1993

Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 1992-December 1992 : annual progress report

James A. Colvocoresses
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

U. S. Fish and Wildlife Service

Sportfish Restoration Project F87R4

January 1992 - December 1992

Prepared by

James A. Colvocoresses

A. Deane Estes

Donald M. Seaver

Virginia Institute of Marine Science

School of Marine Science

College of William and Mary

Gloucester Point, Virginia 23062

Submitted to

Virginia Marine Resources Commission

United States Fish and Wildlife Service

RESULTS

Objective 1: Measure the relative abundance of the 1992 year class of juvenile striped bass from the James, York and Rappahannock river systems.

A total of 1,769 young-of-the-year striped bass were collected from 180 seine hauls during the 1992 index station sampling, and an additional 312 age 0 striped bass were collected in 107 hauls at the auxiliary sites (Fig. 1, Table 1). The adjusted overall mean catch per seine haul (CPUE) for the index stations was 7.32, which is the fifth highest value for the 20 years sampled and significantly lower than only the record index of 1987 (15.75) (Table 2, Fig. 2). This value is about one and a half times the overall average index of 4.75 and the unweighted (by sample size) annual mean index of 4.91, but this favorable overall result was completely attributable to high catch rates in a single tributary system, the Rappahannock (Fig. 3).

The 1992 catch rate in the James drainage as a whole (3.71) was only about two thirds of the historical average, with barely overlapping confidence intervals for the two estimates (Table 3). As during the previous year, the poor results in this system can be clearly traced to extremely low catches in the Chickahominy River, where the 1992 index was again less than one quarter of the average. The 1992 results in the mainstem James, while slightly lower than in 1991, continued to be above but not significantly different from the historical average. Highest catch rates are normally observed in the center of the index station sampling area (particularly stations C1 and J46), but during 1992 there was no indication of a consistent center of abundance and in fact catch rates were often higher both at the lower and upper ends of the entire survey area than in the central reaches

(Fig. 4).

The 1992 results in the York drainage were also very similar to those seen the previous year, with an overall index (3.64) that was very close to the historical average (Table 3). Catch rates in the Pamunkey River have successively declined in the three years since the record value of 14.5 was recorded (Fig. 3) and are now close to being significantly below average (Table 3). A similar decline was seen in the Mattaponi River after a record high of 6.9 was established in 1988. This trend was reversed during 1992 with the index rising to slightly above average, although the difference was not statistically significant (Table 3). In contrast to the situation in the James drainage, all striped bass in the York system were captured at index stations, except for two juveniles caught at the upriver auxiliary stations in the Pamunkey and those captured at M37, an auxiliary station within the historical index area (Figs. 5-6).

The 1992 index in the Rappahannock River (30.92) was six times the historical average (Table 3) and comparable only to the record value of 34.0 recorded in 1987. This dramatically reversed an unprecedented steady decline in juvenile abundance since the 1987 record index value (Fig. 3). Juveniles were primarily concentrated in the index station area but the primary nursery area appeared to be slightly offset upriver compared to the index station area, with the auxiliary site adjacent to the upriver end of the index area (R60) being more productive than the lowermost index station (R28) (Fig. 7). Small numbers of juveniles were seen regularly at all of the upriver auxiliary stations, but the auxiliary stations downstream of the historical sampling area (R12 and R21) failed to produce any juvenile striped bass.

As in most years sampled, the highest catch rates were seen during the early sampling periods, followed by decreasing catch rates in succeeding 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, but a comparison of round by round results with historical monthly averages clearly indicate that temporal usage of the nursery areas in 1992 followed the same pattern that has typically been observed.

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

Collection information and pertinent environmental variables recorded at the time of each collection in 1992 are given in Appendix Table 1 and Tables 5 through 8. No particularly unusual conditions were encountered and all five sampling rounds were completed at the index stations without interruption under nominal conditions. A severe thunderstorm during the second sampling round forced the uppermost auxiliary station on the Mattaponi (M52) to be aborted and vessel engine problems caused delays which prevented the upper auxiliary stations in the Pamunkey (P61) and Rappahannock (R76) being reached before rising tides precluded sampling during the third and fourth rounds, respectively . Hydrographic instrument malfunction or probe damage prevented collection of a very limited amount of supporting data, specifically dissolved oxygen at the upper six Rappahannock stations during the first round (Table 7), pH in the Pamunkey river during the third round (Table 8), and all instrument-measured parameters at the two lower James and York system stations during the second round and the upper two Rappahannock stations during the final round except temperature for former (measured by thermometer) and salinity for the latter (safely inferred as fresh water).

