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

STATE: Maryland

PROJECT NO.: F-61-R-2

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish and Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2005 through October 31, 2006

Executive Summary

The primary objective of the Chesapeake Bay Finfish and 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. The Survey provides information regarding recruitment, relative abundance, age and size structure, growth, mortality, and migration patterns of various fish 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.

Channel catfish population biomass and fishing mortality were determined using a surplus production model. Recruitment trends were determined from long-term Fisheries Service projects, and biological reference points (BRP's) were determined for *status quo* fisheries (254 mm minimum size limit) and for fisheries managed with a higher minimum size limit (356 mm). The surplus production model provided fits for the Head-of-Bay (HOB), the Chester River, and the Choptank River. The model failed to fit data from the Nanticoke, Potomac, and Patuxent rivers. In the HOB, channel catfish biomass increased from low levels in the early 1980's to a time-series high in 1989. Population biomass declined steadily before bottoming in 2000 at 2.4 million pounds, and then rose to over 4 million pounds in 2005. Uncertainty analysis indicated that there was a 52% chance that channel catfish were overfished, but overfishing has not occurred since 2003. The Chester River channel catfish population showed a similar pattern in that population biomass rose from 1980 to 1991, followed by a more gradual decline to a bottom in 2000.

The population biomass increase from 2000-2005 was more muted in the Chester River

than the HOB, and fisheries were operating at fully exploited levels. The model runs for the Choptank River indicated an increasing channel catfish population biomass from 1980-1989. Population biomass declined to a low in 2000 (299,000 pounds) and increased to only 350,000 pounds in 2005. Fishery dependent indices of abundance for the Nanticoke, Potomac, and Patuxent rivers failed to provide definitive insight on population trends.

Recent juvenile channel catfish recruitment appears poor in the HOB, but there were some strong year-classes noted in the Potomac, Patuxent and Nanticoke rivers. However, the Potomac River juvenile channel catfish relative abundance values are far lower than those seen from 1975-1984. A suite of BRP's was determined from a Thompson-Bell type spawning stock biomass per recruit model and a yield per recruit model. For a *status quo* fishery, potential BRP's ranged from $F_{0.1} = 0.25$ to $F_{25\%} = 0.40$; and for a fishery with a higher minimum size limit (356 mm), BRP's ranged from $F_{0.1} = 0.32$ to $F_{25\%} = 0.83$.

Adult American shad indices including lift GM, hook and line GM and relative population estimates in the Susquehanna River have declined since 2002. 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 indicated poor spawning success and was likely related to decrease abundance of adults. Possible factors of this decline include increased mortality of ocean migrant fish through a directed "bait" fishery, and/or increased predation. Adult hickory shad relative abundance indices in Deer Creek remained stable but in the Nanticoke River indices decreased and were likely driven by low flow conditions and higher salinity. Juvenile sampling caught few hickory shad. Adult alewife herring repeat spawning indices and GM CPUEs in the Nanticoke River have not showed a trend but remain very low. Blueback herring repeat spawning indices and GM CPUEs 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 are low and juvenile indices for both species also remain low for the time series.

Weakfish samples collected from pound nets in 2006 were dominated by smaller fish, as in the previous two years, with mean length being the fourth smallest and the stock Relative Stock Density category ($RSD_{stock)}$ the second highest of the time series. Maryland's instantaneous total mortality estimates were 1.35 and 1.44 in 2006 and 2005 respectively, and were similar to the coastal assessment of 1.4 for cohorts since 1995. Summer flounder mean lengths decreased from the time series high in 2005 to a time series low in 2006 and indicated a shift down to RSD_{Stock}. The 2006 flounder length frequency distribution indicated a bimodal distribution with a large increase in smaller flounder. The 2006 bluefish samples indicated a shift back to smaller fish after an increase in larger bluefish in 2005. Mean length and RSD_{stock} values were similar to those before 2005, with small fish still dominating the population. Atlantic croaker mean lengths decreased in 2006 compared to 2005, but still was the 5th highest of the 14 year time series. RSDs for Atlantic croaker indicated a continued dominance of $RSD_{memorable}$ fish and the time series high of RSD_{trophy} fish in 2006. Instantaneous total mortality in 2006 was 0.31 a slight decrease from 2005. Spot mean length in 2006 was the 4th lowest of the 14 year time series and % jumbo spot continued to decrease. The 2005 juvenile index for spot was the highest of the 26 year time series after several years of below average values.

Resident / premigratory striped bass present in the Chesapeake Bay during the summer – fall 2005, pound net and hook and line commercial fisheries ranged from 1 to 14 years of age. Two year old striped bass from 2003 year-class dominated samples taken from pound nets, contributing 41% of the total sample in 2005. During summer and fall 2005 sampling, four year old striped bass from the dominant 2001 year-class comprised 35% of the commercial hook & line harvest and 35% of the pound net harvest.

The 2005-2006 commercial drift gill net fishery harvest was comprised primarily of four and five and 6 year old striped bass from the 2000, 2001and 2002 year-classes. Age groups 4, 5 and 6 contributed approximately 89% of the harvest while age 7 to 13 year-old fish contributed only 5% of the commercial drift gill net harvest**.** Striped bass present in commercial drift gill net samples collected from check stations ranged in age from 13 to 3 (1993 – 2003 year classes)

The spring, 2006 spawning stock survey indicated that there were 15 age-classes of striped bass present on the Potomac River and Upper Bay spawning grounds. These fish ranged in age from 2 to 16 year old fish. The male component of the striped bass spawning stock was represented by striped bass 18 inches and greater for a total of 13 age-classes (striped bass ages 2 to14) of measurable abundance. Striped bass ages 5 through 16 comprised the female spawning stock. In 2006, 84% of the female spawning stock was aged 8 and older, and the percentage of the overall spawning stock (males and females combined) aged 8 and older was 19.0%. The most recent, available estimate of spawning stock biomass (SSB) for coastal females was approximately 55 million pounds in 2004, well above the target SSB of 38.6 million pounds as determined by the Atlantic States Marine Fisheries Commission.

The result of the 2006 Maryland striped bass juvenile recruitment survey was an arithmetic mean (AM) Juvenile Index (JI) for permanent stations of 4.3. The AM = 4.3 indicated a below average striped bass year-class in Maryland's Chesapeake Bay. A total of 561 juvenile striped bass were collected at permanent stations. The arithmetic mean index for 2006 was less than the survey average of 11.9, which is the average of indices taken from 1959 through 1972. These years have been accepted as a period of general striped bass health and provided a target for stock rebuilding. The Choptank River produced an index of 5.8 striped bass per sample while the Nanticoke River produced an index of 3.2. The Potomac River produced an index of 6.7, and the Upper Bay index was 1.6. Juvenile striped bass occurred in 59% of all samples taken during the survey. This year's results were comparable to results in 2002, when biologists observed similar draught conditions during the spring spawning period. Abundance indices for other anadromous species, such as American shad, were also depressed in 2002 and 2006, supporting the theory that large-scale environmental factors such as low flow conditions may cause low recruitment to anadromous fish species in the Chesapeake Bay.

A total of 13,221 striped bass were sampled during the 2005 – 2006 sampling season and 925 were tagged with USFWS internal anchor tags. A total of 4,574 striped bass were sampled during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise and 4,462 striped bass were tagged. A high reward tag (HRT) study was incorporated into the spring fishery-independent spawning stock study 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 April, 2006. A total of 71 striped bass were scanned for the presence of CWTs and two fish (3% of fish scanned) were found to be CWT positive.

During the 2006 spring striped bass trophy season biologists intercepted 139 fishing trips, interviewed 344 anglers, and examined a total of 464 striped bass. The average total length of striped bass sampled was 923 mm TL (36.3 inches), and the average weight was 8.1 kg (21.7 lbs). The most commonly observed age group in the fishery was 10-year-old fish from the dominant 1996 year-class. Average catch rate based on angler interviews was 2.6 fish per hour, a slight drop from catch rate in 2005 of 3.5 fish per hour. The difference in catch rates between years was not statistically significant. Many fishermen reported a drop in catches after May 10 due to warm weather and rapidly increasing water temperatures.

Spring estuarine and stream anadromous ichthyoplankton collections, and summer seining and trawling were used to investigate impervious surface (IS) reference points for Bay fishes. When confined to 2006 data alone, presence-absence of yellow perch larvae in estuarine plankton tows (L_p) was not sensitive to IS; however, range of L_p in Severn River during 2004-2006 (0.27-0.33; IS > 15%) has been consistently lower than observed during 1965-1990 in reference systems (0.35-0.67; IS < 5%). Sampling and analysis of Bush River stream anadromous fish spawning in 2006 (≈13% IS) was designed to be comparable with 1973 collections (an anadromous fish life stage captured by any technique at least once; IS ≈9%). Presence-absence of anadromous fish spawning in Bush River streams was compared with streams on an adjacent, less developed military installation, Aberdeen Proving Ground (APG); ≈3% IS in 1973 and 2006). Nine of 11 potential stream occupations (site and anadromous species combinations in 1973 and 2002) occurred on APG in 2006, while 8 of 22 occurred in the streams in Bush River. In 1973, 16 of 22 combinations were noted in the Bush River, while 10 of 11 occurred in APG. Proportion of stream drift net samples with anadromous fish eggs or larvae present during 2006 was 0.075 (N = 120; SD = 0.024) in the Bush River and 0.393 (N = 28; SD = 0.092) in APG. Anadromous fish spawning coincided with non-urban land-use in the watershed. White perch spawning was detected at 7 sites during 1973, but was not detected in the Bush River during 2006. Yellow perch and herring spawning was still evident. Water quality in the 4 brackish and 4 fresh-tidal tributaries sampled in summer 2006 appeared adequate to support fish.

The only river that showed signs of impairment was Corsica River, where dissolved oxygen (DO) frequently was measured below the 5.0 mg/L criteria. Seine data appeared conducive for calculating a Shannon-Weiner (S-W) diversity index, but too few species were collected by trawl. Presence-absence of white perch, striped bass and blue crabs in bottom trawls during 2003-2005 was negatively related to impervious surface ($r^2 = 0.28$, $p = 0.0001$) in brackish tributaries. This relationship with impervious surface reflected an underlying strong negative, linear response of DO to IS and a strong asymptotic response of species bottom trawl presence-absence (P_i) to DO levels among these species. P_i rose steadily from near 0 to 0.6 as DO increased from 0 to 5.0 mg/L; P_i remained at 0.6 as DO increased to 8.0 mg/L.

APPROVAL

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ACKNOWLEDGEMENTS

The Maryland Department of Natural Resources (MD DNR) would like to thank the Maryland Watermen's Association, and commercial captains Joseph Rohlfing, William Calloway, and Boo Powley and their crews who allowed us to sample their commercial catches. We also wish to thank RMC Environmental Services personnel for their aid in acquiring tag returns and catch data from the fish lifts at Conowingo Dam. Appreciation is also extended to MD DNR Hatchery personnel, Brian Richardson and staff for otolith analysis of juvenile and adult American shad and to Connie Lewis, Fisheries Statistics, for providing commercial landings. We would also like to express appreciation to Captain John Collier and crew of the *R/V Laidly*, for their assistance during the winter trawl survey.

Striped bass were collected for portions of this study from commercial pound nets owned and operated by A. Bramble, K. Collins, J. Dean, C. Edwards, R. Fitzhugh, T. Hallock, J. Janda, L. Murphy and R. Morlock. Experimental drift gill nets were operated by C. Hubbard and R.Graves.

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PROJECT NO. 1
JOB NO. 1

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

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The primary objective of Job 1 is 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. Six sampling rounds were scheduled from early December 2005 through February 2006. 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.

Data from 2003, 2004, and 2005 were limited. The 2003 survey was hampered by ice conditions such that 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.

Choptank River Fishery Independent Sampling

Six experimental fyke nets were used in the Choptank River to sample four resident species on the Choptank River. 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 16 February 2006 through 31 March 2006 (Figure 2). These nets had a 64mm stretch-mesh body and 76mm stretch-mesh in the wings (7.6 m long) and leads (30.5 m long). Nets were set perpendicular to the shore with the wings at 45° angles.

When fished, net hoops were brought aboard first to ensure that all fish were retained.

Fish were then removed and placed into a tub and identified. All yellow perch and a subsample of up to 30 fish of each target species were sexed and measured. All non-target species were counted and released. Otoliths from a subsample of white and yellow perch were removed for age determination.

Upper Chesapeake Bay Fishery Dependent Sampling

Commercial fyke net catches were sampled for yellow perch during early March from the Bush 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 22 February to 28 April, 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 were sexed, measured for total length and a non-random sample of otoliths were 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 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)= $\forall$*length(mmTL)$^{\exists}$) described weight change as a function of length, and the vonBertalanffy growth equation (Length=$L_4(1-e^{-K(t-t_0)})$) 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 $y = -\log_e (1-L/L_4)$, and $y_c = -\log_e (1-L_c/L_4)$, L is total length, L_c is the length of first recruitment to the fisheries and K and L_4 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_4 =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. sites 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 juvenile relative abundance was the geometric mean abundance from all baywide permanent sites, while channel catfish juvenile relative abundance was the geometric mean of all permanent bay-wide sites.

Relative Abundance

Relative abundance of target species was determined as 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 4-6
Yellow perch	Tables 11-14 and Figures 7-10
Channel catfish	Tables 15-17 and Figures 11-13
White catfish	Tables 18-20 and Figures 14-16

Growth

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

Mortality

White perch	Table 26
Yellow perch	Table 27

Recruitment

White perch	Figures 17-18
Yellow perch	Figures 19-20
Channel catfish	Figures 21-22

Relative Abundance

White perch	Tables 28-29
Yellow perch	Tables 30-31 and Figure 23
Channel catfish	Figures 24-25
White catfish	Figure 26

LITERATURE CITED

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

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

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

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

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.

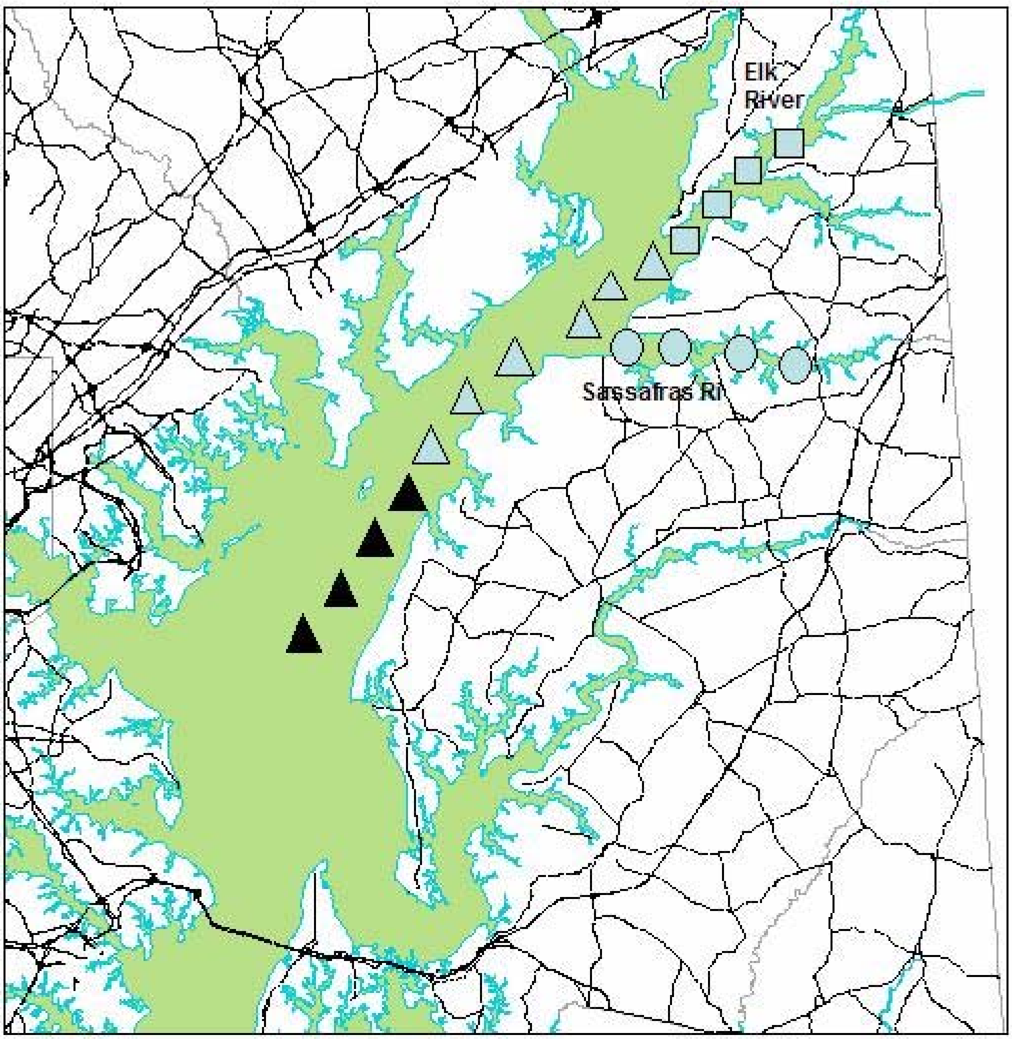


Figure 2. Choptank River fyke net locations, 2006. Triangles indicate sites.

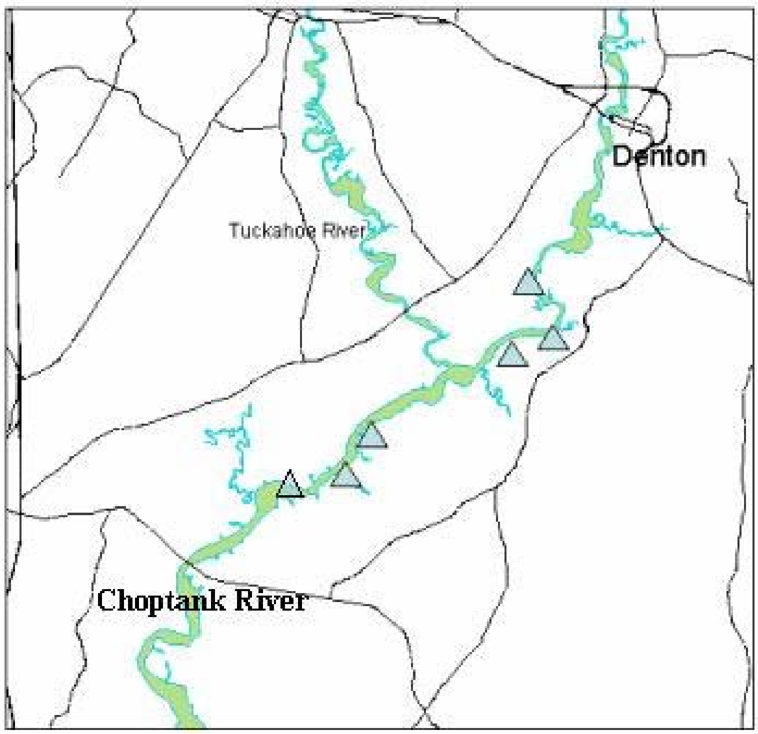


Figure 3. Nanticoke River survey site range, 2006. Circles indicate the range of net locations.

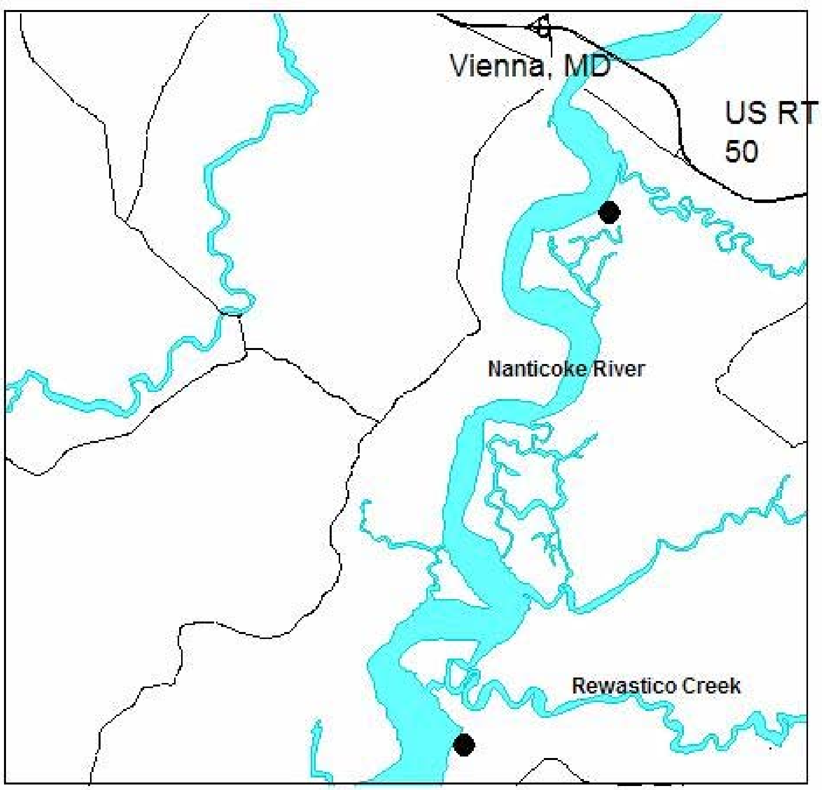


Table 1. White perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2006.

	AGE										
Year	1	2	3	4	5	6	7	8	9	10+	total
2000	1730	4972	2551	3160	1992	2011	3011	244	450	236	20,356
2001	3848	7972	8886	3834	2531	1013	943	1776	261	261	31,326
2002	19	2470	1588	2675	1141	2236	1395	308	656	115	12,603
2003	0	637	2955	382	677	262	693	441	90	298	6,434
2004	NOT SAMPLED										
2005	1072	1882	313	332	177	322	278	67	107	11	4,561
2006	9497	3275	6753	2167	1996	657	410	435	933	169	25,452

Table 2. White perch catch at age matrix from Choptank River fyke net survey, 2000 – 2006.

	AGE										
Year	1	2	3	4	5	6	7	8	9	10+	total
2000	0	36	1908	11021	10946	2074	7199	1010	540	0	34,734
2001	0	459	18269	14111	5521	2368	562	788	202	0	42,278
2002	0	339	11286	6602	3108	3133	681	920	566	69	26,703
2003	0	1226	9263	8146	9397	435	6410	1944	942	1038	38,801
2004	0	0	9374	3023	3619	4272	351	2265	776	649	24,329
2005	0	954	4432	8890	5199	2912	978	201	1375	49	24,990
2006	0	270	17964	704	7765	3760	442	487	271	3877	35,538

Table 3. White perch catch at age matrix from Nanticoke River fyke and pound net survey, 2000 – 2006.

	AGE										
Year	1	2	3	4	5	6	7	8	9	10+	total
2000	0	42	593	6074	6471	2813	1942	365	81	0	18,382
2001	0	0	681	796	3262	1822	689	785	94	38.3	8,167
2002	0	5	1469	1927	504	2124	1132	632	244	13.5	8,051
2003	0	97	318	2559	1567	446	994	652	180	175	6,989
2004	0	6930	3892	12215	3259	1835	1297	1361	443	886	32,120
2005	0	826	1302	5847	3903	5288	2400	1237	1497	2582	24,882
2006	0	0	5759	3280	5298	3488	3590	1287	861	799	24,404

Table 4. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2006.

	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	1197	38	867	87	182	31	82	19	5	0	2,508
2003	2454	2105	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	1410	1939	686	115	14	10	0	0	0	0	4,174

Table 5. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2006.

	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	8514	86	3148	32	9	8	0	6	12,109
2000	0	329	92	1378	27	140	0	7	0	0	1,973
2001	0	878	1986	102	1139	19	72	2	0	0	4,198
2002	0	334	1336	1169	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	1667	137	416	134	55	140	23	52	15	2,639
2006	0	173	1858	176	395	64	66	42	0	7	2,781

Table 6. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2006.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	total
1999	0	0	1621	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	1000	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	1320	414	73	37	0	26	5	1,920
2006	0	32	476	9	848	245	0	1	10	0	1,621

Table 7. Yellow perch catch at age matrix from Nanticoke River fyke and pound net survey, 1999 – 2006.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	Total
1999	0	10	1072	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

Table 8. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2006. 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

Figure 4. White perch length-frequency from 2006 upper Chesapeake Bay winter trawl survey.

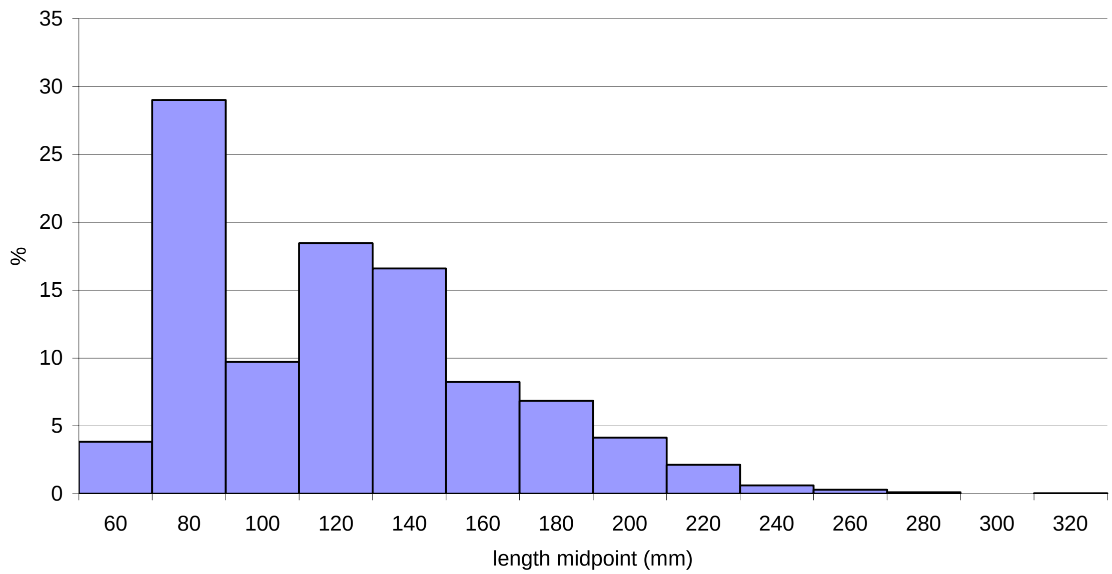


Table 9. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2006. Minimum length cut-offs in parentheses.

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

Figure 5. White perch length-frequency from 2006 Choptank River fyke net survey.

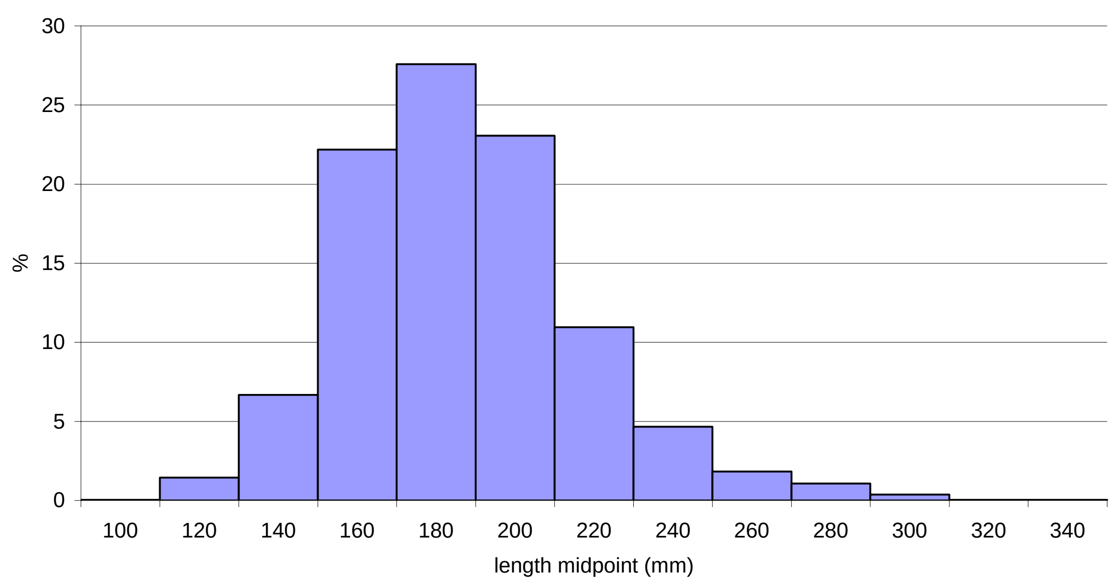


Table 10. Relative stock densities (RSD's) of white perch from the Nanticoke River fyke and pound net survey, 1995 – 2006. Minimum length cut-offs in parentheses.

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

Figure 6. White perch length-frequency from 2006 Nanticoke River fyke and pound net survey.

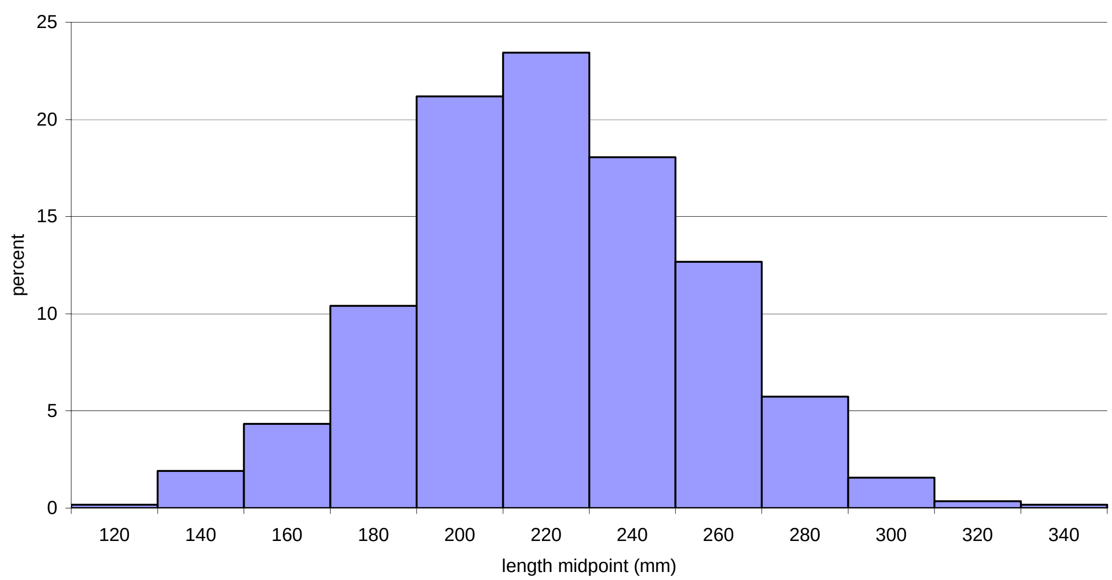


Table 11. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2006. Minimum length cut-offs in parentheses.

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

Figure 7. Yellow perch length-frequency from the 2006 upper Chesapeake Bay winter trawl survey.

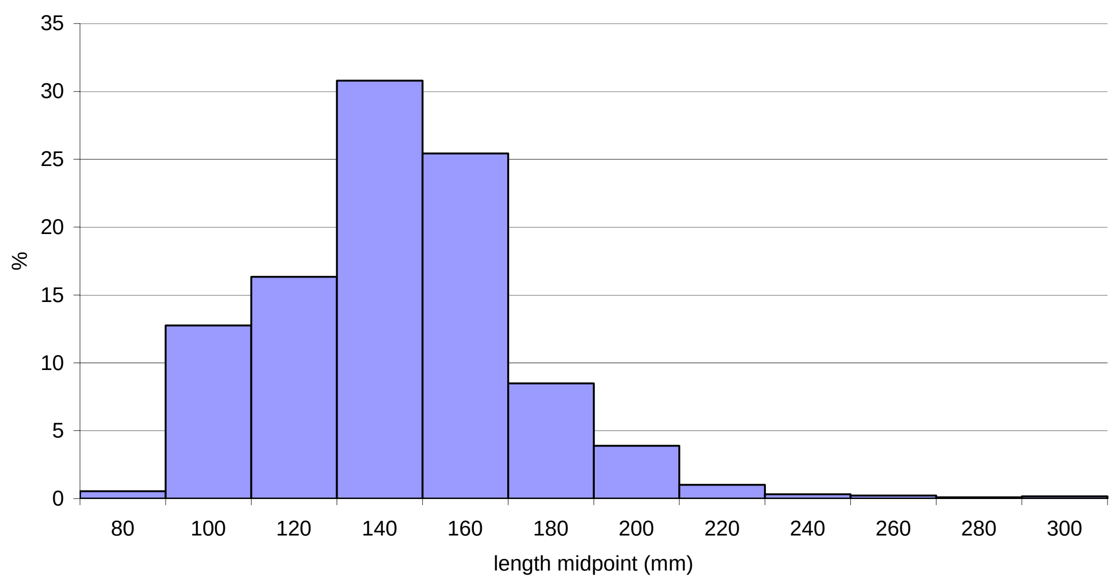


Table 12. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2006. Minimum length cut-offs in parentheses.

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

Figure 8. Yellow perch length-frequency from the 2006 Choptank River fyke net survey.

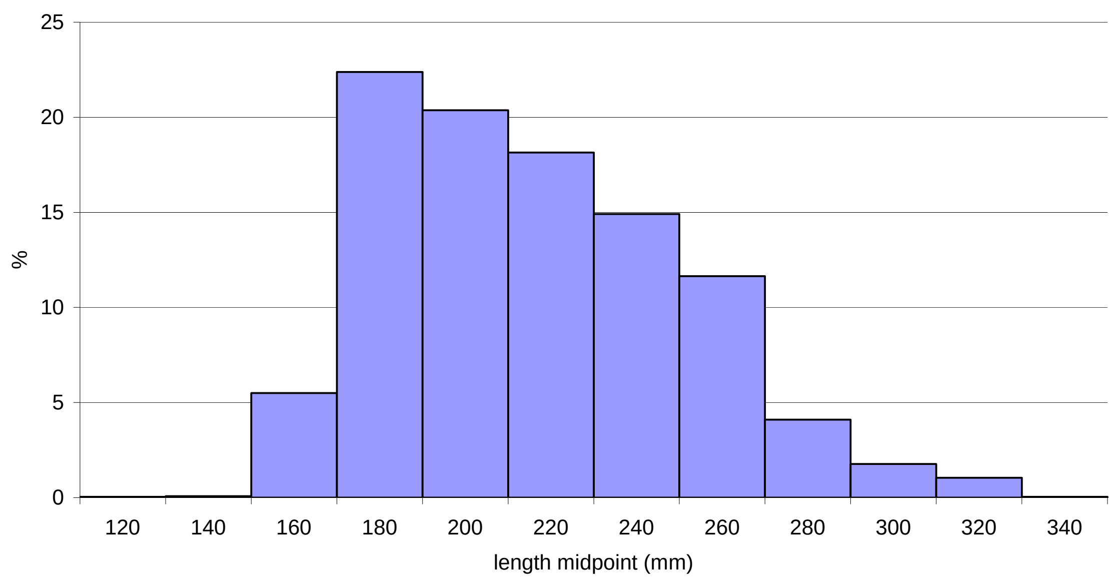


Table 13. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2006. Minimum length cut-offs in parentheses.

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

Figure 9. Yellow perch length frequency from the 2006 upper Chesapeake commercial fyke net survey.

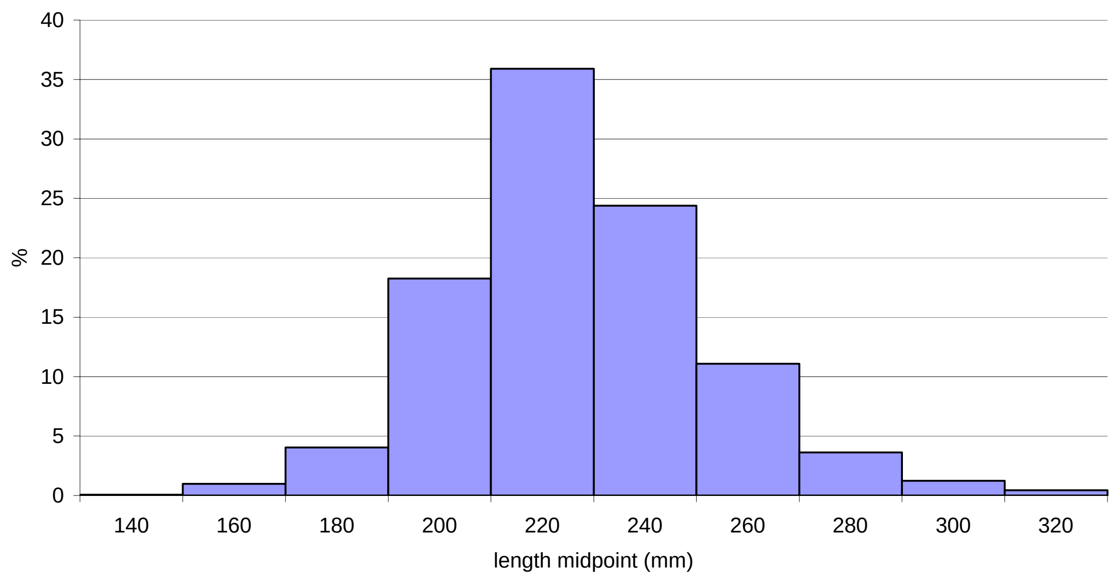


Table 14. Relative stock densities (RSD's) of yellow perch from the Nanticoke River fyke and pound net survey, 1999 – 2006. Minimum length cut-offs in parentheses.

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

Figure 10. Yellow perch length frequency from the 2006 Nanticoke River survey fyke and pound net survey.

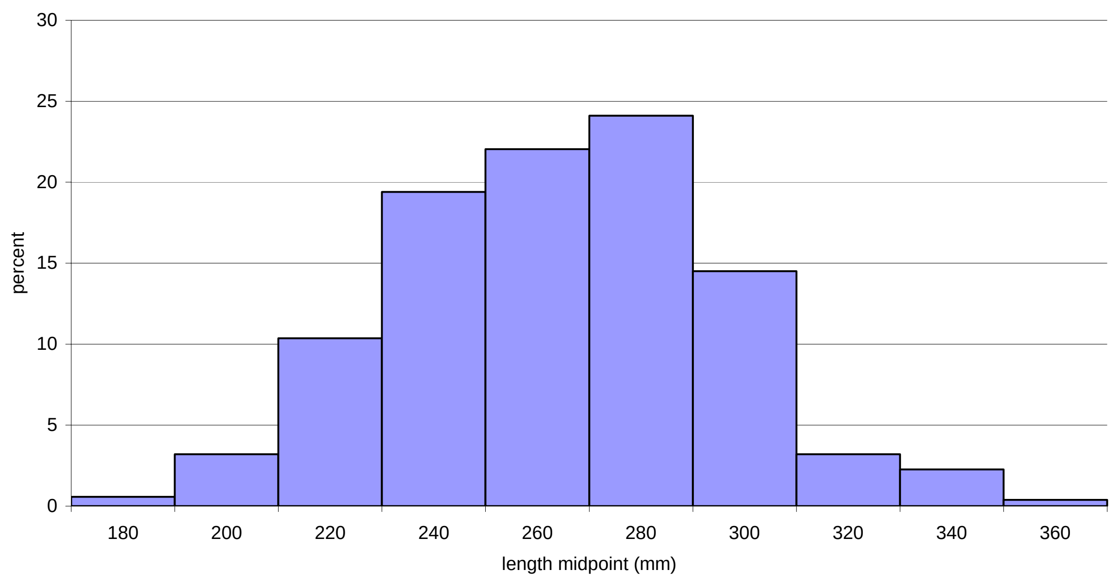


Table 15. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2006. Minimum length cut-offs in parentheses.

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

Figure 11. Length frequency of channel catfish from the 2006 upper Chesapeake Bay winter trawl survey.

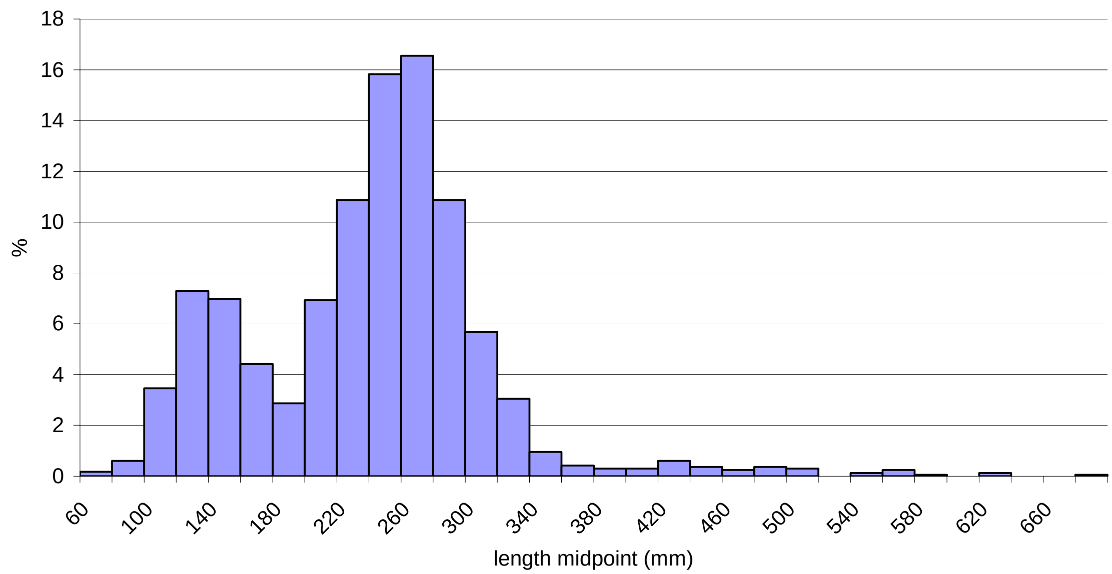


Table 16. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2006. Minimum length cut-offs in parentheses.

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

Figure 12. Channel catfish length frequency from the 2006 Choptank River fyke net survey.

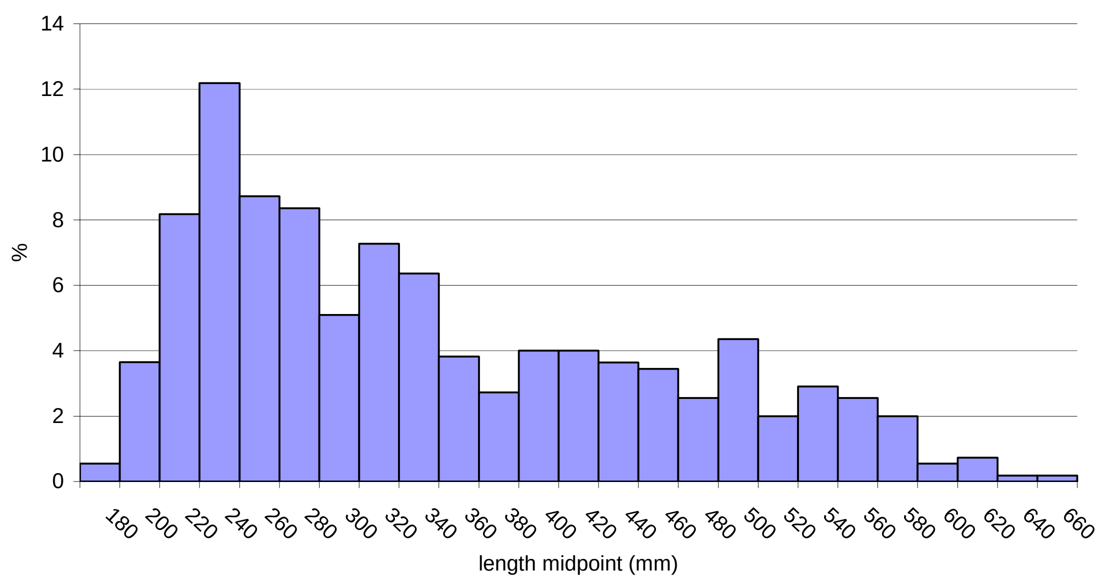


Table 17. Relative stock densities (RSD's) of channel catfish from Nanticoke River fyke and pound net survey, 1995 – 2006. Minimum length cut-offs in parentheses.

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

Figure 13. Channel catfish length frequency from the 2006 Nanticoke River fyke and pound net survey.

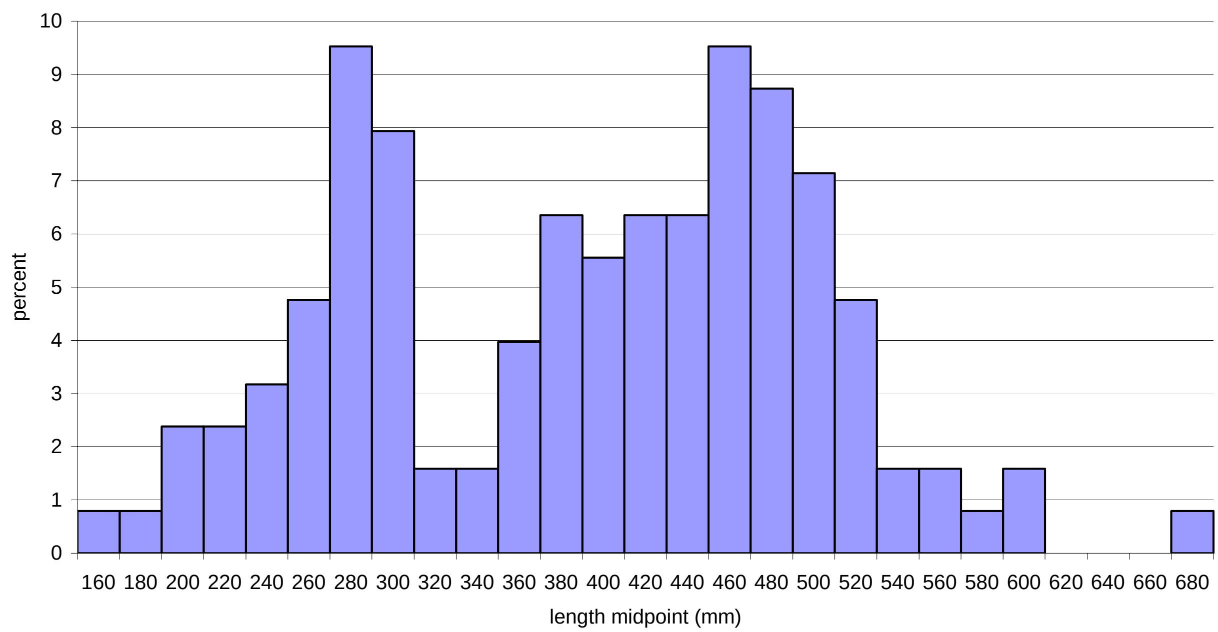


Table 18. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2006. Minimum length cut-offs in parentheses.

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

Figure 14. White catfish length frequency from the 2006 upper Chesapeake Bay winter trawl survey.

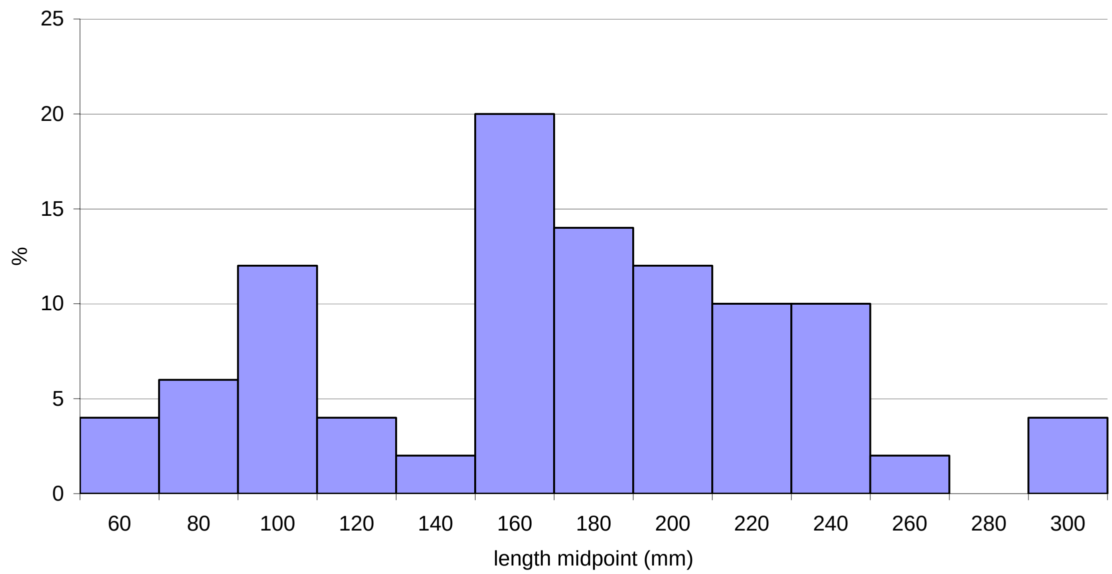


Table 19. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2006. Minimum length cut-offs in parentheses.

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

Figure 15. White catfish length frequency from the 2006 Choptank River fyke net survey.

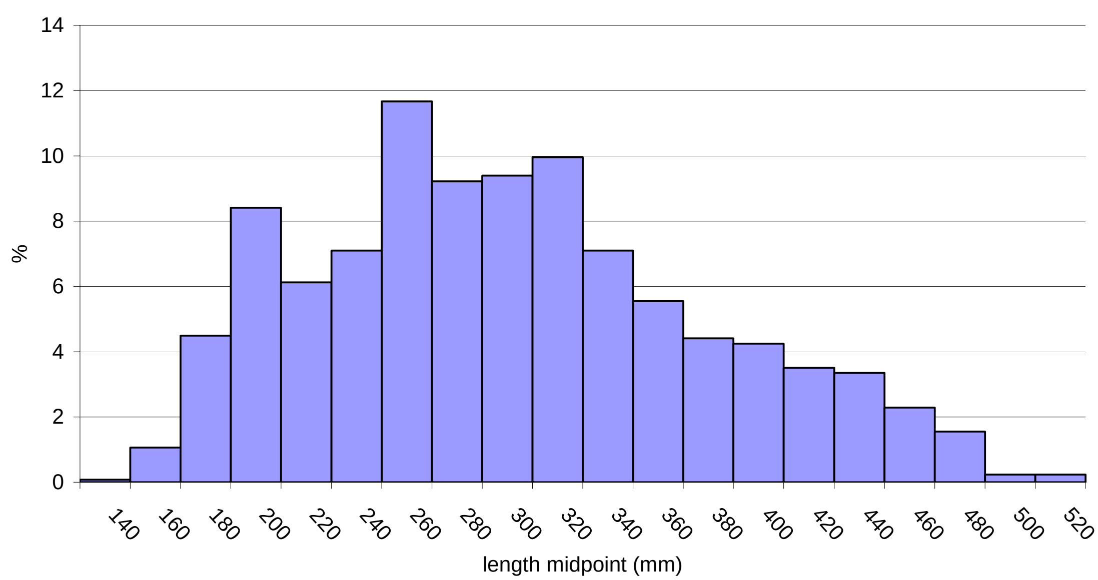


Table 20. Relative stock densities (RSD's) of white catfish from the Nanticoke River fyke and pound net survey, 1995 – 2006. Minimum length cut-offs in parentheses.

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

Figure 16. White catfish length frequency from the 2006 Nanticoke River fyke and pound net survey.

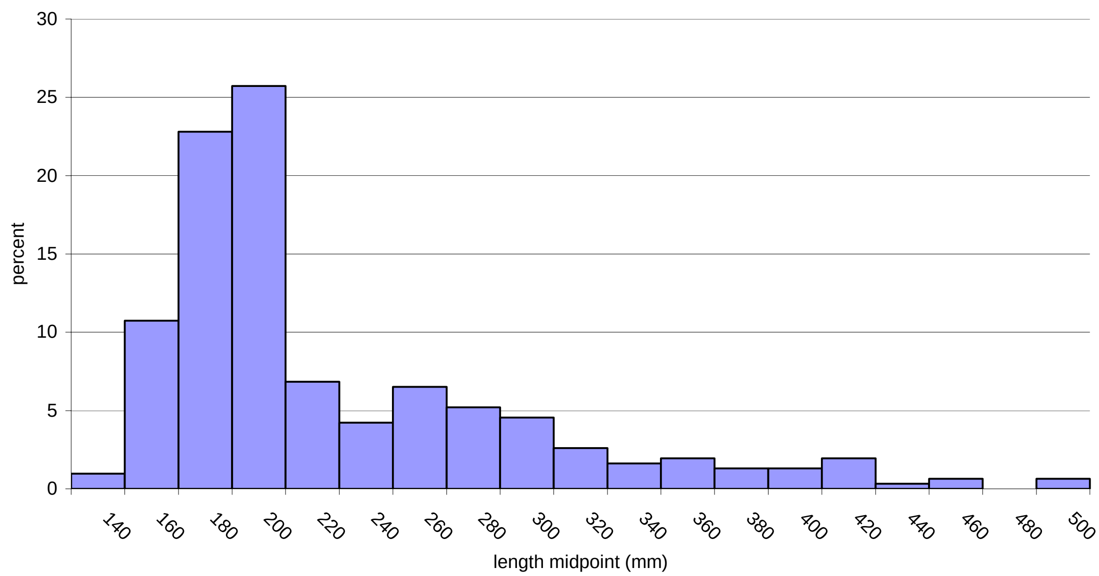


Table 21. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

		allometry		von Bertalanffy		
Sample Year	Sex	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	-1.4
	M	2.1×10^{-4}	2.53	251	0.5	0.56
	Combined	7.0×10^{-6}	3.16	252	0.49	-1.56
2002	F	NSF			NSF	
	M	5.0×10^{-6}	3.2	224	0.34	-1.71
	Combined	NSF		298	0.12	-5.11
2003	F			286	0.37	0.54
	M	NA		247	0.34	-0.42
	Combined			277	0.32	-0.06
2004	F	6.4×10^{-6}	3.17		NSF	
	M	NSF			NSF	
	Combined	4.5×10^{-6}	3.23		NSF	
2005	F	4.8×10^{-6}	3.23	288	0.36	0
	M	4.8×10^{-6}	3.22	374	0.1	-2.1
	Combined	3.8×10^{-6}	3.27	304	0.25	-1.6
2006	F	NSF		285	0.36	0.4
	M	NSF		275	0.42	0.6
	Combined	7.8×10^{-5}	2.69	273	0.4	0.6

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.

		allometry		von Bertalanffy		
Sample Year	Sex	alpha	beta	L-inf	K	t_0
2000	F	1.97×10^{-4}	2.56	272	0.5	1.1
	M	1.4×10^{-4}	2.6	288	0.24	-0.6
	Combined	7.7×10^{-5}	2.72	280	0.36	0.51
2001	F			380	0.1	-2.8
	M	NA			NSF	
	Combined				NSF	
2002	F	1.29×10^{-6}	3.48	328	0.17	-2.5
	M	1.87×10^{-6}	3.4	286	0.22	-1.4
	Combined	1.11×10^{-6}	3.5	327	0.17	-2.2
2003	F			386	0.11	-2.9
	M	NA		263	0.3	-0.21
	Combined			329	0.16	-1.9
2004	F	5.34×10^{-6}	3.22	322	0.25	-0.3
	M	2.36×10^{-6}	3.35	288	0.21	-1.5
	Combined	2.59×10^{-6}	3.35	335	0.18	-1.2
2005	F	2.33×10^{-6}	3.36	313	0.23	-0.53
	M	NSF		313	0.14	-2.65
	Combined	1.5×10^{-6}	3.44	321	0.17	-1.6
2006	F	NA		311	0.22	-1.41
	M			279	.19	-2.54
	Combined			321	0.16	-2.6

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.

		allometry		von Bertalanffy		
Sample Year	Sex	alpha	beta	L-inf	K	t_0
2000	F	NA		277	0.53	-0.2
	M	NA		268	0.26	-1.6
	Combined	NA		264	0.42	-0.9
2001	F	NA		329	0.32	-0.5
	M	NA		308	0.18	-2.2
	Combined	NA		278	0.4	-0.5
2002	F	NA		336	0.23	-2.2
	M	NA		270	0.3	-1.6
	Combined	NA		264	0.5	-0.8
2003	F	NA		264	0.82	0.36
	M	NA		263	0.35	-0.8
	Combined	NA		255	0.5	-0.7
2004	F	NA		306	0.41	-0.4
	M	NA		253	0.34	-1.2
	Combined	NA		259	0.51	-0.5
2005	F	NA		293	0.64	-0.5
	M	NA		244	0.63	0.1
	Combined	NA		258	0.45	-1.6
2006	F	NA		297	.36	-1.05
	M	NA		291	.24	-1.09
	Combined	NA		290	.26	-2

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 or small sample size.

		allometry		von Bertalanffy		
Sample Year	Sex	alpha	beta	L-inf	K	t_0
1998	F	NSF		301	0.32	-1.9
	M	6.7×10^{-6}	3.11	275	0.33	-2.0
	Combined	5.9×10^{-7}	3.57	286	0.38	-1.7
1999	F	4.1×10^{-6}	2.8	272	0.45	-0.9
	M	8.83×10^{-6}	3.06	226	1.47	1.17
	Combined	2.1×10^{-5}	2.92	252	1.07	0.99
2000	F	NSF		272	0.62	0.62
	M	8.39×10^{-7}	3.48	246	0.39	-1.9
	Combined	NSF		254	0.82	0.86
2001	F	NSF		283	0.27	-2.7
	M	9.37×10^{-7}	3.45	230	0.5	-1
	Combined	NSF		240	1.14	0.85
2002	F	NA		329	0.21	-2.9
	M	NA		249	0.38	-1.1
	Combined	NA		266	0.48	-1.1
2003	F	6.68×10^{-7}	3.53	298	0.47	0.03
	M	NSF		246	0.44	-1.1
	Combined	4.14×10^{-7}	3.61	275	0.53	-0.1
2004	F	1.18×10^{-6}	3.43	297	0.75	1.14
	M	NSF		256	0.37	-2.5
	Combined	7.08×10^{-7}	3.52	273	1.04	1.35
2005	F	4.40×10^{-7}	3.62	358	0.25	-0.7
	M	5.61×10^{-7}	3.55	244	0.41	-0.5
	Combined	1.69×10^{-7}	3.79	256	0.64	0.32
2006	F	5.15×10^{-5}	2.75	288	0.34	-2
	M	4.75×10^{-5}	2.73	240	0.41	-2
	Combined	4.72×10^{-5}	2.75	244	0.6	-2

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.

		allometry		von Bertalanffy		
Sample Year	Sex	alpha	beta	L-inf	K	t_0
2000	F			378	0.31	0.1
	M	NA		373	0.16	-2.3
	Combined			370	0.27	-0.4
2001	F			317	0.43	-0.4
	M	NA		276	0.34	-1.8
	Combined			290	0.38	-1.8
2002	F			313	0.52	-0.6
	M	NA		278	0.49	-1
	Combined			299	0.39	-1.7
2003	F			324	0.49	-0.3
	M	NA		273	0.38	-1.4
	Combined			298	0.56	-0.6
2004	F			326	0.43	-1.1
	M	NA		284	0.32	-3.4
	Combined			290	0.68	-0.5
2005	F			332	0.56	-0.1
	M	NA		286	0.68	0.1
	Combined			342	0.35	-1.1
2006	F	NA		313	.73	0.3
	M			297	.57	-0.1
	Combined			301	0.78	0.4

Table 26. Estimated instantaneous fishing mortality rates (F) for white perch. Based on catch curve analysis of ages 6 – 10+.

	2000	2001	2002	2003	2004	2005	2006
Choptank	0.34	0.48	0.25	0.46	0.1	0.58	0.58
Nanticoke	0.42	0.58	0.44	0.31	NR	NR	0.22
Upper Bay trawl	0.09	0.58	0.51	0.13	n/a	0.5	0.12

Table 27. Estimated instantaneous fishing mortality rates (F) for yellow perch.

	2000	2001	2002	2003	2004	2005	2006
Choptank[1]	NR	minimal	0.03	0.05	NR	0.08	minimal
Nanticoke[2]	0.1	0.05	0.06	na	na	na	na
Upper Bay fyke[3]	0.7	0.37	0.39	0.18	0.27	0.37	0.36

[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 17. Baywide young-of-year relative abundance index for white perch, 1962 – 2006, based on Estuarine Juvenile Finfish Survey data. Bold horizontal line=time series average. Error bars indicate 95% confidence interval.

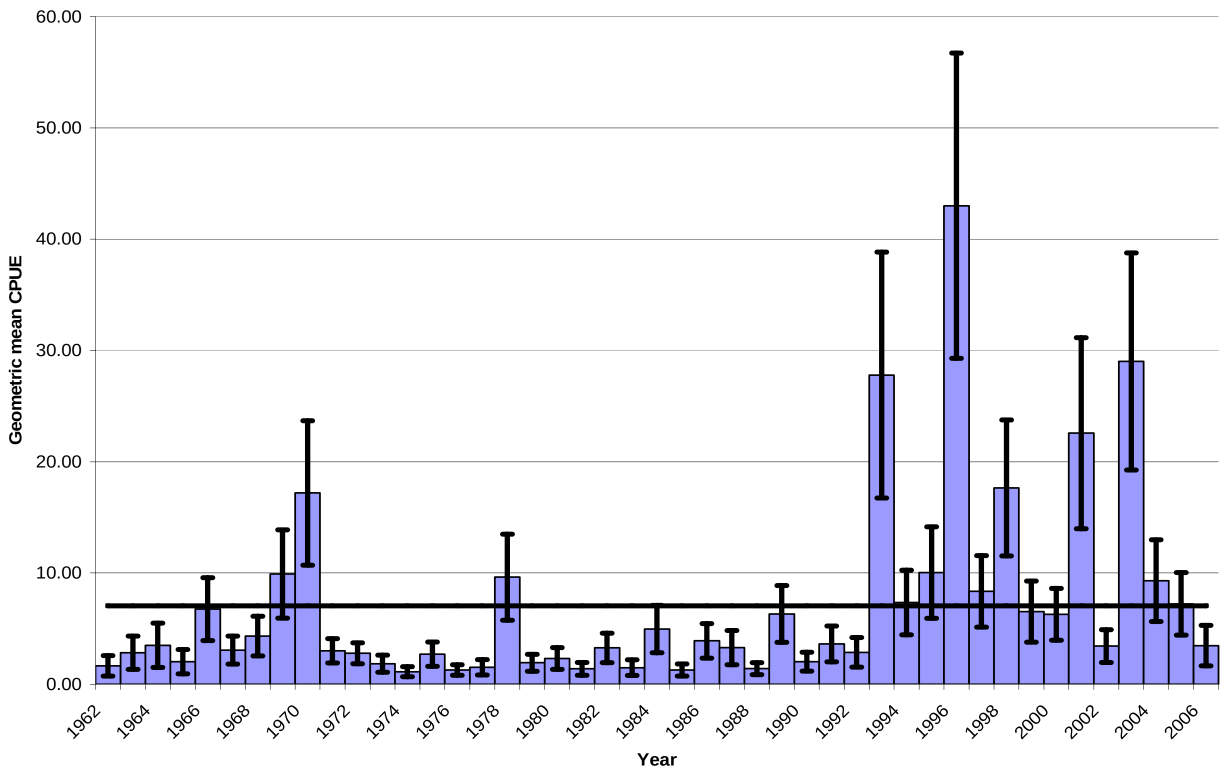


Figure 18. Age 1+ white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

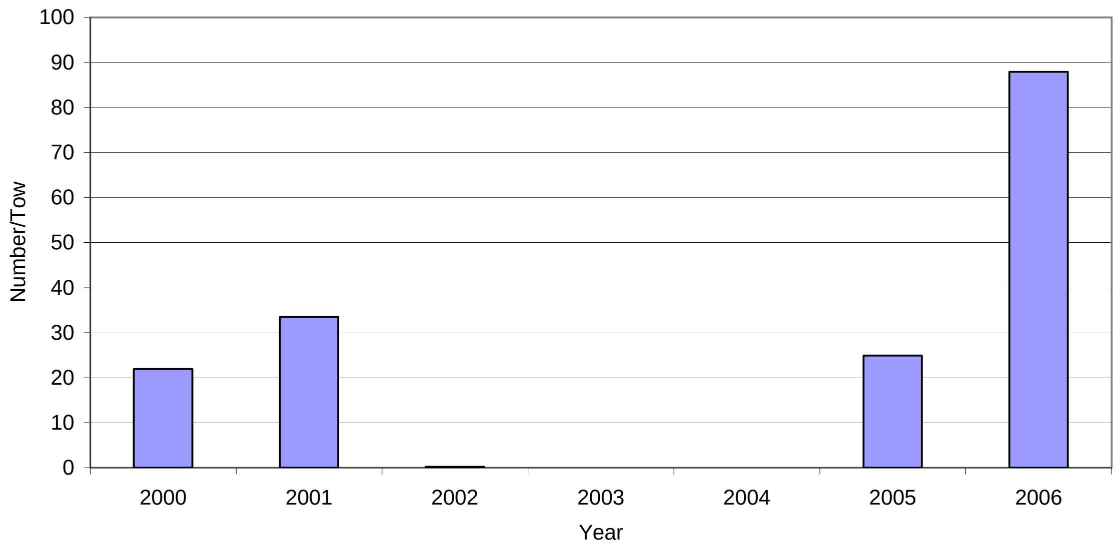


Figure 19. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2006, based on Estuarine Juvenile Finfish Survey data. Bold horizontal line=time series average. Error bars indicate 95% confidence interval.

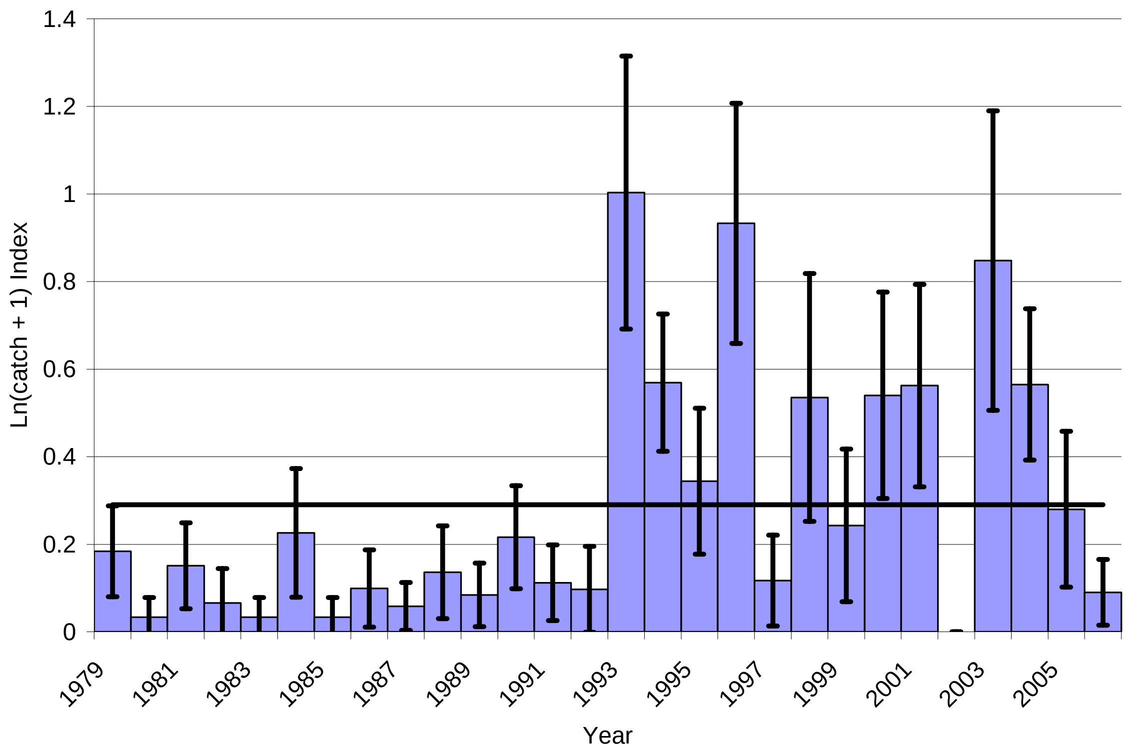


Figure 20. Age 1+ yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

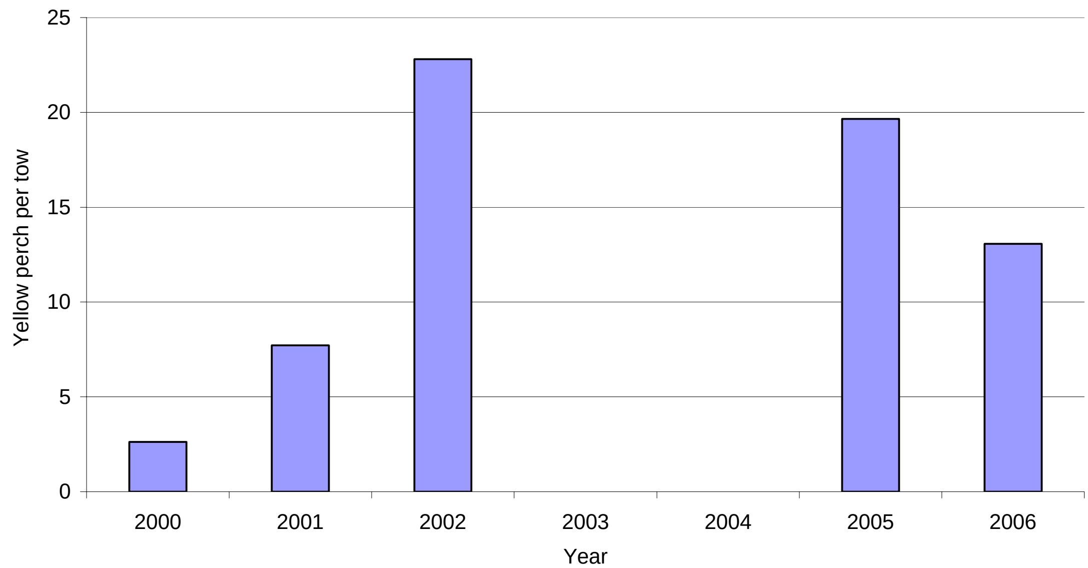


Figure 21. Bay-wide young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average. Error bars indicate 95% confidence intervals.

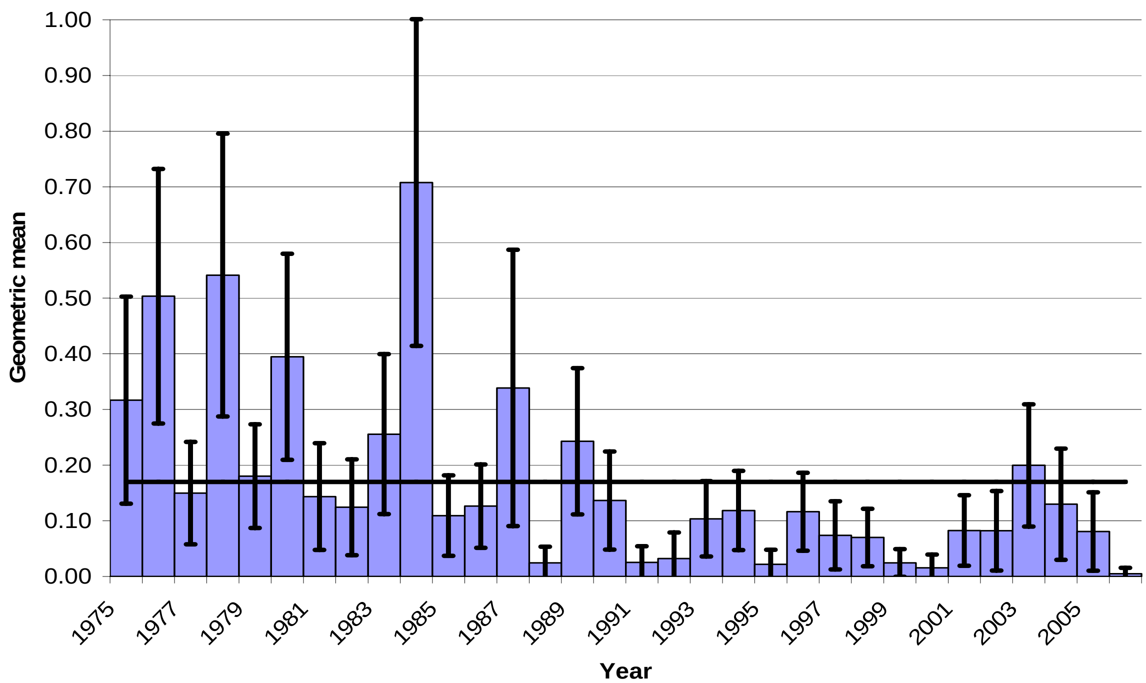


Figure 22. Age 1+ channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

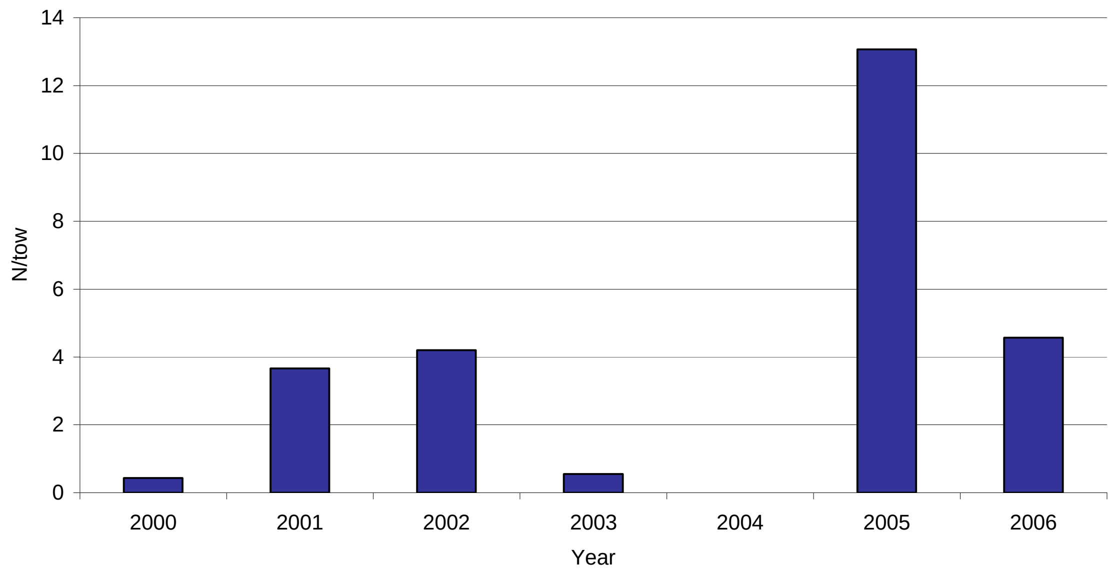


Table 28. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2006.

					AGE							
Year	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2000	21.9	62.9	32.3	40	25.2	25.5	38.1	3.1	5.7	3	257.7	79
2001	33.5	69.3	77.3	33.3	22	8.8	8.2	15.4	2.3	2.3	272.4	115
2002	0.2	22.5	14.4	24.3	10.4	20.3	12.7	2.8	6	1	114.6	110
2003	0	63.7	295.5	38.2	67.7	26.2	69.3	44.1	9	29.8	643.4	20
2004					NOT SAMPLED							
2005	24.93	43.767	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	0.9	1.6	235.7	108

Table 29. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2006.

					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

Table 30. Yellow perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2006.

	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

Table 31. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 1988 – 2006.

	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

Figure 23. Choptank River yellow perch relative abundance from fyke nets, 1988 – 2006. Effort standardized from 1 March – 95% total catch date. Log-transformed trendline statistically significant at P=0.01.

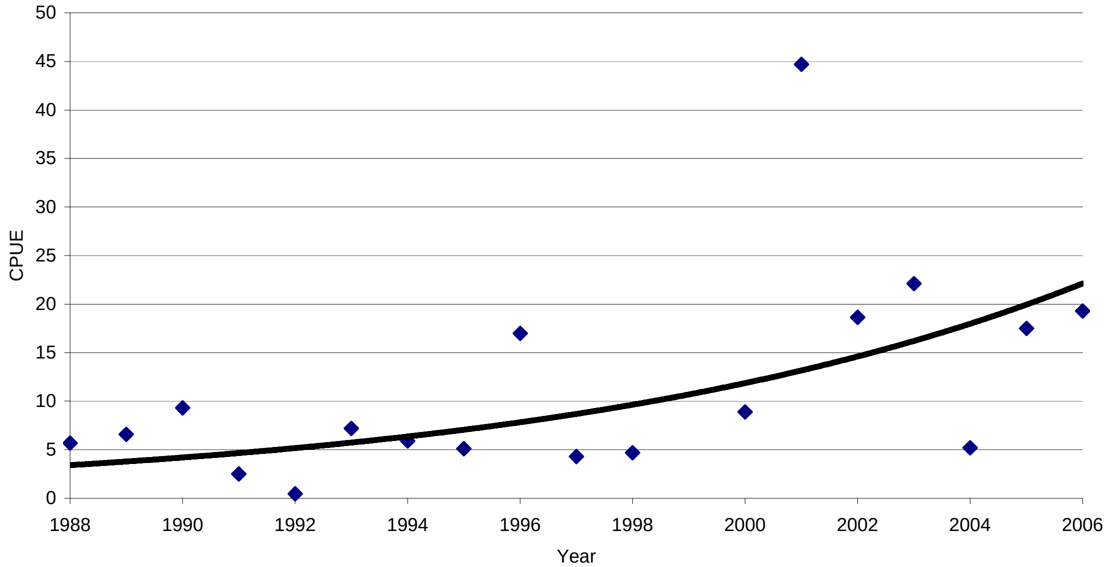


Figure 24. Channel catfish relative abundance (N/tow) from the upper Chesapeake Bay winter trawl survey, 2000-2006. Not surveyed in 2004, small sample sizes in 2003 and 2005.

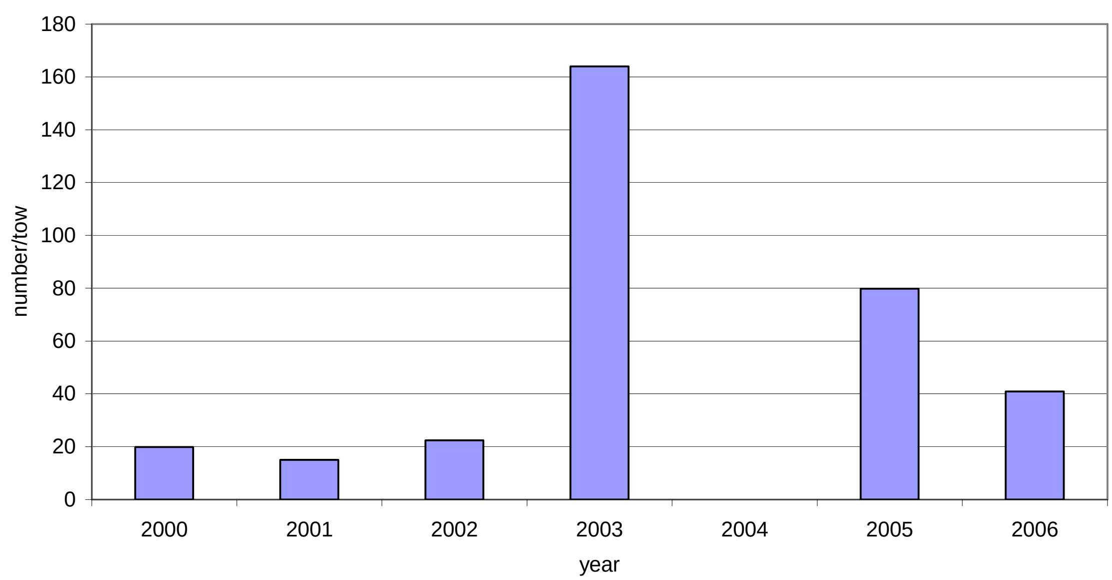


Figure 25. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2006.

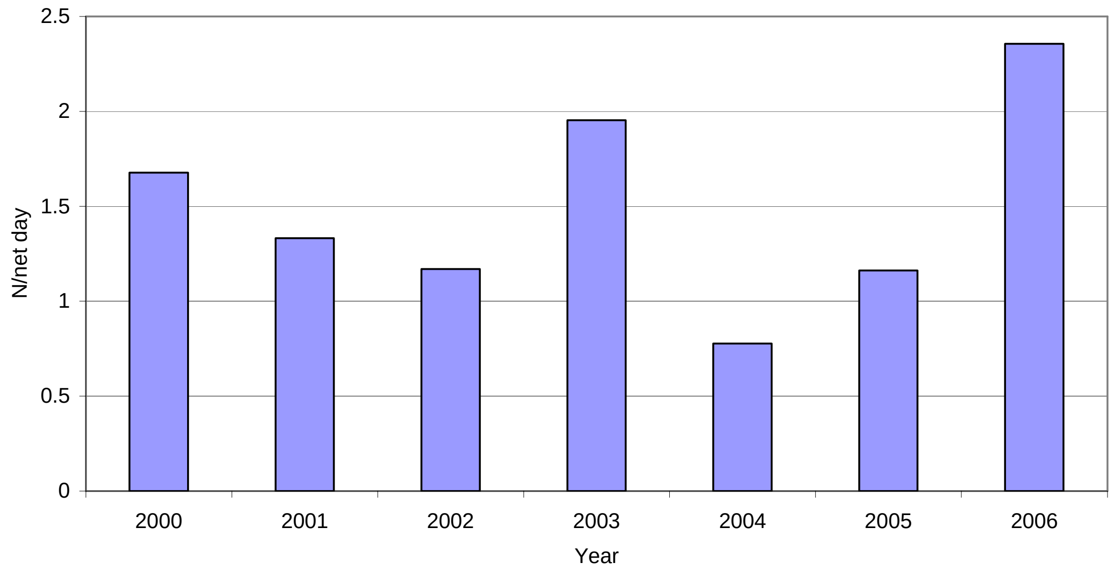
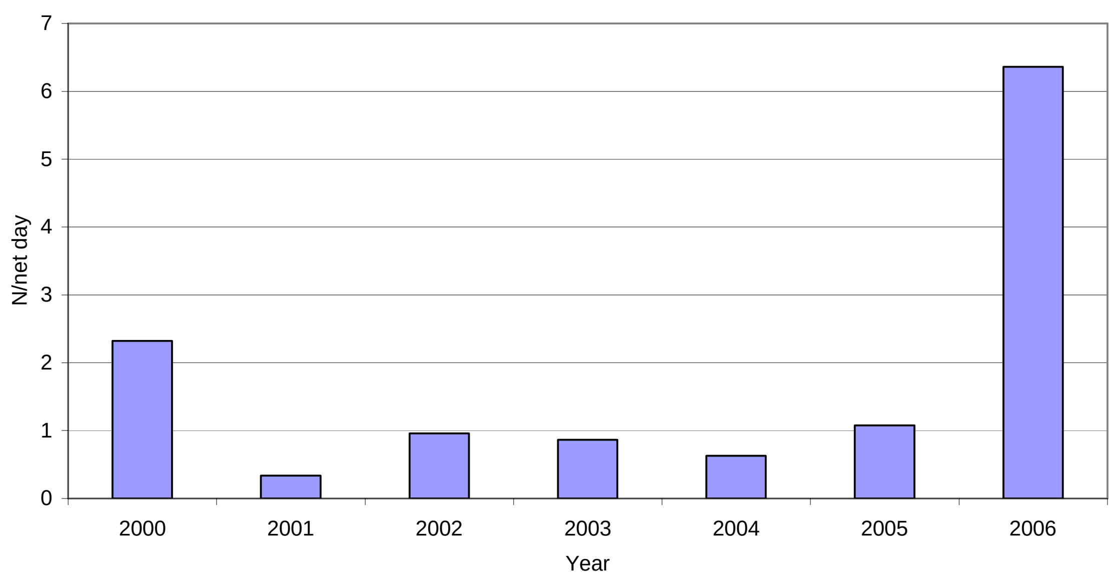


Figure 26. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2006.



PROJECT NO. 1
JOB NO. 2

POPULATION ASSESSMENT OF CHANNEL CATFISH IN MARYLAND, WITH SPECIAL EMPHASIS ON HAED-OF-BAY STOCKS.

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

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

Channel catfish are important to recreational and commercial fishers throughout Maryland's portion of the Chesapeake Bay. Recreational harvest is largely undocumented, and the Marine Recreational Fishery Statistics Survey (MRFSS) harvest estimates are generally imprecise (National Oceanic and Atmospheric Administration, personal communication). A Maryland Department of Natural Resources (MD DNR) creel survey conducted during the spring of 1985 in the lower Susquehanna River estimated that recreational fishers harvested 25,894 channel catfish (Weinrich et al 1986).

The estimated Susquehanna River recreational harvest in 1985 was four times higher than any other year of the survey (1980 – 1984). Commercial channel catfish harvest peaked in 1996 at 2,450,000 lbs. Since then, harvest declined to 742,145 lbs. in 2004, rising again slightly to 799,509 lbs in 2005. At its peak in 1996, channel catfish were the 2nd largest commercial landings by weight of all finfish in Maryland, behind only Atlantic menhaden (3,900,000 lbs). In 2005, channel catfish dropped to the 5th largest commercially harvested finfish.

A pilot assessment of channel catfish by MD DNR was conducted in 1998, however, the report was never finalized. This Job expanded the unpublished report by incorporating additional indices of abundance and a longer time series. Also, the data analysis was approached on a more system-specific basis. Specifically, channel catfish populations were modeled with a surplus production model for the head-of-bay (HOB -- areas north of the Preston Lane Memorial Bridges excluding the Chester River), the Chester, Choptank, Nanticoke, Potomac (including tributaries), and Patuxent Rivers.

METHODS

Landings

Maryland commercial fishery landings were available from the early 1920's, but fishers were only required to report catch as general catfish landings (mixed species, predominately bullheads, channel catfish, and white catfish). Beginning in 1996, commercial fishers were required to report catfish landings as general, channel, or white catfish (*Ameiurus catus)*. The amount of channel catfish reported in the general category for the years 1996 – 2005 was calculated by determining the proportion of channel catfish in the combined white and channel catfish landings. This proportion was then multiplied by the amount of general catfish landed. The estimated annual landings of channel catfish in the general category were then added to the declared channel catfish landings for an estimated total commercial removal. To determine commercial channel catfish landing prior to 1996, the general catfish landings were multiplied by the average proportion of channel catfish of the total declared catfish landings by species for the years 1996 – 2005.

Recreational landings, as estimated by the MRFSS were largely imprecise. However, several years had estimates where the proportional standard error was 30% or less. Estimated harvest from those years was compared to commercial landings to determine the average percentage of recreational landings to commercial landings. The average percentage was then applied to all years of commercial harvest in order to estimate total recreational removals.

Fishery Dependent Relative Abundance Indices

Fishery dependent relative abundance estimates were determined for the fyke net, pot, and pound net fisheries. Effort data for these gear types were available from 1980 – 1984, 1990, and 1992 – 2005. Because commercial catch reporting was done monthly and not on a trip basis, an index of effort was used to standardize landings. This index was the nominal fishing effort, or simply the total number of nets declared by fishers in any month. Only fishers that reported catfish harvest > 500 lbs were used for relative abundance estimates. This eliminated fishers that were not targeting channel catfish. Since recreational harvest estimates were imprecise, no relative abundance estimates for the recreational fishery were developed.

Fishery Independent Relative Abundance Indices

Several fishery independent relative abundance indices were used either qualitatively or included in the surplus production models. Available indices included a spring drift gill net survey in the HOB (Figure 1) and the Choptank River (Figure 2), a MD DNR fyke net survey in the Choptank River (Figure 2), the HOB winter trawl survey (Figure 3), and a juvenile recruitment index for the HOB, the Choptank, Nanticoke, Potomac, and Patuxent Rivers (Figure 4).

Data from the drift gill net survey in the HOB (1984 – 2005; *cf* Project 2, Job 3, Task 2) and the Choptank River (1984 – 1996; Project 1, Job2) were included in the surplus production models for those river systems. Since the surplus production model is a weight-based model, indices based on number were transformed to weight-based indices. Channel catfish weight per gill net set was estimated by determining average channel catfish length per mesh size per gill net set and applying a length-weight formula from the Susquehanna Flats area of the HOB:

$\log_{10}(\text{Wt g}) = 3.09684 \text{ X } \log_{10}(\text{TL cm}) - 2.1622$ (Fewlass 1980). The average weight per gill net set and mesh size was then multiplied by the total number captured per mesh size and net set. The final index was the average total weight per mesh size and set standardized to 1000-gill net yards X hours.

A fyke net survey in the Choptank River (Project 1, Job 2) was used to formulate a river-specific index for channel catfish during 1993 – 2005. Average length per net set was determined, and the same length weight equation used for the drift gill net survey was used to transform numbers caught per set to biomass caught per set. This index was included in the surplus production model runs.

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

The HOB winter trawl survey (Project 1, Job1) provided channel catfish relative abundance and a recruitment index for the HOB. Available data from this survey (2000-2006) were largely unusable due to limited sample size. The recent initiation of this survey precluded its use in the surplus production model.

General surplus production model formulation

Surplus production models fit biomass estimates to the equation

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

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

The model took the form of the Haddon (2001) implementation where a series of biomass estimates were generated to maximize a log-likelihood function by solving for r, K, and initial biomass (B_0). An estimated index was derived from the equation index (I) = $q\ \{(B_{t+1} + B_t)/2\}\ e^{\varepsilon}$, where q was catchability and e^{ε} was the lognormal residual error. This form simplified the solution by not having to solve for a catchability parameter for each index. In this closed form, average catchability for each index was $e^{(1/n)\,\Sigma\,\ln(I_t / B_t)}$. The log function to be maximized was simply the sum of all log-likelihoods multiplied by a weighting factor. For this assessment an inverse variance re-weighting was investigated.

