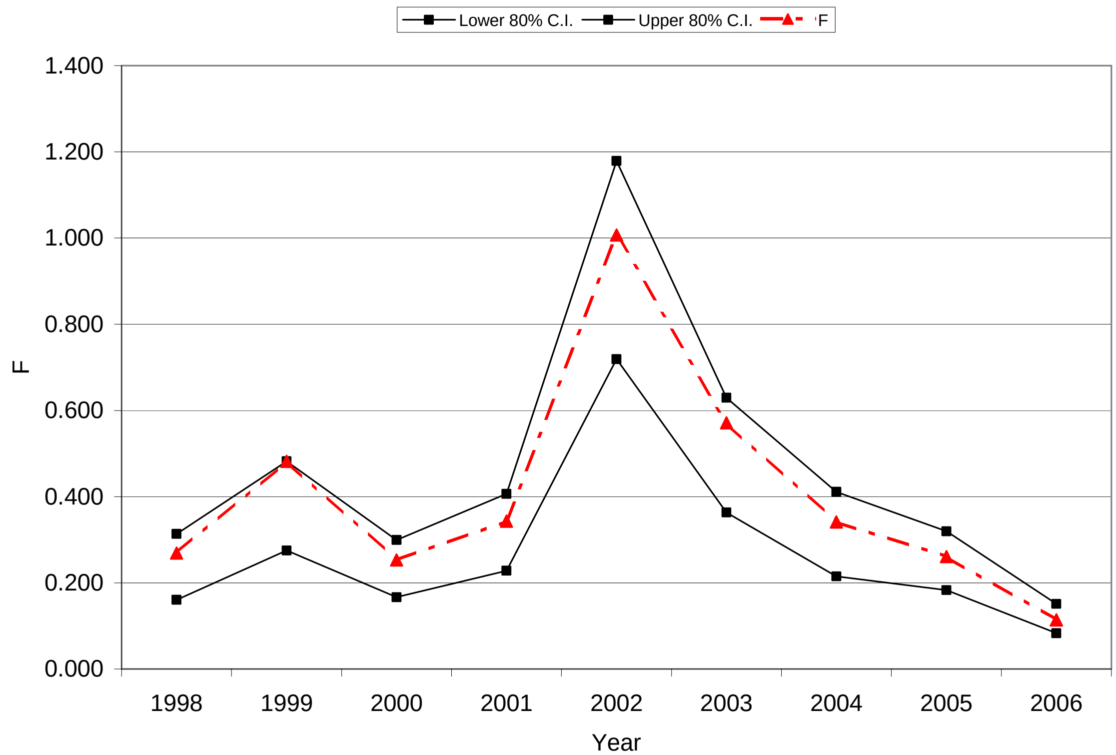


Figure 7. Probability of F exceeding target F (0.48) and limit F (0.63) for upper Chesapeake Bay yellow perch.

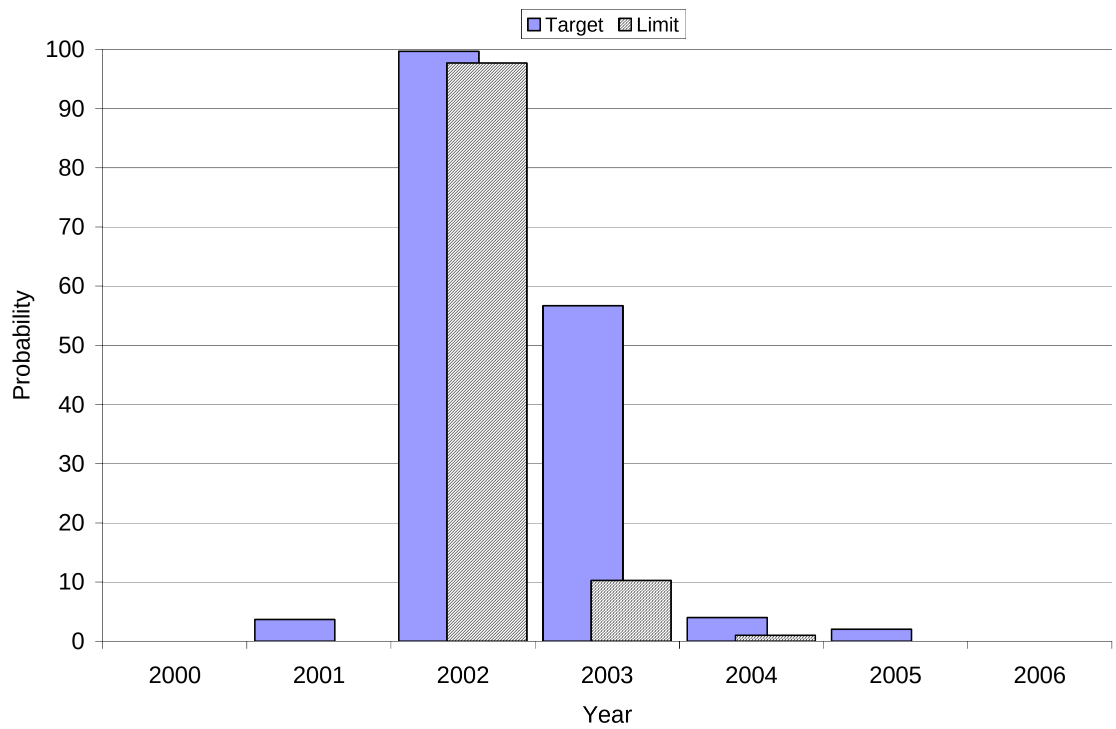
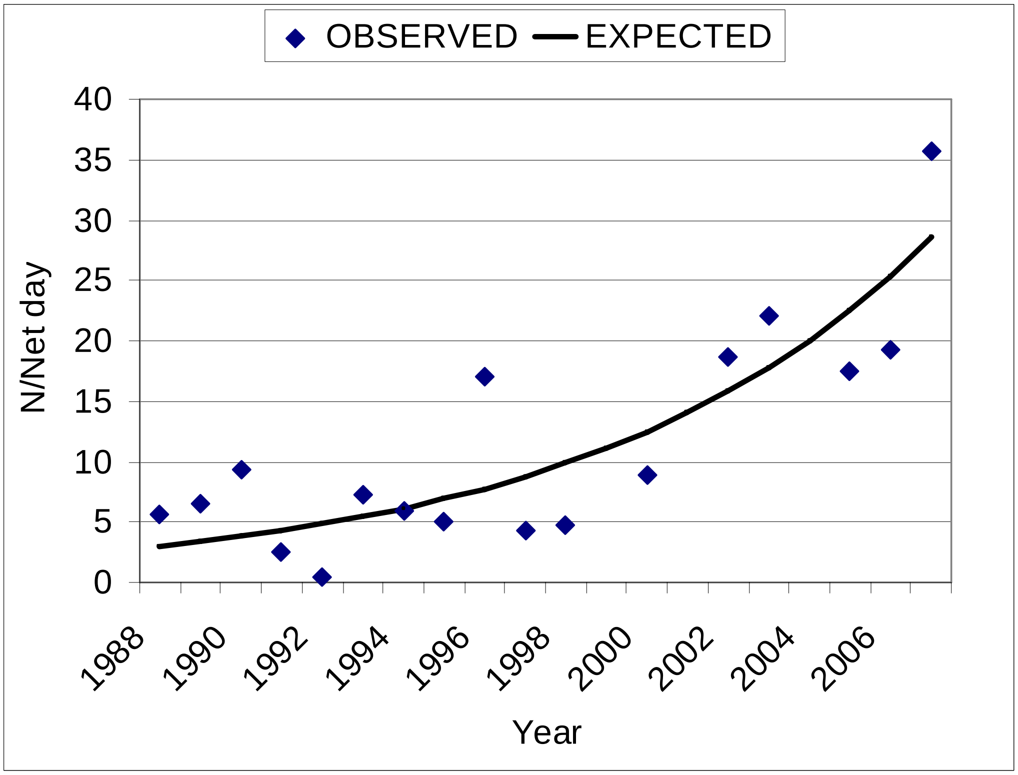


Figure 8. Yellow perch relative abundance from fyke net samples in Choptank River, 1988 – 2007, with statistically significant trend line.



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

STATE: Maryland

PROJECT NO.: F-61-R-3

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish / Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2006 through October 31, 2007

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.

Yellow perch in Maryland tidal waters support both commercial and recreational fisheries. Upper Chesapeake Bay yellow perch population dynamics were described with a statistical catch-at-age model for the time period 1998 – 2006. Yellow perch abundance (age 3 and older) peaked in 1999 at 1.64 million fish before declining to 712,000 fish in 2002. The yellow perch population rose during 2002 – 2006 with abundance in 2006 estimated at 1.55 million fish. Estimated instantaneous fishing mortality ranged from 0.25 to 0.48 during 1998 – 2001 before rising to 1.01 in 2002. Mortality decreased steadily from 1.01 in 2002 to 0.11 in 2006. Based on biological reference points, overfishing occurred in 2002 and possibly 2003, but overfishing did not occur 1998 – 2001 or 2004 – 2006.

Yellow perch population dynamics in the Choptank River were described by analyzing

relative abundance trends from agency fyke net surveys, (1988 – 2007). Analysis indicated a logarithmic increase of approximately 800% during this time period as the population doubled approximately every 5 - 6 years. Low mortality rates over the most recent years were also noted. No violations of F targets or limits were suspected.

Adult American shad indices in the Susquehanna River, including fish lift GM, hook and line GM and relative population estimates have continued to trend downward during the last six years. American shad relative abundance in the Nanticoke River also remained low. Age structures in both systems were unchanged indicating nonselective mortality. The Upper Chesapeake Bay American shad juvenile index for 2007 indicated near record spawning success and was likely related to ideal flow conditions. The low abundance of adult American shad, a coastwide phenomenon, indicates increased mortality on ocean migrant fish possibly through commercial exploitation, increased predation, or a combination of both parameters.

Adult hickory shad relative abundance indices in Deer Creek remained stable while those in the Nanticoke River decreased. Juvenile sampling caught few hickory shad due primarily to gear aversion.

Adult alewife herring repeat spawning indices and GM CPUEs in the Nanticoke River have shown no trend, but remain very low. Blueback herring repeat spawning indices and GM CPUEs have decreased significantly since 1989. Fishing mortality rates, age structure and sex ratios appeared stable for both species during the time series. In general, adult alewife and blueback herring stocks and corresponding juvenile indices for both species have been low for most of the years in the 19 year time series.

Weakfish have experienced a sharp decline in abundance coast wide. Recreational catch estimates by the NMFS for Maryland fell steadily from 475,348 fish in 2000 to 493 fish in 2006. Maryland's commercial weakfish harvest rose slightly to 32,417 pounds in 2006, but was still the third lowest catch on record. The 2007 mean length for weakfish from pound net sampling was 275 mm TL, the second smallest of the time series. The 2007 length frequency distribution and RSD analysis indicate that only smaller weakfish were available in Maryland waters. Fish aged from 2006 pound net sampling were all 4 years of age or younger.

The mean length of summer flounder collected from pound nets was 341 mm TL in 2007, near average for the 15 time series. Relative stock densities in 2007 indicated a shift up from the RSD stock category to the quality category compared 2006. Both commercial and recreational harvest of summer flounder decreased in 2006. The NMFS 2006 coast wide stock assessment concluded that summer flounder stocks were not overfished, but overfishing was occurring.

Mean length of bluefish sampled from pound nets in 2007 was 318 mm TL, 6th highest during the 1993-2007 time period. Length distribution and RSD analysis indicated a modest

shift toward larger bluefish in 2007. Both recreational and commercial bluefish harvest's in Maryland were below average in 2006. The latest coast wide stock assessment indicated bluefish were not overfished and overfishing was not occurring.

The mean length of Atlantic croaker examined from pound net sampling in 2007 was 307 mm TL, the fifth largest mean length of the 15-year time series. RSD analysis for Atlantic croaker indicated a continued dominance of $RSD_{preferred}$ and $RSD_{memorable}$ fish and a time series high of RSD_{trophy} fish. Fish aged from 2006 pound net sampling ranged from 1 – 13 years of age. Maryland Atlantic croaker total commercial harvest for 2006 decreased to 344,318 pounds, while the corresponding recreational harvest estimate of 834,894 fish was similar to the previous two years.

Spot length frequency distributions in 2007 were somewhat truncated, but the mean length remained near the average of the time series. Juvenile indexes have been lower than the long-term average in recent years. Commercial harvest declined in 2006, while recreational catch estimates remained near the average. The percent of spot over 254 mm TL in the pound net samples was one percent, lower than the previous 4 years.

Resident / premigratory striped bass present in the Chesapeake Bay during the summer – fall 2006 pound net and hook and line commercial fisheries ranged from 1 to 14 years of age. Three year old striped bass from the 2003 year-class and 5 year old fish from the 2001 year-class dominated samples taken from pound nets, contributing 32% of the total sample in 2006. Check station sampling determined that five year old striped bass from the dominant 2001 year-class comprised 36% of the commercial hook & line harvest and 37% of the pound net harvest.

The 2006-2007 commercial drift gill net fishery harvest was comprised primarily of four, five and 6 year old striped bass from the 2001, 2002 and 2003 year-classes. Age groups 4, 5 and 6 contributed approximately 78% of the drift gill net harvest while age 7 to 14 year-old fish contributed 22%. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from 4 to 14 (1993 – 2003 year classes)

The spring, 2007 spawning stock survey indicated that there were 16 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 19 years old. Age 4 male striped bass from the 2003 year-class were the most abundant component of the male striped bass spawning stock. Age 11 (1996 year-class) and age 10 (1997 year-class) females were the major contributors to 2007 total female abundance. Age 8 and older females comprised 93% of the female spawning stock in 2007, a 9% increase from 2006.

The 2007 striped bass juvenile index, a measure of striped bass spawning success in Chesapeake Bay, was 13.4, slightly above the 54-year average of 12.0. During beach seine

sampling, 1,768 young-of-year (YOY) striped bass were collected. The Upper Bay and the Nanticoke River both produced above-average numbers of YOY striped bass. Reproduction in the Potomac and Choptank rivers was below average. The healthy level of reproduction in 2007 follows a low index in 2006. Striped bass populations are known for this variable spawning success in which several years of average reproduction are interspersed with occasional large and small year-classes.

During the 2007 recreational trophy season, biologists intercepted 542 fishing trips, interviewed 809 anglers, and examined a total of 301 striped bass. The average total length of striped bass sampled was 861 mm TL (33.8 inches), and the average weight was 6.8 kg (14.9 lbs). Most fish sampled from the trophy fishery were between seven and eleven years old. The 2000 year-class (7 years old) was the most frequently observed year-class, constituting 21% of the sampled harvest. Average catch rate based on angler interviews was 0.5 fish per hour, a drop from the catch rate of 2.6 fish per hour in 2006. New 2007 size limits resulted in considerable change in length frequencies, catch rates, and age structure of the trophy season harvest.

A total of 1,142 striped bass were tagged and released for growth and mortality studies during the spring, 2006 sampling season. Of this sample, 772 were tagged with USFWS internal anchor tags. A total of 370 striped bass were sampled and tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise. A high reward tag (HRT) study was also incorporated into the spring fishery-independent spawning stock study in order to obtain a current estimate of reporting rate. Results were not yet available for this report. Specialized coded wire tag (CWT) sampling was continued on the Patuxent River during 2007. A total of 48 striped bass were scanned for the presence of CWT's , but none were found to be CWT positive.

During 2007, L_p (proportion of estuarine tows containing larval yellow perch) fell within the historic range in the Bush, Corsica and Nanticoke Rivers, and Langford Creek, a tributary to the Chester River. The Severn River estimate was below the historic range. All four estimates of L_p from the Severn River (17% Impervious Surface – IS) during 1998-2007 were less than the historic minimum of $L_p = 0.4$ while only 5 of 16 estimates from remaining systems (IS < 13%) were below $L_p = 0.4$.

Based on presence-absence comparisons with the Bush River stream surveys conducted during the 1970's and recent surveys from the less developed Aberdeen Proving Ground watersheds, it appears that white perch and yellow perch use of historical stream spawning habitat has diminished. Yellow perch postlarvae were quite abundant in the Bush River estuary during the past two years, indicating that loss of stream spawning habitat may not be critical to the population. However, reduced stream spawning could be critical to recreational anglers because this is where and when yellow perch are accessible to the traditional shore-based fishery. Herring/shad presence in streams did not indicate marked changes in spawning activity with watershed development. Viability of eggs and larvae was unknown, but their presence might have represented losses to the population if habitat conditions have become detrimental and spawning behavior has not changed.

Impervious surface (IS) had a significant, positive influence on the odds of juvenile and adult white perch, juvenile spot and striped bass, and all stages of blue crabs (combined) being absent from trawl samples taken in mid-channel bottom habitat. This likely reflected the strong negative relationship between average DO in the bottom habitat and IS in brackish systems, and the strong, positive asymptotic response of presence-absence of these species with dissolved oxygen.

Plots of P_{wpj} or P_{wpa} (proportion of trawls with juvenile or ages 1+ white perch, respectively) against IS by salinity category (fresh or brackish) in Potomac River tributaries suggests that IS has a negative impact, but the impact appears more gradual in fresh-tidal areas than brackish. The difference in IS thresholds between fresh-tidal and brackish tributaries reflect substantial differences in dissolved oxygen (DO) levels in bottom waters. During 2003 – 2007, mean bottom DO in fresh-tidal tributaries (IS < 15%) averaged at saturation or slightly above saturation, regardless of IS. In brackish tributaries, however, bottom DO became increasingly depleted as IS increased and averaged in the hypoxic range past IS $\geq$15%.

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CONTENTS

SURVEY TITLE: CHESAPEAKE BAY FINFISH/HABITAT INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 2
JOB NO 1

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

Prepared by
Robert Sadzinski and Anthony Jarzynski

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 and hickory shad and alewife and blueback herring 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. Long-term mark-recapture 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 provides information from broad geographic ranges and is 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 species sampled in the spring of 2007 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 30 April through 23 May 2007. Two rods were fished simultaneously, with each rod rigged with two shad darts and lead weight added, when necessary, to achieve proper depth. Fish in good physical condition and females not spent or running ripe had a scale sample removed and were quickly tagged and released. A Maryland Department of Natural Resources (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 (2) and fyke nets (6). These nets were sampled at least once per week from 5 March to 27 April 2007. Pound nets were located at the mouth of Mill Creek and Dens Creek while fyke nets were located between river kilometer (rkm) 30.4 and 35.7

(Figure 2). Fish 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 commercial 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.

B. Juveniles

<u>Summer Seining</u>

Juvenile alosines were sampled biweekly from July to October in the Susquehanna, 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 five sites on the Susquehanna River (Figure 3), six on the Chester River (Figure 4) and four on the Pocomoke River (Figure 5). Sites were chosen based on availability seinable beaches, historical spawning importance and their proposed or existing restoration efforts. Targeted 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 the four-alosine species by dividing the total catch, by the number of sites, times the number of site visits resulting in catch-per-seine-per-day.

<u>Presence/Absence of Eggs/Larvae</u>

Successful alosine reproduction in the lower Nanticoke River was indicated by the presence/absence of eggs through bi-weekly ichthyoplankton sampling. The ichthyoplankton net was constructed of 500 μm mesh net with a 500mm metal ring opening. The net was towed for six-minutes at two knots and at the conclusion of the tow the contents were flushed down into masonry jar for presence/absence determination.

Sampling sites on the Nanticoke River repeated historic sampling (J. Mowrer pers. comm. MDNR; Figure 6). 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 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 (1989-2007) for ages 3 to 8. Males and females were analyzed separately.

Relative 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 dumped into a trough and directed past a 4'x10' counting window and identified to species and enumerated by experienced technicians. American shad possessing a tag were counted and the tag color noted. Hourly catch logs by species were then produced by Normandeau personnel and distributed to DNR personnel. Time series analysis of the Petersen relative population estimates (1980-2006) were examined using a linear growth model. Annual catch-per-unit-effort (CPUE) for American shad was calculated as the geometric mean of fish caught per operating hour.

Relative abundance, measured as annual CPUE for alewife and blueback herring and American shad collected from fyke nets in the Nanticoke River were calculated as the geometric mean (based on a $\log_e$-transformation; Sokal and Rohlf 1981) of fish caught per fyke 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 mortality of alosines. 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 2007 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.70:1. Of the 468 fish sampled by this gear, 449 were scale-aged (Table 1). Those American shad not aged directly because of regenerated scales, were not assigned ages.

A total of 65 American shad were captured from the Nanticoke River pound and fyke nets and all were subsequently aged. The 2007 male-female ratio for adult American shad captured in the Nanticoke River was 2.1:1 (Table 1).

Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line in 2007 was 14.1% for males and 17.4% for females (Table 1). The arcsine-transformed proportions of these repeat spawners (sexes combined) had been increasing through 2002 but has been decreasing in recent years (Figure 7). The arcsine-transformed proportions of repeat spawning American shad from fyke and pound nets in the Nanticoke River are presented in Figure 8. There is no trend for the time series ($r^2 = 0.13$ $p = 0.12$).

Relative Abundance

Of the 468 adult American shad sampled in Conowingo tailrace in 2007 (Table 2), 449 (96%) were tagged and 66 (22%) subsequently recaptured from the east lift (Table 3). In 2007, there was one reported recaptured American shad caught from a pound net in the main Chesapeake Bay.

In 2007, the east lift operated from 23 April through 31 May and technicians counted American shad passing the viewing window. Peak passage was on 08 May when 3,025 American shad were recorded.

In 2007, the west lift at Conowingo Dam operated from 30 April to 31 May. The 4,272 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 20 May when 668 American shad were collected. Thirty-one tagged American shad were recaptured in 2007 from the west lift (Table 3).

The Conowingo tailrace American shad relative population estimate in 2007 was 158,148 (95% confidence intervals 200,377-124,717; Table 4 and Figure 9). This estimate was adjusted for 3% tag loss as suggested by Leggett (1976).

Estimates of hook and line and fish lift geometric mean CPUEs have decreased significantly since 2002 (hook and line: r^2=0.75, P= 0.012 and fish lifts: r^2=0.80, P=0.007; Figures 10 and 11). Nanticoke River pound net geometric mean CPUEs for American shad decreased sharply in 2005 and 2006 (Figure 12). The marked increase in 2007 may be the result of restoration stocking. The Nanticoke River fyke net geometric mean CPUEs for American shad have been very low most years and have exhibited no trend (r^2=0.02, P=0.59; Figure 13).

Mortality Estimates

Since American shad do not fully recruit until age seven in the Maryland portion of the Chesapeake Bay, as detected by virgin fish, repeat spawning marks were 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 = 1.35. The average difference between the natural logs of the spawning group frequency, produced Z = 1.31.

American shad mortality rates were not estimated from the Nanticoke River because of low sample sizes in 2007.

Otolith Examination

Of the 155 readable American shad otoliths collected from the west lift at Conowingo Dam in 2007, 52% were classified as non-hatchery fish (Hendricks 2008). Adult American shad otoliths from the Nanticoke River were also sent to Delaware Division of Fish and Wildlife for oxytetracycline (OTC) analysis and results indicate that 83% were non-hatchery fish (M. Stangl pers. Comm.).

b. Juvenile

In the Susquehanna River eight juvenile American shad were caught by haul seine. No juvenile American shad were caught by haul seine in the Chester and Pocomoke rivers.

c. Presence/Absence of Clupeid Eggs

Successful clupeid reproduction in the lower Nanticoke River was determined by the presence of eggs through biweekly tows. Fertilized clupeid eggs were not found in any sample (n = 78). Salinity at plankton tow locations ranged from 0.1 to 1.3 ppm.

d. Quantitative Habitat Analysis

SAV estimates in the upper Chesapeake Bay were obtained from the Tidewater Ecosystem Assessment (L. Karrh, MD DNR pers. Comm.) while upper Chesapeake Bay American shad juvenile indices (geometric mean CPUEs) were obtained from Project 2 Job 3 task 3 (Juvenile Striped Bass Recruitment Assessment). For the first time, in the upper Chesapeake Bay, there was a correlation between SAV density and American shad juvenile indices (1990-2007; r^2=0.58, P=0.02).

2. Hickory Shad

a. Adults

<u>Sex and Age Composition</u>

Since only eight adult hickory shad were collected from the Nanticoke River in 2007, age analysis was not attempted. The 2007 male-female ratio for Nanticoke River adult hickory shad was 7.0:1.

<u>Relative Abundance</u>

Nanticoke River pound net geometric mean CPUEs for adult hickory shad have decreased since 2002 (r^2=0.84, P=0.03 Figure 14) while fyke net geometric mean CPUEs have showed no trend (r^2=0.04, P=0.60; Figure 15).

b. Juveniles

Three locations were selected to characterize or supplement datasets for juvenile hickory shad; the Susquehanna, Chester and Pocomoke rivers. These locations were chosen because they duplicated sampling sites targeting American shad. During summer sampling in the Susquehanna, Chester and Pocomoke rivers, no juvenile hickory shad were collected from these systems.

3. Alewife and Blueback Herring

a. Adults

Sex and Age Composition

The 2007 male:female ratio for Nanticoke River alewife was 1:1.49. Of the 219 alewives, sampled, 218 were aged. For 2007, alewife were present at ages 3-8 with the 2003 year-class (age 4, sexes combined) the most abundant, accounting for 39.9% of the total catch. Females were most abundant at age 5 and males at age 4 (Table 5).

The 2007 male:female ratio for blueback herring was 1:1.05. Of the 78 blueback herring sampled, 74 could be aged. Blueback herring were present at ages 3-7 with the 2003 year-class (age 4, sexes combined) the most abundant accounting for 40.5% 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 2007 was 43.1% and 25.7%, respectively (Table 5). The arcsine-transformed proportion of alewife repeat spawners (sexes combined) indicated no trend (1989-2007; $r^2<0.04$ $P=0.39$), while blueback herring repeat spawning showed a decreasing trend (1989-2007; $r^2=0.45$, $P<0.01$; Figure 16).

Using Speir and Mowrer’s (1987) maturity schedule calculation, 93.18% of male alewife and 97.22% of male blueback herring were mature by age 4. The percentages of female alewife and blueback herring mature by age 4 were 66.92% and 89.47%, respectively.

Length-at-Age

For 2007, Nanticoke River female alewife mean lengths-at-age were greater than corresponding male mean lengths-at-age (Table 6). Blueback herring female mean lengths-at-age were greater than corresponding male lengths-at age except for age 6 (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 6, 7 and 9 have also significantly decreased since 1989 (Table 8).

Relative Abundance

Alewife herring geometric mean CPUEs for the Nanticoke River have varied without trend (1989-2007; r^2=<0.03 P=0.50; Figure 17), while those for blueback herring have significantly decreased (1989-2007; r^2=0.68 P<0.01; Figure 18). Nanticoke River commercial river herring landings (species combined) have significantly decreased since 1989 (r^2=0.71 P<0.01); while the combined CPUEs has shown no trend overtime (1989-2007; r^2=0.07 P=0.27 Figure 19).

Mortality Estimates

Instantaneous mortality (Z) in 2007 for Nanticoke River alewife herring (sexes combined) estimated Z = 1.05 (annual mortality {A} = 65.017%). Since maximum age (T_{max}) for alewife was 7, M = 0.43 and F = 0.62. Estimates of Z for Nanticoke River alewife herring males was 1.42 (annual mortality {A} = 24.17%), and for females Z = 0.90 (annual mortality {A} = 40.66%; Figure 20).

Instantaneous mortality (Z) in 2007 for Nanticoke River blueback herring (sexes combined) estimated Z = 1.35 (annual mortality {A} = 74.08%). If the maximum age (T_{max}) for blueback herring was 7, M = 0.43 and F = 0.92. Estimates of Z for blueback herring males was 0.81 (annual mortality {A} = 57.26) and for females Z = 1.20 (annual mortality {A} = 69.58%; Figure 21).

b. Juvenile

For 2007, juvenile seining in the lower Susquehanna River produced no alewife herring and 206 blueback herring (CPUE of 6.87). Chester River sampling produced one juvenile alewife herring (CPUE = 0.02) and 334 juvenile blueback herring (CPUE = 7.95). No juvenile alewife herring were captured from the Pocomoke River while five juvenile blueback herring (CPUE = 0.18) were collected from this lower shore system.

DISCUSSION

Anadromous Species

1. American shad

a. Adults

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

In the 2007 American shad stock assessment conducted by ASMFC (2007), American shad stocks were declining in most river systems along the east coast. Factors contributing to the decline included predation, ocean harvest as “bait” and bycatch. Because of the difficulty in identifying and differentiating the four alosines, many subadults may be caught as bycatch, appearing as bait in various markets particularly in New England and southern Canada (K Hattala, NY DEC pers comm.).

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 stocks in the Potomac River showed 17% repeat spawners (Walburg and Sykes 1957). During the early 1980’s, repeat spawning was generally less than 10% in the upper Chesapeake Bay (Weinrich et al 1982).

Data from two creel surveys targeting American shad in the Susquehanna River have shown significant decreases in catch-per-angler-hour during the last five years (Tables 9 and 10).

Juveniles

Baywide juvenile American shad production in 2007 was the highest in the time series (Figure 22) and was likely driven by ideal environmental conditions since adult indices have been declining since 2001. Strong juvenile American shad indices were primarily driven by the upper Chesapeake Bay (Figure 23) and Potomac River (Figure 24). In the upper Chesapeake Bay during 2007, 1,122 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 322 were captured from the six auxiliary sites. In both systems the number of hatchery-marked individuals was low and it appears that natural reproduction was driving this index.

The Potomac River juvenile American shad indices also generated by this juvenile survey showed significant increases during the last five years. Results from OTC analysis completed on subsampled juvenile American shad from 2004, showed these fish to be of wild origin.

2. Hickory shad

a. Adults

Adult hickory shad are difficult to capture because of their aversion to fishery independent (fish lifts and ladders) and dependent (pound and fyke nets) gears. Deer Creek, a tributary to the Susquehanna River in Harford County, has the greatest densities of hickory shad in Maryland (Richardson et al 2004). The catch-per-angler-hour (CPAH) in Deer Creek based on Fisheries Service logbook surveys ranged from 4.3 to 8.3 and has varied without trend since 1998 (r^2=0.09, P=0.41; Table 11).

Although hickory shad age analysis has not been completed for the 2007 samples collected from Deer Creek, Richardson (et al 2004) noted that ninety percent of these fish spawned by age four and stocks generally consisted of few virgin fish. Since the oldest fish in these samples were 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. If Z is calculated using the freshwater spawning marks as in American shad, then hickory shad mortality estimates in Deer Creek in 2006 (latest available data) estimated from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 0.32. The average difference between the natural logs of the spawning group frequency produced Z = 0.37.

In general, the resultant Z is attributed to natural mortality since only a catch and release fishery for American and hickory shad exists in Maryland. These low mortality estimates indicate that bycatch mortality or predation on this species is minimum. Based on the low estimated total mortality rates for hickory shad, the factors effecting American shad have not impacted hickory shad as indicated by their low total mortality rates.

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 indices, sampling would need to be initiated four weeks 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. The combined pound net CPUE from 1989-2007 for river herring (species combined) in the Nanticoke River showed no trend, while the blueback herring CPUE decreased during this time period. Alewife herring CPUEs have not exhibited any statistical trend between 1989 and 2007.

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 Fisheries Management Plan for Shad and River Herring which will likely reduce fishing mortality. In 2006, river herring commercial landings in Maryland were 13% of the historical high and with juvenile indices at very low levels adult stocks are also likely to remain at low abundance levels.

b. Juveniles

The catch of juvenile alosine species from the Susquehanna, Chester and Pocomoke rivers was low except for blueback herring in the Susquehanna River. Since this is the third year of sampling for juvenile alosine in these systems, it appears comparisons would be tenuous. Juvenile indices for alewife and blueback herring in the Nanticoke River obtained from the juvenile striped bass recruitment survey (Figures 25 and 26, respectively) indicated low catches for both species. Since juvenile herring prefer salinities less than 2.0 ppm, sampling in the lower Nanticoke River where salinities are normally greater than 2.0 ppm may have precluded their presence.

Baywide juvenile alewife herring production in 2007 was equal to the time series average (0.65) while the 2007 blueback herring index of 1.88 was above the time series average of 1.40 (Figure 27). These juvenile indices indicate that spawning success appeared good for both species even though adult indices are low.

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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 2007.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0	0	0	0	0	
3	17	0	0	0	17	0
4	98	0	64	0	162	0
5	59	21	113	11	172	32
6	9	3	79	28	88	31
7	1	1	5	4	6	5
8	1	1	2	2	3	3
9	0	0	1	1	1	1
Totals	185	26	264	46	449	72
Percent Repeats	14.1%		17.4%		16.0%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	7	0	1	0	8	0
4	22	0	6	0	28	0
5	12	2	9	1	21	3
6	1	0	2	2	3	2
7	2	2	0	0	2	2
8	1	1	1	1	2	2
9	0	0	1	1	1	1
Totals	45	5	20	5	65	10
Percent Repeats	11.1%		25.0%		15.4%	

Table 2. Conowingo Dam tailrace hook and line data, 1982-2007.

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

Table 3. Recaptured American shad in 2007 at Conowingo Dam's east and west lifts by tag color and year.

East Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Pink	2007	66
Orange	2006	6
West Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Pink	2007	31

Table 4. Conowingo tailrace population estimate of adult American shad in 2007.

Chapman's Modification of the Petersen estimate

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

where N = population estimate
M = number of fish tagged
C = number of fish examined for tags
R = number of tagged fish recaptured

<u>2007 survey results:</u>

C = 24,246
M = 436
R = 66

Therefore:

$$N = \frac{(24{,}246 + 1)(436 + 1)}{(66 + 1)} = 158{,}148$$

From Ricker (1975): Calculation of 95% confidence limits based on sampling error using the number of recaptures in conjunction with Poisson distribution approximation.

Using Chapman (1951):

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

where: R^t = tabular value (Ricker p343)

$$\text{Upper } N = \frac{(24{,}246 + 1)(436 + 1)}{(51.88 + 1)} = 200{,}377$$

$$\text{Lower } N = \frac{(24{,}246 + 1)(436 + 1)}{(83.96 + 1)} = 124{,}717$$

Table 5. Numbers of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2007.

Alewives

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	13	0	2	0	15	0
4	49	3	38	1	87	4
5	19	12	40	21	59	33
6	7	7	35	35	42	42
7	0	0	12	12	12	12
8	0	0	3	3	3	3
9	0	0	0	0	0	0
Totals	88	22	130	72	218	94
Percent Repeats	25.0%		55.4%		43.1%	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	11	0	8	0	19	0
4	17	0	13	1	30	1
5	7	4	11	7	18	11
6	1	1	4	4	5	5
7	0	0	2	2	2	2
8	0	0	0	0	0	0
9	0	0	0	0	0	0
Totals	36	5	38	14	74	19
Percent Repeats	13.9%		36.8%		25.7%	

Table 6. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2007.

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						

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				

Table 7. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2007.

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					

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				

Table 8. Regression statistics for alewife and blueback herring in 2007 based on cumulative data.

Alewife	Male				Female			
Age	N	Slope	r^2	P	N	Slope	r^2	P
3	361	-0.123	0.003	0.300	106	+0.011	<0.001	0.964
4	1277	-0312	0.025	<0.001	1132	-0.357	0.036	<0.001
5	1056	-0.305	0.023	<0.001	1506	-0.252	0.018	<0.001
6	434	-0.453	0.051	<0.001	957	-0.334	0.034	<0.001
7	69	-0.989	0.175	<0.001	306	-0.390	0.390	<0.001
8	6	-1.183	0.117	0.506	92	-0.664	0.094	0.003
9					11	-2.397	0.212	<0.154
Blueback herring	Male				Female			
Age	N	Slope	r^2	P	N	Slope	r^2	P
3	178	-0.219	0.019	0.065	42	-0.437	0.097	0.045
4	801	-0.089	0.002	0.178	682	-0.191	0.009	0.009
5	918	-0.062	<0.001	0.366	876	-0.145	0.006	0.028
6	647	-0.509	0.039	<0.001	679	-0.446	0.028	<0.001
7	281	-0.602	0.030	0.004	333	-0.321	0.016	0.022
8	90	-0.259	0.002	0.641	110	-0.284	0.007	0.390
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, 2001-2007.

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

Table 10. Summary of the spring American shad logbook data, 1999-2007.

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	3137	7.76
2001	8	272.5	1647	6.04
2002	8	331.5	1799	5.43
2003	9	530.0	1222	2.31
2004	18	750.0	1035	1.38
2005	18	567.0	533	0.94
2006	19	227.3	305	1.34
2007	10	285.5	853	2.99

Table 11. Summary of the spring hickory shad log book data from Deer Creek, 1998-2007.

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	4980	8.30
1999	15	817	5115	6.26
2000	14	655	3171	4.84
2001	13	533	2515	4.72
2002	11	476	2433	5.11
2003	14	635	3143	4.95
2004	18	750	3225	4.30
2005	18	272.5	1699	6.23
2006	19	762	4905	6.43
2007	17	782.5	3395	4.34

Table 12. Age structure of hickory shad from the Susquehanna River based on scales, 1998-2007.

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	Not Completed							

Figure 1. Location of the 2007 hook and line sampling in Conowingo Dam tailrace.

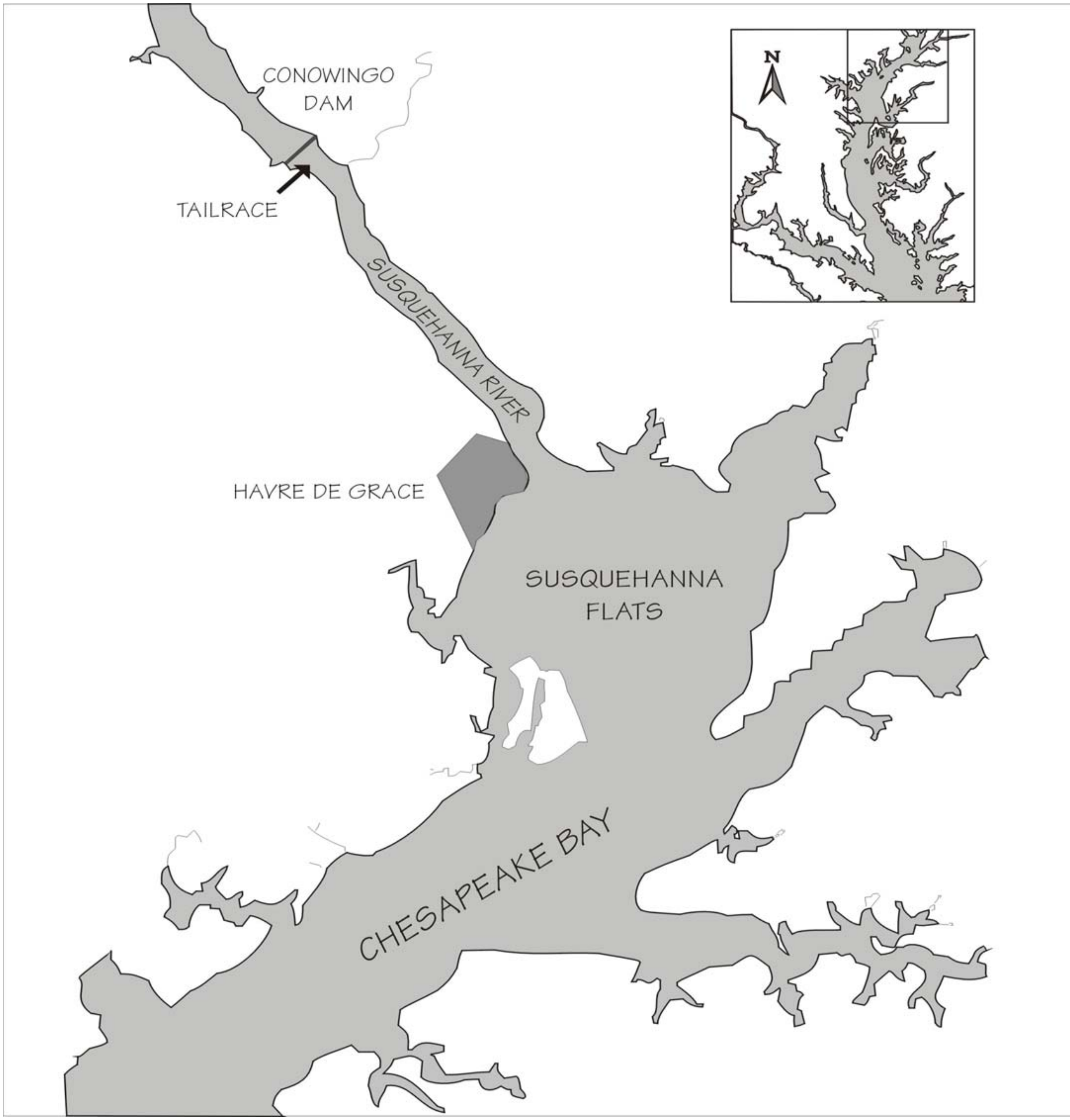


Figure 2. Distribution of the 2007 fyke and pound nets sampled on the Nanticoke River.

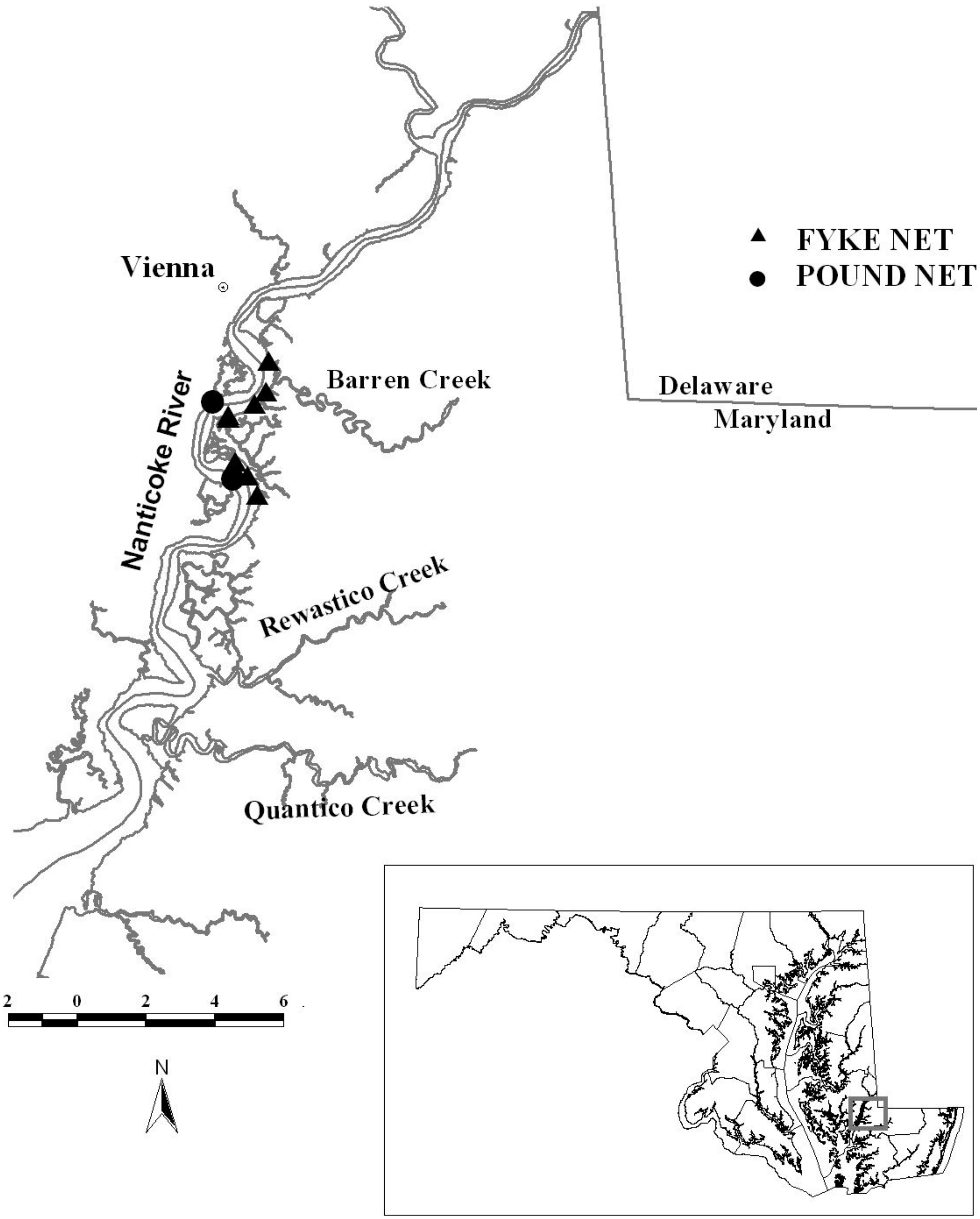


Figure 3. Distribution of the 2007 seine sites (black circles) on the Susquehanna River.

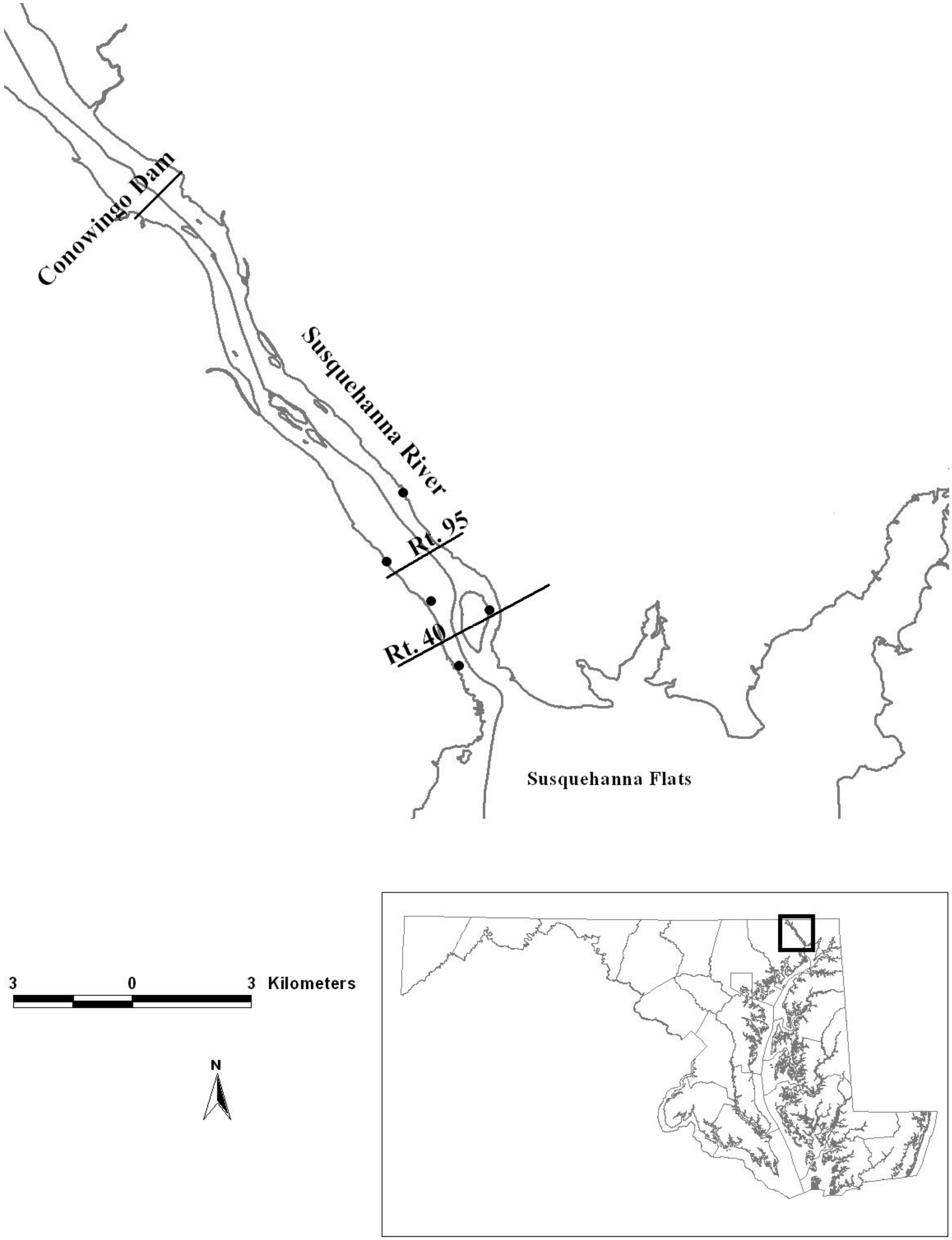


Figure 4. Distribution of the 2007 seine sites on the Chester River (black circles).

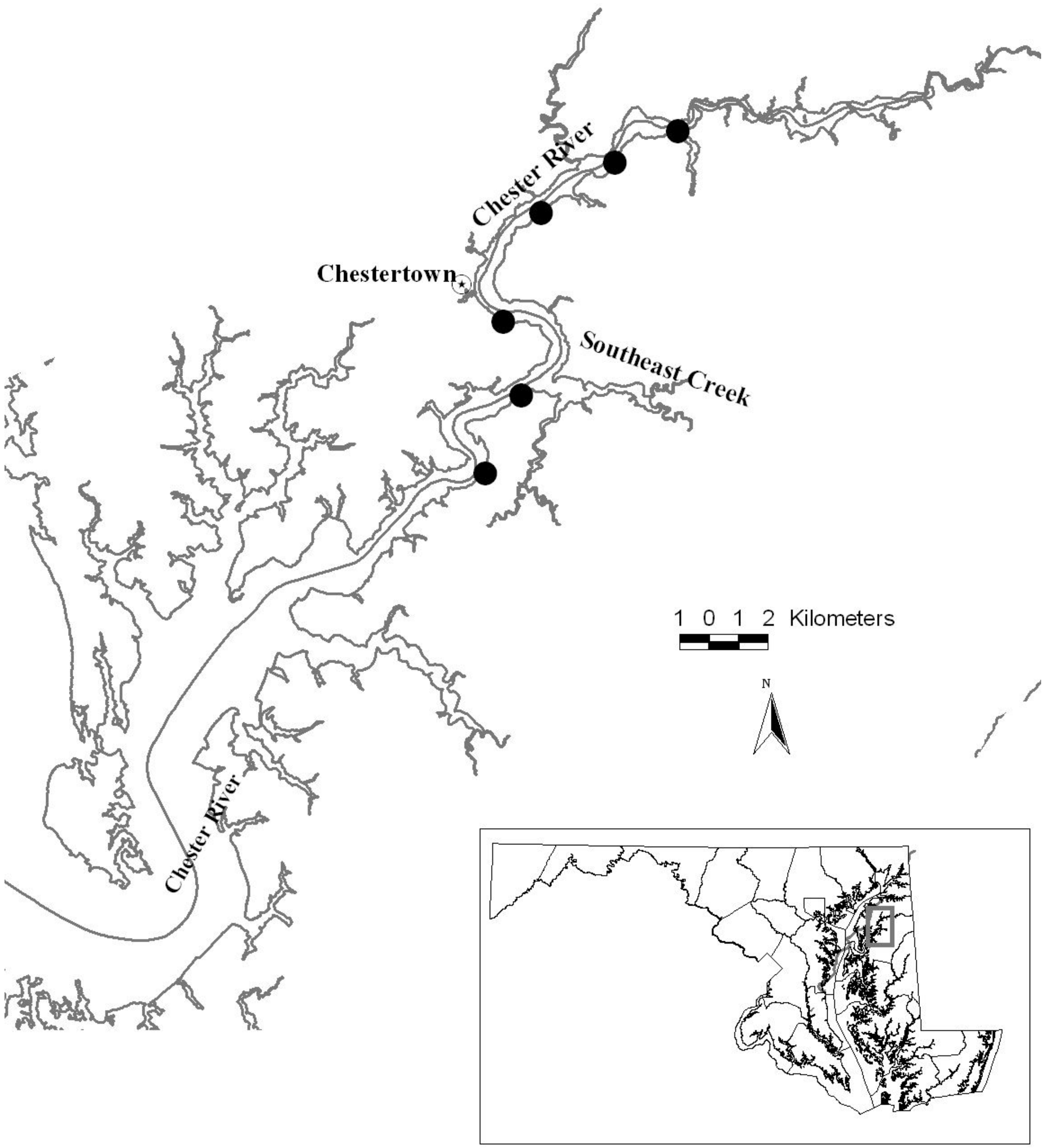


Figure 5. Distribution of the 2007 seine sites on the Pocomoke River (black circles).

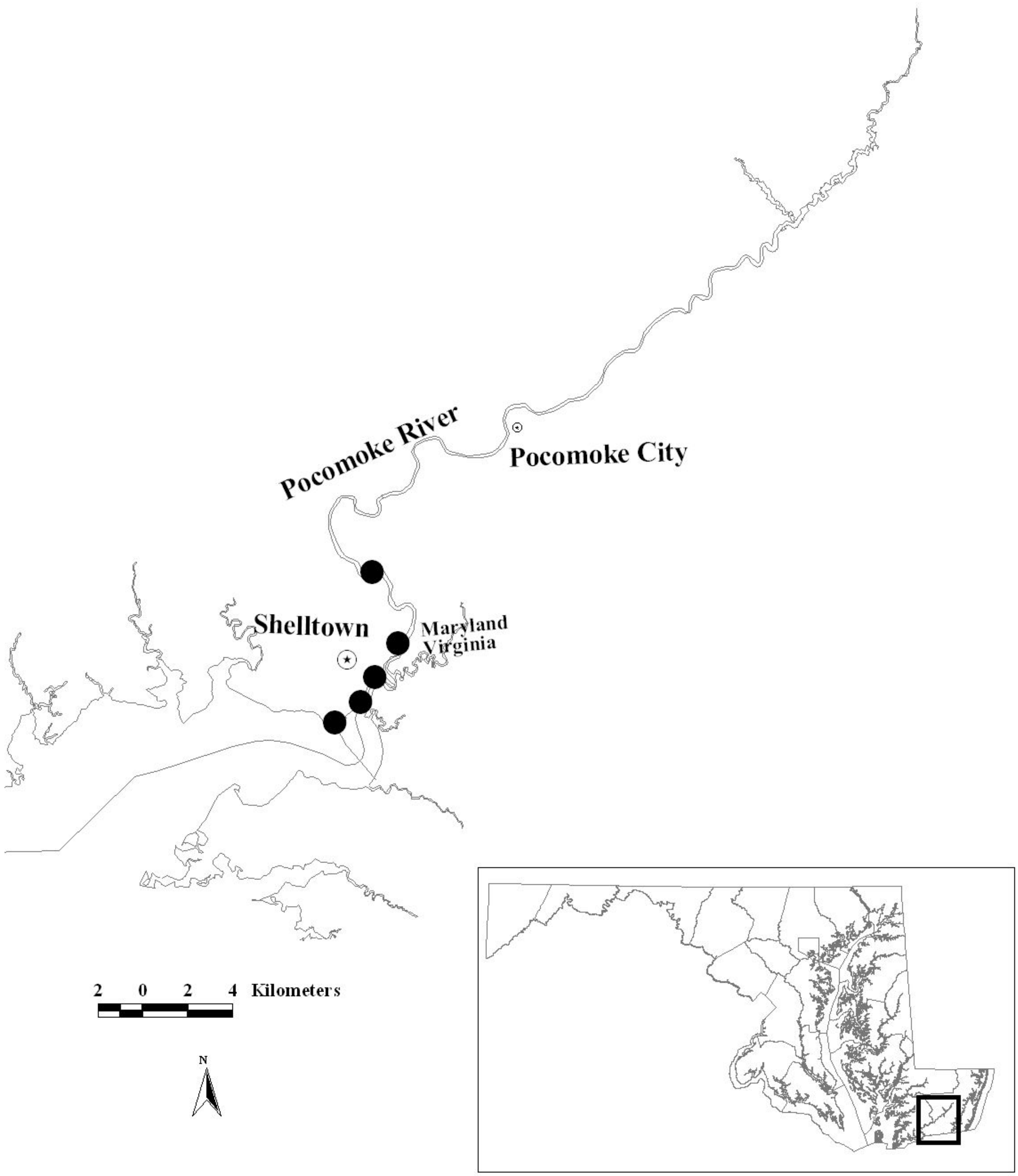


Figure 6. Distribution of the 2007 ichthyoplankton sampling sites on the Nanticoke River.

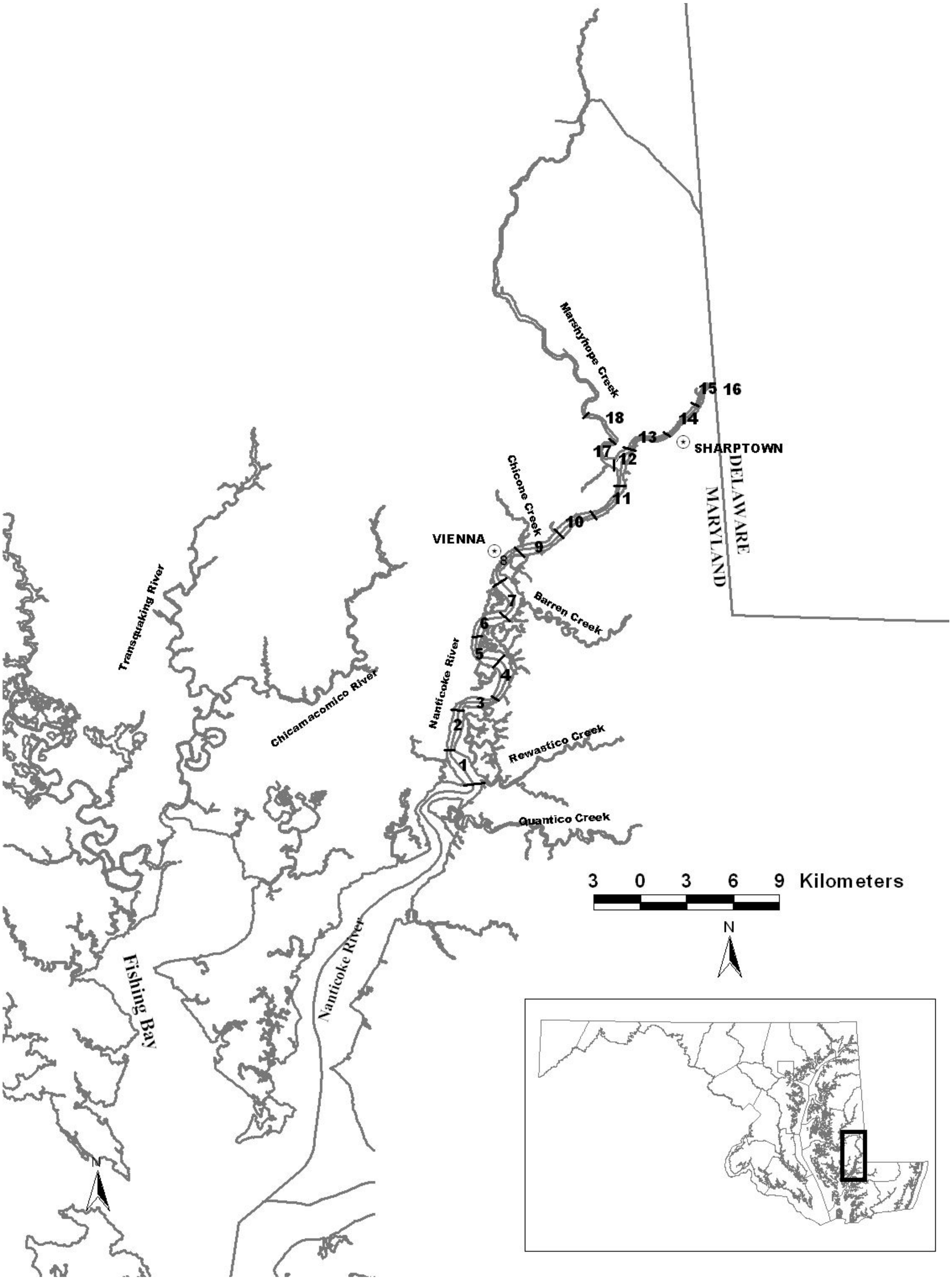


Figure 7. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2007).

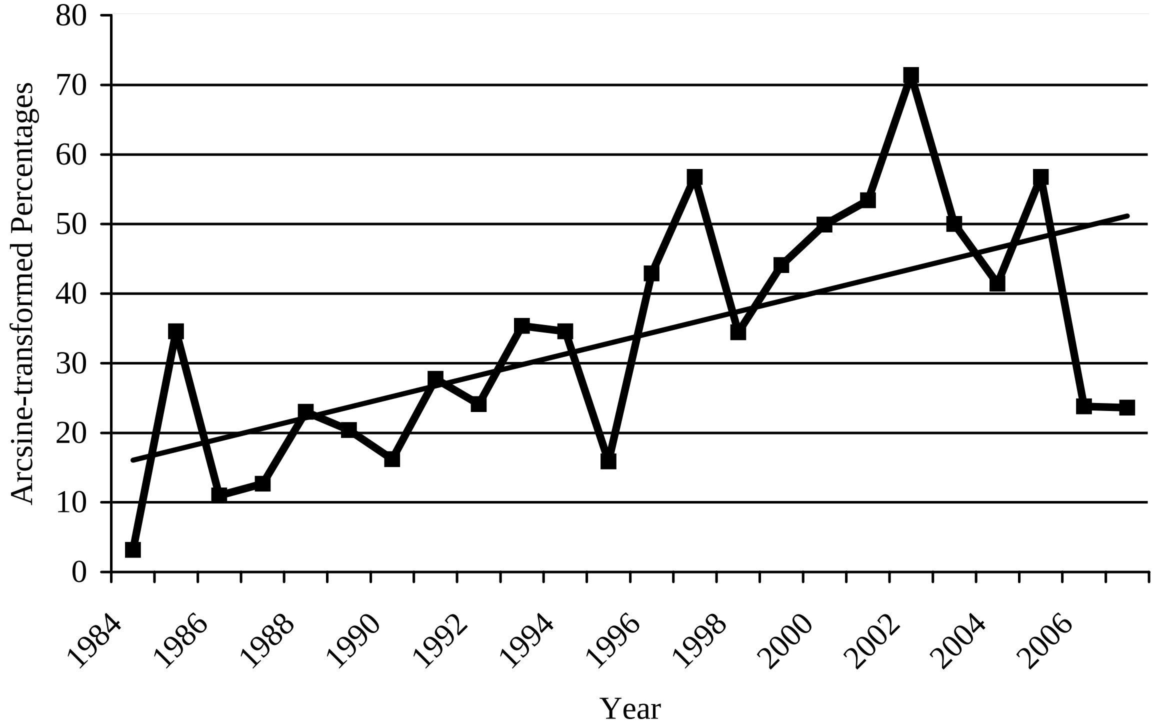


Figure 8. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River (1988-2007).

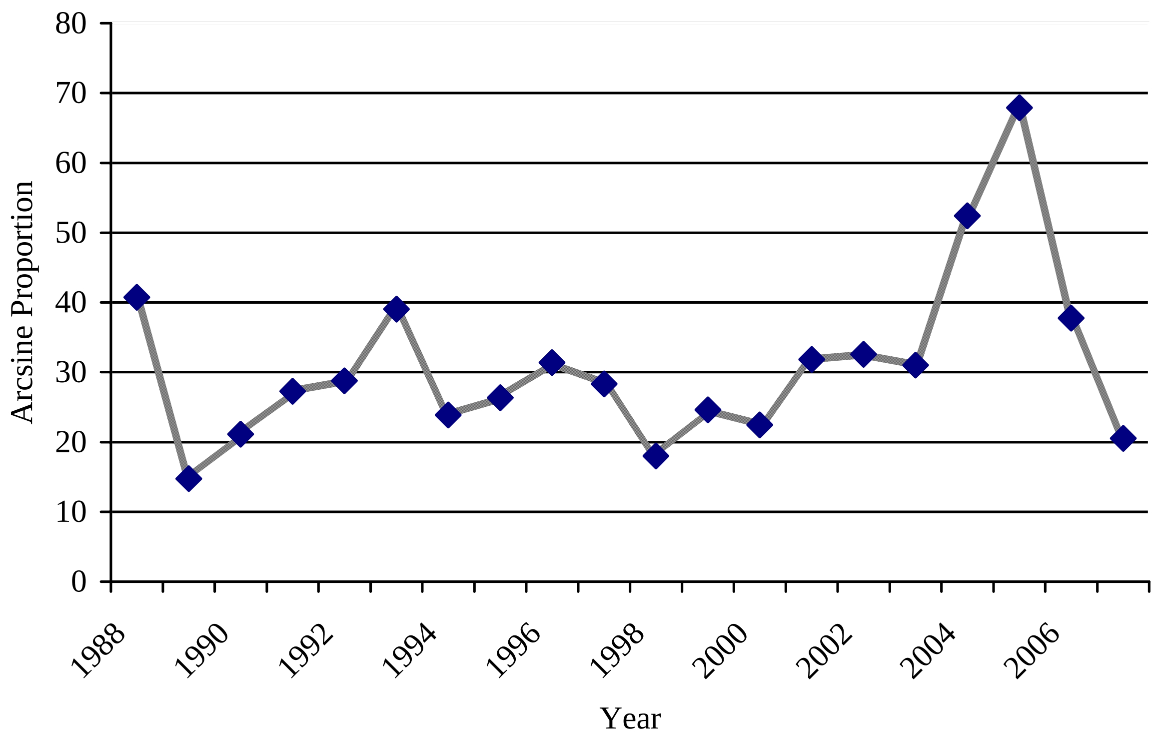


Figure 9. Conowingo Dam tailrace relative estimates of American shad abundance with 95% confidence intervals, 1984-2007.

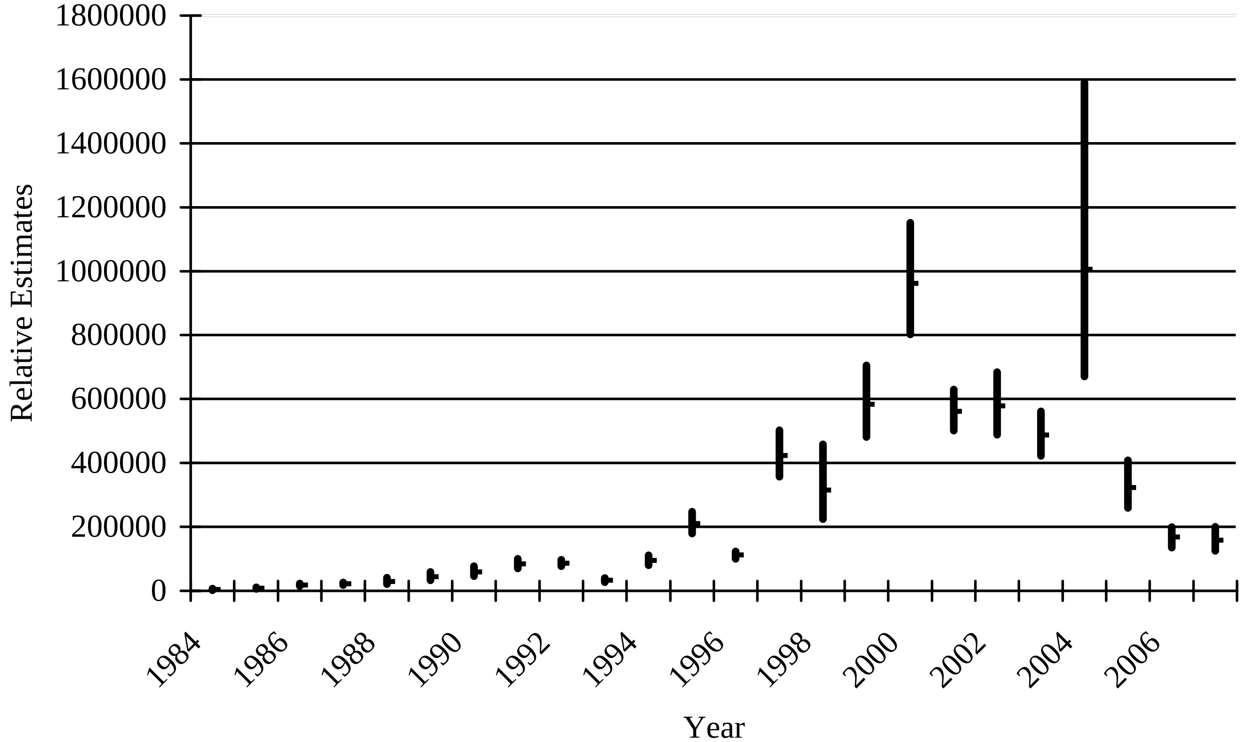


Figure 10. Geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2007.

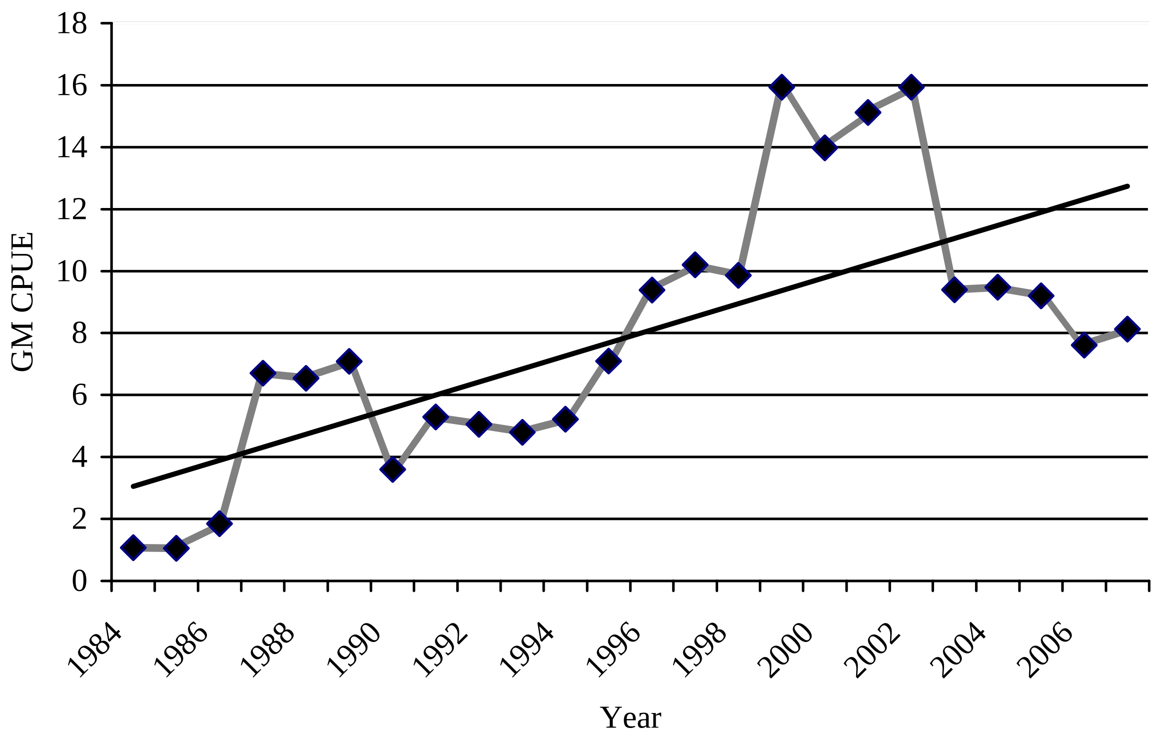


Figure 11. Geometric mean CPUE of American shad from the lifts at Conowingo Dam, 1980-2007.

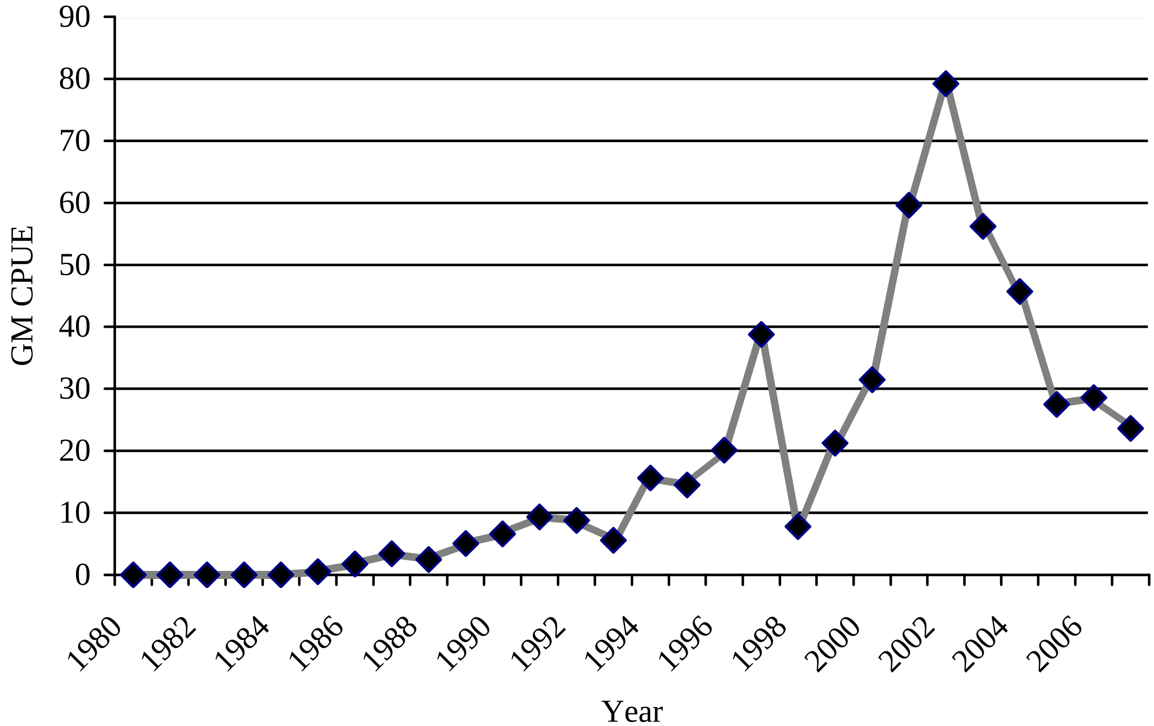
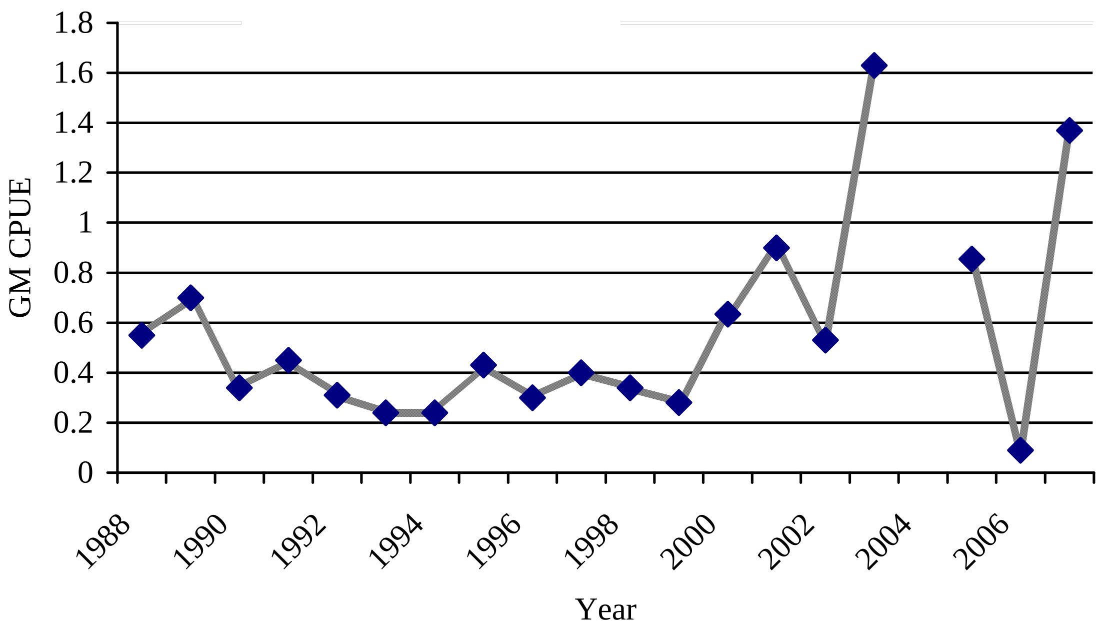


Figure 12. Pound net geometric mean CPUE for American shad from the Nanticoke River, 1988-2007. [1]



[1] No Pound nets were fished in 2004.

Figure 13. American shad geometric mean CPUE from fyke nets on the Nanticoke River.

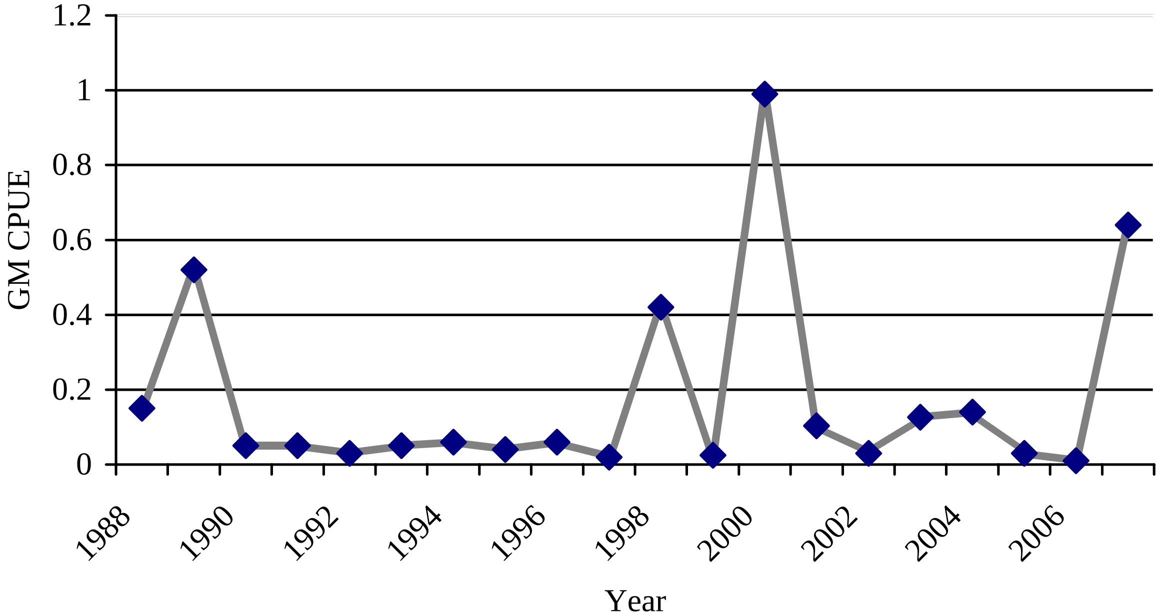
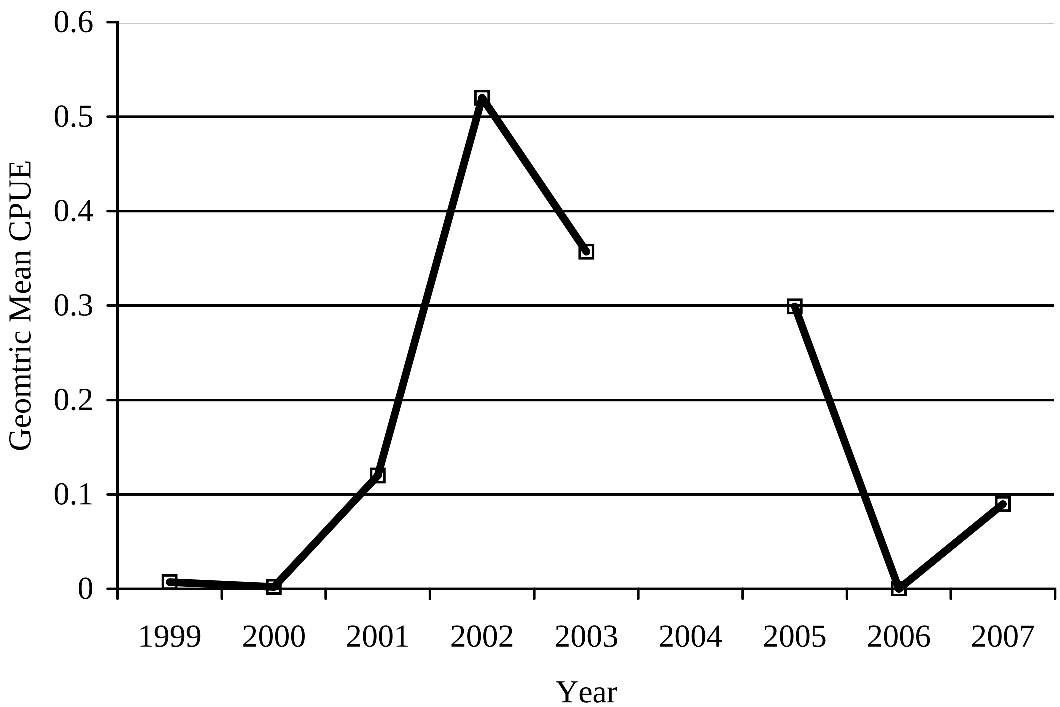


Figure 14. Adult hickory shad geometric mean CPUE from Nanticoke River pound nets, 1999-2007.[2]



[2] No pound nets were set in 2004.

Figure 15. Adult hickory shad CPUE from Nanticoke River fyke nets, 1999-2007.

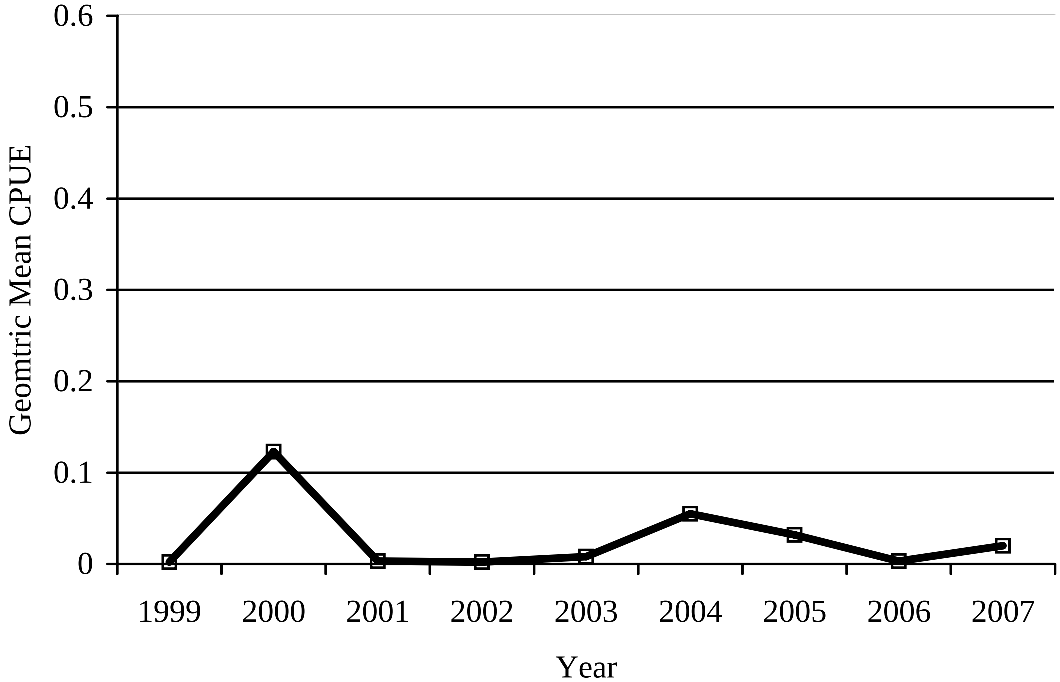


Figure 16. Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes combined) from the Nanticoke River, 1989-2007.

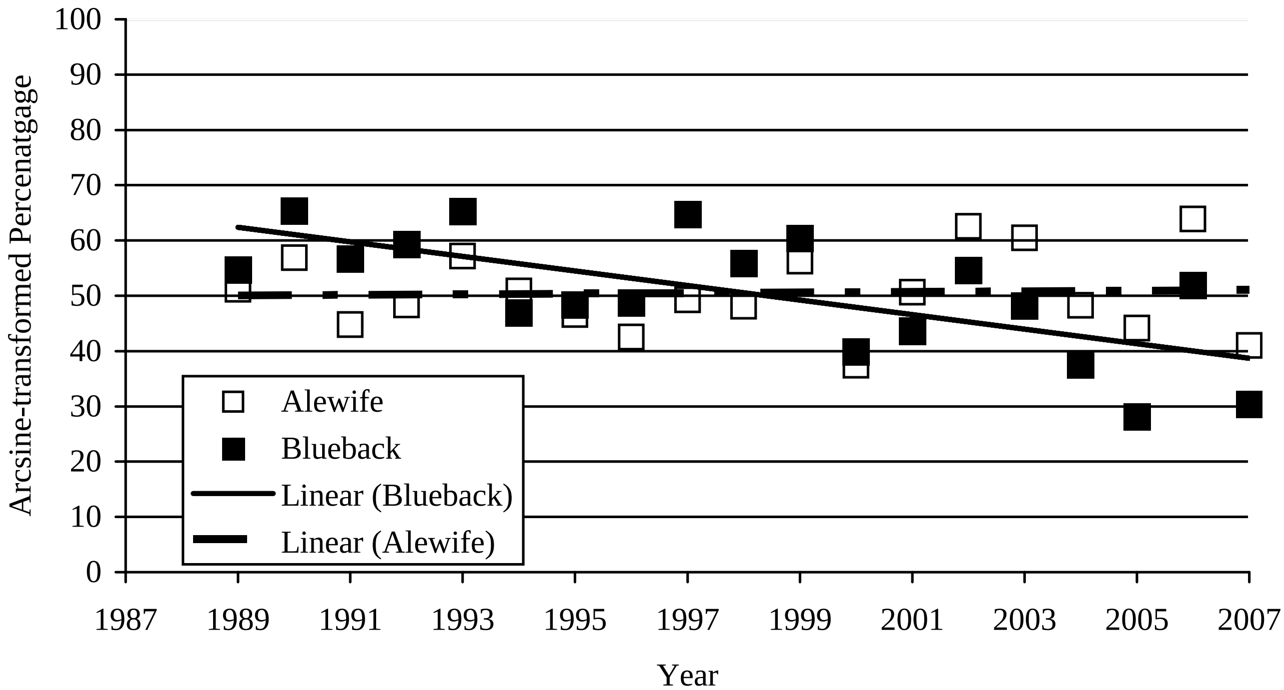


Figure 17. Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1989-2007.

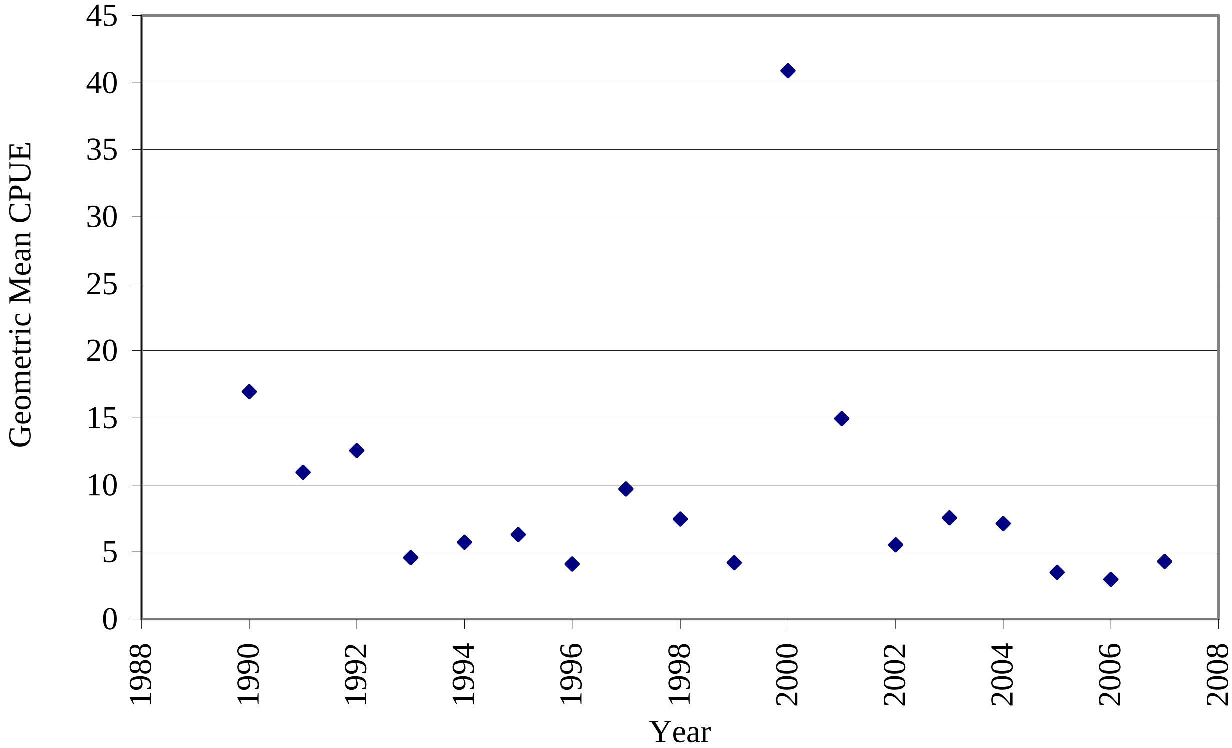


Figure 18. Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2007.

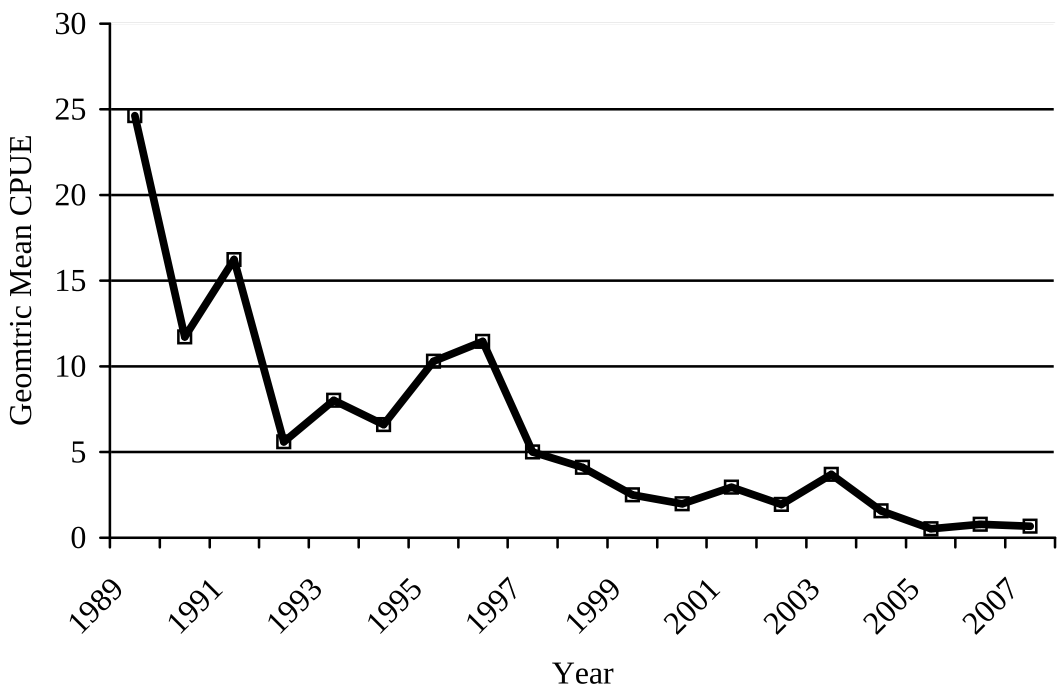


Figure 19. Regression analysis estimates of geometric mean CPUE (alewife and blueback herring combined, 1989-2007), and the total commercial river herring landings in pounds, 1980-2007 from the Nanticoke River.

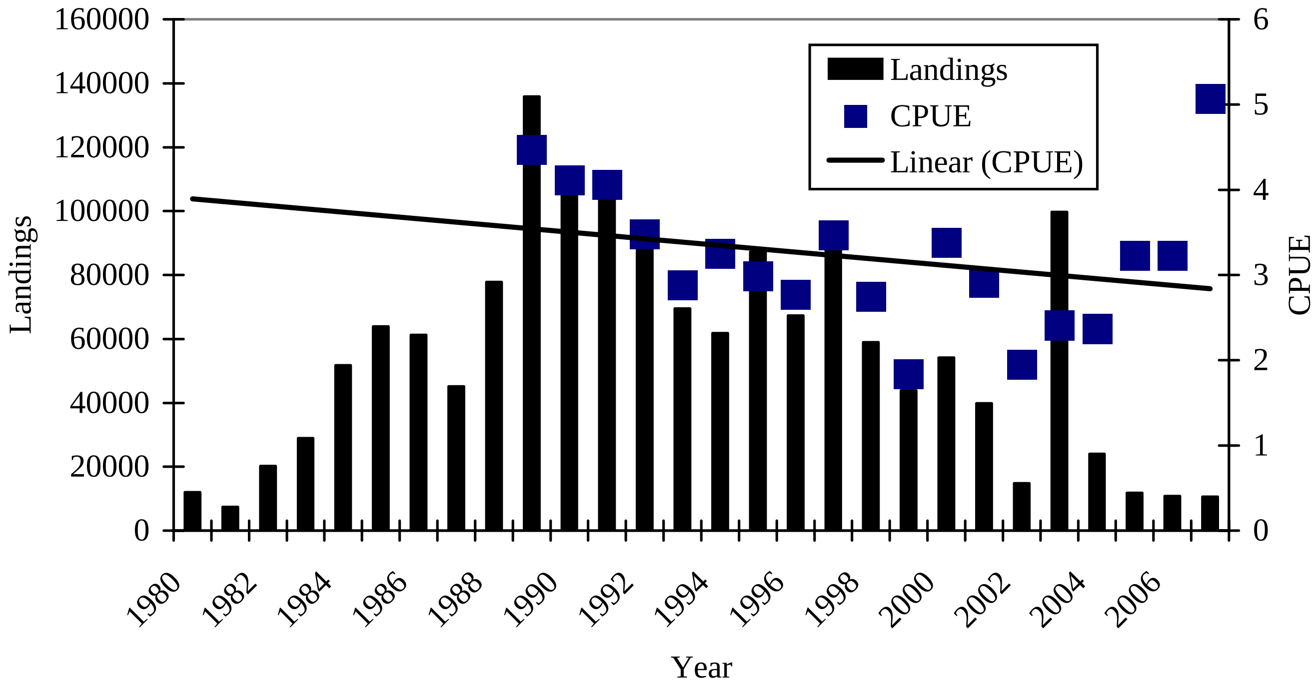


Figure 20. Instantaneous mortality (Z) of Nanticoke River alewife herring (1989-2007).

