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Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 1994-December 1994 : annual progress report

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ANNUAL PROGRESS REPORT

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

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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 nursery areas of Lower Chesapeake Bay. The survey was funded in it's initial period by the U.S. Fish and Wildlife Service and then 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 made jointly 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 1994 sampling period and compares theses results with the previous work.

Specific objectives planned for the 1994 program were too:

1. Measure the relative abundance of the 1994 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, while funded by the U.S. Fish and Wildlife Service, is part of a coast-wide sampling program of striped 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 December 1994.

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 studies 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 1994. During each sampling period beach seine hauls were conducted at eighteen historically sampled sites (index stations) and 22 auxiliary stations along the shores of the James, York and Rappahannock river systems (Fig. 1). Addition of the auxiliary sites 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.

One seine haul was made at each auxiliary station, and two replicate 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 downcurrent 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, the first sample was processed in the period between the two hauls and an intervening period of 30 minutes was allowed between 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 (Sokal and Rohlf 1981) prior to analyses. Subsequently computed mean values were retransformed (i.e. the geometric mean), but because the geometric means of such a strongly

skewed distribution are much smaller than the arithmetic means, for comparative purposes (particularly with respect to the results of the Maryland survey, wherein arithmetic means are reported) the geometric means have been scaled up to the arithmetic means by multiplication by the ratio of the overall arithmetic to geometric means as of the 1984 survey (2.28).

Mean catch rates are contrasted by comparing 95% confidence intervals as estimated by $\pm$ two standard errors (square root of the variance divided by n) of the mean. 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 1994 year class of juvenile striped bass from the James, York and Rappahannock river systems.

A total of 1510 young-of-the-year striped bass were collected from 180 seine hauls during the 1994 index station sampling, and an additional 293 age 0 striped bass were collected in 104 hauls at the auxiliary sites (Fig. 1, Table 1). The adjusted overall mean catch per seine haul (CPUE) for the index stations was 10.48 which is the fourth highest value for the 22 years sampled (Table 2,Fig. 2). This value is about two times the overall average index of 5.56 and the unweighted (by sample size) annual mean index of 5.72. This favorable overall result was seen across all drainages, with all drainages at or near historical highs and suggests that the index is due to a very

strong year class (Fig. 3).

The 1994 catch rate in the James drainage as a whole (10.28) was nearly twice the historical average (Table 3 Fig. 3). The 1994 index in the mainstem James (12.61), was nearly two and one-half times the historical average, while the Chickahominy River results continued a pattern of below average recruitment observed in three of the last four years. Highest catch rates were observed in the center of the index station sampling area (particularly C1 and J36), although the most downriver auxiliary station (J12) was more productive than the most upriver index station (J56) (Table 3 Fig. 4). Due to the strong year class, higher catches were observed throughout the entire sampling area with the highest CPUEs, J12 being the exception, observed at our index stations.

The 1994 index in the York drainage (11.24) was two and one-half times the historical average and second only to 1993's record index (Table 3,Fig. 3). Catch rates in the Pamunkey River were once again extremely high (13.76), marking the second consecutive year that catches have been significantly higher than the historical average (Fig. 3, Table 3). A similar increase was seen in the Mattaponi River where the index (9.61) was near 1993's record level (Table 3). Striped bass in the York system were captured at all stations at least once and the center of abundance was within the index area (Figs. 5-6, Table 1). Abundances in the Mattaponi drainage clearly increased with an upriver progression (Fig. 5). A zero catch at M44 during round 3 caused the total catch at M44 to be slightly less than that at M41 but the trend of higher catches upriver within the index area is quite evident. In the Pamunkey, all stations had consistent catches of juvenile striped bass

(Fig. 6) during each round. Catches at P50 however, were always significantly higher than any other station and it alone accounted for nearly three-quarters of the total catch at the index stations.

The 1994 index in the Rappahannock River (9.71) was approximately twice the historical average (Table 3) although only one-half the value seen in 1993(Fig. 3). Juveniles were primarily concentrated in the index station area and reversed a pattern of upriver displacement of the nursery area seen in 1992 and 1993 (i.e. R60), even though the two uppermost index stations were the most productive and represented the center of juvenile abundance (Fig. 7). Small numbers of juveniles were seen regularly at the upriver auxiliary stations, but the auxiliary stations downstream of the historical sampling area (R12 and R21) produced no juvenile striped bass.

