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

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

PREFACE

The Virginia Institute of Marine Science (VIMS) juvenile striped bass seine survey began in 1967, ran through 1973 and has continued from 1980 through the present. The primary objective of this survey has been the monitoring of the relative annual recruitment success of juvenile striped bass in the 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 program has been jointly supported by the Sportfish Restoration Program (Wallop-Breaux Act) administered through the U.S. Fish and Wildlife Service and the Virginia Marine Resources Commission. This report summarizes the results of the 2004 sampling period and compares these results with the previous years.

Specific objectives for the 2004 program were to:

1. Measure the relative abundance of the 2004 year class of striped bass from the James, York and Rappahannock river systems.
2. Quantify environmental conditions at the time of collection.
3. Examine relationships between juvenile striped bass abundance and measured or proxy 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. Extreme decreases in the commercial harvest of striped bass in the 1970s signaled a steady decline in striped bass abundance. Stocks had declined throughout the east coast but were particularly depressed in Chesapeake Bay. Because the tributaries of the Chesapeake Bay had been identified as the primary spawning and nursery area for the migratory portion of the stock, the concern over the diminishing status led legislative and administrative bodies to take actions intended to halt and reverse the decline of striped bass in Chesapeake Bay and elsewhere along the east coast (ASMFC 2003).

The initiation of federally mandated enforcement of coast-wide striped bass management went through several steps in the early 1980s. In 1981, the Atlantic States Marine Fisheries Commission (ASMFC) developed the Atlantic Coast Striped Bass Interstate Fisheries Management Plan (FMP), which was designed to recommend management measures each state could use to improve the status of striped bass stocks. The Virginia Marine Resources Commission adopted this plan in March 1982 (Regulation 450-01-0034); however, at that time ASMFC did not have regulatory control over individual states and the adoption of the FMP was at each state's discretion. As striped bass populations continued to decline, Congress passed the Atlantic Striped Bass Conservation Act (PL 98-613) in 1984, which made it mandatory for states to follow and enforce management measures in the FMP or face a moratorium on striped bass harvest.

The FMP has been amended six times since 1981 to react to changing situations and conditions related to the management of the stock. Amendment VI to the plan,

adopted in February 2003, requires "producing states" (e.g. Virginia, Maryland, Delaware and New York) to develop and support monitoring programs of recruitment levels. To remain in compliance with the Act, each state must adhere to all provisions in the interstate FMP (ESBS 1993). Virginia has complied with these regulations from their inception through the present.

Virginia's efforts to monitor recruitment of juvenile striped bass began in 1967 with funding from the Commercial Fisheries Development Act of 1965 (PL88-309). This continued until 1973 when the support was terminated. It 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 Sportfish Restoration and Enhancement Act of 1988 (PL 100-448 known as the Dingle-Johnson Act).

Initially, the Virginia program used a 6' x 100' (2m x 30.5m) x 0.25" (6.4mm) mesh bag seine, but after comparison tows with Maryland gear (4' x 100' x 0.25" mesh; 1.2m x 30.5m x 6.4mm mesh) showed virtually no statistical differences in catch, 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), but this was never realized, however, due to various differences in data handling (MD: arithmetic index, VA: geometric index) and state politics. A baywide index using a weighted (by river spawning area) geometric mean was finally developed in 1993 (Austin et al. 1993).

METHODS

Field sampling was conducted during five approximately biweekly sampling periods from July through mid-September of 2004. During each sampling period the seine was hauled at 18 historically sampled sites (index stations) and 22 auxiliary stations along the shores of the James, York and Rappahannock systems (Figure 1). Addition of the auxiliary sites in 1989 was designed to provide better geographic coverage and create larger within-river-system sample sizes so that trends in juvenile abundance could be meaningfully monitored on a system-by-system basis, particularly as the stock size increases and the nursery ground expands.

Collections were made by deploying a 100' (30.5m) long, 4' (1.22m) deep, 1/4" (0.64cm) mesh minnow seine perpendicular to the shoreline until either the net was fully extended or a depth of approximately four feet (1.22m) 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 tow were removed from the net, measured, and held in water-filled buckets until after the second tow, 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, excepting those preserved for life history studies, were returned to the water at the conclusion of sampling.

In this report, comparisons with prior years are made on the basis of the "primary nursery" standardized data set (Colvocoresses 1984); therefore, only the data collected from the months and areas covered during all surveys will be included in the analyses. Data from the auxiliary stations will not be included since there is no direct basis for comparison. Since the frequency distribution of catch size of these collections is extremely skewed and approximates a negative binomial distribution (Colvocoresses 1984), a logarithmic transformation (ln(x+1)) was applied in order to normalize the data prior to analysis (Sokal and Rohlf 1981). Subsequently, computed mean values were retransformed (i.e. the geometric mean) and scaled up arithmetically to allow comparison with Maryland data.

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-overlap by these confidence intervals. Because the standard errors are calculated using the transformed (logarithmic) values, confidence intervals on the retransformed and adjusted scale are non-symmetrical.

RESULTS

Objective 1: Measure the relative abundance of the 2004 year class of juvenile striped bass from the James, York and Rappahannock river systems.

A total of 2614 young-of-the-year striped bass were collected from 180 seine hauls during the 2004 index station sampling and an additional 686 age 0 striped bass were collected in 98 hauls at the auxiliary sites (Table 1, Fig. 1). The adjusted overall

mean catch per seine haul (CPUE) for the index stations in 2004 was 12.70 (Table 2, Fig. 2). This value is significantly higher than the overall average index of 7.21 (non-overlap of confidence intervals), but is significantly lower than the 2003 value (22.89), which is the second highest in the survey's history. The indices for the individual rivers and river systems were significantly greater than their overall average, with the exception of the James River system, whose confidence interval overlapped the overall average, and the Chickahominy River, whose average was lower than the overall average (Table 3).

James System

The 2004 index for the James drainage was 12.13, and its confidence interval encompasses the overall James system average of 9.23 (Table 3, Fig. 3). Juvenile striped bass were widely distributed throughout the James system (Table 1, Fig. 4). Juvenile striped bass were more evenly distributed in the James River in 2004 when compared to 2003. In 2003 catches were greatest around the mouth of the Chickahominy River, while in 2004 the catches were greatest from J22 to J36 and from J46 to J68. The main-stem James catch rate (17.09) was two times greater than its overall average of 8.27. J46 was the James system's highest producing index site. There was a spike in catch at J46 in round one, possibly related to a high level of dissolved oxygen (10.9mg/L) (Table 7). The Chickahominy catch rate (5.70) decreased significantly in 2004 as compared with 2003 (55.41) (Table 1; Fig. 4) (Austin et al. 2004).

York System

The 2004 index in the York drainage (11.50) was two times greater than the historical average (5.64) (Table 3, Fig. 3). All sites in the mainstem York River are auxiliary sites. Striped bass were captured at all of these mainstem sites in 2004, which reflects the strength of the year class. Catches at these sites also occurred in 2003, which was a distinct reversal of catches in 2002 when no striped bass were captured (Table 1; Fig. 5). Striped bass were captured during all visits to Y28 and during four visits to Y15. Severe thunderstorms prevented sampling at Y21 during rounds one and five, but striped bass were captured during two of the three times Y21 was sampled.

The indices in the Pamunkey (15.11) and the Mattaponi (9.29) were both well above their respective overall averages (Pamunkey = 6.67, Mattaponi = 4.96). Catches on the Mattaponi River were greatest at M33, the most down-river site. For the Pamunkey River index stations, greatest catches occurred at P50, the uppermost index station (Fig. 6). Catches at P45, the middle index site, were the second greatest. P36 had good catches during all rounds, but since only one seine haul is made per round at this downriver auxiliary station, catch-per-haul numbers may be unduly elevated.