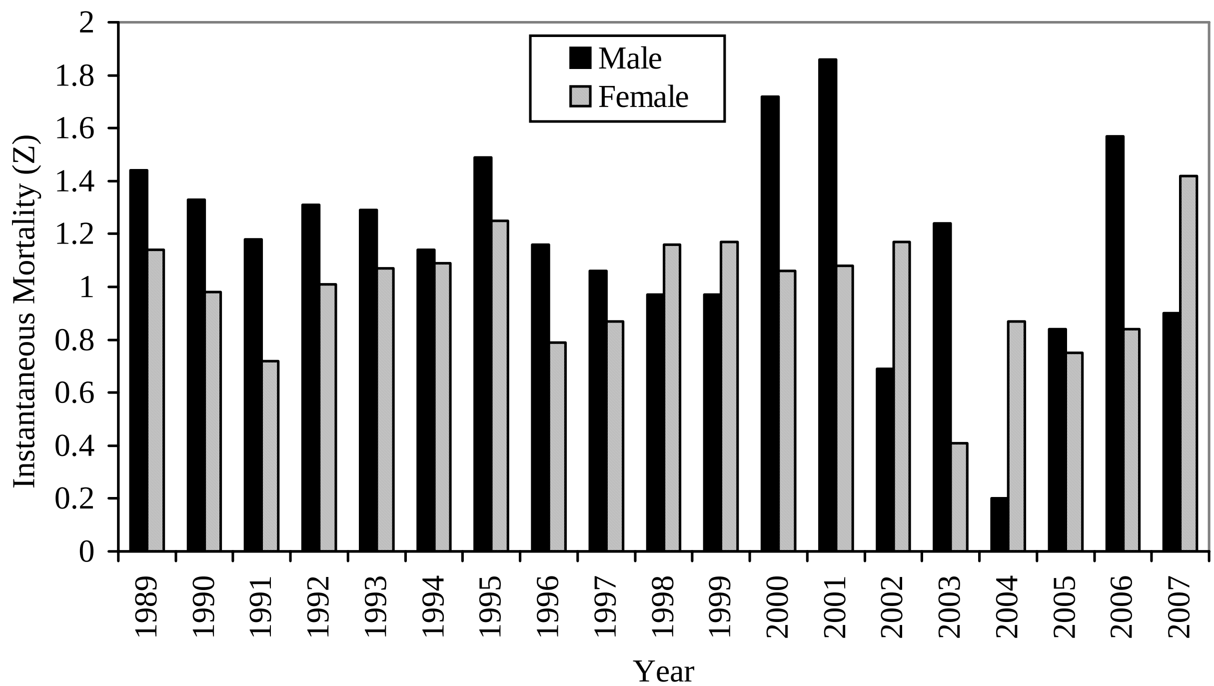


Figure 21. Instantaneous mortality (Z) of Nanticoke River blueback herring (1989-2007).

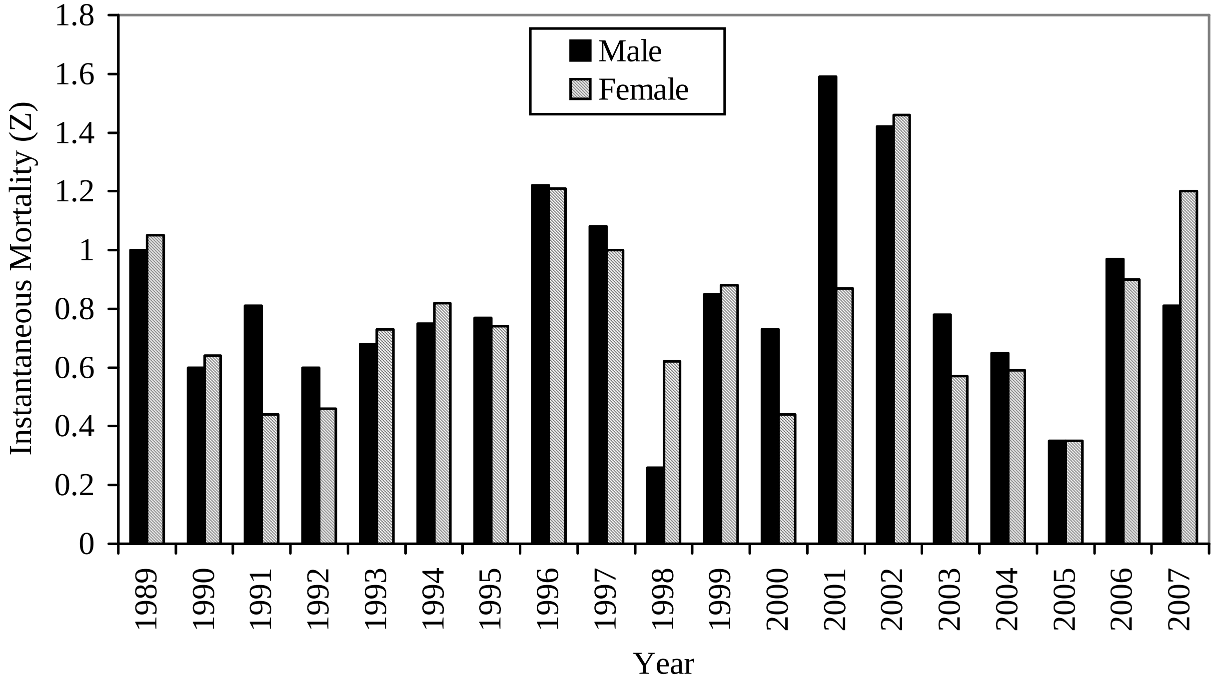


Figure 22. Baywide juvenile American shad geometric mean CPUEs, 1959-2007.

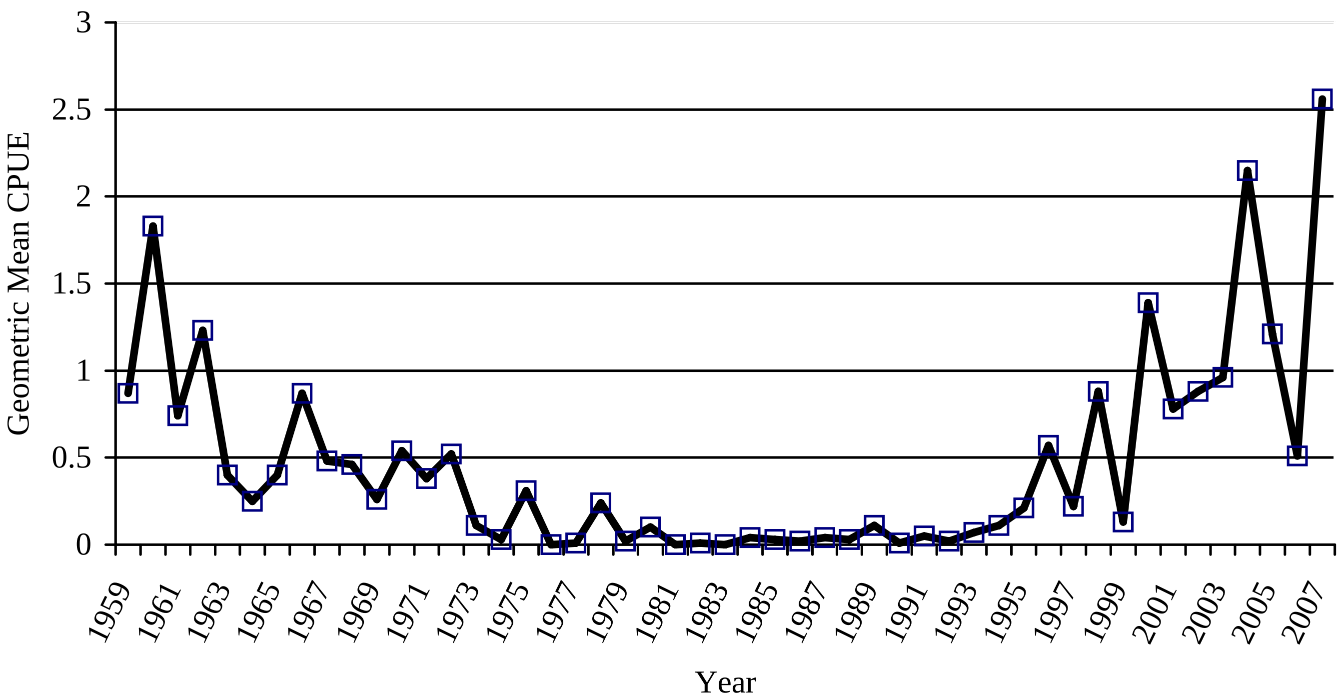


Figure 23. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1959-2007.

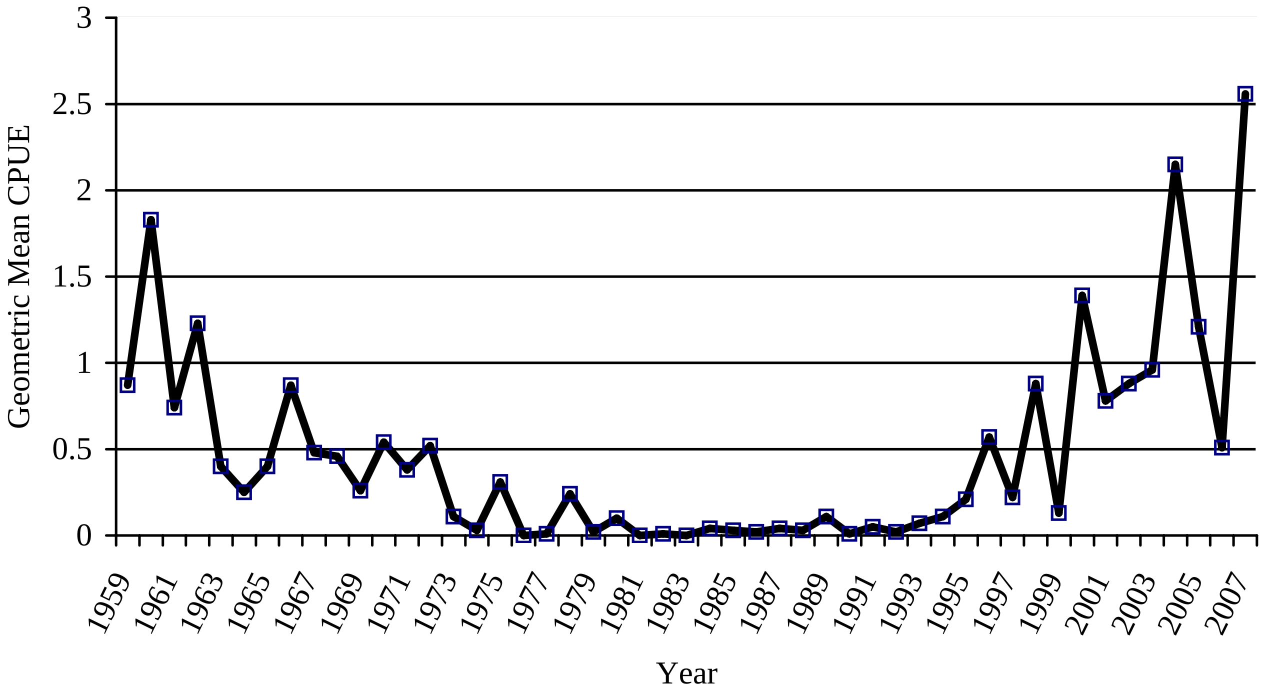


Figure 24. Potomac River geometric mean CPUEs for juvenile American shad, 1959-2007.

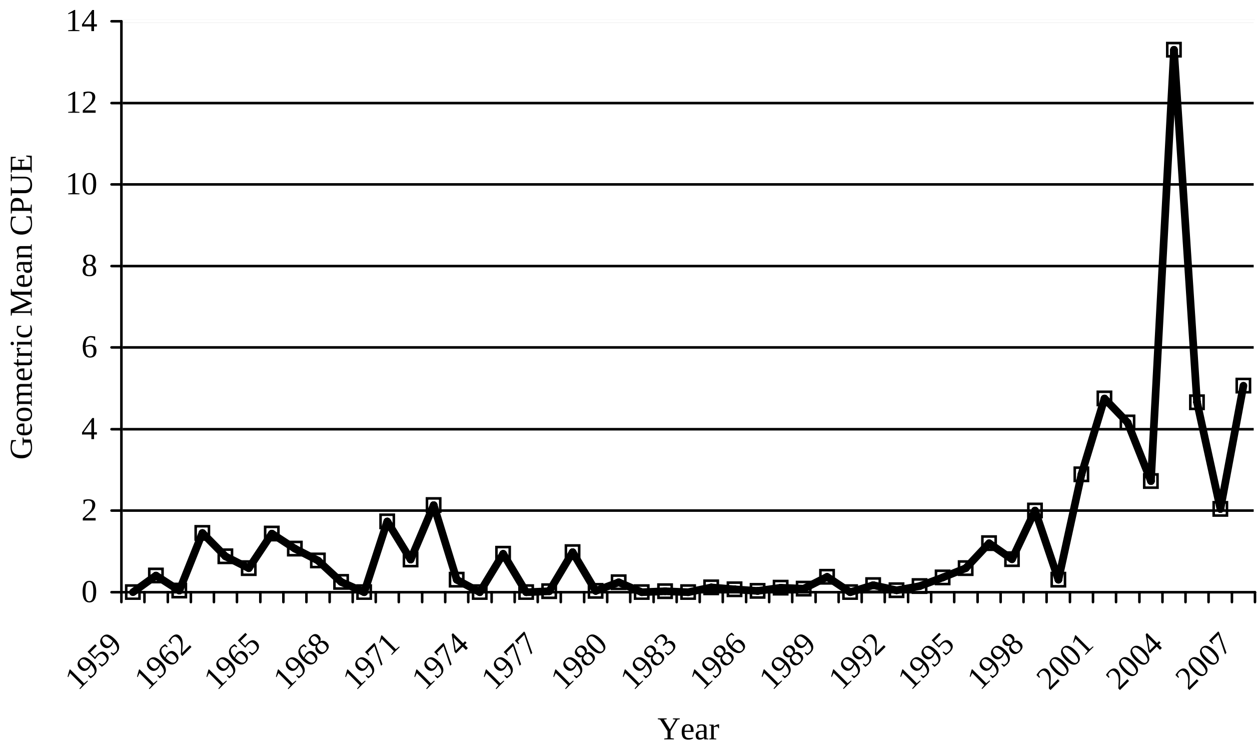


Figure 25. Nanticoke River juvenile alewife herring geometric mean CPUEs, 1959-2007.

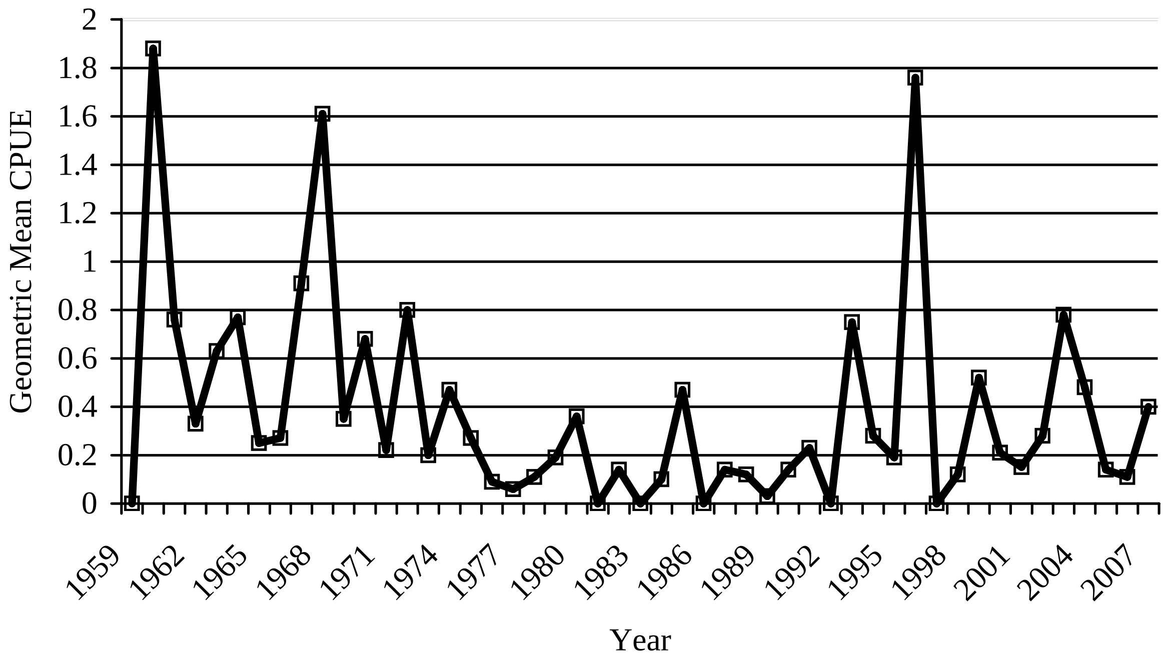


Figure 26. Nanticoke River juvenile blueback herring geometric mean CPUEs, 1959-2007.

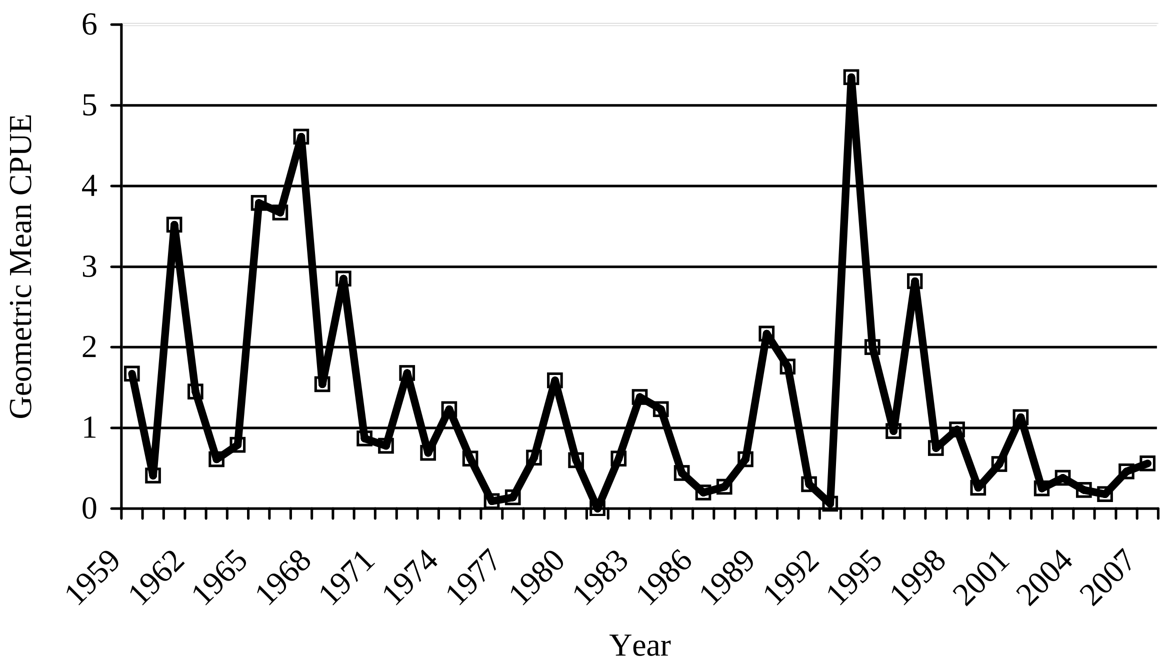
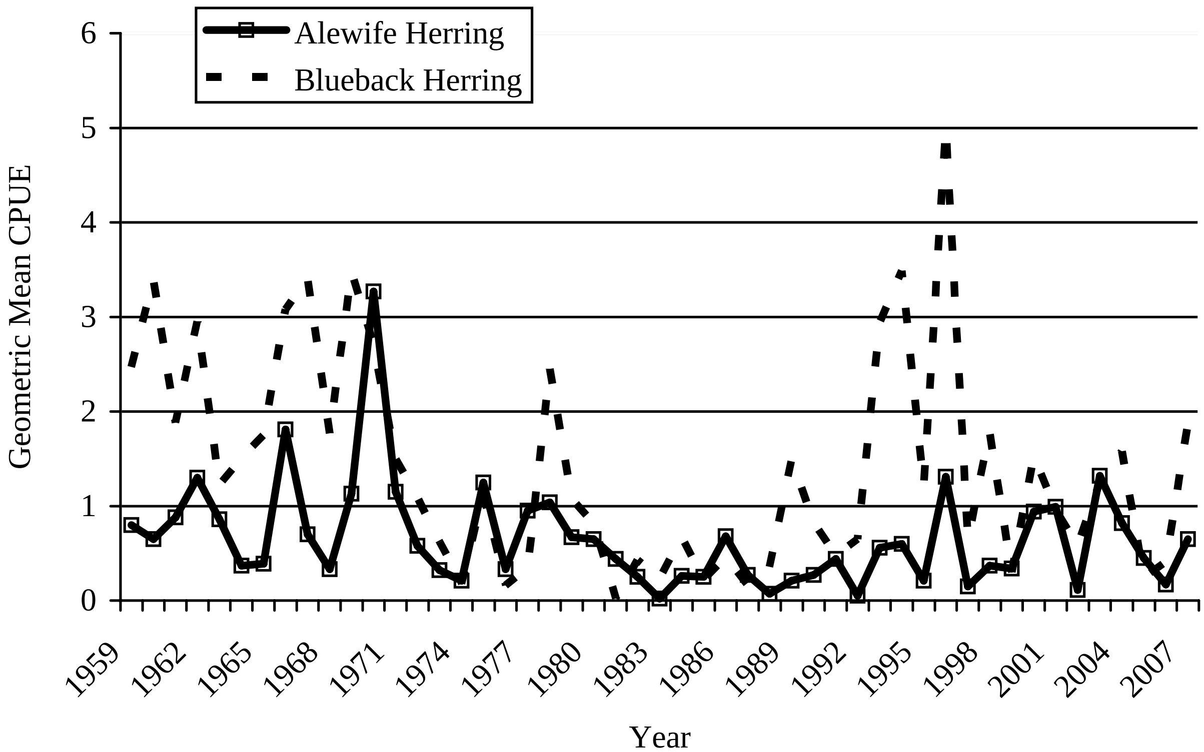


Figure 27. Baywide juvenile alewife and blueback herring geometric mean CPUEs, 1959-2007.



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, bluefish, Atlantic croaker, summer flounder and spot are very important sport fish in Maryland's Chesapeake Bay. Red drum, black drum, spotted seatrout and Spanish mackerel 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 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, Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council. 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 2007 commercial pound nets were sampled from near the mouth of the Potomac River and the lower portion of Maryland's Chesapeake Bay (Figure 1). Each area was sampled once every two weeks, weather and fisherman's schedule permitting. The lower Potomac River was sampled from May 22, 2007 through September, 4 2007, while the lower Chesapeake Bay was sampled from May 29, 2007 to September 18, 2007 (Table 1). 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. Otoliths for ageing, weight to the nearest gram, TL and sex were taken from a sub sample of weakfish and Atlantic croaker. These otoliths were processed and aged by the South Carolina Department of Natural Resources (SC DNR). Otoliths from Atlantic croaker and weakfish collected in 2006 were processed and aged by SC DNR and subsequently returned to Maryland in 2007.

Otoliths were also collected from a sub sample of spot for aging by MD DNR. Aging was not completed in time for inclusion in this report, but will be completed and added to the data base. Non-target species were noted but generally not measured or enumerated (Table 2). Water temperature (°C), salinity (ppt), GPS coordinates (NAD 83), date and hours fished were also recorded at each net.

Menhaden scales were also collected in 2006, but samples were only collected for fish over 179mm FL. These scales (n=300) were aged by two readers at MD DNR in 2007, and only those in which agreement was reached were assigned final ages (n=291).

Analytical Procedures

Commercial and recreational landings for the target species were examined from 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 2006 for this report. Landings from Maryland's 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 and Atlantic croaker from 1999-2002 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 measurements of age zero croaker from the Blue Crab Trawl Survey from June through September 2004 samples (Glenn Davis personnel communication 2007). This trawl data was included to provide age zero fish that have 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 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 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 3).

Length frequency distributions were constructed for weakfish, summer flounder, bluefish, Atlantic croaker, Atlantic menhaden and spot. Pound net length data was divided into 20 mm length groups for each species (i.e. 130 mm length group comprised fish from 130-149 mm).

A length-at-age key was constructed for weakfish and Atlantic croaker using the 2006 age samples, since 2007 samples were not processed by SC DNR in time for inclusion in this report. Age sample and length data were assigned to one-inch TL groups for each species, where the 8 inch length group would include fish from 8.00 to 8.99 inches. The measurements were then applied to the length-at-age key to determine the proportion at age for each species in 2006.

A length-at-age key was also constructed for Atlantic menhaden using the 2006 age data. Aging for 2007 fish had only been completed by one reader by the time of writing, and therefore not included in this report. Age sample and length data were assigned to 20mm FL groups beginning with the 180mm length group (180-199mm FL).

Juvenile indices were calculated for weakfish, Atlantic croaker and spot from the Maryland's Blue Crab trawl survey. The survey uses 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 is towed for 6 min at 4.0-4.8 km/h. The Chester River, Eastern Bay, Choptank River and Patuxent River each contain six fixed sampling locations, Tangier Sound five stations and the Pocomoke Sound eight stations. Each site is sampled once a month from May - October. Juvenile finfish collected by this trawl 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 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. An ANOVA and Tukey-Kramer multiple comparison and range test were used to detect differences between the standardized years (Sokal and Rohlf 1981) using SAS® software (SAS 2006).

RESULTS and DISCUSION

Weakfish

Sixty-one weakfish were present in the 2007 pound net survey, similar to the 2006 sampling season (62 fish), the lowest catch of the 15 year time series. Weakfish mean length decreased slightly in 2007 to 275 mm TL, similar to the 2004 and 2005 mean lengths (Table 4). RSDs for 2007 were similar to those of the past two years, indicating a continued dominance of RSD_{qual} fish (Table 5). However, a slight increase in 2007 RSD_{pref} weakfish compared to the 2004 - 2006 time period was noted. The 2007 length frequency distribution indicated a slight shift to smaller sizes compared to 2006, with over 76% of sampled weakfish between 230 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 - 2007, with far fewer large weakfish encountered. Ninety-three percent of weakfish sampled in 2007 were below the recreational size limit of 331 mm TL (13 inches), and 90 percent were below the commercial size limit of 305 mm TL (12 inches).

In 2006, females accounted for 45% of fish sampled (n=27). Female mean TL and mean weight were 295 mm TL and 249g respectively, while males averaged 285 mm

TL and 222g. 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 appeared to have decreased from 2006 to 2007, but these differences may be artifacts of small sample sizes.

Total commercial landings (Chesapeake Bay and Atlantic Ocean) in 2006 rose slightly to 32,417 pounds, but the Chesapeake Bay portion of those landings accounted for only 1,131 pounds (Figure 3). Total 2006 landings were the third lowest of the 77 year time series and well below Maryland's average of 660,058 pounds per year. The 2006 commercial landings for Chesapeake Bay were the lowest since 1969 and have declined every year since 1998. Maryland recreational anglers harvested an estimated 493 weakfish during 2006, weighing 602 pounds (MRFSS 2007; Figure 4). The number of weakfish harvested by the recreational fishery in 2006 decreased 96% from 2005 estimate (22,164). Maryland anglers released 57,466 weakfish in 2006, a slight increase from 2005 (55,270). Estimated recreational harvest has decreased steadily every year since 2001.

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. However, 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. The 2007 GM of 1.6 decreased from 2006 (2.4), and was the 6th lowest value in the 19-year time series (Figure 5). The 2007 mean of $\log_e$-transformed catches was significantly less than in 1995, 1996 ,2000 and 2001, as determined by Tukey-Kramer multiple comparison and range test (ANOVA $p<0.001$; SAS 2006).

Otoliths from 62 weakfish were aged for 2006, with only ages 0 through 4 present (Table 6). Age composition, based on the 2006 age length key, was 1.6% age 0, 64.5% age one, 21% age two,11.1% age three and 1.6% age 4 (Table 6). This represented a shift to younger fish as compared to 2005, when age one fish accounted for only 37% of the sample and age two comprised 60% of the sample. Sixty-one weakfish were sampled for age in 2007, but ageing has not been completed at this time.

Instantaneous total mortality estimates were Z=1.35 in 2006 and Z=1.44 in 2005 (Table 7). A mortality estimate for 2007 was not calculated due to extremely low sample size. 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 increased in 2002 and 2003, but not to a level that would cause stock decline. The ASMFC stock assessment committee believes this evidence points to an increase in natural mortality as the primary causative agent in the recent weakfish stock decline.

Summer flounder

Summer flounder mean lengths have varied widely the past three years. 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 6^{th} highest mean length (341 mm TL) in 2007 (Table 4). Relative stock densities in 2007 indicated a shift up from the stock category to the quality category compared 2006 (Table 8). The 2007 $RSD_{preferred}$ and $RSD_{memorable}$ values were similar to those of 2006. The 2007 length frequency distribution indicated an increase in flounder from the 270 – 350 mm TL size groups with a corresponding decrease in smaller flounder compared to 2006 (Figure 6). The shift away from a bimodal distribution coupled with the increase in mean size, an increase in moderately sized fish, and a decrease in RSD_{stock} suggests the large 2006 year-class became a dominate component of the 2007 pound net catch. However, the majority of these fish were below the 356 mm TL minimum commercial size limit.

Maryland's commercial summer flounder harvest was 167,972 pounds in 2006, the 7^{th} lowest in the 45-year time series (Figure 7). The long-term commercial harvest average, 1962 – 2004, is 439,821 pounds. In recent years the commercial flounder fishery has been managed by quota. From 2001 to 2004 Maryland harvested 91 to 100 percent of its allotted quota, but only harvested 75% in 2005 and 61% in 2006. The majority of the Maryland commercial harvest comes from the Atlantic Ocean and coastal bays. The recreational harvest estimate of 58,413 fish caught was the 2^{nd} lowest estimate of the 1981-2006 time series (MRFSS 2007; Figure 8). Recreational releases, estimated by MRFSS at 510,970 fish, were in the middle of the range during the same time period. The 2006 estimate represented an increase of 18% from 2005 (Figure 8). The increased incidence of small flounder in the 2006 pound net length frequency distribution is consistent with the large increase in estimated recreational flounder releases in 2006, as these fish would have been bellow the recreational minimum length limit.

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. Recruitment was below average at 25 million fish in 2003 (long-term average = 35 million), average in 2004 at 35 million fish, but well below the long term 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 0.9 to 2.2 during 1982 - 1997, but then fell from approximately F=1.2 in 1997 to F=0.46 in 2003. Fishing mortality 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 during 2001 suggested decreased F and increased SSB. The lower mean length in 2002 could be a signal of increased juvenile survival in recent years, while the increase in mean length in 2005 is 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 318 mm TL during 2007, a slight increase from the 2006 mean of 311 mm TL, and similar to the 2003 mean length of 320 mm TL (Table 4). The 2007 mean length ranks 6th highest for the 15 year time series. The 2007 bluefish RSD_{stock} value was similar to that of 2006, but a small shift up from RSD_{qual} to $RSD_{preferred}$ and $RSD_{memorable}$ did occur (Table 9). Bluefish length frequency distribution in 2007 indicated a reduction in fish less than 229 mm TL compared to the previous three years, but did include more fish greater than 549 mm TL (Figure 9). More than 60% of sampled bluefish in 2007 were between 230 and 329 mm TL.

The 2005 through 2007 samples indicated a shift to a larger grade of bluefish, but RSD_{stock} values (79%, 95% and 94% respectively) indicated that small fish still dominate the population. 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 decreased 50% in 2006 to 46,955 pounds, well below the 1929-2006 average of 176,179 pounds (Figure 10). The 2006 catch was the 12th lowest of the 77-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 similar. Recreational harvests estimates for bluefish were high through most of the 1980's and have since remained stable at a lower level (MRFSS 2007; Figure 11). The 2006 estimate of 511,767 fish harvested was below the time series average of

932,755 fish (Figure 11). Estimated recreational releases increased in 2006 to 850,496 fish, the 4th highest estimate of the time series.

The latest NMFS stock assessment of Atlantic coast bluefish using 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 lengths were similar in 2006 and 2007, increasing slightly from 304 to 307 mm TL, and were, respectively, the 6th and 5th highest means of the 15 year time series (Table 4). RSDs for Atlantic croaker indicated a continued dominance of $RSD_{preferred}$ and $RSD_{memorable}$ fish and the time series high of RSD_{trophy} fish, following the fifth consecutive annual increase in 2007 (Table 10). $RSD_{quality}$ decreased while $RSD_{preferred}$ increased in 2007, most likely indicating continued influence from the 2005 year-class. Length frequency distributions from 2003 – 2005 demonstrated the influence of the strong 2002 year-class, with the mode of each distribution increasing as the year-class ages (Figure 12). In 2006, a secondary peak of 190 mm TL croaker indicates some recruitment from the 2005 year-class. Croaker were most prevalent in the 250 and 270 mm TL length groups in 2007 with a secondary peak around 350 mm TL, representing the 2005 and 2002 year classes respectively (Figure 12).

In 2006, females accounted for 65% (n=164) of the pound net catch and averaged 337 mm TL and 616g, while males averaged 303 mm TL and 427g in weight (n=90). The 2007 sex ratio shifted even farther with females comprising 78% of the sample. 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).

During 2006, Maryland Atlantic croaker total commercial harvest (Chesapeake Bay and Atlantic Ocean) was 344,318 pounds, down 64% from 2005 (Figure 13), and well below the 1929-2006 average of 1,199,272 pounds. Chesapeake Bay commercial landings decreased 72% in 2006. Recreational harvest in 2006 was estimated at 834,894 fish, similar to the past two years (MRFSS 2007; Figure 14). The 2006 recreational releases increased 47% from 2005(MRFSS 2007; Figure 14), and both the recreational harvest and release estimates were above the 1981-2006 averages. Recreational harvest was greater than commercial harvest during 1992 – 1995, 1998 – 2000, 2003 and 2006. While commercial harvest exceeded MRFSS estimates for 1996, 1997, 2001 – 2002 and 2004 – 2005.

The Atlantic croaker juvenile trawl index for 2007 was the third lowest of the 19 year time series (Figure 15), and was significantly lower than 10 other years, as determined by Tukey-Kramer multiple comparison and range test (ANOVA $p<0.001$; SAS 2006). The indices for the past few years have been lower than those of the late 1990s. 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 2006 Atlantic croaker otoliths ranged from age 1 to 13 (n=253), with no age 10-12 fish present (Table 11). The number of Atlantic croaker captured from pound nets in 2006 (n=1,295) was applied to an age-length key for 2005. This application indicated that 36% of the fish were age four, 18% were age two, and

16% were age zero. Age groups one, three, seven and eight each accounted for five to six percent of the fish sampled (Table 12). In 2004, age two accounted for 55% of the sampled fish and in 2005, age three accounted for 55% making the 2002 year-class the dominate cohort for the past three years. Two hundred seventy-seven Atlantic croaker otoliths were collected in 2007, but ageing had not been completed at this time. Instantaneous total mortality in 2007 was Z=0.40 a slight increase from 2006 and the same as 2005 (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 followed with the time series minimum of F=0.03 in 1992. F rose gradually until 1997 were it has remained stable, averaging F=0.10 from 1997 – 2002. SSB estimates from 1992 through 2002 were the highest of the 30-year time series. The conclusion drawn was that the north Atlantic component of the stock is not overfished. F was estimated to be below target and threshold values and SSB above target and threshold values.

Spot

Spot mean length in 2007 was 208 mm TL, ranking in the middle of the 15 year time series (Table 4). The length frequency distribution in 2007 was somewhat truncated, with fish between 190 and 229 mm TL accounting for 63% of the catch (Figure 16). Percent jumbo spot remained low in 2007, with less than 1% of the 2007 sample comprised of spot >254 mm TL (<2% in 2006, 3% in 2005, 13% in 2004 and 10% in 2003).

Commercial harvest fell 66% in 2006 to 28,785 pounds, well below the long-term average (1929 – 2006) of 139,826 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 catches 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. Recreational harvest data from MRFSS indicated that spot harvest since 1981 in Maryland has been variable (MRFSS 2007; Figure 18). Recreational harvest varied from 300,000 fish in 1988 to 3,800,000 fish in 1986, while the number released varied from 200,000 in 1999 to 2,700,000 in 1986 (Figure 18). Contrary to the commercial harvest the 2006 recreational harvest estimate increased to 2,654,033 fish, the fifth highest of the 26 year time series. The release estimate of 1,470,847 fish was also relatively high, and above the long term mean of 1,060,024.

The spot juvenile trawl indices from 1989-2007 were quite variable, with generally higher values in the earlier part of the time series and low values from 2001-2004 (Figure 19). The 2007 GM of 14.1 fish per tow was significantly higher than 10 other years, and was significantly lower than 4 years, as determined by Tukey-Kramer multiple comparison and range test (ANOVA $p<0.001$; SAS 2006).

Pound net spot length-frequency indicated a higher proportion of larger fish during 2001, contracting in 2002, before expanding slightly in 2003 and 2004. 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 2007, could be indicating growth overfishing of the stock. However, recreational harvest and release estimates have been high the past two years. Virginia and North Carolina recently voiced a concern over decreasing spot harvest in their waters, and ASMFC's spot Plan Review Team is currently examining catch and biological information to determine 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 only 2 fish being examined in 2007. 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).

Maryland commercial red drum harvest in 2006, all from the Atlantic coast, totaling 8 pounds, compared to 1,161 pounds in 2002, the second lowest since 1991 (Figure 20). This drop 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 keep one fish over 27 inches per day. Most of these fish were much greater than 27 inches and consequently led to higher landings by weight.

The MRFSS (2007) estimated that recreational fishermen harvested 7,118 fish and released 11,282 red drum in Maryland during 2006 (Figure 21). These estimates have been extremely variable, with estimates of zero catch made for 14 of the 26 years of the 1981 - 2006 time series. Recreational harvest peaked in 1986 at 12,804 fish, while the number of releases peaked in 2002 at 18,412 fish (Figure 21).

Black Drum

Black drum are only occasionally encountered during MD DNR pound net sampling, with only nine being captured in 2007 (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 on the Atlantic coast (Figure 22). Recreational harvest and release estimates from 1981-2005 have been variable ranging from zero, for seven years, to over 13,000 fish in 1984 (MRFSS 2007; Figure 23). From 1995 to 2005 recreational catches have been somewhat more consistent, with fish being harvested, released or both in each year. In 2006 MRFSS estimated 597 black drum were harvested with no releases.

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 length has ranged from 208 – 681 mm FL. Mean length for 2007 was 436 mm FL a slight decline from 439 mm FL in 2006, but still the third highest of the 12 years FL was taken (Table 4). The number of mackerel measured has been low for most years with the largest samples occurring during the past three years (Table 4).

The 2006 commercial harvest of Spanish mackerel in Maryland was 278 pounds a sharp decline compared to recent landings (Figure 24). The 1965 – 2004 average harvest was 6,408 pounds, but harvest was very low from 1965 – 1986 with no catches greater than 3,600 pounds and six years of zero harvest. Commercial harvest has been somewhat more stable since 1987 with a peak of 62,688 pounds in 1991. The majority of mackerel harvest has come from Chesapeake Bay since 1996, but the opposite was true from 1987 – 1995. Recreational harvest estimates peaked in the early to mid 1990's with three years of harvest of approximately 40,000 fish (MRFSS 2007; Figure 25). This followed a period of seven out of ten annual estimates with zero fish captured. Harvest estimates for 1998 – 2006 were variable, ranging from 0 – 20,792 fish with an average of 7,539 fish taken. In 2006, 3,188 fish were harvested, a decline from the 2005 estimate of 21,065 fish (Figure 25).

Spotted Seatrout

Pound net sampling rarely captures spotted seatrout. Only 3 were measured in 2007, the only ones encountered since 1999 (Table 4). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 8,398 pounds from 1991-2006 (Figure 26). Reported 2006 harvest was 295 pounds a decline from 2005 (2,339 pounds). Recreational harvest estimates indicated a modest fishery in the mid 1980's and mid 1990's. Catches become very low to nonexistent from the late 1990's to 2005, with a slight upswing in 2006 (MRFSS 2007; Figure 27). The 1981-2006 average recreational harvest was 15,196 fish, with a 2006 harvest of 5,136 fish and release estimate of 9,721 fish.

Atlantic Menhaden

Mean FL for Atlantic menhaden sampled from commercial pound nets in 2007 was 243 mm FL compared to 238 mm FL in 2006 and 282 mm FL in 2005 (Table 4). The 2006 and 2007 menhaden length frequencies were very similar and robust compared to 2005 (Figure 28). Ages derived from 2006 Atlantic menhaden scales ranged from age 1 to age 6 (n=391; Table 13). Only menhaden greater than 179 mm FL were aged. Applying the number of Atlantic menhaden greater than 179 mm FL captured from pound nets in 2006 (n=787) to an age-length key for 2006, indicated that 38% of the fish were age one and 30% were age two, while the proportion of age groups three through six decreased steadily (Table 14). Scales were taken from 400 fish for age determination in 2007, but ages are not available at this time.

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 1935-2006 was 3.8 million pounds. The 2006 commercial harvest was 4.5 million pounds, with 3.9 million pounds coming from the Chesapeake Bay. The vast majority of Maryland's annual menhaden landings come from the Chesapeake Bay (Figure 29).

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Table 1. Areas sampled, number of nets sampled, mean water temperature and mean salinity by month, 2007.

Area	Month	Number of Nets Sampled	Mean Water Temp. (C)	Mean Salinty (ppt)
Point Lookout	May	1	18.3	10.6
Barren Island	May	2	21.6	11.6
Cedar Point Hollow	May	0		
Point Lookout	June	2	23.0	12.3
Barren Island	June	6	24.2	12.3
Cedar Point Hollow	June	1	24.4	11.9
Point Lookout	July	3	26.1	14.0
Barren Island	July	6	26.3	14.0
Cedar Point Hollow	July	0		
Point Lookout	August	1	26.5	16.2
Barren Island	August	4	26.8	15.8
Cedar Point Hollow	August	1	27.7	15.3
Point Lookout	September	1	26.2	16.7
Barren Island	September	3	22.5	18.0
Cedar Point Hollow	September	0		

Table 2. List of non-target species observed during the 2007 pound net survey.

Atlantic herring – *Clupea harengus*
Atlantic Spadefish – *Chaetodipterus faber*
Atlantic thread herring – *Opisthonema oglinum*
Blackcheek tonguefish – *Symphurus plagiusa*
Butterfish – *Peprilus triacanthus*
Clearnose skate – *Raja eglanteria*
Cownose ray – *Rhinoptera bonasus*
Crevalle jack – *Caranx hippos*
Florida pompano – *Trachinotus carolinus*
Gizzard shad – *Dorosoma cepedianum*
Harvestfish – *Peprilus alepidotus*
Hickory shad – *Alosa mediocris*
Hogchoker – *Trinectes maculates*
Houndfish – *Tylosurus crocodiles*
Ladyfish – *Elops saurus*
Northern puffer – *Sphoeroides maculates*
Northern searobin – *Prionotus carolinus*
Striped Bass - *Morone saxatilis*
Striped burrfish – *Chilomycterus schoepsi*
Striped mullet – *Mugil cephalus*
White Perch - *Morone americana*
Windowpane flounder – *Scophthalamus aquosus*

Table 3. 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 4. Mean length (mm TL), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay pound nets, 1993 - 2007.

		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Weakfish																
	mean length	276	291	306	293	297	337	334	361	334	325	324	273	278	290	275
	std. dev.	46	50	54	54	39	37	53	83	66	65	68	32	39	30	42
	n	435	642	565	1431	755	1234	851	333	76	196	129	326	304	62	61
Summer flounder																
	mean length	347	309	297	335	295	339	325	347	358	324	353	327	374	286	341
	std. dev.	58	104	62	65	91	53	63	46	50	93	56	101	76	92	66
	n	209	845	1669	930	818	1301	1285	1565	854	486	759	577	499	1274	1056
Bluefish																
	mean length	312	316	323	307	330	343	306	303	307	293	320	251	325	311	318
	std. dev.	75	55	54	50	74	79	65	40	41	45	58	60	92	71	70
	n	45	621	912	619	339	378	288	398	406	592	223	581	841	1422	1509
Atlantic croaker																
	mean length	233	259	286	294	301	310	296	302	317	279	287	311	317	304	307
	std. dev.	35	34	42	31	39	40	54	45	37	73	55	43	48	66	54
	n	471	1081	974	2190	1450	1057	1399	2209	733	771	3352	1653	2398	1295	2963
Spot																
	mean length	184	207	206	235	190	230	213	230	239	184	216	208	197	191	208
	std. dev.	28	21	28	28	35	16	25	21	33	36	30	36	37	29	23
	n	309	451	158	275	924	60	572	510	126	681	1354	882	2818	2195	519
Spotted Seatrout																
	mean length		448	452			541	460								414
	std. dev.		86	42				134								43
	n	0	4	6	0	0	1	2	0	0	0	0	0	0	0	3
Black Drum																
	mean length		1106	741	353		1074				435	475	780	1130	1031	1144
	std. dev.		175	454	20		182				190	20	212		228	95
	n	0	2	3	2	0	12	0	0	0	7	4	44	1	8	9
Red Drum																
	mean length						302	332	648		316	506	647	353	366	658
	std. dev.							71			44		468		21	40
	n	0	0	0	0	0	1	16	1	0	177	1	2	1	16	2
Spanish Mackerel (Total Length)																
	mean length	261	391	487	481	520	418	468	455							
	std. dev.	114	55	38	55		45	82	66							
	n	3	78	39	27	1	4	45	35							
Spanish Mackerel (Fork Length)																
	mean length			418	401	437	379		386	406	422	405	391	422	439	436
	std. dev.			34	62				34	34	81	63	95	33	35	51
	n			44	27	1	1		49	19	20	11	8	373	445	158
Menhaden (Fork Length)																
	mean length												262	282	238	243
	std. dev.												28	36	42	41
	n												213	1052	826	854

Table 5. Relative stock density of weakfish from Chesapeake Bay summer pound net survey, 1993 - 2007.

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	36	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		

Table 6. Weakfish mean length (mm TL), mean weight, number sampled and proportion at age by age, 2006.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged	Proportion at Age*
0	260	161	1	1.6
1	283	220	40	64.5
2	291	232	13	21.0
3	310	283	7	11.3
4	414	579	1	1.6

*All weakfish captured were measured and aged, n=62.

Table 7. Weakfish and Atlantic croaker instantaneous total mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2007.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
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

* Insufficient data to calculate 2007 weakfish estimate.

Table 8. Relative stock density of summer flounder from Chesapeake Bay summer pound net survey, 1993 - 2007.

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	

Table 9. Relative stock density of bluefish from Chesapeake Bay summer pound net survey, 1993 - 2007.

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	

Table 10. Relative stock density of Atlantic croaker from Chesapeake Bay summer pound net survey, 1993 - 2006.

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

Table 11. Atlantic croaker mean length (mm TL), mean weight and number sampled by age, 2006.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged
0	207	104	25
1	242	177	21
2	278	300	49
3	329	513	13
4	351	608	83
5	375	707	5
6	377	787	9
7	401	970	19
8	411	1049	22
9	395	940	6
10			0
11			0
12			0
13	467	1347	1

Table 12. Atlantic croaker proportion at age using 2006 pound net survey length and age data (ages: n= 253 and lengths: n=1295).

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13
n	216	81	234	62	476	29	41	65	67	23	0	0	0	1
Proportion at age	16.71	6.25	18.09	4.75	36.76	2.26	3.16	4.99	5.16	1.77	0.00	0.00	0.00	0.10

Table 13. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2006.

Age	Mean Length (mm FL)	Number Aged
1	209	61
2	250	99
3	277	72
4	296	43
5	311	12
6	310	4

Table 14. Atlantic menhaden proportion at age using 2006 pound net survey length and age data (ages: n=345 and lengths: n=1061).

Age	1	2	3	4	5	6
n	336	338	274	168	51	20
Proportion at age	28.3	28.5	23.1	14.1	4.3	1.7

Figure 1. Summer pound net sampling area map for 2007.

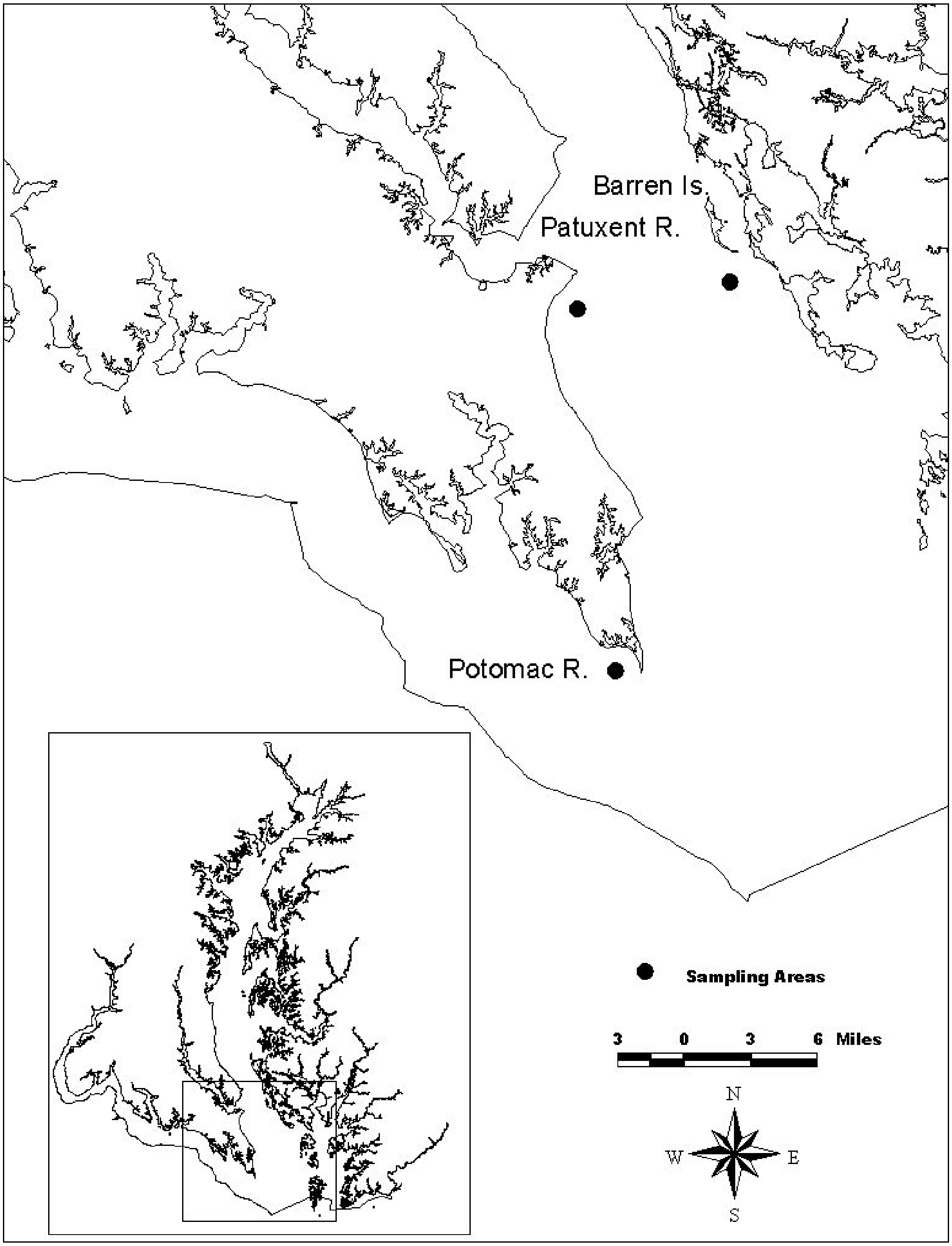


Figure 2. Weakfish length frequency distributions from pound nets, 2004-2007.

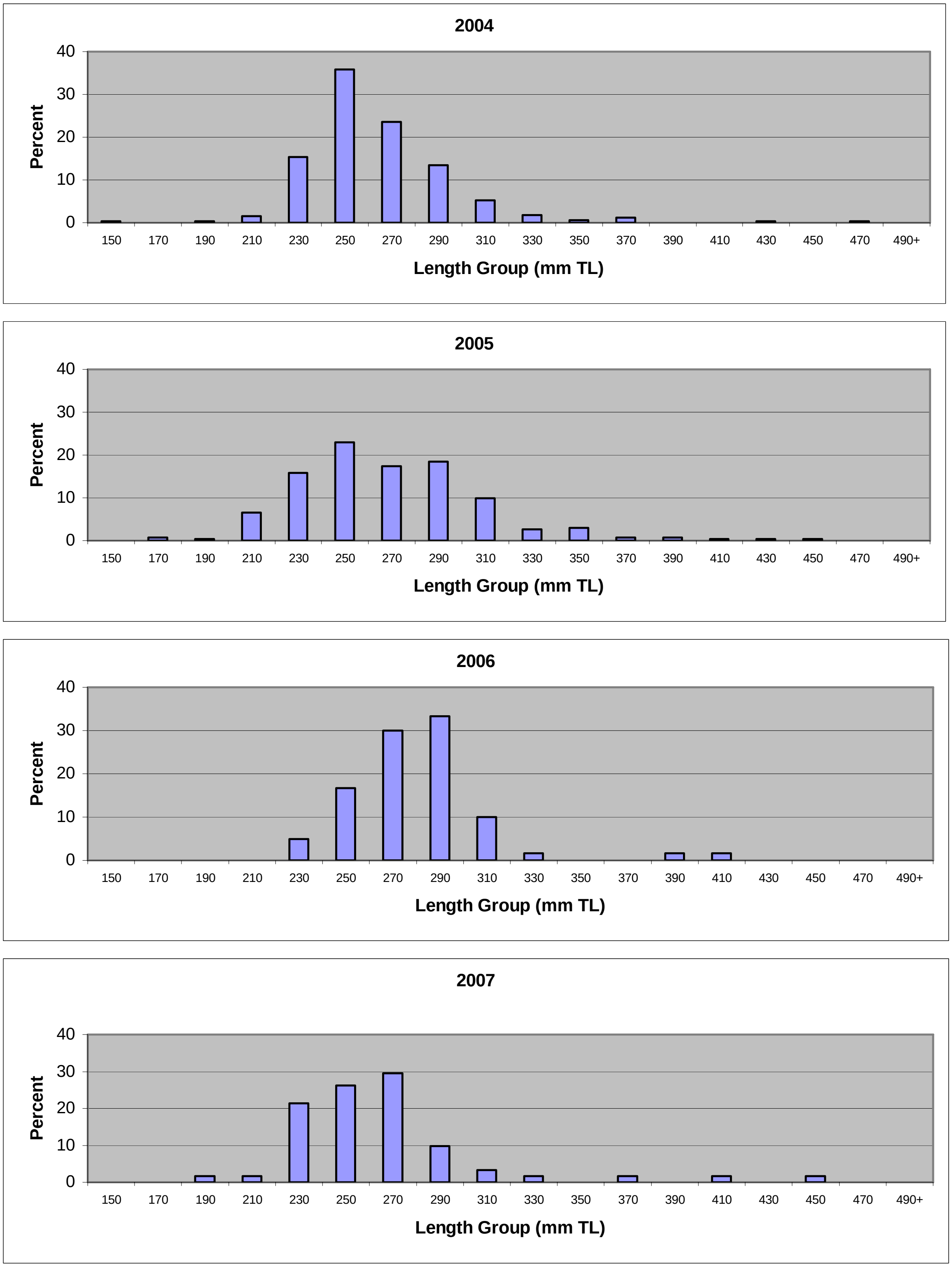


Figure 3. Maryland commercial weakfish landings by area, 1929-2006.

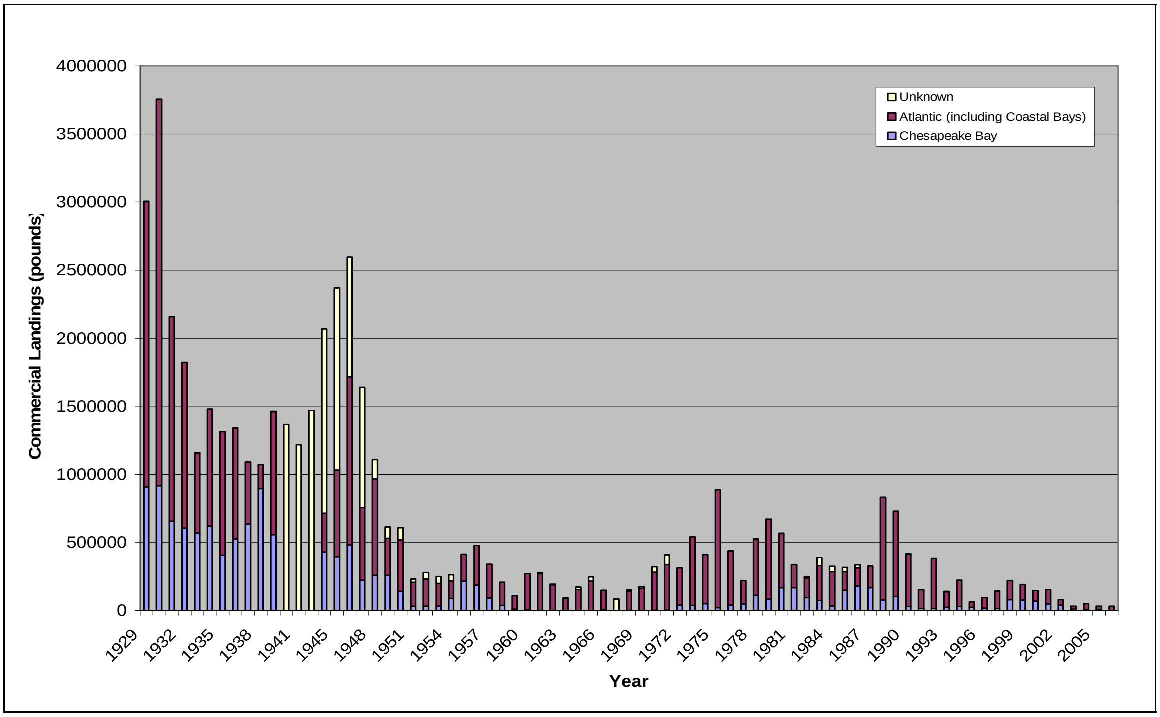


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2006 (Source: MRFSS, 2007).

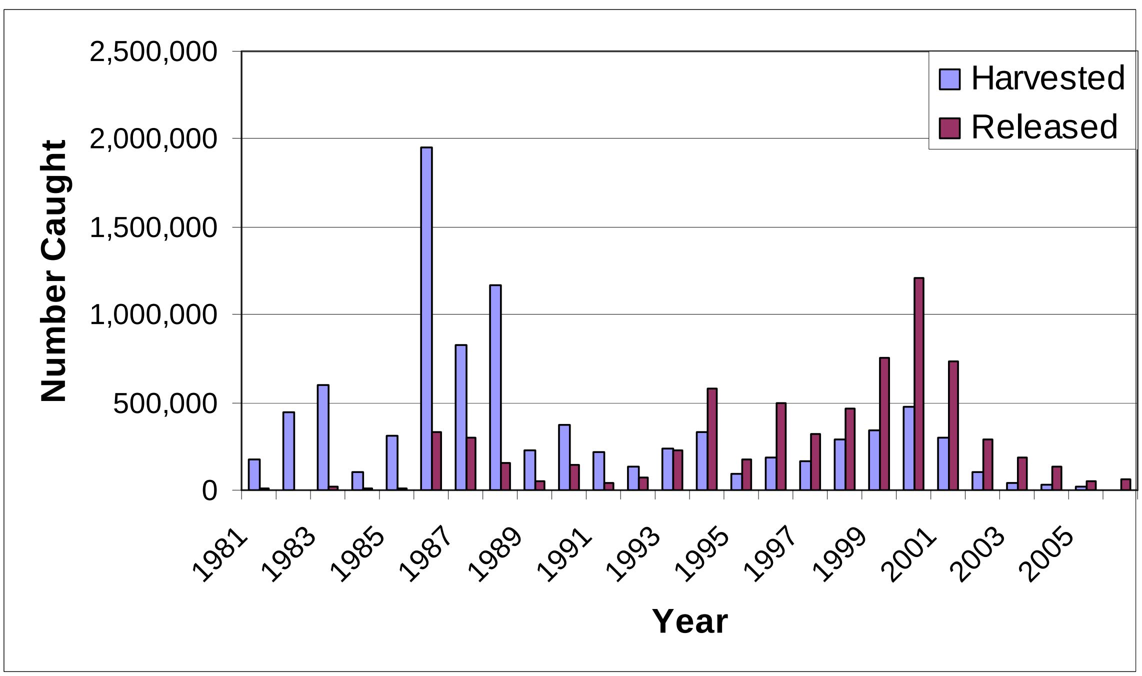
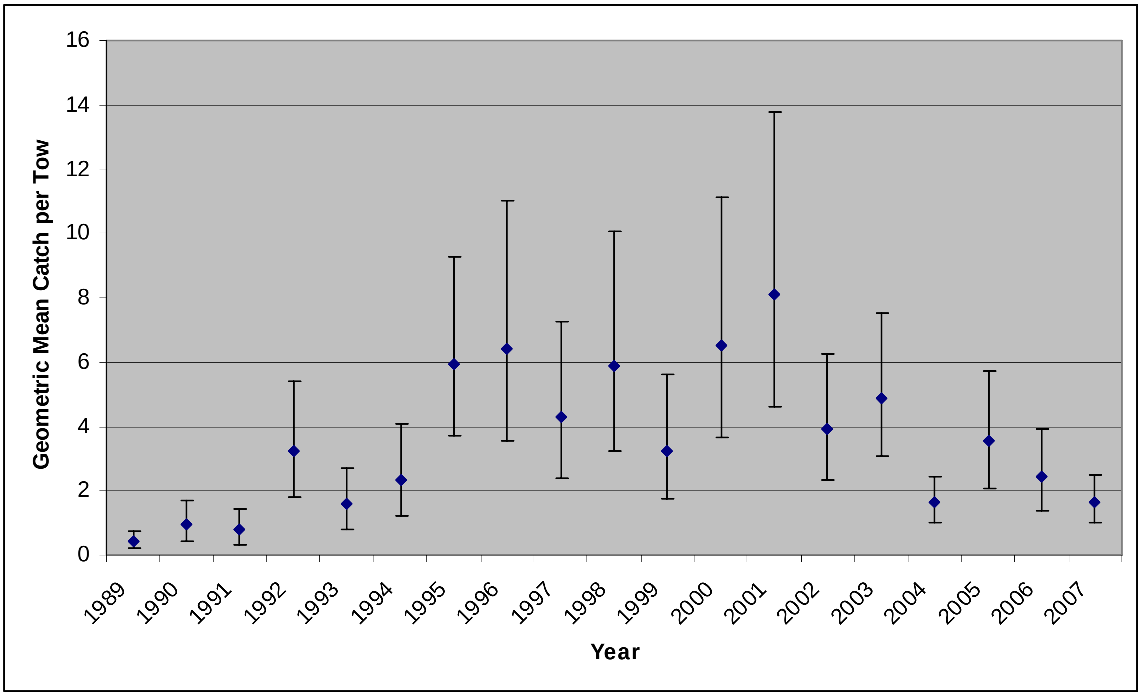


Figure 5. Maryland juvenile weakfish geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2007.



(Note: Confidence intervals were generated by the MEANS Procedure in SAS and are not the standard errors generated by ANOVA.)

Figure 6. Summer flounder length frequency distributions from pound nets, 2004-2007.

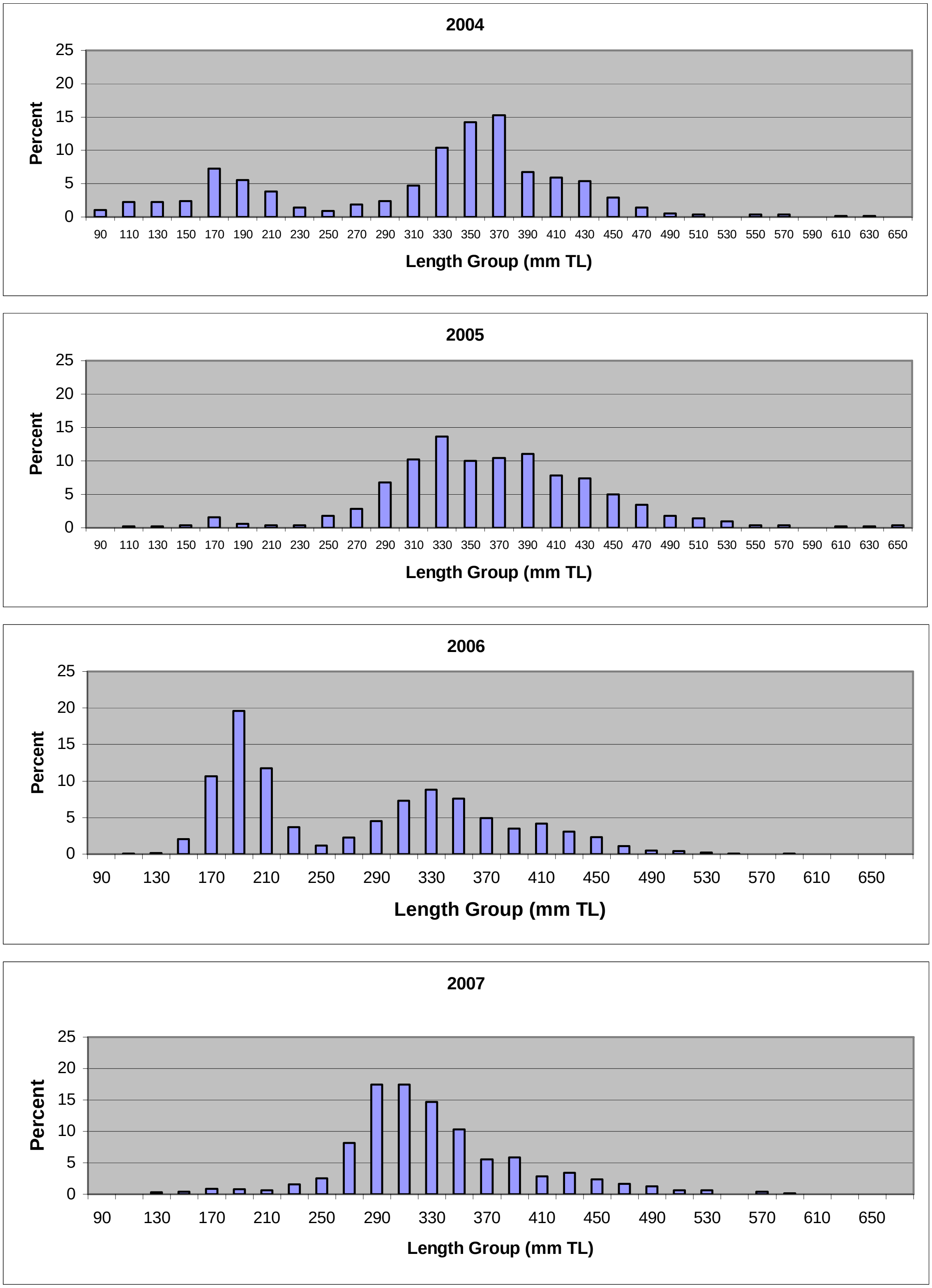


Figure 7. Maryland commercial summer flounder landings by area, 1962-2006.

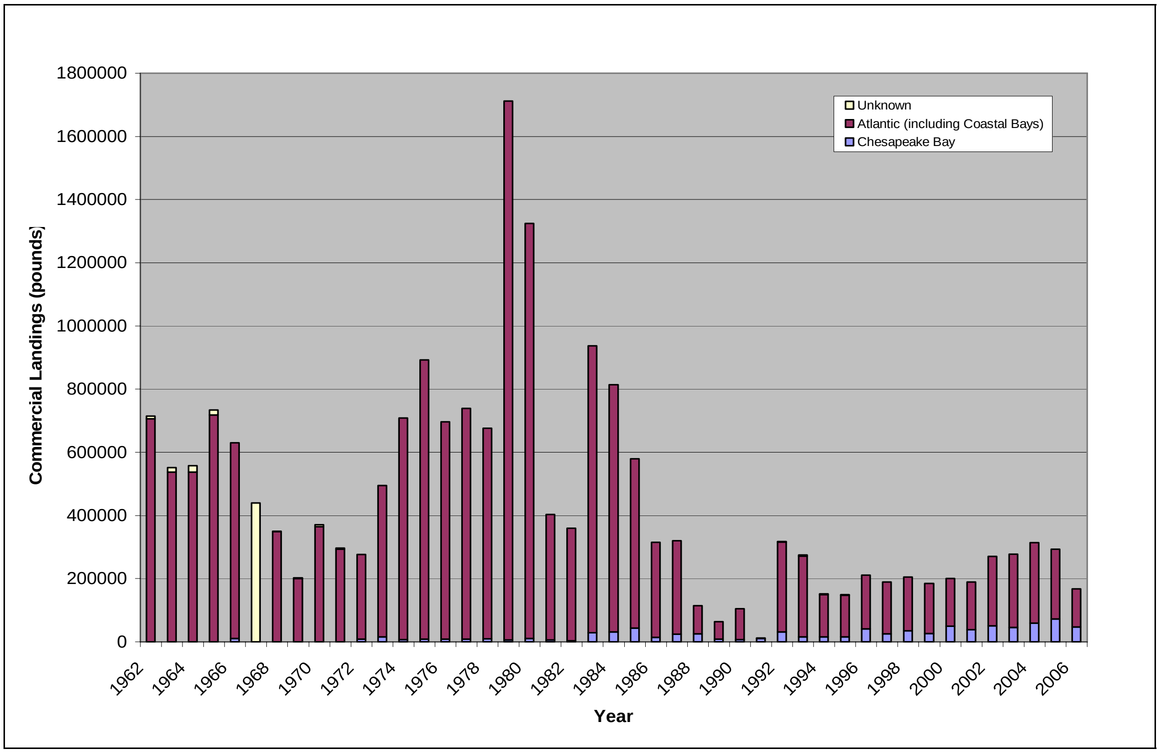


Figure 8. Estimated Maryland recreational summer flounder harvest and releases for 1981-2006 (Source: MRFSS, 2007).

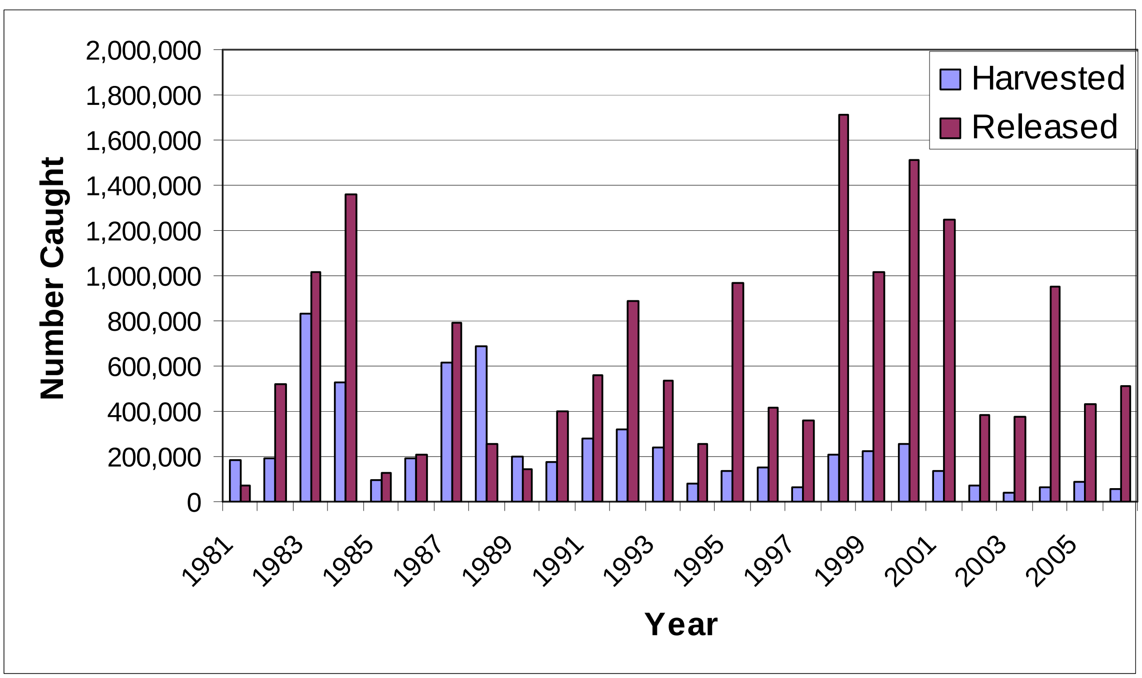


Figure 9. Bluefish length frequency distributions from pound nets, 2004-2007.

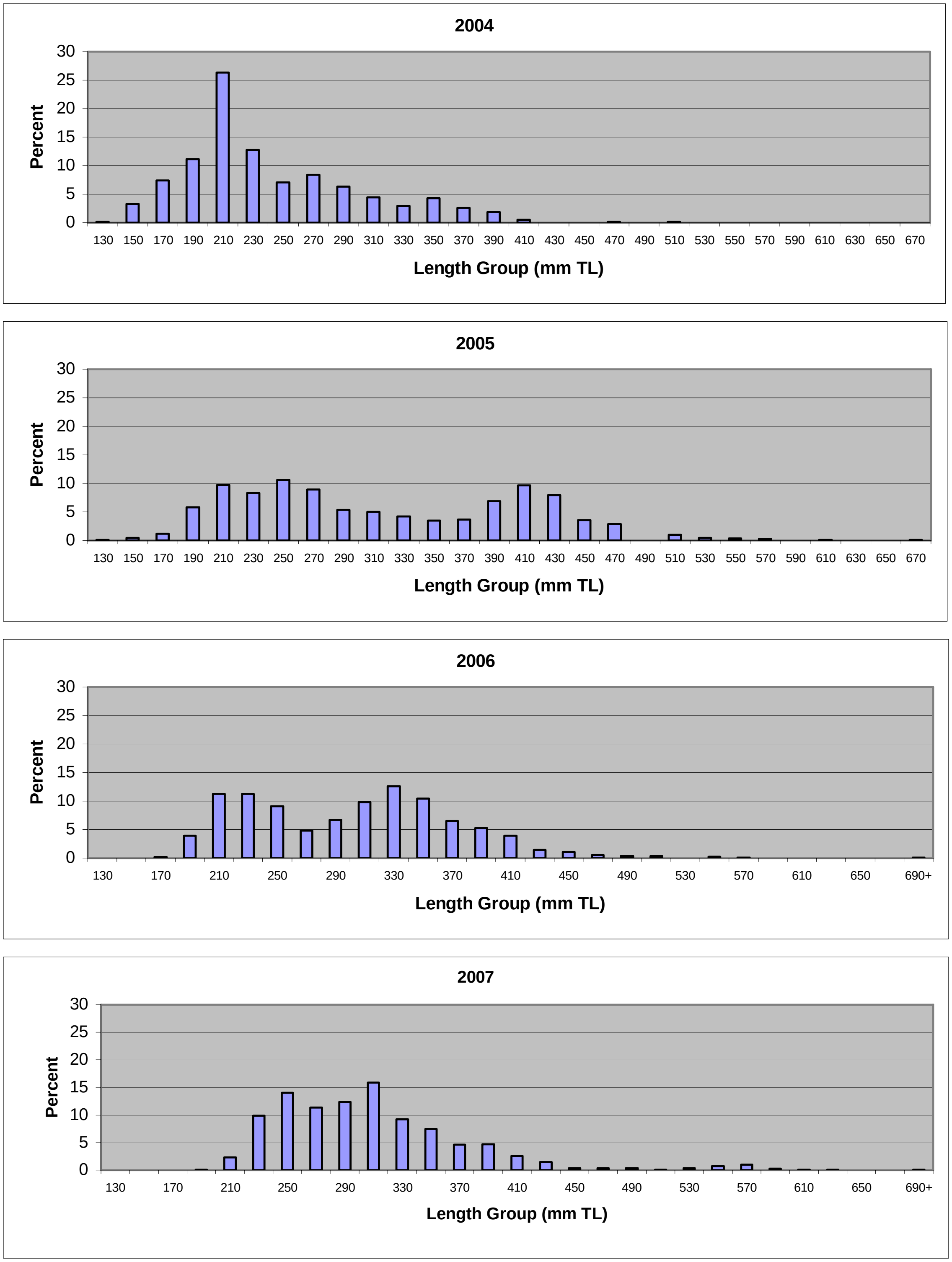


Figure 10. Maryland commercial bluefish landings by area, 1929-2006.

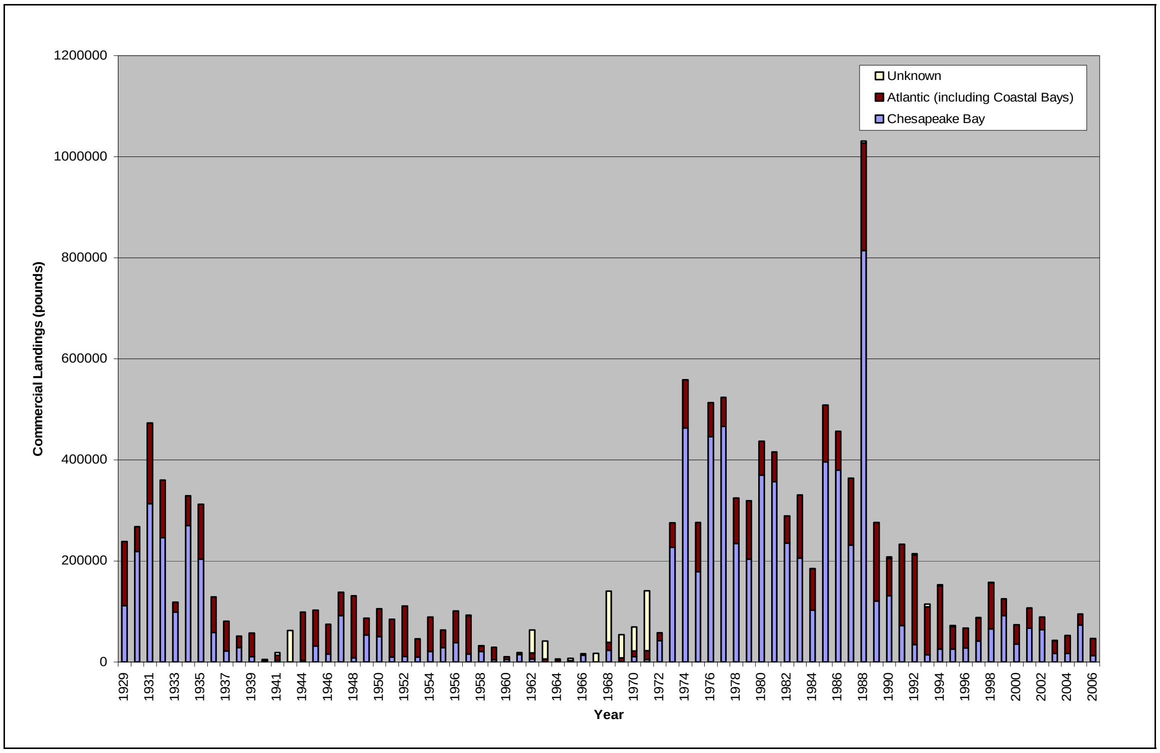


Figure 11. Estimated Maryland recreational bluefish harvest and releases for 1981-2006 (Source: MRFSS, 2007).

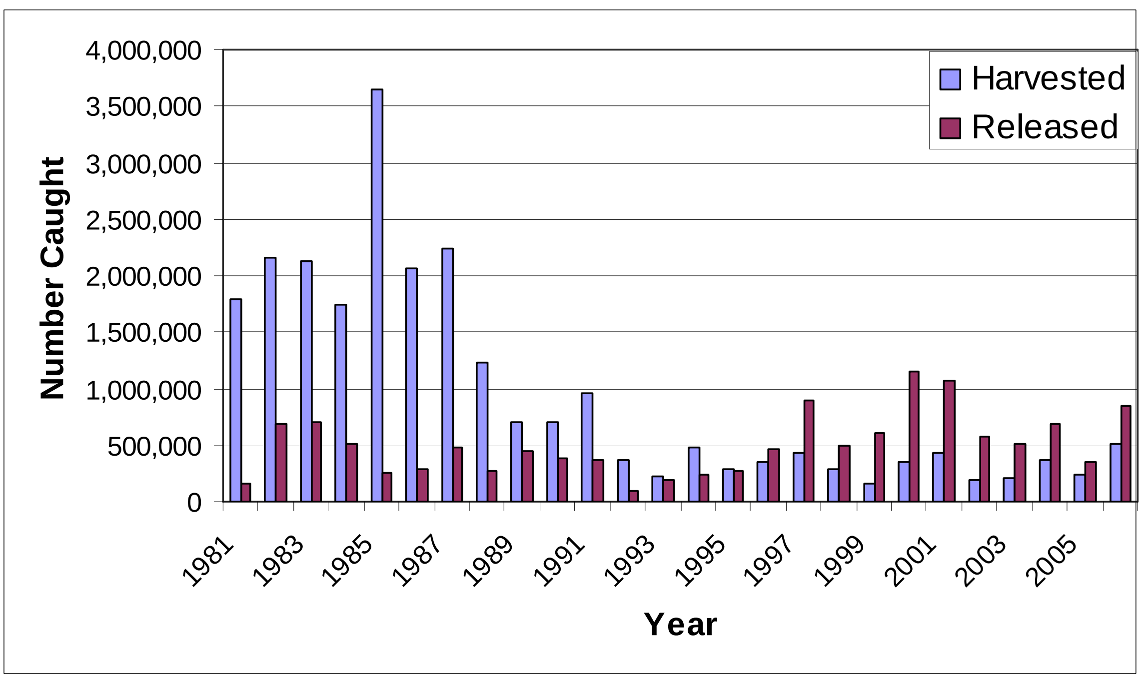


Figure 12. Atlantic croaker length frequency distributions from pound nets, 2004-2007.

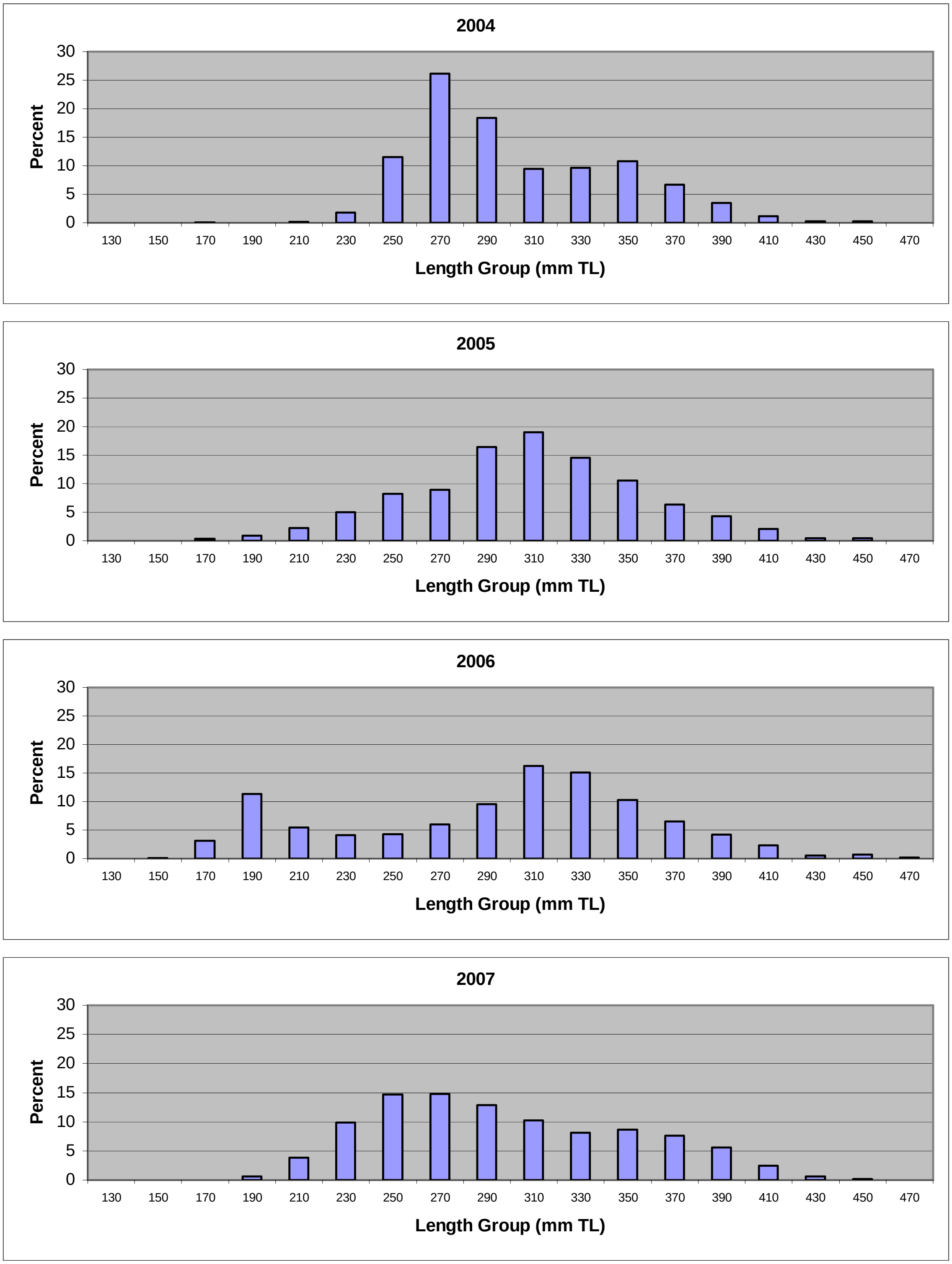


Figure 13. Maryland commercial Atlantic croaker landings by area, 1929-2006.

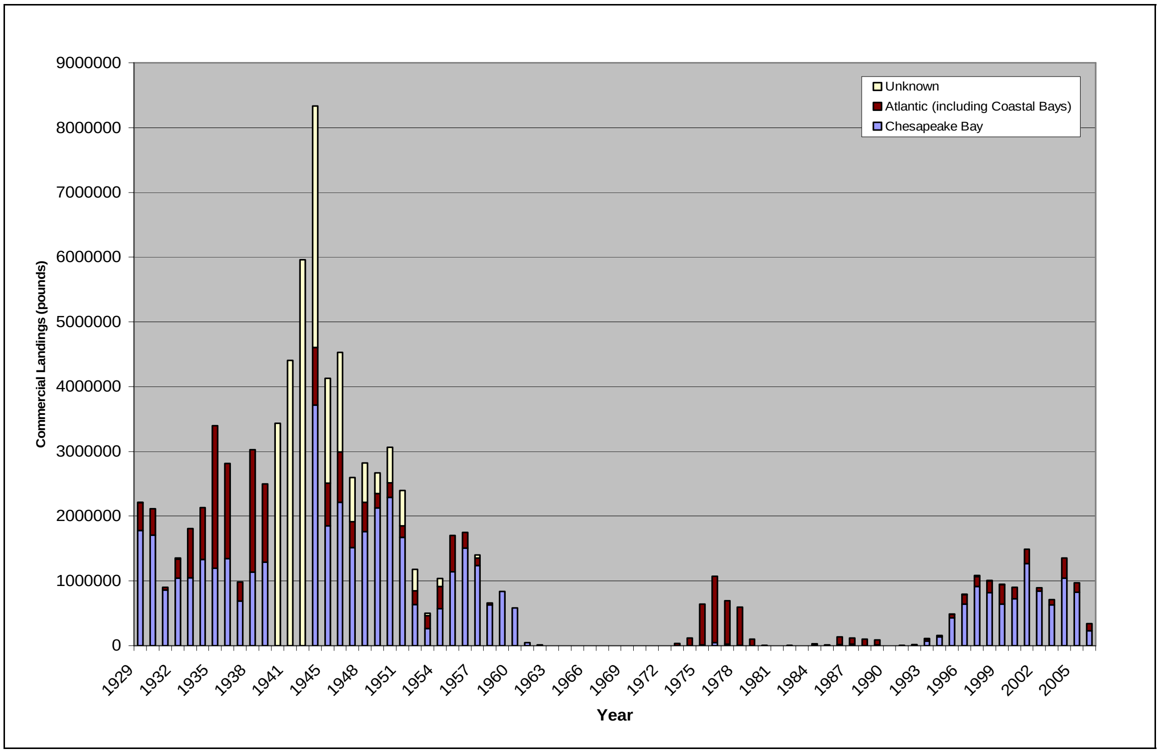


Figure 14. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2006 (Source: MRFSS, 2007).

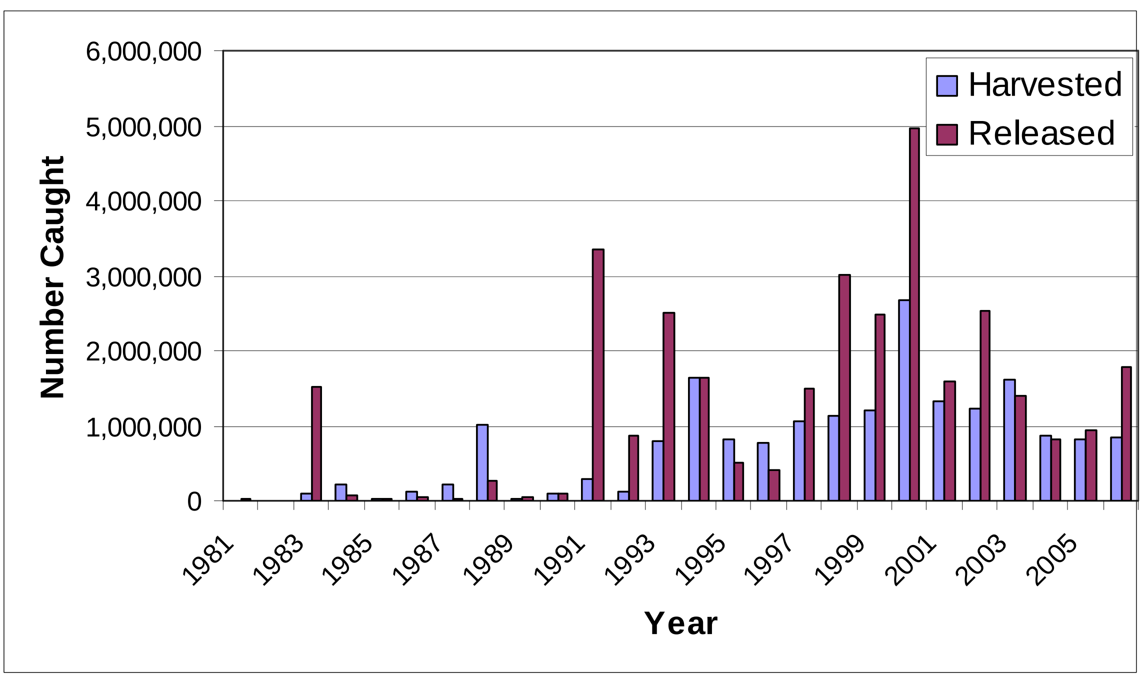
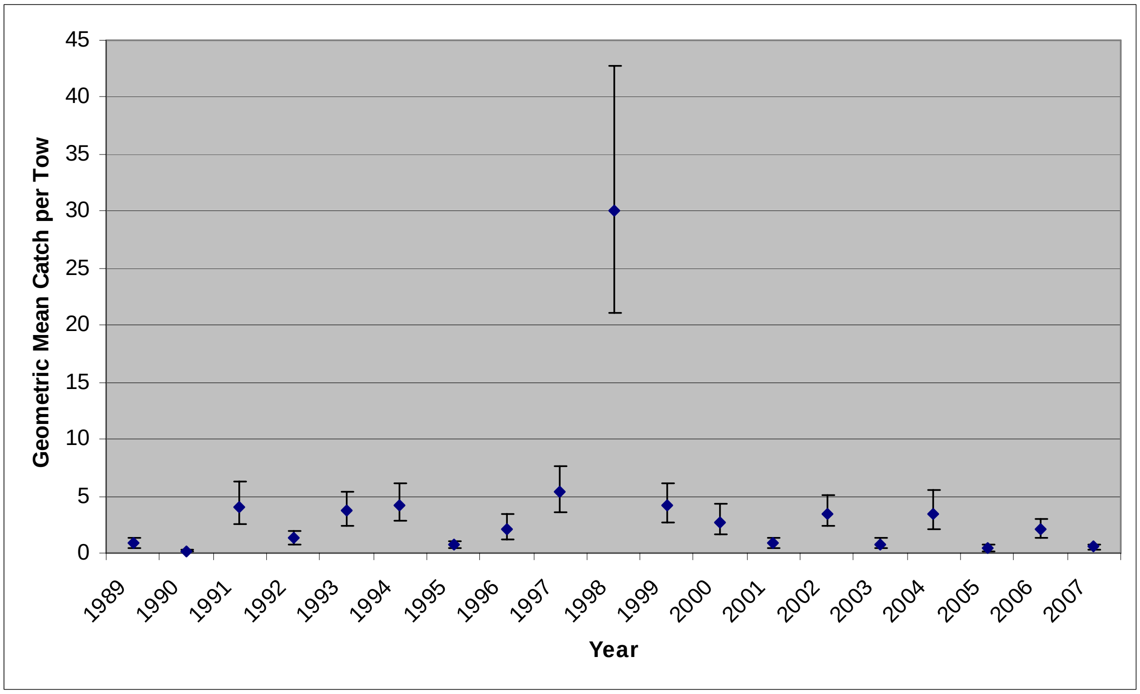
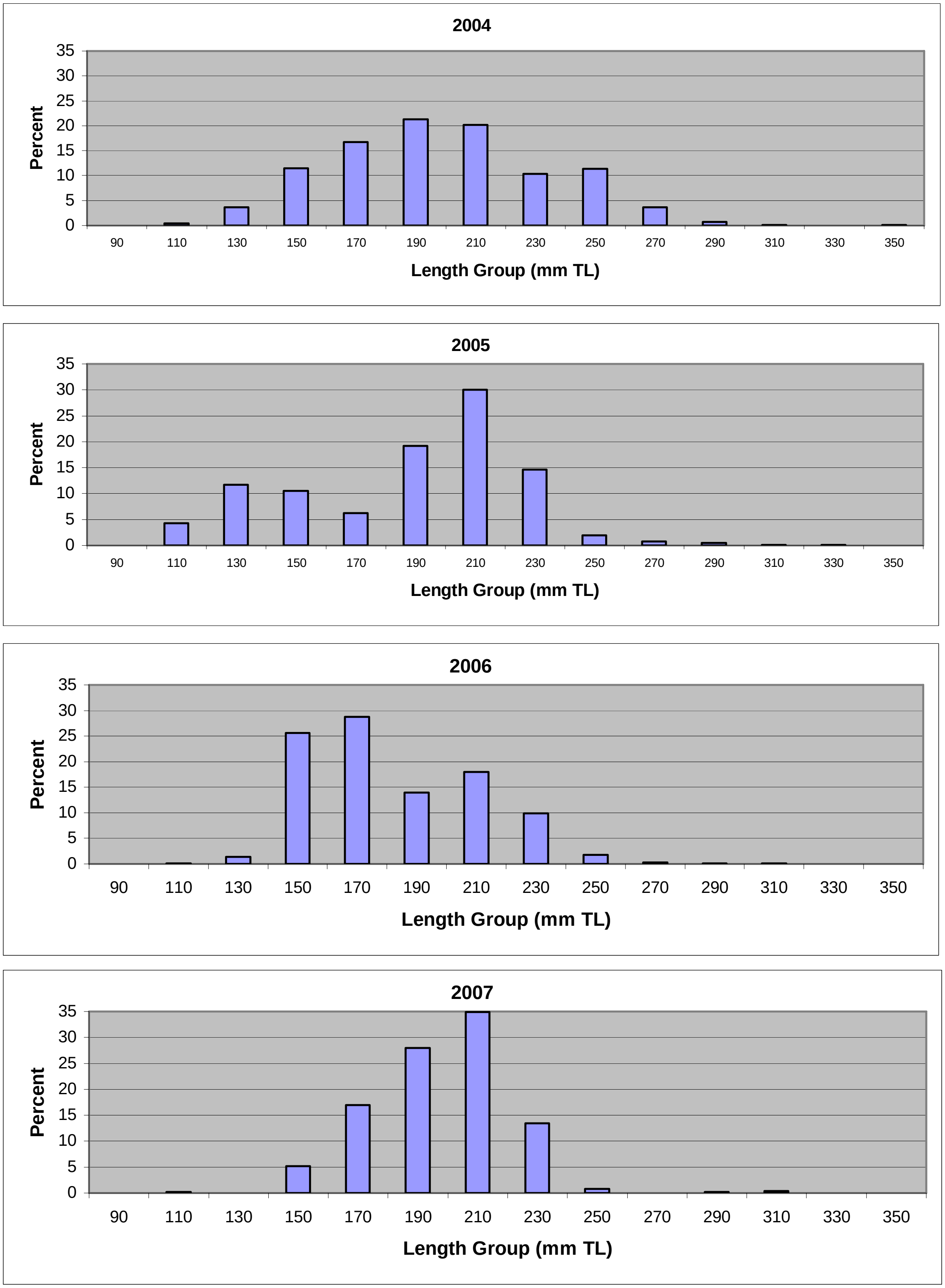


Figure 15. Maryland juvenile Atlantic croaker geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2007.



