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Biology and management of river herring and shad in Virginia : Completion report, 1970-73

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COMPLETION REPORT 1970 - 1973

Biology and Management of River Herring and Shad in Virginia

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Preface

This report represents the final report for the 3-year segment 1970-1973 and the annual report for the contract period 1 October 1972 to 15 October 1973. The project has been active since 1965, thus relevant data has been carried forward, added to, and analyzed in this report. The analysis, however, remains subject to later refinement and possible reinterpretation, because many of the jobs and objectives will require several additional years of study before definitive conclusions can be generalized.

The data presented here supercedes similar tables presented in previous annual reports because we have now standardized methods and solidified our attempts at presenting various yearly indices. The changes in any method of analysis are stated within each subsection. This report, therefore, contains earlier data adjusted with derived correction factors so all units have the same base and assumptions.

References to this report should clearly state that it is a progress report subject to continued refinement with additional data. The conclusions and suggestions do not reflect irrevocable positions by VIMS or the scientists responsible for the research. The National Marine Fisheries Service retains the perogative to interpret our findings independently and this document should not be considered an expression of their opinions.

Job 1 was prepared by W. Wilson, and D. Estes, Jobs 2 and 3 by W. Hoagman, Job 4 by R. St. Pierre and J. Merriner, and Job 6 by J. Merriner. Jackson Davis critically read the MS and contributed many suggestions because of his long association with the project. W. Hoagman supervised the project this contract year as Principal Investigator. The pencil drawings were prepared by Janet Green of VIMS, cover design by W. Hoagman.

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ABSTRACT

This completion report summarizes between six and ten years of data for the American shad, blueback herring, and alewife in Virginia rivers. Adult and juvenile population dynamics are central to the continuing investigation of alosine fishes in Virginia. Feeding selectivity and culture techniques for alosids are also summarized.

The spawning population of alosids in Virginia has declined to one-third of its size prior to 1969. Landing by the foreign fishery coincided with the decline in the Virginia fishery. Growth parameters implicate the foreign fishery as the primary causative factor of the reduced domestic catches from 1970 through 1973.

Year class strength of all species in all Virginia rivers has similarly declined since 1970. Estimates of the absolute juvenile populations in early fall were made for 1970 through 1973. Annual indices of abundance were generated for each species and river. The sampling program for the juvenile abundance survey has been progressively streamlined and standardized.

Primary productivity and food regimes in the various rivers were compared to food habits of juvenile alosines. Usually they consume zooplankton in the same proportion as its abundance in the nursery. Some species to species differences in prey selection were found. All rivers surveyed were light limited. Differences in primary productivity, chlorophyll a or nutrients could not be used to adequately define production of alosines in a given river nor differences in production between rivers.

Culture techniques developed were inadequate to succesfully rear alosines from the egg through the juvenile stage.

Introduction

The Anadromous Alosid project at VIMS has as its basic objective the understanding of the population biology of the alewife (Alosa pseudoharengus), blueback herring (Alosa aestivalis), American shad (Alosa sapidissima) and hickory shad (Alosa mediocris). All of these species spawn in the freshwater tidal sections of the major tributaries to Chesapeake Bay. In these zones (Fig. 1). the juveniles live and grow until falling river temperatures cause a mass emigration through the lower estuaries and out to the Atlantic. The adults return to the ocean after spring spawning and escapement of fishing gear. Our cover depicts the generalized biology of the group.

The study concentrates on the James, York, Rappahannock and Potomac rivers, although limited spawning may take place in any small freshwater tributary. The relative productivity of the rivers as regards yield and year class strength has been assessed from several approaches. The recent fishing activity of the foreign fleet, east of Chesapeake Bay has been monitored and its effect on the inshore run analyzed. These subjects and others are detailed in the various sections.

The spring fishery for the alosids in Virginia historically averaged nearly 30 million pounds. The four species characteristically heralded the fishing season with American shad and its roe bringing the highest return. Alewife and blueback find their way to reduction plants but their roe is often sold separately. Many fishermen capture the alosids for later use as crab bait through summer.

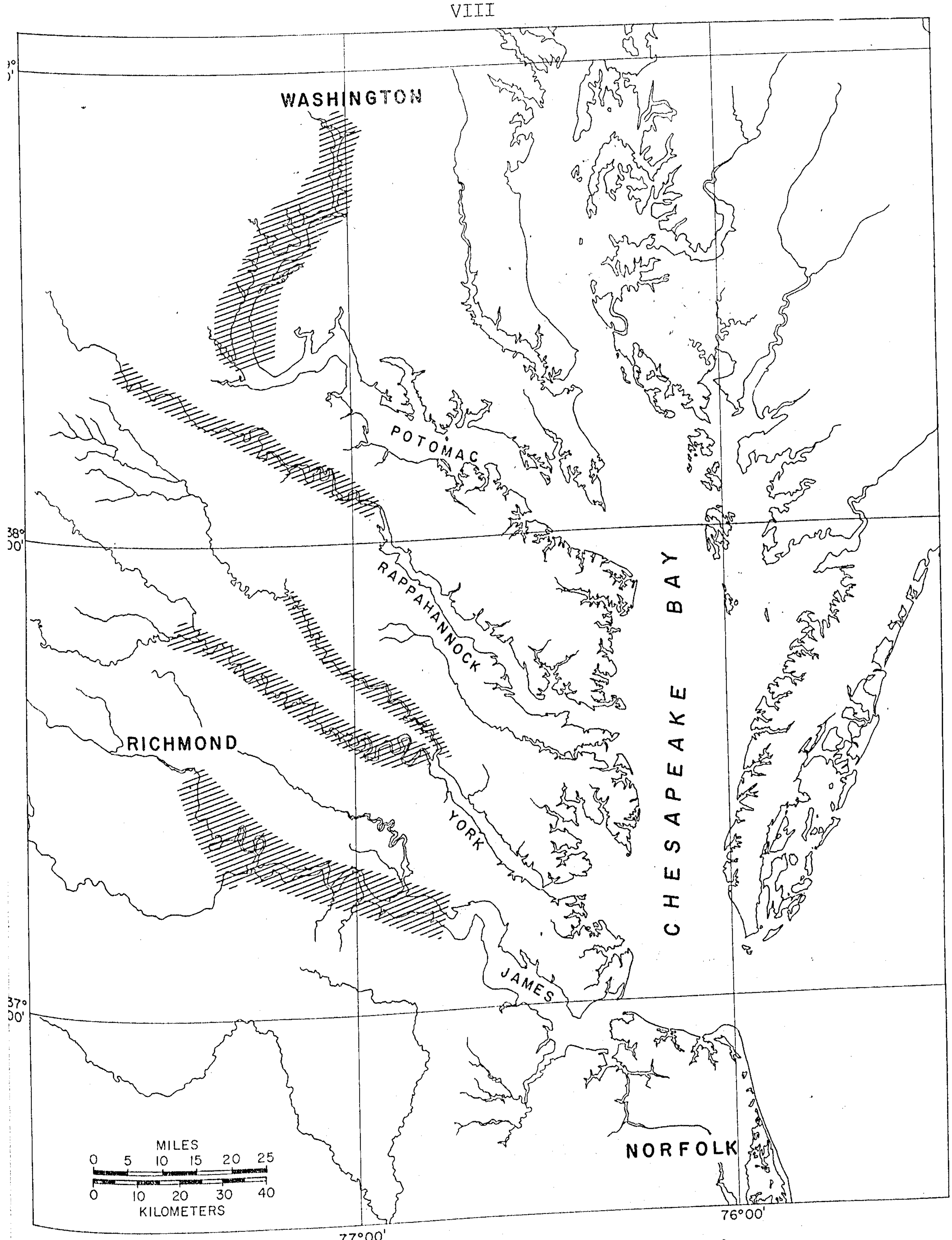


Figure 1. Location chart of the major Alosid nursery zones in Virginia and their relation to the entire estuarine and Chesapeake Bay system. Shaded portions are freshwater nursery zones.

The "down run" of adults occurs as large striped bass and bluefish are making their northerly migration, and serves as an important food potential for the piscavores. In Virginia the adults are repeat spawners and thus can contribute to each year class repetitively. Overall the fishery is an important economics resource and supports or contributes to the success of thousands of individuals during the season.

Within the nursery zones the juvenile alosids are the dominant pelagic species. They typically make up 94 to 100% of our experimental catches in freshwater. Here they are relatively immune from the marine piscavores such as weakfish, striped bass and bluefish which inhabit the higher salinity, lower estuaries during the warmer months. They are planktivorous through emigration and thus capatilize on the high productivity of the zooplankton in the upper rivers. Because of their enormous density and rapid growth, they must be important nutrient reservoirs. They must, therefore, carry to sea some fraction of the natural, municipal and industiral loadings of the upper estuaries but this has not been evaluated yet.

The freshwater resident species utilize the juvenile alosids as a food source, and as they run to sea in late fall, they contribute to the food of the piscavores as they pass out of the Chesapeake Bay mouth. Each year hundreds of millions of young alosids make this emigration to sea from the four major nursery zones.

The contribution of the alosids to the stability of the ecosystem cannot be quantified at present. We are certain they represent an important component of the biological interaction and productivity pathways, however. Even if a commercial fishery did not exist for the adults, it would be a resource worthy of protection because of its biological role. Since the group is very important from many aspects, it deserves careful study to determine the factors which affect its abundance.

This project has run several years and is now clarifying the problems and directing greater emphasis toward understanding the regulatory factors. Management decisions can only be made rationally with such information. The Virginia Institute of Marine Science hopes similar work could be performed on all the groups.

Job 1. Catch-Per-Unit of Effort and Yield in the Spawning Rivers.

The anadromous alosids represent an important natural resource to Virginia and the nation. The Chesapeake tributaries are the main spawning and nursery grounds. Within the last several years (since 1965, at least) the catch and actual abundance of fish (alosids) has been declining. Shad may be the only exception and even river difference often shows reversed abundance in the same year. The Virginia fishermen are naturally very disturbed. This report begins with our catch estimates to establish the yields by river through time. Other sections address causes and other objectives of the program.

Catch-per-unit of effort (c/f) can be used as an indication of the number of fishes that are present in the river systems. Catch-per-unit-effort is calculated by dividing the units of active fishing gear into the total catch for that gear. Catch is measured by obtaining records of the catch from some units of each type of gear in each river system. Total catch is then calculated by multiplying the catch of the index units by the number of units operating. Effort is measured by counting active pound nets during semimonthly aerial surveys. Stake gill nets are counted by boat during the peak fishing period.

Yearly catch-per-unit-effort is calculated by dividing the units of active fishing gear, at the peak, into the total catch for that gear for the season. This gives a seasonal c/f unadjusted for lifts or nights out, that provides some measure of fishing success by river and species. The c/f within a season is calculated by multiplying active pound nets by days out to determine net days. Then net days, divided into total catch for the semimonthly period, give semimonthly c/f by species. All rivers could not be analyzed this way, because some did not have pound nets fished over the entire year.

From 1968 to present, the actual length of each active gill net was determined by counting the number of stakes with mesh between. Between two stakes (poles or net supports) there is 20 feet of mesh, thus (x-1) 20 ft = length of gill net in feet, when x = number of stakes.

Since 1967, the effort in the Virginia pound net fishery has declined sharply (Table 1.1, Fig. 1.1). During the peak fishing period, late April and early May the 1973 average (196) fell 9% below that of 1972 (217) and 35% lower than the 1967 count (305).

However, stake gill nets, primarily for shad, have become more numerous since 1967 (Table 1.3). From 1967 to 1970, the number of nets remained fairly constant in the James and York rivers, but decreased slightly in the Rappahannock River. In 1970, there was a decline in gill nets in all Virginia rivers, but this was due to severe ice conditions during the late winter, which destroyed a number of stands. Since 1970, gill net stands have been increasing in the James and York rivers and remained relatively constant in the Rappahannock River. The total number of nets (345) has been increasing and in 1973 there were 61% more than in 1967 when there were 90. The c/f for gill-netted roe shad in the three rivers has been decreasing since 1967. In 1969, the c/f was 20,425 lb compared to 13,113 lb in 1973. The highest c/f was in 1970 (28,399 lb) and the lowest in 1973. The James and Rappahannock rivers have been decreasing, while the York exhibited somewhat of an increase until 1971, and has been quite stable since. Buck shad were generally not included in c/f as they are sometimes discarded at the net because of poor market value.

Seven-year averages of catch records (Fig. 1.2, 1.3) in the three rivers show the peak periods in the run for both roe and buck shad. The peak occurs in the first half of April for roe shad in all rivers. The James River peaks around the first of April followed by the York River and then the Rappahannock River. Peak runs for buck shad occur from mid-March to mid-April. The York River peaks first, followed by the James River and then the Rappahannock River. The early peak in the York River and the later drop may be due to the fact that these statistics only include those fish brought to the landing. Later in the season, buck shad are usually discarded at the net, as their value decreases. The 7-year averages also showed that the James River catch is more than double the catches of either the York or Rappahannock rivers. Sex ratios have consistently favored the females in all rivers (Tables 1.4, 1.5 and 1.6). In 1969, the sex ratio was 30.5/1 in the York River. The 7-year average catches favored females by more than 2/1 in all rivers and in the York River was over 8/1. This reflects the practice of discarding bucks at the net, but to what degree is not known.

A. <u>James River</u>.

The James River generally has very few active pound nets. Since 1967, during the peak fishing periods of the year, the lowest net count was in 1972 (0) and the highest in 1967 (4). In 1973, there was one pound net in operation.

Gill nets for shad are the primary fishing gear in the James River. The number of stands has remained fairly constant since 1968 (95) showing only a slight increase through the years, reaching a high in 1973 (115)(Table 1.3). The lowest number of gill nets was observed in 1970 where only 65 stands were counted, but in 1971, there were 99 stands. The yearly c/f has steadily declined since 1970 with the highest c/f of roe shad in 1970 (24,912 lb) and the lowest c/f/season in 1973 (9,383 lb). Still, the James annually accounts for more than 70% of the gill net catch in the James, York, and Rappahannock rivers. From March 7 to April 30, 1973 gill nets used as indices in the James River caught an estimated 1,910,656 lb of American ahad (1,075,020 lb roe and 835,636 lb buck shad)(Fig. 1.4 and Table 1.4). Peak catches occurred during late March and early April in 1973 (Fig. 1.5) for both sexes as in other years (Fig. 1.2, 1.3). During the period from March 23 to April 6, 1973, 1,433,038 lb were caught, 75% of the total catch for the year. Sex ratios during the early part of the run favored bucks slightly while the later part of the run favored roe shad. The catch of American shad has been fairly stable in the James from 1969 to 1973.

B. <u>Rappahannock River</u>.

During the period from 1967 to 1973, the number of pound nets fished during the peak period in the Rappahannock River remained relatively constant, with 48 to 54 nets. The c/f has declined steadily for all alosid fishes. The highest c/f of shad was in 1968, when 5,956 lb were caught, and the lowest was in 1973 (467 lb)(Table 1.7, 1.8). The highest c/f of river herring (alewife and blueback) occurred in 1967 (85,577 lb) and the lowest was in 1970 (9,125 lb)(Table 1.7). Total landings by pound nets of American shad and river herring have declined considerably since the late 1960's. The largest catch of American shad was taken in 1968 and the lowest catch taken in 1973 (Fig. 1.6). The largest catch of river herring from 1967 to 1973 was 4 million pounds in 1967, and the lowest was in 1970 when 465 thousand pounds were taken. From 1970 to 1973, the river herring catch has remained low (Fig. 1.7).

Stake gill nets in the Rappahannock River have decreased slightly since 1968 (Table 1.3). The highest number of nets were recorded in 1968 (144) and the lowest in 1970 (94). The number of nets in 1973 (100) declined 12% from 1972 (114). The c/f of roe shad increased during the years from 1968 to 1971, but in 1972 and 1973 c/f dropped off drastically. The 1973 c/f (365 lb) was 90% below that of 1971 (3,528). The 1971 c/f was the highest from 1968 to 1973 and the lowest c/f was in 1973.

The estimated catch of American shad from stake gill nets in the Rappahannock River was 55,630 lb (35,508 lb of roe and 19,122 lb of buck)(Fig. 1.8, Table 1.6). Peak catches occured during late March and early April. Another peak occurred during mid-April after a slight drop in earlier catches. Sex ratios favored roe shad at all times except in the first 2 weeks of the run.

Highest estimated catch of buck American shad occurred in 1971 and the lowest in 1973. Highest estimated catch of roe hickory shad occurred in 1970 and the lowest in 1968 (Fig. 1.9).

C. York River.

Pound nets in the York River were not suitably positioned during 1973 to serve as indices of the run of shad or river herring. Most nets in the York River are situated at or near the mouth of the river. Thus the fish captured may not be exclusively those fish that are entering the river to spawn.

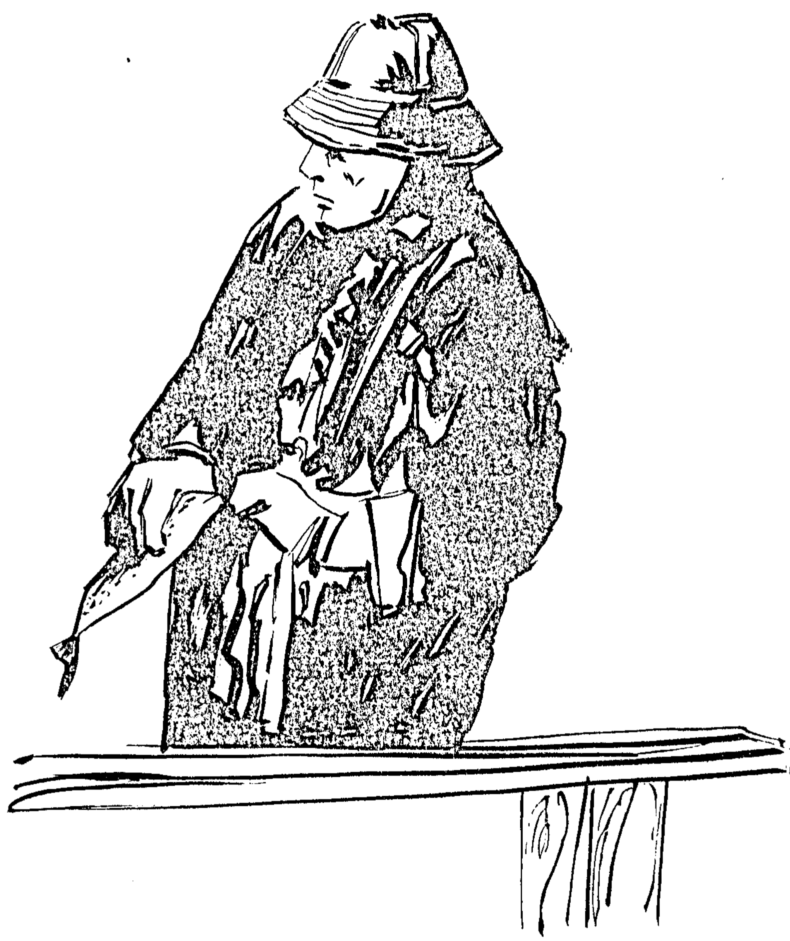
Stake gill nets in the York River caught an estimated 436,461 lb of roe American shad, 53,276 lb of buck American shad, and 13,268 lb of hickory shad (probably roe) in 1973 (Table 1.5, Fig. 1.10). From 1971 to 1973, the catch has been consistently high. Peak catches again occurred in late March and early April (Fig. 1.11). Roe shad were the predominant sex found throughout the run. This may be due partly because many buck shad were discarded at the net due to low market value.

Highest c/f of roe American shad by stake gill nets in the York River since 1967 occurred in 1971 (Table 1.3) and the lowest in 1969. Highest estimated catch of roe American shad occurred in 1973 (Table 1.5) and the lowest in 1970. Highest estimated catch of buck American shad occurred in 1971 and the lowest in 1969. Highest estimated catch of roe hickory shad by stake gill net in the York River since 1967 occurred in 1973 and the lowest in 1968.

D. Potomac River.

In the Potomac River, above mile 15, the catch of river herring (alewife and blueback) declined from 4,722,833 lb in 1972 to 1,384,773 lb in 1973 (Table 1.9). The c/f in 1972 for river herring was 102,457 lb and 49,492 lb in 1973, a decline of 52% from 1972. Highest catch of river herring from 1967 to 1972 (Fig. 1.12) occurred in 1967 and the lowest in 1973. The catch of American shad in the Potomac River declined from 420,986 lb in 1972 to 203,659 lb in 1973, however the catch from 1967 to 1973 shows no revealing trend (Fig. 1.13). Highest catch of roe American shad occurred in 1972 and the lowest in 1970. Highest catch of buck American shad occurred in 1968 and the lowest in 1973.

In Virginia rivers, the fishery for anadromous alosids has declined rapidly. While there is some increase in the gill net effort to catch shad, the c/f for shad has declined considerably since 1970. The 1973 c/f was 63% of 1972 (Table 1.3). The effort in the pound net fishery has decreased since 1967 (Table 1.1). There has been a decline in the c/f of all alosid fishes caught in pound nets. The decline and most probable reasons are more fully explained in Jobs 2 and 3 of this report.



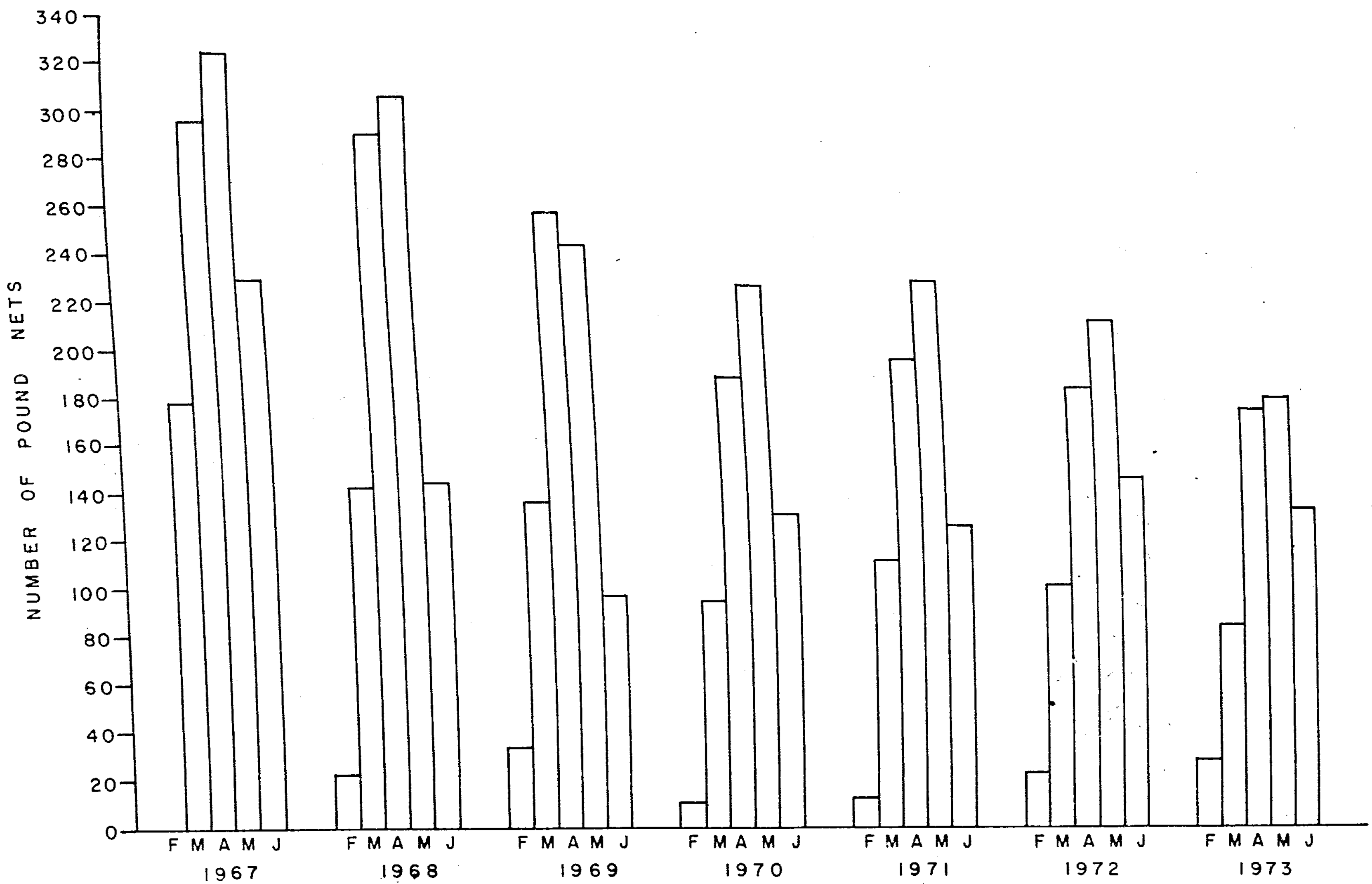


Fig. 1.1. Monthly average number of pound nets in the spring fishery in lower Chesapeake Bay and tributaries, 1967-1973.

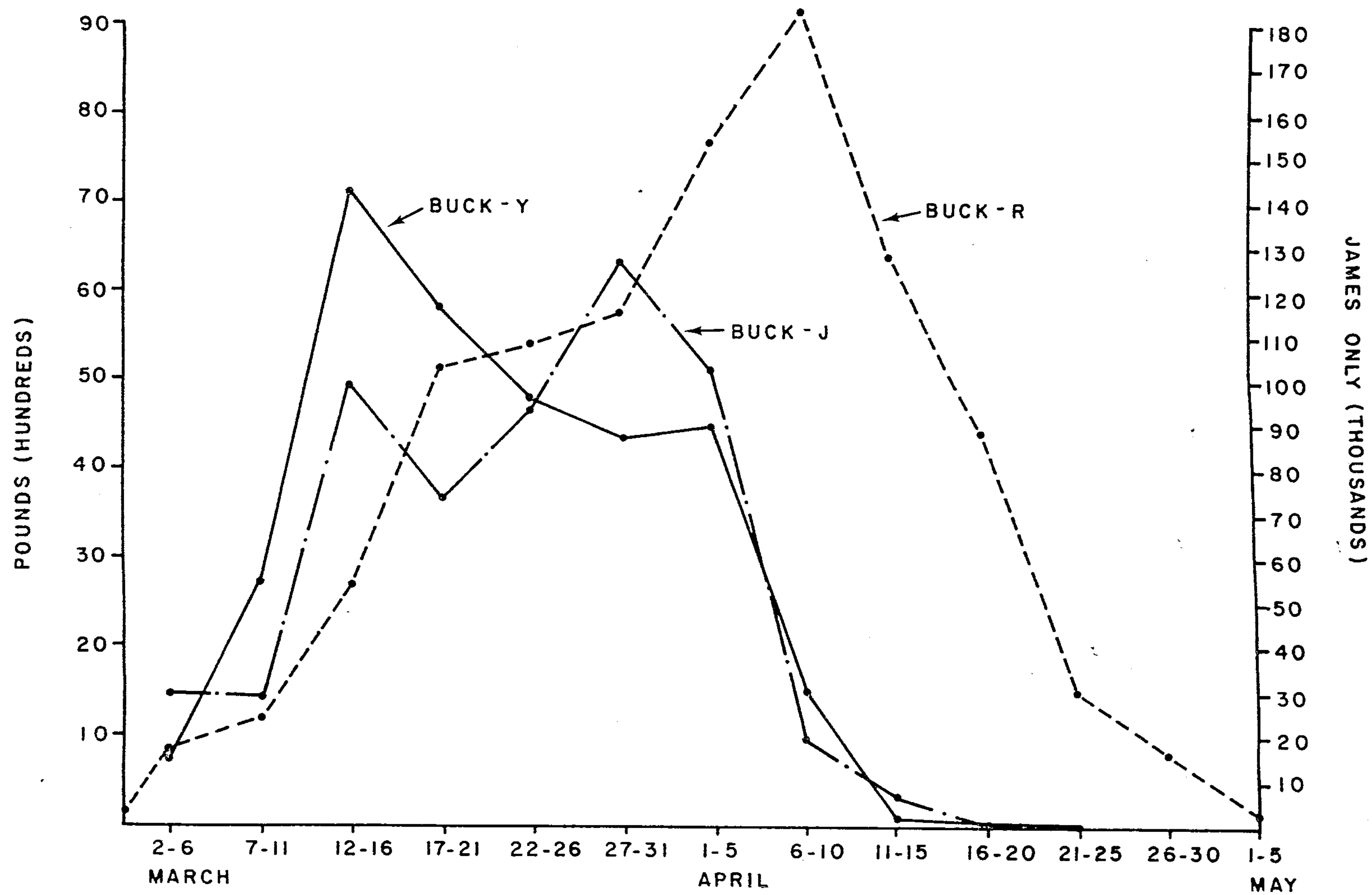


Fig. 1.2. Seven-year (1967-1973) average landings through the spring fishing season by stake gill nets for buck (male) shad in the James (J), York (Y), and Rappahannock (R) rivers of Virginia.

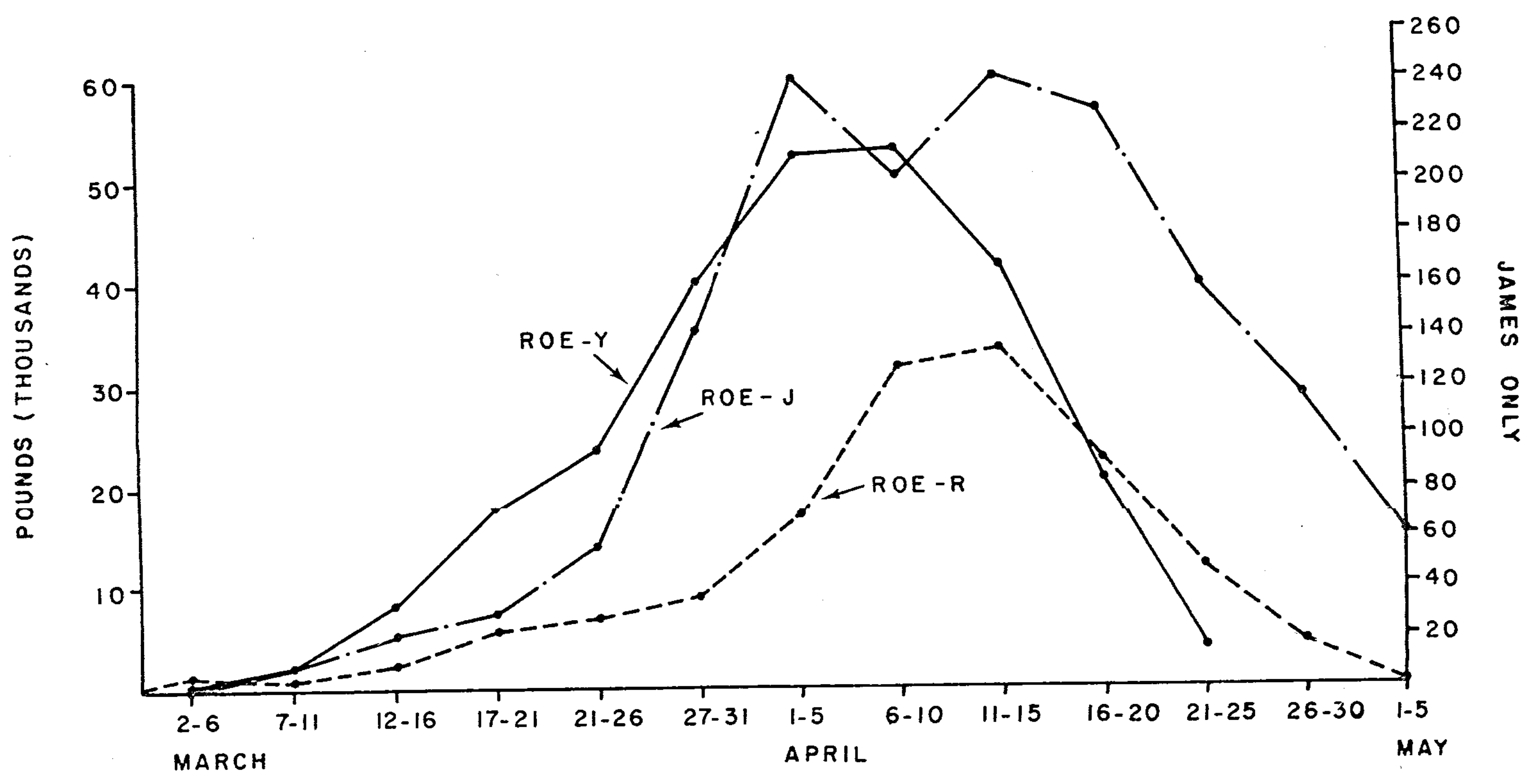


Fig. 1.3. Seven-year (1967-1973) average landings of roe (female) shad by stake gill nets in the James, York, and Rappahannock rivers of Virginia, showing seasonal catch.

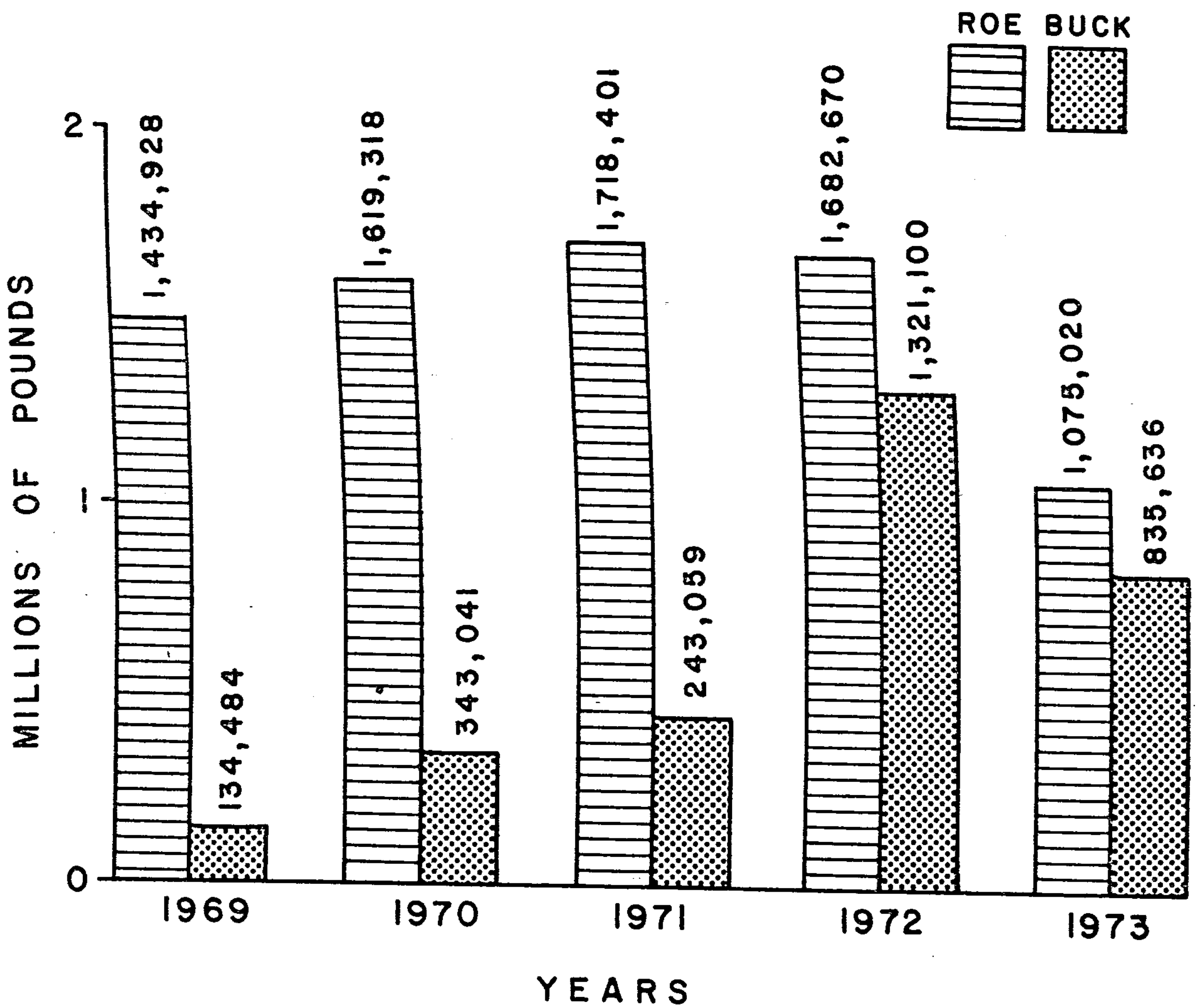


Fig. 1.4. Estimated catch of American shad by stake gill nets by year for the James River, Virginia.

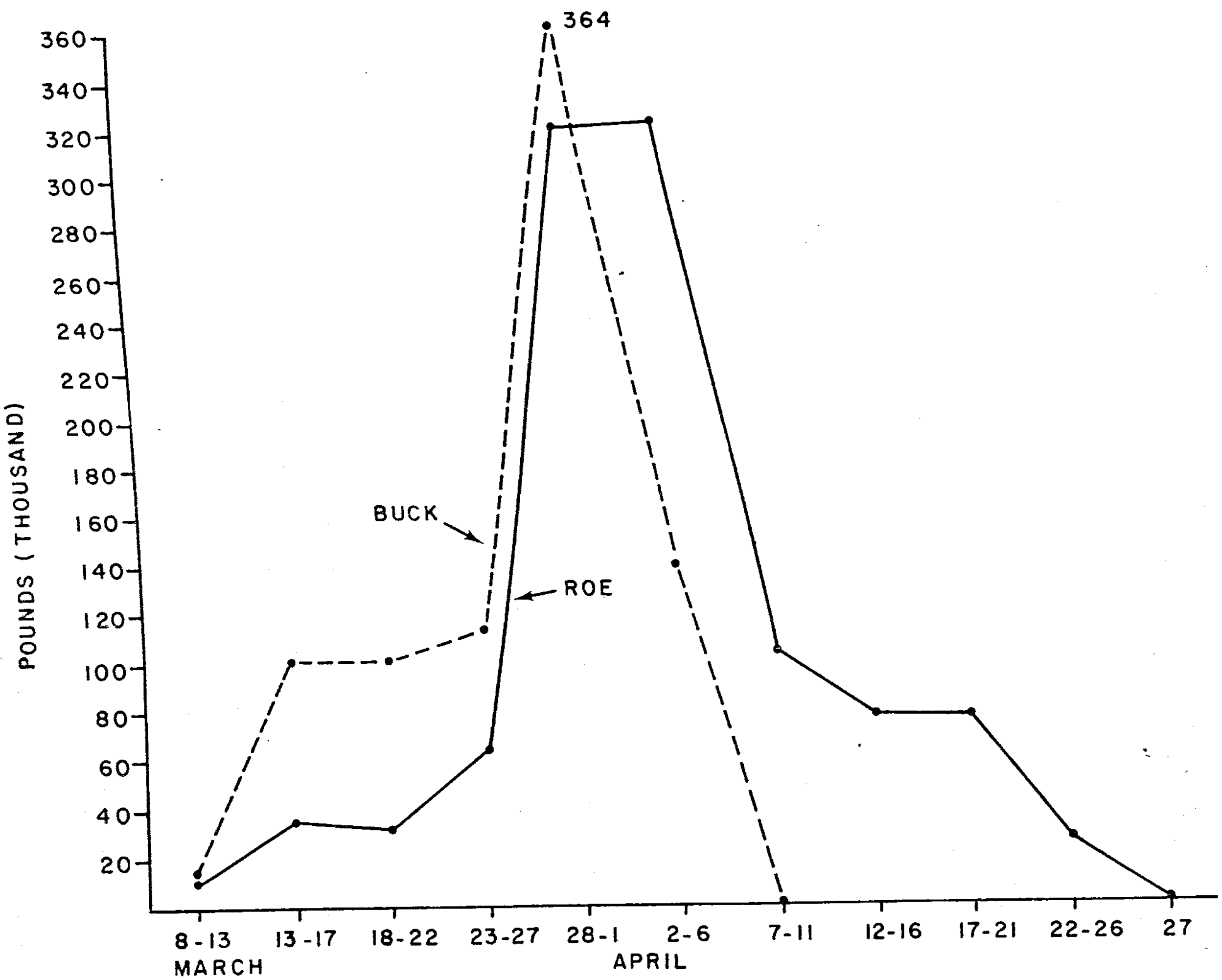


Fig. 1.5. James River 1973 catch of American shad by stake gill nets summed into 5-day intervals.

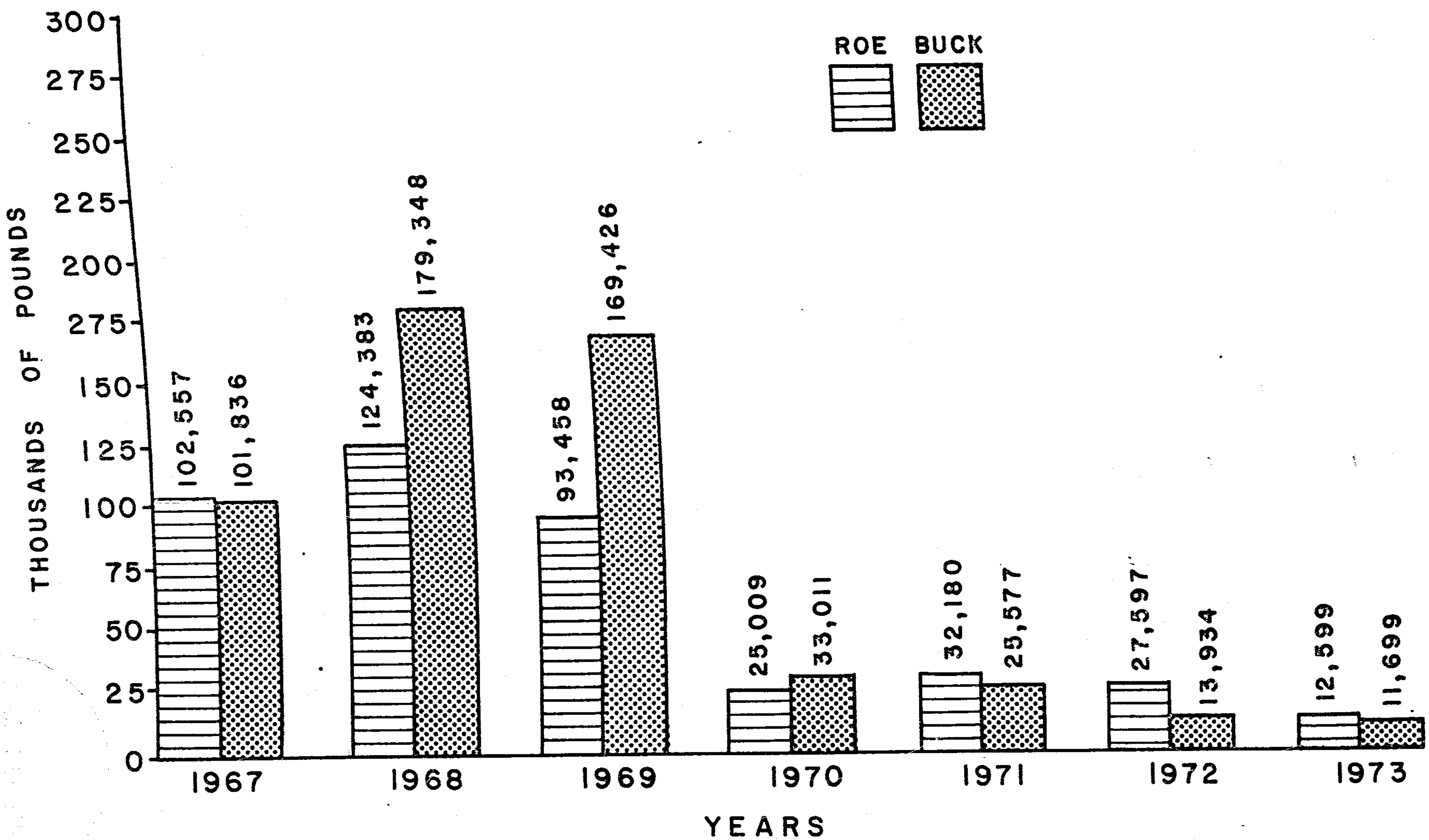


Fig. 1.6. Estimated catch of American shad by pound nets in the Rappahannock River, Virginia.

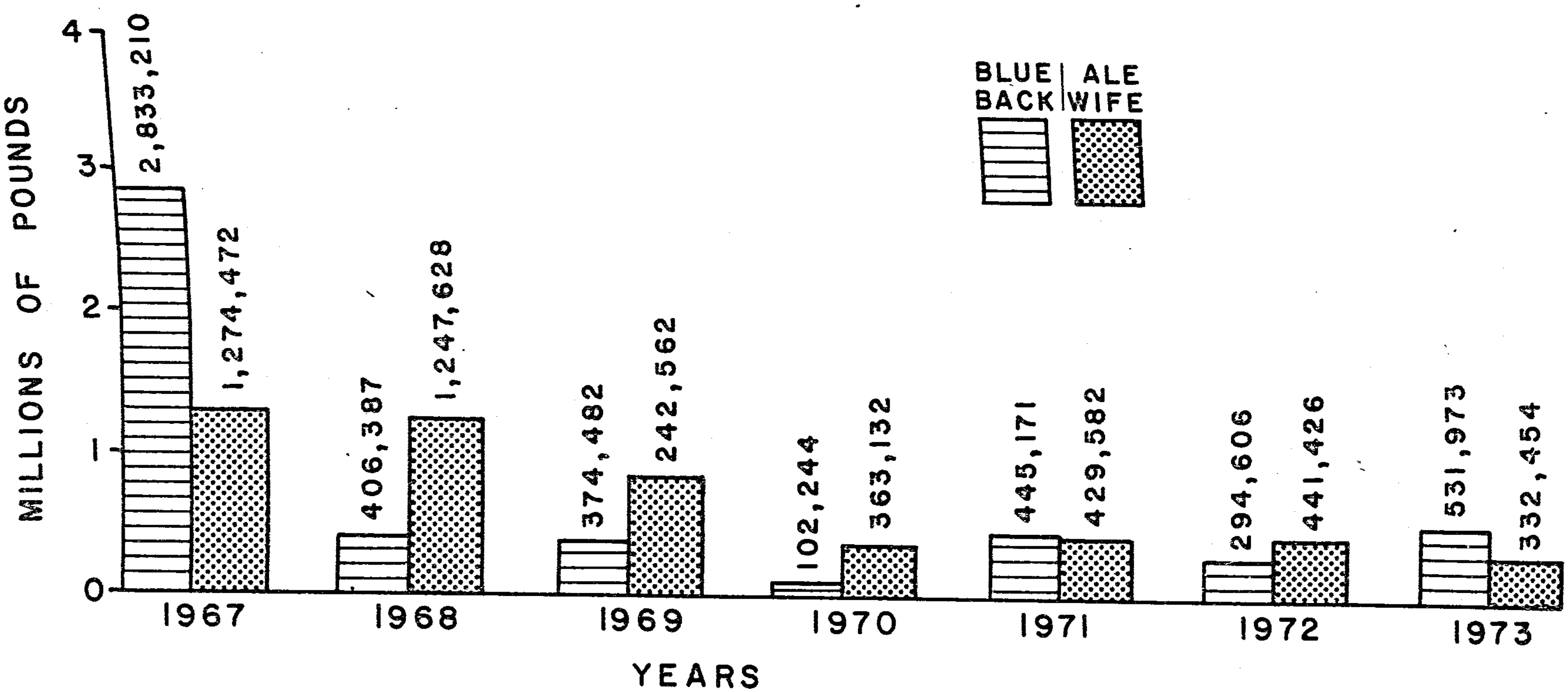


Fig. 1.7. Estimated catch of river herring by pound nets in the Rappahannock River, Virginia, 1967 to 1973.

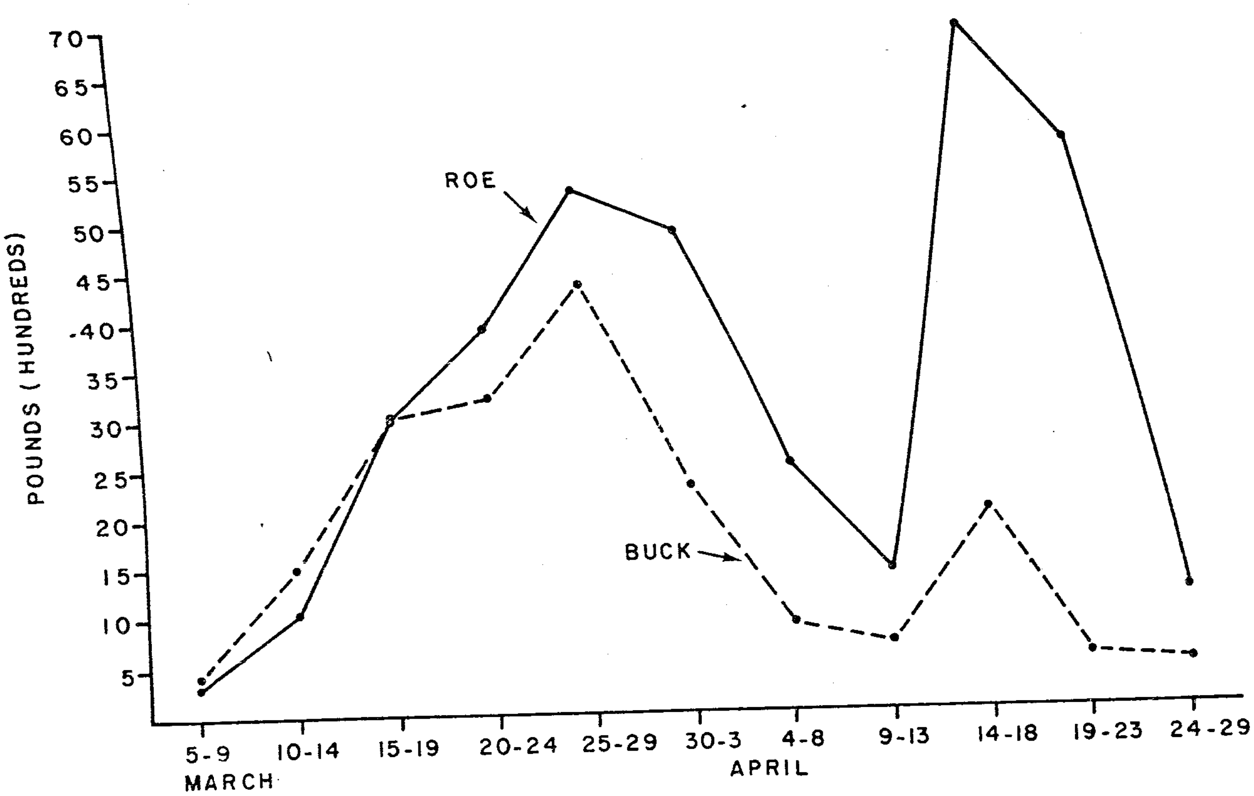


Fig. 1.8. Catch in 1973 of American shad by stake gill nets in the Rappahannock River, Virginia.