The log-likelihood function for an individual index is

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

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

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

Maximum Sustainable Yield = rK/4

B msy = K/2

F msy = r/2

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

Uncertainty

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

Area-specific surplus production model runs

The HOB was defined as the area north of the Preston Lane Memorial Bridges, including all tributaries except the Chester River. Other area model runs included those for the Chester, Choptank, Nanticoke, Potomac, and Patuxent Rivers. Total removals were area-specific commercial catches plus a constant percentage for recreational harvest. All combinations of fishery dependent and fishery independent indices of relative abundance with and without weighting were used in model runs (Table 1). Starting values and bounds for r, K, and B_0 were also area specific (Table 2).

Spawning Stock Biomass per Recruit and Biological Reference Points

A Thompson-Bell Spawning Stock Biomass per Recruit analysis (SSB/R) was used to estimate biological reference points (Gabriel *et al.* 1989). Reference points were determined with this model for channel catfish fisheries with a 254 mm minimum size limit (status quo) and a 356 mm (14 inch; TL) minimum size limit. The 356 mm minimum size limit SSB/R analysis was chosen because a questionnaire of harvesters in the Chesapeake Bay indicated that their market was for channel catfish considerably larger than the 254 mm minimum size limit (Sauls et al 1998). The model uses recruitment vectors and fishery selection patterns to scale F and the number mature at age to define SSB/R more precisely. The Thompson-Bell modification determines the number (N_{ts}) and weight (W_{ts}) available at spawning as

$$N_{ts} = N_t * e^{-((c * s_t * F) + d*M)} \qquad [13]$$

$$\text{where } N_t = N_{t-1} * e^{-((p_{t-1} * F) + M)} \qquad [14]$$

$$\text{and } W_{ts} = fr_{ts} * N_{ts} * W_t \qquad [15]$$

where c is the fraction of F before spawning, s is the fraction vulnerable to harvest at age (partial recruitment vector), d is the fraction of M that occurs before spawning, fr_{ts} is the fraction mature at age t, and W_t is the mean weight at age (Table 3). Mean length at age was determined from von Bertalanffy parameters for channel catfish pooled from several areas throughout Chesapeake Bay during 1996 - 1999 (L_{∞}=749 K = 0.14 t_0 = -0.39). Similarly, weight at age was determined by substituting length at age into an allometric growth equation for HOB channel catfish ($\alpha = 2.04X10^{-6}$ $\beta = 3.247$; Rothschild et al. 1992). The selectivity pattern (s_t) was determined as percent channel catfish lengths at age greater than the minimum size limit from the same data set that provided the von

Bertalanffy equation. An arbitrary initial cohort of 100,000 at age 0 was used and the assessment was run for 13 age-classes. Instantaneous natural mortality (M) was assumed and held constant at 0.25. The fraction mature at age was determined from a Weibull curve fitted to maturity at length data from the Susquehanna River (Fewlass 1980). Maturity at age was then estimated by applying the predicted von Bertalanffy length-at-age to predicted maturity at length.

The Thompson-Bell SSB/R analysis was constructed as a Microsoft Excel spreadsheet (Microsoft Corporation 1993). An initial run with F = 0 determined the unfished (virgin) spawning stock biomass. A range of percent maximum spawning potential was selected as reference points ($F_{15\%}$ - $F_{35\%}$ in 5% increments). These reference points are the level of F that preserved the corresponding percentage of an unfished spawning stock biomass (Goodyear 1993). The biomass corresponding to the various reference points were identified, and the Goal Seek option (Microsoft Corporation 1993) was used to determine what instantaneous fishing mortality rates produced 15%, 20%, 25%, 30% and 35% of unfished SSB. The model was also run with F values of 0 to 1.2 in increments of 0.1 to produce a SSB/R curve.

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

$$N_t = N_{t-1} * \ e^{-(s_{t-1} * F + M)} \qquad [16]$$

$$\text{and yield} = W_t *((s_t*F)/(s_t*F+M))*(1-e^{-(s_t*F+M)})*N_t. \quad [17]$$

Selectivity-at-age vectors (s_t) were the same as the SSB/R model. Yield was determined for F ranging from 0 - 1.2 in increments of 0.1, except the yield at F=0.01 was determined in order to find the slope of the line at the origin in order to determine $F_{0.1}$.

RESULTS

Landings

Bay-wide commercial landings were generally steady between 300,000 lbs – 600,000 lbs from 1929 – 1984. Landings rose after 1984 to a peak of 2.45 million lbs in 1996 before falling to approximately 800,000 pounds in 2005 (Figure 5). Recreational catch estimates from the MRFSS were not informative, except for the estimates in 1983, 1985, 1991-1994, and 1996-1999. Each of these estimates had proportional standard errors less than or equal to 30%, and recreational harvest estimates for these years averaged 21.2% of the commercial harvest.

Fishery Dependent Relative Abundance Indices

Head-of-Bay

Commercial fyke net indices indicated a rising relative abundance from 1980 through the early 1990's, peaking in 1996. Values fell until 2002 before rising again from 2003-2005. Fish pot relative abundance estimates rose through 2003, and pound net relative abundance rose to a peak in 2000, but fell dramatically in 2002 (Figure 6).

Chester River

The Chester River commercial fyke net relative abundance index generally declined from a peak value in 1990, while the fish pot index peaked in 1996 and declined through 2002. Recent fish pot relative abundance values have increased (Figure 7). The pound net relative abundance index increased from 1980 – 1992, fell sharply, bottoming in 2000, and subsequently rose to medium levels during 2001 – 2005.

Choptank River

Choptank River commercial fyke net and fish pot relative abundance indices were similar from the early 1990's through 2005. The relative abundance indices were fairly stable throughout the time-period, with an increasing trend from 2001-2004. Pound net relative abundance values indicated a decreasing trend from 1993 –2001, but increasing through 2005 (Figure 8).

Nanticoke River

Fyke net and fish pot relative abundance indices were also similar in Nanticoke River. Both indices exhibited a peak in 1999, followed by a decreasing trend through 2002. The pound net index showed little variation, but values for 2003 and 2005 were very high compared to the rest of the time series (Figure 9).

Potomac River

Potomac River commercial relative abundance indices from the fyke net fishery and pound net fishery were largely uninformative, probably due to higher salinity levels than in other areas where channel catfish are harvested. However, fish pot data declined linearly from 1984 – 2002, with no landings in 2004 or 2005 (subject to the 500 lb cut-off; Figure 10).

Patuxent River

The three commercial indices each provided a different outlook on channel catfish relative abundance from this system. The fyke net index indicated channel catfish abundance rose from the early 1990's through 2000, and declined thereafter. The fish pot relative abundance index was largely unchanged over that time-period, while the pound net index indicated a decline in relative abundance from 1999 through 2005 (Figure 11).

Fishery Independent Relative Abundance Indices

Head-of-Bay

There were four fishery independent indices available from the Head-of-Bay. The experimental drift gill net survey, designed to assess striped bass spawning stock abundance, covered years 1982 – 2005. This index provided biomass-based estimates of relative abundance. Biomass exhibited distinct peaks in 1986, 1994, and 2005. The 2005 peak appears anomalous, but regardless, biomass was very low during 1998 – 2000 (Figure 12).

The upper Bay winter trawl, initiated during the winter of 1999 – 2000, provided a relative estimate of channel catfish numbers (all sizes) and an index of age 1+ relative abundance. Sample years 2003 – 2005 were characterized by limited sample sizes, so discussion will be focused on years 2000- 2002 and 2006. Regression analysis of log-transformed abundance indices indicated an increasing stock for the years with adequate sample sizes ($y = 0.13(\ln(CPUE)) + 2.73$; $P=0.047$; $r^2= 0.91$; Figure 13).

Head-of-Bay juvenile seine sampling provided an index of recruitment for channel catfish. Recruitment was markedly higher from 1975 – 1989 than in recent years (Figure 14). The winter trawl also provides an age 1+ index of abundance, and if lagged one year, this index can be compared to the young-of-year (yoy) index from the seine survey. Winter trawl abundance of age 1+ channel catfish indicated low recruitment of the 1999 year-class (2000 sample year), and relatively stable recruitment among the 2000, 2001, and 2005 year-classes (Figure 15). The juvenile seine survey indicated little to no recruitment from those year-classes.

Choptank River

Experimental drift gill net data from the spring striped bass spawning stock survey were available from 1983 – 1996, except for 1984 and 1995. Biomass estimates of relative abundance generally increased from 1983 – 1989, and then fell precipitously in the early 1990's before rising to higher levels during 1994 – 1996 (Figure 16). Similar to the gill net survey, the spring fyke net survey (1993 – 2005) showed an increase from 1993 – 1995. This index then declined for three years before increasing slightly to average levels during 1999 – 2002 (Figure 17). More recent relative biomass values have declined. Recruitment, as described by the EJFS seine survey, indicated increased recruitment from 1994 – 2004. However, notably weak recruitment was evident in 1995, 1999, 2000, and 2005 (Figure 18).

Nanticoke River

No fishery independent data existed for Nanticoke River adult channel catfish. However, a recruitment index from the EJFS seine survey was developed. In general, recruitment has been poor since 1994, but relatively strong year-classes were noted in 2003 and 2005 (Figure 19).

Potomac River

Potomac River fishery independent data were also limited to the EJFS seine survey. Recruitment was strong and stable from 1975 – 1984 (Figure 20). Recruitment since 1984 has been poor, except for a relatively strong year-class in 2004.

Patuxent River

Recruitment of channel catfish in the Patuxent River has been quite variable, but strong year-classes were noted in 1987, 1996, 2001, and 2003 (Figure 21). No fishery independent data from the Patuxent River were available for analysis.

Surplus production models

Head-of-Bay

The model was run with all combinations of indices with and without weighting. Generally, all runs fell into three classes, nonsensical or failed fits, runs that were at or near carrying capacity for long periods of time, and fits that indicated population building through the mid-1990's with a decrease until the early 2000's followed by an increase in recent years. Only model runs from the latter class were considered as representative of channel catfish population dynamics in the HOB. The final model run selection was somewhat subjective because all of the successful runs indicated similar population responses. The final run contained the commercial fyke net relative abundance, commercial fish pot relative abundance, and the MD DNR experimental drift gill net relative abundance index. The final run was selected because it contained a fishery independent index that covered time periods of missing data from the commercial fishery indices. The final model run was un-weighted.

Estimated parameters r, K, and B_0 were 0.64, 7.6 million pounds, and 3.1 million pounds, respectively. Biomass increased from 3.1 million pounds in 1980 to 6.4 million pounds in 1989. Channel catfish biomass then fell rather quickly to 2.4 million pounds in 2000, but nearly doubled to 4.1 million pounds in 2005 (Figure 22).

Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ K or 3.8 million pounds. F_{msy} was estimated as ½ r or 0.32. Maximum sustainable yield was estimated rK/4 or 1.22 million pounds. Ratios of $B:B_{msy}$ and $F:F_{msy}$ indicated a period of increasing biomass and low F from 1980 – 1988. Fishing mortality then rose to unsustainable levels from 1989 – 2001 (Figure 23). After 2001, however, F declined and population biomass increased.

Bootstrapping provided estimates of uncertainty for this model. The intrinsic rate of increase (r) was precisely estimated (CV=29%), but estimates for K and B_0 were less precise (CV= 45% and 55%, respectively). Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than r and K in model outputs and subsequent management advice. Coefficients of variation of annual biomass estimates ranged from 23% - 55%, and were fairly imprecise after 1996. In the final year of the assessment (2005), there was a 52% chance that channel catfish biomass was below B_{msy}, and a 0% chance that overfishing occurred.

Chester River

There were no fishery independent indices of abundance available from the Chester River. The final run contained the commercial fyke net relative abundance index and the commercial pound net relative abundance index. The final run was unweighted.

Estimated parameters r, K, and B_0 were 0.68, 1.2 million pounds, and 206,000 pounds, respectively. Biomass increased from 206,000 pounds in 1980 to 957,000 pounds in 1992. Population biomass fell to 473,000 pounds in 2000, but then increased to 573,000 pounds in 2005 (Figure 24).

Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ K or 585,000 pounds. F_{msy} (1/2 r) was 0.34, and maximum sustainable yield was 199,000 pounds. Ratios of $B:B_{msy}$ increased from less than 0.4 in 1980 to levels greater than one from 1984 – 1998. In recent years, $B:B_{msy}$ increased from 0.8 in 2000 to near unity in 2005 (Figure 25). Fishing mortality was above F_{msy} 1995 – 2005, except for lower F levels in 2000 and 2003. Estimated removals (commercial and recreational) were below MSY during 2003 – 2005.

Parameter estimates for r, K, and B_0 were very precise. CV values were 12%, 9%, and 20%, respectively. Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than r and K in model outputs and subsequently management advice. Annual biomass estimates were also very well estimated, as CV's ranged from 11% - 34%. In the final year of the assessment (2005), there was a 57% chance that the channel catfish population was overfished, and a 39% chance that overfishing occurred in the Chester River.

Choptank River

The final run included the commercial pound net relative abundance index, the commercial fish pot relative abundance index, and the MD DNR experimental drift gill net index. The final run was unweighted.

Estimated parameters r, K, and B_0 were 0.55, 660,000 pounds, and 109,000 pounds, respectively. Biomass increased from 109,000 pounds in 1980 to 489,000 pounds in 1996. Population biomass fell to 299,000 pounds in 2000, and then increased to nearly 400,000 pounds in 2002. Population biomass fell to 350,000 pounds in 2005 (Figure 26).

Biomass at maximum sustainable yield (B_{msy}) was estimated as ½ K or 330,000 pounds. F_{msy} (1/2 r) was 0.28, and maximum sustainable yield was 90,000 pounds. Ratios of $B:B_{msy}$ increased from less than 0.36 in 1980 to levels greater than one from 1985 – 2005, except for 2005 (Figure 27). Fishing mortality was above F_{msy} during 1990 –1992, 1998, 1999, and 2002 --2005. Estimated removals (commercial and recreational) were above MSY for 6 of 10 years over the period 1996 - 2005.

Although results of the model run were somewhat intuitive, bootstrapping exercises suggested that no management information would be forthcoming from this model. Coefficients of variation ranged from 58% to over 100% for annual biomass estimates. In addition, between half and one-third of the bootstrap iterations failed to give plausible model runs for the Choptank River.

Nanticoke River, Potomac River, and Patuxent River

Model runs from the Nanticoke, Potomac, and Patuxent rivers failed to produce reliable baseline model results and were not considered for any assessment input.

Spawning stock biomass per recruit and biological reference points

Biological reference points were determined with spawning stock biomass per recruit and yield per recruit models under status quo regulations (Gabriel et al. 1989). Percent maximum spawning potential (%MSP) reference points ranged from F=0.27

(35% MSP) to F=0.63 (15% MSP; Table 4). Yield per recruit reference points were $F_{0.1}$ = 0.25 and F_{max} = 0.36.

Fishing mortality reference points from the surplus production models are not strictly comparable to these reference points because SSB/R reference points are numbers based and surplus production F rates are weight based. However, if the surplus production F rates roughly approximate mortality, the HOB and the Chester River F rates produced %MSP values of 70% and 27%, respectively.

Analysis of SSB/R and YPR models of channel catfish fisheries operating under a 356 mm minimum size limit indicated that similar MSP values can be attained with rates of fishing that are 2 to 3 times higher compared to fisheries that operate under a 254 mm minimum size limit (Tables 4,5).

DISCUSSION

Channel catfish provide important recreational and commercial fisheries while occupying an important ecological niche among brackish – tidal fresh ecosystems in Maryland's portion of the Chesapeake Bay. The primary objective of this Job was to describe channel catfish abundance trends throughout this Bay region. Three area specific models ran well for the HOB, the Chester River, and the Choptank River, but uncertainty analysis for the Choptank River model run indicated that it would be inappropriate to use the results for management purposes.

The HOB surplus production model indicated a growing channel catfish population through 1989 followed by a fairly rapid decline through 2000. Abundance estimates in the final year of the assessment (2005) were 10% above overfished levels, but uncertainty analysis indicated that there was a 52% chance that biomass was below B_{msy}, the level of biomass that can sustain removals at a level near MSY. Harvest levels (commercial and recreational combined) routinely have been below MSY since 1999. Analysis of the trends of biomass and F shows that biomass started to decline prior to the rise in F where population declines would be expected. Harvest, and presumably effort, increased on this declining stock and exacerbated the population decline during the 1990's. Given stock declines prior to increased F rates, recruitment failure is a likely cause in the negative population dynamics suggested by the model during 1989 – 2000. Recent recruitment, determined from the EJFS seine survey in the HOB, is a fraction of the levels seen during the period 1975 – 1990.

The Chester River surplus production model run was similar to the HOB model results. The primary difference was that the recent recovery was somewhat muted in the Chester River when compared to the relative biomass increase in the HOB. All three available fishery dependent relative abundance indices indicated increased biomass levels since at least 2001. Therefore, population abundance probably increased at a slightly higher rate than the model output suggested. Estimated commercial and recreational harvest has been below MSY during 2002 – 2005, but from the period 1994 – 2002, harvests exceeded MSY in all years except 2000. Harvest in excess of MSY may have prevented the Chester River stock from increasing to the same degree as the HOB.

Model results from the Choptank River run were intuitive, but bootstrap analysis indicated that the model was unstable. The MD DNR biomass based fyke net index (1993 – 2005) was generally declining, which was at odds with the fishery dependent indices. The divergence with the fishery dependent indices precluded the use of the MD

DNR fyke net survey data in the final model run. The MD DNR drift gill net survey only provided data to 1996, but was important as it covered a range of years where fishery dependent relative biomass indices were not available. Despite fairly consistent trends in the commercial index, the instability of the model precluded it from being used for management input. Estimates of channel catfish recruitment from the EJFS seine survey indicated a decidedly linearly increase since the late 1980's. Recruitment from 2001 – 2004 was particularly strong despite landings that generally exceeded MSY.

Nanticoke River model runs failed because the fishery dependent indices of relative abundance were either uninformative (noisy) or gave signals of population expansion or compression that conflicted with other fishery dependent indices. Neither index of relative abundance suggested a full population cycle, which is imperative for the surplus production model to fit the data correctly (Prager, 1994). Therefore, no management input for the Nanticoke River was produced.

Potomac River model runs were not successful because data from any one index was sporadic and a fishery independent adult index of biomass was not available. No management input was forthcoming from this effort, but recruitment was considerably higher from 1975 – 1984 compared to years after that time period. Relatively low recruitment suggests that channel catfish abundance is no better than stable in the Potomac River.

Patuxent River model runs failed because there was not a full population cycle, necessary for the model to set K and determine r estimates. As such, no management input could be produced. Qualitatively, the fyke net survey (fishery dependent) suggested that there was a slight population increase that peaked in 1999, and then declined from 2000 – 2005. Pound net and fish pot CPUE were similar in that the 1980 indices were high compared to any other year, and that these indices had an intermediate peak in the mid 1990's followed by declines through the early 2000's. Strong year-classes noted in 2001 and 2003 bode well for future channel catfish production in the Patuxent River.

Setting biological reference points with the SSB/R model is advisable, given the failure of the model runs to fit the data in several systems. The %MSP approach is relatively robust. Generally, fish stocks that do not have formal assessments are managed for MSP values between 25% MSP and 35% MSP (Mace and Sissenwine 1993). Exceptions would include long-lived, slow growing fishes. The current 254 mm minimum size limit provides little protection from over-harvest since channel catfish do not mature until 280 mm – 350 mm in the Chesapeake Bay region. However, Sauls et al. (1998) indicated that the market preference for commercially harvested channel catfish was for fish > 381 mm (15 inch; TL). Such fish were destined for live market fee fishing ponds in the mid-west. Since commercial markets and probably recreational preferences were for channel catfish substantially larger than 254 mm, the results of the SSB/R model for a 254 mm size at entry into the fisheries are only illustrative in comparison to runs that have larger lengths at first entry into the fisheries. Since the commercial fishery targeted larger channel catfish, a SSB/R model was run with a 356 mm minimum size limit. Comparisons of %MSP reference points between a fishery with a 356 mm minimum size limit and a fishery with a 254 mm minimum size limit suggested that the fishery with the 356 mm minimum size limit can harvest channel catfish at roughly twice the rate as a fishery with a 254 mm minimum size limit and attain the same MSP.

Channel catfish in the Chesapeake Bay region, an introduced but naturalized species, face some distinct difficulties that may hamper population growth to levels that approach those during the late 1980's. An unquantifiable factor that could directly influence channel catfish abundance is the expansion of other introduced ictalurids. In the Potomac River, blue catfish (*I. furcatus*) have become a naturalized species and inter-specific competition is likely. Over the past several years, commercial fishermen in the HOB have caught flathead catfish (*Pylodictis olivaris*) in increasing numbers. These catches (verified by MD DNR) have become more common, and similar inter-specific competition between channel catfish and flathead catfish may be inevitable.

LITERATURE CITED

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

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

Goodyear, C.P. 1993. Spawning stock biomass per recruit in fisheries management: Foundation and current use. Pages 67-81 *in* S.Smith, J. Hunt, and D. Rivard, editors. Canadian Special Publication Fisheries and Aquatic Sciences 120.

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

Mace, P. and M. Sissenwine. 1993. How much spawning per recruit is enough? Pages 101-118 *in* S.Smith, J. Hunt, and D. Rivard, editors. Canadian Special Publication Fisheries and Aquatic Sciences 120.

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

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

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

Rothschild, B., J. Ault, B. Huang, A. Holmes, and L. Baylis. 1992. Program development for efficient finfish sampling and stock assessment of northern Chesapeake Bay multi-species complexes. University of Maryland, Chesapeake Bay Laboratory, UMCEES CBL 092-050, Solomons, Maryland.

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

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

Table 1. List of fishery dependent and independent indices available for inclusion in the surplus production models, by system (MD DNR FYKE=fishery independent fyke net survey; MD DNR DGNF= fishery independent drift gill net survey, EJFS=MD DNR juvenile finfish seining survey; all other indices were fishery dependent).

INDEX	**RIVER OR SYSTEM**					
	Head-of-Bay	Chester River	Choptank River	Nanticoke River	Potomac River	Patuxent River
Fyke Net	**X**	**X**	**X**	**X**	**X**	**X**
Pound Net	**X**	**X**	**X**	**X**	**X**	**X**
Fish Pots	**X**	**X**	**X**	**X**	**X**	**X**
DNR DGNF	**X**		**X**			
DNR FYKE			**X**			
EJFS	**X**		**X**	**X**	**X**	**X**

Table 2. Starting values and upper and lower bounds for estimated parameters of the surplus production model, r=intrinsic rate of increase, K=carrying capacity in thousand pounds, B_0=Initial biomass in thousand pounds.

	Lower Bound	**Starting value**	**Upper Bound**	**Lower Bound**	**Starting value**	**Upper Bound**
	Head-of-Bay			**Chester River**		
r	0.1	0.5	1.5	0.05	0.75	1.50
K	2,000	6,000	10,000	500	2,500	10,000
B_0	100	750	1,500	70	175	5,000
	Choptank River			**Nanticoke River**		
r	0.05	0.5	1.25	0.05	0.75	1.25
K	1	750	10,000	10	2,000	10,000
B_0	10	100	1,000	35	100	5,000
	Potomac River			**Patuxent River**		
r	0.1	0.5	1.5	0.05	0.75	1.25
K	2,000	6,000	10,000	100	500	10,000
B_0	100	750	1,500	30	75	5,000

Table 3. Input variables for Thompson-Bell spawning stock biomass per recruit and yield per recruit models. P 254 = partial recruit vector for a 254 mm minimum size limit, p356 = partial recruit vector for a 356 mm minimum size limit, f=fraction mature, c=proportion of fishing mortality before spawning, d=proportion of natural mortality before spawning, and M=instantaneous natural mortality.

Age	p 254	p 356	f	c	d	M
1	0	0	0	0.5	0.5	0.25
2	0.18	0	0.01	0.5	0.5	0.25
3	0.38	0.01	0.37	0.5	0.5	0.25
4	0.65	0.16	0.99	0.5	0.5	0.25
5	0.9	0.59	1	0.5	0.5	0.25
6	0.98	0.86	1	0.5	0.5	0.25
7	1	0.93	1	0.5	0.5	0.25
8	1	0.96	1	0.5	0.5	0.25
9	1	0.97	1	0.5	0.5	0.25
10	1	0.97	1	0.5	0.5	0.25
11	1	1	1	0.5	0.5	0.25
12	1	1	1	0.5	0.5	0.25
13	1	1	1	0.5	0.5	0.25

Table 4. Biological reference points for channel catfish from spawning stock biomass per recruit and yield per recruit analyses assuming a 254 mm TL minimum size limit (MSP=maximum spawning potential).

Reference Pt.	$F_{15\%}$	$F_{20\%}$	$F_{25\%}$	$F_{30\%}$	$F_{35\%}$	$F_{0.1}$	F_{MAX}
F	0.63	0.49	0.40	0.32	0.27	0.25	0.36
% MSP	15	20	25	30	35	38	27

Table 5. Biological reference points for channel catfish from spawning stock biomass per recruit and yield per recruit analyses assuming a 356 mm TL minimum size limit (MSP=maximum spawning potential).

Reference Pt.	$F_{15\%}$	$F_{20\%}$	$F_{25\%}$	$F_{30\%}$	$F_{35\%}$	$F_{0.1}$	F_{MAX}
F	1.87	1.18	0.83	0.63	0.49	0.32	0.72
% MSP	15	20	25	30	35	46	27

Figure 1. Head-of-Bay juvenile finfish seine site (numbered circles and triangles) and drift gill net set locations (hatched area).

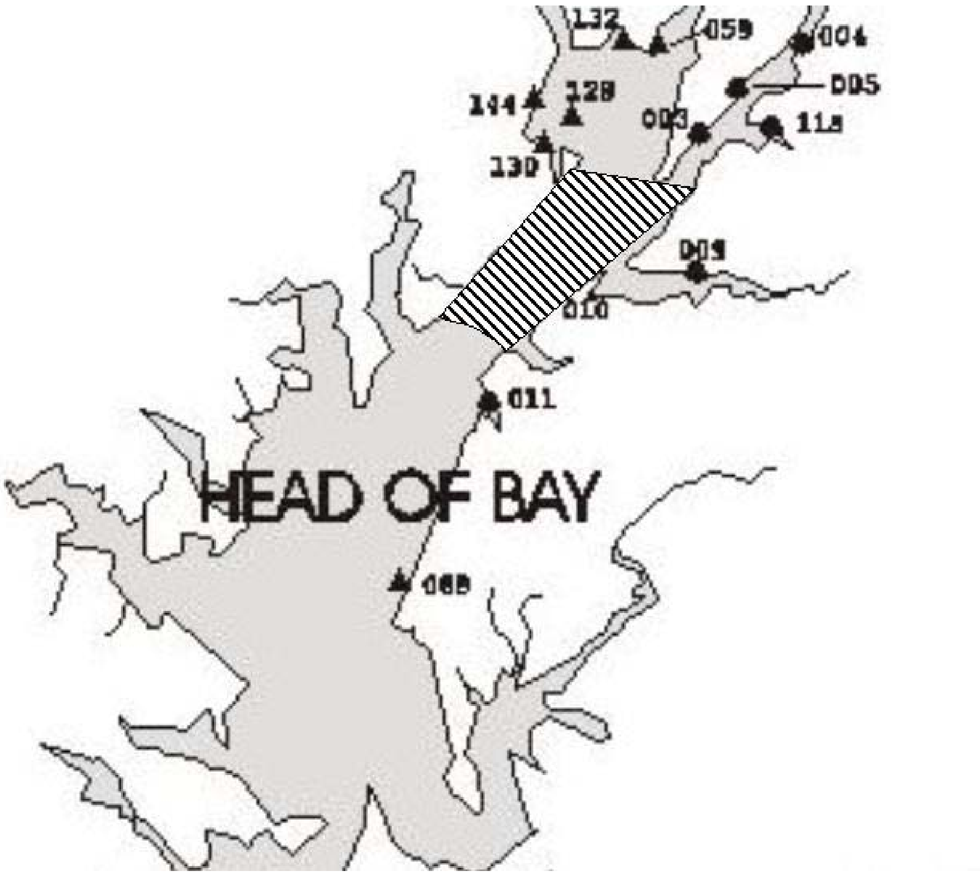


Figure 2. Choptank River MD DNR fyke net locations (triangles) and stream reach of drift gill net sampling (arrows).

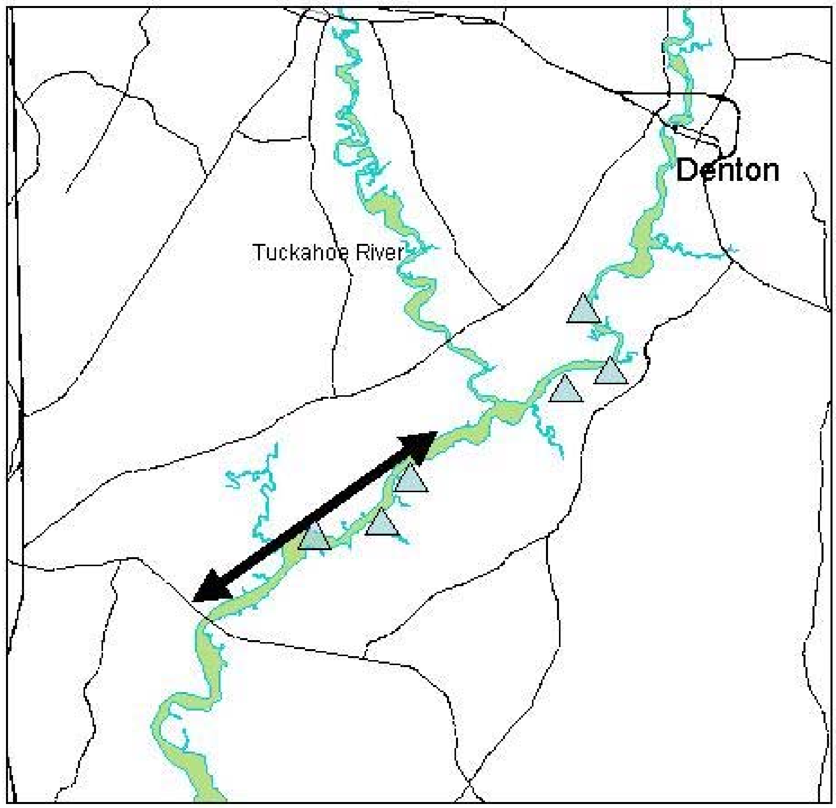


Figure 3. Head-of-Bay winter trawl sites (triangles=main bay sites, squares=Elk River sites, circles=Sassafras River sites).

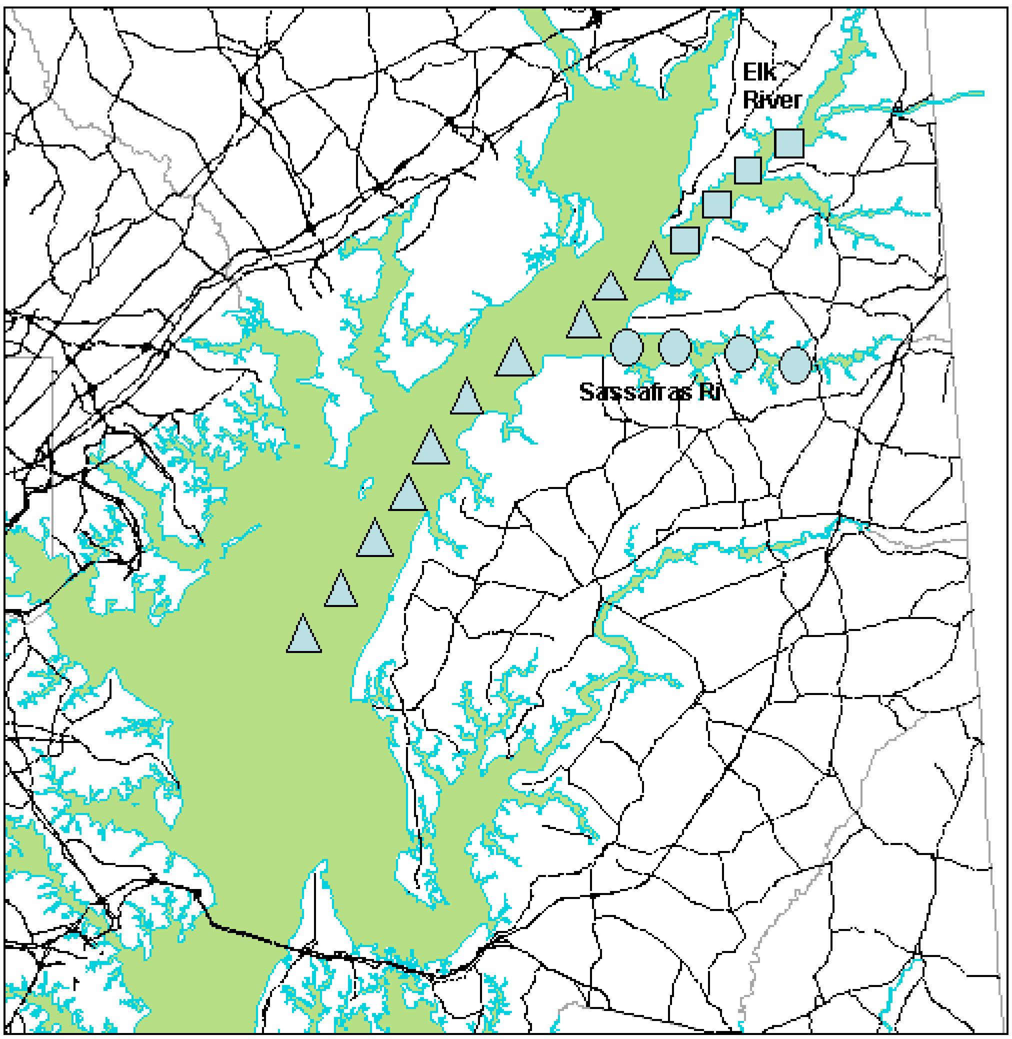


Figure 4. Estuarine Juvenile Finfish Survey seine site locations.

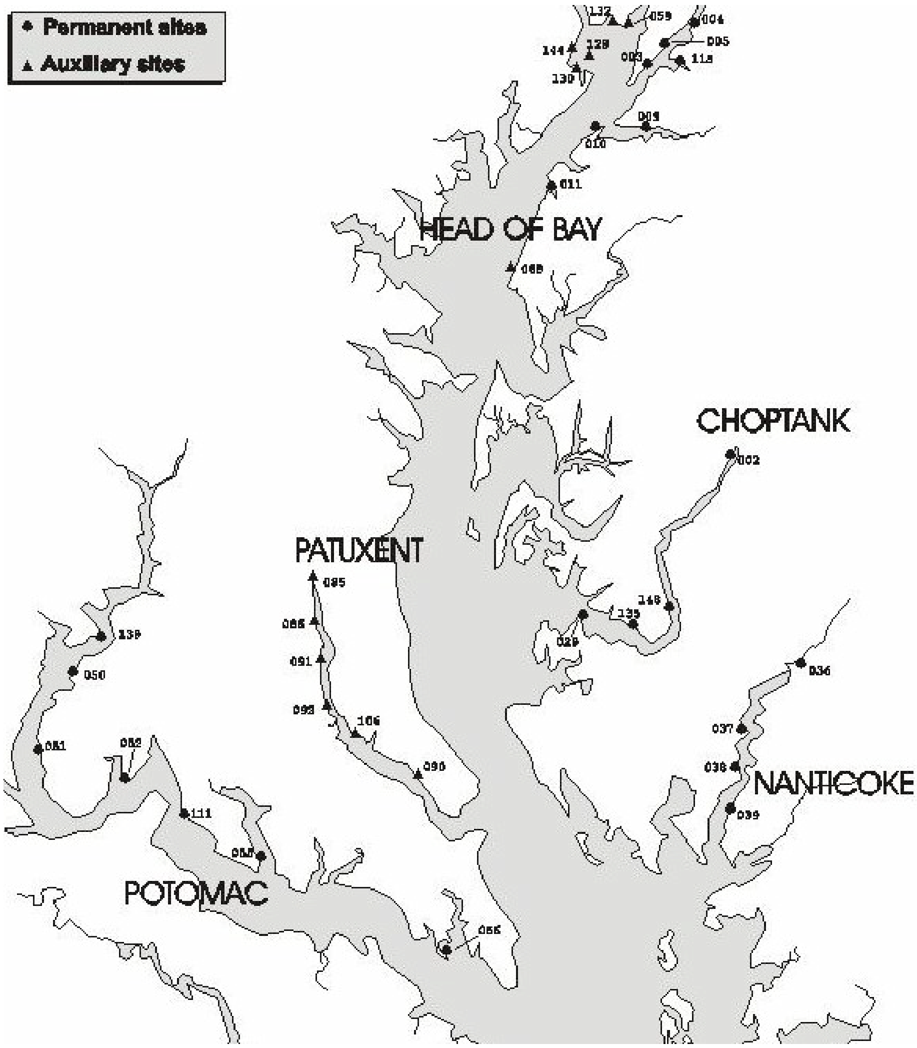


Figure 5. Chesapeake Bay commercial channel catfish landings, 1929 – 2005.

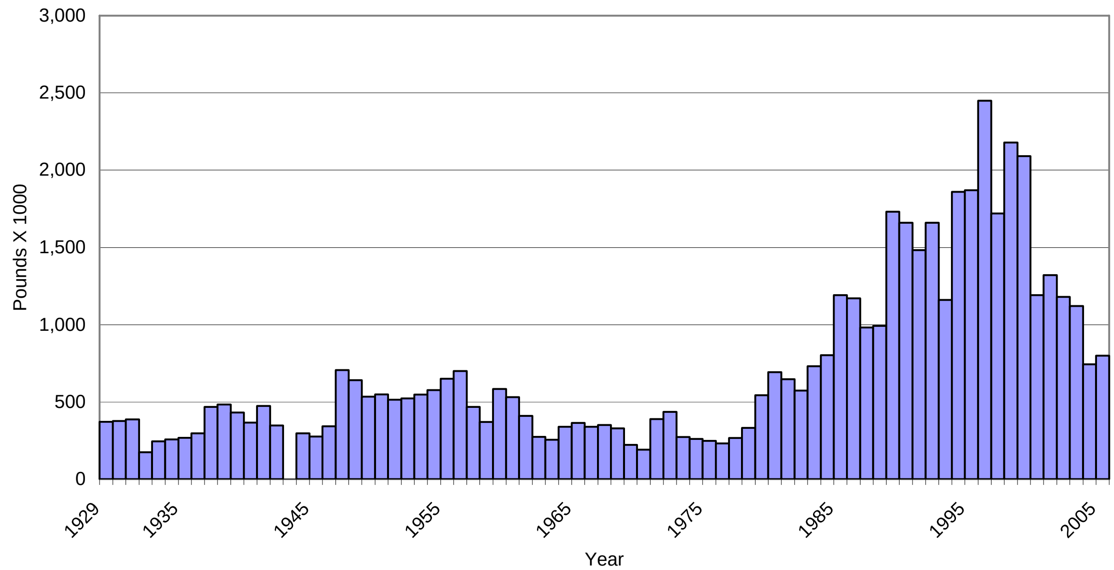


Figure 6. Head-of-Bay fishery dependent relative abundance indices for channel catfish, 1980 – 2005.

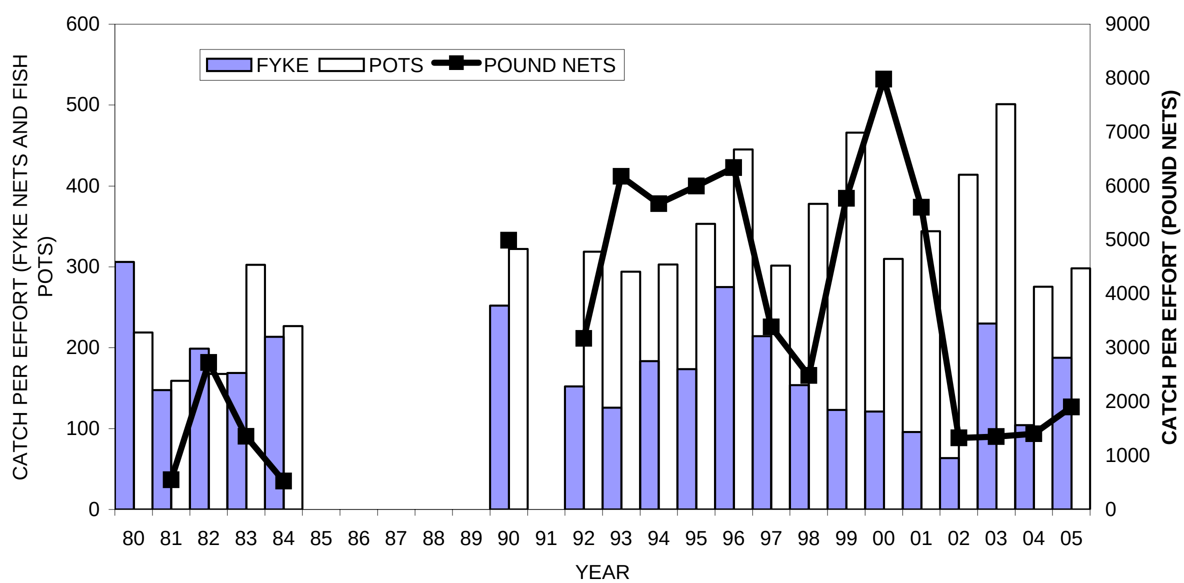


Figure 7. Chester River fishery dependent relative abundance indices for channel catfish, 1980 – 2005.

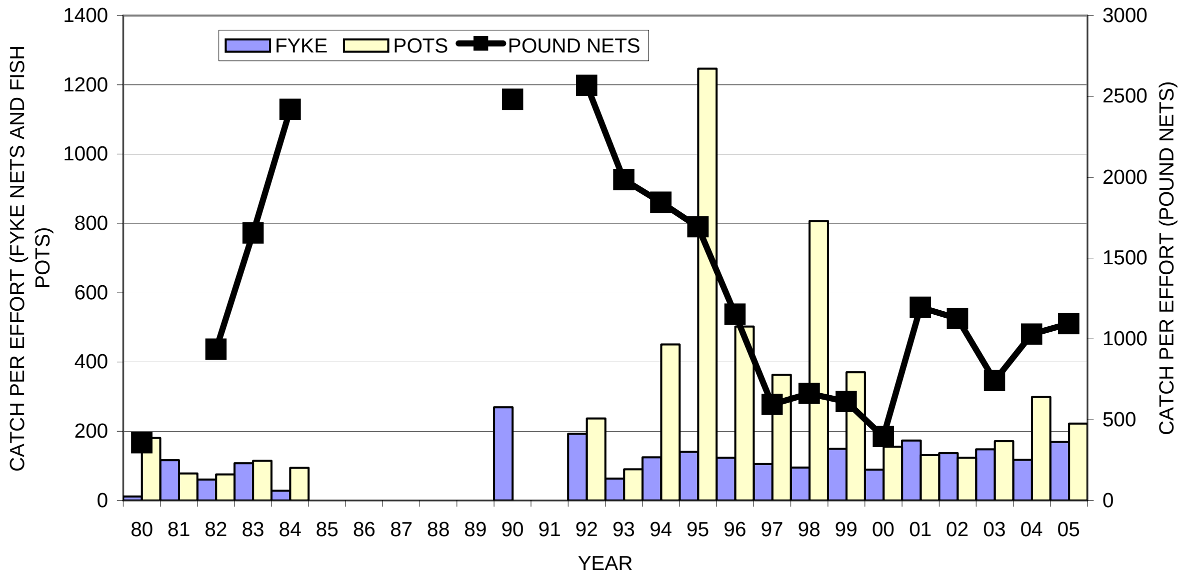


Figure 8. Choptank River fishery dependent relative abundance indices for channel catfish, 1980 – 2005.

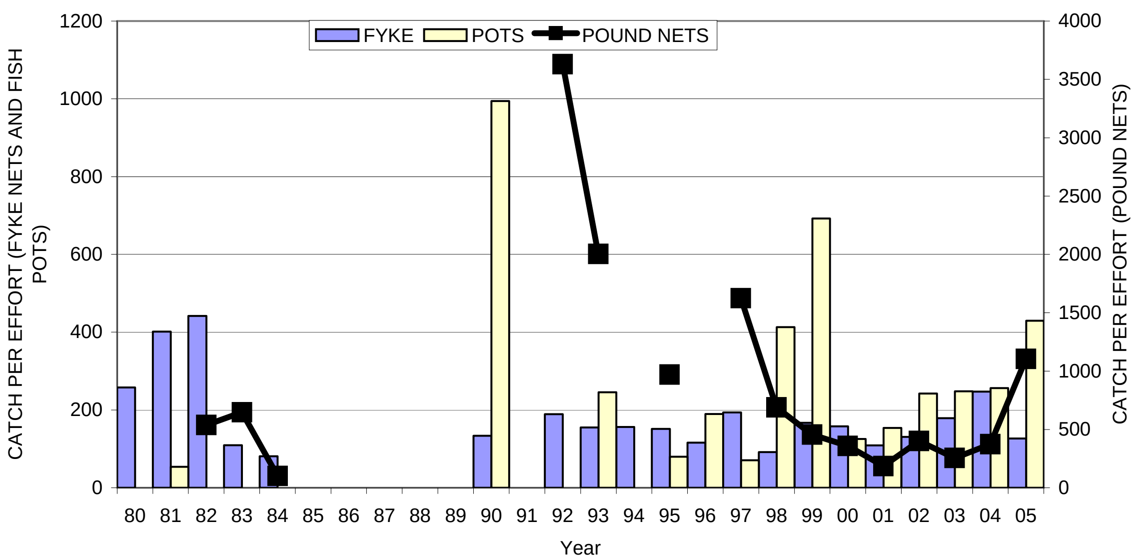


Figure 9. Nanticoke River fishery dependent relative abundance indices for channel catfish, 1980-2005.

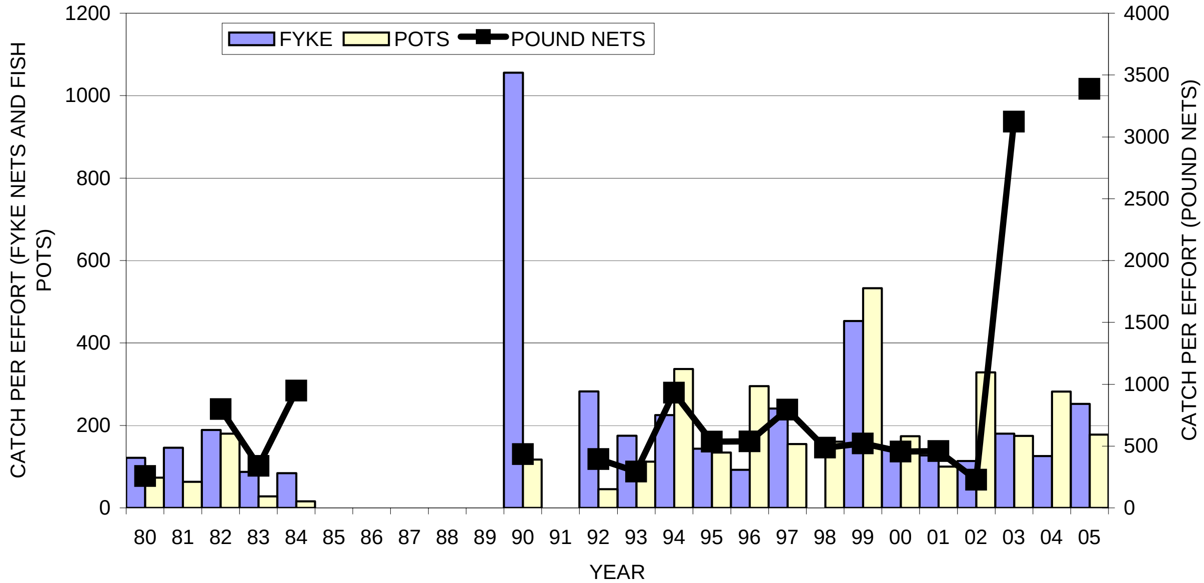


Figure 10. Potomac River fishery dependent relative abundance indices for channel catfish, 1980-2005.

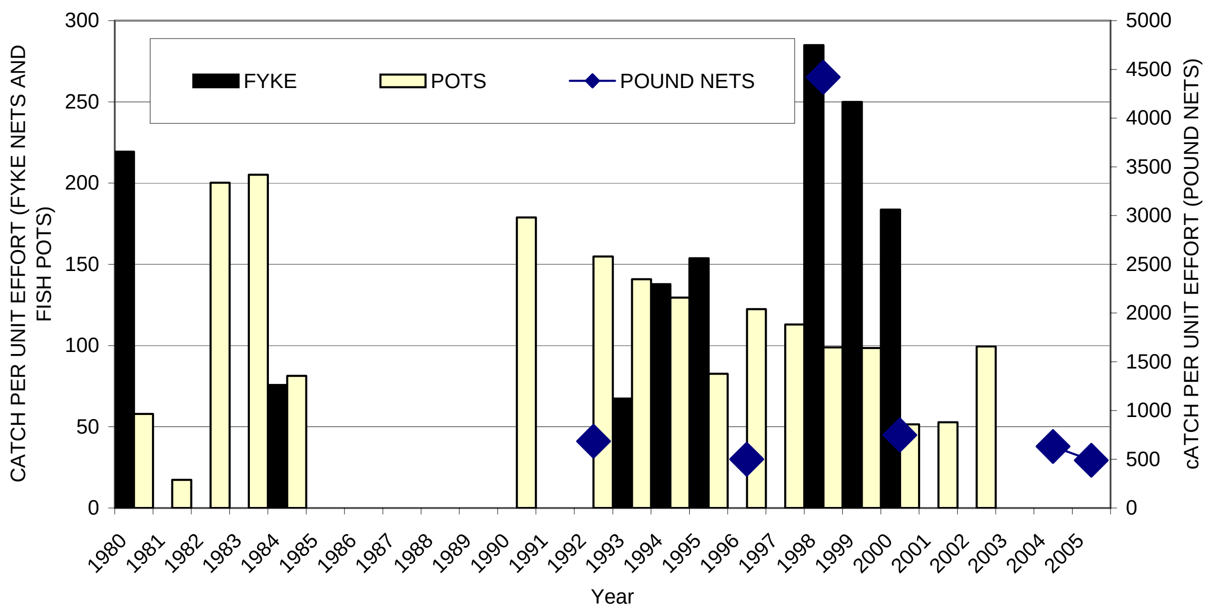


Figure 11. Patuxent River fishery dependent relative abundance indices for channel catfish, 1980-2005.

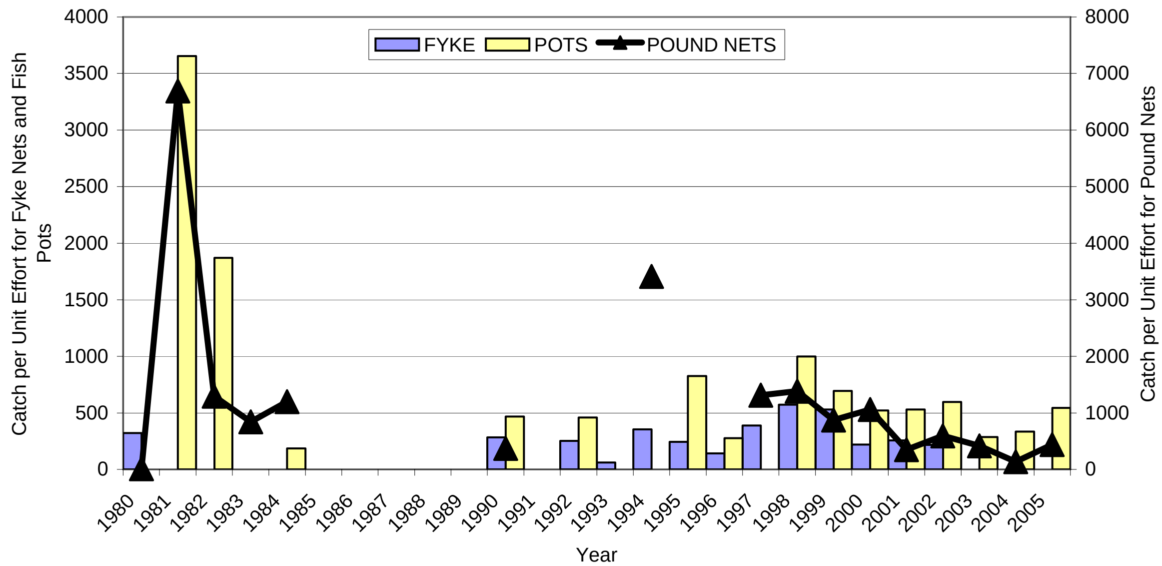


Figure 12. Head-of-Bay fishery independent drift gill net index for channel catfish, 1982 – 2005. Note: 2005 index value = 60, axis truncated to better show trends in previous years.

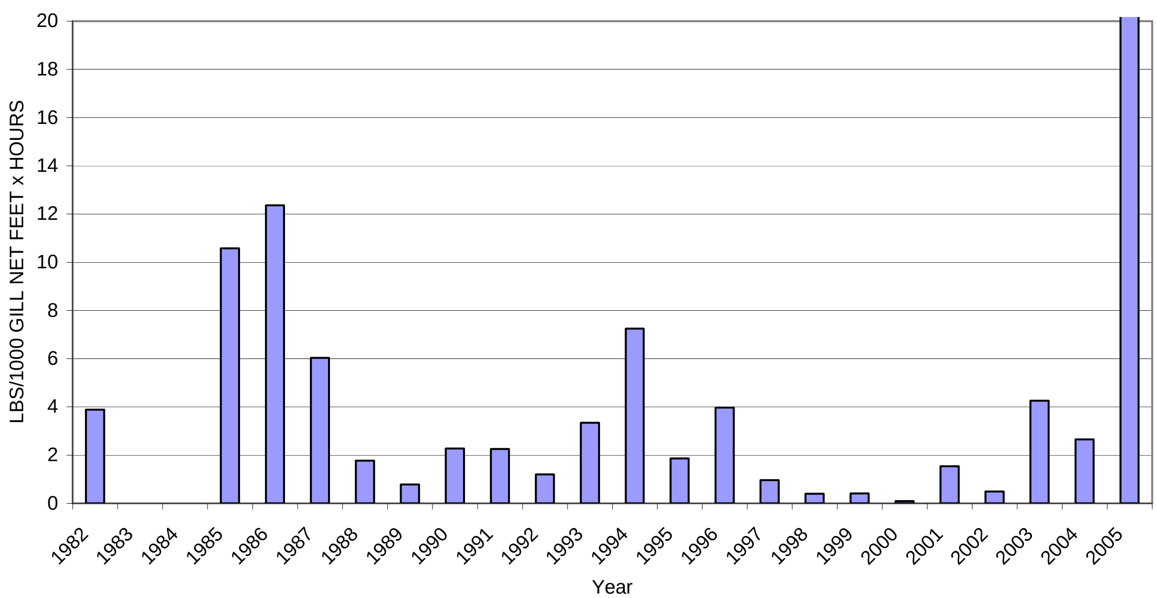


Figure 13. Head-of-Bay fishery independent winter trawl survey channel catfish index (all ages), 2000 – 2006. Note: Small sample sizes during 2003 – 2005.

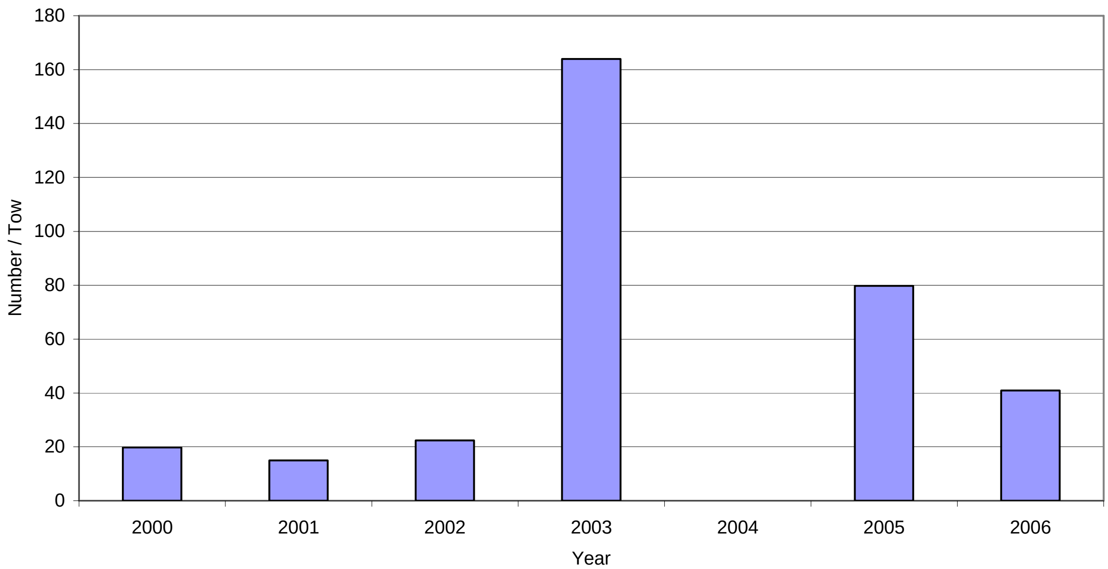


Figure 14. Head-of-Bay channel catfish fishery independent young-of-year index from juvenile finfish seine survey, 1975-2005.

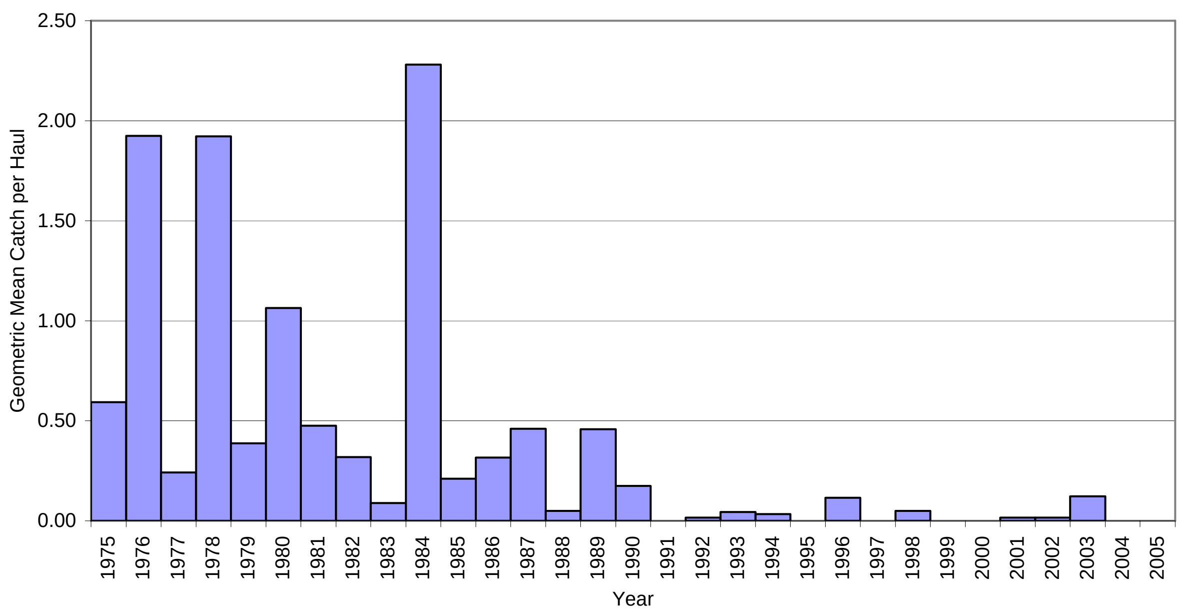


Figure 15. Head-of-Bay channel catfish fishery independent winter trawl survey age 1+ index. Year-class above data, small sample sizes during 2003 – 2005.

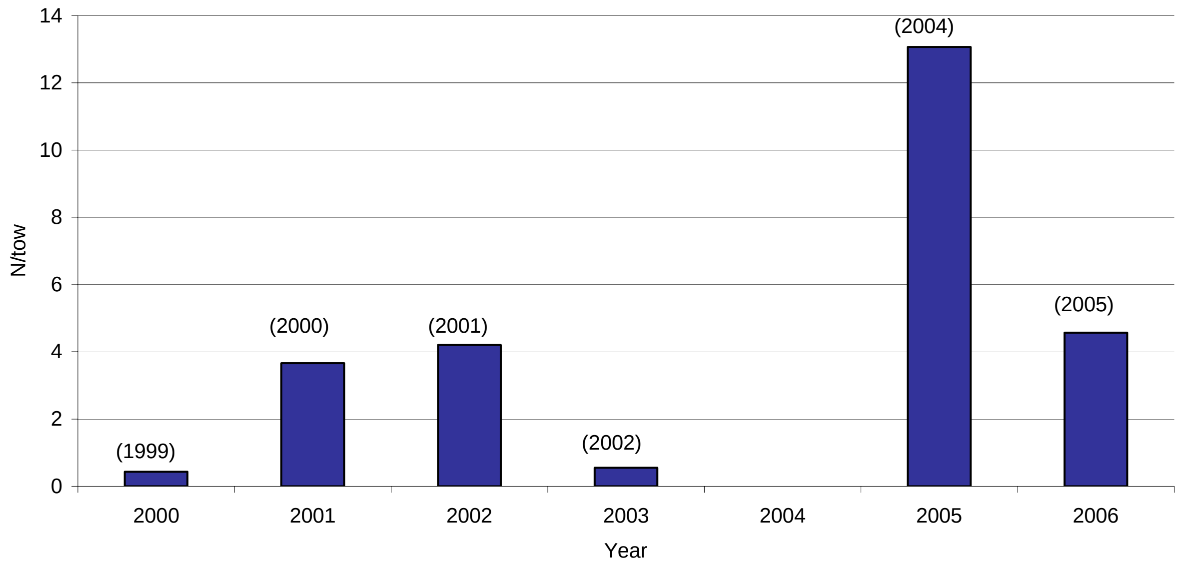


Figure 16. Choptank River fishery independent drift gill net index for channel catfish, 1983 – 1996.

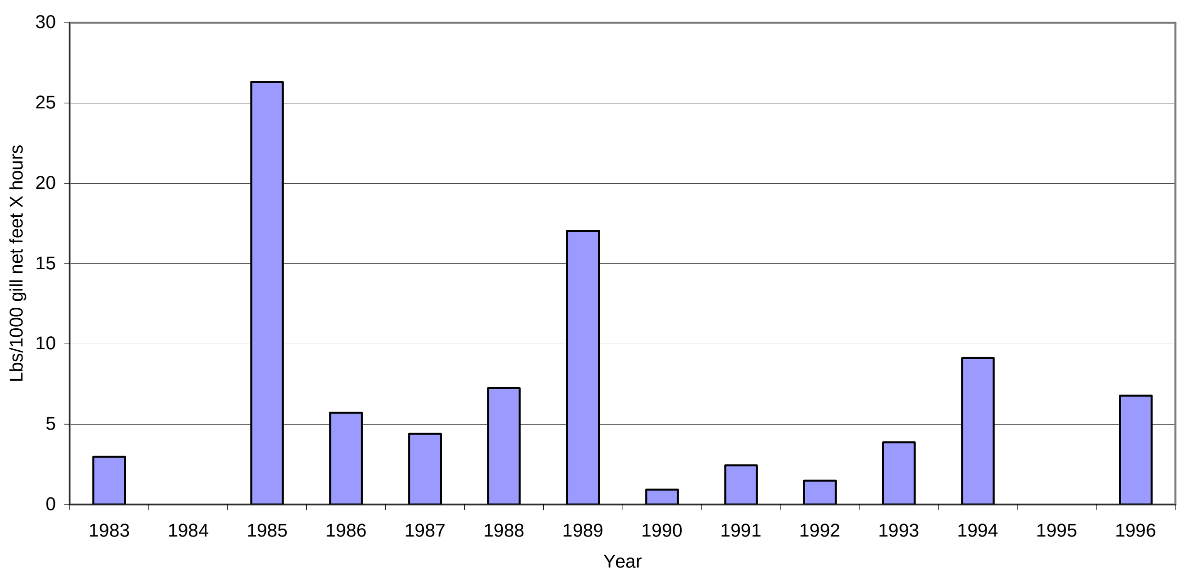


Figure 17. Channel catfish relative abundance index from fishery independent fyke net survey, 1993-2005.

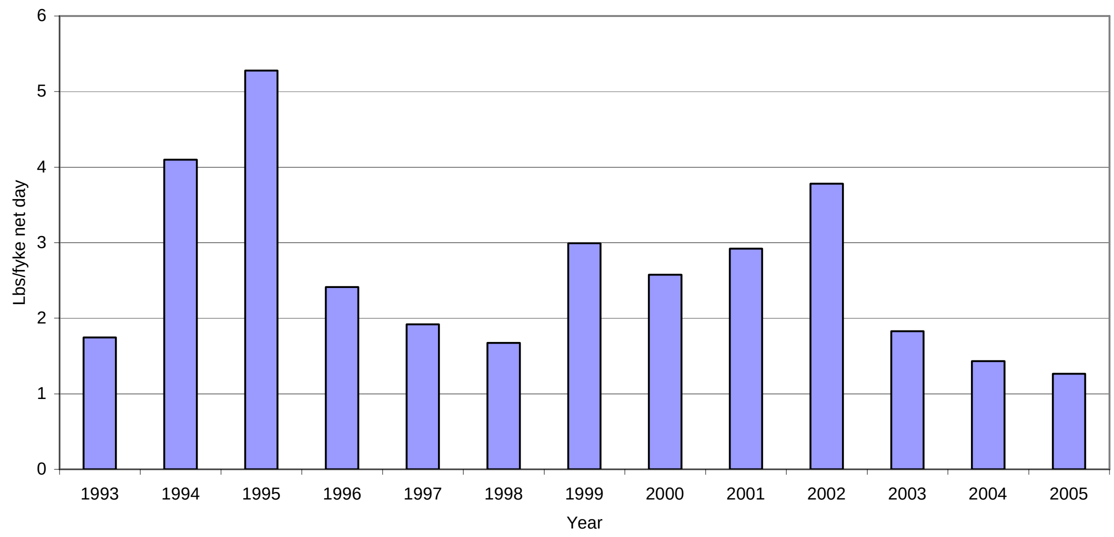


Figure 18. Choptank River channel catfish fishery independent young-of-year index from juvenile finfish seine survey, 1975-2005.

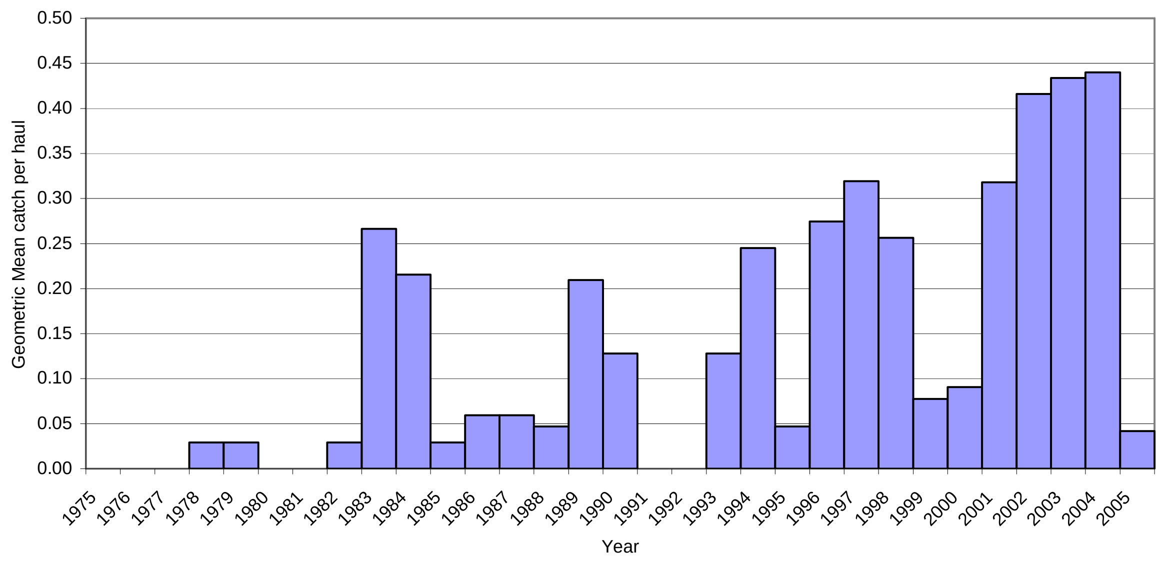


Figure 19. Nanticoke River channel catfish fishery independent young-of-year index from juvenile finfish seine survey, 1975-2005.

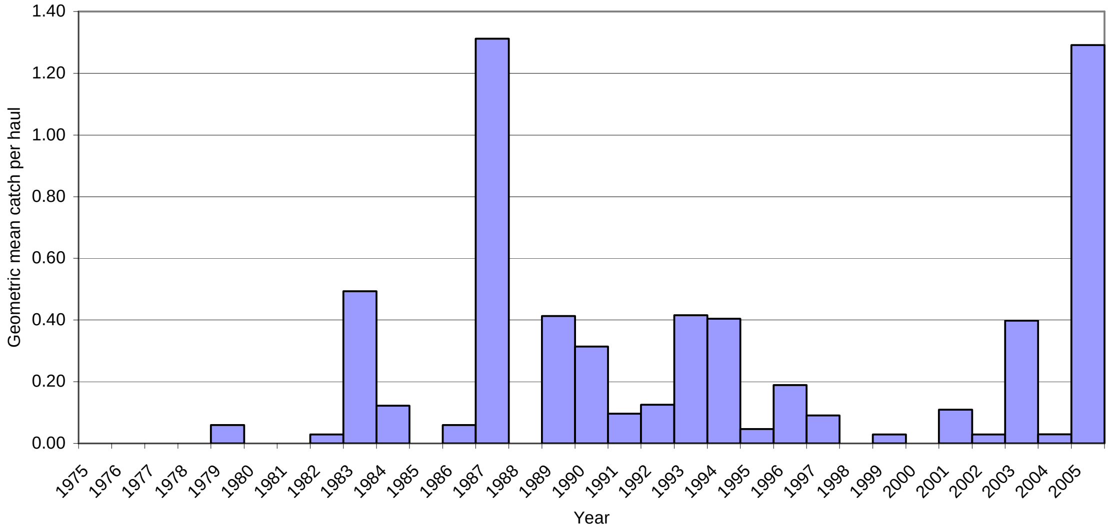


Figure 20. Potomac River channel catfish fishery independent young-of-year index from juvenile finfish seine survey, 1975-2005.

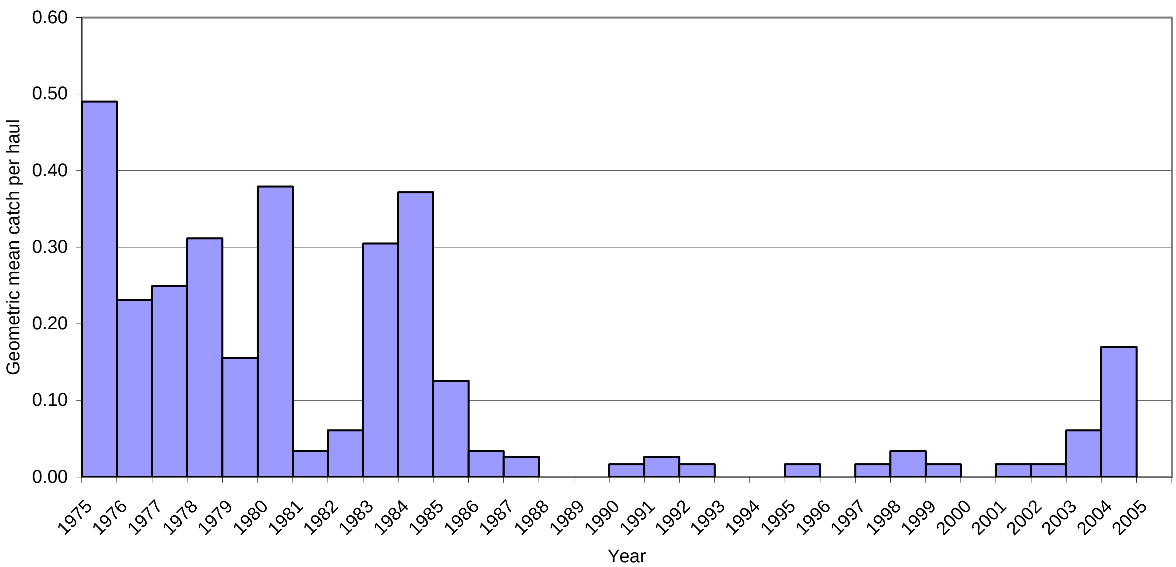


Figure 21. Patuxent River channel catfish fishery independent young-of-year index from juvenile finfish seine survey, 1983-2005.

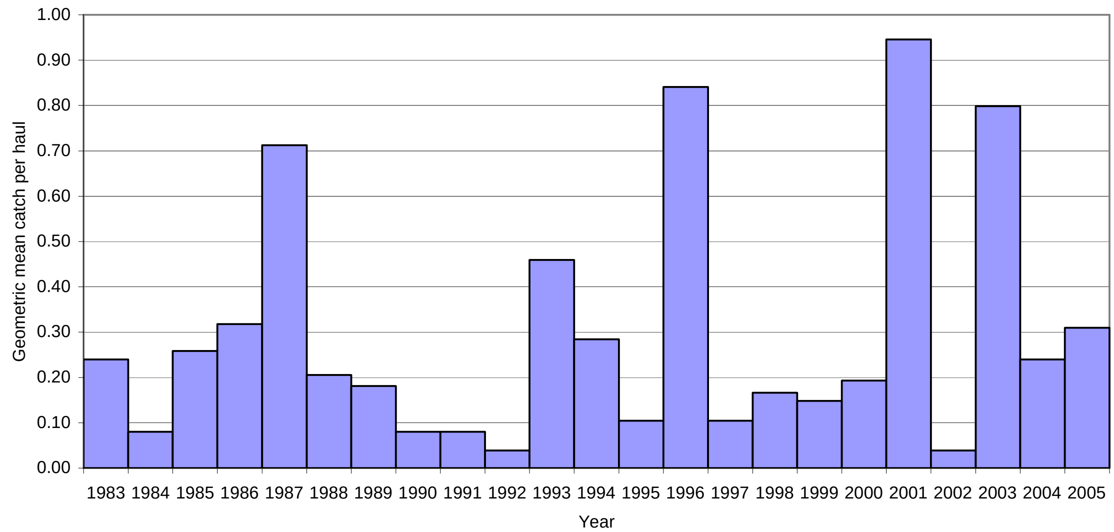


Figure 22. Head-of-Bay channel catfish biomass estimates and 80% Confidence interval from surplus production model. Diamonds=annual estimate; Dashed line = 80% Confidence intervals.

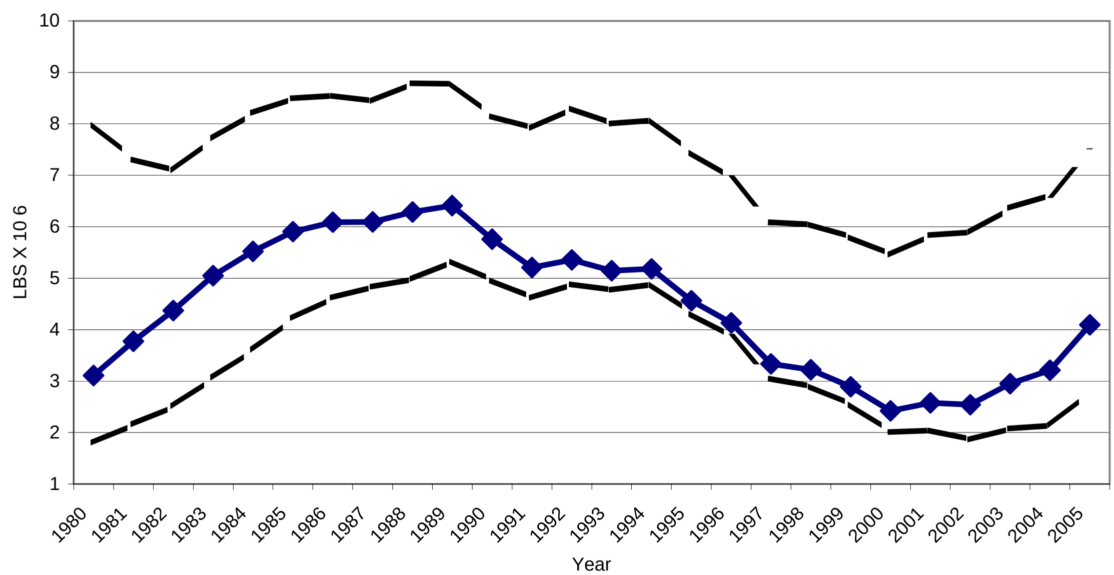


Figure 23. Head-of-Bay channel catfish biomass and instantaneous fishing mortality ratios from surplus production models. Biomass ratio < 1 indicates overfished status and F ratio > 1 indicates that overfishing is occurring.

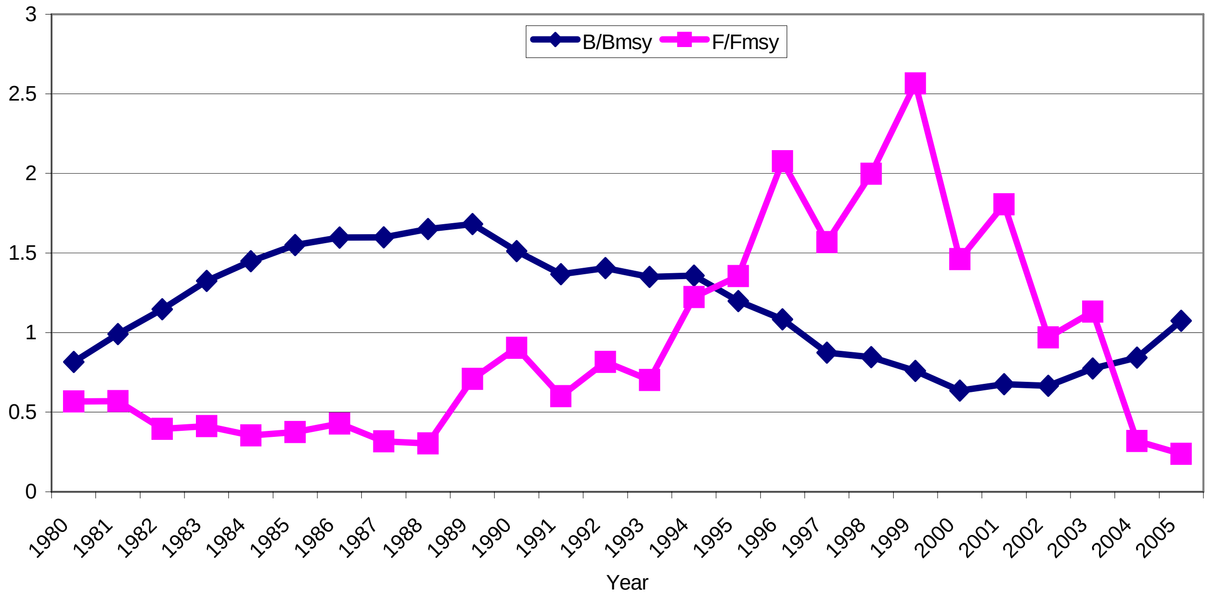


Figure 24. Chester River channel catfish biomass estimates and 80% Confidence interval from surplus production model. Diamonds=annual estimate; Dashed line = 80% Confidence intervals.

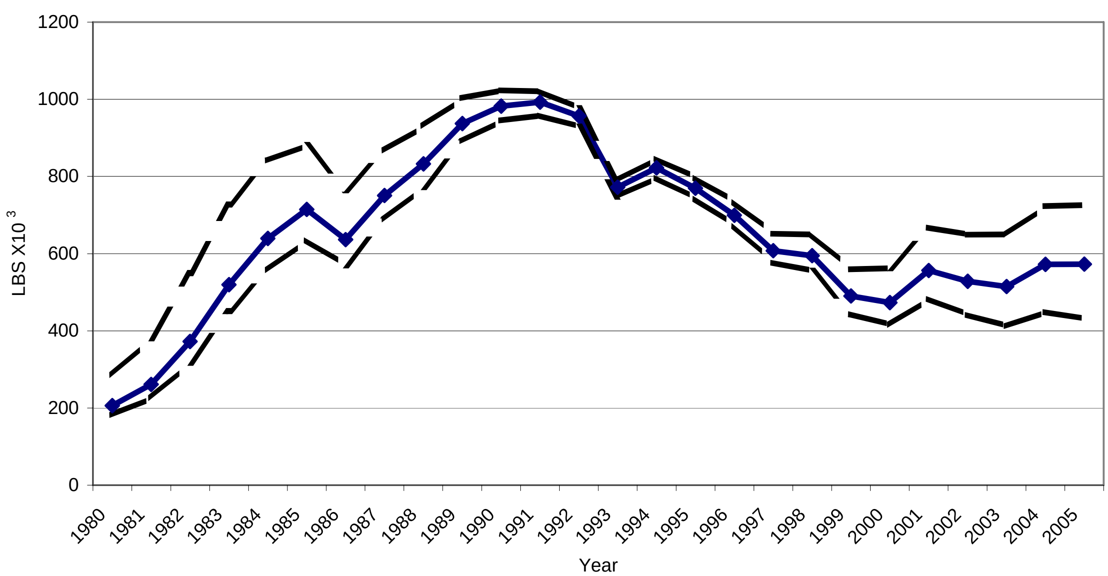


Figure 25. Chester River channel catfish biomass and instantaneous fishing mortality ratios from surplus production models. Biomass ratio < 1 indicates overfished status and F ratio > 1 indicates that overfishing is occurring.

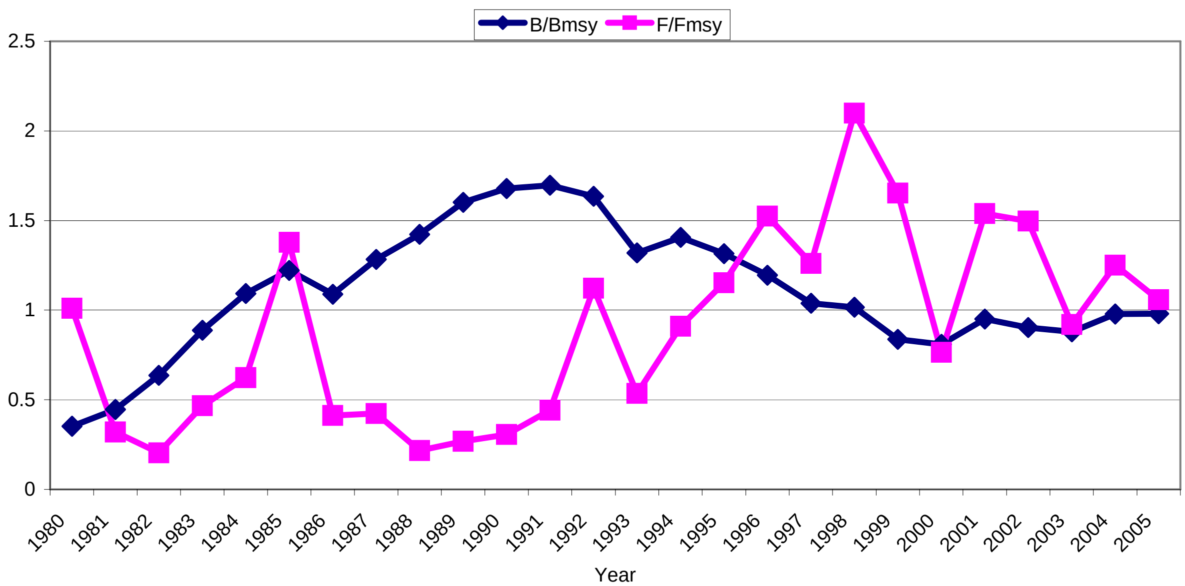


Figure 26. Choptank River channel catfish biomass estimates and 80% Confidence interval from surplus production model. Diamonds=annual estimate; Dashed line = 80% Confidence intervals.

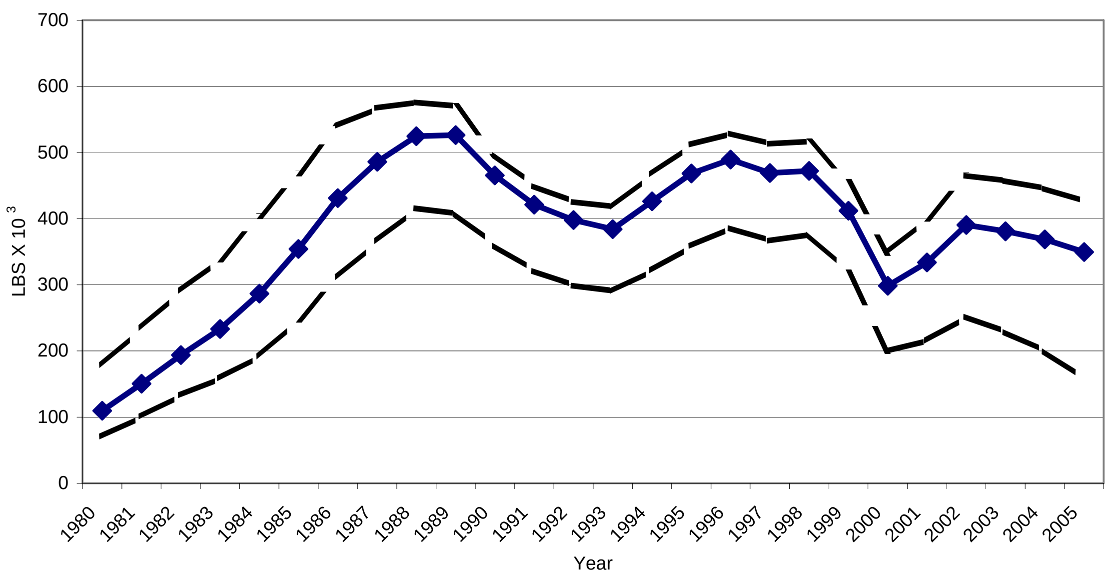
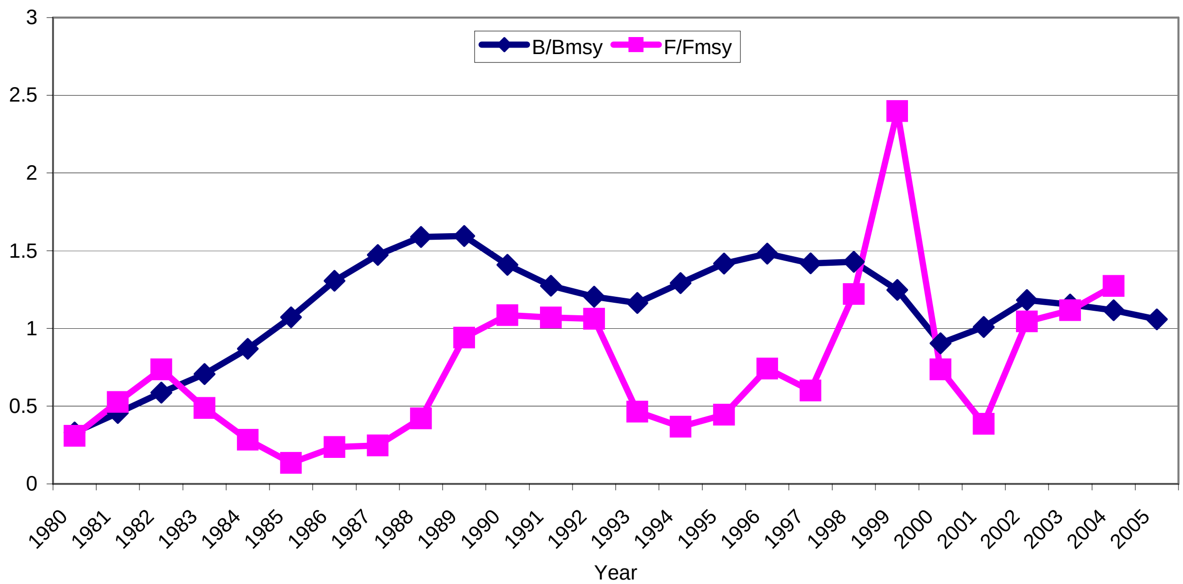


Figure 27. Choptank River channel catfish biomass and instantaneous fishing mortality ratios from surplus production models. Biomass ratio < 1 indicates overfished status and F ratio > 1 indicates that overfishing is occurring.



PROJECT NO. 2
JOB 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 Job 1 was to assess trends in stock status of four anadromous *Alosa* species in Maryland's portion of Chesapeake Bay and selected tributaries. Information for American and hickory shad and alewife and blueback herring in Maryland tributaries was collected using both fishery independent and dependent surveys and included the collection of both juveniles and adults. 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 Conowingo Dam tailrace. 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 Program, Atlantic States Marine Fisheries Commission (ASMFC), Mid-Atlantic Fishery Management Council (MAFMC), and Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC).

METHODS

I. Field Operations

A. Collection of Adults

Susquehanna River

American shad were angled from the Conowingo tailrace (Figure 1) on the Susquehanna River two to five times per week from 25 April through 31 May 2006. 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 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 one pound net and 8 fyke nets. These nets were sampled at least once per week from 22 February to 28 April 2006. The pound net was located at the mouth of Mill Creek while fyke nets were located between 30.4 and 35.7 river kilometer (rkm; 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.

Biological Data

Adult anadromous species sampled in the spring of 2006 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.

