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Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 1993-December 1993 : 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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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 bass recruitment conducted from New England to North Carolina under the coordination of the Atlantic States Marine Fisheries Commission (ASMFC). Virginia's efforts started in 1967 with funding from the Commercial Fisheries Development Act of 1965 (PL88-309) and continued until 1973 when the program was cut. It was instituted in 1980 with Emergency Striped Bass Study funds (PL 96-118, 16 U.S.C. 757g, the "Chafee Amendment"), and since 1989 has been funded by the Wallop-Breaux expansion of the Sportfish Restoration and Enhancement Act of 198 (PL - , known as the Dingle-Johnson Act).

ASMFC, in 1981, adopted the Atlantic Coast Striped Bass Interstate Fisheries Management Plan which was then adopted by the Virginia Marine Resources Commission 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 1993.

Originally, the Virginia program used a 6' x 100' (2m x 30.5m) .25" (6.4mm) bag seine, but after comparison tows with Maryland gear, 4' x 100', .25" mesh (1.2m x 30.5m, 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

Sampling was conducted during five bi-weekly sampling periods from early July (5 July) through early September (9 September) 1993. A round consisted of replicate tows at each of 18 index stations and a single haul at each of 22 auxiliary stations on the James, Chickahominy, Mattaponi, Pamunkey, and Rappahannock rivers (Figure 1). Addition of the auxiliary sites in 1989 made it possible to provide wider geographic coverage, particularly during drought or wet years when the nursery grounds are displaced up or downriver past the index stations.

All collections were made by hand deployment of a 100' (30.5m) by 4' (1.2m), 1/4" (0.64cm) bar mesh minnow seine set perpendicular to the shore. The net was set until fully extended or until a depth of four feet was encountered. The upstream end of the net was held fixed on the beach as the body of the net was swept downstream and back onto shore. Ideally this provided a quadrant of a circle with a radius of approximately 100' (30.5m). Tidal currents and/or drop-offs (>4' depth) often resulted in a smaller sweep.

All fish caught during the first tow at index stations were maintained alive in buckets and not released until after the second tow. All fish were identified to species and counted. All striped bass and all individuals, or a subsample of at least 25, of other species were measured to the nearest mm fork length (or total length as appropriate). Water temperature, salinity, dissolved oxygen and pH were measured after the first haul using a HYDROLAB Surveyor II ® water quality instrument. A secchi disk reading was also made at each station. Sample time, tidal stage and weather conditions were recorded at the time of each haul. At those stations where two hauls were made, a 30 minute pause was observed between the first and second collection to allow conditions to return to "normal". The first sample was processed during this intervening period. All fishes were returned alive to the river, except those retained for later laboratory analyses.

Index Computation

Only the "standard index stations" from the primary nursery ground were used to compute the index and plot in time series with previous years. Abundance data were logarithmically transformed prior to analyses and generation of the indices. Subsequent mean values were retransformed and expressed as a geometric mean. Since geometric means tend to be smaller than arithmetic means, a scaling factor (2.28) was introduced in 1984, the year Virginia converted from arithmetic to geometric means, so that continuity of the long term data set could be maintained. Colvocoresses (1984) discussed the rationale for this logarithmic transformation in an earlier report.

Ricker Spawner-Recruit Relationship

This analysis was conducted in collaboration with J. Loesch and B. Hill, also here at VIMS, as part of their study entitled, "Evaluation of striped bass stocks in VA: Tagging and monitoring studies". Their pound net CPUE data for the spring and fall 1984 through 1993 fishing seasons on the Rappahannock River were used (Hill and Loesch 1993). An index of adult spawners was derived following the age of maturity relationships of Merriman (1941) and Mansueti and Hollis (1963): Twenty five percent of age IV females are sexually mature, 70% at age V, and 95-100% at age VI. The spring up-river CPUE data for females in the spawning reaches (greater than river mile 37) were adjusted by the above maturation schedule. In other words, the CPUE of age IV females taken above river mile 37 was multiplied by .25, age V by .70, and age VI and greater by 1.00. These numbers were added to give a female on-the-spawning-grounds CPUE or spawning stock index. This spawning stock abundance index was used as the value for the spawner in the Ricker spawner-recruit model. The juvenile index (Rappahannock, Virginia and weighted Virginia) for that year was the recruitment input (Table 12). Data were analyzed using PC-SAS on the Fisheries Data Management Unit (FDMU) network.

Relation of index to subsequent year class strength

The data were also examined following the juvenile index for each spawning year through the fall pound net CPUE for each subsequent year for ages I^+ through III^+.

Linear regression was run using the juvenile indices as the independent variable and the subsequent I-III age classes as the dependent variable.

RESULTS

Objective 1: <u>Measure the relative abundance of the 1993 year class of juvenile striped bass from the James, York and Rappahannock river systems.</u>

A total of 2323 young-of-the-year striped bass were collected from 180 seine hauls during the 1993 index station sampling, and an additional 935 were collected in 99 hauls at the auxiliary sites (Fig. 1, Table 1). The geometric index, an adjusted overall mean catch per seine haul (CPUE) for the index stations, was 18.12, the highest value for the 21 years sampled (Figure 2). This value is about three and a half times the overall average index of 5.30 and the unweighted (by sample size) annual mean index of 5.54 (Table 2). This favorable overall result occurred across all drainages, with all but the Rappahannock recording historical highs and suggests that the index is due to an extremely strong year class (Fig. 3).

The 1993 catch rate in the James drainage (James and Chickahominy) as a whole (23.63) was nearly four times the historical average and the highest value ever recorded for the system (Table 3, Fig. 3). The extremely high catch rates in the James drainage reversed a declining trend recorded during the previous four years in this system. The 1993 index in the mainstem James (28.71), was nearly six times the historical average and significantly higher than in 1992. The Chickahominy River results also showed a dramatic increase over the previous two years when catch rates were at an all time low. Highest catch rates were observed in the center of the index station sampling area (particularly C1 and J46), although the distribution of fish was much more uniform than in 1992 (Table 1, Fig. 4).

The York drainage in 1993 established a record index (13.83) that was three times the historical average and nearly four times higher than 1992 (Table 3). Catch rates in the Pamunkey River rebounded to an all time high (16.34) after four successive years of declining catches (Fig. 3, Table 3). A similar increase was seen in the Mattaponi River where a record high of 12.18 was established (Table 3). Similar to the situation in the James drainage, striped bass in the York system were captured at all stations at least twice and the center of abundance was within the central reaches of the index area (Figs. 5-6, Table 1).

The 1993 index in the Rappahannock River (18.99) was three and a half times the historical average (Table 3) and the third highest value recorded for the drainage. Juveniles were primarily concentrated in the index station area but the primary nursery area appeared to be offset slightly upriver when compared to the index station area, with the auxiliary site adjacent to the upriver end of the index area (R60) being more productive than all the index stations except R44, in the central reach of the index area (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) produced only one juvenile striped bass, the only striped bass captured below R28 in the survey's history.

In contrast to most years sampled, the highest catch rates were seen during the latter rounds, with round four being substantially higher than previous rounds, followed by a decreased catch rate in round five (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. Results from 1993 indicate a deviation from the normally observed pattern, with August being the month of highest abundance, rather than July. This was probably the result of a later spring spawn.

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

Collection information and pertinent environmental variables recorded at the time of each collection in 1993 are given in 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. Severe thunderstorms on the Rappahannock (R21) and the Pamunkey Rivers (P55 & 61) forced the cancellation of these stations during the first and third rounds respectively. Vessel engine problems caused delays which prevented the upper auxiliary stations in the Rappahannock (R69 & 76) being reached before rising tides precluded sampling during the fourth round. High water associated with storms prevented sampling in the upper Rappahannock (R60, 65 & 76) during the fifth round and the Pamunkey (P61) during the first round and high winds prevented reaching Y21 on the York during the second round. Hydrographic instrument malfunction or probe damage prevented collection of a very limited amount of supporting data, specifically dissolved oxygen and pH at the upper six Rappahannock stations during the first round and the upper six stations in the James during the fifth round (Tables 7 and 8).

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 1993 followed the normally observed pattern, i.e. a definitive trend towards higher catches at lower salinities (Table 9). There was no relation between catch and salinity between any of the five rounds.

Catch rates with respect to water temperature in 1993 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. Low pH values (<6.5) were only observed in the York system and the lowermost stations on the James during the first round in 1993 (Table 8), and there was no evidence of any negative effect on juvenile distribution. Secchi depth readings were generally low (<0.5 m) except for the upper York system and lower Rappahannock. 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.

Objective 4 Provide survey results in a timely manner to concerned regulatory and management bodies.

The results of the 1993 survey were communicated to the Virginia Marine Resources Commission (VMRC) at the 20 September 1993 Fisheries Management Advisory Committee/VMRC. A more detailed report and discussion was presented at the annual Striped Bass Research Workshop held in Alexandria, VA on 15 and 16 February, 1994. These data were also communicated to the Striped Bass Technical Committee, ASMFC via the VMRC representative.

Objective 5 Examine relationships between the juvenile index and subsequent year class strength using age/size data from VIMS' pound net (1980-1993) monitoring program.

The juvenile indices for the Rappahannock River and state-wide Virginia, index (1980-1993), and the subsequent year class strength as indexed by the spring and fall pound net CPUE (1984-1993) from Hill and Loesch (1993) are presented in Tables 12a-12c. The juvenile indices and index of spawning stock used in the Ricker Model are found in Table 12d. The dominant 1987 (at that time record year class) showed up in pound nets, although not in the age I-III numbers one might expect. It was however, the dominant year class on the spawning grounds in 1993. The 1985 year class, not dominant based upon the juvenile index, made the strongest showing in the fall pound net catches as age I-III juveniles (Table 12b-c). This apparently strong year-class, from a relatively small juvenile index, was an outlier in the regression and reduced the r^2.

The regression for juvenile index vs I^+ was highly significant for the Rappahannock juvenile index and Virginia state-wide index ($P = 0.007$ and 0.006, $r^2 = .86$ and $.88$). The weighted Virginia index was also significant ($P = 0.01$, $r^2 = .83$). The juvenile indices were not significant when regressed on the II and III^+ (Table 13b). No analyses could be run on the I^+ vs II^+ as there were insufficient years with catch for both year classes.The record juvenile index of 1993 was produced by a record number of spawning adults if the Rappahannock is indicative of the Virginia portion of the Bay (Tables $12d_1$, $12d_2$). Significant numbers of spawning age fish, ages IV-IX, were collected by Hill and Loesch during the spring 1993 run. The apparently dominant (age VI) 1987 year class was very abundant on the spawning ground, as were age VII and VIII females.

The results of the Ricker spawner-recruit model did not yield a significant coeficient of determination (Table 13a). The best coefficient of determination was for the weighted Virginia index (r^2= 0.49 and 0.45, P= 0.78 and 0.10).

DISCUSSION AND CONCLUSIONS

The striped bass juvenile indices recorded in the Virginia Chesapeake Bay nursery areas in 1993 were the highest on record (Figure 2). Recruitment success in the York system was the highest for the entire time series. Not only was the York system high, but for the first time fish were abundant in both the Pamunkey and Mattaponi Rivers. Over the years the Pamunkey has been a consistent but low level producing river interspersed with occasional high production. Until 1993, however the Mattaponi has never been a good producer (Figure 3). Levels of juvenile abundance in the James system also set a new record. The index for the James system has often been carried by the Chickahominy. For example, the record 1970 year class was almost entirely a product of the Chickahominy River (index 40). This year however, both the Chickahominy and the main stem James were productive (Figure 3). The nursery ground on the James, which was diffuse during 1992, was clearly defined in 1993. Highest counts were obtained at river mile stations J29 and J36 during 1992, but in 1993 the center of abundance was at J46 (Table 1, Fig. 4). Chickahominy station C1, traditionally a major producer, yielded very few fish in 1992 (Colvocoresses et al 1993) but regained its position as a major contributor to the index in 1993 as large catches were made over all five rounds (Table 1).

The Rappahannock River, a major contributor to the dominant 1987 year class, and the only river to produce substantial numbers in 1992 which resulted in an "average" state-wide index in 1992, produced its third highest year class and contributed to the record 1993 index. As with the James, the center of abundance in 1993 was farther upriver than in 1992. During 1992 fish were abundant from river mile R37 to R55, where as in 1993 they were evenly distributed from R44 to R55, with most at R44 and R55 (Table 1), and at R60 the adjacent upriver auxillary station.

If one looks only at recruitment patterns since the resurrection of the survey in 1980 (Figures 2 & 3) there appears to be two recruitment modes. The first is the period of low, probably failure level recruitment from 1980 to the mid-1980's. If one looks at Maryland's data it is possible to extrapolate this failure period in Virginia's recruitment back to the early 1970's. The Virginia recruitment, although low during the early 1980's does show evidence of a very slow natural recovery. Then a second period of high, but variable recruitment from 1987 to the present. This sudden apparent recovery is probably due to the 1981 Atlantic States Marine Fisheries Commission striped bass Interstate Fisheries Management Plan enhancing the gradual natural recovery. Now, as we look at recruitment levels since 1987 it becomes apparent that the dominant and standard setting 1970 year class was not that large by comparison.

A primary reason for the increase in areal coverage provided by the auxillary stations was to provide a better basis for evaluating the extent and utilization of juvenile habitat in these systems (Colvocoresses et al 1988). 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 has shown that there is also some utilization of areas above and below these zones, particularly when large year classes are present or abnormal salinity regimes cause some spatial displacement of the primary zones. Clearly this has been the case in 1993.

The year-to-year variability of the subsystems of each river, and the main stem rivers themselves make clear the difficulty of providing an accurate state-wide, and in fact Bay-wide index of annual juvenile recruitment (Heimbuch et al. 1983, Colvocoresses and Austin 1987, Colvocoresses et al 1993). The revised Interstate Striped Bass Management Plan (ASMFC 1991), calls for the development of bay and coast-wide juvenile indices as key elements for monitoring and evaluating the effects of relaxed fishing restrictions under the provisions of Amendment 4. This issue was addressed with support from the Chesapeake Bay Stock Assessment Committee (CBSAC) and in 1993 a Bay-wide index was developed from scaled, geometric means, weighted by area of spawning ground in each producing river (Austin et al 1993). Although the index cannot be verified due to the lack of a commercial harvest and/or sufficient Bay-wide fishery-independent data collection program, there is evidence that dominant year classes can be followed through the Virginia stock in future years (Austin 1993).

The lack of a strong density-dependent Spawner-Recruit relationship for the striped bass has been documented in the literature (see for example the reviews by Richkus et al 1980 and Richkus et al 1993). The density-independence and the importance of environmental factors early in the life cycle of the Chesapeake Bay stock has been demonstrated (Ulanowicz and Polgar 1980, Logan 1985, Uphoff 1989, Houde and Rutherford 1992) by various investigators. Never-the-less, there has been no attempt to examine the spawner and subsequent recruitment relationship using fishery-independent means as we have done here. This has been due to the lack of a time series of fishery independent data. The lack of a significant spawner-recruit relationship using spring pound net CPUE from but a single river (Rappahannock) is not unexpected; therefore the next step is to attempt to apply environmental factors to the Ricker model as Tang (1985) did with blue crabs and Nelson et al (1977) did with menhaden.

Our efforts here are also the first to validate the juvenile index with CPUE from a fishery-independent monitoring program. Again, past efforts were hampered by the lack of post young-of-the-year verification data. Both by inspection (Table 12) and regression (Table 13) it is clear that, with a single exception (1985), the juvenile index is validated by the subsequent year abundance of I-III$^+$ cohorts in fall Rappahannock River pound net catches. It is indeed unfortunate that the time series is only for one river. Why the 1985 juvenile index is so poor, with such a strong showing of cohorts in subsequent years can be explained by a change in sampling strategy. In 1985, as in previous years, the juvenile striped bass sampling only went up-river to mile 50 on the Rappahannock; subsequently river mile 55 was initiated. During "dry" years (1985 and 1993) the nursery ground is displaced some five miles or so upriver. The consequence of this is the 1985 sampling protocol missed the center of young-of-the-year abundance, resulting in an index "...that should be considered artificially depressed." (Colvocoresses 1985).

