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Estimation of Parameters of Striped Bass Populations and Description of the Fishery of Lower Chesapeake Bay: Final Report

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ESTIMATION OF PARAMETERS OF STRIPED BASS POPULATIONS AND DESCRIPTION OF THE FISHERY OF LOWER CHESAPEAKE BAY

(FA-Virginia-AFS-4-2)

INTRODUCTION

A demand for management of anadromous fish stocks has been voiced in recent years as a protective response to increasing population pressures along the Atlantic Coast of the United States. Anadromous fishes, because of their habits of reproduction, are most affected by the rapidly expanding megalopolis of the East Coast and resulting pollution of coastal waters. One of the best known and most sought after anadromous species is the striped bass, Morone saxatilis (Walbaum).

Effective management practices for striped bass are being sought by cooperating coastal states, but have thus far been hampered by a lack of knowledge of basic population parameters. While the biology and habits of striped bass are fairly well studied, population parameters such as mortality rates are not, and intelligent management decisions must be based upon them.

The present project was proposed after review of results from the Chesapeake Bay Cooperative Striped Bass Program (Mansueti, 1961; Massmann and Pacheco, 1961; Lewis, 1961) and following the suggestions for further research of Sykes (1961). Our proposal included five principal objectives: 1) to estimate the seasonal age composition of striped bass stocks in lower Chesapeake Bay, 2) to determine the age selectivity of fishing gear

types employed in Virginia coastal waters, 3) to measure the proportion of total catch taken by each type of fishing gear, including the sport catch, 4) to estimate mortality rates for striped bass during their river-resident phase, and 5) to estimate relative abundance of individual year-classes.

This is a final report for this project[1], initiated in May 1967, and terminated on June 30, 1970. Certain of the five objectives, because of their dependency on accumulating tag returns, are necessarily incomplete. These aspects of the research, when complete, will be published in the form of journal articles. Results are presented below within objectives and include all data accumulated through the projects termination date.

DESCRIPTION OF THE FISHERY

The coastal Virginia fishery for striped bass is scattered and diverse, employing commercial trawlers, pound nets, fyke nets, haul seines, and gill nets, in addition to an active sport fishery. In the commercial fishery, pound nets are fished most consistently and at semi-permanent locations, being lifted only during brief periods for cleaning, to prevent possible ice damage, or because of nuisance factors such as abundant jellyfish. Commercial trawlers are, by law, limited to offshore fishing. Therefore, striped bass are available to this gear only in winter months, especially in cold winters when river populations are apparently driven to the warmer coastal waters. Gill nets range from the small mesh "spot nets" and "perch nets", employed in summer and late fall to winter,

[1]Three annual progress reports have previously been submitted (see Project Publications and Reports, page 39).

respectively, to large mesh "shad nets", used for spring runs of spawning fish. Haul seines are used sporadically throughout the warmer months, but most effectively in the spring. Sport fishing is intensive in the lower Chesapeake Bay, especially along the Chesapeake Bay Bridge-Tunnel in spring and fall, extending from the Bay mouth to the fresh-water regions of major river systems throughout the period from April through December. Sport fishing occurs day and night--by surface-and deep-trolling during the day, by use of artificial lures under lights at night, and with the use of bait at all hours.

Commercial landings of striped bass in Virginia[2] for the years 1930-1969 are shown in Fig. 1. The annual landings during this forty-year period have varied nine-fold, from a low in 1934 to a recent record high in 1966. Although the general trend in landings (and striped bass populations) has been increasing during this period, there are two definite peaks of abundance, one in the post-World War II years, the other in the 1960's, separated by a period of 16 years. Landings in the most recent years show a slight decline, on the average. The extent of the decline will depend, in large part, on contributions to the catches by dominant year-classes, such as the 1966 year-class (Grant and Joseph, 1969; Grant, Burrell, and Kriete, 1971).

[2] Data obtained from Koo (1970) for the years 1930-1966, and from "C.F.S." annual summaries of Virginia landings for the years 1967-1969. The latter series is published by cooperation between state agencies and the U. S. Bureau of Commercial Fisheries.

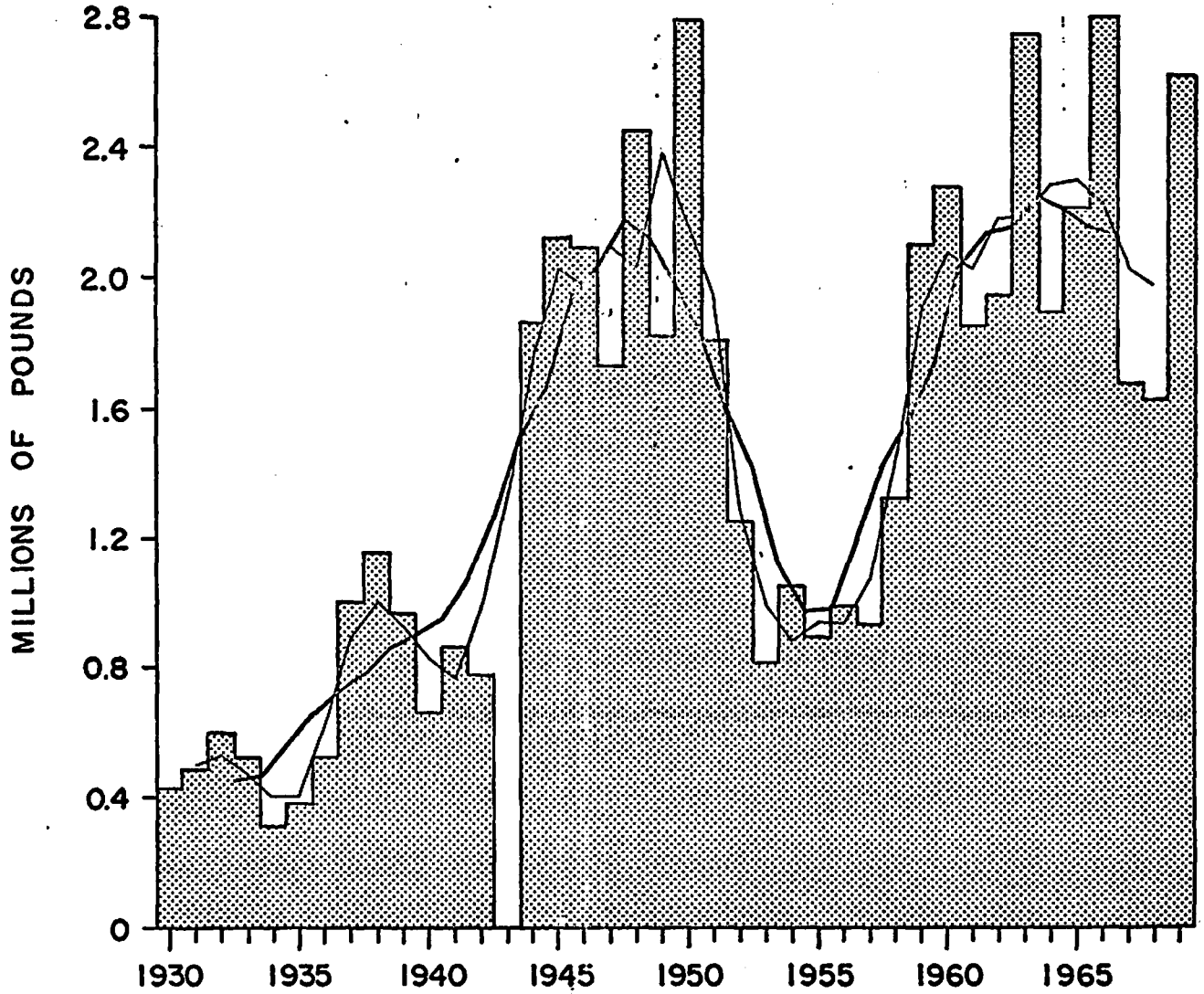

Fig. 1. Annual landings of striped bass in Virginia, 1930-1969. Moving averages (indicated by heavy line for 6-yr average and light line for 3-yr average) incorporate an interpolated value of 1,321,000 pounds for 1943.

RESULTS

Objective 1 - Estimation of seasonal age composition of striped bass in lower Chesapeake Bay

The estimation of age composition of fish populations from sampled catches assumes that the catch is representative of the natural population. Although none of the gear-types in use in Virginia waters can be said to completely meet that assumption, pound net and fyke net catches include a wide range of sizes of striped bass and are believed to closely approximate a representative sample of local populations. These two gear-types, therefore, were considered "non-selective" and were sampled as an estimate of the age composition of striped bass stocks residing in the James, York, and Rappahannock rivers.

Samples of approximately 50 striped bass were obtained from each river system semi-monthly, except during periods when nets were not being fished, or striped bass were not being caught in sufficient numbers. Fork lengths were recorded to the nearest millimeter, and scales removed from the area prescribed by Merriman (1941). Dried scales were mounted on cellulose acetate slides with Time Tape (Professional Tape Co., Riverside, Illinois) and impressions of their sculpture obtained by use of a Carver hydraulic press. Fish were aged by counting annular rings at a magnification of 15X, and back-calculations of length at each age were made using an Eberbach scale projector at a magnification of 43X. The latter procedure also provided confirmation of aging. Cases of disagreement were re-examined.

Age analysis of samples from the James, York, and Rappahannock rivers is summarized in Tables 1-3. Data are given in quarterly periods within

fiscal years, which coincide well with the life history of striped bass. In Virginia waters spawning occurs from late April to June. Annular rings are formed on scales at approximately the same time. Fiscal years, rather than calendar years, most closely approximate growth years for these striped bass. Dominance of particular year-classes is also fairly consistent among quarterly periods within fiscal years.