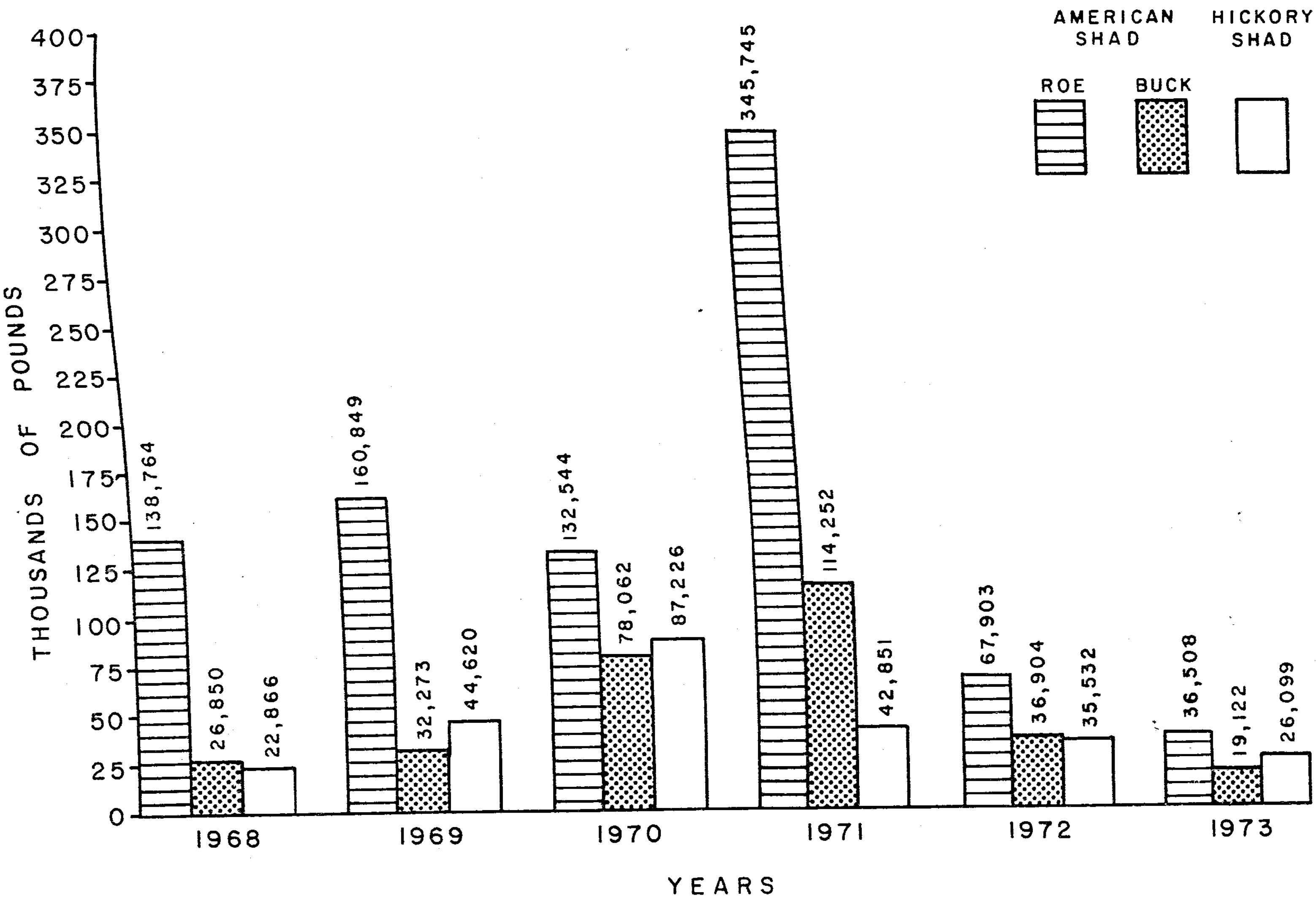


Fig. 1.9. Estimated catch of American and hickory shad by stake gill nets in the Rappahannock River, Virginia, 1968 to 1973.

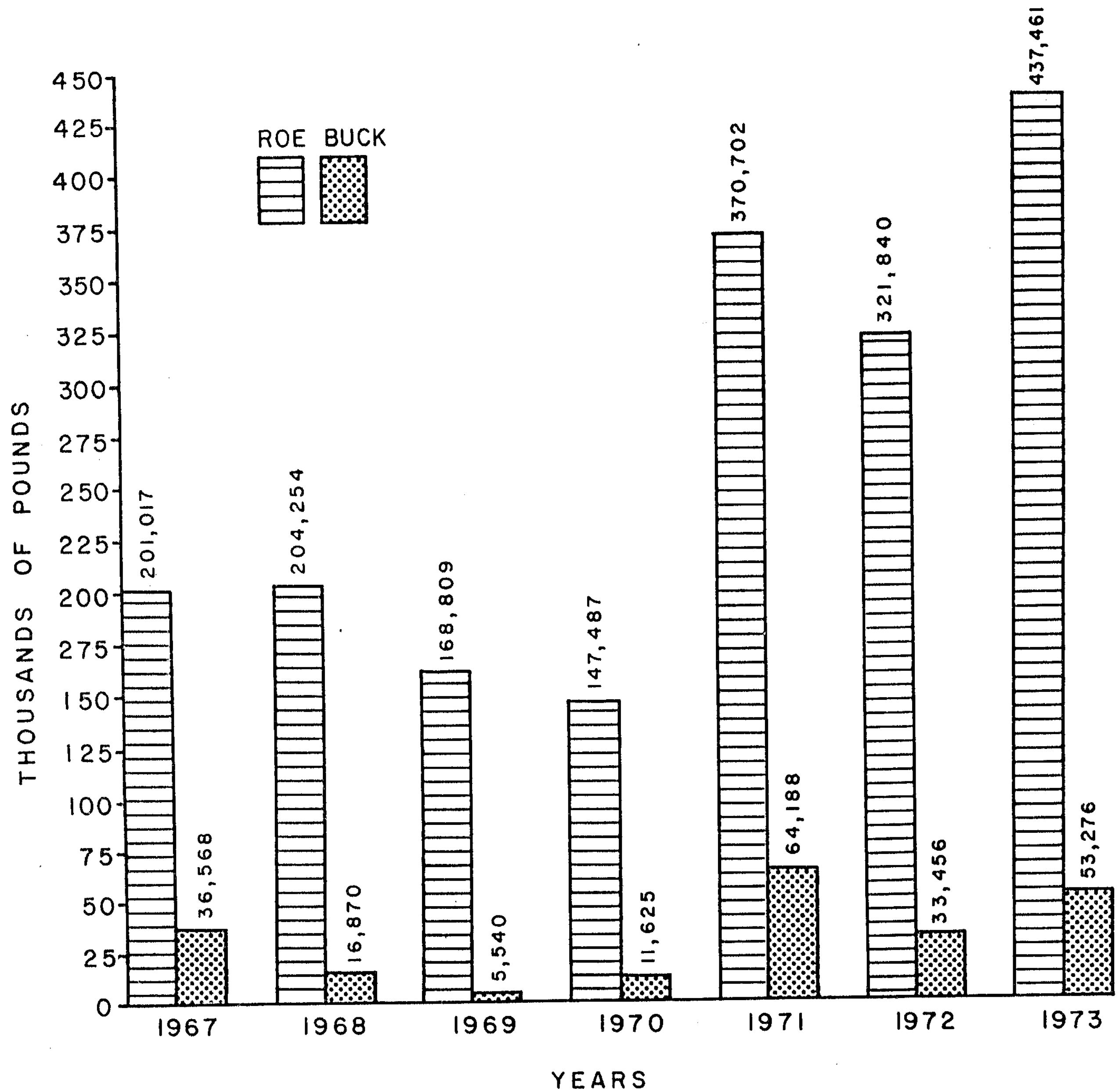


Fig. 1.10. Estimated catch of American and hickory shad by stake gill nets in the York River, Virginia, 1967 to 1973.

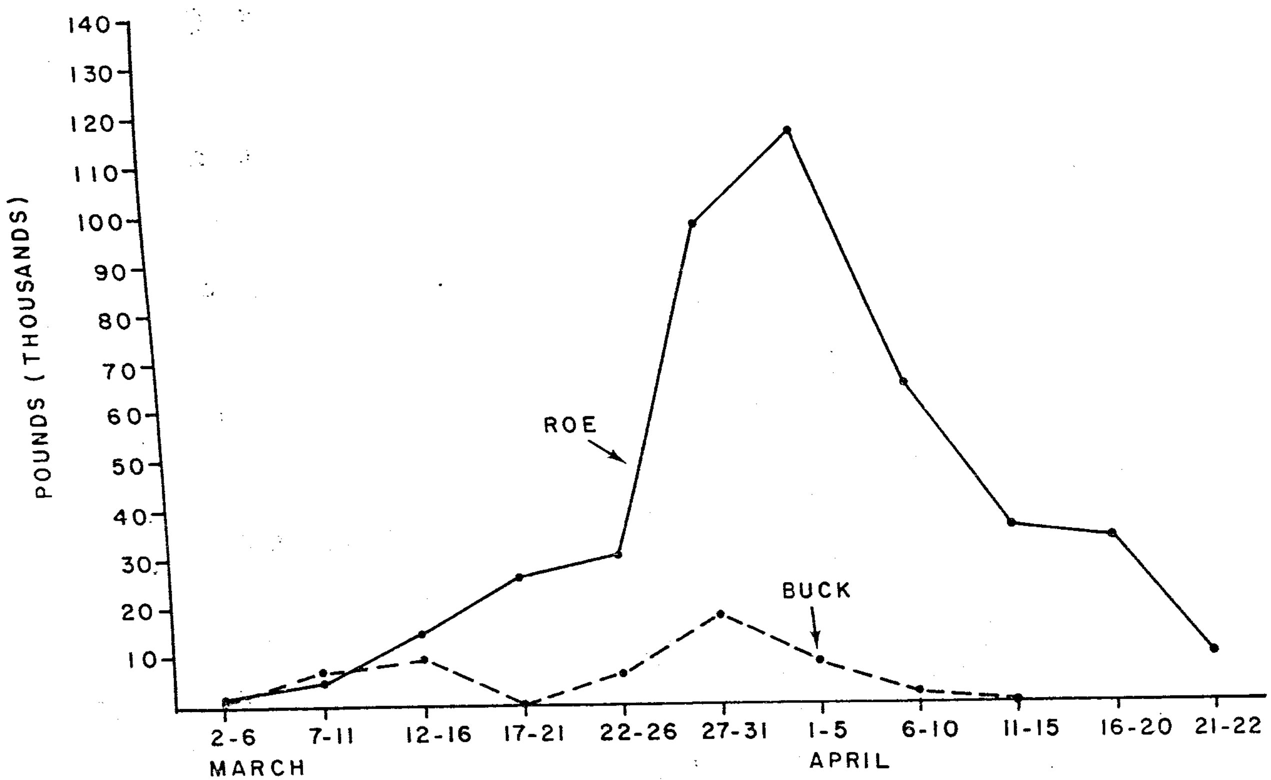


Fig. 1.11. Catch by stake gill nets in 1973 of American shad through the season in the York River, Virginia, summed into 5-day intervals.

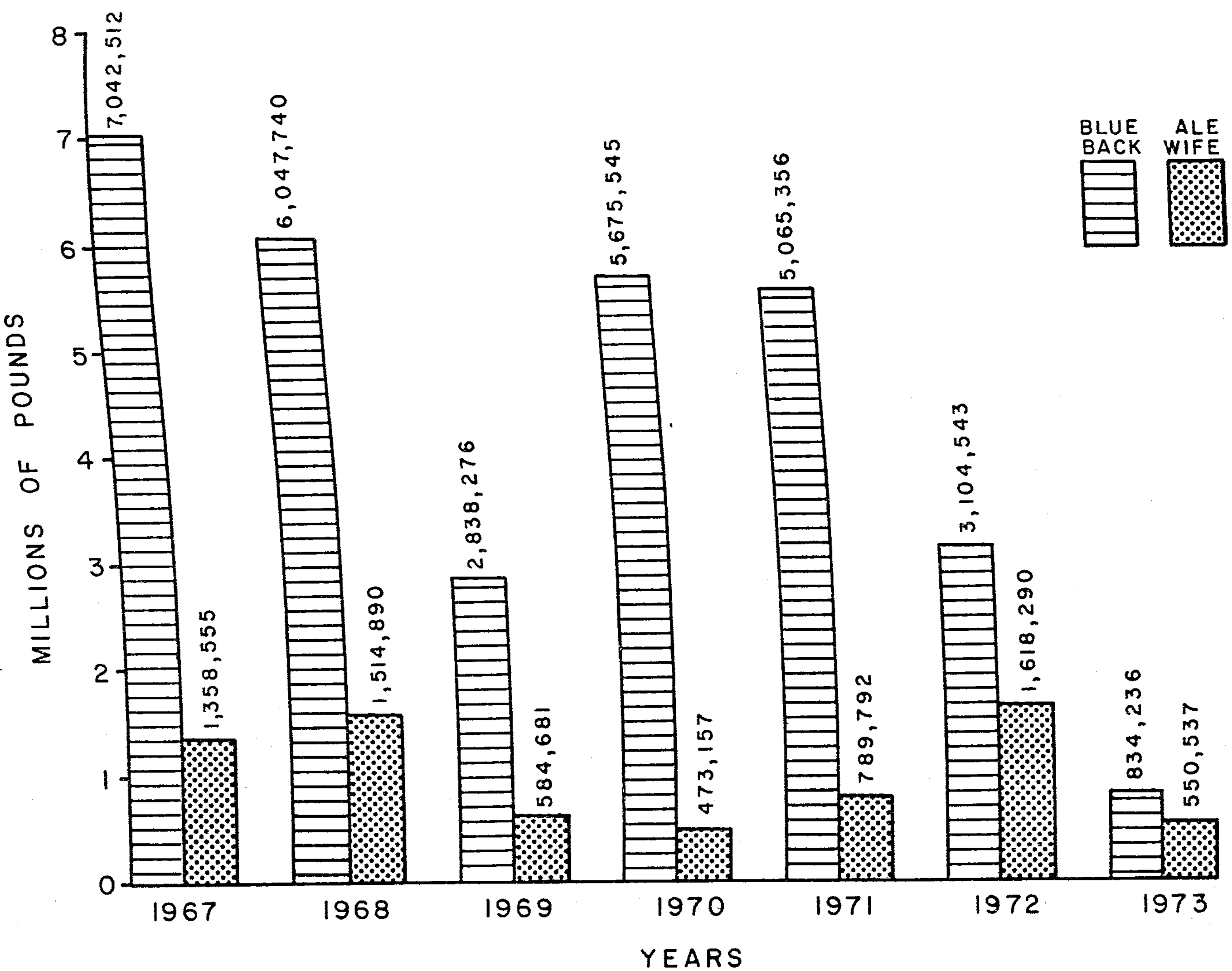


Fig. 1.12. Landings of river herring in the Potomac River, 1967 to 1973.

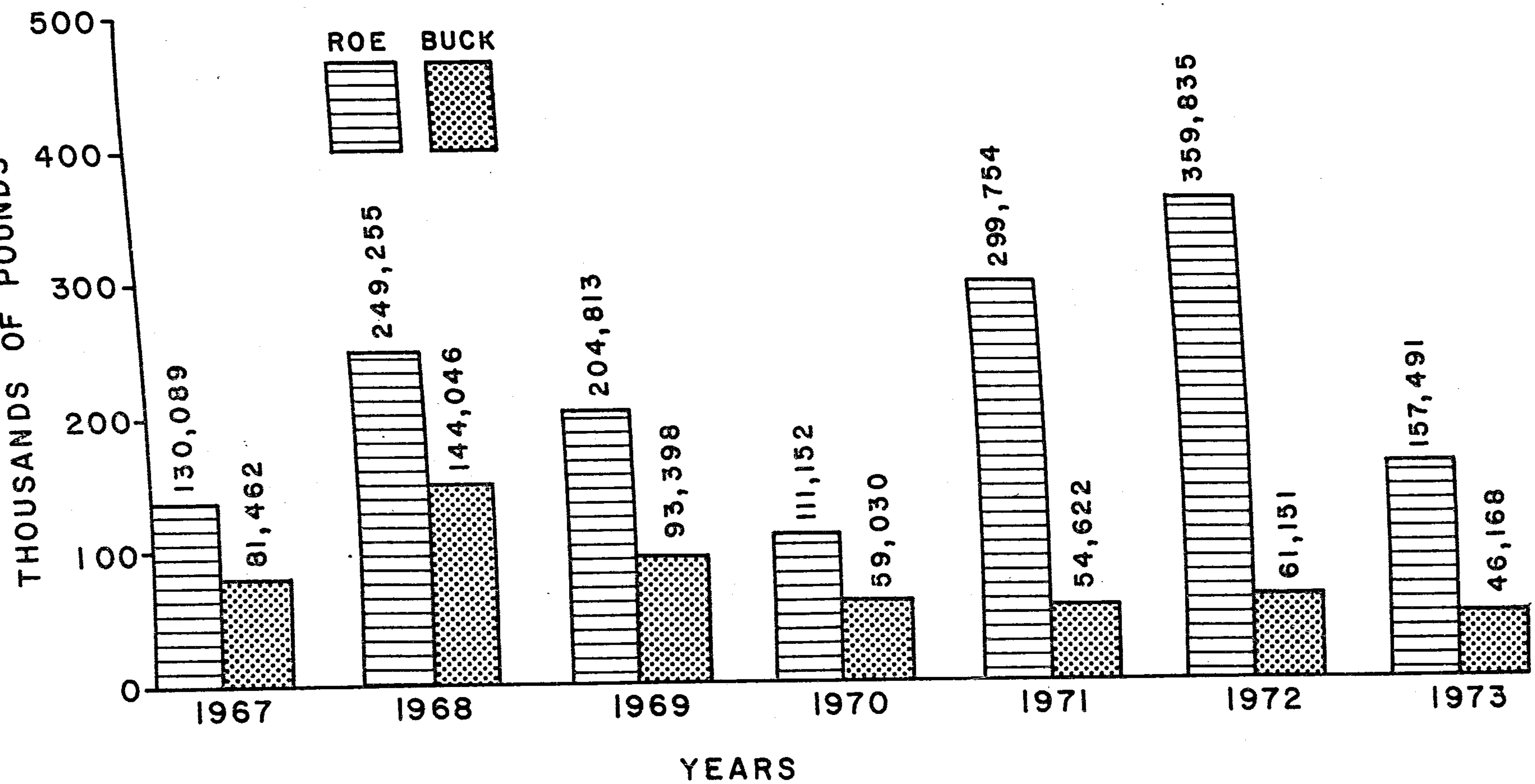


Fig. 1.13. Landings of American shad in the Potomac River, 1967 to 1973.

Table 1.1. Average number of pound nets by semimonthly period in Chesapeake Bay and Virginia tributaries, 1967 to 1973. 1st refers to the dates 1-15th, and 2nd to dates 16th to end of month.

Year	February		March		April		May		June		Total		Avg. No. of nets during peak period
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	
1967			122	234	295		314	332	302	156			
Avg. No			178		295		323		229		1,025		305
1968		22	99	186	269	309	317	293	196	92			
Avg. No.	22		142		289		305		144		902		313
1969		33	86	187	230	285	278	208		96			
Avg. No.	33		136		257		243		96		765		281
1970		10	56	133	163	213	238	215	170	91			
Avg. No.	10		94		188		226		130		648		226
1971		12	89	134	177	214	228		176	74			
Avg. No.	12		111		195		228		125		671		221
1972		22	84	117	157	210	224	198	178	113			
Avg. No.	22		100		183		211		145		661		217
1973		27	57	109	156	192	200	159	164	100			
Avg. No.	27		83		174		179		132		595		196

Table 1.2. Number of pound nets in Chesapeake Bay and tributaries, spring, 1973. Counted from low flying aircraft, only active nets included.

Area	Feb 17	Mar 2	Mar 15	Apr 3	Apr 19	May 4	May 17	Jun 5	Jun 21
James River	0	0	1	1	1	0	0	0	1
York River	2	3	3	7	6	7	6	6	6
Rappahannock River	6	27	43	50	52	51	38	25	6
Potomac River	0	2	11	30	45	47	29	39	11
Cape Henry to Willoughby Point	3	3	4	3	5	5	6	4	4
Old Point to Tue Marsh Point	1	1	4	5	6	4	4	5	5
Back River	0	2	5	5	5	5	5	5	5
Poquoson River	2	2	2	2	2	2	2	2	0
York Spit	0	0	0	2	3	3	1	2	5
Mobjack Bay	0	1	2	2	3	3	5	5	1
New Point to Stingray Point	2	4	8	16	21	20	18	22	18
Piankatank River	1	1	3	3	4	4	4	4	3
Windmill Point to Smith Point	8	9	21	25	31	30	17	21	14
Great Wicomico River	0	0	0	1	0	0	1	4	3
Easter Shore-N. of Hungar Creek	0	0	0	0	0	0	0	0	1
Eastern Shore-S. of Hungar Creek	2	2	2	4	7	19	23	20	17
Total	27	57	109	156	191	200	159	164	100

Table 1.3. Number of stake gill nets fished in Virginia river systems 1967-1973 and catch of roe shad per net per season, in pounds.

River system	1967	1968	1969	1970	1971	1972	1973
			Number of Nets				
York	90	86	94	71	109	96	130
James	NA	95	83	65	99	99	115
Rappahannock	NA	144	120	94	98	114	100
Total	90	325	297	230	306	309	345
			c/f/season				
York	2,234	2,375	1,796	2,077	3,401	3,353	3,365
James	NA	NA	17,289	24,912	17,358	16,997	9,383
Rappahannock	NA	964	1,340	1,410	3,528	596	365
Total	2,234	3,339	20,425	28,399	24,287	20.946	13,113
			Total Catch				
York	201,060	204,250	168,824	147,467	370,709	321,888	437,450
James	NA	NA	1,434,987	1,619,280	1,718,442	1,682,703	1,079,045
Rappahannock	NA	138,816	160,800	132,540	345,744	67,944	36,500
Total	201,060	85,175	6,066,225	6,531,770	7,431,822	6,472,314	4,523,985

NA - Not available

Table 1.4. Estimates of yield of American shad by 5-day intervals for the James River gill net fishery.

	1967	1968	1969	Roe 1970	1971	1972	1973	Average
Mar. 2-6			0	1,950	1,287	0	0	647
7-11			0	27,278	1,485	3,828	8,648	8,247
12-16			403	36,464	19,620	11,946	36,984	21,083
17-21			2,751	40,458	23,584	53,196	24,840	28,965
22-26			24,932	131,924	48,650	44,253	31,050	56,161
27-31			197,018	92,594	42,725	140,349	240,074	142,552
Apr. 1-5			321,000	107,043	143,825	259,743	367,908	239,903
6-10			251,712	130,390	207,300	235,884	182,206	201,498
11-15			206,701	233,720	329,375	398,013	40,480	241,657
16-20			200,250	166,198	383,800	293,007	97,014	228,053
21-25			120,865	271,987	206,150	155,760	42,458	159,444
26-30			109,296	254,122	157,800	67,947	3,358	117,104
May 1-5				125,190	152,800	18,744		59,346
			1,434,928	1,619,318	1,718,401	1,682,670	1,075,020	1,506,067
Buck								
Mar. 2-6			0	6,143	11,880	127,550	0	29,115
7-11			3,000	59,910	4,554	64,900	10,396	28,552
12-16			1,500	59,670	49,791	275,000	105,478	98,288
17-21			9,490	62,424	43,104	157,300	93,748	73,213
22-26			9,105	110,614	38,830	273,900	34,040	93,297
27-31			45,149	42,267	36,900	160,050	350,474	126,968
Apr. 1-5			58,558	0	58,000	154,000	241,500	102,411
6-10			0	16,250	0	79,200	0	19,090
11-15			7,222	0	0	27,500	0	6,944
16-20			0	0	0	1,650	0	330
21-25			0	0	0	0	0	0
26-30			0	0	0	0	0	0
May 1-5					0	0	0	0
			134,484	343,041	243,059	1,321,100	835,636	575,464
		Sex ratio	10.6/1	4.7/1	7.1/1	1.3/1	1.3/1	2.6/1

Table 1.5. Estimates of yield of American shad by 5-day intervals for the York River gill net fishery.

	1967	1968	1969	Roe 1970	1971	1972	1973	Average
Mar. 2-6	0	0	0	0	0	0	1,591	227
7-11	4,937	0	33	1,223	594	3,552	5,234	2,225
12-16	15,266	1,969	24	1,750	13,925	9,384	14,529	8,121
17-21	20,288	28,743	388	1,875	20,340	27,168	25,965	17,824
22-26	37,212	11,260	10,732	14,089	26,973	35,136	30,356	23,680
27-31	41,784	30,228	32,398	15,750	19,835	44.112	97,924	40,290
Apr. 1-5	30,524	41,277	47,330	16,600	63,261	52,200	116,807	52,571
6-10	23,752	47,657	41,864	35,925	124,929	31,752	65,260	53,019
11-15	18,576	30,963	26,932	44,625	71,820	63,096	36,076	41,726
16-20	8,678	12,157	7,280	12,500	29,025	42,600	33,741	20,854
21	0	0	1,828	3,150	0	11,760	9,978	3,817
	201,017	204,254	168,809	147,487	370,702	321,840	437,461	264,510
				Buck				
Mar. 2-6	4,065	0	0	0	0	0	1,106	739
7-11	7,608	0	66	1,125	0	3,648	6,468	2,702
12-16	7,879	1,914	54	2,125	20,385	7,944	9,491	7,113
17-21	8,220	4,136	423	1,875	5,508	20,520	0	5,812
22-26	6,696	2,506	4,464	6,500	6,145	1,344	5,981	4,805
27-31	2,100	1,694	533	0	7,996	0	18,071	4,342
Apr. 1-5	0	3,715	0	0	19,683	0	8,060	4,494
6-10	0	1,982	0	0	4,471	0	4,099	1,507
11-15	0	690	0	0	0	0	0	99
16-20	0	232	0	0	0	0	0	33
21-	0	0	0	0	0	0	0	0
	36,568	16,870	5,540	11,625	64,188	33,456	53,276	31,646
Sex Ratio	5.5/1	12.1/1	30.5/1	12.7/1	5.8/1	9.6/1	8.2/1	8.4/1

Table 1.6. Estimates of yield of American shad by 5-day intervals for the Rappahannock River gill net fishery.

	1967	1968	1969	1970	1971	1972	1973	Average
Roe								
Feb. 25-Mar. 1					1,766			294
Mar. 2-6		0	0	0	6,983	252	43	1,213
7-11		0	171	483	4,131	224	248	876
12-16		575	338	2,825	5,404	112	2,859	2,018
17-21		6,127	2,763	4,617	16,279	364	3,346	5,582
22-26		7,992	3,610	13,862	13,246	504	1,802	6,836
27-31		4,460	10,965	11,804	20,120	1,008	5,134	8,915
Apr. 1-5		12,874	29,246	16,485	37,237	1,008	4,862	16,952
6-10		22,389	45,356	32,596	83,139	3,640	2,946	31,677
11-15		26,925	40,749	20,777	97,209	11,760	3,446	33,477
16-20		37,270	18,615	21,194	35,022	15,288	7,822	22,531
21-25		15,415	8,634	7,501	17,440	18,228	3,990	11,868
26-30		4,752	402	400	7,769	13,412	0	4,456
Mar. 1-5						2,103		351
		138,764	160,849	132,544	345,745	67,903	36,508	147,052
Buck								
Feb. 25-Mar. 1					555	56		102
Mar. 2-6		0	0	0	4,472	448	0	820
7-11		0	286	1,046	4,170	1,232	415	1,192
12-16		533	622	4,698	5,642	980	3,547	2,670
17-21		2,925	2,558	7,765	11,610	2,968	2,846	5,112
22-26		4,208	2,882	14,145	7,923	1,736	1,430	5,387
27-31		2,520	5,360	11,450	7,581	3,584	4,091	5,764
Apr. 1-5		3,640	8,501	9,918	19,199	2,492	2,274	7,671
6-10		3,295	5,765	13,855	26,894	4,480	924	9,202
11-15		4,914	4,172	5,480	16,412	6,636	901	6,419
16-20		3,718	1,409	5,628	8,481	5,348	2,146	4,455
21-25		445	483	3,134	853	3,556	543	1,502
26-30		652	245	943	460	2,548	0	808
May 1-5						840		140
		26,850	32,273	78,062	114,252	36,904	19,122	51,243
Sex ratio		5.2/1	5.0/1	1.7/1	3.0/1	1.8/1	1.9/1	2.9/1

Table 1.7. Yearly c/f of the pound net fishery in the Rappahannock River, 1967-1973, in pounds/net/season.

Year	c/f Roe Shad	c/f Buck Shad	c/f Alewife	c/f Blueback	All Species Combined
1967	2,137	2,122	26,552	59,025	89,836
1968	2,439	3,517	24,463	7,968	38,387
1969	1,716	3,196	15,897	7,066	27,875
1970	490	647	7,120	2,005	10,262
1971	619	492	8,261	8,561	17,933
1972	511	258	8,174	5,456	14,399
1973	242	225	6,393	10,230	17,090

Table 1.8. Catch by pound nets (in pounds) in the Rappahannock River, 1973.[1]

			American Shad					
			Roe			Buck		
Date	Av. No. of Nets	No. Days Fished	Av. Catch Index Nets[2]	Estimated Total Catch	c/f	Av. Catch Index Nets[2]	Estimated Total Catch	c/f
March 5-15	21	9	2.6	491	23	13.6	2,570	122
March 16-31	35	8	5.9	1,652	47	12.6	3,528	101
April 1-15	37	7	27.3	7,071	191	10.4	2,694	73
April 16-31	37	8	10.3	3,049	82	8.9	2,634	71
May 1-15	35	6	1.6	336	10	1.3	273	8
May 16-25	27	7	-	-	-	-	-	-
Total				12,599			11,699	

[1] Only nets between RA-10 and RA-55 were sampled.

[2] Catch per day out.

Table 1.9. Total *Alosa* catch and catch-per-unit of effort by pound net (in pounds) by month in the Potomac River, 1973.[1]

	American Shad				
	March	April	May	June	Total
Catch					
Roe	2,919	117,856	36,459	221	157,455
Buck	3,104	28,256	14,297	511	46,168
Combined Total	6,023	146,112	50,756	732	203,623
Catch-per-unit of effort					
Roe	265	2,619	1,258	20	
Buck	282	628	493	46	

	Herring				
	March	April	May	June	Total
Catch					
Alewife	40,300	169,942	318,130	22,165	550,537
Blueback	40,297	568,936	136,341	88,662	843,236
Combined Total	80,597	738,878	454,471	110,827	1,384,773
Catch-per-unit of effort					
Alewife	3,664	3,776	10,970	2,015	
Blueback	3,663	12,643	4,701	8,060	

(1) Above mile 10 only

Job 2. Adult Population Parameters

A. A Test of Scale Sampling and Seasonality.

In previous years we have sampled fish caught by two fishermen (operating five to seven nets) in all rivers. In 1973 we began obtaining samples from three fishermen semimonthly in the Potomac and Rappahannock, and continued with two fishermen in the York, James and Chickahominy. We took 50 pounds of mixed catch from each fisherman to better determine the species ratios of alewife and blueback in the Potomac and Rappahannock. Fifty American shad and hickory shad were sampled concurrently.

From these fish, we took scales and common measurements from 50 of each species. From 1967 to 1970, we read 50 scales per species for each semimonthly period, but questioned the adequacy of this sample size. In 1971 and 1972 we took scales from an additional 50 fish in each sampling period. However the samples of 100 fish did not provide more precise information than did samples of 50.

As a test we separated the 1971 blueback collection into two groups of 50 each. These two groups were read independently by two persons, the readings combined into first or second group, and the two groups were compared over the entire season. The test fish were taken from Rappahannock pound nets from 15 April to 9 June 1971. The nine sampling periods should have produced 450 of each group, but some samples were unreadable so we obtained 443 first 50's, and 447 second 50's. Full data from the test readings are given in Tables 2.1 and 2.2.

The seasonal summary showed no difference between the first 50 scales read and the second 50 (Fig. 2.2). There was some variability within semimonthly periods (Fig. 2.1) but no trend was evident. The mean age from the first 50 was 4.742 years, and the second 50, 4.747 years. The assumption that 50 fish were drawn randomly from a large sample of blueback, was thus nearly perfectly met. From this we concluded there was no need to gather 100 scale samples, and discontinued the procedure during the 1973 sampling season.

The sex ratio changed seasonally in 1971. The first third of the run had equal numbers of males and females, the second third had slightly more females, and the last third had distinctly more males (Table 2.2). The overall sex ratio was 1.22 ♂ to 1.0 ♀.

The age structure did not change seasonally. Age V's were dominant throughout for both males and females.

For age composition analysis, two large samples taken anytime during the run would serve as well as the nine samples of 50 (or 100) taken throughout the season. For estimates of sex ratios, and species composition, the entire run needs to be sampled.

We believe the 1971 run was normal (Fig. 1.5) and reflects the general condition. Alewife and shad may display greater variability within sampling period, or even some seasonality of age composition and sex ratio. We will test these species this year.

B. Estimates of the Commercial Landings by Two Sampling Programs.

The *Alosa* project has as one of its objectives, the estimation of the pounds and number landed, by river, of the three primary species (blueback, alewife and shad). These data are gathered semimonthly from the start of each season by taking samples of the commercial catch, and used with aerial net counts and log books placed with cooperating fishermen. These are used to generate numbers in the run by age and total pounds landed within the spawning river. We sample from mile 15 upward in each river because we want fish that have selected their river of spawning.

In 1971 the National Marine Fisheries Service began a program of sampling the alosids (and other groups) by dockside sampling of landings from the lower Potomac River, the Chesapeake Bay and the lower Rappahannock River.

The Potomac, Chesapeake Bay near Reedville, and the Rappahannock account for practically all of the commercial catch of alewife and blue-back in Virginia. If the NMFS sampling program of 1971-1973[(1)] reflected the run of these two species, and the program covered the entire run, then the ratio between alewife and blueback should be approximately the same as our data combined for the two rivers.

The ratios were very dissimilar (Table 2.3). In 1971 the NMFS ratio of alewife to blueback was 0.0812, and VIMS was 0.2212; in 1972 the ratios were 0.8174 and 0.6059, and in 1973 they were 0.2150 and 0.6463. The NMFS program began in late April 1971 and continued through May. This was well after the main alewife run and could account for the disparity. In 1972 and 1973 the NMFS sampled from February through early June, but the ratio was close only in 1972. In 1973 the Potomac had an early run of alewife but the fishermen in the lower river did not fish. The NMFS report for 1973 shows one Potomac sampling location and landings of 539 MT of blue-back and only 87 MT of alewife. Because the run was small overall the fishery only operated for about 3 weeks. Similarly, another Potomac landing point showed 126 MT of blueback and only 21 MT of alewife.

(1) An appraisal of the 1971 Chesapeake Bay herring fishery, by M. L. Parrack, NMFS, Woods Hole, Mass. 18 pp (unpublished MS).

NMFS samples from the lower Rappahannock showed landings of 734 MT of blueback compared to 263 MT of alewife in 1973. In 1972 the catch at the same landing was 460 MT of blueback and 1,086 MT of alewife. For the years 1972 and 1973 the NMFS sampling program and VIMS detected the same reverse dominance in the Rappahannock. The ratio between alewife to blueback in 1972 was: 1.498 (VIMS) and 2.31 (NMFS) and for 1973; 0.625 (VIMS) and 0.358 (NMFS).

Of the fishermen that have nets above mile 15 in the Potomac and Rappahannock, some land their fish at plants that NMFS sampled. Thus the two sets of estimates are not entirely distinct and the total run cannot be pooled from the two. Our objective is to determine the species composition and landings of the spawning run in each river; whereas the NMFS program determined the species composition and the total landings for the state. The NMFS program provided valuable data to help complete the analysis of river herring in Virginia, but we cannot use it to determine spawning run composition by river, such as in Table 1.5 and 1.7 (Job 1). The ratio between alewife and blueback is apparently very different in the lower rivers and bay proper, compared to their ratios in the spawning river. Furthermore American and hickory shad were not detailed in the NMFS program, so we must rely exclusively on our sampling program for these species.

C. Mortality Rates.

Our program uses samples of the commercial catch to determine age structure and spawning history. From measurements of weight, log book information, and species ratios we can estimate mortality rates by spawning class and between years by deriving c/f estimates by age. Alewife and blueback are combined into a single group called river herring because

NMFS does not separate the species in their landing statistics, nor does the offshore fleet. We further combine the catches from the Potomac and Rappahannock rivers because the vast majority are captured there.

The virgin spawners typically make up approximately 55-70% of the entire catch (Table 2.4). The c/f estimates of this group are followed each year as the fish spawn in successive years, yielding annual mortality estimates (a) by spawning group (Table 2.5). The average c/f for the 0 spawning group (virgins) has dropped considerably since 1965-1968 and in 1973 it was only 27.6, the lowest on record. The highest was an average of 122.9 fish per net in 1967 and in 1965 the index was 122.5. Since 1970, no year had an index greater than 37.0.

The calculated mortality rates between first spawning and the second increased steadily from 1965 to 1968, rising from 54.1% to 80.3%. In 1969 the annual mortality as measured by our statistics, dropped to 53.7% and rose again from 75-85% per year from 1970 to 1972 (Table 2.5). The mortality rates are calculated from the ratio of the c/f's for ones/zeros, twos/ones, etc. The low 1969 value is attributed to low abundance of the virgins returning to spawn, because their c/f was well below 1968 and 1970 virgins. The 1968 spawning class had an index of only 18.9 in 1969 compared to fish of spawning class I of 29.5 in 1968 and 28.4 in 1970 (Table 2.4). The 1967 spawning class, at its third spawning in 1969, had an index of 7.5 compared to the third spawning of the 1966 class of 20.7 and the third spawning of the 1968 class of 16.4.

These figures show quite conclusively that 1969 was a poor year not because of year class failure, but because the three dominant spawning classes experienced heavy mortality before the 1969 spawning run. The Virginia catch, and c/f by spawning class in 1969 was below normal

(Table 2.4). We believe the heavy mortality was directly due to the 24 million pounds captured by the foreign fleet in spring of 1969 (Table 2.6). The year before (1968) the foreign fleet (in ICNAF Subarea 6) took only 2.6 million pounds. In 1970 the fleet took 14.8 million pounds, and in 1971, 20.8 million pounds.

The mortality of 53.7% for Age 0 fish between 1969 and 1970 does not provide any clues by itself, and after 1969 the mortality rates merely indicate the differences between years of a depressed population. The mortality rates calculated from the spawning run fish show their decrease in numbers only after the age of 4 or 5 (first spawning). If these fish are exploited heavily at sea before first spawning, the mortality rates could stabilize at relatively moderate levels from age 50 to 9 and the population could continue to be low. For example, if prerecruits experience a higher fishing mortality at sea (before first spawning) than the adult fish after first spawning, the age 5-9 mortality rate could even drop to 30-50% per year and the populations still be under too heavy exploitation.

In 1971 the USSR agreed to limit its catch of river herring in ICNAF subarea 6, to 3,000 MT (6.6 million pounds). However, East Germany took 5,794 MT (12.8 million pounds) in 1971. The foreign fleet usually fishes between Cape Hatteras and Delaware Bay during February and March. Their catches could contain significant quantities of river herring migrating toward the spawning grounds in Chesapeake Bay. The foreign fleet usually moves northeast as sea temperatures rise, reaching Georges Bank in June. The migratory pattern of river herring is not well known at sea, however we know they move NE after spawning in Chesapeake Bay. Thus the mature adults could experience prespawning ocean fishing mortality; and the prerecruits and post spawning adults could be continually fished to some extent because of their migratory behavior.

We have no information on age structure of river herring captured by the foreign fleet. The Soviet Union has agreed to provide scientific information to American researchers, but to date these data has not been received. It would be important to know, for example, the frequency distribution by age of the 2,000 MT captured in 1971 and 1972 by the Soviets; or perhaps the time versus catch composition during the fleet migration to the NE. If distinct stocks of river herring exist at sea, these may mingle before migration or run separately to particular spawning grounds. It seems most probable that the foreign fleet catches would typically be dominated by mature adults destined to spawn in Virginia, and prerecruits that would spawn within the next two years in Virginia.

The mortality rate increased steadily from 1965 to 1969, fell to 39.7% between 1969 and 1970, then rose to 87.1% between 1970 and 1971. From 1971 to 1972 the mortality dropped from 87.1% to 68.9%. The low 1969-1970 value (Table 2.5) to 39.7% was partially due to the presence of a strong year class appearing as 0 group fish in 1970, after the poor year of return in 1969. These fish were heavily exploited before the next spawning (86.5%), but still gave a c/f index of 14.8 as group I in 1971, and a c/f of 4 as group II in 1972 (Table 2.4).

The Virginia fishery has not increased or decreased efficiency to bias the c/f values, and we suspect the same proportion escapes during both low and high abundance. In theory the total effort of the spring fishery has declined, however (Table 2.4). The pattern of a (or M) and changing c/f could be due to reproductive failure but evidence presented in Job 3 does not support this. The increase in foreign fleet catch parallels the change in population patterns described here and below, and the timing of of the abrupt changes in c/f spawning group implicates the foreign fleet further as contributing to an overexploited fishery.

The inverse relationship between Virginia landings and foreign fleet landings (Fig. 2.6) from 1968 to 1972 further suggests a direct negative effect on Virginia fishermen due to offshore fishing. Section D (follows) explores this in greater detail.

D. Changes in Population Parameters of Fish in the Commercial Fishery 1966-1973.

An unfished stock has a collection of population parameters that reflect the stability of the stock. These measures include the average length, average weight, average age, and the age composition. Under exploitation these parameters change and such change can often be used to determine mortality rates and rate of exploitation (Ricker, 1958). The most typical changes are for average length, weight and age to decrease. With the increase in foreign catch all of these parameters shifted abruptly downward.

Between the point of no fishing and too much fishing, there are an infinite number of equilibria between fishing effort and stock size, one of which is the maximum sustained yield. At MSY the stock is merely at one level in its equilibrium recruitment potential. Thus by following the population parameters, clues to the MSY relationship can often be determined exclusive of the yield models of Beverton and Holt (1957), Ricker (1958) or Schaeffer (1968).

We have summarized the data bank for alewife, blueback, and American shad from 1967 to 1973 to detect changes in the basic stock parameters of the spawning runs. These data are detailed in Tables 2.7-2.10. Except for a one-third reduction in effort, there has been no change in the commercial fishery for the clupeids in Virginia or in the Potomac River. The alewife, blueback and shad are fully vulnerable to the gear from their first spawning run onward and there are no size limits.

1. Change in length. The average length of alewife and blueback in the Potomac River fell sharply from 1968 to the 1969 spawning run (Fig. 2.3). Blueback continued to fall in 1970. From 1970 through 1973 both species

regained their pre-1969 length; however alewife fell sharply between 1972 and 1973. Rappahannock River fish did not show the pronounced 1969 decline. Alewife average length rose steadily after 1969, reaching a peak of 256 mm in 1972. Blueback fell steadily from 1966 to 1971; rose sharply in 1972, then leveled off (Fig. 2.4).

The Potomac River since 1965, has yielded 2-9 times as many river herring as the Rappahannock River and thus represents better the conditions of the entire stock at sea. We have postulated earlier (Davis et al., 1973) that the river herring stock, as a whole, was not overexploited because domestic plus foreign landings have remained near previous levels. This view was apparently incorrect because with 1972 and 1973 data, and the analysis of population parameters in this report; it now appears the river herring were over-exploited from 1969 to 1971. The foreign fleet took huge quantities in 1969 and 1970 and this increased effort offshore reduced the availability of fish inshore. The change in average length in the Potomac River clearly marks this offshore (prespawning) take. From 10,950 MT in 1969 the foreign catch (in ICNAF subarea 6) dropped to 4,972 MT in 1972 (Table 2.6). This decreased fishing pressure enabled the stocks to re-build themselves and average length returned to former levels.

2. Change in weight. The decrease in average fish length in the Virginia commercial catch was not compensated by an adjustment in average weight for the years of heavy offshore exploitation. In 1969 the average alewife weight dropped to 184 from 229 g in 1968. Blueback weight fell from 205 g in 1968 to 175 g in 1969 (Fig. 2.5). After 1969, the average weight of both species climbed back to pre-1969 levels. The foreign fleet captures prespawning river herring between January and April when they are congre-gated off the Virginia coast. Thus we would not expect any growth compen-sation in the short interval before they arrive in Virginia.

The decline in average length and weight and subsequent return to normal with less fishing is an important feature in understanding the stock potential of river herring. If the combined fishery had not taken fewer fish in the period 1970-1973, each year would have been made up of a greater proportion of small fish. This certainly would have compounded the problem and led to a distinct case of fishing beyond MSY.

3. Change in age composition. A commercial fishery which captures all ages proportionate to their abundance would reflect little change in age composition at various stock equilibria provided recruitment remains fairly stable. A sudden increase in exploitation usually increases the mortality of the older age groups the most. The sudden decrease in average length and weight does not appear the result of lower recruitment, but rather the elimination of the older age groups. Age VII alewife were always present before 1969 but none were in our sample of the 1969 Virginia spawning run (Table 2.8). Age VIII blueback similarly had always been present, but were absent in 1969. From 1970 to 1973 these age groups were again present.

4. Change in sex ratio. No trend or sudden change in sex ratio was evident in the Virginia commercial catch 1966-1973 (Tables 2.8 and 2.10). Even in 1969, the offshore fishery apparently took equal proportions of males and females. The spawning potential, from this aspect, did not contribute to the long-term decline in Virginia landings.

5. Summary of parameter analysis. The analysis of key population parameters has involved many thousands of man-hours collecting scales, reading them, and summarizing the data. We have presented the entire data bank for the project, since 1966, to gain insight into the major events. Of great importance has been the arrival of the foreign fleet and its impact on the coastal fisheries, and have therefore, presented full details available from our program.

For alewife and blueback (river herring) there has been a pronounced stock-wide effect that can be directly related to increased exploitation by foreign nationals. What was formerly being cropped by domestic fishermen, was taken by the foreign fleet before these fish returned to spawn in the Chesapeake Bay tributaries.

More seriously, however, the stock apparently was fished beyond maximum sustained yield in 1969 and 1970. This resulted in an immediate change in population parameters and required three to four years to return to normal. The Virginia landings have not returned to normal though. We suspect that 1969 was the breaking point. From the 50% adult abundance in 1969, the year class strength was probably affected. The majority of these fish would first return in 1973. But 1973 produced very low yields in Virginia even though the basic population parameters of the adult stock now appears identical to 1966-1968 (Fig. 2.6).

Average length and weight has now returned to "normal" levels yet 1972 and 1973 were years of low yield in Virginia. If the age structure were still depressed, the only explanation would be increased growth rate compensatory to lower stock density. However, the age structure has also returned to normal (Table 2.8 and 2.10) with equivalent sizes at age. Therefore while some growth compensation is not entirely ruled out, we believe the stock is presently stabilizing at a much lower abundance. Fishing mortality probably operates proportional to all age groups in Virginia, whereas offshore it is probably greatest on the prerecruits. Samples of fish from the Virginia catch could continue to show a stable age structure, but the absolute abundance may remain low as the stock "rebuilds."

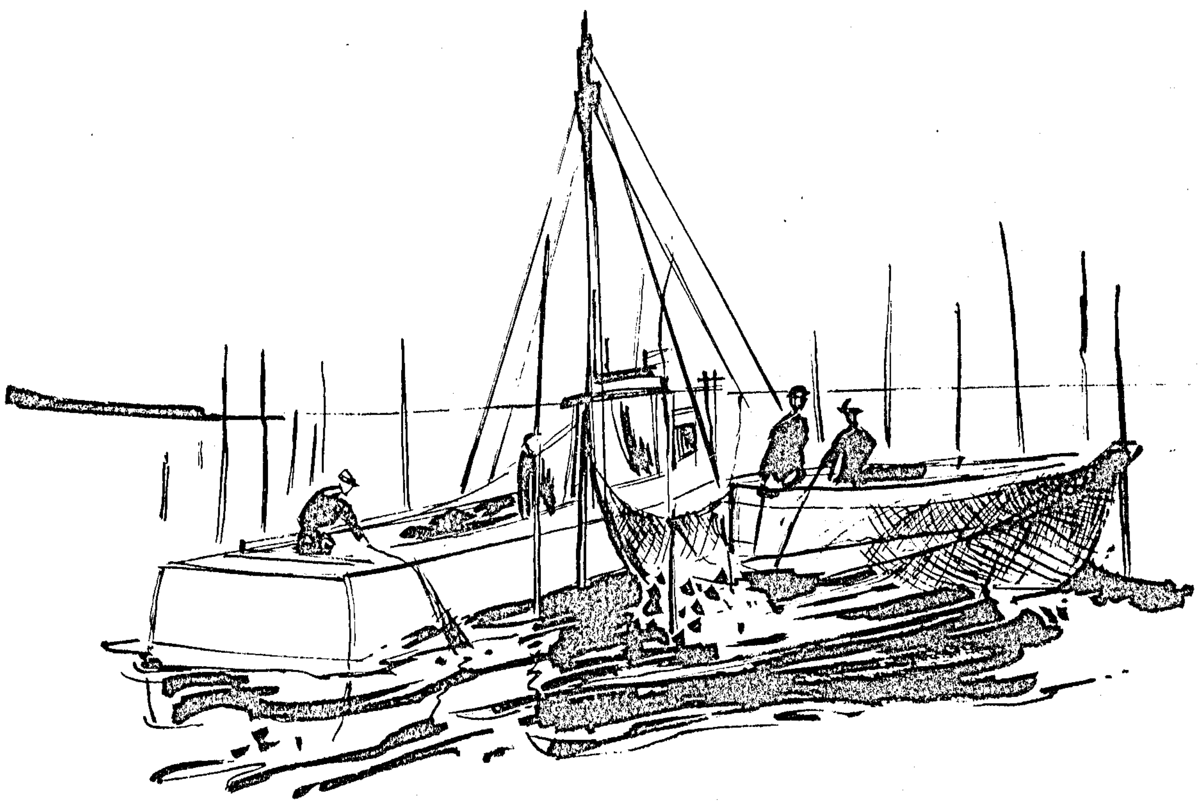
Year class strength fell from 1970 to 1972, but a good year class was produced in 1973 (see Job 3 this report). This may herald a return to previous population levels if these fish are not exploited heavily at sea.

The total river herring catch (U.S. and foreign) in 1972 was 15,120 MT, the lowest on record (Table 2.6). Virginia and North Carolina landings in 1973 fell 30% from 1972. The 1966-1971 USA catch averaged 22,770 MT, whereas the total catch 1966-1971 averaged 24,552 MT. Our population data and c/f estimates show both species were overexploited in 1969 but subsequent years showed a return to former levels of length and weight. The 35,302 MT taken in 1969 (all landings) hurt the fishery in all categories. This take apparently exceeded the MSY for river herring. In 1970, 1971 and 1972 the take of 21.5, 21.2 and 15.1 MT allowed the stock some rebuilding time.

