ANNUAL PROGRESS REPORT

Estimation of Juvenile Striped Bass Relative Abundance in the Virginia Portion of Chesapeake Bay

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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 2005 sampling period and compares these results with previous years.

Specific objectives for the 2005 program were to:

1. estimate the relative abundance of the 2005 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 the 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 2005. 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). (Site R76 was not sampled in 2005; see Results.) Auxiliary sites were added in 1989 to provide better geographic coverage and increased 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 (1.22 m) deep, 0.25 in (0.64 cm) 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, pH and dissolved oxygen concentrations were measured after the first haul using a Hydrolab Reporter® 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-overlaping 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: <u>Estimate the relative abundance of the 2005 year class of juvenile striped bass from the James, York and Rappahannock river systems.</u>

In 2005, 1352 young-of-the-year striped bass were collected from 180 seine hauls at index stations and 596 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 2005 is 9.09, which is not significantly different from the historical average index of 7.27 (Table 2, Figure 2).

James System

The 2005 index for the James drainage is 10.78, which is not significantly different from the historical James drainage index of 9.28 (Table 3, Figure 3). However, the 2005 mainstem James (not including the Chickahominy River) index is 13.52, which is significantly greater than the historical mainstem James index of 8.43. Juvenile striped bass were widely distributed in the James River in 2005. Individuals were collected in early July (round one) at both the most downstream station (J12) and the most upstream station (J78) (Table 1, Figure 4).

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 2005 Chickahominy River index is 6.64, which is not significantly different from the historical Chickahominy index of 11.23 (Table 3).

York System

The 2005 index in the York drainage (6.10) was not statistically different from the historical York drainage index of 5.66 (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 2005 (Table 1). Catches in the mainstem of the York River also occurred in 2003 and 2004 (Austin et al. 2004, Austin et al. 2005), 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 four visits to Y21, and on the four visits to Y15, which was not sampled in late July due to weather.

The 2005 indices for the Pamunkey (8.67) and the Mattaponi (4.57) rivers were not significantly different from their respective historical averages (Pamunkey = 6.75, Mattaponi = 4.95, Table 3). Catches on the Mattaponi River were greatest in early July (round one) at index stations M33 and M44 and in mid July (round two) at M41 and M44 (Table 1, Figure 5). In subsequent months, catches decreased. For the Pamunkey River index stations, largest catches occurred at the uppermost index stations, P45 and P50 (Table 1, Figure 6). Index station P42 catches were low from July to September, whereas auxiliary station P36 had moderate catches throughout the sampling season (Table 1).

Rappahannock System

The 2005 index for the Rappahannock River was 12.49, which is statistically greater than the historical average of 7.50 (Table 3). The greatest numbers of striped bass were captured in late July. Overall, catches were greatest at the three uppermost index sites (R44, R50 and R55) with R55 being the most productive site (Table 1, Figure 7). Catches at these three sites accounted for 79% of the total catch for the river in 2005. Juvenile striped bass were distributed widely in the river in 2005 as evidenced by their capture at the two downriver auxiliary sites (R10 and R21) in July and September. The uppermost auxiliary station, R76, was not sampled in 2005 due to encroachment of vegetation at the sampling area, which prevented efficient deployment of the seine.

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 2005, our catches peaked in early July (round one) (Table 4.) Catches in late July (round two) decreased by 30%, catches in early August (round three) decreased by 41% relative to late July. A slight increase of 8% was observed in late August (round four), but this was followed by a 16% decrease in early September (round five).

Bayside and Eastern Shore Stations

Fifty-two young-of-the-year striped bass were captured at seine survey stations in Chesapeake Bay from June until early August. The majority (36 fish) were captured in July at Guard Shore recreation area (station name Bloxom), which is adjacent to Pocomoke Sound; four more striped bass were captured at Bloxom in August.

Young-of-the-year striped bass were also captured at four other stations in the lower Chesapeake Bay (fewer than three fish per haul per site). In June, small young-of-the-year striped bass (32-36 mm FL) were captured as far downstream as Willoughby Spit at the mouth of the James River and at First Landing State Park (Virginia Beach). Fish were also captured at Willoughby Spit, Fisherman Island National Wildlife Refuge and at Silver Beach (bayside Eastern Shore) in early July.

Objective 2: <u>Quantify environmental conditions at the time of collection.</u>

Collection information and pertinent environmental variables recorded at the time of each collection in 2005 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. Generally, salinities in 2005 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 2004 through February 2005) and spring (March through May 2005) had precipitation that was below average. The amount of precipitation in Virginia remained below average throughout the 2005 sampling period.

In 2005, water temperatures were greater than normal (i.e. more than one standard deviation greater than the mean water temperature for each station since 1989) in at least one sampling event in every river except the York River (Table 6). This can be partially explained by the above average air temperatures recorded in late July, August and early September of 2005. The normal pattern of higher temperatures in mid summer and slowly declining temperatures during late summer was well defined in 2005 as in other years. Water temperatures varied from those observed in 2004 because 2005 was characterized by less precipitation and higher air temperatures. 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 these effects on site-specific striped bass abundances are not easily assessed.

None of the dissolved oxygen (DO) levels measured during the survey in 2005 are considered hypoxic (less than 2-3 mg/L). Most sites 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, although P50 tended to have low values of dissolved oxygen during all sampling rounds.

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

In 2005, as in the past, we observed greater catches of young-of-the-year striped bass at lower salinities within the primary nursery area (Table 9, Figure 8). No index station exceeded 10.9 ppt salinity (Table 5). Table 9 shows the relationship of juvenile striped bass catches with respect to historical and 2005 salinity gradients within each river system. In 2005, the percentage of catch observed in low salinities (0-4 ppt) was slightly greater than that observed historically (96% in 2005 vs. 93% all years) (Table 8). Juvenile striped bass were captured at downstream auxiliary sites in the early rounds of the 2005 survey in areas with salinities greater than 10.9 ppt. In particular, catches at Y15 and Y21 in 2005 were greater than their respective means for all years, while average salinities were similar (Table 9). Salinity is not the only factor accounting for the distribution of striped bass in 2005.

Catch rates in 2005 followed the historical pattern with respect to water temperature: most fish (97%) 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 causative effect of water temperature on juvenile fish distribution.

No discernable pattern related to DO is present in the raw catch data. Station P50 had the lowest recorded DO levels on the Pamunkey (4.4 mg/L; Table 7), but had the highest and most consistent catch rate of all the Pamunkey stations.

