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

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Leonard S. Machut
Mary C. Fabrizio

Department of Fisheries Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia

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EXECUTIVE SUMMARY

The 2008 striped bass juvenile abundance index is 7.97 and is not significantly different from the historic average of 7.51. Additional methods of calculating the regional index support this conclusion. Catches in the James River were significantly higher than it's historic average and offset the significantly lower catches recorded in the York River. The 2008 Rappahannock River index is not significantly different from the historic average. Striped bass catches at auxiliary stations provide greater spatial coverage of the nursery grounds and suggest that juvenile striped bass were broadly distributed throughout the sampling area in 2008.

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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. Beginning in 1980, funds were provided by the National Marine Fisheries Service under the Emergency Striped Bass Study program. Commencing with the 1989 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 2008 sampling period and compares these results with previous years.

INTRODUCTION

Striped bass (*Morone saxatilis*) is 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; Chesapeake Bay stock abundances were particularly depressed. Because the tributaries of Chesapeake Bay had been identified as primary spawning and nursery areas, fishery managers 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 (VMRC) adopted this plan in March 1982 (Regulation 450-01-0034), but the 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" (i.e., 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 a 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) but has not been regularly computed.

Objectives for the 2008 program were to:

1. estimate the relative abundance of the 2008 year class of striped bass in 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.

METHODS

Field sampling was conducted during five biweekly sampling periods from July through mid-September 2008. During each sampling period, the seine was hauled at 18 historically sampled sites (index stations) and 21 auxiliary stations within the James, York and Rappahannock river systems (Figure 1). Auxiliary sites were added in 1989 to provide better geographic coverage, 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 nursery ground expansion.

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 (1.2 m) was encountered, and then pulling the offshore end down-current and back to the shore. During each round a single haul was made at each auxiliary station and duplicate hauls, with a 30-minute interlude, were made at each index station. Every fish collected during a haul was removed from the net, and held in water-filled buckets until after the second haul was completed. Individual striped bass were measured to the nearest mm fork length. For all other species, a sub-sample of up to 25 individuals was measured to the nearest mm fork length (or total length if appropriate). All fish captured, except those preserved for life history studies, were returned to the water at the conclusion of sampling.

At each sampling location, 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 for each haul.

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 in the calculation of the annual indices. The index of relative abundance for striped bass is calculated as the adjusted overall mean catch per seine haul such that

$$Index = (\exp(\ln(totnum + 1)) - 1) \times 2.28$$

where *totnum* is the total number of striped bass collected per seine haul. Because the frequency distribution of the catch is skewed and approximates a negative binomial distribution (Colvocoresses 1984), a logarithmic transformation ($\ln(totnum+1)$) was applied to the data prior to analysis (Sokal and Rohlf 1981). Mean values are back-transformed and scaled up arithmetically ($\times$ 2.28) to allow for comparisons with Maryland data. Thus, a "scaled" index refers to an index that is directly comparable with the Maryland index.

In accordance with suggestions made by Rago et al. (1995), the Virginia juvenile striped bass index has also been recomputed using only the first haul at each index station. Additionally, due to the rehabilitation of Chesapeake Bay striped bass stocks, and subsequent relaxation of commercial and recreational fisheries regulations in the Chesapeake Bay in 1990 (ASMFC 2003), the seine survey dataset can be separated into three distinct periods:

- 1967 – 1973: an early period of monitoring;
- 1980 – 1989: a decade reflecting severe population depression during which temporary fishing moratoria were in place; and,

- 1990 – Present: a period of post-recovery and regulation targeting the development of a sustainable fishery.

An average index value for the 1990 – 2008 time period was calculated using only the first haul at each index site and was compared with the annual index value to provide a benchmark for interpreting recruitment strength during the post-recovery period.

Throughout this report mean catch rates are compared using 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 AND DISCUSSION

Virginia Regional Juvenile Index of Abundance

In 2008, 1,518 young-of-year striped bass were collected from 180 seine hauls at index stations and 404 individuals were collected from 104 hauls at the auxiliary stations (Table 1). Using data from both hauls, the estimated index for 2008 is 7.97 (LCI = 6.33, UCI = 9.93; Table 2), which is not significantly different from the historic average index of 7.51 (LCI = 7.20, UCI 7.84; Figure 2). The "historic index" refers to a summation of all survey years from 1967 to the present.

However, even with a 30-minute interlude between sampling at index stations, second hauls are not independent samples and violate a key assumption necessary for making inferences from a sample mean (Rago et al. 1995). Previous reports have noted fewer catches in the second haul (e.g. Hewitt et al. 2007, 2008) which may artificially lower the geometric mean when data from the second hauls are included in the

computation of the index. Using only the first haul at each index station, the annual and historic indices were recalculated. In 2008, 867 young-of-year striped bass were collected resulting in an index estimate of 10.15 (LCI = 7.56, UCI = 13.42, Table 3) which is not significantly different from the recomputed first-haul historic index of 8.15 (LCI = 7.69 – 8.63). It is important to note that all annual striped bass estimates in Table 3 have been adjusted to account for single hauls. By developing a 2008 index based solely on the first haul at all index sites a more robust estimate of juvenile abundance can be determined for Virginia waters.

The inclusion of a comparison between the present year's annual recruitment and a post-recovery period index (1990 – Present) provides additional information on the pattern of striped bass annual recruitment in relation to a more recent average that reflects the current status of the stock. The 2008 Virginia-wide index of 10.15 (LCI = 7.56, UCI = 13.42) is not significantly different from the mean index for the post-recovery period (index = 12.07; LCI = 11.25, UCI = 12.94) suggesting that 2008 was an average year.

Ongoing research at VIMS suggests that a Chesapeake Bay-wide index, computed from Virginia and Maryland data combined could provide a more complete and robust estimate of relative young-of-year recruitment for Chesapeake Bay striped bass (Woodward 2009). This may be particularly appropriate to consider in years when individual state indices provide divergent estimates of year-class strength because such a pattern may simply reflect annual changes in the spatial distribution and contribution of nursery areas throughout the Chesapeake Bay, rather than overall changes in the abundance of recruits.

As a whole, striped bass recruitment success in the Virginia portion of the Chesapeake Bay is variable among years and among nursery areas within years. No significant differences were apparent when comparing the 2008 annual index against any of the three measures of striped bass relative recruitment (traditional historic index, first-haul only index, and mean index from 1990 through present day). This suggests that striped bass from the Virginia portion of the Chesapeake Bay exhibited an average recruitment in 2008. Young-of-year abundance was low in 1999 and 2002, but strong year classes were observed in 1998, 2000, 2001, 2003 and 2004. This was followed by average recruitment in 2005 and above average recruitment in both 2006 and 2007. Thus, a year of average recruitment is not uncommon, and rather is instead expected. Continued monitoring of recruitment success will be an important factor in determining management strategies to protect the spawning stock of Chesapeake Bay striped bass. The size of the nursery area was generally similar to previous years with greater numbers of juvenile fish found in the James and Rappahannock Rivers than in the York River watershed.

Individual Watershed Juvenile Index of Abundance

Juvenile striped bass were widely distributed in the James River in 2008 (Table 1). The 2008 index for the James drainage is 15.19 (LCI = 11.13, UCI 20.49), which is significantly higher than the historic James drainage index of 9.78 (LCI = 9.11, UCI = 10.49; Table 4). This difference is due to significantly higher catches in the James River proper. The 2008 main stem James (excluding the Chickahominy River) index is 18.90 (LCI = 12.95, UCI = 27.17) compared to the historic index of 9.10 (LCI = 8.35, UCI = 9.91). No statistical difference was found in the Chickahominy River between the 2008

index (9.61; LCI = 5.69, UCI = 15.45) and the historic index (11.29; LCI = 9.96, UCI = 12.75). Catches at the Chickahominy River stations were variable throughout the sampling season. Collections at C3 were highest in early July but declined sharply in subsequent weeks (Table 1). This contrasts with catches at C1 which increased through early August before decreasing in late August and September. Catches at Chickahominy River index stations were less than those made during 2007 but were greater than those observed in 2006. Throughout the James River watershed five of six index sites had higher index averages than their respective historic averages, the lone exception being C3 (Table 5). Roughly 43% of all young-of-year striped bass captured in the James drainage were from station J46; and, this sampling site consistently produced the highest catches in the James River by round (Table 1). In total number of striped bass caught, J46 was the most productive site sampled during 2008 in Virginia waters. Since 1990, J46 has consistently ranked among the top three productive index stations.