Seasonal changes in age composition are slight (Tables 1-3). Larger migratory striped bass are more frequent in winter and spring catches, although these older fish occasionally appear in catches throughout the year. Young-of-the-year striped bass do not appear in these "non-selective" catches in significant numbers until spring months of the year following their hatch.

James River samples (Table 1) were dominated by two-year-old striped bass in all three sampling years, i.e. the 1965 year-class during the first year of sampling (July 1967-June 1968), the 1966 year-class (although weakly) the following year, and the 1967 year-class during the final year. The 1967 year-class appeared to the strongest of these recent year-classes in the James River.

York River samples (Table 2) were dominated by one-year-old striped bass throughout the three year period, most strongly by the dominant 1966 year-class in the first year of sampling.

The comparative strength of the 1966 year-class was most strongly reflected in Rappahannock River samples (Table 3), where it dominated catches as one-year-olds during the first sampling year and again as two-year-olds the following year. This difference in strength of a given year-class between river systems is discussed by Grant and Joseph (1969).

The dominance of catches by slightly older fish in the James River, as compared with those of the York and Rappahannock rivers, is believed due to a slower growth rate in the James River, although this question needs further study.

The full three years of data are shown in Fig. 2, where the percent age composition within river systems is summarized by sampling years. James River catches differed from those of the York and Rappahannock rivers in that they were consistently dominated by two-year-old striped bass. York River catches were dominated by one-year-olds in all three years, while Rappahannock catches were dominated by two-year-olds in the second year of sampling due to the strength of the 1966 year-class.

Table 1. Age composition of non-selective commercial striped bass catches in the James River, Virginia, July 1967—June 1970.

Quarterly Period	Number of Fish in Year-Class													Sample Total
	'69	'68	'67	'66	'65	'64	'63	'62	'61	'60	'59	'58	older	
Jul-Sept 1967	x	x	-	-	35	24	1	1	1	1	-	-	-	63
Oct-Dec	x	x	1	19	122	10	2	0	3	-	-	-	-	157
Jan-Mar 1968	x	x	-	9	8	4	0	1.	0	0	1	2	1	26
Apr-Jun	x	x	-	22	39	34	8	2	8	12	8	4	2	139
Percent Subtotal	x	x	0.3	13.0	53.0	18.7	2.9	1.0	3.1	3.4	2.3	1.6	0.8	
Jul-Sept 1968	x	-	70	189	94	27	4	1	2	0	0	1	-	388
Oct-Dec	x	-	97	89	13	-	-	-	-	-	-	-	-	199
Jan-Mar 1969	x	(no samples)												0
Apr-Jun	x	-	154	108	16	19	10	8	3	5	2	1	1	327
Percent Subtotal	x	-	35.1	42.2	13.5	5.0	1.5	1.0	0.5	0.5	0.2	0.2	0.1	
Jul Sept 1969	-	31	235	58	3	4	0	1	2	-	-	-	-	334
Oct-Dec	-	8	85	13	-	-	-	-	-	-	-	-	-	106
Jan-Mar 1970	-	1	3	2	-	-	-	-	-	-	-	-	-	6
Apr-Jun	19	33	81	29	10	3	2	5	4	2	2	1	-	191
Percent Subtotal	3.0	11.5	63.4	16.0	2.0	1.1	0.3	0.9	0.9	0.3	0.3	0.2	-	

Table 2. Age composition of non-selective commercial striped bass catches in the York River, Virginia, July 1967-June 1970.

	Number of Fish in Year Class														
Quarterly Period	'69	'68	'67	'66	'65	'64	'63	'62	'61	'60	'59	'58	older	un-known	Sample Total
Jul-Sept 1967	x	x	-	317	22	4	-	-	-	-	-	-	-	-	343
Oct-Dec	x	x	-	112	20	1	-	-	-	-	-	-	-	-	133
Jan-Mar 1968	x	x	-	16	13	11	-	-	-	-	-	-	-	-	40
Apr-Jun	x	x	2	119	21	2	0	0	0	0	0	1	1	-	146
Percent Subtotal	x	x	0.3	85.2	11.5	2.7	0	0	0	0	0	0.2	0.2	-	
Jul-Sept 1968	x	-	84	126	5	0	1	0	0	0	1	1	-	-	218
Oct-Dec	x	1	274	210	27	4	-	-	-	-	-	-	-	1	517
Jan-Mar 1969	x	1	178	151	40	14	4	1	1	-	-	-	-	-	390
Apr-Jun	x	11	191	75	15	3	3	1	0	2	1	3	-	-	305
Percent Subtotal	x	0.9	50.8	39.3	6.1	1.5	0.6	0.1	0.1	0.1	0.1	0.3	-	0.1	
Jul-Sept 1969	-	221	149	13	2	2	-	-	-	-	-	-	-	-	387
Oct-Dec	8	225	200	47	11	2	1	0	2	0	1	-	-	-	497
Jan-Mar 1970	-	1	4	6	1	-	-	-	-	-	-	-	-	-	12
Apr-Jun	41	84	33	10	2	3	2	-	-	-	-	-	-	-	175
Percent Subtotal	4.6	49.6	36.0	7.1	1.5	0.7	0.3	0	0.2	0	0.1	-	-	-	

Table 3. Age composition of non-selective commercial striped bass catches in the Rappahannock River, Virginia, July 1967-June 1970.

	Number of Fish in Year Class													
Quarterly Period	'69	'68	'67	'66	'65	'64	'63	'62	'61	'60	'59	'58	older	Sample Total
Jul-Sept 1967	x	x	-	124	11	2	-	-	-	-	-	-	-	137
Oct-Dec	x	x	2	280	48	11	2	0	0	0	0	1	-	344
Jan-Mar 1968	x	x	-	84	25	17	4	6	19	6	1	14	2	178
Apr-Jun	x	x	6	217	12	2	0	1	0	1	-	-	-	239
Percent subtotal	x	x	0.9	78.5	10.7	3.6	0.7	0.8	2.1	0.8	0.1	1.7	0.2	
Jul-Sept 1968	x	-	81	220	1	2	-	-	-	-	-	-	-	304
Oct-Dec	x	4	124	256	8	1	-	-	-	-	-	-	-	393
Jan-Mar 1969	x	-	36	139	14	4	1	0	2	1	-	-	-	197
Apr-Jun	x	30	121	146	8	0	1	0	2	2	3	4	-	317
Percent subtotal	x	2.8	29.9	62.8	2.6	0.6	0.2	0	0.3	0.2	0.2	0.3	-	
Jul-Sept 1969	-	156	110	47	3	3	-	-	-	-	-	-	-	319
Oct-Dec	-	152	113	32	3	-	-	-	-	-	-	-	-	300
Jan-Mar 1970	-	17	35	40	2	1	0	0	1	1	0	2	-	99
Apr-Jun	28	142	20	44	4	5	1	1	0	2	0	7	-	254
Percent subtotal	2.9	48.0	28.6	16.8	1.2	0.9	0.1	0.1	0.1	0.3	0	0.9	-	

