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Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 2006-December 2006 : annual progress report

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ANNUAL PROGRESS REPORT

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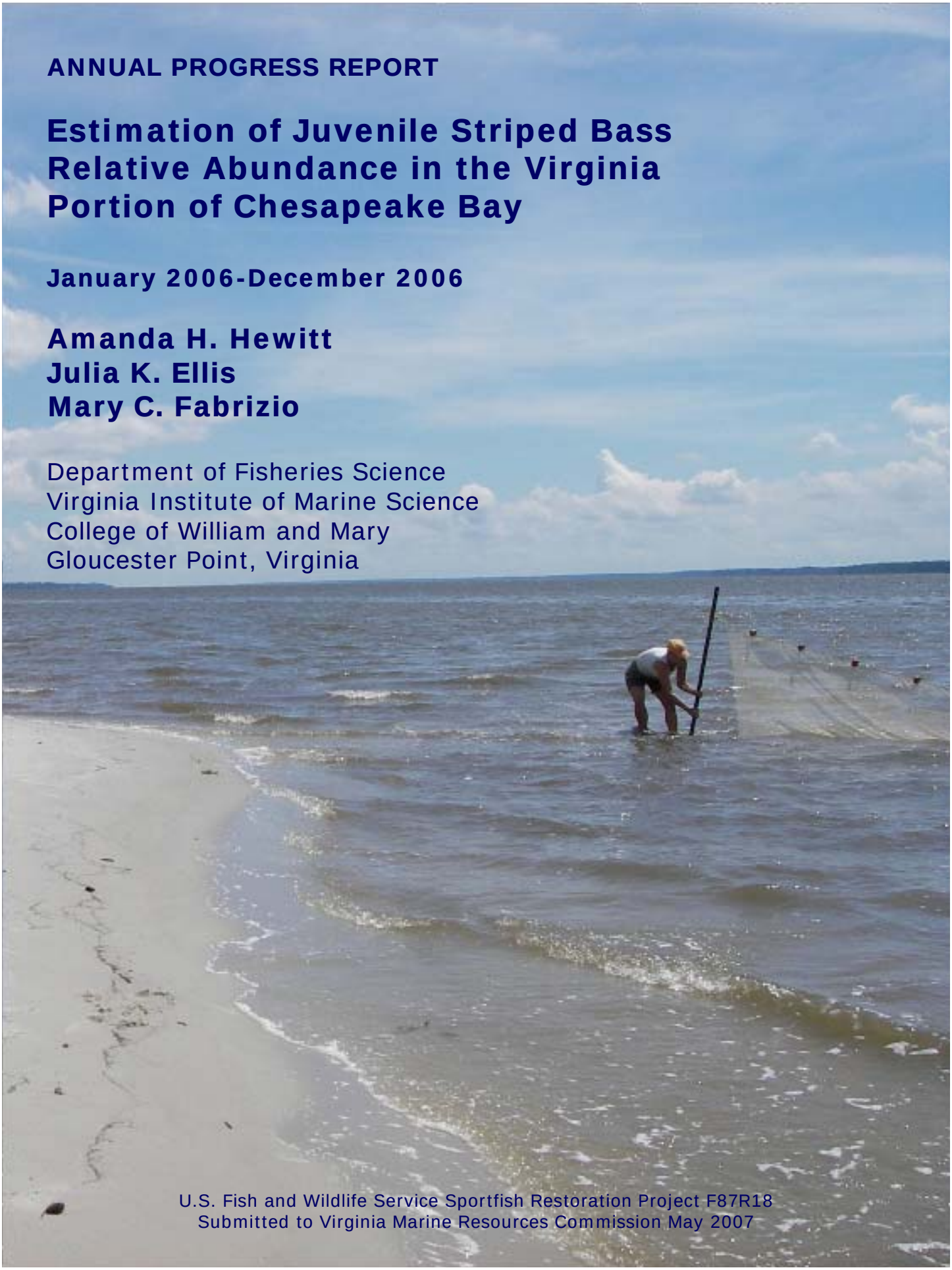

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PREFACE

The primary objective of the Virginia Institute of Marine Science juvenile striped bass survey is to monitor the relative annual recruitment success of juvenile striped bass in the major Virginia nursery areas of lower Chesapeake Bay. The U.S. Fish and Wildlife Service initially funded the survey from 1967 to 1973. After a hiatus ending in 1980, funds were provided by the National Marine Fisheries Service under the Emergency Striped Bass Study program. Commencing with the 1988 annual survey, the work was jointly supported by Wallop-Breaux funds (Sport Fish Restoration Act) administered through the U.S. Fish and Wildlife Service and the Virginia Marine Resources Commission. This report summarizes the results of the 2006 sampling period and compares these results with previous years.

Specific objectives for the 2006 program were to:

1. estimate the relative abundance of the 2006 year class of striped bass from the James, York and Rappahannock river systems,
2. quantify environmental conditions at the time of collection and
3. examine relationships between juvenile striped bass abundance and environmental and biological data.

INTRODUCTION

Historically, the Atlantic striped bass (*Morone saxatilis*) has been one of the most commercially and recreationally sought-after fish species on the east coast of the United States. Decreases in the commercial harvest of striped bass in the 1970s paralleled the steady decline in abundance of striped bass along the east coast; abundance of the Chesapeake Bay stock was particularly depressed. Because the tributaries of Chesapeake Bay had been identified as the primary spawning and nursery area for the migratory portion of the stock, fishery managers made recommendations and eventually enacted regulations intended to halt and reverse the decline of striped bass in Chesapeake Bay and elsewhere along the east coast (ASMFC 2003).

In 1981, the Atlantic States Marine Fisheries Commission (ASMFC) developed the Atlantic Coast Striped Bass Interstate Fisheries Management Plan (FMP), which included recommendations on management measures to improve the status of the stocks. The Virginia Marine Resources Commission adopted this plan in March 1982 (Regulation 450-01-0034), but ASMFC did not have regulatory authority for fisheries management in individual states at that time. As striped bass populations continued to decline, Congress passed the Atlantic Striped Bass Conservation Act (PL 98-613) in 1984, which required states to either follow and enforce management measures in the FMP or face a moratorium on striped bass harvests. Since 1981 the FMP was amended six times to address changes in the management of the stocks. Amendment VI to the plan, adopted in February 2003, requires "producing states" (e.g. Virginia, Maryland, Delaware and New York) to develop and support programs to monitor recruitment.

Well before the FMP requirement, Virginia began monitoring the annual recruitment of juvenile striped bass with funding from the Commercial Fisheries Development Act of 1965 (PL88-309). This monitoring, begun in 1967, continued until 1973. Monitoring of striped bass recruitment was re-instituted in 1980 with Emergency Striped Bass Study funds (PL 96-118, 16 U.S.C. 767g, the "Chafee Amendment"), and since 1989 has been funded by the Wallop-Breaux expansion of the Sport Fish Restoration and Enhancement Act of 1988 (PL 100-448, “the Dingle-Johnson Act”).

Initially, the Virginia program used a 6 ft x 100 ft (2 m x 30.5 m) x 0.25 in (6.4 mm) mesh bag seine, but comparison tows with Maryland gear (4 ft x 100 ft x 0.25 in mesh; 1.2 m x 30.5 m x 6.4 mm mesh) showed virtually no statistical differences in catch, and Virginia adopted the "Maryland seine" (Colvocoresses 1984). The gear comparison study aimed to standardize methods thereby allowing baywide examination of recruitment success (Colvocoresses and Austin 1987); this was never realized due to remaining differences in data analysis (MD: arithmetic index, VA: geometric index). A baywide index using a geometric mean weighted by river spawning area was finally developed in 1993 (Austin et al. 1993).

METHODS

Field sampling was conducted during five biweekly sampling periods from July through mid-September of 2006. During each sampling period the seine was hauled at 18 historically sampled sites (index stations) and 21 auxiliary stations along the shores of the James, York and Rappahannock systems (Figure 1). Auxiliary sites were added in 1989 to provide better geographic coverage and increase sample sizes within each river system and to permit monitoring of trends in juvenile abundance within each river system. Such

monitoring was desirable in light of increases in stock size and expansion of the nursery ground.

Collections were made by deploying a 100 ft (30.5 m) long, 4 ft (1.2 m) deep, 0.25 in (6.4 mm) mesh minnow seine perpendicular to the shoreline until either the net was fully extended or a depth of about 4 ft (1.22 m) was encountered, pulling the offshore end down-current and back to the shore. Duplicate hauls were made at each index station during each round, and a single haul was made at each auxiliary station during most rounds. At index stations, all fish taken during the first haul were removed from the net, measured, and held in water-filled buckets until after the second haul, then released. All fish collected were identified and counted; all striped bass were measured; and all individuals or a sub-sample of at least 25 individuals of other species were measured to the nearest mm fork length (or total length if appropriate). Salinity, water temperature and dissolved oxygen concentrations were measured after the first haul using a YSI water quality sampler. Sampling time, tidal stage and weather conditions were recorded at the time of each haul. When two hauls were made, an intervening period of 30 minutes was allowed between hauls and the first sample was processed during this interlude. All fishes captured, except those preserved for life history studies, were returned to the water at the conclusion of sampling.

