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FISH AND WILDLIFE SERVICE
PERFORMANCE REPORT

STATE: Maryland

PROJECT NO.: F-61-R-1

PROJECT TYPE: Research and Monitoring

PROJECT TITLE: Chesapeake Bay Finfish and Habitat Investigations.

PROGRESS: ANNUAL X

PERIOD COVERED: November 1, 2004 through October 31, 2005

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.

White perch population abundance, fishing mortality (F), recruitment trends, and biological reference points were determined and Bay wide white perch abundance was assessed using a surplus production model. Model results indicated steady population growth during 1980 – 1993, followed by a slight decline through 2004. Fishing mortality increased during the time series. Biomass in 2004 was above recommended levels, and fishing mortality was below threshold levels indicating that the stock is not considered over-fished and that over-fishing is not occurring. Bay-wide juvenile production has generally been strong since 1993. Choptank River white perch stocks were assessed with a catch survey analysis. The model indicated increasing population growth since 1989, and was estimated to be near 4.5 million fish in 2005. A suite of biological reference points (BRP's) were determined from a Thompson-Bell type spawning stock biomass per recruit model and a yield per recruit model. Potential BRP's ranged from $F_{0.1} = 0.30$ to $F_{15\%}=1.72$. Assessing harvest levels and historic F levels indicated appropriate BRP's would be near F=0.80.

Adult American shad indices including lift geometric means (GM), hook and line GM and relative population estimates in the Susquehanna River were lower this year compared to the previous four years. American shad relative abundance in the Nanticoke River also remained low. Age structure in both systems had not changed while the trend in repeat spawning increased. American shad juvenile indices in all areas indicated very good spawning success, well above the thirty-year average.

Adult hickory shad relative abundance indices in Deer Creek were stable in 2005. However, in the Nanticoke River, indices increased and were likely driven by hatchery replenishment. Juvenile sampling caught few hickory shad. Adult alewife herring repeat spawning indices and GM CPUEs in the Nanticoke River have indicated no significant trend while blueback herring repeat spawning indices and GM CPUEs have decreased significantly since 1989. Fishing mortality rates, age structure and sex ratios appeared stable for both species during the time series. Juvenile indices for both species also appeared stable.

Weakfish samples collected from pound nets in 2005 were dominated by smaller fish, with mean total length being the third smallest and the RSD_{stock} the second highest of the time series. Maryland's instantaneous total mortality estimates were 1.44 in 2005 and 1.29 in 2004, similar to the coastal assessment of 1.4 for cohorts since 1995. Summer flounder mean lengths from Maryland pound nets in 2005 were the greatest of the time series, indicating a shift to $RSD_{Preferred}$. The 2005 bluefish samples indicated a shift to larger fish, but RSD_{stock} values (79%) indicated that small fish still dominate the population. Atlantic croaker mean lengths continued to increase in 2005 and RSDs indicated a shift from preferred in 2004 to memorable and trophy in 2005. Instantaneous total mortality in 2005 was 0.24, a slight decrease from 2004. The 2005 shift in spot length frequency to a bimodal distribution, decreased in mean size and reduction in % jumbo spot, appears to be a function of a large 2005-year class.

Resident / premigratory striped bass sampled from the Summer – Fall 2004, pound net and hook and line commercial fisheries ranged from 3 to 13 years of age. In 2004, four year old striped bass comprised approximately 36% of the pound net and hook-and-line harvest while age 5 fish contributed 13% and 15% to the pound net and hook-and-line harvests, respectively. The 2004-2005 commercial drift gill net fishery harvest was comprised primarily of four and five year old striped bass from the 2000 and 2001 year-classes. Age groups 4 and 5 contributed approximately 84% of the harvest while 6 to 11 year-old fish comprised 16% of the commercial drift gill net harvest. Striped bass present in commercial drift gill net samples collected from check stations ranged in age from 11 to 4 (1994 – 2001 year classes)

During the spring 2005 striped bass spawning stock survey, 16 different age classes were sampled. The male component was represented by 2 to12 year-old fish while age groups 5 through 19 comprised the majority of the female spawning stock. In 2005, 97% of the female spawning stock was age 8 and older. Spring 2005 trophy season sampling indicated that the age distribution of the trophy harvest consisted of striped bass between 6 and 16 years of age. The age distribution was dominated by 8 to 12 year old female striped bass, with the dominant 1996 year-class (9 year-old fish) being most frequently observed. The length distribution of fish sampled during the survey was dominated by striped bass between 820mm to 940 mm TL and averaged 893 mm TL.

A total of 2348 juvenile striped bass were collected at 22 permanent stations in 2005. The juvenile index (JI) of 17.8, was greater than the time-series average (12.0), with juveniles occurring in 90% of all samples. The Choptank River index of 55.2 was more than double the time-series average of 20.7, but the Nanticoke River index of 1.5, was less than the time-series average of 8.5. The Potomac River index of 10.3, was greater than the time-series average of 8.6, while the Upper Bay index, 13.2, was slightly above the time-series average of 12.3.

A total of 7,807 striped bass were sampled during the 2004 – 2005 sampling season and 5,053 were tagged with USFWS internal anchor tags. During the 2004 summer and fall, 2004 stock assessment and directed fishing mortality rate studies, 3,772 and 1,281 striped bass were tagged and released in the Maryland waters of the Chesapeake Bay, respectively. A total of 4,263 striped bass were tagged during the cooperative USFWS / SEAMAP Atlantic Ocean tagging cruise. During the 2004-2005 sampling season, none of the 805 striped bass scanned for coded wire tags (CWT's) in Maryland waters were positive. Specialized CWT sampling was also conducted on the Patuxent River during April, 2005. A total of 83 striped bass were scanned for the presence of CWTs and four fish were found to be CWT positive.

Impervious surface (IS) reference points (ISRPs) were evaluated for use as possible parameters in fish management in brackish Chespaeake Bay tributaries. Development of ISRPs involved determining functional relationships between impervious cover and bottom dissolved oxygen (DO), bottom DO, and white perch, blue crab, and juvenile striped bass relative abundance in eight mesohaline tributaries. There was a significant negative relationship between mean bottom DO during 2003-2005 and percent IS in the watershed. This relationship indicated that the target bottom DO of 5 mg/L would occur at 2% IS and the 3 mg/L threshold was met at 11% IS. Relative abundance in mesohaline bottom trawls strongly increased as DO rose to 4.0 mg/ and then leveled. Seine catches inshore did not change as bottom DO diminished. The effect of diminished bottom habitat on abundance could not be explicitly quantified, but a great deal more habitat is potentially lost when bottom waters become unsuitable, compared to what is preserved inshore

APPROVAL

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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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SURVEY TITLE: CHESAPEAKE BAY FINFISH/HABITAT INVESTIGATIONS

CONTENTS (Continued)

PROJECT NO. 1
JOB NO.1

Population Vital Rates Of Resident Finfish In Selected Tidal Areas Of Maryland's Chesapeake Bay

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

The primary objective of Job 1 is to provide data and analysis from routine monitoring in a convenient format. 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 several technical reports and provided the basis for sound management recommendations for recreationally important resident tidal finfish 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 also divided into two strata; shallow water (< 6m) and deep water (>6m).

Each site visit was randomized for depth strata and directional components.

The winter trawl survey employed a 7.6 m 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, the trawl was retrieved into the boat by winch and the catch was emptied into a culling board. A minimum of 30 fish per species were sexed and measured. Non-random samples of yellow 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 2004 through February 2005, but severe mechanical malfunctions precluded completion of the full sampling season. Only 1-½ rounds were completed.

Choptank River

Five experimental fyke nets sampled the four resident species on the Choptank River. Nets were set at river kilometers 65.4, 66.6, 72.5, 74.4 and 78.1 and were fished two to three times per week from 17 February through 6 April (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 45Eangles.

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.

Severn River

Four fyke nets, targeting white and yellow perch were set on the Severn River from 14.5 to 19.4 rkms (Figure 3) and fished three times per week from 18 February through 11 April. These nets were similar in design and employment to those fished on the Choptank River. When fished, net hoops were brought aboard first to ensure that all fish were retained. Fish were then removed and placed into a tub of water and identified. All yellow perch, a minimum of fifty white perch and catfish species were measured and sexed. Non-random samples of yellow and white perch otoliths were removed for age determination.

Upper Chesapeake Bay Fishery Dependent Sampling

Commercial fyke net catches were sampled for yellow perch during early March from Northeast River and the Bush River. All yellow perch were measured (unculled) except when catches were prohibitively large. A subsample was purchased for otolith extraction and subsequent age determination.

Nanticoke River

From 4 March - 29 April, resident species were sampled from fyke nets set by commercial fishermen on the Nanticoke River. The fyke nets were set from Barren Creek (35.7 rkm) downstream to Monday’s Gut (30.4 rkm; Figure 4). Fyke net sites and dates nets were fished were at the discretion of the commercial fishermen. Captured yellow perch were sexed, measured for total length and a non-random sample of otoliths removed based on an age-at-length key. Thirty randomly selected white perch and all yellow perch from the fyke nets were sexed and measured. 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 and white perch in the Choptank, Nanticoke and Severn rivers and upper Chesapeake Bay. However, no age data were available for the upper Bay trawl survey due to small sample sizes from the truncated sampling season. Age-at-length keys for yellow 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.

<u>Length-frequency</u>

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.

<u>Growth</u>

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).

<u>Mortality</u>

Catch curves for Choptank, Nanticoke and Severn rivers 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. Severn River yellow perch F was not estimated because there is no commercial or recreational fishery in Severn River, and other surveys suggest Severn River yellow perch M may vary considerably from the assumed 0.25 (Sadzinski et al 2002).

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 0.375 (K) and 292 mm (L_4; Piavis and Uphoff 1999). Yellow perch L_c was 216 mm.

Recruitment

Recruitment data were provided from age 1+ abundance in the winter trawl survey and the Estuarine Juvenile Finfish Survey (see Project 2, Job2, Task 3 of this report). Cohort splitting was used to determine young-of-year (yoy) abundance in the winter trawl survey. Any yellow perch < 130 mm, white perch < 110 mm, and channel catfish < 135 mm were assumed yoy. Since white catfish abundance was not well represented in the upper Bay trawl catches, data were not compiled. 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 head-of bay sites.

Relative Abundance

Relative abundance of target species was determined as grand mean abundance from all surveys where reliable effort data were available. 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. For white perch and yellow perch, relative abundance (CPUE) at age was determined from the catch-at-age matrices.

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 1-4
Yellow perch	Tables 5-9

Population Length Structures

White perch	Tables 10-13 and Figures 5-8
Yellow perch	Tables 14-18 and Figures 9-13
Channel catfish	Tables 19-21 and Figures 14-16
White catfish	Tables 22-24 and Figures 17-19

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

Figure 1. Upper Chesapeake Bay winter trawl survey locations, 2005. Triangles indicate Bay sites, circles indicate Sassafras River sites, and squares indicate Elk River sites.

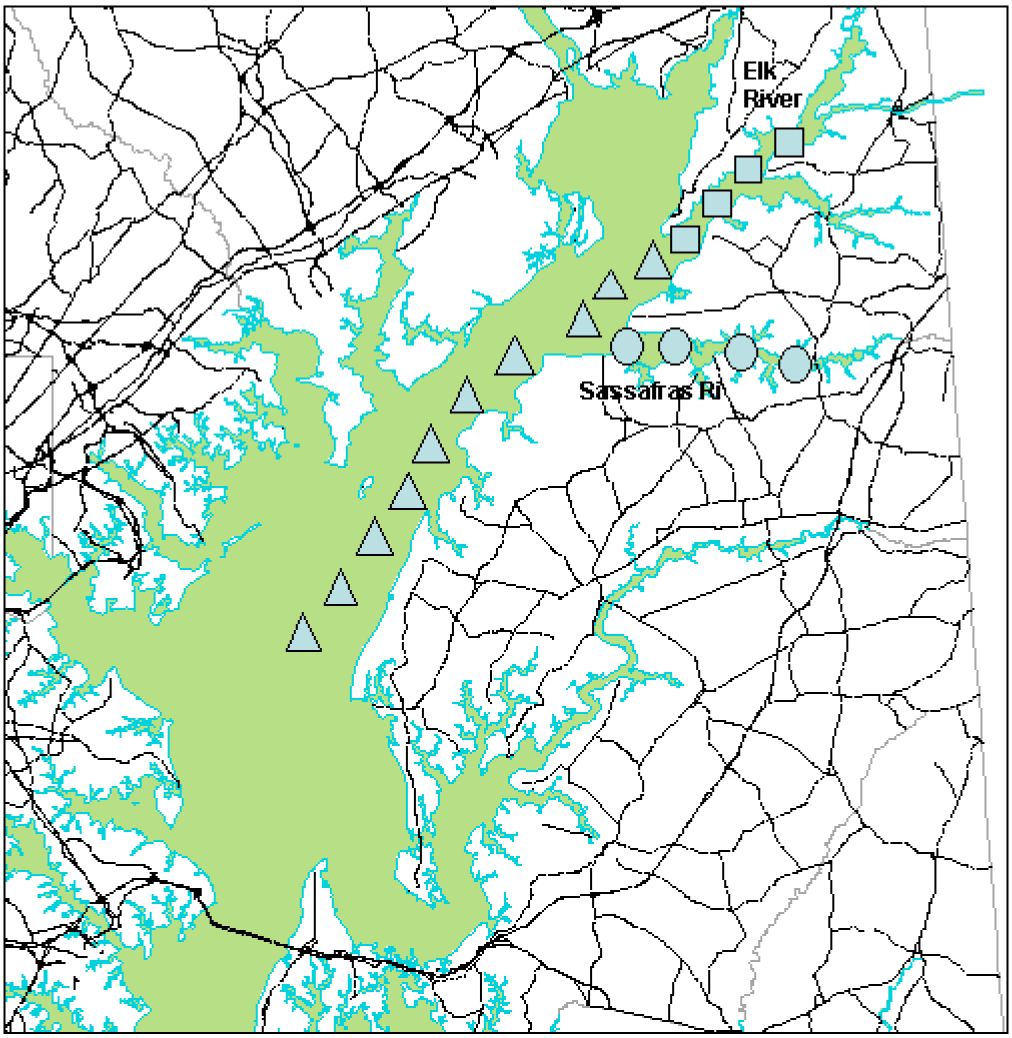


Figure 2. Choptank River fyke net locations, 2005. Triangles indicate sites.

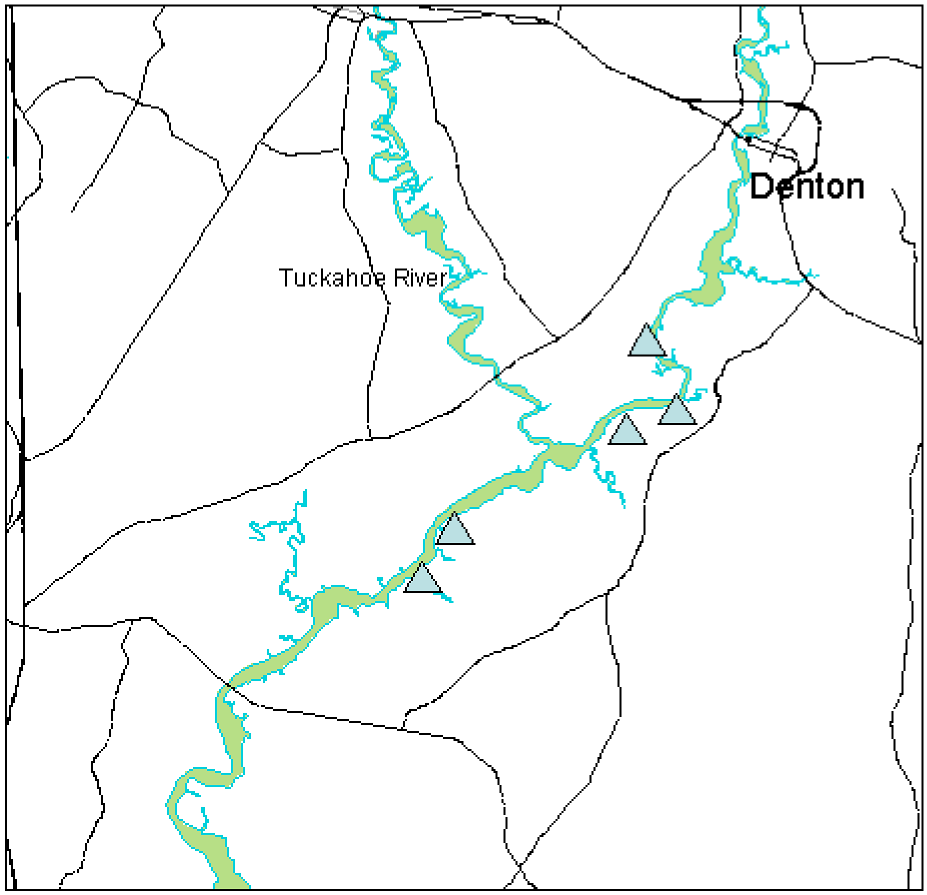


Figure 3. Severn River fyke net locations, 2005. Triangles indicate sites.

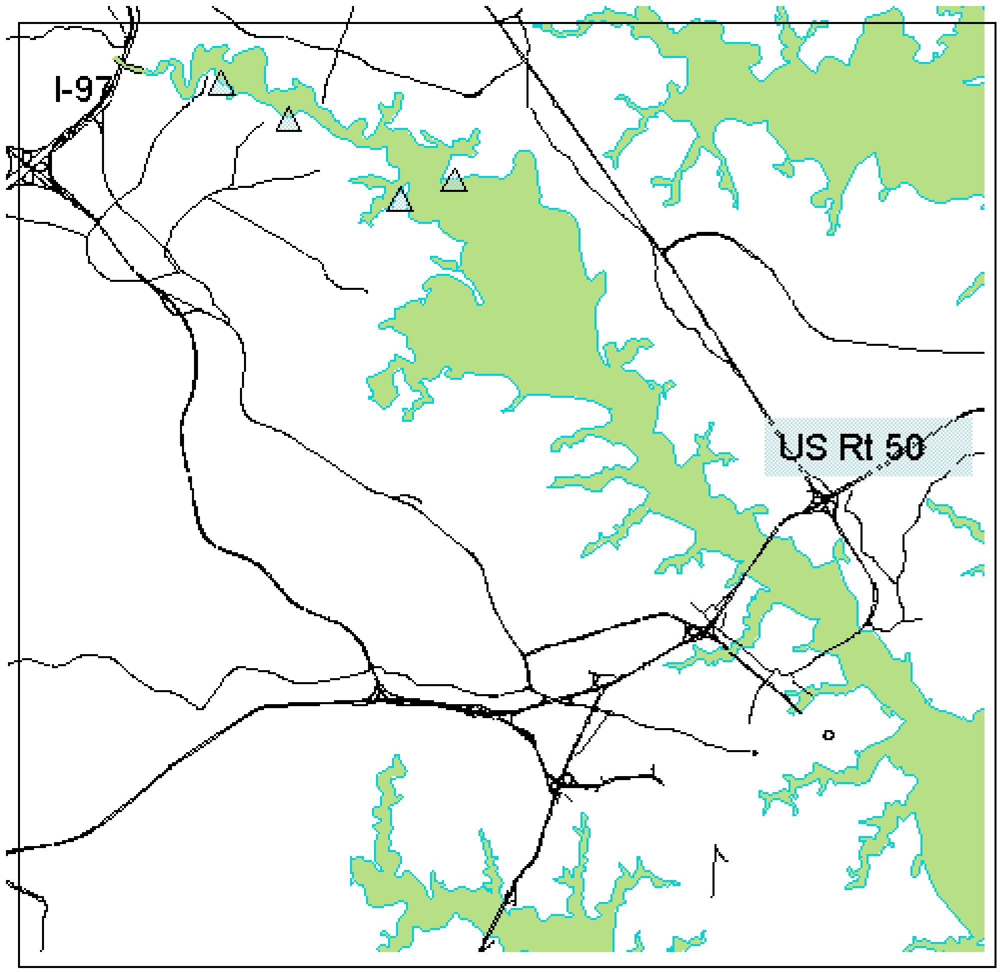


Figure 4. Nanticoke River survey site range, 2005. Circles indicated the range of net locations.

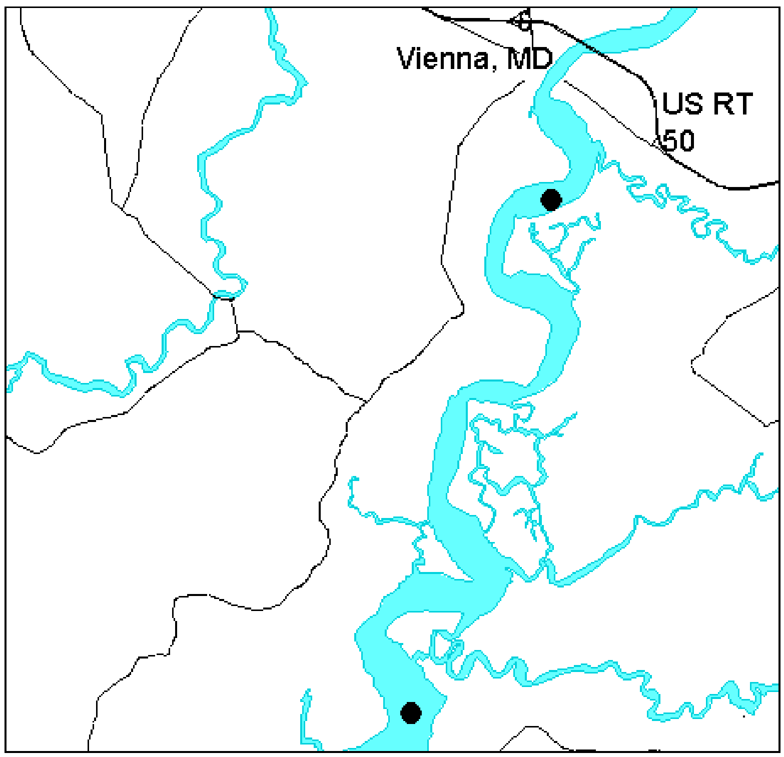


Table 1. White perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2005.

	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

Table 2. White perch catch at age matrix from Choptank River fyke net s survey, 2000 – 2005.

	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

Table 3. White perch catch at age matrix from Severn River fyke net survey, 2001 – 2005.

	AGE										
Year	1	2	3	4	5	6	7	8	9	10+	total
2001	0	0	241	817	7084	702	1312	716	21	0	10,893
2002	0	20	986	755	678	5925	289	455	153	0	9,263
2003	0	689	5032	554	1724	547	4526	1563	855	693	16,182
2004	0	0	3541	957	478	574	1722	1435	287	354	9,569
2005	0	171	1165	3758	1346	817	925	1894	1999	1023	13,098

Table 4. White perch catch at age matrix from Nanticoke River survey, 2000 – 2005.

	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	24882

Table 5. Yellow perch catch at age matrix from upper Chesapeake Bay winter trawl survey, 2000 – 2005.

	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	2508
2003	2454	2105	106	203	95	53	0	0	0	0	5016
2004					NOT SAMPLED						
2005	451	1	369	7	13	1	2	1	0	0	845

Table 6. Yellow perch catch at age matrix from Choptank River fyke net survey, 1988 – 2005.

	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	1709
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	12109
2000	0	329	92	1378	27	140	0	7	0	0	1973
2001	0	878	1986	102	1139	19	72	2	0	0	4198
2002	0	334	1336	1169	38	430	104	51	3	0	3465
2003	0	369	440	922	333	34	226	35	32	2	2392
2004	0	60	504	177	120	103	0	61	0	7	1032
2005	0	1667	137	416	134	55	140	23	52	15	2639

Table 7. Yellow perch catch at age matrix from Severn River fyke net survey, 2001 – 2005.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	total
2001	0	0	314	94	983	33	77	0	0	0	1501
2002	7	100	90	410	102	1549	20	34	0	0	2312
2003	0	56	22	0	198	32	367	11	0	89	775
2004	0	204	158	47	5	492	69	428	13	11	1427
2005	0	2192	347	110	40	0	231	71	135	0	3126

Table 8. Yellow perch catch at age matrix from upper Chesapeake Bay commercial fyke net survey, 1999 – 2005.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	total
1999	0	0	1621	33	337	408	28	0	2	0	2429
2000	0	35	138	2937	129	369	211	0	0	0	3819
2001	0	0	83	90	432	17	9	17	0	0	648
2002	0	52	117	528	56	1000	14	39	53	0	1859
2003	0	27	565	78	361	45	418	6	15	25	1540
2004	0	4	473	499	62	50	3	43	2	2	1138
2005	0	18	27	1320	414	73	37	0	26	5	1920

Table 9. Yellow perch catch at age matrix from Nanticoke River survey, 1999 – 2005.

	AGE										
	1	2	3	4	5	6	7	8	9	10+	Total
1999	0	10	1072	323	295	22	0	4	14	22	1762
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	1242
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

Table 10. Relative stock densities (RSD's) of white perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2005. Minimum length cut-offs in parentheses.

Year	Stock (125 mm)	Quality (200 mm)	Preferred (255 mm)	Memorable (305 mm)	Trophy (380)
2000	76.9	22.1	0.9	0.1	0
2001	89.8	9.9	0.3	0	0
2002	87.1	12	0.8	0	0
2003	84	14.3	1.2	0.5	0
2004	NOT SAMPLED				
2005	83.9	16.1	0	0	0

Figure 5. White perch length-frequency from 2005 upper Chesapeake Bay winter trawl survey.

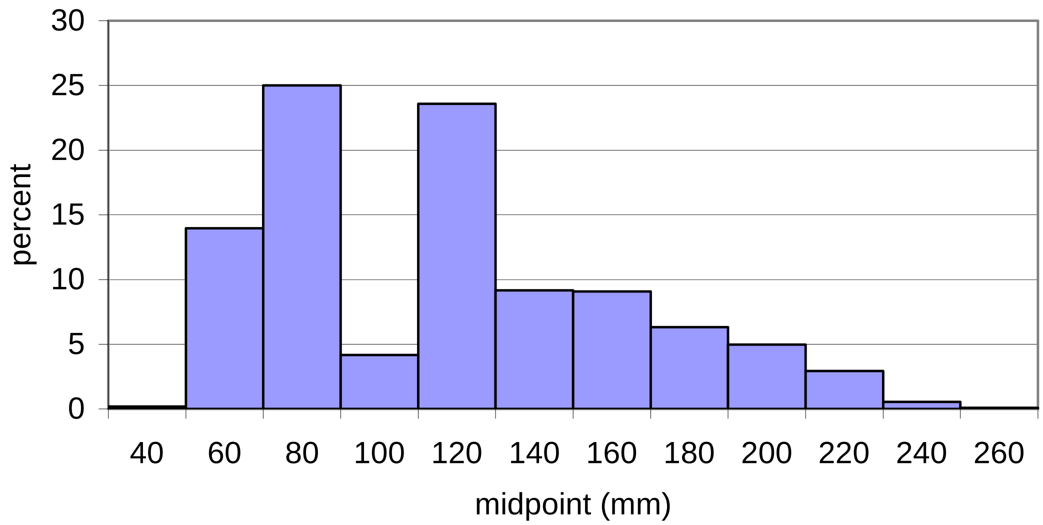


Table 11. Relative stock densities (RSD's) of white perch from the Choptank River fyke net survey, 1993 – 2005. Minimum length cut-offs in parentheses.

Year	Stock (125 mm)	Quality (200 mm)	Preferred (255 mm)	Memorable (305 mm)	Trophy (380)
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	<1	0.0
2005	78.5	19.9	1.5	0.1	0.0

Figure 6. White perch length-frequency from 2005 Choptank River fyke net survey.

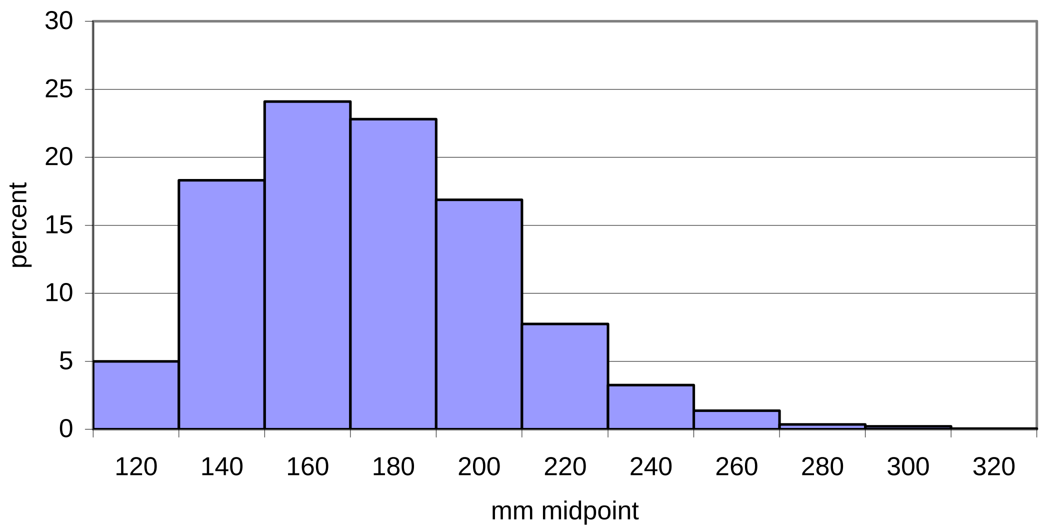


Table 12. Relative stock densities (RSD's) of white perch from the Severn River fyke net survey, 2001 – 2005. Minimum length cut-offs in parentheses.

Year	Stock (125 mm)	Quality (200 mm)	Preferred (255 mm)	Memorable (305 mm)	Trophy (380)
2001	14.7	79.6	5.6	<1	0.0
2002	6.6	81.6	11.2	<1	0.0
2003	33.8	51.1	13.7	1.4	0.0
2004	35.7	57.2	6.1	<1	<1
2005	19.1	71.4	8.7	0.8	0.0

Figure 7. White perch length-frequency from 2005 Severn River fyke net survey.

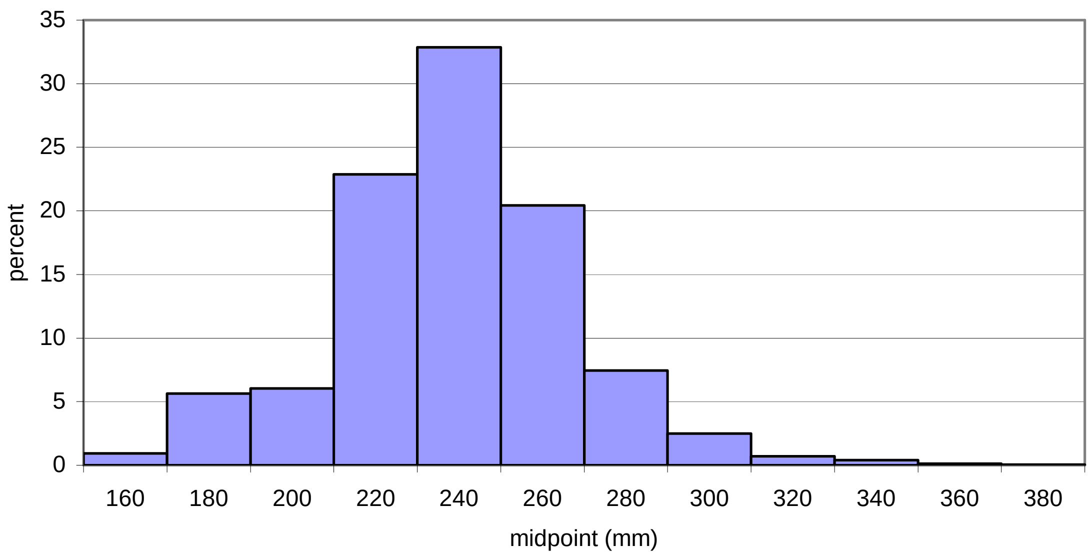


Table 13. Relative stock densities (RSD's) of white perch from the Nanticoke River survey, 1995 – 2005. Minimum length cut-offs in parentheses.

Year	Stock (125 mm)	Quality (200 mm)	Preferred (255 mm)	Memorable (305 mm)	Trophy (380)
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

Figure 8. White perch length-frequency from 2005 Nanticoke River survey.

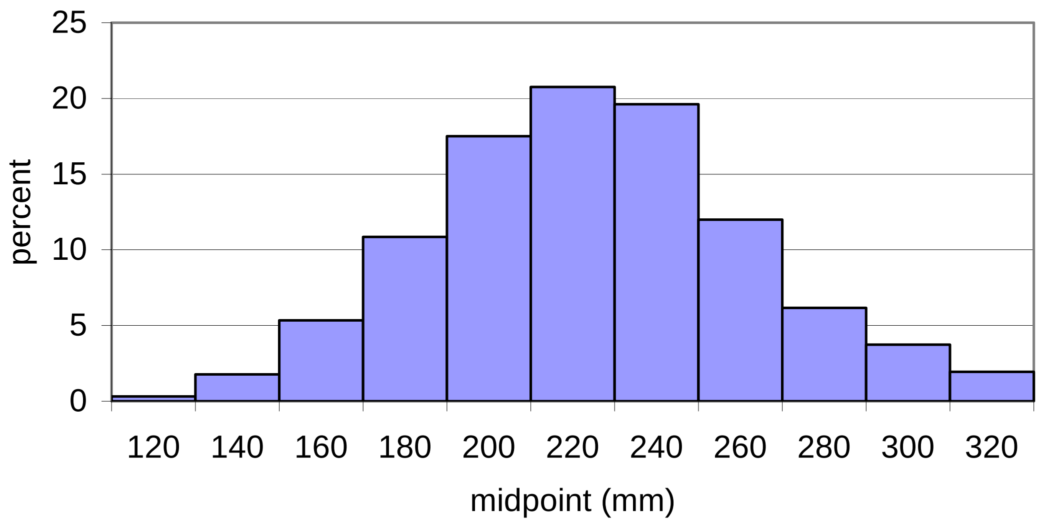


Table 14. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay winter trawl survey, 2000 – 2005. Minimum length cut-offs in parentheses.

	Stock (140 mm)	Quality (216 mm)	Preferred (255 mm)	Memorable (318 mm)	Trophy (405 mm)
2000	89	10	1		
2001	90.6	7.9	1.4		
2002	87.8	10.7	1.5		
2003	87	7	4	1	
2004		NOT SAMPLED			
2005	98.6	1.4			

Figure 9. Yellow perch length-frequency from the 2005 upper Chesapeake Bay winter trawl survey.

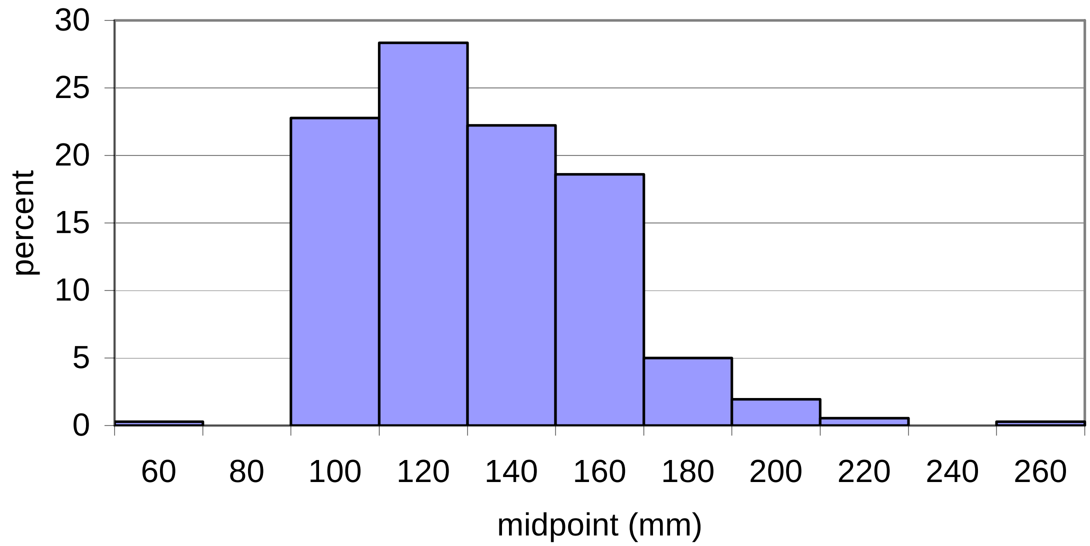


Table 15. Relative stock densities (RSD's) of yellow perch from the Choptank River fyke net survey, 1989 – 2005. Minimum length cut-offs in parentheses.

	Stock (140 mm)	Quality (216 mm)	Preferred (255 mm)	Memorable (318 mm)	Trophy (405 mm)
1989	66.7	24.4	8.2	0.7	
1990	64.8	27.3	7.8		
1991	58.7	23.4	18		
1992	45.3	26.4	24.5	3.8	
1993	34.6	31.7	30.3	3.3	
1994	23.4	33.6	36.6	6.4	
1995	45.5	28.1	23.1	3.3	
1996	74.1	18.2	7.2	0.5	
1997	57.5	29.3	12.9	0.3	
1998	10.5	72.9	16	0.6	
1999	86	12	2	0.04	
2000	72	19	9	0.2	
2001	84	13	3	0.9	
2002	60	33	7	<1	
2003	67	27	5	<1	
2004	54	35	11	<1	
2005	75	17	7	1	

Figure 10. Yellow perch length-frequency from the 2005 Choptank River fyke net survey.

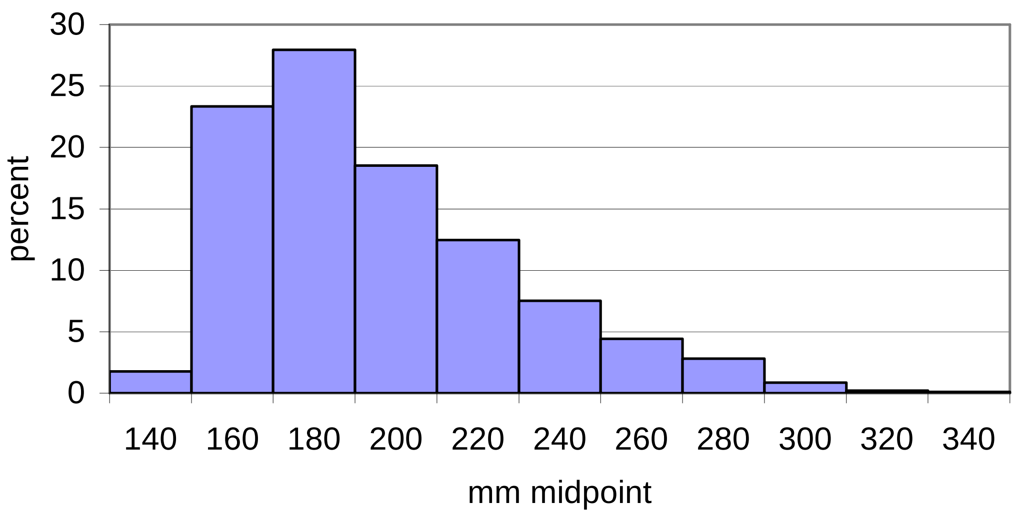


Table 16. Relative stock densities (RSD's) of yellow perch from the Severn River fyke net survey, 2001 – 2005. Minimum length cut-offs in parentheses.

	Stock (140 mm)	Quality (216 mm)	Preferred (255 mm)	Memorable (318 mm)	Trophy (405 mm)
2001	10.2	57.4	32	0.3	
2002	2	35	61	2	
2003	6	19	70	6	
2004	7	13	64	16	
2005	51.6	24.2	19.5	4.7	

Figure 11. Yellow perch length-frequency from the 2005 Severn River fyke net survey.

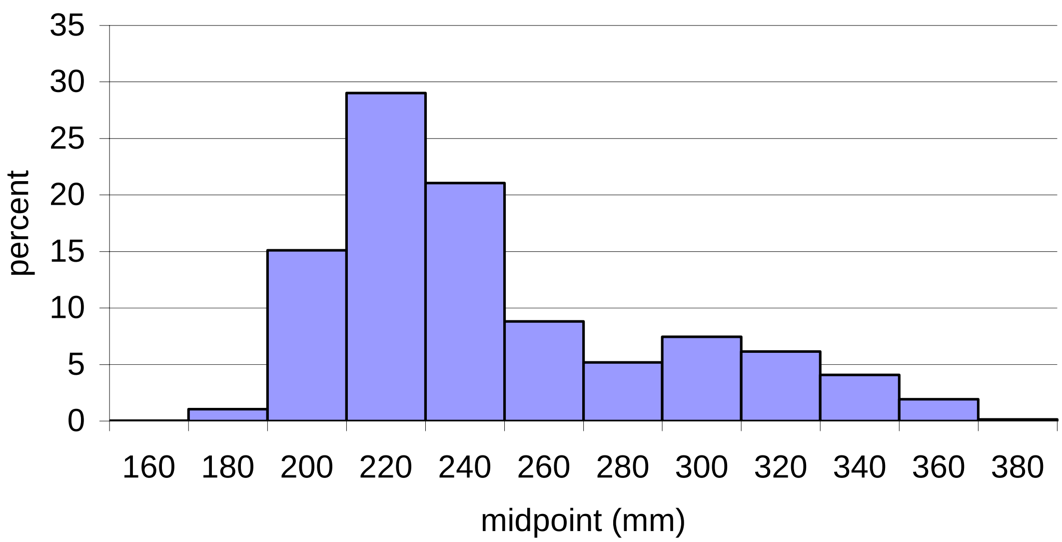


Table 17. Relative stock densities (RSD's) of yellow perch from the upper Chesapeake Bay commercial fyke net survey, 1988, 1990, 1998 – 2005. Minimum length cut-offs in parentheses.

	Stock (140 mm)	Quality (216 mm)	Preferred (255 mm)	Memorable (318 mm)	Trophy (405 mm)
1988	71.8	25.3	3.1		
1990	6.7	71.7	21	0.1	
1998	7	68	24	1	
1999	40	52	7	0.2	
2000	55	37	8	0.1	
2001	27	49	24		
2002	18	63	19	<1	
2003	19	56	24	1	
2004	10	66	24	<1	
2005	45.2	42.2	12.1	0.5	

Figure 12. Yellow perch length frequency from the 2005 upper Chesapeake commercial fyke net survey.

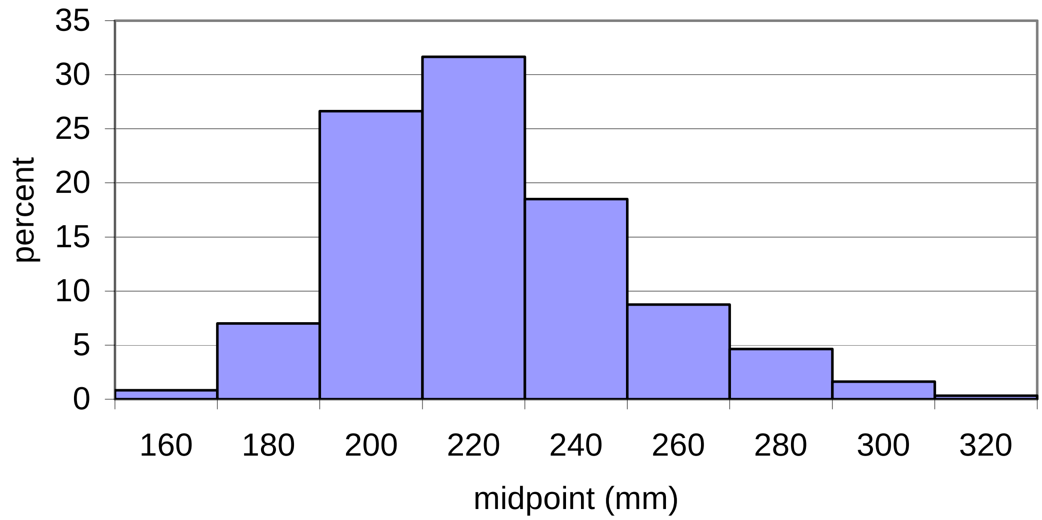


Table 18. Relative stock densities (RSD's) of yellow perch from the Nanticoke River survey, 1999 – 2005. Minimum length cut-offs in parentheses.

	Stock (140 mm)	Quality (216 mm)	Preferred (255 mm)	Memorable (318 mm)	Trophy (405 mm)
1999	12.4	28.8	55.6	3.2	
2000	3.1	19.5	72	5.2	
2001	2.4	22.2	66.6	8.9	
2002	3	19	62	16	
2003	11	47	36	6	
2004	2	27	61	10	
2005	16.2	33.8	38.7	11.3	

Figure 13. Yellow perch length frequency from the 2005 Nanticoke River survey.

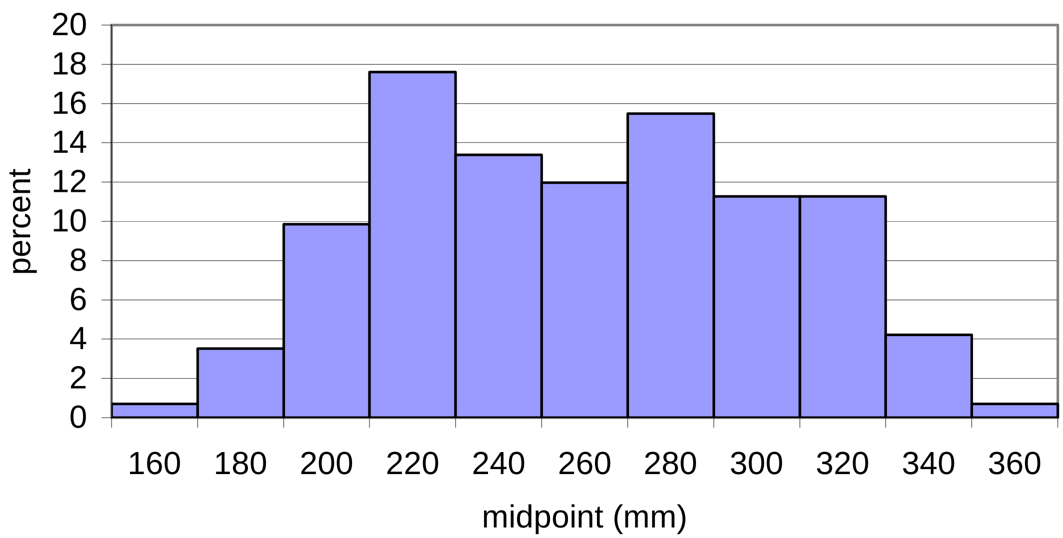


Table 19. Relative stock densities (RSD's) of channel catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2005. Minimum length cut-offs in parentheses.

	Stock (255 mm)	Quality (460 mm)	Preferred (510 mm)	Memorable (710 mm)	Trophy (890 mm)
2000	88.5	4.5	6.4	0.6	
2001	92.7	2.5	4.7		
2002	89.4	7.3	3.2		
2003	90	5	5		
2004			NOT SAMPLED		
2005	73.8	10	16.2		

Figure 14. Length frequency of channel catfish from the 2005 upper Chesapeake Bay winter trawl survey.

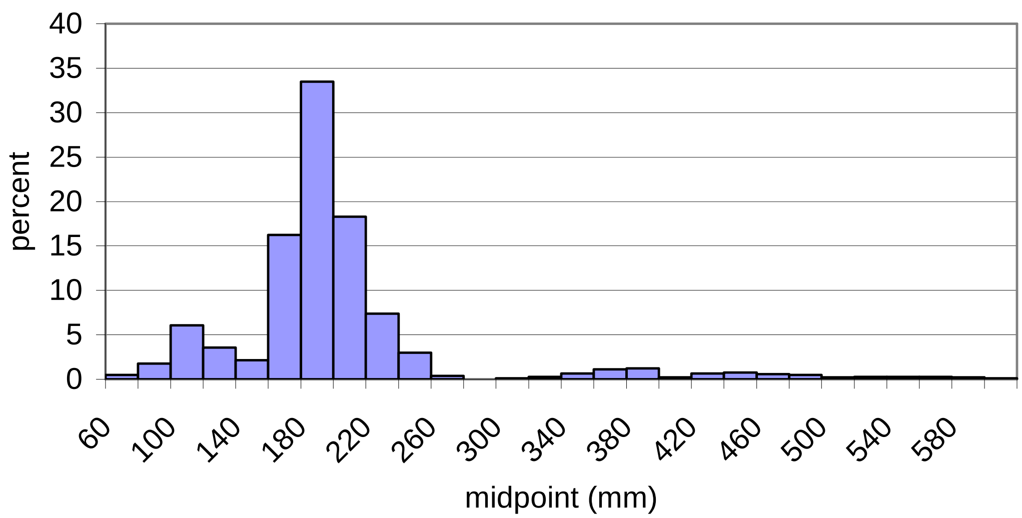


Table 20. Relative stock densities (RSD's) of channel catfish from the Choptank River fyke net survey, 1993 – 2005. Minimum length cut-offs in parentheses.

	Stock (255 mm)	Quality (460 mm)	Preferred (510 mm)	Memorable (710 mm)	Trophy (890 mm)
1993	53.4	24	22.6		
1994	61.9	15.8	22.2		
1995	21	20.4	58.6		
1996	40.8	14.1	35.6		
1997	19.8	16.4	63.8		
1998	33.3	9.2	57.5		
1999	31.3	10.6	58.1		
2000	63.7	8.4	27.9		
2001	53.2	6.7	40.1		
2002	19.8	14.3	65.9		
2003	84	6	10		
2004	59	10	31		
2005	79	9	12		

Figure 15. Channel catfish length frequency from the 2005 Choptank River fyke net survey.

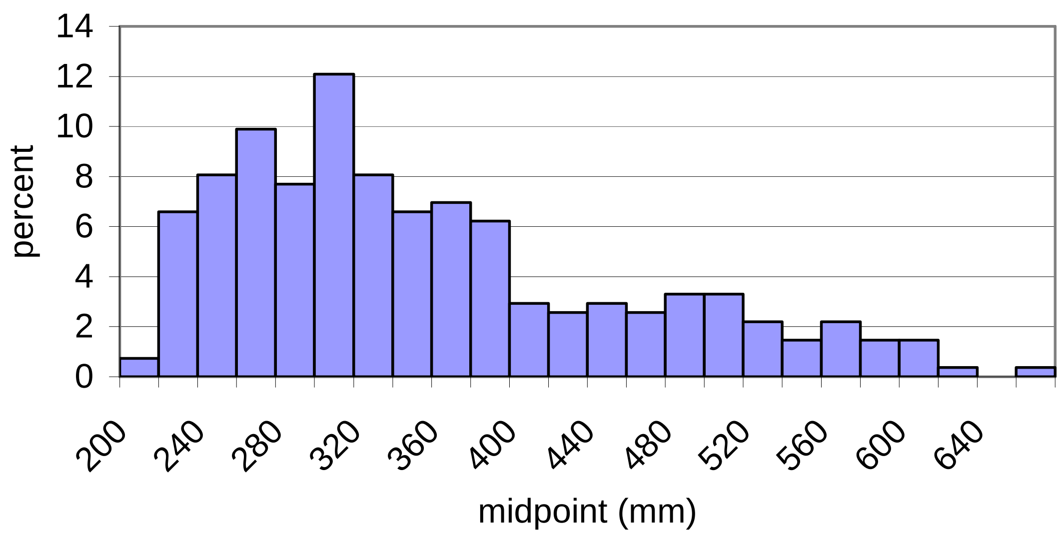


Table 21. Relative stock densities (RSD's) of channel catfish from Nanticoke River survey, 1995 – 2005. Minimum length cut-offs in parentheses.

	Stock (255 mm)	Quality (460 mm)	Preferred (510 mm)	Memorable (710 mm)	Trophy (890 mm)
1995	72.3	19.4	8.2		
1996	65.8	23.8	10.4		
1997	62.2	27.5	10.2		
1998	60.3	27.7	12		
1999	80.6	14.6	4.7		
2000	70.9	22.1	7.1		
2001	70.2	22.9	6.9		
2002	56.4	31.1	12.5		
2003	52	29	18		
2004	61	28	11		
2005	48.8	30.6	20.6		

Figure 16. Channel catfish length frequency from the 2005 Nanticoke River survey.

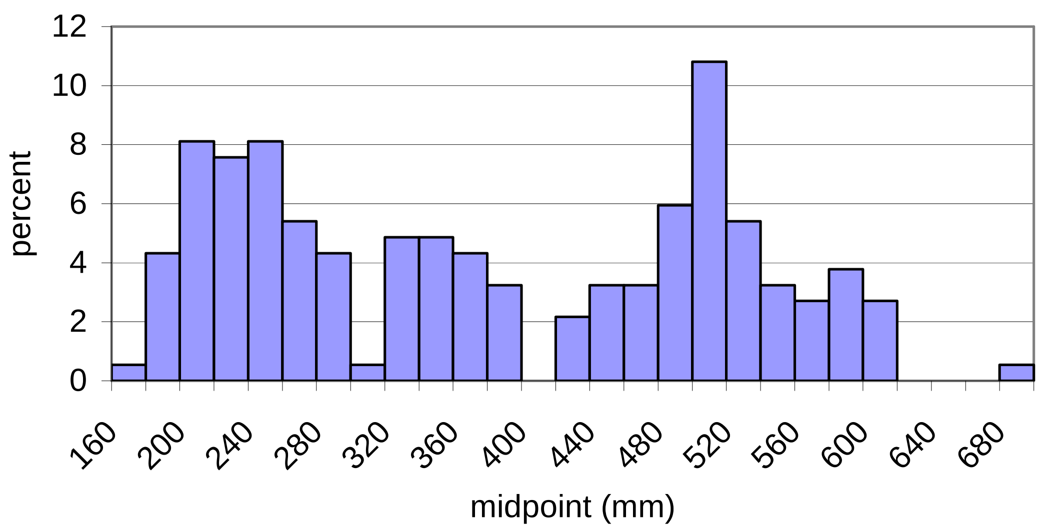


Table 22. Relative stock densities (RSD's) of white catfish from the upper Chesapeake Bay winter trawl survey, 2000 – 2005. Minimum length cut-offs in parentheses.

	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		
2002	57.1	42.9			
2003	85	15			
2004			NOT SAMPLED		
2005	96.6	3.4			

Figure 17. White catfish length frequency from the 2005 upper Chesapeake Bay winter trawl survey.

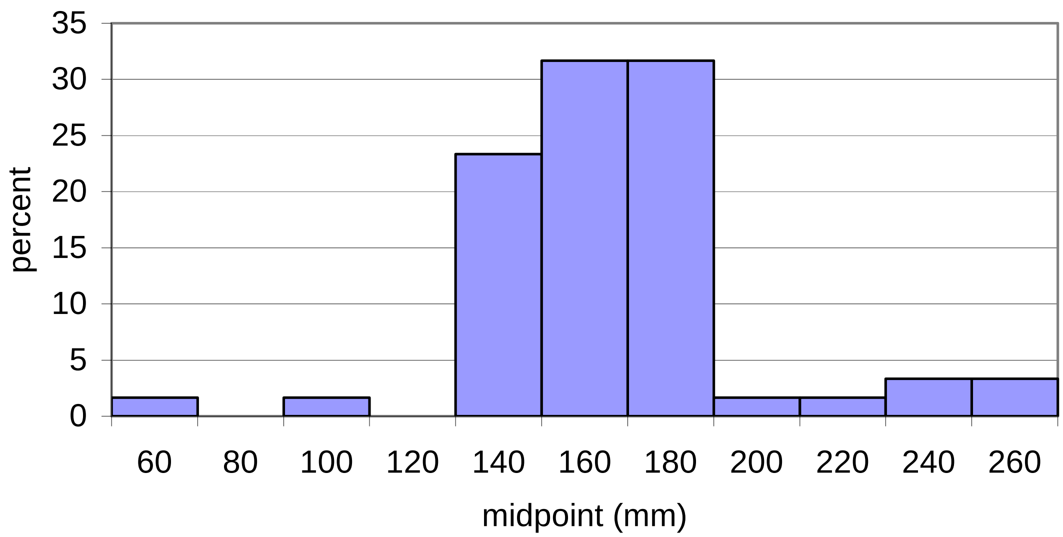


Table 23. Relative stock densities (RSD's) of white catfish from the Choptank River fyke net survey, 1993 – 2005. Minimum length cut-offs in parentheses.

	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	
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
1998	42.6	44.1	2.9	10.3	0.5
1999	44.8	38.6	5.9	10.8	
2000	50.6	29.2	7.6	12.4	0.3
2001	44.8	29.5	4.8	20	1
2002	7.8	38.9	15.4	35.5	2.4
2003	25	36	12	26	<1
2004	23	61	14	2	
2005	37	41	16	6	

Figure 18. White catfish length frequency from the 2005 Choptank River fyke net survey.

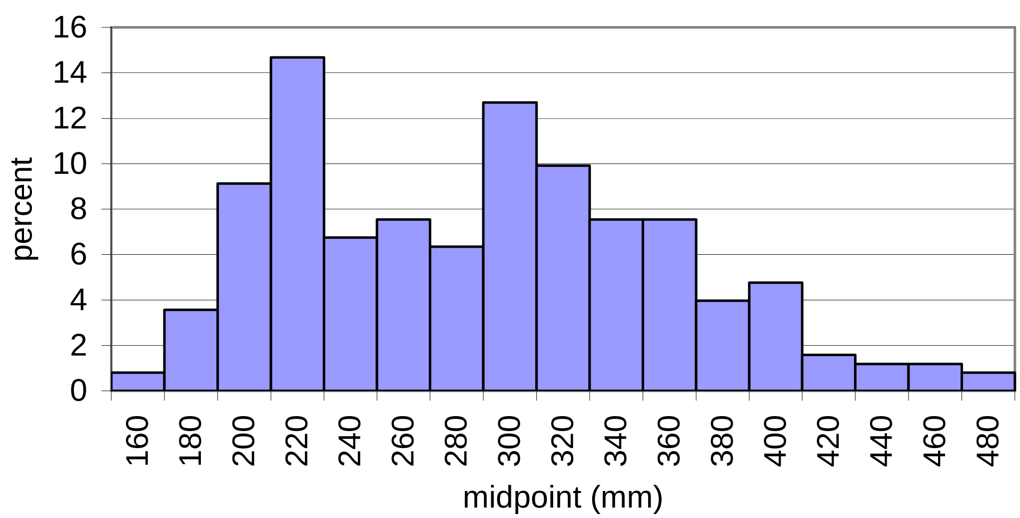


Table 24. Relative stock densities (RSD's) of white catfish from the Nanticoke River survey, 1995 – 2005. Minimum length cut-offs in parentheses.

	Stock (165 mm)	Quality (255 mm)	Preferred (350 mm)	Memorable (405 mm)	Trophy (508 mm)
1995	35.7	32.8	14.3	16.6	<1
1996	42.4	36.9	10.5	9.6	<1
1997	42.1	37.4	10.9	8.2	1.4
1998	27.9	48.2	17.4	6	
1999	41	34.5	14.4	10.1	
2000	39.9	42.1	12	6	
2001	46.2	28.2	16	9	1
2002	37	34.6	15.2	12.8	<1
2003	18	32	24	25	<1
2004	13	45	35	7	
2005	47	30.3	13.6	9.1	

Figure 19. White catfish length frequency from the 2005 Nanticoke River survey.

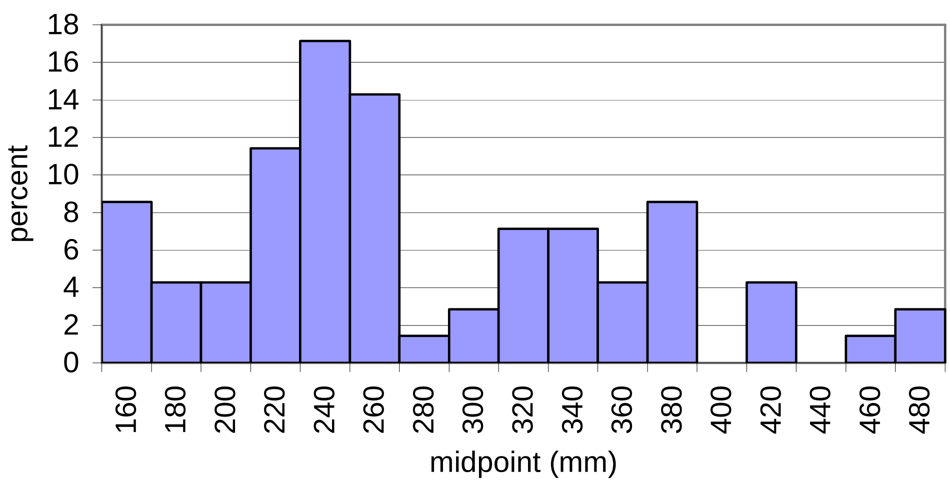


Table 25. White perch growth parameters from Choptank River for males, females, and sexes combined. NA=data not available NSF=no solution found or small sample size.

		allometry		von Bertalanffy		
Sample Year	Sex	alpha	beta	L-inf	K	t_0
2000	F	2.1 X 10-5	2.95	267	0.39	0.92
	M	2.2 X 10-5	2.92	236	0.4	0.79
	Combined	1.3 X 10-5	3.04	271	0.33	0.71
2001	F	7.7 X 10-6	3.14	252	0.51	-1.4
	M	2.1 X 10-4	2.53	251	0.5	0.56
	Combined	7.0 X 10-6	3.16	252	0.49	-1.56
2002	F	NSF			NSF	
	M	5.0 X 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 X 10-6	3.17		NSF	
	M	NSF			NSF	
	Combined	4.5 X 10-6	3.23		NSF	
2005	F	4.8 X 10-6	3.23	288	0.36	0
	M	4.8 X 10-6	3.22	374	0.1	-2.1
	Combined	3.8 X 10-6	3.27	304	0.25	-1.6

Table 26. White perch growth parameters from Severn 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
2001	F	5.83 X 10-5	2.77			
	M	3.3 X 10-5	2.86		NSF	
	Combined	4.52 X 10-6	3.23			
2002	F	2.8 X 10-5	2.92	368	0.16	-1.6
	M	3.6 X 10-5	2.85	351	0.12	-2.8
	Combined	1.0 X 10-5	3.1	374	0.14	-1.8
2003	F			302	0.28	-0.37
	M	NA		277	0.29	-0.56
	Combined			307	0.25	-0.58
2004	F	2.19 X 10-6	3.35	284	0.28	-0.9
	M	1.7 X 10-5	2.97	259	0.33	-0.58
	Combined	5.58 X 10-5	2.75	276	0.29	-0.72
2005	F	2.65 X 10-4	2.5	287	0.27	-0.4
	M	3.80 X 10-5	2.84	250	0.32	-0.89
	Combined	1.08 X 10-4	2.66	270	0.34	-0.08

Table 27. 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 X 10-4	2.56	272	0.5	1.1
	M	1.4 X 10-4	2.6	288	0.24	-0.6
	Combined	7.7 X 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 X 10-6	3.48	328	0.17	-2.5
	M	1.87 X 10-6	3.4	286	0.22	-1.4
	Combined	1.11 X 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 X 10-6	3.22	322	0.25	-0.3
	M	2.36 X 10-6	3.35	288	0.21	-1.5
	Combined	2.59 X 10-6	3.35	335	0.18	-1.2
2005	F	2.33 X 10-6	3.36	313	0.23	-0.53
	M	NSF		313	0.14	-2.65
	Combined	1.5 X 10-6	3.44	321	0.17	-1.6

Table 28. 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

Table 29. Yellow perch growth parameters from Severn 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					
	M					
	Combined					
2001	F	5.62×10^{-7}	3.16	308	0.39	-0.4
	M	3.37×10^{-6}	3.23	270	0.35	-1.4
	Combined	1.35×10^{-6}	3.41	288	0.42	-0.2
2002	F	4.76×10^{-6}	3.21	314	0.39	-0.9
	M	1.3×10^{-5}	3	276	0.42	-1
	Combined	4.9×10^{-7}	3.6	284	0.59	-0.2
2003	F			297	0.48	-0.5
	M			295	0.24	-0.9
	Combined			295	0.41	-1
2004	F	3.1×10^{-5}	2.86	309	0.58	-0.5
	M	1.7×10^{-4}	2.53	263	0.26	-1.4
	Combined	1×10^{-5}	3.04		SNF	
2005	F	1.2×10^{-6}	3.44	321	0.65	0.2
	M	9.29×10^{-6}	3.06	298	0.51	0
	Combined	1.03×10^{-6}	3.46	317	0.52	-0.1

Table 30. 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	No Data		329	0.21	-2.9
	M	No Data		249	0.38	-1.1
	Combined	No Data		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

Table 31. 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

Table 32. Estimated instantaneous fishing mortality rates (F) for white perch. Based on catch curve analysis of ages 6 – 10+.

	2000	2001	2002	2003	2004	2005
Choptank	0.34	0.48	0.25	0.46	0.1	0.58
Nanticoke	0.42	0.58	0.44	0.31	NR	NR
Severn	n/a	0.19	0.15	0.57	0.1	NR
Upper Bay trawl	0.09	0.58	0.51	0.13	n/a	0.5

Table 33. Estimated instantaneous fishing mortality rates (F) for yellow perch.

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

[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 20. Baywide young-of-year relative abundance index for white perch, 1962 – 2005, based on Estuarine Juvenile Finfish Survey data. Bold horizontal line=time series average.

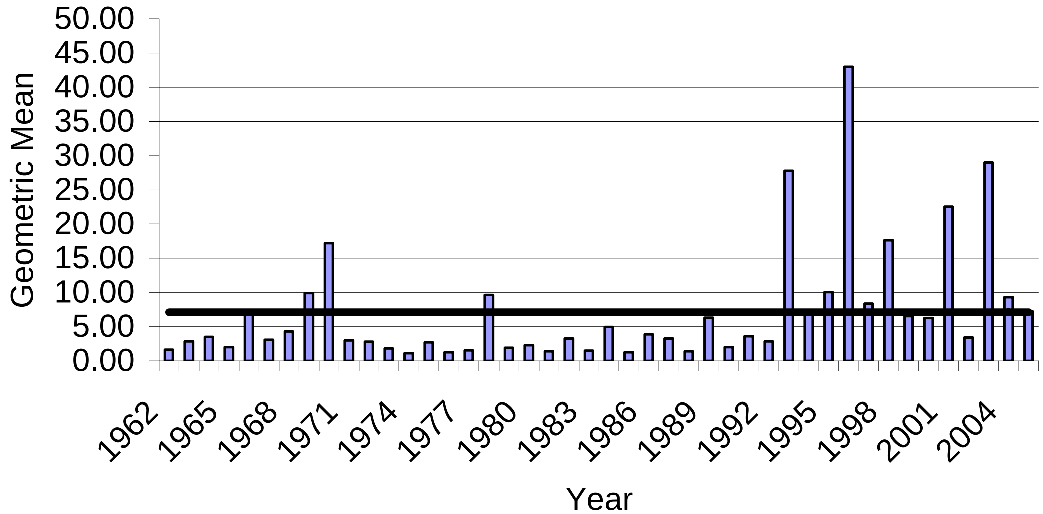


Figure 21. Young-of-year white perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

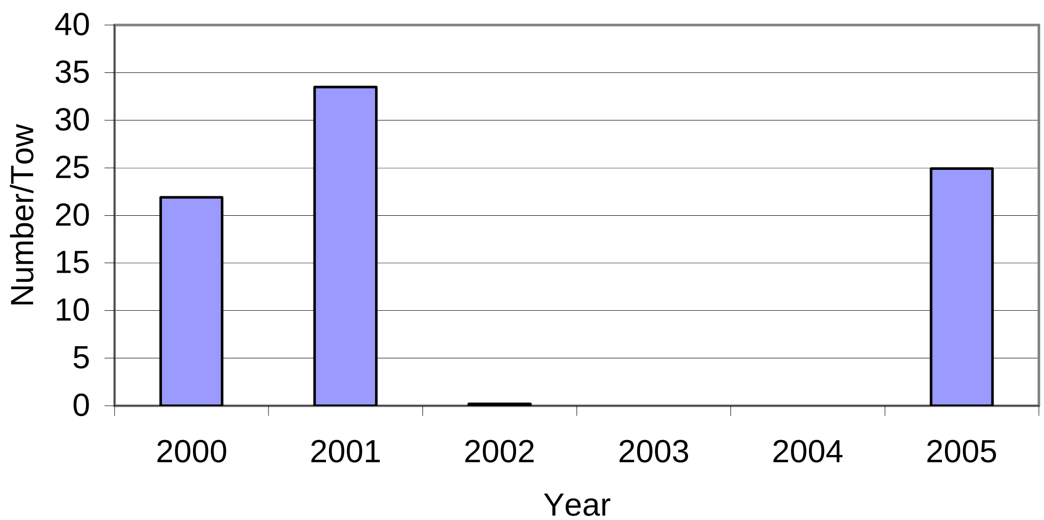


Figure 22. Head-of-Bay young-of-year relative abundance index for yellow perch, 1979 – 2005, based on Estuarine Juvenile Finfish Survey data. Bold horizontal line=time series average.

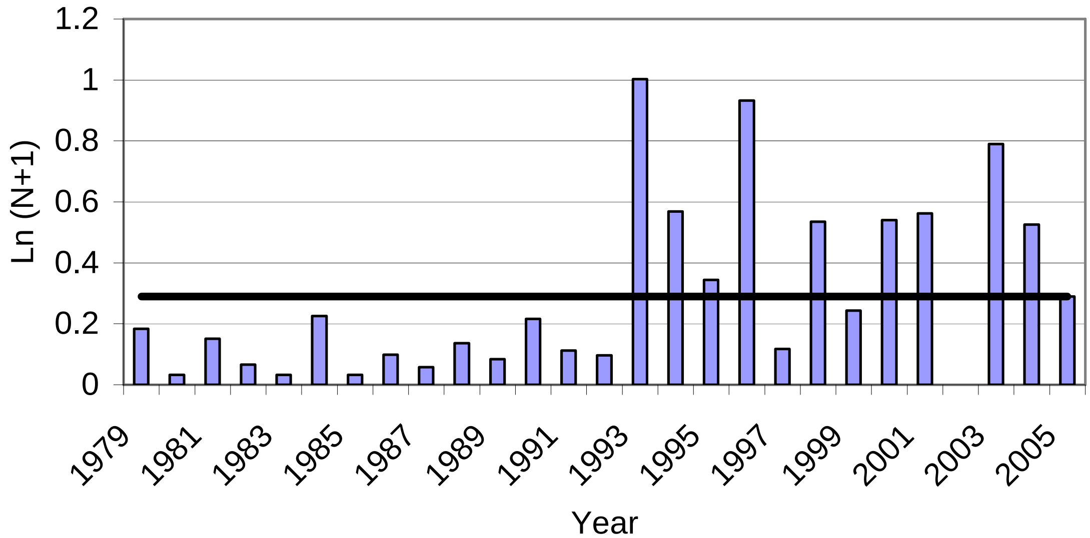


Figure 23. Young-of-year yellow perch relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

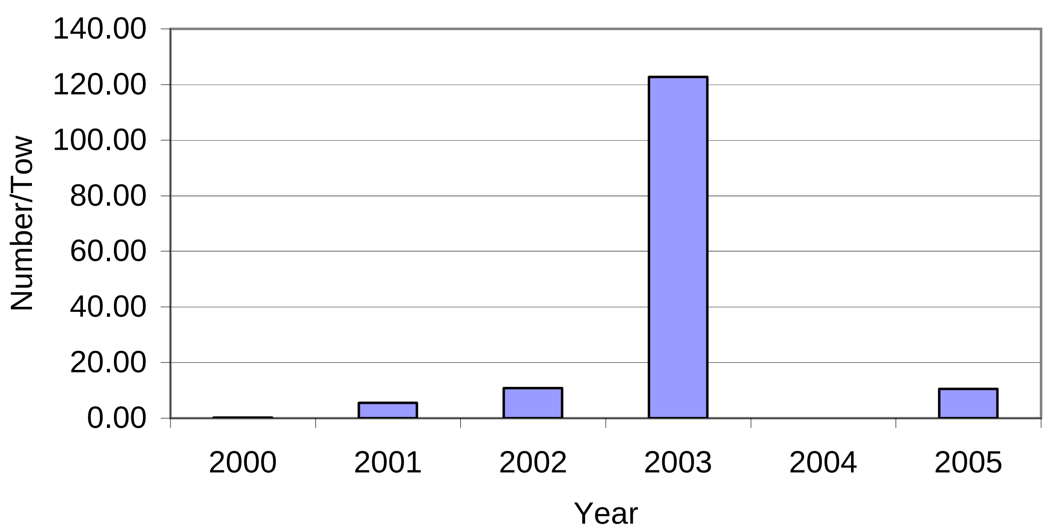


Figure 24. Head-of-Bay young-of-year channel catfish relative abundance from Estuarine Juvenile Finfish Survey. Bold horizontal line=time series average

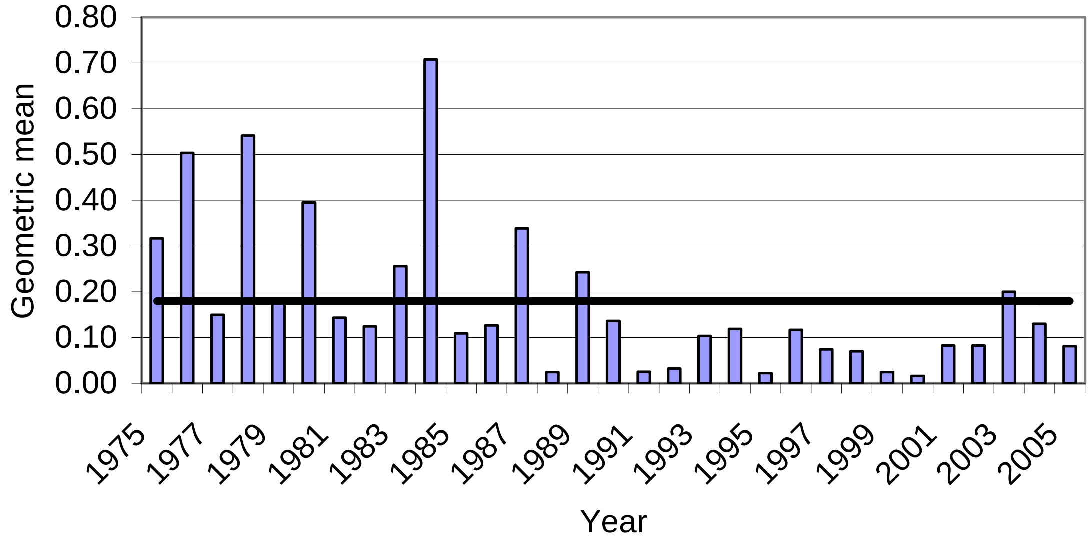


Figure 25. Young-of-year channel catfish relative abundance from upper Chesapeake Bay winter trawl survey. Not sampled in 2004, small sample sizes 2003 and 2005.

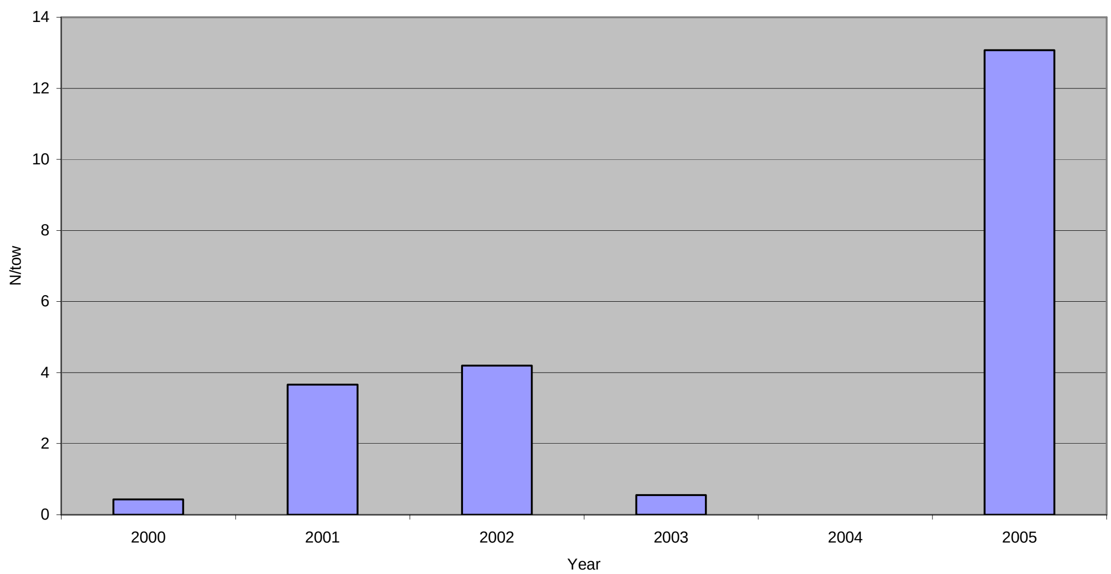


Table 34. White perch relative abundance (N/tow) and total effort from the upper Chesapeake Bay winter trawl survey, 2000 – 2005.

	AGE											
Year	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2000	21.9	62.9	32.3	40	25.2	25.5	38.1	3.1	5.7	3	257.7	79
2001	33.5	69.3	77.3	33.3	22	8.8	8.2	15.4	2.3	2.3	272.4	115
2002	0.2	22.5	14.4	24.3	10.4	20.3	12.7	2.8	6	1	114.6	110
2003	0	63.7	295.5	38.2	67.7	26.2	69.3	44.1	9	29.8	643.4	20
2004					NOT SAMPLED							
2005	24.9	43.77	7.3	7.7	4.1	7.5	6.5	1.6	2.49	0.3	106.2	43

Table 35. White perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2005.

	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

Table 36. White perch relative abundance (N/net day) and total effort from the Severn River fyke net survey, 2001 – 2005.

	AGE											
Year	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2001	0.0	0.0	1.3	4.5	39.4	3.9	7.3	4.0	0.1	0.0	60.5	180
2002	0.0	0.1	3.1	2.4	2.1	18.6	0.9	1.4	0.5	0.0	29.0	319
2003	0.0	4.9	35.9	4.0	12.3	3.9	32.3	11.2	6.1	5.0	115.6	140
2004	0.0	0.0	20.1	5.4	2.7	3.3	9.8	8.2	1.6	2.0	53.1	176
2005	0.0	0.8	5.2	16.6	6.0	3.6	4.1	8.4	8.8	4.5	58.0	226

Table 37. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2005.

	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	10.49	0.02	8.58	0.16	0.30	0.02	0.05	0.02	0.00	0.00	19.65	43

Table 38. Yellow perch relative abundance (N/net day) and total effort from the Choptank River fyke net survey, 2000 – 2005.

	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

Table 39. Yellow perch relative abundance (N/net day) and total effort from the Severn River fyke net survey, 2001 – 2005.

	AGE											
	1	2	3	4	5	6	7	8	9	10+	sum CPE	total effort
2001	0.00	0.00	1.83	0.55	5.72	0.19	0.45	0.00	0.00	0.00	8.73	172
2002	0.02	0.31	0.28	1.29	0.32	4.86	0.06	0.11	0.00	0.00	7.25	319
2003	0.00	0.39	0.15	0.00	1.39	0.23	2.58	0.08	0.00	0.63	4.40	142
2004	0.00	1.16	0.90	0.27	0.03	2.80	0.39	2.43	0.07	0.06	8.11	176
2005	0.00	9.70	1.54	0.49	0.18	0.00	1.02	0.31	0.60	0.00	13.83	226

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

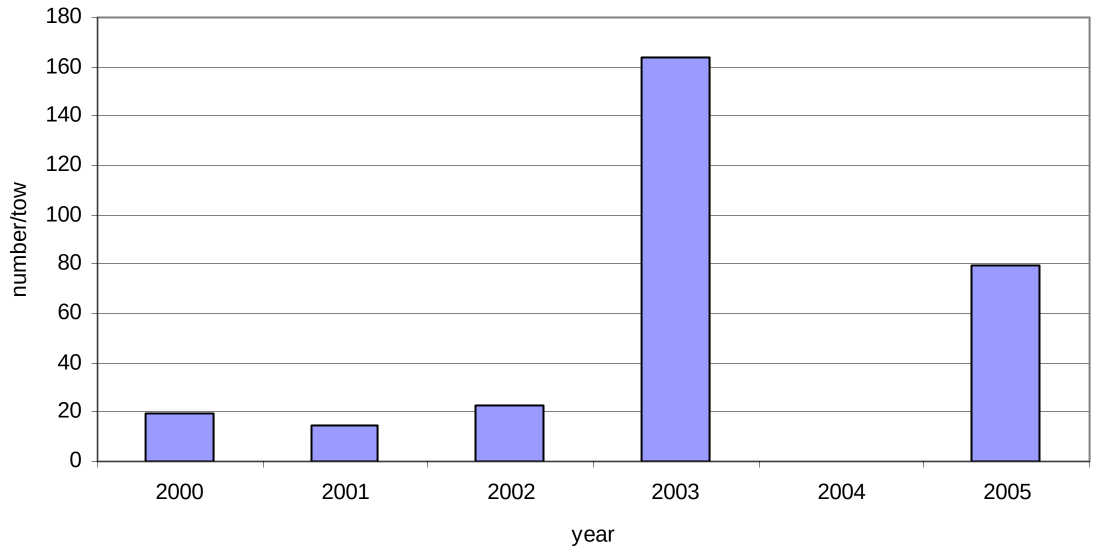


Figure 27. Channel catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2005.

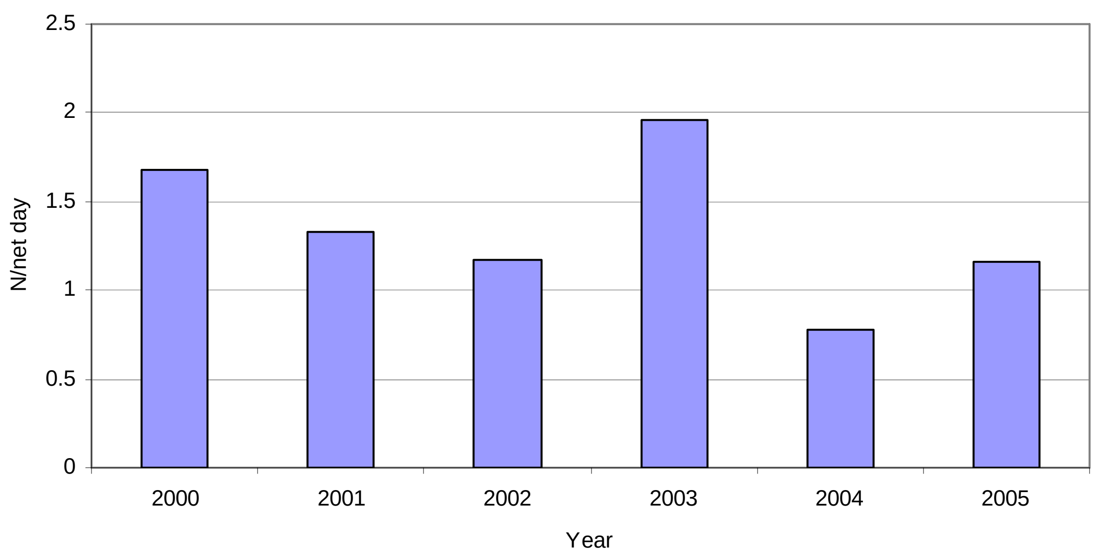
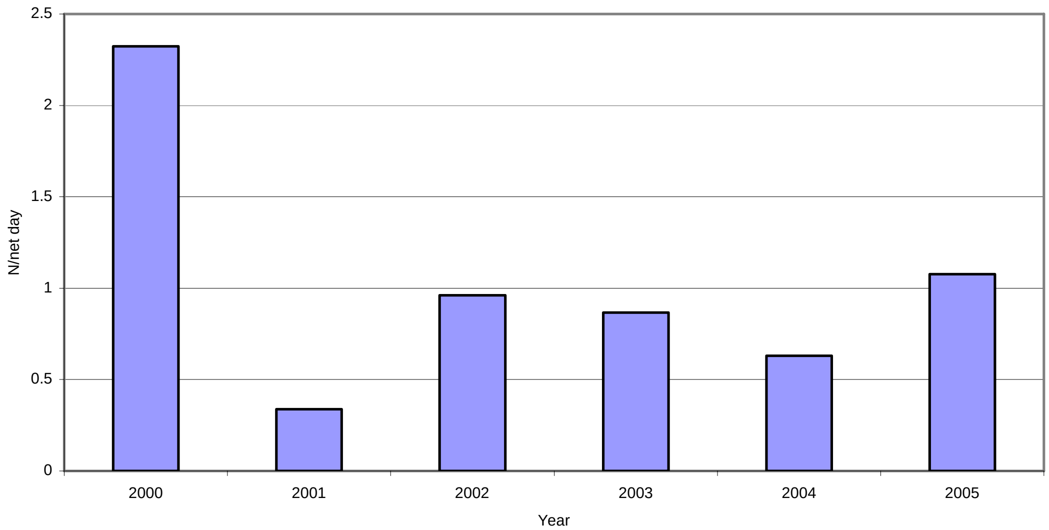


Figure 28. White catfish relative abundance (N/net day) from the Choptank River fyke net survey, 2000 – 2005.



PROJECT NO. 1
JOB NO. 2

Population Assessment Of White Perch In Maryland With Special Emphasis On Choptank River Stocks

Prepared by Paul G. Piavis and Edward Webb, III

INTRODUCTION

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

White perch fisheries are important in the Chesapeake Bay region. Based on the Marine Recreational Fisheries Statistics Survey (MRFSS; National Marine Fisheries Service, personal communication), Maryland's 2004 recreational white perch landings were 519,000 pounds, and have averaged 541,000 pounds during the period 2000 – 2004, based on the Marine Recreational Fisheries Statistics Survey (MRFSS; National Marine Fisheries Service, personal communication). White perch also support a robust commercial fishery in Maryland. Commercial white perch landings were 1,178,000 pounds in 2004, and averaged 1,593,000 pounds over the period 2000 – 2004.

Since no synoptic assessment of white perch has been conducted in Chesapeake Bay, fishery dependent and independent data, along with various statistical models were utilized to assess white perch stocks, baywide and specifically in the Choptank River.

Parameters investigated included abundance, mortality, recruitment/production, catch-per-unit-of-effort, and age and growth. This assessment will provide important information regarding management of this species, particularly in the upcoming preparation of the Chesapeake Bay White Perch Fisheries Management Plan.

METHODS

Bay-wide surplus production modeling

Fisheries Catch per Unit Effort Indices

Commercial landings and catch per unit effort (CPUE) indices were determined from DNR commercial catch records. Landings data exist prior to World War II, but associated effort data are only available for 1980 – 1984, 1990, and 1992 – 2004. Three primary white perch commercial fisheries were used for relative abundance indexes; fyke net, drift gill net, and pound nets. For fyke and pound nets, effort can only reliably be ascribed as numbers of nets fished, while drift gill net effort was determined as pounds per 1000 yard hours fished.

All recreational landings and CPUE indices were determined from the MRFSS between 1981 – 2004 (National Marine Fisheries Service, personal communication). Effort was defined as those trips targeting white perch or catching white perch. CPUE was defined as pounds per 100 angler hours.

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

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, quantified 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.

Choptank River White Perch Assessment

Site Description

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

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

Field operations

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

When fished, net hoops were brought aboard first to ensure that all fish were retained. Fish were then removed and placed into a sorting tank and identified. All fish were counted and a subsample of 30 white perch were sexed and measured (mm TL). Otoliths were extracted for age determination in 1992, and 1999 - 2005.

Effort varied considerably as the project moved from a pilot phase to a more integrated monitoring program for white perch, yellow perch, channel catfish, and white catfish. Only two fyke net sets were monitored during 1989 - 1991. Three fyke net sets were used during 1992, and five fyke net sets were fished from 1993 to 2005. Locations were consistent between 1993 - 2005, except for the uppermost net where conflicts arose with commercial gear. This necessitated moving this net set approximately 500 m down stream.

CSA Model structure

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

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

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

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

$$r_t = R_t\, q \quad [2]$$

and,

$$p_t = P_t\, q\, \Phi \quad [3]$$

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

Substituting [2] and [3] into equation [1] yields

$$r_{t+1} = (r_t + p_t / \Phi) \, e^{-M} - q \, C_t \, e^{-Mt(1 - Tt)} \qquad [4]$$

CSA Error structure

Adding a process error term (ε) into [4] yields

$$r_{t+1} = (r_t + p_t / \Phi) \, e^{-M \, \varepsilon} - q \, C_t \, e^{-M \, (1 - Tt)\varepsilon} \qquad [5]$$

Measurement error (η and δ) is similarly incorporated into [2] and [3]

$$p_t = P_t \, q \, e^{\eta} \qquad [6]$$

$$r_t = R_t \, q \, \Phi \, e^{\delta} \qquad [7]$$

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

$$SSQ = \lambda_\varepsilon \, \Sigma \, \varepsilon^2 + \Sigma \, \eta^2 + \lambda_\delta \, \Sigma \, \delta^2 \qquad [8]$$

where λ_{ε}, λ_δ , and λ_η are weighting factors. Equation [8] yields 3i-2 residual errors and 2i parameters to be fitted (q, $r_{1 \ldots i}$, $p_{1 \ldots i-1}$; Collie and Sissenwine 1983).

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

$$SSQ = \lambda_\eta \, \Sigma \, \eta^2 + \lambda_\delta \, \Sigma \, \delta^2 \qquad [9]$$

This yields i+1 parameters to be estimated with i-2 df. The model was run with the National Marine Fisheries Service Fisheries Toolbox, CSA version 2.0.1.4 (National Oceanic and Atmospheric Administration, personal communication).

Abundance and mortality estimation

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

$$h_t = C_t /((P_{t+1} + R_{t+1}) * e^{-Mt*Tt}) \quad [10]$$

Total instantaneous mortality (Z_t) was

$$\log_e ((R_t + P_t)/(R_{t+1})). \quad [11]$$

Total instantaneous fishing mortality (F) was

$$F_t = Z_t - M_t . \quad [12]$$

Inputs

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

Harvest estimates were determined for the commercial and recreational fisheries. Commercial harvesters are required to submit monthly landings reports by river system, in pounds, to the Maryland Department of Natural Resources. Numbers of commercially harvested white perch were determined by dividing pounds harvested (by gear type) by estimated average weight of legal white perch. Average legal weight by gear type was determined from several sources. Average length of fyke net caught white perch was taken from Fisheries Service survey nets. An allometric equation was applied to the average length to determine average weight. Average length of white perch caught in the gill net fishery was determined from data collected between 1989 - 1994 and 1996 by the Fisheries Service striped bass spawning stock gill net survey in Choptank River. Data from the Fisheries Service upper Bay striped bass spawning stock survey was used for the 1995 and 1997 –2005 length estimate. An allometric equation was applied to average length to determine average weight.

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

Relative catchability of pre-recruits (Φ) was set at 1.0 because length-frequencies indicated that white perch were recruited to the gear below the lower cut-off for pre-recruits. Natural mortality (M) was 0.20. An initial catchability for the runs was set at 5.0×10^{-6}. Fraction of year that the survey preceded the fishery (T) was 0.5.

Uncertainty

The model was bootstrapped 1,000 times by resampling residuals and adding them to the natural logarithm of the observed indices, then re-exponentiating the values. Mean, standard deviation and CV's were calculated for q and each estimate of P_t and R_t, exclusive of terminal year P. Confidence intervals (80%) were determined from cumulative p**ercent distributions of the bootstrapped parameter estimates.**

Spawning Stock Biomass per Recruit and Biological Reference Points

A Thompson-Bell Spawning Stock Biomass per Recruit analysis (SSB/R) following the procedures of Gabriel *et al.* (1989) was utilized to determine the percentage of SSB/R of an unfished stock that current harvest was producing. Reference points were also determined with this model. 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 1). Mean length at age was determined from von Bertalanffy parameters for female white perch from years 1999 - 2002, pooled (L_∞=319 K = 0.1751 t_0 = -0.9323). Similarly, weight at age was determined by substituting length at age into the allometric growth equation for female white perch from Choptank River, 1999 - 2002 ($\alpha = 7.9X10^{-6}$ $\beta = 3.129$). The selectivity pattern (s_t) was determined as percent of female white perch lengths at age greater than the minimum size limit. Proportion mature at age (fr_{ts}) was taken from a white perch study in Lake Erie (Schaefer and Margraf 1987). Cursory observations from the Fisheries Service winter trawl survey and other fyke net observations indicate that these values reflect the condition of Choptank River white perch maturity schedules. An arbitrary initial cohort of 100,000 at age 0 was used and the assessment was run for 15 age-classes.

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

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

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

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

Fishery dependent trends

Commercial landings exhibited two time periods of relatively high landings since 1929, one during the mid 1960's and the latest from the mid 1990's through 2004 (Figure 2). Recreational landings during 1981 – 2004, as estimated by MRFSS, indicated peak landings in 1997, similar to commercial landings if the same time period is considered (Figure 3).