We can, therefore, predict with some confidence that the MSY of river herring, under present environmental conditions, is between 23 and 28 MT per year. Landings above this (during normal recruitment) will force the stock down and landings below this will allow rebuilding. Exceptional year classes will always allow greater take, and poor year classes will yield less.

Of major concern to the domestic fishermen is who will take the fish. The foreign fleet, since 1969, has taken 31 to 44% of the entire river herring catch. Even the low foreign catch of 4.972 MT in 1972 represented 33% of the total landings. Thus the proportion of the landings taken by foreign national has not changed since 1969 (Table 2.6).

To support an MSY of 23-28 MT the total stock must be stable at 57 to 70 MT, if we use a conservative annual mortality of 60%. With greater knowledge of recruitment and how it, in turn, depends on year class strength, we should soon be able to estimate stock size a year in advance. By do doing we can then estimate the maximum landings that could be taken without damaging the stock. This could lead to some quota system and insure maximum landings through time.



Literature Cited

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest. Series II, Vol XIX. Min. of Agric. Fish and Food. London. 533 pp.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. No. 119. Fish. Res. Bd. Canada. Ottawa, Ontario. 300 pp.

Schaeffer, M. B. 1968. Methods of estimating effects of fishing on fish populations. Trans. Amer. Fish. Soc. 97(3):231-241.

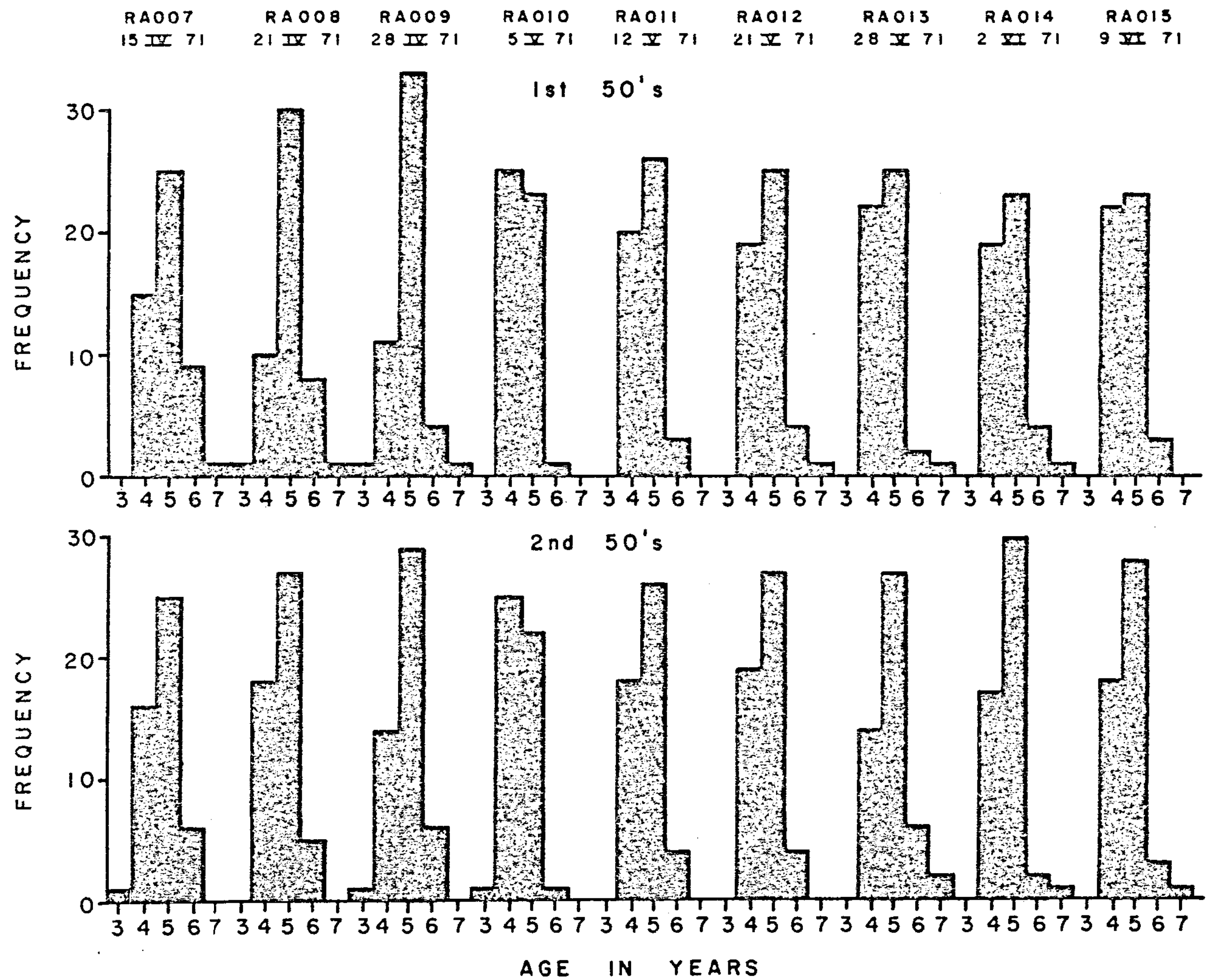


Fig. 2.1 Age frequency histograms for the 1st 50 and 2nd 50 scale samples for blueback herring, 1971, Rappahannock River.

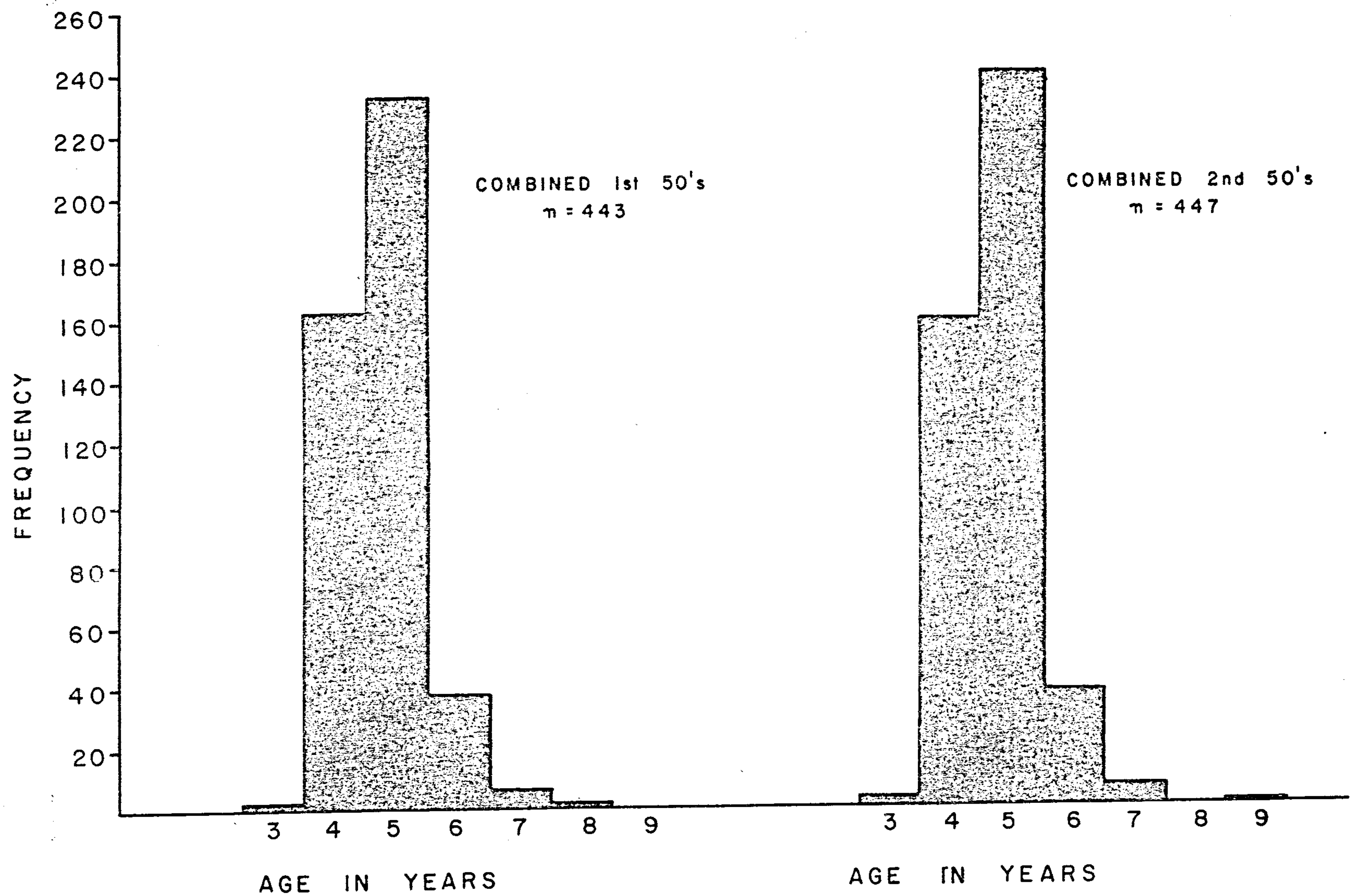


Fig. 2.2. Combined data from Fig. 2.1 to show overall similarity of samples when summed across season. Blueback herring, 1971, Rappahannock River.

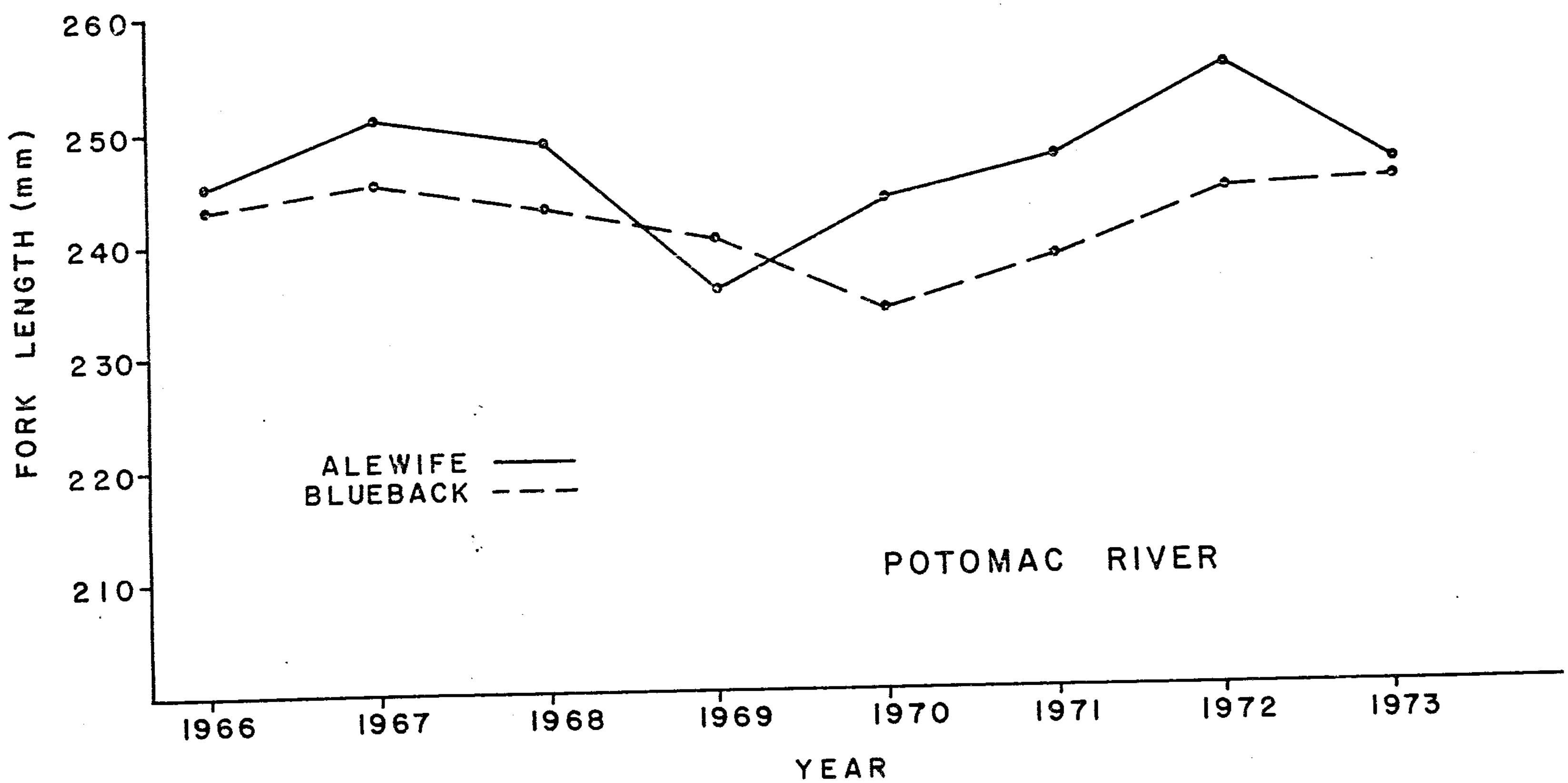


Fig. 2.3. Seasonal average fork length of sexes combined for alewife and blueback herring in the landings from the Potomac River, 1966 to 1973.

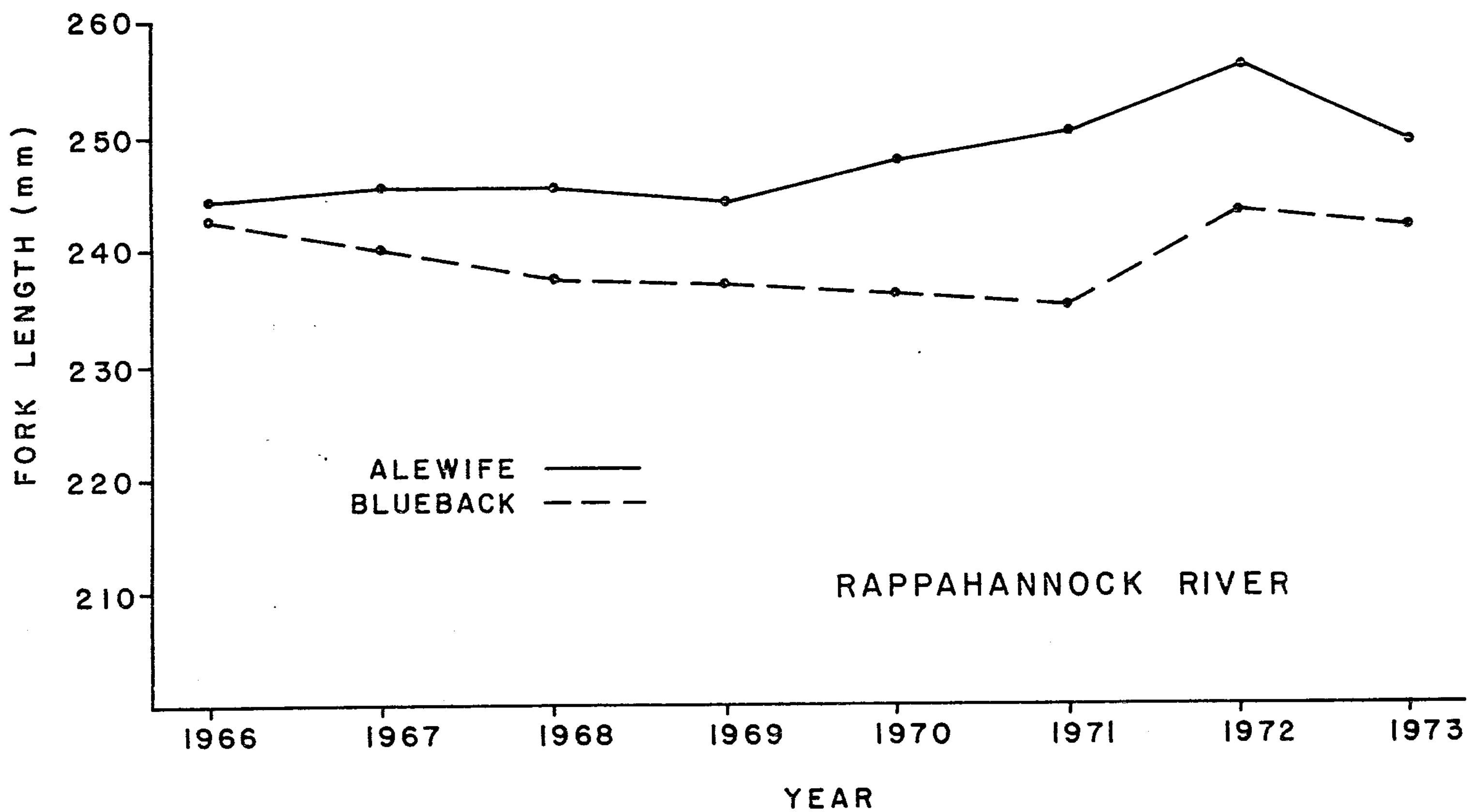


Fig. 2.4. Seasonal average fork length for sexes combined for alewife and blueback herring in landing from the Rappahannock River, 1966 to 1967.

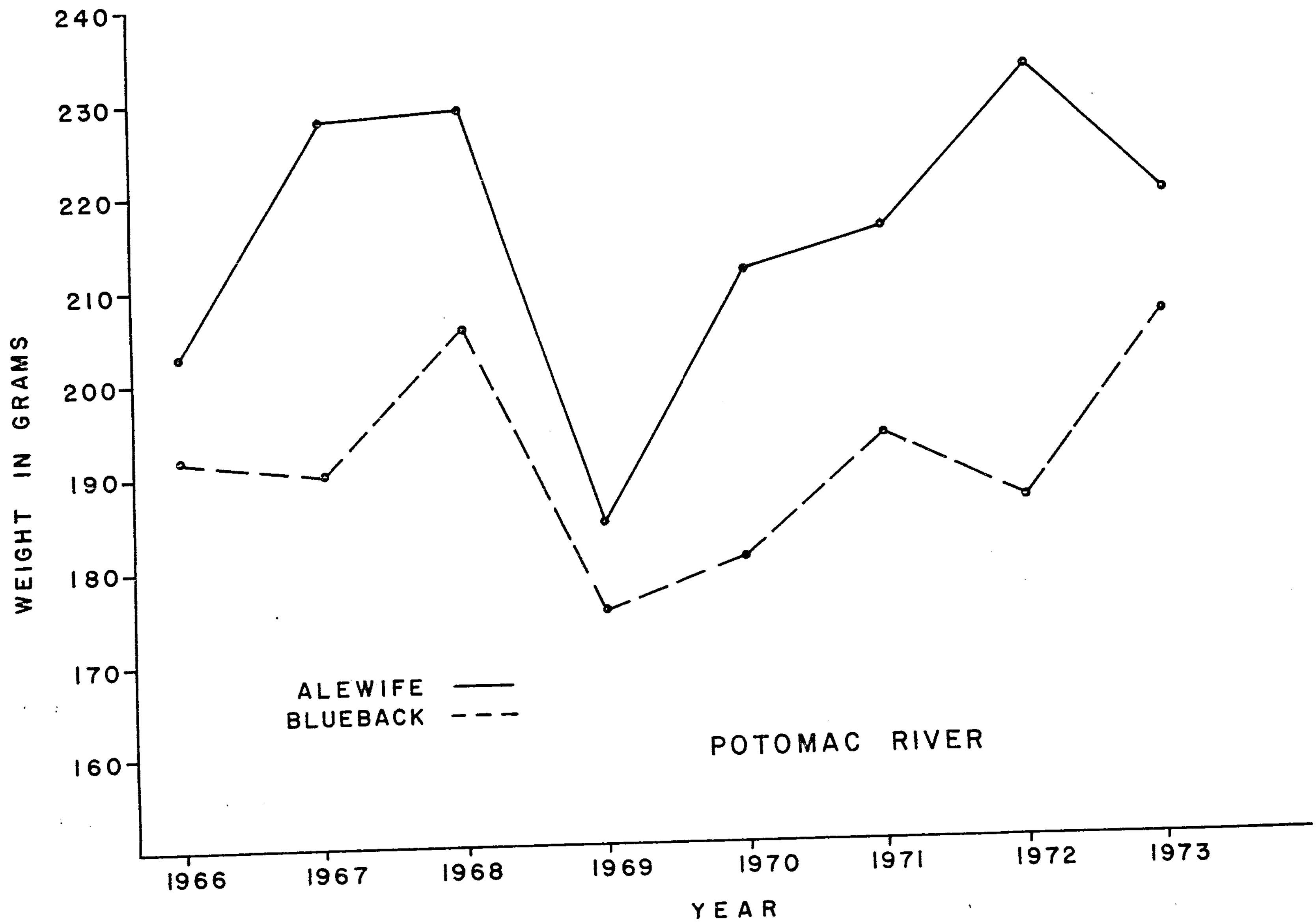


Fig. 2.5. Average weight using combined data for season and sex, for alewife and blueback in landings from the Potomac River, 1966 to 1973.

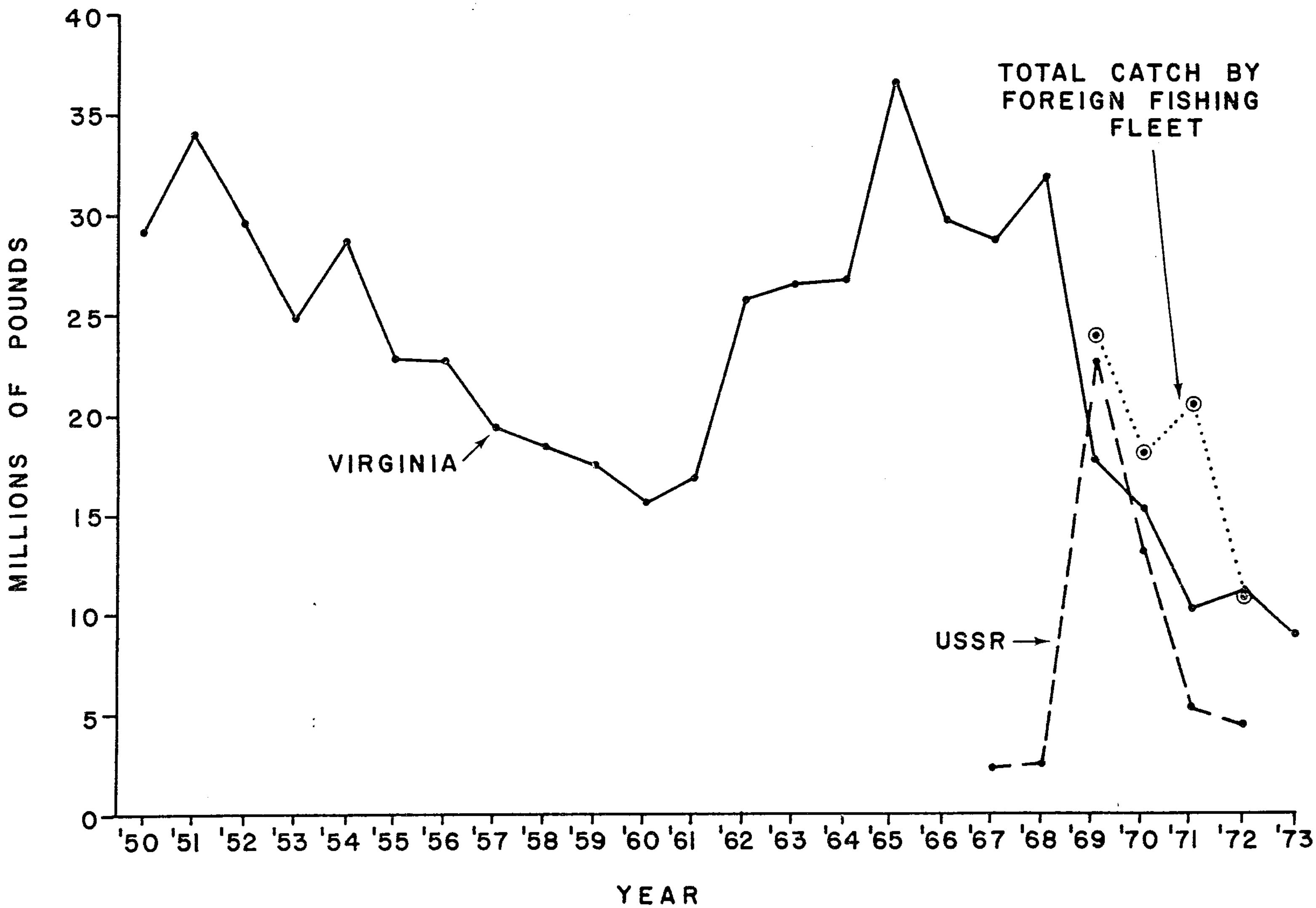


Fig. 2.6. Landings of river herring (alewife and blueback combined) in Virginia from lower Chesapeake Bay and tributaries; and total foreign fleet catch and USSR catch of same in the Middle Atlantic Bight.

Table 2.1. Summary of age distributions and spawn check distributions of blueback from the Rappahannock River - 1971.

Coll.#		Age Group							No. Spawn Checks					
Date		3	4	5	6	7	8	9	0	1	2	3	4	n
RA007	1st 50	0	15	25	9	1	0	0	25	17	7	1	0	50
15 IV 71	2nd 50	1	16	25	6	2	0	0	25	16	8	1	0	50
RA008	1st 50	1	10	30	8	1	0	0	18	24	7	1	0	50
21 IV 71	2nd 50	0	18	27	5	0	0	0	26	20	4	0	0	50
RA009	1st 50	1	11	33	4	1	0	0	24	19	6	1	0	50
28 IV 71	2nd 50	1	14	29	6	0	0	0	23	21	6	0	0	50
RA010	1st 50	0	25	23	1	0	0	0	33	15	1	0	0	49
5 V 71	2nd 50	1	25	22	1	0	0	0	33	15	0	1	0	49
RA011	1st 50	0	20	26	3	0	0	0	36	10	3	0	0	49
12 V 71	2nd 50	0	18	26	4	0	0	0	29	16	3	0	0	48
RA012	1st 50	0	19	25	4	1	0	0	26	17	5	1	0	49
21 V 71	2nd 50	0	19	27	4	0	0	0	24	21	5	0	0	50
RA013	1st 50	0	22	25	2	1	0	0	29	18	3	0	0	50
28 V 71	2nd 50	0	14	27	6	2	0	1	27	15	6	1	1	50
RA014	1st 50	0	19	23	4	1	1	0	25	16	5	1	1	48
2 VI 71	2nd 50	0	17	30	2	1	0	0	29	18	3	0	0	50
RA015	1st 50	0	22	23	3	0	0	0	25	21	2	0	0	48
9 VI 71	2nd 50	0	18	28	3	1	0	0	28	19	2	1	0	50
Grand Totals		5	323	473	75	12	1	1	485	318	76	9	2	443
														447
Totals	1st 50's	2	163	233	38	6	1	0	241	157	39	5	1	
	2nd 50's	3	160	240	37	6	0	1	244	161	37	4	1	
														890
	Mean Age (1st 50's) = 4.742							%	54.5	35.7	8.5	1.0	0.3	
	Mean Age (2nd 50's) = 4.747													

Table 2.2. Age composition by sex for 890 blueback, Rappahannock River - 1971.

		Age Group 3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	7 M	7 F	Sample Ratio By Sex M	F
RA007 15 IV 71	1st	0	0	11	4	13	12	4	5	0	1		
	2nd	1	0	8	8	13	12	1	5	1	1		
	Total	1	0	19	12	26	24	5	10	1	2	52	48
RA008 21 IV 71	1st	0	1	8	2	14	16	4	4	0	1		
	2nd	0	0	11	7	10	17	3	2	0	0		
	Total	0	1	19	9	24	33	7	6	0	1	50	50
RA009 28 IV 71	1st	1	0	5	6	15	18	3	1	0	1		
	2nd	1	0	7	7	18	11	1	5	0	0		
	Total	2	0	12	13	33	29	4	6	0	1	51	49
RA010 5 V 71	1st	0	0	10	15	7	16	1	0	0	0		
	2nd	1	0	16	9	12	10	1	0	0	0		
	Total	1	0	26	24	19	26	2	0	0	0	48	50
RA011 12 V 71	1st	0	0	10	10	11	15	0	3	0	0		
	2nd	0	0	5	13	14	12	2	2	0	0		
	Total	0	0	15	23	25	27	2	5	0	0	42	55
RA012 21 V 71	1st	0	0	12	7	8	17	1	3	0	1		
	2nd	0	0	12	7	7	20	1	3	0	0		
	Total	0	0	24	14	15	37	2	6	0	1	41	58
RA013[(a)] 28 V 71	1st	0	0	13	9	20	5	0	2	0	1		
	2nd	0	0	12	2	20	7	3	3	0	2		
	Total	0	0	25	11	40	12	3	5	0	3	68	32
RA014[(b)] 2 VI 71	1st	0	0	14	5	15	8	2	2	0	1		
	2nd	0	0	12	5	24	6	1	1	0	1		
	Total	0	0	26	10	39	14	3	3	0	2	69	29
RA015 9 VI 71	1st	0	0	16	6	15	8	0	3	0	0		
	2nd	0	0	13	5	21	7	2	1	1	0		
	Total	0	0	29	11	36	15	2	4	1	0	68	30
Grand Totals		4	1	195	127	257	217	30	45	2	10		
Combined		5		322		474		75		12		489	401

(a) Plus one age 9 female

(b) Plus one age 8 male

Table 2.3. Estimates of commercial landings of alewife and blueback and the ratios to one another. All landings given in thousands of pounds.

	VIMS Program						NMFS	
	Potomac		Rappahannock		Combined		Combined	
	Alewife	Blueback	Alewife	Blueback	Alewife	Blueback	Alewife	Blue-back
1971	789.8	5,065.4	429.6	445.2	1,219.4	5,510.6	772.1	9,498.0
Ratio	0.1559		0.9644		0.2212		0.0812	
1972	1,618.3	3,104.5	441.4	294.6	2,059.7	3,399.1	4,948.0	6,053
Ratio	0.5212		1.4983		0.6059		0.8174	
1973	550.5	834.2	332.5	532.0	883.0	1,366.2	1,581.6	7,355.2
Ratio	0.6599		0.6250		0.6463		0.2150	

Table 2.4. Estimates of the landings of river herring in the Potomac and Rappahannock rivers combined, by spawning check history. Units are thousands of fish and c/f is catch/net/season, by spawning class.

Year, Total Number, c/f	Spawning Checks 0	1	2	3	4	5	6	Total & Yearly c/f(1)	No. of Pound Nets(2)
1965	17,890	4,258	2,018	973	333	0	0	25,472	146
CPE	122.5	29.2	13.8	6.6	2.3	0	0	174.5	
1966	11,826	7,915	5,573	1,277	495	0	0	27,086	139
CPE	85.1	56.9	20.6	9.2	3.6	0	0	194.9	
1967	15,603	3,964	2,574	594	321	34	23	23,113	127
CPE	122.9	31.2	20.3	4.7	2.5		0.2	182.0	
1968	12,238	3,927	2,759	951	204	65	3	20,147	133
CPE	92.0	29.5	20.7	7.2	1.5	0.5		151.5	
1969	7,336	2,243	886	455	38	4	0	10,962	119
CPE	61.6	18.9	7.5	3.8	0.4		0	92.1	
1970	10,655	2,754	1,593	613	362	14	0	15,991	97
CPE	109.8	28.4	16.4	6.3	3.7	0.2	0	164.9	
1971	2,998	1,470	506	72	22	0	0	5,068	99
CPE	30.3	14.8	5.1	0.7	0.2	0	0	51.2	
1972	3,885	472	502	131	50	5		5,045	106
CPE	36.6	4.5	4.7	1.2	0.5	0.1		47.6	
1973	2,681	817	444	140	33	0	0	4,115	
CPE	27.6	8.4	4.6	1.4	0.4	0	0	42.4	97

(1) Catch per net per season, all ages combined
(2) In the last half of April, only nets above mile 10 used

Table 2.5. Annual mortality estimates of the river herring stock of the Potomac and Rappahannock rivers, Virginia, in percent per year by spawning class.(1)

Spawning Class	Between spawning classes (years of return) 0-1	1-2	2-3	3-4	4-5	5-6	Total mortality between years, all ages combined(2)
1965	54.1	64.5	64.7	95.5	56.2	100.0	37.2
1966	63.9	33.5	83.6	2.6	100.0	100.0	70.0
1967	76.1	74.8	15.2	96.5	50.0	100.0	67.4
1968	80.3	13.0	95.6	28.6	100.0		80.1
1969	53.7	83.1	76.5	66.6			39.7
1970	86.5	68.2	70.2				87.1
1971	85.2	0.0					77.5
1972	77.1						68.9

(1) From CPE estimates by spawning class of Table 2.

(2) From combined CPE differences by year of landing, excluding the recruits of each following year.

Table 2.6. Catch of river herring (alewife and blueback) in the inshore fishery and in ICNAF subarea 6 by various countries. Catch is in metric tons, round weight.[1]

	INSHORE			OFFSHORE						
	Virginia	North Carolina	Total U.S.A.	U.S.S.R.	East Germany	Bulgaria	Poland	Total Foreign	Total All Countries	Foreign Catch As % of Total Catch
1966[2]	13,182	5,680	21,178						21,178	
1967	12,776	8,387	22,201	981				981	23,182	
1968	14,663	7,044	23,649	1,075	126	0		1,201	24,850	4
1969	13,814	8,966	24,352	10,380		570		10,950	35,302	31
1970	6,827	5,227	14,888	5,954		746		6,700	21,588	31
1971	4,666	5,745	11,799	2,275	5,794	526	819	9,419	21,213	44
1972	5,069	5,079	10,609	2,048	2,371	146	407	4,972	15,120	32
1973	4,056	3,584	7,640	800	1,036	279	338			
1966-69 Average	14,108	7,519	22,770							
1970-73 Average	5,154	4,984	11,234							
1966-71 Average									24,552	

[1] One metric ton = 2,204.6 lb.

[2] First year of subarea 6 ICNAF statistics

Table 2.7. Mean length, mean weight, and sex ratio of alewife, blueback, and American shad from the Potomac River commercial catch, 1966-1973.

Length is in millimeters, fork length. Weight is in grams.

	Alewife						Blueback						American Shad					
	Males			Females			Males			Females			Males			Females		
Year	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number
1973 Apr 16-30	231.3	177.1	28	250.0	214.3	42	236.1	188.9	101	253.0	230.3	126						
May 1-15	230.3	151.0	134	247.7	179.6	154	238.8	174.6	66	249.5	219.5	59	417.6	932.5	12	481.6	1565.7	7
Season Average	230.5	155.5	162	248.2	187.0	196	237.2	183.2	167	251.9	226.9	185	417.6	932.5	12	481.6	1565.7	7
Males and Females Combined Best Estimate	246.5	219.0	358				244.9	206.2	352				441.2	1165.8	19			
1972 Apr 1-15	247.4	233.6	74	259.6	309.6	92	238.8	210.0	4				435.6	1391.6	38	474.0	1992.2	12
Apr 16-30	244.3	217.9	35	266.9	288.6	54	240.5	188.8	150	256.2	235.9	138	419.5	770.8	31	463.5	1092.1	41
May 1-15	250.5	190.5	42	258.6	222.6	54	239.6	172.7	248	249.0	201.2	283	404.4	1006.3	8	462.3	1675.0	30
May 16-31	249.0	176.2	62	259.6	199.4	54	240.4	150.1	58	250.5	175.1	50						
Jun 1-15	250.1	184.1	23	260.6	200.6	25	236.9	160.1	199	244.0	185.3	214						
Season Average	248.2	203.7	236	260.9	257.6	279	239.1	170.9	659	249.0	201.2	685	425.9	1070.4	77	464.6	1432.8	83
Males and Females Combined	255.1	232.9	515				244.1	186.3	1344				446.0	1258.4	160			
1971 Apr 1-15	239.3	219.9	23	257.0	282.9	32	236.0	201.4	80	246.9	234.6	49						
Apr 16-30	239.5	176.5	46	251.7	211.8	58	236.2	185.0	134	247.7	217.1	136	394.8	371.6	16	456.7	1547.5	[illegible]
May 1-15	240.3	181.6	7	254.9	260.1	9	227.8	171.0	149	241.5	211.8	209	397.4	976.4	37	452.6	1600.3	[illegible]
May 16-31	232.4	170.6	5	252.1	202.4	9	233.5	170.0	201	242.0	190.4	159	384.5	907.5	36	447.4	1042.5	[illegible]
Season Average	239.1	188.7	81	253.6	236.2	108	233.0	178.2	564	243.6	208.9	553	396.6	974.8	89	454.0	1616.4	[illegible]
Males and Females Combined	247.4	215.8	189				238.3	193.4	1117				430.4	1352.8	195			

Table 2.7. (Continued)

Year	Alewife						Blueback					
	Males			Females			Males			Females		
	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number
1970 Apr 16-30	237.0	205.9	20	252.3	252.9	26	231.3	168.4	320	244.3	202.5	219
May 1-15	243.1	181.8	20	246.6	225.6	14	227.1	165.3	160	237.7	193.1	143
May 16-31	233.8	172.9	9	239.0	187.8	6	228.5	170.3	228	237.0	201.8	139
Jun 1-15				245.5	171.5	2	236.3	172.4	71	243.7	205.6	28
Season Average	238.9	190.0	49	248.7	233.4	48	229.8	168.7	779	240.5	199.9	529
Males and Females Combined	243.74	211.5	97				234.1	181.3	1308			
1969 Apr 16-30	231.2	163.8	38	244.2	205.5	55	234.3	169.2	133	247.6	198.2	104
May 1-15	228.1	152.8	10	241.4	201.9	14	226.3	148.6	103	242.3	194.0	91
May 16-31	207.3	134.3	4	228.0	151.8	4	233.0	153.3	56	243.9	187.7	44
Season Average	228.6	159.6	52	242.5	202.3	73	231.2	158.9	292	244.9	194.7	239
Males and Females Combined	236.7	184.5	125				237.4	175.0	531			
1968 Apr 1-15	242.3	214.8	38	255.6	264.2	48	235.1	182.6	7			
Apr 16-30	239.9	210.7	22	255.9	253.2	23	239.2	204.5	150	250.1	241.8	139
May 1-15	241.0	174.0	20	250.2	213.7	12	233.5	169.1	91	246.5	204.5	109
May 16-31							237.7	177.1	43	245.9	205.5	57
Season Average	241.7	203.5	80	255.1	253.9	83	237.1	188.9	291	248.0	221.7	305
Males and Females Combined	248.5	229.1	163				242.7	205.7	596			

Table 2.7. (Continued)

Year		Alewife Males Average Length	Alewife Males Average Weight	Alewife Males Number	Alewife Females Average Length	Alewife Females Average Weight	Alewife Females Number
1967	Apr 1-15	242.3	211.1	38	257.9	268.5	37
	Apr 16-30	244.3	206.6	9	255.3	247.4	13
	May 1-15	240.2	173.4	14	256.4	225.4	30
	May 16-31				265.5	216.0	4
	Jun 1-15						
Season Average		241.[illegible]	201.7	61	257.2	247.4	84
Males and Females Combined		250.[illegible]	228.1	145			
1966	Apr 16-30	233.[illegible]	179.4	19	252.7	237.7	38
	May 1-15	234.[illegible]	181.0	18	247.5	194.2	28
	May 16-31	243.[illegible]	159.4	5	264.0	184.0	1
	Jun 1-15	235.[illegible]	150.0	1			
Season Average		235.[illegible]	177.1	43	250.7	218.7	67
Males and Females Combined		244.[illegible]	202.4	110			

Year		Blueback Males Average Length	Blueback Males Average Weight	Blueback Males Number	Blueback Females Average Length	Blueback Females Average Weight	Blueback Females Number
1967	Apr 1-15	242.8	201.5	16	259.8	248.4	10
	Apr 16-30	242.7	195.2	43	254.9	234.3	37
	May 1-15	237.3	172.5	78	250.3	215.1	68
	May 16-31	237.4	168.3	117	249.9	203.1	157
	Jun 1-15	240.1	163.1	84	245.5	184.7	77
Season Average		239.0	173.0	338	249.8	206.0	349
Males and Females Combined		244.5	189.8	678			
1966	Apr 16-30	242.3	205.5	81	252.8	240.0	64
	May 1-15	236.0	182.7	81	248.6	221.5	73
	May 16-31	236.4	161.3	99	248.5	185.1	94
	Jun 1-15	235.1	151.1	41	242.6	179.4	18
Season Average		237.7	177.5	302	249.1	209.5	249
Males and Females Combined		242.9	192.0	551			

Year		American Shad Males Average Length	American Shad Males Average Weight	American Shad Males Number	American Shad Females Average Length	American Shad Females Average Weight	American Shad Females Number
1967	Apr 1-15	249.0		1			
	Apr 16-30	397.6		19	432.0		31
	May 1-15						
	May 16-31						
	Jun 1-15						
Season Average		390.6		20	432.0		31
Males and Females Combined		415.7		51			

Table 2.8. Age composition of alewife, blueback, and American shad from the Potomac River commercial catch, by sex and half-month intervals, 1966-1973.

			Alewife								Blueback							American Shad							
			Number At Age							Semi-Monthly	Number At Age						Semi-Monthly	Number At Age							Semi-Monthly
Year	Month	Sex	3	4	5	6	7	8	9	Total	3	4	5	6	7	8	Total	3	4	5	6	7	8	9	Total
1973	Apr	M	0	16	10	0	1	0	0	27	0	33	33	14	6	0	86	0	0	0	0	0	0	0	0
	16-30	F	0	17	16	5	4	0	0	42	0	35	63	27	6	0	131	0	0	0	0	0	0	0	0
	May	M	2	53	6	5	2	0	0	68	4	82	27	13	5	0	131	0	6	4	1	1	0	0	12
	1-15	F	3	37	15	7	4	4	0	70	3	59	32	20	8	7	129	0	0	3	3	0	1	0	7
Season Total		M	2	69	16	5	3	0	0	95	4	92	60	27	11	0	194	0	6	4	1	1	0	0	12
		F	3	54	31	12	8	4	0	112	3	94	95	47	14	7	165	0	0	3	3	0	1	0	7
Sexes Combined			5	123	47	17	11	4	0	207	7	186	155	74	15	7	259	0	6	7	4	1	1	0	19
1972	Apr	M	1	6	8	6	2	1	0	24	0	1	1	0	0	0	2	0	1	9	13	11	2	2	38
	1-15	F	1	6	6	7	2	2	0	24	0	0	0	0	0	0	0	0	0	1	9	2	0	0	12
	Apr	M	6	6	3	4	3	1	0	23	1	12	16	22	3	1	55	0	5	11	12	3	0	0	37
	16-30	F	2	7	12	6	5	1	0	33	0	10	12	16	4	2	44	0	3	16	12	8	1	0	40
	May	M	6	11	6	13	2	1	0	39	0	29	23	11	3	0	66	0	1	7	0	0	0	0	8
	1-15	F	9	11	13	12	3	1	0	49	0	39	28	7	4	1	79	0	4	10	9	6	1	0	30
	May	M	1	14	6	3	0	1	0	25	0	9	6	7	1	0	23	0	0	0	0	0	0	0	0
	16-31	F	2	12	1	2	0	1	0	18	0	11	7	2	3	1	24	0	0	0	0	0	0	0	0
	Jun	M	4	4	5	6	1	1	1	22	0	25	12	7	2	1	47	0	0	0	0	0	0	0	0
	1-15	F	3	8	2	9	1	1	0	24	0	21	16	15	0	0	52	0	0	0	0	0	0	0	0
Season Total		M	18	41	28	32	8	5	1	133	1	76	58	47	9	2	193	0	7	27	25	14	2	2	77
		F	17	44	34	36	11	6	0	148	0	81	63	40	11	4	199	0	7	27	30	16	2	0	82
Sexes Combined			35	85	62	68	19	11	1	281	1	157	121	87	20	6	392	0	14	54	55	30	4	2	159

Table 2.8. (Continued)

Year Month	Sex	Alewife 3	Alewife 4	Alewife 5	Alewife 6	Alewife 7	Alewife 8	Alewife 9	Alewife Semi-Monthly Total	Blueback 3	Blueback 4	Blueback 5	Blueback 6	Blueback 7	Blueback 8	Blueback Semi-Monthly Total
		Number at Age								Number at Age						
1971 Apr 1-15	M	0	8	12	2	1	0	0	23	0	18	11	3	0	0	32
	F	0	7	20	4	1	0	0	32	0	7	4	6	0	0	17
Apr 16-30	M	3	13	15	2	0	0	0	33	0	23	24	5	0	0	52
	F	0	13	16	4	0	0	0	33	0	10	25	8	0	0	43
May 1-15	M	1	1	5	0	0	0	0	7	0	21	15	2	0	0	38
	F	0	3	3	2	1	0	0	9	0	28	30	1	1	0	60
May 16-31	M	0	2	3	0	0	0	0	5	1	22	22	3	1	0	49
	F	0	2	6	1	0	0	0	9	1	19	24	5	0	1	50
Season Total	M	4	24	35	4	1	0	0	68	1	84	72	13	1	0	171
	F	0	25	45	11	2	0	0	83	1	64	83	20	1	1	170
Sexes Combined		4	49	80	15	3	0	0	151	2	148	155	33	2	1	341
1970 Apr 16-30	M	1	17	1	1	0	0	0	20	0	47	12	12	1	1	73
	F	1	17	2	1	2	1	2	26	0	21	12	7	3	2	45
May 1-15	M	0	8	7	1	0	0	0	16	1	37	4	3	0	0	45
	F	2	9	4	1	0	1	0	17	0	25	8	5	1	1	40
May 16-31	M	1	7	1	0	0	0	0	9	2	44	11	1	1	0	59
	F	2	3	1	0	0	0	0	6	0	18	7	4	0	0	29
Jun 1-15	M	0	2	0	0	0	0	0	2	1	21	4	3	1	1	31
	F	0	0	0	0	0	0	0	0	0	8	3	2	0	0	13
Season Total	M	2	34	9	2	0	0	0	47	4	149	31	19	3	3	209
	F	5	29	7	2	2	2	2	49	0	72	30	18	4	2	126
Sexes Combined		7	63	16	4	2	2	2	96	4	221	61	37	7	5	335

Table 2.8. (Continued)

Year	Month	Sex	Alewife Number at Age 3	4	5	6	7	8	9	Alewife Semi-Monthly Total	Blueback Number at Age 3	4	5	6	7	8	9	Blueback Semi-Monthly Total
1969	Apr	M	6	3	1	1	0	0	0	11	3	23	9	2	1	0	0	38
	16-30	F	4	7	1	2	0	0	0	15	0	12	14	2	3	0	0	31
	May	M	5	0	0	0	0	0	0	5	9	27	12	0	1	0	0	49
	1-15	F	3	2	0	0	0	0	0	5	2	25	10	3	1	0	0	41
	May	M	2	2	0	0	0	0	0	4	3	12	5	5	3	0	0	28
	16-31	F	2	0	0	1	0	0	0	3	1	6	8	5	1	0	0	21
Season Total		M	13	5	1	1	0	0	0	20	15	62	26	7	5	0	0	115
		F	9	9	1	2	0	0	0	22	3	43	32	10	5	0	0	93
Sexes Combined			22	14	2	3	0	0	1	42	18	105	58	17	10	0	0	208
1968	Apr	M	0	3	9	3	1	0	0	16	0	3	1	0	0	0	0	4
	1-15	F	0	3	7	2	1	0	0	13	0	0	0	0	0	0	0	0
	Apr	M	1	7	5	6	0	0	0	19	2	17	14	18	8	0	1	60
	16-30	F	0	4	3	7	3	0	0	17	0	16	21	17	4	2	0	60
	May	M	0	6	3	3	1	0	0	13	0	12	18	5	4	0	0	39
	1-15	F	1	5	2	3	3	0	0	14	0	13	17	6	0	1	0	37
	May	M	0	0	0	0	0	0	0	0	0	3	9	0	0	0	0	12
	16-31	F	0	0	0	0	0	0	0	0	0	1	6	2	0	0	0	9
Season Total		M	1	16	17	12	2	0	0	48	2	35	44	23	12	0	1	117
		F	1	12	12	12	7	0	0	44	0	30	44	25	4	3	0	106
Sexes Combined			2	38	29	24	9	0	0	92	2	65	88	48	16	3	1	223

Table 2.8. (Continued)

Year Month	Sex	Alewife 3	Alewife 4	Alewife 5	Alewife 6	Alewife 7	Alewife 8	Alewife 9	Alewife Semi-Monthly Total	Blueback 3	Blueback 4	Blueback 5	Blueback 6	Blueback 7	Blueback 8	Blueback Semi-Monthly Total
1967 Apr 1-15	M	3	7	5	6	2	0	0	23	0	1	2	5	0	0	8
	F	2	6	9	5	3	1	1	27	0	1	2	1	2	0	6
Apr 16-30	M	2	4	2	1	0	0	0	9	0	5	10	7	2	1	25
	F	2	2	4	2	1	2	0	13	0	7	4	6	2	0	19
May 1-15	M	1	4	3	3	1	0	0	12	3	16	13	9	2	1	44
	F	0	5	8	5	1	1	0	20	0	7	10	10	4	1	32
May 16-31	M	0	0	0	0	0	0	0	0	0	21	14	4	3	0	42
	F	0	0	1	1	0	1	0	3	0	19	12	9	4	0	44
Jun 1-15	M	0	0	0	0	0	0	0	0	0	34	10	2	1	0	47
	F	0	0	0	0	0	0	0	0	2	26	8	0	1	0	37
Season Total	M	6	15	10	10	3	0	0	44	3	77	49	27	8	2	166
	F	4	13	22	13	5	5	1	63	2	60	36	26	13	1	138
Sexes Combined		10	28	32	23	8	5	1	107	5	137	85	53	21	3	304
1966 Apr 16-30	M	6	8	3	1	0	0	0	18	0	21	22	13	2	3	61
	F	3	17	6	12	0	0	0	38	0	9	9	12	5	1	36
May 1-15	M	6	5	3	4	0	0	0	18	4	24	15	11	1	0	55
	F	4	13	5	1	2	0	0	25	2	17	14	10	2	0	45
May 16-31	M	0	0	1	1	0	0	0	2	5	14	16	14	6	0	55
	F	0	0	0	1	0	0	0	1	2	11	14	13	4	1	45
Jun 1-15	M	0	0	0	0	0	0	0	0	0	19	12	5	1	1	38
	F	0	0	0	0	0	0	0	0	1	5	4	2	0	0	12
Season Total	M	12	13	7	6	0	0	0	38	9	78	65	43	10	4	209
	F	7	30	11	14	2	0	0	64	5	42	41	37	11	2	138
Sexes Combined		19	43	18	20	2	0	0	102	14	120	106	80	21	6	347

Table 2.9. Mean length, mean weight, and sex ratio of alewife, blueback, and American shad from the Rappahannock River commercial catch, 1966-1973.

Length is in millimeters, fork length. Weight is in grams.