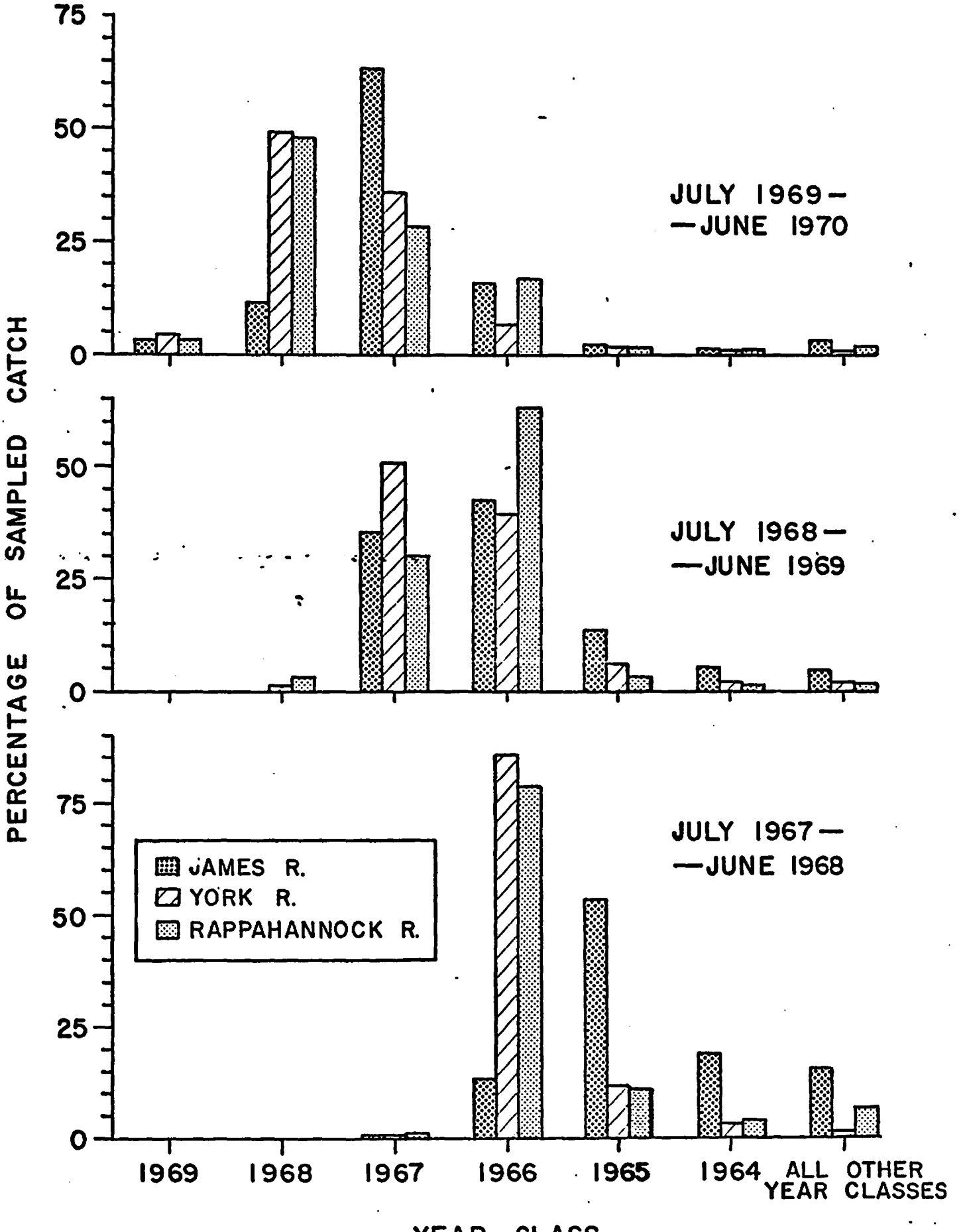

Fig. 2. Age composition of sampled pound and fyke net catches in the James, York, and Rappahannock rivers, July 1967-June 1970.

Objective 2 - Age selectivity of fishing-gear types employed in Virginia waters.

While pound nets and fyke nets catch all but the smallest striped bass in approximate proportion to their availability, other gear-types were considered at the outset of this project to select for certain sizes or ages of striped bass. Especially selective are the gill-nets. Size (and age) distribution of gill-net catches varies directly with the size of mesh in these nets (Trent and Hassler, 1968), and is predictable. Selection of certain sizes from striped bass stocks by sport catches and commercial haul seines has not been examined. Haul seines might reasonably be expected to be as non-selective as are pound nets and fyke nets, but seasonal selection may occur as a result of schooling habits of striped bass.

Commercial haul seine, gill-net, and sport catches were sampled for two and one-half years (through December 1969) to estimate age selectivity. Estimates were obtained by comparison of age composition with similar data from non-selective-gear samples. Sampling of York River sport catches and winter-spring Rappahannock River gill-net catches was continued beyond December 1969 to satisfy special interests in these fisheries.

Commercial Haul Seines

The age composition of commercial haul seine samples is summarized within semi-annual periods in Table 4. Catches were dominated throughout by one- and two-year-old striped bass, i.e. those fish in their second and third growing years. Dominance of two-year-olds depended on strong year classes persisting in the fishery, especially evident in the Rappahannock River catches of the 1966 year-class. Selection, as measured

by comparison of age distribution in haul seine catches with age distribution in non-selective samples, was strongest during the first half of the calendar year. All such January-June distributions differed from non-selective age distributions at a highly significant level ($p < 0.01$). Most differences consisted of haul seine catches of small fish in proportions higher than expected. The single exception to this was the small sample obtained from the Rappahannock River, in which the 1966 year-class was caught in a proportion greater than expected.

The age distribution of haul seine catches in the July-December period, on the other hand, was usually similar to that of non-selective catches. No significant difference was found in six comparisons, significant differences in three. Two of the latter were contributed to by high catches of small fish, and the third was a case of older fish appearing in greater numbers than expected.

Gill-nets

Only two of the 16 age distributions listed in Table 5 were not significantly different from compared non-selective distributions. One other comparison was significantly different at the 95% confidence level; all others were highly significant ($p < 0.01$). Gill-nets generally selected for striped bass in their third and fourth growing season (2-to-3-year-olds), catching both younger and older age groups in proportions smaller than expected. All catches during the first half of the calendar year differed from non-selective samples ($p < 0.01$), a reflection of the employment of "shad nets" having a mesh size of four to five inches.

The dominance of the 1966 year-class was again evident in the age distribution of gill-net catches. It was the dominant year-class in 9 of the 16 distributions listed in Table 5. It successively dominated Rappahannock River catches during the three years of sampling, first as

one-year-olds, then two-year-olds, and finally as three-year-olds in the January-June 1970 period (Grant, Burrell, and Kriete, 1971). The 1966 year-class was also strong in the York River, but less so in the James River (Grant and Joseph, 1969).

Sport Catches

The majority of chi-square comparisons of sport catch with non-selective age distributions (Table 6) showed a selection for younger striped bass by hook-and-line. This pattern was consistent, however, only in the January-June periods. In the latter half of the calendar years, greater numbers than expected of one-, two-, or three-year-old striped bass were taken by the sport fishery, and lesser numbers of either younger or older fish.

Sport catches were dominated by one- and two-year-old striped bass. The influence of the strong 1966 year-class was not as evident as in haul seine and gill-net catches.

Table 4. Age composition of sampled commercial haul seine catches. Numbers within parentheses were excluded from chi-square comparisons with non-selective age distributions. Only those year-classes containing five or more individuals in non-selective samples were used in the analysis.

Semi-annual		Number of Fish in Year-Class													Chi-	
Period	River	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	Total	Square	Significance
July-Dec 1967	James	-	-	(0)	9	104	12	(1)	(2)	(1)	(0)	(0)	(0)	129	5.11	n.s.
	York	-	-	(0)	133	3	1	(0)	(0)	(0)	(0)	(0)	(0)	137	7.69	*
	Rappahannock	-	-	(0)	63	4	0	(0)	(0)	(0)	(0)	(0)	(0)	67	4.78	n.s.
Jan-June 1968	James	-	-	(0)	80	17	38	0	(0)	0	0	4	0	140	150.50	**
	York	-	-	(11)	136	1	2	(0)	(0)	(0)	(0)	(0)	(1)	151	38.83	**
July-Dec 1968	James	-	(0)	60	82	38	9	(3)	(5)	(6)	(4)	(1)	(1)	209	2.96	n.s.
	York	-	(0)	122	119	6	(5)	(0)	(0)	(0)	(0)	(0)	(0)	252	2.39	n.s.
	Rappahannock	-	(1)	125	171	3	(0)	(0)	(0)	(0)	(0)	(0)	(0)	300	21.12	**
Jan-June 1969	James	-	(0)	364	310	9	9	2	0	(4)	(0)	(0)	(0)	698	414.88	**
	York	-	14	581	304	19	3	2	(1)	(1)	(0)	(0)	(0)	925	79.68	**
	Rappahannock	-	0	7	41	2	(0)	(0)	(0)	(0)	(0)	(0)	(0)	50	13.77	**
July-Dec 1969	James	(0)	1	26	1	(1)	(0)	(1)	(0)	(0)	(0)	(0)	(0)	30	4.88	n.s.
	York	0	88	177	53	9	(3)	(2)	(2)	(0)	(0)	(0)	(0)	334	100.86	**
	Rappahannock	(0)	53	26	11	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	90	3.67	n.s.

(* significant difference compared with non-selective gear samples, $p < 0.05$; ** highly significant, $p < 0.01$; n.s. = significant, $p > 0.05$)

Table 5. Age composition of sampled gill-net catches. Numbers within parentheses were excluded from chi-square comparisons with non-selective age distributions. Only those year-classes containing five or more individuals in non-selective samples were used in the analysis.

Semi-annual		Number of Fish in Year-Class													Chi-	
Period	River	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	Total	Square	Significance
July-Dec 1967	James	-	-	(0)	19	163	127	(7)	(3)	(1)	(1)	(1)	(0)	322	142.14	**
	York	-	-	(0)	6	1	1	(0)	(0)	(0)	(0)	(0)	(0)	8	10.90	**
	Rappahannock	-	-	(0)	35	3	4	(0)	(0)	(0)	(0)	(0)	(0)	42	8.19	*
Jan-June 1968	James	-	-	(0)	9	122	153	5	(3)	1	2	0	0	295	215.54	**
	York	-	-	(0)	172	12	5	(3)	(0)	(1)	(0)	(0)	(2)	195	27.59	**
	Rappahannock	-	-	0	191	6	3	(0)	0	0	0	(0)	0	200	52.11	**
July-Dec 1968	James	-	(0)	39	73	34	5	(0)	(0)	(1)	(0)	(0)	(0)	152	2.42	n.s.
	York	-	(0)	104	160	6	(1)	(0)	(0)	(0)	(0)	(0)	(0)	271	19.28	**
	Rappahannock	-	(0)	54	347	5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	406	53.38	**
Jan-June 1969	James	-	(0)	24	282	47	21	7	2	(4)	(2)	(0)	(1)	340	303.75	**
	York	-	1	244	159	69	23	2	(0)	(2)	(3)	(1)	(2)	506	41.25	**
	Rappahannock	-	0	63	328	18	(7)	(0)	(1)	(0)	(0)	(0)	(0)	417	97.37	**
July-Dec 1969	James	(0)	42	293	33	(2)	(1)	(2)	(0)	(0)	(0)	(0)	(0)	373	16.45	**
	York	1	127	223	65	2	(0)	(0)	(0)	(0)	(0)	(0)	(0)	418	105.80	**
	Rappahannock	(0)	84	63	24	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	171	1.92	n.s.
Jan-June 1970	Rappahannock	0	13	62	129	3	3	(4)	(1)	(8)	(2)	(0)	4	229	219.18	**

(* significant difference compared with non-selective gear samples, $p < 0.05$; **highly significant, $p < 0.01$; n.s. = non significant, $p > 0.05$)

Table 6. Age composition of sampled sport catches. Numbers within parentheses were excluded from chi-square comparisons with non-selective age distributions. Only those year-classes containing five or more individuals in non-selective samples were used in the analysis.

