2000

Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 1999-December 1999 : annual progress report

Herbert M. Austin
Virginia Institute of Marine Science

A. Dean Estes
Virginia Institute of Marine Science

Donald M. Seaver
Virginia Institute of Marine Science

ANNUAL PROGRESS REPORT

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

January 1999 - December 1999

Herbert M. Austin
A. Deane Estes
Donald M. Seaver

Department of Fisheries Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, VA 23062

U.S. Fish and Wildlife Service
Sportfish Restoration Project F87R11

Submitted to
Virginia Marine Resources Commission
March 2000

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

We are deeply indebted to the many landowners on the tributaries of Chesapeake Bay that have graciously allowed us to conduct sampling on their property. We thank the Mariners Museum, Jamestown 4-H Camp, Powhatan Resorts, and the United States Army at Fort Eustis for their permission to sample. We would also like to thank the many students and staff who assisted in the field sampling and data compilation of this report.

Funding was provided by a grant from the United Stated Fish and Wildlife Service (Sportfish Restoration Project F87R11) through the Virginia Marine Resources Commission to the Virginia Institute of Marine Science.

LIST OF TABLES

LIST OF FIGURES

PREFACE

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile striped bass seine survey from 1967 through 1973 and from 1980 through the present. The primary objective has been the monitoring of the relative annual recruitment success of juvenile striped bass in the spawning and nursery areas of Lower Chesapeake Bay. Initially (1967-1973), the survey was funded by the U.S. Fish and Wildlife Service and when reinstated in 1980 with funding from the National Marine Fisheries Service under the Emergency Striped Bass Study program. Commencing with the 1988 annual survey, support of the program has been jointly made through 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 1999 sampling period and compares these results with the previous work.

Specific objectives planned for the 1999 program were to:

1. Measure the relative abundance of the 1999 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

The estimation of juvenile striped bass abundance in Virginia waters, funded by the U.S. Fish and Wildlife Service, is part of a coast-wide sampling program of striped bass recruitment conducted from New England to North Carolina under the coordination of the Atlantic States Marine Fisheries Commission (ASMFC). Virginia's efforts started in 1967 with funding from the Commercial Fisheries Development Act of 1965 (PL88-309) and continued until 1973 when the program 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).

The Atlantic Coast Striped Bass Interstate Fisheries Management Plan was developed by ASMFC, in 1981, then adopted by the Virginia Marine Resources Commission (VMRC) in March 1982 (Regulation 450-01-0034). Amendment IV to the plan requires "producing states" (e.g. Virginia, Maryland, Delaware and New York) to develop and support monitoring programs of recruitment levels. This became a mandate when Congress passed the Atlantic Striped Bass Conservation Act in 1984 (reauthorization 1991, PL102-130). To remain in compliance with the Act, each state must adhere to all provisions in the interstate FMP (ESBS 1993). Virginia has done this through December 1999.

Originally, 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) showed virtually no statistical differences in catch, Virginia adopted the "Maryland seine" (Colvocoresses 1984). The original purpose of the gear comparison study was to standardize methods thereby allowing a Bay-wide examination of recruitment success (Colvocoresses and Austin 1987). This was never realized however, for various differences in data handling (MD: arithmetic index, VA: geometric index) and state politics. A Bay-wide index using a weighted (by river spawning area) geometric mean was finally developed in 1993 (Austin, Colvocoresses and Mosca 1993).

METHODS

Field sampling was conducted during five approximately biweekly sampling periods from July through mid-September of 1999. During each sampling period beach seine hauls were conducted at eighteen historically sampled sites (index stations) and twenty-three auxiliary stations along the shores of the James, York and Rappahannock systems (Fig. 1). Addition of the auxiliary sites in 1989 was made to provide better geographic coverage and create larger within-river-system sample sizes so that trends in juvenile abundance can be meaningfully monitored on a system by system basis, particularly as the stock size increases and the nursery ground expands.

One seine haul was made at each auxiliary station, and two duplicate hauls made at each index station during each sampling round. Collections were made by deploying a 100' (30.5m) long, 4' (1.22m) deep, 1/4" (0.64cm) bar mesh minnow seine perpendicular to the shoreline (either until the net was fully extended or a depth of approximately four feet was encountered), pulling the offshore

end down-current and back to the shore. In the case of index stations, all fish taken during the first tow were removed from the net and held in water-filled buckets until after the second tow. All fish collected were identified and counted, and all striped bass and all individuals or a sub-sample of at least 25 individuals of other species 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 instrument. 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 the interlude between the two hauls. All fishes captured, excepting those preserved for life history studies, were returned to the water at the conclusion of sampling.

In the present report, comparisons with prior years will be made on the basis of the 'primary nursery' standardized data set (Colvocoresses 1984), i.e. 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 analyses (Sokal and Rohlf 1981). Subsequently computed mean values were retransformed (i.e. the geometric mean) and scaled up 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 1999 year class of juvenile striped bass from the James, York and Rappahannock river systems.

A total of 442 young-of-the-year striped bass were collected from 180 seine hauls during the 1999 index station sampling, and an additional 175 age 0 striped bass were collected in 102 hauls at the auxiliary sites (Fig. 1, Table 1). The adjusted overall mean catch per seine haul (CPUE) for the index stations was 2.80, the lowest index in Virginia since 1985 when harvest restrictions were imposed. (Table 2, Fig. 2). This value was less than half the overall average index of 6.22 and was significantly below the 1998 value (13.25). Indices for each river system were less than their overall average and each individual river was less than its respective overall average.

The 1999 catch in the James drainage was 5.33, lower than the 1998 index (16.02) and the overall average (7.55)(Table 3, Fig. 3). The main-stem James (6.49) catch rate was slightly less than its overall average (6.65). The Chickahominy catch rate (3.45) fell again in 1999 to slightly over one-third its overall average (9.68). Juvenile striped bass were caught throughout the James system during 1999 except at the lowest auxiliary site (Table 3, Fig. 4). Distribution peaked in the mid-portion of the nursery area with decreasing catches in both the upper and lower reaches. Consistent catches were made at most sites except the down-river (J12, J22) and up-river (J74, J78) sites and

J62, another up-river auxiliary site. The greatest number of striped bass was captured at J56 and J46.

The 1999 index in the York drainage (0.64) was the lowest on record for the system and well below the historical average (5.09)(Table 3, Fig. 3). The catch in the Pamunkey (0.91) and the Mattaponi (0.45) were also well below their respective overall averages (Pamunkey (5.81), Mattaponi (4.60)) Only thirty-three juvenile striped bass were captured in seventy seine hauls in the York system.

All sites in the York River proper are auxiliary sites and none produced striped bass during the 1999 sampling season. Highest catches on the Mattaponi River occurred at M37, an auxiliary site within the lower reaches of the index area (Fig. 5). A total of twenty-six juvenile striped bass were captured on the Mattaponi River in 1999 and fifty percent of those were caught at M37 where only one tow per round was made (Table 1).

In the Pamunkey River, highest catches occurred at P50, the upper index site (Figure 6). Fifteen of twenty-two total juvenile striped bass were caught at P50. Only two striped bass were captured at auxiliary sites in the Pamunkey River. The auxiliary sites in the Pamunkey River were not completed during round 4 due to high water and high winds from Hurricane Dennis. The up-river auxiliary sites in both the Mattaponi and Pamunkey were not sampled during round 5 due to high tides caused by the imminent approach of Hurricane Floyd.

The 1999 index in the Rappahannock River was 4.55 while the historic average is 6.40 (Table 3). Highest catches were at the two uppermost index sites (R50, R55) where R55 produced three times

as many fish as R50 (131 vs 39) (Table 1, Fig. 7). Up-river auxiliary sites (R69, R76) produced fish during most sampling visits though not in great numbers. All sites in the Rappahannock River were sampled each round in 1999.

Because the number and precise timing of sampling rounds has 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, catch rates are highest during July and into early-August and taper off in the later rounds of August and September and in 1999 this pattern was observed. (Table 4)(Austin et al, 1999).

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

Collection information and pertinent environmental variables recorded at the time of each collection in 1999 are given in Tables 5 through 8. Generally, 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 basis. In past years, we calculated the mean value across all stations. Since we sometimes failed to sample auxiliary sites, we will only take a mean value for index sites which are always sampled unless we have instrument failure.