Recreational CPUE indicated increasing relative abundance from the early 1980's through 1992, followed by a decline and leveling in recent years (Figure 4). Commercial fyke net CPUE suggested near linearly increasing relative abundance from 1980 –2004 (Figure 5). Commercial drift gill net CPUE increased early in the time series with slightly lower values in recent years, compared to the 1997 peak (Figure 6). Commercial pound net CPUE reflected no clear trend, but relative abundance appeared relatively high in the early 1980's, and a general decline since 1997 (Figure 7).

Fishery independent survey trends

Juvenile abundance has been above average since the mid 1990's (Figure 8). Since 1993, the index was at or above the time-series average (1962 – 2005) in 10 of 13 years. Previous to 1993, reproduction was near or above average in only 4 of 31 years. The Fisheries Service winter trawl survey provided limited data on white perch abundance. Relative abundance decreased during 2000 – 2002, increased greatly in 2003, but sample size in 2003 was very low (*cf* Job 1).

Bay-wide surplus production model

The model was run with all combinations of indices (recreational CPUE, fyke net CPUE, drift gill net CPUE and pound net CPUE) 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 with minimal fishing mortality, and fits that indicated population building through the late 1990's with a decrease in recent years. Only model runs from the latter category were considered as representative of white perch population dynamics. The final model run was selected subjectively by examining population and F trends. Many of the runs indicated decreasing stocks with relatively high biomass and low F for extended periods. These "non-intuitive" runs were discarded as possible solutions. The final run selected contained recreational CPUE, drift gill net CPUE, and pound net CPUE with near equal weighting (pound net =1.0; drift gill net = 1.03; and recreational = 1.22).

Estimated parameters, r, K, and B_0 were 0.5, 18.2 million pounds and 3.9 million pounds, respectively. Biomass increased from a low of 3.9 million pounds in 1980 to a high value of 15.09 million pounds during 1992, but has remained relatively high since 1992 (Figure 9). Instantaneous fishing mortality (F) declined and remained low during the mid-1980's – early 1990's, but increased somewhat for the remainder of the time series (Figure 9).

Biomass at maximum sustainable yield (B_{msy}) was estimated as 1/2K or 9.1 million pounds. F_{msy} was estimated as 1/2r or 0.25. Maximum sustainable yield was estimated as rK/4 or 2.3 million pounds. Ratios of $B:B_{msy}$ and $F:F_{msy}$ were within acceptable ranges, that is, $B/B_{msy} > 1$ and $F/F_{msy} < 1$ for large portions of the time series (Figure 10).

In the final year of the assessment (2004) F was 40% below F_{msy} and biomass was 23% > B_{msy}. Similarly, total estimated removals averaged 2.1 million pounds during the most recent 5-year period, 2000 – 2004, below the 2.3 million pound MSY estimate. The 2004 harvest estimate was 1.7 million pounds.

Uncertainty

Parameter estimates for r, K, and B_0 were moderately precise. CV values were 29.6%, 21.9% and 24.2%, respectively with median values were close to final estimates (Table 2). Initial biomass (B_0) is generally regarded as a nuisance parameter that has lower importance than r and K in model outputs. Annual biomass estimate CV's ranged from 21.9% – 46.3%. Confidence interval (80%) of bootstrapped runs indicated a widening spread. However, 97% of the bootstrapped 2004-biomass values exceeded B_{msy} (Figure 11). Bootstrapped F values were correspondingly below F_{msy} indicating a 94% chance overfishing is not occurring.

Choptank River White Perch Assessment

Fishery dependent commercial fyke net CPUE indicated an increasing trend over the period 1989 – 2004. Fishery independent Fisheries Service fyke net samples, on a similar weight basis, mimicked the fishery dependent CPUE (Figure 12). Pre-recruit fishery independent CPUE values peaked in 2003, but showed a generally increasing trend over the time-series (Figure 13). Recruited white perch CPUE was flat between 1989 – 1995, and then increased through 2005 (Figure 14).

Choptank River white perch data fit the CSA model well. Total population abundance in numbers increased from 949,000 white perch during 1989 to 4.3 million fish in 2005 (Figure 15). Pre-recruit abundance (185 mm – 203 mm) ranged from 478,000 white perch in 1991 to 2.4 million in 2005. Recruited white perch ranged from 440,000 white perch in 1989 to 1.9 million fish in 2005. Instantaneous fishing mortality (F) increased through 1997 followed by a general decline through 2004 (Figure 16). Final year F was 0.47.

Examination of pre-recruit residuals indicated a period of negative residuals for the first 5 years and positive residuals over the last 6 years (Figure 17). The years of negative residuals coincides with reduced sampling effort relative to subsequent years. Recruit residuals showed no discernible pattern (Figure 18), save for a period of negative residuals since 2001, although 4 of the 5 negative residuals were very small.

Uncertainty

Bootstrap evaluation of the model indicated precise results. Pre-recruit abundance fit very well with CV's ranging from 13% to 34% (Table 3). CV's of fully recruited white perch ranged from 26% to 36%. CV's of F ranged from 20% to 27%. Catchability was very precisely estimated at 13.7% (CV). Confidence intervals (80%) of pre-recruit and recruit abundance were also determined from bootstrap samples (Figures 19, 20).

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 (Gabriel et al. 1989). Percent maximum pawning potential (%MSP) reference points ranged from F=0.47 (35% MSP) to 1.12 (20% MSP; Table 4). Yield per recruit reference points were $F_{0.1} = 0.30$ and $F_{max} = 0.75$. Choptank River F from the CSA was equal to $F_{35\%}$.

DISCUSSION

Chesapeake Bay Assessment

The model used was selected because of available data. Lack of long-term age data precluded age based assessments such as VPA's. Lack of fisheries independent data on a bay-wide scale precludes using such methods as CSA or stock synthesis type models. The biomass dynamic model for the bay-wide assessment yields good results. The population data seem to have a full population cycle that is critical for the model to fit the data. The bay-wide assessment will not be sensitive to localized population declines, but juvenile abundance data provided by the Estuarine Juvenile Finfish Survey (Project 2, Job 2, Task 3) indicate healthy reproduction in all 8 regions surveyed. Adult population data such as age data and length distributions should be monitored on a watershed basis where practicable.

Chesapeake Bay white perch stocks are at relatively high levels with moderate fishing mortality. Stocks have declined since 1992, but remain above reasonable benchmarks. Incorporating model and data uncertainty into the assessment also indicates a high likelihood that population levels are above biomass at maximum sustainable yield. Similarly, F levels are reasonable given model and data uncertainty.

Harvest levels exceeded MSY in 1997 and 2000, but this occurred at high population levels causing a slight decline in abundance. Juvenile production has also been at high levels, which mitigates any short-term violation of MSY. Harvest in 2004 was comfortably below MSY.

Choptank River Assessment

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

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

Spawning stock biomass per recruit (SSB/R) and yield per recruit biological reference points (BRP) for white perch

Results from the SSB/R and YPR analyses were intuitive. Examination of Choptank River population trajectory and F rates are constructive in determining BRPs. For example, the population continued to increase with F estimates in the 0.4 – 0.85 range. Given the resilience of white perch, F 30% (0.60) could provide enough spawning stock to maintain and increase population levels. This level should be considered as a target F rate. Threshold levels would then be approximately F_{max} (0.75) or $F_{25\%}$ (0.80).

Biological reference points derived from the SSB/R or YPR analyses are not directly comparable to F rates derived from the biomass dynamic model. The biomass dynamic model should be interpreted as a bay-wide picture of the population trajectory, and F estimates are based on biomass. The biomass-based estimate would not be completely comparable to the numbers based estimates of fishing mortality derived from the SSB/R or YPR analyses. Watershed-specific or regional estimates of F need to be determined and compared to BRP's.

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Table 1. Input variables for Thompson-Bell spawning stock biomass per recruit and yield per recruit models. p = partial recruit vector, f=fraction mature, c=proportion of fishing mortality before spawning, d=proportion of natural mortality before spawning, and M=instantaneous natural mortality.

Age	p	s	c	d	M
1	0	0	0.41	0.25	0.2
2	0	0.62	0.41	0.25	0.2
3	0.33	1	0.41	0.25	0.2
4	0.5	1	0.41	0.25	0.2
5	0.71	1	0.41	0.25	0.2
6	0.88	1	0.41	0.25	0.2
7	0.96	1	0.41	0.25	0.2
8	1	1	0.41	0.25	0.2
9	1	1	0.41	0.25	0.2
10	1	1	0.41	0.25	0.2
11	1	1	0.41	0.25	0.2
12	1	1	0.41	0.25	0.2
13	1	1	0.41	0.25	0.2
14	1	1	0.41	0.25	0.2
15	1	1	0.41	0.25	0.2

Table 2. Uncertainty parameters for Bay-wide white perch biomass dynamic model. (r=intrinsic rate of increase, Std Dev=standard deviation, and CV=coefficient of variation). K and biomass parameters are in pounds.

Parameter	Estimate	Mean	Median	Std Dev	CV
r	0.500	0.566	0.52327367	0.168	0.296
K	18,200,000	20,565,718	19,748,238	4,968,570	0.242
Bo	3,900,000	3,220,409	3,272,701	705,968	0.219
B 1981	4,352,655	3,518,780	3,587,565	865,120	0.246
B 1982	5,268,802	4,388,522	4,423,011	1,201,462	0.274
B 1983	6,302,342	5,493,898	5,174,493	1,833,431	0.334
B 1984	7,685,417	7,115,509	6,368,298	2,879,882	0.405
B 1985	8,981,645	8,799,641	7,467,526	4,076,488	0.463
B 1986	10,583,852	10,781,237	9,070,141	4,934,176	0.458
B 1987	12,046,377	12,572,620	10,717,581	5,464,516	0.435
B 1988	13,267,395	14,054,003	12,305,136	5,684,932	0.405
B 1989	13,924,662	14,937,032	13,523,804	5,724,585	0.383
B 1990	14,765,898	15,994,856	14,756,193	5,709,604	0.357
B 1991	14,936,588	16,349,913	15,018,679	5,585,650	0.342
B 1992	15,086,014	16,692,182	15,352,592	5,502,751	0.330
B 1993	15,027,052	16,797,890	15,534,391	5,412,935	0.322
B 1994	14,581,966	16,503,356	15,342,385	5,354,105	0.324
B 1995	14,238,222	16,306,557	15,183,735	5,351,899	0.328
B 1996	14,237,291	16,428,567	15,270,652	5,363,536	0.326
B 1997	13,544,571	15,820,179	14,652,419	5,349,303	0.338
B 1998	12,352,190	14,741,592	13,645,933	5,420,542	0.368
B 1999	12,470,705	15,006,622	13,931,219	5,598,892	0.373
B 2000	12,619,309	15,211,433	14,130,090	5,651,208	0.372
B 2001	12,114,436	14,731,113	13,661,311	5,671,999	0.385
B 2002	12,035,691	14,710,996	13,634,951	5,771,594	0.392
B 2003	12,006,299	14,707,300	13,649,291	5,834,014	0.397
B 2004	11,811,497	14,522,695	13,489,118	5,887,247	0.405

Table 3. Uncertainty estimates for Choptank River white perch assessment. (q= catchability)

Parameter	Estimate	Mean	Std Dev	CV
q	24.5	25.5	3.49	0.138
Pre-recruit 1989	0.509	0.518	0.162	0.312
Pre-recruit 1990	0.981	0.976	0.238	0.424
Pre-recruit 1991	0.478	0.486	0.167	0.344
Pre-recruit 1992	1.067	1.073	0.218	0.203
Pre-recruit 1993	1.09	1.099	0.239	0.217
Pre-recruit 1994	1.113	1.101	0.272	0.248
Pre-recruit 1995	1.28	1.3	0.296	0.228
Pre-recruit 1996	1.717	1.708	0.371	0.217
Pre-recruit 1997	2.084	2.102	0.366	0.174
Pre-recruit 1998	1.25	1.267	0.363	0.287
Pre-recruit 1999	1.99	1.968	0.42	0.214
Pre-recruit 2000	1.28	1.308	0.383	0.293
Pre-recruit 2001	1.704	1.7	0.422	0.248
Pre-recruit 2002	1.351	1.352	0.435	0.322
Pre-recruit 2003	1.905	1.926	0.593	0.308
Pre-recruit 2004	1.965	1.994	0.681	0.342
Pre-recruit 2005	2.413	2.361	0.322	0.136
Recruit 1989	0.44	0.449	0.154	0.344
Recruit 1990	0.474	0.489	0.154	0.315
Recruit 1991	0.738	0.746	0.198	0.266
Recruit 1992	0.538	0.551	0.181	0.329
Recruit 1993	0.485	0.5	0.177	0.354
Recruit 1994	0.5	0.521	0.185	0.655
Recruit 1995	0.653	0.66	0.218	0.301
Recruit 1996	0.651	0.673	0.242	0.359
Recruit 1997	0.838	0.85	0.301	0.354
Recruit 1998	0.635	0.659	0.239	0.362
Recruit 1999	0.941	0.974	0.315	0.323
Recruit 2000	0.973	0.982	0.336	0.343
Recruit 2001	0.948	0.979	0.326	0.334
Recruit 2002	1.173	1.195	0.377	0.316
Recruit 2003	1.38	1.398	0.434	0.31
Recruit 2004	1.765	1.798	0.57	0.317
Recruit 2005	1.916	1.966	0.69	0.351
F 1989	0.49	0.51	0.13	0.26
F 1990	0.48	0.5	0.11	0.22
F 1991	0.62	0.64	0.16	0.25
F 1992	1	1.03	0.23	0.23
F 1993	0.95	0.98	0.23	0.23

F 1994	0.7	0.74	0.18	0.24
F 1995	0.89	0.92	0.22	0.23
F 1996	0.83	0.88	0.21	0.24
F 1997	1.32	1.36	0.27	0.2
F 1998	0.5	0.51	0.13	0.26
F 1999	0.9	0.95	0.22	0.23
F 2000	0.67	0.69	0.18	0.25
F 2001	0.62	0.64	0.15	0.23
F 2002	0.4	0.43	0.11	0.26
F 2003	0.42	0.44	0.12	0.26
F 2004	0.47	0.49	0.13	0.27

Table 4. Biological reference points for white perch from spawning stock biomass per recruit and yield per recruit analyses (MSP=maximum spawning potential).

Reference Pt.	$F_{15\%}$	$F_{20\%}$	$F_{25\%}$	$F_{30\%}$	$F_{35\%}$	$F_{0.1}$	F_{MAX}
F	1.72	1.12	.8	0.6	0.47	0.3	0.75
% MSP	15	20	25	30	35	46	26

Figure 1. Choptank River fyke net locations, 2005. Circles indicate locations.

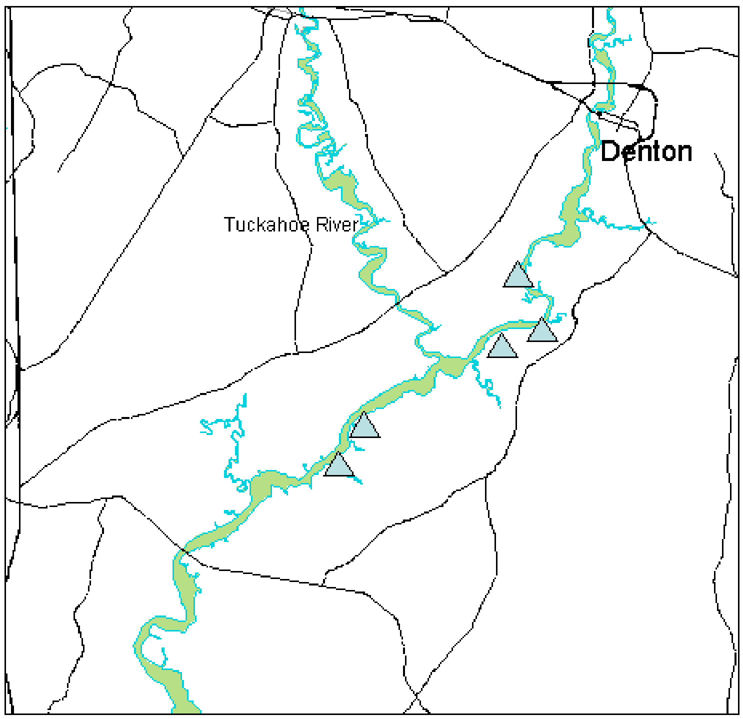


Figure 2. Commercial white perch landings in Maryland, 1929 - 2004

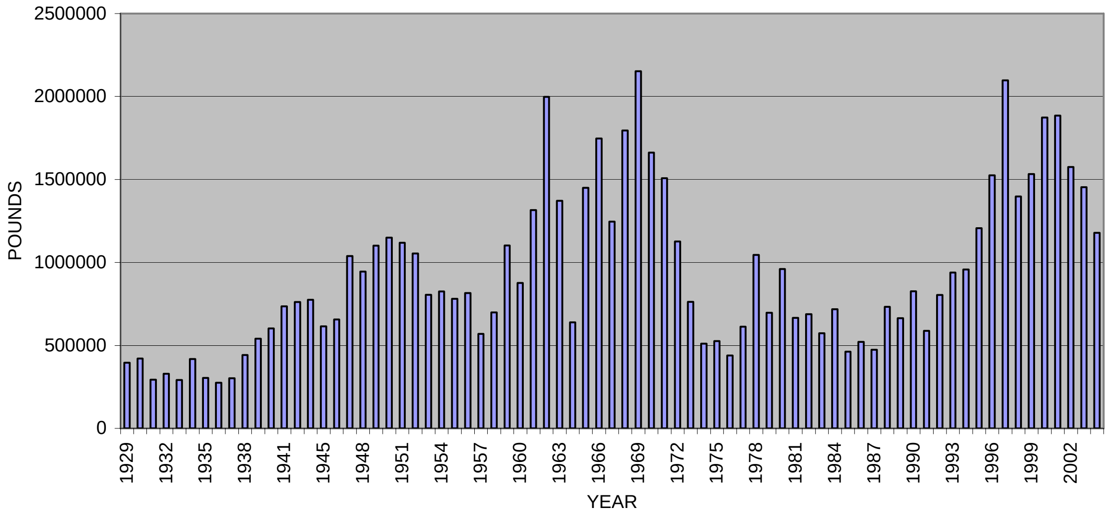


Figure 3. Recreational white perch landings estimates from Marine Recreational Fishery Statistics Survey, 1981 - 2004

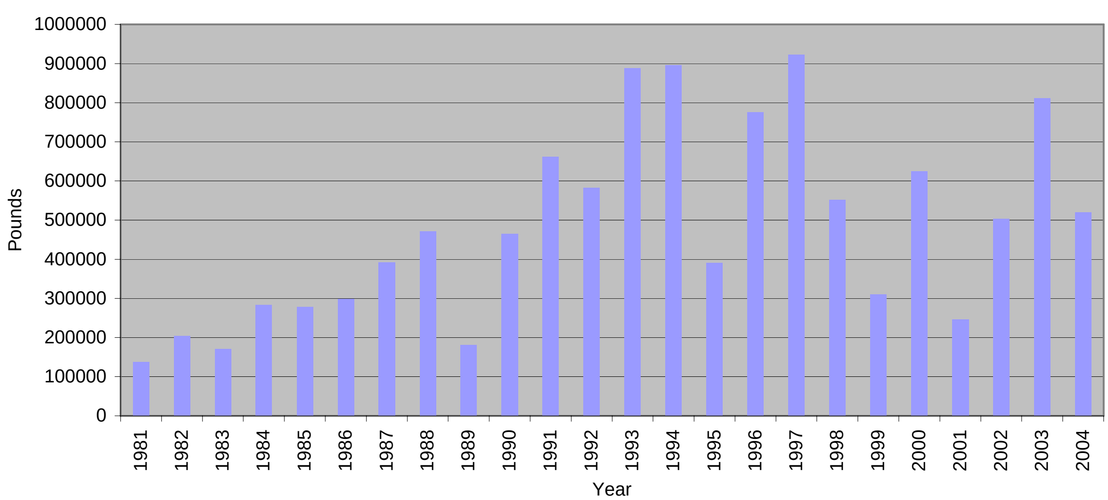


Figure 4. Recreational white perch catch per unit effort index

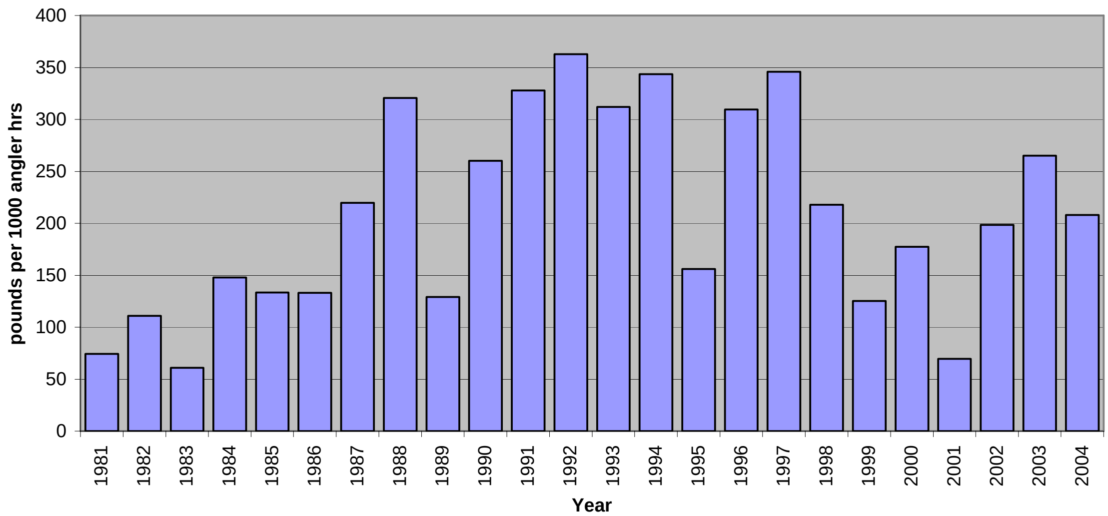


Figure 5. Commercial white perch fyke net catch per unit effort index, 1980 - 2004

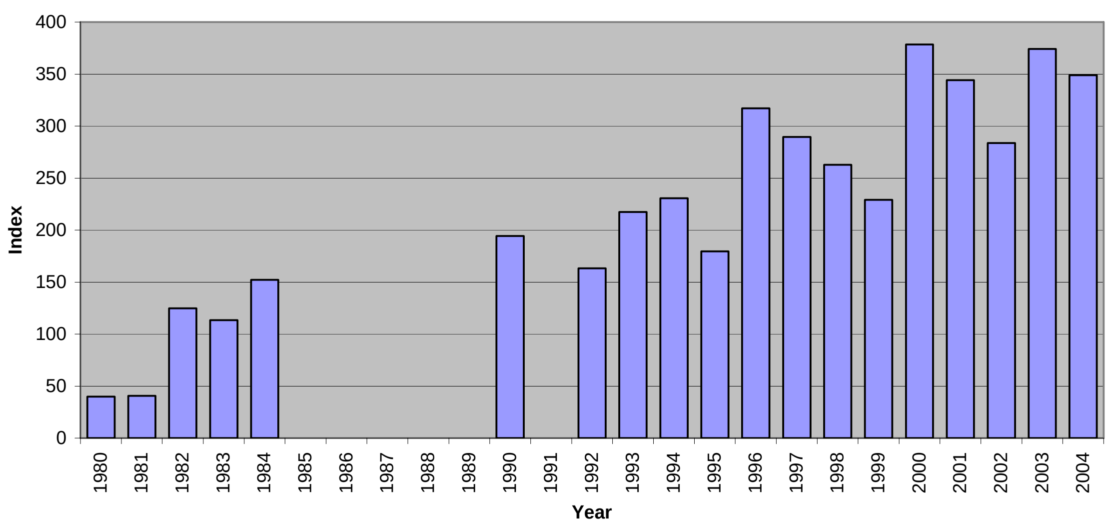


Figure 6. Commercial white perch drift gill net catch per unit effort index, 1980 - 2004

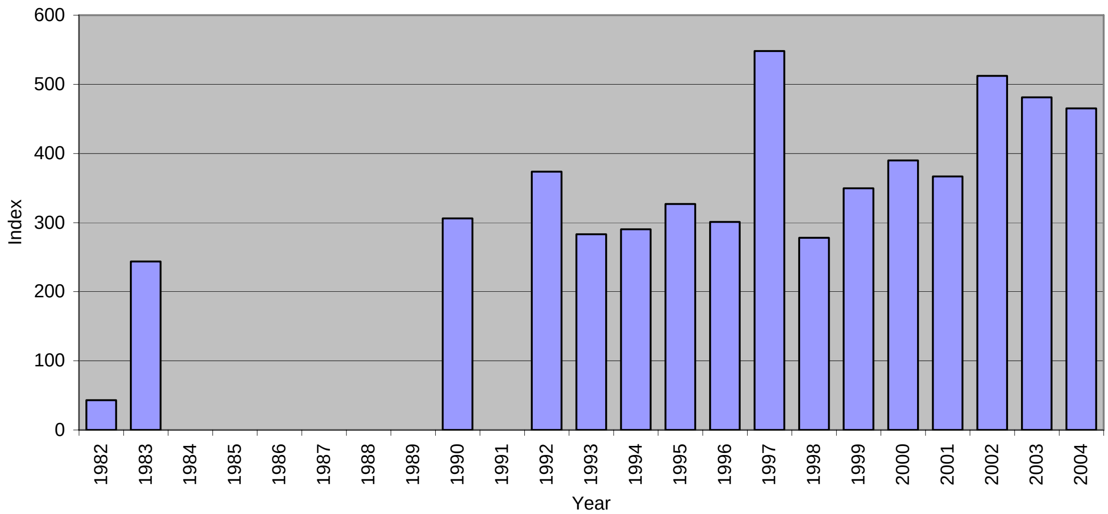


Figure 7. Commercial white perch pound net catch per unit effort index, 1980 - 2004

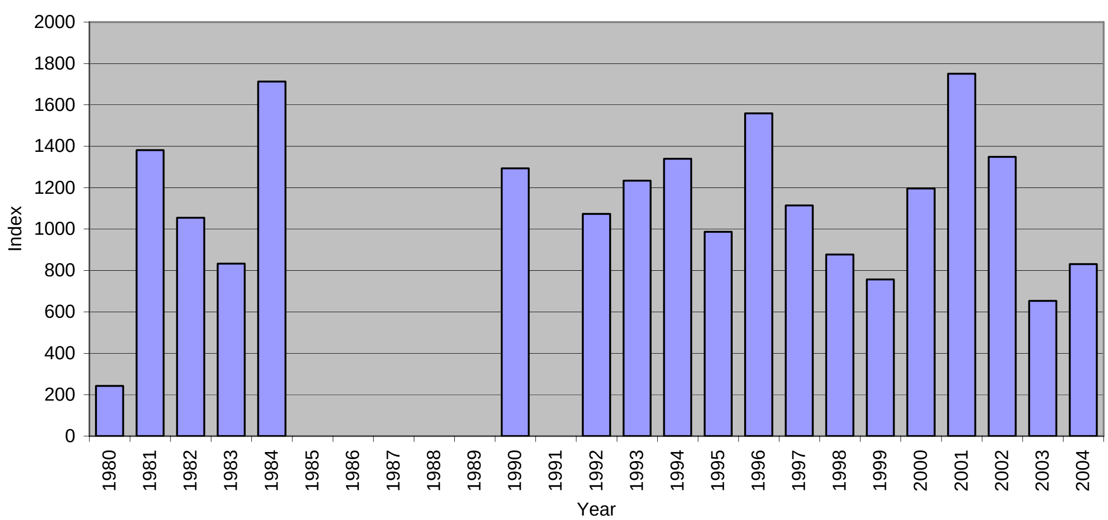


Figure 8. Young-of-year white perch index, bay-wide, 1962 - 2005, with time series average

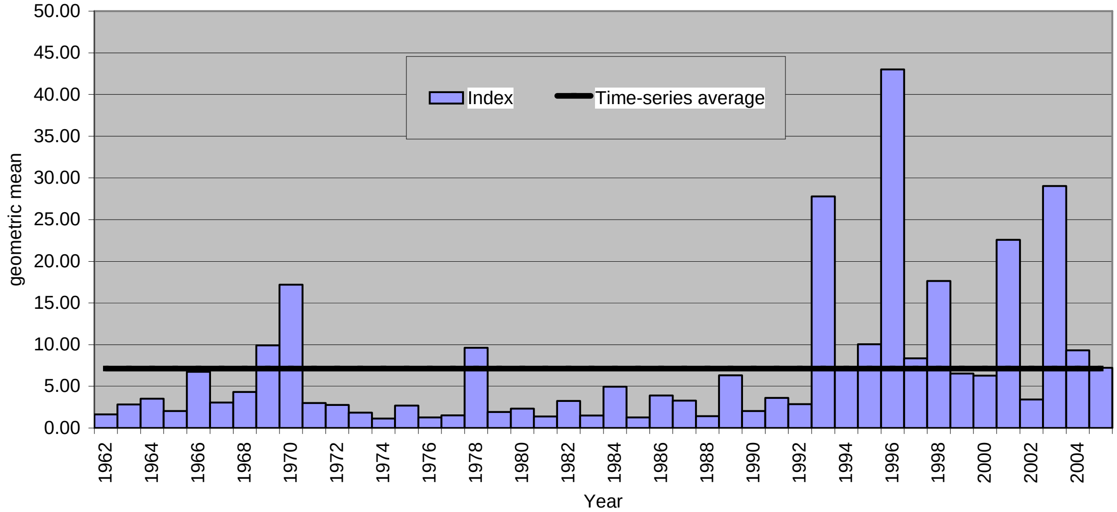


Figure 9. White perch population estimates and F estimates from bay-wide biomass dynamic model, 1980 - 2004

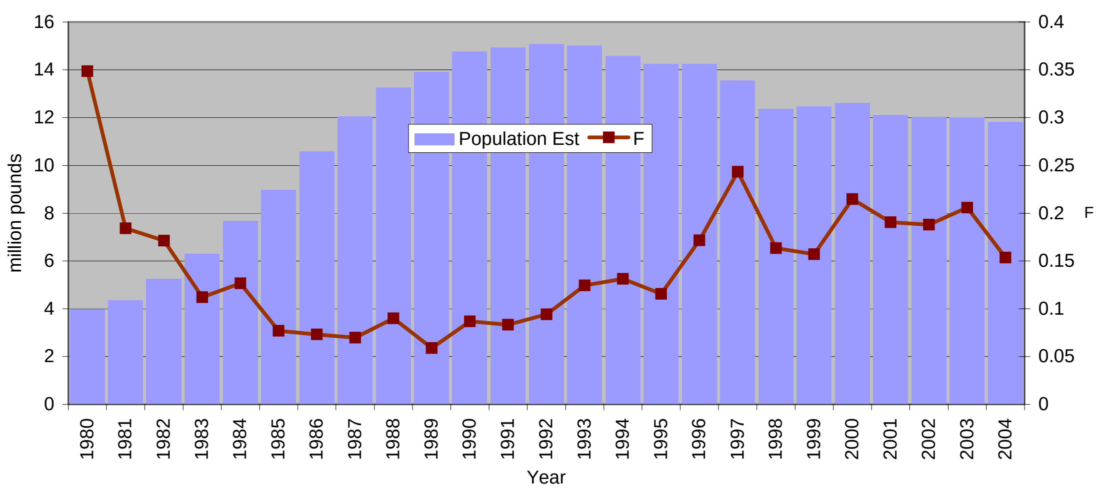


Figure 10. Relative biomass and instantaneous fishing mortality estimates for white perch from the bay-wide biomass dynamic model, 1980 - 2004

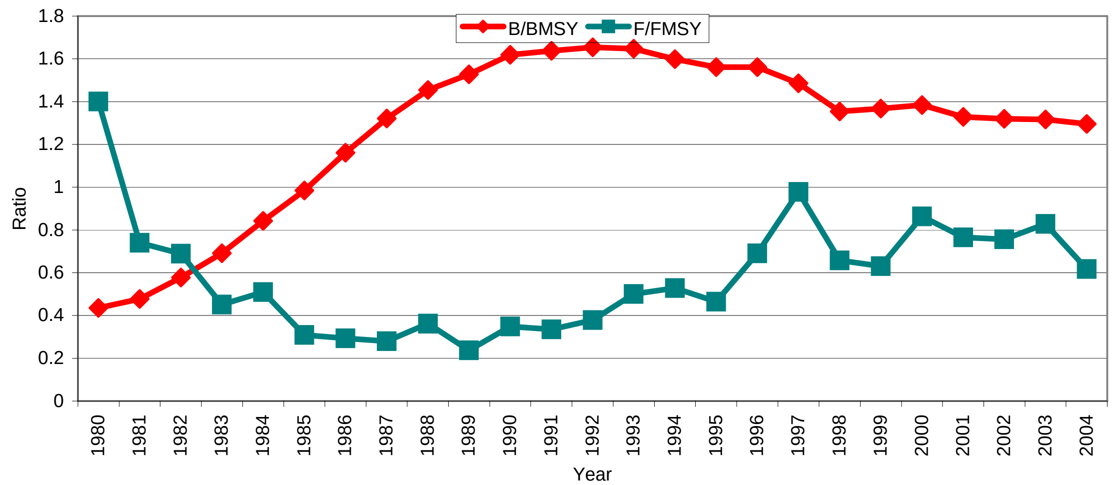


Figure 11. Bay-wide white perch biomass estimate with 80% confidence intervals and median estimates

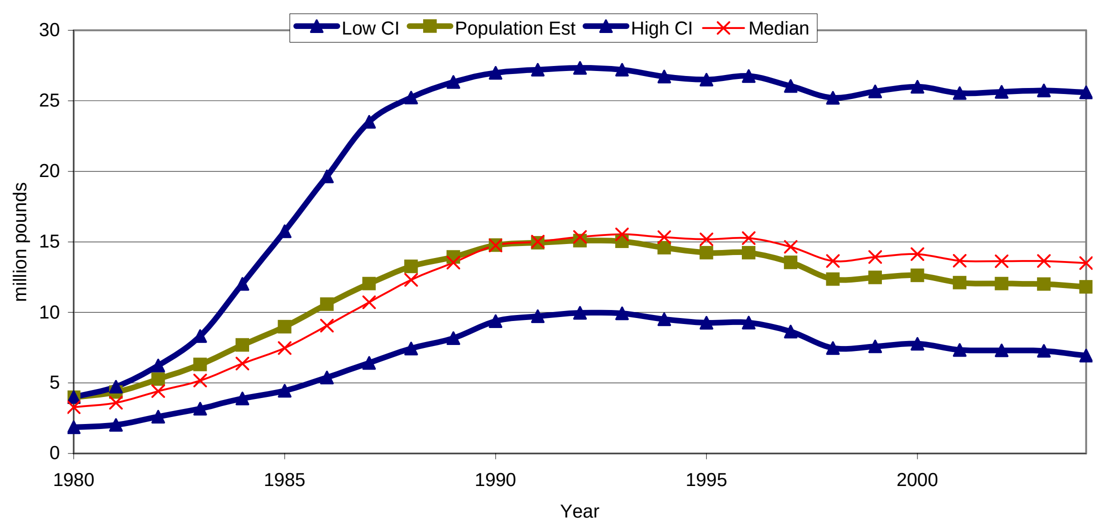


Figure 12. Z-transformed commercial and DNR fyke net catch per unit effort, 1989 - 2004

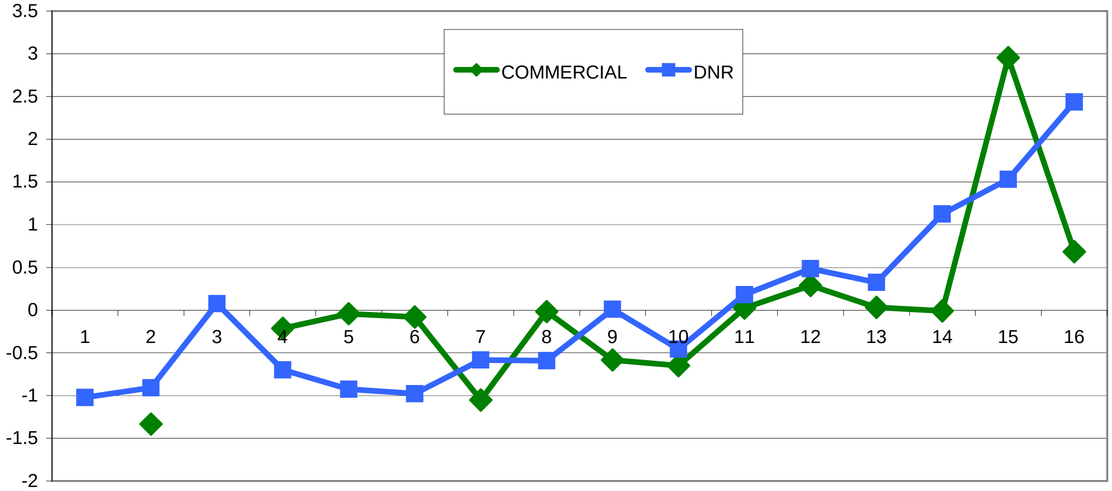


Figure 13. Choptank River white perch pre-recruit (185 mm - 202 mm TL) index, 1989 - 2005

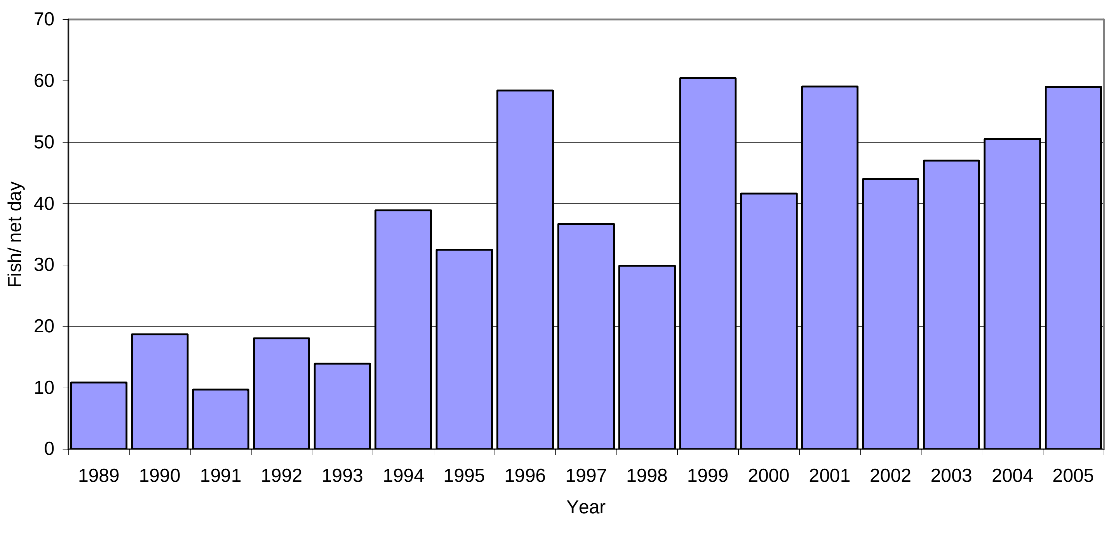


Figure 14. Choptank River white perch recruit (> 202 mm TL) index, 1989 - 2005

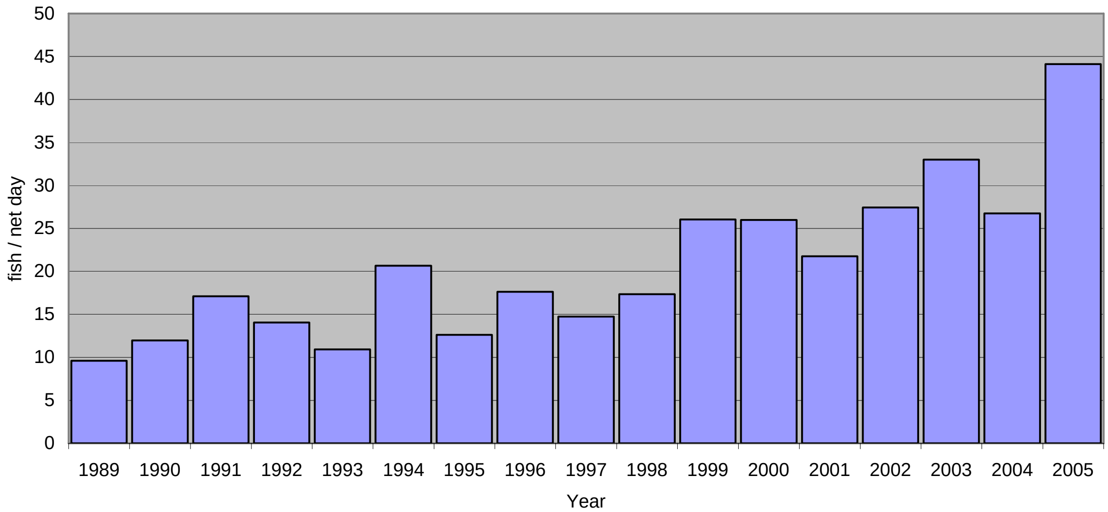


Figure 15. Pre-recruit (185 mm - 202 mm TL) and recruit (>202 mm TL) white perch population abundance estimates for Choptank River white perch from Catch Survey Analysis, 1989 - 2005

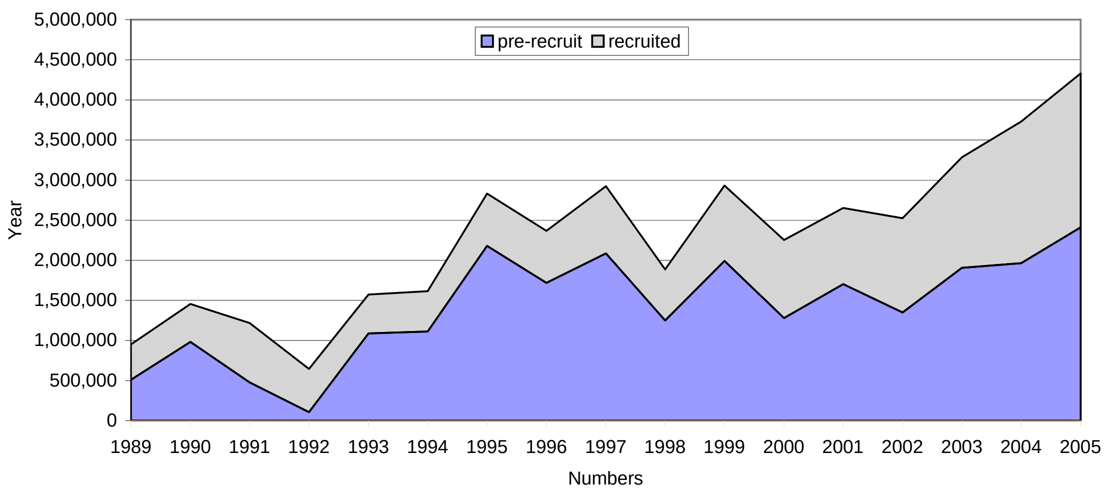


Figure 16. Instantaneous fishing mortality (F) estimates for Choptank River white perch, 1989 - 2004

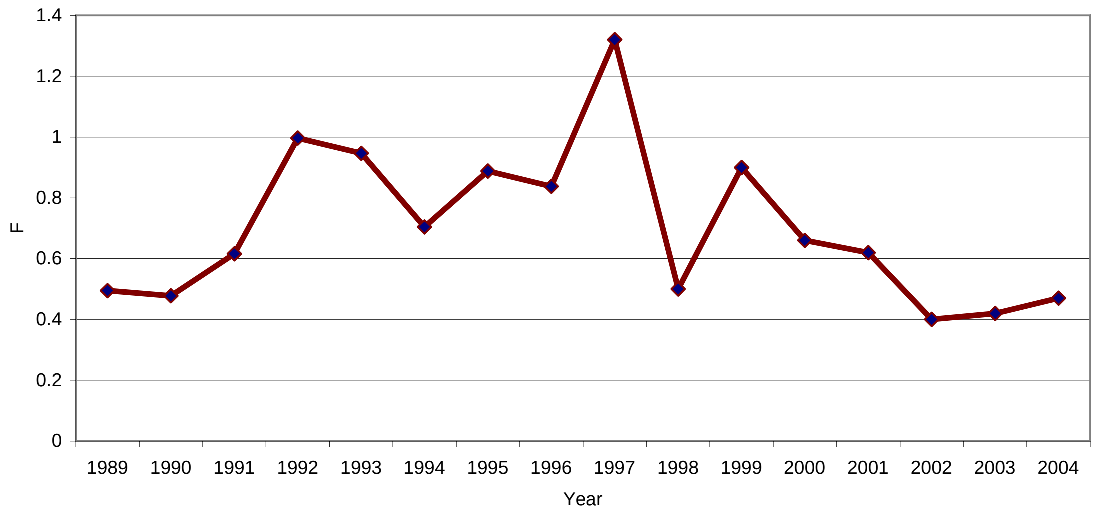


Figure 17. Residual error of pre-recruit white perch index from Choptank River Catch Survey Analysis

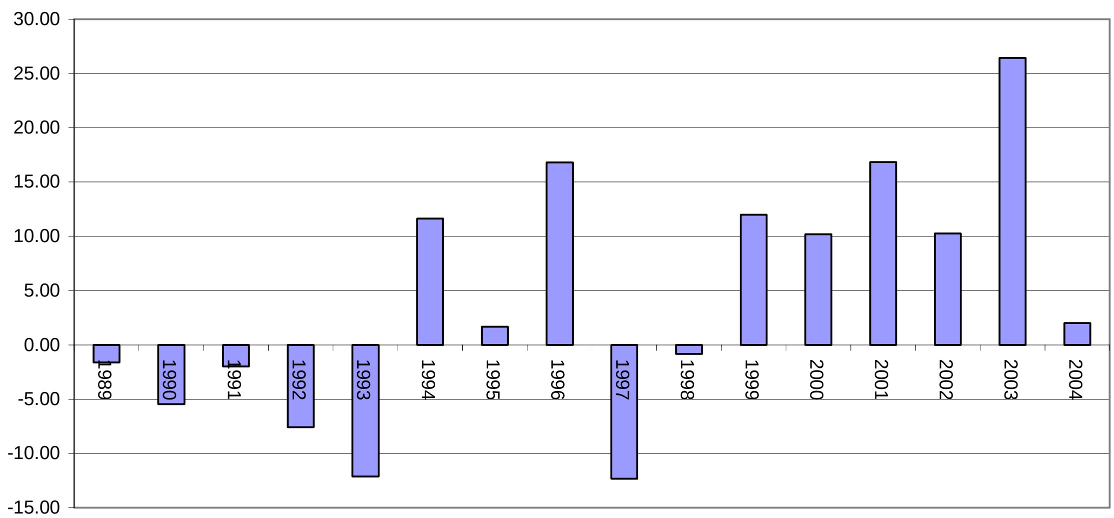


Figure 18. Residual error of recruited white perch index from Choptank River Catch Survey Analysis

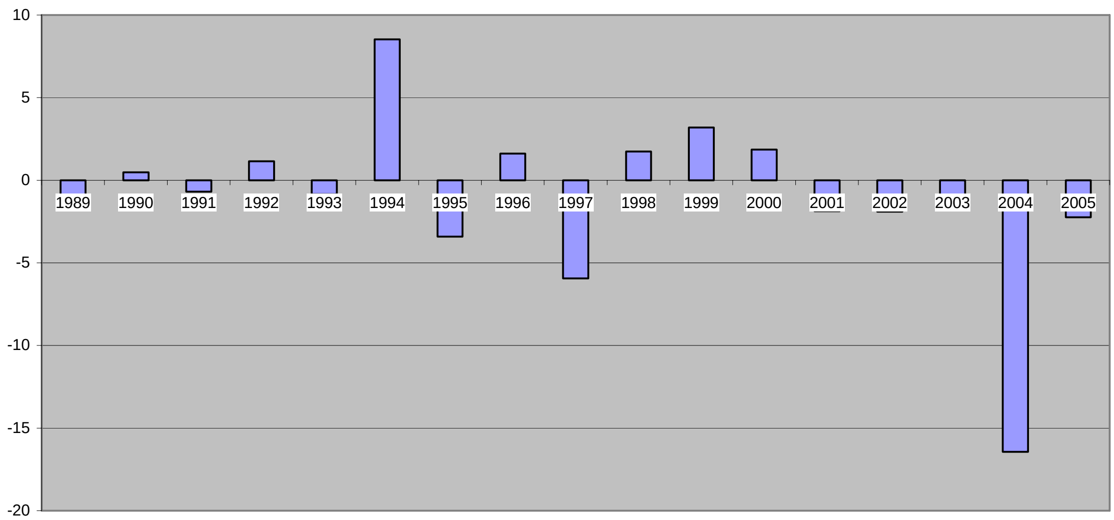


Figure 19. Pre-recruit white perch abundance estimates for Choptank River with 80% confidence intervals

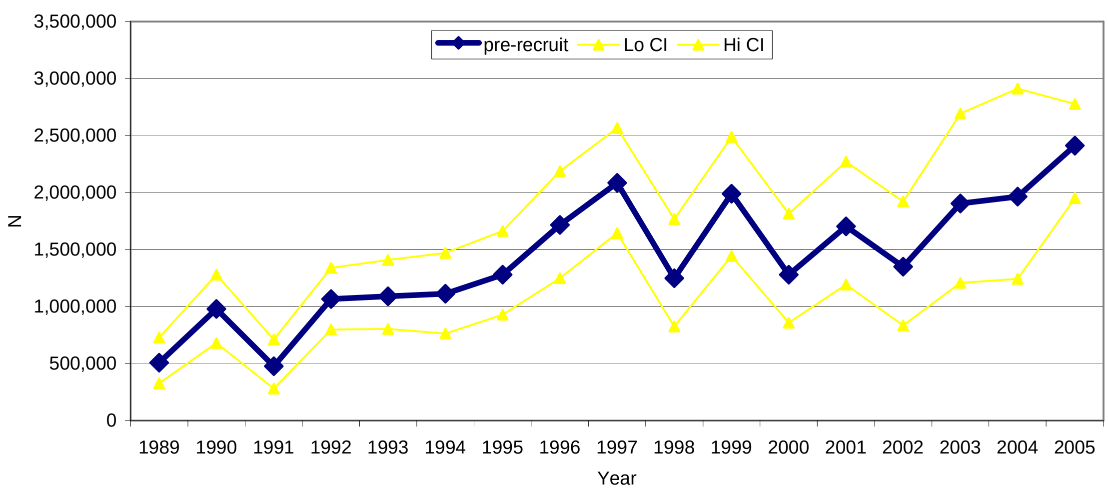
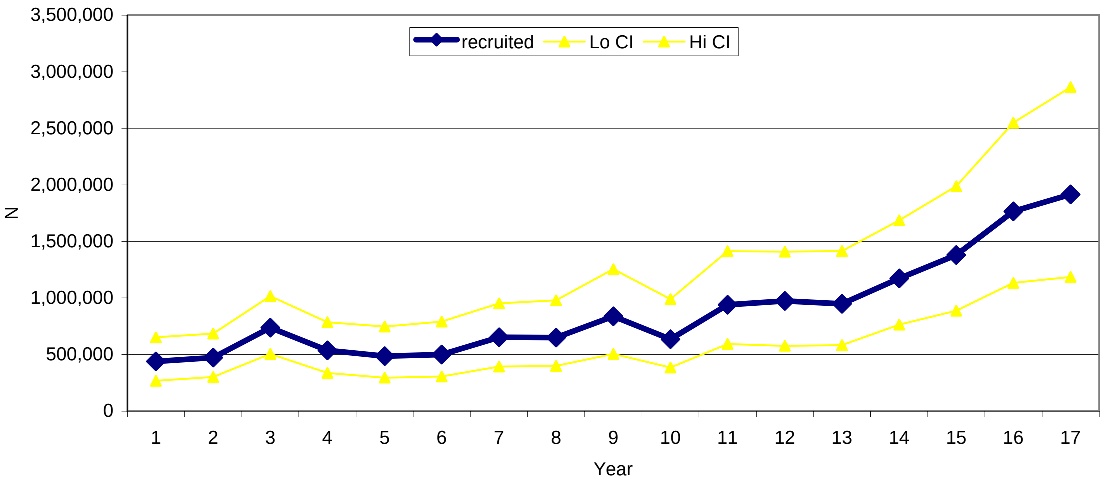


Figure 20. Recruited white perch abundance estimates for Choptank RIver with 80% confidence intervals



PROJECT NO. 2
JOB NO. 1

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

Prepared by Robert Sadzinski and Anthony Jarzynski

INTRODUCTION

The primary objective of Job 1 was to assess trends in stock status of four anadromous Alosa species in Maryland's portion of Chesapeake Bay and selected tributaries. A second objective was to identify possible data deficiencies in Alosa restoration tributaries. Information for American and hickory shad and alewife and blueback herring in Maryland tributaries was collected using both fishery independent and dependent gear and included 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, while sampling Fisheries Service fyke nets in the Choptank and Severn rivers. A mark-recapture experiment was utilized to estimate American shad relative abundance in the Conowingo 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, Atlantic States Marine Fisheries Commission (ASMFC), Mid-Atlantic Fishery Management Council (MAFMC) and the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC).

METHODS

A. Adults

Field Operations

Adult anadromous species sampled in the spring of 2005 were sexed (when possible) by expression of gonadal products and fork length (mm FL) measured. Scales from American shad, hickory shad, alewife herring and blueback herring were removed below the insertion of the dorsal fin. A minimum of four scales per fish were cleaned, mounted between two glass slides and read for age and spawning history using a Bell and Howell MT-609 microfiche reader. The scale edge was counted as a year-mark since it was assumed that each fish had completed a full year's growth at the time of capture.

Susquehanna River

American shad were angled from the Conowingo tailrace (Figure 1) on the Susquehanna River two to five times per week from 26 April through 21 May 2005. 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 quickly tagged and released. A Maryland Department of Natural Resources (DNR) Fisheries Service hat was given to fishers as reward for returned tags.

Nanticoke River

American and hickory shad and alewife and blueback herring in the Nanticoke River were collected from one pound net and 6-10 fyke nets. These nets were sampled at least once per week from 24 February to 20 April 2005. The pound net was located at the mouth of Mill Creek while fyke nets were located between 30.4 and 35.7 rkm (river kilometer; 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.

B. Juveniles

Summer Seining

Juvenile alosines were sampled biweekly from July to October in the Susquehanna, Chester and the Pocomoke rivers using a 30.5 x1.2m x 6.4mm mesh haul seine. Seine sites were located a minimum of 0.5 miles apart and consisted of 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 ability 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 :m 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 (J. Mowrer pers. comm. MDNR; Figure 6) and divided the river into 18 one-mile cells and randomly choosing ten cells. Because of time constraints and the difficulty of determining species on the boat, presence of alosine (eggs or larvae) was only recorded.

II. Statistical Analyses

A. Adults

Age composition

Age-at-length keys were constructed by determining the proportion-at-age by sex for American shad per 20-mm length group and applying that proportion to the total number of fish in that increment. Since all American shad scale samples were read, 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 (1989-2005) 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 (1980-2005) 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.

Quantitative Habitat Analysis

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

RESULTS

1. American shad

a. Adult

Sex and Age Composition

The 2005 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.62:1. Of the 412 fish sampled by this gear, 386 were aged directly from their scales (Table 1). Those American shad not aged directly because of regenerated scales, were assigned ages based on the 2005 age\length key.

A total of 46 American shad were captured from the Nanticoke River pound and fyke nets and 39 (85%) subsequently aged. The 2005 male-female ratio for adult American shad captured in the Nanticoke River was 0.96:1 (Table 1).

Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line was 29.5% for males and 30.1% for females. The arcsine-transformed proportions of these repeat spawners (sexes combined) have been increasing since 1984 (r^2=0.68, P=0.002; Figure 7).

The percentage of repeat spawning American shad from fyke nets in the Nanticoke River was 26.3% for males and 65.0% for females. The arcsine-transformed proportions of these repeat spawners (1988-2005, sexes combined) have increased since 1988 (r^2=0.48, P=0.05; Figure 8).

Relative Abundance

Of the 412 adult American shad sampled (Table 2) in Conowingo tailrace, 394 (98%) were tagged and 112 (29%) subsequently recaptured from the east lift (Table 3). There were no reported recaptures of tagged American shad outside the Conowingo tailrace. In 2005, the east lift operated from 15 April through 17 May and technicians counted 55,703 American shad passing the viewing window. Peak passage was on 11 May when 5,235 American shad were recorded.

In 2005, the west lift at Conowingo Dam operated from 27 April to 3 June. The 3,896 American shad caught in the west lift were either returned to the tailrace, used for experimentation or retained for hatchery operations. Peak capture from the west lift was on 15 May when 625 American shad were collected. Eleven tagged American shad were recaptured in 2005 from the west lift (Table 3).

The Conowingo tailrace American shad relative population estimate in 2005 was 322,920 (95% confidence intervals 259,413-407,743; Table 4 and Figure 9). This estimate was adjusted for 3% tag loss as suggested by Leggett (1976).

Estimates of hook and line (1984-2005) and fish lift (1980-2005) geometric mean CPUEs have increased linearly (hook and line: r^2=0.79, P<0.001 and fish lifts: r^2=0.81, P<0.001; Figures 10 and 11). Nanticoke River pound net geometric mean CPUE for American shad has also increased linearly since 1988 (r^2=0.50, P<0.04; Figure 12) while fyke net geometric mean CPUEs for American shad have been very low most years and showed no trend (r^2<0.01, P=0.92; Figure 13).

Mortality Estimates

Since American shad do not fully recruit until age seven in the Maryland portion of the Chesapeake Bay, as detected by virgin fish, repeat spawning marks were 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 = 1.07. The average difference between the natural logs of the spawning group frequency, gave a Z = 1.18.

Otolith Examination

Of the 274 readable American shad otoliths collected from the west lift at Conowingo Dam in 2005, 35% were classified as wild. Adult American shad otoliths were also collected from the Nanticoke River but analysis has not yet been completed.

b. Juvenile

Relative abundance of juvenile American shad in the Susquehanna River was very low with only one shad caught during the summer seining. In the Chester and Pocomoke rivers, no juvenile American shad were caught by haul seine.

c. Presence/Absence of Clupeid Eggs

Successful clupeid reproduction in the lower Nanticoke River was determined by the presence of eggs through biweekly tows. Fertilized clupeid eggs were found in 5% of the samples (n = 80) and salinity during these positive tows was 0.1ppm. Salinity at all tow locations was less than 2.0ppm and at 88% of the sites, it was less than or equal to 0.5ppm.

d. Quantitative Habitat Analysis

SAV estimates in the upper Chesapeake Bay were obtained from personnel from Tidewater Ecosystem Assessment 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 (r^2=0.36, P=0.21).

2. Hickory Shad

a. Adults

Sex and Age Composition

The 2005 male: female sex ratio for hickory shad sampled from the Nanticoke River was 0.67:1 (N = 14). Mean length of hickory shad sampled from the Nanticoke River was 360mm FL and mean weight was 760g. Age determination has not been completed.

Relative Abundance

Nanticoke River pound net geometric mean CPUEs for adult hickory shad have increased linearly since 1988 (r^2=0.25, P=0.04; Figure 14), however, fyke net geometric mean CPUEs have been very low and showed no trend (r^2=0.07, P=0.88; Figure 15).

b. Juveniles

Three locations 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 the Susquehanna River no juvenile hickory shad were collected. Sampling in the Chester and the Pocomoke rivers produced six juvenile hickory shad in each of these systems.

3. Alewife and Blueback Herring

a. Adults

Sex and Age Composition

The 2005 male: female ratio for Nanticoke River alewife was 1:1.46. Of the 172 alewives, sampled, 169 were aged. Alewife were present at ages 3-8 and the 2001 year-class (age 4, sexes combined) was the most abundant year-class in 2005, accounting for 39.6% of the total catch (Table 5.

The 2005 male: female ratio for blueback herring was 1:1.63. Of the 21 blueback herring sampled, 18 were aged. Blueback herring were present at ages 3-6 and the 2001 year-class (age 4, sexes combined) was the most abundant accounting for 50% of the catch. Males were most abundant at ages 3 and 4 and females were most abundant at age 4 (Table 5).

Repeat Spawning

The percentages of alewife and blueback herring repeat spawning (sexes combined) from the Nanticoke River was 48.21% and 22.22%, respectively (Table 5). The arcsine-transformed proportion of alewife repeat spawners (sexes combined) indicated no trend (1989-2005; r^2<0.01 P=0.96; Figure 16), while blueback herring repeat spawning showed a decreasing trend (1989-2005; r^2=0.44, P<0.01; Figure 16).

Using Speir and Mowrer's (1987) maturity schedule calculation, 87.1% of male alewife and 87.5% of male blueback herring were mature by age 4. The percentages of female alewife and blueback herring mature by age 4 were 61% and 90%, respectively.

Length-at-Age

Nanticoke River female alewife and blueback herring mean lengths-at-age were greater than corresponding male mean lengths-at-age (Table 6 and Table 7, respectively). 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 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 (1989-2005; r^2=<0.01 P=0.86; Figure 17), while those for blueback herring have significantly decreased (1989-2005; r^2=0.66 P<0.01; Figure 18). Both Nanticoke River commercial river herring landings and CPUEs have significantly decreased since 1989 (r^2=0.63 P<0.01; r^2=0.49 P<0.01, respectively; Figure 19).

Mortality Estimates

Instantaneous mortality (Z) in 2005 for Nanticoke River alewife herring (sexes combined) estimated Z = 0.93 (annual mortality {A} = 60.5%). Since maximum age (T_{max}) for alewife was 8, M = 0.38 and F = 0.55. Specific estimates of Z by sex for Nanticoke River alewife herring are presented in Figure 20.

Instantaneous mortality (Z) in 2005 for Nanticoke River blueback herring (sexes combined) estimated Z = 0.55 (annual mortality {A} = 42.3%). If the maximum age (T_{max}) for blueback herring was 6, M = 0.50 and F = 0.05. Estimates of Z for blueback herring males and females were identical, Z = 0.35 (A = 29.5%; Figure 21).

b. Juvenile

The Susquehanna River juvenile sampling produced one alewife herring and 1,056 blueback herring with corresponding CPUEs of 0.02 and 21.12, respectively. Chester River sampling produced 16 juvenile alewife herring (CPUE = 0.36) and 63 juvenile blueback herring (CPUE = 1.43). No juvenile alewife herring were produced from the Pocomoke River while seven juvenile blueback herring (CPUE = 0.16) were collected from this system.

DISCUSSION

Anadromous Species

1. American shad

a. Adults

All American shad commercial fisheries in Atlantic Ocean waters were closed on 31 December 2004. Since this fishery resulted in landings of mixed stocks in excess of 1.2 million lbs (ASMFC 1998) 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 in) for 2005 showed significant decreases.

Factors contributing to this decline in relative abundance may include cooler water temperature, poor recruitment 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 (pers comm. K Hattala, NY DEC).

Since aging techniques for American shad using scales has been shown to be somewhat tenuous (McBride et al 2005), freshwater spawning marks may hold the best means of non-lethal aging and the highest accuracy for an age-based assessment of survival and mortality. Mortality rates for Chesapeake Bay stocks of American shad (Z = 1.07-1.71) 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 three years (Tables 9 and 10). Since estimates of relative abundance have fluctuated and river flows highly influence catch, conclusions drawn from these creel CPAH should be considered somewhat tenuous.

b. Juveniles

Baywide juvenile American shad indices were substantially higher during the last five years compared to the previous 30 years (Figure 22). These increases were primarily driven by the upper Chesapeake Bay (Figure 23) and Potomac River indices (Figure 24). In the upper Chesapeake Bay during 2005, 115 juvenile American shad were captured at seven permanent sites by the juvenile striped bass recruitment assessment in fourteen hauls and 129 were captured from the six auxiliary sites. Juvenile American shad indices for the upper Chesapeake Bay based on these long-term data have increased exponentially since 1980 ($r^2 = 0.32$ $P<0.001$).

The Potomac River juvenile American shad indices also generated by the juvenile striped bass recruitment assessment have shown significant increases since the late 1990s. Results from OTC analysis completed on subsampled juvenile American shad from 2004, have shown all fish collected to be non-hatchery. These strong juvenile indices for the upper Chesapeake Bay and Potomac River demonstrate sufficient spawning habitat and suitable water quality in these systems.

Sampling for juvenile American shad from the six sites in the Susquehanna River during 2005 was unsuccessful. Possible reasons for the low numbers of juveniles sampled in the river include a migration downriver 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 4.3 to 8.3 and has varied without trend since 1998 (r^2=0.28, P=0.18; Table 11).

Richardson (et al 2004) noted that ninety percent of hickory shad in Deer Creek 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 in Deer Creek in 2004 (latest available data) estimated from the spawning group frequency plotted against the corresponding number of times spawned resulted in a Z = 0.41. The average difference between the natural logs of the spawning group frequency and produced Z = 0.51.

In general, the resultant Z is attributed to natural mortality since only a catch and release fishery for American and hickory shad exists in Maryland. Limited data on hickory shad negates drawing conclusions but based on these 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 four weeks earlier.

3. Alewife and blueback herring

a. Adults

The commercial river herring fishery on the Nanticoke River is a mixed fishery and fishers do not differentiate between alewife and blueback herring. The combined pound net CPUE of river herring in the Nanticoke River decreased during 1989-2005, as did the blueback herring CPUE. Alewife herring CPUEs have not exhibited any statistical trend between 1989 and 2004.

b. Juveniles

The catch of juvenile alosine species on the Susquehanna, Chester and Pocomoke rivers was low except for blueback herring on the Susquehanna River. Since this is the first year of sampling for juvenile alosine in these systems, comparisons could not be made. Juvenile indices for alewife and blueback herring in the Nanticoke River obtained from the juvenile striped bass recruitment survey (Figures 25 and 26, respectively) caught very few of either species. Since juvenile herring prefer salinities less than 2.0ppm, sampling in the lower Nanticoke River where salinities are normally greater than 2.0ppm may have precluded their presence.

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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 2005.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	2	0	0	0	2	0
3	8	0	0	0	8	0
4	64	1	35	0	99	1
5	37	13	81	9	118	22
6	32	24	92	41	124	65
7	5	5	27	20	32	25
8	1	1	1	1	2	2
Totals	149	44	236	71	385	115
Percent Repeats	29.5%		30.1%		29.9%	

Nanticoke River

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	2	0	0	0	2	0
4	7	0	2	0	9	0
5	6	1	6	2	12	3
6	2	2	7	6	9	8
7	1	1	3	3	4	4
8	1	1	1	1	2	2
9	0	0	1	1	1	1
Totals	19	5	20	13	39	18
Percent Repeats	26.3%		65.0%		46.2%	

Table 2. Conowingo Dam tailrace hook and line data, 1982-2005.

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

Table 3. Recaptured American shad in 2005 at Conowingo Dam's east and west lifts by tag color and year.

East Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Green	2005	78
Pink	2004	27
Orange	2003	4
Yellow	2003	2
Blue	2002	1
West Lift		
Tag Color	**Year Tagged**	**Number Recaptured**
Green	2005	9
Orange	2003	2

Table 4. Conowingo tailrace population estimate of adult American shad in 2005.

Chapman's Modification of the Petersen estimate

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

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

2005 survey results:

C = 65,411
M = 389
R = 78

Therefore:

$$N = \frac{(65{,}411 + 1)(389 + 1)}{(78 + 1)} = 322{,}920$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N = \frac{(65{,}411 + 1)(389 + 1)}{(62.5 + 1)} = 407{,}743$$

$$\text{Lower } N = \frac{(65{,}411 + 1)(389 + 1)}{(97.3 + 1)} = 259{,}413$$

Table 5. Numbers of adult alewife and blueback herring and repeat spawners by sex and age sampled from the Nanticoke River in 2005.

Alewives

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	6	0	0	0	6	0
4	39	2	28	1	67	3
5	19	16	24	11	43	27
6	5	5	27	26	32	31
7	1	1	17	17	18	18
8			3	3	3	3
9						
Totals	70	24	99	58	169	82
Percent Repeats	34.29		58.59		48.52	

Blueback Herring

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	3	0	1	0	4	0
4	3	0	6	0	9	0
5	2	2	1	0	3	2
6	0	0	2	2	2	2
7						
8						
9						
Totals	8	2	10	2	18	4
Percent Repeats	25.0		20.0		22.22	

Table 6. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River 1989-2005.

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					

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				

Table 7. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2005.

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						

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					

Table 8. Regression statistics for alewife and blueback herring in 2005 based on cumulative data.

Male								
Age	**N**	**Slope**	**r^2**	**P**	**N**	**Slope**	**r^2**	**P**
3	345	-0.214	0.007	0.130	102	+0.001	<0.001	0.997
4	1215	-0.347	0.024	<0.001	1079	-0.482	0.044	<0.001
5	1015	-0.305	0.018	<0.001	1410	-0.316	0.020	<0.001
6	416	-0.553	0.059	<0.001	898	-0.379	0.035	<0.001
7	69	-0.989	0.175	<0.001	290	-0.467	0.059	<0.001
8	6	-1.183	0.117	0.506	85	-0.937	0.123	<0.001
9					11	-2.397	0.212	<0.154
Male								
Age	**N**	**Slope**	**r^2**	**P**	**N**	**Slope**	**r^2**	**P**
3	166	-0.039	<0.001	0.774	33	+0.108	0.004	0.725
4	778	-0.016	<0.001	0.823	656	-0.079	0.002	0.320
5	896	-0.012	<0.001	0.867	843	-0.111	0.003	0.135
6	643	-0.485	0.034	<0.001	669	-0.363	0.016	<0.001
7	280	-0.750	0.043	<0.001	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, 2001-2005.

Year	**Number of Interviews**	**Total Fishing Hours**	**Total Catch of American Shad**	**Mean Number of American shad caught per hour**
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49

Table 10. Summary of the spring American shad logbook data, 1999-2005.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of American shad Caught	Mean Number of American shad caught per hour
1999	7	160.5	463	2.88
2000	10	404.0	3137	7.76
2001	8	272.5	1647	6.04
2002	8	331.5	1799	5.43
2003	9	530.0	1222	2.31
2004	18	750.0	1035	1.38
2005	18	567.0	533	0.94

Table 11. Summary of the spring hickory shad log book data from Deer Creek, 1998-2005.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad Caught	Mean Number of Hickory Shad Caught per Hour
1998	19	600	4980	8.30
1999	15	817	5115	6.26
2000	14	655	3171	4.84
2001	13	533	2515	4.72
2002	11	476	2433	5.11
2003	14	635	3143	4.95
2004	18	750	3225	4.30
2005	18	272.5	1699	6.23

Table 12. Age structure of hickory shad from the Susquehanna River based on scales, 1998-2005.

Year	Number per Age Group						
	II	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
1998	68	176	104	18	0	1	0
1999	45	351	98	4	2	0	0
2000	19	106	115	39	3	2	0
2001	11	121	72	31	4	0	0
2002	20	94	89	25	8	4	0
2003	1	22	30	21	4	1	1
2004	0	7	19	22	15	15	3
2005	Not yet done						

Figure 1. Location of the 2005 hook and line sampling in Conowingo Dam tailrace.

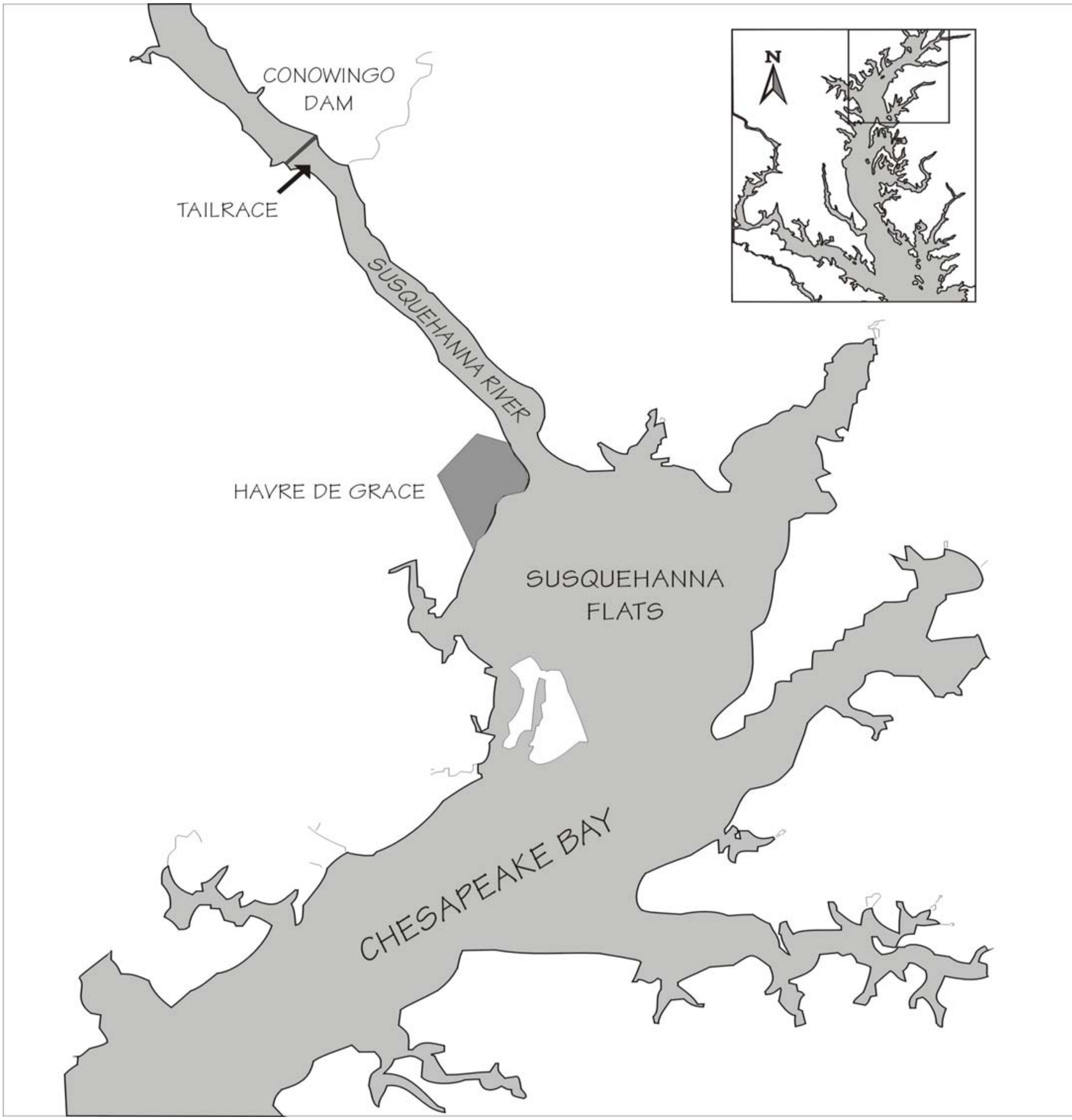


Figure 2. Distribution of the 2005 fyke and pound nets sampled on the Nanticoke River.

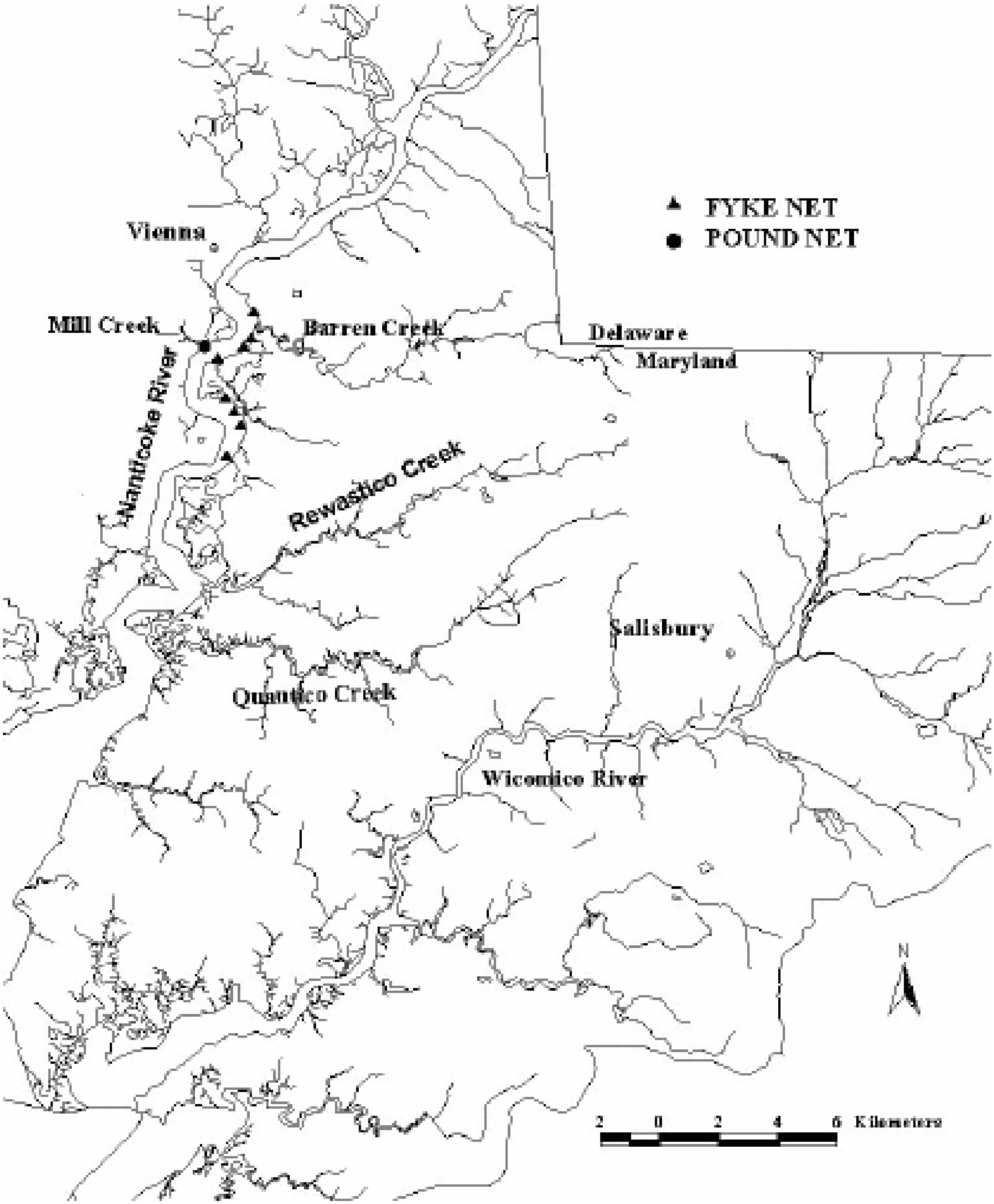


Figure 3. Distribution of the 2005 seine sites (black circles) on the Susquehanna River.

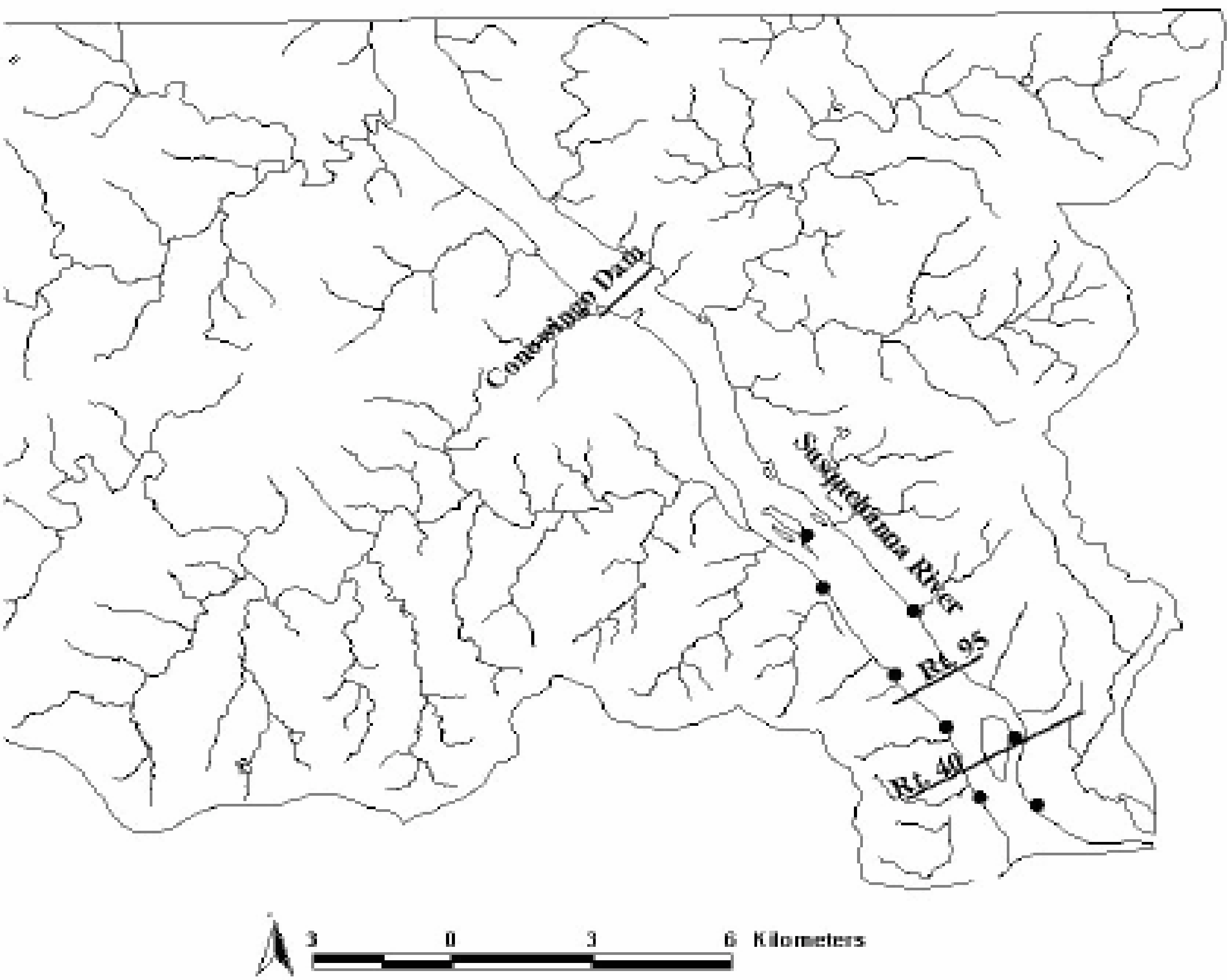


Figure 4. Distribution of the 2005 seine sites on the Chester River (black circles).

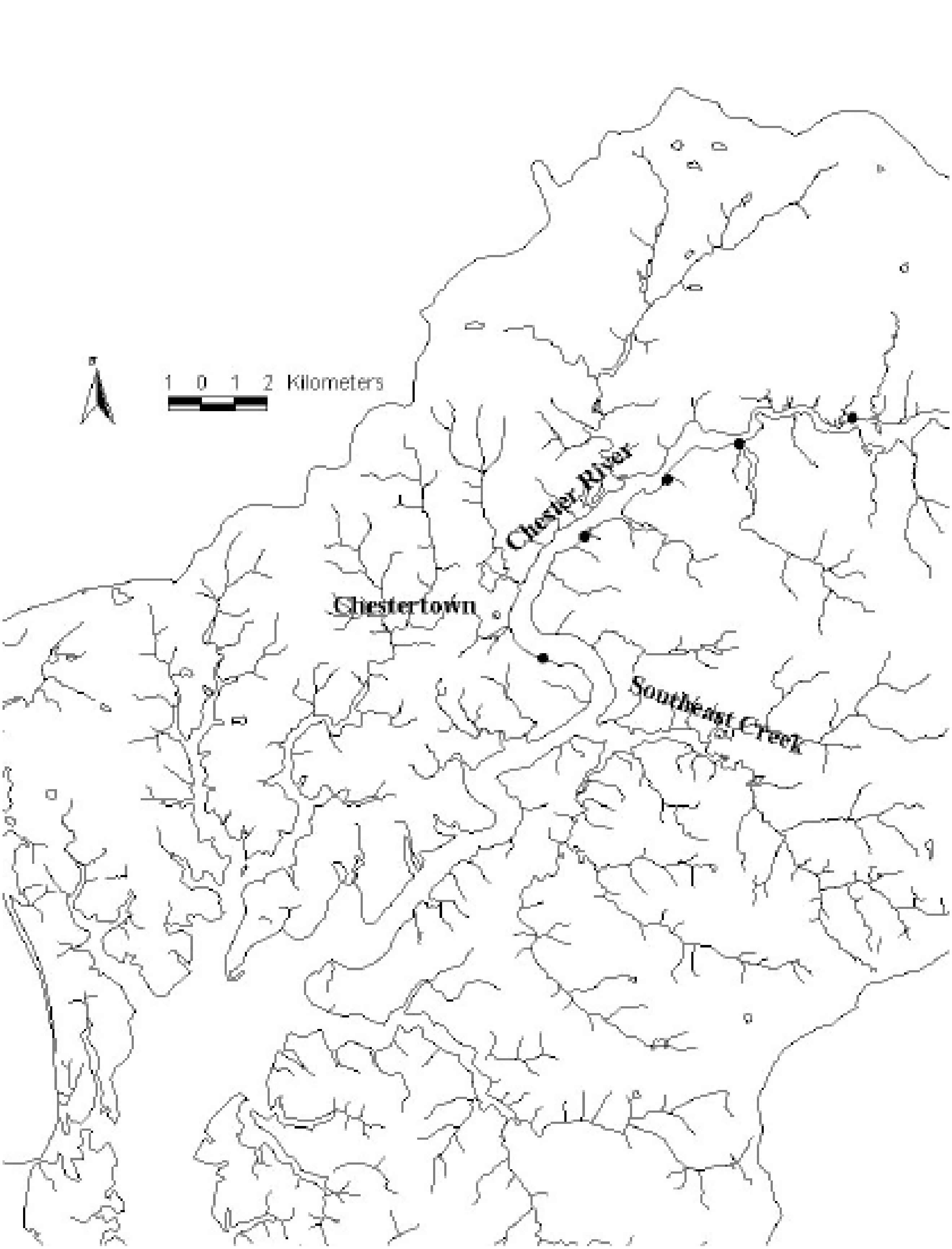


Figure 5. Distribution of the 2005 seine sites on the Pocomoke River (black circles).

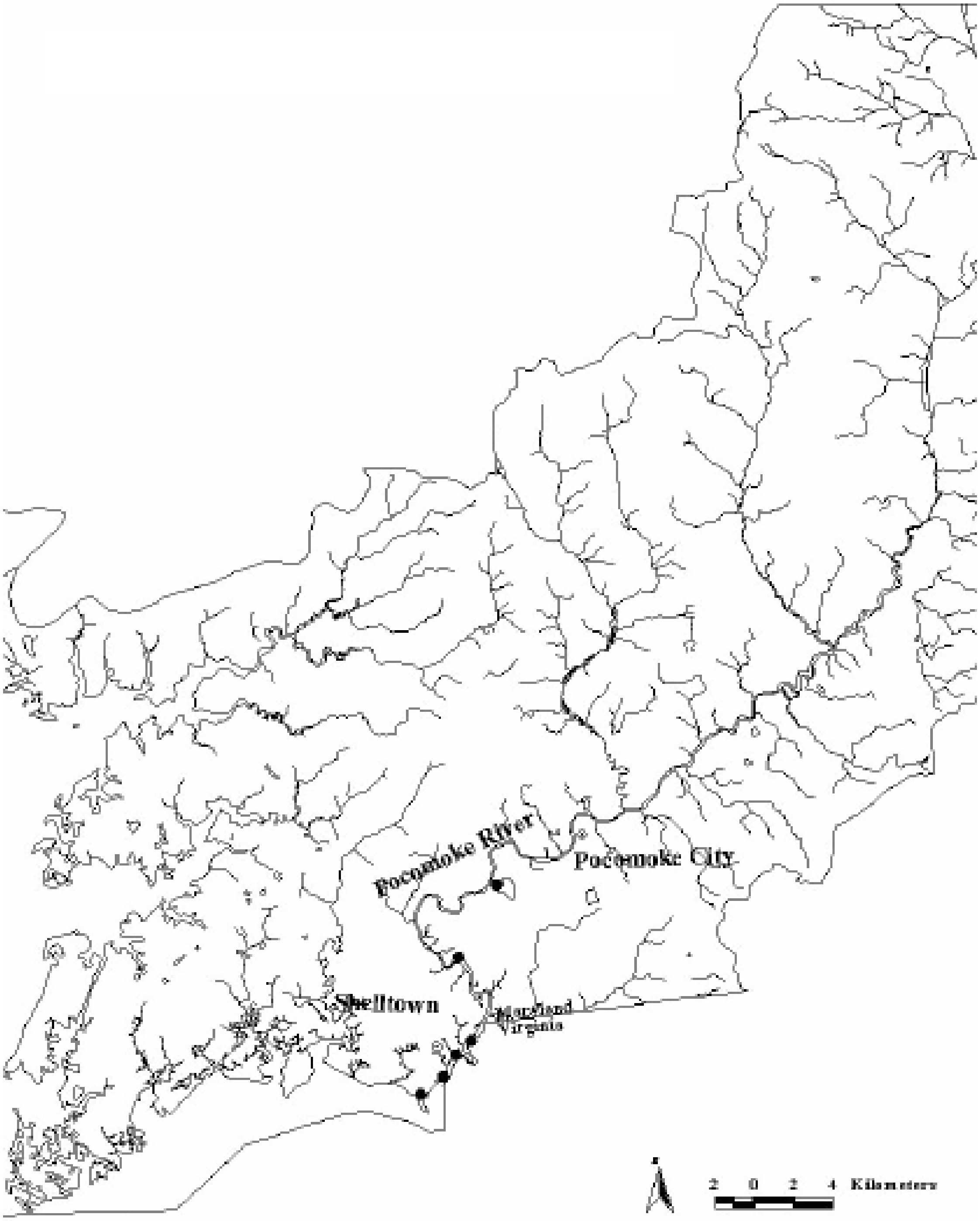


Figure 6. Distribution of the 2005 ichthyoplankton sampling sites on the Nanticoke River.

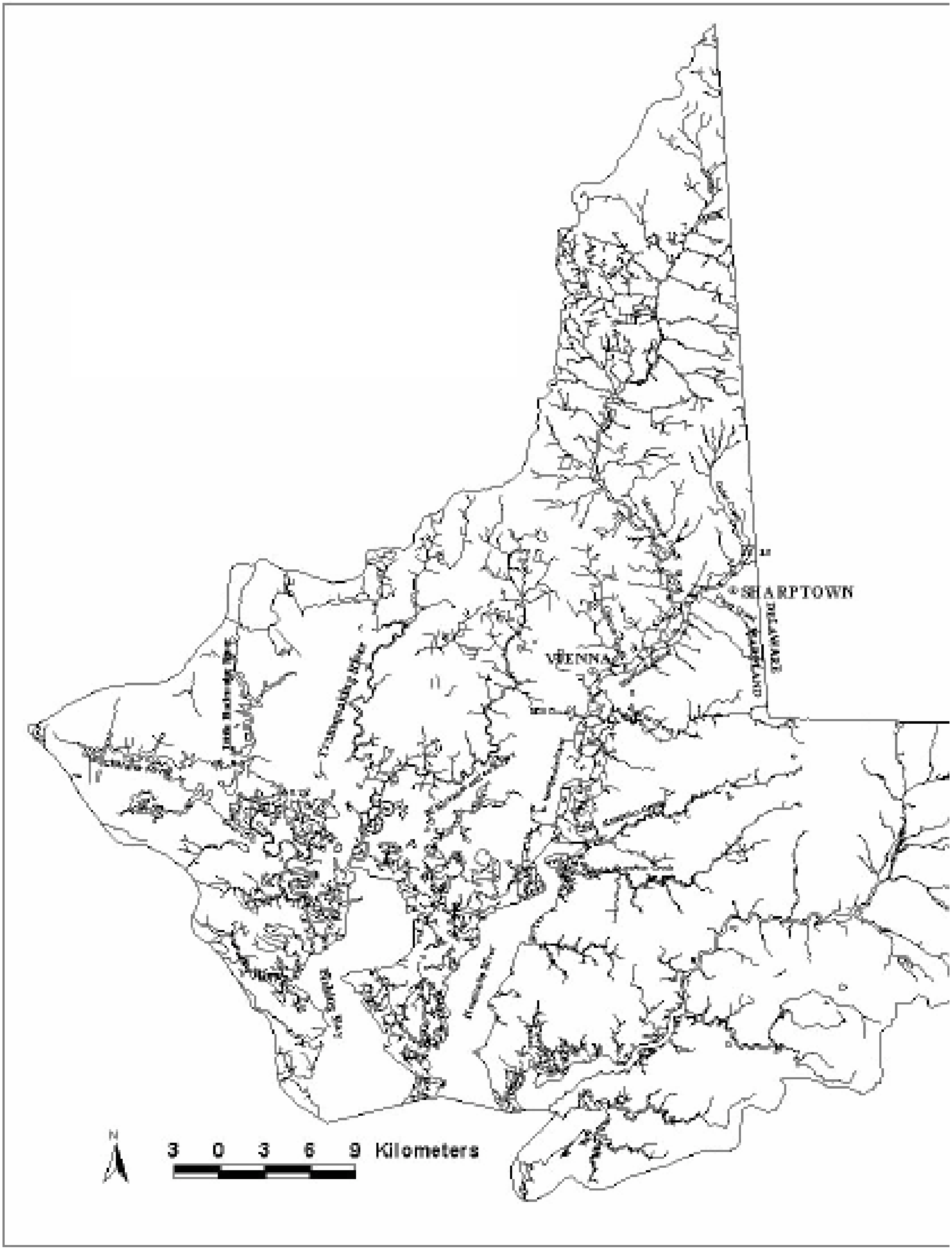


Figure 7. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2005).