DISCUSSION

Virginia striped bass exhibited average recruitment in 2005 with YOY fish evenly distributed throughout the nursery area. While the index for the James system did not significantly differ from its historical index, the mainstem James index for 2005 was significantly greater than the historical James mainstem index. The wide range of stations in the James where striped bass were captured in early July (J12 through J78) likely reflects the wider area of acceptable temperatures that occur at the beginning of the summer. The 2005 seine season was characterized by fewer thunderstorms, which may have had localized effects on catches. Catches in the York system were close to historical averages with the exception of the mainstem York auxiliary sites Y15 and Y21, whose index values were greater the historical indices for those stations. It is also possible that catches at these stations exhibit greater annual variability due to variation in winds. Y15 and Y21 are oriented to the summer's prevailing southwesterly wind direction and have 1-2 miles of fetch. Rappahannock River catches in 2005 showed similar patterns to 2004 catches, with R44, R50 and R55 as the most productive stations. The distribution of YOY striped bass was spatially more extensive (fish captured from R10 to R69) and less concentrated at the index stations, resulting in a lower overall index for the Rappahannock River.

Catches at bay and Eastern Shore stations reflected the wide range of the striped bass nursery in 2005. As with the striped bass stations at the edges of the nursery in the main sampling area, catches were low. This leads us to postulate that catches at bay and Eastern Shore stations reflected the dispersal of YOY striped bass from upstream nursery areas. Bloxom catches were likely dispersed from a nearby nursery area, such as the Pocomoke River. Fish caught at Willoughby Spit and First Landing State Park may have dispersed from one of the tributaries of the lower James River.

The association between water quality parameters and catches did not vary from historical patterns on a large scale. The decrease in index values from 2004 to 2005 may be the result of decreased precipitation and greater air temperatures in 2005. In addition, the expansion of the nursery range observed in 2005 may be the result of 2005 weather, with its daily variations and overall seasonal trends. Dissolved oxygen did not appear to be a major factor affecting catches; station P50 had the lowest recorded DO levels on the Pamunkey in 2005, but had the highest and most consistent catch rate of all Pamunkey stations in 2005.

Some low catches at index and auxiliary stations may be due to physical changes at the sites that reduced haul efficiency. For example, in the James River, auxiliary stations J74 and J78 have become extremely muddy with flocculated sediment that prevents efficient seining. These stations may be moved and/or combined in the future if another suitable location in those areas can be found. Extremely muddy substrate is also problematic at auxiliary station R76 and index station P42.

The 1989 addition of auxiliary stations to the survey has provided better overall coverage of the James, York and Rappahannock systems' nursery areas. 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 relative contribution of the auxiliary sites. They 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 could 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 YOY 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. 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 2005. 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	J74	J78	TOT.
	Round	1	2	ns	13/16	8/3	1	19/4	45/15	12/10	49	35/7	36	36	1	10	322
		2	0	19	3/2	4/10	7	5/0	7/0	10/5	60	14/7	11	8	4	0	176
		3	0	3	1/5	10/3	ns	5/2	3/3	13/7	21	6/5	1	4	0	0	92
		4	1	8	1/0	14/7	0	0/1	4/4	21/43	19	6/4	3	10	1	0	147
		5	3	9	0/0	15/0	0	0/1	6/0	23/9	ns	9/2	1	1	ns	ns	79
																	816
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55							
	Round	1	8	14	2	7	5/2	33/13	31/13	6							134
		2	ns	2	3	7	2/0	6/7	31/5	10							73
		3	3	2	6	21	0/0	4/2	17/8	7							70
		4	2	3	3	15	2/1	3/1	11/2	12							55
		5	3	0	1	12	0/0	2/1	10/7	3							39
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	Round	1				29/0	12	4/9	17/6	5/4	2						88
		2				0/4	10	18/13	17/1	0/0	2						65
		3				6/2	11	1/8	5/0	0/0	2						35
		4				0/3	8	0/0	2/3	1/13	2						32
		5				3/0	1	1/0	1/0	0/0	1						7
																	598
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76			
	Round	1	0	2	5/0	1/1	ns	14/4	2/3	28/45	ns	6	6	ns			117
		2	0	5	3/2	1/2	6	4/5	14/14	77/31	2	6	5	ns			177
		3	2	0	5/3	2/2	0	7/5	15/7	10/18	3	2	3	ns			84
		4	0	1	3/4	4/5	2	2/3	8/5	6/18	2	ns	3	ns			66
		5	1	1	1/1	2/3	4	2/8	15/6	25/19	1	0	1	ns			90
																	534
																	1948

ns = no sample taken

Table 2. Catch of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) summarized by year (adjusted 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.	Adjust. 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
Overall (1967-2005)	38694	1.43	1.19	7.27	6.95-7.61	4749

Table 3. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2005 summarized by drainage and river.

	2005				All Years Combined (1967-2005)			
Drainage River	Total Fish	Adjust. Mean	C.I. (±2 SE)	N (hauls)	Total Fish	Adjust. Mean	C.I. (±2 SE)	N (hauls)
JAMES	487	10.78	7.75-14.73	60	15348	9.28	8.60-10.01	1578
James	363	13.52	9.43-19.05	40	9009	8.43	7.69-9.24	1060
Chickahominy	124	6.64	3.21-12.22	20	6339	11.23	9.82-12.81	518
YORK	395	6.10	4.17-8.60	70	11215	5.66	5.26-6.08	1802
Pamunkey	219	8.67	5.10-13.95	30	5885	6.75	6.01-7.55	766
Mattaponi	176	4.57	2.60-7.34	40	5360	4.95	4.50-5.42	1036
RAPPAHANNOCK	470	12.49	9.11-16.89	50	12131	7.50	6.86-8.18	1369
OVERALL	1352	9.09	7.45-11.02	180	38694	7.27	6.95-7.61	4749

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2005 summarized by sampling period and month.

	2005				All Years Combined (1967-2005)			
Month (Round)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (hauls)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (hauls)
July (1st)	461	18.06	12.21-26.26	36	11766	10.90	9.89-11.98	998
(2nd)	324	10.28	6.41-15.87	36	9374	8.28	7.50-9.12	1009
Aug. (3rd)	190	8.33	5.73-11.77	36	6948	6.67	6.05-7.33	1001
(4th)	205	7.45	4.86-10.98	36	6237	6.44	5.78-7.16	865
Sept. (5th)	172	4.94	2.73-8.11	36	4164	5.59	4.99-6.24	739