At 3.49 (LCI = 2.37, UCI = 4.88), the 2008 index for the York drainage is significantly lower than the historic index of 5.74 (LCI = 5.36, UCI = 6.14). This was the lowest drainage-specific index observed in 2008 (Figure 3), and represents a continued decline from 2007 (6.08), 2006 (11.40) and 2005 (10.78). No index sites are located on the main stem of the York River although three auxiliary stations are present; the watershed index is compiled from sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. Although the 2008 Mattaponi River index (4.36; LCI = 2.60, UCI = 6.77) is not statistically different from the historic average (5.09; LCI = 4.65, UCI = 5.54), the 2008 index for the Pamunkey River (2.50; LCI = 1.32, UCI = 4.07) is significantly lower than the historic average (6.71; LCI =

6.02, UCI = 7.46) and represents the lowest individual river index in the 2008 sampling season. The Pamunkey River index in 2008 was the lowest index value observed in any river since 2002.

Within the York River watershed, highest catches were at M44, P50 and M33, although catch rates at these stations within 2008 were dissimilar. Catches peaked at M44 in early July and then declined, whereas catches at M33 peaked during late July and early August. Catches at P50 and other Pamunkey and Mattaponi index sites were highly variable with peak catches occurring throughout the 2008 sampling season (Table 1).

The 2008 index for the Rappahannock River is 9.83 (LCI = 6.05, UCI 15.31), which is not statistically different from the historic average of 7.75 (LCI = 7.12, UCI = 8.42). Catches in 2008 were greatest at the two uppermost index sites (R50 and R55) with R55 being the most productive site (Table 1). These two sites accounted for 70% of the total catch in the Rappahannock River drainage in 2008 and have dominated annual catches in this drainage for several years.

The James River system had the highest index value and served to bolster the overall regional index by offsetting the significantly lower catches in the York River drainage. Lower catches of young-of-year striped bass in the York River drainage were due to low juvenile abundance in the Pamunkey River. The Pamunkey River index is the third lowest value in the last 20 years, better than collections only in 1999 and 2002. The Mattaponi index was not significantly different from the historic average, and catches at York River auxiliary sites did not vary greatly between 2008 and previous years. Seine collections made by a VIMS graduate student showed similar patterns in both the Mattaponi and Pamunkey rivers in 2008 (B. Williams, unpublished data). The reason for

the low catches observed in the Pamunkey River is unclear; however, yearly riverine index values are characterized by periodic changes in catch rates (Figure 3).

Striped Bass Collections from Auxiliary Stations

The 1989 addition of auxiliary stations to the survey has provided better overall coverage of nursery areas in the James, York and Rappahannock drainages as upriver and downriver auxiliary sites allowed us to delineate the upper and lower limits of the nursery range. These auxiliary stations revealed that in years of low or high river flow, the spatial extent of nursery areas could change relative to river flow. Additionally, in years of high juvenile abundance the nursery area generally expanded both up and down-river. This interannual flux in the collection of young-of-year striped bass at auxiliary sites was evident in 2008.

For the first time since 2005, a single young-of-year striped bass was collected from J12 (Table 1). In 2006, when J77 replaced J74 and J78 (which could no longer be seined) as the uppermost James River sampling station, no striped bass were collected (Hewitt et al. 2007). However, J77 has proven to be an adequate auxiliary site because fish were detected at this site in 2007 (Hewitt et al. 2008) and 2008 (Table 1). Their persistence through 2008 suggests young-of-year striped bass use this auxiliary site. Catches at the upstream and downstream auxiliary sites suggest juvenile striped bass were broadly distributed throughout the James River nursery in 2008.

All stations in the main stem York River are auxiliary. No juvenile striped bass were captured at Y15 during 2008, although young-of-year fish had been collected at this location from 2003 – 2007. Young-of-year striped bass were collected in 2008 from Y21 during late July (round 2) and from Y28 in all rounds except for the first (Table 1).

Catches in all auxiliary sites on the main stem of the York River were lower than historic averages (Table 5).

Similarly, no striped bass were caught in the uppermost auxiliary sites in the Pamunkey and Mattaponi rivers. The lack of fish at P55 may have been due to the inability to accurately sample in dense hydrilla (*Hydrilla verticillata*) vegetation using a 100-ft seine. Although hydrilla was also present at M52, enough open space was available to deploy and retrieve the seine. However, no striped bass were collected from M52. Given the altered state of habitat at these sites in recent history, it is unclear whether striped bass were present in this general location during the sampling season (that is, perhaps juvenile striped bass were present at the site but were not detected). If continued sampling difficulties persist, it may prove worthwhile to examine alternative sites.

As in 2007, few fish were collected at R10 and none at R21 (Table 1). Few fish were collected at these sites in 2005 or 2006 (Austin et al. 2006, Hewitt et al. 2007). These sites have favorable substrate and no potential seine obstructions which suggest that these sites may have lower value as nursery areas due to consistently high salinities during average discharge years. R75, added in 2006 to replace R76, was comparatively productive as 10 young-of-year striped bass were collected throughout the 2008 sampling season; no fish were collected in 2006 and only 2 were collected in 2007. This suggests that this site is a suitable auxiliary station for monitoring upstream limits of juvenile striped bass.

Comparisons Between Index and Auxiliary Sites

Direct comparisons between auxiliary and index sites are problematic due to different sampling methods. Figures 4 through 7 show catch rates at all stations with index station catches reported as an average of two hauls. Past analyses 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 overemphasize the contribution of the auxiliary sites relative to the index sites. Figures 4 through 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 detect 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 and robust estimate of relative year-class strength (Rago et al. 1996).

Sampling Round Comparison

In 2008, our catches were greatest in early July (round one) when 571 young-of-year striped bass were collected (Table 6). Catches in late July (round two) decreased by 38%, and catches in early August (round three) decreased by 33% relative to late July. However, unlike the previous three years, continual decreases in catches were observed during round 4 in late August (19%) and during round 5 in early September (16%). 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) because fish disperse to deeper water and are large enough to effectively avoid capture.

Environmental Conditions And Potential Relationships to Juvenile Striped Bass Abundance

The distribution of juveniles within the nursery may be affected by water quality parameters during sampling. Pertinent environmental variables recorded at the time of each collection in 2008 are presented in Tables 7 through 9. 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 variability is partially explained by temperature and precipitation in the winter and spring preceding sampling (Wood 2000). Data from the National Climate Data Center (NCDC; 2009) indicated that whereas winter (December 2007 through February 2008) precipitation was “below normal”, spring (March through May 2008) was characterized by “above normal” precipitation rates. Comparatively, precipitation within the Maryland portion of the Chesapeake Bay was “near normal” over the winter, but was characterized by “much above normal” precipitation during the spring (NCDC 2009). Summer rainfall in Virginia was characterized as “below normal” and salinities were above historic averages during this time.

As in previous years, the pattern of high water temperatures in the mid summer and slowly declining temperatures during the late summer was well defined in 2008 (Table 7). Similar to 2007, temperatures were slightly elevated during early September in relation to temperatures in preceding years (2005 and 2006). However, the effects of these events on site-specific striped bass abundances can not be easily assessed. Catch rates in 2008 followed the historic pattern with respect to water temperature: most fish (99.9%) were captured in waters between 25.0 and 34.9 ^{o}C (Table 10). Water

temperatures in these systems reflect the long-term weather patterns of summer, but also exhibit significant day-to-day and river-to-river variation. Sampling takes place at shallow shoreline areas that are easily affected by local events such as thunderstorms and by small-scale spatial and temporal variations associated with time of sampling (e.g. morning versus afternoon or tidal stage). 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.

