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Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 1998-December 1998 : annual progress report

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ANNUAL PROGRESS REPORT

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

January 1998 - December 1998

by

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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 to the 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 1998 sampling period and compares these results with the previous work.

Specific objectives planned for the 1998 program were to:

1. Measure the relative abundance of the 1998 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'a 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 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 adopted 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 Decemer 1998.

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 1998. 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). Another auxiliary site was added in the James River (J42) in 1998 to fill in a gap in the areal coverage in the nursery area section of that river. Addition of the auxiliary sites in 1989 was made to provide better geographic coverage and, once a sufficient time series of data is developed, 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) and then leaving the onshore brail in a fixed position while pulling the offshore end down-current and back to the shore, resulting in the sweeping of a quarter circle quadrant. 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 subsample 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 1997 year class of juvenile striped bass from the James, York and Rappahannock river systems.

A total of 2084 young-of-the-year striped bass were collected from 180 seine hauls during the 1998 index station sampling, and an additional 648 age 0 striped bass were collected in 94 hauls at the auxiliary sites (Fig. 1, Table 1). The adjusted overall mean catch per seine haul (CPUE) for the index stations was 13.25 or 42 percent greater than the 1997 index (9.35) and was the fourth highest index on record in Virginia. (Table 2, Fig. 2). This value was more than double the

overall average index of 6.45 but was not a significant increase over the 1997 value. Indices for each river system were more than double their overall average and all individual rivers, except the Chickahominy, exceeded its respective overall average.

The 1998 catch rate in the James drainage (16.02) was forty percent higher than the 1997 average (11.48) and was over twice the overall average (7.68)(Table 3, Fig. 3). The mainstem James (21.14) catch rate was the fourth highest on record and more than three times its overall average (6.66). The Chickahominy catch rate (8.9) fell in 1998 to slightly below its overall average (10.15).Juvenile striped bass were caught throughout the James system during 1998 (Table 3, Fig. 4). Distribution peaked in two areas, one downriver at J22 (an auxiliary site) and at J46, an index site near the center of the nursery area. Consistent catches were made at most sites except the extreme downriver (J12) and upriver (J78) sites and J68, another upriver auxiliary site. The greatest number of striped bass was captured at J46 (342) and J22 (286). Half of the striped bass at J22 were caught in round 5, perhaps indicating a downstream movement of fish from the lower nursery area as the summer progressed. An upriver auxiliary site, J62, adjacent to the index area, produced high catches in rounds one and two but produced very few fish thereafter, a pattern also seen in 1997. Most auxiliary sites in the James system were not sampled during round 5 due to vessel breakdowns. Those auxiliary sites accessible by vehicle were sampled.

The 1997 index in the York drainage (10.70) was nearly double the historical average (5.46) and the fourth highest on record for the system (Table 3, Fig. 3). The catch rate in the Pamunkey

(20.04) was over three times its historical average (6.21), and the highest on record for that river. The Mattaponi index (6.36) was twenty-eight percent higher than its historical average (4.94) (Table 3, Fig. 3). The Mattaponi index has historically remained at low levels and the 1998 value though not significantly high, is higher than its overall average.

All sites in the York River proper are auxiliary sites. Y28, an auxiliary site just downriver of the nursery area on both the Mattaponi and Pamunkey Rivers, produced striped bass during all rounds. Y21, another auxiliary site, produced striped bass in all rounds except round 4, while Y15 only produced a single fish in round 1.

Highest catches on the Mattaponi River occurred at M33, the lowest index site and M41, the next index site upriver (Figure 5). Though situated midway between M33 and M41, M37 was not a productive site except in round 5. Y28, an auxiliary site downriver of the index area and in the mainstream York, was the next highest producing site. However, consistent catches were made from Y21, 12 miles below the index area, through M47, the uppermost index site.

In the Pamunkey River, highest catches were made at P45, the middle index site (Figure 6). Consistent catches were made from Y21 to P55, the former being an auxiliary site 21 miles downriver of the index area and the latter being just upriver of the index area. The catches at Y28, which were third highest when examined with the Mattaponi River, were overshadowed by the higher catches in the Pamunkey. P45 and P50, the two upriver index sites, produced 72 percent

of all fish captured in the York/Pamunkey system (529 of 735 fish). P36, P55, and P61 were not sampled during round 4 due to a coastal storm that caused the loss of available beach at those sites. The 1998 index in the Rappahannock River (14.11) was more than double the historical average (6.51)(Table 3). This value was the sixth highest value recorded for the Rappahannock River. Confidence intervals from the 1997 and 1998 values overlapped therefore 1998 was not judged to be a significant increase over 1997. Highest catches were at the three uppermost index sites (R44,R50,R55) but catches on either side of this area were greatly reduced (Fig. 7). This pattern has been observed for a number of years with the only variation occurring in 1996 when record numbers were observed and we suspect that striped bass dispersed further downriver. Coastal storms and subsequent high tides caused the loss of available beach at several upriver auxiliary sites during rounds 1 and 5 and sampling was not conducted.

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. In 1998, this pattern was observed but catches in the last two rounds did not decrease as sharply as those observed in 1997 (Table 4)(Austin et al, 1998).

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

Collection information and pertinent environmental variables recorded at the time of each collection in 1997 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.

Generally, salinities were lower in 1998 than in 1997 (Table 5)(Austin et al, 1998). Salinities at downriver sites were 2-3 part per thousand lower than those recorded in 1997. The Palmer Drought Index indicated that the spring/summer period of 1998 was wetter than normal (Palmer, 1964). The coastal plain remained normal to moist the entire summer while piedmont areas were moist through mid-August but quite dry in late August and September.

Water temperatures were nearly the same in 1998 (Table 6) as in 1997 (Austin et al, 1998), following the normal pattern of higher temperature in the early rounds and temperature slowly declining during the later rounds. Temperature readings 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 1998.

pH levels during the 1998 sampling were consistent with previous years (Table 8). Generally the James and Rappahannock systems had pH values that were slightly basic. The Pamunkey River was near neutral pH and the Mattaponi River had pH values that were slightly acidic. We had no pH values in 1997 due to faulty equipment but pH values in past reports indicate the observed pattern in 1998 is normal.

All index sites were completed without interruption, however some hydrological data were not collected due to malfunctions of the Hydrolab 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 1998 followed the normally observed pattern i.e. a definitive trend towards higher catches at lower salinities within the primary nursery area (Table 8). Overall, mean catches were highest in the areas of lowest salinities (0-4.9ppt). Though the overall trend was not affected, it is noteworthy that J22, an auxiliary site in the 5-9.9 parts per thousand salinity range produced 286 striped bass, while Y28 and R28, both corresponding closely in salinity, produced only 32 fish each (Tables 1 and 5).