Table 5. Salinity (parts per thousand) at seine survey stations in 2005. 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	J74	J78
	Round	1	14.1	ns	4.1	1.9	0.5	1.1	1.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1
		2	15.6	6.8	2.9	1.8	0.6	0.9	0.8	0.1	0.1	0.1	0.2	0.1	0.1	0.1
		3	14.2	7.7	5.1	2.6	ns	1.0	0.9	0.2	0.1	0.1	0.2	0.1	0.2	0.2
		4	15.9	9.5	5.6	2.5	1.0	1.5	1.4	0.3	0.2	0.1	0.2	0.1	0.1	0.1
		5	17.6	10.3	8.3	3.9	1.4	2.2	1.9	0.5	ns	0.2	0.2	0.2	ns	ns
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	15.2	12.6	8.7	2.8	0.7	0.2	0.1	0.1						
		2	ns	13.5	9.9	2.8	0.6	0.2	0.1	0.1						
		3	15.9	12.9	10.4	3.5	1.0	0.3	0.1	0.1						
		4	16.5	13.9	11.0	5.0	1.8	0.5	0.3	0.1						
		5	17.8	15.1	12.5	5.6	2.2	0.8	0.4	0.2						
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				2.8	0.9	0.4	0.1	0.0	0.0					
		2				2.7	0.7	0.3	0.1	0.0	0.0					
		3				3.5	1.2	0.4	0.1	0.1	0.1					
		4				4.9	2.5	1.1	0.2	0.1	0.0					
		5				6.5	3.8	1.8	0.5	0.2	0.1					
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Round	1	12.5	10.3	8.8	5.9	ns	1.5	0.4	0.2	ns	0.1	0.1	ns		
		2	11.5	10.9	8.4	4.1	1.5	0.1	0.1	0.1	0.1	0.1	0.1	ns		
		3	13.1	11.8	9.4	5.5	2.6	1.2	0.2	0.1	0.1	0.1	0.1	ns		
		4	13.8	12.3	9.5	4.5	3.1	1.9	0.5	0.2	0.0	ns	0.1	ns		
		5	14.9	13.4	10.9	6.3	4.2	2.4	0.6	0..3	0.1	0.1	0.1	ns		

ns = no sample taken

Table 6. Water temperature (^{o}C) recorded at seine survey stations in 2005. 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 2005. Index stations are indicated by bold font.

Drainage																
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
	Round	1	30.3	ns	30.6	27.2	29.5	29.2	28.7	29.7	28.5	28.6	30.1	31.1	30.6	29.9
		2	32.2	31.6	31.2	27.1	30.3	28.0	29.8	31.0	30.4	30.4	32.6	33.0	31.7	32.3
		3	31.4	32.8	29.8	28.5	ns	29.3	29.5	30.1	30.0	30.6	33.8	33.1	32.9	32.7
		4	28.3	28.2	30.3	27.7	30.3	29.2	29.1	30.6	30.0	30.4	33.7	32.8	33.3	31.6
		5	26.1	25.4	27.5	24.5	27.4	26.4	25.6	27.3	ns	25.2	26.6	29.0	ns	ns
YORK		Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
	Round	1	29.0	29.4	28.4	29.3	29.1		29.7	29.6	30.0					
		2	ns	29.5	30.5	31.1	30.8		31.2	31.1	31.5					
		3	30.5	30.2	27.5	29.3	29.6		30.1	29.7	30.1					
		4	31.4	31.0	27.2	28.7	29.3		29.2	28.9	29.6					
		5	29.1	29.2	24.2	26.0	26.3		26.7	26.7	27.0					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				28.6	28.6	28.4	29.2	30.7	29.8					
		2				30.9	31.3	30.6	31.7	34.4	33.0					
		3				29.3	29.5	29.4	30.1	31.5	31.2					
		4				28.4	28.7	28.2	28.4	28.9	28.1					
		5				24.8	26.3	25.3	25.8	26.5	26.1					
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	Round	1	26.9	26.8	27.2	26.9		ns	26.3	29.7	30.1	ns	29.7	29.6	ns	
		2	32.4	31.9	29.4	30.9		31.4	32.0	30.5	30.9	30.6	30.1	30.8	ns	
		3	30.0	30.5	29.1	29.8		29.9	30.4	30.9	30.9	30.5	33.7	33.2	ns	
		4	28.2	28.2	27.5	27.0		27.8	28.4	29.6	29.3	29.1	ns	29.8	ns	
		5	25.7	26.3	23.8	24.2		24.9	24.7	27.8	28.1	27.2	27.6	28.3	ns	

ns = no sample taken

Table 7. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2005. 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 2005. Index stations are indicated by bold font.

Drainage		Station														
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
	Round	1	6.7	ns	7.2	6.1	7.6	6.7	6.3	6.5	5.5	7.2	8.3	6.8	4.7	4.6
		2	6.8	6.6	7.3	6.7	6.4	6.5	5.2	5.4	4.6	5.9	8.2	5.8	5.3	5.9
		3	7.0	7.0	6.2	4.8	ns	4.9	4.3	3.5	3.9	6.0	10.7	6.7	6.9	6.2
		4	4.9	5.3	5.8	4.6	6.3	5.7	4.5	7.6	4.5	5.3	11.2	6.6	7.6	5.9
		5	4.4	6.0	7.3	6.2	8.3	7.8	6.4	5.0	ns	6.4	8.7	7.3	ns	ns
YORK		Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
	Round	1	6.2	6.6	6.1	5.6	5.3		5.5	4.6	6.2					
		2	ns	4.8	5.9	5.5	5.4		5.0	4.4	6.2					
		3	6.2	4.5	4.6	4.5	4.1		5.5	4.5	4.6					
		4	7.0	6.8	4.5	3.5	4.7		5.5	4.4	5.1					
		5	6.9	7.5	5.2	4.5	5.6		5.4	4.8	4.8					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				4.1	4.2	3.6	4.7	6.8	4.9					
		2				3.4	3.5	3.3	4.2	4.7	5.0					
		3				3.6	3.2	4.1	4.5	5.7	4.5					
		4				3.9	4.2	4.5	4.2	6.5	6.1					
		5				4.8	4.3	4.9	4.1	6.3	5.5					
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	Round	1	6.7	6.7	5.8	5.7		ns	6.9	6.7	6.7	ns	6.5	7.2	ns	
		2	8.2	6.3	5.1	6.6		6.3	5.8	5.4	6.1	4.7	5.9	4.1	ns	
		3	8.6	6.3	4.8	5.3		5.9	6.4	5.8	5.0	6.2	6.5	7.5	ns	
		4	6.0	6.1	5.6	4.5		4.5	6.3	5.7	5.4	5.2	ns	4.5	ns	
		5	7.3	6.9	7.4	7.1		6.5	6.8	5.3	6.3	6.2	6.8	5.1	ns	

ns = no sample taken

Table 8. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2005 summarized by salinity.