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Table 1. Catch per seine haul of young-of-the-year striped bass during the 1993 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	6	6	9/7	17/12	17/2	8/3	7/7	21	12/3	14	3	3	5	162
2	2	8	9/2	6/5	14/22	11/0	32/35	75	13/10	8	0	44	7	303
3	1	8	6/17	22/10	18/25	4/0	18/107	17	1/0	8	0	29	5	296
4	7	28	15/30	30/40	64/21	5/2	96/74	18	14/11	7	2	15	5	484
5	8	13	3/12	34/26	17/10	4/1	16/58	5	3/6	0	0	8	0	224
														1469

YORK

Station / Round	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55	P61	TOT.
1	1	2	2	16	23/5	11/16	4/3	11	ns	94
2	3	ns	9	39	9/3	4/6	25/2	32	11	143
3	0	0	3	22	2/2	12/4	26/30	ns	ns	101
4	0	0	9	38	13/1	8/4	23/15	18	1	130
5	3	5	6	8	4/1	24/4	11/9	15	10	100

Station / Round	**M33**	M37	**M41**	**M44**	**M47**	M52	TOT.
1	1/0	1	12/14	2/1	3/0	0	34
2	10/7	4	6/8	7/6	1/3	0	52
3	7/1	2	0/3	5/13	11/6	0	48
4	4/5	3	1/7	18/14	21/7	3	83
5	9/2	7	11/5	11/19	38/23	4	129
							914

RAPPAHANNOCK

Station / Round	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	TOT.
1	0	ns	4/6	5/2	4	16/46	20/11	17/12	72	6	2	17	243
2	0	0	2/7	2/8	1	14/30	10/6	19/7	63	ns	3	4	176
3	0	1	0/0	18/3	15	5/7	11/2	29/8	33	3	3	8	146
4	0	0	3/1	7/6	3	34/28	31/20	26/13	17	4	ns	ns	193
5	0	0	2/2	3/6	0	27/18	11/8	20/18	ns	ns	2	ns	117
													875
													3258

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
Overall	15692	1.20	1.119	5.30	4.97-5.64	2582
Unweighted Annual Mean				5.54		21

* adjusted figure (see 1984 report)

Table 3. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1993 summarized by drainage and river.

Drainage River	1993						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
James	1083	2.43	1.073	23.63	17.36-31.91	60	5733	1.30	1.157	6.06	5.43-6.75	851
James	835	2.61	1.012	28.71	20.22-40.39	40	3136	1.16	1.103	4.99	4.35-5.69	573
Chickahom.	248	2.07	0.915	15.84	8.67-27.73	20	2597	1.58	1.217	8.79	7.29-10.53	278
York	626	1.96	0.879	13.83	10.78-17.60	70	4058	1.08	0.947	4.40	4.01-4.82	962
Pamunkey	304	2.10	0.915	16.34	11.51-22.84	30	2065	1.14	1.017	4.85	4.16-5.60	406
Mattaponi	322	1.85	0.821	12.18	8.55-17.03	40	1993	1.03	0.891	4.10	3.63-4.60	556
Rappahannock	614	2.23	0.921	18.99	14.11-25.31	50	5901	1.25	1.253	5.70	5.01-6.45	769
Overall	2323	2.19	0.975	18.12	15.35-21.30	180	15692	1.20	1.119	5.30	4.97-5.64	2582

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1993 summarized by sampling period and month.

	1993						All Years Combined					
Month	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)	341	2.01	0.896	14.67	10.29-20.57	36	6418	1.45	1.169	7.42	6.65-8.25	800
(2nd)	361	2.11	0.803	16.52	12.10-22.29	36						
Aug. (3rd)	433	1.94	1.165	13.66	8.53-21.23	36	5891	1.26	1.111	5.73	5.17-6.33	939
(4th)	712	2.59	1.003	28.04	19.42-40.08	36						
Sept. (5th)	476	2.31	0.877	20.61	14.81-28.38	36	3383	0.94	1.021	3.55	3.13-4.00	843
Overall	2323	2.19	0.975	18.12	15.35-21.30	180	15692	1.20	1.119	5.30	4.97-5.64	2582

Table 5. Salinity (parts per thousand) recorded at 1993 seine survey stations.

Drainage

JAMES

Station / Round	J12	J22	**J29**	**J36**	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	**J74**	J78	MEAN
1	15.4	6.7	2.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
2	11.7	10.5	6.6	2.5	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
3	ns	ns	6.6	2.9	1.5	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2*
4	19.7	11.8	7.7	0.0	2.9	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	3.4
5	9.1	11.7	7.9	5.2	3.5	2.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	3.2
														1.8

YORK

Station / Round	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55	P61	MEAN
1	16.0	13.8	9.6	2.4	0.0	0.0	0.0	0.0	ns	3.2
2	20.3	ns	14.1	5.2	1.1	0.0	0.0	0.0	0.0	3.8*
3	12.5	16.6	14.7	6.0	2.0	0.4	0.1	ns	ns	4.7
4	17.6	15.0	14.6	7.0	2.9	0.8	0.2	0.0	0.0	4.6
5	20.7	17.7	15.2	8.6	3.9	1.5	0.6	0.3	0.0	5.6
										4.4

Station / Round	**M33**	M37	**M41**	**M44**	**M47**	M52	MEAN
1	2.8	0.5	0.0	0.0	0.0	0.0	
2	7.1	4.1	1.3	0.0	0.0	0.0	(included
3	4.9	2.6	0.8	0.0	0.0	0.0	above)
4	6.8	3.4	1.4	0.0	0.0	0.0	
5	8.9	4.7	2.3	0.3	0.0	0.0	

RAPPAHANNOCK

Station / Round	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	MEAN
1	12.3	ns	8.4	3.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3*
2	13.2	12.7	10.5	4.8	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7
3	15.4	14.7	11.9	6.2	3.3	2.1	0.4	0.0	0.0	0.0	0.0	0.0	4.5
4	14.7	14.6	11.1	6.2	4.1	2.1	0.5	0.0	0.0	0.0	0.0	0.0	4.4
5	16.6	15.6	12.9	8.4	4.8	3.2	1.0	0.0	0.0	0.0	0.0	0.0	5.2
													4.0
													3.4

* biased downward due to missing data from lower stations.

Table 6. Water temperature (°C) recorded at 1993 seine survey stations.

Drainage

JAMES

Station / Round	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
1	30.1	29.4	29.2	28.1	32.3	31.1	31.4	34.2	30.0	31.0	31.8	32.0	32.3	31.0
2	27.7	27.0	30.0	27.4	29.5	29.4	29.7	29.9	30.0	34.1	32.3	33.0	30.4	30.0
3	28.8	27.8	29.3	26.2	28.1	28.1	29.1	28.7	28.3	30.9	30.9	32.5	29.7	29.1
4	27.0	26.0	29.3	23.4	28.3	28.1	29.1	28.9	27.3	29.2	29.6	30.6	28.5	28.1
5	29.4	30.1	30.4	26.9	28.5	28.3	30.0	28.0	28.0	32.0	32.0	34.0	31.0	29.9
														29.6

YORK

Station / Round	Y15	Y21	Y28	P36	P42		P45	P50	P55	P61	MEAN
1	30.9	33.1	30.0	30.4	30.6		31.0	31.6	33.7	ns	31.4
2	26.2	ns	26.8	28.5	29.4		29.5	29.3	29.8	29.8	28.8
3	26.7	25.6	26.4	27.9	28.1		28.1	28.1	ns	ns	27.2
4	26.1	28.0	27.1	27.8	27.9		28.5	28.0	28.4	27.9	27.8
5	26.7	26.3	26.3	27.8	28.1		28.6	28.5	29.0	28.3	27.8
											28.6

Station / Round	M33	M37	M41	M44	M47	M52	MEAN
1	31.0	30.9	30.4	31.6	31.9	32.6	
2	28.8	28.7	28.6	29.0	29.3	29.0	(included above)
3	27.3	27.1	26.8	27.1	26.9	27.1	
4	27.5	27.7	27.6	27.7	28.6	28.9	
5	27.9	27.9	27.2	27.8	28.2	28.8	

RAPPAHANNOCK

Station / Round	R12	R21	R28	R37		R41	R44	R50	R55	R60	R65	R69	R76	MEAN
1	30.5	ns	30.7	31.8		32.9	32.7	27.5	27.8	28.0	26.5	28.0	28.0	29.5
2	27.2	28.3	25.1	31.3		30.8	31.5	29.3	29.7	29.2	ns	29.6	30.5	29.3
3	30.4	29.4	26.1	28.1		28.3	29.1	29.1	29.4	29.0	29.2	29.7	30.3	29.0
4	24.8	28.9	26.6	28.0		28.3	29.5	28.0	28.0	28.4	28.1	ns	ns	27.9
5	30.3	29.1	30.0	27.9		28.7	29.0	30.0	30.0	ns	ns	30.0	ns	29.4
														29.0
														29.1

Table 7. Dissolved oxygen (parts per million) recorded at 1993 seine survey stations.

Drainage

JAMES

Station / Round	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
1	5.1	5.5	5.6	6.8	8.0	6.9	8.8	10.4	10.6	12.4	7.3	7.5	8.9	8.0
2	6.8	3.6	7.4	6.5	7.9	7.0	8.5	6.7	8.6	10.0	5.8	5.9	5.7	7.0
3	6.5	7.4	4.7	6.1	6.8	5.4	6.9	6.1	7.3	10.7	5.7	6.2	6.6	6.7
4	5.9	6.7	4.9	8.8	7.6	6.1	7.7	8.7	8.3	11.3	5.5	6.1	6.0	7.2
5	4.5	5.5	6.0	6.9	7.5	6.1	6.9	ns	ns	ns	ns	ns	ns	6.2
														7.0

YORK

Station / Round	Y15	Y21	Y28	P36	P42		P45	P50	P55	P61	MEAN
1	4.8	6.6	5.4	6.4	6.1		4.8	4.5	4.9	ns	5.1
2	6.1	ns	4.8	5.3	5.9		6.1	5.7	4.7	5.8	5.1
3	4.7	4.1	5.2	5.2	5.6		6.4	5.3	ns	ns	5.0
4	5.5	7.1	6.0	5.4	5.8		5.6	5.4	5.3	4.5	5.3
5	5.6	5.1	5.4	5.8	5.2		4.9	5.1	4.9	4.2	5.0
											5.1

Station / Round	M33	M37	M41	M44	M47	M52	MEAN
1	5.2	5.2	4.9	5.0	3.9	4.3	(included above)
2	4.2	4.2	5.2	4.4	4.8	4.2	
3	4.4	4.9	5.5	4.6	4.4	5.1	
4	4.6	4.5	4.7	4.8	4.7	5.2	
5	3.9	4.5	3.4	4.3	4.2	5.0	

RAPPAHANNOCK

Station / Round	R12	R21	R28	R37	R41	R44	R50	R55	R60	R65	R69	R76	MEAN
1	5.4	ns	6.6	7.1	6.1	6.5	ns	ns	ns	ns	ns	ns	6.3
2	3.9	6.5	6.6	7.4	8.6	8.9	6.7	7.0	5.8	ns	5.4	7.0	6.7
3	9.2	6.7	6.5	8.2	8.1	8.8	7.7	6.6	5.9	7.5	6.3	6.5	7.3
4	6.3	7.3	5.2	7.0	7.6	7.5	7.0	6.8	5.0	5.8	ns	ns	6.6
5	7.0	5.8	6.0	4.9	5.5	6.4	ns	ns	ns	ns	ns	ns	5.9
													6.6
													6.2

Table 8. pH recorded at 1993 seine survey stations.

Drainage														
JAMES														
Station	J12	J22	J29	J36	C1	C3	J46	J51	J56	J62	J68	J74	J78	MEAN
Round														
1	6.0	5.7	7.3	7.2	8.0	7.1	7.8	7.8	8.7	8.7	7.0	7.5	7.6	7.4
2	7.7	7.6	8.1	7.7	8.3	7.8	8.9	8.8	9.2	9.6	7.9	8.2	8.1	8.3
3	8.2	7.4	8.1	7.5	8.0	7.7	8.2	8.3	8.9	9.4	7.6	8.3	8.5	8.2
4	7.6	7.7	8.1	7.1	8.0	7.5	8.2	8.7	8.3	9.4	7.7	7.9	8.0	8.0
5	7.5	7.9	7.9	7.6	7.9	7.4	7.9	ns	ns	ns	ns	ns	ns	7.7
														7.9
YORK														
Station	Y15	Y21	Y28	P36	P42		P45	P50	P55	P61				
Round														
1	6.2	6.2	5.5	5.6	5.6		5.4	5.1	5.5	ns				5.5
2	7.7	ns	7.3	7.0	7.3		7.5	7.6	7.5	7.6				7.2
3	7.9	7.5	7.3	7.1	7.2		7.3	7.2	ns	ns				7.1
4	7.0	7.0	7.3	7.0	7.0		7.0	6.9	7.1	7.1				6.9
5	7.8	7.4	7.2	7.1	6.9		7.0	7.0	6.9	7.1				6.9
														6.7
Station				M33	M37	M41	M44	M47	M52					
Round														
1				5.6	5.3	5.4	5.2	5.1	5.1					
2				7.0	7.0	6.9	6.9	6.9	6.8					(included above)
3				6.9	6.9	6.9	6.8	6.8	6.8					
4				6.9	6.7	6.6	6.8	6.8	6.8					
5				6.9	6.8	6.7	6.7	6.6	6.3					
RAPPAHANNOCK														
Station	R12	R21	R28	R37		R41	R44	R50	R55	R60	R65	R69	R76	
Round														
1	7.1	ns	7.1	ns		5.8	6.9	ns	ns	ns	ns	ns	ns	6.7
2	7.7	7.8	8.1	8.3		8.5	9.0	7.8	8.1	7.6	ns	7.6	7.9	8.0
3	8.4	8.1	7.9	8.2		7.5	8.6	7.8	7.9	7.8	8.1	7.8	8.2	8.0
4	7.6	8.0	7.8	7.7		7.9	8.7	7.4	7.2	7.3	7.5	ns	ns	7.7
5	8.1	7.8	7.8	7.3		7.4	7.3	ns	ns	ns	ns	ns	ns	7.6
														7.6
														7.4

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

	1993						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	2066	2.23	0.984	19.33	16.12-23.10	150	14305	1.29	1.123	5.98	5.59-6.39	2172
5-9.9	244	2.16	0.711	17.43	12.47-24.07	24	1276	0.91	1.063	3.39	2.72-4.15	284
10-14.9	6	0.88	0.816	3.20	0.53-8.38	6	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	2323	2.19	0.975	18.12	15.35-21.30	180	15692	1.13	1.092	4.76	4.45-5.07	2582

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 1993 summarized by water temperature.

	1993						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	70	3.57	0.198	79.00	59.18-105.23	2	1146	0.75	0.869	2.55	2.16-2.97	429
25-29.9	1779	2.23	0.980	18.90	15.58-22.84	132	10334	1.19	1.082	5.24	4.83-5.68	1613
30-34.9	474	2.02	0.930	14.94	10.81-20.37	46	4020	1.42	1.245	7.15	6.04-8.41	438
Overall	2323	2.19	0.975	18.12	15.35-21.30	180	15579	1.22	1.121	5.45	5.11-5.81	2510

Table 11. Catch ratios between adjusted mean CPUE at index and auxiliary stations by drainage, 1989-1993.