In this report, comparisons of recruitment indices with prior years are made for the “primary nursery” area only (Colvocoresses 1984) by using data collected from months and areas sampled during all years (index stations). Thus, data from auxiliary stations are not included. Because the frequency distribution of the catch is skewed and approximates a negative binomial distribution (Colvocoresses 1984), a logarithmic

transformation (ln(x+1)) was applied to normalize the data prior to analysis (Sokal and Rohlf 1981). Mean values are back-transformed and scaled up arithmetically (x2.28) to allow comparison with Maryland data. Thus, a "scaled" index refers to an index that is directly comparable with the indices from Maryland.

Mean catch rates are contrasted by comparing 95% confidence intervals. Reference to "significant" differences between means in this context will be restricted to cases of non-overlapping confidence intervals. Because standard errors are calculated from transformed (logarithmic) values, confidence intervals on the back-transformed and scaled indices are non-symmetrical.

RESULTS

Objective 1: Estimate the relative abundance of the 2006 year class of juvenile striped bass from the James, York and Rappahannock river systems.

In 2006, 1408 young-of-the-year striped bass were collected from 180 seine hauls at index stations and 319 were collected from 96 hauls at the auxiliary stations (Table 1, Figure 1). The index of relative abundance for the index stations is calculated as the adjusted overall mean catch per seine haul. The estimated index for 2006 is 10.10, which is significantly greater than the historical average index of 7.36 (Table 2, Figure 2). ("Historical" refers to all survey years from 1967 to the present.)

James River System

The 2006 index for the James drainage is 11.16, which is not significantly different from the historical James drainage index of 9.35 (Table 3, Figure 3). However, the 2006 mainstem James (not including the Chickahominy River) index is 14.52, which is significantly greater than the historical mainstem James index of 8.61. Juvenile striped

bass were fairly widely distributed in the James River in 2006, with the exception of the most downstream and upstream auxiliary stations (Table 1). Individuals were collected downstream in early July (round one) at auxiliary station J22 and the upstream station (J68) (Table 1, Figure 4). Auxiliary station J77 replaced auxiliary stations J74 and J78, which had become difficult to sample due to increasing mud levels.

Catches at the Chickahominy River index stations (C1 and C3) were highest in early July (round one) and declined sharply in subsequent months (Table 1, Figure 4). The 2006 Chickahominy River index is 6.32, which is not significantly different from the historical Chickahominy index of 11.01 (Table 3).

York River System

The 2006 index for the York drainage (11.40) was statistically greater than the historical York drainage index of 5.83 and was the greatest index value by drainage (Table 3, Figure 3). All stations in the mainstem York River are auxiliary, and juvenile striped bass were captured at all of these stations (Y15, Y21 and Y28) in 2006 (Table 1). Catches in the mainstem of the York River also occurred in 2003, 2004, and 2005 (Austin et al. 2004, Austin et al. 2005, Austin et al. 2006), which was a distinct reversal from 2002 when no striped bass were captured at York River mainstem stations. Striped bass were captured on all visits to Y28, on three visits to Y21, and on two visits to Y15. All York River auxiliary stations were sampled in all rounds in 2006.

The 2006 indices for the Pamunkey (16.21) and the Mattaponi (8.64) rivers were significantly greater than their respective historical averages (Pamunkey = 6.99, Mattaponi = 5.06, Table 3). Catches at Mattaponi River index stations were greatest in early August (round three) at M33, in late July (round two) at M41, and in early

September (round five) at M44 and M47 (Table 1, Figure 5). All Mattaponi stations' index values were greater than their historical averages (Table 9). For the Pamunkey River index stations, largest catches occurred at the uppermost index station, P50, and catches at most stations peaked in early and late July (Table 1, Figure 6).

Rappahannock River System

The 2006 index for the Rappahannock River was 7.47, which is not statistically different than the historical average of 7.50 (Table 3) but is lower than the 2005 index for the Rappahannock (12.49). The greatest numbers of striped bass were captured in early July (round one). Overall, catches were greatest at the two uppermost index sites (R50 and R55) with R55 being the most productive site (Table 1, Figure 7). Catches at these two sites accounted for 74% of the total catch for the river in 2006. Juvenile striped bass were captured at least once at all stations this year with the exception of the new auxiliary station R75. R75 replaced auxiliary station R76, which was becoming difficult to seine due to the encroachment of vegetation.

Sampling Round Comparison

Generally, raw catch values are highest during July and early August (rounds one, two, and three) and taper off in late August and September (rounds four and five) as fish disperse to deeper water and grow large enough to effectively avoid capture. In 2006, our catches were greatest in early July (round one) (Table 4). Catches in late July (round two) decreased by 22%, and catches in early August (round three) decreased by 19% relative to late July. A slight increase of 13% was observed in late August (round four), but this was followed by a 29% decrease in early September (round five).

Bayside and Eastern Shore Stations

Striped bass were captured at two bayside Eastern Shore stations in 2006: Kiptopeke and Bloxom (Guard Shore). Two small young-of-the-year (39 mm) fish were caught in late June at Kiptopeke. The remaining catches (17 fish) occurred at Guard Shore recreation area (station name Bloxom) from June through September, with no more than four fish caught per tow. Size of fish captured increased from 51-56 mm in late June to 74-128 mm in early September. Catches of striped bass occurred at fewer Eastern Shore stations in 2006 (2) than in 2005 (5).

Objective 2: Quantify environmental conditions at the time of collection.

Collection information and pertinent environmental variables recorded at the time of each collection in 2006 are given in Tables 5 through 7. Direct round-by-round comparisons of environmental and water quality parameters are difficult because of local site conditions and variations, so we examined this on a broader scale.

Striped bass recruitment is correlated with temperature and rainfall trends for the winter and spring preceding sampling (Wood 2000), and their distribution within the nursery may be affected by water quality parameters during sampling. Generally, salinities in early 2006 were greater than average (Table 5, Figure 8). Data from the National Climate Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html) indicated that both winter (December 2005 through February 2006) and spring (March through May 2006) were characterized by below average precipitation. The spring period was the fifth driest on record. The amount of precipitation in Virginia remained below average in June and July, but August and September rainfall were above average and salinity had decreased by September.

In summer 2006 (the sampling period), water temperatures were greater than normal (i.e. more than one standard deviation greater than the mean water temperature for each station since 1989) at half of the sampling events in the Mattaponi River (Table 6). The remaining rivers had some recorded temperatures that were above normal, but these were in the minority of sampling events. The normal pattern of higher temperatures in mid summer and slowly declining temperatures during late summer was well defined in 2006 as in other years. Summer water temperatures varied from those observed in 2005 because 2006 was characterized by more precipitation and milder air temperatures than in 2005. Water temperatures in these systems reflect long-term weather patterns of summer, but also exhibit significant variation from day to day and from river to river. These small-scale spatial and temporal variations are associated with time of sampling (e.g. morning versus afternoon or tidal stage) and local events such as thunderstorms. Sampling takes place at shallow shoreline areas that are easily affected by local weather events, and the effects of these local events on site-specific striped bass abundances are not easily assessed.

None of the dissolved oxygen (DO) levels measured during the survey in 2006 are considered hypoxic (less than 2-3 mg/L). Most sites in the primary nursery area had at least one DO measurement that was more than one standard deviation less than the mean DO recorded from 1989 to the present at each station (Table 7). For the most part, lower than average values occurred inconsistently by round and station.

Objective 3: Examine relationships between juvenile striped bass abundance and environmental and biological data.

In 2006, as in the past, we observed greater catches of young-of-the-year striped bass at lower salinities within the primary nursery area (Table 8, Figure 8). No index station exceeded 12.7 ppt salinity (Table 5). Table 9 shows the relationship of juvenile striped bass catches with respect to historical and 2006 salinity gradients within each river system. In 2006, the percentage of catch observed in low salinities (0-4 ppt) was slightly less than that observed historically (86% in 2006 vs. 93% all years) (Table 8). Juvenile striped bass were captured at downstream auxiliary sites in the early rounds of the 2006 survey in areas with salinities greater than 12.7 ppt (e.g. YK15: 18.6 ppt). In particular, catches at Y15 and Y21 in 2006 were greater than their respective means for all years, and average salinities were also greater (Table 9). Salinity is not the only factor accounting for the distribution of striped bass in 2006.