Year	Alewife						Blueback						American Shad					
	Males			Females			Males			Females			Males			Females		
	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number	Average Length	Average Weight	Number
1973 Feb 1-15	248.8	232.5	73	260.0	267.2	27												
Feb 16-28	245.3	235.3	62	256.5	294.2	37												
Mar 1-15	245.3	243.2	176	260.3	306.7	129												
Mar 16-31	240.7	212.5	167	259.3	283.6	168	230.4	175.8	23	246.0	205.5	4	375.5	805.9	32	440.7	1563.0	14
Apr 1-15	240.1	205.1	52	252.6	256.3	48	232.0	183.7	94	245.7	218.7	40	395.2	882.2	9	474.5	2010.0	11
Apr 16-30	235.5	188.1	10	249.7	239.5	17	226.4	174.0	192	242.6	209.3	127						
May 1-15	238.5	182.5	56	253.0	219.9	67	236.6	185.6	92	251.2	224.5	116						
Season Average	243.2	222.5	596	257.6	276.7	493	230.3	179.0	401	246.6	216.6	287	379.8	882.6	41	445.6	1759.7	25
Males and Females Combined Best Estimate	249.7	247.0	1089				236.9	194.7	688				404.7	1214.8	66			
1972 Feb 16-28	248.3	242.3	126	261.9	302.2	38							348.0	681.0	1			
Mar 1-15	247.4	204.7	307	263.0	308.8	207							390.5	861.8	24	446.7	1138.0	3
Mar 16-31	252.6	255.6	130	267.8	327.0	174				216.0	216.0	1	400.0	1019.0	31			
Apr 1-15	249.2	233.0	125	269.8	312.8	158	221.6	151.3	18	246.5	215.6	14						
Apr 16-30	246.8	211.1	75	265.6	279.1	72	237.7	189.9	144	252.8	234.5	104	419.3	1241.5	28	469.1	1838.8	54
May 1-15	247.6	206.4	40	265.9	241.8	60	241.4	168.8	235	249.6	203.4	275	401.5	1017.5	8	465.1	1657.4	46
May 16-31	246.9	163.7	37	250.9	173.2	40	239.1	152.2	175	249.8	185.7	148						
Jun 1-15	243.9	165.1	56	262.6	213.6	35	236.5	162.4	133	244.0	191.2	192						
Season Average	248.3	217.8	896	265.2	294.3	784	238.5	167.3	705	248.5	201.3	734	403.0	1041.9	92	466.7	1755.7	103
Males and Females Combined	256.2	253.5	1680				243.6	184.6	1439				436.6	1418.9	195			

Table 2.9. (Continued)

Alewife

Year	Males Average Length	Males Average Weight	Males Number	Females Average Length	Females Average Weight	Females Number
1971 Mar 1-15	246.6	244.7	204	259.2	292.4	114
Mar 16-31	243.9	230.6	184	256.0	280.8	242
Apr 1-15	243.9	224.6	69	255.4	280.9	105
Apr 16-30	239.6	177.2	22	251.3	225.9	27
May 1-15	241.6	177.6	31	255.3	233.9	28
May 16-31	233.0	173.5	2	249.3	214.3	9
Jun 1-15	236.0	154.7	6	250.0	216.0	3
Season Average	244.5	228.3	523	256.1	276.2	528
Males and Females Combined	250.3	252.4	1051			
1970 Mar 1-15	244.6	238.5	60	265.3	298.1	40
Mar 16-31	243.8	236.2	147	259.0	290.0	112
Apr 1-15	242.1	218.6	54	257.0	266.3	112
Apr 16-30	243.6	193.7	122	250.6	228.8	127
May 1-15	236.4	176.2	13	249.6	204.8	23
May 16-31	234.7	169.0	3	248.4	226.0	5
Season Average	240.3	218.2	404	255.9	260.4	419
Males and Females Combined	248.2	239.7	823			

Blueback

Year	Males Average Length	Males Average Weight	Males Number	Females Average Length	Females Average Weight	Females Number
1971 Mar 1-15						
Mar 16-31	232.3	172.4	7	256.5	222.3	10
Apr 1-15	230.9	185.5	123	245.0	220.8	108
Apr 16-30	228.5	167.3	158	240.3	199.1	190
May 1-15	230.2	168.0	165	239.7	198.3	198
May 16-31	230.4	156.9	192	242.7	175.2	193
Jun 1-15	230.2	138.9	281	238.3	152.8	112
Season Average	230.1	159.1	926	241.2	190.0	811
Males and Females Combined	235.3	173.5	1737			
1970 Mar 1-15						
Mar 16-31	237.8	185.4	24	243.0	206.0	6
Apr 1-15	227.1	155.9	64	246.7	187.7	36
Apr 16-30	232.9	172.1	103	242.7	200.6	118
May 1-15	232.3	164.2	241	239.6	183.9	133
May 16-31	235.8	159.5	185	247.3	197.8	15
Season Average	233.1	164.1	617	242.1	191.8	308
Males and Females Combined	236.1	173.3	925			

American Shad

Year	Males Average Length	Males Average Weight	Males Number	Females Average Length	Females Average Weight	Females Number
1971 Mar 1-15						
Mar 16-31	421.3	1243.1	27	469.1	1785.0	19
Apr 1-15	417.5	1204.6	55	454.0	1633.2	45
Apr 16-30	412.4	1080.1	44	443.1	1474.4	38
May 1-15	397.8	954.8	29	443.3	1457.2	49
May 16-31						
Jun 1-15						
Season Average	413.0	1129.2	155	449.7	1555.2	151
Males and Females Combined	431.1	1339.4	306			
1970 Mar 1-15	404.4	1253.9	16	431.4	1310.8	13
Mar 16-31	402.8	1375.6	77	439.8	1434.0	73
Apr 1-15	398.8	1416.9	40	457.0	1552.9	48
Apr 16-30	410.0	1038.5	15	450.4	1486.8	14
May 1-15						
May 16-31						
Season Average	402.6	1339.4	148	445.6	1466.7	148
Males and Females Combined	424.1	1403.1	296			

Table 2.9. (Continued)

Year	Alewife Males Average Length	Alewife Males Average Weight	Alewife Males Number	Alewife Females Average Length	Alewife Females Average Weight	Alewife Females Number	Blueback Males Average Length	Blueback Males Average Weight	Blueback Males Number	Blueback Females Average Length	Blueback Females Average Weight	Blueback Females Number	American Shad Males Average Length	American Shad Males Average Weight	American Shad Males Number	American Shad Females Average Length	American Shad Females Average Weight	American Shad Females Number
1969 Mar 16-31	243.2	213.7	110	255.3	257.6	90												
Apr 1-15	236.5	196.6	46	252.9	249.1	63	236.3	181.1	87	248.0	225.8	49	402.5	1508.1	43	444.8	1455.5	55
Apr 16-30	234.5	163.5	72	244.4	196.5	81	230.9	163.2	142	242.0	192.2	120	393.2	1491.6	5	440.2	1450.5	33
May 1-15	229.5	152.5	10	242.6	176.8	14	228.0	150.5	95	242.8	177.0	100						
May 16-31	224.0	140.5	2	245.5	190.5	2	233.3	138.9	57	245.2	164.5	43						
Season Average	238.6	192.2	240	250.4	230.6	250	231.8	160.5	381	243.6	188.8	312	401.5	1505.4	48	443.1	1453.6	88
Males and Females Combined	244.6	211.8	490				237.1	173.2	643				428.4	1472.2	136			
1968 Mar 1-15	237.3	233.2	78	255.4	277.4	22							283.0	1361.0	1			
Mar 16-31	243.3	226.9	128	256.0	277.3	72							405.0	1439.4	39	451.5	1523.5	36
Apr 1-15	240.5	215.0	98	254.2	267.1	92	238.5	181.2	12	259.0	228.0	2	389.3	1603.7	58	448.7	1507.0	42
Apr 16-30	235.2	181.1	69	247.2	222.8	67	228.9	173.3	141	239.7	202.7	144	390.5	1639.6	31	441.0	1422.6	49
May 1-15							230.7	142.6	41	240.6	163.3	59	385.2	1709.8	5	433.2	1346.7	20
May 16-31	240.0	185.0	1	262.5	240.0	2	237.9	170.8	98	246.6	197.5	102						
Season Average	239.8	216.5	374	253.0	259.0	255	232.6	168.9	292	242.3	193.6	307	393.2	1563.3	134	444.7	1461.1	47
Males and Females Combined	245.2	233.7	629				237.6	181.6	599				420.1	1511.3	281			

Table 2.9. (Continued)

Year	Alewife Males Average Length	Alewife Males Average Weight	Alewife Males Number	Alewife Females Average Length	Alewife Females Average Weight	Alewife Females Number	Blueback Males Average Length	Blueback Males Average Weight	Blueback Males Number	Blueback Females Average Length	Blueback Females Average Weight	Blueback Females Number
1967 Mar 1-15	240.6	216.2	59	250.6	254.5	41						
Mar 16-31	239.6	206.3	98	252.1	252.1	89						
Apr 1-15	240.1	199.1	100	250.5	233.8	98	243.9	196.3	29	255.4	226.2	15
Apr 16-30	238.9	174.4	10	247.3	214.8	13	234.7	183.4	56	245.5	208.1	33
May 1-15	239.3	178.4	44	250.5	195.9	45	234.2	164.9	99	245.9	193.7	101
May 16-31	237.8	167.2	13	252.5	198.0	21	230.2	144.3	77	244.9	181.8	113
Season Average	239.8	199.5	324	251.0	233.1	307	234.2	166.3	261	246.0	192.2	262
Males and Females Combined	245.2	215.8	631				240.1	179.3	523			
1966 Mar 16-31	239.2	204.8	148	250.7	241.0	141						
Apr 1-15	236.8	198.0	83	250.9	246.2	104	239.8	199.2	31	252.9	244.3	15
Apr 16-30	238.3	190.7	16	247.9	212.5	22	236.4	194.7	97	249.3	234.6	103
May 1-15	235.1	163.0	49	250.4	190.5	37	233.6	171.4	28	246.6	205.1	38
Season Average	237.8	195.2	296	250.4	234.6	304	236.6	191.4	156	249.0	228.3	156
Males and Females Combined	244.2	215.2	600				242.8	209.9	312			

Table 2.10. Age composition of alewife, blueback, and American shad from the Rappahannock River commerical catch,' by sex and half-month intervals, 1966-1973.

Alewife

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1973	Feb 1-15	M	0	17	8	3	1	0	0	29
		F	0	11	7	3	0	0	0	21
	Feb 16-28	M	0	14	13	8	0	0	0	25
		F	0	6	5	1	2	1	0	15
	Mar 1-15	M	0	45	25	14	4	2	0	90
		F	1	27	13	11	6	2	0	40
	Mar 16-31	M	1	52	19	7	2	0	0	81
		F	1	47	27	9	9	2	1	96
	Apr 1-15	M	0	34	13	5	0	0	0	52
		F	0	28	10	6	4	0	0	48
	Apr 16-30	M	1	5	4	0	0	0	0	10
		F	0	11	2	3	1	0	0	17
	May 1-15	M	0	21	12	6	0	1	0	40
		F	0	33	14	6	5	0	0	58
Season Total		M	2	188	94	43	7	3	0	337
		F	2	163	78	39	27	5	1	315
Sexes Combined			4	351	172	82	34	8	1	652

Blueback

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1973	Feb 1-15	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	Feb 16-28	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	Mar 1-15	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	Mar 16-31	M	0	11	7	4	1	0	0	23
		F	0	4	0	0	0	0	0	4
	Apr 1-15	M	0	58	17	16	3	0	0	94
		F	1	20	14	4	0	0	0	39
	Apr 16-30	M	1	38	25	16	2	0	0	82
		F	0	36	15	9	6	2	0	68
	May 1-15	M	0	28	25	9	2	0	0	64
		F	0	30	39	13	3	1	0	86
Season Total		M	1	135	74	45	8	0	0	263
		F	1	90	68	26	9	3	0	197
Sexes Combined			2	225	142	71	17	3	0	460

American Shad

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1973	Feb 1-15	M								
		F								
	Feb 16-28	M								
		F								
	Mar 1-15	M								
		F								
	Mar 16-31	M	1	17	12	2	0	0	0	32
		F	0	4	5	2	3	0	0	14
	Apr 1-15	M	0	9	0	0	0	0	0	9
		F	0	2	4	2	2	1	0	11
	Apr 16-30	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	May 1-15	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
Season Total		M	1	26	12	2	0	0	0	41
		F	0	6	9	4	5	1	0	25
Sexes Combined			1	32	21	6	5	1	0	66

Table 2.10. (Continued)

Alewife

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1974	Feb	M	2	21	10	3	1	0	0	37
	16-29	F	1	5	1	1	2	0	1	11
	Mar	M	2	19	38	14	6	0	0	79
	1-15	F	2	11	27	18	4	1	0	63
	Mar	M	0	10	18	15	1	0	0	44
	16-31	F	0	7	17	21	3	4	0	52
	Apr	M	1	10	12	16	2	1	0	42
	1-15	F	0	11	7	24	12	2	0	56
	Apr	M	2	14	15	9	4	1	1	46
	16-30	F	0	9	16	15	10	1	1	52
	May	M	2	12	11	10	2	0	0	37
	1-15	F	2	7	18	15	7	5	0	54
	May	M	3	20	6	3	2	2	0	36
	16-31	F	6	13	7	6	4	1	0	37
	Jun	M	6	13	6	4	0	0	0	29
	1-15	F	2	8	2	4	3	2	0	15
Season Total		M	18	119	116	74	18	4	1	350
		F	13	71	95	104	45	16	2	346
Sexes Combined			31	190	211	178	63	20	3	696

Blueback

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1974	Feb	M	0	0	0	0	0	0	0	0
	16-29	F	0	0	0	0	0	0	0	0
	Mar	M	0	0	0	0	0	0	0	0
	1-15	F	0	0	0	0	0	0	0	0
	Mar	M	0	0	0	0	0	0	0	0
	16-31	F	0	0	0	0	0	0	0	0
	Apr	M	0	0	2	2	1	0	0	5
	1-15	F	0	0	3	6	1	0	0	10
	Apr	M	0	7	16	18	9	2	0	52
	16-30	F	0	3	17	20	5	1	0	46
	May	M	0	8	25	9	1	1	0	44
	1-15	F	0	13	51	33	5	0	0	102
	May	M	0	31	14	7	2	0	0	54
	16-31	F	0	14	16	11	4	0	0	45
	Jun	M	0	32	20	3	1	0	0	56
	1-15	F	0	20	16	4	0	1	0	41
Season Total		M	0	78	77	39	14	3	0	211
		F	0	50	103	44	15	2	0	214
Sexes Combined			0	128	180	83	29	5	0	425

American Shad

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1974	Feb	M	0	0	0	1	0	0	0	1
	16-29	F	0	0	0	0	0	0	0	0
	Mar	M	0	3	15	5	1	0	0	24
	1-15	F	0	1	1	1	0	0	0	3
	Mar	M	1	10	11	6	3	0	0	31
	16-31	F	0	0	0	0	0	0	0	0
	Apr	M	0	0	0	0	0	0	0	0
	1-15	F	0	0	0	0	0	0	0	0
	Apr	M	0	6	12	8	7	0	0	33
	16-30	F	0	1	18	18	14	2	0	43
	May	M	0	2	3	1	1	0	0	7
	1-15	F	0	1	20	16	4	2	0	43
	May	M	0	0	0	0	0	0	0	0
	16-31	F	0	0	0	0	0	0	0	0
	Jun	M	0	0	0	0	0	0	0	0
	1-15	F	0	0	0	0	0	0	0	0
Season Total		M	1	21	41	21	12	0	0	96
		F	0	3	39	35	18	4	0	99
Sexes Combined			1	24	80	56	30	4	0	195

Table 2.10. (Continued)

Year Month	Sex	Alewife								Blueback								American Shad							
		Number at Age								Number at Age								Number at Age							
		3	4	5	6	7	8	9	Semi-Monthly Total	3	4	5	6	7	8	9	Semi-Monthly Total	3	4	5	6	7	8	9	Semi-Monthly Total
1971 Mar	M	1	15	28	4	1	0	0	60	0	0	0	0	0	0	0	0								
1-15	F	1	8	19	11	1	0	0	40	0	0	0	0	0	0	0	0								
Mar	M	0	7	27	5	1	0	0	40	0	2	5	0	0	0	0	7								
16-31	F	1	11	31	12	2	1	0	58	0	0	3	4	2	0	0	9								
Apr	M	5	16	17	3	0	0	0	41	1	29	44	7	1	0	0	82								
1-15	F	1	10	30	9	0	0	0	50	0	17	33	15	3	0	0	68								
Apr	M	0	14	11	2	0	0	0	27	2	31	57	11	0	0	0	101								
16-30	F	0	13	10	3	1	0	0	27	1	22	62	12	2	0	0	99								
May	M	0	12	15	3	0	0	0	30	1	41	44	4	0	0	0	90	0	24	44	10	2	0	0	80
1-15	F	0	13	10	3	1	1	0	28	0	47	53	5	0	0	0	105	1	5	53	26	0	0	0	85
May	M	0	1	0	1	0	0	0	2	0	49	55	5	0	0	0	109	0	20	39	8	3	0	0	70
16-31	F	1	1	5	2	0	0	0	9	0	25	49	11	4	0	1	90	0	8	39	9	1	0	0	57
Jun	M	1	1	3	0	0	0	0	5	0	57	73	5	1	1	0	137	0	0	0	0	0	0	0	0
1-15	F	0	2	1	0	0	0	0	3	0	21	29	7	2	0	0	59	0	0	0	0	0	0	0	0
Season Total	M	7	66	101	25	5	1	0	205	4	209	278	32	2	1	0	526	0	44	83	18	5	0	0	150
	F	4	58	106	40	5	2	0	215	1	132	229	54	13	0	1	430	1	13	92	35	1	0	0	142
Sexes Combined		11	124	207	65	10	3	0	420	5	341	507	86	15	1	1	956	1	57	175	53	6	0	0	192

Table 2.10. (Continued)

Alewife

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1970	Mar 1-15	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	Mar 16-31	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	Apr 1-15	M	2	18	10	2	3	2	0	37
		F	2	32	26	14	8	3	0	85
	Apr 16-30	M	0	10	11	2	0	0	0	23
		F	0	7	11	3	5	1	0	27
	May 1-15	M	0	1	0	0	0	0	0	1
		F	0	3	2	0	2	0	0	7
	May 16-31	M	9	37	28	14	9	0	0	97
		F	5	45	30	15	5	1	0	101
Season Total		M	11	66	49	18	12	2	0	158
		F	7	87	69	32	20	5	0	220
Sexes Combined			18	153	118	50	32	7	0	378

Blueback

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1970	Mar 1-15	M	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	Mar 16-31	M	0	5	14	2	0	1	0	22
		F	0	2	2	1	0	0	0	5
	Apr 1-15	M	0	13	14	2	0	0	0	29
		F	1	6	7	2	0	0	0	16
	Apr 16-30	M	2	27	9	3	1	0	0	42
		F	0	31	13	2	1	0	0	47
	May 1-15	M	2	43	10	5	1	2	0	63
		F	1	10	9	2	0	1	0	23
	May 16-31	M	0	18	11	3	1	0	0	33
		F	0	2	3	2	1	0	0	8
Season Total		M	4	106	58	15	3	3	0	189
		F	2	51	34	9	2	1	0	99
Sexes Combined			6	157	92	24	5	4	0	288

American Shad

Year	Month	Sex	Number at Age 3	4	5	6	7	8	9	Semi-Monthly Total
1970	Mar 1-15	M	1	4	10	1	0	0	0	16
		F	0	2	9	2	0	0	0	13
	Mar 16-31	M	1	30	35	8	1	0	0	75
		F	0	13	48	11	1	0	0	73
	Apr 1-15	M	2	23	13	1	1	0	0	40
		F	2	11	28	6	1	0	0	48
	Apr 16-30	M								
		F								
	May 1-15	M								
		F								
	May 16-31	M								
		F								
Season Total		M	4	57	48	10	2	0	0	121
		F	2	26	85	19	2	0	0	134
Sexes Combined			6	83	133	29	4	0	0	255

Table 2.10. (Continued)

			Alewife								Blueback							
			Number at Age							Semi-Monthly	Number at Age							Semi-Monthly
Year	Month	Sex	3	4	5	6	7	8	9	Total	3	4	5	6	7	8	9	Total
1969	Mar	M	1	16	25	10	1	0	0	53								
	16-31	F	0	17	9	13	4	2	1	46								
	Apr	M	7	16	2	4	0	0	0	29	0	18	15	3	2	1	0	39
	1-15	F	3	14	10	13	3	0	3	46	0	11	5	3	1	1	0	21
	Apr	M	7	16	3	4	0	0	0	30	5	35	2	6	1	0	0	49
	16-30	F	4	21	10	1	2	0	0	38	1	16	15	1	1	1	0	35
	May	M	1	2	0	1	0	0	0	4	6	26	17	2	1	1	0	53
	1-15	F	0	3	1	1	0	0	0	5	1	23	6	3	3	0	1	37
	May	M	2	0	0	0	0	0	0	2	6	12	5	4	0	2	0	29
	16-31	F	1	1	0	0	0	0	0	2	0	8	7	4	1	1	0	21
Season Total		M	18	50	30	19	1	0	0	118	17	91	39	15	4	4	0	170
		F	8	56	30	28	9	2	4	137	2	58	33	11	6	3	1	114
Sexes Combined			26	106	60	47	10	2	4	255	19	149	72	26	10	7	1	284

Table 2.10. (Continued)

Year	Month	Sex	Alewife 3	Alewife 4	Alewife 5	Alewife 6	Alewife 7	Alewife 8	Alewife 9	Alewife Semi-Monthly Total	Blueback 3	Blueback 4	Blueback 5	Blueback 6	Blueback 7	Blueback 8	Blueback 9	Blueback Semi-Monthly Total
1968	Mar	M	4	10	21	6	0	0	0	41	0	0	0	0	0	0	0	0
	1-15	F	0	2	7	0	0	0	0	9	0	0	0	0	0	0	0	0
	Mar	M	2	24	24	15	2	0	0	67	0	0	0	0	0	0	0	0
	16-31	F	0	7	20	3	3	0	0	33	0	0	0	0	0	0	0	0
	Apr	M	5	24	25	4	3	0	0	41	1	3	5	0	1	0	0	10
	1-15	F	0	11	19	3	4	0	1	38	0	0	0	0	0	0	0	0
	Apr	M	14	22	14	9	2	0	1	62	6	28	11	7	4	1	0	57
	16-30	F	7	20	13	4	5	0	1	50	5	35	13	9	8	2	1	73
	May	M	0	0	0	0	0	0	0	0	2	11	8	3	0	0	0	24
	1-15	F	0	0	0	0	0	0	0	0	0	11	7	2	0	0	0	20
	May	M	0	1	0	0	0	0	0	1	0	25	9	2	2	0	0	38
	16-31	F	0	0	0	2	0	0	0	2	1	15	15	3	3	0	0	37
Season Total		M	25	81	84	34	7	0	1	232	9	67	33	12	7	1	0	129
		F	7	40	59	12	12	0	2	132	6	61	35	14	11	2	1	130
Sexes Combined			32	121	143	46	19	0	3	364	15	128	68	26	18	3	1	259

Table 2.10. (Continued)

Year	Month	Sex	Alewife: Number at Age 3	4	5	6	7	8	9	Alewife: Semi-Monthly Total	Blueback: Number at Age 3	4	5	6	7	8	9	Blueback: Semi-Monthly Total
1967	Apr	M	9	26	6	1	0	0	0	42	0	1	14	5	5	5	1	26
	1-15	F	5	21	5	1	0	0	0	32	0	1	5	4	2	2	0	14
	Apr	M	11	45	21	8	9	1	0	95	0	3	12	10	4	1	0	30
	16-30	F	4	10	6	3	3	1	0	27	0	1	13	5	1	0	0	20
	May	M	0	0	0	0	0	0	0	0	4	23	22	10	1	0	0	60
	1-15	F	0	0	0	0	0	0	0	0	1	16	12	4	2	0	0	35
	May	M	0	0	0	0	0	0	0	0	5	7	7	4	3	0	0	26
	16-31	F	0	0	0	0	0	0	0	0	0	20	9	6	1	0	0	36
Season Total		M	20	71	27	9	9	1	0	137	9	34	55	29	13	2	0	142
		F	9	31	11	4	3	1	0	59	1	38	39	19	6	2	0	105
Sexes Combined			29	102	38	13	12	2	0	196	10	72	94	48	19	4	0	247
1966	Mar	M	8	10	11	1	0	0	0	30	0	0	0	0	0	0	0	0
	16-31	F	4	8	1	5	1	0	0	19	0	0	0	0	0	0	0	0
	Apr	M	15	19	6	4	2	0	0	46	5	12	5	1	0	0	0	23
	1-15	F	3	22	8	11	4	0	0	48	4	4	4	0	0	0	0	12
	Apr	M	3	7	3	1	1	1	0	16	1	7	13	5	0	0	0	26
	16-30	F	5	8	5	3	0	0	0	21	0	1	9	9	3	2	0	24
	May	M	13	7	4	1	1	0	0	26	0	0	0	0	0	0	0	0
	1-15	F	7	2	2	10	1	2	0	24	0	0	0	0	0	0	0	0
Season Total		M	39	43	24	7	4	1	0	118	6	19	18	6	0	0	0	49
		F	19	40	16	29	6	2	0	112	4	5	13	9	3	2	0	36
Sexes Combined			58	83	40	36	10	3	0	230	10	24	31	15	3	2	0	85

Job 3. Juvenile Population Dynamics

A. Evaluation of Sampling Scheme.

Contagion among individuals in a three-dimensional sample space usually results in data that follow a negative binomial and has high variance (Snedecor and Cochran, 1967). In previous years each tow for juvenile alosids was 5-minutes long. By doubling the tow time we reduced the variance of the catch in 1973, and adopted this unit of effort as standard.

In 1972 we demonstrated that the 5x5 ft Cobb trawl produced mean catches with the same variance as the 10x10 ft Cobb trawl, and the ratios of the species caught were the same for both nets even when channel and shoal surface stations were compared (Davis et al., 1972). Because of this, we standardized nets in 1972 and used only the 5x5 ft Cobb for all vessels; however, the variance[(1)] continued to approach 100% of the mean. The usual procedure is to perform data adjustment with the log or square root transformation before the variance is computed. With such data transformation, reality of catch information is often lost, making comparison between years more tenuous. In 1973 we performed the following experiment before the full scale survey began.

On July 10 and 11, 1973 the R/V Brooks made alternate 5- and 10-min tows at 33 stations in the James River. At each station a 5x5 ft Cobb was towed at the surface. The north shore, channel, and south shore were sampled, each with 22 tows from mile 55 to 65 at 1-mile intervals. Blueback herring, alewife and American shad were counted and measured. The catch for the 33 tows of five minutes and 33 tows of ten minutes is given in Tables 3.1 to 3.3.

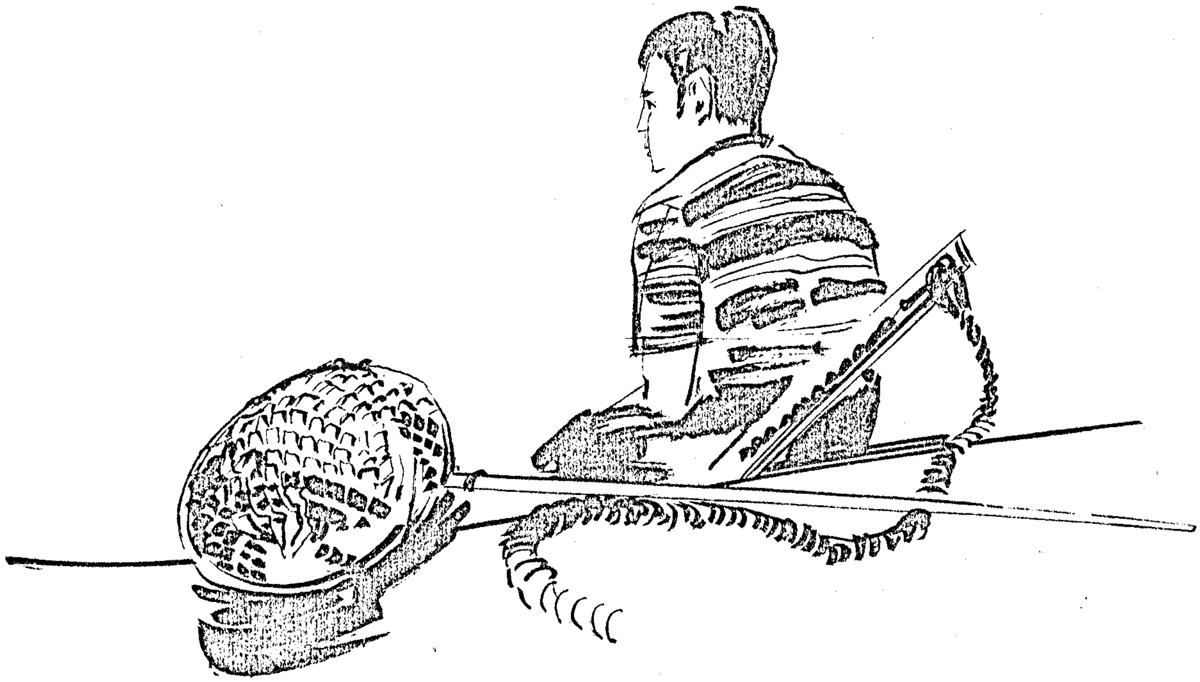
(1) Coefficient of variation

The ratios of total catch between 10- and 5-min tows for blueback, shad and alewife were 1.893, 2.255 and 1.967 with an overall average of 2.038 (Table 3.4). The 10-min tows took almost exactly double the fish of the 5-min tows.

For blueback the coefficient of variation fell from 68% for 5-min tows to 47% for 10-min tows; for shad it dropped from 139% to 103%, and for alewife it fell from 158% to 130%. This represents a gain in precision of the mean of 30.4% for blueback, 25.9% for shad and 17.5% for alewife (Table 3.4). Thus the means generated by 10-min tows have greater accuracy and reflect the extant population approximately one-fourth to one-third better than with 5-min tows. If alewife and shad were as abundant as blueback, we expect their statistics would reflect a similar drop in variation.

The means of the 5- and 10-min tows for each species were significantly different for blueback and shad but not alewife. The correlation coefficient was significant only for shad, but this statistic is important only if few tows are made and results extrapolated from them.

Ten-minute tows smooth the Poisson distribution and tend to eliminate the contagion error of the samples. Because the overall catch ratio averaged 2.038, we can adjust previous years' catches for comparison with 10-min tows. This has been done for all c/f data in this section. Since the variation of the mean dropped significantly with greater tow time, the 1973 survey was performed with 10-min tows, and the number made was two-thirds of the 1972 totals. This gave a 50% greater towing time (total minutes) than in 1972.



II. Annual Index of Abundance.

A. Refinement of annual index.

Before 1973, only surface tows were used to estimate year class strength but midwater tows were taken in every year except 1972. We have now found it necessary to utilize midwater tow data and this section defines the adjustments made to derive the standard index. The James, York, Rappahannock and Potomac rivers were sampled by two vessels between August 6 and September 7, 1973. The R/V Brooks sampled shoal water and the R/V Langley sampled deeper water in the nursery zones (Fig. 1). Each vessel used the 5x5 ft Cobb trawl and tow times of 10 minutes. The Langley made surface and midwater tows at alternate miles and towed both depths at 5-mile intervals. The Brooks made only surface tows.

Midwater trawling was eliminated in 1972 because factorial analysis of 3 years of data (1969-1971) in the James River failed to demonstrate any significant difference between surface and midwater species distribution. The surface tows merely caught greater numbers of all species. However, in 1973, alewife and shad were conspicuously absent from surface tows in the James River and several midwater tows indicated they were lower in the water column. Therefore, the 1973 sampling scheme was altered to that described in the preceding paragraph. Total towing time was increased approximately 1.5 times over 1972 (Table 3.5) and in every year the survey has been conducted from mid-August to mid-September.

The annual index of yearclass strength of each species in each river is the mean catch per tow averaged from a nonuniform linear and vertical distribution of juveniles. Thus, some limits must be set on nursery boundaries and means from different vessels and depths must be weighted and combined. We have chosen to analyze all data comparatively, and continue with our system of presenting arithmetic and geometric means derived without initial data transformation.

Before 1973, midwater tows were taken at 5-mile intervals. The overall towing effort was small (Table 3.5), but nevertheless indicates that the distribution of species was not constant, with depth, and the c/f comparisons often reflected opposite abundance indices (Tables 3.6 and 3.9). All rivers showed wide disparity between midwater and surface tows depending on species. If the relative abundance indices, c/f ratios, Table 3.10) were nearly constant for a particular species and had a small range of variation, then one could use only surface tows (or only midwater tows) to derive its annual index of yearclass strength. Our several years of trawling indicates that no trend was evident for any species or river.

When the *Langley* surface c/f is compared to its midwater c/f (Tables 3.6 and 3.9), the changing nature of the species distribution can be appreciated. The ratios of catch by species, river, and year clearly show the greatest abundance of blueback to be near the surface, and midwater for alewife and shad (Table 3.10). In most years alewife were 2 to 5 times more abundant in midwater than surface (ratios 0.5 to 0.2) and shad varied considerably with ratios ranging from 15.6 to 0.07, but overall with greater midwater abundance.

Except for the James River in the early years, no pattern exists that would allow selection of either surface or midwater c/f as the most appropriate index to yearclass strength. In many instances, the midwater c/f reverses the conclusions drawn from the surface c/f, and in all cases data adjustment is necessary to derive an index that accurately defines the yearclass strength for that species in that river.

This third dimension of tow depth presents a peculiar averaging problem. Only one vessel made both types of tows, and the effort devoted to midwater tows was small between 1969 and 1971. A weighted average cannot be used because the populations are not homogeneous to depth as they appear to be for horizontal distribution across the river. The *Langley* and *Brooks* surface catches (average c/f) can be combined by weighting, because previous analyses (Davis et al., 1972) from all rivers indicated that the species were distributed in similar ratios over deep and shoal water.

Thus two options are available: (1) Assume the midwater distribution over the shoals is proportional to the midwater distribution over deep water as measured by the *Langley*, or (2) Use only the *Langley* data and average its surface and midwater c/f with an unweighted scheme. We feel option (1) is preferable because we suspect the juveniles are distribued similarly at 8 ft to 18 ft in water to 20 ft deep, as in water of the same depth over depths greater than 20 ft. The second option would define the "channel" zone best, but would then discard important data from the shoals.

Our primary assumptions are then: (A) if a greater number of mid-water tows were taken by the Langley, over deep water, the average c/f would approximate the determined c/f but have less variance, and (B) if the Brooks had made midwater tows in the shallower water, the species ratios between surface and midwater would be similar to that found by the Langley.

This averaging scheme is the best alternative and refines the year-class strength estimates determined by surface catches alone. These "best estimates" of yearclass strength are given in Table 3.11. Surface c/f estimates in 1972 were adjusted with the average ratio for that species, by river, as determined in Table 3.10.

B. Yearclass strength, 1973.

Blueback young were significantly more numerous in 1973 than in 1972 in three nursery zones, about even in one, and decidedly down in one. Alewife were the same. Juvenile shad were up in four rivers and down in one. The Potomac River had a weak yearclass for every species and the James River had a good yearclass for every species.

The James River annual index for all species was approximately double that of 1972 but still only 29% for blueback, 6% for alewife, and 42% for American shad compared with 1970-1971 (Table 3.11).

The Pamunkey branch of the York River also had a stronger year for all species than 1972. Blueback increased by 10 times, alewife by nearly two, and shad by one and one-half. Yet compared with the 1970-1971 average, blueback were only 87% as abundant, alewife 13% as abundant, shad in 1973 were 200% as abundant compared to the 1970-1971 average.

The Mattaponi branch of the York River reflected no gain for blueback, but alewife were up three times and shad up four times over 1972. Compared with the 1970-1971 average, blueback juveniles were 15% as abundant, alewife 180% as abundant, and shad 387% as abundant.

The Rappahannock River also produced a good yearclass compared with 1972. Blueback yearclass strength was doubled, alewife had a slight decrease, and shad were up four times. Compared with the 1970-1971 average, blueback were 754% as abundant, alewife 600% as abundant, and shad 200% as abundant. Yearclass strength has been increasing since 1970.

The Potomac River produced the smallest yearclass of the last four years for every species. Compared with 1972, blueback were only 8% as abundant, alewife 15% as abundant, and shad 10% as abundant. Compared with the 1970-1971 average, juvenile blueback were only 5% as abundant, alewife at 6% abundance and shad at 30% abundance.

The juvenile alosids captured in surface water by the Langley over deep water, and by the Brooks over shallow water, were abundant in the same relative ratios (Table 3.7). As in previous years, the vast majority (typically above 85%) of all specimens captured were blueback. However, we have demonstrated that alewife and shad are usually far more abundant in midwater, therefore, the more accurate percentages for the entire nursery zone to 6 m are given in Table 3.12.

Midwater data compared with surface data (Table 3.8 and 3.9) indicate the preference of alewife and shad for the middle depths. The distribution with depth is clarified in Table 3.10 for a particular species. Blueback, by any analysis, outnumber all other species by at least a factor of eight in all rivers except the Mattaponi branch of the York River, which in 1970 had over 50% blueback.

The percentage abundance of the species (Table 3.12) does not indicate that any species is becoming dominant or extinct in any Virginia river. The percentages with some minor exceptions, have been fairly steady since 1970. This suggests that conditions for poor or good yearclasses operate across all species within a river and are river specific rather than species specific.

The stronger 1973 yearclass could reverse the declining catches by Virginia fishermen if these fish are recruited to the spawning migration in four years. If, instead, they are captured prior to spawning by the off-shore fleet, the Virginia adult catch probably will continue to decline after 1974. The 1970 yearclass of river herring was the best we have measured and adults from it should return to spawn in 1974. If 1974 is a poor year, then we will have further evidence that the off-shore fleet is catching a significant portion of the stock and affecting the inshore fisheries negatively.

C. General Index of Year Class Strength.

Yearclass strength should ideally be expressed in absolute numbers at some standard period (or size) after hatching. When several rivers contribute progeny to a stock, the mean c/f by river and species cannot be averaged to determine yearclass strength of the stock, because the rivers differ in size (x volume). Therefore, a final expansion factor which weights the river volume (section and depth which contain juveniles) must be multiplied by the annual index. We have utilized the volumetric statistics of Cronin (1971) and made some assumptions regarding the frequency distribution of juveniles with depth.

Since our grand average c/f (Table 3.11) reflects the surface and midwater densities to 5 m, we should have the river volumes to 5 m, but these data are not available. Cronin (1971) provides areal data by 5-mile increments and total volume of the segments, but river volume by depth contour has never been calculated. As a first approach, we could take the area of the nursery zones and consider it to have vertical sides. The areal statistics multiplied by 5 would then give the volume in m^3 down to 5 m. The major nurseries have extensive shoals in their lower third but, for the most part, the shore drop-off is rapid and the water quickly becomes 4-5 m. Over most of the zone the water is deeper than 5 m and through each zone a 10 m navigation channel is maintained. To account for shoals and other areas that are less than 5 m; we assume these zones cause the entire nursery zone to average only 4 m. This assumption is conservative because we know young alosids are often found below 5 m, in water 6-15 m deep.

The 5x5 ft Cobb trawl used in our work strains 1,062 m^3 in 10 minutes when towed at 2 k. We typically make random tows in regard to tide, depth and time of day. By using two boats we cover the entire river and the hundred or more tows from surface and midwater provide a reliable grand mean for the species and river. We can, therefore, use our grand c/f and compute total present by taking

$$N = \frac{\text{Vol of Nursery zone}}{\text{Vol of tow}} \cdot \text{Grand c/f}$$

for each species and river.

In 1970, the James River produced (contained in early fall), 1,633 M young blueback, 118 M alewife, and 30 M young shad (Table 3.13). The Rappahannock River, although very productive from the standpoint of fish per cubic meter, actually had a small input to the entire stock. The Potomac which typically had a low mean c/f for all species, produced 131 to 4 M blueback 1970-1973. Overall, the Potomac about equalled the Rappahannock River for blueback, produced more for alewife and shad. The York River, although small, has always produced fair quantities of alosids.

The James and York rivers produced the most shad, with the Rappahannock River the least. Of all the rivers the York was the most stable from 1970 to 1973 for production of young alosids. Table 3.11 compares the relative productivity of the rivers whereas Table 3.13 compares the contribution of each river to the entire stock.

The trend in total juvenile production for each species was downward from 1970 to 1972, and was reversed somewhat in 1973 (Fig. 3.1). However, the James River dominates all others, making it difficult to predict future yields even from the combined data. The juveniles produced in the James probably do not contribute to the yield in the Potomac and Rappahannock rivers because the fish tend to select their nursery river at spawning time. If only Potomac and Rappahannock juvenile production is considered, the overall prediction is for poor yields to continue. The James River, at present, has only a minor fishery for river herring, so its high juvenile production may not contribute much to the state yield in several years.

Hurricane Agnes in June of 1972 flooded the James and Rappahannock rivers, sending massive amounts of fresh water to Chesapeake Bay. This abnormal and huge freshet may have retarded production in the James River but seems to have stimulated production in the Rappahannock River (Table 3.13). The York River, which was little affected had a poor year for blueback but a good to normal year for alewife and shad. The Potomac River was likewise little affected and had a good year for blueback, alewife and shad juveniles. Thus in two flooded rivers the results were opposite and in two "unflooded" rivers the production was opposite in 1972. Overall 1972 was a poor year for every species, but the overt contradictions in production by river and species, do not allow us to conclude Agnes had anything close to a devastating effect on alosid production.

The Virginia blueback, alewife and shad commercial fishery will probably experience the result of the poor 1972 year class (all species, all rivers totaled) in 1976-1978. From 1974 to 1976 we expect adult catch to decline because each succeeding year will be supported by a weaker year class. But as Fig. 3.1 shows, the return to normal will probably not be sudden because the 1973 year class increased only slightly over 1972.

Literature Cited

Cronin, W. B. 1971. Volumetric, areal, and tidal statistics of the Chesapeake Bay estuary and its tributaries. Spec. Rep. 20, Chesapeake Bay Inst., Johns Hopkins Univ. Ref. 71-2. 135 pp.

Davis, W. J., W. J. Hoagman, J. V. Merriner, R. A. St. Pierre, and W. L. Wilson. 1972. Biology and Utilization of Anadromous Alosids. Ann. Rep. Anad. Fish Program, Virginia Inst. of Marine Sci. AFC-7-2. 132 pp.

Snedocor, G. W., and G. Cochran. 1967. Statistical Methods. Iowa State Univ. Press. Ames, Iowa. 593 pp.

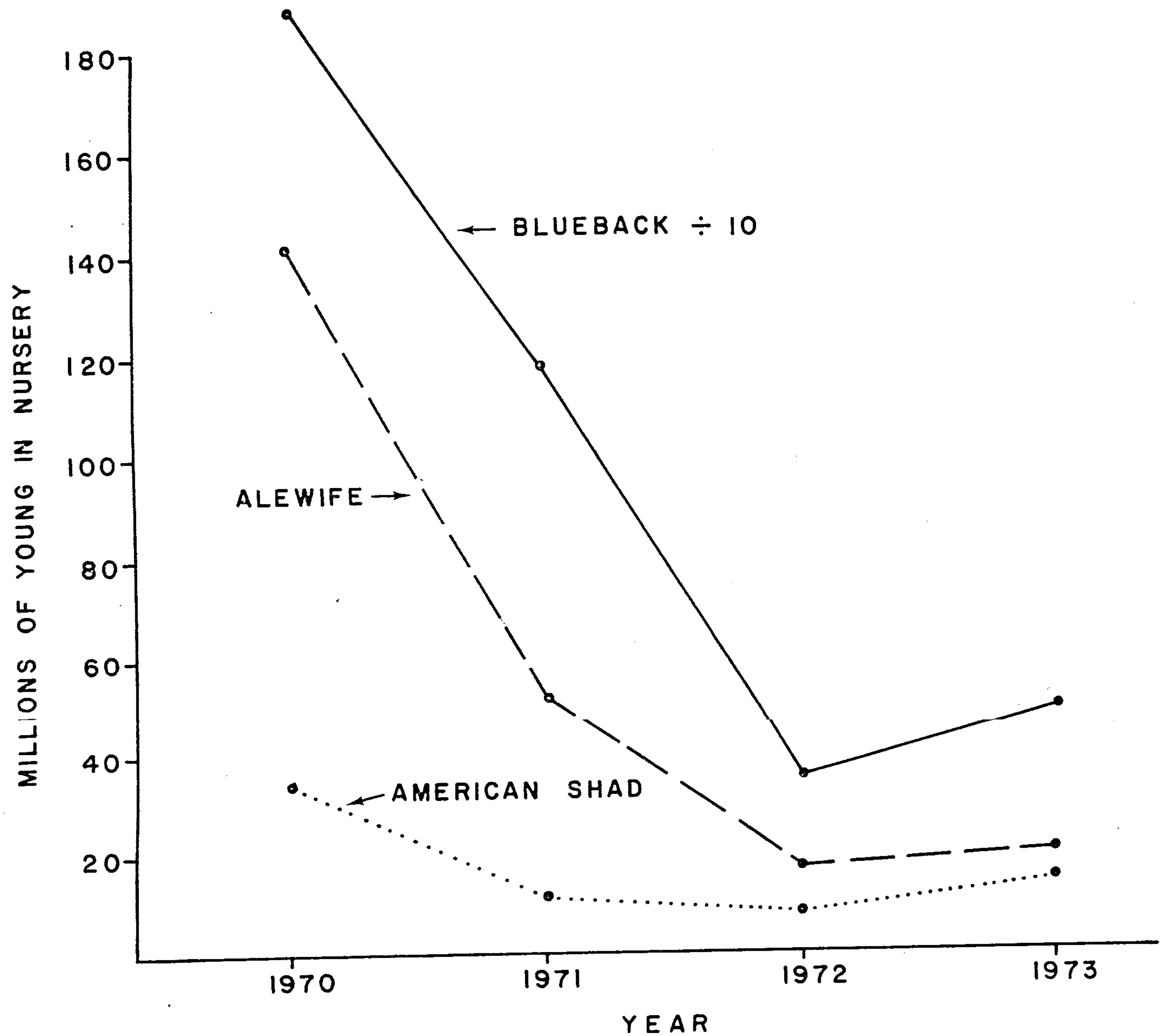


Fig. 3.1. Year class strength of alewife, blueback herring, and American shad expressed as total estimated number of young (Aug.-Sept.) in all major nursery zones (Fig. 1) for 1970 to 1973. Data from Table 3.13.

Table 3.1. Blueback herring caught by the R/V Brooks July 10 and 11, 1973 in the James River using a 5x5 ft Cobb net at the surface, and alternating tow times.

Stations	South Shore		Channel		North Shore	
	5 Min	10 Min	5 Min	10 Min	5 Min	10 Min
JA 55	4,550	3,061	759	8,645	750	7,632
JA 56	1,936	1,632	2,576	4,632	2,076	2,470
JA 57	5,664	1,891	265	791	1,468	5,168
JA 58	1,170	5,364	2,568	6,521	3,184	2,660
JA 59	5,418	6,513	3,011	5,537	2,739	6,742
JA 60	2,088	3,992	3,731	6,214	7,655	4,440
JA 61	1,224	4,046	3,948	2,804	1,203	6,336
JA 62	2,459	7,656	4,744	2,040	669	2,702
JA 63	2,916	9,799	5,980	9,083	4,527	8,265
JA 64	3,348	7,410	2,816	4,472	483	4,418
JA 65	360	3,860	8,364	22,044	1,767	3,638
Total	31,133	55,224	38,762	72,783	26,521	54,471

Table 3.2. American shad caught by the R/V Brooks July 10 and 11, 1973 in the James River using a 5x5 ft Cobb net at the surface, and alternating tow times.

Stations	South Shore		Channel		North Shore	
	5 Min	10 Min	5 Min	10 Min	5 Min	10 Min
JA 55	1	11	6	30	6	36
JA 56	13	32	4	4	7	60
JA 57	58	50	15	47	3	8
JA 58	10	81	0	10	28	21
JA 59	45	57	13	149	210	176
JA 60	24	40	0	91	14	16
JA 61	11	21	14	42	13	55
JA 62	77	145	88	34	13	49
JA 63	72	349	23	31	9	15
JA 64	13	52	55	56	14	148
JA 65	20	100	102	198	16	34
Total	344	938	320	692	333	618

Table 3.3. Alewife caught by the R/V Brooks July 10 and 11, 1973 in the James River using a 5x5 ft Cobb net at the surface, and alternating tow times.

Stations	South Shore 5 Min	South Shore 10 Min	Channel 5 Min	Channel 10 Min	North Shore 5 Min	North Shore 10 Min
JA 55	4	2	10	30	210	0
JA 56	17	57	8	16	15	105
JA 57	39	21	0	4	5	8
JA 58	0	0	12	0	17	350
JA 59	0	19	0	54	102	178
JA 60	124	152	21	117	216	64
JA 61	11	35	14	22	5	33
JA 62	17	45	16	194	32	14
JA 63	108	492	80	124	54	165
JA 64	47	39	0	0	15	68
JA 65	20	0	0	0	10	9
Total	387	862	161	561	681	994

Table 3.4 Statistics for experimental sampling of 5- and 10-min tows by the R/V Brooks in July, 1973 in the James River, Virginia. N = 33 for each type tow.

	Blueback 5 Min	Blueback 10 Min	American Shad 5 Min	American Shad 10 Min	Alewife 5 Min	Alewife 10 Min	Average 5m	Average 10m
Total Catch	96,416	182,478	997	2,248	1,229	2,417		
Ratio of Total Catch	1.893		2.255		1.967		2.038	
Mean Catch	2,720	5,079(1)	30.8	69.3	37.4	73.4(2)		
Standard Dev.	1,838	2,391	42.5	71.4	55.7	107.5		
Coef. of Variation	67.7%	47.1%	138.9%	103.0%	157.6%	130.1%	118.2%	98.8%
Increase in Precision	30.4%		25.9%		17.5%		28.2%(3)	
t-value	4.355		2.621		1.792			
Significance	$p \leq 0.001$		$p \leq 0.025$		ns at p = 0.05			
Corr. Coef-ficient	+ 0.178		+ 0.534		+ 0.295			
Significance	ns at p = 0.05		$p \leq 0.01$		ns at p = 0.05			

(1) Without JA 65

(2) Without JA 63

(3) Without alewife data

Table 3.5. Trawling effort with pelagic trawls for juvenile alosids in Virginia rivers. Five-minute tows made in 1969-1972, and 10-min tows made in 1973.