Similiar to most years sampled, the highest catch rates were seen during the early rounds, followed by a decreased catch rate in later rounds (Table 4). Because the number and precise timing of sampling rounds has varied throughout the history of the sampling program, results by sampling period cannot be compared on a directly corresponding basis. 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. Results from 1994 indicate a return to the normally observed pattern, with July being the month of highest abundance versus 1993 when highest catches were in August.

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

Collection information and pertinent environmental variables recorded at the time of each collection in 1994 are given in Tables 5 through 8. No particularly unusual conditions were encountered and all five sampling rounds were completed at the index stations. Severe thunderstorms on the Pamunkey River forced the cancellation of P55and P61 during the first round, while rising water from a coastal storm caused us to lose the available beach at R65 and R76 during the fourth round. The middle auxiliary station on the James (J62) could not be sampled during the first two rounds due to the construction of a residential area adjacent to the site and a suitable replacement site was not be located until the third round.

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 1994 followed the normally observed pattern i.e. a definitive trend towards higher catches at lower salinities (Table 9). There was no apparent relationship between catch and salinity between any of the five rounds. Overall mean catches were highest in the areas of lowest salinities (0-4.9ppt), however there were some exceptions, notably J12 (Fig. 4) and R28 (Fig.7) where catch rates were generally higher than at stations just upriver from these sites. Station J12 is a higher salinity station (10-14.9ppt) and R28 is an intermediate salinity station (5-9.9ppt).

Catch rates with respect to water temperature in 1994 clearly adhered to the pattern seen in most previous years, i.e. catch rates varied directly with water temperature (Table 10). As noted in previous reports, this relationship is considered to be largely the result of a coincident

downward progression of both catch rates and temperature as the survey season progresses (at least after the second sampling round) rather than any causative effect of water temperature on juvenile distribution. The increased size and thus the increased gear escapement or avoidance play a larger role in this trend.

Data on pH, dissolved oxygen concentrations and secchi disc visibility depth readings have only been recorded with the seine collections since the expansion of the sampling program in 1989. Dissolved oxygen concentrations generally exceed 5 ppm outside of the York system, and should have little or no effect on juvenile striped bass distributions. The lowest dissolved oxygen concentrations observed during 1994 sampling occurred during the second sampling round at the lowermost Mattaponi station (M33) and at the lowest Rappahannock station (R12), when concentrations were around 4 ppm (Table 7). Juvenile striped bass were collected during both visits on the Mattaponi and R12 has never produced a striped bass. Low pH values (<6.5) were observed in the Mattaponi during round 3, in the two lower York stations (Y15 and Y21), and in a few James stations (J22 and C3 in round 2; J12 in round 4) (Table 8). There was no evidence of any negative effect on juvenile distribution. All of these parameters, as well as those previously discussed and undoubtedly others which are not currently measured, probably exert complex and interrelated effects on juvenile striped bass distribution, catchability and survival, and more years of data will be required before meaningful assessments of the effects of the newly measured parameters can be attempted.

DISCUSSION AND CONCLUSIONS

The striped bass juvenile indices recorded in the Virginia Chesapeake Bay nursery areas in 1994 were all well above historical averages (Table 3). The index as a whole was nearly twice the historical average. Only the Chickahominy (two index stations) had an individual index value that fell below the historical average. Even so, it was only slightly below the average despite having reduced catches in all but the first round (Fig. 4). Though the index (10.48) was nearly twice the historical average, it was slightly more than half of the 1993 record index value (18.12). Each river system contributed nearly equally to the index (Table 3) and no one system drove the index (as in 1987 and 1992), making 1994 a strong overall year class. The 1994 overall index value was the fourth highest index recorded in the Virginia Chesapeake Bay nursery areas (Table 2). Virginia has now experienced two consecutive large and strong year classes that should heavily contribute to the continued recovery of striped bass stocks. Additionally, in seven of the last eight years the indices have been above the historical average and all seven surpassed the 1970 index, generally accepted as "the" dominant year class. The slow natural recovery and enhancement seen since the inception of the Interstate Fisheries management plan, and noted by Austin et. al. in 1993, certainly continued in 1994 and should contribute heavily to future spawning stocks.