Catch rates in 2006 followed the historical pattern with respect to water temperature: most fish (87%) were captured in waters between 25 and 34.9 ^{o}C (Table 10). As noted in previous reports, this relationship is considered to be largely the result of a coincident downward progression of both catch rates and temperature as the survey season progresses (beyond early August) rather than any direct effect of water temperature on juvenile fish distribution.

Dissolved oxygen measured at the time of sampling does not seem to have a direct effect on indices. DO values lower than the mean at a station (shaded values in Table 7) do not necessarily correspond with low catches at that station (Table 1).

DISCUSSION

Virginia striped bass exhibited greater than average recruitment in 2006 with young-of-the-year fish evenly distributed throughout the primary nursery area. The

nursery area was more compressed in 2006 than in 2005, when fish were more dispersed to auxiliary sites.

The York River drainage had the greatest index value by drainage in 2006, due to larger than average catches in the Mattaponi River. Catches at all index stations in the York drainage (Pamunkey and the Mattaponi rivers) were greater than their respective historic indexes. In 2005, only two York drainage index stations had greater than average index values.

The James drainage index did not vary much from 2005 (11.16 vs. 10.78). In general, stations had average catches. In 2006, the Chickahominy stations (C1 and C3) and J56 had index values lower than their historical indexes. Catches at upper James auxiliary stations were down from 2005. Seine tows at J77, which replaced J74 and J78, resulted in zero striped bass; however, striped bass were captured at J77 on a June site reconnaissance trip. It is possible that after June, striped bass young-of-the-year were not as far upriver as J77. Further sampling at that station in 2007 should help determine if J77 is an area used by striped bass young-of-the-year.

Catches on the Rappahannock River were down in 2006 with an index of 7.47 versus 12.49 in 2005. Only two Rappahannock stations (R28 and R50) had indices greater than their historic averages. Only two fish were caught at stations R10 and R21, the most downriver stations.

Catch of young-of-the-year striped bass at only two Eastern Shore stations (Guard Shore and Kiptopeke) also suggests a compressed nursery in 2006.

The association between water quality parameters and catches did not vary from historical patterns on a large scale. The slight variation in index values from 2005 to

2006 is likely the result of many factors, including small-scale variations in weather and tide. In addition, the compression of the nursery range observed in 2006 may be the result of 2006 weather. Dissolved oxygen did not appear to be a major factor affecting catches.

More years of sampling will help determine if new auxiliary stations J77 and R75 are suitable striped bass habitat in years when the nursery is expanded.

The 1989 addition of auxiliary stations to the survey has provided better overall coverage of nursery areas in the James, York and Rappahannock systems. These auxiliary stations have revealed that in years of low or high river flow, nursery areas may shift up or down-river. Additionally, in years of high abundance the nursery area generally expands both up and down-river. Figures 4-7 show catch per haul at all stations with index station catches representing an average of two hauls. Past analyses have demonstrated that catches are consistently greater in the first haul of any given set of seine hauls. Because only one haul is made at the auxiliary sites, the figures may over-emphasize the contribution of the auxiliary sites relative to the index sites. Figures 4-7 are included only to demonstrate the spatial distribution of the year class in the river systems. Catches from auxiliary sites are important because they allow us to see a shift in the spatial distribution that may partially explain variation in catch rates at the index sites. Reducing hauls at index sites to one per site and including some of the auxiliary sites in the index may lead to a more precise estimate of relative year-class strength but would elevate the recalculated indices (Rago et al. 1996).

Striped bass recruitment success in the Virginia portion of Chesapeake Bay is variable among years and among nursery areas within years. Striped bass young-of-the-

year abundance was low in 1999 and 2002, but strong year classes were observed in 1998, 2000, 2001, 2003 and 2004. Recruitment in 2005 was average and in 2006 was above average. Continued monitoring of recruitment success will be an important factor in determining management strategies to protect the spawning stock of Chesapeake Bay striped bass.

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Table 1. Catch of young-of-the-year striped bass per seine haul in 2006. Two hauls were made per sampling round at each of the index stations (bold).

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Round Total
	Round	1	0	8	10/9	2/5	1	15/13	3/5	1/9	9	2/0	17	1	0	110
		2	0	5	16/14	8/6	2	9/12	6/1	7/13	2	2/1	18	0	ns	122
		3	0	6	7/5	16/12	4	1/1	2/2	18/6	0	7/0	1	7	0	95
		4	0	11	21/24	24/23	1	1/4	1/1	23/30	3	2/2	1	1	0	173
		5	0	21	7/5	7/11	4	3/2	0/1	6/1	1	7/2	4	12	0	94
														James Total		594
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	0	2	1	5	13/3	14/0	31/25	3						97
		2	3	11	1	1	8/3	14/8	21/31	1						102
		3	0	0	6	2	9/6	2/9	29/15	0						78
		4	3	0	1	4	1/7	10/6	7/16	ns						55
		5	0	3	4	ns	0/0	2/4	27/10	ns						50
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				14/0	20	13/15	5/7	0/1	ns					75
		2				12/3	18	19/11	4/1	0/0	1					69
		3				20/5	26	3/3	2/11	0/5	10					85
		4				1/1	8	1/1	2/2	11/7	0					34
		5				3/0	3	10/7	11/10	10/12	ns					66
														York Total		711
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75		
	Round	1	0	1	6/13	0/1	1	3/6	20/17	53/55	16	0	1	0		193
		2	1	0	4/9	0/0	0	1/2	8/11	24/13	0	6	0	0		79
		3	0	0	2/5	1/0	2	0/0	3/15	15/7	2	1	0	ns		53
		4	0	0	6/6	0/0	2	0/0	4/2	27/2	2	2	3	0		56
		5	0	0	1/1	0/0	1	0/0	10/8	16/3	ns	0	1	ns		41
														Rappahannock Total		422
														2006 Catch		1727

ns = no sample

Table 2. Catch of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) summarized by year (scaled mean = back-transformed mean of ln (x+1) * 2.28, the ratio of overall arithmetic and geometric means through 1984).

Year	Total Fish	Mean 1n (x+1)	Std. Dev.	Scaled Mean	C.I. (± 2 SE)	N (hauls)
1967	209	1.07	0.977	4.40	2.82-6.45	53
1968	208	0.93	0.900	3.50	2.35-4.94	66
1969	207	0.78	0.890	2.71	1.80-3.84	77
1970	461	1.31	1.121	6.17	4.27-8.63	78
1971	178	0.76	0.857	2.61	1.76-3.64	81
1972	96	0.39	0.575	1.07	0.73-1.45	119
1973	139	0.53	0.790	1.59	0.98-2.32	87
1980	228	0.74	0.900	2.52	1.68-3.53	89
1981	165	0.52	0.691	1.57	1.10-2.09	116
1982	323	0.78	0.967	2.71	1.85-3.74	106
1983	296	0.91	0.833	3.40	2.53-4.42	102
1984	597	1.09	1.059	4.47	3.22-6.02	106
1985	322	0.72	0.859	2.41	1.78-3.14	142
1986	669	1.12	1.036	4.74	3.62-6.06	144
1987	2191	2.07	1.228	15.74	12.4-19.8	144
1988	1348	1.47	1.127	7.64	6.10-9.45	180
1989	1978	1.78	1.119	11.23	9.15-13.7	180
1990	1249	1.44	1.096	7.34	5.89-9.05	180
1991	667	0.97	0.951	3.76	2.96-4.68	180
1992	1769	1.44	1.247	7.32	5.69-9.28	180
1993	2323	2.19	0.975	18.12	15.4-21.3	180
1994	1510	1.72	1.034	10.48	8.66-12.6	180
1995	926	1.22	1.045	5.45	4.33-6.75	180
1996	3759	2.41	1.227	23.00	18.8-28.1	180
1997	1484	1.63	1.097	9.35	7.59-11.4	180
1998	2084	1.92	1.139	13.25	10.8-16.1	180
1999	442	0.80	0.862	2.80	2.19-3.50	180
2000	2741	2.09	1.240	16.18	13.06-19.92	180
2001	2624	1.98	1.271	14.17	11.33-17.60	180
2002	813	1.01	1.085	3.98	3.05-5.08	180
2003	3406	2.40	1.18	22.89	18.84-27.71	180
2004	1928	1.88	1.04	12.70	10.54-15.22	180
2005	1352	1.61	1.05	9.09	7.45-11.02	180
2006	1408	1.69	1.04	10.10	8.31-12.18	180
Overall (1967-2006)	40102	1.44	1.19	7.36	7.04-7.70	4929

Table 3. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2006 summarized by drainage and river.