	R/V Langley				R/V Brooks		Total Towing Time Surface and Midwater
	Surface		Midwater		Surface		
	Tows	Minutes	Tows	Minutes	Tows	Minutes	
James							
1969	20	100	10	50			100
1970	46	230	10	50	38	190	470
1971	46	230	10	50	40	200	480
1972	92	460			73	365	825
1973	33	330	16	160	66	660	1,150
York-Pamunkey							
1970	30	150	3	15	35	175	340
1971	21	105	5	25	30	150	280
1972	42	210			66	330	540
1973	14	140	14	140	52	520	800
York-Mattaponi							
1970	25	125	4	20	25	125	270
1971	21	105	3	15	21	105	225
1972	44	220			50	250	470
1973	10	100	10	100	42	420	620
Rappahannock							
1970	31	155	5	25	26	130	310
1971	31	155	7	35	31	155	345
1972	62	310			62	310	620
1973	19	190	25	250	36	360	800
Potomac							
1970	31	155	7	35			190
1971	31	155	7	35	30	150	340
1972	62	310			62	310	620
1973	22	220	21	210	62	620	1,050

Table 3.6. *Effort and catch per unit of effort (c/f) for juvenile blueback, alewife, and American shad. Surface samples only; using the 5x5 Cobb trawl for 10 minutes. River miles refer to distance from river mouth at Chesapeake Bay; 1969-1972 data from 5-min tows (1972 Annual Report) multiplied by 2.038 for comparison with 10-min tows of 1973.*

River and Miles		R/V Langley					R/V Brooks			
		1969	1970	1971	1972	1973	1970	1971	1972	1973
James 35-80	Tows	20	46	46	92	33	38	40	73	66
c/f Blueback		497.9	3128.9	1481.2	691.3	1424.9	5199.1	1888.4	462.4	727.9
Alewife		73.9	191.0	16.3	3.1	0.4	355.8	44.8	5.1	4.2
A. Shad		47.7	36.1	6.1	5.1	1.0	61.3	9.7	4.1	7.8
York-Pamunkey 30-60	Tows		30	21	42	14	35	30	66	52
c/f Blueback			177.1	32.0	9.0	17.7	145.3	811.5	23.2	10.8
Alewife			17.7	2.6	1.6	0.8	11.6	6.3	1.4	0.3
A. Shad			3.3	1.4	1.8	1.9	6.7	2.1	4.3	3.4
York-Mattaponi 30-50	Tows		25	21	44	10	25	21	50	42
c/f Blueback			321.0	3.1	22.4	1.8	24.9	0.7	10.6	0.6
Alewife			12.6	10.2	6.1	0.5	7.1	0.1	0.2	0.02
A. Shad			9.4	8.4	9.2	12.4	13.0	9.6	4.7	4.1
Rappahannock 50-80	Tows		31	31(a)	62	19	26	31	62	36
c/f Blueback			69.1	67.9	203.0	556.4	135.9	45.0	290.8	646.6
Alewife			0.7	3.1	18.1	33.6	1.6	0.9	23.8	23.4
A. Shad			0.4	0.1	0.4	0.4	0.6	0.4	0.1	0.6
Potomac 65-95	Tows		31	31(a)	62	22		30(b)	62	62
c/f Blueback			214.0	3.9	37.7	1.1		27.3	22.2	3.6
Alewife			2.4	0.2	0.2	0.1		0.1	1.8	0.02
A. Shad			0.4	0.2	0.2	0.02		0.3	0.5	0.02

(a) Samples taken in November, juvenile migration probably underway

(b) Samples taken in October, juvenile migration probably underway

Table 3.7. Percentage distribution of the three principal *Alosa* species captured by the Langley and Brooks in the major Virginia rivers. Surface tows only.

River and Year	Blueback		Alewife		American Shad	
	Langley	Brooks	Langley	Brooks	Langley	Brooks
James						
1969	80.4		11.9		7.7	
1970	93.2	92.4	5.7	6.3	1.1	1.3
1971	98.5	97.2	1.1	2.3	0.4	0.5
1972	98.8	98.1	0.4	1.1	0.8	0.8
1973	99.9	98.4	0.0	0.6	0.1	1.1
York-Pamunkey						
1970	89.4	88.8	8.9	7.1	1.7	4.1
1971	88.9	99.0	7.2	0.8	3.8	0.3
1972	72.6	80.3	12.9	4.8	14.5	14.9
1973	86.8	74.5	3.9	2.1	9.3	23.4
York-Mattaponi						
1970	93.6	55.3	3.7	15.8	2.7	28.9
1971	14.3	6.7	47.0	1.0	38.7	92.3
1972	59.4	68.4	16.2	1.3	24.4	30.3
1973	12.2	12.8	3.4	0.0	84.4	87.2
Rappahannock						
1970	98.4	98.4	1.0	1.2	0.6	0.4
1971	95.5	97.2	4.4	1.9	0.1	0.9
1972	91.6	92.4	8.2	7.6	0.2	
1973	94.2	96.4	5.7	3.5	0.1	0.1
Potomac						
1970	98.7		1.1		0.2	
1971	90.7	98.5	4.7	0.4	4.6	1.1
1972	99.0	90.6	0.5	7.3	0.5	2.0
1973	91.7	99.7	8.3	0.3	0.0	0.0

Table 3.8. Average catch per unit of effort estimates for the principal alosids in the nursery areas of Virginia rivers. R/V Langley and R/V Brooks data weighted and combined from Table 3.6. Catch adjusted for tow time, surface only.

River and Year	Total Tows[a]	Blueback	Alewife	American Shad	Average Blueback & Alewife[b]	Average All Species[b]
James						
1969	20	498	74	48	192	121
1970	84	4,065	266	48	1,040	373
1971	86	1,671	30	8	224	74
1972	165	590	4	5	49	23
1973	99	960	3	6	54	26
York-Pamunkey						
1970	65	160	12	5	44	21
1971	51	491	5	2	50	17
1972	108	18	2	3	6	5
1973	66	12	0.4	3	2	2
York-Mattaponi						
1970	50	173	10	11	42	27
1971	42	2	5	9	3	4
1972	94	16	3	7	7	7
1973	52	1	0.1	6	0.3	0.9
Rappahannock						
1970	57	100	1	0.5	10	7
1971	62	56	2	0.3	11	3
1972	124	247	21	0.3	72	12
1973	55	615	27	1	129	26
Potomac						
1970	31	214	2	0.4	21	6
1971[b]	61	15	0.2	0.2	2	0.9
1972	124	30	1	0.4	5	2
1973	84	3	0.1	0	0.5	

(a) Surface tows only, 1969-1972 were 5-min tows, 1973 were 10-min tows.

(b) Samples taken in mid-November.

Table 3.9. Midwater trawl c/f and percentage distribution for the R/V *Langley* in Virginia rivers. All expressed as 10-min tows with a 5x5 Cobb trawl.

River and Zone	1969 c/f	1969 %	1970 c/f	1970 %	1971 c/f	1971 %	1973 c/f	1973 %
James - Mile 35-80								
Blueback	28.0	84.8	481.5	83.4	1511.9	93.1	160.5	85.7
Alewife	3.4	10.3	62.4	10.8	96.3	5.9	11.6	6.2
American Shad	1.6	4.9	33.1	5.8	16.4	1.0	15.1	8.1
York-Pamunkey 30-50								
Blueback			95.1	87.6	11.9	10.4	315.1	92.4
Alewife			11.4	10.5	99.4	87.3	16.6	4.9
American Shad			2.1	1.9	2.6	2.3	9.1	2.7
York-Mattaponi 30-50								
Blueback			4.5	48.9	20.5	31.3	28.1	22.7
Alewife			4.2	45.7	40.8	62.4	54.0	43.7
American Shad			0.5	5.4	4.1	6.3	41.5	33.6
Rappahannock 50-80								
Blueback			116.6	85.3	30.9	94.8	501.4	91.8
Alewife			19.5	14.3	1.6	4.9	43.9	8.1
American Shad			0.6	0.4	0.1	0.3	0.6	0.1
Potomac 65-95								
Blueback			122.7	70.4	3.7	82.[illegible]	5.7	78.1
Alewife			51.0	29.3	0.6	13.3	1.5	20.5
American Shad			0.6	0.3	0.2	4.4	0.1	1.4

Table 3.10. Ratios of average catch between surface and midwater tows from R/V Langley in the Virginia rivers. All data adjusted to 10-min tows with 5x5 Cobb trawl. Data from Tables 3.6 and 3.9.

River	Species	1969	1970	1971	1973	Average all years[a]
James	Blueback	17.9	6.52	0.97	8.9	5.63
	Alewife	21.7	3.10	0.17	0.03	0.77
	A. Shad	29.8	1.13	0.37	0.07	0.97
York-Pamunkey	Blueback		1.90	2.7	0.56	1.41
	Alewife		1.6	0.03	0.48	0.28
	A. Shad		1.6	0.54	0.21	0.56
Mattaponi	Blueback		71.3	0.15	0.06	0.86
	Alewife		4.2	0.25	0.01	0.22
	A. Shad		6.6	2.0	0.30	1.59
Rappahannock	Blueback		0.59	2.2	1.1	1.12
	Alewife		0.04	1.9	0.77	0.38
	A. Shad		15.6	1.32	0.67	2.38
Potomac	Blueback		1.71	1.1	0.03	0.38
	Alewife		0.05	0.33	0.07	0.10
	A. Shad		0.67	1.0	1.0	0.65
Average All Rivers[a]	Blueback		3.88	0.99	0.39	1.13
	Alewife		0.53	0.23	0.09	0.22
	A. Shad		2.61	0.83	0.21	0.36

(a) Geometric mean

Table 3.11. Annual index of yearclass strength for all species in all rivers using the combined data of two vessels and the midwater and surface samples. Figures are average c/f defined as a 10-min tow with the 5x5 Cobb trawl. Data from Tables 3.8 and 3.9.

River and Year	Total Tows	Blueback	Alewife	American Shad	Average Blueback and Alewife[a]	Average of All Species[a]
James						
1969	30	263.0	39.0	25.0	101.3	63.5
1970	94	2,273.0	164.0	41.0	610.6	248.2
1971	96	1,591.0	63.0	12.0	316.6	106.3
1972	165	368.0	4.6	4.9	41.1	20.2
1973	105	560.0	7.3	11.0	63.9	35.6
York-Pamunkey						
1970	68	128.0	12.0	3.6	39.2	17.7
1971	56	251.0	52.0	2.3	114.2	31.1
1972	108	15.0	5.5	4.2	9.1	7.0
1973	80	164.0	8.5	6.0	37.3	20.3
York-Mattaponi						
1970	54	89.0	7.1	5.8	25.1	15.4
1971	45	11.0	23.0	6.6	15.9	11.9
1972	94	17.3	8.3	5.7	12.0	9.4
1973	62	15.0	27.0	24.0	20.1	21.3
Rappahannock						
1970	62	108.0	10.0	0.6	32.9	8.7
1971	69	44.0	1.9	0.2	9.1	2.5
1972	124	234.0	38.1	0.2	94.4	12.1
1973	80	558.0	36.0	0.8	141.7	25.2
Potomac						
1970	38	169.0	27.0	0.5	67.5	13.2
1971	68	8.9	0.4	0.2	1.9	0.9
1972	124	54.0	5.5	1.0	17.2	6.7
1973	105	4.5	0.8	0.1	1.9	0.7

(a) Geometric mean

Table 3.12. Percentage distribution of the juvenile alosids from the combined c/f of the R/V Langley and R/V Brooks, surface and midwater. Data from Table 3.11.

River and Year	Blueback	Alewife	American Shad
James			
1969	80.4	11.9	7.7
1970	91.7	6.6	1.7
1971	95.5	3.8	0.7
1972	97.5	1.2	1.3
1973	96.8	1.3	1.9
York-Pamunkey			
1970	89.1	8.4	2.5
1971	82.2	17.0	0.8
1972	60.7	22.3	17.0
1973	91.9	4.8	3.3
York-Mattaponi			
1970	87.3	7.0	5.7
1971	27.1	56.7	16.2
1972	55.3	26.5	18.2
1973	22.7	40.9	36.4
Rappahannock			
1970	91.1	8.4	0.5
1971	95.4	4.1	0.4
1972	85.9	14.0	0.1
1973	93.8	6.1	0.1
Potomac			
1970	86.0	13.7	0.3
1971	93.7	4.2	2.1
1972	89.3	9.1	1.6
1973	83.3	14.8	1.9

Table 3.13. General estimates of yearclass strength and estimates of numbers of young alosids in Virginia rivers between August and September.

River and Miles included	Area in nursery zone, $10^6 m^2$	Volume in nursery zone, $10^6 m^3$	Volumes equated to smallest zone	Species	Estimated number present in early Fall, in millions. 1970	1971	1972	1973
James 35-80	190.8	763.2	15.97	Blueback	1633.2	1143.3	264.5	402.4
				Alewife	117.8	45.3	3.3	5.2
				American Shad	29.5	8.6	3.3	7.9
York-Pamunkey 30-60	25.6	102.4	2.15	Blueback	12.3	24.2	14.4	15.8
				Alewife	1.2	5.0	5.3	8.1
				American Shad	3.5	2.2	4.0	5.7
York-Mattaponi 30-50	11.9	47.8	1.00	Blueback	4.0	0.5	0.8	0.7
				Alewife	0.3	1.1	0.4	1.2
				American Shad	0.3	0.3	0.3	1.1
Rappahannock 50-80	32.4	129.4	2.71	Blueback	13.2	5.4	28.5	68.0
				Alewife	1.2	0.2	4.6	4.4
				American Shad	0.07	0.02	0.02	0.09
Potomac 65-95	206.2	824.8	17.26	Blueback	131.3	6.9	42.0	3.5
				Alewife	21.0	0.3	4.3	0.6
				American Shad	0.4	0.2	0.8	0.07
			Total					
				Blueback	1794.0	1180.3	350.2	490.4
				Alewife	141.5	51.9	17.9	19.5
				American Shad	33.8	11.3	8.4	14.9
			Total					
				All Species	1969.3	1243.5	376.5	524.8

Job 4. Community Structure and Trophic Dynamics of *Alosa* Nursery Areas

A. The Rivers and Their General Features

Nursery areas for *Alosa sapidissima*, *A. pseudoharengus* and *A. aestivalis* were located and mapped for the James, York, Rappahannock, and Potomac river systems (Fig. 1) during 1968 through 1970 for project FA AFC 1 Virginia. The length of the primary nursery zone in these rivers ranges from 30 to over 50 miles. Alosine fishes utilize both mainstream and tributaries within these freshwater areas. However, production of juvenile *Alosa* spp. within these zones differs both between rivers and between years (see Job 3 of this report). Given this background, our goal was to describe the nursery zone utilized by alosine fishes in a physical, chemical, and biological sense. Thus, we would have an understanding of the total system relative to this group of fishes and be able to provide plausible reasons for the variability in production between rivers and years.

The magnitude of the problem posed under this job dictated that our efforts be oriented toward discrete segments of the nursery system, i.e., physical and chemical factors, phyto- and zooplankton populations, and the predatory and competing fish populations. Where possible, we attempted to sample simultaneously for as many parameters as practical at each station. The data for 1971 and 1972 were presented in progress reports AFC 7-1 and 2, respectively. This completion report for 1970-1973 includes a summary of our efforts to define the various attributes of the nursery zone and the role of alosine fishes within it.

The James, York, Rappahannock, and Potomac river systems contribute approximately 40% of the freshwater input into the Chesapeake Bay.

Each river differs from the others in concentrations of dissolved minerals and nutrients as well as land use patterns.

The James River has a drainage basin of approximately 10,000 $miles^2$ and lies in four physiographic provinces: coastal plain, Piedmont, Blue Ridge Mountains, and ridge and valley. Tidal fluctuations in water level exist from the river mouth to Richmond, approximately 85 nautical miles inland. Flows, as measured above Richmond, have ranged from 320 cf/s to 325,000 cf/s with an average annual discharge of 7,500 cf/s.

Nutrient enrichment in the tidal portion of the James River originates from the Richmond metropolitan area (Mile 84) and the Hopewell area (Mile 65). Brehmer (1972) reported approximately 2.7 MT of phosphorous and 8.2 MT of nitrogen in various forms being added per day by effluents from Richmond. Additional loading from industrial and domestic sources occurs at Hopewell.

High nutrient concentrations and plankton populations typify most of the alosine nursery area in the James River. Nutrients concentrations (Total N, NO_2+NO_3, and PO_4) in the James River are higher than in other Virginia tributaries monitored in our survey and approximate values presented by Jaworski, Villa and Hettling (1969) for the Potomac River near Washington, D.C. An oxygen sag occurs downriver from the Richmond sewage outfall with values of 1 ppm or less occurring as far downstream as Mile 75 in late summer. In this sense the James River may be characterized as an enriched environment with the attendant problem of potential D.O. blocks in mainstream areas.

The Potomac River drainage basin includes 14,670 miles^2 from its headwaters on the eastern slope of the Appalachian Mountains to its mouth at Smith Point. The tidal portion of the river extends from the Fall Line near Washington, D.C. to the river mouth, approximately 100 nautical miles. Discharge as measured near Washington ranges from 1,000 to 90,000 cf/s with an annual average flow of 11,000 cf/s.

Nutrient enrichment is evident in mainstream from Washington, D.C. (Mile 95) to below Quantico, Virginia (Mile 60). Reports detailing the various nutrient and chemical attributes of the upper Potomac River include Jaworski, Villa, and Hettling (1969); Jaworski (1969); and Jaworski, Leer, and Villa (1971). Nutrient loading of the Potomac River in the nursery area for alosine fishes is greater and more widespread than that in the James River. Washington, D.C. contributes approximately 10 tons N/day and 6 tons P/day. The upper tidal portion of the Potomac River (miles 70-94) has depressed D.O. values due to the nutrient load and plankton bloom during summer months. Algal growth becomes quite noticeable in summer when <u>Microcystis aerginosa</u>, a blue green alga, forms a dense layer at the water surface in the mainstream Potomac as far downriver as Quantico (Carpenter, Pritchard, and Whaley, 1969).

The Rappahannock River has a drainage basin of 2,700 miles^2 and is tidal from its mouth to the Fall Line at Fredericksburg (approximately 95 nautical miles). Discharge, as measured at Fredericksburg, has ranged from 5 to 140,000 cf/s with an average annual flow of 1,600 cf/s (Brehmer, 1972).

Nutrient loading in the Rappahannock River occurs in the vicinity of Fredericksburg from domestic and industrial effluents. The magnitude of the N and P additions to this river is lower than that for either the James or Potomac river. Dissolved oxygen values are depressed for approximately 20 miles downriver from Fredericksburg with the lowest values occurring in late summer during periods of high water temperature and low flow.

The York River system has a drainage basin of 2,660 miles^2. It includes both the Pamunkey and Mattaponi rivers. Average annual flow is approximately 2,200 cf/s with extremes of 300 and 37,800 cf/s (Brehmer, 1972). Nutrient enrichment within the alosine nursery area of the York River comes from agricultural sources in the upper basin and a pulp mill plant located at West Point with its discharge in the Pamunkey River (Mile 29). Nutrient levels in the nursery areas of the York system approximate those of the Rappahannock River (Brehmer, 1972).

Each river system differs in the type of habitat found along its shoreline in the tidal portion (Table 4.1) and in the contribution of organic material of plant origin to each system. Wetlands of all types are an integral part of the estuary and are significant in a number of ways to the ecology of the system (i.e., nutrient cycling, sediment trap, food source, primary production, detritus production, etc.). Tidal fresh- and saltwater marshes have been researched intensively in recent years and are of great importance to the ecology of the estuary. The James River ranks highest in total acreage of bordering wetlands (47,991 acres), the York is second with 36,769 acres, Rappahannock is third with 33,812 acres and the Potomac is fourth with 18,349 acres. The York system has the greatest acreage of fresh- and saltwater marsh (23,482 acres) followed by the James (18,161 acres), Rappahannock 15,496 acres) and Potomac (8,835 acres).

The size of the alosid nursery area, mainstream plus tributary, varies six-fold between these river systems: Potomac, 60,979 acres; James, 41,417 acres; Rappahannock, 15,599 acres; and York, 10,994 acres (Table 4.2). One might expect production of juvenile alosid fishes to be a function of size of the nursery area, in which case the above order should rank production of juveniles. Given the significance of marshes to estuarine systems and their biological productivity, a potential ranking could be based upon the amount of marsh per acre of nursery area in each system. In this framework the York system is first (2.1 acre marsh/acre open water) followed by the Rappahannock (1.0), James (0.4), and Potomac (0.3).

Each of the foregoing features contributes its share to the production of alosine fishes. However, the ultimate question lies in definition of the importance of each factor to the production of these juvenile finfishes.

B. Sampling Plan

A survey of the biotic and abiotic characteristics of the alosine nursery areas was conducted during the 1971 season. Description of the nursery area within each tributary posed the immediate problem of sampling intensity, significant parameters, and personnel allocation. All five nurseries were sampled during the 1971 season on a monthly schedule (James, Pamunkey, Mattaponi, Rappahannock, and Potomac rivers). Three stations were selected in each river (Fig. 4.1) with the middle station approximating the center of the alosine juvenile abundance and the other stations in the upriver and downriver third of the nursery zone. Water chemistry, nutrients, and primary productivity data were collected during the first week of each month (May through October). Fish and plankton data were collected during the third week of each month (May through October) at the same stations. Parameters monitored in each nursery during 1971 are listed in Table 4.3. Water quality and partial analyses of food habits data were presented in Davis et al. (1971).

The data base developed during 1971 provided a general description and characterization of the alosine nursery area as well as same year comparative data between nurseries. However, it did not allow a critical evaluation of intranursery fluctuations in nutrients, productivity, and plankton populations. We concluded that an indepth analysis of a single nursery area would provide a better understanding of the parameters and their relationship to alosine fishes. Given this information, we could relate trends within the nursery to the descriptive data base developed in 1971 and arrive at meaningful comparisons.

The James River nursery zone was selected for intensive study during the summer of 1972. Production of alosine fishes in this system is high and considerable background data exist for various physical, chemical and biological factors.

Five stations were selected within the nursery zone of the James River (Fig. 4.2): three mainstream (continued from 1971 program), one in Turkey Island Oxbow, and one in Powells Creek (4 miles downstream from Hopewell). All stations were in known nursery waters for alosine fishes. Each station was visited weekly from May 15 through

August 8 and biweekly thereafter through September. Parameters monitored at each station are given in Table 4.4. Physical, chemical, nutrient, productivity, alosine growth, zooplankton community, and stomach content data were collected simultaneously. Some of these data were presented in Davis et al. (1972).

Comparisons between nursery zones relative to basin characteristics, physical factors, and primary productivity provide a relative ranking of habitats and a means of assessing alosine production in each river system. Natural fluctuations in the above parameters are a product of multiple factors and their interactions.

Our field program amassed a considerable data file on the physical and chemical characteristics of the nursery zones in 1971. The variability within particular parameters at each level of analysis (station to station, season, and river to river) ruled out detailed comparisons between rivers. Trends in parameters, however, were evident and were discussed in Davis et al. (1972). Project data for the river systems are compared with data from Jaworski and Hettling (1970) as a preface to information on the alosine fishes in the various rivers.

C. Nutrients

Nutrient data from the James River near Richmond, the Rappahannock River near Fredericksburg, the Potomac River at Great Falls, the Patuxent River at Route 50 bridge, and the Susquehanna River at Conowingo Dam were reported by Jaworski and Hettling (1970) and are summarized in Table 4.5. Data for the James River near Dutch Gap in 1972 are also given. Mean monthly concentrations of total Kjeldahl nitrogen,

NO_2 nitrogen, NO_3 nitrogen and total PO_4 are shown for the period June through October 1969.

Phosphate concentrations were highest in the Patuxent River (2.2 to 5.6 ppm) and lowest in the Susquehanna River (0.09 to 0.15 ppm). Phosphate fluctuations were slight in all rivers except the Patuxent. Mean summer concentrations of PO_4 were typically less than 0.6 ppm. Data from Dutch Gap (James River, 1972) were similar to those for the Potomac River in 1969.

Total Kjeldahl nitrogen levels (TKN) were greatest in the Patuxent River (1.25 to 2.45 ppm) and generally lowest in the Susquehanna and Rappahannock rivers. The James and Potomac rivers were intermediate in TKN with concentrations ranging from 0.4 to 1.1 ppm.

Inorganic nitrogen (NO_2 and NO_3) was highest in the Patuxent River (1.55 to 2.60 ppm) and lowest in the Rappahannock River. Variability in the monthly values for NO_2 and NO_3 exceeds that for PO_4 and TKN and is attributable to fluctuations in river discharge. Inorganic nitrogen concentrations at Dutch Gap (James River, 1972) were comparable to those reported for the Patuxent, and were two to five times greater than concentrations in the James in 1969.

Nutrient concentrations and distributions within the alosid nursery areas are not of high predictive value in the assessment of alosine fish production in tidal estuaries. The alosine nursery areas are not nutrient limited in the sense that applies to lakes or upland fresh-water streams. Rather, primary production in these estuarine areas is limited by the depth of light penetration and surface area. Agricultural runoff, industrial effluent, and domestic sewage, coupled with tidal flushing of the bordering marshland, contribute to the nutrient pool for nursery areas. Addition of nutrients to the water does increase the productivity potential of the affected system. With tidal action, the nursery area for alosines and other estuarine fishes experiences a longer exposure to these nutrients, and thus the productivity of the estuarine waters is much greater than lakes and non-tidal streams. Because of this, each attribute must first be examined singly.

D. Standing Crop and Primary Productivity

Primary productivity rates and estimates of standing crop in the nursery zone are the bases for trophic analysis and energy flow. An understanding of these characteristics and their fluctuations or patterns is necessary to answer such questions as, "Why is this zone a nursery for alosine fishes?" or "Why is river X a better producer of alosine fishes than river Y?" The analytic techniques employed in this analysis were C^{14} uptake and fluorometry after Strickland and Parsons (1968).

Standing crop within the areas of the rivers studied was variable between stations and between rivers during the same sample interval. Chlorophyll a concentrations represent an estimate of the standing crop of primary producers in the water column and, while not directly related to nutrient loading, they do reflect relative eutrophication of the systems. The problems associated with predictive significance of standing crop as estimates of production, lie in the different values obtained depending upon river discharge (turbidity), tidal stage, time of day sampled, dominant species, and methodology (Flemer et al., 1970). Thus, comparisons of a detailed nature between rivers and between years become tenuous at best. Standing crop, as indicated by Chlorophyll a, increases during the summer and parallels the gradual increase in water temperature of the river (Fig. 4.3). Highest standing crop does not occur at the upriver end of the alosine nursery; rather, the middle and lower portions in each river have greater populations of phytoplankton. This is attributed to the location of point sources of nutrients in the form of industrial and domestic sewage from cities situated on the James (Richmond), Rappahannock (Fredericksburg), and Potomac (Washington metropolitan area). The mineralization phase of sewage decomposition, which essentially contributes NO^3 and PO^4 to the water, is generally completed near the middle zone of the alosine nursery. The similarity of the Mattaponi and Pamunkey to the other rivers is attributed to the predominance of forested areas in the upper nursery area and farming in the middle and lower areas. Thus, release of nutrients to the system in the forested areas is less than from tilled land. This is reflected by the abundance of the phytoplankton population.

A ranking of the nurseries on the basis of phytoplankton standing crop Chlorophyll a follows that expected from the magnitude of nutrient loading, i.e., Potomac, James, Rappahannock, Pamunkey, and Mattaponi rivers (Fig. 4.3). Data from the three stations in each river were pooled to obtain the data points plotted. Discrete station to station variations in the pattern of standing crop within a single nursery are shown for the James River in 1972 (Fig. 4.4). The greater standing crop in the tributary stream, Powells Creek, relative to the other stations is of significance (Fig. 4.4). Mainstream and oxbow stations are quite similar throughout the season, both in magnitude and pattern of Chlorophyll a. The 1972 season was not typical in that there were three peaks of flood waters flushing the system (Fig. 4.5). The pulses in standing crop data for 1972 indicate development of successive bloom conditions following periods of high runoff.

Primary productivity was highest in each river during the month of June in 1971, coincident with development of early summer bloom conditions in the nursery areas (Fig. 4.6). Springtime levels of primary productivity were generally less than 5 $mgC \cdot m^3 \cdot hr$ in all rivers. Productivity rates generally ranged from 10 to 30 $mgC \cdot m^3 \cdot hr$ during June through August. The aberrant value for the lower station in the Rappahannock River during June (109 $mgC \cdot m^3 \cdot hr$) is attributed to absorption of isotope by suspended silt in the water. The variability in the data between stations, months, and rivers cited earlier is plainly evident in the data points shown. A trend toward an early summer peak followed by a stabilization at a lower rate of primary productivity was evident.

Ranking the rivers on the basis of total primary productivity placed the Potomac as most productive, followed by the James, Rappahannock, Pamunkey, and Mattaponi rivers, respectively (Table 4.6). The order obtained was due to the influence of the relative surface areas in the rivers. Ranks attained, by comparing primary productivity over a standard area within the various rivers (1,000 m^2), were different from that expected, i.e., Potomac, Pamunkey, James, Rappahannock, and Mattaponi rivers (Table 4.7).

Primary productivity data from the James River in 1972 demonstrated depression of photosynthesis during high runoff periods and different effects for flood waters in mainstream waters and tributaries.

Passage of Tropical Storm Agnes and its flood waters, which occurred in late June, caused a reduction in the depth of 10% light penetration in the mainstream and oxbow stations (Fig. 4.7), with a corresponding decline in primary productivity (Fig. 4.8). Two additional high discharge periods (July 8 and August 2, Fig. 4.5) caused similar responses. These effects, however, were not evident in Powells Creek during the same periods (Figs. 4.7 and 4.8).

The waters of the tributaries were more uniform in clarity and had higher primary productivity rates than did mainstream waters. The productivity rates for Powells Creek ranged from 1.2 to 24.5 $mgC \cdot m^3 \cdot hr$ while the Hopewell station ranged from 0.06 to 16.7 $mgC \cdot m^3 \cdot hr$ (Fig. 4.8). This suggests a need to define the production of juvenile alosine fishes in the tributaries compared to the production in the mainstream.

E. Alosine Food Habits and Zooplankton in the Nursery Zone

The food habits of alosine fishes have been analyzed for estuaries (Massmann, 1963; Burbidge, 1974) and lakes (Brooks and Dodson, 1965; Hutchinson, 1971; Morsell and Norden, 1968; and Norden, 1968). Most authors have indicated some degree of selection for prey items by individual species. In this study we sampled five nurseries and examined the three dominant alosines which occur in each nursery. This represents a broad geographic area and allows comparison of food habits between nurseries. Insights into the partitioning of the food resources among co-occurring alosine fishes are also gained. We are continuing this study to evaluate the energy budget of alosine fishes in the James River.

In the summer of 1971 juvenile alosine fishes were collected from three stations in each of five nurseries (Fig. 4.1) by means of a 5 X 5 ft Cobb midwater trawl. Young alewife, blueback and American shad were sampled monthly from June through October in the James River. Collections made during July and August in the Mattaponi, Pamunkey, Rappahannock, and Potomac rivers were selected for internursery comparisons of food habits. Fishes taken with the trawl were counted, measured and preserved in 10% formalin for laboratory analysis of stomach contents. Up to ten specimens/species per river/month were retained for analysis.

Zooplankton samples were obtained concurrently with fish collections by pump and meter net techniques. The pump sample (100 gal of water from the surface to 5 m depth) was obtained by filtering the water through two nets of different mesh size. The water was passed first through 202 micron Nitex and then 35 micron Nitex. Organisms retained in these two nets were fixed in the field with 4% formalin and returned to the laboratory for analysis. A meter net (376 micron mesh) was towed for 5 min concurrently to census larger zooplankton and to provide a check on pump avoidance.

Selectivity indices (E) were generated for the food categories of alosines following Ivelev (1961):

$$E = (r_i - p_i) / r_i + p_i)$$

Where r_i is the percent of plankter i in the stomach and p_i is the percent of plankter i in the plankton. The range obtainable with this index is +1 to -1. E values represent the degree to which food organisms are selected or avoided by the fish.

F. Results of Feeding Study

1. James River

Zooplankton in pump samples from the James River near Hopewell (JA 63) during June through October 1971 included cladocera (31 to 82%), immature copepods (16 to 66%), and adult copepods (1 to 6%) (Table 4.8). Other organisms, including insects, ostracods, etc., totalled less that 1% of the zooplankton sample. Rotifers were often present in large numbers in the 35 micron net portion of the samples but were not categorized as a major zooplankton component since juveniles do not normally feed on them. Larval and postlarval alosines, however, do utilize rotifers as food items (Davis et al., 1970).

Pump samples from the James River included seven species of cladocerans and six species of copepods (Table 4.9). The dominant cladoceran throughout the study period was Bosmina coregoni (82%) and the second most abundant form was Diaphanosoma branchyurum (11%). The remaining five species, (Daphnia parvula, Camptocercus rectirostris, Leydigia acanthocercoides, Leptodora kindtii, and Alonella acutirostris) in aggregate represented only 7% of the individuals in the samples. Cyclopoid nauplii and copepodites represented 94% of the juvenile copepods in the samples and Acartia tonsa was the most abundant adult form of copepod. Adult copepods, large cladocerans (i.e., Leptodora kindtii), insects, and fish larvae were not adequately sampled by the pump technique. Meter net collections taken at the same station and date provide a better estimate of relative abundance for the larger zooplankton species. Quantification of the meter net data was not attempted in this study since flow meters were not used during the collections.

Three cladocerans (*Leptodora kindtii*, *Daphnia parvula*, and *Diaphanosoma branchyurum*) made up 71% by number of the meter net catch from the James River during June through October in 1971. Fish larvae (mostly *Anchoa mitchilli*) and adult copepods (*Cyclops*, *Eucyclops*, *Diaptomus* and *Eurytomora* represented 13.5 and 11% of the meter net catches, respectively.

Blueback - Only two bluebacks were collected during June in the James River and each measured 22 mm FL. The 30 food items in their stomachs were cladocerans (27%), immature copepods (46%) and adult copepods (27%). At this small size, rotifers could have been a major food item, but post-mortem digestion would account for their apparent absence in the food item list.

In July, 10 bluebacks consumed 41% cladocerans (*B. coregoni* and *D. branchyurum*) and 59% juvenile copepods. In August, September, and October, 10 bluebacks were taken each month for stomach analysis. Mean lengths increased from 48 mm in August to 58.1 mm in October. Cladocerans made up 85 to 96% of the diet each month with immature copepods contributing the remaining 4 to 13%. Food habits of bluebacks are summarized in Fig. 4.9 for the data from the James River in the summer of 1971.

Bluebacks appear to randomly feed upon small zooplankton in the James River. Immature copepods and the cladocerans *B. coregoni* and *D. branchyurum* represented 94% of all organisms in the pump samples and 97% of all food items in the stomachs.

Cyclops vernalis, *Eucyclops agilis*, *Diaptomus reighardi*, *Eurytemora affinis* and fish larvae, though well represented in the meter net collections (24% numerically), were rarely found in the stomachs of blueback herring (1%). Bluebacks of this size may actively avoid the larger plankters since alewife of similar sizes had ingested the larger plankters.

<u>Alewife</u> - The six alewives taken in June averaged 33 mm FL and the composition of the food items, by number was larval anchovy (47%), immature copepods (29%), and cladocera (19%).

In July, the stomach contents of nine alewives, included 68% cladocera and 30% immature copepods. Stomachs of 10 alewives in August contained 58% adult copepods, 30% cladocera and 6% juvenile copepods. The September sample of 10 fish indicated a shift back to cladocera (86%) as the major food. Stomachs from nine alewives taken in October were almost empty (a total of 59 food items present). This suggests a reduction in feeding intensity prior to downriver migration. Food habits of alewife juveniles are summarized in Fig. 4.10 for data from the James River in 1971.

During the 5-month study period, alewives ingested 59% cladocerans and immature copepods and 41% adult copepods, insects and fish. It appears that alewives are actively selecting larger organisms. <u>Bosmina coregoni</u> and <u>D. branchyurum</u> were the dominant cladocerans in the stomachs and <u>Eucyclops agilis</u> was the dominant copepod.

<u>American Shad</u> - The collections of American shad in June revealed that this species also fed on larval anchovies, if available. During July, August, and September, cladocerans represented 77 to 97% of the food items in shad stomachs with adult copepods and immature copepods splitting the remainder. These fishes (10 each month) averaged 58.4 (July) to 74.8 mm FL (September). In October, stomach contents of eight shad which averaged 75.8 mm FL contained 77% insects (mostly

coleopterans). However, as with the alewife, the stomachs contained little food with only 17 items per stomach. Food habits of the American shad juveniles are summarized in Figure 4.11 for data from the James River in 1971.

The food habits of American shad in the James River were intermediate between those of the blueback herring and alewife (Fig. 4.12). Cladocerans and juvenile copepods represented 80% of the food items numerically and adult copepods, fish larvae, insects, and other items made up the remaining 20%. Of the three species examined, it appears that the shad diet most closely reflects the plankton crop in the nursery (Fig. 4.13). Bluebacks apparently avoid the larger organisms (selective for smaller items) and alewives select larger copepods and cladocera.

2. Pamunkey River

Fish and plankton collections in the Pamunkey River were made during July and August of 1971 in the vicinity of the Pamunkey Indian Reservation, approximately 50 miles from the mouth of the York River. The standing crop of zooplankton from the pump samples in July was 55% cladocerans (mostly *B. coregoni*), 42% immature copepods, and 3% adult copepods, Tables 4.10 and 4.11). In August, cladocerans represented only 24% of the sample and immature copepods made up 75%. As in the James River, the composite meter net collections in the Pamunkey River reflected a different composition. Small organisms such as *B. coregoni* and juvenile copepods were rare in the meter net (mesh size selection). Dominant zooplankton in these collections were the cladoceran, *Leptodora kindtii* (59% numerically, water mites (hydrocarinids) (21%), and the adult copepods C. vernalis, E. agilis, D. reighardi, and E. affinis (12%).

Bluebacks - Stomachs from 10 bluebacks each month (July and August) were used in the analysis of food habits for the Pamunkey River (Fig. 4.14). In July, stomachs from bluebacks which averaged 41 mm FL contained 98% cladocerans (mostly B. coregoni). In August the bluebacks continued to feed heavily on Bosmina (90%) but also included immature copepods (7%) and ostracods (2%).

Alewife - Alewives used for stomach analysis included 10 fish taken in July and eight fish taken in August (Fig. 4.14). In July, the stomach contents of alewives included 67% cladocerans (mostly D. branchyurum), 26% juvenile copepods, and 6% adult copepods. The collection of alewives for August came from a station 15 miles further downriver than the July collection. This sample suggested different feeding habits in the two areas because no cladocerans were consumed. Immature copepods represented 35% of the food items numerically, adult copepods were 6% and the remaining 59% of the diet consisted of mysid shrimp. The meter net collection at this station consisted of 98% mysids.

American Shad - July and August samples of American shad were taken from the upriver location. In July, stomachs of 10 fish contained 45% cladocerans, 26% immature copepods, 11% adult copepods, and 18% ostracods and insects (Fig. 4.14). In August, however, 10 shad of similar size had eaten 13% cladocerans, 47% immature copepods, 26% adult copepods, and 14% ostracods and insects.

The comparative food habits of alosine fishes in the Pamunkey River (Fig. 4.15) suggest a greater degree of selectivity in feeding than in the James River. Lower density of forage items in the Pamunkey River appears to result in different grazing strategies by the same species of fish in different rivers.

3. Mattaponi River

Juvenile alosine fishes and plankton in the Mattaponi River were collected in the vicinity of Mantapike, 45 miles above the mouth of the York River. The July zooplankton sample contained 82% juvenile copepods, 13% cladocerans (*D. branchyurum* and *B. coregoni*) and 4% adult copepods (Table 4.12). In August, juvenile copepods were 98% of the plankton standing crop in the pump sample. Meter net collections were, as in the other rivers, quite different. Cladocerans (mostly *Leptodora*) represented 38% of the catch, adult copepods made up 4%, insects and mites contributed 51%, and other crustaceans made up 6% of the catch (Table 4.10).

Blueback - Stomach contents of 10 blueback herring taken in July consisted of 75% adult copepods, 21% juvenile copepods, and 4% cladocerans. In August, the diet of three bluebacks consisted of 79% juvenile copepods, 17% adult copepods and 2% cladocerans (Fig. 4.16).

Alewife - Alewives from the Mattaponi River showed similar food preferences. In July, stomachs from 10 fish contained 78% adult copepods and 20% juvenile copepods. In August, nine fish had eaten 45% adult copepods and 48% juvenile copepods as well as 6% cladocerans (Fig. 4.16).

American Shad - Ten American shad collected in July from the Mattaponi River consumed mostly copepods (35% adults and 50% juveniles) (Fig. 4.16). In August, nine shad had consumed 76% adult copepods and 20% juvenile copepods.

In summary, all three species in the Mattaponi River during both months consumed 85-98% copepods, by number, while the plankton crop from the pump samples consisted of 85 to 98% copepods. Differences between species did exist in the proportion of adult and immature copepods which were present in the fish stomachs (Fig. 4.17).

4. Rappahannock River

In July and August 1971, plankton and fish collections were made at a station five miles above Port Royal on the Rappahannock River. The July sample of zooplankton contained 40% cladocerans, mostly *B. coregoni*, 54% immature copepods and 6% adult copepods. In August, cladocerans made up 50% of the sample and 49% of the sample consisted of immature copepods (Table 4.13 and 4.14). Meter net collections in the same period consisted of 66% cladocerans (mostly *L. kindtii*), 25% adult copepods (*E. affinis*, *E. agilis*, and *C. vernalis*), and 8% insects and mites.

Bluebacks - Ten bluebacks collected in July for stomach analysis had a mean length of 35 mm FL, and their stomachs contained 74% cladocerans (mostly *B. coregoni*) and 26% adult copepods. In August, 10 fish had eaten 69% cladocerans and 29% adult copepods (Table 4.13 and Fig. 4.18).

Alewife - Ten alewife taken in July consumed 93% cladocerans and 7% adult copepods (Table 4.13 and Fig. 4.19). In August, however, 10 alewives consumed 62% cladocerans, 21% adult copepods, and 17% immature copepods.

American Shad - No American shad were collected in July of 1971 from the Rappahannock River stations. The August collections yielded seven American shad whose diet was 52% cladocerans, 45% adult copepods, and 3% insects and arachnids (Table 4.13 and Fig. 4.18).

It appears that all three alosines examined from the Rappahannock River are avoiding juvenile copepods and actively selecting the adult form (Fig. 4.19).

5. Potomac River

Fish and plankton collections from the Potomac River in July and August of 1971 were made in mainstream near Quantico. The plankton pump sample taken in July consisted of 62% cladocerans (mostly *B. coregoni* and *Leydigia acanthocercoides*), 37% immature copepods, and 1% adult copepods. In August, cladocerans made up 84% of the zooplankton sample and copepods contributed only 14% (juveniles) and 2% (adult) to the sample. Meter net collections in the same area consisted of 91% cladocerans (mostly *D. parvula*, *D. branchyurum*, and *L. kindtii*), 6% adult copepods and 3% insects and mites (Tables 4.14 and 4.15).

Blueback - Stomach analysis performed on 10 bluebacks in July revealed that cladocerans represented 48% of the food items numerically with *L. acanthocercoides* being dominant followed by immature copepods (36%) and adult copepods (15%). In August, the 10 fish examined had eaten 90% cladocera, 7% immature copepods and 3% ostracods (Fig. 4.20).

Alewife - Alewives were considerably larger than the bluebacks taken in a given sample. The July sample of 10 alewives revealed a diet consisting of 44% cladocerans (mostly *L. acanthocercoides* and *B. coregoni*), 46% immature copepods and 10% ostracods. In August, 10 alewives had consumed 61% cladocerans, 20% immature copepods, 18% ostracods, and 1% adult copepods (Fig. 4.20).

American Shad - No American shad were collected in the Potomac River during the July period. Three shad collected in August had consumed 44% cladocerans, 36% immature copepods, and 17% ostracods (Fig. 4.20).

The juvenile alosine fishes in the Potomac River appear to be randomly feeding upon small planktonic crustaceans and algae, in that stomach contents closely approximate the standing crop of zooplankton (Fig. 4.21 and Tables 4.14 and 4.21). All species of *Alosa* in the Potomac River had consumed a considerable quantity of blue-green algae.

A listing of major food items in the stomachs of blueback herring, alewives, and American shad from all of the rivers surveyed during July and August of 1971 is presented in Tables 4.16 through 4.20. Composite meter net collections for July and August in each river are given in Table 4.21.

Electivity indices suggest a partitioning of the food resources in the nursery areas by the three *Alosa* species examined (Table 4.22). Indices were calculated for the pump samples of zooplankton and stomach content data from the James River. Blueback consistently selected for cladocerans throughout the summer months (+.09 to +.48) and against all life stages of copepods (-.05 to -.72). In contrast, Burbidge (1974) found a strong positive selection for adult copepods. Alewives, however, have a strong preference for adult copepods (-.50 to +.93) and a weak selection for cladocerans (-.38 to +.33). Immature copepods are strongly selected against by the alewife (-.30 to -.52). American shad electivity values were inconsistent for adult copepods and cladocera. This is attributed to relative dominance of these organisms in a given sampling period. The "other" category of food items which includes ostracods, insects, and fish is more important in the food habits of the American shad than for either river herring species.

G. Discussion and Summary of Feeding Habits

Feeding biology is a complex aspect of fish life history and even more difficult in a comparison of co-occurring fishes of similar feeding habits. Whether or not a fish eats any given prey item may depend upon the morphology of the fish, fish size, time of day, preference for that item, size of prey, density of prey item being considered, etc. A complete food habits study should include collections of fish and prey organisms at various depths and time intervals throughout the day and night.

Preferred food items have been reported for the American shad and alewife but blueback herring are considered as random feeders on the zooplankton. Juvenile shad in the Mattaponi River actively feed upon surface insects during the early evening (Massmann, 1963). Brooks and Dodson (1965) and Hutchinson (1971) noted selective feeding by alewives on the largest zooplankters available until these prey items were eliminated or reduced to that density where it was not profitable, in an energy sense, for the fish to continue "hunting."

Burbidge (1974) concluded that blueback herring in the James River were largely random filter feeders with their diet closely reflecting the zooplankton standing crop. The data presented herein tend to support that hypothesis if only the pump samples of zooplankton are considered. Larger food items, principally the cladoceran Leptodora, ostracods, fish larvae, and adult copepods taken in the meter net collections were rarely found in the stomach contents of blueback herring. This was true even when larger forms dominated the zooplankton complex present in the nursery area. This observation indicates avoidance of larger plankters by blueback. The functional basis for this avoidance of larger prey by blueback is unresolved. Analysis of mouth gape, gill raker length, and gill raker spacing relative to fish size for each species of Alosa is in progress. These data will be related to prey size and food habits to assess the question of avoidance or selection of prey by alosine fishes in the nursery area.

Alewives appear to select larger food items although some ingestion of the abundant smaller forms would be unavoidable during feeding. Juvenile alewives held in the laboratory have been observed to select individual food items in situations of low prey density and they are known to eat larval fishes (Hoagman, 1974).

The feeding habits of juvenile American shad appear to be intermediate to those of the blueback and alewife. Of the three Alosa species studied, the diet of the American shad most closely coincides with the zooplankton standing crop as shown by the combined pump and meter net collections.

Larval fishes have not been reported as food items of alosids in the estuarine nursery areas. However, when larval fishes were available in fair concentrations (as in the James River during June), then both the alewife and American shad will consume them in appreciable quantities.

A primary concern for accurate assessment of the feeding biology of planktivorous fishes is definition of the standing crop of available prey organisms at the time that the fishes are taken. The pump samples used in this study (100 gal=0.38 m^3) are quantitative in that a fixed volume of water was strained. The problem with this technique is the tendency for larger zooplankton to avoid or be repelled by the pump head. This bias was present in our samples as shown by the composition of the standing crop of zooplankton from the meter net samples. The major drawback to the meter net is the difficulty in quantification of samples. Towing speed, current speed, and backwash due to clogging contribute to errors in quantities of water actually strained in a net set. The Clark-Bumpus net, though metered, also tends to backwash, thus causing similar bias in the data. Small C-B nets have the added bias of gear avoidance much like the pump technique. Understanding and acknowledging the limitations of the sampling technique and schedule, the results of the present study are interpreted as a comparative synopsis of feeding habits of alosine fishes in five major nurseries of Virginia during the summer of 1971.

The Mattaponi River is strikingly different from the other rivers surveyed when considering the composition of the zooplankton. Cladocerans (mostly B. coregoni) represented between 24 and 84% of all zooplankton in the pump samples from the James, Pamunkey, Rappahannock, and Potomac rivers during July and August. However, cladocerans amounted to only 11.7 and 1.9% during the same month in the Mattaponi River. The percent composition of adult copepods in all rivers was low in the pump samples with the maximum contribution to the sample amounting to only 5.6% in July (Rappahannock) and 5.8% in August (James). Immature copepods in all rivers, constituted 37 to 82% of the zooplankton numerically in July and 14 to 98% of the zooplankton in August. In both months of comparative data, the greatest numbers of young copepods were taken in the Mattaponi and the least were taken in the Potomac.

During July and August collectively, the zooplankton standing crop (mean number/m^3) from the pump samples was greatest in the Potomac River (12,125) followed by the James (11,252), Rappahannock (10,719), Mattaponi (4,221), and Pamunkey (4,004) (Tables 4.11 and 4.14). This ranking by abundance of zooplankton coincides with the rankings by productivity and standing crop of phytoplankton (Chlorophyll a) in the various rivers during the summer of 1971.

The diet of blueback herring during July and August in the nursery area is largely composed of cladocerans and immature copepods. Numerically, these two food groups represented 70 to 100% of the food for this species in all samples except the July collection from the Mattaponi River (when they represented only 25% of the diet). Blueback herring feed mainly on the more abundant, smaller members of the zooplankton in all rivers.

Food intake of alewife changed from small zooplankters in July to larger prey organisms in August. Cladocerans and juvenile copepods constituted between 80 and 98% of all food items consumed by alewives in all rivers in July (mean length of fish = 56 mm FL). In August, smaller zooplankton species accounted for only 35 to 80% of the food in the stomachs of alewives (average length = 68 mm FL) while still contributing 94 to 99% to the zooplankton standing crop. Therefore, smaller alewives, similar to blueback in size, appear to feed randomly upon dominant items in the zooplankton. Larger alewives actively select larger food items, as documented in lake situations by Brooks and Dodson (1965), Hutchinson (1971), and Wells (1970).

American shad in the James River fed primarily upon smaller zooplankters in July and August (88 and 92% of their food, numerically). In other rivers however, shad were more selective for larger organisms with the August, Mattaponi River sample being most extreme (75% adult copepods in the stomach contents).

H. Fish Community Structure, Competition, and Predation in the Nursery

Analysis of community structure in alosine fish nurseries requires evaluation of competition and predation among co-occurring forms within the area. Although complete predator-prey relationships and food habits analysis were not conducted for this contract, certain relationships between species were developed to provide basic knowledge of the relative numbers, biomass, and food habits of the fishes in the nursery areas.

Summer juvenile abundance surveys in Virginia rivers provide estimates of the population size for alosine fishes during a period of peak biomass (see Job 3 of this report). However, these surveys do not provide adequate biomass data for the other members of the ichthyofauna, particularly the predators. Species expected to be predatory upon alosine eggs, larvae, and juveniles tend to disperse to shoal feeding and spawning areas in the spring and summer months. Increased water temperature during this period results in higher metabolic rates and mobility of the fishes which, in turn, increases escapement of the sampling gear by the larger individuals.