B. Collection of Juveniles

Summer Seining

Juvenile alosines were sampled biweekly from July to October in the Susquehanna, Chester and Pocomoke rivers using a 30.5m x 1.2m x 6.4mm mesh haul seine. Seine sites were located a minimum of 0.5 miles apart and consisted of eight sites on the Susquehanna River (Figure 3), six on the Chester River (Figure 4) and six on the Pocomoke River (Figure 5). Sites were chosen by the availability of 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.

Presence/Absence of Eggs/Larvae

Successful alosine reproduction in the lower Nanticoke River was determined by the presence/absence of eggs through biweekly 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 a masonry jar for presence/absence determination.

Sampling sites on the Nanticoke River repeated historic sampling patterns (J. Mowrer pers. comm. MDNR; Figure 6). The river was divided into 18 one-mile cells in which ten cells were randomly selected for sampling. Because of time constraints and the difficulty of determining species on site, 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, an age was only assigned when scales were unreadable.

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 (1989-2006) 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. Annual catch-per-unit-effort (CPUE) for American shad was calculated as the geometric mean of fish caught per lift hour. Time series analysis of the Petersen relative population estimates (1980-2006) were examined using a linear growth model.

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. Annual CPUE of upper Bay American shad captured by hook and line was calculated as the geometric mean of fish caught per boat hour. Nanticoke River pound net CPUEs and commercial landings of alewife and blueback herring (species combined) were analyzed for trends using linear regression.

Mortality Estimates

Two methods were utilized to estimate total instantaneous mortality of alosines and both were based on the number of repeat spawning marks. 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.

<u>Quantitative Habitat Analysis</u>

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 2006 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.63:1. Of the 360 fish sampled by this gear, 338 (94%) were aged directly from their scales and spawning history determined (Table 1). Those American shad not aged directly because of regenerated scales, were not assigned an age.

A total of 9 American shad were captured from the Nanticoke River pound and fyke nets and all were subsequently aged. The 2006 male-female ratio for adult American shad captured in the Nanticoke River was 3.5:1 (Table 1).

Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line was 16.2% for males and 16.3% for females. The arcsine-transformed proportions of these repeat spawners (sexes combined) had been increasing until 2006 when it decreased to very low levels in the time series (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.

Relative Abundance

In 2006, the east lift operated from 03 April through 05 June and technicians counted 56,899 American shad passing the viewing window. Peak passage was on 03 May when 6,130 American shad were recorded. There were 80 of the 360 (22%) tagged American shad recaptured from the east lift (Table 2) and there were no reported recaptures of tagged American shad outside the Conowingo tailrace.

In 2006, the west lift at Conowingo Dam operated from 19 April to 2 June. The 3,970 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 14 May when 339 American shad were collected. Fourteen tagged American shad were recaptured in 2006 from the west lift (Table 2).

The Conowingo tailrace American shad relative population estimate in 2006 was 168,165 (95% confidence intervals 135,455-199,493; Table 3 and Figure 9). This estimate was adjusted for 3% tag loss as suggested by Leggett (1976).

Of the 360 adult American shad sampled (Table 4) in Conowingo tailrace in 2006, all were tagged. Total hours fished was significantly less in 2006 because of inclement weather and time constraints. Estimates of hook and line and fish lift geometric mean CPUEs have decreased significantly since 2002 (hook and line: r^2=0.75, P= 0.78 and fish lifts: r^2=0.75, P=0.026; Table 4 and Figures 10 and 11). Nanticoke River pound net geometric mean CPUEs for American shad have also decreased sharply over the last two years (Figure 12) while fyke net geometric mean CPUEs for American shad have been very low most years and showed no trend (r^2<0.001, P=0.89; Figure 13). The 2006 value of 0.09 is the lowest in the time series.

Mortality Estimates

Since American shad do not fully recruit until age seven in the Maryland portion of the Chesapeake Bay, as detected by scale analysis, repeat spawning marks were used in place of age-structured analysis. In the Conowingo Dam tailrace, mortality estimates from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 1.39. The average difference between the natural logs of the spawning group frequency, gave a Z = 1.41.

Otolith Examination

Of the 274 readable American shad otoliths collected from the west lift at Conowingo Dam in 2006, 50% were classified as wild (M. Hendricks pers. comm. Pennsylvania Fish and Boat Commission). No adult American shad otoliths were analyzed for OTC marks from the Nanticoke River.

a. Juvenile

In the Susquehanna, Chester and Pocomoke rivers, no juvenile American shad were caught by haul seine.

b. 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 = 80). Salinity at all tow locations ranged from 0.1 to 5.4 ppm.

c. Quantitative Habitat Analysis

Estimates of submerged aquatic vegetation (SAV) abundance in the upper Chesapeake Bay were obtained from MD DNR Resource Assessment Service personal, 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). In the upper Chesapeake Bay, no correlation was found between SAV density and American shad juvenile indices (1990-2005; r^2=0.36, P=0.21).

2. Hickory Shad

a. Adults

Sex and Age Composition

Only two hickory shad were sampled from the Nanticoke River in 2006; consequently no age analysis was attempted.

Relative Abundance

Nanticoke River pound net geometric mean CPUEs for adult hickory shad have decreased since 2001 (r^2=0.85, P=0.07 Figure 14). Fyke net geometric mean CPUEs have been very low and showed no trend over the same time period (r^2=0.04, P=0.64; Figure 15).

b. Juveniles

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

3. Alewife and Blueback Herring

a. Adults

Sex and Age Composition

The 2006 male:female ratio for Nanticoke River alewife was 1:2.02. Of the 157 alewives, sampled, 155 were aged. Alewives were present at ages 3-8 and the 2001 year-class (age 5, sexes combined) was the most abundant year-class in 2006, accounting for 50.32% of the total catch (Table 5).

The 2006 male: female ratio for blueback herring was 1:1.65. Of the 69 blueback herring sampled, 68 were aged. Blueback herring were present at ages 3-7 and the 2001 year-class (age 5, sexes combined) was the most abundant cohort, accounting for 54.41% of the catch. Males and females were most abundant at age 5 (Table 5).

Repeat Spawning

The percentages of alewife and blueback herring repeat spawning (sexes combined) from the Nanticoke River was 80.65**%** and 61.76%, respectively (Table 5). The arcsine-transformed proportion of alewife repeat spawners (sexes combined) indicated no trend (1989-2006; r^2<0.04 P=0.46; Figure 16), while blueback herring repeat spawning showed a decreasing trend (1989-2006; r^2=0.37, P<0.01; Figure 16).

Using Speir and Mowrer's (1987) maturity schedule calculation, 72% of male alewife and 76.9% of male blueback herring were mature by age 4. The percentages of female alewife and blueback herring mature by age 4 were 67.6% and 85.7%, respectively.

Length-at-Age

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 ages 3 and 7 (Table 7). Mean length-at-age for Nanticoke River alewife females ages 4 to 8 and males ages 4 to 7 have decreased significantly since 1989 (Table 8). Regressions of blueback herring lengths for females ages 5-7 and males at ages 6 and 7 have also significantly decreased since 1989 (Table 8).

Relative Abundance

Alewife herring geometric mean CPUEs for the Nanticoke River have varied without trend (1989-2006; r^2=<0.01 P=0.64; Figure 17), while those for blueback herring have significantly decreased (1989-2006; r^2=0.67 P<0.01; Figure 18). Both Nanticoke River commercial river herring landings and CPUEs have significantly decreased since 1989 (r^2=0.68 P<0.01; r^2=0.39 P<0.01, respectively; Figure 19).

Mortality Estimates

Instantaneous mortality (Z) in 2006 for Nanticoke River alewife herring (sexes combined) estimated Z = 0.98 (annual mortality {A} = 62.47%). Since maximum age (T_{max}) for alewife was 8, M = 0.38 and F = 0.55. Estimates of Z for Nanticoke River alewife herring males was 1.57 (annual mortality {A} = 79.2%), and for females Z = 0.84 (annual mortality {A} = 56.83%; Figure 20).

Instantaneous mortality (Z) in 2006 for Nanticoke River blueback herring (sexes combined) estimated Z = 1.02 (annual mortality {A} = 63.94%). If the maximum age (T_{max}) for blueback herring was 7, M = 0.43 and F = 0.59. Estimates of Z for blueback herring males was 0.97 (annual mortality {A} = 62.09) and for females Z = 0.90(annual mortality {A} = 59.34%; Figure 21).

b. Juvenile

No juvenile alewife or blueback were captured in the Susquehanna River juvenile sampling sites in 2006. Chester River sampling produced 5 juvenile alewife herring (CPUE = 0.14) and 42 juvenile blueback herring (CPUE = 1.2). On the Pocomoke River 4 alewife herring (CPUE = 0.125) and 8 juvenile blueback herring (CPUE = 0.25) were collected.

DISCUSSION

Anadromous Species

1. American shad

a. Adults

All American shad commercial fisheries in Atlantic Ocean waters were closed on 31 December 2004 (ASMFC 1998). Since this fishery resulted in landings of mixed stocks in excess of 1.2 million pounds and no Chesapeake Bay American shad fishery exists, increases in relative abundance indicators have been expected. However, the three indicators (tailrace relative population estimates, Conowingo Dam lift geometric means and Nanticoke River pound net CPUEs) for 2006 showed significant declines.

Factors contributing to the decline in American shad relative abundance may include predation and ocean harvest as "bait". 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 pers. comm, NY Dept. Env. Cons.).

Since aging techniques for American shad using scales has been shown to be somewhat tenuous (McBride et al 2006), freshwater spawning marks may be the most accurate assessment of survival and mortality. Mortality rates for Chesapeake Bay stocks of American shad averaged Z = 1.40 and are within the range of reported Z estimates from other studies (ASMFC 1998). 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-hour during the last five years (Tables 9 and 10). Since estimates of relative abundance have fluctuated and river flows highly influence catch, conclusions drawn from these creels should be considered somewhat tenuous.

b. Juveniles

Baywide juvenile American shad indices have decreased significantly since 2004 (Figure 22). These decreases were primarily driven by the upper Chesapeake Bay (Figure 23) and Potomac River indices (Figure 24). In the upper Chesapeake Bay during 2006, 10 juvenile American shad were captured at seven permanent sites by the (Maryland Juvenile Striped Bass Survey) in forty-two hauls and three were captured from the six auxiliary sites. The Potomac River juvenile American shad indices also generated by this assessment have shown significant decreases since 2004. These low juvenile indices in the last two years for the upper Chesapeake Bay and Potomac River may demonstrate the decreasing trend in abundance of adults.

Sampling for juvenile American shad from the six sites in the Susquehanna River during 2006 was unsuccessful. Possible reasons for the absence of juveniles include downstream migration related to food availability, lower salinity gradient, adverse water temperatures and predation.

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 CPAH = 4.3 to 8.3 and has varied without trend since 1998 (r^2=0.09, P=0.41; Table 11).

Richardson (et al 2004) noted that ninety percent of hickory shad in Deer Creek have spawned by age four and stocks generally consisted of few virgin fish. The oldest fish in their sample from Deer Creek was age eight (Table 12). Using Hoenig's (1983) estimation of natural mortality ($\ln(M_x) = 1.46 - 1.01\{\ln(t_{max})\}$), M = 0.53. If Z is calculated using the freshwater spawning marks as in American shad, then hickory shad mortality estimates for Deer Creek in 2004 (latest available data) resulted in a Z = 0.25. The average difference between the natural logs of the spawning group frequency produced Z = 0.32.

In general, the resultant Z is attributed to natural mortality since catch and release for hickory shad is only permitted in Maryland. Limited data on hickory shad negates drawing specific conclusions but based on the estimated mortality rates, fishing mortality appears to be minimal.

b. Juveniles

Sampling using haul seines during the mid summer and fall likely missed juvenile hickory shad because of their large size, gear avoidance and preference for deeper water. Since adults may spawn from late March to late April, up to six weeks before American shad, 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 approximately 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 pound net CPUEs of river herring (species combined) in the Nanticoke River from cooperating watermen decreased during 1989-2006, as did the blueback herring CPUE. Alewife herring CPUEs have not exhibited any statistical trend between 1989 and 2006.

Depleted river herring stocks on the east Coast have triggered Connecticut, Rhode Island, Massachusetts and North Carolina to close their recreational and commercial river herring fisheries. In 2006, river herring commercial landings in Maryland were 8% of the historical high and with juvenile indices at very low levels, stocks are likely to continue this decline.

b. <u>Juveniles</u>

The catch of juvenile alosine species on the Chester and Pocomoke rivers was low with none being captured on the Susquehanna River. Since this is the second year of sampling for juvenile alosine in these systems, comparisons would be tenuous. Results from the Maryland Juvenile Striped Bass Survey in the Nanticoke River indicated few of either species were collected (Figures 25 and 26, respectively). 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 and subsequent capture.

CITATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Mowrer, J. 2000. Resident and migratory juvenile finfish recruitment survey. *In* Stock assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay. Maryland Department of Natural Resources, Report F-54-R. Annapolis, Maryland.

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

Piavis, P., R. Sadzinski, and Jarzynski, T. 2001. Stock assessment of selected adult resident and migratory finfish in Maryland's Chesapeake Bay. *In* Stock Assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay. Maryland Department of Natural Resources, Report F-54-R. Annapolis, Maryland.

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

Richardson, B. R. P. Morin, M. W. Baldwin and C. P. Stence. 2004. Restoration of American shad and hickory shad in Maryland's Chesapeake. 2003 Final Progress Report. Maryland Department of Natural Resources, Report F-57-R. Annapolis, Maryland.

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

Sadzinski, R.A., J. H. Uphoff, Jr. and P.G. Piavis. (In Press). Evaluating recovery of American shad in the tidal Susquehanna River. Transactions American Fisheries Society.

Sadzinski, R., A. Jarzynski, P. Piavis and M. Topolski. 2002. Stock assessment of selected adult resident and migratory finfish in Maryland's Chesapeake Bay. Pages I.1 - I.96 in 2001 Stock assessment of selected resident and migratory recreational finfish species within Maryland's Chesapeake Bay. Maryland Department of Natural Resources, Federal Aid Annual Report F-54-R, Annapolis, Maryland.

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

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

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

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

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

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

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

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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 2006.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0	--	0	--	0	--
3	17	0	1	0	18	0
4	62	2	95	0	157	2
5	43	12	74	7	117	19
6	6	5	19	8	25	13
7	2	2	12	12	14	14
8	0	--	6	6	6	6
9	0	--	1	1	1	1
Totals	130	21	208	34	338	55
Percent Repeats	16.2		16.3		16.3	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	2	0	0	--	2	0
4	1	0	0	--	1	0
5	2	2	2	0	4	2
6	0	--	0	--	0	--
7	0	--	0	--	0	--
8	1	1	0	--	1	1
9	0	--	0	--	0	--
Totals	6	2	2	0	8	3
Percent Repeats	33.3		0		37.5	

Table 2. Recaptured American shad in 2006 at Conowingo Dam's east and west lifts by tag color and year.

East Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Orange	2006	80
Green	2005	1
Yellow	2003	1
Blue	2002	2
West Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Orange	2006	14

Table 3. Conowingo tailrace population estimate of adult American shad in 2006.

Chapman's Modification of the Petersen estimate (Chapman 1951):

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

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

<u>2006 survey results:</u>

C = 39,596
M = 343
R = 80

Therefore:

$$N = \frac{(39596 + 1)\,(343 + 1)}{(80 + 1)} = 168{,}165$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N = \frac{(39{,}597 + 1)\,(343 + 1)}{(64.28 + 1)} = 199{,}493$$

$$\text{Lower } N = \frac{(39{,}597 + 1)\,(343 + 1)}{(99.56 + 1)} = 135{,}455$$

Table 4. Conowingo Dam tailrace hook and line data, 1982-2006.

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

Table 5. Numbers of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2006.

Alewives

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	4	0	2	0	6	0
4	13	4	15	2	28	6
5	22	21	56	55	78	76
6	11	11	24	24	35	35
7			4	4	4	4
8			4	4	4	4
9						
Totals	50	36	105	89	155	125
Percent Repeats	72.00		84.76		80.65	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	1	0	1	0	2	0
4	6	0	13	0	19	0
5	15	15	22	17	37	32
6	3	3	6	6	9	9
7	1	1			1	1
8						
9						
Totals	26	19	42	23	68	42
Percent Repeats	73.08		54.76		61.76	

Table 6. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2006.

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						

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				

Table 7. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2006.

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				

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					

Table 8. Regression statistics for alewife and blueback herring in 2006 based on cumulative data.

Alewife		**Male**				**Female**		
Age	**N**	**Slope**	r^2	**P**	**N**	**Slope**	r^2	**P**
3	348	-0.188	0.006	0.166	104	+0.073	<0.001	0.781
4	1228	-0.361	0.028	<0.001	1094	-0.421	0.037	<0.001
5	1037	-0.312	0.021	<0.001	1466	-0.277	0.019	<0.001
6	427	-0.526	0.063	<0.001	922	-0.359	0.034	<0.001
7	69	-0.989	0.175	<0.001	294	-0.450	0.058	<0.001
8	6	-1.183	0.117	0.506	89	-0.686	0.086	0.005
9					11	-2.397	0.212	<0.154
Blueback herring		**Male**				**Female**		
Age	**N**	**Slope**	r^2	**P**	**N**	**Slope**	r^2	**P**
3	167	-0.055	<0.001	0.686	34	-0.223	0.017	0.467
4	784	-0.028	<0.001	0.691	669	-0.075	0.002	0.323
5	911	-0.022	<0.001	0.752	865	-0.152	0.006	0.027
6	646	-0.503	0.038	<0.001	675	-0.413	0.023	<0.001
7	281	-0.602	0.030	0.004	331	-0.334	0.016	0.023
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, 2001-2006.

Year	Number of Interviews	Total Fishing Hours	Total Catch of American Shad	Mean Number of American Shad Caught Per Hour (CPAH)
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

Table 10. Summary of the spring American shad logbook data, 1999-2006.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of American Shad Caught	Mean Number of American Shad Caught Per Hour (CPAH)
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	820.5	747	0.91

Table 11. Summary of the spring hickory shad log book data from Deer Creek, 1998-2006.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad Caught	Mean Number of Hickory Shad Caught per Hour (CPAH)
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

Table 12. Age structure of hickory shad from the Susquehanna River based on scales, 1998-2006.

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	Not yet done							

Figure 1. Location of the hook and line sampling in Conowingo Dam tailrace in 2006.

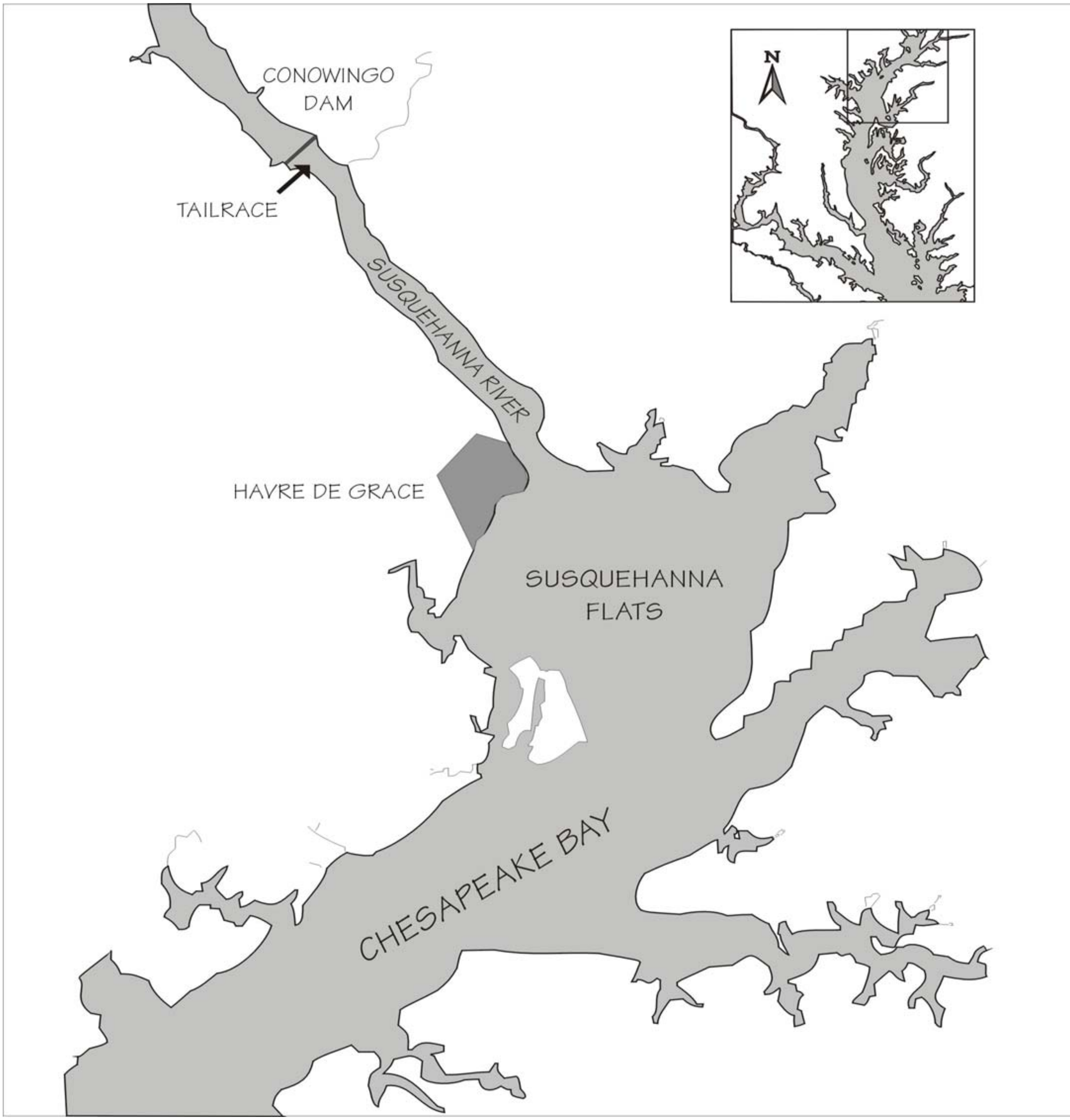


Figure 2. Distribution of the fyke and pound nets sampled on the Nanticoke River in 2006.

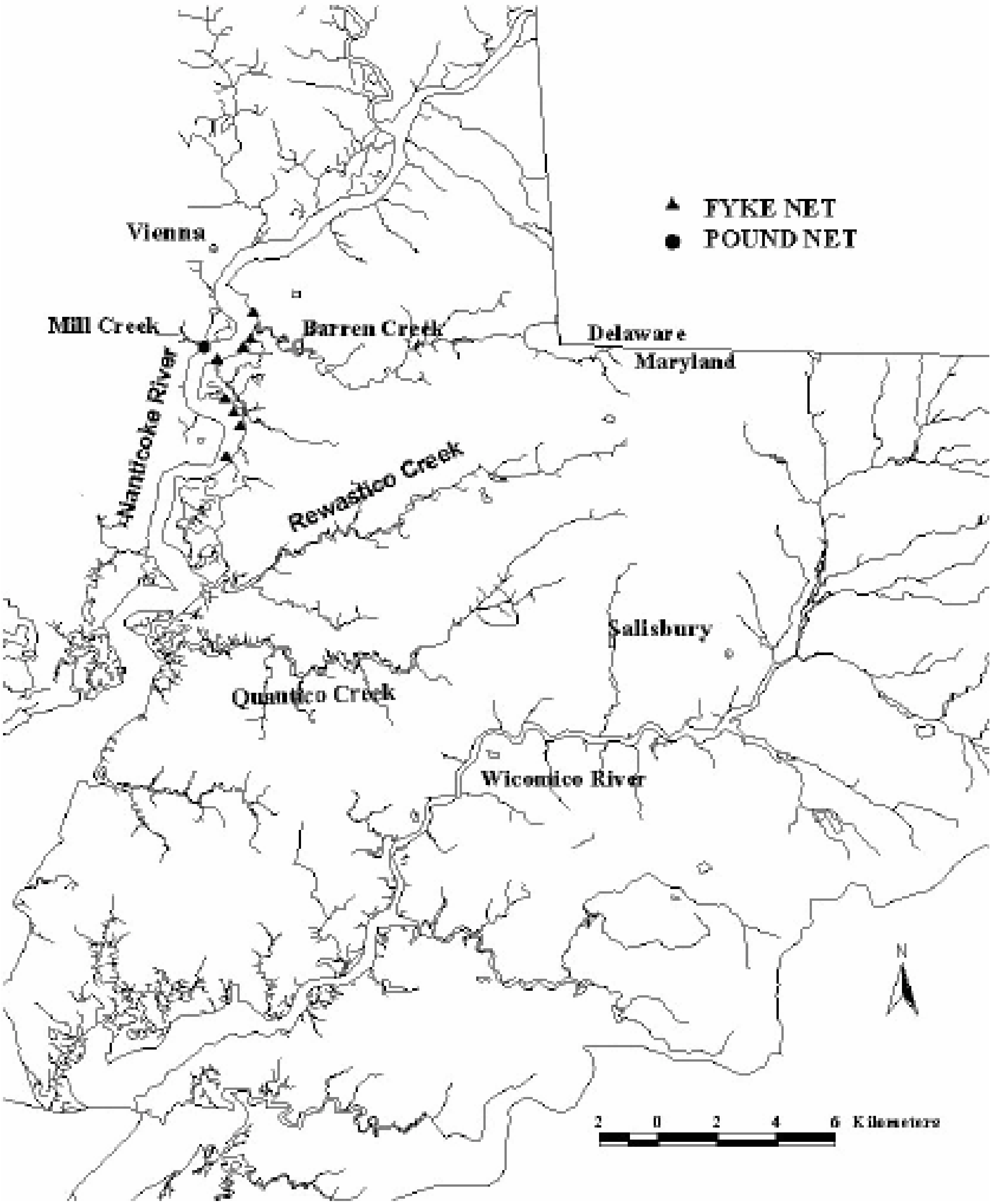


Figure 3. Distribution of the seine sites (black circles) on the Susquehanna River in 2006.

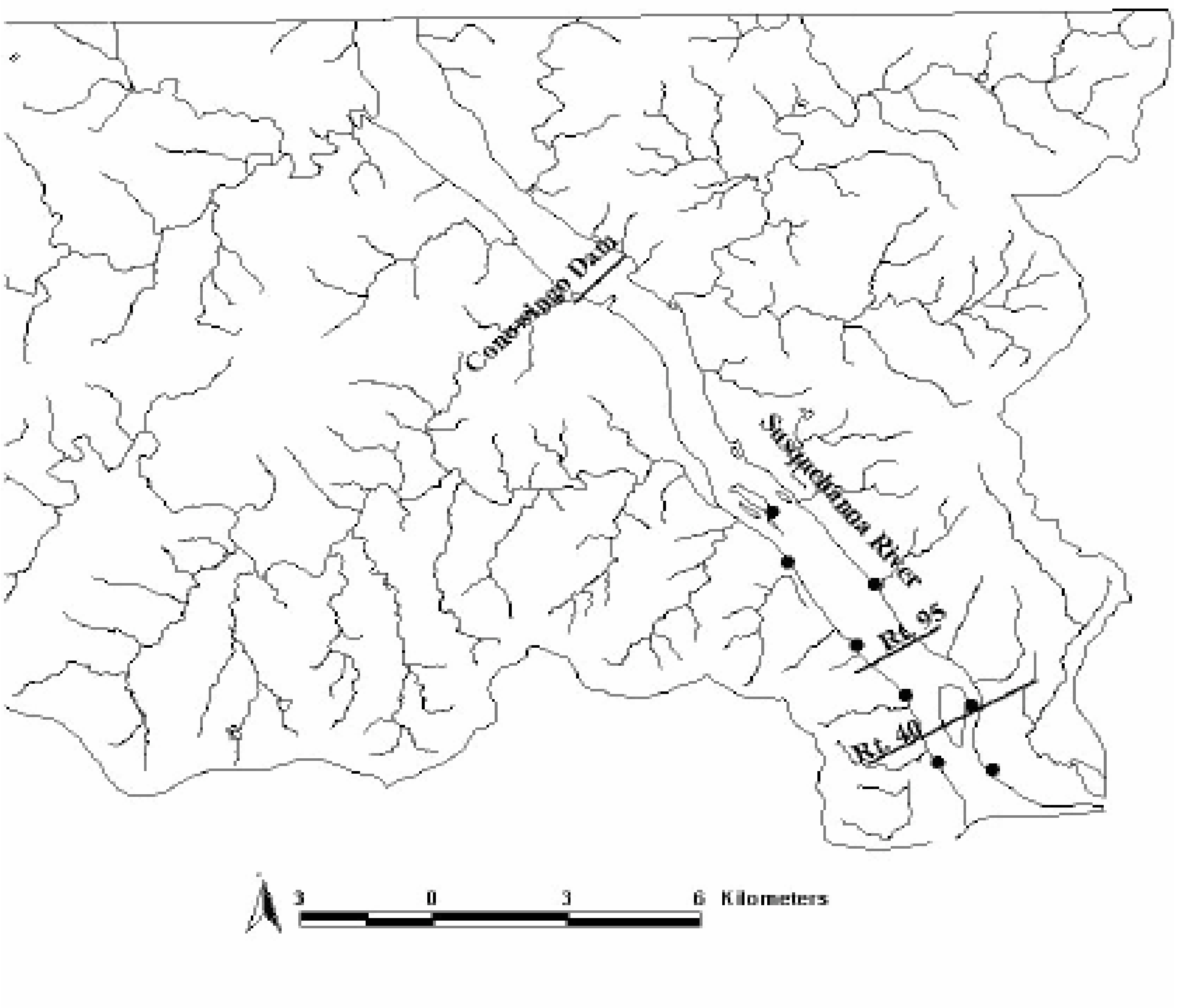


Figure 4. Location of the seine sites on the Chester River in 2006 (black circles).

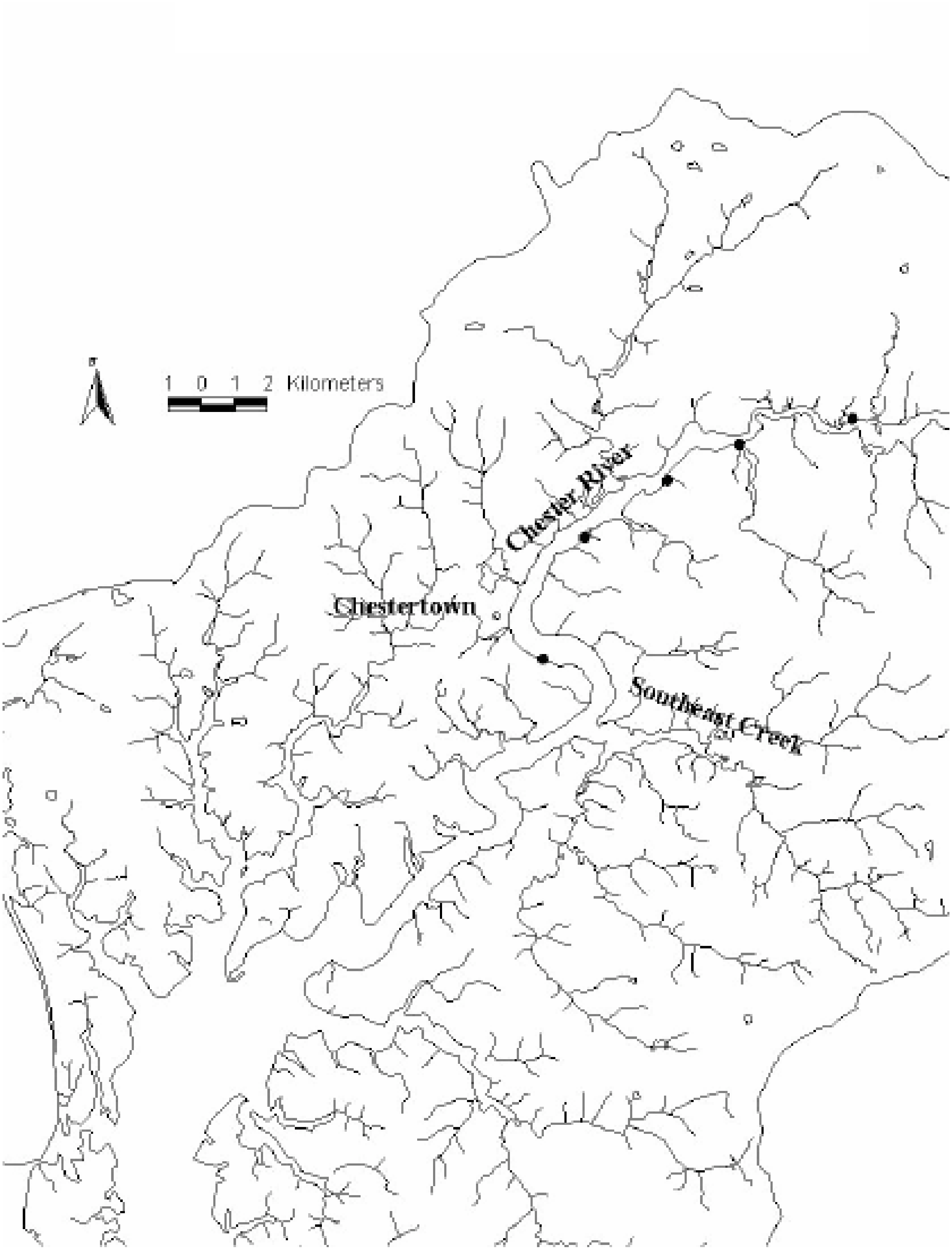


Figure 5. Distribution of the seine sites on the Pocomoke River in 2006 (black circles).

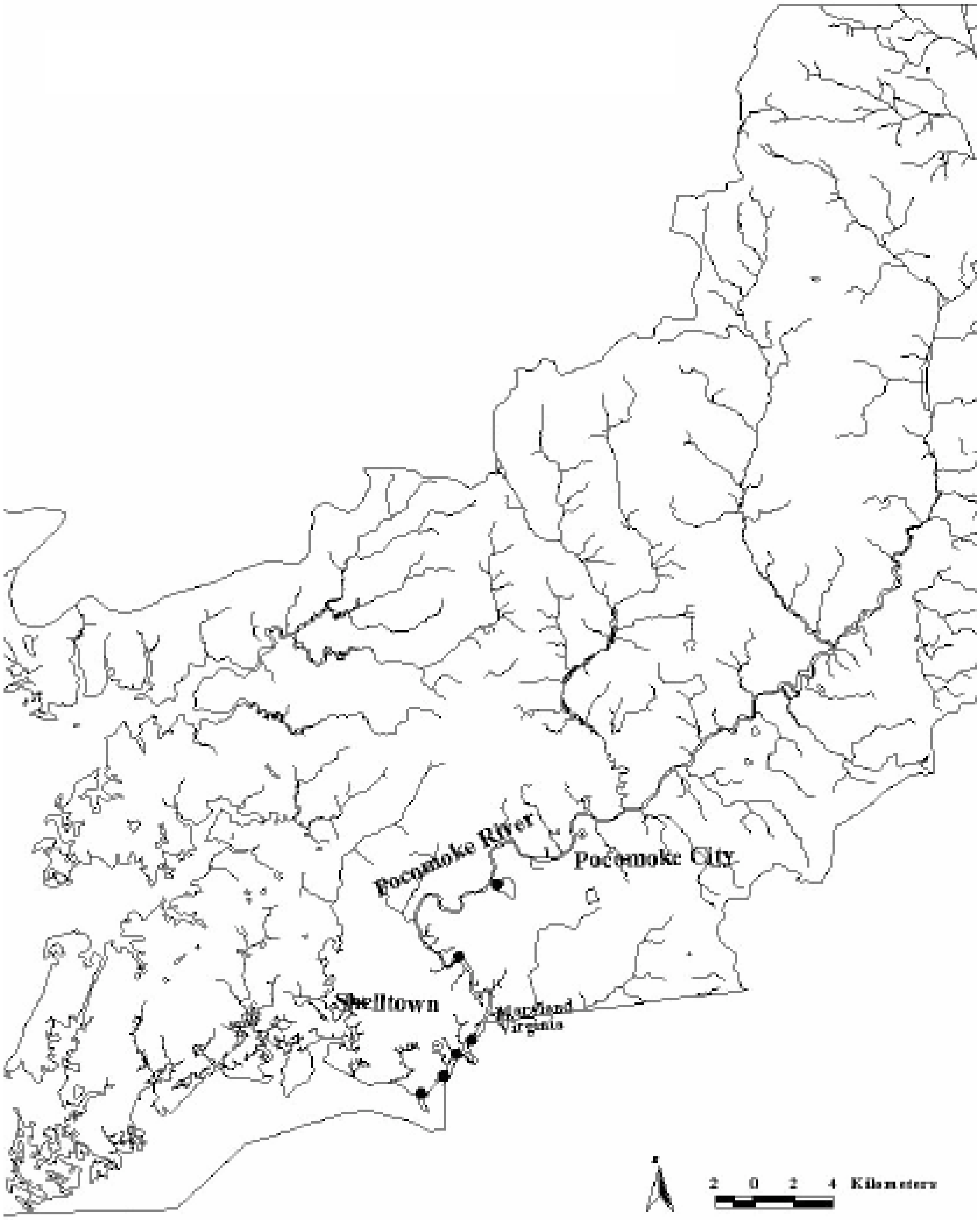


Figure 6. Location of ichthyoplankton sampling sites on the Nanticoke River in 2006.

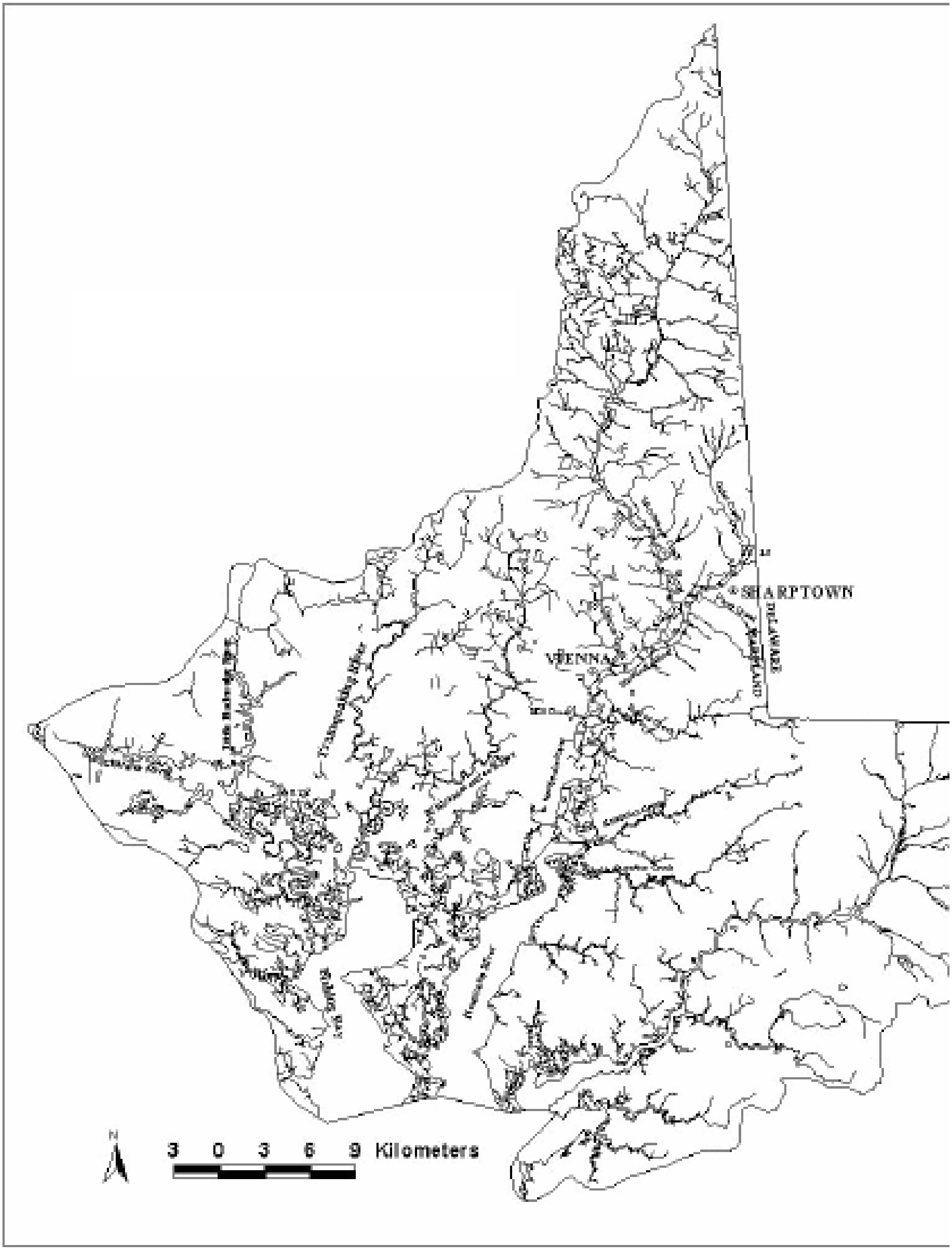


Figure 7. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2006).

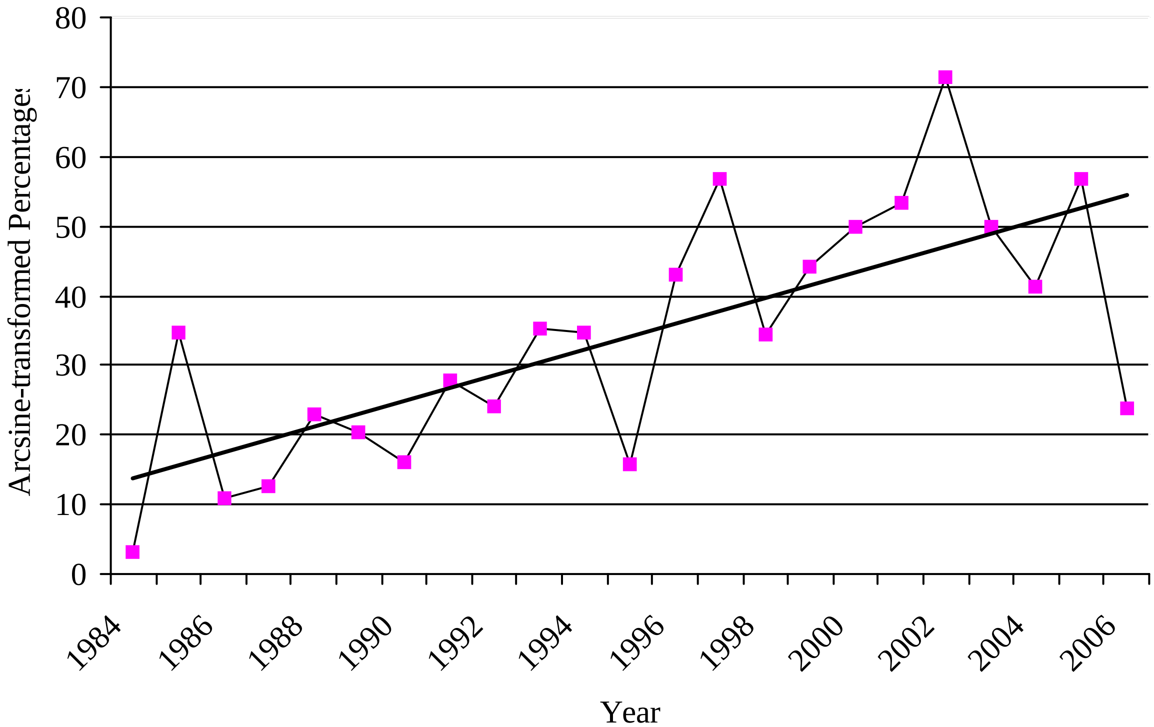


Figure 8. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River (1988-2006).

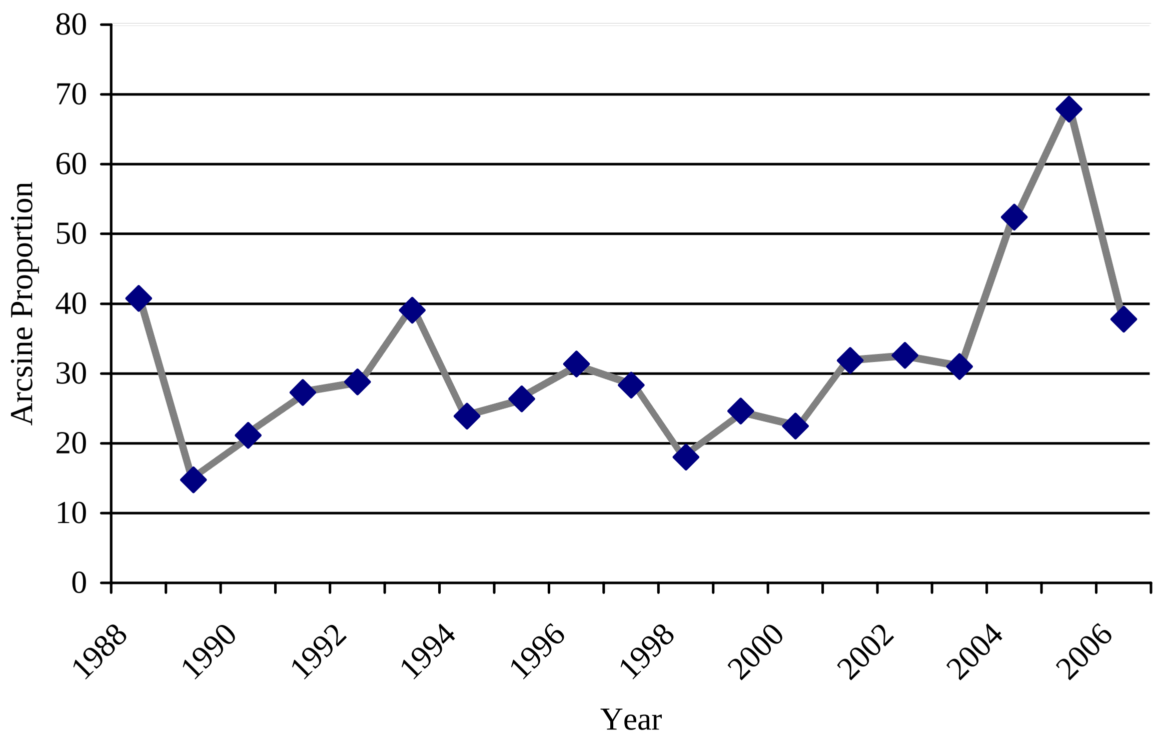


Figure 9. Conowingo Dam tailrace relative estimates of American shad abundance with 95% confidence intervals, 1984-2006.

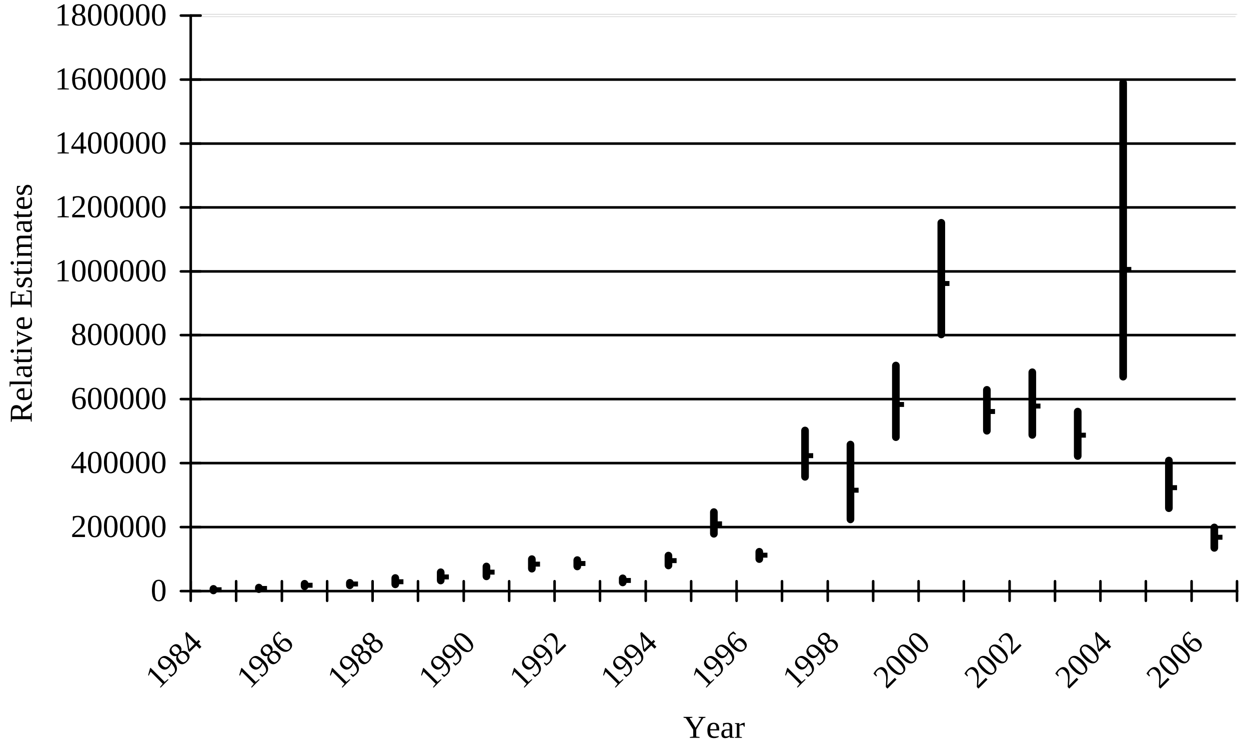


Figure 10. Geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2006.

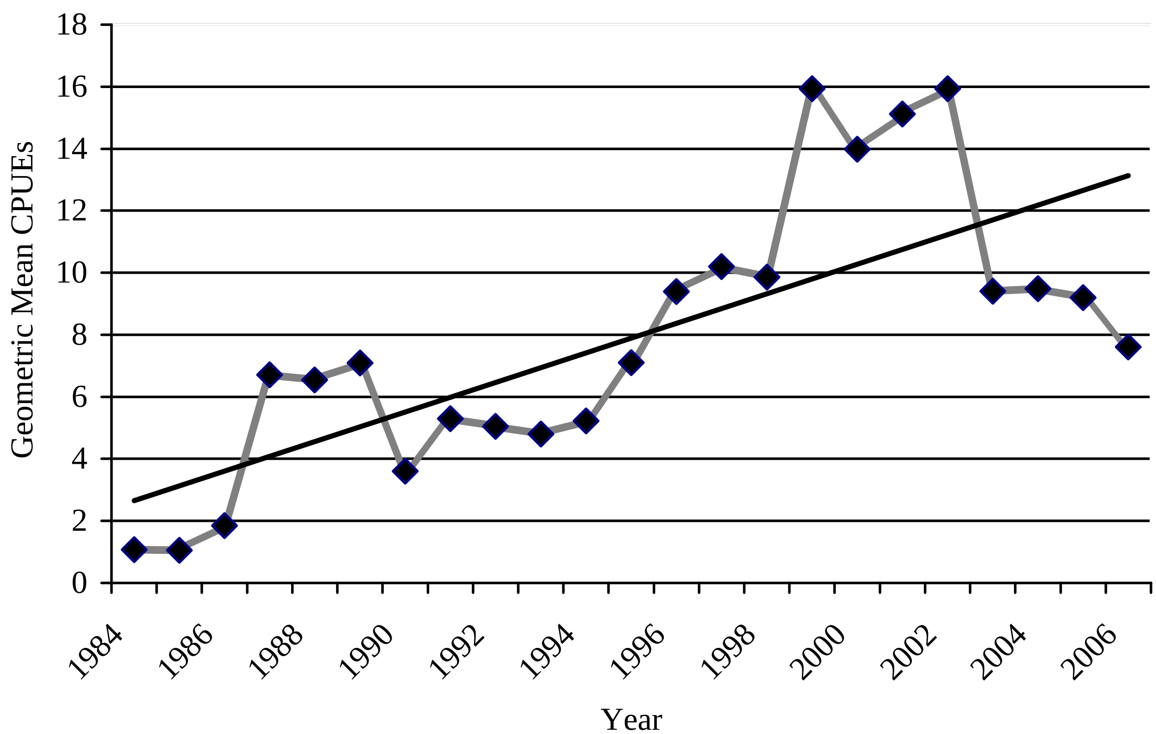


Figure 11. Geometric mean CPUE of American shad from the lifts at Conowingo Dam.

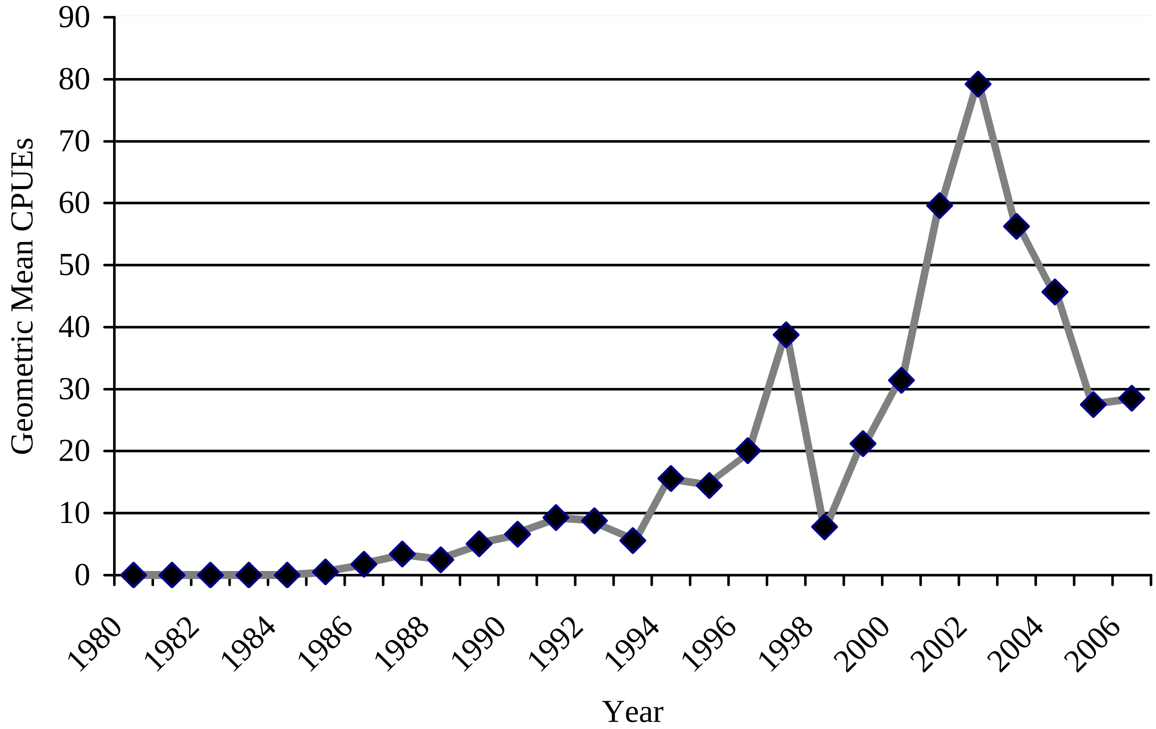
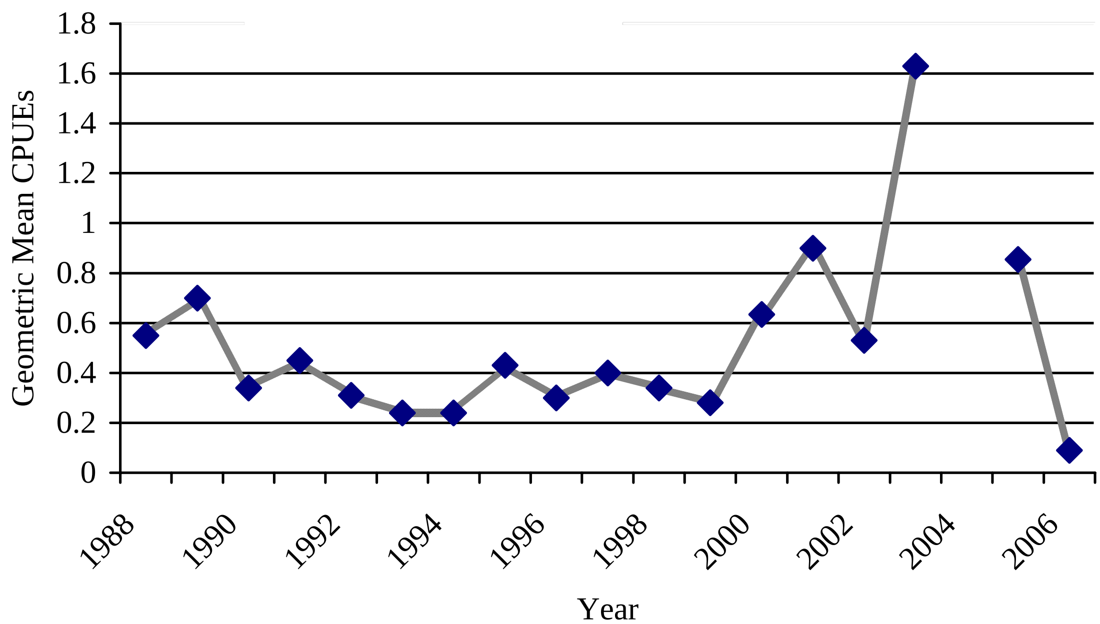


Figure 12. Pound net geometric mean CPUE for American shad from the Nanticoke River, 1988-2006. [1]



[1] No Pound nets were fished in 2004.

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

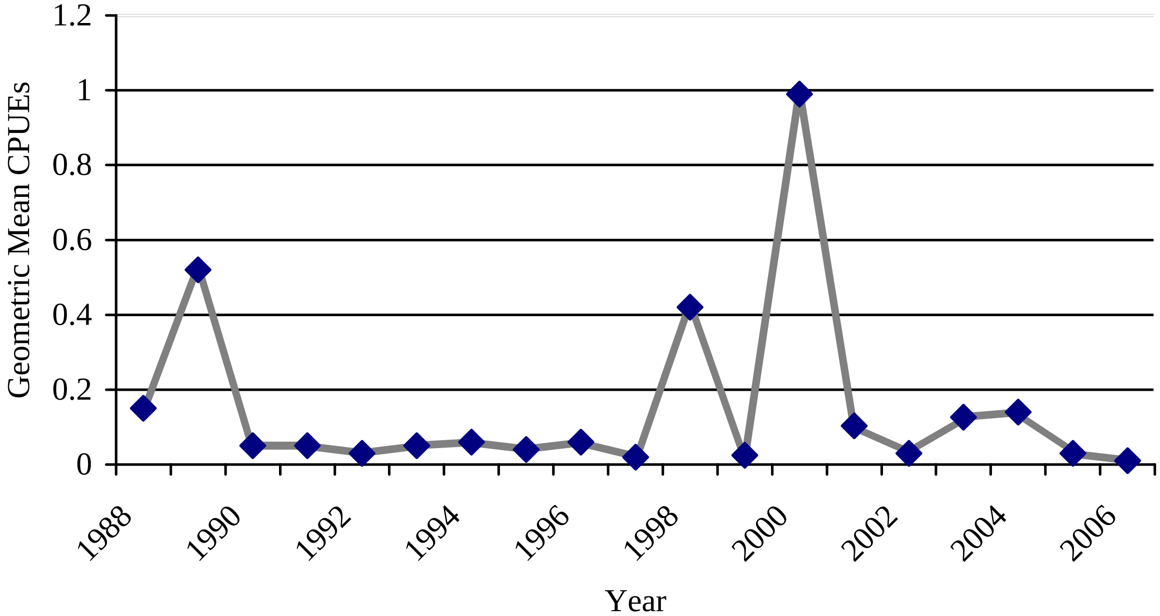
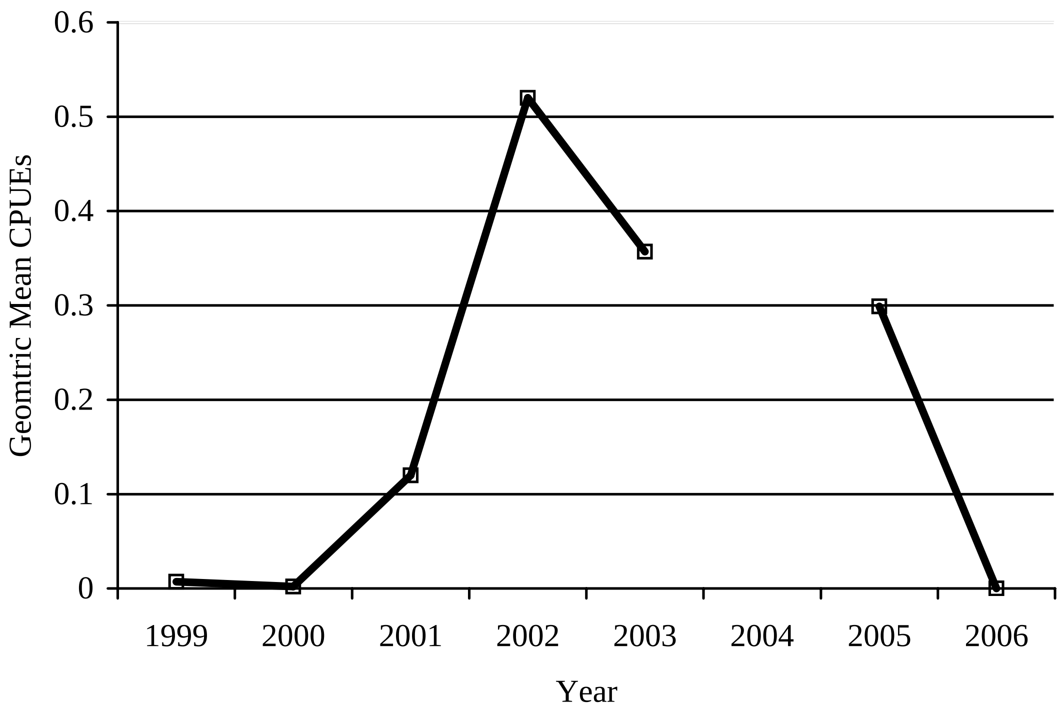


Figure 14. Adult hickory shad geometric mean CPUE from Nanticoke River pound nets, 1999-2006.[2]



[2] No pound nets were set in 2004.

Figure 15. Adult hickory shad CPUE from Nanticoke River fyke nets, 1999-2006.

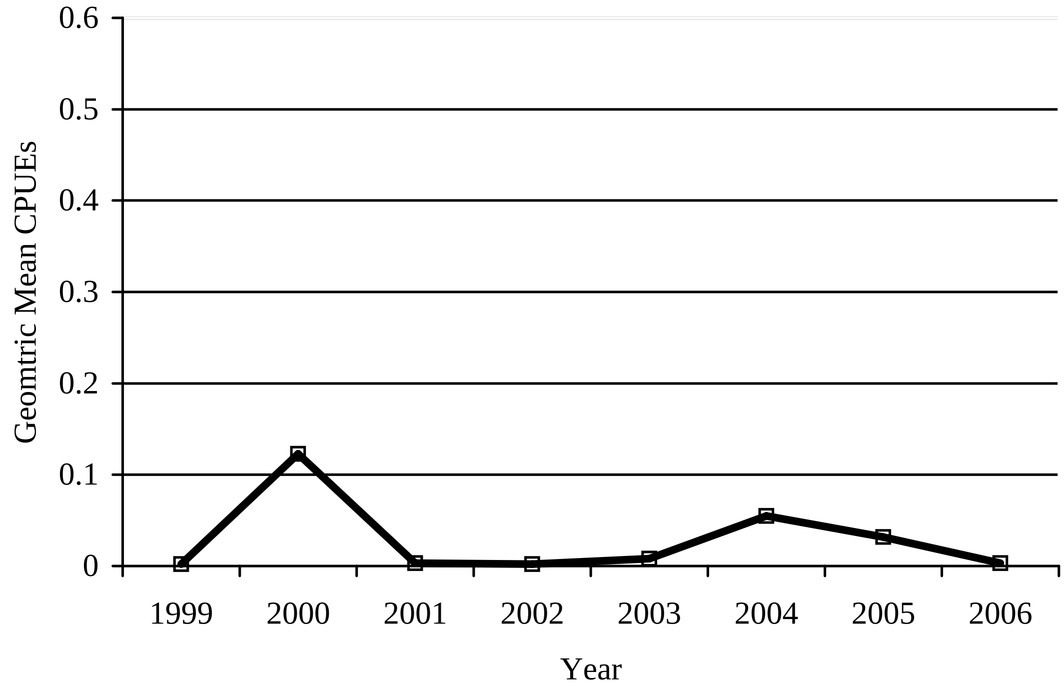


Figure 16. Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes combined) from the Nanticoke River, 1989-2006.

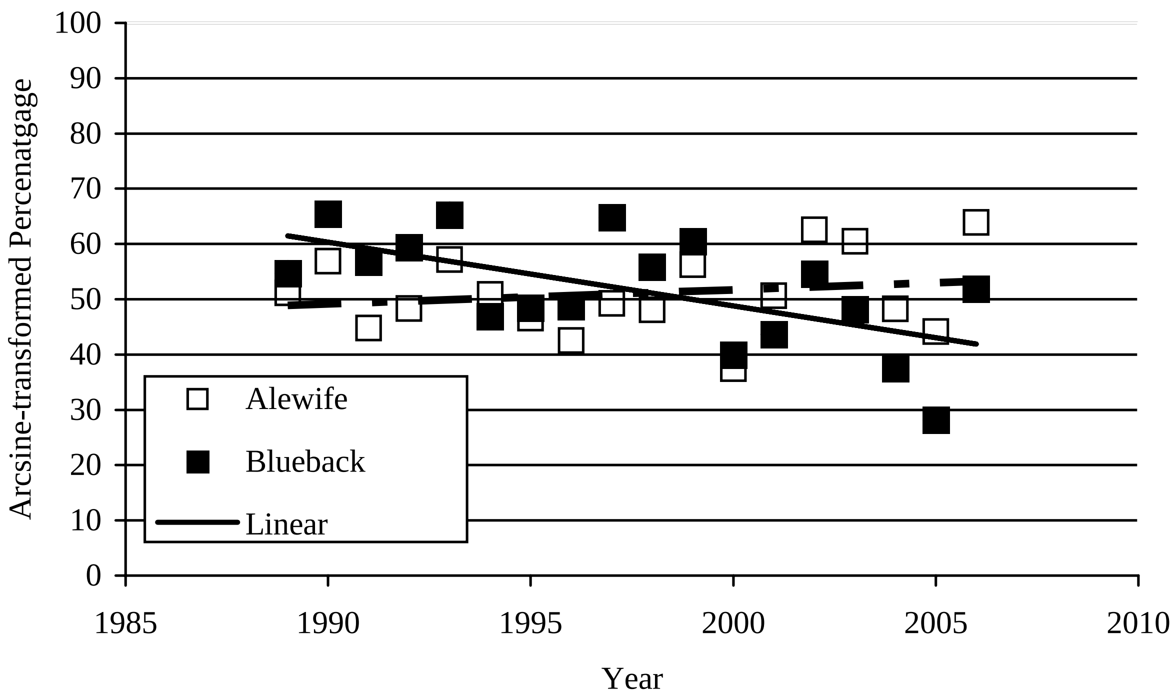


Figure 17. Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1990-2006.

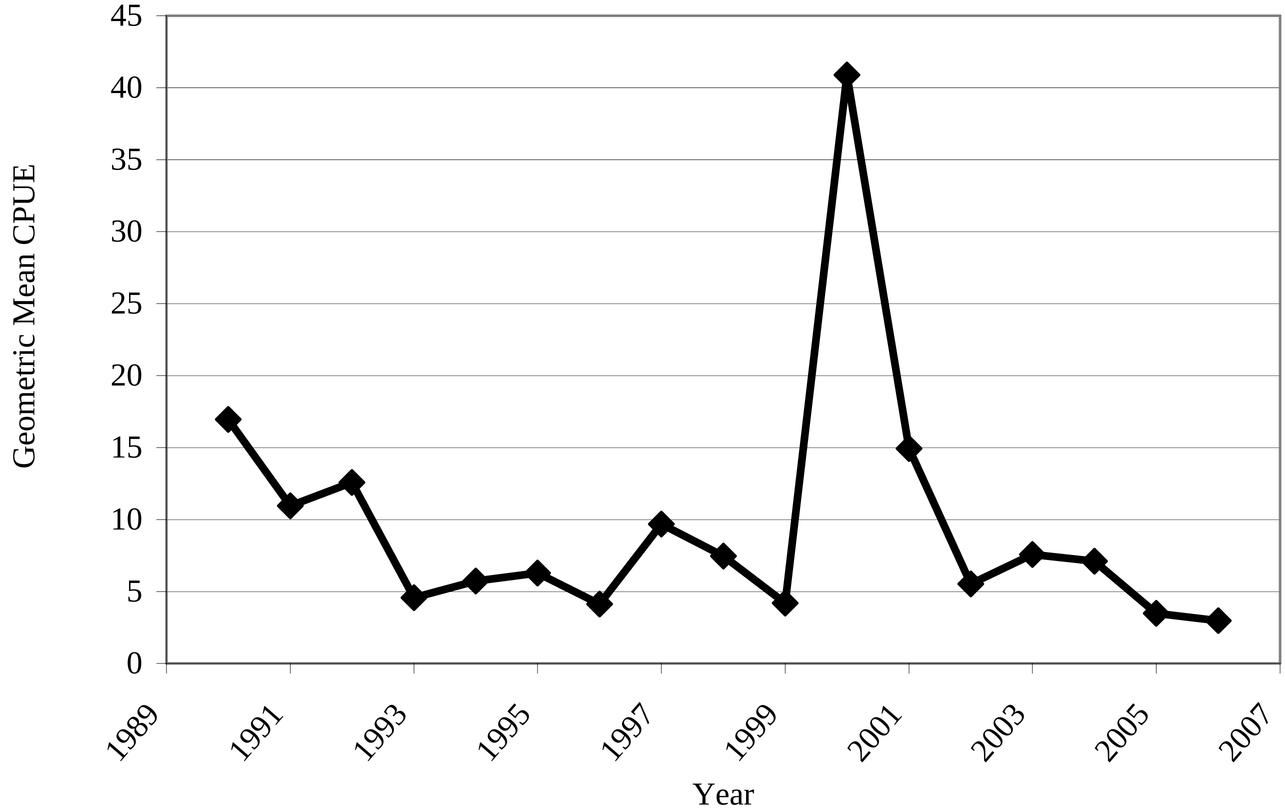


Figure 18. Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2006.

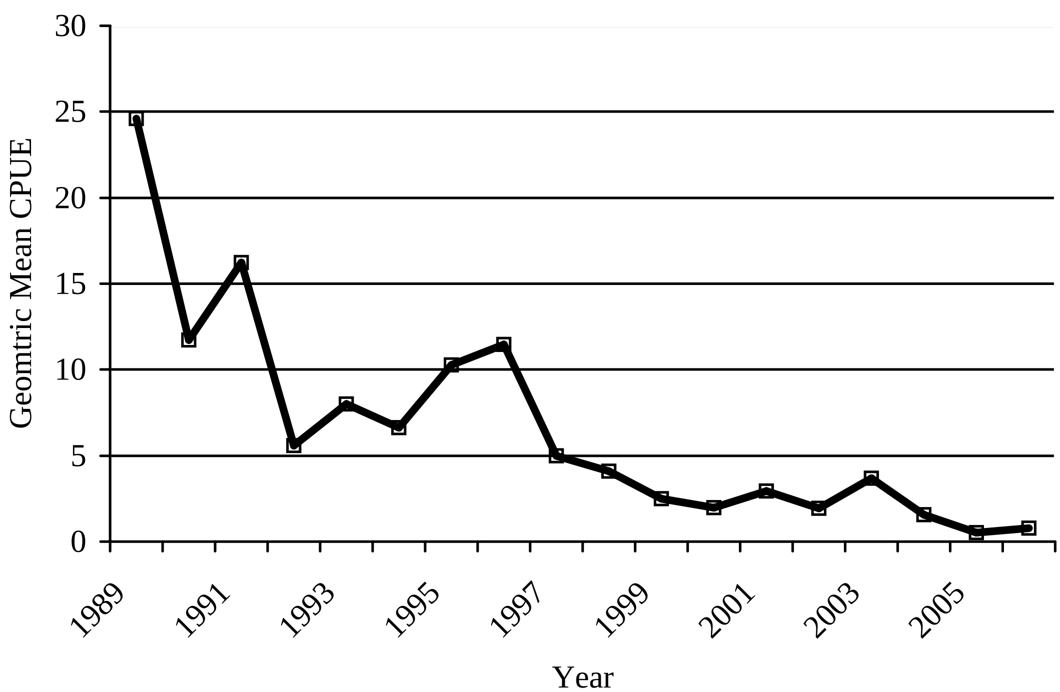


Figure 19. Regression analysis estimates of geometric mean CPUE (alewife and blueback herring combined, 1989-2006), and the total commercial river herring landings in pounds, 1980-2006 from the Nanticoke River.

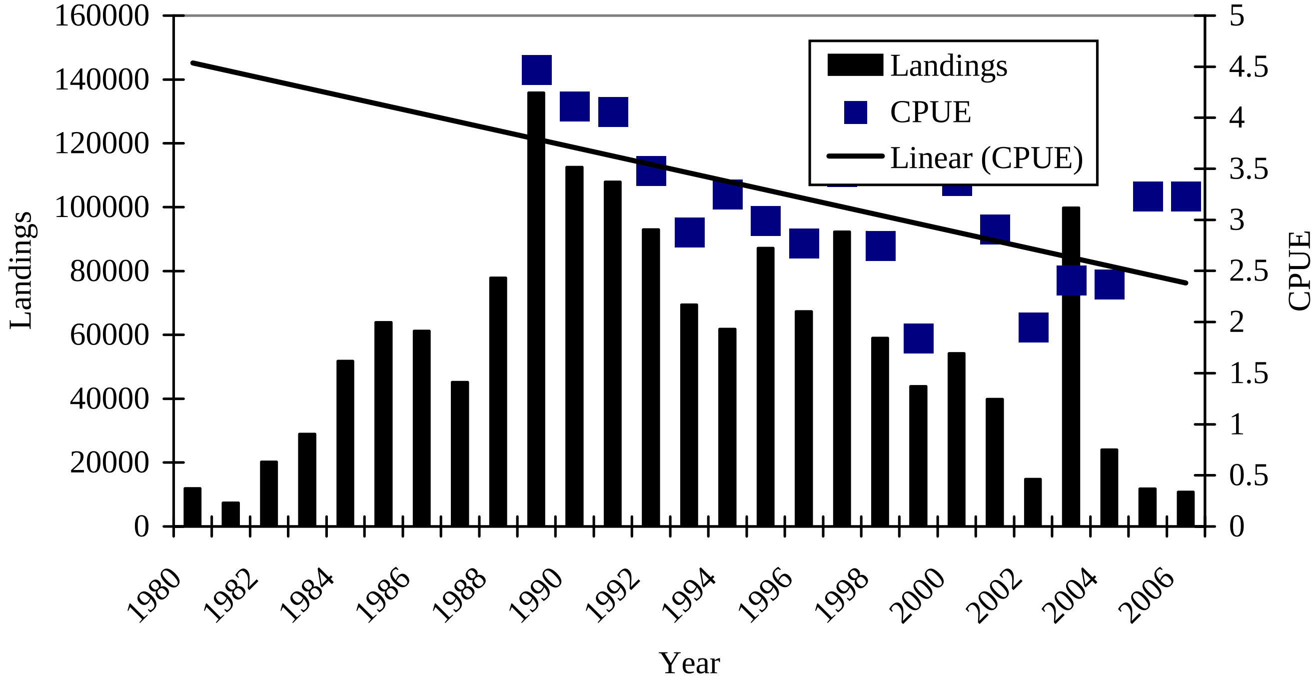


Figure 20. Instantaneous mortality (Z) of Nanticoke River alewife herring (1989-2006).

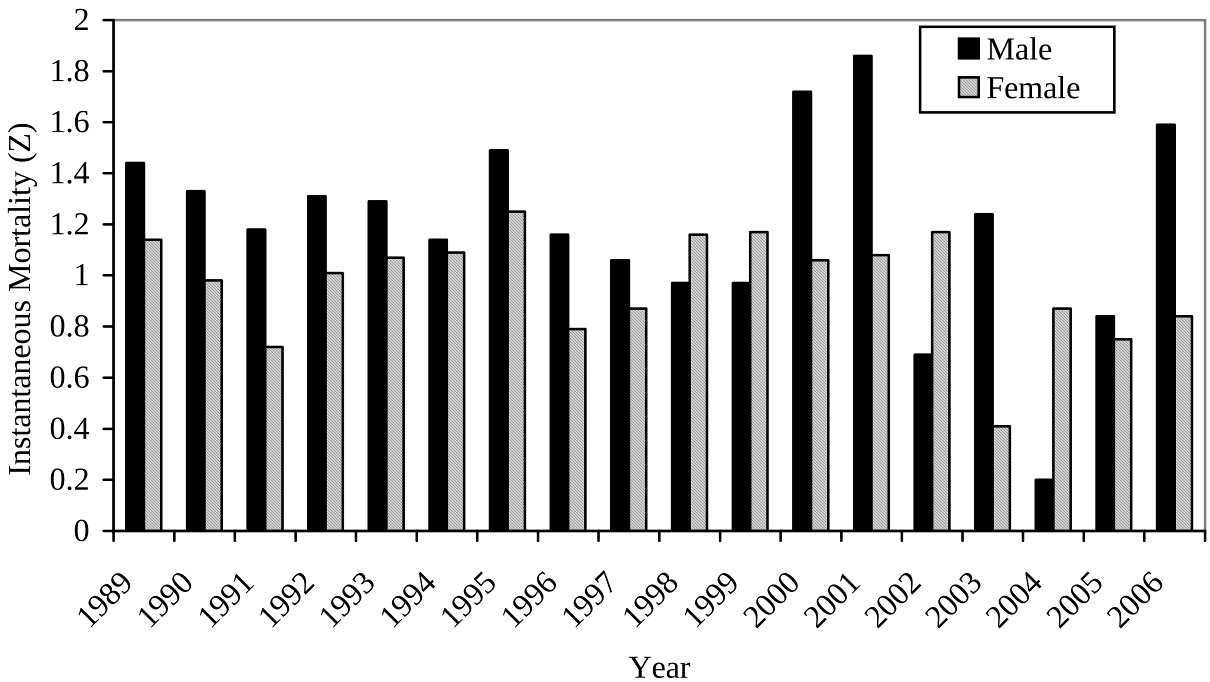


Figure 21. Instantaneous mortality (Z) of Nanticoke River blueback herring (1989-2006).

Figure 22. Baywide juvenile American shad geometric mean CPUEs and 95% confidence intervals , 1959-2006.

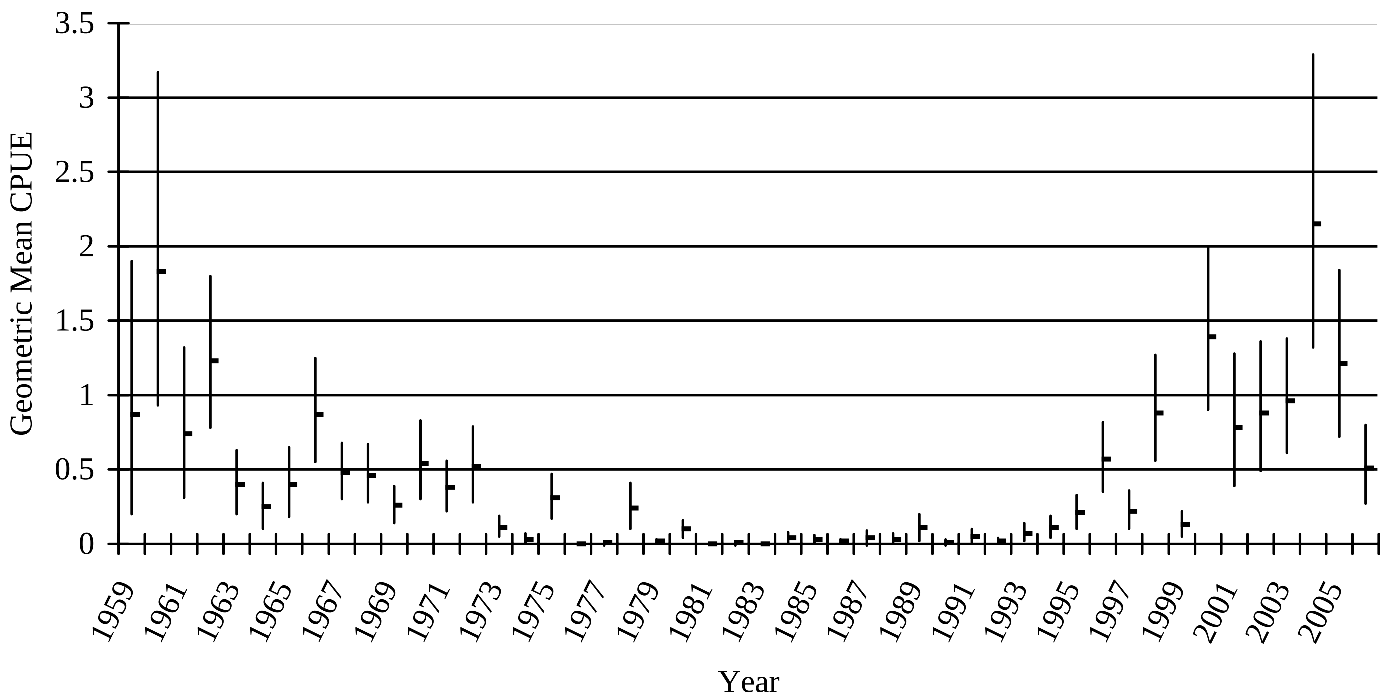


Figure 23. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs and 95% confidence intervals, 1980-2006.

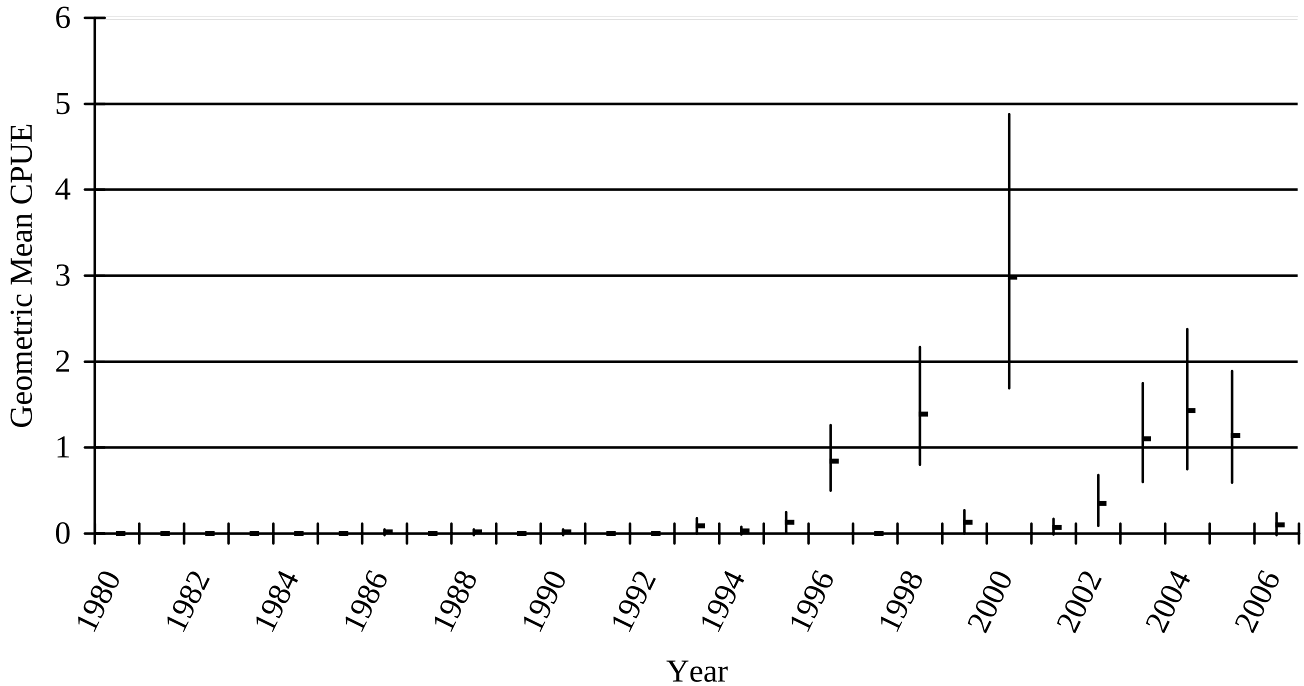


Figure 24. Potomac River geometric mean CPUEs for juvenile American shad and 95% confidence intervals, 1980-2006.

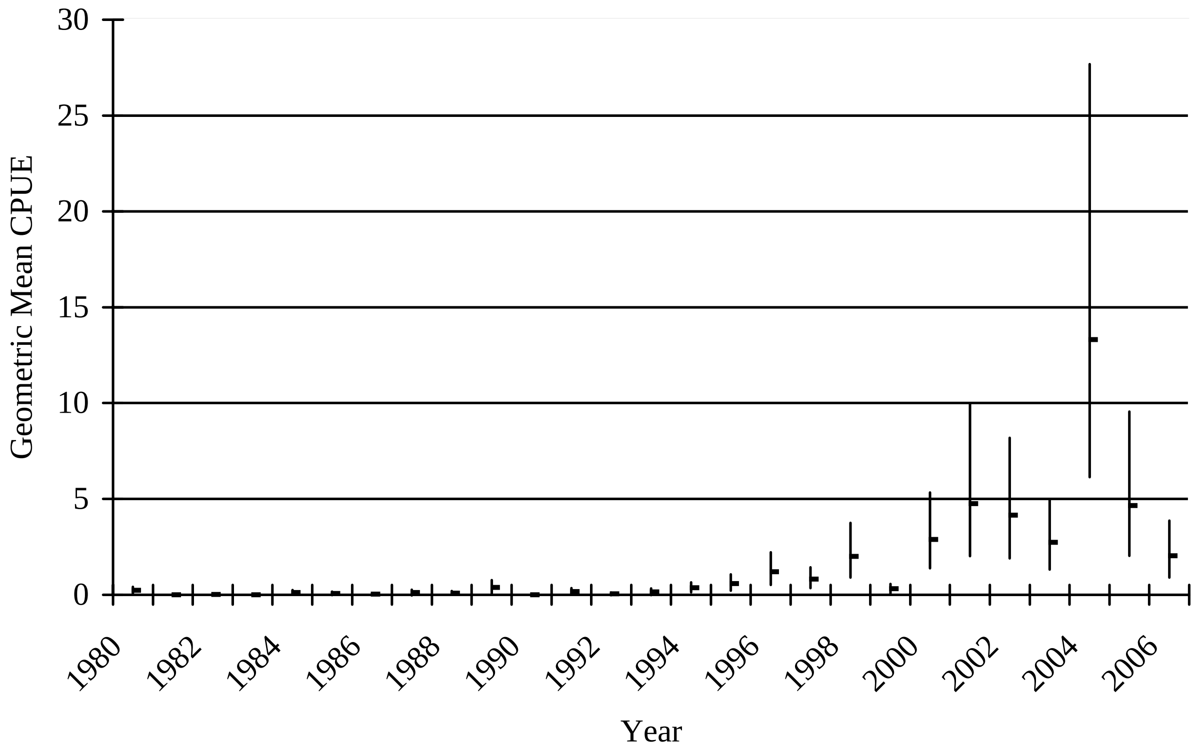


Figure 25. Juvenile alewife herring geometric mean CPUEs from the Nanticoke River, 1980-2006.