Drainage River	2006 Total Fish	2006 Scaled Mean	2006 C.I. (±2 SE)	2006 N (hauls)	All Years Combined (1967-2006) Total Fish	All Years Combined (1967-2006) Scaled Mean	All Years Combined (1967-2006) C.I. (±2 SE)	All Years Combined (1967-2006) N (hauls)
JAMES	454	11.16	8.34-14.72	60	15802	9.35	8.68-10.05	1638
James	371	14.52	10.38-20.02	40	9380	8.61	7.87-9.41	1100
Chickahominy	83	6.32	3.77-9.93	20	6422	11.01	9.66-12.51	538
YORK	574	11.40	8.45-15.17	70	11789	5.83	5.42-6.25	1872
Pamunkey	331	16.21	10.47-24.54	30	6186	6.99	6.25-7.80	796
Mattaponi	243	8.64	5.76-12.55	40	5603	5.06	4.61-5.53	1076
RAPPAHANNOCK	380	7.47	4.66-11.41	50	12511	7.50	6.87-8.17	1419
OVERALL	1408	10.10	8.31-12.18	180	40102	7.36	7.04-7.70	4929

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2006 summarized by sampling period and month.

	2006				All Years Combined (1967-2006)			
Month (Round)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (hauls)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (hauls)
July (1st)	389	13.21	8.31-20.38	36	12155	10.97	9.98-12.04	1034
(2nd)	302	12.27	8.17-17.98	36	9676	8.40	7.62-9.23	1045
Aug. (3rd)	244	9.53	6.26-14.06	36	7192	6.75	6.14-7.41	1037
(4th)	276	9.08	5.63-14.02	36	6513	6.54	5.88-7.24	901
Sept. (5th)	197	7.33	4.59-11.15	36	4361	5.66	5.07-6.30	775

Table 5. Salinity (parts per thousand) at seine survey stations in 2006. York system includes Pamunkey and Mattaponi rivers. Index stations are indicated by bold font.

Drainage														
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77
Round	1	16.2	6.8	2.1	0.3	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1
	2	16.9	6.6	3.9	1.4	0.5	0.5	0.4	0.1	0.1	0.1	0.2	0.1	ns
	3	18.9	9.9	9.7	4.8	1.7	2.1	1.7	0.4	0.1	0.1	0.2	0.1	0.1
	4	22.6	14.0	8.5	5.7	3.4	3.7	3.3	1.6	0.5	0.2	0.2	0.2	0.2
	5	14.4	6.9	4.7	2.5	0.6	1.0	0.9	0.2	0.1	0.1	0.1	0.1	0.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
Round	1	18.0	14.6	7.6	1.3	0.4	0.1	0.1	0.1					
	2	18.6	16.0	11.4	2.9	1.1	0.2	0.1	0.1					
	3	19.8	17.4	15.6	7.8	4.1	0.9	0.3	0.2					
	4	21.3	18.6	15.0	9.1	5.2	2.0	0.7	ns					
	5	16.7	13.1	10.2	ns	2.3	0.5	0.3	ns					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
Round	1				2.9	0.5	0.1	0.0	0.0	ns				
	2				3.7	0.9	0.3	0.0	0.0	0.0				
	3				8.1	3.9	1.8	0.2	0.1	0.0				
	4				9.9	6.3	3.2	0.8	0.6	0.1				
	5				3.0	0.8	0.3	0.1	0.0	ns				
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
Round	1	15.7	14.1	12.2	5.3	1.3	0.4	0.1	0.0	0.0	0.0	0.0	0.0	
	2	15.9	14.0	11.0	6.0	2.6	1.0	0.1	0.1	0.0	0.0	0.0	0.1	
	3	15.8	14.5	12.7	8.1	3.1	2.3	0.8	0.2	0.1	0.1	0.1	ns	
	4	16.5	15.1	12.5	8.4	5.4	3.8	1.9	1.0	0.3	0.1	0.1	0.1	
	5	16.6	13.9	9.6	3.9	2.7	1.3	0.6	0.3	ns	0.1	0.1	ns	

ns = no sample taken

Table 6. Water temperature (°C) recorded at seine survey stations in 2006. York system includes Pamunkey and Mattaponi rivers. Shaded values are more than one standard deviation greater than the mean water temperature recorded at that station from 1989 to 2006. Index stations are indicated by bold font.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
	Round	1	32.4	33.8	30.1	27.3	28.4	28.7	28.3	29.0	26.6	26.9	29.5	29.0	28.5
		2	32.9	33.3	32.2	27.5	30.5	28.6	28.9	30.4	28.9	28.2	29.2	31.2	ns
		3	30.2	30.3	28.9	27.6	27.4	27.7	28.2	29.4	29.6	29.7	32.0	32.4	32.0
		4	26.9	27.4	30.1	26.5	28.9	27.5	27.8	28.9	27.6	27.4	29.1	30.5	29.8
		5	25.8	25.5	25.8	23.5	23.9	24.2	23.7	23.7	24.5	23.9	25.3	24.1	24.7
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	30.2	29.7	27.6	27.7	28.2	28.1	28.4	29.0					
		2	30.8	30.2	27.3	28.8	29.0	28.9	30.4	31.5					
		3	28.6	26.8	25.3	27.3	27.4	28.4	28.6	28.8					
		4	26.9	27.3	27.1	28.2	28.4	29.0	29.4	ns					
		5	23.5	22.5	21.6	ns	23.4	23.7	23.4	ns					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				28.9	29.5	28.4	30.9	33.0	ns				
		2				29.8	30.2	29.6	31.2	33.0	32.4				
		3				27.5	27.9	27.3	27.9	29.5	28.7				
		4				28.5	28.6	28.4	29.0	29.6	29.7				
		5				23.4	23.2	23.0	22.7	22.8	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	Round	1	30.6	28.4	27.3	28.1	29.3	30.4	27.9	27.8	27.1	28.1	28.6	27.7	
		2	30.5	30.5	27.1	28.4	29.7	30.4	30.3	30.0	29.7	30.5	31.5	31.4	
		3	26.9	26.7	27.0	27.4	24.6	26.5	30.9	31.1	31.4	31.2	32.0	ns	
		4	29.8	29.0	26.9	27.1	27.7	29.1	28.1	28.7	28.6	28.9	29.9	30.0	
		5	23.7	23.7	23.1	23.6	23.9	24.0	22.8	23.4	ns	24.3	22.0	ns	

ns = no sample taken, *= new station for 2006

Table 7. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2006. York system includes Pamunkey and Mattaponi rivers. Shaded values are more than one standard deviation less than the mean dissolved oxygen concentrations recorded at that station from 1989 to 2006. Index stations are indicated by bold font.

Drainage														
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
Round	1	8.9	9.4	6.1	6.7	6.5	7.9	5.8	5.5	5.2	7.2	11.8	7.1	6.4
	2	7.8	6.8	7.6	5.5	6.9	6.4	5.3	5.8	4.4	7.0	8.2	6.0	ns
	3	9.6	6.0	6.0	3.8	5.7	5.1	4.9	3.9	4.0	4.9	9.6	6.3	5.1
	4	5.6	4.3	6.1	5.7	6.6	6.4	5.6	5.1	4.3	6.1	7.5	6.2	6.3
	5	6.7	7.2	7.0	5.6	7.5	6.2	6.2	5.8	5.3	6.5	6.9	6.4	6.9

YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55
Round	1	7.2	6.6	5.1	4.5	4.9	5.0	4.9	5.0
	2	5.7	5.3	5.5	4.7	5.0	4.7	4.8	6.4
	3	5.5	4.8	5.5	3.6	4.7	5.3	5.2	5.7
	4	3.8	4.0	4.7	4.1	4.5	5.3	4.4	ns
	5	5.9	6.5	5.3	ns	4.3	3.9	4.2	ns

	Station	**M33**	M37	**M41**	**M44**	**M47**	M52
Round	1	3.5	3.8	3.5	4.3	7.5	ns
	2	3.7	3.6	3.8	4.6	6.6	5.2
	3	3.5	3.3	3.7	4.0	4.5	5.3
	4	3.7	4.9	5.1	4.3	5.0	5.5
	5	3.9	3.9	3.9	4.2	4.1	ns

RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*
Round	1	8.3	6.2	6.1	6.2	6.3	6.3	7.3	7.8	7.2	8.8	5.5	6.3
	2	7.8	6.7	5.5	5.1	4.9	6.1	5.8	5.9	6.0	7.6	7.0	6.1
	3	5.5	5.5	4.7	4.5	7.5	5.5	5.4	5.2	4.4	6.7	5.9	ns
	4	6.2	5.9	5.3	5.4	5.1	6.7	6.0	6.4	5.9	7.0	6.2	5.3
	5	6.7	7.2	6.6	6.5	5.4	7.1	5.9	6.8	ns	5.4	4.3	ns

ns = no sample taken, *= new station for 2006

Table 8. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2006 summarized by salinity.