Semi-annual		Number of Fish in Year-Class														
Period	River	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	Total	Chi-Square	Significance
Jul-Dec 1967	James	-	-	(0)	6	163	76	(16)	(13)	(11)	(4)	(5)	(1)	295	45.90	**
	York	-	-	(5)	855	176	23	(2)	(0)	(0)	(1)	(0)	(0)	1062	95.86	**
	Rappahannock	-	-	(0)	11	1	1	(0)	(0)	(0)	(0)	(0)	(0)	11	1.43	n.s.
Jan-June 1968	James	-	-	(0)	2	3	6	2	(0)	0	1	0	0	14	7.96	n.s.
	York	-	-	(27)	225	22	3	(0)	(0)	(0)	(0)	(0)	(0)	277	32.94	**
July-Dec 1968	James	-	(0)	45	64	11	3	(1)	(1)	(2)	(2)	(0)	(0)	129	10.13	*
	York	-	(1)	54	72	11	(3)	(1)	(1)	(2)	(2)	(0)	(0)	147	7.98	*
	Rappahannock	-	(1)	90	57	5	(0)	(0)	(0)	(0)	(0)	(0)	(0)	153	71.24	**
Jan-June 1969	James	-	(0)	75	13	3	2	1	0	(2)	(0)	(0)	(0)	96	37.07	**
	York	-	5	189	45	1	(0)	(0)	(0)	(0)	(0)	(0)	(0)	240	69.26	**
July-Dec 1969	James	(0)	10	68	5	(0)	(0)	(0)	(0)	(1)	(0)	(0)	(0)	84	7.07	*
	York	4	201	210	10	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(1)	427	29.87	**
	Rappahannock	(0)	5	4	2	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	11	0.41	n.s.
Jan-June 1970	York	17	63	24	4	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	108	9.12	*

(* significant difference compared with non-selective gear samples, $p < 0.05$; ** highly significant, $p < 0.01$; n.s. = non-significant, $p > 0.05$)

Objective 3 - Estimate of proportional catches by the various fishing-gear types

Complete and accurate statistics on Virginia striped bass landings, sub-divided into classes of fishing gear, are unavailable. Although the number of issued commercial fishing licenses may be used to detect trends in fishing effort and changes in gear use, actual poundage of striped bass landed by each gear would remain a matter of conjecture. In addition, no estimate could be made of the proportion of striped bass landed by sport fishermen.

Assuming that tagged fish have an equal chance of being caught in the various gear-types, and that tags are returned equally by the various classes of fishermen, then tag returns may be used to estimate the proportions of fish landed by each type of gear. Extrapolation of these estimated proportions to actual pounds of striped bass landed is risky in that new errors may be introduced and already existing errors magnified. Therefore, we elected to estimate relative proportions of landings within gear types from proportions of total tags returned and accompanied by information on the fishing gear employed.

Dates, location, and methods of tagging striped bass in Virginia rivers are listed in Table 7. Tagged striped bass were released in four distinct periods: the winters of 1968-1970 and the summer-fall season of 1968. A total of 10,296 tags were applied. The change from streamer disc tags to internal anchor tags (Dell, 1968) was necessitated by the snagging of disc tags in gill nets (Grant, Burrell, Richards, and Joesph, 1970). Length and age distribution of all tagged fish are provided in the Appendix to this report. Age distribution of tagged striped bass is summarized in Table 8. One-year-old striped bass (those in their

second growing year) were the dominant age-group tagged in each winter period. Two-year-olds were dominant in the summer-fall 1968 tagging due to the strength of the 1966 year-class in the Rappahannock River.

Certain segments of the tagging data cannot be utilized in the estimation of proportional catches. The first season of tagging, winter 1968, revealed an inherent fault in the type of tag employed. Streamer disc tags were snagged by gill nets, resulting in excessive numbers of returns from this class of fishing gear. The substitution of internal anchor tags (Dell, 1968), beginning with the summer-fall 1968 tagging period, eliminated this source of bias. A different sort of problem arose during summer 1968 tagging of James River striped bass. These failed to disperse from the site of tagging, most of them being recaptured in the same pound nets from which they were tagged, and in a relatively short period of time. Both the winter 1968 and James River summer 1968 tagging data segments, therefore, failed to meet some basic assumptions of our method of estimation, as mentioned early in this section, so have been eliminated from consideration. Remaining data are summarized in Table 9, where the percentages of returns from each type of gear are listed within tagging periods and rivers of tag release.

Considerable difference between river systems is evident in Table 9. Pound nets caught a consistently higher proportion of tagged fish in the Rappahannock River; sport catches of tagged striped bass in the York River were even greater, proportionally. A combination of all data (last column of Table 9) reflects the relative importance of the various gear types. In decreasing order of catch size, the gear types are: pound nets, sport catch, gill nets, and haul seines. These four classes of gear accounted for over 98% of all tag recaptures.

Table 7. Releases of tagged striped bass in Virginia rivers, 1968-1970.

Date	River	Number of Fish Tagged	Tag Types	Fishing Gear Employed
(1968)				
Jan 29-Feb 7	York	1468	Streamer disc & dart	30' trawl
Feb 13-20	Rappahannock	1178	"	"
Feb 27-28	James	85	"	"
Mar 5-6	York	464	"	"
	Total winter 1968	3195		
June 17-Nov 26	York	392	Internal anchor	Hook & Line
July 3, 8	Rappahannock	1494	"	Pound net
July 29-Aug 2	James	553	"	"
	Total summer-fall 1968	2439		
(1969)				
Jan 8-Feb 25	York	114	Internal anchor	30' trawl
Jan 15-Feb 19	Rappahannock	1161	"	"
Mar 12-18	James	301	"	"
Mar 25	York	771	"	Haul Seine
Apr 1	James	544	"	"
	Total winter 1969	2891		
(1970)				
Jan 19-Mar 12	York	1020	Internal anchor	30' trawl
Feb 5- Mar 2	Rappahannock	124	"	"
Mar 23-Apr 10	Rappahannock	627	"	Pound net
	Total winter 1970	1771		
	3-year total	10,296		

Table 8. Age distribution of striped bass tagged in Virginia rivers, 1968-1970.

Tagging Season	River	Number of Fish Tagged in Year-Class										
		1969	1968	1967	1966	1965	1964	1963	1962	1961	unknown	Total
Winter 1968	James	-	-	35	39	8	3	-	-	-	-	85
	York	-	-	588	1301	37	3	1	-	1	1	1932
	Rappahannock	-	-	134	1005	38	-	1	-	-	-	1178
	Subtotal	-	-	757	2345	83	6	2	-	1	1	3195
Summer-Fall 1968	James	-	-	404	118	23	6	-	-	2	-	553
	York	-	-	212	162	17	1	-	-	-	-	392
	Rappahannock	-	-	224	1247	17	1	-	-	-	5	1494
	Subtotal	-	-	840	1527	57	8	-	-	2	5	2439
Winter 1969	James	-	6	528	298	7	5	1	-	-	-	845
	York	-	9	594	259	15	3	3	1	1	-	885
	Rappahannock	-	128	922	108	1	-	-	-	-	2	1161
	Subtotal	-	143	2044	665	23	8	4	1	1	2	2891
Winter 1970	York	352	621	42	4	-	-	1	-	-	-	1020
	Rappahannock	29	388	186	143	4	1	-	-	-	-	751
	Subtotal	381	1009	228	147	4	1	1	-	-	-	1771
3-year Totals		381	1152	3869	4684	167	23	7	1	4	8	10,296
Percent of tagged fish		3.7	11.2	37.6	45.5	1.6	0.2	0.1	0.0	0.0	0.1	100.0

Table 9. Share of returns (in percent) from the various types of fishing gear. Returns lacking information on recapture gear have been excluded. All other tags returned through June 30, 1970 are included.

	Tagging Period and River of Release							
	Summer - Fall 1968			Winter 1969		Winter 1970		Combined Periods
	York	Rappahannock	James	York	Rappahannock	York	Rappahannock	and Rivers
Pound nets	9.8	67.4	9.7	12.8	42.3	11.7	44.3	39.7
Gill nets	26.8	9.1	14.0	29.4	11.5	16.7	35.0	18.8
Haul seines	4.9	3.0	40.9	7.3	24.2	10.0	8.2	13.0
Peeler traps	-	2.3	-	-	1.1	-	0.5	1.0
Fyke nets	4.9	-	2.2	0.9	-	-	-	0.5
Offshore trawls	-	-	-	-	0.5	-	1.1	0.3
VIMS 30 ft trawl	-	0.4	-	-	-	-	-	0.1
Sport catch	53.7	17.8	33.3	49.5	20.3	61.7	10.9	26.6
Total No. of Returns	41	264	93	109	182	60	183	932

Objective 4 - Estimation of mortality rates

Total Mortality

In an earlier report (Grant, 1969) estimates of total mortality were given for individual river populations of striped bass and based on winter 30 ft trawl sampling. These estimated mortality rates varied widely (0.247-0.828) due to uneven year-class size, an inherent characteristic of Atlantic coast populations. The method (Jackson, 1939) assumes constant recruitment and, therefore, is not expected to provide accurate estimates of total mortality for a species such as striped bass (Ricker, 1958; Robson and Chapman, 1961). The method can be useful, however, in obtaining a rough approximation of total mortality rates, providing that the relative strength of year-classes is known.