Catch rates with respect to water temperature in 1998 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 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 utilization of a particular area in two ways: when turbitity is extremly high fish arre 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 1998 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 1998 was significantly higher than the historical average (Table 2) and was an increase over the 1997 index (Austin et al, 1998). No individual system unduly influenced the overall index as each system index was significantly above its historical average. The 1998 yearclass was the fourth highest on record and can be considered a dominant yearclass and a definite continuation of the successful recruitment that has been observed since the mid-80's. The 1998 yearclass should contribute to an already large and growing spawning stock.

The spring and summer of 1998 were warm, though not hot, with slightly more rainfall than normal, leading to somewhat lower meteorological and hydrological parameters and distributional patterns that varied by river system. The Pamunkey and Rappahannock Rivers had highest catches at upriver sites while the Mattaponi catches were at lower sites. The James had good catches along the entire river with high catches near the center of the nursery area and below the nursery area. On 2 June, the VIMS Juvenile Bluefish Seine Survey collected striped bass from Willoghby Spit at the mouth of the James and Seashore State Park near the mouth of Chesapeake Bay. We theorize that these fish are from the James River. With a warm winter and spring we believe these fish were probably from an earlier spawn in a large yearclass and they moved down the estuary as competition for nursery area increased. A similar situation occurred with the record 1996 yearclass.

The strong year classes of late probably reflect a substantial increase in spawning stock due to stringent harvest regulations in place since implementation of the ASMFC Interstate Fisheries Management Plan. Refinements to our sampling program have focused on the spatial and temporal usage of the nursery areas and probably served to give us a more precise estimate of yearclass strength.

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 over the past twelve years. This pattern is consistent with an increase in spawning stock size resulting from the stringent harvest regulations in place over the period since 1985.

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 salinities there may be a shift in the traditional nursery areas up or downriver. 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.

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Table 1. Catch of young-of-the-year striped bass per seine haul during the 1998 survey. Two hauls were made per sampling round at each of the historical index stations (bold).

Drainage

JAMES

Station / Round	J12	J22	**J29**	**J36**	**J42**	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	TOT.
1	0	11	10/1	7/13	4	20/18	3/1	7/17	10	2/1	60	2	10	0	197
2	0	12	4/22	25/11	6	27/13	5/0	52/54	10	2/14	31	2	5	3	298
3	0	56	9/4	21/6	7	16/12	3/2	49/38	13	3/6	6	1	2	0	254
4	1	64	7/5	11/10	3	9/1	0/0	39/11	4	43/10	3	0	27	0	248
5	1	143	2/4	8/13	ns	8/2	1/2	53/22	ns	1/0	ns	ns	ns	ns	260
															1157

YORK

Station / Round	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55	P61	TOT.
1	1	9	15	4	3/0	19/4	28/13	8	1	105
2	0	3	4	11	0/1	93/9	11/4	23	1	160
3	0	2	9	10	8/0	113/23	33/28	16	2	244
4	0	0	8	ns	2/1	58/24	16/5	ns	ns	114
5	0	3	1	22	11/4	11/6	19/12	22	1	112

Station / Round	**M33**	M37	**M41**	**M44**	**M47**	M52	TOT.
1	30/5	2	24/10	1/2	1/1	1	77
2	3/2	1	7/2	0/4	6/2	1	28
3	9/4	1	2/10	11/1	1/4	0	43
4	12/5	ns	1/3	2/0	0/0	ns	23
5	3/3	16	3/1	1/3	0/4	0	34
							940

RAPPAHANNOCK

Station / Round	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	TOT.
1	1	0	2/5	0/1	0	11/12	15/3	40/25	ns	ns	3	ns	118
2	0	0	4/3	1/0	8	32/20	34/11	63/15	2	3	5	6	207
3	0	1	3/2	0/0	1	8/10	31/8	25/10	6	ns	4	1	110
4	0	ns	0/1	0/0	ns	12/3	19/27	28/16	2	0	0	1	109
5	0	0	9/3	5/1	9	10/20	6/5	18/5	ns	ns	ns	ns	91
													635
													2732

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 the 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
Overall	25388	1.34	1.163	6.45	6.11-6.80	3490
Unweighted Annual Mean				6.79		26

Table 3. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1998 summarized by drainage and river.

	1998						All Years Combined					
Drainage River	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
James	760	2.08	1.096	16.02	11.51-22.01	60	9650	1.47	1.199	7.68	7.00-8.40	1158
James	617	2.33	1.028	21.14	14.64-30.13	40	5450	1.37	1.156	6.66	5.95-7.43	780
Chickahom.	143	1.59	1.083	8.90	4.61-15.87	20	4200	1.70	1.256	10.15	8.65-11.87	378
York	742	1.74	1.141	10.70	7.60-14.77	70	7634	1.22	1.048	5.46	5.02-5.92	1313
Pamunkey	559	2.28	1.262	20.04	11.80-33.10	30	3771	1.31	1.111	6.21	5.45-7.05	557
Mattaponi	183	1.33	0.850	6.36	4.33-9.03	40	3863	1.15	0.994	4.94	4.44-5.48	756
Rappahannock	582	1.97	1.174	14.11	9.48-20.57	50	8104	1.35	1.243	6.51	5.85-7.22	1019
Overall	2084	1.92	1.139	13.25	10.82-16.12	180	25388	1.34	1.163	6.45	6.11-6.80	3490

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1998 summarized by sampling period and month.

Month	1998						All Years Combined					
	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
July (1st)	355	1.90	1.061	12.97	8.43-19.44	36	7056	1.61	1.186	9.08	8.14-10.11	746
(2nd)	556	2.09	1.260	16.13	9.82-25.73	36	6418	1.43	1.202	7.27	6.47-8.14	757
Aug. (3rd)	513	2.11	1.139	16.56	10.61-25.27	36	4609	1.26	1.107	5.75	5.13-6.43	749
(4th)	381	1.74	1.290	10.67	6.14-17.63	36	4303	1.29	1.159	6.01	5.27-6.82	614
Sept. (5th)	279	1.75	0.911	10.90	7.45-15.58	36	2797	1.24	1.094	5.63	4.88-6.46	487

Table 5. Salinity (parts per thousand) recorded at 1998 seine survey stations.