Generally, salinities were higher in 1999 than in 1998 (Table 5)(Austin et al, 1999). Salinities at down-river sites were considerably higher than those recorded in 1998, sometimes registering two times higher. The Palmer Drought Index (Palmer, 1964) indicated that the spring/summer period of 1999 was drier than normal and followed a period of record wet condition in 1998. Moderate to

extreme drought conditions existed across the Virginia drainages from April until mid-September when multiple hurricanes passed through the area in a short expanse of time. Although Hurricane Dennis occurred between rounds 4 and 5 and caused significant flooding in the area, the effect on salinity in round 5 was minimal.

Overall, water temperatures were slightly lower in 1999 (Table 6) than in 1998 (Austin et al, 1999). The normal pattern of higher temperature in the early rounds and temperature slowly declining during the later rounds varied somewhat in 1999. Round 1 temperatures were lower in 1999 and rose to average levels by rounds 2 and 3. Temperatures dropped considerably from round 3 to round 4 in the James and York Rivers probably due to the influence of freshwater input from a hurricane which stalled off the North Carolina coast for a week. Temperature readings in these estuaries are not only affected by the long term weather patterns of summer but significant variations from day to day and river to river can be caused by time of sampling (morning versus afternoon, etc) and local events such as thunderstorms. We sample the shallow shoreline areas and these are easily affected by such conditions.

Dissolved oxygen levels were generally within the norms expected during this sampling period (Table 7). No depressed readings that affected catches were observed in 1999.

pH levels during the 1999 sampling were slightly elevated over precious years during rounds 1 through 4 (Table 8). Presumably this was due to the extended drought conditions observed until the end of round 4. After the precipitation from Hurricane Dennis, pH values returned to levels observed in previous years. Generally the James and Rappahannock systems have pH values that are slightly

basic. The Pamunkey River is near neutral pH and the Mattaponi River has pH values that are slightly acidic.

All index sites were completed without interruption, however some hydrological data were not collected due to malfunctions of the water quality instrument.

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 1999 followed the normally observed pattern i.e. a definitive trend towards higher catches at lower salinities within the primary nursery area (Table 8). Figure 8 shows the relationship of juvenile striped bass catches with respect to historical salinity gradients within each river system. This figure shows the data from 1967 to present and represents the long term trend while Figure 9 shows the salinity gradients for 1999. Overall, catches were highest in the areas of lowest salinities (0-4.9ppt) for both the long term and 1999. Though the overall trend was not affected, the higher salinities affected the proportion of catch in higher salinities. The historical catch percentage in 5-9.99 ppt nearly doubled in 1999 and the percentage of total catch in 10-14.9 ppt was eight times higher. These deviations from the norm were more likely the result of the elevated salinities in the lower nursery area plus the lower overall catches than a shift in salinity preference. Salinity gradients were extended ten or more miles up-river from the historical gradients.

Catch rates with respect to water temperature in 1999 clearly adhered to the pattern seen in most years, i.e. catch rates varied directly with water temperature at the time of collection (Table 9). Most fish are captured in the 25-30°C range which is the normal water temperature range during our

sampling. 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 play a larger role in this trend. Generally, catches within the sampling season are not governed by water temperatures and the overall relationship between catch and water temperature within the sampling season is probably coincidental.

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. pH values during our sampling are generally near neutral to slightly basic outside of the Mattaponi River. Secchi disc readings are a relative measure of turbidity and can affect catches in two ways: when turbitity is extremely high fish are more vulnerable to our gear and when it is low (e.g. greater clarity) net avoidance becomes a potential problem. We saw no high turbidity episodes in 1999 and though secchi readings are not presented herein, the data are collected, stored, and are available upon request.

DISCUSSION AND CONCLUSIONS

The striped bass juvenile index recorded in the Virginia Chesapeake Bay nursery areas in 1999 was significantly lower than both the historical average (Table 2) and the 1998 index (Austin et al,

1999). It was the lowest index recorded since 1985 when stringent harvest regulations of the ASMFC Interstate Fisheries Management Plan were implemented. Though all rivers and river systems were below historical averages, the York system exerted the greatest negative influence on the overall index. The 1999 York index was the lowest recorded and unduly affected the overall value. Table 11 shows the indices for the river systems from 1967 to present. Since 1990, the Rappahannock River had three (90, 91, & 95) indices that were lower than the 1999 value. Likewise, the James system has had two indices since 1990 (91 & 92) that were lower. In each of these instances, the other two systems had good recruitment that supported the overall index at higher levels. In 1999, the James and Rappahannock had only marginal recruitment and the York system had poor recruitment resulting in the low overall index.

The spring and summer of 1999 were warm, with considerably less rainfall than normal, leading to higher salinities and pH. The Pamunkey and Rappahannock Rivers had highest catches at up-river sites while the Mattaponi catches were at lower sites. The James had catches along the entire river with highest catches in the upper nursery area and above.

Sampling at the former Bluefish Seine Survey sites in the lower James River and Chesapeake Bay produced no striped bass in 1999.

The weak recruitment of juvenile striped bass in 1999 was likely a result of the drought conditions that produced very little river flow during late spring of 1999. Conditions resulting from the low flow were not conducive to successful recruitment in the Virginia portion of Chesapeake Bay. This is caused by a combination of, a shrinking nursery ground that was displaced further up-

river and changes in zooplankton abundance and availability.

Striped bass recruitment success in the Virginia portion of Chesapeake Bay remains variable between years and between the different nursery areas within years. However, these fluctuations have been bracketing a much higher average until 1999. 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 areal coverage of the nursery areas. These additional areas of coverage have revealed that in years of high or low salinity there may be a shift in the traditional nursery areas up or down-river. Figures 4-7 represent average catch per haul at all sites and 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 tend to over-emphasize the relative contribution of the auxiliary sites. They are included only to demonstrate the spatial distribution of the yearclass. 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 may lead to a more precise estimate of relative year-class strength but it will undoubtedly elevate the recalculated indices.

LITERATURE CITED

ASMFC. 1991. Supplement to the striped bass FMP-Amendment No. 4. ASMFC Fisheries Management Report, Washington, D.C.

Austin, H.M., A.D. Estes and D.M. Seaver. 1999. Estimation of Juvenile Striped Bass Relative Abundance in the Virginia Portion of Chesapeake Bay. Ann. Rep. 1998. Virginia Institute of Marine Science, Gloucester Pt. Virginia. 32 p.

Austin, H.M., J.A. Colvocoresses and T.A. Mosca III. 1993. Develop a Chesapeake Bay-wide Young-of-the-Year striped bass index. Final Report, CBSAC Coop. Agree. No. NA16FUO393-01, 59p + 2 app.

Colvocoresses, J.A. and H.M. Austin. 1987. Development of an index of juvenile striped bass abundance for the Chesapeake Bay System: I. An evaluation of present measures and recommendations for future studies. Va. Inst. Mar. Sci. Spec. Sci. Rep. No. 120. 108p.

Colvocoresses, J. A. 1984. Striped bass research, Virginia. Part I: Juvenile striped bass seining program. Ann. Rep. 1987-88. Virginia Institute of Marine Science, Gloucester Point, Virginia. 64 p.

ESBS. 1993. Emergency Striped Bass Research Study, Report for 1991. Prepared by the U.S.F&W.S., ASMFC, and the NMFS/NOAA. 35 p.

Palmer, W. C. 1965. Meteorological drought. U.S. Dept. of Commerce, Office of Climatology, U.S. Weather Bur., Washington, D.C., Research paper No.45, 58pp.

Sokal, R.R. and F.J Rohlf. 1981. Biometry. W.H. Freeman and Co., San Francisco, CA. 851 p.

Table 1. Catch of young-of-the-year striped bass per seine haul during the 1999 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	0	0/0	3/7	12	1/2	2/1	9/2	5	9/2	0	7	6	0	68
	2	0	0	1/1	2/8	3	11/2	1/1	20/5	8	12/5	0	6	0	0	86
	3	0	2	1/0	5/3	11	2/0	1/0	2/3	10	15/5	2	6	0	0	67
	4	ns	ns	1/1	2/1	ns	3/0	4/3	0/6	6	7/1	2	0	2	0	39
	5	0	0	2/7	7/1	6	1/1	4/1	2/3	2	5/1	0	1	6	1	51
																311
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	1	0	0	0	0	1/0		1/0	2/2	0	0					6
	2	0	0	0	0	0/0		1/0	0/0	0	0					1
	3	0	0	0	1	1/0		0/0	0/0	0	1					3
	4	ns	ns	ns	ns	0/0		0/0	2/3	ns	ns					5
	5	0	0	0	0	0/0		1/0	6/0	0	ns					7
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	1				1/0	5	0/4	0/0	0/0	0						10
	2				1/1	2	0/0	0/0	0/0	0						4
	3				1/0	1	0/0	0/1	0/1	0						4
	4				0/0	ns	0/0	0/0	0/0	ns						0
	5				3/0	5	0/0	0/0	0/0	ns						8
																48
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	1	2	0	6/0	1/0		16	4/1	1/9	25/12	4	0	1	9		91
	2	0	0	0/3	1/1		0	2/0	4/3	15/13	0	1	2	8		53
	3	0	0	0/0	1/1		0	4/0	8/4	21/9	0	2	1	3		54
	4	0	0	0/0	1/4		1	0/1	3/1	14/5	1	0	1	2		34
	5	0	0	0/0	0/0		0	0/0	3/3	4/13	1	1	1	0		26
																258
																617

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 ln (x+1) * 2.28, the ratio of overall arithmetic and geometric means through 1984).