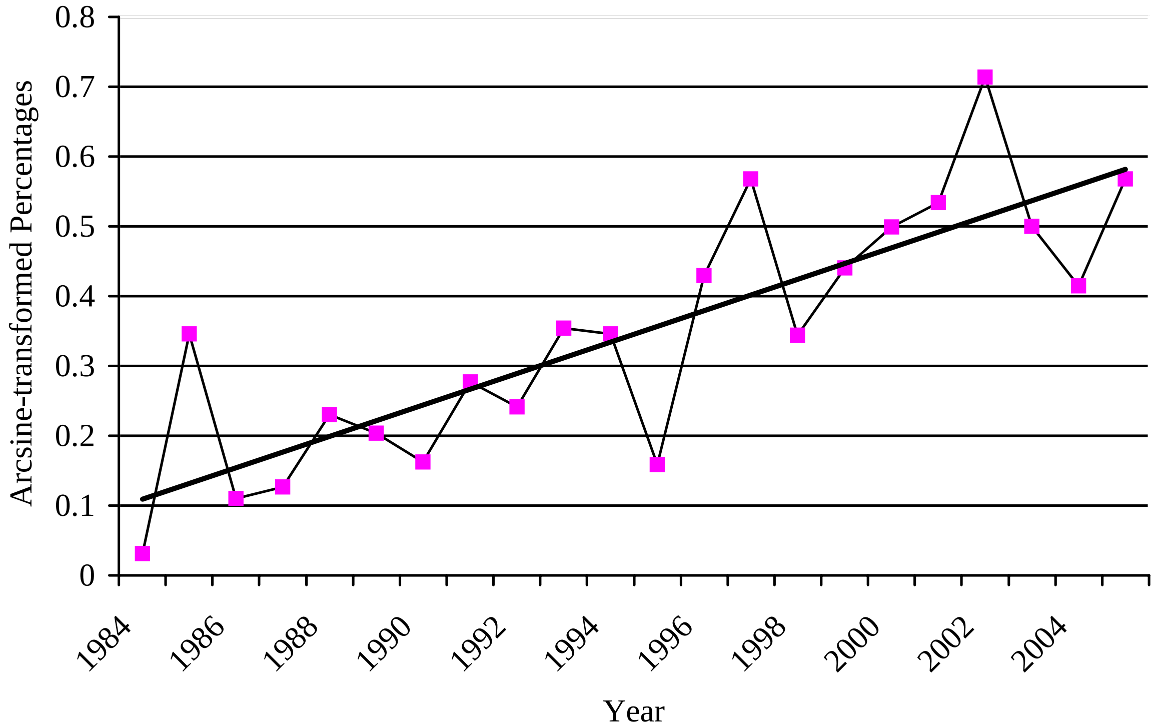


Figure 8. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Nanticoke River (1984-2005).

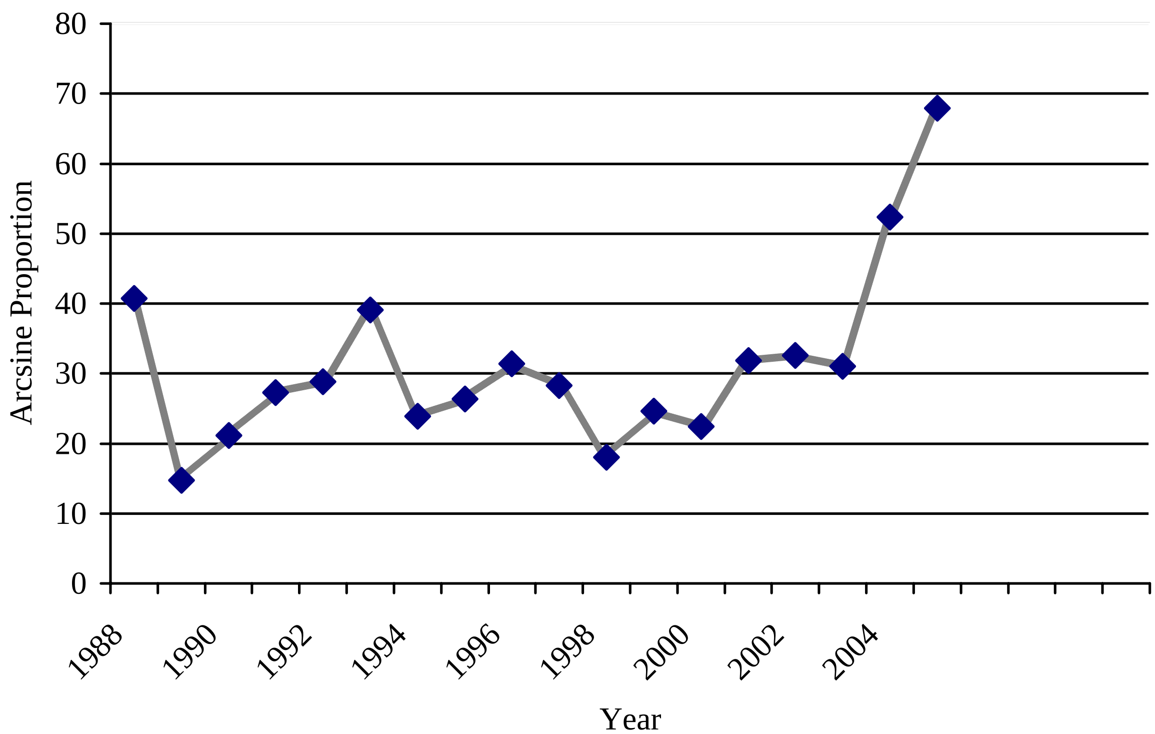


Figure 9. Conowingo Dam tailrace relative estimates of American shad abundance with 95% confidence intervals, 1984-2005.

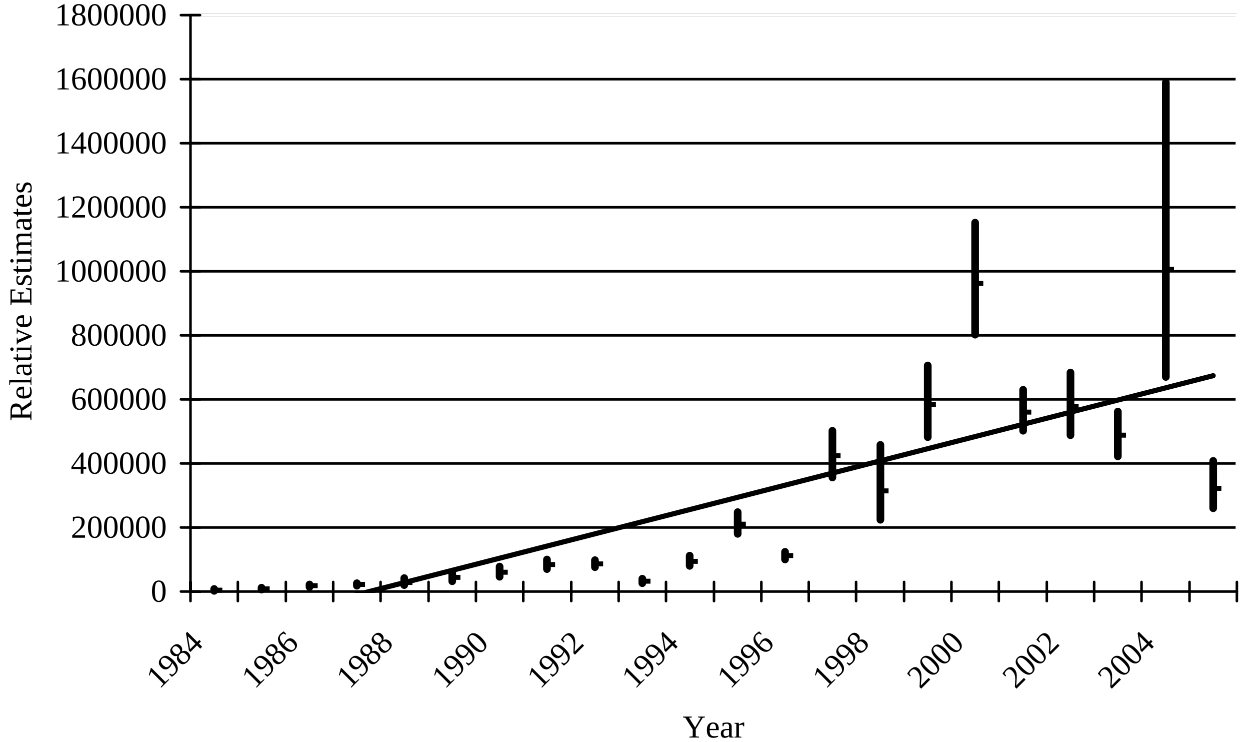


Figure 10. Geometric mean CPUE from Conowingo Dam tailrace hook and line sampling.

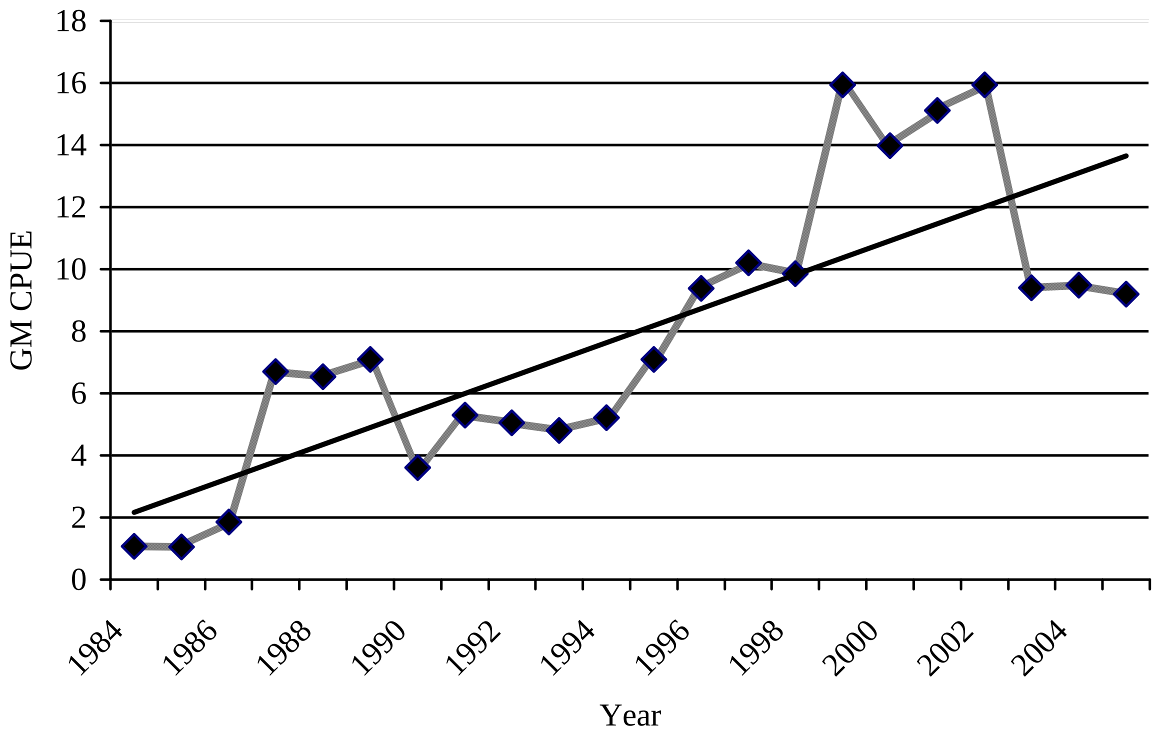


Figure 11. Geometric mean CPUE of American shad from the lifts at Conowingo Dam.

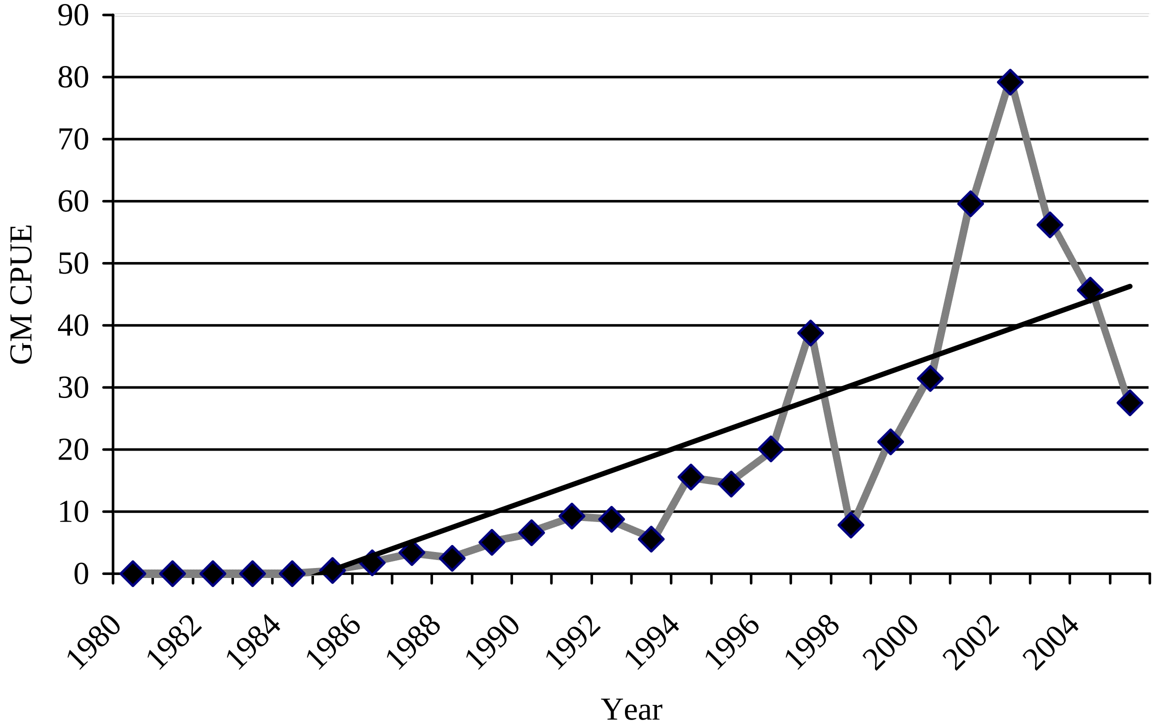
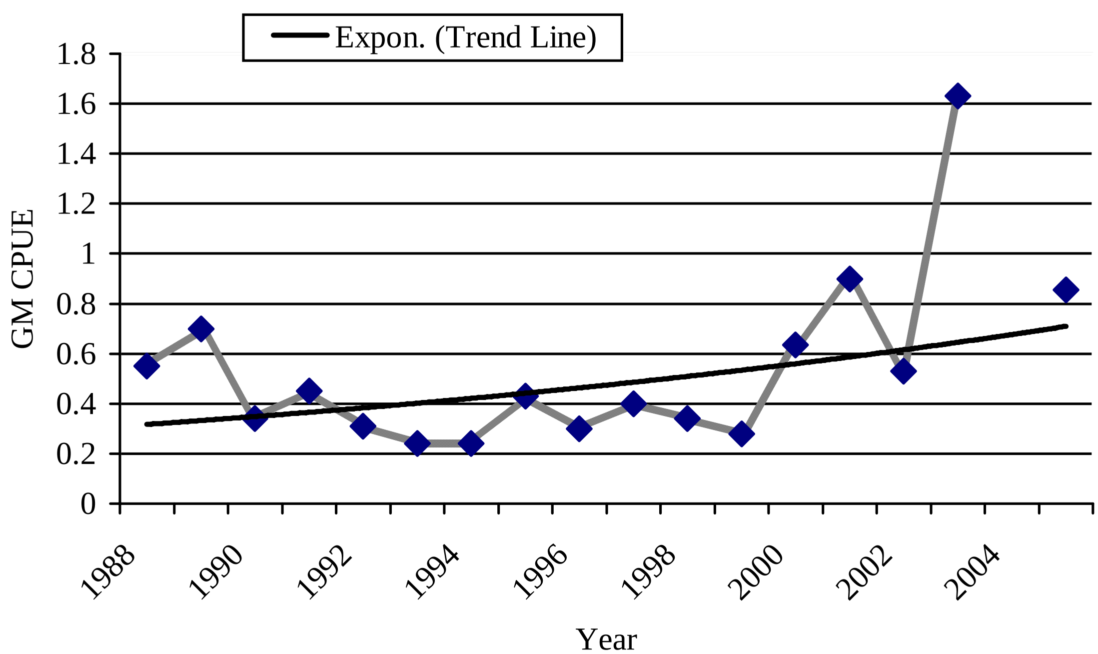


Figure 12. Pound net geometric mean CPUE and exponential trend line for American shad from the Nanticoke River, 1988-2005. [1]



[1] No Pound nets were fished in 2004.

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

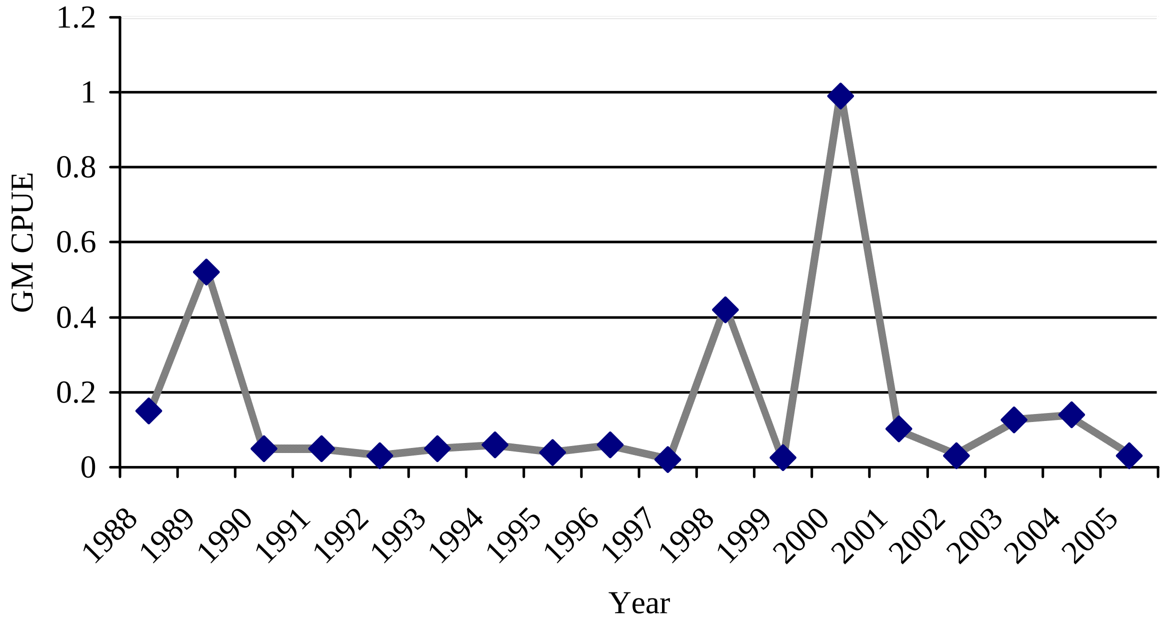
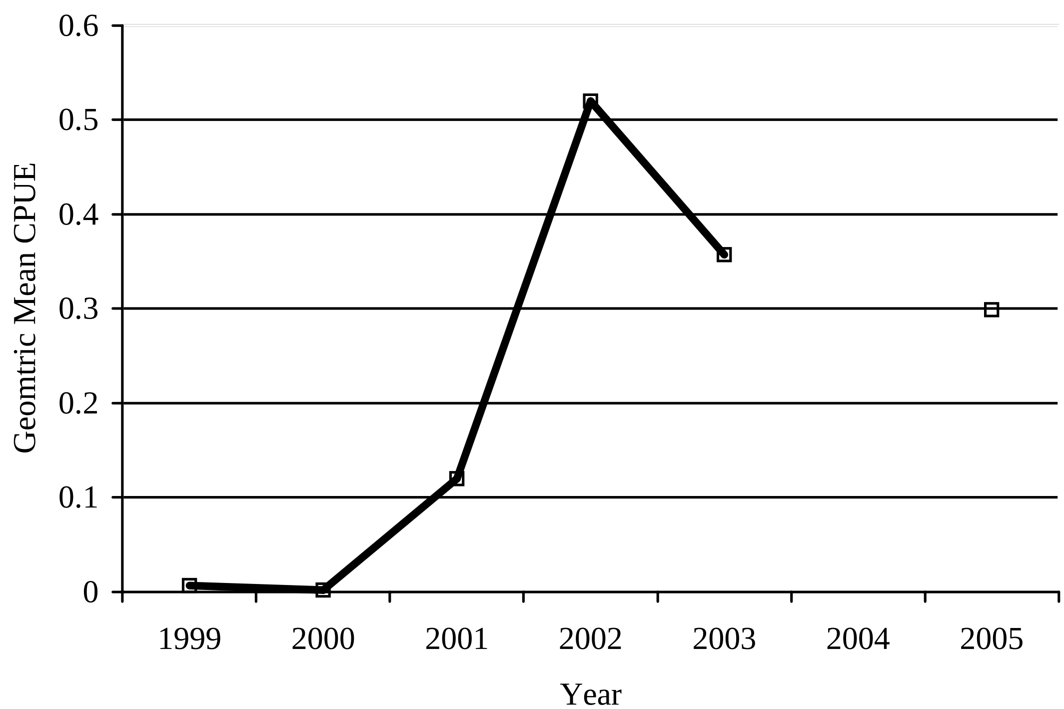


Figure 14. Adult hickory shad geometric mean CPUE from Nanticoke River pound nets, 1999-2005.[2]



[2] No pound nets were set in 2004.

Figure 15. Adult hickory shad CPUE from Nanticoke River fyke nets, 1999-2005.

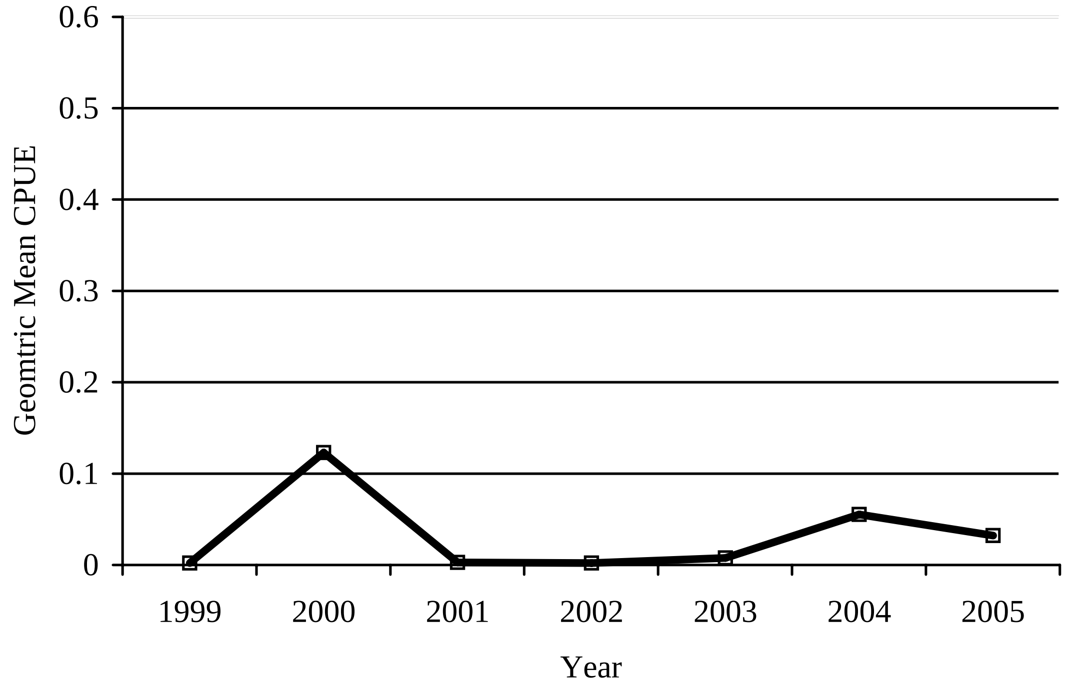


Figure 16. Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes combined) from the Nanticoke River, 1989-2005.

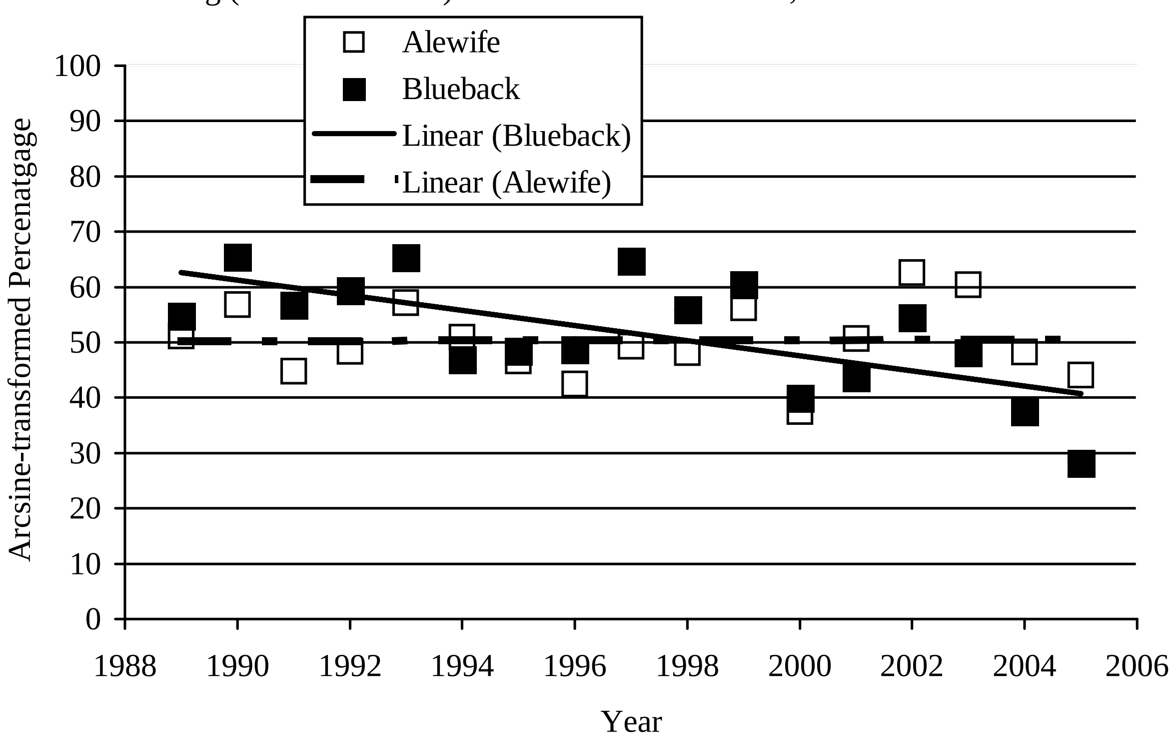


Figure 17. Geometric mean CPUEs of adult alewife herring sampled from the Nanticoke River, 1989-2005.

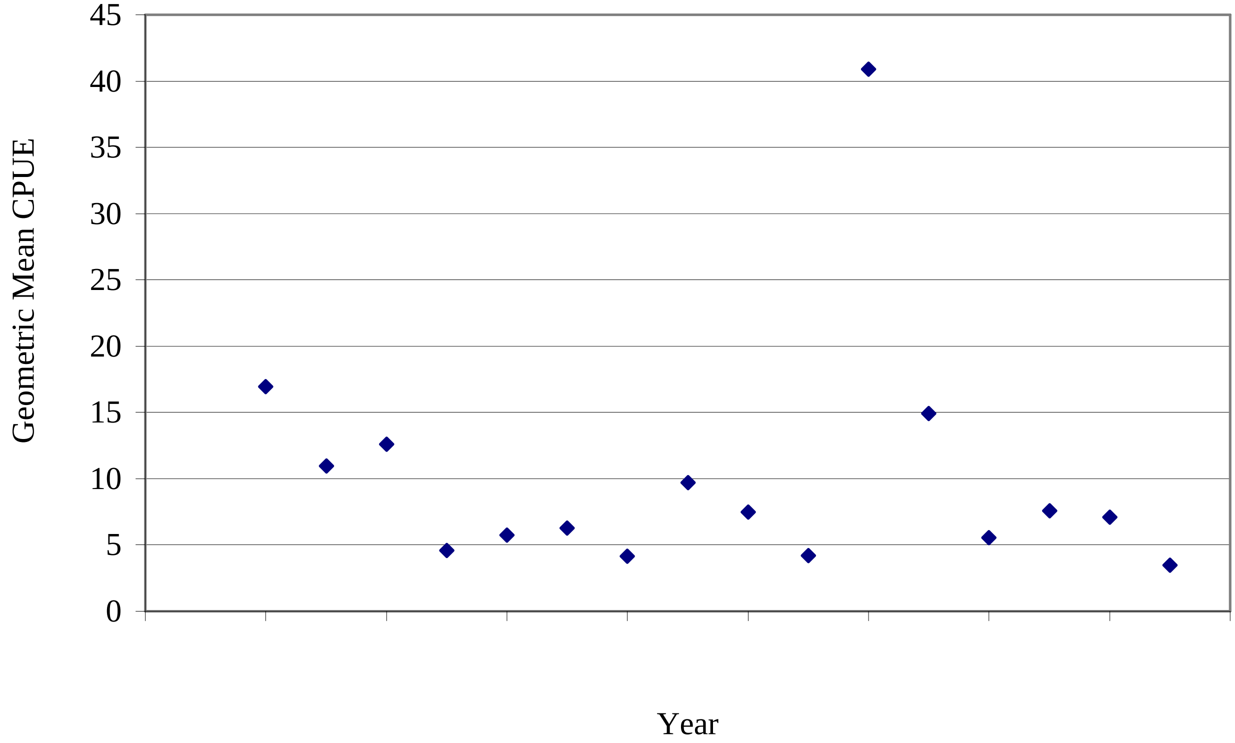


Figure 18. Geometric mean CPUEs of blueback herring sampled from the Nanticoke River, 1989-2005.

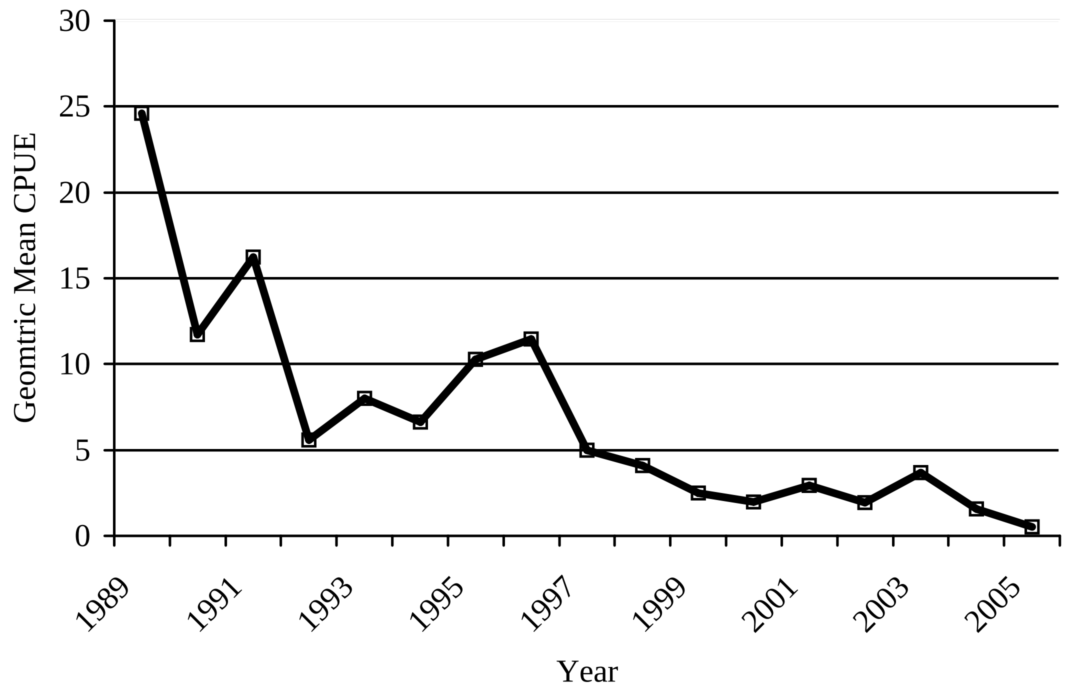


Figure 19. Regression analysis estimates of geometric mean CPUE (alewife and blueback herring combined, 1989-2005), and the total commercial river herring landings in pounds, 1980-2005 from the Nanticoke River.

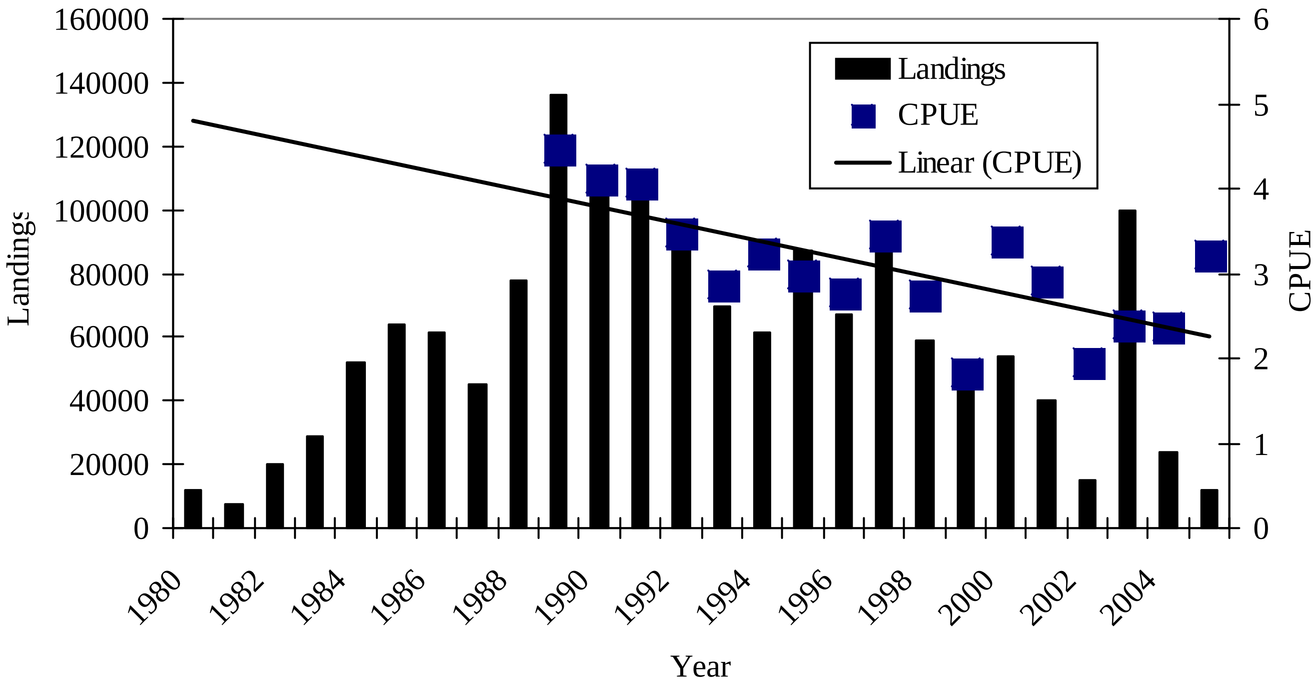


Figure 20. Instantaneous mortality (Z) of Nanticoke River alewife herring (1989-2005).

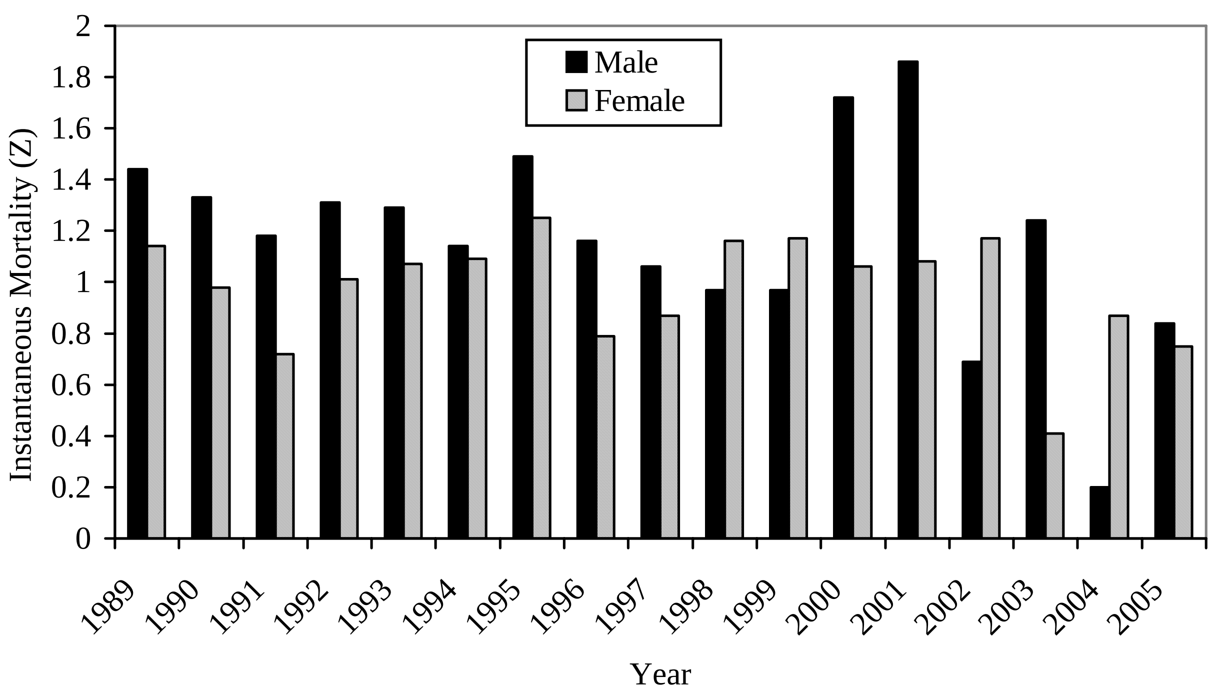


Figure 21. Instantaneous mortality (Z) of Nanticoke River blueback herring (1989-2004).

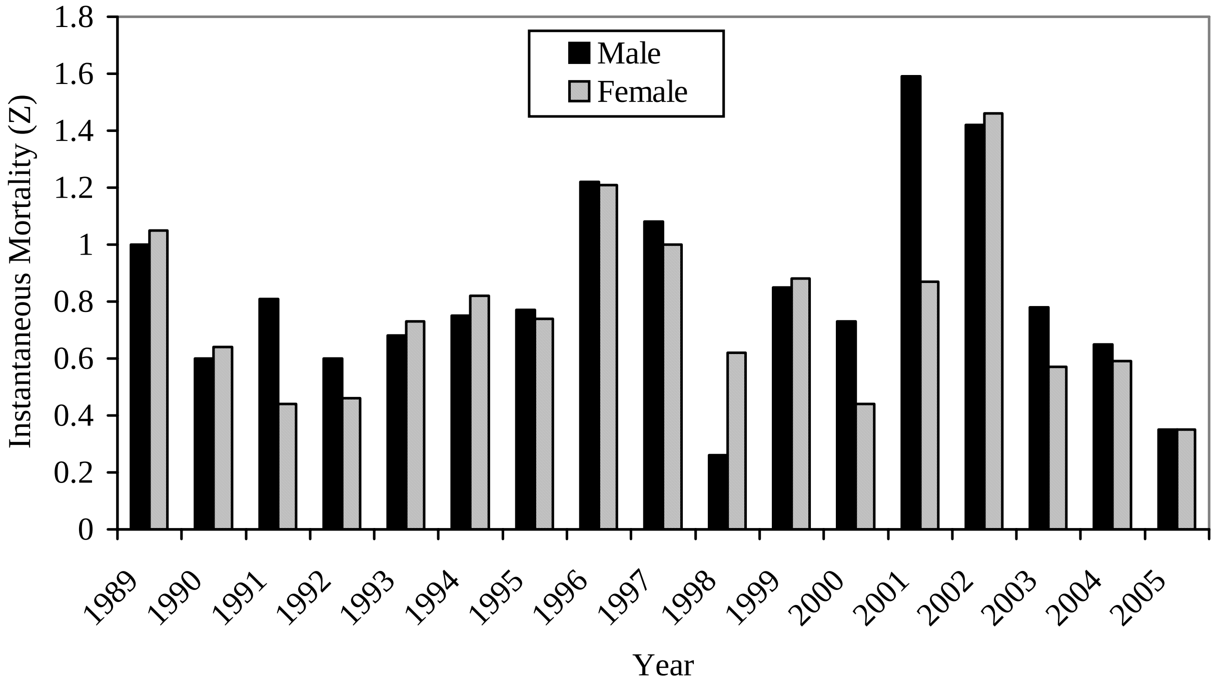


Figure 22. Baywide juvenile American shad geometric mean CPUEs, 1959-2005.

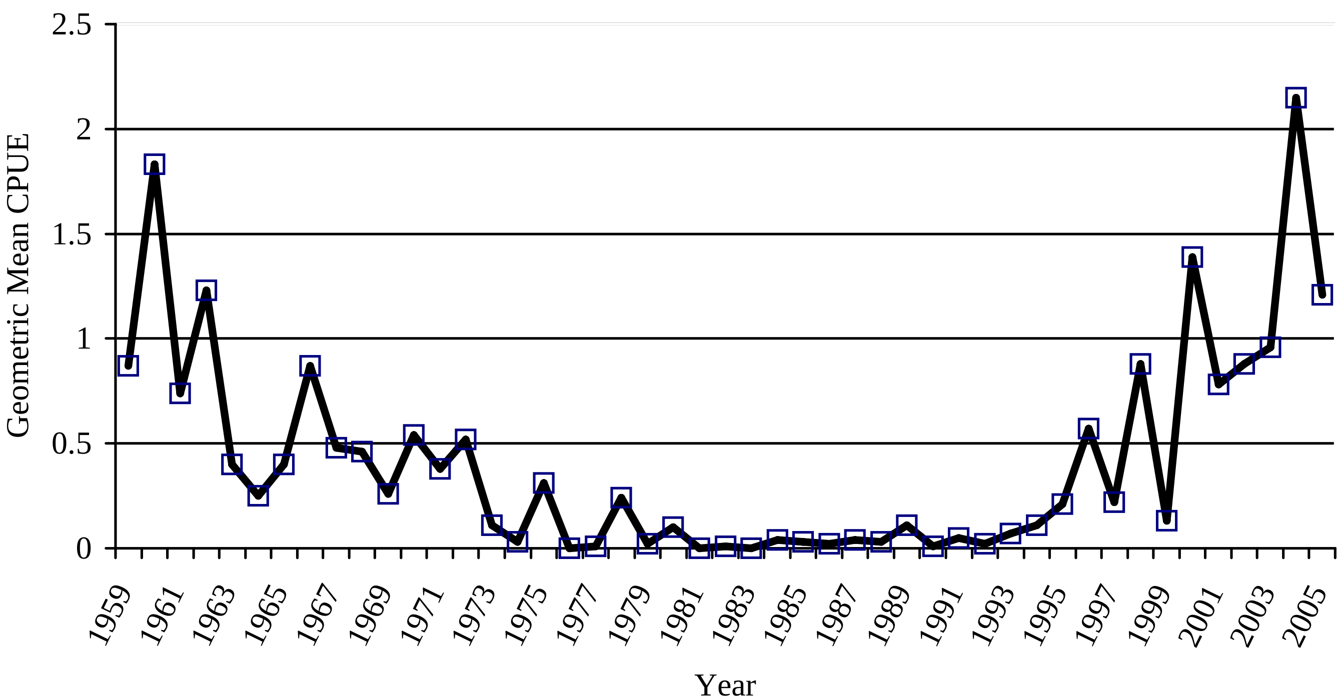


Figure 23. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1980-2005.

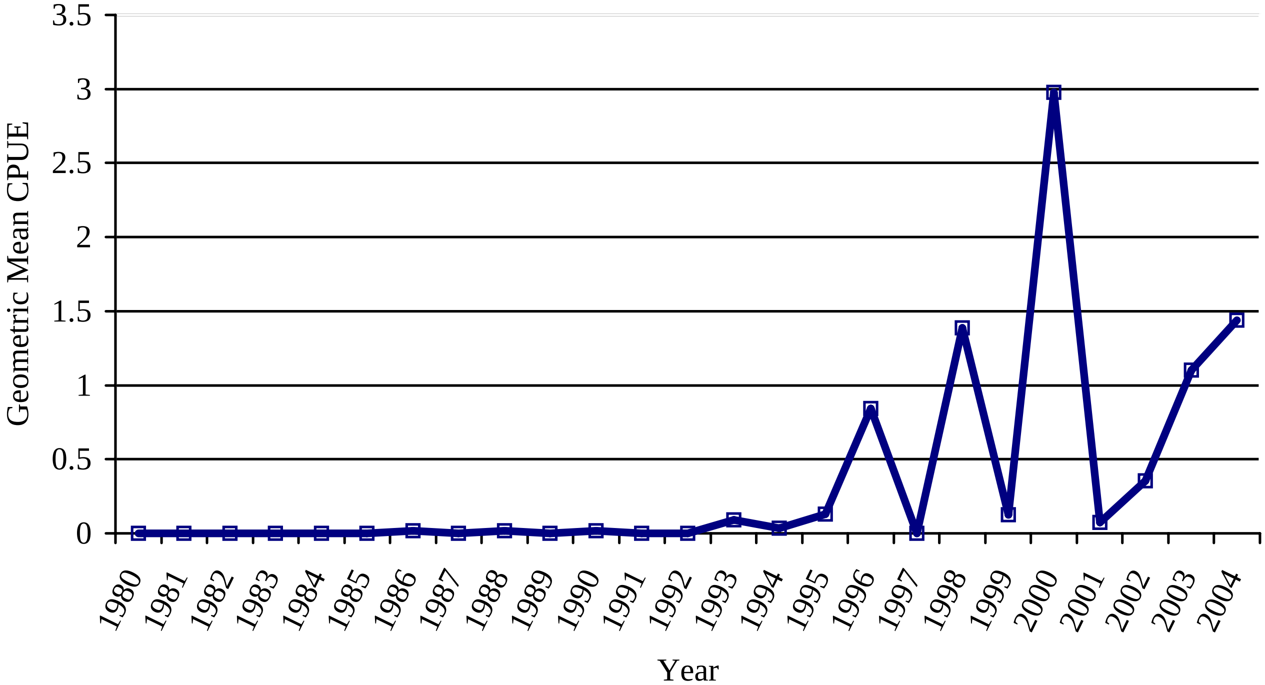


Figure 24. Potomac River geometric mean CPUEs for juvenile American shad, 1980-2005.

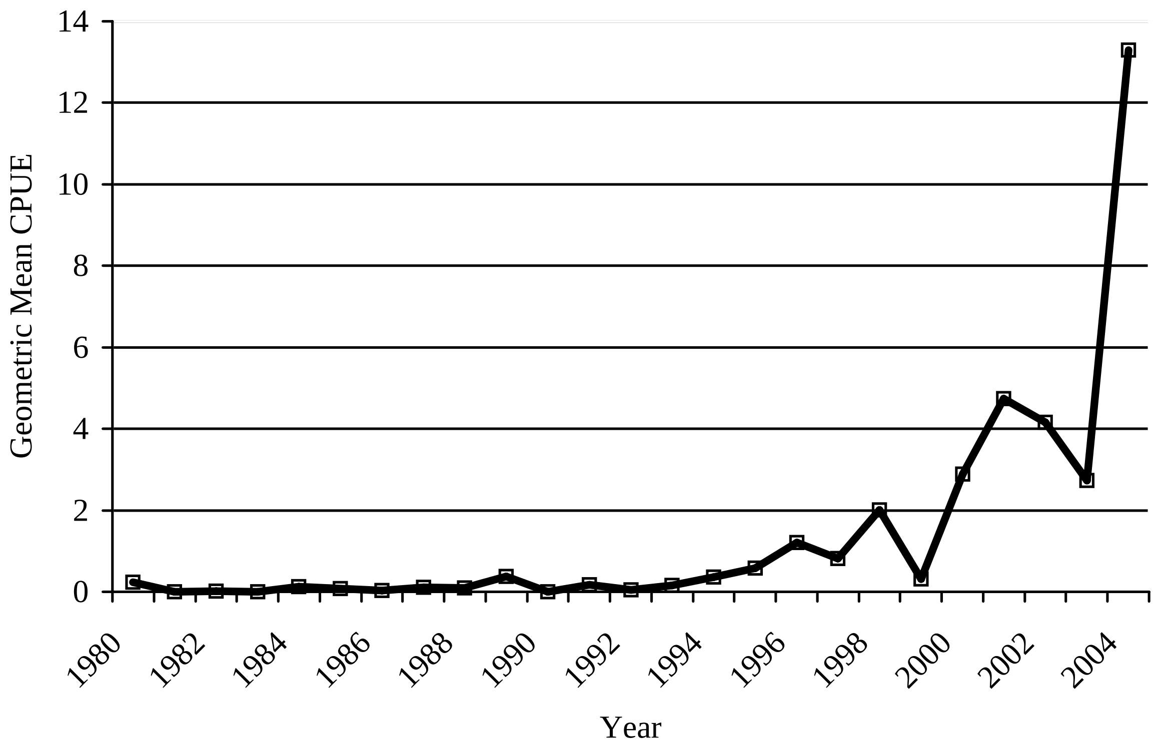


Figure 25. Juvenile alewife herring geometric mean CPUEs from the Nanticoke River, 1980-2005.

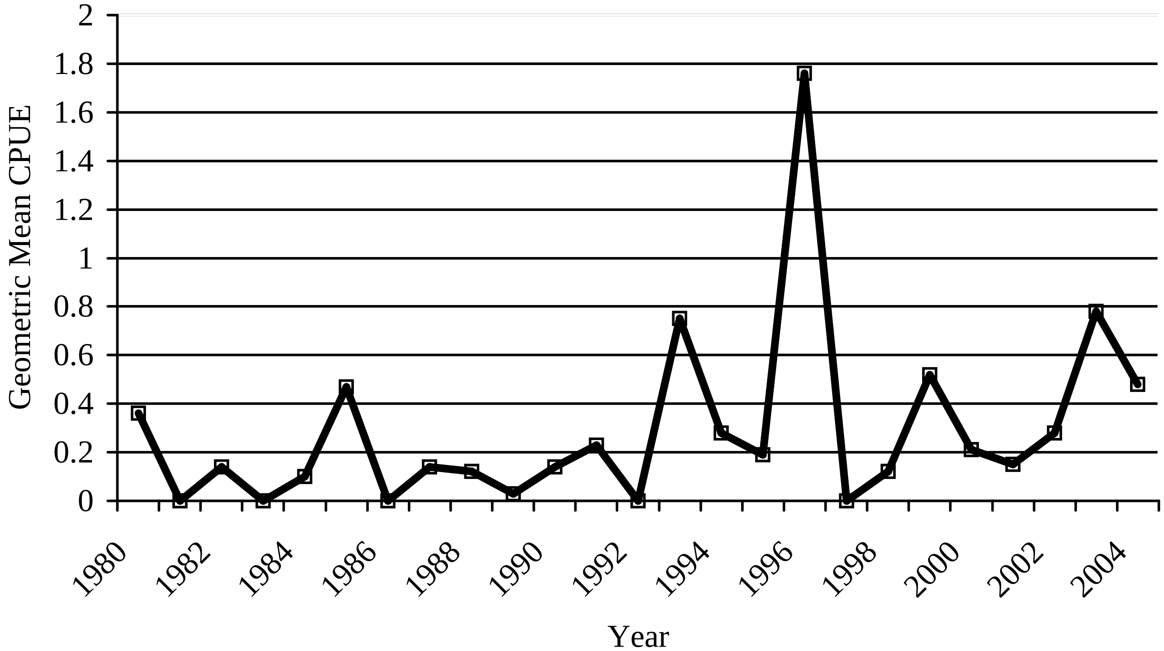
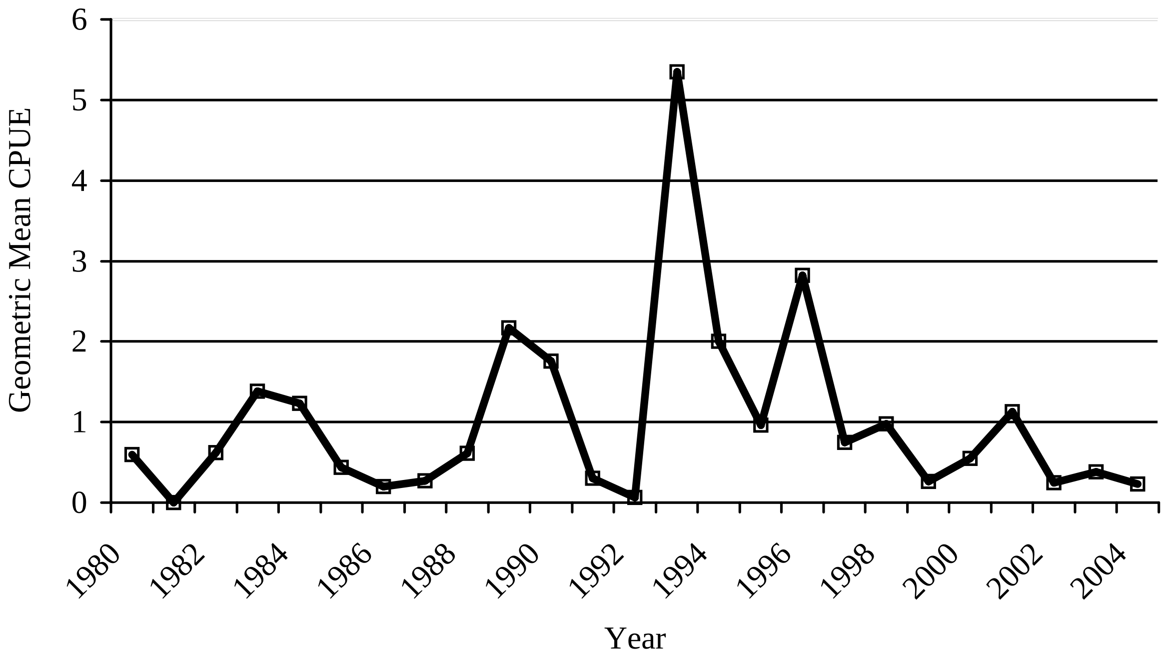


Figure 26. Nanticoke River juvenile blueback herring geometric mean CPUEs, 1980-2005.



PROJECT NO. 2
JOB NO. 2

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

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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, sex and relative abundance. Weakfish, bluefish, Atlantic croaker, summer flounder and spot are all 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 since 1993. The data collected from this effort provides information for the preparation and updating of stock assessments and fishery management plans for the Chesapeake Bay, Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council. This information is also utilized by the MD DNR in managing the state⸜s valuable migratory finfish resources through the regulatory/statutory process.

METHODS

Sampling Procedures

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, from June 2, 2005 through September 8, 2005 (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 taken from 25 of the measured fish. Otoliths for ageing, weight to the nearest gram, TL and sex were taken from a sub sample of weakfish and Atlantic croaker. These 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). These data sets are not finalized until the spring of the following year; therefore, landings data are through 2004 for this report.

Instantaneous 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: $y = -\log_e (1-L/L_4)$, and $y_c = -\log_e (1-L_c/L_4)$, L = total length, L_c = length of first recruitment to the fisheries, K = growth coefficient and L_4 = length that an average fish would achieve if it continued to grow, K and L_4 are von Bertalanffy parameters. Von Bertalanffy parameters for weakfish and Atlantic croaker were estimated from ages (otoliths) determined from the Chesapeake Bay pound net survey during 1999 (Jarzynski *et al* 2000). Parameters for weakfish were L_4 = 840 mm TL and K= 0.08. L_c was 305 mm TL. Parameters for Atlantic croaker were L_4 = 375.6 mm TL and K= 0.37. L_c was 225 mm TL.

Relative stock density (RSD) was used to characterize length distributions for weakfish, summer flounder, bluefish and Atlantic croaker (Gablehouse 1984). Incremental RSD's group fish into five broad descriptive length categories; **stock**, **quality**, **preferred**, **memorable** and **trophy**. The minimum length of each category is based on all-tackle world records such that the minimum stock length is 20 - 26%, minimum quality length is 36 - 41%, minimum preferred length is 45 - 55%, minimum memorable length is 59 - 64% and minimum trophy length is 74 - 80% of the world record lengths. Minimum lengths were assigned from either the cut-offs listed by Gablehouse (1984) or derived from world record lengths recorded by the International Game Fish Association (Table 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 2004 age samples. 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 2004.

RESULTS and DISCUSION

Weakfish

The number of weakfish sampled in the 2005 pound net survey was similar to 2004, 304 and 326 fish respectively (Table 3). Weakfish averaged 278 mm TL in 2005 and 273 in 2004 (Table 3), and RSDs for 2005 were similar to those of 2004, indicating a decrease in RSD_{qual} fish and a modest decline of RSD_{pref} weakfish compared to previous years (Table 4). The 2005 mean length was the third smallest of the time series and the RSD_{stock} was the second highest of the time series. The 2005 length frequency distribution indicated a slight expansion over 2004, with the 250 mm TL class remaining dominant (Figure 2).

Chesapeake Bay weakfish length-frequencies were truncated between 1993 - 1998. While from 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 during the survey.

In 2004 68% of the fish sampled (n=59) were female with a mean TL of 296 mm and mean weight of 256g. Males averaged 291 mm TL and 236g. 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. Mean lengths between years were similar while mean weights were slightly higher in 2005. The sex ratio was much more balanced in 2005. Differences in mean weights and sex ratios may be artifacts of small sample sizes, especially in 2004.

Total commercial landings rose 59% from 2003 harvest levels to 49,519 pounds in 2004 (Figure 3). However, 2004 landings were still well below Maryland's 1975-2003 average of 170,678 pounds per year. Maryland recreational anglers harvested an estimated 29,714 weakfish during 2004 weighing 34,229 pounds (MRFSS 2005; Figure 4). The number of weakfish harvested by the recreational fishery in 2004 decreased 25% from 2003 estimates (41,048 weakfish; Figure 4). Maryland anglers released 127,979 weakfish in 2004, nearly 30% less than 2003 (180,827).

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.

Otoliths from 59 weakfish were aged for 2004. With only ages 1 through 3 present (Table 5). Age composition, based on the 2004 age length key, was 55% age one, 37% age two and 8% age three (Table 6). One hundred nine weakfish were sampled for age in 2005, but ageing has not been completed at this time.

Instantaneous total mortality estimates were 1.44 in 2005 and 1.29 in 2004 (Table 7). Maryland's length-based estimate for 2005 was 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 gave 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 increased from 327 mm TL in 2004 to a time series high of 374 mm TL in 2005 (Table 3). Relative stock densities in 2005 indicated a shift from the quality category to the preferred category over 2004 (Table 8). The 2005 RSD_{stock} of 20 equaled the time series low in 2001. The 2005 length frequency distribution indicated a decrease in smaller flounder, but an increase in larger flounder, compared to 2004 (Figure 5).

Maryland's commercial summer flounder harvest was 314,095 pounds in 2004, which ranked as the 18th lowest in the 43-year time series (Figure 6). The long-term commercial harvest average, 1962 – 2004, is 449,551 pounds. The recreational harvest estimate of 67,858 fish caught was the 3rd lowest estimate of the 1981-2004 time series

(MRFSS 2005; Figure 7). Recreational releases were the 7^{th} highest during the same time period at 997,207 fish (Figure 7). More restrictive size and bag limits in recent years are likely reasons for the increase in releases and reduction in harvest.

Virtual population analysis (VPA), conducted in 2004 by NMFS, indicated that summer flounder recruitment along the Atlantic coast declined between 1983 - 1988 (NMFS 2005). Recruitment since 1988 was generally higher, with the 2002 year-class being the largest (50.7 million recruits) since 1986. Recruitment was below average at 27 million fish in 2003 (long-term average = 38 million), and closer to the average in 2004 at 33 million fish. The coastal assessment found that F varied from 0.9 to 2.2 during 1982 - 1997, but has fallen recently from approximately F=1.2 in 1997 to F=0.4 in 2004. Summer flounder stocks were not overexploited and SSB exceeded the biomass threshold.

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. The increase in mean length in 2005 is likely a result of growth and survival of the 2002-year class. Large RSD_{stock} levels in 2002 grew into RSD_{qual} during 2003, and RSD_{pref} in 2004 and 2005. The RSD analysis, which indicates cohort growth into RSD_{qual} and RSD_{pref}, also suggested improved recruitment during the early 2000's.

Bluefish

Bluefish averaged 251 mm TL during 2004, a record low for the time series (Table 3). Mean length increased 74 mm in 2005 to 325 mm TL, similar to the 2003 mean length of 320 mm TL. This variability follows the 1999 – 2002 time period when mean lengths had been in a narrow range (293 mm TL - 307 mm TL). Relative stock densities were similar from 1993 – 2004, but 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 bimodal distribution indicates the presence of age zero and age one bluefish in the 2005 pound net samples.

Pound net sampling in 2005 indicated that bluefish length distribution increased and expanded in 2005 compared to 2000 – 2004, when only smaller bluefish were available to anglers. The 2005 samples indicated a shift to a larger grade of bluefish, but RSD_{stock} values (79%) 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 postulated as reasons for this displacement.

Maryland bluefish commercial harvest in 2004 totaled 52,683 pounds compared to the 1929-2004 average of 178,987 pounds (Figure 9). The 2004 catch was the 15th lowest of the 75-year time series. Recreational harvest estimates for bluefish were high through most of the 1980’s and have since remained stable at a lower level (MRFSS 2005; Figure 10). The 2004 estimate of 319, 006 fish harvested was the 7th lowest of the 24-year time series (Figure 10).

Bluefish recruitment in Maryland has been variable, but showed a declining trend since the early 1980's (Mowrer 2004). The juvenile index indicated relatively strong year-classes in 1997 and 1999.

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 increased from 287 mm TL in 2003 to 311 mm TL in 2004 and to 317mm TL in 2005 (Table 3). RSDs for Atlantic croaker indicated a large shift from quality to preferred in 2004, and a shift from preferred to memorable and trophy in 2005 (Table 10). In 2005 the RSD_{trophy} category was the highest in the time series, and the $RSD_{memorable}$ category second highest. RSD_{stock} increased in 2005, indicating an influx of younger fish. Length frequency distributions from 2003 – 2005 demonstrate the influence of the strong 2002 year-class, with the mode of each distribution increasing as the year-class ages (Figure 11).

In 2004 females accounted for 69% of the catch and averaged 328 mm TL and 491g, while males averaged 311 mm TL and 407g in weight (n=161). The sex ratio remained the same from 2004 to 2005. Mean lengths and weights in 2005 were 344 mm TL and 587g for females and 310 mm TL and 417g for males (n=191). The increase in both mean length and weight are likely related to the more abundant 1998 and 2002 year-classes. However this can not be confirmed until the 2005 ages become available.

During 2004 Atlantic croaker commercial harvest was 1,354,982 pounds (Figure 12), while recreational harvest was estimated at 866,933 fish (MRFSS 2005; Figure 13). The 2004 recreational harvest was half that of 2003, but still ranked 15th in the 24-year time series (MRFSS 2005; 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, but commercial harvest was greater than the MRFSS estimate for 1996, 1997, 2001 – 2002 and 2004.

Ages derived from 2004 Atlantic croaker otoliths ranged from age 1 to 11 (n=161), with no age 8 or 10 fish present (Table 11). Applying number of Atlantic croaker captured from pound nets (n=1,653) to an age-length key for 2004, indicated that 55% of the fish were age two and 23% were age six. Age groups three, four and five each accounted for five to seven percent of the fish sampled (Table 12). One hundred ninety-one Atlantic croaker otoliths were collected in 2005, but ageing had not been completed at this time. Instantaneous total mortality in 2005 was 0.24 a slight decrease from 2004 (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 with F below target and threshold values and SSB above target and threshold values.

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. Pound nets may select larger and older Atlantic croaker. Therefore, the data would indicate and artificial decrease in mortality estimates. It is not clear at this time how the colder 2003 and 2004 winters effected recruitment to the spawning stock.

Spot

Spot mean length in 2005 was 197 mm TL (Table 3). The length frequency distribution shifted from a single to a bimodal distribution with peeks at 130 - 149 mm and 210 – 229 mm length groups. A reduction in fish >250 mm TL was noted, with less than 3% of the 2005 sample comprised of jumbo spot (>254 mm TL, compared to 13% in 2004 and 10% in 2003(Figure 14).

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, 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 2004 was 177,914 pounds, slightly above the long-term average (1929 – 2004) of 142,047 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 2005; Figure 16). For 2004, 1,500,000 spot were harvest and 600,000 released.

Red Drum

Red drum are rarely encountered in the pound net sampling, with only one fish being examined in 2005. The number of red drum sampled peaked in 2002 (Table 3), 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.

Maryland commercial red drum harvest in 2004 was 12 pounds, compared to 1,161 pounds in 2002, the second lowest since 1991(Figure 17). This drop may not reflect a 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.

The MRFSS (2005) estimated that recreational fishermen did not harvest or capture and release any red drum in Maryland during 2004 (Figure 18). It is very unlikely no red drum were harvested in 2004. However, estimates of zero catch were made for 13 of the 24 years of the 1981 - 2004 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 captured in the MD DNR pound net sampling (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 have been variable ranging from zero, for seven of the 24 years, to over 13,000 fish in 1984 (MRFSS 2005; Figure 20). From 1995 to 2004 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. During this time period length has ranged from 208 – 567 mm FL. Mean length for 2005 was 422 mm FL (Table 3). The number of mackerel measured has been low for most years (Table 3).

The 2004 commercial harvest of Spanish mackerel in Maryland was 14,069 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 mid 1990's with three years of harvest of approximately 40,000 fish (MRFSS 2005; Figure 22). This followed a period in which seven of the ten year estimates were zero fish captured.

Estimates for 1998 – 2004 were variable ranging from 0 – 15,219 fish with an average of 6,197, and 8,304 being harvested in 2004 (Figure 22).

Spotted Seatrout

Spotted seatrout are rarely captured by the pound net sampling, 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 9,409 pounds from 1991-2004 (Figure 23). Reported 2004 harvest was only 401 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 2005; Figure 24).

Atlantic Menhaden

Mean fork length for Atlantic menhaden sampled from commercial pound nets in 2005 was 282 mm FL (n=1052). Lengths ranged from 101 mm FL to 399 mm FL. Scales were taken from 345 fish for age determination, but ages are not available at this time.

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Table 1. Areas sampled, number of nets sampled, mean water temperature and mean salinty by month, 2005.

Area	Month	Number of Nets Sampled	Mean Water Temp. (C)	Mean Salinty (ppt)
Point Lookout	June	2	21.4	10.85
Barren Island	June	9	24	10.88
Cedar Point Hollow	June	0		
Point Lookout	July	2	27.8	11.85
Barren Island	July	6	21.8	12.8
Cedar Point Hollow	July	0		
Point Lookout	August	2	28.2	13.1
Barren Island	August	1	27.6	14.7
Cedar Point Hollow	August	1	28.1	13.4
Point Lookout	September	0		
Barren Island	September	3	25.4	15.3
Cedar Point Hollow	September	1	25.9	14.8

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 - 2005.

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

Table 4. Relative stock density of weakfish from Chesapeake Bay summer pound net survey, 1993 - 2005.

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		

Table 5. Weakfish mean length, mean weight and number sampled by age, 2004.

Age	Mean Length (mm)	Mean Weight (g)	Number Aged
1	252	166	24
2	304	258	23
3	361	404	12

Table 6. Weakfish proportion at age using 2004 pound net survey length and age data (59 ages and 326 lengths).

Age	1	2	3
n	181	120	25
Proprtion at age	55.52	36.81	7.67

Table 7. Weakfish and Atlantic croaker total instantaneous mortality rate estimates from Chesapeake Bay pound net data, 1999 – 2005.

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

Table 8. Relative stock density of summer flounder from Chesapeake Bay summer pound net survey, 1993 - 2005.

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	

Table 9. Relative stock density of bluefish from Chesapeake Bay summer pound net survey, 1993 - 2005.

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		

Table 10. Relative stock density of Atlantic croaker from Chesapeake Bay summer pound net survey, 1993 - 2005.

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

Table 11. Atlantic croaker mean length (mm TL), mean weight and number sampled by age, 2004.

Age	Mean Length (mm)	Mean Weight (g)	Number Aged
1	285	264	1
2	283	295	78
3	283	296	7
4	310	411	8
5	352	578	11
6	368	659	43
7	407	842	9
8			
9	426	920	1
10			
11	431	1002	3

Table 12. Atlantic croaker proportion at age using 2004 pound net survey length and age data (161 ages and 1653 lengths).

age	1	2	3	4	5	6	7	8	9	10	11
n	10	907	83	89	115	386	51	0	3	0	10
Proprtion at age	0.63	54.88	5.00	5.36	6.93	23.34	3.09	0.00	0.18	0.00	0.59

Figure 1. Summer pound net sampling area map for 2005.

Figure 2. Weakfish length frequency distributions from pound nets, 2003-2005.

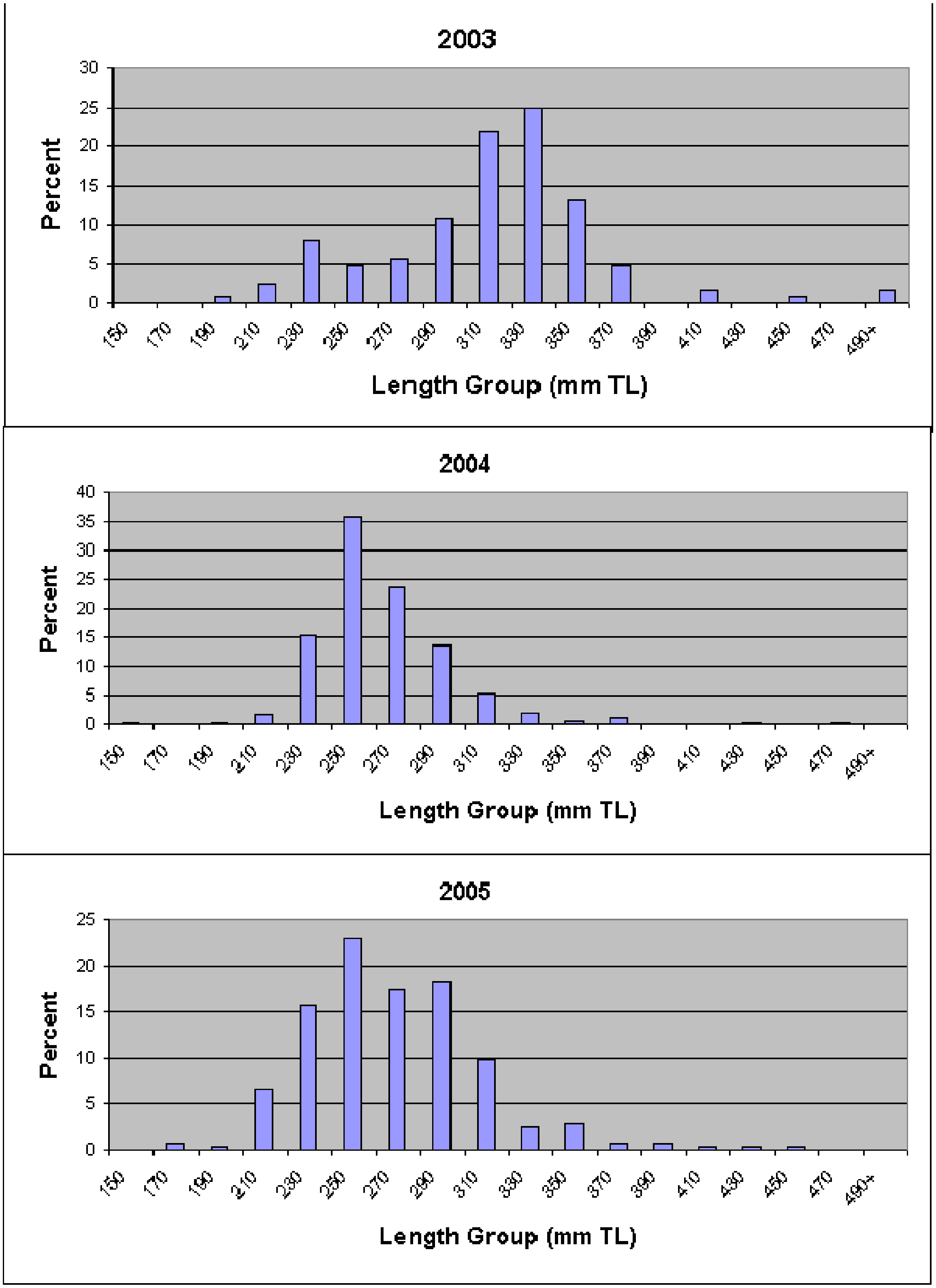


Figure 3. Maryland commercial weakfish landings from 1975-2004.

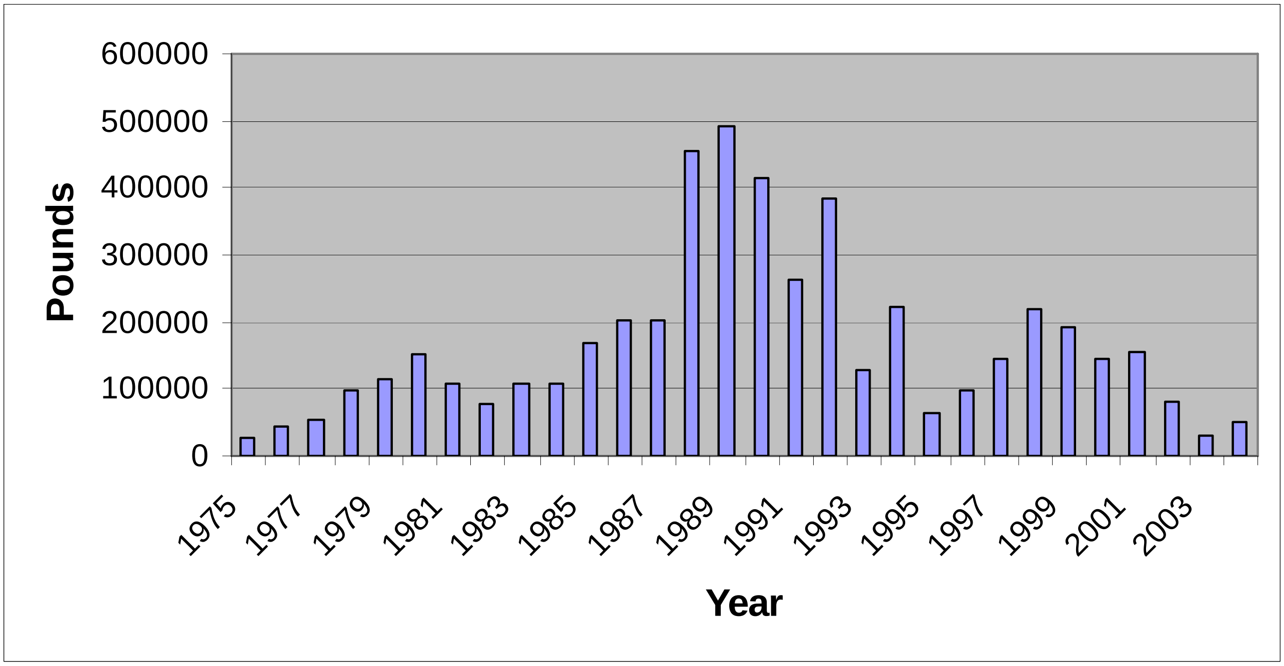


Figure 4. Estimated Maryland recreational weakfish harvest and releases for 1981-2004 (Source: MRFSS, 2005).

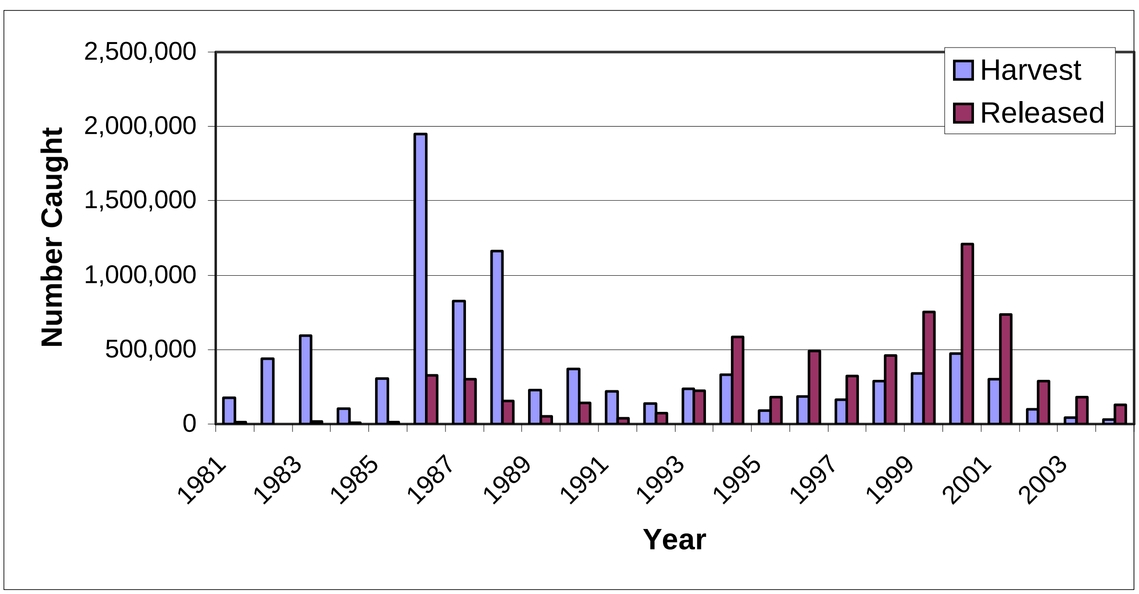


Figure 5. Summer flounder length frequency distributions from pound nets, 2003-2005.

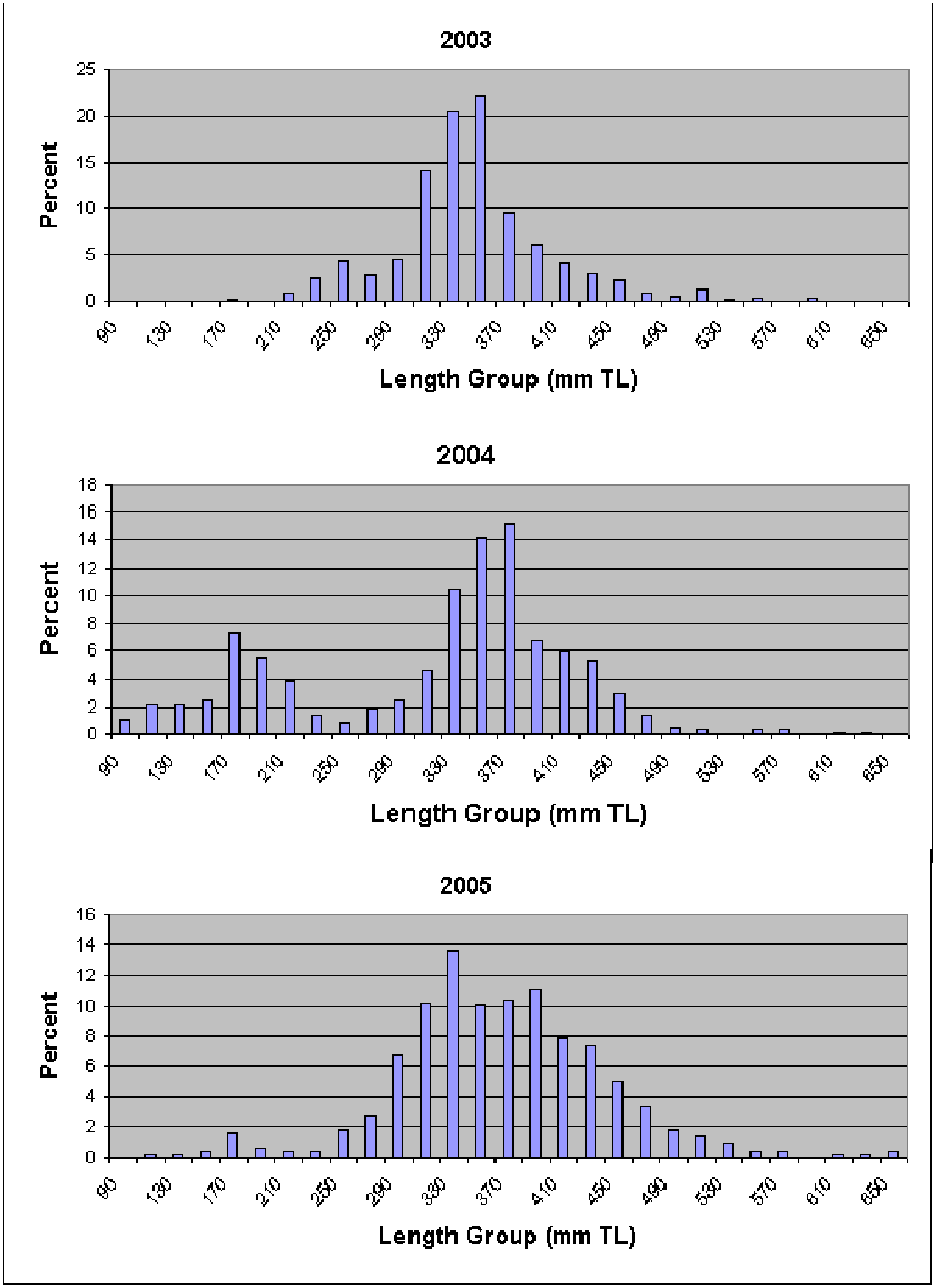


Figure 6. Maryland commercial summer flounder landings from 1962-2004.

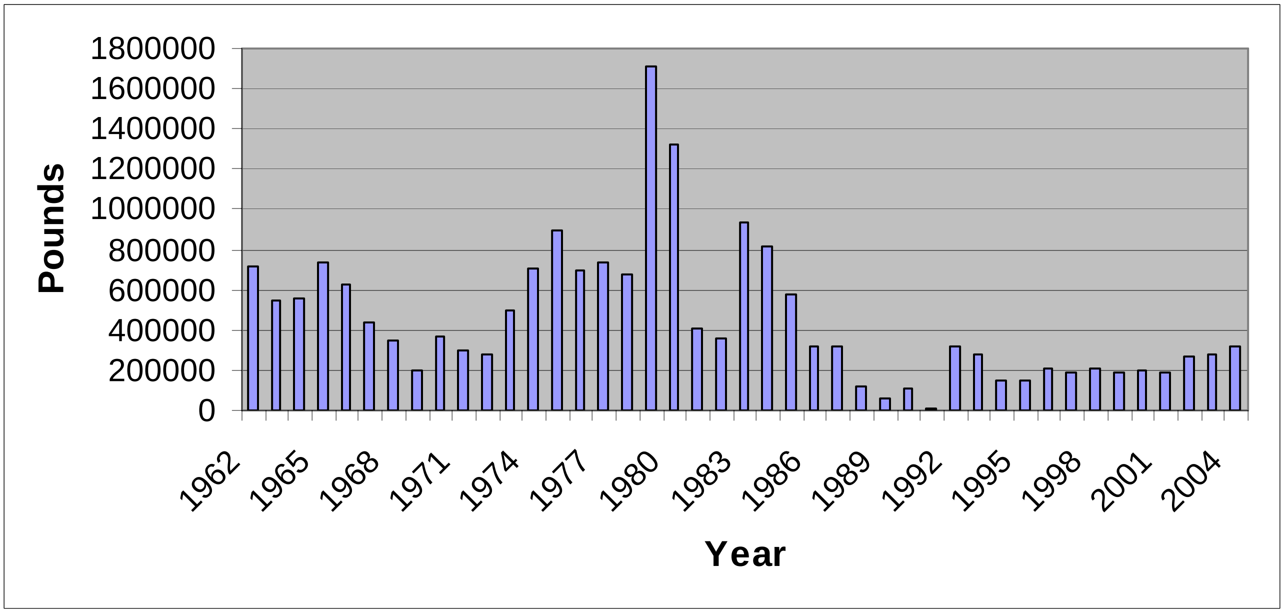


Figure 7. Estimated Maryland recreational summer flounder harvest and releases for 1981-2004 (Source: MRFSS, 2005).

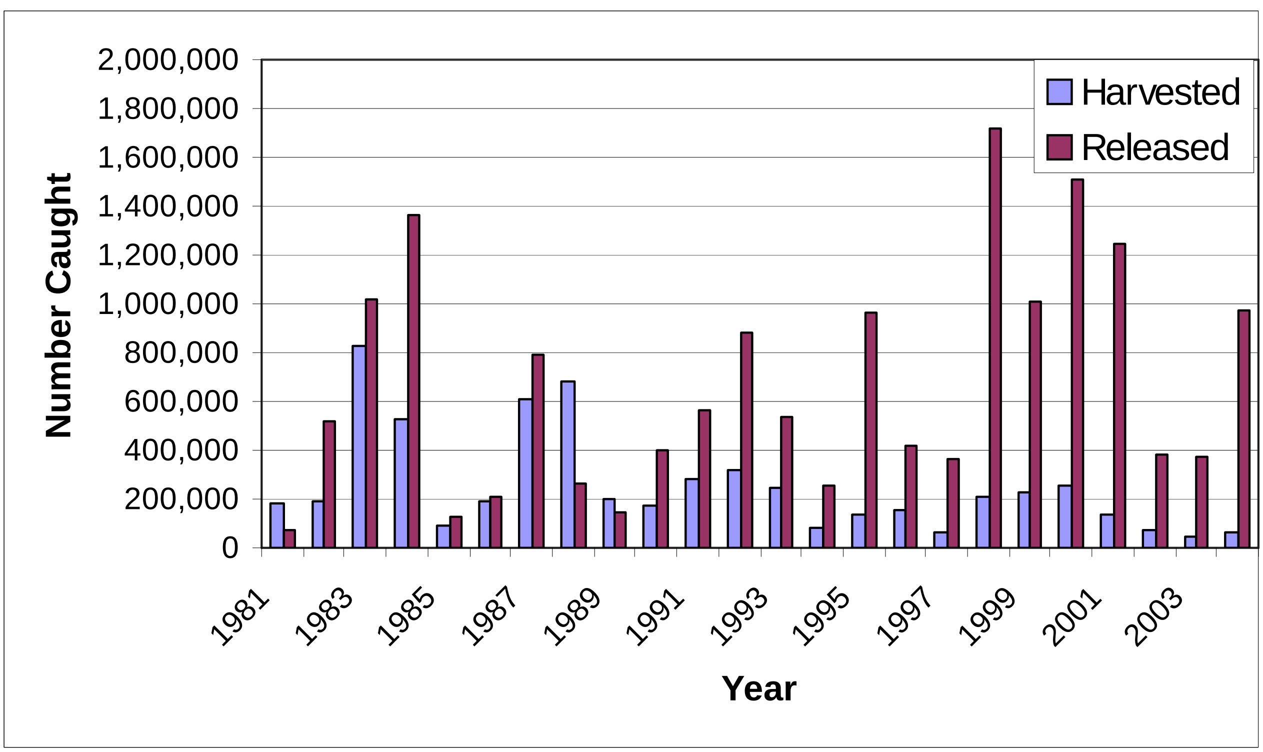


Figure 8. Bluefish length frequency distributions from pound nets, 2003-2005.

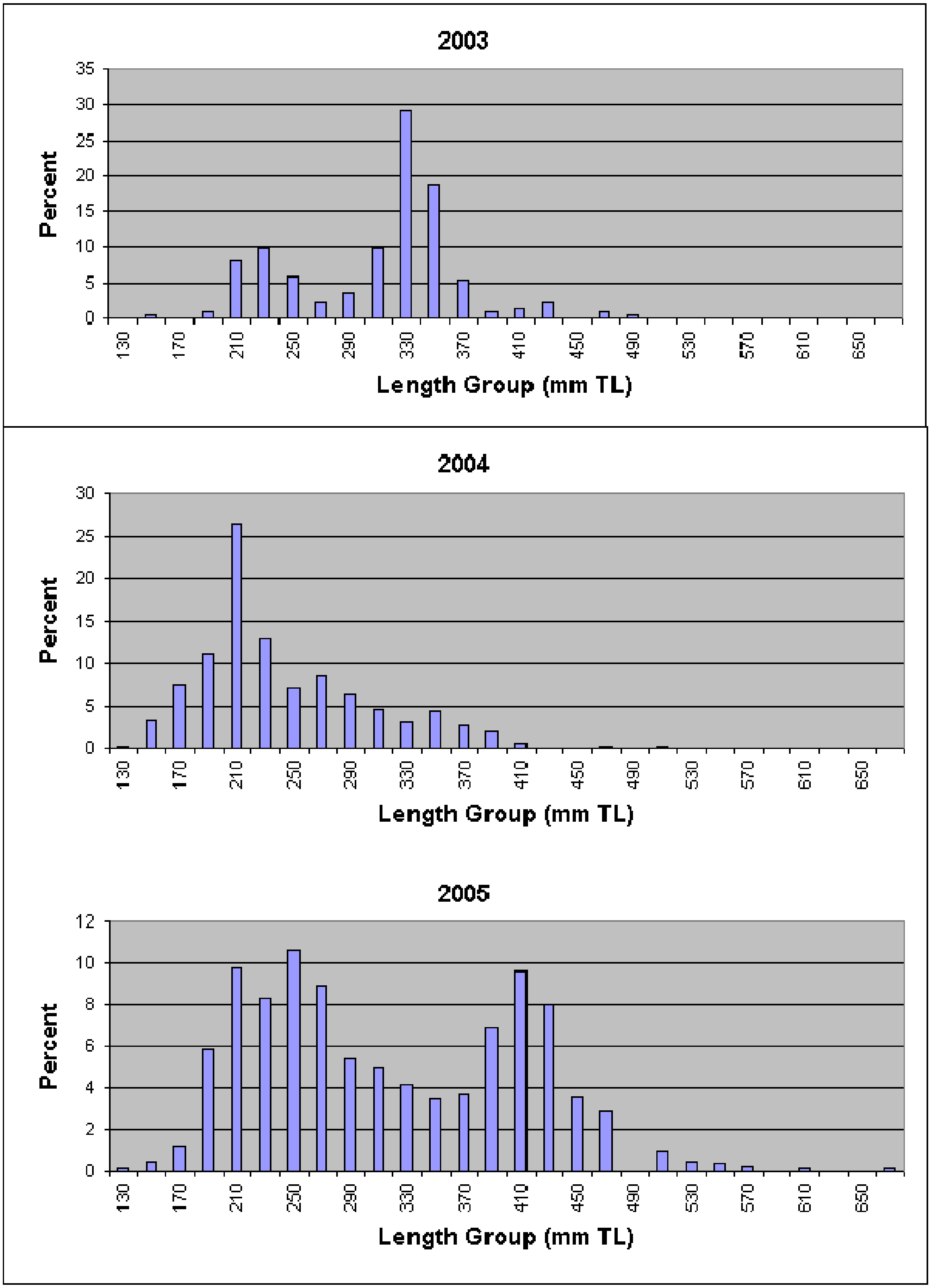


Figure 9. Maryland commercial bluefish landings from 1929-2004.