Drainage															
JAMES															INDEX STATION
Station	J12	J22	**J29**	**J36**	**J42**	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	**MEAN**
Round															
1	13.6	5.9	2.8	0.6	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.7
2	12.5	6.1	6.4	2.6	0.6	0.5	0.7	0.2	0.1	0.1	0.2	0.1	0.1	0.1	1.6
3	14.2	8.2	5.0	4.0	ns	ns	0.8	0.2	0.1	0.1	0.2	0.1	0.1	0.2	2.0
4	12.9	8.5	4.5	2.3	1.2	1.2	1.1	0.3	0.2	0.1	0.2	0.1	0.1	0.1	1.6
5	15.0	8.0	6.2	3.5	ns	2.2	2.0	0.8	ns	0.5	ns	ns	ns	ns	2.4
															1.7

YORK															
Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
Round															
1	14.4	11.5	ns	2.4	0.2		0.1	0.0	0.0	0.0					0.5
2	15.2	11.9	9.6	2.9	0.7		0.2	0.1	0.0	0.1					0.9
3	16.1	13.5	10.7	4.0	1.3		0.4	0.2	0.1	0.1					1.2
4	16.2	13.9	11.8	ns	3.1		1.5	0.6	ns	ns					2.0
5	15.0	12.0	12.5	5.4	5.1		2.6	ns	ns	ns					3.9
															1.7
Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
Round															
1				2.7	0.6	0.2	0.0	0.0	0.0						
2				3.4	1.4	1.4	0.2	0.1	0.0						(included
3				5.1	3.4	1.4	0.2	0.1	0.0						above)
4				6.3	ns	1.5	0.6	0.3	ns						
5				ns	ns	ns	ns	ns	ns						

RAPPAHANNOCK														
Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
Round														
1	10.1	9.3	6.9	3.2	0.7	0.1	0.0	0.0	ns	ns	0.0	ns	2.0	
2	11.6	10.9	8.5	3.8	1.1	0.4	0.1	0.1	0.0	0.0	0.0	0.0	2.6	
3	12.1	11.4	9.0	4.4	2.5	1.5	0.4	0.1	0.0	ns	0.0	0.0	3.1	
4	13.1	ns	9.6	5.5	ns	1.7	0.2	0.3	0.1	0.1	0.0	0.1	3.5	
5	14.2	ns	10.9	6.3	3.4	2.0	1.6	1.0	ns	ns	ns	ns	4.4	
													3.1	

Table 6. Water temperature (°C) recorded at 1998 seine survey stations.

Drainage															
JAMES															INDEX STATION
Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	**MEAN**
Round															
1	30.4	31.4	26.0	25.7	28.7	28.0	28.1	29.9	27.5	27.4	29.4	30.2	30.3	29.9	27.5
2	29.2	28.7	27.3	26.8	29.4	29.3	29.0	30.2	29.5	28.8	30.7	32.3	32.9	32.3	28.6
3	26.7	27.8	29.3	26.5	27.4	27.3	27.9	28.7	25.7	26.4	29.0	29.7	31.3	29.2	27.7
4	27.8	27.7	30.0	25.6	32.5	27.8	23.3	30.1	27.3	25.3	27.4	29.7	28.9	28.1	27.0
5	26.7	26.1	27.1	20.6	ns	24.1	24.2	25.2	ns	26.0	ns	ns	ns	ns	24.5
															27.1
YORK															
Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
Round															
1	26.9	29.2	26.0	27.5	27.7		28.4	28.0	29.6	28.1					28.4
2	31.9	31.6	27.7	28.7	29.0		29.6	28.9	29.2	28.8					29.4
3	28.9	28.9	27.2	28.0	28.5		28.7	28.9	30.0	29.4					28.7
4	28.8	29.9	28.2	ns	28.8		29.0	28.9	ns	ns					29.1
5	26.7	27.2	22.6	24.7	25.0		24.9	24.9	24.6	23.4					25.6
															28.2
Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
Round															
1				27.6	27.6	27.6	28.1	31.2	29.4						
2				28.7	29.0	28.4	29.4	32.2	31.1						(included
3				28.0	28.0	27.9	28.4	30.5	29.8						above)
4				28.4	ns	28.6	29.2	30.8	ns						
5				25.0	26.7	26.1	25.6	27.8	26.7						
RAPPAHANNOCK															
Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
Round															
1	30.7	29.5	26.5	27.9		28.2	28.7	27.5	27.8	ns	ns	28.2	ns		27.7
2	27.5	29.8	29.7	28.9		28.5	29.4	29.8	31.2	30.0	30.1	30.8	31.9		29.8
3	27.5	28.4	27.5	27.8		27.8	28.1	27.8	27.9	27.6	ns	28.6	29.0		27.8
4	26.0	ns	27.3	27.9		ns	30.3	27.0	27.3	26.8	27.2	27.0	29.2		28.0
5	18.9	ns	21.4	23.9		22.6	23.4	27.8	27.4	ns	ns	ns	ns		24.8
															27.6

Table 7. Dissolved oxygen (milligrams per liter) recorded at 1998 seine survey stations.

Drainage															
JAMES															**INDEX STATION MEAN**
	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	
	Round															
	1	6.7	8.1	7.2	7.2	7.9	7.5	6.6	8.5	6.7	6.3	7.7	6.2	6.1	6.4	7.2
	2	3.8	5.0	6.8	6.2	8.5	7.5	6.0	6.2	6.1	7.1	10.0	6.3	6.6	6.8	6.6
	3	5.9	7.6	7.5	7.1	7.1	6.3	5.9	5.5	6.9	7.0	8.5	6.5	7.1	7.4	6.6
	4	7.2	7.1	8.4	6.9	9.5	8.5	7.4	7.7	6.3	7.0	10.1	7.0	7.5	6.7	7.7
	5	ns	ns	6.8	8.2	ns	8.8	7.9	8.1	ns	8.6	ns	ns	ns	ns	8.1
																7.2
YORK																
	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	Round															
	1	4.9	5.6	5.4	6.2	6.7		6.4	5.1	6.1	5.9					5.9
	2	8.7	6.9	5.3	5.1	5.8		5.4	4.6	4.3	4.0					5.2
	3	5.9	6.2	5.4	4.6	5.9		5.7	5.5	5.6	5.0					5.3
	4	7.5	7.3	5.8	ns	5.9		5.4	5.6	ns	ns					5.7
	5	ns	ns	5.9	5.9	6.2		6.9	5.9	5.8	6.6					6.3
																5.7
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	Round															
	1				5.9	5.5	4.5	5.3	7.6	6.2						
	2				4.1	4.9	5.2	5.1	6.5	5.8						(included above)
	3				3.7	4.1	4.7	5.0	6.9	5.7						
	4				4.9	ns	5.3	5.5	7.0	ns						
	5				ns	ns	ns	ns	ns	ns						
RAPPAHANNOCK																
	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Round															
	1	8.2	7.0	6.6	6.1		6.1	7.8	6.8	7.3	ns	ns	6.9	ns		6.9
	2	5.7	7.0	7.6	5.9		5.8	7.2	7.0	7.0	7.0	7.0	7.6	6.9		6.9
	3	5.5	5.7	7.5	5.9		6.0	5.6	7.5	7.3	6.7	ns	7.3	7.1		6.8
	4	5.0	ns	6.6	6.6		ns	7.5	7.2	7.8	6.3	8.6	6.9	7.3		7.1
	5	8.1	ns	8.1	7.8		8.5	7.9	6.1	6.5	ns	ns	ns	ns		7.3
																7.0

Table 8. pH recorded at 1998 seine survey stations.