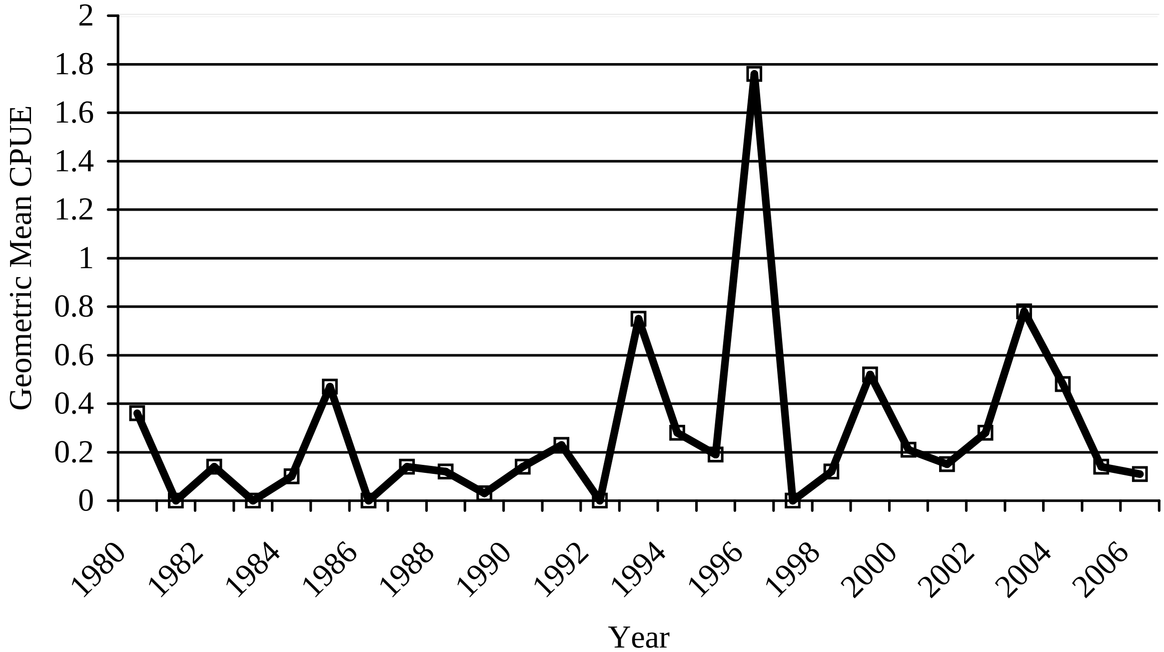
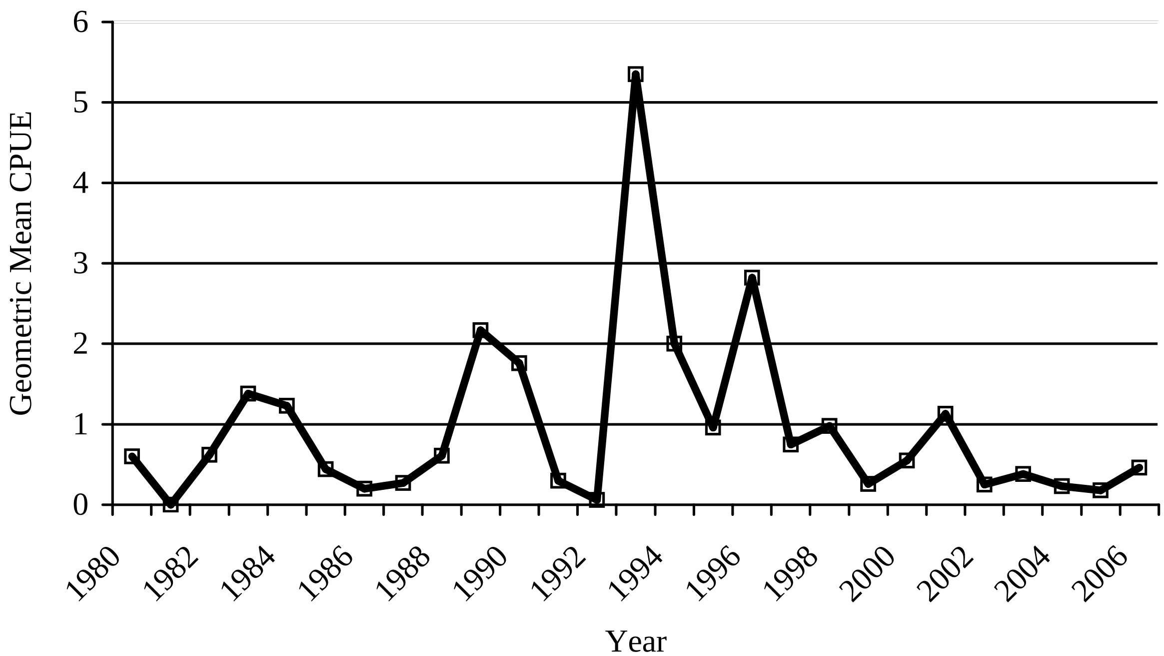


Figure 26. Nanticoke River juvenile blueback herring geometric mean CPUEs, 1980-2006.



PROJECT NO. 2
JOB NO. 2

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

Prepared by Harry W. Rickabaugh Jr.

INTRODUCTION

The primary objective of 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 lower 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 states valuable migratory finfish resources through the regulatory/statutory process.

METHODS

Sampling Procedures

During 2006 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 2, 2006 through September 5, while the lower Chesapeake Bay was sampled from July 11 to September 19 (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 taken randomly 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 otolithis were processed and aged by the South Carolina Department of Natural Resources. Water temperature (°C), salinity (ppt), GPS coordinates, date and hours fished were also recorded at each net.

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). Since these data sets are not finalized until the spring of the following year; landings data are through 2005 for this report.

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

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

were 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 for 2003-2006 mortality estimates were derived from pooled ages (otoliths; n = 480) determined from the Chesapeake Bay pound net survey from 2003-2005. Parameters for weakfish were L_∞ = 840 mm TL and K= 0.08. L_c was 305 mm TL. Parameters for 1999-2002 Atlantic croaker estimates were L_∞ = 375.6 mm TL and K= 0.37. Parameters for 2003-2006 Atlantic croaker estimates were L_∞ = 458.7 mm TL and K=0.21. L_c for Atlantic croaker was 225 mm TL for all years.

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 2).

Length frequency distributions were constructed for weakfish, summer flounder, bluefish, Atlantic croaker and spot. Pound net length data was divided into 20 mm length groups for each species.

A length at age key was constructed for weakfish and Atlantic croaker using the 2005 age samples, as 2006 samples were not processed by SC DNR in time for inclusion in this report. Age sample and length data were assigned to one-inch length groups for each species. The measurements were then applied to the length-at-age key to determine the proportion at age for each species in 2005.

RESULTS and DISCUSION

Weakfish

Sixty-two weakfish were sampled in the 2006 pound net survey, a decrease from the 2005 sampling season (326 fish) and was the lowest catch of the 14 year time series (Table 3). Weakfish mean length increased slightly in 2006 to 290 mm TL compared to

278 in 2005. RSDs for 2006 were similar to those of the past two years, indicating a continued dominance of RSD_{qual} fish and little to no RSD_{pref} weakfish compared to the 1998 to 2003 time period (Table 4). The 2006 mean length was the fourth smallest of the time series and the RSD_{stock} was the second highest of the time series. The 2006 length frequency distribution indicated a slight contraction over 2005, with over 60% of sampled weakfish between 270 and 299 mm TL (Figure 2).

Chesapeake Bay weakfish length-frequencies were truncated from 1993 – 1998, while in 1999 and 2000 length-frequencies contained considerably more weakfish greater than 380 mm TL. However, this trend reversed during 2001 - 2005, with far fewer large weakfish encountered. Ninety-five percent of weakfish sampled in 2006 were below the recreational size limit of 331 mm (13 inches), and 82 percent were below the commercial size limit of 305 mm (12 inches).

In 2005, females accounted for 49% of fish sampled (n=109). Female mean TL and mean weight were 296 mm and 281g respectively, while males averaged 295 mm TL and 256g. In 2006 females averaged 295 mm TL and 249g and accounted for 45% of fish sampled (n=27), while male mean length and weight was 285 mm TL and 222g respectively. Mean lengths between years were similar while mean weights were higher in 2005. Differences in mean weights may be artifacts of small sample sizes.

Total commercial landings in 2005 fell to 30,983 pounds after a modest 2004 increase (Figure 3). 2005 landings were the second lowest of the time series and well below Maryland's 1975-2004 average of 166,672 pounds per year. Maryland recreational anglers harvested an estimated 22,074 weakfish during 2005 weighing 17,474 pounds (MRFSS 2006; Figure 4). The number of weakfish harvested by the recreational fishery in 2005 decreased 26% from 2004 estimate (29,714). Maryland anglers released 56,299 weakfish in 2005, 56% less than 2004 (127,979). Estimated recreational harvest and releases have decreased steadily every year since 2001.

Mowrer (2004) reported increased juvenile abundance from 1989 - 1998 in Pocomoke and Tangier sounds. However, the 1999 juvenile index declined to levels last seen in the early 1990's, and this lack of recruitment may explain poor commercial and recreational landings between 2001 and 2002. However, relative abundance of juvenile weakfish was higher from 2000 – 2003, before declining significantly in 2004. Since 2004, harvest has continued to decline. The 2005 juvenile index increased and was similar to 2000 - 2003 levels (James Mowrer personal communication, 2006).

Otoliths from 109 weakfish were aged for 2005, with only ages 1 through 4 present (Table 5). Age composition, based on the 2005 age length key, was 49% age one, 47% age two, 3% age three and 1% age 4 (Table 6). This was a slight improvement from 2004 when the maximum age of weakfish sampled was three years old, with age one fish accounting for 57% of the sample. Sixty-two weakfish were sampled for age in 2006, 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). Maryland's length-based estimates were similar to the coastal assessment of 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 weakfish stock decline.

Summer flounder

Summer flounder mean lengths decreased from the time series high 374 mm TL in 2005 to a time series low of 286 mm TL in 2006 (Table 3). Relative stock densities in 2006 indicated a shift down to the stock category over 2005 (Table 8). The 2006 RSD_{stock} of 57 was the second highest of the time series. The 2006 length frequency distribution indicated a bimodal distribution with a large increase in smaller flounder, and subsequent decrease in larger flounder, compared to 2005 (Figure 5). The bimodal distribution coupled with the decrease in mean size and increase in RSD_{stock} suggests a large year-class recruiting to the fishery.

Maryland's commercial summer flounder harvest was 293,264 pounds in 2005, the 18th lowest in the 44-year time series (Figure 6). The long-term commercial harvest average, 1962 – 2004, is 445,999 pounds. The recreational harvest estimate of 85,212 fish caught was the 6th lowest estimate of the 1981-2005 time series (MRFSS 2006; Figure 7). Recreational releases, estimated by MRFSS at 435,527 fish, were in the middle of the range during the same time period. This represented a decrease of 55% from 2004 (Figure 7). The low incidence of smaller flounder in the 2005 pound net length frequency distribution is consistent with the large decrease in estimated flounder releases in 2005.

Virtual population analysis (VPA), conducted in 2006 by 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, and 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} 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 311 mm TL during 2006, a slight decrease from the 2005 mean of 325 mm TL, and similar to the 2003 mean length of 320 mm TL (Table 3). The 2006 mean length ranks in the middle of the 14 year time series. The 2006 relative stock densities were similar to those from 1993 – 2004, after a shift to RSD_{qual} bluefish occurred in 2005 (Table 9). Bluefish length frequency distribution expanded in 2005 compared to 2003 and 2004 (Figure 8). The 2006 length frequency distribution indicates a reduction in large blue fish compared to 2005, but still exhibited a more robust distribution than 2003 and 2004.

The 2005 and 2006 samples indicated a shift to a larger grade of bluefish, but RSD_{stock} values (79% and 95% 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 increased in 2006 to 94,766 pounds from 52,683 pounds in 2004, but was still below the 1929-2005 average of 177,879 pounds (Figure 9). The 2005 catch was the 34th lowest of the 76-year time series. Recreational harvests estimates for bluefish were high through most of the 1980's and have since remained stable at a lower level (MRFSS 2006; Figure 10). The 2005 estimate of 247,521 fish harvested was the 5th lowest of the 24-year time series (Figure 10).

Bluefish recruitment in Maryland has been variable, but has shown a declining trend since the early 1980's (Mowrer 2004). The juvenile index indicated a relatively strong year-class in 1997, but the index has remained at low levels since.

The latest NMFS stock assessment of Atlantic coast bluefish using VPA indicated that F has decreased since 1991 from a high of 0.41 to 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 decreased from 317 mm TL in 2005 to 304 mm TL in 2006, but still was the 5th highest of the 14 year time series (Table 3). RSDs for Atlantic croaker indicated a continued dominance of $RSD_{memorable}$ fish and the time series high of RSD_{trophy} fish in 2006 (Table 10). $RSD_{quality}$ increased in 2006, indicating an influx of younger fish presumably 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 11). In 2006, a secondary peak of 190 mm TL croaker indicates some recruitment from the 2005 year-class.

In 2005, females accounted for 68% (n=132) of the pound net catch and averaged 344 mm TL and 587g, while males averaged 310 mm TL and 417g in weight (n=60). The sex ratio remained similar in 2006 with 65% being female. Mean lengths and weights in 2006 were 337 mm TL and 616g for females (n=164) and 303 mm TL and 427g for males (n=90).

During 2005 Atlantic croaker commercial harvest was 972,801 pounds, down 24% from 2004 (Figure 12), while recreational harvest was estimated at 825,578 fish (MRFSS 2006; Figure 13). The 2005 recreational harvest decreased 5% from 2004, and ranked 12th in the 25-year time series (MRFSS 2006; Figure 13). Atlantic croaker abundance in Chesapeake Bay has increased in recent years. Recreational harvest was greater than commercial harvest during 1992 – 1995, 1998 – 2000 and 2003. Commercial harvest was greater than MRFSS estimates for 1996, 1997, 2001 – 2002 and 2004 – 2005.

Mowrer (2004) reported generally stronger Atlantic croaker juvenile indices from 1993 – 2002 than in previous years in Maryland's Chesapeake Bay. The 2003 year-class was weaker, with the 2004 year-class rebounding. The 2005 index dropped to a value similar to 2003 (James Mowrer personal communication, 2006). 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. Since pound nets may select larger and older Atlantic croaker, the data may indicate an artificial decrease in mortality estimates.

Ages derived from 2005 Atlantic croaker otoliths ranged from age 1 to 11 (n=190), with no age 9 fish present (Table 11). The number of Atlantic croaker captured from pound nets in 2005 (n=2,818) was applied to an age-length key for 2005, and indicated that 51% of the fish were age three, 11% were age seven, and 10% were age one. Age groups two, four, six and eight each accounted for five to eight percent of the fish sampled (Table 12). In 2004, age two accounted for 55% of the sampled fish and age six accounted for 23%, making the 1998 and 2002 year-classes the two most dominate cohorts for both the 2004 and 2005 pound net samples. Two hundred fifty-nine Atlantic croaker otoliths were collected in 2006, but ageing had not been completed at this time. Instantaneous total mortality in 2006 was Z=0.31 a slight decrease from 2005 (Table 7).

In 2004, the ASMFC Atlantic Croaker Technical Committee completed a stock assessment using an age structured production model. 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 2006 was 191 mm TL, the 4th lowest of the 14 year time series (Table 3). The length frequency distribution indicated fish between 150 and 189 mm TL accounted for over 50% of the catch (Figure 14). Percent jumbo spot remained low in 2006, with less than 2% of the 2006 sample comprised of spot >254 mm TL (3% in 2005, 13% in 2004 and 10% in 2003).

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 and 2006, appears to be a function of a large 2005 year-class. 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.

Commercial harvest in 2005 was 84,254 pounds, 52% lower than 2004 and well bellow the long-term average (1929 – 2005) of 141,288 pounds (Figure 15). 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. Recreational harvest data from MRFSS indicated that spot harvest since 1981 in Maryland has been variable (Figure 16). 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 (MRFSS 2006; Figure 16). For 2004, 2,000,000 spot were harvest and 2,200,000 released both above there respective long term averages. In 2005, recreational catch increased while commercial catch decreased. This may be explained by the greater number of small spot from the 2005 year-class being discarded by commercial fishermen, but retained by recreational anglers.

Juvenile spot indices for Maryland's portion of Chesapeake Bay indicated a declining trend from 1980 – 2004 with three of the five lowest values occurring from 2002 – 2004 (Mowrer 2004). The 2005 index was highest of the time series (James Mowrer personal communication, 2006).

Red Drum

Red drum are rarely encountered in the pound net sampling, with only 16 fish being examined in 2006. The number of red drum sampled peaked in 2002 (Table 3); 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 2005 was 37 pounds, compared to 1,161 pounds in 2002, the second lowest since 1991(Figure 17). 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 therefore led to higher landings by weight.

The MRFSS (2006) estimated that recreational fishermen did not harvest or capture and release any red drum in Maryland during 2005 (Figure 18). It is very unlikely no red drum were harvested during this period. However, estimates of zero catch were made for 14 of the 25 years of the 1981 - 2005 time series. Recreational harvest peaked in 1986 at 12,804 fish, while the number of releases peaked in 2002 at 18,412 fish (Figure 18).

Black Drum

Black drum are only occasionally encountered during MD DNR pound net sampling, with only eight being captured in 2006 (Table 3). 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 19). 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 2005; Figure 20). From 1995 to 2005 recreational catches have been somewhat more consistent, with fish being harvested, released or both in each year.

Spanish Mackerel

Spanish mackerel have been measured for fork length, total length or both in each year of the pound net sampling. Since 2001, only fork lengths have been taken, to be consistent with data collected by other state and federal agencies. During this time period length has ranged from 208 – 567 mm FL. Mean length for 2006 was 439 mm FL, the highest of the 11 years FL was taken (Table 3). The number of mackerel measured has been low for most years with the largest samples occurring in 2005 and 2006 (Table 3).

The 2004 commercial harvest of Spanish mackerel in Maryland was 7,252 pounds. The 1965 – 2004 average harvest was 7,694, but harvest was very low from 1965 – 1986 with no catches greater than 3,600 pounds and six years of zero harvest (Figure 21). Commercial harvest has been somewhat more stable since 1987 with a peak of 62,688 pounds in 1991. Recreational harvest estimates peaked in the early to mid 1990's with three years of harvest of approximately 40,000 fish (MRFSS 2006; Figure 22). This followed a period in which seven out of ten annual estimates were zero fish captured. Harvest estimates for 1998 – 2005 were variable, ranging from 0 – 21,065 fish with an average of 8,055 fish taken. In 2005, 21,065 fish were harvested (Figure 22).

Spotted Seatrout

The pound net sampling rarely captures spotted seatrout, and no seatrout have been measured since 1999 (Table 3). Commercial harvest of spotted seatrout in Maryland averaged 44,921 pounds from 1944-1954, zero pounds from 1955 – 1990 and 8,938 pounds from 1991-2005 (Figure 23). Reported 2005 harvest was 2,339 pounds. Recreational harvest estimates indicated a modest fishery in the mid 1980's and the mid 1990's, with catches becoming very low to nonexistent from the late 1990's to the present (MRFSS 2006; Figure 24). The 1981-2005 average recreational harvest was 15,607 fish, with a 2005 harvest of 4,048 fish.

Atlantic Menhaden

Mean FL for Atlantic menhaden sampled from commercial pound nets in 2006 was 238 mm FL (n=823) compared to 282 mm FL (n=1077) in 2005. In 2006 lengths ranged from 157 mm FL to 372 mm FL. Ages derived from 2005 Atlantic menhaden scales ranged from age 1 to age 5 (n=345; Table 13). Only menhaden greater than 179 mm FL were aged. Applying the number of Atlantic menhaden captured from pound nets in 2005 (n=1,061) to an age-length key for 2005, indicated that 43% of the fish were age three and approximately 25% were ages two and four. Age groups one and five each accounted for three percent of the fish sampled (Table 14). The proportion of age one fish is probably greater than indicated, due to having no age samples for fish under 180 mm FL. Scales were taken from 297 fish for age determination in 2006, 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 25). 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 1935-2005 was 3.8 million pounds.

CITATIONS

ASMFC (Atlantic States Marine Fisheries Commission). 2002. Amendment 2 to the Interstate Fisheries Management Plan for Red Drum. Washington, D.C. 159p.

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

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

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

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

Jarzynski, T., P. Piavis and R. Sadzinski. 2000. Stock assessment of selected adult resident and migratory finfish in Maryland=s Chesapeake Bay. *In* Stock Assessment of selected resident and migratory recreational finfish species within Maryland=s Chesapeake Bay. Maryland Department of Natural Resources, Report F-54-R. Annapolis, Maryland.

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

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

NMFS (National Marine Fisheries Service). 2005. 41st Northeast Regional Stock Assessment Workshop (41st SAW). Document 05-14. Woods Hole, MA.

Mowrer, J. 2004. Resident and migratory juvenile finfish recruitment survey. *In* Stock assessment of selected resident and migratory recreational finfish species within Maryland=s Chesapeake Bay. Maryland Department of Natural Resources, Report F-54-R. Annapolis, Maryland.

MRFSS. 2006. Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division.

CITATIONS (Continued)

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

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

Terceiro M. 2006. Stock assessment of summer flounder for 2006. U.S. Dep. Commer., *Northeast Fish. Sci. Cent. Ref. Doc*. 06-17; 119 p.

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Figure 25. Figure 25. Maryland commercial Atlantic menhaden landings, 1935-2005.

Table 1. Areas sampled, number of nets sampled, mean water temperature and mean salinity by month, 2006.

Area	Month	Number of Nets Sampled	Mean Water Temp. (C)	Mean Salinty (ppt)
Point Lookout	May	1	22.3	13.5
Barren Island	May	0		
Cedar Point Hollow	May	0		
Point Lookout	June	1	21.0	14.6
Barren Island	June	0		
Cedar Point Hollow	June	0		
Point Lookout	July	2	26.4	13.0
Barren Island	July	6	27.3	11.6
Cedar Point Hollow	July	1	26.0	12.2
Point Lookout	August	2	28.2	13.0
Barren Island	August	9	27.8	12.7
Cedar Point Hollow	August	2	28.2	13.1
Point Lookout	September	1	23.9	14.9
Barren Island	September	1	23.2	13.7
Cedar Point Hollow	September	1	22.7	13.0

Table 2. 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 3. Mean length (mm TL), standard deviation, and sample size of summer migrant fishes from Chesapeake Bay pound nets, 1993 - 2006.

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

Table 4. Relative stock density of weakfish from Chesapeake Bay summer pound net survey, 1993 - 2006.

Year	Stock	Quality	Preferred	Memorable	Trophy
1993	89	10	1	<1	
1994	90	9	1		<1
1995	74	23	3		
1996	77	22	1		
1997	90	9	1		
1998	58	39	2	<1	
1999	61	33	5	<1	
2000	48	29	20	2	
2001	58	35	5	1	
2002	73	18	8		<1
2003	67	30	2	<1	
2004	96	3	1		
2005	94	5	1		
2006	95	5			

Table 5. Weakfish mean length (mm TL), mean weight and number sampled by age, 2005.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged
1	248	162	37
2	313	299	60
3	342	389	9
4	412	620	3

Table 6. Weakfish proportion at age using 2005 pound net survey length and age data (109 ages and 304 lengths).

Age	1	2	3	4
n	148	143	10	3
Proportion at age	48.71	46.90	3.44	0.95

Table 7. Weakfish and Atlantic croaker total instantaneous mortality rate estimates (Z) from Chesapeake Bay pound net data, 1999 – 2006.

	1999	2000	2001	2002	2003	2004	2005	2006
Weakfish	0.74	0.4	0.62	0.58	0.73	1.29	1.44	1.35
Atlantic croaker	0.54	0.48	0.37	0.26	0.32	0.28	0.24	0.21

Table 8. Relative stock density of summer flounder from Chesapeake Bay summer pound net survey, 1993 - 2006.

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	

Table 9. Relative stock density of bluefish from Chesapeake Bay summer pound net survey, 1993 - 2006.

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		

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

Table 11. Atlantic croaker mean length (mm TL), mean weight and number sampled by age, 2005.

Age	Mean Length (mm TL)	Mean Weight (g)	Number Aged
1	228	146	22
2	255	211	9
3	309	393	73
4	334	495	11
5	380	821	3
6	385	729	18
7	395	809	33
8	411	905	19
9			0
10	454	1295	1
11	427	1014	1

Table 12. Atlantic croaker proportion at age using 2005 pound net survey length and age data (190 ages and 2398 lengths).

Age	1	2	3	4	5	6	7	8	9	10	11
n	242	115	1235	183	35	176	274	133	0	2	3
Proportion at age	10.10	4.80	51.48	7.62	1.47	7.33	11.45	5.56	0.00	0.07	0.13

Table 13. Atlantic Menhaden mean length (mm FL) and number sampled by age, 2005.

Age	Mean Length (mm FL)	Number Aged
1	227	11
2	260	87
3	287	148
4	302	91
5	319	8

Table 14. Atlantic menhaden proportion at age using 2005 pound net survey length and age data (345 ages and 1061 lengths).

Age	1	2	3	4	5
n	29	274	452	272	33
Proportion at age	2.74	25.86	42.61	25.64	3.15

Figure 1. Summer pound net sampling area map for 2006.

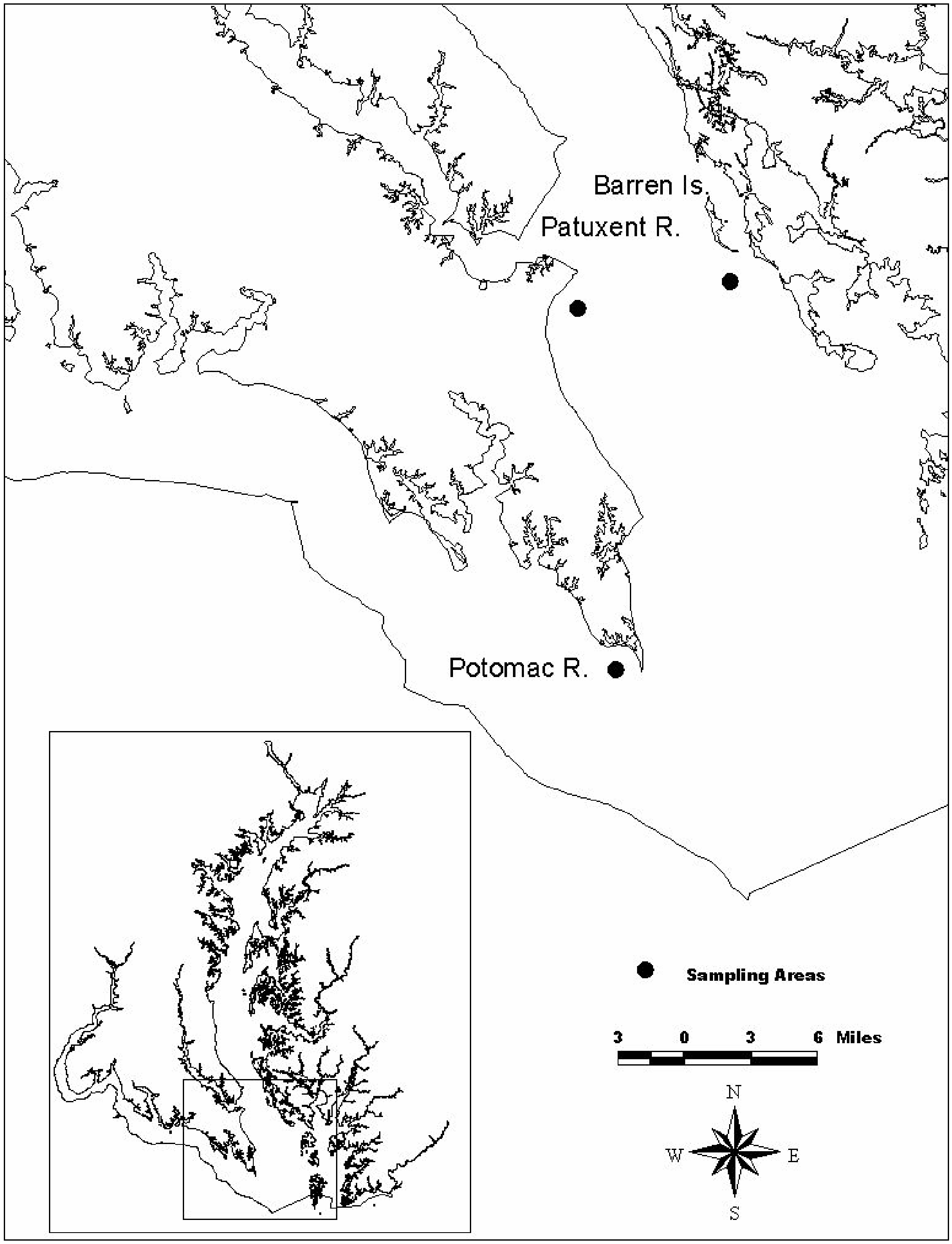


Figure 2. Weakfish length frequency distributions from pound nets, 2003-2006.

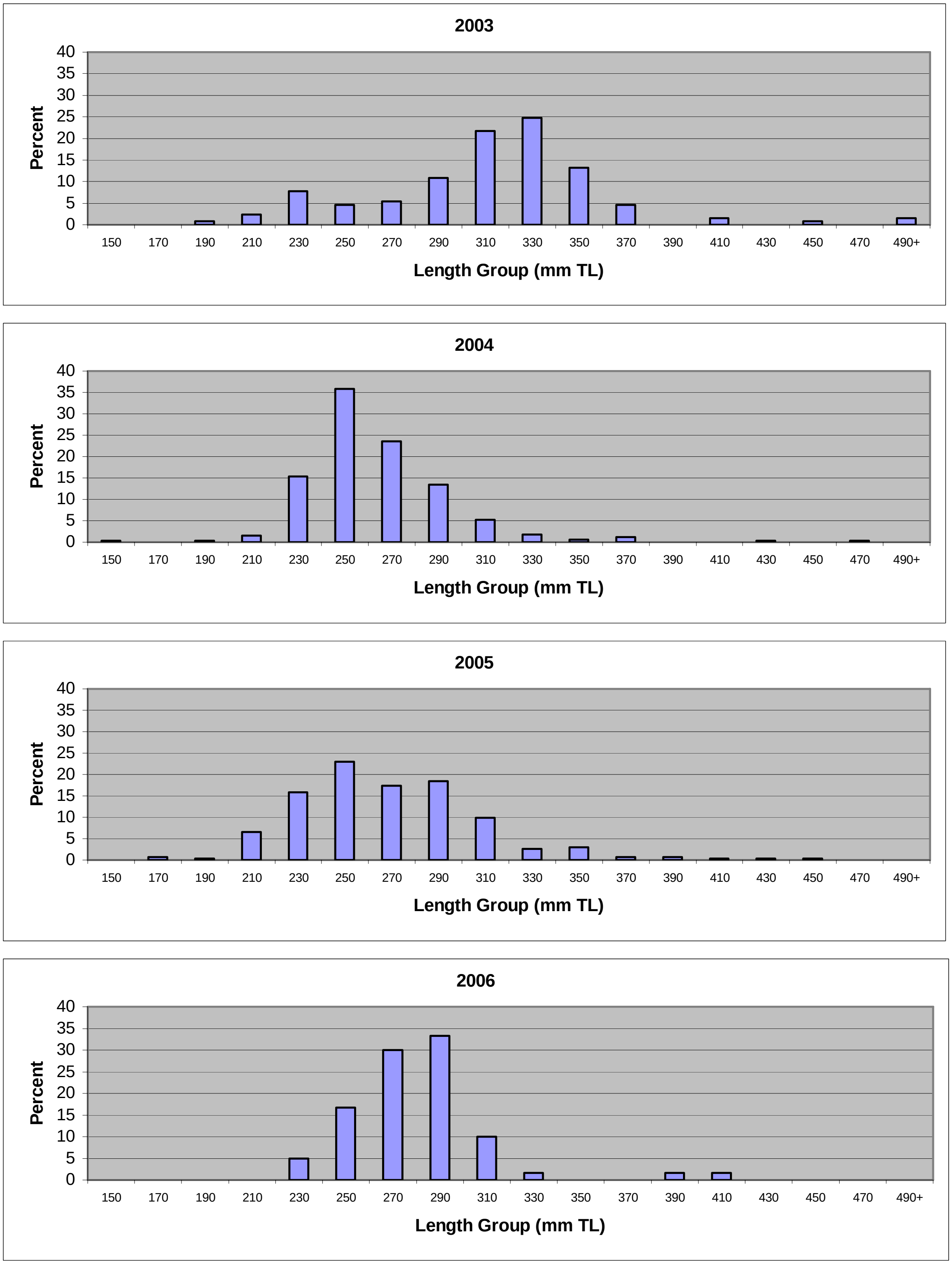


Figure 3. Maryland commercial weakfish landings, 1975-2005.

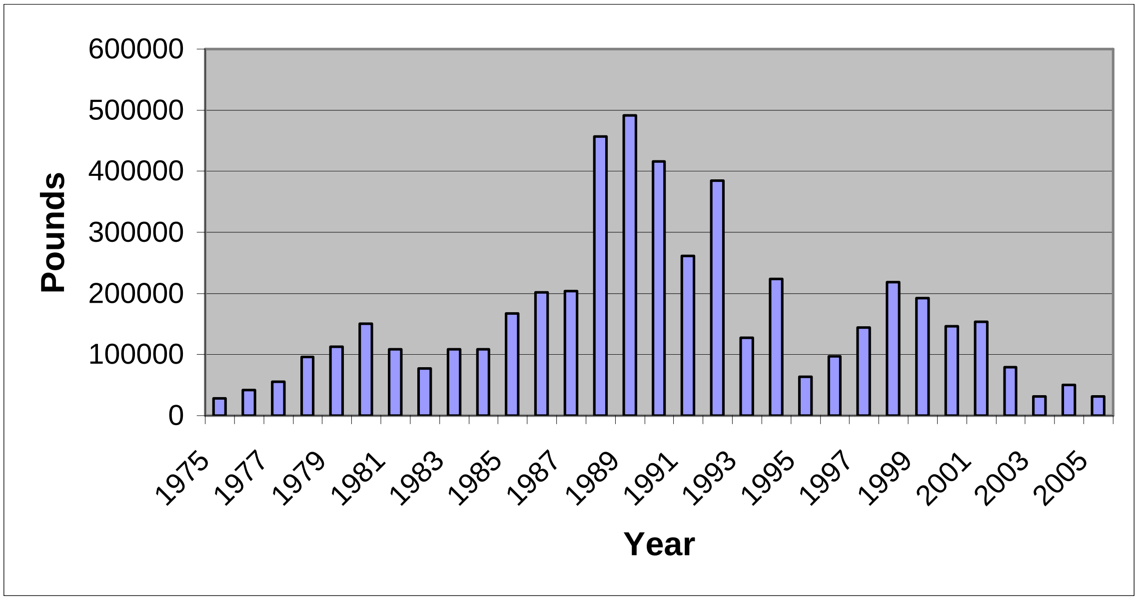


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2005 (Source: MRFSS, 2006).

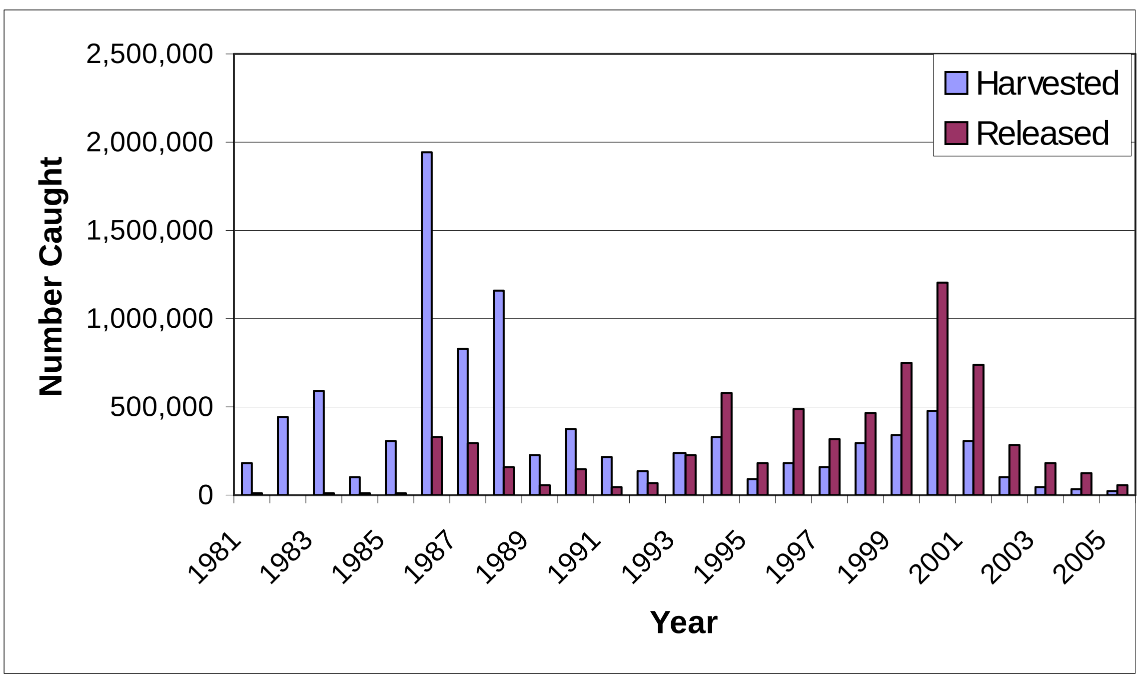


Figure 5. Summer flounder length frequency distributions from pound nets, 2003-2006.

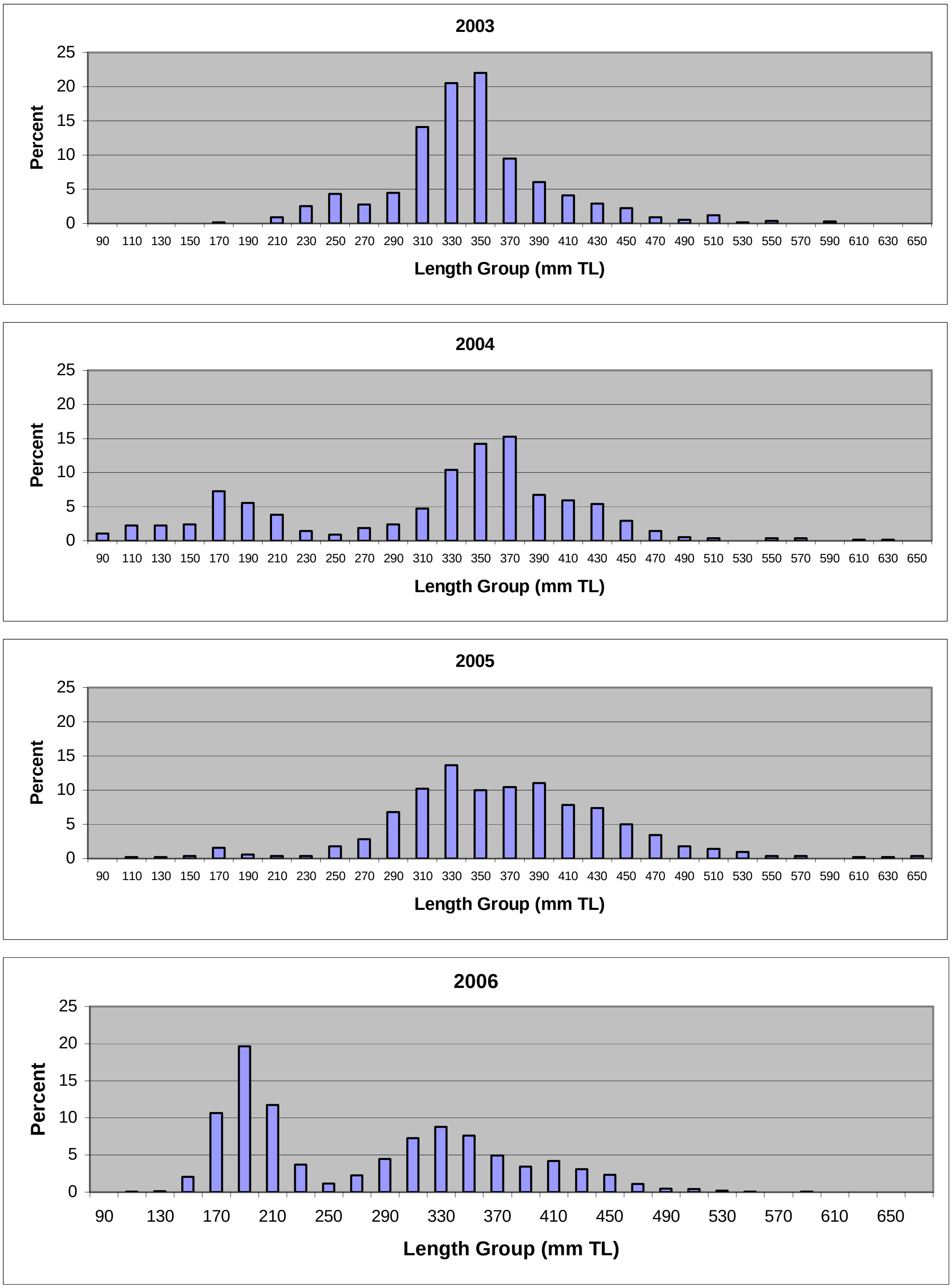


Figure 6. Maryland commercial summer flounder landings, 1962-2005.

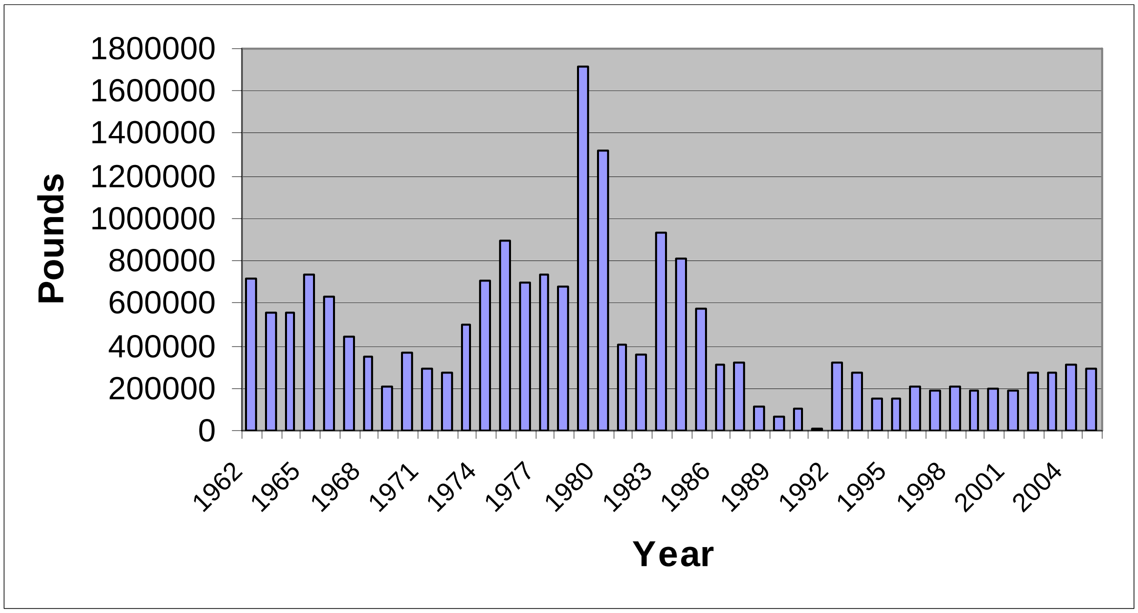


Figure 7. Estimated Maryland recreational summer flounder harvest and releases for 1981-2005 (Source: MRFSS, 2006).

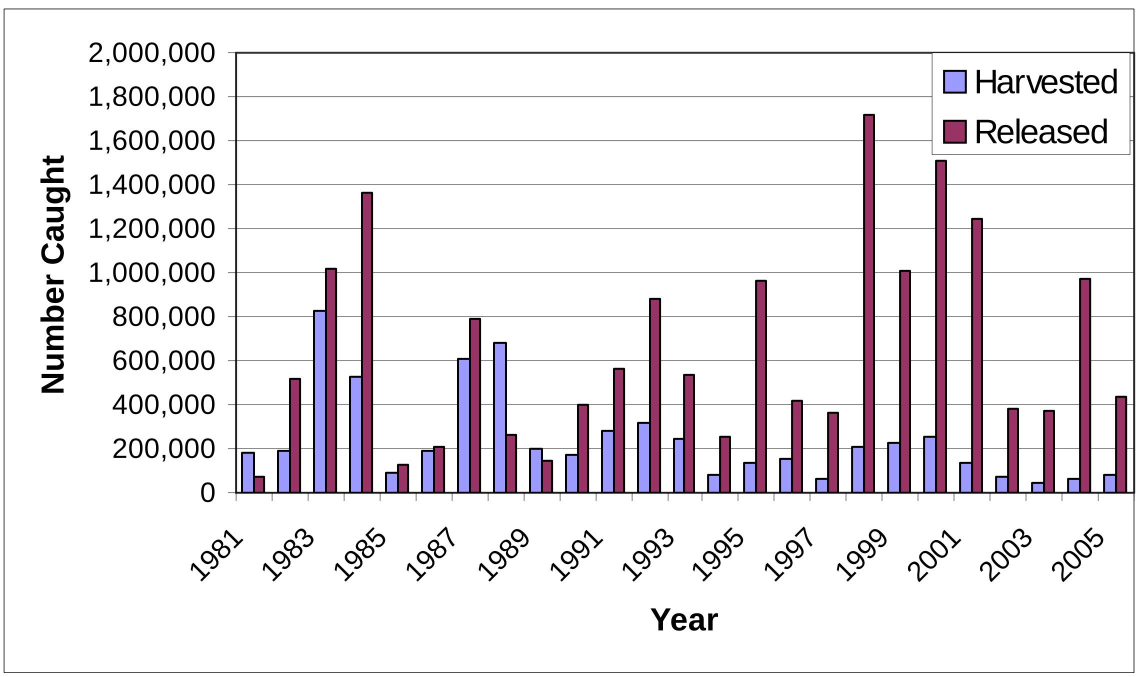


Figure 8. Bluefish length frequency distributions from pound nets, 2003-2006.

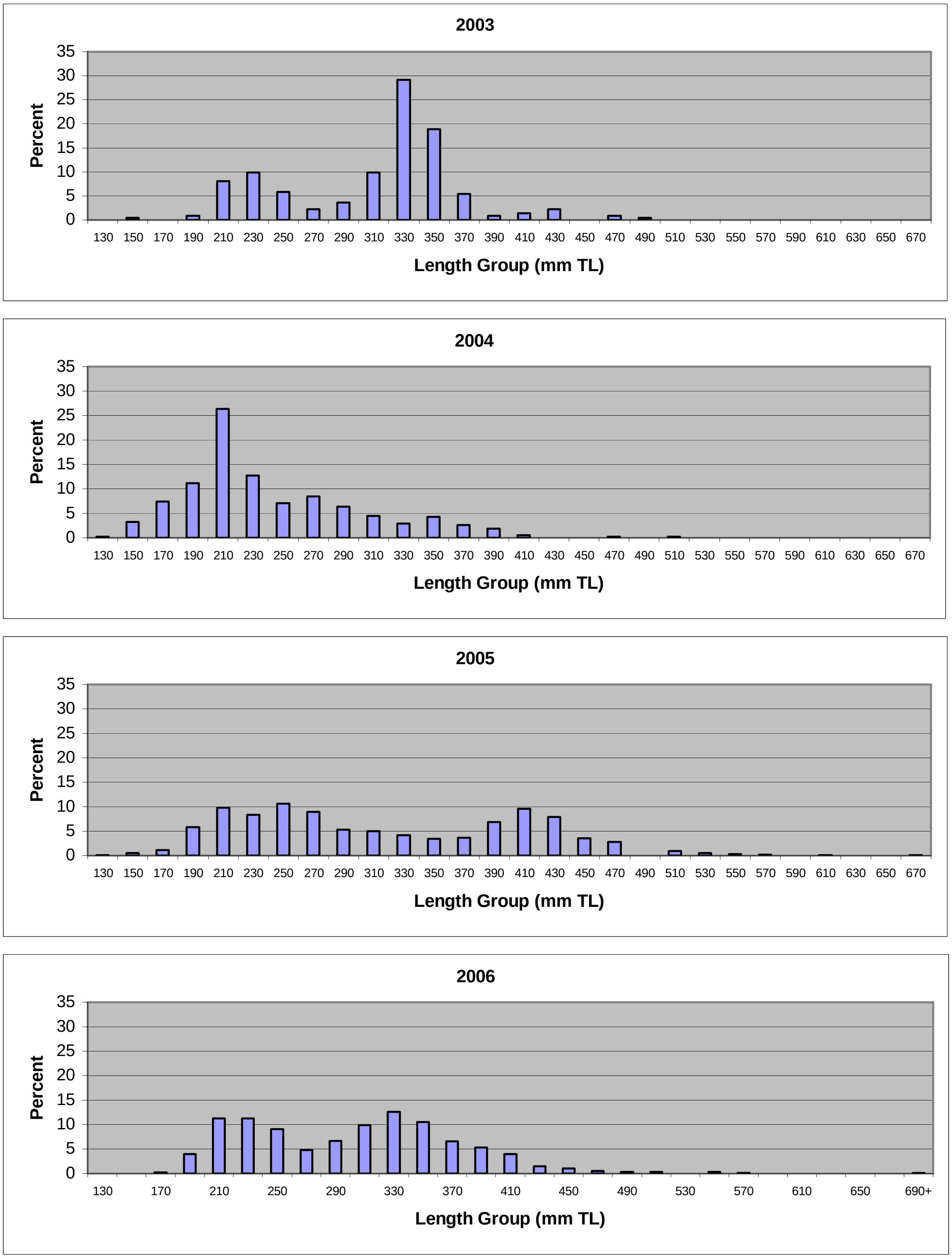


Figure 9. Maryland commercial bluefish landings, 1929-2005.

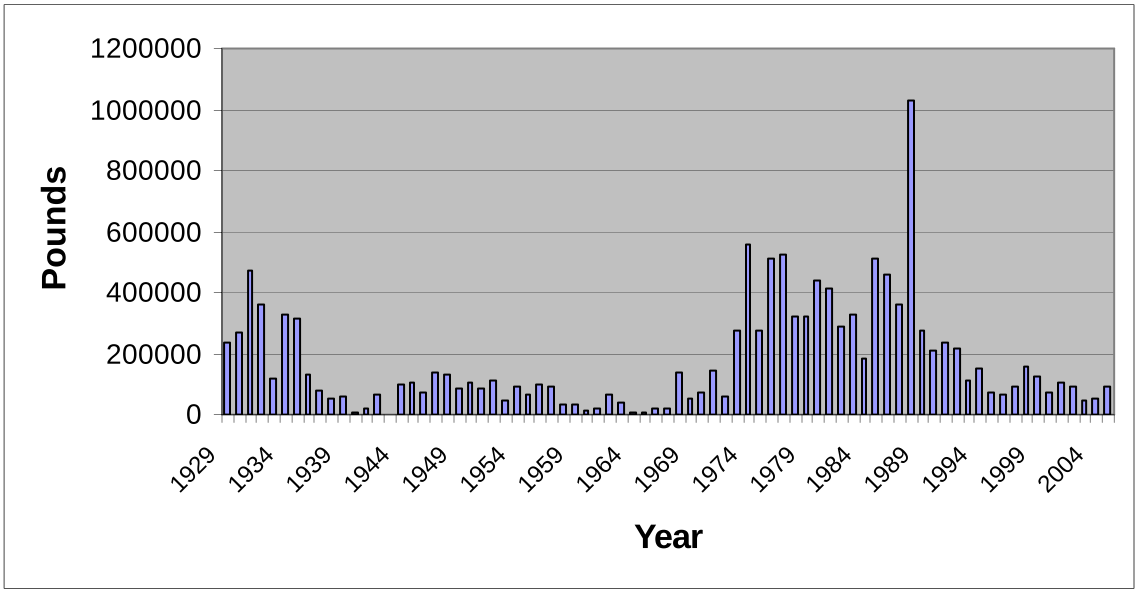


Figure 10. Estimated Maryland recreational bluefish harvest and releases for 1981-2005 (Source: MRFSS, 2006).

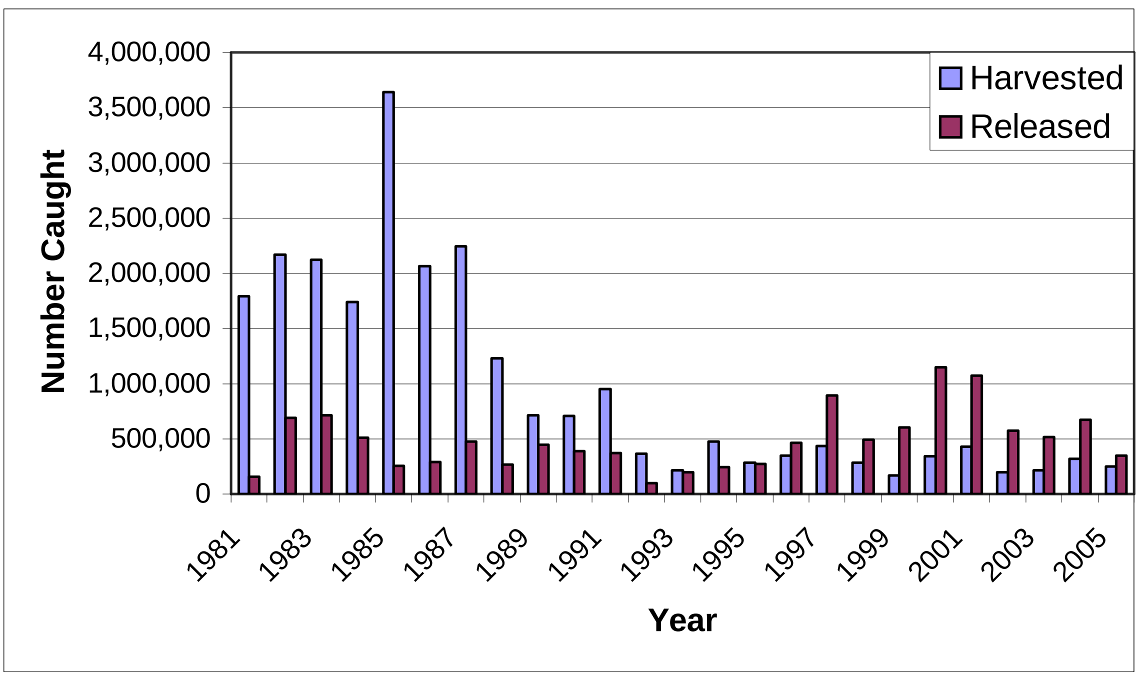


Figure 11. Atlantic croaker length frequency distributions from pound nets, 2003-2006.

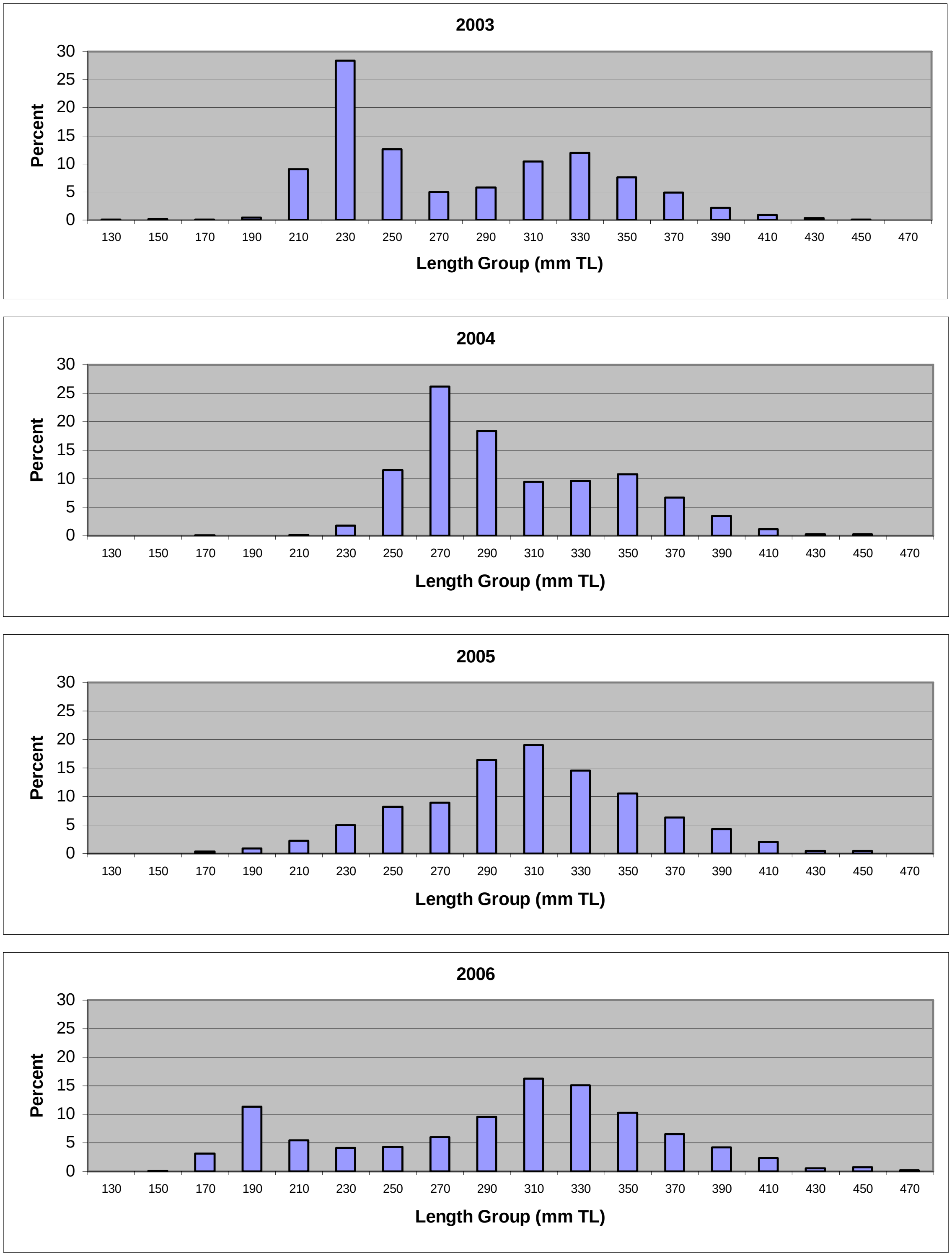


Figure 12. Maryland commercial Atlantic croaker landings, 1929-2005.

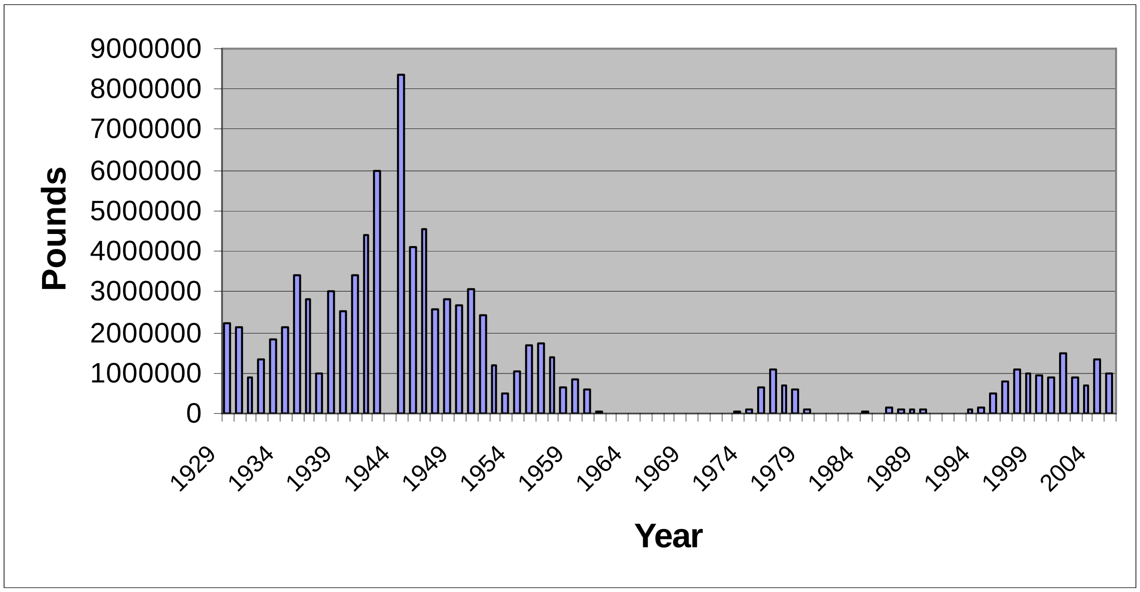


Figure 13. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2005 (Source: MRFSS, 2006).

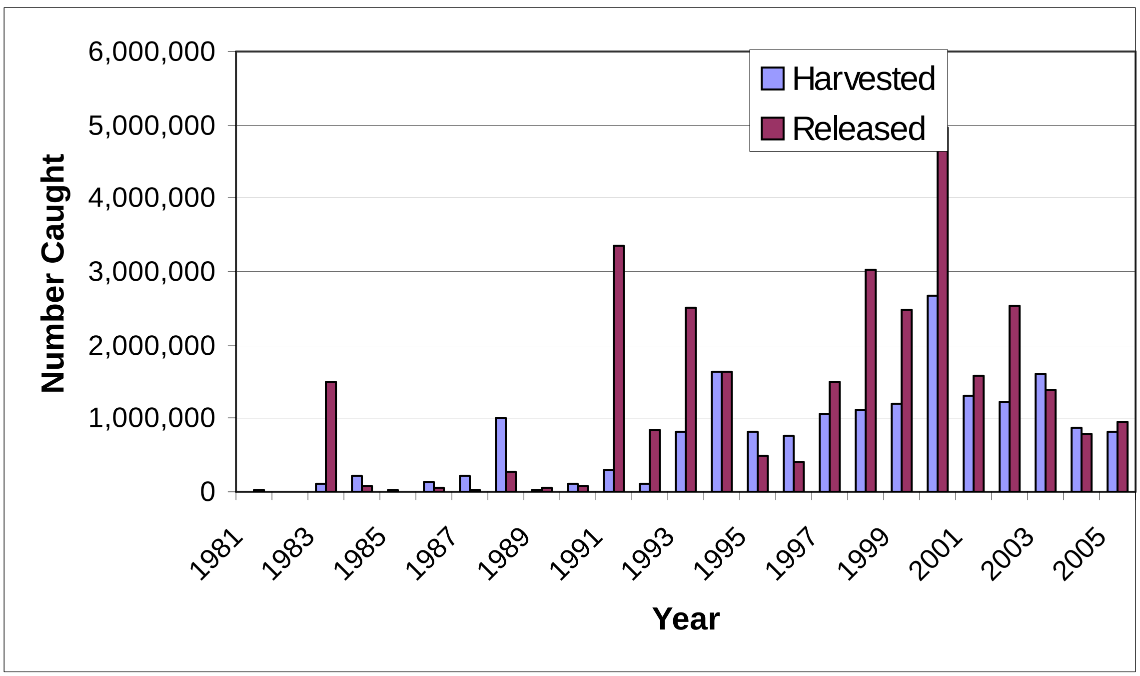


Figure 14. Spot length frequency distributions from pound nets, 2003-2006.

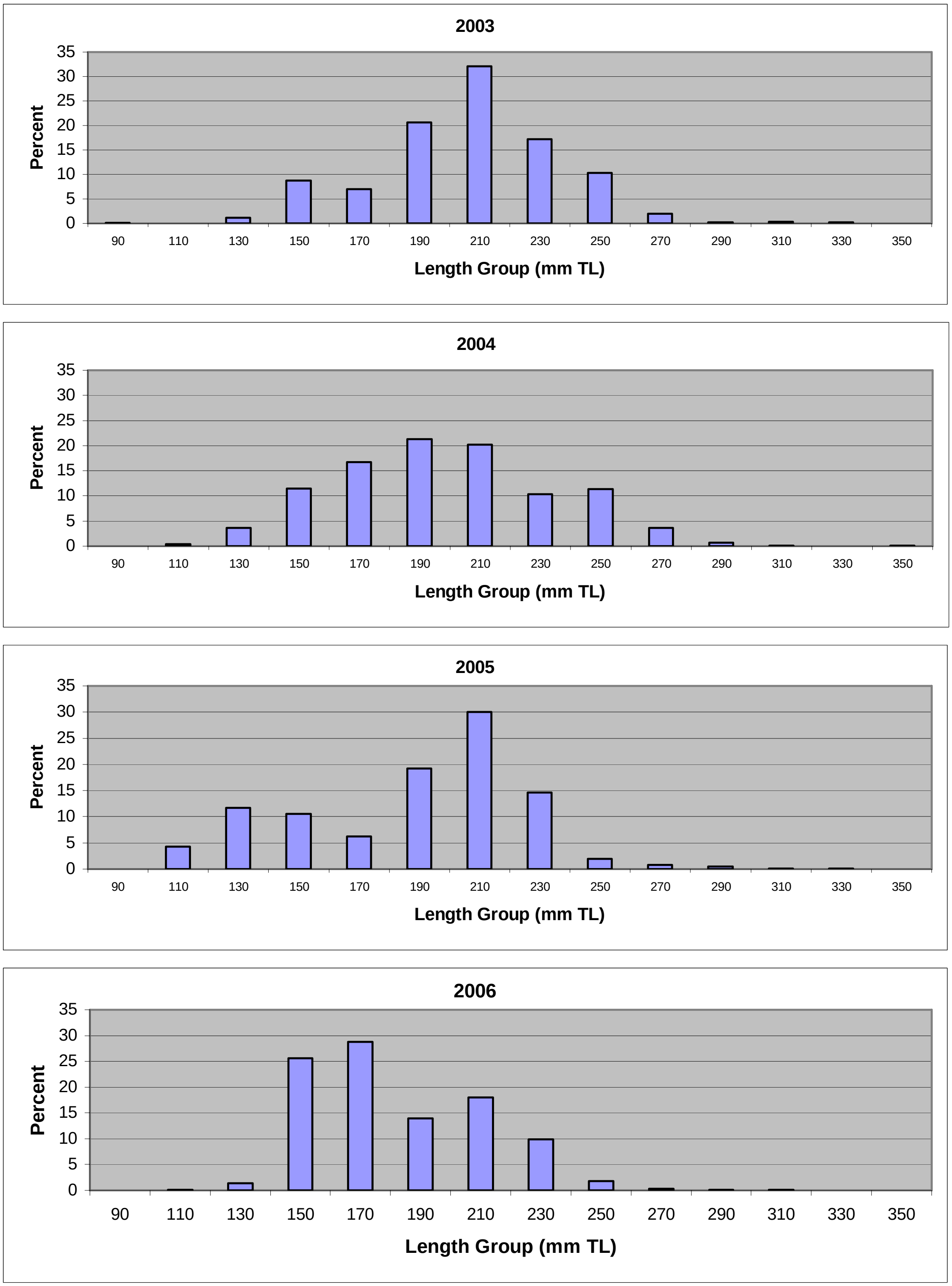


Figure 15. Maryland commercial spot landings, 1929-2005.

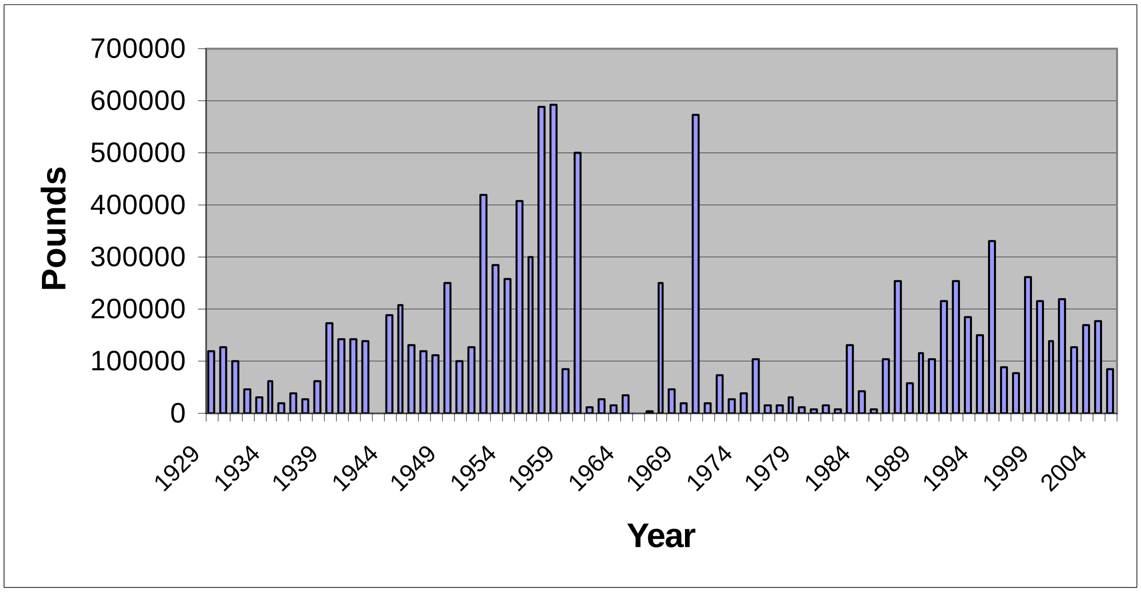


Figure 16. Estimated Maryland recreational spot harvest and releases for 1981-2005 (Source: MRFSS, 2006).

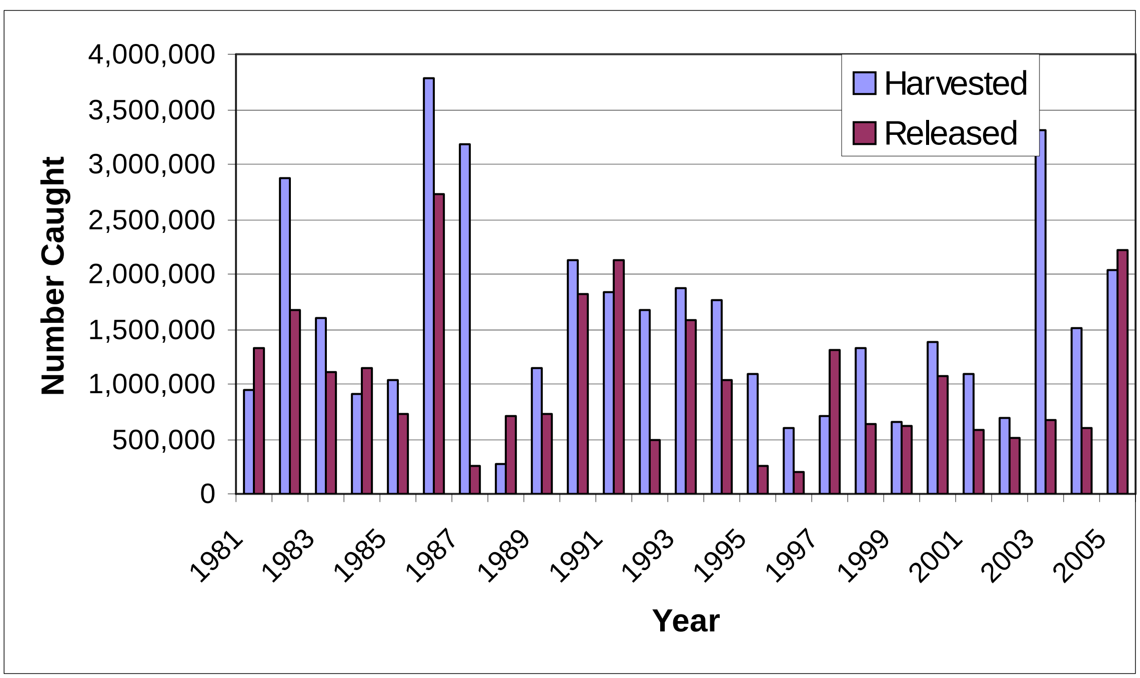


Figure 17. Maryland commercial red drum landings, 1958-2005.

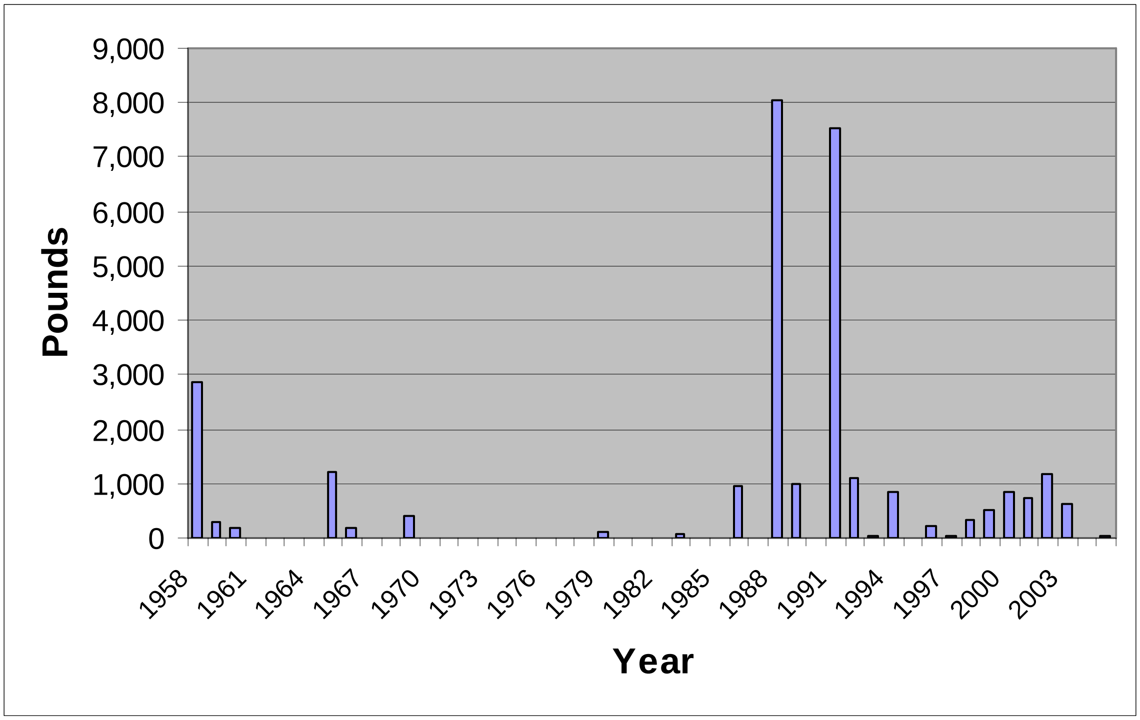


Figure 18. Estimated Maryland recreational red drum harvest and releases for 1981-2005 (Source: MRFSS, 2006).

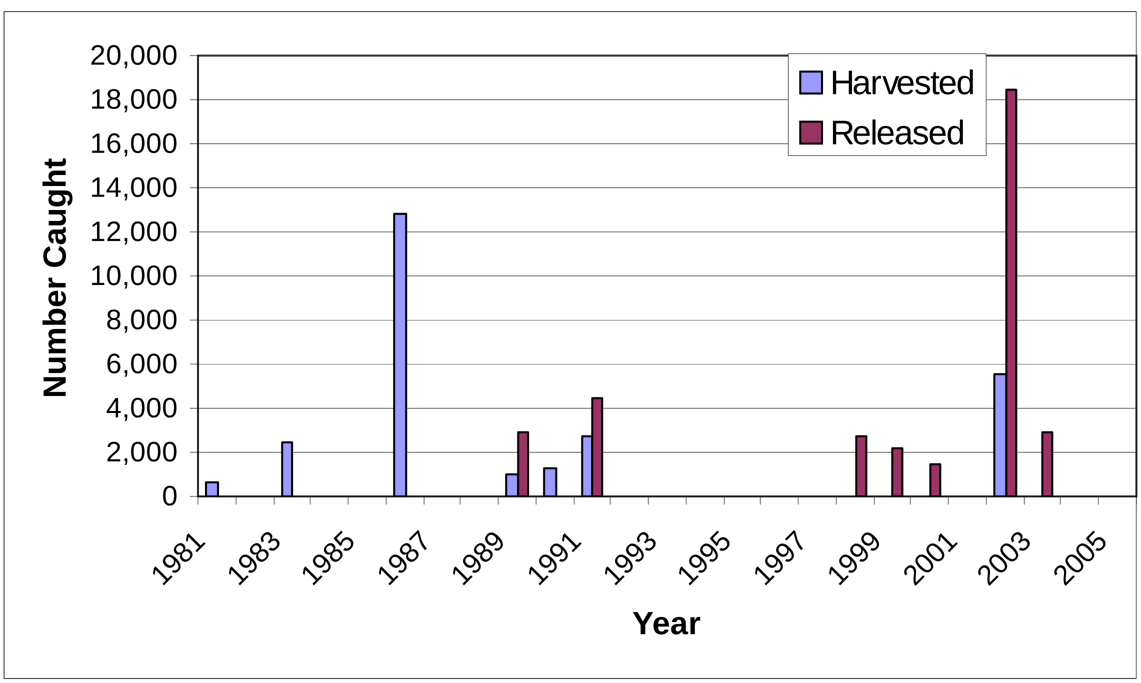


Figure 19. Maryland commercial black drum landings, 1929-2005.

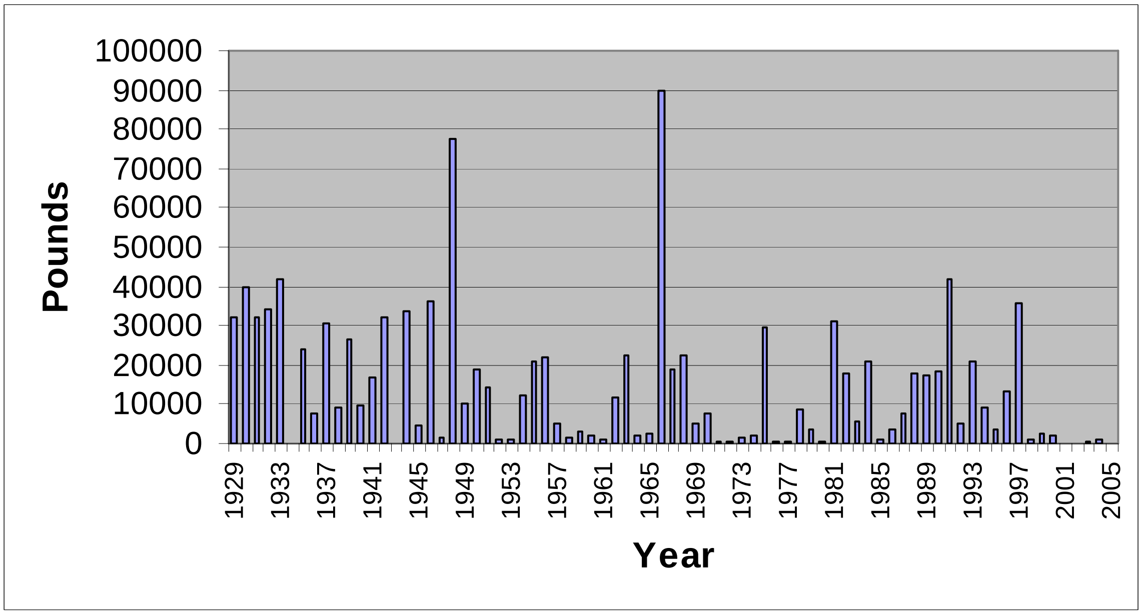


Figure 20. Estimated Maryland recreational black drum harvest and releases for 1981-2005 (Source: MRFSS, 2006).

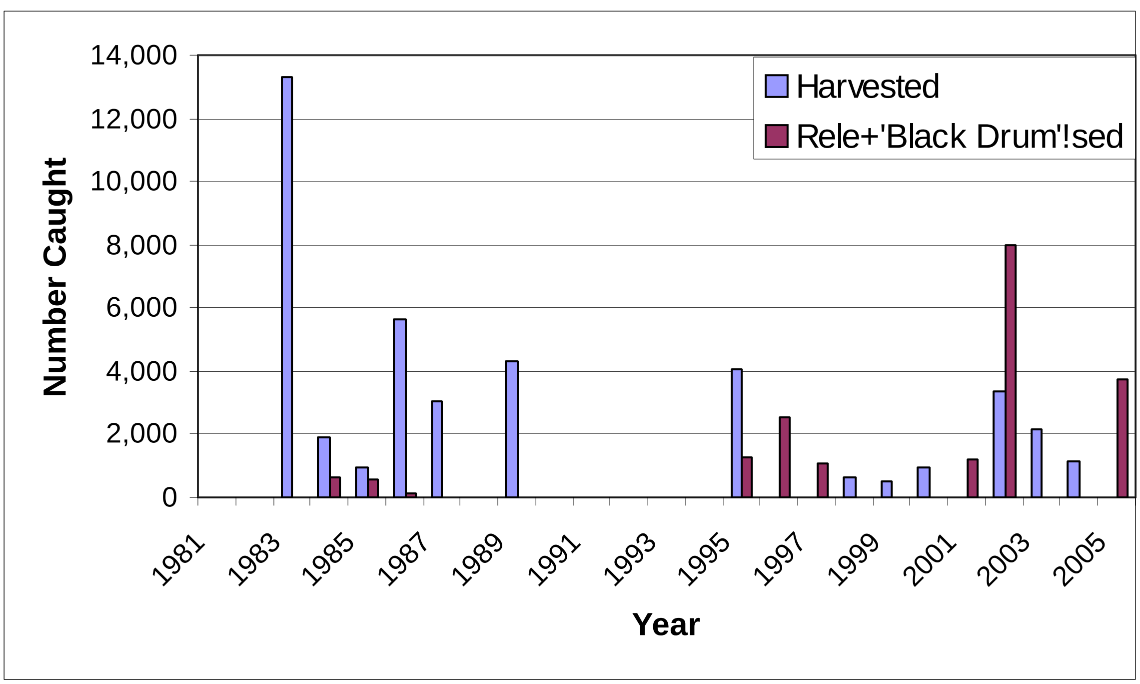


Figure 21. Maryland commercial Spanish mackerel landings, 1965-2005.

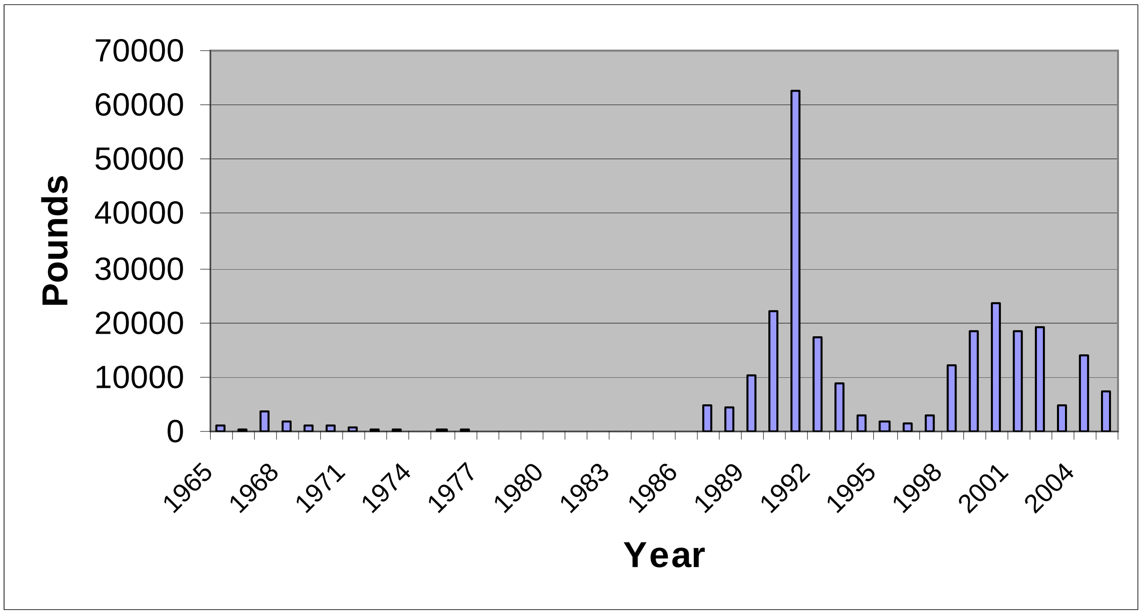


Figure 22. Estimated Maryland recreational Spanish mackerel harvest and releases for 1981-2005 (Source: MRFSS, 2006).

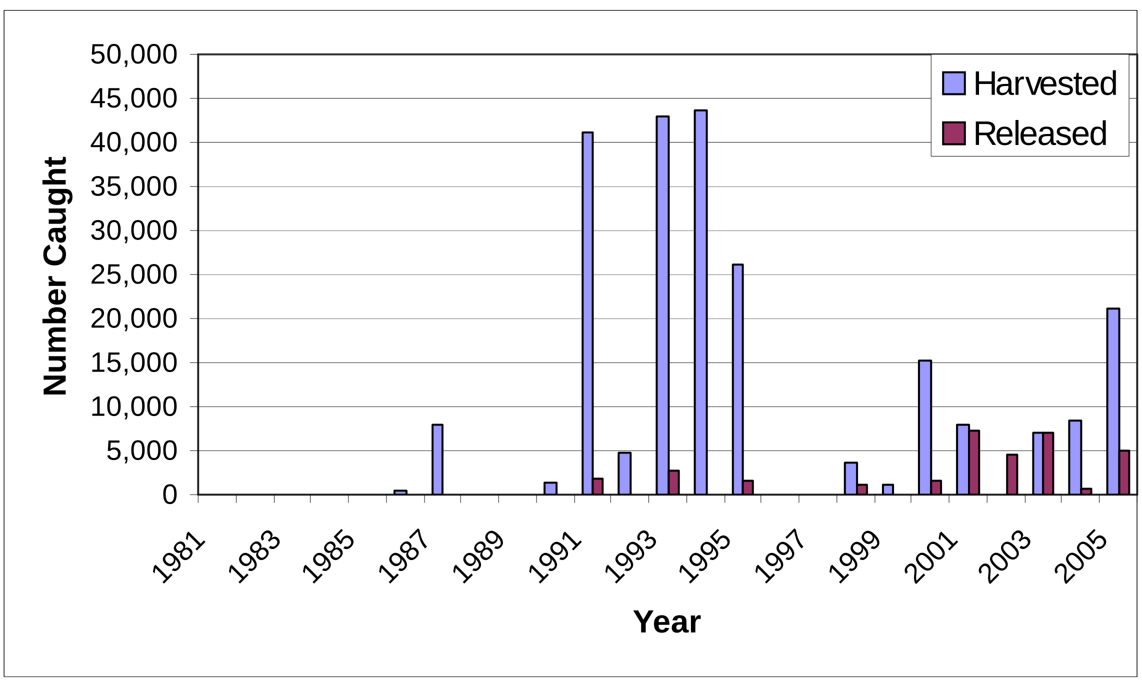


Figure 23. Maryland commercial spotted seatrout landings, 1944-2005.

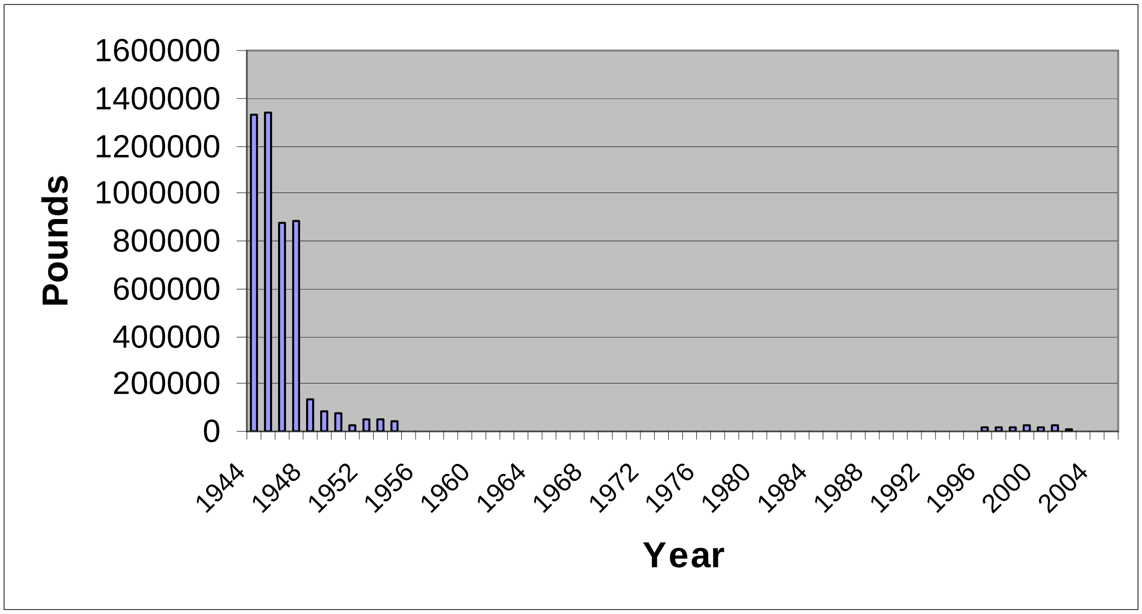


Figure 24. Estimated Maryland recreational spotted seatrout harvest and releases for 1981-2005 (Source: MRFSS, 2006).