Rappahannock System

The 2004 index in the Rappahannock River was 15.36, more than double the historic average of 7.35 and three times the 2002 index of 4.96 (Table 3) (Austin et al. 2003). Round one produced the highest numbers of striped bass in the Rappahannock. Catches were greatest at the three uppermost index sites (R44, R50 and R55) with R55 being the most productive site (Table 1, Fig. 7). Catches at these three sites accounted for

68 percent of the total catch for the river in 2004. Juvenile striped bass were not captured at the two downriver auxiliary sites (R10 and R21); however, they were captured at all index sites, and were concentrated in the upper half of the defined nursery area.

Round Comparison

Because the number and precise timing of sampling rounds have varied throughout the history of the sampling program, results by sampling period cannot be directly compared. However, temporal usage of the nursery area can be evaluated by comparing round-by-round results with historical monthly averages. Generally, raw catch values are highest during July and early August and taper off in the later rounds of August and September as fish disperse to deeper water and grow large enough to effectively avoid capture. In 2004 the catch peaked in early July (Table 4.) There was a 61% decrease in catch from round one to round two and then an 11% increase from rounds two to three. The catches continued to drop off between rounds three and four and four and five by 47% and 24%, respectively.

Bluefish Sites

Twenty-two young-of-the-year striped bass were captured at the former Bluefish Seine Survey sites in Chesapeake Bay and seaside Eastern Shore. In June, one was captured at Kiptopeke State Park on the bayside Eastern Shore, one at the Wachapreague Inlet on the seaside of the Eastern Shore and four at Bloxom. (Bloxom is located on the bayside of the Eastern Shore in Pocomoke Sound, and these fish probably came from a

nearby nursery area.) In July, eight striped bass were captured at Bloxom. In August, six were captured at Bloxom, and in September two were captured at Bloxom.

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

Collection information and pertinent environmental variables recorded at the time of each collection in 2004 are given in Tables 5 through 8. Direct round-by-round comparisons of environmental and water quality parameters are difficult because of local site conditions and variations, so they must be examined on a broader scale.

Generally, salinities in 2004 were similar to those measured in 2003, although some downstream sites did have greater salinities in 2004 (Table 5) (Austin et al. 2004). Data from the National Climate Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html) indicated that conditions in 2004 in Virginia were drier in January, February, and March, but became wet in spring of 2004 with greater than average rainfall in April and May. Wet conditions remained throughout the sampling season.

In 2004, mean water temperatures at each station were within one standard deviation of the mean water temperatures recorded from 1989 through 2003 (Table 6). The normal pattern of higher temperatures in the early rounds and slowly declining temperatures during the later rounds was well defined in 2004 as in other years. Water temperatures by round varied somewhat from 2003 readings since there were frequent weather events that affected water temperatures during the 2003 sampling season. Water temperature readings in these estuaries are not solely affected by the long term weather patterns of summer; significant variations from day to day and river to river can be caused by 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.

Mean dissolved oxygen (DO) levels in 2004 were generally within one standard deviation of the mean DO recorded from 1989 through 2003, with the exception of three stations in the Pamunkey River (P42, P45, P50) (Table 7). A high dissolved oxygen reading at J46 in the first round corresponded with a high striped bass catch at the site. Slightly depressed levels were recorded at the lowermost sites in the Pamunkey River in late August, and although catches did drop in late August, catches dropped at all Pamunkey sites during later rounds (Table 1; Fig. 6).

The mean pH levels at each station in 2004 were within one standard deviation of the mean pH recorded from 1989 through 2003 (Table 8). Generally the James and Rappahannock systems have pH values that are slightly basic and this held true for the 2004 season. The Pamunkey River is usually near neutral pH (7), but in 2004 the values were more acidic during rounds four and five. The Mattaponi River had pH values that were slightly acidic during all the rounds.

All index sites were completed without interruption. Some auxiliary sites were not sampled due to severe thunderstorms in the area and the subsequent loss of available sampling beach due to rising tide levels.

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

Overall distribution of catch rates with respect to salinity in 2004 followed the normally observed pattern of higher catches at lower salinities within the primary nursery area (Table 9). No index site had a salinity reading greater than 8.4ppt (Table 5). There

were catches made at auxiliary sites where higher salinity readings were found, but their numbers were small as a general rule. Only the downriver auxiliary sites in the major rivers had salinity readings that surpassed 9.9ppt (Table 5). Table 10 shows the relationship of juvenile striped bass catches with respect to historical and 2004 salinity gradients within each river system. Table 10 clearly shows that the defined salinity regimes were displaced downriver considerable distances. Overall, catches were highest in the areas of lowest salinities (0-4.9ppt) for both the long term and 2004, but the percentage of catch was higher in 2004 (97% in 2004 vs. 93% overall) (Table 9).

Catch rates with respect to water temperature in 2004 clearly adhered to the historical pattern: most fish are captured in the 25-30^{o}C ranges (Table 11). 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 (at least after the second sampling round) rather than any causative effect of water temperature on juvenile distribution. The growth and subsequent gear escapement or movement of fish into deeper waters usually plays a larger role in this trend.

Data on pH, dissolved oxygen concentrations, and Secchi disc visibility depth readings have been recorded with the seine collections since the expansion of the sampling program in 1989. Dissolved oxygen concentrations generally exceeded 5mg/l outside of the York system, and have little or no effect on juvenile striped bass distributions. However, the depressed dissolved oxygen concentrations in the Pamunkey River coincided with decreased catches, although catches generally decline in the later rounds. pH values during our sampling are generally near neutral to slightly basic outside of the Mattaponi River and like dissolved oxygen appear to have little effect.

Secchi disc readings are a relative measure of turbidity which can affect catches in two ways: when turbidity is extremely high fish are more vulnerable to our gear, and when it is low (i.e. greater clarity) net avoidance becomes a potential problem. We saw no high turbidity episodes in 2004, and though secchi readings are not presented herein, the data are collected, stored, and are available upon request.

DISCUSSION AND CONCLUSIONS

The recruitment of striped bass in the lower Chesapeake Bay in 2004 was significantly above the average index value over the history of the survey. The 2004 index was only half that of 2003; however, 2003 was an extremely wet year, which produced a large year class and the second highest index value since sampling began. As in 2003, the salinities measured in 2004 were depressed and the freshwater/saltwater interface in each river was displaced downstream. As a result, the nursery areas were extended downstream and striped bass were caught at downstream auxiliary stations, with the exception of those in the Rappahannock River.

The James River system index did not differ significantly from its overall average. This is likely due to the negative effect of the depressed index value from the Chickahominy River. Hurricane *Isabel* (of September 2003) greatly changed the bank structure of index station C3. As a result, the habitat in the river has more woody debris, slower water velocities, and an increase in aquatic vegetation. These new conditions may have affected the abundance of juvenile striped bass in the area or our ability to sample them effectively. We will attempt to sample there again in 2005, however, if conditions continue to deteriorate, using an alternative site may provide better information about recruitment in the Chickahominy River.