While striped bass recruitment success in the Virginia portion of Chesapeake Bay clearly remains highly variable between years and between the different nursery areas within years, it is evident that these fluctuations have been bracketing a much higher average over the past eight years. This pattern is consistent with a possible increase in spawning stock size resulting from the stringent harvest regulations in place over the period.

The 1994 catch was well represented by the index stations with only a couple of the auxiliary stations, J12 (a higher salinity station on the James) and R60 (a low salinity station on the Rappahannock) outproducing some index stations (Fig. 4-7). The Rappahannock station was adjacent to the index area but J12 is the lowermost station on the James. There seems to be no explanation for why this station attracted striped bass in those numbers. However, the addition of these auxiliary stations was to provide a better areal coverage of the systems. These additional areas of coverage have revealed that in years of high or low salinities and abundances there may be a shift in the traditional nursery areas (salinities) either up or downriver or there may be a dispersion of fish up and/or downriver (abundance). Though the main nursery area seemed well represented by the index stations in 1994, there was some use of both upriver and downriver auxiliary sites in all rivers as 1994 was a large yearclass. The only exception occurred in the lower Rappahannock where only one striped bass has been captured since the inception of sampling these auxiliary sites.

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Table 1. Catch per seine haul of young-of-the-year striped bass during the 1994 survey. Two hauls were made per sampling round at each of the historical index stations (bold).

Drainage

JAMES

Station / Round	J12	J22	**J29**	**J36**	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	TOT.
1	10	4	2/0	10/7	41/37	5/1	12/6	5	6/1	ns	1	0	3	151
2	25	2	9/10	18/15	4/1	2/1	12/12	13	24/4	ns	4	7	2	165
3	6	1	6/2	8/6	9/10	1/1	12/4	6	9/7	16	1	0	5	110
4	15	2	9/6	2/6	15/9	0/0	1/4	1	6/6	0	2	3	1	88
5	0	2	16/10	5/5	2/2	0/0	4/4	5	1/0	0	0	0	0	56
														570

YORK

Station / Round	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61				
1	0	5	4	5	2/3		5/6	16/22	4	2				74
2	0	2	4	3	1/2		7/0	8/11	ns	ns				39
3	1	0	1	2	26/2		8/6	74/29	8	3				159
4	0	1	0	1	3/0		6/2	41/19	0	1				74
5	0	1	1	5	5/1		4/3	18/6	0	3				47

Station / Round				**M33**	M37	**M41**	**M44**	**M47**	M52					
1				15/5	3	0/3	1/2	4/4	0					36
2				0/1	9	24/15	8/1	50/9	1					118
3				1/1	5	15/8	0/0	10/1	4					45
4				0/1	5	16/4	44/5	15/16	0					106
5				0/0	1	12/1	10/3	57/13	0					97
														795

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Station / Round	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
1	0	0	19/8	0/1		1	4/4	19/9	29/13	4	5	0	9	126
2	0	0	4/3	4/2		6	2/1	20/15	31/37	10	1	1	4	141
3	0	0	7/5	1/7		4	2/4	13/11	18/9	8	0	0	1	90
4	0	0	3/0	1/3		2	8/0	3/1	17/1	3	ns	1	ns	43
5	0	0	0/2	1/1		4	1/0	5/3	8/11	0	0	0	2	38
														438
														1803