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	**INDEX STATION MEAN**
	Round															
	1	7.7	7.8	7.6	7.7	8.4	7.8	7.5	8.5	7.8	8.0	8.1	7.6	7.6	7.8	7.9
	2	7.5	7.6	7.5	7.5	8.6	8.0	7.5	7.7	7.8	8.1	8.8	7.6	8.0	8.1	7.7
	3	7.5	7.7	7.7	7.6	8.0	7.6	7.3	7.7	7.6	8.0	8.7	7.8	8.1	8.0	7.7
	4	7.9	7.8	8.1	7.7	8.7	8.2	7.7	8.2	8.2	8.3	9.0	8.0	8.4	8.5	8.0
	5	ns	ns	7.6	7.4	ns	8.0	7.0	8.3	ns	8.3	ns	ns	ns	ns	7.8
																7.8
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61					
	Round															
	1	7.3	7.2	7.2	7.0	7.1		7.2	7.1	7.3	7.0					6.9
	2	8.0	7.7	7.3	7.0	7.0		7.1	6.9	7.0	7.0					6.9
	3	7.9	7.4	7.3	7.0	7.0		7.0	7.0	7.0	7.1					6.9
	4	7.9	7.7	7.4	ns	7.1		7.1	7.2	ns	ns					7.0
	5	ns	ns	7.3	7.3	7.3		7.4	7.4	7.2	7.4					7.4
																7.0
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	Round															
	1				6.8	6.9	6.7	6.7	6.8	6.6						
	2				6.8	6.8	6.7	6.7	6.9	6.7						(included above)
	3				6.8	6.8	6.8	6.8	7.0	6.8						
	4				7.0	ns	6.8	6.9	6.9	ns						
	5				ns	ns	ns	ns	ns	ns						
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Round															
	1	8.1	7.9	7.5	7.2		7.0	7.6	7.3	7.5	ns	ns	7.0	ns		7.4
	2	7.6	7.8	7.9	7.3		7.0	7.5	7.5	7.7	7.6	7.6	8.0	8.2		7.6
	3	7.7	7.9	7.8	7.3		7.0	7.4	7.7	7.7	7.4	ns	7.6	7.6		7.6
	4	7.7	ns	7.4	7.6		ns	7.9	7.8	7.9	7.7	8.9	7.9	8.0		7.7
	5	7.8	ns	7.7	7.7		7.8	7.8	7.6	7.6	ns	ns	ns	ns		7.7
																7.6

Table 9. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1998 summarized by salinity.

	1998						All Years Combined					
Salinity (ppt.)	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
0-4.9	1956	1.99	1.175	14.39	11.51-17.86	154	23543	1.43	1.167	7.27	6.87-7.69	2976
5-9.9	128	1.50	0.790	7.92	5.21-11.63	26	1726	0.99	1.049	3.85	3.22-4.55	376
10-14.9							117	0.42	0.616	1.18	0.81-1.60	119
15-19.9							2	0.07	0.219	0.17	-0.06-0.43	19
Overall	2084	1.92	1.139	13.25	10.82-16.12	180	25388	1.34	1.163	6.45	6.11-6.80	3490

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1998 summarized by water temperature.

Temp. (deg. C)	1998 Total	1998 Mean ln(x+1)	1998 Std. Dev.	1998 Adjust. Mean	1998 C.I. (± 2 SE)	1998 N	All Years Combined Total	All Years Combined Mean ln(x+1)	All Years Combined Std. Dev.	All Years Combined Adjust. Mean	All Years Combined C.I. (± 2 SE)	All Years Combined N
15-19.9							79	0.81	0.908	2.85	1.40-4.86	30
20-24.9	130	1.75	0.962	10.86	6.07-18.40	18	1737	0.87	0.960	3.15	2.71-3.64	509
25-29.9	1678	1.93	1.137	13.45	10.74-16.74	144	18518	1.44	1.163	7.38	6.92-7.85	2334
30-34.9	276	1.98	1.352	14.23	6.45-28.96	18	4674	1.50	1.210	7.90	6.88-9.04	524
Overall	2084	1.92	1.139	13.25	10.82-16.12	180	25388	1.34	1.163	6.45	6.11-6.80	3490