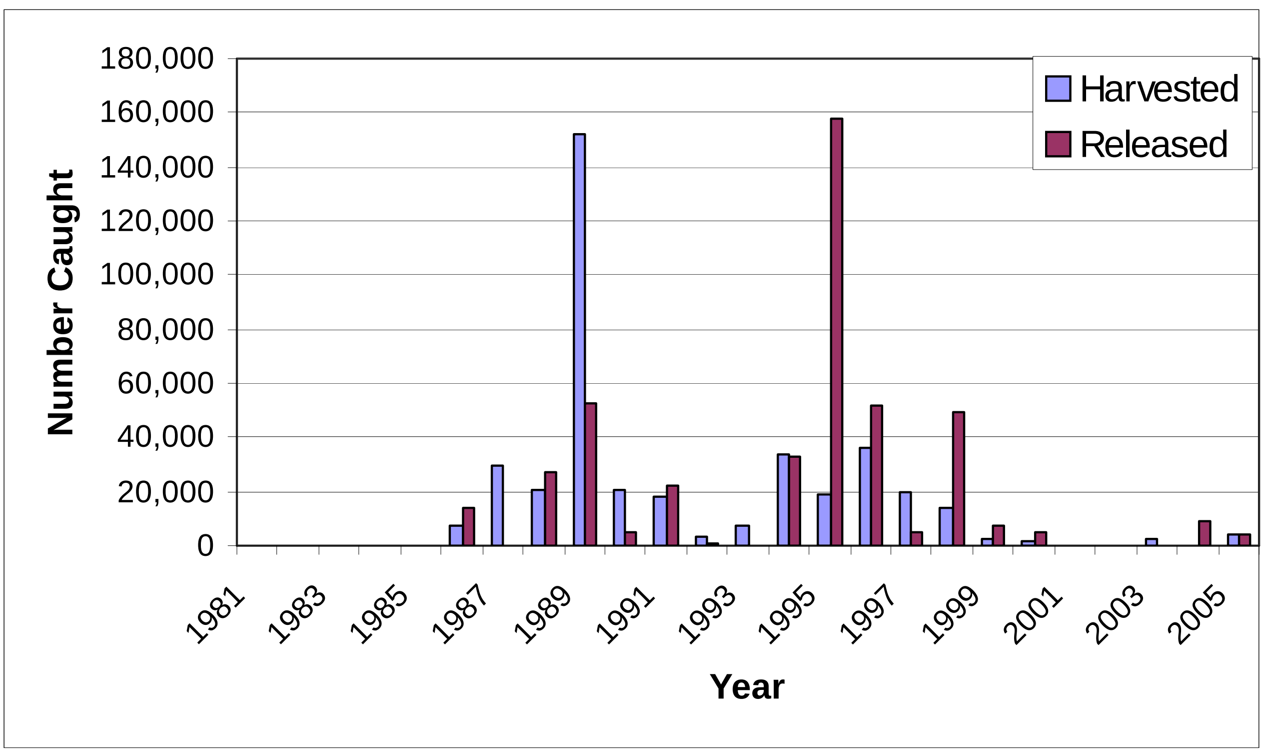
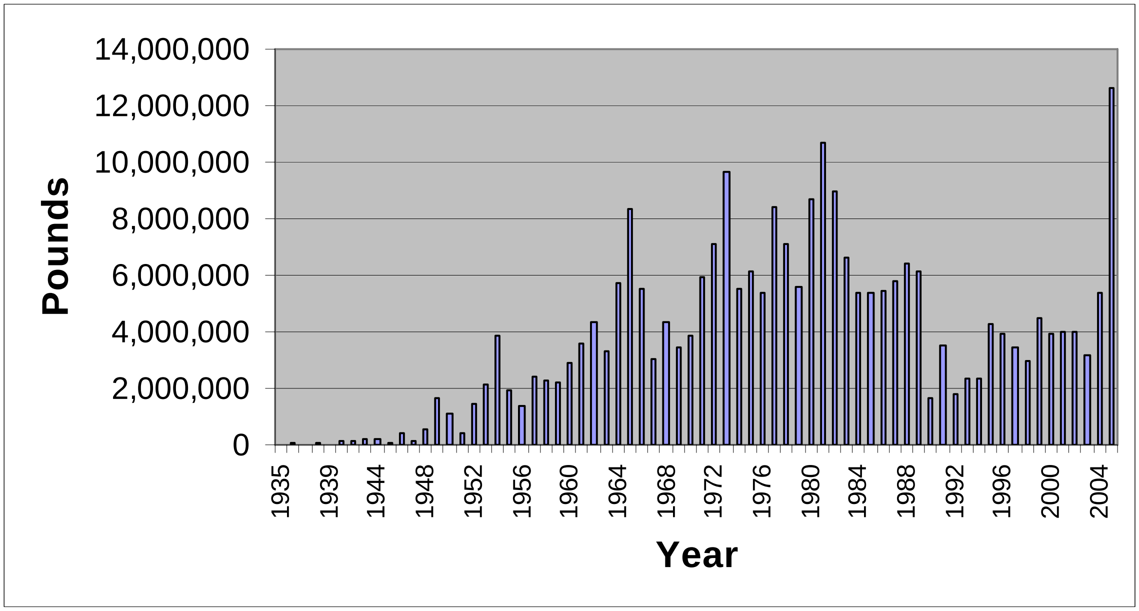


Figure 25. Maryland commercial Atlantic menhaden landings, 1935-2005.



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 2005 Maryland striped bass (Morone saxatilis) pound net and commercial hook-and-line harvest. The 2005 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 task 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 2005 commercial fisheries seasons were used to characterize the length and age structure of the entire 2005 Chesapeake Bay commercial harvest and the majority of the recreational harvest (Fegley 2001).

METHODS

Commercial pound net monitoring

Between 1993 and 1999, both pound net monitoring and the tagging study 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 watermen 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 watermen 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 during pound net monitoring, to the length distribution of check station sampled striped bass.

Pound net sampling occurred monthly from June through November 2005 (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 2005, 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. To address questions concerning fish condition in late summer/early fall, a random sub-sample of striped bass has been weighed in October, since 1997. 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.

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

All striped bass harvested in Maryland's commercial striped bass fishery are required to pass through a MD DNR approved check station (see Project 2, Job 3, Task 5A). Check stations across Maryland were randomly sampled for pound net and hook-and-line harvested fish each month from June through November 2005 (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 logs and selecting from those landing 8% or more of the monthly harvest to date. Stations that reported the higher harvests were sampled more frequently. This method generally dispersed the sampling effort so that sample sizes were proportional to landings.

Scale samples were removed from 2 fish per 10-millimeter length group from striped bass less than 650 mm TL and from all striped bass greater than 650 mm TL from pound net and hook-and-line harvested fish. Scales taken from the pound net monitoring survey were combined with check station scales for ageing.

Analytical Procedures

Scale ages from the pound net and check station surveys were applied to all fish sampled. The number of scales read per length group varied depending on the size of the fish. The decision to apply ages from the pound net fishery to hook-and-line fish was based on the 1999 study in which 511 striped bass sampled from pound nets and 303 fish sampled from commercial hook-and-line check stations were aged (Fegley, 2001). An analysis of covariance (Sokal and Rohlf 1995) test conducted to examine possible differences in length-at-age of striped bass harvested in the two fisheries indicated no age*gear interaction (P>F=0.8532), indicating that pound net and hook-and-line harvested striped bass exhibit nearly identical age-length relationships, and that ages derived from one fishery may be applied to the other. This is not surprising since both fisheries are concurrent within Maryland, and minimum and maximum size regulations are identical.

Age composition of the pound net and hook-and-line fisheries was estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). The first stage refers to total length samples taken during the surveys, which was assumed to be a random sample of the commercial harvest. In this case, the length frequencies from hook-and-line and pound net check stations were combined with the pound net monitoring length frequency. In stage 2, a random sub-sample of scales was aged. These scales were selected in proportion to the length frequency of the initial sample. The total number of scales to be aged was determined using a Vartot analysis which is a derived index measuring the precision of an age-length key (Kimura 1977, Lai 1987). Regardless of the sample size indicated by the Vartot analysis, 10 fish in each length category over 700 mm TL were aged.

Year-class was determined by reading acetate impressions of the scales placed in microfiche readers, and age was calculated by subtracting year-class from collection year. The resulting ages were used to construct an age-length key. The catch-at-age for each fishery was calculated by applying the age-length key to the hook-and-line and pound net length frequencies, and expanding the resulting age distribution to the landings.

In order to examine recruitment into the pound net and hook-and-line fisheries, the age structure of the harvest over time was examined. The age structure of the harvest for the 2005 hook-and-line and pound net fisheries was also compared to previous years.

Mean lengths and weights 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) 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. 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 2005 striped bass pound net study, striped bass were sampled from one pound net in the Upper Bay, four pound nets in the Middle Bay, and four pound nets in the Lower Bay (see Project 2, Job 3, Task 4). The nine 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 198 to 957 mm TL. In 2005, 56% of striped bass collected from full net samples were less than legal size, while 63% of fish from partially sampled nets were sub-legal. Mean total length and weight by age for striped bass sampled from pound nets are presented in Tables 2 and 3.

In 2005, 210 fish from check stations and pound net monitoring surveys were aged. Striped bass sampled from the pound nets ranged from 1 to 14 years of age. Two-year-old fish from the 2003 year-class dominated the pound net catch, contributing 41% in 2005, up from 3% in 2004, while age 3 fish from the 2002 year-class composed only 15% of the sample (Figures 2 and 3). This lower catch of 3 year-old fish may be attributed to the poor juvenile index in 2002 (Job 2 Task 2). Age 4 fish contributed 24% in 2005, which was 13% less than the contribution in 2004. Age 5 fish contributed 13%, slightly more than in 2004. Striped bass aged 6 and over accounted for only 6. 4% of the pound net sample in 2005 whereas in 2004, their contribution was 18.8%. 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).

Hook-and-line check station sampling

The 2005 hook-and-line harvest accounted for 14.1% of the Maryland Chesapeake Bay total commercial harvest in 2005 (see Project 2, Job 3, Task 5A). Striped bass sampled from the 2005 hook-and-line fishery ranged from 424 – 939 mm TL (Figure 4) and from 2 to 13 years of age (Figure 5). Four year-old striped bass from the dominant 2001 year-class contributed 35% to the hook-and-line harvest, slightly less than in 2004. Age 5 fish from the 2000 year-class contributed 30% which was almost double the contribution in 2004. Age 6 fish from the 1999 year-class accounted for only 10% of the 2005 harvest, which was 8% less than last year's contribution. Fish aged 7 years old from the 1998 year-class accounted for 5.8%, half as much as in 2004. Striped bass aged 8 and over contributed 3.4% to the overall harvest which was the same in 2004.

In 2005, 3.5% of the striped bass sampled at hook-and-line check stations were sub legal (< 457 mm TL). Striped bass in the 470-510 mm TL length groups accounted for 55% of the 2005 hook-and-line harvest, which was slightly more than in 2004 (Figure 6). The contribution of striped bass in the 530-630 mm TL length groups decreased slightly in 2005. Fish between 650 – 690 mm TL contributed only 5%. In general, few large fish were available to the 2005 hook-and-line fishery. Only 3.4% of hook-and-line fish sampled during the season were over 700 mm TL. Of these larger striped bass, forty-five percent were harvested in June, composing 8.9% of the June sample. These fish were rarely encountered from July through October, with contributions ranging from 0 in September to 3.8% in August. Historically, these fish have not been available in large numbers during the summer (MDDNR 2002).

Length and age frequencies of fish sampled from hook-and-line check stations were almost identical to fish sampled from the pound net fishery.

Pound net check station sampling

In 2005, the pound net harvest accounted for 25.6% of the Maryland Chesapeake Bay total commercial harvest. Striped bass sampled ranged from 435 –911 mm TL. Legal-sized striped bass sampled from the 2005 pound net fishery ranged from 3 to 13 years of age. As in the hook-and-line fishery, four-year-old fish from the 2001 year-class dominated the pound net harvest, contributing 35% to the total harvest. This is similar to the harvest in 2004. Age 5 fish contributed 30% to the pound net harvest, which was more than the contribution of five-year-old striped bass in 2005 (12.7%). Age 6 fish from the 1999 year-class accounted for 10% of the pound net harvest, eight % less than in 2004. Fish aged 7 years old from the 1998 year-class accounted for 1.8 %, compared to 5.8% in 2004. The contribution of striped bass aged 8 and over was 4.4%, less than their contribution in 2004 (10%).

In 2005, 1.9 % of the striped bass sampled at pound net check stations were sub-legal (< 457 mm TL). Striped bass in the 470 -510 mm TL length groups accounted for 55% of the 2005 pound net harvest, which was slightly more than in 2004. The contribution of striped bass in the 530 – 630 mm TL length groups decreased slightly in 2005 to 33%, from 36% in 2004. Fish between 650 – 690 mm TL composed only 4.5% In general; few large fish were available to the 2005 fishery. Only 4.7% of pound net fish sampled during the season were over 700 mm TL. In 2005, these larger striped bass were harvested most frequently in June (13.6%) and July (10%) with a small percentage harvested in November (4.3%) (Figure 7). This differs from 2004 when large fish were only encountered in June (17.2%) and November (16.4%) in 2004 and in greater frequencies than this year.

Monitoring summary

In 2005, striped bass ranging from 457 to 550 mm TL were harvested almost equally in both fisheries (Figure 5). This year, older fish were again scarce through 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 - 2000 (Figure 8). Since 2001, there has been no apparent trend for 5 and 6 year-old fish, while annual mean lengths of age 4 fish have shown a slight, though not significant, decreasing trend over time. Duncan's multiple range test (p=0.05) of mean length-at-age showed no significant differences from 2001 to 2005, for four, five, and six year-old striped bass. Age 7 striped bass were similar to age 7 fish in 2001 and 2004. Eight year-old striped bass from the 1997 year-class were only significantly different from age 8 striped bass in 2002, while 9 year-old striped bass from the very large 1996 year-class were no different than 9 year-old striped bass in any other year since 2001. Striped bass aged 10 were only different from fish aged 10 in 2002, and eleven year-old striped bass were similar to age 11 fish in all years. The estimated 2005 catch-at-age of hook and line and pound net fisheries is presented in table 4.

CITATIONS

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

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

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

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

Lai, Han-Lin. 1987. Optimum allocation for estimating age composition using an age-length key. Fishery Bulletin. 85:2 179-183.

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

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

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

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Table 3. 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 2005.

Table 4. Estimated catch-at-age of striped bass landed by Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2005.

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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 2005.

Figure 4. Length frequency of striped bass sampled during the 2005 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2005. 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 2005. Note – pound net check station sampling began in 2000.

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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 1990 through 2005. 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.

Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2005 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 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 Chesapeake Bay, June through November 2005. Mean lengths are weighted by the sample n-at-length in each age.

Age	Year-class	n Aged	Weighted Mean Length (mm TL)
3	2002	5	471
4	2001	21	516
5	2000	22	573
6	1999	19	633
7	1998	27	686
8	1997	22	763
9	1996	24	830
10	1995	11	819
11	1994	9	891
12	1993	1	884
13	1992	2	933
14	1991	1	950

Table 3. 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 2005.

Age	Year-class	n Aged	Weighted Mean Weight (kg)
3	2002	5	1.0
4	2001	21	1.2
5	2000	22	1.4
6	1999	19	2.1
7	1998	27	2.6
8	1997	22	3.5
9	1996	24	4.8
10	1995	11	5.3
11	1994	9	6.8
12	1993	1	6.9
13	1992	2	8.4
14	1991	1	8.2

*Mean weights-at-age were calculated based on the age-length key and length and weight measurements of individual fish.

Table 4. Estimated catch-at-age of striped bass landed by Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2005.

Year-class	Age	Hook and Line		Pound Net	
		Landings in Numbers of Fish	Percent of Total	Landings in Numbers of Fish	Percent of Total
2004	1	0	0	0	0
2003	2	32	0.04	101	0.07
2002	3	13010	15.06	19746	13.73
2001	4	30696	35.53	50442	35.08
2000	5	25966	30.05	43364	30.16
1999	6	8664	10.03	14690	10.22
1998	7	5066	5.86	9110	6.34
1997	8	1595	1.85	2591	1.80
1996	9	806	0.93	2263	1.57
1995	10	301	0.35	773	0.54
1994	11	222	0.26	418	0.29
1993	12	0	0	127	0.09
1992	13	40	0.05	158	0.11
1991	14	0	0	0	0
Total Landings		**86397**		**143784**	

*Landings (number of fish) are calculated as the pounds of fish reported to DNR by check stations 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 2005.

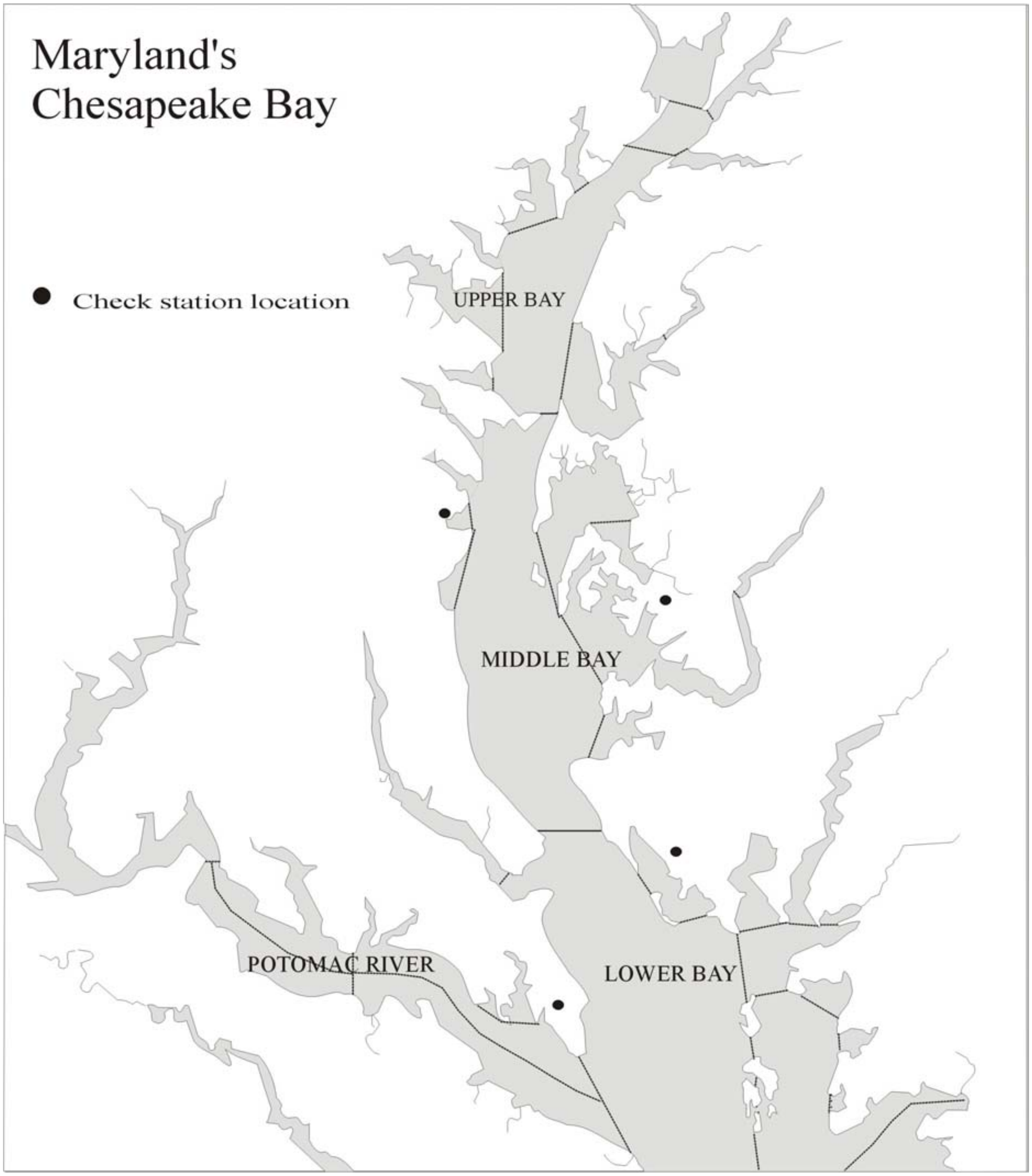
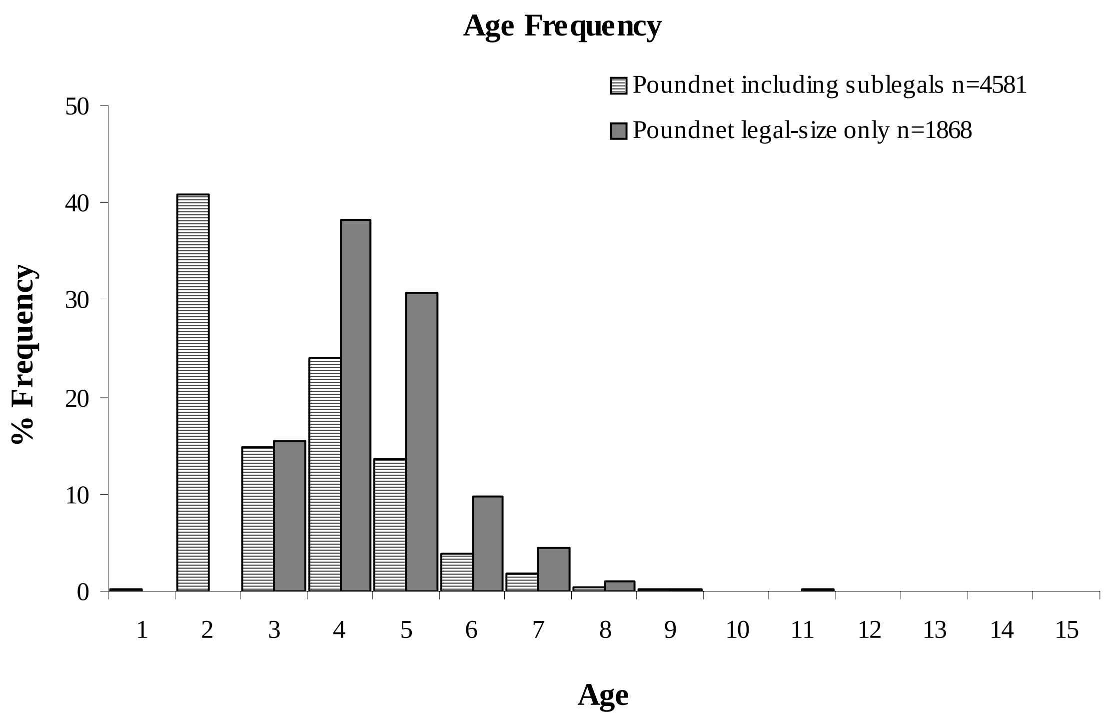


Figure 2. Age and length (mm TL) frequencies of striped bass sampled from Maryland Chesapeake Bay pound net monitoring study June through November 2005.



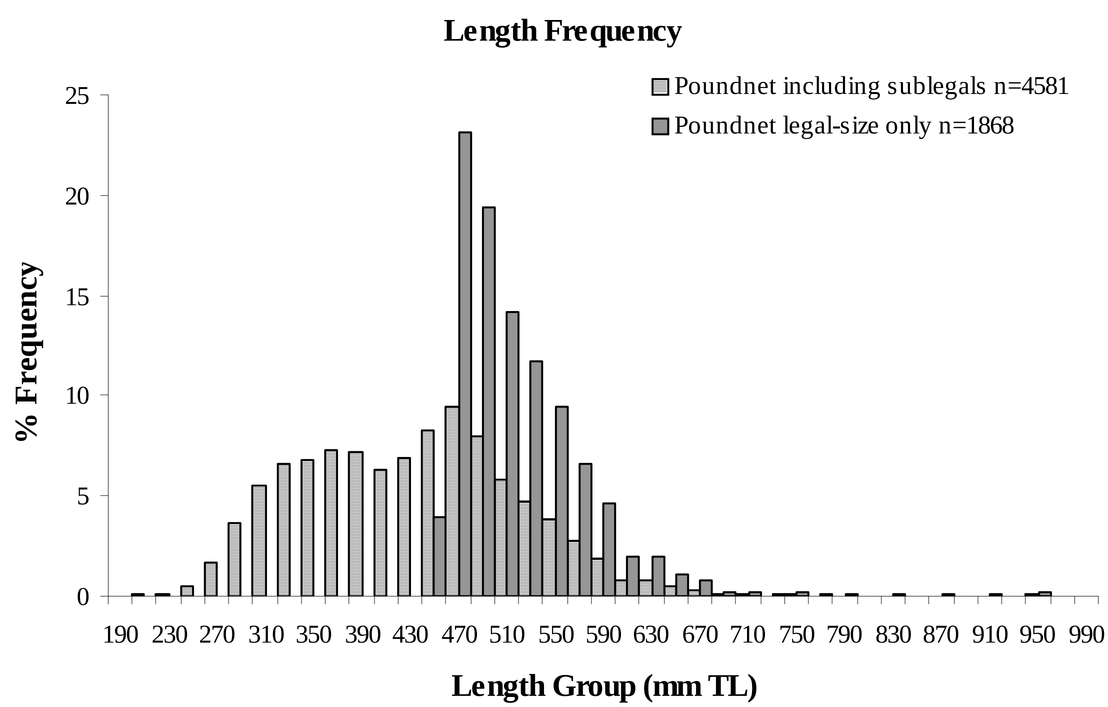


Figure 3. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net monitoring study from 1996 through 2005.

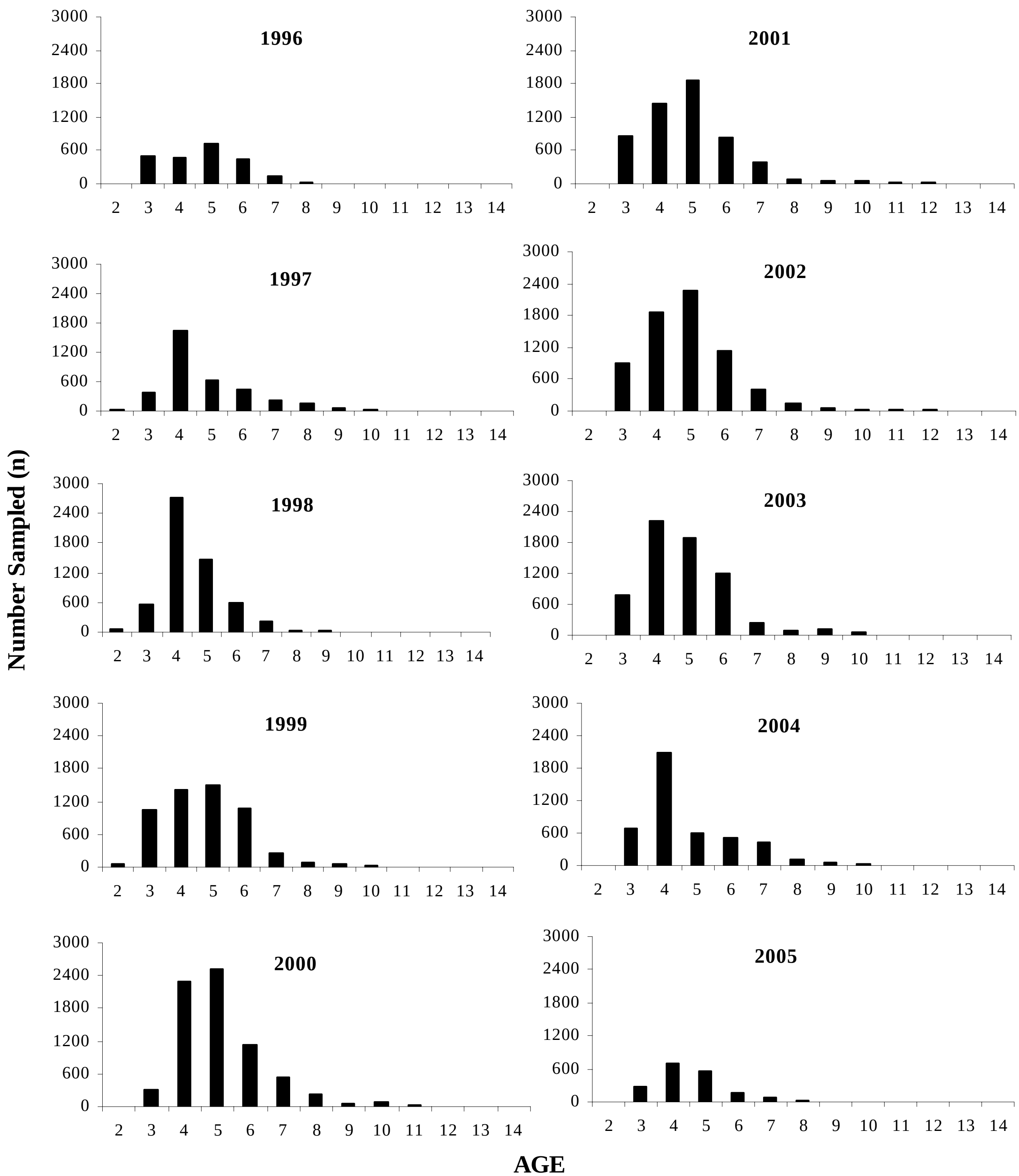


Figure 4. Length frequency of striped bass sampled during the 2005 pound net monitoring, pound net check station and hook-and-line check station surveys. All fish were sampled from June through November 2005. Pound net monitoring length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

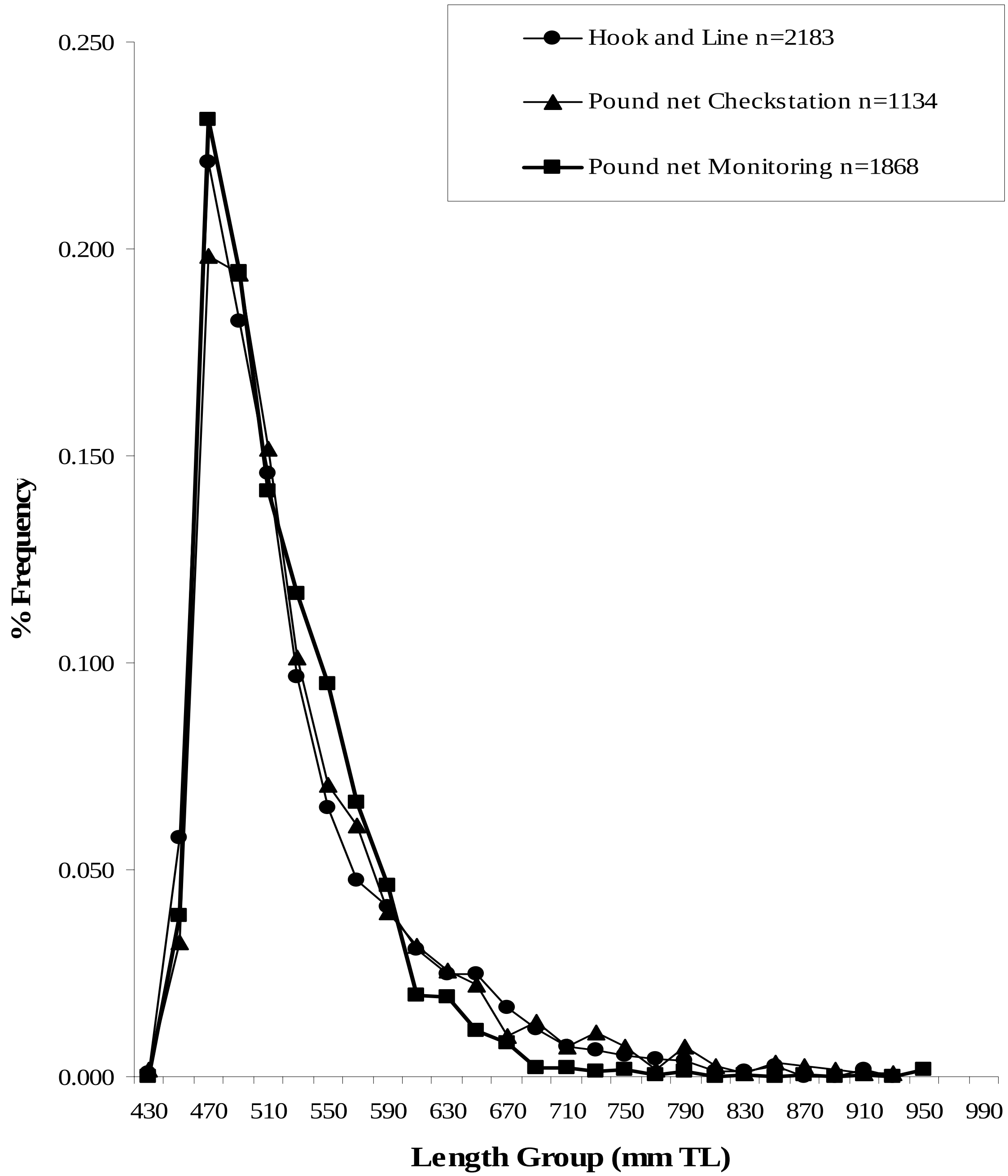


Figure 5. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, 1999 through 2005. Note – pound net check station sampling began in 2000.

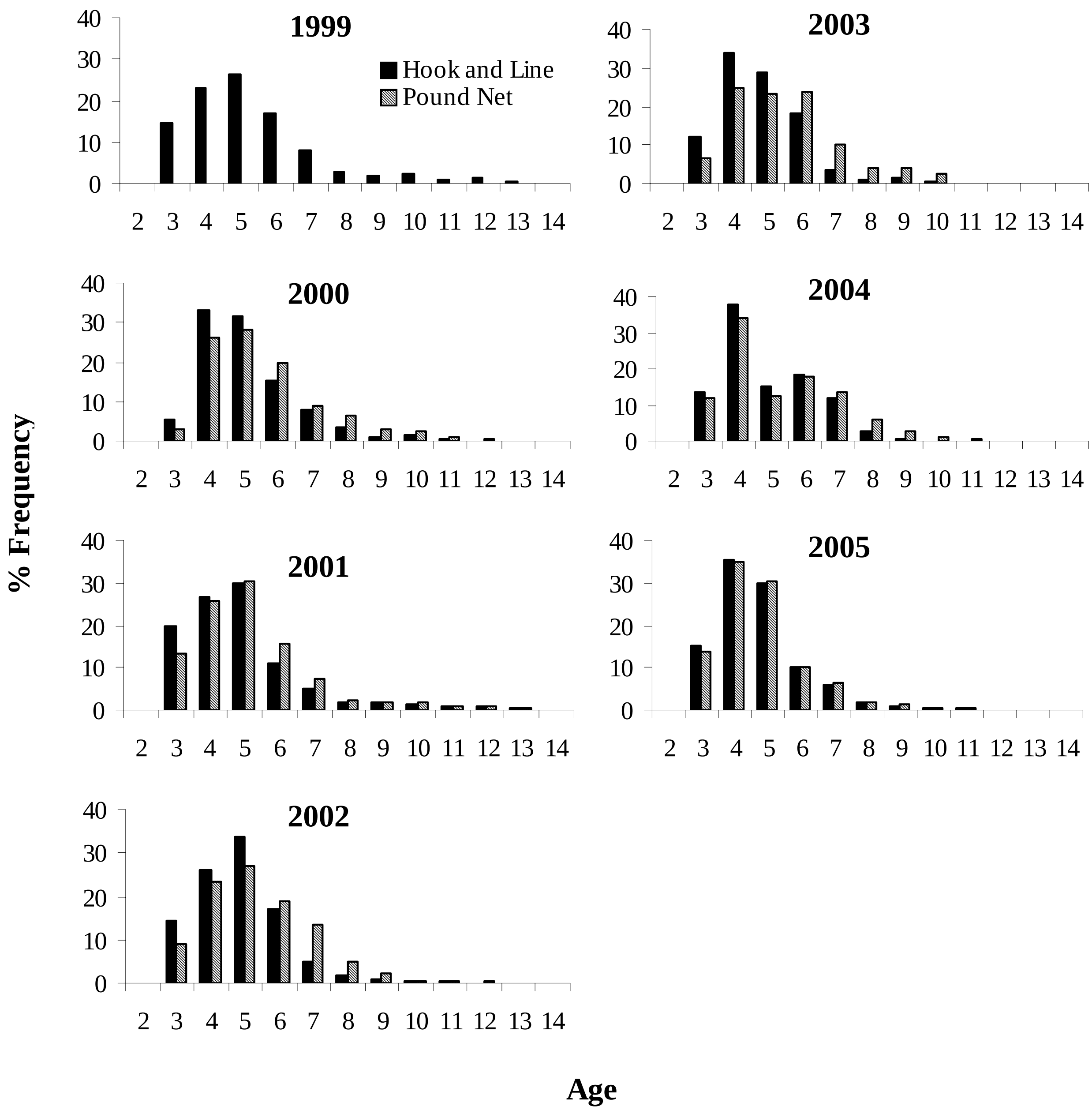
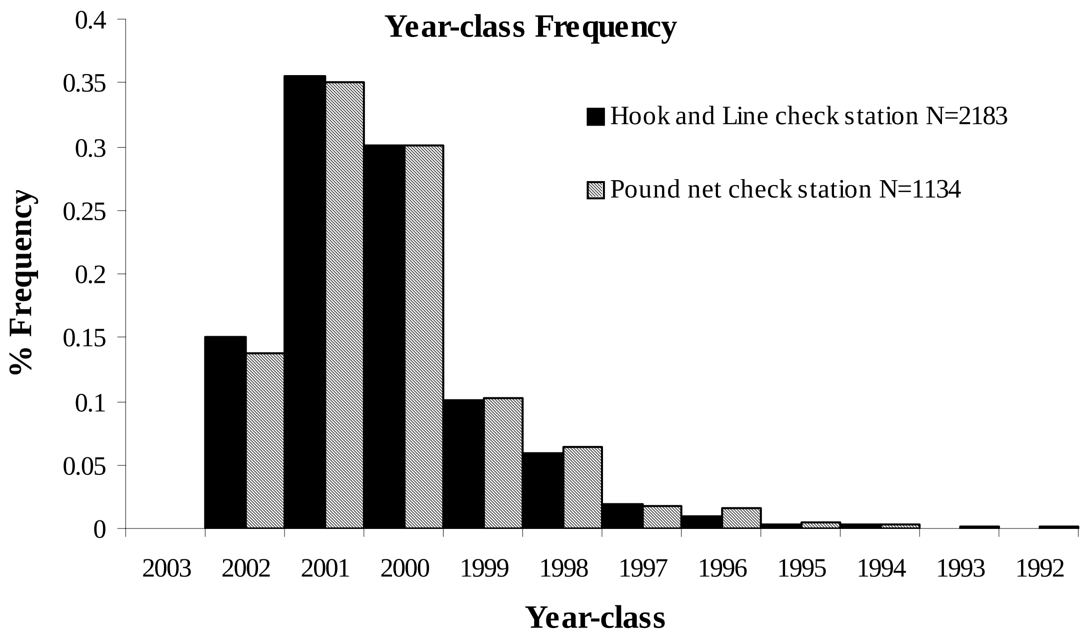


Figure 6. Year-class and length frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net check stations, June through November 2005.



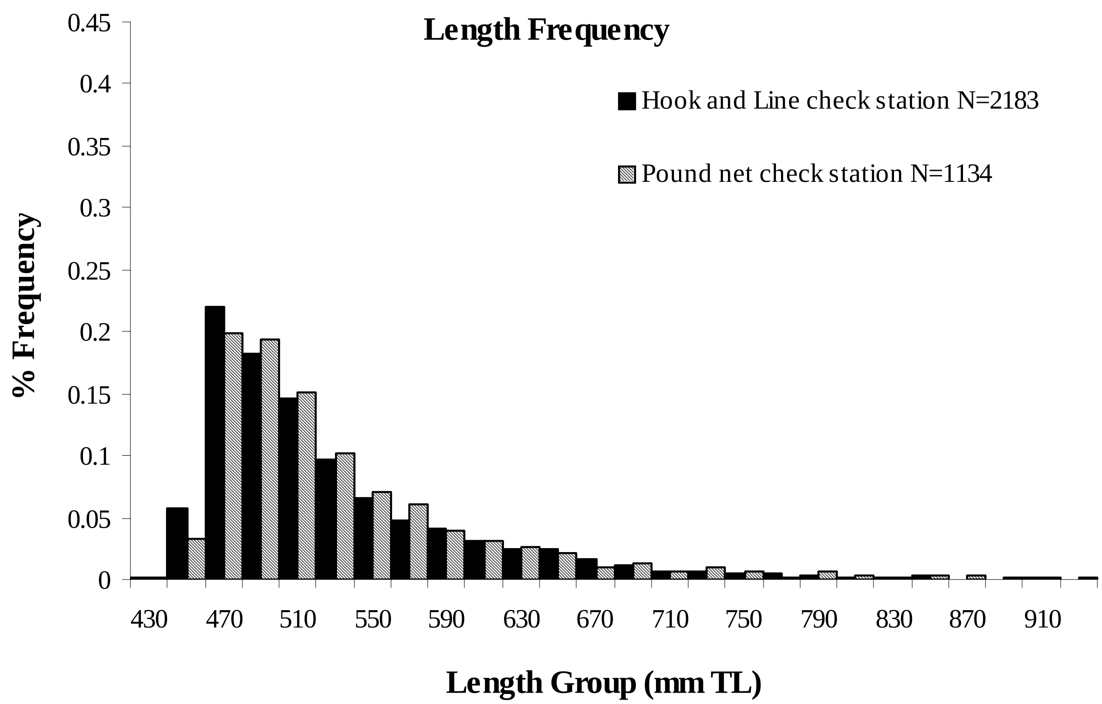


Figure 7. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2005.

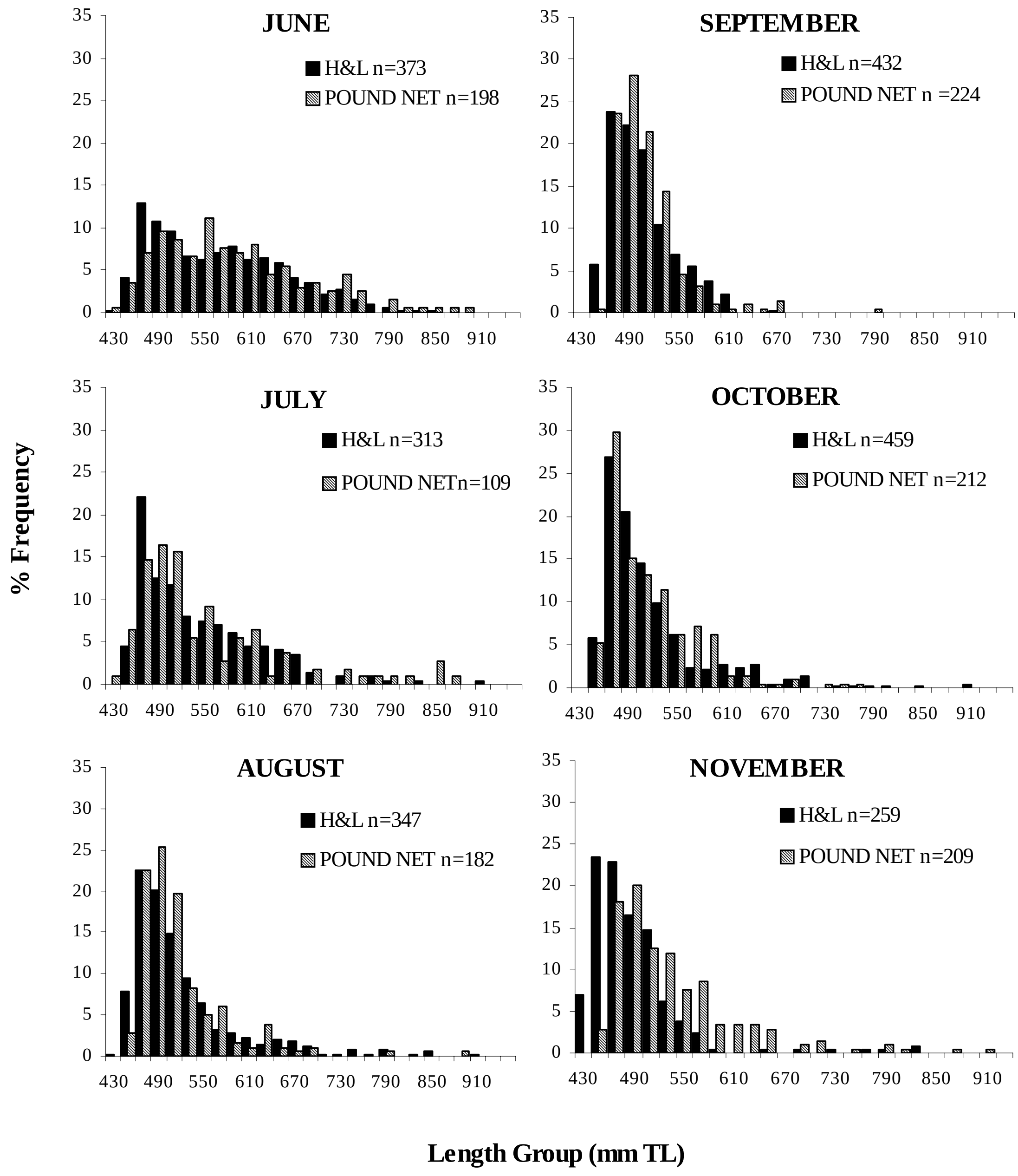
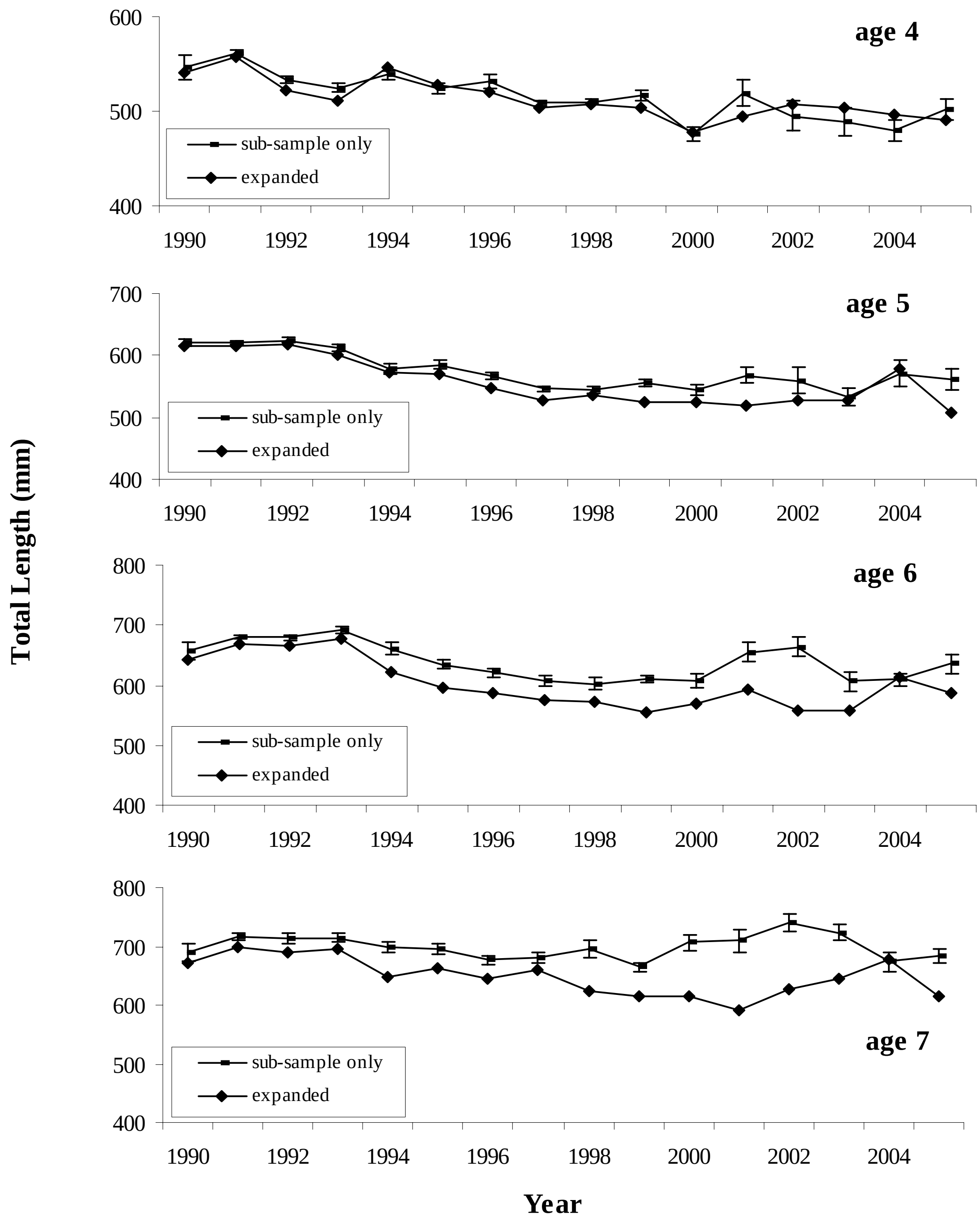


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets 1990 through 2005. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating 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 Erik Zlokovitz

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, 2005-February 28, 2006 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 from this task were used to monitor temporal trends in length and weight-at-age of resident/pre-migratory striped bass. These data also contributed to the construction of the Maryland catch-at-age matrix utilized in the Atlantic States Marine Fisheries Commission (ASMFC) coastal striped bass stock assessment.

METHODS

Data collection procedures

All striped bass harvested in Maryland's commercial striped bass fishery are required to pass through a MD DNR approved check station. Striped bass check stations were sampled according to a stratified random sampling design where strata were defined as either high-use or medium-use check stations. Based on landings from the previous year, individual check stations which processed 8% or greater of the entire catch were designated high-use. Medium-use stations were those which processed between 3% and 7.9% of the catch. High-use and medium-use stations were sampled at a 3 to 1 ratio; one medium-use station was sampled for every 3 visits to a high-use station with a sample intensity of one visit per week for the duration of the fishery. Low-use sites were not sampled due to low landings in recent years. Days and stations were randomly selected each month, although the results of the random draw were frequently modified because of weather, check station hours, and other logistical concerns. Sampling was distributed as evenly as possible between geographic areas. 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 provided 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. In cases where fewer than 300 fish were checked in, all striped bass were sampled. Scales were taken randomly from 2 fish per 10 mm length group per visit for fish less than 700 mm TL, and from all fish 700 mm TL and larger. Striped bass larger than 700 mm TL were scanned for coded wire hatchery tags (CWTs).

Analytical procedures

Age composition of the sample was estimated via two-stage sampling (Kimura 1977, Quinn and Deriso 1999). In stage one, a random sample of lengths was taken from the total catch. In stage 2, a sub-sample of scales was aged. The total number of scales to be aged was determined using a Vartot analysis, and every fish over 700 mm TL was aged. 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 2005-2006 winter gill net harvest was estimated by applying the sample age distribution to the total landings. Because the winter gill net season straddles two calendar years, ages were calculated by subtracting year-class (assigned by scale readers) from the year in which the fishery ended. For example, for the December 2005 – February 2006 gillnet season, the year used for age calculations is 2006.

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) 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.

In order 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 2005-2006 harvest was compared to that of previous years back to 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 60.3% of the total Maryland Chesapeake commercial harvest, by weight, during the 2005 calendar year. A total of 3606 striped bass were measured and 123 striped bass were aged from the December, 2005- February, 2006 harvest.

Commercial gill netters have been limited to nets with 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 drift gill net striped bass 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 the fish landed in most years were between 4 and 8 years old. However, the contribution of individual year-classes to the overall landings has varied between years. According to the estimated catch-at-age analysis, the 2005-2006 commercial drift gill net harvest consisted primarily of striped bass from the 2002, 2001 and 2000 (age 4, 5, and 6) year-classes

(Table 1). Age 4, 5, and 6 fish composed 89% of the harvest, while 7-13 year-old fish contributed only 5% to the total. The youngest fish observed in the 2005-2006 sampled harvest were age 3. Age 3 fish have not been present in the sampled harvest since 2003 and have composed less than 7% of the sample in any given year during the period 1994-2006.

The mean lengths and weights-at-age of the aged sub-sample and the estimated means from the expansion technique are given in Tables 2 and 3. In most cases, expanded mean lengths and weights-at-age were slightly lower than sub-sampled means for fish ages 5-13. Striped bass were recruited into the 2005-2006 winter gill net fishery at age 3 (2003 year-class), with an expanded mean length and weight of 496 mm TL and 1.56 kg, respectively. The 2001 year-class (age 5) was most commonly observed in the sampled landings, composing 41% of the harvest, with an expanded mean length of 509 mm TL, and an average weight of 1.68 kg. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 13, 1993 year-class) were 805 mm TL and 5.88 kg, respectively.

Length frequency distributions by check station area are presented in Figure 3. The length frequency distributions were dominated by fish in the 470-550 mm TL range. Distributions were similar when comparing the northern and eastern area check stations. Sub-legal fish composed 3.2% of the bay wide sampled harvest, a percentage comparable to that observed in the summer/fall commercial hook and line fishery (See Project 2, Job 3, Task 1A, this report).

Time series of sub-sampled and expanded mean lengths and weights for the period 1994-2006 are shown in Figures 4 and 5. Mean length-at-age and weight-at-age have been variable over time, with no clear trends. Large confidence intervals and low sample sizes of fish age 7 and older make trends difficult to discern. Expanded and sub-sampled mean lengths and weights were well correlated at for ages 4 and 5, but began to diverge at age 6. Expanded means were generally lower than sub-sampled means for fish older than age 5 during the 1994-2006 time period.

In recent years, few CWT positive striped bass have been documented at gill net check stations. No striped bass scanned positive for the presence of coded wire hatchery tags during the 2005-2006 gill net season.

CITATIONS

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

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

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

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

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Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2006. (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.

Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2005 - February 2006.

Year-Class	Age	Catch
2003	3	18,751
2002	4	80,161
2001	5	132,860
2000	6	75,978
1999	7	13,243
1998	8	1,190
1997	9	2,094
1996	10	564
1995	11	374
1994	12	0
1993	13	120
	Total	**325,335**

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 2005-February 2006.

Year-Class	Age	n fish aged	Mean TL (mm) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean TL (mm)
2003	3	3	474	208	496
2002	4	14	462	889	480
2001	5	30	549	1473	509
2000	6	33	619	841	533
1999	7	11	678	147	530
1998	8	11	704	13	698
1997	9	11	757	23	684
1996	10	6	787	7	789
1995	11	3	774	4	783
1994	12	0		0	
1993	13	1	811	1	805
Total		**123**		**3606**	

Table 3. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2005-February 2006.

Year-Class	Age	n fish aged	Mean Weight (kg) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean weight (kg)
2003	3	3	1.37	208	1.56
2002	4	14	1.30	889	1.41
2001	5	30	2.15	1473	1.68
2000	6	33	2.82	841	1.92
1999	7	11	3.72	147	1.91
1998	8	11	4.31	13	4.03
1997	9	11	5.14	23	4.02
1996	10	6	5.85	7	5.62
1995	11	3	5.46	4	5.64
1994	12	0		0	
1993	13	1	6.06	1	5.88
Total		**123**		**3606**	

Figure 1. Registered Maryland Chesapeake Bay check stations.

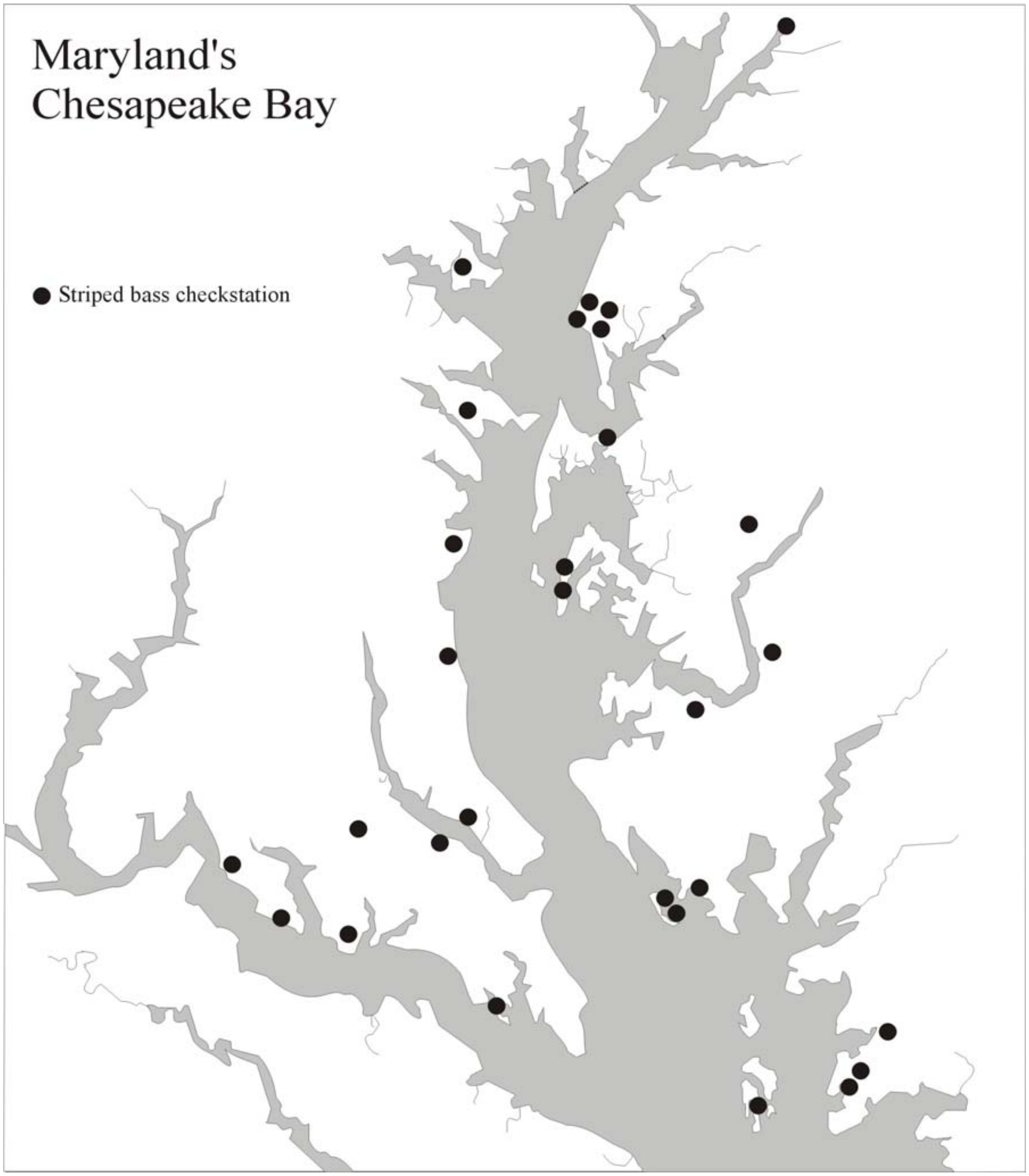
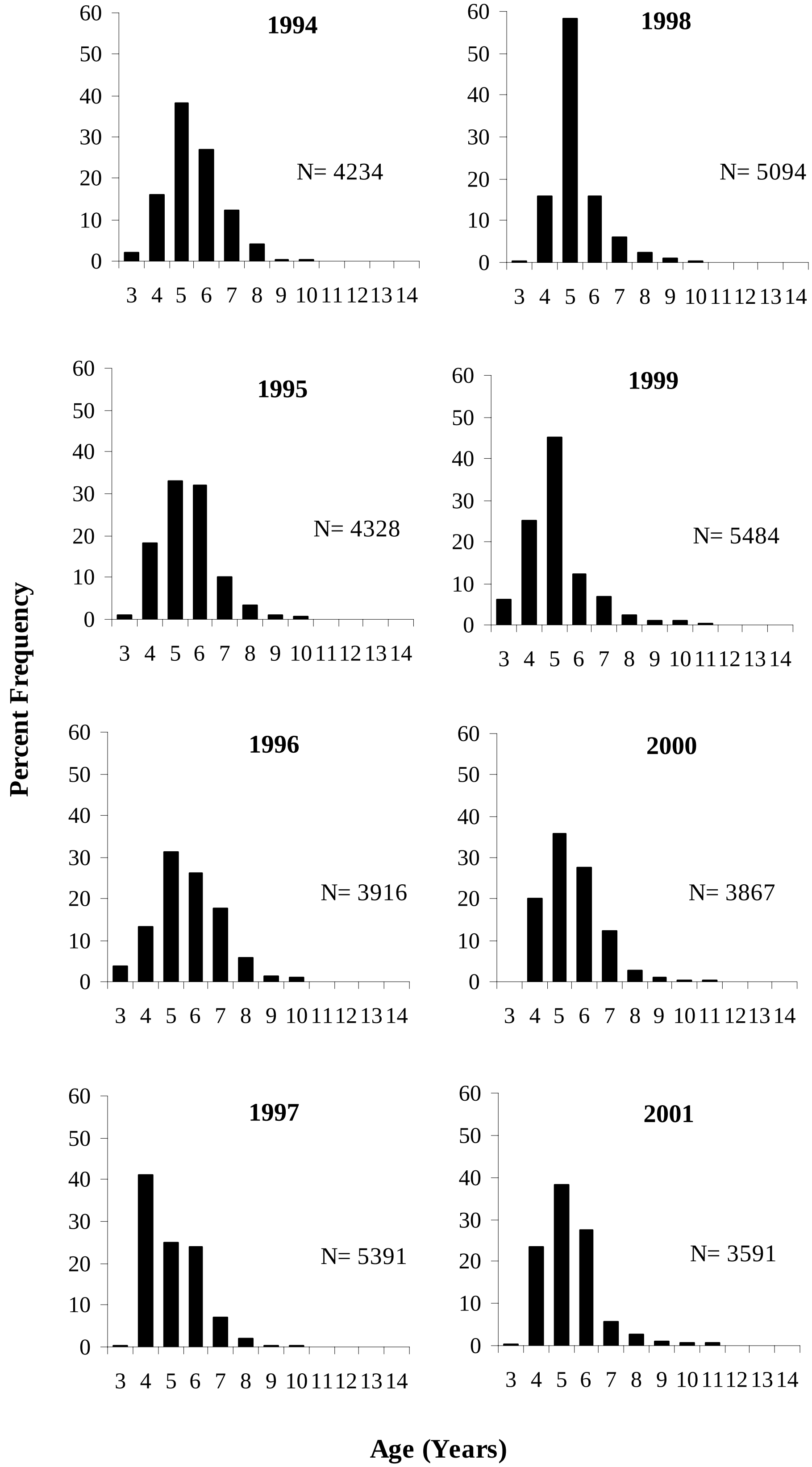


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gillnet landings, 1994-2006.



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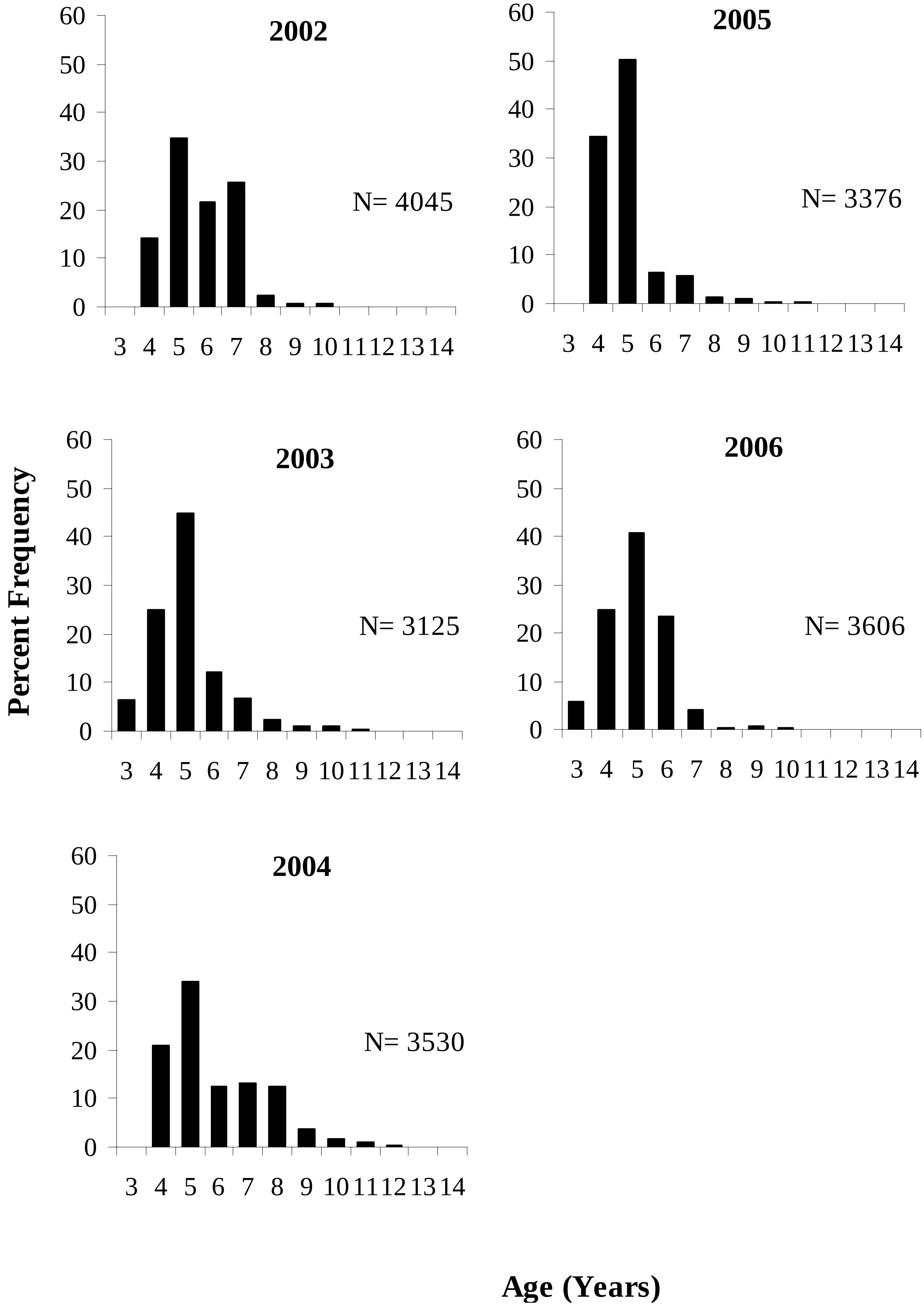

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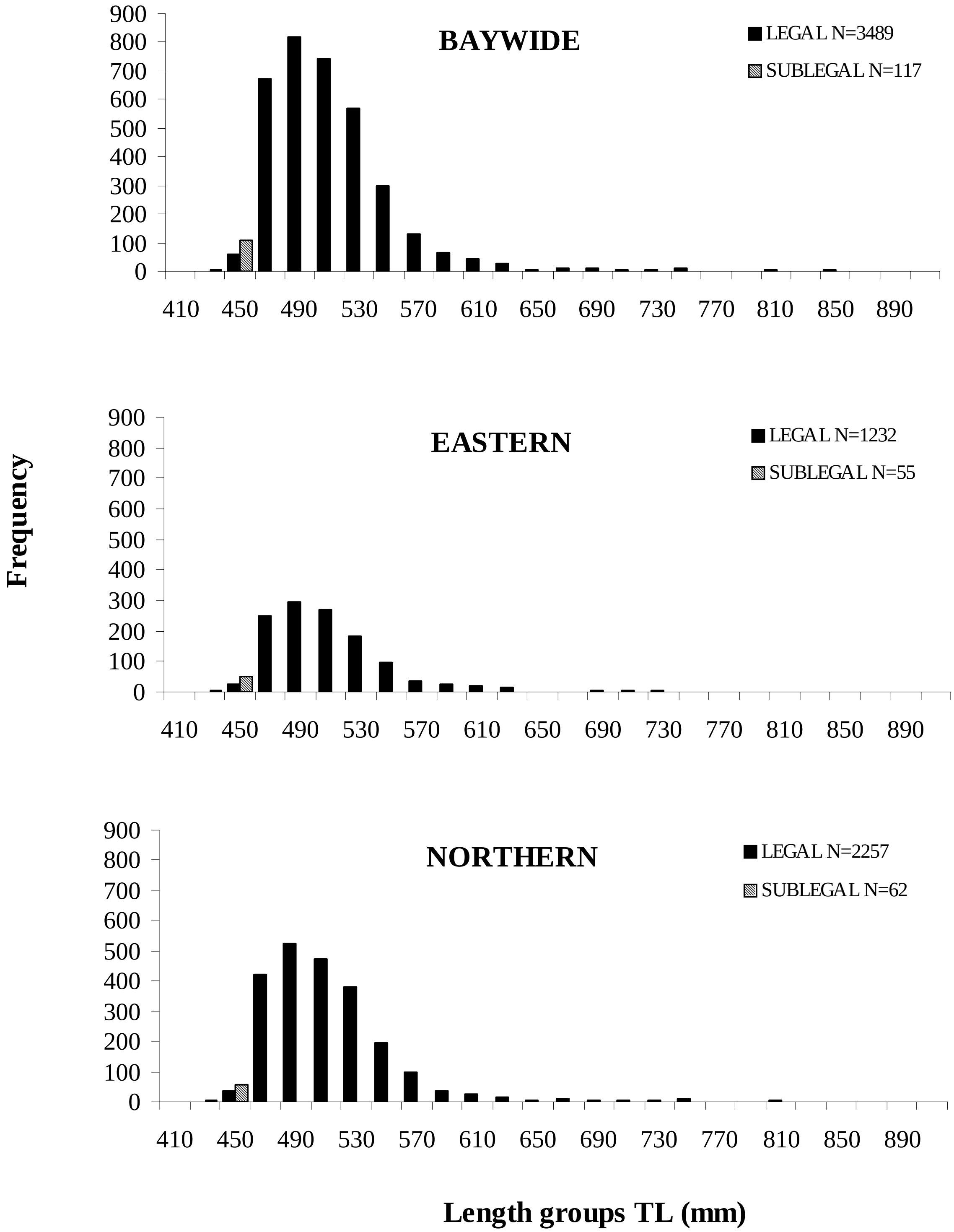

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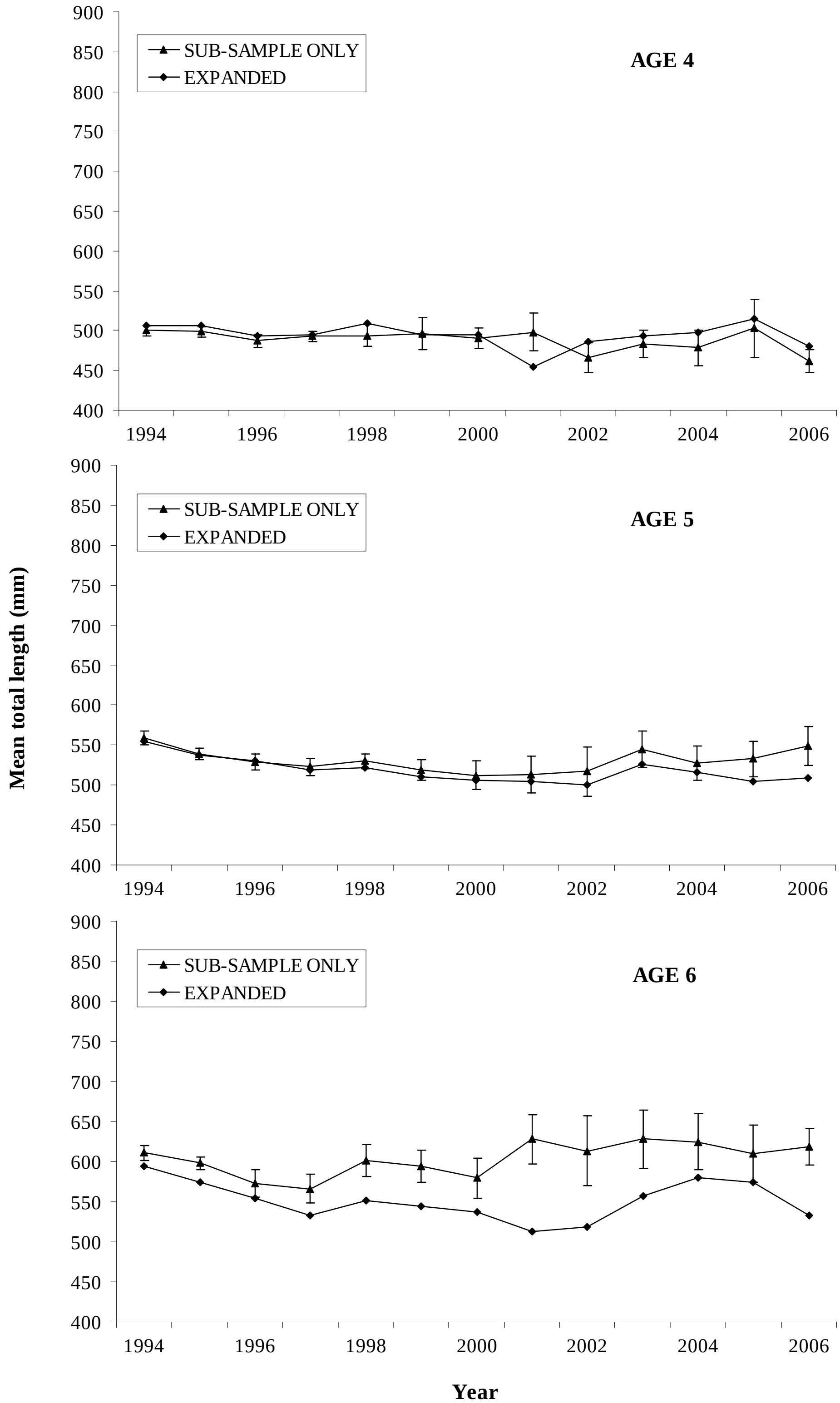

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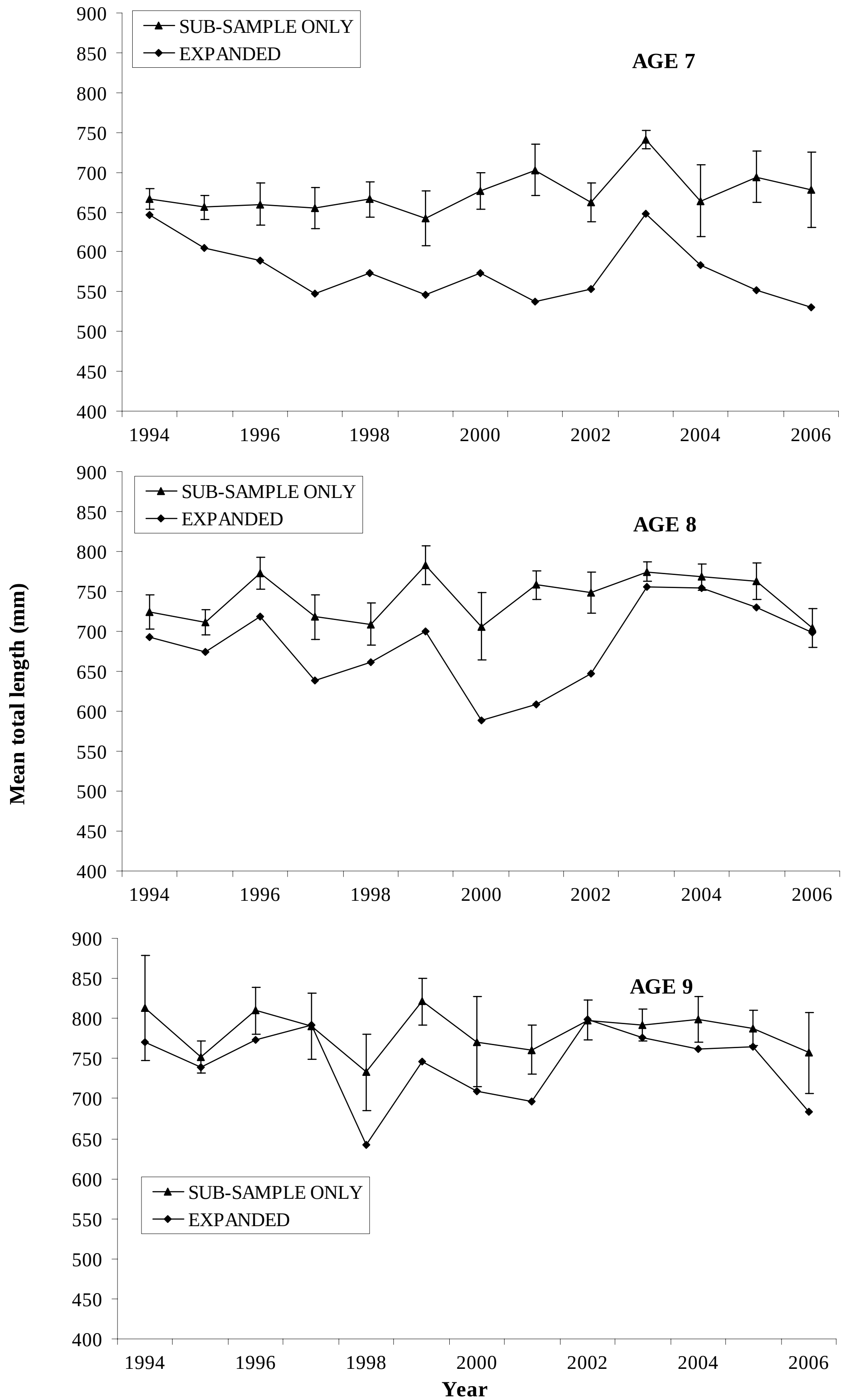


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2006. (95% confidence intervals are shown around each point). Expanded means (estimated from entire sample) are also shown. The year refers to the year in which the season ended.

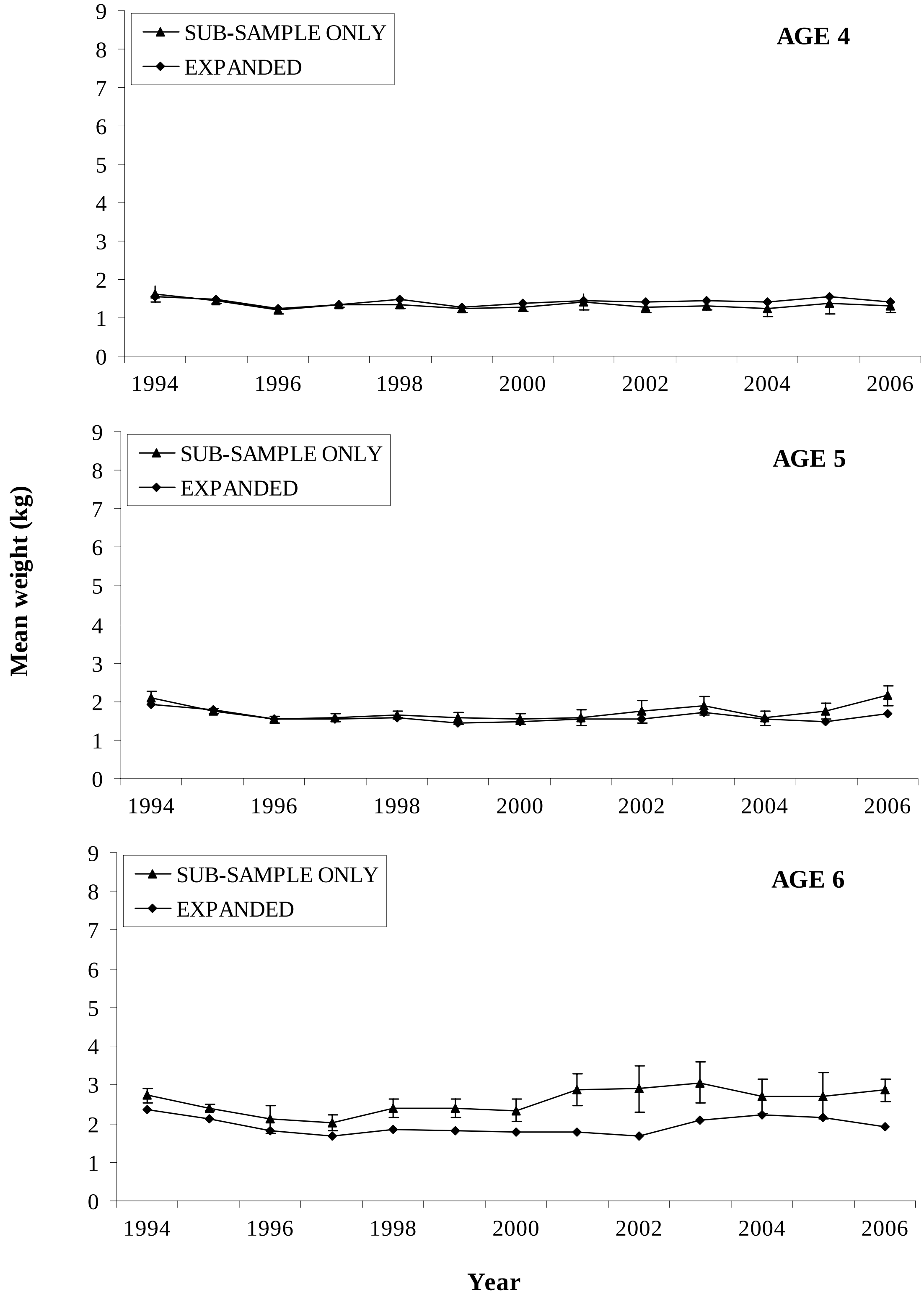
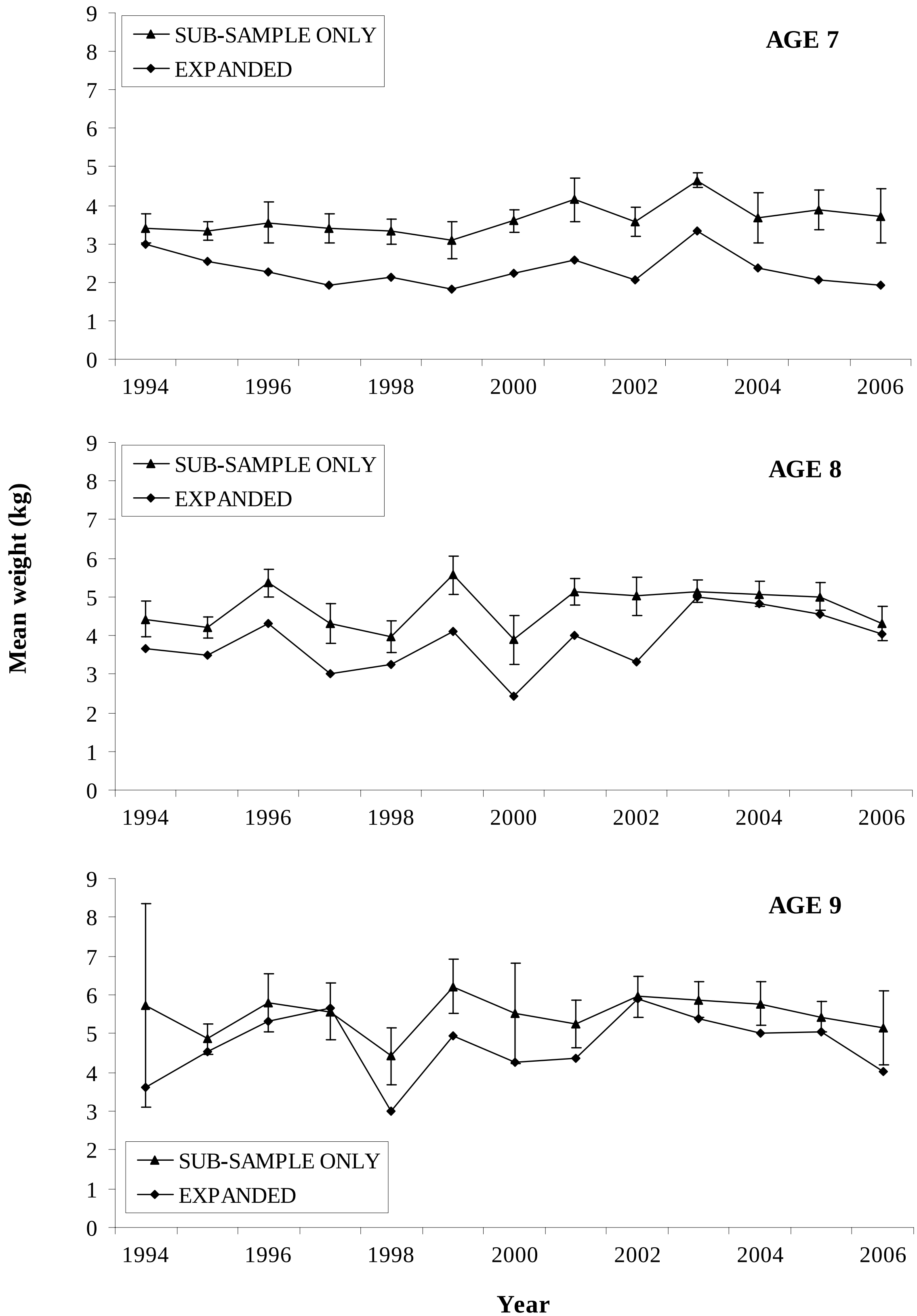


Figure 5. (Continued.)



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

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

INTRODUCTION

The primary objective of 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. The virtual population analysis (VPA) indices produced 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 2006 (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 29 to May 11 for a total of 30 sample days. In the Upper Bay, sampling was conducted from April 3 to May 16 for a total of 23 sample days.

Individual mesh 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, due to 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 3 to 10 feet between each panel. Overall soak times for each panel ranged from 11 to 105 minutes.

Sampling locations were assigned using a stratified random design. The Potomac River and Upper Bay spawning areas were each considered a stratum. One randomly chosen site per day was fished in each spawning area. Sites were chosen from a grid superimposed on a map of each system. The Potomac River grid consisted of 40 0.5-square-mile quadrants, and the Upper Bay grid consisted of 31 1-square-mile quadrants. GPS, 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. Samples were taken from 2-3 randomly chosen male striped bass per 10 mm length group, per week, for a maximum of 10 scales per length group over the entire season. Scales were 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 created in 2003 was again used in 2006. This procedure designated two sex-specific groups of scales pooled from both the spring gill net sampling and the spring striped bass recreational season creel sampling (see Project No. 2, Job No. 3, Task 5B) (Barker et al., 2003). Beginning in 2004, scales from the Patuxent River CWT survey (see Project No. 2, Job No. 3, Task 6) were also used to fill gaps in the ALK in larger length groups (Table 1). These fish were assumed to be similar to striped bass sampled from the gill net and recreational creel surveys, but due to 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 2006. 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 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.

The 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. Because the Choptank River has not been sampled since 1996, values for 1997-2006 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):

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

  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 was 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 data are presented in a time-series by area (Tables 2-7).

The 2006 un-weighted CPUEs for Upper Bay males (581) and Upper Bay females (46) were the fifth and seventh highest in their respective time-series. However, the un-weighted CPUE for Potomac males (268) was the fourth lowest in the time-series (average=504). The un-weighted CPUE for Potomac females (44) was the sixth highest in the time series, above the average of 28.

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 2006 selectivity-corrected total weighted CPUE (506) was approximately equal to the 2005 value (500) and the time series average of 512.

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. Coefficient of Variation (CV) analysis indicated a small variance in CPUE, as 76% of the CV values were less than 0.10 and 94% were less than 0.25 (Table 11). CV values greater than 1.0 were limited to older age-classes sampled during and immediately following the moratorium. The increased variability was probably related 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 (90%, Table 12) and weighted (91%, Table 13) pooled total CPUEs. Upper Bay males contributed 71% to the weighted and 62% to the un-weighted total CPUEs. Males from the 2003 year-class contributed the most (53%) to the pooled weighted CPUE.

The highest weighted CPUEs for Potomac River females were from the 1993 (22%) and 1996 (21%) year-classes. In the Upper Bay, females were more evenly spread between age-classes. The highest weighted CPUEs for Upper Bay females were from the 1993 year-class (15%), fish older than age 15 (14%) and the 1996 year-class (13%).

As in previous years, Upper Bay fish accounted for most of the total CPUE. The 1998 year-class was barely present in the pooled weighted CPUEs, contributing less than 3% to the total.

<u>Temperature and catch patterns</u>

Surface water temperatures on the Potomac River increased steadily throughout the 2006 survey. Daily water temperatures ranged from 8.9 °C to 19.4 °C. Daily CPUEs on the Potomac suggest that spawning activity peaked in late April and indicate a smaller peak in spawning activity in mid April (Figure 2). Catches of male striped bass remained consistent throughout the survey. Biologists observed striped bass eggs in the water on May 4, 2006, although this observation did not coincide with the peak in CPUE.

Surface water temperatures on the Upper Bay increased steadily during the spawning survey from 10.9 °C to 18.6 °C. Conowingo Dam did not release water during the 2006 survey, which may have caused more consistent temperatures than were seen in 2005. As on the Potomac, daily female CPUEs from the Upper Bay show a distinct peak in spawning activity during late April (Figure 3). Catches of Upper Bay females were otherwise consistent while the catch of males peaked in mid April.

In both surveys, air temperatures fluctuated greatly, mostly because it was not recorded at the same time each day. No clear patterns were observed relating air temperature to catch in either system.

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

In 2006, 661 male striped bass and 83 females were caught in the Potomac River, while 954 male and 64 female striped bass were caught in the Upper Bay.

Mean lengths of male striped bass collected from the Potomac River and Upper Bay were significantly different ($p = 0.01$) in 2006. Male striped bass sampled from the Potomac River had a mean length of 493 mm TL, while males from the Upper Bay had a mean length of 476 mm TL. Upon visual analysis of the length distributions from each system, the difference in mean size was shown to be caused by the large catch of smaller striped bass in the Upper Bay (Figure 4).

Male striped bass on the Potomac ranged from 278 mm TL to 994 mm TL. Male striped bass ranging between 410 and 530 mm TL composed 58 % of the Potomac River male catch in

2006. The length distribution of male striped bass from the Potomac River was influenced by striped bass from the large 2003 year-class. The 2003 year-class was evident in both the uncorrected and corrected CPUE peaks between 310 and 470 mm TL (Figure 5). The small peak between 810 mm TL and 830 mm TL, representing the 1996 year-class, is more evident in the corrected CPUE. The peak at 990 mm TL is only evident in the corrected CPUE values, and is composed of the 1994 and 1995 year-classes.

Male striped bass on the Upper Bay ranged from 227 mm TL to 994 mm TL. Male striped bass between 350 and 450 mm TL contributed 54 % to the total of the catch of males in the Upper Bay. The length distribution of male striped bass from the Upper Bay was also dominated by small striped bass from the 2003 year-class. The uncorrected and corrected CPUE values reflect the influence of the 2003 year-class over a wide spread of length groups from 310 mm TL to 470 mm TL (Figure 5). The 1996 and 1997 year-classes contributed to the peaks in the length distribution at 810 and 830 mm TL, which is more obvious in the corrected CPUEs. As in the Potomac River length distribution, the peak at 990 mm TL is only evident in the corrected CPUE values, and is composed of the 1994 and 1995 year-classes.

Mean lengths of female striped bass sampled from the Potomac River and Upper Bay in 2006 were not significantly different (p=0.50). Female striped bass sampled from the Potomac ranged from 808 to 1176 mm TL and had a mean length of 954 mm TL, while females sampled in the Upper Bay ranged from 521 to 1168 mm TL and had a mean length of 943 mm TL.

Female striped bass between 890 mm TL and 990 mm TL constituted 55% of the total female 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 950 mm TL, representing primarily the 1996 year-class (Figure 6). Application of the selectivity model to the data corrected the catch upward across the length distribution. The CPUE peak at 930 mm was mainly comprised of the 1996 year-class. The strong 1993 year-class is evident in the peak at 1110 mm TL, while the 1990 year-class also contributed to the high corrected CPUE at 1110 mm TL.