Year	Total	Mean ln (x+1)	Std. Dev.	Adjust Mean	C.I. (± 2 SE)	N
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
Overall	25830	1.32	1.156	6.22	5.91-6.55	3670

Table 3. Catch of young-of-the-year striped bass per seine haul in primary nursery area in 1999 summarized by drainage and river.

Drainage River	1999 Total	1999 Adjust. Mean	1999 C.I. (2 ± SE)	1999 N	All Years combined Total	All Years combined Adjust. Mean	All Years combined C.I. (±2 SE)	All Years combined N
James	208	5.33	3.99-6.96	60	9858	7.55	6.90-8.24	1218
James	167	6.49	4.56-8.96	40	5617	6.65	5.97-7.39	820
Chickahom.	41	3.45	2.09-5.22	20	4241	9.68	8.28-11.26	398
York	33	0.64	0.33-0.98	70	7667	5.09	4.68-5.51	1383
Pamunkey	20	0.91	0.34-1.60	30	3791	5.81	5.10-6.59	587
Mattaponi	13	0.45	0.13-0.81	40	3876	4.60	4.13-5.10	796
Rappahannock	201	4.55	2.86-6.78	50	8305	6.40	5.77-7.08	
Overall	442	2.80	2.19-3.50	180	25830	6.22	5.91-6.55	3670

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1999 summarized by sampling period and month.

	1999				All Years Combined			
Month	Total	Adjust. Mean	C.I. (± 2 SE)	N	Total	Adjust. Mean	C.I. (± 2 SE)	N
July (1st)	108	3.50	2.01-5.52	36	7164	8.73	7.84-9.71	782
(2nd)	114	3.45	1.09-5.59	36	6532	7.05	6.29-7.87	793
Aug. (3rd)	89	2.64	1.37-4.34	36	4698	5.58	4.98-6.22	785
(4th)	63	2.20	1.19-3.52	36	4366	5.74	5.05-6.50	650
Sept. (5th)	68	2.37	1.28-3.79	36	2865	5.35	4.66-6.11	523

Table 5. Salinity (parts per thousand) recorded at 1999 seine survey stations. York system includes Pamunkey an Mattaponi Rivers.

Drainage																
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	TOT.
	Round															
	1	16.2	8.7	6.6	4.6	2.2	2.6	2.2	1.0	0.5	0.1	0.2	0.2	0.2	0.2	2.9
	2	20.2	12.8	ns	4.9	2.8	2.9	2.7	1.4	0.5	0.3	0.2	0.2	0.2	0.2	2.4
	3	18.4	12.0	9.0	5.8	4.2	4.5	4.0	2.4	1.0	0.5	0.3	0.2	0.3	0.3	4.4
	4	ns	ns	9.8	6.9	ns	5.5	5.2	ns	1.4	0.8	0.4	0.3	0.3	0.3	5.6
	5	7.2	2.6	7.7	4.5	1.8	3.5	4.0	0.8	0.6	0.4	0.2	0.2	0.1	0.0	3.5
																3.8
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	1	18.0	14.9	12.8	6.1	2.8		1.1	0.7	0.4	0.1					1.7
	2	21.0	18.5	15.0	9.0	4.0		0.0	0.0	0.0	0.0					3.0
	3	20.5	17.8	15.0	9.6	5.4		3.0	1.8	1.3	0.1					4.1
	4	ns	ns	ns	ns	4.9		3.3	2.5	ns	ns					4.8
	5	10.8	8.0	4.8	7.7	4.3		2.5	1.7	0.8	ns					3.8
																3.5
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	1				*	5.5	2.9	1.0	0.5	0.2						
	2				9.8	*	4.7	1.8	0.6	0.4						
	3				10.1	8.1	5.1	2.2	1.4	0.6						
	4				11.8	ns	7.0	3.7	0.6	ns						
	5				9.5	7.3	4.6	2.6	1.4							
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	1	15.7	15.2	13.0	9.0		7.1	4.5	3.0	2.0	0.9	0.6	0.0	0.0		6.3
	2	16.6	16.3	14.2	10.1		7.1	ns	3.7	2.6	1.2	0.7	0.3	0.1		7.7
	3	17.0	17.0	15.1	11.6		9.0	7.2	4.8	3.4	1.9	1.3	0.5	0.1		8.4
	4	18.1	17.3	15.4	11.5		8.8	7.5	5.7	4.5	2.6	2.0	0.9	0.1		8.9
	5	18.0	17.4	15.2	10.4		8.7	7.6	5.6	4.1	0.1	1.7	0.3	0.1		8.6
																8.0

* = bad data; ns = no sample taken

Table 6. Water temperature (°C) recorded at 1999 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	TOT.
	Round															
	1	31.8	33.3	26.7	24.9	26.1	25.0	24.9	26.6	26.5	25.6	25.8	28.3	30.5	28.4	25.6
	2	29.9	30.6	ns	28.8	30.8	30.0	30.2	30.8	29.9	29.8	32.9	33.3	34.5	32.4	29.9
	3	31.0	32.0	30.7	27.8	29.0	27.9	28.6	29.2	28.4	27.4	28.4	30.3	32.6	30.3	28.6
	4	ns	ns	25.1	26.3	ns	23.7	24.5	ns	27.2	26.8	27.0	28.6	30.1	27.7	25.3
	5	22.4	22.1	25.2	24.4	24.8	25.0	25.0	24.8	24.7	24.5	25.6	26.4	25.8	25.9	24.8
																26.8
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	1	28.2	29.2	25.0	26.1	26.6		26.8	26.6	27.1	27.9					27.8
	2	27.0	28.4	27.8	27.8	27.8		28.3	28.3	28.9	28.3					29.1
	3	27.3	29.5	30.8	28.2	28.8		29.2	29.4	29.9	29.1					29.3
	4	ns	ns	ns	ns	24.7		24.8	25.2	ns	ns					24.0
	5	22.5	23.3	23.4	24.8	24.6		24.8	24.6	24.2	ns					24.6
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						27.0
	1				27.8	27.6	27.5	28.2	31.1	30.9						
	2				29.8	23.6	29.4	29.0	31.3	31.2						
	3				28.8	28.8	28.6	29.0	31.1	31.0						
	4				23.5	ns	23.3	23.5	23.2	ns						
	5				24.8	24.8	24.7	24.7	24.2	ns						
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	1	21.7	23.5	23.0	23.0		24.1	23.0	28.6	28.4	28.7	27.1	28.0	28.0		25.2
	2	30.9	31.1	27.9	28.4		29.5	ns	29.5	29.6	29.7	29.3	30.2	30.6		28.9
	3	29.8	29.6	27.0	28.3		28.6	28.6	28.3	28.5	27.9	27.2	29.2	30.4		28.1
	4	25.9	27.9	27.1	26.4		24.0	27.0	27.2	27.2	27.0	26.6	27.6	28.0		27.0
	5	26.1	26.2	24.2	24.6		25.7	26.1	25.4	25.7	25.7	26.3	26.3	26.4		25.2
																26.9