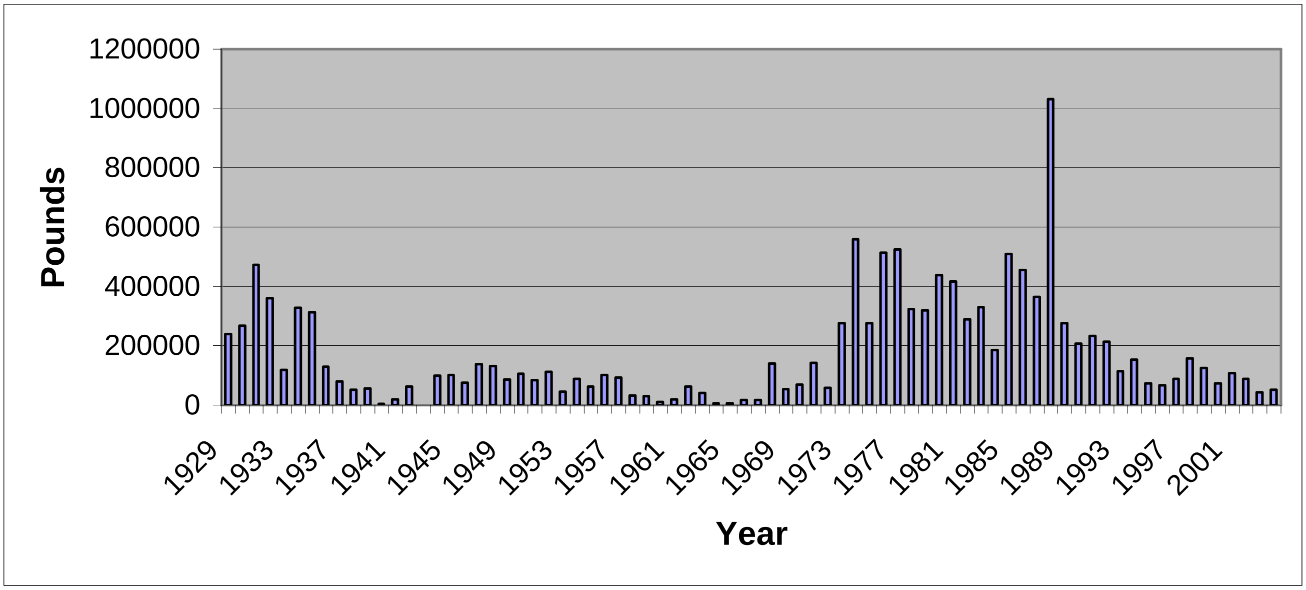


Figure 10. Estimated Maryland recreational bluefish harvest and releases for 1981-2004 (Source: MRFSS, 2005).

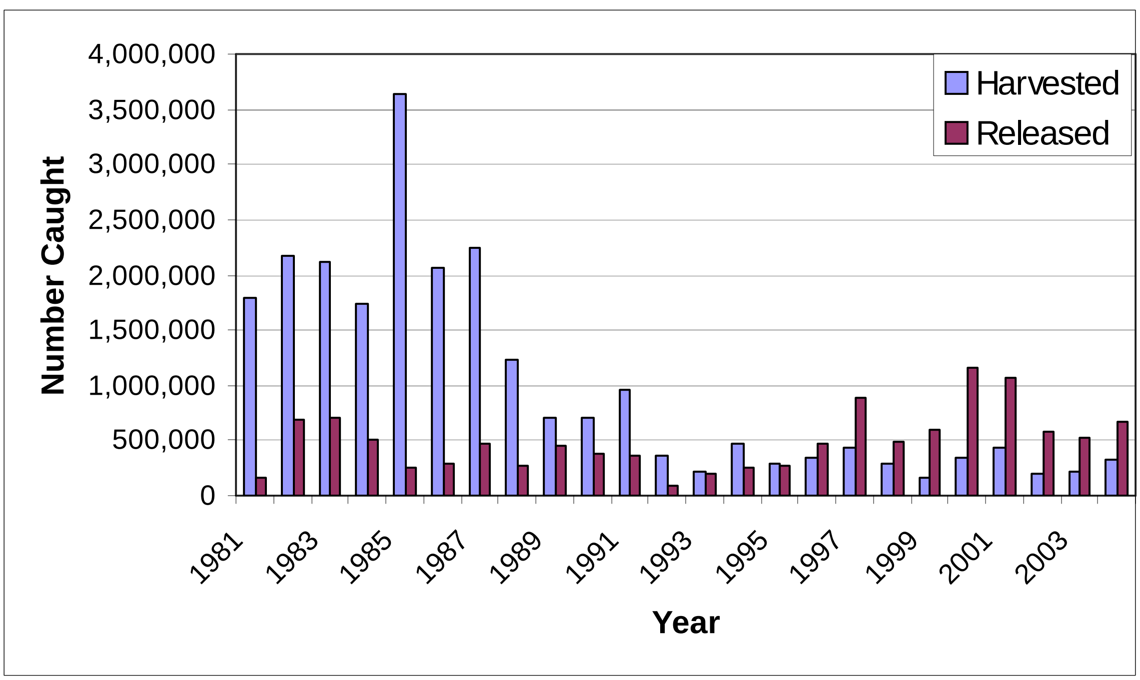


Figure 11. Atlantic croaker length frequency distributions from pound nets, 2003-2005.

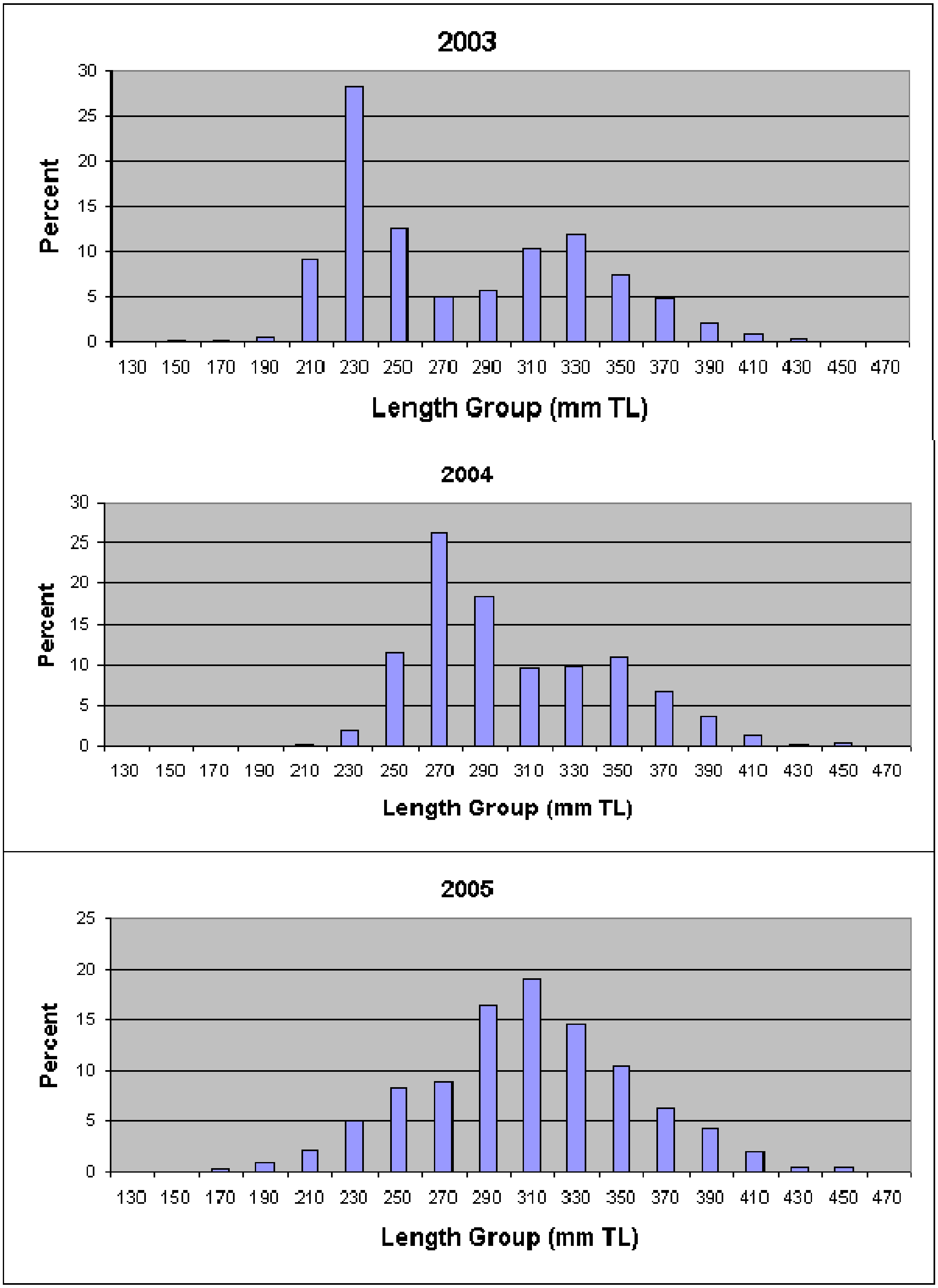


Figure 12. Maryland commercial Atlantic croaker landings from 1929-2004.

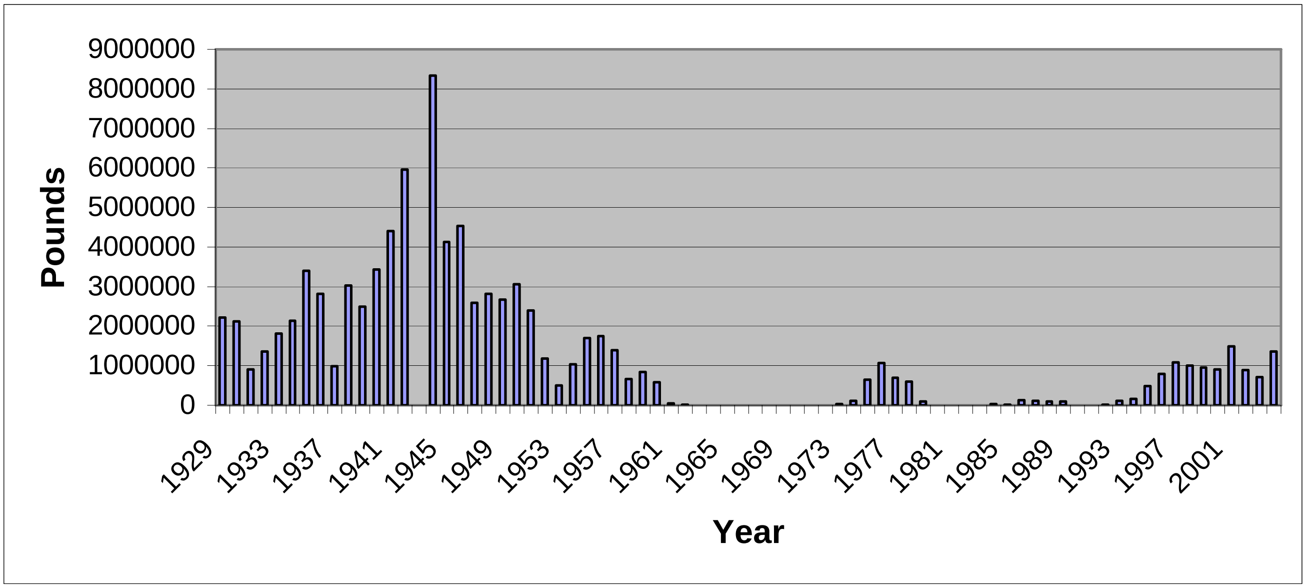


Figure 13. Estimated Maryland recreational Atlantic croaker harvest and releases for 1981-2004 (Source: MRFSS, 2005).

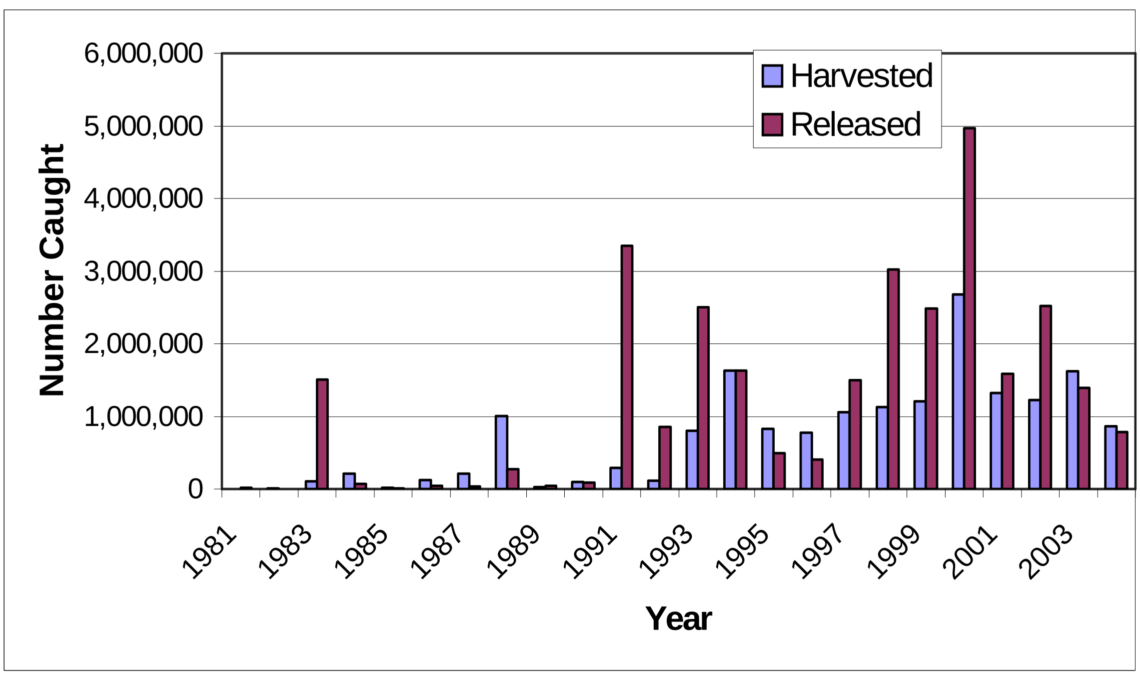


Figure 14. Spot length frequency distributions from pound nets, 2003-2005.

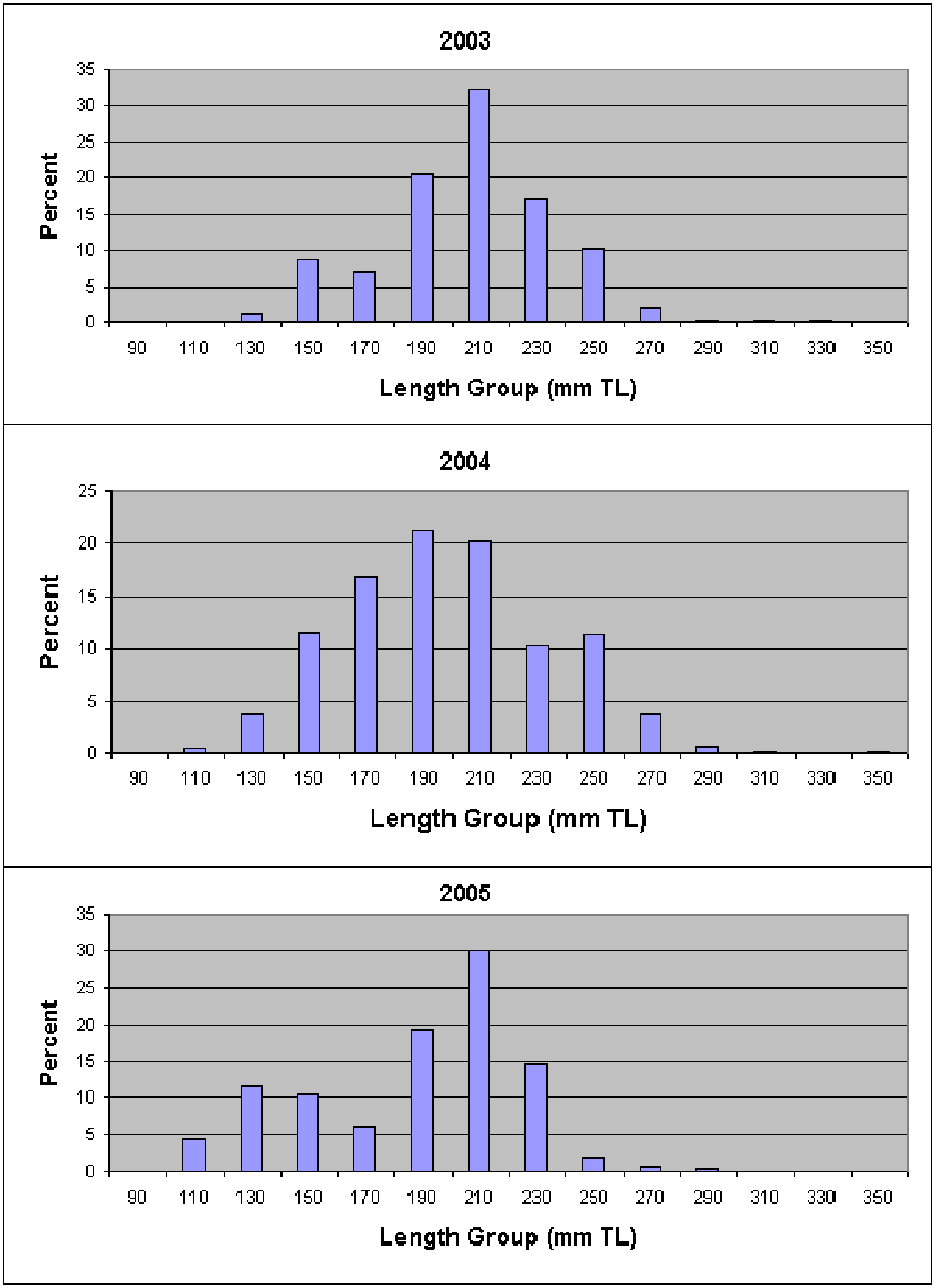


Figure 15. Maryland commercial spot landings from 1929-2004.

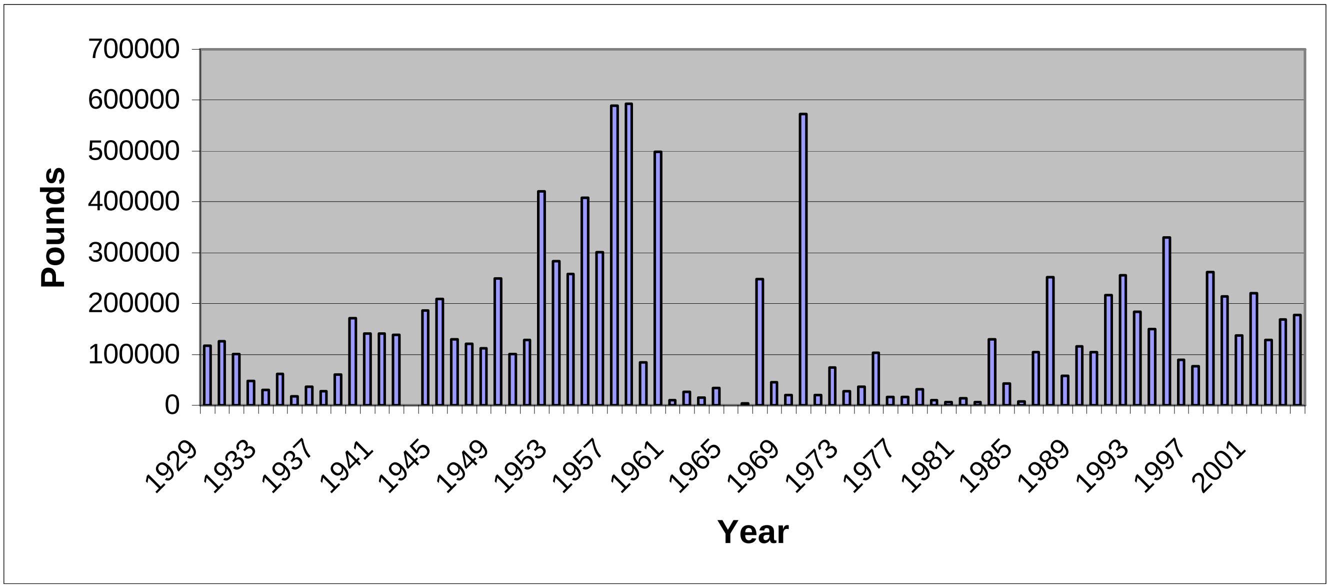


Figure 16. Estimated Maryland recreational spot harvest and releases for 1981-2004 (Source: MRFSS, 2005).

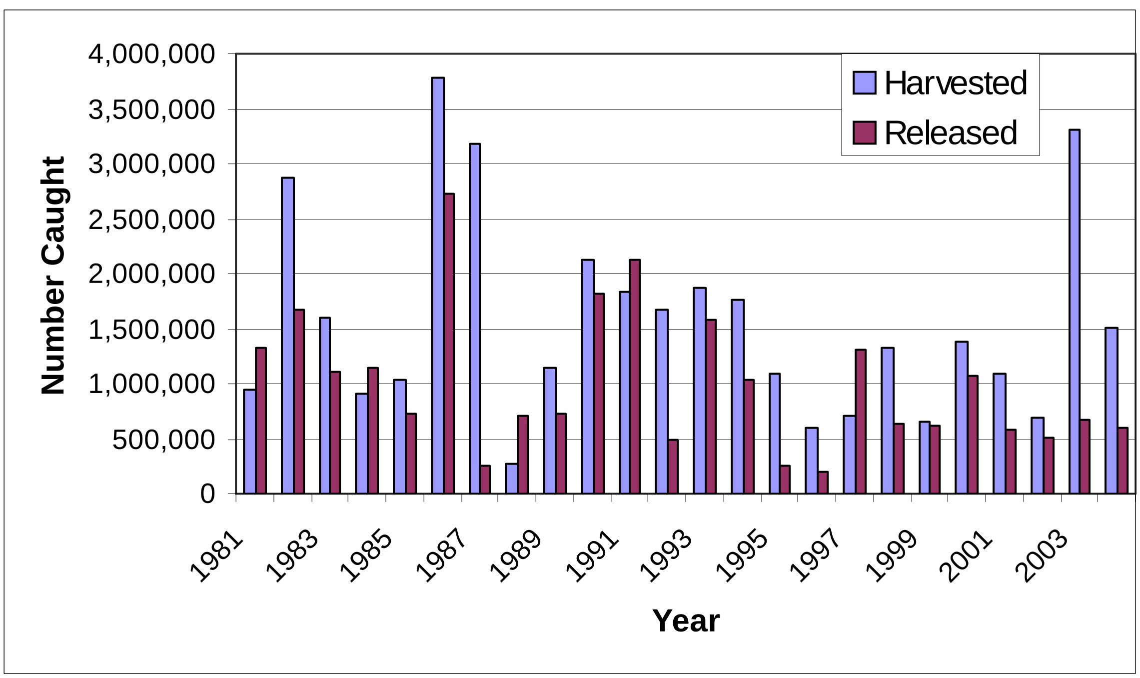


Figure 17. Maryland commercial red drum landings from 1958-2004.

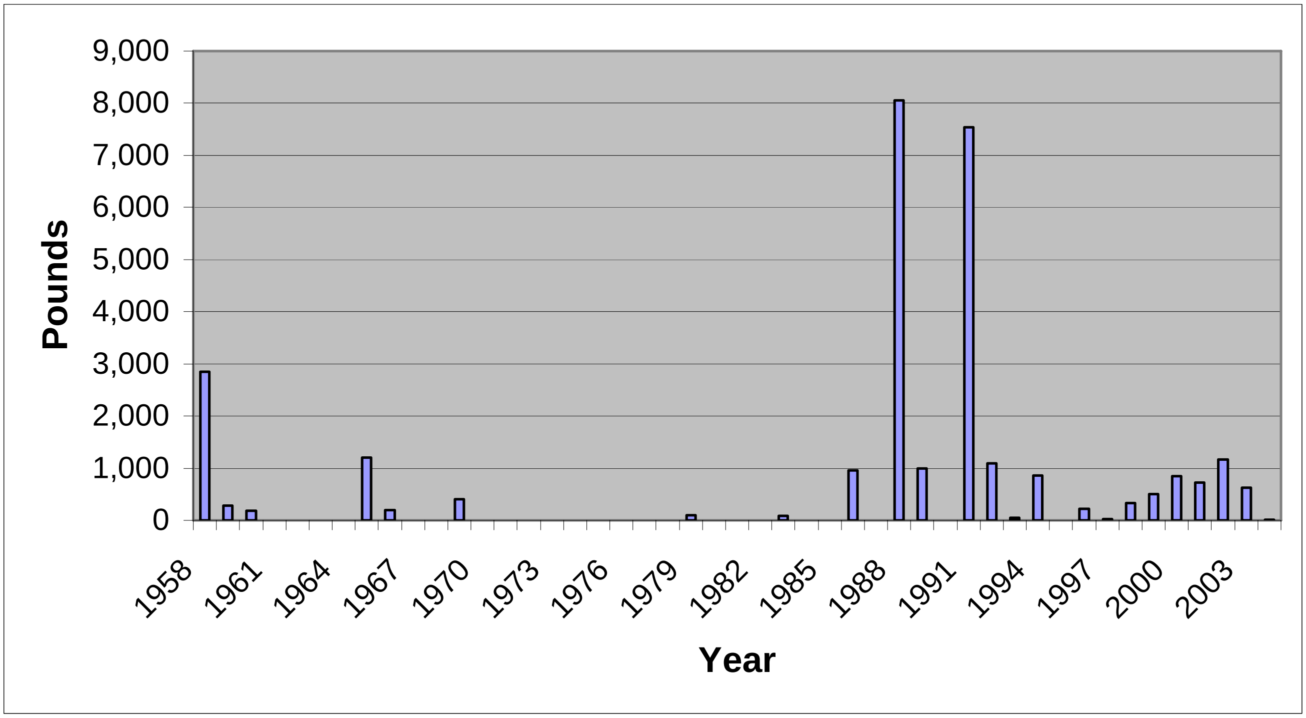


Figure 18. Estimated Maryland recreational red drum harvest and releases for 1981-2004 (Source: MRFSS, 2005).

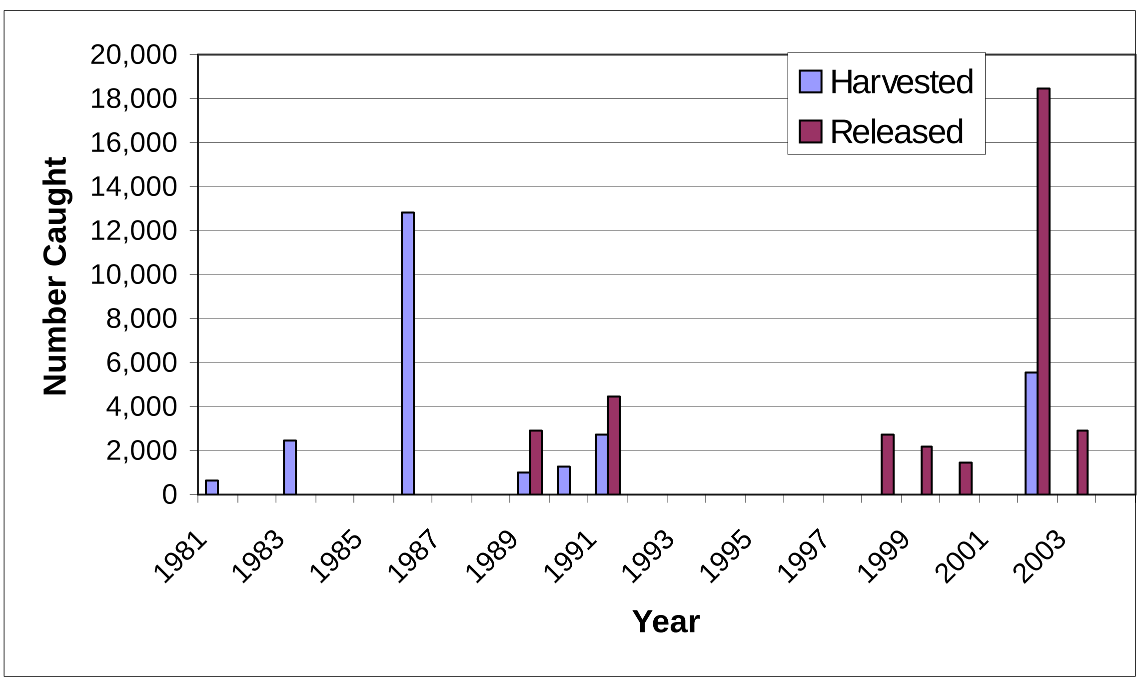


Figure 19. Maryland commercial black drum landings from 1929-2004.

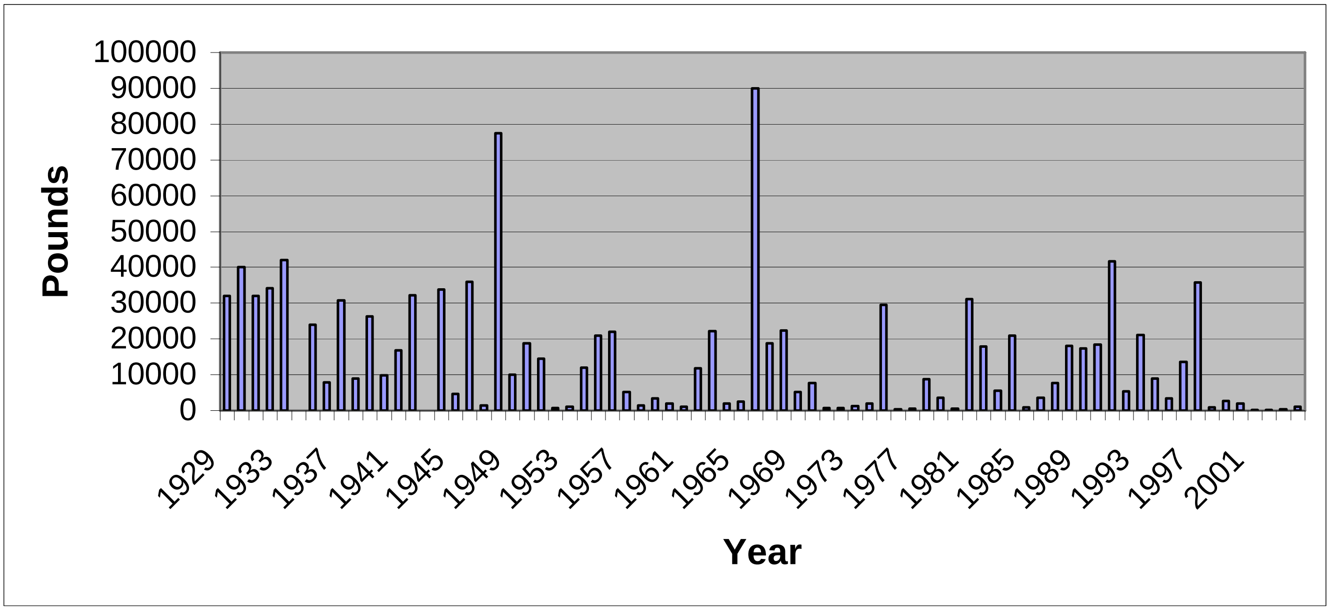


Figure 20. Estimated Maryland recreational black drum harvest and releases for 1981-2004 (Source: MRFSS, 2005).

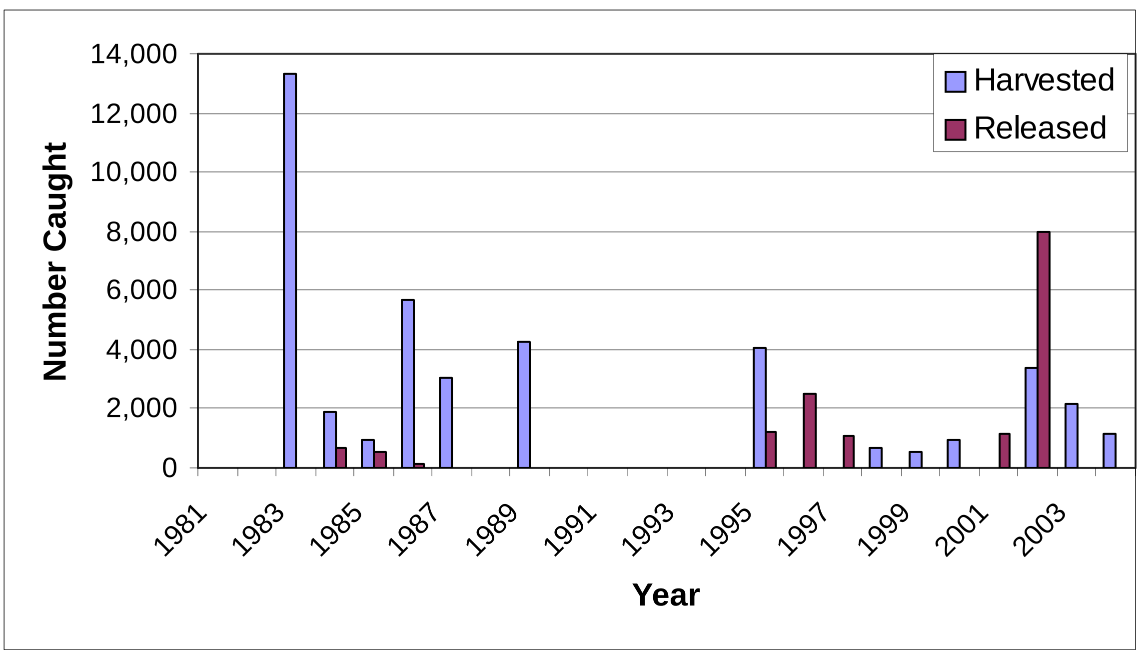


Figure 21. Maryland commercial Spanish mackerel landings from 1965-2004.

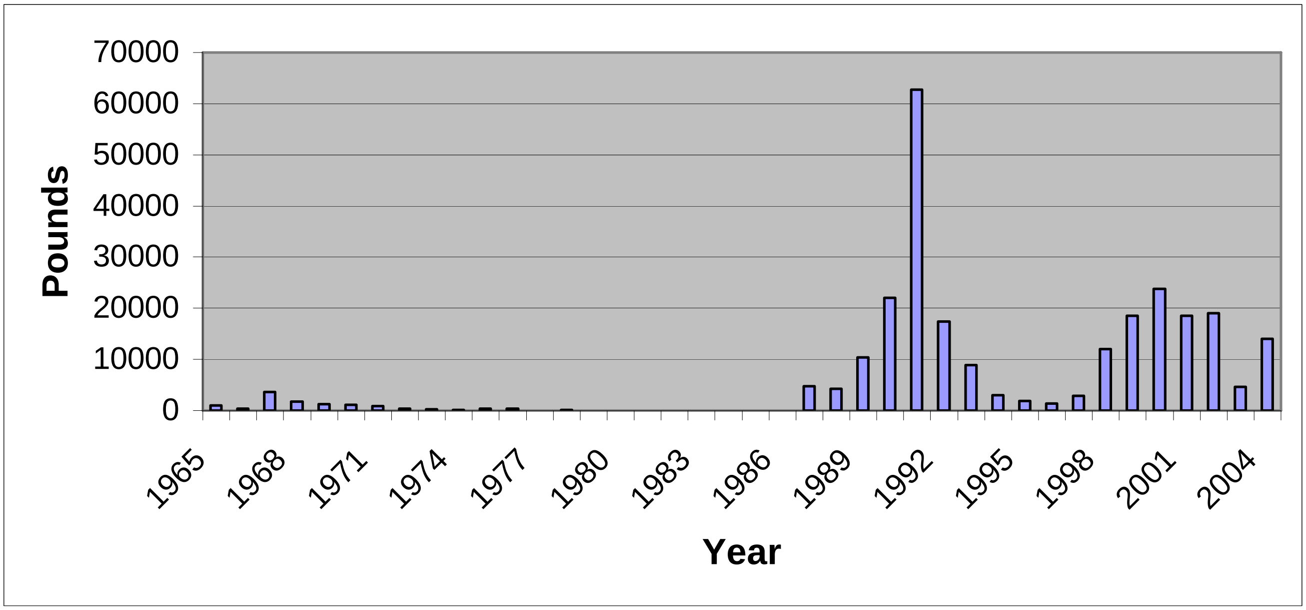


Figure 22. Estimated Maryland recreational Spanish mackerel harvest and releases for 1981-2004 (Source: MRFSS, 2005).

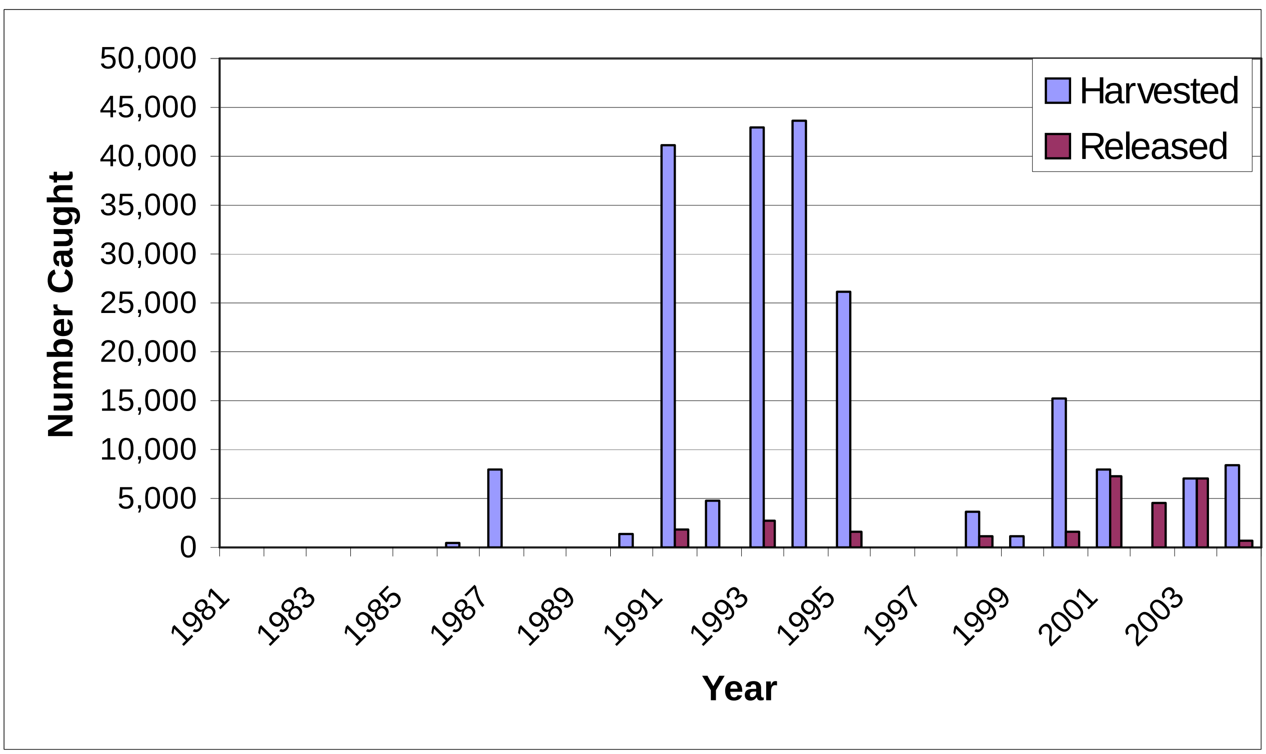


Figure 23. Maryland commercial spotted seatrout landings from 1944-2004.

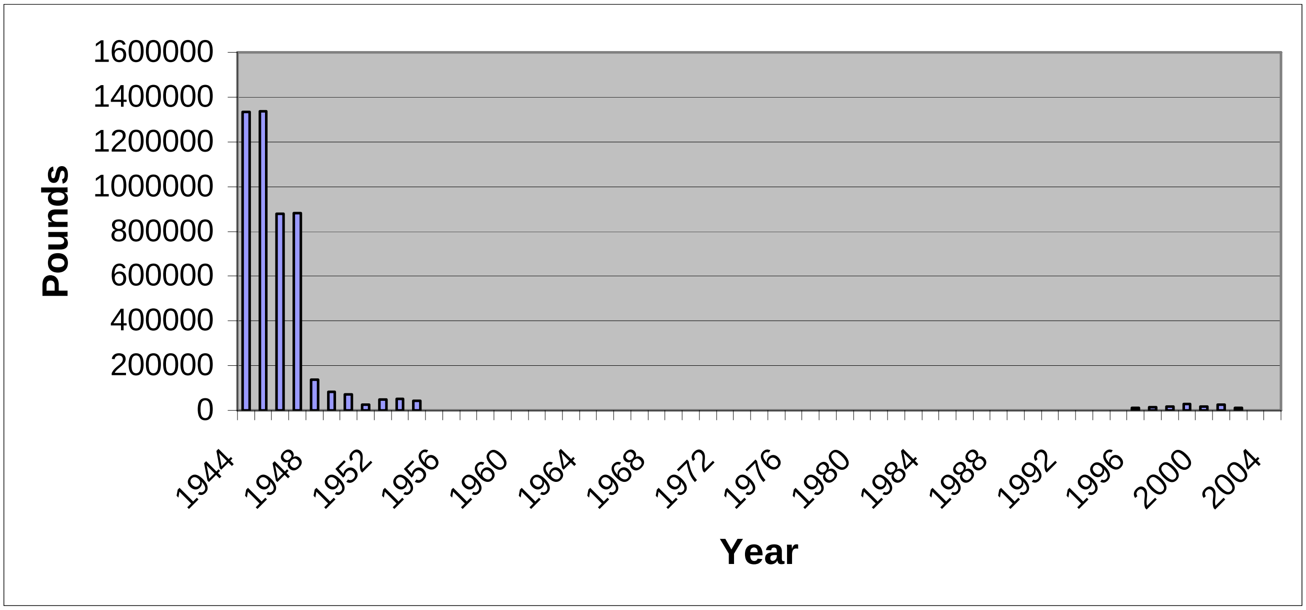
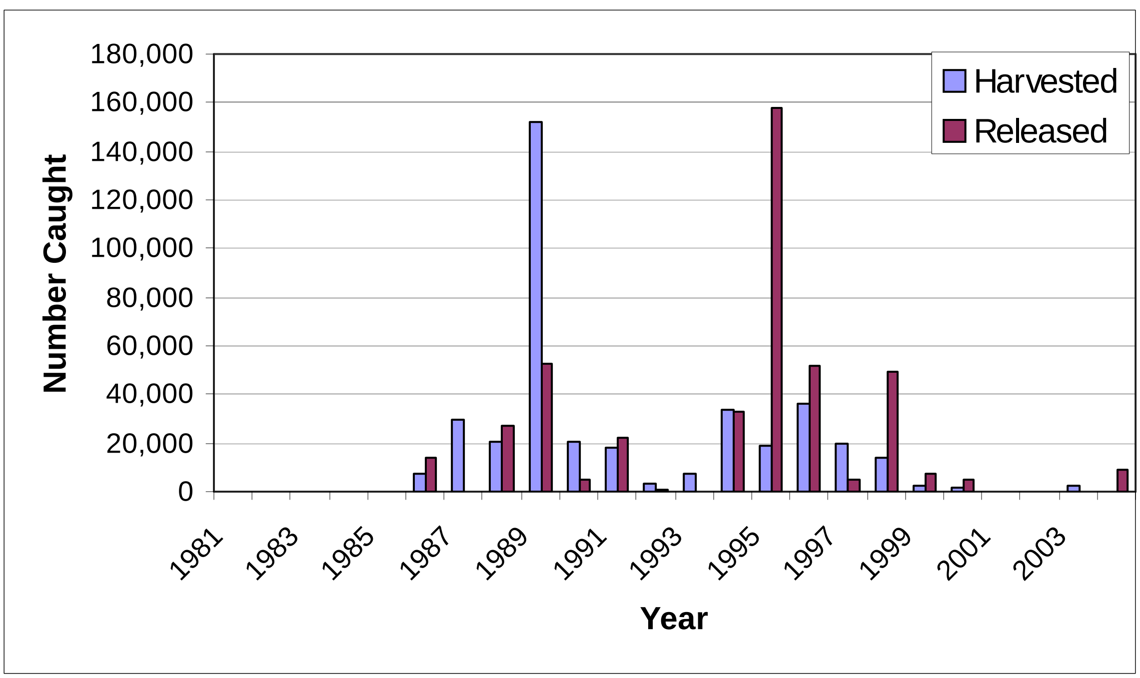


Figure 24. Estimated Maryland recreational spotted seatrout harvest and releases for 1981-2004 (Source: MRFSS, 2005).



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 2004 Maryland striped bass (Morone saxatilis) pound net and commercial hook-and-line harvest. The 2004 pound net season ran from 6 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 striped bass coastal stock assessment. Length and age distributions constructed from the 2004 commercial fisheries seasons were used to characterize the length and age structure of the entire 2004 Chesapeake Bay commercial harvest and the majority of the recreational harvest (Fegley 2001).

METHODS

Commercial pound net monitoring

Since 1993, commercial pound net monitoring has 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). Both pound net monitoring and the tagging study were restricted to legal-size striped bass (total length (TL) $\geq$ 457 mm TL or 18 inches TL) until 2000. 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.

From 1993-1999 it was assumed that the size and age structure of tagged striped bass 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. This allowed for the direct comparison of the length distribution of striped bass sampled from pound nets during tagging to the length distribution of check station-sampled striped bass.

Pound net monitoring (tagging)

Pound net sampling occurred during five rounds from May through October 2004 (Table 1). Each round was 10 to 11 days long. Maryland waters of the Chesapeake Bay were subdivided into 3 regions; the Upper Bay (Susquehanna Flats south to the Bay Bridge), the Middle Bay (Bay Bridge south to a line stretching between Cove Point and Swan Harbor), and the Lower Bay (Cove Point/Swan Harbor south to the Virginia line (see Project 2 Job 3 Task 4, Figure 1). For each round, an optimum number of fish to be sampled was determined for each Bay region (see Project 2 Job 3 Task 4). The pound nets sampled were not randomly selected, but were chosen according to watermen's schedules and the best chance of attaining the target sample size for the tagging study.

During 2004, striped bass were sampled from pound nets in the 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.

At each net sampled, 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. If the net was fully sampled, all striped bass (including sub-legal fish) were measured for total length (mm TL) and, healthy, legal-size fish (≥457 mm total length) were tagged with USFWS internal anchor streamer tags. If the pound net was partially sampled, legal-size striped bass were targeted for tagging. If striped bass were in poor condition, length measurement and presence and category of external anomalies were noted prior to release. To address questions concerning fish condition in late summer/early fall, a random sub-sample of striped bass was weighed during round 5 (October 18- October 27). In all sample rounds, scales were removed from 3 fish per 10-millimeter length group per area.

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 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 2004 (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 hook-and-line, 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 from all striped bass greater than 650 mm TL were taken from pound net and hook-and-line harvested fish. Scales taken from the pound net tagging survey were combined with check station scales to fill in gaps in the length frequency for fish over 650 mm TL. Fish greater than 700 mm were scanned for CWT tags at hook-and-line and pound net check stations (see Project 2 Job3 Task 6 A).

Analytical Procedures

Scale ages of fish <650 mm TL from the pound net tagging survey were applied to fish sampled at hook-and-line and pound net check stations. Scale ages of fish ≥ 650 mm TL from the check station surveys were applied to fish sampled during the pound net tagging survey to increase the sample size of larger fish. In addition, 10 fish from each length group ≥ 700 mm TL were aged regardless of gear type. 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) testing for 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 tagging length frequency. In stage 2, a random sub-sample of scales was aged which 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 theVartot 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. Also, the age structure of the harvest for the 2004 hook-and-line and pound net fisheries was 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 tagging, pound net check station, and hook-and-line check stations samples were examined.

RESULTS and DISCUSSION

Pound net and hook-and-line harvests accounted for 28.4% and 19.9%, respectively, of the Maryland Chesapeake Bay total commercial harvest in 2004. During the 2004 tagging study, striped bass were sampled from 8 pound nets in the middle Bay, and 4 nets in the lower Bay (see Project 2 Job 3 Task 4). Samples could not be obtained from the upper Bay because there are very few fishermen using pound nets in that area. The 12 nets in the lower and middle Bay were sampled a total of 43 times during the study.

In 2004, a total of 256 fish from check stations and tagging surveys were aged. Legal-sized striped bass sampled from the 2004 pound net and hook-and-line fisheries ranged from 3 to 13 years of age. Four-year-old fish from the 2000 year class dominated both pound net and hook-and-line fisheries, comprising 34% and 38% of the harvests respectively in these 2 gears (Table 2.). Age 5 fish contributed 13% and 15% to the pound net and hook-and-line harvests respectively, which, was slightly less than the contribution of five-year-old striped bass in 2003. Age 6 fish from the 1998 year class accounted for 18.0% of both the pound net and hook-and-line harvests. Age four striped bass from the 2000 year class were also important contributors to the tagging study, constituting 46% of legal-sized striped bass sampled.

Mean lengths-at-age of striped bass were slightly larger than in 2003, with the exception of age four fish. (Table 3) Mean weights-at-age of fish sampled in 2004 were greater than in 2003 for all ages except age 7 (Table 4)(MDDNR 2003). Historically, the pound net fishery has relied heavily on 4, 5 and 6 year-old fish (Figures 2 and 3). Since hook-and-line check station sampling began in 1999, four to six year old fish have been the most prevalent year-classes in the hook-and-line harvest (Figure 3).

The contribution of age 3 and 4 fish increased from 2003 in both fisheries while the contribution of age 5 striped bass decreased in both fisheries in 2004. A decrease was also observed in the percentage of 6 year old fish harvested by the pound net fishery in 2004. The contributions of ages 7 and 8 striped bass from the 1997 and 1996 year classes have increased slightly in both fisheries. The contribution of age 9 and older striped bass decreased from 2003 (Figure 3). In 2004, 15% and 23% of the landings for the hook-and-line and pound net fisheries, respectively, were fish age 7 and older.

In 1999, expansion of pound net sampling to include all months from June through November and the inception of concurrent sampling at commercial hook-and-line check stations provided the opportunity for a more thorough characterization of the size and age structure of summer resident striped bass. In general, few large fish (≥650 mm TL) were available to the 2004 hook-and-line and pound net fisheries (Figures 4 and 5). Striped bass over 700 mm TL were harvested in June and November by pound net fishermen. These fish were rarely encountered from

July through October in either fishery. Historically these fish have not been available in large numbers during the summer (MDDNR 2000).

Fish over 700 mm TL accounted for approximately 17% of the fish harvested by pound net fishermen in both June and November (Figure 6). Fish greater than 700 mm accounted for nearly 7% of the total pound net harvest in 2004, a 5% increase from 2003.

In 2004, striped bass over 700 mm TL accounted for only 1% of the total hook-and-line harvest, consistent with the 2003 value of 0.8%. The numbers of larger fish encountered by hook-and-line fisherman in October and November were slightly fewer than in 2003 (MDDNR 2003).

In 2004 striped bass under 550 mm TL were harvested almost equally in both fisheries (Figure 5) unlike previous years (MDDNR 2002,2003). This year, older fish were scarce through the summer and smaller fish, especially the 2000 year class were more abundant, leaving smaller fish to fill individual pound net quotas.

Length frequencies of fish sampled during the tagging study were very similar to fish sampled from the hook-and-line fishery (Figure 7). Smaller fish were encountered slightly more frequently during the pound net tagging and hook-and-line check station monitoring than during pound net check station monitoring.

Bay-wide, the average length 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. Duncan's multiple range test showed a significant difference between mean length at age for 2003 and 2004 age 7 striped bass, while all other ages were not significantly different from 2003.

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LIST OF TABLES

LIST OF FIGURES

Table 1. Summary of sampling areas, sampling dates, surface temperature, surface salinity and numbers of fish encountered during the 2004 Maryland Chesapeake Bay commercial pound net tagging survey.

Round Start Date	**Area**	**Number of Nets Sampled**	**Mean Water Temp. (C)**	**Mean Salinity (ppt)**	**Number of Fish Sampled**
1 / 5-11-2004	Upper	---	---	---	---
	Middle	3	21.2	7.8	573
	Lower	2	22.2	9.3	228
2 / 6-23-2004	Upper	---	---	---	---
	Middle	1	23.8	9.3	275
	Lower	2	23.6	11.7	448
3 / 8-2-2004	Upper	---	---	---	---
	Middle	5	25.1	8.2	708
	Lower	2	26.4	13.6	333
4 / 9-21-2004	Upper	---	---	---	---
	Middle	1	21.2	---	649
	Lower	3	22.9	9.7	609
5 / 10-18-2004	Upper	---	---	---	---
	Middle	2	16.8	9.7	1688
	Lower	4	17.0	---	646

Table 2. Estimated catch-at-age of striped bass landed by Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2004.

Age	Year-class	Hook-and-line Landings*		Pound net Landings*	
		Number of fish	Percent of total	Number of fish	Percent of total
3	2001	17143	13.4	24128	11.8
4	2000	48592	38.1	69395	33.9
5	1999	19056	14.9	25965	12.7
6	1998	23390	18.3	36902	18.0
7	1997	15082	11.8	28021	13.7
8	1996	3205	2.5	11792	5.7
9	1995	786	.62	5313	2.5
10	1994	151	.12	1959	1.0
11	1993	76	.06	629	.31
12	1992	49	.04	341	.17
13	1991	11	.01	481	.23
Total Landings (Number of fish)		**127541**		**204926**	

*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 MDDNR check station monitoring surveys.

Table 3. Mean length-at-age (mm TL) of legal-size striped bass (≥457 mm TL/18 in TL) for ages 3-13 sampled from commercial pound net and hook-and-line fisheries in Maryland Chesapeake Bay, June through November 2004. Mean lengths are weighted by the sample n-at-length in each age.

Age	Year-class	N Aged	Weighted Mean Length (mm TL)
3	2001	7	487
4	2000	21	498
5	1999	14	571
6	1998	33	610
7	1997	41	673
8	1996	32	748
9	1995	34	796
10	1994	18	824
11	1993	9	840
12	1992	5	875
13	1991	4	868

Table 4. 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 2004.

Age	Year-class	Number Of Fish Sampled For Length and Weight	Mean Weight (kg)*
3	2001	364	1.06
4	2000	1037	1.08
5	1999	402	1.30
6	1998	514	1.71
7	1997	349	1.89
8	1996	98	2.80
9	1995	34	4.03
10	1994	10	5.65
11	1993	4	5.89
12	1992	2	7.36
13	1991	2	7.40

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

Figure 1. Locations of Chesapeake Bay commercial pound net and hook-and-line check stations sampled from June through November 2004.

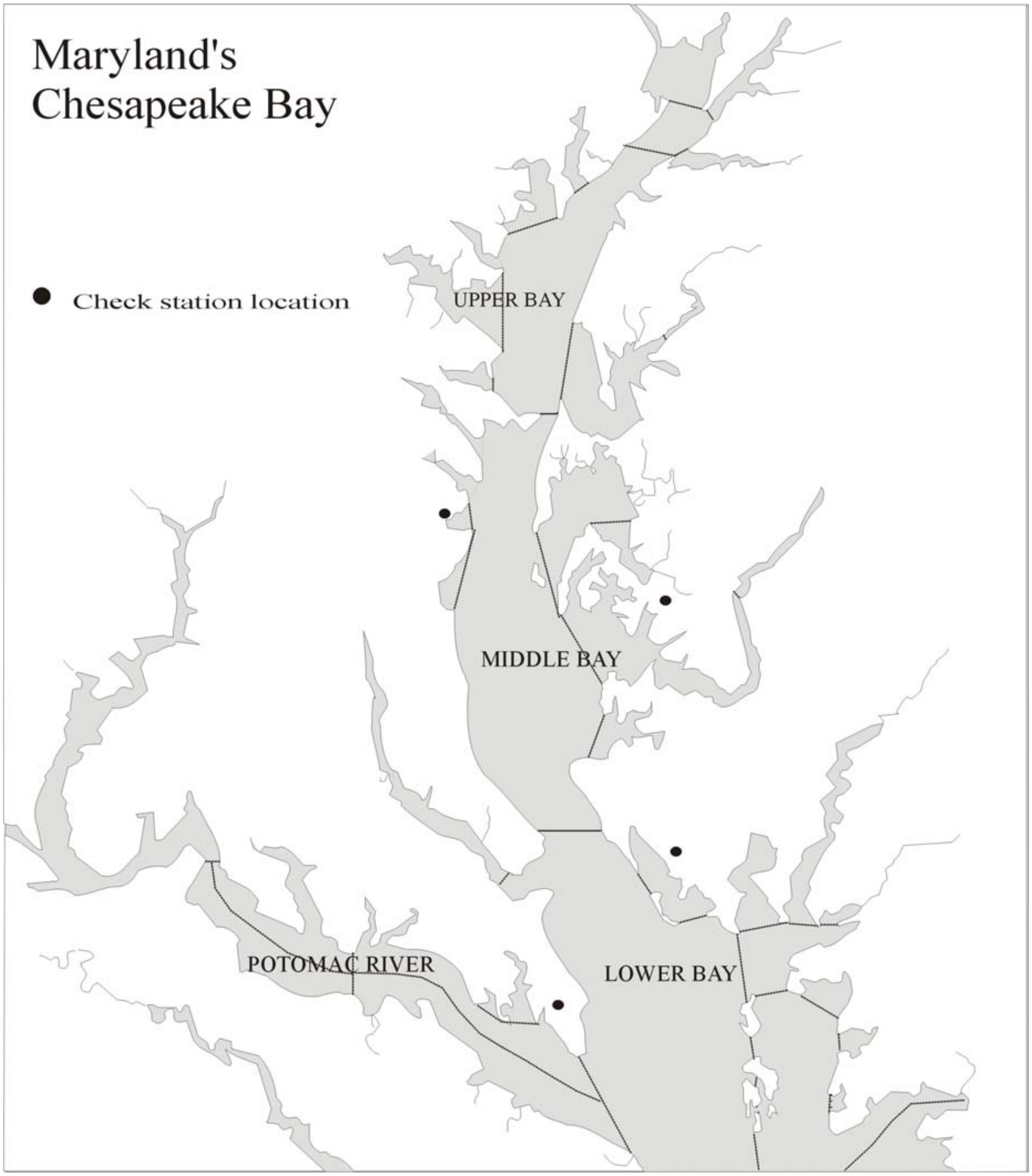


Figure 2. Age structure of striped bass (≥457 mm TL/18 in TL) sampled from Maryland Chesapeake Bay commercial pound net tagging study from 1996 through 2004.

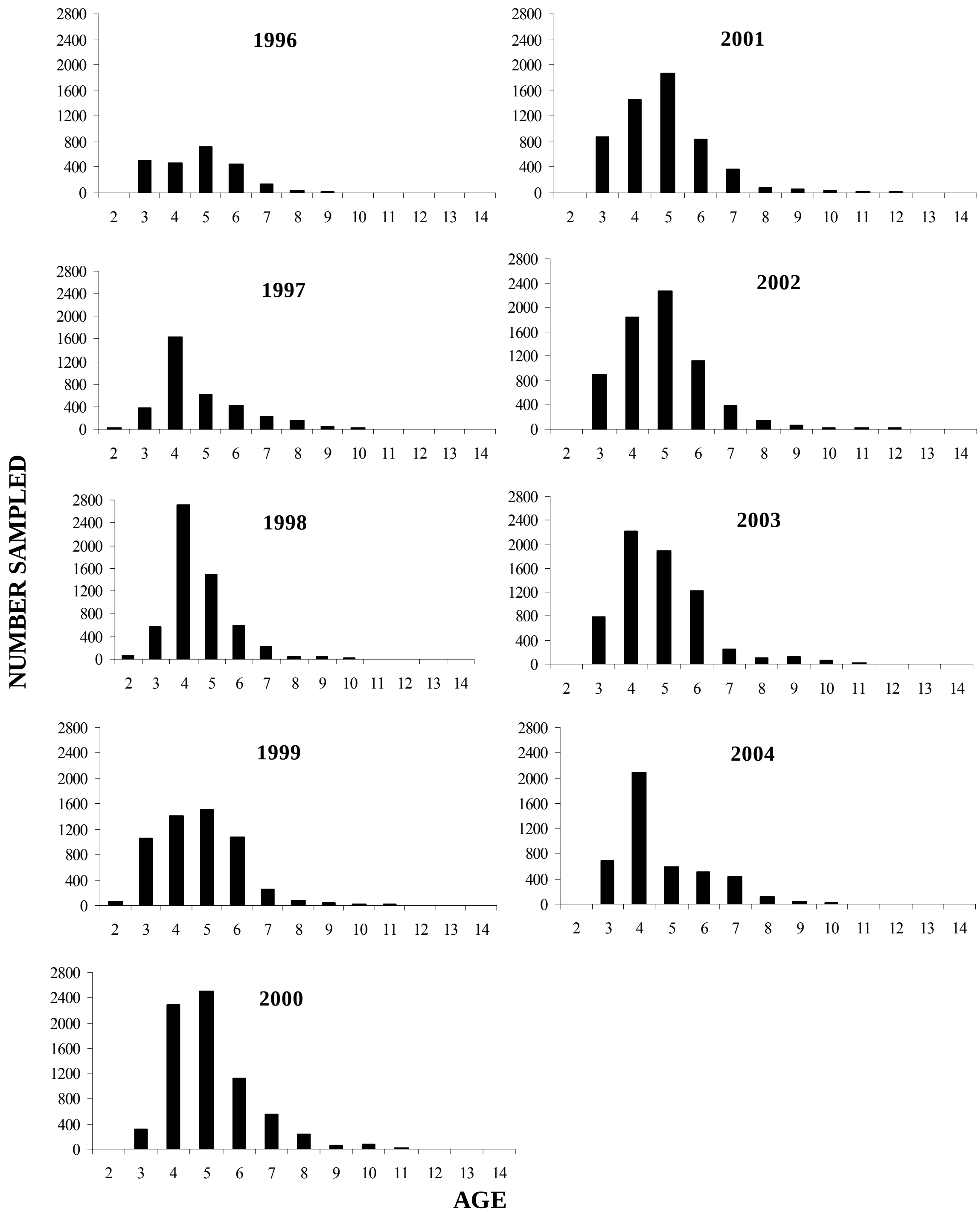


Figure 3. Age structure of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries 1999 through 2004. Note – pound net check station sampling began in 2000.

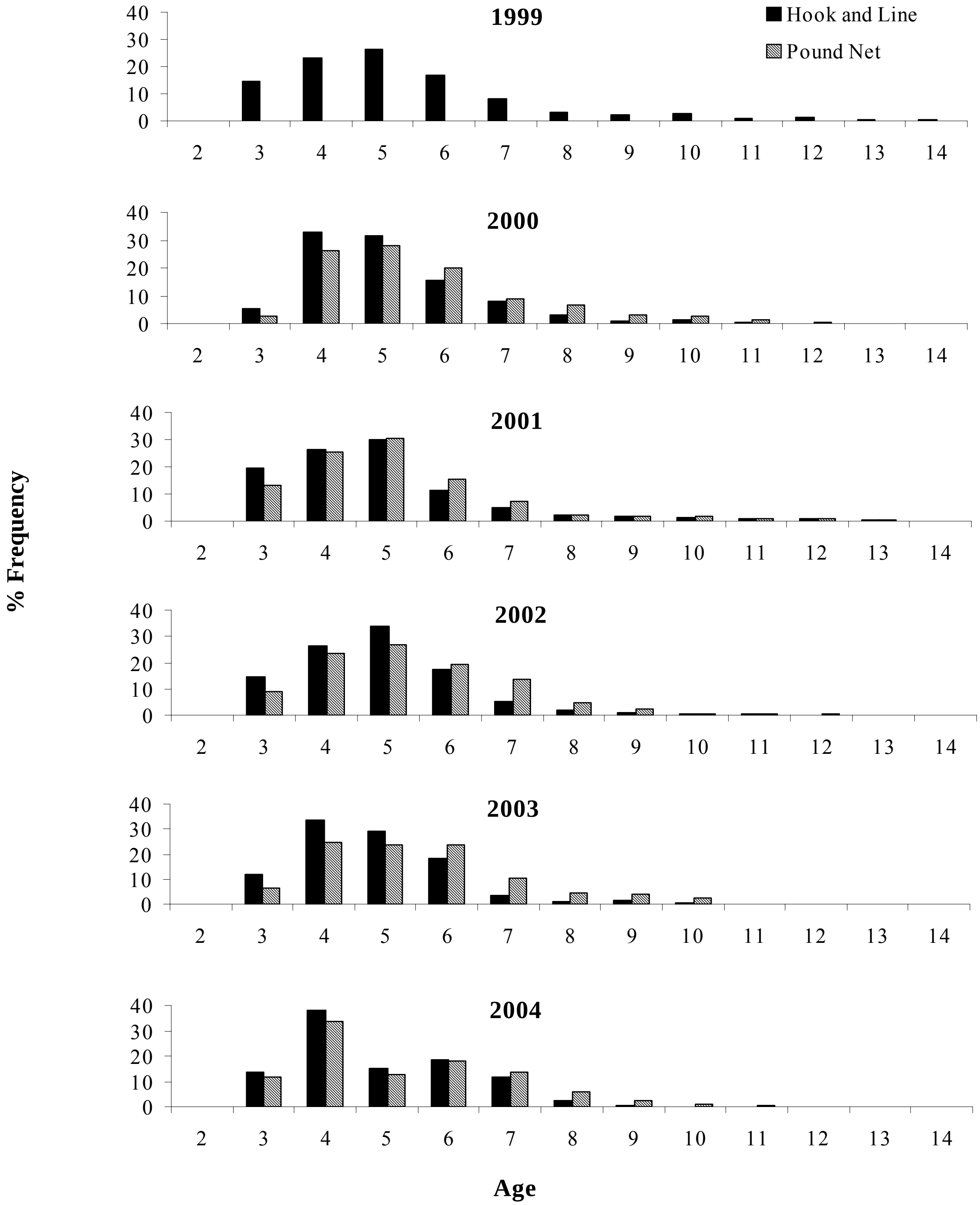
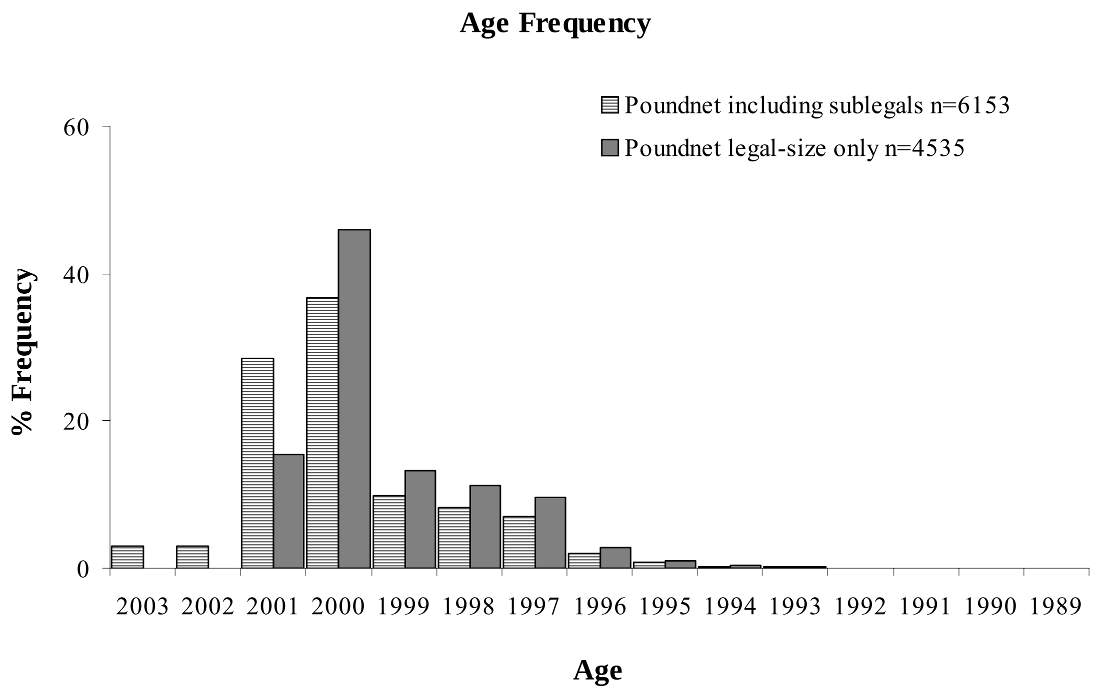


Figure 4. Age and length (mm TL) frequencies of striped bass sampled from Maryland Chesapeake Bay pound net tagging study, May through October 2004.



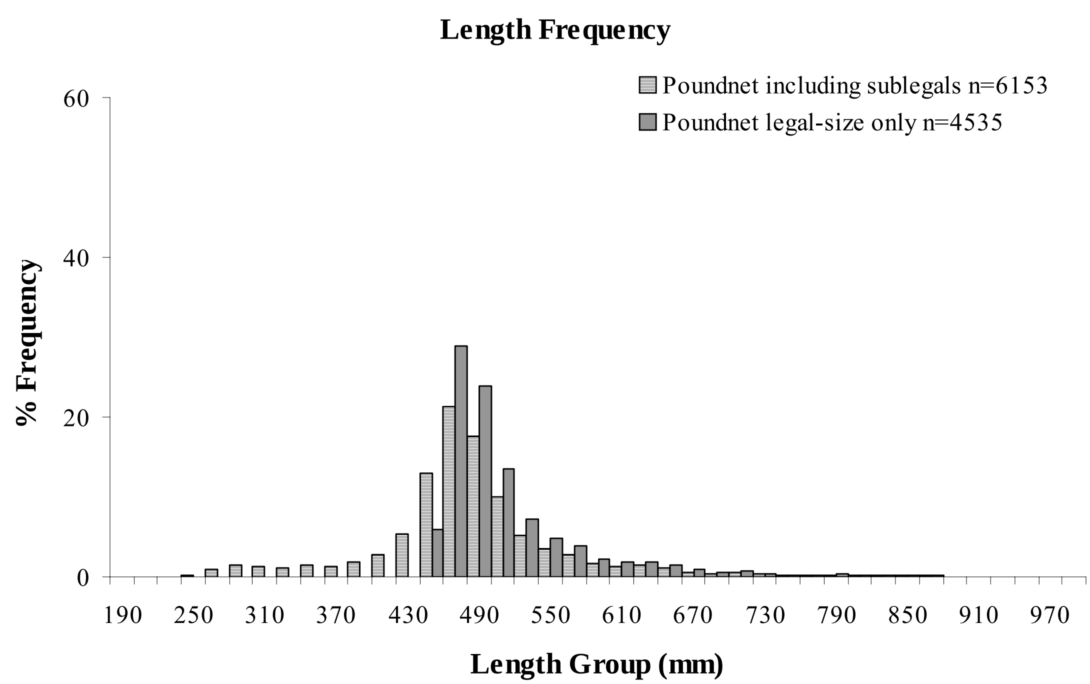
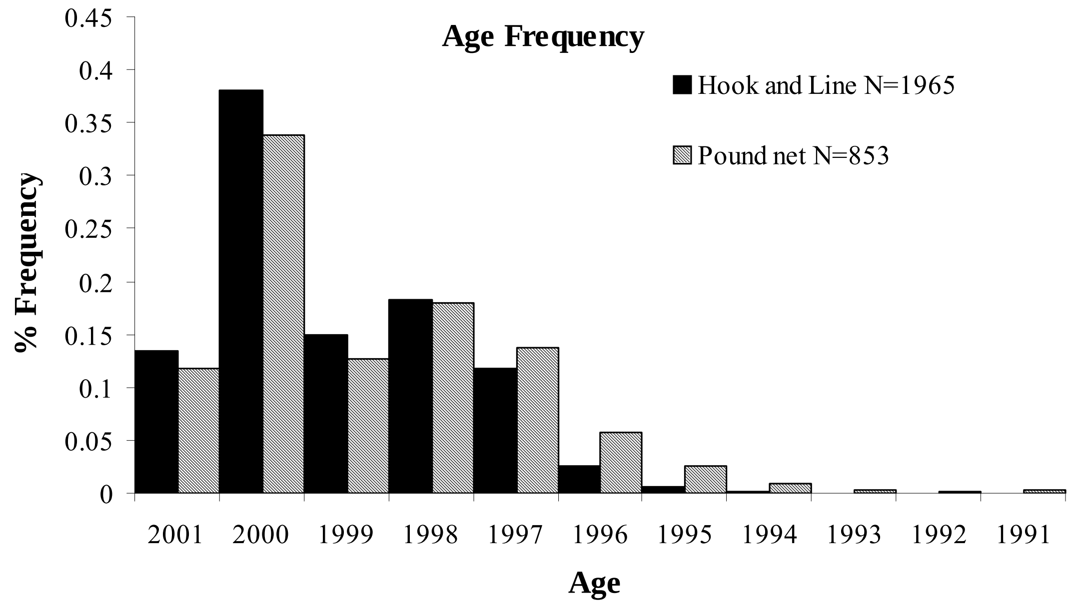


Figure 5. Age and length (mm TL) frequencies of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2004.



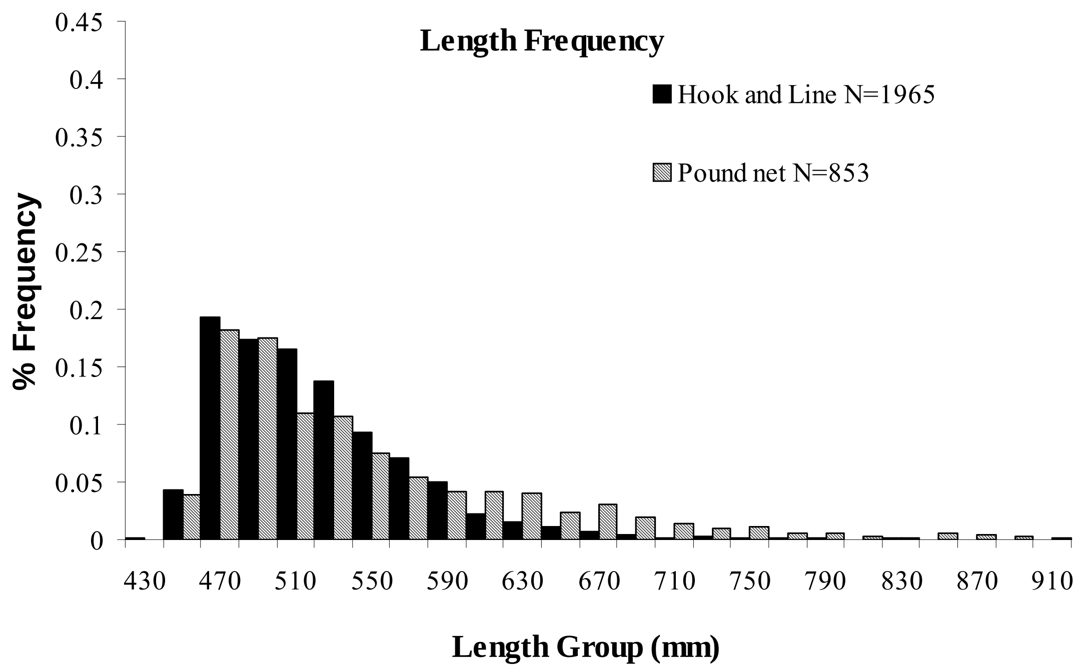


Figure 6. Month-specific length distributions of striped bass sampled from Maryland Chesapeake Bay commercial hook-and-line and pound net fisheries, June through November 2004.

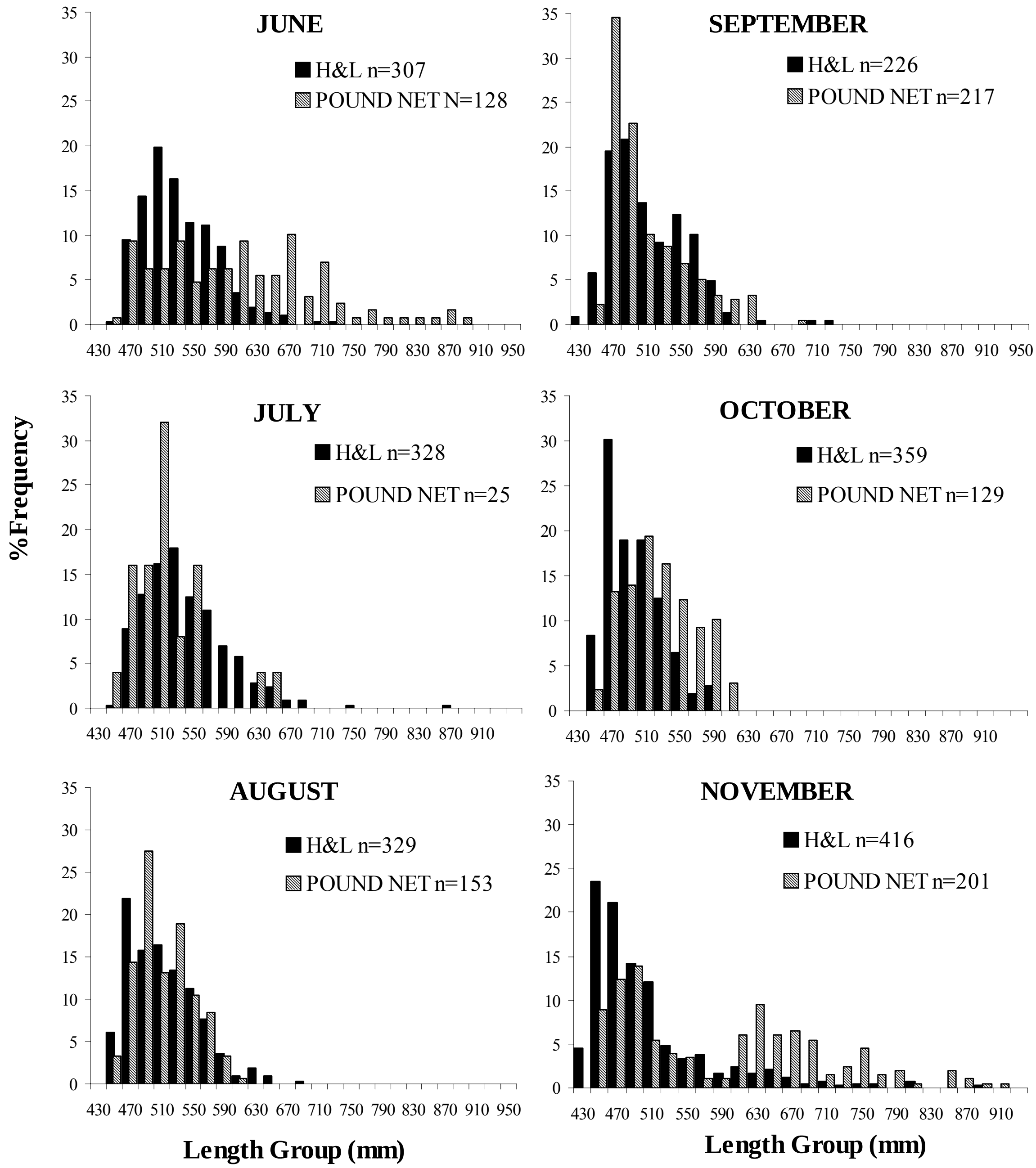


Figure 7. Length frequency of striped bass sampled during the 2004 pound net tagging, pound net check station, and hook-and-line check station surveys. All fish were sampled from May through November 2004. Tagging length frequency is for legal-size fish only (≥457 mm TL/18 in TL).

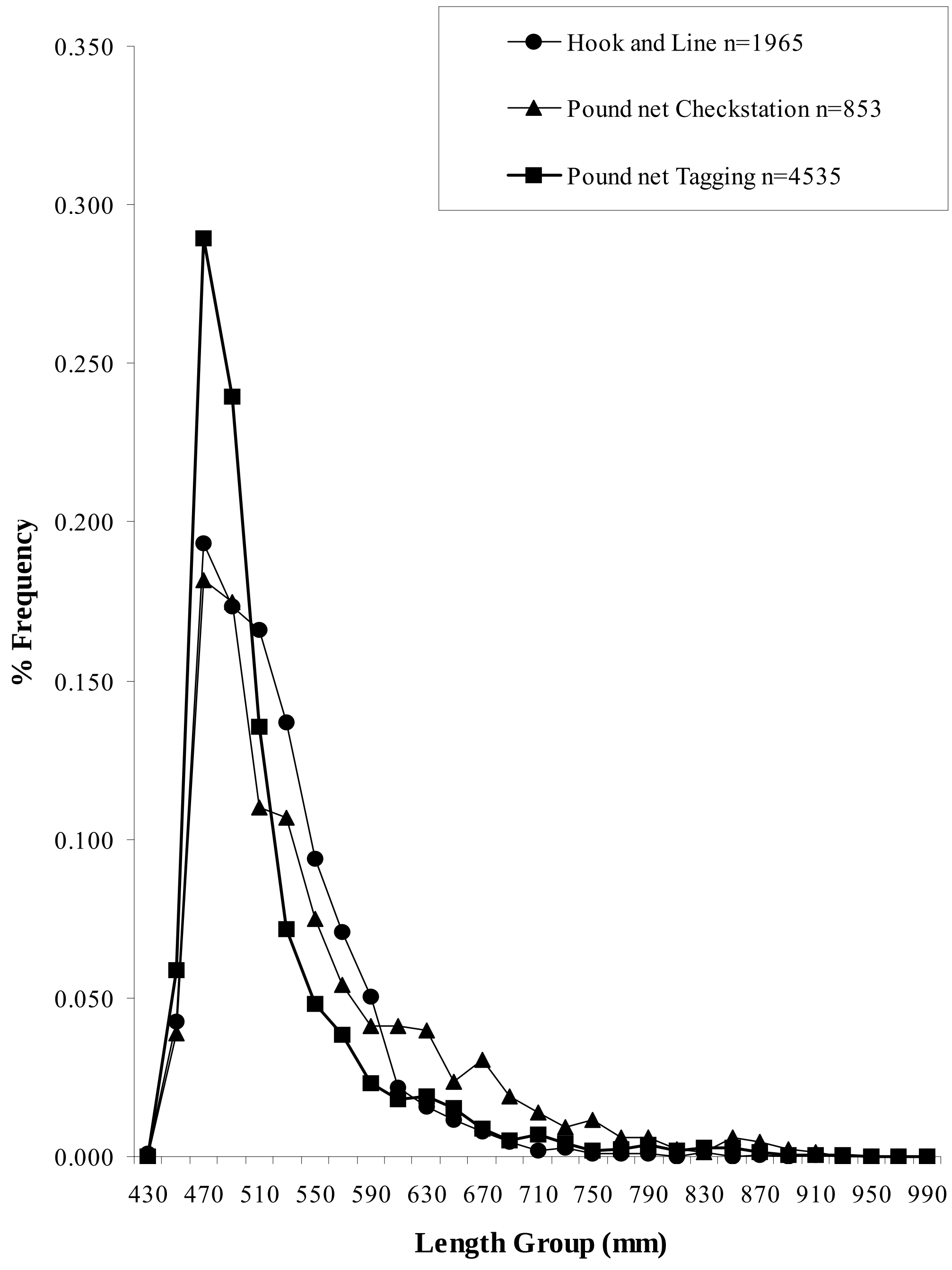
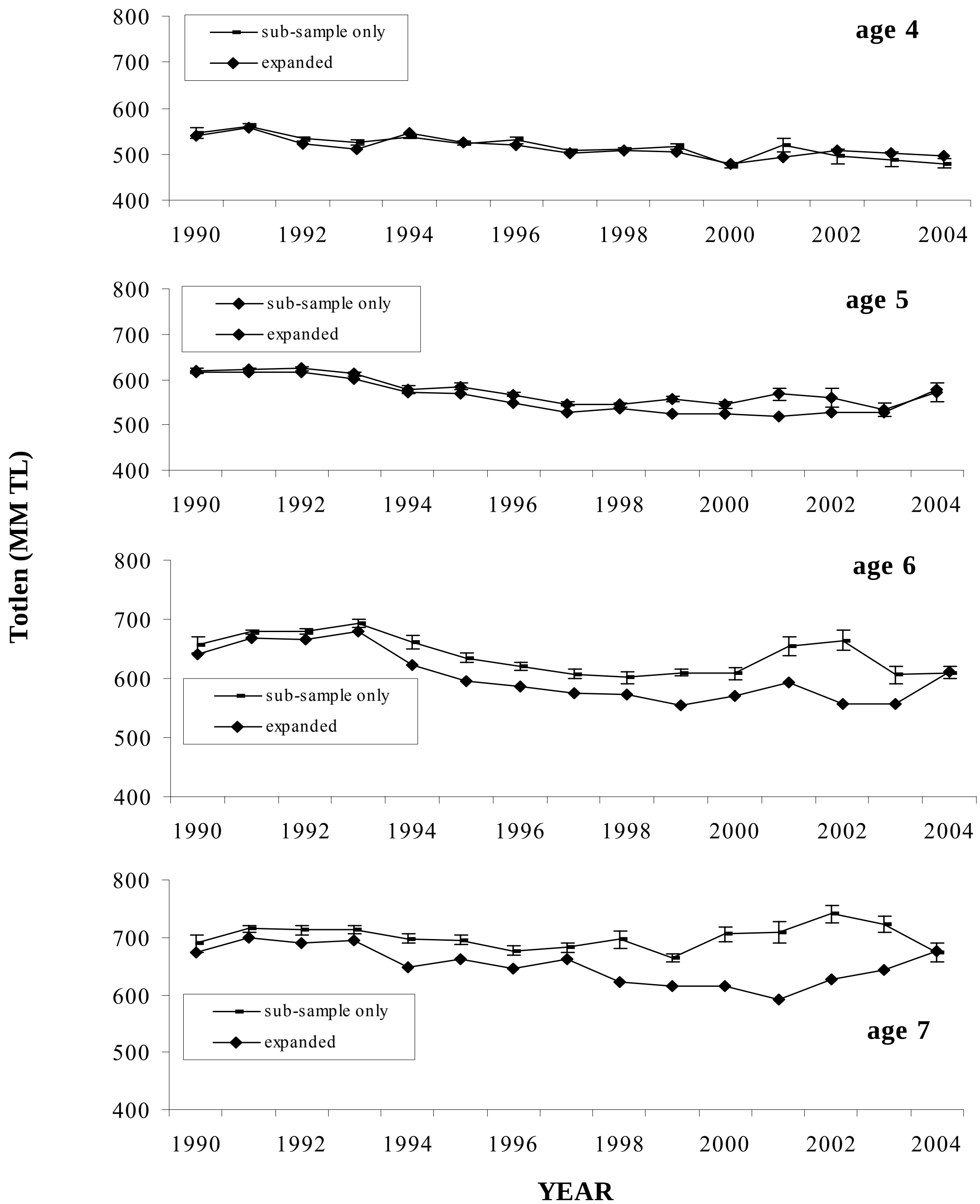


Figure 8. Mean lengths for legal-size striped bass (≥457 mm TL) by year for 4, 5, 6, and 7 year-old striped bass sampled from Maryland Chesapeake Bay pound nets 1990 through 2004. Mean lengths were calculated by using sub-sampled ages only and by expanding ages to sample length frequency before calculating 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 and Craig Weedon

INTRODUCTION

The primary objective of Task 1B was to characterize the size and age structures of striped bass sampled from the December 1, 2004-February 28, 2005 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 survey 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 ASMFC coastal striped bass stock assessment.

METHODS

Data collection procedures

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 the previous year's landings, individual check stations which landed 8% or greater of the entire catch were designated high-use. Medium-use stations were those which landed 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. The northern-most check stations sampled in this survey were located in Rock Hall, while the southern-most station was located in Cambridge (Figure 1).

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. If time permitted, more than 300 fish were measured. In cases where fewer than 300 fish were checked in, all striped bass were sampled. Scales were taken randomly from 2 fish per 1 cm 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) with a Northwest Marine Technology detector wand. Protocol dictated that any fish registering positive was purchased for CWT, otolith, and scale extraction.

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 2004-2005 winter gill net harvest was estimated by applying the sample age distribution to the total landings.

Mean lengths and weights at-age were calculated by year class for the 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 this year's harvest (2004-2005) was compared to that of previous years back to the 1994-1995 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.

RESULTS and DISCUSSION

The winter drift gill net commercial fishery accounted for 51.6% of the total Maryland Chesapeake commercial harvest, by weight, during the 2004 calendar year. A total of 3376 striped bass were measured and 139 striped bass were aged from the December, 2004- February, 2005 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 magnitude of individual year-classes in the landings has varied between years (Figure 2). The 2004-2005 commercial drift gill net harvest consisted primarily of striped bass from the 2001 and 2000 (age 4 and 5) year-classes (Table 1, Figure 2). Age 4 and 5 fish composed 84% of the harvest, while 6-11 year-old fish contributed only 16% to the total. There was a decrease of age 7, 8, and 9 striped bass in the 2004-2005 gill net harvest when compared to the 2003-2004 season (Figure 2). There were no fish over 11 years old in the estimated catch-at-age, in contrast to the 2003-2004 season, when 12 and 13 year-old fish were observed (Zlokovitz 2004). The youngest fish observed in the 2004-2005 sampled harvest were age 4. Age 3 fish have not appeared in the sampled harvest since 2003, and have appeared in only 2 out of the last 6 seasons (Figure 2). Age 3 fish have composed less than 7% of the sample in any given year during the period 1994-2005.

The actual 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. Striped bass were recruited into the 2004-2005 winter gill net fishery at age 4 (2001 year-class), with an expanded mean length and weight of 515 mm TL and 1.55 kg, respectively. The 2000 year-class (age 5) was most commonly observed in the sampled landings, composing 50% of the harvest, with an expanded mean length of 504 mm TL, and an average weight of 1.47 kg. The higher expanded mean length and weights-at-age of age 4 fish when compared to age 5 fish may be related to differences in sample size of those two year-classes. The expanded mean length and weight of the oldest fish in the aged sub-sample (age 11, 1994 year-class) were 777 mm TL and 5.50 kg.

The expanded length distributions were dominated by fish in the 470-550 mm TL range (Figure 3). There was a noticeable decrease in the presence of larger (>700 mm TL) striped bass in the 2004-2005 harvest when compared with the 2003-2004 winter gill net season (Zlokovitz 2004).

Mean length-at-age and weight-at-age have been variable, with no clear trends, during the sample years 1994-2005 (sample year = year in which the season ended; e.g. the 2004-2005 gill net season would be sample year 2005) (Figures 4 and 5). Large confidence intervals and low sample sizes of fish age 6 and older make trends difficult to discern.

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 2004-2005 gill net season (See Project 2, Job 3,Task No.6A, this report).

CITATIONS

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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.

Zlokovitz, E. 2004. Winter Stock Assessment and Commercial Fishery Monitoring. In: Investigation of Striped Bass in Chesapeake Bay, USFWS Federal Aid Report, F-42-R-17, 2003-2004, Job No.1B (p 29-38). Maryland DNR, Fisheries Service, 204 pp.

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Table 1. Estimated catch-at-age of striped bass (numbers of fish) landed by the Maryland Chesapeake Bay commercial drift gill net fishery, December 2004- February 2005.

Year-Class	Age	Catch
2001	4	100,622
2000	5	147,298
1999	6	18,908
1998	7	17,016
1997	8	4,412
1996	9	2,640
1995	10	1,345
1994	11	1,009
	Total	**293,250**

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 2004-February 2005.

Year-Class	Age	n fish aged	Mean TL (mm) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean TL (mm)
2001	4	14	503	1158	515
2000	5	26	533	1696	504
1999	6	15	610	218	575
1998	7	17	694	196	551
1997	8	27	763	51	729
1996	9	21	788	30	764
1995	10	11	800	15	780
1994	11	8	793	12	777
Total	**---**	**139**	**----**	**3376**	**----**

Table 3. Mean weights (kg) by year-class of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2004-February 2005.

Year-Class	Age	n fish aged	Mean Weight (kg) of Aged sub-sample	Estimated # at-age in sample	Expanded Mean weight (kg)
2001	4	14	1.39	1158	1.55
2000	5	26	1.74	1696	1.47
1999	6	15	2.73	218	2.16
1998	7	17	3.87	196	2.04
1997	8	27	5.01	51	4.56
1996	9	21	5.44	30	5.06
1995	10	11	5.90	15	5.52
1994	11	8	6.02	12	5.50
Total	**---**	**139**	**----**	**3376**	**----**

Figure 1. Registered Maryland Chesapeake bay check stations sampled for commercial drift gill net-harvested striped bass, December 2004-February 2005.