As on the Potomac River, 55 % of the female corrected CPUE in the Upper Bay was comprised of striped bass between 890 and 990 mm TL. A range of sizes similar to the Potomac River was present among female fish sampled from the Upper Bay, but smaller females in the 530, 610 and 690 mm TL length groups were also encountered (Figure 6). These smaller females, from the 2000 and 2001 year-classes, are rarely encountered on the spawning grounds. The corrected CPUE value at 790 reflects the 1999 year-class. The highest corrected and uncorrected CPUE values at 970 mm can be attributed to the 1994 and 1995 year-classes. High values of corrected CPUE from 1070 mm TL to 1170 mm TL represent the 1990-1994 year-classes.

Length at age

Age- and sex-specific LAAs are presented in Tables 14 and 15. Information from the area-specific length-at-age (LAA) relationships reflected known biology of the species, as there was a significant difference between LAA for the male and female spawning stocks encountered in the Potomac and Upper Bay in 2006 ($P>F < 0.001$). The scale allocation procedure created in 2003 was validated for the 2006 analysis by results of an analysis of covariance that showed no significant age*area interaction for male ($P>F = 0.65$) and female ($P>F = 0.07$) striped bass. Common male and female ALKs were subsequently developed to include fish from the Potomac River, Upper Bay and the spring recreational creel sampling. Patuxent River CWT survey fish were also included in the ALK, but the age*area interaction could not be tested due to small sample sizes.

When comparing LAA between 2005 and 2006, only gillnet fish were used. Fish sampled during the creel survey were harvested and subject to different minimum size limits between years. LAA has been relatively stable since the mid 1990s (Figures 7 and 8). All mean lengths-at-age of male striped bass sampled in 2006 showed no significant differences from those in 2005, at any age (t-tests, $\alpha = 0.05$). All ages of female striped bass in 2006 were similar in mean length to female striped bass captured in 2005, except for the 10 year-old females from the 1996 year-class. Age 10 female striped bass in 2006 (n=21), were significantly different (P>F = 0.01) from age 10 females in 2005 (n=16). This may be due to the differential growth rates between small and large year- classes.

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

There were 15 age-classes sampled in 2006, ranging from 2 - 16 years old (Tables 14 and 15). All striped bass age 4 and younger were male, while females ranged from ages 5 - 16. Age 3 males (2003 year-class) were by far the most abundant from the catch of males, while Age 13 (1993 year-class) and age 10 (1996 year-class) females were the major contributors to the 2006 total female CPUE. The abundance of two through five 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). Females younger than age 7 have been uncommon in the spawning stock since 1996. However, in 2006, two 5 year-olds and one 6 year-old female were captured on the Upper Bay. This may be a result of the strong 2001 year-class. Age 8+ females composed 84% of the female spawning stock in 2006 (Figure 10), while age 8+ females composed over 90% of the female spawning stock from 2002 to 2005. The contribution of males ages 11 and older increased through 2004, while in 2005 no males over the age of 12 were captured on the spawning grounds. In 2006, males up to the age of 14 were encountered.

The percentage of the overall sample (males and females combined) age 8 and older has varied without trend since 1996 (Figure 11). The percentage of age 8+ fish among males and females is heavily influenced by strong year-classes and shows cyclical variations (Figure 9). Although the relative number of older fish 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 (Figure 11), the last six years of data suggest that male fish are living longer and female fish are maturing at older ages (Figure 9).

The most recent estimate of spawning stock biomass (SSB) for coastal females was approximately 55 million pounds in 2004, well above the SSB target of 38.6 million pounds and the threshold of 30.9 million pounds (ASMFC 2005). Coastal estimates for 2005 are not yet available. MD DNR estimates of female spawning stock biomass generated from the Upper Bay remain high in 2006 and fluctuate with no trend (Table 16, Figure 12). Potomac River female SSB continues to vary without trend, although the 2006 value (462) was above average.

CITATIONS

ASMFC 2005. Atlantic States Marine Fisheries Commission Striped Bass Technical Committee. 2005 Stock Assessment Report for Atlantic Striped Bass: Catch –at-Age Based VPA and Tag Release\Recovery Based Survival Estimation. November 2006.

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

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

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

Helser, T. E., Geaghan, J. P. and Condrey, R. E. 1998. Estimating gill net selectivity using nonlinear response surface regression. Can. J. Fish. Aquat. Sci. 55. 1328-1337.

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

Richards, R. A. and Rago, P. J. 1999. A case history of effective fishery management: Chesapeake Bay striped bass. N. Am. J. Fish. Man. 19:356-375.

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

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Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area, late March through May 2006. 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.

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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 2006. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift gill net. Note different scales.

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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, 1985-2006 (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. *

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Table 1. Number of scales aged per sex, area, and survey, by length group (mm TL), in 2006.

Length Group (mm)	Males					Females				
	Upper Bay	Potomac	Creel	Patuxent	Total	Upper Bay	Potomac	Creel	Patuxent	Total
270	0	1	0	0	**1**	0	0	0	0	**0**
290	3	2	0	0	**5**	0	0	0	0	**0**
310	3	3	0	0	**6**	0	0	0	0	**0**
330	3	2	0	0	**5**	0	0	0	0	**0**
350	2	5	0	0	**7**	0	0	0	0	**0**
370	3	3	0	0	**6**	0	0	0	0	**0**
390	4	3	0	0	**7**	0	0	0	0	**0**
410	2	3	0	0	**5**	0	0	0	0	**0**
430	3	2	0	0	**5**	0	0	1	0	**0**
450	2	4	0	0	**6**	0	0	2	0	**2**
470	2	3	0	0	**5**	0	0	6	0	**6**
490	2	4	0	0	**6**	0	0	7	0	**7**
510	3	2	0	0	**5**	0	0	3	0	**3**
530	4	4	0	0	**8**	1	0	5	0	**6**
550	2	2	0	0	**4**	0	0	4	0	**4**
570	5	4	0	0	**9**	0	0	3	0	**3**
590	5	4	0	0	**9**	0	0	2	0	**2**
610	5	3	1	0	**9**	1	0	3	0	**4**
630	5	4	1	0	**10**	0	0	1	0	**1**
650	5	6	0	0	**11**	0	0	0	0	**0**
670	5	3	1	0	**9**	0	0	1	0	**1**
690	5	5	2	0	**12**	1	0	0	0	**1**
710	4	2	6	0	**12**	0	0	1	0	**1**
730	6	3	2	0	**11**	0	0	1	0	**1**
750	6	4	4	0	**14**	0	0	0	0	**0**
770	4	4	3	0	**11**	0	0	1	0	**1**
790	4	6	4	0	**14**	0	0	1	0	**1**
810	5	5	2	0	**12**	0	1	2	0	**3**
830	4	6	6	0	**16**	2	5	3	0	**10**
850	5	4	5	0	**14**	4	4	1	0	**9**
870	5	6	6	0	**17**	4	5	2	0	**11**
890	4	0	7	0	**11**	7	8	0	0	**15**
910	4	3	6	0	**13**	0	7	5	0	**12**
930	3	2	5	0	**10**	4	8	1	0	**13**
950	1	0	3	0	**4**	9	7	0	0	**16**
970	2	1	0	0	**3**	10	7	0	0	**17**
990	1	1	1	0	**3**	5	6	1	0	**12**
1010	0	0	3	0	**3**	1	3	3	2	**9**
1030	0	0	2	0	**2**	2	5	2	0	**9**
1050	0	0	3	0	**3**	2	6	3	2	**13**
1070	0	0	3	0	**3**	2	1	3	1	**7**
1090	0	0	2	0	**2**	2	2	2	1	**7**
1110	0	0	3	0	**3**	1	1	3	2	**7**
1130	0	0	1	0	**1**	2	2	1	0	**5**
1150	0	0	4	0	**4**	0	0	4	1	**5**
1170	0	0	0	0	**0**	1	1	0	0	**2**
1190	0	0	1	0	**1**	0	0	1	0	**1**
1210	0	0	0	0	**0**	0	0	0	0	**0**
1230	0	0	0	0	**0**	0	0	0	0	**0**
1250	0	0	1	0	**1**	0	0	1	0	**1**
Total	**131**	**119**	**88**	**0**	**338**	**61**	**79**	**80**	**9**	**228**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985 - 2006 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**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985 - 2006 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**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985 - 2006 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**

Table 5. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985 - 2006 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**

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	**11.6**
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	**18.2**
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	**37.5**
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	**42.8**
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	**115.1**
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	**114.1**
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	**138.1**
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	**113.4**
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	**117.3**
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	**72.5**
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	**214.1**

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 – 2006) 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**

Table 9. Lower confidence limits (95%) of the pooled, weighted, annual age-specific CPUEs (1985 – 2006) 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	*

* 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 – 2006) 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	*

* 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 – 2006) 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	*

* 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 2006. 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 Potomac	Females Upper Bay	Males Potomac	Males Upper Bay
2005	1	**0.0**	0.0	0.0	0.0	0.0	0.0
2004	2	**17.5**	19.5	0.0	0.0	8.6	8.9
2003	3	**484.9**	14.0	0.0	0.0	139.8	345.1
2002	4	**75.9**	18.1	0.0	0.0	23.4	52.6
2001	5	**93.2**	18.3	0.0	3.2	36.3	53.7
2000	6	**55.0**	4.6	0.0	5.3	15.4	34.4
1999	7	**26.9**	4.9	0.2	3.2	6.5	17.0
1998	8	**23.7**	4.1	0.8	0.3	7.0	15.6
1997	9	**35.5**	5.2	6.3	4.3	8.3	16.7
1996	10	**41.9**	3.9	9.3	5.9	9.3	17.4
1995	11	**26.2**	3.4	4.2	3.5	7.5	11.0
1994	12	**21.2**	2.3	5.2	4.9	4.8	6.3
1993	13	**18.3**	0.6	9.6	6.8	0.6	1.3
1992	14	**5.9**	0.2	2.3	2.3	0.4	1.0
≤1991	15+	**13.1**	0.8	6.5	6.6	0.0	0.0
Total		**939.2**		**44.4**	**46.2**	**267.7**	**580.9**
% of Total				**4.7**	**4.9**	**28.5**	**61.8**
% of Sex				**49.0**	**51.0**	**31.5**	**68.5**
% of Potomac				**14.2**		**85.8**	
% of Upper Bay					**7.4**		**92.6**

Table 13. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area, late March through May 2006.* 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
2005	1	**0.0**	0.0	0.0		0.0	
2004	2	**8.8**	1.7	0.0	0.0	3.3	5.5
2003	3	**266.0**	52.6	0.0	0.0	53.9	212.1
2002	4	**41.3**	8.2	0.0	0.0	9.0	32.3
2001	5	**49.0**	9.7	0.0	2.0	14.0	33.0
2000	6	**30.3**	6.0	0.0	3.2	5.9	21.1
1999	7	**15.0**	3.0	0.1	2.0	2.5	10.4
1998	8	**12.8**	2.5	0.3	0.2	2.7	9.6
1997	9	**18.5**	3.7	2.4	2.6	3.2	10.2
1996	10	**21.5**	4.3	3.6	3.6	3.6	10.7
1995	11	**13.4**	2.7	1.6	2.1	2.9	6.8
1994	12	**10.7**	2.1	2.0	3.0	1.8	3.9
1993	13	**8.9**	1.8	3.7	4.2	0.2	0.8
1992	14	**3.0**	0.6	0.9	1.4	0.1	0.6
≤1991	15+	**6.6**	1.3	2.5	4.0	0.0	
Total		**505.7**		**17.1**	**28.4**	**103.2**	**357.0**
% of Total				**3.4**	**5.6**	**20.4**	**70.6**
% of Sex				**37.6**	**62.4**	**22.4**	**77.6**
% of Potomac				**14.2**		**85.8**	
% of Upper Bay					**7.4**		**92.6**

* 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 2006.

AGE	AREA	N	MEAN	LOWER CI (95%)	UPPER CI (95%)	SD	SE
2	POTOMAC	2	295.5	73.1	517.9	24.7	17.5
	UPPER	0	-	-	-	-	-
	COMBINED	2	295.5	73.1	517.9	24.7	17.5
3	POTOMAC	24	374.4	353.3	395.4	49.9	10.2
	UPPER	23	370.1	346.4	393.8	54.8	11.4
	COMBINED	47	372.3	357.1	387.5	51.8	7.6
4	POTOMAC	6	476.3	426.6	526.1	47.4	19.4
	UPPER	4	403.3	289.1	517.4	71.8	35.9
	COMBINED	10	447.1	399.7	494.5	66.3	21.0
5	POTOMAC	16	539.7	514.3	565.0	47.6	11.9
	UPPER	7	537.9	491.8	584.0	49.9	18.8
	COMBINED	23	539.1	518.8	559.5	47.1	9.8
6	POTOMAC	9	665.6	616.7	714.5	63.6	21.2
	UPPER	23	611.5	580.1	643.0	72.7	15.2
	COMBINED	32	626.7	600.2	653.2	73.5	13.0
7	POTOMAC	10	701.7	632.4	771.0	96.9	30.6
	UPPER	15	682.2	636.8	727.7	82.1	21.2
	COMBINED	25	690.0	654.2	725.9	86.9	17.4
8	POTOMAC	20	754.6	707.9	801.3	99.7	22.3
	UPPER	13	762.7	708.0	817.4	90.6	25.1
	COMBINED	33	757.8	724.2	791.4	94.9	16.5
9	POTOMAC	16	788.6	746.7	830.4	78.5	19.6
	UPPER	16	807.7	752.4	863.0	103.7	25.9
	COMBINED	32	798.1	765.3	830.9	91.0	16.1
10	POTOMAC	11	805.0	735.5	874.5	103.5	31.2
	UPPER	17	793.5	747.4	839.6	89.6	21.7
	COMBINED	28	798.0	761.7	834.3	93.6	17.7
11	POTOMAC	3	870.7	601.9	1139.4	108.2	62.5
	UPPER	7	849.6	755.0	944.2	102.3	38.7
	COMBINED	10	855.9	785.5	926.3	98.4	31.1
12	POTOMAC	2	934.5	242.0	1627.0	77.1	54.5
	UPPER	5	891.6	786.0	997.2	85.1	38.0
	COMBINED	7	903.9	830.7	977.0	79.1	29.9
13	POTOMAC	0	-	-	-	-	-
	UPPER	0	-	-	-	-	-
	COMBINED	0	-	-	-	-	-
14	POTOMAC	1	814.0	.	.	.	.
	UPPER	0	-	-	-	-	-
	COMBINED	1	814.0	-	-	-	-

Table 15. Mean length-at-age (mm TL) statistics for female striped bass collected in the Potomac River and the Upper Bay, as well as all females combined, late March through May 2006.

AGE	AREA	N	MEAN	LOWER CI (95%)	UPPER CI (95%)	SD	SE
5	POTOMAC	0	-	-	-	-	-
	UPPER	2	568.5	*	*	*	*
	COMBINED	2	568.5	*	*	*	*
6	POTOMAC	1	699.0	-	-	-	-
	UPPER	0	-	-	-	-	-
	COMBINED	1	699.0				
7	POTOMAC	0	-	-	-	-	-
	UPPER	0	-	-	-	-	-
	COMBINED	0	-	-	-	-	-
8	POTOMAC	2	857.5	508.1	1206.9	38.9	27.5
	UPPER	0	-	-	-	-	-
	COMBINED	2	857.5	508.1	1206.9	38.9	27.5
9	POTOMAC	21	886.6	865.4	907.8	46.6	10.2
	UPPER	9	905.2	864.8	945.6	52.6	17.5
	COMBINED	30	892.2	874.1	910.2	48.3	8.8
10	POTOMAC	21	949.0	919.4	978.7	65.1	14.2
	UPPER	16	915.1	888.5	941.8	50.1	12.5
	COMBINED	37	934.4	914.1	954.6	60.8	10.0
11	POTOMAC	10	937.8	918.9	956.8	26.5	8.4
	UPPER	11	931.4	897.2	965.5	50.8	15.3
	COMBINED	21	934.4	916.1	952.8	40.2	8.8
12	POTOMAC	11	976.9	936.5	1017.3	60.1	18.1
	UPPER	10	997.5	958.6	1036.5	54.5	17.2
	COMBINED	21	986.7	960.8	1012.7	57.0	12.4
13	POTOMAC	9	1038.7	1008.4	1068.9	39.3	13.1
	UPPER	6	1029.0	974.2	1083.8	52.2	21.3
	COMBINED	15	1034.8	1010.8	1058.8	43.4	11.2
14	POTOMAC	1	1086.0	-	-	-	-
	UPPER	2	1062.5	243.0	1882.1	91.2	64.5
	COMBINED	3	1070.3	906.6	1234.1	65.9	38.1
15	POTOMAC	1	1092.0	-	-	-	-
	UPPER	2	1111.5	393.6	1829.4	79.9	56.5
	COMBINED	3	1105.0	961.9	1248.1	57.6	33.3
16	POTOMAC	3	1144.0	1073.0	1215.0	28.6	16.5
	UPPER	2	1121.5	962.7	1280.3	17.7	12.5
	COMBINED	5	1135.0	1103.6	1166.4	25.3	11.3

*Due to low sample sizes, the confidence intervals exceeded known biological limits.

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

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

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, late March - May 2006.

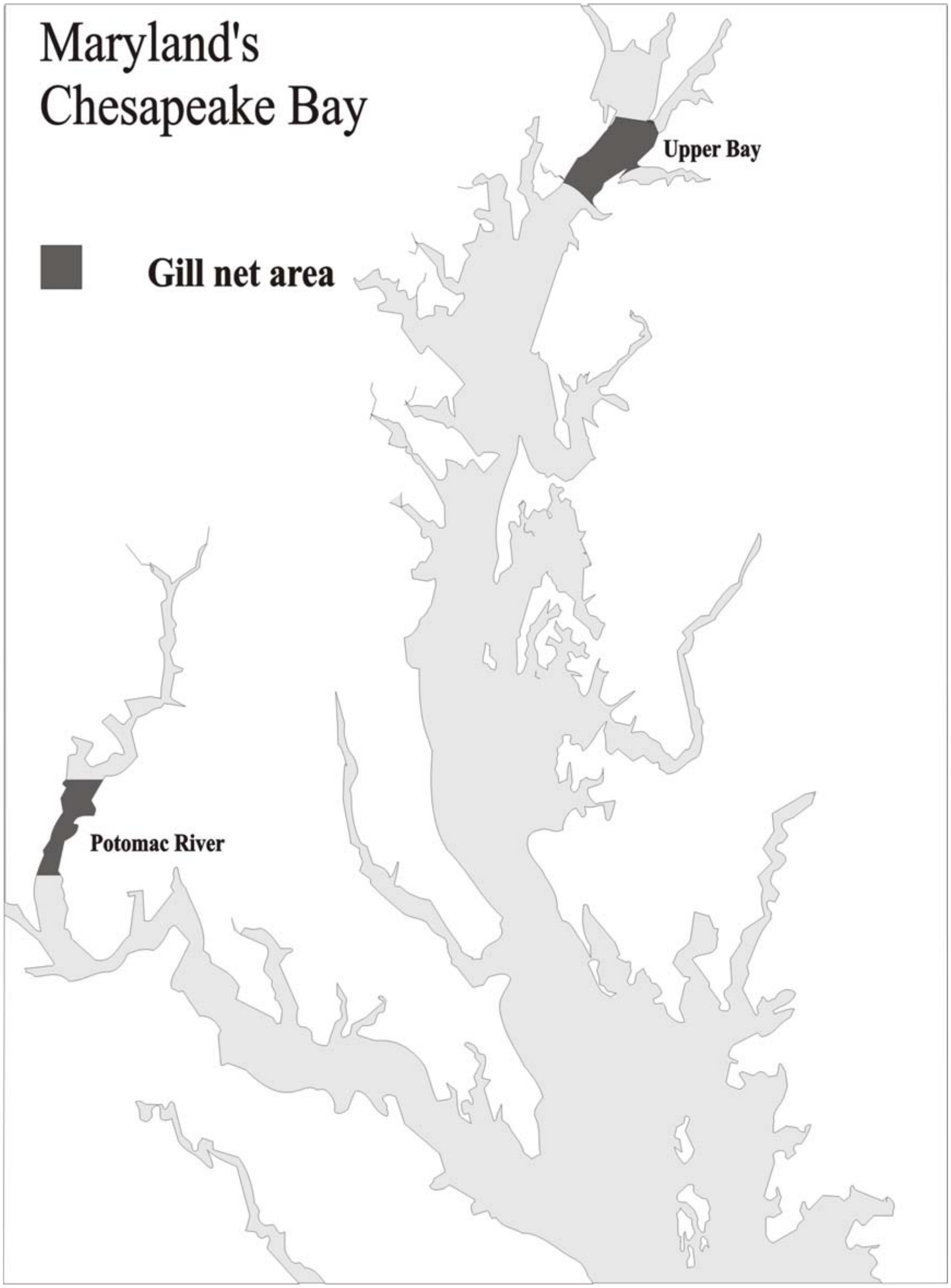


Figure 2. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Potomac River, late March through May 2006. Effort is standardized as 1000 square yards of experimental gill net per hour. Note different scales.

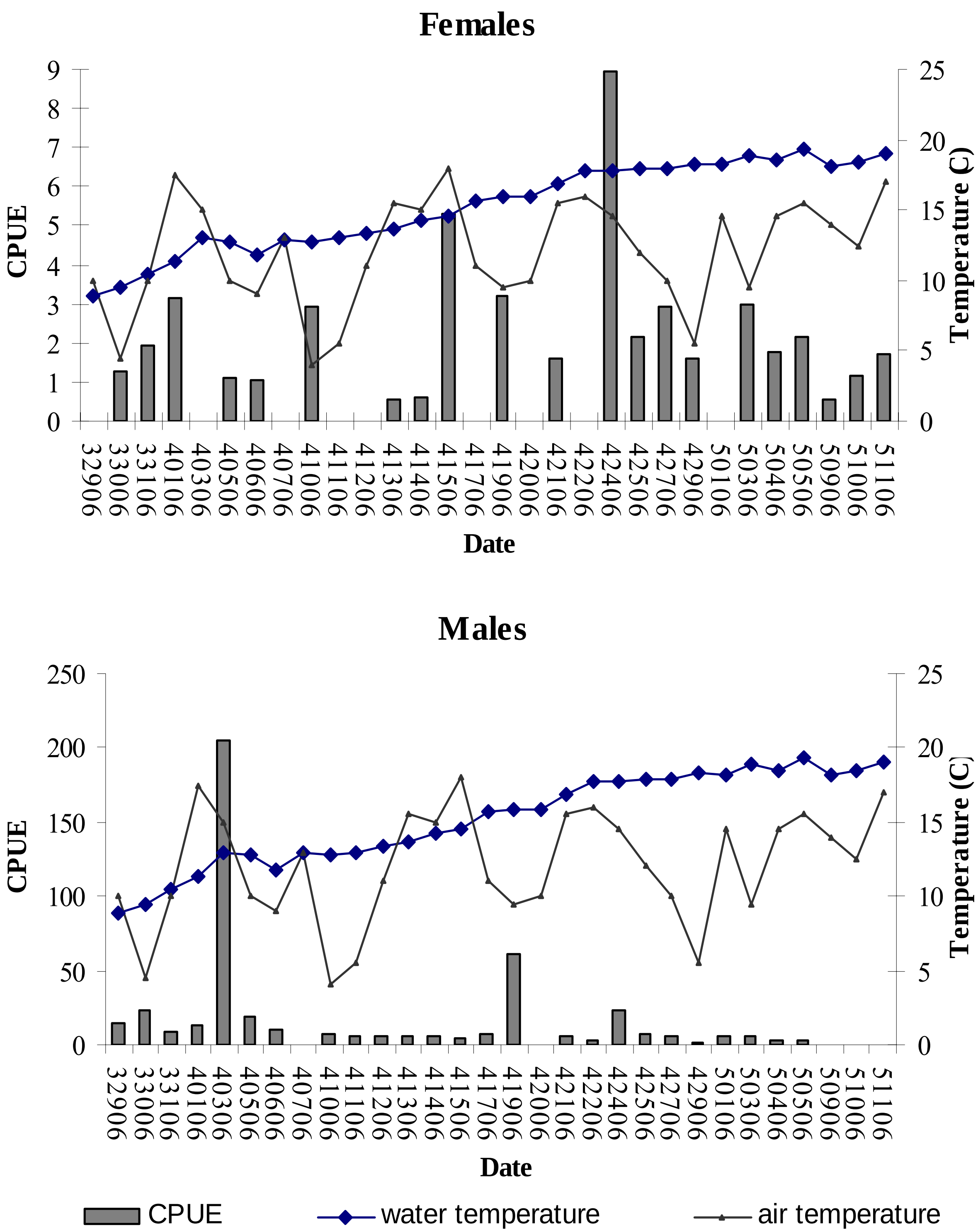
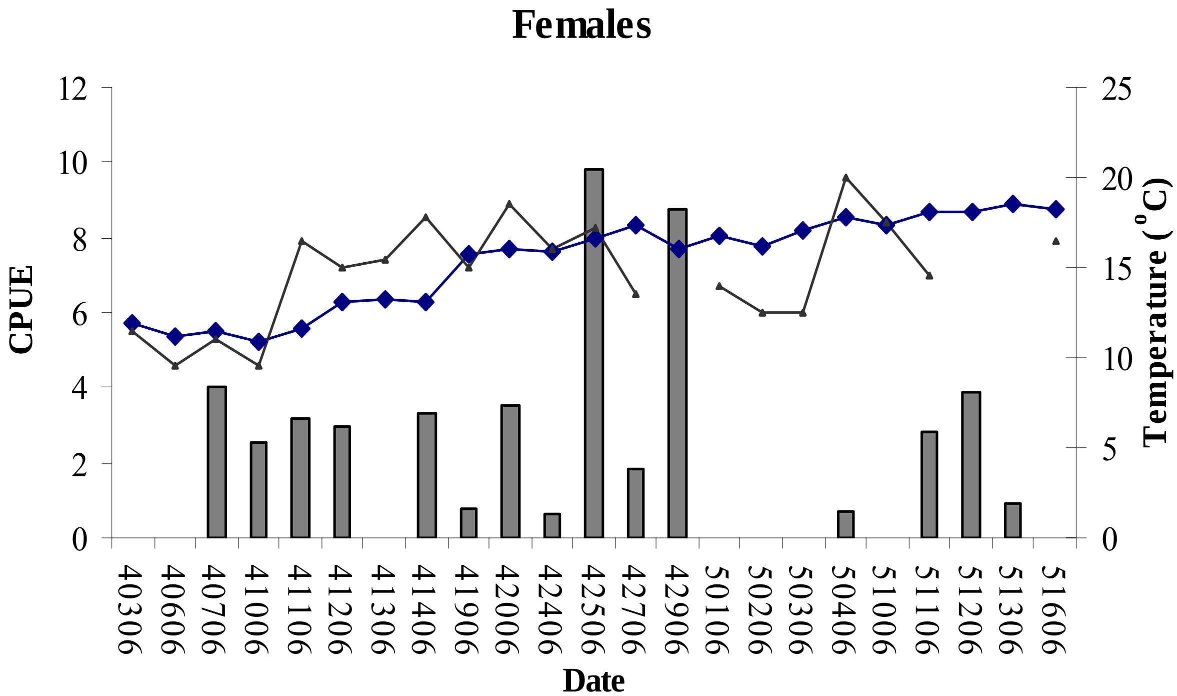


Figure 3. Daily effort-corrected catch of female and male striped bass, with surface water and air temperatures in the spawning reach of the Upper Chesapeake Bay, April through May 2006. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.



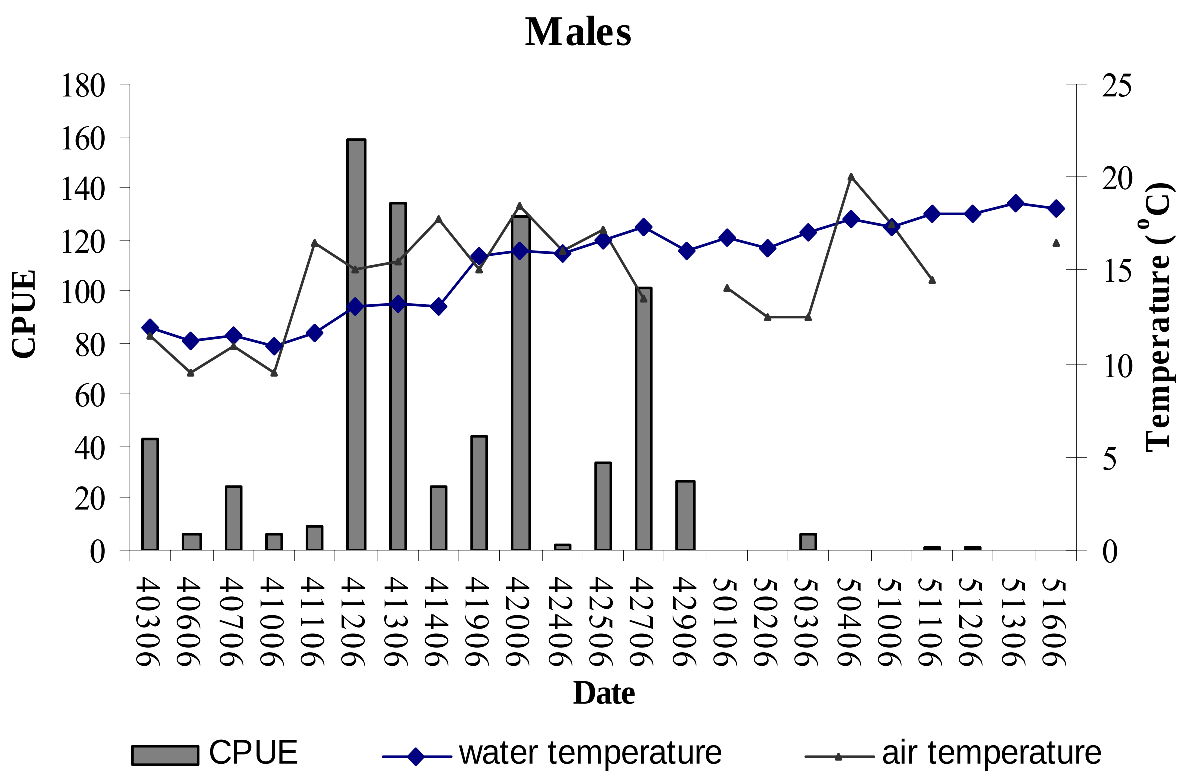
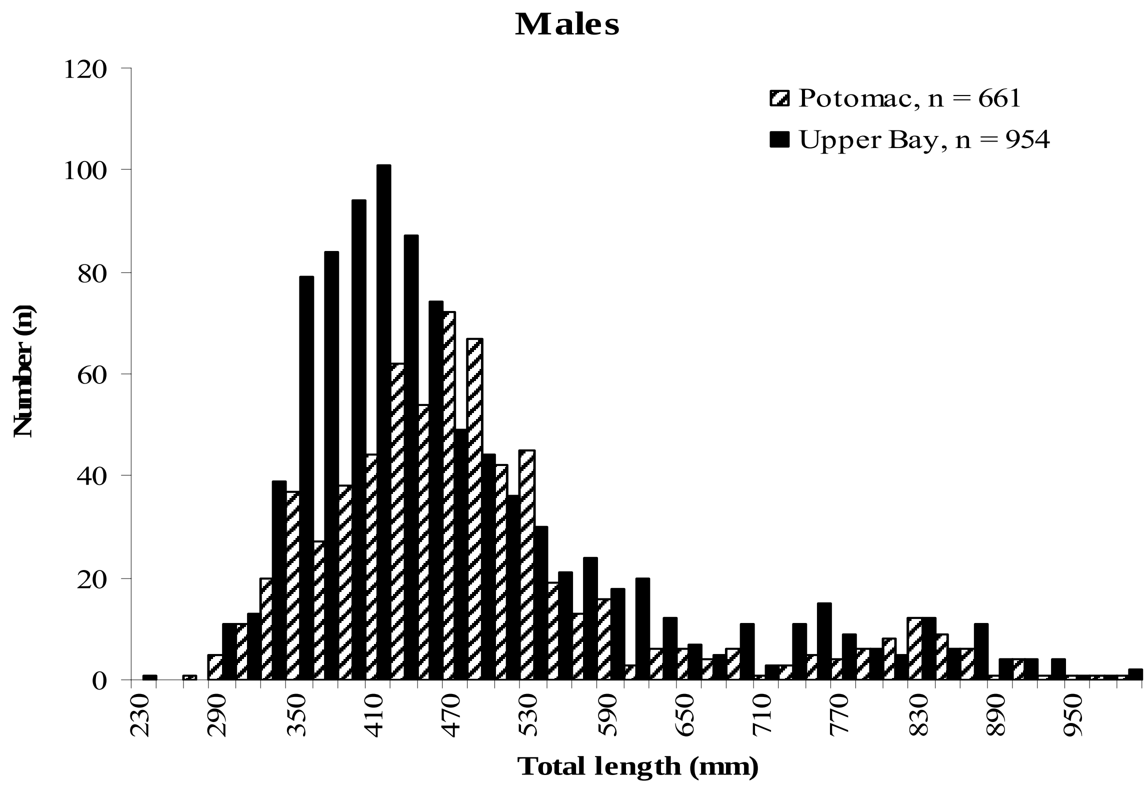


Figure 4. Length frequency of male and female striped bass from the spawning areas of the Upper Chesapeake Bay and Potomac River, March through May 2006.



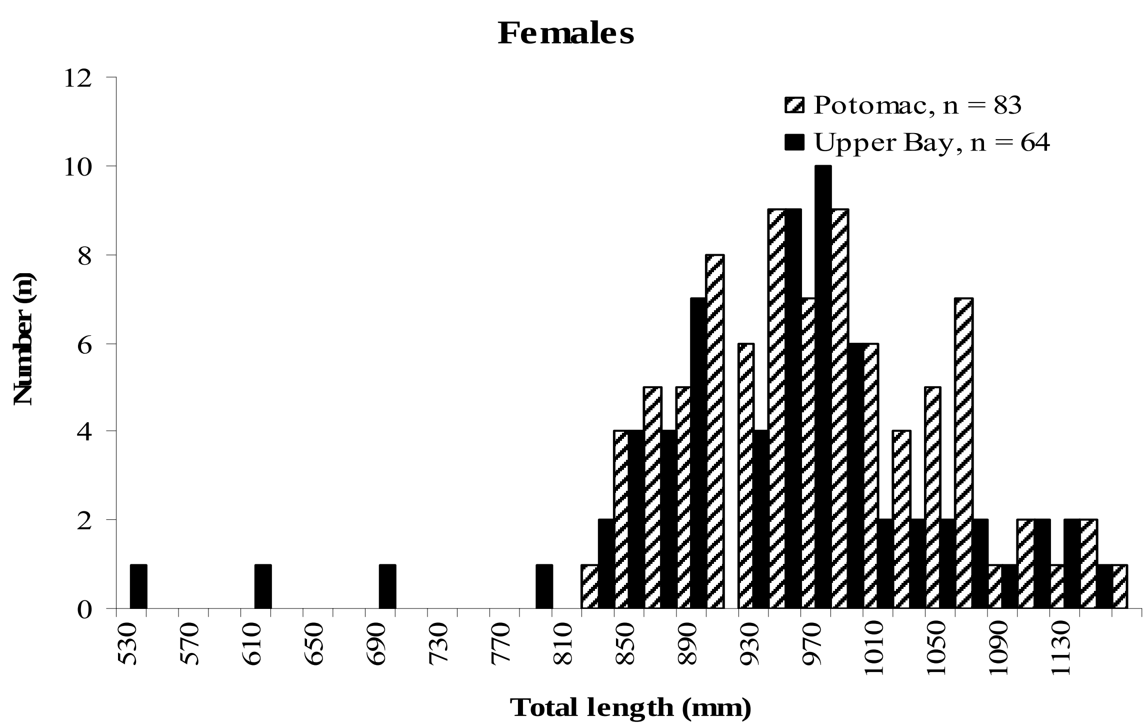
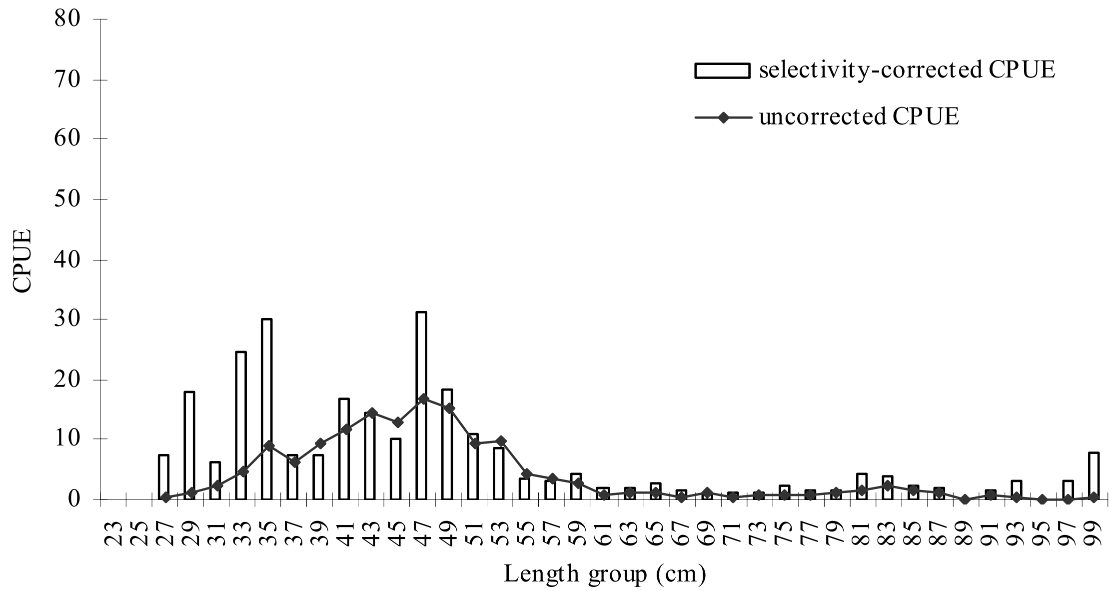


Figure 5. Length group CPUE (uncorrected and corrected for gear selectivity) of male striped bass collected from spawning areas of the Upper Bay and Potomac River, late March - May 2006. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net. Note different scale.

Potomac River



Upper Bay

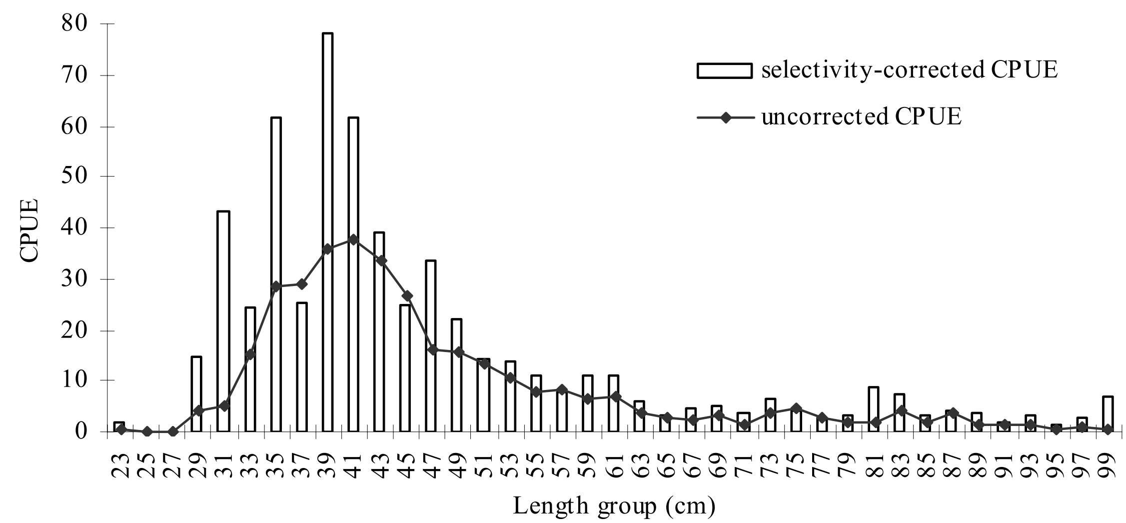
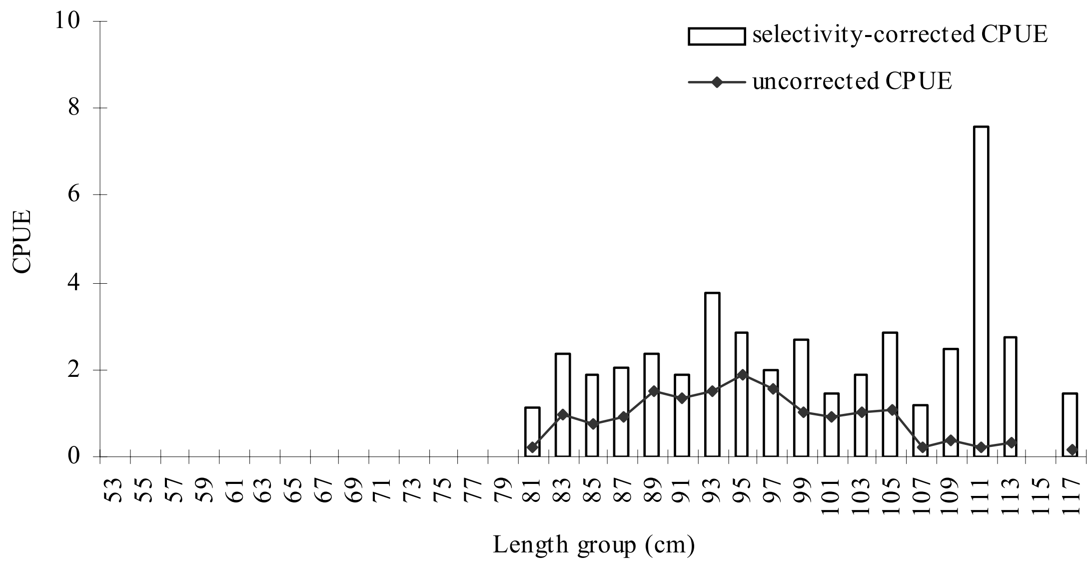


Figure 6. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, late March - May 2006. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.

Potomac River



Upper Bay

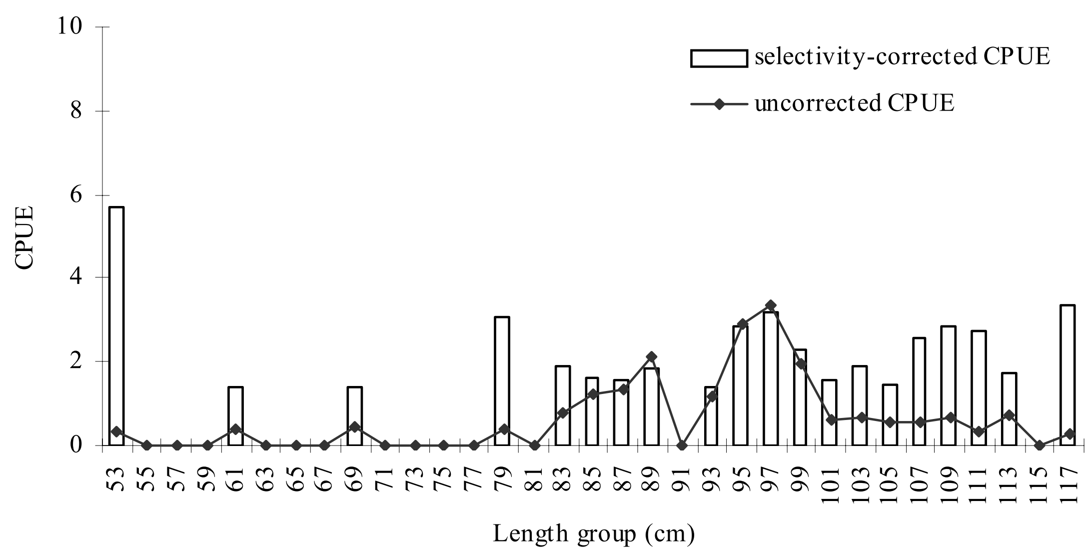


Figure 7. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Upper Chesapeake Bay in April and May, 1985-2006. Error bars are 95% confidence intervals.

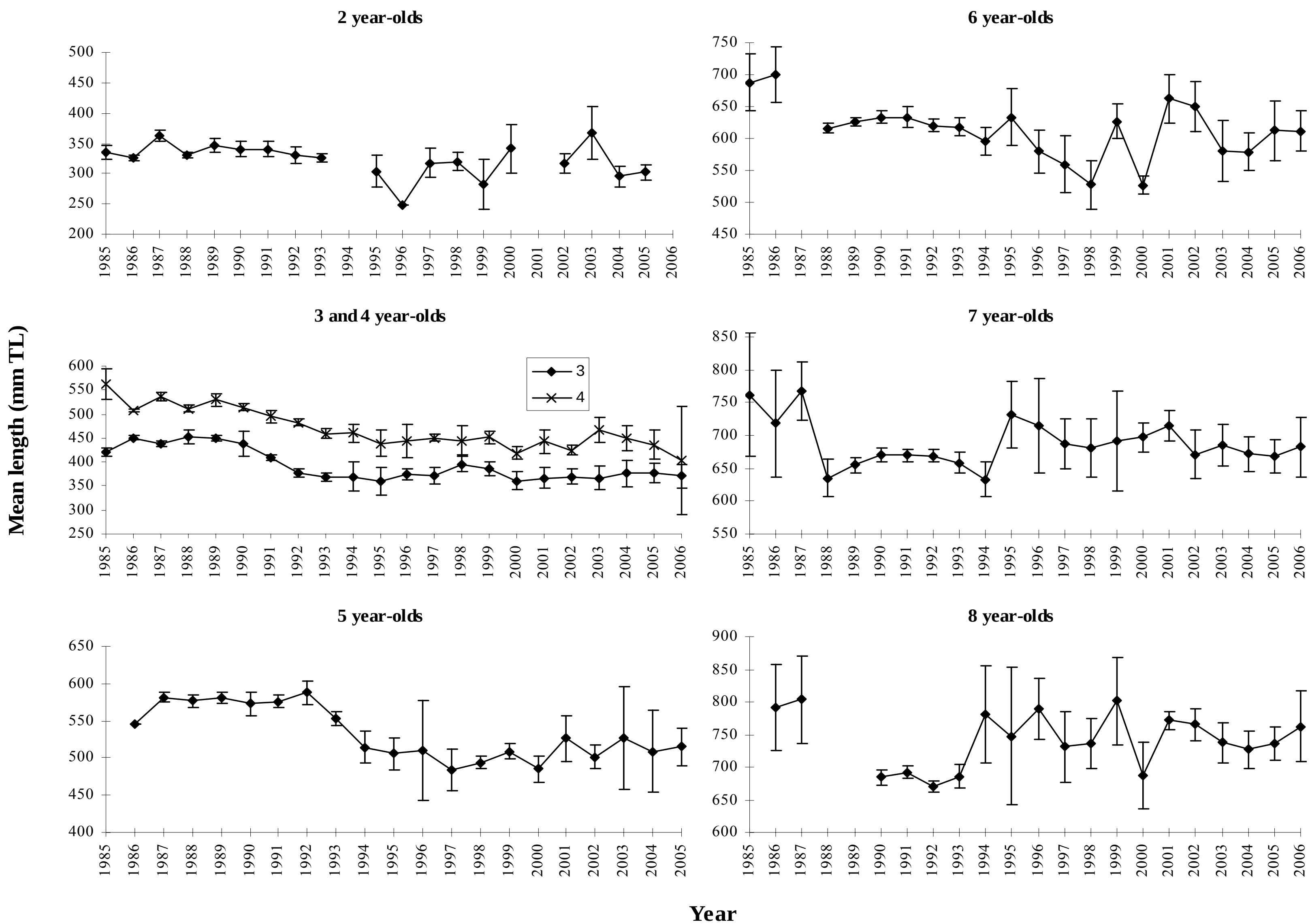


Figure 8. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River during late March through May, 1985-2006. Error bars are 95% confidence intervals. Note the Potomac River was not sampled in 1994.

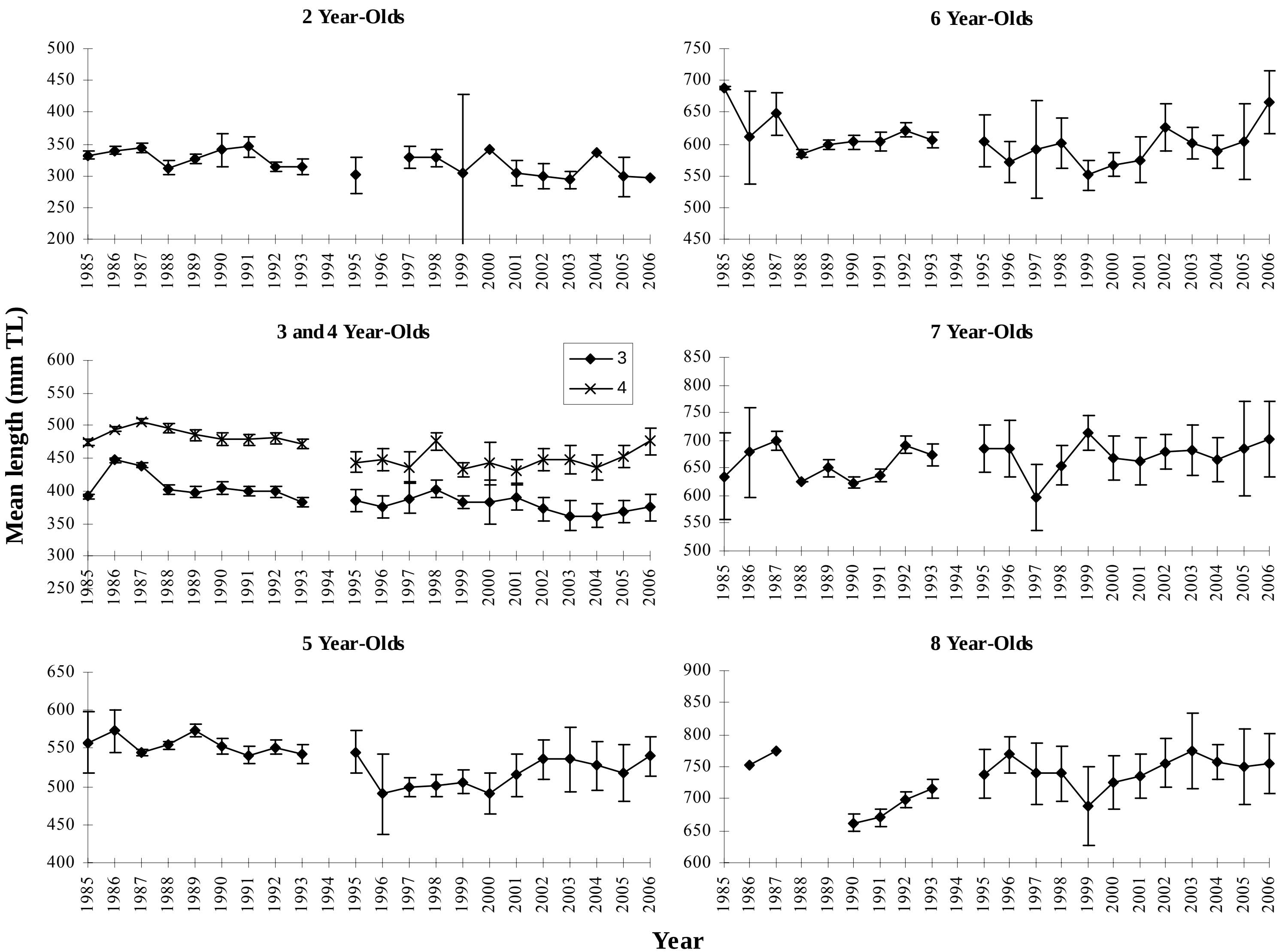


Figure 9. Maryland Chesapeake Bay spawning stock indices used in the 2006 coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

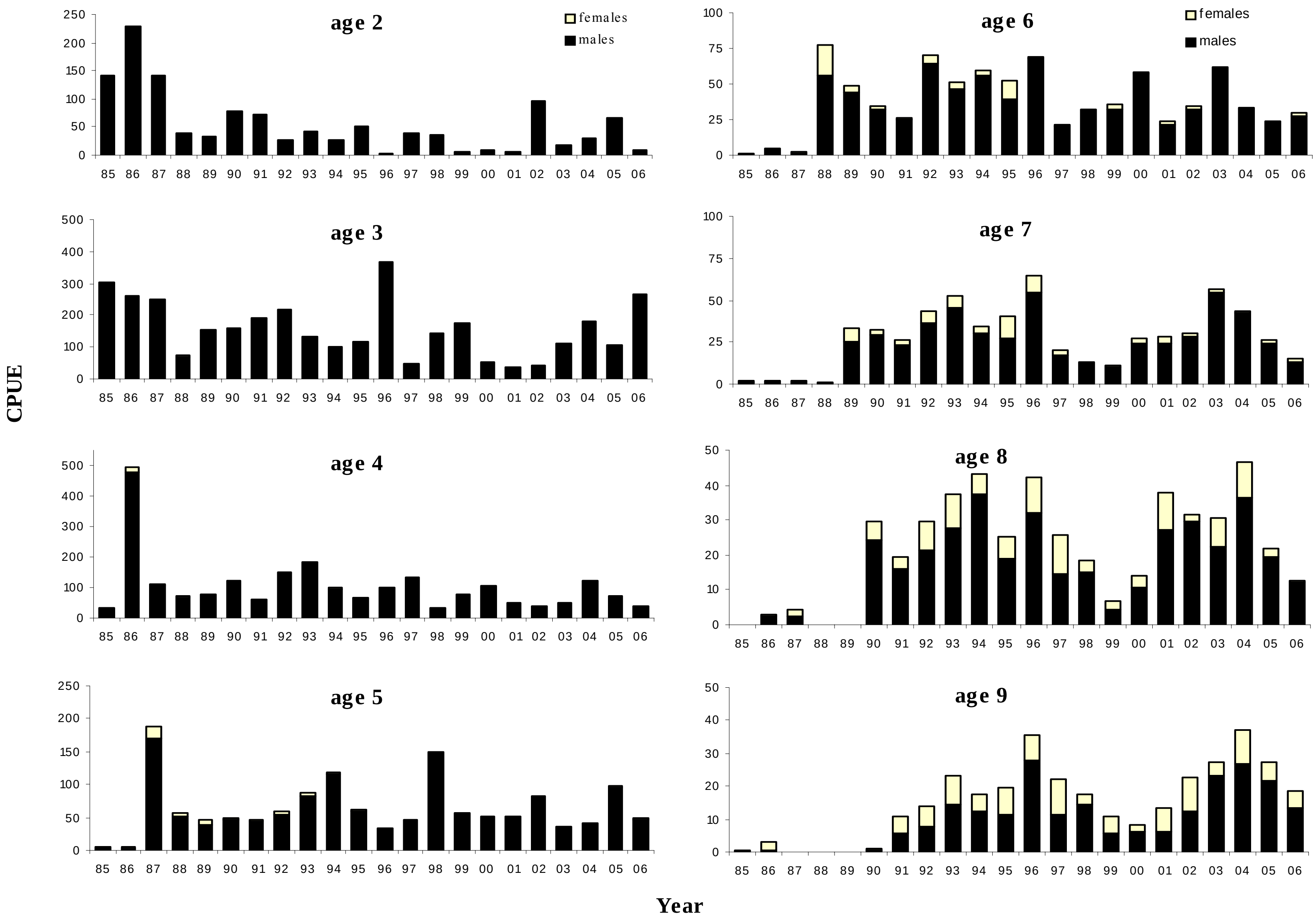


Figure 9. Continued.

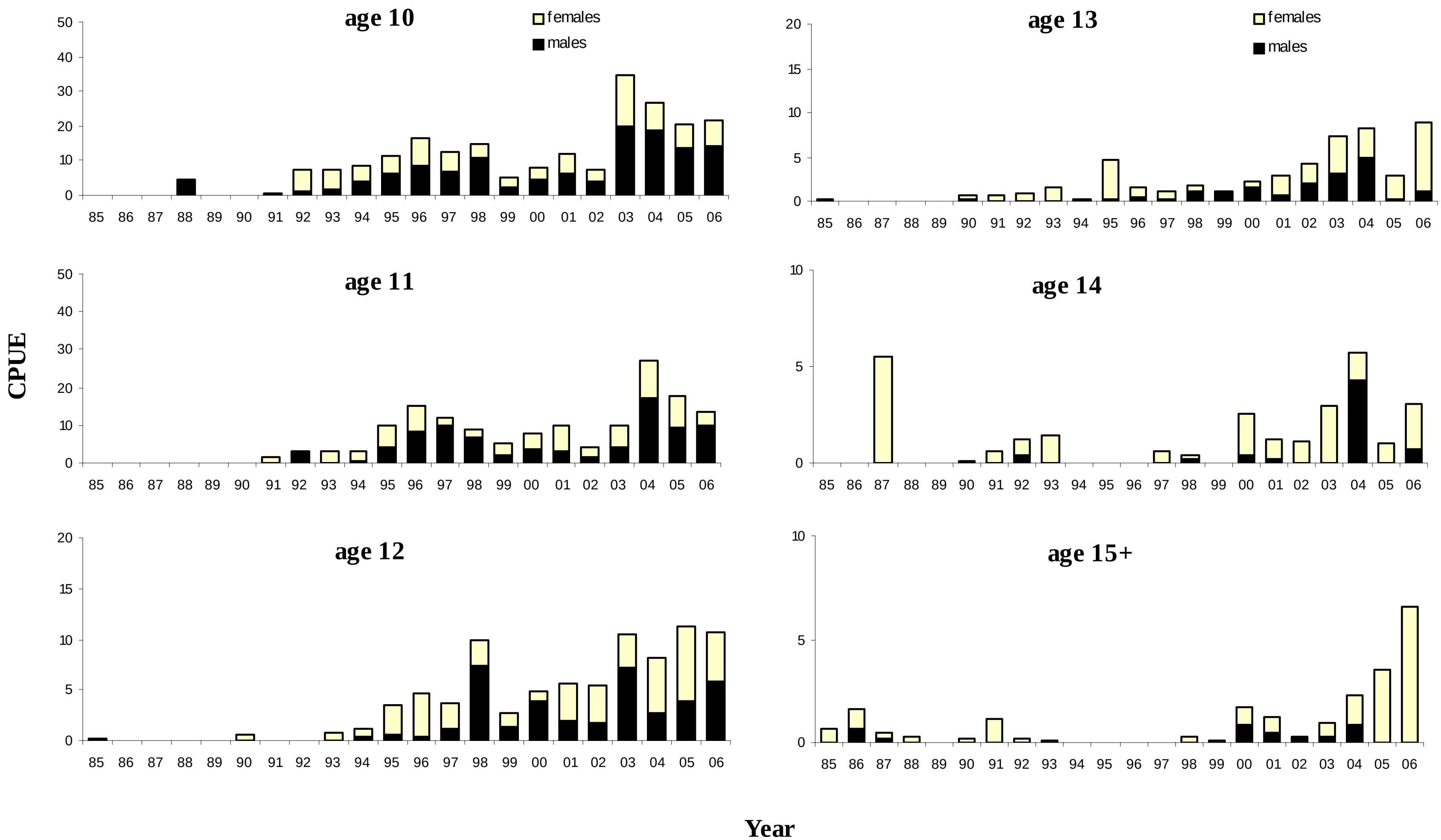
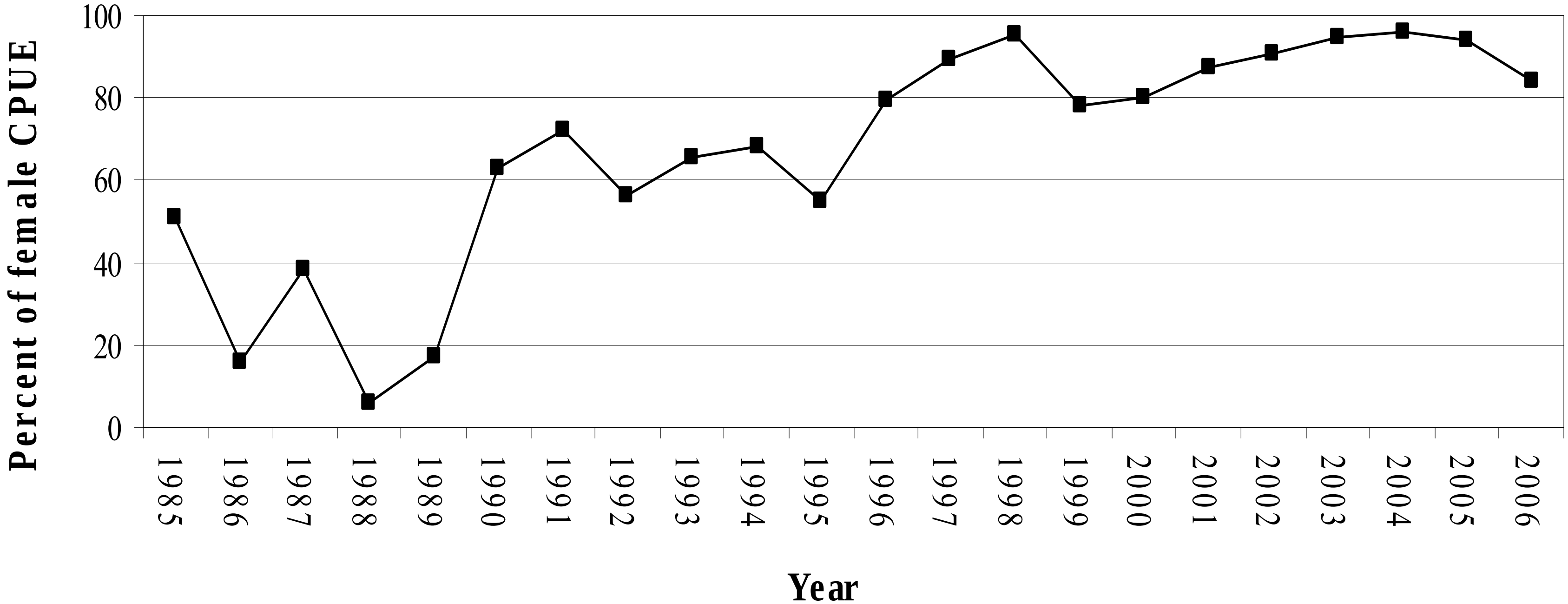
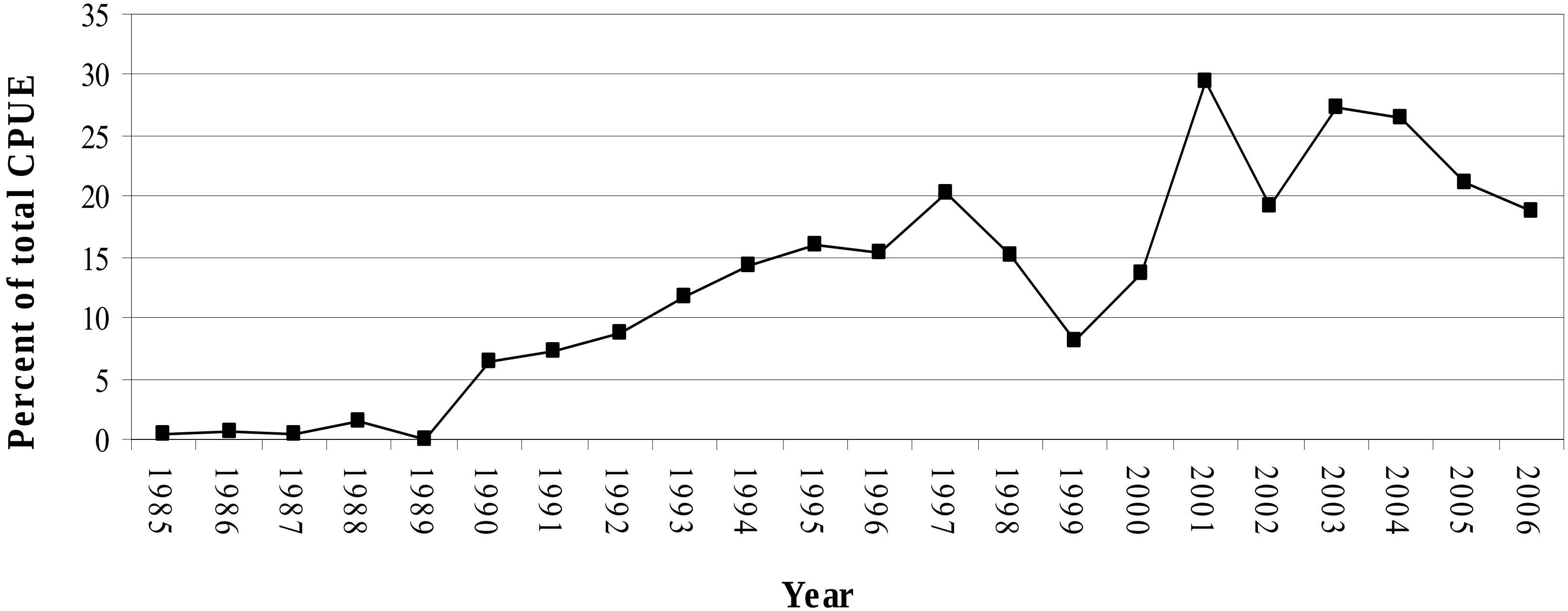


Figure 10. Percentage (selectivity-corrected CPUE) of female striped bass that were age 8 and over sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, late March through May, 1985-2006 (Choptank River to 1996). Effort is 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.*



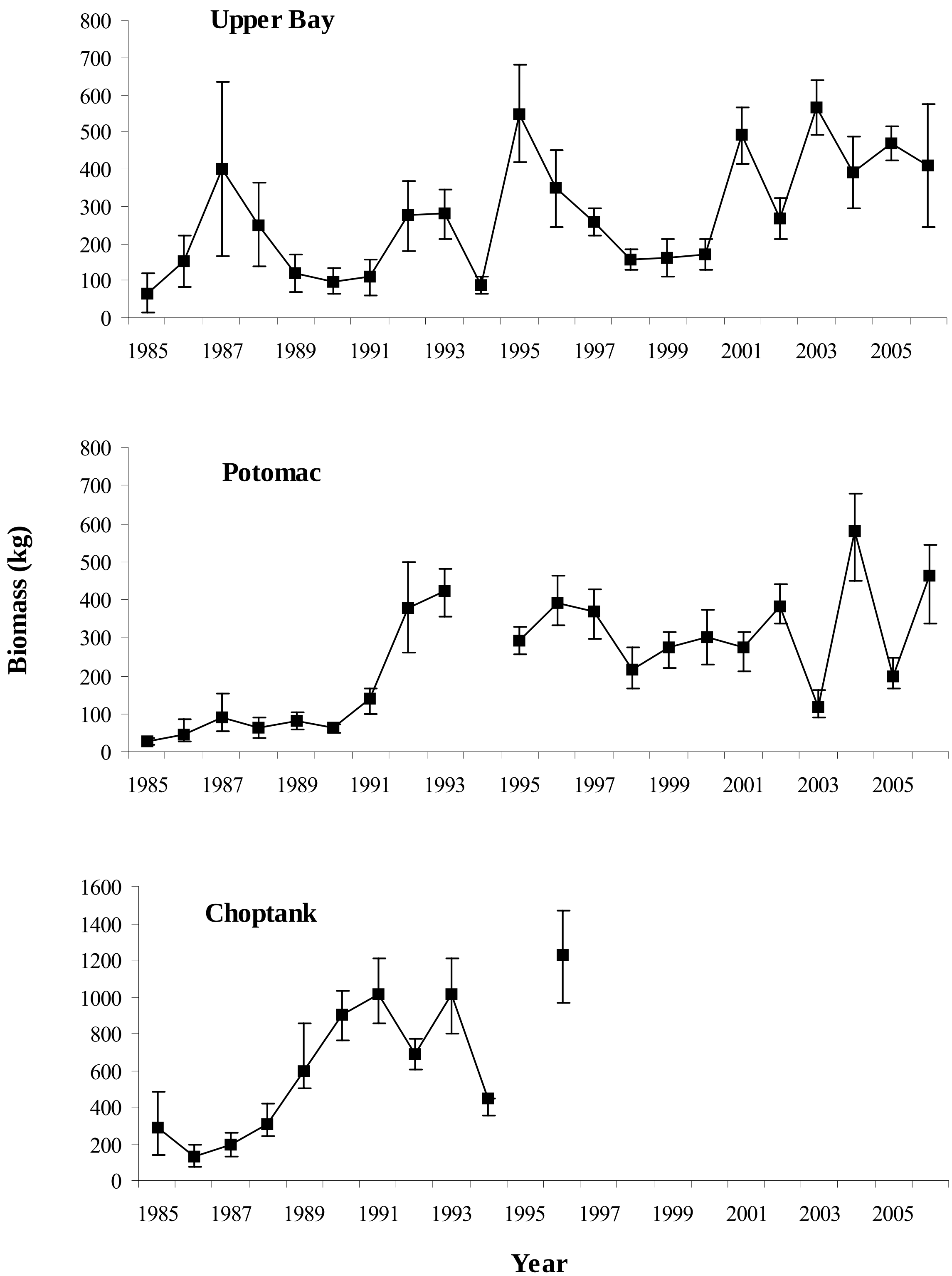
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59 Potomac River=0.37 Choptank River=0.04
(1997 - Present): Upper Bay=0.615 Potomac River=0.385 (Hollis 1967)

Figure 11. Percentage (selectivity-corrected CPUE) of male and female striped bass age 8 and over sampled from experimental drift gill net sets in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, late March through May, 1985-2006 (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 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 are derived annually from sampling at 22 fixed stations within Maryland's portion of the Chesapeake Bay (Table 1, Figure 1). Sample sites are divided among four of the major spawning and nursery areas; seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank rivers. Stations have been sampled continuously since 1954, with changes in some station locations.

Sampling is 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 produces a total of 132 samples from which Bay-wide means are calculated.

From 1954 to 1961, juvenile surveys included various 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 are 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 $\pm$ 2 standard errors), and provide a visual depiction of sample variability.

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

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

Bay-wide annual indices are compared to the *target period average* (TPA). The TPA is the average of indices from 1959 through 1972. These years have been suggested as a period of stable biomass and general stock health (ASMFC 1989) and "an appropriate stock rebuilding target" (Gibson 1993). The TPA provides a fixed reference representing an average index produced by a healthy population. This 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 561 juvenile striped bass were collected at permanent stations in 2006. Individual samples yielded between zero and 55 YOY striped bass. The AM of 4.3 was less than the time-series average (11.9) and the TPA (12.0) (Table 2, Figure 2). The GM of 1.78 (Table 3, Figure 3) was also less than the time-series average (4.32) and the TPA (4.32). The PPHL was 0.59, indicating that 59% 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 2006 $\log_e$-mean significantly smaller than 23 years of the time-series, and significantly greater than four years of the time-series. The 2006 $\log_e$-mean was not discernible from 22 years of the time-series.

System Means

Head of Bay - In 42 samples, 65 juveniles were collected at the Head of Bay sites, resulting in the AM of 1.6, less than the time-series average (12.1) and the TPA of 17.3 (Table 2, Figure 5). The GM of 0.95 was also less than the time-series average (5.76) 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 2006 Head of Bay year-class indiscernible from the 18 smallest year-classes of the time-series.

Potomac River - A total of 281 juveniles was collected in 42 samples. The AM of 6.7 was less than the TPA of 9.2 and the time-series average of 8.6 (Table 2, Figure 5). The GM of 2.42 was also less than the time-series average (3.70) 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 2006 significantly greater than 10 years, and significantly less than 10 years of the time-series. The 2006 $\log_e$-mean was not significantly different than the 29 other years of the time-series.

Choptank River - A total of 139 juveniles was collected in 24 Choptank River samples. The AM of 5.8 was approximately one-fourth the time-series average of 20.7 and half the TPA of 10.8 (Table 2, Figure 5). The GM of 2.81 was also less than the time-series average (8.22) and the 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 2006 year-class smaller than 13 years, and not significantly different than 31 years of the time-series. The 2006 year-class was significantly larger than only five other years of the time-series.

Nanticoke River - A total of 76 juveniles was collected in 24 samples on the Nanticoke River. The AM was 3.2, considerably less than the time-series average of 8.3 and the TPA of 8.6 (Table 2, Figure 5). The GM of 1.65 was also less than the time-series average of 3.68 and the TPA of 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 2006 significantly smaller than 11 years of the time-series. The 2006 index was statistically indiscernible from the remaining 38 years of the time-series.

Auxiliary Indices

At the **Head of Bay auxiliary sites**, 10 juveniles were caught in 15 samples, producing an AM of 0.67, considerably lower than the time-series average of 5.89. The GM of 0.31 was also lower than its time-series average of 2.79 (Table 5).

On the **Patuxent River**, 18 samples yielded 18 juveniles for an AM of 1.0 and a GM of

0.66 (Table 5). Both indices were lower than their respective 24-year averages.

DISCUSSION

Survey results indicated a below-average striped bass year-class in Maryland's Chesapeake Bay in 2006. The bay-wide AM and GM were both less than half their respective long-term averages and TPAs (Tables 2 and 3). Duncan's multiple range test found the 2006 bay-wide Log Mean significantly greater than just the four smallest year-classes measured by the survey (1981, 1959, 1983, 1988). Agreement among indices creates more certainty that they represent actual changes in YOY striped bass abundance. This year's results were comparable to those of 2002, when biologists observed similar drought conditions during the spring spawning period. Relative abundance indices for several other anadromous species were also depressed in both years (http://www.dnr.state.md.us/fisheries/juvindex/index.html), lending credence to the theory that large-scale environmental factors like low flow conditions may be responsible for low recruitment.

Juvenile striped bass were caught in only 59% of the 132 samples collected (PPHL=0.59). Sample size ranged from 0 to 55 resulting in very narrow confidence intervals around the AM and GM (Tables 2 and 3). These narrow confidence intervals are typical of measures of small year-classes.

Recruitment in individual spawning areas in 2006 was consistently low. Recruitment was poorest in the Head of Bay, where the AM and GM were both below the first quartile of their respective time-series. The Head of Bay produced the lowest PPHL of the four major spawning areas (0.55). The Choptank, Nanticoke, and Potomac rivers' GMs all fell below the median value of their time series. The Choptank River produced the highest PPHL of the four major spawning areas as 71% of samples collected there contained YOY striped bass.

Results in auxiliary systems support those from permanent survey sites. Head of Bay auxiliary sites, located primarily on the Susquehanna Flats, produced the fourth lowest AM and GM of the 24-year time-series. Patuxent River indices were the sixth lowest of the 24-year time series. Indices in both auxiliary systems were below the first quartile of the 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. This use, plus the utility of age 1 indices as a potential fishery independent verification of the YOY index, 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≤ 0.001)(Figure 10). The equation that best described this relationship was, C_1 =0.191481 x C_0 - 0.069744, 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 (0.25) was less than the predicted index of 0.32, as indicated by the negative residual (Figure 11). Examination of residuals (Figure 11) showed 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. However, estimates of future abundance of age 1 striped bass are less reliable for dominant year-classes. Lower than expected abundance of age 1 striped bass may be an indication of density-dependent processes operating at high levels of abundance, such as cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

CITATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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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

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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.

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
9	Sassafras River	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
1991	3.9	2.5	12.2	1.1	4.4

Table 2. Continued.

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1992	1.3	22.1	4.3	4.3	9.0
1993	23.0	36.4	105.5	9.3	39.8
1994	23.4	3.9	19.3	21.5	16.1
1995	4.4	8.7	17.7	10.4	9.3
1996	25.0	48.5	154.4	43.6	59.4
1997	8.3	10.6	7.3	3.5	8.0
1998	8.3	10.8	32.6	3.8	12.7
1999	3.1	15.7	48.2	18.7	18.1
2000	113.3	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
Average	12.1	8.6	20.7	8.3	11.9
TPA*	17.3	9.2	10.8	8.6	12.0

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

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

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1955	1.49	3.78	2.36	2.26	2.26
1956	6.88	4.50	6.22	5.29	5.29
1957	1.92	1.78	1.16	1.40	1.40
1958	22.07	3.93	11.01	11.12	11.12
1959	0.95	0.61	0.09	0.59	0.59
1960	3.18	2.44	4.31	3.01	3.01
1961	7.46	12.82	5.40	6.61	6.61
1962	3.73	6.70	3.14	4.25	4.25
1963	3.01	0.54	2.01	1.61	1.61
1964	15.41	9.15	4.92	9.04	9.04
1965	0.76	0.92	2.18	1.56	1.56
1966	15.89	4.95	5.52	6.24	6.24
1967	3.92	1.03	2.80	2.28	2.28
1968	6.13	0.39	3.85	2.69	2.69
1969	12.21	0.12	2.55	2.81	2.81
1970	13.71	10.97	25.41	12.48	12.48
1971	10.45	3.48	2.51	4.02	4.02
1972	4.95	0.96	5.36	3.26	3.26
1973	11.92	1.10	0.43	2.33	2.33
1974	6.79	0.66	3.55	2.62	2.62
1975	2.34	3.56	2.71	2.81	2.81
1976	2.70	1.46	0.89	1.58	1.58
1977	4.99	0.78	0.81	1.61	1.61
1978	6.51	3.33	2.65	3.75	3.75
1979	4.56	1.15	1.12	1.73	1.73
1980	1.43	1.04	0.58	1.01	1.01
1981	0.17	0.68	0.84	0.59	0.59
1982	2.98	3.50	5.68	3.54	3.54
1983	0.61	0.62	0.64	0.61	0.61
1984	2.23	1.42	2.13	0.81	1.64
1985	0.19	1.45	1.78	0.94	0.91
1986	0.90	3.09	0.32	1.24	1.34
1987	0.16	3.01	3.06	1.36	1.46
1988	2.25	0.22	0.40	0.28	0.73
1989	8.54	1.15	28.10	1.94	4.87
1990	2.20	0.38	1.34	0.56	1.03
1991	1.99	0.84	4.42	0.52	1.52

Table 3. Continued.

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
1992	0.87	6.00	2.07	1.72	2.34
1993	15.00	15.96	27.87	4.56	13.97
1994	12.88	2.01	7.71	9.06	6.40
1995	2.85	4.47	9.96	3.76	4.41
1996	14.92	13.45	33.29	18.80	17.46
1997	6.15	3.67	3.95	1.74	3.91
1998	4.32	4.42	21.10	2.74	5.50
1999	1.91	5.84	20.01	5.52	5.34
2000	8.84	3.52	12.53	10.86	7.42
2001	7.15	5.01	86.71	20.31	12.57
2002	1.35	3.95	0.38	4.89	2.20
2003	11.89	12.81	20.56	3.25	10.83
2004	4.17	2.36	9.52	9.65	4.85
2005	8.48	7.92	16.81	1.07	6.91
2006	0.95	2.42	2.81	1.65	1.78
Average	5.76	3.70	8.22	3.68	4.27
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
Average	12.2	207.8	1.45	93.89	0.70	0.62	0.77	
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
AVG	28.63	7.47		5.89	2.79	

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

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

Table 6. Continued.

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

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

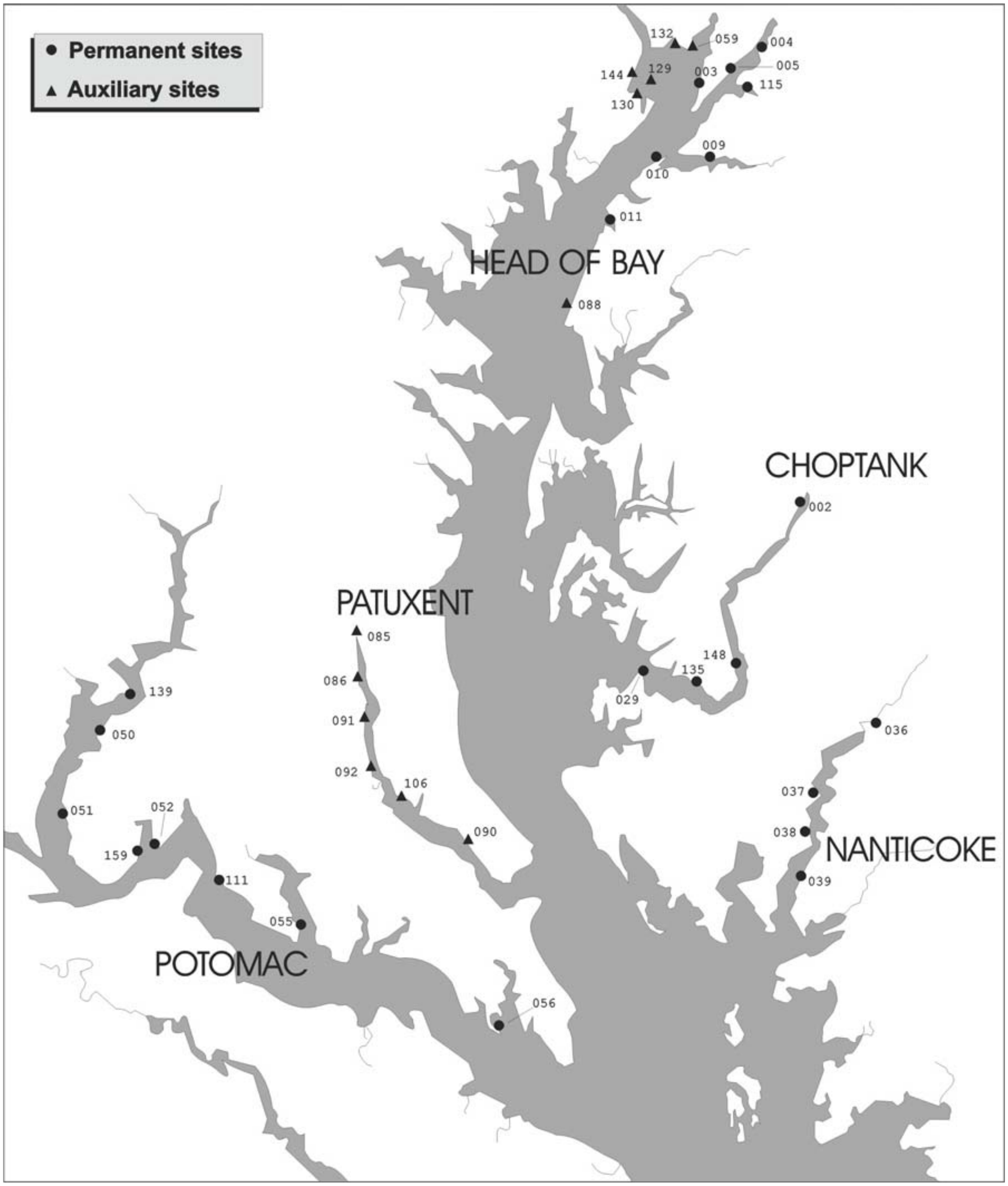


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

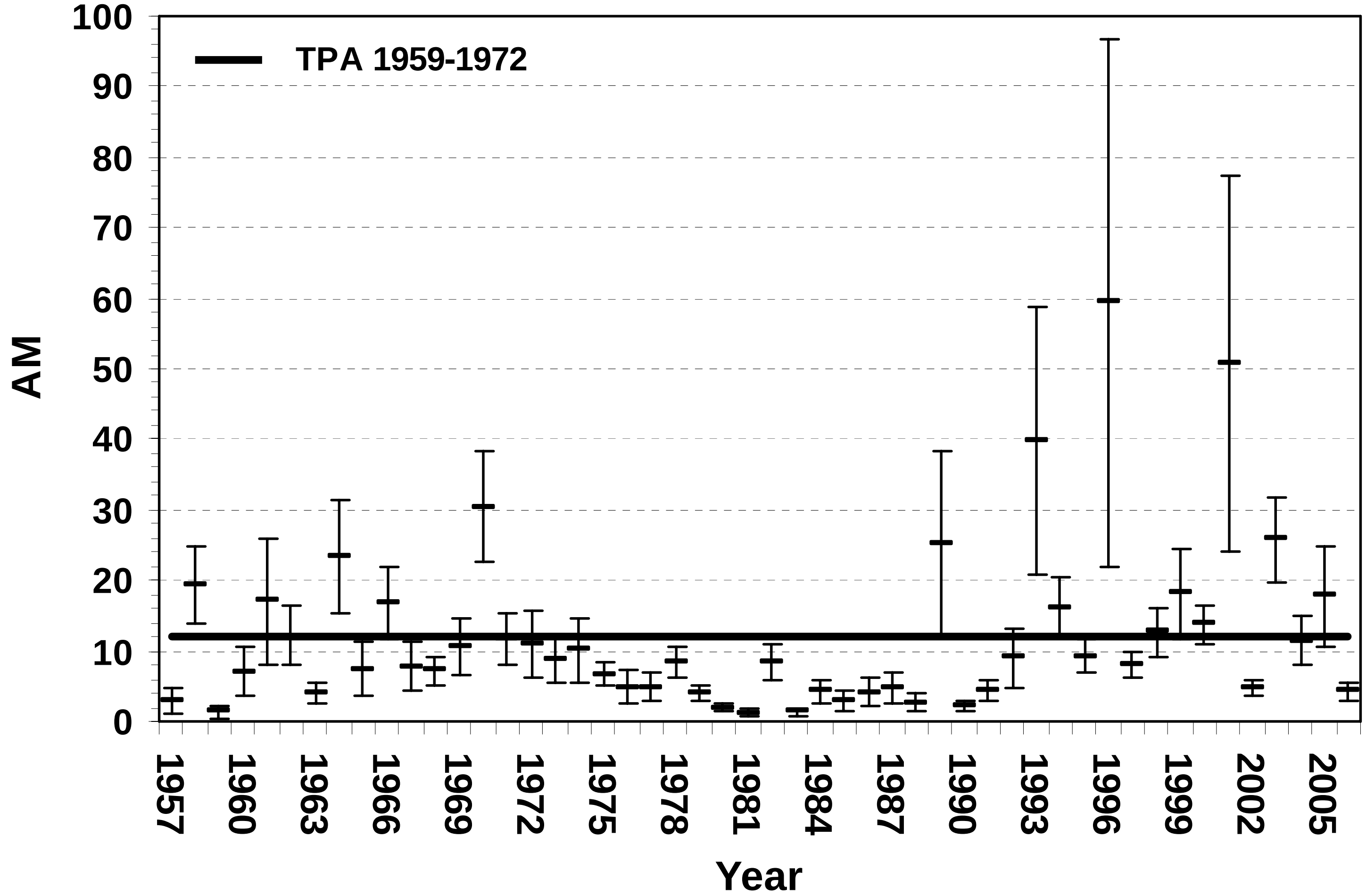


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

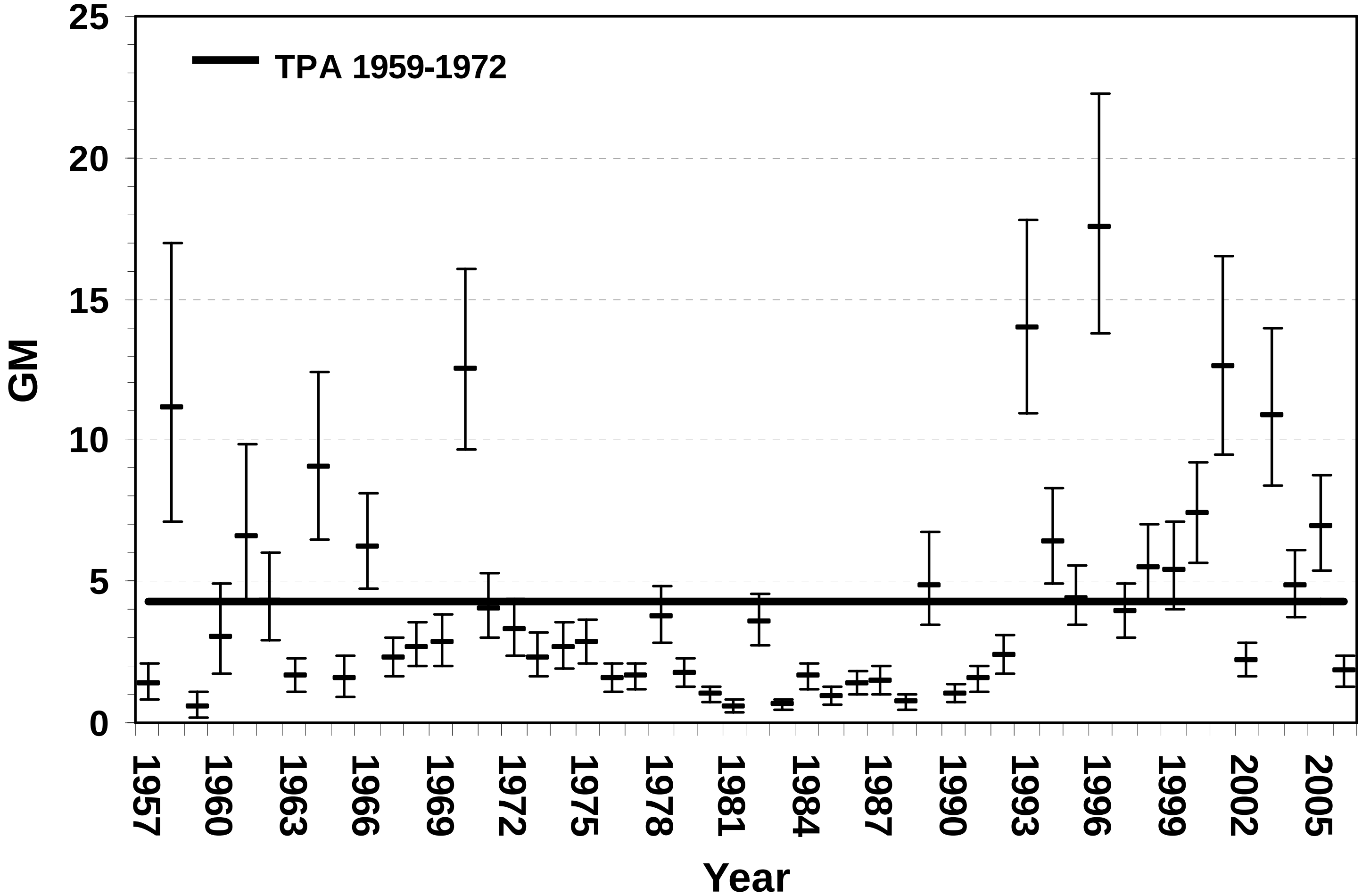


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL).