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	219	1.11	0.993	4.61	2.97-6.77	53
1968	218	0.96	0.906	3.70	2.50-5.19	66
1969	219	0.82	0.908	2.91	1.94-4.11	77
1970	469	1.34	1.115	6.42	4.47-8.93	77
1971	185	0.81	0.847	2.83	1.95-3.90	80
1972	103	0.42	0.588	1.19	0.83-1.59	116
1973	139	0.53	0.790	1.59	0.98-2.32	84
1980	229	0.75	0.901	2.54	1.70-3.56	89
1981	165	0.52	0.691	1.57	1.10-2.09	116
1982	324	0.78	0.968	2.71	1.86-3.75	106
1983	300	0.93	0.832	3.48	2.60-4.51	102
1984	464*	1.07	1.009	4.36	3.18-5.80	106
1985	322	0.72	0.859	2.41	1.78-3.14	142
1986	672	1.13	1.038	4.75	3.63-6.08	144
1987	2192	2.07	1.228	15.75	12.4-19.9	144
1988	1349	1.47	1.127	7.64	6.11-9.45	180
1989	1981	1.78	1.119	11.23	9.15-13.7	180
1990	1248	1.44	1.095	7.34	5.89-9.05	180
1991	668	0.98	0.951	3.78	2.98-4.70	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
Overall	17202	1.24	1.121	5.56	5.23-5.90	2762
Unweighted Annual Mean				5.76		22

* adjusted figure (see 1984 report)

Table 3. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1994 summarized by drainage and river.

	1994						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	428	1.71	0.928	10.28	7.60-13.68	60	6161	1.32	1.148	6.29	5.66-6.97	911
James	287	1.88	0.744	12.61	9.49-16.56	40	3423	1.21	1.097	5.34	4.69-6.05	613
Chickahom.	141	1.37	1.164	6.65	3.03-12.76	20	2738	1.57	1.213	8.63	7.20-10.28	298
York	710	1.71	0.928	11.24	7.60-13.68	70	4768	1.12	0.977	4.73	4.32-5.17	1032
Pamunkey	336	1.95	1.054	13.76	8.64-21.29	30	2401	1.20	1.039	5.26	4.54-6.04	436
Mattaponi	374	1.65	1.208	9.61	5.84-15.15	40	2367	1.07	0.927	4.37	3.88-4.89	596
Rappahannock	372	1.66	1.004	9.71	6.74-13.64	50	6273	1.28	1.242	5.90	5.22-6.64	819
Overall	1510	1.72	1.034	10.48	8.66-12.60	180	17202	1.24	1.121	5.56	5.23-5.90	2762

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1994 summarized by sampling period and month.

Month	1994 Total	1994 Mean ln(x+1)	1994 Std. Dev.	1994 Adjust. Mean	1994 C.I. (± 2 SE)	1994 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
July (1st)	322	1.83	1.005	11.98	7.92-17.65	36	7108	1.48	1.163	7.77	7.01-8.59	872
(2nd)	368	1.92	1.054	13.33	8.70-19.90	36						
Aug. (3rd)	333	1.87	0.965	12.49	8.42-12.49	36	6497	1.29	1.112	6.00	5.44-6.60	1011
(4th)	273	1.59	1.082	8.95	5.55-13.82	36						
Sept. (5th)	214	1.39	1.018	6.88	4.25-10.58	36	3597	0.93	1.013	3.47	3.09-3.88	879
Overall	1510	1.72	1.034	10.48	8.66-12.60	180	17202	1.24	1.121	5.56	5.23-5.90	2762

Table 5. Salinity (parts per thousand) recorded at 1994 seine survey stations.

Drainage
JAMES

Station / Round	J12	J22	**J29**	**J36**	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	MEAN
1	14.4	7.3	4.5	0.6	0.5	1.1	0.1	0.1	0.1	ns	0.1	0.1	0.1	2.4
2	3.7*	7.2	4.5	1.0	0.9	1.7	0.2	0.1	0.1	ns	0.1	0.1	0.1	1.6
3	15.4	7.4	4.4	0.5	0.4	1.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.3
4	14.7	5.1	2.3	0.2	0.3	0.4	0.1	0.2	0.1	0.2	0.1	0.0	0.0	1.8
5	15.9	3.4	4.8	0.6	0.4	1.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.1
														2.1

YORK

Station / Round	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61				
1	15.2	12.6	9.0	2.1	0.4		0.1	0.1	0.1	0.0				2.8
2	17.0	13.5	9.8	2.1	0.5		0.1	0.1	ns	ns				3.5
3	16.4	12.5	8.6	1.2	0.1		0.0	0.0	0.0	0.0				2.6
4	16.5	11.7	8.4	0.3	0.0		0.0	0.0	0.0	0.0				2.6
5	16.6	14.1	9.8	2.5	0.3		0.1	0.0	0.0	0.0				3.2
														3.0