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
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
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

Table 12a

Juvenile Index (Rapphannock River and Virginia) and Spring Rappahannock River pound net CPUE (Females)(Hill and Loesch 1993)

Year Class	Rappahannock Index	Virginia Index	All River			Above Mile 37				
			1^+	2^+	3^+	4^+	5^+	6^+	7^+	8^+
1980	0.75	2.54						n.f.	0.14	0.00
1981	0.88	1.57					n.f.	0.18	0.00	0.18
1982	1.98	2.71				n.f.	1.75	0.04	0.55	0.63
1983	3.77	3.48			n.f.	4.86	0.31	2.27	0.88	0.25
1984	2.57	4.36		n.f.	0.72	0.69	0.18	0.50	0.63	0.14
1985	0.80	2.41	n.f.	0.19	0.39	0.00	0.13	1.63	0.24	0.71
1986	4.49	4.75	0.00	0.75	1.93	0.00	1.50	0.54	0.93	-
1987	34.03	15.75	0.53	0.17	1.00	2.63	1.19	4.50	-	
1988	14.55	7.64	0.00	1.91	0.60	0.36	3.71	-		
1989	9.87	11.23	0.00	0.30	0.14	0.21	-			
1990	4.14	7.34	0.15	0.07	0.14	-				
1991	3.56	3.78	0.05	0.07	-					
1992	30.92	7.32	0.00	-						
1993	18.10	18.12	-							

n.f. No funding

Table 12b

Juvenile Index (Rapphannock River and Virginia)
and
Fall Rappahannock River pound net CPUE (Females)(Hill and Loesch 1993)

Year Class	Rappahannock Index	Virginia Index	1^+	2^+	3^+	4^+	5^+	6^+
1980	0.75	2.54			-	0.25		0.00
1981	0.88	1.57		-	0.50		0.00	0.00
1982	1.98	2.71	-	1.88		0.54	0.60	0.05
1983	3.77	3.48	0.21		1.94	1.46	0.05	0.61
1984	2.57	4.36		6.15	4.27	1.03	1.00	n.f.
1985	0.80	2.41	23.00	17.61	6.69	2.49	n.f.	0.51
1986	4.49	4.75	0.50	13.83	10.90	n.f.	1.53	0.00
1987	34.03	15.75	2.40	9.42	n.f.	3.66	1.00	-
1988	14.55	7.64	0.97	n.f.	5.86	7.75	-	
1989	9.87	11.23	n.f.	3.94	8.50	-		
1990	4.14	7.34	0.00	8.25	-			
1991	3.56	3.78	2.00	-				
1992	30.92	7.32	-					
1993	18.10	18.12						

n.f. = No funding in 1990

Table 12c

Fall Rappahannock River pound net CPUE (male & female) (Hill and Loesch 1993)

Year Class	Rappahannock Index	Virginia Index	1^+	2^+	3^+	4^+	5^+	6^+
1980	0.75	2.54			-	0.38		0.00
1981	0.88	1.57		-	0.90		0.06	0.04
1982	1.98	2.71	-	7.86		0.93	0.71	0.11
1983	3.77	3.48	1.00		5.33	3.82	1.11	0.19
1984	2.57	4.36		15.40	7.14	5.21	1.76	n.f.
1985	0.80	2.41	29.33	25.25	16.43	9.14	n.f.	0.64
1986	4.49	4.75	1.36	30.60	32.71	n.f.	3.46	0.25
1987	34.03	15.75	3.46	29.52	n.f.	9.29	4.20	-
1988	14.55	7.64	1.52	n.f.	21.40	38.80	-	
1989	9.87	11.23	n.f.	8.57	56.50	-		
1990	4.14	7.34	0.00	35.25	-			
1991	3.56	3.78	6.50	-				
1992	30.92	7.32	-					
1993	18.10	18.12						

Table $12d_1$

Ricker Spawner-Recruit Function

Juvenile Index (Rappahannock River and Virginia)
vs
Spring
Rapphannock River pound net CPUE for 4^+-6^+ Females
(Above River Mile 37)

Spawning Year	Spawning Stock	Rappahannock	Virginia
		Recruitment	
1987	2.62	34.04	15.75
1988	0.43	14.55	7.64
1989	2.40	9.87	11.23
1990	0.59	4.14	7.34
1991	3.33	3.56	3.78
1992	1.46	30.92	7.32
1993	7.15	18.10	18.12

Table $12d_2$

Ricker Spawner-Recruit Function

Juvenile Index (Rappahannock River and Virginia)
vs
Spring
Rapphannock River pound net CPUE for 4^+-=or>8^+ Females
(Above River Mile 37)

Spawning Year	Spawning Stock	Rappahannock	Virginia
		Recruitment	
1987	3.01	34.04	15.75
1988	0.43	14.55	7.64
1989	3.22	9.87	11.23
1990	2.65	4.14	7.34
1991	4.84	3.56	3.78
1992	2.16	30.92	7.32
1993	11.93	18.10	18.12

Table 13

Ricker

Spawner-Recruit Relationships

Striped Bass

Spawner	Recruit	F	P	r^2
Rapp Ri 4-6+	Va Index	4.52	0.87	0.48
Rapp Ri 4-8+	Va Index	3.21	0.13	0.39
Rapp Ri 4-6+	Rapp Index	3.32	0.12	0.40
Rapp Ri 4-8+	Rapp Index	2.69	0.16	0.35
Rapp Ri 4-6+	Wgtd Va Indx	4.90	0.78	0.49
Rapp Ri 4-8+	Wgtd Va Indx	4.05	0.10	0.45

Table 14

Regression

of

Juvenile Indices vs Subsequent year Pound Net CPUE

	df	F	SE	P	r^2
Rappahannock River Index vs I^+	5	25.58	0.0376	0.01	0.86
Rappahannock River Index vs II^+		0.62		0.47	0.13
Rappahannock River Index vs III^+		0.49		0.52	0.11
Virginia State-wide Index vs I^+	5	28.73	0.0259	0.01	0.88
Virginia State-wide Index vs II^+		2.37		0.20	0.37
Virginia State-wide Index vs III^+		2.67		0.18	0.40
Virginia weighted Index vs I^+	5	19.11	0.0298	0.01	0.83
Virginia weighted Index vs II^+		2.18		0.21	0.35
Virginia weighted Index vs III^+		0.36		0.58	0.08

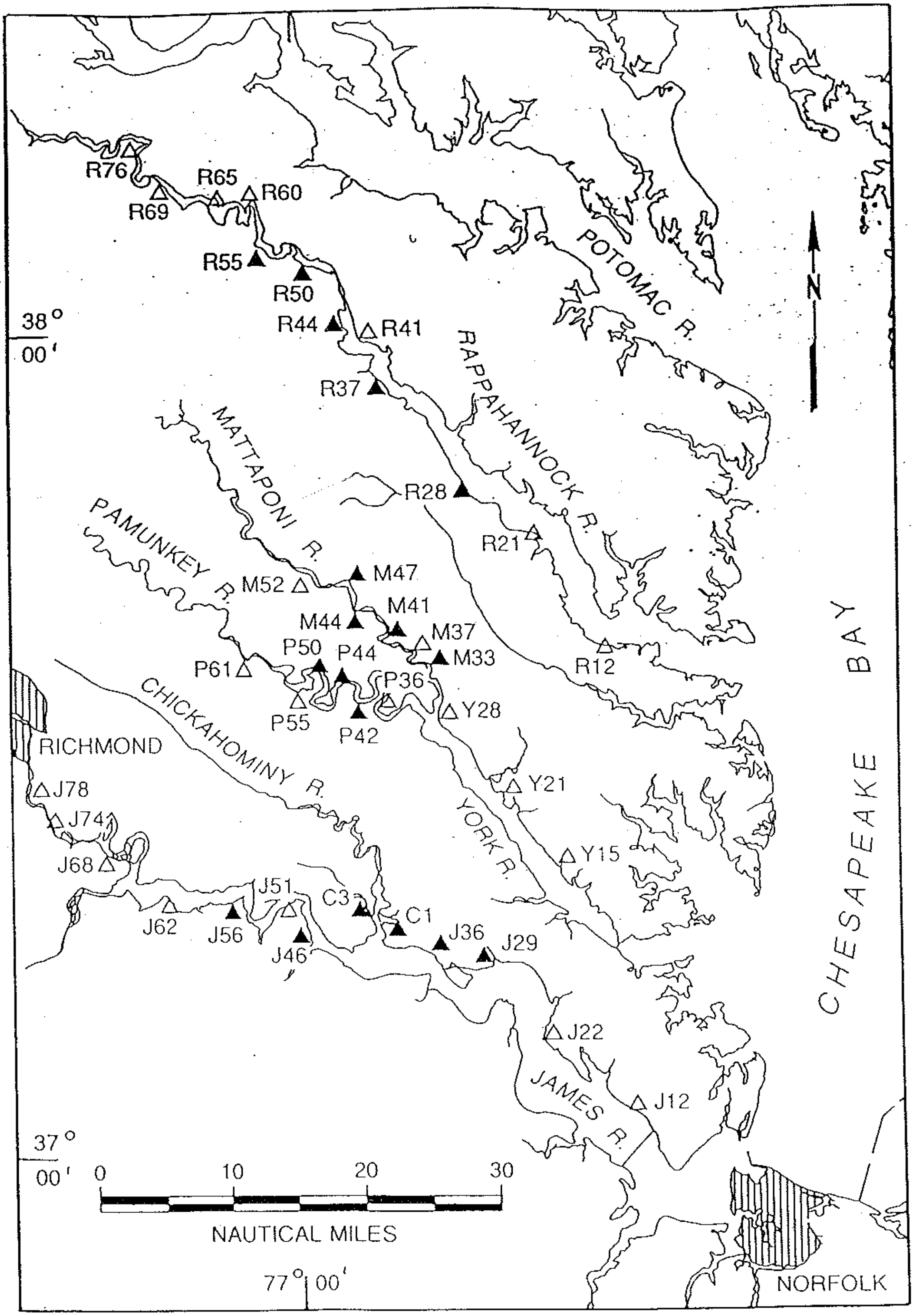


Figure 1. 1993 juvenile striped bass seine survey sampling locations. Numeric portion of station designations indicate river mile from mouth. Solid triangles are index stations, open ones auxiliary stations.

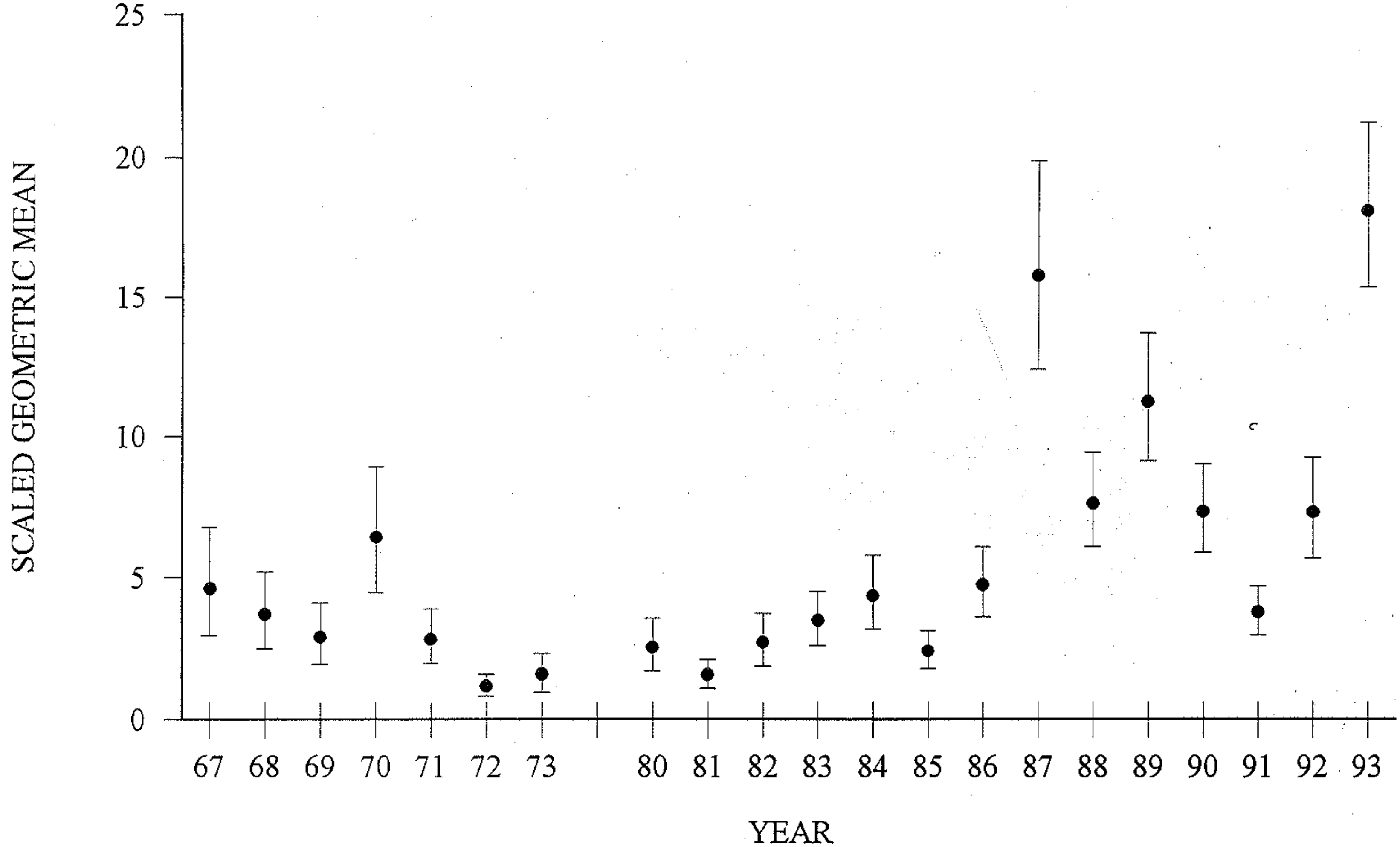


Figure 2. Scaled average catch per seine haul of young-of-the-year striped bass in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean.