(Note: Confidence intervals were generated by the MEANS Procedure in SAS and are not the standard errors generated by ANOVA.)

Figure 16. Spot length frequency distributions from pound nets, 2004-2007.



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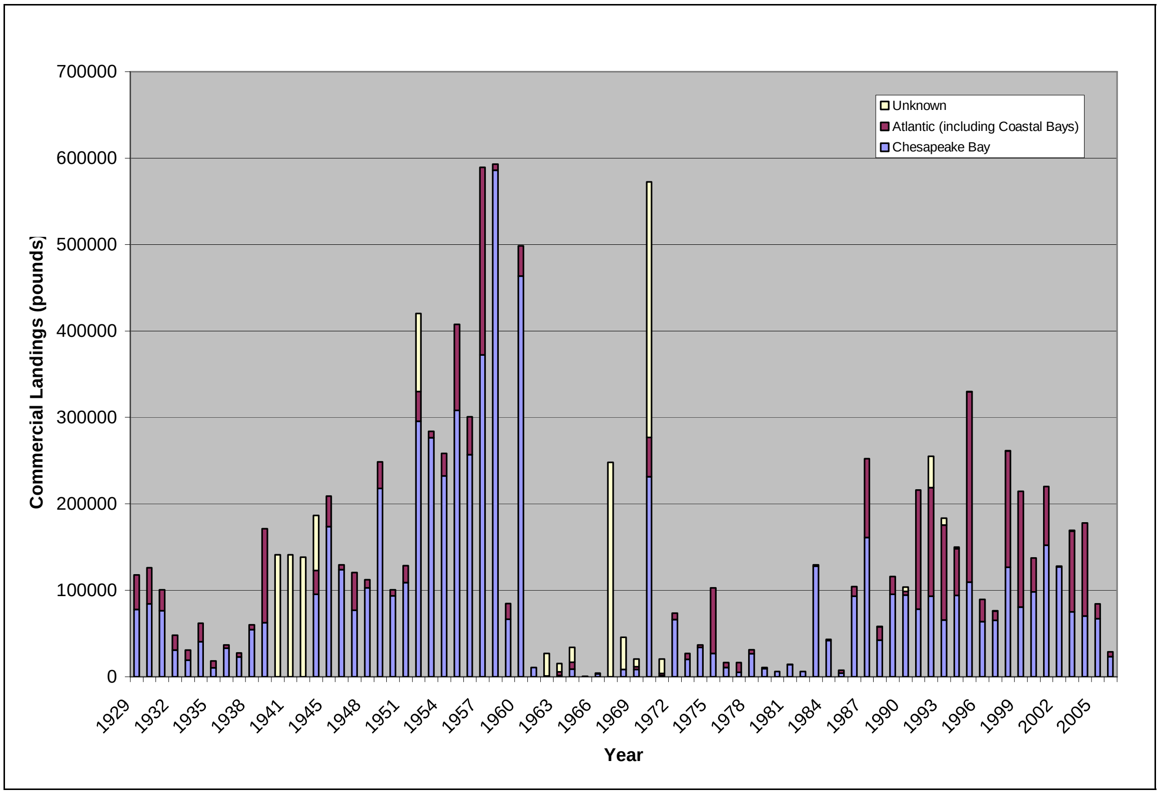


Figure 18. Estimated Maryland recreational spot harvest and releases for 1981-2006 (Source: MRFSS, 2007).

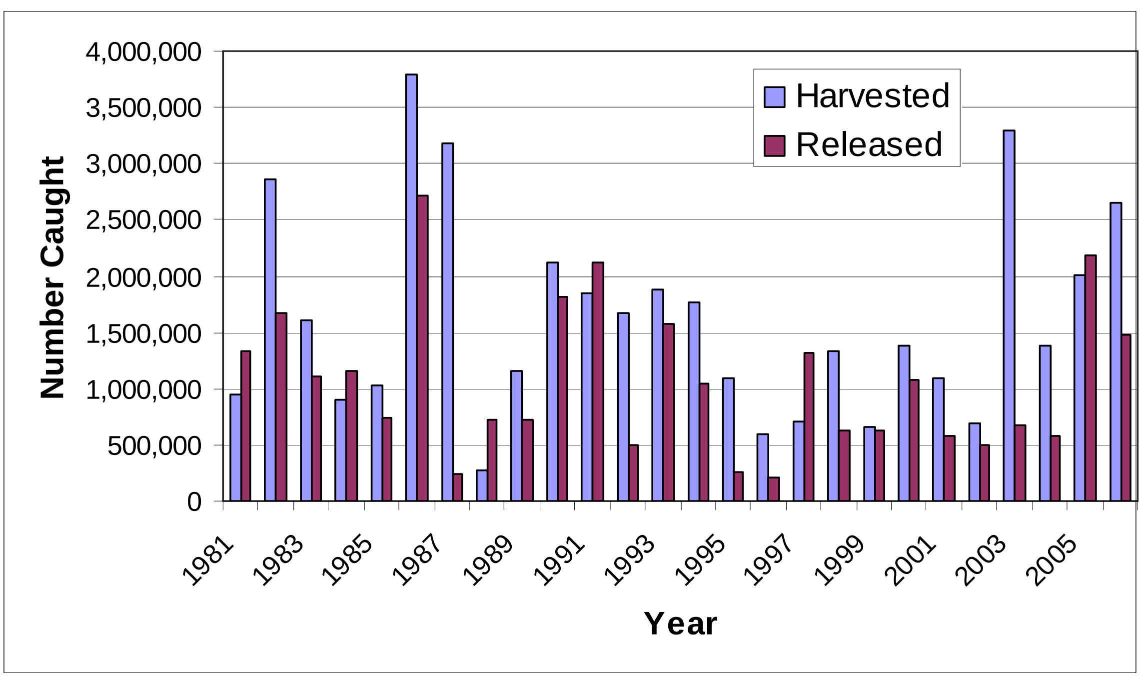
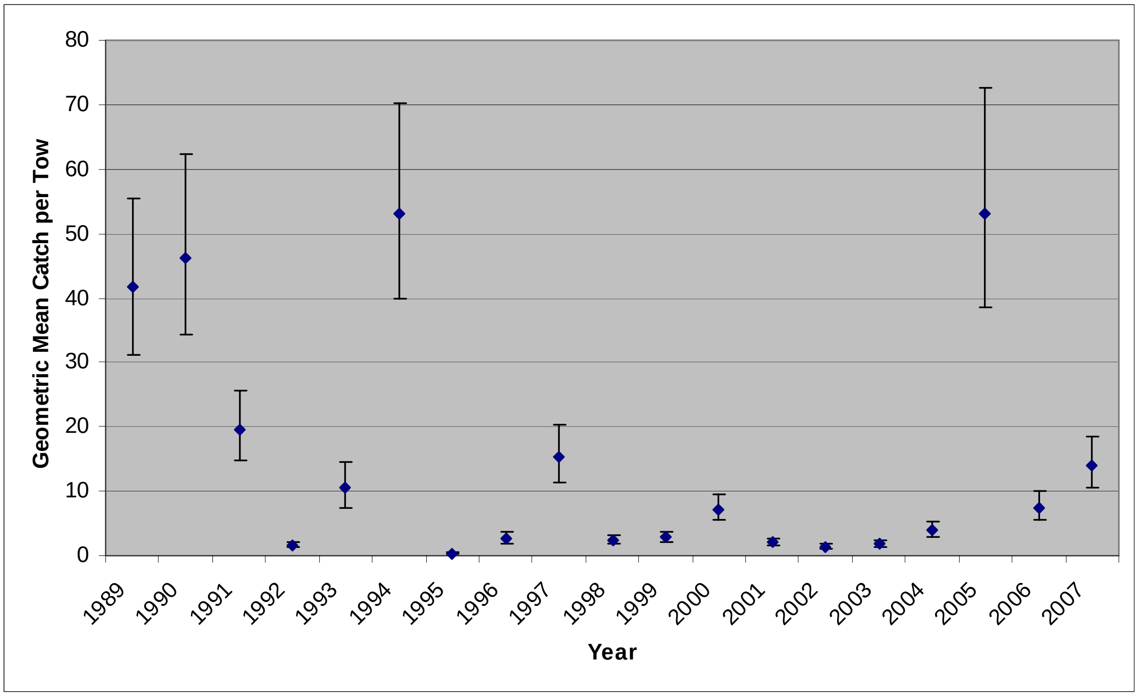


Figure 19. Maryland juvenile spot geometric mean catch per trawl and 95% confidence intervals for Maryland's lower Chesapeake Bay, 1989 – 2007.



(Note: Confidence intervals were generated by the MEANS Procedure in SAS and are not the standard errors generated by ANOVA.)

Figure 20. Maryland commercial red drum landings by area, 1958-2006.

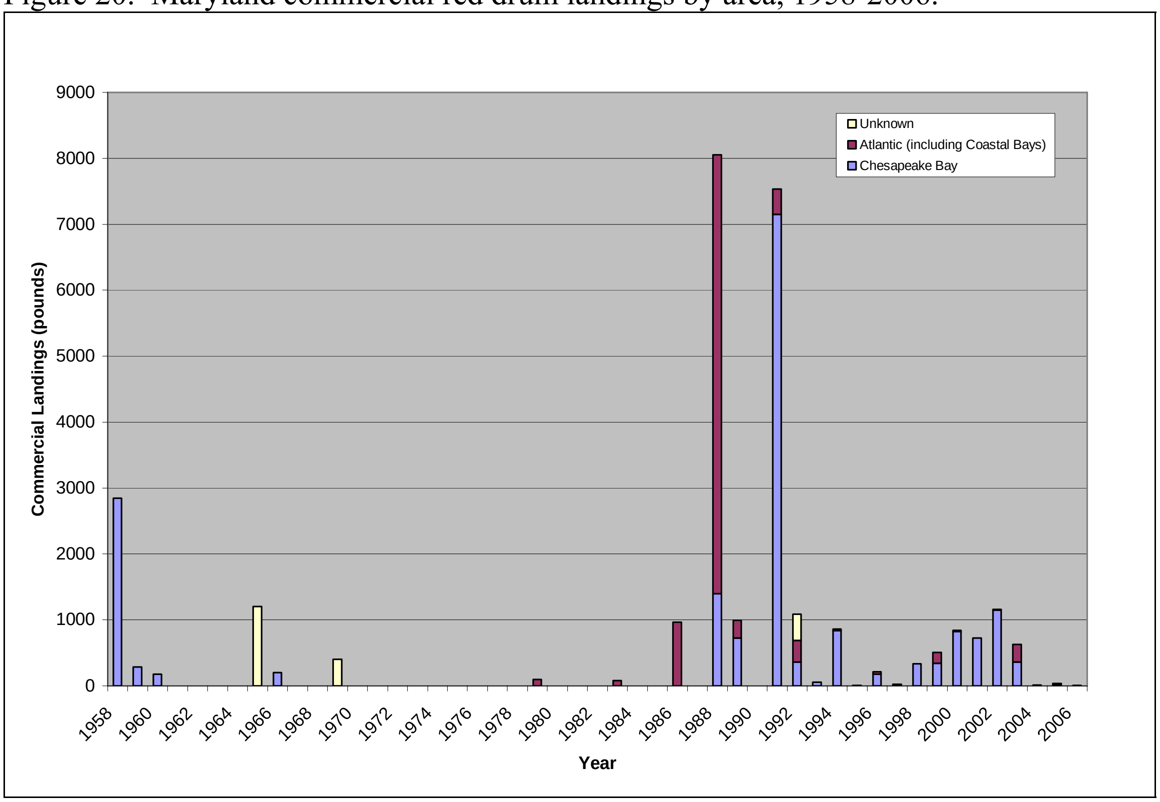
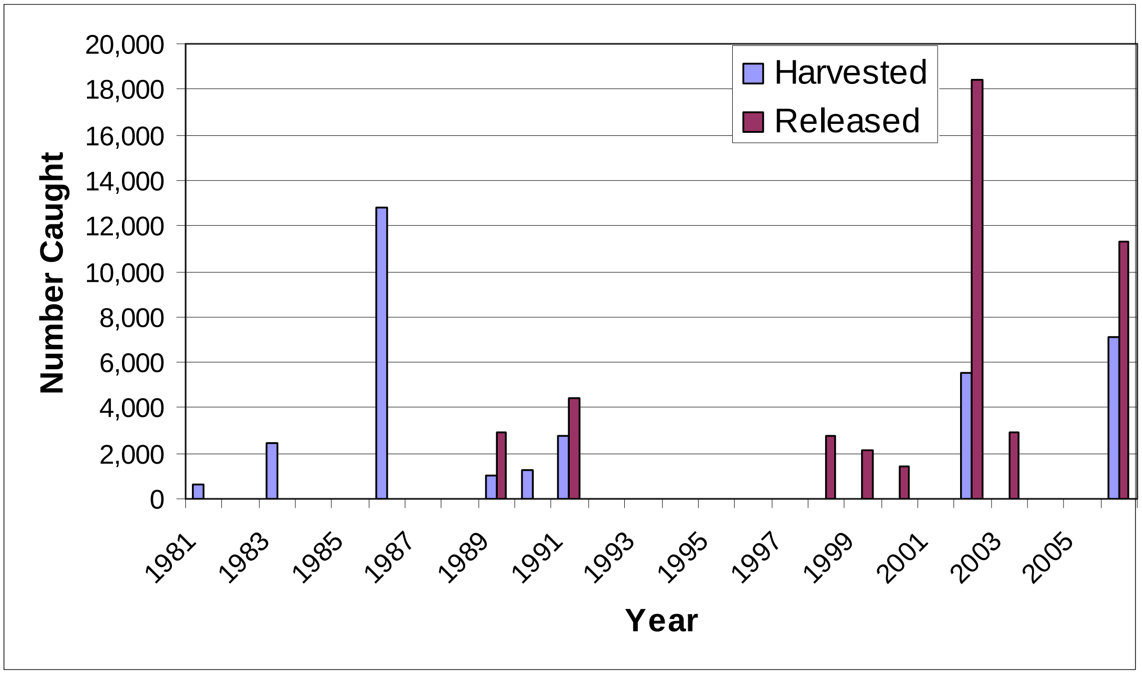


Figure 21. Estimated Maryland recreational red drum harvest and releases for 1981-2006 (Source: MRFSS, 2007).



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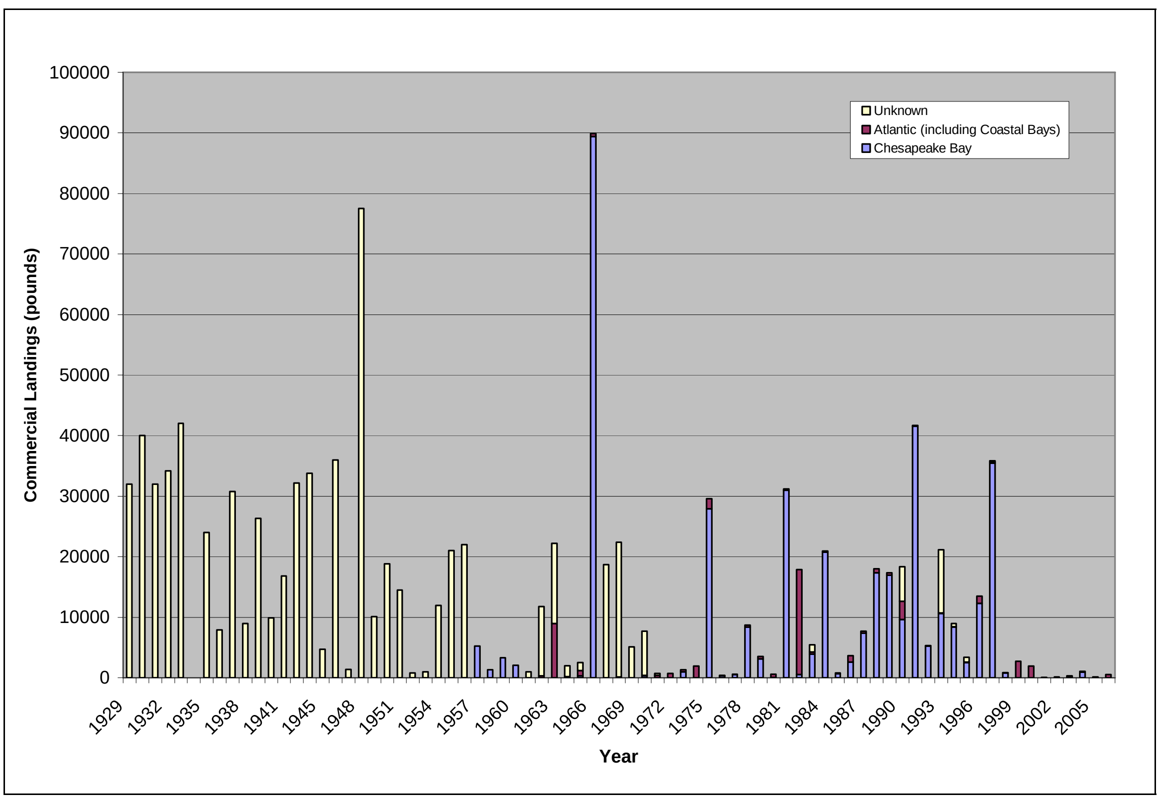
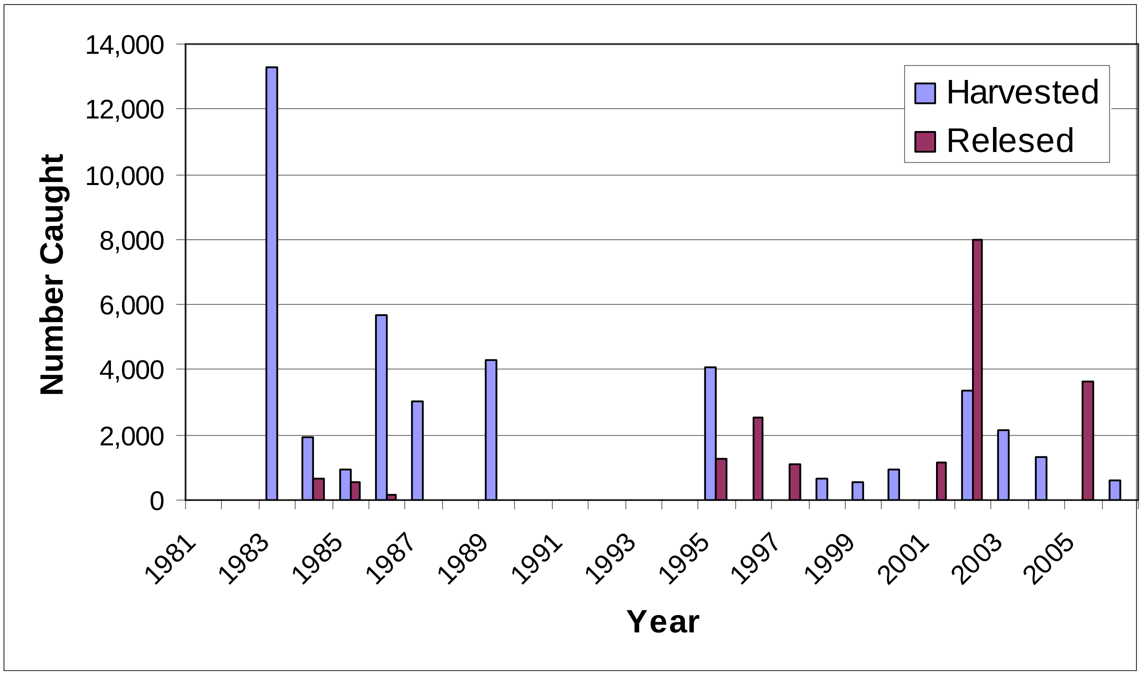


Figure 23. Estimated Maryland recreational black drum harvest and releases for 1981-2006 (Source: MRFSS, 2007).



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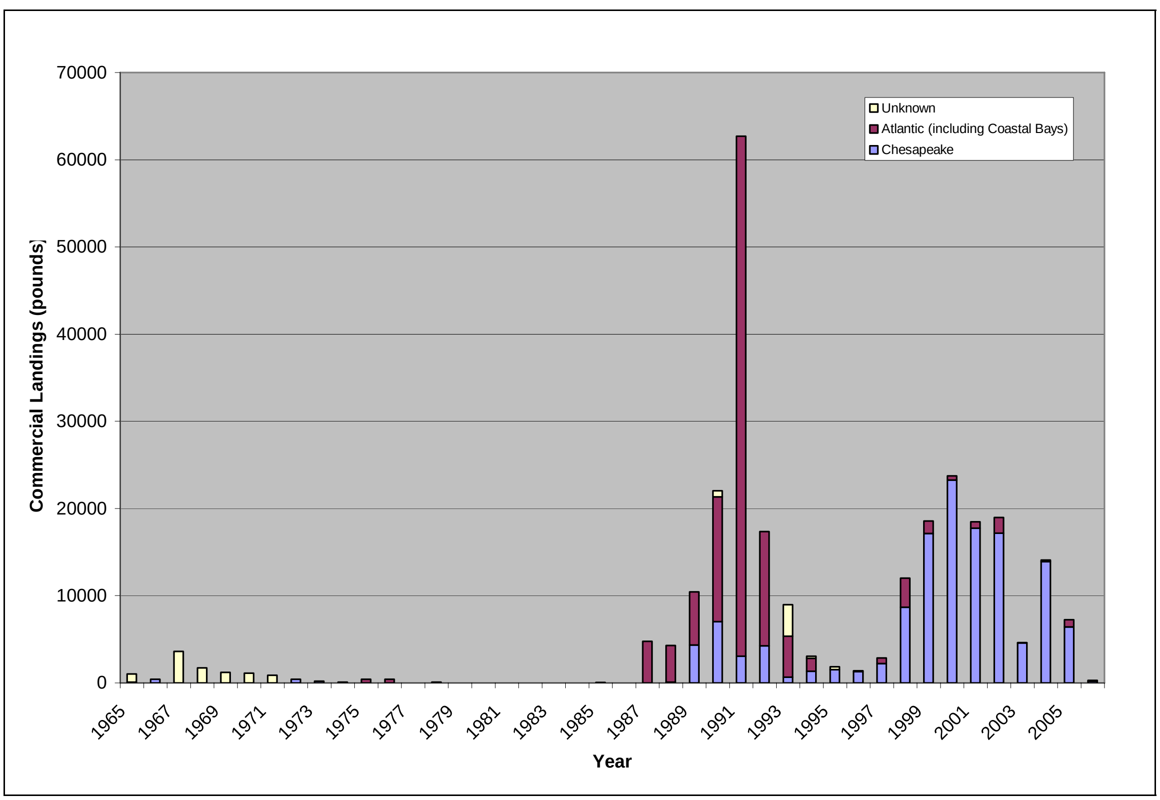

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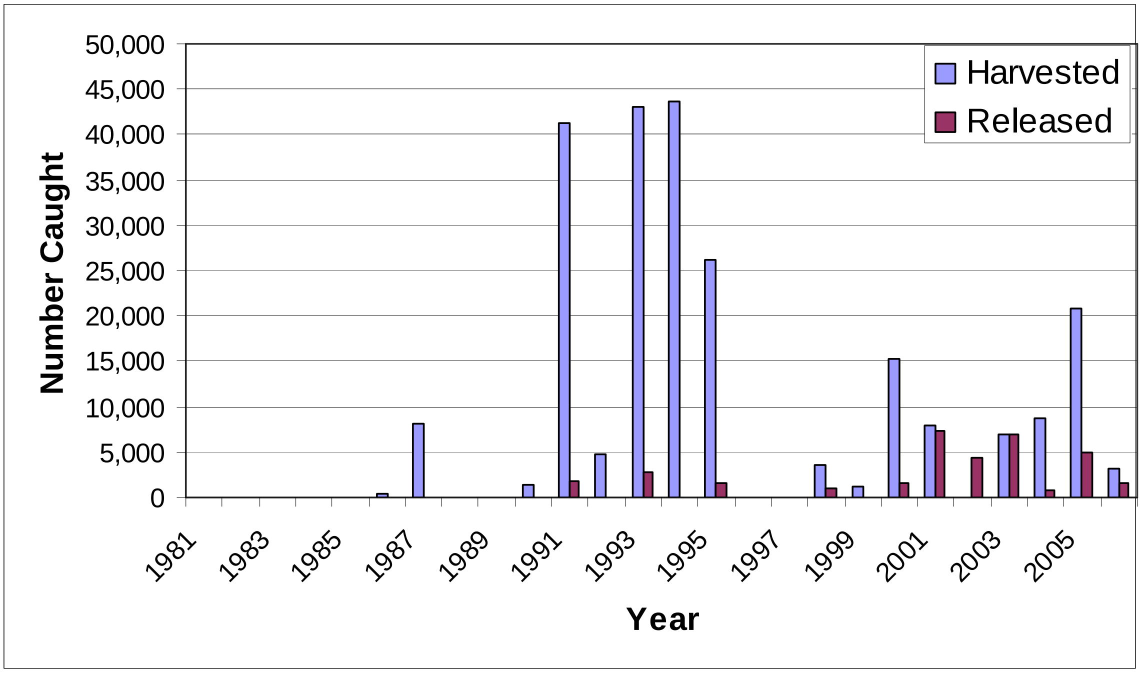

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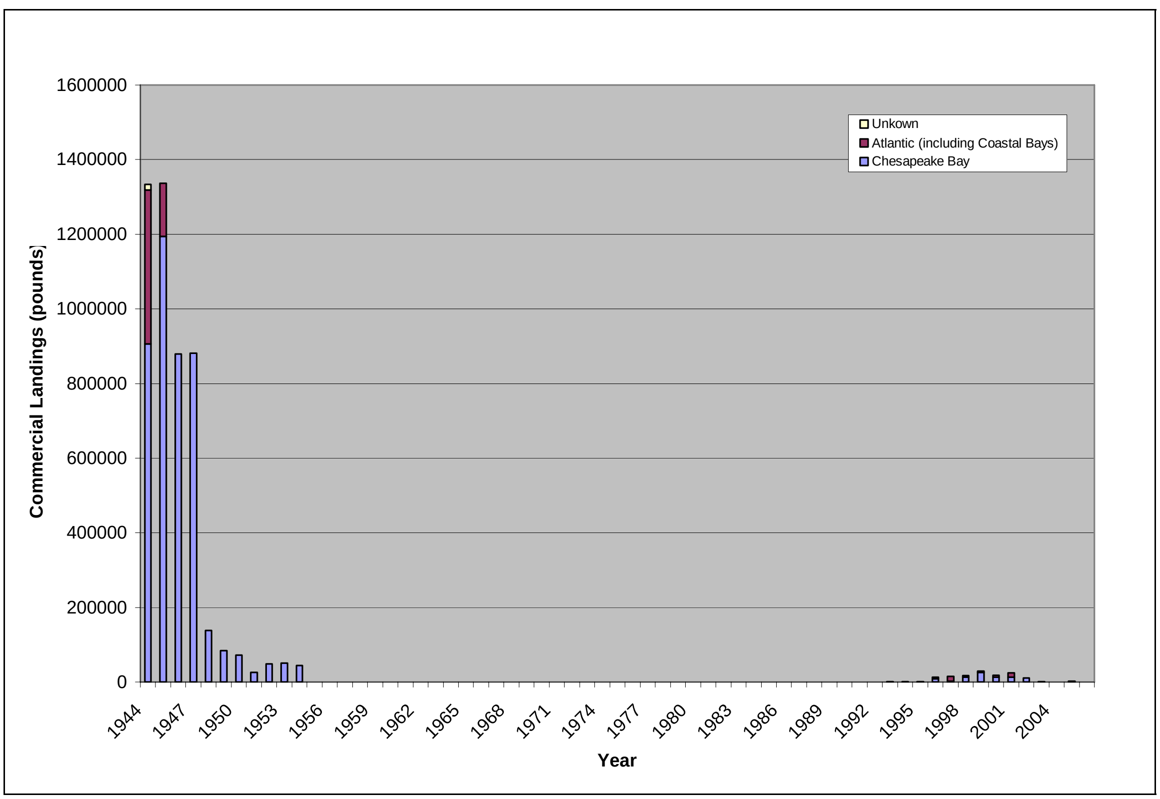

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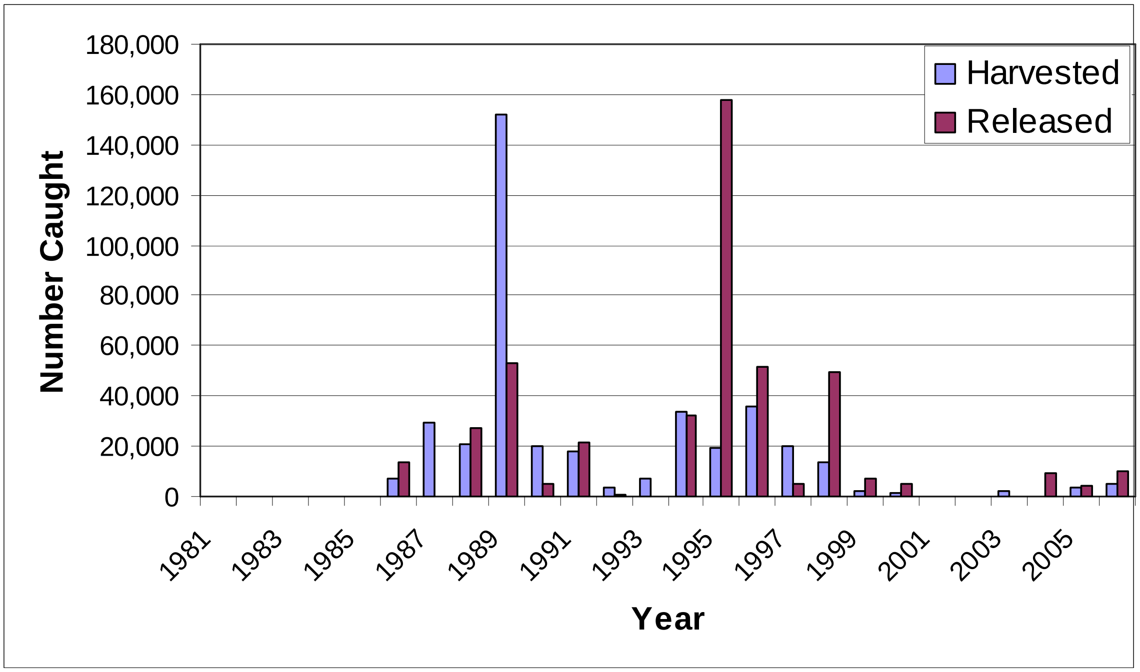

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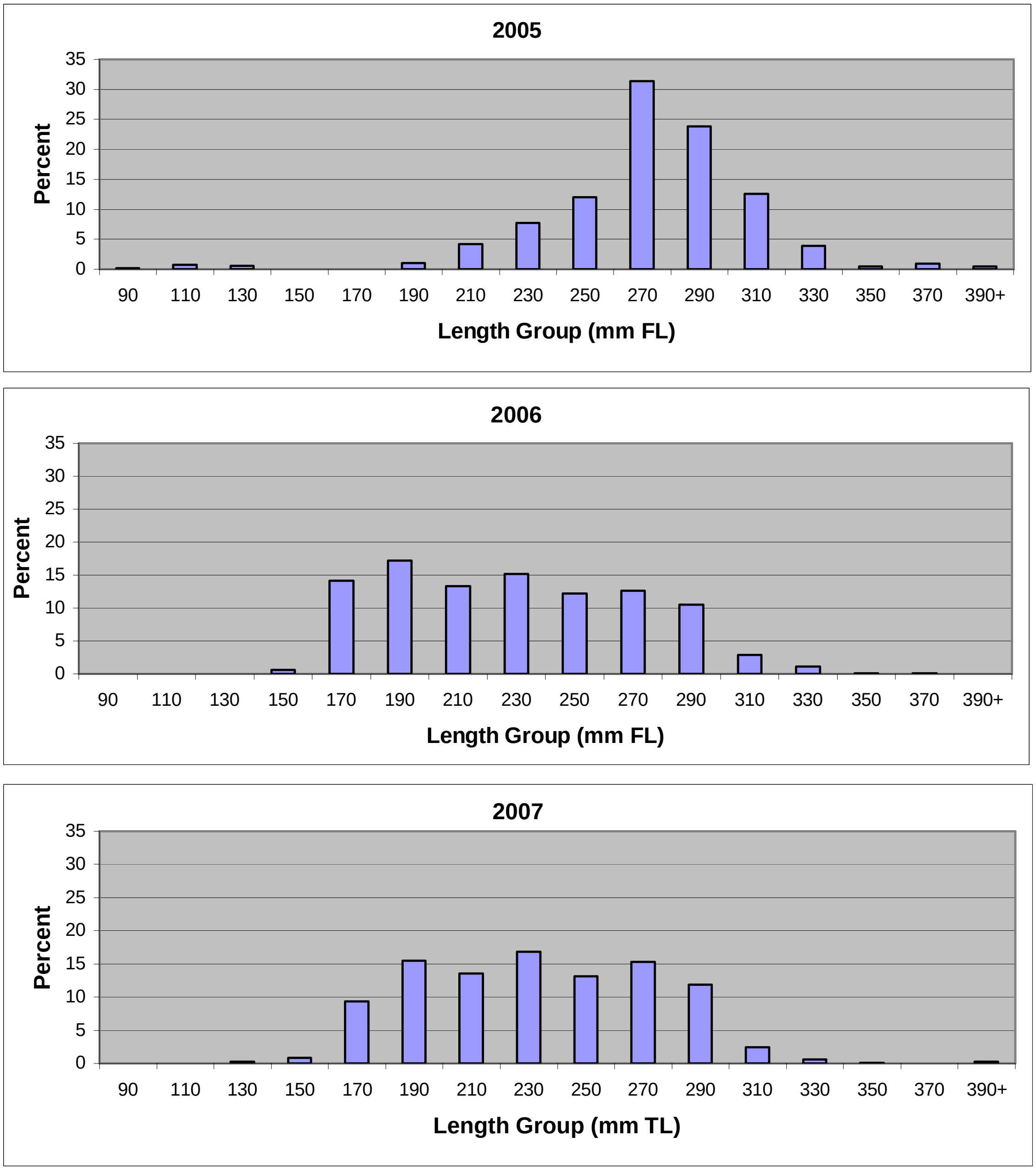
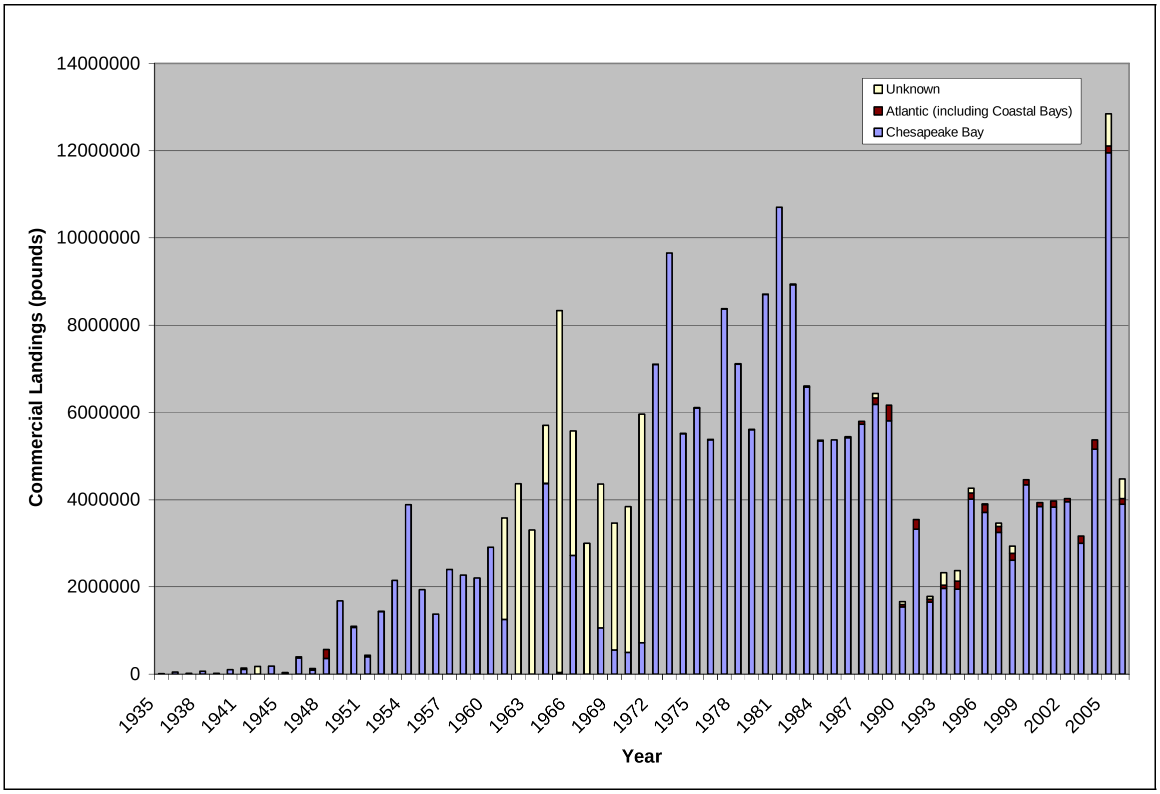


Figure 29. Maryland commercial Atlantic menhaden landings by area, 1935-2006.



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 Task 1A was to characterize the size and age structures of the 2006 Maryland striped bass (Morone saxatilis) commercial pound net and hook-and-line harvest. The 2006 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 target resident/pre-migratory striped bass.

In addition to characterizing the size and age structure of the commercial harvest, data from this survey are used to monitor temporal trends in size-at-age of the harvest. These data also provide the foundation for the construction of the Maryland catch-at-age matrix, which is used in the Atlantic States Marine Fisheries Commission (ASMFC) striped bass coastal stock assessment. Length and age distributions constructed from the 2006 commercial fisheries seasons were used to characterize the length and age structure of the entire 2006 Chesapeake Bay commercial harvest and the majority of the recreational harvest (Fegley 2001).

METHODS

Commercial pound net monitoring

Between 1993 and 1999, pound net monitoring and 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 in commercial pound nets. 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 striped bass 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 has been questioned in recent years with the realization that commercial fishermen sometimes remove 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 would 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 2006 (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 2006, 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 gain an understanding of 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 presence and category of external anomalies were noted. 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. 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 > 700 mm TL.

<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 randomly sampled for pound net and hook-and-line harvested fish each month from June through November 2006 (Figure 1). For pound nets, sample targets of 100 fish per month were established from June through August, and 200 fish per month for September through November. This monthly allocation reflects consistent historic pattern of fall harvest levels, which normally increase 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 . 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 a 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 conducted 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 may be applied to the other(Fegley 2001). 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 2006 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 2006 striped bass pound net study, striped bass were sampled from one pound net in the Upper Bay, three pound nets in the Middle Bay, and one pound net in the Lower Bay (see Project 2, Job 3, Task 4). The five nets in the Upper, Middle and Lower Bay were sampled a total of 16 times during the study.

Striped bass sampled from pound nets ranged from 197-890 mm TL (Figure 2). In 2006, 57% of striped bass collected from full net samples were less than legal size, while 41% of fish from partially sampled nets were sub-legal. Mean total lengths by age for striped bass sampled from pound nets are presented in Table 2.

In 2006, 205 fish from check stations and pound net monitoring surveys were aged. Striped bass sampled at check stations, from pound nets, ranged from 1 to 14 years of age (Figure 2). Three year-old fish from the strong 2003 year-class dominated the sample from the pound net catch, contributing 38% in 2006. Age 4 fish from the 2002 year-class composed only 18% of the sample, slightly less than in 2005 (Figure 3, Table 3). This lower catch of 4 year-old fish can be attributed to the poor juvenile index in 2002 (Project2, Job 3, Task 2). Age 5 fish contributed 22% in 2006; almost double the contribution in 2005. Striped bass aged 6 and over were uncommon again in 2006, and accounted for only 5.2 % of the sample, similar to their contribution in 2005 (4.0%). Fish greater than age 8 composed only 3.1 % of the sample in 2006. 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>

The 2006 hook-and-line harvest accounted for 24% of the Maryland Chesapeake Bay total commercial harvest in 2006 (see Project 2, Job 3, Task 5A). Mean lengths-at-age and weights-at-age from the 2006 hook-and-line and pound net fisheries combined, are shown in Tables 4 and 5. The estimated 2006 catch at age of the hook-and-line fishery is presented in Table 6.

Striped bass sampled from the hook-and-line fishery ranged from 425 to 959 mm TL (Figure 4) and from 3 to 14 years of age (Figure 5).The majority of the harvest was composed of three to five year-old striped bass. Three year old fish from the strong 2003 year class accounted for 21% of the total, more than in 2005. Age 4 striped bass from poor 2002 year class contributed 23%, which was two–thirds their contribution in 2005. Age five fish from the dominant 2001 year-class contributed 37% to the hook-and-line harvest, which was slightly more than in 2005 (30%). Fish aged 8 years old accounted for 3%, only slightly more than in 2005. Striped bass older than age 8 contributed very little to the overall harvest in 2006 (1%).

In 2006, 2106 striped bass were sampled at hook-and-line check stations, and 4% of those fish sampled were sub legal (< 457 mm TL). Striped bass in the 470-550 mm length groups accounted for 70% of the hook-and-line harvest, more than in 2005 (Figure 6). Fish greater than 650 mm TL contributed only 5% to the total harvest. As in past years, few large fish were available to the hook-and-line fishery. All larger striped bass over 700 mm TL were harvested in June or July and were not encountered during the rest of the season (Figure 7). Historically, these fish have not been available in large numbers during the summer (MDDNR 2002). Striped bass sampled after July ranged between 430 and 690 mm TL.

Pound net check station sampling

The pound net harvest accounted for 32% of the Maryland Chesapeake Bay 2006 commercial harvest. Mean lengths-at-age and weights-at-age from the 2006 hook-and-line and pound net fisheries combined, are shown in Tables 4 and 5. The estimated 2006 catch at age of the hook-and-line fishery is presented in Table 6.

Striped bass sampled ranged from 445 to 891 mm TL (Figure 4). Legal-sized striped bass sampled from the pound net fishery ranged from 3 to 14 years of age (Figure 5). Fish aged three to five contributed 81% of the 2006 total pound net harvest. Five year-old fish from the 2001 year-class also dominated the pound net harvest again in 2006, contributing 39% to the total harvest. The contribution of striped bass aged 8 and over was 5%, slightly more than in 2005 (4%).

Sub-legal striped bass (< 457 mm TL) made up less than 4% sample at pound net check stations. Striped bass in the 470 -550 mm TL length groups accounted for 76% of the 2006 pound net harvest, which was slightly more than in 2005(Figure 6). The contribution of striped bass in the 570–630 mm TL length groups decreased over half to 15% from 2005. Fish greater than 650 mm

TL composed only 6% of the sample. In general; few large fish were available to the 2006 fishery (Figure 7).

Monitoring summary

Striped bass ranging from 457 to 550 mm TL were harvested almost equally in both fisheries, with a greater number of large fish being harvested from the pound net fishery (Figure 6). In 2006, older fish were again scarce throughout the summer and smaller fish, especially the 2001 year-class, were more abundant, accounting for the majority of the harvest. 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 2006, for three, four, and five year-old striped bass. Six year-old striped bass from 2006 are no different than those sampled in all years except 2002. Age 7 striped bass were similar to other age 7 fish only in 2004 and 2005. Eight year-old striped bass from the 1998 year-class were significantly shorter than all previous years. Nine year-old striped bass were no different than 9 year-old striped bass sampled in any other year except 2003. Aged 10 striped bass from 1996 were different from fish aged 10 in all years, and eleven year-old striped bass were similar to age 11 fish in all years except in 2002. Age sample sizes were too small for ages greater than 11 to be analyzed by a Duncan's test.

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LIST OF FIGURES

Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2006 Maryland Chesapeake Bay commercial pound net monitoring survey.

Month	Area	Number of Nets Sampled	Mean Water Temp. °C	Mean Salinity(ppt)	Number of Fish Sampled
	Upper	1	21.3	10.1	6
June	Middle	3	21.6	9.7	276
	Lower	2	20.1	9.5	151
	Upper	-	-	-	-
July	Middle	1	29	10.3	81
	Lower	1	28.5	12.4	217
	Upper	-	-	-	-
August	Middle	1	28.5	11.7	613
	Lower	2	-	-	383
	Upper	-	-	-	-
September	Middle	-	-	-	-
	Lower	1	24.7	16.1	501
	Upper	-	-	-	-
October	Middle	1	22.9	14.8	307
	Lower	1	19.3	16.4	470
	Upper	-	-	-	-
November	Middle	1	.	-	813
	Lower	1	13.4	16.1	533

Table 2. Mean length-at-age (mm TL) of striped bass sampled from pound nets in Maryland's Chesapeake Bay, June through November 2006.

Year-class	Age	n	Mean length (mm Tl)	STD	STDERR	LCLM	UCLM
2005	1	5	255	56	25	185	324
2004	2	19	314	36	8	296	331
2003	3	30	426	49	9	407	444
2002	4	15	499	52	13	470	528
2001	5	37	582	73	12	558	606
2000	6	22	615	57	12	590	640
1999	7	16	654	57	14	624	684
1998	8	20	690	60	14	661	718
1997	9	15	749	55	14	718	779
1996	10	10	758	61	19	714	802
1995	11	12	834	56	16	799	870
1994	12	1	841	.	.	.	.
1993	13	2	885	9	7	802	967
1992	14	1	849	.	.	.	.

Table 3. Number of striped bass, by age, sampled at check stations, from pound nets, in Maryland's Chesapeake Bay, June through November 2006

Year-class	Age	Pound Net Monitoring	
		Number sampled at age (n)	Percent of Total
2005	1	49	1
2004	2	517	13
2003	3	1523	38
2002	4	724	18
2001	5	882	22
2000	6	210	5
1999	7	68	2
1998	8	48	1
1997	9	3	0
1996	10	4	0
1995	11	2	0
1994	12	0	0
1993	13	1	0
1992	14	0	0
Total Sample		**4030**	**100**

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 2006.

Year-class	Age	n	Mean length (mm Tl)	STD	STDERR	LCLM	UCLM
2003	3	8	483	33	12	455	511
2002	4	12	517	40	11	492	543
2001	5	37	582	73	12	558	606
2000	6	22	615	57	12	590	640
1999	7	16	654	57	14	624	684
1998	8	20	690	60	14	661	718
1997	9	15	749	55	14	718	779
1996	10	10	758	61	19	714	802
1995	11	12	834	56	16	799	870
1994	12	1	841	.	.	.	.
1993	13	2	885	9	7	802	967
1992	14	1	849	.	.	.	.

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 2006. Mean weights are weighted by the sample n-at-length in each age.

Age	Year-class	n Aged	Weighted Mean Weight (kg)
3	2003	8	1.02
4	2002	12	1.15
5	2001	37	1.38
6	2000	22	1.85
7	1999	16	2.21
8	1998	20	2.35
9	1997	15	3.86
10	1996	10	3.69
11	1995	12	5.91
12	1994	1	6.56
13	1993	2	6.93
14	1992	1	6.56

*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 2006.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Numbers of Fish	Percent of Total	Landings in Numbers of Fish	Percent of Total
2003	3	34,981	20.6	37,461	17.4
2002	4	39,761	23.4	47,266	21.9
2001	5	62,246	36.6	80,775	37.5
2000	6	18,722	11.0	27,471	12.7
1999	7	6,630	3.9	9,747	4.5
1998	8	5,306	3.1	7,839	3.6
1997	9	999	0.6	1,948	0.9
1996	10	892	0.5	1,477	0.7
1995	11	452	0.3	1,116	0.5
1994	12	32	0.0	115	0.1
1993	13	0	0.0	289	0.1
1992	14	32	0.0	115	0.1
Total Landings		**170,054**	**100**	**215,618**	**100**

*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.

Figure 1. Locations of Chesapeake Bay commercial pound net and hook-and-line check stations sampled from June through November 2006.

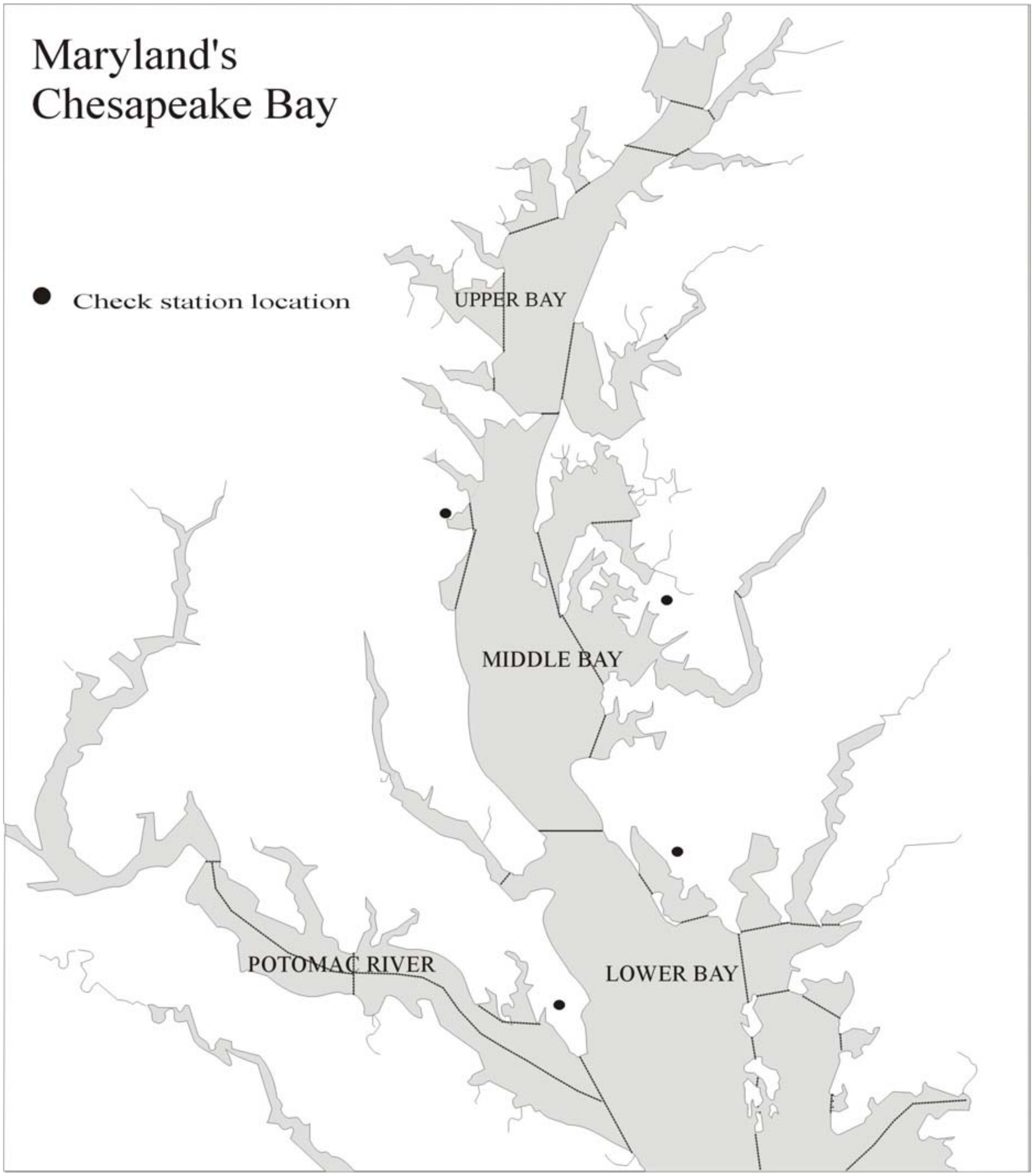


Figure 2. Age and length (mm TL) frequencies of striped bass sampled during Maryland Chesapeake Bay pound net monitoring study June through November 2006.

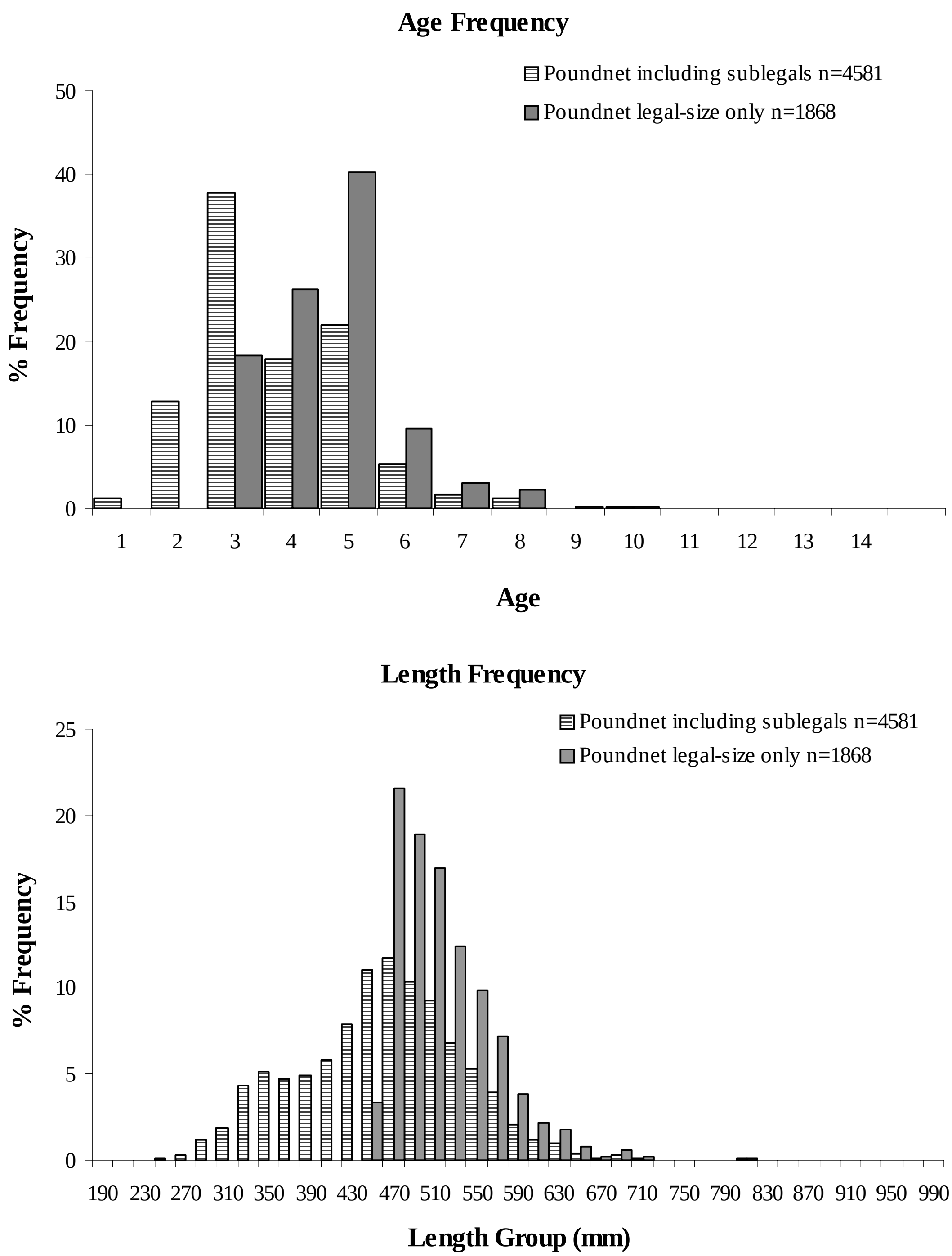


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2006.

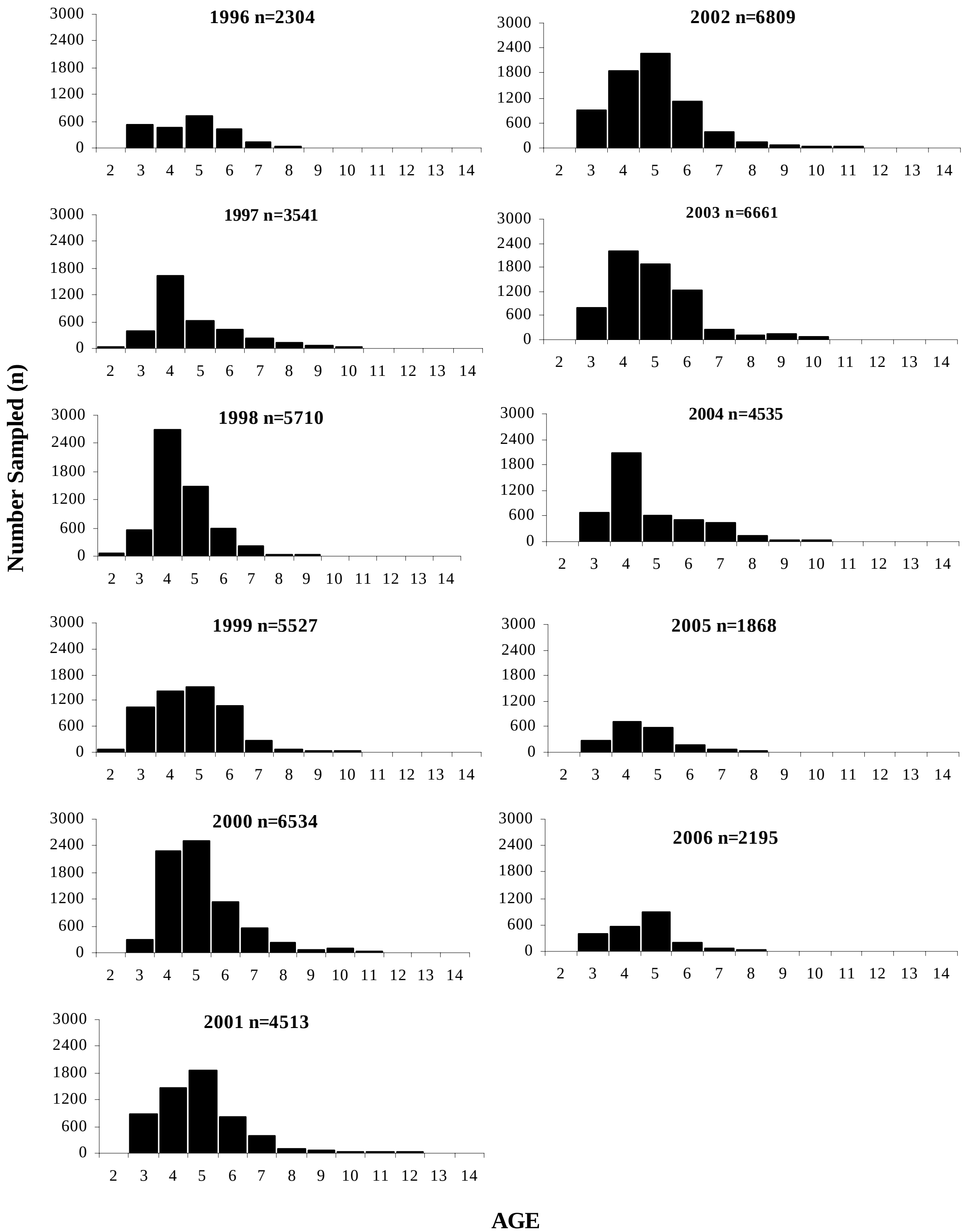


Figure 4. Length frequency of striped bass sampled during the 2006 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2006. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

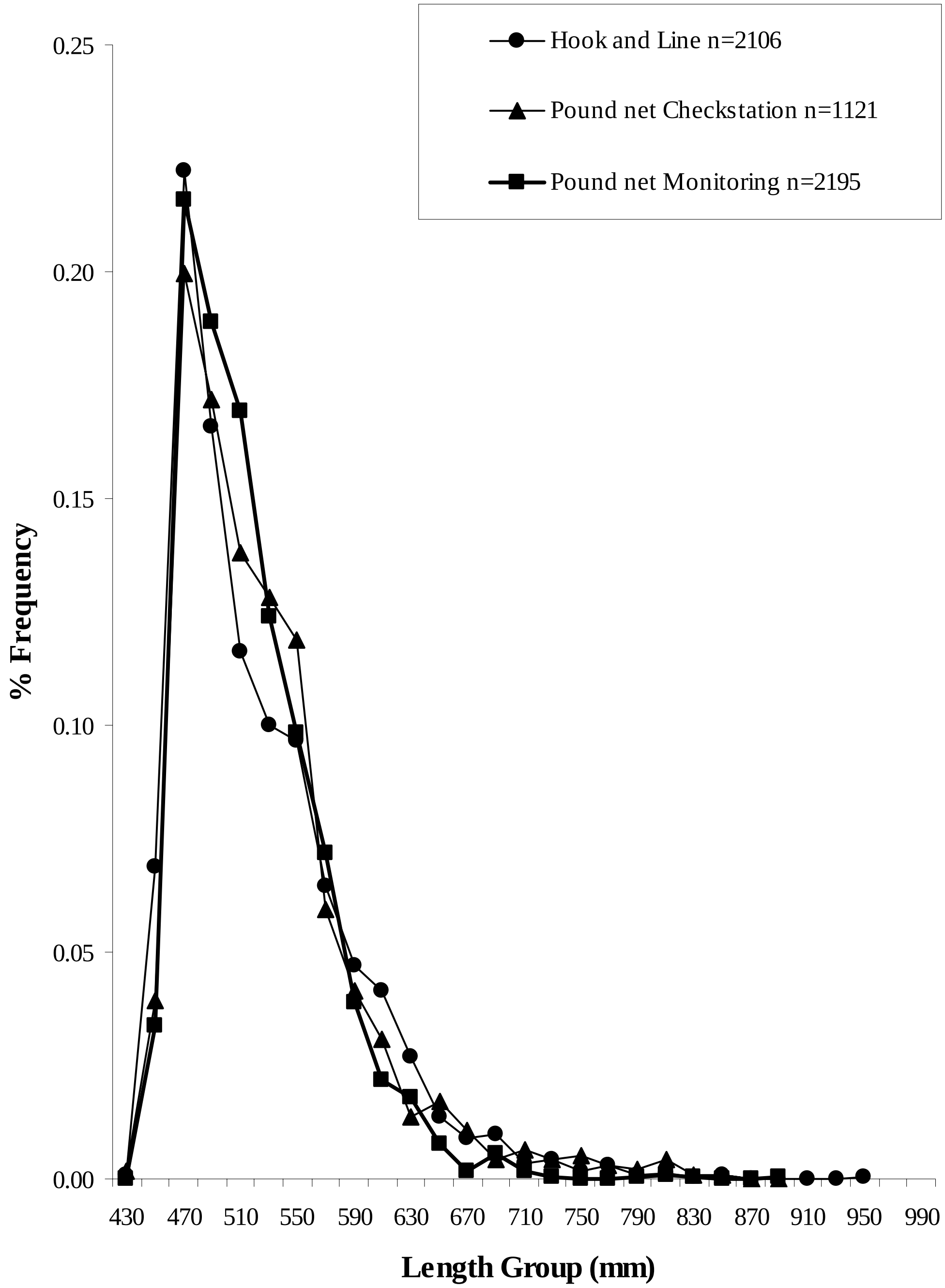


Figure 5. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2006. Note – pound net check station sampling began in 2000.

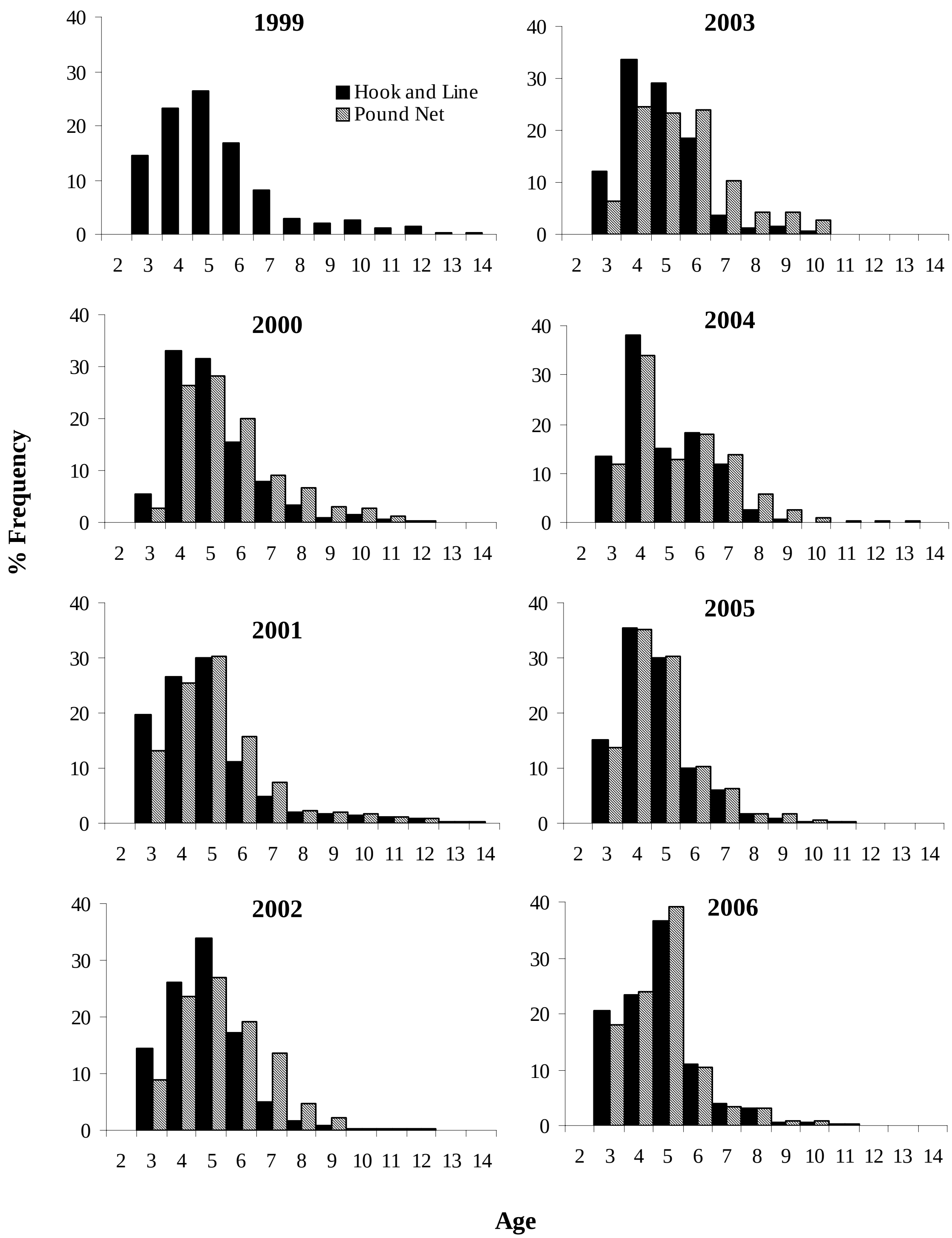
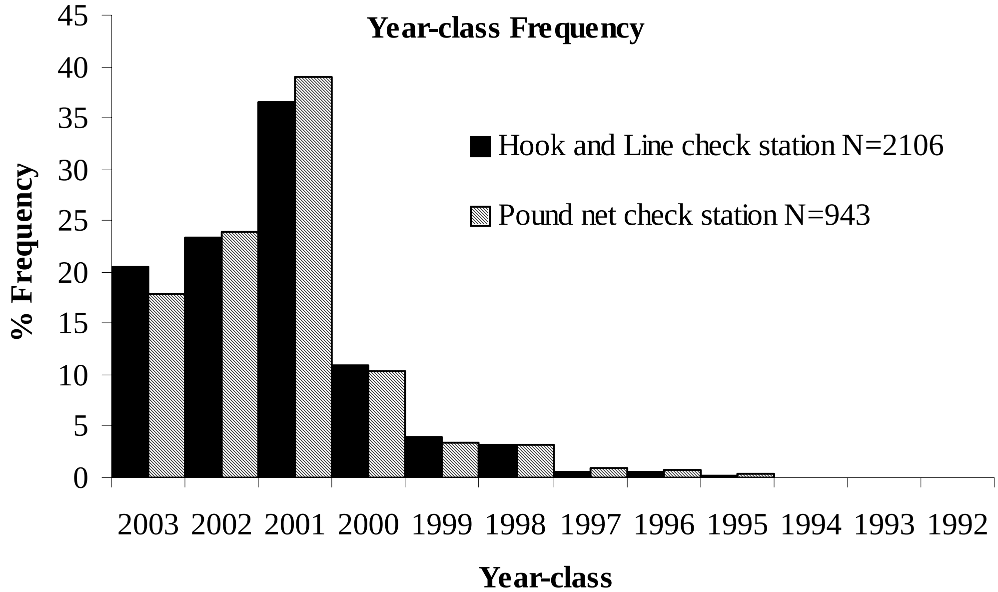


Figure 6. Year-class and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2006.



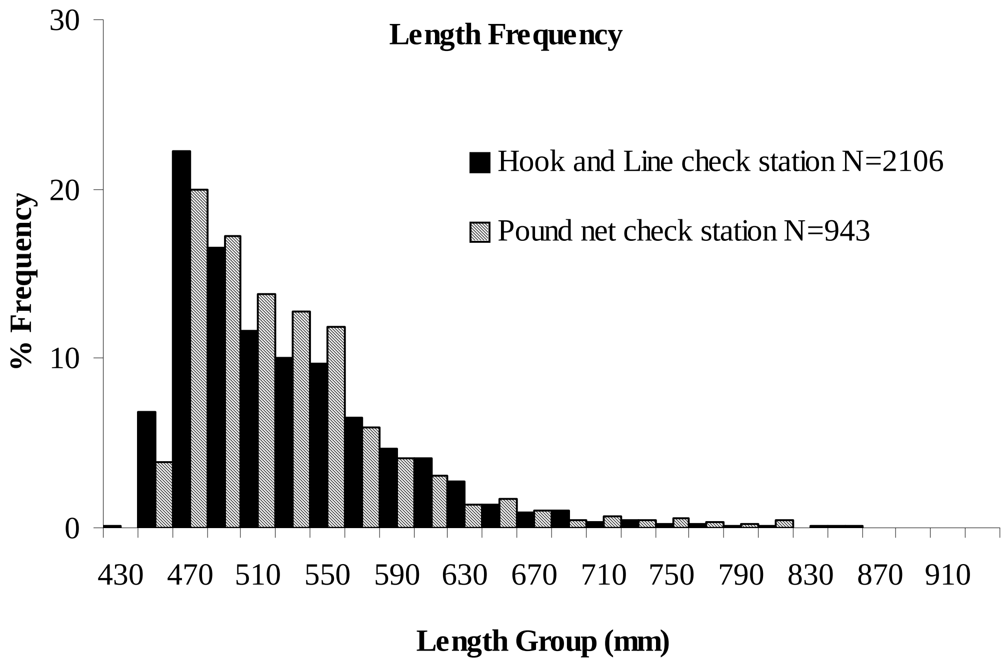


Figure 7. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2006.

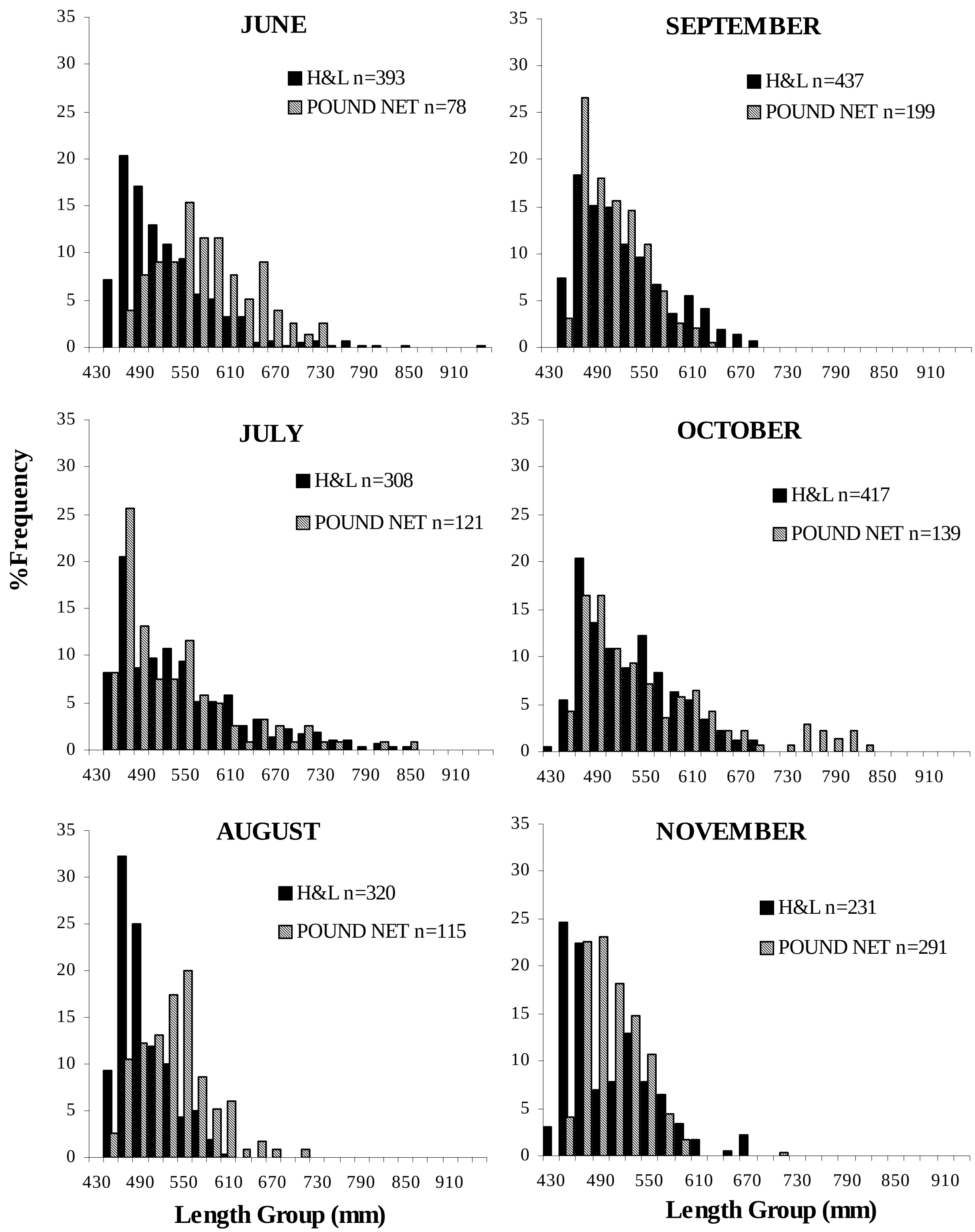
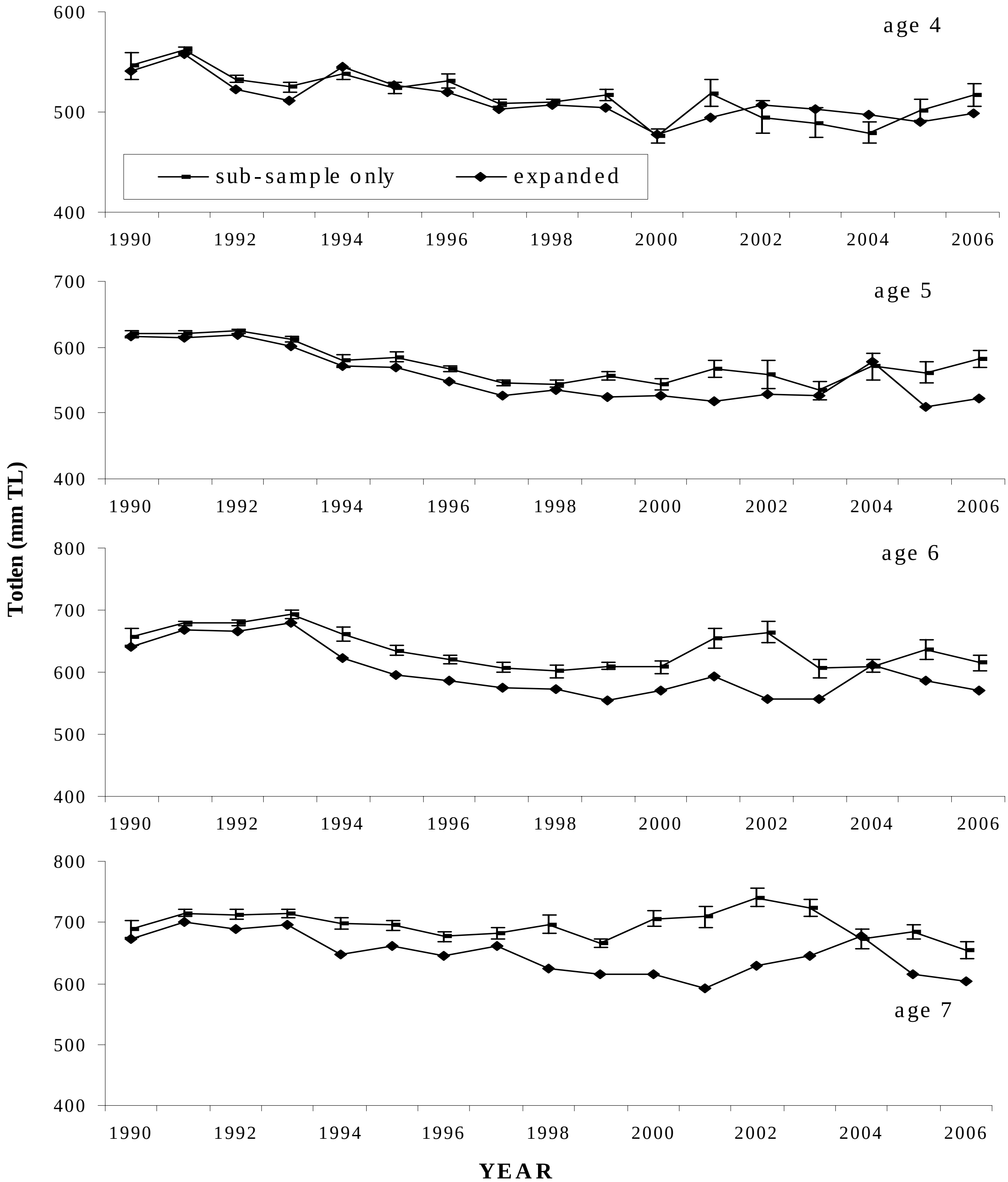


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets and commercial hook-and-line and pound net check stations,1990 through 2006.Chesapeake Bay Mean lengths were calculated by using sub-sampled 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 Task 1B was to characterize the size and age structures of striped bass (*Morone saxatilis*) sampled from the December 1, 2006 - February 28, 2007 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 the commercial harvest, data were used to monitor temporal trends in length and weight-at-age of resident/pre-migratory striped bass. These data 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 MD DNR approved check station. Thus, 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 fish availability to the fishery. 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 at Annapolis, 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 1000 fish in December and 1250 fish in both January and February, for a total target sample size of 3500. 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. Scales were taken from all fish greater than or equal to 700 mm TL.

<u>Analytical procedures</u>

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 2006-2007 winter gill net harvest was estimated by applying the sample age distribution to 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 2006 – February 2007 gillnet season, the year used for age calculations was 2007.

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 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 in 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 2006-2007 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 42% of the total Maryland Chesapeake commercial harvest, by weight, during the 2006 calendar year. A total of 3063 striped bass were measured and 183 striped bass were aged from the December 2006 - February 2007 harvest. The sample size obtained was slightly less than the target; a direct result of the fishery closure for all but 10 days in December 2006 as a result of exceeding the quota in January and February 2006.

Commercial gill nets have been limited to mesh sizes no less than 5 and no greater than 7 inches since the gill net 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 2006-2007 commercial drift gill net harvest consisted primarily of striped bass from the 2003 and 2001 (age 4 and 6) year-classes (Table 1), comprising 68% of the total harvest. 2001 and 2003 were also above average year classes for striped bass. 7-14 year-old fish contributed only 22% to the total, however, this contribution was much greater in the 2006-2007 gill net harvest compared to only 5% in 2005-2006 (Zlokovitz 2007) and 9% in 2004-2005 (Zlokovitz and Weedon 2006). The youngest fish observed in the 2006-2007 sampled harvest were age 4, although in other years, including 2005-2006, the youngest fish observed were age 3.

Mean lengths and weights-at-age of the aged sub-sample and the estimated means from the expansion technique are presented in Tables 2 and 3. Expanded mean lengths and weights-at-age were generally slightly lower than sub-sampled means. Striped bass were recruited into the 2006-2007 winter gill net fishery at age 4 (2003 year-class), with an expanded mean length and weight of 491 mm TL and 1.43 kg. The 2003 (age 4) and 2001 (age 6) year-classes were most commonly observed in the sampled landings, comprising 40% and 28% of the harvest respectively. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 14, 1993 year-class) were 806 mm TL and 6.14 kg.

Length frequency distributions by check station area are presented in Figure 3. Distributions were similar when comparing the northern and eastern area check stations as the length frequency distributions for both areas were dominated by fish in the 470-610mm TL range. Sub-legal fish composed less than 1% of the bay-wide sampled harvest.

The time series of sub-sampled and expanded mean lengths and weights for the period 1994-2007 are shown in Figures 4 and 5. Mean length-at-age and weight-at-age have been variable over time, with no obvious trends in growth over the 14 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 2006 - February 2007.

Year-Class	Age	Catch	Percentage of the Catch
2004	3	0	0
2003	4	68,042	40
2002	5	16,845	10
2001	6	49,061	28
2000	7	12,038	7
1999	8	7,337	4
1998	9	7,770	5
1997	10	5,397	3
1996	11	4,830	3
1995	12	315	0.2
1994	13	225	0.1
1993	14	354	0.2
	Total	172,214	

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 2006-February 2007.

Year-Class	Age	n fish aged	Mean TL (mm) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean TL (mm)
2003	4	18	485	1,210	491
2002	5	7	546	300	542
2001	6	32	626	873	557
2000	7	22	712	214	654
1999	8	20	759	130	729
1998	9	30	816	138	799
1997	10	26	848	96	800
1996	11	23	845	86	821
1995	12	1	799	6	789
1994	13	2	905	4	907
1993	14	2	880	6	806
Total		**183**		**3063**	

Table 3. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2006-February 2007.

Year-Class	Age	n fish aged	Mean Weight (kg) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean weight (kg)
2003	4	18	1.38	1,210	1.43
2002	5	7	2.04	300	1.90
2001	6	32	3.06	873	2.16
2000	7	22	4.34	214	3.50
1999	8	20	5.21	130	4.74
1998	9	29	6.16	138	5.97
1997	10	26	7.28	96	6.15
1996	11	23	7.20	86	6.49
1995	12	1	6.77	6	5.64
1994	13	2	9.29	4	8.58
1993	14	2	8.16	6	6.14
Total		**182**		**3063**	

Figure 1. Registered Maryland Chesapeake Bay check stations sampled for commercial drift gill net-harvested striped bass, December 2006-February 2007.

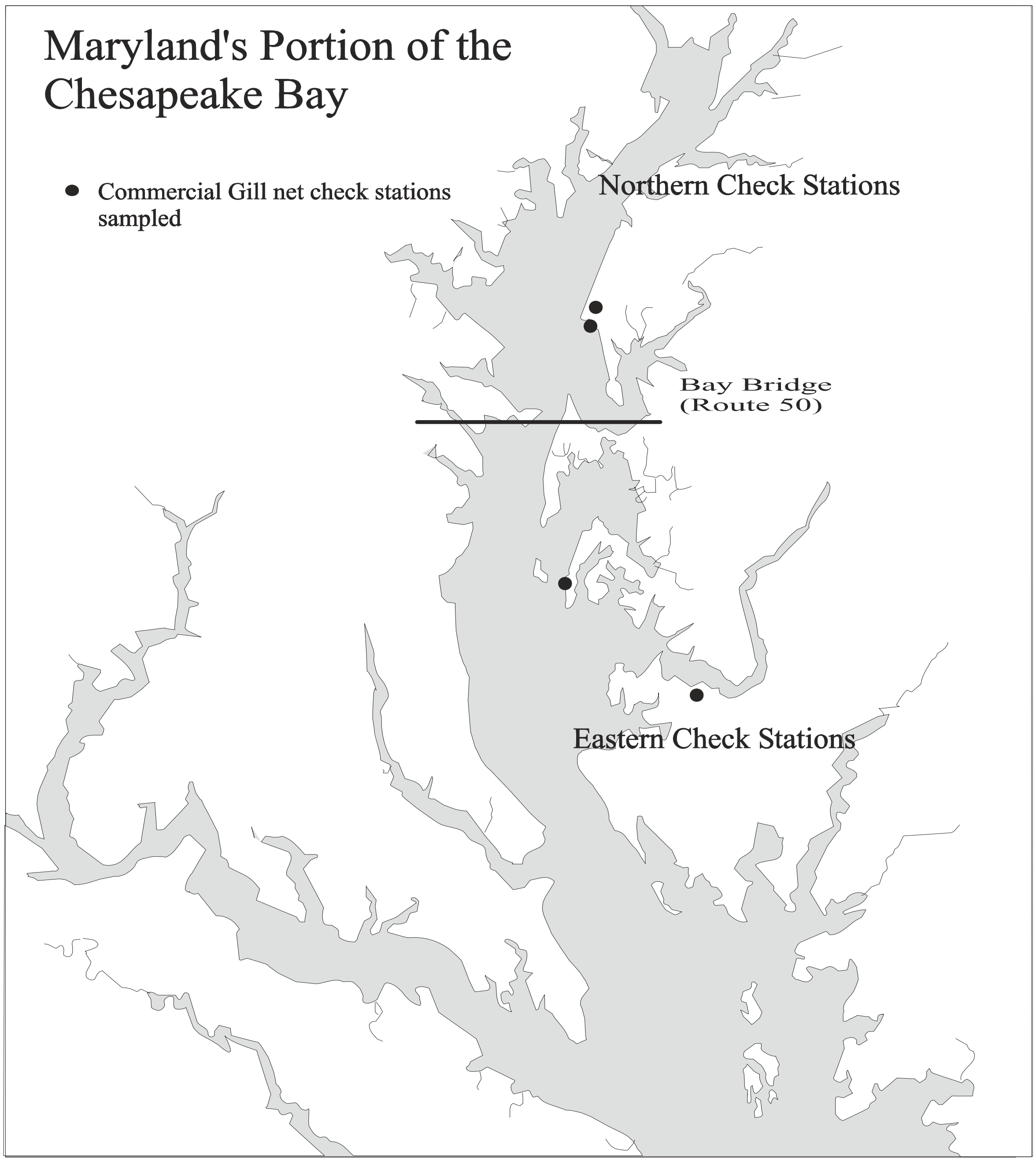


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gillnet landings, 1994-2007.

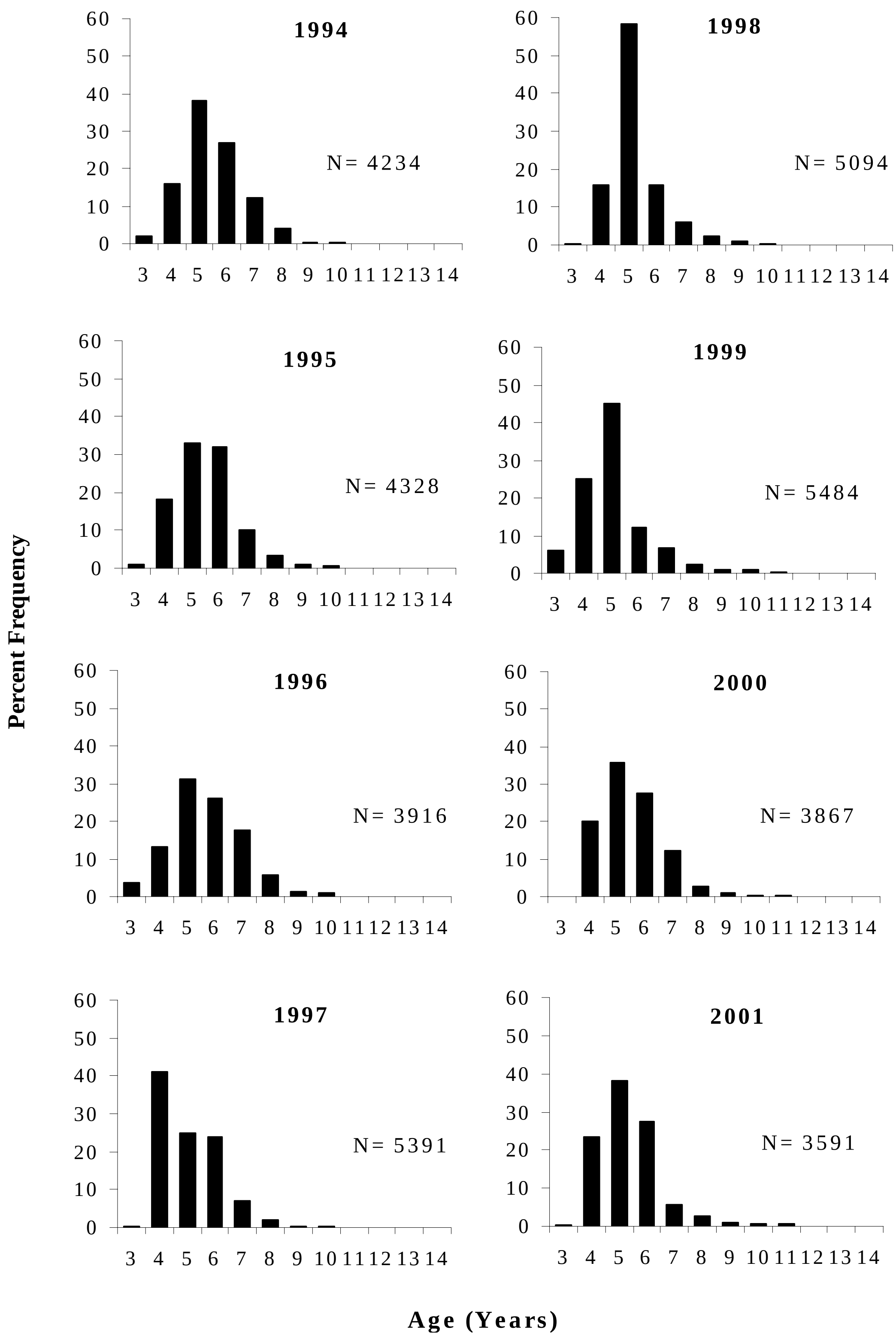


Figure 2. (Continued).