ns = no sample taken

Table 7. Dissolved oxygen (milligrams per liter) recorded at 1999 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	TOT.
	Round															
	1	6.7	7.7	6.6	5.1	6.8	5.8	5.6	6.1	5.6	6.1	6.5	5.8	5.3	5.0	5.9
	2	6.5	8.4	ns	5.3	7.3	5.4	5.6	5.2	5.9	5.7	9.7	6.2	6.9	6.3	5.4
	3	7.5	8.4	6.9	6.2	6.1	6.0	6.6	5.1	5.1	6.7	9.0	4.8	4.7	6.2	6.3
	4	ns	ns	6.7	6.3	ns	5.2	5.6	ns	5.9	6.7	7.3	5.0	6.3	6.5	6.1
	5	7.8	9.2	7.8	6.7	7.9	6.5	6.9	8.1	6.2	6.5	5.6	5.3	6.2	6.6	7.1
																6.2
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	1	4.9	6.0	5.2	3.7	5.1		5.2	4.8	4.8	5.3					5.2
	2	4.7	5.9	ns	ns	ns		ns	ns	ns	ns					5.7
	3	4.8	6.4	7.2	4.8	5.5		5.7	5.4	7.4	6.1					5.7
	4	ns	ns	ns	ns	5.3		5.8	6.4	ns	ns					5.9
	5	8.0	10.2	8.9	6.2	6.0		6.8	5.3	5.5	ns					5.7
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						5.6
	1				3.6	3.9	5.5	5.4	6.6	4.5						
	2				4.8	8.8	4.5	5.9	7.4	6.4						
	3				5.2	5.3	5.0	6.1	7.3	6.0						
	4				4.9	ns	5.8	6.1	6.9	ns						
	5				5.4	4.9	5.3	5.8	5.0	ns						
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	1	6.2	6.9	7.2	5.7		4.7	6.1	4.7	5.6	5.4	7.2	ns	ns		5.9
	2	9.4	6.7	6.1	6.6		6.7	ns	7.0	ns	6.0	7.9	7.3	6.2		6.6
	3	8.2	6.8	6.1	6.1		5.0	6.9	5.3	5.9	6.2	7.3	7.4	8.2		6.1
	4	4.3	6.8	6.4	5.6		4.6	6.1	6.3	6.4	5.8	6.1	6.7	6.6		6.2
	5	7.9	8.5	7.7	7.4		6.1	6.5	7.0	7.6	6.8	7.7	6.9	6.9		7.2
																6.4

ns = no sample taken

Table 8. pH recorded at 1999 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	TOT.
	Round															
	1	8.2	8.4	8.1	7.7	8.2	7.9	7.8	7.9	8.0	8.3	8.2	8.1	8.1	8.2	8.0
	2	8.3	8.5	ns	7.8	8.4	7.8	7.8	8.0	8.2	8.9	7.8	8.4	8.9	8.5	8.0
	3	8.3	8.4	8.3	8.0	8.1	8.8	7.8	7.9	8.0	8.4	9.1	8.2	8.5	8.7	8.2
	4	ns	ns	7.9	7.9	ns	7.7	7.6	ns	8.0	8.3	8.6	8.1	8.4	8.3	7.9
	5	7.3	7.7	7.5	7.2	7.8	7.1	7.0	7.5	7.3	7.4	7.3	7.1	7.5	7.3	7.3
																7.9
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	1	8.0	8.1	7.6	7.4	7.5		7.7	7.7	7.8	8.0					7.7
	2	7.8	7.8	ns	ns	ns		ns	ns	ns	ns					7.4
	3	8.1	8.3	8.2	7.6	7.6		7.6	7.6	7.8	8.0					7.5
	4	ns	ns	ns	ns	7.4		7.4	7.5	ns	ns					7.5
	5	7.6	8.0	7.8	6.8	6.7		6.8	6.7	6.8	ns					6.8
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						7.4
	1				7.6	7.5	7.5	7.8	7.8	7.9						
	2				7.5	8.2	7.3	7.4	7.3	7.3						
	3				7.6	7.4	7.4	7.4	7.6	7.2						
	4				7.4	ns	7.2	7.2	7.0	Ns						
	5				7.1	7.1	6.8	7.0	6.4	Ns						
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	1	8.1	8.3	8.3	7.7		7.4	7.4	7.4	7.5	7.6	8.2	ns	ns		7.7
	2	8.7	8.3	8.1	7.8		7.7	ns	7.5	7.7	7.7	8.8	8.2	8.4		7.8
	3	8.5	8.3	8.2	7.8		7.5	7.8	7.7	7.7	7.8	8.7	8.3	8.6		7.8
	4	8.0	8.3	8.2	7.8		7.3	7.7	7.7	7.5	7.5	7.7	7.8	8.1		7.8
	5	7.6	7.6	7.6	7.1		6.8	6.9	6.9	6.7	6.7	7.0	7.1	7.2		7.1
																7.6

ns = no sample taken

Table 9. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1999 summarized by salinity.

	1999				All Years Combined			
Salinity (ppt.)	Total	Adjust. Mean	C.I. (± 2 SE)	N	Total	Adjust. Mean	C.I. (± 2 SE)	N
0-4.9	368	3.39	2.50-4.45	120	23911	7.08	6.70-7.48	3095
5-9.9	55	2.23	1.37-3.29	38	1781	3.68	3.11-4.31	414
10-14.9	19	1.75	0.65-3.25	16	135	1.24	0.89-1.64	135
15-19.9					2	0.13	-0.05-0.32	25
Overall	442	2.80	2.19-3.50	180	25830	6.22	5.91-6.55	3669

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1999 summarized by water temperature.

	1999				All Years Combined			
Temp. (deg. C)	Total	Adjust. Mean	C.I. (± 2 SE)	N	Total	Adjust. Mean	C.I. (± 2 SE)	N
15-19.9					79	2.85	1.40-4.86	30
20-24.9	64	1.58	0.87-2.46	50	1801	2.99	2.59-3.43	559
25-29.9	326	3.50	2.60-4.57	110	18844	7.16	6.73-7.61	2443
30-34.9	42	2.79	0.70-6.35	14	4716	7.72	6.73-8.82	538
Overall	442	2.80	2.19-3.50	180	25830	6.22	5.91-6.55	3670

Table 11. Virginia Juvenile Striped Bass Seine Survey Annual Indices.

Year	James	York	Rappahannock	Combined
1967	7.60	1.74	4.71	4.61
1968	1.50	3.46	6.98	3.70
1969	2.45	2.86	3.47	2.91
1970	10.58	3.28	5.64	6.42
1971	1.67	1.81	5.07	2.83
1972	0.70	1.89	0.80	1.19
1973	0.89	3.25	1.21	1.59
1980	4.77	2.51	0.75	2.54
1981	1.20	2.42	0.88	1.57
1982	2.71	3.28	1.98	2.71
1983	4.43	2.63	3.77	3.48
1984	5.59	4.80	2.57	4.36
1985	2.94	3.42	0.80	2.41
1986	8.63	2.67	4.49	4.75
1987	18.80	7.29	34.03	15.75
1988	6.80	5.06	14.55	7.64
1989	15.40	9.29	9.87	11.23
1990	12.21	6.72	4.18	7.34
1991	4.50	3.37	3.56	3.78
1992	3.71	3.64	30.92	7.32
1993	23.70	13.70	18.10	18.12
1994	10.28	11.29	9.70	10.49
1995	8.08	6.31	2.41	5.45
1996	42.62	15.78	18.18	23.05
1997	9.22	6.49	9.52	8.24
1998	16.02	10.84	14.18	13.33
1999	5.33	0.64	4.55	2.80
Overall (thru 1998)	7.68	5.46	6.51	6.45