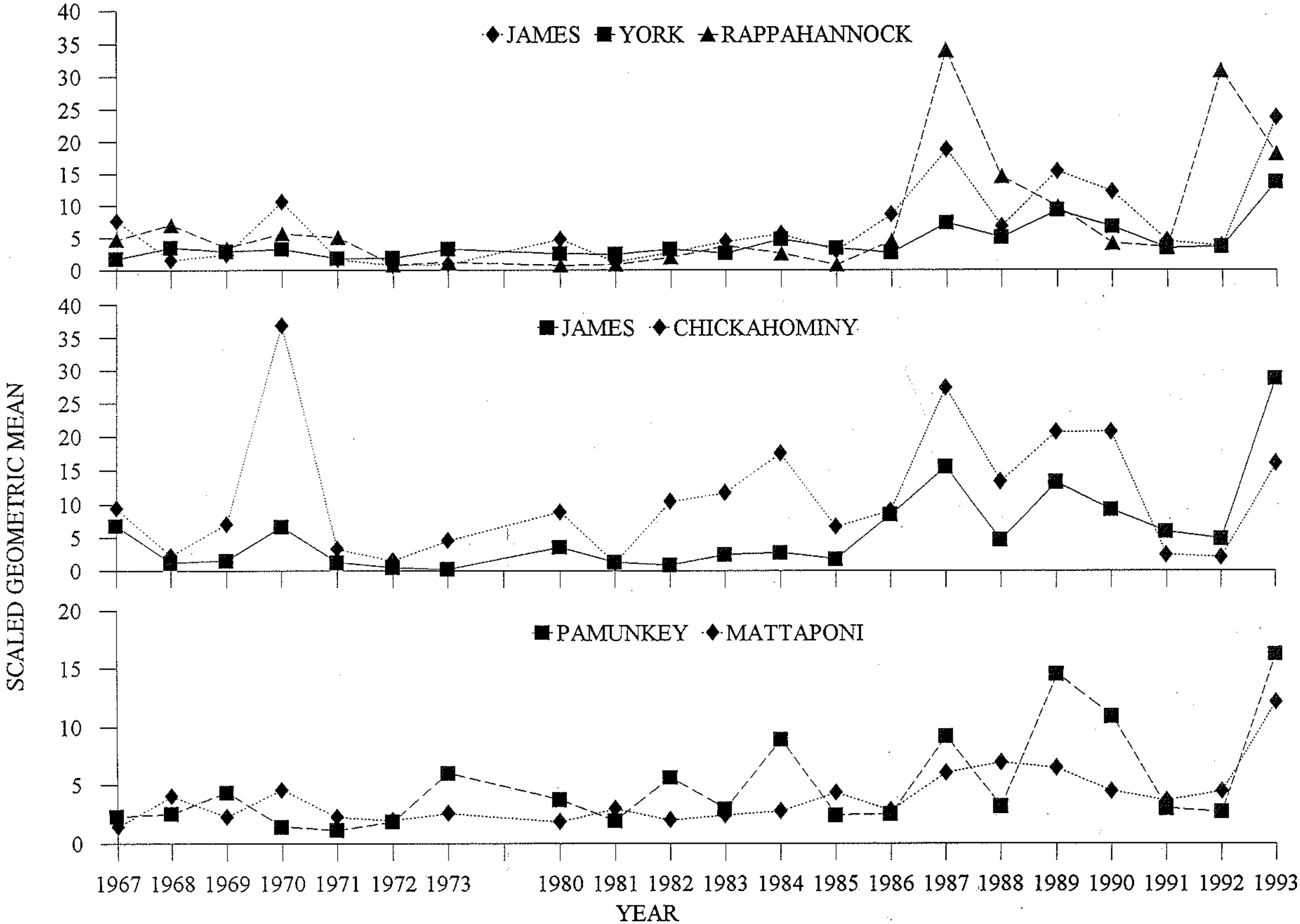


Figure 3. Adjusted average annual catch per seine haul of young-of-the-year striped bass in the primary nursery area by drainage and river.

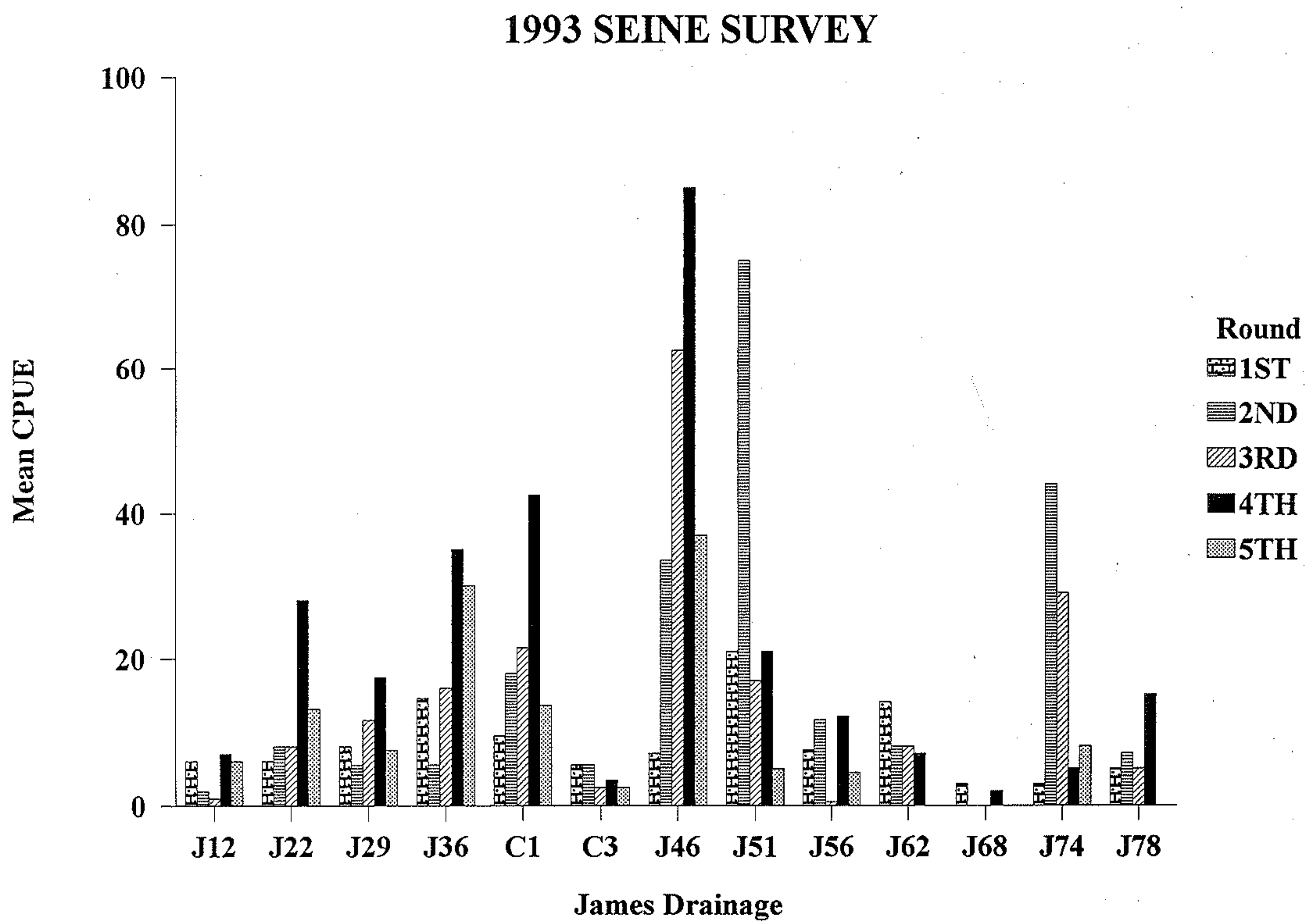


Figure 4. Average catch per seine haul of young-of-the-year striped bass by station in the James drainage in 1993.

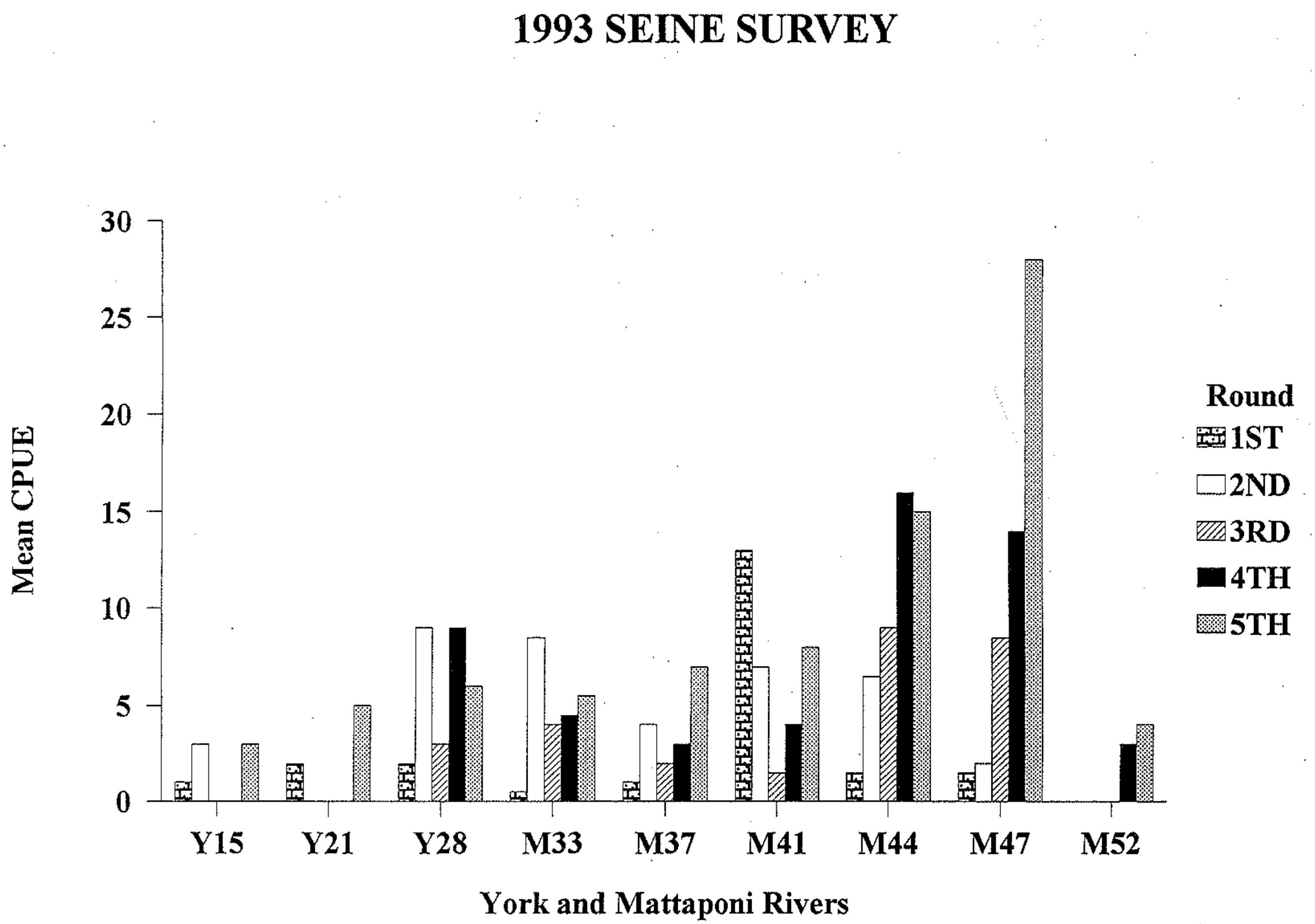


Figure 5. Average catch per seine haul of young-of-the-year striped bass by station in the Mattaponi and York rivers in 1993.

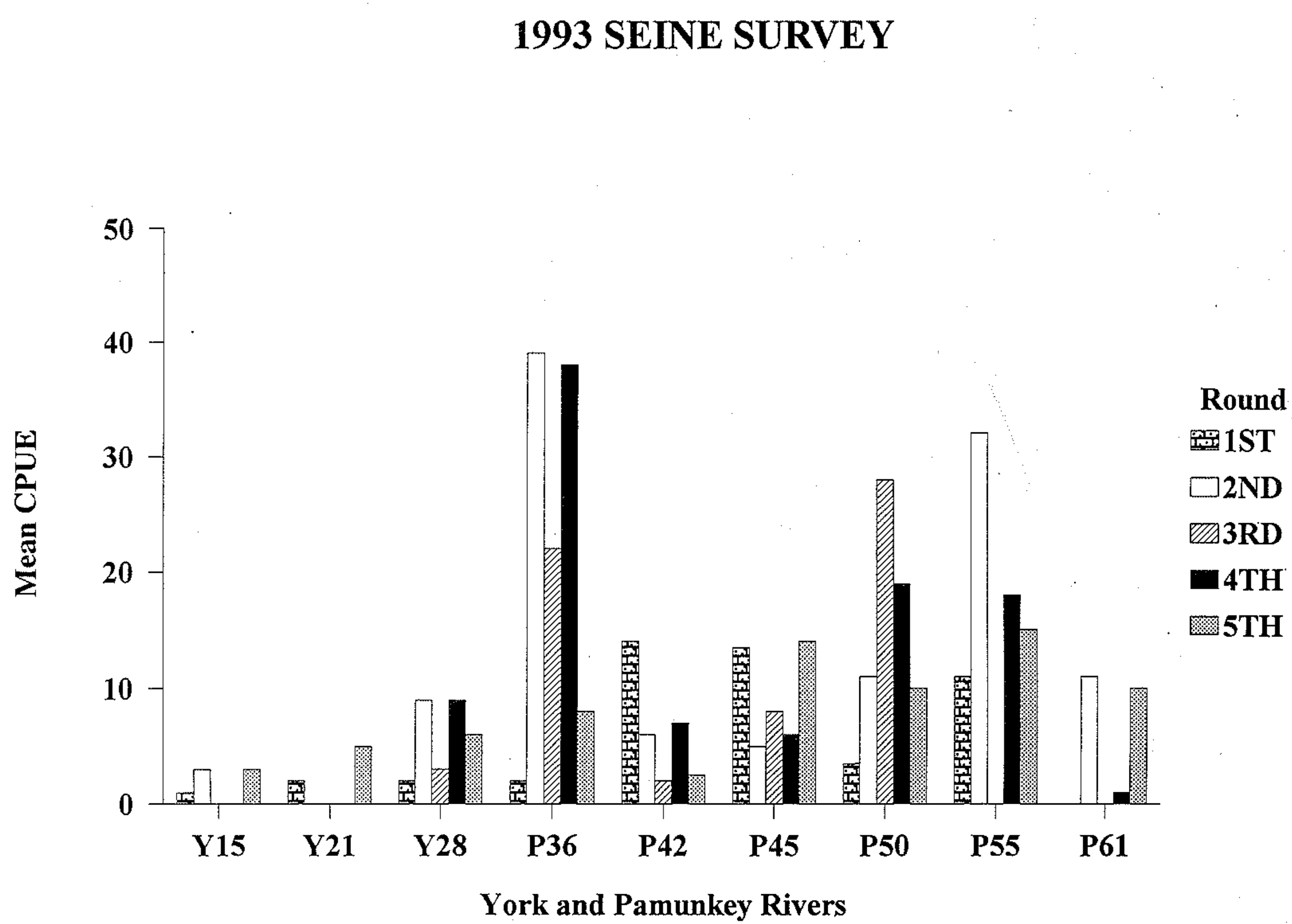


Figure 6. Average catch per seine haul of young-of-the-year striped bass by station in the Pamunkey and York rivers in 1993.