Station / Round				**M33**	M37	**M41**	**M44**	**M47**	M52					
1				2.0	0.7	0.1	0.0	0.0	0.0					
2				1.7	0.6	0.2	0.0	0.0	0.0					(included
3				0.7	0.1	0.0	0.0	0.0	0.0					above)
4				1.5	0.4	0.1	0.0	0.0	0.0					
5				3.8	1.5	0.3	0.0	0.0	0.0					

RAPPAHANNOCK

Station / Round	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
1	11.4	13.8	7.4	3.0		0.0	0.4	0.1	0.1	0.0	0.0	0.0	0.0	2.8
2	11.8	11.3	9.0	4.0		1.4	0.8	0.1	0.1	0.0	0.0	0.0	0.0	3.2
3	11.5	10.8	7.7	2.4		0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.8
4	13.5	9.7	7.1	0.6		0.1	0.1	0.0	0.0	0.0	ns	0.0	ns	3.1
5	14.5	11.3	9.4	3.6		1.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.6
														2.9
														2.2

* questionable reading.

Table 6. Water temperature (°C) recorded at 1994 seine survey stations.

Drainage
JAMES

Station	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
Round														
1	28.1	30.2	30.2	27.2	28.5	29.5	29.7	29.1	29.3	ns	31.7	33.9	31.8	30.0
2	27.1	25.1	30.4	27.0	28.3	28.7	29.5	29.4	28.9	ns	31.6	32.2	30.4	29.1
3	26.6	26.2	28.1	24.7	26.1	26.5	27.7	28.3	28.0	28.5	29.1	29.8	29.4	27.6
4	25.4	24.7	27.4	24.5	25.8	26.4	27.2	26.5	26.3	29.2	25.9	24.1	24.0	26.0
5	22.0	24.5	25.2	22.3	23.7	23.8	24.8	24.0	23.1	24.2	25.9	25.9	24.7	24.2
														ÄÄÄÄÄÄÄ
														27.2

YORK

Station	Y15	Y21	Y28	P36	P42		P45	P50	P55	P61				
Round														
1	29.5	28.1	28.6	29.4	29.8		30.2	30.3	31.3	31.0				30.0
2	26.4	26.8	27.6	28.9	29.3		29.4	29.7	ns	ns				28.4
3	28.8	28.6	25.1	26.4	26.9		26.9	26.6	27.4	27.1				27.2
4	24.4	24.5	24.3	25.9	26.6		26.6	26.4	25.6	24.8				25.8
5	27.0	28.5	24.4	24.6	25.3		25.8	24.8	25.3	24.8				25.3
														ÄÄÄÄÄÄÄ
														27.3

Station			M33	M37	M41	M44	M47	M52					
Round													
1			29.4	29.9	29.9	30.6	30.9	31.2					
2			28.5	28.4	28.5	28.5	28.6	28.4					(included
3			27.1	27.7	26.6	27.4	28.0	27.8					above)
4			26.1	26.5	26.0	26.5	26.6	25.5					
5			24.5	25.1	24.1	24.2	26.9	24.4					

RAPPAHANNOCK

Station	R12	R21	R28	R37		R41	R44	R50	R55	R60	R65	R69	R76	
Round														
1	32.1	27.9	29.2	31.1		31.1	32.3	29.3	29.3	29.5	30.7	30.2	30.2	30.2
2	27.0	27.3	30.2	28.8		28.9	29.5	30.4	30.4	30.3	30.6	31.5	31.3	29.7
3	23.9	28.2	25.3	25.8		26.6	27.4	27.4	27.6	27.9	29.0	27.8	27.8	27.1
4	24.4	25.3	26.5	27.3		26.5	27.7	26.5	27.3	26.0	ns	25.6	ns	26.3
5	22.3	23.0	23.6	25.3		24.6	25.1	25.5	25.7	26.0	25.1	25.7	25.8	24.8
														ÄÄÄÄÄÄÄ
														27.7
														ÄÄÄÄÄÄÄ
														27.4

Table 7. Dissolved oxygen (parts per million) recorded at 1994 seine survey stations.