The above average recruitment of striped bass in 2004 can be attributed to average or slightly above average rainfall and cool conditions in the spring months. These conditions provide favorable river flow for the survival of larvae and juveniles in the months preceding and during sampling. The environment resulting from these flow/temperature conditions is more conducive to successful recruitment in the Virginia portion of Chesapeake Bay. Wood (2000) found that weather in March affects springtime temperatures and rainfall (thus river flow and planktonic communities) and can affect the recruitment success of anadromous fishes. With the persistence of the winter Ohio Valley High climate pattern, cold and fresh conditions extend into March and as a result the suitable anadromous fish nursery areas are extended both spatially and temporally benefiting recruitment. When the Azores-Bermuda High dominates March, warm and dry conditions are present in spring, which are not as conducive to anadromous fish recruitment success. Conditions in Virginia were wet in April and May; that trend continued through September. The lack of an extremely wet March could explain the disparity between the very high recruitment seen in 2003 versus the good to above average recruitment seen in 2004.

Striped bass recruitment success in the Virginia portion of Chesapeake Bay remains variable between years and among the different nursery areas within years. These fluctuations had been bracketing a much higher average with the exception of 1999 and 2002 when weak recruitment occurred. The strong year classes in 1998, 2000, 2001, 2003 and 2004 should adequately overcome any weak year classes that may have resulted from the low 1999 and 2002 recruitment. 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 addition of auxiliary stations in 1989 has provided better overall coverage of the nursery areas. These additional areas of coverage have revealed that in years of high or low river flow there may be a shift in the traditional nursery areas up or down-river. Additionally, in years of high abundance the nursery area generally expands both up and down river. Figures 4-7 represent average catch per haul at all sites; past analyses have demonstrated that catches are consistently higher in the first haul of any given set of seine hauls. Since 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. They are important in that they allow us to see a shift in distribution that could be affecting catches at the index sites. Reducing hauls at index sites to one per site and including some of the auxiliary sites in the index and deleting others might lead to a more precise estimate of relative year-class strength but it would undoubtedly elevate the recalculated indices (Rago et al. 1996).

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Table 1. Catch of young-of-the-year striped bass per seine haul during the 2004 survey. Two hauls were made per sampling round at each of the historical index stations (bold).

Drainage																	
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	TOT.
	Round	1	0	29	24/5	25/22	6	17/9	1/3	74/152	15	1/7	83	32	ns	ns	505
		2	0	15	3/2	15/11	0	3/2	0/7	1/9	9	12/1	21	5	2	2	120
		3	0	26	7/3	25/10	2	7/8	19/0	5/7	18	35/5	8	8	4	0	197
		4	0	10	15/16	8/20	1	3/1	0/0	2/5	3	9/2	2	7	0	1	105
		5	3	31	3/5	4/1	1	2/3	1/1	4/2	0	12/5	2	13	0	ns	93
																	1020
YORK		Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55						
	Round	1	2	ns	1	50	7/4		37/16	71/27	ns						215
		2	8	2	2	35	5/0		22/10	19/11	2						116
		3	1	0	5	11	1/2		12/12	44/10	6						104
		4	1	3	6	18	3/0		1/6	12/7	12						69
		5	0	ns	14	16	3/1		23/6	3/0	ns						66
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	Round	1				1/12	9	7/12	5/9	4/6	2						67
		2				7/0	23	38/7	14/4	6/3	0						102
		3				69/14	ns	0/1	7/11	1/1	4						108
		4				27/2	1	2/4	6/0	1/0	5						48
		5				9/1	ns	5/7	4/3	1/0	ns						30
																	925
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Round	1	0	0	10/6	11/25		0	26/16	33/37	71/75	21	9	6	5		351
		2	0	0	8/4	3/5		3	9/13	15/25	31/12	3	7	2	1		141
		3	0	0	2/2	4/4		6	5/1	16/4	13/8	16	5	0	0		86
		4	0	0	12/5	1/3		0	2/0	12/2	7/2	0	0	3	ns		49
		5	0	ns	4/3	4/8		0	1/1	4/3	11/2	0	1	0	0		42
																	669
																	2614

ns = no sample taken

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

Year	Total	Mean 1n (x+1)	Std. Dev.	Adjust Mean	C.I. (± 2 SE)	N (tows)
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
Overall	37342	1.43	1.20	7.21	6.88-7.55	4569

Table 3. Catch of young-of-the-year striped bass per seine haul in primary nursery area in 2004 summarized by drainage and river.

	2004				All Years Combined			
Drainage River	Total Fish	Adjust. Mean	C.I. (±2 SE)	N (sites)	Total Fish	Adjust. Mean	C.I. (±2 SE)	N (sites)
JAMES	661	12.13	8.70-16.64	60	14861	9.23	8.53-9.97	1518
James	574	17.09	11.88-24.21	40	8646	8.27	7.52-9.08	1020
Chickahominy	87	5.70	2.97-9.86	20	6215	11.46	9.99-13.10	498
YORK	686	11.50	8.34-15.60	70	10820	5.64	5.24-6.07	1732
Pamunkey	375	15.11	9.71-24.14	30	5636	6.67	5.93-7.49	736
Mattaponi	311	9.29	6.08-13.72	40	5184	4.96	4.51-5.44	996
RAPPAHANNOCK	581	15.36	11.15-20.89	50	11661	7.35	6.70-8.04	1319
OVERALL	1928	12.70	10.54-15.22	180	37342	7.21	6.88-7.55	4569

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2004 summarized by sampling period and month.

	2004				All Years Combined			
Month (Round)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)
July (1st)	868	30.63	20.70-44.85	36	11305	10.68	9.67-11.78	962
(2nd)	337	14.03	9.62-20.07	36	9050	8.21	7.42-9.07	973
Aug. (3rd)	375	13.46	8.94-19.79	36	6758	6.61	5.98-7.29	965
(4th)	198	7.40	4.75-11.04	36	6032	6.40	5.73-7.13	829
Sept. (5th)	150	6.95	5.04-9.35	36	3992	5.63	5.01-6.30	703

Table 5. Salinity (parts per thousand) recorded at 2004 seine survey stations. York system includes Pamunkey and Mattaponi Rivers.

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
Round	1	10.0	4.2	0.9	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.1	ns	ns
	2	15.3	7.0	2.8	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
	3	9.4	2.4	1.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	4	10.2	2.8	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	5	8.7	3.2	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	ns
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
Round	1	13.6	ns	8.1	1.9	0.2		0.1	0.1	ns					
	2	16.0	12.8	8.8	0.9	0.1		0.1	0.1	0.1					
	3	8.6	6.9	2.4	0.1	0.0		0.0	0.0	0.0					
	4	9.2	6.8	1.7	0.0	0.0		0.0	0.0	0.0					
	5	8.2	ns	0.3	0.0	0.0		0.0	0.0	ns					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
Round	1				1.0	0.2	0.2	0.0	0.0	0.0					
	2				1.1	0.2	0.1	0.0	0.0	0.0					
	3				0.0	ns	0.0	0.0	0.0	0.0					
	4				0.0	0.0	0.0	0.0	0.0	0.0					
	5				0.0	ns	0.0	0.0	0.0	ns					
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
Round	1	12.1	10.4	8.4	3.8		0.5	0.6	0.2	0.1	0.1	0.1	0.0	0.1	
	2	12.2	10.8	8.2	4.6		1.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	
	3	12.5	9.4	5.3	1.3		0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
	4	12.8	11.1	7.0	2.1		0.6	0.1	0.1	0.0	0.0	0.0	0.0	ns	
	5	13.3	ns	6.7	2.4		1.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	

ns = no sample taken

Table 6. Water temperature (^{o}C) recorded at 2004 seine survey stations. York system includes Pamunkey and Mattaponi Rivers.