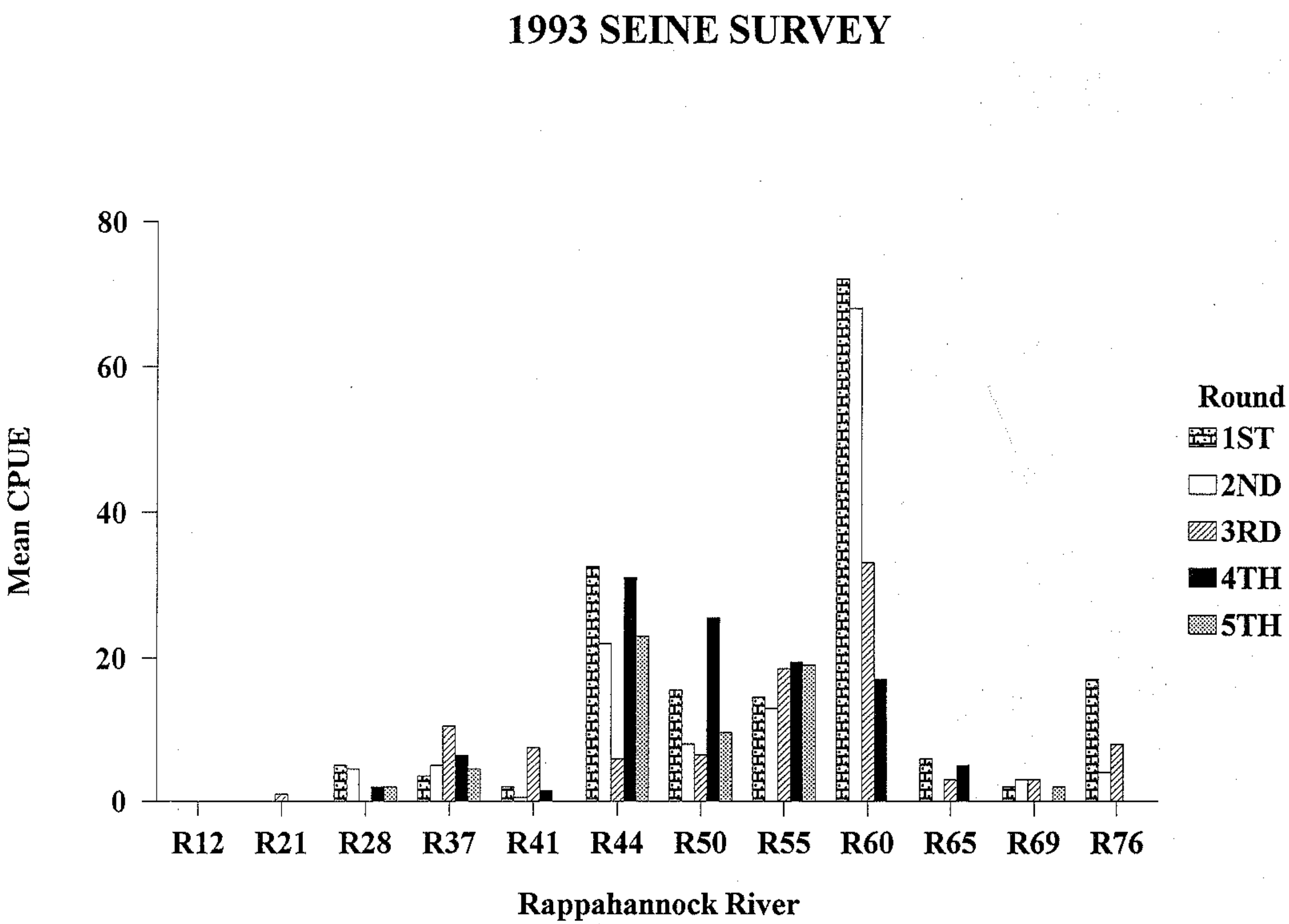
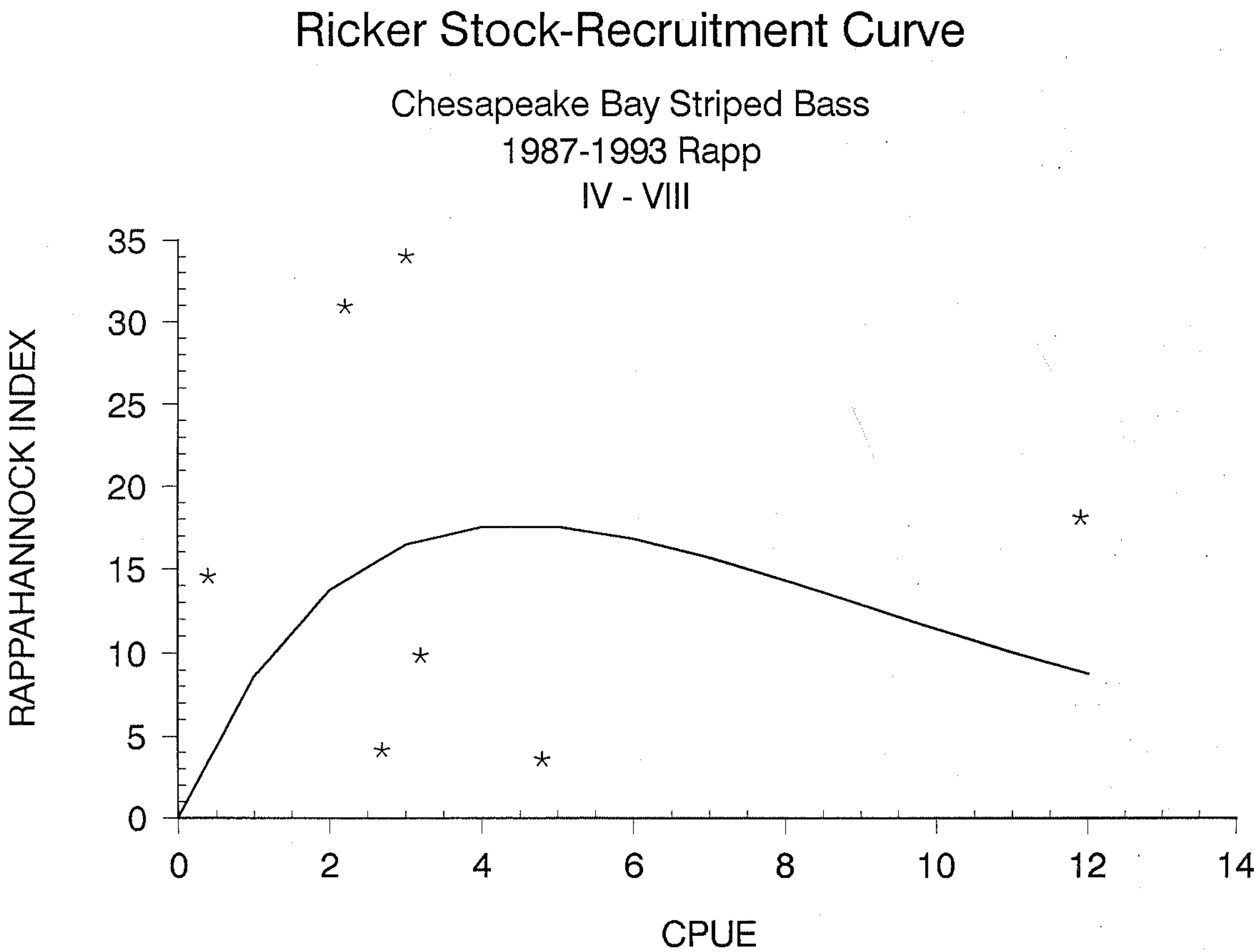
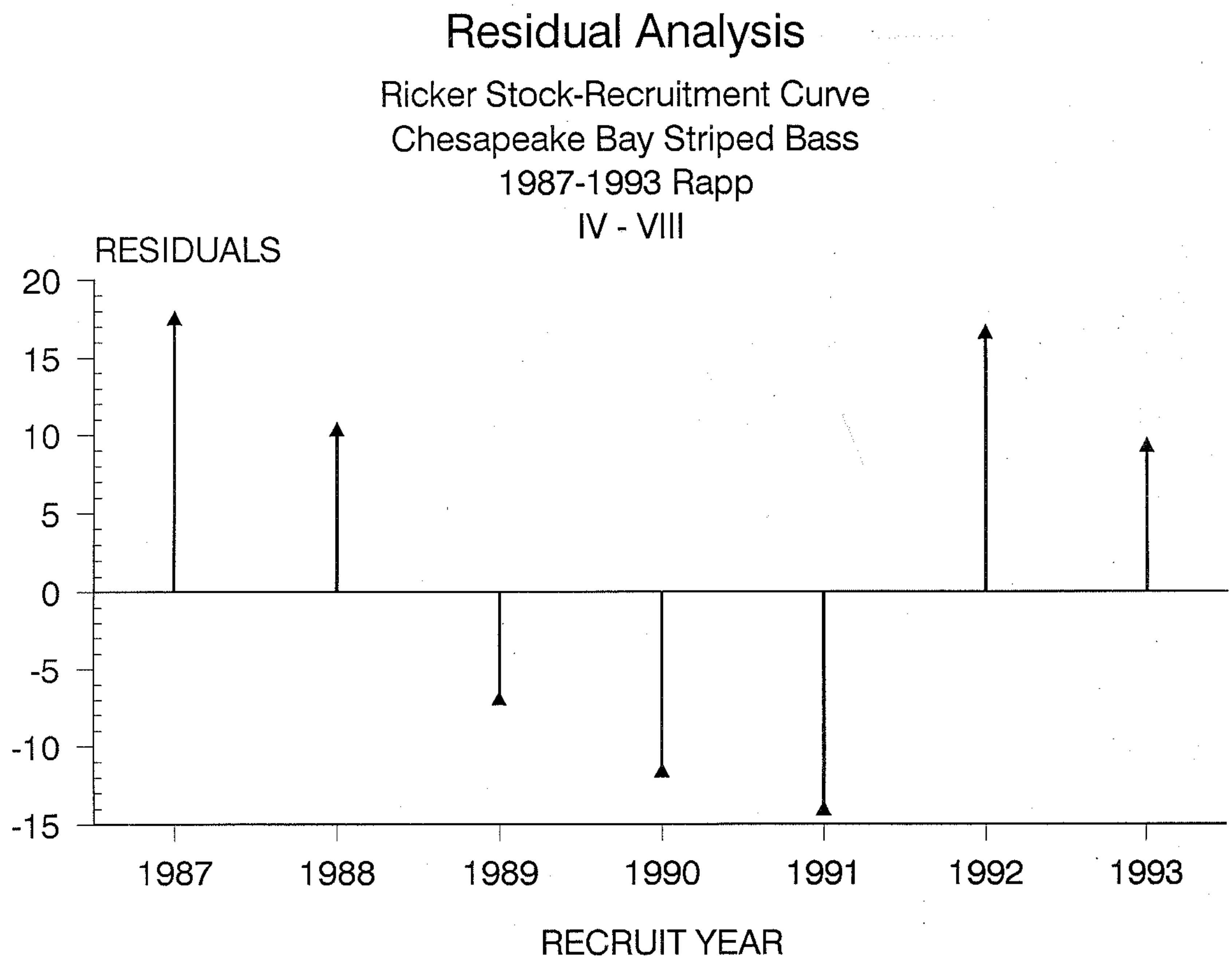
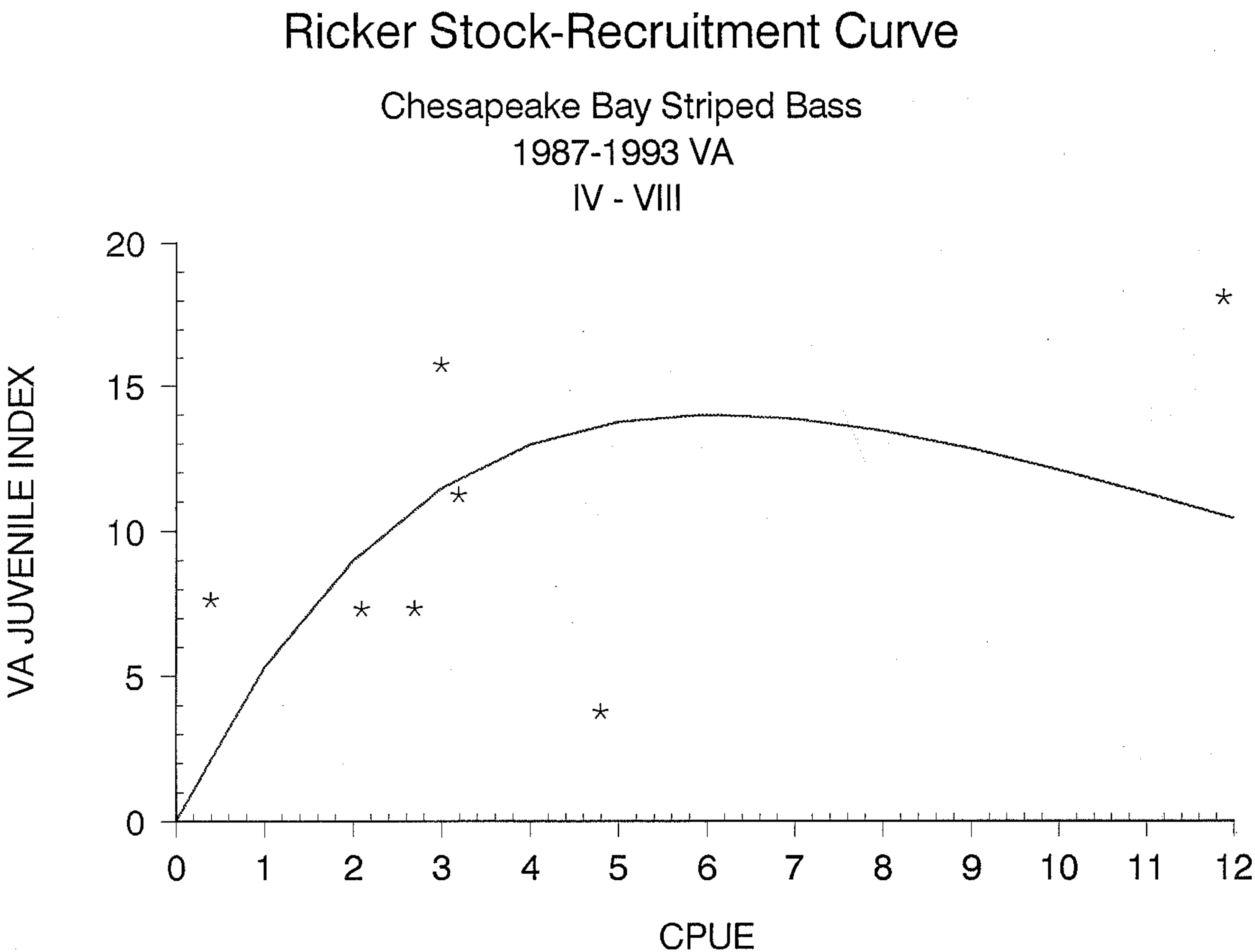
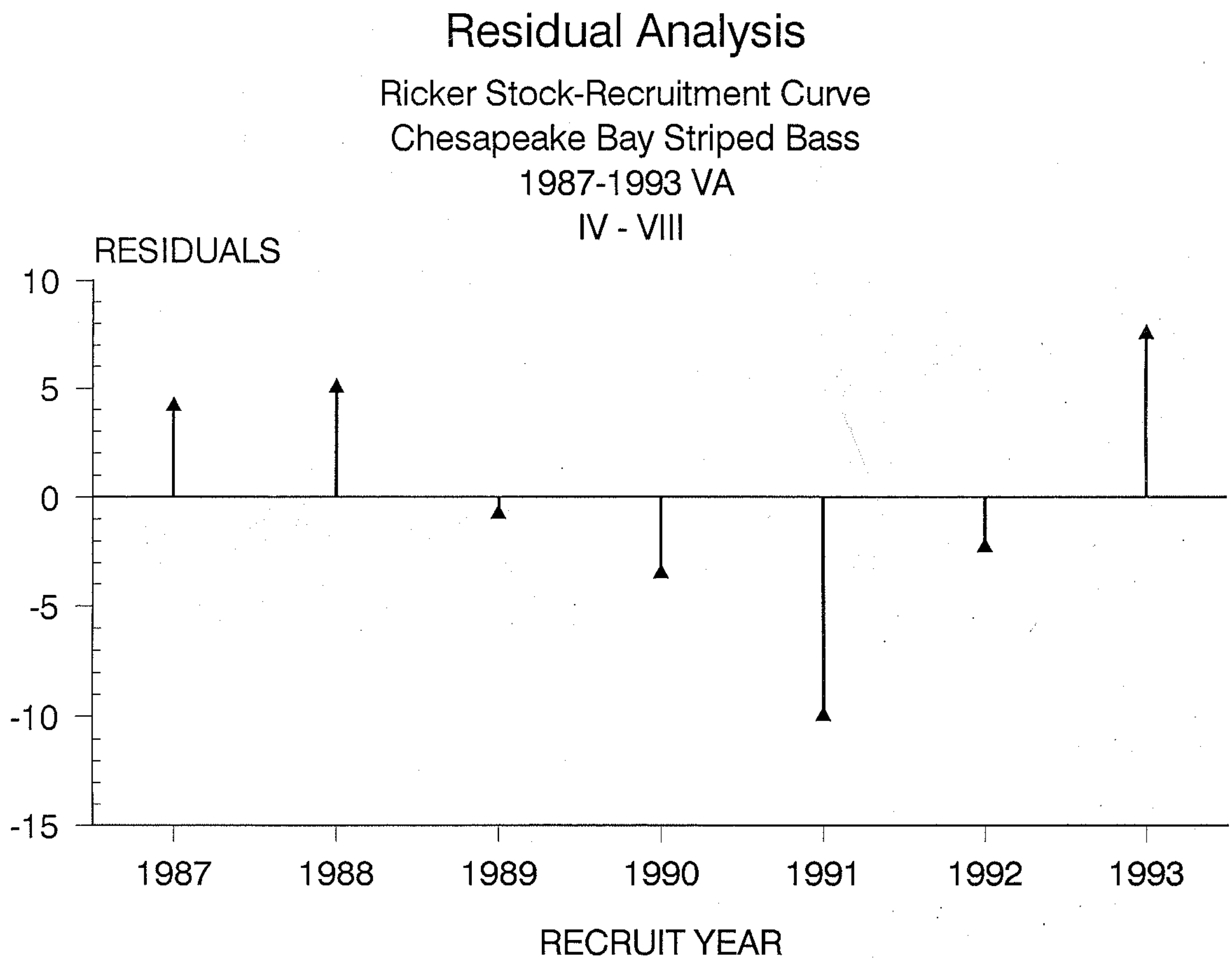


Figure 7. Average catch per seine haul of young-of-the-year striped bass by station in the Rappahannock River in 1993.