	2006				All Years Combined (1967-2006)			
Salinity (ppt)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)
0-4.9	1214	10.70	8.69-13.08	150	37193	8.44	8.05-8.85	4131
5-9.9	143	5.99	2.62-11.67	22	2608	4.13	3.61-4.70	580
10-14.9	51	13.12	8.88-18.97	8	299	1.83	1.40-2.30	189
15-19.9	0	0	0	0	2	0.11	0-0.28	29
Overall	1408	10.10	8.31-12.18	180	40102	7.36	7.04-7.70	4929

Table 9. Average salinity (Avg. Sal., ppt) and corresponding striped bass indices recorded at seine survey stations from 1967 to 2006 and in 2006. York system includes Pamunkey and Mattaponi rivers. Index stations are indicated by bold font. Shaded values indicate 2006 index values greater than 1967 to 2006 index values.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
	1967-2006	Avg. Sal.	13.7	7.2	4.4	2.3	1.3	1.3	1.1	0.6	0.2	0.2	0.2	0.1	0.1
		Index	2.7	15.0	7.2	12.4	7.0	15.7	7.0	16.9	14.1	5.4	7.7	5.2	0.0
	2006	Avg. Sal.	17.8	8.8	5.8	2.9	1.3	1.5	1.3	0.5	0.2	0.1	0.2	0.1	0.1
		Index	0.0	20.5	23.6	21.4	4.9	9.5	4.0	18.0	4.5	4.1	11.1	5.3	0.0
YORK		Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55				
	1967-2006	Avg. Sal.	16.2	13.2	10.1	3.7	1.5		0.7	0.4	0.3				
		Index	1.0	1.8	4.8	10.3	3.7		9.8	12.8	6.0				
	2006	Avg. Sal.	18.9	15.9	12.0	5.3	2.6		0.7	0.3	0.1				
		Index	1.7	3.9	4.8	6.1	7.6		11.6	44.0	2.3				
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2006	Avg. Sal.				4.0	2.0	1.1	0.4	0.3	0.1				
		Index				6.3	8.0	6.9	4.1	4.0	1.4				
	2006	Avg. Sal.				5.5	2.5	1.1	0.2	0.1	0.0				
		Index				7.2	27.6	13.8	10.0	5.3	4.1				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*
	1967-2006	Avg. Sal.	14.0	12.7	9.8	5.2		3.0	2.0	0.9	0.5	0.2	0.2	0.1	0.1
		Index	0.4	1.0	2.3	3.5		4.5	8.4	11.2	37.8	7.4	4.4	3.1	0.0
	2006	Avg. Sal.	16.1	14.3	11.6	6.3		3.0	1.8	0.7	0.3	0.1	0.1	0.1	0.1
		Index	0.3	0.3	9.8	0.3		2.4	1.5	18.5	32.9	5.7	2.5	1.7	0.0

ns = no sample taken, *= new station for 2006

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2006 summarized by water temperature.

	2006				All Years Combined (1967-2006)			
Temp. (°C)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)
15-19.9	0	0	0	0	79	2.85	1.40-4.86	30
20-24.9	185	7.05	4.28-10.99	34	2550	3.61	3.17-4.09	657
25-29.9	931	10.20	8.01-12.87	116	30755	8.31	7.89-8.75	3465
30-34.9	292	14.22	9.09-21.65	30	6328	8.73	7.76-9.79	678
Overall	1408	10.10	8.31-12.18	180	40102	7.36	7.04-7.70	4929

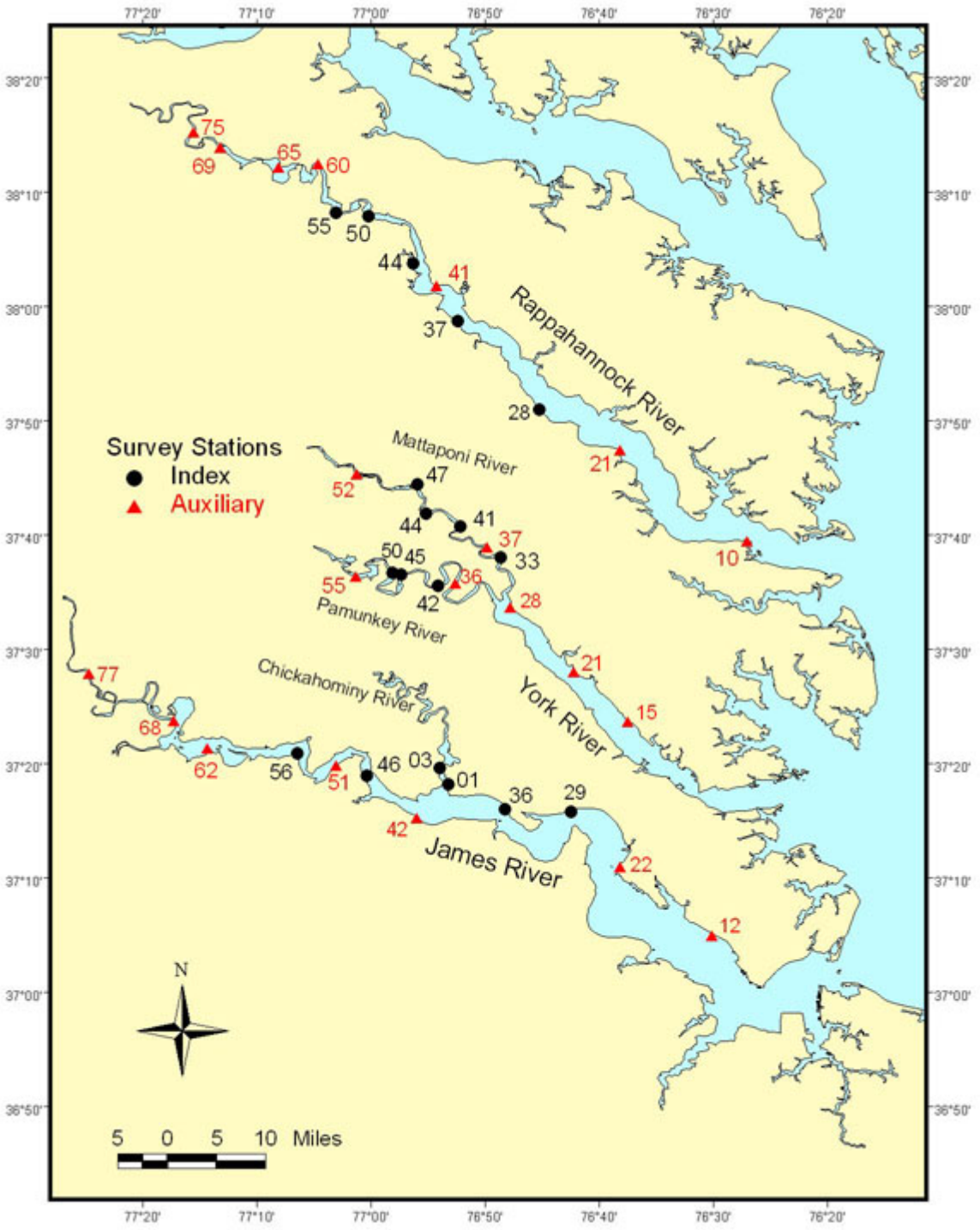

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designations indicates river mile from mouth. Auxiliary stations R75 (Rappahannock) and J77 (James) are new in 2006, replacing R76 and J74/J78, respectively.