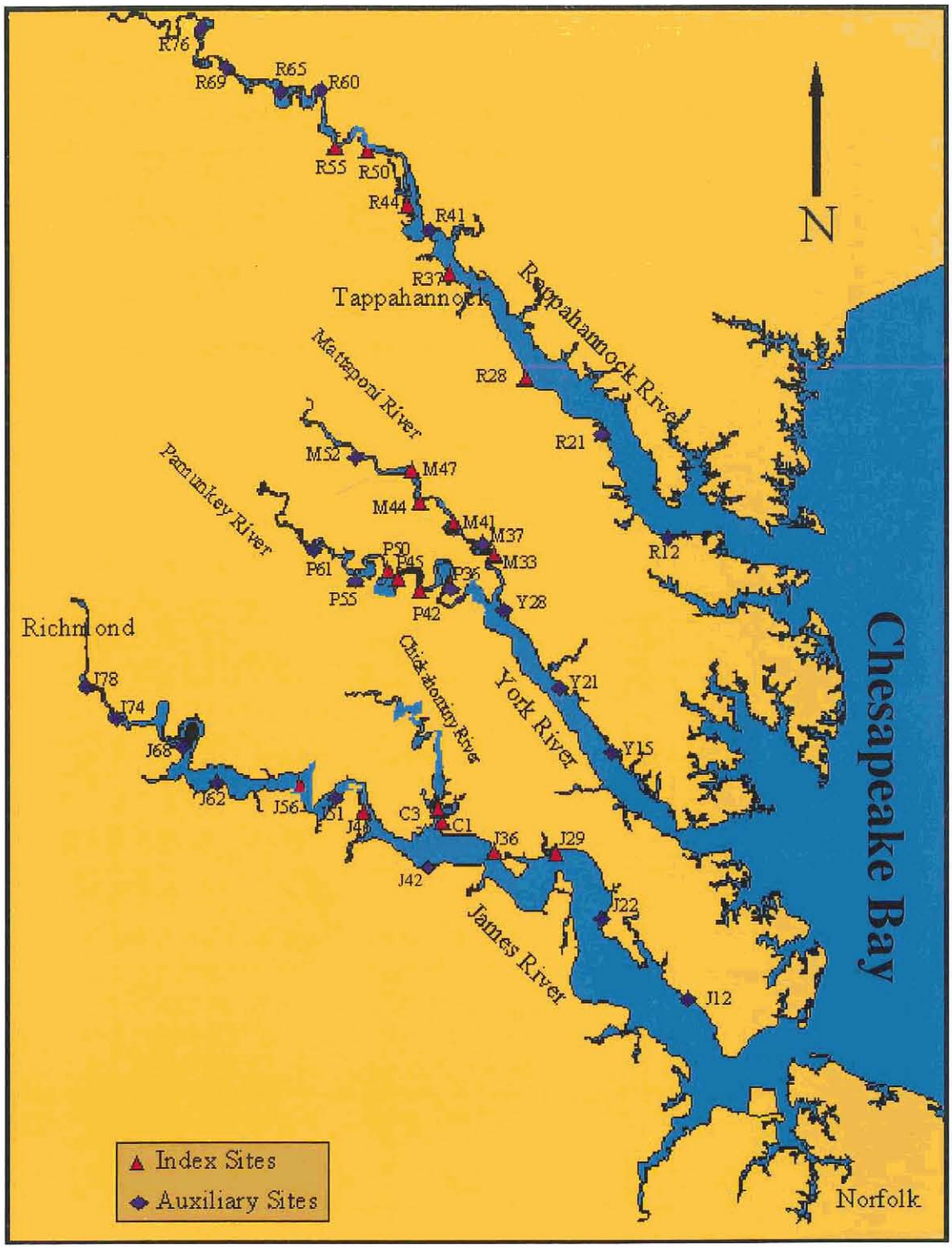

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designations indicate river mile from the mouth.

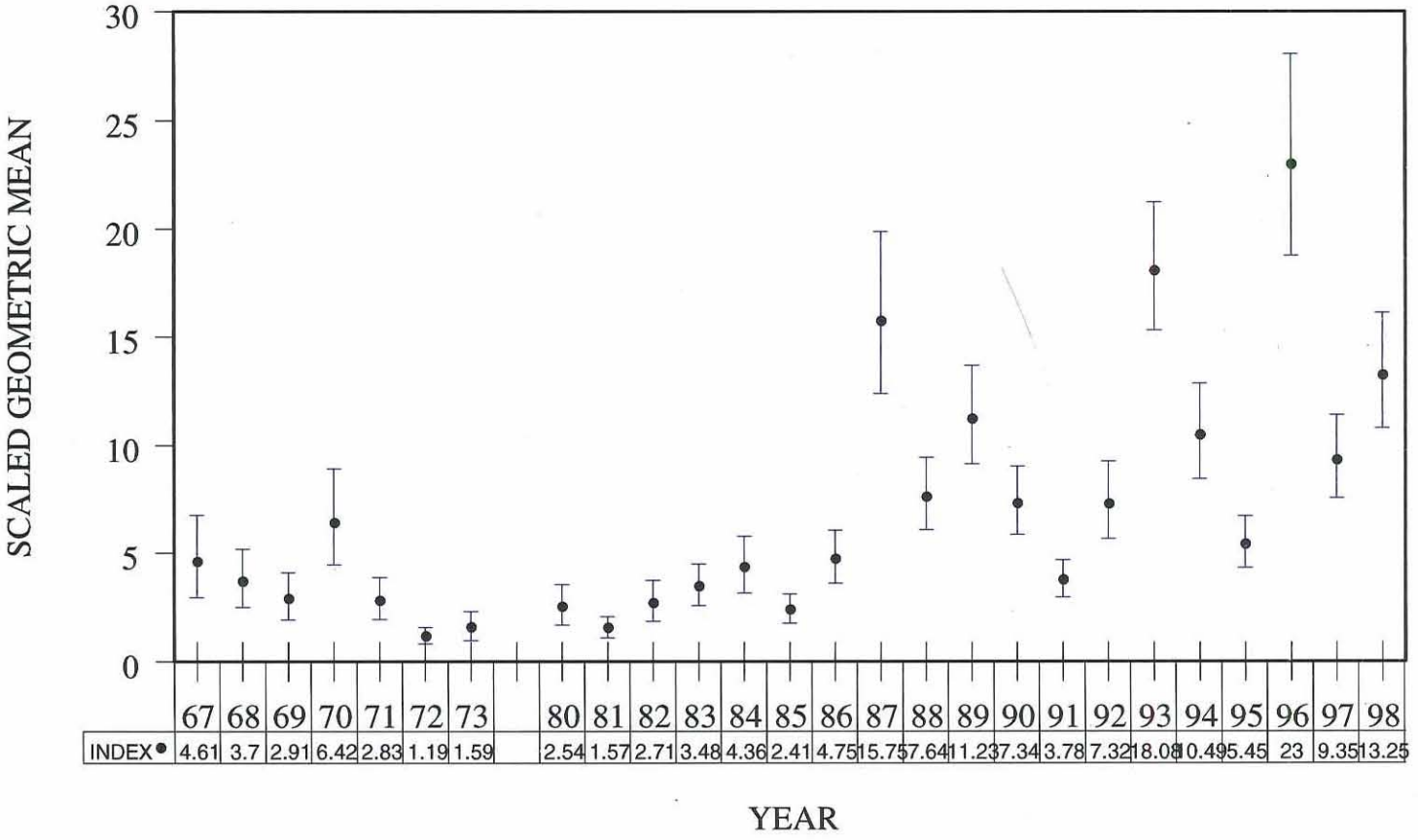

Figure 2. Scaled average catch of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ±2 standard errors of the mean