Ricker Stock-Recruitment Curve
Chesapeake Bay Striped Bass
1987-1993 Rapp
IV - VIII
RAPPAHANNOCK INDEX
CPUE
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14


Residual Analysis
Ricker Stock-Recruitment Curve
Chesapeake Bay Striped Bass
1987-1993 Rapp
IV - VIII
RESIDUALS
20
15
10
5
0
-5
-10
-15
1987
1988
1989
1990
1991
1992
1993
RECRUIT YEAR


Ricker Stock-Recruitment Curve
Chesapeake Bay Striped Bass
1987-1993 VA
IV - VIII
VA JUVENILE INDEX
0
5
10
15
20
0 1 2 3 4 5 6 7 8 9 10 11 12
CPUE



Residual Analysis
Ricker Stock-Recruitment Curve
Chesapeake Bay Striped Bass
1987-1993 VA
IV - VIII
RESIDUALS
10
5
0
-5
-10
-15
1987
1988
1989
1990
1991
1992
1993
RECRUIT YEAR

Appendix

An Analysis of Finfish Species Taken in The Juvenile Striped Bass Survey

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School of Marine Science/Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, VA

Executive Summary

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile striped bass beach seine survey since 1967, except the period 1974-1979 when funding was suspended. During the survey one-hundred-twenty-three species have been captured in addition to striped bass. Several of these species are ecologically and/or economically important to the Chesapeake Bay system.

Juvenile indices for the ten most abundant species and several others of economic/ecological importance were calculated. Several distinct temporal trends were identified:

1) decreasing abundance throughout the survey period
2) a period of increasing and highly variable abundance during the early to mid-1980's and
3) a trend of increasing abundance during the latter half of the 1980's.

Several species, including the mummichog, banded killifish, Atlantic silverside and striped killifish exhibited a trend of decreasing abundance. Mummichogs and banded killifish were relatively abundant during the first two years of the survey (1967-1968) and then show a low but variable abundance. Striped killifish and Atlantic silversides have shown the most dramatic decreases. Striped killifish were quite abundant during the first two years (67-68) then dropped precipitously in 1969, a pattern that has continued through the present. In fact all index values since 1969 have been 1/2 to 1/10 as large as that in 1968. Atlantic silversides have not declined as sharply as striped killifish, but the overall abundance has markedly decreased since 1970. This is particularly disturbing in light of the silversides importance as forage for piscivirous species such as bluefish, grey trout and striped bass.

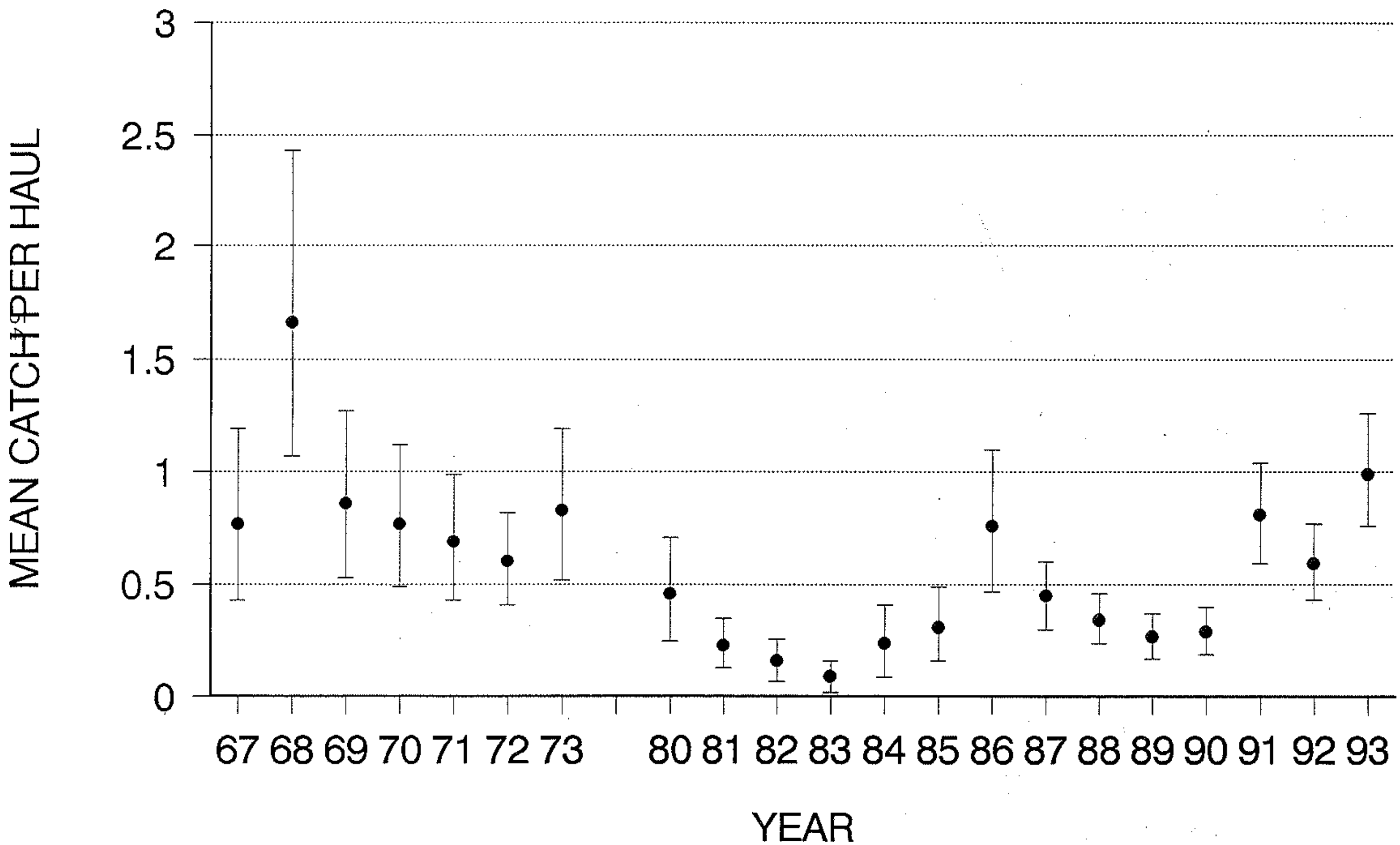
Species conforming to the second trend - highly variable increases in the early to mid-1980's - were inland silversides, rough silversides, menhaden, bluefish and bay anchovy. Inland silversides were relatively abundant during the early-1980's, declined slightly in the mid-80's, increased during the late-80's and has consistently declined since 1989. Rough silversides also showed a marked increase in the mid-1980's and have declined since rapidly since 1985. Menhaden abundances were similar to rough silversides, with relatively high abundance during the early to mid-1980's and then dropping substantially in the late-80's and early-1990's. Bluefish abundances increased steadily during the early-80's and then began a cycle of a very high year followed by an average year. This trend continued until 1988 when for the next three years (89-91) the index hovered around the average, nearly bottomed out in 1992 and rebounded in 1993. Bay anchovy has shown a similar pattern to bluefish with periods of high abundance followed by periods of low abundance. Interestingly, bay anchovy declined sharply during the early-80's just as bluefish started increasing, then increased when bluefish abundances were boom or bust (84-88) before dropping dramatically in 1988. Abundances have been low during the early-90's, although the average has crept slowly upward.

Three species have shown a definitive upward trend since the mid-1980's; hogchokers, threadfin shad and gizzard shad. Threadfin shad were rarely caught prior to 1987, but have been an important part of the upriver (freshwater) community in recent years. This increase in abundance is likely due to the addition of our auxiliary sites in 1989, resulting in more freshwater habitats being sampled. Gizzard shad abundances also increased in the mid 1980's and in fact since 1987 all index values have exceeded the historical average. Hogchokers have shown the most persistent increase in abundance during the last nine years and index values have been three to four times higher than those for the first twelve years of the survey.