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
Round	1	27.8	30.0	31.1	29.4	34.3	32.2	30.3	32.4	27.3	27.8	30.7	29.9	ns	ns
	2	27.3	27.6	31.2	27.7	31.6	30.1	29.4	30.6	28.9	29.1	31.7	30.9	30.0	29.5
	3	28.7	29.4	30.0	27.2	28.5	29.7	29.0	29.2	28.5	28.9	31.1	30.3	30.6	30.7
	4	28.3	29.5	27.1	24.9	26.5	25.9	25.9	26.3	24.8	24.5	26.6	25.3	23.6	24.9
	5	26.7	27.4	27.5	25.6	27.9	27.2	27.0	27.3	26.5	26.3	25.5	25.4	24.6	ns
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
Round	1	32.6	ns	28.1	28.5	28.9		29.2	29.2	ns					
	2	26.5	26.4	28.1	28.7	29.1		29.5	29.5	30.5					
	3	29.8	29.3	27.1	27.8	30.0		26.5	28.5	28.0					
	4	26.8	25.9	25.7	25.5	25.2		25.3	25.0	25.5					
	5	25.3	ns	24.7	24.0	24.4		24.4	23.9	ns					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
Round	1				28.3	28.8	28.5	29.8	31.0	29.4					
	2				28.5	28.3	28.6	28.6	28.3	27.4					
	3				27.0	ns	26.8	26.0	25.3	25.0					
	4				23.6	25.6	25.1	25.6	26.5	26.2					
	5				25.5	ns	24.7	24.8	29.6	ns					
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
Round	1	31.5	30.5	29.6	30.4		30.7	31.9	27.3	28.7	27.4	30.9	29.3	28.3	
	2	31.5	29.9	26.6	27.9		27.9	29.3	29.1	29.2	29.0	29.4	29.0	29.4	
	3	27.8	27.7	26.7	28.0		27.7	28.3	27.1	27.4	27.4	28.7	29.0	28.7	
	4	26.6	26.3	24.5	24.8		25.2	25.9	25.3	26.0	25.3	26.5	26.9	ns	
	5	28.0	ns	25.5	27.2		27.1	27.9	27.5	28.4	28.0	28.8	28.4	28.7	

ns = no sample taken

Table 7. Dissolved oxygen (milligrams per liter) recorded at 2004 seine survey stations. York system includes Pamunkey and Mattaponi Rivers. Stations where dissolved oxygen was not measured are indicated by dashes (--). Shaded columns indicate mean DO values less than one standard deviation from the recorded mean DO of that station from 1989 to 2003.

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
Round	1	6.2	7.2	7.8	7.3	8.6	9.2	7.4	10.9	7.2	8.8	9.3	8.2	ns	ns
	2	5.6	6.0	7.6	6.1	8.1	7.8	5.2	5.8	6.5	8.9	10.7	7.2	6.3	6.3
	3	9.0	9.6	6.9	7.5	7.7	7.1	6.1	5.5	4.5	6.7	11.4	8.8	6.5	6.2
	4	10.6	9.6	6.7	7.8	6.8	7.8	5.4	4.2	4.7	5.2	4.1	6.1	6.0	6.8
	5	7.0	6.7	7.1	6.9	8.0	7.0	5.8	5.4	5.3	6.0	4.4	4.9	4.5	ns

YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55
Round	1	7.2	ns	6.1	4.3	4.3		5.3	5.2	ns
	2	6.7	4.6	4.6	4.8	4.9		5.2	4.6	5.9
	3	11.7	8.6	4.6	4.3	--		--	--	--
	4	9.2	6.5	5.2	5.9	5.1		4.6	5.0	5.0
	5	7.3	ns	5.0	3.5	4.9		4.2	3.5	ns

	Station				**M33**	M37	**M41**	**M44**	**M47**	M52
Round	1				3.8	4.4	4.3	4.6	5.3	5.0
	2				3.9	3.7	4.5	--	3.6	4.6
	3				3.4	ns	3.8	3.8	4.6	5.8
	4				4.2	4.2	5.1	5.6	5.5	5.4
	5				3.9	ns	4.0	3.8	5.0	ns

RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76
Round	1	6.5	7.3	7.6	7.4		6.4	8.2	6.4	7.0	8.2	8.8	9.4	6.2
	2	7.2	6.7	6.1	6.8		6.1	7.2	7.7	7.0	6.8	9.1	6.7	6.0
	3	7.2	7.1	6.4	7.0		5.0	7.0	6.8	6.7	7.5	8.1	6.3	6.3
	4	8.4	6.0	6.3	7.7		6.5	8.6	6.8	6.4	6.0	7.4	6.8	ns
	5	7.8	ns	7.3	7.1		6.8	8.5	7.0	7.6	5.4	7.5	7.2	6.3

ns = no sample taken

Table 8. pH recorded at 2004 seine survey stations. York system includes Pamunkey and Mattaponi Rivers. Stations where pH was not measured are indicated by dashes (--).

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
Round	1	7.7	8.0	8.1	8.0	9.1	8.7	7.9	9.2	7.6	8.3	8.8	7.9	ns	ns
	2	7.6	7.4	8.0	7.5	8.8	8.2	7.5	7.4	7.5	8.9	9.1	7.7	8.0	7.9
	3	8.3	8.7	7.6	7.7	8.1	7.9	7.3	7.3	7.2	7.7	8.4	7.4	7.5	7.7
	4	8.4	8.5	7.6	7.8	7.7	7.8	7.3	7.2	7.3	7.3	7.1	7.2	7.2	7.6
	5	7.7	7.7	7.6	7.7	8.5	7.3	6.9	7.1	7.2	7.3	6.9	6.8	7.1	ns

YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55
Round	1	7.8	ns	7.2	6.9	7.0		7.1	7.2	ns
	2	7.6	7.0	7.0	7.0	7.2		7.1	7.1	7.3
	3	8.2	7.8	6.9	7.0	--		--	--	--
	4	7.9	7.3	6.9	7.1	6.9		6.8	6.9	6.8
	5	7.5	ns	6.9	6.6	6.5		6.4	6.3	ns

	Station				**M33**	M37	**M41**	**M44**	**M47**	M52
Round	1				6.8	6.9	6.8	6.9	6.9	6.1
	2				6.8	6.8	6.9	6.8	6.8	6.7
	3				6.7	ns	6.7	6.5	6.6	6.5
	4				6.7	6.7	6.6	6.6	6.7	6.7
	5				6.6	ns	6.6	6.3	6.5	ns

RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76
Round	1	7.2	8.0	7.9	7.8		7.1	7.6	7.7	7.9	8.0	9.2	8.5	7.3
	2	8.1	7.8	7.5	7.7		7.1	8.2	8.1	7.9	7.8	9.0	7.5	7.4
	3	8.0	7.8	7.2	7.6		6.9	7.2	7.4	7.5	7.3	7.7	7.1	7.1
	4	8.1	7.6	7.3	7.5		7.1	7.6	7.6	7.5	7.4	8.0	7.2	ns
	5	7.9	ns	7.5	7.8		7.3	8.0	7.6	7.6	7.6	7.9	7.5	7.4

ns = no sample taken

Table 9. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2004 summarized by salinity.

	2004				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	1872	12.80	10.52-15.48	170	34675	8.29	7.89-8.71	3825
5-9.9	56	11.11	7.42-16.20	10	2419	4.08	3.54-4.68	536
10-14.9	0	0	0.0-0.0	0	246	1.59	1.19-2.02	179
15-19.9	0	0	0.0-0.0	0	2	0.11	-0.04-0.28	29
Overall	1928	12.70	10.54-15.22	180	37342	7.21	6.88-7.55	4569

Table 10. Average salinity (parts per thousand) and corresponding striped bass indices recorded at seine survey stations from 1967 to 2004 and in 2004. York system includes Pamunkey and Mattaponi Rivers.