Surveys of the fish community were conducted during the winter months of 1972 and 1973 in Virginia rivers to assess the species composition of the resident fishes and to determine the biomass of each species in each nursery area. Each survey included four replicate 1/4-mile bottom tows with a 30 ft lined semiballoon trawl at each 5-mile mark from the river mouth to the head of navigation.

Major competitor species in the alosine nurseries were identified by their known food habits. Planktivorous species such as the bay anchovy (*Anchoa mitchilli*), Atlantic menhaden (*Brevoortia tyrannus*), gizzard shad (*Dorosoma cepedianum*), and the threadfin shad (*D. petenense*) plus several omnivores, primarily freshwater minnows and shiners represent the primary competitors with *Alosa* during the summer months.

Anchovies were the most abundant competitor of the alosines in all rivers, but their distribution pattern in the estuary suggests a segregation of the habitat by spatial means. Anchovies coexist with alosines only in the lower portion of the nursery area during summer months. Competition for food resources of the estuary from anchovies would be most evident during the seaward migration of alosine juveniles in late fall. The reduced food consumption of alosines in late summer (premigration period) suggests that this competition might not be as severe as intuitively expected.

We consider the greatest competition to any given alosine species for both food and space in the nursery area to be from other alosines. Compared to the abundance of alosine fishes, the density of other competitors in the nursery areas is insignificant, particularly at surface and midwater depths.

In the summer of 1971, aggregate species weights were recorded at all stations in the rivers. Expanding this biomass indicator to include the 1972 juvenile abundance survey, the two-year total catches of fishes demonstrated the preponderance of juvenile alosines in the fish community of mainstream nursery areas. The catch of alosines accounted for 81% of the biomass of all competitor species per tow in the James River (54 kg), and 86% in the Rappahannock River (19.4 kg). The Potomac River was sampled in November, 1971 (due to vessel problems) and possibly does not reflect the true alosine biomass in that system.

Alosine fishes are available to predators within the nursery zone throughout the spring and early summer months. Eggs of river herring and shad are available to several benthic and epibenthic feeders such as the white perch (*Morone americana*); white catfish, channel catfish, and brown bullhead (*Ictalurus catus*, *I. punctatus*, and *I. nebulosus*, respectively); American eel (*Anguilla rostrata*); carp (*Cyprinus carpio*); hogchoker (*Trinectes maculatus*) and others. Alosine larvae and juveniles are more susceptible to predation by pelagic species such as the striped bass (*Morone saxatilis*), longnose gar (*Lepisosteus osseus*), sunfishes (*Micropterus* and *Lepomis* species), pickerels (*Esox* species), and percids (*Perca flavescens* and *Etheostoma*). The six most abundant predator species in each river account for 96.9

to 99.8% of the entire resident fish population based upon the winter trawl data for 1972 and 1973 (Table 4.23 and Fig. 4.22). White perch rank first in abundance and biomass in the York, Rappahannock, and Potomac rivers (62 to 77% biomass). White perch in the James River, however, have declined drastically since 1971 (St. Pierre and Hoagman, 1974) and accounted for only 2.1% of the total predator biomass in 1972 and 1973. The three catfish species combined accounted for 17 to 21% of the predator biomass in all rivers except the James where they represented 88% of the fishes taken in the survey (biomass). Hogchoker, striped bass, and cyprinids were the remaining more abundant predatory species. The American eel and longnose gar are not adequately sampled with the trawl during the winter months and their true position in the ranking of predators is unknown.

The magnitude of the competitor species in a numeric and biomass sense are not reflected by the relative biomass estimates presented from the winter trawl surveys. The community structure data is biased by the biology of particular fish species. Menhaden and alosines are typically absent and anchovies tend to stay in the higher salinity areas nearer the river mouth in the winter. Dominant competitors of the alosine fishes are listed in Table 4.23 but the rank, abundance, and biomass values represent only the winter situation.

Total biomass estimates are lowest from the James River (4.76 kg/tow) for both years combined, and increase progressively to the northernmost river, the Potomac (16.65 kg/tow). Total numbers of fish caught during the two winter surveys (excluding anchovies) were also lowest in the James River (20,332) and highest in the Potomac (70,527). The James River, lying nearest the mouth of the Chesapeake

Bay, provided the largest species list during both years of the winter survey (34 and 37, respectively). A progressive northward decline in the species list occurred, with the Potomac having only 24 species.

I. Discussion of Community Structure

White perch in the York, Rappahannock, and Potomac rivers undoubtedly account for the major portion of the predation upon Alosa eggs and larvae in these systems. In the James River, channel catfish and brown bullhead probably assume the dominant role of predation upon eggs and larvae. Both of these catfishes typically feed upon benthic invertebrates, small fishes and detritus. Direct correlation of juvenile alosine abundance to predator loads in each system would not be valid with the present data. We would need estimates of predator population size to make a meaningful analysis.

The southerly estuaries are more diverse (particularly in the meso-polyhaline zones) and northern rivers are more homogeneous, sustaining a considerably greater biomass of fishes. The James River, however, typically supports the largest alosine population of the Virginia tributaries (Job 3). The high productivity and standing crop of zooplankton in the James River may explain the larger annual crop of alosines. As mentioned previously, competition from anchovies in the rivers is limited largely to the lower freshwater and transition zones. The presence of larval anchovy in the stomach contents of alewives and American shad may indicate that anchovy in its larval stage is important as a food item for Alosa, but as juveniles and adults this species is a competitor of Alosa. The James River further differs from the other estuaries in that it sustains the only population of threadfin shad in the major Virginia tributaries (primarily in the oxbow area of the river system).

Predatory species such as bluefish and weakfish feed upon adult *Alosa* after spawning and upon the juveniles during their seaward migration. Once in the Atlantic Ocean, the role of various predatory fishes and the number of species exerting an effect is unknown at this time. An undetermined loss of juvenile alosine fishes can be attributed to the various gulls, terns, and other piscivorous birds that follow the schools of young fish in the nursery.

J. Production of Juvenile Alosa Relative to Nursery Zone Characteristics

Total production of juvenile alosines in Virginia tributaries of Chesapeake Bay has fluctuated widely but in 1973 had declined to approximately one-fourth of its 1970 level. However, the abundance data obtained from each river indicates a high degree of independence for each river relative to the other rivers. Physical, chemical, and biological attributes of the several rivers are considerably different from each other, but each factor measured was varying at its own rate. No pattern was evident among them to explain the observed fluctuations in yearclass production between rivers in the same year, nor in between one river over the several years of the Project. Thus, the decline in the stocks of alosine fishes has been attributed to fishing (see Job 2).

The surface area of open waters available in the nursery zone of alosines, as well as bordering wetlands, is an obvious feature of the rivers which would separate the nurseries as to potential for production of alosine fishes. Following this line of thought, the ranking for potential juvenile production is Potomac, James, Rappahannock, Pamunkey, and Mattaponi. This order is not consistently found in the data obtained under Job 3. The ranking obtained on the basis of bordering marsh/open water area is York, Rappahannock, James, and Potomac rivers, but this also does not fit the observed data on yearly alosine production in Virginia rivers. Areas in the nursery zone, as presented in this job (Table 4.2), differ slightly from those cited in Job 3 (Table 3.13). The former were developed to separate the mainstream and tributary waters, whereas the latter areas are a composite of both habitat types presented by Cronin (1971). Separation of mainstream and tributary areas for Job 4 was desired to provide more information on the amount of each available habitat type.

The variability of individual parameters extant in the biological systems studied precludes formulation of cause and effect statements relative to production of alosine fishes. Relationships between observed alosine production and nutrients, standing crop of phytoplankton, primary productivity, zooplankton standing crop, and coinhabiting fishes are unclear. However, many significant aspects of the alosine nursery areas have been documented in the pursuit of our job objectives.

K. <u>Summary of Job 4</u>

1. Alosine fishes occupy a niche in the tidal freshwaters of the estuary which is not appreciably utilized by the resident fish fauna. The presence of a threadfin shad population in the oxbow reaches of the James River presents an opportunity to evaluate competition between the alosines and threadfin shad.

2. Competition among the *Alosa* species probably is more severe than between *Alosa* species and other resident fishes, except for threadfin shad.

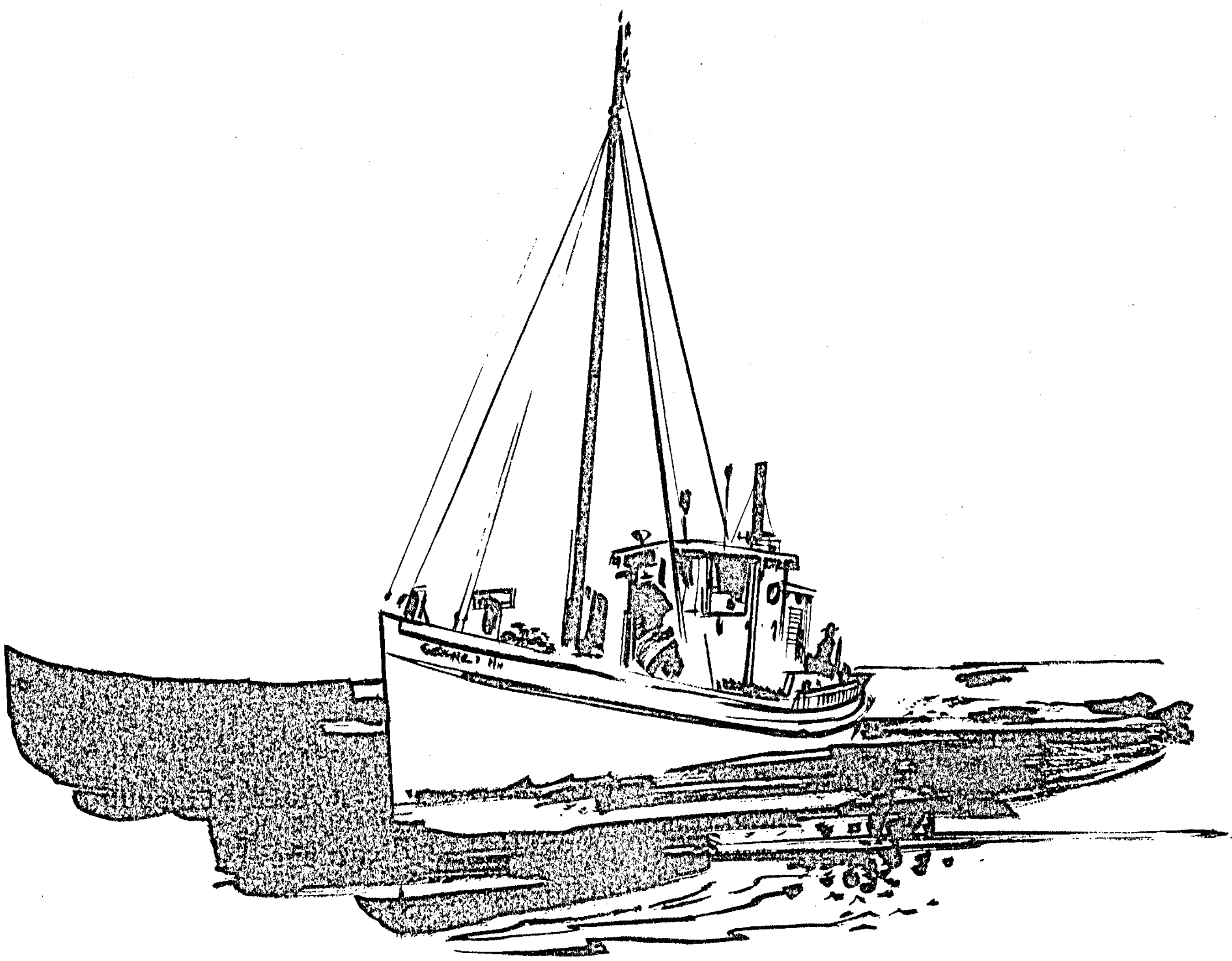
3. Nutrient loading and higher phytoplankton standing crop in the enriched waters of the James and Potomac rivers result in higher production of alosine fishes. An inconsistent trend to this generality is apparent when the James and Potomac rivers are compared. Both rivers are highly developed and enriched, yet the James is consistently a better producer of alosine juveniles.

4. Tributary streams are more stable in nutrient levels and other biological indices than are the mainstream areas of the major tributary rivers during periods of high runoff (i.e., Tropical Storm Agnes). The significance of small streams in the nursery zone may be greater than previously thought. The contribution of the tributary streams relative to mainstream areas in the total production of alosine juveniles should receive further investigation.

5. Blueback, alewife, and American shad partition the nursery area by both spatial distribution and food habits. This aspect of their ecology is currently under more intensive study with a continuing energetics analysis on alewife.

6. Juvenile alosines dominate the ichthyofauna of the tidal-freshwater reaches of rivers in Virginia during summer.

7. White perch dominate the resident fish fauna of the nursery zone during the winter months in the York, Rappahannock, and Potomac river systems. Channel and white catfish and brown bullhead dominate the nursery zone of the James River during the winter.



Literature Cited

Brehmer, M. L. 1972. Biological and chemical study of Virginia's estuaries. VPI-SU Wat. Resources Res. Center. Bull. 45, 69 p.

Brooks, J. L., and S. I. Dodson. 1965. Predation, body size, and composition of plankton. Science. 150:28-35.

Burbidge, R. G. 1972. Distribution, growth, selective feeding and energy transformations of young-of-the-year buleback herring, *Alosa aestivalis* (Mitchilli), in the James River, Virginia. Ph.D. Diss., Univ. Virginia, Charlottesville. 130 p.

Burbidge, R. G. 1972. Distribution, growth, selective feeding and energy transformations of young-of-the-year blueback herring, *Alosa aestivalis* (Mitchilli), in the James River, Virginia. Trans. Amer. Fish. Soc. 103:297-311.

Carpenter, J. H., D. W. Pritchard, and R. C. Whaley. 1969. Observations of eutrophication and nutrient cycles in some coastal plain estuaries. *In* Eutrophication: Causes, Consequences, and Correctives. Nat. Acad. Sci. Washington, D. C. 210-221 p.

Cronin, W. B. 1971. Volumetric, areal and tidal statistics of the Chesapeake Bay estuary and its tributaries. Spec. Rep. 20 Chesapeake Bay Inst., Johns Hopkins Univ. Ref. 71-72. 135 pp.

Davis, J., J. P. Miller, and W. L. Wilson. 1970. Biology and utilization of anadromous alosids. Completion Report, NMFS, Anadromous Fish Project VA-AFC-1.

Davis, J., J. V. Merriner, W. J. Hogman, R. A. St. Pierre, and W. L. Wilson. 1971. Biology and utilization of anadromous alosids. Annual Progress Report, Anadromous Fish Project. VA-AFC-7-1.

Davis, J., J. V. Merriner, W. J. Hoagman, R. A. St. Pierre, and W. L. Wilson. 1972. Biology and utilization of anadromous alosids. Annual Progress Report, Anadromous Fish Project. VA-AFC-7-2.

Flemer, D. A., D. H. Hamilton, C. W. Keefe, J. A. Mihursky. 1970. The effects of thermal loading and water quality on estuarine primary production. Final Rep., Office of Water Resources Res. USDI, Mimeo, 217 p., Nat. Res. Inst. Ref. No. 71-6.

Hoagman, W. J. 1974. Feeding by alewives (*Alosa pseudoharengus*) on larval lake whitefish (*Coregonus clupeaformis*) in the laboratory. J. Fish. Res. Bd. Canada. 31(2):229-230.

Hutchinson, B. P. 1971. The effect of fish predation on the zooplankton of ten Adirondack lakes, with particular reference to the alewife, *Alosa pseudoharengus*. Trans. Amer. Fish. Soc., 100:325-335.

Ivelev, V. S. 1961. Experimental ecology of the feeding of fishes. (Transl. from Russian by D. Scott) Yale Univ. Press, New Haven. 302 p.

Jaworski, N. A. 1969. Nutrients in the upper Potomac River Basin. USDI, FWPCA, Chesapeake Tech. Support Lab. Mid.-Atlantic Reg., Tech. Rep. No. 15, 92 p.

Jaworski, N. A., D. W. Lear, and O. Villa. 1971. Nutrient management in the Potomac estuary. EPA, Water Qual. Office, Tech. Rep. No. 45, 64 p.

Jaworski, N. A., O. Villa, and L. J. Hettling. 1969. Nutrients in the Potomac River Basin. USDI, FWPCA, Chesapeake Tech. Support Lab., Mid.-Atlantic Region. Tech. Rep. No. 9, 40 p.

Massmann, W. H. 1963. Summer food of juvenile American shad in Virginia waters. Chesapeake Sci. 4:167-171.

Morsell, J. W., and C. R. Norden. Food habits of the alewife, Alosa pseudoharengus (Wilson) in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 96-102 p.

Norden, C. R. 1968. Morphology and food habits of the larval alewife, Alosa pseudoharengus (Wilson), in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 103-110 p.

St. Pierre, R. A., and W. J. Hoagman. 1974. Drastic reduction of the white perch (Morone americana) population in the James River, Virginia. Chesapeake Sci. (in press).

Wass, M. L., and T. D. Wright. 1969. Coastal wetlands of Virginia. Interim report to the governor and general assembly. Spec. Sci. Rep., Appl. Mar. Sci. and Oceanogr. Eng., No. 10, VIMS, 154 p.

Wells, L. 1970. Effects of alewife predation on zooplankton populations in Lake Michigan. Limnol. and Oceanogr. 15:556-565.

Table 4.1. Tidal wetlands acreage in Virginia in the major tributaries to Chesapeake Bay.[1]

River System	Wetland Type					
	Wooded Marsh	Marsh	Open Creeks	Wood-land	Tidal Flats	Total
Potomac	1,790	8,835	6,601	0	1,123	18,349
Rappahannock	6,689	15,496	10,785	100	722	33,812
York	3,083	23,482	5,939	1,134	3,131	36,769
James	17,676	18,164	7,604	763	3,784	47,991

[1] From Wass and Wright (1969)

Table 4.2. Spawning and nursery areas of alosine fishes in major rivers of Virginia.[2]

River System	Spawning and Nursery Areas: Mainstream River Miles	Mainstream Acres	Tributaries River Miles	Tributaries Acres	Total Acres
Potomac	60-95	44,963	35-95	16,016	60,979
James	35-84	38,659	35-84	2,758	41,417
Rappahannock	40-93	13,737	30-93	1,862	15,599
Pamunkey	30-70	6,325	30-70	790	7,145
Mattaponi	30-60	3,776	30-60	103	3,879
York (Pamunkey and Mattaponi)		10,101		893	10,994

[2] From Davis et al., 1970

Table 4.3. A list of parameters monitored on a monthly schedule in the alosine nursery grounds of Virginia between May and October, 1971.

<u>Physical Parameters</u>

Discharge rate (cf/s)
Turbidity a) submarine photometer (10% light penetration in cm)
b) secchi disc (in 0.1 m)
Temperature (C, 5 m intervals and bottom)

<u>Chemical Parameters</u> (5 m intervals and bottom)

Salinity (ppt)
Dissolved Oxygen (ppm)
Nitrate (ppb)
Phosphate (ppb)
pH
Alkalinity (ppm $CaCO_3$)

<u>Biological Parameters</u>

Chlorophyll a (ppb, surface and bottom)
C^{14} primary productivity ($mg \cdot m^3 \cdot hr$)
Fish species list (surface and midwater with Cobb trawl, bottom with 30-ft semiballoon otter trawl)
Fish lengths (mm FL, up to 50 species/tow)
Fish abundance (total/species per tow)
Stomach contents of fishes (up to 10 species/month per nursery)
Fish egg and larvae (meter net)
Zooplankton (meter net, qualitative)
(pump sample, quantitative, 100 gal, 202 micron)
(pump sample, quantitative, 100 gal, 35 micron)
(pump sample, quantitative 100 gal, 35 micron)
Phytoplankton (pump sample, quantitative, 1 qt, 35 micron filter)
Nannoplankton (pump sample, quantitative, 1 qt, 35 micron filter)

Table 4.4. A list of parameters monitored at five stations in the James River between May and October, 1972

Physical Parameters

Discharge rate (cf/s)
Turbidity a) submarine photometer (10% light penetration in cm)
b) secchi disc (in 0.1 m)
Temperature (C, 5 m intervals and bottom

Chemical Parameters (5 m intervals and bottom)

Salinity (ppt)
Dissolved Oxygen (ppm)
Inorganic Carbon (ppm)
Organic Carbon (ppm)
Total Carbon (ppm)
NH_3-N (ppm) surface and bottom only
NO_2-N (ppm) surface and bottom only
NO_3-N (ppm) surface and bottom only
Total Inorganic Carbon (ppm) surface and bottom only
Orthophosphate (ppm) surface and bottom only
Total Phosphate (ppm) surface and bottom only

Biological Parameters

Chlorophyll a (mg/m^3)
C^{14} Primary productivity ($mgC \cdot m^3 .hr$)
Zooplankton species list
Zooplankton species abundance
Fish species list
Fish species abundance
Alosa spp food habits
Fish species lengths
Alosa spp lengths

Table 4.5. Mean monthly nutrient data for several estuaries of Chesapeake Bay in June-October, 1969[1], and at Dutch Gap in 1969 and 1972 (James River, Mile 73).

	Mean Monthly Concentration				
Total kjeldahl Nitrogen as N (Mg/l)	June	July	Aug.	Sept.	Oct.
Susquehanna	0.75	0.75	0.42	0.75	0.80
Patuxent	2.45	1.50	1.25	1.40	1.75
Potomac	0.48	0.85	0.70	1.07	0.90
Rappahannock	0.57	0.80	0.55	0.63	0.60
James (1969)	0.40	1.10	0.69	0.80	0.38
James (1972)	0.69	0.66	0.72	0.89	...
Nitrate and Nitrite as N (mg/l)					
Susquehanna	0.38	0.45	1.10	0.60	0.65
Patuxent	1.82	2.60	1.55	2.18	1.89
Potomac	0.04	0.60	0.58	0.37	0.41
Rappahannock	0.60	0.43	0.32	0.21	0.22
James (1969)	0.83	0.40	0.58	0.40	0.80
James (1972)	1.78	1.93	2.28	2.29	...
Total Phosphorus as PO_4-P (mg/l)					
Susquehanna	0.12	0.12	0.15	0.09	0.13
Patuxent	3.62	4.34	2.20	3.08	5.60
Potomac	0.60	0.46	0.40	0.42	...
Rappahannock	0.41	0.23	0.15	0.20	0.26
James (1969)	0.10	0.40	0.24	0.15	0.14
James (1972)	0.38	0.46	0.40	...	...

1 From Jaworski and Hettling (1970).

Table 4.6. Total primary productivity values for the mainstream and tributary areas in the alosine nursery zones during 1971.

River	Total Primary Productivity[1] (kgC/hr)	Percent of Grand Total
Potomac	3,704	63.8
James	1,228	21.1
Rappahannock	531	9.1
Pamunkey	260	4.5
Mattaponi	85	1.5

[1] Total Primary Productivity in kg Carbon/hr= [(Acres from Table 4.2) X (0.40469 hectares per acre) X (10^4 m^2/hectare) X (depth of 10% light in meters) X (primary productivity rate, mean mgC·m^3·hr) X (1 gram/1,000 mg) X (1 kg/1,000 g)]

Table 4.7. Primary productivity values for 1,000 m^2 surface waters in the alosine nursery zones of five rivers during the summer of 1971.

River	Primary Productivity ($gC \cdot hr \cdot 1{,}000\ m^2$)
Potomac	15.0
Pamunkey	8.9
James	7.3
Rappahannock*	6.1
Mattaponi	5.4

* Aberrant June value at lower station deleted from computations.

Table 4.8. Comparison of stomach contents of juvenile alosines and zooplankton abundance for the James River in 1971.

	June		July		August		September		October	
	number/ cubic meter	per- cent	number/ cubic meter	per- cent	number/ cubic meter	per- cent	number/ cubic meter	per- cent	number/ cubic meter	per- cent
Pump Samples										
Cladocera	1,336	82	6,575	34	1,962	60	2,504	71	568	31
Immature Copepod	263	16	12,193	64	1,134	34	863	25	1,220	66
Adult Copepod	11	1	442	2	192	6	126	4	63	3
Others	11	1	0	...	5	...	0	...	0	...
	number/ stomach	per- cent	number/ stomach	per- cent	number/ stomach	per- cent	number/ stomach	per- cent	number/ stomach	per- cent
Blueback										
Cladocera	8	27	441	41	324	85	549	96	302	87
Immature Copepod	14	46	618	59	42	11	25	4	45	13
Adult Copepod	8	27	1	...	11	3	0	...	0	...
Others	0	...	2	...	5	1	0	...	0	...
Number of Fish/$\bar{x}$ FL mm	2/22.0		10/41.5		10/48.0		10/49.6		10/58.1	
Alewife										
Cladocera	121	19	168	68	92	30	86	86	21	36
Immature Copepod	183	29	74	30	18	6	6	6	21	36
Adult Copepod	10	2	0	...	182	58	1	1	4	7
Others	16	3	6	2	19	6	7	7	12	21
Fish Larvae	294	47	0	...	0	...	0	...	0	...
Number of Fish/$\bar{x}$ FL mm	6/33.0		9/52.6		10/60.0		10/64.6		9/65.2	

Table 4.8. (Continued)

	June		July		August		September		October	
	number/ stomach	per- cent	number/ stomach	per- cent	number/ stomach	per- cent	number/ stomach	per- cent	number/ stomach	per- cent
American Shad										
Cladocera	31	8	1,736	77	307	85	838	97	17	13
Immature Copepod	4	1	239	11	26	7	0	...	0	...
Adult Copepod	5	1	280	12	13	4	14	2	13	10
Others	62	16	1	...	17	4	11	1	103	77
Fish Larvae	291	74	5	...	0	...	0	...	0	...
Number of Fish/$\bar{x}$ FL mm	10/37.6		10/58.4		10/72.0		10/74.8		8/75.8	

Table 4.9. *Zooplankton abundance for the James River station near Hopewell (Mile 64), from monthly pump samples during June-October, 1971.*

Group Species	June		July		August		September		October	
	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent
Cladocera										
Alonella acutirostris					192	5.8	95	2.7	53	2.9
Bosmina coregoni	1,262	77.8	5,134	26.7	1,633	49.6	2,041	58.5	505	27.2
Camptocercus rectirostris	10	0.6	...	...	...	...	...	...	...	...
Daphnia parvula	32	2.0	137	0.7	...	...	242	6.9	11	0.6
Diaphanosoma branchyurum	11	0.7	1,094	5.7	116	3.5	126	3.6	...	...
Leptodora kindtii	...	...	210	1.1	21	0.6	...	...	...	...
Leydigia acanthocercoides	21	1.3	...	...	...	...	...	...	...	...
TOTAL	1,337	82.4	6,575	34.2	1,962	59.5	2,504	71.7	569	30.7
Copepoda (Adult)										
Acartia tonsa	11	0.7	305	1.6	8	0.2	116	3.3	63	3.4
Eucyclops agilis	...	...	11	...	...	...	...	...	...	...
Eurytemora affinis	...	...	95	0.5	...	...	11	0.3	...	...
Unident. calanoid	...	...	32	0.2	...	...	...	...	...	...
Unident. cyclopoid	...	...	...	...	184	5.6	...	...	...	...
TOTAL	11	0.7	443	2.3	192	5.8	127	3.6	63	3.4
Copepoda (Immature)										
Calanoid juveniles	21	1.3	600	3.1	87	2.6	84	2.4	84	4.5
Cyclopoid juveniles	242	14.9	11,593	60.4	1,047	31.8	778	22.3	1,136	61.3
TOTAL	263	16.2	12,193	63.5	1,134	34.4	862	24.7	1,220	65.8

Table 4.9. (Continued)

Group Species	June		July		August		September		October	
	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent
Other										
Fish Larvae	11	0.7	...	...	...	...	...	...	...	...
Acarina	...	...	...	...	...	...	...	...	...	...
Isopoda	...	...	...	...	3	0.1	...	...	...	...
TOTAL	11	0.7	0	0	6	0.2	0	0	0	0
Rotifera*										
Brachionus calyciflurus	389	...	...	...	...	...	484	...	105	...
Filinia longiseta	42	...	...	...	...	...	694	...	494	...
Kellicottia bostoniensis	...	...	...	...	...	...	32	...	95	...
Keratella spp.	831	...	...	...	...	...	1,157	...	589	...
TOTAL	1,262	...	0	...	0	...	2,367	...	1,283	...
GRAND TOTALS	1,622	100.0	19,211	100.0	3,294	99.9	3,493	100.0	1,852	99.9

* Not included in grand totals.

Table 4.13. *Comparison of stomach contents of juvenile alosine fishes and zooplankton abundance for the Pamunkey River in 1971.*

	July		August	
Pump Sample	number/cubic meter	percent	number/cubic meter	percent
Cladocera	2,452	55	842	23
Immature Copepod	1,872	42	2,662	75
Adult Copepod	116	3	32	1
Others	0	...	21	1
Blueback	number/stomach	percent	number/stomach	percent
Cladocera	825	98	755	90
Immature Copepod	7	1	57	7
Adult Copepod	1	...	6	...
Others	4	1	23	3
Number of Fish/$\bar{x}$ FL mm	10/41.0		10/48.0	
Alewife				
Cladocera	213	67	0	...
Immature Copepod	82	26	29	35
Adult Copepod	20	6	5	6
Other	4	1	48	59
Number of Fish/$\bar{x}$ FL mm	10/51.8		8/59.6	

Table 4.11. Zooplankton abundance in the Pamunkey (YP-50) and Mattaponi (YM-45) rivers from monthly pump samples during July and August, 1971.

	Pamunkey River				Mattaponi River			
	July		August		July		August	
Group Species	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent
Cladocera								
Bosmina coregoni	2,262	50.8	810	22.8	147	11.7	137	1.9
Daphnia parvula	21	0.5	11	0.3	...	...	...	...
Diaphanosoma branchyurum	179	4.0	21	0.6	21	1.7	...	...
TOTAL	2,462	55.3	842	23.7	168	13.4	137	1.9
Copepoda (Adult)								
Acartia tonsa	74	1.6	21	0.6	47	3.7	11	0.2
Eurytemora affinis	21	0.5	11	0.3	...	...	...	...
Unidentified	21	0.5	...	...	...	...	...	...
TOTAL	116	2.6	32	0.9	47	3.7	11	0.2
Copepoda (Immature)								
Calanoid Juveniles	179	4.0	53	1.5	126	10.0	337	4.7
Cyclopoid Juveniles	1,694	38.1	2,609	73.3	905	72.0	6,701	93.2
TOTAL	1,873	42.1	2,662	74.8	1,031	82.0	7,038	97.9
Others								
Ostracoda	...	...	11	0.3	11	0.9	...	...
Insects	...	...	11	0.3	...	...	...	...
TOTAL	...	...	22	0.6	11	0.9	...	...

Table 4.11. (Continued)

	Pamunkey River				Mattaponi River			
	July		August		July		August	
Group Species	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent
Rotifera*								
Brachionus calyciflorus	...	...	84	...	...	...	42	...
Filinia longiseta	116	...	7,501	...	63	...	84	...
Keratella spp.	421	...	1,063	...	1,473	...	1,694	...
TOTAL	537	...	8,648	...	1,536	...	1,820	...
GRAND TOTALS	4,451	100.0	3,558	100.0	1,257	100.0	7,186	100.0

*Not included in grand totals.

Table 4.12. Comparison of stomach contents of juvenile alosine fishes and zooplankton abundance for the Mattaponi River in 1971.

	July		August	
Pump Sample	number/cubic meter	percent	number/cubic meter	percent
Cladocera	168	13	137	2
Immature Copepod	1,031	82	7,038	98
Adult Copepod	47	4	11	...
Others	11	1	0	...
Blueback	number/stomach	percent	number/stomach	percent
Cladocera	11	4	2	2
Immature Copepod	64	21	95	79
Adult Copepod	227	75	20	17
Other	1	...	3	2
Number of Fish/$\bar{x}$ FL mm	10/39.7		3/39.9	
Alewife				
Cladocera	12	1	20	6
Immature Copepod	170	20	173	48
Adult Copepod	659	78	160	45
Other	5	1	3	1
Number of Fish/$\bar{x}$ FL mm	10/46.0		9/48.7	

Table 4.12. (Continued)

American Shad	July		August	
	number/stomach	percent	number/stomach	percent
Cladocera	12	6	8	2
Immature Copepod	109	50	74	20
Adult Copepod	76	35	284	76
Other	19	9	10	2
Number of Fish/$\bar{x}$ FL mm	10/49.2		9/52.7	

Table 4.13. Comparison of stomach contents of juvenile alosine fishes and zooplankton abundance for the Rappahannock River in 1971.

	July			August	
Pump Sample	number/cubic meter		percent	number/cubic meter	percent
Cladocera	5,650		40	3,629	50
Immature Copepod	7,711		54	3,553	49
Adult Copepod	800		6	53	1
Others	42		....	0	...
Blueback	number/stomach		percent	number/stomach	percent
Cladocera	627		74	145	69
Immature Copepod	0		...	1	...
Adult Copepod	215		26	60	29
Others	0		...	4	2
Number of Fish/$\bar{x}$ FL mm		10/35.0		10/41.5	
Alewife					
Cladocera	4,547		93	3,470	62
Immature Copepod	0		...	947	17
Adult Copepod	323		7	1,169	21
Others	0		...	25	...
Number of Fish/$\bar{x}$ FL mm		10/48.8		10/68.4	

Table 4.15. (Continued)

American Shad	July number/stomach	July percent	August number/stomach	August percent
Cladocera	0	0	1,735	52
Immature Copepod	0	0	0	...
Adult Copepod	0	0	1,498	45
Others	0	0	101	3
Number of Fish/$\bar{x}$ FL mm			7/72.7	

Table 4.14. Zooplankton abundance in the Rappahannock (RA-73) and Potomac (PT-65) rivers from monthly pump samples during July and August, 1971.

	Rappahannock River				Potomac River			
	July		August		July		August	
Group Species	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent
Cladocera								
Alonella acutirostris	200	1.4	21	0.3	21	0.2	...	...
Bosmina coregoni	5,355	37.7	3,251	44.9	4,050	23.1	2,367	35.1
Ceriodaphnia lacustris	...	...	...	...	389	2.2	1,063	15.8
Daphnia parvula	21	0.2	21	0.3	2,167	12.4	1,336	19.8
Diaphanosoma branchyurum	21	0.2	252	3.5	673	3.8	74	1.1
Leptodora kindtii	21	0.2	21	0.3	53	0.3	...	...
Leydigia acanthocercoides	32	0.2	63	0.9	3,451	19.7	821	12.2
TOTAL	5,650	39.9	3,629	50.2	10,804	61.7	5,661	84.0
Copepoda (Adult)								
Acartia tonsa	673	4.7	53	0.7	147	0.8	126	1.9
Eurytemora affinis	126	0.9	...	...	11	0.1	11	0.1
TOTAL	799	5.6	53	0.7	158	0.9	137	2.0
Copepoda (Immature)								
All Juveniles	7,711	54.3	3,553	49.1	6,533	37.3	947	14.0
TOTAL	7,711	54.3	3,553	49.1	6,533	37.3	947	14.0
Other								
Ostracoda	...	...	...	...	11	0.1	...	...
Insects	43	0.3	...	...	...	...	...	...
TOTAL	43	0.3	...	...	11	0.1	...	...

Table -.14. (Continued)

	Rappahannock River				Potomac River			
	July		August		July		August	
	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent	number/cubic meter	percent
Rotifera*								
Branchionus colycitlorus	32	...	32	...	379	...	32	...
B. havanaensis	...	...	...	...	21	...	21	...
Filinia longiseta	42	...	442	...	1,988	...	63	...
Rellimottia bostoniensis	...	...	21	...	...	...	...	...
Keratella spp.	526	...	7,932	...	1,809	...	116	...
Tetramastix opoliersis	...	...	200	...	...	...	...	...
Trichocera cylindrica	179	...	558	...	...	...	...	...
TOTAL	779	...	9,185	...	4,197	...	232	...
GRAND TOTALS	14,203	100.1	7,235	100.0	17,506	100.0	6,745	100.0

* Not included in grand totals.

Table ..15. Comparison of stomach contents of juvenile alosine fishes and zooplankton abundance for the Potomac River in 1971.

	July		August	
Pump Sample	number/cubic meter	percent	number/cubic meter	percent
Cladocera	10,804	62	5,660	84
Immature Copepod	6,533	37	947	14
Adult Copepod	158	1	137	2
Others	11	...	0	...
Blueback	number/stomach	percent	number/stomach	percent
Cladocera	445	48	396	90
Immature Copepod	334	36	29	7
Adult Copepod	144	15	0	...
Others	6	1	14	3
Number of Fish/x̄ FL mm	10/56.6		10/50.7	
Alewife				
Cladocera	1,521	44	232	61
Immature Copepod	1,595	46	77	20
Adult Copepod	0	...	6	1
Other	334	10	68	18
Number of Fish/x FL mm	10/81.1		10/92.4	

Table 4.15. (Continued)

American Shad	July number/stomach	July percent	August number/stomach	August percent
Cladocera	0	0	39	44
Immature Copepod	0	0	32	36
Adult Copepod	0	0	0	...
Others	0	0	18	20
Number of Fish/$\bar{x}$ FL mm			3/83.0	

Table 4.16. Major food items in stomachs of juvenile blueback herring taken from five Virginia rivers in July, 1971.

Group species	James River number/ cubic meter	James River per-cent	Pamunkey River number/ cubic meter	Pamunkey River per-cent	Mattaponi River number/ cubic meter	Mattaponi River per-cent	Rappahannock River number/ cubic meter	Rappahannock River per-cent	Potomac River number/ cubic meter	Potomac River per-cent
Cladocera										
Alonella acutirostris	...	...	...	...	...	...	...	...	138	14.8
Bosmina coregoni	186	17.5	807	96.4	4	1.3	591	70.2	80	8.6
Diaphanosoma branchyurum	243	22.8	...	...	3	1.0	...	...	9	1.0
Leydigia acanthocercoides	...	...	...	...	...	...	20	2.4	182	19.6
All Others	12	1.1	18	2.2	4	1.3	16	1.9	36	3.9
TOTAL	441	41.4	825	38.6	11	3.6	627	74.5	445	47.9
Copepoda (Adult)										
Eurytemora affinis	1	0.1	...	...	20	6.6	50	5.9	...	...
Others (Unidentified)	...	...	1	0.1	207	68.3	165	19.6	144	15.5
TOTAL	1	0.1	1	0.1	227	74.9	215	25.5	144	15.5
Copepoda (Immature)										
Calanoid Juveniles	457	43.0	...	...	11	3.6	...	...	...	2.6
Cyclopoid Juveniles	161	15.1	7	0.8	53	17.5	...	...	310	33.4
TOTAL	618	58.1	7	0.8	64	21.1	...	...	224	36.0
All Others	4	0.4	4	0.5	1	0.3	...	...	6	0.6
GRAND TOTAL	1,064	100.0	837	100.0	303	99.9	842	100.0	929	100.0
Number of Fish/$\bar{x}$ FL mm	41.5		41.0		39.7		35.0		56.6	

Table 4.17. Major food items in stomach of juvenile blueback herring taken from five Virginia rivers in August, 1971.

Group species	James River		Pamunkey River		Mattaponi River		Rappahannock River		Potomac River	
	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent	number/ cubic meter	per-cent
Cladocera										
Alonella acutirostris	...	...	...	...	...	...	...	...	166	37.8
Bosmina coregoni	319	83.5	745	88.6	1	0.8	118	56.2	87	19.8
Daphnia parvula	4	1.1	...	...	...	...	12	5.7	121	27.6
Diaphanosoma branchyurum	1	0.2	10	1.2	1	0.8	...	...	21	4.8
Others	...	...	...	...	...	...	15	7.1	1	0.2
TOTAL	324	84.8	755	89.8	2	1.6	145	69.0	396	90.2
Copepoda (Adult)										
Eurytemora affinis	2	0.5	1	0.1	...	...	...	...	...	...
Others (Unidentified)	9	2.4	5	0.6	20	16.7	60	28.6	...	...
TOTAL	11	2.9	6	0.7	20	16.7	60	28.6	...	...
Copepoda (Immature)										
Calanoid Juveniles	21	5.5	10	1.2	5	4.2	...	...	4	0.9
Cyclopoid Juveniles	21	5.5	47	5.6	90	75.0	1	0.5	25	5.7
TOTAL	42	11.0	57	6.8	95	79.2	1	0.5	29	6.6
All Others	5	1.3	23	2.7	3	2.5	4	1.9	14	3.2
GRAND TOTALS	382	100.0	841	100.0	120	100.0	210	100.0	439	100.0
Number of Fish/$\bar{x}$ FL mm	48.0		48.0		39.7		41.5		50.7	

Table 4.18. Major food items in stomachs of juvenile alosines taken from five Virginia rivers in July, 1971.

Group species	James River number/ cubic meter	James River per- cent	Pamunkey River number/ cubic meter	Pamunkey River per- cent	Mattaponi River number/ cubic meter	Mattaponi River per- cent	Rappahannock River number/ cubic meter	Rappahannock River per- cent	Potomac River number/ cubic meter	Potomac River per- cent
Cladocera										
Bosmina coregoni	59	23.8	21	6.6	6	0.7	4,039	82.8	612	17.8
Daphnia parvula	1	0.4	...	...	...	...	499	10.2	84	2.4
Diaphanosoma branchyurum	106	42.7	192	60.2	...	...	2	...	60	1.7
Leydigia acanthocercoides	2	0.8	...	...	6	0.7	5	0.1	765	22.2
Others	...	...	...	...	...	...	2	...	...	...
TOTAL	168	67.7	213	66.8	12	1.4	4,547	93.2	1,521	44.1
Copepoda (Adult)										
Eurytemora affinis	...	...	...	...	72	8.5	70	1.4	...	...
Others (Unidentified)	...	...	20	6.3	587	69.4	263	5.4	...	...
TOTAL	...	...	20	6.3	659	77.9	333	6.8	...	...
Copepoda (Immature)										
Calanoid Juveniles	55	22.2	22	6.9	22	2.6	...	...	203	5.9
Cyclopoid Juveniles	19	7.7	60	18.8	148	17.5	...	...	1,392	40.3
TOTAL	74	29.9	82	25.7	170	20.1	...	...	1,595	46.2
All others	6	2.4	4	1.2	5	0.6	1	...	334[1]	9.7
GRAND TOTALS	248	100.0	319	100.0	846	100.0	4,881	100.0	3,450	100.0
Number of Fish/$\bar{x}$ FL mm	9/52.6		10/51.3		10/46.0		10/48.8		10/81.1	

1 Ostracods.

Table 4.19. Major food items in stomachs of juvenile alosines taken from five Virginia rivers in August, 1971.

Group species	James River number/cubic meter	James River per-cent	Pamunkey River number/cubic meter	Pamunkey River per-cent	Mattaponi River number/cubic meter	Mattaponi River per-cent	Rappahannock River number/cubic meter	Rappahannock River per-cent	Potomac River number/cubic meter	Potomac River per-cent
Cladocera										
Alonella acutirostris	3	1.0	...	...	...	...	...	...	87	22.7
Bosmina coregoni	57	18.3	...	...	1	0.2	3,140	56.0	42	11.0
Daphnia parvula	...	...	...	...	2	0.6	5	0.1	19	5.0
Diaphanosoma branchyurum	31	10.0	...	...	15	4.2	294	5.2	6	1.6
Leydigia acanthocercoides	...	...	...	...	...	...	28	0.5	77	20.1
Others	1	0.3	...	...	2	0.6	3	...	1	0.2
TOTAL	92	29.6	0	...	20	5.6	3,470	61.8	232	60.6
Copepoda (Adult)										
Eurytemora affinis	...	...	...	...	34	9.6	3	...	3	0.8
Others (Unidentified)	182	58.5	5	6.1	126	35.4	1,166	20.8	3	0.8
TOTAL	182	58.5	5	6.1	160	45.0	1,169	20.8	6	6.6
Copepoda (Immature)										
Calanoid Juveniles	1	0.3	13	15.9	98	27.5	340	6.1	32	8.4
Cyclopoid Juveniles	17	5.5	16	19.5	75	21.1	607	10.8	45	11.7
TOTAL	18	5.8	29	35.4	173	48.6	947	16.9	77	20.1
All Others	19[2]	6.1	48[1]	58.5	3	0.8	25[2]	0.5	68[2]	17.7

Table 4.19. (Continued)

Group species	James River		Pamunkey River		Mattaponi River		Rappahannock River		Potomac River	
	number/ cubic meter	per- cent	number/ cubic meter	per- cent	number/ cubic meter	per- cent	number/ cubic meter	per- cent	number/ cubic meter	per- cent
GRAND TOTALS	311	100.0	82	100.0	356	100.0	5,611	100.0	383	100.0
Number of Fish/$\bar{x}$ FL mm	10/60.0		8/59.6		9/48.7		10/68.4		10/92.4	

1 Mostly mysid shrimp.

2 Mostly ostracods.

Table 4.20. *Major food items in stomachs of juvenile American shad taken from five Virginia rivers in July and August, 1971.*

July

Group species	James River number/ cubic meter	James River per- cent	Pamunkey River number/ cubic meter	Pamunkey River per- cent	Mattaponi River number/ cubic meter	Mattaponi River per- cent	Rappahannock River number/ cubic meter	Rappahannock River per- cent	Potomac River number/ cubic meter	Potomac River per- cent
Cladocera										
Bosmina coregoni	1,557	68.9	58	38.7	6	2.8	0	0	0	0
Diaphanosoma branchyurum	167	7.4	2	1.3	2	0.9	0	0	0	0
Other	12	0.5	7	4.7	4	1.9	0	0	0	0
TOTAL	1,736	76.8	67	44.7	12	5.6	0	0	0	0
Copepoda (Adult)										
Eurytomora affinis	2	0.1	1	0.7	3	1.4	0	0	0	0
Others (Unidentified)	278	12.3	15	10.0	73	33.8	0	0	0	0
TOTAL	280	12.4	16	10.7	76	35.2	0	0	0	0
Copepoda (Immature)										
Calanoid Juveniles	189	8.4	2	1.3	5	2.3	0	0	0	0
Cyclopoid Juveniles	50	2.2	37	24.7	104	48.1	0	0	0	0
TOTAL	239	10.6	39	26.0	109	50.4	0	0	0	0
All Others	6	0.3	28[1]	18.6	19[2]	8.8	0	0	0	0
GRAND TOTAL	2,261	100.1	150	100.0	216	100.0	0	0	0	0
Number of Fish/x FL mm	10/58.4		10/48.0		10/49.2					

Table 4.20. (Continued)

Group species	James River number/ cubic meter	James River per-cent	Pamunkey River number/ cubic meter	Pamunkey River per-cent	Mattaponi River number/ cubic meter	Mattaponi River per-cent	Rappahannock River number/ cubic meter	Rappahannock River per-cent	Potomac River number/ cubic meter	Potomac River per-cent
	August									
Cladocera										
Bosmina coregoni	302	83.2	23	7.2	2	0.5	1,313	39.4	33	37.1
Diaphanosoma branchyurum	...	...	13	4.1	2	0.5	337	10.1	...	...
Leydigia acanthocercoides	...	...	...	...	2	0.5	78	2.3	5	5.6
Others	5	1.4	4	1.2	2	0.5	7	0.2	1	1.1
TOTAL	307	84.6	40	12.5	8	2.1	1,735	52.0	39	43.8
Copepoda (Adult)										
Eurytemora affinis	3	0.8	31	9.7	10	2.7	5	0.2	...	...
Others (Unidentified)	10	2.7	51	16.0	274	72.8	1,493	44.8	...	...
TOTAL	13	3.5	82	25.7	284	75.5	1,498	45.0	...	...
Copepoda (Immature)										
Calanoid Juvenile	4	1.1	19	6.0	6	1.6	...	...	13	14.6
Cyclopoid Juvenile	22	6.1	132	41.4	68	18.1	...	...	19	21.4
TOTAL	26	7.2	151	47.4	74	19.7	...	...	32	36.0
All Others	17[1]	4.7	46[1]	14.4	10	2.7	101[2]	3.0	18[1]	20.2
GRAND TOTAL	363	100.0	319	100.0	376	100.0	3,334	100.0	89	100.0
Number of Fish/x FL mm	10/79.0		10/50.9		9/52.7		7/72.7		3/83.0	

1 Mysid shrimp

2 Ostracods

Table --.21. Summary of meter net catches from five Virginia rivers during July-August, 1971 (combined).[1]

Group Species	James (JA-63)	Pamunkey (YP-50)	Mattaponi (YM-45)	Rappahannock (RA-73)	Potomac (PT-68)
Cladocera					
Bosmina coregoni	29	20	...	62	391
Ceriodaphnia lacustris	...	37	68	123	1,823
Daphnia parvula	249	135	9	604	10,270
Diaphanosoma branchyurum	92	18	...	225	3,872
Leptodora kindtii	3,781	2,328	699	4,829	3,703
Moina brachiata	50	1	...	...	16
Others	16	12	10	9	86
TOTAL	4,217	2,551	786	5,852	20,161
Copepoda					
Acartia tonsa	76	5	...	149	593
Cyclops vernalis	124	72	45	272	259
Diaptomus reighardi	120	94	...	1	1
Eucyclops agilis	115	137	24	286	280
Eurytemora affinis	101	180	...	1,469	121
Other Adults	16	7	1	...	2
Immature	...	...	3	109	1
TOTAL	552	495	73	2,286	1,257
All other Crustaceans	3	7	117	7	16
Insects and Acarines	56	908	1,042	700	650
Fish Larvae	827	...	...	...	...
All Other	4	4	33	51	2
GRAND TOTAL	5,659	3,965	2,051	8,896	22,086

1 Tabulated values are the total number from a 5-min surface tow at each station each month.

Table 4.22. Electivity values for juvenile alosine fishes from the James River in 1971.

Species and Food Category	June	July	August	September	October
Blueback					
Cladocera		+.09	+.17	+.15	+.48
Adult Copepod		...	-.21	...	...
Immature Copepod		-.05	-.50	-.72	-.67
Other		...	...	...	...
Mean Fish Length (mm FL)		42	48	50	58
Alewife					
Cladocera	-.38	+.33	-.34	+.09	+.08
Adult Copepod	+.96	...	+.80	-.50	+.30
Immature Copepod	-.52	-.36	-.69	-.60	-.30
Other	+.32	...	...	...	...
Mean Fish Length (mm FL)	33	53	60	64	65
American Shad					
Cladocera	-.45	+.38	+.17	+.15	-.40
Adult Copepod	+.40	+.66	-.25	-.26	+.49
Immature Copepod	-.60	-.70	-.65	...	...
Other	+.96	...	...	...	...
Mean Fish Length (mm FL)	38	58	69	75	76

Table 4.23. Comparison of predator competitor loads in four rivers based upon combined bottom trawl data from winters of 1972 and 1973.