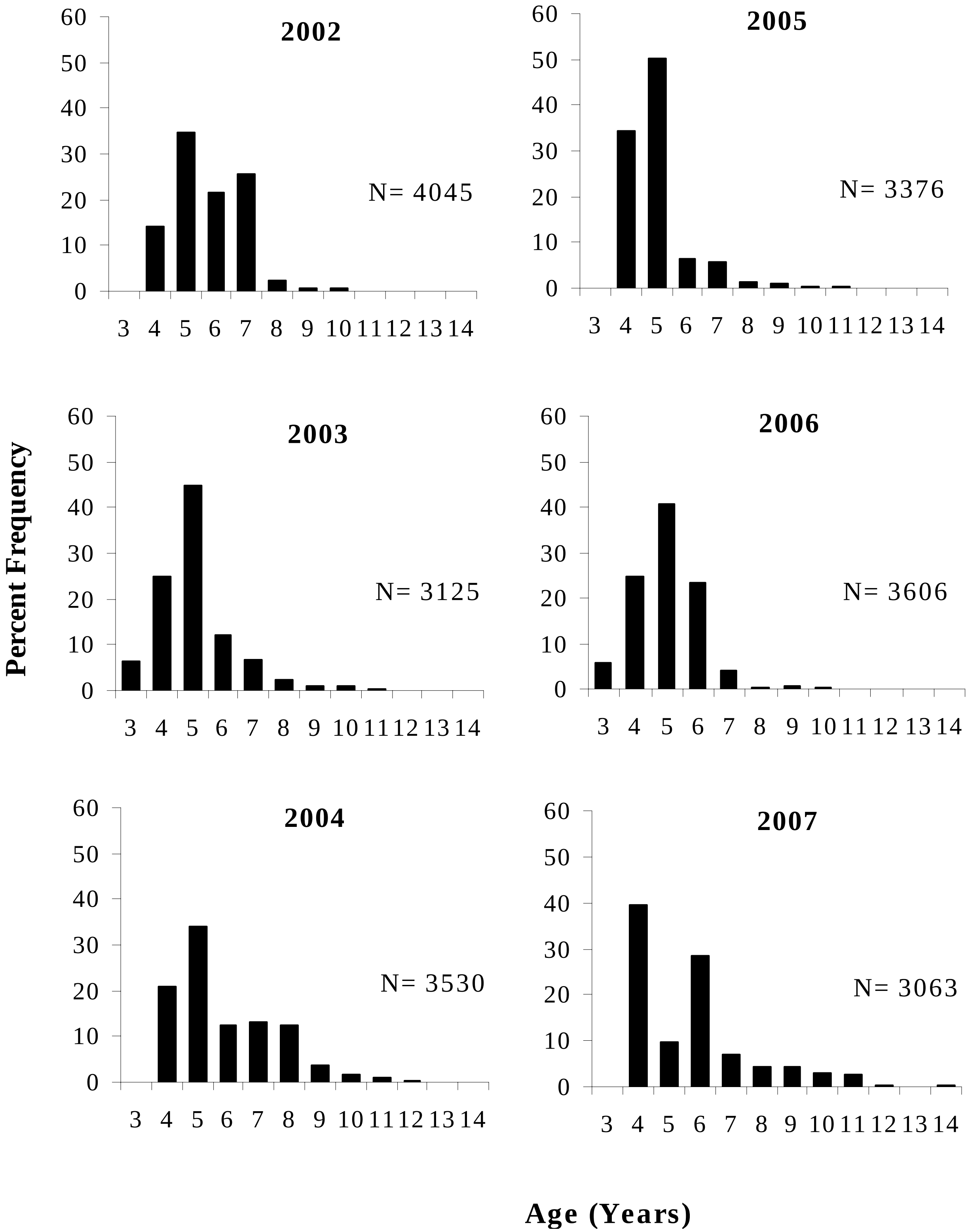


Figure 3. Length frequency distributions, by area and bay-wide, of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2006-February 2007.

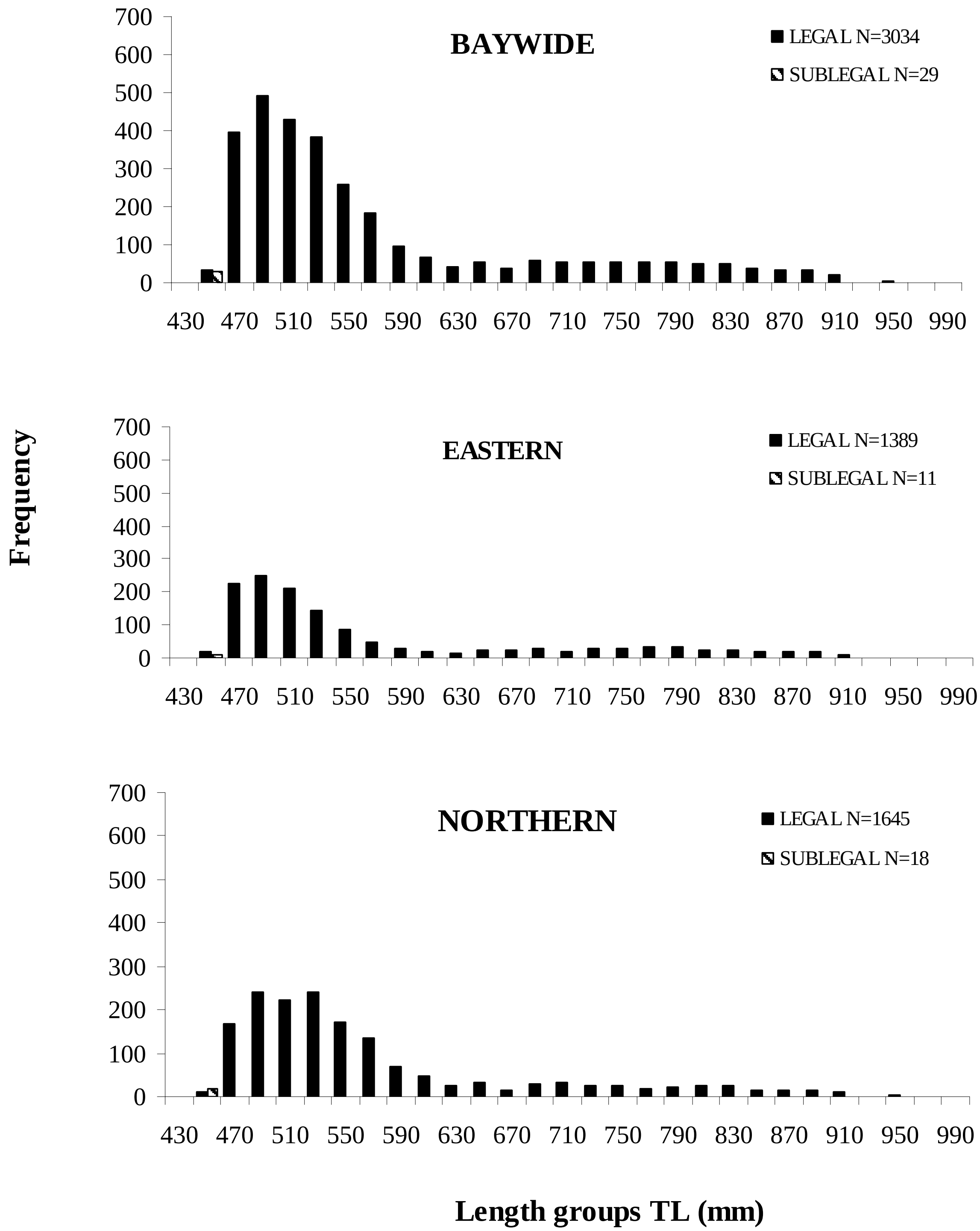


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2007 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. The year refers to the year in which the season ended.

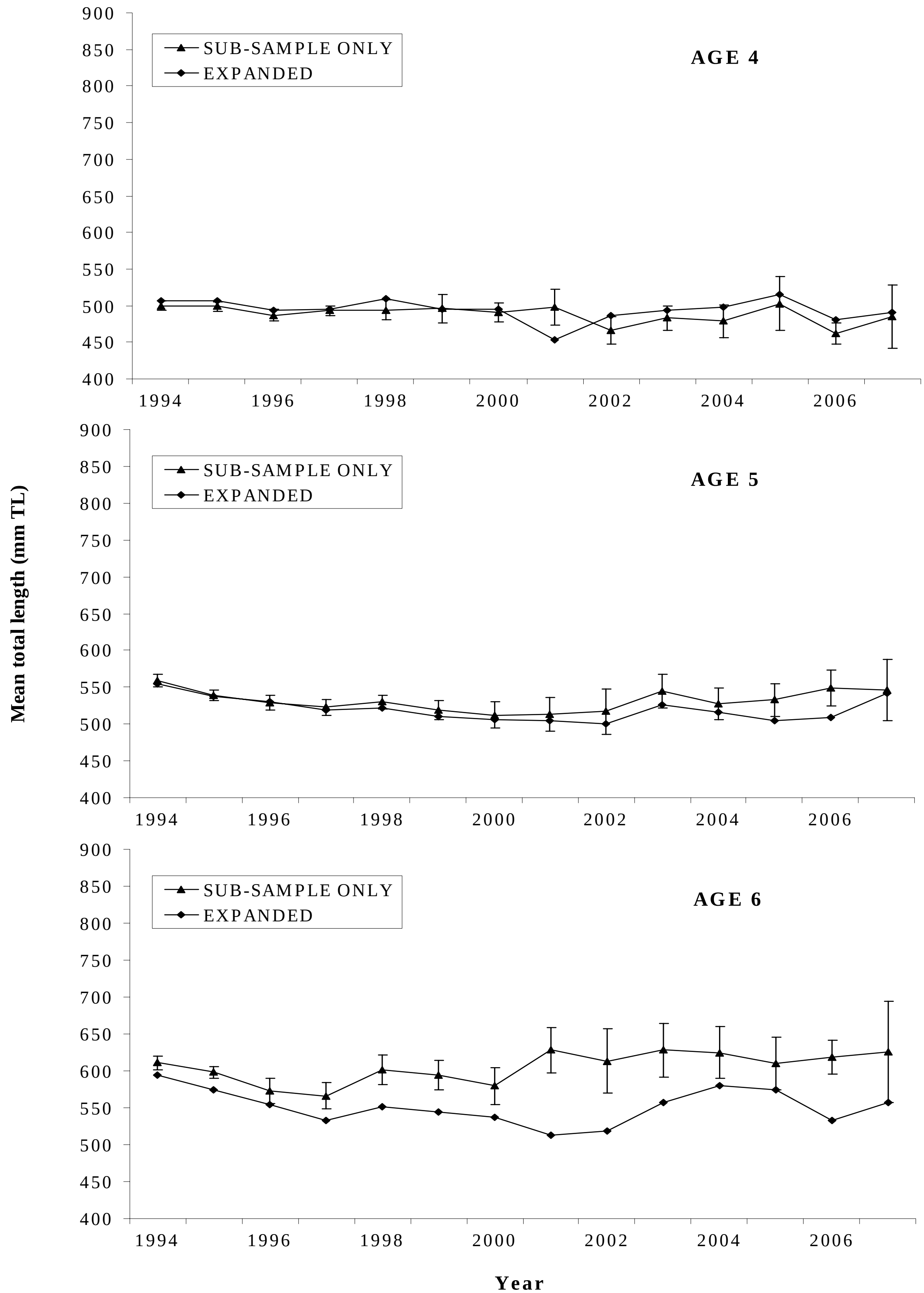


Figure 4. (Continued.)

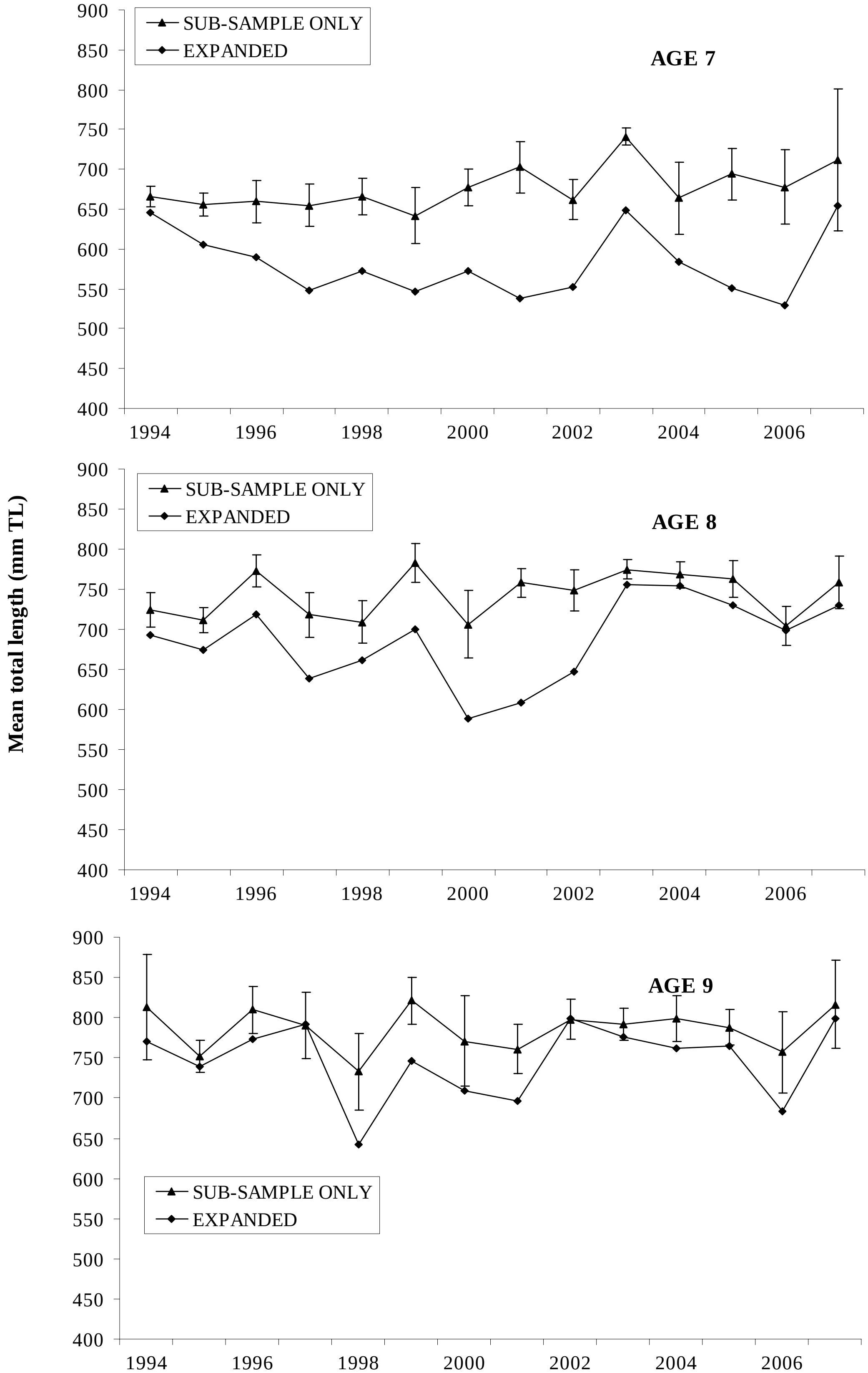


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2007 (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. The year refers to the year in which the season ended.

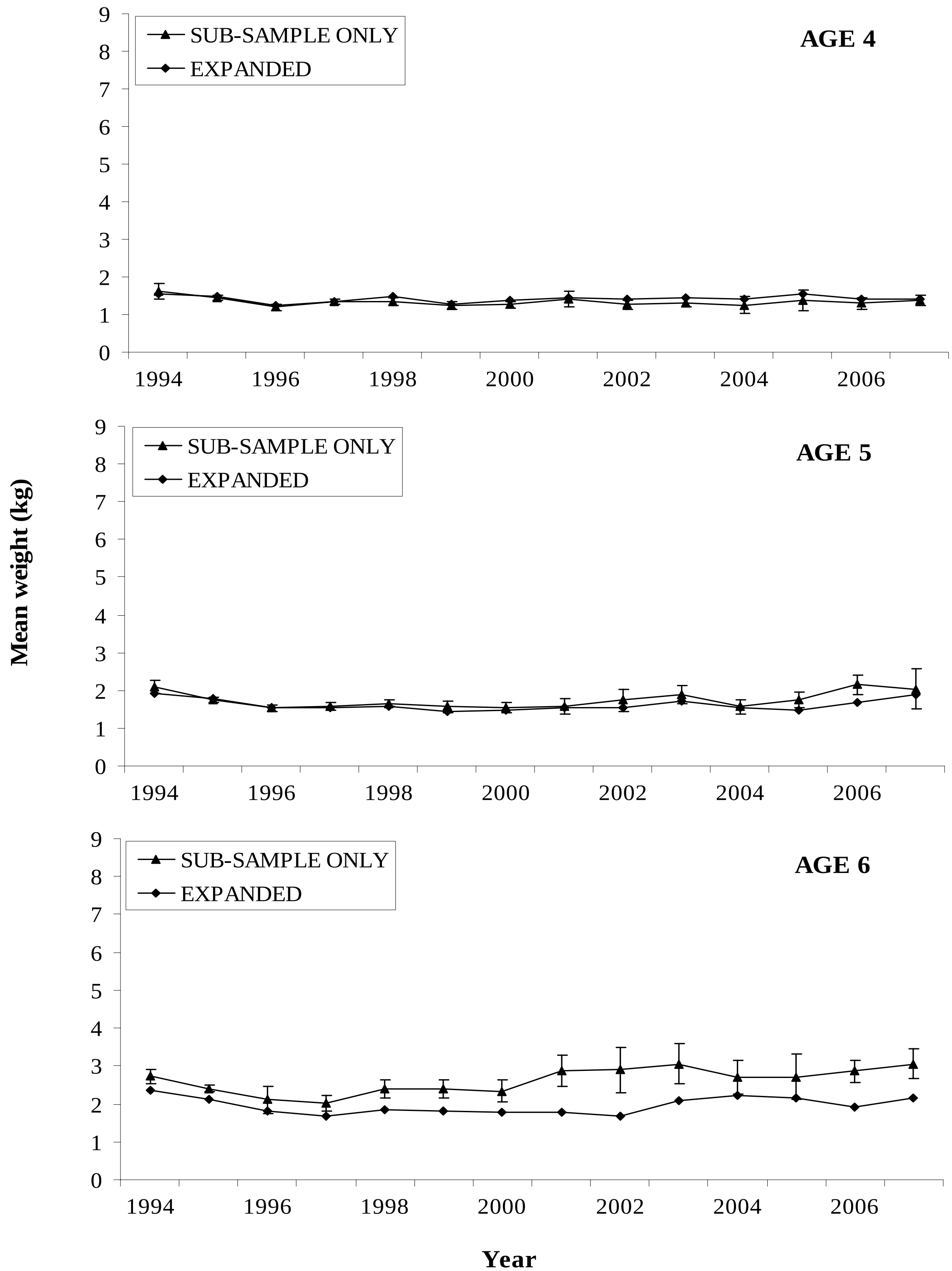
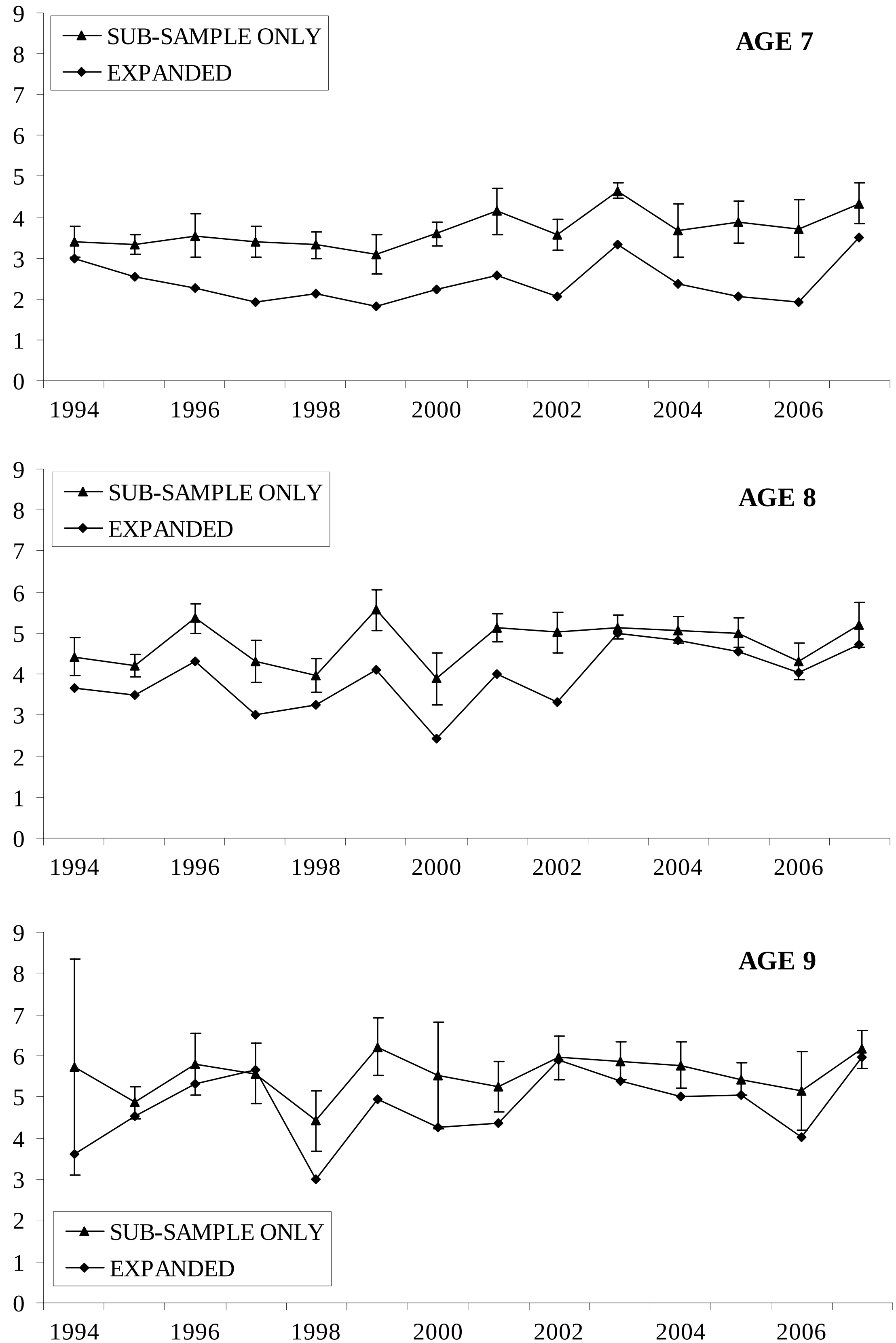


Figure 5. (Continued.)



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

ATLANTIC COAST STOCK ASSESSMENT AND COMMERCIAL HARVEST MONITORING

Prepared by Luke Whitman

INTRODUCTION

The primary objective of Job 3, Task 1C was to characterize the size and age structure of commercially harvested striped bass from Maryland's Atlantic coast. Trawls and gill nets were permitted during the Atlantic season, which occurred between November 1, 2006 and April 30, 2007. This fishery was managed with a 24 inch total length (TL) size limit and an annual quota of 126,396 pounds. Monitoring 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 showed that 85% of striped bass harvested on 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 20 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 of fish from the Atlantic coast fishing season, November 2006 through April 2007. For stage two, a sub-sample of scales from Atlantic coast striped bass was aged. The age-length key (ALK) was then constructed using ages of fish only from the calendar year 2006, because of time constraints, and applied to data collected from the entire 2006 - 2007 fishing season. The total number of scales to be aged was determined using a Vartot analysis, which is a derived index measuring the precision of an ALK (Kimura 1977, Lai 1987).

Year-class was determined by reading acetate impressions of the scales placed in microfiche readers. Age was calculated by subtracting year-class from collection year with the resulting ages used to construct the ALK. The catch-at-age for each fishery was calculated by applying the ALK to the length frequencies of fish harvested by the Atlantic fishery.

Finally, the age distribution of the total Atlantic coast harvest from November 2006 through April 2007 was estimated by applying the sample age distribution to the total landings. Mean lengths and weights at-age were calculated by year-class for the sub-sample of fish.

RESULTS and DISCUSSION

Sampling at coastal check stations was conducted on 16 days. A total of 417 fish were measured and weighed. The ALK was developed from 181 scale samples collected during a pilot study in January, 2006. In following years, this survey will develop an ALK from scales collected concurrently with lengths and weights of harvested fish.

Most striped bass harvested by the Atlantic coast fishery were ages five through eight (Table 1). Some striped bass were recruited into the Atlantic coast fishery at age 4, but because of the 24 inch minimum size limit few younger fish were caught. Age 6 fish were most common in the sample, composing 36% of the estimated harvest and 28% of the aged sample (Figure 1).

Striped bass sampled at Atlantic coast check stations had a mean length of 705 mm TL and mean weight of 3.6 kg. The most common length groups in the sample were between 630 and 670 mm TL (Figure 2). Recently recruited Age 4 fish had a mean length of 622 mm TL and mean weight of 2.3 kg (Tables 2 and 3). Age 6 striped bass had a mean length of 702 mm TL and mean weight of 3.4 kg (Tables 2 and 3).

All of the 82 fish sampled for a sex ratio were accurately identified as male or female. Female striped bass composed 74% of the sampled harvest while males accounted for the remaining 26%. In contrast, the sex ratio of fish sampled from the 2004 and 2005 Chesapeake Bay winter gill net fishery were 85% male and 15% female (Durell et al. 2005).

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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. This estimate is based on ages of striped bass sampled during the calendar year 2006.

Year-Class	**Age**	**Catch**	**Percent**
2002	4	1,975	1.4
2001	5	25,363	17.6
2000	6	52,241	36.3
1999	7	19,045	13.2
1998	8	21,067	14.6
1997	9	11,345	7.9
1996	10	8,814	6.1
1995	11	2,493	1.7
1994	12	113	0.1
1993	13	595	0.4
1992	14	390	0.3
1991	15	566	0.4
	Total	**144,007**	**100%**

Table 2. Mean total lengths (mm TL) by year class of striped bass sampled from Atlantic coast fishery during the calendar year 2006 and estimates of the number at age for fish sampled during the fishing season, November 2006 – April 2007.

Year Class	**Age**	**n fish aged**	**Mean TL (mm) of Aged sub-sample**	**Estimated # at-age in sample**
2002	4	3	622	6
2001	5	21	660	73
2000	6	51	702	151
1999	7	26	755	55
1998	8	29	768	61
1997	9	22	816	33
1996	10	17	853	26
1995	11	7	889	7
1994	12	---	---	0
1993	13	2	1011	2
1992	14	1	956	1
1991	15	2	1049	2
Total	**---**	**181**	**---**	**417**

Table 3. Mean weights (kg) by year class of striped bass sampled from Atlantic coast fishery during the calendar year 2006 and estimates of the number at age for the fish sampled from the fishing season, November 2006 – April 2007.

Year Class	**Age**	**n fish aged**	**Mean Weigh (kg) of Aged sub-sample**	**Estimated # at-age in sample**
2002	4	3	2.3	6
2001	5	21	2.7	73
2000	6	51	3.4	151
1999	7	26	4.3	55
1998	8	29	4.7	61
1997	9	22	5.9	33
1996	10	17	6.7	26
1995	11	7	7.3	7
1994	12	---	---	0
1993	13	2	10.5	2
1992	14	1	9.8	1
1991	15	2	11.9	2
Total	**---**	**181**	**---**	**417**

Figure 1. Age distribution of striped bass sampled from the Atlantic coast fishery during the calendar year 2006.

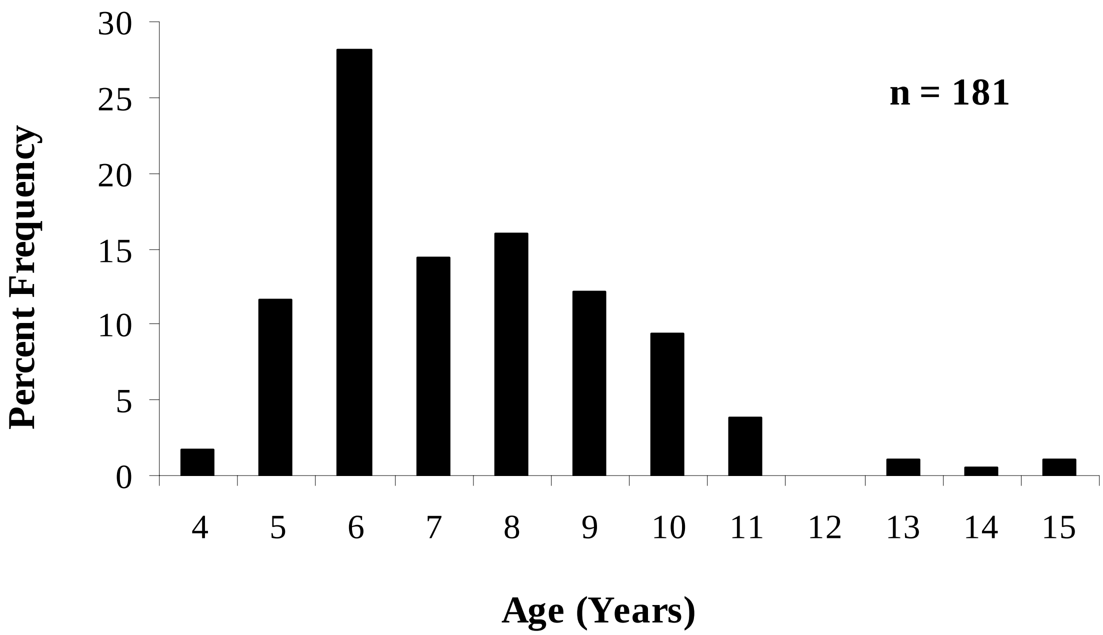
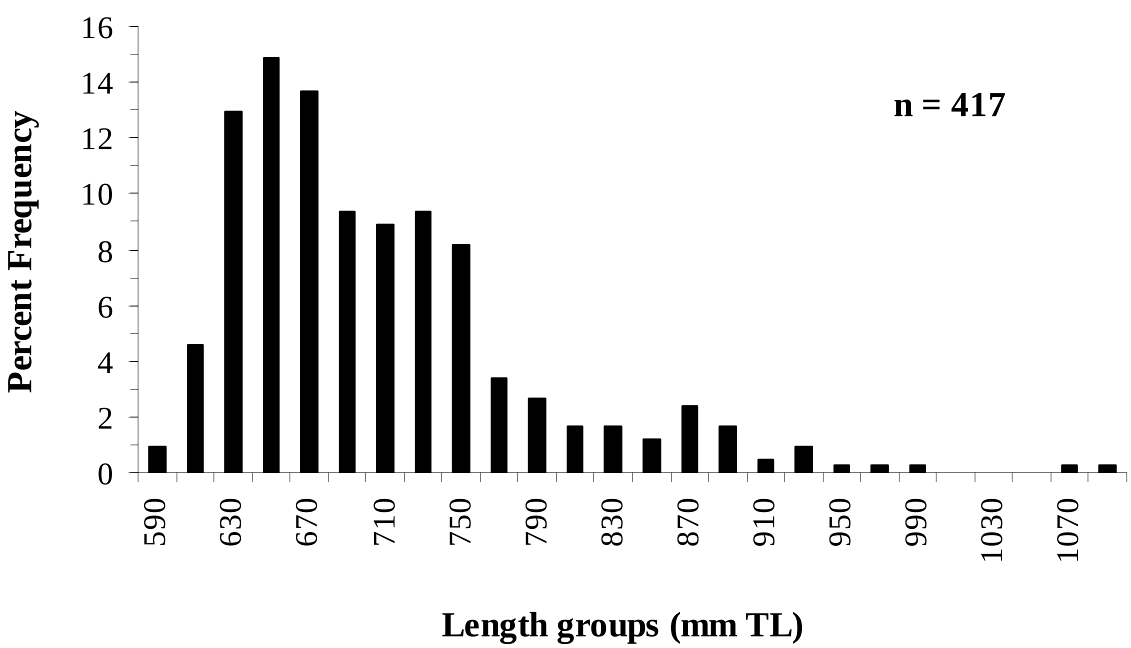


Figure 2. Length distribution of striped bass sampled from the Atlantic coast fishery, November 2006 – April 2007.



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Lisa Warner, Luke Whitman and Beth A. Versak

INTRODUCTION

The primary objective of Project 2, Job 3, Task 2 was to generate estimates of relative abundance-at-age for striped bass in Chesapeake Bay. 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 second objective was to characterize the status of the 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 also calculated.

METHODS

Data Collection Procedures

Multi-panel experimental drift gill nets were deployed in the Potomac River and in the upper Chesapeake Bay in 2007 (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 17 for a total of 35 sample days. In the upper Bay, sampling was conducted from April 2 to May 14 for a total of 25 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 9 to 82 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 removed from the left side of the fish, between the lateral line and the first dorsal fin. 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. 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, no fish were 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). 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 5B) (Barker et al., 2003). Beginning in 2004, scales from the Patuxent River CWT survey (Project No. 2, Job No. 3, Task 6) were also used to fill gaps in the ALK in larger length groups (Table 1). 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

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 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). These coefficients have been used since that time.

CPUEs for individual mesh sizes and length groups were calculated for each spawning area in 2007. CPUE is 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 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.

Sex-specific ALKs were applied to the appropriate vectors of selectivity-corrected length group CPUE to attain estimates of selectivity-corrected year-class CPUE. 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 1997-2007 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 1 year through 15-plus years.

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. The method followed the procedure given in Cochran (1997), 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. Therefore, when sampling of the Choptank ceased in 1997, previous years were not recalculated excluding the Choptank.

RESULTS AND DISCUSSION

CPUEs and variance

Annual CPUE calculations produced four vectors of selectivity-corrected sex- and age-specific CPUE values. The un-weighted time series data are presented by area in Tables 2-7.

The 2007 un-weighted CPUE for Potomac females (26) ranked eleventh of 22 years in the time series, just below the average of 28 (Table 2). The un-weighted CPUE for Potomac males (97) was the second lowest in the time-series, with both of these low values occurring in the last three years (Table 3). The upper Bay female CPUE (45) ranked ninth in the time series, greater than time series average of 35 (Table 4). The un-weighted CPUE for upper Bay males was 229, the fourth lowest in the time series and well below the time series average of 435 (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 2007 selectivity-corrected total weighted CPUE (397) was below the 2006 value of 506 and the time series average of 507.

Confidence intervals were calculated for the pooled and weighted CPUEs (Tables 9 and 10). Confidence intervals 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 78% of the CV values were less than 0.10 and 88% were less than 0.25 (Table 11). CV values greater than 1.0 were limited to older age-classes sampled during and immediately following the moratorium. The increased variability 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 (82%, Table 12) and weighted (84%, Table 13) pooled total CPUEs. Upper Bay males contributed 58% to the un-weighted and 65% to the weighted total CPUEs. Similar to other years, males from the 2003 year-class dominated the pooled, weighted CPUE in 2007, contributing 36% to the total CPUE.

Weighted CPUEs for Potomac River females were distributed across many year-classes. Contributions from the 1996 year-class were the greatest at 7.5% 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-classes, contributing 11.4% to the Upper Bay female un-weighted CPUE. The next greatest contribution was from the 15+ age group which contributed 7.1%.

As in previous years, Upper Bay fish accounted for most of the total CPUE, contributing 69% to the total un-weighted and 78% to the weighted CPUEs, respectively.

Temperature and catch patterns

Surface water temperatures on the Potomac River decreased during the early part of the 2007 survey then increased steadily from mid-April until the survey’s end. Daily water temperatures ranged from 8.5 °C to 21.2 °C. Daily female CPUEs on the Potomac suggested an increase in spawning activity in the third week in April, with the highest catch occurring on May

2 (Figure 2). Male striped bass exhibited a similar pattern with catches increasing during the third week in April and peaking on April 27, shortly before the highest female catch. Biologists observed striped bass eggs in the water on April 24 just after the period of increased catches of both males and females.

Surface water temperatures on the upper Bay increased steadily during the spawning survey from 7.3 °C to 19.3 °C. As on the Potomac River, daily female CPUEs from the upper Bay indicated a distinct peak in spawning activity during the third week in April (Figure 3). Catches of upper Bay females were inconsistent for the remainder of the survey. Highest catches of male striped bass in the upper Bay corresponded with a brief increase in female catches during the first week of May, a pattern seen in both systems.

In both systems, air temperatures increased gradually over the length of the entire survey with a cold spell occurring in the second week of April, just prior to the onset of increased catches of both sexes.

Length composition of the stock

In 2007, 341 male striped bass and 64 females were caught in the Potomac River, while 560 males and 62 females were caught in the upper Bay (Figure 4).

Mean lengths of male striped bass collected from the Potomac River (478 mm TL ± 7.0 SE) and upper Bay (509 mm TL ± 5.4 SE) were significantly different (p = 0.0005) in 2007. Examination of the length distributions from each system showed that the mean size was affected by the higher catch of smaller striped bass in the Potomac River.

Male striped bass on the Potomac ranged from 229 to 978 mm TL. The length distribution was influenced by the contribution of striped bass from the large 2003 year-class. Male striped bass ranging between 390 and 490 mm TL comprised 63% of the Potomac River male catch in 2007 (Figure 5). The peak at 950 mm TL, representing the 1996 year-class, was only evident in the corrected CPUE values.

Male striped bass on the upper Bay ranged from 310 to 1007 mm TL. Male striped bass between 410 and 490 mm TL contributed 59% to the total catch of males in the upper Bay. Similar to the Potomac River, 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, as fish from the 2003 ranged from 290 to 610 mm TL (Figure 5). The small peak at 790 mm TL, made up of the 1998 year-class, was only evident in the corrected CPUE values.

Mean lengths of female striped bass sampled from the Potomac River and upper Bay in 2007 were not significantly different ($p = 0.83$). Female striped bass sampled from the Potomac ranged from 810 to 1140 mm TL (mean = 957, ± 7.0 SE), while females sampled in the upper Bay ranged from 769 to 1177 mm TL (mean = 953 ± 11.0 SE)(Figure 6).

Female striped bass between 910 and 990 mm TL constituted 61% of the total female uncorrected CPUE, and 38% of the corrected CPUE in the Potomac River. The length distribution of female striped bass from the Potomac River showed the highest uncorrected CPUE peak occurring at 910 mm TL, representing mostly the 1996 year-class (Figure 6). Application of the selectivity model to the data corrected the catch upward across the length distribution. The highest corrected CPUEs occurred at 910 and 1130 mm TL and were attributed to fish aged 14 and 15 from the 1992 and 1993 year-classes, respectively.

In the upper Bay, 66% of the female uncorrected CPUE, and 47% of the corrected CPUE was comprised of striped bass between 870 and 990 mm TL . The uncorrected CPUE peak value at 930 mm TL reflects the contribution of the 1996 year-class, while the contributions of the return spawners from several year-classes comprise the 990 mm TL length group. The 1993 year-class is noticeable in the uncorrected CPUE values of the 1070 mm TL length group. The highest corrected CPUEs were in the 810, 870 and 910 mm TL length groups representing the 1995-1998 year-classes. Corrected CPUE contributions in the 1090 and 1170 mm length groups are composed of the 1993 and 1991 year-classes, respectively.

Length at age (LAA)

Age and sex-specific LAA relationships are presented in Tables 14 and 15. Information from the area-specific LAA relationships reflected known biology of the species, as there was a significant difference between LAA for the male and female components of the spawning stock encountered in the Potomac and upper Bay in 2007 ($p < 0.0001$). The scale allocation procedure implemented in 2003 was validated for the 2007 analysis by results of an analysis of covariance that showed no significant age by area interaction for male ($p = 0.52$) and female ($p = 0.20$) striped bass. Separate male and female ALKs were subsequently developed to include fish from the Potomac River, upper Bay and the spring recreational creel sampling (Project 2,Job 3,Task 5B). 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.

Since harvested fish sampled during the creel survey were subject to different minimum size limits between years only gillnet fish were used to compare LAA between 2006 and 2007. Male and female LAA have been relatively stable since the mid 1990's (Figures 7 and 8). Mean lengths-at-age of male and female striped bass sampled in 2007 showed no significant differences from those in 2006, at any age (t-tests, $\alpha = 0.05$).

Age composition of the stock

Sixteen age-classes were sampled, ranging from 2-19 years old (Tables 14 and 15). All striped bass aged six and younger were male, while females ranged from ages 7-19. Aged four males (2003 year-class) were by far the most abundant male cohort, while age eleven females (1996 year-class) were the major contributors to the total female CPUE (Tables 14 and 15). The abundance of 2-5 year-old 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. In 2007, males up to the age of 16 were encountered. Females younger than age 7 have been uncommon in the spawning stock since 1996, with none encountered in 2007 (Figure 9).

In 2007, age 8+ females composed 93% of the female spawning stock (Figure 10), an 11% increase from 2006. The percentage of the overall sample (males and females combined) age 8 and older has varied without trend since 1996 (Figure 11). The 2007 value of 30% was a 58% increase over the contribution in 2006. The percentage of age 8+ fish among males and females was heavily influenced by strong year-classes and shows cyclical variations (Figure 9). Although the relative number of older fish dropped 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).

Prior to 2007, 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). MD DNR estimates of female SSB generated from the upper Bay have been above the time-series average of 282 since 2003

(Table 16, Figure 12). Potomac River female SSB continues to vary without trend, although the 2007 value (263) was only slightly above the time-series average of 247 and well below the 2006 value of 462.

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2007.

	Males					Females				
Lgrp(mm)	**Upper Bay**	**Potomac**	**Creel**	**Patuxent**	**Total**	**Upper Bay**	**Potomac**	**Creel**	**Patuxent**	**Total**
230	0	1	0	0	**1**	0	0	0	0	**0**
250	0	1	0	0	**1**	0	0	0	0	**0**
270	0	1	0	0	**1**	0	0	0	0	**0**
290	0	2	0	0	**2**	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	3	0	0	**6**	0	0	0	0	**0**
430	3	3	0	0	**6**	0	0	0	0	**0**
450	3	3	2	0	**8**	0	0	0	0	**0**
470	3	3	4	0	**10**	0	0	5	0	**5**
490	3	3	3	0	**9**	0	0	3	0	**3**
510	3	3	4	0	**10**	0	0	4	0	**4**
530	3	3	1	0	**7**	0	0	1	0	**1**
550	3	3	0	0	**6**	0	0	0	0	**0**
570	6	4	4	0	**14**	0	0	2	0	**2**
590	5	5	4	0	**14**	0	0	0	0	**0**
610	5	5	1	0	**11**	0	0	3	0	**3**
630	5	5	1	0	**11**	0	0	1	0	**1**
650	6	1	4	0	**11**	0	0	1	0	**1**
670	9	1	0	0	**10**	0	0	2	0	**2**
690	5	2	3	0	**10**	0	0	0	0	**0**
710	3	2	4	0	**9**	0	0	2	0	**2**
730	4	1	7	1	**13**	0	0	5	0	**5**
750	5	5	0	0	**10**	0	0	5	0	**5**
770	5	3	6	0	**14**	1	0	15	0	**16**
790	5	0	7	0	**12**	1	0	14	0	**15**
810	2	3	5	2	**12**	2	1	13	0	**16**
830	5	1	4	0	**10**	1	0	14	0	**15**
850	3	1	8	1	**13**	0	2	15	0	**17**
870	3	6	5	1	**15**	5	4	9	0	**18**
890	4	2	6	1	**13**	6	2	12	0	**20**
910	2	0	1	0	**3**	5	5	5	0	**15**
930	5	2	0	0	**7**	5	5	5	0	**15**
950	2	1	0	0	**3**	5	6	4	0	**15**
970	1	1	0	0	**2**	2	5	0	4	**11**
990	0	0	1	0	**1**	6	4	0	3	**13**
1010	1	0	0	0	**1**	5	2	3	0	**10**
1030	0	0	0	0	**0**	1	4	7	1	**13**
1050	0	0	0	0	**0**	1	3	5	0	**9**
1070	0	0	0	0	**0**	4	2	5	0	**11**
1090	0	0	0	0	**0**	1	2	5	1	**9**
1110	0	0	0	0	**0**	0	0	2	1	**3**
1130	0	0	0	0	**0**	2	0	1	0	**3**
1150	0	0	0	0	**0**	0	1	0	1	**2**
1170	0	0	0	0	**0**	2	0	1	1	**4**
Total	**130**	**95**	**85**	**6**	**316**	**55**	**48**	**169**	**12**	**284**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985-2007 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**
AVG																**28**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985-2007 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**
AVG																**475**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985-2007 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**
AVG																**35**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985-2007 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**
AVG																**435**

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**

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**

Table 8. Mean values of the pooled, weighted, annual age-specific CPUEs (1985–2007) 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	17.1	43.7	138.5	26.2	27.0	23.7	13.1	16.2	18.5	30.9	15.0	5.8	11.0	10.7	**397**
AVG																**507**

Table 9. Lower confidence limits (95%) of the pooled, weighted, annual age-specific CPUEs (1985–2007) 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	16.1	42.4	136.0	25.7	26.5	22.7	11.9	15.1	17.8	28.0	14.1	5.5	9.4	*

* Notes: Shadings note negative values that have been changed to zero. Confidence intervals could not be calculated on combined CIs for age class 15+.

Table 10. Upper confidence limits (95%) of the pooled, weighted, annual age-specific CPUEs (1985–2007) 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	18.1	44.9	141.1	26.8	27.6	24.6	14.2	17.2	19.3	33.7	16.0	6.1	12.6	*

* Note: Confidence intervals could not be calculated on combined CIs for age class 15+.

Table 11. Coefficients of Variation of the pooled, weighted, annual age-specific CPUEs (1985–2007) 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	0.03	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.02	0.05	0.03	0.02	0.07	*

* Note: CV values >1.00 are noted by shadings. CVs could not be calculated on combined CVs for age class 15+

Table 12. Un-weighted striped bass catch per unit effort (CPUE) by year-class, late March through May 2007. 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
2006	1	0.0	0.0	0.0	0.0	0.0	0.0
2005	2	17.1	4.3	0.0	0.0	10.6	6.5
2004	3	43.7	11.0	0.0	0.0	16.9	26.8
2003	4	138.5	34.9	0.0	0.0	37.3	101.2
2002	5	26.2	6.6	0.0	0.0	5.3	21.0
2001	6	27.0	6.8	0.1	0.5	5.6	20.9
2000	7	23.7	6.0	0.4	3.4	4.3	15.7
1999	8	13.1	3.3	0.9	2.8	2.1	7.3
1998	9	16.2	4.1	1.4	4.3	2.6	7.8
1997	10	18.5	4.7	3.2	5.5	2.8	7.1
1996	11	30.9	7.8	7.5	11.4	5.4	6.5
1995	12	15.0	3.8	4.5	5.0	1.0	4.5
1994	13	5.8	1.5	1.4	1.4	0.8	2.2
1993	14	11.0	2.8	3.8	3.8	2.0	1.4
≤1992	15+	10.7	2.7	3.2	7.1	0.1	0.2
Total		397.4		26.3	45.2	96.8	229.1
% of Total				6.6	11.4	24.3	57.6
% of Sex				36.8	63.2	29.7	70.3
% of Potomac				21.4		78.6	
% of Upper Bay					16.5		83.5

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area*, late March through May 2007. 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
2006	1	0.0	0.0	0.0	0.0	0.0	0.0
2005	2	8.1	3.7	0.0	0.0	4.1	4.0
2004	3	23.0	10.7	0.0	0.0	6.5	16.4
2003	4	76.6	35.5	0.0	0.0	14.4	62.2
2002	5	14.9	6.9	0.0	0.0	2.0	12.9
2001	6	15.3	7.1	0.0	0.3	2.2	12.8
2000	7	13.5	6.3	0.1	2.1	1.6	9.6
1999	8	7.4	3.4	0.3	1.7	0.8	4.5
1998	9	9.0	4.2	0.5	2.6	1.0	4.8
1997	10	10.0	4.6	1.2	3.4	1.1	4.3
1996	11	16.0	7.4	2.9	7.0	2.1	4.0
1995	12	8.0	3.7	1.7	3.1	0.4	2.8
1994	13	3.1	1.4	0.5	0.8	0.3	1.4
1993	14	5.4	2.5	1.5	2.4	0.8	0.8
≤1992	15+	5.3	2.5	1.2	3.9	0.0	0.1
Total		215.5		10.1	27.3	37.3	140.8
% of Total				4.7	12.7	17.3	65.3
% of Sex				27.1	72.9	20.9	79.1
% of Potomac				21.4		78.6	
% of Upper Bay					16.2		83.8

* 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 2007.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2005	2	POTOMAC	6	287	242	333	43.5	17.8
		UPPER	3	318	308	329	4.2	2.4
		COMBINED	9	298	269	327	37.8	12.6
2004	3	POTOMAC	9	341	310	372	40.0	13.3
		UPPER	8	375	354	395	24.7	8.7
		COMBINED	17	357	338	376	37.0	9.0
2003	4	POTOMAC	20	434	407	461	58.0	13.0
		UPPER	24	454	422	486	76.1	15.5
		COMBINED	44	445	424	466	68.4	10.3
2002	5	POTOMAC	6	529	464	594	62.2	25.4
		UPPER	6	557	484	629	69.1	28.2
		COMBINED	12	543	502	584	64.3	18.6
2001	6	POTOMAC	14	590	565	615	43.0	11.5
		UPPER	15	609	576	642	59.1	15.3
		COMBINED	29	600	580	620	52.0	9.6
2000	7	POTOMAC	14	657	611	703	79.6	21.3
		UPPER	13	651	611	691	66.5	18.4
		COMBINED	27	654	625	682	72.3	13.9
1999	8	POTOMAC	4	693	434	951	162.5	81.3
		UPPER	10	707	636	778	99.4	31.4
		COMBINED	14	703	637	769	114.0	30.5
1998	9	POTOMAC	5	849	766	932	66.7	29.8
		UPPER	17	728	695	760	63.0	15.3
		COMBINED	22	755	719	791	81.1	17.3
1997	10	POTOMAC	10	793	755	831	53.0	16.8
		UPPER	11	824	770	877	79.8	24.1
		COMBINED	21	809	778	840	68.5	15.0
1996	11	POTOMAC	4	855	683	1028	108.5	54.2
		UPPER	13	818	773	863	74.6	20.7
		COMBINED	17	827	785	869	81.5	19.8
1995	12	POTOMAC	1	921	.	.	.	.
		UPPER	6	907	838	976	65.8	26.9
		COMBINED	7	909	853	965	60.3	22.8
1994	13	POTOMAC	.	.	.	.	.	.
		UPPER	3	937	881	993	22.7	13.1
		COMBINED	3	937	881	993	22.7	13.1
1993	14	POTOMAC	1	978	.	.	.	.
		UPPER	1	951	.	.	.	.
		COMBINED	2	965	793	1136	19.1	13.5
1991	16	POTOMAC	1	862	.	.	.	.
		UPPER	.	.	.	.	.	.
		COMBINED	1	862	.	.	.	.

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 2007.

YEAR-CLASS	AGE	AREA	N	MEAN	LCL	UCL	SD	SE
2000	7	POTOMAC	.	.	.	.	.	.
		UPPER	1	769	.	.	.	.
		COMBINED	1	769	.	.	.	.
1999	8	POTOMAC	.	.	.	.	.	.
		UPPER	1	784	.	.	.	.
		COMBINED	1	784	.	.	.	.
1998	9	POTOMAC	.	.	.	.	.	.
		UPPER	4	862	809	915	33.6	16.8
		COMBINED	4	862	809	915	33.6	16.8
1997	10	POTOMAC	9	907	871	942	46.1	15.4
		UPPER	11	932	884	981	72.5	21.8
		COMBINED	20	921	892	950	61.9	13.8
1996	11	POTOMAC	21	944	919	968	53.7	11.7
		UPPER	19	939	914	964	52.0	11.9
		COMBINED	40	941	925	958	52.3	8.3
1995	12	POTOMAC	7	964	918	1011	50.1	18.9
		UPPER	9	981	926	1037	72.6	24.2
		COMBINED	16	974	941	1007	62.4	15.6
1994	13	POTOMAC	1	1040	.	.	.	.
		UPPER	3	980	785	1176	78.6	45.4
		COMBINED	4	995	883	1108	70.8	35.4
1993	14	POTOMAC	5	1021	917	1125	83.9	37.5
		UPPER	4	1071	1034	1109	23.5	11.8
		COMBINED	9	1043	992	1095	66.5	22.2
1992	15	POTOMAC	4	1055	978	1132	48.5	24.3
		UPPER	.	.	.	.	.	.
		COMBINED	4	1055	978	1132	48.5	24.3
1991	16	POTOMAC	1	1140	.	.	.	.
		UPPER	2	1145	954	1336	21.2	15.0
		COMBINED	3	1143	1105	1181	15.3	8.8
1988	19	POTOMAC	1	1177	.	.	.	.
		UPPER	.	.	.	.	.	.
		COMBINED	1	1177	.	.	.	.

Table 16. Index of spawning biomass by year, for female striped bass $\geq$ 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
Average	282.06	619.38	246.68

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, late March - May 2007.

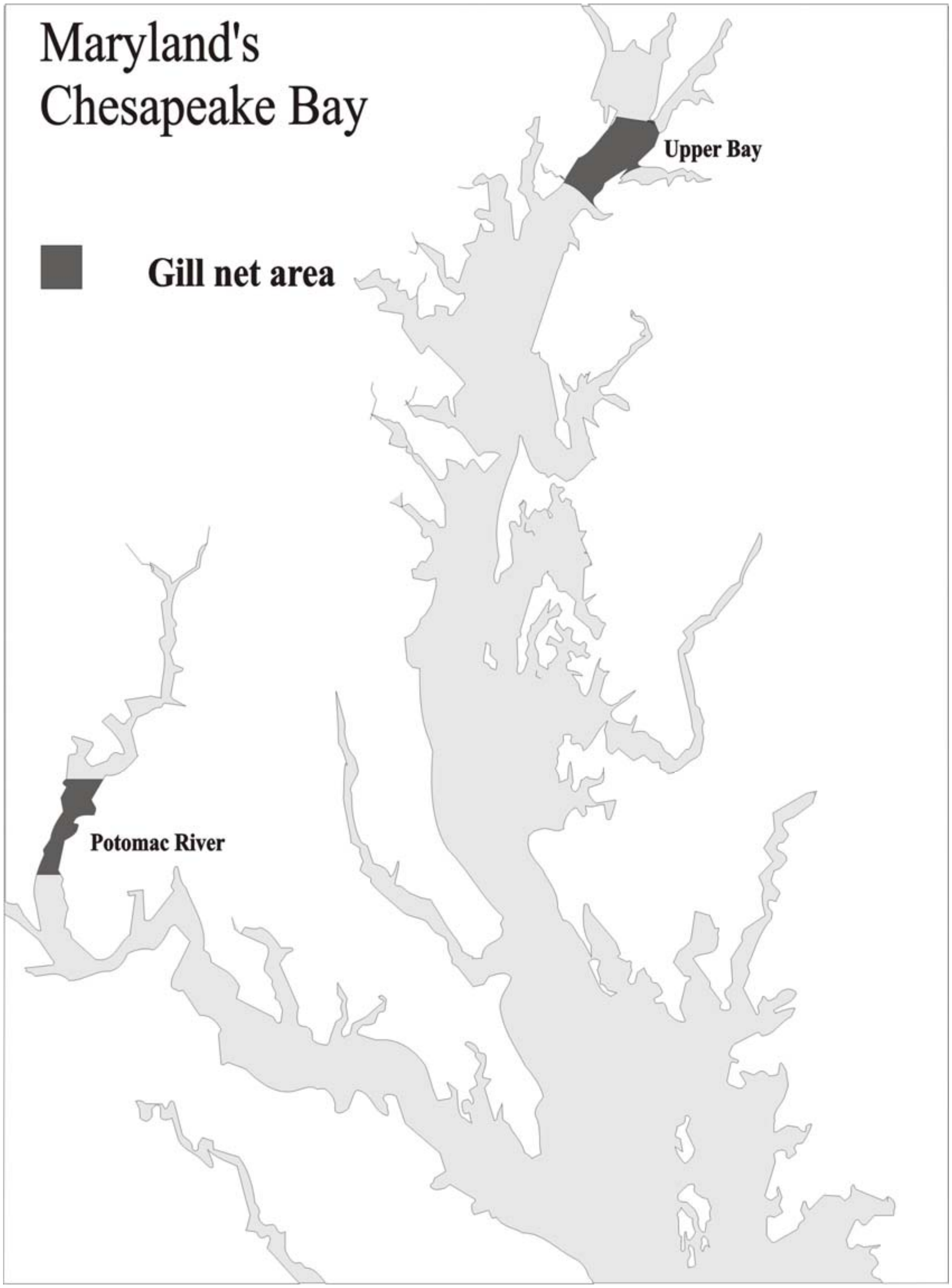


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, late March through May 2007. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

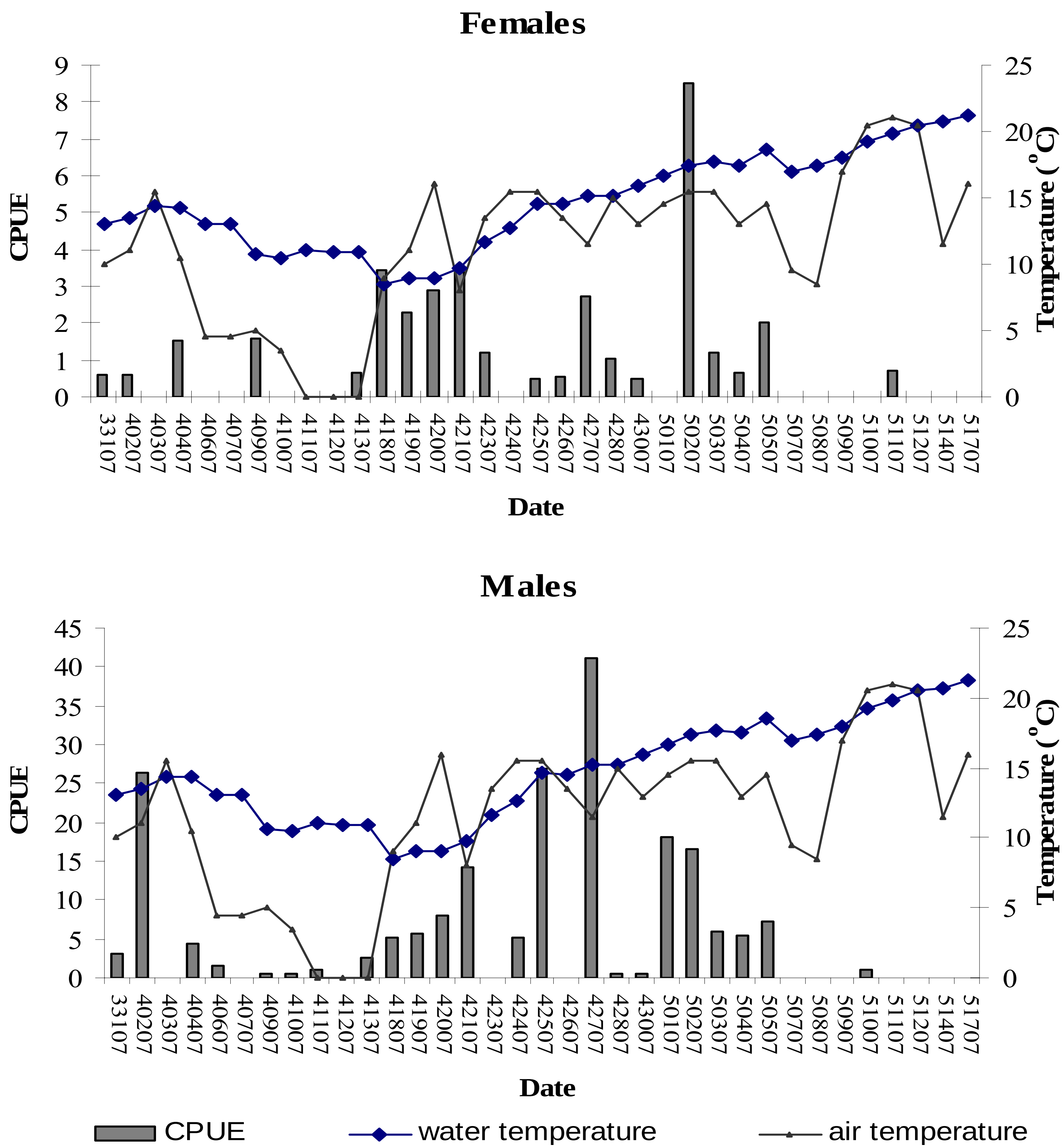


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Upper Chesapeake Bay, April through May 2007. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

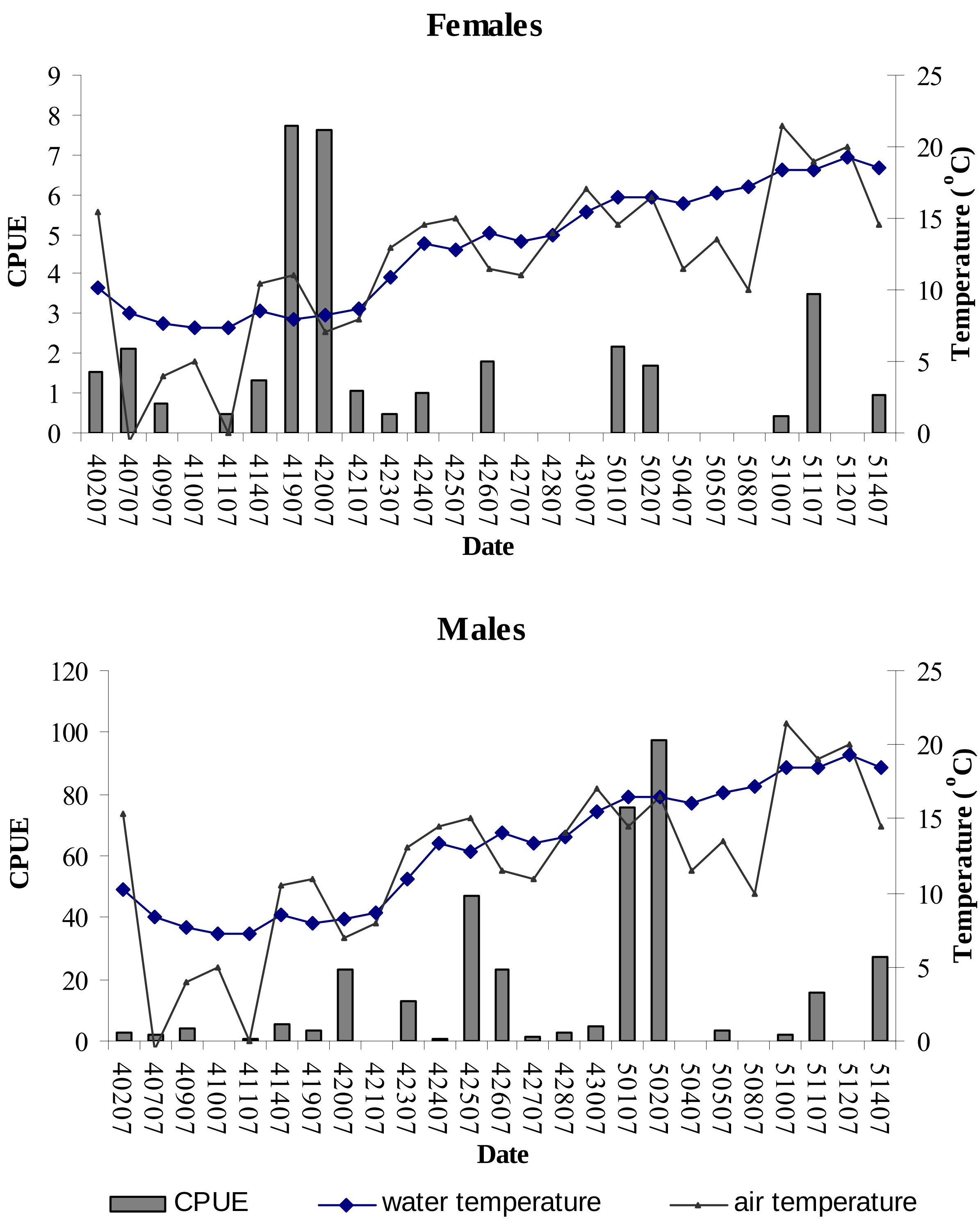
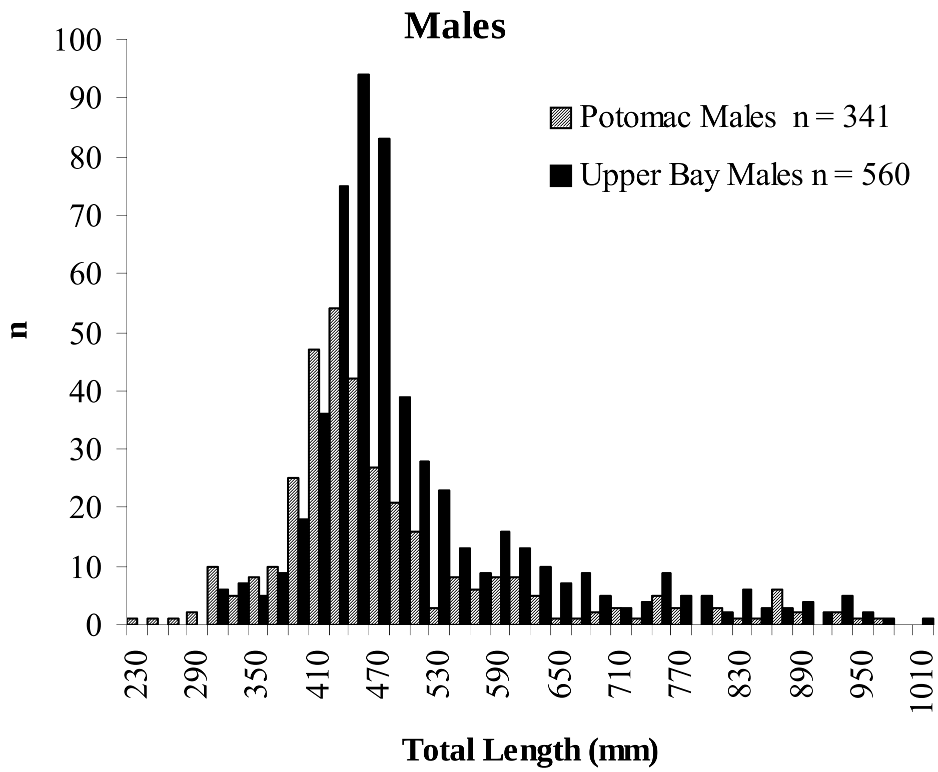


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, March through May 2007. Note different scale.



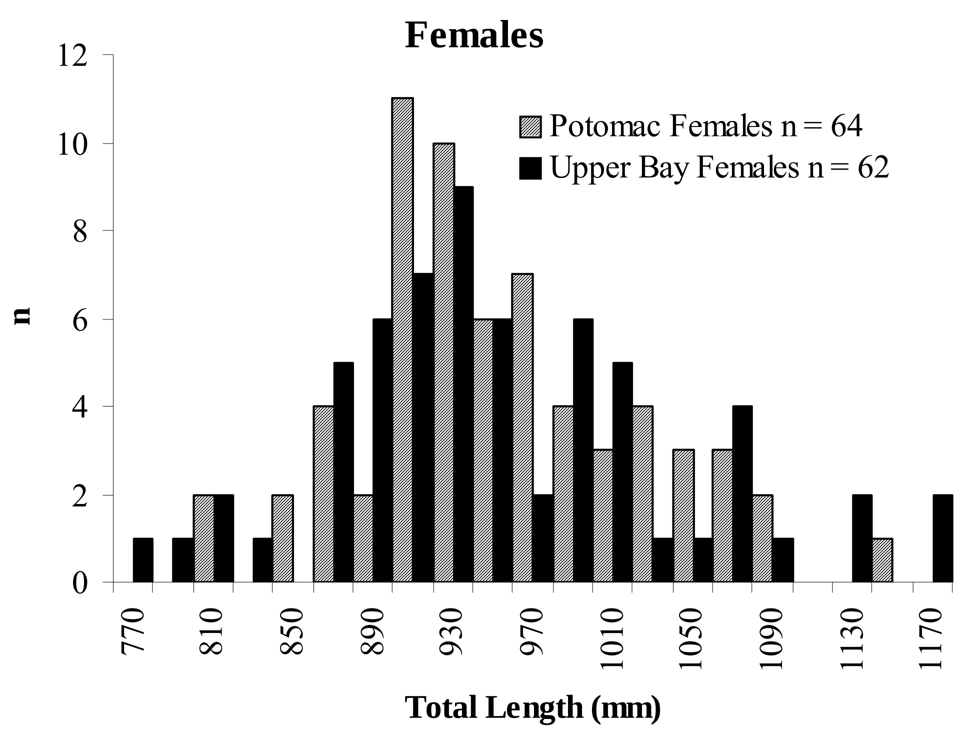
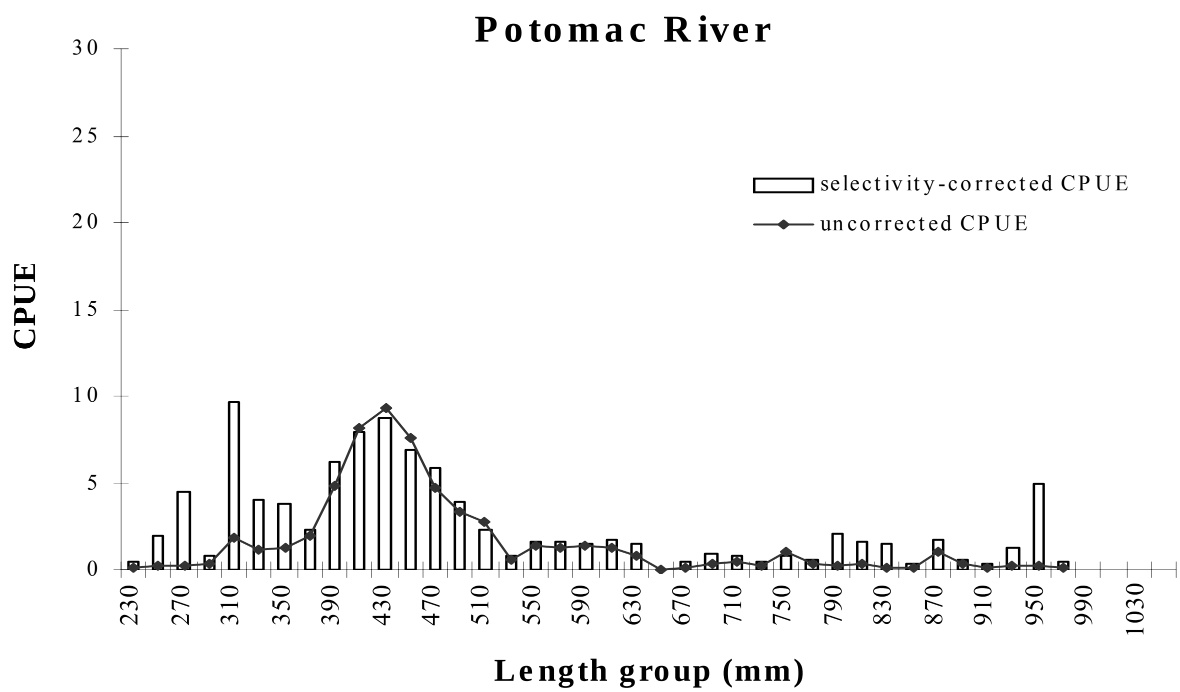


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, late March-May 2007. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



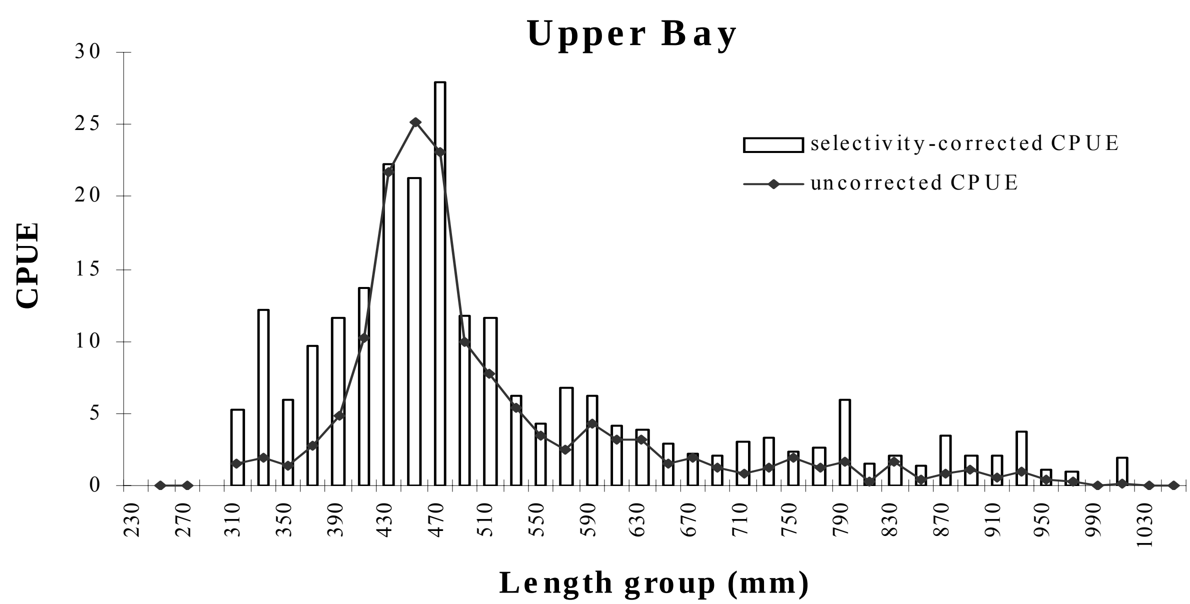
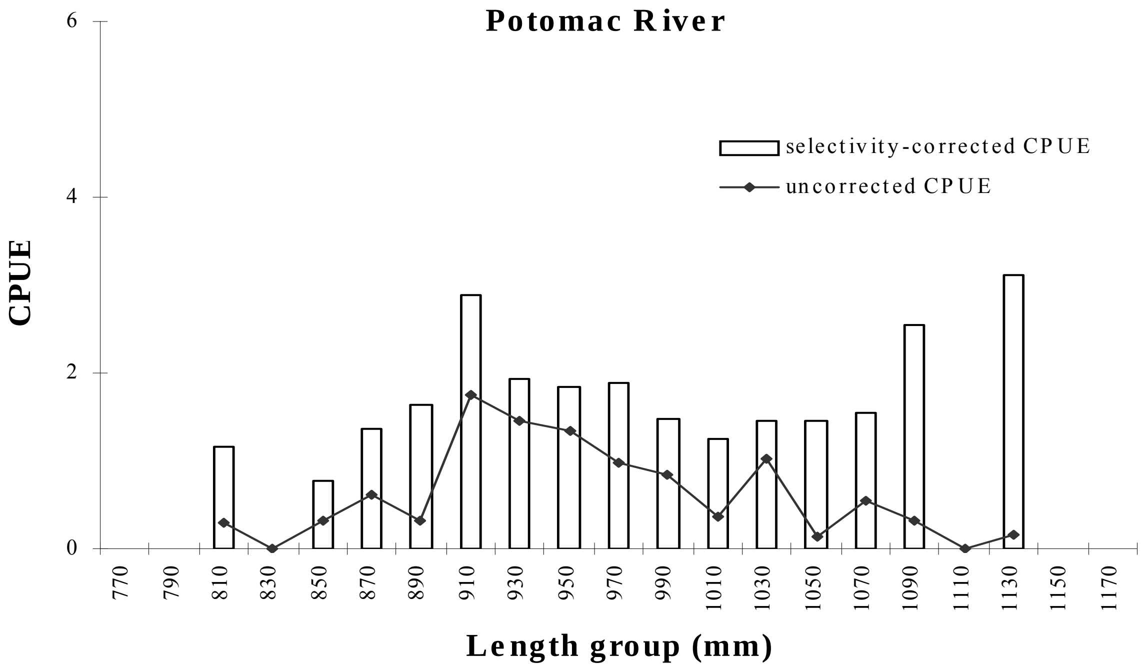


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, late March - May 2007. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



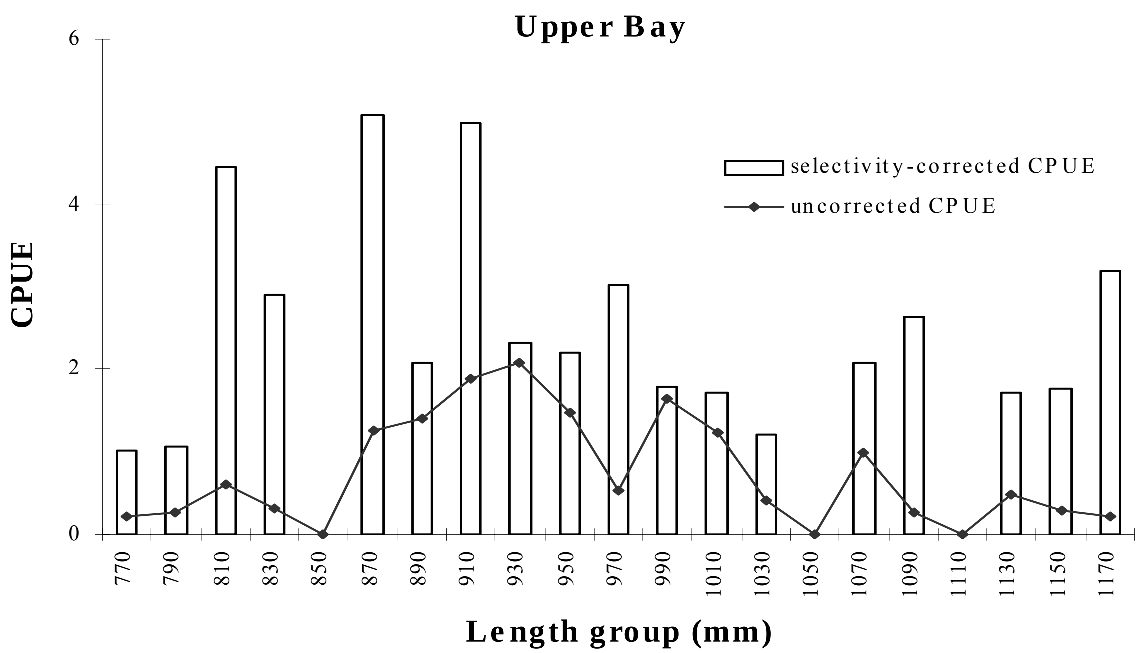


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during late March through May, 1985-2007. Error bars are 95% confidence intervals. The Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

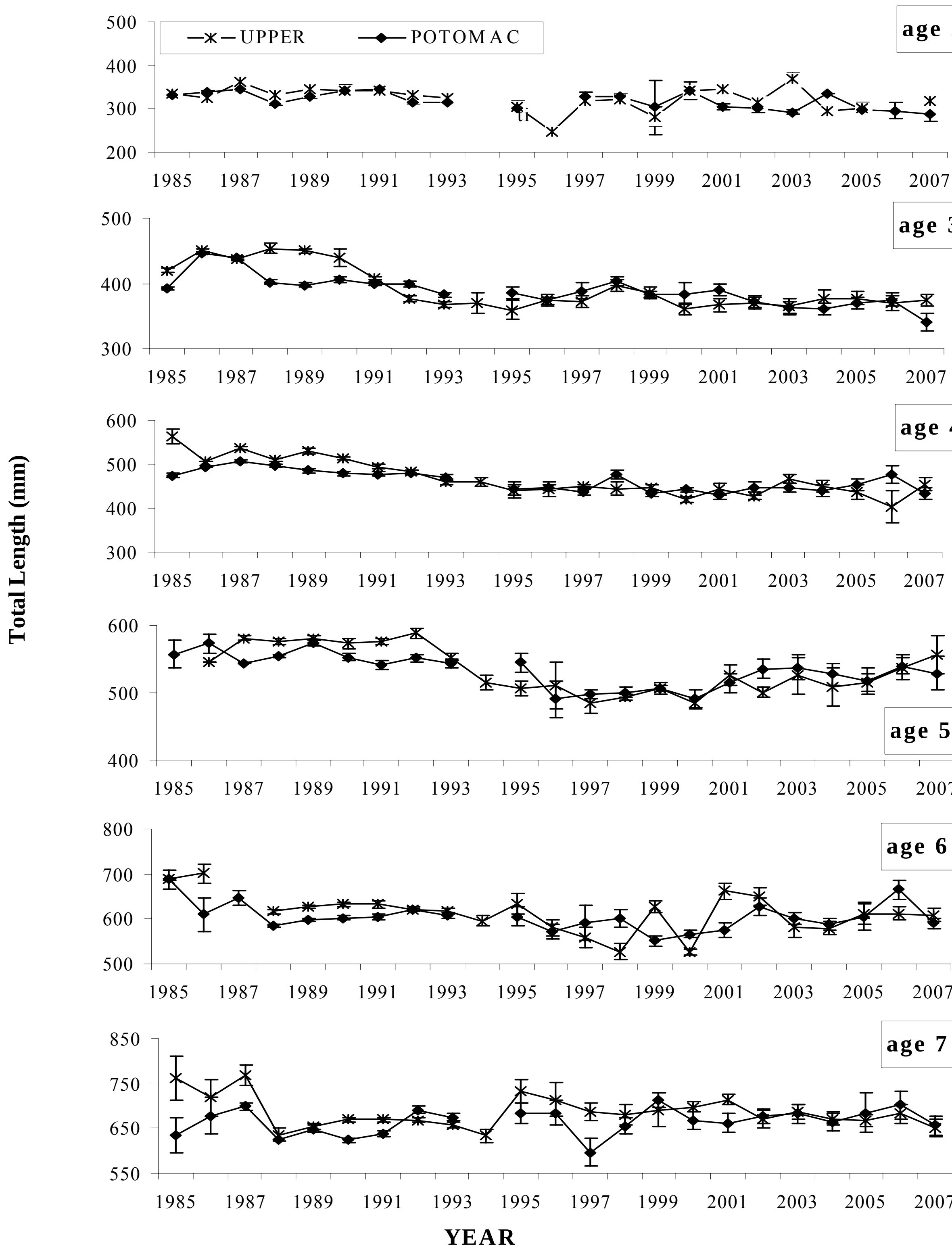


Figure 7. Continued.

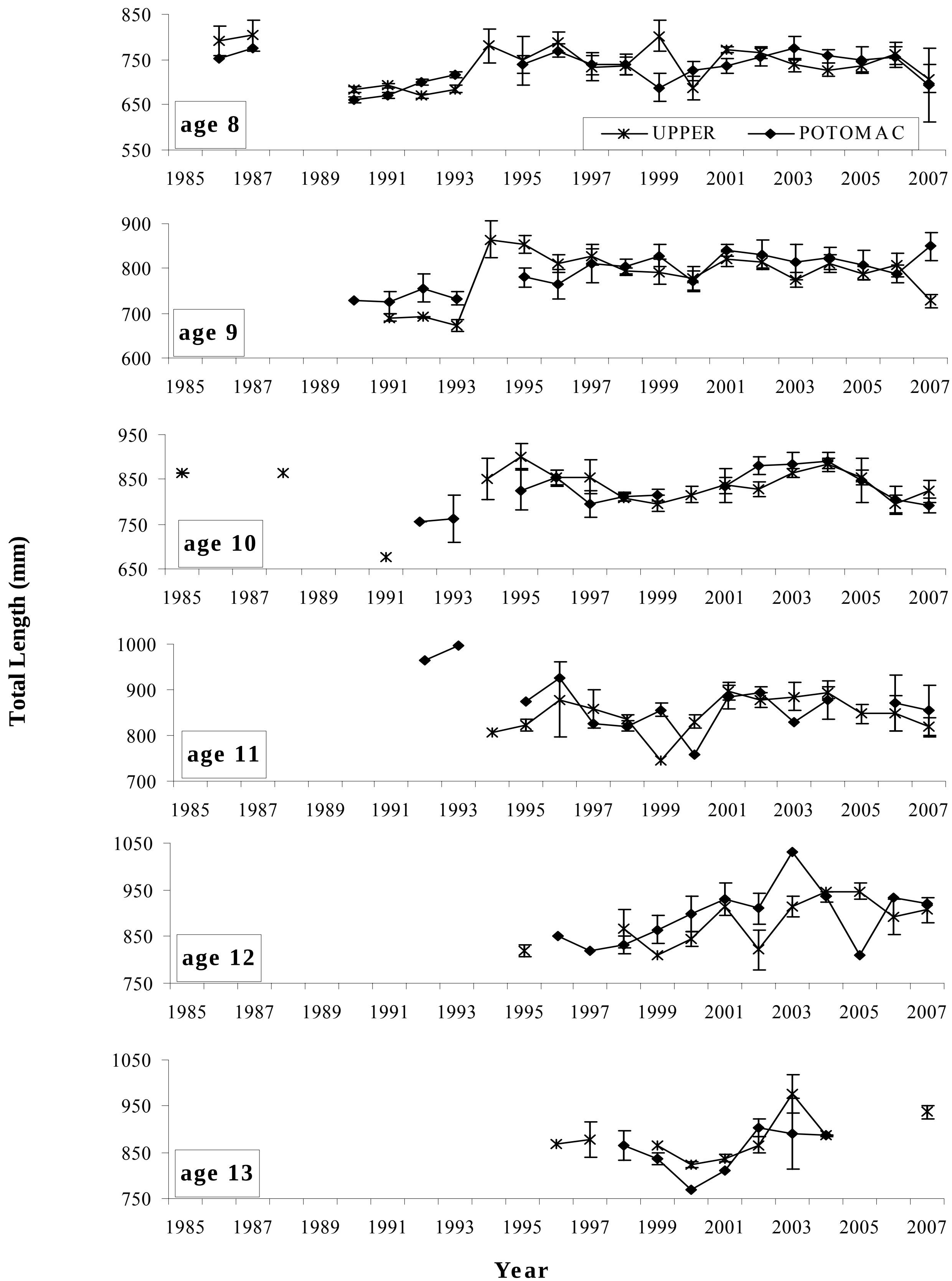


Figure 8. Mean length (mm TL) by year for individual ages of female striped bass sampled from spawning areas of the Potomac River and Upper Chesapeake Bay during late March through May, 1985–2007. Error bars are 95% confidence intervals. Note the Potomac River was not sampled in 1994. *Note difference in scales on y-axis.

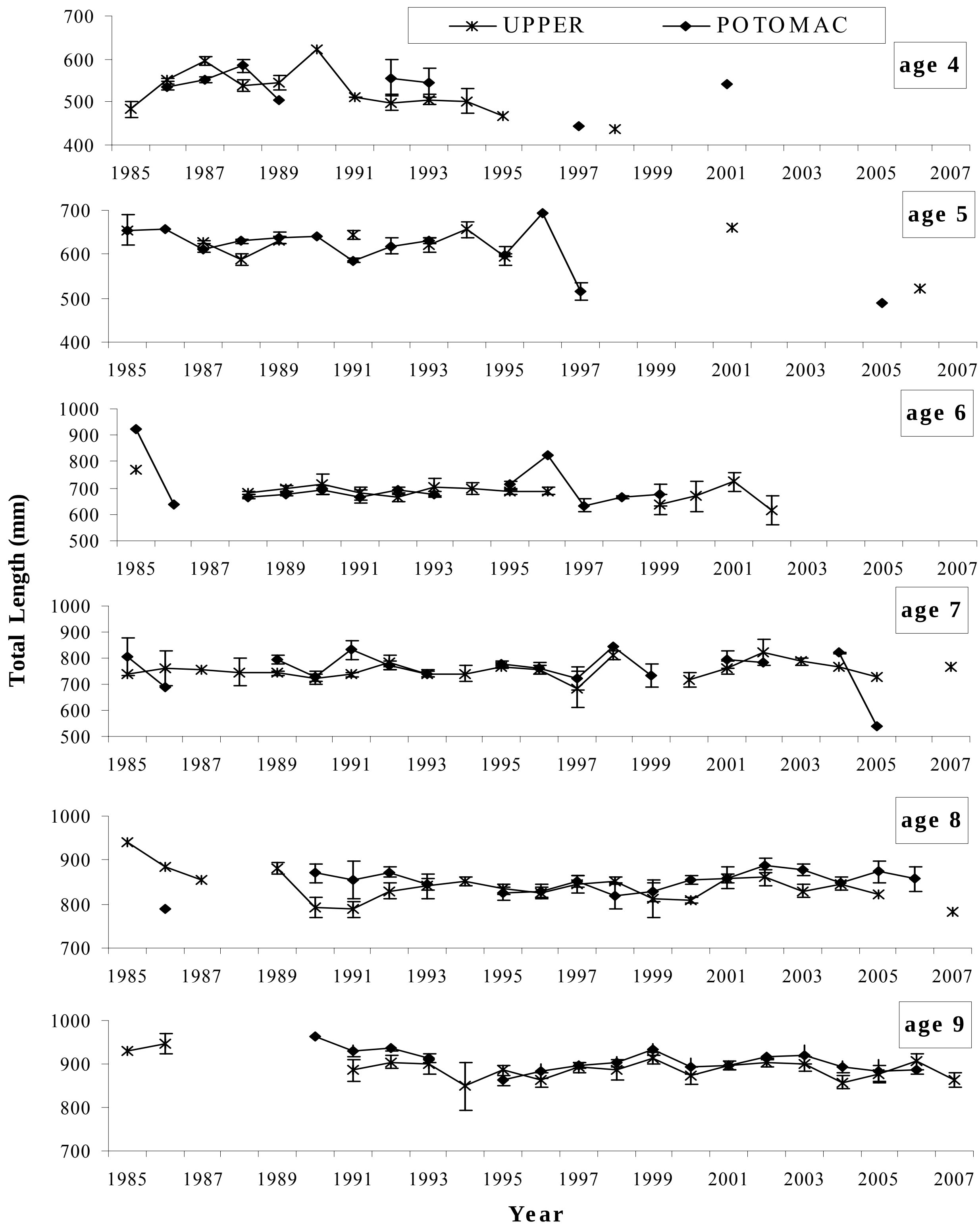


Figure 8. Continued.