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
1967-2004	Avg. Sal.	13.3	7.0	4.3	2.3	1.4	1.3	1.1	0.6	0.3	0.2	0.2	0.1	0.1	0.1
	Index	3.0	14.5	6.9	12.0	9.4	15.9	7.1	16.4	13.7	5.13	7.4	4.8	7.6	4.1
2004	Avg. Sal.	10.7	3.9	1.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Index	0.7	46.7	14.1	25.1	3.3	9.6	3.1	17.9	12.7	13.2	22.4	23.9	2.2	1.9
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
1967-2004	Avg. Sal.	16.1	13.0	10.0	3.6	1.5		0.7	0.4	0.3					
	Index	0.9	1.5	4.7	10.0	3.7		9.8	11.7	5.8					
2004	Avg. Sal.	11.1	8.8	4.3	0.6	0.1		0.0	0.0	0.0					
	Index	3.5	2.9	9.6	51.2	4.4		25.2	26.4	12.5					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
1967-2004	Avg. Sal.				4.0	2.0	1.1	0.4	0.3	0.1					
	Index				6.4	7.0	6.7	3.9	4.0	1.2					
2004	Avg. Sal.				0.4	0.1	0.1	0.0	0.0	0.0					
	Index				14.1	15.6	11.1	11.4	3.7	4.7					
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
1967-2004	Avg. Sal.	13.9	12.6	9.8	5.2		3.1	2.0	1.0	0.6	0.3	0.2	0.1	0.0	
	Index	0.3	0.9	2.1	3.6		4.6	8.7	10.8	37.5	7.7	4.5	3.0	4.9	
2004	Avg. Sal.	12.6	10.4	7.1	2.8		0.7	0.2	0.1	0.1	0.1	0.1	0.0	0.1	
	Index	0. 0	0.0	11.1	11.6		2.2	9.1	23.6	29.2	7.6	6.7	3.3	2.0	

Table 11. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2004 summarized by water temperature.

	2004				All Years Combined			
Temp. (deg. 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	144	10.82	6.61-17.01	20	2330	3.45	3.00-3.93	613
25-29.9	1378	12.44	10.01-15.34	136	29090	8.26	7.82-8.71	3235
30-34.9	406	16.25	9.32-27.31	24	5453	8.20	7.20-9.30	592
Overall	1928	12.70	10.54-15.22	180	37342	7.21	6.88-7.55	4569

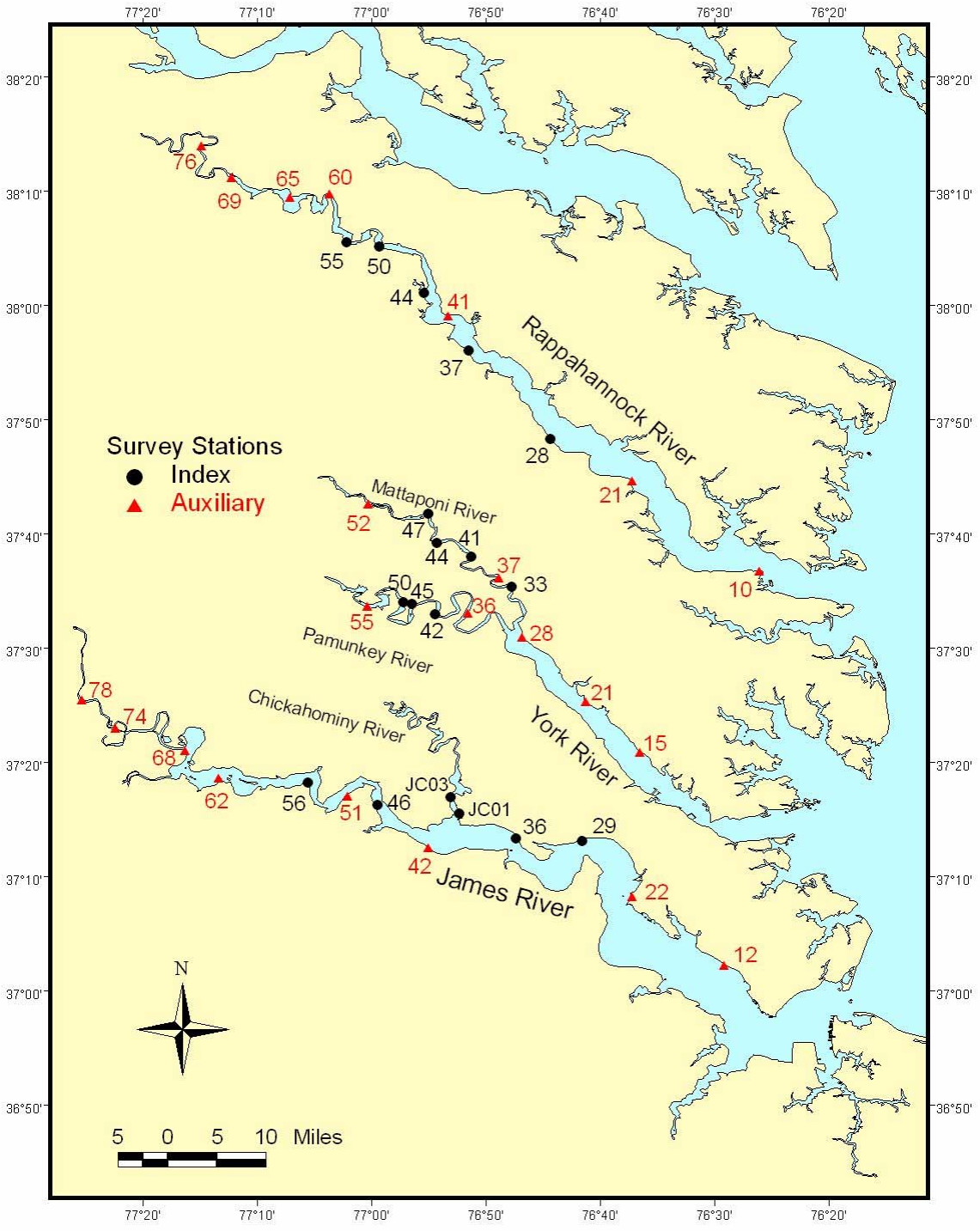

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designations indicates river mile from mouth.