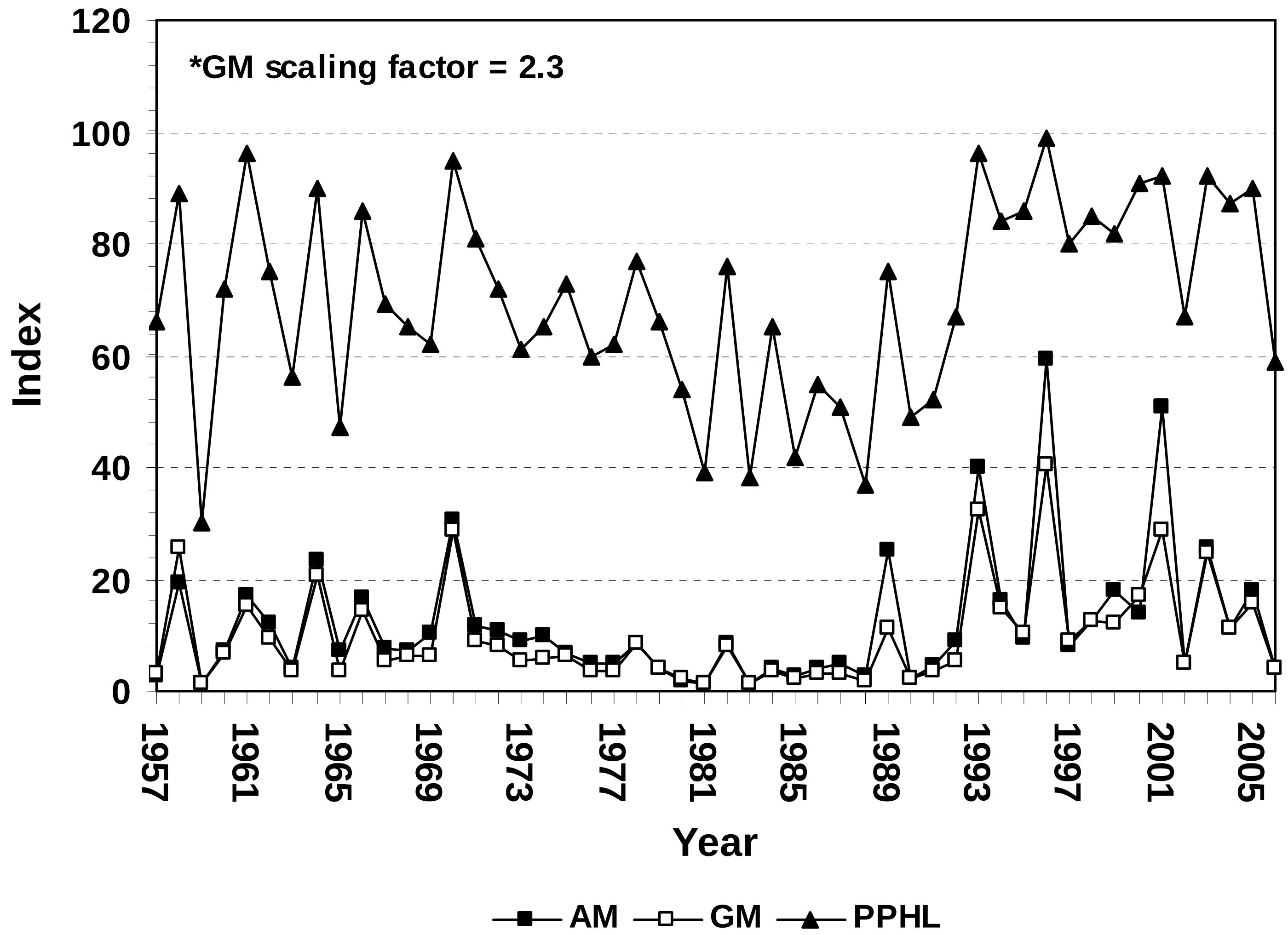


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

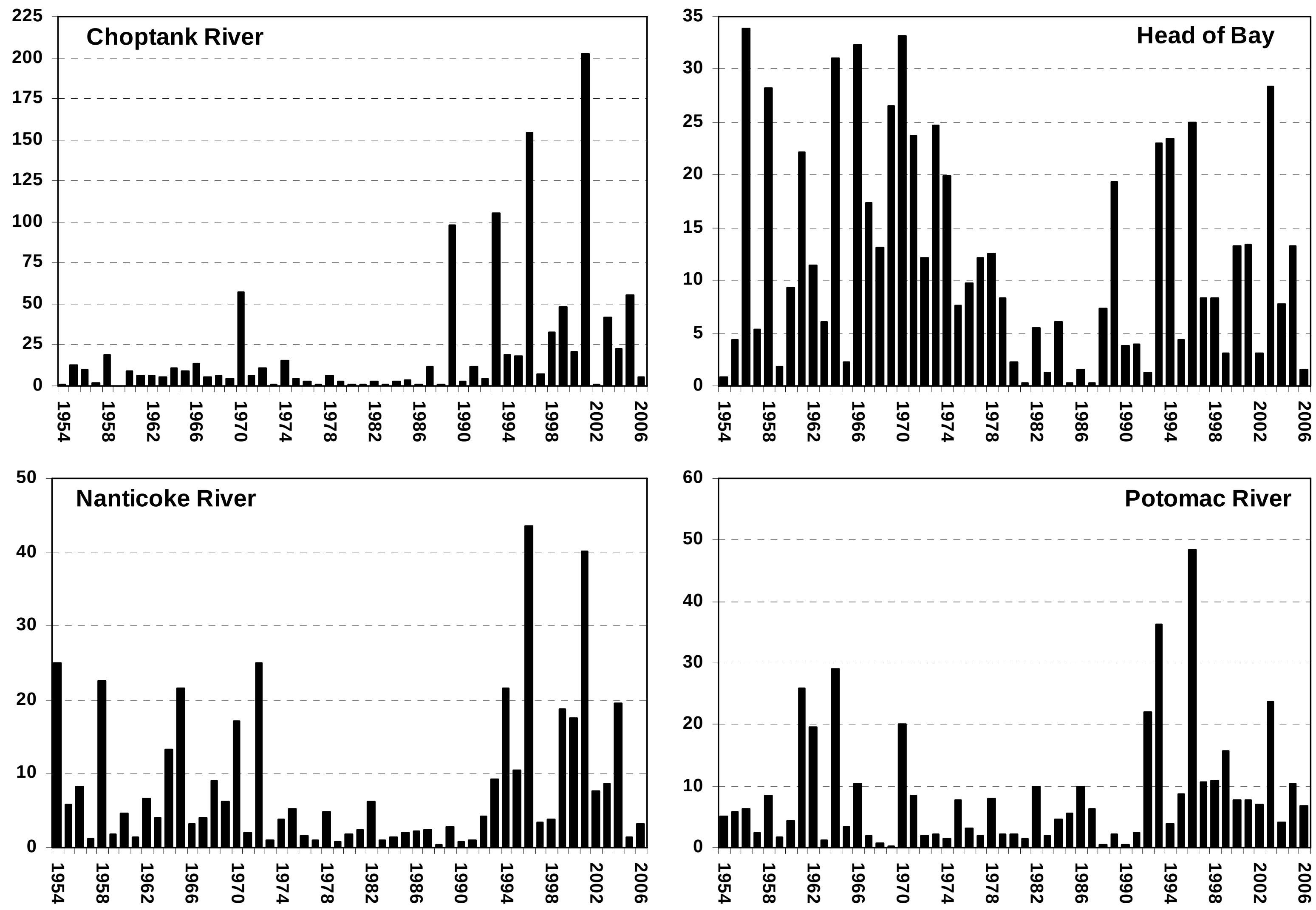


Figure 6. Head of Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

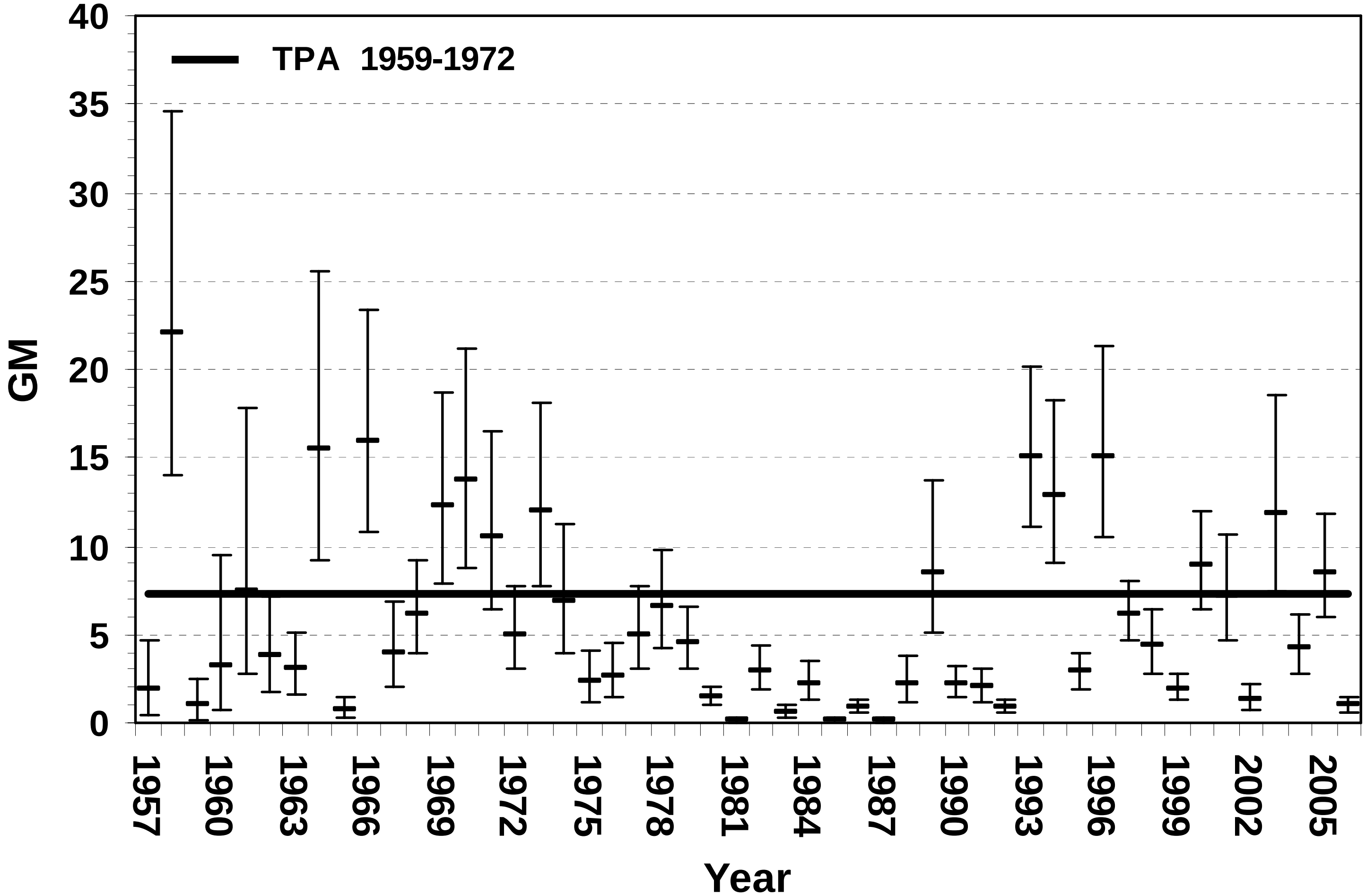


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

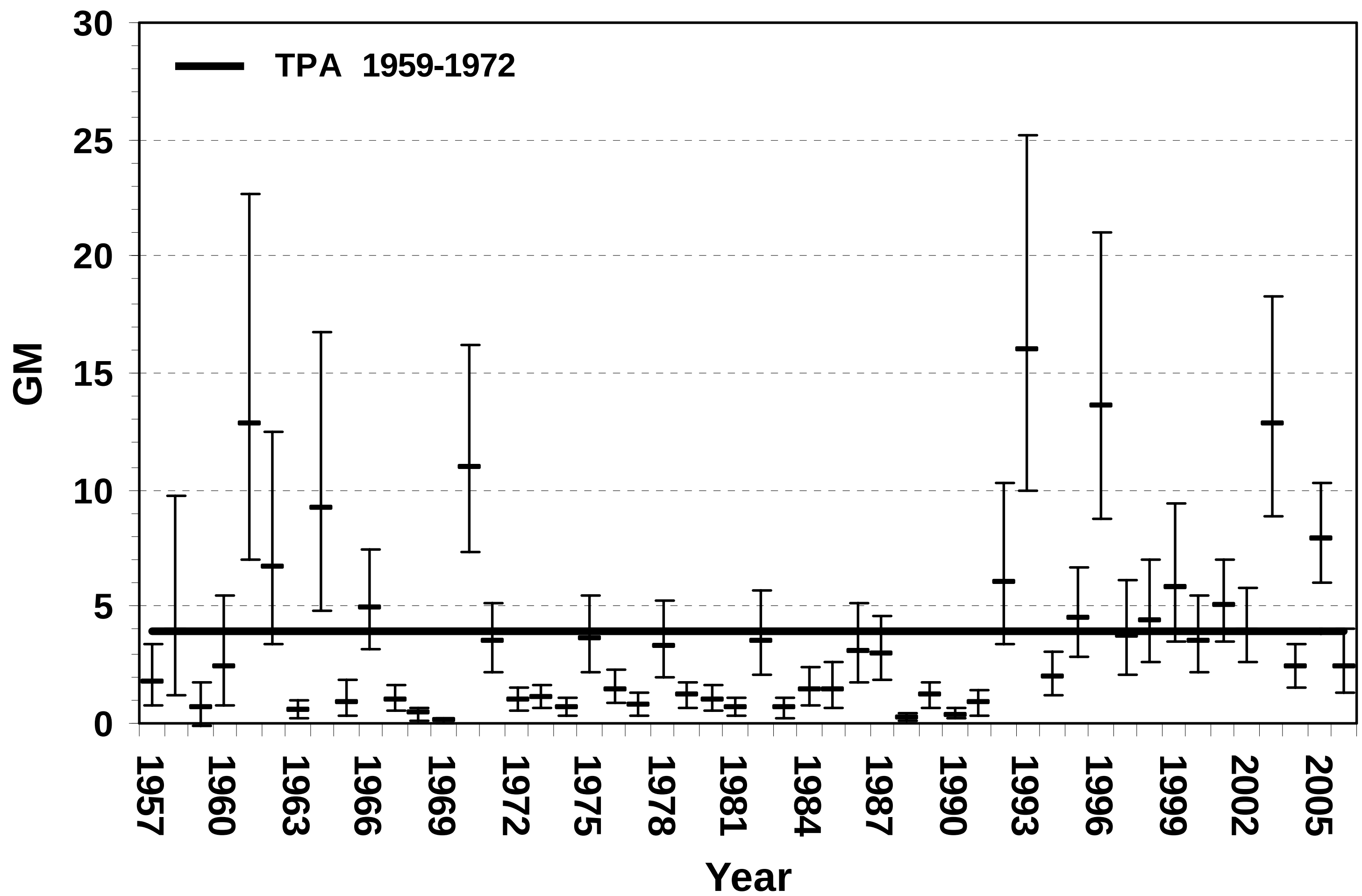


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

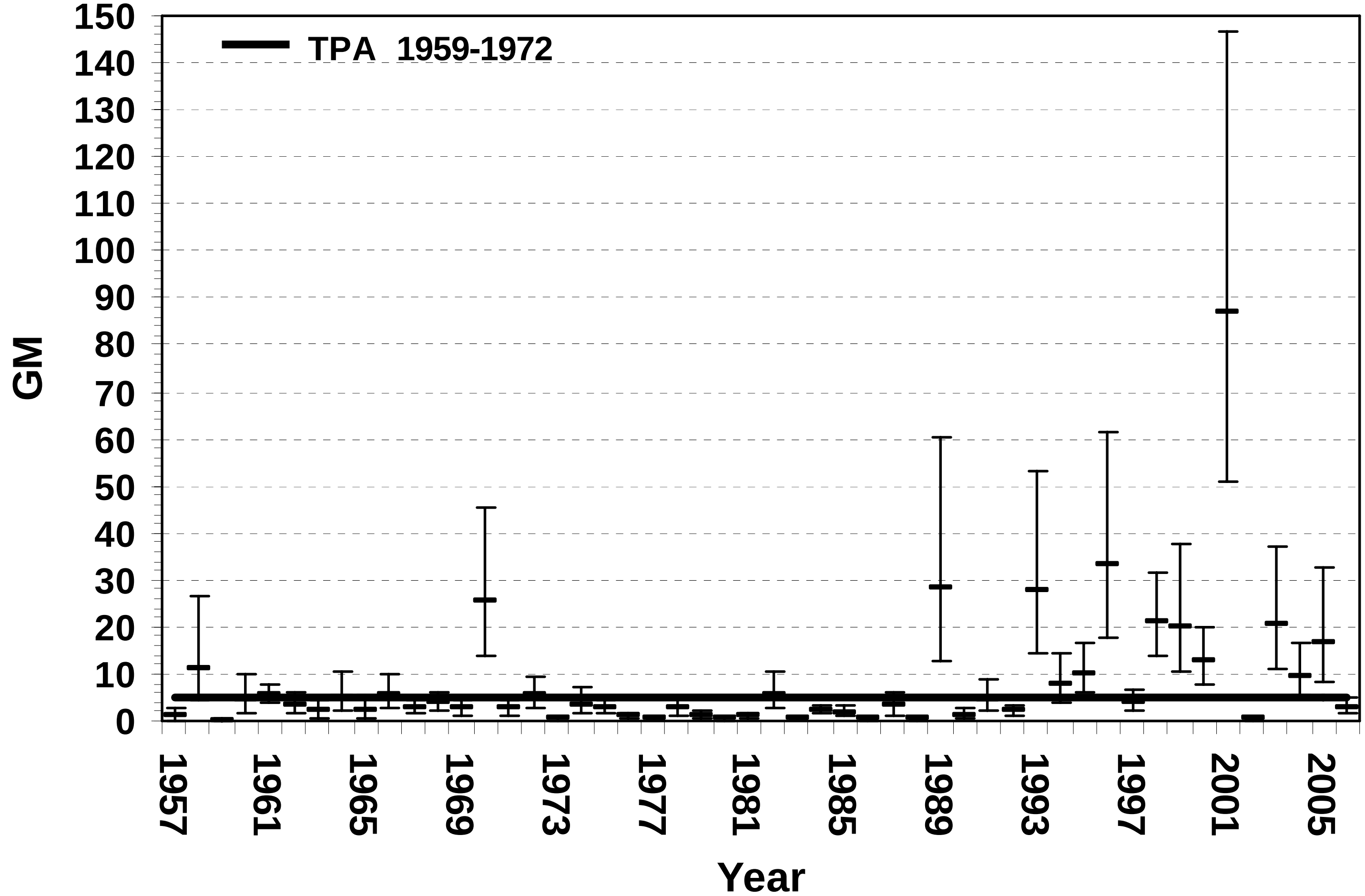


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

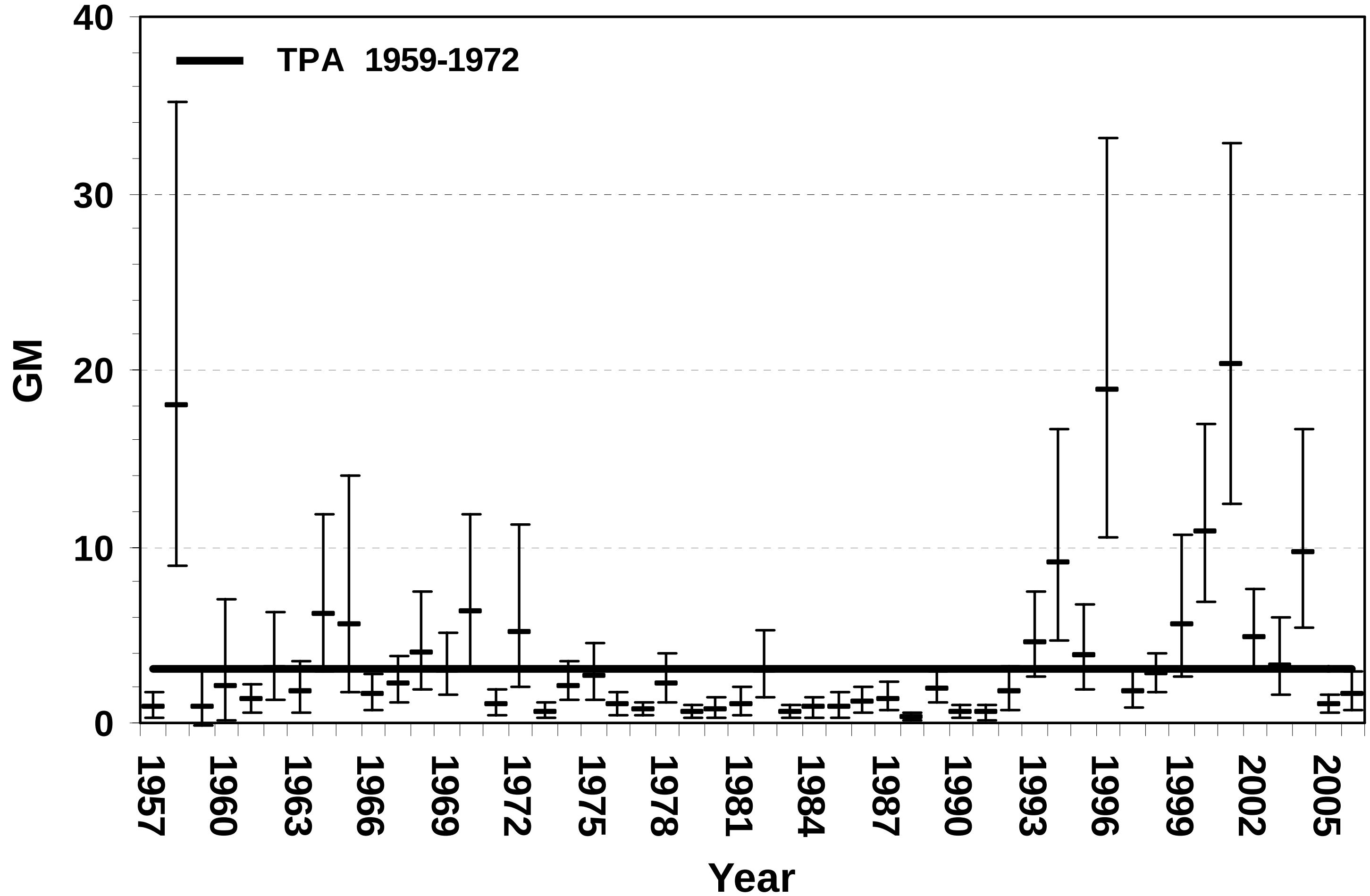


Figure 10. Regression of age 1 on age 0 striped bass.

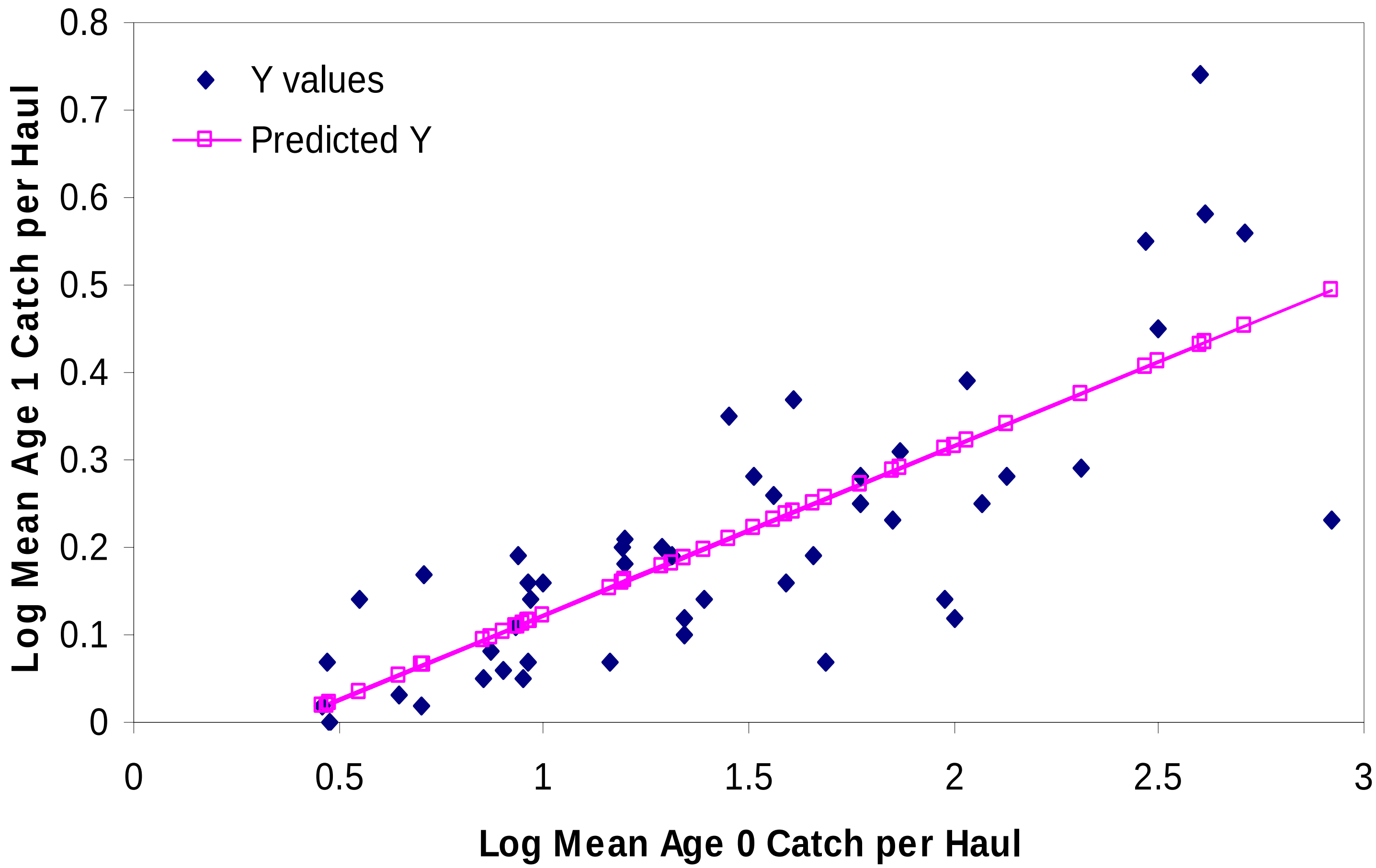
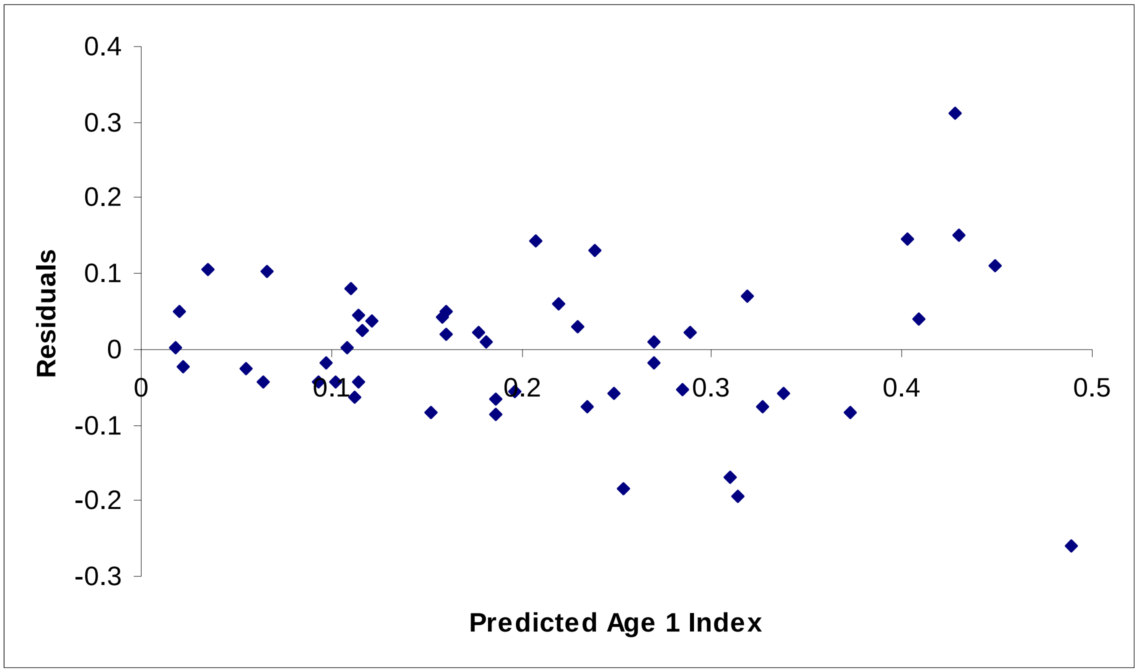
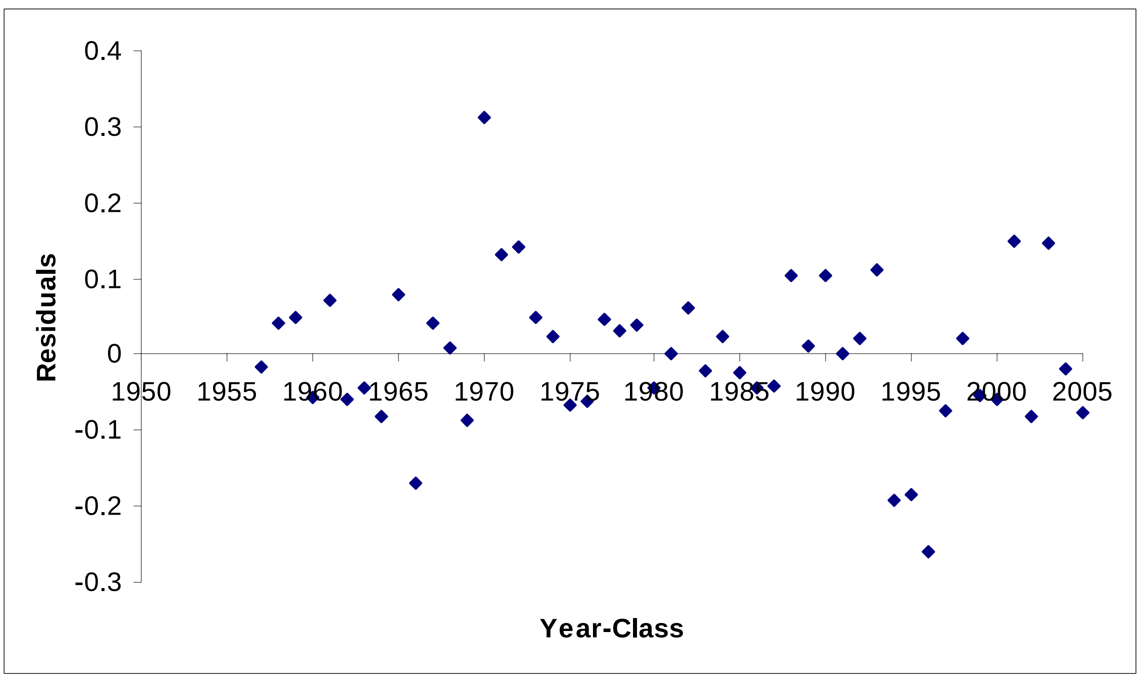


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 2005 through spring 2006. The Maryland Department of Natural Resources (MD DNR) tagged striped bass as part of the U. S. 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 respective fish data were forwarded to the USFWS, with the captor providing recovery information directly to the USFWS. The information generated from this data is used to evaluate stock dynamics (mortality rates, survival rates, growth rates, etc.) of Atlantic coast striped bass stocks. A special study was initiated in 2006 to obtain a current estimate of tag reporting rate.

METHODS

Sampling procedures

In 2005, the summer/fall directed fishing mortality rate (F) study was eliminated. However, sampling continued from pound nets of cooperating commercial fishermen during the summer and fall stock assessment sampling (see Task No. 1A) even though tags were not applied. Instead, tagging data from the spring spawning stock study (see Task No. 2) were used to calculate a

Chesapeake Bay fishing mortality (F).

From late March through May 2006, 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 healthy fish 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. 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.

Along with the standard USFWS tags, high reward tags were applied to every sixth, healthy fish. Data obtained from the recaptures of these tagged fish will be used to obtain a current estimate of reporting rate.

Additionally, from January 19 to January 28, 2006, 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 at speeds ranging from 2.8 to 3.3 knots at depths of 30 to 82 feet (9.1 – 25.0 m) for 0.02 to 0.57 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

A comparative analysis of the 1993-2002 spring and fall tagging data showed that the spring data would produce similar estimates of fishing mortality for Chesapeake Bay; consequently the summer-fall directed fishing mortality effort was discontinued (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 an exploitation rate from which the 2005-2006 estimate of fishing mortality for Chesapeake Bay was derived (Sharov and Versak, in preparation). Male fish 18 to 28 inches are generally recognized to be Chesapeake Bay residents, while the larger fish are predominantly coastal migrants. Release and recapture data from Maryland was combined with similar data from Virginia to produce a Baywide estimate of F.

Survival rates from fish tagged during the spring in Maryland were also estimated in a separate analysis. These rates were based on historic release and recovery data and were estimated using tag-recovery models (Brownie et al. 1985) and subsequent extensions of those models. Estimates of survival, fishing mortality and recovery rates 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). 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 estimates for fish released in spring 2006 will not be completed until after 3/27/07, the estimates will not appear in this report.

Reporting rate will be estimated using release and recapture data obtained from the high reward tags and standard tags applied in the spring. Methods will be consistent with those in Rugolo et al. (1994) and Hornick et al. (2000). However, since the recovery period of one year for these tags is not complete at this time, results will be provided in a separate report.

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

This component of sampling monitored the size and sex characteristics of striped bass spawning in the Potomac River and the upper Chesapeake Bay. Sampling occurred between March 29, 2006 and May 16, 2006. The goal was to tag as many healthy striped bass as possible. In 2006, 1,767 striped bass were sampled and 925 (52%) were tagged as part of the routine spring sampling (Table 1). Of those 925 tags, 153 were high reward tags. Tagging stopped when water temperatures exceeded 70^{o}F. 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 mortality. In this case, biologists measured all fish but were only able to tag a sub-sample. Typically, these large samples were smaller-sized fish and, therefore, a higher proportion of larger fish 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 2006 (598 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (523 mm TL) (Figure 2).

Tag releases and recaptures from both Maryland and Virginia's data will be used to estimate a combined Bay-wide instantaneous fishing mortality rate (F) for the 2005-2006 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. More specific methods and analytical details can be found in Sharov and Versak (in preparation). The analysis is not complete at this time and, therefore, results will not be presented in this report.

Estimates of survival and fishing mortality for the Chesapeake Bay spawning stock will be presented in the 2007 report of the ASMFC Striped Bass Tagging Subcommittee.

USFWS cooperative tagging cruise

The primary objective of the tagging cruise was to apply tags to as many striped bass as possible. As a result, 4,462 (98%) of the 4,574 striped bass sampled on the cruise were tagged (Table 2). There was no significant difference ($P<0.05$) between mean total lengths of tagged fish (715 mm TL) versus the entire measured sample (715 mm TL) of striped bass during 2006 (Figure 2). The 2006 mean total lengths were significantly greater than the mean total lengths (582 mm TL – tagged and total sample) of the 2005 cruise. The NC DMF is presently completing age determination for the 2006 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.

CITATIONS

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. In: Second International Symposium on Information Theory. Edited by B. N. Petrov and F. Csaki. Budapest: Akademiai Kiado.

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

Buckland, S. T., Burnham, K. P., and Augustin, N. H., 1997. Model selection: an integral part of inference. Biometrics 53:603-618.

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

Hornick, H.T., B.A. Rodgers, R.E. Harris and J. Zhou. 2000. Estimate of the 1999 striped bass rate of fishing mortality in Chesapeake Bay. Maryland Department of Natural Resources. Annapolis, Maryland, and the Virginia Institute of Marine Science, Gloucester Point, Virginia. 10 pp.

Rugolo, L.J., P.W. Jones, R.K. Schaefer, K.S. Knotts, H.T. Hornick, and J.L. Markham. 1994. Estimation of Chesapeake Bay-wide exploitation rate and population abundance for the 1993 striped bass stock. Maryland Department of Natural Resources. Annapolis, Maryland. 101pp.

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

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

White, G. C. and Burnham, K. P., 1997. Program MARK - survival estimation from populations of marked animals. Colorado State University, Fort Collins, Colorado. Submitted to Bird Study.

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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.

Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, March - May 2006.

SYSTEM	INCLUSIVE RELEASE DATES	TOTAL FISH SAMPLED	TOTAL FISH TAGGED	APPROXIMATE TAG SEQUENCES [a]
Potomac River	3/29/06-5/16/06	749	387	490501 - 490829 566101 - 566163 [d]
Upper Chesapeake Bay	4/3/06-5/16/06	1,018	538	488697 - 489000 489734 - 489887 565851 - 565940 [d]
Spring spawning survey totals:		1,767 [b]	925 [c]	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes 2 USFWS tag recoveries, 1 American Littoral Society tag recovery and 1 fish with a missing length.
[c] Total tagged includes 1 fish with a missing length.
[d] These sequences are high reward tags.

Table 2. Summary of USFWS internal anchor tags applied to striped bass during the 2006 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)	1/19/06-1/28/06	4,574	4,462	527001 – 530650 538501 – 539000 543651 – 543963 544001 – 544050
Cooperative tagging cruise totals:		4,574 [b]	4,462 [c]	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes 6 USFWS tag recoveries and 35 fish with missing lengths.
[c] Total tagged includes 3 fish with missing lengths.

Figure 1. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, March - May 2006.

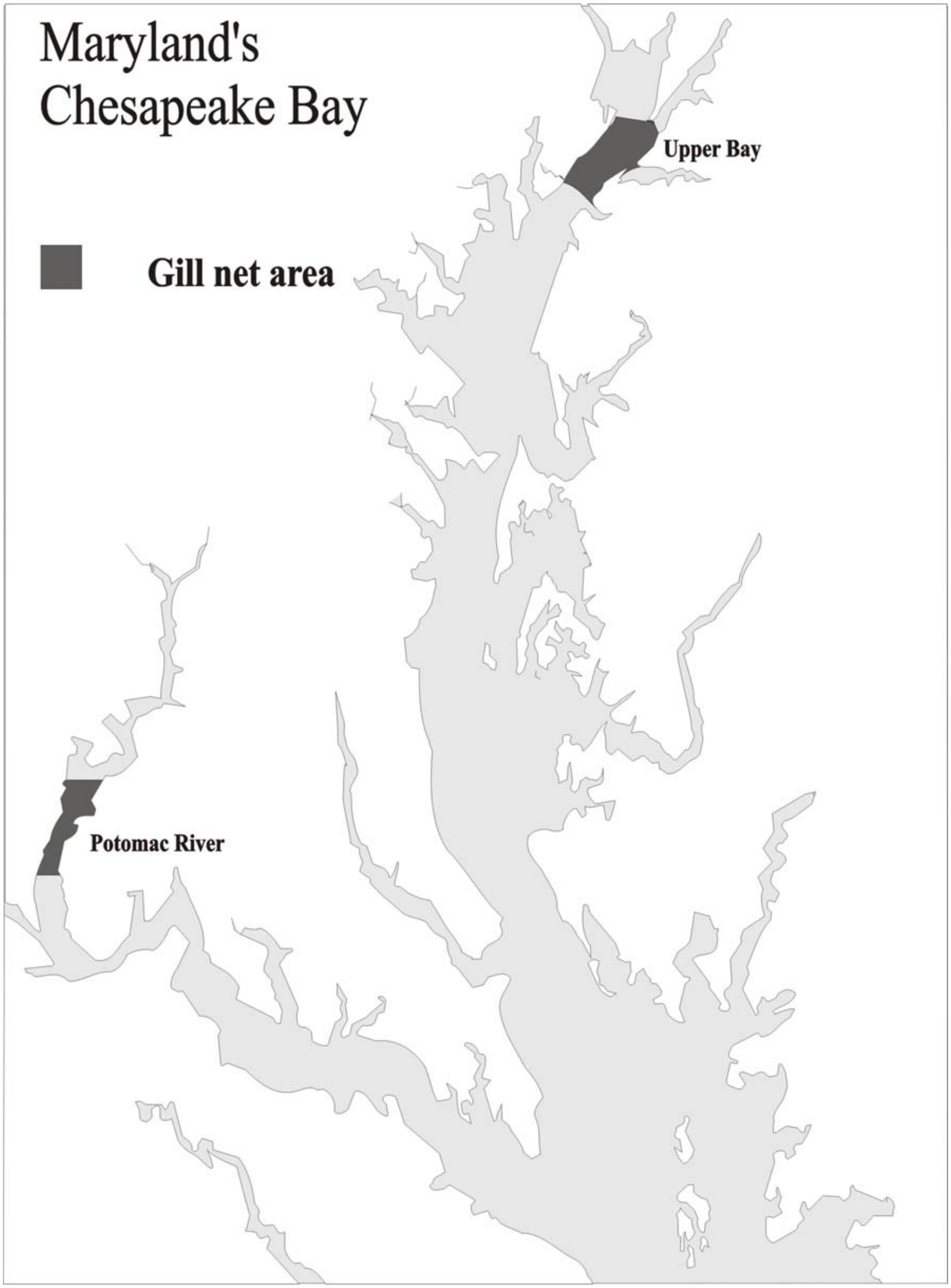
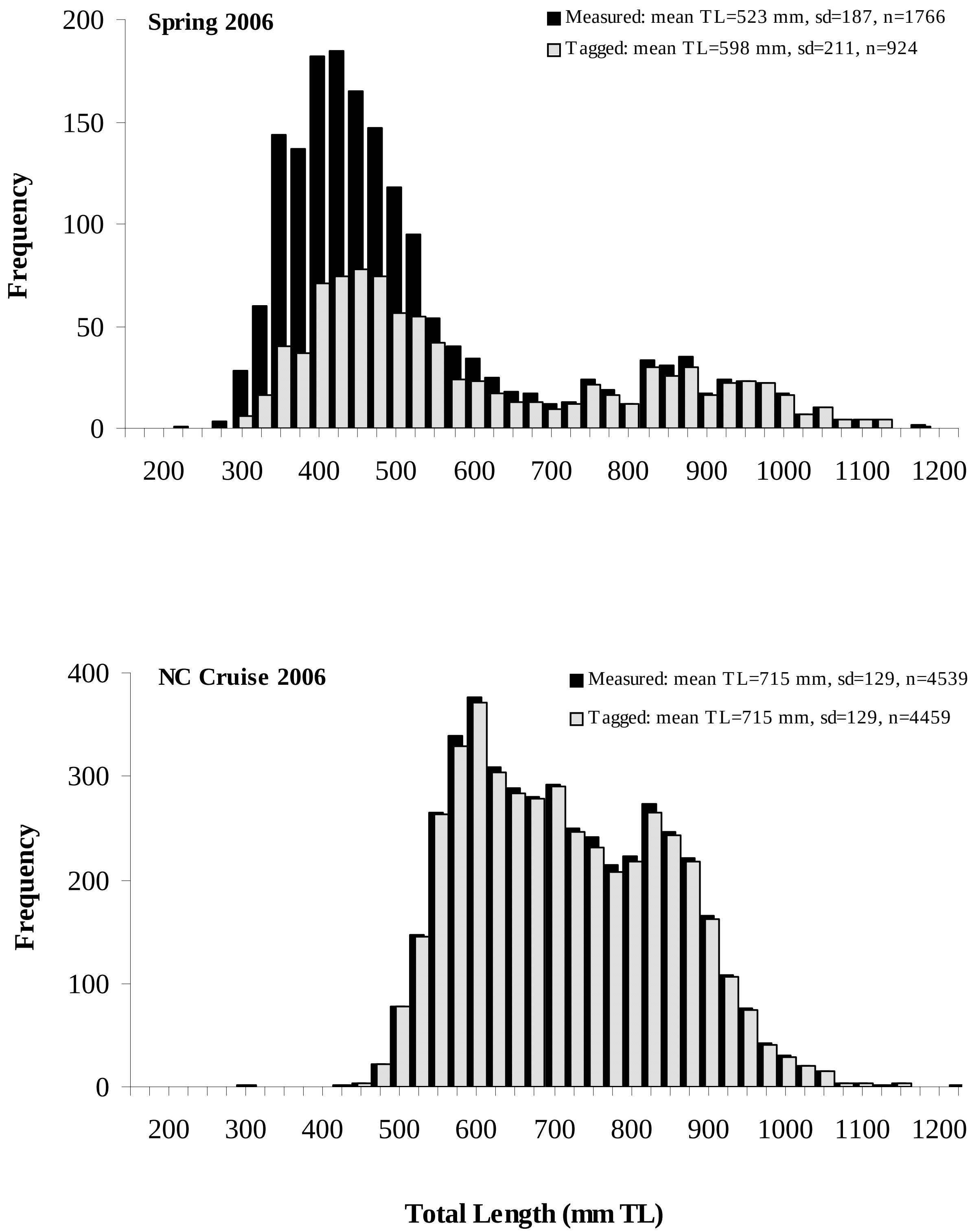


Figure 2. Length frequencies of striped bass measured and tagged during the spring in Chesapeake Bay and offshore during the SEAMAP tagging cruise. Note different scales.



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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Luke Whitman

INTRODUCTION

The primary objective of Task 5A was to characterize the commercial striped bass harvest in 2005. The Maryland Department of Natural Resources (MD DNR) changed the organization of its commercial quota system from a seasonal to a calendar year system in 1999. Maryland completed its sixteenth year of commercial fishing under the quota system since the striped bass fishing moratorium was lifted in 1990. The 2005 commercial quota for the Chesapeake Bay and its tributaries was 2,066,322 pounds with an 18 to 36 inch (TL) slot limit. The commercial fishery received 42.5 % of the state's total Chesapeake Bay striped bass quota. There was a separate quota of 126,396 pounds, with a 24-inch (TL) minimum size for the State's jurisdictional waters off the Atlantic Coast.

The Chesapeake Bay 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 conditionally transferred to another gear type within the striped bass fishery for that season.

Each fishery was managed with specific seasons. The hook-and-line fishery was open on selected days from June 14 to November 30, 2005. The pound net fishery was open from June 1 through November 30, 2005. The haul seine fishery was open from June 1 to November 30, 2005. The Chesapeake Bay drift gill net season was split, with the first segment from January 3 through February 28, 2005 and the second segment from December 1 through December 31, 2005. 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, 2005 and November 1 through December 31.

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 are analyzed with the primary objective of presenting a post-moratoria summary of baseline data on commercial catch and CPUE.

METHODS

In March 2004, 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, 2004 was established for receipt of their 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 fisheries' 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, 2,008,687 pounds of striped bass were harvested in 2005. This represented 97.2 % of the Chesapeake quota for the 2005 commercial fishing season. The estimated number of fish landed was 587,990. The Chesapeake drift gill net fishery contributed 60.3 % (pounds) of the total landings and the pound net fishery contributed

25.6 % (pounds). The hook-and-line fishery harvested the remaining 14.1 % by weight. The haul seine fishery did not harvest any striped bass for the third consecutive year (Table 3).

Maryland's Atlantic Coast landings were 46,871 pounds. The estimated number of fish landed was 6,105. This represented 37.1 % of the Atlantic Quota. The trawl fishery accounted for the majority (72 %) of the Atlantic harvest (Table 3).

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, in this report). The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 3.59 pounds. Mean weights by specific gear type were similar, ranging from 3.28 to 3.81 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 3.81 pounds per fish.

Striped bass harvested from the Atlantic Coast averaged 7.72 pounds (Table 4). This average was calculated from data provided by check station reports.

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 2005, the hook and line fishery CPUE was 163 pounds per trip, which was a decrease from 2004. The pound net fishery CPUE was 200 pounds per trip, showing an increase from 2004. The CPUE for the Chesapeake Bay gill net fishery was 329 pounds per trip, the highest level in 15 years (Table 5, Figure 4).

The hook and line fishery continues to have the lowest CPUE of all the Cheasapeake Bay fisheries, with the exception of 2004. Over the past three years, the gill net fishery had the highest average CPUE value (302 lbs per trip), followed by the pound net fishery (209 lbs per trip) and the hook-and-line fishery (179 lbs per trip).

The Atlantic trawl fishery CPUE was 378 pounds per trip in 2005. The Atlantic trawl fishery CPUE peaked in 1995 (994 lbs per trip) when the quota was increased, but has stabilized since 1996, averaging 439 pounds per trip over the past ten years. The 2005 CPUE for the Atlantic gill net fishery was 170 pounds per trip, which remains below the ten year average of 217 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).

CITATIONS

Atlantic States Marine Fisheries Commission (ASMFC) 2005. 2005 Stock Assessment Report for Atlantic Striped Bass: Catch-at-Age based VPA and tag release/recovery based survival estimation. A report by the ASMFC Striped Bass Technical Committee.

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

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

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

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

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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 2005.

Figure 4. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by gear type, 1990- 2005. 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), 1990-2005. Trips were determined as days fished when striped bass catch was reported.

Table 1. Striped bass commercial harvest quotas (lbs) by gear type for the 2005 calendar year.

GEAR TYPE	TOTAL ADJUSTED HARVEST QUOTA (Pounds)
Haul Seine, Pound Net	516,581
Hook & Line	712,881
Drift Gill Net	836,860
CHESAPEAKE TOTAL	**2,066,322**
Atlantic: Trawl, Gill Net	126,396
MARYLAND TOTAL	**2,192,718**

Table 2. Individual season and daily harvest allocations (lbs) and the number of declared striped bass fishermen for the 2005 calendar year.

AREA	GEAR TYPE	NUMBER DECLARED	DAILY ALLOCATION (pounds)	SEASONAL ALLOCATION (pounds)
BAY & TRIBUTARIES	Haul Seine	5	750	1,250
	Pound Net	153	200 [1]	1,100[1]
	Hook&Line (H&L)	149	800 [2]	none
	Gill Net / H&L	833	500, 2500[3]	none
ATLANTIC COAST	Atlantic Trawl	38	none	1,900
	Atlantic Gill Net	33	none	1,900

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.

2. The hook and line fishery was managed by a weekly allocation.

3. The gill net fishery was managed by a weekly allocation of 500 pounds in January and February and 2,500 pounds in December.

Table 3. Summary striped bass commercial harvest statistics by gear type for the 2005 calendar year.

AREA	GEAR TYPE	POUNDS[1]	ESTIMATED[1] NUMBER of FISH	TRIPS[2]
CHESAPEAKE BAY[3]	Haul Seine	0	0	0
	Pound Net	513,519	203,073	2,610
	Hook & Line	283,803	91,834	1,773
	Gill Net	1,211,365	293,083	3,742
	Chesapeake Total Harvest	**2,008,687**	**587,990**	**8,125**
ATLANTIC COAST	Trawl	33,974	4,342	101
	Gill Net	12,897	1,763	90
	Atlantic Total Harvest	**46,871**	**6,105**	**191**
MARYLAND TOTALS		**2,055,558**	**594,095**	**8,316**

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 2005 calendar year.

AREA	GEAR TYPE	AVERAGE WEIGHT (pounds)	SAMPLE NUMBER
CHESAPEAKE BAY[3]	Haul Seine[1]	0	0
	Pound Net[2]	3.55	1,040
	Hook-and-Line[2]	3.28	2,083
	Gill Net[2]	3.81	3,378
	Chesapeake Total Harvest[2]	**3.59**	**6,501**
ATLANTIC COAST	Trawl [1]	7.82	NA
	Gill Net[1]	7.32	NA
	Atlantic Total Harvest[1]	**7.72**	**NA**

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 2005.

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

Figure 1. Map of the 2005 Maryland authorized commercial striped bass check stations.

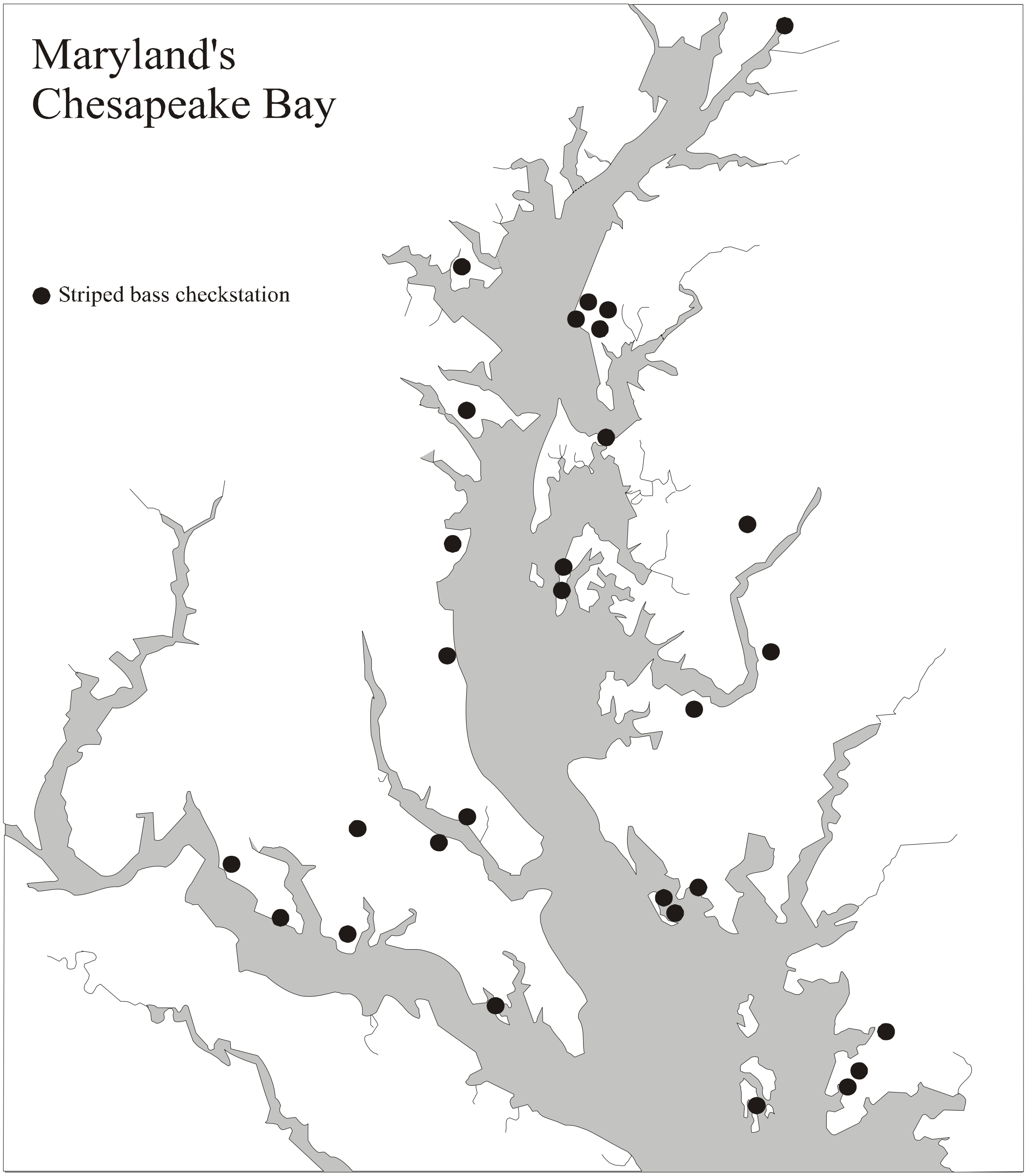


Figure 2. Maryland's Chesapeake Bay pound net and hook and line fishery cumulative striped bass landings from check stations daily call-in reports, June-November 2005.

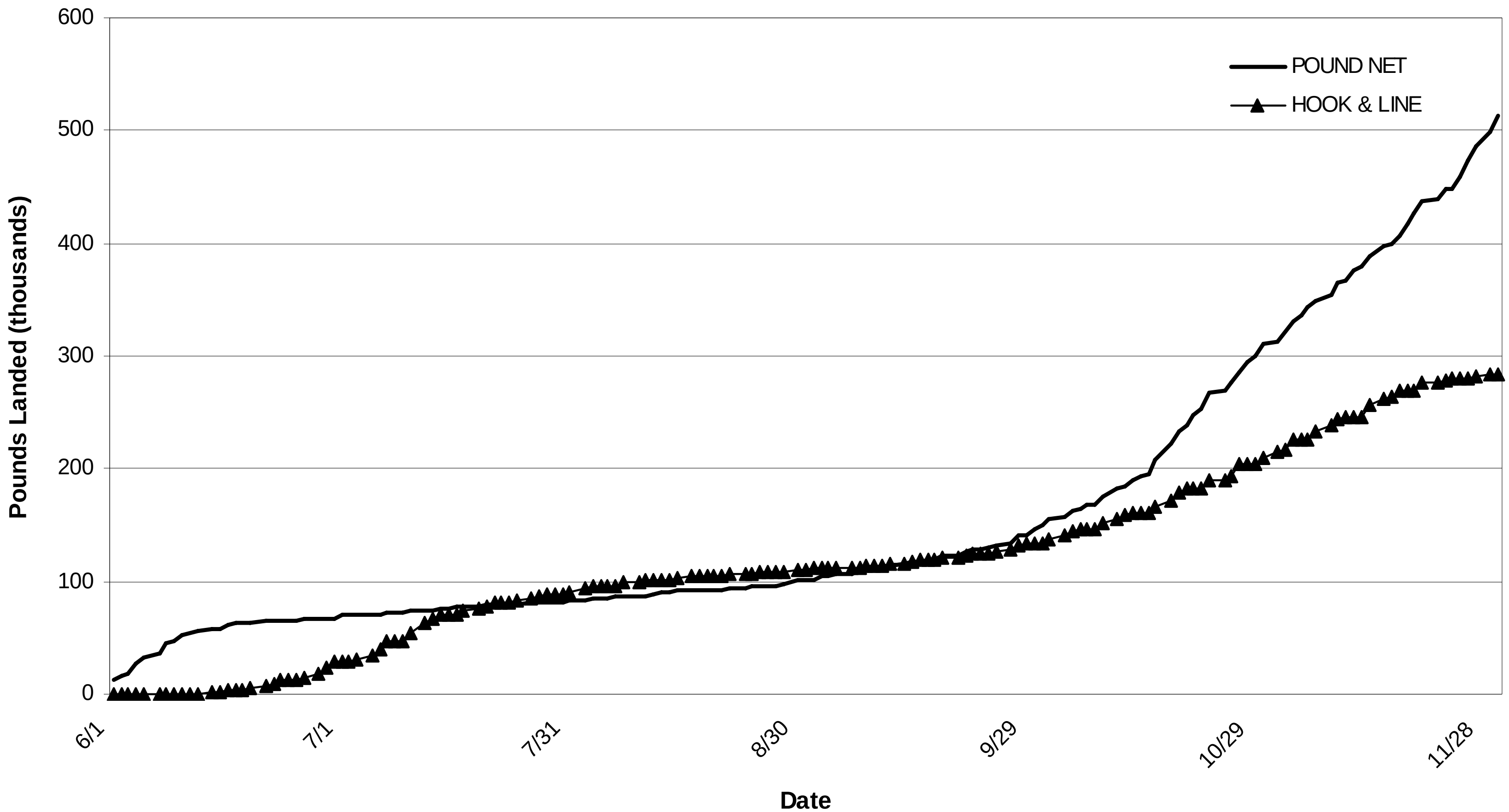
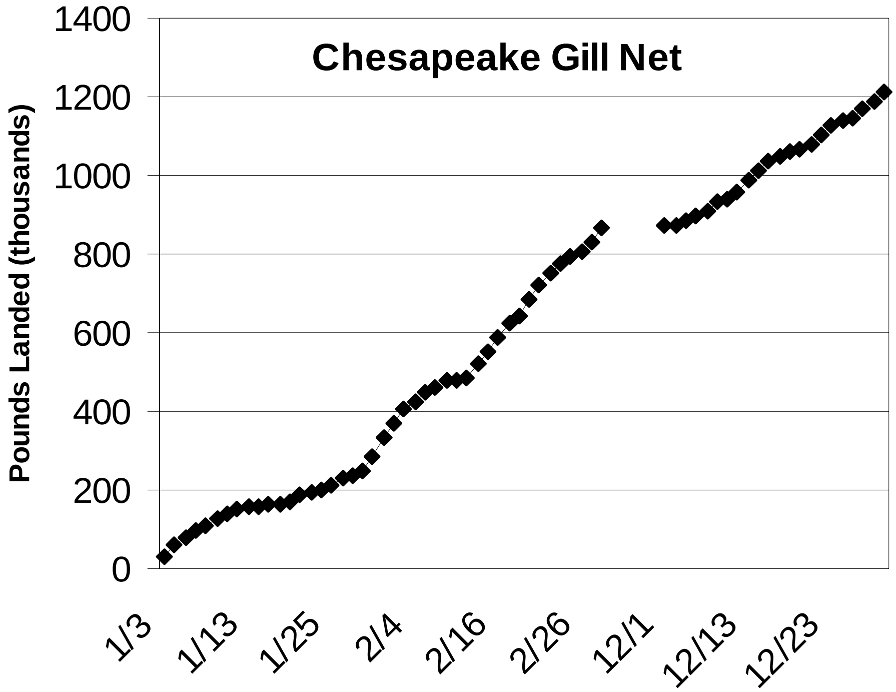


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fishery (combined) cumulative striped bass landings from check stations daily call-in reports, January- December 2005.



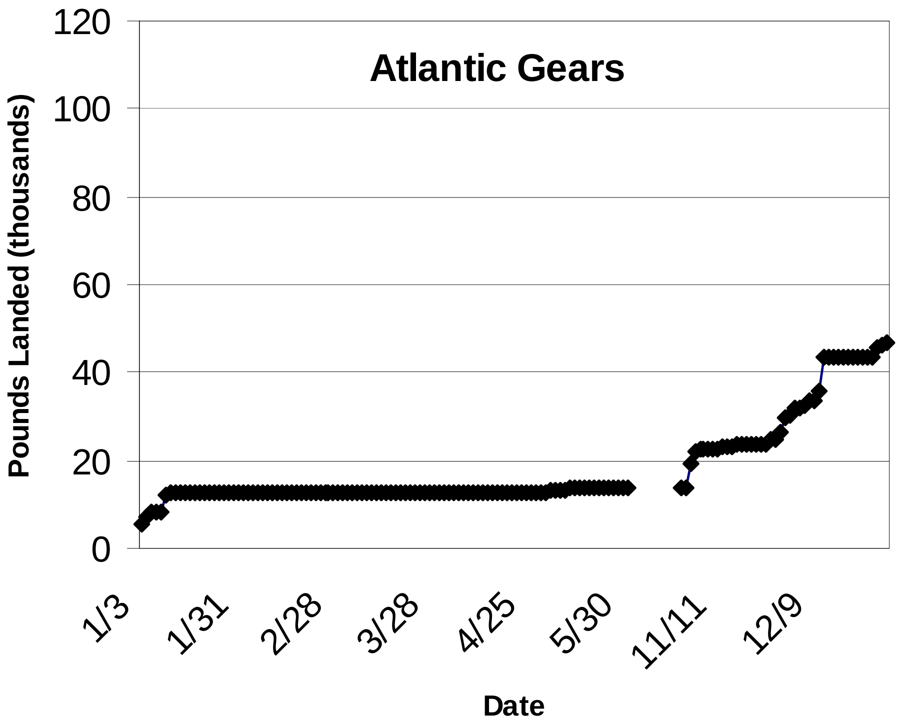


Figure 4. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by gear type, 1990- 2005. Trips were determined as days fished when striped bass catch was reported.

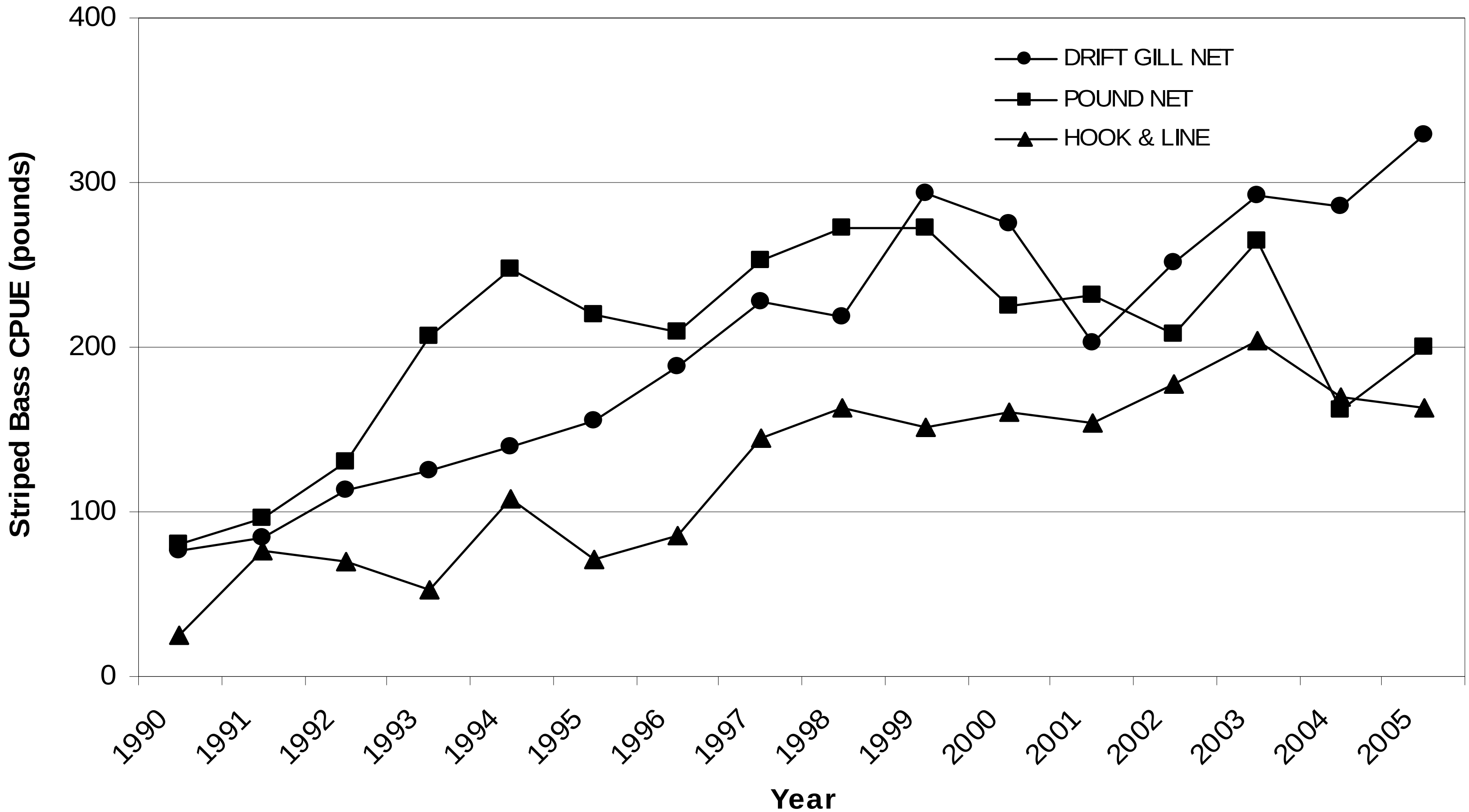
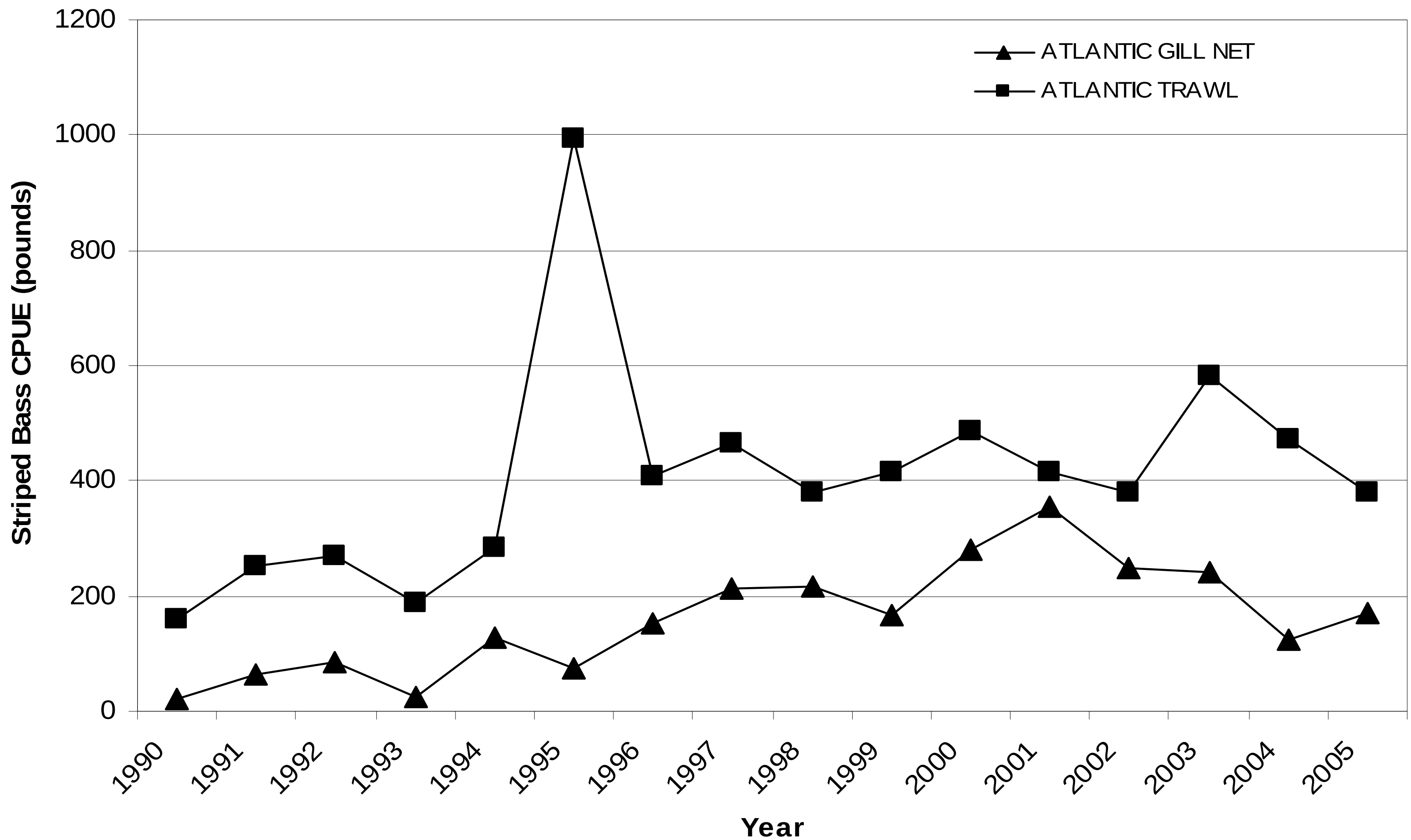


Figure 5. Maryland's Atlantic gill net and trawl fishery striped bass catch (pounds) per trip (CPUE), 1990-2005. Trips were determined as days fished when striped bass catch was reported.



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

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

Prepared by Erik Zlokovitz and 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 2006 recreational spring trophy season. This portion of the recreational fishery began on the third Saturday in April, and continued through May 15.

A portion of the Atlantic migratory striped bass stock returns to the Chesapeake Bay 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). During warmer springs, out-migration may occur much earlier. 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 the 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 trophy season restrictions have progressively been liberalized since 1991 as stock abundance increased (Table 1). The 2006 season was 31 days long (April 15 – May 15), with a 1 fish per person, per day, creel limit. The minimum size limit was raised from 28 inches to 33 inches. Areas open for fishing during the spring trophy season are shown in Figure 1.

The Maryland Department of Natural Resources (MD DNR) Striped Bass Stock Assessment Survey initiated a dockside creel survey for the spring season fishery in 2002. The objectives of the survey were to:

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,

5. Collect scales and otoliths for an ongoing ageing validation study of older fish, and

6. Scan fish for the presence of coded wire hatchery tags (CWTs) necessary to collect known-age samples (scales and otoliths).

METHODS

Dockside creel surveys were conducted 3-4 days per week at high-use charter boat marinas and public boat ramps (Table 2), 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 limit of 1 legal sized fish, per person, per day. Charter boats often caught their limit and returned to the dock as early as 8:00 AM. At public boat ramps, private boats returned throughout the day, with no fixed schedule. Sites were not chosen with 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/western shores. 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.

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 season sampling target for 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 2006, 76 scales were read, and the age structure was estimated for the entire trophy season creel survey length sample using the combined age-length key.

The season sampling target for otoliths was 15 otolith pairs per 20 mm length group, for each sex. Otolith extraction required two cuts into a fish head with a hacksaw to cut off the top of the skull. A vertical 1 inch cut starting on top of the fish head was made on a line with the pre-opercular flap, followed by a horizontal cut towards the forward end of the fish's upper jaw. The top of the skull was pried off with a stiff, heavy bladed knife, leaving the brain exposed. After removal of the brain and fatty tissue, the saggital otolith pair was partially visible in slots behind and below the brain. Otoliths were removed with tweezers and stored dry in labeled plastic vials. These samples will be held by MDDNR until shipped to a regional processing laboratory.

Spawning condition was determined based on descriptions of gonad maturity presented in Snyder's *Fisheries Techniques* (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 CWTs using a Northwest Marine Technology detector wand. Fish were scanned on the left cheek, at the standard hatchery tag implantation site. If a fish scanned positive for a CWT, the cheek, otoliths and scale sample were retained for tag extraction and age validation. All biological data were subsequently analyzed to provide information on length, weight, age, sex ratio and spawning condition.

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. Catch 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 trophy 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 also 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, the number of anglers interviewed, and the number of striped bass examined each year are presented in Table 5A. The majority of trips sampled in 2006 were from charter boats, but private boats were also sampled (Table 5B). Most fishing activity during the spring trophy season was 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 length distribution of the catch in 2006 was dominated by fish between 840 mm and 980 mm TL (33 to 39 inches) (Figure 2). The regulatory change of 2006 which increased the minimum size from 28 to 33 inches skewed the length distribution toward larger fish relative to previous years. The overall shift in distribution may also be related to the growth of fish from the dominant 1996 year class. Striped bass less than 32.75 inches TL were defined as sub-legal to allow for measurement error, and accounted for 3.7 % of the sample.

Mean length.

In 2006, the mean length for all sexes combined (923 mm TL), females (929 mm TL), and males (886 mm TL) increased when compared with those observed during the 2002-2005 surveys (Table 6A, Figure 3). The mean length of females was greater than the mean length of males. Based on 95% confidence intervals, mean length of males was significantly greater than all years except 2005. Mean lengths of all sexes combined and females increased significantly when compared with average lengths from 2005.

Mean daily length of female striped bass was consistent over time during the 2006 spring trophy season, similar to the pattern observed in 2005. 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 2006 fish (8.1 kg) increased when compared to mean weights observed in previous years (Table 6B). Based on 95% confidence intervals, the mean weight of all sexes combined and females increased significantly from 2005 (Figure 5). The mean weight of females was greater than the mean weight of males, which is consistent with data from previous years.

Age Structure

The age distribution of striped bass from the sampled dockside harvest in 2006 consisted of fish between 6 and 21 years of age (Figure 6). The age distribution was dominated by 9-13 year-old females, with the dominant 1996 year-class (10 years old in 2006) being most frequently observed. The 1996 year-class constituted 31.5% of the sampled harvest during the 2006 trophy season. The same 1996 year-class was evident as 9 year-olds in the 2005 survey, which constituted 27.5 % of the sampled harvest.

The age distribution of the spring season recreational harvest during the years 2002-2006 is consistent with striped bass biology described in the literature. Approximately 50% of the Chesapeake Bay striped bass females are sexually mature by 6 years old and join the spring spawning migration from the Atlantic coast into Chesapeake Bay (ASMFC 2002). Females grow bigger than males, and most striped bass over 13.6 kg (30.0 lb) are females (Bigelow and Schroeder 1953).

Sex Ratio

The data included three designations for sex: female, male and unknown. As in past years, the 2006 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 86% of the 2006 sampled harvest. When the data were analyzed including unknown-sex fish, females composed approximately 85% of the sampled harvest. If the fish of unknown sex were assumed to be female, the percent of females was 86%. These results are consistent with the average proportion of females seen during the years 2002-2005, which ranged from 82%-88% when the three methods of calculation were used.

Spawning Condition

Percent pre-spawn females.

Spawning condition of the female portion of the catch was a prime initiator of 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 through 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 trophy fishery during the first two weeks of May. Data from the 2006 spring season survey showed that 41% of females caught between April 15 and May 15, 2006 were in pre-spawn condition (Table 8), the lowest percentage of pre-spawn females documented since the inception of the spring season creel survey in 2002.

Daily spawning condition of females.

The percent of pre-spawn females harvested ranged from 11% to 97% on any given day during the 2006 trophy season (Figure 7). Data from 2006 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 was observed in 2003, 2004, and 2005.

<u>Presence of Coded Wire Hatchery Tags (CWTs)</u>

A total of 385 striped bass were scanned for presence of CWTs during the 2006 Maryland spring recreational season (April 15-May 15). Of these fish, none were found to have CWTs.

CATCH RATES AND FISHING EFFORT

Harvest Per Unit Effort

The majority of trips intercepted in 2006 were charter boat trips (Table 5B), but creel survey interview data was used to obtain harvest rate estimates for both charter and private vessels. Most charter boats take 6 clients per trip and fish until the legal limit of 1 fish per person is reached. Harvest per trip (HPT) was calculated from charter boat logbooks and creel survey interviews using only fish kept and landed during each trip.

Mean HPT results from charter boat logbooks and charter boat interviews (5.3 and 6.0 fish per trip, respectively) were similar (Table 9A). Mean HPT in 2006 was similar to that of 2005. Some charter boats are licensed to carry more than six passengers, which may result in mean harvests of greater than six fish per trip in some years. In 2006, charter boats were observed carrying up to 20 anglers and landing up to 20 fish per trip. Mean HPT from private boat interviews (1.4) was significantly lower than HPT from charter boats.

Mean harvest per angler, per trip (HPA) was calculated by dividing the total number of fish landed on a vessel by the number of people in the fishing party. HPA was approximately 1.0 fish per person for charter anglers, and 0.5 fish per person for private anglers (Table 9B). Charter boat anglers usually caught their limit of one fish per person, while private boat anglers did not reach their limit on some trips.

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 2006 were the second highest in 5 year time series of the spring trophy season creel survey. Mean CPT was 6.6 fish per trip in 2006, compared with 8.3 fish per trip in 2005. Mean CPH was 2.6 fish per hour in 2006 compared with 3.5 fish per hour in 2005. Overlapping confidence intervals indicate that there was no significant change in catch rates between 2005 and 2006.

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 trophy season. Charter boats typically troll with 10-20 lines, and may fish up to 7 days per week. Also, charter captain experience 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 (8.7) was similar to CPT from logbook data (8.0). Mean CPT from logbook data in 2006 increased compared to 2005 (6.9). Examination of confidence intervals showed no significant increase in CPT calculated from the interview data from 2005 to 2006. Mean CPH calculated from interview data (3.4) was slightly higher than CPH from logbook data (2.2). Charter boat CPH in 2006 was similar to catch rates in 2005 and increased when compared to 2002-2004 (Tables 10C and 10D). During the years 2002-2006, 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 trophy season. Interview data showed that mean daily CPH declined slightly over time in some years, but generally varied without trend since 2002 (Figure 8).

Number of lines fished

Starting in 2004, data were collected on the number of lines fished by each interviewed fishing party in order to refine estimates of effort. Most anglers reported trolling multiple lines as the preferred fishing method. Each vessel in the combined fleet of charter and private boats trolled an average of 11 lines during the 2006 trophy season. Larger charter vessels generally trolled more lines because of wider beams, use of multiple rod holders and planer boards, and larger fishing parties. The number of lines trolled varied from 2 on small private vessels (18-20 feet in length) to 32 on the largest charter vessels (greater than 30 feet in length).

SOCIO-ECONOMIC DATA

Angler Characterization

States of residence and gender.

In 2006, 139 trips were intercepted and 344 anglers were interviewed during the period April 15-May 15 (Table 5A). Fourteen states of residence were represented in 2006 (Table 11). Most anglers were from Maryland (68%), Virginia (17%), and Pennsylvania (7%), similar to the distribution of states of residence observed during previous years. The majority (92%) of interviewed anglers were male, and only 8% were female (Table 12).

Distance traveled and money spent.

The median distance that anglers traveled to charter boat ports or boat ramps in 2006 was 50 miles one-way, similar to median distance traveled during previous years (Table 13). The median cost of a fishing trip, per person, was $100 in 2006, also similar to the 2002-2005 period (Table 14).

Fishing experience and ranking of trips.

In 2006, interviewed anglers had an average of 18 years of fishing experience for striped bass in the Chesapeake Bay (Table 15). Most anglers (75%) stated that striped bass fishing had improved in the years that they had been fishing (Table 16). The majority of anglers ranked their fishing trip as “excellent” (69%); 16% gave a rank of “good”, 5% “fair”, and 10% “poor” (Table 17). The majority of anglers (54%) ranked the quality of their trip based on the pleasant setting or general atmosphere while fishing (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 (27%), number of fish (11%), or size of fish (8%).

Quality of fishery and satisfaction with regulations.

The majority of interviewed anglers (96%) stated that a quality recreational fishery for striped bass exists in Maryland (Table 19). Most anglers (70%) expressed satisfaction with current regulations (Table 20).

CITATIONS

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

Atlantic States Marine Fisheries Commission. 2002. 2002 Stock Assessment Report For Atlantic Striped Bass. Striped Bass Technical Committee Special Report. October 2002. 36 pp.

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

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

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

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

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

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

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

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

Goshorn D.M., R.K. Schaefer and J.H. Uphoff. 1992. Historical trends in harvest rate and female spawning condition of large striped bass during May. Fisheries Technical Report Series No. 4. Maryland DNR.

Jones P.W. and A. Sharov. 2003. A Stock Size Based Method of Estimating the Spring Coastal Migrant Striped Bass Fishery Harvest Cap in Chesapeake Bay. Maryland Department of Natural Resources, Tawes State Office Building B-2. Annapolis Maryland. 4 pages.

CITATIONS (Continued)

Kernehan R.J., M.R. Headrick and R.E. Smith. 1981. Early life history of striped bass in the Chesapeake and Delaware Canal and vicinity. Trans. Am. Fish. Soc. 110:137-150.

Mansueti R.J. 1961. Age, growth and movement of the striped bass taken in size selective fishing gear in Maryland. Chesapeake Sci. 2: 9-36.

Mansueti R.J. and E.H. Hollis. 1963. Striped bass in Maryland tidewater. Nat. Res. Instit. of the Univ. of Md., Solomons Md. Maryland Dept. of Tidewater Fisheries, Annapolis, Md.

Merriman D. 1941. Studies on the striped bass of the Atlantic coast. US Fish. Wildl. Serv. Fish. Bull. 50: 1-77.

Pearson J.C. 1938. The life history of the striped bass, or rockfish, Roccus saxatilis (Walbaum). Bull. U.S. Bur. Fish., 49 (28): 825-851.

Raney E.C. 1952. The life history of the striped bass. Bingham Oceanogr. Collect., Yale Univ. Bull. 14: 5-97.

Raney E.C. 1957. Subpopulations of the striped bass in tributaries of Chesapeake Bay. US Fish Wildl. Serv. Spec. Sci. Rep. Fish. 208: 85-107.

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

Setzler E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker and J.A. Mihursky. 1980. Synopsis of biological data on striped bass. Natl. Mar. Fish. Serv., FAO Synopsis No. 121. 69 pp.

Snyder D.E. 1983. Fish eggs and larvae. In *Fisheries Techniques, p. 189*. L.A. Nielsen and D.L. Johnson, eds. Southern Printing Co., Blacksburg, Va.

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

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

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

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Table 1. History of MD DNR-Fisheries Service regulations for Maryland striped bass spring trophy seasons, 1991-2006.

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

Table 2. Survey sites for the Maryland striped bass spring season creel survey, 2002-2006. Sites are listed in a clockwise direction around Maryland's section of the Chesapeake Bay. Site numbers with asterisks indicate new sites added in 2006.

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 (Kent Island)	03
Eastern Shore-Middle Bay	Queen Anne Marina (Kent Island)	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 (under Rt. 4 bridge).	*17
Western Shore-Lower Bay	Solomons Island-Harbor Marina (near CBL)	*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 (Charter Boat)	12
Western Shore-Upper Bay	Sandy Pt. State Park Boat Ramp and Beach	11

Table 3. Biological data collected by the Maryland striped bass spring season creel survey, 2006.

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, 2006.

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, from opening day through May 15 of each year.

	Trips Intercepted	Anglers Interviewed	Fish Examined
2002	187	458	503
2003	181	332	478
2004	138	178	462
2005	54	93	275
2006	139	344	464
Total	**699**	**1405**	**2182**

Table 5B. Number of trips, by type (Fishing Mode) intercepted by the Maryland striped bass spring season creel survey, from opening day through 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

Table 6A. Mean lengths of striped bass (mm TL) with 95% confidence limits sampled by the Maryland striped bass spring season creel survey, from opening day 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)

Table 6B. Mean weights of striped bass (kg) with 95% confidence limits sampled by the Maryland striped bass spring season creel survey, from opening day 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)

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

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
Mean	**82**	**87**	**88**

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

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)

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)

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)

Table 10B. Mean catch, effort, and catch per hour, with 95% confidence limits, for private boats only, 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)

Table 10C. Mean catch, effort, and catch per hour, with 95% confidence limits, for charter boats only, 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)

Table 10D. Mean catch, effort, and catch per hour, with 95% confidence limits, calculated from the Maryland Charter Boat log 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)

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

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

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

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

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

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

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

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

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

Figure 1. MDDNR Map showing legal open and closed striped bass fishing areas in Chesapeake Bay during spring trophy season, April 15-May 15, 2006.

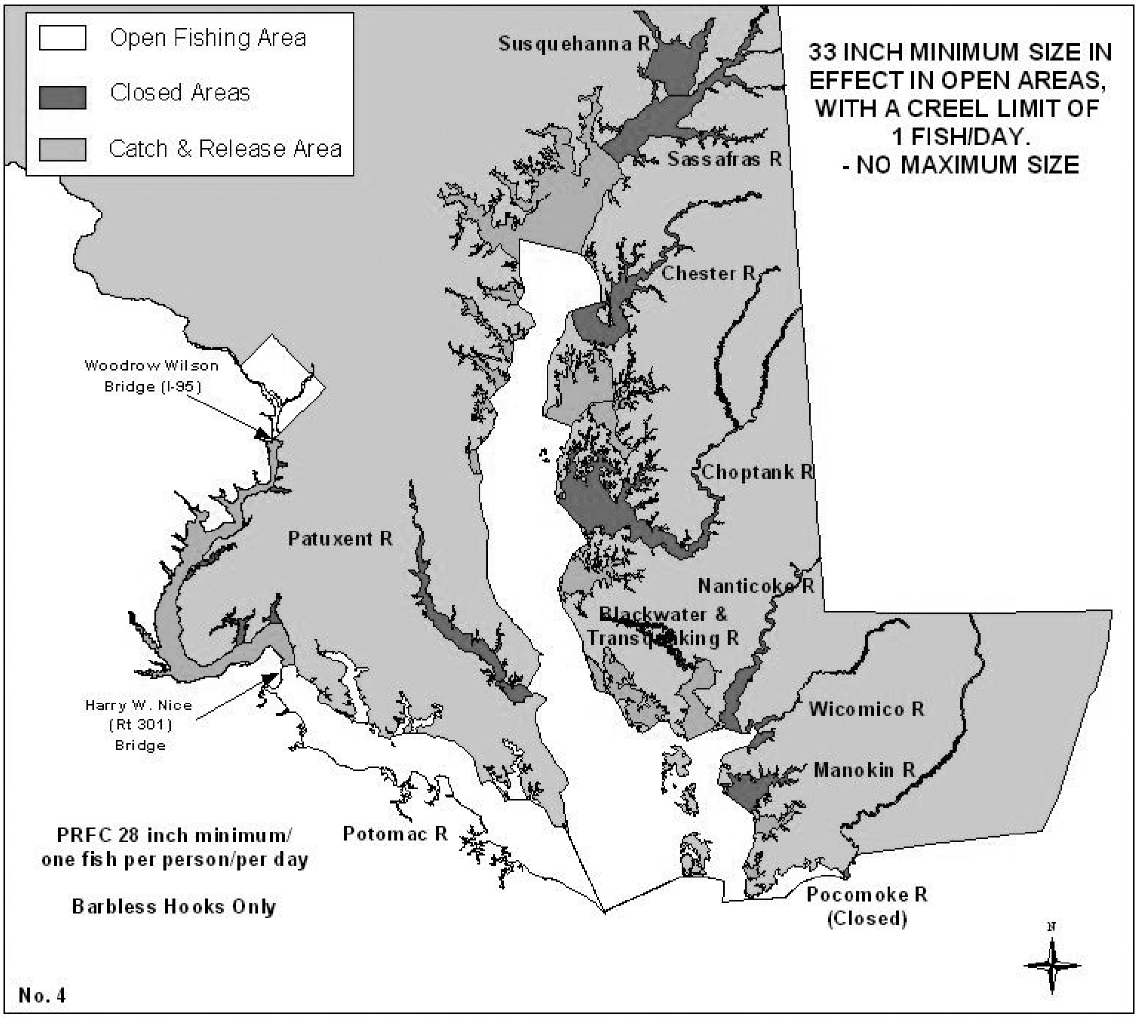


Figure 2. Length distribution of striped bass sampled by year, during the Maryland striped bass spring season creel survey, through May 15.