Two sets of data have been used in calculating total mortality rates: 1) 30-ft semi-balloon trawl catches during the months of January-March, and 2) pound net samples taken during October-December. These two sets of data have been used to average total mortality over slightly different age-groups. For trawl data,

$$s = \frac{I + II + III}{0 + I + II}$$

where 0, I, ... are the numbers of striped bass of Age 0, I, ..., and s is survival rate. Total mortality is then calculated as 1 - s. This selection of age groups reflects the assumption that the trawl catches younger age groups (0 - III) in proportion to their abundance.

For pound net data,

$$s = \frac{II + III + IV}{I + II + III}$$

thus estimating mortality rates for a slightly older set of age groups (apparently one year older, but actually only six months older due to the choice of sampling seasons). Available estimates are given in Table 10, where the effects of a strong 1966 year-class are evident in mortality estimates for the York and Rappahannock rivers. Calculated rates are high in 1967 when the 1966 year-class first entered trawl catches, and generally decrease thereafter. Exceptions to this are limited to two estimates---the 1970 estimate from York River trawl catches, and the 1968 estimate from Rappahannock River pound nets. The first exception was caused by a relatively large catch of the 1969 year-class, and the latter by poor catches of the 1967 year-class relative to continued good catches of the 1966 year-class. Two obvious sources of error in this type of mortality rate estimation are, therefore, evident. They are annual differences in year-class strength and differences between river systems in year-class success.

With such variable recruitment from year-to-year and river-to-river, it is necessary to utilize tag-and-recapture methods for estimation of mortality rates (Ricker, 1958). For total mortality rates, at least two years of data are required. Since our first year's tagging utilized a tag that was inadequate, the initial point for our mortality estimates is the winter of 1969 (warm season tagging as in 1968 was not repeated in subsequent years because of problems stemming from excessive fouling of tags and failure of tagged fish to disperse from the site of tagging).

Since two full years of tag-and-recovery data will not be available until April 1, 1971, these total mortality estimates cannot be incorporated in this report. The following equation (Ricker, 1958: 128) will be used in these calculations:

$$\hat{s}_1 = \frac{R_{12}\, M_2}{M_1\, (R_{22} + 1)}$$

where R_{12} = recaptures of first-year tags in the second year, R_{22} = recaptures of second-year tags in the second year, M_1 and M_2 = number of fish tagged at the start of the first and second year, respectively, and $\hat{s}_1$ = estimate of the survival rate during year 1. These estimates will be obtained for individual year-classes and river systems.

Annual Fishing Mortality

Estimates of annual fishing mortality rates are available for those tagging periods and rivers for which tags have been at large for one year. These calculated rates are given in Table 11. Estimates are restricted to a single year-class and river system, and are modified by two correction factors: 1) the total number of tagged fish were reduced by 10% to account for estimated tagging mortality, and 2) the total number of returns was increased by 10% to account for non-response.

Calculated annual fishing mortality rates vary directly with the age of striped bass tagged. Rates listed in Table 11 range from 0.09-0.12 for striped bass tagged when in the 0 age group, 0.12-0.25 for age group I fish, 0.10-0.58 for age group II, and 0.43-0.48 for age group III. Low rates for youngest fish are due, at least in part, to incomplete recruitment

to the fisheries, especially the gill-net fishery. The highest fishing mortality rate observed (0.58) occurred among 1965 year-class striped bass tagged in the Rappahannock River just before forming their third annual ring. The high mortality, therefore occurred during their fourth year of life. The same year-class of striped bass, tagged in summer 1968 (after forming their third annulus) was again subjected to high mortality (0.43-0.48).

Table 10. Total mortality rate estimates of Virginia striped bass populations, calculated by the Jackson indirect method. Sample size in parentheses.

Sampling Data	River System	Year of Estimate 1967	1968	1969	1970	Combined Years
30-ft Trawl Catches Jan-Mar	James	0.258(66)	0.675(43)	0.247(73)	0.833(30)	0.416(212)
	York	0.828(606)	0.760(362)	0.590(195)	0.881(260)	0.788(1423)
	Rappahannock	0.787(494)	0.707(42)	0.697(195)	0.514(72)	0.737(803)
	all rivers	0.778(1166)	0.747(447)	0.581(463)	0.804(362)	0.739(2438)
Pound Nets, Oct-Dec	James	0.097(125)	0.604(149)	0.043(93)	---	0.290(367)
	York	0.842(133)	0.604(342)	0.510(290)	---	0.610(765)
	Rappahannock	0.820(341)	0.319(389)	0.502(300)	---	0.538(1030)
	all rivers	0.674(599)	0.478(880)	0.442(683)	---	0.521(2162)

Table 11. Currently available estimates of annual fishing mortality rates among Virginia resident populations of striped bass.

Year Class	Age-group When tagged	Tagging Season	River	Number Tagged	Corrected (A)	Number Returns	Corrected (B)	Annual Fishing Mortality (B/A)
1965	II	Winter 1968	York	37	33.3	5	5.5	0.165
			Rappahannock	38	34.2	18	19.8	0.579
	III	Summer 1968	James	23	20.7	9	9.9	0.478
			Rappahannock	17	15.3	6	6.6	0.431
1966	I	Winter 1968	York	1301	1170.9	189	207.9	0.178
			Rappahannock	1005	904.5	205	225.5	0.249
	II	Summer-fall 1968	James	118	106.2	34	37.4	0.352
			York	162	145.8	13	14.3	0.098
			Rappahannock	1247	1122.3	225	247.5	0.221
		Winter 1969	James	298	268.2	39	42.9	0.160
			York	259	233.1	35	38.5	0.165
			Rappahannock	108	97.2	32	35.2	0.362
1967	0	Winter 1968	York	588	529.2	44	48.4	0.091
			Rappahannock	134	120.6	13	14.3	0.119
	I	Summer-fall 1968	James	404	363.6	66	72.6	0.200
			York	212	190.8	23	25.3	0.133
			Rappahannock	224	201.6	22	24.2	0.120

Table 11. (continued)

Year Class	Age-group When tagged	Tagging Season	River	Number Tagged	Corrected (A)	Number Returns	Corrected (B)	Annual Fishing Mortality (B/A)
1967	I	Winter 1969	James	528	475.2	62	68.2	0.144
			York	594	534.6	74	81.4	0.152
			Rappahannock	922	829.8	142	156.2	0.188
1968	0	Winter 1969	Rappahannock	128	115.2	12	13.2	0.115

Objective 5 - Relative abundance of year-classes

The relative abundance of individual year-classes of striped bass passing through the fishery during the life of this project has been estimated from three different sampling methods and periods. These include 1) a minnow seine survey of young-of-the-year striped bass in the James, York, and Rappahannock rivers, conducted July-October of each year, 2) young fish trawl surveys of these rivers during winter months, and 3) commercial sampling during the initial period of a year-class entry into the fishery.

Minnow Seine Surveys

From six to eight standard seining stations were established in each of the three river systems. These were sampled semi-monthly during the period July-October in each year beginning in 1967, using a 100 x 6 ft minnow seine having a 1/4-inch bar mesh.

Indices of abundance for each year-class have been obtained from the total catch per total effort for each river, with a unit of effort consisting of one seine haul. Older striped bass are excluded from these calculations. These data show (Fig. 3) not only differences in overall year-class abundance, but distinct differences in year-class success between river systems. Catch-per-unit-effort in the Rappahannock River was similar in all three years, but dipped to a low in 1968 in both the James and York rivers. In 1969, catch-per-unit-effort remained at a low in the York River, while doubling in the James. Generally, the 1967 year-class appeared to be the most abundant of the three, although none of these year-classes were particularly strong ones.