	2005				All Years Combined			
Salinity (ppt)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)
0-4.9	1304	10.33	8.35-12.67	156	35979	8.37	7.97-8.78	3981
5-9.9	46	3.66	2.26-5.50	22	2465	4.07	3.54-4.64	558
10-14.9	2	2.28	2.28-2.28	2	248	1.59	1.20-2.02	181
15-19.9	0	0	0	0	2	0.11	-0.04-0.28	29
Overall	1352	9.09	7.45-11.02	180	38694	7.27	6.95-7.61	4749

Table 9. Average salinity (ppt) and corresponding striped bass indices recorded at seine survey stations from 1967 to 2005 and in 2005. 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	J74	J78
	1967-2005	Avg. Sal.	13.5	7.1	4.3	2.3	1.3	1.3	1.1	0.56	0.25	0.18	0.15	0.12	0.10	0.10
		Index	2.9	14.7	6.8	12.0	7.6	15.3	7.2	16.8	15.0	5.4	7.6	5.2	7.2	4.0
	2005	Avg. Sal.	15.5	8.6	5.2	2.5	0.9	1.3	1.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1
		Index	2.0	18.7	4.7	12.9	2.3	4.4	9.7	29.1	75.3	16.6	11.2	16.4	2.5	1.9
YORK		Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
	1967-2005	Avg. Sal.	16.1	13.1	10.0	3.6	1.5		0.7	0.4	0.3					
		Index	1.0	1.7	4.8	10.6	3.6		9.8	12.1	6.2					
	2005	Avg. Sal.	16.3	13.6	10.5	3.9	1.3		0.4	0.2	0.1					
		Index	8.1	5.7	6.1	26.0	1.8		9.9	24.2	15.9					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	1967-2005	Avg. Sal.				4.0	2.0	1.1	0.4	0.3	0.1					
		Index				6.3	7.4	6.7	4.0	3.9	1.3					
	2005	Avg. Sal.				4.1	1.8	0.8	0.2	0.1	0.0					
		Index				4.5	15.8	6.2	6.4	2.2	4.0					
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	1967-2005	Avg. Sal.	13.8	12.6	9.7	5.2		3.0	2.0	0.9	0.6	0.2	0.2	0.1	0.0	
		Index	0.5	1.0	2.2	3.7		4.7	8.8	11.0	38.1	7.5	4.5	3.2	4.9	
	2005	Avg. Sal.	13.2	11.7	9.4	5.3		2.9	1.4	0.4	0.2	0.1	0.1	0.1	ns	
		Index	1.3	3.1	5.2	4.8		5.0	10.7	17.2	51.0	4.4	5.7	7.4	ns	

ns = no sample taken

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2005 summarized by water temperature.

	2005				All Years Combined (1967-2005)			
Temp. (°C)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Adjust. 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	35	4.8	1.79-10.03	10	2365	3.47	3.03-3.94	623
25-29.9	734	8.09	6.30-10.25	114	29824	8.25	7.83-8.70	3349
30-34.9	583	12.66	8.83-17.80	56	6036	8.52	7.55-9.60	648
Overall	1352	9.09	7.45-11.02	180	38694	7.27	6.95-7.61	4749

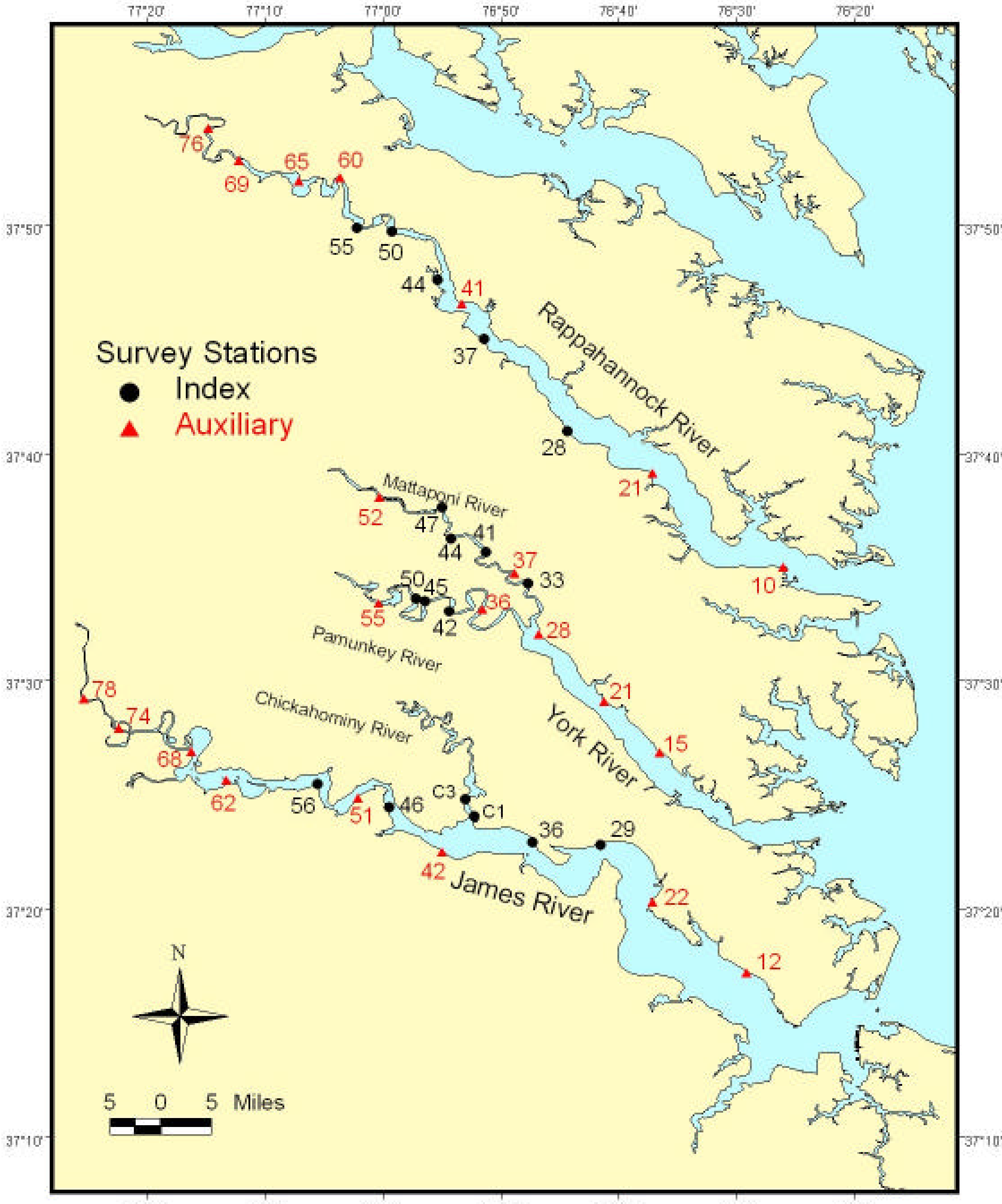

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designations indicates river mile from mouth.