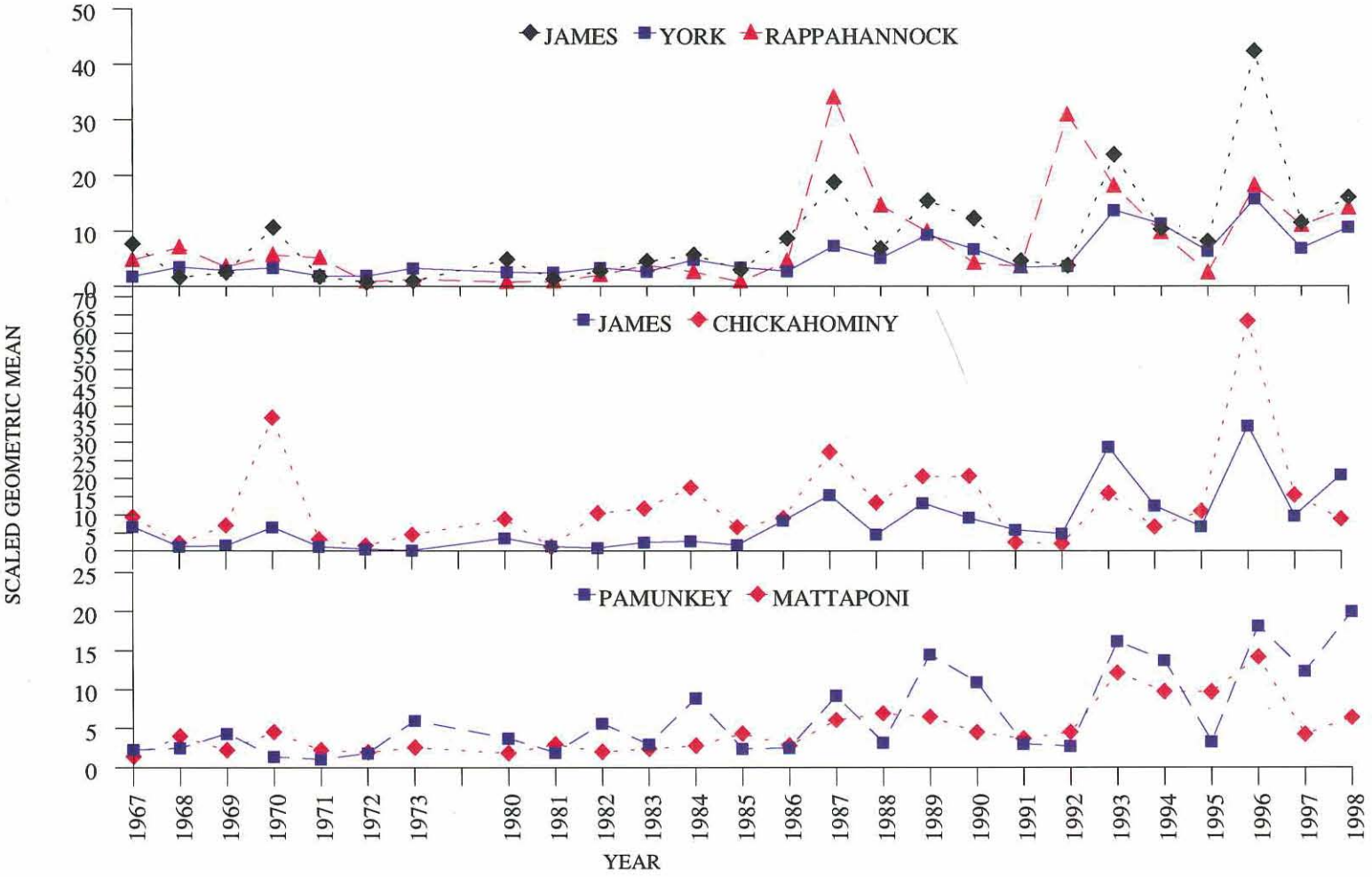

Figure 3. Adjusted average annual catch of young-of-the-year striped bass per seine haul in the primary nursery area by drainage and river.