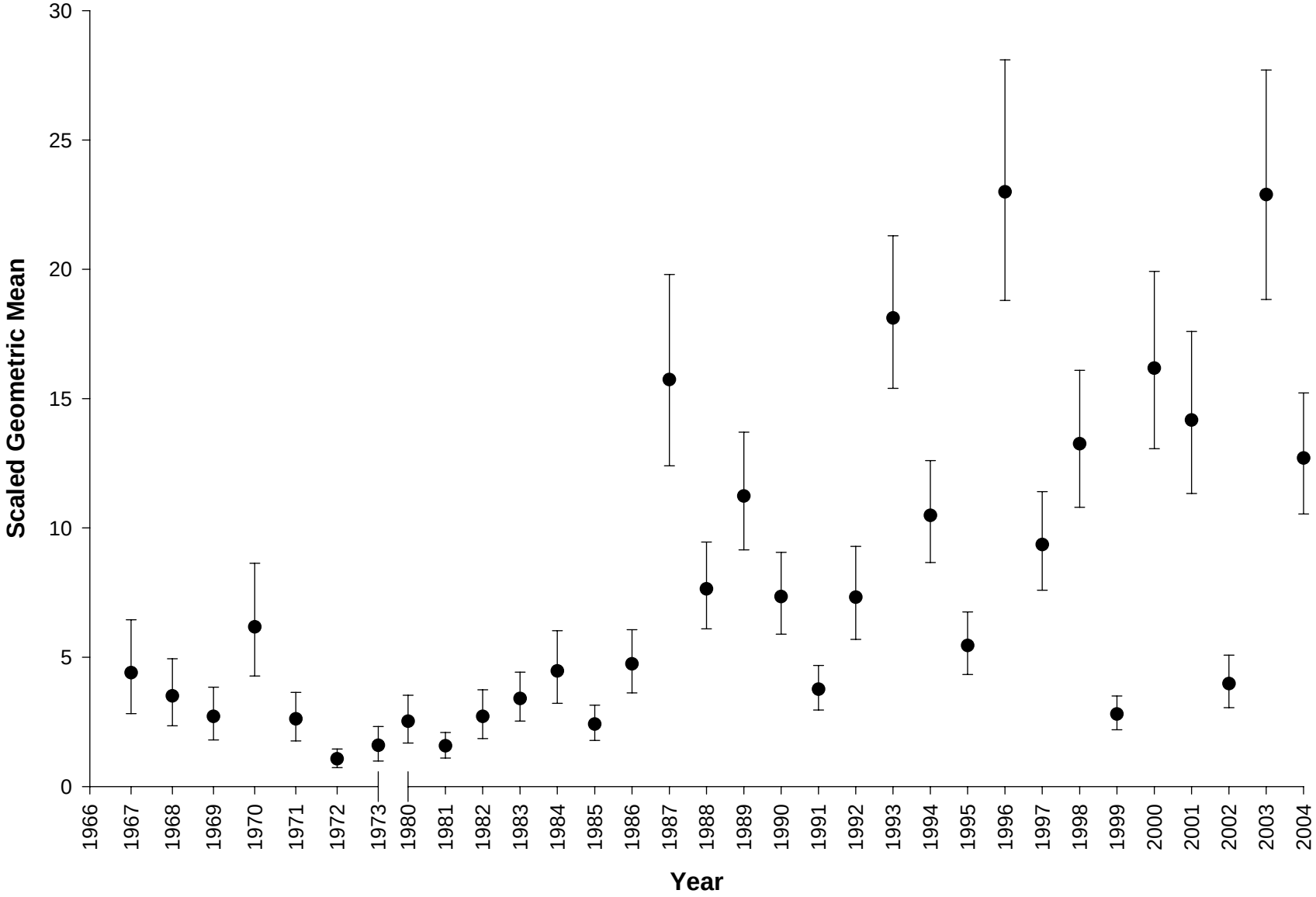

Figure 2. Scaled geometric mean of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by $\pm$ 2 standard errors of the mean.

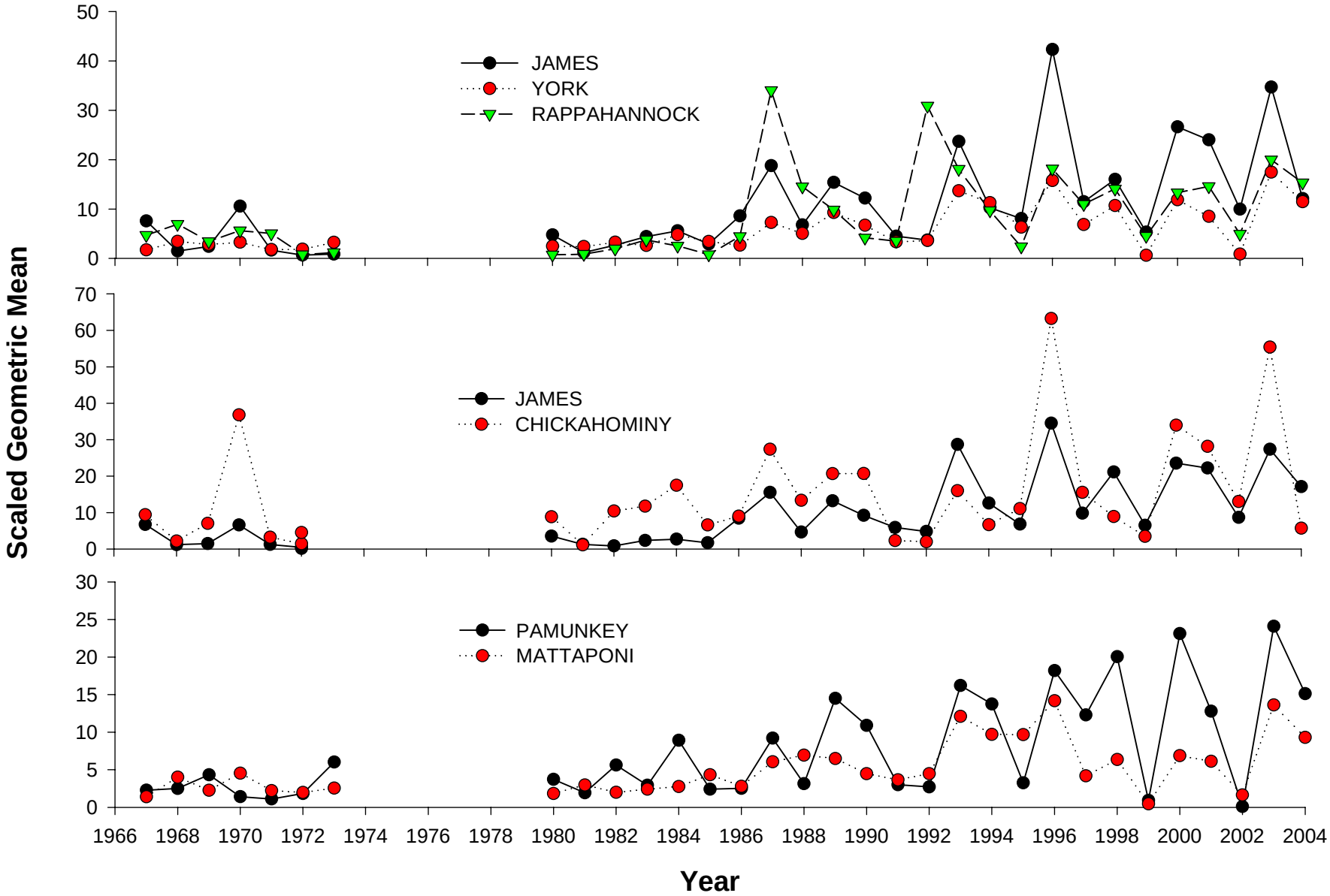

Figure 3. Scaled geometric mean of young-of-the-year striped bass per seine haul in the primary nursery area by drainage and river.