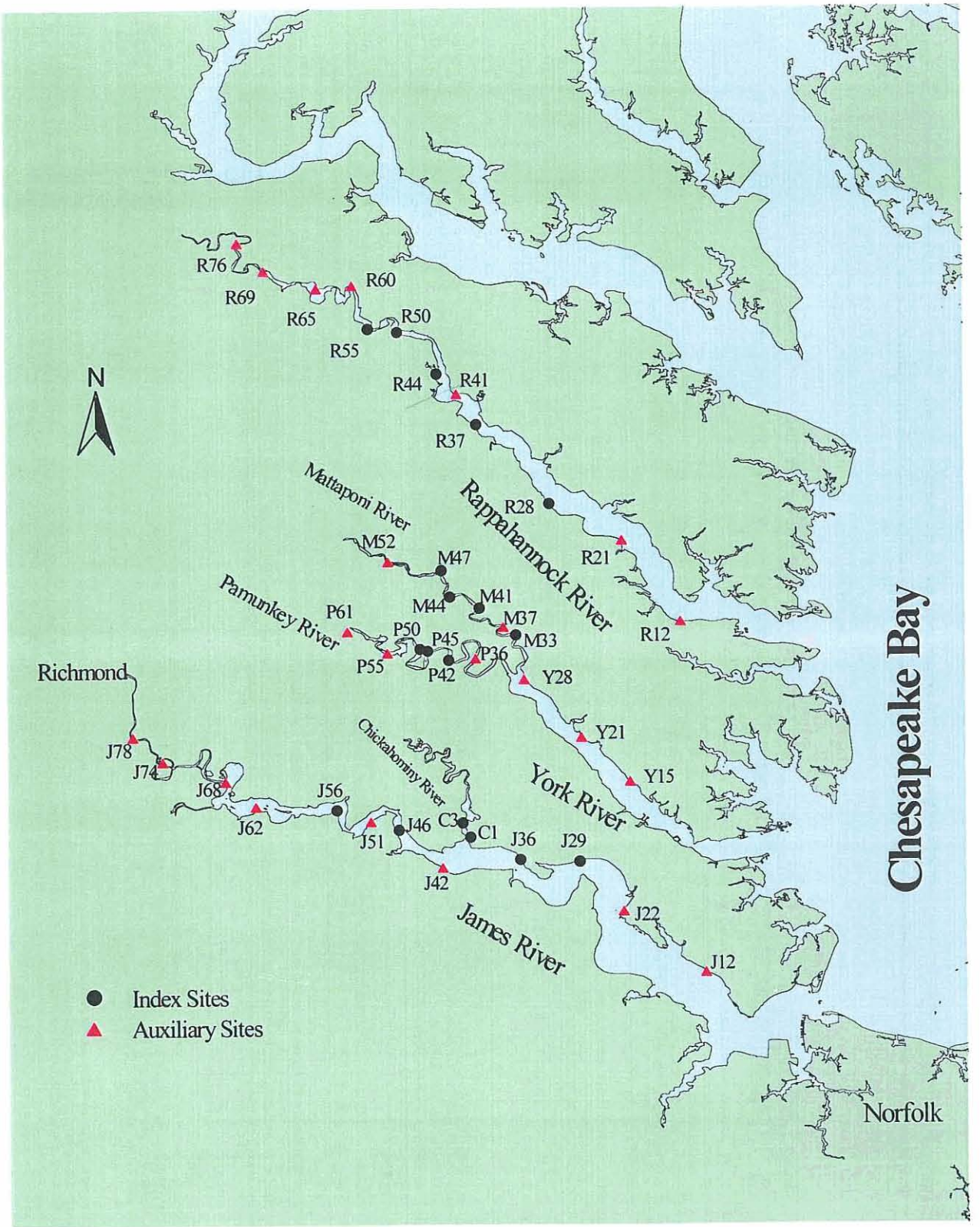

Figure 1. Juvenile striped bass seine survey stations. Numeric portions correspond to miles from river mouth.

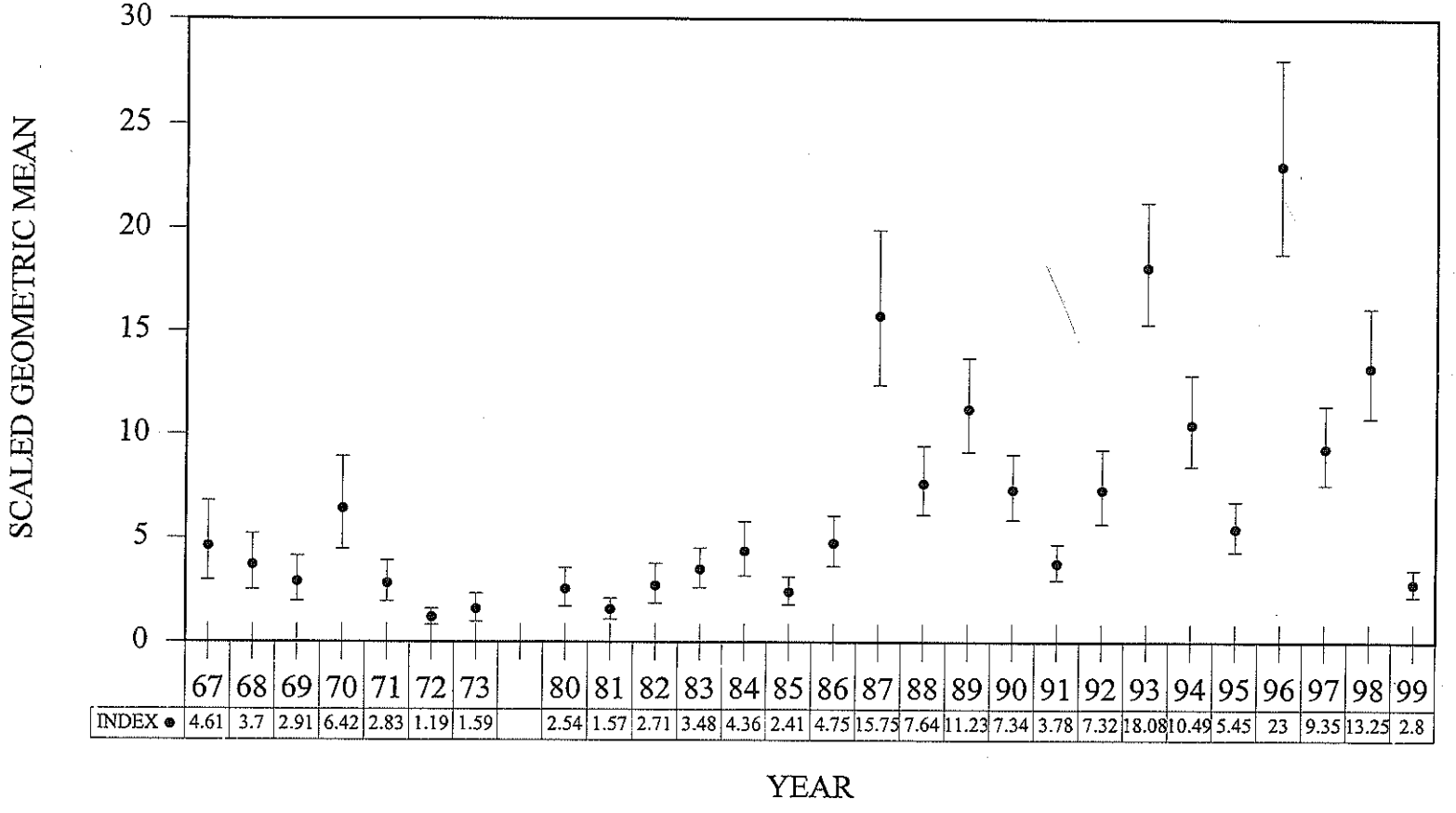

Figure 2. Scaled average catch of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by $\pm$ 2 standard errors of the mean.