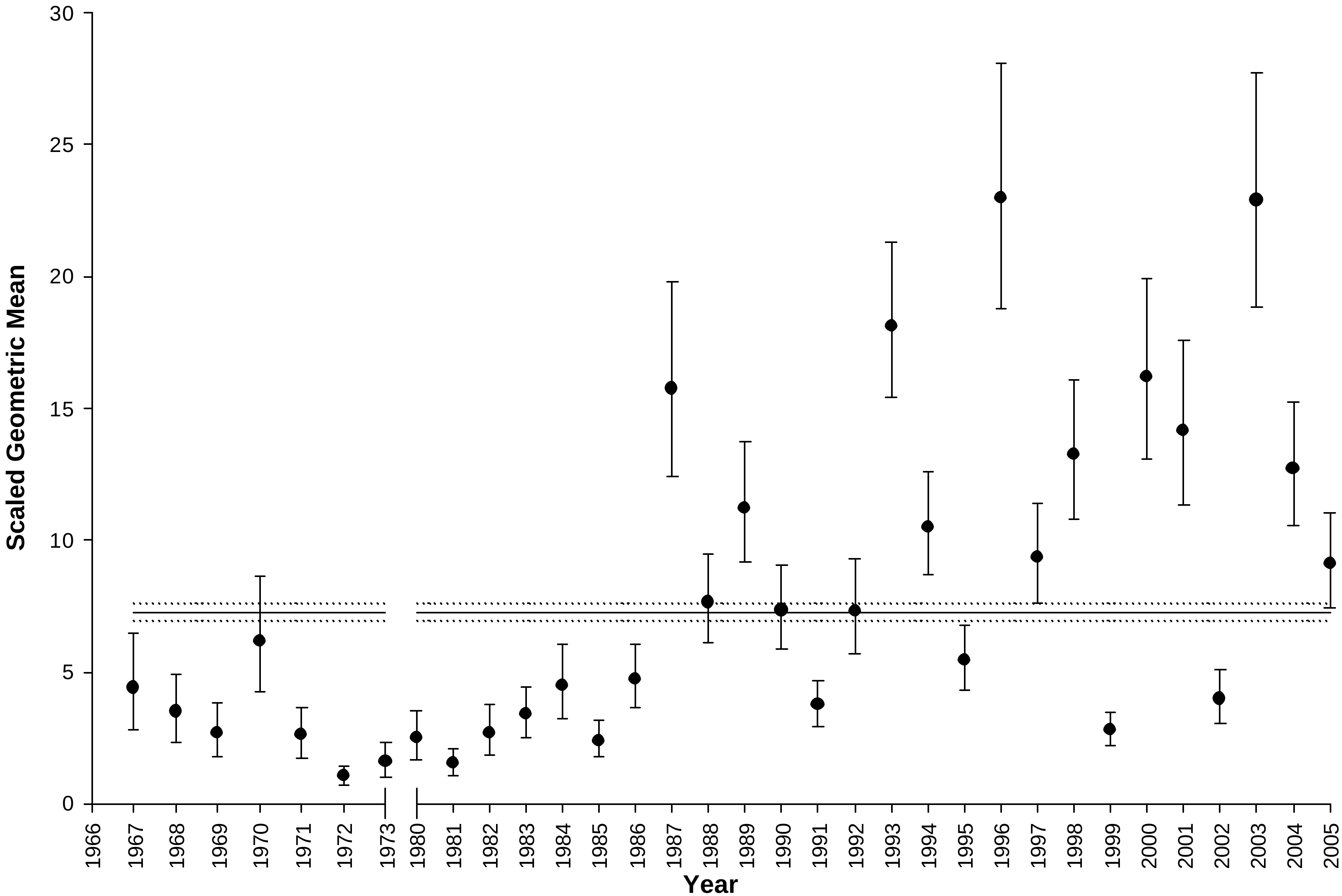

Figure 2. Scaled geometric mean of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate historical geometric mean (solid) and confidence intervals (dotted) for 1967-2005.

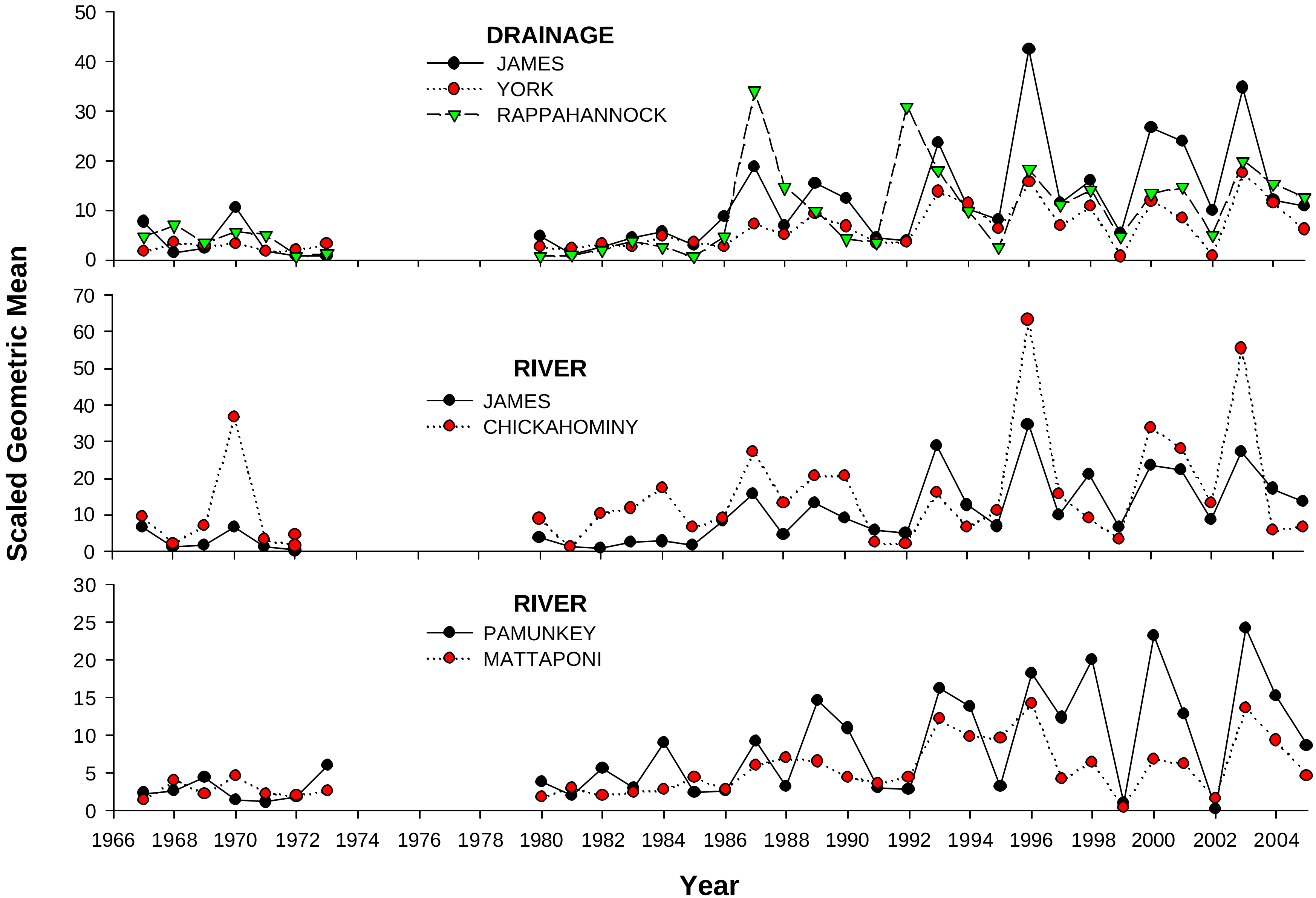

Figure 3. Scaled geometric mean of young-of-the-year striped bass per seine haul in the primary nursery area by drainage and river.