List of Figures

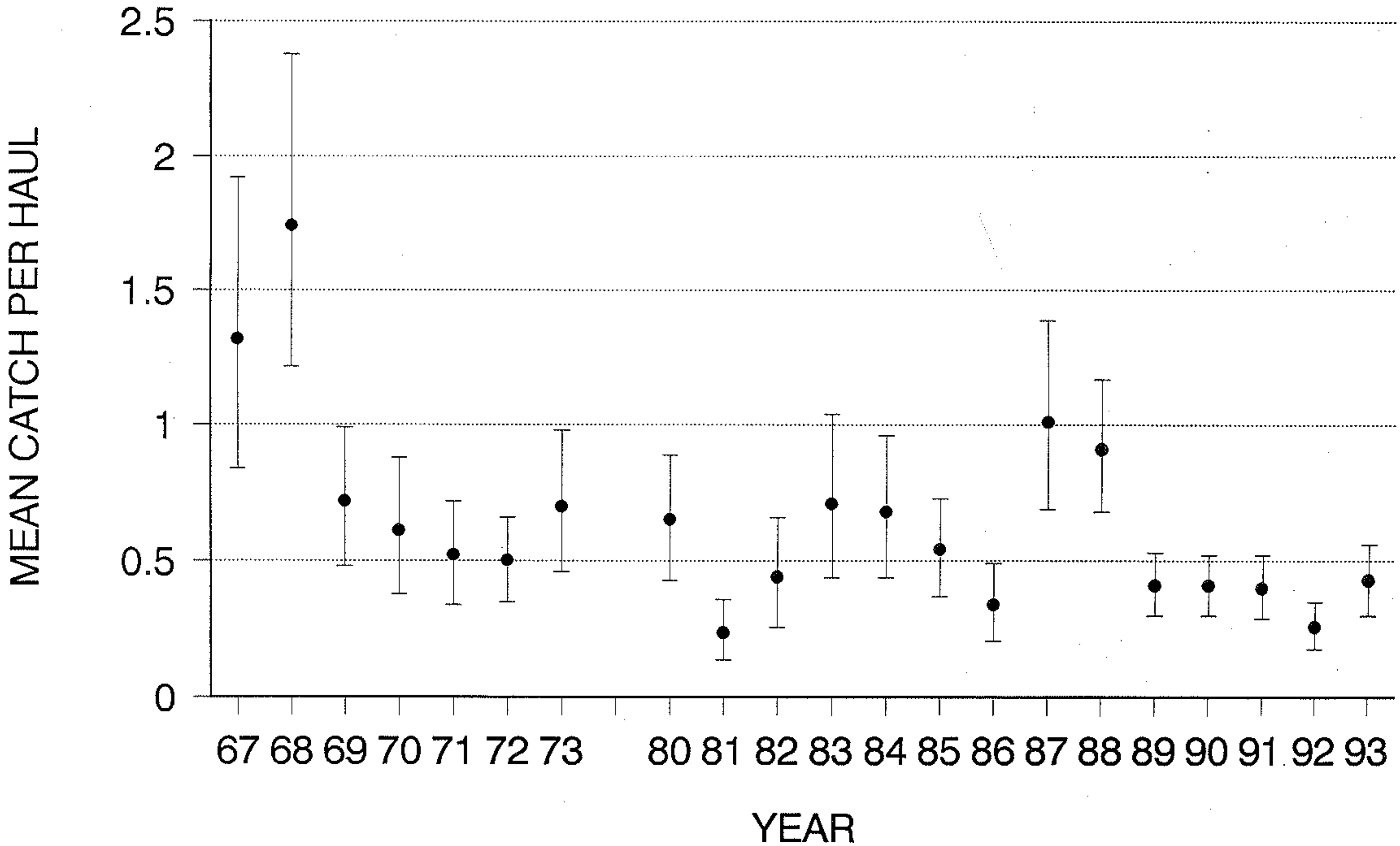
Juvenile Seine Indices

Mummichog



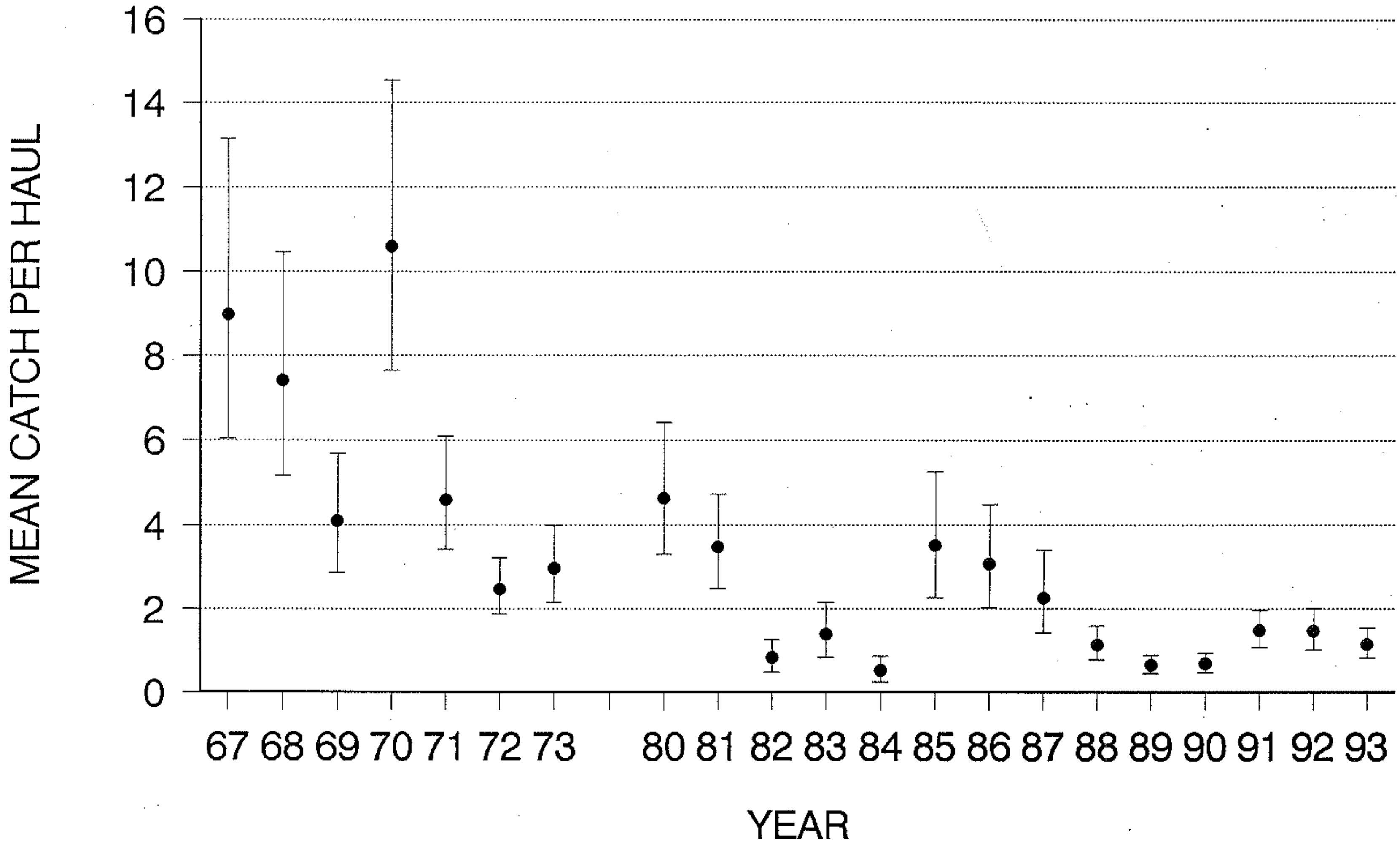
Juvenile Seine Indices

Banded Killifish



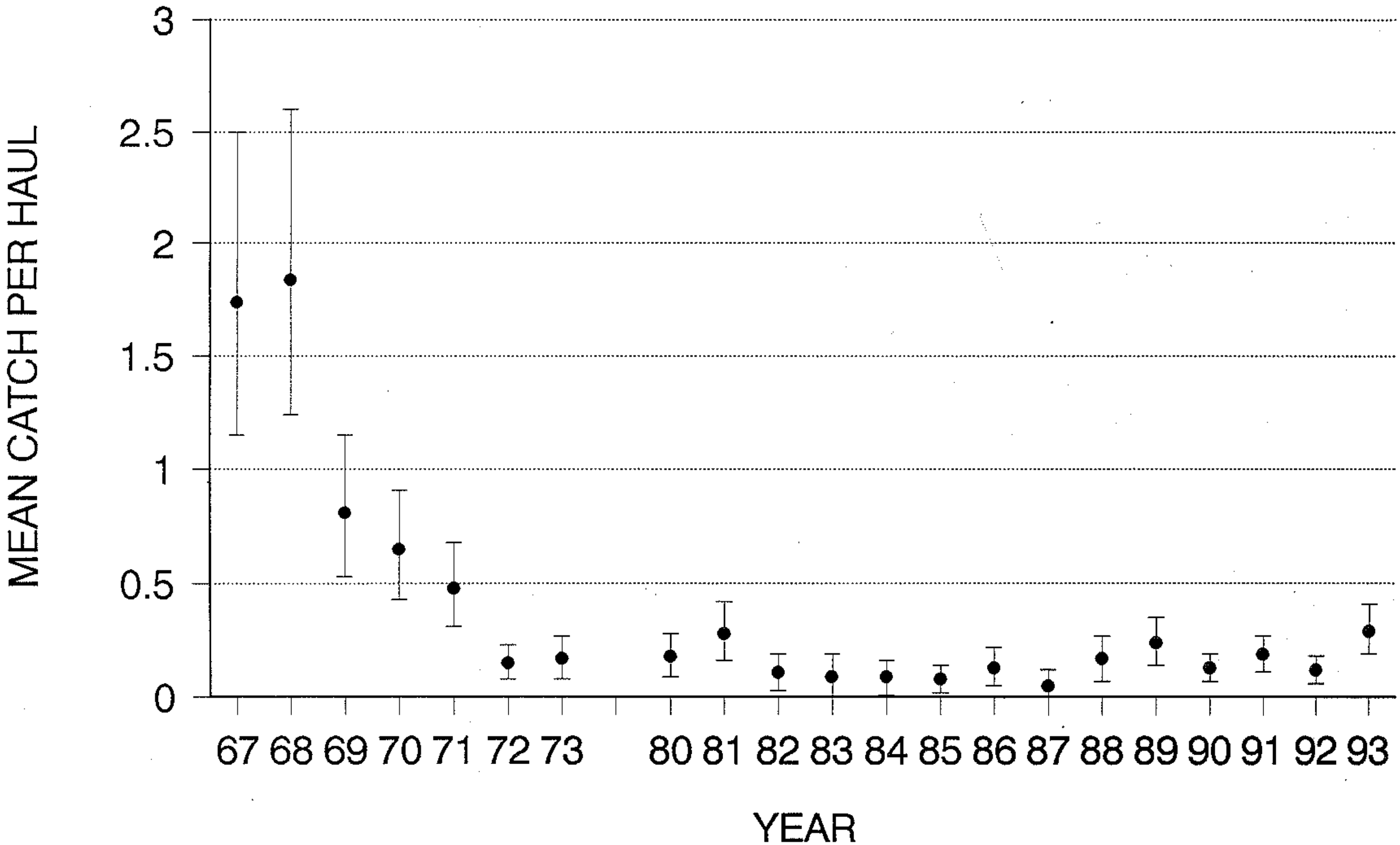
Juvenile Seine Indices

Atlantic Silversides



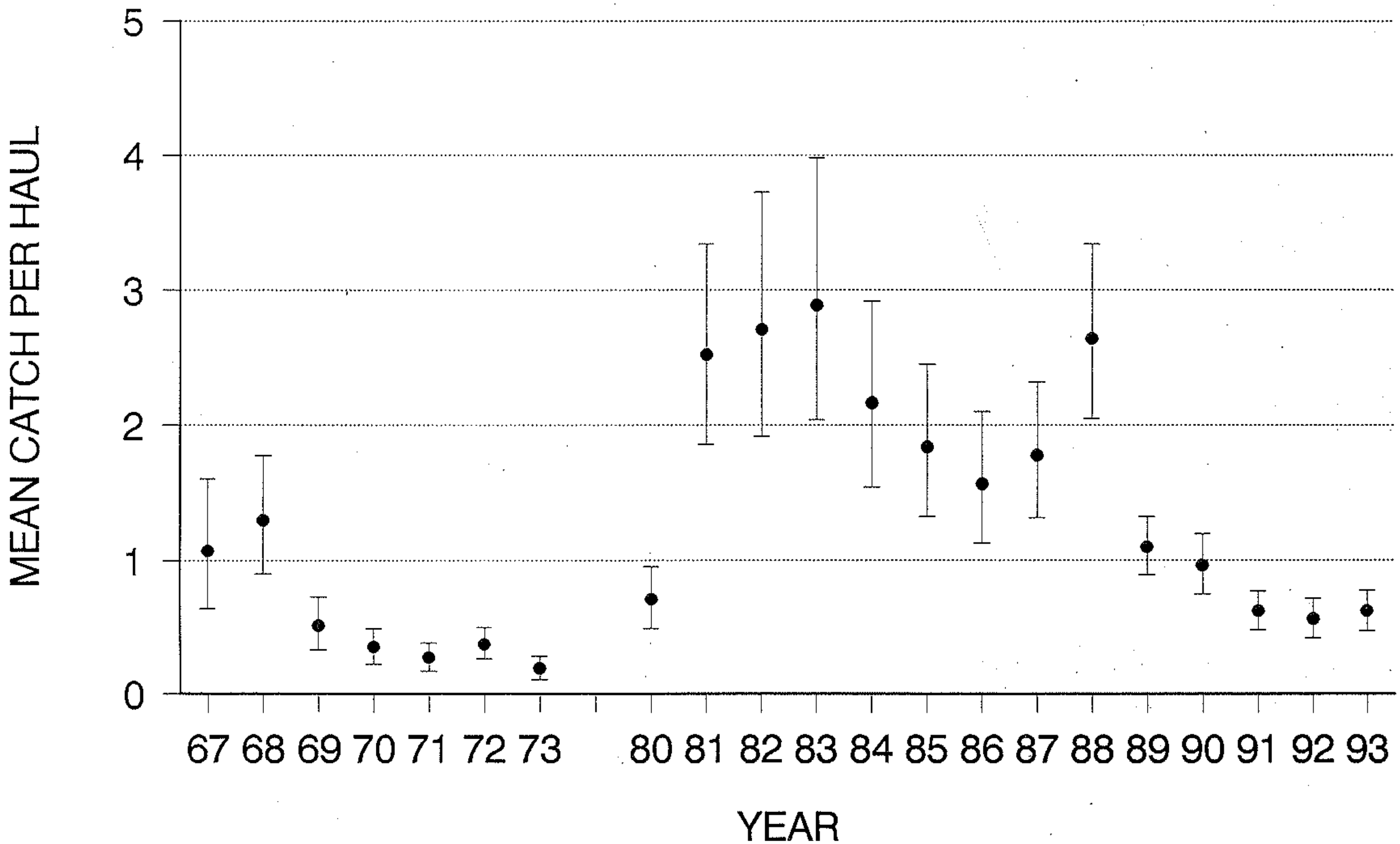
Juvenile Seine Indices

Striped Killifish



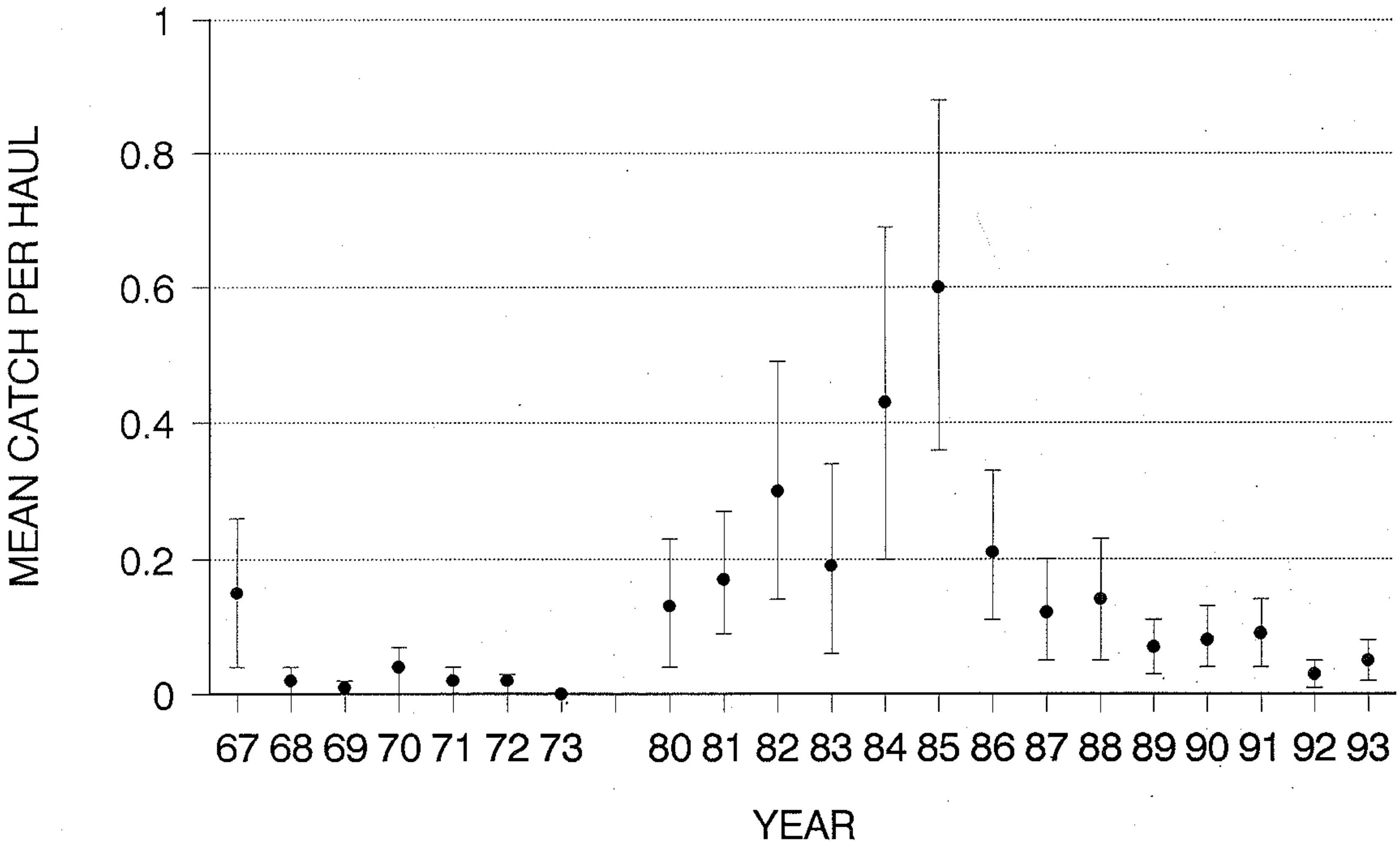
Juvenile Seine Indices

Inland Silversides