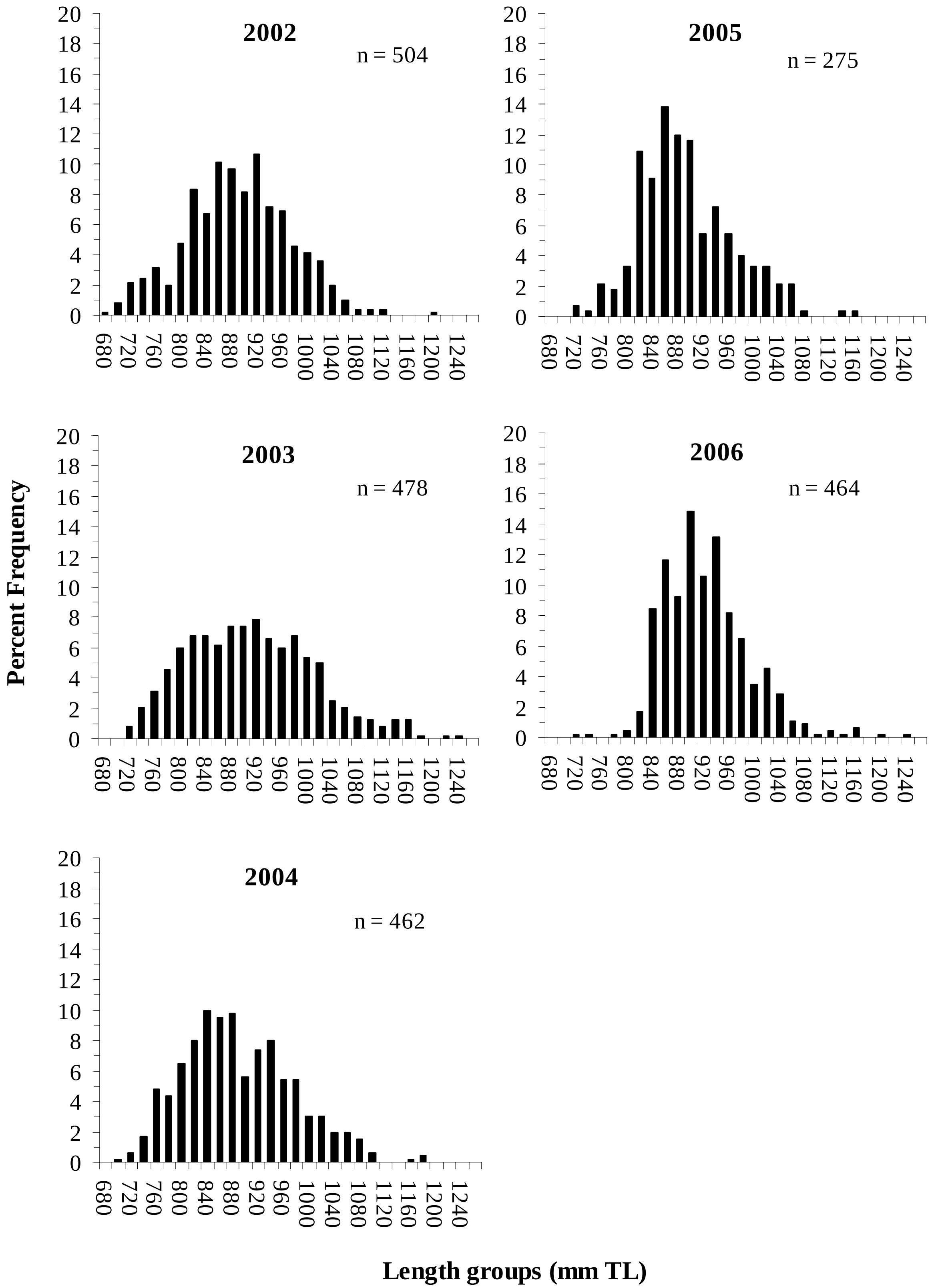


Figure 3. Mean length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

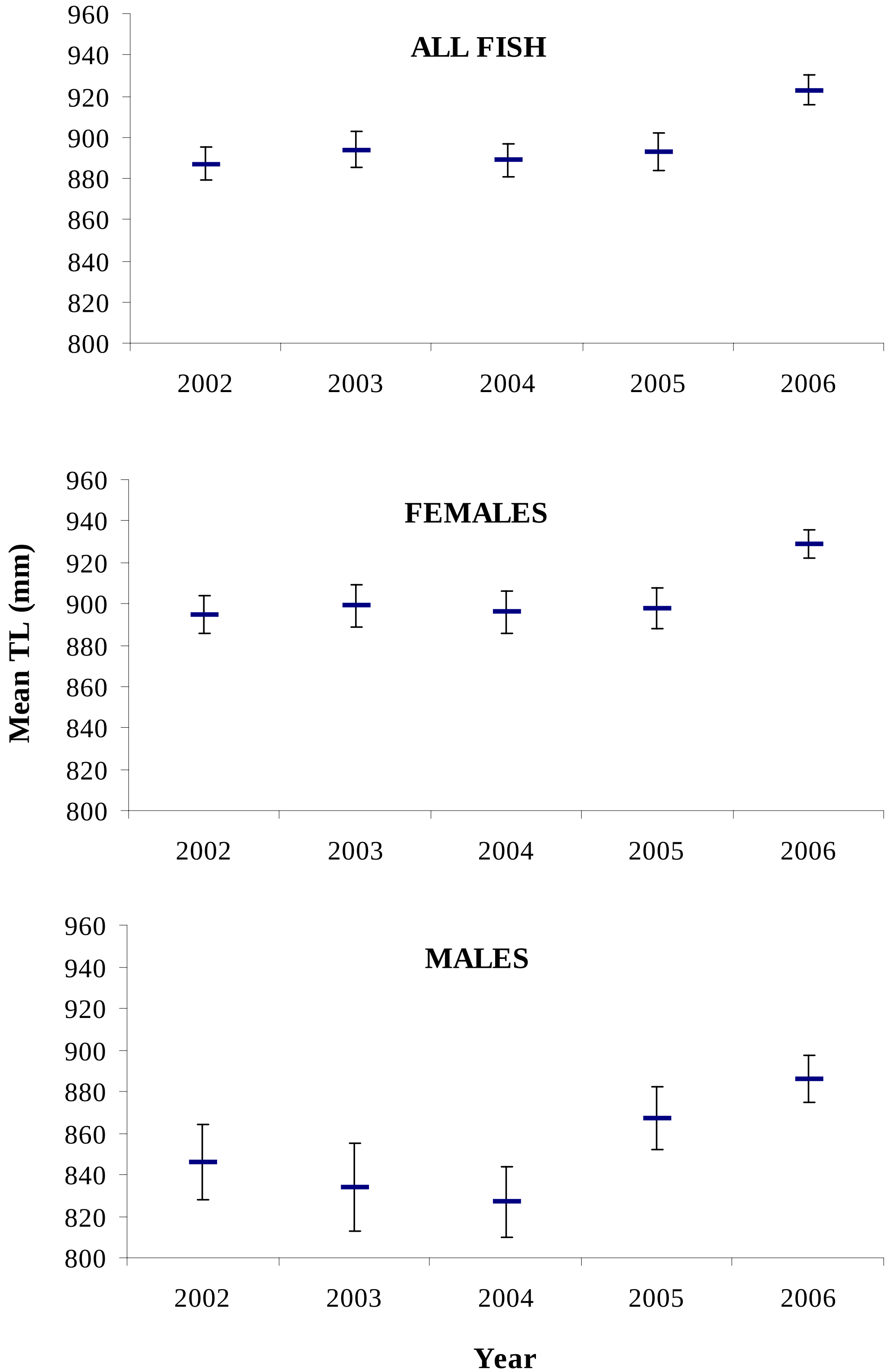


Figure 4. Mean daily length of female striped bass with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

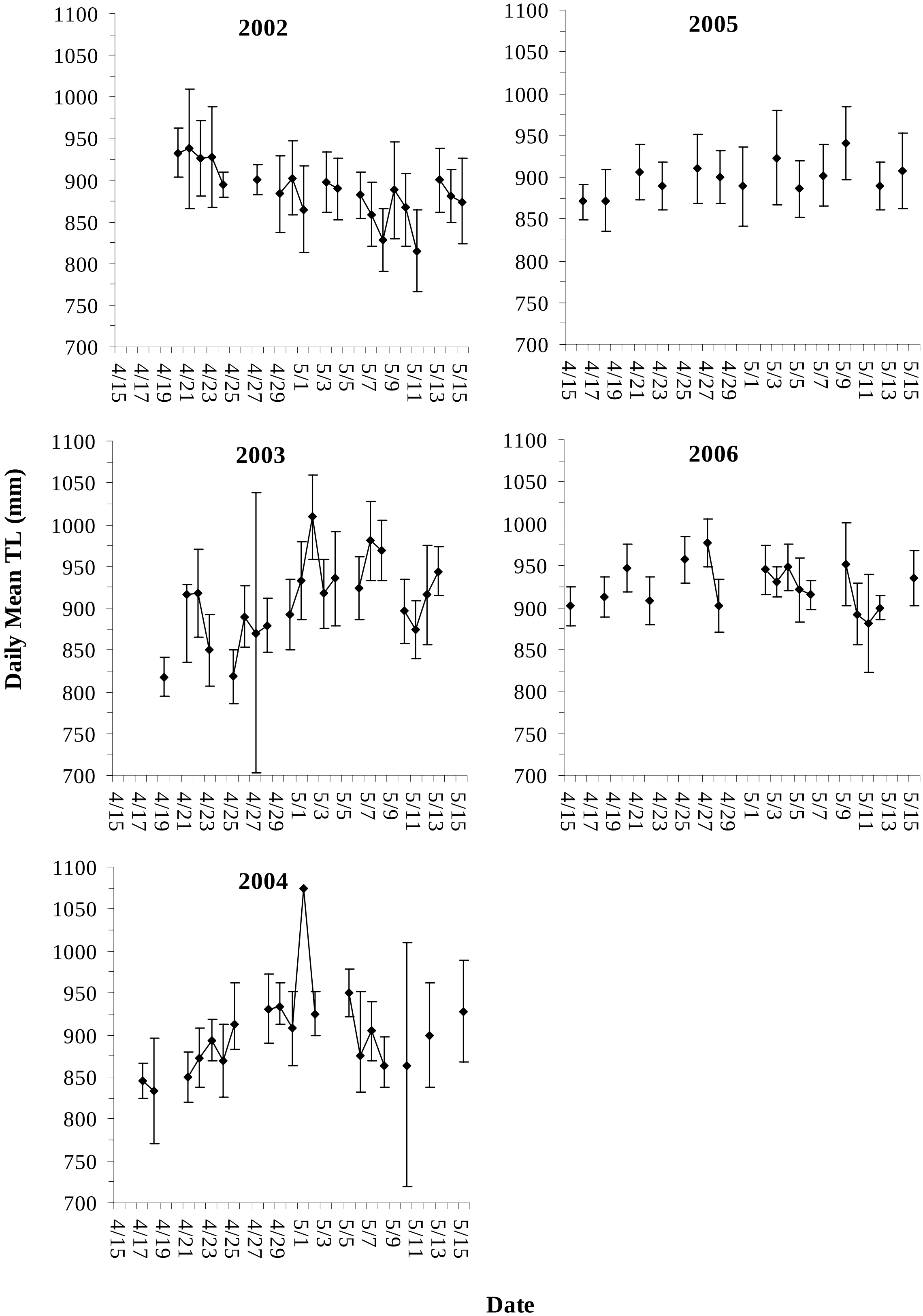


Figure 5. Mean weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey, through May 15.

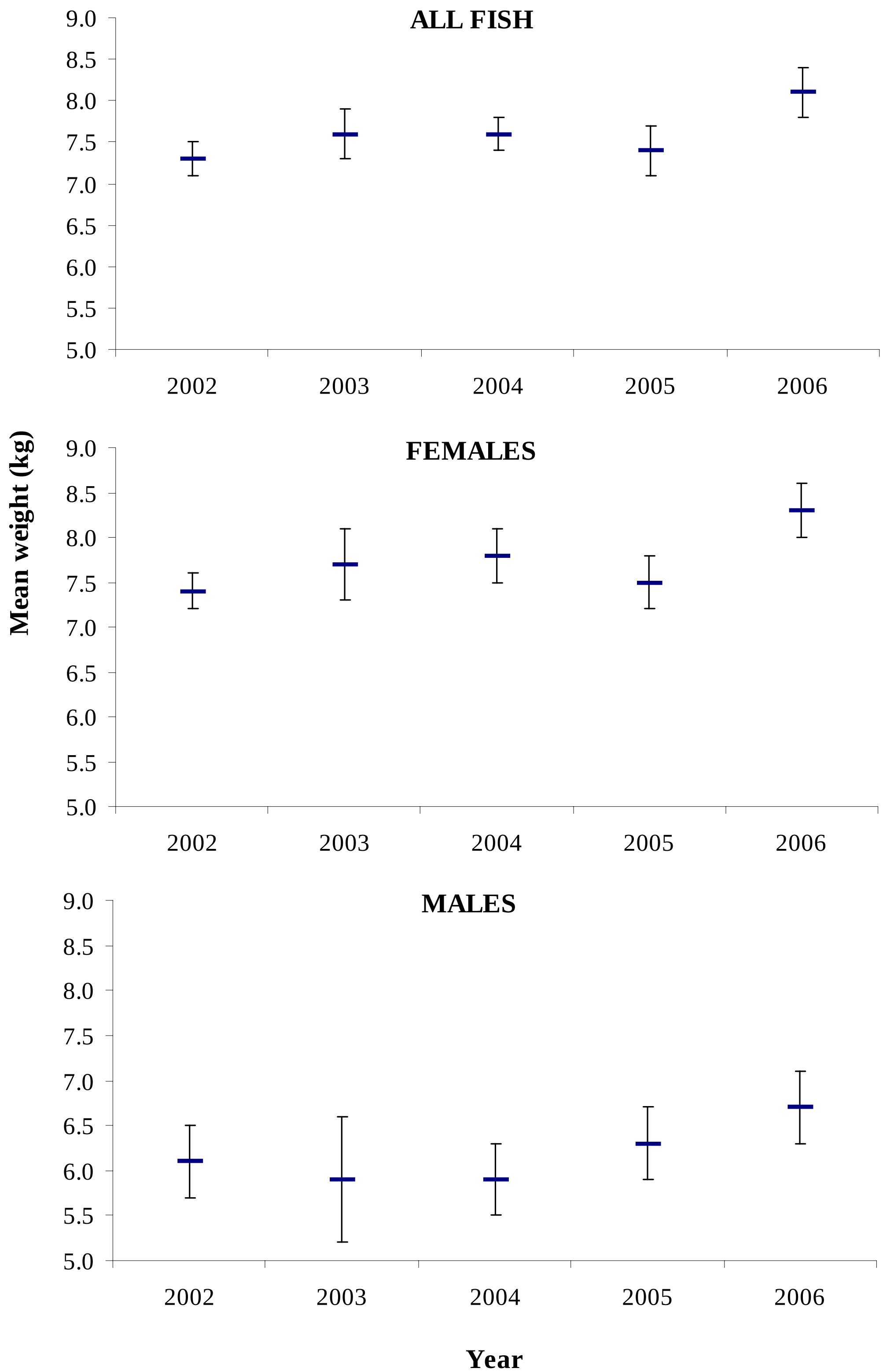


Figure 6. Age distribution of striped bass sampled by the Maryland striped bass spring season creel survey, through May 15.

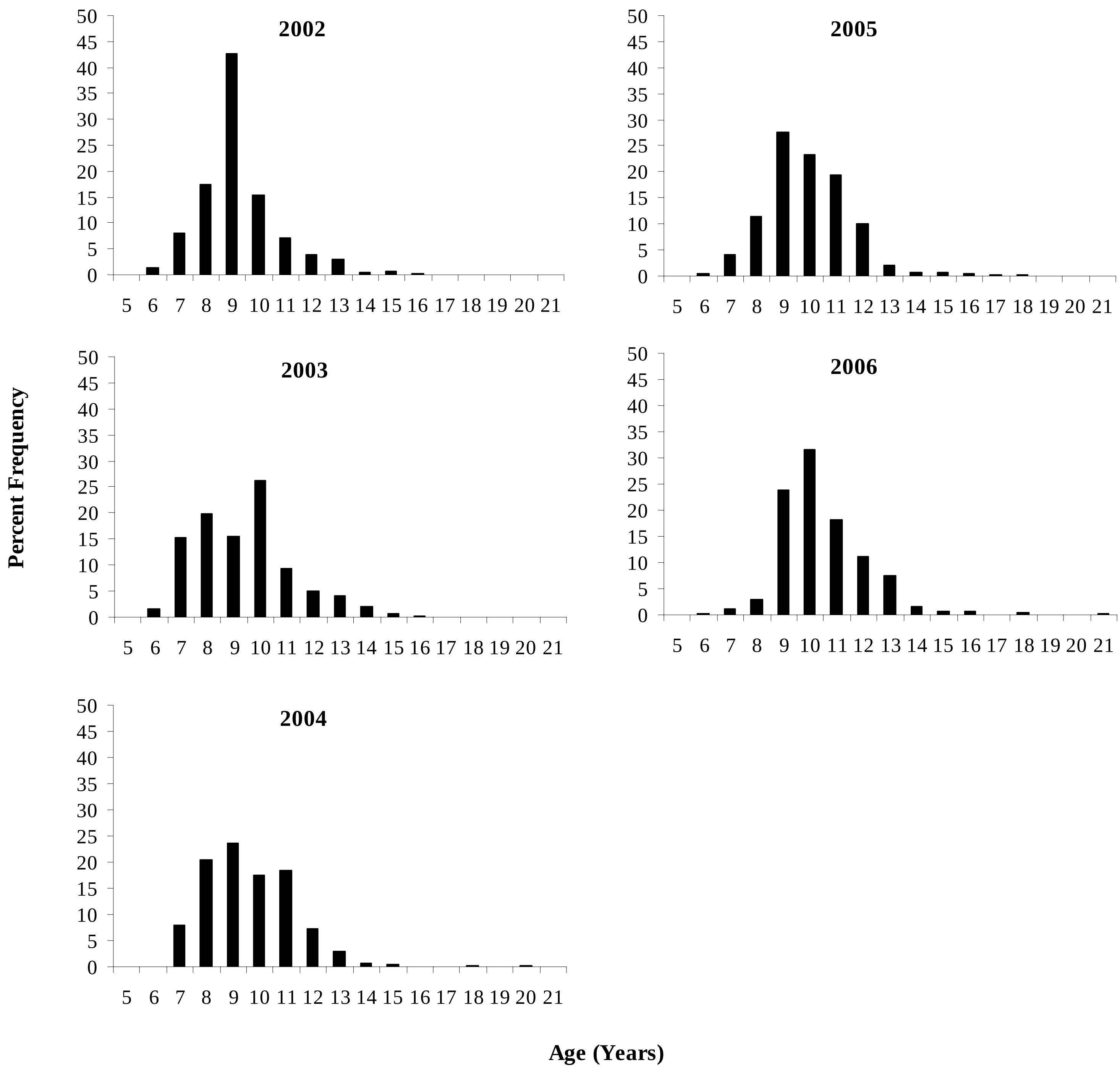


Figure 7. Daily percent of female striped bass in pre-spawn condition sampled by the Maryland striped bass spring season creel survey, through May 15.

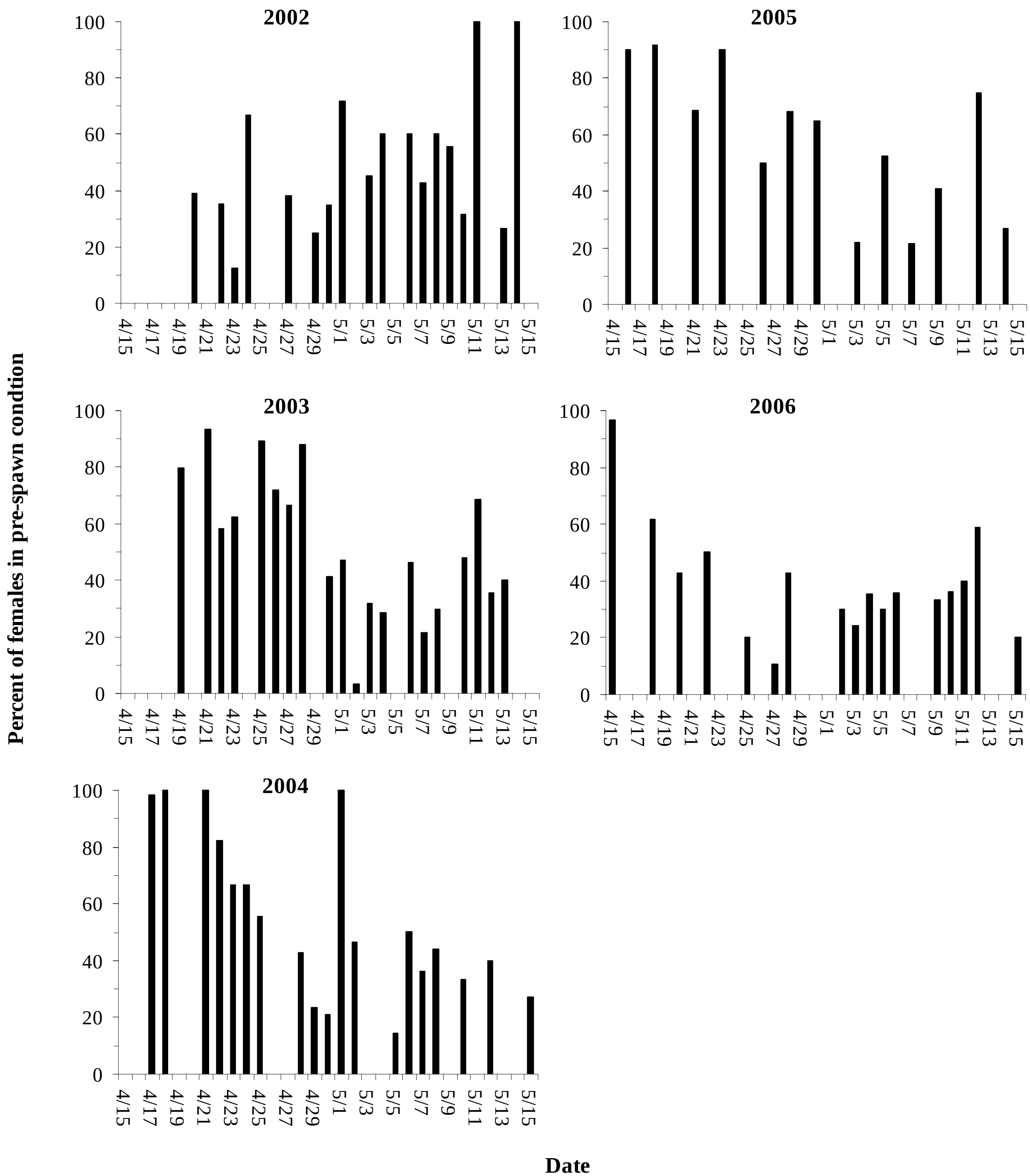
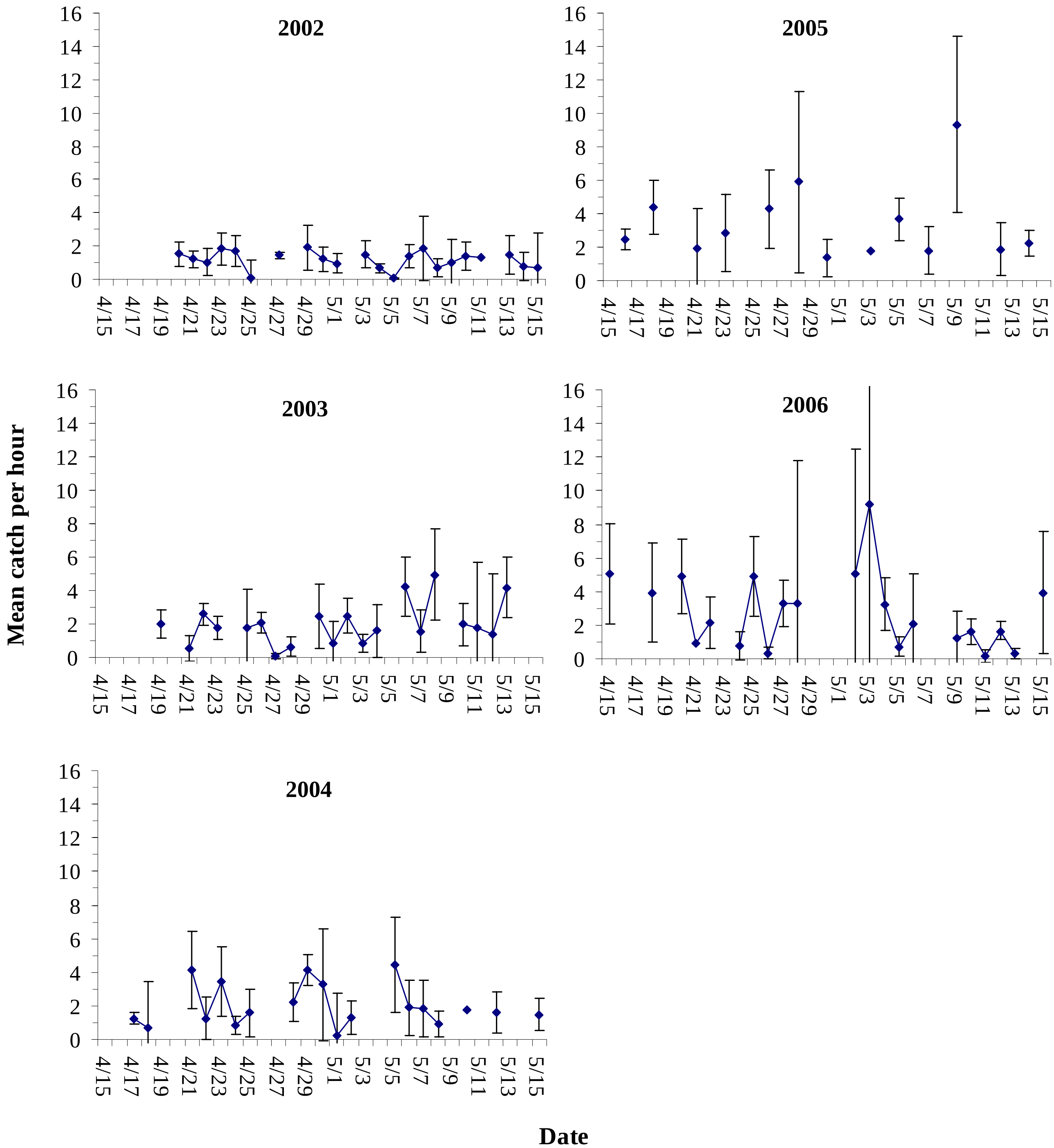


Figure 8. Daily mean catch per hour of striped bass with 95% confidence intervals, calculated from angler interview data collected by the Maryland striped bass spring season creel survey, through May 15.



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. 6

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

Prepared by Erik Zlokovitz and Beth Versak

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) and released in Maryland waters between 1985 and 1995. They are a valuable source of data for validating ageing techniques by direct comparison of hatchery data, scales and otoliths. Since 1986, the search for these fish continued annually, but in recent years very few have been encountered (Versak, 2006). Because striped bass may return to their natal rivers to spawn, sampling efforts for 2006 were focused on the spawning reaches of the Patuxent River where hatchery produced fish were released. By concentrating sampling in this system, the chances of encountering CWT marked fish would be increased.

METHODS

Sampling effort was focused on the freshwater portion of the upper Patuxent River in the area between Spice Creek and Whites Landing (Figure 1) during the time period April 6, 2006 through April 19, 2006. The sampling was designed according to reports of historical abundance of spawning striped bass in this area (D. Cosden, personal communication, MD DNR Inland Fisheries Division) and on catches from surveys conducted in 2003, 2004, and 2005 (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 reach 10-11 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 amps. 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 (the side droppers, or boat itself). The size and effectiveness of the electrofishing field depended on control settings and conductivity of the water. 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 were 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

Of the 71 striped bass scanned for the presence of CWTs on the Patuxent River during April, 2006, two fish (3 % of fish scanned) were found to be CWT positive. Sampling was conducted on three days, with a total effort of approximately 4 hours of actual shocking time recorded on the electrofishing boats (Table 1).

The mean length of all striped bass sampled was 871 mm TL (minimum=716 mm TL, maximum=1150 mm TL, median=886 mm TL). Forty-three females were captured, constituting 55% of the sampled fish. A data summary of the two CWT positive fish is shown in Table 2. These two fish were aged by scale examination at MDDNR and the CWTs were read by USFWS personnel in Annapolis, Maryland. The CWTs showed that both fish were 14 years old, and were released from hatcheries on the Patuxent River in 1992. One fish was under-aged by one year, and one fish was aged correctly by scale examination (Table 2).

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 of age. These 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

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

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

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

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

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Table 2. Hatchery-reared striped bass collected during the electrofishing survey on the Patuxent River, 2006.

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Figure 1. Location of Patuxent River electrofishing sites, April, 2006.

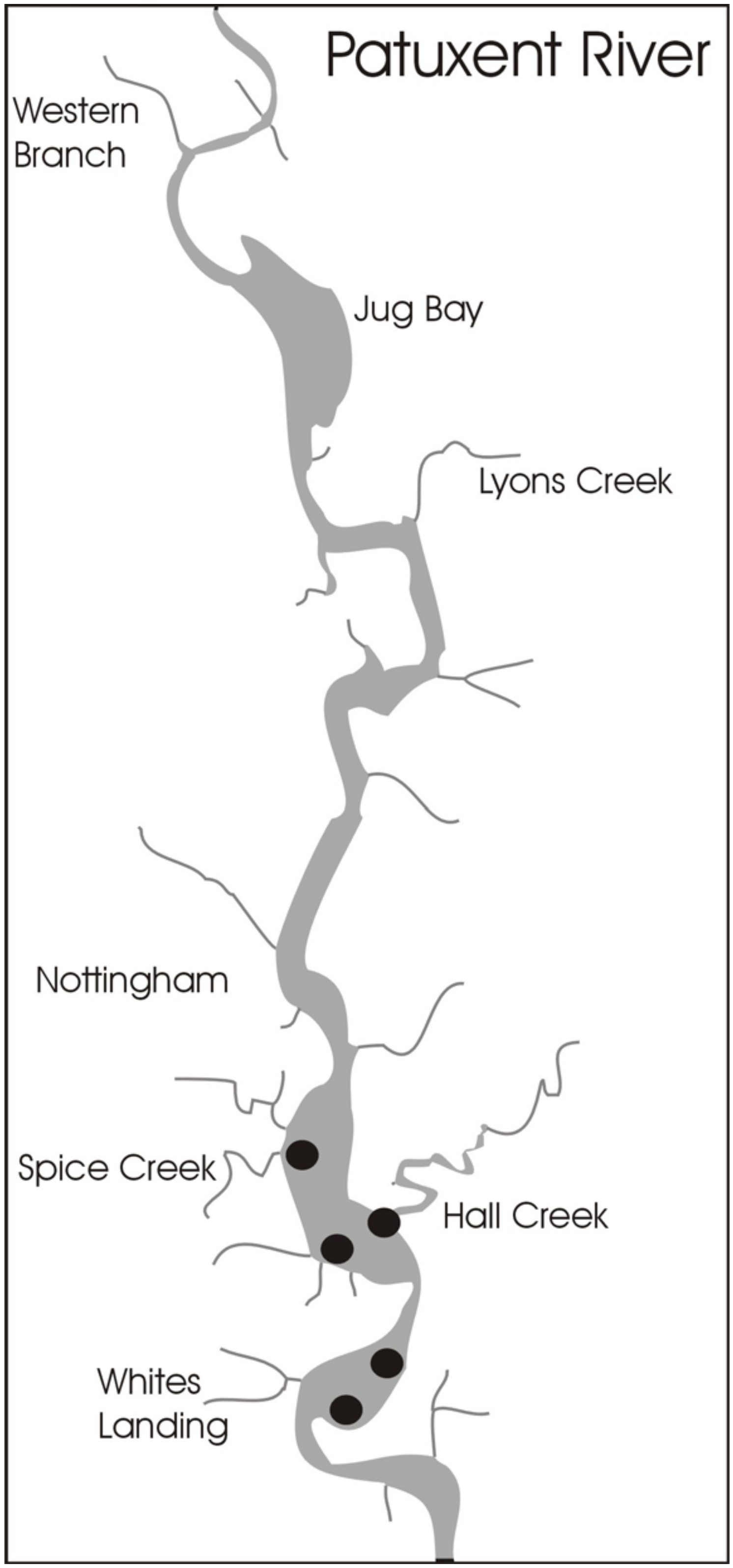
Table 1. Electrofishing survey targeting hatchery-reared striped bass on the Patuxent River, 2006. Data summary by date, for all sites combined.

DATE	# FISH SCANNED	# CWT POSITIVE	TOTAL EFFORT (SECS)	MEAN LENGTH (MM TL)	% FEMALE	% MALE	MEAN WATER TEMP (°C)
4/06/06	32	1	4095	901	59	41	14.0
4/11/06	37	1	6993	902	65	35	14.5
4/19/06	2	0	2350	>750	100	0	19.2

Table 2. Hatchery-reared striped bass collected during the electrofishing survey on the Patuxent River, 2006.

DATE	SITE	TL (MM)	SEX	SCALE YEAR-CLASS	CWT YEAR-CLASS	RELEASE SITE
4/06/06	Hall Creek Flats	885	M	1993	1992	Patuxent River
4/11/06	Spice Creek	1009	F	1992	1992	Patuxent River

Figure 1. Location of Patuxent River electrofishing sites, April, 2006.



PROJECT NO. 2
JOB NO. 4

INTER-GOVERNMENT COORDNATION

prepared by Harry T. Hornick and Eric Q. Durell

The objective of Job 4 was for Survey personnel to participate 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 participates 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.

ASMFC Technical Committee representative participated in the preparation of the ASMFC American shad Stock Assessment Report

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, and determine if a new stock assessment is warranted.

Atlantic sturgeon

ASMFC Technical Committee representative attended the annual Atlantic sturgeon Technical Committee meetings, the Atlantic sturgeon By-Catch Workshop and prepared the ASMFC Annual American sturgeon 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 served as the Technical Committee chairman and produced the required 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 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 Chesapeake Finfish Stock Monitoring Workshop and presented an overview of current fisheries monitoring activities and research.

Project staff participated in the USGS/NOAA Workshop on Mycobacteriosis in Striped Bass.

Striped Bass Data Sharing and Web Page Development

To augment data sharing efforts, the Striped Bass Stock Assessment (SBSA) project staff in 2002 developed a web page within the MD DNR web site presenting historic Juvenile Striped Bass Survey (Job 2, 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. For the period October 2005 to December 2006 the web site averaged over 3240 visits per month (Table 1). 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, October 2005 to December 2006.

Month	Visits
October 2005	2,704
November	2,169
December	N/A
January 2006	2,358
February	2,531
March	3,895
April	3,253
May	3,863
June	3,563
July	3,692
August	3,173
September	3,349
October	3,525
November	3,314
December 2006	3,997

Project staff continue to provide Maryland striped bass data and biological samples to other state, federal, private and academic researchers. These included the US Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), University of Maryland, Virginia Institute of Marine Sciences, Georgetown University, the Pennsylvania State University, the University of Rhode Island, the Hudson River Foundation, and the states of Delaware, New York and Virginia. For the past contract year, (October 1, 2005 through October 31, 2006) the following specific requests for information have been directly 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, charter boat and commercial fishery harvest and CPUE 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 index data.

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

-Dr. Steve Giodano, NOAA, Chesapeake Bay Office.
Provision of striped bass anomaly data.

-Dr. Matthew Hamilton, Georgetown University.
Provision of striped bass scale samples to be used for gene mapping, and cloning of microsatellite markers.

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

-Dr. Karin E. Limburg, SUNY-ESF, Syracuse, NY.
Fisheries dependent and fisheries independent information for anadromous fisheries in MD.

- 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 index data.

-Dr. Daniel McKiernan, Massachusetts Division of Marine Fisheries (MA DMF).
Provision of current striped bass fishery regulations and status of enforcement and biological monitoring activities, and striped bass commercial fishery information.

-Mr. Rob O'Reilly, Virginia Marine Resources Commission.
Provision of current and historical striped bass commercial fishery data; results of fishery dependent monitoring programs and striped bass juvenile index data.

-University of Maryland (U MD - CEES).
Provided nine (9) staff with current striped bass anomaly data, striped bass juvenile index, American shad juvenile index data, commercial landings data, spring trophy season and biological samples.

-The Interjurisdictional Project also provided related biological information and reports to forty eight (48) additional scientists, students and concerned stakeholders.

PROJECT NO. 3
JOB NO. 1

DEVELOPMENT OF HABITAT-BASED REFERENCE POINTS FOR CHESAPEAKE BAY FISHES OF SPECIAL CONCERN IN 2006: IMPERVIOUS SURFACE AS A TEST

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

INTRODUCTION

Fisheries management uses biological reference points (BRPs) to determine how many fish can be safely harvested from a stock (Sissenwine and Shepherd 1987). The primary objective of Project 3 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 (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 the objective of Project 3 in 2003- 2005 and this exploration was continued in 2006.

Land is converted to impervious surface 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 impervious surface occupied more than ten percent 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 is warmer than water draining forests or other porous lands and 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 impervious cover model that expresses the relationship of fluvial stream quality to impervious surface. This model supports the concept of a "ten percent rule" and further describes watersheds with 11-25% impervious cover as impacted and those with more than 25% as unable to support freshwater aquatic life (Cappiella and Brown 2001). Beach (2002) has proposed a "ten percent rule" for impervious surface in a watershed; crossing this development threshold leads to impairment of freshwater stream function and deterioration of its biota. Measurable adverse physical and chemical changes in tidal creek ecosystems were described by Holland et al. (2004) when impervious cover exceeded 10-20% and living resources responded when impervious cover exceeded 20-30%. A strong relationship between impervious surface and dissolved oxygen was found during 2003-2005 in the Chesapeake Bay tributaries that were sampled by this project (McGinty et al. 2006).

Dissolved oxygen (DO) is an ideal habitat variable to study because fish require well-oxygenated water and it provides insight into both the metabolic and pollution status of a waterbody (Limburg and Schmidt 1990), and it is easily measured in the field. 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 fish reproduction could be caused by anthropogenic chemicals (Colborn and Thayer 2000), persistent hypoxic oxygen conditions (Rudolph et al. 2003), and alteration of hyrdrologic features in streams (Konrad and Booth 2005) needed for anadromous fish spawning habitat. 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).

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 impervious surface. Strong, negative relationships between impervious surface and freshwater biotic communities and the threshold concept has been supported by McGinty et al. (2006) in brackish sub-estuaries of Chesapeake Bay. However, ocean waters or large volumes of out-of-basin freshwater (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 impervious surface thresholds higher.

Impervious surface 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 impervious surface 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 impervious surface on specific finfish populations would give 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 2006 included further evaluation of data collected in previous years, 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 improve our understanding of habitat degradation effects 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 impervious surface on target fish species populations and habitats.

METHODS

Impervious Surface Estimates

Table 1 summarizes percent impervious surface (IS) cover, non-water watershed area, and tidal water surface area estimates for watersheds sampled in 2006. Estimates for Bush River, Corsica River, and Mattawoman Creek were from the University of Towson 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). Impervious surface estimated for Tred Avon River was from King et al. (2004) because an estimate for this watershed was not available elsewhere. Remaining estimates were based on Maryland Department of Planning (or MDDOP 1994a) estimates available from Surf Your Watershed: 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. 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.

Upper-Bay Sampling Areas

The Bohemia River, a watershed of 26,502 acres with 2,666 surface acres of tidal water, is located on Maryland's Eastern Shore in Cecil County (Figure 2). Its predominant land use is agriculture with 64% of its watershed being used for that purpose. The remaining land use consists of forests cover (21%), wetlands (9%), and urban (6%). Impervious surface covers 0.7% of the watershed.

The Bush River, a watershed of 36,964 acres with 7,966 acres of tidal water) is located on the western shore north of Baltimore. It had the second highest level of impervious surface (12.8%) of all rivers sampled this year. It is predominately forested (48% of the watershed) with urban areas comprising 24% of the watershed, agriculture, 22% and wetlands, 6% (Figure 3).

Mid-Bay Sampling Areas

Corsica River, a tributary of the Chester River, has a watershed of 23,924 acres of which 4.0% is impervious surface (Figure 4). Tidal water comprised 1,256 acres. Approximately 65% of the watershed is in agriculture, 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 Corsica River restoration is available at (http://www.mde.state.md.us/ResearchCenter/Publications/General/eMDE/vol2no3/corsica.asp).

Fishing Bay, located on the Eastern Shore, was the largest watershed sampled this year at 98,060 acres (Figure 5). It has 19,038 acres of tidal water. Wetlands and forests each represented 41% of the watershed. Agriculture occupies 15% of the watershed and urbanized areas 1%. Impervious surface accounts for 0.8% of the watershed.

Langford Creek, a tributary of the Chester River, is located in on the Eastern Shore. Its confluence with the Chester River lies directly across from the mouth of the Corsica River (Figure 6). Its watershed (0.9% IS) is very similar in size (23,871 acres with 2,905 acres of tidal water) and land-use to Corsica River. Agriculture occupies 69% of the watershed; forests occupy 26%; urban areas comprised 4%; and wetlands, 1%.

Tred Avon River is a tributary of the Choptank River on the Eastern Shore (Figure 7). Its watershed comprises 23,518 acres and tidal waters occupy 4,338 acres. Agriculture comprised 39% of the watershed; forest, 38%; urban land, 22%; and wetlands less than 1%. Impervious surface covers 5.6% of the watershed.

Potomac Sampling Areas

Two tidal-fresh tributaries of the Potomac River were sampled in 2006. Mattawoman Creek's watershed is 60,300 acres and has 8.5% IS. Forest occupies 63% of the watershed; urban areas, 22%; agriculture covers 14%; 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 contains 16.7% IS. 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 or sets containing a target species and life stage. Interpretation of absence can pose interpretation problems (Green 1979) and sampling and analyses were generally designed to confine presence-absence to areas and times where species and life stages in question had been documented.

Estuarine Larval Presence-Absence Sampling

Yellow perch larval presence-absence sampling was conducted in the upper tidal reaches of Bush, Corsica, and Severn rivers 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 was used to collect larvae at 10 sites per system on 2-3 days each week in the upper estuaries (Figure 10). Sites were sampled with little spacing between tows because the larval nurseries were small. Extent of area sampled was determined from larval presence in surveys conducted during the 1970s and 1980s (O'Dell 1987). 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 during nine dates between March 27 and April 27, 2006.

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 brought back to the lab for sorting.

The proportion of tows with yellow perch larvae (L_p) was determined annually for dates spanning the first catch through the last date that larvae were consistently present. Uphoff et al. (2005) reviewed presence-absence of yellow perch larvae in past Choptank and Nanticoke River collections and found that starting dates during the first or early in the second week of April were typical and end dates occurred during the last week of April through the first week of May. Sampling during 2006 was designed to begin by the first full week of April and ended after larvae were absent for two consecutive sampling rounds. Confidence intervals (95%) were constructed using the normal distribution to approximate the binomial distribution (Uphoff 1997).

Yellow perch larval presence-absence in the tidal Bush, Corsica, and Severn rivers was compared to a record of L_p developed from historic data collected in the tidal Nanticoke (1965-1971) and Choptank rivers (1986-1990 and 1998-2003), collections in the Nanticoke River during 2004-2006 (See Job 1), and Severn River during 2001-2005. Severn River collections during 2004-2005 used identical methods employed in 2006; a composite estimate for 2001-2003 (plotted as 2002) was formulated because annual sampling was inadequate during these years (Uphoff et al. 2005). 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 in the same manner used for striped bass eggs (Uphoff 1997). 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 Choptank and Nanticoke rivers are described in Uphoff (1997).

Choptank River and Nanticoke River collections made prior to 1991were 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. 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).

Salinity (‰) and temperature data (°C) collected during 2006 were compared to requirements of yellow perch larvae (Piavis 1991) to determine the extent and duration of suitable habitat. Negative impact was inferred from any measurement not meeting the habitat requirements and the suitability of each parameter was indicated by the percentage of measurements not meeting the requirement. Temperatures > 20 °C and salinity > 2 $^{o}/_{oo}$ were considered detrimental. Means and standard errors (SE) of all temperature and salinity measurements (all dates and sites) were estimated for each system.

Bush River Stream Ichthyoplankton Sampling

During 2006, sampling and analysis of Bush River stream anadromous fish spawning was designed to be comparable with 1973 collections (O'Dell et al. 1975). O'Dell et al. (1975) only reported whether an anadromous fish species was present in a stream or not (captured by any technique at least once).

We added sites in 2006 on an adjacent, less developed military installation (Aberdeen Proving Ground or APG) to determine if development of the Bush River watershed could possibly explain changes in spawning distribution. APG is a military installation and has been largely protected from development since the initial (historic) study that was conducted in 1973 (Figure 11; O'Dell et al. 1975). If development in Bush River was reflected by diminished anadromous fish habitat occupation, then differences in anadromous fish presence-absence between the developed Bush River (less like 1973) and APG (more like 1973) should have been evident. This analytical approach approximated an experiment in a single watershed with control (little change in land use) and experimental (considerable change in land use) treatments.

Twelve stations in the Bush River watershed where anadromous fish spawning was documented in 1973 (O'Dell et al. 1975) were sampled with plankton nets during 2006; six of these stations were also sampled with fish traps. Three stations in Swan Creek and four stations on APG where anadromous fish spawning was documented in 1973 were also sampled (Figure 11).

Ichthyoplankton samples were collected from weekly 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 the Chesapeake Bay National Estuarine Research Reserve. 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 mason 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 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 each week during March 20 through May 15, 2006.

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 0.61 m 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. Traps could not be set in APG streams because of base restrictions.

Change in anadromous spawning in Bush River and APG streams between 1973 and 2006 was estimated by comparing the actual number of sites where spawning was detected in either 1973 or 2006 with potential spawning. Potential spawning was estimated as the sum of sites (counting each potential site only once) where spawning was detected in either year. We calculated the proportions of plankton drift net sets that contained an anadromous fish egg or larvae during 2006 and their 95% confidence intervals (CI; Ott 1977) for the Bush River and APG sites after eliminating three sites that did not have eggs or larvae present in either 1973 or 2006. Presence of anadromous fish spawning was plotted onto land-use. Impervious surface in Bush River and APG drainages during 1973 and 2002 was estimated by applying impervious coefficients (Zielinski, 2002) to 1973 and 2002 land cover data (Maryland Office of Planning, 1994b, 2002). These estimates were rescaled to be proportional to the 12.8% IS University of Towson estimate for Bush River watershed.

Summer Estuarine Seining and Trawling

During 2006, we changed from many of the watersheds sampled during 2003-2005 to (1) better define the relationship of impervious surface, 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 2006 were Mattawoman Creek, Piscataway Creek, Bush River, and Bohemia River (Figure 1); impervious surface was estimated to cover about 1-16% of these watersheds. Corsica River, Tred Avon River, Langford Creek, and Blackwater/Fishing Bay were brackish water (greater than 2‰) tributaries located on the Eastern Shore that were estimated to have less than 6% impervious surface (Table 1). Corsica River, Tred Avon River, and Blackwater/Fishing Bay are located near towns that are undergoing development (Centerville, Easton, and Cambridge, respectively). Langford Creek was selected as a control system (particulary for 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 which had three sites, and Fishing Bay which had five sites. Variation in number of sites reflected the size of systems studied. 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.

We originally planned on sampling the Blackwater River only, but its sharply defined channel precluded seining and heavy detritus loads made trawling for six minutes unachievable at most sites. After two attempts at sampling the Blackwater River, we moved to Fishing Bay. Fishing Bay receives the Blackwater River and was sampled in the early 1990s (Carmichael et al. 1992).

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 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 (units) 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.

Trawling and seining were used to sample fish. Target species were striped bass, yellow perch, white perch, alewife, blueback herring, alewife, 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 X 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 2004), was used to sample inshore habitat. The float-line was rigged with 38.1 mm X 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. 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, the maximum depth of the seine area, 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.

Data Analysis of 2006 Collections

Water quality data were compared to fish habitat criteria (Table 3) 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.

We analyzed white perch size class relative abundance in tidal-fresh areas. White perch presence-absence was responsive to impervious surface, they were prevalent in our samples, and represented the most widespread gamefish available to anglers in a tributary (McGinty et al. 2006). Proportion of tows with white perch in a size category (juvenile < 100 mm, small adults 100 – 200 mm, and large, harvestable adults ≥ 200 mm) sampled by trawling in the tidal-fresh watersheds was plotted against impervious surface of the watershed. The 200 mm minimum for harvestable white perch corresponded to the lower bound of the quality-sized increment in Relative Stock Density analysis (Piavis and Webb 2006).

A Shannon-Wiener Index (S-W Index) was developed to compare species diversity among trawl and seine collections in the eight watersheds (Krebs 1972). Trawls sampled all watersheds, but seining could not be conducted in Mattawoman and Piscataway creeks because of dense aquatic vegetation. The S-W Index was calculated for each gear as –(P_i)*(Log_2 P_i); where, P_i = proportion of species i in the community (the number of individuals of species i is divided by the total number of individuals in community). S-W indices increase as both richness and evenness increase (Krebs 1972). Seine or trawl S-W indices were regressed against impervious surface.

The influence of IS on total number of species (T_w) collected by trawl was explored. First, sensitivity of total number of species (T_w) collected by trawl in a watershed to sampling effort was examined by regressing T_w against total number of trawls (N_w). An additional variable was added to the regression; the number of species comprising 90% of the catch (S_w) after a preliminary plot indicated that some systems trawl samples were dominated by one species (white perch) while the remainder were dominated by 3-6 species. Residuals were then plotted against IS to explore its effect on T_w for brackish and fresh-tidal systems.

Data Analysis of 2003 – 2005 Collections

This analysis was originally developed for a presentation at the 2006 American Fisheries Society Meeting after last year's annual report (McGinty et al. 2006) and we felt it was a significant development that should be reported. Data were evaluated to test the effects of impervious surface on target species presence-absence. The relationship of the proportion of bottom tows (P_i) with species *i* (white perch, striped bass, and blue crab in this case) with impervious surface was explored using linear regression. These species were chosen because they were among the most abundant species captured, they were present in all systems sampled, were important commercially and recreationally, and were species readily identifiable to stakeholders.

A nonlinear response of P_i to DO levels among these species was illustrated by estimating P_i in 2003-2005 bottom trawl collections within 1 mg/L DO increments and then fitting a nonlinear Weibull function (Prager et al. 1989) to P_i versus DO midpoint using Proc NLIN in SAS (Gauss-Newton algorithm). An initial solution was estimated using Solver in Excel. This regression used P_i of the three species in a single analysis after inspection of the initial plot did not suggest species-specific responses. The Weibull model described the increase in P_i as an asymmetric, asymptotic function of DO category: $P_i = K\{1 - \exp[-(DO / S)^b]\}$; where K is the asymptotic P_i as DO category approaches infinity; S the value DO at which $P_i = 0.63 \times K$; and b is a shape factor (Prager *et al.* 1989).

RESULTS AND DISCUSSION

Estuarine Yellow Perch Larval Presence Absence

Proportions of tows with larval yellow perch in tidal Severn River (L_p = 0.27, SD = 0.05; 17.0 % IS), Corsica River (L_p = 0.47, SD = 0.06; 4.0% IS), and Nanticoke River ((L_p = 0.35, SD = 0.09; 1.2% IS; Uphoff et al. 2005) were below the reference systems' historic mean L_p (0.66; Figure 12). Proportions of tows with larval yellow perch in Bush River (L_p = 0.79, SD = 0.05; 12.8% IS) was above the reference systems' historic mean (Figure 12). The risk of falling below the "typical" historic minimum of $L_p = 0.4$ was 98% in Severn River, 12% in Corsica River, near 0% in Bush River, and 62% in Nanticoke River.

Impervious cover was a poor predictor of L_p in the tidal tributaries during 2006; however, measurements of L_p from Severn River since 2001 have averaged about half (0.26) of L_p from the Nanticoke River during the same period (0.50; Figure 13). Severn River has consistently ranked last of systems studied since 2001. Only 1 of 9 historic collections from the two reference systems was as low as Severn River during 2001-2006 (Figure 13).

Estimated L_p in Severn River was based on seven collection dates during March 28-April 18, 2006 (N = 70); samples were also collected on April 21 and 28, but larvae were not present and these dates were removed from calculations. Larvae were collected at the uppermost six stations. Temperatures were always below the habitat requirement (< 20 °C), while salinity (mean = 7.59 $^{o}/_{oo}$, SE = 0.76) was never optimal (< 2 $^{o}/_{oo}$).

Larvae were present at all 10 stations in Bush River during March 29 - April 19, 2006 (N = 70). Larvae were not present during additional collections during March 27, April 25, and April 27; these dates were excluded from analysis. Temperature (90 measurements) and salinity (89 of 90; mean = 0.82 $^{o}/_{oo}$, SE = 0.05) were within the habitat requirement range. Bush River is very close to the Susquehanna River and could receive a large amount of freshwater input from outside its watershed.

Larvae were present at 9 of 19 stations in the Nanticoke River during 2006. They were collected on April 3, 7, and 10; samples collected during April 13 and 17 did not contain larvae but were included in the calculation of L_p. Inclusion of these dates provided continuity with end dates of past surveys (Uphoff et al. 2005). Sampling conducted during April 20, 24, and 28 was not used to estimate L_p. Four downstream stations and the uppermost station in Marshyhope Creek were sampled, but not included in the estimation of L_p because yellow perch larvae were never collected. L_p was estimated from 31 samples representing suitable temporal and spatial conditions. All temperature measurements were within the habitat requirement (N = 67, mean = 16.09 °C, SE = 0.24), but 20 of 67 salinity measurements (mean = 1.45 $^{o}/_{oo}$, SE = 0.18) exceeded the habitat requirement.

When confined to 2006 data alone, L_p did not seem sensitive to impervious surface. It may be necessary to accumulate time-series to determine the pattern in L_p. Severn River L_p has ranked last since consistent sampling was initiated in 2004 and pooled 2001-2003 data did not indicate a different result (Figure 13). The range of L_p in Severn River during 2004-2006 (0.27-0.33) has been much lower than observed in the Choptank and Nanticoke reference systems during the reference period (0.35-0.67; Figure 13).

Interpretation of annual L_p was clouded because multiple processes were represented. Measurement of L_p integrates the product of egg production, and egg and 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. 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.

Our judgment of L_p in the tributaries during 2006 was based upon comparisons with rural Eastern Shore systems because long time-series did not exist for our non-reference systems. These reference rivers have larger watersheds and more extensive regions of fresh-tidal water than the brackish tributaries (Severn and Corsica rivers) we sampled. Uphoff et al. (2005) cautioned that comparability of smaller brackish tributaries with rural Eastern Shore reference systems could be biased. However, fresh-tidal Bush River exhibited high L_p in 2006, while the Nanticoke River fell within the low estimates of the Corsica and Severn rivers.

Salinities within Severn and Corsica rivers' estuarine nurseries were nearly always too high for eggs and larvae during the dry spring of 2006. Since 2001, the Severn River's estuarine larval nursery has been characterized by frequent violations of the salinity criterion of $2^{o}/_{oo}$, even though annual conditions ranged from extremely dry to extremely wet (Uphoff et al. 2005). Limited historic descriptions of upper Severn River salinity suggested that the nursery was less brackish ($2.5^{o}/_{oo}$ or less) in the 1950s through the 1970s than at present (Uphoff et al. 2005). Salinity was $3.8\text{-}4.4^{o}/_{oo}$ during 1977 when the same region of Corsica River was sampled (2006 mean salinity = $5.6^{o}/_{oo}$; O'Dell 1987). As development increases, rainfall flows faster across the ground and more of it reaches fluvial streams rather than recharging groundwater (Cappiella and Brown 2001; Beach 2002). In natural settings, very little rainfall is converted to runoff and about half is infiltrated into underlying soils and the water table (Cappiella and Brown 2001). These pulses of runoff alter stream flow patterns and could be at the root of the suggested change in salinity at the head of the Severn River estuary (Uphoff et al. 2005). Increased use of road salt to de-ice roadways, especially in high IS areas, has lead to increases in salinity in freshwater streams in the northeastern US (Kaushal et al. 2005). Mortality related to salinity may offer a partial explanation of variation in L_p among tributaries studied in 2006. Mortality of yellow perch eggs and prolarvae in experiments generally increased with salinity and was complete by 12‰ (Sanderson 1950; Victoria et al. 1992). Average mortalities of eggs placed in aquaria at about 15ºC containing Severn River water with mean salinities of 0.0‰, 5.5‰, and 11.7‰

were 33%, 54%, and 100%, respectively (Sanderson 1950). Laboratory experiments with yellow perch eggs and prolarvae from Sassafras, Severn, and Wicomico (western shore) rivers indicated complete mortality of both life stages at approximately 12‰ (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‰. Abnormal behavior of larvae held for about a week at 8‰ suggested that delayed mortality would occur. Severn River prolarvae generally grouped into the highest mortality group and Wicomico River (≈ 2% IS) typically displayed the lowest mortality regardless of salinity treatment (Victoria et al. 1992).

Bush River Stream Sampling

Comparisons of present and historic data suggested deterioration of anadromous fish spawning and larval habitat in the streams of the Bush River watershed over the last thirty years. O'Dell et al. (1975) determined that white perch, yellow perch, alewife, and blueback herring spawned in the watershed. McGinty (2006) found Bush River stream sites that supported white perch and yellow perch spawning in 1973 no longer did so in 2005. Impervious cover represented 8.7% of the Bush River watershed in 1973 and 12.8% in 2002.

Overall, anadromous fish spawning (white and yellow perch, and herring) in 2006 was more likely to occur at sites in the low development portion of the watershed (APG; 3.5% IS) than in the highly developed portion (12.8% IS). Nine of 11 potential stream occupations (site and anadromous species combinations) indicated by historic collections occurred on APG property during 2006, while 8 of 22 occurred in the streams in Bush River watershed. During 1973, 10 of 11 potential stream occupations occurred in APG streams and

16 of 22 occurred in Bush River streams. The proportion of samples during 2006 with anadromous fish eggs or larvae present was 0.075 (N = 120; SD = 0.024) in Bush River and 0.393 (N = 28; SD = 0.092) in APG (3.5% IS).

During 1973, white perch were present at 8 Bush River sites and 4 APG sites (O'Dell 1975). In 2006, white perch were absent from Bush River streams, but were observed at 3 sites on APG (low IS watershed; Figure 14). Seven Bush River and 4 APG sites were potential spawning locations.

In 1973, yellow perch spawning was indicated in 4 Bush River sites and 3 sites had yellow perch present in 2006 (one occupied historically and two new sites; Figure 15). Six Bush River sites and 3 APG sites had potential for spawning. Two sites on APG property had yellow perch spawning in 2006 (out of 3 historically; Figure 15). Samples from APG streams contained numerous yellow perch larvae, while Bush River samples would commonly contain single larvae.

Herring (alewife and/or blueback herring) were observed at 5 Bush River and 4 APG stations in 1973 (Figure 16). In 2006, 5 Bush River stations had herring present and only 2 were in common with 1973. Herring spawning was detected at 4 APG stations during 1973 and 3 in 2006. Nine sites in Bush River and 4 APG sites were potential spawning sites (Figure 16). Herring were not observed in Winter's Run, the largest subwatershed of Bush River. Historically this basin supported a large run of herring. A fish ladder was installed in 1990 on Winter's Run to aid in fish passage, however the number of fish passed has drastically declined (Jim Thompson, MDDNR, personal communication).

These changes in spawning distribution were largely a reflection of diminished habitat. Estimates of Head-of-Bay biomass of white perch (Piavis and Webb 2006) and yellow perch (J. Uphoff, unpublished assessment) in recent years (through 2004) were high and juvenile indices (http://www.dnr.state.md.us/fisheries/juvindex/) have been as high or higher than in the early 1970s. Alewife and herring populations in the Head-of-Bay may be at lesser status; catch-per-effort at the Conowingo Dam fish lifts were very low during 2003-2005 (R. Sadzinski, MD DNR, personal communication), and juvenile indices were moderate to low since 2000 (http://www.dnr.state.md.us/fisheries/juvindex/).

Box and whisker plots of stream water quality were plotted to determine if there were apparent difference between sites where anadromous fish eggs, larvae, or adults (anadromous spawning) were present or absent (Figure 17). Anadromous spawning was present in areas where temperature, salinity and conductivity were higher and the range of these conditions was narrower (with the exception of salinity) than where they were absent (Figure 17). These sites were lower in the watershed in areas that were tidally influenced. There was some overlap in water quality conditions where spawning was present and where it was absent.

When the presence of anadromous fish spawning (Figures 14-16) was plotted onto land-use in the developed portion of the watershed (Figure 3), anadromous fish spawning locations in 2006 coincided with non-urban land-use in the watershed. Sites where spawning was absent were in both urban and non-urban land-use. The land cover map suggested that spawning locations were in forest or wetland. We may be able to recreate a general land use map for 1973 and overlay spawning locations from the same period (O'Dell 1975).

Urbanization is a collection of landscape actions that lead to changes in stream conditions (Konrad and Booth 2005). Hydrologic and water quality changes from urbanization can be ecologically significant, leading to changes in community structure (Konrad and Booth 2005). At this stage, we can identify changes in use of Bush River drainage streams by anadromous fish for spawning but cannot identify what stream features have been altered.

Volunteers provided much more widespread sampling than would have been possible with project staff alone. A total of 176 ichthyoplankton samples were collected out of the 201 expected (Table 4). Sites were not sampled if conditions precluded safe sampling, or if volunteers cancelled and were not replaced. Sampling with wire traps by volunteers was inconsistent, but anadromous fish were captured by traps at only one site during 2006.

We believe that stream spawning habitat has declined in the Bush River given the comparison of the 2005 (McGinty, 2006) and 2006 data to 1973 (O'Dell 1975). However, our analysis may be biased. Sites on Aberdeen Property were generally located in tidal waters, whereas most of the sampling sites in the Bush River were non-tidal stream sites. Sampling in 2005 was limited to ichthyoplankton collections, so comparisons between 1973 (O'Dell 1975) and 2005 (McGinty 2006) may have been biased by the lack of wire trap sampling. We intend to repeat this sampling in 2007 and move sites in the Bush River down to the tidal area to determine if the lower reaches of the Bush River are supporting spawning and nursery functions that have apparently been lost in the upper stream reaches. Additional wire trap sampling and pooling of 2005-2007 ichthyoplankton data should minimize or relieve this bias entirely.

Summer Seining and Trawling

Water temperature measurements >31°C comprised about 16-17% of measurements in three systems; temperatures this high were not recorded in the remaining 5 systems (Table 5; Figure 18). Frequency of DO < 3 mg/L displayed greater range in fresh-tidal tributaries, but brackish tributaries display greater range in percent of observations < 5 mg/L (Table 5; Figure 19). Fishing Bay often had salinity measurements in excess of the criterion (> 13‰) for our non-marine species; violations were much less frequent or non-existent for remaining systems (Table 5; Figure 20).

Corsica River DO was frequently measured below the 5.0 mg/L criterion this year, as in previous years (Table 5; McGinty, et al. 2006). Corsica River received significant organic loading for an undetermined amount of time from a failing wastewater treatment plant that is likely contributing to the low oxygen conditions.

Median Secchi depth was generally below 0.5 meters in all rivers except Mattawoman and Piscataway creeks, and Tred Avon River (Figure 21). Mattawoman and Piscataway creeks (fresh-tidal) had abundant submerged aquatic vegetation that could have increased water clarity (Kemp et al. 2005). Piscataway and Mattawoman creeks had 89% and 42% of their tidal surface area covered in SAV based on 2005 SAV acreage estimates from Virginia Institute of Marine Science:
http://www.vims.edu/bio/sav/sav05/report/execsum_page.html.
Bush and Bohemia rivers have less surface area covered in SAV, 9% and 34%, respectively. In the Potomac River estuary, improved sewage treatment in Washington, DC, produced a sharp reduction in phosphorous that lead to improved clarity in the tidal-fresh region (Kemp

et al. 2005). Even though clarity was relatively low, Bush River did not display any detrimental temperature or DO conditions at relatively high IS. An explanation for higher clarity in Tred Avon River is not apparent. Clarity in many regions of the Bay is largely controlled by interactions between plankton and suspended sediments (Kemp et al. 2005).

Seining effort varied this year due to high tides and SAV (Table 6). High tides prevented seining on occasion in Bush River, Corsica River, and Langford Creek. Mattawoman Creek, Piscataway Creek, and Bohemia River sites were not seined because submerged aquatic vegetation (SAV) was too dense. Mattawoman Creek sites were covered with SAV over the entire sampling period. Piscataway Creek and Bohemia River had less dense SAV coverage in July, but sites were overwhelmed afterward.

Bohemia River seining produced the greatest number of species (28). Bush and Tred Avon rivers both had 26 species; Langford Creek, 23; Corsica River, 21; Fishing Bay, 17; and Piscataway Creek, 12. Bohemia River also had the greatest number of species that comprised 90% of the catch. Bush and Tred Avon rivers ranked second, followed by Corsica River, Piscataway Creek, Langford Creek and Fishing Bay. The Bush River had the greatest catch per seine haul (240.6), followed by Bohemia River, Corsica River, Tred Avon, Piscataway Creek, Langford Creek and Fishing Bay (Table 6).

Trawling was conducted at all stations (Table 7). Mattawoman Creek and Tred Avon River both had 20 species identified in the trawl; Bohemia River, 19; Bush River, 18; Piscataway and Langford creeks, 15; and Corsica River and Fishing Bay, 14. The Bush River had the greatest number of species comprising 90% of trawl catch (6), while one species (white perch) comprised 90% of the catch in Langford Creek and Corsica River. However, Langford Creek had the greatest catch per effort, followed by the Corsica River, Bush River, Bohemia River, Mattawoman Creek, Tred Avon River and Piscataway Creek (Table 7). Submerged vegetation covered Piscataway Creek by late summer and trawl efficiency may have been reduced.

White perch adults were consistently present in trawls (Table 8) and seines (Table 9), except in Fishing Bay and Piscataway Creek. Juvenile white perch were abundant in the tidal-fresh sampling areas (Bohemia, Bush, Mattawoman, Piscataway) in trawls, and less prevalent in seines. The remaining target species were either absent or less frequently sampled (Tables 8 and 9).

Differences in the relative abundance of white perch by size class were not evident in the three fresh-tidal watersheds that had 13% or less impervious cover (Figure 23). However, relative abundance was reduced in the watershed with close to 17% impervious surface and white perch in the harvestable size class were absent. The range in impervious surface in our brackish tributaries was too low to make this comparison; however, it is possible to explore 2003-2005 data to confirm if this phenomenon is widespread.

Shannon-Weiner (S-W) indices calculated for 2006 were plotted by watershed and gear (Figure 25). Generally, seine data appears more conducive for formulating a S-W index. Number of species comprising 90% of the catch (by number) in seine samples (6.4, SE = 1.9) was significantly higher than in trawl samples (mean = 3.7, SE = 1.8; t-test, $P < 0.01$) and the seine S-W index (described above) is generally supportive of expected changes associated with development. Trawl S-W indices were not reflective of levels of impervious surface and catches were dominated by few species. Low trawl S-W indices in Corsica River and Langford Creek largely reflected dominance of white perch in these systems (they alone comprised 90% of fish collected by trawl there; Table 7). Significant relationships between the S-W index and impervious surface for the trawl was not suggested by regression analysis ($P = 0.20$, $r^2 = 0.26$; Figure 26); however, a relationship was suggested for the seine data ($P = 0.08$, $r^2 = 0.59$; Figure 27).

Total number of species (T_w) collected by trawl in a watershed was significantly related to total number of trawls (N_w) and number of species comprising 90% of the catch (S_w). Correlation analysis did not indicate a close correlation ($r > 0.8$) of N_w and S_w, so these were treated as independent variables in the multiple regression (Ricker 1975). The relationship was described by the equation $T_w = 0.58 * N_w + 1.48 * S_w - 0.39$. This regression explained 85% of variation; and regression coefficients for N_w (SE = 0.14) and S_w (SE = 0.32) were significant at $P < 0.005$, but the intercept was not significant ($P = 0.92$, SE = 3.61). A plot of residuals against IS indicated that T_w in fresh-tidal systems was higher than predicted by the regression and lower in brackish systems (Figure 28). Classification of Bohemia River as fresh-tidal or brackish was critically important for interpreting this analysis. If Bohemia River was fresh-tidal, an increase in T_w with IS was suggested and Mattawoman Creek (residual = 2) represents an outlier, i.e., there was a higher number of species present than would have been predicted. If Bohemia River was omitted or grouped with brackish tributaries, then T_w would decline with IS in both cases, but lower T_w would be likely in brackish tributaries (Figure 28).

It seems prudent to select another low IS fresh-tidal system to replace Bohemia River. Bohemia River may not have truly represented a fresh-tidal tributary because the proximity of the Chesapeake and Delaware Canal allowed marine species from Delaware Bay access without migrating up Chesapeake Bay. The appearance of Atlantic croaker as a dominant species in Bohemia River and not in any other system indicated that the close proximity of C and D Canal allowed for more of a brackish water community than fresh-tidal.

A prominent objective of this year's sampling was to better understand the impact of impervious surface on tidal-fresh fish communities. In general, year-to-year fluctuations in inputs and estuarine distributions of freshwater, suspended sediments, and nutrients affect stratification, circulation, productivity, and organism abundance (Kemp et al. 2005). Fresh-tidal watersheds in this study are adjacent to large freshwater inputs (Potomac or Susquehanna rivers). They also lack salinity, so a major source of differences in density that impedes mixing and promotes stratification in brackish systems is lacking (Odum 1971; Reid and Wood 1976; Kemp et al. 2005). Nutrient inputs from the Susquehanna and Potomac river drainages are somewhat different in concentration (Sprague et al. 2000).). Interactions between plankton and suspended nutrients, combined with nonlinear feedback may produce regional responses that impact habitat quality for fishes (Kemp et al. 2005). SAV beds are more abundant in fresh-tidal Potomac River tributaries and this could influence their ecological and biogeochemical processes (Kemp et al. 2005). We will continue to sample these areas to further explore the effects of impervious surface on tidal-fresh habitats and develop a better understanding of the processes that impact the fish community in these areas.

2003-2005 Data Analysis

Presence-absence of white perch, striped bass and blue crabs in bottom trawls during 2003-2005 was negatively related to impervious surface (Figure 28A.; $r^2 = 0.28$, $p = 0.0001$; see McGinty et al. 2006 for systems sampled). Slopes and intercepts of species-specific regressions were not different based on their 95% confidence intervals and a single relationship for all three species was described by the equation: P_i = -3.08•IS + 0.68; where P_i is the proportion of tows with white perch adults, striped bass juveniles, and blue crabs. This relationship with impervious surface reflects an underlying strong negative, linear response of DO to IS (McGinty et al. 2006) and a strong positive asymptotic response of P_i to DO levels among these species. The asymptotic relationship of P_i to DO category was described by $P_i = 0.541 \bullet \{1 - \exp[-(DO/2.510^{1.96})]\}$ ($r^2 = 0.85$, $P < 0.0001$; Figure 28 B). Approximate standard errors for K, S, and b were 0.030, 0.273, and 0.519, respectively. This response was strongly supportive of 3.0 mg/L limits and 5.0 mg/L DO targets evaluated in 2005 (McGinty et al. 2006). The 3.0 mg/L target was near the P_i -DO inflection point (2.5 mg/L) and 5.0 mg/L approximated where the P_i -DO relationship became asymptotic (Figure 12 B). 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 Neuse River Estuary, North Carolina. Fish abundance generally increased with DO (Bell and Eggleston 2004).

CITATIONS

Arnold, C. L., and C. J. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association 62:243-258.

ASMFC (Atlantic States Marine Fisheries Commission). 2001. Amendment 1 to the Interstate Fishery Management Plan for Atlantic menhaden. Fishery Management Report No. 37. Washington, D.C.

Beach, D. 2002. Coastal sprawl: the effects of urban design on aquatic ecosystems in the United States. Pew Oceans Commission, Arlington, Virginia.

Bell, G. W., and D. B. Eggleston. 2004. Species-specific avoidance responses by blue crabs and fish to chronic and episodic hypoxia. Marine Biology 146:761-770.

Bengston, D. A., L. J. Buckley, and G. Klein-MacPhee. 1993. Introduction. In L. A. Fuiman, editor. Water quality and the early life stages of fishes. American Fisheries Society Symposium 14, Bethesda, Maryland.

Cappiella, K., and K. Brown. 2001. Impervious cover and land use in the Chesapeake Bay watershed. Center for Watershed Protection, Ellicott City, MD.

Carmichael, J., M. Roberts, B. Richardson, and S. J. Jordan. 1992. Fish sampling in eight Chesapeake Bay tributaries. CBRM-HI-92-2, Maryland Department of Natural Resources, Annapolis.

Chesapeake Bay Program. 1991. Chesapeake Bay Atlantic croaker and spot fishery management plan. Chesapeake Executive Council Agreement Commitment Report 1991. Annapolis, Maryland.

Colborn, T. and K. Thayer. 2000. Aquatic ecosystems: harbingers of endocrine disruption. Ecological Applications 10:949-957.

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

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York, New York.

Holland, A. F., D. M. Sanger, C. P. Gawle, S. B. Lerberg, M. S. Santiago, G. H. M. Riekerk, L. E. Zimmerman, and G. I. Scott. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298:151-178.

Kaushal, S. S., P. M. Groffman, G. E. Likens, K. T. Belt, W. P. Stack, V. B. Kelly, L. E. Band, and G. T. Fisher. 2005. Increased salinization of fresh water in the northeastern United States. Proceedings of the National Academy of Sciences 102:13517-13520.

Kemp, W. M., and 17 coauthors. 2005. Eutrophication of Chesapeake Bay: historical trends and ecological interactions. Marine Ecology Progress Series 303:1-29.

King, R.S., J.R. Beaman, D.F. Whigham, A.H. Hines, M.E. Baker, and D.E. Weller. 2004. Watershed land use is strongly linked to PCBs in white perch in Chesapeake Bay subestuaries. *Environ. Sci. Technol.* 38:6546-6552.

Konrad, C. P., and D. B. Booth. 2005. Hydrologic changes in urban streams and their ecological significance. Pages 157-177 *in* L. R. Brown, R. H. Gray, R. H. Hughes, and M. R. Meador, editors. Effects of urbanization on stream ecosystems. American Fisheries Society Symposium 47, Bethesda, Maryland.

Krebs, C. J. 1972. Ecology: the experimental analysis of distribution and abundance. Harper and Row, New York.

Limburg, K.E. and R. E. Schmidt. 1990. Patterns of fish spawning in Hudson River tributaries: response to an urban gradient? Ecology 71:1238-1245.

Lippson, A. J., and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Maryland Department of Natural Resources, PPSP-MP-13, Annapolis, Maryland.

Living Resources Subcommittee. 1991. Habitat Requirements for Chesapeake Bay Living Resources. Second Edition. Chesapeake Bay Program, Annapolis, Maryland.

Mangel, M. and P.E. Smith. 1990. Presence-absence sampling for fisheries management. Canadian Journal of Fisheries and Aquatic Science 47:1875-1887.

Maryland Department of Planning, 2003. 2002 Land Use Land Cover Data, Maryland. Baltimore, MD.

Maryland Department of Planning, 2004a. 2004 Land Use Land Cover Data, Maryland. Baltimore, MD.

Maryland Department of Planning, 2004b. 1973 Land Use Land Cover Data, Maryland. Baltimore, MD.

McGinty, M. 2006. Larval Fish Sampling in the Bush River, 2006. Final Report to Chesapeake Bay National Estuarine Research Reserve. Maryland Department of Natural Resources. Annapolis, Maryland.

McGinty, M., J. Uphoff, R. Lukacovic, J. Mowrer, and B. Pyle. 2006. Development of habitat based reference points for Chesapeake Bay fishes of special concern: impervious surface as a test case. Chesapeake Bay Finfish/Habitat Investigations 2006, Project 3. Maryland Department of Natural Resources, Annapolis, Maryland.

O'Dell, C.J. 1987. Status of yellow perch (*Perca flavescens*) in Maryland, 1987: a situation paper on the biology, distribution, stocks, and fisheries of yellow perch with suggested study needs and management actions. Maryland Department of Natural Resources, Annapolis, Maryland.

Odum, E. P. 1971. Fundamentals of Ecology. W. B. Sauders, Philadelphia.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxbury Press. North Scituate, Massachusetts

Pearce, J.B. 1991. Collective effects of development on the marine envionment. Oceanologca Acta 11:287-298.

Piavis, P.G. 1991. Yellow perch *Perca flavescens*. Pages 14.1 – 14.15 *in* S.L. Funderburk, S.J. Jordan, J.A. Mihursky, and D. Riley, editors. Habitat requirements for Chesapeake Bay living resources, 2nd edition. Chesapeake Bay Program, Living Resources Subcommittee, Annapolis, Maryland.

Piavis, P. G., and E. Webb III. 2006. Population vital rates of resident finfish in selected tidal areas of Maryland's Chesapeake Bay. Project 1, Job 1, Chesapeake Bay Finfish/Habitat Investigations: 2006. Maryland Department of Natural Resources, U.S. Fish and Wildlife Service Performance Report F-61-R-1, Annapolis.

Prager M.H., Saila S.B. & Recksiek C.W. (1989) FISHPARM: a microcomputer program for parameter estimation of nonlinear models in fishery science, second edition. Old Dominion University Oceanography Technical Report 87-10, Norfolk, VA, USA, 18 pp.

Reid, G. K., and R. D. Wood. 1976. Ecology of inland waters and estuaries. D. Van Norstrand Company, New York.

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

Sanderson, A. E. 1950. A study of the effect of the brackish waters of the Severn River on the hatchability of the yellow perch *Perca flavescens*, Mitchill. University of Maryland. Problems course paper. Unpublished manuscript.

Sisenwine, M.P., and J. G. Shepherd. 1987. An alternative perspective on recruitment overfishing and biological reference points. Canadian Journal of Fisheries and Aquatic Sciences 44:913-918.

Sprague, L. A., M. J. Langland, S. E. Yochum, R. E. Edwards, J. D. Blomquist, S. W. Phillips, G. W. Shenk, and S. D. Preston. 2000. Factors affecting nutrient trends in major rivers of the Chesapeake Bay watershed. Water Resources Investigations Report 00-4218. U.S. Geological Survey, Richmond, VA.

Uphoff, J. H. 1997. Using egg presence-absence to derive probability based management criteria for upper Chesapeake Bay striped bass. North American Journal of Fisheries Management 17:663-676.

Uphoff, J., M. McGinty, B. Richardson, P. Piavis, H. Speir, and M.F. Topolski. 2005. Interim assessment of yellow perch *Perca flavescens* habitat and population dynamics in Severn River, a suburbanized Chesapeake Bay sub-estuary. Fisheries Tech. Rep. Series, Number 46. Maryland Department of Natural Resources, Fisheries Service, Stevensville, MD.

U.S. Environmental Protection Agency. 2003. Ambient water quality criteria for dissolved oxygen, water clarity and chlorophyll a for the Chesapeake Bay. U.S. EPA. Washington, D.C.

Victoria, C.J., B.S. Wilkerson, R.J. Klauda, and E.S. Perry. 1992. Salinity tolerance of yellow perch eggs and larvae from coastal plain stream populations in Maryland, with comparison to a Pennsylvania lake population. Copeia (3):859-865.

Yellow perch workgroup. 2002. Maryland tidewater yellow perch fishery management plan. Maryland Department of Natural Resources, Annapolis, Maryland.

Zielinski, J. 2002. Watershed vulnerability analysis. Center for Watershed Protection. Ellicott City, Maryland.

Table 1. Percent impervious cover, total watershed (non-water) acres, and area of tidal water for the watersheds sampled in 2006.

Area	Watershed	% Impervious Cover	Total Watershed Acres	Tidal water area
Upper-Bay	Bohemia River	0.7	26,502	2,666
Upper-Bay	Bush River	12.8	36,964	7,966
Mid-Bay	Corsica River	4.0	23,903	1,256
Mid-Bay	Fishing Bay	0.8	98,060	19,038
Mid-Bay	Langford Creek	0.9	28,871	2,906
Potomac	Mattawoman Creek	8.5	60,300	1,848
Potomac	Piscataway Creek	16.7	43,579	858
Mid-Bay	Tred Avon River	5.6	23,518	4,338

Table 2. Percentage of acres by land use type in the Aberdeen Proving Ground Watershed and the Bush River watershed. (Bush River watershed includes Swan Creek. Source: Maryland Office of Planning, 2001, 2003.)

	APG		Bush	
Landuse	**1973**	**2000**	**1973**	**2000**
Urban	41.6	40.5	17.5	34.1
Agriculture	1.4	1.2	38.0	27.4
Forest	44.5	43.6	42.2	35.4
Wetland	12.5	14.6	2.1	2.8
Barren	0	0	0.1	0.2

Table 3. Water quality requirements for juvenile (J) and adult (A) target species (Chesapeake Bay Program 1991; Living Resources Subcommittee 1991; ASMFC 2001; Yellow Perch Workgroup 2002).

Water Quality Criteria Requirements	Striped Bass	Yellow Perch	White Perch	Alewife	Blueback Herring	American Shad	Spot	Atlantic Croaker	Atlantic Menhaden
TEMPERATURE (^oC)	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 4. Total number of ichthyoplankton samples collected by site for the Bush River. Sampling was conducted weekly beginning the first week in March and ending the second week in May.

STATION	STREAM	WATERSHED	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	TOTAL
BBR1	Bynum Run	Bush	1	0	1	1	1	1	1	1	1	1	1	10
BBR2	Bynum Run	Bush	1	0	0	1	1	1	1	1	1	1	1	9
BCE1	Back Creek	APG	N/A	N/A	1	0	1	1	1	1	0	1	1	7
BCR1	Cranberry Run	Bush	0	0	1	1	1	1	1	1	1	1	1	9
BGR1	Grays Run	Bush	0	0	1	1	1	1	1	1	1	1	1	9
BHH1	Ha Ha Branch	Bush	0	1	1	1	1	1	1	1	1	1	1	10
BJR1	James Run	Bush	1	0	1	1	1	1	1	1	1	1	1	10
BJR2	James Run	Bush	1	0	1	1	1	1	1	1	1	1	1	10
BOP1	Otter Point Cr.	Bush	1	1	1	1	1	1	1	1	1	1	1	11
BSC1	Swan Creek	Swan	1	1	1	1	1	1	1	1	1	1	1	11
BSC2	Swan Creek	Swan	1	1	1	1	1	1	1	1	1	1	1	11
BSC3	Swan Creek	Swan	1	1	0	1	1	1	1	1	1	1	0	9
BSR1	Sod Run	Bush	0	0	1	1	1	1	1	1	1	1	1	9
BUN1	Unnamed Trib.	Bush	0	0	1	1	1	1	1	0	1	1	1	8
BWR1	Winters Run	Bush	1	1	1	1	1	1	1	1	1	1	1	11
BWR2	Winters Run	Bush	1	1	1	1	1	1	1	1	1	1	1	11
MOS1	Mosquito Cr.	APG	N/A	N/A	1	0	1	1	1	1	0	1	1	7
ROM1	Romney Creek	APG	N/A	N/A	1	0	1	1	1	1	0	1	1	7
WDR1	Woodrest Cr.	APG	N/A	N/A	1	0	1	1	1	1	0	1	1	7
TOTAL EXPECTED			15	15	19	19	19	19	19	19	19	19	19	201
TOTAL COLLECTED			10	7	17	15	19	19	19	18	15	19	18	176
PERCENT COLLECTED			66	46	89	78	100	100	100	94	78	100	94	87

Table 5. Percentage of time overall habitat conditions (all depths in the channel and nearshore) did not support the highest maximum temperature, threshold and target D.O. and the lowest maximum salinity for the target species during July-September, 2006

Watershed	% Impervious	Percent Temperature > 31°C	Percent DO < 3.0 mg/L	Percent DO < 5.0 mg/L	Percent Salinity >13 ppt
Bohemia	0.7	17.1	5.3	21.1	0.0
Bush	12.8	0.0	0.0	0.0	0.0
Corsica	4.0	16.9	21.1	49.3	0.0
Fishing Bay	0.8	15.5	1.9	1.9	59.6
Langford	0.9	0	1.1	20.4	0.0
Mattawoman	8.5	0	9.8	21.6	0.0
Piscataway	16.7	0	35.3	35.3	0.0
Tred Avon	5.6	0	4.2	22.1	6.3

Table 6. Catch statistics and impervious cover in seines by river in 2006

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Seine
Bohemia	19	28	Atlantic menhaden White perch White perch YOY Gizzard shad Banded killifish Pumpkinseed Mummichog Bay anchovy Spottail shiner Inland silverside	0.7	4203	221.2
Bush	20	26	Gizzard shad Atlantic menhaden Spottail shiner Pumpkinseed White perch Bay anchovy Silvery minnow	12.8	4812	240.6
Corsica	18	21	White perch Mummichog Bay anchovy Atlantic menhaden Striped killifish Atlantic silverside	2.3	2673	148.5
Fishing Bay	112	17	Atlantic silverside Bay anchovy Atlantic needlefish Mummichog	0.8	802	66.8
Langford	21	23	White perch Atlantic silverside Striped killifish Bay anchovy Atlantic menhaden	0.9	1446	68.9
Mattawoman	0	0		8.5	0	0
Piscataway	3	12	White perch YOY American shad Tesselated darter Banded killifish Spottail shiner Largemouth bass	16.7	354	118
Tred Avon	24	26	White perch Atlantic silverside Mummichog Striped killifish Striped bass YOY Banded killifish Bay anchovy	5.6	2909	145.4

Table 7. Catch statistics and impervious cover in trawl by river in 2006.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Seine
Bohemia	24	19	White perch YOY White perch Atlantic croaker Bay anchovy Hogchoker	0.7	3011	125.5
Bush	18	18	White perch Pumpkinseed White perch YOY Brown bullhead Gizzard shad Bay anchovy	12.8	2912	161.8
Corsica	24	14	White perch White perch YOY	4.0	6320	263.3
Fishing Bay	16	14	Bay anchovy Hogchoker Weakfish White perch	0.8	2318	144.9
Langford	24	15	White perch	0.9	7003	291.8
Mattawoman	24	20	White perch YOY White perch Spottail shiner Bay anchovy	8.5	2448	102.0
Piscataway	18	15	White perch YOY Spottail shiner Tesslated darter	16.7	1268	70.4
Tred Avon	24	20	Bay anchovy White perch Spot Weakfish Hogchoker	5.6	1764	73.5

Table 8. Percentage of total trawl catch comprising each target species by river, 2006.

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.
Bohemia	0.000	0.000	0.000	16.731	0.000	1.096	0.000	0.129	24.017	31.592	0.097	0.000
Bush	0.000	0.000	0.000	0.000	0.000	0.034	0.034	0.034	38.908	14.080	0.721	0.515
Corsica	0.000	0.000	0.079	0.032	0.000	3.910	0.016	0.032	84.392	6.968	0.016	0.000
Fishing Bay	0.000	0.000	0.075	0.411	0.000	0.971	0.000	0.000	4.330	0.224	0.000	0.000
Langford	0.000	0.000	0.014	0.028	0.000	2.752	0.014	0.057	90.551	0.028	0.000	0.000
Mattawoman	0.364	0.162	0.000	0.000	0.000	0.202	0.040	1.214	22.956	57.126	0.162	0.000
Piscataway	0.158	0.158	0.000	0.000	0.000	0.000	0.000	0.789	2.287	56.151	0.473	0.000
Tred Avon	0.000	0.000	0.090	0.495	0.000	8.555	0.135	2.476	14.453	0.090	0.000	0.000

Table 9. Percentage of total seine catch comprising each target species by river, 2006.

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.
Bohemia	0.261	0.000	23.261	2.682	1.448	0.071	0.024	0.071	23.071	8.806	0.356	0.000
Bush	0.125	0.000	11.949	0.000	0.478	0.083	0.187	0.125	3.824	1.309	0.395	0.312
Corsica	0.522	0.000	10.101	0.000	0.000	1.155	0.112	0.037	42.974	0.186	0.224	0.000
Fishing Bay	0.000	0.000	0.000	0.340	0.000	1.812	0.113	0.793	0.793	0.000	0.000	0.000
Langford	0.070	0.000	4.893	0.000	0.000	0.276	0.207	0.138	44.314	0.069	0.138	0.000
Piscataway	0.000	19.774	0.000	0.000	3.955	0.000	0.000	0.000	0.848	40.961	0.000	0.000
Tred Avon	0.033	0.000	2.689	0.033	0.000	1.737	0.033	3.310	45.821	1.409	0.000	0.000