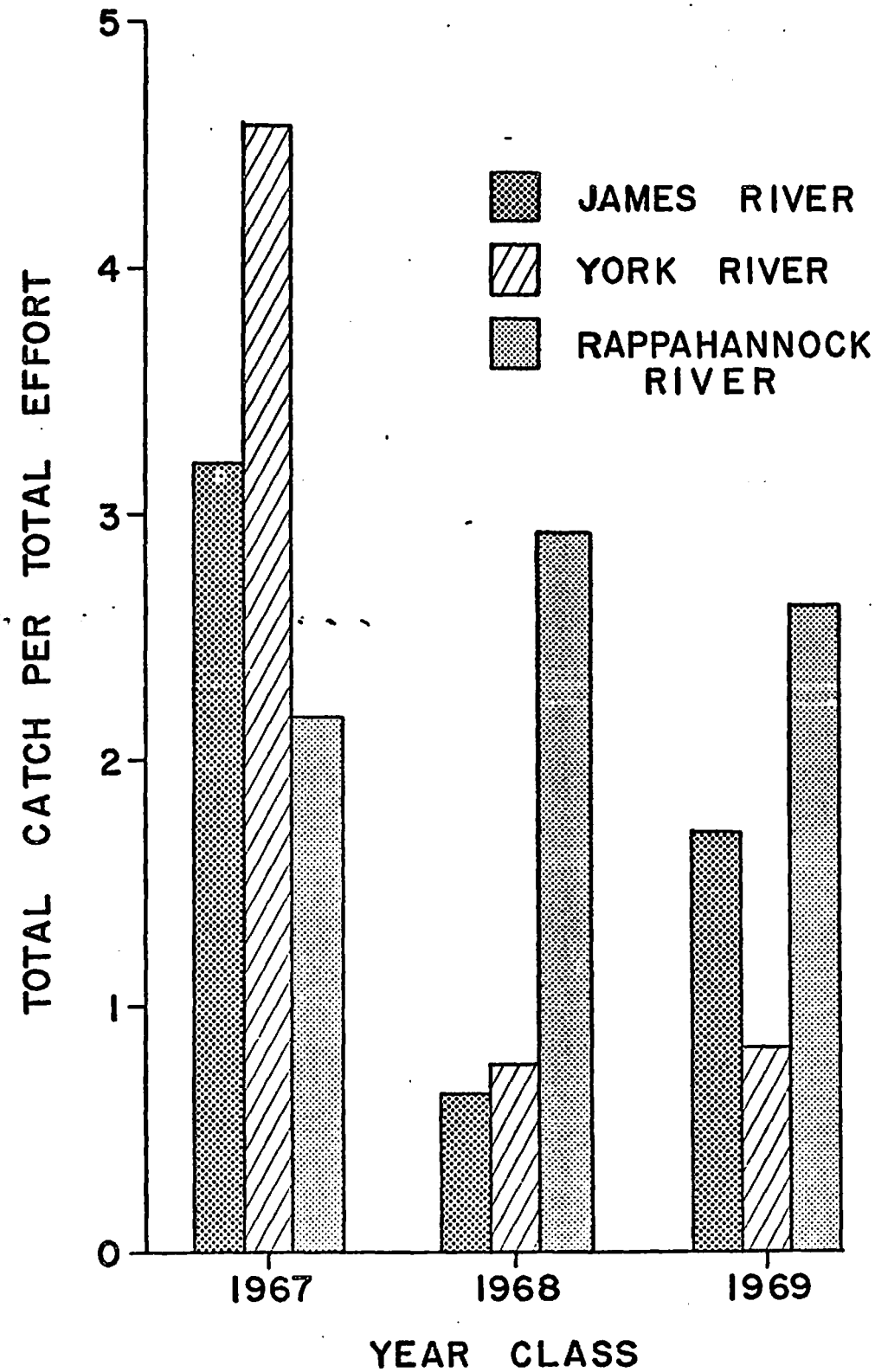

Fig. 3. Catch per minnow seine haul of 1967, 1968, and 1969 young-of-the-year striped bass in the James, York, and Rappahannock rivers. Based on semi-monthly surveys, July-October.

Young-Fish Trawl Surveys

The movement of striped bass into river channels during cooler months and slowing of their metabolism leaves them most vulnerable to a small trawl during winter months. Catch-per-unit-effort data from 30-ft trawl catches during the three-month period January-March, therefore, allow a second estimate of the relative strength of in-coming year-classes. In this case, the unit of effort selected is one hour of trawling.

The 1966 year-class, a dominant one in the York and Rappahannock rivers (Grant and Joseph, 1969), is included in these estimates (Fig. 4) from the collections frozen before the start of this project. Estimates of year-class abundance from trawl surveys, therefore, are available for the four year-classes 1966-1969. Catch-per-unit-effort varied from a high of over 110 per trawl hour in the York and Rappahannock rivers (1966 year-class) to less than five per trawl hour in the James River (1968 year-class). In general, and disregarding river differences, results show one dominant year-class (1966) and three of only moderate strength (1967-1969).

Differences between rivers in the magnitude of indices may not be of any significance, because of the very possible difference in catchability of striped bass at the selected stations. Therefore, only annual comparisons within river systems are valid. For example, the low magnitude of James River indices, compared with those from the York and Rappahannock rivers, are not considered to denote a small population of striped bass in the James. On the other hand, comparison of James River indices among years is considered a valid means for assessing relative year-class strength. Interpreted in this manner, Fig. 4 shows the 1966 and 1968 year-classes to be relatively poor ones in the James River, and the 1967 year-class

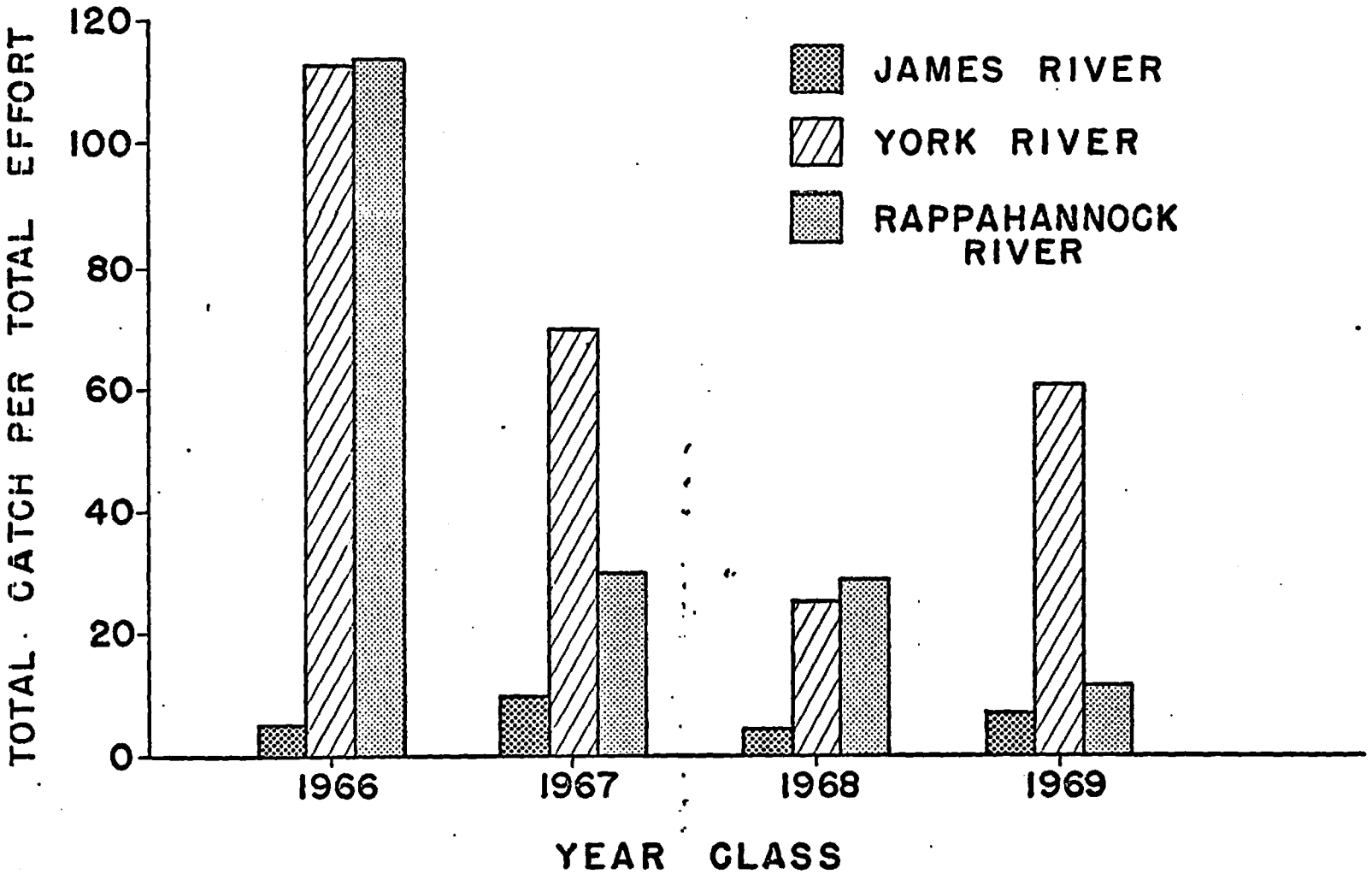

Fig. 4. Catch per trawl hour of four striped bass year-classes in the James, York, and Rappahannock rivers. Based on 30-ft semi-balloon trawl catches during winter months (January-March) of calendar year following hatch.

to be strongest. The 1966 year-class, on the other hand, was much the strongest in both the York and Rappahannock rivers. Other year-classes were of low to moderate strength in these two rivers, with the 1968 year-class the poorest in the York River, and the 1969 year-class appearing to be the weakest in the Rappahannock River.

Entry into Commercial Fishery

Although striped bass less than one year old appear in unculled non-selective commercial catches as early as October of their hatching year, reliable indications of year-class strength are not available until the following summer. These fish are then beginning their second year of growth and are less likely culled from catches. Data are available from the summers of 1967-1969, thereby providing estimates of relative abundance for the year-classes 1966-1968. In the absence of catch and effort records, it has been necessary to express results as percentage of sampled catch within the year-class of interest (Fig. 5).

Results are similar to previous comparisons of year-class strength, i.e. a strong 1966 year-class in the York and Rappahannock rivers, and considerably weaker ones thereafter. The 1967 year-class again appeared to be the strongest, relatively, in the James River. The 1968 year-class, however, showed more strength than expected from trawl estimates in both the York and Rappahannock rivers.