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 1992 showed a very different pattern than has been evident during most other years and for the data set as a whole, i.e. a definitive trend towards higher catches at lower salinities (Table 9). During 1992 the overall mean catch rates were highest at intermediate salinities (5-10 ppt), but examination of the data sets shows this result to be a sampling artifact related to the extremely high juvenile striped bass population levels in the Rappahannock in 1992 rather than a deviation from the previously observed preference for lower salinity waters. Eight of the ten hauls made at index stations at salinities between 5 and 10 ppt were done in the Rappahannock, while only 34 of 162 collections made at salinities less than 5 ppt were from the Rappahannock. Within the Rappahannock itself catch rates were still highest within the lowest salinity interval (53.4 vs. 28.0 in the 5-10 ppt interval).

Catch rates with respect to water temperature in 1992 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. No relationships between water temperatures and catch rates are evident within sampling rounds.

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 had little or no effect on juvenile striped bass distributions. The lowest dissolved oxygen concentrations observed during 1992 sampling occurred during the first three sampling rounds at the lowermost Mattaponi station (M33), when concentrations were around 4 ppm (Table 7). Juvenile striped bass were collected during two of these three visits, and while greater numbers of juveniles were collected upriver of this site where oxygen concentrations were higher, none were collected downstream where D.O. was also higher (Table 1). Low pH values (<6.5) were likewise only observed in the Mattaponi during 1992 (Table 8) and there was no evidence of any negative effect on juvenile distribution, with the highest catch being observed at a pH of 6.4 (M47, second round). Secchi depth readings were generally low (<0.5 m) except for the upper York system and lower Rappahannock (Appendix Table 1). 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 several more years of data will be required before even preliminary 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 1992 were collectively well above average, but only due to an extremely large rebound in juvenile production in the Rappahannock River. Recruitment success in the York system was only average and levels of juvenile abundance in the James system, while only marginally below average compared to the entire data set, were clearly below average by recent standards and are at historic lows in the Chickahominy River. The distribution of striped bass juveniles within the James system during the past two years has been enigmatic, with no evidence of a primary nursery zone and catch rates at the auxiliary stations being about the same as at index stations (Table 11). None of the physical and environmental data collected with the seine collections suggest any reason why the central reaches are not presently the preferred habitat that they appeared to be during previous surveys, particularly the lower Chickahominy River station which has been historically the most consistent and productive sampling site. There may presently be adverse water quality conditions near the mouth of this river caused by some unknown and currently unmeasured parameter. If the peculiar distribution persists during 1993 collections a more specific investigation may be warranted.

Although it would obviously be preferable that there be a broader base for the overall favorable recruitment success in the Virginia striped bass nursery areas in 1992, it is nevertheless reassuring to see a reverse in the declining trend seen the previous two years and particularly welcome to see a major improvement in the Rappahannock River, where year class strength appeared to have steadily declined since reaching record levels in 1987 (the longest and largest declining trend seen in any tributary during the history of the survey). Five of the six highest overall Virginia striped bass juvenile indices have now been recorded during the past six years, with all of these values approximating or exceeding the previous historical high set in 1970, when a dominant year class is widely accepted to have been produced in Chesapeake Bay. 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 becoming evident that these fluctuations have been bracketing a much higher average over the course of the past six years. This pattern is consistent with a possible increase in spawning stock size resulting from the stringent harvest regulations in place over the period.