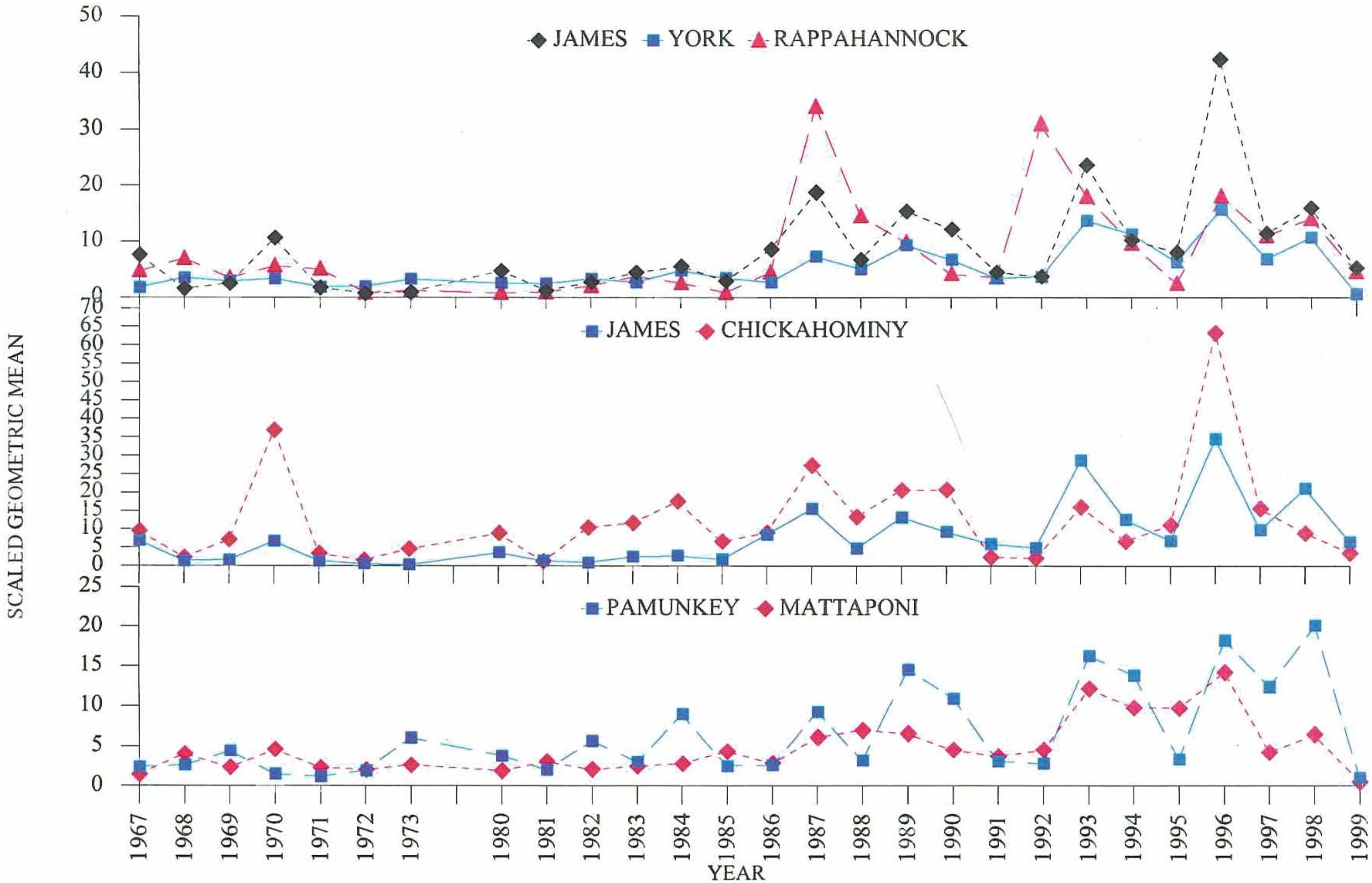

Figure 3. Adjusted average annual catch of young-of-the-year striped bass per seine haul in the primary nursery area by drainage and river.

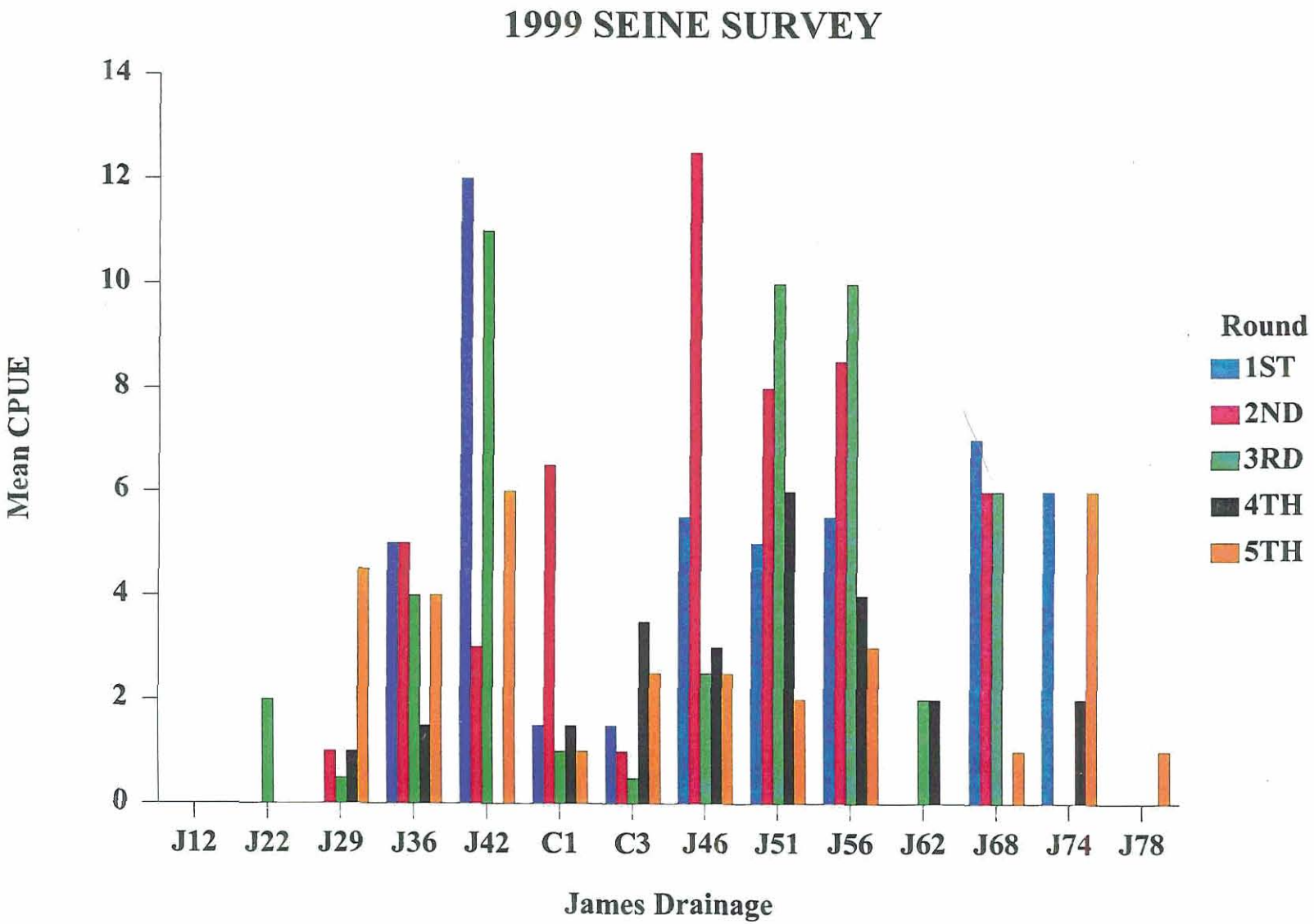

Figure 4. Average catch of young-of-the-year striped bass per seine haul by station in the James drainage.

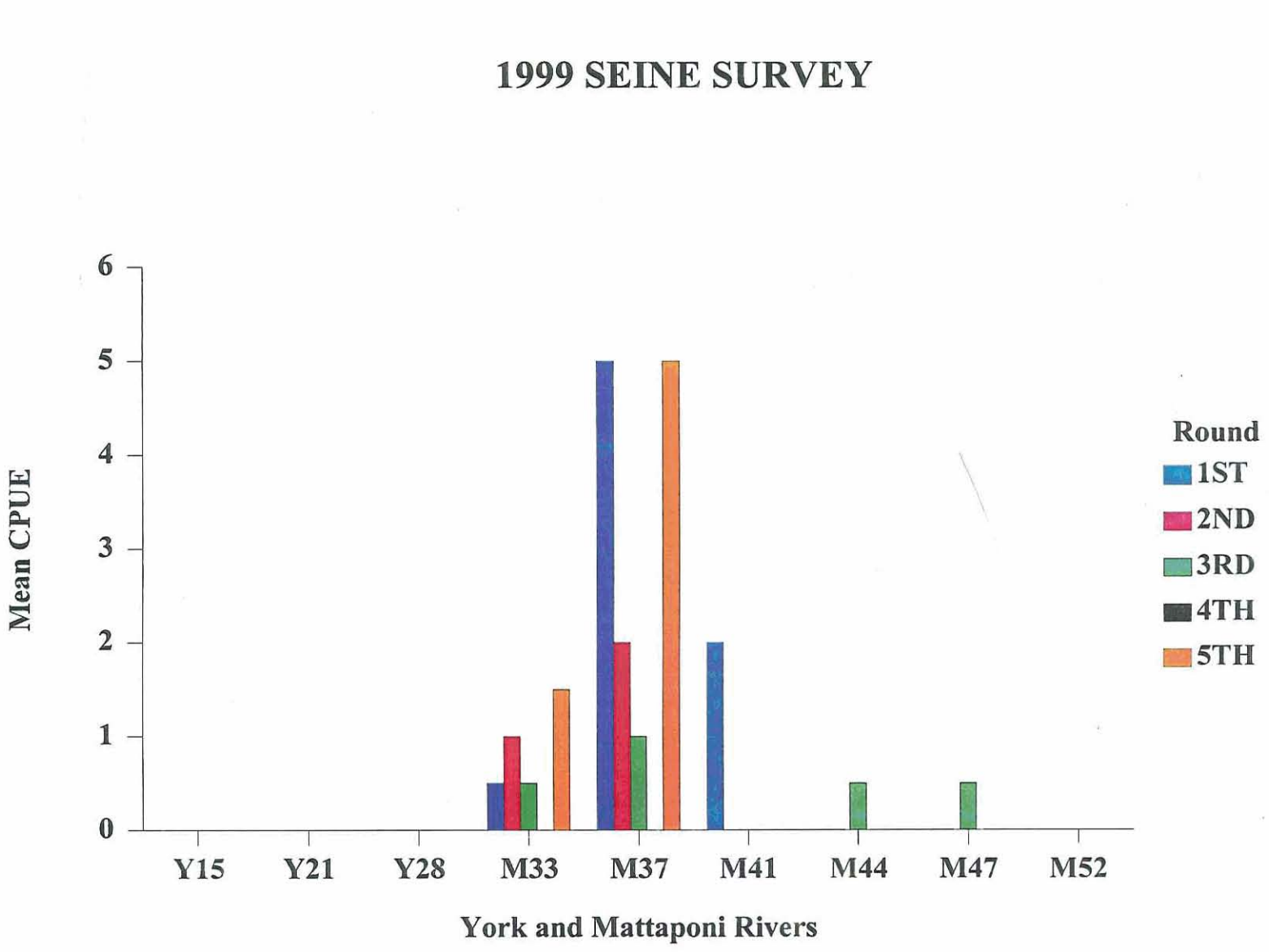

Figure 5. Average catch of young-of-the-year striped bass per seine haul by station in the Mattaponi and York rivers.