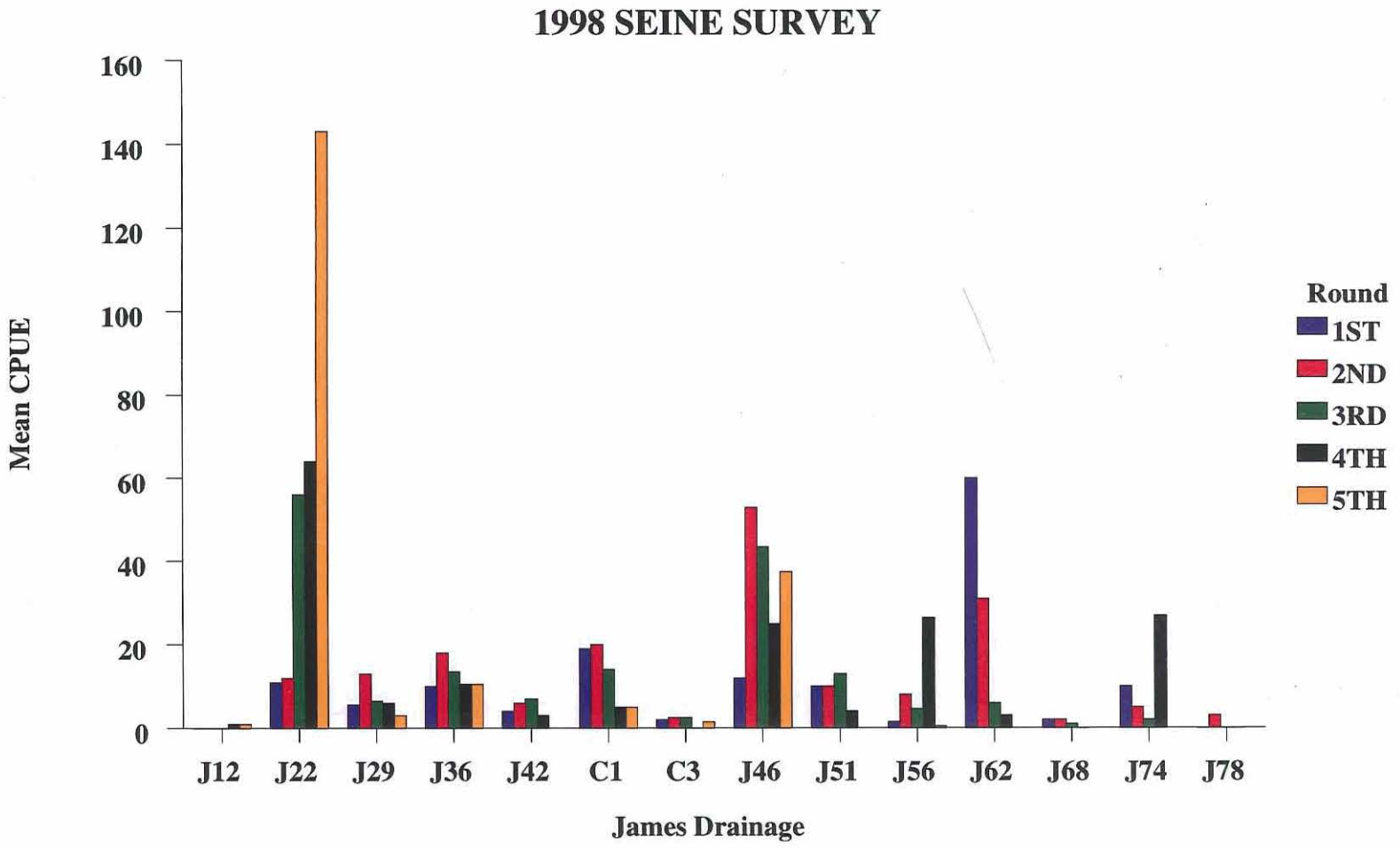

Figure 4. Average catch of young-of-the-year striped bass per seine haul by station in the James drainage.

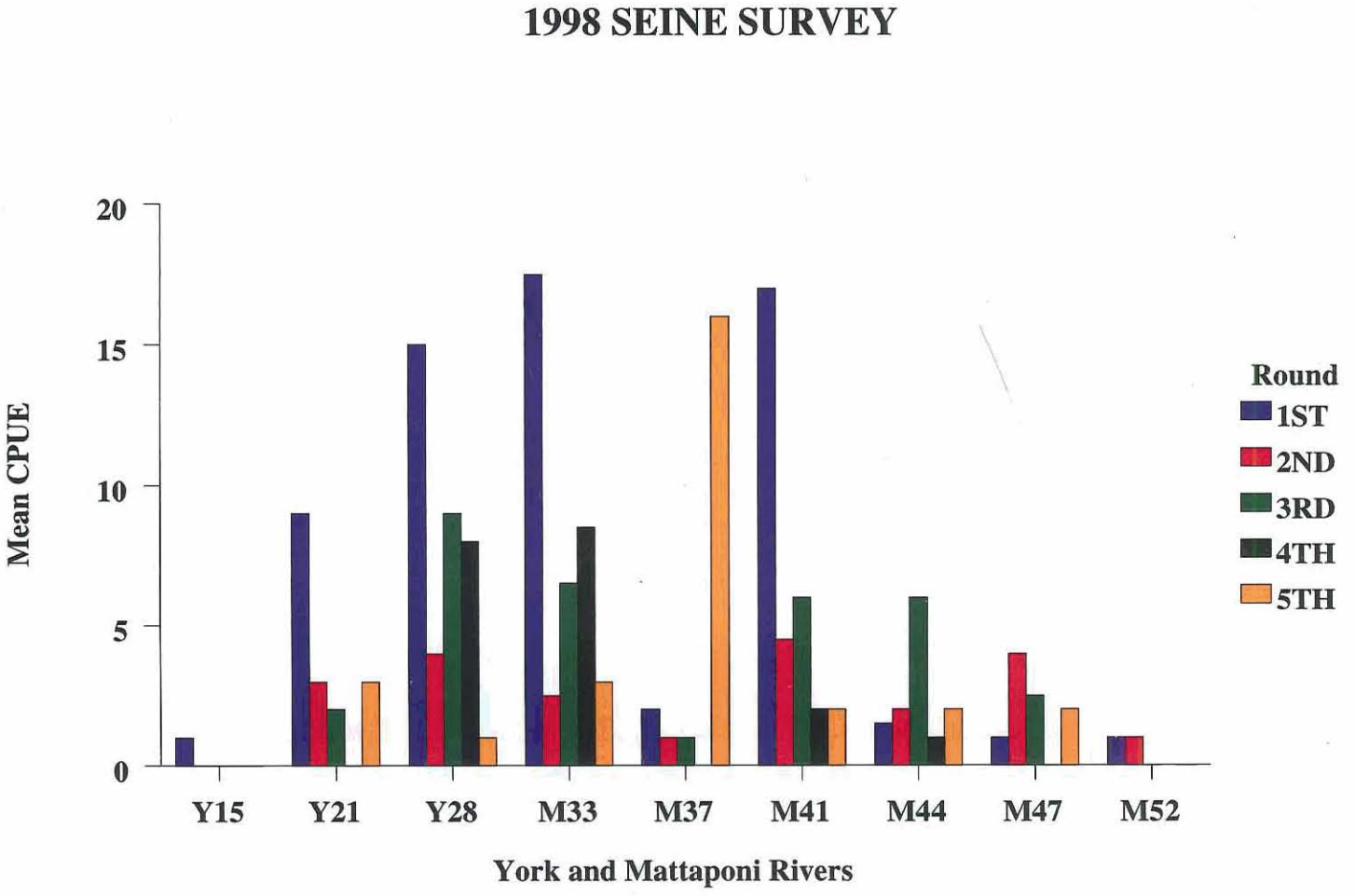

Figure 5. Average catch of young-of-the-year striped bass per seine haul by station in the Mattaponi and York rivers.