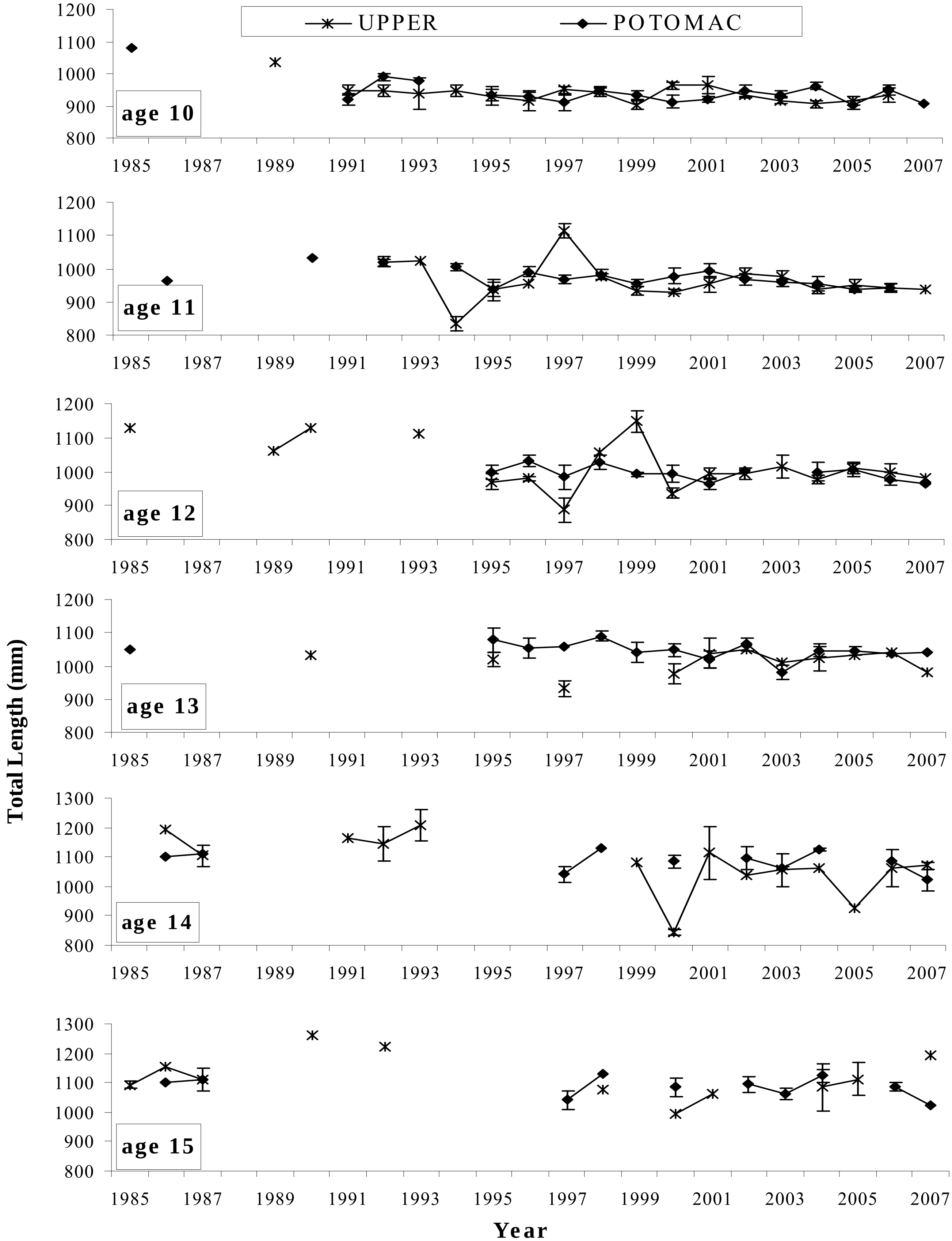


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the 2007 coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

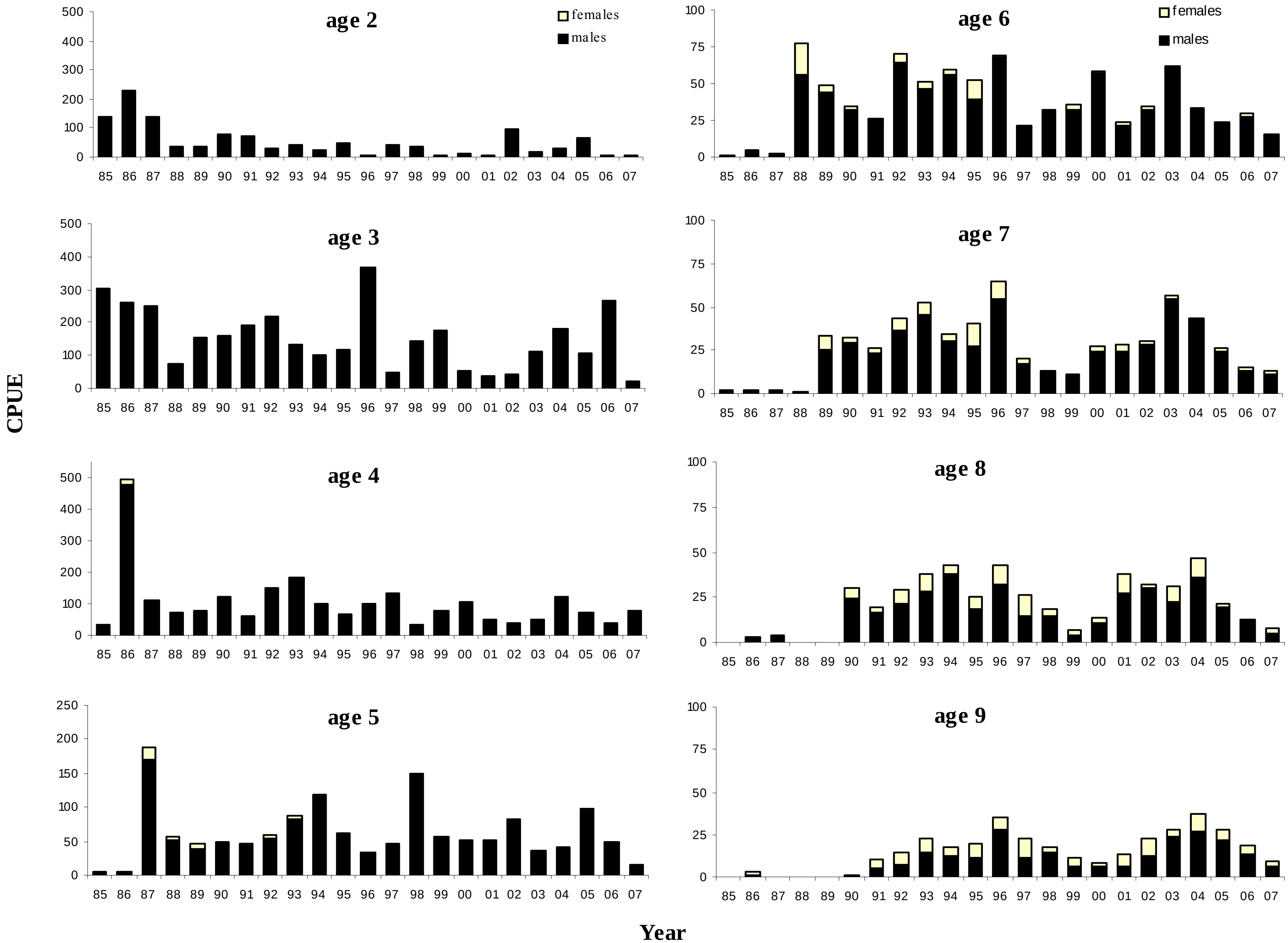


Figure 9. Continued.

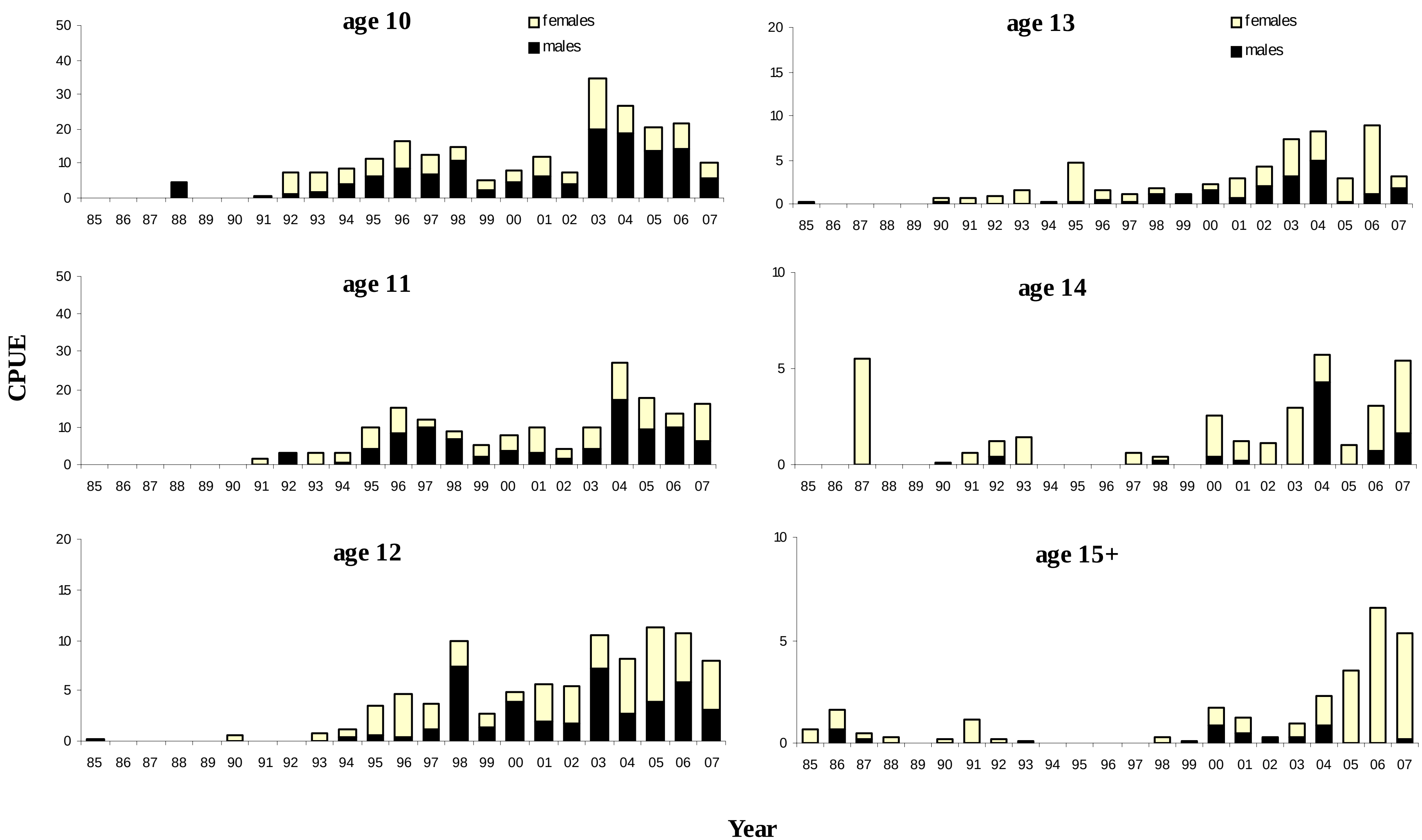
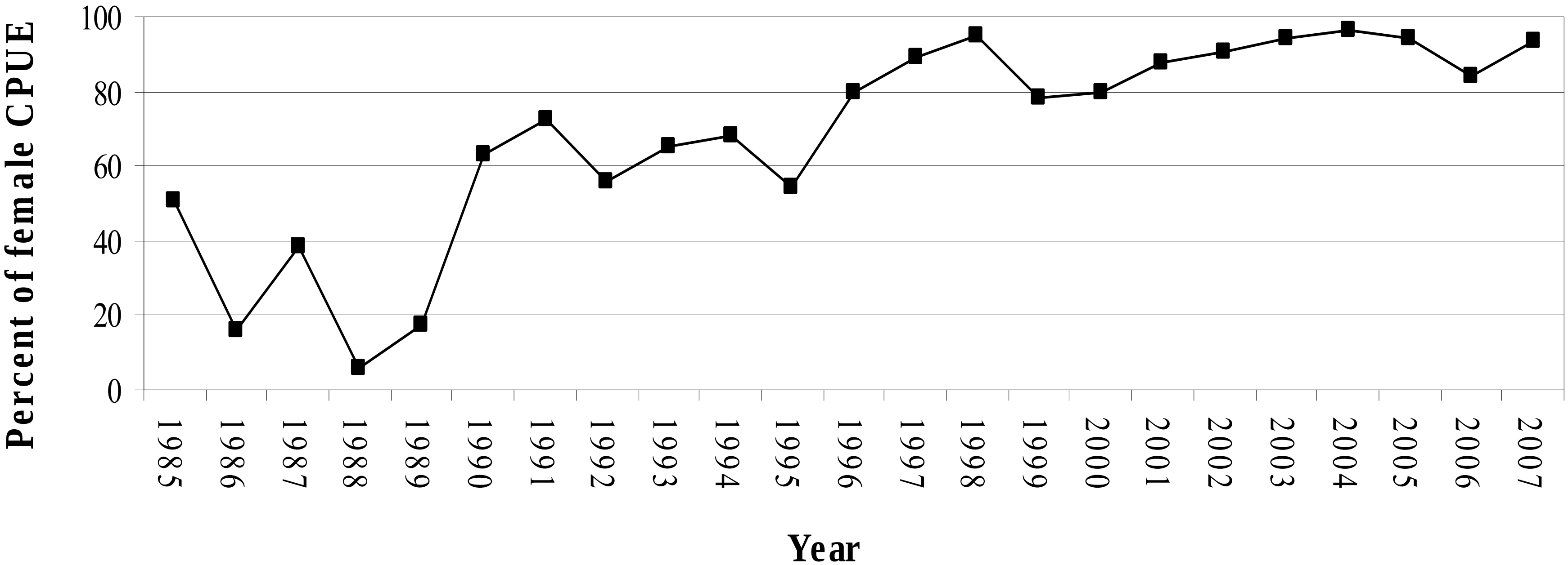
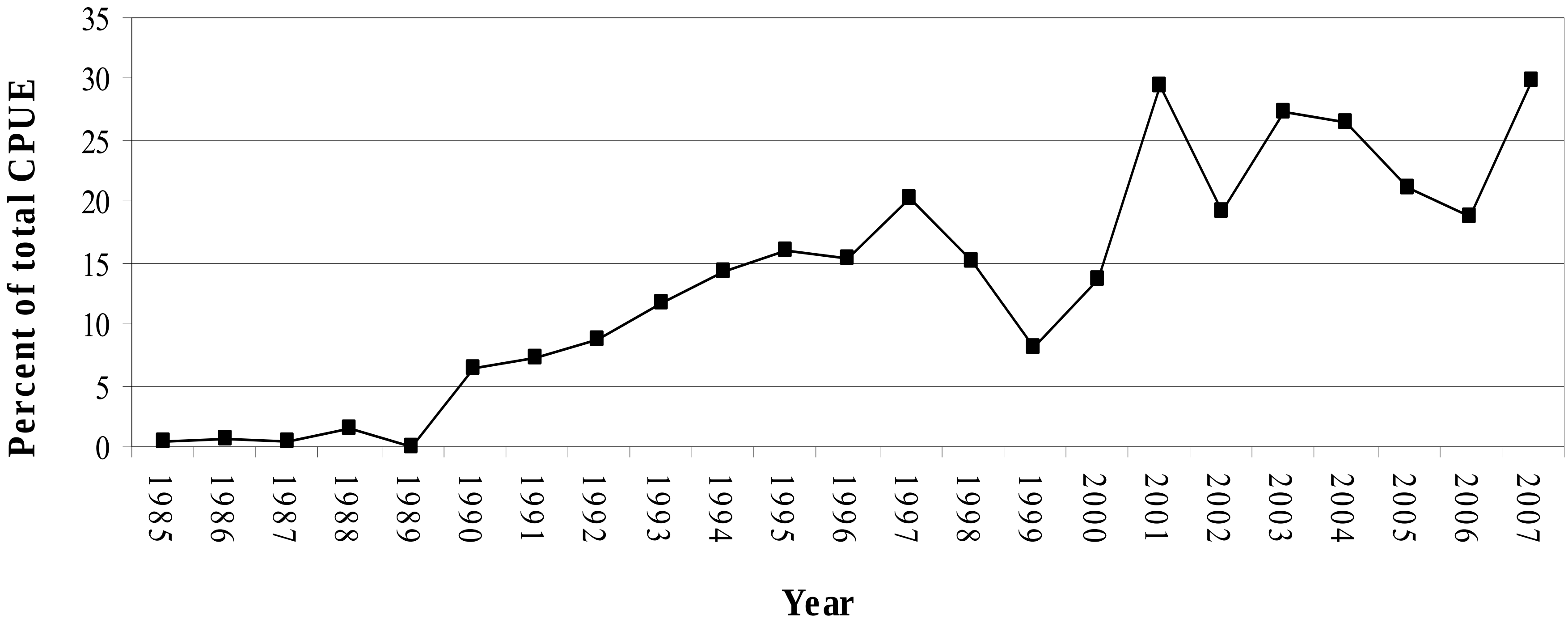


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and older sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, late March through May, 1985-2007 (Choptank River to 1996). Effort is 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.*



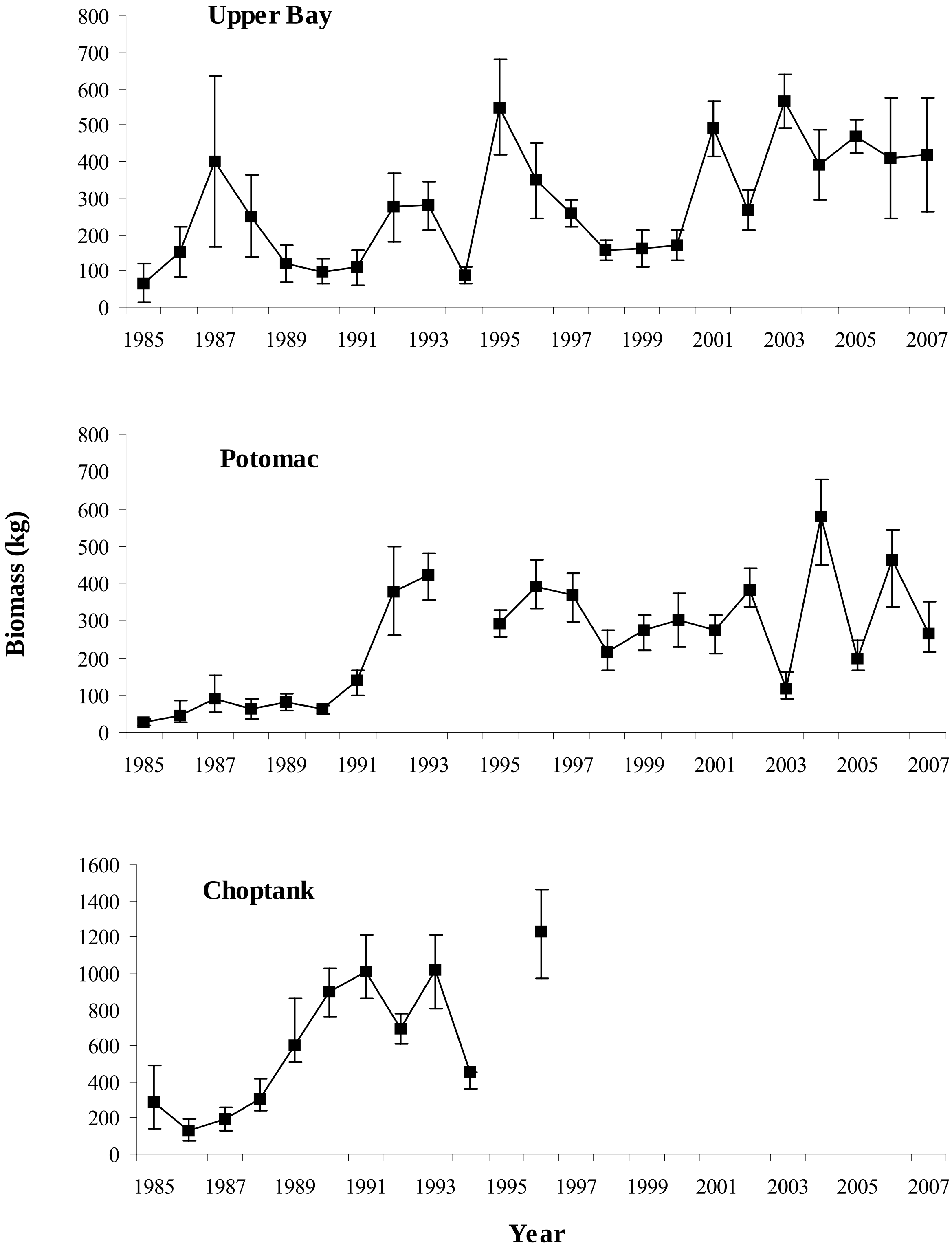
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59; Potomac River=0.37; Choptank River=0.04.
(1997 - Present): Upper Bay=0.615; Potomac River=0.385 (Hollis 1967).

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, 1985-2007 (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 Job 3 was to document annual year-class success for young-of-the-year (YOY) striped bass (*Morone saxatilis*) in Maryland's 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 area and four each in the Nanticoke and Choptank rivers. Stations have been sampled continuously since 1954, with changes in some station locations. This year, for example, the Sassafras River site at Ordinary Point was surrounded by riprap and could not be sampled. A new site was established directly across the river at the Sassafras Natural Resources Management Area.

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.

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.

Auxiliary stations have been sampled on an inconsistent basis and were not included in survey indices. These data enhance geographical coverage in rivers with permanent stations or provide information from other river systems. They are also useful for replacement of permanent stations when necessary. Replicate hauls at auxiliary stations were discontinued in 1992 to conserve time and allow increased geographical coverage of spawning areas. Auxiliary stations were sampled at the Head of Bay (Susquehanna Flats and one downstream station) and the Patuxent River (Table 1, Figure 1).

Sample Protocol

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

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

Additional data were collected at each site and sample round. These included: time of first haul, maximum distance from shore, weather, maximum depth, surface water temperature (^{o}C), tide stage, surface salinity (ppt), primary and secondary bottom substrates, and submerged aquatic vegetation within the sample area (ranked by quartiles). Dissolved oxygen (DO), pH, and turbidity (secchi disk) were added in 1997. All data were entered and archived in Statistical Analysis System (SAS) databases (SAS 1990).

Estimators

The most 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 are compared to the *target period average* (TPA). The TPA is the average of indices from 1959 through 1972. These years have been suggested as a period of stable biomass and general stock health (ASMFC 1989) and "an appropriate stock rebuilding target" (Gibson 1993). The TPA provides a fixed reference representing an average index produced by a healthy population. A fixed reference is an advantage over the time series average that is revised annually and may be significantly biased by long-term trends in annual indices.

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

RESULTS

Bay-wide Means

A total of 1,768 juvenile striped bass were collected at permanent stations in 2007. Individual samples yielded between 0 and 138 YOY striped bass. The AM of 13.4 was greater than the time-series average (11.9) and the TPA (12.0) (Table 2, Figure 2). The GM of 5.12 (Table 3, Figure 3) was also greater than the time-series average (4.29) and the TPA (4.32). The PPHL was 0.83, indicating that 83% 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 2007 $\log_e$-mean significantly smaller than seven years of the time-series, and significantly greater than 27 years of the time-series. The 2007 $\log_e$-mean was not discernible from 16 years of the time-series.

System Means

Head of Bay - In 42 samples, 850 juveniles were collected at the Head of Bay sites, resulting in an AM of 20.2, greater than the time-series average (12.2) and the TPA of 17.3 (Table 2, Figure 5). The GM of 8.21was also greater than the time-series average (5.80) 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 2007 Head of Bay year-class to be significantly smaller than only the dominant 1958 year-class. The 2007 $\log_e$-mean was indiscernible from 25 year-classes and greater than 24 year-classes of the time-series.

Potomac River - A total of 205 juveniles was collected in 42 samples. The AM of 4.9 was less than the TPA (9.2) and the time-series average (8.5) (Table 2, Figure 5). The GM of 2.20 was also less than the time-series average (3.67) 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 2007 Potomac River year-class significantly greater than just seven years, and significantly less than 10 years of the time-series. The 2007 $\log_e$-mean was not significantly different than the 33 other years of the time-series.

Choptank River - A total of 343 juveniles was collected in 24 Choptank River samples. The AM of 14.3 was less than the time-series average of 21.0 but greater than the TPA of 10.8 (Table 2, Figure 5). The GM of 7.87 was also fell between it's time-series average (8.22) 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 2007 Choptank River year-class smaller than 10 years, and not significantly different than 21 years of the time-series. The 2007 year-class was significantly larger than the remaining 21 years of the time-series.

Nanticoke River - A total of 370 juveniles was collected in 24 samples on the Nanticoke River. The AM was 15.4, considerably greater than the time-series average (8.4) and the TPA (8.6) (Table 2, Figure 5). The GM of 5.41 was also greater than the time-series average (3.71) 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 2007 index significantly smaller than just the top three years of the time-series (2001, 1996, and 1958). The 2007 index was statistically indiscernible from 23 years of the time-series and significantly greater than 24 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 80 juveniles were caught in 15 samples, resulting in an AM of 5.3 and a GM of 2.72. Both indices were approximately equal to their respective time-series averages (Table 5).

On the **Patuxent River**, 18 samples yielded 274 juveniles for an AM of 15.2 and a GM of 6.07 (Table 5). Both indices were greater than their respective 25-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 an average 2007 striped bass year-class for Maryland's portion of the Chesapeake Bay. The AM and GM were both slightly above their respective time-series and TPA averages, but lower confidence limits bracketed the averages of both estimators (Tables 2 and 3, Figures 2 and 3). The Log Mean was also slightly above the long-term average (Table 4). Agreement among indices creates more certainty that they represent actual changes in YOY striped bass abundance.

Juvenile striped bass were widely distributed, occurring in 83% of this year's samples (PPHL=0.83). This value was higher than the long-term average of 70% (Table 4). Individual samples yielded between 0 and 138 YOY striped bass, resulting in the relatively narrow confidence intervals around the means (Figures 2 and 3) and below-average coefficients of variation for the AM and Log Mean (Table 4).

Recruitment in individual spawning areas was variable. Recruitment in the Nanticoke River was relatively high, with the AM and GM indices above the third quartile value of the time series. Indices in the Choptank River and Head of Bay were also above average, at or near the 75^{th}

percentile of the time-series. Recruitment in the Potomac River, however, was well below average. Potomac River AM and GM indices were approximately half their respective TPA values and the GM was the lowest observed since 1994. The Potomac also yielded the lowest PPHL (0.67) of any system surveyed.

Results in the auxiliary Head of Bay system, located primarily on the Susquehanna Flats, were slightly below average. This is in contrast to the above-average recruitment observed at permanent Head of Bay sites, where large numbers of YOY striped bass were sampled in the nearby Elk River. Healthy recruitment was observed in the auxiliary Patuxent River system, where the AM was the fifth highest of the 25-year time series.

RELATIONSHIP OF AGE 0 TO AGE 1 INDICES

INTRODUCTION

Indices of age 1 (yearling) striped bass (Table 6) developed from the Maryland juvenile striped bass survey were tested for relationship to YOY indices by year-class. Previous analysis yielded a significant relationship with age 0 indices explaining 73% ($P \leq 0.001$) of the variability in age 1 indices one year later (MD DNR 1994). The strength of this relationship led to the incorporation of the age 1 index into the coastal striped bass virtual population analysis (VPA) 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 =0.61, $p \leq 0.001$)(Figure 10). The equation that best described this relationship was, $C_1 = 0.192647 \times C_0 - 0.07255$, where C_1 is the age 1 index and C_0 is the age 0 index. While still significant, the model has lost predictive power since 1994 (when r^2 =0.73). The addition of quadratic and cubic terms yielded even poorer fits.

This year's index of age 1 striped bass (0.07) was less than the predicted index of 0.12, as indicated by the negative residual (Figure 11). Examination of residuals 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 predation, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

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LIST OF TABLES

LIST OF FIGURES

Table 1. Maryland juvenile striped bass survey sample sites.

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

Table 2. Continued.

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1991	3.9	2.5	12.2	1.1	4.4
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
Average	12.2	8.5	21.0	8.4	11.9
TPA*	17.3	9.2	10.8	8.6	12.0

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

Table 3. Maryland juvenile striped bass survey geometric mean catch per haul at permanent sites.

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1955	1.49	3.78	2.36	2.26	2.26
1956	6.88	4.50	6.22	5.29	5.29
1957	1.92	1.78	1.16	1.40	1.40
1958	22.07	3.93	11.01	11.12	11.12
1959	0.95	0.61	0.09	0.59	0.59
1960	3.18	2.44	4.31	3.01	3.01
1961	7.46	12.82	5.40	6.61	6.61
1962	3.73	6.70	3.14	4.25	4.25
1963	3.01	0.54	2.01	1.61	1.61
1964	15.41	9.15	4.92	9.04	9.04
1965	0.76	0.92	2.18	1.56	1.56
1966	15.89	4.95	5.52	6.24	6.24
1967	3.92	1.03	2.80	2.28	2.28
1968	6.13	0.39	3.85	2.69	2.69
1969	12.21	0.12	2.55	2.81	2.81
1970	13.71	10.97	25.41	12.48	12.48
1971	10.45	3.48	2.51	4.02	4.02
1972	4.95	0.96	5.36	3.26	3.26
1973	11.92	1.10	0.43	2.33	2.33
1974	6.79	0.66	3.55	2.62	2.62
1975	2.34	3.56	2.71	2.81	2.81
1976	2.70	1.46	0.89	1.58	1.58
1977	4.99	0.78	0.81	1.61	1.61
1978	6.51	3.33	2.65	3.75	3.75
1979	4.56	1.15	1.12	1.73	1.73
1980	1.43	1.04	0.58	1.01	1.01
1981	0.17	0.68	0.84	0.59	0.59
1982	2.98	3.50	5.68	3.54	3.54
1983	0.61	0.62	0.64	0.61	0.61
1984	2.23	1.42	2.13	0.81	1.64
1985	0.19	1.45	1.78	0.94	0.91
1986	0.90	3.09	0.32	1.24	1.34
1987	0.16	3.01	3.06	1.36	1.46
1988	2.25	0.22	0.40	0.28	0.73
1989	8.54	1.15	28.10	1.94	4.87
1990	2.20	0.38	1.34	0.56	1.03

Table 3. Continued.

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1991	1.99	0.84	4.42	0.52	1.52
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
Average	5.80	3.67	8.22	3.71	4.29
TPA*	7.27	3.93	5.00	3.12	4.32

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

Table 4. Maryland Chesapeake Bay arithmetic mean (AM) and log mean with coefficients of variation (CV), proportion of positive hauls (PPHL) with 95% confidence intervals (CI), and number of seine hauls (n) for juvenile striped bass.

Year	AM	CV (%) of AM	Log Mean	CV (%) of Log Mean	PPHL	Low CI	High CI	n
1957	2.9	205.5	0.87	100.72	0.66	0.52	0.80	44
1958	19.3	94.2	2.50	48.56	0.89	0.79	0.99	36
1959	1.4	198.3	0.47	171.23	0.30	0.14	0.45	34
1960	7.1	149.2	1.39	86.32	0.72	0.58	0.87	36
1961	17.0	183.3	2.03	61.04	0.96	0.90	1.02	46
1962	12.2	160.8	1.66	82.85	0.75	0.66	0.84	88
1963	4.0	182.6	0.96	111.85	0.56	0.45	0.66	88
1964	23.5	162.3	2.31	60.35	0.90	0.83	0.96	88
1965	7.4	247.7	0.94	140.06	0.47	0.36	0.57	88
1966	16.7	184.8	1.98	67.16	0.86	0.80	0.92	132
1967	7.8	263.9	1.19	100.40	0.69	0.61	0.77	132
1968	7.2	175.3	1.31	94.10	0.65	0.57	0.73	132
1969	10.5	224.0	1.34	104.40	0.62	0.54	0.70	132
1970	30.4	157.5	2.60	52.73	0.95	0.91	0.99	132
1971	11.8	187.0	1.61	80.43	0.81	0.74	0.88	132
1972	11.0	250.8	1.45	91.54	0.72	0.64	0.80	132
1973	8.9	229.2	1.20	110.90	0.61	0.53	0.70	132
1974	10.1	261.9	1.29	102.42	0.65	0.57	0.74	132
1975	6.7	152.2	1.34	86.76	0.73	0.66	0.81	132
1976	4.9	279.4	0.95	113.88	0.60	0.51	0.68	132
1977	4.8	236.4	1.96	113.00	0.62	0.54	0.70	132
1978	8.5	145.6	1.56	77.24	0.77	0.69	0.84	132
1979	4.0	182.1	1.00	100.24	0.66	0.58	0.74	132
1980	2.0	174.8	0.70	114.68	0.54	0.45	0.62	132
1981	1.2	228.2	0.46	150.34	0.39	0.30	0.47	132
1982	8.4	160.1	1.51	79.73	0.76	0.68	0.83	132
1983	1.4	268.0	0.48	152.37	0.38	0.30	0.46	132
1984	4.2	228.2	0.97	106.58	0.65	0.57	0.73	132
1985	2.9	253.0	0.65	152.02	0.42	0.33	0.33	132
1986	4.1	272.2	0.85	121.40	0.55	0.47	0.64	132
1987	4.8	262.1	0.90	124.54	0.51	0.42	0.59	132
1988	2.7	313.8	0.55	170.46	0.37	0.29	0.45	132
1989	25.2	309.1	1.77	90.18	0.75	0.68	0.82	132
1990	2.1	174.8	0.71	120.74	0.49	0.41	0.58	132
1991	4.4	203.8	0.93	120.27	0.58	0.43	0.60	132

Table 4. Continued.

Year	AM	CV (%) of AM	Log Mean	CV (%) of Log Mean	PPHL	Low CI	High CI	n
1992	9.0	267.0	1.20	105.19	0.67	0.59	0.75	132
1993	39.8	279.1	2.71	49.53	0.96	0.93	0.99	132
1994	16.1	150.4	2.00	66.96	0.84	0.78	0.90	132
1995	9.3	153.3	1.69	66.42	0.86	0.80	0.92	132
1996	59.4	369.2	2.92	45.50	0.99	0.96	1.00	132
1997	8.0	135.6	1.59	70.98	0.80	0.74	0.87	132
1998	12.7	164.8	1.87	65.72	0.86	0.78	0.92	132
1999	18.1	208.4	1.85	77.45	0.80	0.75	0.88	132
2000	13.8	120.8	2.13	53.69	0.91	0.86	0.96	132
2001	50.8	308.9	2.61	57.22	0.92	0.88	0.97	132
2002	4.7	141.3	1.16	91.89	0.67	0.59	0.75	132
2003	25.8	136.9	2.47	55.42	0.92	0.88	0.97	132
2004	11.4	177.8	1.77	67.01	0.87	0.81	0.93	132
2005	17.8	237.3	2.07	59.12	0.90	0.86	0.95	132
2006	4.3	178.6	1.02	103.67	0.59	0.51	0.67	132
2007	13.4	177.3	1.81	71.92	0.83	0.76	0.89	132
Average	12.1	207.2	1.46	93.45	0.70	0.63	0.78	
TPA*	12.0	194.8	1.52	93.18	0.71	0.62	0.80	

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
AVG	28.09	7.42		5.87	2.79	
MED	4.10	1.95		2.95	1.91	

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

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

Table 6. Continued.

Year-class	Age 0	Age 1
1993	2.71	0.56
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	NA

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

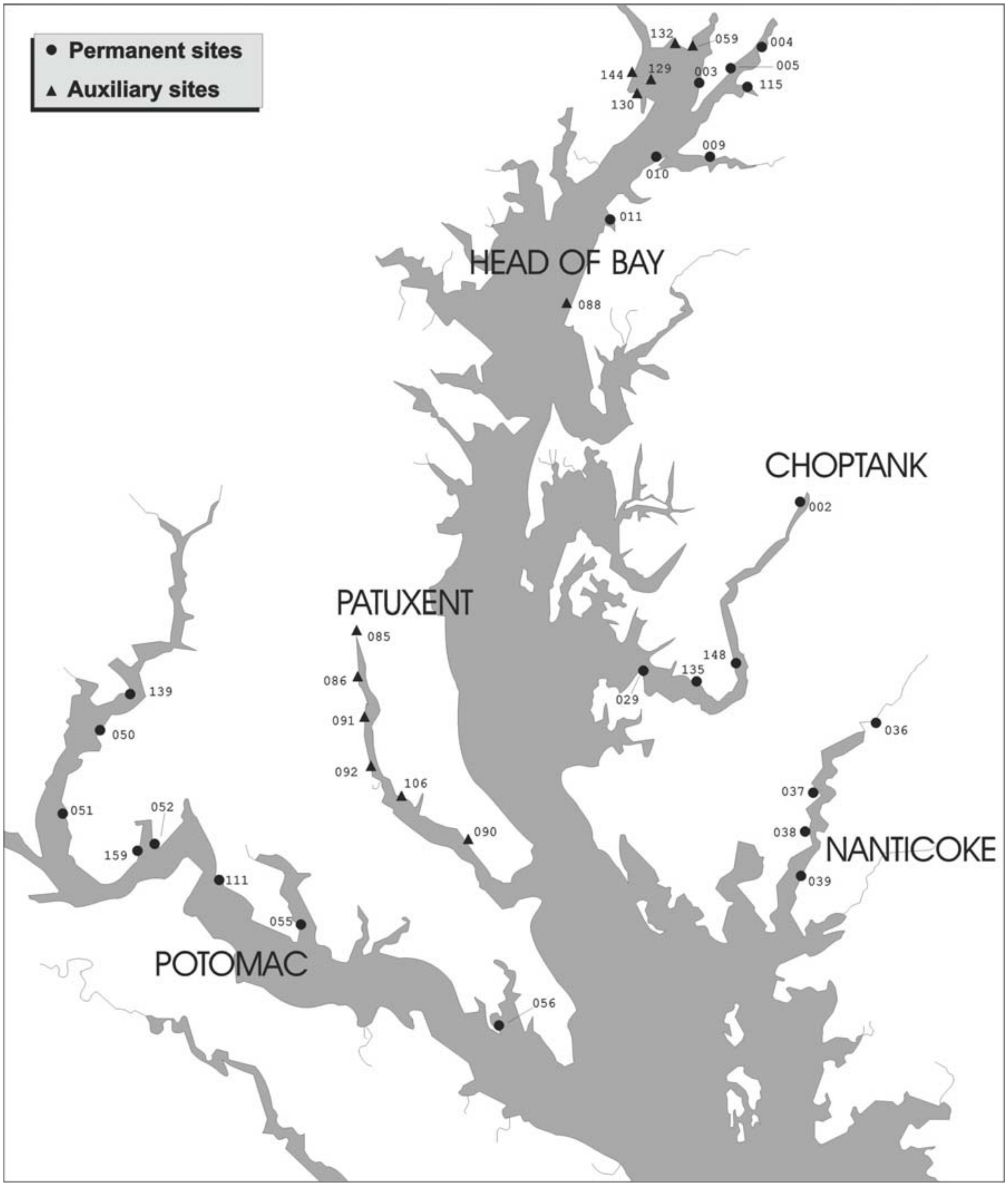


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

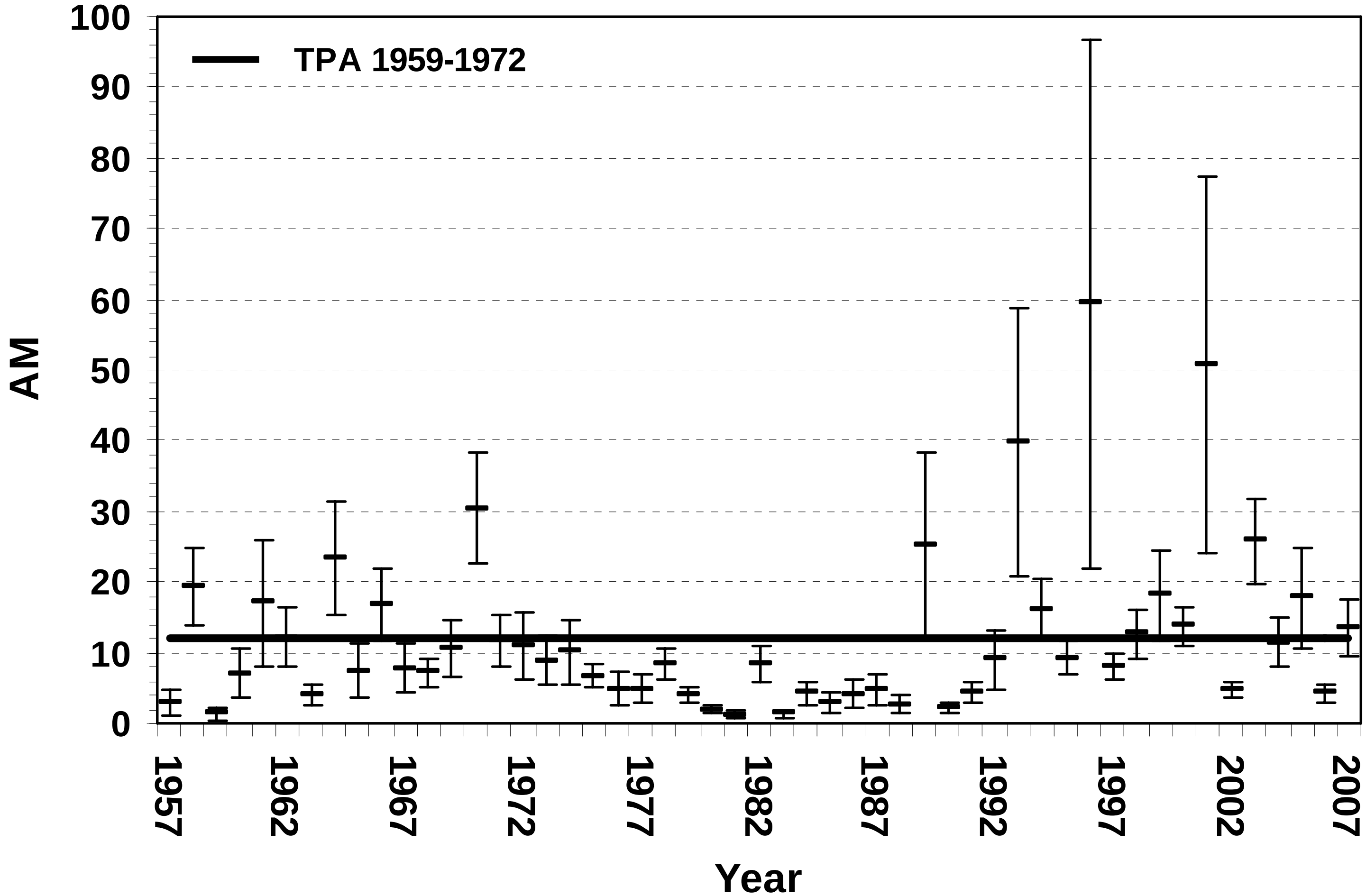


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

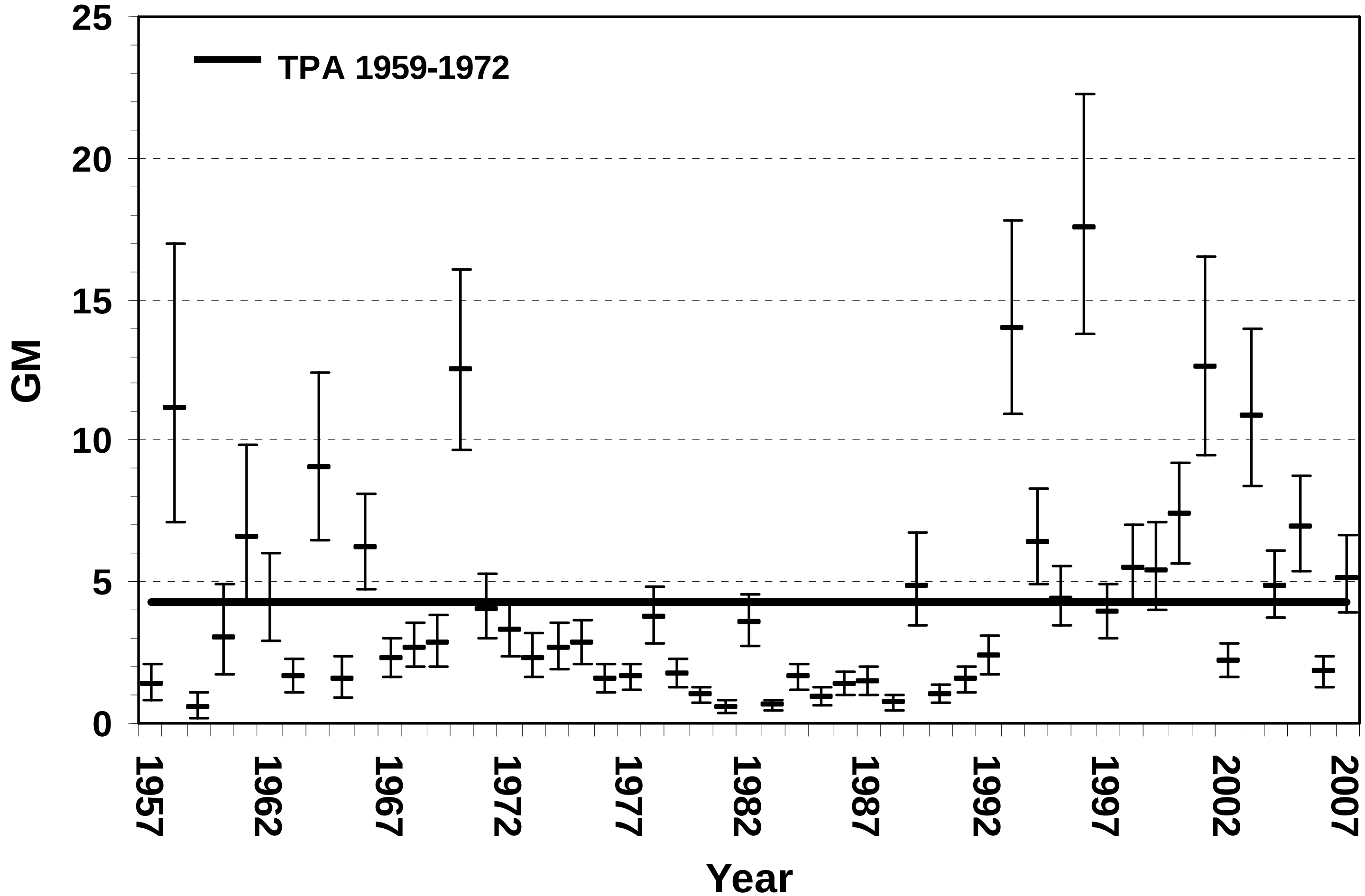


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL).

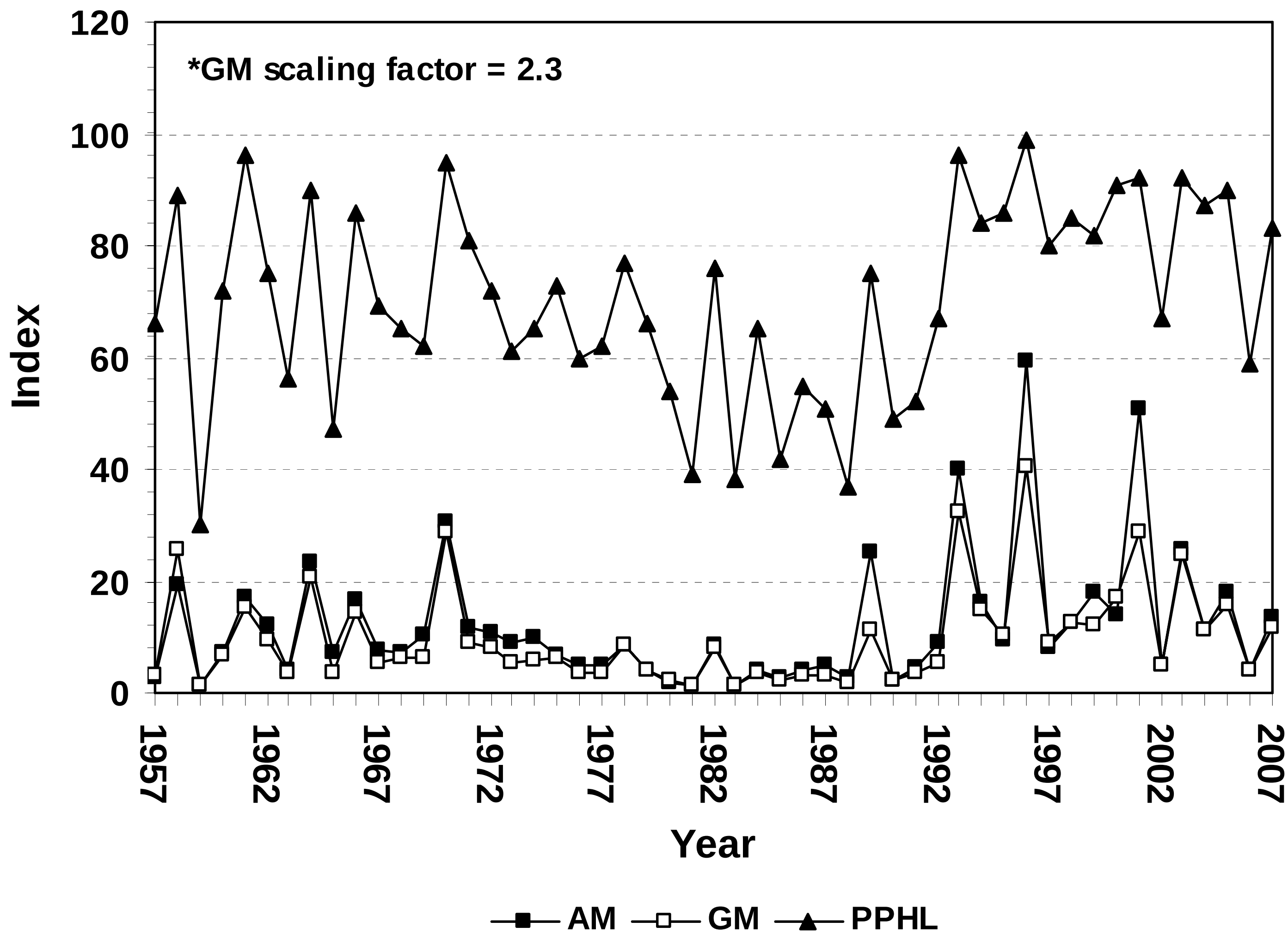


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

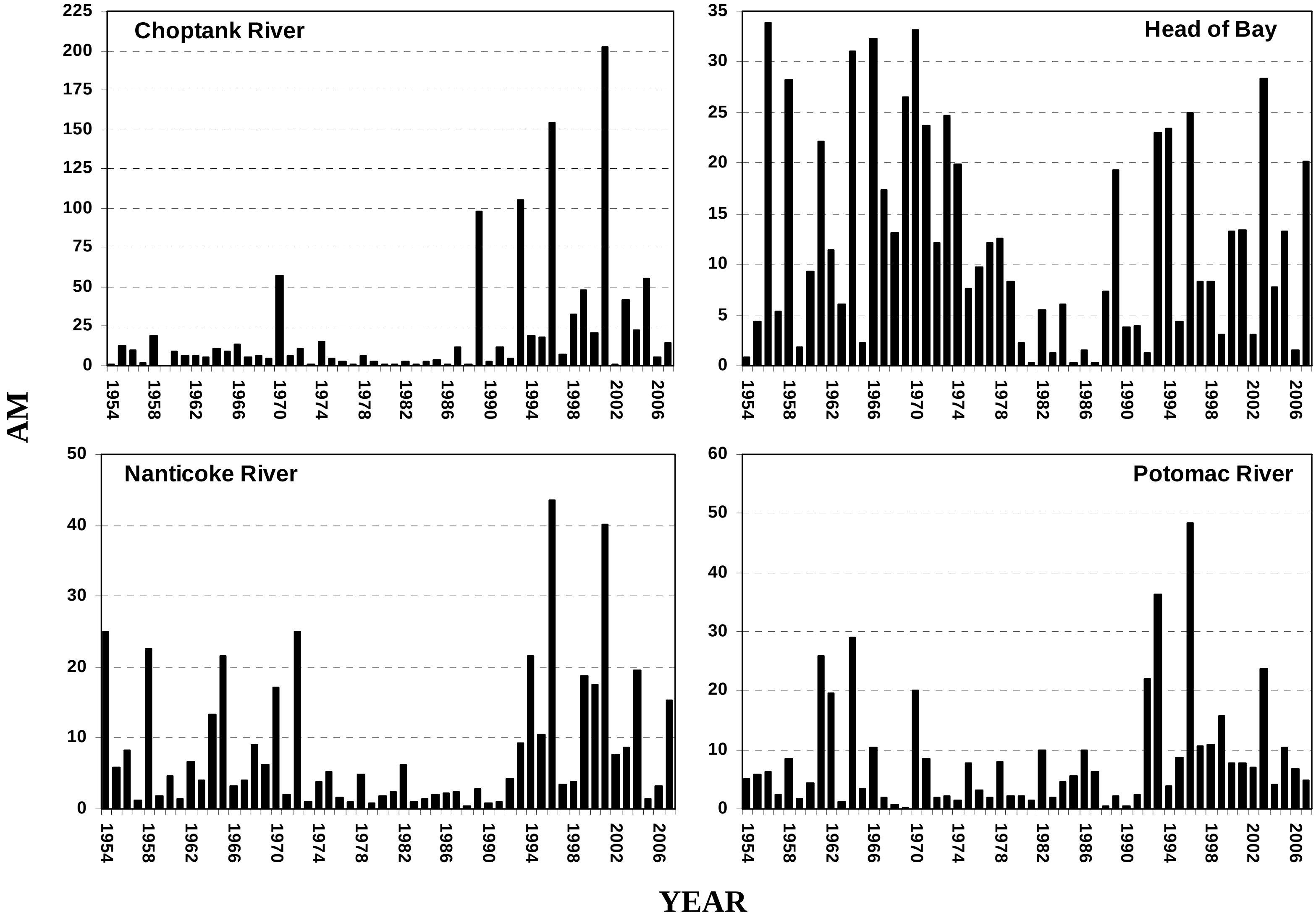


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

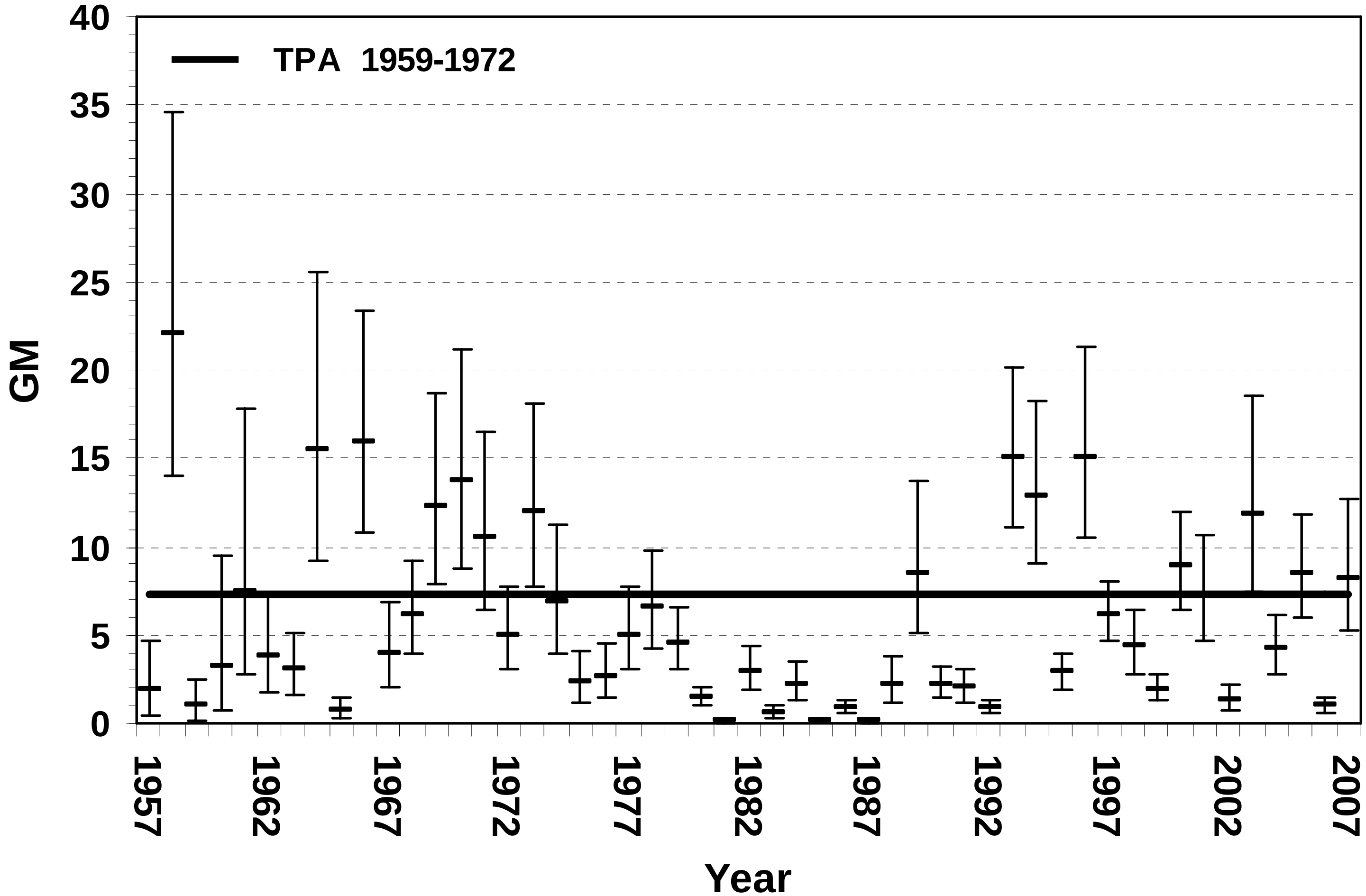


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

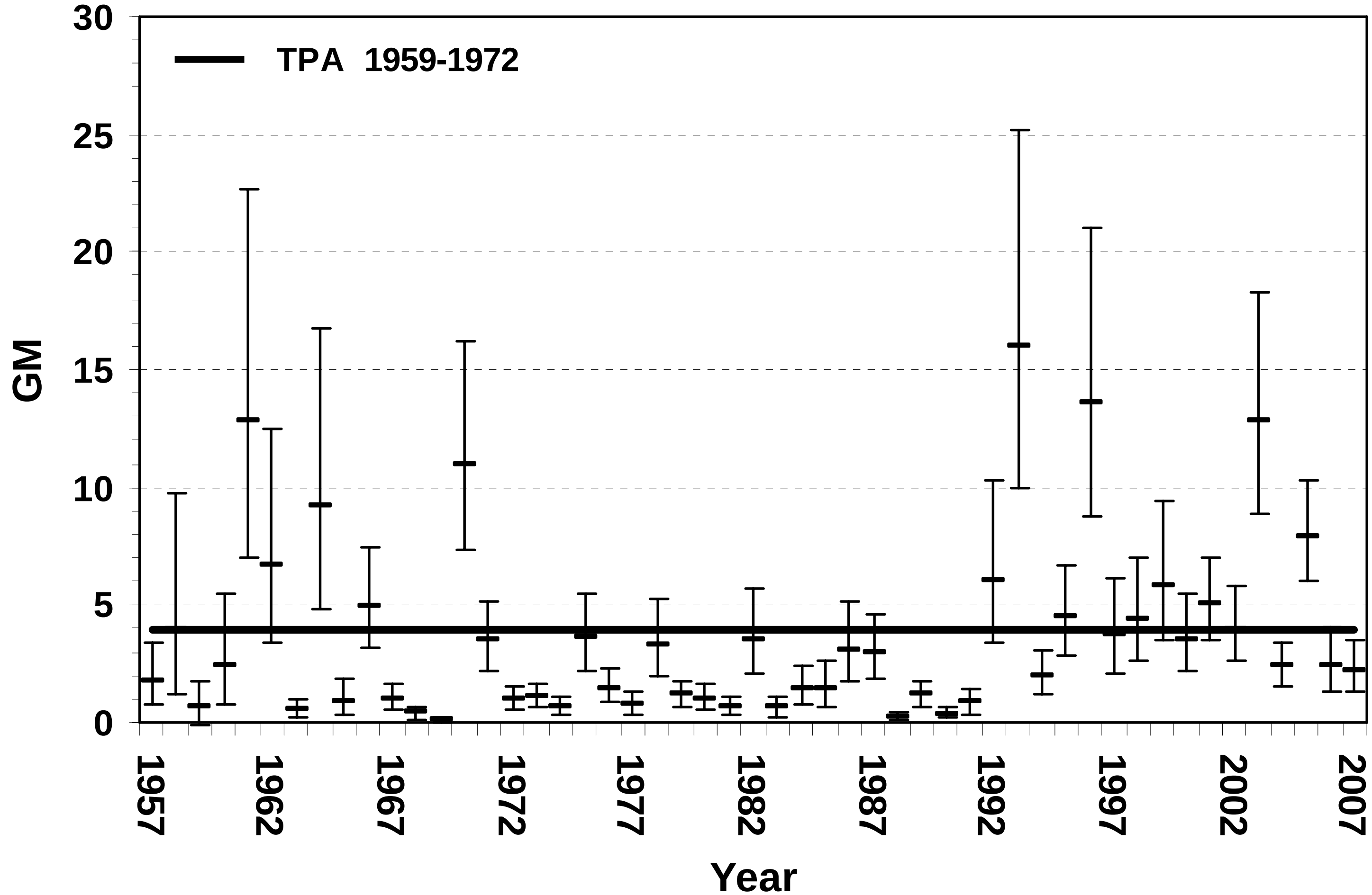


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

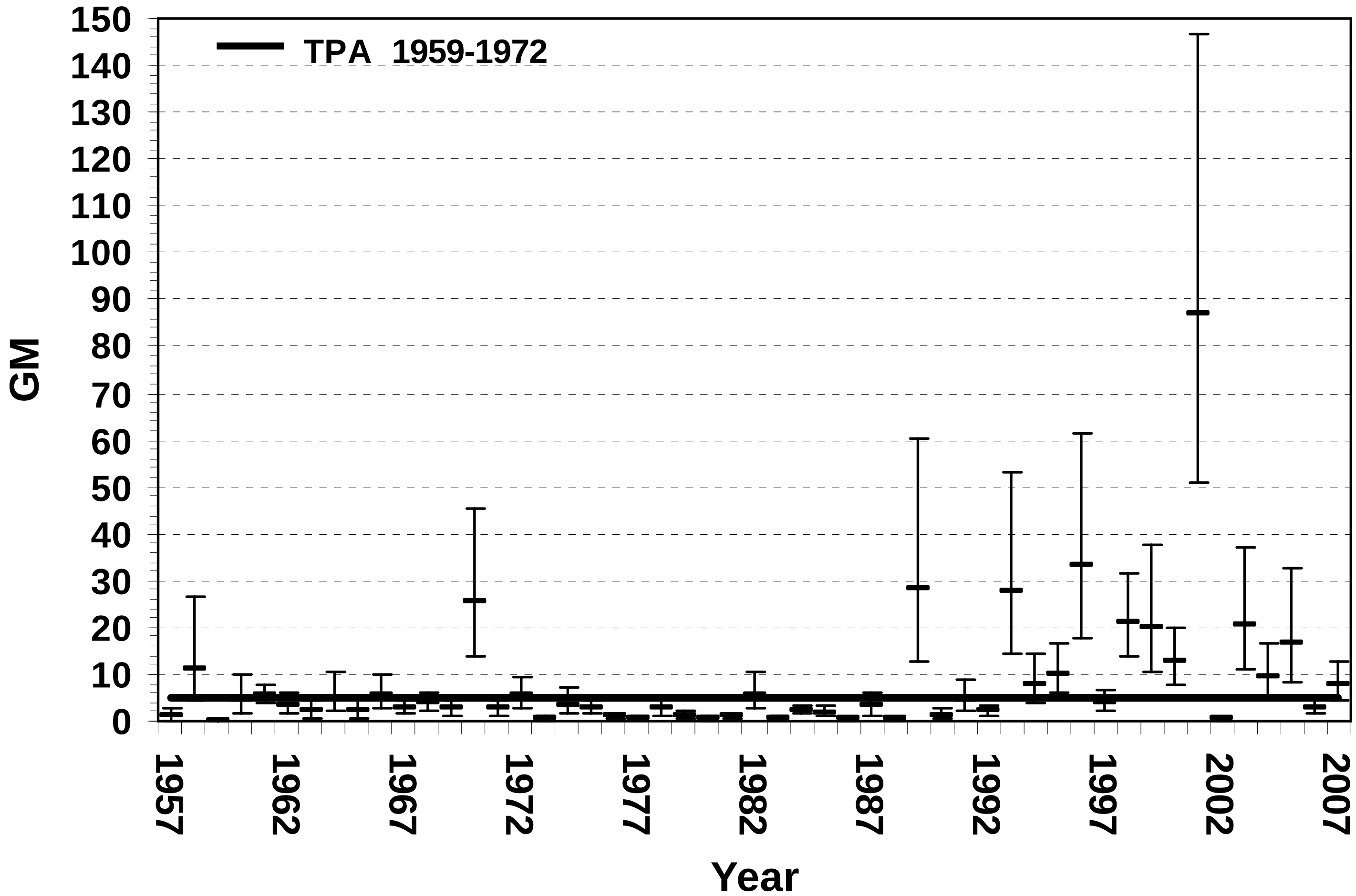


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

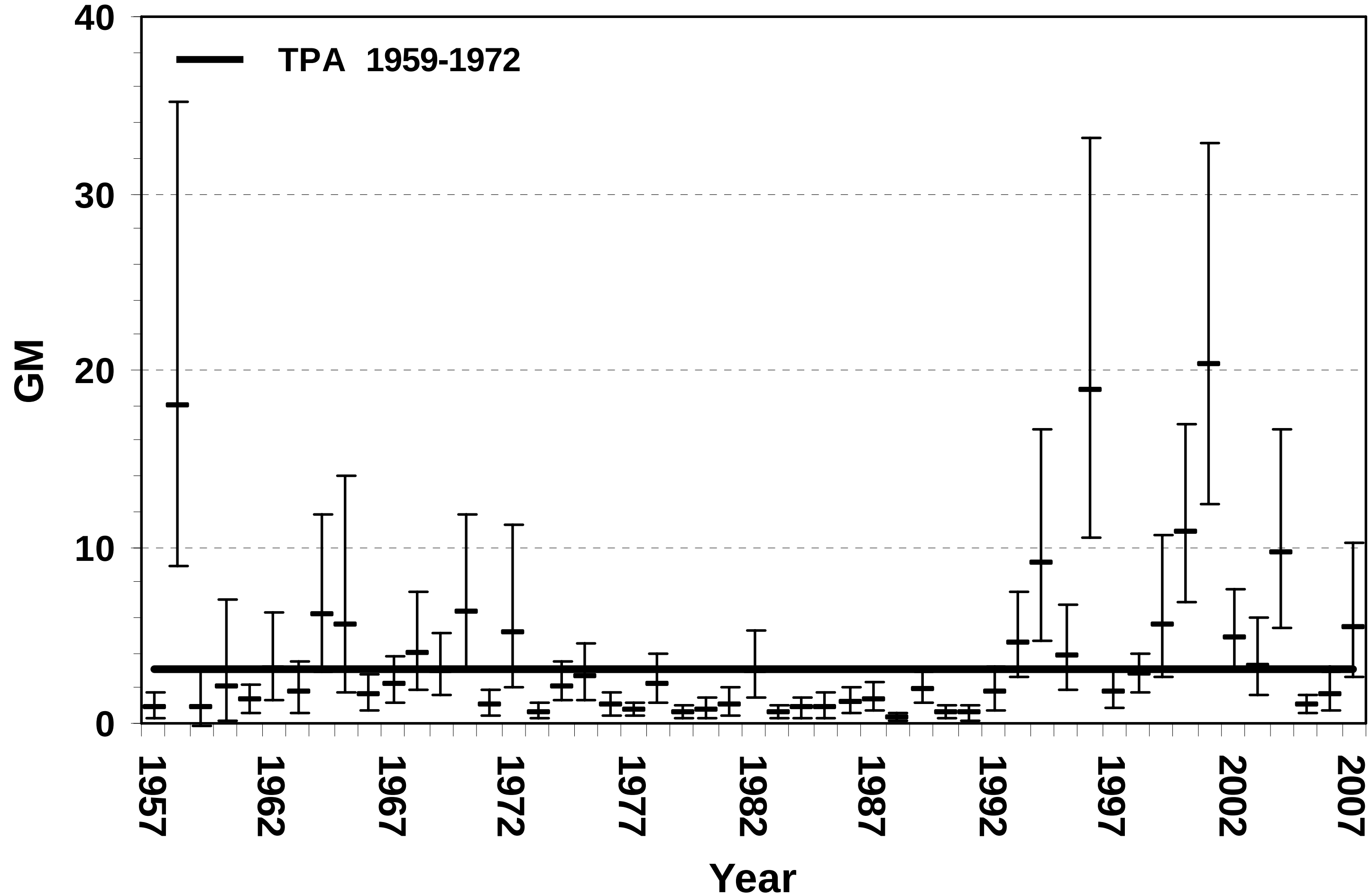


Figure 10. Regression of age 1 on age 0 striped bass.

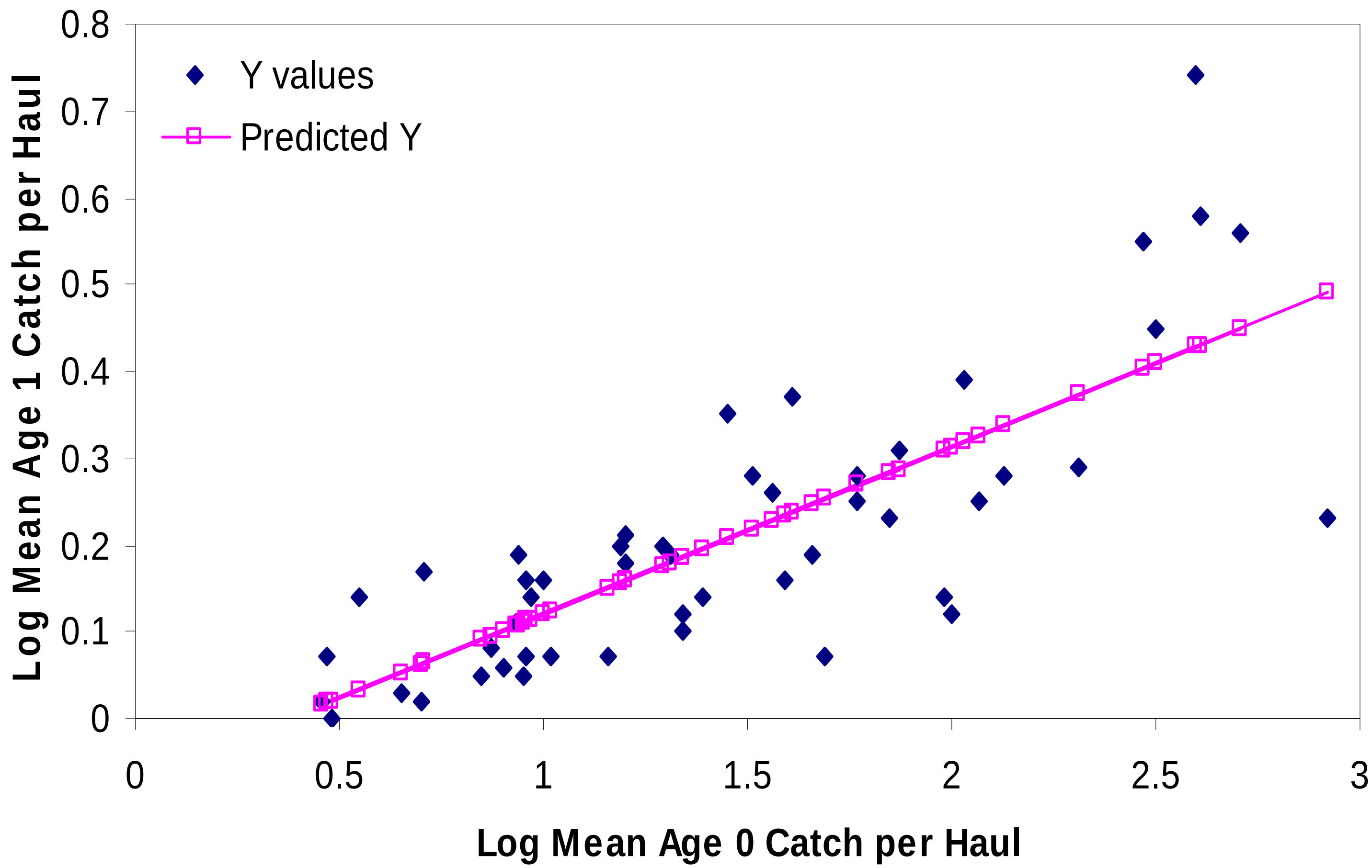
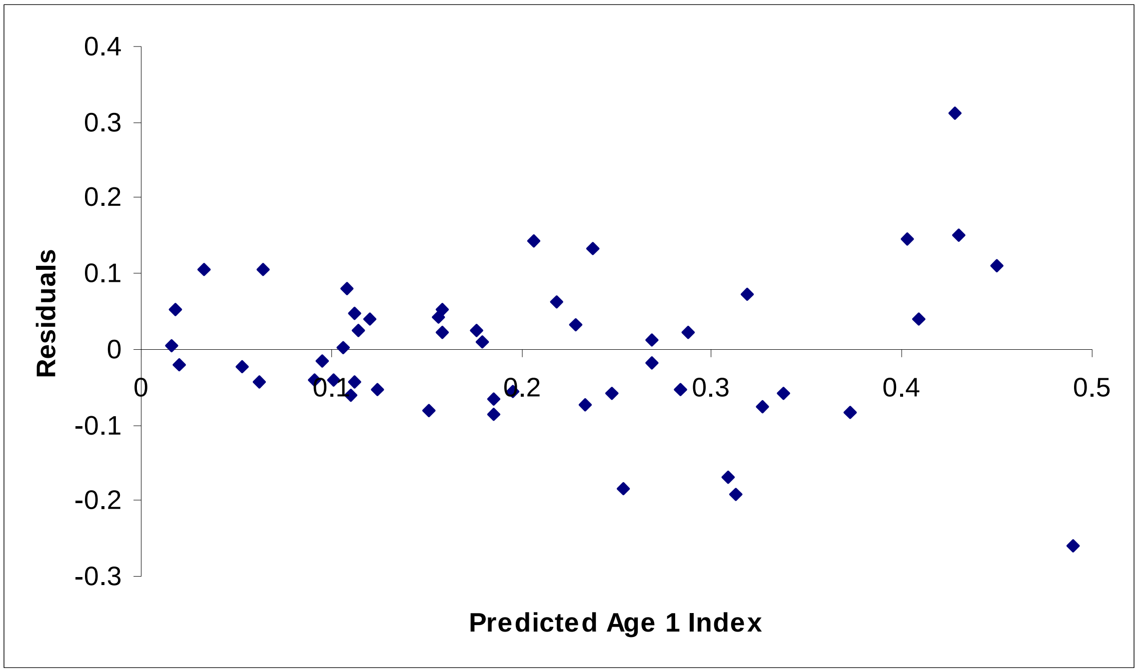
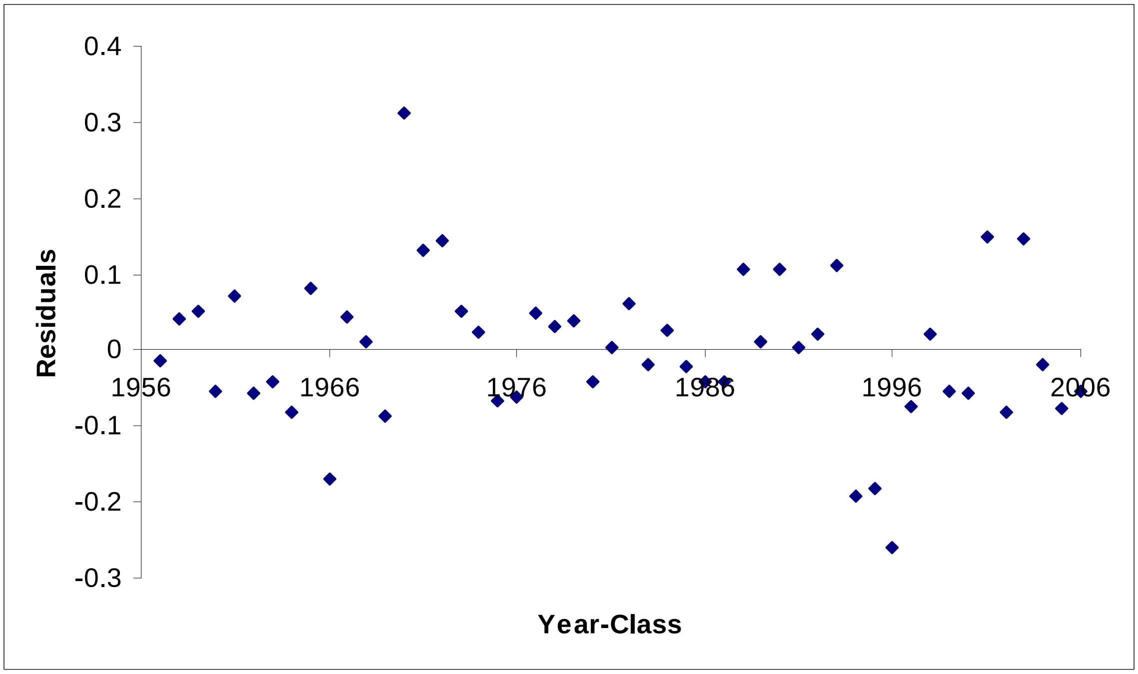


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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

STRIPED BASS TAGGING

Prepared by Beth A. Versak

INTRODUCTION

The primary objective of Task 4 was to summarize all striped bass tagging activities in Maryland's portion of the Chesapeake Bay, and the North Carolina offshore cruise during the time period of summer 2006 through spring 2007. 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 was expanded in 2007 to all the major producer areas to obtain a coast-wide estimate of tag reporting rate.

METHODS

Sampling procedures

From late March through May 2007, 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 Task No. 2) (Figure 1). Fish sampled during this study were measured for total length (TL) to the nearest millimeter (mm) and examined for sex, maturation stage and external anomalies. Internal anchor tags were applied to all healthy fish, regardless of size, and scale samples were collected from a sub-sample for age determination. Scales were taken from two to three male fish per week per 10-mm length group, up to 700 mm TL. No more than 10 scale samples per 10-mm length group were taken over the course of the survey. Scale samples were taken from all female fish and all males over 700 mm TL. Tagging stopped when water temperatures exceeded 70°F.

Along with the standard USFWS tags, high reward tags were applied to every fifth, healthy fish ≥457 mm TL. Data obtained from the recaptures of these tagged fish will be used to obtain a current estimate of reporting rate, which is used in the estimation of fishing mortality (Hoenig et al. 2006).

Additionally, from January 18 to January 24, 2007, 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 Cape Henry, Virginia, to Cape Hatteras, North Carolina. Sampling was conducted 24 hours a 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 185 times at speeds ranging from 2.3 to 3.0 knots at depths of 32 to 90 feet (9.8 – 27.4 m) for 0.17 to 0.38 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, based on historic release and recovery data, 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*", to the observed release and recovery data. Candidate models were based on knowledge of the biology of the species and were assumed to describe fish survival and tag recovery over time (Brownie et al. 1985; Burnham et al. 1995). The computer program, MARK, computes survival and recovery rates via numerical maximum likelihood estimation techniques and determines model fit using Akaike's Information Criteria (AIC) and chi-square goodness of fit (Akaike 1973; White and Burnham 1997). Survival estimates were then further derived by using a weighted average of survival rates from the best fitting models (Buckland et al. 1997). Survival was then converted to total mortality, which along with exploitation, were used as inputs to Baranov's catch equation to compute F. 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 2007 will not be completed until after 3/27/08, these estimates will not appear in this report.

A comparative analysis of the 1993-2002 spring and fall tagging data showed that the spring data would produce similar estimates of fishing mortality (F) for Chesapeake Bay; consequently the summer-fall directed fishing mortality effort was discontinued in 2005 (Sharov and Jones 2003). Tag release and return data from spring male fish, ≥457 mm TL and <711 mm TL (18 – 28 inches TL), were used to develop the 2006-2007 estimate of F for Chesapeake Bay (Sharov 2007). 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 (2007).

Reporting rate will be estimated using the ratio of standard-reward recoveries to high-reward recoveries from the spring tagging. The 2007 study was conducted in the three major producer areas; Chesapeake Bay, Delaware River and the Hudson River. A coastwide estimate of reporting rate, as well as area specific estimates will be calculated. The approach can be found in Hoenig et al. (2006) and will be similar to the methodologies used in past 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 2007 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 striped bass that were tagged and all striped bass measured for total length (SAS 1990). This was done to determine if the tagged fish were representative of the entire sample. Lengths were considered different at $P < 0.05$.

RESULTS AND DISCUSSION

Spring tagging

The spring sampling component monitored the size and sex characteristics of striped bass spawning in the Potomac River and the upper Chesapeake Bay. Sampling occurred between March 31, 2007 and May 17, 2007. In 2007, 1,029 striped bass were sampled and 772 (75%) were tagged as part of this routine spring sampling (Table 1). Of those 772 tags, 91 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 this case, biologists measured all fish but were only able to tag a sub-sample. Typically, these large concentrations of fish were of a smaller-size, 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 2007 (579 mm) was significantly greater ($P<0.05$) than that of the sampled population (554 mm)

(Figure 2).

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 2006-2007 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. Fishing morality estimates from the three methods ranged from 0.05 to 0.14, and were all below the target F=0.27 set by ASMFC. Specific methods and results are described in Sharov (2007).

Estimates of survival and fishing mortality for the Chesapeake Bay spawning stock will be presented in the 2008 report of the ASMFC Striped Bass Tagging Subcommittee.

USFWS cooperative tagging cruise

All of the 370 striped bass sampled on the SEAMAP cruise in 2007 were tagged (Table 2). Fish were widely distributed and difficult to locate in 2007, with the majority being encountered at, and north of, the mouth of Chesapeake Bay. This area is not typically sampled during the cruise. The mean total length of fish captured and tagged on the 2007 cruise was 825 mm (Figure 2) was significantly greater than the mean total lengths of the 2006 cruise (715 mm – tagged and total sample; P<0.0001). The NC DMF is presently completing age determination for the 2007 cruise via scale analysis.

Estimates of survival and fishing mortality based on fish tagged in the 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 2007.

SYSTEM	INCLUSIVE RELEASE DATES	TOTAL FISH SAMPLED	TOTAL FISH TAGGED	APPROXIMATE TAG SEQUENCES [a]
Potomac River	3/29/06-5/16/06	406	315	507001 - 507281 575001 - 575034 [c]
Upper Chesapeake Bay	4/3/06-5/16/06	623	457	489001 – 489409 575076 – 575132 [c]
Spring spawning survey totals:		1,029 [b]	772	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes 1 fish with a missing length.
[c] These sequences are high reward tags.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2007 SEAMAP cooperative tagging cruise.

SYSTEM	INCLUSIVE RELEASE DATES	TOTAL FISH SAMPLED	TOTAL FISH TAGGED	APPROXIMATE TAG SEQUENCES [a]
Nearshore Atlantic Ocean (Cape Henry, VA to Cape Hatteras, NC)	1/18/07-1/24/07	370	370	548501 – 548870
Cooperative tagging cruise totals:		370	370	

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

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, March - May 2007.

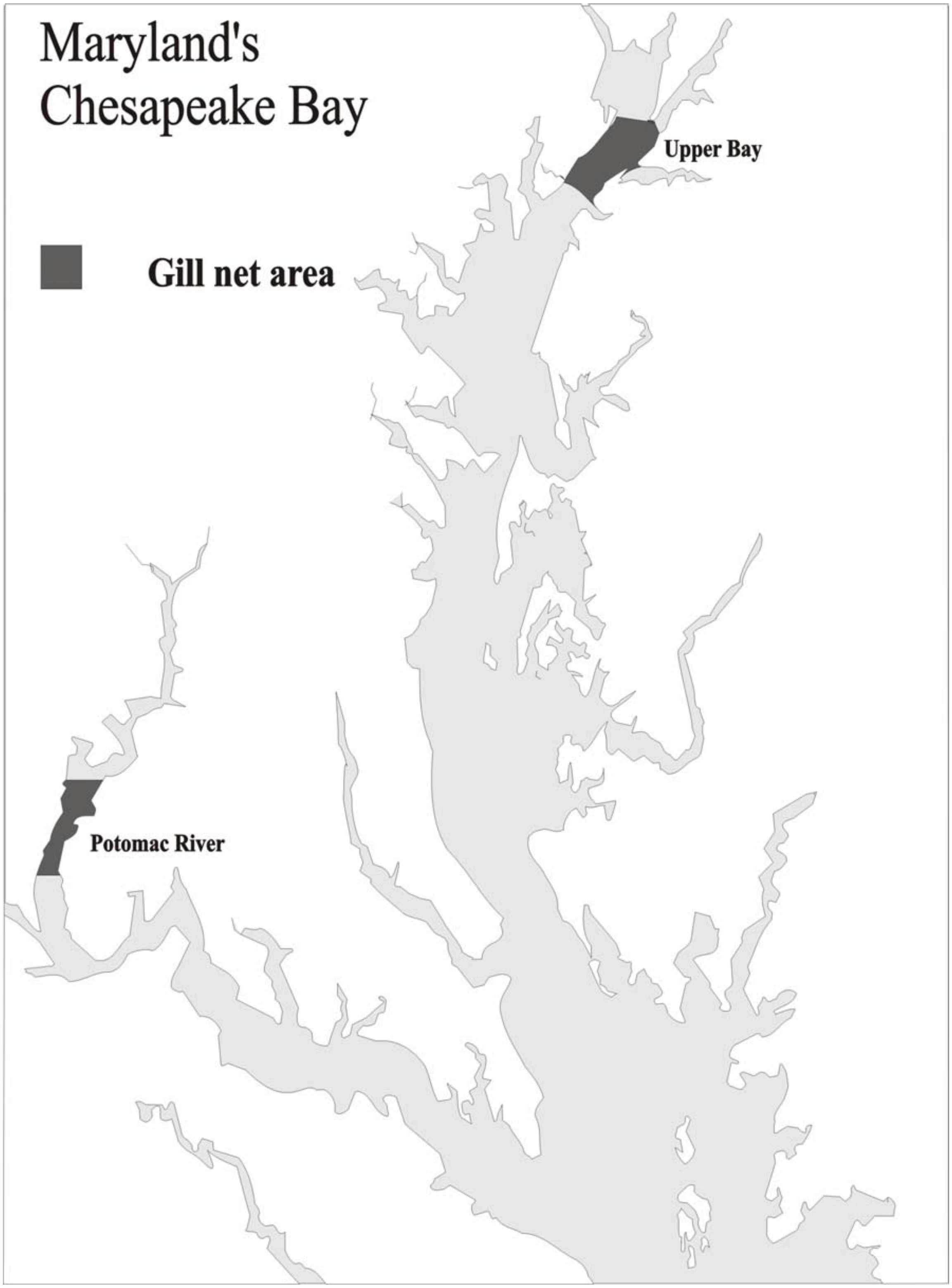
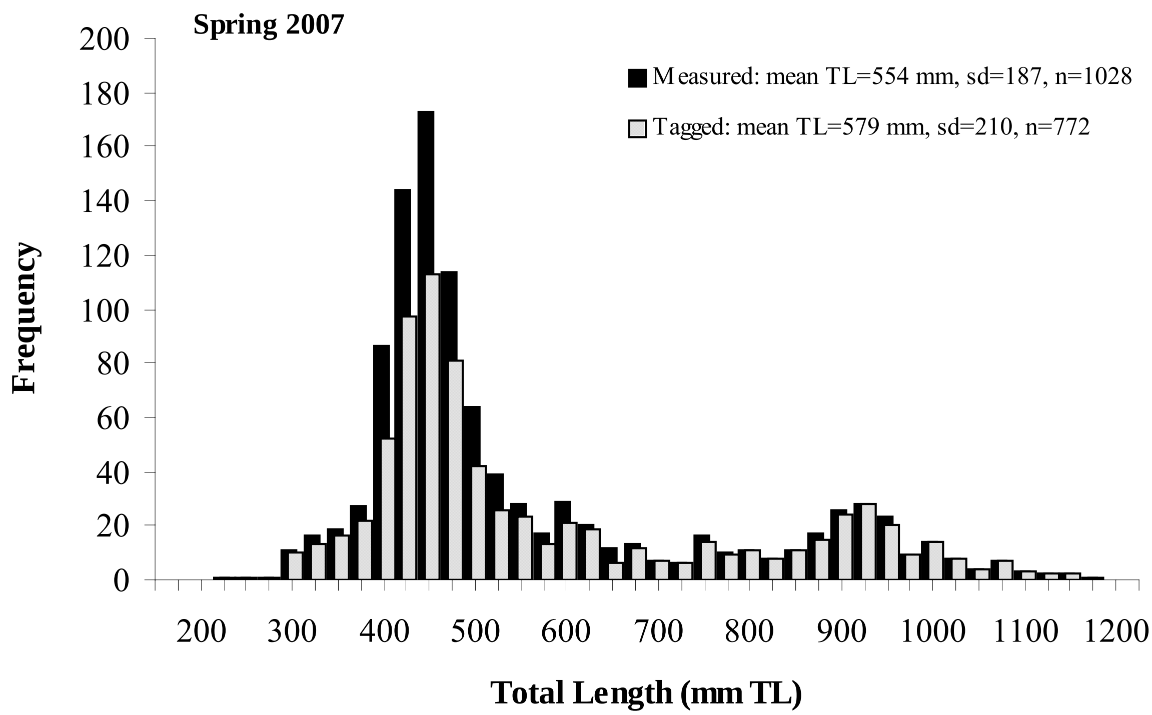
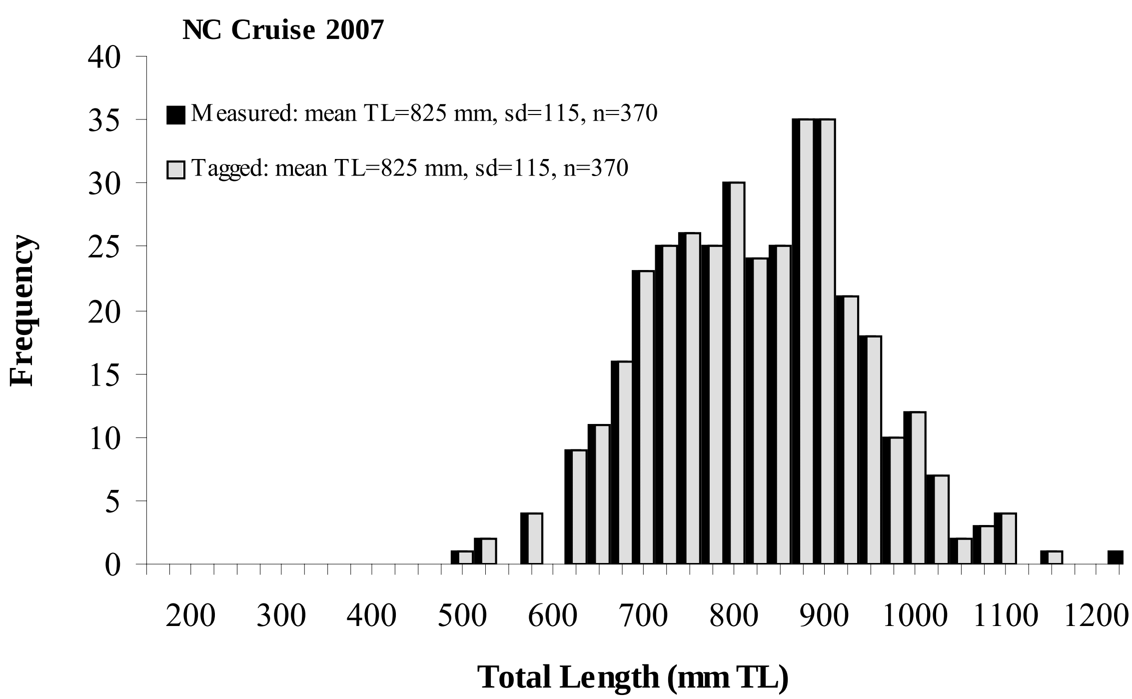


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay and offshore during the SEAMAP tagging cruise. Note different scales.





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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Luke Whitman

INTRODUCTION

The primary objectives of Task 5A were to quantify the commercial striped bass harvest in 2006 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 seventeenth year of commercial fishing under the quota system since the striped bass fishing moratorium was lifted in 1990. The 2006 commercial quota for the Chesapeake Bay and its tributaries was 2,134,114 pounds with an 18 to 36 inch total length (TL) slot limit. The commercial fishery received 42.5% of the state's total Chesapeake Bay striped bass quota. There was 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, 2006. The pound net fishery was open from June 1 through November 30, 2006. The haul seine fishery was open from June 1 to November 30, 2006. The Chesapeake Bay drift gill net season was split, with the first segment from January 3 through February 28, 2006 and the second segment from December 1 through December 31, 2006. The Atlantic Coast fishery consisted of two gear types, the Atlantic drift gill net and the

Atlantic trawl. Both gear types were permitted during the Atlantic season, which occurred in two segments: January 1 through April 30, 2006 and November 1 through December 31, 2006.

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 has 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 March 2005, 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 legal gear. A deadline of August 31, 2005 was established for receipt of declaration. MD DNR charged a fee to participants based upon the type of license they 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, counted, weighed, and verified that all the fish were tagged. Check stations were also responsible for recording 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 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 provided by the MD DNR Fisheries Service. 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.

RESULTS AND DISCUSSION

On the Chesapeake Bay and its tributaries, 2,116,257 pounds of striped bass were harvested in 2006. This represented 99% of the Chesapeake quota for the 2006 commercial fishing season. The estimated number of fish landed was 778,635 (Table 3). The Chesapeake drift gill net fishery contributed 44% (pounds) of the total landings and the pound net fishery contributed 32 % (pounds). The hook-and-line fishery harvested the remaining 24% by weight. The haul seine fishery harvested a small number of fish for the first time in four years.

Maryland's Atlantic Coast landings were 91,093 pounds (Table 3). The estimated number of fish landed was 10,535. This represented 72% of the Atlantic Quota. The trawl and gill net fisheries were nearly equal in their contribution to the Atlantic harvest.

MD DNR biologists performed direct sampling of striped bass at Chesapeake Bay check stations to characterize the harvest of commercial striped bass fisheries (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 3.44 pounds. Mean weights by specific gear type were similar, ranging from 3.12 to 3.77 pounds (Table 4). Market factors and gear selectivity contributed to this consistency. The largest striped bass landed in the Chesapeake Bay were taken by gill net, with an average weight of 3.77 pounds per fish.

Striped bass were also sampled at Atlantic coast check stations to characterize coastal harvest (Project 2, Job 3, Task 1C, in this report). Striped bass sampled from the Atlantic Coast fishery averaged 8.60 pounds (Table 4).

Commercial CPUE Trends

The estimated number of pounds was taken from check station log sheets (Table 3). The number of fishing trips in which striped bass were landed was estimated from MFRs. The total of pounds landed was divided by the number of trips to calculate an estimate of CPUE. In 2006, the hook and line fishery CPUE was 251 pounds per trip, which was a sharp increase from 2005. The pound net fishery CPUE was 360 pounds per trip, again a large increase from 2005. The CPUE for the Chesapeake Bay gill net fishery was 340 pounds per trip, the highest level in 16 years (Table 5, Figure 4).

The hook and line fishery continues to have the lowest CPUE of all the Chesapeake Bay fisheries, with the exception of 2004. Over the past four years, the gillnet fishery had the highest average CPUE value (305 lbs per trip), followed by the pound net fishery (247 lbs per trip) and the hook-and-line fishery (197 lbs per trip).

The Atlantic trawl fishery CPUE was 873 pounds per trip in 2006. This value is similar to the peak seen in 1995 (994 lbs per trip) when the Atlantic quota was increased. Overall, the catch has been stable since 1996, averaging 478 pounds per trip over the past eleven years. The 2006 CPUE for the Atlantic gill net fishery was 315 pounds per trip, which is above the eleven year average of 226 pounds per trip (Table 5, Figure 5).

In summary, 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 similar CPUE trends since 1996. Such positive trends in CPUE are consistent with an increase in overall striped bass stock abundance estimates as determined by the Atlantic States Marine Fisheries Commission (ASMFC 2005).

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Table 1. Striped bass commercial harvest quotas (lbs) by gear type for the 2006 calendar year.