A primary reason for the large increase in areal coverage provided by the newly added auxiliary stations was to provide a better basis for evaluating the extent and utilization of juvenile habitat in these systems. Although the highest catch rates and centers of abundance have generally been observed in the areas bracketed by the historical index stations, previous sampling outside of these primary nursery areas had shown that there was also some utilization of areas both above and below these zones, particularly when large year classes were present or abnormal salinity regimes caused some spatial displacement of the primary zones. The James River data for the past two years has shown that considerable dispersion from the primary nursery areas can occur as well at low population levels during years of normal runoff. An original concern prompting the expanded geographic coverage had been that nursery zone expansion occurring in years of large juvenile population sizes (assumed to be a result of dispersion due to competitive effects) might result in an underestimate of relative population sizes. If the pattern observed during the first four years of expanded sampling proves to hold, index values based only on the primary nursery zone catches may actually provide relative underestimates during years of ***lower*** overall abundance. At least in the James and Rappahannock systems, a much higher proportion of juveniles were taken at index stations during years of high abundance (Table 11). Data for the York system was anomalous in this regard, but the York is a considerably different type of system from the other two, with a much smaller drainage area and the primary nursery area occurring in two small and semi-discrete areas in small tributaries. It is difficult to classify distributions as normal or abnormal based on only four years of data, but it is already clear that the distribution patterns exhibited by juvenile striped bass can vary greatly between river systems and years and expansion of the sampling frame will provide crucial data for documenting and interpreting these phenomena. The newly collected data on pH and dissolved oxygen concentrations suggests that the water chemistry of the various nursery areas may be considerably different and equally variable as well. To what extent these factors effect juvenile striped bass distribution, and possibly availability to the sampling gear, will need to be a focus of future investigations once a sufficient time series of data can be obtained.

Since it is clear that the relative contributions of the various Chesapeake Bay subsystems to the overall reproductive success of striped bass in the Bay as a whole varies greatly from year to year (Heimbuch et al. 1983, Colvocoresses and Austin 1987), an optimal Chesapeake Bay juvenile striped bass index will need to incorporate appropriate weighting factors for each of the major spawning/nursery areas. The revised Interstate Striped Bass Management Plan (ASMFC 1989), calls for the development of baywide and coastwide juvenile indices as key elements for monitoring and evaluating the effects of relaxed fishing restrictions under the provisions of Amendment 4. This applies not only for any future fusion of the present Maryland and Virginia indices, but should also be considered within each state's survey. Present contributions of each state's tributaries to the overall index are according to sampling effort, which is only loosely tied to potential production (i.e. size of system). Efforts are presently underway to identify and test weighting factors based on potential spawning and juvenile habitat areas, historical commercial catch contributions, and estimations of absolute juvenile population sizes using releases of marked hatchery-reared juveniles. It is clear that this is an area which will require considerable future investigation, particularly in view of the very different patterns of recruitment success seen in recent years as compared to the past.

LITERATURE CITED

Colvocoresses, J. A. 1988. Striped bass research, Virginia. Part I: Juvenile striped bass seining program. Annu. Rep. 1987-88. Virginia Institute of Marine Science, Gloucester Point, Virginia. 43 p.

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. 108 p.

Heimbuch, D. G., P. W. Jones and B. J. Rothschild. 1983. An analysis of Maryland's juvenile striped bass index of abundance. UMCEES Ref. No. 83-51 CBL.

Table 1. Catch per seine haul of young-of-the-year striped bass during the 1992 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	0	1	10/6	13/7	3/3	3/2	4/3	20	5/0	0	4	1	6	91
2	1	4	4/5	2/3	0/1	1/1	8/2	3	0/1	0	6	8	7	57
3	0	16	3/1	3/0	1/0	4/1	3/0	0	3/0	0	4	1	2	42
4	1	15	7/0	5/2	2/0	0/0	4/1	0	0/1	0	2	0	2	42
5	0	16	4/4	2/1	2/0	0/0	0/1	0	1/2	0	1	0	0	34
														266

YORK

Station / Round	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55	P61	TOT.
1	0	0	0	0	1/0	4/2	5/3	0	1	16
2	0	0	0	0	5/5	10/1	0/1	0	0	22
3	0	0	0	0	2/2	3/1	1/0	1	ns	10
4	0	0	0	0	2/0	0/1	0/0	0	0	3
5	0	0	0	0	3/0	0/3	0/0	0	0	6

Station / Round	**M33**	M37	**M41**	**M44**	**M47**	M52	TOT.
1	0/0	2	2/1	0/1	9/2	0	17
2	2/0	5	6/2	6/9	21/7	ns	58
3	1/0	6	7/2	14/5	9/1	0	45
4	0/1	5	5/4	1/1	3/2	0	22
5	0/0	6	2/0	1/1	1/3	0	14
							213

RAPPAHANNOCK

Station / Round	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	TOT.
1	0	0	0/4	85/24	18	46/23	38/29	42/26	28	1	7	3	374
2	0	0	1/1	62/27	11	146/167	42/25	54/19	34	2	2	11	604
3	0	0	4/0	16/5	0	79/15	15/13	41/16	1	4	1	8	218
4	0	0	0/0	14/16	9	46/21	16/6	51/32	1	1	2	ns	215
5	0	0	0/0	13/19	17	4/3	6/10	99/16	0	1	1	2	191
													1602
													2081

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
Overall	13235	1.13	1.092	4.75	4.45-5.07	2402
Unweighted Annual Mean				4.91		20

* adjusted figure (see 1984 report)

Table 3. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1992 summarized by drainage and river.