Drainage														
JAMES														
Station	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
Round														
1	6.4	6.1	6.5	5.3	7.8	6.7	6.7	7.9	8.5	ns	6.4	5.7	6.7	6.6
2	6.8	7.4	7.4	6.7	7.7	6.3	6.2	6.2	6.8	ns	6.2	5.0	5.9	6.6
3	ns	ns	8.7	7.8	7.6	7.3	5.7	6.3	6.2	7.6	5.7	5.5	7.3	6.9
4	6.8	7.6	8.5	7.4	8.9	7.3	7.9	6.3	5.8	5.8	6.1	7.1	6.9	7.1
5	4.8	5.9	8.6	6.9	8.4	7.4	7.8	6.1	6.4	8.5	6.7	7.5	7.7	7.1
														ÄÄÄÄÄÄÄ
														6.9
YORK														
Station	Y15	Y21	Y28	P36	P42		P45	P50	P55	P61				
Round														
1	8.2	7.0	5.8	5.0	5.3		5.4	5.6	6.5	ns				6.0
2	7.5	6.4	5.8	4.9	5.4		7.0	6.4	ns	5.8				5.4
3	ns	ns	6.6	5.1	5.8		6.0	5.3	5.6	ns				5.5
4	6.7	6.1	6.7	5.6	7.0		7.2	6.4	5.8	4.5				5.9
5	6.0	8.4	6.8	6.4	6.5		6.6	6.5	5.4	4.2				6.1
														ÄÄÄÄÄÄÄ
														5.8
Station				M33	M37	M41	M44	M47	M52					
Round														
1				6.2	5.3	5.5	5.9	6.0	5.4					
2				3.9	3.9	4.4	5.4	4.7	4.9					(included
3				4.4	5.4	7.2	4.3	4.9	5.3					above)
4				5.5	5.2	4.8	4.5	5.6	5.4					
5				4.6	5.4	5.4	4.9	6.0	5.6					
RAPPAHANNOCK														
Station	R12	R21	R28	R37		R41	R44	R50	R55	R60	R65	R69	R76	
Round														
1	8.5	6.0	7.0	7.2		7.7	8.0	6.7	6.8	7.0	7.7	7.3	7.2	7.4
2	3.6	5.5	8.7	6.5		6.6	7.1	6.4	5.6	6.5	6.9	6.0	6.5	6.3
3	6.9	6.6	7.9	8.3		8.4	9.3	5.2	5.1	5.1	6.4	6.0	4.8	6.7
4	6.0	6.0	7.5	8.5		7.6	8.4	5.9	6.6	7.1	ns	5.6	ns	6.9
5	4.3	5.8	7.6	6.9		7.8	7.4	6.3	5.7	4.7	5.9	7.0	6.4	6.3
														ÄÄÄÄÄÄÄ
														6.7
														ÄÄÄÄÄÄÄ
														6.5

Table 8. pH recorded at 1994 seine survey stations.

Drainage
JAMES

Station	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
Round														
1	7.9	8.2	8.2	8.0	8.5	6.7	8.5	8.7	8.7	ns	7.9	8.0	8.1	8.2
2	6.6	6.3	8.2	7.6	8.4	6.3	8.0	8.0	8.4	ns	7.4	7.5	7.8	7.7
3	7.9	7.9	8.2	8.0	8.6	7.3	7.6	7.7	7.6	7.8	7.2	7.3	7.8	7.8
4	6.2	ns	8.3	8.1	8.6	7.3	7.9	7.1	7.5	7.3	7.4	7.2	7.2	7.6
5	7.6	8.1	8.3	7.8	8.5	7.4	8.2	8.0	7.9	8.1	8.0	8.3	8.7	8.1
														ÄÄÄÄÄÄÄ
														7.9