In 2008, as in the past, we observed greater catches of young-of-year striped bass at lower salinities within the primary nursery area (Table 11). No index station exceeded 11.6 ppt salinity although salinity was as high as 21.5 ppt at the farthest downstream auxiliary sites (Table 8). Table 5 shows the relationship of juvenile striped bass catches with respect to historic and 2008 salinity gradients within each river system. In 2008, the percentage of catch observed in low salinities (0.0 – 4.9 ppt) was lower than that observed historically (85% in 2008 vs. 92% all years; Table 11). The catch in mid-range salinities (5.0 – 9.9 ppt) was nearly double the historic average (13% in 2008 vs. 7% all years). Juvenile striped bass were captured at downstream auxiliary sites during early rounds of the 2008 survey in areas with salinities ranging from 9.0 ppt to over 17.2 ppt, although catches were lower than those observed in lower salinity, upstream sites. Salinity is not the only factor affecting the spatial distribution of striped bass in 2008.

None of the dissolved oxygen (DO) levels measured during the survey in 2008 are considered hypoxic (less than 2-3 mg/L; Table 9). Approximately half of the sampling sites in the primary nursery area had at least one DO measurement that was more than

one standard deviation (SD) less than the mean DO recorded from 1989 to the present at each station (Table 9). Lower than average values occurred inconsistently temporally and spatially. Dissolved oxygen measured at the time of sampling does not seem to have a direct effect on detection because DO values more than one SD less than the mean at a station (shaded values in Table 9) do not necessarily correspond with low catches at that station.

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Table 1. Catch of young-of-year striped bass per seine haul in 2008. Two hauls were made per sampling round at each of the index stations (bold).

Drainage															Round
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Total
	Round	1	1	6	1/2	10/4	24	10/12	12/3	131/79	18	5/4	13	3	1	339
		2	0	3	3/12	6/4	16	16/10	4/0	35/71	19	5/5	9	27	2	247
		3	0	11	19/12	13/12	5	17/11	4/1	9/25	16	5/6	10	37	0	213
		4	0	4	3/5	3/9	5	6/4	6/2	36/20	9	5/1	1	9	0	128
		5	0	3	4/12	12/12	ns	4/1	1/0	28/9	5	1/0	0	1	2	95
														James Total		1022
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	0	0	0	12	0/3	2/0	12/8	0						37
		2	0	2	5	9	0/0	3/0	2/1	0						22
		3	0	0	2	1	3/1	0/1	6/3	0						17
		4	0	0	3	0	1/0	8/0	1/0	0						13
		5	0	0	1	0	1/0	0/0	1/1	0						4
		Station	0	2	11	**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				4/1	13	1/1	20/34	6/2	0					82
		2				11/5	4	7/2	4/11	3/0	0					47
		3				11/0	0	2/1	5/1	2/8	0					30
		4				1/0	1	0/0	1/0	1/0	0					4
		5				0/0	0	1/0	0/4	7/0	0					12
						33	18	15	80	29				York Total		268
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75		
	Round	1	10	0	6/8	2/2	12	18/21	14/23	63/47	0	0	1	0		227
		2	0	0	4/0	0/0	0	8/3	13/10	67/31	0	7	1	3		147
		3	0	0	6/3	0/0	11	1/0	12/1	29/8	0	2	3	4		80
		4	0	0	0/1	2/0	14	0/2	5/0	44/25	0	3	2	1		99
		5	0	0	11/0	0/0	6	8/3	3/4	10/23	0	10	0	1		79
													Rappahannock Total			632

ns = no sample

2008 Catch	1922

Table 2. Catch of young-of-year striped bass in the primary nursery areas of Virginia (index stations) summarized by year, where x = total fish, Index $= (\exp(\ln(x+1)) - 1) \times 2.28$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	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	463	1.31	1.113	6.15	4.27-8.57	78
1971	178	0.75	0.855	2.56	1.72-3.58	81
1972	96	0.38	0.578	1.05	0.71-1.42	118
1973	139	0.51	0.782	1.52	0.94-2.22	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
2007	1999	1.83	1.18	11.96	9.66-14.70	180
2008	1518	1.50	1.17	7.97	6.33- 9.93	180
Overall (1967-2008)	43619	1.46	1.19	7.51	7.20-7.84	5289

Table 3. Catch of young-of-year striped bass in the primary nursery areas of Virginia (index stations) using only the 1st haul (Rago et al. 1995) summarized by year, where x = total fish, Index = $(\exp(\ln(x+1)) - 1) \times 2.28$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1967	209	1.07	0.98	4.40	2.82-6.45	53
1968	208	0.93	0.90	3.50	2.35-4.94	66
1969	207	0.78	0.89	2.71	1.8-3.84	77
1970	463	1.31	1.11	6.15	4.27-8.57	78
1971	178	0.75	0.86	2.56	1.72-3.58	81
1972	96	0.38	0.58	1.05	0.71-1.42	118
1973	139	0.51	0.78	1.52	0.94-2.22	87
1980	216	0.82	0.96	2.90	1.85-4.21	72
1981	112	0.64	0.74	2.05	1.28-2.99	58
1982	172	0.86	0.96	3.10	1.86-4.71	54
1983	185	0.99	0.94	3.86	2.44-5.71	51
1984	377	1.27	1.09	5.81	3.72-8.63	53
1985	216	0.94	0.92	3.54	2.4-4.97	71
1986	449	1.35	1.07	6.53	4.56-9.06	72
1987	1314	2.27	1.22	19.77	14.25-27.13	72
1988	820	1.57	1.21	8.66	6.2-11.85	90
1989	1427	2.06	1.18	15.68	11.71-20.77	90
1990	720	1.58	1.12	8.76	6.44-11.7	90
1991	462	1.17	1.05	5.04	3.59-6.85	90
1992	1143	1.65	1.31	9.63	6.76-13.41	90
1993	1241	2.34	0.89	21.36	17.31-26.25	90
1994	969	1.93	1.09	13.37	10.17-17.4	90
1995	559	1.37	1.07	6.71	4.89-8.99	90
1996	2326	2.60	1.27	28.29	21.11-37.69	90
1997	931	1.83	1.14	11.92	8.9-15.76	90
1998	1365	2.12	1.22	16.66	12.35-22.23	90
1999	274	0.92	0.91	3.43	2.43-4.64	90
2000	1528	2.22	1.23	18.70	13.91-24.9	90
2001	1671	2.16	1.32	17.52	12.7-23.89	90
2002	486	1.17	1.13	5.03	3.48-7.01	90
2003	2042	2.50	1.26	25.61	19.09-34.13	90
2004	1129	2.07	1.04	15.75	12.19-20.19	90
2005	835	1.79	1.07	11.42	8.64-14.9	90
2006	767	1.76	1.06	11.02	8.34-14.36	90
2007	1271	2.09	1.21	16.07	11.95-21.39	90
2008	867	1.70	1.11	10.15	7.56-13.42	90
Overall (1967-2008)	27374	1.52	1.23	8.15	7.69-8.63	2953

Table 4. Catch of young-of-year striped bass per seine haul in the primary nursery area in 2008 summarized by drainage and river.