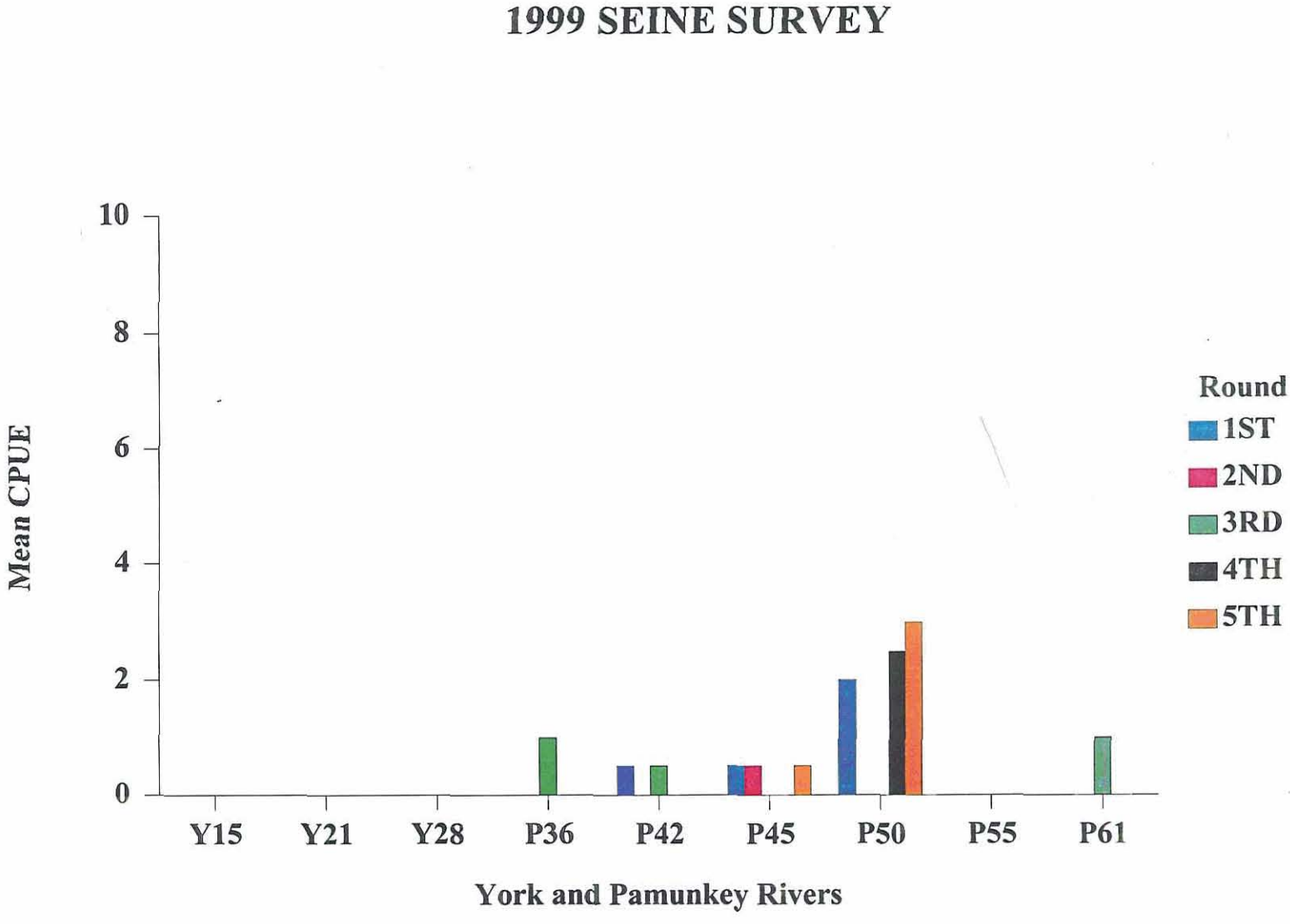

Figure 6. Average catch of young-of-the-year striped bass per seine haul by station in the Pamunkey and York rivers.

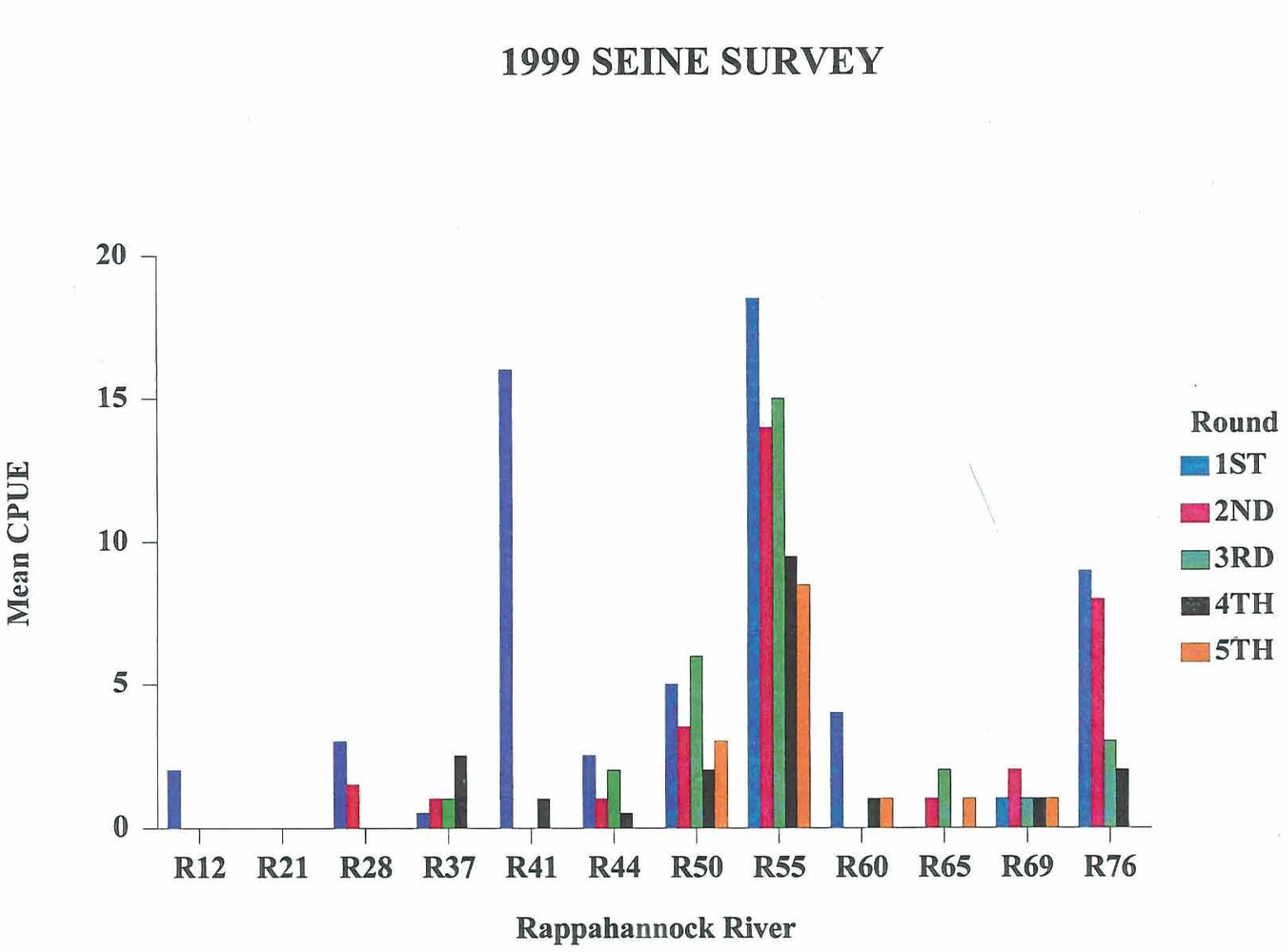

Figure 7. Average catch of young-of-the-year striped bass per seine haul by station in the Rappahannock River.