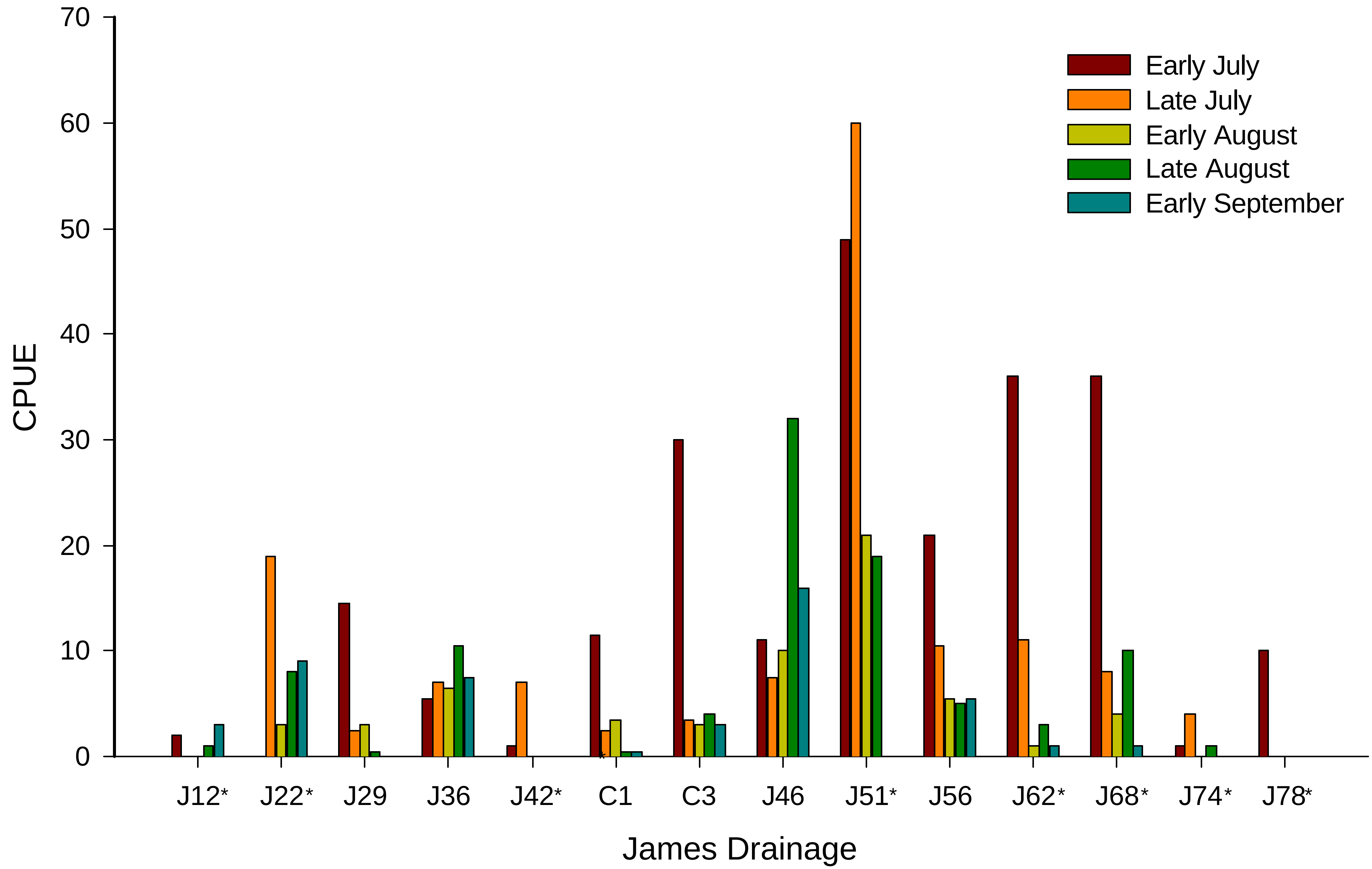

Figure 4. Catch of young-of-the-year striped bass by station in the James River drainage in 2005. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