	1992						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	145	0.96	0.735	3.71	2.67-4.96	60	4519	1.21	1.111	5.37	4.79-6.00	791
James	121	1.14	0.749	4.82	3.32-6.72	40	2302	1.05	1.029	4.26	3.70-4.87	533
Chickahom.	24	0.63	0.586	1.99	1.00-3.27	20	2217	1.54	1.203	8.31	6.83-10.0	258
York	187	0.95	0.805	3.64	2.61-4.90	70	3430	1.01	0.918	3.95	3.58-4.35	892
Pamunkey	55	0.78	0.719	2.71	1.56-4.21	30	1760	1.06	0.994	4.31	3.67-5.02	376
Mattaponi	132	1.08	0.850	4.46	2.87-6.54	40	1670	0.96	0.857	3.70	3.27-4.17	516
Rappahannock	1437	2.68	1.394	30.92	20.1-47.0	50	5286	1.18	1.245	5.17	4.51-5.90	719
Overall	1769	1.44	1.247	7.32	5.69-9.28	180	13235	1.13	1.092	4.75	4.45-5.07	2402

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1992 summarized by sampling period and month. Second sampling period was done during 28 July-4 August; fourth during 26 August-3 September.

Month	1992						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)	406	1.72	1.248	10.48	6.14-17.1	36	5422	1.36	1.165	6.63	5.89-7.44	718
(2nd)	647	1.83	1.402	11.93	6.63-20.4	36						
Aug. (3rd)	271	1.42	1.129	7.11	4.16-11.4	36	4908	1.19	1.079	5.21	4.69-5.78	881
(4th)	244	1.21	1.223	5.36	2.80-9.20	36						
Sept. (5th)	201	1.01	1.085	3.98	2.08-6.70	36	2905	0.85	0.971	3.03	2.68-3.41	803
Overall	1769	1.44	1.247	7.32	5.69-9.28	180	13235	1.13	1.092	4.75	4.45-5.07	2402

Table 5. Salinity (parts per thousand) recorded at 1992 seine survey stations.

Drainage

JAMES

Station Round	J12	J22	**J29**	**J36**	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	MEAN
1	15.6	7.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
2	ns	ns	3.8	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5*
3	11.0	6.4	5.6	2.2	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
4	15.1	7.0	3.6	1.4	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
5	15.3	7.7	4.9	2.1	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
														1.8

YORK

Station Round	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55	P61	MEAN
1	19.8	16.0	12.3	3.4	0.2		0.0	0.0	0.0	0.0	3.7
2	ns	ns	10.8	2.4	0.0		0.0	0.0	0.0	0.0	1.1*
3	15.3	11.4	9.4	0.8	0.0		0.0	0.0	0.0	ns	2.5
4	15.8	12.7	9.6	1.6	0.0		0.0	0.0	0.0	0.0	2.8
5	15.9	12.3	9.8	1.3	0.0		0.0	0.0	0.0	0.0	2.7
											2.6

Station Round	**M33**	M37	**M41**	**M44**	**M47**	M52	MEAN
1	3.5	1.7	0.0	0.0	0.0	0.0	
2	0.9	0.0	0.0	0.0	0.0	0.0	(included above)
3	0.0	0.0	0.0	0.0	0.0	0.0	
4	1.6	0.0	0.0	0.0	0.0	0.0	
5	1.2	0.0	0.0	0.0	0.0	0.0	

RAPPAHANNOCK

Station Round	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	MEAN
1	16.8	16.8	13.1	9.0	2.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	5.0
2	15.7	15.2	11.2	6.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3
3	15.7	14.5	11.6	4.8	2.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	4.1
4	15.7	14.5	11.5	7.0	3.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	4.4
5	14.7	12.3	8.5	4.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
													4.2
													2.8

* biased downward due to missing data from lower stations.

Table 6. Water temperature (°C) recorded at 1992 seine survey stations.