YORK

Station	Y15	Y21	Y28	P36	P42		P45	P50	P55	P61				
Round														
1	6.1	6.2	7.6	7.6	7.5		7.7	8.0	8.0	7.8				7.4
2	8.0	7.8	7.4	7.2	7.2		7.3	7.4	6.9	ns				7.2
3	7.6	7.5	7.0	7.0	7.0		7.0	6.8	7.0	6.7				6.8
4	7.8	7.4	7.4	7.2	7.3		7.2	6.8	7.5	6.5				7.0
5	8.0	7.9	7.4	7.5	7.6		7.8	7.8	7.8	7.7				7.4
														ÄÄÄÄÄÄÄ
														7.2

Station				M33	M37	M41	M44	M47	M52					
Round														
1				7.5	7.6	7.5	7.6	7.3	7.5					
2				7.0	6.9	6.8	7.2	7.3	6.5					(included
3				6.2	6.4	6.3	6.4	6.3	6.2					above)
4				6.8	6.8	6.7	6.7	6.6	6.5					
5				6.9	7.2	7.1	7.0	7.0	6.7					

RAPPAHANNOCK

Station	R12	R21	R28	R37		R41	R44	R50	R55	R60	R65	R69	R76	
Round														
1	8.5	7.7	7.9	8.0		8.3	8.6	8.0	8.2	8.4	8.8	8.5	7.9	8.3
2	7.2	7.6	8.3	7.5		7.6	7.7	7.6	7.5	7.3	7.9	7.4	7.6	7.6
3	7.4	7.7	7.9	7.2		7.7	8.8	6.7	6.7	6.8	6.9	6.8	6.9	7.3
4	7.4	7.6	7.9	8.7		7.8	8.5	7.1	7.4	7.3	ns	6.8	ns	7.7
5	7.9	7.3	7.9	7.5		8.0	7.6	7.6	7.7	7.4	7.5	7.5	7.4	7.6
														ÄÄÄÄÄÄÄ
														7.7
														ÄÄÄÄÄÄÄ
														7.6

Table 9. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1994 summarized by salinity.

	1994						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	1459	1.74	1.040	10.68	8.77-12.92	170	15764	1.32	1.123	6.26	5.87-6.66	2342
5-9.9	51	1.45	0.932	7.48	3.13-15.33	10	1327	0.93	1.062	3.49	2.82-4.25	294
10-14.9							109	0.42	0.629	1.19	0.79-1.64	107
15-19.9							2	0.07	0.219	0.17	-0.06-0.43	19
Overall	1510	1.72	1.034	10.48	8.66-12.60	180	17202	1.24	1.121	5.56	5.23-5.90	2762

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1994 summarized by water temperature.

	1994						All Years Combined					
Temp. (deg. C)	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
15-19.9							79	0.81	0.908	2.85	1.40-4.86	30
20-24.9	97	1.25	0.914	5.65	3.18-9.24	24	1243	0.79	0.895	2.73	2.33-3.17	453
25-29.9	1214	1.79	1.038	11.38	9.14-14.07	134	11548	1.32	1.114	6.24	5.79-6.70	1747
30-34.9	199	1.82	1.036	11.84	6.80-19.68	22	4219	1.50	1.229	7.98	6.87-9.22	460
Overall	1510	1.72	1.034	10.48	8.66-12.60	180	17089	1.25	1.122	5.72	5.38-6.07	2690

Table 11. Catch ratios between adjusted mean CPUE at index and auxiliary stations by drainage, 1989-1994.

Drainage	Year	Index	Auxiliary	Ratio
James	1989	15.40	3.40	4.53
	1990	12.21	2.94	4.15
	1991	4.50	4.94	0.91
	1992	3.71	3.63	1.02
	1993	23.70	5.85	4.05
	1994	12.61	5.43	2.32
York	1989	9.29	3.01	3.09
	1990	6.72	2.61	2.58
	1991	3.37	2.22	1.52
	1992	3.64	0.68	5.35
	1993	13.70	4.01	3.42
	1994	11.29	3.44	3.28
Rappahannock	1989	9.87	1.47	6.71
	1990	4.18	1.43	2.92
	1991	3.56	2.12	1.68
	1992	30.92	4.40	7.02
	1993	18.10	3.36	5.39
	1994	9.70	2.46	3.94