	2008				All Years Combined (1967-2008)			
Drainage River	Total Fish	Scaled Mean	C.I. (±2 SE)	N (hauls)	Total Fish	Scaled Mean	C.I. (±2 SE)	N (hauls)
JAMES	762	15.19	11.13 - 20.49	60	17514	9.78	9.11 - 10.49	1758
James	638	18.90	12.95 - 27.17	40	10610	9.10	8.35 - 9.91	1180
Chickahominy	124	9.61	5.69 - 15.45	20	6904	11.29	9.96 - 12.75	578
YORK	215	3.49	2.37 - 4.88	70	12453	5.74	5.36 - 6.14	2012
Pamunkey	58	2.50	1.32 - 4.07	30	6412	6.71	6.02 - 7.46	856
Mattaponi	157	4.36	2.60 - 6.77	40	6041	5.09	4.65 - 5.54	1156
RAPPAHANNOCK	541	9.83	6.05 - 15.31	50	13652	7.75	7.12 - 8.42	1519
OVERALL	1518	7.97	6.33 - 9.93	180	43619	7.51	7.20 - 7.84	5289

Table 5. Striped bass indices recorded at all survey stations in 2008 compared to historic (1967 – 2008) values with corresponding annual and historic average salinities (Avg. Sal., ppt). The York drainage 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*
	1967-2008	Avg. Sal.	14.2	7.6	4.6	2.5	1.6	1.4	1.3	0.6	0.3	0.2	0.2	0.1	0.2
		Index	2.3	15.1	7.2	12.6	9.0	15.3	7.4	18.8	14.8	5.8	8.2	6.0	0.9
	2008	Avg. Sal.	19.1	11.3	8.4	5.5	2.9	3.6	3.3	1.6	0.6	0.3	0.2	0.2	0.2
		Index	0.3	11.0	12.5	17.5	23.1	17.2	5.0	73.3	27.6	6.9	9.1	19.8	1.8
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1967-2008	Avg. Sal.	16.4	13.5	10.4	3.9	1.7	0.7	0.4	0.3					
		Index	1.1	1.7	4.9	10.0	3.7	9.0	12.1	5.5					
	2008	Avg. Sal.	19.5	16.9	13.4	6.1	2.9	0.7	0.4	0.2					
		Index	0.0	0.6	3.9	4.7	1.4	1.6	5.3	0.0					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2008	Avg. Sal.				4.3	2.3	1.1	0.4	0.3	0.1				
		Index				6.0	7.4	6.4	4.5	4.2	1.3				
	2008	Avg. Sal.				7.3	3.8	1.4	0.5	0.3	0.0				
		Index				3.8	3.9	2.3	8.4	4.2	0.0				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	1967-2008	Avg. Sal.	14.1	12.8	9.9	5.3	3.2	2.0	0.9	0.6	0.2	0.2	0.1	0.1	
		Index	0.6	0.9	2.5	3.5	4.8	8.5	11.6	39.3	6.1	4.3	3.1	0.4	
	2008	Avg. Sal.	14.8	13.2	10.4	5.2	3.1	1.6	0.6	0.4	0.2	0.1	0.1	0.1	
		Index	1.4	0.0	5.5	0.9	13.6	7.9	12.9	65.7	0.0	6.9	2.7	3.2	

*= new station in 2006

Table 6. Catch of young-of-year striped bass in the primary nursery areas of Virginia in 2008 summarized by sampling round and month.

	2008				All Years Combined (1967-2008)			
Month (Round)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (hauls)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (hauls)
July (1st)	571	15.65	9.71 - 24.54	36	13372	11.32	10.33 - 12.38	1106
(2nd)	356	9.73	5.77 - 15.64	36	10443	8.59	7.83 - 9.41	1117
Aug. (3rd)	238	8.76	5.60 - 13.19	36	7735	6.88	6.28 - 7.52	1109
(4th)	192	4.65	2.49 - 7.78	36	7035	6.59	5.96 - 7.27	973
Sept. (5th)	161	4.60	2.51 - 7.60	36	4829	5.72	5.14 - 6.34	847

Table 7. Water temperature (^{o}C) recorded at seine survey stations in 2008. The York drainage includes the 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	29.3	30.4	31.3	26.1	28.4	27.2	27.3	28.2	27.7	27.4	29.3	30.8	30.4
	2	28.0	30.7	32.1	28.1	32.3	30.1	30.3	31.5	27.5	27.6	31.8	31.2	30.8
	3	29.5	28.2	31.6	28.1	31.2	30.2	29.4	30.9	29.8	28.1	30.0	32.2	30.5
	4	27.9	27.0	28.3	25.1	26.5	27.0	27.0	28.2	26.7	26.5	28.4	29.2	30.2
	5	26.1	25.6	28.0	25.9	ns	28.2	27.4	28.9	26.7	26.9	29.7	29.7	27.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
Round	1	27.3	26.5	25.2	26.7	26.8	27.4	27.2	27.1					
	2	27.5	27.6	28.1	29.6	30.0	30.6	31.1	32.1					
	3	27.6	27.4	27.4	28.9	29.6	30.0	29.9	29.8					
	4	26.7	26.5	24.9	26.7	27.0	27.7	27.5	27.8					
	5	25.6	25.9	26.0	26.5	27.0	27.2	27.2	26.9					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
Round	1				26.7	27.4	27.5	27.8	29.6	28.8				
	2				29.1	29.1	29.3	29.8	30.3	32.3				
	3				28.6	28.9	29.0	29.3	29.8	29.9				
	4				27.3	27.4	26.9	27.8	29.6	29.6				
	5				27.0	27.1	28.7	27.1	27.0	27.4				
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
Round	1	29.9	28.7	26.4	26.9	27.7	27.4	28.3	28.8	28.6	29.2	28.9	29.5	
	2	32.1	31.7	28.7	29.4	31.0	32.6	28.2	29.4	29.2	31.1	30.4	31.3	
	3	31.3	29.6	26.7	28.5	29.0	28.3	28.9	29.4	29.6	29.6	30.4	30.3	
	4	28.3	28.2	24.9	25.7	27.4	27.5	27.1	26.7	27.5	29.9	29.2	28.9	
	5	29.3	28.2	26.8	27.4	28.7	29.0	26.4	27.3	28.1	28.2	27.3	27.7	

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

Table 8. Salinity (ppt) recorded at seine survey stations in 2008. The York drainage includes the 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	17.2	9.0	5.4	3.0	1.6	1.9	1.7	0.5	0.1	0.1	0.2	0.2	0.2
	2	19.1	11.4	7.4	4.0	2.1	2.2	2.0	0.7	0.2	0.2	0.2	0.1	0.2
	3	19.8	12.0	8.6	5.9	3.1	3.8	3.4	1.6	0.5	0.2	0.2	0.2	0.2
	4	21.5	13.6	10.7	7.8	4.9	5.1	4.6	3.2	1.2	0.6	0.3	0.2	0.3
	5	17.7	10.6	9.7	6.6	ns	5.1	5.0	1.9	0.8	0.4	0.3	0.2	0.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
Round	1	17.7	14.5	10.0	3.3	1	0.2	0.1	0.1					
	2	19.2	16.0	12.7	4.4	1.8	0.4	0.1	0.1					
	3	19.6	17.2	14.2	7.0	3.3	0.1	0.4	0.2					
	4	21.0	19.0	16.2	8.7	4.7	1.5	0.7	0.4					
	5	20.2	17.8	14.0	7.2	3.5	1.5	0.8	0.2					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
Round	1				5.1	1.6	0.2	0.1	0.1	0.0				
	2				6.5	2.4	0.3	0.1	0.1	0.0				
	3				8.1	4.4	1.0	0.3	0.2	0.0				
	4				8.4	5.0	2.7	0.7	0.7	0.1				
	5				8.6	5.7	2.9	1.1	0.6	0.1				
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
Round	1	13.5	12.1	9.0	3.2	1.3	0.4	0.1	0.1	0.1	0.1	0.1	0.1	
	2	14.3	12.8	10.2	4.5	1.8	0.7	0.1	0.1	0.1	0.1	0.1	0.1	
	3	14.8	12.9	10.2	5.3	2.7	1.4	0.3	0.1	0.1	0.1	0.1	0.1	
	4	15.4	14.2	11.2	6.1	4.6	2.5	1.0	0.5	0.2	0.1	0.1	0.1	
	5	15.8	14.2	11.6	7.0	5.0	3.2	1.6	1.0	0.3	0.2	0.1	0.1	