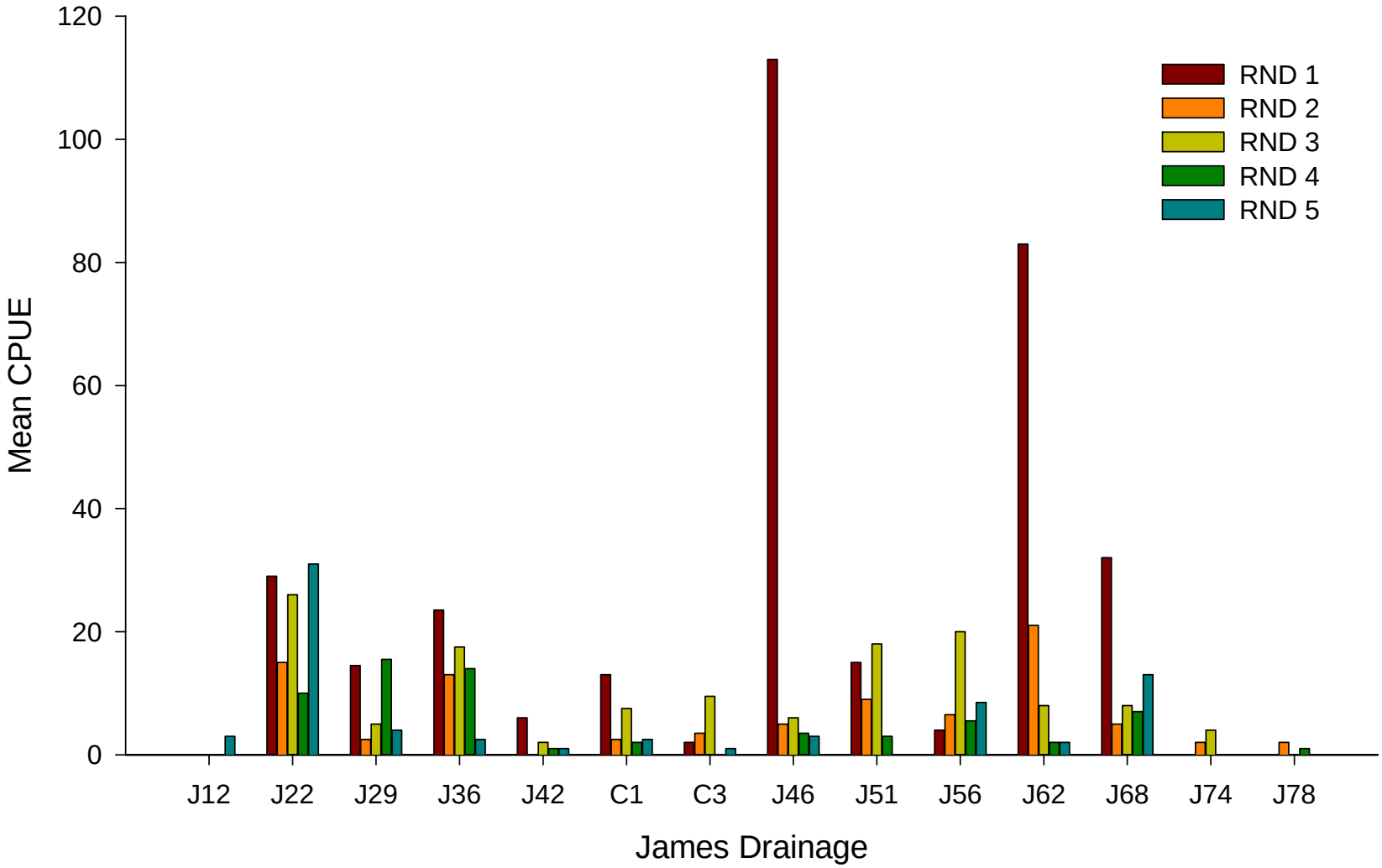

Figure 4. Average catch of young-of-the-year striped bass per seine haul by station in the James drainage in 2004.

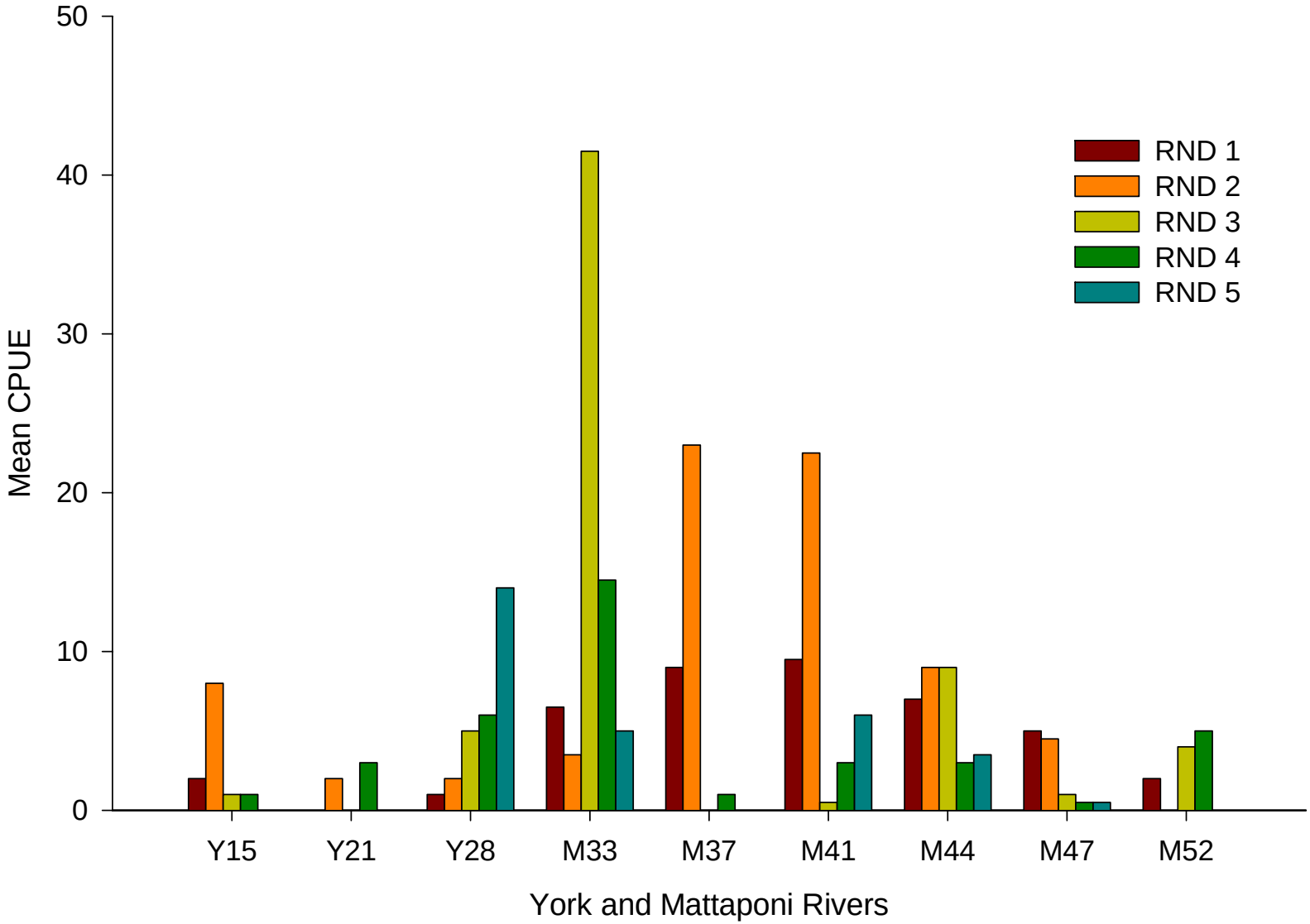

Figure 5. Average catch of young-of-the-year striped bass per seine haul by station in the Mattaponi and York Rivers in 2004.