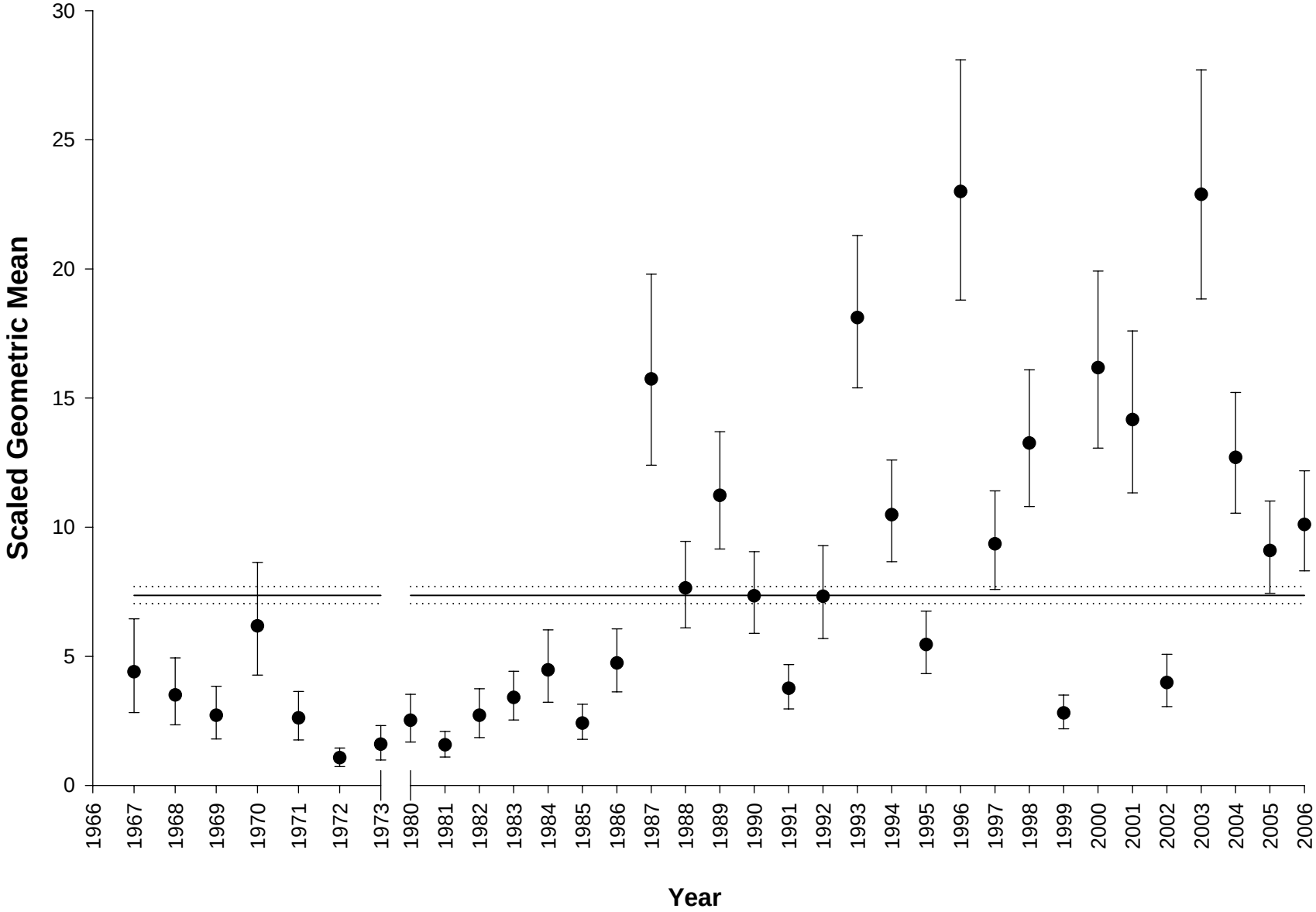

Figure 2. Scaled geometric mean of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by $\pm$ 2 standard errors of the mean. Horizontal lines indicate historical geometric mean (solid) and confidence intervals (dotted) for 1967-2006.

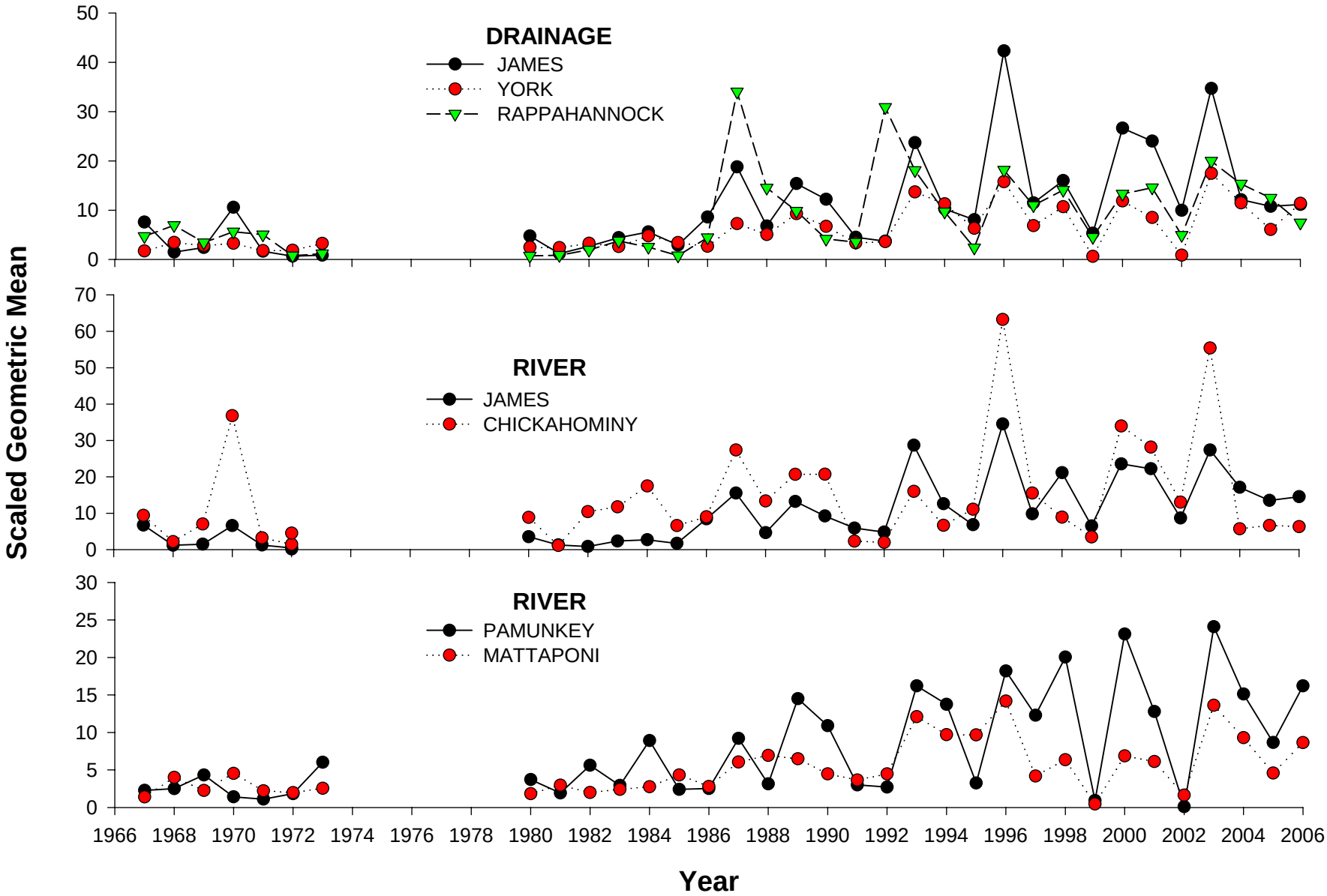

Figure 3. Scaled geometric mean of young-of-the-year striped bass per seine haul in the primary nursery area by drainage and river.