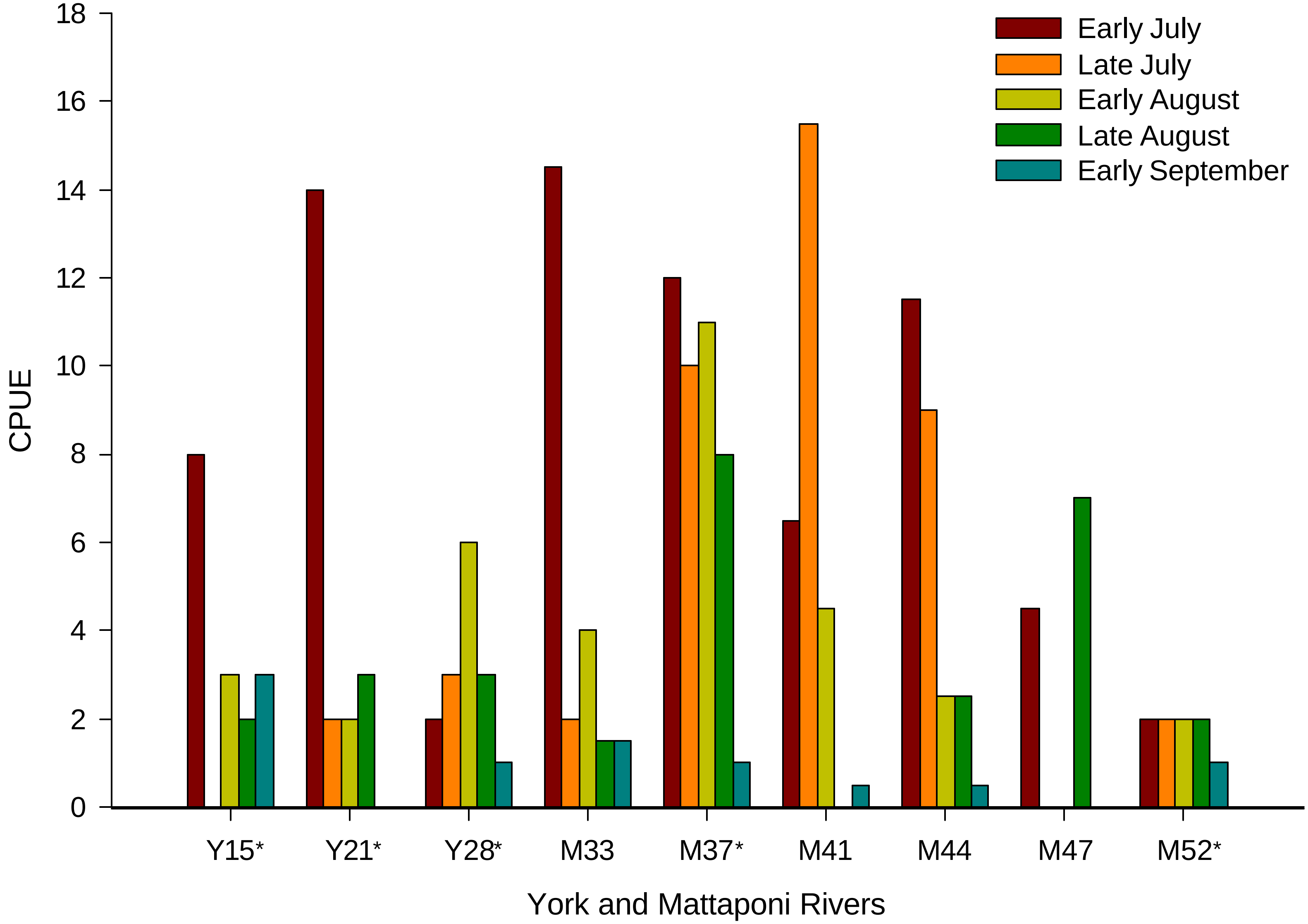

Figure 5. Catch of young-of-the-year striped bass by station in the York and Mattaponi rivers in 2005. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

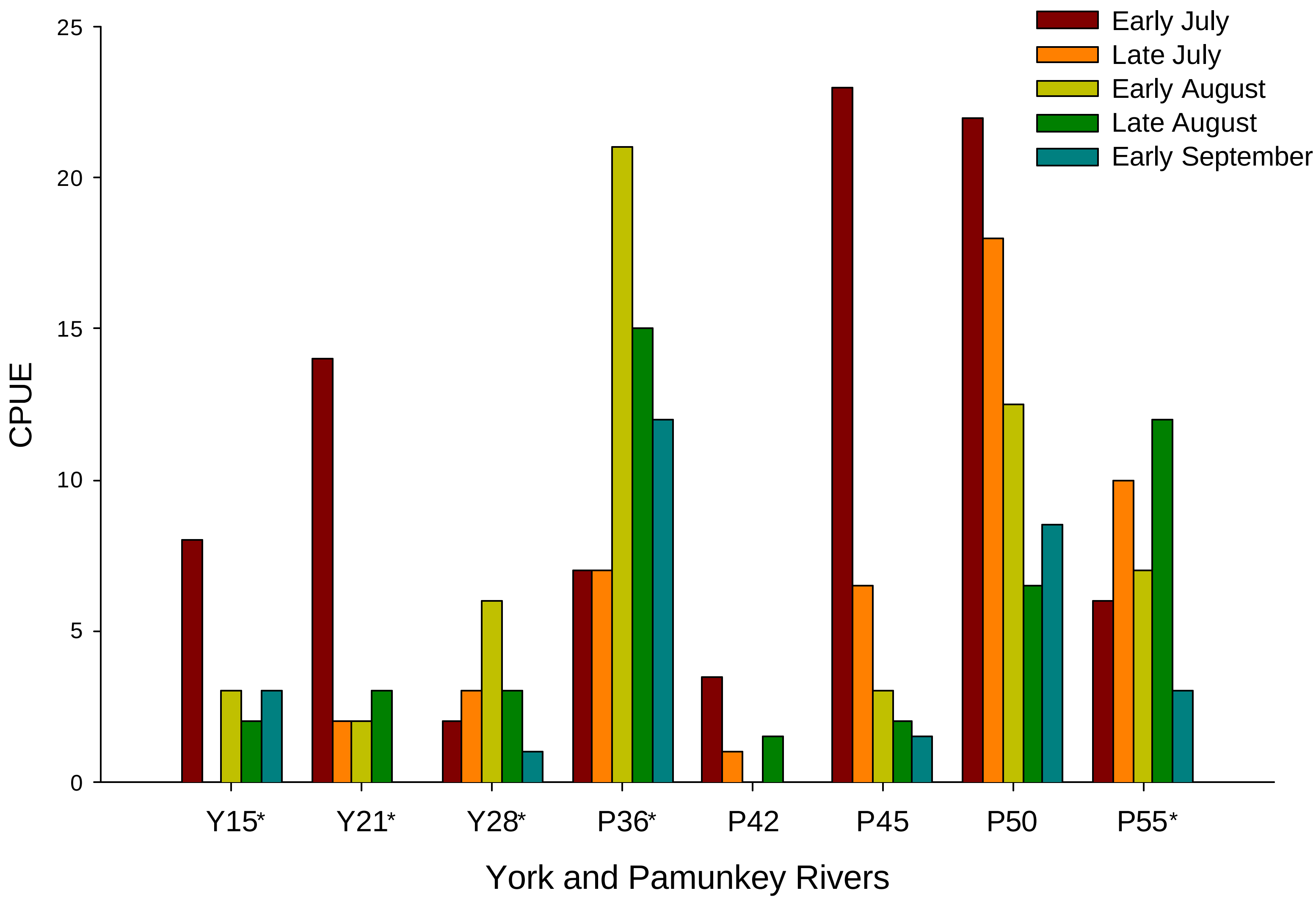

Figure 6. Catch of young-of-the-year striped bass by station in the York and Pamunkey rivers in 2005. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