	James River (139 Tows)				York River (118 Tows)			
Predators	Total number	Total kgs. all tows	Percent weight	Rank by weight	Total number	Total kgs. all tows	Percent weight	Rank by weight
White Perch	106	11.9	2.1	6	12,953	793.4	65.5	1
Hogchoker	931	24.2	4.2	4	9,132	149.6	12.4	3
Channel Catfish	7,097	310.9	54.1	1	613	25.5	2.1	5
White Catfish	1,732	26.3	4.6	3	2,965	188.1	15.5	2
Brown Bullhead	1,562	167.6	29.2	2	4	...	...	...
Striped Bass	14	5.0	0.8	8	177	35.1	2.9	4
American Eel	153	6.0	1.0	7	80	4.0	0.3	...
Cyprinidae	2,871	16.8	2.9	5	647	4.0	0.3	...
Percidae	695	2.4	0.4	...	1,134	4.0	0.3	...
Others	62	3.7	0.6	...	48	8.7	0.7	6
TOTAL	15,223	574.8			27,753	1,212.4		
Competitors								
All Alosa	4,738	30.3	35.0	2	1,797	14.2	26.9	2
Bay Anchovy	46,051	48.2	55.7	1	20,977	20.4	38.7	1
Gizzard Shad	92	4.8	5.5	3	78	6.4	12.1	4
Menhaden	264	2.1	2.4	4	221	1.4	2.7	5
Other	15	1.1	1.3	5	563	10.3	19.5	3
TOTAL	51,160	86.5			23,636	52.7		
Mean Total Biomass (kg/tow)			4.76				10.72	

Table 4.23. (Continued)

	Rappahannock River (130 Tows)				Potomac River (126 Tows)			
Predators	Total number	Total kgs. all tows	Percent weight	Rank by weight	Total number	Total kgs. all tows	Percent weight	Rank by weight
White Perch	33,745	899.0	62.0	1	60,660	1,542.8	77.2	1
Hogchoker	15,659	201.3	13.9	2	355	9.9	0.5	3
Channel Catfish	4,281	109.6	7.6	4	244	6.4	0.3	6
White Catfish	4,259	120.6	8.3	3	111	1.9	0.1	7
Brown Bullhead	269	37.1	2.6	5	4,375	418.2	20.9	2
Striped Bass	183	28.1	1.9	7	103	9.2	0.5	4
American Eel	93	3.5	0.2	8	12	1.2	0.1	8
Cyprinidae	3,148	36.2	2.5	6	462	7.6	0.4	5
Percidae	2,119	14.4	1.0	...	47	0.9	...	...
Others	7	0.4	...	...	12	0.1	...	...
TOTAL	63,763	1,450.2	...	...	66,381	1,998.2	...	...
Competitors								
All Alosa	1,914	10.6	22.2	2	361	3.3	3.3	2
Bay Anchovy	39,113	28.8	60.2	1	207	0.1	0.1	5
Gizzard Shad	76	5.0	10.5	3	3,438	92.7	92.6	1
Menhaden	172	1.4	2.9	5	326	2.9	2.9	3
Other	129	2.0	4.2	4	21	1.1	1.1	4
TOTAL	41,404	47.8	...	...	4,353	100.1	...	...
Mean Total Biomass (kg/tow)			11.52				16.65	

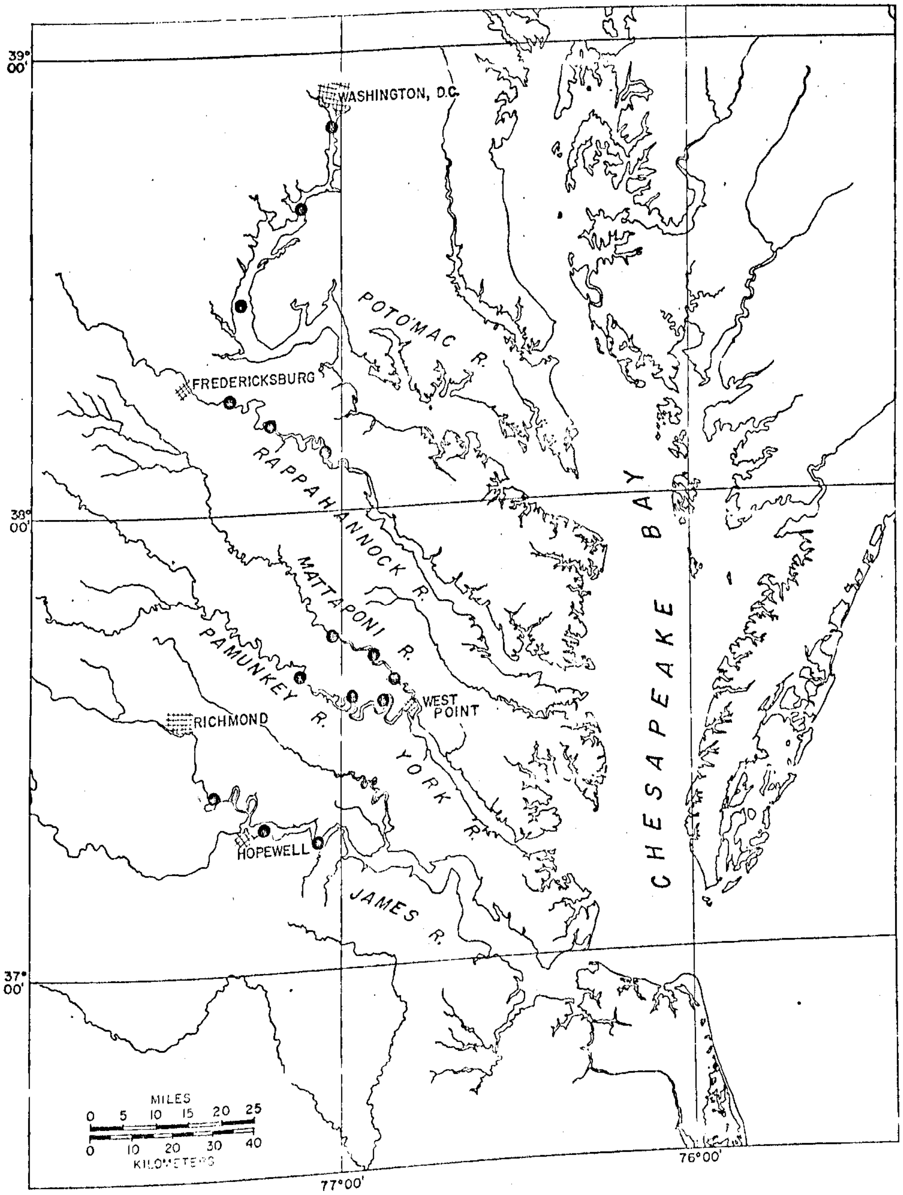


Figure 4.1. Map of Tidewater, Virginia showing sampling stations for field program in 1971.

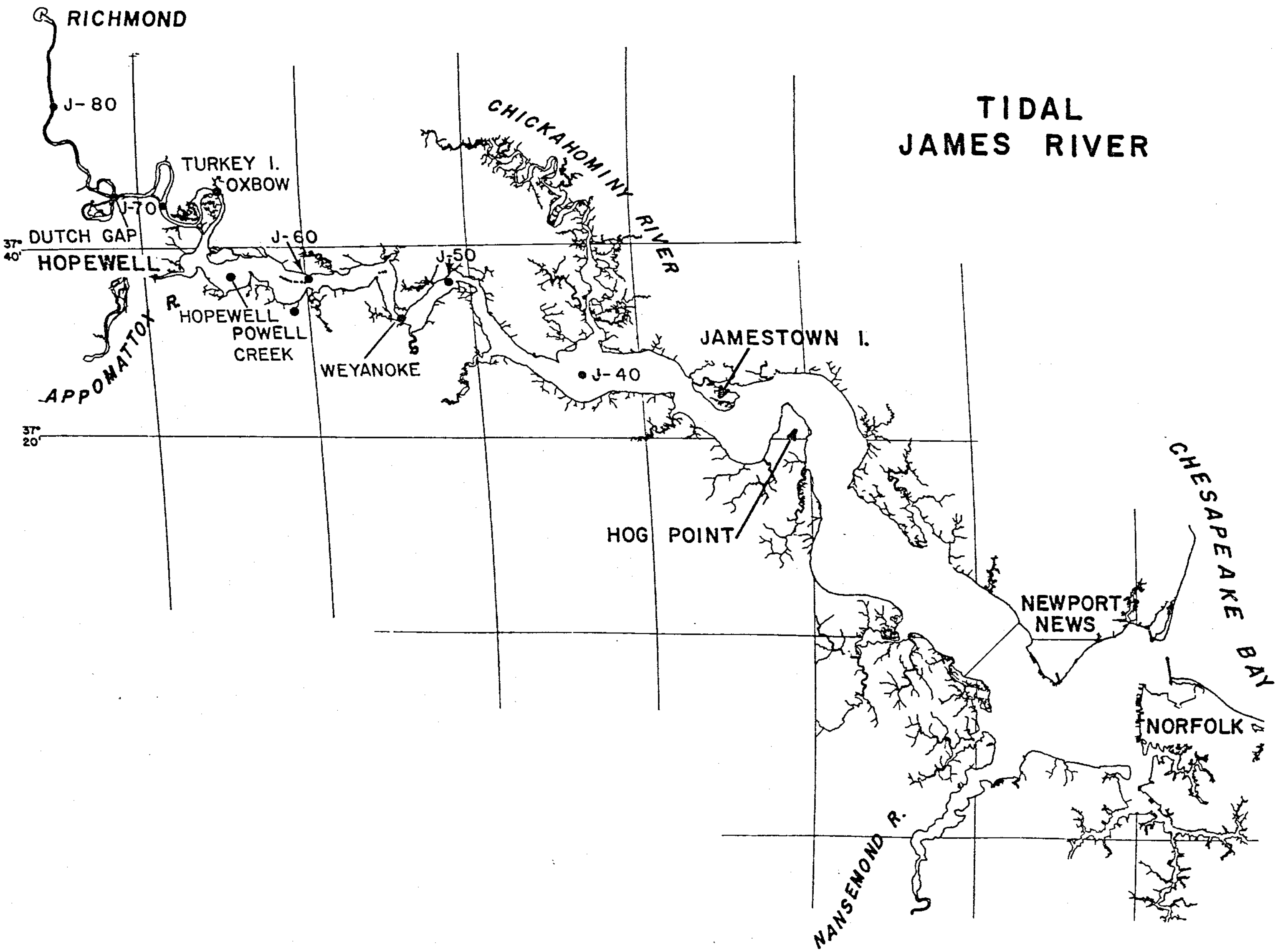


Figure 4.2. Location map of the tidal James River, Virginia, showing sampling staions for field program in 1972.

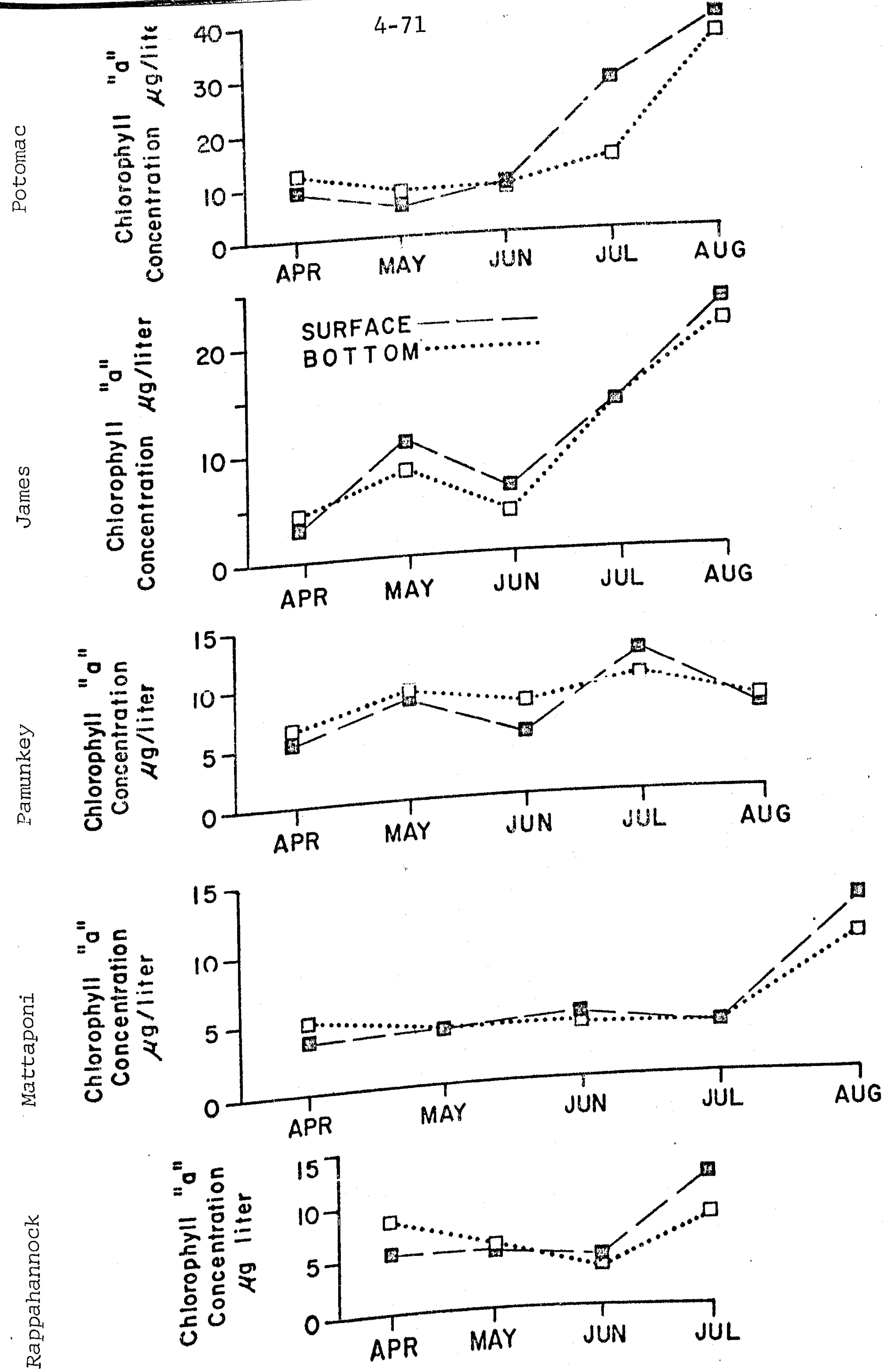


Figure 4.3. Standing crop of phytoplankton as measured by Chlorophyll a in five alosine nurseries during the summer months of 1971.

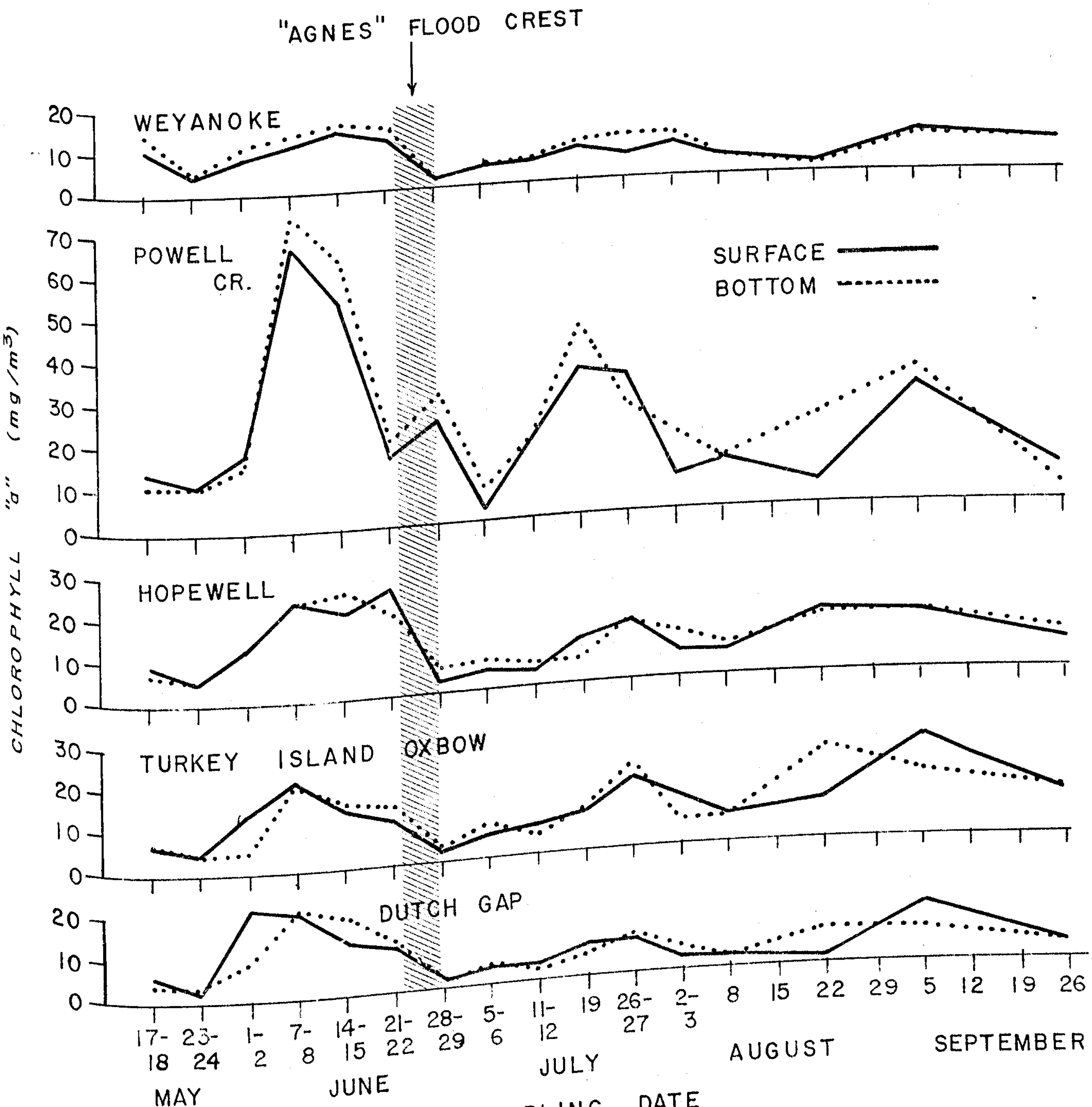


Figure 4.4. Chlorophyll a concentrations at five stations in the James River, 1972.

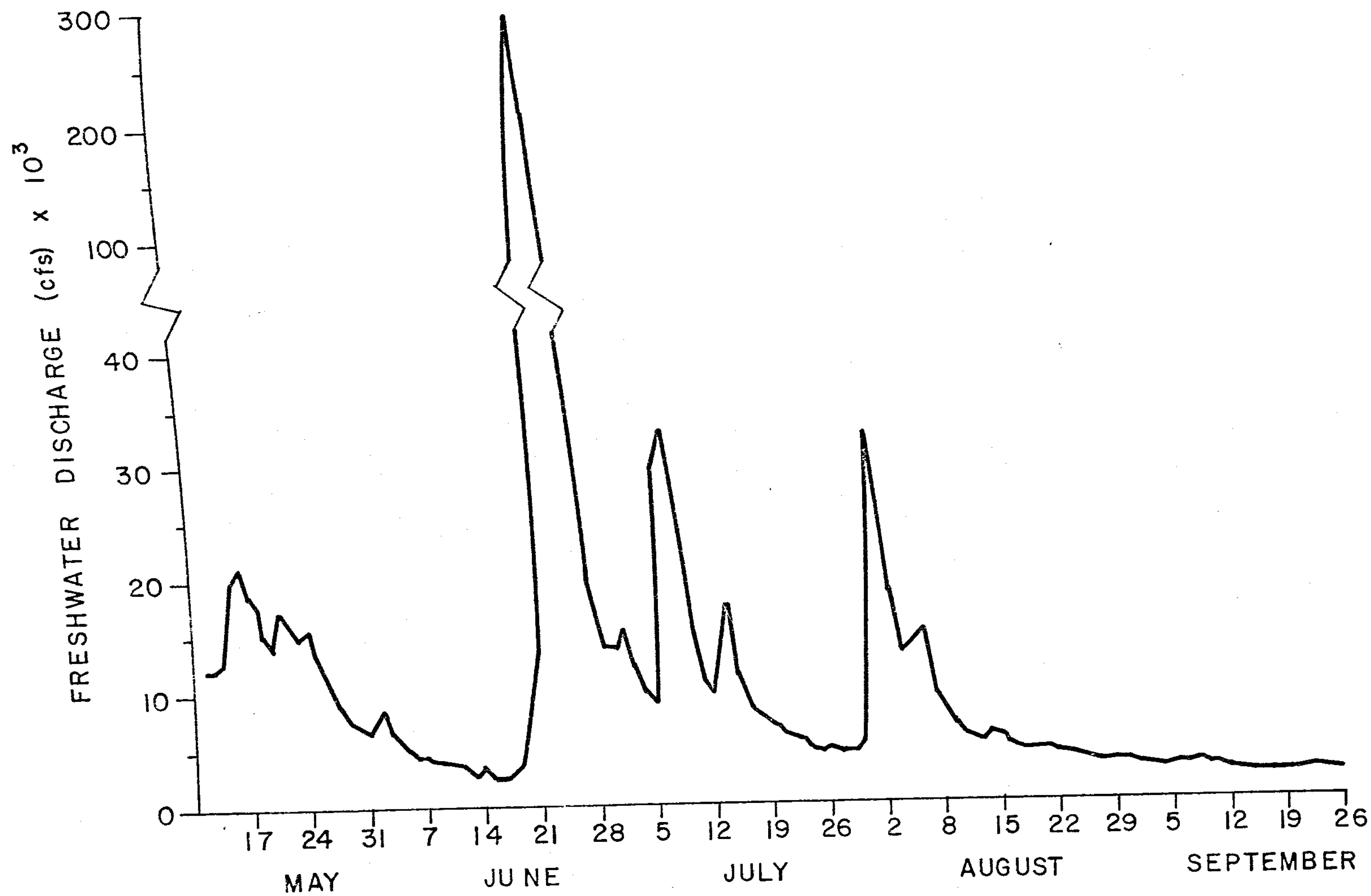


Figure 4.5. Daily record of freshwater discharge (cf/s) of the James River at Richmond for the period 15 May to 26 September, 1972.

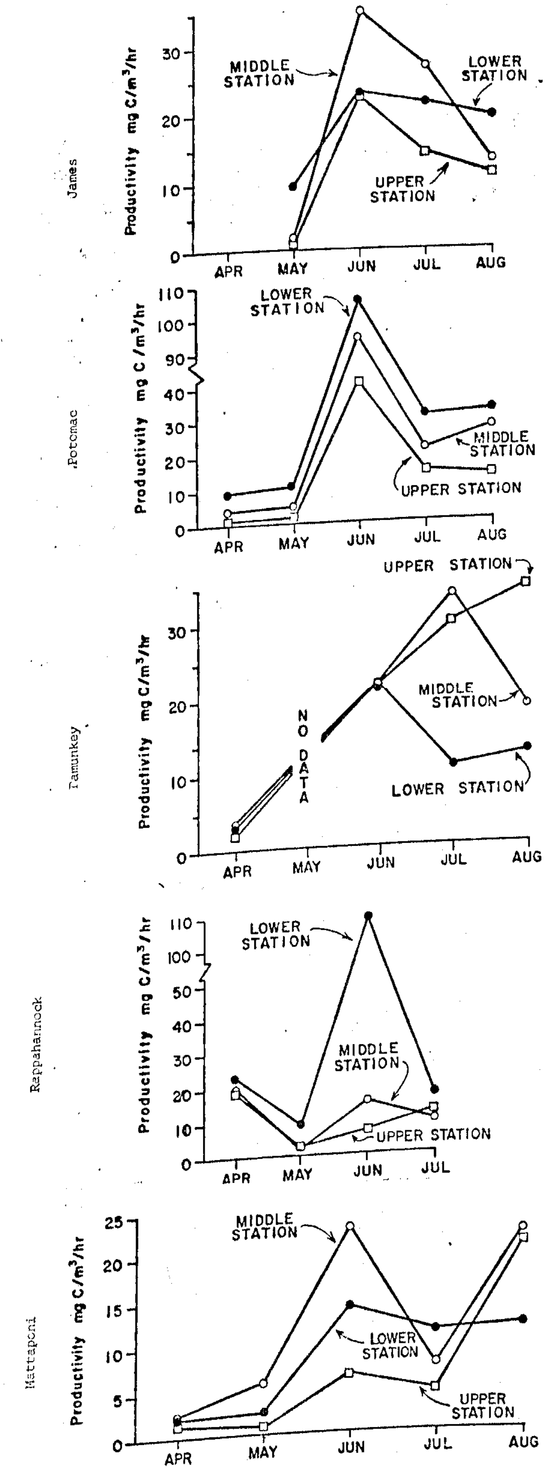


Figure 4.6. C^{14} primary productivity in five alosine nurseries during the summer months of 1971.

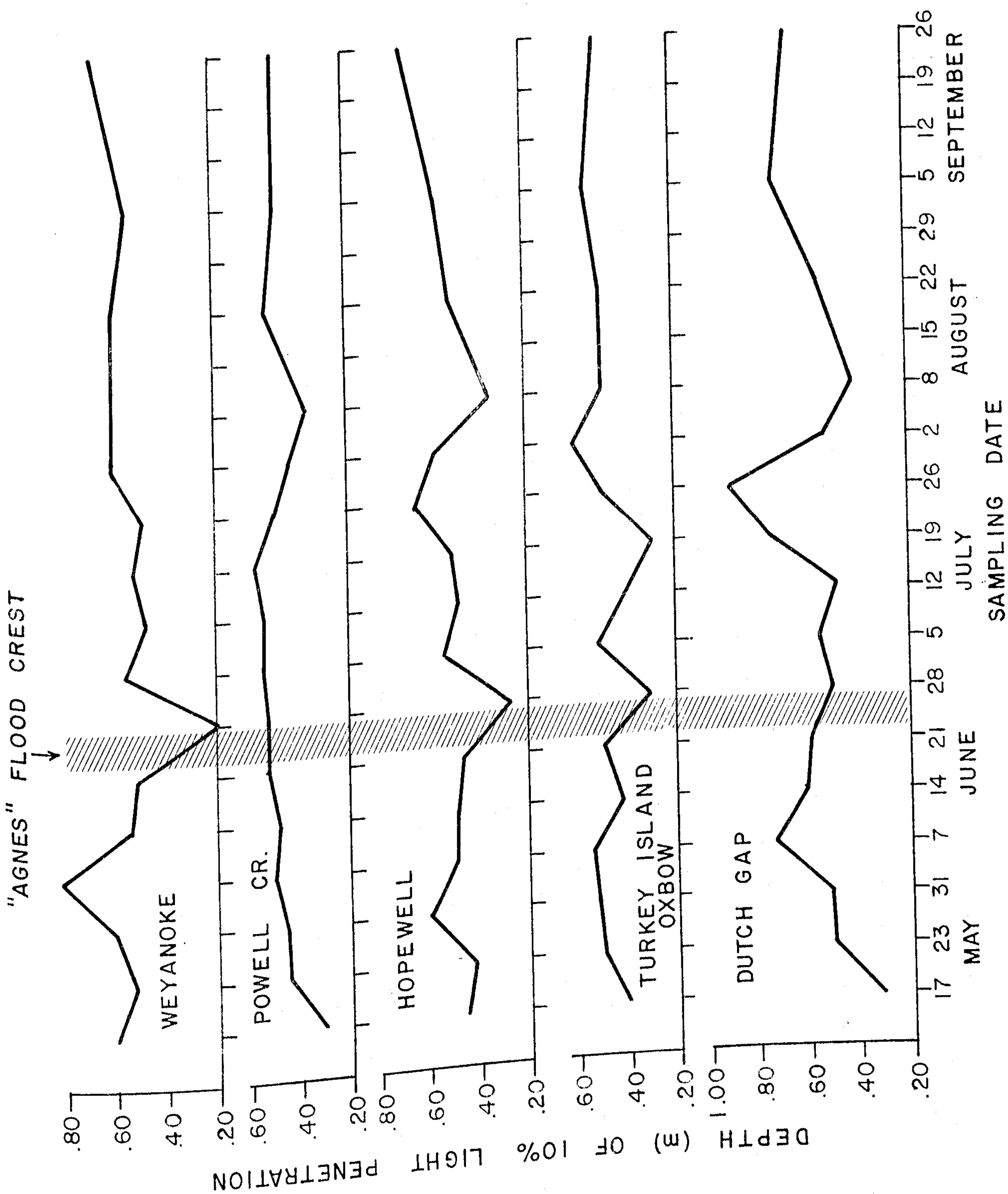


Figure 4.7 Depth of 10% light penetration at five stations in the James River, 1972.

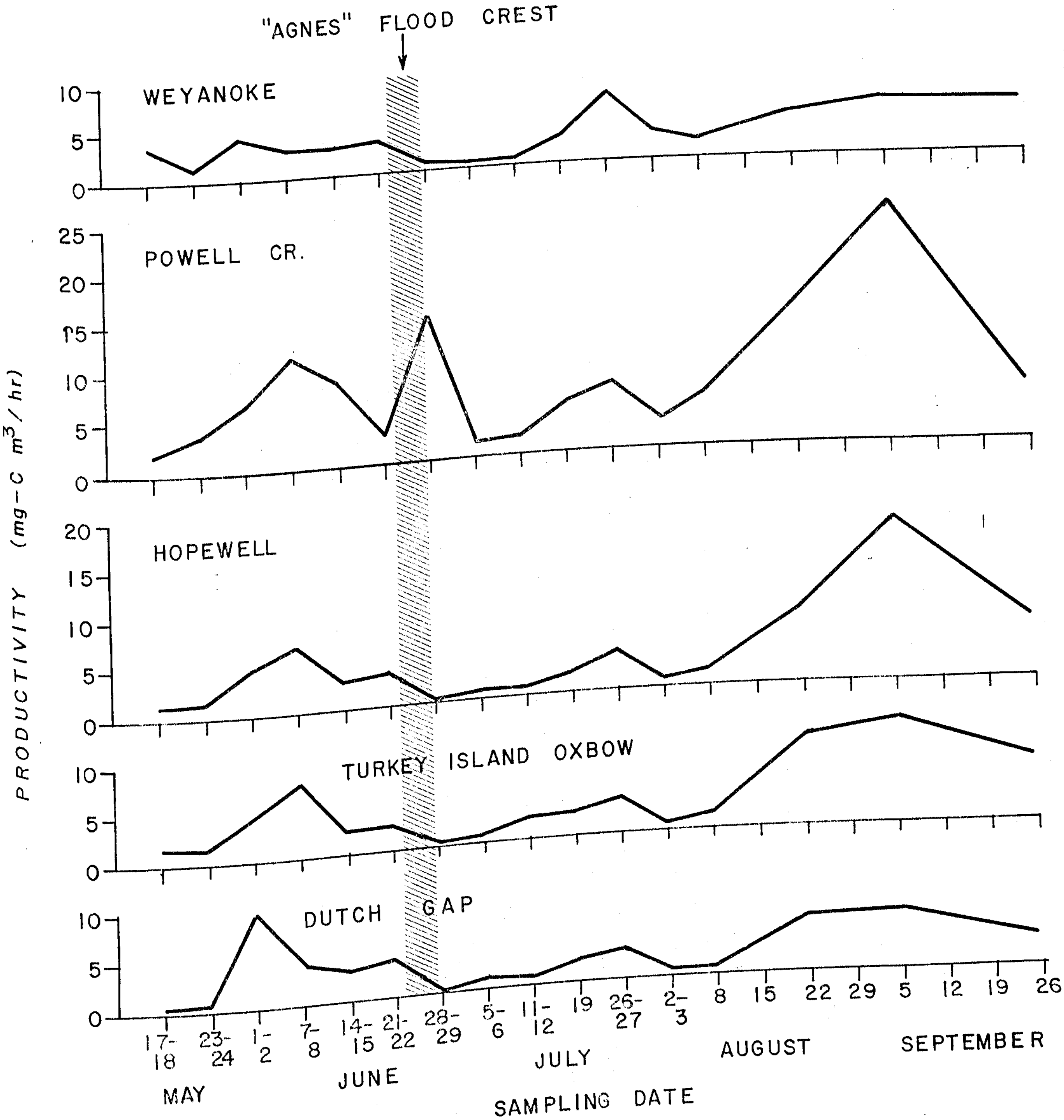


Figure 4.8. C^{14} primary productivity at five stations in the James River, 1972.

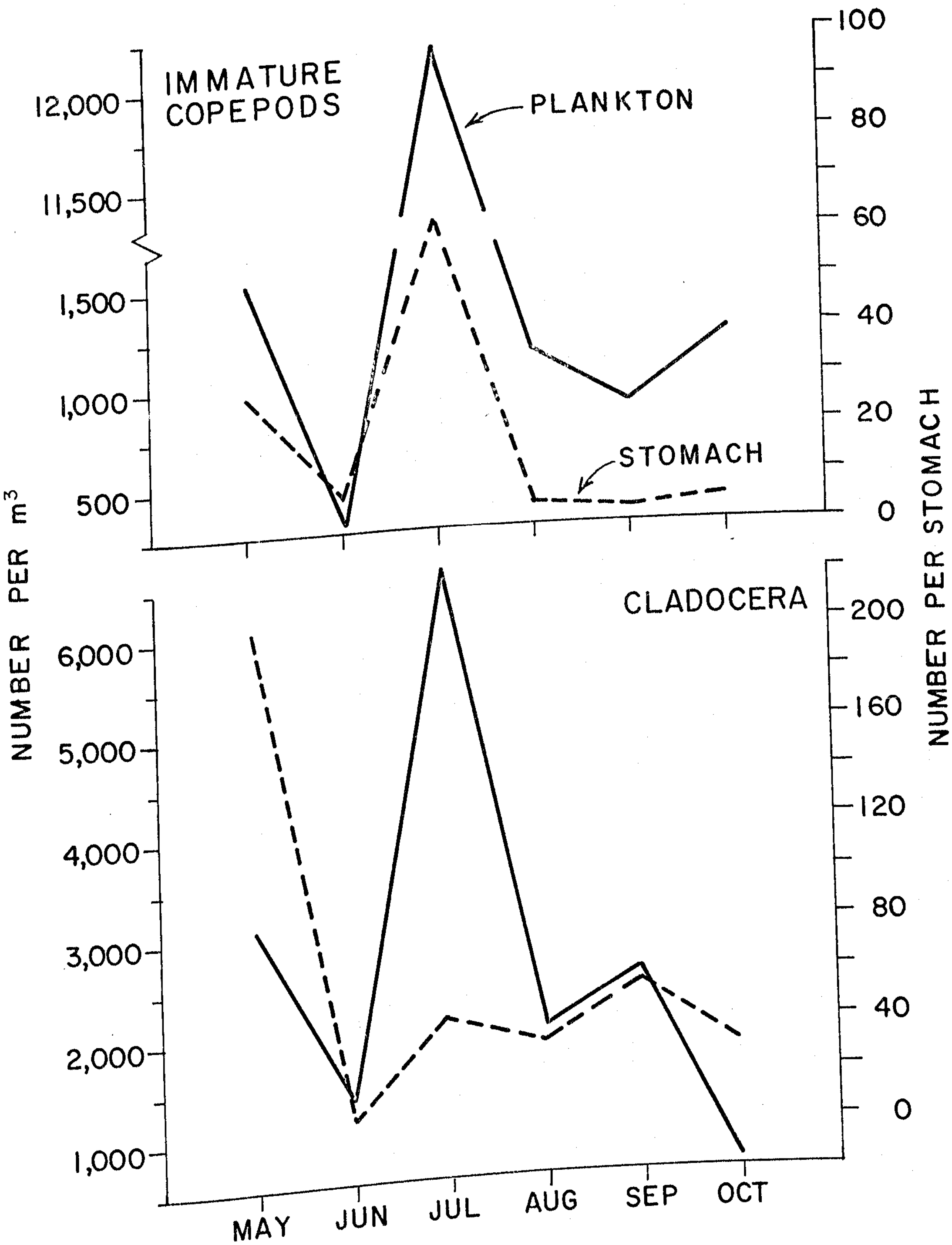


Figure 4.9. Comparison of stomach contents of blueback and pump samples of zooplankton from the James River in 1971 (all stations combined).

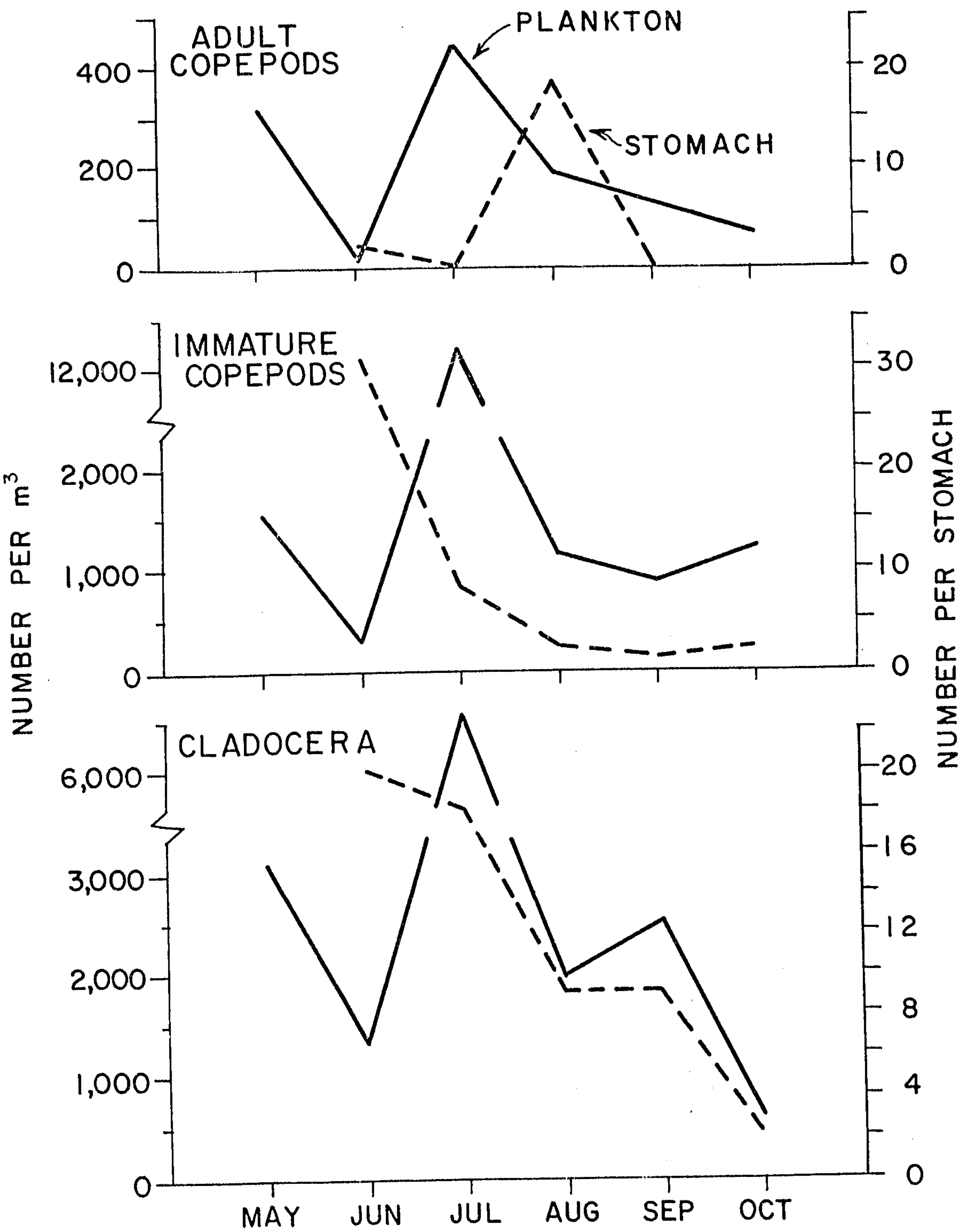


Figure 4.10. Comparison of stomach contents of alewife and pump samples of zooplankton from the James River in 1971 (all stations combined).

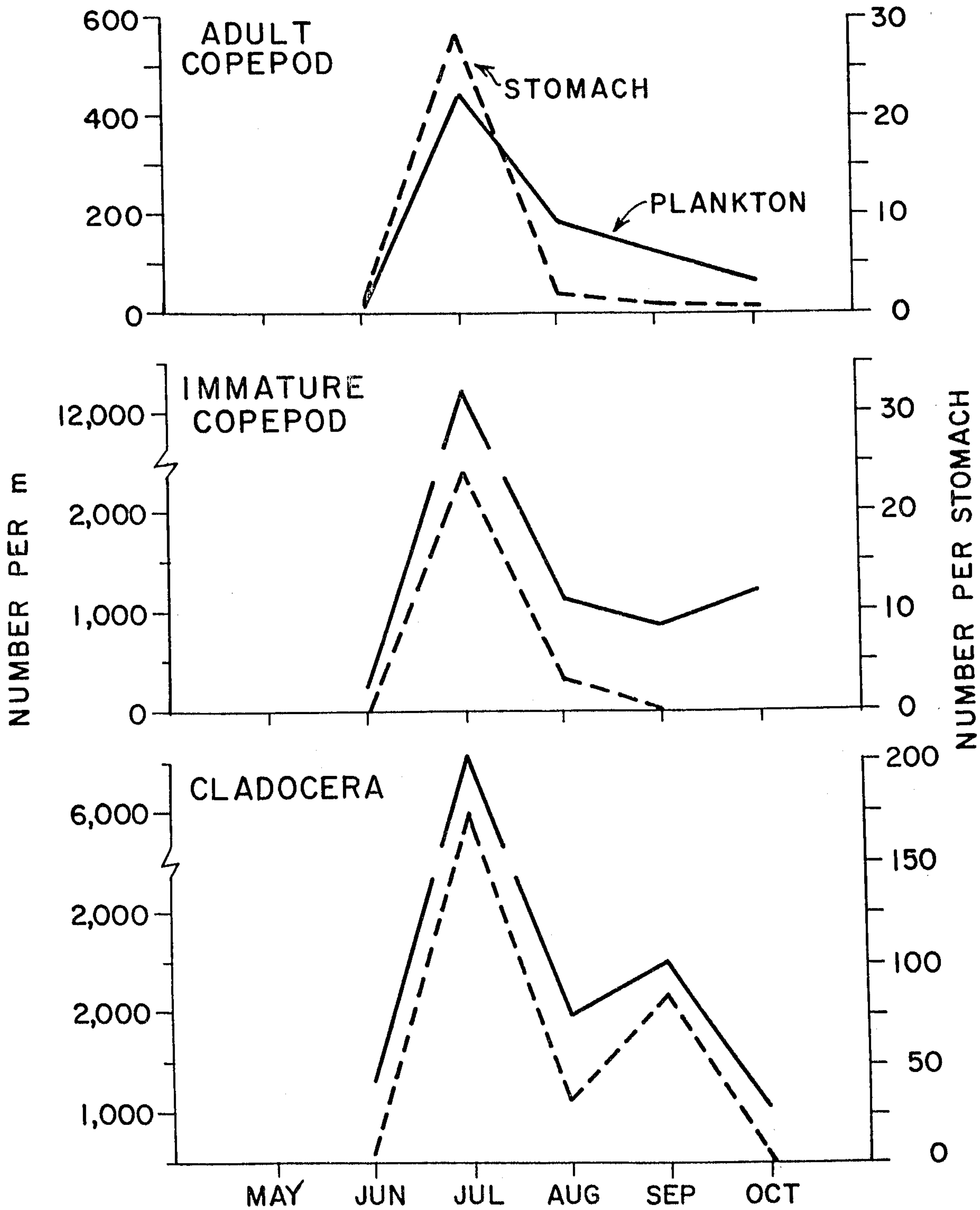


Figure 4.11. Comparison of stomach contents of American shad and pump samples of zooplankton from the James River in 1971 (all stations combined).

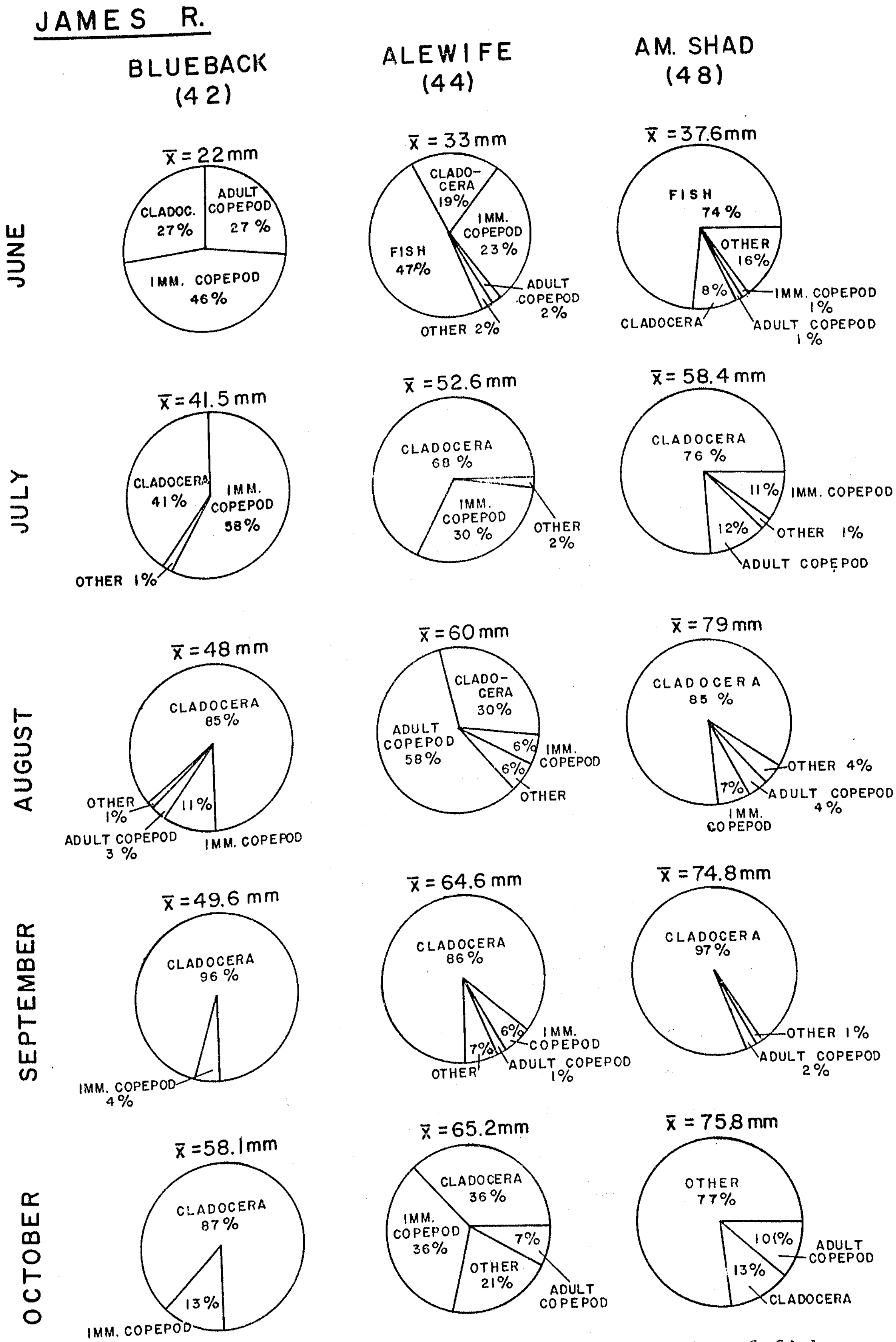


Figure 4.12. Comparative food habits and mean lengths of fish examined for three species of alosines in the James River during 1971.

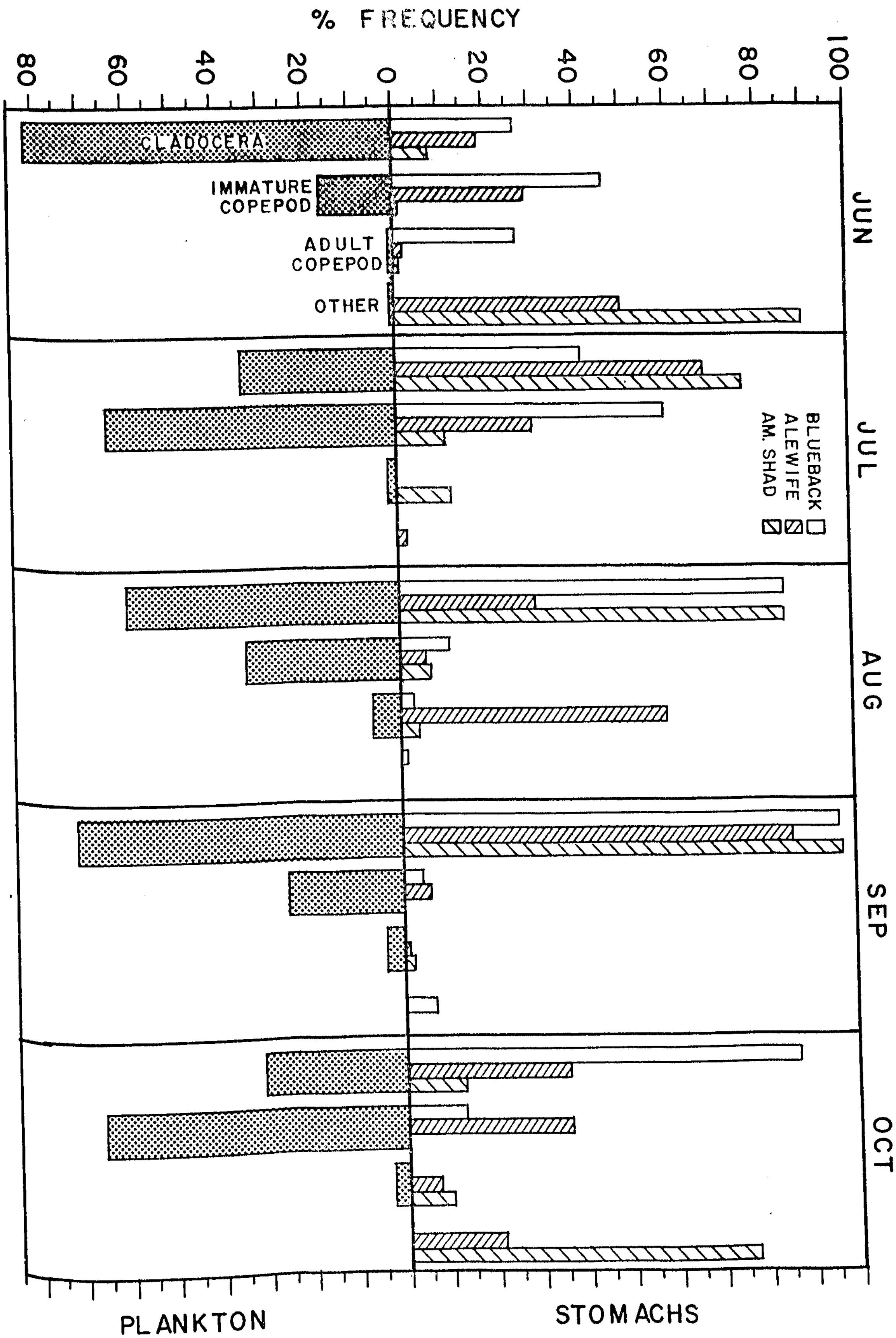


Figure 4.13. Comparison of foods consumed by alosine juveniles and zooplankton abundance in the James River during 1971.