ns = no sample taken; *new station in 2006

Table 9. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2008. The York drainage includes the Pamunkey and Mattaponi rivers. Shaded values are more than one standard deviation (SD) less than the mean dissolved oxygen concentrations recorded at that station from 1989 to 2008. 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	8.8	7.7	7.2	7.1	6.6	7.6	6.3	5.1	6.0	8.2	12.9	7.2	4.6
	2	7.0	7.1	5.7	5.6	6.7	5.7	5.6	5.3	5.6	7.0	11.8	7.5	7.2
	3	7.5	6.5	6.8	4.9	7.3	5.7	5.5	4.9	4.5	6.0	7.6	5.8	5.0
	4	5.2	6.4	7.0	5.1	7.0	6.0	5.3	5.6	5.0	6.6	9.8	6.0	7.0
	5	5.8	5.5	7.2	6.0	ns	7.5	4.8	5.4	5.4	8.5	8.5	5.9	5.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
Round	1	6.6	6.1	6.1	3.9	4.8	5.3	5.3	6.9					
	2	6.2	5.0	5.3	5.1	5.3	5.8	5.5	7.8					
	3	6.0	4.9	4.9	3.6	4.7	5.2	4.6	5.2					
	4	5.0	4.5	4.7	4.4	5.1	5.8	4.8	4.7					
	5	4.8	5.2	4.9	5.4	4.6	5.4	4.9	5.0					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
Round	1				4.6	3.8	4.5	4.4	4.3	5.5				
	2				4.3	3.7	4.3	4.1	4.9	6.1				
	3				3.5	3.7	3.9	4.0	3.6	6.3				
	4				4.2	4.7	5.5	4.6	6.0	4.2				
	5				4.7	4.8	4.6	5.8	5.8	4.4				
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
Round	1	7.5	6.7	5.9	5.8	7.2	7.2	6.7	6.4	6.5	9.2	6.7	6.0	
	2	5.7	6.2	5.8	5.9	7.8	7.3	3.9	4.9	4.3	5.8	8.1	8.5	
	3	6.5	6.7	6.1	5.8	7.4	7.1	5.4	5.5	4.7	6.6	6.5	6.1	
	4	6.5	6.8	6.8	6.4	6.3	6.9	6.8	7.1	6.7	6.8	5.7	6.9	
	5	8.2	6.5	6.9	7.3	7.0	7.7	7.4	7.1	5.6	8.5	6.0	6.1	

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

Table 10. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2008 summarized by water temperature.

	2008				All Years Combined (1967-2008)			
Temp. (°C)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)
15.0 - 19.9	0	0.00	0.00 - 0.00	0	79	2.85	1.40 - 4.86	30
20.0 - 24.9	1	0.94	0.00 - 4.17	2	2561	3.62	3.17 - 4.09	661
25.0 - 29.9	1248	7.94	6.16 - 10.08	149	33528	8.43	8.02 - 8.86	3752
30.0 - 34.9	269	9.04	4.89 - 15.61	29	7061	8.79	7.85 - 9.81	747
Overall	1518	7.97	6.33 - 9.93	180	43619	7.51	7.20 - 7.84	5289

Table 11. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2008 summarized by salinity.

	2008				All Years Combined (1967-2008)			
Salinity (ppt)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)
0.0 - 4.9	1294	8.77	6.65 - 11.39	132	40335	8.62	8.23 - 9.02	4400
5.0 - 9.9	191	6.46	3.98 - 9.92	38	2926	4.32	3.81 - 4.87	649
10.0 - 14.9	33	4.78	1.71 - 10.20	10	356	2.02	1.59 - 2.49	211
15.0 - 19.9	0	0.00	0.00 - 0.00	0	2	0.11	0.00 - 0.28	29
Overall	1518	7.97	6.33 - 9.93	180	43619	7.51	7.20 - 7.84	5289

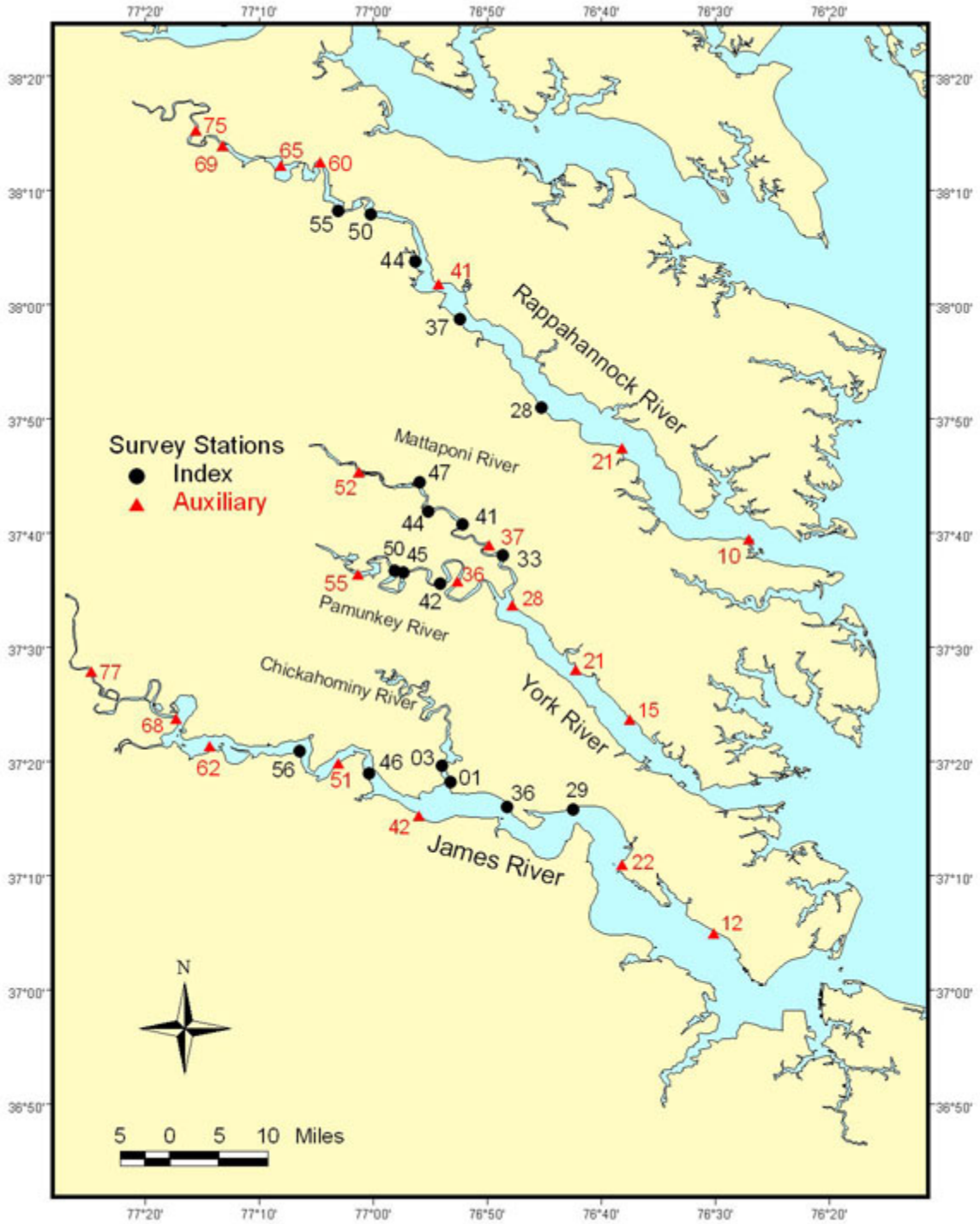

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designation indicates river mile from mouth. Auxiliary stations R75 (Rappahannock) and J77 (James) are new in 2006, replacing R76 and J74/J78, respectively.