Drainage

JAMES

Station Round	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
1	29.5	31.7	26.6	27.3	29.8	30.0	30.4	31.3	28.9	29.8	31.1	31.6	32.4	30.0
2	28.5	30.0	26.1	26.8	28.1	28.9	29.7	29.6	27.1	29.0	30.0	29.3	28.3	28.6
3	26.7	28.8	26.7	24.9	25.5	26.3	26.6	26.6	27.0	27.9	29.8	29.3	28.1	27.2
4	28.2	30.3	28.7	23.0	25.7	26.1	27.5	27.1	26.4	28.5	28.6	30.5	28.6	27.6
5	27.3	29.7	26.5	22.2	23.5	24.0	25.3	25.2	25.8	26.4	28.8	27.6	27.1	26.1
														27.9

YORK

Station Round	Y15	Y21	Y28	P36	P42	P45	P50	P55	P61	MEAN
1	27.6	27.9	27.8	28.6	29.4	29.9	30.2	30.9	30.7	29.2
2	ns	26.2	26.3	27.7	28.4	28.2	28.0	28.7	27.2	27.7
3	25.1	25.0	24.3	24.5	24.8	24.5	24.0	24.0	ns	24.4
4	25.9	25.2	24.3	24.8	26.4	26.7	26.5	27.3	26.6	26.0
5	25.2	24.3	23.1	24.7	24.9	24.7	24.7	24.8	25.0	24.8
										26.5

Station Round	M33	M37	M41	M44	M47	M52	MEAN
1	28.6	28.5	28.2	28.9	30.5	30.8	
2	28.0	28.0	27.6	28.0	28.0	ns	(included
3	24.7	24.6	24.3	24.1	23.9	23.7	above)
4	25.9	26.0	25.5	25.9	27.2	26.3	
5	25.1	25.6	24.6	25.0	25.3	25.1	

RAPPAHANNOCK

Station Round	R12	R21	R28	R37	R41	R44	R50	R55	R60	R65	R69	R76	MEAN
1	31.3	29.4	28.2	30.3	29.9	30.5	29.2	29.8	30.0	32.5	30.0	31.2	30.2
2	30.8	29.4	26.4	27.3	28.5	29.4	27.0	27.3	26.8	25.7	28.2	27.1	27.8
3	26.1	25.9	25.1	25.4	26.7	25.6	27.5	28.4	28.0	28.1	28.9	28.7	27.0
4	27.7	26.9	26.4	27.3	27.1	27.5	26.1	26.7	26.9	27.3	26.8	ns	27.0
5	21.3	24.4	21.9	23.8	23.9	24.2	26.2	26.6	27.0	27.4	ns	ns	24.7
													27.4
													27.2

Table 7. Dissolved oxygen (parts per million) recorded at 1992 seine survey stations.

Drainage

JAMES

Station / Round	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
1	8.8	8.9	7.0	7.0	9.3	6.3	9.5	10.2	8.5	7.3	6.6	6.1	6.2	7.8
2	ns	ns	4.5	6.6	7.7	6.5	7.2	7.8	7.1	8.8	6.0	6.9	5.6	6.8
3	7.4	7.9	5.2	4.7	5.8	5.5	5.5	4.7	6.1	8.2	6.3	6.7	7.4	6.3
4	5.9	5.6	7.8	5.5	9.5	6.9	6.8	6.3	7.4	8.1	7.3	7.7	9.0	7.2
5	6.4	8.7	5.5	7.1	8.8	7.9	6.7	6.5	7.0	7.4	6.3	7.7	8.0	7.2
														7.1

YORK

Station / Round	Y15	Y21	Y28	P36	P42	P45	P50	P55	P61	MEAN
1	7.6	6.7	6.2	5.9	6.3	5.7	6.4	4.7	5.1	5.6
2	ns	ns	5.1	4.7	6.2	6.3	4.9	6.1	4.9	5.0
3	5.0	6.6	4.7	5.6	5.5	5.8	5.4	5.2	ns	5.4
4	5.6	7.9	4.9	5.0	5.3	6.1	5.5	5.4	5.7	5.6
5	6.0	5.4	5.6	5.4	6.0	6.4	6.0	5.5	5.7	5.6
										5.5

Station / Round	M33	M37	M41	M44	M47	M52	MEAN
1	3.8	4.4	4.9	4.7	5.8	5.7	
2	4.1	4.3	5.1	4.5	4.2	ns	(included
3	3.9	4.8	5.6	5.3	6.0	6.6	above)
4	4.7	4.9	5.1	5.6	6.5	6.2	
5	5.0	5.3	5.2	5.2	5.7	6.0	