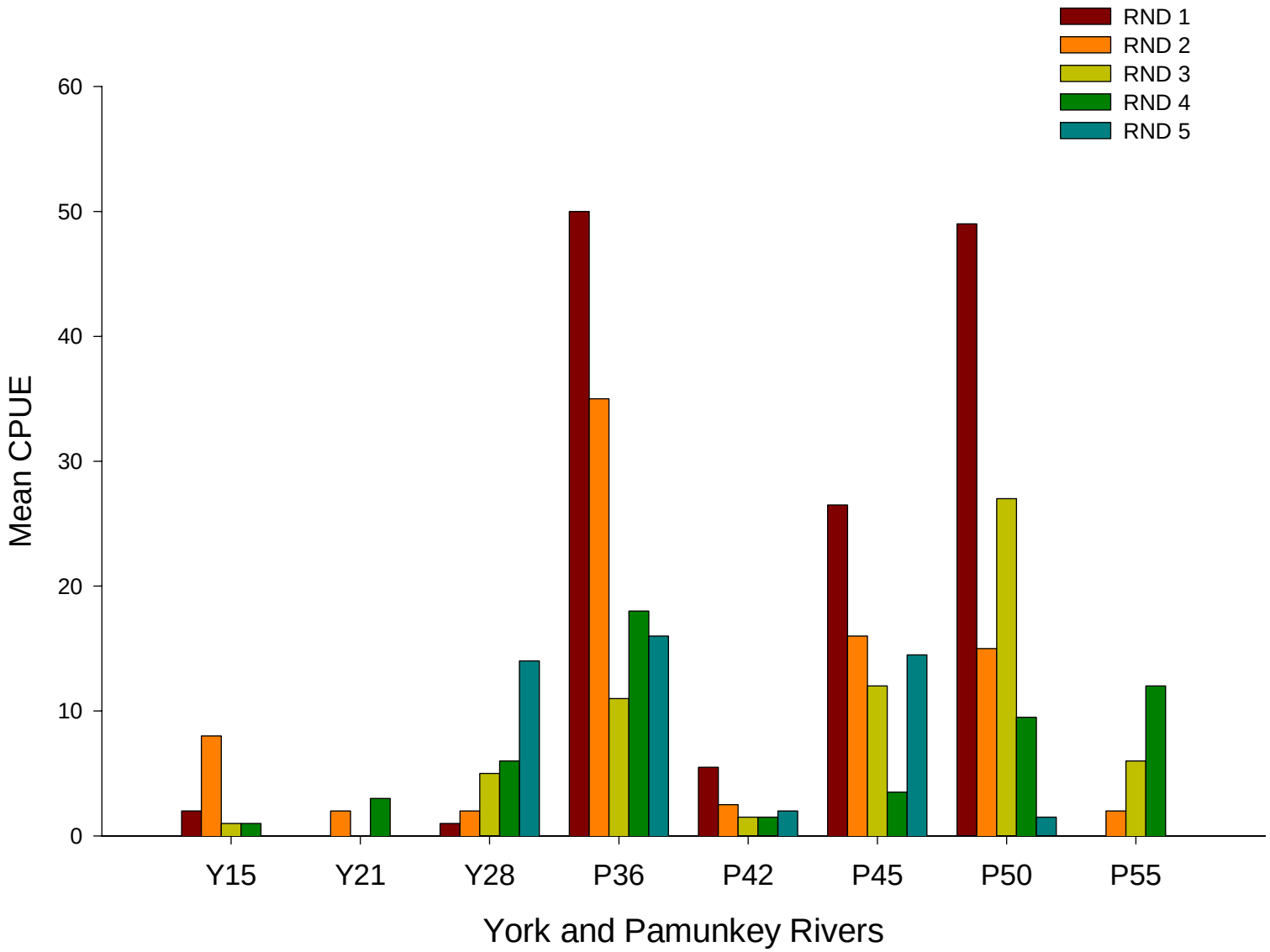

Figure 6. Average catch of young-of-the-year striped bass per seine haul by sation in the Pamunkey and York rivers in 2004.

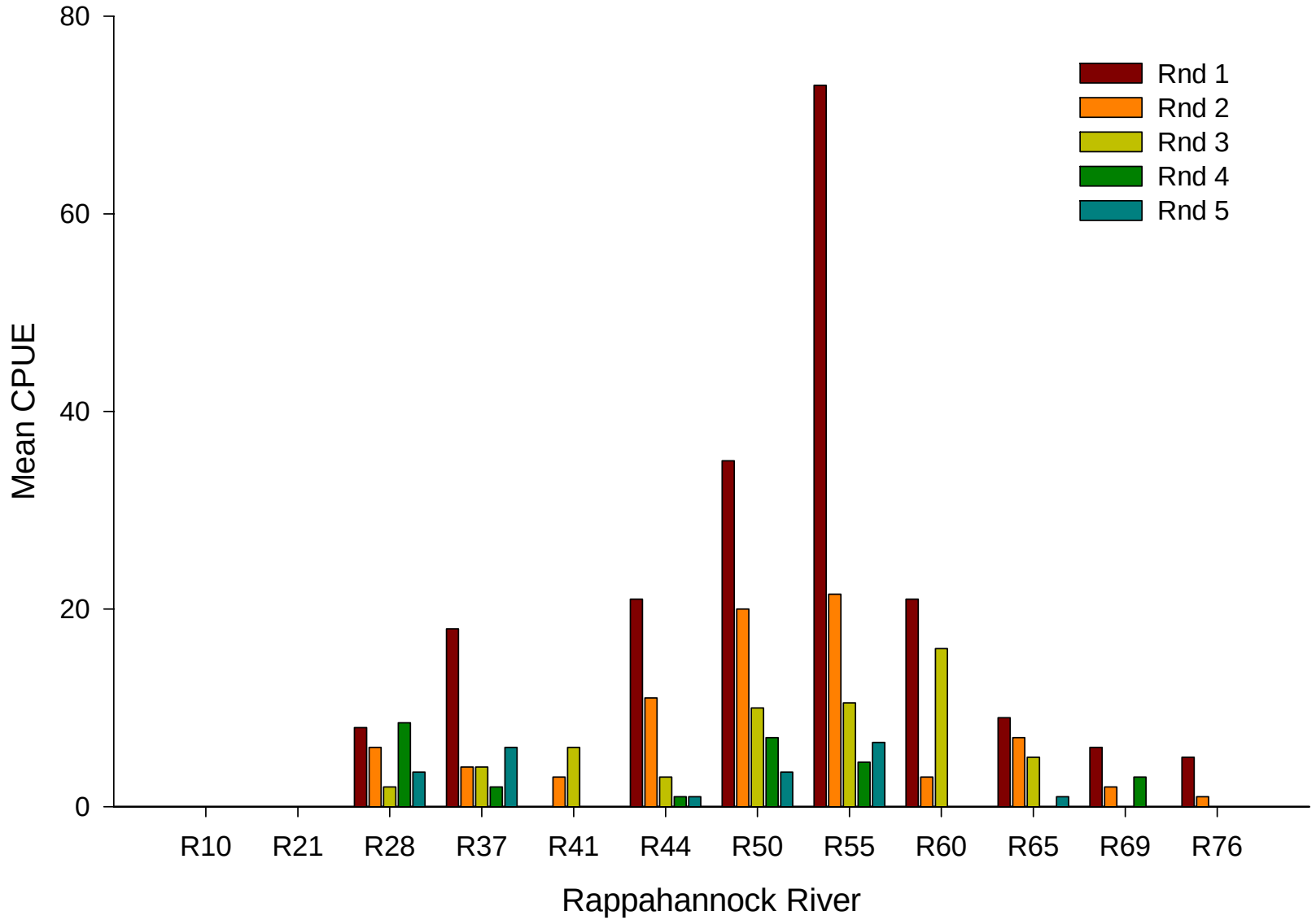

Figure 7. Average catch of young-of-the-year striped bass per seine haul by station in the Rappahannock River in 2004.