GEAR TYPE	TOTAL ADJUSTED HARVEST QUOTA
Haul Seine, Pound Net	533,529
Hook and Line	736,269
Drift Gill Net	864,316
CHESAPEAKE TOTAL	**2,134,114**
Atlantic: Trawl, Gill Net	126,396
MARYLAND TOTAL	**2,260,510**

Table 2. Individual season and daily harvest allocations (lbs) and the number of declared striped bass fishermen for the 2006 calendar year.

AREA	GEAR TYPE	NUMBER DECLARED	DAILY ALLOCATION (pounds)	SEASONAL ALLOCATION (pounds)
BAY & TRIBUTARIES	Haul Seine	4	750	1,250
	Pound Net	147	200 [1]	1,100[1]
	Hook & Line	170	300	none
	Gill Net / HL	832	500	none
ATLANTIC COAST	Atlantic Trawl	34	none	1,950
	Atlantic Gill Net	39	none	1,950

1. Pound net daily and season allocations were based on: 200 pounds daily per net, 1,100 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 2006 calendar year.

AREA	GEAR TYPE	POUNDS[1]	ESTIMATED[1] NUMBER of FISH	TRIPS[2]
CHESAPEAKE BAY[3]	Haul Seine	84	26	1
	Pound Net	672,614	268,156	1,871
	Hook & Line	514,019	193,221	2,046
	Gill Net	929,540	317,232	2,738
	Chesapeake Total Harvest	2,116,257	778,635	6,656
ATLANTIC COAST	Atlantic Trawl	45,383	5,142	52
	Atlantic Gill Net	45,710	5,393	145
	Atlantic Total Harvest	91,093	10,535	197
MARYLAND TOTALS		2,207,350	789,170	6,853

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 2006 calendar year.

AREA	GEAR TYPE	AVERAGE WEIGHT (pounds)	SAMPLE NUMBER
CHESAPEAKE BAY[3]	Haul Seine[1]	3.23	NA
	Pound Net[2]	3.13	944
	Hook-and-Line[2]	3.12	2,106
	Gill Net[2]	3.77	2,973
	Chesapeake Total Harvest[2]	3.44	6,023
ATLANTIC COAST	Trawl [2]	7.06	108
	Gill Net[2]	8.60	437
	Atlantic Total Harvest[2]	8.60	545

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. Striped bass average catch per trip (CPUE) in pounds by gear type, 1990 to 2006.

YEAR	HOOK - AND-LINE	POUND NET	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	264.4	292.3	240.2	581.8
2004	169.9	162.4	258.2	123.7	473.6
2005	163.3	199.5	329.0	170.4	378.7
2006	251.2	359.5	339.5	315.2	872.8

Figure 1. Map of the 2006 Maryland authorized commercial striped bass check stations.

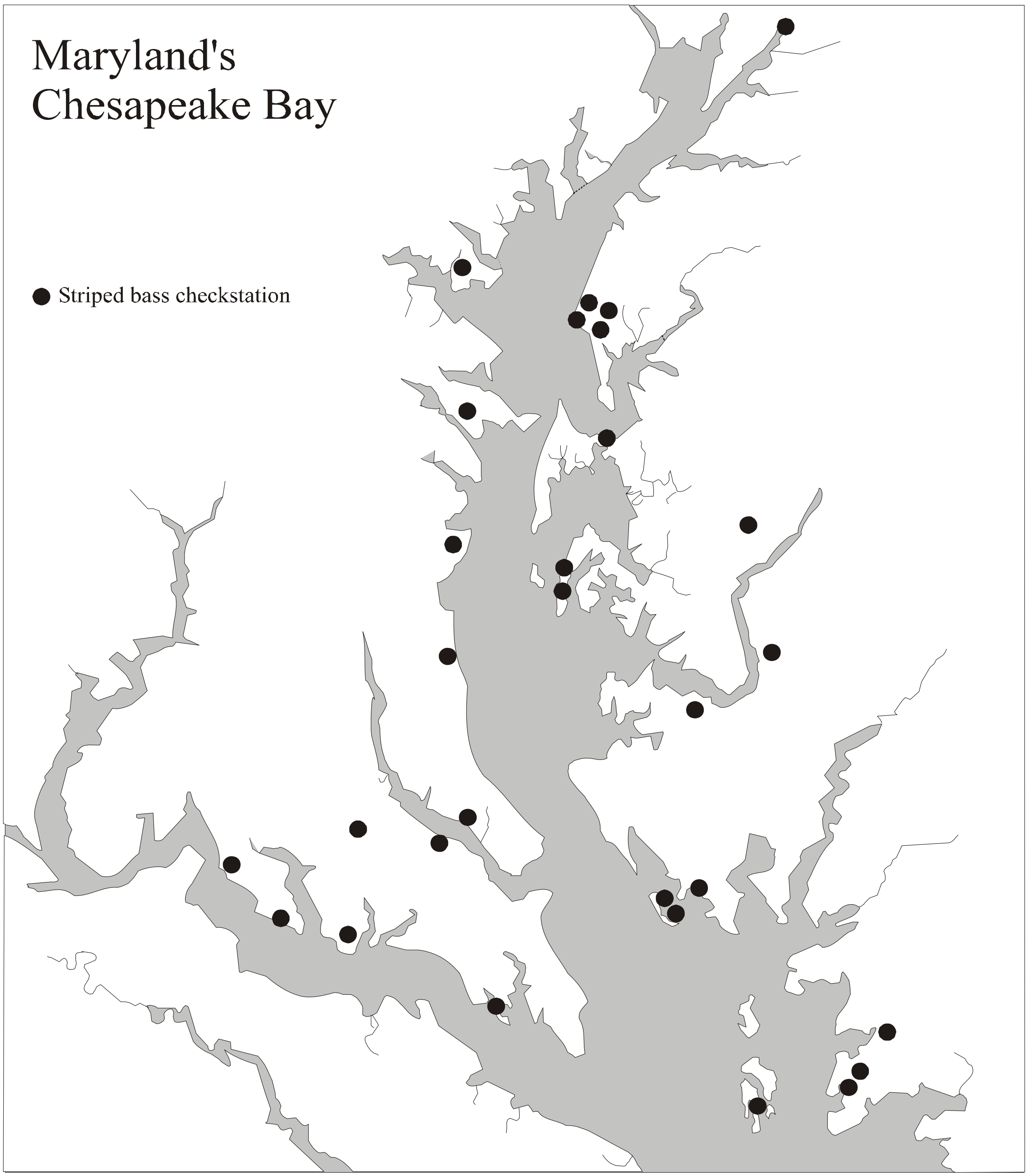


Figure 2. Maryland's Chesapeake Bay pound net and hook and line fishery cumulative striped bass landings from check stations daily call-in reports, June-November 2006.

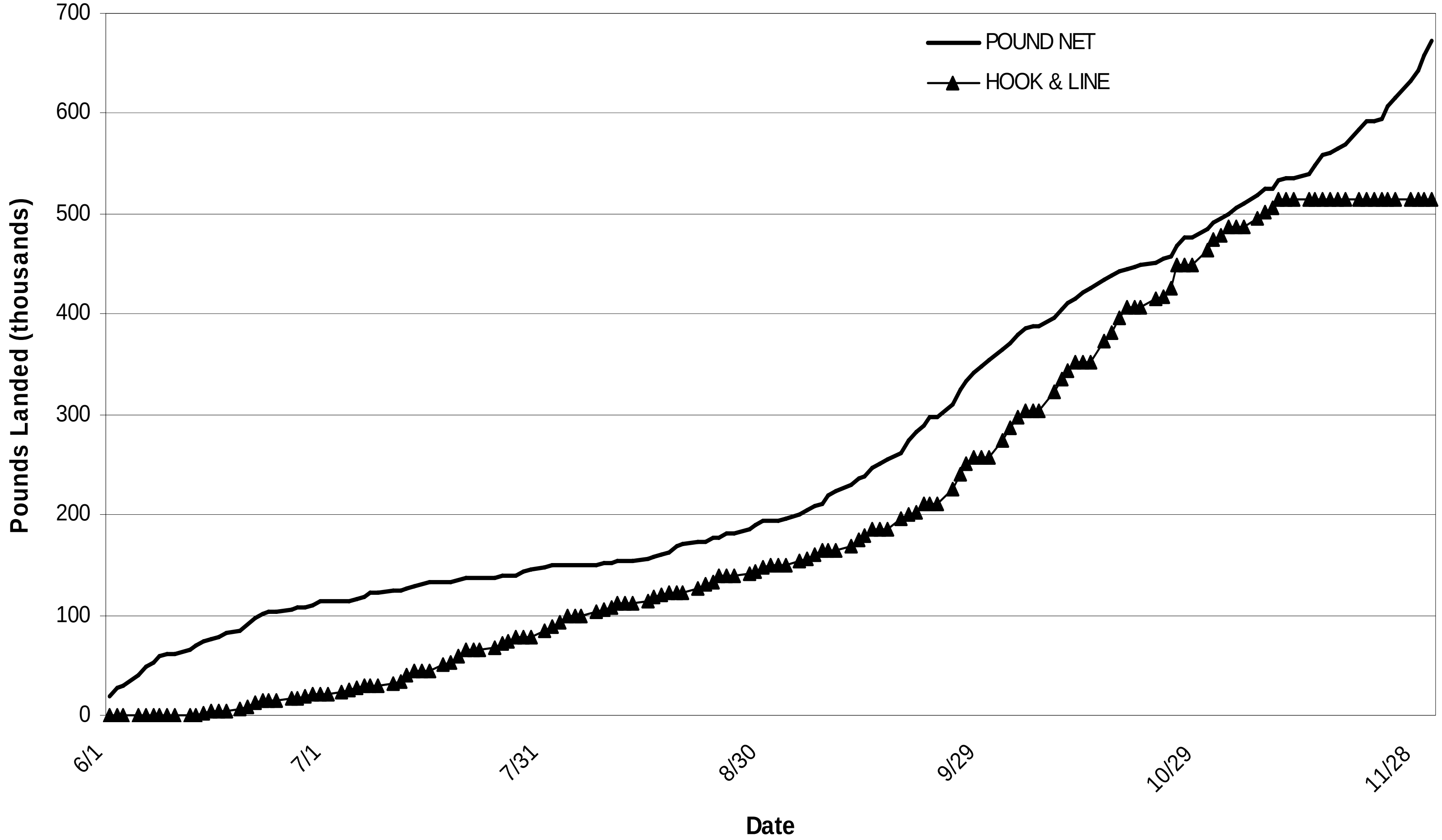
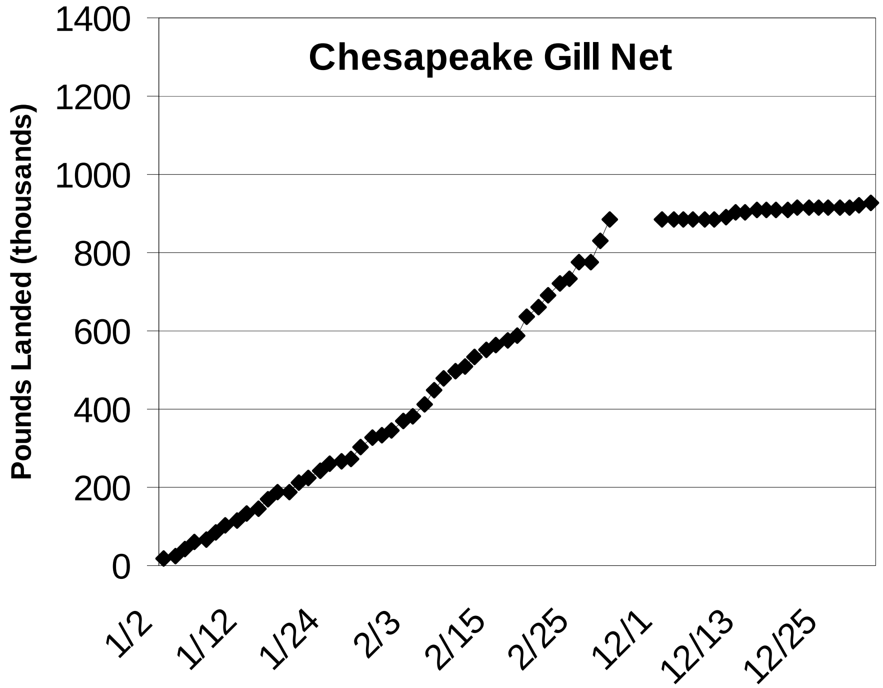


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fishery (combined) cumulative striped bass landings from check stations daily call-in reports, January- December 2006.



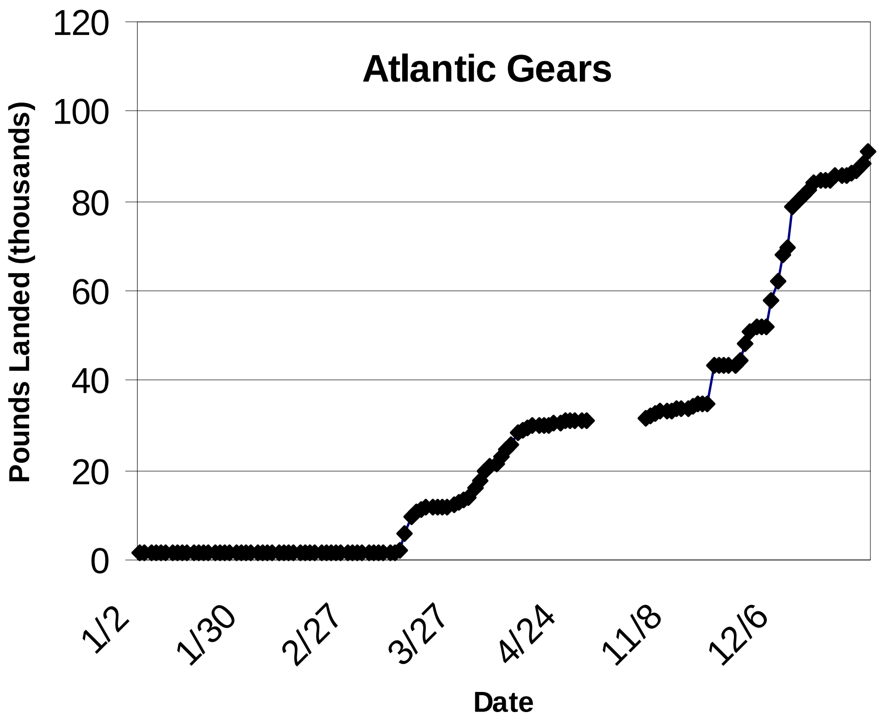


Figure 4. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by gear type, 1990- 2006. Trips were determined as days fished when striped bass catch was reported.

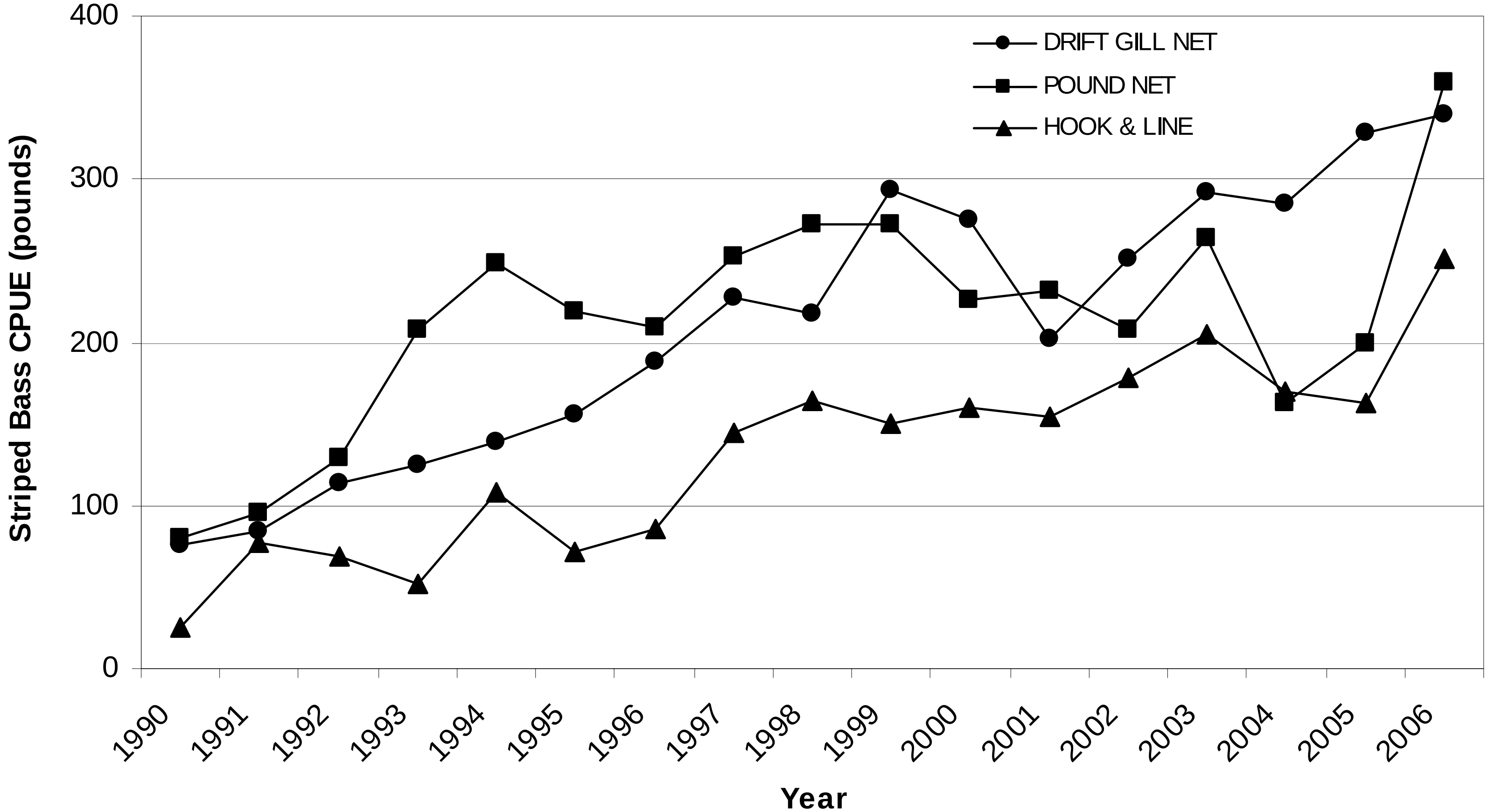
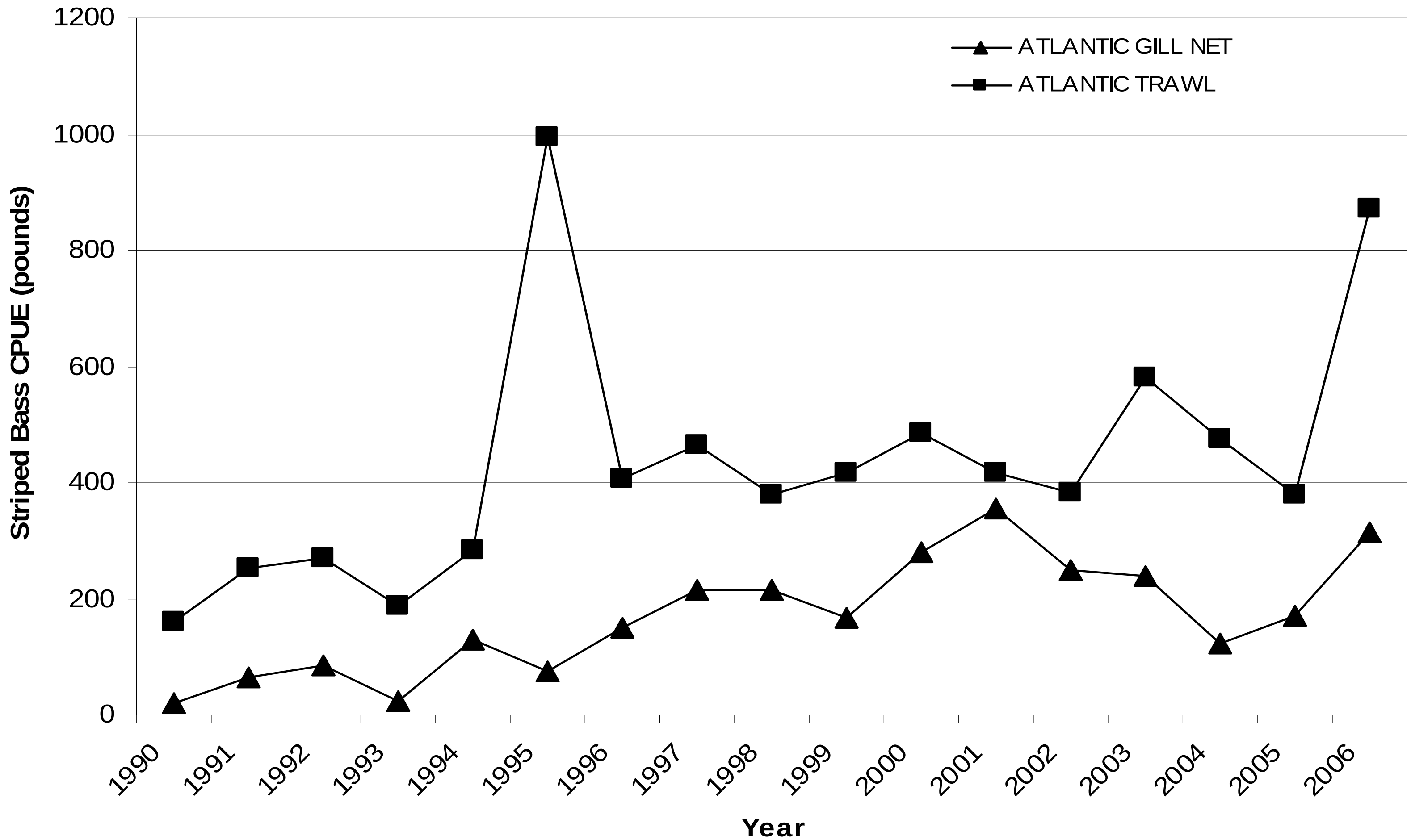


Figure 5. Maryland's Atlantic gill net and trawl fishery striped bass catch (pounds) per trip (CPUE), 1990-2006. Trips were determined as days fished when striped bass catch was reported.



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

CHARACTERIZATION OF THE STRIPED BASS SPRING RECREATIONAL SEASON AND SPAWNING STOCK IN MARYLAND

Prepared by Luke Whitman

INTRODUCTION

The primary objective of Task 5B was to characterize the size, age and sex composition of striped bass (*Morone saxatilis*) sampled from the 2007 recreational spring season, which began on Saturday April 21 and continued through May 15. In 2007, the survey was expanded to include more data from private boat anglers for comparison with a concurrent telephone survey targeting private boat fisherman.

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 1 fish per season creel limit (Speir et al. 1999). The spring season restrictions have become progressively liberal since 1991 as stock abundance increased (Table 1). The 2007 season was 25 days long (April 21 – May 15), with a one fish per person, per day, creel limit. A slot limit was put in place, allowing anglers to keep one fish between 28 and 35 inches or over 41 inches. Fishing is open 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 Survey initiated a dockside creel survey for the spring fishery in 2002. The survey was expanded in 2007 in order to better estimate catch per unit of effort 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 3-4 days per week at high-use charter boat marinas (Table 2A), with much of the sampling effort focused on weekends when recreational fishing activity was highest. 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 8:00 AM. Biologists arrived at the chosen site between 8:00 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, or no boat trailers were parked in the ramp parking lot), biologists moved to the nearest site in search of higher fishing activity. Sites were not chosen by a true random draw. More preference was given to high-use sites to ensure a sufficient sample size of fish and angler interviews. Geographic coverage was spread out as much as possible between the middle and lower Bay and eastern and western shores.

A separate creel survey was conducted at public boat ramps to specifically target private boat anglers. Access sites were randomly selected from a list of 12 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 sights 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 9 AM-2 PM. Anglers were only interviewed after their trip was complete and shore-based anglers were interviewed as encountered.

Biological Data Collection

Biologists approached anglers and requested permission to collect data from their 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 varies between years. In 2007, 174 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 collecting otoliths was 15 otolith pairs per 20 mm length group, for each sex. Otoliths were extracted by using a hacksaw to make a transverse cut form 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 is 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 read 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 (Snyder 1983). 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.

Striped bass were scanned for the presence of coded wire tags (CWTs) between 2002 and 2006. This practice was discontinued in 2007 because in recent years an extremely small number of striped bass have been found with CWTs. The hatchery program that applied the tags ended in 1996 and it has since become unnecessary to scan the fish for CWTs.

Calculation of Harvest and Catch Rates

Survey personnel interviewed 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, CPT and CPH were also calculated from charter boat log data. Charter boat captains are required to submit logbooks to MD DNR which indicate 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. CPH was calculated by dividing total catch obtained from charter boat logs by average trip length in hours from creel survey interview data.

The analysis of catch rates from charter boat logs used a sub-set of data to include only fishing that occurred in areas specified in the MD DNR regulations (see Figure 1) during the spring season (April 15-May 15). Data from the catch-and-release fishery in the Susquehanna Flats area were excluded.

Socio-economic data collection

Survey personnel interviewed anglers to obtain socio-economic data (Table 4). The socio-economic interview questions are shown in Section B of Appendix 1.

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. Most trips sampled in 2007 were from private boats, although charter boats were also sampled 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

The new 2007 size limits were clearly reflected in the length distribution. The catch was dominated by fish between 840 mm and 900 mm TL (33 to 35 inches). Only 6% of the sampled harvest was greater than 41 inches (1041 mm) (Figure 2). Striped bass that fell within the prohibited segment of the slot limit made up 8.7% of the sampled harvest.

Mean length

In 2007, the mean length for all sexes combined (861 mm TL) decreased compared with those observed during the 2002-2006 surveys (Table 6A, Figure 3). The mean length of females (869 mm TL) was greater than the mean length of males (827 mm TL), which is typical of the biology of the species. Based on 95% confidence intervals, the mean lengths of all sexes combined, females, and males decreased significantly when compared with average lengths from 2006.

Mean daily length of female striped bass was consistent over time during the 2007 spring trophy season, similar to the pattern observed in 2006. This is in contrast to mean daily length data in 2002 and also to other studies, when larger females were caught earlier in the season (Figure 4) (Goshorn et al.1992, Barker et al. 2003).

Mean weight

The mean weight of 2007 fish (6.8 kg) decreased compared to mean weights observed in previous years (Table 6B). Based on 95% confidence intervals, the mean weight of males, females, and all fish combined decreased significantly from 2006 (Figure 5). The mean weight of females was greater than the mean weight of males, which is consistent with data from previous years. Females tend to grow bigger than males, and most striped bass over 13.6 kg (30.0 lb) are females (Bigelow and Schroeder 1953).

<u>Age Structure</u>

The age distribution of striped bass from the sampled harvest in 2007 consisted of fish between 6 and 16 years of age (Figure 6). As with the length distribution, the age distribution was affected by the new size limits placed on the spring fishery. The age distribution was more even than in previous years, with most fish between seven and 11 years old. The 2000 year-class (7 years old in 2007) was most frequently observed, constituting 21% of the sampled harvest. The 1996 year-class was not nearly as well represented as in previous years, constituting only 11% of the sampled harvest. By contrast, in 2006, the 1996 year class constituted 32% of the sampled harvest from the creel survey.

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2007 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 80% of the 2007 sampled harvest. When the data were analyzed including unknown-sex fish, females composed approximately 83% of the sampled harvest. If the fish of unknown sex were assumed to be female, the percent of females was 84%. These results are consistent with the average proportion of females seen during the years 2002-2006, which ranged from 82-87% 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 2007 spring season survey showed that 64% of females caught between April 21 and May 15 were in pre-spawn condition (Table 8), the highest percentage documented by the spring season creel survey.

Daily spawning condition of females

The percent of pre-spawn females harvested ranged from 11% to 90% on any given day during the 2007 spring fishery (Figure 7). Data from 2007 indicated that pre-spawn females were more likely to be caught early in the season, and the percentage of pre-spawn females declined during the survey period (r^2 =0.22). A similar decline has been observed between 2003 and 2006.

CATCH RATES AND FISHING EFFORT

Harvest Per Trip

The majority of trips intercepted in 2007 were private boat trips because of increased efforts to improve our understanding of private boat fishing effort (Table 5B). Creel survey interview data was used to obtain harvest rate estimates for both charter and private vessels. Most charter boats take six clients per trip and fish until the legal limit of one fish per person is reached. Harvest per trip (HPT) was calculated from charter boat logbooks and creel survey interviews using only fish kept during each trip.

Mean HPT results from charter boat logbooks and charter boat interviews were similar (4.3 and 4.9 fish per trip, respectively) (Table 9A). Mean HPT in 2007 was much less than that of 2006. Mean HPT from private boat interviews (0.7) was much lower than HPT from charter boats.

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 was calculated separately from both charter boat logbook data and interview data, which were 0.69 and 0.8 fish per person respectively (Table 9B). HPA for private anglers was 0.3 fish per person and was calculated from interview data (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 combined charter and private boat interview data. Catch rates in 2007 were much lower than all other years. The decrease is influenced by the large number of private boat trips included in the 2007 calculation and regulation changes designed to reduce harvest. Mean CPT was 2.1 fish per trip in 2007, compared with 6.6 fish per trip in 2006. Mean CPH was 0.5 fish per hour in 2007 compared with 2.6 fish per hour in 2006. Confidence intervals indicate that there was a significant decrease in catch rates between 2006 and 2007.

Comparison of Catch Rates from Charter and Private Boats

In all years, charter boats caught more fish per trip and per hour than private boats (Tables 10B and 10C). 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 among the captains enables them to track daily movements of migratory striped bass and consistently operate near larger aggregations of fish.

Comparison of Charter Boat Catch Rates from Two Data Sources

Calculations of mean CPT and mean CPH were made from charter boat logbook data (Table 10D) and compared to CPT and CPH values calculated from creel survey interviews of charter fishing parties (Table 10C). The comparison was made to examine differences in reported catch rates between the two data sources. Mean CPT from creel survey data (8.3) was much higher than CPT from logbook data (4.3). Mean CPT from logbook data in 2007 decreased greatly compared to 2006 (8.0), but examination of confidence intervals showed no significant increase in CPT calculated from the interview data from 2006 to 2007. Mean CPH calculated from interview data (2.1) was higher than CPH from logbook data (0.9). Charter boat CPH in 2007 was lower than CPH in 2006 (Tables 10C and 10D). During the years 2002-2007, interview data generally yielded higher CPT and CPH than logbook data, but confidence intervals frequently overlapped. As a result, differences between the two data sources were not significant.

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 generally varied without trend since 2002 (Figure 8).

<u>SOCIO-ECONOMIC DATA</u>

<u>Angler Characterization</u>

States of residence and gender.

In 2007, 515 trips were intercepted and 809 anglers were interviewed during the period April 21-May 15 (Table 5A). Thirteen states of residence were represented in 2007 (Table 11). Most anglers were from Maryland (68%), Virginia (17%), and Pennsylvania (7%), which is similar to the distribution of states of residence observed during previous years. The majority (93%) of interviewed anglers were male, and only 7% were female (Table 12).

Distance traveled and money spent.

The median distance that anglers traveled to charter boat ports or boat ramps in 2007 was 30 miles one-way, somewhat less than the median distance traveled during previous years (Table 13). The median cost of a fishing trip, per person, was $50 in 2007, also less than the 2002-2005 period (Table 14). As with CPUE data, these decreases may result from the large number of private angler interviews.

Fishing experience and ranking of trips.

In 2007, interviewed anglers had an average of 23 years of fishing experience for striped bass in the Chesapeake Bay (Table 15). Most anglers (49%) stated that striped bass fishing had improved in the years that they had been fishing (Table 16). Nineteen percent of anglers ranked their fishing trip as “excellent”; 28% gave a rank of “good”, 17% “fair”, and 36% “poor” (Table 17). The majority of anglers (56%) ranked the quality of their trip based on the number of fish they caught (Table 18). Some anglers were more interested in the quantity or quality of the catch, and based their trip rankings on the combination of number and size of fish (7%) or size of fish (3%). Also, thirty-four percent of the anglers were interested in the general setting of being out on the water.

Quality of fishery and satisfaction with regulations.

The majority of interviewed anglers (84%) stated that a quality recreational fishery for striped bass exists in Maryland (Table 19). Most anglers (64%) expressed satisfaction with current regulations (Table 20).

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Table 1. History of MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2007.

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

Table 2A. Survey sites for the Maryland striped bass spring season dockside creel survey, 2002-2007. 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	Kentmoore 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, 2007.

Relative Use	**Access Intercept Site**
High	Sandy Point
	Cambridge City Ramps
Medium	Chesapeake Beach
	Breezy Point
	Solomons Island
	Matapeake
	Kent Narrows
	Tilghman Island (Dogwood Harbor)
Low	Point Lookout
	Ft. Armistead
	Rock Hall
	Gootee's

Table 3. Biological data collected by the Maryland striped bass spring season creel survey, 2007.

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, 2007.

Angler and Catch Data Collected
Number of hours fished
Number of lines fished
Boat type: charter or private
Number of anglers on boat
Number of fish kept
Number of fish released
Money spent on this trip
Distance traveled for this trip
Overall quality of fishing experience
Satisfaction with current regulations

Table 5A. Numbers of trips intercepted, anglers interviewed, and fish examined by the Maryland striped bass spring season creel survey, through May 15.

	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

Table 5B. Number of trips, by type (Fishing Mode) intercepted by the Maryland striped bass spring season creel survey, May 15 of each year.

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

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)

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)

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

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
Mean	**82**	**87**	**87**

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	184	64	104	36

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)

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)

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)

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)

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)

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	1607	**4.3** (4.2-4.4)	**4.6** (4.1-5.0)	**0.9** (0.8-1.0)

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

Table 12. Percent of male and female anglers interviewed by the Maryland striped bass spring season creel survey.

Year	% Male	% Female
2002	95	5
2003	96	4
2004	96	4
2005	97	3
2006	92	8
2007	93	7

Table 13. Distance (miles) traveled from angler's residence to marina or boat ramp.

Year	Minimum	Maximum	Median	Mean
2002	1.0	500	60	68
2003	0.0	2500	55	78
2004	1.5	3000	60	134
2005	2.5	600	60	79
2006	0.0	1600	50	87
2007	0.0	3000	30	52

Table 14. Dollars spent (per day) by anglers on fishing trips during Maryland spring striped bass season.

Year	Minimum	Maximum	Median	Mean
2002	0	500	100	104
2003	0	1300	80	90
2004	0	1000	100	114
2005	0	1200	100	148
2006	0	1000	100	111
2007	0	3000	50	63

Table 15. Interviewed angler's experience (years) fishing in Chesapeake Bay.

Year	Minimum	Maximum	Median	Mean
2002	0	60	10	13
2003	0	75	20	20
2004	0	68	12	16
2005	0	64	20	23
2006	0	60	15	18
2007	0	70	21	23

Table 16. Percent of interviewed anglers stating that striped bass fishing has improved, declined, or stayed the same in Chesapeake Bay.

Year	Improved (%)	Declined (%)	Unchanged (%)
2002	84	10	6
2003	85	14	1
2004	78	11	11
2005	81	1	18
2006	75	8	17
2007	49	30	21

Table 17. Percent of anglers ranking quality of striped bass spring season fishing trip as excellent, good, fair, or poor.

Year	Excellent (%)	Good (%)	Fair (%)	Poor (%)
2002	47	26	17	10
2003	60	22	7	11
2004	48	26	16	9
2005	77	20	2	1
2006	69	16	5	10
2007	19	28	17	36

Table 18. Basis of angler's ratings (percentage) of striped bass spring season fishing trips.

Year	Number of fish caught (%)	Size of fish caught (%)	Both number and size (%)	Setting (%)
2002	17	4	23	56
2003	17	36	11	36
2004	25	14	46	15
2005	5	8	63	24
2006	11	8	27	54
2007	56	3	7	34

Table 19. Percent of interviewed anglers stating that Maryland has a quality striped bass fishery.

Year	Yes (%)	No (%)
2002	99	1
2003	97	3
2004	97	3
2005	94	6
2006	96	4
2007	84	16

Table 20. Percent of interviewed anglers expressing satisfaction with striped bass fishing regulations.

Year	Satisfied (%)	Not Satisfied (%)
2002	68	32
2003	84	16
2004	70	30
2005	59	41
2006	70	30
2007	64	36

Figure 1. MDDNR Map showing legal open and closed striped bass fishing areas in Chesapeake Bay during spring trophy season, April 21-May 15, 2007.

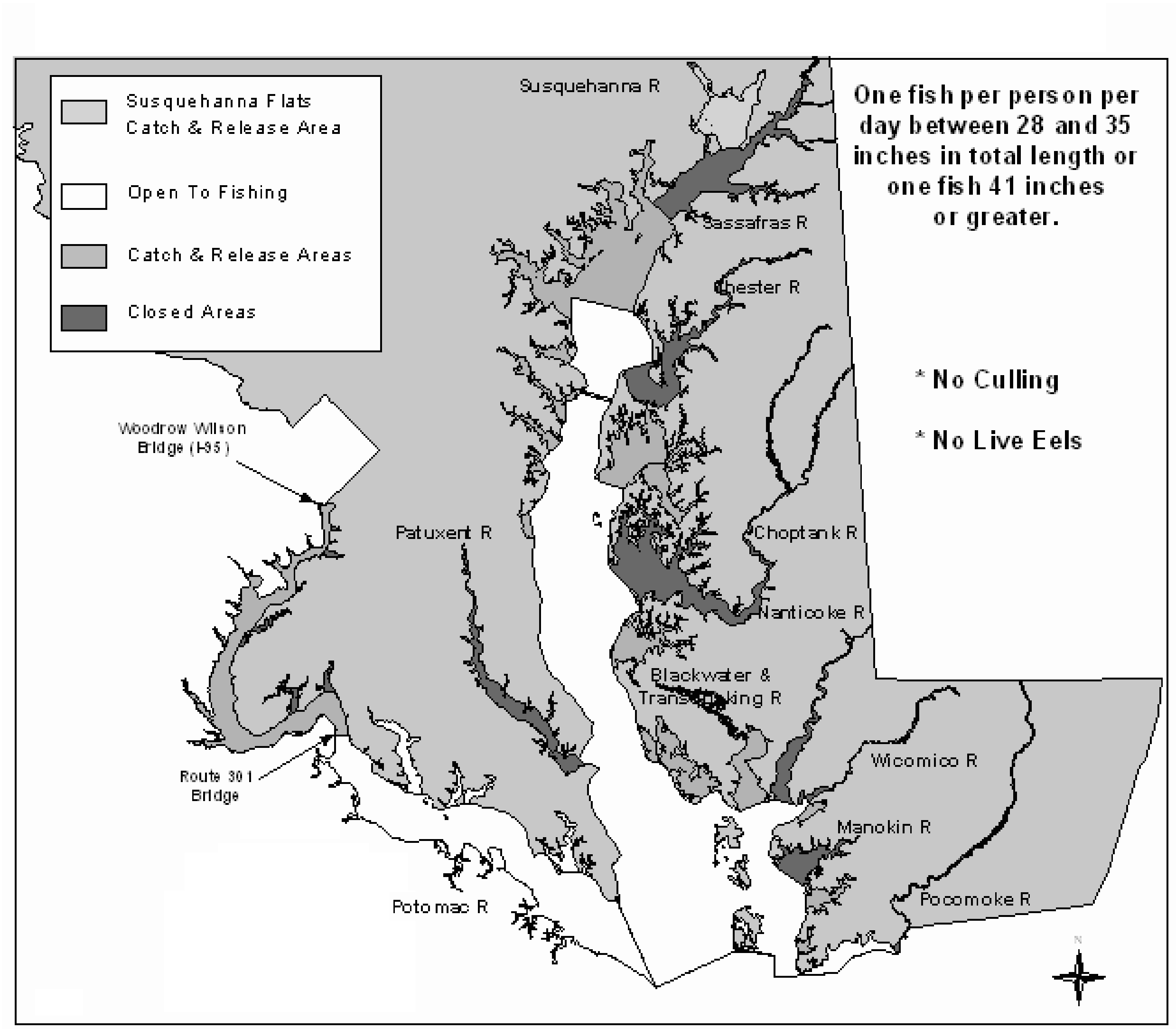


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

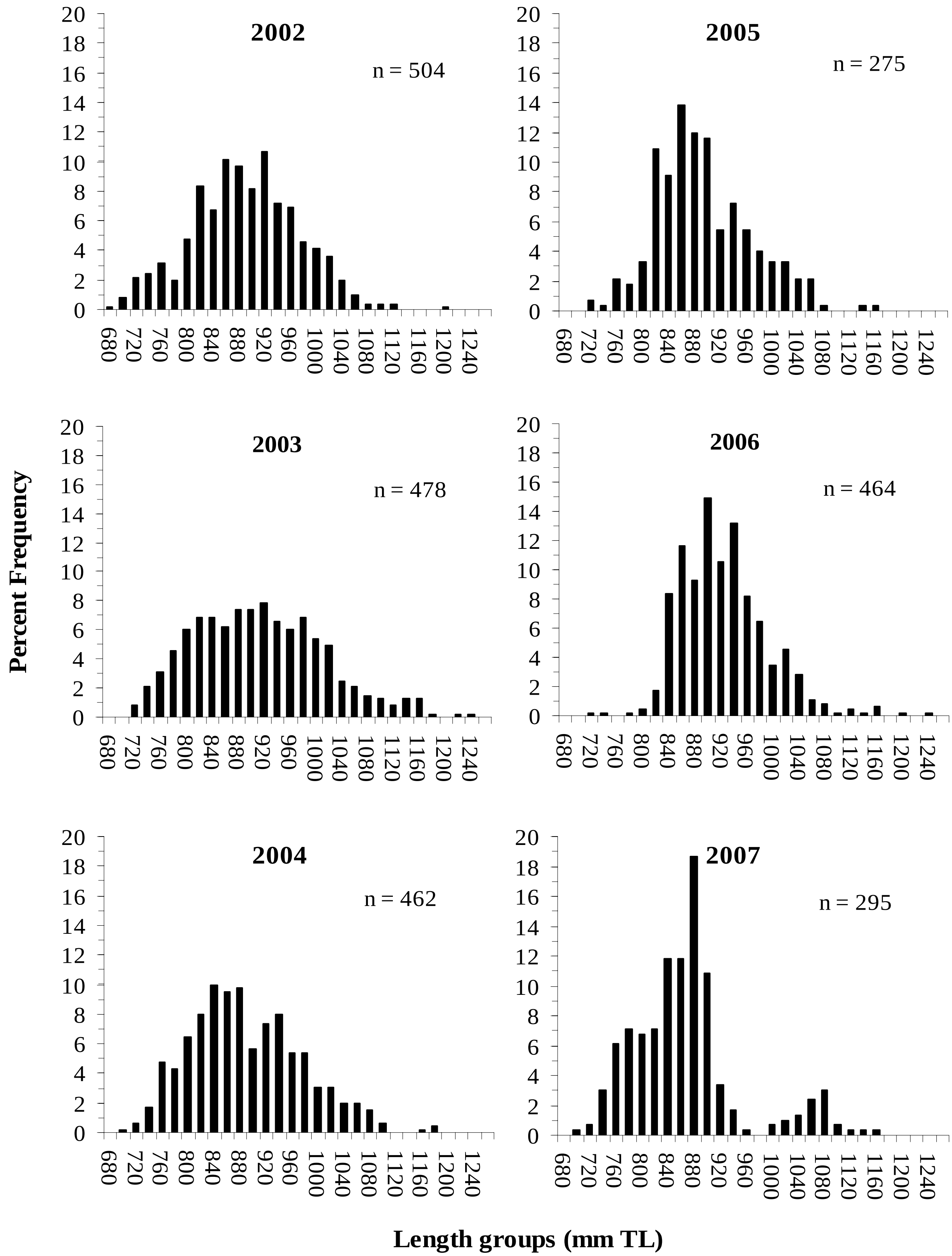


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

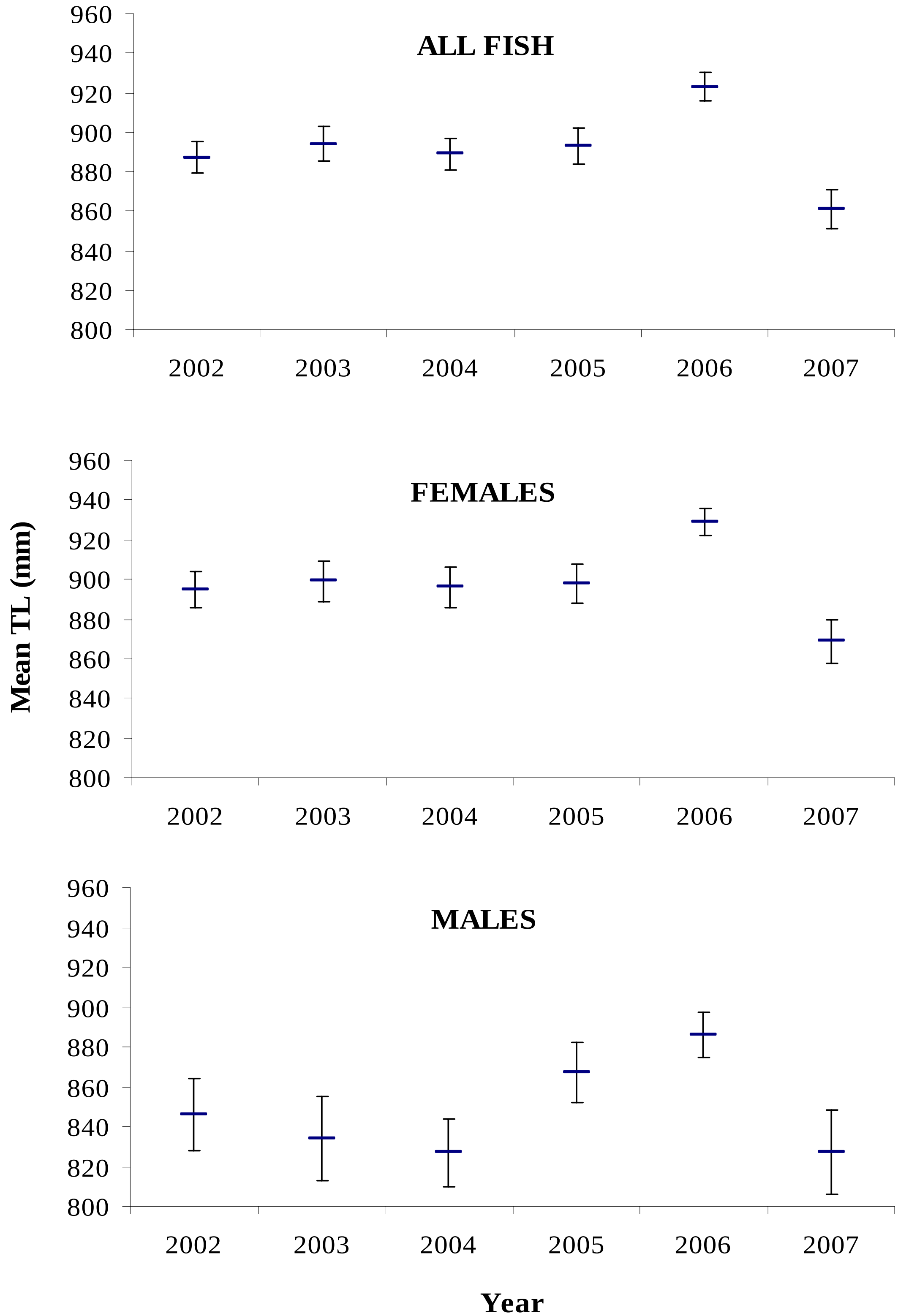


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

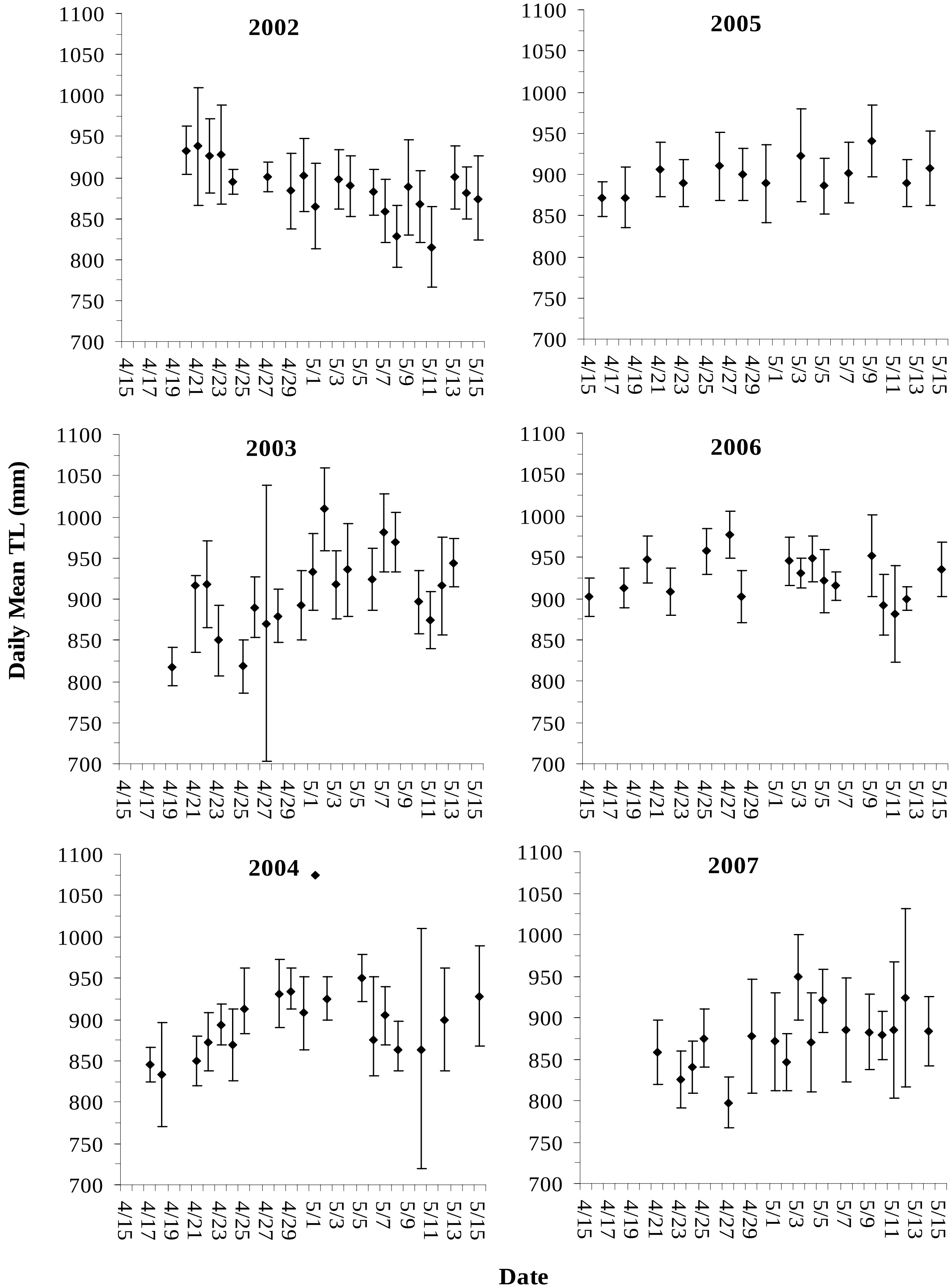


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

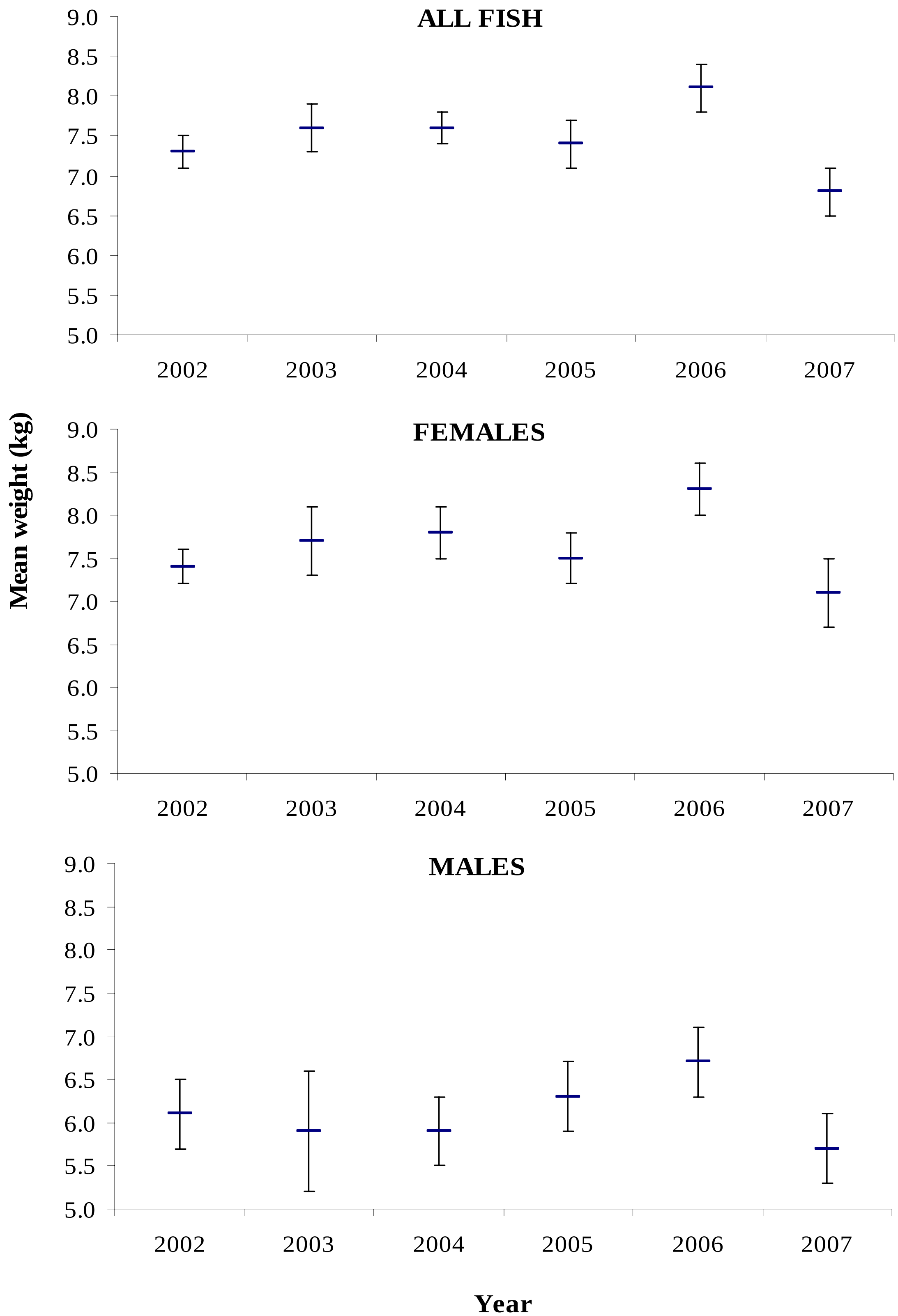


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

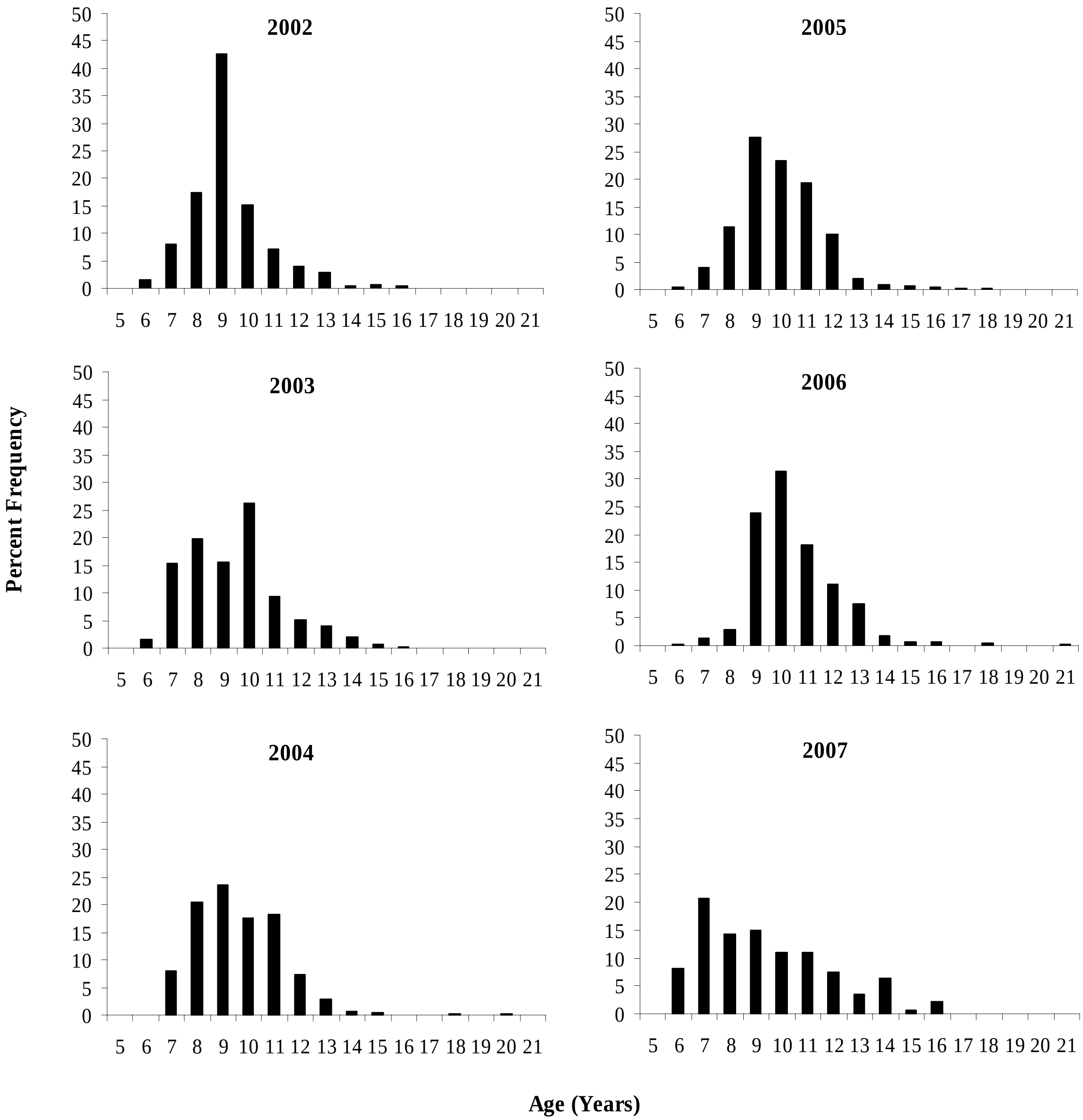


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

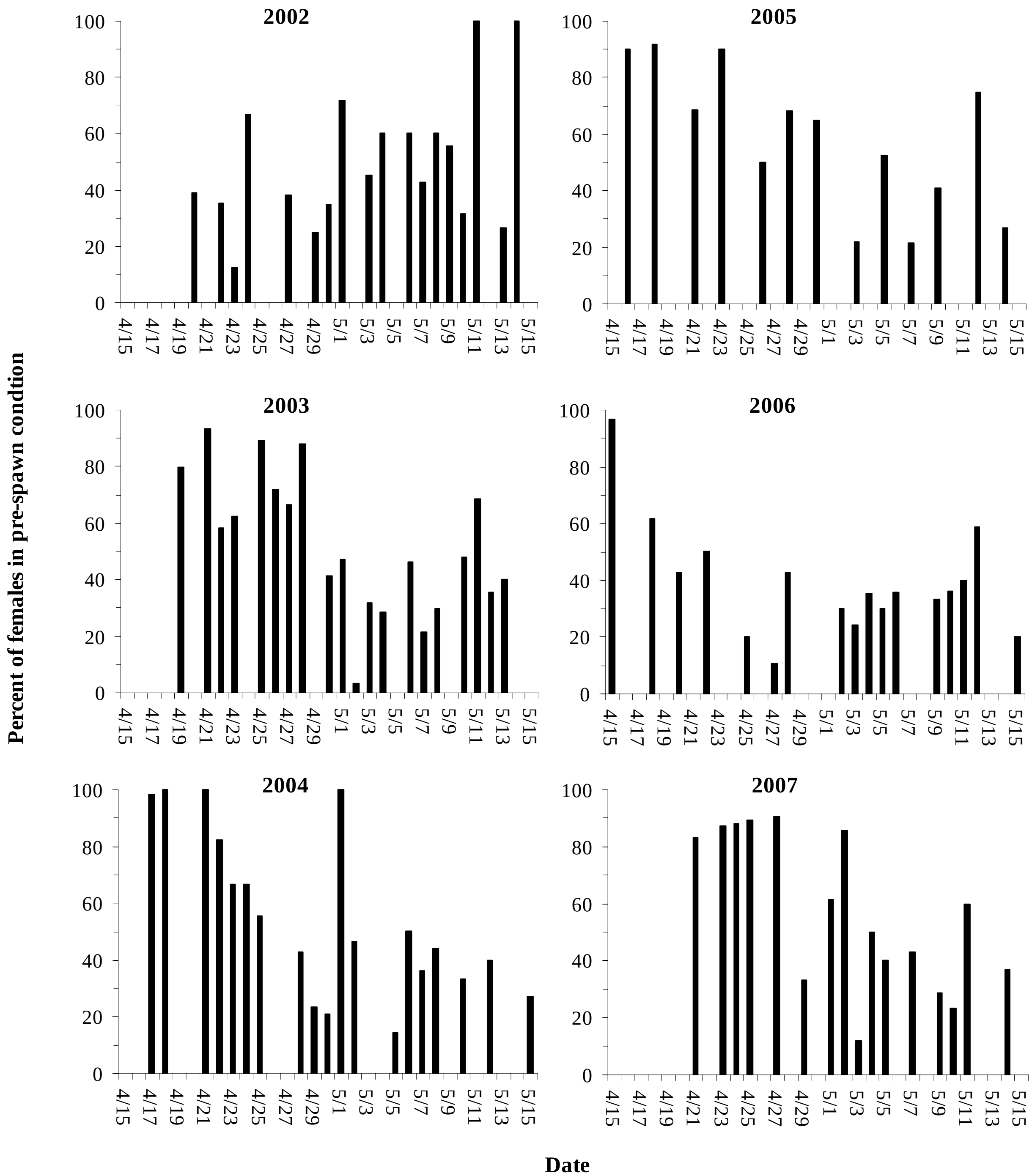
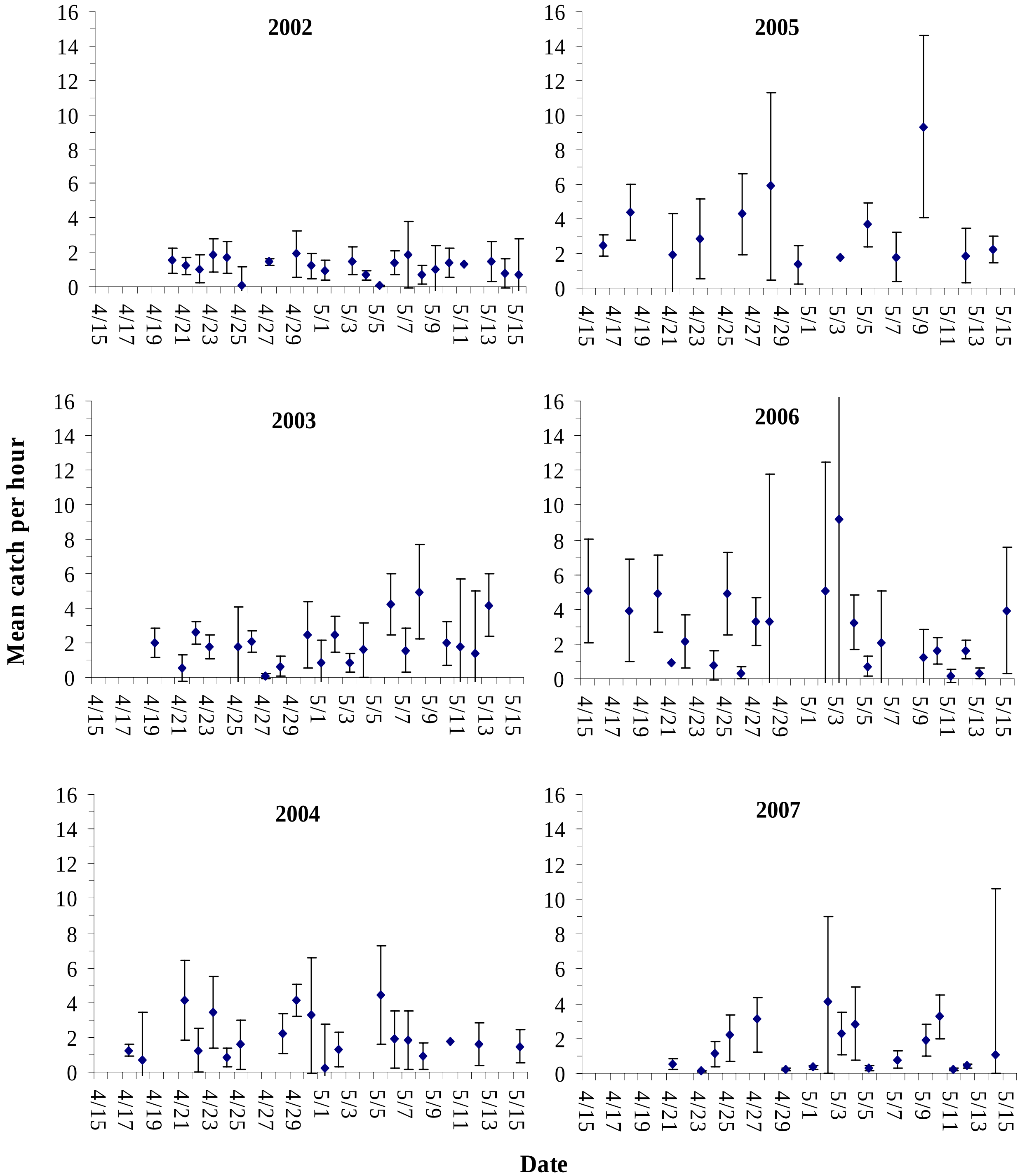


Figure 8. Daily mean catch per hour of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15.



APPENDIX I

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

SECTION A. (INTERVIEW BACKGROUND AND FISH DATA)

1.) Biologist Initials: **2.)** Date: (Month/Day/Year)

3.) Location: (Charter boat port/Boat Ramp) **4.)** Time:

5.) Interview#/Boat #:

6.) Were you fishing from Private or Charter Boat?

7.) How many hours did you fish today? (Line in-Lines out)

8.) How many lines did you fish today?

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

10.) How many striped bass were caught and released by your party?

11.) How many anglers were in your party today?

12.) Would you mind if I measure and weigh the striped bass that you brought back to the dock? (For biological research) Yes or No.

13.) Would you mind if I remove otoliths (earstones) and cut the belly of these fish, to check if they are male or female? Yes or No.

DATA FORM FOR LANDED CATCH (Measure Striped Bass)

Fish #	Boat #	TL (mm)	Weight (Kg or lbs)	Sex M/F/ U	Spawn Cond. Code (1=pre- 2=post- 3=unk.)	Anom. & Distrib.	Scales? (0=no, 1=yes)	Otoliths or head retained (0=no, 1=yes

APPENDIX I (Continued)

SECTION B. (ANGLER-SOCIOECONOMIC DATA AND QUALITY OF FISHERY)

1.) Gender (M/F) **2.)** What is your state of residence?

3.) Distance traveled to site: (one-way miles)

4.) Approximate Amount of money spent (Gas,Food,Tackle, Fare, Tip, not including Fishing Licence).

5.) How many years have you been fishing for rockfish in Maryland? (Angler avidity)

6.) How would you rate your overall rockfishing experience today?

A. Poor
B. Fair
C. Good
D. Excellent

7.) Would you base that rating on:

A. Number of fish caught
B. Size of fish caught
C. Combination of number and size
D. General atmosphere and setting (don't care too much about how many fish were caught).

8.) In your opinion, has the rockfishing in MD improved, declined, or remained the same in the years that you have been fishing?

9.) Are you happy (satisfied) with the current MD Bay rockfish regulations? (Size limits, creel limits, season restrictions) Yes or No

10.) In your opinion, do we have a "quality" SB fishery in Maryland's portion of Chesapeake Bay? Yes or No

If no, what changes would you like to see?

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 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. Management of this 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 2007 spring season was open from April 21 to May 15 with a creel limit of one fish per person, per day, from 28-35 inches or larger than 41 inches. After May 15, the creel limit became 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 21 to June 15.

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 (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). Fiscal constraints limited the telephone survey to the first seven weeks of the eight week study period. Spring harvest estimates in previous years have shown that the migrant harvest in the last two weeks of the season is very low (0.7% in 2006; Barker et. al. 2006). Therefore, Week 7 estimates were applied to Week 8.

Fisheries Service supplied the contractor with two licensing data sets: a data set of 2007 Bay Sport licenses sold up to April 20, 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 in three time increments: up to the beginning of the spring season, April 20; from April 21-May 15; from May 16-June 15. 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 analysis and 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. 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 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 from the internet-based Maryland Volunteer Striped Bass Angler Survey, consistent with migratory harvest estimates reported in previous years (Barker et al. 2006, 2007). 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

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 54,062 license records. Approximately 800 licensees were called each calling week with an average of 53% of those calls resulting in completed interviews (Table 3). The use of a targeted data base is more efficient than a random-digit-dial survey because it greatly reduces the number of phone calls necessary to characterize fishing effort.

Estimation of Effort

Telephone interviews showed that licensed participation in the fishery ranged from a high of 19% in the first week of the season to 7% in Week 3, with a general pattern of decline through the course of the seven week period (Table 4). Over 78,000 licensed anglers participated in the 2007 fishery during the study period (Table 5).

Interview data revealed that the average angler made approximately 1.6 fishing trips during the study period. When expanded to the estimated number of participating licensed anglers, this resulted in nearly 121,000 recreational fishing trips taken (Table 6).

Estimation of Harvest per Trip (HPT)

During the access-intercept survey, a total of 941 recreational anglers (924 boat-based; 17 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. A one-way analysis of variance (ANOVA) showed no difference in overall mean HPT between the two surveys (p=0.25).

Weekly mean HPT results were similar for both surveys, with overlapping confidence intervals in all weeks (Table 7, Figure 1). The greatest divergence between the two data sources occurred in week 5. An analysis of covariance (ANCOVA) showed a weak interaction between survey type and survey week (p=0.05). However, this was the first full week of increased creel limits (from 1 fish per day to 2 fish per day) and decreased minimum size requirements (from 28 inches to 18 inches), which may have influenced the behavior of some anglers. A one-way ANOVA showed that mean HPT increased significantly (p=0.001) after the regulatory change.

Estimation of Total Harvest

Weekly HPT estimates were multiplied by estimates of licensed trips to determine weekly harvest (Table 7). Total harvest using access-intercept catch rates was 38,435 fish. Total harvest using catch rates derived from the telephone survey was 41,935 fish, a difference of 3,500 fish (8%). Agreement between the two methods indicated a lack of recall bias in the telephone survey. Pollock et al. (1994) found that telephone survey data are reliable for memorable experiences such as catching a trophy-sized fish.

Estimation of Migratory Harvest

Cooperating striped bass anglers submitted length data for 884 fish to the Volunteer Striped Bass Angler Survey in 2007. Length frequencies were developed by approximate two-week time intervals (Table 8, Figure 2). Sixteen of the fish measurements provided were sub-legal or fell within the prohibited slot limit. These illegal fish appear in later steps of the analysis. 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 9-12. The same procedures using telephone survey data are presented in Tables 13-16. The estimate of migratory harvest using the access intercept HPT was 10,888 fish, while the estimate using the telephone survey HPT was 11,779 fish, a difference of 891 fish (7.5%; Table 17).

The general 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 68% in the May 1-15 time increment to 7% in the June 1-15 increment (Figure 3). Approximately 1.5% of the migratory harvest was composed of fish of prohibited sizes.

Comparison of Results to Previous Reporting Method

Using MRFSS and Volunteer Striped Bass Angler Survey data, Barker et al. (2007) estimated the total Maryland harvest from April 21 to June 15, 2007 by private recreational anglers at 84,912 fish with a migrant harvest of 26,229 fish. These estimates are approximately double the values derived from the telephone survey. Harvest estimates derived from the telephone survey and MRFSS data are presented for comparison in Table 18.

By using a license sales data frame, this study estimated effort and catch of licensed anglers only. Maryland's licensing system currently issues a Bay Sport Boat License, which allows everyone on board a licensed boat to fish recreationally without purchasing individual licenses. There is, therefore, a potentially substantial, but indeterminate, amount of license-exempt effort that could not captured by the methods described in this report. The MRFSS (2007) survey protocol of random-digit-dialing in coastal counties would account for license-exempt effort.

To determine whether license-exempt effort could account for the two-fold difference in the MRFSS estimate, angler-intercept survey results were examined to determine the weekly average number of anglers on a boat. The boat captain's fishing effort was accounted for in the telephone survey protocol because boat licenses were included in the sample frame. The fishing effort of passengers on the boat who may not have purchased a personal license was not quantified. For the purpose of calculating a theoretical upper limit of spring harvest, it was assumed that all passengers aboard a boat did not own a personal license and were exempt from the licensing requirements by virtue of the boat license. Weekly harvest estimates previously derived from the telephone survey were multiplied by the average number of anglers per boat to arrive at a figure of 107,930 fish (Table 19). This represented the theoretical upper limit of the total recreational harvest during the study period. The same time intervals, length frequencies, and migration probabilities were applied to estimate the upper limit of migratory harvest. The MRFSS-derived migratory harvest estimate of 26,229 fish fell below the theoretical upper limit of 32,536 fish derived from the telephone survey (Table 20). Calculation of the theoretical upper limits of total and migratory harvest assumed the unlikely scenario that every guest on every boat trip was not licensed, so the actual harvest was certainly less than this estimate.

This study resulted in a range of harvest estimates representing different degrees of unlicensed effort. The telephone survey-based estimate of migratory harvest (11,779 fish) was the theoretical minimum value, assuming no unlicensed angler effort. The MRFSS-based estimate of migratory harvest (26,229 fish) represented approximately 55% unlicensed angler effort. Finally, the theoretical upper limit of 32,536 migratory fish harvested represented approximately 64% unlicensed angler effort. Interview questions in the telephone survey and access-intercept creel survey will be modified in 2008 to obtain better estimates of license-exempt effort.

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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
Apr 21-27	April 28-May 4
April 28-May 4	May 5-11
May 5-11	May 12-18
May 12-18	May 19-25
May 19-25	May 26-June 1
May 26-June 1	June 2-8
June 2-8	June 9-15

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

License Type	Up to April 20	April 21-May 15	May 16-June 15	TOTAL
Short-term	235	474	1,297	2,006
Boat	32,170	5,527	7,846	45,543
Individual	19,022	15,488	27,338	61,848
Commercial	6,500			6,500
TOTAL	**57,927**	**21,489**	**36,481**	**115,897**
TOTAL (excluding short-term)	**57,692**	**21,015**	**35,184**	**113,891**
CUMULATIVE TOTAL	**57,692**	**78,707**	**113,891**	

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

Calling Week	# of Calls Made	# of Interviews	Success Rate
1	800	413	0.52
2	799	451	0.56
3	797	425	0.53
4	796	449	0.56
5	800	386	0.48
6	820	439	0.54
7	820	429	0.54
TOTAL	**5,632**	**2,992**	**0.53**

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	75	328	403	0.19
2	69	377	446	0.15
3	50	371	421	0.12
4	30	410	440	0.07
5	36	350	386	0.09
6	47	390	437	0.11
7	33	389	422	0.08

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	0.19	57,692	10,737
2	0.15	78,707	12,177
3	0.12	78,707	9,348
4	0.07	78,707	5,366
5	0.09	113,891	10,622
6	0.11	113,891	12,249
7	0.08	113,891	8,906
*8	0.08	113,891	8,906
TOTAL			**78,311**

* Telephone survey not conducted in Week 8, so Week 7 values were used

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	75	130	1.73	10,737	18,610
2	69	102	1.48	12,177	18,000
3	50	68	1.36	9,348	12,713
4	30	53	1.77	5,366	9,481
5	36	49	1.36	10,622	14,458
6	47	65	1.38	12,249	16,940
7	33	57	1.73	8,906	15,383
*8	33	57	1.73	8,906	15,383
TOTAL	**373**	**581**		**78,311**	**120,968**

* Telephone survey not conducted in Week 8, so Week 7 values were used

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

Week	Total Licensed Trips	HPT (access – intercept)	Harvest (access-intercept) # of fish	HPT (telephone survey)	Harvest (telephone survey) # of fish
1	18,610	0.30	5,493	0.21	3,934
2	18,000	0.28	4,971	0.32	5,684
3	12,713	0.19	2,466	0.29	3,726
4	9,481	0.36	3,455	0.23	2,188
5	14,458	0.25	3,579	0.54	7,831
6	16,940	0.40	6,721	0.46	7,776
7	15,383	0.38	5,875	0.35	5,398
*8	15,383	0.38	5,875	0.35	5,398
TOTAL	**120,968**		**38,435**		**41,935**

* Telephone survey not conducted in Week 8, so Week 7 values were used

Table 8. Length frequencies developed from the internet-based Volunteer Striped Bass Angler Survey used in the calculation of migratory striped bass harvest. Shaded cells represent sizes prohibited by regulation.

	Analysis Interval				
Length Group (inches)	**April 21-30**	**May 1-15**	**May 16-31**	**June 1-15**	**TOTAL**
17	0	0	0	2	2
18	0	0	20	4	24
19	0	0	26	5	31
20	0	0	16	10	26
21	0	0	11	6	17
22	0	0	17	6	23
23	0	0	15	6	21
24	0	0	15	8	23
25	0	0	8	4	12
26	1	0	8	4	13
27	0	2	10	1	13
28	3	2	3	3	11
29	36	10	4	1	51
30	37	17	5	3	62
31	34	19	3	3	59
32	48	21	2	1	72
33	55	36	3	1	95
34	82	49	7	1	139
35	43	48	4	0	95
36	2	3	5	0	10
37	1	3	2	0	6
38	0	0	0	0	0
39	0	0	0	0	0
40	0	2	0	0	2
41	2	3	1	0	6
42	17	12	1	0	30
43	4	17	0	0	21
44	3	6	0	0	9
45	3	3	0	0	6
46	1	1	0	0	2
47	1	0	0	0	1
48	0	2	0	0	2
TOTAL	**373**	**256**	**186**	**69**	**884**

Table 9. Probability-based estimate of migratory striped bass harvest from April 21-30, 2007 using harvest per trip value derived from the MD DNR access-intercept survey. Shaded cells represent fish of sizes prohibited by slot-limit regulations.

April 21-30					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
26	0.0528	0.00	15	1	14
27	0.0831	0.00	0	0	0
28	0.1283	0.01	44	6	39
29	0.1930	0.10	530	102	428
30	0.2797	0.10	545	152	392
31	0.3868	0.09	501	194	307
32	0.5061	0.13	707	358	349
33	0.6247	0.15	810	506	304
34	0.7300	0.22	1,208	882	326
35	0.8146	0.12	633	516	117
36	0.8771	0.01	29	26	4
37	0.9206	0.00	15	14	1
38	0.9496	0.00	0	0	0
39	0.9683	0.00	0	0	0
40	0.9803	0.00	0	0	0
41	0.9878	0.01	29	29	0
42	0.9924	0.05	250	248	2
43	0.9953	0.01	59	59	0
44	0.9971	0.01	44	44	0
45	1.0000	0.01	44	44	0
46	1.0000	0.00	15	15	0
47	1.0000	0.00	15	15	0
TOTAL		**1.00**	**5,493**	**3,209**	**2,284**

Table 10. Probability-based estimate of migratory striped bass harvest from May 1-15, 2007 using harvest per trip value derived from the MD DNR access-intercept survey. Shaded cells represent fish of sizes prohibited by slot-limit regulations.

May 1-15					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
27	0.0831	0.01	58	5	53
28	0.1283	0.01	58	7	51
29	0.1930	0.04	290	56	234
30	0.2797	0.07	494	138	356
31	0.3868	0.07	552	213	338
32	0.5061	0.08	610	309	301
33	0.6247	0.14	1,046	653	392
34	0.7300	0.19	1,423	1,039	384
35	0.8146	0.19	1,394	1,136	259
36	0.8771	0.01	87	76	11
37	0.9206	0.01	87	80	7
38	0.9496	0.00	0	0	0
39	0.9683	0.00	0	0	0
40	0.9803	0.01	58	57	1
41	0.9878	0.01	87	86	1
42	0.9924	0.05	349	346	3
43	0.9953	0.07	494	491	2
44	0.9971	0.02	174	174	1
45	1.0000	0.01	87	87	0
46	1.0000	0.00	29	29	0
47	1.0000	0.00	0	0	0
48	1.0000	0.01	58	58	0
TOTAL		**1.00**	**7,436**	**5,042**	**2,394**

Table 11. Probability-based estimate of migratory striped bass harvest from May 16-31, 2007 using harvest per trip value derived from the MD DNR access-intercept survey.

May 16-31					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.11	1,479	0	1,479
19		0.14	1,923	0	1,923
20		0.09	1,183	0	1,183
21		0.06	813	0	813
22		0.09	1,257	0	1,257
23		0.08	1,109	0	1,109
24		0.08	1,109	0	1,109
25		0.04	592	0	592
26	0.0528	0.04	592	31	560
27	0.0831	0.05	740	61	678
28	0.1283	0.02	222	28	193
29	0.1930	0.02	296	57	239
30	0.2797	0.03	370	103	266
31	0.3868	0.02	222	86	136
32	0.5061	0.01	148	75	73
33	0.6247	0.02	222	139	83
34	0.7300	0.04	518	378	140
35	0.8146	0.02	296	241	55
36	0.8771	0.03	370	324	45
37	0.9206	0.01	148	136	12
38	0.9496	0.00	0	0	0
39	0.9683	0.00	0	0	0
40	0.9803	0.00	0	0	0
41	0.9878	0.01	74	73	1
42	0.9924	0.01	74	73	1
TOTAL		**1.00**	**13,755**	**1,807**	**11,948**

Table 12. Probability-based estimate of migratory striped bass harvest from June 1-15, 2007 using harvest per trip value derived from the MD DNR access-intercept survey.

June 1-15					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.06	702	0	702
19		0.07	877	0	877
20		0.15	1,754	0	1,754
21		0.09	1,052	0	1,052
22		0.09	1,052	0	1,052
23		0.09	1,052	0	1,052
24		0.12	1,403	0	1,403
25		0.06	702	0	702
26	0.0528	0.06	702	37	665
27	0.0831	0.01	175	15	161
28	0.1283	0.04	526	68	459
29	0.1930	0.01	175	34	142
30	0.2797	0.04	526	147	379
31	0.3868	0.04	526	204	323
32	0.5061	0.01	175	89	87
33	0.6247	0.01	175	110	66
34	0.7300	0.01	175	128	47
TOTAL		**1.00**	**11,751**	**830**	**10,921**

Table 13. Probability-based estimate of migratory striped bass harvest from April 21-30, 2007 using harvest per trip (HPT) value derived from the QuanTech telephone survey. Shaded cells represent fish of sizes prohibited by slot-limit regulations.

April 21-30					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
26	0.0528	0.00	11	1	10
27	0.0831	0.00	0	0	0
28	0.1283	0.01	32	4	28
29	0.1930	0.10	380	73	306
30	0.2797	0.10	390	109	281
31	0.3868	0.09	359	139	220
32	0.5061	0.13	506	256	250
33	0.6247	0.15	580	362	218
34	0.7300	0.22	865	631	233
35	0.8146	0.12	454	369	84
36	0.8771	0.01	21	19	3
37	0.9206	0.00	11	10	1
38	0.9496	0.00	0	0	0
39	0.9683	0.00	0	0	0
40	0.9803	0.00	0	0	0
41	0.9878	0.01	21	21	0
42	0.9924	0.05	179	178	1
43	0.9953	0.01	42	42	0
44	0.9971	0.01	32	32	0
45	1.0000	0.01	32	32	0
46	1.0000	0.00	11	11	0
47	1.0000	0.00	11	11	0
TOTAL		**1.00**	**3,934**	**2,298**	**1,636**

Table 14. Probability-based estimate of migratory striped bass harvest from May1-15, 2007 using harvest per trip (HPT) value derived from the QuanTech telephone survey. Shaded cells represent fish of sizes prohibited by slot-limit regulations.

May 1-15					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
27	0.0831	0.01	74	6	67
28	0.1283	0.01	74	9	64
29	0.1930	0.04	368	71	297
30	0.2797	0.07	625	175	450
31	0.3868	0.07	698	270	428
32	0.5061	0.08	772	391	381
33	0.6247	0.14	1,323	827	497
34	0.7300	0.19	1,801	1,315	486
35	0.8146	0.19	1,764	1,437	327
36	0.8771	0.01	110	97	14
37	0.9206	0.01	110	102	9
38	0.9496	0.00	0	0	0
39	0.9683	0.00	0	0	0
40	0.9803	0.01	74	72	1
41	0.9878	0.01	110	109	1
42	0.9924	0.05	441	438	3
43	0.9953	0.07	625	622	3
44	0.9971	0.02	221	220	1
45	1.0000	0.01	110	110	0
46	1.0000	0.00	37	37	0
47	1.0000	0.00	0	0	0
48	1.0000	0.01	74	74	0
TOTAL		**1.00**	**9,410**	**6,380**	**3,030**

Table 15. Probability-based estimate of migratory striped bass harvest from May16-31, 2007 using harvest per trip (HPT) value derived from the QuanTech telephone survey.

May 16-31					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.11	1,913	0	1,913
19		0.14	2,487	0	2,487
20		0.09	1,531	0	1,531
21		0.06	1,052	0	1,052
22		0.09	1,626	0	1,626
23		0.08	1,435	0	1,435
24		0.08	1,435	0	1,435
25		0.04	765	0	765
26	0.0528	0.04	765	40	725
27	0.0831	0.05	957	80	877
28	0.1283	0.02	287	37	250
29	0.1930	0.02	383	74	309
30	0.2797	0.03	478	134	345
31	0.3868	0.02	287	111	176
32	0.5061	0.01	191	97	95
33	0.6247	0.02	287	179	108
34	0.7300	0.04	670	489	181
35	0.8146	0.02	383	312	71
36	0.8771	0.03	478	420	59
37	0.9206	0.01	191	176	15
38	0.9496	0.00	0	0	0
39	0.9683	0.00	0	0	0
40	0.9803	0.00	0	0	0
41	0.9878	0.01	96	95	1
42	0.9924	0.01	96	95	1
TOTAL		**1.00**	**17,795**	**2,337**	**15,458**

Table 16. Probability-based estimate of migratory striped bass harvest from June 1-15, 2007 using harvest per trip (HPT) value derived from the QuanTech telephone survey.

June 1-15					
Length Group (inches TL)	**Probability of Migration**	**Length Frequency Ratio**	**Expanded Length Frequency**	**Number of Migrants**	**Number of Residents**
18		0.06	645	0	645
19		0.07	806	0	806
20		0.15	1,611	0	1,611
21		0.09	967	0	967
22		0.09	967	0	967
23		0.09	967	0	967
24		0.12	1,289	0	1,289
25		0.06	645	0	645
26	0.0528	0.06	645	34	610
27	0.0831	0.01	161	13	148
28	0.1283	0.04	483	62	421
29	0.1930	0.01	161	31	130
30	0.2797	0.04	483	135	348
31	0.3868	0.04	483	187	296
32	0.5061	0.01	161	82	80
33	0.6247	0.01	161	101	60
34	0.7300	0.01	161	118	44
TOTAL		**1.00**	**10,795**	**763**	**10,033**

Table 17. Comparison of migratory and resident striped bass harvest estimates derived from telephone and access intercept surveys from April 21-June 15, 2007.

Interval	Harvest with Access-intercept HPT			Harvest with Telephone Survey HPT		
	Migrant	**Resident**	**TOTAL**	**Migrant**	**Resident**	**TOTAL**
Apr 21-30	3,209	2,284	5,493	2,298	1,636	3,934
May 1-15	5,042	2,394	7,436	6,380	3,030	9,410
May 16-31	1,807	11,948	13,755	2,337	15,458	17,795
June 1-15	830	10,921	11,751	763	10,033	10,796
TOTAL	**10,888**	**27,547**	**38,435**	**11,779**	**30,156**	**41,935**

Table 18. Comparison of recreational harvest estimates derived from telephone survey and MRFSS data (Barker et. al. 2007) from April 21-June 15, 2007.

Interval	Harvest Estimates from Telephone Survey			Harvest Estimates from MRFSS Data		
	Migrant	**Resident**	**TOTAL**	**Migrant**	**Resident**	**TOTAL**
Apr 21-30	2,298	1,636	3,934	8,627	6,139	14,766
May 1-15	6,380	3,030	9,410	12,622	6,211	18,833
May 16-31	2,337	15,458	17,795	3,190	21,096	24,286
June 1-15	763	10,033	10,796	1,790	25,237	27,027
TOTAL	**11,779**	**30,156**	**41,935**	**26,229**	**58,683**	**84,912**

Table 19. Total harvest derived from telephone survey and average number of anglers per boat used to estimate upper limit of harvest with angler-exempt effort.

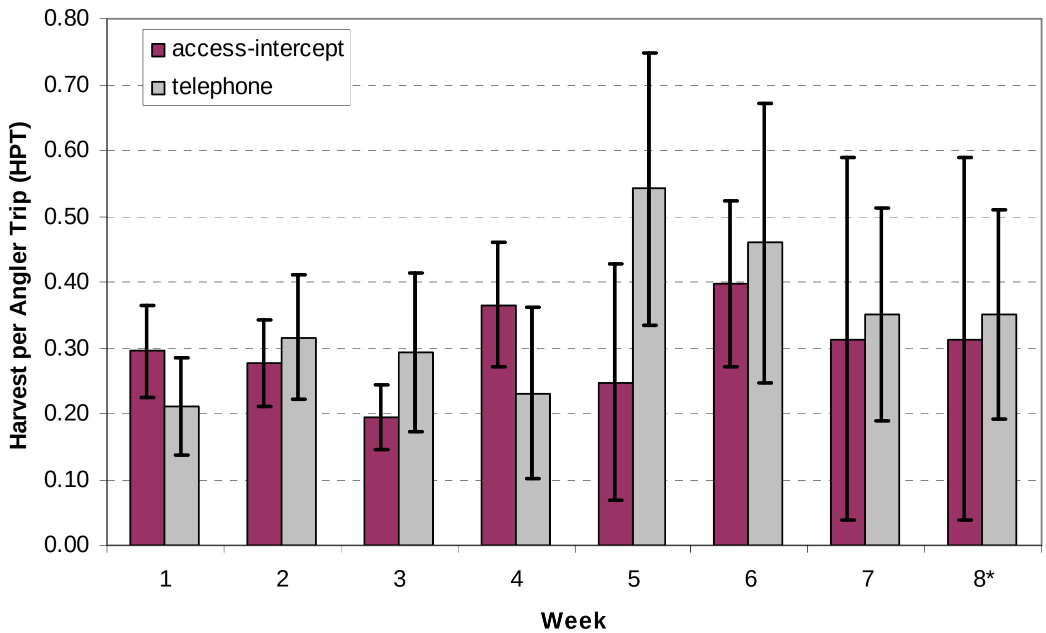
Week	Total Harvest	# of Anglers per Boat	Upper Limit of Harvest
1	3,934	2.8	11,204
2	5,684	2.5	14,395
3	3,726	2.6	9,548
4	2,188	2.6	5,776
5	7,831	2.5	19,809
6	7,776	2.7	20,660
7	5,398	2.5	13,269
*8	5,398	2.5	13,269
TOTAL	**41,935**		**107,930**

* Telephone survey not conducted in Week 8, so Week 7 values were used

Table 20. Comparison of MRFSS derived harvest estimates with theoretical upper limits of telephone survey derived estimates.

Interval	Harvest Estimates from MRFSS Data			Upper Limit of Harvest with License-Exempt Effort and Telephone Survey Data		
	Migrant	**Resident**	**TOTAL**	**Migrant**	**Resident**	**TOTAL**
Apr 21-30	8,627	6,139	14,766	14,956	10,643	25,599
May 1-15	12,622	6,211	18,833	10,390	4,934	15,324
May 16-31	3,190	21,096	24,286	5,315	35,153	40,468
June 1-15	1,790	25,237	27,027	1,875	24,664	26,539
TOTAL	**26,229**	**58,683**	**84,912**	**32,536**	**75,394**	**107,930**

Figure 1. Comparison of weekly harvest per trip (HPT) estimates derived from MD DNR access intercept survey and QuanTech telephone survey.



* Telephone survey not conducted in Week 8, so Week 7 values were used

Figure 2. Length frequencies developed from the internet-based Volunteer Striped Bass Angler Survey used in calculations of migratory striped bass harvest. Dark bars represent fish in length groups prohibited by regulation.