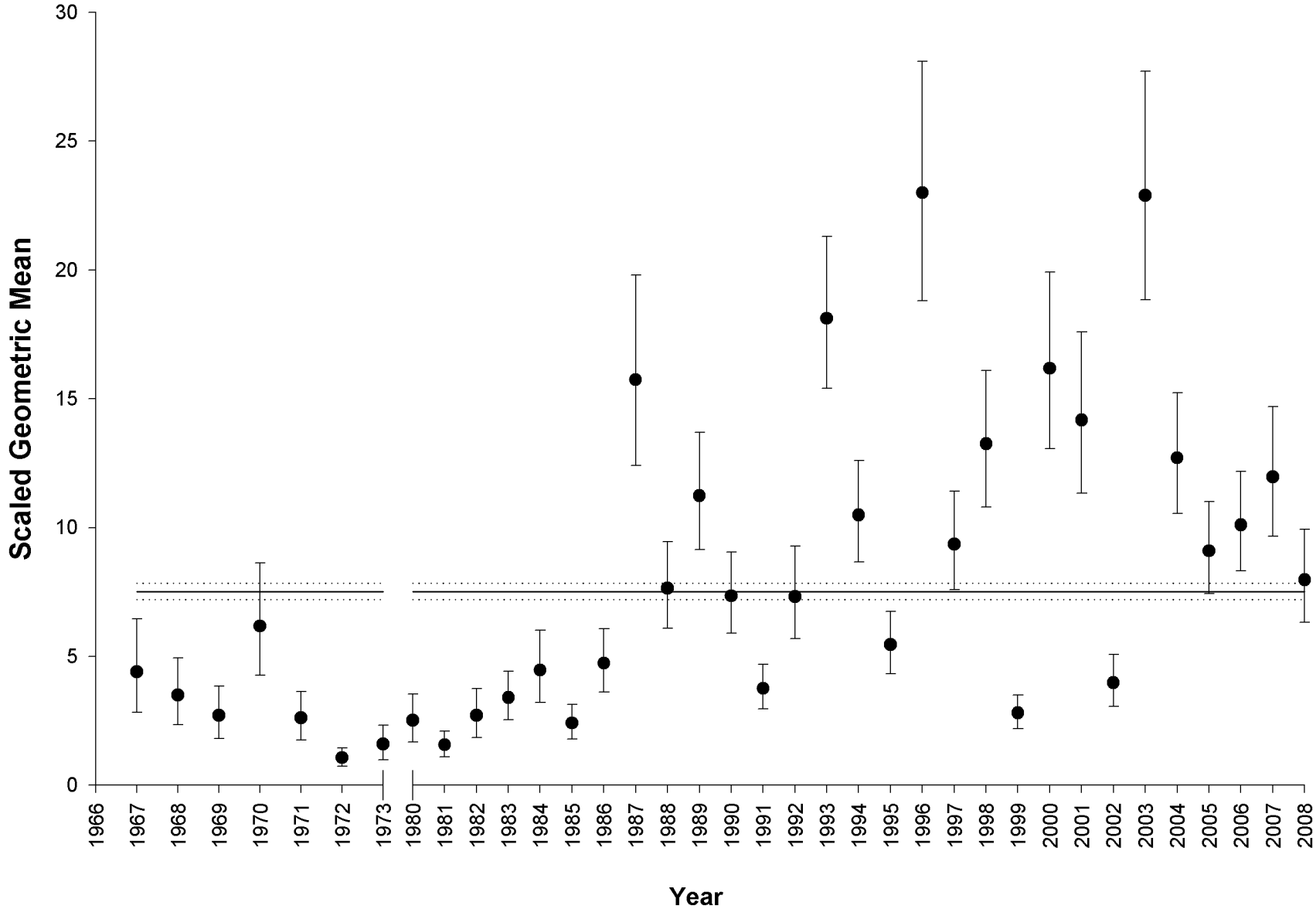

Figure 2. Scaled geometric mean of young-of-the-year striped bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate historical geometric mean (solid) and confidence intervals (dotted) for 1967-2008.

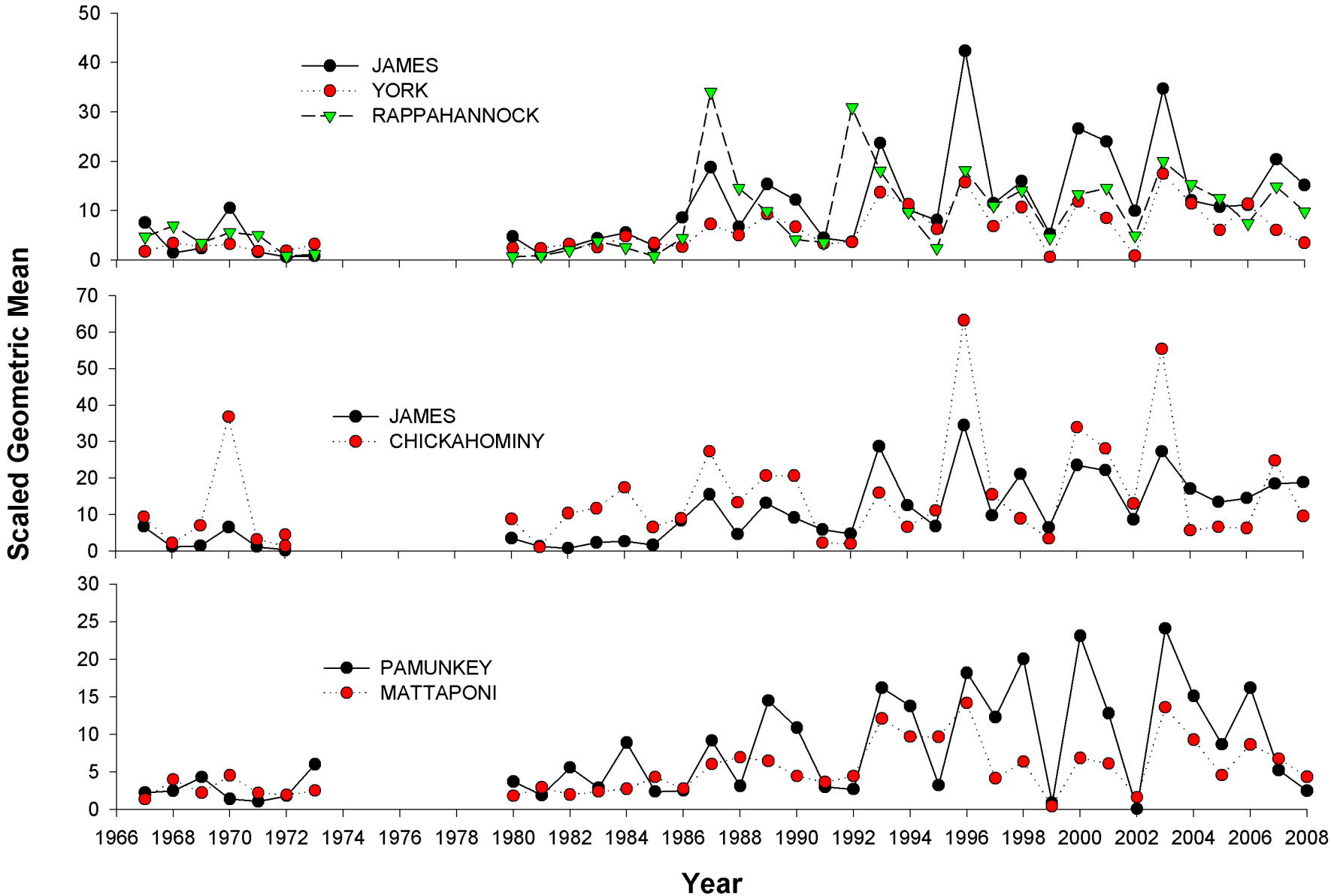

Figure 3. Scaled geometric mean of young-of-the-year striped bass in the primary nursery areas of Virginia (index stations) by drainage and river.