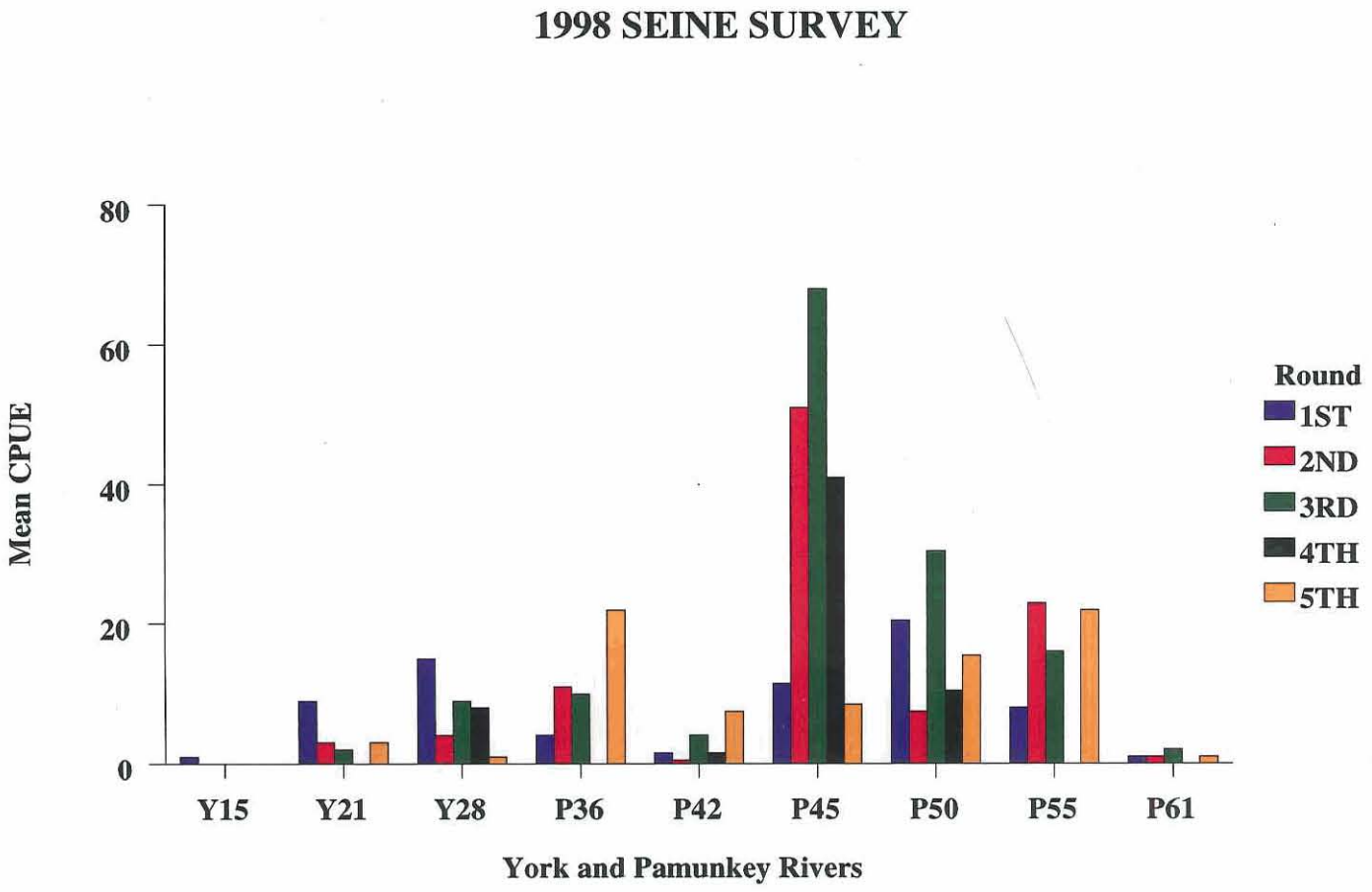

Figure 6. Average catch of young-of-the-year striped bass per seine haul by station in the Pamunkey and York rivers.

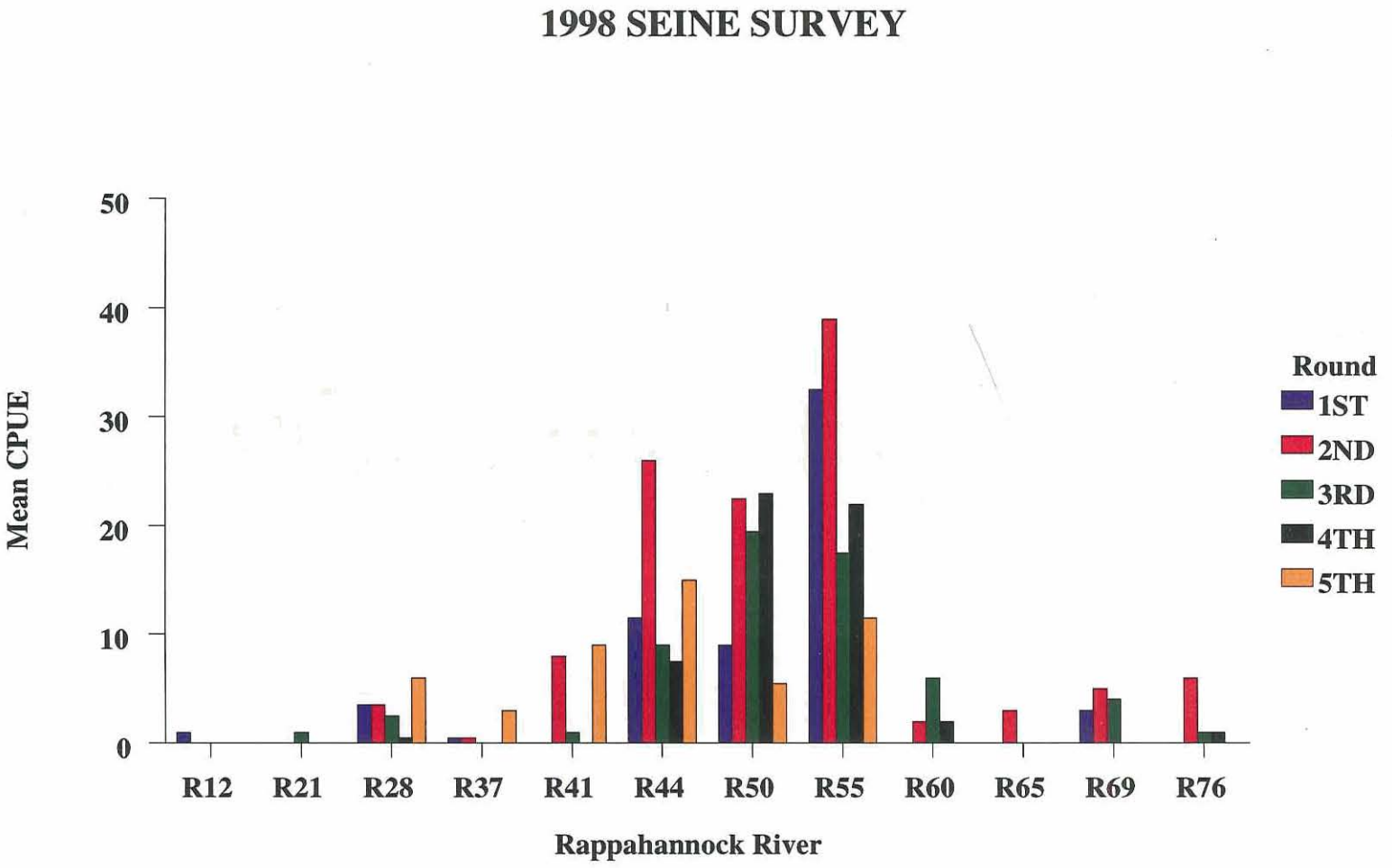

Figure 7. Average catch of young-of-the-year striped bass per seine haul by station in the Rappahannock River.