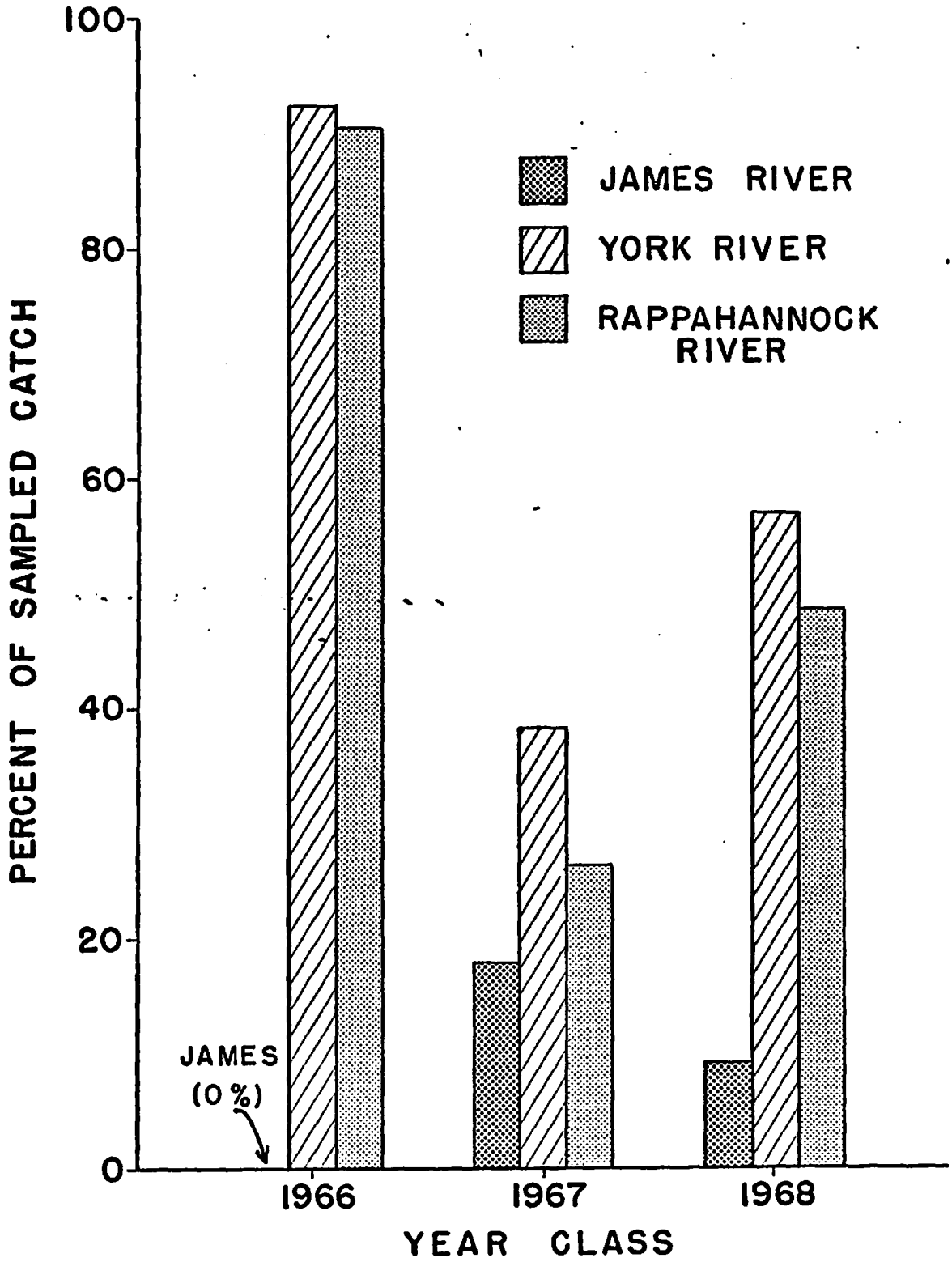

Fig. 5. Relative abundance of the 1966-1969 year-classes of striped bass in three Virginia rivers, expressed as percent of sampled non-selective catches during the summer months (July-September) of calendar year following hatch.

DISCUSSION

The diversity of Virginia's striped bass fishery, which employs pound nets, fyke nets, gill nets, haul seines, and commercial trawlers (in addition to an extensive sport fishery), causes considerable difficulty in sampling the catch. Landings reports subdivide total catches into regional areas, but not into catches by individual gear types. The number of logbooks that would be necessary for an accurate estimate of catch and effort from the scattered and diverse fishery in Virginia is excessive. Total landings, as reported for the past forty years, reveal no evidence of the six-year cycle of abundance shown for Maryland catches (Koo, 1970). Virginia striped bass landings, since a low in 1934, have increased to two fairly equal peaks, separated by a period of 16 years.

The age composition of Virginia striped bass stocks, as estimated from non-selective pound and fyke net samples, varies little seasonally. Although more older, migrating individuals are evident during and shortly after spring spawning runs, at least a few large fish are taken throughout the year. A perfectly non-selective type of fishing gear, catching a species having equal recruitment from year to year and constant mortality rates, would capture this species in numbers declining predictably from youngest to oldest ages. Departures from this hypothetical age composition in our actual data stem from three principal factors: 1) striped bass are not fully recruited to the pound and fyke net fishery until they attain one year of age, i.e. this "non-selective" actually selects against young-of-the-year fish, 2) recruitment is highly variable, with differences between overall year-class strength and differences in spawning success among river systems, and 3) mortality rates apparently increase with advance in age.

The first factor was most important to our results. York River catches were dominated by one-year-olds throughout the three years of sampling; Rappahannock River catches were dominated by one-year-olds in two of the three years, and by two-year-olds in one sampling year; James River catches were dominated by two-year-olds in all three years. The latter case may be due to a difference in growth rates between river systems, a possible fourth factor.

The effect of strong year-classes (variable recruitment) was evident in Rappahannock River populations, where the 1966 year-class was dominant in two successive years, first as one-year-olds, then as two-year-olds. Increasing mortality rates among older fish, the third factor, then shifted dominance back to one-year-olds (the 1968 year-class) in the third year.

Age selectivity occurs in varying degree and direction in catches of haul seines, gill nets, and sport catches. Haul seines are least selective, compared with our "non-selective" nets. They appeared to select for somewhat younger striped bass during the first half of the calendar year. Sport catches by hook-and-line also selected for younger fish early in the year, perhaps because of some reduction in the feeding activity of larger, spawning striped bass. Selection during the last half of the year varied---toward either older or younger fish. Gill nets were most selective, catching mainly striped bass in their third or fourth growing season, and fewer than expected of both younger and older fish.

Several problems arose in estimating the proportions of total catch taken by the various classes of fishing gear. For completely accurate estimates, a "perfect tag" is needed---one that has an equal chance of

being recaptured in any of the gear types in use, after being randomly dispersed through the population by its bearers, and remain equally available to such gear throughout the year. Streamer disc tags, used in the first season of tagging were found to snag easily in gill nets; a substitution of internal anchor tags with a vinyl streamer (Dell, 1968) corrected this source of bias. Fish tagged during warm months were, in some cases, observed to remain in the immediate vicinity of release, thereby biasing estimates toward the particular class of gear fished most heavily in that area. Data biased in either of the above two fashions were therefore eliminated from this analysis.

One possible source of error could not be eliminated. Tag returns decrease logarithmically with increased time at large, thereby increasing the chances of recapture in fishing gear heavily employed in the season immediately following tag releases, decreasing the chance of recapture in gear fishing seasonally later in the year. This type of error may be examined by comparison of results from summer 1968 tagging with those from winter 1969 tagging (Table 9) and within river systems. Differences in the share of returns taken by the various gear-types in the York River between the two seasons of tagging are slight. In the Rappahannock River, however, pound nets recaptured a much larger share of tagged fish after summer tagging (67.4%) than after winter tagging (42.3%). Inversely, comparable haul seine shares of recaptures were 3.0% and 24.2%. With this source of error in mind, but not eliminated, data were nevertheless combined to provide an overall estimate of the proportions of total catch taken by each gear type. Over 98% of all tag returns were taken by four types of gear: pound nets (39.7%), sport catches (26.6%), gill nets (18.8%), and haul seines (13.0%). The true proportion of total catch taken by

gill nets is undoubtedly higher than our estimate, since a large number of striped bass were tagged at a size too small to be caught in this gear. Similarly, offshore trawl catches contribute to a substantial portion of total Virginia landings, but are taken in an area beyond that frequented by our resident stocks, consist of mixed stocks of older striped bass, and cannot be expected to yield a percentage of returns comparable to their actual share of landings.

Although based on returns of differently designed tags, the observation of Massmann and Pacheco (1961) on recapture gear may be compared with ours. Recaptures of striped bass tagged in the James, York, and Rappahannock rivers during 1957 and 1958 occurred mostly in gill nets, rather than pound nets. However, both streamer disc tags and Petersen tags, employed by Massmann and Pacheco (1961), are selectively snagged by gill nets. Sport catches, on the other hand, may have increased significantly in the past ten years. Massmann and Pacheco (1961) reported only 12% of returns from this source (based on total returns with recapture gear information) compared with our 26.6%.

Total mortality rates calculated by the Jackson method have been included in this report only as a crude alternative to a more accurate estimate, based on tagging data, that will be available after April 1, 1971. Jackson estimates assume constant recruitment, so are extremely sensitive to such differences in year-class strength as are characteristic of striped bass. Estimates for individual years and rivers, based on winter trawl catches, varied from 0.247 to 0.881 for age groups 0-III. Similar estimates, but based on fall pound net collections, varied from 0.097 to 0.842 for age groups I-IV. Combining data for several years within river systems

(Table 10) reduces the variation contributed by variable year-class strength and provided estimates varying from 0.416 to 0.788 from trawl data, and from 0.290 to 0.610 from pound net data. However, these estimates will be abandoned in favor of tag-and-recapture estimates, when the latter become available.

Annual fishing mortality rates, calculated from the number of tags returned within one year of release, have been estimated for each year-class within river systems and for each tagging period. In general, rates increased with increase in age through the first four age groups. This finding points out the futility of evaluating the success of tagging programs by comparing tag return rates without reference to the size (or age) of the fish tagged. In striped bass, among ages 0-IV, the older the fish tagged, the greater the chance of its recapture.