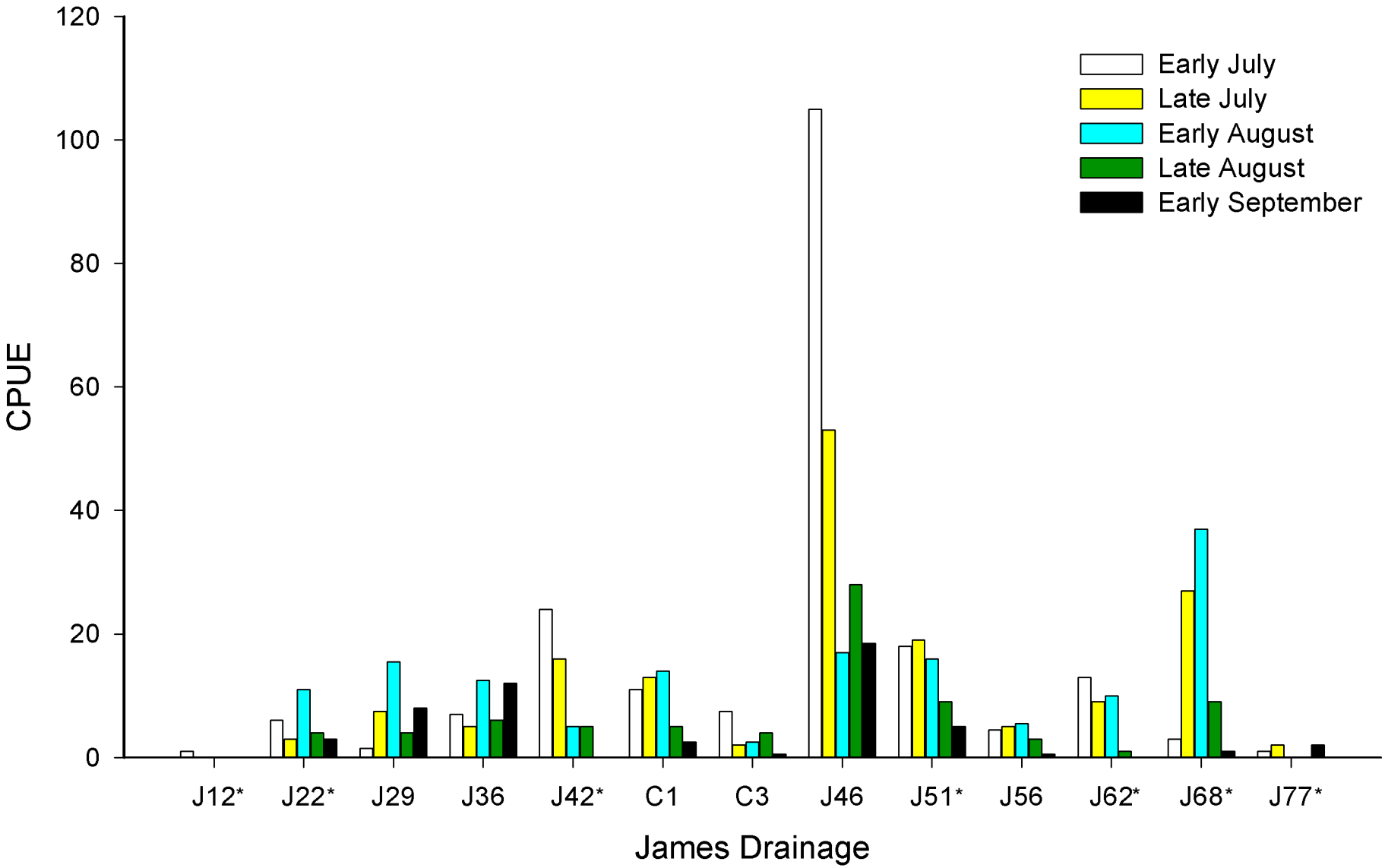

Figure 4. Catch of young-of-year striped bass by station in the James River drainage in 2008. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

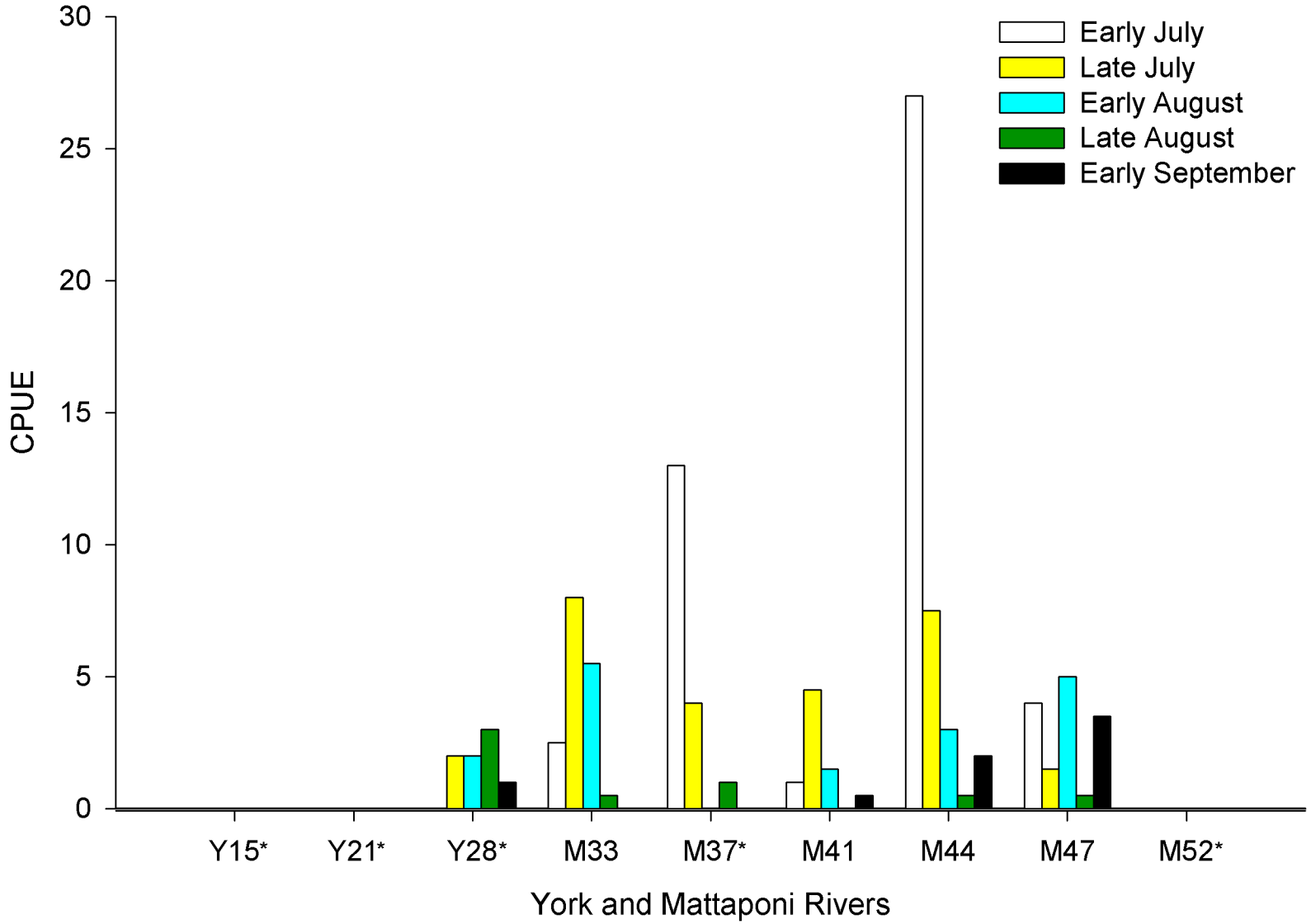

Figure 5. Catch of young-of-year striped bass by station in the York and Mattaponi rivers in 2008. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