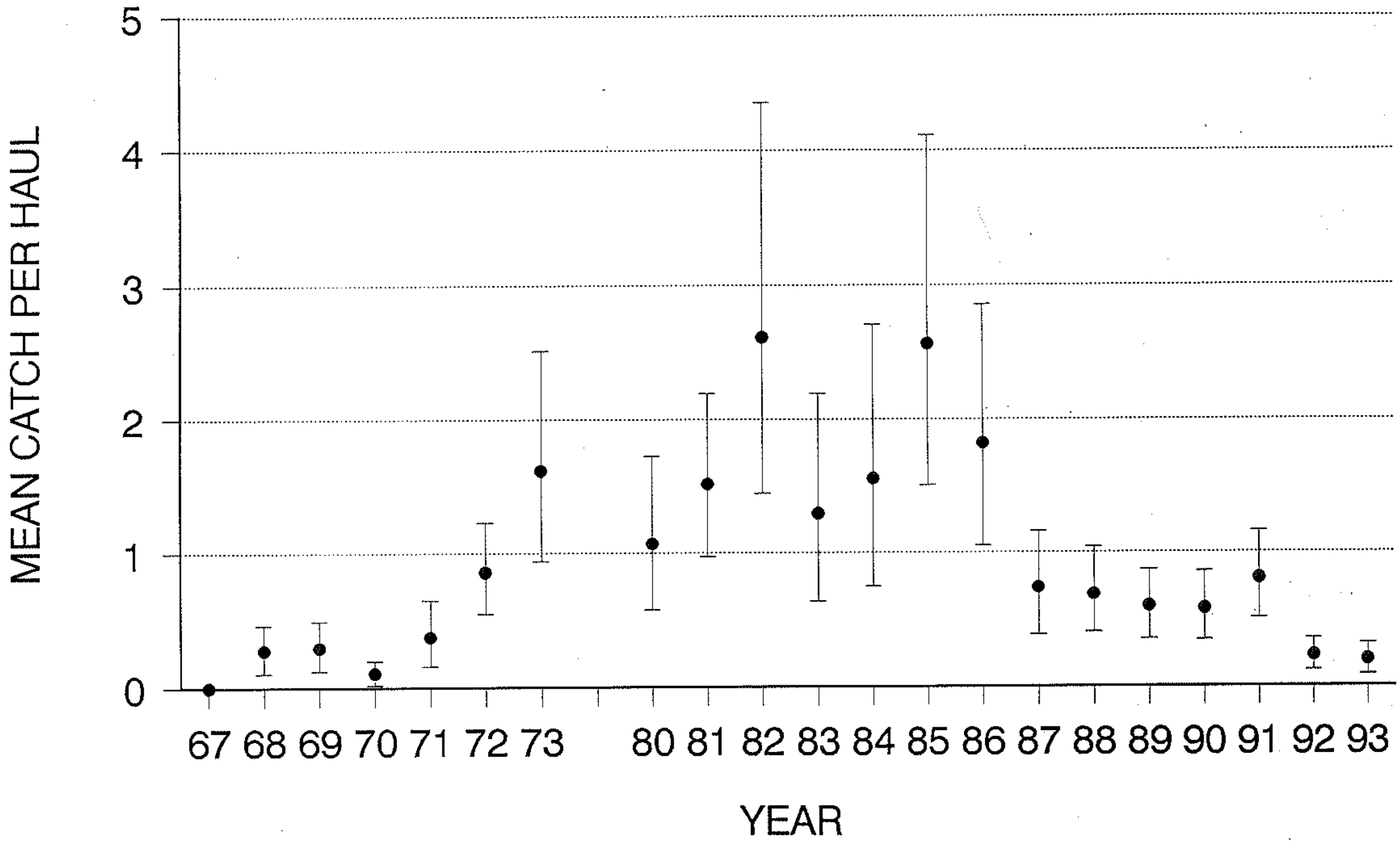
Juvenile Seine Indices

Rough Silversides



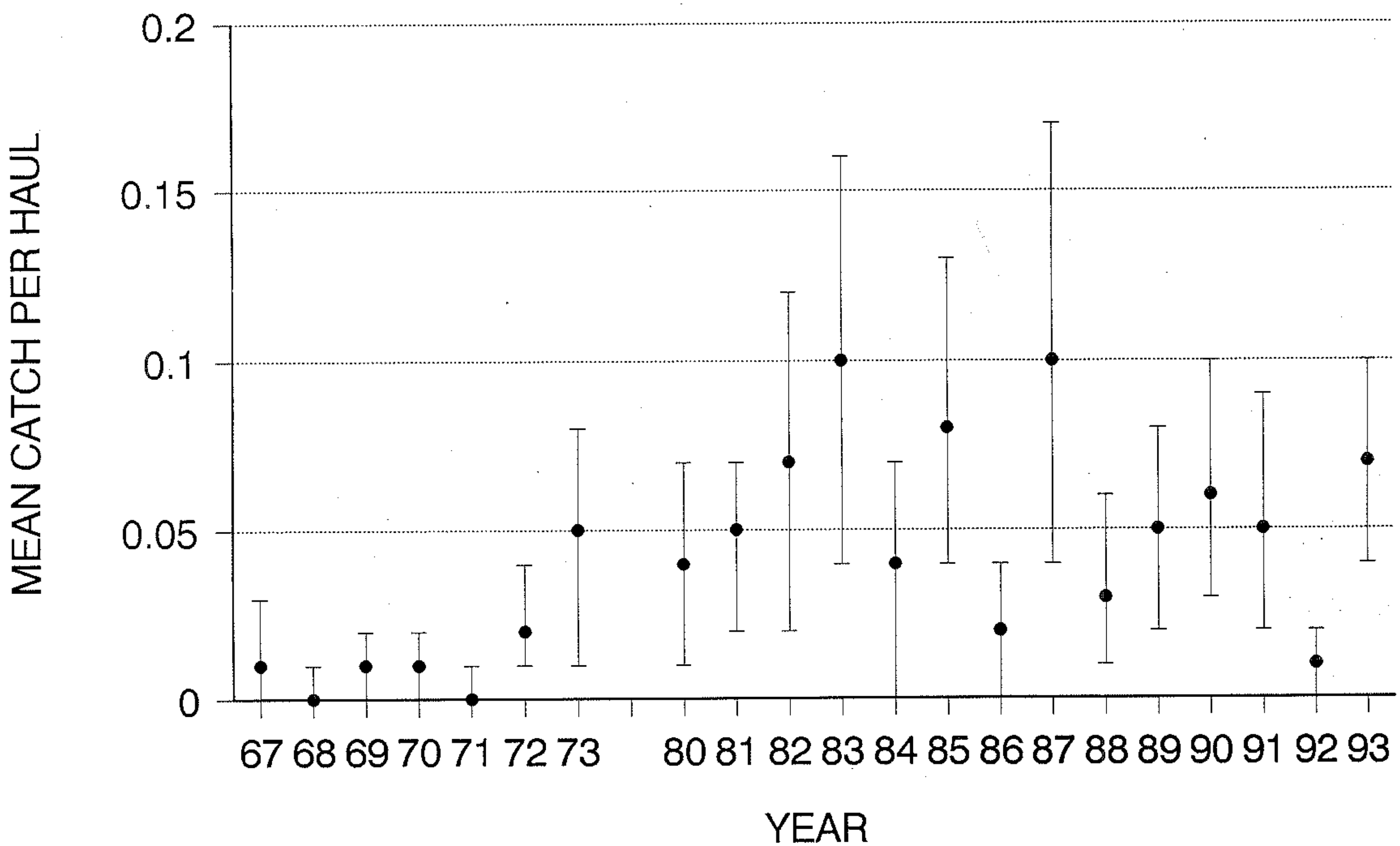
Juvenile Seine Indices

Menhaden



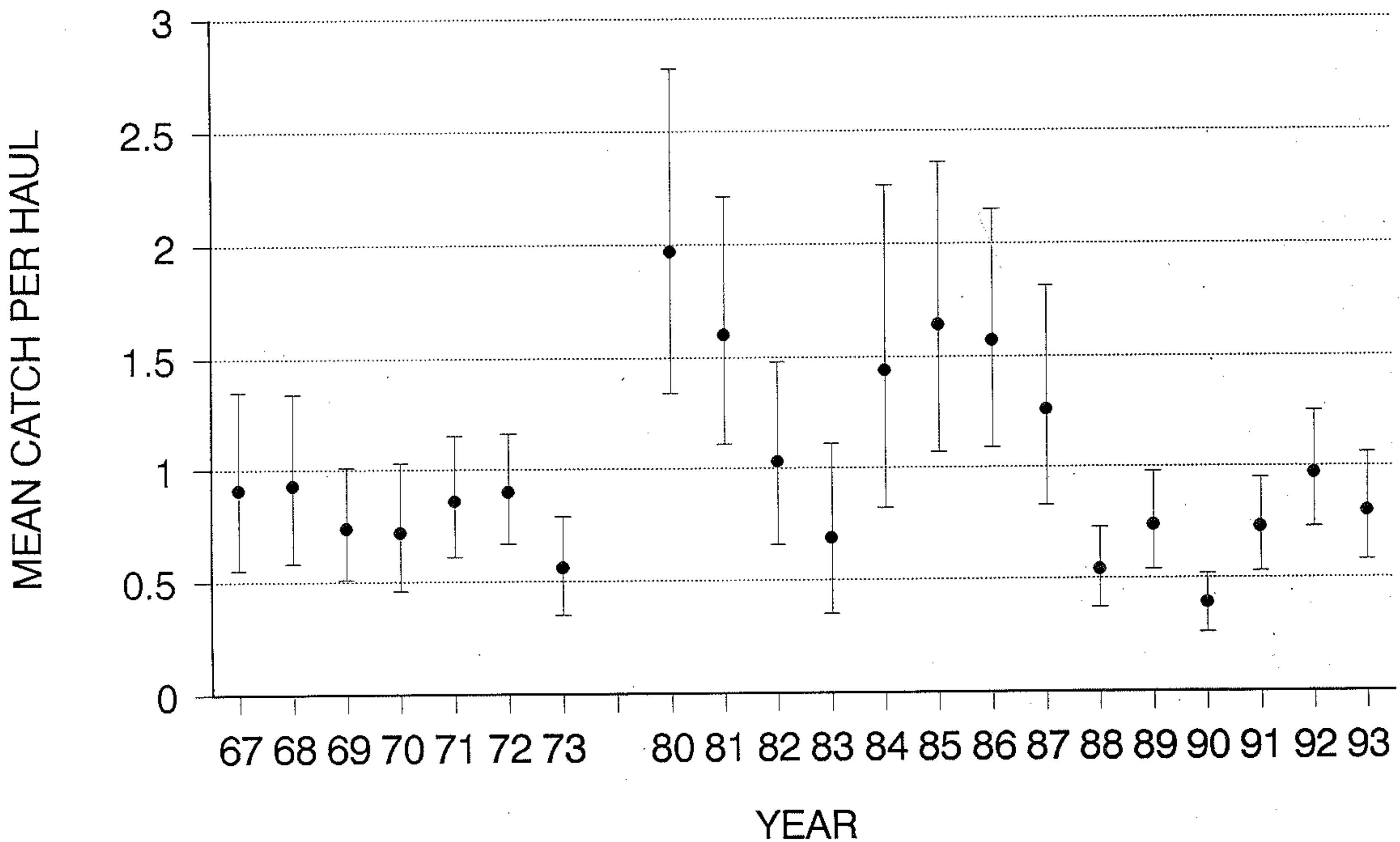
Juvenile Seine Indices

Bluefish



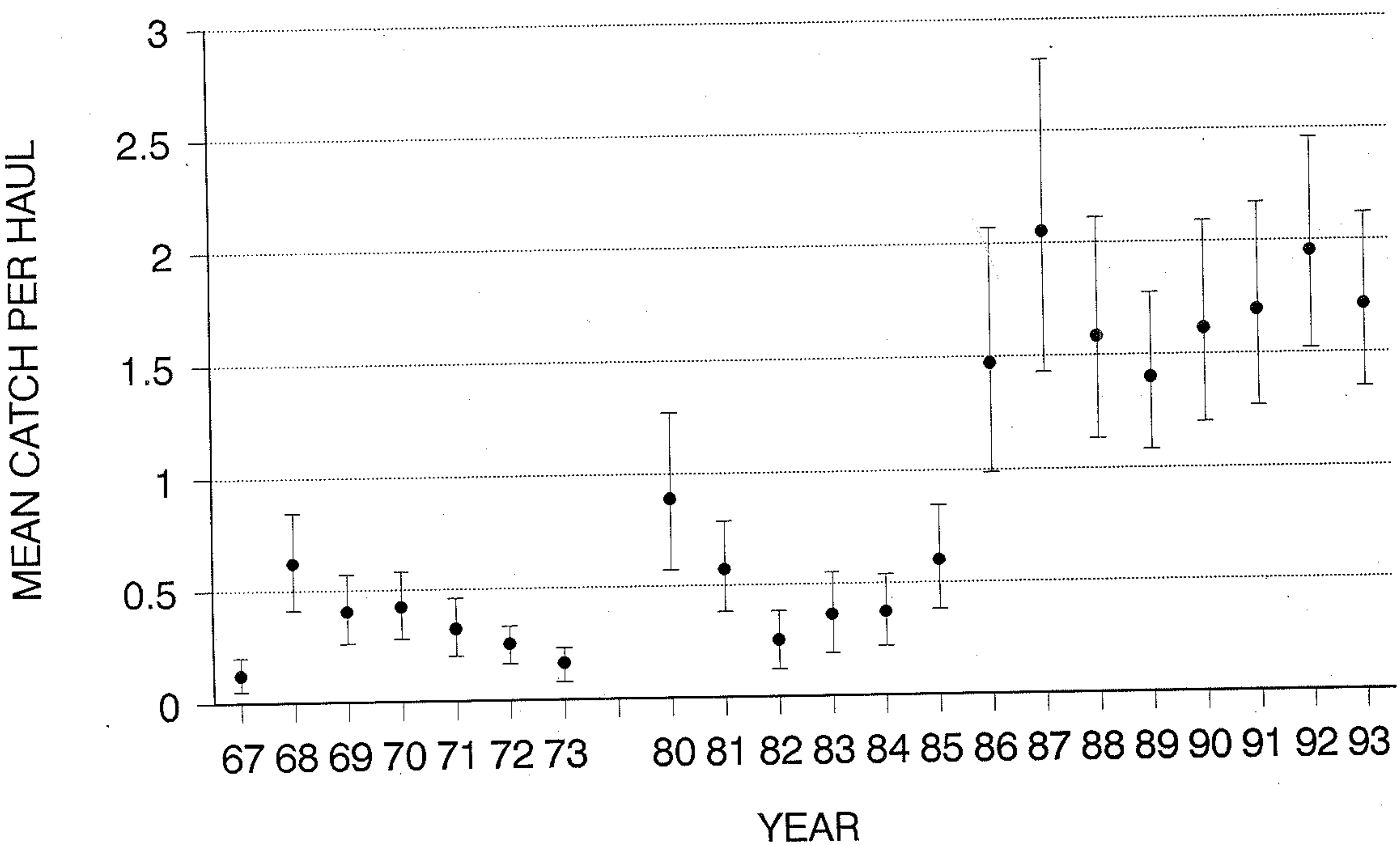
Juvenile Seine Indices

Bay Anchovy



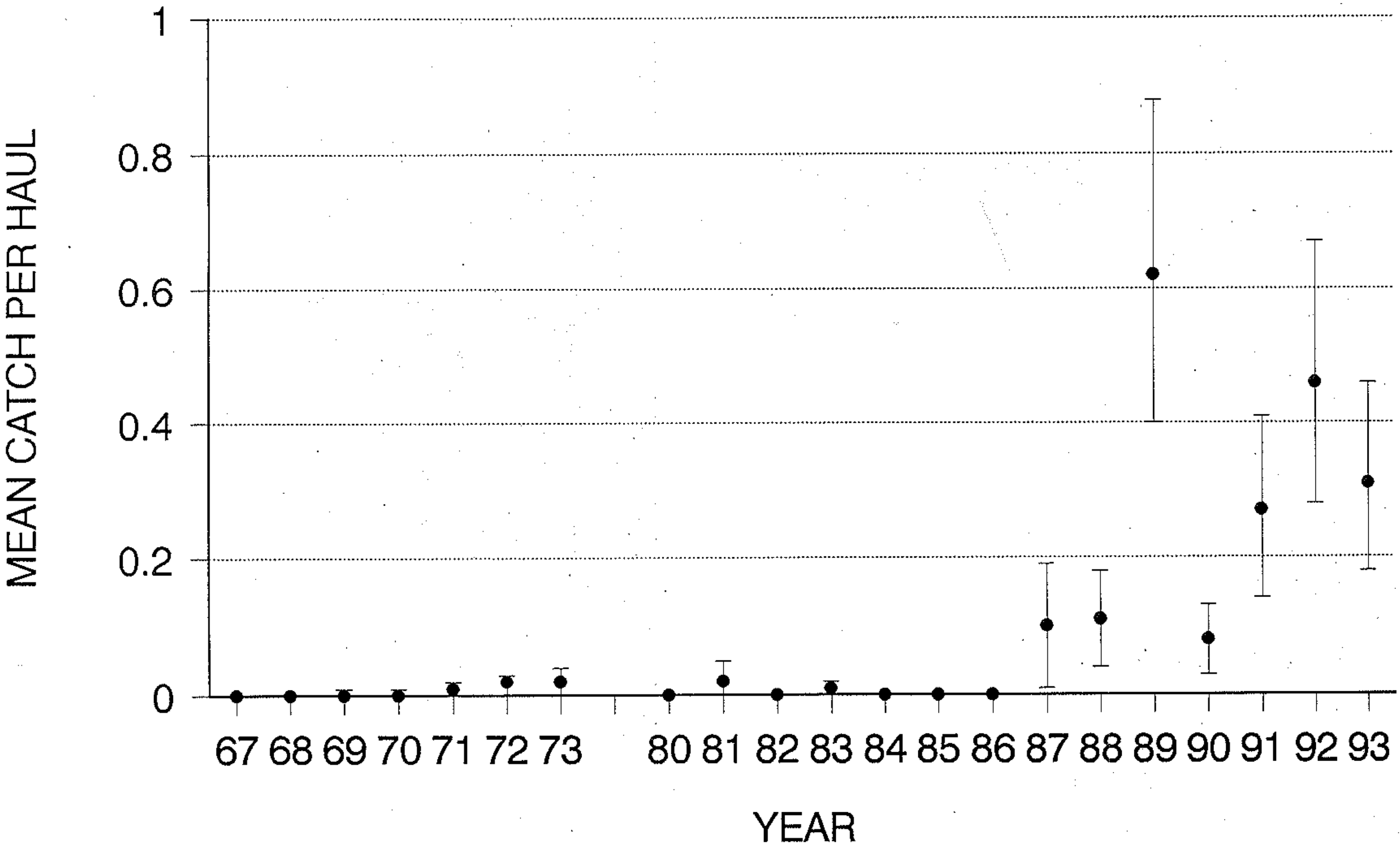
Juvenile Seine Indices

Hogchoker



Juvenile Seine Indices

Threadfin Shad



Juvenile Seine Indices

Gizzard Shad