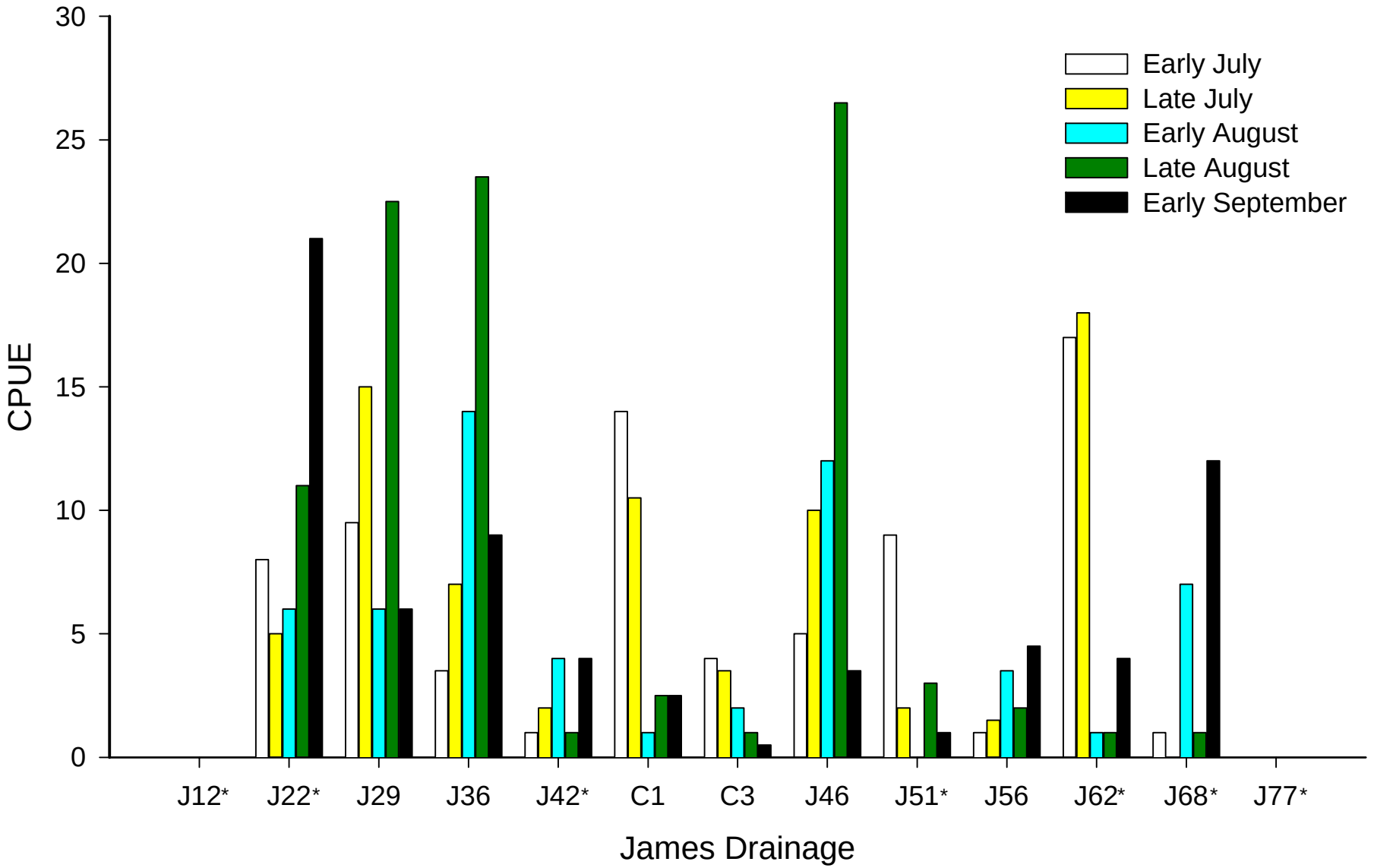

Figure 4. Catch of young-of-the-year striped bass by station in the James River drainage in 2006. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

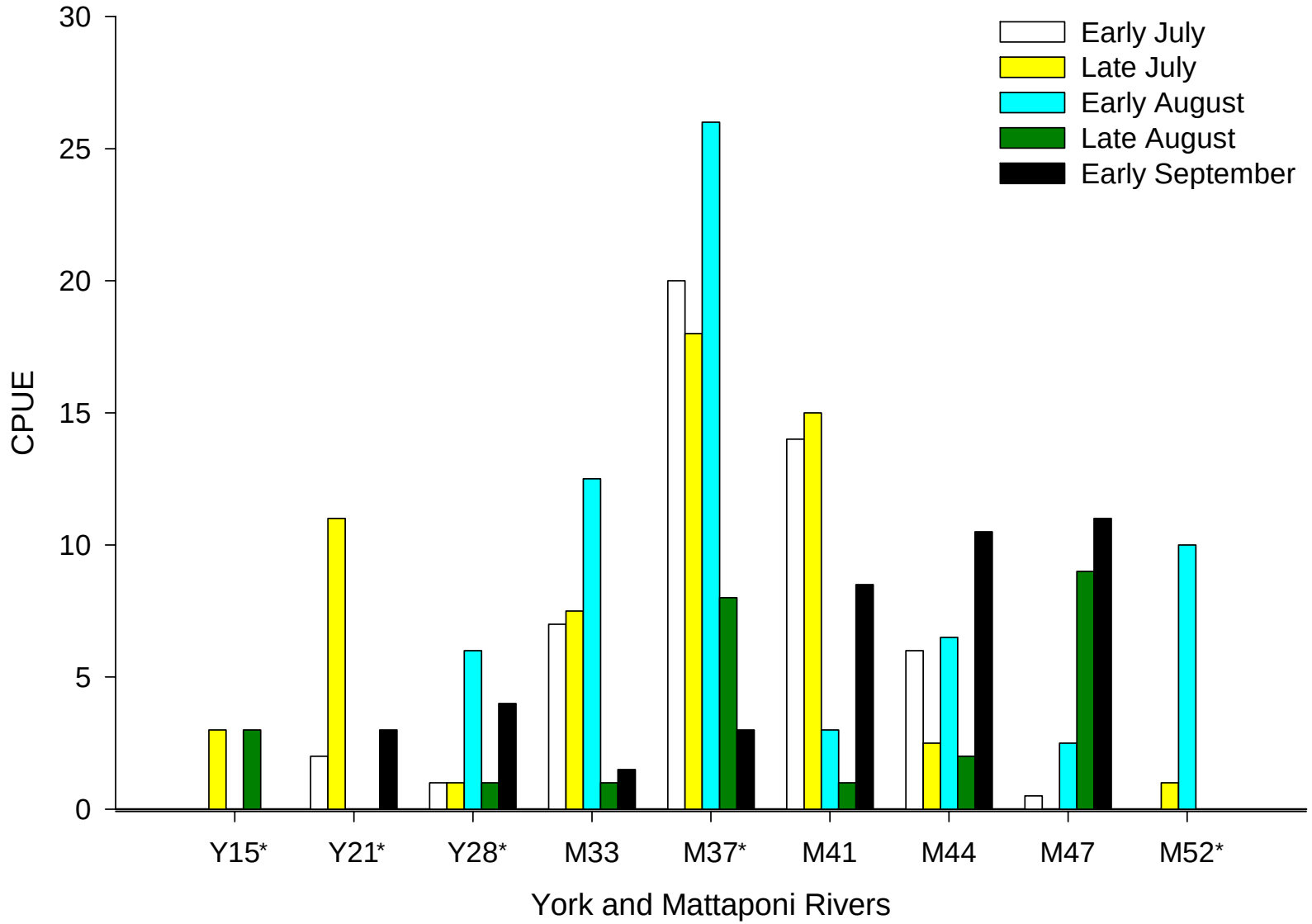

Figure 5. Catch of young-of-the-year striped bass by station in the York and Mattaponi rivers in 2006. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

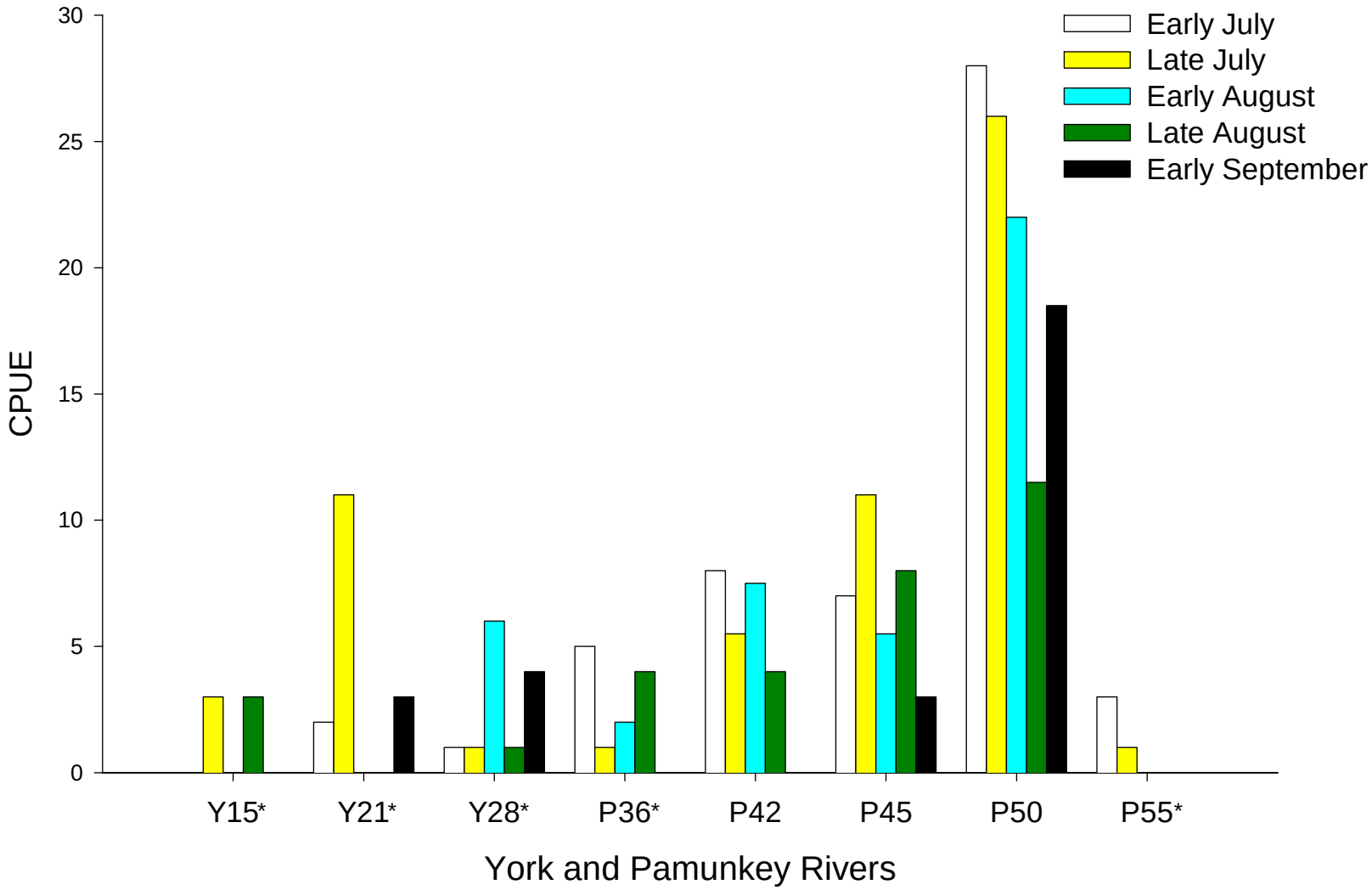

Figure 6. Catch of young-of-the-year striped bass by station in the York and Pamunkey rivers in 2006. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