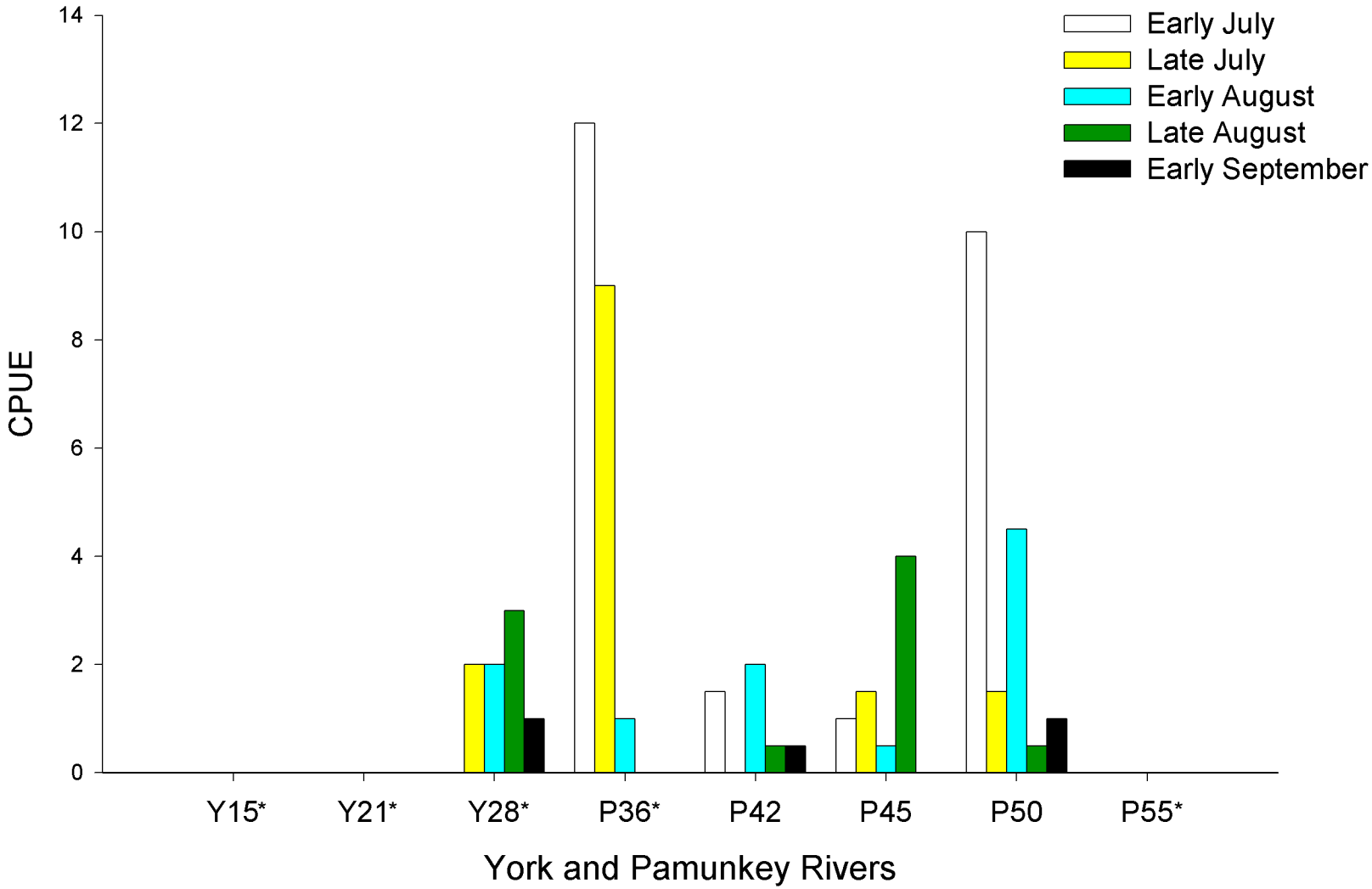

Figure 6. Catch of young-of-year striped bass by station in the York and Pamunkey rivers in 2008. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

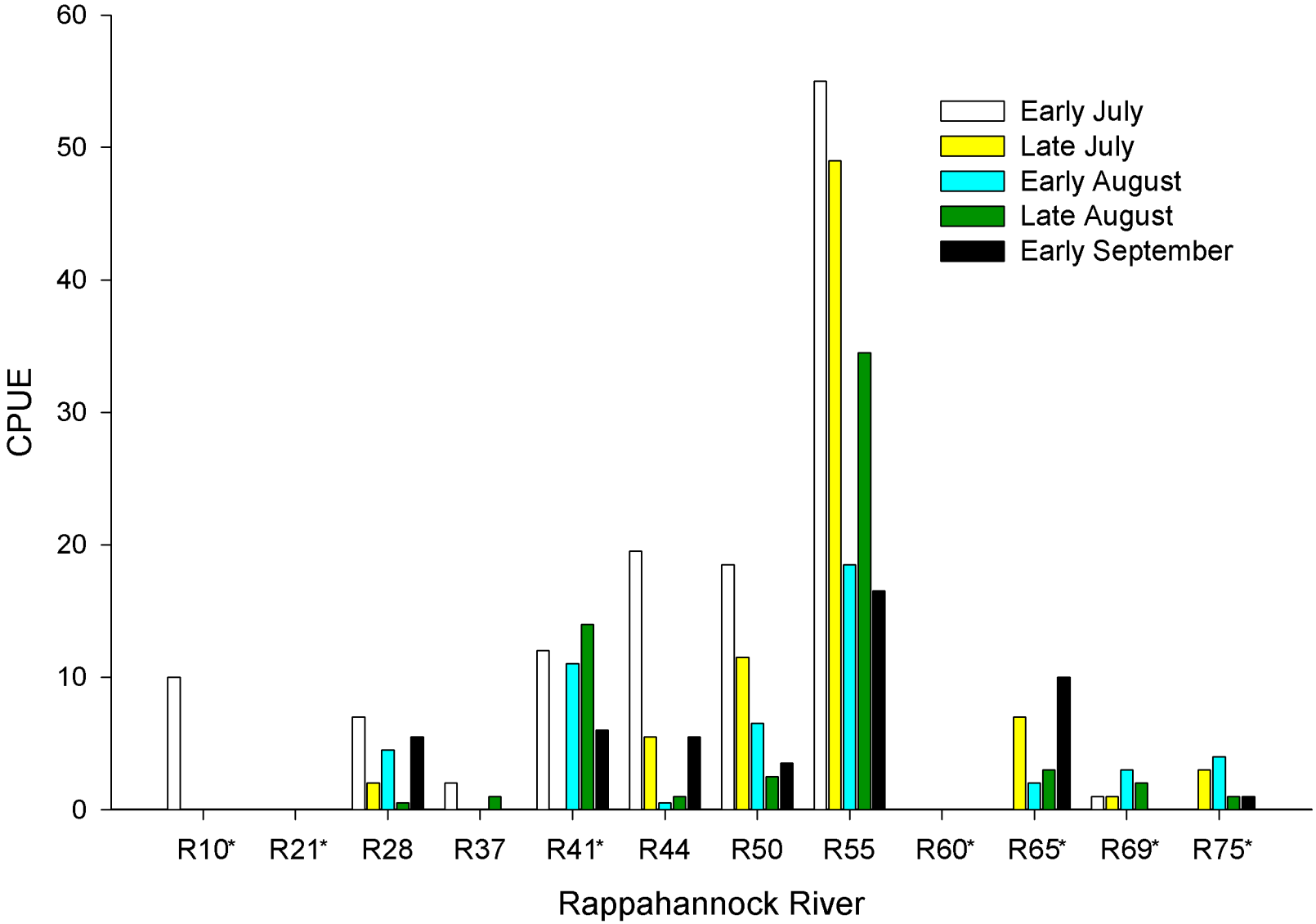

Figure 7. Catch of young-of-year striped bass by station in the Rappahannock River in 2008. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.