RAPPAHANNOCK

Station / Round	R12	R21	R28	R37	R41	R44	R50	R55	R60	R65	R69	R76	MEAN
1	8.7	6.4	4.4	5.9	7.9	6.9	ns	ns	ns	ns	ns	ns	6.7
2	6.6	7.3	6.0	5.7	7.1	6.2	6.9	7.5	6.1	6.3	8.1	4.9	6.6
3	7.7	6.9	6.6	6.8	6.3	6.4	7.5	8.3	6.2	6.5	5.5	8.1	6.9
4	6.7	6.6	4.6	6.6	7.2	7.1	7.9	8.4	7.0	8.5	7.0	ns	7.1
5	7.9	7.9	7.6	7.9	7.7	8.8	7.6	7.3	7.2	9.3	ns	ns	7.9
													7.0
													6.5

Table 8. pH recorded at 1992 seine survey stations.
Drainage

JAMES

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

YORK

Station / Round	Y15	Y21	Y28	P36	P42	P45	P50	P55	P61	MEAN
1	7.4	7.2	6.7	6.6	6.6	6.8	6.8	6.6	6.6	6.8
2	ns	ns	6.9	6.9	7.0	7.1	7.2	ns	7.4	6.9
3	7.4	7.3	6.7	ns	ns	ns	ns	ns	ns	6.8
4	7.2	7.4	7.0	6.8	6.9	7.0	6.9	7.0	6.9	6.8
5	7.5	7.4	7.0	7.0	7.0	7.8	7.2	7.0	6.8	7.0
										6.8

Station / Round	M33	M37	M41	M44	M47	M52	MEAN
1	6.4	6.4	6.5	6.5	6.5	6.4	
2	6.6	6.7	7.1	6.6	6.4	ns	(included above)
3	6.8	6.7	7.0	6.6	6.6	6.4	
4	6.5	6.5	6.7	6.5	6.7	6.5	
5	6.6	6.7	6.8	6.7	6.6	6.6	

RAPPAHANNOCK

Station / Round	R12	R21	R28	R37	R41	R44	R50	R55	R60	R65	R69	R76	MEAN
1	7.7	7.4	7.0	6.8	6.8	6.9	7.2	7.3	7.1	7.3	7.1	7.1	7.1
2	8.0	7.6	7.4	7.1	6.9	7.0	6.9	8.0	7.9	7.9	8.2	7.8	7.6
3	7.9	7.6	7.3	6.9	7.1	7.0	7.3	8.2	7.3	7.5	7.3	7.5	7.4
4	7.9	7.7	7.3	7.1	7.3	7.4	7.8	7.9	7.4	7.7	7.4	ns	7.5
5	7.7	7.8	7.5	7.4	7.2	7.6	7.3	7.4	7.2	8.1	ns	ns	7.5
													7.4
													7.3

Table 9. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1992 summarized by salinity.

	1992						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	1527	1.43	1.215	7.23	5.58-9.23	162	12070	1.22	1.098	5.43	5.06-5.81	2009
5-9.9	232	2.28	1.646	19.94	5.57-60.7	10	1032	0.80	1.017	2.77	2.17-3.45	260
10-14.9	10	0.58	0.706	1.77	0.18-4.40	8	96	0.39	0.611	1.10	0.71-1.54	101
15-19.9							2	0.07	0.219	0.17	-0.06-0.43	19
Overall	1769	1.44	1.247	7.32	5.69-9.28	180	13200	1.13	1.092	4.76	4.45-5.07	2389

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1992 summarized by water temperature.

	1992						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	110	0.95	0.874	3.60	2.15-5.53	38	1077	0.75	0.869	2.55	2.16-2.97	427
25-29.9	1450	1.51	1.300	8.01	5.91-10.7	130	8553	1.19	1.082	5.24	4.83-5.68	1481
30-34.9	209	2.23	1.157	18.93	8.59-39.1	12	3413	1.42	1.245	7.15	6.04-8.41	380
Overall	1769	1.44	1.247	7.32	5.69-9.28	180	13122	1.15	1.094	4.89	4.57-5.22	2330

Table 11. Catch ratios between adjusted mean CPUE at index and auxiliary stations by drainage, 1989-1991.

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
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
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