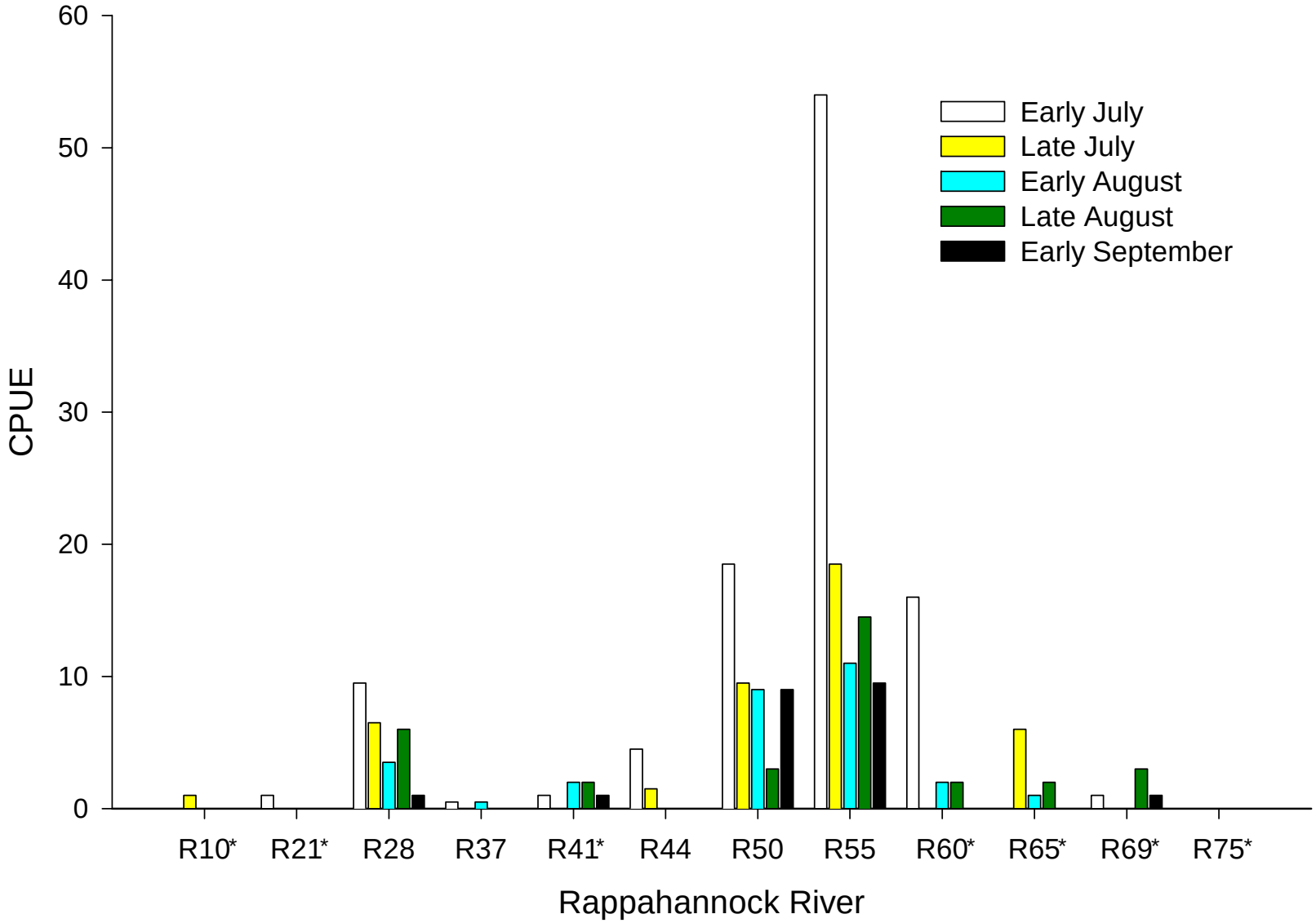

Figure 7. Catch of young-of-the-year striped bass by station in the Rappahannock River in 2006. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

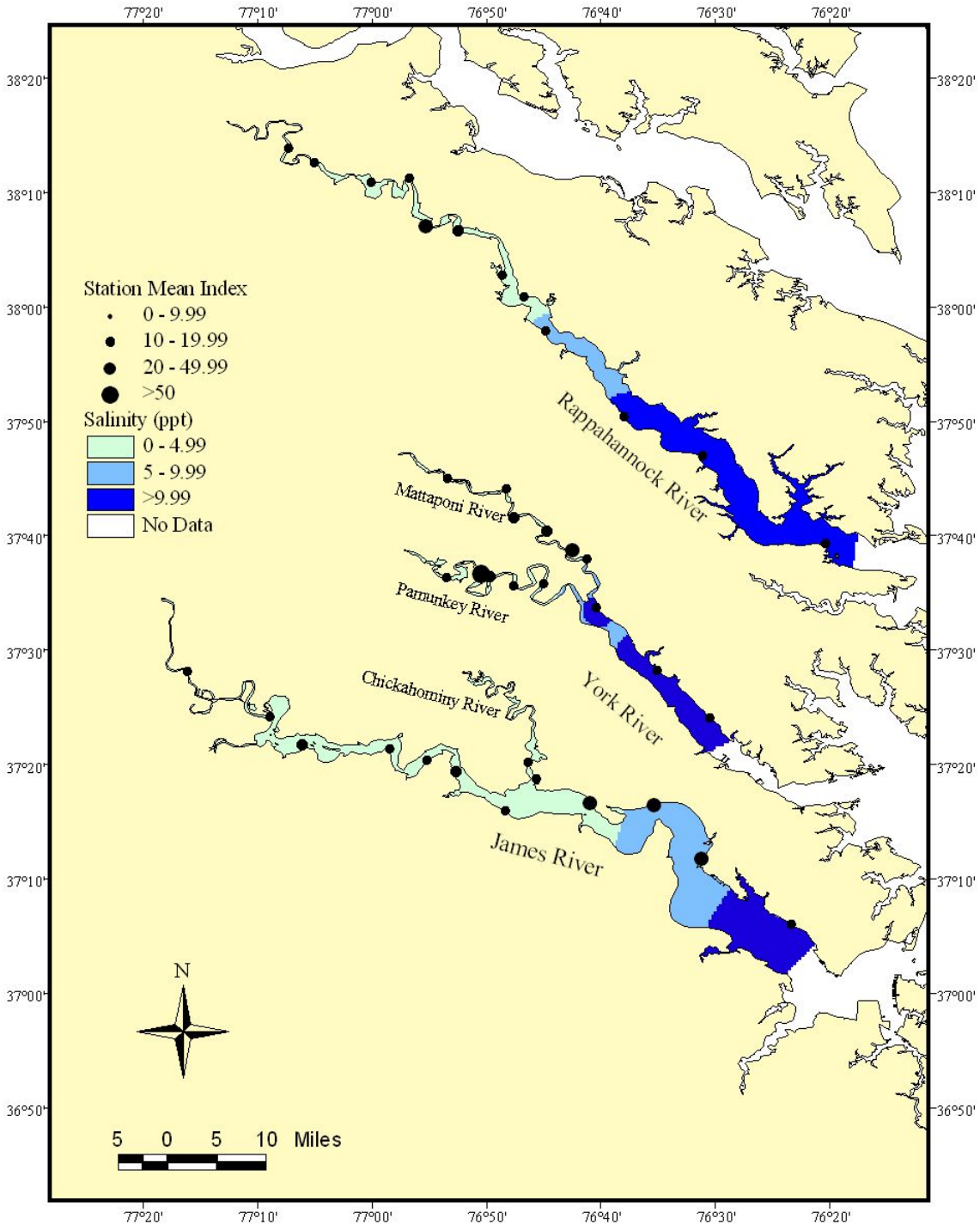

Figure 8. Scaled geometric mean index for young-of-the-year striped bass by station and salinity in 2006.