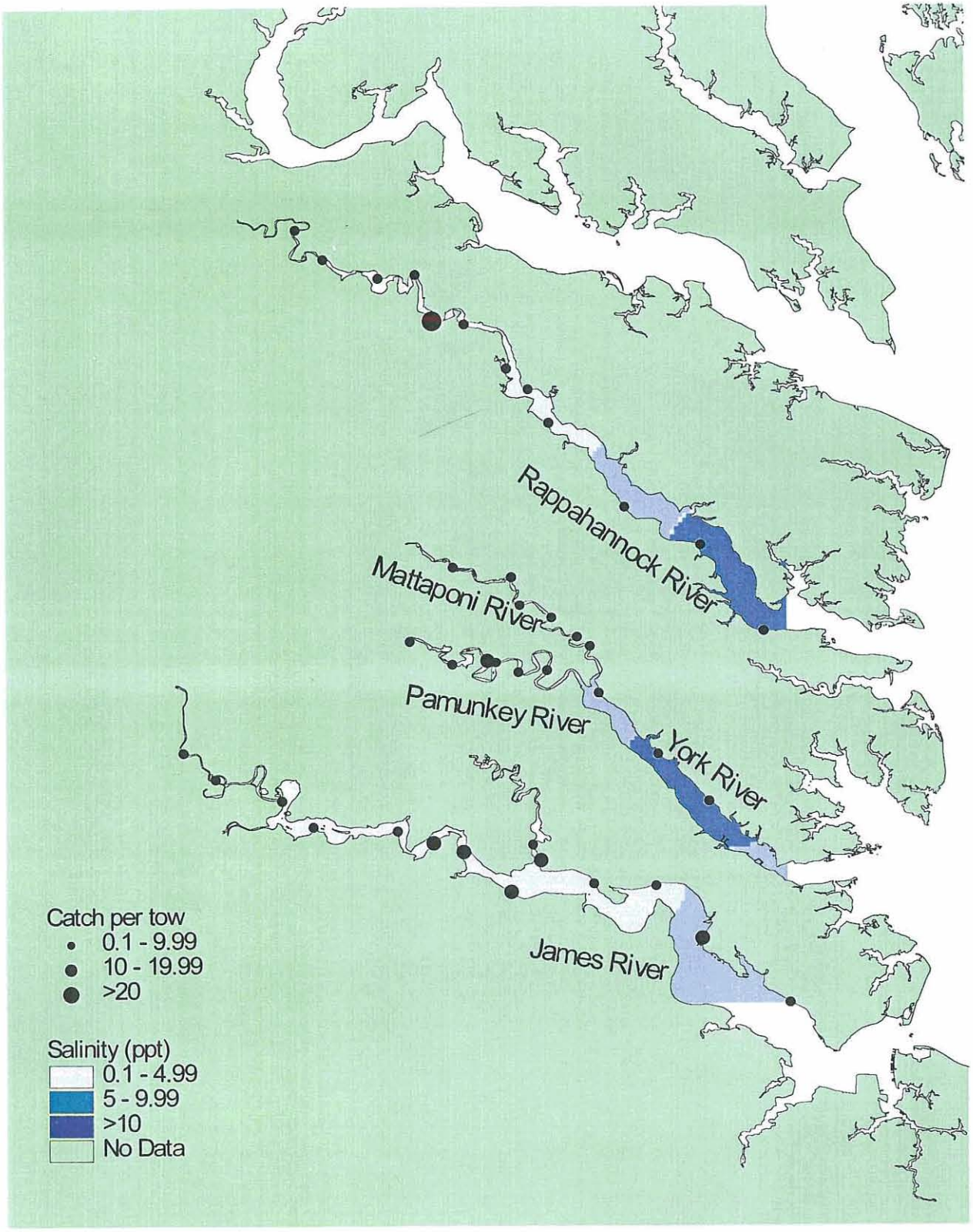

Figure 8. Catch per unit effort of young-of-the-year striped bass with respect to salinity from 1967-1999.

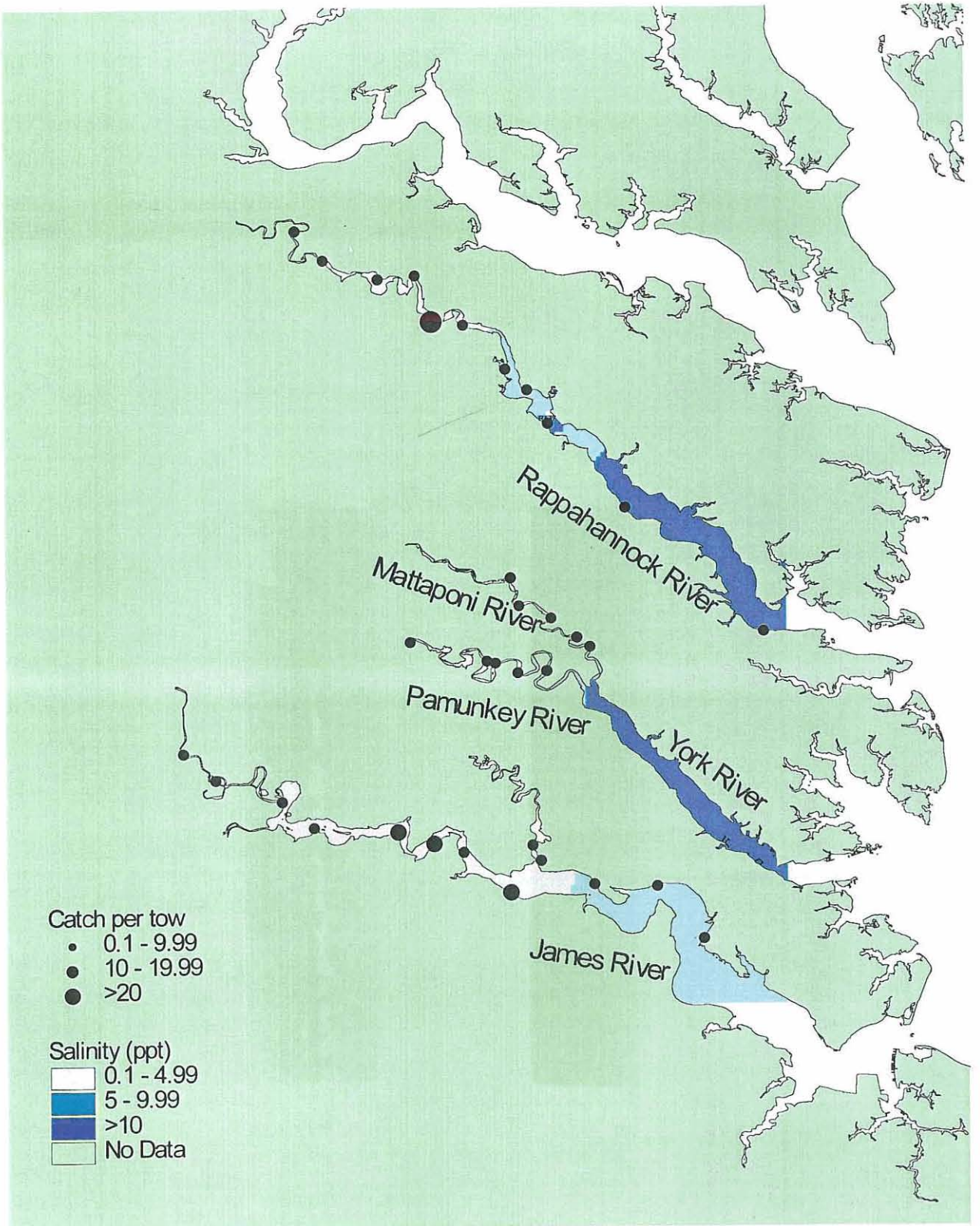

Figure 9. Catch per unit effort of young-of-the-year striped bass with respect to salinity in 1999.