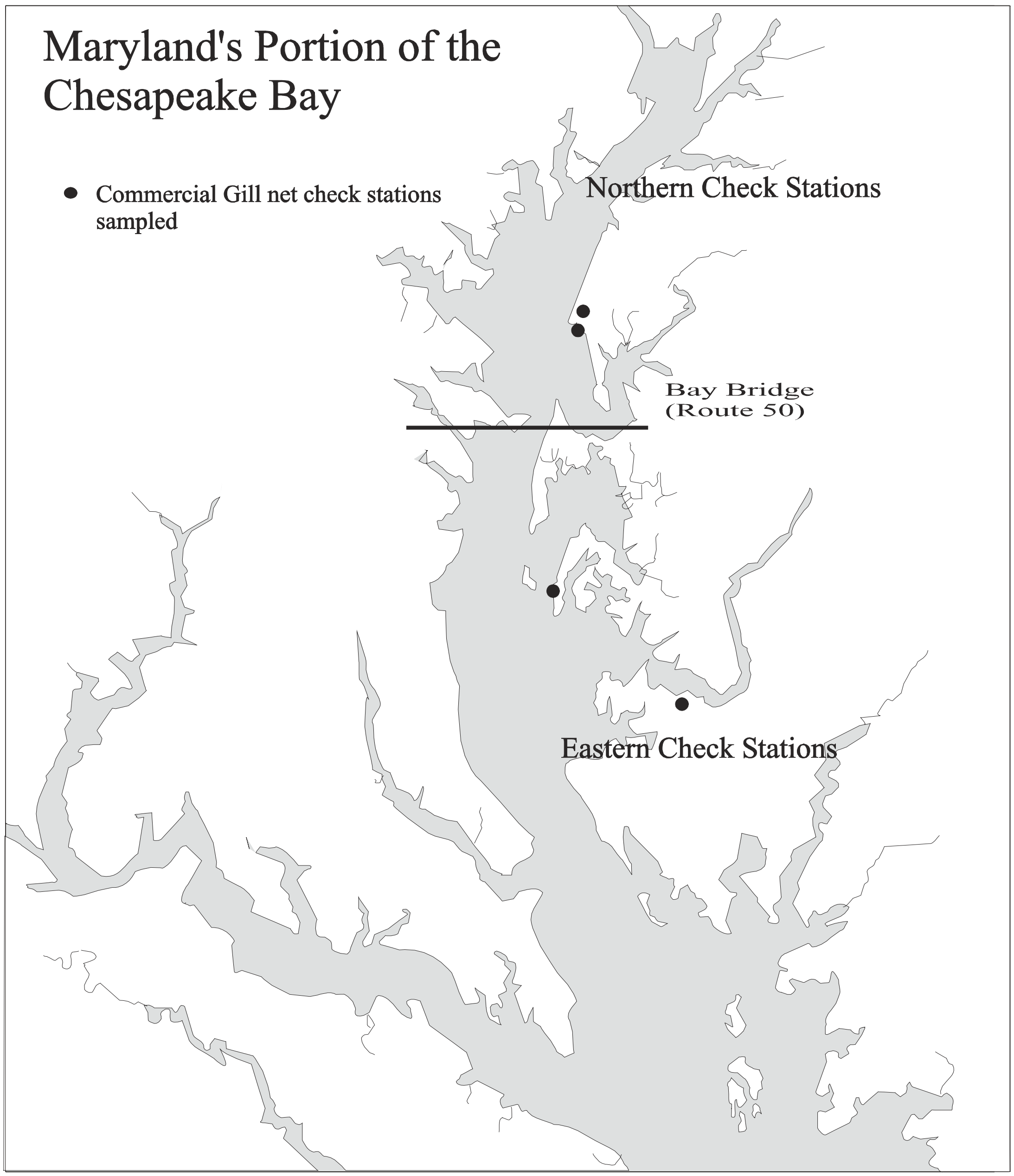


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994 - 2005.

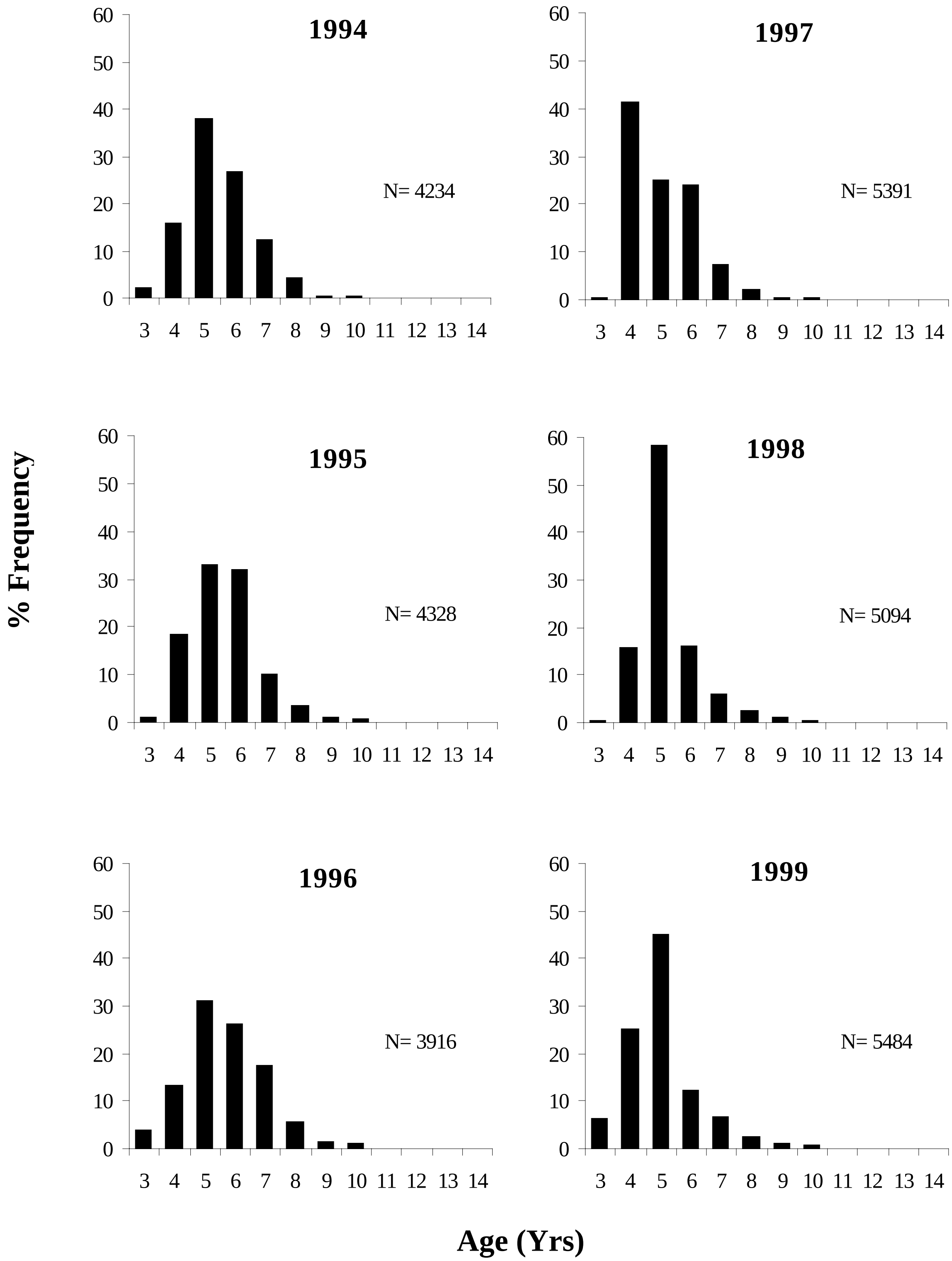


Figure 2. Age distribution of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994 - 2005 (Continued).

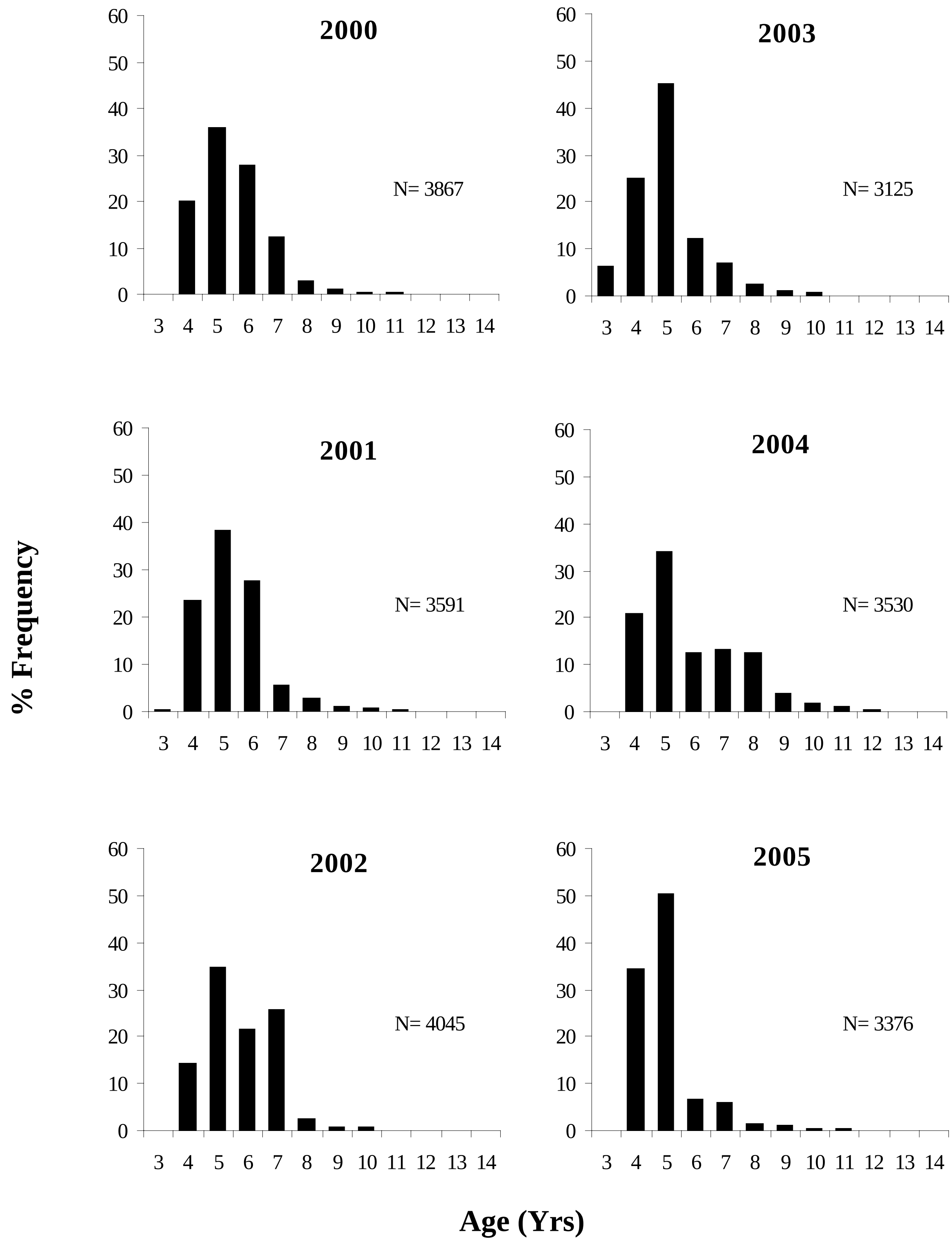


Figure 3. Length frequency distributions, by area and bay-wide, of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, December 2004-February 2005.

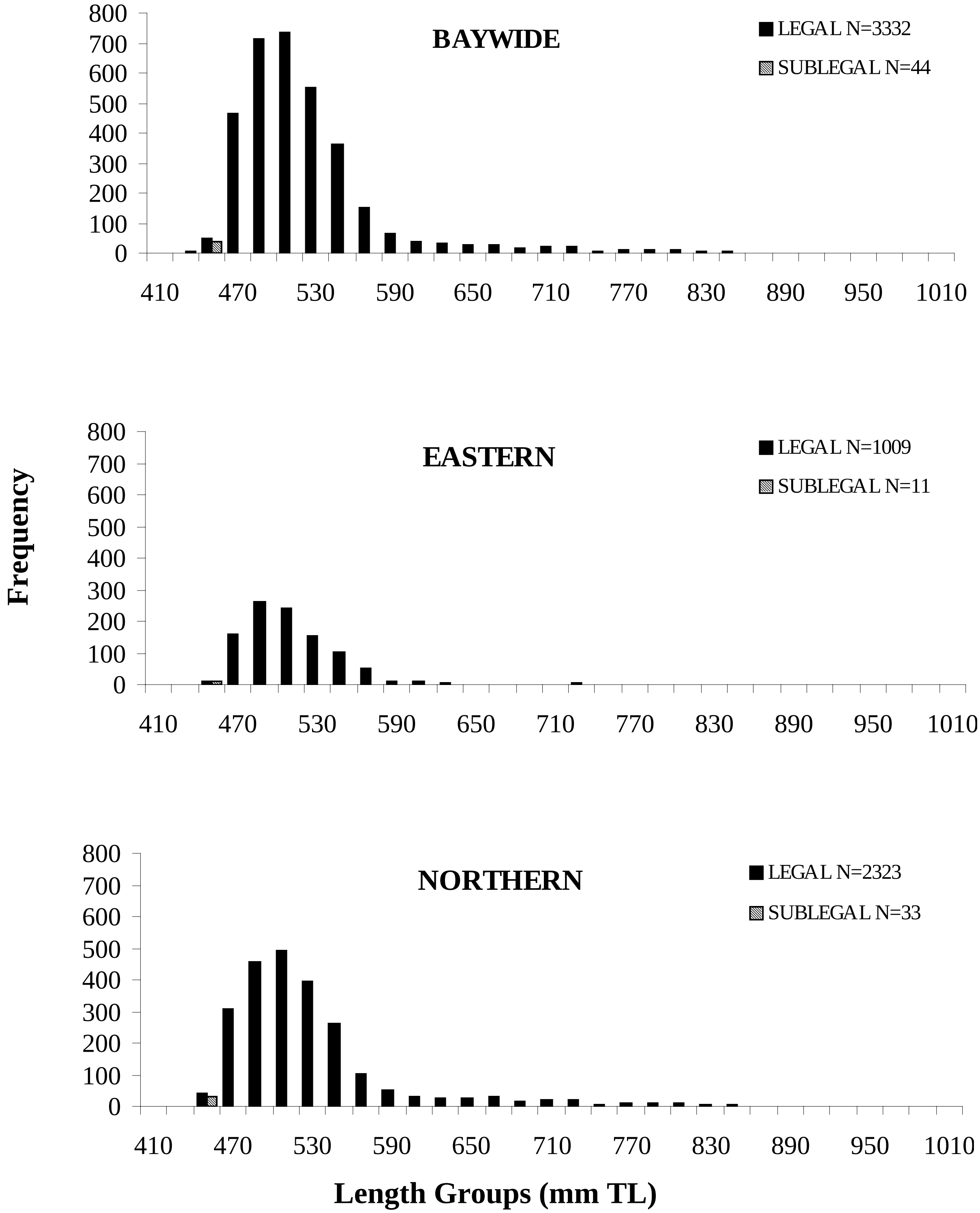


Figure 4. Mean total lengths (mm TL) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net landings, 1994-2005. (95% confidence intervals are shown around each point). The sample year refers to the year in which the season ended.

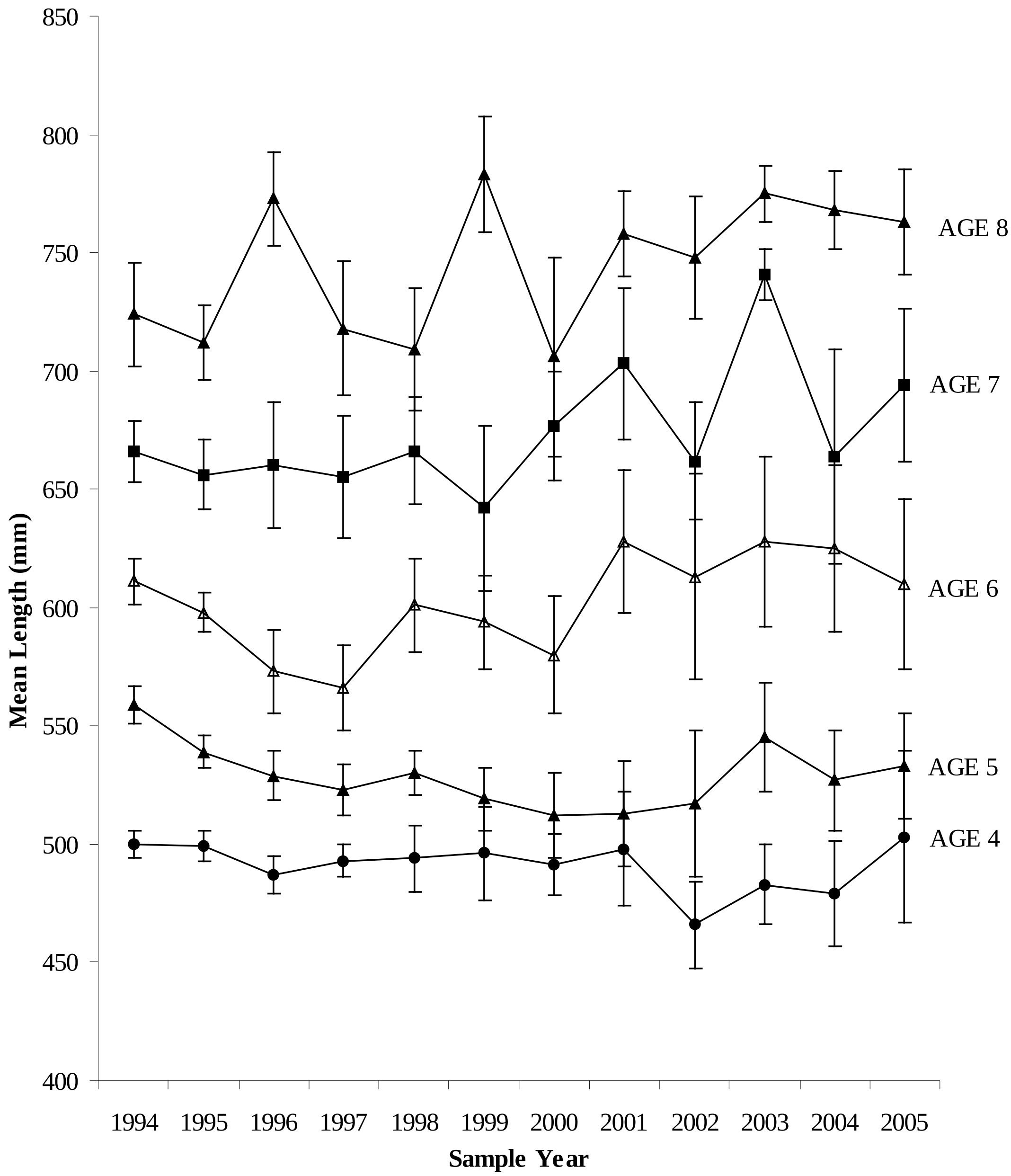
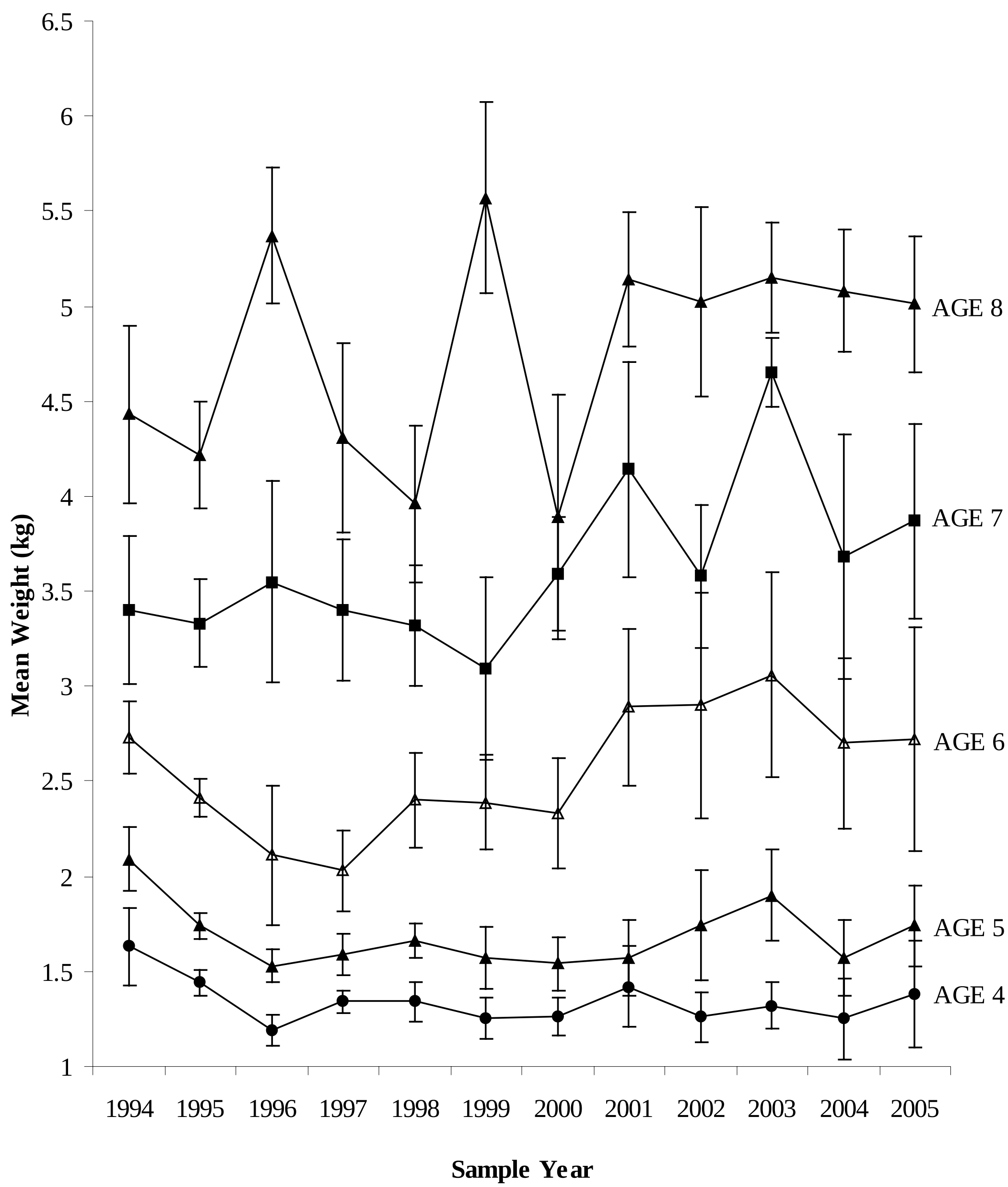


Figure 5. Mean weights (kg) of the aged sub-sample, by year, for individual age-classes of striped bass sampled from the Maryland Chesapeake Bay commercial drift gill net fishery, 1994-2005. (95% confidence intervals are shown around each point). The sample year refers to the year in which the season ended.



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

CHARACTERIZATION OF STRIPED BASS SPAWNING STOCKS IN MARYLAND

Prepared by Lisa Warner, Craig Weedon 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 2005 (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 30 to May 10 for a total of 29 sample days. In the Upper Bay, sampling was conducted from April 5 to May 19 for a total of 24 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 the 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 10 to 147 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 (TL-mm), 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 1 cm 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) wands, very few fish were checked for binary CWTs (see Project No. 2, Job No. 3, Task 6A).

Analytical Procedures

Development of age-length keys

Although area- and sex-specific age-length keys (ALKs) were used in the development of catch-per-unit-effort (CPUE), additional analyses were performed to develop ALKs utilized for other data analyses. The 2003 scale allocation procedure was used again in 2005. This procedure designated two sex-specific groups of scales pooled from both the spring gill net sampling and the spring striped bass recreational season sampling (Barker et al., 2003). The number of scales to be aged was determined by examination of the previous year's spring gill net ALK. Approximately twice as many scales were aged as the number of ages represented per length group. For length groups <700 mm TL, scales were read from Potomac and Upper Bay gill net fish, along with striped bass recreational season scales to fill in the gaps. For length groups >700 mm TL, scales were read from Potomac fish, Upper Bay fish and spring striped bass recreational season fish in equal proportions.

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 2005. 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 corrected CPUEs were then averaged across meshes using a mean, weighted by the capture efficiency of the mesh, resulting in a vector of selectivity-corrected length group CPUEs for each spawning area and sex.

Final 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 1997-2005 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.

Whereas 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 and included:

- 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 ($\alpha = 0.05$);

- Trends in the age composition of the Bay spawning stock were examined. The percentage of the female spawning stock, and the total stock, older than age 8 was calculated;

- An index of spawning potential (ISP) was produced by converting the selectivity-corrected length group CPUE of female striped bass over 500 mm TL to biomass using the regression equation (Rugolo and Markham 1996):

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

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

RESULTS AND DISCUSSION

CPUEs and variance

The annual CPUE calculations produce four vectors of sex- and age-specific CPUE values. The time-series of sex- and area-specific, selectivity-corrected, year-class CPUEs are presented in Tables 1-6. These values are pooled for use in the coast-wide annual striped bass stock assessment. The 2005 CPUEs for Upper Bay males (702) and Upper Bay females (51) were the 3rd and 4th highest in their time-series. Total CPUE for Potomac males (76) was the lowest in the time-series (average=504). Total CPUE for Potomac females (23) was slightly below the time-series average of 28. The time-series of the pooled age-specific indices for ages

1 through 15-plus years is presented in Table 7. The 2005 value (498) is slightly below the time-series average of 512.

The confidence limits associated with these pooled CPUEs are presented in Tables 8 and 9. CPUE variance was remarkably small, as demonstrated by the Coefficient of Variation (CV) analysis (Table 10). Seventy-six percent of CV values were less than 0.10 and 95% were less than 0.25. CV values greater than 1.0 were limited to older age-classes sampled during and immediately following the moratorium, so the increased variability of the estimates was probably related to small sample sizes. Confidence intervals could not be calculated for the 15-plus age group because those values are the sum of multiple age-class CPUEs. If a value is present in the 15-plus column, then the 15-plus age group is made up of only 15-year-old fish (Tables 8-10).

The relative contribution of CPUEs, both weighted and unweighted by spawning area, and pooled by sex and area, are presented in Tables 11 and 12. Females contributed a relatively small portion to the total pooled CPUE (Table 11). The Upper Bay dominated the weighted, pooled, total CPUE, because of the large contribution of the Upper Bay males (86%) (Table 12). As in previous years, males dominated (91.9%) the weighted, pooled 2005 CPUE.

Temperature and catch patterns

During the 2005 survey, Potomac River surface water temperatures increased gradually from 8.6 °C on March 30 to a peak of 17.2 °C on April 21, and decreased to 16.5 °C by the end of the survey. Daily CPUEs were greatest during mid and late April, with another small spike in male and female CPUE occurring during the first week of May, indicating three peaks in spawning activity (Figure 2). Biologists observed striped bass eggs in the water on April 28, further evidence of a late-April peak in spawning activity.

Upper Bay surface water temperatures exhibited a wider range than the Potomac, possibly related to releases from the nearby Conowingo Dam on the Susquehanna River. Daily water temperatures ranged from 7.4 °C to 18.4 °C. Three peaks in Upper Bay female CPUE also occurred in mid and late April and early May (Figure 3). The first peak was associated with a sudden increase in water temperature on April 11, but the others occurred during periods of stable water temperatures.

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

Length at age

Information from the area-specific length-at-age (LAA) relationships reflected known biology of the species, and appeared to indicate a migration effect for females and a local population effect for males. There was a significant difference between LAA for the male and female spawning stocks encountered in the Potomac and Upper Bay ($P>F <0.001$), consistent with the known behavioral biology of the species. There was no significant effect by area on LAA for male striped bass ($P>F = 0.33$). LAA did not vary between spawning areas (Upper Bay and Potomac River) for female striped bass, as indicated by an insignificant age*area interaction in the analysis of covariance model (females: $P>F = 0.32$).

Ages determined by reading scales from the spring creel sampling (Project No. 2, Job No. 3, Task 5B this report) were used to supplement the male ALK. This approach was validated by results of an analysis of covariance that showed no significant age*survey interaction (males:

P>F = 0.10). A common male ALK was subsequently developed to include fish from the Potomac River, Upper Bay and the spring recreational creel sampling.

Ages determined by reading scales from the spring creel sampling were also used to supplement the female ALK. This approach was validated by results of an analysis of covariance that showed no significant age*survey interaction (females: P>F = 0.39). A common female ALK was also developed to include fish from the Potomac River, Upper Bay and the spring recreational creel sampling. Age- and sex-specific LAAs are presented in Tables 13 and 14.

There were 16 age-classes sampled in 2005, ranging from 2 to 19 years old (Tables 13 and 14). All striped bass age 4 and younger were male while female spawners ranged from ages 5 to 19, with 53% from the 1994 and 1995 year-classes (ages 11 and 10).

The LAA has been relatively stable since the mid 1990s. Mean length-at-age of male striped bass sampled in 2005 showed no significant differences ($\alpha = 0.05$) from those in 2004 (Figures 4 and 5).

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

The size composition of striped bass sampled from the Potomac River and the Upper Bay could not be statistically compared in 2005 because of the small sample size from the Potomac River. It was assumed that the data would follow the patterns of past years, so the length distributions were treated similarly. During the sampling period, 203 male striped bass were captured from the Potomac River and 1319 males from the Upper Bay. Most (75%) male striped bass ranged between 31 and 55 cm TL. The length distribution of male striped bass from the Upper Bay was dominated by these smaller striped bass. There are two very strong peaks representing the strong 2003 and 2001 year-classes. The 2001 year-class fish are evident in both the uncorrected and corrected CPUE peak at 47 cm, while the 2003 peak is more obvious in the corrected CPUE only (Figure 6). The shape of the length distribution of Potomac River male fish was similar, but flattened, because of the small sample size (n = 203). When the data were corrected for selectivity, the peaks in the length distributions in both areas corresponded with the uncorrected CPUE estimates. Estimates of relative abundance of fish on the extreme left of the size distribution were then corrected upward (Figure 6). The Potomac sample size was too low to show any clear year-class patterns. The record 1996 year-class is not evident in either system for males. These selectivity-corrected abundance estimates are also presented in Tables 2 and 4.

The length distributions of female spawners sampled from the two regions were comparable (Figure 7). On the Potomac River 44 female striped bass were captured, and 82 on the Upper Bay. The length distribution of all females ranged from 49 to 117 cm TL. Twenty-nine percent of the female corrected CPUE in the Upper Bay was seen in the 91, 93 and 107 cm length groups (Figure 7). The uncorrected and corrected CPUE peak at 91 cm, and the corrected peak at 93 cm clearly reflect the record 1996 year-class (n = 12). A smaller peak at 101 cm in the corrected CPUE may represent the dominant 1993 year-class (n=12). When corrected for selectivity, two similar peaks occur at 97 and 107 cm that are not consistent with actual females seen, or strong year-classes.

A similar range of sizes was present among female fish sampled from the Potomac River, but a few females in the 49 and 53 cm length groups were also encountered. Females in these smaller length groups are rarely encountered on the spawning grounds. Application of the selectivity model to the data corrected the catch upward across the length distribution (Figure 7). The corrected CPUE peaks at 101 and 103 cm most likely represent the 1993 year-class (n = 6), although the uncorrected CPUE does not show the same pattern. No clear peak exists in either the corrected or uncorrected CPUE to represent the 1996 year-class on the Potomac. These selectivity-corrected abundance estimates are also presented in Tables 1 and 3.

Age composition of the stock

The overall age composition of the striped bass spawning stock has shifted toward older fish in recent years. The abundance of 2 through 5 year-old striped bass in the Maryland Chesapeake Bay spawning stock has been variable since 1985, with clear peaks of abundance during strong year-classes (Figure 8). Females younger than age 7 have become increasingly uncommon since 1996. In 2005, a 5 year-old female, which is rarely seen, was captured on the Potomac River. No 6 year-old females were encountered in 2005. Older females have contributed more than 90% of the sampled female spawning stock for the past four years (Figure 9).

The contribution of males to the older age-classes (ages 11-plus) indicated an increase through 2004, while in 2005 no males over the age of 12 were captured on the spawning grounds. This resulted in the percentage of the overall stock (males and females combined) aged 8 and older to drop slightly (Figure 10). The percentage of age 8-plus fish among males and females is heavily influenced by strong year-classes. 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 10), the 2001-2004 data suggest that male fish are living longer and female fish are maturing at older ages. Unusually low catches on the Potomac River in 2005 contributed to the low CPUE estimates for male fish.

The coastal female spawning stock biomass for 2004 was approximately 55 million pounds, well above the SSB target of 38.6 million pounds and the threshold of 30.9 million pounds (ASMFC 2005). MD DNR estimates of female spawning stock biomass generated from the Upper Bay continue to show an increasing trend. While the 2004 Potomac female SSB (579) was the highest value in the time-series (Table 15), the 2005 value (196) showed a dramatic decrease, dropping below the time-series average of 235 (Table 15, Figure 11).

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Table 1. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Potomac River during the 1985 - 2005 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**

Table 2. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Potomac River during the 1985 - 2005 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**

Table 3. Estimates of selectivity-corrected age-class CPUE by year for female striped bass captured in the Upper Bay during the 1985 - 2005 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**

Table 4. Estimates of selectivity-corrected age-class CPUE by year for male striped bass captured in the Upper Bay during the 1985 - 2005 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**

Table 5. 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 6. 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 7. Mean values of the pooled, weighted, annual age-specific CPUEs (1985 – 2005) 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	67.2	104.9	73.4	96.4	24.1	25.7	21.6	27.3	20.3	17.4	11.3	2.9	1.0	4.5	**498**

Table 8. 95% lower confidence limits of the pooled, weighted, annual age-specific CPUEs (1985 – 2005) 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	64.0	100.0	70.8	92.6	23.2	24.7	20.8	26.2	19.1	16.3	10.1	2.6	0.9	*

* 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 9. 95% upper confidence limits of the pooled, weighted, annual age-specific CPUEs (1985 – 2005) 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	70.4	109.8	75.9	100.3	25.1	26.6	22.3	28.3	21.4	18.4	12.4	3.3	1.2	*

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

Table 10. Coefficients of Variation of the pooled, weighted, annual age-specific CPUEs (1985 – 2005) 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	0.07	*

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

Table 11. Unweighted striped bass catch per unit effort (CPUE) by year-class, late March through May 2005. Values are presented by sex, area, and percent of total. CPUE is number of fish per hour in 1000 yards of experimental drift net.

		Pooled					
		Unweighted	%	Females		Males	
Year-class	**Age**	**CPUE**	**of total**	**Potomac**	**Upper Bay**	**Potomac**	**Upper Bay**
2004	1	**0.0**	0.0	0.0	0.0	0.0	0.0
2003	2	**114.3**	19.5	0.0	0.0	11.2	103.0
2002	3	**175.7**	14.0	0.0	0.0	10.2	165.5
2001	4	**125.8**	18.1	0.0	0.0	15.0	110.8
2000	5	**165.0**	18.3	1.9	0.0	16.7	146.3
1999	6	**41.3**	4.6	0.0	0.2	4.8	36.4
1998	7	**44.3**	4.9	1.6	1.4	4.5	36.8
1997	8	**37.0**	4.1	0.6	3.3	3.6	29.4
1996	9	**47.2**	5.2	2.7	8.0	4.0	32.5
1995	10	**35.3**	3.9	2.5	9.0	3.1	20.7
1994	11	**30.9**	3.4	4.6	10.2	1.9	14.2
1993	12	**20.4**	2.3	4.1	9.5	1.2	5.6
1992	13	**5.4**	0.6	1.7	3.4	0.0	0.3
1991	14	**1.9**	0.2	0.8	1.2	0.0	0.0
≤1990	15+	**7.0**	0.8	4.1	4.8	0.0	0.0
Total		**851.5**		**24.6**	**50.8**	**76.3**	**701.6**
% of Total				**2.9**	**6.0**	**9.0**	**82.4**
% of Sex				**32.6**	**67.4**	**9.8**	**90.2**
% of Potomac				**24.4**		**75.6**	
% of Upper Bay					**6.8**		**93.2**

Table 12. Striped bass catch per unit effort (CPUE) by year-class, weighted by spawning area, late March through May 2005. Spawning area weights used: Potomac (0.385), Upper Bay (0.615). 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
2004	1	**0.0**	0.0	0.0	0.0	0.0	0.0
2003	2	**67.2**	13.5	0.0	0.0	4.3	62.9
2002	3	**104.9**	21.1	0.0	0.0	3.9	100.9
2001	4	**73.4**	14.7	0.0	0.0	5.8	67.6
2000	5	**96.4**	19.4	0.7	0.0	6.4	89.3
1999	6	**24.1**	4.8	0.0	0.1	1.8	22.2
1998	7	**25.7**	5.2	0.6	0.9	1.7	22.4
1997	8	**21.6**	4.3	0.2	2.0	1.4	18.0
1996	9	**27.3**	5.5	1.0	4.9	1.6	19.8
1995	10	**20.3**	4.1	1.0	5.5	1.2	12.6
1994	11	**17.4**	3.5	1.8	6.2	0.7	8.6
1993	12	**11.3**	2.3	1.6	5.8	0.4	3.4
1992	13	**2.9**	0.6	0.6	2.1	0.0	0.2
1991	14	**1.0**	0.2	0.3	0.7	0.0	0.0
≤1990	15+	**4.5**	0.9	1.6	2.9	0.0	0.0
Total		**497.8**		**9.5**	**31.0**	**29.4**	**428.0**
% of Total				**1.9**	**6.2**	**5.9**	**86.0**
% of Sex				**23.4**	**76.6**	**6.4**	**93.6**
% of Potomac				**24.4**		**75.6**	
% of Upper Bay					**6.8**		**93.2**

Table 13. 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 2005.

AGE	GROUP	N	MEAN	LCL	UCL	SD	SE
2	**POTOM**	3	299.3	230.6	368.1	27.7	16
	UPPER	14	301.9	288.1	315.7	23.9	6.4
	COMBINED	17	301.5	289.3	313.7	23.7	5.7
3	**POTOM**	9	369	348.7	389.3	26.4	8.8
	UPPER	10	377.2	352.9	401.5	34.0	10.8
	COMBINED	19	373.3	358.8	387.8	30.1	6.9
4	**POTOM**	12	453.1	423.8	482.4	46.1	13.3
	UPPER	8	436.5	399.4	473.6	44.4	15.7
	COMBINED	20	446.5	425.4	467.5	45	10.1
5	**POTOM**	12	517.8	475.3	560.2	66.8	19.3
	UPPER	17	514.6	487.2	542	53.3	12.9
	COMBINED	29	515.9	493.8	538	58.1	10.8
6	**POTOM**	10	603.8	535.3	672.3	95.7	30.3
	UPPER	12	612	559.9	664.1	82	23.7
	COMBINED	22	608.3	570	646.6	86.4	18.4
7	**POTOM**	9	685.2	586.3	784.1	128.7	42.9
	UPPER	32	667.9	641.8	694	72.4	12.8
	COMBINED	41	671.7	644.5	698.9	86.2	13.5
8	**POTOM**	9	749.1	679.8	818.5	90.2	30.1
	UPPER	35	735.6	708.9	762.3	77.7	13.1
	COMBINED	44	738.4	714.2	762.6	79.5	12
9	**POTOM**	7	806.9	727.4	886.3	85.9	32.5
	UPPER	46	789.5	762.7	816.3	90.4	13.3
	COMBINED	53	791.8	767.2	816.4	89.2	12.3
10	**POTOM**	5	847	708.6	985.4	111.5	49.8
	UPPER	30	855	823	887	85.6	15.6
	COMBINED	35	853.9	823.7	884	87.8	14.8
11	**POTOM**	0	.	.	.	.	.
	UPPER	19	847	802.1	891.9	93.2	21.4
	COMBINED	19	847	802.1	891.9	93.2	21.4
12	**POTOM**	1	810	.	.	.	.
	UPPER	7	947.3	907.8	986.8	42.7	16.1
	COMBINED	8	930.1	877.8	982.5	62.6	22.1

Table 14. 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 2005.

AGE	GROUP	N	MEAN	LCL	UCL	SD	SE
5	**POTOM**	1	490	.	.	.	.
	UPPER	0	.	.	.	.	.
	COMBINED	1	490	.	.	.	.
7	**POTOM**	1	538	.	.	.	.
	UPPER	1	729	.	.	.	.
	COMBINED	2	633.5	*	*	*	*
8	**POTOM**	2	874	569.1	1178.9	33.9	24
	UPPER	1	821	.	.	.	.
	COMBINED	3	856.3	759.7	952.9	38.9	22.5
9	**POTOM**	7	883.1	818.9	947.4	69.4	26.2
	UPPER	12	878.3	835.4	921.1	67.5	19.5
	COMBINED	19	880.1	848.1	912	66.3	15.2
10	**POTOM**	10	902.4	878.6	926.2	33.2	10.5
	UPPER	20	905.7	882.3	929.1	49.9	11.2
	COMBINED	30	904.6	888	921.2	44.5	8.1
11	**POTOM**	8	955.3	904.1	1006.4	61.1	21.6
	UPPER	26	949.7	924.9	974.4	61.2	12.0
	COMBINED	34	951	929.9	972	60.3	10.3
12	**POTOM**	6	1004.3	951.4	1057.3	66.1	27
	UPPER	12	1011.6	979.6	1043.5	50.3	14.5
	COMBINED	18	1009.2	982.2	1036.1	54.2	12.8
13	**POTOM**	4	1043.8	980.1	1107.4	40	20
	UPPER	4	1030.8	976.4	1085.1	34.1	17.1
	COMBINED	8	1037.3	1007.9	1066.6	35.1	12.4
14	**POTOM**	0	.	.	.	.	.
	UPPER	1	926	.	.	.	.
	COMBINED	1	926	.	.	.	.
15	**POTOM**	1	1006	.	.	.	.
	UPPER	2	1084	*	*	*	*
	COMBINED	3	1058	834.3	1281.7	90.1	52
16	**POTOM**	0	.	.	.	.	.
	UPPER	1	1112	.	.	.	.
	COMBINED	1	1112	.	.	.	.
19	**POTOM**	1	1180	.	.	.	.
	UPPER	0	.	.	.	.	.
	COMBINED	1	1180	.	.	.	.

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

Table 15. 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 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

Figure 1. Drift gill net sampling locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, late March - May 2005.

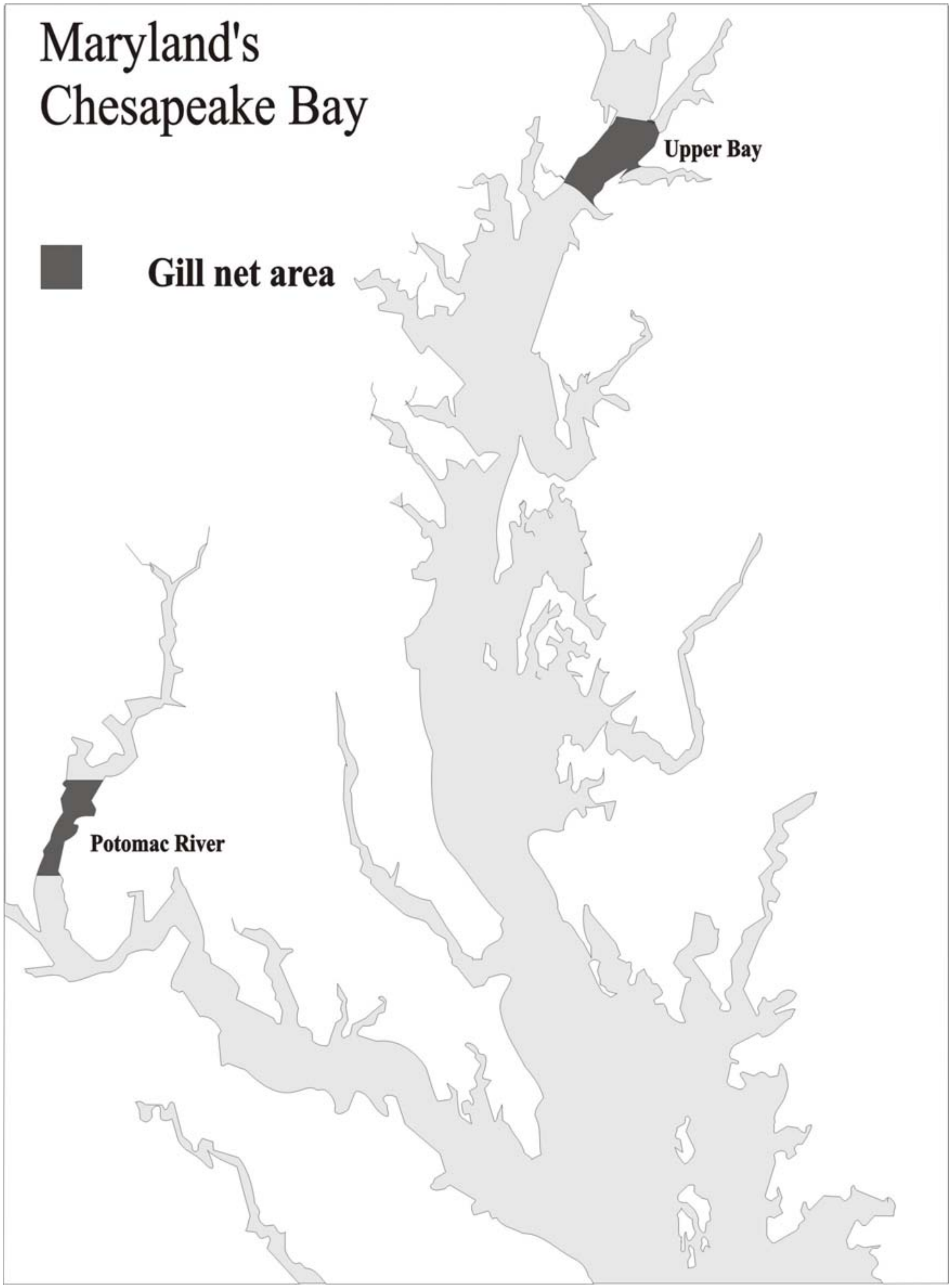


Figure 2. Effort-corrected catch of female and male striped bass, with surface water and air temperatures, by day, in the spawning reach of the Potomac River, late March through May 2005. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

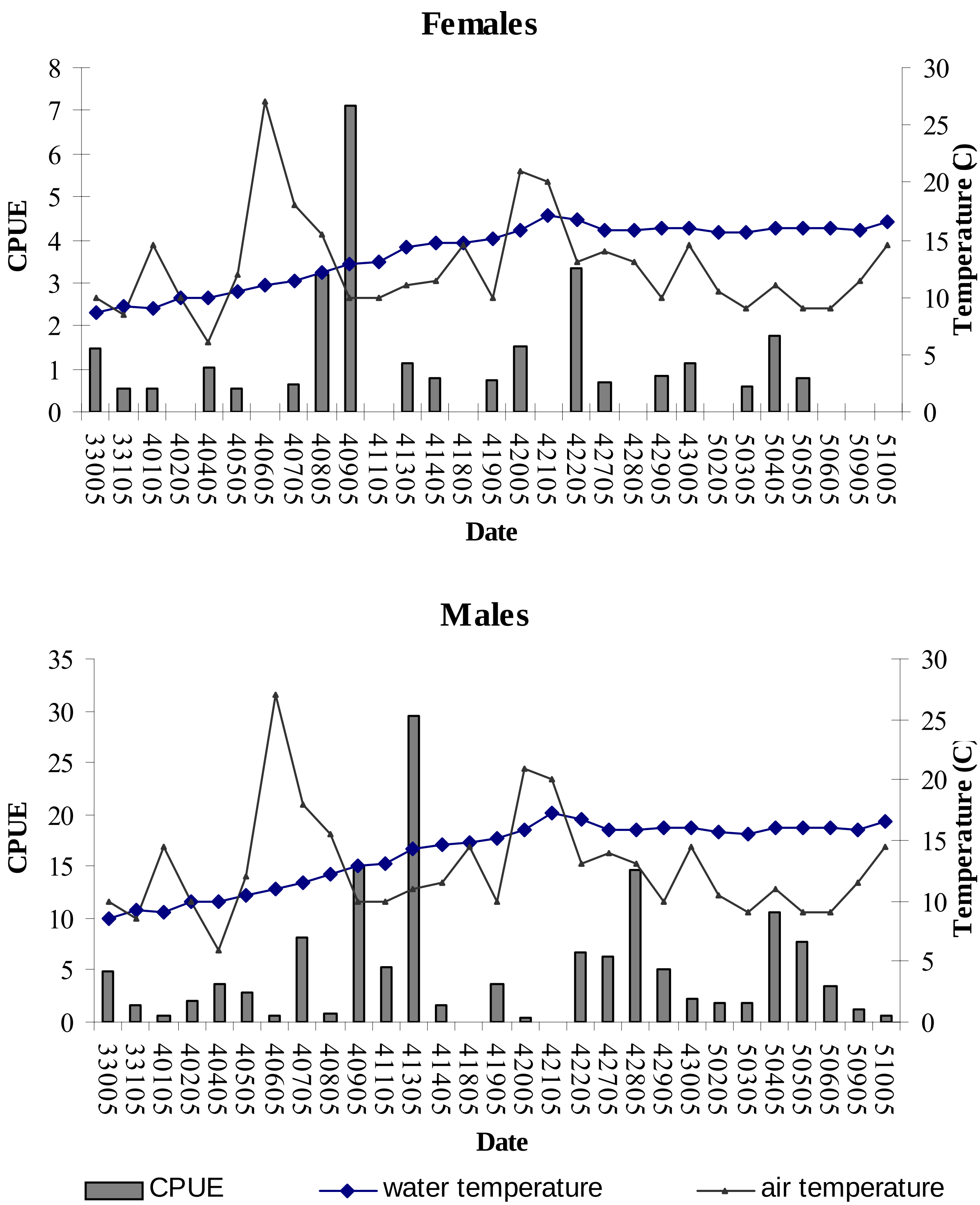


Figure 3. Effort-corrected catch of female and male striped bass, with surface water and air temperatures, by day, in the spawning reach of the Upper Chesapeake Bay, April through May 2005. Effort is standardized as 1000 square yards of experimental drift gill net per hour. Note different scales.

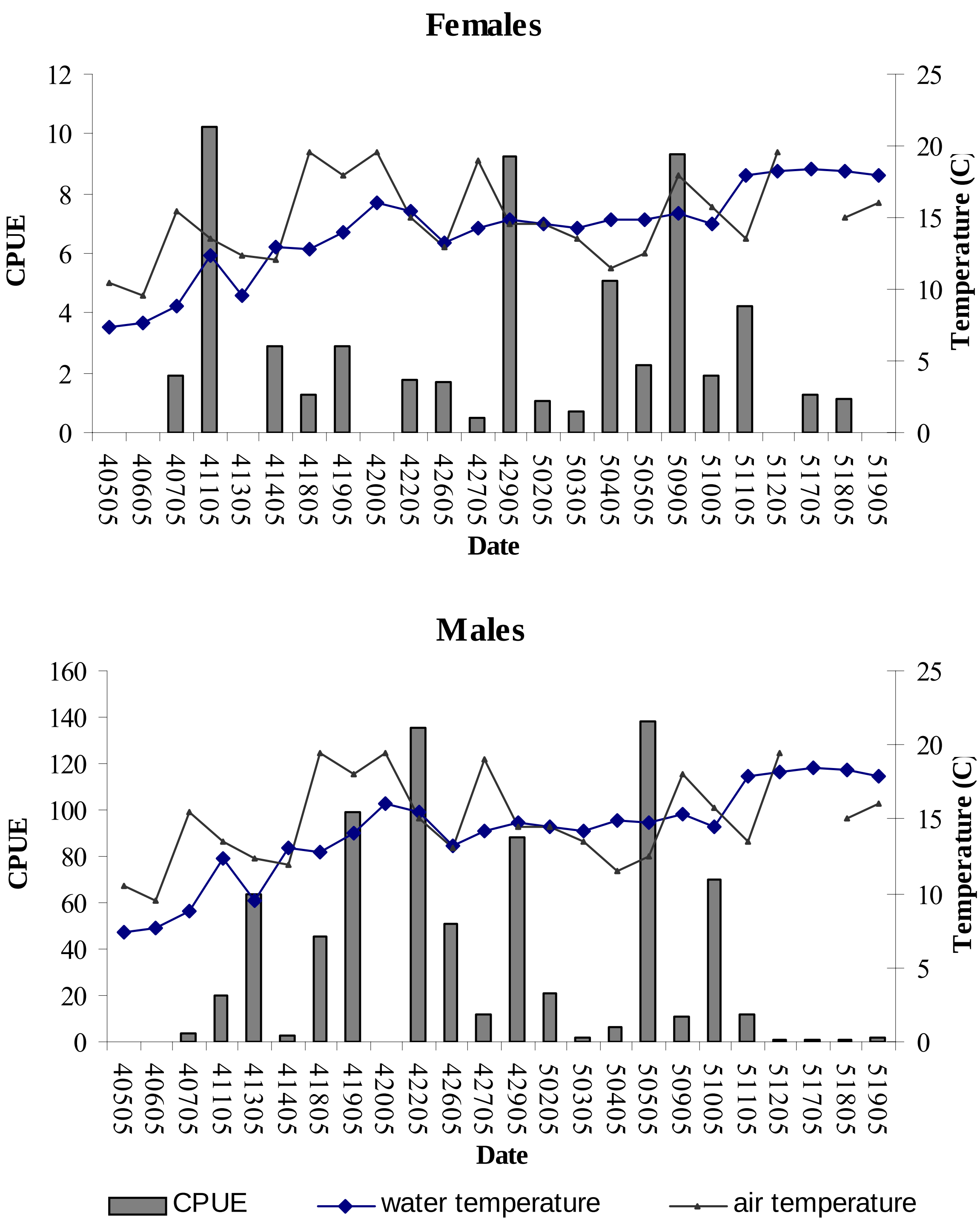


Figure 4. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Upper Chesapeake Bay in April and May, 1985-2005. Error bars are 95% confidence intervals.

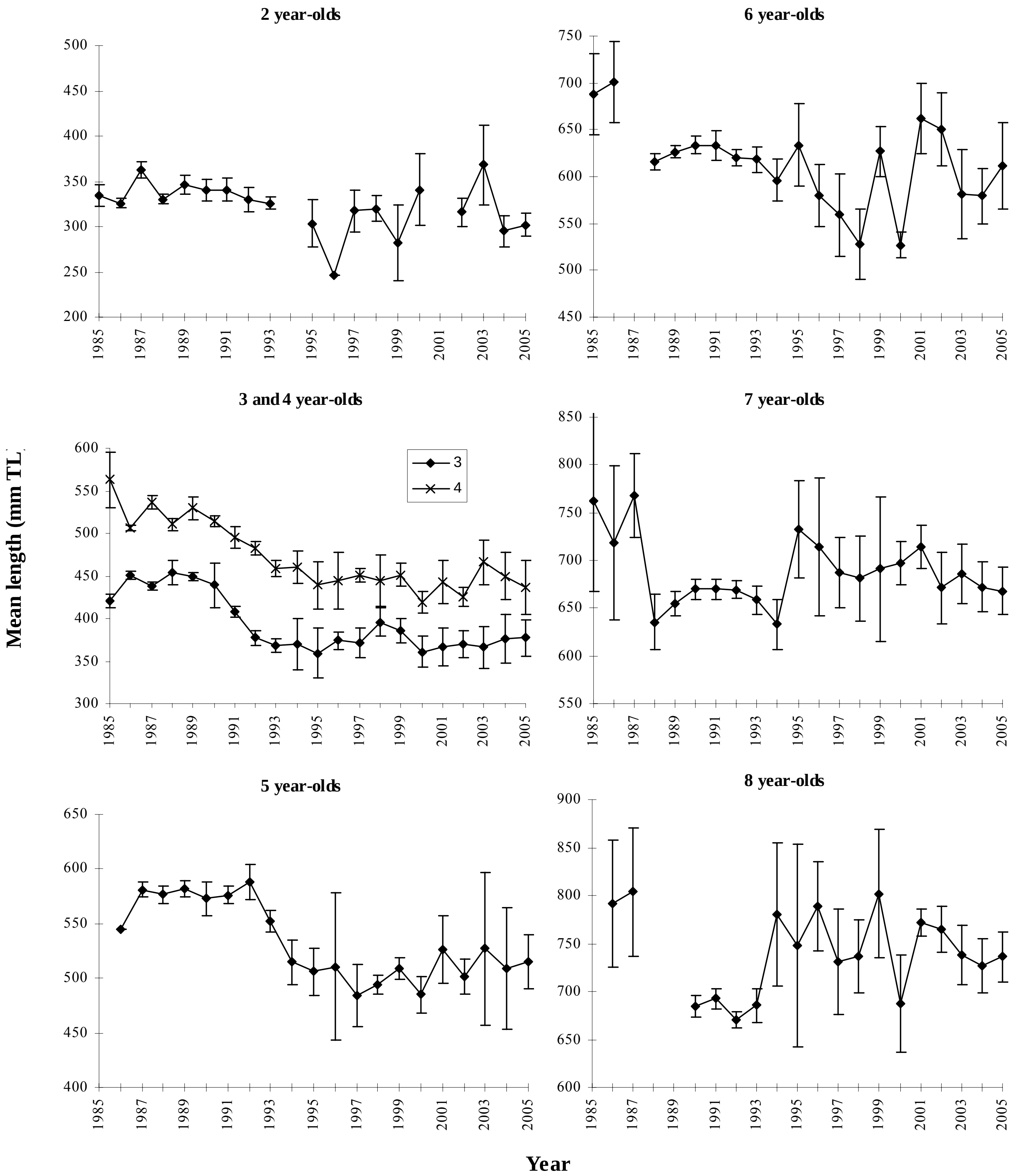
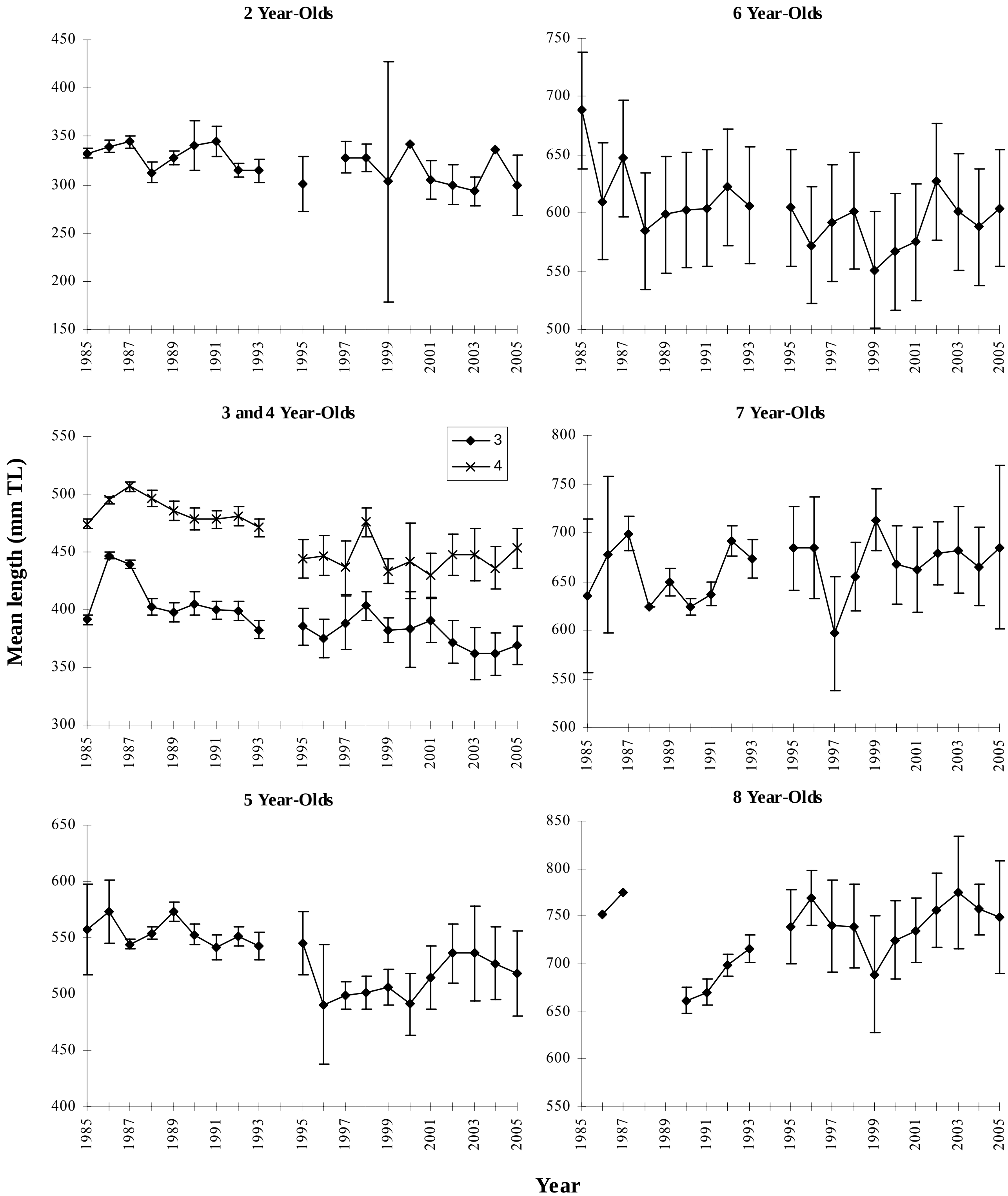
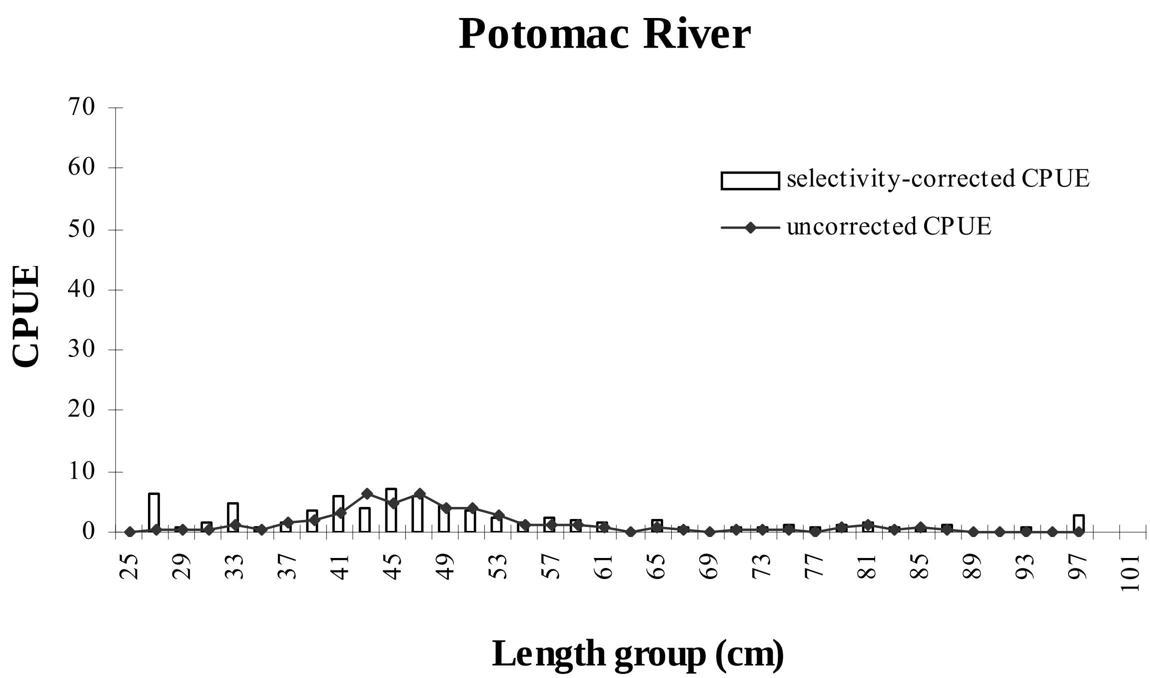


Figure 5. Mean length (mm TL) by year for individual ages of male striped bass sampled from spawning areas of the Potomac River during late March through May, 1985-2005. Error bars are 95% confidence intervals.



Note: The Potomac River was not sampled in 1994.

Figure 6. 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 2005. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.



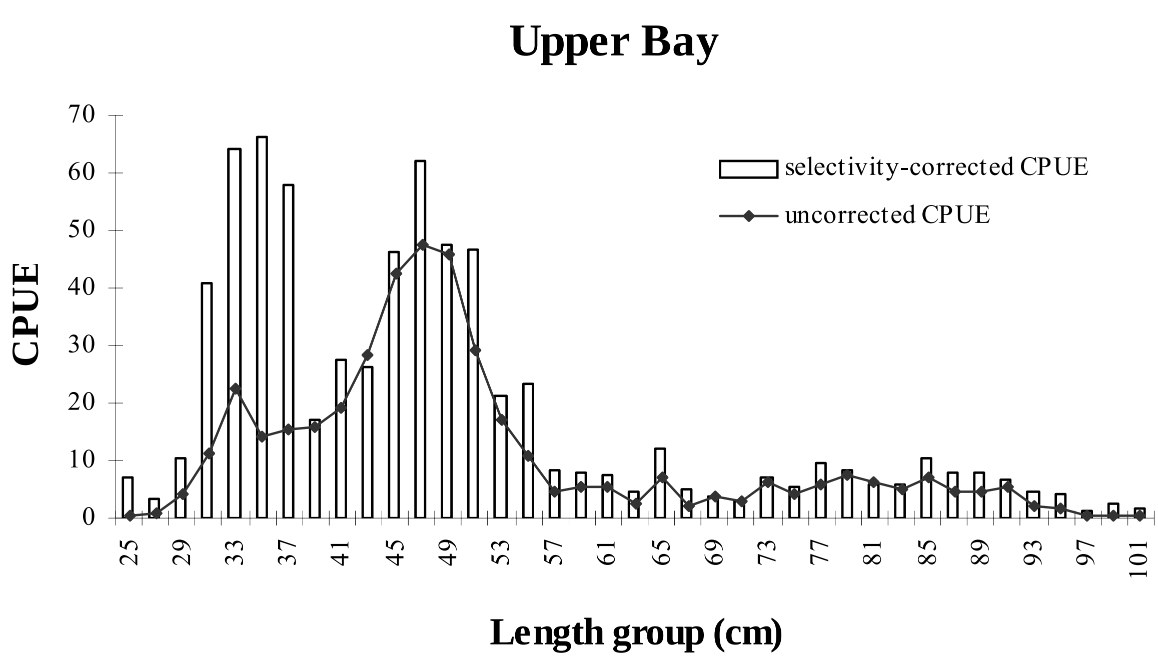
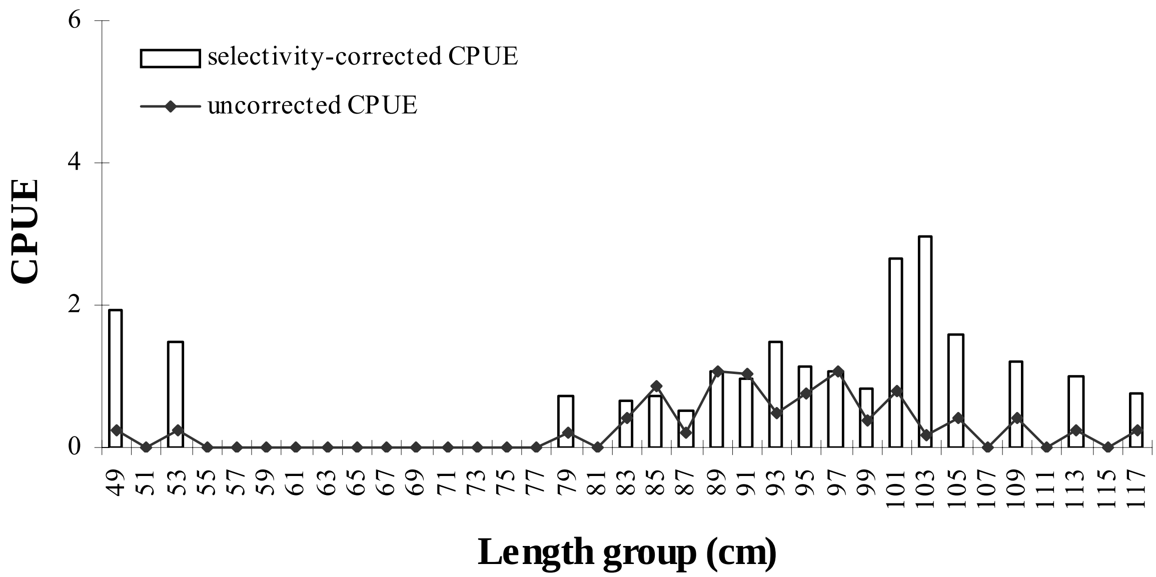


Figure 7. Length group CPUE (uncorrected and corrected for gear selectivity) of female striped bass collected from spawning areas of the Upper Bay and Potomac River, late March - May 2005. CPUE is the number of fish captured per hour in 1000 square yards of experimental drift net.

Potomac River



Upper Bay

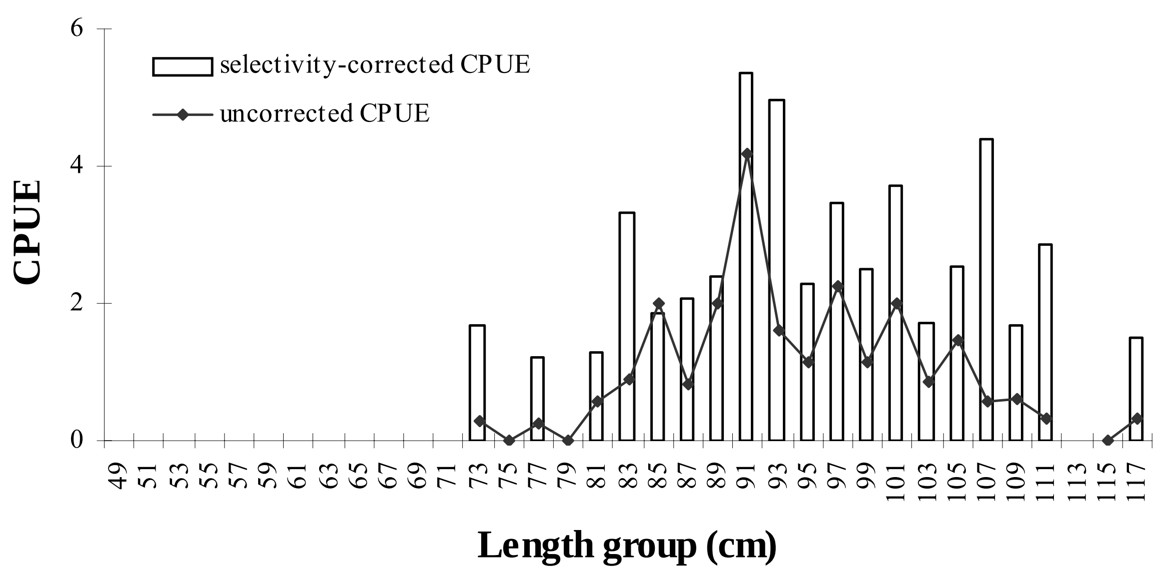


Figure 8. Maryland Bay spawning stock indices used in the 2005 coastal assessment. These are selectivity-corrected estimates of CPUE by year for ages 2 through 15-plus. Areas and sexes are pooled, although the contribution of sexes is shown in the stacked bars. Note different scales.

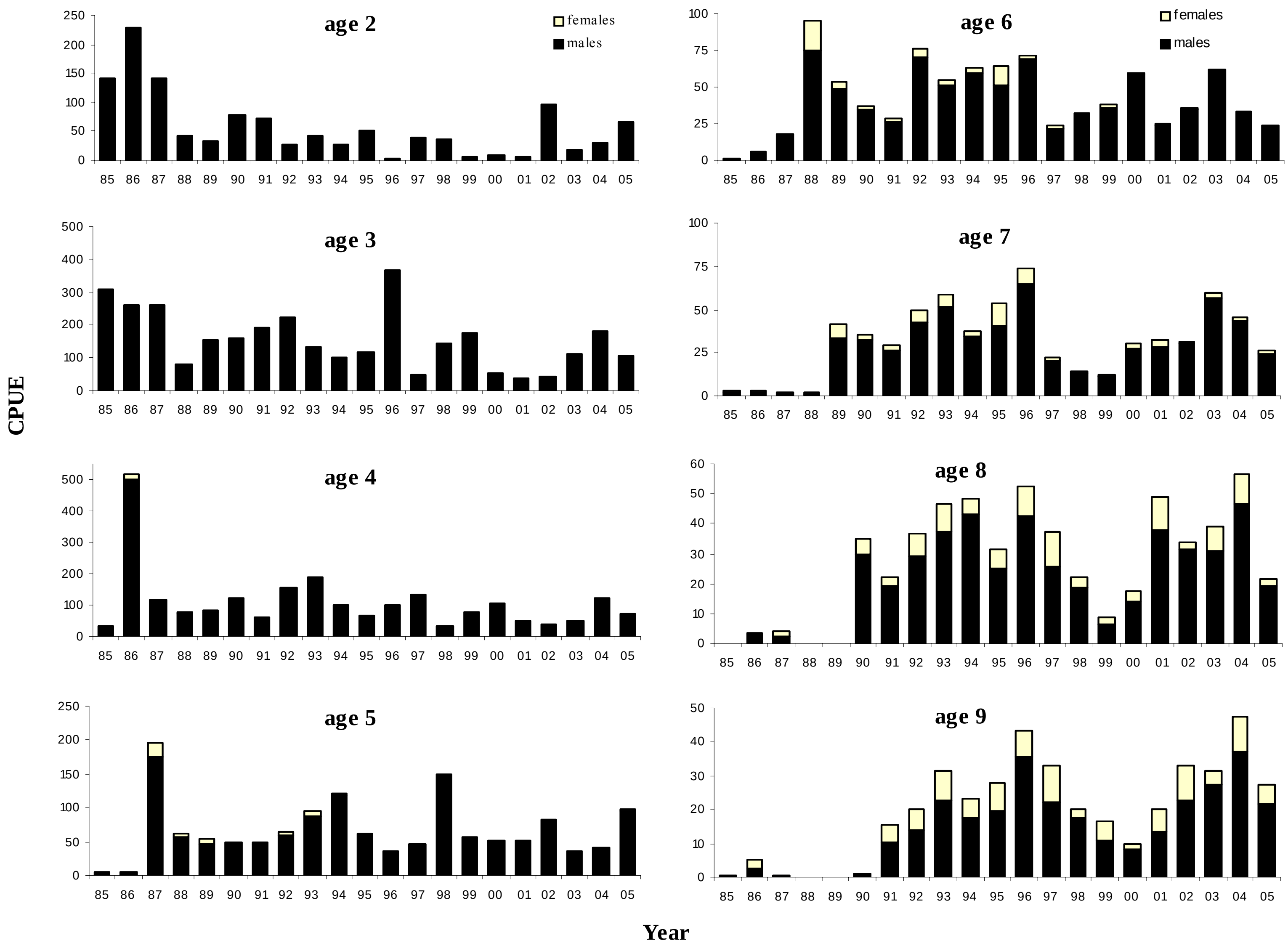


Figure 8. Continued.

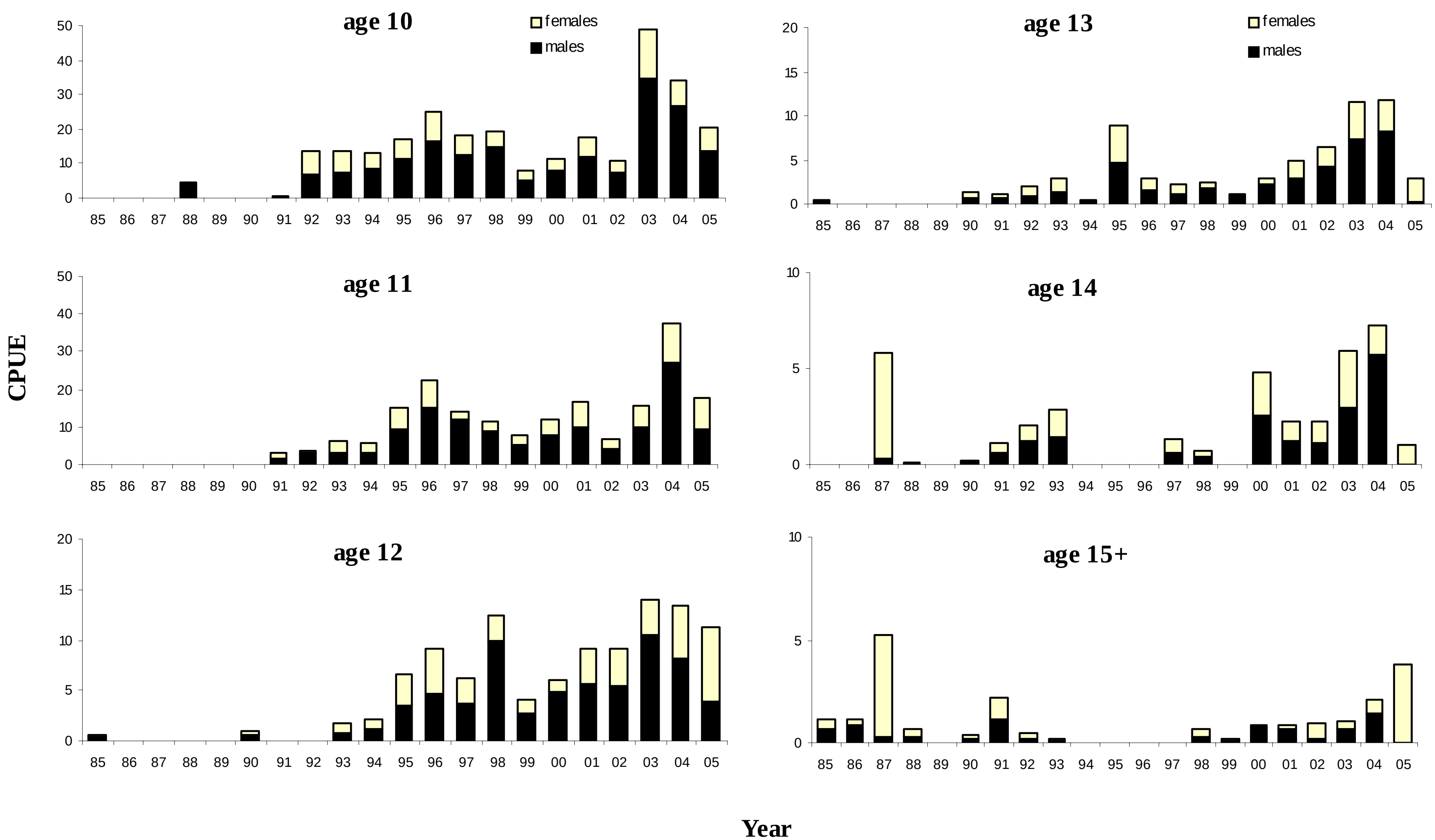
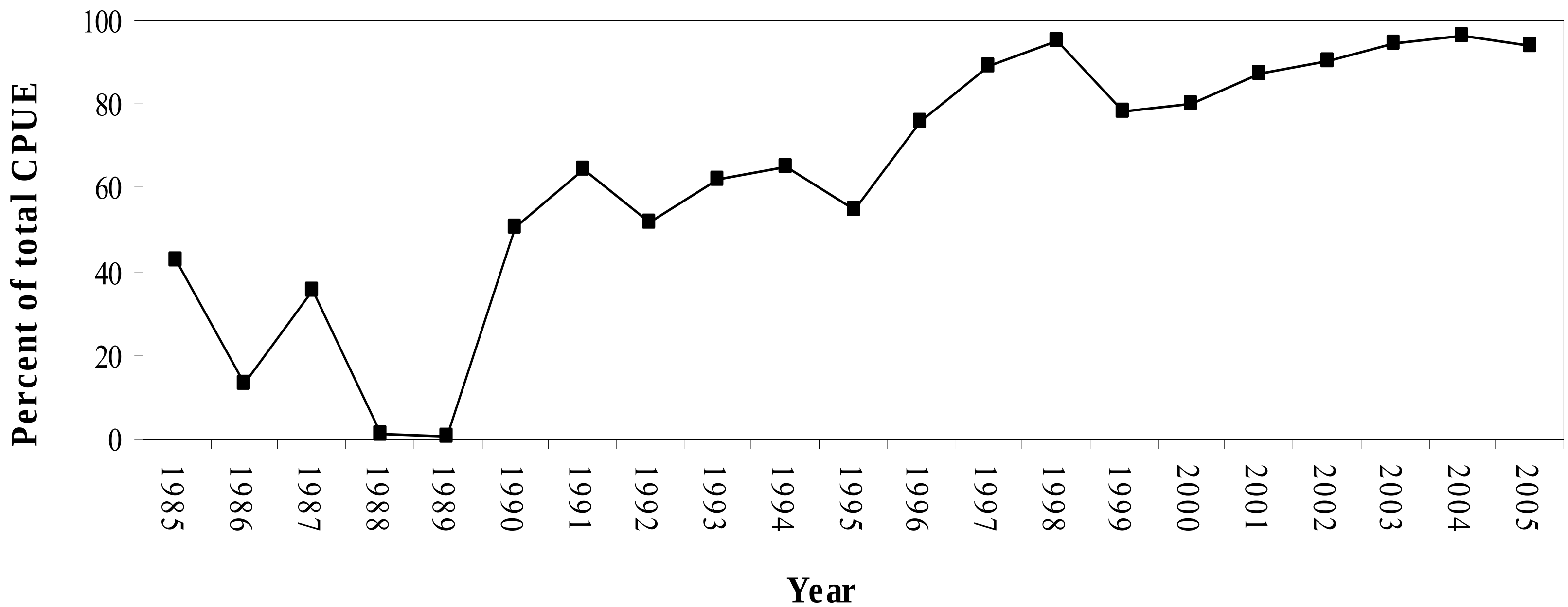
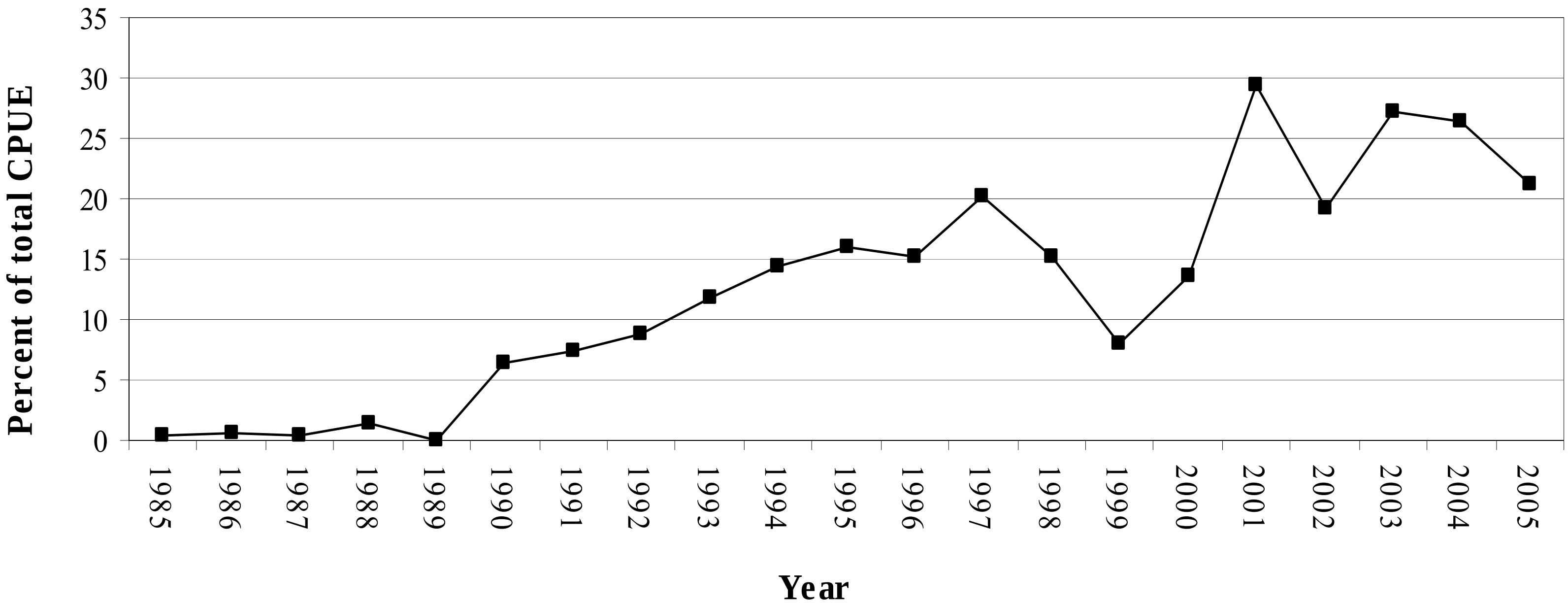


Figure 9. Percentage (selectivity-corrected CPUE) of female striped bass age 8 and over sampled from experimental drift gill nets set in spawning reaches of the Potomac River, Choptank River and the Upper Chesapeake Bay, late March through May, 1985-2005 (Choptank River to 1996). Effort is standardized 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. *



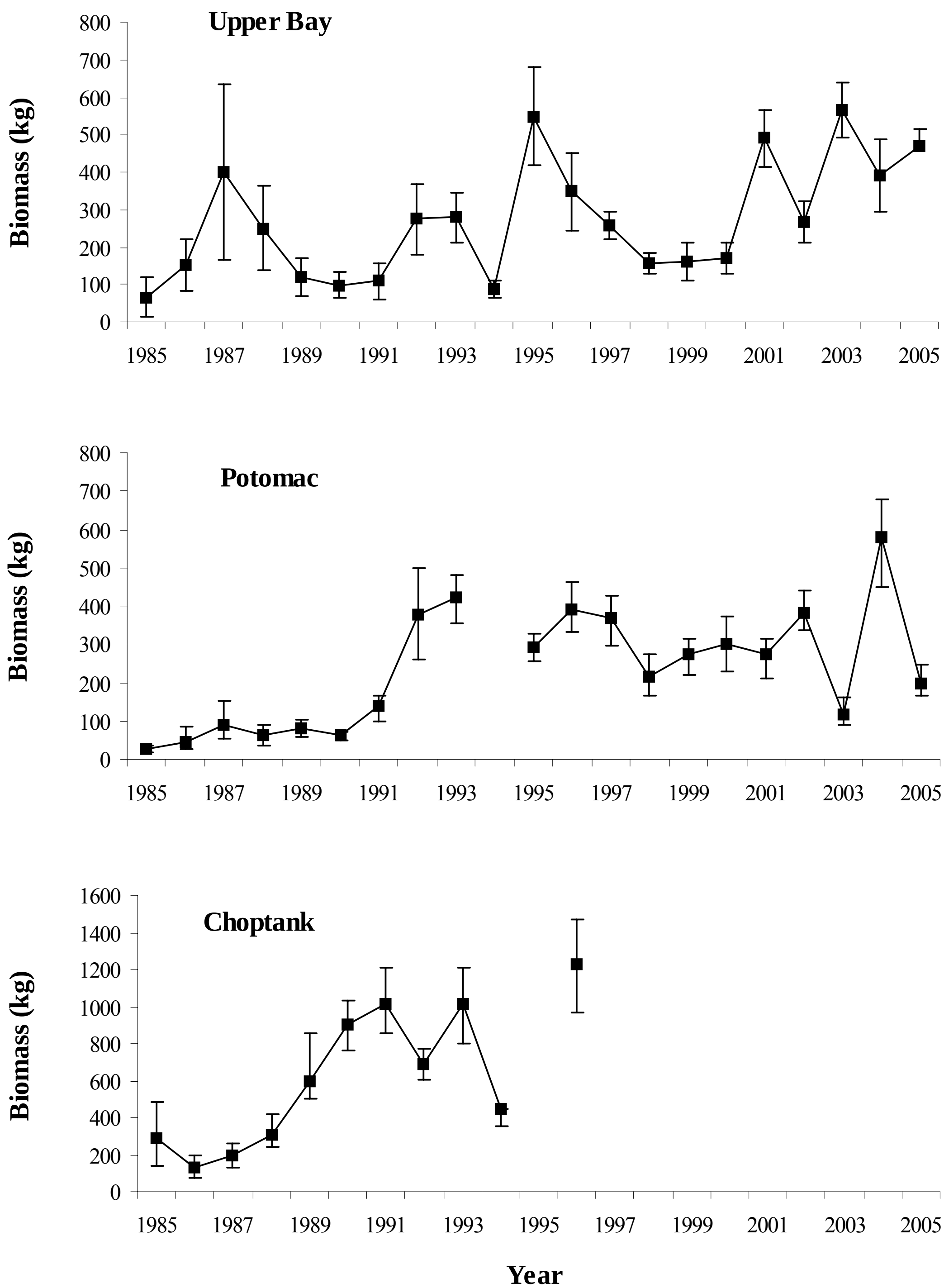
*Weights for spawning areas (1985 - 1996): Upper Bay=0.59 Potomac River=0.37 Choptank River=0.04
(1997 - Present): Upper Bay=0.615 Potomac River=0.385 (Hollis 1967)

Figure 10. 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, 1985-2005 (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. Biomass 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 Task 3 is 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). They 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 estimates of catch-per-haul are calculated.

From 1954 to 1961, juvenile surveys included various stations and rounds resulting in sample sizes ranging from 34 to 46. Indices derived for this period included only stations which were 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 known 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). Goodyear (1985) validated this index as a predictor of harvest in the Chesapeake Bay. The AM has also been used to predict harvest in New York waters (Schaefer 1972). The AM is an unbiased estimator of the mean regardless of the underlying frequency distribution (McConnaughey and Conquest 1992). The AM, however, is sensitive to high sample values (Sokol and Rolhf 1981). Additionally, detection of significant differences between annual arithmetic means is often not possible due to high variances (Heimbuch et al. 1983; Wilson and Wiesburg 1991).

The geometric mean (GM) was adopted by the Atlantic States Marine Fisheries Commission (ASMFC) Striped Bass Technical Committee in 1992 as the preferred index of relative abundance. The GM is calculated from the $\log_e(x+1)$ transformation, where x is an individual seine haul catch. One is added to all catches in order to transform zero catches, because the log of 0 does not exist (Ricker 1975). Since the $\log_e$-transformation stabilizes the variance of catches (Richards 1992) the GM estimate is more precise than the AM and is not as sensitive to a single large sample value. It is almost always lower than the AM (Ricker 1975). The GM is presented with 95% confidence intervals (CIs), which are calculated as antilog ($\log_e$ (x+1) mean ± 2 standard errors), and provide a visual depiction of sample variability.

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

Comparison of these three estimators 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 chosen as a period of stable biomass and general stock health (ASMFC 1989) and "an appropriate stock rebuilding target" (Gibson 1993). The TPA provided 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. Terms 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 2348 juvenile striped bass were collected at permanent stations in 2005. Individual samples yielded between zero and 311 YOY striped bass. The AM of 17.8 was greater than the time-series average (12.0) and the TPA (12.0) (Table 2, Figure 2). The GM of 6.91 (Table 3, Figure 3) was also greater than the time-series average (4.32) and the TPA (4.32). The PPHL was 0.90, indicating that 90% 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 ($p=0.05$) ranked the 2005 $\log_e$-mean higher than 32 years of the time-series, and not significantly different than 10 years of the time-series. The 2005 $\log_e$-mean was significantly smaller than only six years of the time-series.

Coefficient of variation (CV) of the AM was 237.3% (Table 4), indicating a slightly larger variation between catches than has typically been observed (time-series average=208.4%).

System Means

Head-of-Bay - In 42 samples, 556 juveniles were collected at the Head-of-Bay sites, resulting in the AM of 13.2. This was slightly higher than the time-series average of 12.3, but lower than the TPA of 17.3 (Table 2, Figure 5). The GM of 8.58 was greater than both the time-series average (5.85) 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 ($p=0.05$) ranked 2005 significantly greater than 23 years, and significantly less than just one year of the survey (1958). The 2005 results were not discernable from 24 other years of the time-series.

Potomac River - A total of 432 juveniles was collected in 42 samples. The AM of 10.3 was greater than the TPA of 9.2 and the time-series average of 8.6 (Table 2, Figure 5). The GM of 7.92 was also greater than the time-series average (3.72) 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 2005 significantly greater than 34 years, and significantly less than just two years of the time-series (1993, 2003). It was not discernable from 12 other years of the time-series.

Choptank River - A total of 1,324 juveniles was collected in 24 Choptank River samples. The AM of 55.2 was more than double the time-series average of 20.7 and approximately five times the TPA of 10.8 (Table 2, Figure 5). The GM of 16.81 was also greater than the time-series average (8.33) 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 2005 year-class greater than 35 years, and not significantly different than 12 years of the time-series. The 2005 year-class was significantly smaller than only one year of the time-series (2001).

Nanticoke River - A total of 36 juveniles was collected in 24 samples on the Nanticoke River. The AM was 1.5, considerably less than the time-series average of 8.5 and the TPA of 8.6 (Table 2, Figure 5). The GM of 1.07 was approximately one-third the time-series average of 3.72 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 2005 significantly less than 16 years of the time-series. The 2005 index was statistically indiscernible from the remaining 32 years of the time-series.

Auxiliary Indices

At the **Head-of-Bay auxiliary sites**, 83 juveniles were caught in 15 samples, producing an AM of 5.53, slightly lower than the time-series average. The GM of 4.35 was higher than its time-series average (Table 5).

On the **Patuxent River**, 18 samples yielded 161 juveniles for an AM of 8.94 and a GM of 3.91 (Table 5). Both indices were lower than their respective 23 year averages.