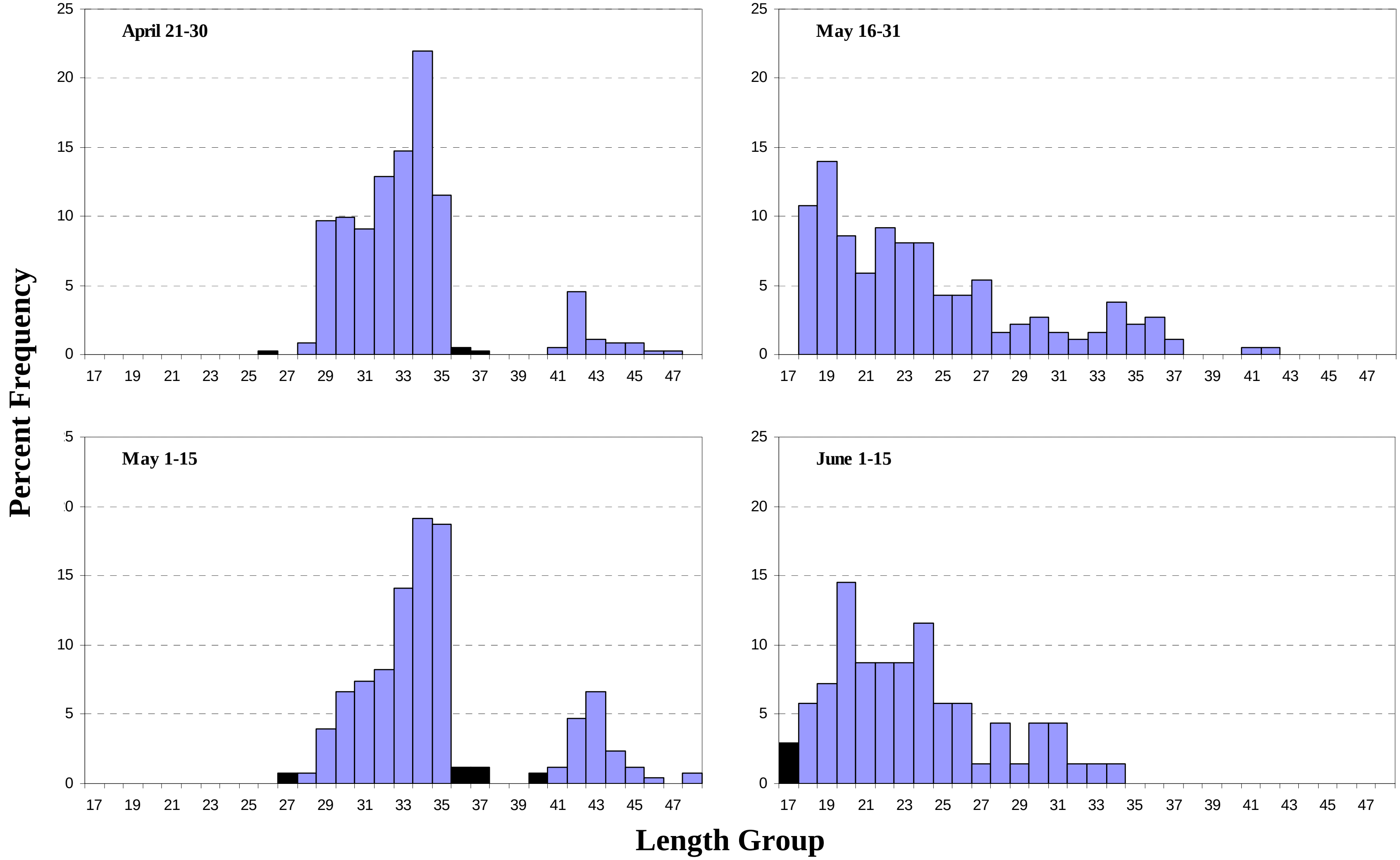
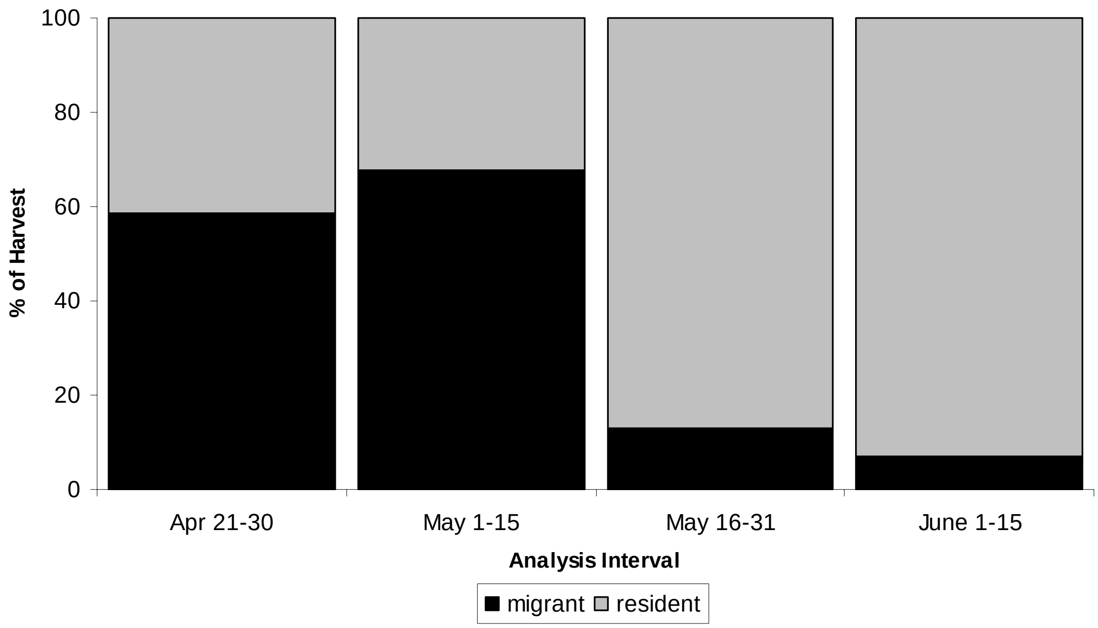


Figure 3. Estimated contribution of migratory and resident/pre-migratory striped bass harvested from April 21-June 15, 2007.



Appendix 1. Questionnaire used for 2007 telephone survey.

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

Saturday- Friday weeks defined as: April 21-27
Apr 28-May 4
May 5-11
May 12-18
May 19-25
May 26-June 1
June 2-8

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 your most recent trip, did you fish from a charter boat?

If YES, interview is over, we will focus on private effort
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?

If PRIVATE BOAT, go to 5.
If SHORE/PIER/JETTY, go to 8.

5. Did you launch the boat at a public-access boat ramp?

If YES, go to 6.
If NO, go to 8.

6. In what county is the public launch facility located?

Dropdown of counties: Anne Arundel, Baltimore, Calvert, Caroline, Cecil, Charles, Dorchester, Harford, Kent Prince Georges, Queen Anne's, Somerset, St. Mary's, Talbot, Wicomico, Unknown

7. What is the name of the public launch facility?

Dropdown of sites: Sandy Pt., Cambridge city ramps, Chesapeake Beach, Breezy Pt., Solomon's Is., Matapeake, Kent Narrows, Tilghman Is., Point Lookout, Ft. Armistead, Rock Hall, Gootee's, Other (write-in)

8. How many people were in your party?

9. 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), Other

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

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

12. How many striped bass did you personally catch and keep?

13. How many striped bass did you personally catch and release?

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 and Erik Zlokovitz

INTRODUCTION

The primary objective of Task 6 was to collect hatchery-reared, known-age striped bass from the Patuxent River. These fish were marked with coded wire tags (CWTs) as fingerlings and released in Maryland waters between 1985 and 1995. They are 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 2007. 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 reports 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.

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 annode (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 annode. 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 750 mm TL or larger were netted, measured, scanned for CWTs and sexed by expression of gonadal products. The presence of a CWT in the left cheek area was detected 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 2007, sampling was limited to three days; April 2, April 5 and April 9. Forty-eight striped bass were scanned for the presence of CWTs and none were found to be positive. A total effort of approximately two and half hours of actual shocking time was recorded on the electrofishing boats (Table 1).

The mean total length of the 48 striped bass measured was 925 mm (minimum=702 mm, maximum=1225 mm, median=913 mm). Of the 52 fish encountered, 32 (62%) were females.

Although no hatchery fish were encountered in 2007, 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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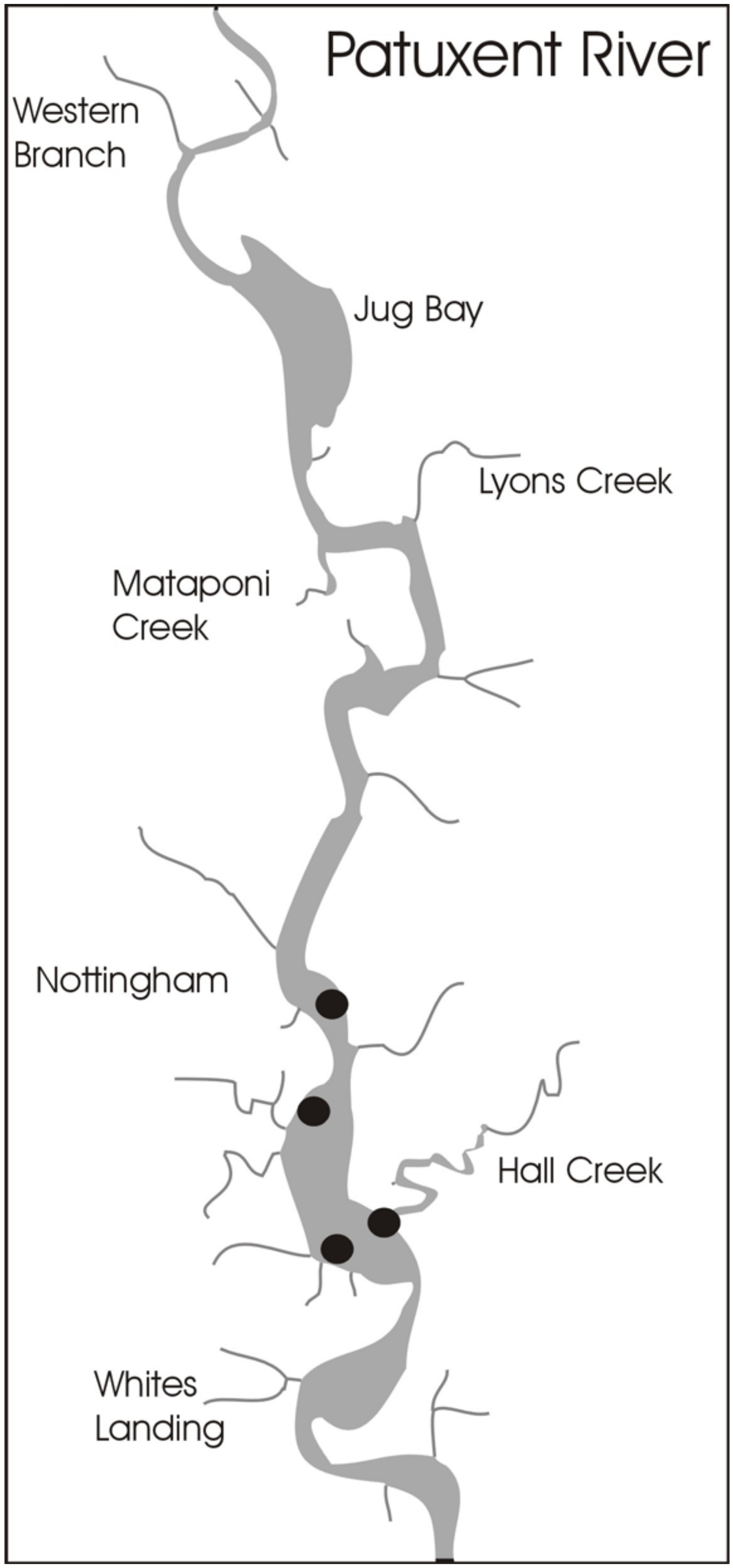
LIST OF TABLES

LIST OF FIGURES

Table 1. Electrofishing survey targeting hatchery-reared striped bass on the Patuxent River, 2007. 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)
4/02/07	26	0	2439	934	69	31	15.5
4/05/07	1	0	2700	1048	20	80	14.0
4/09/07	21	0	4279	907	62	38	8.3

Figure 1. Location of Patuxent River electrofishing sites, April, 2007.



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.

Survey information was used to formulate management plans for thirteen finfish species as well as providing evidence of compliance with state and federal regulations. In addition, 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. 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, 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.

Staff attended Mid-Atlantic Region and Southeast Region Stock Assessment meetings to discuss American shad and river herring stock status along the Atlantic coast.

Atlantic croaker:

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

Atlantic sturgeon:

ASMFC Technical Committee representative attended the annual Atlantic sturgeon Technical Committee meetings and prepared the ASMFC Annual American sturgeon Status Compliance Report for Maryland.

Bluefish:

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

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

Red Drum:

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

Weakfish:

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

Striped Bass:

Project staff served as Maryland alternate representatives to the ASMFC Striped Bass Scientific and Statistical Committee, the Striped Bass Stock Assessment Subcommittee, and produced Maryland's Annual Striped Bass Status Compliance Report.

Project staff served on the ASMFC Striped Bass Tagging Working Group, 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.

Striped Bass Data Sharing and Web Page Development

To augment data sharing efforts, project staff in 2002 developed a web page within the MD DNR web site presenting historic Juvenile Striped Bass Survey (Job 3, Task 3) results. This effort has enabled the public to access striped bass 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 January to December 2007 are presented in Table 1. Web page visits in October and November were unusually high because the 2007 results were advertised with a link from the main Fisheries Service page. Activity reports were not available in some months because of corrupted computer files. 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, January to December 2007.

Month	Visits
January 2007	3,498
February	3,474
March	3,576
April	3,409
May	N/A
June	N/A
July	3,692
August	N/A
September	2,455
October	23,979
November	16,032
December 2007	N/A

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, 2006 through October 31, 2007) 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, directed Chesapeake Bay fishing mortality (F) rate study estimates, 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.

- Robyn Byers, KCI Technologies, Inc.
Provision of historic Wye River seine survey 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. Lora Clarke, Stony Brooke University.
Provision of striped bass juvenile survey data.

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

- National Marine Fisheries Service, NOAA, Chesapeake Bay Program Staff.
Provision of results from fishery dependent monitoring programs, striped bass juvenile index data, and Atlantic menhaden juvenile survey data.

-Dr. Gary Nelsen, NMFS-NOAA.
Striped bass 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 (5) staff with current striped bass anomaly data, striped bass juvenile index, American shad juvenile index data, recreational and commercial landings data, spring trophy season data and biological samples.

-The Interjurisdictional Project also provided related biological information and reports to forty one (41) additional scientists, students and concerned stakeholders.

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

STATE: Maryland

PROJECT NO.: F-61-R-3

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish / Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2006 through October 31, 2007

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.

Yellow perch in Maryland tidal waters support both commercial and recreational fisheries. Upper Chesapeake Bay yellow perch population dynamics were described with a statistical catch-at-age model for the time period 1998 – 2006. Yellow perch abundance (age 3 and older) peaked in 1999 at 1.64 million fish before declining to 712,000 fish in 2002. The yellow perch population rose during 2002 – 2006 with abundance in 2006 estimated at 1.55 million fish. Estimated instantaneous fishing mortality ranged from 0.25 to 0.48 during 1998 – 2001 before rising to 1.01 in 2002. Mortality decreased steadily from 1.01 in 2002 to 0.11 in 2006. Based on biological reference points, overfishing occurred in 2002 and possibly 2003, but overfishing did not occur 1998 – 2001 or 2004 – 2006.

Yellow perch population dynamics in the Choptank River were described by analyzing

relative abundance trends from agency fyke net surveys, (1988 – 2007). Analysis indicated a logarithmic increase of approximately 800% during this time period as the population doubled approximately every 5 - 6 years. Low mortality rates over the most recent years were also noted. No violations of F targets or limits were suspected.

Adult American shad indices in the Susquehanna River, including fish lift GM, hook and line GM and relative population estimates have continued to trend downward during the last six years. American shad relative abundance in the Nanticoke River also remained low. Age structures in both systems were unchanged indicating nonselective mortality. The Upper Chesapeake Bay American shad juvenile index for 2007 indicated near record spawning success and was likely related to ideal flow conditions. The low abundance of adult American shad, a coastwide phenomenon, indicates increased mortality on ocean migrant fish possibly through commercial exploitation, increased predation, or a combination of both parameters.

Adult hickory shad relative abundance indices in Deer Creek remained stable while those in the Nanticoke River decreased. Juvenile sampling caught few hickory shad due primarily to gear aversion.

Adult alewife herring repeat spawning indices and GM CPUEs in the Nanticoke River have shown no trend, but remain very low. Blueback herring repeat spawning indices and GM CPUEs have decreased significantly since 1989. Fishing mortality rates, age structure and sex ratios appeared stable for both species during the time series. In general, adult alewife and blueback herring stocks and corresponding juvenile indices for both species have been low for most of the years in the 19 year time series.

Weakfish have experienced a sharp decline in abundance coast wide. Recreational catch estimates by the NMFS for Maryland fell steadily from 475,348 fish in 2000 to 493 fish in 2006. Maryland's commercial weakfish harvest rose slightly to 32,417 pounds in 2006, but was still the third lowest catch on record. The 2007 mean length for weakfish from pound net sampling was 275 mm TL, the second smallest of the time series. The 2007 length frequency distribution and RSD analysis indicate that only smaller weakfish were available in Maryland waters. Fish aged from 2006 pound net sampling were all 4 years of age or younger.

The mean length of summer flounder collected from pound nets was 341 mm TL in 2007, near average for the 15 time series. Relative stock densities in 2007 indicated a shift up from the RSD stock category to the quality category compared 2006. Both commercial and recreational harvest of summer flounder decreased in 2006. The NMFS 2006 coast wide stock assessment concluded that summer flounder stocks were not overfished, but overfishing was occurring.

Mean length of bluefish sampled from pound nets in 2007 was 318 mm TL, 6th highest during the 1993-2007 time period. Length distribution and RSD analysis indicated a modest

shift toward larger bluefish in 2007. Both recreational and commercial bluefish harvest's in Maryland were below average in 2006. The latest coast wide stock assessment indicated bluefish were not overfished and overfishing was not occurring.

The mean length of Atlantic croaker examined from pound net sampling in 2007 was 307 mm TL, the fifth largest mean length of the 15-year time series. RSD analysis for Atlantic croaker indicated a continued dominance of $RSD_{preferred}$ and $RSD_{memorable}$ fish and a time series high of RSD_{trophy} fish. Fish aged from 2006 pound net sampling ranged from 1 – 13 years of age. Maryland Atlantic croaker total commercial harvest for 2006 decreased to 344,318 pounds, while the corresponding recreational harvest estimate of 834,894 fish was similar to the previous two years.

Spot length frequency distributions in 2007 were somewhat truncated, but the mean length remained near the average of the time series. Juvenile indexes have been lower than the long-term average in recent years. Commercial harvest declined in 2006, while recreational catch estimates remained near the average. The percent of spot over 254 mm TL in the pound net samples was one percent, lower than the previous 4 years.

Resident / premigratory striped bass present in the Chesapeake Bay during the summer – fall 2006 pound net and hook and line commercial fisheries ranged from 1 to 14 years of age. Three year old striped bass from the 2003 year-class and 5 year old fish from the 2001 year-class dominated samples taken from pound nets, contributing 32% of the total sample in 2006. Check station sampling determined that five year old striped bass from the dominant 2001 year-class comprised 36% of the commercial hook & line harvest and 37% of the pound net harvest.

The 2006-2007 commercial drift gill net fishery harvest was comprised primarily of four, five and 6 year old striped bass from the 2001, 2002 and 2003 year-classes. Age groups 4, 5 and 6 contributed approximately 78% of the drift gill net harvest while age 7 to 14 year-old fish contributed 22%. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from 4 to 14 (1993 – 2003 year classes)

The spring, 2007 spawning stock survey indicated that there were 16 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 19 years old. Age 4 male striped bass from the 2003 year-class were the most abundant component of the male striped bass spawning stock. Age 11 (1996 year-class) and age 10 (1997 year-class) females were the major contributors to 2007 total female abundance. Age 8 and older females comprised 93% of the female spawning stock in 2007, a 9% increase from 2006.

The 2007 striped bass juvenile index, a measure of striped bass spawning success in Chesapeake Bay, was 13.4, slightly above the 54-year average of 12.0. During beach seine

sampling, 1,768 young-of-year (YOY) striped bass were collected. The Upper Bay and the Nanticoke River both produced above-average numbers of YOY striped bass. Reproduction in the Potomac and Choptank rivers was below average. The healthy level of reproduction in 2007 follows a low index in 2006. Striped bass populations are known for this variable spawning success in which several years of average reproduction are interspersed with occasional large and small year-classes.

During the 2007 recreational trophy season, biologists intercepted 542 fishing trips, interviewed 809 anglers, and examined a total of 301 striped bass. The average total length of striped bass sampled was 861 mm TL (33.8 inches), and the average weight was 6.8 kg (14.9 lbs). Most fish sampled from the trophy fishery were between seven and eleven years old. The 2000 year-class (7 years old) was the most frequently observed year-class, constituting 21% of the sampled harvest. Average catch rate based on angler interviews was 0.5 fish per hour, a drop from the catch rate of 2.6 fish per hour in 2006. New 2007 size limits resulted in considerable change in length frequencies, catch rates, and age structure of the trophy season harvest.

A total of 1,142 striped bass were tagged and released for growth and mortality studies during the spring, 2006 sampling season. Of this sample, 772 were tagged with USFWS internal anchor tags. A total of 370 striped bass were sampled and tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise. A high reward tag (HRT) study was also incorporated into the spring fishery-independent spawning stock study in order to obtain a current estimate of reporting rate. Results were not yet available for this report. Specialized coded wire tag (CWT) sampling was continued on the Patuxent River during 2007. A total of 48 striped bass were scanned for the presence of CWT's , but none were found to be CWT positive.

During 2007, L_p (proportion of estuarine tows containing larval yellow perch) fell within the historic range in the Bush, Corsica and Nanticoke Rivers, and Langford Creek, a tributary to the Chester River. The Severn River estimate was below the historic range. All four estimates of L_p from the Severn River (17% Impervious Surface – IS) during 1998-2007 were less than the historic minimum of $L_p = 0.4$ while only 5 of 16 estimates from remaining systems (IS < 13%) were below $L_p = 0.4$.

Based on presence-absence comparisons with the Bush River stream surveys conducted during the 1970's and recent surveys from the less developed Aberdeen Proving Ground watersheds, it appears that white perch and yellow perch use of historical stream spawning habitat has diminished. Yellow perch postlarvae were quite abundant in the Bush River estuary during the past two years, indicating that loss of stream spawning habitat may not be critical to the population. However, reduced stream spawning could be critical to recreational anglers because this is where and when yellow perch are accessible to the traditional shore-based fishery. Herring/shad presence in streams did not indicate marked changes in spawning activity with watershed development. Viability of eggs and larvae was unknown, but their presence might have represented losses to the population if habitat conditions have become detrimental and spawning behavior has not changed.

Impervious surface (IS) had a significant, positive influence on the odds of juvenile and adult white perch, juvenile spot and striped bass, and all stages of blue crabs (combined) being absent from trawl samples taken in mid-channel bottom habitat. This likely reflected the strong negative relationship between average DO in the bottom habitat and IS in brackish systems, and the strong, positive asymptotic response of presence-absence of these species with dissolved oxygen.

Plots of P_{wpj} or P_{wpa} (proportion of trawls with juvenile or ages 1+ white perch, respectively) against IS by salinity category (fresh or brackish) in Potomac River tributaries suggests that IS has a negative impact, but the impact appears more gradual in fresh-tidal areas than brackish. The difference in IS thresholds between fresh-tidal and brackish tributaries reflect substantial differences in dissolved oxygen (DO) levels in bottom waters. During 2003 – 2007, mean bottom DO in fresh-tidal tributaries (IS $<$ 15%) averaged at saturation or slightly above saturation, regardless of IS. In brackish tributaries, however, bottom DO became increasingly depleted as IS increased and averaged in the hypoxic range past IS $\geq$15%.

APPROVAL

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Maryland Fisheries Service
Maryland Department of Natural Resources

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ACKNOWLEDGEMENTS

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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

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PROJECT NO. 3
JOB NO. 1

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

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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 is 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.

The development of ISRPs involves determining functional relationships between a watershed's area covered in impervious cover (or IS; paved surfaces, buildings, and compacted soils) and habitat quality (water quality, physical structure, etc) or a species response (habitat occupation, abundance, distribution, mortality, recruitment success, growth, etc). Exploring these relationships for a suite of focal species was an important functional component of Project 3.

Land is converted to IS as human population grows and by most measures, human impacts have grown faster than the population (Beach 2002). A variety of studies have documented deterioration of freshwater aquatic ecosystems as IS occupied more than 10% of watershed area (Cappiella and Brown 2001; Beach 2002). Impervious surface increases runoff volume and intensity in streams, leading to physical instability, and increased erosion and sedimentation. This runoff, warmer than water draining forests or other porous lands, becomes a source of thermal pollution. Impervious surface runoff transports a wide variety of excess nutrients that contribute to algae blooms, hypoxia, and anoxia (Beach 2002). The Center for Watershed Protection (http://www.cwp.org/) has developed an IS cover model that expresses the relationship of fluvial stream quality to IS. This model supports the concept of a "10% rule" and further describes watersheds with 11-25% IS as impacted and those with more than 25% as unable to support freshwater aquatic life (Cappiella and Brown 2001). This rule seems to apply to tidal waters where at least some salinity is present as well (Holland et al. 2004; McGinty et al. 2006; Uphoff et al. 2007). Measurable adverse physical and chemical changes in tidal creek ecosystems were described by Holland et al. (2004) when IS exceeded 10-20% and living resources responded negatively when IS exceeded 20-30%. A strong relationship between IS and dissolved oxygen (DO) was found during 2003-2005 in brackish Chesapeake Bay tributaries that were sampled by this project (McGinty et al. 2006).

Dissolved oxygen is an ideal habitat variable to study because fish require well-oxygenated water, it provides insight into both the metabolic and pollution status of a waterbody (Limburg and Schmidt 1990), and is easily measured in the field. Bell and Eggleston (2004) found that several species of fish and blue crabs in a trawl survey strongly avoided hypoxic conditions, particularly chronic hypoxia, in the brackish Neuse River Estuary, North Carolina. Hypoxia also can disrupt endocrine function associated with successful reproduction (Rudolph *et al.* 2003). Habitat issues associated with impervious surface are not limited to just DO and it is recognized that development *per se*, urbanization and industrialization, contribute significantly to contaminant loads, eutrophication, and physical degradation of coastal areas (Pearce 1991; Beach 2002). Disruption of reproduction in fish could be caused by anthropogenic chemicals (Colborn and Thayer 2000) and alteration of hyrdrologic features in streams needed for anadromous fish spawning habitat (Konrad and Booth 2005). In Maryland's portion of Chesapeake Bay, excessive concentrations of PCBs and organochlorine pesticides have lead to consumption advisories for organochlorine compounds in white perch in most suburbanized estuaries (Maryland Department of Environment, www.mde.state.md.us). These advisories reflect a strong relationship of contamination in Bay white perch with impervious surface (King et al. 2004). Experiments with Atlantic croaker indicated maternal transfer of PCBs to eggs and larvae would result in reduced growth rates and impair behaviors associated with avoidance of predators (McCarthy et al. 2003). Westin et al. (1985) observed slightly better survival of striped bass larvae from eggs with lower concentrations of organochlorine compounds (including PCBs).

Anadromous fish populations in the Hudson River (Limburg and Schmidt 1990) and estuarine fish communities in Chesapeake Bay (Carmichael et al. 1992) appear to respond to development negatively, although their responses have been related to urban land-use in general rather than specifically to IS. Strong, negative relationships between IS and freshwater biotic communities and the threshold concept have been supported in brackish sub-estuaries of Chesapeake Bay (McGinty et al. 2006; Uphoff et al. 2007). However, large volumes of out-of-basin water (such as Susquehanna River water in high flow years) entering the Bay's sub-estuaries may serve as a source of relatively clean water that dilutes the effect of upstream watershed inputs and may push IS thresholds higher.

IS is increasingly used as an indicator tool by local planning and zoning agencies because of compelling scientific evidence of its effect in freshwater systems and because it is a critical input variable in many water quality and quantity models (Arnold and Gibbons 1996; Cappiella and Brown 2001). Chesapeake Bay watershed IS targets and thresholds would be useful for county and state growth planning, watershed-based citizen groups, and interstate finfish habitat management, as well as Maryland Fisheries Service needs. Defining the impact of IS on specific finfish populations would provide managers a better understanding of how degraded habitats influence fish production and allow them to account for these effects in managing individual fisheries.

Project activities in 2007 included continued evaluation of data collected in previous years (2003-2005), spring yellow perch larval presence-absence sampling, spring stream anadromous fish icthyoplankton collections, and summer sampling of estuarine tributary fish communities. Larval sampling was added to further understanding of the effects of habitat degradation and loss on fish populations. Larvae have been found to be extremely sensitive to anthropogenic inputs to the environment (Bengtston et al. 1993). These efforts were collectively aimed at defining the impact of IS on target fish species populations and habitats.

METHODS

Based on recommendations in Uphoff et al. (2007), the Northeast River was substituted for the Bohemia River, while the Wye River was sampled instead of the Blackwater River and Fishing Bay.

Impervious Surface Estimates

Table 1 summarizes percent IS cover, non-water watershed area, and tidal water surface area estimates for watersheds sampled in 2007. Estimates for 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). IS estimated for the Tred Avon River was from King et al. (2004) because an estimate for this watershed was not available elsewhere. Remaining watershed estimates were based on Maryland Department of Planning (or MDDOP 1994a) data available from http://mddnr.chesapeakebay.net/wsprofiles/surf/prof/prof.html.

Surface area of water, 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 downriver-most points on opposite shores.

General land-use for all watersheds (i.e., percent urban, forest, etc.; all non-water acreages) was based on MDDOP (1994a). Urban land-use consisted of low through high density residential and industrial designations.

Eight watersheds were sampled in 2007, two in the upper Bay, four mid-Bay and two in the Potomac drainage (Figure 1).

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 IS (12.8%) of all rivers sampled this year (Table 1). It is predominately forested (48% of the watershed) with urban areas comprising 24% of the watershed, agriculture, 22% and wetlands, 6% (Figure 2).

The Northeast River is a moderately urbanized watershed in Cecil County, Maryland. It covers 40,377 acres, has 3,908 acres of tidal water, and has 6.1% impervious cover (Table 1). It is 15.9% urban, 39.1% agriculture, 45.2% forest 0.1% wetland and 0.4% barren (Figure 3).

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 IS (Figure 4; Table 1). 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 is available at http://www.mde.state.md.us/ResearchCenter/Publications/General/eMDE/vol2no3/corsica.asp.

Langford Creek, another tributary of the Chester River, is also located in on Maryland's Eastern Shore. Its confluence with the Chester River lies directly across from the mouth of the Corsica River (Figure 5). Its 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 1). Agriculture occupies 69% of the watershed, forests occupy 26%, urban areas comprised 4%, and wetlands, 1%.

The Tred Avon River is a tributary of the Choptank River on the Eastern Shore (Figure 6). Its watershed comprises 23,518 acres and tidal waters occupy 4,338 acres. Urban land comprises 22% of the watershed, agriculture 39%, forest 38%, and wetlands less than 1%. IS covers 5.6% of the watershed (Table 1).

The Wye River, on Maryland's Eastern Shore, drains land in both Talbot and Queen Anne's County. The watershed covers 50,460 acres, tidal water covers 6,142 acres, and 1.2% of the watershed is IS (Table 1). It is dominated by agriculture which comprises 69.9% of the watershed. Forest covers 25.9%, urban land 3.9%, wetlands 0.7 and barren land 0.1% (Figure 7).

<u>Potomac Sampling Areas</u>

Two tidal-fresh tributaries of the Potomac River were sampled in 2007. Mattawoman Creek's watershed is 60,300 acres with 1,799 acres of tidal water and 8.5% IS (Table 1). Forest occupies 63% of the watershed, agriculture covers 14%, urban areas 22%, and wetlands, 1 % (Figure 8). Mattawoman Creek has extensive military holdings within the watershed. The fluvial and tidal portion of Mattawoman Creek 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.

Piscataway Creek is located upriver of Mattawoman Creek and its 43,579 acre watershed (916 acres of tidal water) has 14.9% IS (Table 1). Almost half (49%) of its watershed is forested and another third is urbanized (34%). Agricultural covers 16% and wetlands, 1% (Figure 9).

General Statistical Considerations: Presence-Absence Sampling

Presence-absence was used to answer important management questions because it reduced expensive sample processing, was robust to errors and biases in sampling, and reduced statistical concerns about contagious distributions and high frequency of zeros; Green 1979; Mangel and Smith 1990; Uphoff 1997). Presence-absence was calculated as the proportion of tows 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). Interpretation of absence can pose problems (Green 1979) so consequently, sampling and analyses were generally designed to confine presence-absence to areas and times where species and life stages in question had been documented.

Estuarine Yellow Perch Larval Presence-Absence Sampling

Yellow perch larval presence-absence sampling was conducted in the upper tidal reaches of the Nanticoke, Bush, Corsica, and Severn rivers and Langford Creek during late March through April. 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).

A conical plankton net towed from a boat collected larvae at 10 sites per system on 2-3 days each week in the upper portion of the estuaries sampled (Figure 10). Nets were 0.5-m in diameter, 1.0-m long, and had 0.5 mm mesh. Plankton nets were towed for two minutes at about 2.8 km per hour. Larval sampling occurred during late March through mid-May, 2007.

Sites on the Bush, Corsica, and Severn rivers and Langford Creek were sampled with little spacing between tows because larval nurseries were small. Extent of area to be sampled was determined from bounds of larval presence in surveys conducted during the 1970s and 1980s (O'Dell 1987).

The Nanticoke River was divided into 18 1.61-km (1-mile) segments that spanned the striped bass spawning ground where historic surveys were conducted (described below; Uphoff 1997; Uphoff et al. 2005). The striped bass spawning area on the mainstem Nanticoke River was divided into upriver, midriver, and lower river subareas containing 5-6 segments and Marshyhope Creek, a tributary that contained 2 additional segments (Uphoff 1997). Maps detailing segment locations can be found in Uphoff (1997). Ten distinct segments were sampled with a single tow once a trip. Sample trips were made two times per week. Sampling segments were selected randomly in proportion to subarea size. Tows were not made at a site when salinity exceeded 2 $^{o}/_{oo}$; a substitution was made by randomly choosing a site upstream. Nanticoke River sampling was piggybacked onto multispecies sampling conducted by another Survey Project (Project 2, Job 1).

Each sample was emptied into a glass jar and checked for larvae. If a jar contained enough detritus to obscure examination, it was emptied into a pan with a dark background and observed through a magnifying lens. Detritus was moved with a probe or forceps to free larvae for observation. On a few occasions, detritus loads or wave action prevented thorough examination, so 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 in past Choptank and Nanticoke River collections and found that starting dates during the first or early in the second week of April were typical and end dates occurred during the last week of April through the first week of May. Sampling during 2007 was designed to begin by the first full week of April and ended after larvae were absent (or nearly so) for two consecutive sampling rounds. In years where larvae disappeared quickly, sampling rounds into the third week of April were included 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 2007 in the tidal Bush, Corsica, and Severn rivers and Langford Creek was compared to a record of L_p developed from collections in the tidal Nanticoke (1965-1971 and 2004-2006) and Choptank rivers (1986-1990 and 1998-2003), Mattawoman Creek (1990), and Severn River (2004-2006).

Volunteers from the Arlington Echo Outdoor Education Center conducted Severn River collections in 2007 based on the sampling design described above. These volunteers were trained in sampling and identification by project personnel and were accompanied by staff biologists on several occasions.

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

Choptank River and Nanticoke River collections made prior to 1991 were considered an historic reference and their mean L_p (0.66) was used as an estimate of central tendency. Nine of 11 reference estimates of L_p fell between 0.4-0.8 and this was used as the range of the “typical” minimum and maximum. The 95% CI’s of L_p of rivers sampled during 2007 were compared to the mean and “typical” range of historic values. Risk of L_p during 2006 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 1998-2007 was linearly influenced by IS. Estimates were available for the Choptank River (1998-2004: IS = 2.1%), Nanticoke River (2004-2007; IS = 1.2%), Severn River (2004-2007; IS = 17.0%), Bush River (2006-2007; IS = 12.8%), Corsica River (2006-2007; IS = 4.0%), and Langford Creek (2007; IS = 0.9%).

Means and standard errors (SE) of salinity measurements (dates and sites used to calculate L_p) were estimated for each system. Uphoff et al. (2007) compared salinity (‰) and temperature data (°C) during the larval stage to requirements of yellow perch larvae (temperatures > 20 °C and salinity > 2 $^{o}/_{oo}$ were considered detrimental; Piavis 1991) to determine the extent and duration of suitable habitat in the past. There has been little indication that temperature has been a major factor influencing 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). Historic mean salinities relevant to time periods and stations used to estimate L_p were calculated for years and systems where these data were readily available. These mean salinities were plotted and linearly regressed against L_p to examine this relationship and to evaluate whether salinity > 2 $^{o}/_{oo}$ was detrimental. Data were available for Choptank River collections during 1998, 2000, and 2001, Nanticoke River during 2006-2007, Severn River during 2004-2007, Bush and Corsica rivers during 2006-2007, and Langford Creek during 2007.

Bush River Stream Ichthyoplankton/Adult Sampling

Sampling in the Bush River streams was continued in 2007 with modifications to the original sampling design. The initial effort was designed to revisit stations sampled in 1972 by O'Dell et al, (1975) to determine if stream spawning by white perch, yellow perch, and herring species had changed. This initial effort showed an apparent decline in use of habitat in the streams of the Bush River (McGinty et al, 2006). The hypothesis was proposed that increased urbanization contributed to this loss of habitat, because the Bush River watershed had increased IS between 1972 (8.7%) and 2000 (12.8%). In 2006, the hypothesis was tested by expanding sampling to the adjacent watershed on a military installation (Aberdeen Proving Grounds, APG) where development had remained unchanged over the same thirty-year period (IS = 3.5%;). Sites on APG had significantly higher presence of migratory fish than sites in the Bush River (Uphoff et al, 2007). However, one weakness in this comparison was that sites on APG had to be located near head of tide or in tidal areas, because of restricted access. Bush River sites were usually located in non-tidal streams.

Three additional stations in tidal waters were sampled in the Bush River in 2007, to examine if differences in locations could bias comparisons. A study conducted in the Severn River that examined yellow perch responses to habitat (Uphoff et al, 2005) suggested adults used downstream tidal habitat when upstream fluvial habitats were compromised. APG sites could not be sampled in 2007 because of base restrictions. A total of fourteen sites were sampled in the Bush River (Figure 11). Nine of these sites were in freshwater, five in tidally influenced areas. Egg and larval samples were collected weekly at each station, when feasible. Adults were sampled using wire traps at nine sampling stations.

Ichthyoplankton samples were collected from March through May. Samples were evaluated to determine presence of target anadromous species (white perch, yellow perch, alewife and blueback herring). Citizen volunteers were trained to collect samples with oversight by a volunteer coordinator provided by Harford County. Samples were collected using stream drift nets made of 360-micron mesh, attached to a square frame with a 300 X 460 mm opening. The frame was connected to a wood handle so that the net could be held in place and a threaded collar was placed on the end of the net where a mason jar was connected to collect the sample. Nets were placed in the stream with the opening facing upstream for five minutes. The nets were then retrieved and rinsed in the stream, by repeatedly dipping the lower part of the net and splashing water on the outside of the net to avoid sample contamination. The jar was then removed from the net. A sample label describing site, date, time and collectors was placed in the jar. The jar was sealed and placed in a cooler for transport. After a team finished sampling for the day, they would turn their samples over to the coordinator, who would then fix 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. 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. Samples were 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 removed and identified under a microscope. Eggs and larvae were retained in small vials and fixed with formaldehyde for verification. Ten percent of the samples were sorted twice in order to assess sorting efficiency.

Wire fish traps were set in six streams where anadromous fish were not documented in 2005, but were present in 1973 (O'Dell et al. 1975). Traps were set once a week in 4 fluvial and 2 tidal tributaries of the Bush River from March 20 through May 15, 2007.

Traps were constructed of 25.4 mm mesh chicken wire formed into cylinders 1.22 m long and 0.46 m wide. One end was crimped and secured with heavy single strand wire leaving an approximately 102 mm opening to retrieve any captured fish. A small opening was secured shut with a hook also constructed of single strand wire. The other end of the wire cylinder was left open. A 25.4 mm wire mesh funnel was fitted into the open end and tapered from 457 mm at the mouth to 102 mm over a 0.61m distance.

Traps were deployed in streams with the open end facing downstream in areas of constricted flow so that migrating fish would be likely to encounter them. Traps soaked for 24 hours. They were not anchored, but were secured to bank structures by a heavy cord to prevent loss during high flow from storm events. The traps were not baited.

After 24 hours the traps were retrieved and any fish captured were identified. Anadromous fish were measured and sex was determined. Water temperature and conductivity were measured at each site at the time of retrieval

Presence of white perch, yellow perch and herring/shad as eggs, larvae, or adults 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 stations with eggs, larvae, or adults of the target species present and their 95% CI's were compared to historical presence to determine if there has been a change in habitat use. The additional tidal sites were examined for presence of any life stage to determine if target species were using downstream habitat for spawning.

Summer Estuarine Seining and Trawling

During 2007, most of the systems sampled in 2006 were revisited. Sampling in the Bohemia River was discontinued, because of concerns that salinity intrusion (probably from the Chesapeake and Delaware Canal) was altering the fish community meant to represent fresh-tidal habitat. The Northeast River was substituted. Sampling in Fishing Bay was discontinued, and the Wye River on the Eastern Shore substituted in its place. It was felt that these changes would 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). Fresh-tidal tributaries (2‰ or less salinity) sampled in 2007 were Mattawoman Creek, Piscataway Creek, Bush River, and Northeast River (Figure 1). IS was estimated to cover from 1-16% of these watersheds. The Corsica River, Tred Avon River, Langford Creek, and Wye River were brackish water (greater than 2‰) tributaries located on the Eastern Shore that were estimated to have less than 6% IS (Table 1). The

Corsica River, Tred Avon River, and Wye River are located near towns that are undergoing development (Centerville, Easton, and Wye Mills, respectively). Langford Creek was selected as a control system (particulary for the Corscia River) because it is not located near towns that are the foci of development on the Eastern Shore.

Four evenly spaced sample sites were located in the upper two-thirds of each tributary, except for Piscataway Creek, which contained three sites. Sites were not located near the subestuary's mouth to reduce influence of mainstem Bay or Potomac River waters on measurements of watershed water quality.

Each fixed site was sampled once a visit and there were two visits each month during July-September. All sites on one river were sampled on the same day. Sites were numbered from upstream (site 1) to downstream. The crew leader flipped a coin each day to determine whether to start upstream or downstream. This coin-flip somewhat randomized potential effects of location and time of day on catches and dissolved oxygen concentrations. However, sites located in the middle would likely not be influenced by the random start location as much as sites on the extremes because of the bus-route nature of the sampling design. If certain sites needed to be sampled on a given tide then the crew leader deviated from the sample route to accommodate this need. Trawl sites were generally in the channel, adjacent to seine sites. At some sites, seine hauls could not be made because of permanent obstructions, thick aquatic vegetation, 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 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 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. This allowed the same general area to be trawled regardless of tide direction. A single tow was made for six minutes at 3.2 km/hr (2.0 miles/hr) at a 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 had 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 sweeo. 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 of water 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 plants 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 2) and reported as deviations from a target or limit (McGinty et al. 2006). These were examined by watershed to determine habitat suitability for target species. Percent of violations of these requirements were calculated by river. Water quality data were plotted in box and whisker plots by watershed.

Presence-absence was used as an index of relative abundance for each target species in nearshore (seine) or bottom waters (trawl) because their catch distributions were not normally distributed, nor could normality be induced by transformation

(McGinty et al. 2006). Counts pooled across species (total number of target or all species) were normally distributed after $\log_e$-transformation (McGinty et al. 2006). Comparisons were made within and not across habitats represented by bottom trawls and seines.

Logistic Regression of Absence in 2003 – 2005 Collections from Brackish Tributaries

The influence of IS and several other variables on presence of target species in individual bottom tows or seine hauls was explored with logistic regression. Other variables considered were mean water temperature and salinity (Table 3), distance from major spawning or nursery area (for white perch ages 1+ and YOY, and striped bass YOY; Table 4) or distance from the mouth of Chesapeake Bay (spot YOY and all blue crab life stages; Table 4), and relative regional abundance of each target species life stage (Table 5). Dissolved oxygen was not featured as a parameter in logistic regression analyses with IS because of their strong association (McGinty et al. 2006).

Logistic regression analysis was confined to brackish tributaries (mean salinity 4.2 - 11.4 ‰) and species with unambiguous interpretation of absence (Wright 1998). To minimize ambiguity in interpreting absence (Green 1979), The chance that each of our species would occur at least once at a given site during 2003-2005 was determined. Seine and trawl catches at each site, and calculated percentage of sites where each species was encountered once or more with either gear were compiled.

Brackish tributaries analyzed were the Magothy, Severn, South, West, Rhode, Miles, Corsica, and Wicomico rivers, and St. Clement's and Breton bays (Figure 12). The Magothy and Wicomico rivers were only sampled during 2003, but the remaining watersheds were sampled all three years. Freshwater systems were not well represented during 2003-2005 and, therefore, not included in this analysis. As a result the fresh-tidal Piscataway and Nanjemoy creeks were excluded after 2003 and only Mattawoman Creek was sampled throughout this time span.

Distance of a tributary from a major striped bass spawning area or white perch nursery area was measured from the approximate center of either area illustrated in Lippson (1973) to mouth of each tributary (Table 4). Potomac River tributaries were assigned a distance from the Potomac River spawning area while the remaining Bay tributaries were assigned a distance from the Head-of-Bay spawning area. For spot and blue crabs, distance from the mouth of Chesapeake Bay was used to test whether the occupation of a site and date was influenced by distance from marine waters (Table 4).

Regional (Potomac River or Head-of-Bay) relative abundances of YOY white perch, striped bass, and spot were estimated as geometric mean catches per seine haul by the Maryland Juvenile Striped Bass Survey (Bonzek et al. 2007; Durell and Weedon 2008; Table 5). Annual regional geometric mean seine catches of ages 1+ were also used for ages 1+ white perch (E. Durell, MD DNR, personal communication). Annual densities of all life stages of blue crabs in a Chesapeake Bay winter dredge survey were used as an index of baywide relative abundance (Maryland Fisheries Service 2007; Table 5).

Stepwise selection, a combination of forward and backward logistic model building that tests variables for entry and removal, was used to derive models for each species and life stage combination (SAS 1995; Wright 1998). Only the five main effects were considered. A minimum of 50 times as many observations as predictor variables and N equaled 588 for trawls and 519 for seines should have been present in this analysis

(Wright 1998). Stepwise selection is iterative and involves many tests of individual coefficients that increases the Type I error rate because multiple comparisons are made without adjustment to the level of significance (SAS 1995; Wright 1998). Specification of a very small significance level and cross-validation samples are recommended (SAS 1995; Wright 1998). Additional samples were unavailable for cross-validation, but $P<0.0001$ was specified to retain variables. Likelihood ratios, maximum rescaled R^2, Wald Chi-square test statistics, and odds ratio estimates with 95% Wald CI's described overall fit of models featuring the subset of parameters selected (SAS 1995; Wright 1998).

Impervious Surface and White Perch Presence-Absence in Fresh Systems 2003-2007

A prominent objective of the 2007 sampling was to better understand the impact of IS on tidal-fresh fish communities. Previous results of logistic regressions in brackish tributaries (below) indicated that occupation of bottom habitat was likely influenced by IS and distance from a main spawning/nursery area for anadromous fish or from the mouth of the Bay for species originating from more marine areas. An exploratory linear regression approach that could account for distance and IS was developed and applied to white perch juveniles and ages 1+ presence-absence data in Potomac River tributary collections during 2003-2007.

In 2003, six fresh to brackish Potomac River tributaries were selected for study (Rickabaugh et al. 2004). Budget reductions and study design changes resulted in variation in annual sampling: Piscataway Creek was sampled in 2003 and 2006; Mattawoman Creek, 2003-2007; Nanjemoy Creek, 2003; Wicomico River, 2003; and St.

Clements and Breton Bays, 2003-2005. These previous studies indicated that IS exhibited an asymmetric U-shaped gradient as IS for these three fresh-tidal tributaries fell with distance from Washington DC; Piscataway Creek, 14.9%, Mattawoman Creek, 8.5%, and Nanjemoy Creek, 0.9%. IS in brackish water tributary watersheds then rose slightly with distance from Washington; Wicomico River 3.8%, Saint Clements Bay4.3%, and Breton Bay 5.1%. Other physical factors varied with distance as well; salinity increased with downstream distance (r = +0.93) while SAV and DO were generally higher in fresh-tidal areas (Uphoff et al. 2007). Nanjemoy Creek is the approximate center of the Potomac River's white perch nursery (Lippson 1973).

The linear regression analysis proceeded in several steps. First, annual proportions of trawls with white perch juveniles (P_{wpj}) or ages 1+ (P_{wpa}; ages 1+) were regressed against distance from the white perch nursery. Since distance and IS were negatively correlated (r = -0.75, P = 0.09, N = 5) this close correlation necessitated the choice of distance or IS as an independent variable (Ricker 1975). Distance was measured from the center of the white perch larval nursery illustrated in Lippson (1973), to the mouth of each tributary. Nanjemoy Creek approximated the center (D = 0) and distance upstream was assigned a negative value to indicate direction (Piscataway Creek D = -39.2 and Mattawoman Creek D = -23.6). Distance downstream was assigned a positive value (Wicomico River, D = 22.9; St. Clements Bay, D = 28.7; and Breton Bay, D = 30.8). Since examination of scatter plots of D and P_{wpj} or P_{wpa} suggested the possibility of linear (P_{wpj} or P_{wpa} versus D) or quadratic (P_{wpj} or P_{wpa} versus D and D^2) relationships forward selection was used to evaluate whether linear or quadratic models described trends best. Entry level for explanatory variables was specified at P = 0.15. (Afifi and Clark 1984).

Residuals of the regressions of P_{wpj} or P_{wpa} against distance (R_{wpj} or R_{wpa}, respectively) were separated into fresh-tidal (Piscataway, Mattawoman, and Nanjemoy creeks) and brackish categories and plotted and regressed against IS. These residuals measured relative site occupation (mean ≈ 0) after accounting for the influence of D on the likelihood of being present or absent (positive values indicated greater occupation than expected and negative residuals indicated less).

RESULTS AND DISCUSSION

Estuarine Yellow Perch Larval Presence Absence

Proportion of tows with larval yellow perch in the tidal Severn River during 2007 (L_p = 0.30, SD = 0.05, N = 70; 17.5 % IS) was significantly lower than reference systems' historic distribution of L_p (Figure 13) based on 95% confidence interval overlap. Nanticoke River (L_p = 0.55, SD = 0.06, N = 58; 1.2% IS) fell between the historic mean and minimum. Proportions of tows with larval yellow perch in the Bush River (L_p = 0.92, SD = 0.03, N = 100; 12.8% IS), Corsica River (L_p = 0.83, SD = 0.05, N = 59; 4.0% IS), and Langford Creek (L_p = 0.83, SD = 0.06; N = 36; 0.9% IS) were significantly above the reference systems' historic mean. The Bush River exceeded the historic maximum range, while the Corsica River and Langford Creek overlapped it (Figure 13) The risk of falling below the "typical" historic minimum of L_p = 0.4 during 2007 was 95% in the Severn River and near zero in the remaining systems.

The Severn River L_p has been consistently poor (below the historic minimum) since 2004 while the Nanticoke River L_p has fallen in the historic range 3 of 4 times since 2004 and below it once (Figure 14). During 2006-2007, the Corsica River L_p has fallen within the historic range while the Bush River L_p has been at or exceeded the historic maximum (Figure 14).

The linear regression of IS and L_p during 1998-2007 was not significant (r^2 = 0.04, P = 0.42; Figure 15); however, measurements of L_p from Severn River suggested a threshold value of IS may exist. All four L_p estimates from the Severn River (17% IS) were less than the historic minimum of 0.4 while only 5 of 16 estimates from remaining systems (IS < 13%) were below 0.4 (Figure 15).

Mean salinity was not linearly related to L_p (r^2 = 0.06, P = 0.40), 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 16). The suggested mean salinity threshold at 4‰ was considerably greater than the 2‰ habitat requirement used previously (Piavis 1991). Below 4‰, there was wide variation in L_p (Figure 16).

Interpretation of the influence of salinity on L_p may be clouded by the Severn River representing 3 of 4 values; the other point was from the Corsica River. One observation for the Severn River was at a mean salinity that resulted in higher L_p elsewhere (Langford Creek L_p = 0.83 at 3.5 ‰). Other factors related to IS, could be suppressing L_p in the Severn River (Uphoff et al. 2005) and high salinity is coincidental or constitutes a minor contribution. The Severn River generally grouped 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‰ while abnormal behavior of larvae held for about a week at 8‰ suggested that delayed mortality would occur (Victoria et al. 1992).

Interpretation of annual L_p is not straightforward because it integrates the product of egg production and egg through larval survival. All of these factors would need to be moderate to high to produce average to strong L_p, but only one needs to be low to result in low L_p. Natural variation in L_p was historically high, and has remained high in more recent years when systems other than the Severn River are considered. The pattern of low and sustained below normal L_p exhibited in the Severn River may be the indication of IS-related impacts. However, the Bush River has high IS (12.8%) and exhibited excellent values of L_p during 2006-2007.

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 River does not appear to conform to a lognormal distribution and may adhere to a uniform or dome-shaped distribution (Figure 17). This suggests survival may not be independent across egg through postlarval stages.

Judgment of L_p in recent years was based upon comparisons with rural Eastern Shore systems in the past because long time-series did not exist for the non-reference systems. These reference rivers have larger watersheds and more extensive regions of fresh-tidal water than some brackish tributaries (Severn and Corsica rivers and Langford Creek) we 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 or Choptank rivers (and excluding Severn River) during 2006-2007 have compared favorably with the historic reference systems (Figure 14).

In the next several years, monitoring of L_p will move into systems other than the Severn River with IS > 5% to fill in data gaps in Figures 15 and 16.

<u>Bush River Stream Sampling</u>

Fourteen stations were sampled in the Bush River in 2007 (Figure 18). Effort was fairly consistent among sites. Yellow perch and white perch were not present in 2007 ichthyoplankton samples (Table 6). Herring/shad were present in ichthyoplankton samples at all sites (Table 6). Yellow perch adults were not present in traps, but ripe white perch adults were observed in two trap samples (Table 7). Herring/shad were observed at six of the nine trap stations sampled (Table 7). During 2005-2007, 21 of the original 26 stations were revisited (Figure 18). Historic distribution and presence in 2005 –2007 is shown in Figures 19-21 and Table 8. White perch were originally observed at 12 stations in 1972 (APG and Bush River). Between 2005 and 2007, white perch were present at only 5 APG and Bush River stations. In the Bush River, white perch were only found at two stations, Otter Point and Unnamed tributary, both tidal stations. At APG stations, white perch were observed at three of four stations where they had been historically present. All stations in APG were tidally influenced (Figure 19, Table 8).

Yellow perch were historically observed at seven APG and Bush River stations and present at 6 stations in 2003 – 2007. They reoccupied only one station in the Bush River where they were originally documented. In APG they were found at two of the three original stations where they were originally observed (Figure 20, Table 8).

Herring were present at 12 APG and Bush River stations in 1972 and 12 in recent sampling. However, the distribution of spawning habitat use appears to have changed. In the Bush River, herring were observed at four of the seven stations where they were historically present. They were also observed at four additional stations in the Bush River where they had not been present historically. Herring occupied three of four original stations in APG and were present in Swan Creek at two stations when they had only been present at one historically (Figure 21, Table 8).

Percent presence by species and year was calculated. For each year, presence at the sites sampled was compared to the historical presence at those same sites. Figure 22 shows the presence by species comparing each year to the historical presence with 95% confidence intervals. Variation among years was observed, and could be attributed to differing effort among years and also natural variation in spawning success or spawning habitat use. Herring presence did not appear to be significantly different from historical presence in any year. White perch did appear to be different when comparing the proportion and the 95% confidence intervals, suggesting that white perch were no longer using the fluvial streams for spawning. Yellow perch were different from historical distribution in 2005 and 2007, but similar to historical distribution in 2006. This difference could be related to annual changes in habitat suitability. However, there is little empirical data to suggest which habitat parameters were limiting yellow perch spawning.

Collaboration with a project conducting habitat evaluations in selected Bush River streams will continue in 2008. By applying a paired watershed approach and comparing data between streams that support spawning and streams that do not support spawning, parameters can be identified that may be limiting spawning activities in areas where spawning historically occurred. This will be useful information in directing restoration planning. Bush River sampling will continue in 2008 and APG sites will be revisited to develop a larger sample size. Additionally, the number of stream miles that were used historically will be calculated and compared to present use to see if there is a significant loss in stream use between present and historical data.

2007 Data Analysis

Water quality data were examined to determine if habitat requirements were met for the target species (Table 9). The Tred Avon and Bush rivers were the only systems sampled in 2007 that had temperature violations but these violations (2.1%) were infrequent (Table 9). Median temperatures varied slightly among the rivers sampled, with the Corsica showing the greatest range (Figure 23). Salinity violations were only observed in two rivers, the Tred Avon (17.7%) and the Wye (13.3%) (Table 9).

Distributions of salinities were expected based on the salinity classification for each tributary (Figure 24).

Dissolved oxygen concentrations were examined to determine how often oxygen requirements were not met. Data from the inshore and offshore sites and all depths in the water column were integrated. Offshore bottom dissolved oxygen was examined separately to determine the prevalence of low oxygen off shore. All of the mesohaline rivers had violations of the 5 mg/L dissolved oxygen requirement. The Corsica River had the greatest percentage of violations throughout the water column at 41.0% and the Tred Avon River the least at 10.8%. The Corsica also had the greatest percentage (20.5%) of dissolved oxygen less than 3.0 mg/L. The Wye River had the lowest percentage of violations with only 20% less than 5.0 mg/L and no observations less than 3.0 mg/L (Table 9). The Corsica River had the highest frequency of dissolved oxygen violations in the bottom water at both the 5.0 mg/L and the 3.0 mg/L criteria. In fact, the percentage of time the Corsica bottom waters were less than 5.0 mg/l was almost double that of the other mesohaline tributaries, and the 3.0 mg/L violations were observed five times more often in the Corsica River than the other mesohaline tributaries. It is likely that the sewage spill that occurred in 2004 deposited significant organic debris that is still contributing to low oxygen in the bottom waters. When the data distributions of the composite dissolved oxygen measurements (whole water column, nearshore and offshore) were compared, all rivers showed median values above the 5.0 mg/L criteria (Figure 25). The Corsica was the only river oserved where the lower quartile of the distribution fell below the 5.0 mg/L criteria. This appears to be driven by the high frequency of violations in the channel. Figure 26 shows that the Corsica River is the only system where the median bottom dissolved fell below the 5.0 mg/L criteria.

The fresh-tidal systems had fewer violations of the 5.0 mg/L criteria than the mesohaline systems, and no violations of the 3.0 mg.L criteria (Table 9). No violations were observed in Piscataway Creek; however, it was only sampled twice in July, because submerged aquatic vegetation became too thick for effective sampling. It is interesting to note that of the three fresh-tidal systems that were consistently sampled, the Bush River had the best dissolved oxygen profiles in both the water column integrated measures and the bottom oxygen measures (Figures 25 and 26). However, this watershed had the second highest percent impervious surface. The working hypothesis states that high impervious cover contributes to habitat degradation and attendant fish population effects. However, these data suggest that the impervious surface is not contributing to hypoxic conditions in low salinity tributaries as was suggested in the mesohaline tributaries previously studied (Uphoff et al., 2007). Flushing and circulation may be better in these low salinity systems because they do not stratify in the warm summer months, preventing hypoxia. These systems are also typically shallower than their mesohaline counterparts (average depth of mesohaline tribs ranges from 2.1 to 4.1 m; fresh-tidal 0.6 to 2.1 m). Based on visual observations of the stations sampled, the low salinity systems support more SAV than the mesohaline systems, which could be contributing to the better oxygen conditions that were observed. However, of the three fresh-tidal systems, Mattawoman Creek had the most extensive beds of SAV (McGinty, personal observation) and also the greatest number of oxygen violations. It is possible that the increase in SAV has contributed to the organic load in the deeper waters of Mattawoman Creek as the plants die off and sink to the bottom, or that these beds are so extensive that night time respiration demands are contributing to hypoxic conditions during the diurnal cycle.

Secchi depths varied considerably among the rivers sampled (Figure 27). However, Mattawoman and Piscataway creeks had the highest median secchi depths, indicating better clarity. This can be directly attributed to the extensive coverage of SAV in these systems.

The Northeast River was the only fresh-tidal system that could be sampled continuously by seining in 2007 (Table 10). Mattawoman and Piscataway creeks could not be seined at all because of the dense coverage of submerged aquatic vegetation. Seining also had to be discontinued at two sites on the Bush River because of dense vegetation. Seining in the Northeast and Bush rivers produced 28 species and the highest catch per unit of effort (CPUE) of systems seined. Blueback herring, gizzard shad, and white perch juveniles were most abundant. Of the mesohaline tributaries sampled, Langford Creek had the highest number of species captured by the haul seine (28), followed by the Corsica River (24); Wye River (22) and the Tred Avon River (18). Both theCorsica and Tred Avon rivers had seven species comprising 90% of the catch while the Wye River had six and Langford Creek, five. There were differences in the catch composition of these top species among systems. Mummichogs, white perch adults, striped killifish and Atlantic silversides were among the top 90% in all four mesohaline systems. Blueback herring were the top 90% only in the Corsica River and Langford Creek. White perch juveniles and spot were in the top 90% of catch in the Corsica and Tred Avon rivers, Atlantic menhaden in the Tred Avon and Wye rivers, and bay anchovy in the Wye River only. It is possible that the dominance of blueback herring in the

Corsica River and Langford Creek was related to proximity to blueback herring spawning areas. Both of these rivers are tributaries to the Chester River, a documented spawning watershed.

Piscataway Creek was sampled twice in 2007, but trawling had to be discontinued once vegetation became too dense. Piscataway Creek catch data are presented in Table 11.

The Bush River had the highest number of species captured and the highest CPUE by bottom trawl of the tidal-fresh rivers. Number of species encountered trawling was very similar between Mattawoman Creek (21) and Northeast River (22; Table 11). However the catch per effort was much less in Mattawoman Creek with only 91.4 fish per trawl, while the Northeast River produced 149.9 fish per trawl. Mattawoman Creek had greater richness with five species comprising 90% of the catch but the Northeast only three (Table 11). Mattawoman Creek contained abundant SAV coverage (45% coverage in 2006; http://www.vims.edu/bio/sav/index.html), even in the shallow channel areas while the Northeast River did not (3% coverage in 2006; http://www.vims.edu/bio/sav/index.html). There appears to be a strong possibility that the abundance of SAV in Mattawoman Creek contributed to the difference observed between these systems.

Trawl sampling in Langford Creek and the Tred Avon River captured 17 species while the Wye River produced 16, and the Corsica River 13 (Table 11). The Tred Avon River had the highest number of species comprising 90% of catch (5) followed bye the Wye and Corsica rivers both had 4, and Langford Creek with 3. CPUE varied among systems: Langford Creek 347.0 fish per trawl; Wye River 205.8; Corsica River 189.2;

and Tred Avon River 142.4. White perch adults, bay anchovy and spot comprised the top 90% of trawl catch in all four brackish systems. Bay anchovy was the most abundant species in the Tred Avon and Wye rivers, while adult white perch were dominant in both the Corisca River and Langford Creek. Species comprising 90% of the trawl catch were white perch juveniles in the Corsica Riverr, striped bass juveniles in the Tred Avon and Wye rivers, and weakfish in the Tred Avon River. Like the seine, the two southern most rivers contained a higher prevalence of marine species, while estuarine associated species were predominant in the two Chester River tributaries (Table 11).

In comparing species richness and composition among systems, it's interesting to note that the Corsica River had the lowest richness in both the trawl and lowest bottom DO among rivers sampled in 2007. There has been a notable decline in bottom DO in Corsica River in recent years.

The proportion of seines and trawls with each target species present is presented in Tables 12 and 13. Alosines were more prevalent in 2007 than in past years (Uphoff et al. 2007). Alewife and blueback herring were observed in every watershed except for the Tred Avon River. American shad were captured in the Bush River, Mattawoman Creek, and Northeast River. Alewife herring and American shad were most prevalent in Bush River bottom trawls in Northeast River seine samples. Atlantic menhaden were collected by haul seine in all systems except for the Northeast River. The proportion of seine hauls containing blueback herring was greatest in Bush River, while the proportion of trawls with blueback herring was greatest in Langford Creek and the Northeast River. Atlantic croaker were only observed in the Tred Avon River while spot were observed in every system. Striped bass adults were observed in all rivers except the Northeast, but were only present in a small proportion of both seine and trawl samples. Striped bass juveniles were observed in both gear types all rivers sampled as were white perch juveniles and adults. Yellow perch presence was spotty as in previous years with the Bush River producing the highest frequencies of occurrence for both juveniles and adults. White perch continue to be the most consistently observed target species in the eight rivers sampled (Tables 12 and 13).

<u>Logistic Regression of Absence in 2003 – 2005 Collections from Brackish Tributaries</u>

Target species had nearly a 90% or greater chance of occurring at least once at any site; absence from a site was likely to represent a loss of suitable habitat rather than an area that was originally unsuitable. Spot YOY were found at least once at 89% of sites, ages 1+ white perch were found at 97% of sites, and blue crabs, YOY white perch and YOY striped bass were found at all sites.

Log-likelihood ratios of all logistic regression models were significant at $P < 0.0001$ (Table 14). Maximum rescaled R^2 indicated most, if not all, models explained a small to modest amounts of variation. The two best fitting models explained 50-58% of variation (white perch YOY in shore-zone or bottom habitat, respectively), while remaining models explained 9-40%.

IS had a significant, negative influence on the odds of any target species being present in trawl samples taken in mid-channel bottom habitat (Table 15). IS was the only variable to appear as a significant parameter in all five sets of logistic regressions for bottom-channel habitat. Blue crabs were only influenced by IS, but additional parameters influenced odds that target species of finfish were present (Table 15).

The odds of white perch YOY being present in bottom trawls increased as regional abundance increased, and decreased with salinity (Table 15). The odds of ages 1+ white perch being present were positively influenced by regional abundance and negatively influenced by salinity. Increasing mean water temperature decreased odds of striped bass YOY being present in bottom channel trawls. The odds of YOY spot being present were positively influenced by mean water temperature and salinity (Table 15).

Logistic regressions of presence in the shore-zone did not indicate an influence of IS on the odds of the target finfish being present, but did indicate a positive influence on blue crabs (Table 16). Regional relative abundance and distance parameters associated with potential for migration influenced presence of target species in the shore-zone. Regional abundance indices positively influenced the odds of all target species being present in the shore-zone, while distance had a negative influence on odds of white perch (YOY and ages 1+) and blue crabs being present. Salinity and temperature influenced the odds of white perch YOY being present in shore-zone samples (Table 16).

Striped bass, spot, and blue crabs migrated into the tributaries sampled, but white perch also have the potential to spawn there as well (Lippson 1973). The combination of distance from spawning area or nurseries for anadromous species or Bay mouth for marine species and regional abundance indices was intended to describe potential for migration into a tributary in logistic regression analyses. However, there is often strong regional coherence in year-class success among spawning guilds that reflects climatic patterns (Austin 2002) and successful spawning of white perch within a tributary could have the same pattern as regional indices. In addition, other tributaries such as the Miles River, adjacent to the Choptank River, and the Corsica River, located within the Chester

River may have contributed to the numbers of migrating striped bass and white perch. Figure 12).

Impervious Surface and White Perch Presence-Absence in Tidal-Fresh Systems

Quadratic relationships best described the relationship of distance from the center of the Potomac River larval nursery (*D*) and the proportion of bottom trawls with white perch juveniles (P_{wpj}; R^2 = 0.87, P < 0.0001; Table 17) or ages 1+ (P_{wpa}; R^2 = 0.83, P < 0.0001; Table 17). These relationships described a dome-shaped relationship, with peak P_{wpj} and P_{wpa} of ≈ 1.0 predicted at Nanjemoy Creek (D = 0.0 miles) and tapering to P_{wpj} ≈ 0.6 and P_{wpa} ≈ 0.5 with distance upstream to Piscataway Creek (D = -39.2 miles). As distance downstream increased, predictions of P_{wpj} and P_{wpa} fell to ≈ 0.1 and ≈ 0.3, respectively at Breton Bay (D = 28.7 miles).

Plots of R_{wpj} or R_{wpa} against IS did not readily suggest relationships, especially for brackish tributaries where the range in IS was quite limited in the Potomac River (Figure 28). R_{wpj} and R_{wpa} for brackish tributaries were more dispersed than for fresh-tidal tributaries.

Ultimately, this analytical approach did not yield clear results because of terrible confounding among distance, salinity, and IS. IS was more tightly related to D than indicated by the original correlation analysis because the slope of the relationship of IS versus D varied with distance. This variations was dependant on whether D reflected increasing fresh-tidal conditions (heading upstream from the center of the white perch nursery at D = 0, Nanjemoy Creek, towards Washington D.C.; linear slope = 0.36, r^2 = 0.99) or increasing brackish conditions (heading downstream from D = 0; slope = 0.13, r^2

= 0.97). Plotting P_{wpj} and P_{wpa} against IS by salinity category (fresh or brackish) in Potomac River tributaries suggests that IS has a negative impact, but the impact appears more gradual in fresh-tidal areas than brackish (Figure 29).

Expanding the plot of P_{wpj} and P_{wpa} against IS by salinity category to all systems sampled during 2003-2007 (Figure 30) provides further evidence of differences indicated by Potomac River tributaries. Brackish water tributaries exhibited considerably more scatter in P_{wpj} and P_{wpa} than freshwater tributaries. Occupation of site and date combinations ranged from 0-1.0 in brackish tributaries and 0.6-1.0 in fresh-tidal ones. Highest potential occupation is near 1.0 at less than 5% IS in brackish tributaries and at 13% IS or less in fresh-tidal tributaries. In brackish tributaries, maximum occupation fell to approximately 0.6 between 5% and 10% IS, and to <0.4 at IS of 15-20% IS. Maximum occupation of fresh-tidal tributaries fell to 0.6 at 15% IS. The trend in fresh-tidal tributary maximum P_{wpj} and P_{wpa} with is between 13% and 15% IS which potentially intersects with the brackish tributary maximum P_{wpj} and P_{wpa} at 17% IS (Figure 30).

The difference in IS thresholds between fresh-tidal and brackish tributaries reflect substantial differences in levels of DO in bottom waters (Figure 31). During 2003-2007, mean bottom DO in fresh-tidal tributaries averaged 7-9 mg/L without apparent trend with IS (8-15%). These DO levels represent levels at saturation or slightly above (APHA 1975). In fresh-tidal tributaries with occasional incursions of salinity (mixed systems; Bohemia River and Nanjemoy Creek), DO was between 5 and 6 mg/L at low IS (< 1%); levels near or slightly below saturation. In brackish tributaries, bottom DO becomes increasingly depleted as IS increases, and averages in the hypoxic range (2 mg/L; Hagy

2004; Kemp et al. 2005) past 15% IS. Salinity is a major source of differences in density that impedes mixing and promotes stratification in brackish systems (Odum 1971; Reid and Wood 1976; Eby and Crowder 2002; Kemp et al. 2005). Water column stratification is a major influence on oxygen depletion in Chesapeake Bay (Kemp et al. 2005).

SAV beds are more abundant in fresh-tidal tributaries which could influence ecological and biogeochemical processes (Kemp et al. 2005). The percentage of tributary surface acreage covered by SAV during 2003-2006 was determined using annual VIMS SAV coverage estimates (http://www.vims.edu/bio/sav/index.html). These estimates of SAV coverage were then plotted against mean bottom DO for the fresh-tidal and mixed tributaries (Potomac River tributaries, plus Bohemia and Bush rivers; Figure 32). This plot did not indicate a strong relationship between SAV coverage and DO in these tributaries. Levels of bottom DO in fresh-tidal tributaries reflected absence of salinity, but were not dependent on SAV coverage. Undoubtedly, SAV contributed to DO levels in fresh-tidal tributaries, but did not necessarily drive DO dynamics

It would appear that fresh-tidal tributaries do not exhibit IS-DO related conditions that are detrimental to fish habitat as readily as brackish tributaries, but other IS related problems remain in fresh-tidal tributaries. Impervious surface increases 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, removal of substrate, 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).

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Table 1. Percent impervious cover, total non-water acres, and area of tidal water for the watersheds sampled in 2007.

Area	Watershed	% Impervious	Total Acres	Tidal water area
Upper-Bay	Bush River	12.8	36,964	7,966
Mid-Bay	Corsica River	4.0	23,903	1,256
Mid-Bay	Langford Creek	0.9	28,871	2,906
Potomac	Mattawoman Creek	8.5	60,300	1,848
Upper-Bay	Northeast	6.1	40,377	3,884
Potomac	Piscataway Creek	14.9	43,579	858
Mid-Bay	Tred Avon River	5.6	23,518	4,338
Mid-Bay	Wye	1.2	50,460	6,142

Table 2. Water quality requirements for juvenile (J) and adult (A) target species.

Water Quality Criteria Requirements	Striped Bass	Yellow Perch	White Perch	Alewife	Blueback Herring	American Shad	Spot	Atlantic Croaker	Atlantic Menhaden
TEMPERATURE (^{o}C)	14.0-26.0 J	19.0 -24.0 J	15.2 - 31.0 J	17.0 - 23.0 J	11.5 - 28.0 J	15.6 - 23.90 J	6.0 - 25.0 J	17.5 - 28.2 J	16.9 - 28.2 J
	20.0 – 22.0 A Preferred	12.0 – 22.0 A	21.5 – 22.8 A preferred	16.0 – 22.0 A	8.0-22.8 A	8.0-30.0 A	12.0 - 24.0 A	14.9 - 31.4 A	6.0 - 25.0 A
SALINITY (ppt)	0 – 16.0 J	0 – 5.0 J	0 – 8.0 J	0 – 28.0 J	0 – 28.0 J	0 – 30.0 J	0.1-25.0 J	0.5 - 21.0 J	0.5 - 15.0 J
		5.0 – 8.0 J preferred		0 – 5.0 J optimum	0 – 5.0 J optimum	0 – 5.0 J optimum			
	14.0 – 21.0 A	0 – 13.0 A	0 – 18.0 A	0 – 35.0 A	0 – 35.0 A	0 – 35.0 A	4.0-29.0 A	4.0 - 21.0 A	4.0.- 29.0 A
	10.0 – 27.0 A tolerated								
DISSOLVED OXYGEN (mg/l)	>5.0 J, A	minimum of 5.0 J A	minimum of 5.0 – 7.0 J/A	minimum of 3.6 J A	minimum of 3.6 J	4.0 – 5.0 J A	2 - >5.0 J A		> 4.5 J, A
				> 5.0 preferred	> 5.0 preferred	>5.0 preferred	>5.0 preferred		

Table 3. Mean salinity (‰) and temperature (°C) for tributaries during July-early October, 2003-2005 sampling. Blank indicates sampling was discontinued.

Tributary	Parameter	2003	2004	2005
Magothy River	Salinity	4.9		
	Temperature	25.7		
Severn River	Salinity	5.4	6.4	8.4
	Temperature	26.2	27.4	28.0
South River	Salinity	6.2	7.3	10.2
	Temperature	25.5	25.8	27.6
Rhode River	Salinity	6.9	8.4	11.1
	Temperature	25.1	27.0	27.8
West River	Salinity	7.5	8.5	11.4
	Temperature	25.0	26.8	28.0
Corsica River	Salinity	4.2	6.1	7.5
	Temperature	25.7	27.2	28.5
Miles River	Salinity	8.2	9.9	11.1
	Temperature	25.6	25.7	28.0
Breton Bay	Salinity	6.9	8.9	9.8
	Temperature	26.6	27.0	28.6
St. Clements Bay	Salinity	7.8	9.6	11.3
	Temperature	26.0	26.1	27.9
Wicomico River	Salinity	5.6		
	Temperature	25.4		

Table 4. Distance to mouth of tributary (km) from mouth of Chesapeake Bay (marine), or center of Potomac or Head-of-Bay striped bass spawning areas illustrated in Lippson (1973), or center of white perch nursery in Lippson (1973).

Tributary	Marine	Region	Striped bass	White perch
Magothy River	240.3	Head of Bay	57.1	47.6
Severn River	229.8	Head of Bay	67.6	58.1
South River	221.4	Head of Bay	76.0	66.5
Rhode River	217.6	Head of Bay	81.1	70.3
West River	216.9	Head of Bay	80.5	71.0
Corsica River	261.0	Head of Bay	82.1	70.3
Miles River	232.1	Head of Bay	101.1	55.8
Breton Bay	165.6	Potomac	99.5	49.6
St. Clements Bay	169.0	Potomac	96.1	46.2
Wicomico River	178.3	Potomac	86.7	36.9

Table 5. Regional indices of relative abundance used in logistic regression analysis of target species and life stages. Indices for fish are geometric means per standard seine haul (Durell and Weedon 2008); crab relative abundance is indicated by density estimated by a winter dredge survey (Maryland Fisheries Service 2007).

		Index		
Species and stage	Location	2003	2004	2005
White perch YOY	Potomac	20.1	5.6	6.4
White perch YOY	Head-of-Bay	69.1	22.2	15.4
White perch adult	Potomac	3.2	4.7	2.0
White perch adult	Head-of-Bay	2.1	4.4	6.2
Striped bass YOY	Potomac	12.8	2.4	7.9
Striped bass YOY	Head-of-Bay	11.9	4.2	8.5
Spot YOY	Potomac	0.5	0.7	1.9
Spot YOY	Head-of-Bay	0.02	0.03	1.3
Blue crab, all	Baywide	39.8	30.7	45.3

Table 6. Total samples collected by site for the Bush River, and percent presence of white perch, yellow perch and shad or herring observed as eggs or larvae.

TIDAL CLASSI-FICATION	STATION	STREAM	WATERSHED	Number of Samples Expected	Number of Samples Collected	Percent Presence Yellow perch	Percent Presence White perch	Percent Presence Shad/Herring
Nontidal	BBR1	Bynum Run	Bush	10	10	0	0	30
Nontidal	BCR1	Cranberry Run	Bush	10	9	0	0	11
Nontidal	BGR1	Grays Run	Bush	10	10	0	0	30
Tidal	BGRT	Grays Run	Bush	10	10	0	0	30
Nontidal	BHH1	Ha Ha Branch	Bush	10	9	0	0	11
Tidal	BHHT	Ha Ha Branch	Bush	10	10	0	0	20
Nontidal	BJR1	James Run	Bush	10	10	0	0	50
Tidal	BOP1	Otter Point Cr.	Bush	10	9	0	0	56
Nontidal	BSC1	Swan Creek	Swan	10	8	0	0	38
Nontidal	BSC2	Swan Creek	Swan	10	8	0	0	50
Nontidal	BSC3	Swan Creek	Swan	10	8	0	0	38
Tidal	BUN1	Unnamed Trib.	Bush	10	10	0	0	20
Nontidal	BWR1	Winters Run	Bush	10	9	0	0	33
Tidal	BWRT	Winters Run	Bush	10	9	0	0	56

Table 7. Total trap samples collected by station for the Bush River, and percent presence of white perch, yellow perch and shad or herring observed as adults.

STATION	STREAM	WATERSHED	Tidal Classisfication	Number of Samples Collected	Percent Presence Yellow perch	Percent Presence White perch	Percent Presence Shad/Herring
BBR1	Bynum Run	Bush	NONTIDAL	8	0	0	25
BCR1	Cranberry Run	Bush	NONTIDAL	8	0	0	25
BGR1	Grays Run	Bush	NONTIDAL	8	0	0	25
BHH1	Ha Ha Branch	Bush	NONTIDAL	8	0	0	0
BJR1	James Run	Bush	NONTIDAL	8	0	0	37.5
BOP1	Otter Point Cr.	Bush	TIDAL	8	0	12.5	12.5
BSC1	Swan Creek	Swan	NONTIDAL	8	0	0	13.5
BUN1	Unnamed Trib.	Bush	TIDAL	8	0	12.5	0
BWR1	Winters Run	Bush	8	8	0	0	0

Table 8. Bush River historic presence of target species compared to presence observed in 2005 to 2007. Blank spaces denote sample not taken. OPC = Otter Point Creek.

					Herring				White perch				Yellow perch			
TIDAL CLASSIFICATION	AREA	IS	STREAM	SITE	1973	2005	2006	2007	1973	2005	2006	2007	1973	2005	2006	2007
TIDAL	Aberdeen	2.4	Back		1		0		1		1		1		0	
TIDAL	Aberdeen	2.4	Mosquito		1		1		1		1		1		1	
TIDAL	Aberdeen	2.4	Romney		1		1		1		0		0		0	
TIDAL	Aberdeen	2.4	Woodrest		1		1		1		1		1		1	
NONTIDAL	Bush	13.4	Bynum	1	0	1	1	1	1	0	0	0	0	0	1	0
NONTIDAL	Bush	13.4	Bynum	2	0	0	0		0	0	0		0	0	0	
NONTIDAL	Bush	13.6	Cranberry		1	0	0	1	1	0	0	0	1	0	0	0
NONTIDAL	Bush	3.9	Grays	1	0	1	1	1	1	0	0	0	1	0	1	0
NONTIDAL	Bush	3.9	Grays	2	1	0	0		1	0	0		0	0	0	
NONTIDAL	Bush	14.8	Haha		0	0	1	1	0	0	0	0	0	0	0	0
NONTIDAL	Bush	4.7	James	1	0	1	1	1	0	0	0	0	0	0	0	0
TIDAL	Bush	15.4	OPC		1	1	1	1	1	0	0	1	0	0	1	0
NONTIDAL	Bush		Sod		1	0	0		0	0	0		1	0	0	
TIDAL	Bush		Unnamed 2		1	1	1	1	1	0	0	1	0	0	1	0
NOTIDAL	Bush	17.1	Winter	1	1	0	0	1	1	0	0	0	0	0	0	0
NONTIDAL	Bush	17.1	Winter	2	1	0	0		1	0	0	0	1	0	0	
NOTIDAL	Swan		Swan	1	1	0	0	1	0	0	0	0	0	0	0	0
NONTIDAL	Swan		Swan	2	0	1	1	1	0	0	0	0	0	0	0	0
NOTIDAL	Swan		Swan	3	0	1	0	1	0	0	0	0	0	0	0	0

Table 9. Percentage of time overall habitat conditions (all depths in the channel and near shore) did not support the highest maximum temperature, threshold and target D.O. and the lowest maximum salinity for the target species during July-September, 2007 and percentage of time bottom dissolved oxygen in the channel was below 5.0 mg/L and 3.0 mg/L.

Salinity Calssification	Watershed	Percentage Impervious	Temperature > 31°C	DO < 5.0 mg/L	DO < 3.0 mg/L	Salinity >13 ppt	Bottom DO < 5.0 mg/L	BottomDO < 3.0 mg/L
Mesohaline	Langford	0.9	0.0	22.2	1.6	0.0	27.8	5.6
Mesohaline	Wye	1.2	0.0	20.0	0.0	13.3	29.2	0.0
Mesohaline	Corsica	4.0	0.0	41.0	20.5	0.0	54.2	29.2
Mesohaline	Tred Avon	5.6	2.1	10.8	1.1	17.7	26.1	4.3
Fresh-tidal	Northeast	6.1	0.0	3.5	0.0	0.0	8.3	0.0
Fresh-tidal	Mattawoman	8.5	0.0	13.3	0.0	0.0	16.7	0.0
Fresh-tidal	Bush	12.8	2.1	2.1	0.0	0.0	0.0	0.0
Fresh-tidal	Piscataway	16.7	0.0	0.0	0.0	0.0	0.0	0.0

Table 10. Catch statistics and impervious cover in seines by river in 2007.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Seine
Langford	22	28	Atlantic silverside Blueback herring White perch Striped killifish Mumichog	0.9	3787	172.2
Corsica	18	24	Mummichog White perch Blueback herring White perch juvenile Atlantic silberside Striped killifish Spot	4.0	3131	173.9
Mattawoman				8.5		
Bush	15	28	Blueback herring Gizzard shad White perch juvenile Banded killifish Spottail shiner Pumpkinseed Bay anchovy	12.8	5398	359.9
Wye	24	22	White perch Atlantic silverside Mummichog Striped killifish Atlantic menhaden Bay anchovy	1.2	3348	139.5
Tred Avon	24	18	White perch Atlantic menhaden Atlantic silverside Mummichog Striped killifish White perch juvenile Spot	5.6	2928	122.0
Northeast	24	28	Blueback herring Gizzard shad White perch juveniles Alewife White perch	6.1	6655	277.2
Piscataway				16.7		

Table 11. Catch statistics and impervious cover in trawl by river in 2007.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Trawl
Langford	24	17	White perch Bay anchovy Spot	0.9	8326	347.0
Corsica	24	13	White perch Bay anchovy White perch juvenile Spot	4.0	4540	189.2
Mattawoman	24	21	White perch juvenile White perch Spottail shiner Bay anchovy Pumpkinseed	8.5	2193	91.4
Bush	18	23	White perch juvenile White perch Bay anchovy Pumpkinseed Spottail shiner	12.8	7025	390.3
Wye	24	16	Bay anchovy Spot White perch Striped bass juvenile	1.2	4938	205.8
Tred Avon	24	17	Bay anchovy Spot White perch Striped bass juvenile Weakfish	5.6	3417	142.4
Northeast	24	22	White perch juvenile White perch adult Bay Anchovy	6.1	3597	149.9
Piscataway	6	8	White perch juvenile White perch Striped bass juvenile Largemouth bass Tessellated darter	16.7	48	8.0

Table 12. Proportion of trawls with individual target species present, 2007.

River	Alewife	American Shad	Atlantic Menhaden	Atlantic Croaker	Blueback Herring	Spot	Striped Bass Adult	Striped Bass Juv.	White Perch Adult	White Perch Juv.	Yellow Perch Adult	Yellow Perch Juv.
Bush	0.61	0.56	0.00	0.00	0.11	0.72	0.06	0.28	0.94	1.00	0.61	0.06
Corsica	0.04	0.00	0.00	0.00	0.12	0.92	0.00	0.38	1.00	0.83	0.00	0.00
Langford	0.04	0.00	0.00	0.00	0.08	0.96	0.04	0.67	0.92	0.79	0.00	0.00
Mattawoman	0.12	0.25	0.00	0.00	0.04	0.12	0.04	0.58	0.92	0.96	0.08	0.04
Northeast	0.25	0.00	0.00	0.00	0.12	0.04	0.00	0.08	0.96	0.96	0.04	0.08
Piscataway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.50	0.00	0.00
Tred Avon	0.00	0.00	0.04	0.04	0.00	1.00	0.04	0.67	0.62	0.25	0.00	0.00
Wye	0.04	0.00	0.04	0.00	0.00	1.00	0.04	0.92	0.92	0.38	0.00	0.00

Table 13. Proportion of seines with individual target species present, 2007.

River	Alewife	American Shad	Atlantic Menhaden	Atlantic Croaker	Blueback Herring	Spot	Striped Bass Adult	Striped Bass Juv.	White Perch Adult	White Perch Juv.	Yellow Perch Adult	Yellow Perch Juv.
Bush	0.40	0.40	0.13	0.00	0.73	0.53	0.13	0.53	0.53	0.93	0.20	0.40
Corsica	0.11	0.00	0.06	0.00	0.28	0.72	0.11	0.67	1.00	0.94	0.17	0.11
Langford	0.14	0.00	0.14	0.00	0.45	0.36	0.14	0.77	0.95	0.73	0.14	0.04
Northeast	0.71	0.83	0.00	0.00	0.67	0.08	0.00	0.46	0.79	0.96	0.25	0.25
Tred Avon	0.00	0.00	0.17	0.00	0.00	0.75	0.04	0.88	0.92	0.71	0.00	0.00
Wye	0.004	0.00	0.21	0.00	0.08	0.46	0.08	0.92	1.00	0.38	0.00	0.00

Table 14. Maximum (Max) rescaled R^2, likelihood ratio (LR), and degrees of freedom (DF), for final logistic regression developed from stepwise selection. All models were significant at $P < 0.0001$.

	Gear and habitat			
	Trawl bottom channel		Seine shore-zone	
Species and life stage	Max R^2	LR (DF)	Max R^2	LR (DF)
White perch YOY	0.58	323.7 (4)	0.50	234.5 (4)
White perch ages 1+	0.23	104.7 (3)	0.15	59.2 (2)
Striped bass YOY	0.24	114.4 (2)	0.09	28.0 (1)
Spot YOY	0.40	209.4 (3)	0.35	152.0 (1)
Blue crab, all stages	0.22	104.9 (1)	0.13	51.0 (2)

Table 15. Summary statistics of parameters selected by stepwise logistic regressions of target species presence in bottom trawls in mid-channel versus percent impervious surface (IS, %), mean temperature (°C) or salinity (‰), regional relative abundance (Index), and distance (Distance, in miles) from major spawning area (white perch or striped bass) or mouth of Chesapeake Bay (spot and blue crab). Each retained parameter has a single degree of freedom. All reported terms are significant at $P \leq 0.0001$. N = 588.

Parameter	Coefficient	SE	Wald $\chi 2$	Odds ratio	Odds lower 95%	Odds upper 95%
			White Perch YOY			
Intercept	-16.8394	4.3136	15.24			
IS	-0.4351	0.0402	116.98	0.647	0.598	0.700
Index	0.0592	0.0079	56.48	1.061	1.045	1.078
Salinity	-0.8257	0.0977	71.40	0.438	0.362	0.530
Temperature	0.8861	0.1722	26.49	2.426	1.731	3.399
			White Perch Adult			
Intercept	2.6580	0.4725	31.64			
IS	-0.1720	0.0209	67.73	0.842	0.808	0.877
Index	0.3971	0.0756	27.60	1.488	1.283	1.725
Salinity	-0.4042	0.0619	42.67	0.667	0.591	0.754
			Striped Bass YOY			
Intercept	17.0022	2.4033	50.05			
IS	-0.15471	0.0227	47.91	0.855	0.817	0.894
Temperature	-0.6154	0.0898	47.00	0.54	0.453	0.644
			Spot YOY			
Intercept	-18.7912	2.7887	45.40			
IS	-0.163	0.0275	36.07	0.848	0.803	0.895
Salinity	0.3149	0.0652	23.36	1.370	1.206	1.557
Temperature	0.6348	0.1136	31.23	1.887	1.510	2.357
			Blue Crab (all stages)			
Intercept	1.1891	0.1669	50.77			
IS	-0.1938	0.0234	68.72	0.824	0.787	0.862

Table 16. Summary statistics of parameters selected by stepwise logistic regressions of target species presence in shore-zone haul seines versus percent impervious surface (IS, %), mean temperature (°C) or salinity (‰), regional relative abundance (Index), and distance (Distance, in miles) from major spawning area (white perch or striped bass) or mouth of Chesapeake Bay (spot and blue crab). Each retained parameter has a single degree of freedom. All reported terms are significant at $P \leq 0.0001$. N = 519.

Parameter	Coefficient	SE	Wald $\chi 2$	Odds ratio	Odds lower 95%	Odds upper 95%
			White Perch YOY			
Intercept	-18.1072	4.0059	20.43			
Salinity	-0.3227	0.0808	15.94	0.724	0.618	0.849
Temperature	0.8835	0.1591	15.94	2.419	1.771	3.305
Distance	-0.1462	0.0230	40.25	0.864	0.826	0.904
Index	0.1219	0.0198	37.98	1.130	1.087	1.174
			White Perch Adult			
Index	0.4888	0.0706	47.86	1.630	1.419	1.872
Distance	-0.664	0.0162	16.88	0.936	0.907	0.966
			Striped Bass YOY			
Index	0.1738	0.0338	26.52	1.190	1.114	1.2721
			Spot YOY			
Intercept	-1.8845	0.1624	134.66			
Index	1.9525	0.1800	117.68	7.046	4.952	10.026
			Blue Crab (all stages)			
Intercept	4.7209	0.7071	44.57			
IS	0.0732	0.018	16.55	1.076	1.039	1.114
Distance	-0.034	0.00548	41.82	0.965	0.955	0.976

Table 17. Summary of quadratic regression results of proportion of bottom trawls with white perch juveniles or ages 1+ and distance (D) from larval nursery.

Juvenile (P_{wpj})					
Parameter	Estimate	SE	F	P	Partial Correlation
D	-0.0115	.00149	60.08	<0.0001	0.55
D^2	-0.00059	0.00011	29.54	0.0002	0.32
Intercept	1.0369	0.0949	119.49	<0.0001	
Ages 1+ (P_{wpa})					
D	-0.0067	0.0012	29.17	0.0002	0.43
D^2	-0.00054	0.00009	34.10	<0.0001	0.40
Intercept	1.0545	0.0794	176.39	<0.0001	

Figure 1. Watersheds sampled in 2007.