The three methods of estimating relative abundance of individual year-class, i.e. from minnow seine and 30 ft semi-balloon trawl catch-per-unit-effort data and from percentage of non-selective commercial catches, can only be evaluated after several years of sampling. Paired observations needed to examine correlation of methods are now limited to only two or three per river system. At least three are needed to provide a test of significance (since degrees of freedom equals n-2). However, two significant correlations have been obtained from these sets of indices: 1) a correlation coefficient of 0.997 ($n = 3$, $p = <.05$) for minnow seine and winter trawl indices from the James River, and 2) a correlation coefficient of 0.890 ($n = 9$, $p=<0.01$) for winter trawl and summer non-selective commercial catches from the three rivers combined.

In addition to the results discussed above, data have accumulated and been stored that will provide valuable information not directly necessary for reaching objectives of this study. These data include: 1) abundant age, length, and weight observations on striped bass, together with back-calculations of length at various ages, 2) information on migration obtained from tag returns, 3) filed plastic impressions of scales suitable for a microscopic examination of seasonal growth patterns and possible differences between river systems in scale pattern (natural tags), 4) identifications, enumeration, and measurements of fish species associated with striped bass in our sampling programs, 5) hydrographic observations at each sampling station, and 6) preserved collections from several year-classes of striped bass from the James, York, and Rappahannock rivers, suitable for a meristic study of differences between rivers and year-classes.

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APPENDIX

Table A1. Fork length and age distribution of striped bass tagged in the James River, winter 1968.

Midpoint of 15 mm size-class (fork length)	Year-class				
	1967	1966	1965	1964	Total
140	2				2
155	14	3			17
170	11	6			17
185	6	5			11
200	2	3			5
215		3	1		4
230		1			1
245		3	1		4
260		2			2
275		3			3
290		2			2
305		3	3		6
320		3			3
335		1	2		3
350				1	1
365		1	1		2
380					0
395					0
410				1	1
425					0
440					0
455				1	1
	35	39	8	3	85

Table A2. Fork length and age distribution of striped bass tagged in the York River, winter 1968.

Midpoint of 15 mm size-class (fork length)	Year-class								
	1967	1966	1965	1964	1963	1962	1961	Unknown age	Total
140	2								2
155	242	5							247
170	244	22							266
185	87	51							138
200	9	96							105
215	4	133							137
230		139							139
245		174	1						175
260		202	5						207
275		169	5						174
290		150	4						154
305		76	4						80
320		47							47
335		22	4						26
350		12	3						15
365		1	3						4
380			5						5
395			1	1					2
410				1					1
425			1						1
440									0
455		1							1
470									0
485									0
500			1	1					2
.									.
.									.
.									.
.									.
635					1				1
.									.
.									.
.									.
.									.
695								1	1
..									.
.									.
.									.
.									.
755							1		1
no length		1							1
Total	588	1301	37	3	1	0	1	1	1932

Table A3. Fork length and age distribution of striped bass tagged in the Rappahannock River, winter 1968.

Midpoint of 15 mm size-class (fork length)	Year-class					
	1967	1966	1965	1964	1963	Total
155	29	4				33
170	49	22				71
185	47	40				87
200	7	83				90
215	1	117				118
230	1	144				145
245		147	1			148
260		143	2			145
275		117	1			118
290		88	5			93
305		58	5			63
320		27	5			32
335		11	5			16
350		3	1			4
365			2			2
380			4			4
395			2			2
410			4			4
425						0
440						0
455						0
470			1			1
485						0
500					1	1
no length		1				1
Total	134	1005	38	0	1	1178

Table A4. Fork length and age distribution of striped bass tagged in the James River, summer 1968.

Midpoint of 15 mm size-class (fork length)	Year-class					
	1967	1966	1965	1964	1961	Total
140	1					1
155	7	1				8
170	35	2				37
185	117	12				129
200	107	7				114
215	53	8	1			62
230	37	13				50
245	26	13	1			40
260	15	10				25
275	4	12				16
290	2	9	1			12
305		11	2			13
320		7	3			10
335		3	2			5
350		4	5			9
365			2			2
380		5	2	2		9
395		1	3			4
410						0
425						0
440			1			1
455						0
470				2		2
.						.
.						.
.						.
.						.
590				1		1
605					1	1
620				1		1
635						0
650					1	1
Total	404	118	23	6	2	553

Table A5. Fork length and age distribution of striped bass tagged in the York River, summer-fall 1968.

Midpoint of 15 mm size-class (fork length)	Year-class				
	1967	1966	1965	1964	Total
170	1				1
185	3				3
200	10				10
215	24	1			25
230	39	1			40
245	46	3			49
260	34	12			46
275	25	19			44
290	17	16			33
305	6	26			32
320	4	23			27
335	1	19	3		23
350	2	9	2		13
365		11	2		13
380		8	2		10
395		5			5
410		4	1		5
425		2	4		6
440		1			1
455		2	1		3
470			1	1	2
485					0
500			1		1
Total	212	162	17	1	392

Table A6. Fork length and age distribution of striped bass tagged in the Rappahannock River, summer 1968.

Midpoint of 15 mm size-class (fork length)	Year-class					
	1967	1966	1965	1964	unknown	Total
185	1					1
200	9					9
215	22	2				24
230	72	22				94
245	77	81				158
260	41	202				243
275	2	202				204
290		163				163
305		179	1			180
320		151	2			153
335		113	2			115
350		79	5			84
365		36	4			40
380		13				13
395		4	1			5
410						0
425♀						0
440			1			1
455			1			1
470						0
485				1		1
no length					5	5
Total	224	1247	17	1	5	1494

Table A7. Fork length and age distribution of striped bass tagged in the James River, winter 1969

Midpoint of 15 mm size-class (fork length)	Year-class						
	1968	1967	1966	1965	1964	1963	Total
170	1	3					4
185	2	12	1				15
200	3	16					19
215		21					21
230		32	1				33
245		34					34
260		52	2				54
275		76	3				79
290		72	6				78
305		79	10				89
320		49	13				62
335		46	21				67
350		24	48				72
365		9	61				70
380		3	56				59
395			30				30
410			24				24
425			6				6
440			9	1			10
455			5	1			6
470			1				1
485							0
500				1			1
515				2			2
530				1			1
545				1			1
560							0
575							0
590					2		2
605							0
620					2		2
635					1		1
650						1	1
no length			1				1
Total	6	528	298	7	5	1	845

Table A8. Fork length and age distribution of striped bass tagged in the York River, winter 1969.

Midpoint of 15 mm size-class (fork length)	Year-class								
	1968	1967	1966	1965	1964	1963	1962	1961	Total
170	1								1
185	1	9							10
200	4	10							14
215	3	6							9
230		13							13
245		40	1						41
260		74	1						75
275		93	1						94
290		85	1						86
305		78	8						86
320		86	8						94
335		45	14						59
350		30	29	2					61
365		22	38	1					51
380		3	38						41
395			41	1					42
410			34						34
425			26						26
440			10	1					11
455			7						7
470			1	1					2
485				1	1				2
500			1	1					2
515				3	1				4
530									0
545				3					3
560									0
575									0
590				1	1				2
605									0
620									0
635						1			1
650						1			1
665						1			1
680									0
695									0
710							1		1
.									.
.									.
.									.
.									.
860								1	1
Total	9	594	259	15	3	3	1	1	885

Table A9. Fork length and age distribution of striped bass tagged in the Rappahannock River, winter 1969.

Midpoint of 15 mm size-class (fork length)	Year-class					
	1968	1967	1966	1965	unknown	Total
140	1					1
155						0
170		1				1
185	56	51				107
200	45	157				202
215	13	198				211
230	9	179				188
245	2	118	2			122
260	1	73	1			75
275		54	7			61
290		39	5			44
305		28	10			38
320		9	14			23
335		13	10			23
350		2	17			19
365			14			14
380			11			11
395			11			11
410			2			2
425			3			3
440						0
455			1			1
470				1		1
no length	1				2	3
Total	128	922	108	1	2	1161

Table A10. Fork length and age distribution of striped bass tagged in the York River, winter 1970.

Midpoint of 15 mm size-class (fork length)	Year-class					
	1969	1968	1967	1966	1963	Total
200	167	58				225
215	138	144				282
230	36	144				180
245	10	117				127
260	1	54				55
275		40	3			43
290		22	3			25
305		19	2			21
320		13	4			17
335		5				5
350		5	7			12
365			6			6
380			6			6
395			7	1		8
410			2			2
425						0
440			1	1		2
455						0
470				1		1
485			1	1		2
.						.
.						.
.						.
.						.
590					1	1
Total	352	621	42	4	1	1020

Table A11. Fork length and age distribution of striped bass tagged in the Rappahannock River, winter 1970.

Midpoint of 15 mm size-class (fork length)	Year-class						
	1969	1968	1967	1966	1965	1964	Total
200	20	18					38
215	8	58					66
230	1	68					69
245		47	1				48
260		25					25
275		34	2				36
290		35	1				36
305		27	3				30
320		28	5				33
335		30	11				41
350		7	14				21
365		7	23	1			31
380		2	24	1			27
395		2	39	5			46
410			23	14			37
425			21	19			40
440			13	21			34
455			6	22			28
470				12			12
485				17			17
500				8			8
515				8			8
530				6			6
545				4	1		5
560				3			3
575				2	2		4
590					1		1
605							0
620							0
635						1	1
Total	29	386	186	143	4	1	751