DISCUSSION

All measures of relative abundance indicate a strong 2005 year-class for striped bass in Chesapeake Bay. Agreement among indices creates more certainty that they represent actual changes in YOY striped bass abundance. The bay-wide AM and GM were both above their respective long term averages and TPAs. The lower confidence interval of the AM overlaps the TPA and long-term average value (Figure 2), but the lower confidence interval of the GM does not overlap its TPA value (Figure 3). The Log Mean was also considerably higher than its long-term average and TPA (Table 4), ranking ninth highest since 1957 and above the third quartile. Duncan's multiple range test ranked the 2005 Log Mean significantly smaller than just six other years of the time-series. Those six years (1958, 1970, 1993, 1996, 2001, 2003) are among the dominant year-classes measured by the seine survey.

The 2005 striped bass year-class was widely and evenly distributed in Maryland's portion of the Chesapeake Bay, occurring in 90 % (PPHL=0.90) of the 132 samples. This was higher than the time-series average and TPA. The confidence intervals around the PPHL do not overlap those of its TPA (Table 4). Individual samples yielded between 0 and 311 YOY striped bass, resulting in fairly narrow confidence interval around the AM and GM as compared to the dominant year-classes of 1996 and 2001, for example, when sample ranges were 2,340 and 1,491, respectively.

Recruitment in individual spawning areas in 2005 was above average with the exception of the Nanticoke River. The AM and the GM in the Nanticoke were far below their respective time-series and TPA values. Both estimators are the lowest measured since 1991. Duncan's multiple range test did not rank the 2005 index greater than any year of the time-series.

The Head-of-Bay and Potomac River both produced AM and GM indices exceeding their respective time-series averages. The Potomac River GM was more than double the TPA and time-series average. Duncan's multiple range test found the log means in these systems to be indiscernible from the dominant year-classes of 1996 and 2001.

Choptank River samples produced the largest total number of YOY striped bass and the largest individual sample value of the year (311). Duncan's multiple range test found the 2005 Choptank log mean significantly smaller than only the large 2001 value, and indiscernible from 12 others, including the dominant year-classes of 1993, 1996, and 2003.

Results in auxiliary systems were fairly consistent. The Patuxent River AM and GM were the eighth highest of the 22 year time-series. Head-of-Bay sites, located primarily on the Susquehanna Flats, produced the seventh highest GM and the ninth highest AM of the time-series. Indices in both auxiliary areas were between the second and third quartile. Sample size in the Head-of-Bay has fluctuated in recent years due to an abundance of submerged aquatic vegetation at sample sites, which prevents the use of a beach seine.

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 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 ($r^2 = 0.62$, $p \leq 0.001$)(Figure 10). The equation that best described this relationship was, $C_1 = 0.193891 \times C_0 - 0.07163$, 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 very close to the predicted index of 0.27, as indicated by the small negative residual (Figure 11). Examination of residuals (Figure 11) shows that this regression equation can be used to predict subsequent yearling striped bass abundance with reasonable certainty in the case of average sized year-classes like that of 2004. 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 predation, cannibalism, increased competition for food, increased spatial distribution, or overwintering mortality. Higher than expected abundance of age 1 striped bass may identify particularly good conditions that enhanced survival.

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Table 1. Maryland juvenile striped bass survey sample sites.

Site Number	River or Creek	Area or Nearest Land Mark
	HEAD-OF-CHESAPEAKE BAY SYSTEM	
* 58	Susquehanna Flats	North side Spoil Island, 1.9 miles south of Tyding's Park
* 130	Susquehanna Flats	North side of Plum Point
* 144	Susquehanna Flats	Tyding's Estate, west shore of flats
* 132	Susquehanna Flats	0.2 miles east of Poplar Point
* 59	Northeast River	Carpenter Point, K.O.A. Campground beach
3	Northeast River	Elk Neck State Park beach
4	Elk River	Welch Point, Elk River side
5	Elk River	Hyland Point Light
115	Bohemia River	Parlor Point
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	Indianhead, 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. Maryland juvenile striped bass survey sample sites (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

Table 2. Maryland juvenile striped bass survey arithmetic mean catch per haul at permanent sites (continued).

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
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	0.3	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
1992	1.3	22.1	4.3	4.3	9.0
1993	23.0	36.4	105.5	9.3	39.8
1994	23.4	3.9	19.3	21.5	16.1
1995	4.4	8.7	17.7	10.4	9.3
1996	25.0	48.5	154.4	43.6	59.4
1997	8.3	10.6	7.3	3.5	8.0
1998	8.3	10.8	32.6	3.8	12.7
1999	3.1	15.7	48.2	18.7	18.1
2000	13.3	7.8	21.2	17.6	13.8
2001	13.4	7.8	201.9	40.1	50.8
2002	3.1	7.0	0.7	7.8	4.7
2003	28.4	23.6	41.8	8.7	25.8
2004	7.8	4.0	22.8	19.5	11.4
2005	13.2	10.3	55.2	1.5	17.8
AVERAGE	12.3	8.6	20.7	8.4	12.0
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	2.22	2.26
1956	6.88	4.50	6.22	4.03	5.29
1957	1.92	1.78	1.16	0.89	1.40
1958	22.07	3.93	11.01	17.89	11.12
1959	0.95	0.61	0.09	0.85	0.59
1960	3.18	2.44	4.31	2.01	3.01
1961	7.46	12.82	5.40	1.28	6.61
1962	3.73	6.70	3.14	3.09	4.25
1963	3.01	0.54	2.01	1.69	1.61
1964	15.41	9.15	4.92	6.08	9.04
1965	0.76	0.92	2.18	5.51	1.56
1966	15.89	4.95	5.52	1.57	6.24
1967	3.92	1.03	2.80	2.25	2.28
1968	6.13	0.39	3.85	3.93	2.69
1969	12.21	0.12	2.55	2.96	2.81
1970	13.71	10.97	25.41	6.29	12.48
1971	10.45	3.48	2.51	1.07	4.02
1972	4.95	0.96	5.36	5.16	3.26
1973	11.92	1.10	0.43	0.63	2.33
1974	6.79	0.66	3.55	2.11	2.62
1975	2.34	3.56	2.71	2.62	2.81
1976	2.70	1.46	0.89	1.02	1.58
1977	4.99	0.78	0.81	0.71	1.61
1978	6.51	3.33	2.65	2.26	3.75
1979	4.56	1.15	1.12	0.54	1.73
1980	1.43	1.04	0.58	0.78	1.01
1981	0.17	0.68	0.84	1.09	0.59
1982	2.98	3.50	5.68	2.96	3.54
1983	0.61	0.62	0.64	0.59	0.61

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

Year	Head-of-Bay	Potomac River	Choptank River	Nanticoke River	Bay-wide
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
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
AVERAGE	5.85	3.72	8.33	3.72	4.32
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	0.96	113.00	0.62	0.54	0.70	132
1978	8.4	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	103.58	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	0.52	0.43	0.60	132
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

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 (continued).

Year	AM	CV(%) of AM	Log Mean	CV(%) of Log Mean	PPHL	Low CI	High CI	n
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	0.82	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
AVG.	12.2	208.4	1.46	93.69	0.70	0.63	0.78	
TPA	12.0	194.8	1.52	93.18	0.71	0.62	0.80	

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

	Patuxent River			Head-of-Bay		
Year	**AM**	**GM**	**n**	**AM**	**GM**	**n**
1983	0.06	0.04	18	0.58	0.33	12
1984	0.61	0.39	18	0.92	0.43	12
1985	3.17	1.95	18	1.00	0.24	12
1986	2.44	1.17	18	0.92	0.54	12
1987	2.94	0.94	17	0.33	0.26	9
1988	0.59	0.40	17	1.62	1.07	21
1989	1.39	0.92	18	10.43	1.91	21
1990	0.28	0.17	18	4.95	2.24	21
1991	0.94	0.53	18	2.15	0.98	20
1992	9.50	1.85	18	0.50	0.26	20
1993	104.30	47.18	18	28.00	11.11	21
1994	4.10	2.82	18	6.30	2.31	21
1995	7.28	3.46	18	2.95	1.15	21
1996	420.39	58.11	18	12.40	4.69	20
1997	7.33	2.72	18	2.70	2.18	20
1998	13.22	7.58	18	2.94	1.51	16
1999	7.28	5.39	18	3.62	2.13	13
2000	9.67	5.03	18	8.60	5.68	15
2001	17.28	10.01	18	19.47	6.62	15
2002	1.22	0.69	18	1.00	0.42	15
2003	61.11	22.17	18	16.06	11.79	16
2004	2.11	1.29	18	7.73	4.40	15
2005	8.94	3.91	18	5.53	4.35	15
AVG	29.83	7.77		6.12	2.90	

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

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

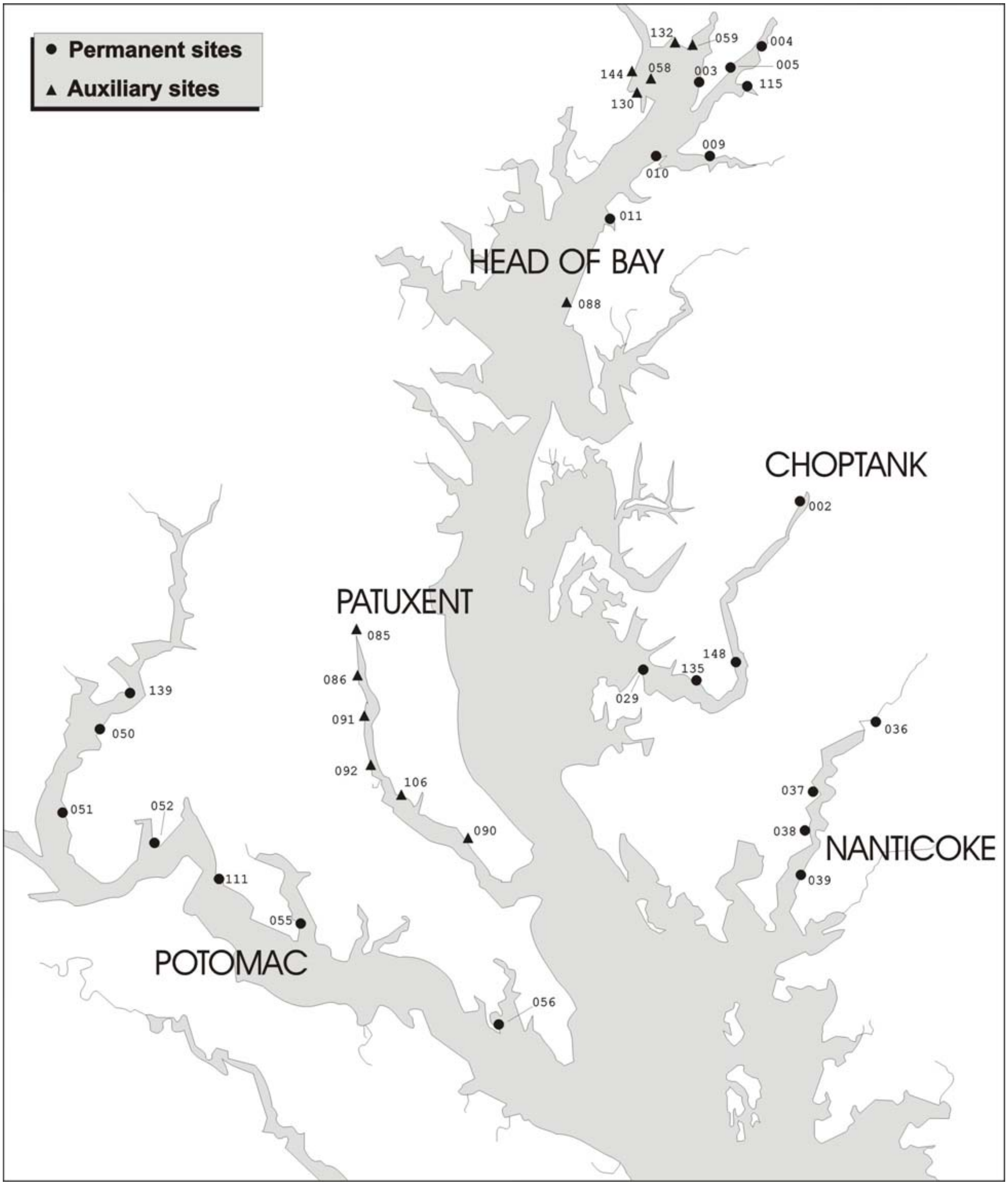


Figure 2. Maryland Chesapeake Bay arithmetic mean (AM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

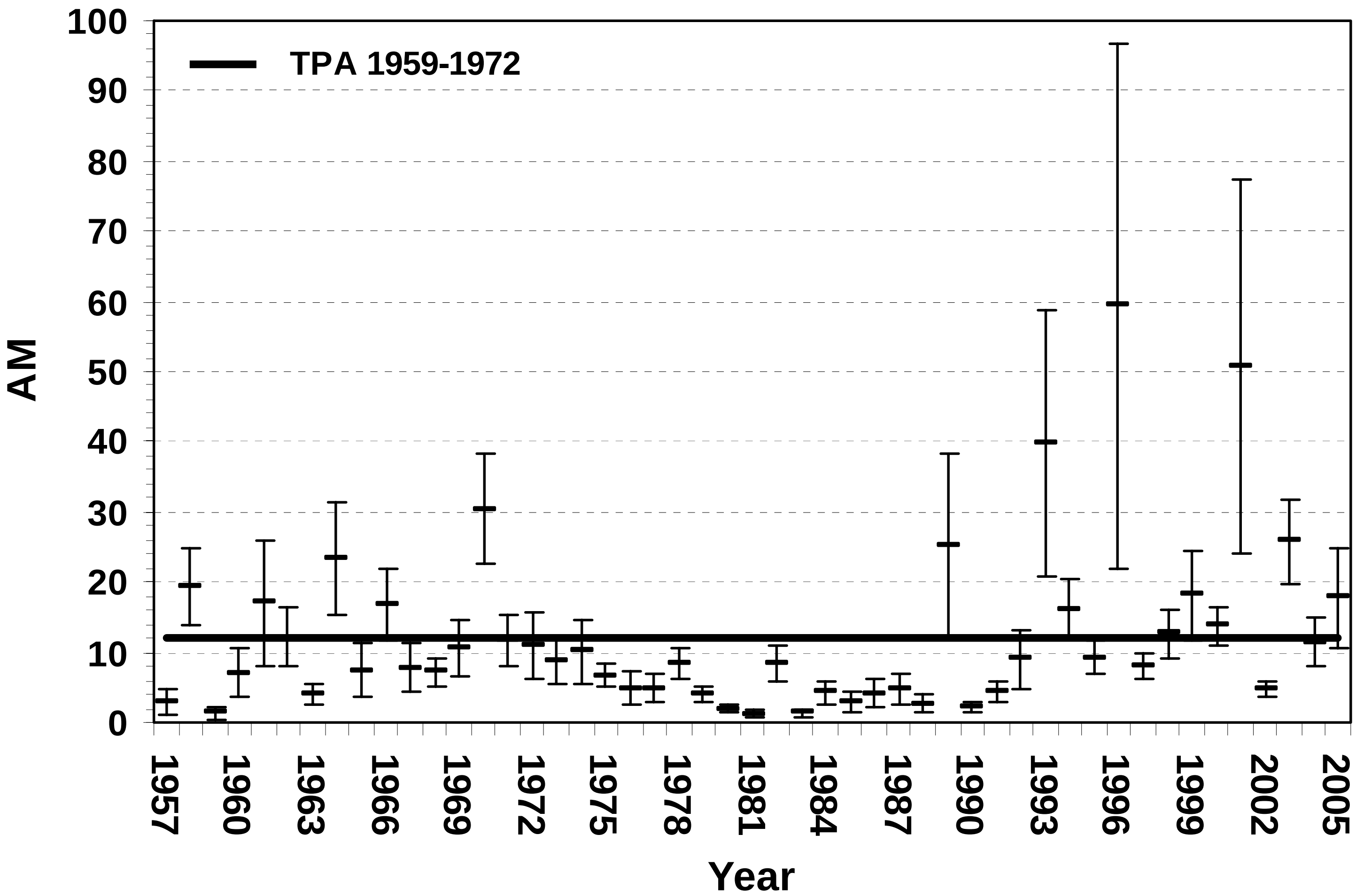


Figure 3. Maryland Chesapeake Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

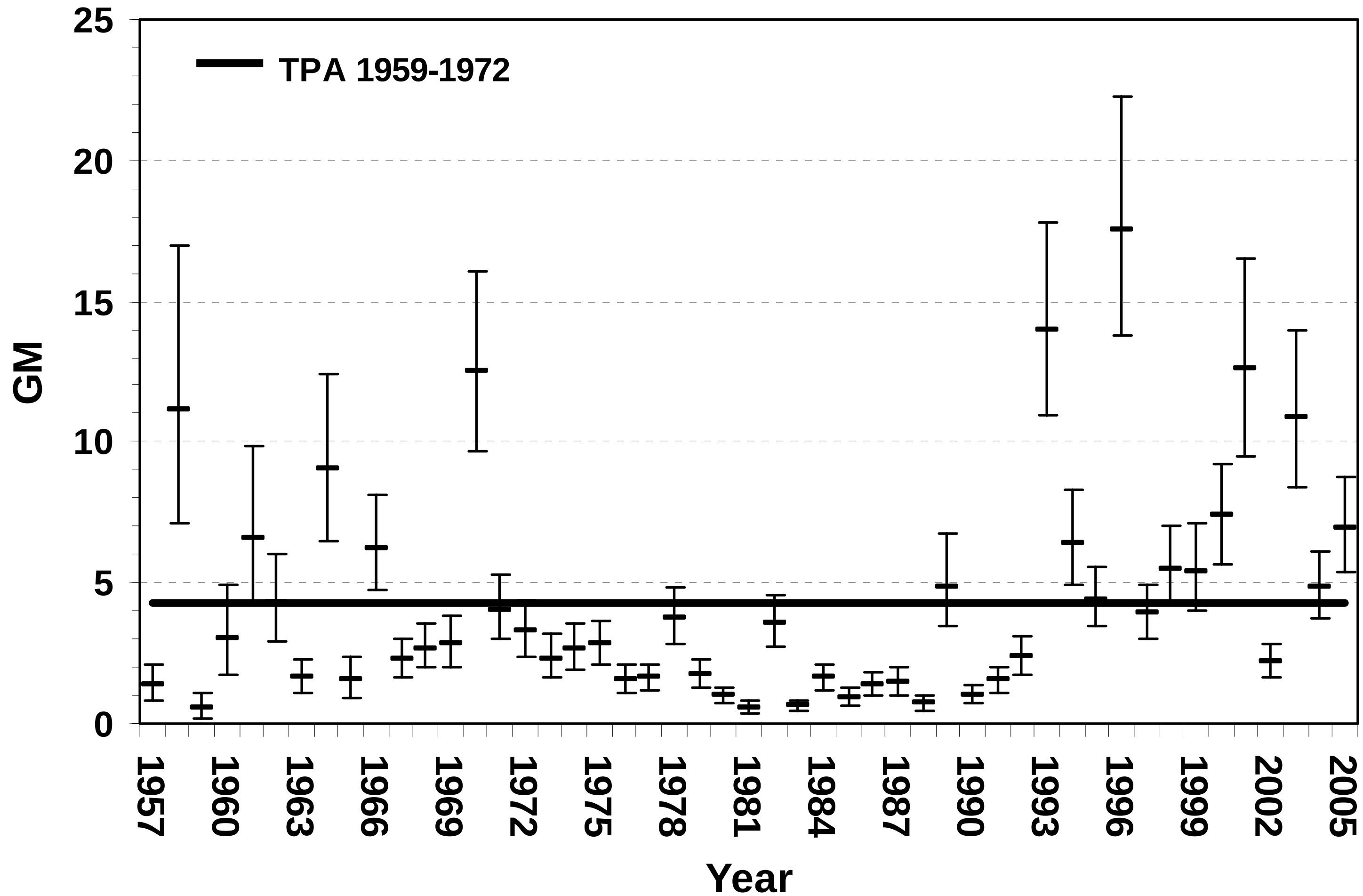


Figure 4. Maryland Chesapeake Bay juvenile striped bass indices. Arithmetic mean (AM), scaled geometric mean (GM)*, and proportion of positive hauls (PPHL).

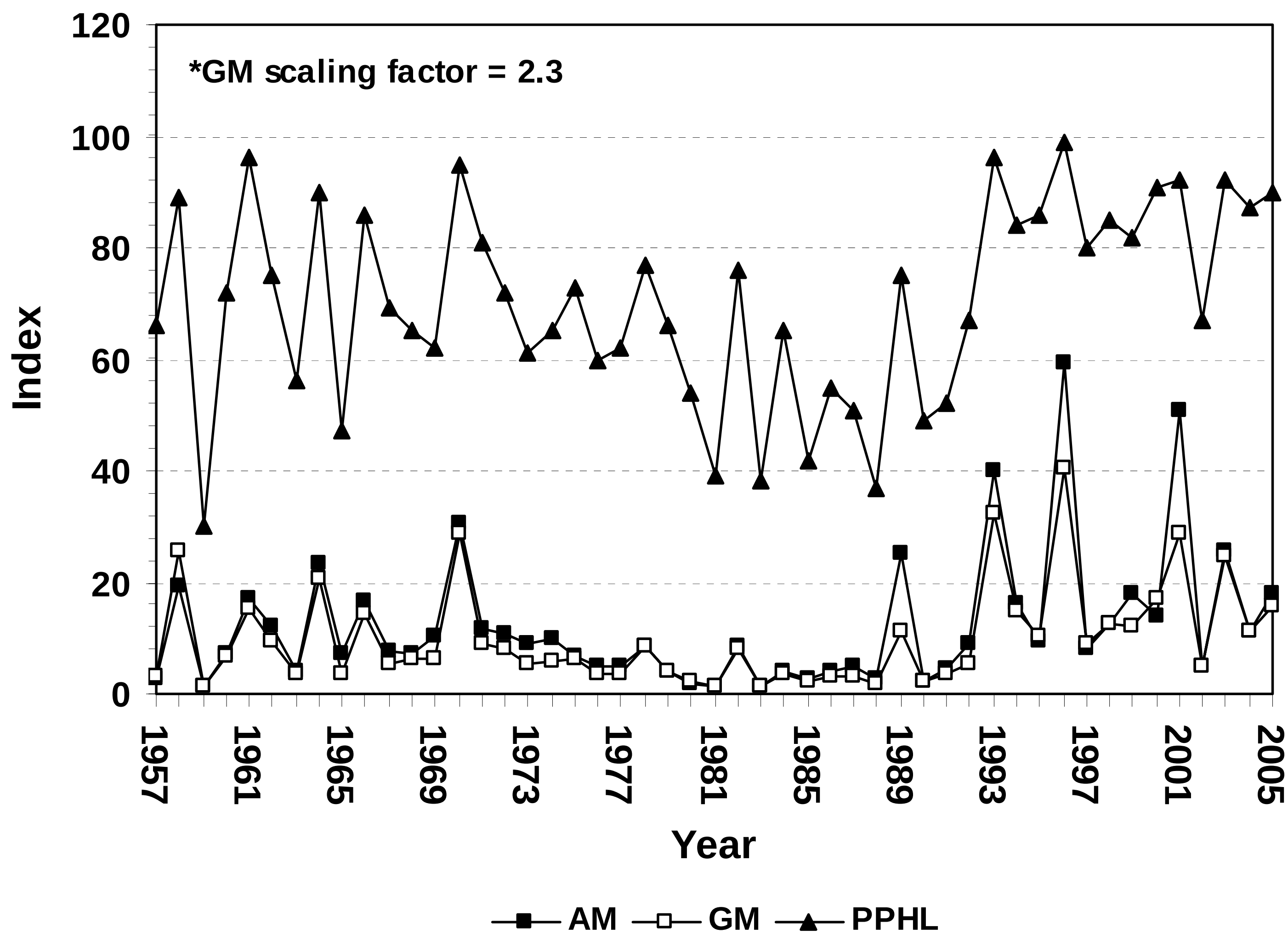


Figure 5. Arithmetic mean (AM) catch per haul by system for juvenile striped bass. Note different scales.

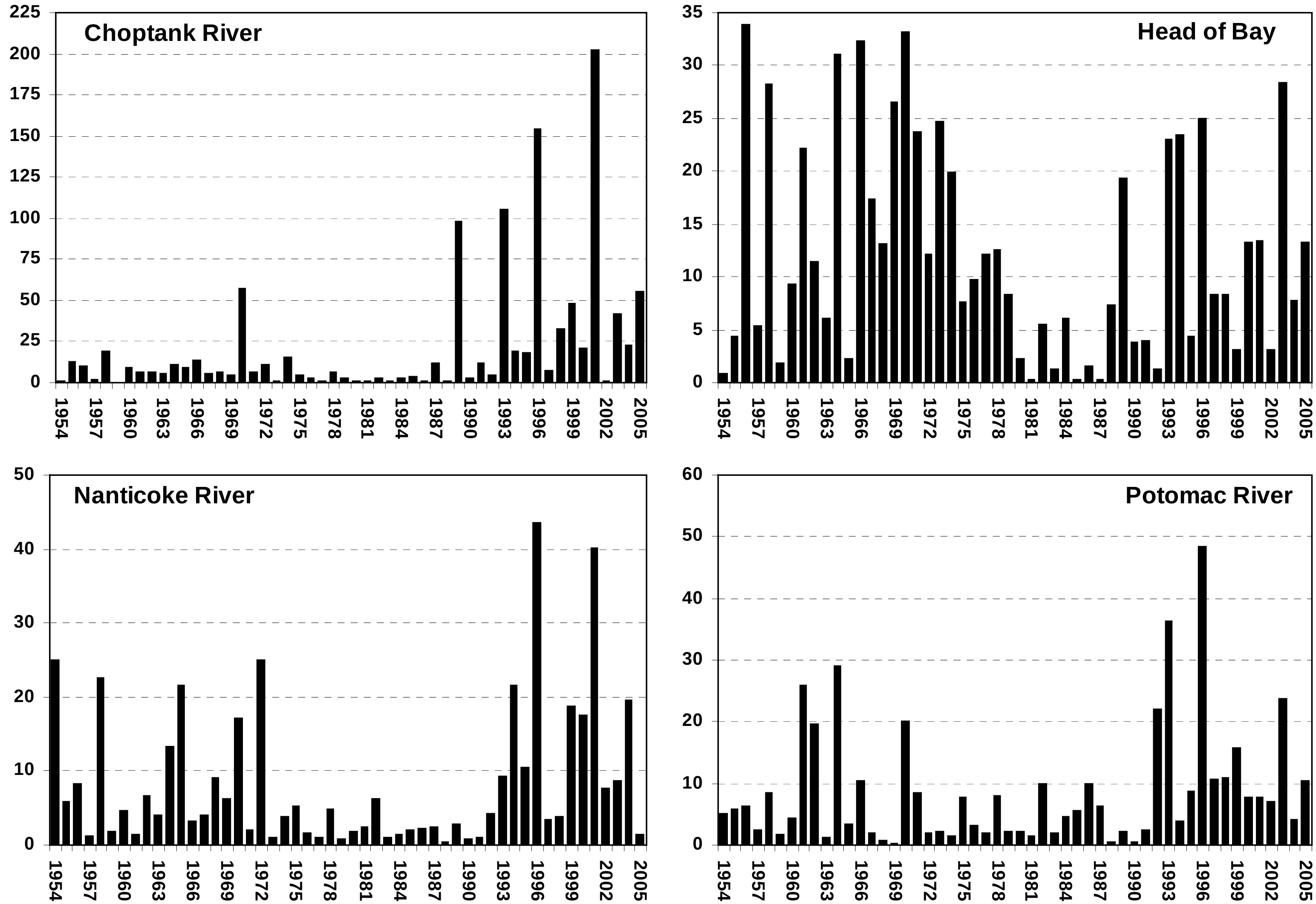


Figure 6. Head-of-Bay geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

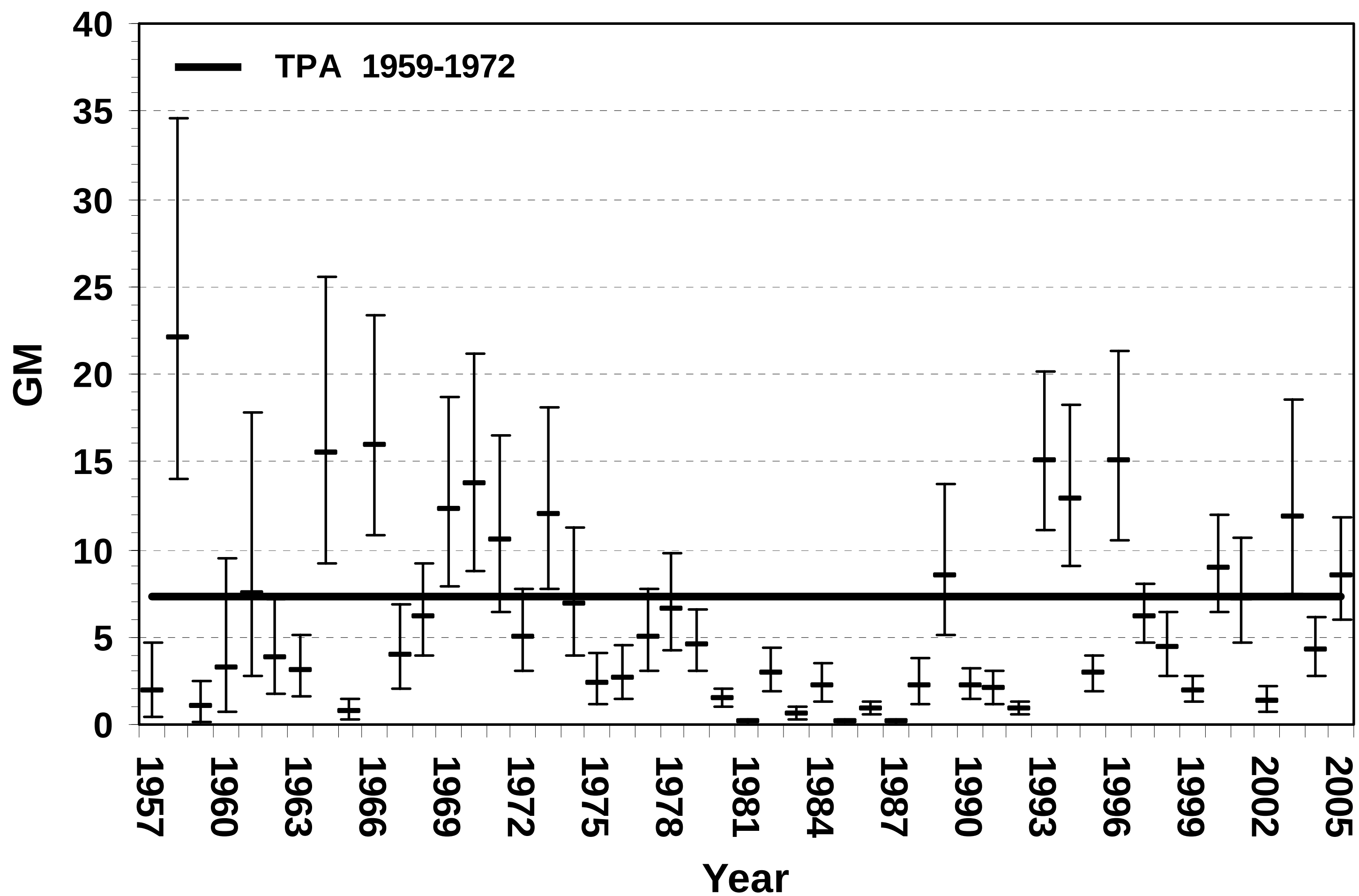


Figure 7. Potomac River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

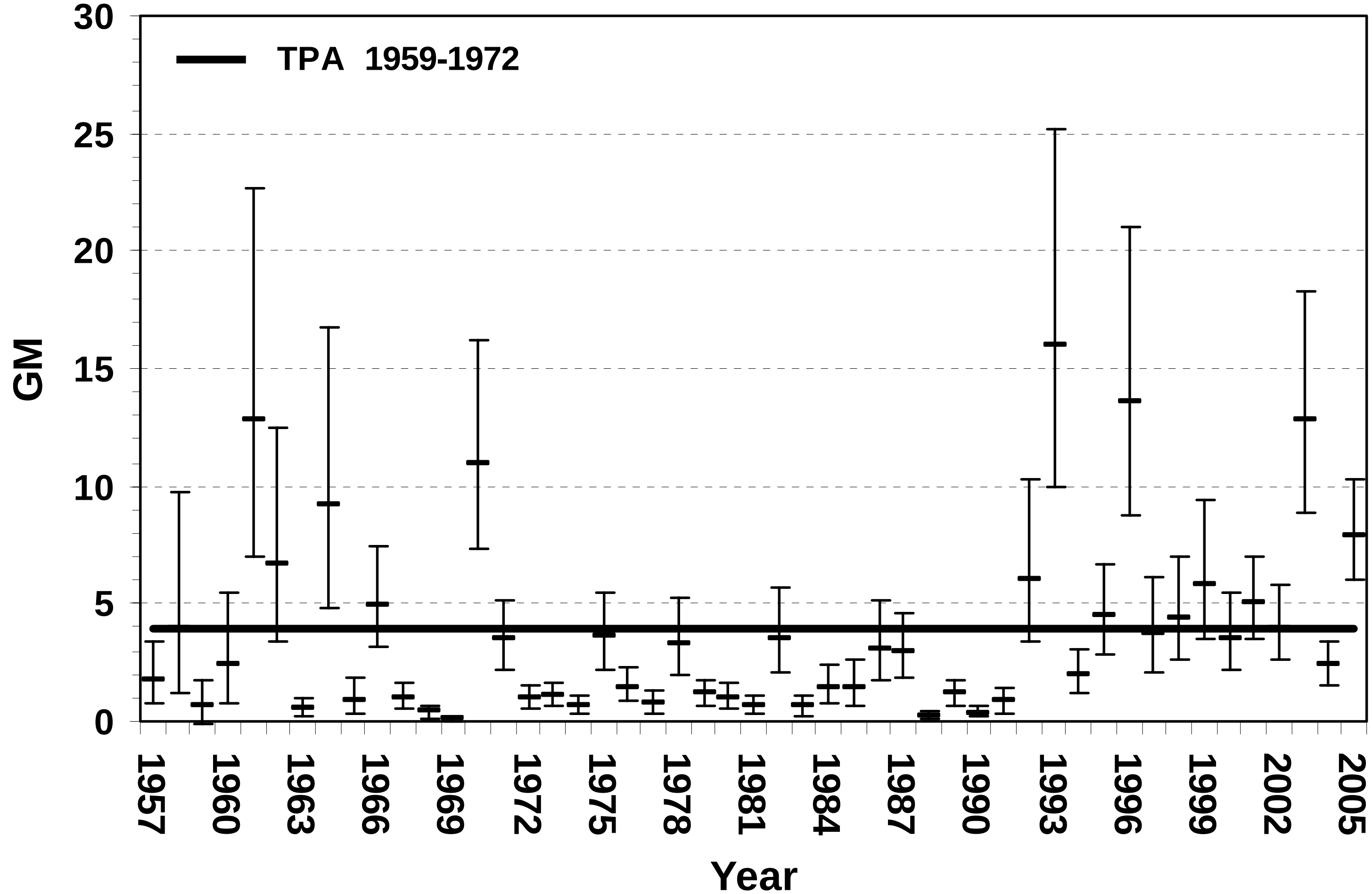


Figure 8. Choptank River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

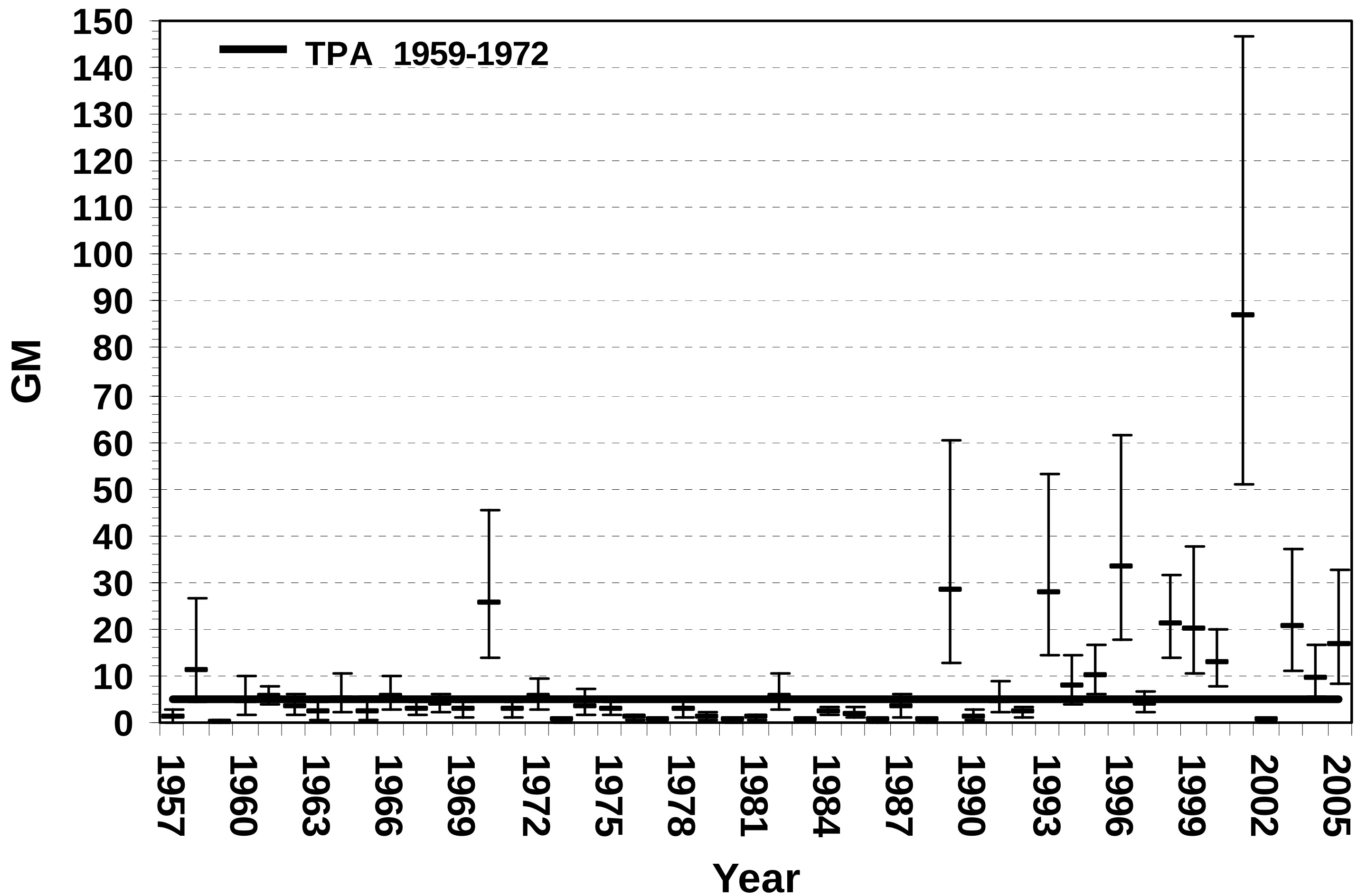


Figure 9. Nanticoke River geometric mean (GM) catch per haul and 95% confidence intervals (+/- 2 SE) for juvenile striped bass with target period average (TPA).

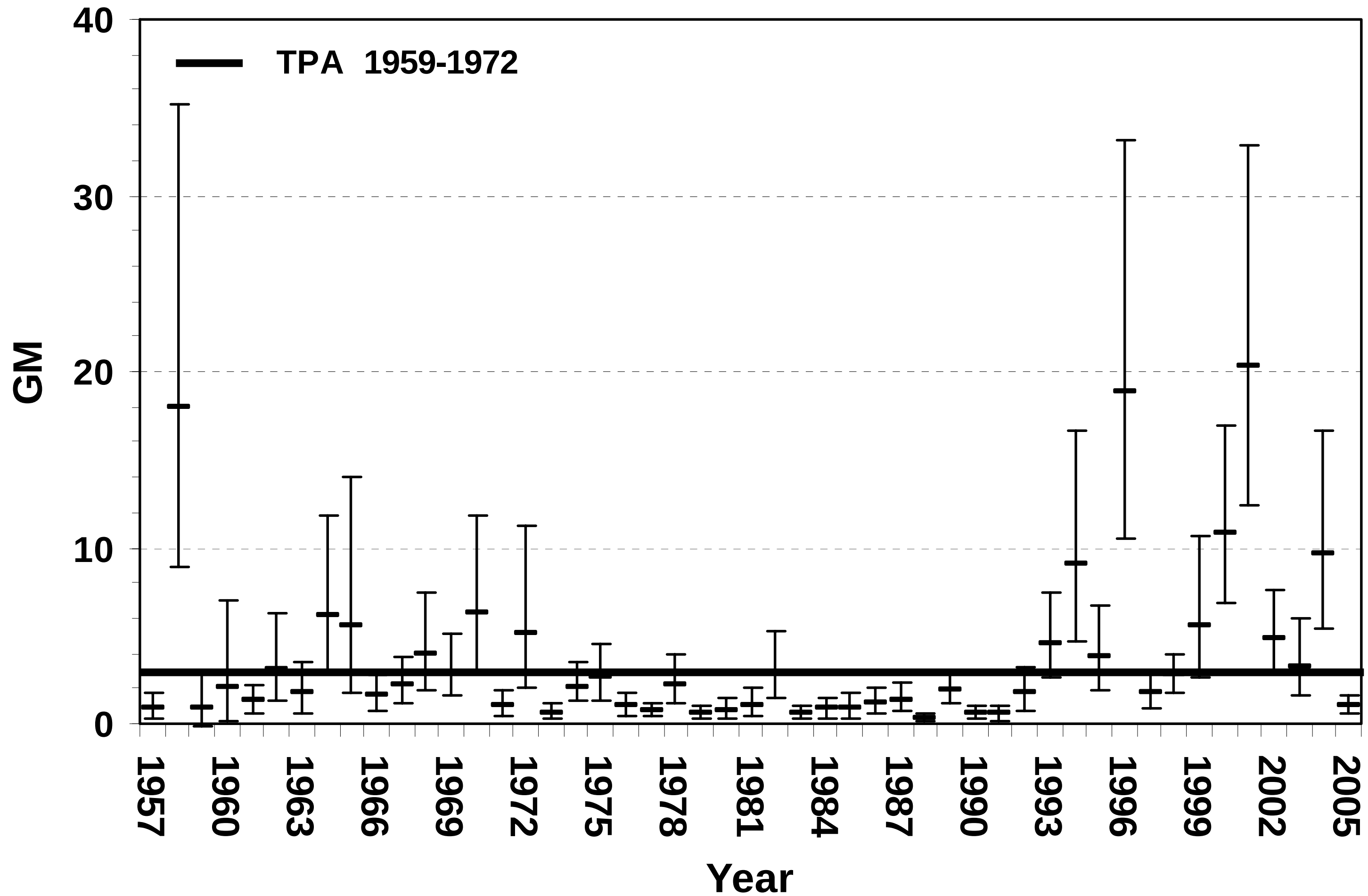


Figure 10. Regression of age 1 on age 0 striped bass.

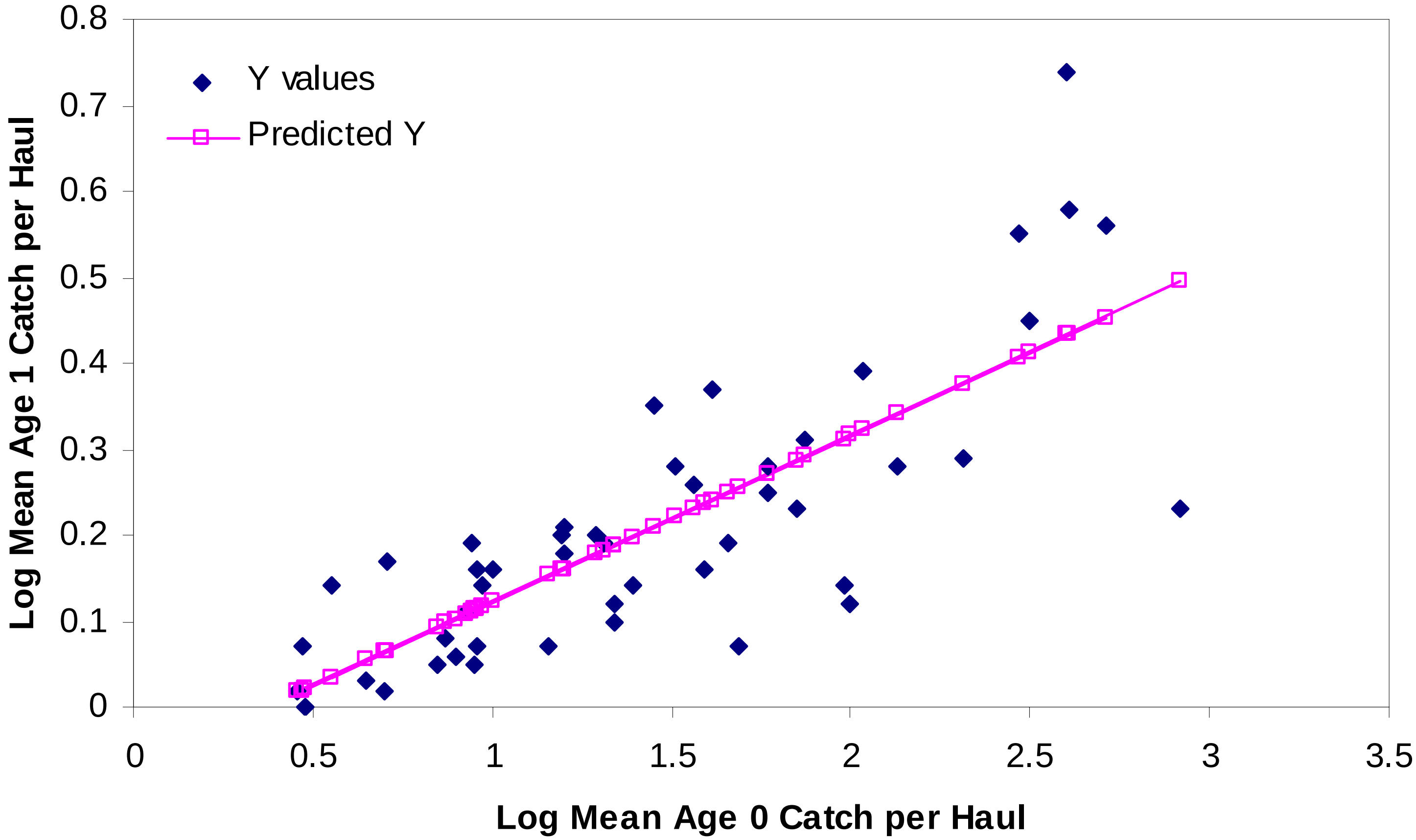
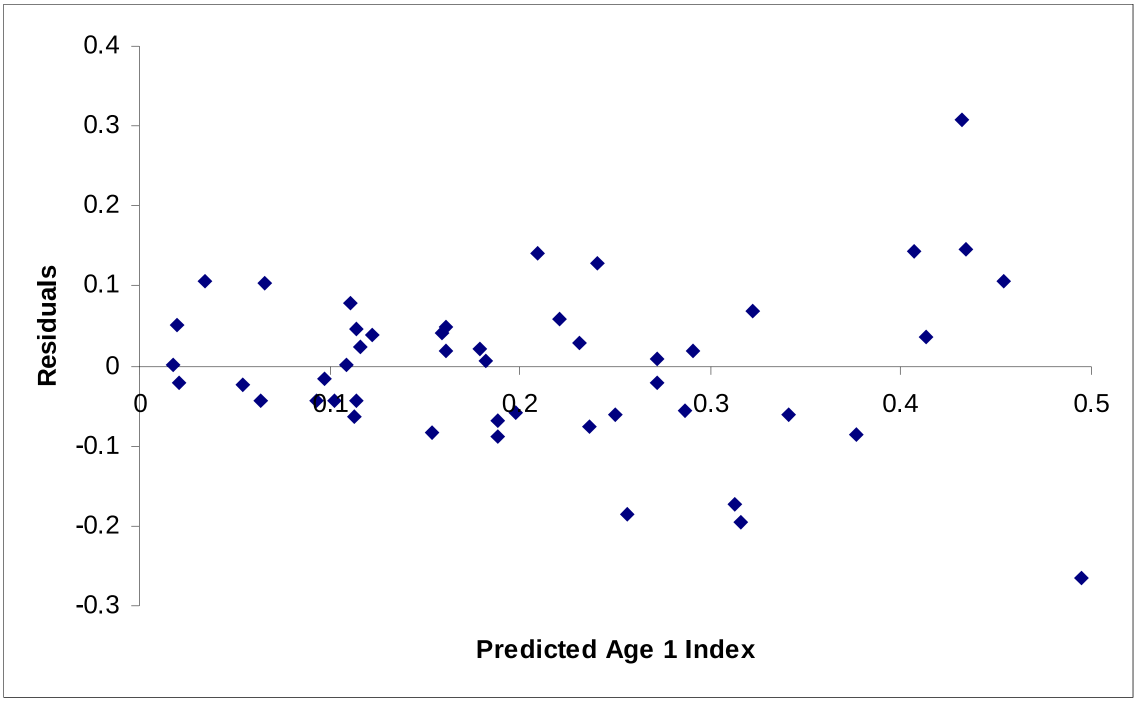
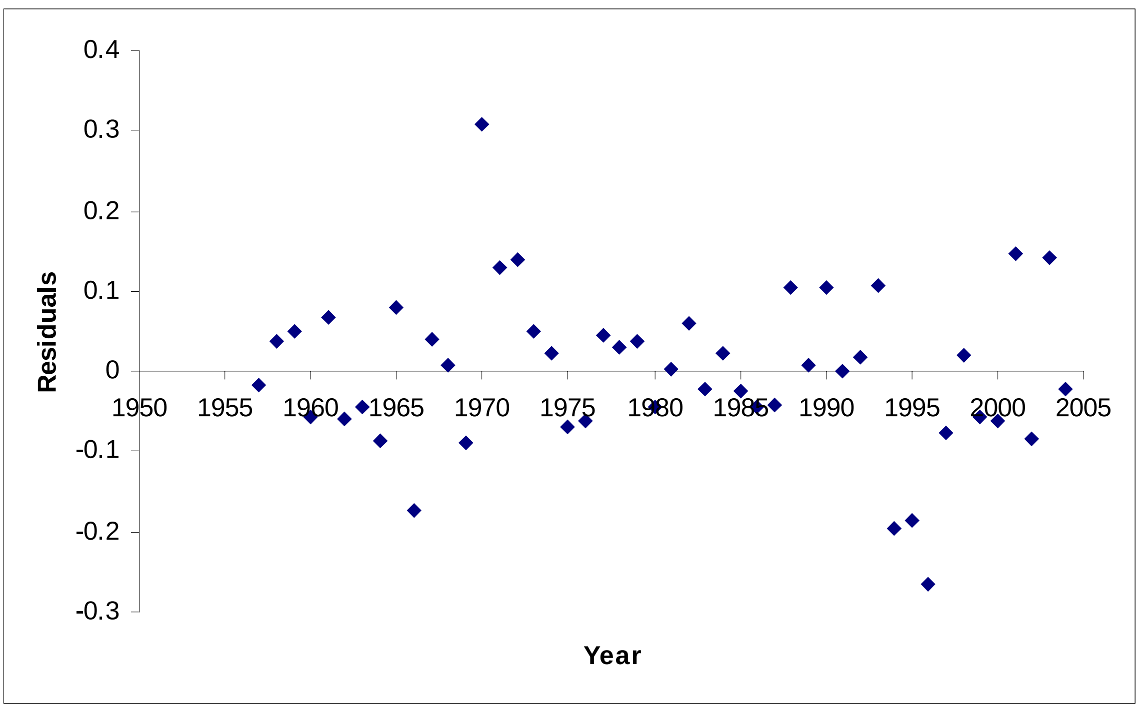


Figure 11. Residuals of age 1 and age 0 striped bass regression.





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 2004 through spring 2005. The Maryland Department of Natural Resources (MD DNR) tagged striped bass as part of the United States Fish and Wildlife Service's (USFWS) Cooperative Coastal Striped Bass Tagging Program. Fish were tagged from the Chesapeake Bay resident/pre-migratory and spawning stocks, and from the Atlantic coastal stock. Subsequently, tag numbers and 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.

METHODS

Sampling procedures

Striped bass were tagged in Maryland's portion of the Chesapeake Bay during two separate studies. The first study was designed to estimate the 2004 directed instantaneous fishing mortality rate (F) (Figure 1). Fish were tagged in the upper, middle and lower regions of the Chesapeake Bay concurrently with the summer and fall stock assessment sampling (see Task No. 1A).

Fish were sampled from the pound nets of cooperating commercial fishermen throughout the summer and fall during five rounds of tagging. Fish were removed from the pound nets and placed in a holding tank aboard the sampling boat prior to application of internal anchor tags. Scales were collected from three fish per 10-mm length group, per area, in each tagging round. Scale samples were taken from all fish over 700 mm TL.

The second study was a fishery-independent spawning stock study in which tags were applied to fish captured with experimental multi-panel drift gill nets in the upper Chesapeake Bay and the Potomac River from late March through May 2005 (see Task No. 2) (Figure 2). 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 or 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.

Additionally, from January 25 to February 2, 2005, 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 2.4 to 4.5 knots at depths of

34 to 106 feet (10.4 – 32.3 m) for 0.03 to 0.72 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 or 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 into 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

Tag release and return data from legal sized fish ($\geq$457 mm TL) released for the summer-fall directed fishing mortality study were used in a logistic regression analysis to determine the 2004-2005 estimate of fishing mortality for Chesapeake Bay (Hornick et al. 2005). The bay-wide study was conducted concurrently by MD DNR and the Virginia Marine Resources Commission (VMRC) to produce an estimate of fishing mortality for the entire Chesapeake Bay.

Data from tags applied in the fall and spring were analyzed separately because it is generally recognized that striped bass tagged in the fall are predominantly Chesapeake Bay residents, whereas those tagged in the spring are a mixture of residents and coastal migrants. Survival rates from fish tagged during the spring in Maryland 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 2005 will not be completed until after 3/27/06, these estimates will not be stated in this report.

Estimates of survival, fishing mortality and recovery rates for the North Carolina tagging data were calculated using the same methods as Maryland's spring tagging data. 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

A total of 7,807 striped bass were sampled in Maryland's portion of Chesapeake Bay between May 11, 2004 and May 19, 2005 and 5,053 (65%) were subsequently tagged and released (Table 1 and Table 2). An additional 4,298 striped bass were sampled offshore during the SEAMAP winter cooperative tagging cruise, of which 4,263 were tagged and released (Table 3).

Summer/Fall tagging

During the summer/fall (May - October) of 2004, 61% (3,772 fish) of striped bass sampled from pound nets were tagged and released (Table 1). Sub-legal fish (<457 mm TL) captured in the pound nets were also measured in order to supplement the age-length key for the resident stock and to obtain discard data for the recreational fishery. Length measurements from 1,618 sub-legal fish (26% of fish sampled) were taken and scale samples collected from a representative sub-sample. Only legal sized fish ($\geq$ 457 mm TL) were tagged and used in the analysis for the fall directed fishing mortality estimate (Hornick et al. 2005). The mean total length of striped bass tagged during the summer and fall of 2004 (509 mm TL) was significantly different ($P<0.05$) from the mean total length of the entire sample (483 mm TL) due to the inclusion of sub-legal fish (Figure 3).

With sampling expanded to include sub-legal striped bass, the length frequency distribution of the sample was more representative of the total Chesapeake Bay striped bass pre-migratory population, rather than just legal-sized fish. However, several cooperating fishermen cull their catch, selecting larger, more valuable fish for sale, and those fish were unavailable to the sampling program. Consequently the length frequency may not fully represent fish larger than 28 inches (711 mm TL) present in the Chesapeake Bay during the summer and fall.

Tag releases and recaptures from both Maryland and Virginia's data were used to estimate a combined Bay-wide instantaneous fishing mortality rate (F) for the 2004-2005 recreational, charter boat, and commercial fisheries for the entire Chesapeake Bay. More specific methods and analytical details may be found in Hornick, et al. 2005. The Bay-wide estimate of F, directly attributable to the combined recreational, charter boat, and commercial fisheries, was F = 0.06. Estimated non-harvest mortality, M = 0.10, (ASMFC 1998) was added to F to obtain the final estimate of total Bay-wide fishing mortality of F = 0.16 (Hornick et al. 2005). The variance of 0.0004 was equivalent to a CV of 32.4%. This analysis indicates that resident Chesapeake Bay striped bass were fished below the target of F = 0.27 set by the ASMFC (ASMFC 2003).

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. The goal was to tag as many healthy striped bass as possible. In 2005, 1,652 striped bass were sampled and 1,281 (78%) were tagged as part of the routine spring sampling (Table 2). 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 2005 (570 mm TL) was significantly greater ($P<0.05$) than that of the sampled population (551 mm TL) (Figure 3).

Estimates of survival and fishing mortality for the Chesapeake Bay spawning stock will be presented in the next report of the ASMFC Striped Bass Tagging Working Group (ASMFC 2005).

USFWS cooperative tagging cruise

The primary objective of the tagging cruise was to apply tags to as many striped bass as possible, and as a result, 99% of the striped bass sampled on the cruise were tagged (Table 3). There was no significant difference ($P<0.05$) between mean total lengths of tagged fish (582 mm TL) versus the entire measured sample (582 mm TL) of striped bass during 2005 (Figure 3). The 2005 mean total lengths were significantly smaller than the mean total lengths (623 mm TL – tagged and total sample) of the 2004 cruise. Large numbers of smaller fish were encountered in 2004 and 2005; however, fewer large fish were captured in 2005. The NC DMF is presently completing age determination for the 2005 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 Working Group (ASMFC 2005).

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Table 1. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay, May - October 2004.

SYSTEM	INCLUSIVE RELEASE DATES	TOTAL FISH SAMPLED	TOTAL FISH TAGGED	APPROXIMATE TAG SEQUENCES [a]
Main Chesapeake Bay	5/11/04-10/27/04	6,155	3,772	468042 - 469000 483296 - 485493 485501 - 486143
Directed fishing mortality study totals:		6,155 [b]	3,772 [c]	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes 46 USFWS tag recoveries, 2 fish with missing lengths and 1,618 sub-legal fish (<457 mm TL).
[c] Total tagged includes 2 fish with missing lengths and 2 sub-legal fish (<457 mm TL).

Table 2. Summary of USFWS internal anchor tags applied to striped bass in Maryland's portion of Chesapeake Bay and Potomac River, March - May 2005.

SYSTEM	INCLUSIVE RELEASE DATES	TOTAL FISH SAMPLED	TOTAL FISH TAGGED	APPROXIMATE TAG SEQUENCES [a]
Potomac River	3/30/05-5/10/05	249	232	489501 - 489733
Upper Chesapeake Bay	4/5/05-5/19/05	1,403	1,049	485494 - 485499 485581 486145 - 486499 488001 - 488696
Spring spawning survey totals:		1,652 [b]	1,281	

[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 and 2 fish with missing lengths.

Table 3. Summary of USFWS internal anchor tags applied to striped bass during the 2005 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)	1/25/05-2/2/05	4,298	4,263	496001 - 500273
Cooperative tagging cruise totals:		4,298 [b]	4,263 [c]	

[a] Not all tags in reported sequences were applied; some tags were lost, destroyed, or applied out of order.
[b] Total sampled includes 8 USFWS tag recoveries, 2 American Littoral Society tag recoveries and 1 fish with a missing length.
[c] Total tagged includes 1 fish with a missing length.

Figure 1. Tagging locations of Chesapeake Bay commercial pound nets sampled from May through October 2004. Numbers within dotted lines indicate area NOAA codes.

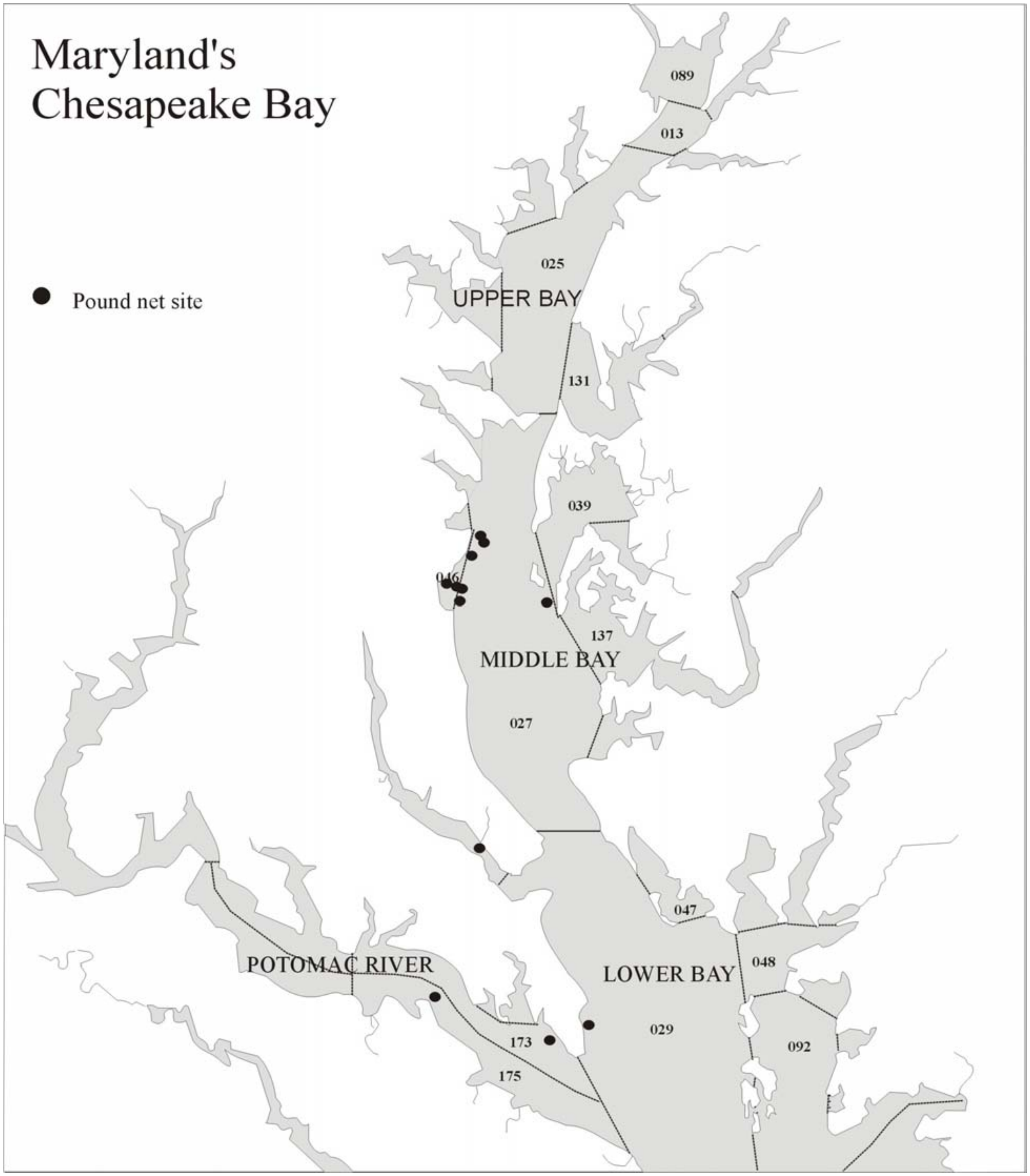


Figure 2. Tagging locations in spawning areas of the Upper Chesapeake Bay and the Potomac River, March - May 2005.

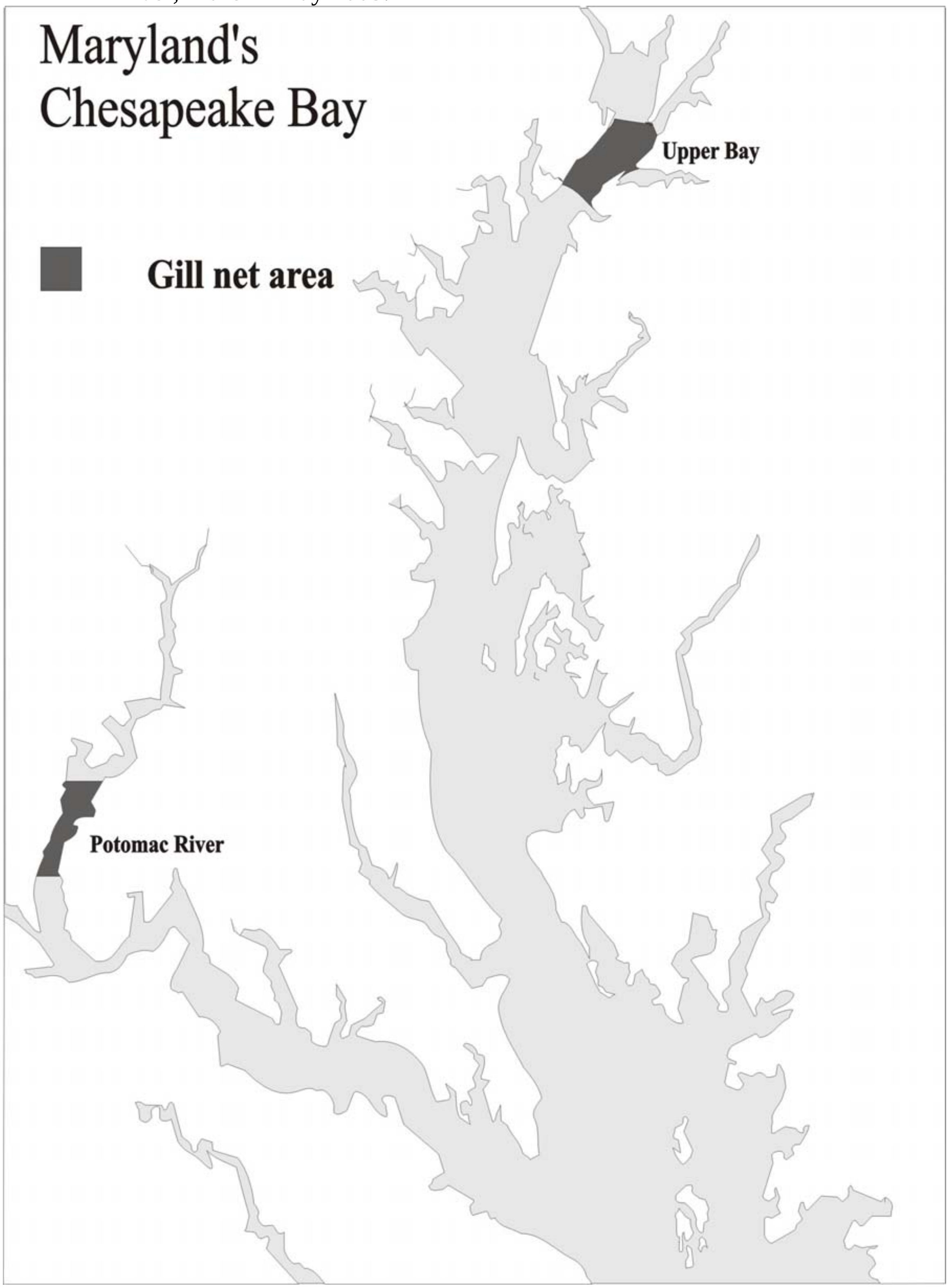
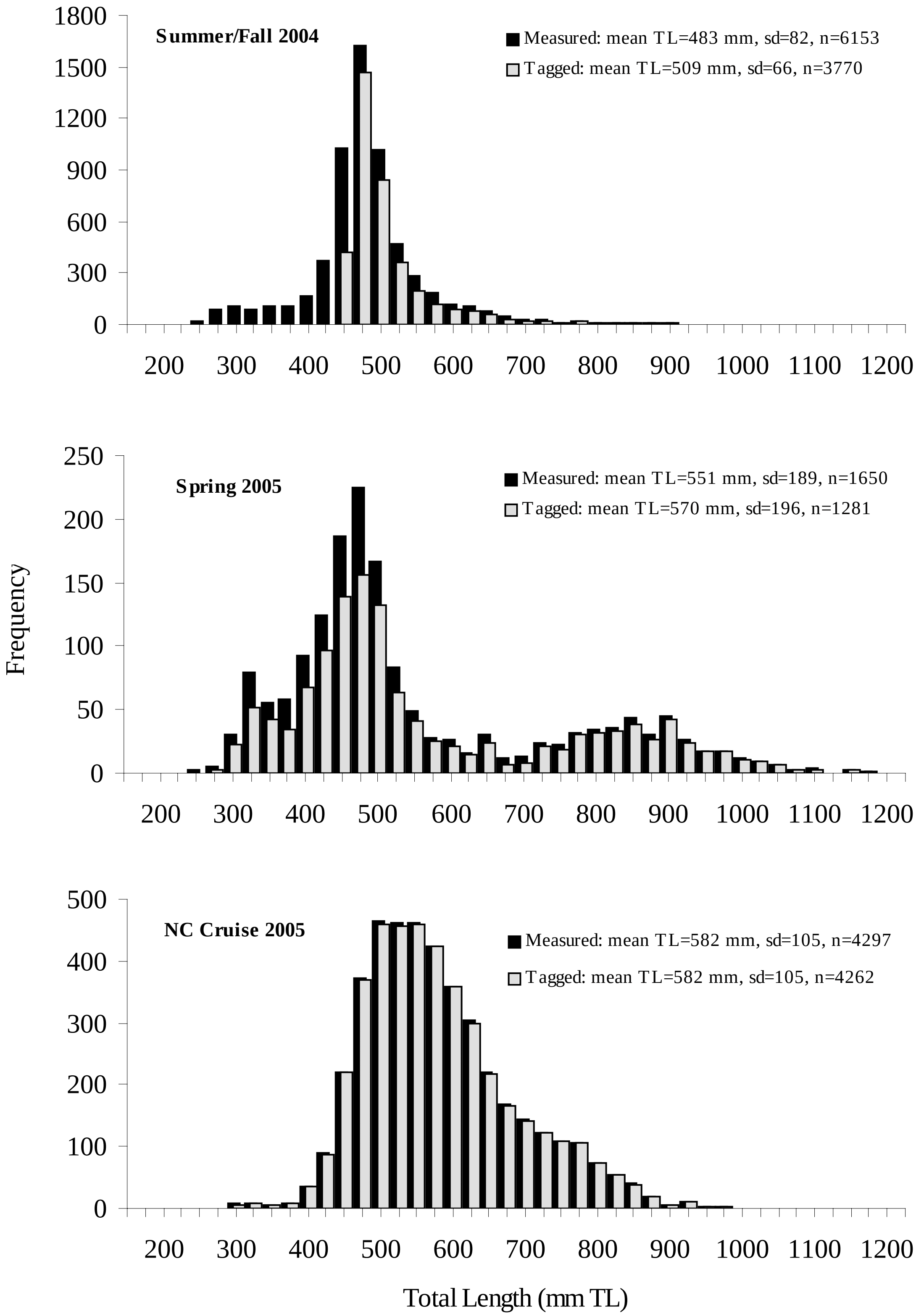


Figure 3. Length frequencies of striped bass measured and tagged during the summer, fall and spring in Chesapeake Bay, and offshore during the SEAMAP tagging cruise. Note different scales.



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

COMMERCIAL FISHERY HARVEST MONITORING

Prepared by Craig Weedon and Harry T. Hornick

INTRODUCTION

The primary objective of Task 5 is to characterize the commercial striped bass harvest in 2004. The Maryland Department of Natural Resources (MDDNR) changed the organization of its commercial quota system from a seasonal to a calendar year system in 1999.

Maryland completed its fifteenth commercial fishing year utilizing a quota system since the striped bass fishing moratorium was lifted in 1990. The 2004 commercial quota for the Chesapeake Bay and its tributaries was 1,873,000 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 separate quota of 126,398 pounds, with a 24-inch (TL) minimum size for the State's jurisdictional waters off the Atlantic Coast.

The Chesapeake Bay quota was further subdivided by gear type. The hook-and-line and drift gill net fisheries were combined, and allotted 75% of the quota. The pound net and haul seine fisheries were allotted the remaining 25% (Table 1). When the allotted quota for a fishery (gear type) was not landed, it was transferred to another fishery.

Discrete seasons were defined and managed for each fishery. The hook-and-line (HL) fishery was open on selected days from June 14 to November 30, 2004. The pound net (PN) fishery was open from June 1 through November 30, 2004. The haul seine (HS) fishery was open from June 7 to November 30, 2004. The Chesapeake Bay drift gill net (GN) season was split, with the first segment from January 1 through February 28, 2004, and the second segment from December 1-December 31, 2004. The Atlantic Coast fishery consisted of two gear types, Atlantic drift gill net (AG), and Atlantic trawl (AT). Both gear types were permitted during the

Atlantic season, which occurred in two segments: January 1 through April 30, 2004 and November 1 through December 31, 2004.

Striped bass commercial harvest data has been used as a general measure of stock size (Schaefer 1972, Goodyear 1985). Catch per unit effort (CPUE) data has traditionally been more widely used outside of the Chesapeake Bay as an indicator of stock status (Ricker 1975, Cowx 1991). Catch and effort data provides useful information regarding the various components of a fishery, and group patterns of use of the fisheries resource. CPUE estimates are used as indicators of stock abundance in fisheries where there is little or no fisheries independent data on stock size. Therefore, Maryland striped bass commercial fishery CPUE estimates will be examined and compared to fishery independent trends in relative abundance of Chesapeake Bay striped bass.

METHODS

In March 2003, commercial finfish license holders were notified by the MDDNR that participation in the striped bass fishery required a declaration of intent to fish using a legal gear. A deadline of August 31, 2003 was established for receipt of their declaration. The Department charged a fee to participants based upon the type of license they held. Participants who held a Tidal Fishing License (TFL) were required to pay $100.00. Participants who held an Unlimited Finfish Harvester License (FIN) or Hook and Line License (HLI), 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 the Department.

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 MDDNR, counted, weighed, and verified that all the fish were tagged. They 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 MDDNR and report the total pounds of striped bass they had checked the previous day (Figures 2-3). These reports allowed MDDNR to monitor the fisheries' daily progress towards their respective quotas. Check stations were also required to keep daily written logs detailing the activity of each fisherman, which were returned weekly by mail to MDDNR. Individual fishermen were then required to return their striped bass permit to the Department at the end of the season.

Individual fishermen were also required to report their striped bass harvest on an additional monthly fishing report (MFR) provided by the 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 monthly fishing report: Day of Month, NOAA Fishing Area, Gear Code, Quantity of Gear, Duration, Number of Sets, Trip Length (hours), Number of Crew, Pounds (by species).

Catch data collected from the check stations and effort data from the MFRs for striped bass fishermen were analyzed with the primary objective of presenting a post-moratoria summary of baseline data on commercial catch and CPUE. Catch per unit effort estimations by gear type were derived by dividing total pounds landed by gear by the number of reported trips from the MFRs.

RESULTS AND DISCUSSION

On the Chesapeake Bay and its tributaries, 1,784,086 pounds of striped bass were harvested in 2004. This represented 95.3 % of the Chesapeake quota for the 2004 commercial fishing season. The estimated number of fish landed was 625,810. The Bay drift gill net fishery contributed 51.6 % (pounds) of the total landings and the pound net fishery contributed 28.4 % (pounds). The hook-and-line fishery harvested the remaining 20 % (pounds). The haul seine fishery did not harvest any striped bass for the second consecutive year (Table 3).

Maryland's Atlantic Coast landings were 115,453 pounds. The estimated number of fish landed was 14,090. This represented 91.3 % of the Atlantic Quota. The trawl fishery accounted for the majority (76 %) of the Atlantic harvest (Table 3).

DNR biologists performed direct sampling of striped bass at Chesapeake Bay check stations to characterize the harvest of commercial striped bass fisheries (Tasks 1A and 1B, this report). The mean weight per fish of striped bass harvested in Chesapeake Bay, regardless of gear type, was 4.23 pounds. Mean weights by specific gear type were consistent, ranging from 3.01 to 5.01 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 5.01 pounds per fish.

Striped bass harvested from the Atlantic Coast averaged 8.19 pounds (Table 4). Biological sampling is not currently performed at Atlantic check stations, so the average weight of striped bass harvested was calculated using data from 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 pound landed was divided by the number of trips to calculate an estimate of catch per unit of effort (CPUE). Calendar year 2004 showed drops in CPUE for the hook and line (170 lbs per trip) and pound net fisheries (162 lbs per trip) from the high CPUE values in 2003 (204, and 264 lbs per trip, respectively). The gill net CPUE remained near its previous high at 285 pounds per trip (Table 5, Figure 4).

The hook-and-line CPUE has exhibited the lowest CPUE estimates (pounds per trip) of the three fisheries since 1990, except in 2004, when it exceeded the pound net fishery CPUE. Over the past three years, the gillnet fishery had the highest average CPUE value of 276 pounds per trip, followed by the pound net fishery (211 lbs per trip) and the hook-and-line fishery (184 lbs per trip).

The Atlantic trawl fishery CPUE was 473 pounds per trip in 2004. The Atlantic trawl fishery CPUE peaked in 1995 (994 lbs per trip) when the quota was increased, but has stabilized since 1996, averaging 445 pounds per trip over the past nine years. The 2004 CPUE for the Atlantic gill net fishery was 123 pounds per trip, the lowest value since 1996. It has averaged 222 pounds per trip over the past nine years.

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 striped bass fishery has demonstrated similar CPUE trends since 1996. Such positive trends in CPUE are consistent with an increase in overall striped bass stock abundance as determined from fishery independent surveys conducted by the Department and by other states on the Atlantic coast (ASMFC 2005).

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Table 1. Striped bass commercial harvest quotas (lbs) by gear type for the 2004 calendar year.

GEAR TYPE	TOTAL ADJUSTED HARVEST QUOTA
Haul Seine, Pound Net	468,250
Hook and Line	646,185
Drift Gill Net	758,564
CHESAPEAKE TOTAL	**1,873,000**
Atlantic: Trawl, Gill Net	126,396
MARYLAND TOTAL	**1,999,396**

Table 2. Individual season and daily harvest allocations (lbs) and the number of declared striped bass fishermen for the 2004 calendar year.

AREA	GEAR TYPE	NUMBER DECLARED	DAILY ALLOCATION (pounds)	SEASONAL ALLOCATION (pounds)
BAY & TRIBUTARIES	Haul Seine	7	750	1,250
	Pound Net	162	200 [1]	1,100[1]
	Hook & Line	1,155	800 [2]	none
	Gill Net / HL	1,005	500	none
ATLANTIC COAST	Atlantic Trawl	30	none	2,350
	Atlantic Gill Net	29	none	2,350

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. Hook and Line were managed by a weekly allocation.

Table 3. Summary striped bass commercial harvest statistics by gear type for the 2004 calendar year.

AREA	GEAR TYPE	POUNDS[1]	ESTIMATED[1] NUMBER of FISH	TRIPS[2]
CHESAPEAKE BAY[3]	Haul Seine	0	0	0
	Pound Net	507,140	204,925	3,122
	Hook & Line	355,629	127,541	2,093
	Gill Net	921,317	293,344	3,230
	Chesapeake Total Harvest	1,784,086	625,810	8,445
ATLANTIC COAST	Atlantic Trawl	87,757	10,981	138
	Atlantic Gill Net	27,696	3,109	187
	Atlantic Total Harvest	115,453	14,090	325
MARYLAND TOTALS		1,899,539	639,900	8,770

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 2004 calendar year.

AREA	GEAR TYPE	AVERAGE WEIGHT (pounds)	SAMPLE NUMBER
CHESAPEAKE BAY[3]	Haul Seine[1]	0	0
	Pound Net[2]	3.79	852
	Hook-and-Line[2]	3.01	1,964
	Gill Net[2]	5.01	3,577
	Chesapeake Total Harvest[2]	4.23	6,393
ATLANTIC COAST	Trawl [1]	7.99	NA
	Gill Net[1]	8.90	NA
	Atlantic Total Harvest[1]	8.19	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 2004.

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

Figure 1. Map of the 2004 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 2004.

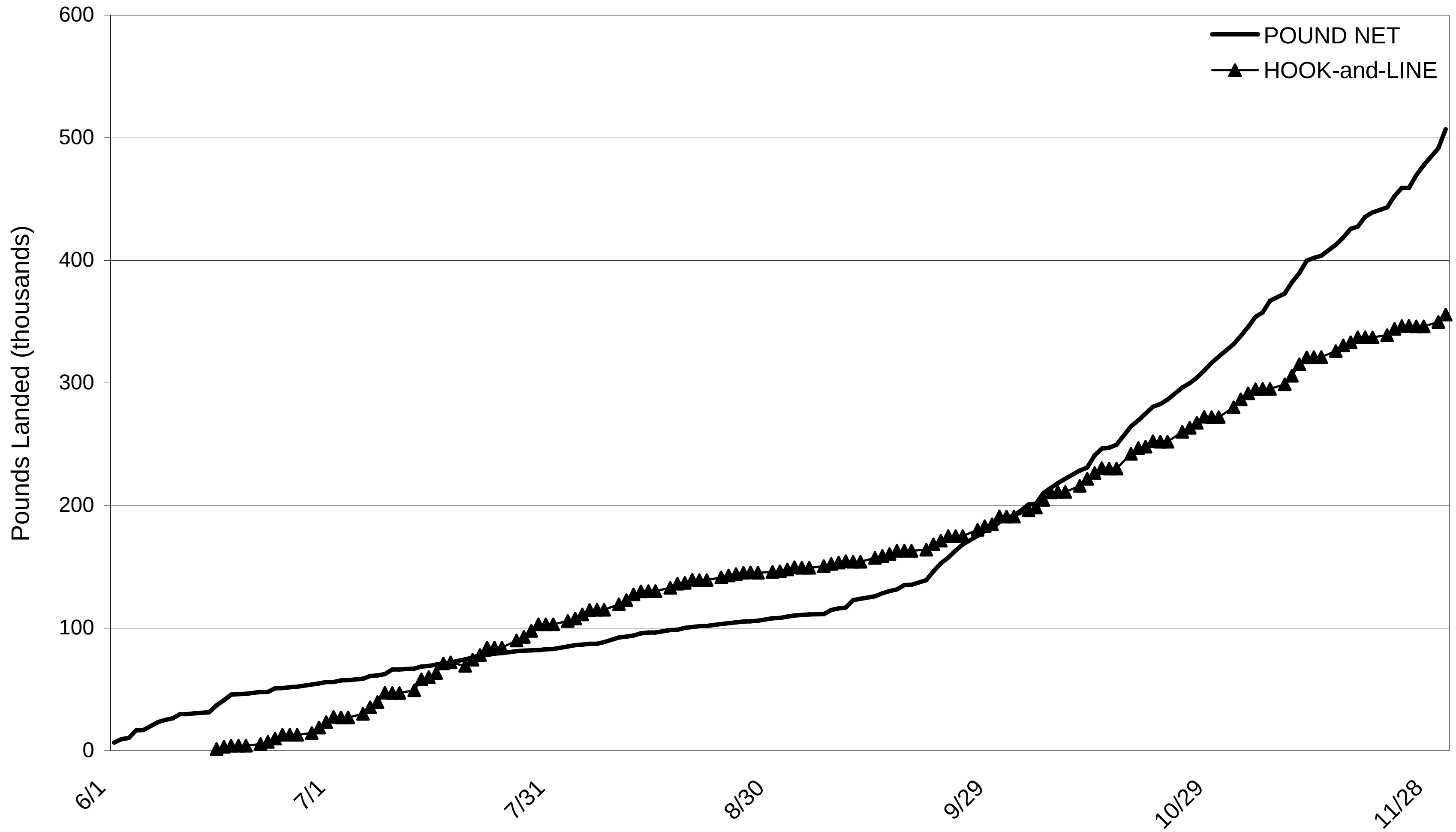
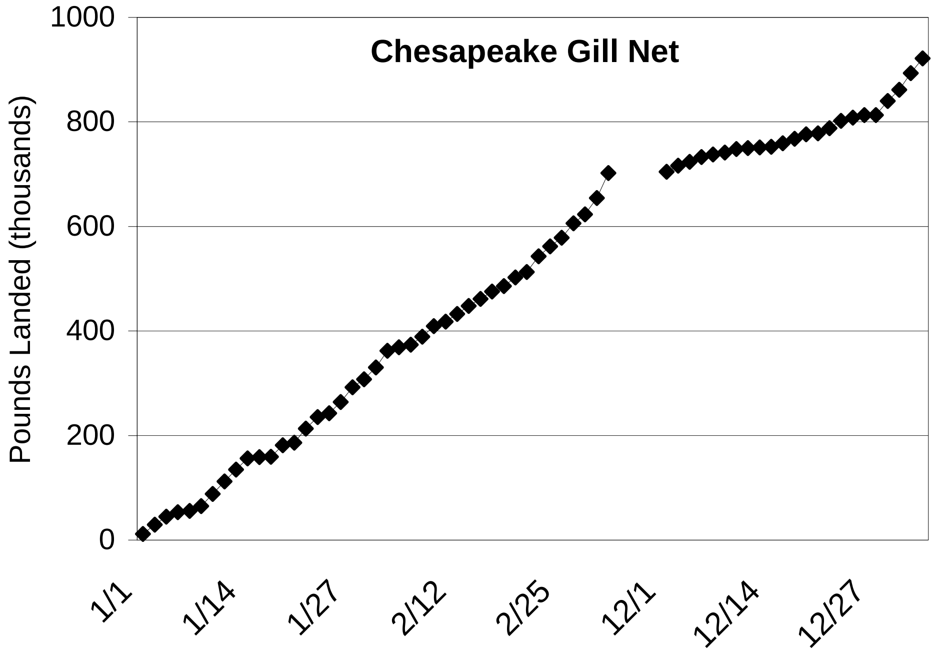


Figure 3. Maryland's Chesapeake Bay gill net and the Atlantic trawl and gill net fishery (combined) cumulative striped bass landings from check stations daily call-in reports, January- December 2004.



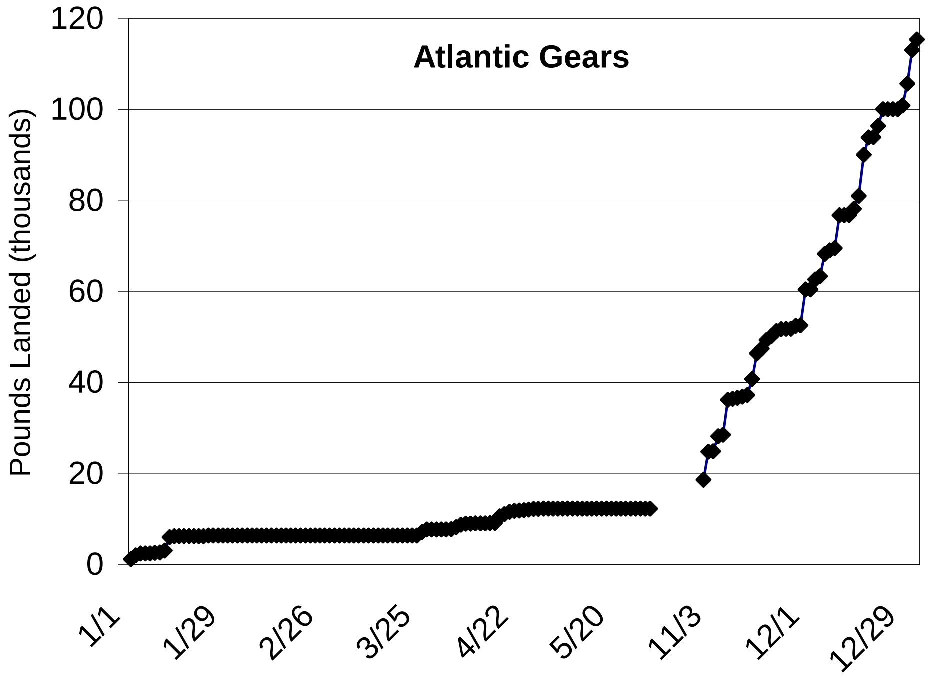


Figure 4. Maryland's Chesapeake Bay striped bass catch (pounds) per trip (CPUE) by gear type, 1990- 2004. Trips were determined as days fished when striped bass catch was reported.

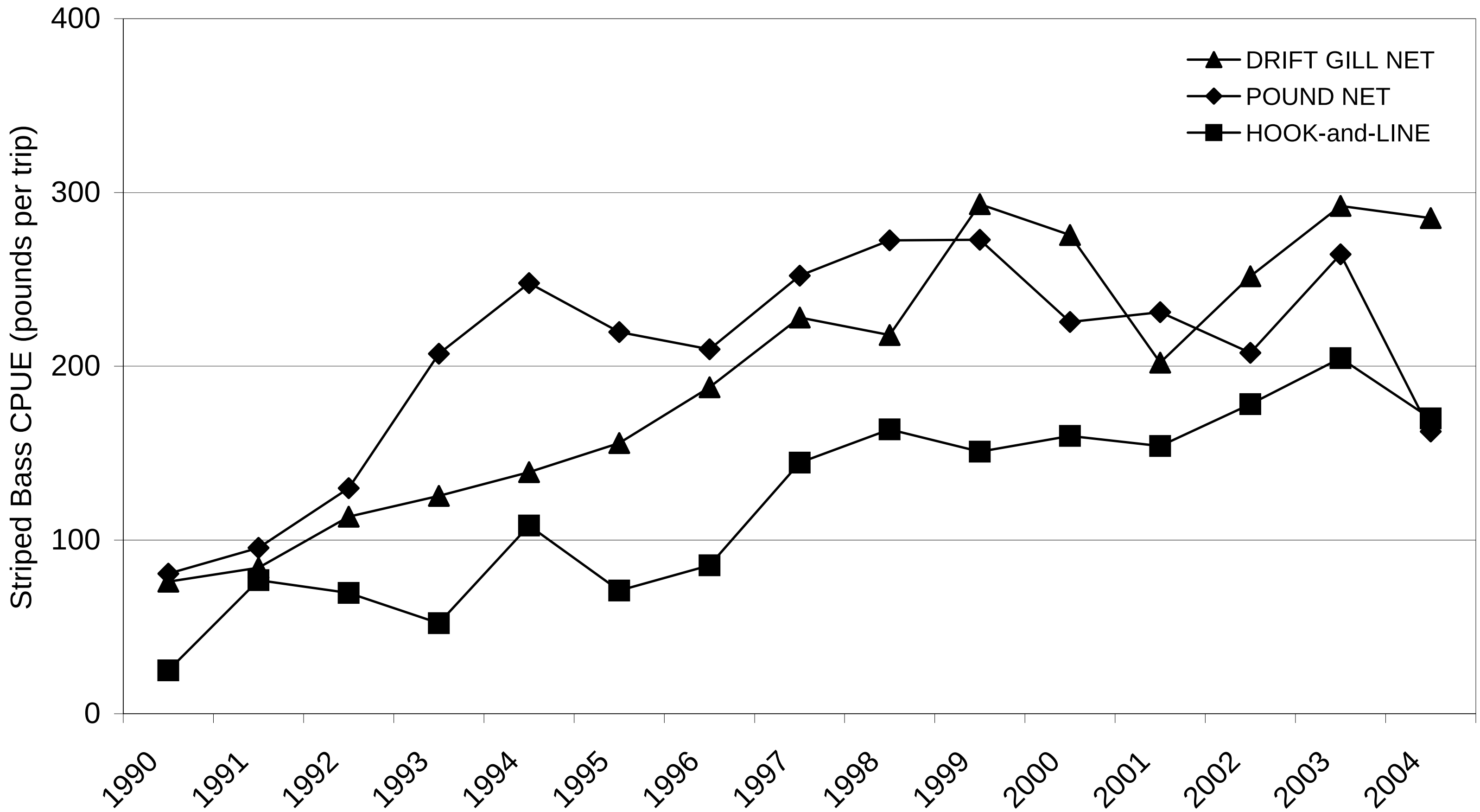
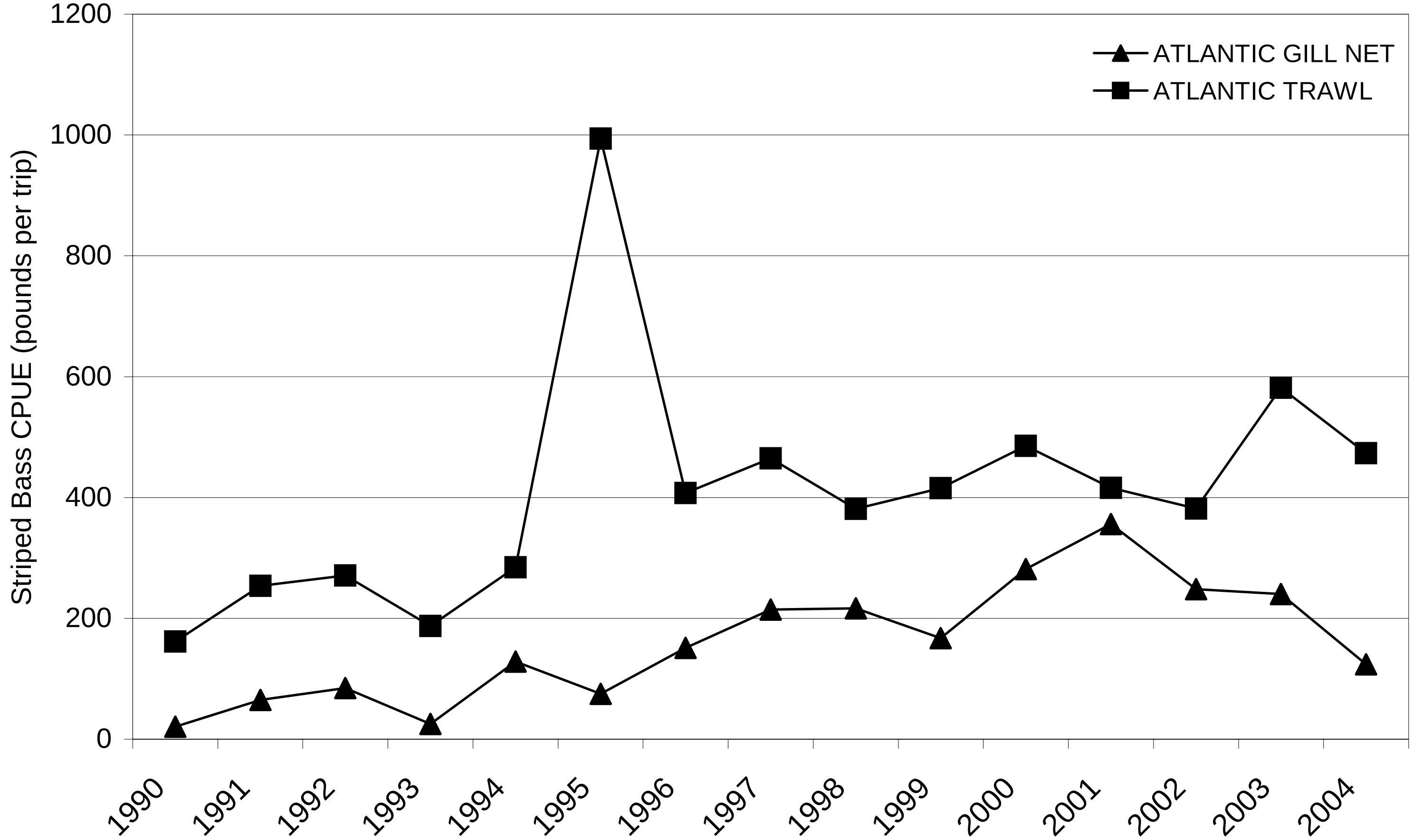


Figure 5. Maryland's Atlantic gill net and trawl fishery striped bass catch (pounds) per trip (CPUE), 1990-2004. Trips were determined as days fished when striped bass catch was reported.