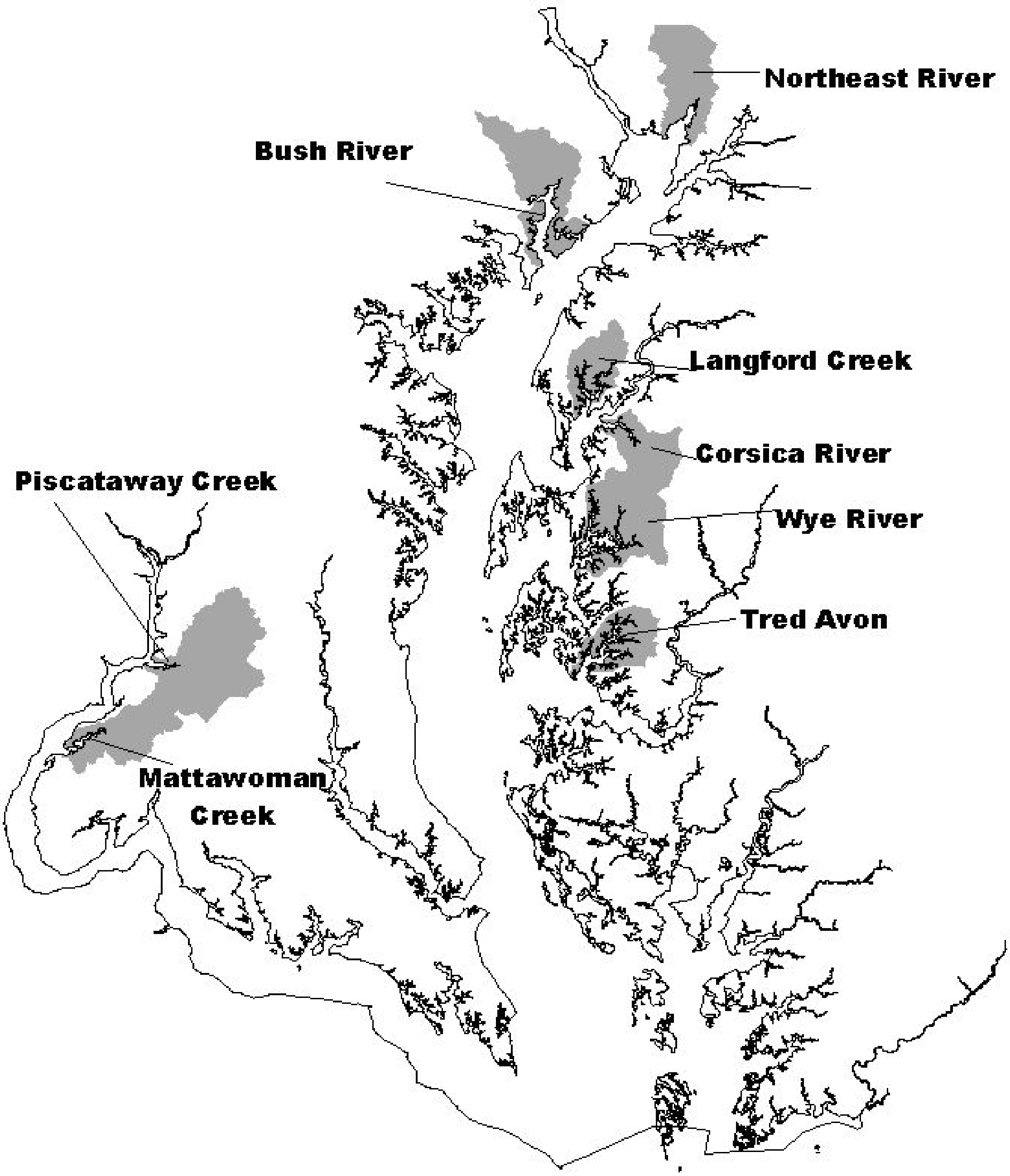

Figure 2. Land use and sampling stations n the Bush River watershed.

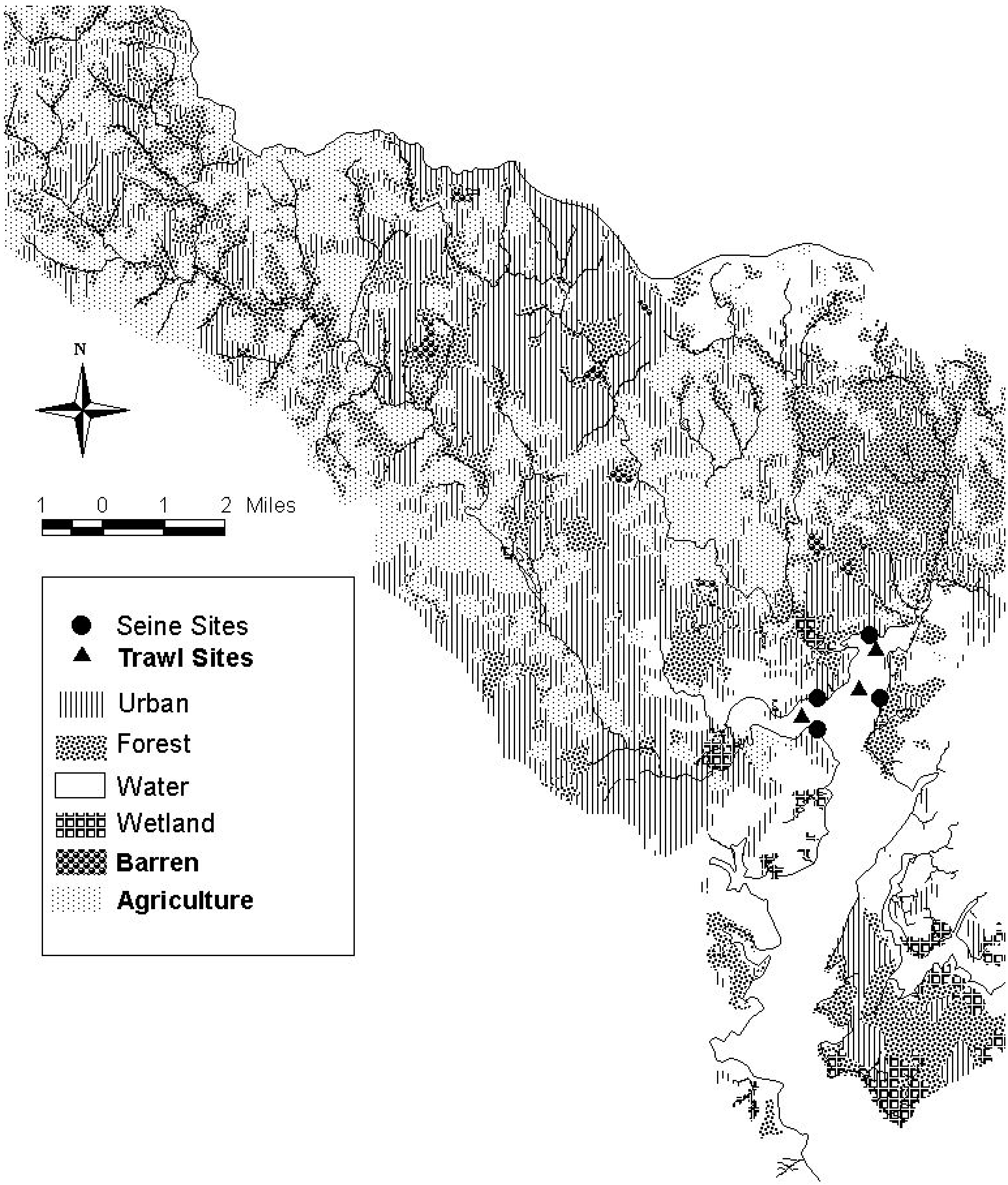

Figure 3. Land use and sampling stations in the Northeast River watershed.

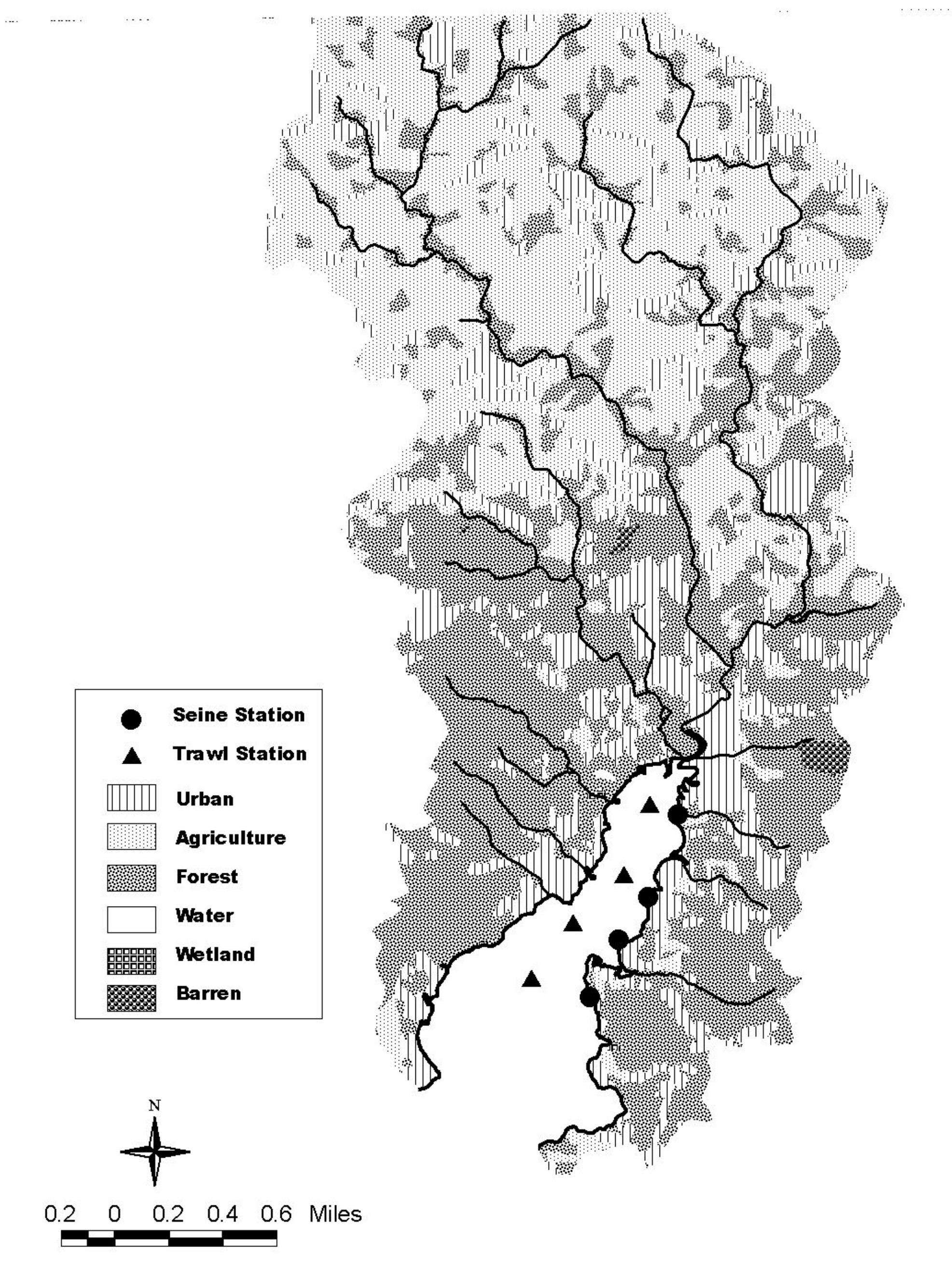

Figure 4. Land use and sampling stations in the Corsica River watershed.

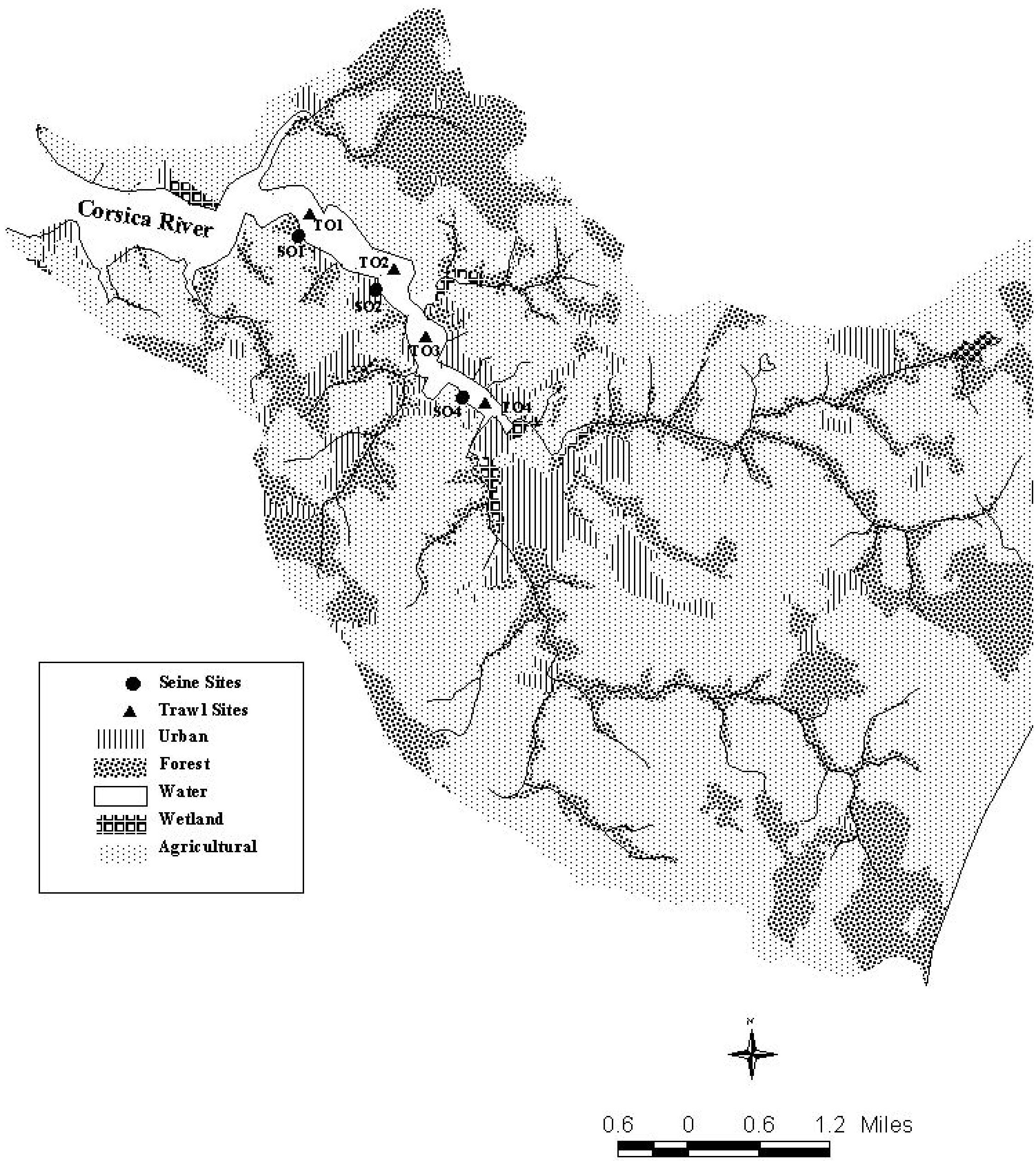

Figure 5. Land use and sampling stations in the Langford Creek watershed.

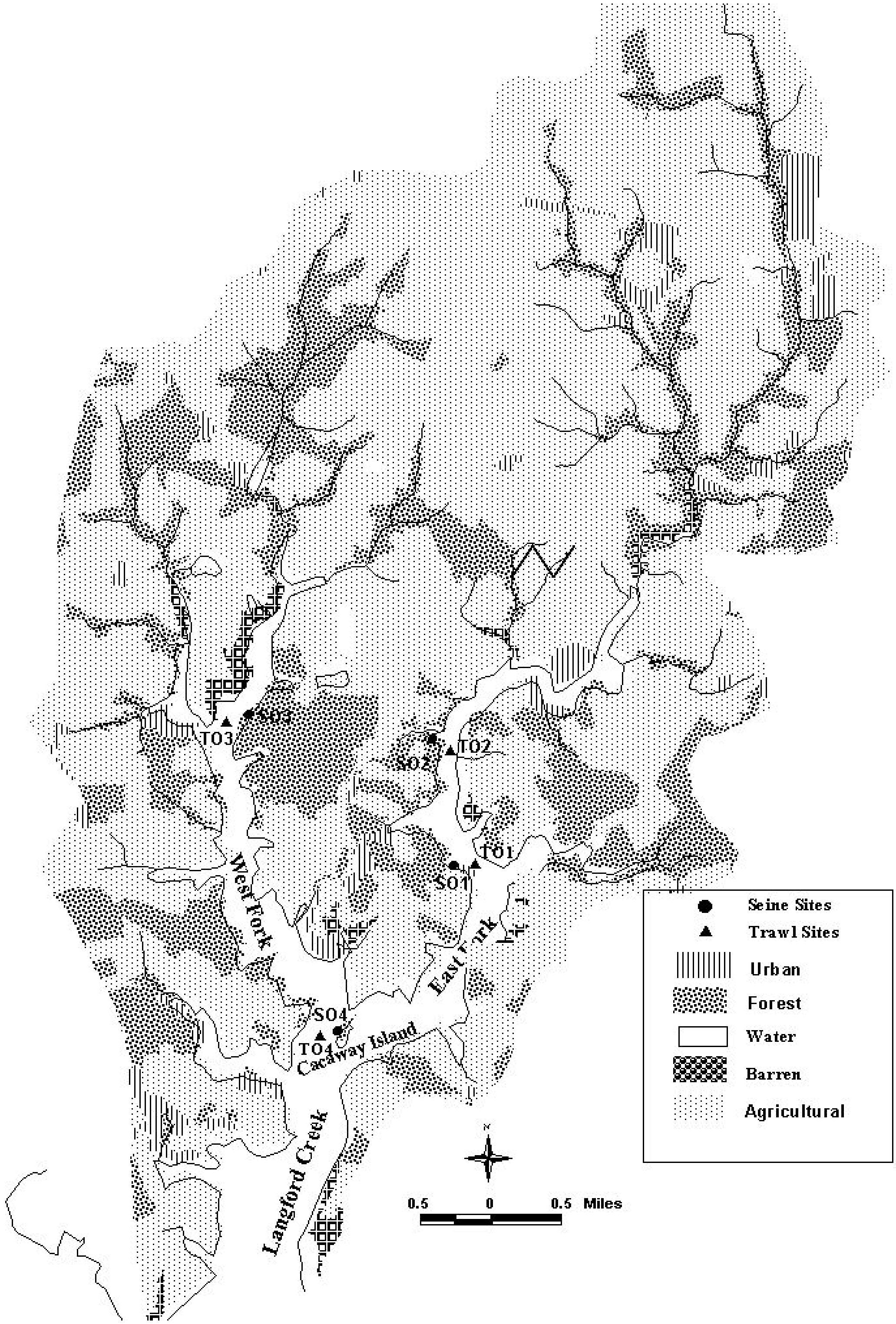

Figure 6. Land use and sampling stations in the Tred Avon watershed.

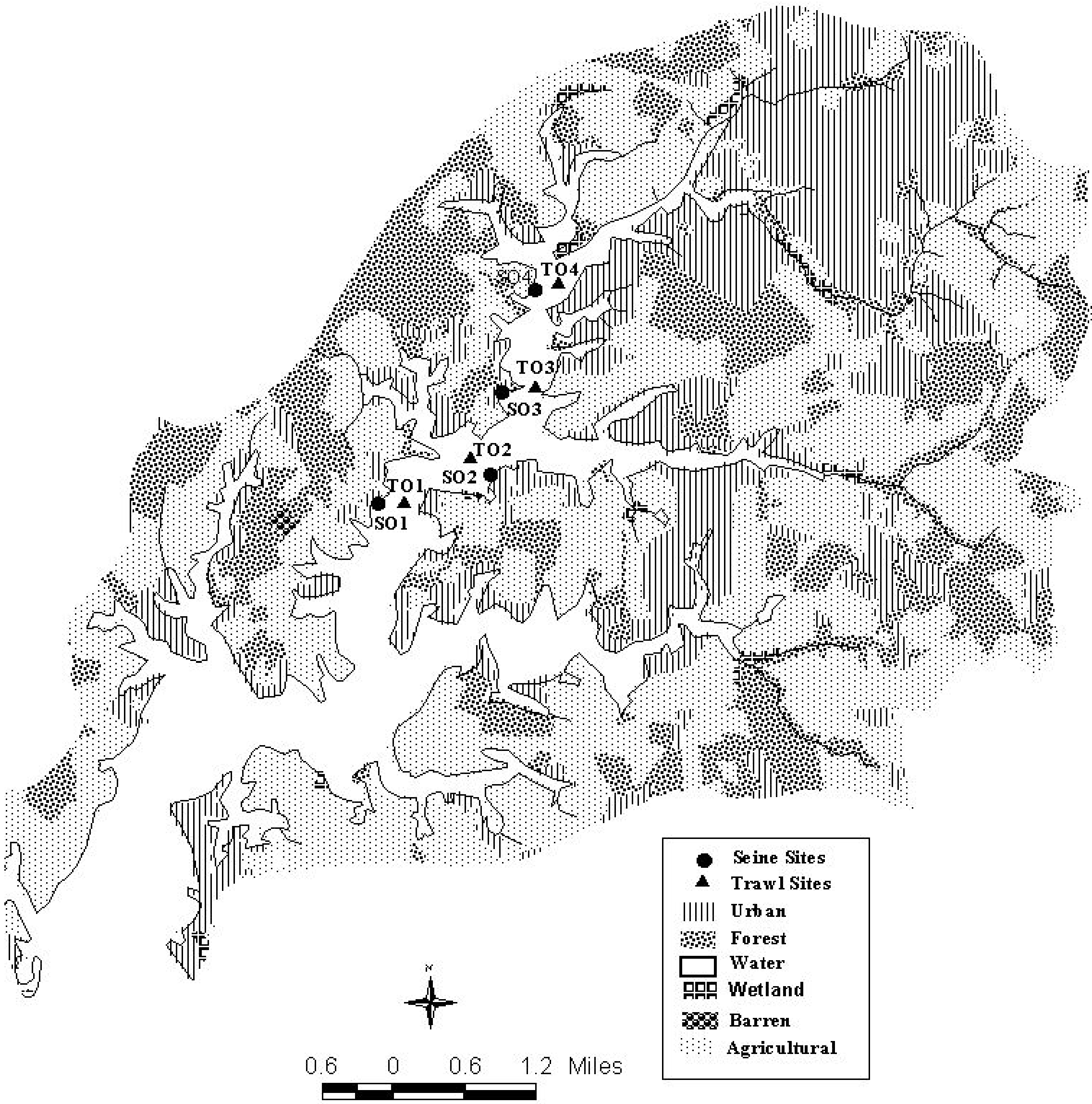

Figure 7. Land use and sampling stations in the Wye River watershed.

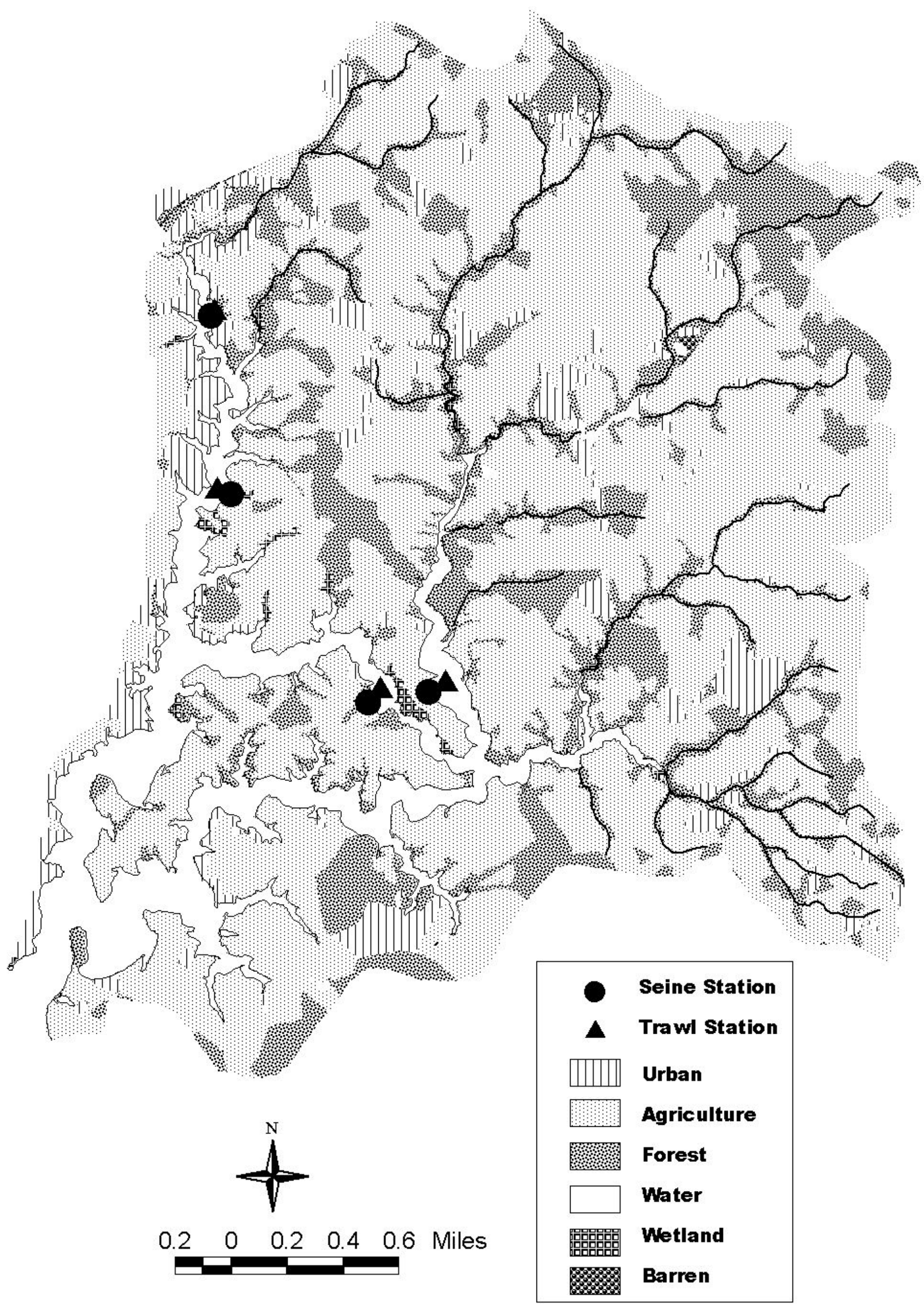

Figure 8. Land use and sampling stations in the Mattawoman Creek watershed.

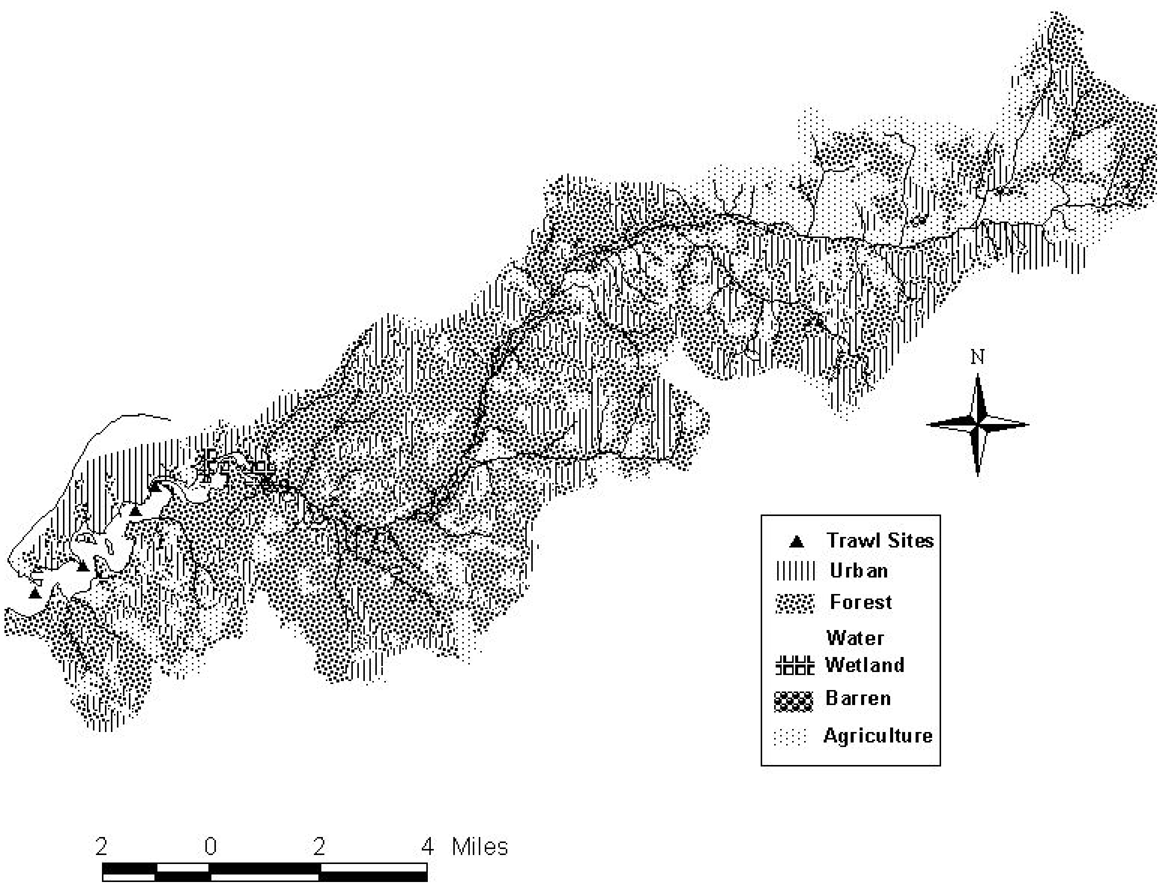

Figure 9. Land use and sampling stations in the Piscataway Creek watershed.

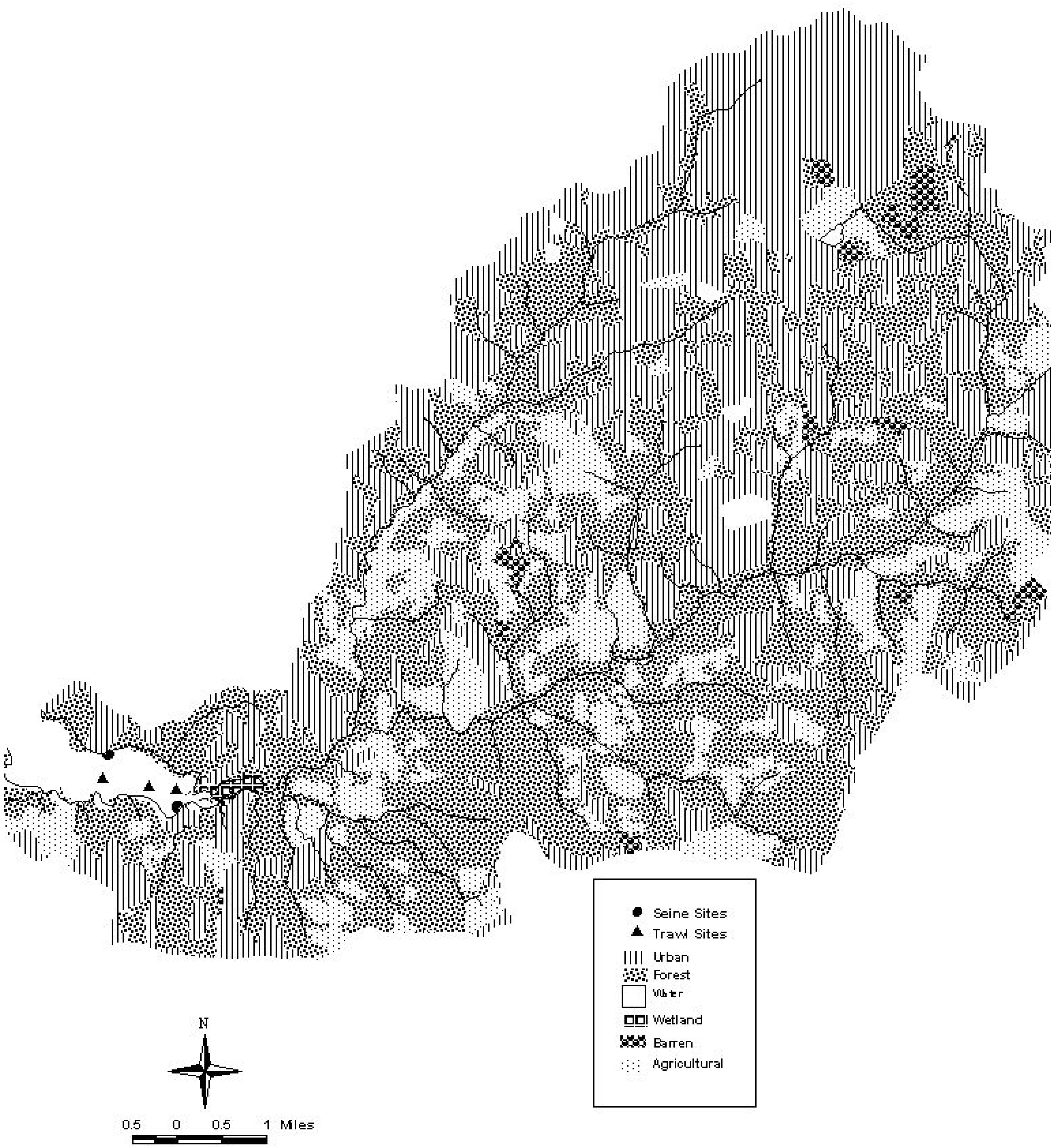

Figure 10. Sampling areas and stations for the spring yellow perch larval presence absence study.

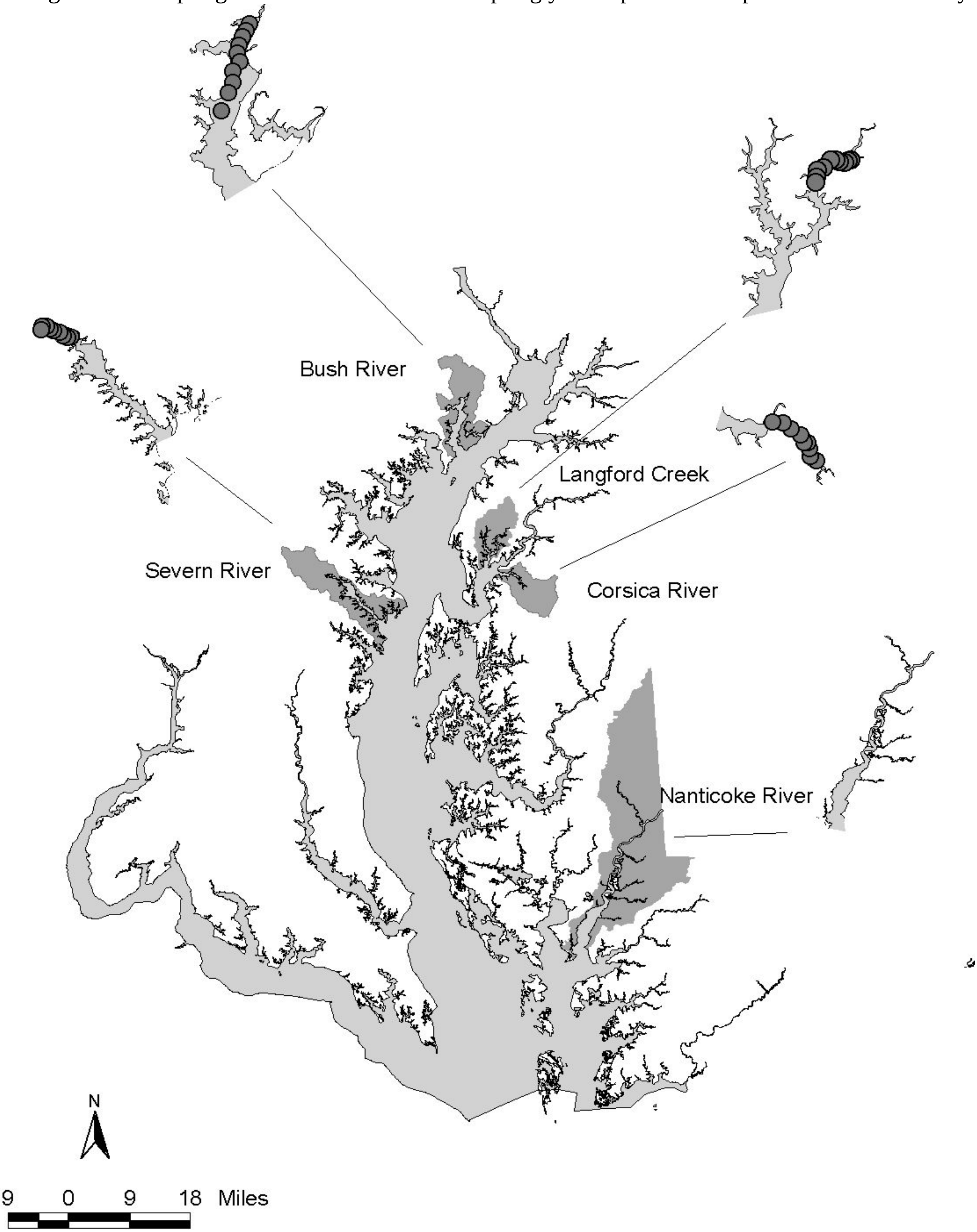

Figure 11. Sampling areas and stations for the spring Bush River ichthyoplankton survey.

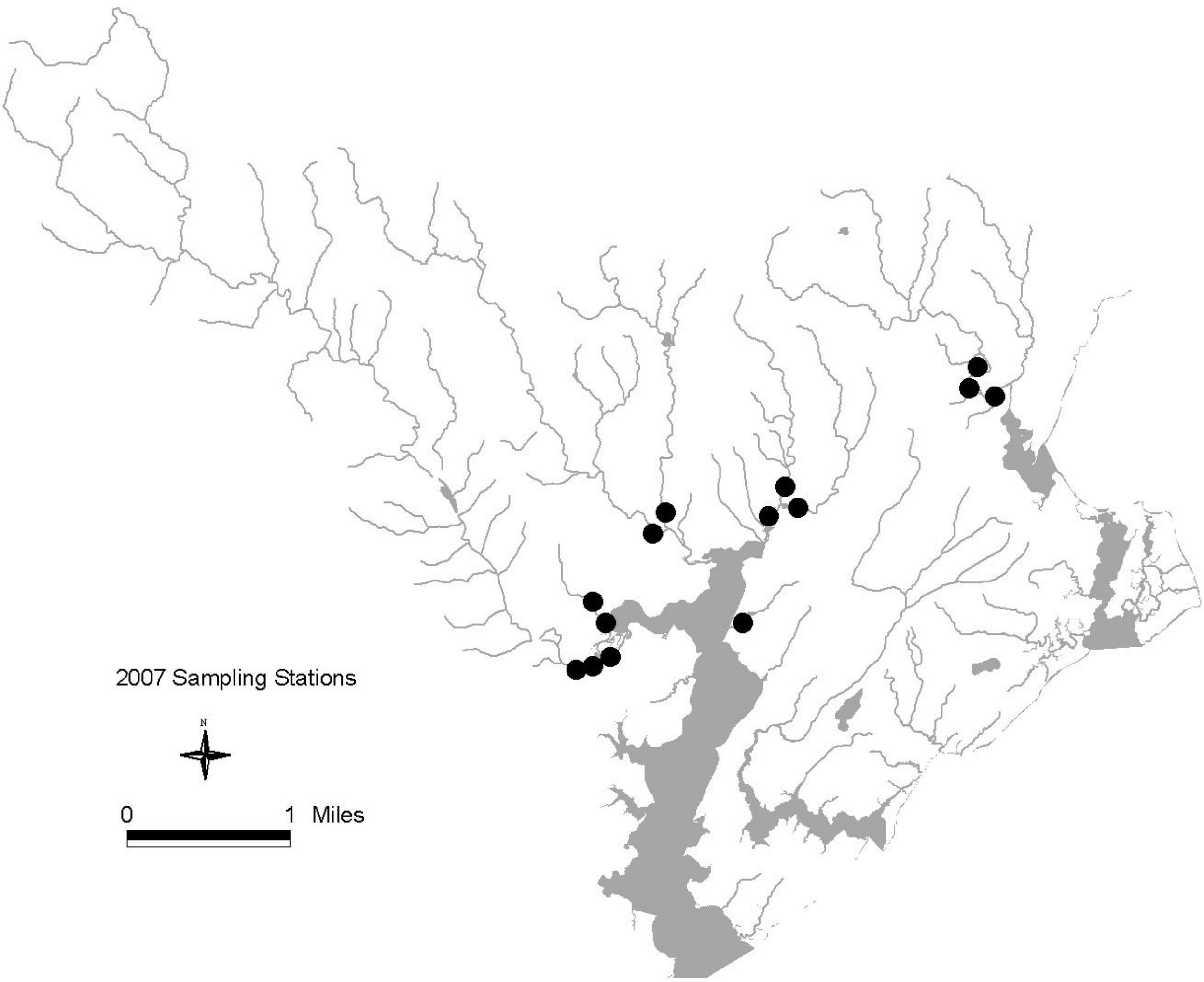

Figure 12. Rivers sampled during 2003 – 2005 and their watersheds (grey boundaries). Important regions are identified in bold.

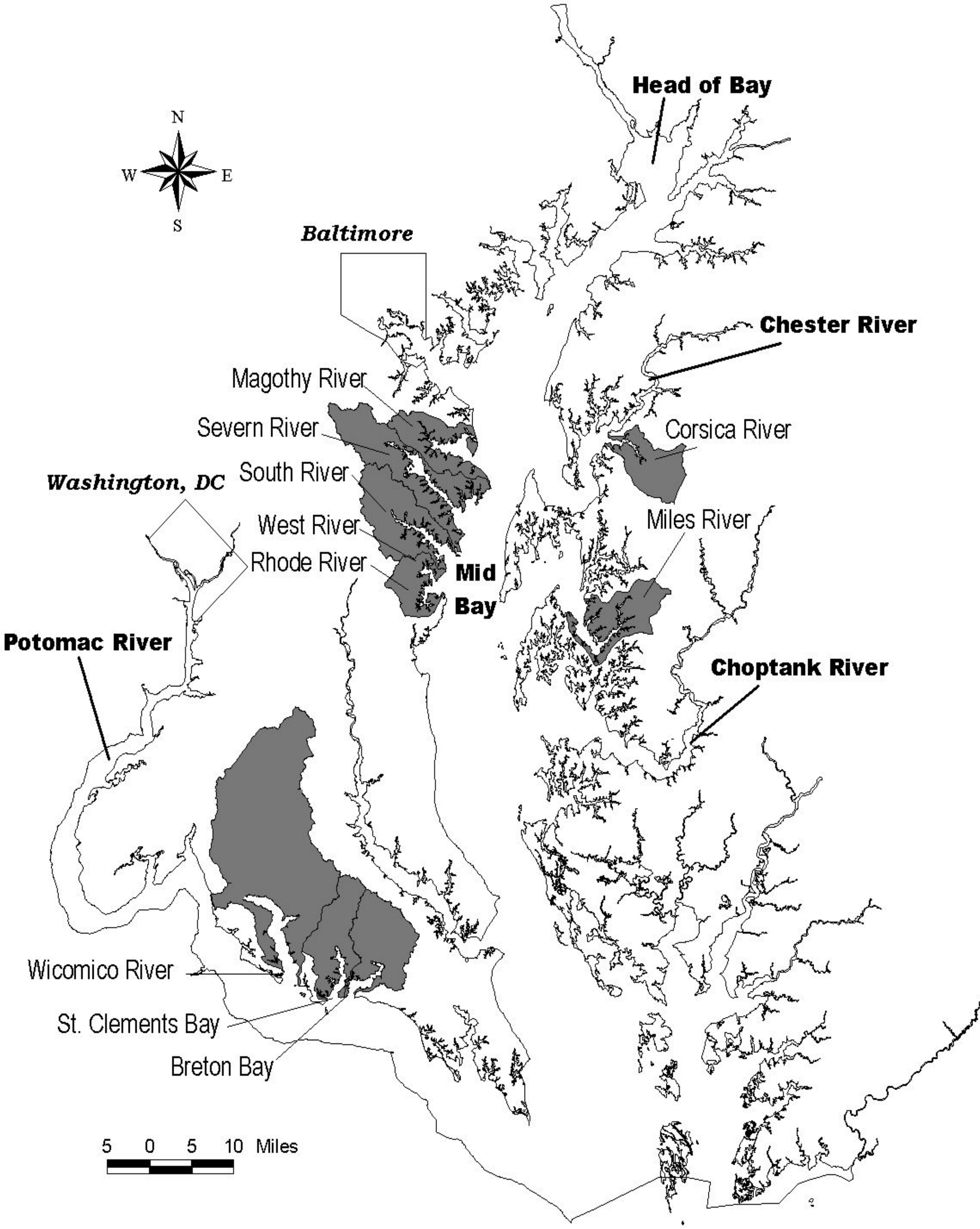

Figure 13. Proportion of tows with larval yellow perch and its 95% confidence interval in systems studied during 2007. High and low points of "Historic" data indicate spread of 9 of 11 points and midpoint is the mean of historic period.

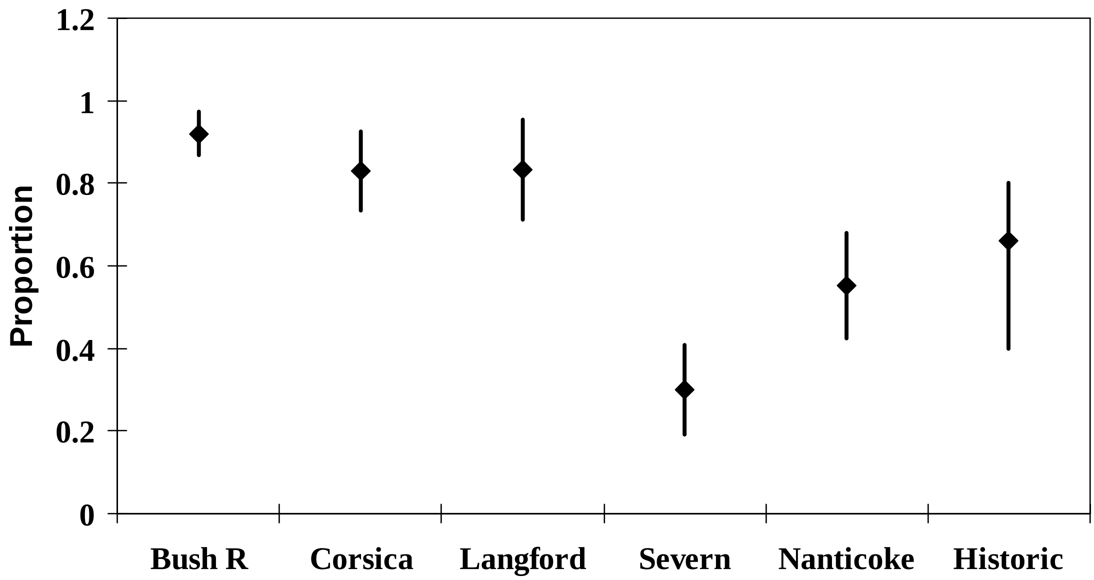

Figure 14. Proportion of tows with yellow perch larvae, by river, during 1965-2007. Lines indicates reference system (Nanticoke and Choptank rivers) and period (prior to 1991) mean and "typical" range.

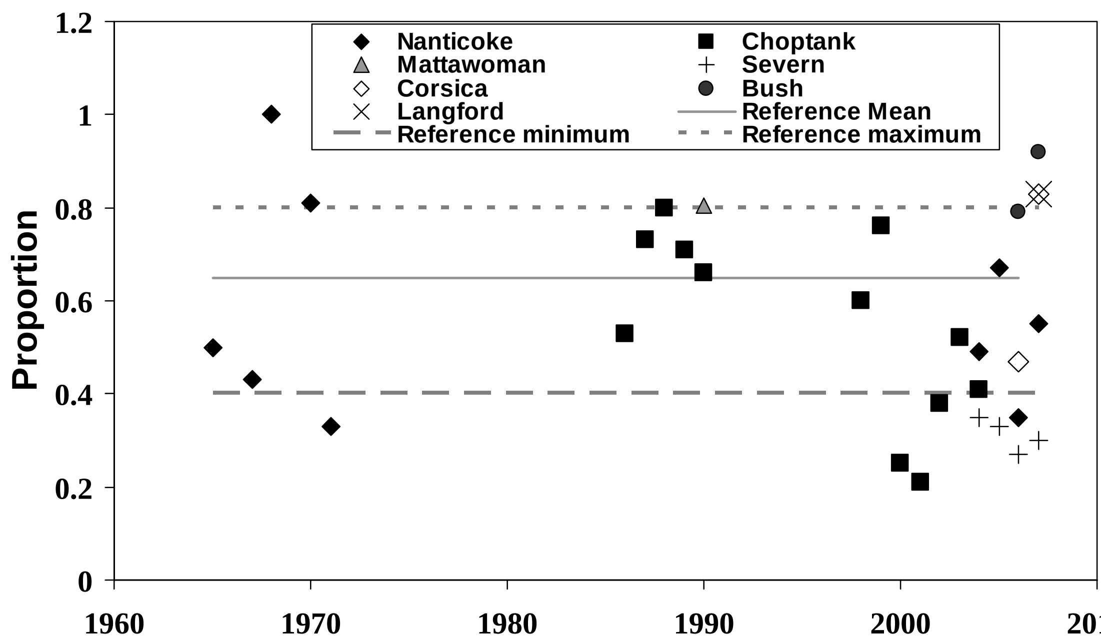

Figure 15. Plot of impervious surface (% of watershed) versus proportion of plankton tows with yellow perch larvae.

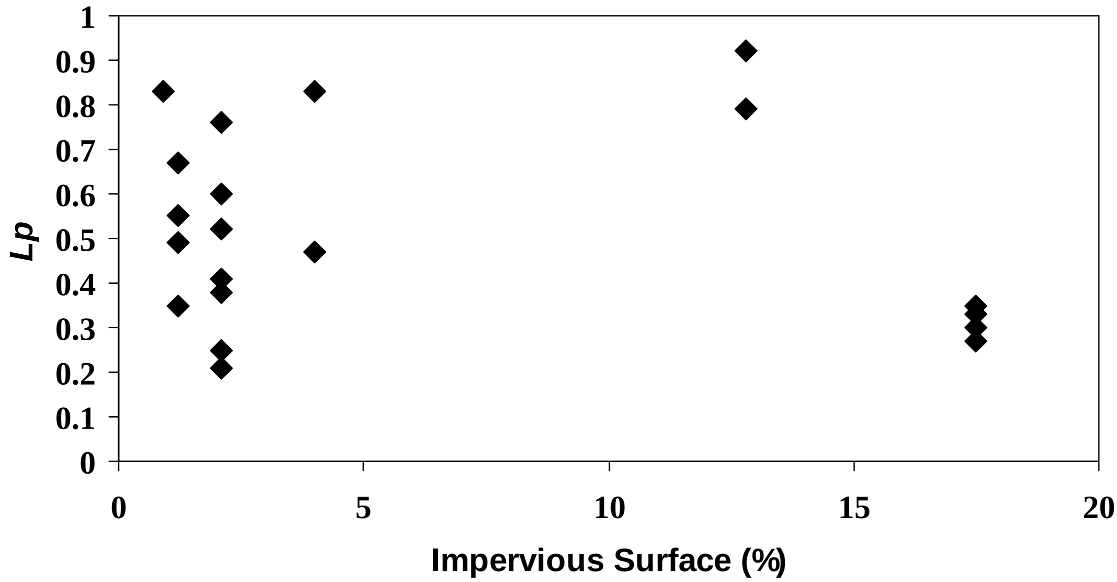

Figure 16. Plot of mean salinity in nursery area versus proportion of plankton tows with yellow perch larvae (*Lp*). Empty squares indicate Severn River and solid diamonds indicate remaining systems.

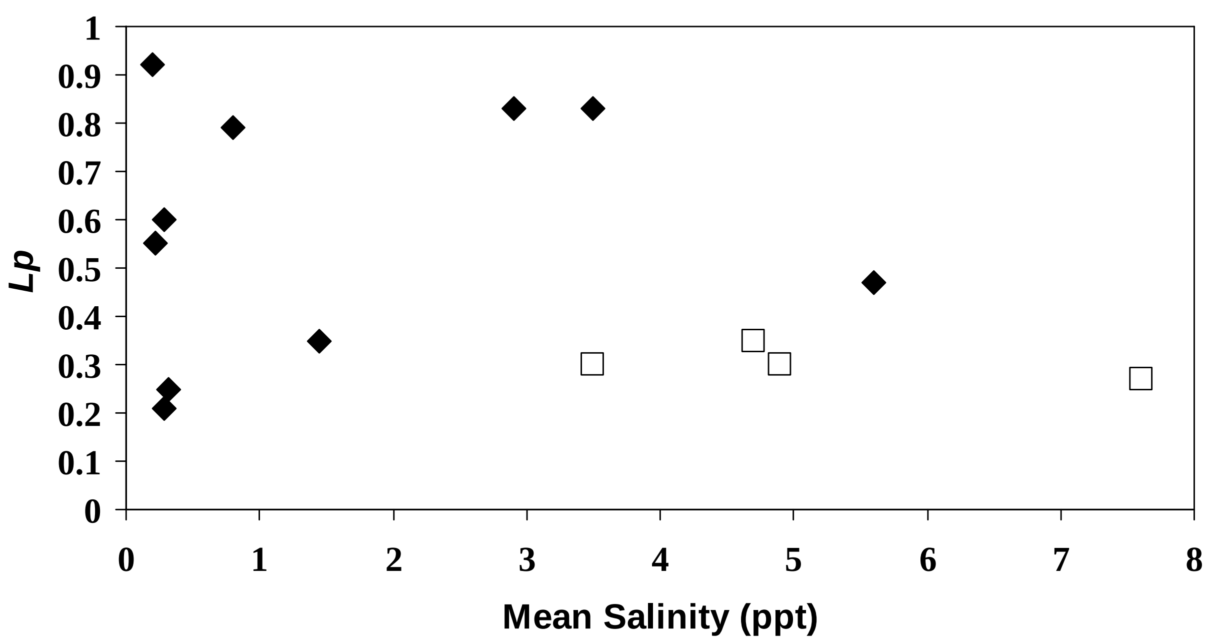

Figure 17. Number (N) of estimates of proportion of plankton tows with yellow perch larvae (Lp) falling within a category during 1965-2007. Severn River is omitted due to possible suppression of Lp due to factors related to impervious surface.

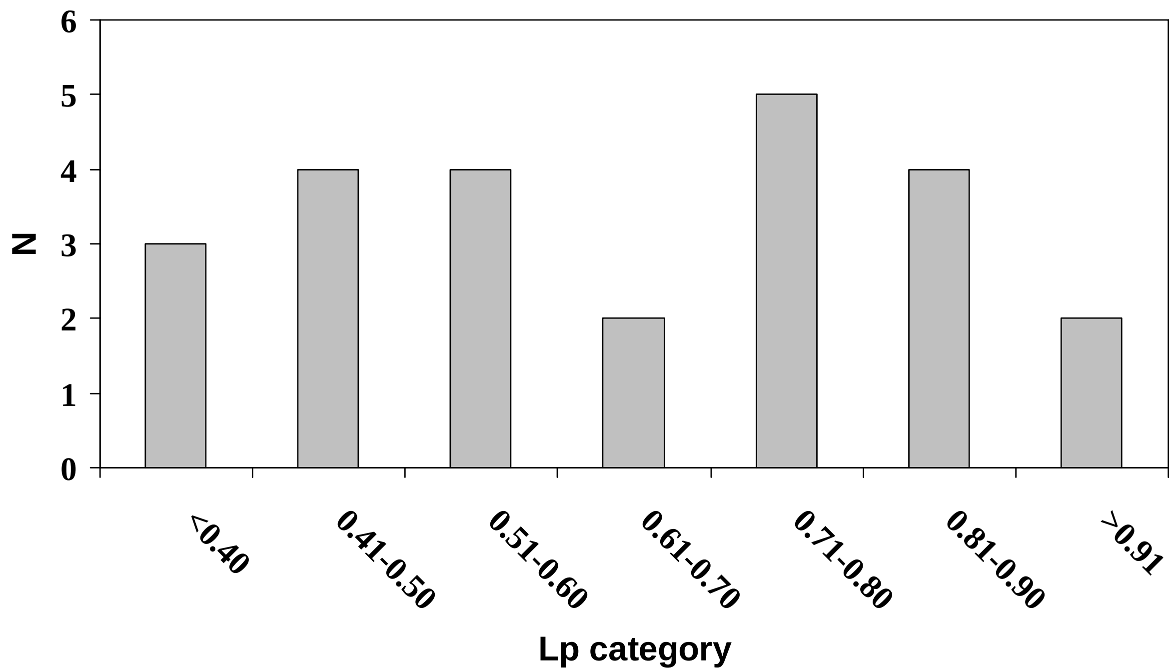

Figure 18. Ichthyoplankton sites sampled in the Bush River historically and recently.

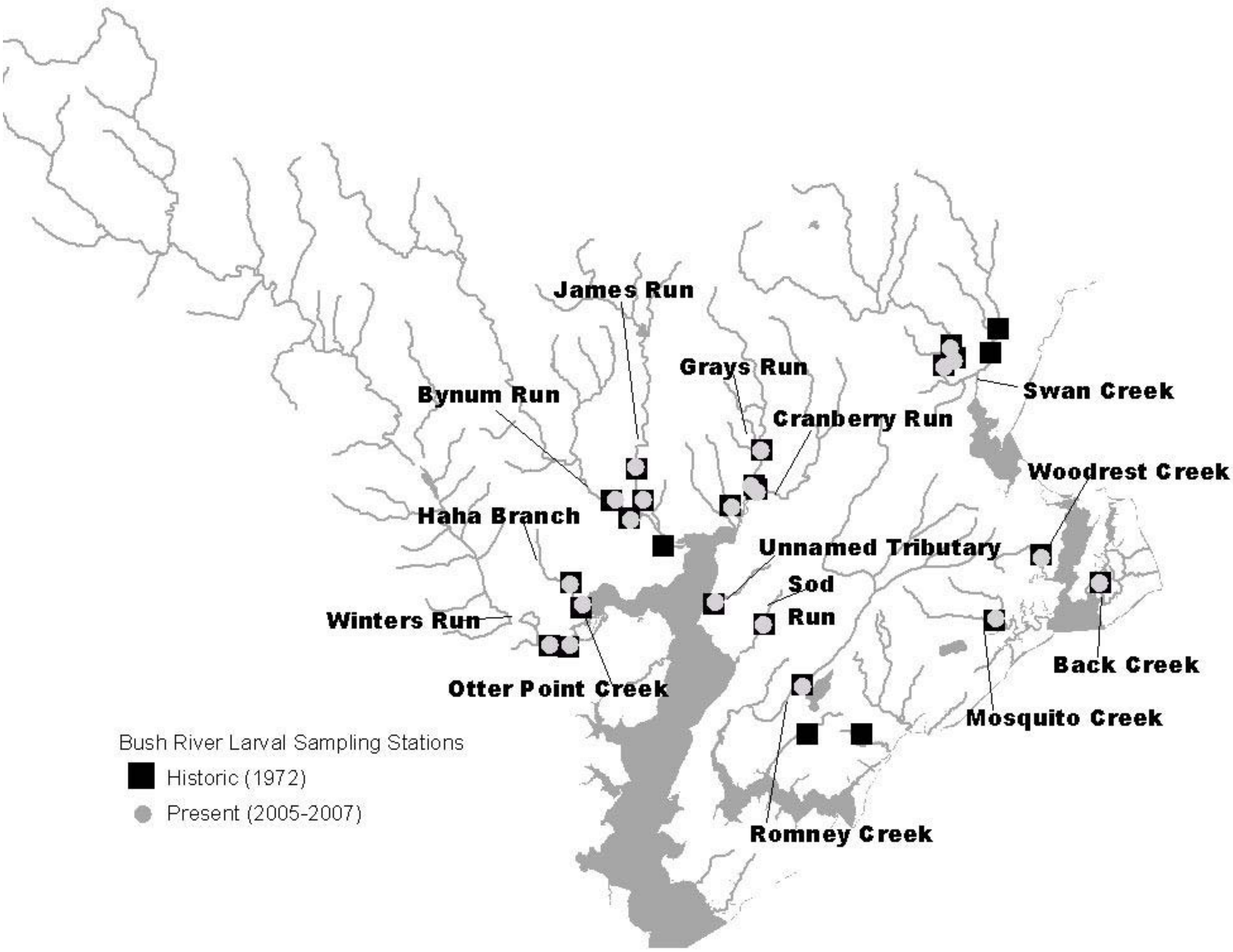

Figure 19. Bush River white perch egg and larval historical presence compared to presence in 2005 through 2007.

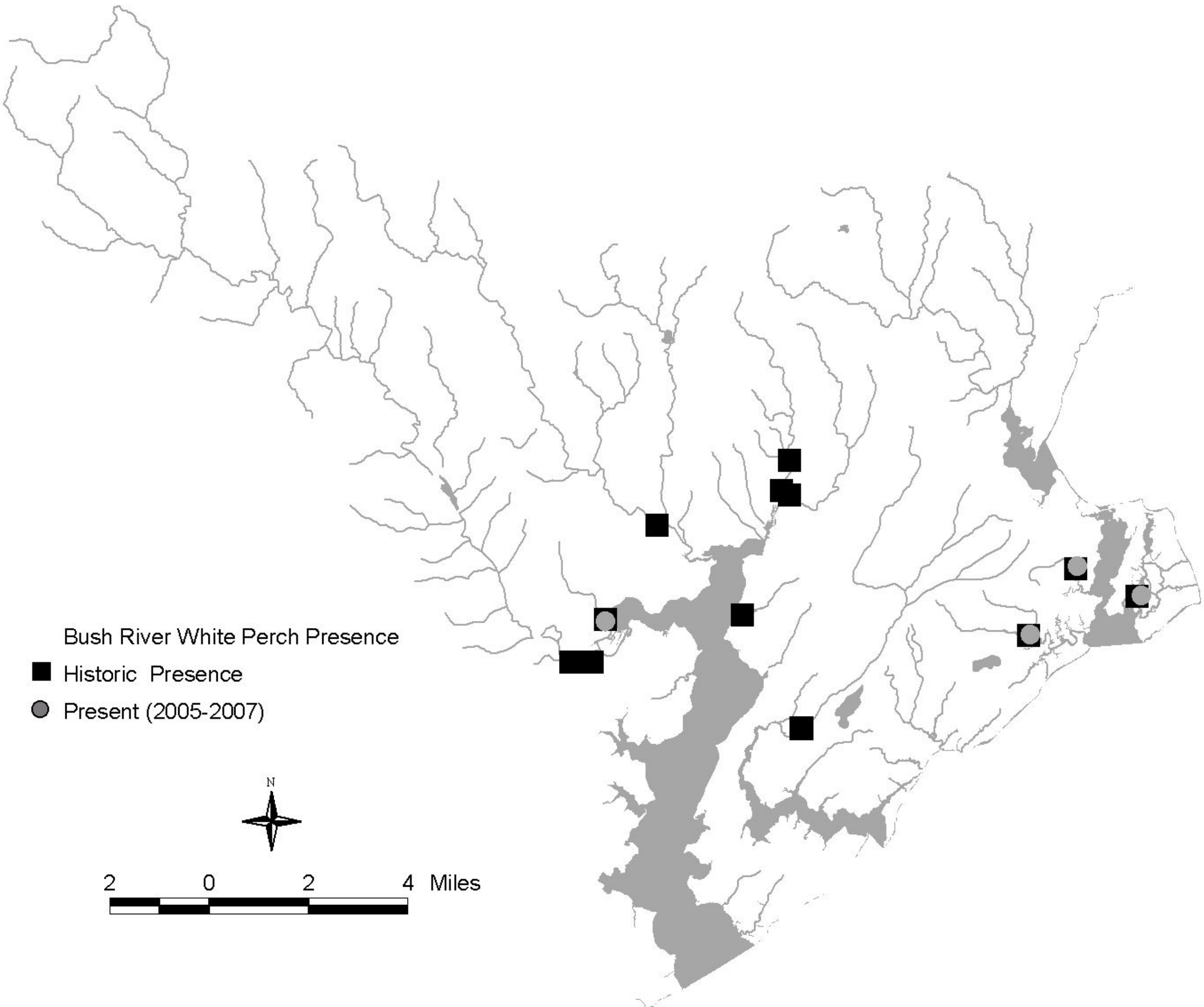

Figure 20. Bush River yellow perch egg and larval historical presence compared to presence in 2005 through 2007.

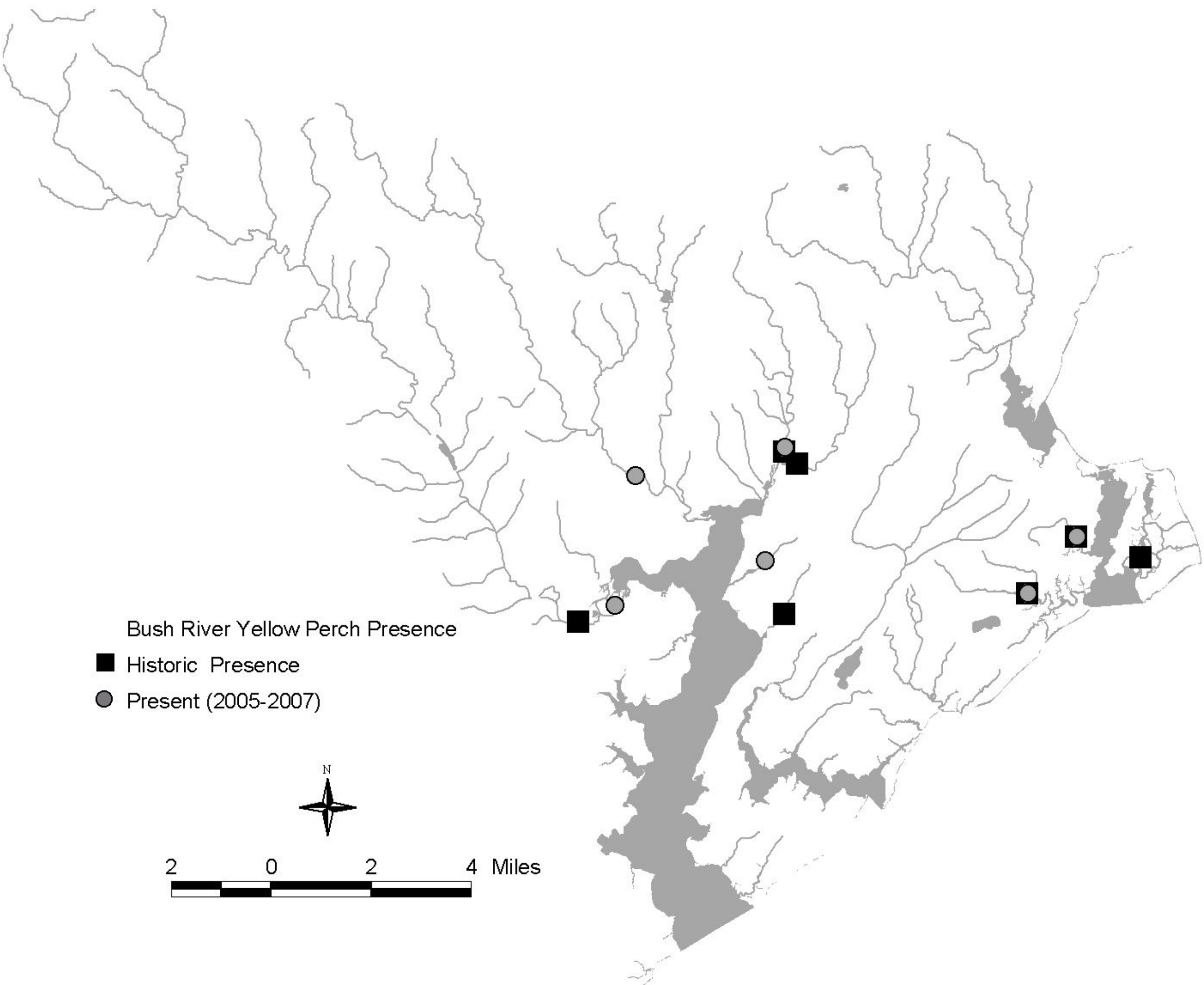

Figure 21. Bush River shad and herring/shad egg and larval historical presence compared to presence in 2005 through 2007.

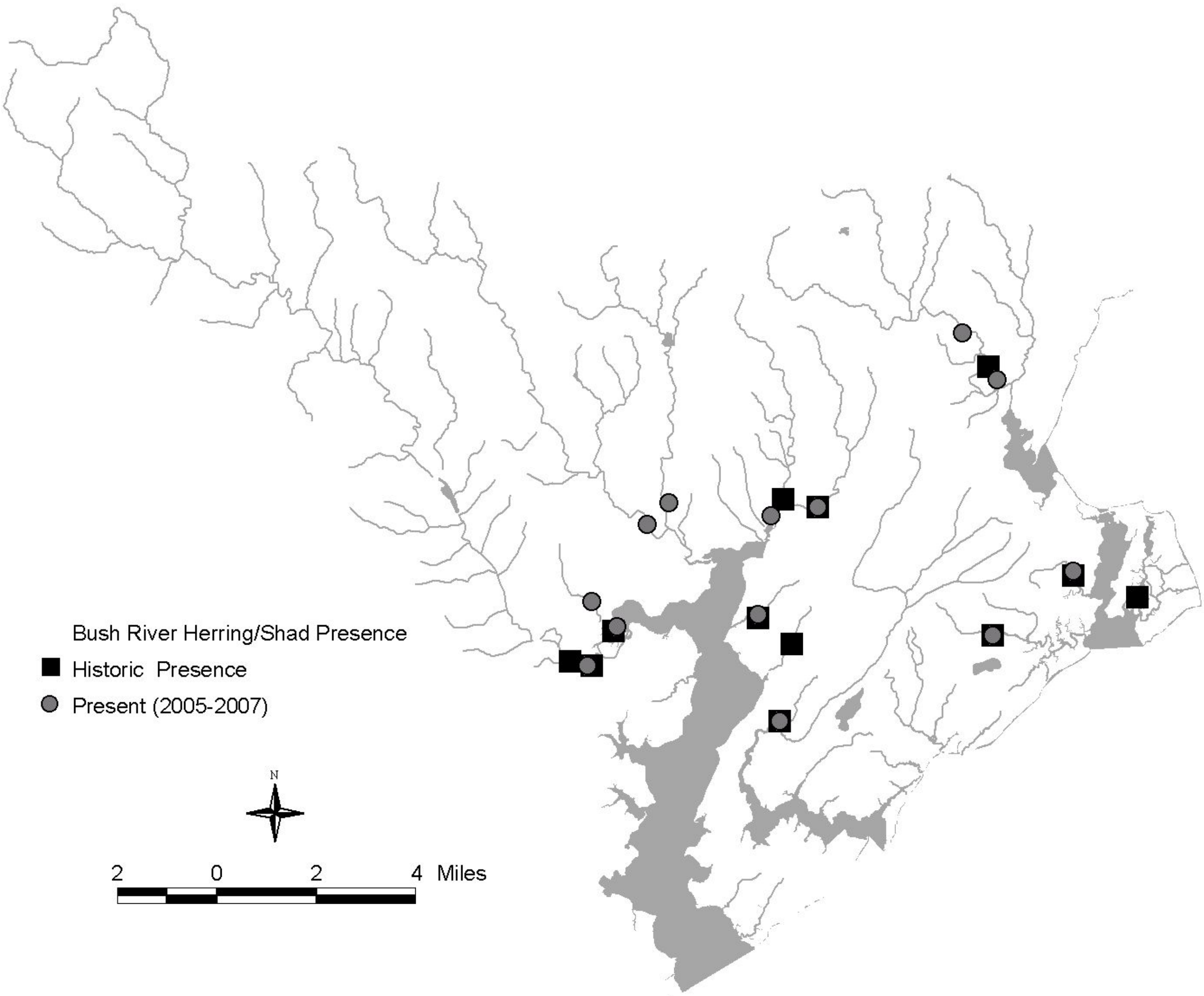

Figure 22. Proportion of stations with target species present by year.

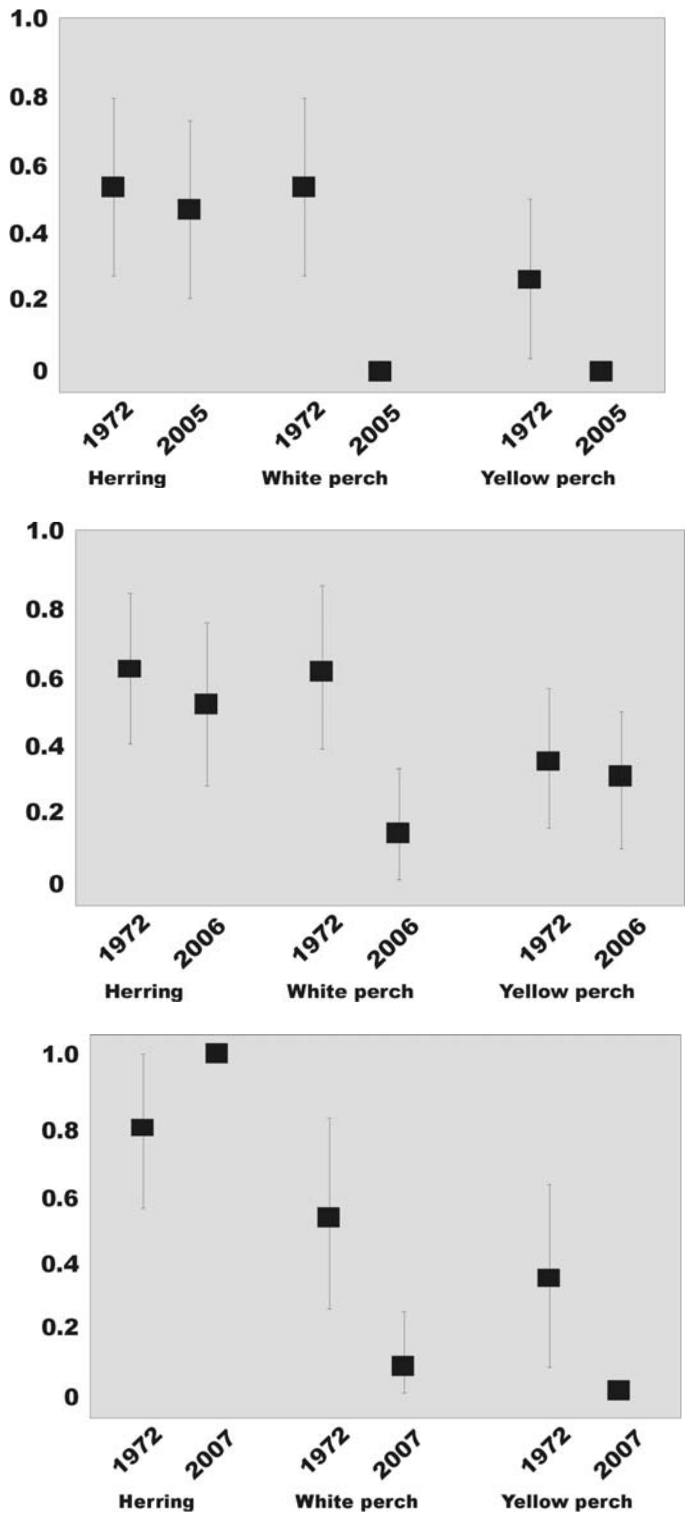

Figure 23. Distribution of temperature data for rivers sampled in 2007. Data include nearshore and offshore water column integrated data. The highlighted area indicates temperatures that are outside of the mean highest acceptable temperature for all target species combined. (Dark bar is the median, gray 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.)

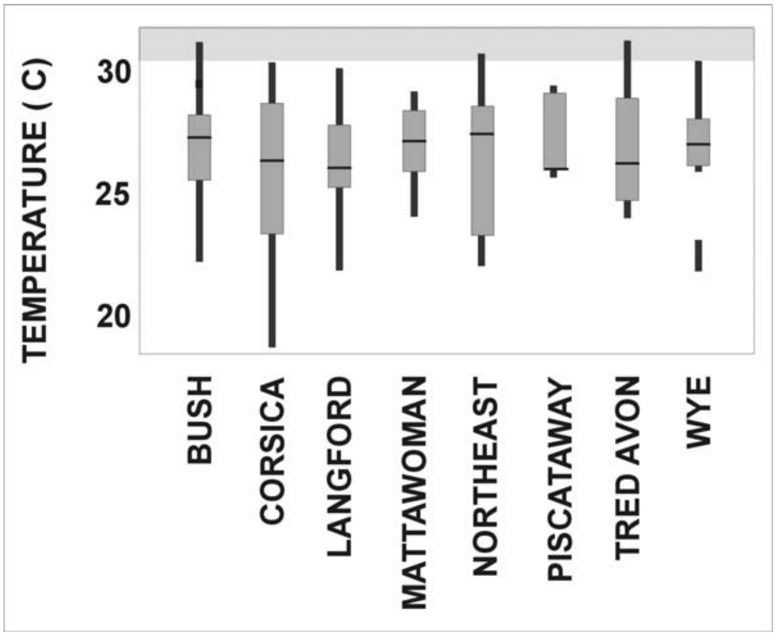

Figure 24. Distribution of salinity data for rivers sampled in 2007. Data include nearshore and offshore water column integrated data. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.) Horizontal line indicates salinity maximum for non-marine target species.

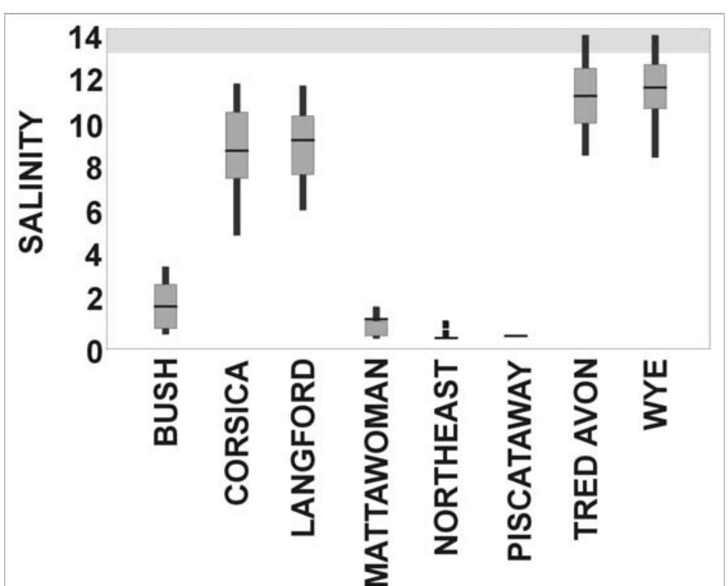

Figure 25. Distribution of dissolved oxygen data for rivers sampled in 2007. Data include nearshore and offshore water column integrated data. The highlighted area indicate dissolved oxygen concentrations below the 5.0 mg/L threshold. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

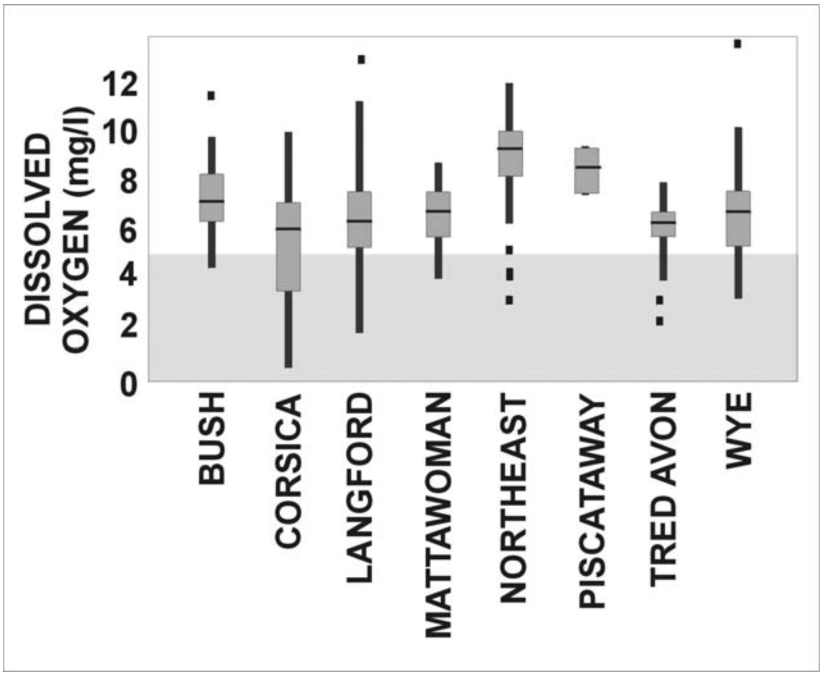

Figure 26. Distribution of bottom dissolved oxygen for rivers sampled in 2007. The gray shaded area represents concentrations below the 5.0 mg/l criteria. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

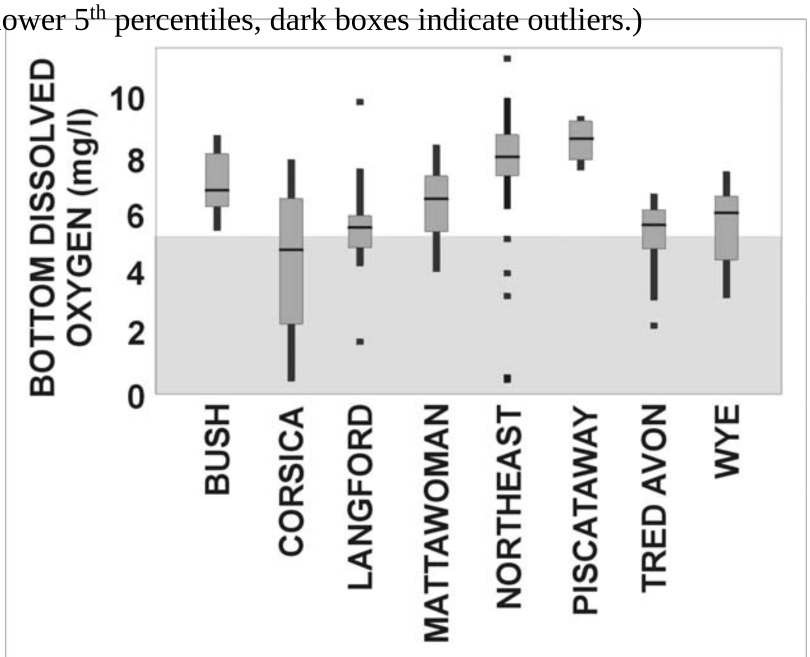

Figure 27. Distribution of Secchi depth data for rivers sampled in 2007. (Dark bar is the median, gray box represents the upper 75th percentile and the lower 25th percentile, black bars indicate the upper 95th and lower 5th percentiles, dark boxes indicate outliers.)

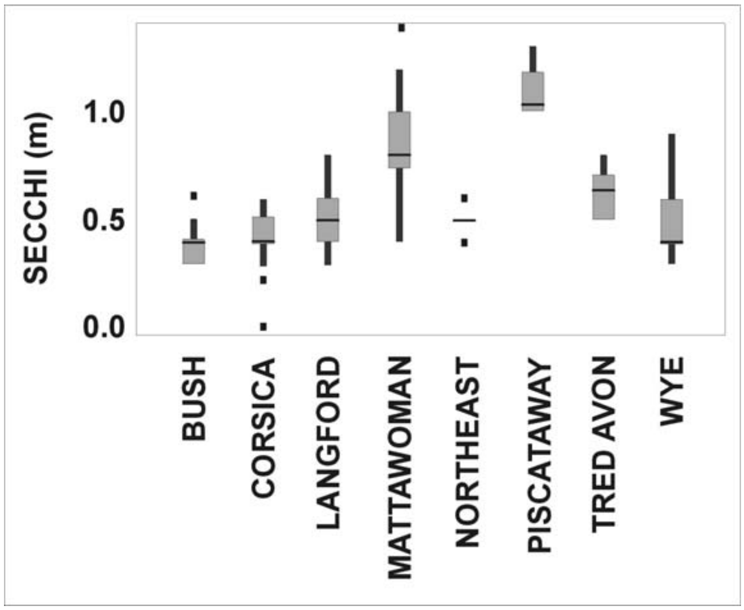

Figure 28. Plots of the residuals of the quadratic relationship of proportion of tows with white perch juveniles or ages 1+ and distance from the spawning area against percent impervious surface for Potomac River tributaries sampled during 2003-2007. Fresh indicates fresh-tidal tributaries (mean salinity < 2 ‰) and brackish indicates salinity > 2 ‰. Two observations are hidden.

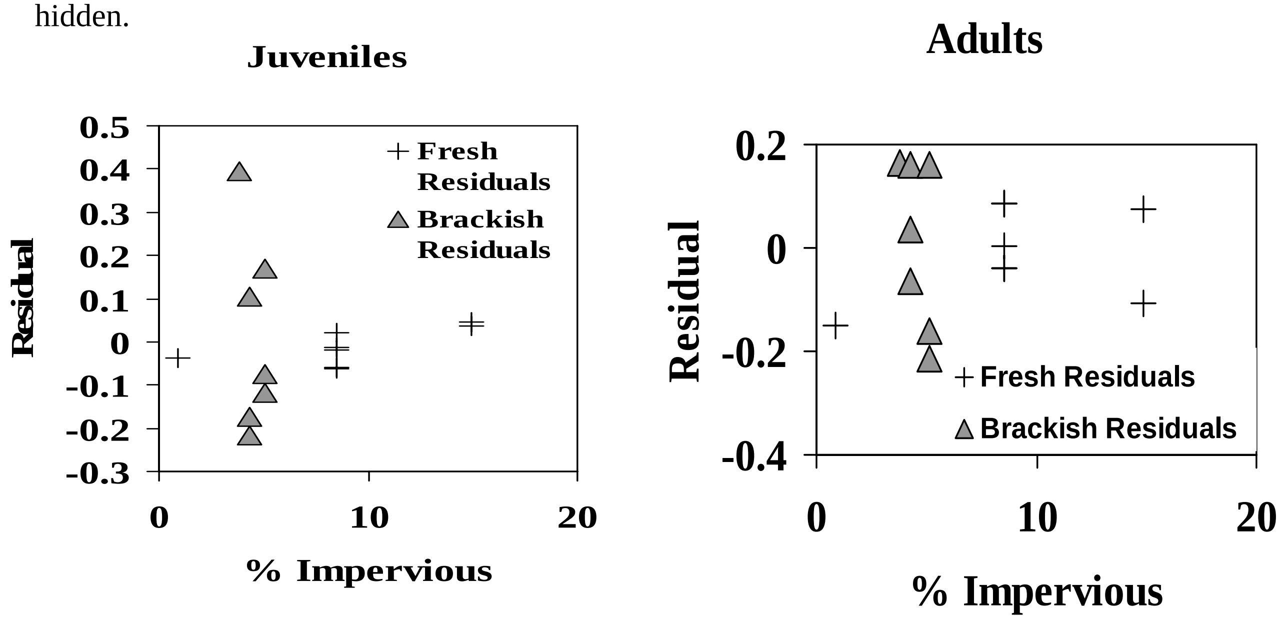

Figure29. Proportion of bottom trawls with white perch juveniles or ages1+ plotted against impervious surface (IS) in Potomac River tributaries, 2003-2007. Brackish indicates salinity is greater than 2 ‰ and fresh is less than 2 ‰.

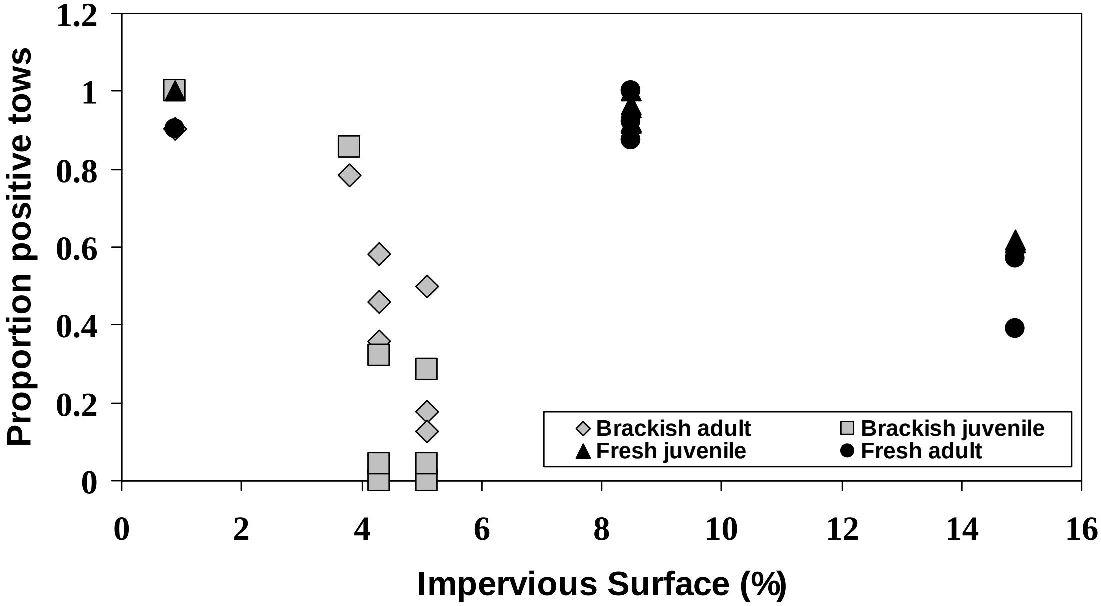

Figure 30. Proportion of bottom trawls with white perch juveniles or ages 1+ plotted against impervious surface (IS) for all tributaries, 2003-2007. Brackish indicates salinity is greater than 2 ‰ and fresh is less than 2 ‰.

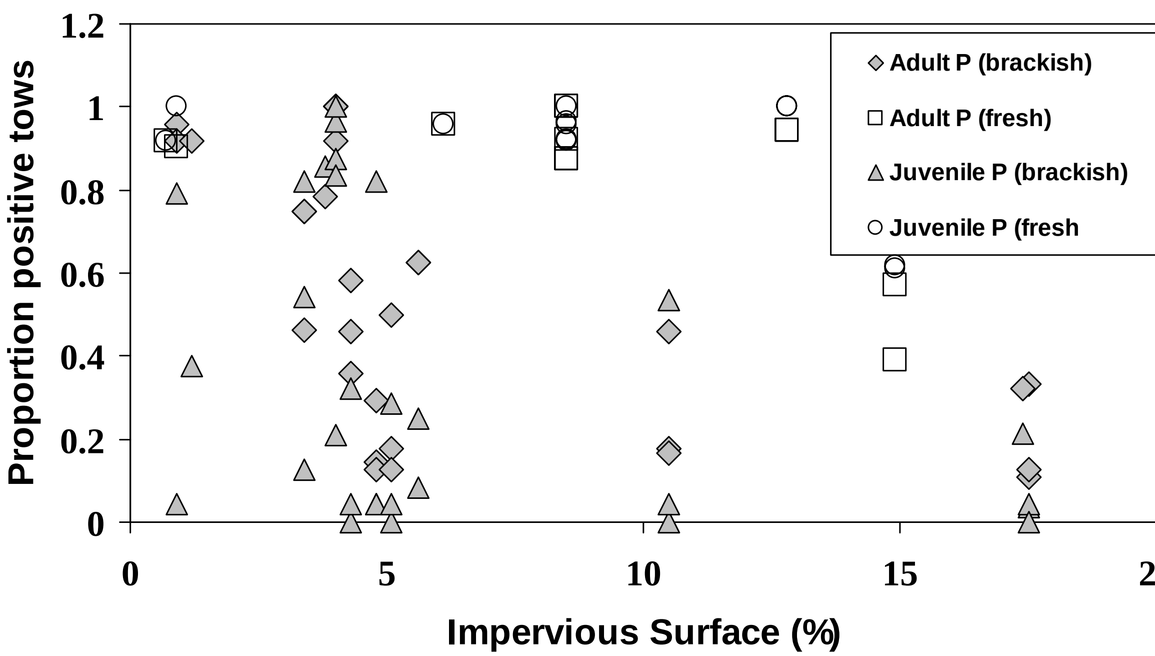

Figure 31. Mean bottom DO during summer sampling plotted against impervious surface for tidal-fresh, brackish, and mixed (fresh-tidal with salinity intrusions) Chesapeake Bay tributaries, 2003-2007. Brackish indicates salinity is greater than 2 ‰ and fresh is less than 2 ‰.

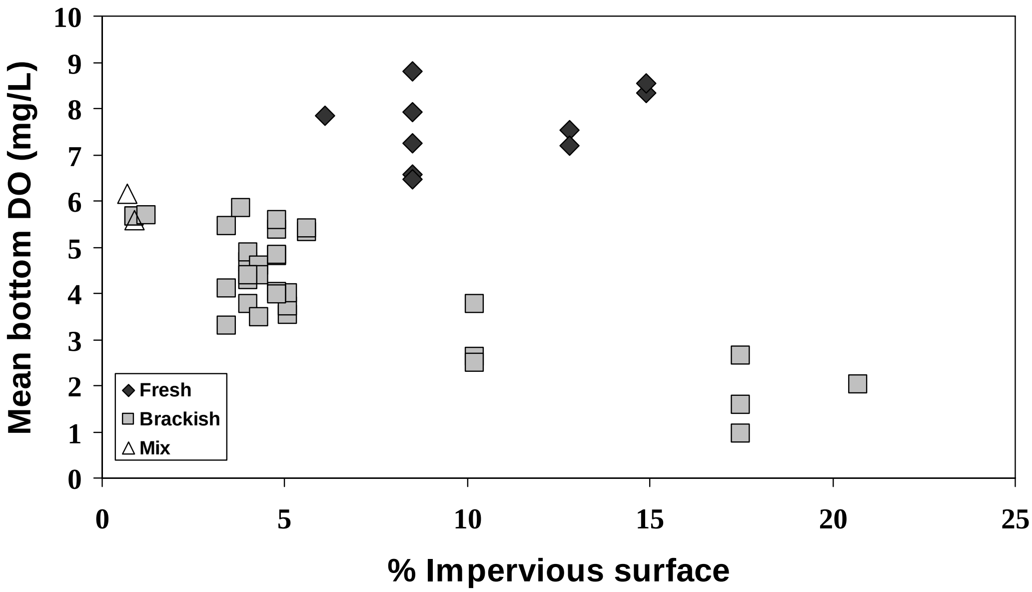

Figure 32. Mean bottom DO plotted against SAV coverage in fresh-tidal and mixed salinity (fresh-tidal with salinity incursions) tributaries, 2003-2006. Fresh indicates salinity less than 2 ‰.