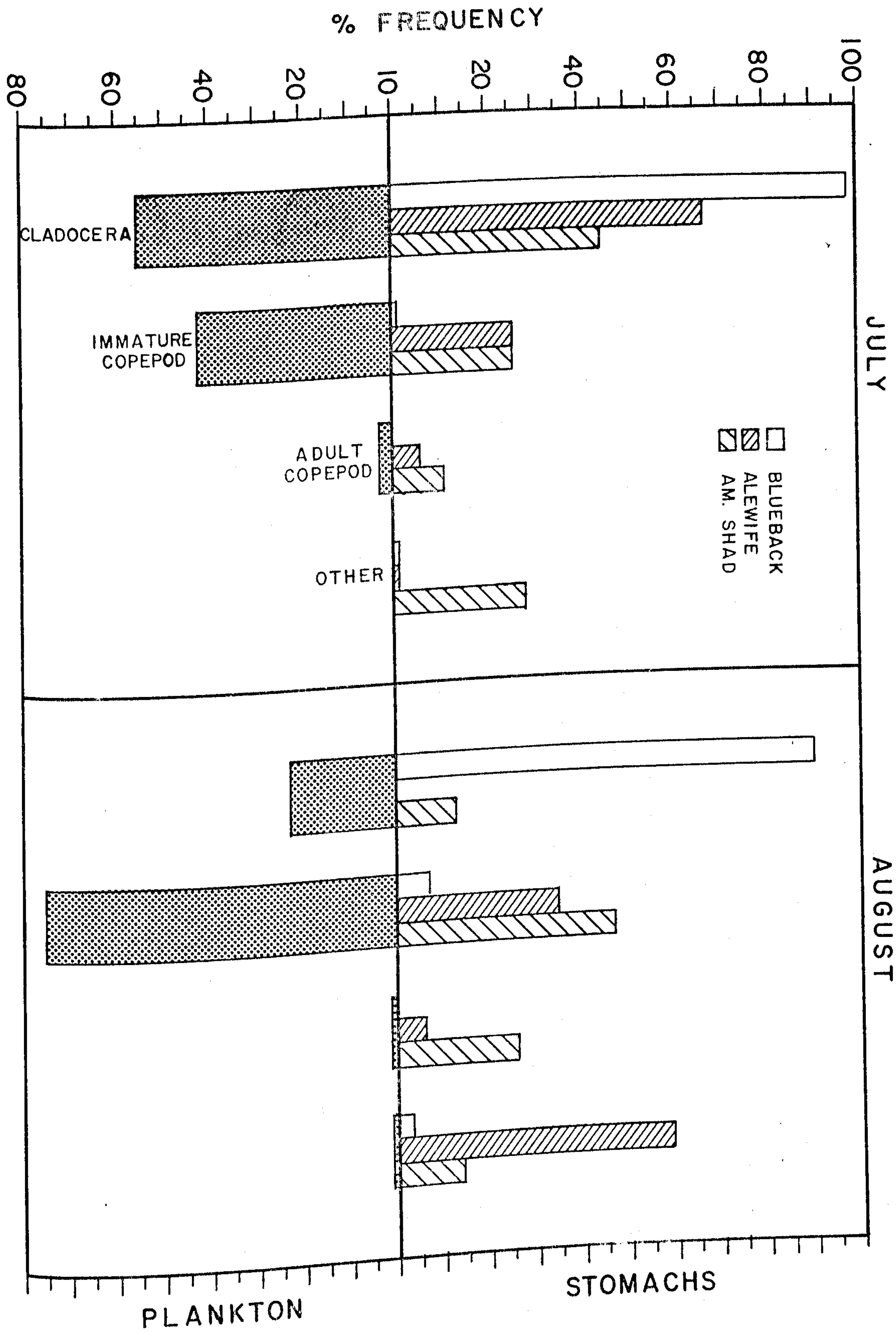


Figure 4.14. Comparison of foods consumed by alosine juveniles and zooplankton abundance in the Pamunkey River during July and August, 1971.

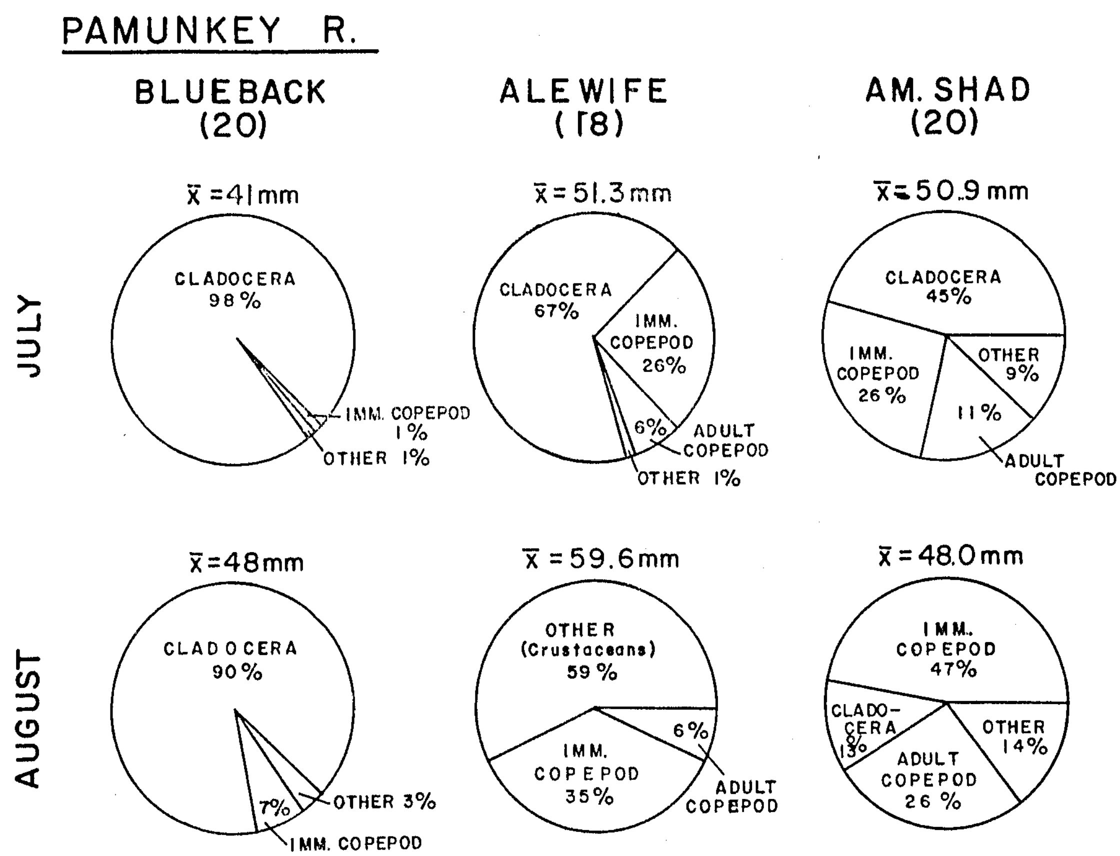


Figure 4.15. Comparative food habits and mean lengths of fish examined for three species of alosines in the Pamunkey River during July and August, 1971.

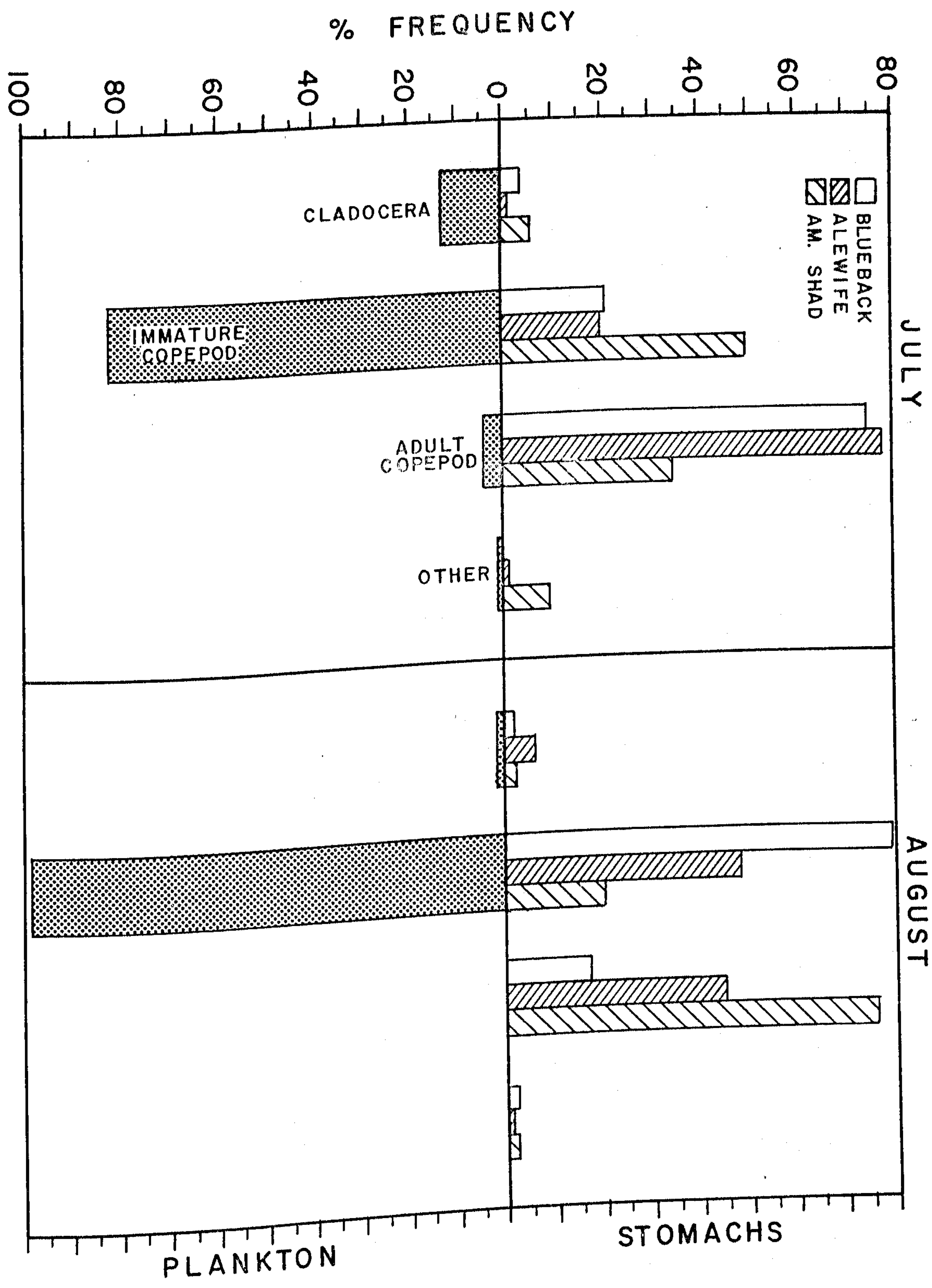


Figure 4.16. Comparison of foods consumed by alosine juveniles and zooplankton abundance in the Mattaponi River during July and August, 1971.

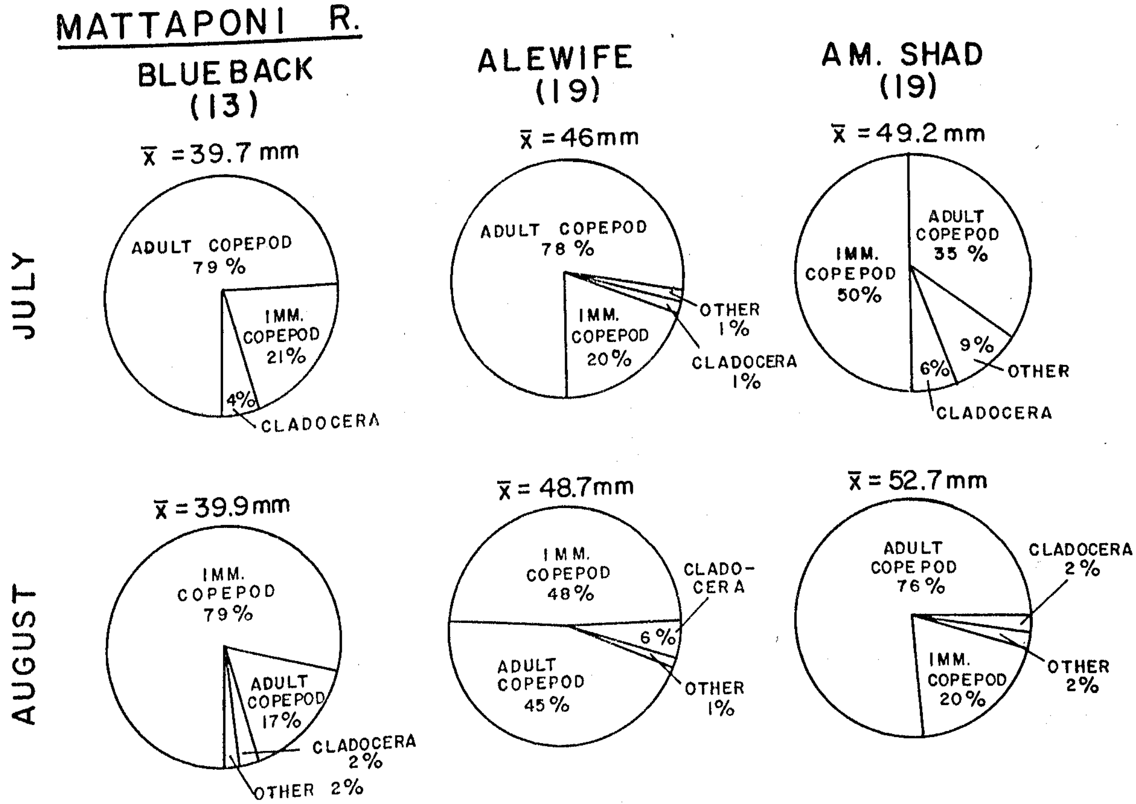


Figure 4.17. Comparative food habits and mean length of fish examined for three species of alosines in the Mattaponi River during July and August, 1971.

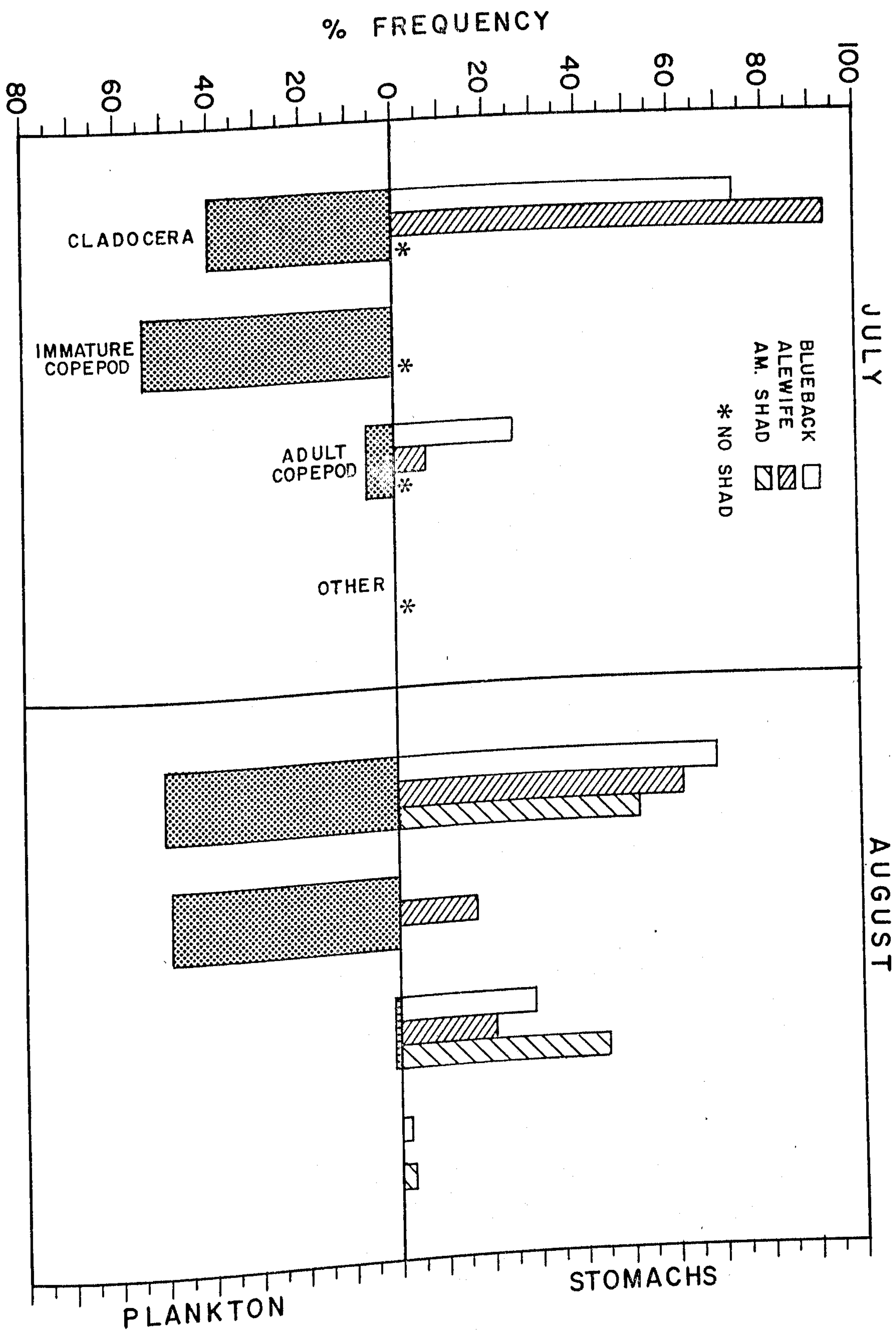


Figure 4.18. Comparison of foods consumed by alosine juveniles and zooplankton abundance in the Rappahannock River during July and August, 1971.

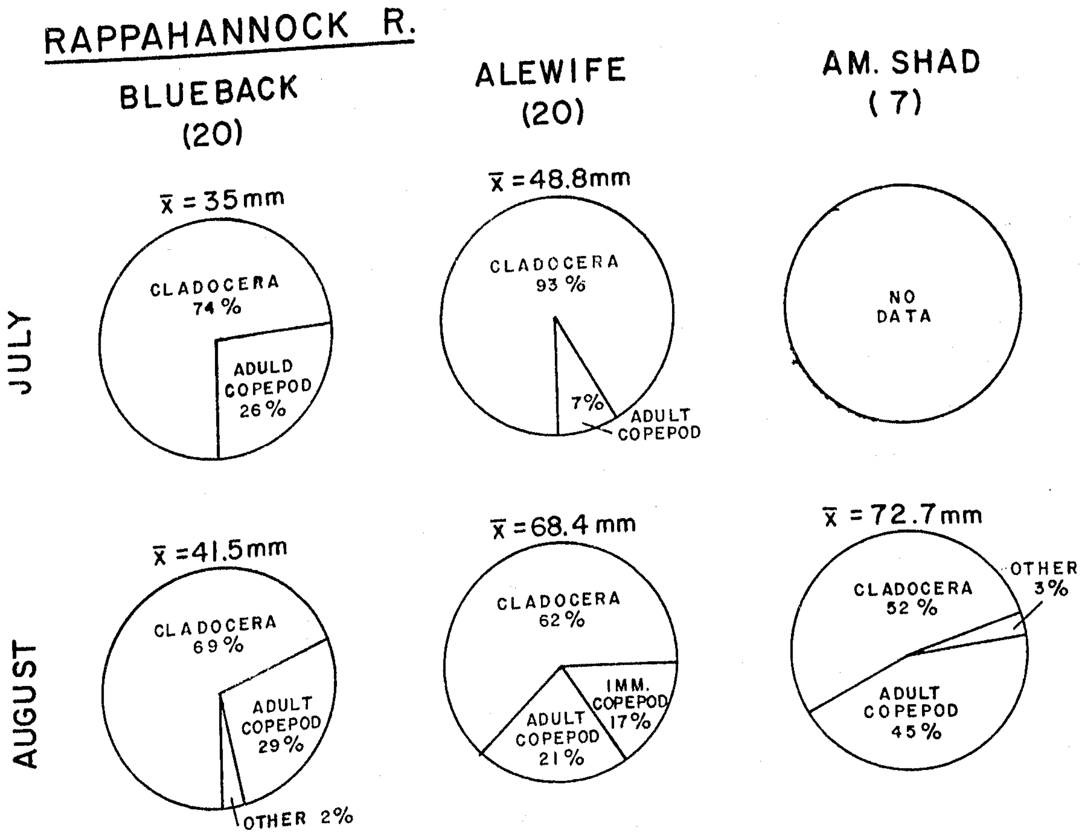


Figure 4.19. Comparative food habits and mean length of fish examined for three species of alosines in the Rappahannock River during July and August, 1971.

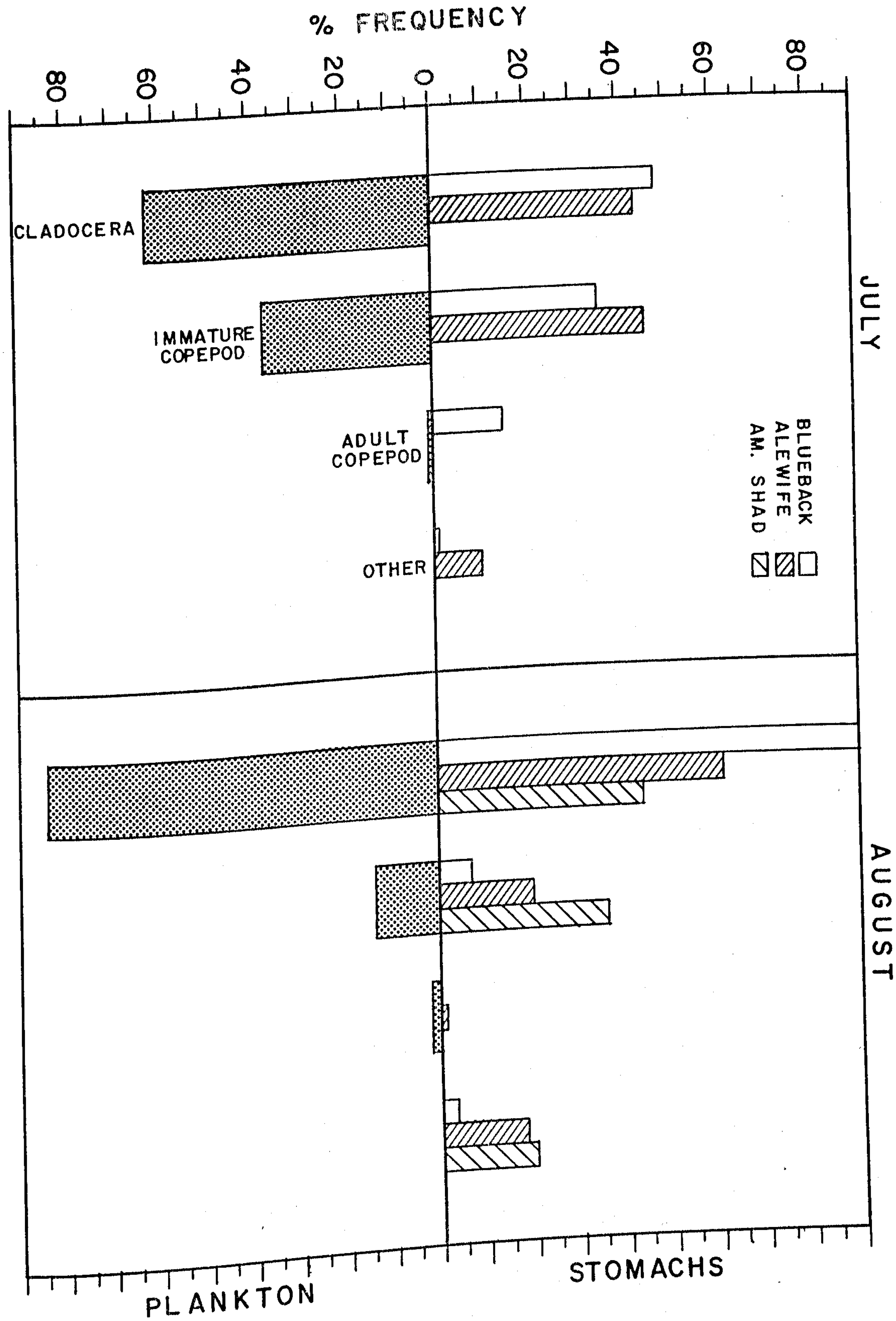


Figure 4.20. Comparison of foods consumed by alosine juveniles and zooplankton abundance in the Potomac River during July and August, 1971.

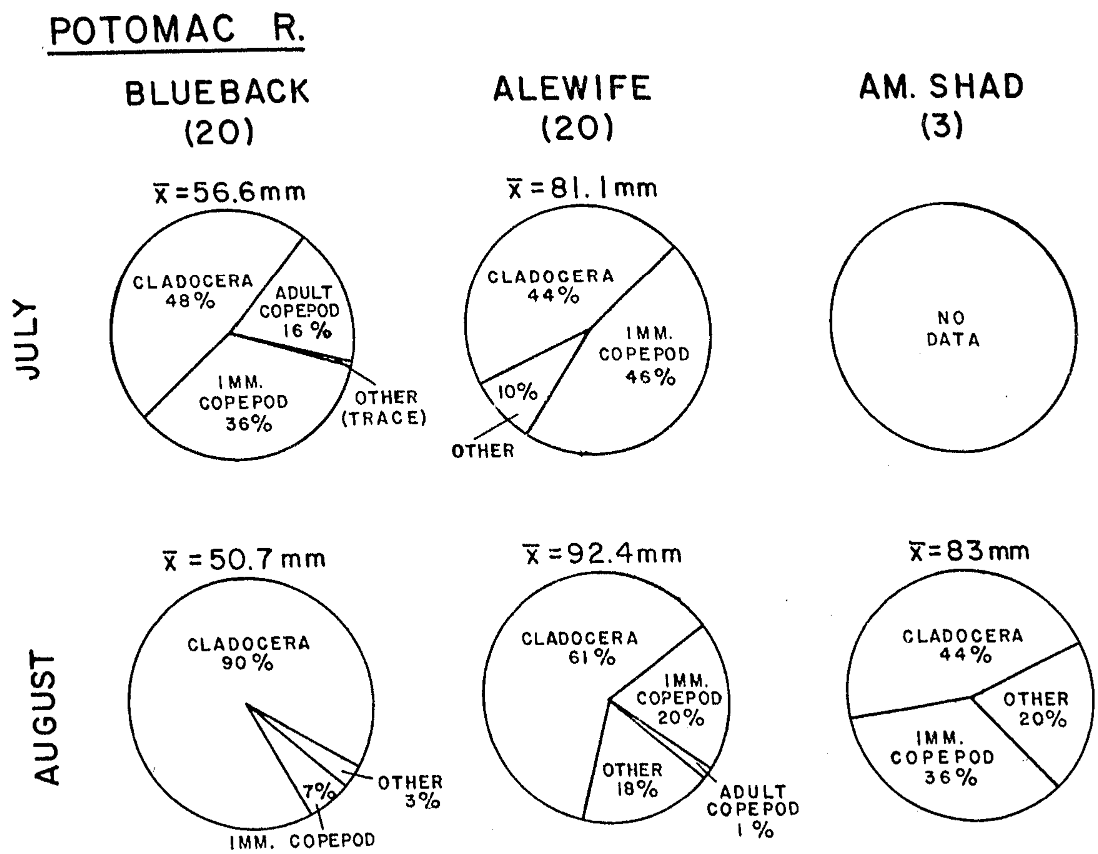


Figure 4.21. Comparative food habits and mean length of fish examined for three species of alosines in the Potomac River during July and August, 1971.

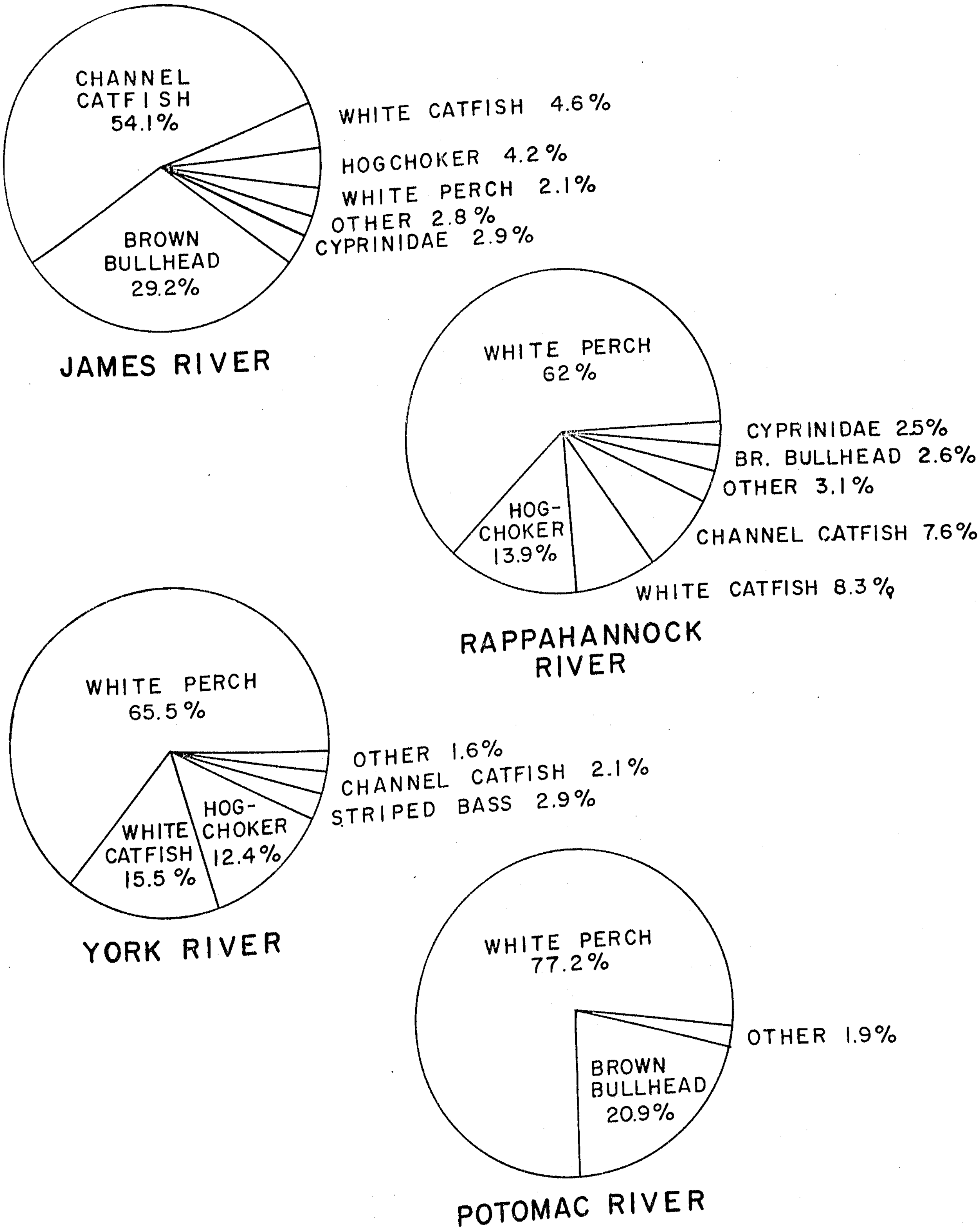


Figure 4.22. Species composition of the resident fish population during the winters of 1972 and 1973 (data combined) in the alosid nursery areas of four Virginia rivers.

Job 6. Development of culture technique.

The intent of this phase of our research program was to develop a culture methodology for the alewife and blueback from the egg through juvenile life stage. Young fishes at various ages would thus be available for experimental studies, experimental animals would be of the same parentage, and experimental animals would have a known history of exposure to various environmental factors.

Representative series of specimens from the various experimental matings were preserved for a reference collection and as descriptive material for embryonic and larval development of the fishes. Hybrid crosses were attempted to evaluate the potential success of interbreeding between river herrings in nature and to provide larvae of known parentages. The alewife and blueback utilize the same habitat as spawning grounds and their spawning seasons overlap in time. We have seen adult representatives in the commercial catch which appear to be hybrids from both reciprocal crosses. Comparison of the progeny from these crosses will hopefully assist in clarifying the existing identification problem for larval alosine fishes.

1973 Studies - The rearing of larval alosids during the spring of 1973 was attempted in the culture facilities at VIMS. The experimental crosses were alewife x alewife, blueback x blueback, and ♂ alewife x ♀ blueback. Adult fish were captured in tributaries of the James River. Methods of capture, fertilization and culture techniques were similar to those of previous years with some minor modifications in later attempts.

Methods and Materials

The adult fish were captured on the spawning ground by gill net, dip net and/or cast net. Fish having suitable gonad condition were then transferred to a holding tub until fish of both sexes were captured, whereupon the eggs were stripped into the bottom of a shallow plastic pan and fertilized. Later eggs were stripped onto a sheet of netting in the bottom of the pan and fertilized. This change eliminated unnecessary mechanical damage to the eggs as they were transferred to incubation trays.

The fertilized eggs were then transported to the culture facilities and placed in incubation trays to hatch. The eggs were examined daily to determine egg development, mortality, and larval development.

The culture trays used were of several types. One system consisted of a reservoir holding approximately 150 gal, 3 trays with a flowing-water system above the reservoir and another reservoir above the trays to provide a supply of water. The water was pumped from the bottom reservoir to the tank at the top. Water was then gravity-fed by plastic hose to each individual tray from the top tank. At the discharge end of each tray a hose led back to the bottom reservoir thereby creating a continuous flowing system. Water was passed through glasswool and charcoal filters on its return to the reservoir. In each tray a piece of netting was suspended approximately 1 inch above the bottom and the eggs were placed upon this for incubation. This arrangement created a reasonable simulation of natural conditions and provided water circulation above and below the eggs.

Other incubation tanks consisted of aquaria with netting suspended under the water surface and the eggs were placed on the netting for incubation. Two air stones placed in each tank provided aeration and water circulation. Water in these tanks was filtered through glasswool and charcoal.

A fungicide (Wardley's Stainless) was added to the culture systems after the eggs were placed in them. Dead eggs and embryos were attacked by fungi and through subsequent fungus growth, the live eggs nearby became smothered. Approximately 1 oz of fungicide per 50 gal of water was added each 2 wk. This treatment did not satisfactorily control the fungus.

Food for the larval fish was obtained from a nearby freshwater pond. Pond water was poured through a 35 µ plankton net to concentrate the food organisms. Approximately 40-60 gal of water were strained for each feeding and resuspended in 1 to 2 gal of water. The concentrate was then placed in the culture tanks at the rate of approximately 1 qt to 20 gal thus approximating natural food concentrations. The concentrate was examined under a microscope to ascertain presence of food organisms. Green algae, diatoms, rotifers, veliger larvae, insect larvae, and other zooplankters were in the concentrate.

Samples were taken from the culture trays at 12 or 24 hr intervals depending upon the stage of development of the animals. The samples were examined under a dissecting microscope to determine the developmental stage of the fish. From each of these samples approximately 10 fish were preserved in 10% formalin to provide series of each cross through their development stages.

Results

A. <u>Alewife x alewife</u>

On April 30, 1973, adult male and female alewife were obtained from Courthouse Creek in James City County. The eggs were stripped and fertilized at the collection site. Live eggs in the 2-4 cell stage were placed in the continuous flow culture trays at VIMS 5 hr later.

At 24 hr, a sample was removed and examined. Of 42 eggs in the sample, nine were dead representing a mortality of 21%.

At 48 hr, mortality exceeded 50% with large clumps of eggs dying and being engulfed by fungus. In live eggs, the embryos were at the tail free stage and beginning to show movement.

At 60 hr, hatching had begun and by 72 hr most of the eggs had hatched. Many of the newly hatched larvae were being entrapped in the fungus masses. These fish became entangled in the hyphae and subsequently died. Several clumps of fungus were removed and the live larvae picked from them. These larvae were transferred to another tray but were in poor condition.

At 4 days, most of the larvae in the tray were dead or near death. After 5 days, all the larvae were dead.

Larvae that were removed from the clumps of fungus and transferred to another tray were apparently weakened by their prior encounters with fungus. They could not swim well enough to escape the flow toward the drain and were killed on the discharge screen.

B. Blueback x blueback

On May 9, 1973, adult bluebacks were collected from Diascund Creek, a tributary of the Chickahominy River. The eggs were stripped, fertilized and returned to the culture facilities at VIMS. Embryos were in the 2-4 cell stage when they were placed in two incubation trays and an aquarium.

At 20 hr, the embryos had developed to the tail bud stage. Mortality was estimated at 50-60% in the trays and 80-90% in the aquarium.

At 44 hr, larvae were hatching but mortality in all systems was very high. Most of the eggs were dead and matted by fungus.

On the fifth day, all fish larvae in the trays were dead, again apparently killed by entanglement in the fungus and encounters with the drain screen. In the aquarium however, many larvae were alive. By the sixth day all larvae in the aquarium were dead.

C. Blueback x blueback and hybrids

On May 15, 1973, adult bluebacks were collected from Diascund Creek. These fish were stripped and fertilized at the collection site. One female blueback was fertilized with sperm from a male alewife. The eggs were stripped onto pieces of netting placed in the plastic pans. The netting was transferred to the tanks and trays at VIMS for incubation. The eggs were in the 2-4 cell stage of development when transferred. The alewife x blueback eggs were maintained separately from the blueback eggs.

At 19 hr, embryos were developing an early tail bud. The embryos from the hybrid cross had less mortality than the blueback embryos.

At 43 hr, a difference in embryonic mortality was quite apparent between blueback and hybrid egg lots. The blueback embryos had from 40 to 50% mortality in aquaria and 60-70% mortality in the trays. The hybrid cross had only 10-20% mortality. Embryos of both groups were almost fully developed at this time.

At 67 hr, the larvae were hatching out in all trays and tanks. The mortality in the hybrid cross was still far less than in the blueback embryos.

At 92 hr, the incubation netting was removed and many larvae were present in all tanks. The trays had the lowest number of larvae.

At 5 days (118 hr), the larvae were alive and swimming. The yolk sac was approximately half absorbed and the mouth parts were beginning to develop on the larvae.

At day 6, the mouth parts of the blueback larvae were well-developed and yolk sacs were nearly gone. The hybrids were in poor condition. A power failure resulted in a termination of aeration and water circulation in the tank containing the hybrids. The larvae were alive (heart beating) for several hours after this, but all eventually died. Until the power failure, hybrid larvae seemed more vigorous than the blueback larvae.

On day 7, the blueback had absorbed their yolk sac and their mouths were nearly fully developed.

On the eighth day, concentrated plankton was added to the tanks. Two days later, the remaining larvae in one large tank were transferred to a large circular tank with a biological filter and more concentrated plankton was added.

On day 11, no fish were visible in the aquaria and only a few were sighted in the large tank. On the fifteenth day no fish were sighted in any tank and all were assumed dead.

Discussion

Culture of marine fishes bloomed in the late 1800's and has continued with an ever-increasing pace and scope (Shelborne, 1964). Interest has centered upon the commercially important species and the methodology for the production of young fishes. These young fishes i.e. plaice, sea herring, salmon, rainbow trout, etc., have been utilized for experimental studies of tolerance and preferenda as well as replacement or replenishment of depleted stocks. The breadth of interests in larval fishes spans the areas of identification, anatomy, physiology, nutrition and growth, culture methods, swimming speed, sampling gear efficiency, population dynamics, etc. The importance of larval fish and their ecology to adult stocks of commercial fishes has been taken for granted for many years. The national and international concern for management of the marine and estuarine fisheries has brought about a renewed interest in larval fish ecology. Today, researchers are engaged in discrete studies of larval and juvenile fishes the world over as evidenced by the

FAO sponsored international symposium on the early life history of fish held at Oban, Scotland in May, 1973.

Culture of alosine species in the U.S. dates back to the early hatchery operations for American shad in the mid 1800's (Walburg and Nichols, 1967). Construction of dams, channel dredging, increased urban and industrial development and the attendant waste and chemical additions to the water in the various streams along the eastern seaboard prompted a rebirth of concern for anadromous fish stocks. The VIMS research program has documented the spawning and nursery areas, monitored the commercial catch by the domestic fishery for age structure and status of the stock, described the abiotic and biotic characteristics of the nursery area, and maintained a program to ascertain relative year class strength in the various tributaries. Realizing the need for controlled experimental information on alosine fishes relative to fluctuations in natural factors and habitat alterations, VIMS sought to develop a methodology for culturing alewife and blueback from the egg through juvenile life stages. Young fishes would then be available to scientists for evaluation of fish tolerance and preference to various factors or conditions in the water, fish behavior, and fish physiology.

Development of culture methodology for the alewife and blueback will provide study material for the description of the young stages from known parentage and subsequently a functional identification scheme for all life stages. Alewife and blueback in the egg and larval stages are difficult to distinguish from each other (Mansueti and Hardy, 1967; Lippson, 1974). Several methods to differentiate between these forms and other clupeids have been developed (Chambers, 1969; Wang,* pers. comm.) but none have the assurance of a pure series for each species.

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These methods utilized time of spawning season as a separating mechanism to provide study material of each species from field collections.

These descriptions and identification aids will be applicable to baseline environmental data banks, research programs under the anadromous fish act, environmental impact surveys by consulting firms, and laboratory research programs on behavior and physiology.

Several persons have reported attempts to rear alewife and/or blueback from the egg through juvenile stages, but no one has succeeded to date. Literature citations include Fahy, 1964; Leim, 1924; Cooper, 1961; Mansueti, 1956, Norden, 1967; Odell, 1934; and Cianci, 1969. On-going programs include those of Ichthyological Associates (J.C.S. Wang), Texas Instruments (W. Tarplee), and N.U.S. Corporation (B. Marcy).

Summary of 1972-1973 Culture Experiments

1) Adult *Alosa pseudoharengus* and *A. aestivalis* taken from streams in spawning condition can be used as sources of viable eggs and sperm. However, each fish should be checked for condition of the eggs before stripping. Only those fish with "free flowing" eggs should be used to assure a high percent fertilization. Additional tests should be conducted to assess the period of time after ovulation in which fertility remains high. These tests could be patterned after those developed for striped bass culturists at Monck's Corner, S. C. (Bayless, 1973). Gill net sets of short duration and seining are suggested as collection techniques which minimize injury to the fish. We have had better fertilization and hatching success using field fertilization rather than transporting adult fish to the laboratory for egg taking and fertilization.

2) Fertilization percentage for alewife and blueback eggs stripped at the site of capture exceeds 75%. The "semi-dry" method of artificial

fertilization gave better results in our study than either the dry or wet method. Cianci (1969) obtained a high fertilization rate using the "wet method."

3) Artificially fertilized eggs are slightly adhesive and this property causes some problems in transfer of eggs from the stripping pans to the incubation chambers. In nature the eggs probably develop a thin coating of detritus and sediment and do not stick to the spawning substrate with the same tenacity as the artificially stripped eggs in our experiments. The addition of clay material to the incubation water after stripping should reduce the adhesive properties of the eggs and facilitate handling of the eggs in the culture facility. Schubel and Wang (1973) concluded that suspended sediment such as that from dredging operations did not alter hatching success. However, their results with alewife eggs are of questionable value since test eggs in sediment-laden water had a greater percent hatch than did control eggs in clear water.

4) Hatching success for river herring eggs in the culture facility was dependent upon condition of the eggs used in a given test and degree of fungus matting on incubating eggs. Typically, about 50% of the eggs hatched in a given test. Production of alewife and blueback sac fry has been reported by each of other studies attempting culture of river herring. Hatching percent in our study, however, was generally higher than in earlier reports.

5) Fungus growth on dead eggs in the culture trays and aquaria is a source of additional mortality to the developing embryos and to newly hatched larvae. Treatment with Wardley's Stainless Fungus Remedy has been marginally successful, but does not alleviate the problem. Fungus growth represents a chronic problem for fish egg

incubation when natural stream water is used. Costs of fungus control by chemical means, although the results have only been marginally successful thus far, are far less than those for manual removal of dead eggs. We recommend the use of a fungistat during incubation and suggest experimental tests of several compounds and concentrations before adopting a standard treatment for any culture operations.

6) Time of first hatch in a given experiment was 50 to 55 hr at 22.2 C for alewife and blueback, with blueback having a shorter incubation period than alewife. Other reported hatching times and temperatures for alewife are 15 days at 7.2 C, 3.9 days at 20-21.1 C, and 2.1 days at 29.4 C (Edsall, 1970); 6 days at 15.6 C (Bigelow and Welsh, 1925); 3-5 days at 20 C (Mansueti and Hardy, 1967); 2-4 days at 22.2 C (Belding, 1921); 6 days at 15 C (Schubel and Wang, 1973); and 4.5 days at 12.2 C (Cianci, 1969). Cianci (1969) found maximum hatching of blueback after 57 hours at 22.8 C.

7) Newly hatched alewife and blueback larvae are unable to stem a slight current. They swim toward the water surface in a nonflowing system, then pause and sink. The larvae repeat this behavior pattern for 2-3 min before resting on the bottom of the aquarium. Mouth parts become functional 2 days after hatching. At this time the yolk has been reduced to approximately one-third its original volume. The swim-up and sinking behavior pattern continues through this stage. Mansueti (1956) and Cianci (1969) cited similar behavior for the yolk sac fry. The significance of this activity is probably related to feeding. Given that the eggs of river herring are demersal in nature the movements of the larvae toward the water surface would a) allow

greater dispersion of young fish since water currents are greater at mid-depth than either the surface or bottom of the water column, b) bring them into that portion of the water column in which their prey (rotifers, copepods and other plankters) would be most abundant, and c) place the larvae in an optimal position for sighting the prey organisms (prey outlined against lighter background).

8) We have been unable to consistently rear the larvae hatched in the laboratory beyond yolk sac absorption. The small size of the larvae at the time of mouthpart development effectively prevents direct observations of larval feeding. Foods presented to the larvae included copepod nauplii, rotifers, ciliates, diatoms, desmids, powdered fish food, etc. Cianci (1969) and others have tried similar items but have found no evidence of food in the digestive tract of the young river herring. Our earlier studies (Virginia AFC 1) documented rotifer and copepod nauplii as food items for alosids less than 8 mm in length. The reason for the continued failure of culture operations for alosine fishes at the time of first feeding may be insufficient food of a proper size (Richards and Palko, 1969). We plan to place a more dense suspension of microzooplankton in the rearing aquaria in the 1974 experiments.

9) We have produced several reference series of eggs, embryos, and yolk sac larvae for alewife, blueback, and their hybrids which are available for loan to agencies conducting ichthyo-plankton surveys. We are going to prepare photographs and line drawings of the embryonic and larval stages.

10) Juvenile alosids (alewife, blueback, and American shad, size 40-90 mm FL) collected from Virginia streams have been held in the

laboratory for several months. The tanks most suitable for this are circular fiberglass units of approximately 4 ft in diameter and 2.5 ft deep. Juveniles readily feed on brine shrimp nauplii which are offered to the fish daily.

Literature Cited

Bayless, J. D. 1973. Artificial propogation and hybridization of striped bass, Morone saxatilis (Walbaum). South Carolina Wildl. and Mar. Res. Dep. Rep. 135 p.

Belding, D. C. 1921. A report upon the alewife fisheries of Massachusetts. Dep. Conserv. Div. Fish and Game. 135 p.

Bigelow, H. B. and W. W. Welsh. 1925. Fishes of the Gulf of Maine. Bull. U.S. Bur. Fish., 20(1):567.

Chambers, J. R. 1969. Methods of distinguishing larval alewife (Alosa pseudoharengus) from larval blueback herring (Alosa aestivalis). Unpub. MS. Thesis, College of William and Mary. 30 p.

Cianci, J. M. 1969. Larval development of the alewife, Alosa pseudoharengus Wilson, and the glut herring, Alosa aestivalis Mitchell. Unpub. MS. Thesis, Univ. Connecticut. 62 p.

Cooper, R. A. 1961. Early life history of the alewife, Alosa pseudoharengus, Unpub. MS. Thesis, Univ. Rhode Island. 58 p.

Edsall, T. A. 1970. The effect of temperature on the rate of development and survival of alewife eggs and larvae. Trans. Amer. Fish. Soc. 99(2):376-380.

Fahey, W. E. 1964. A temperature controlled saltwater circulating apparatus for developing fish eggs and larvae. J. Conserv. 28:364-384.

Leim. A. H. 1924. The life history of the shad [Alosa sapidissima (Wilson)] with special reference to factors limiting its abundance. Contrib. Can. Biol. (NS) 2(11):163-284.

Lippson, A. J. 1974. A manual of developmental stages of fishes of the tidewater portion of the Potomac River and its tributaries. Mimeo. Rep. for Potomac River Ichthyopplankton Workshop, Johns Hopkins Univ. Baltimore, Maryland. 1 p.

Mansueti, R. J. 1956. Alewife herring eggs and larvae reared successfully in the lab. Maryland Tidewater News 13(1):2-3.

Mansueti, A. J. and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay Region. An atlas of egg, larval, and juvenile stages. Part 1. Natur. Resour. Inst., Univ. Maryland. 202 p.

Norden, C. R. 1967. Development and identification of the larval alewife, Alosa pseudoharengus (Wilson), in Lake Michigan. Proc. 10th Conf. Great Lakes Res. 1967:70-78.

Odell, T. T. 1934. The life history and ecological relationships of the alewife, Pomolobus pseudoharengus (Wilson), in Seneca Lake, N.Y. Ph.D. Thesis, Cornell Univ., Ithaca, New York

Richards, R. J. and B. J. Palko. 1969. Methods used to rear the thread herring, Opisthonema oglinum, from fertilized eggs. Trans Amer. Fish Soc. 98(3):527-529.

Schubel, J. R. and J. C. S. Wang. 1973. The effects of suspended sediment on the hatching success of Perca flavescens (Yellow perch), Morone americana (White perch), Morone saxatilis (striped bass), and Alosa pseudoharengus (alewife) eggs. Chesapeake Bay Inst. Johns Hopkins Univ., Special Report 30, Mimeo report. 77 p.

Shelborne, J. E. 1964. The artificial propagation of Mar. Fish. Adv. Mar. Biol. 2:1-83.

Walburg, C. H. and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic Coast of the United States, 1960. B.S.F. and Wildl. Spec. Sci. Report-Fish. No. 550. 105 p.