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 Beth Versak

INTRODUCTION

The primary objective of Task 5B is to characterize the size, age and sex composition of striped bass sampled from the 2005 recreational spring trophy season. This portion of the spring 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 every spring (Merriman 1941; Raney 1957; Chapoton and Sykes 1961; Dovel 1971; Kernehan et al. 1981.) Mansueti and Hollis (1963) report that the spawning season can extend from April through June. After spawning, these fish leave the tributaries and migrate down the main stem of the Bay to their summer feeding grounds in the Atlantic Ocean. During warm and dry springs, large spawning striped bass may leave the Bay earlier, with catches of these large fish declining after mid-May.

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; 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 spring season opened in 1991 with a 16-day season, 36-inch minimum size, and a 1 fish per season creel limit (Speir et al. 1999). The spring season restrictions have progressively been liberalized. The 2005 season was 30 days long (April 16 – May 15) with a 28-inch minimum size limit and a 1 fish per person, per day, creel limit.

The Maryland Department of Natural Resources (MD DNR) Striped Bass Stock Assessment Project initiated a dockside creel survey for the spring season fishery in 2002. The 2005 survey constituted the fourth year of sampling this fishery. The objectives of the survey were to:

1. Develop a time series of relative abundance of the component of the harvested Chesapeake Bay spawning stock 28” and longer,
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 cheeks for the presence of coded wire hatchery tags (CWTs) in order to collect known-age samples (scales and otoliths).

METHODS

Dockside creel surveys were conducted at high-use charter boat marinas and public boat ramps (Table 1). Surveys were conducted 3-4 days per week, with much of the sampling effort focused on weekends when recreational fishing activity was highest. The number of boats intercepted, the number of anglers interviewed, and the number of striped bass examined each year are presented in Table 2A. The majority of trips sampled in 2005 were from charter boats, but private boats were also sampled each year (Table 2B).

Due to the half-day structure of some charter trips, charter boats returned in two waves. Return times varied depending on how fast customers reached the legal creel limit of 1 fish > 28" 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 the majority of boats returning from noon to dark. Biologists arrived at the scheduled 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 lot), biologists moved to the nearest site in search of higher fishing activity.

Biologists approached anglers and requested permission to collect data from their catch (Table 3). Total length (mm TL) and weight (kg) were measured. Biologists randomly spot-checked survey weight measurements against certified marina scales to gauge accuracy. The sampling protocol for age structures was to collect 12 scales per 10 mm length group up to 1000 mm TL, for each sex. Scales were collected from every fish greater than 1000 mm TL. These 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 age-length keys. The sampling target for otoliths was 15 otolith pairs per 20 mm length group, for each sex. Otoliths were collected on-site, or heads were collected, placed in labeled bags and retained in coolers and freezers, so that otoliths could be extracted at a later date. The biological data were subsequently analyzed to provide information on length, weight, age, sex ratio and spawning condition.

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 identified with certainty. Ovaries that were swollen and either orange (early phase) or green (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.

Survey personnel also interviewed anglers to obtain socioeconomic information (Table 4) as well as information from which to develop Catch per Trip (CPT) and Catch per Hour (CPH). The survey form is provided as Appendix I. 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.

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. CPT and CPH were calculated from trips during the Trophy Season fishing period (on or about April 16-May 15) of each year. 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. About 20% of the logbook data was excluded each year using this criteria, but sample sizes still ranged from 1000-2000 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 CPT and CPH analysis used a sub-set of data to include only fishing that occurred in areas specified in the MD DNR regulations during the Trophy Season. Data from the catch-and-release fishery in the Susquehanna Flats area were excluded.

The trophy fishery is dominated by charter boat activity, in which a group of fish can be associated with a particular boat or group of fishermen, but fish cannot be assigned to a specific fisherman. Therefore, the socioeconomic and biological portions of the survey could not be directly linked.

RESULTS AND DISCUSSION

Length and Weight

Length distribution of fish.

The length distribution of the catch in 2005 was dominated by fish between 820 mm and 940 mm TL (32 to 37 inches). This is similar to the length distributions observed in previous years (Figure 1).

Average length of fish.

In 2005, the average length for all sexes combined (893 mm TL) and females (898 mm TL) remained similar to lengths observed during the 2002-2004 surveys. The average length of females was greater than the average length of males (867 mm) (Table 5A, Figure 2). Duncan's Multiple Range Test showed that the average length of males in 2005 increased significantly from males sampled in 2004 (p = 0.05). However, average weight of males did not increase significantly with the increase in length.

Mean daily length of female striped bass was more consistent in 2005 than in previous years. This is in contrast to average daily length data in 2002 and also from other studies, when larger females were caught earlier in the season (Figure 3) (Goshorn et al.1992, Barker et al. 2003).

Average weight of fish.

The average weight of 2005 fish (7.3 kg) was similar to average weights observed in previous years. The average weight of females was greater than the average weight of males, which is consistent with data from previous years (Figure 4, Table 5B).

Age Structure

The age distribution of striped bass from the sampled dockside harvest was similar to that observed in previous years, consisting of fish between 6 and 16 years of age (Figure 5). The age distribution was dominated by 8-12 year-old females, with the dominant 1996 year-class (9 year-old fish) being most frequently observed from examination of scale samples. The 1996 year-class composed nearly 30% of the sampled harvest during the 2005 Trophy Season. The same year-class was evident as 8 year-olds in last year's survey, when they composed over 45% of the sampled harvest.

The age distribution of the spring season recreational harvest during the years 2002-2005 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 2005 spring season harvest was dominated by female striped bass (Table 6A). 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 are female (Table 6B).

When the data were analyzed using only known-sex fish, females composed approximately 86% of the 2005 sampled harvest (Table 6B). 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%. Those results are consistent with the average proportion of females seen during the years 2002-2005, which ranged from 81%-89% when the three methods of calculation were used (Table 6B).

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) looked at 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 2005 spring season survey showed that 63% of females caught between April 16 and May 15, 2005 were in pre-spawn condition (Table 7). This was the highest 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 21% to 92% on any given day during the 2005 trophy season (Figure 6). Data from 2005 indicated that pre-spawn females were more likely to be caught early in the season. The percentage of pre-spawn females declined during the survey period ($r^2 = 0.49$). A similar decline was observed in 2003 and 2004.

Presence of Coded Wire Hatchery Tags (CWTs)

A total of 251 striped bass were scanned for presence of CWTs during the 2005 Maryland spring recreational season (April 16-May 15). Of these fish, none were found to have CWTs.

Catch Per Unit Effort

Table 8A shows mean catch per trip (CPT) and mean catch per hour (CPH) calculated from interview data when combining charter and private boat trips. The majority of trips intercepted in 2005 were charter boat trips (Table 2B). Most charter boats take 6 clients per trip and fish until the legal limit of 1 fish per person is reached. This should cause the mean CPT to be approximately 6 fish per trip, per boat. However, some charter boats are licensed to carry more than six passengers. In 2005, charter boats were observed carrying up to 17 anglers and landing up to 15 fish per trip. Therefore, average catch was approximately 8 fish per trip in 2005 (Table 8A).

In 2005, the average catch per trip (8.1) increased slightly from 2004 (6.0) (Table 8A). CPH also increased**,** from 1.9 in 2004 to 3.4 in 2005. This was partially caused by a reduction in effort, measured as average trip length (3.1 hours in 2005 compared to 4.2 in 2004), indicating that fishing boats spent less time on the water and caught more fish than in previous years.

In all years, charter boats caught more fish per trip and per hour than private boats (Tables 8B and 8C). This lower catch rate in private boats is probably influenced by the lower number of lines trolled on smaller private boats and the lower number of days that private boats are able to fish during the trophy season. Charter boats may fish up to 7 days per week, and are able to track daily movements of migratory striped bass and consistently operate near larger aggregations of fish. In 2005, only one private boat was intercepted, and this boat caught no fish.

Charter boat interview and logbook data both indicate that CPT and CPH increased in 2005 when compared to 2004 (Tables 8C and 8D). Catch rates in 2005 increased when compared to 2003 and 2004, and doubled the 2002 catch rates (Tables 8C and 8D, Figure 7).

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 average daily CPH declined slightly over time in some years, but generally varied without trend since 2002 (Figure 7).

Starting in 2004, data were collected on the number of lines trolled by each interviewed party (vessel) in order to refine estimates of effort. Each vessel in the combined fleet of charter and private boats trolled an average of 14 lines during the 2005 Trophy Season. Larger charter vessels generally trolled more lines because of increased available space (wider beams), use of multiple rod holders and planer boards, and larger fishing parties. The number of lines trolled varied from 5 on small private vessels (18-20 feet in length) to 24 on the largest charter vessels (greater than 30 feet in length).

Angler Characterization

In 2005, 54 trips were intercepted and 93 anglers were interviewed during the period April 16-May 15 (Table 2A). Nine state residences were represented in 2005 (Table 9). Most anglers were from Maryland (73%), Virginia (14%), and Pennsylvania (4%), similar to the distribution of states of residence observed during the 2002-2004 surveys.

In 2005, 97% of interviewed anglers were male, and 3% were female (Table 10). The median distance that anglers traveled to charter boat ports or boat ramps was 60 miles one-way (min = 2.5, max = 600) to reach the charter boat port or boat ramp. This was similar to median distance traveled during the 2002 –2004 period (Table 11). The median cost of a fishing trip, per person, was $100 (min = $0, max = $1200) in 2005, similar to the 2002-2004 period (Table 12).

In 2005, interviewed anglers had an average of 23 years (median = 20 years) of fishing experience for striped bass in the Chesapeake Bay (Table 13). Most anglers (81%) stated that striped bass fishing had improved in the years that they had been fishing (Table 14). The majority of anglers ranked their fishing trip as “excellent” (77%); 20% gave a rank of “good”, 2% “fair”, and only 1% “poor” (Table 15). The majority of anglers ranked the quality of their trip based on a combination of the number and size of fish caught (63%) (Table 16). Other reasons for trip ratings were general atmosphere (24%), size of fish (8%), and quantity of fish (5%).

The majority of interviewed anglers (94%) stated that a quality recreational fishery for striped bass exists in Maryland (Table 17). More than half of anglers (59%) expressed satisfaction with regulations (Table 18).

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Table 1. Survey sites for the Maryland striped bass spring season creel survey. Sites are listed in a clockwise direction around Maryland's section of the Chesapeake Bay (North to South on the Eastern Shore, and South to North on the Western Shore).

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	Kentmore Marina (Kent Island)	03
Eastern Shore-Middle Bay	Knapps Narrows Marina	13
Eastern Shore-Middle Bay	Tilghman Is./Buddy Harrison Fleet	05
Western Shore-Lower Bay	Pt. Lookout State Park	16
Western Shore-Lower Bay	Solomon's Island/Bunky's Charter Boats	06
Western Shore-Lower Bay	Solomon's Island/Calvert Marina	07
Western Shore-Middle Bay	Breezy Point Fishing Center	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-Upper Bay	Sandy Point State Park Boat Ramp	11

Table 2A. Numbers of trips intercepted, anglers interviewed, and fish examined by the Maryland striped bass spring season creel survey, 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
Total	**560**	**1061**	**1718**

Table 2B. Number of trips, by type (Fishing Mode) intercepted by the Maryland striped bass spring season creel survey, 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

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

Measurement or Test	Units or Categories
Total length (TL)	to nearest millimeter (mm)
Weight	kilograms (kg) to hundredths (i.e. 5.43 kg)
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.

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

Year	TL - All fish	TL -Females	TL - 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)

Table 5B. Mean weights of striped bass (kg) with 95% confidence limits sampled by the Maryland striped bass spring season creel survey, through May 15.

Year	Mean weight (kg) All fish	Mean weight (kg) Females	Mean weight (kg) Males
2002	**7.3** (7.1-7.5)	**7.4** (7.2-7.6)	**6.1** (5.7-6.4)
2003	**7.6** (7.3-7.9)	**7.7** (7.3-8.0)	**5.9** (5.2-6.6)
2004	**7.6** (7.4-7.8)	**7.8** (7.5-8.0)	**5.9** (5.5-6.4)
2005	**7.3** (7.1-7.6)	**7.5** (7.2-7.8)	**6.4**(6.0-6.7)

Table 6A. 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 (If assume U are 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

Table 6B. Percent females, using three different calculation methods, sampled by the Maryland striped bass spring season creel survey, through May 15.

Year	%F, including U	%F, excluding U	%F, if assume that U are female
2002	68	83	86
2003	84	92	92
2004	88	90	90
2005	85	86	86
Mean	**81**	**88**	**89**

Table 7. 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 %

Table 8A. Catch, effort, and catch per hour calculated from the Maryland striped bass spring season creel survey interview data, through May 15. Charter and Private Boats are combined. Catch is defined as number of fish harvested plus number of fish released.

Year	n	Avg. catch/trip	Avg. hours/trip	Avg. catch/hour
2002	171	5.8	5.4	1.2
2003	163	6.6	4.5	1.9
2004	129	6.0	4.2	1.9
2005	52	8.1	3.1	3.4

Table 8B. Catch, effort, and catch per hour calculated from the Maryland striped bass spring season creel survey interview data, through May 15. Private Boats only. Catch is defined as number of fish harvested plus number of fish released.

Year	n	Avg. catch/trip	Avg.hours/trip	Avg. catch/hour
2002	41	1.6	4.9	0.3
2003	63	1.8	5.4	0.5
2004	42	3.5	4.6	1.0
2005	1	0.0	2.5	0.0

Table 8C. Catch, effort, and catch per hour calculated from the Maryland striped bass spring season creel survey interview data, through May 15. Charter Boats only. Catch is defined as number of fish harvested plus number of fish released.

Year	n	Avg. catch/trip	Avg. hours/trip	Avg. catch/hour
2002	130	7.2	5.5	1.5
2003	100	9.6	4.0	2.8
2004	86	7.3	4.0	2.4
2005	51	8.2	3.1	3.5

Table 8D. Catch, effort, and catch per hour calculated from the Maryland Charter Boat log data, using only striped bass data from trips reported in the upper-Bay, mid-Bay and lower-Bay open fishing areas through May 15. Catch is defined as number of fish harvested plus number of fish released. Mean hours per trip from creel survey interview data are shown here and used for Catch/Hour calculations.

Year	**n**	**Avg. catch/trip**	**Avg. hours/trip** (From creel interview data)	**Avg. catch/hour**
2002	1487	5.5	5.5	1.0
2003	1420	7.3	4.0	1.8
2004	1629	7.3	4.0	1.8
2005	1994	6.9	3.1	2.2

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

Table 10. 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 %

Table 11. 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

Table 12. Dollars (per day) spent 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

Table 13. Interviewed angler's experience (years) fishing in Chesapeake Bay.

Year	Minimum	Maximum	Median	Mean
2002	0	60	9.5	13
2003	0	75	20	20
2004	0	68	12	16
2005	0	64	20	23

Table 14. 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 %

Table 15. 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 %

Table 16. 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 (Atmosphere)
2002	17 %	4 %	23 %	56 %
2003	17 %	36 %	11 %	36 %
2004	25 %	14 %	46 %	15 %
2005	5 %	8 %	63 %	24 %

Table 17. 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 %

Table 18. 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 %

Figure 1. Length distribution of striped bass harvested, by year, sampled by the Maryland striped bass spring season creel survey.

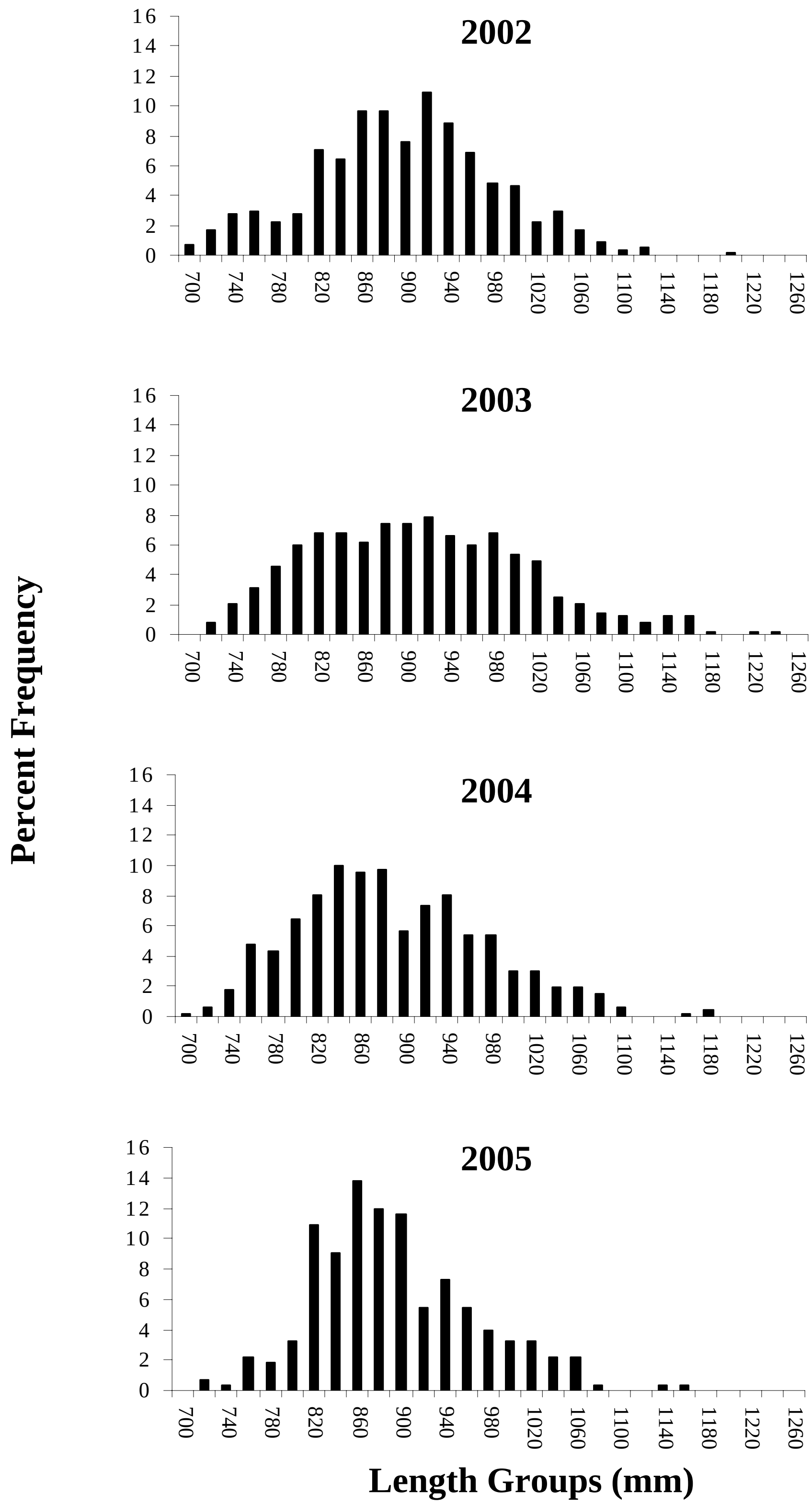


Figure 2. Average length of striped bass (mm TL) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey.

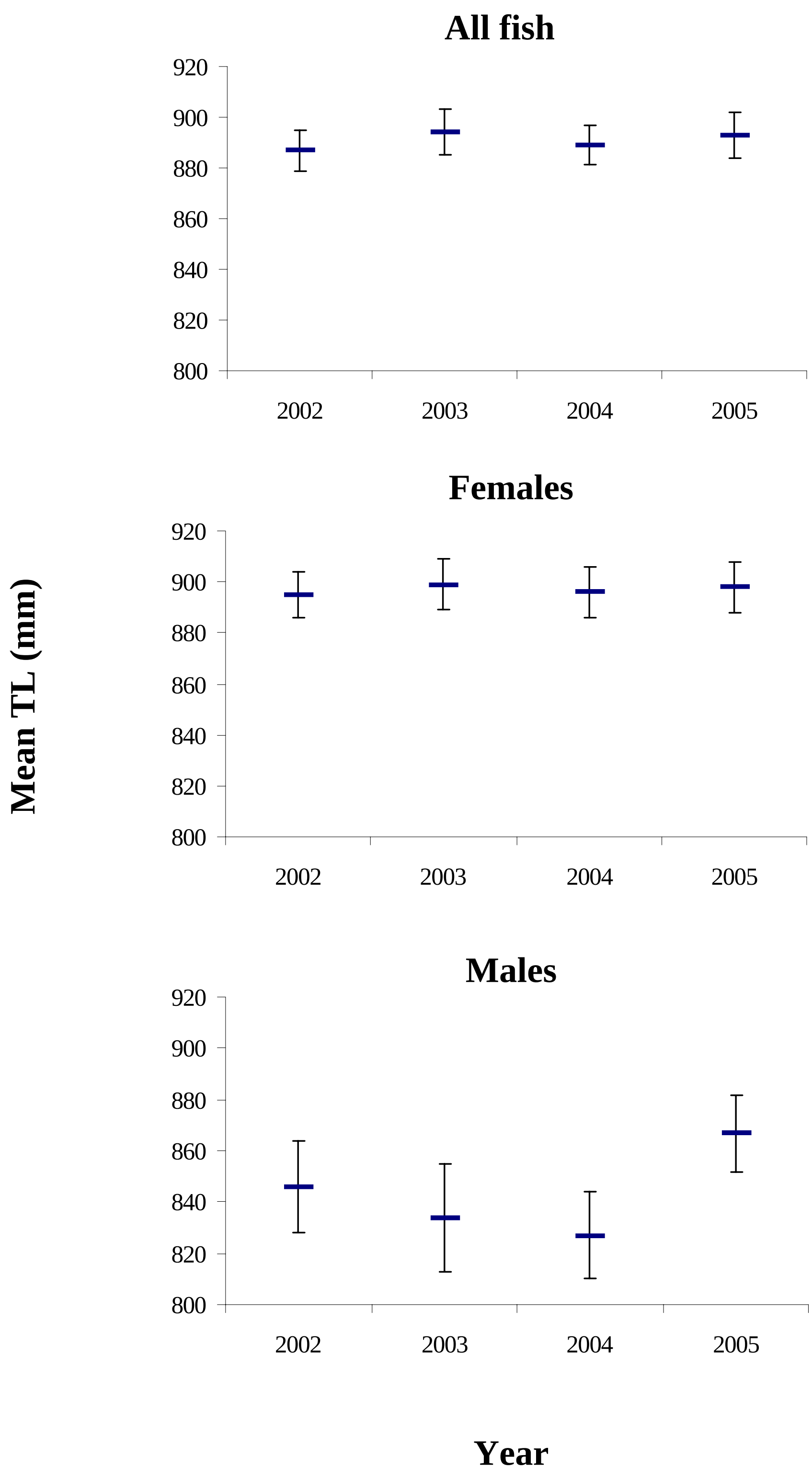


Figure 3. Average daily length of female striped bass, sampled by the Maryland striped bass spring season creel survey.

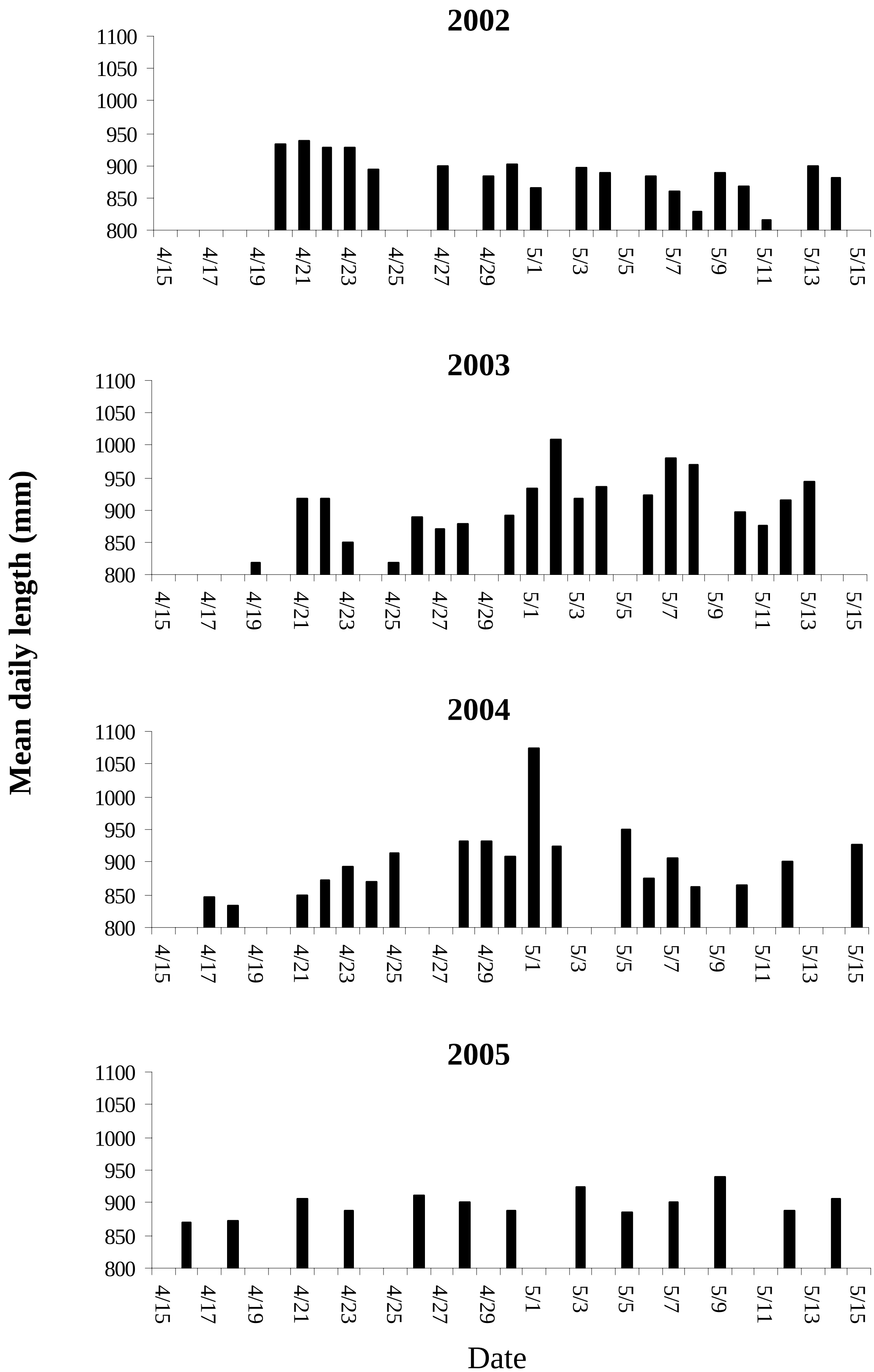


Figure 4. Average weight of striped bass (kg) with 95% confidence intervals, sampled by the Maryland striped bass spring season creel survey.

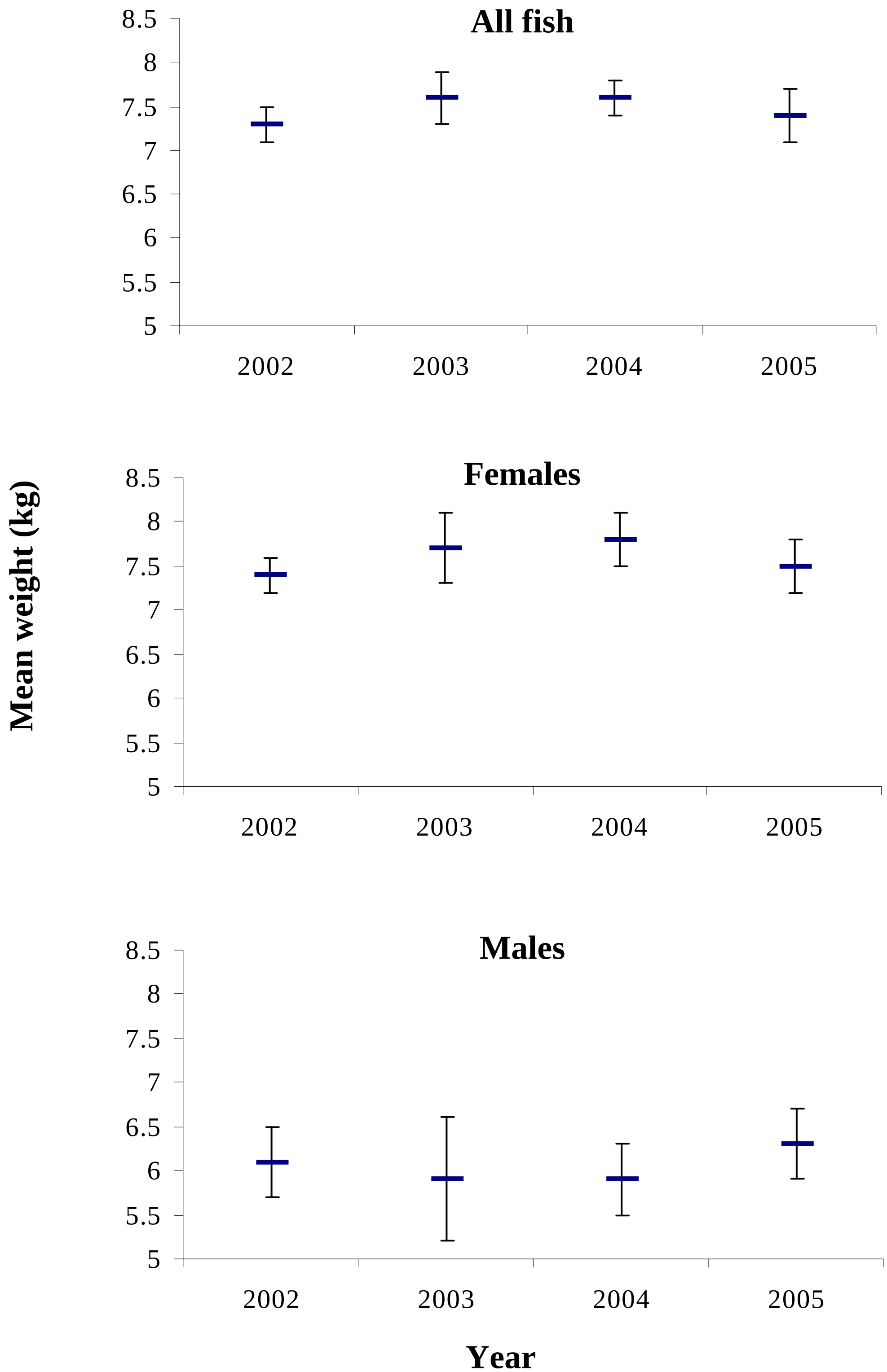


Figure 5. Age distribution of harvested striped bass, sampled by the Maryland striped bass spring season creel survey.

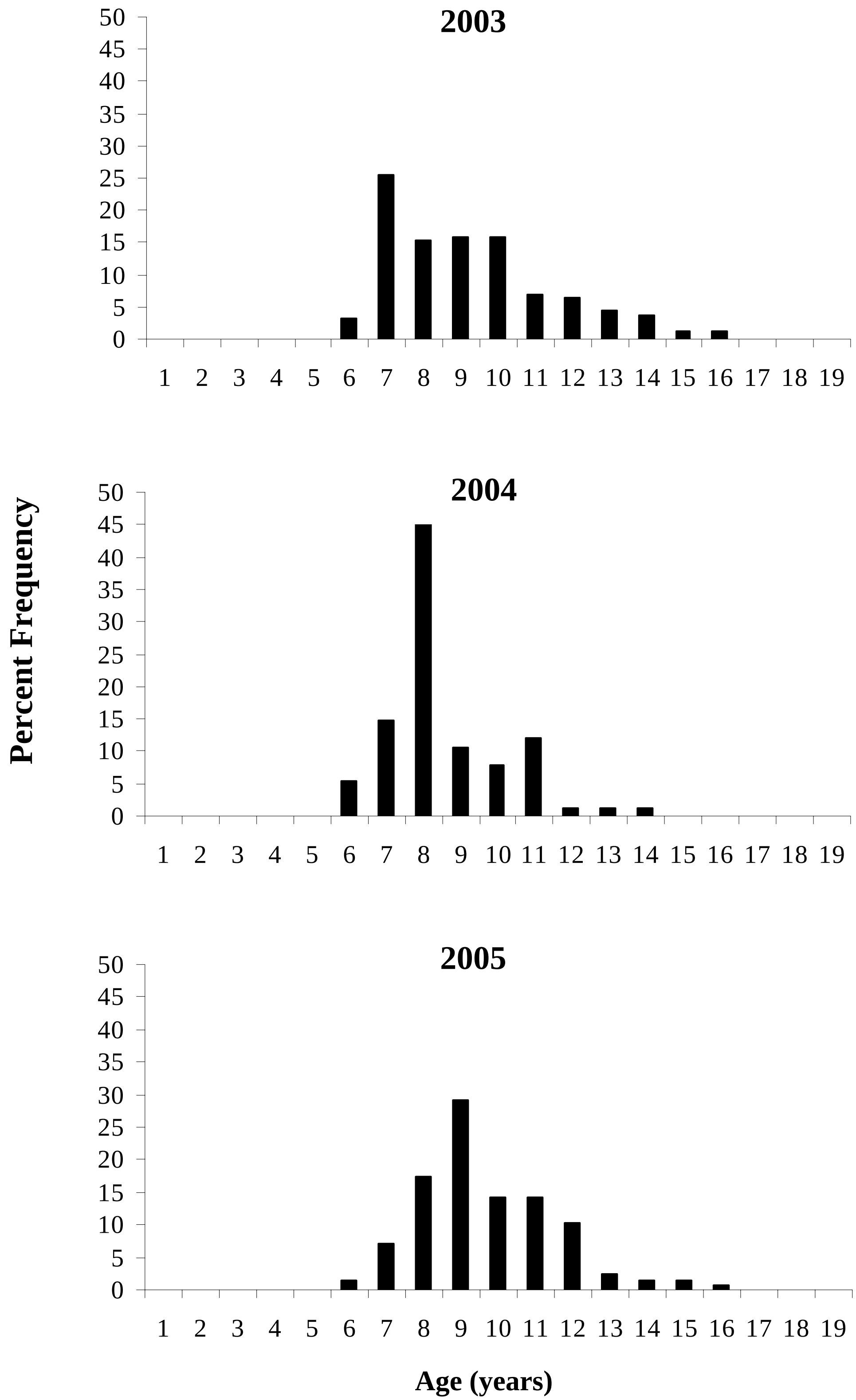


Figure 6. Daily percent pre-spawn female striped bass sampled by the Maryland striped bass spring season creel survey.

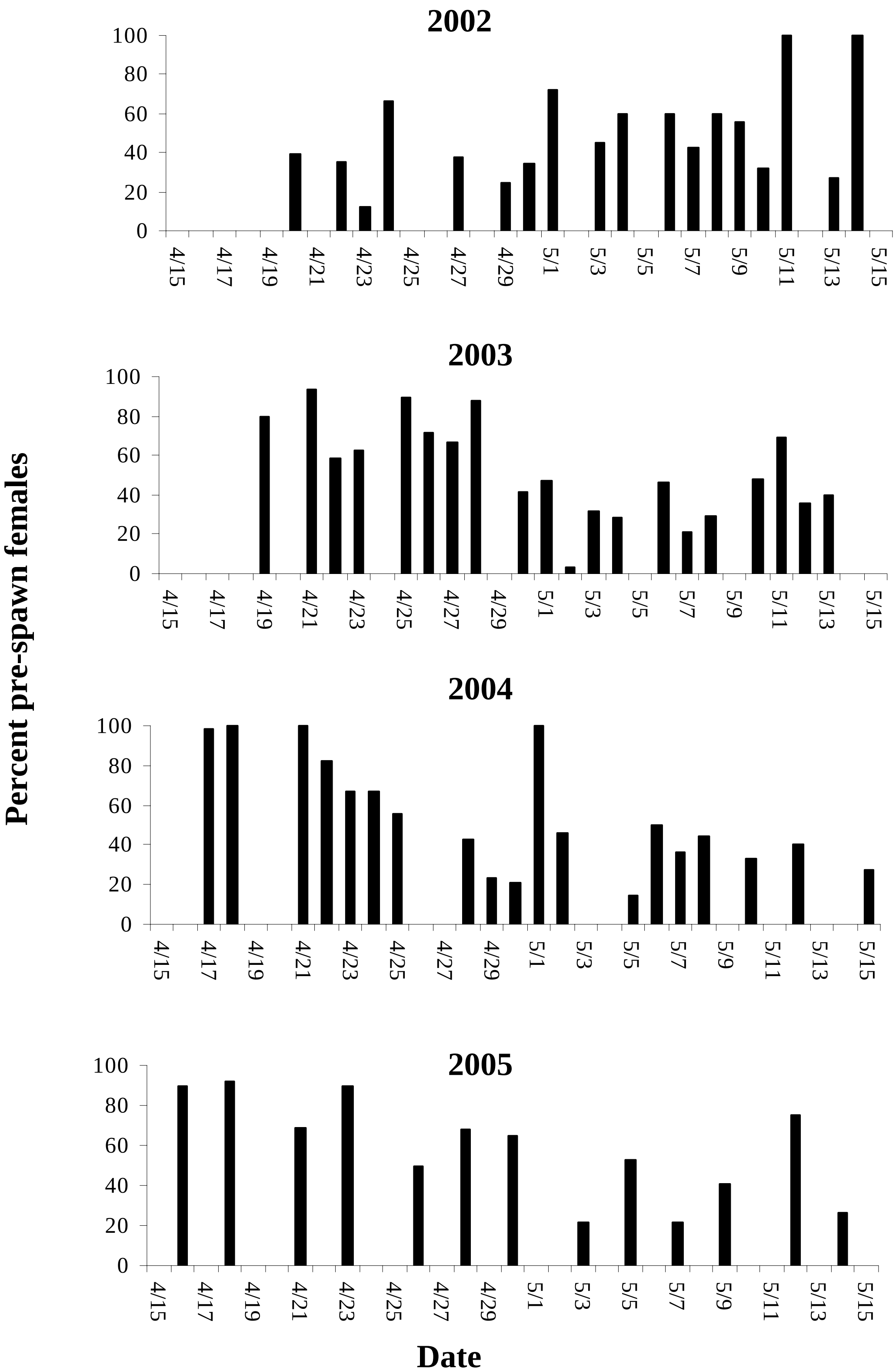
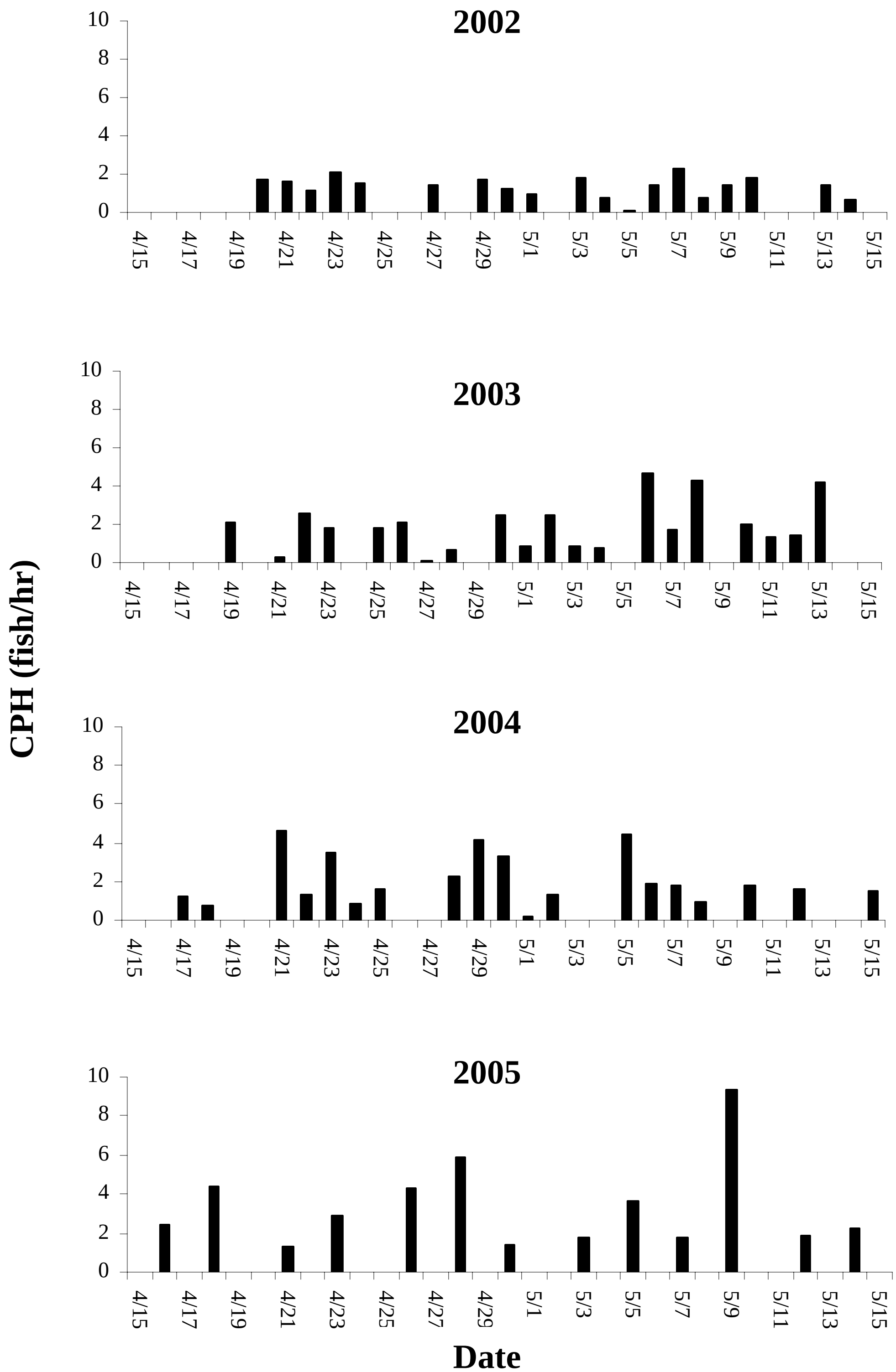


Figure 7. Daily catch per hour of striped bass, calculated from angler interview data collected by the Maryland striped bass spring season creel survey.



APPENDIX I

QUESTIONNAIRE FOR 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 troll 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 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 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

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 or declined 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 No

10.) In your opinion, do we have a "quality" SB fishery in Maryland's portion of Chesapeake Bay? Yes No
If no, what changes would you like to see?

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

HATCHERY STOCKING CONTRIBUTION TO WILD STOCK STRIPED BASS IN MARYLAND CHESAPEAKE BAY AND TRIBUTARIES

prepared by Beth A. Versak

INTRODUCTION

The primary objective of Task 6A was to determine the presence of hatchery implanted coded wire tags (CWTs) and their subsequent hatchery contribution to Maryland's striped bass population. Although encountered infrequently, these known-age fish are a valuable source of data for validating ageing techniques by direct comparison of scales and otoliths.

In 1985, Maryland Department of Natural Resources (MD DNR), in cooperation with the U.S. Fish and Wildlife Service (USFWS) began stocking selected rivers throughout the Chesapeake Bay with juvenile hatchery produced striped bass implanted with CWTs. This program, never intended to provide full restoration, was initiated to supplement the spawning stocks until a viable population was restored (ASMFC 1996). Approximately 6.9 million fish were stocked in the Patuxent, Choptank, Nanticoke, and Chester rivers, and the upper Chesapeake Bay from 1985 through 1995. Stocking efforts were reduced to 210,000 fish in 1994 and 165,000 fish in 1995 when striped bass stocks were declared recovered and hatchery production ceased.

METHODS

The scanning process utilized a Northwest Marine Technology CWT detector wand supplied by the USFWS. Fish were scanned on the left cheek at the tag implantation site. Since hatchery stocking ended in 1995, sampling was adjusted based on the projected length of these age ten-plus fish during the current sample year. The majority of fish scanned for CWTs were greater than 700 millimeters total length (mm TL).

During the spring spawning stock surveys of 2005 (see Project No. 2, Job No. 3, Tasks No. 2 and 5B), CWT positive fish were sacrificed to recover the CWT, and otoliths removed. In an effort to validate the scale reading technique, scales were collected and aged from all CWT positive fish. Cheeks from sacrificed fish were supplied to the USFWS in Annapolis, Maryland for tag removal and hatchery identification.

Monitoring of the commercial hook and line, pound net and winter gill net fisheries occurred in 2004 and 2005. Since harvested fish were sold commercially, cheek portions could not be removed, as this would reduce their market value. When possible, CWT positive fish were purchased from seafood markets for tag and otolith removal and subsequent hatchery origin and age determination.

Large fish sampled during the 2005 North Carolina coastal tagging cruise were also scanned for CWTs. CWT positive fish were sacrificed, sexed, and scale and otolith samples taken. Scales were forwarded to the North Carolina Division of Marine Fisheries for ageing. Cheeks were taken by the USFWS for CWT analysis.

RESULTS

During the summer/fall, winter, and spring sampling in 2004 - 2005, a total of 805 striped bass (6% of the total fish sampled) were scanned in Maryland for the presence of CWTs. No hatchery fish were encountered during any of these tasks.

Summer/Fall 2004

There were no hatchery striped bass encountered in Maryland's fall pound net survey (Table 1). Staff sampled 6,155 striped bass, but scanned only 65 for CWTs, as most fish encountered were less than 700 mm TL.

The commercial hook and line and pound net fisheries were also monitored at authorized striped bass check stations. Sixty-one striped bass were scanned for the presence of CWTs and none were identified as being of hatchery origin.

Winter 2004-2005

No hatchery striped bass were encountered at winter drift gill net check stations. Northern and eastern check stations were sampled, and 180 out of 3,376 striped bass were scanned (Table 1).

Spring 2005

The spawning stocks in the upper Chesapeake Bay and Potomac River were sampled in March, April and May 2005. In the upper Chesapeake Bay, 173 striped bass were scanned for the presence of CWTs (Table 1). No hatchery fish were encountered. No fish on the Potomac River were scanned in 2005, due to a lack of CWT detector wands.

Maryland DNR staff also conducted a creel survey during the spring trophy striped bass recreational fishery (see Task No. 5B). During this survey, an additional 326 large fish were scanned for CWTs (Table 1). No CWT positive fish were encountered.

North Carolina Tagging Survey 2005

MD DNR, in conjunction with the USFWS, National Marine Fisheries Service, Atlantic States Marine Fisheries Commission, and North Carolina Division of Marine Fisheries participated in the eighteenth annual SEAMAP cooperative tagging cruise (see Project No. 2, Job No. 3, Task No. 4). Of the 4,298 fish sampled during the 2005 cruise, 107 were scanned. For the seventh consecutive year, no hatchery striped bass were observed (Table 1).

DISCUSSION

The 1985 – 1995 stocking efforts were intended to help supplement the spawning stock of striped bass in Chesapeake Bay rivers. However the overall contribution of this effort was low and continues to decrease each year (Figure 1). There has been a downward trend in occurrence of hatchery origin striped bass in spawning ground surveys since 1992 (Table 2). With Fisheries Service sampling producing no hatchery fish for several years, an effort was made to target specific areas most likely to produce CWT positive fish (see Task No. 6B). Strong natural reproduction in 1993, 1996, 2001 and 2003 continues to dilute the hatchery population, which continues to decline from natural and fishing mortalities. Larger striped bass are also migrating from the Chesapeake Bay to the coast, further diluting the number of hatchery-produced fish present in the Bay. While the overall contribution of hatchery striped bass is insignificant, the few fish still encountered provide an excellent means for validating scale and otolith ageing techniques.

CITATIONS

ASMFC, 1996. Evaluation of Anadromous Striped Bass Enhancement Efforts with Emphasis on Chesapeake Bay Stocking Activities, Special Report No. 53.

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Table 1. Summary of hatchery striped bass recovered during Maryland's Chesapeake Bay stock assessment activities and the coastal tagging survey.

Summer/Fall Pound Net (May - Oct. 2004)

System	Total Caught	Number Scanned	Number Positive	Percent Positive
Upper Bay	0	0	0	0
Middle Bay	3,851	51	0	0
Lower Bay	2,304	14	0	0
TOTAL	6,155	65	0	0

Fall Hook and Line/Pound Net (June - Nov. 2004)

System	Total Caught	Number Scanned	Number Positive	Percent Positive
TOTAL	2,818	61	0	0

Winter Gill Net (Dec. 2004 - Feb. 2005)

System	Total Caught	Number Scanned	Number Positive	Percent Positive
Eastern	1,020	0	0	0
Northern	2,356	180	0	0
TOTAL	3,376	180	0	0

Spring Spawning Stock (March - May 2005)

System	Total Caught	Number Scanned	Number Positive	Percent Positive
Potomac R.	249	0	0	0
Upper Bay	1,403	173	0	0
Creel sites	553	326	0	0
TOTAL	2,205	499	0	0

Coastal Tagging Survey (Jan. – Feb. 2005)

System	Total Caught	Number Scanned	Number Positive	Percent Positive
TOTAL	4,298	107	0	0

Table 2. Summary of hatchery striped bass recovered in Maryland and the coastal tagging surveys, 1991 - 2005.

YEAR	SURVEY	TOTAL SCANNED	PERCENT POSITIVE
1991 to 1992	Fall Pound Net	3,662	6.8
	Winter Gill Net	1,787	3.4
	Spring Spawning Stock	6,012	3.4
	Coastal Tagging Survey	858	1.9
1992 to 1993	Fall Pound Net	2,588	4.3
	Winter Gill Net	2,036	2.8
	Spring Spawning Stock	6,582	2.0
	Coastal Tagging Survey	577	5.9
1993 to 1994	Fall Pound Net	2,033	3.5
	Winter Gill Net	4,235	6.0[a]
	Spring Spawning Stock	3,300	3.2
	Coastal Tagging Survey	1,641	3.6
1994 to 1995	Fall Pound Net	1,200	2.2
	Winter Gill Net	4,328	2.3[a]
	Spring Spawning Stock	3,385	1.2
	Coastal Tagging Survey	585	2.9
1995 to 1996	Fall Pound Net	2,688	1.6
	Winter Gill Net	4,755	1.6[a]
	Spring Spawning Stock	5,118	1.4
	Coastal Tagging Survey	678	1.0
1996 to 1997	Fall Pound Net	1,725	1.4
	Winter Gill Net	5,340	0.6[a]
	Spring Spawning Stock	2,303	0.4
	Coastal Tagging Survey	1,373	0.6

[a] Weighted mean based upon percent sampled by area

Table 2. Summary of hatchery striped bass recovered in Maryland and the coastal tagging surveys, 1991 - 2005 (Continued).

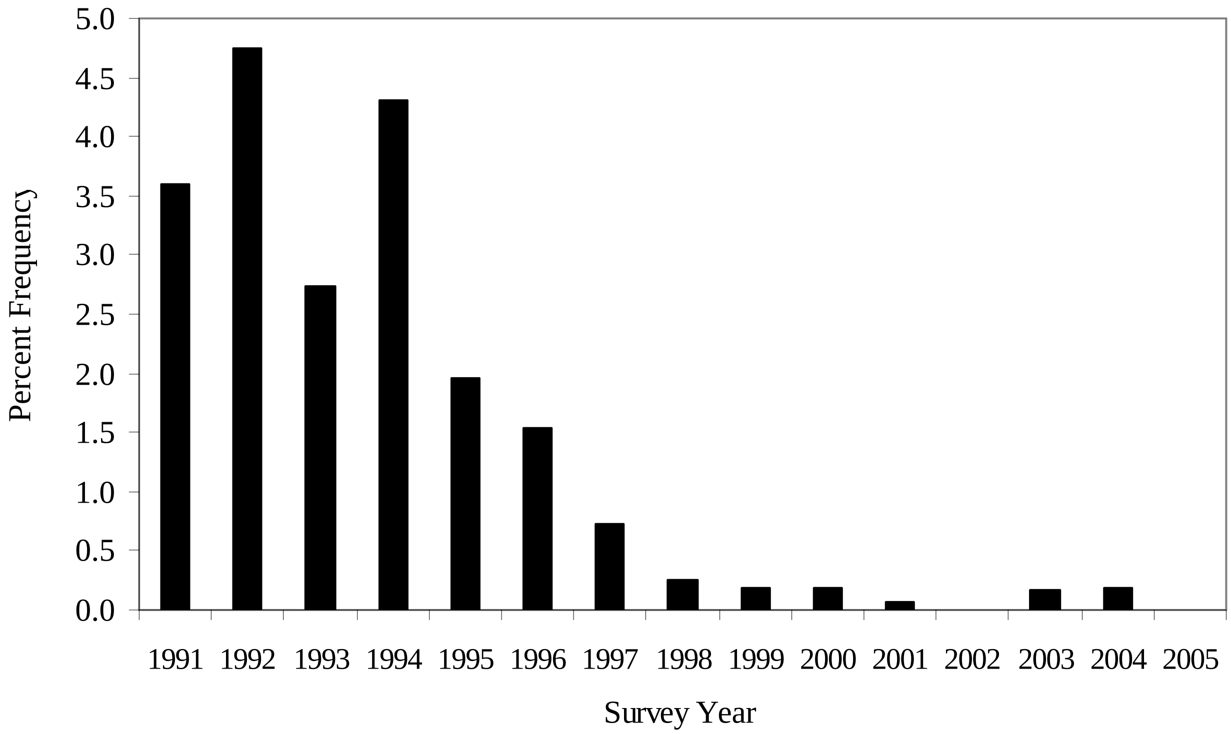
YEAR	SURVEY	TOTAL SCANNED	PERCENT POSITIVE
1997 to 1998	Fall Pound Net	2,526	0.7
	Winter Gill Net	5,097	0.1[a]
	Spring Spawning Stock	2,738	0.2
	Coastal Tagging Survey	424	0.2
1998 to 1999	Fall Pound Net	3,581	0.28
	Winter Gill Net	4,974	0.20[a]
	Spring Spawning Stock	1,818	0
	Coastal Tagging Survey	163	0
1999 to 2000	Fall Pound Net	3,535	0.08
	Fall Hook and Line	1,648	0.36
	Winter Gill Net	3,583	0.11[a]
	Spring Spawning Stock	1,024	0.49
	Coastal Tagging Survey	3,321	0
2000 to 2001	Fall Pound Net	5,892	0.08
	Hook & Line/Pound Net	2,156	0.19
	Winter Gill Net	2,321	0
	Spring Spawning Stock	844	0
	Coastal Tagging Survey	984	0
2001 to 2002	Fall Pound Net	959	0
	Hook & Line/Pound Net	235	0
	Winter Gill Net	2,952	0
	Spring Spawning Stock	215	0
	Coastal Tagging Survey	479	0

[a] Weighted mean based upon percent sampled by area

Table 2. Summary of hatchery striped bass recovered in Maryland and the coastal tagging surveys, 1991 - 2005 (Continued).

YEAR	SURVEY	TOTAL SCANNED	PERCENT POSITIVE
2002 to 2003	Fall Pound Net	0	0
	Hook & Line/Pound Net	11	0
	Winter Gill Net	372	0
	Spring Spawning Stock	854	0.23
	Coastal Tagging Survey	753	0
2003 to 2004	Fall Pound Net	0	0
	Hook & Line/Pound Net	3	0
	Winter Gill Net	641	0.54
	Spring Spawning Stock	448	0
	Coastal Tagging Survey	105	0
2004 to 2005	Fall Pound Net	65	0
	Hook & Line/Pound Net	61	0
	Winter Gill Net	180	0
	Spring Spawning Stock	499	0
	Coastal Tagging Survey	107	0

Figure 1. Percent frequency of hatchery striped bass sampled in Maryland's Chesapeake Bay. Note: survey year runs fall through summer. (Example: 1991 includes fall 1990 – summer 1991).



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

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 6B was to summarize sampling efforts to obtain hatchery-reared, known-age striped bass on the Patuxent River. These fish, released in Maryland waters between 1985 and 1995 are a valuable source of data for validating ageing techniques by direct comparison of hatchery data, scales and otoliths. The search for hatchery fish continued during annual surveys, but in recent years very few have been encountered (See Project 2, Job 3, Task No. 6A, this report). For the third year, Maryland Fisheries Service staff conducted a spring electrofishing survey to locate hatchery-reared striped bass with implanted coded wire tags (CWTs). Sampling efforts were focused on the spawning reach of the Patuxent River during the spring spawning season because the majority of the hatchery-stocked fish were released in this system. Striped bass may return to their natal rivers to spawn, increasing the chances of encountering CWT tagged fish on the Patuxent River during this time.

METHODS

Sampling effort was focused on the freshwater portion of the Patuxent River in the area between Spice Creek and Whites Landing (Figure 1). Sampling began on April 5, 2005 and continued through April 19, 2005.

Since hatchery stocking ended in 1995, only fish which were approximately 700 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. CWT positive fish were sacrificed and scales and otoliths were collected for age validation purposes. The CWT was extracted and read 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

The majority of the electrofishing on the Patuxent River took place in the Hall Creek Flats area, since the highest concentrations of fish were encountered there in 2003 and 2004. If shocking did not produce any striped bass within 10-15 minutes, sampling was moved to other sites. Water depth ranged from two to thirty feet.

A total of 83 striped bass were scanned for the presence of CWTs on the Patuxent River during April, 2005. Sampling was conducted on four days, with a total effort of approximately 9 hours of actual shocking time recorded on the electrofishing boats (Table 1). Four fish (5 % of fish scanned) were found to be CWT positive.

The survey time period was planned according to reports of historical abundance of spawning striped bass in the upper Patuxent River (D. Cosden, personal communication, MD DNR) and on catches from surveys conducted in 2003 and 2004 (Zlokovitz and Versak 2003, Versak and Zlokovitz 2004). Striped bass are generally encountered at the Patuxent River staging and spawning areas when water temperatures reach 10-11 ºC in late March or early April.

Since the Hall Creek Flats area historically produced the most fish, most sampling effort was applied in this area. Striped bass appeared to be staging in the shallow mud flats opposite the mouth of Hall Creek (2 – 6 feet deep), which tend to warm faster than deep channel areas. On clear, sunny afternoons, water temperature at this location may be 2-3 ºC warmer than the surrounding deep channel areas. Catch rates increased after the first trip on April 5, and were consistently high during the period April 8-April 19, when photoperiod increased and water temperature stabilized above 10-11 ºC. No females were caught on the first trip, but the percentage of females in the sampled catch increased during the latter part of the survey time period (Table 1). Similar catch patterns were observed in previous years (Zlokovitz and Versak 2003, Versak and Zlokovitz 2004).

The mean length of all striped bass sampled (including fish not scanned for CWTs) was 871 mm TL (n=92, minimum=465 mm TL, maximum=1200 mm TL, median=873 mm TL). Forty-seven females were captured, constituting 45% of the sampled fish. The four CWT positive fish (one male, three females) ranged from 922 to 1050 mm TL, with a mean length of 977 mm TL. These four fish were aged by scale examination and the tags read by U. S. Fish and Wildlife Service (USFWS) personnel in Annapolis, Maryland. The CWTs showed that the fish ranged in age from 13 to 18. Two fish were under-aged and one fish was over-aged by scale examination (Table 2). Scale and CWT derived ages were in agreement for one fish. The oldest fish, an 18 year-old, 1006 mm TL female captured on April 19, 2005, was from a MD DNR hatchery release on the Patuxent River in 1987.

Three out of four of the hatchery-reared fish captured in 2005 were originally tagged and released in the Patuxent River. The only exception was a 13 year-old, 1050 mm TL female, which was released in the Nanticoke River in 1992 (Table 2).

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. The comparison of these scale and tag ages supports the assumption that scales become less reliable for ageing older fish (> 12 years old).

ACKNOWLEDGEMENTS

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

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.

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.

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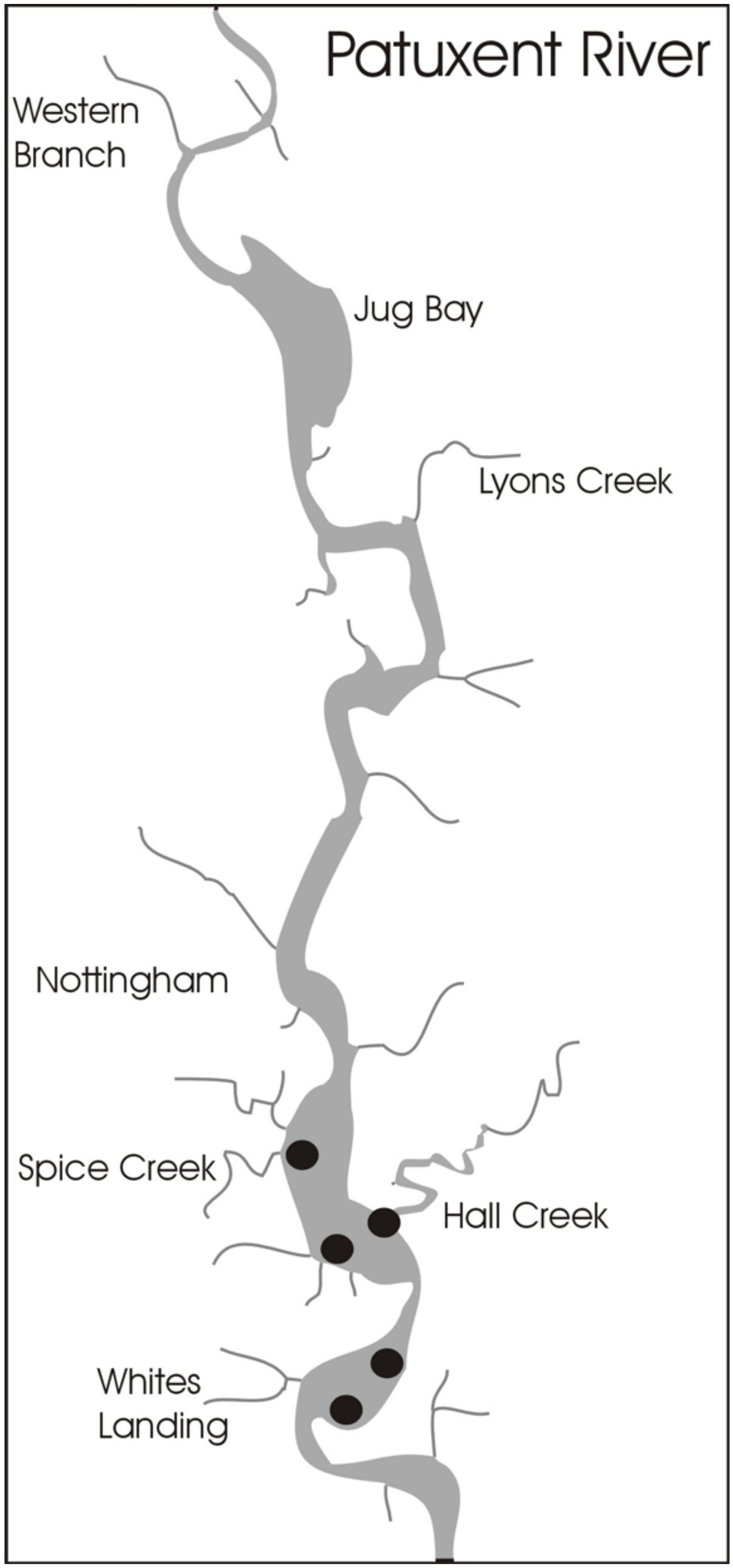
Table 1. Electrofishing survey targeting hatchery-reared striped bass on the Patuxent River. Data summary by date, for all sites combined.

DATE	# FISH SCANNED	# CWT POSITIVE	TOTAL EFFORT (SECS)	MEAN LENGTH (MM TL)	% FEMALE	% MALE	MEAN WATER TEMP (°C)
4/05/05	5	0	18,060	728	0	100	11.2
4/08/05	37	0	5,613	892	35	65	10.8
4/12/05	26	2	3,962	916	54	46	15.0
4/19/05	15	2	4,807	912	87	13	16.5

Table 2. Hatchery-reared striped bass collected during the electrofishing survey on the Patuxent River, 2005.

DATE	SITE	TL (MM)	SEX	SCALE YEAR-CLASS	CWT YEAR-CLASS	RELEASE SITE
4/12/05	Hall Creek Flats	929	M	1992	1988	Patuxent River
4/12/05	Hall Creek Flats	1050	F	1988	1992	Nanticoke River
4/19/05	Hall Creek Flats	922	F	1992	1992	Patuxent River
4/19/05	Hall Creek Flats	1006	F	1993	1987	Patuxent River

Figure 1. Location of Patuxent River electrofishing sites, April, 2005.



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), Mid-Atlantic Migratory Fish Council (MAMFC), Chesapeake Bay Living Resources Subcommittee (CBLRS), and the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRAC), required current stock assessment information in order to assess management measures. The Survey staff also participated in ASMFC, US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) fishery research and management forums.

Survey information was used to formulate management plans for thirteen finfish species as well as providing evidence of compliance with state and federal regulations. In addition, direct participation by Survey personnel as representatives to these various management entities provided effective representation of Maryland interests through the development, implementation and refinement of management options for Maryland and 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 ASMFC American shad Technical Committee meeting to approve annual state report, discuss closure of the ocean fishery and river-specific fisheries, and prepared the ASMFC Annual American shad Status Compliance Report for Maryland.

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

Staff attended a stock assessment workshop for American shad stocks in the Delaware basin and assisted in stock assessment analysis.

Staff attended a PRFC Finfish Advisory Board meeting and presented information on stock status and hatchery operations for Potomac River American shad.

Project staff attended Mid-Atlantic Region and Southeast Region Stock Assessment Workshop meetings as Maryland representative to discuss American shad and river herring stock status along the Atlantic coast.

Atlantic croaker

ASMFC Technical Committee representative attended the annual ASMFC Atlantic croaker Technical Committee meeting to approve annual state status report, review the latest stock assessment, and prepared the ASMFC Annual Atlantic croaker Status Compliance Report for Maryland.

Survey personnel served on the ASMFC Plan Development Team for Atlantic Croaker to develop Amendment 1 to the Atlantic Croaker Fishery Management Plan

Bluefish:

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

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

Habitat Assessment:

MD DNR Staff attended Chesapeake Bay Program, Living Resources Subcommittee Meetings to update the group on the MD DNR impervious surface project and the estuarine yellow perch project. Staff described the impacts of impervious cover on aquatic habitats and fish.

Staff presented research regarding fish, fish habitat, and development to the Lower Potomac Tributary Strategy Team, the Charles County Commissioners and the Charles County Planning Commission.

Red Drum:

ASMFC Technical Committee representative attended the annual ASMFC Red Drum Technical Committee meeting and prepared the ASMFC Annual Red Drum Status Compliance Report for Maryland.

Tautog:

ASMFC Technical Committee representative attended the ASMFC Tautog Technical Committee and Stock Assessment Sub-Committee meetings and produced the required ASMFC Annual Tautog Status Compliance Report.

ASMFC Technical Committee representative prepared an updated Tautog Stock Assessment Report for Maryland and reviewed the ASMFC Tautog Coastal Stock Assessment Report.

Weakfish:

ASMFC Weakfish Technical Committee representative served as the Technical Committee chairman. Staff attended annual ASMFC Weakfish Technical Committee and Stock Assessment Sub-Committee meetings and produced the required ASMFC Annual Weakfish Status Compliance report

ASMFC Technical Committee representative constructed catch-at-age matrices using length and age data from Chesapeake Bay pound nets for the ASMFC Weakfish Technical Committees coastal stock assessment.

Personnel conducted surplus production and proportional stock density analyses for stock assessment.

Striped Bass:

The Project Leader and staff serve as Maryland alternate representatives to the ASMFC Striped Bass Scientific and Statistical Committee, the Striped Bass Stock Assessment Subcommittee, and produce Maryland's State's Annual Striped Bass Compliance Report to ASMFC.

The Project Leader and staff serve on the ASMFC Striped Bass Tagging Working Group, the ASMFC Interstate Tagging Committee, and as Maryland representatives to the Potomac River Fisheries Commission (PRFC) Finfish Advisory Board and the PRFC Blue Crab Advisory Board.

Data Sharing and Web Page Development

To augment data sharing efforts, 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 SBSA project data directly. The web page, http://www.dnr.state.md.us/fisheries/juvindex/index.html, is updated annually in October. For the period December 2004 to Sept 2005 the web site averaged over 2000 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, December 2004 to September 2005.

Month	Visits
December 2004	1,186
January 2005	1,743
February	1,401
March	2,211
April	2,111
May	2,431
June	2,206
July	3,457
August	1,724
September	1,595

The Project continues to provide Maryland striped bass data and biological samples to other state, federal, private and academic researchers. These have included the USFWS, National Marine Fisheries Service (NMFS), University of Maryland, Virginia Institute of Marine Sciences, Georgetown University, the State of Virginia, Pennsylvania State University, East Carolina University, University of Rhode Island, the Hudson River Foundation, the State of Delaware, and the State of New York. For the past contract year, (October 1, 2004 through October 31, 2005) the following specific requests for information have been directly accommodated by Staff:

-Atlantic States Marine Fisheries Commission (ASMFC) Staff.
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 juvenile index data; striped bass fishery regulations, striped bass recreational, charter boat and commercial fishery harvest and CPUE data.

-Mr. Seth Berry, NDW, Indianhead, U.S. Navy.
Provision of striped bass spawning stock data.

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

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

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

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

-Mr. Dharam Juneja, D.C. Department of Health, Fisheries and Wildlife Division.
Provision of juvenile striped bass index data.

National Marine Fisheries Service, NOAA, Chesapeake Bay Program Staff.
Provision of results from fishery dependent monitoring programs, striped bass juvenile index data, 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; striped bass commercial fishery information.

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

-Dr. Anthony Overton, East Carolina University.
Provision of juvenile striped bass survey data.

-Ms. Debra Parthree, VIMS, Center for Coastal Resources Management.
Provision of striped bass stomach samples for diet analysis and prey item quantification.

University of Maryland (U MD - CEES).
Provision of current striped bass anomaly data, striped bass juvenile index, American shad juvenile index data, and biological samples.

-The Interjurisdictional Project also provided related biological information and summary reports, published reports, research reports, CPUE data from historical experimental drift gill net surveys in table form, directed Chesapeake Bay fishing mortality (F) rate study estimates; juvenile index data in table form, and USFWS Annual F42-R Series Federal Reports to forty eight (48) additional scientists, students and concerned citizens.

PROJECT NO. 3
JOB NO. 1

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

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

INTRODUCTION

The primary objective of Job 1 is to evaluate the concept of using impervious surface reference points (ISRPs) as a tool for effective fisheries management. Fisheries management is increasingly using biological reference points (BRPs) to determine how many fish can be safely harvested from a stock (Sissenwine and Shepherd 1987).

The development of ISRPs involves determining functional relationships between impervious cover and water quality (primarily dissolved oxygen) or a species population response (abundance, distribution, mortality, recruitment success, growth, etc). Dissolved oxygen is an ideal response variable because fish require well-oxygenated water and because it can provide insight into both the metabolic and pollution status of a waterbody (Limburg and Schmidt 1990). Exploring these relationships for the suite of focal species was the objective of Project 4 in 2003, 2004 and was continued again in 2005.

Impervious surface is increasingly used as an indicator tool by local planning and zoning agencies because of compelling scientific evidence in freshwater systems and because it is a critical input variable in many water quality and quantity models (Cappiella and Brown 2001). Estuarine and marine 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.

METHODS

A candidate watershed matrix was constructed by Rickabaugh et al. (2004) from historic data to guide selection of sampling systems. Thirteen small watersheds (< 69,000 acres) were selected from two regions (mid-Bay and Potomac River) of Maryland's Chesapeake Bay. During 2004, a reduction in the number of field crews from two to one necessitated a reduction in watersheds sampled. The Magothy River was dropped from mid-Bay, while the Wicomico River, Nanjemoy Creek and Piscataway Creek were dropped from the Potomac River. These reductions allowed for the retention of a two-week sampling interval.

The Corsica, Miles, Rhode, South, Severn and West rivers in the mid-Bay region were sampled during 2005 while Breton Bay, Saint Clements Bay, and Mattawoman Creek were sampled in the Potomac River (Figure 1). Impervious cover in these systems spanned 3-18% of watershed area (Table 1). Four evenly spaced sample sites were located in the upper two-thirds of each tributary. Sites were not located near the mouth to reduce influence of the mainstem Bay or Potomac River waters on measurements of watershed water quality.

Mid-Bay Sampling Areas

The South and Severn rivers are located on Maryland's western shore in Anne Arundel County, MD, between Annapolis and Baltimore (Figure 1). They are suburbanized systems that have experienced development explosions since the late 1960's and have impervious cover (surface) of 10.2% (Figure 2) and 17.5% (Figure 3), respectively (Table 1; Uphoff et al. 2005). The Rhode and West rivers are located on the western shore of the Chesapeake Bay, south of Annapolis. These watersheds are less developed, dominated by forest and agriculture, and have low (4.8%) impervious coverage (Figure 4, Table 1). The Corsica and Miles rivers are located in rural areas on Maryland's Eastern Shore. These systems are dominated by agriculture and have 4.0 and 3.4% impervious cover, respectively (Figures 5 and 6, Table 1).

Two mesohaline systems on the lower Potomac River were sampled; Saint Clements and Breton bays are both located in Saint Mary's County. These systems were dominated by forest cover, had respective impervious surface (IS) cover of 4.3% and 5.1%, and have experienced increasing development in recent years (Figures 7 and 8; Table 1).

One tidal-fresh tributary of the Potomac River was sampled in 2005. Mattawoman Creek (Figure 9) is located in Charles County, Maryland on the Potomac River and contains 8.5% IS (Table 1). Mattawoman Creek has extensive forest cover and military holdings within the watershed. The fluvial and tidal portion of Mattawoman Creek in Charles County has been slated for development to 15% IS. This potential development provided incentive to keep this one tidal-fresh system in the sampling design. A significant fraction of the stream is located in Prince Georges County and is zoned for low IS development.

Field Sampling Methods

Each fixed site was sampled once a visit with two visits occurring each month during July-September. All sites on one river were sampled on the same day, except St. Clements and Breton bays which were sampled the same day to reduce mileage and travel time. 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) and salinity (ppt) 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, to the nearest 0.1 m, was taken 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 populations. Gear specifications and techniques were selected to be compatible with other Fisheries Service surveys.

A 4.9 m (16ft) semi-balloon otter trawl was used to sample fishes in mid-channel bottom habitat. The trawl was constructed of treated nylon mesh netting measuring 38.1 mm (1½ inch) stretch in the body and 33 mm (1¼ inch) stretch in the codend, with an untreated 12 mm (½ inch) stretch knotless mesh liner. The headrope was equipped with floats, while the footrope was equipped with a 3.2 mm (1/8 inch) chain. The net used 0.61 m (24 inch) long by 0.30 m (12 inch) high trawl doors attached to a 6.1 m (20 ft) bridle leading to an 24.4 m (80 ft) towrope. Trawling was in the same direction as the tide. The trawl was set up tide of the actual site location far enough to pass the site halfway through the tow. This allowed the same general area to be trawled regardless of tide direction. A single tow was made for six minutes at 3.2 km/hr (2.0 miles/hr) at a site on each visit. The contents of the trawl were emptied into a tub for processing.

An untreated 30.5 m • 1.2 m (100 ft • 4 ft) bagless knotted 6.4 mm (¼ inch) 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 • 66 mm (1½ • 2½ inch) floats spaced at 0.61 m (24 inch) intervals, while 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 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 199 mm were considered to be of harvestable size and all captured were measured to the nearest millimeter.

Data Analysis

Temperature, salinity and dissolved oxygen data from each system were summarized over all depths and sites (hereafter composite measurements) to identify differences in habitat conditions. In addition, bottom dissolved oxygen distributions by system were examined separately. Summer bottom D.O was emphasized because this was the most likely habitat and season to be affected by increased impervious surface. Carmichael et al. (1992) found a strong association of summer bottom trawl species richness and land use in Chesapeake Bay tidal tributaries. These summaries were presented as a series of box and whisker plots. Median bottom DO values in each system sampled during 2003 (Rickabaugh et al. 2004), 2004 (McGinty et al. 2005), and 2005 (this report) were regressed against IS percentage.

Habitat suitability was judged by the percentage of measurements that met or exceeded criteria. Acceptable ranges and optimal levels of water quality parameters (Table 2) were gathered for the target species based on guidelines developed by the Chesapeake Bay Program (1991), Funderburk et al. (1991), ASMFC (2001), and the Yellow Perch Workgroup (2002). Temperature and salinity preferences varied among life stage and species. Overall temperature requirements ranged between 8.0 and 31.4 °C and salinity between 0.0 and 30.0 ppt. Water temperature and salinity thresholds of 31 ºC and 13.0 ppt., respectively, were selected as indicators of adverse habitat conditions.

Two DO criteria were evaluated (5.0 mg/L and 3.0 mg/L) as potential targets and thresholds (respectively) for both habitat and fisheries management strategies. Concentrations of dissolved oxygen of 5.0 mg/L or greater were considered desirable for survival of the target species (Funderburk et al, 1992). Concentrations less than 3.0 mg/L have been shown to significantly reduce survival (US EPA, 2003).

The relationship of percent of DO measurements (all depths in the channel and nearshore) below the target or threshold in 2005 and percent impervious surface was tested with linear regression. Additional regression analysis was conducted with target or threshold percentages from 2004. Examination of the scatter plot of 2004-2005 data for < 3.0 mg/L suggested categorical regression as an analytical approach. The two years were coded as 0 and 1 (2004 and 2005, respectively) and used with percent impervious surface as independent variables in a multiple regression (Neter and Wasserman 1974). This test assumed that the slopes of the DO versus impervious surface were equal, but intercepts (years) were different (Neter and Wasserman 1974). Scatter plots of DO <5.0 mg/L target versus impervious surface did not readily suggest an analytical strategy.

Mean annual (2003-2005) bottom dissolved oxygen at the uppermost two stations was regressed against the percentage of impervious surface in each watershed to determine the effect of impervious surface. These stations were selected to maximize the signal from the watershed and minimize the influence of intrusions of DO conditions from mainstem Bay or Potomac River. Intrusions of low DO mainstem waters into downstream tributary stations were suspected to have occurred during 2004 (McGinty et al. 2005). This predictive relationship was used to identify levels of impervious surface that would produce mean DO that equaled proposed 5.0 mg/L target and 3.0 mg/L limits.

It was hypothesized that inshore relative abundance (seine catches) could increase at bottom DO below the threshold as species attempted to escape from poor oxygen conditions in offshore bottom waters. The alternate hypothesis was that DO would affect overall distribution (relative abundance would increase positively in both habitats as bottom DO increased).

Bottom DO was categorized into mg/L increments. Catch distributions of individual target species were not normally distributed and normality could not be induced because of high frequency of zero catches. Proportion (P) of trawls or seine hauls (Pt or Ps) with each target species and its 95% confidence interval was calculated for each bottom DO increment (Ott 1977). A criterion (sample size greater than five divided by the smaller proportion, P or 1-P) was used to determine whether the number of samples in an interval was adequate for use of the normal distribution approximation of the binomial distribution (Ott 1977). If this criterion was not met, this estimate was excluded from further analysis. Remaining Pt and Ps for each eligible target species was plotted by DO category.

Pt or Ps were determined for all target species combined for bottom DO categories. These proportions were at or very near 1.0 at DO increments above 2-3 mg/L and did not offer resolution among most bottom DO categories. As an alternative, seine or trawl category mean log10 catch of target species and 95% confidence intervals (2003-2005 pooled) was estimated. Total number of target species came close to being normally distributed after log10 transformation and analysis proceeded with it as the dependent variable. Log-transformation (base 10 in our case) is generally applicable to field distributions of animal catches or samples (Green 1979). Normality of the mean of log10 target species catches in seines or trawls was determined using the Kolgorov-Smirnov test (Schlotzhauer and Littel 1997) for catches at DO 4 mg/L or greater. For this test, trawl and seine data were compiled using bottom DO. Catches made when this DO criterion was not met were eliminated, because there would be a high frequency of zeros reflecting unsuitable habitat.

Means and 95% confidence intervals of each DO category's log10-transformed catches (2003-2005 pooled) of target species abundance (species pooled) were plotted by gear type against bottom dissolved oxygen category midpoint to determine the influence of low oxygen. Examination of the seine data suggested linear regression was appropriate for testing the trend in target species. A nonlinear, asymptotic Weibull function was fit to mean log10 abundance of target species in bottom trawls against the bottom dissolved oxygen concentration. The Weibull model described the increase in target species as an asymmetric, asymptotic function of DO category midpoint: $T_d = T_k\{1 - \exp[-(W / S)^b]\}$; where T_d is the log10 abundance of target species in bottom trawls at a given level of DO; T_k the asymptotic log10 abundance of target species in bottom trawls as DO approaches infinity; S the value of DO were $T_d = 0.63 \times T_k$; and b is a shape factor (Prager *et al.* 1989). The Weibull model was fit using Solver in Excel to minimize the sum of squared differences in observed and predicted T_d. Model fit was described by calculating r^2.

RESULTS

Water quality

Water temperatures in the systems sampled between July and September ranged from 22.5 to 33.1 °C (Figure 10), close to a 2°C increase over 2004 (McGinty et al, 2004). Median temperatures were again similar among rivers, ranging from 27.1 to 28.6°C. Four rivers showed temperatures higher than the 31.0°C criteria for the target species (Table 3).

Salinity ranged from 0.1 to 14.2 ppt with the median salinity for each river ranging from 0.1 to 11.4 ppt (Figure 11). With tidal-fresh Mattawoman Creek removed, median salinity was 7.7 to 11.4 ppt. Salinities were higher than 2003 and 2004 (Rickabuagh et al, 2003; McGinty et al, 2004). Salinity was greater than the 13 ppt habitat criterion in six rivers (Table 3).

Water column composite (surface to bottom) dissolved oxygen (DO) measurements ranged from 0.0 to 11.6 mg/L during 2005 (Figure 12). Median composite DO was again similar among rivers when Mattawoman Creek was excluded, ranging from 5.0 to 6.2 mg/L. Mattawoman Creek was the exception; median water column DO was 7.6 mg/L (Figure 12). Median bottom dissolved oxygen for all rivers combined was 4.0 mg/L. Median bottom DO ranged from 0.2 mg/L for the Severn River to 7.3 mg/L for Mattawoman Creek (Figure 13).

All rivers sampled except Mattawoman Creek had dissolved oxygen measurements less than 3.0 mg/L (Table 3). During 2005, percent of watershed in IS was linearly related to percent of DO measurements (all depths in the channel and nearshore) < 3 mg/L (r^2 = 0.46, P = 0.04), but was a poor predictor of the percentage of measurements <5 mg/L (r^2 = 0.85, P = 0.85). Considerable improvement in fit was gained by excluding Mattawoman Creek (the only freshwater, tidal tributary) from the regression when the criterion was < 3 mg/L DO (r^2 = 0.72, P = 0.007), but not when the criterion was < 5 mg/L.

Categorical regression of 2004-2005 data for < 3.0 mg/L was significant (R^2 = 0.61, P = 0.0023), indicating both year category (P = 0.024) and percent IS (P = 0.0028) were significant influences on the how often measurements fell below the threshold (Figure 14). Frequency of below threshold measurements was predicted to have been higher at all levels of impervious cover during 2005. Combining data from 2004 and 2005 did little to illuminate the statistical relationship with percentage of measurements < 5 mg/L (Figure 15). The predominately agricultural Miles and Corsica rivers had high frequencies of DO < 5 mg/L even though they had low impervious surface (Figure 15). Without these two systems, an asymptotic, nonlinear relationship was suggested.

There was a significant negative relationship (p = 0.0001, $r^{2\,=}$ 0.6625) between mean bottom dissolved oxygen for the two uppermost stations in each river during 2003-2005 and percent IS in the watershed. This relationship indicated that target bottom DO, 5 mg/L would occur at 4% IS. The 3 mg/L threshold was met at 10% IS (Figure 16).

Fish Distribution

General catch statistics for the seine and the trawl are presented in Tables 4 and 5. Seining effort (Table 4) was reduced in several rivers in 2005 because of the presence of abundant submerged vegetation in several sites. The total number of species observed in the seine declined in all rivers except the Miles where one additional species was observed in 2005 when compared to 2004. The number of species that comprise 90% of the catch either increased or remained the same as in 2004, with the exception of Mattawoman Creek, which declined from 9 species in 2004 to 2 species in 2005 and the West River which went from 5 in 2004 to 3 in 2005. Between 2004 and 2005, dominant species in the seine shifted from Atlantic silverside to mummichog in Breton Bay and the Corsica River, and to Atlantic menhaden in Miles River. All other rivers continued the same pattern of species dominance observed in 2004. Total catch and catch per effort declined in all rivers except St. Clements Bay, which exhibited a slight increase in 2005.

Trawl effort remained constant between 2004 and 2005 (Table 5), but like the seine, the number of species declined in all rivers, except the West (remained the same). The number and type of species that comprise 90% of the catch declined or remained the same in all rivers, except the Severn, where one additional species was added. Spot were noticeably more common in 2005 compared to 2003-2004. Spot appeared as one of the top three species in all rivers sampled in 2005 with the exception of fresh-tidal Mattawoman Creek. More fish were captured in Breton Bay, Rhode River, South River, St. Clements Bay and West River trawls during 2005 than the previous two years, while lower catches were observed in Mattawoman Creek, and the Corsica, Miles and Severn rivers.

Of the nine target species, spot and white perch were well represented in trawl samples (Table 6). The dominant target species varied by river for the seine, with Atlantic menhaden dominating the catch in the Miles and South rivers, spot in Breton Bay, Rhode River and West River, and white perch in the remaining systems (Table 7).

Bottom Dissolved Oxygen and Fish Distribution During 2003-2005

Samples containing adult striped bass, adult yellow perch, and Atlantic croaker were too few to meet the sample size criterion for inclusion in this analysis. Confidence intervals of Pt and Ps were too broad to differentiate relative abundance among DO categories for alewife (Figure 17) and blueback herring (Figure 18). Most Atlantic menhaden estimates of bottom DO category Pt were not significantly different from zero (Figure 19), indicating either trawling was not effective for sampling menhaden or they did not extensively use the bottom habitat that trawls would target. Precision of Atlantic menhaden Ps allowed for differentiation from zero, but a trend was not evident across bottom D.O, categories (Figure 19). These characteristics pre-empted analysis for habitat shifting of Atlantic menhaden. Yellow perch juveniles were rare in trawls (Figure 20) and estimates of Pt were not significantly different from zero across DO categories. Ps of yellow perch juveniles was much higher in seine hauls at the lowest DO category (<1 mg/L) than remaining categories and there were no differences among remaining categories based on confidence interval overlap (Figure 20). The apparent increase in relative abundance of nearshore yellow perch at low DO may have reflected stocking efforts in the South and Severn rivers during 2003-2005 (Uphoff et al. 2005). These two rivers generally have the poorest DO conditions and juvenile yellow perch abundance has been artificially enhanced.

Sampling of striped bass and white perch juveniles (Figures 21 and 22), white perch adults (Figure 23), and spot (Figure 24) was intense enough for precise estimates of Pt and Ps. In general, 95% confidence intervals of Ps and Pt were narrow for DO categories less than 8.0 mg/L. Confidence intervals of Ps generally overlapped across categories and did not strongly indicate a trend in relative abundance inshore. Pt strongly increased as DO rose to 4.0 mg/L for these species and life stages. Pt leveled or increased slightly for these species as D.O category increased beyond 4.0 mg/L. Hypotheses regarding distribution and bottom DO were not supported by trends in Ps and Pt for these target species. A change in Ps was not indicated as bottom DO improved and Pt rose.

Proportion of seine or trawls with target species within a DO category was often at or near 1, except for Pt when bottom DO category fell below 4.0 mg/L (Figure 25). Target species log10 abundance in trawls exhibited a marked increase in abundance at 3.0-4.0 mg/L bottom dissolved oxygen, after which an asymptotic relative abundance was reached. A Wiebull function of DO category midpoint and log10 mean abundance of target species explained 91% of variation and indicated a bottom DO - relative abundance asymptote at the 4.5 mg/L midpoint. Although subtle, log10 mean seine catch of target species declined linearly with DO category 3-4 mg/L ($r2 = 0.67$, $P = 0.0038$; Figure 26). Change in mean log10-transformed seine catch (Cs) with bottom DO category midpoint (Dc) was described by the equation: $C = -0.145*Dc + 4.19$. This analysis supported the hypothesis that relative abundance of target species would shift away from nearshore habitat to bottom habitat once DO conditions improved.

DISCUSSION

Average bottom DO, and frequency of water column DO measurements below the proposed thresholds for fish habitat (3.0 mg/L) were strongly and negatively related to impervious surface in our Chesapeake Bay tributaries where salinity was present. The relationship of impervious surface and frequency of water column DO measurements below the proposed DO target (5.0 mg/L) did not emerge from this analysis. Proposed DO thresholds and targets for fish habitat were supported by target species relative abundance in relation to dissolved oxygen. Relative abundance of adequately sampled target species had begun to drop sharply at 3.0 mg/L and had stabilized at its positive asymptote by 5.0 mg/L. The 3.0 mg/L threshold was met at 10% impervious surface. Average percent impervious surface at the target bottom DO, 5.0 mg/L, equaled 4%.

Significant year effects were suggested for the impervious surface – DO relationship (frequency of bottom measurements below the threshold) by categorical regression of 2004-2005 data. Dissolved oxygen could vary annually due to organic and nutrient loading, and temperature and salinity (Gross 1977). Water temperatures and salinity were higher in 2005 than the previous two years of study.

The relationship of bottom DO and target species relative abundance seems clear; a plateau of relative abundance is reached between 3.0 and 5.0 mg/L. It is less clear how use of nearshore habitat may be altered by DO. Presence-absence of each target species in seines (Ps) did not support either hypothesis about habitat shifts because of changes in bottom DO concentration (i.e., fish would increasingly move from nearshore to bottom habitat as DO increased or relative abundance would increase positively in both habitats as bottom DO increased). Significant changes in Ps based on confidence interval overlap across the spectrum of bottom DO were not apparent. Use of bottom habitat, indicated by Pt, increased rapidly as DO increased to the threshold 3.0 mg/L and leveled or continued a slight increase by the target 5.0 mg/L. Analysis of trends in log10-transformed relative abundance of all target species combined with DO supported the hypothesis that relative abundance of target species would shift away from nearshore habitat to bottom habitat once DO conditions improved. With log10 transformation of catch, nearshore relative abundance of all target species declined linearly over the range of DO, while relative abundance in the bottom habitat maintained the same positive asymptotic shape exhibited in plots of each adequately sampled target species Pt.