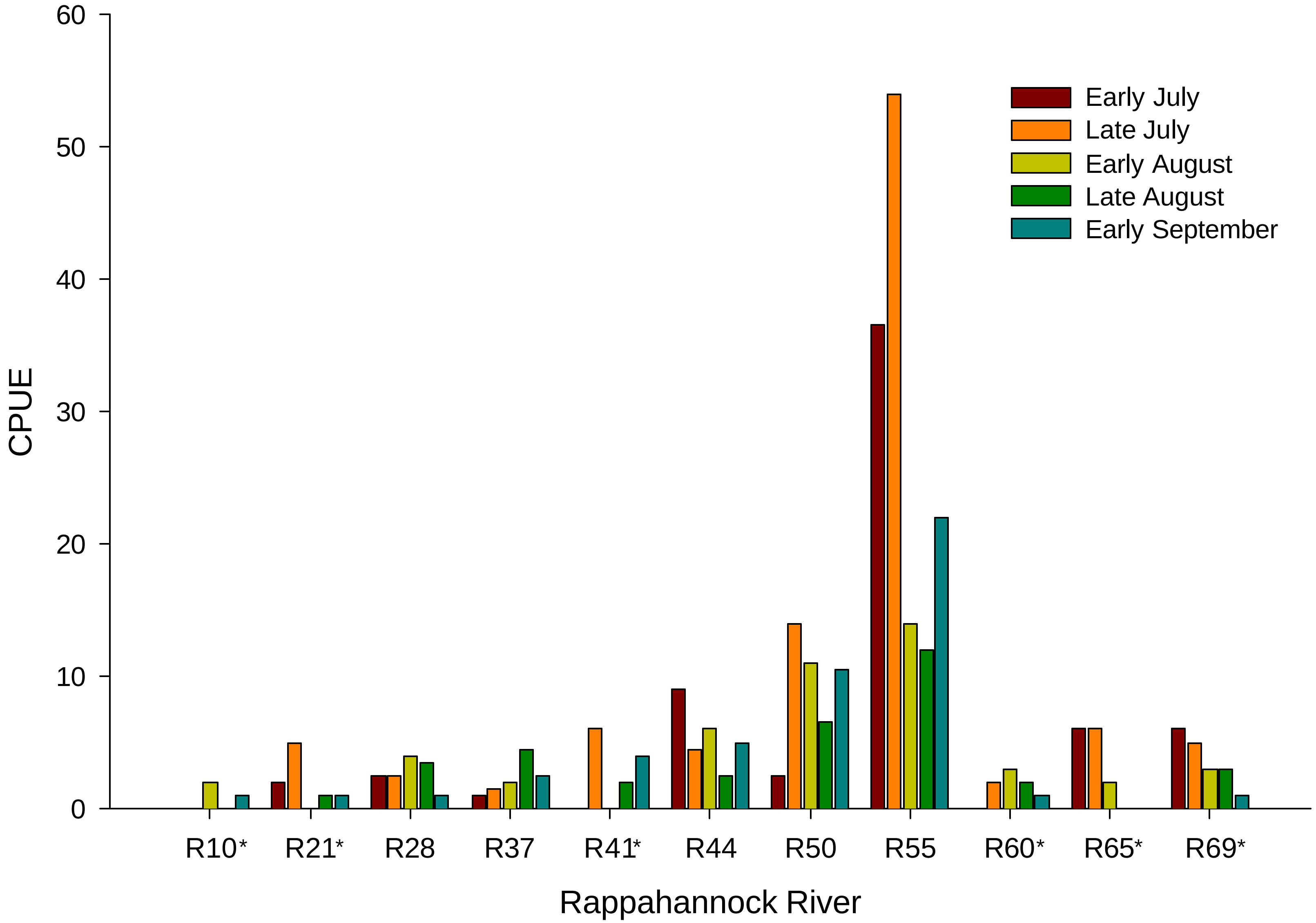

Figure 7. Catch of young-of-the-year striped bass by station in the Rappahannock River in 2005. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

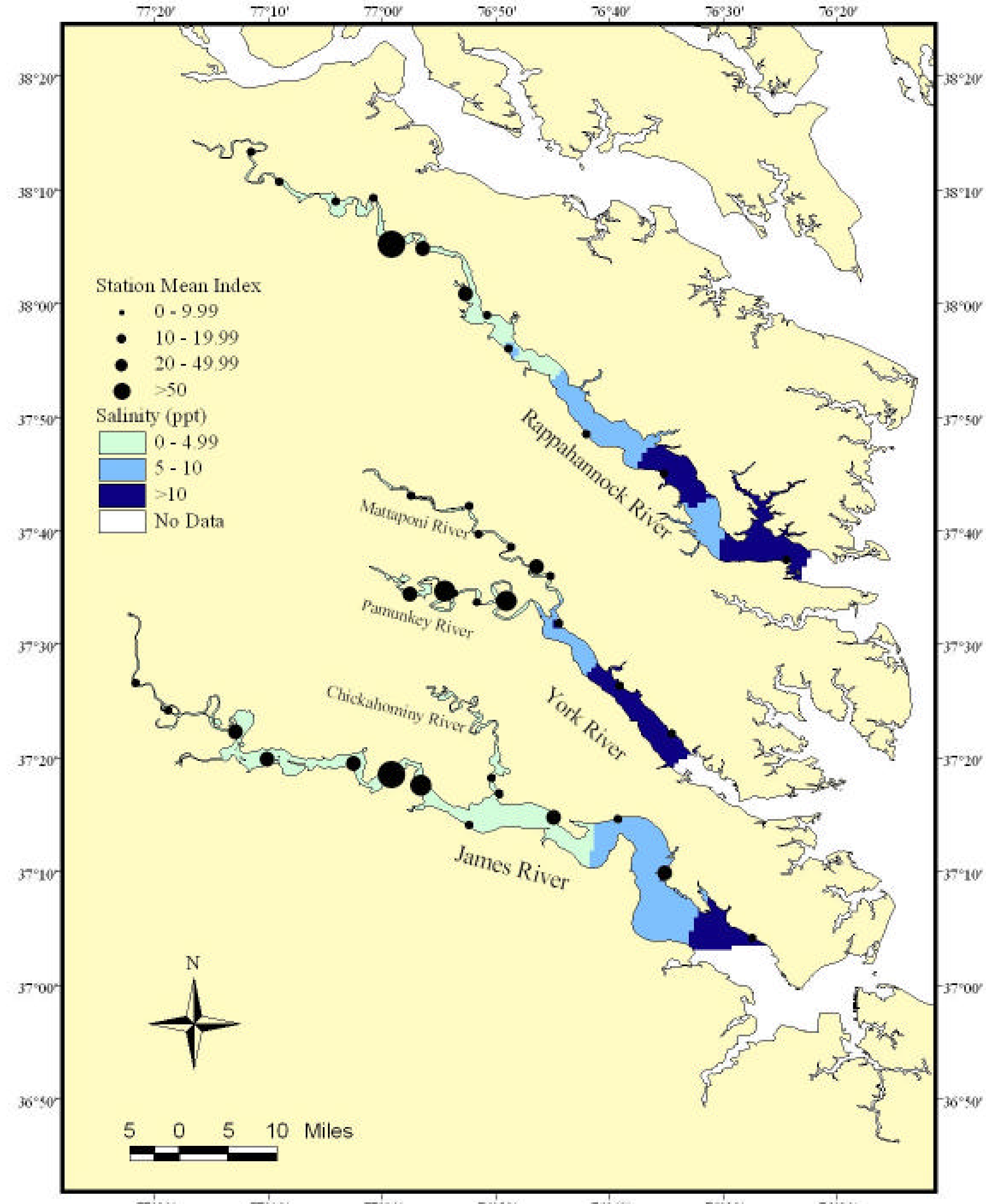

Figure 8. Scaled geometric mean index for young-of-the-year striped bass by station and salinity in 2005.