Relative changes in seine and trawl catches in response to D.O conditions are important to note because seine sampling is relied upon by MD DNR and other Bay managers and scientists as an indicator of population status for striped bass and other species. It is possible that seine abundance may remain unchanged or increase when offshore conditions are poor. This could lead to an inflated estimate of relative abundance based on nearshore sampling when abundance could be decreasing because of bottom habitat loss. Crowding in the nearshore habitat, if accompanied by decreased growth due to competion, could lead to later losses related to size-based processes such as predation and starvation (Perrson and Bronmark 2002). It may be wise to check systematic increases in seine relative abundance against bottom DO or impervious surface levels to see if habitat shifting rather than increased abundance is indicated.

An increase in bottom habitat relative abundance was suggested for white perch and a decrease for juvenile striped bass as DO category exceeded 6-7 mg/L. This could reflect the influence of tidal-fresh Mattawoman Creek. This tributary provided the majority of information at this high level of DO. White perch are quite abundant there as well and this could have lead to biased conclusions at the highest DO categories. Mattawoman Creek and this portion of the Potomac River are major spawning and nursery areas for white perch (Lippson et al. 1979). Other brackish water tributaries in this study may have been lesser spawning areas themselves and are not adjacent to a major spawning region. Mattawoman Creek is located at the upper margin of striped bass spawning and juvenile distribution in the Potomac River (Lippson et al. 1979).

The relationship between bottom dissolved oxygen and impervious surface was strong in the mesohaline habitats and largely mimics impervious surface-water quality trends in freshwater (Cappiella and Brown 2001; Beach 2002). It appears that in order to achieve 5.0 mg/L, a watershed with a brackish estuary cannot exceed an impervious surface threshold of 3.5 – 5 %. This is consistent with studies of brook trout in Maryland streams. Morgan et al (2004) and Boward et al (1999), reported that brook trout were not found in streams with IS >2%. A more recent study found that brook trout were found in streams with IS up to 5% (S. Stranko, MD DNR, personal communication).

If the minimum dissolved oxygen threshold is set at 3.0 mg/L then the impervious surface threshold can not exceed 10%, consistent with the generally accepted threshold of 10% for freshwater habitats (Cappiella and Brown 2001; Beach 2002).

These thresholds do not appear to apply well in the tidal-fresh habitats sampled. Possible reasons could be that the tidal-fresh tributaries that were sampled had extensive submerged aquatic vegetation coverage (Orth et al. 2005) that may affect DO much differently than in brackish systems with less coverage. Salinity related stratification that would impair mixing of "good water" from the mainstem would be greatly reduced or absent. In the coming years, focus will shift to more tidal-fresh tributaries to try and understand these differences.

Habitat conditions may not always reflect only impervious surface influence in tributaries studied. During 2003-2004, the sewage treatment plant at the head of the Corsica River, one of our low impervious surface watersheds, malfunctioned. Sporadic sewage system failures and overloading of sewage plants after hurricanes have occurred in other systems as well.

This study has focused on the extent target species can occupy habitat in Bay tributaries subject to different levels of impervious surface. However, there are indications that reproductive success could be impaired by conditions associated with high levels of development. The Severn River (17% IS) has been closed to yellow perch harvest since 1989 in response to largely unknown, but assumed detrimental habitat conditions (Uphoff et al. 2005). During 2001-2003, Fisheries Service assessed yellow perch habitat in this heavily developed watershed by combining stock assessment (larvae-adults), experimental stocking (larvae-juveniles), and water quality monitoring (temperature, salinity, dissolved oxygen). At this time, depressed egg and larval viability appear to be critical factors suppressing the resident population. Two significant habitat quality issues potentially impacting yellow perch population dynamics were described in this study of Severn River – possible salinity intrusion into the upper tidal spawning area and larval nurseries because of landscape changes, and poor summer DO throughout juvenile and adult habitat. Salinities in the historic nursery were frequently above habitat requirements for larvae (93% of measurements) and dissolved oxygen violations were common for juveniles and adults in summer (≈5% at the surface, 20-40% at mid-depth, 70-80% at the bottom; Uphoff et al. 2005). Experiments by Rudolph et al. (2003) with common carp indicated that frequent exposure to hypoxic conditions could result in reduced reproductive success. Ovaries of yellow perch are repopulated with new germ cells during late spring and summer after resorptive processes are complete (Ciereszko et al. 1997; Malison 2004). This is when poor DO conditions were common in the Severn River and, if DO is linked to egg viability, these are likely the processes affected (Uphoff et al. 2005). PCB concentrations in white perch fillets were closely related to IS, and levels in the Severn River were the fourth highest of 14 Chesapeake Bay tributaries studied (King *et al*. 2004). Anthropogenic chemicals such as PCBs disrupt endocrine function associated with reproduction and are associated with depressed survival, malformation, and abnormal chromosome division of eggs and larvae (Longwell *et al.* 1992, 1996; Colborn and Thayer 2000, Rudolph *et al.* 2003

At this point, the overall effect of diminished bottom habitat on target species populations cannot be exactly quantified. Relative changes in trawl catch at the bottom of the channel as DO has changed has been documented. This effect is not restricted to deep areas; the uppermost sites sampled are often no deeper than 2 meters with bottom DO often as low there as at deeper sites when impervious surface is high. Poor DO is not uncommon at mid-depths in many of our brackish tributaries. Its source can be intrusion of mainstem waters at the mouth (not uncommon in downstream stations of Potomac River lower tributaries) or from development (upstream sites on the western shore).

Little comfort can be taken with the concept that fish simply move inshore and there will not be a great impact of diminished offshore habitat. At best, it appears that relative abundance inshore remains unchanged as bottom DO declines. Inshore habitat is essentially the linear perimeter of a tributary, while offshore bottom habitat represents area. A great deal more habitat is potentially lost when bottom waters become unsuitable, compared to what is preserved in the shore zone.

Recommendations for Impervious Surface Reference Points

A general impervious surface – fisheries management framework for resident species such as yellow and white perch should be considered. In systems with low impervious surface (less than 5%), fish habitat would generally be considered unimpaired and management actions that deal with fishing mortality or age at entry would be presumed as most appropriate. As impervious surface increases from 5 to 10%, habitat loss would likely have a negative influence on population dynamics. For example, in watersheds where impervious surface is 10% (mean bottom DO is predicted at 3 mg/L), we would predict that target fish abundance in bottom habitat would be reduced by about 70%. So, between 5% and 10% impervious surface, management measures would go from not needing to compensate for habitat loss to potentially compensating for a 70% reduction in abundance if the DO and log10 combined target species relationship abundance is used directly. Fisheries managers would need to contemplate compensating for additional habitat-related losses by increasingly drastic adjustments to harvest and by lobbying successfully for land use changes and increased pollution control with responsible agencies. At or above this level of habitat stress, successful preservation or restoration of resident stocks by traditional fisheries management adjustments becomes unlikely and an all or nothing harvest approach could be considered. A fishery could be closed entirely or restrictions could be lifted entirely depending on the philosophical leanings of managers because a sustainable harvest strategy has been foregone because of habitat loss. Harvest management is only going to succeed at high impervious surface levels if coupled with substantial habitat restoration initiatives.

These proposed impervious surface thresholds correspond closely to impervious surface based predictions of PCB-related human consumption advisories (unweighted regression with two high PCB points excluded) for white perch in Bay tributaries (King et al. 2004). One meal per month would be recommended when impervious surface is about 5%, half a meal at about 10%, and consumption is not recommended when impervious cover occupies 20% of the watershed.

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Table 1. Percent impervious cover and total acres for the watersheds sampled in 2005. Data are 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.

Area	Watershed	% Impervious	Total Acres
Mid Chesapeake Bay	Corsica	4.0	23,964.81
Mid Chesapeake Bay	Miles	3.4	27,372.64
Mid Chesapeake Bay	Severn	17.5	44,247.06
Mid Chesapeake Bay	South	10.2	36,433.36
Mid Chesapeake Bay	West/Rhode	4.8	16,272.72
Potomac River	Breton Bay	5.1	35,099.09
Potomac River	Mattawoman	8.5	59,887.89
Potomac River	St. Clements	4.3	29,626.16

Table 2. Water quality requirements for juvenile (J) and adult (A) target species.

Water Quality Criteria Requirements	Striped Bass	Yellow Perch	White Perch	Alewife	Blueback Herring	American Shad	Spot	Atlantic Croaker	Atlantic Menhaden
TEMPERATURE (°C)	14.0-26.0 J	19.0 -24.0 J	15.2 - 31.0 J	17.0 - 23.0 J	11.5 - 28.0 J	15.6 - 23.9.0 J	6.0 - 25.0 J	17.5 - 28.2 J	16.9 - 28.2 J
	20.0 – 22.0 A Preferred	12.0 – 22.0 A	21.5 – 22.8 A preferred	16.0 – 22.0 A	8.0-22.8 A	8.0-30.0 A	12.0 - 24.0 A	14.9 - 31.4 A	6.0 - 25.0 A
SALINITY (ppt)	0 – 16.0 J	0 – 5.0 J	0 – 8.0 J	0 – 28.0 J	0 – 28.0 J	0 – 30.0 J	0.1-25.0 J	0.5 - 21.0 J	0.5 - 15.0 J
		5.0 – 8.0 J preferred		0 – 5.0 J optimum	0 – 5.0 J optimum	0 – 5.0 J optimum			
	14.0 – 21.0 A	0 – 13.0 A	0 – 18.0 A	0 – 35.0 A	0 – 35.0 A	0 – 35.0 A	4.0-29.0 A	4.0 - 21.0 A	4.0.- 29.0 A
	10.0 – 27.0 A tolerated								
DISSOLVED OXYGEN (mg/l)	>5.0 J, A	minimum of 5.0 J A	minimum of 5.0 – 7.0 J/A	minimum of 3.6 J A	minimum of 3.6 J	4.0 – 5.0 J A	2 - >5.0 J A		> 4.5 J, A
				> 5.0 preferred	> 5.0 preferred	>5.0 preferred	>5.0 preferred		

Table 3. 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 in 2005.

Watershed	% Impervious	Percent Temperature > 31°C	Percent DO < 3.0 mg/L	Percent DO < 5.0 mg/L	Percent Salinity >13 ppt
Breton	5.1	9.9	12.7	23.5	28.4
Corsica	4.0	9.2	15.5	48.7	0.0
Mattawoman	8.5	6.7	0.0	0.0	0.0
Miles	3.4	7.0	23.5	45.3	14.0
Rhode	4.8	0.0	6.3	29.5	13.6
Severn	17.5	0.0	41.4	44.1	0.0
South	10.2	0.0	26.9	41.8	4.4
St. Clements	4.3	0.0	10.6	27.8	26.7
West	4.8	0.0	8.6	24.4	17.1

Table 4. Catch statistics and impervious cover in seines by river in 2005.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Seine
Breton	18	21	Mummichog Atlantic silverside Spot White perch adult Striped killifish Striped bass YOY	5.1	1604	89.1
Corsica	18	21	Mummichog Atlantic silverside White perch adult Spottail shiner White perch YOY Banded killifish Striped killifish	4.0	8627	479.3
Mattawoman	1	5	Banded killifish White perch YOY	8.5	53	53
Miles	18	23	Atlantic menhaden Atlantic silverside White perch Adult Mummichog Striped killifish Spot White perch YOY	3.4	4439	246.6
Rhode	12	14	Atlantic silverside Striped killifish Spot Inland silverside Bay anchovy	4.8	2816	234.7
Severn	23	17	Atlantic silverside White perch YOY Banded killifish White perch Adult Atlantic menhaden Spot Striped killifish	17.5	4626	201.1
South	24	20	Atlantic menhaden Atlantic silverside Spot Striped bass YOY Inland silverside Bay anchovy	10.2	6255	260.6
St. Clements	24	27	Atlantic silverside Mummichog White perch YOY Banded killifish Striped killifish Spot Striped bass YOY	4.3	5945	247.7
West	6	16	Atlantic silverside Spot Striped bass YOY	4.8	2355	392.5

Table 5. Catch statistics and impervious cover in trawl by river in 2005.

River	Number of Samples	Number of Species	Species Comprising 90% of Catch	Percent Impervious	Total Catch	Number of Fish per Seine
Breton	24	11	Bay anchovy Spot	5.1	1612	67.2
Corsica	24	18	White perch Adult White perch YOY Spot	4.0	3998	166.6
Mattawoman	24	25	White perch YOY Spottail shiner White perch Adult Blueback herring	8.5	5375	224.0
Miles	24	16	Spot White perch YOY White perch Adult	3.4	2280	95.0
Rhode	12	11	Spot Bay anchovy	4.8	2050	170.8
Severn	24	3	Bay anchovy White perch Adult Spot	17.5	20	0.8
South	24	11	Spot Bay anchovy	10.2	1409	58.7
St. Clements	24	9	Spot Bay anchovy White perch Adult	4.3	1073	44.7
West	12	12	Spot Bay anchovy	4.8	2004	167.0

Table 6. Percentage of total trawl catch comprising each target species by river, 2005.

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.
Breton	0.372	0.000	0.062	0.000	0.062	40.261	0.000	1.489	0.620	0.062	0.000	0.000
Corsica	0.100	0.000	0.050	0.000	0.175	22.811	0.050	0.000	40.345	31.366	0.250	0.000
Mattawoman	0.130	0.056	0.019	0.000	2.679	0.707	0.019	0.540	8.763	64.093	0.409	0.037
Miles	0.044	0.000	0.088	0.000	0.000	44.254	0.044	1.228	23.553	23.860	0.000	0.000
Rhode	0.293	0.000	0.439	0.000	0.049	54.292	0.000	2.489	1.610	0.195	0.000	0.000
Severn	0.000	0.000	0.000	0.000	0.000	20.000	0.000	0.000	40.000	0.000	0.000	0.000
South	0.142	0.000	0.142	0.000	0.000	72.676	0.142	1.987	2.342	0.071	0.000	0.000
St. Clements	0.186	0.000	0.000	0.000	0.000	59.646	0.280	1.305	17.241	0.652	0.000	0.000
West	0.000	0.000	0.649	0.000	0.000	71.507	0.000	0.200	0.200	0.000	0.000	0.000

Table 7. Percentage of total seine catch comprising each target species by river, 2005.

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.
Breton	0.187	0.000	1.683	0.000	0.000	16.147	0.935	4.551	11.721	0.187	0.000	0.000
Corsica	0.220	0.000	1.855	0.000	0.015	1.611	0.116	0.209	9.876	5.355	0.046	0.232
Mattawoman	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30.189	0.000	0.000
Miles	0.000	0.000	25.569	0.000	0.000	4.348	0.113	2.410	19.780	2.658	0.000	0.000
Rhode	0.000	0.000	0.000	0.000	0.000	4.652	0.000	3.232	0.994	0.036	0.000	0.000
Severn	0.000	0.000	7.847	0.000	0.000	4.604	0.281	2.270	9.274	13.057	0.000	0.195
South	0.000	0.000	56.899	0.000	0.208	2.654	0.032	2.494	2.014	1.631	0.080	0.911
St. Clements	0.421	0.034	0.841	0.000	0.034	4.979	1.733	3.230	9.537	0.151	0.000	0.017
West	0.000	0.000	2.590	0.000	0.000	20.425	0.000	2.930	2.675	0.552	0.000	0.000

Figure 1. Watersheds sampled in 2005.

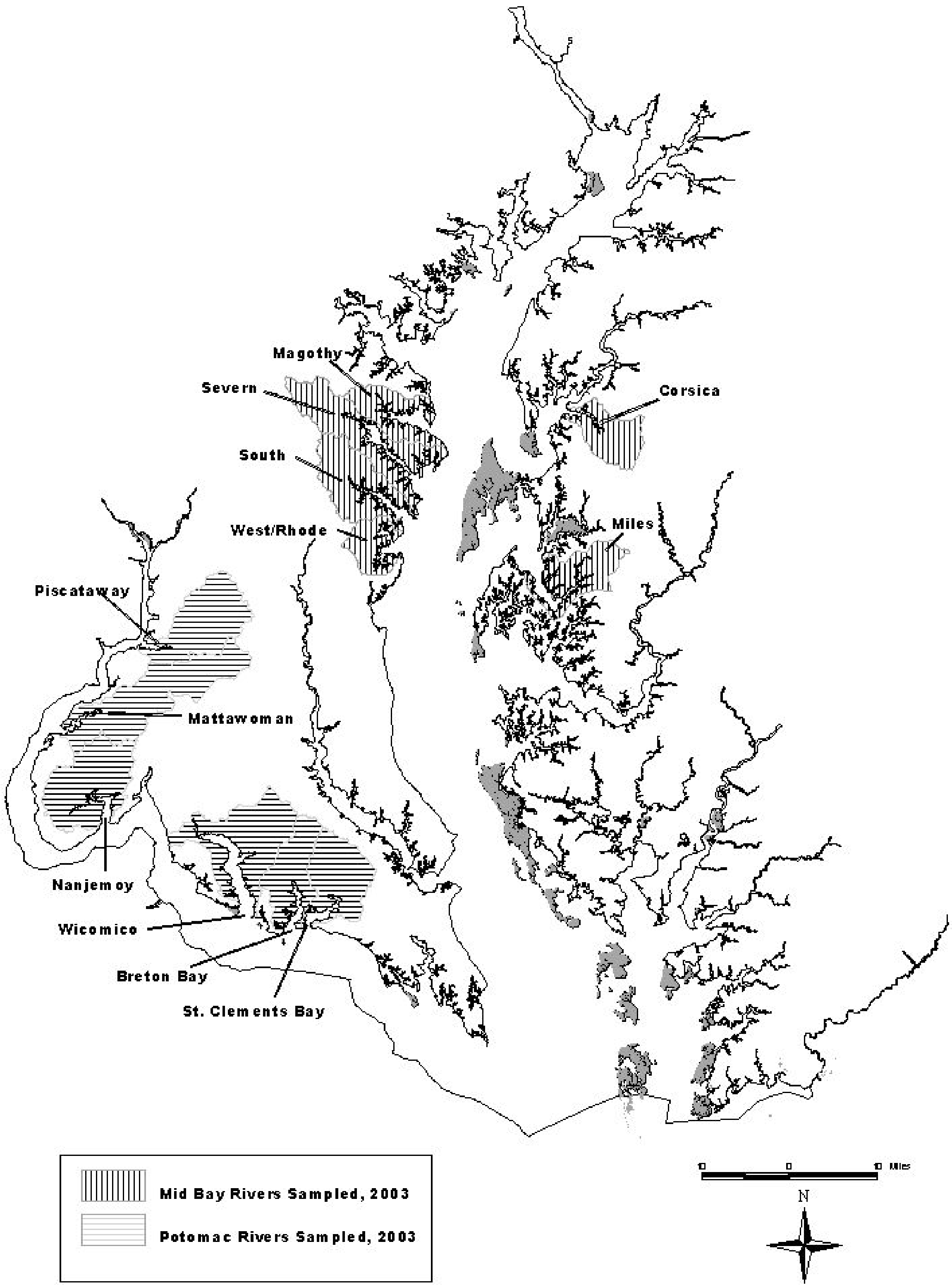

Figure 2. South River watershed with seine and trawl stations sampled in 2005.

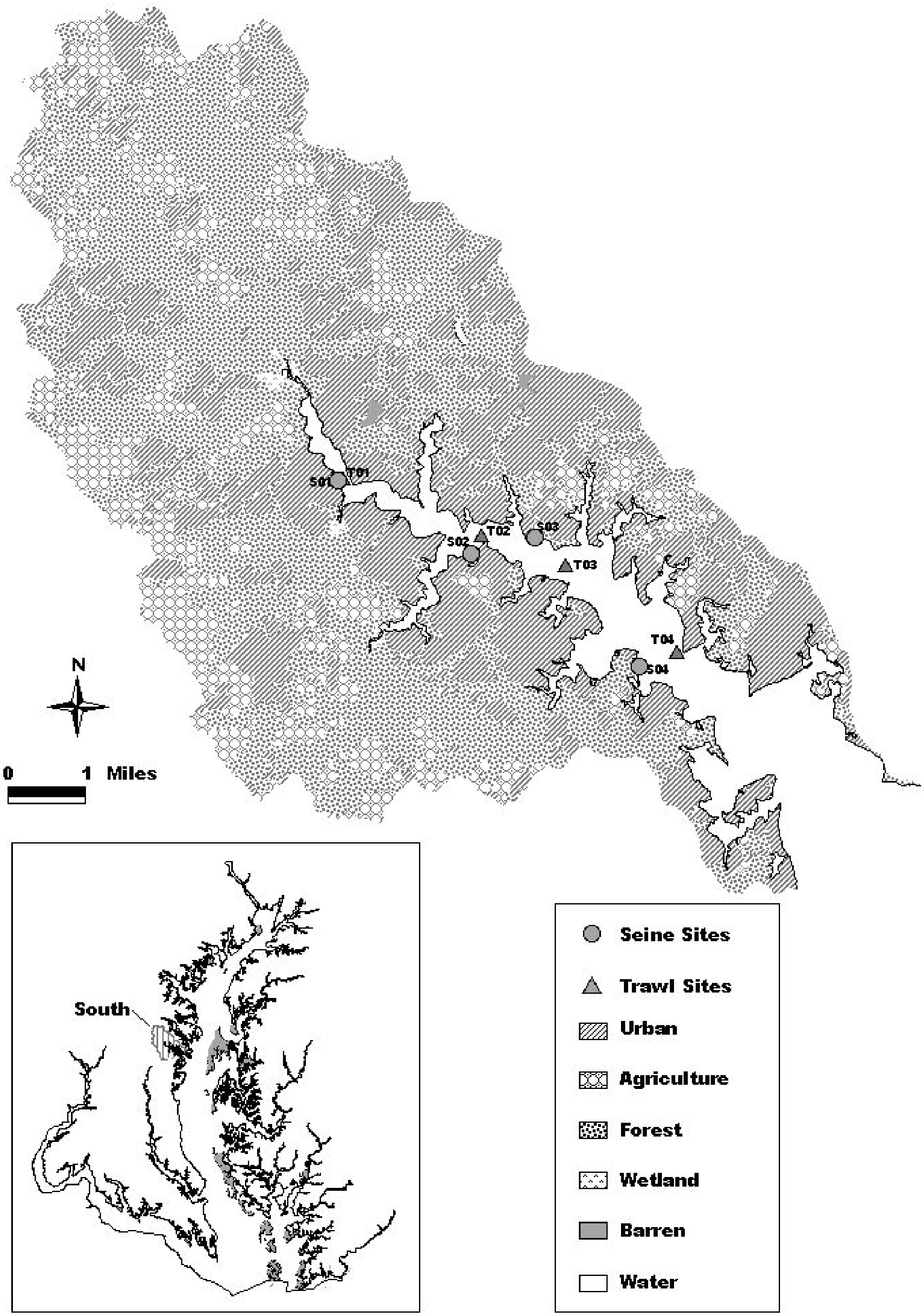

Figure 3. Severn River watershed with seine and trawl stations sampled in 2005.

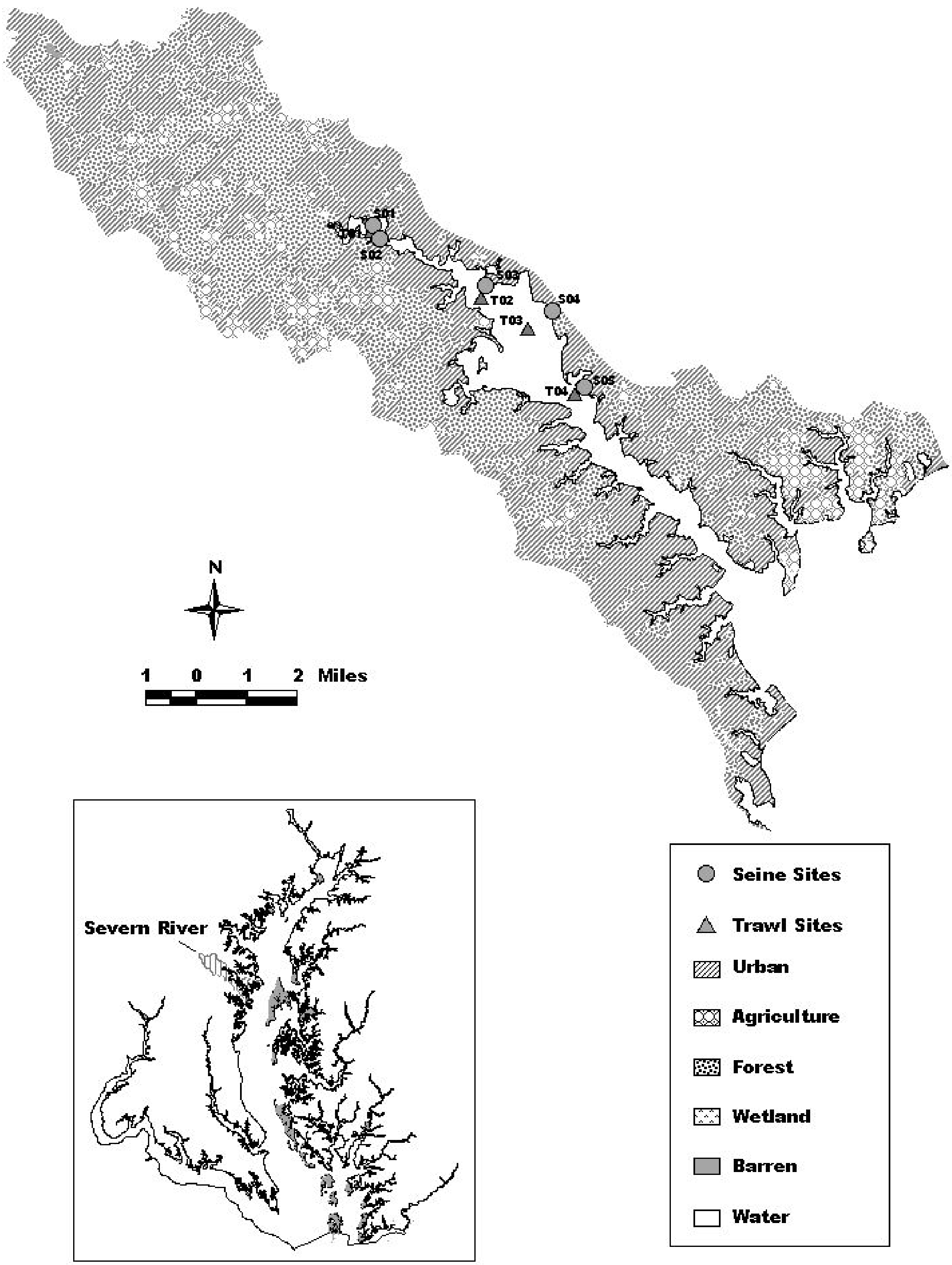

Figure 4. Rhode and West watershed with seine and trawl stations sampled in 2005.

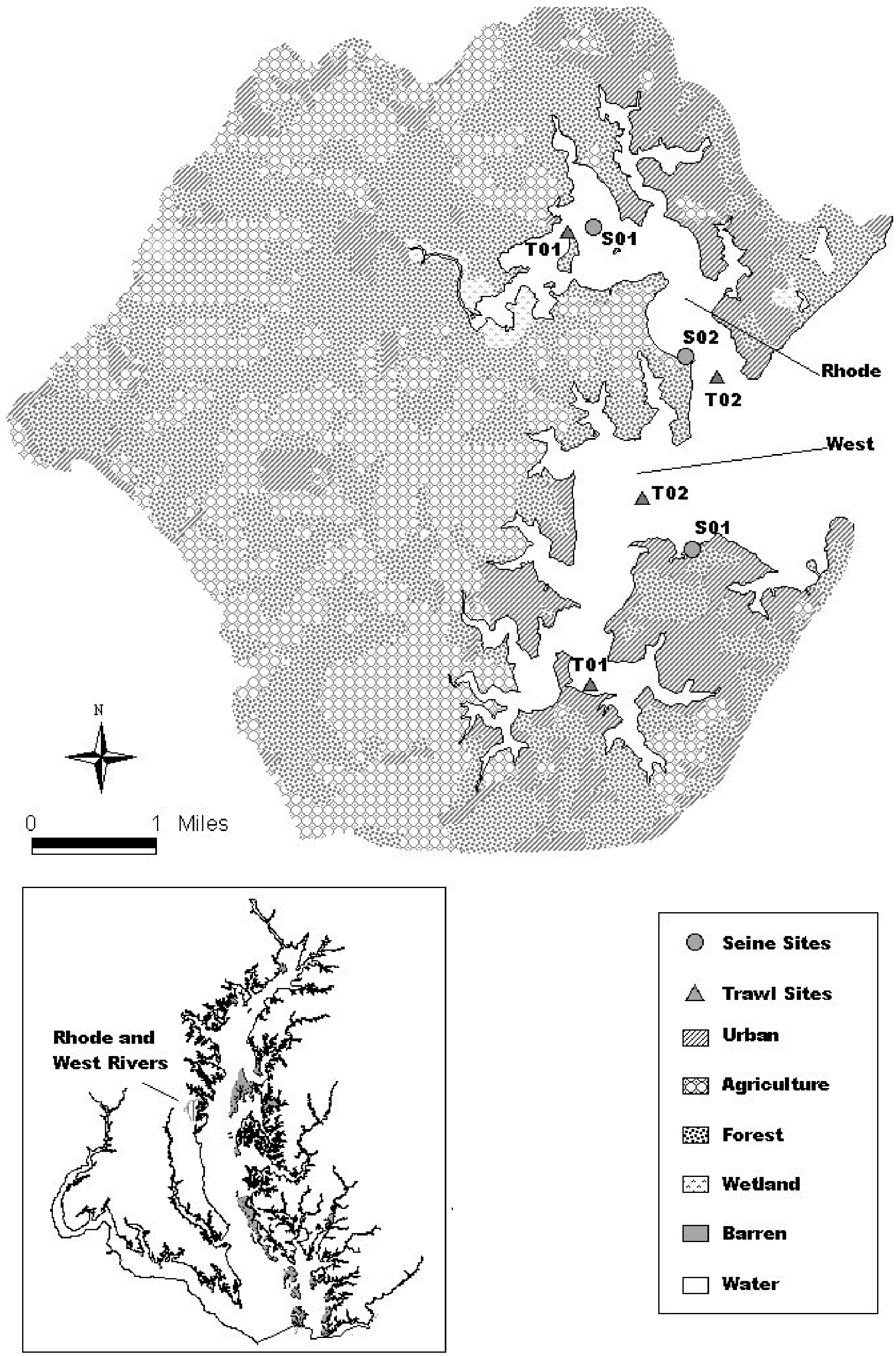

Figure 5. Corsica River watershed with seine and trawl station sampled in 2005.

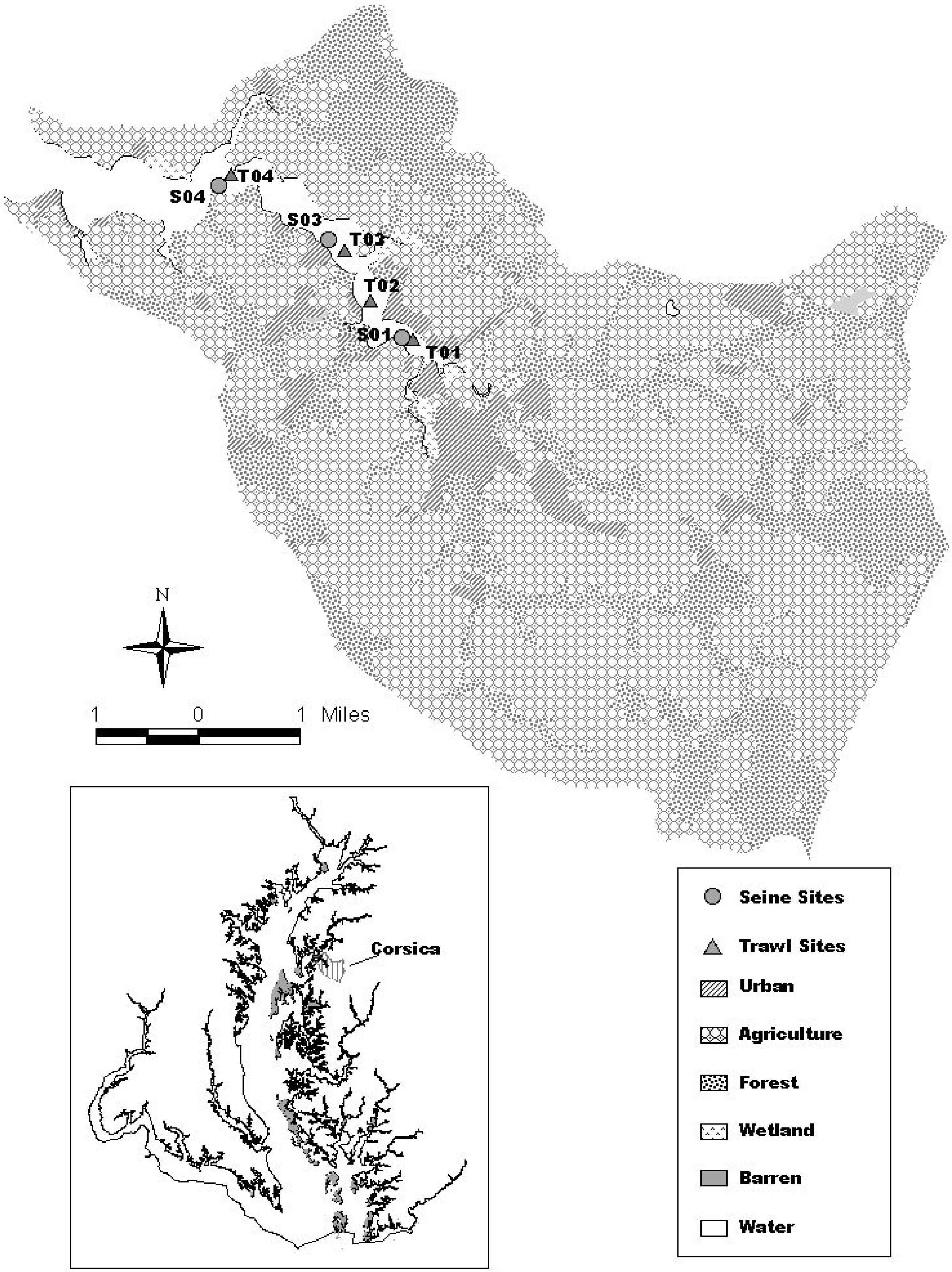

Figure 6. Miles River watershed with seine and trawl stations sampled in 2005.

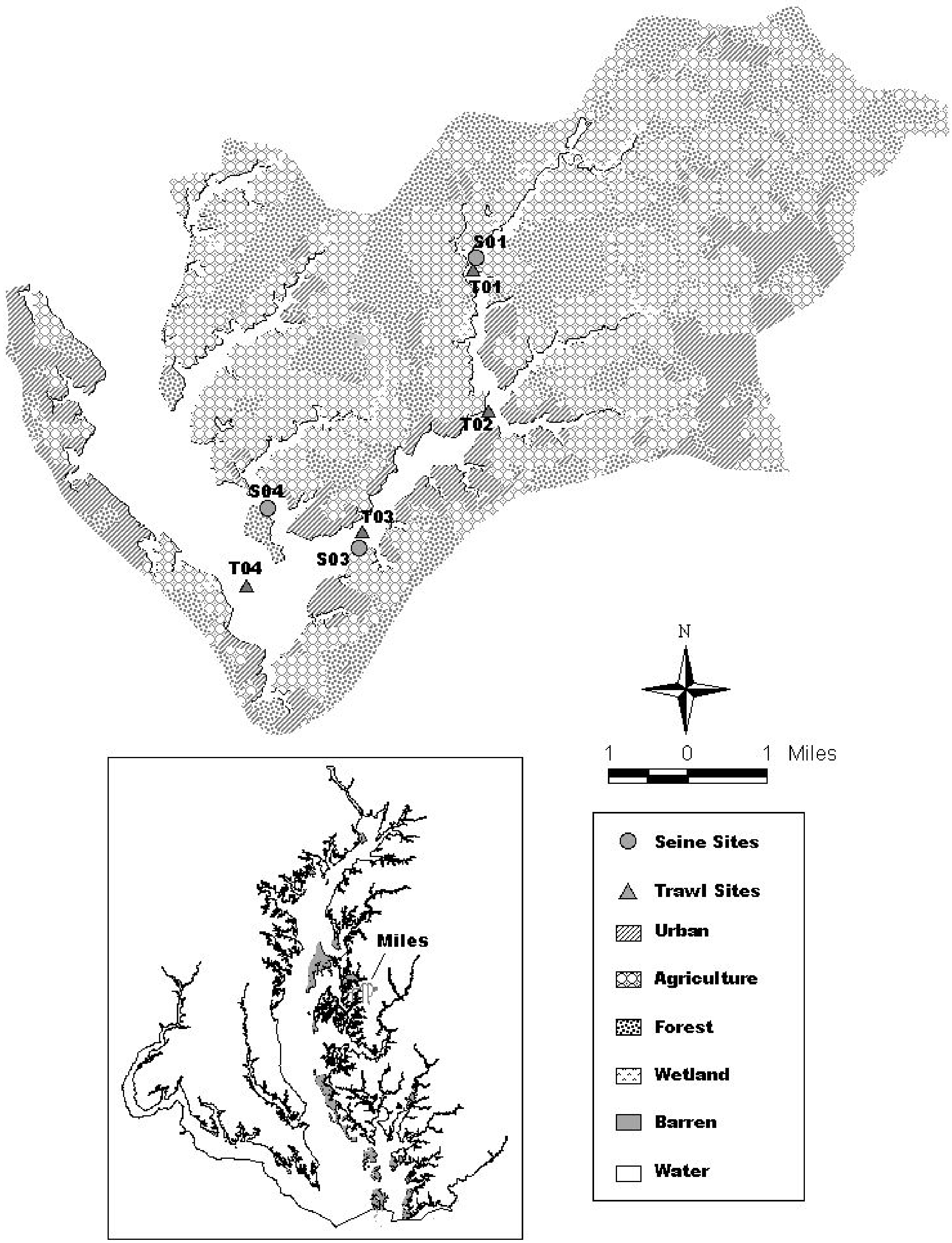

Figure 7. St. Clements Bay watershed with seine and trawl stations sampled in 2005.

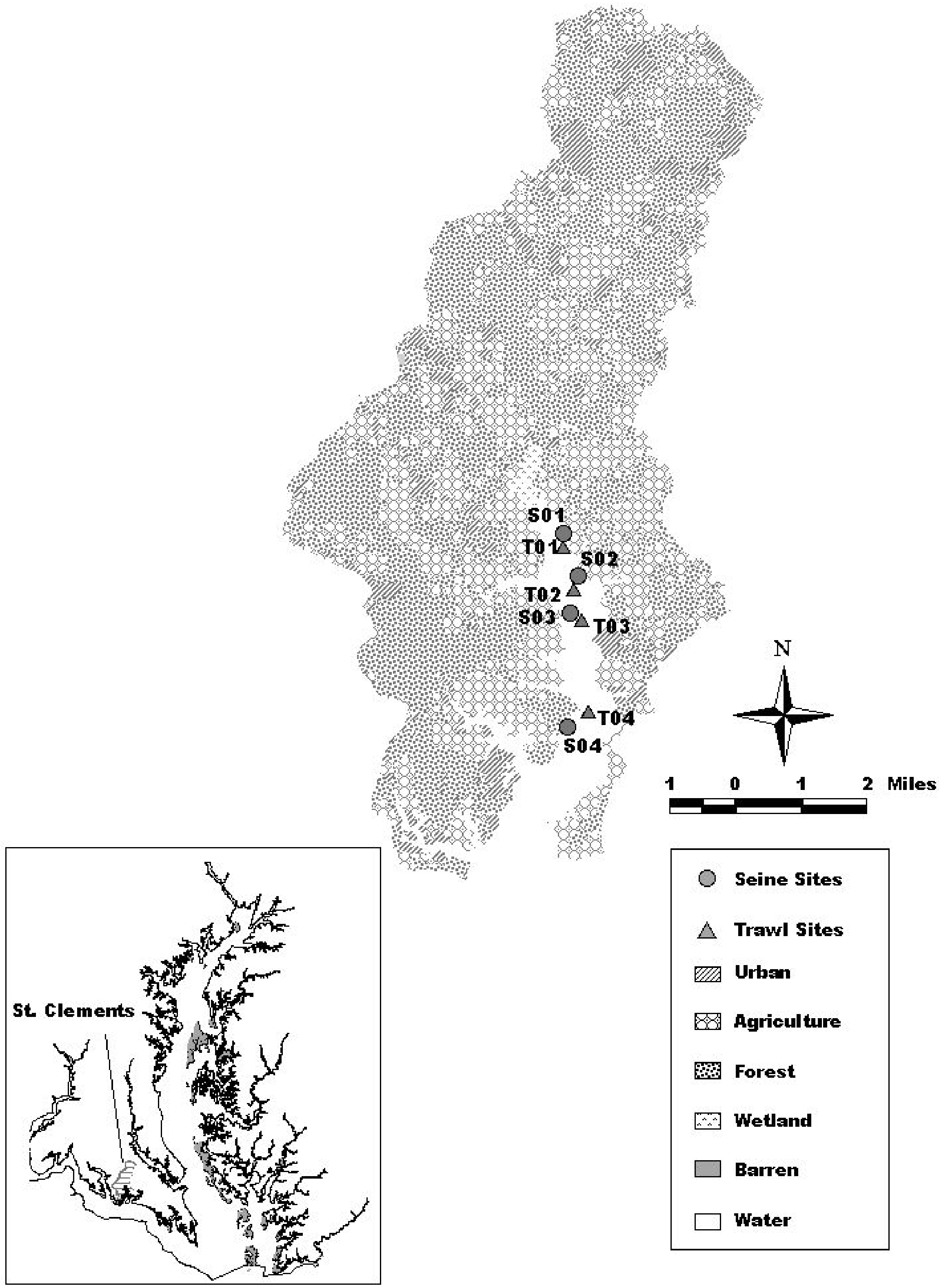

Figure 8. Breton Bay watershed with seine and trawl stations sampled in 2005.

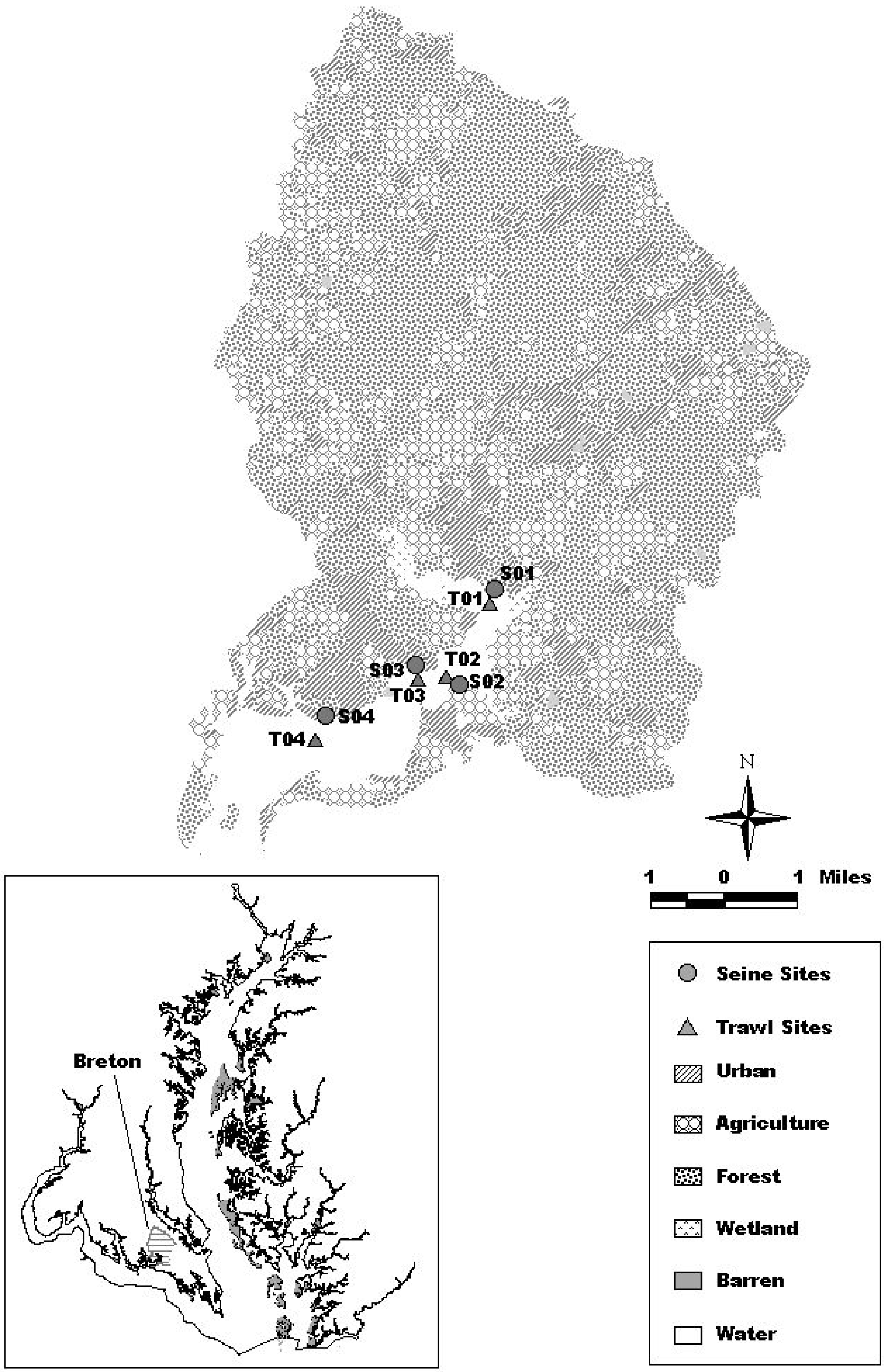

Figure 9. Mattawoman Creek watershed with seine and trawl stations sampled in 2005.

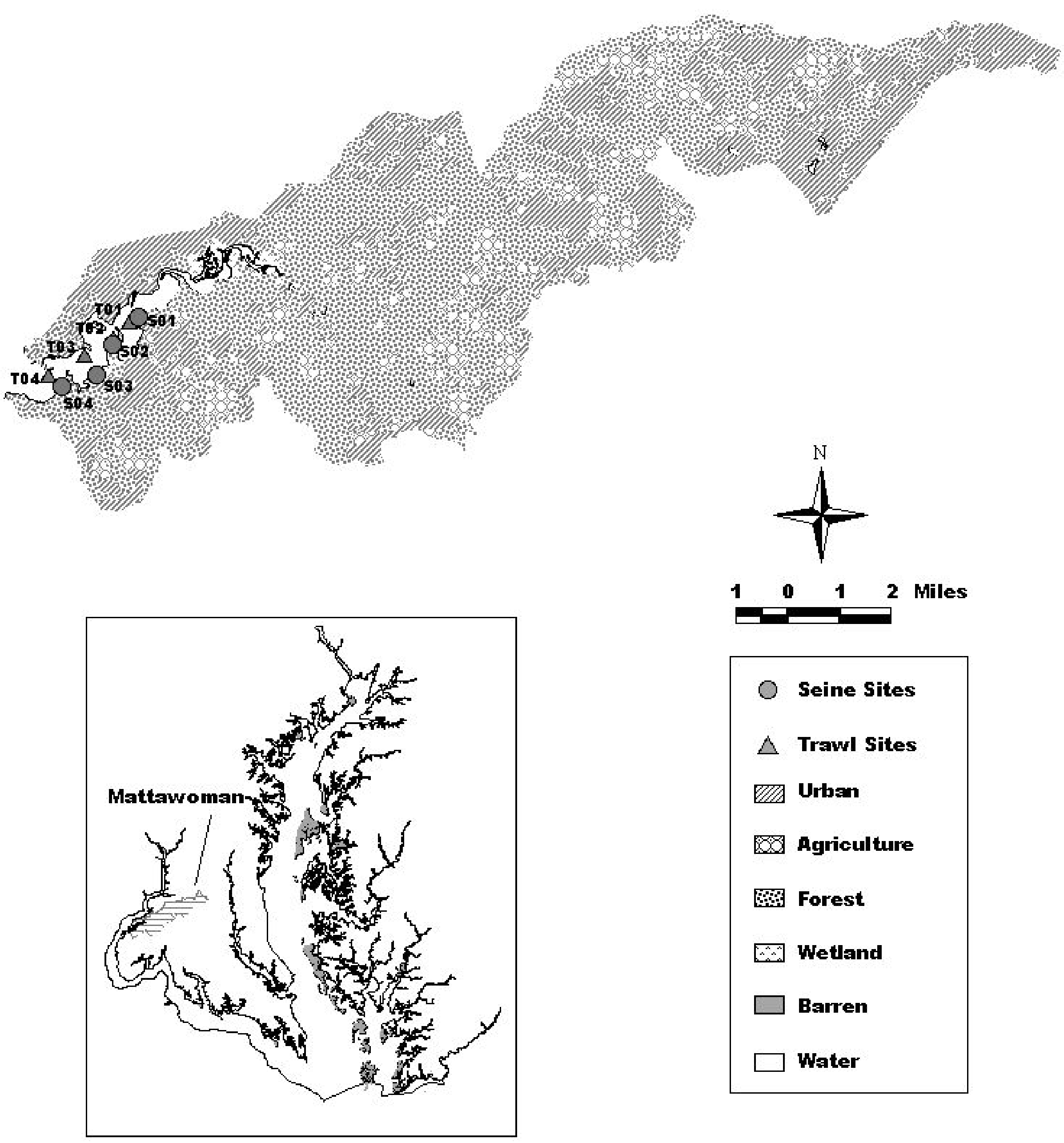

Figure 10. Distribution of 2005 composite temperature by river. Dark bar is the sample median, large box represents the 25-75% interval, narrow boxes are the 5 - 95% interval, and small black squares represent outliers. The shaded area represents preferred habitat values.

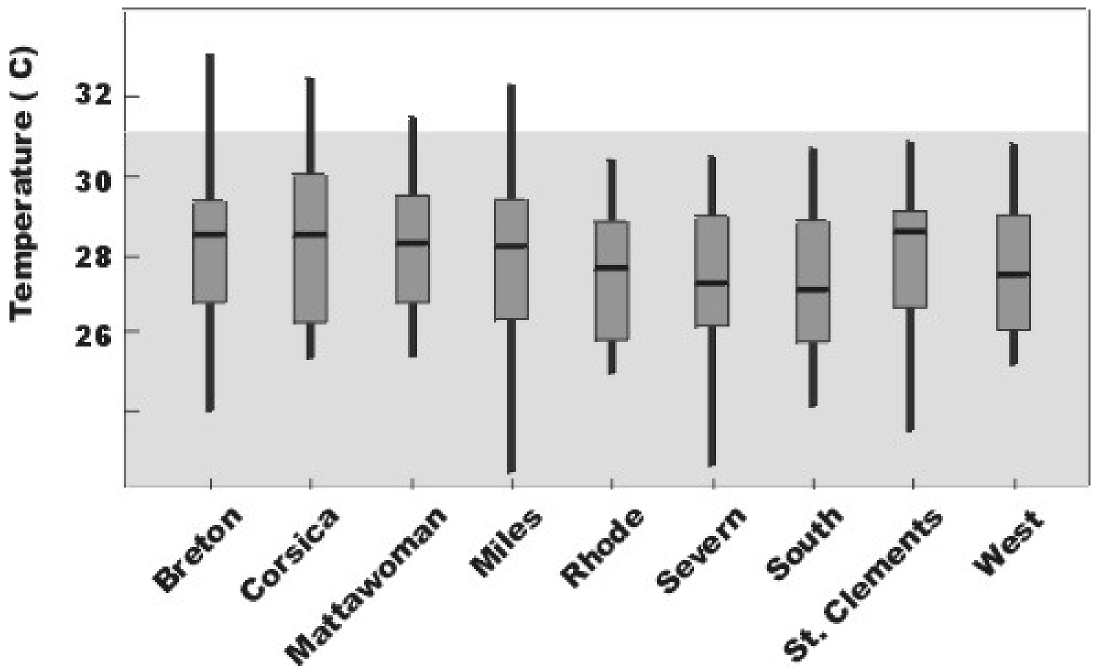

Figure 11. Distribution of the 2005 composite salinity by river. Dark bar is the sample median, large box represents the 25-75% interval, narrow boxes are the 5 - 95% interval, and small black squares represent outliers. The shaded area represents preferred habitat values.

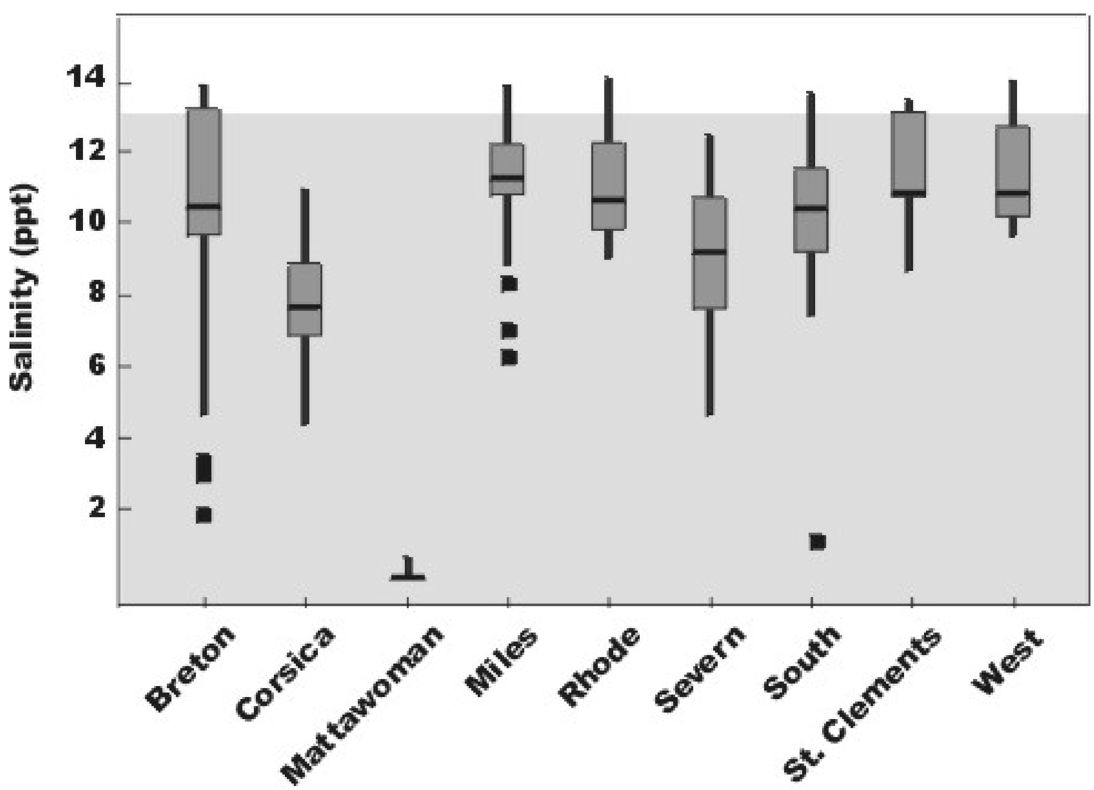

Figure 12. Distribution of 2005 composite dissolved oxygen by river. Dark bar is the sample median, large box represents the 25-75% interval, narrow boxes are the 5 - 95% interval, and small black squares represent outliers. The shaded area represents preferred habitat values.

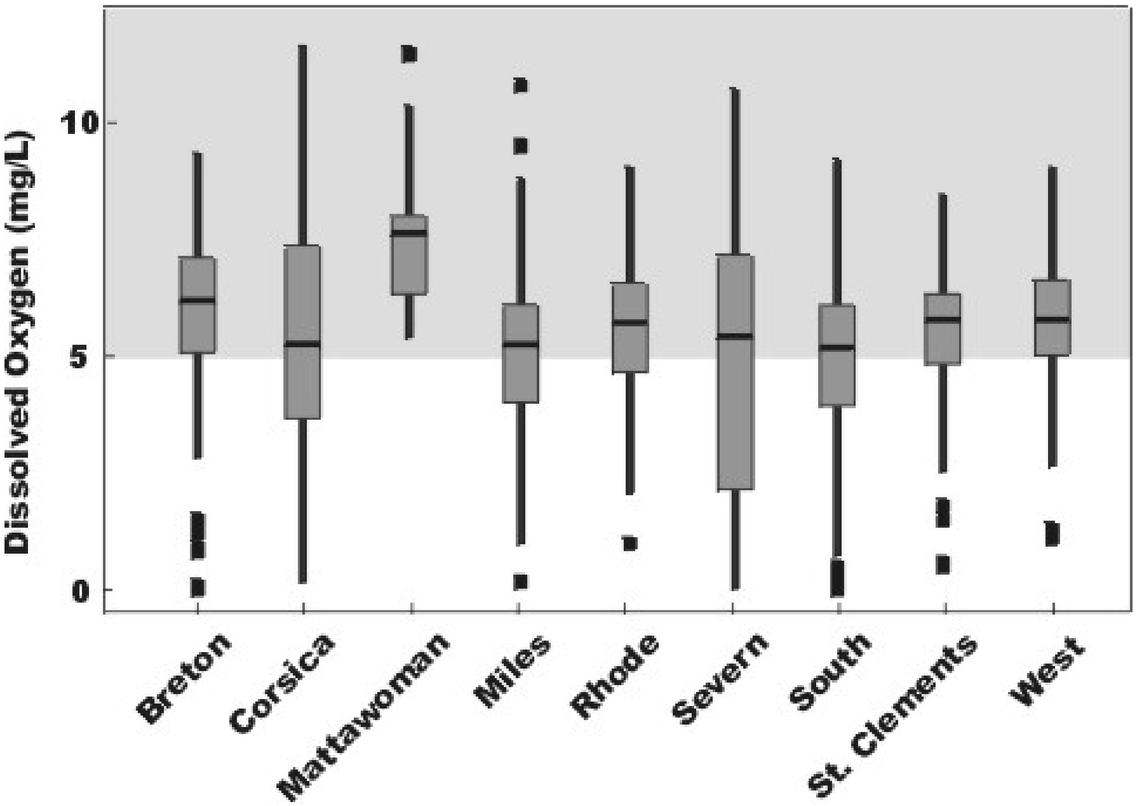

Figure 13. Distribution of 2005 composite bottom dissolved oxygen by river. Dark bar is the sample median, large box represents the 25-75% interval, narrow boxes are the 5 - 95% interval, and small black squares represent outliers. The shaded area represents preferred habitat values.

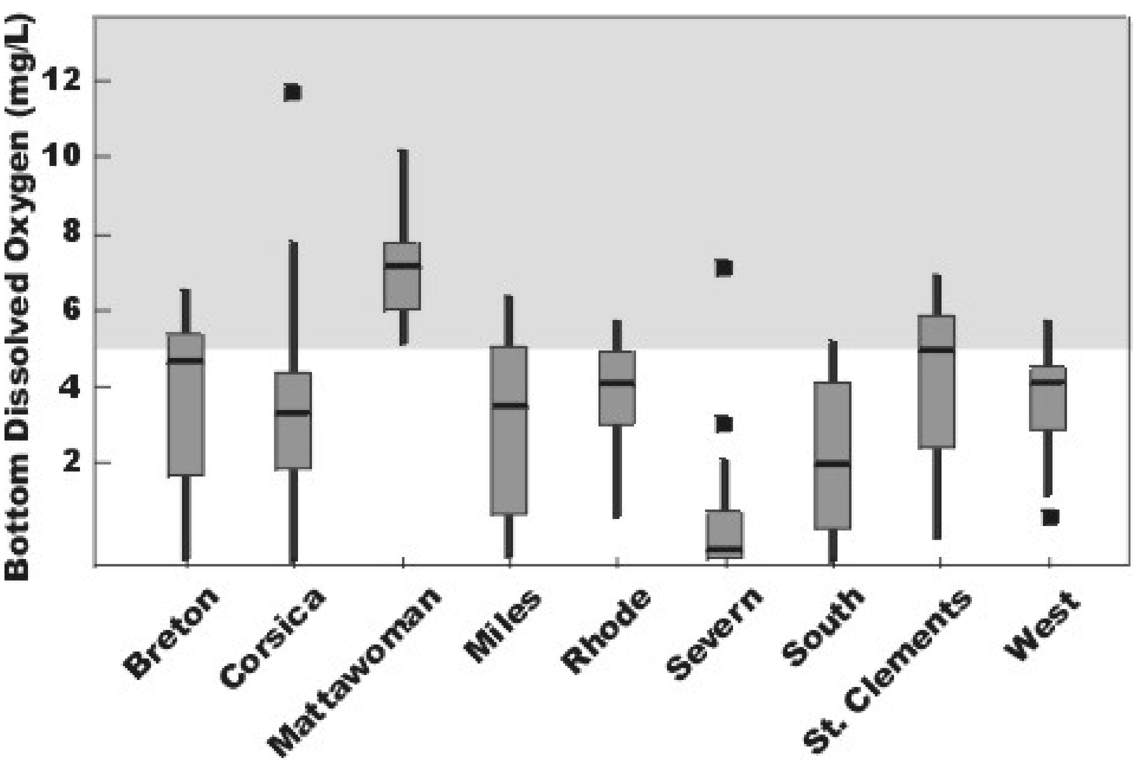

Figure 14. Observed and predicted percentage of dissolved oxygen (D.O>) measruement <3.0 mg/L from categorical regression of year and percent impervious surface.

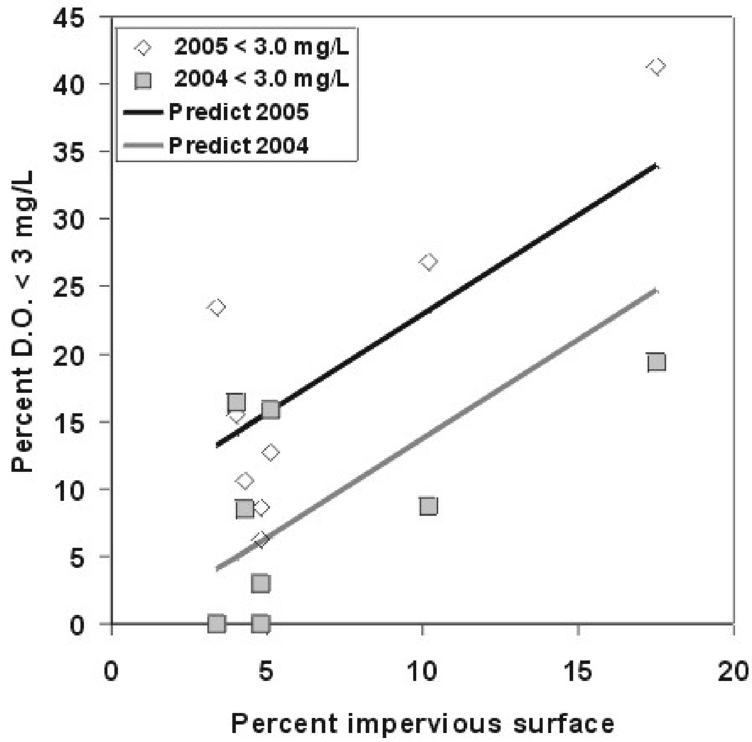

Figure 15. Observed percentage of dissolved oxygen (D.O.) measurements < 5.0 mg/L versus percent impervious surface. Tributaries with high agriculture (Ag) use in the watershd are designated by filled symbols.

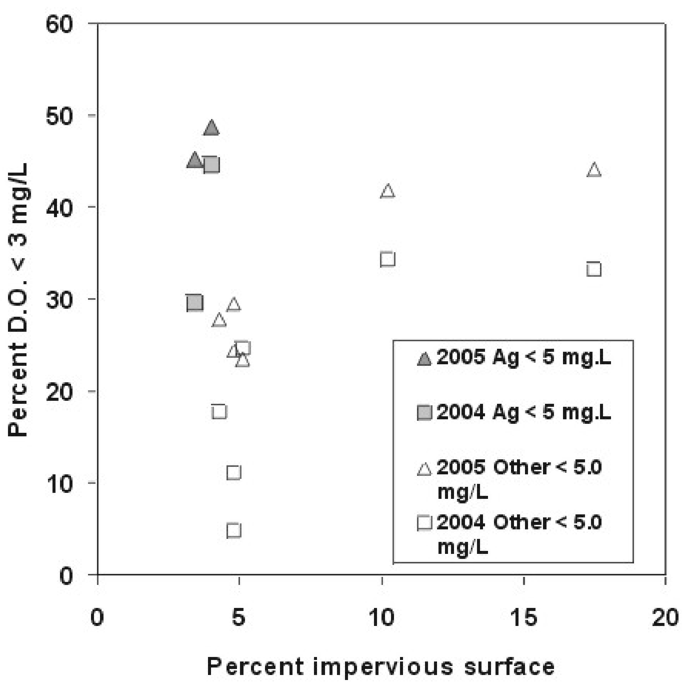

Figure 16. Regression of mean bottom dissolved oxygen against percent watershed in imperviou surface based on data collected during 2003-2005, by river station year for stations 1 and 2 (upper most stations in the watershed). Tidal fresh tributaries were excluded (denoted by the x).

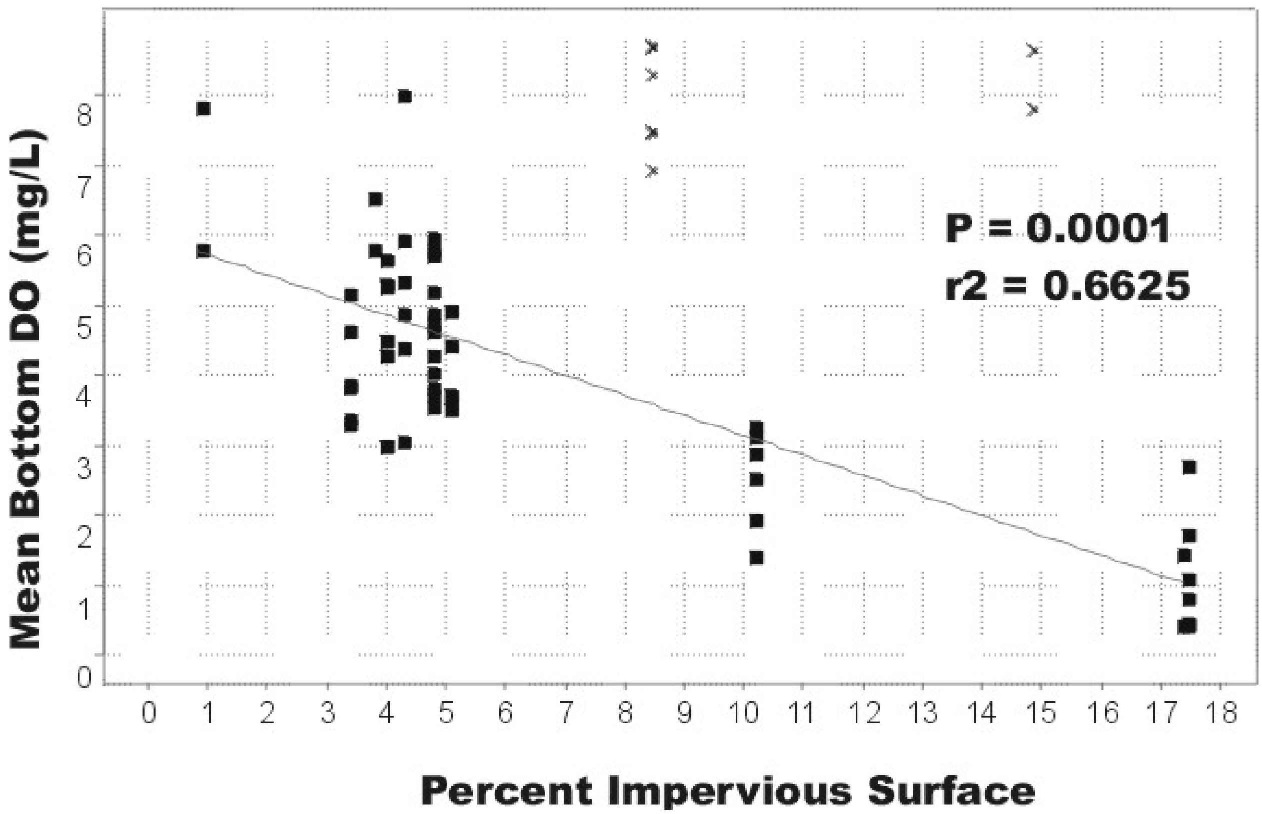

Figure 17. Proportion of alewife in the seine and trawl samples by bottom dissolved oxygen category.

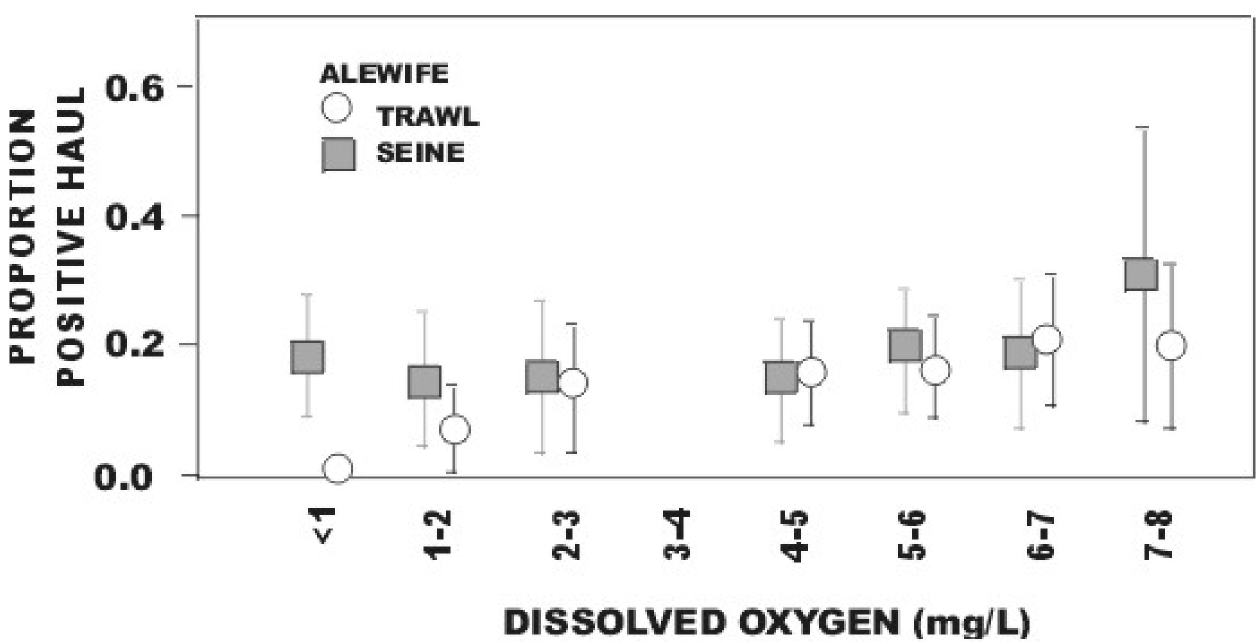

Figure 18 Proportion of blueback herring in the seine and trawl samples by bottom dissolved oxygen category.

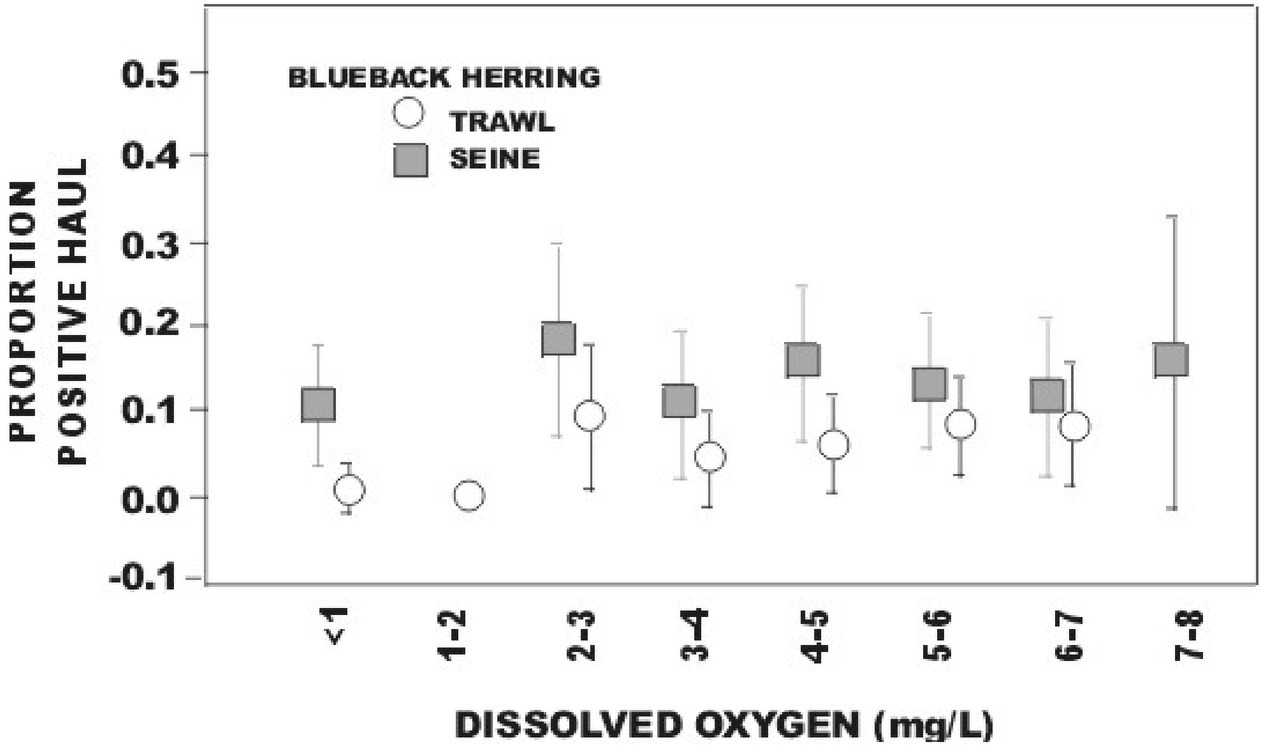

Figure 19. Proportion of Atlantic menhaden in the seine and trawl samples by bottom dissolved oxygen category.

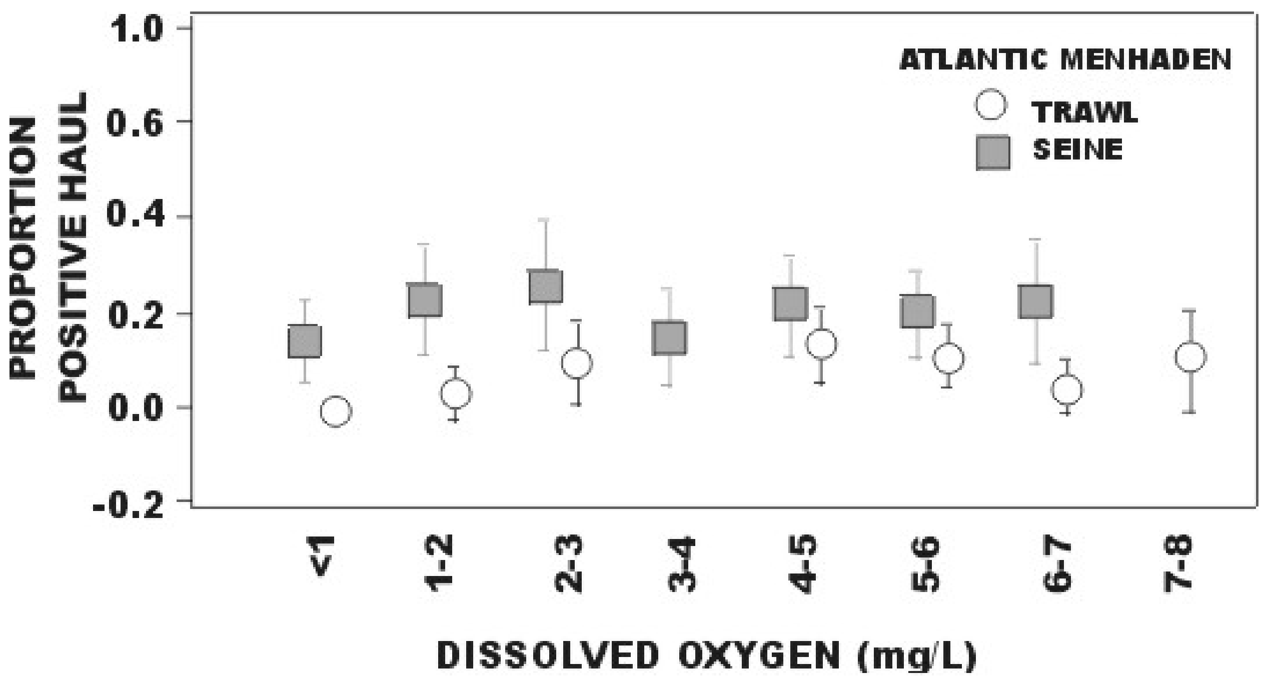

Figure 20. Proportion of yellow perch juveniles in the seine and trawl samples by bottom dissolved oxygen category.

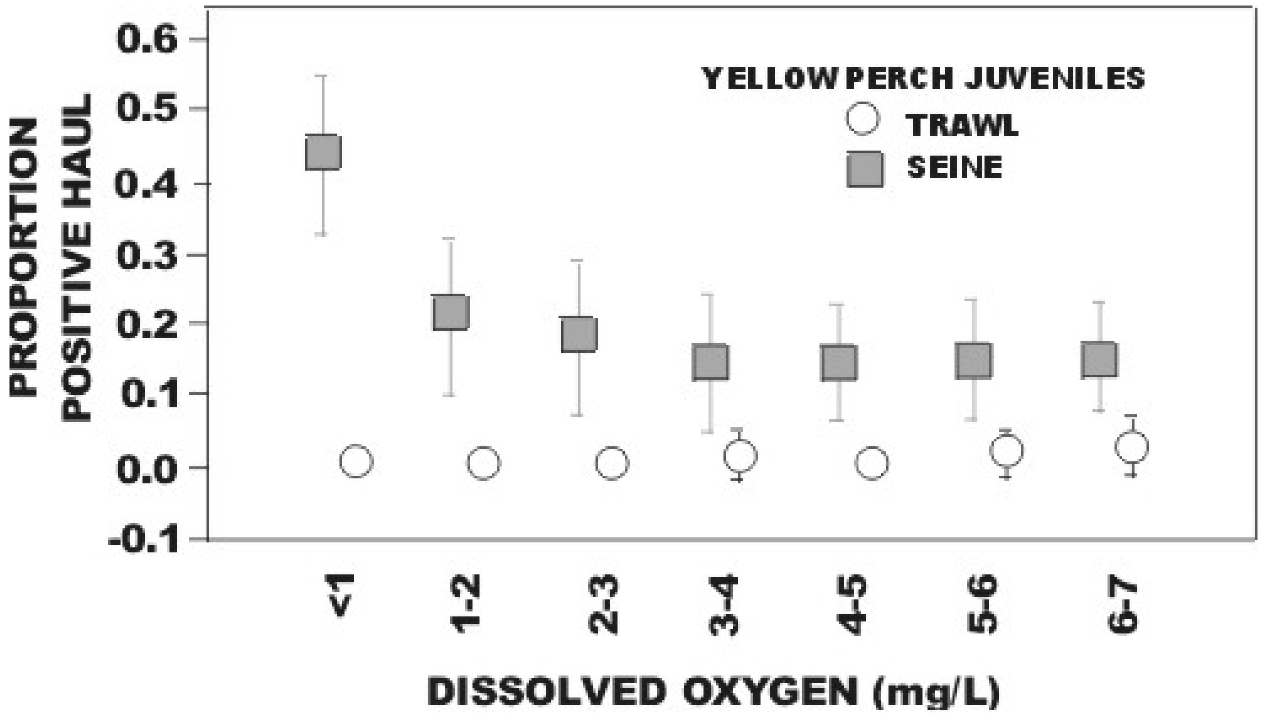

Figure 21. Proportion of striped bass juveniles in the seine and trawl samples by bottom dissolved oxygen category.

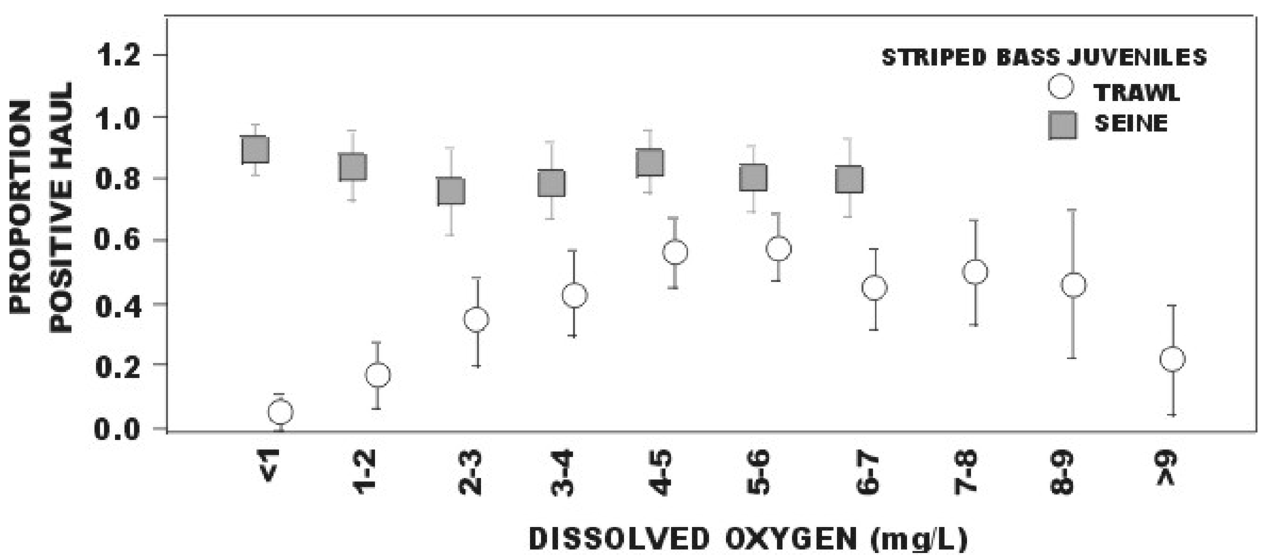

Figure 22. Proportion of white perch juveniles in the seine and trawl samples by bottom dissolved oxygen category.

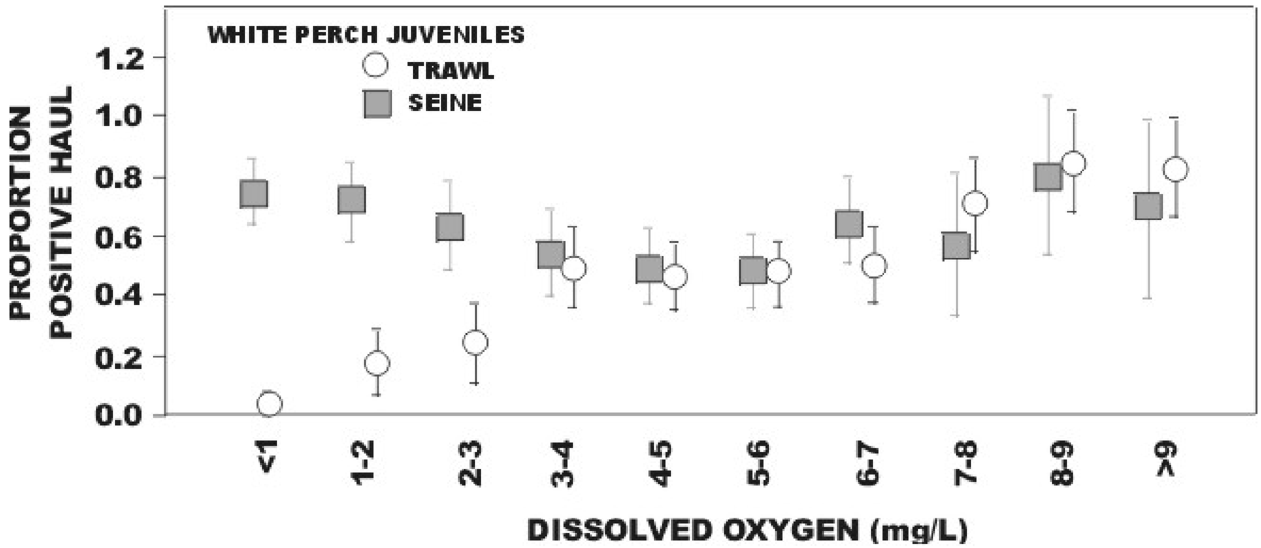

Figure 23. Proportion of white perch adults in the seine and trawl samples by bottom dissolved oxygen category.

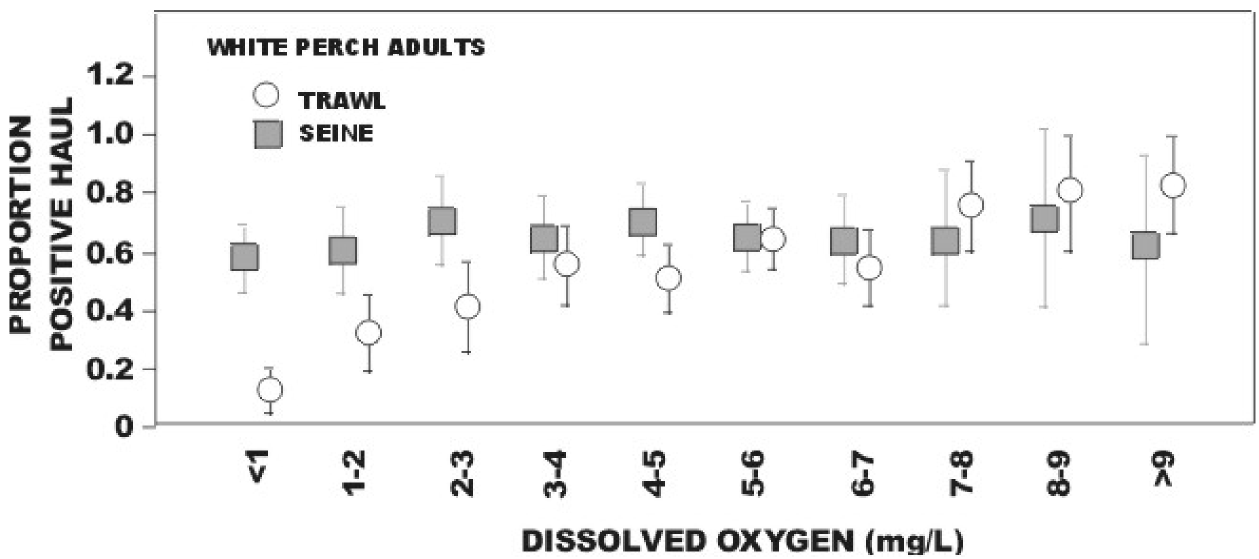

Figure 24. Proportion of spot in the seine and trawl samples by bottom dissolved oxygen category.

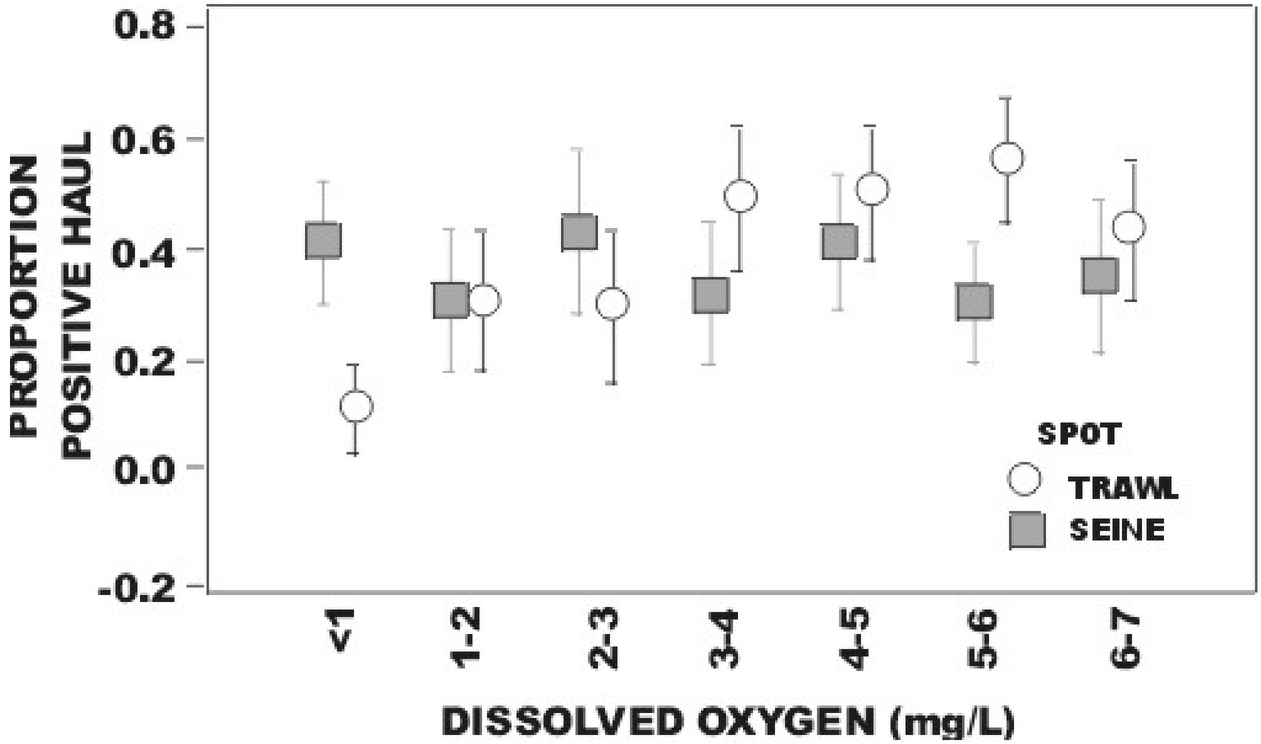

Figure 25. Proportion of all target species in the seine and trawl samples by bottom dissolved oxygen category.

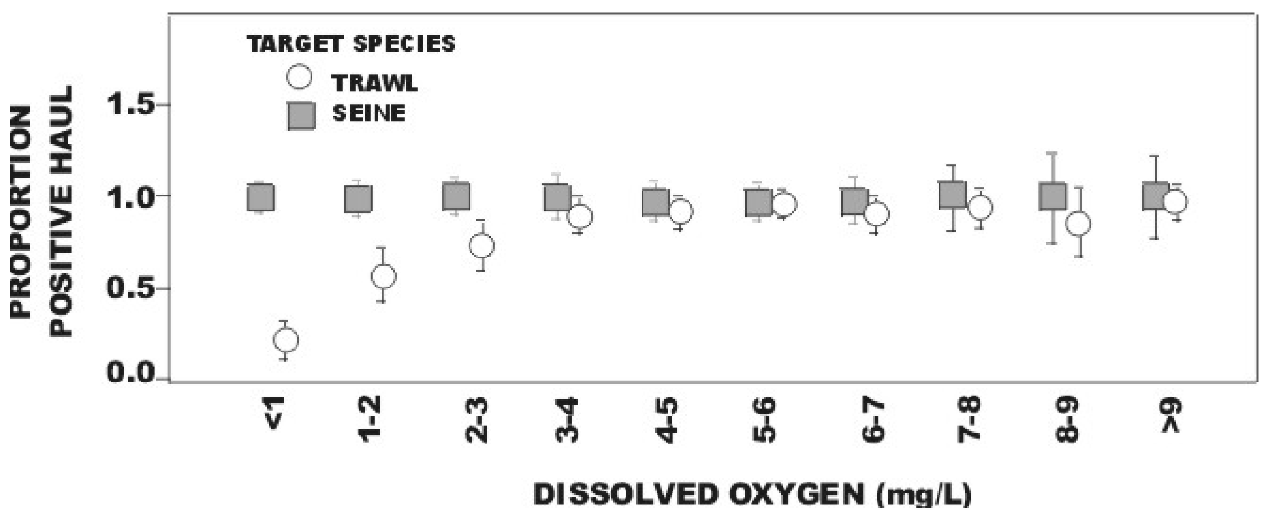

Figure 26. Log 10 mean abundance of all target species combined with 95% confidence inervals in the seine and trawl samples against the bottom dissolved oxygen category.