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Biology and utilization of anadromous alosids: Annual progress report (October 1, 1969 - September 30, 1970)

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et al

COMPLETION REPORT

Embodying

ANNUAL PROGRESS REPORT

ANADROMOUS FISH PROJECT

Project No: Virginia AFC-1

Project Period: 3 March 1967 - 30 September 1970

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COMPLETION REPORT

ANADROMOUS FISH PROJECT VIRGINIA AFC-1

Biology and Utilization of Anadromous Alosids

Introduction

This report is a completion report in the contractual sense, but a progress report in the scientific sense. It includes the annual progress report on work accomplished during the period October 1, 1969 and September 30, 1970 in addition to a summary of work done since the inception of the project in March, 1967. We have completed Phase 3, Location of Spawning Sites and Nurseries, but the other phases were not designed to have reached the terminal stage at this point in the investigation.

Phase 1 concerning mortality rates requires data collected during several years. Since inception of this project, only one yearclass has passed completely through the fishery from recruitment to extinction. Formulation of management procedure requires mortality data based on several yearclasses, not just one.

Phase 2 is an annually repetitive inventory of the status of the fishery. Continuation for several years is necessary in order to detect trends and to perceive the effects on the fishery of events which influence preproductive success.

In this report the objective of each phase is stated, the procedures used in attaining the objective are given, and then the results are presented. Each phase is independently paginated, and tables and figures follow the text in each phase. The four appendices follow Phase 4.

PHASE 1

Age Composition and Mortality Rates

The objective is to estimate the age composition and annual mortality rate of each of the four species of Alosa in each river system. Age and spawning history were to be determined from scales taken from samples of fish obtained from each river. Mortality rates were to be determined from the decline in numbers of each year-class each successive year in the fishery and, probably more usefully, from the decline in numbers of each spawning-class. We also indicated that we hoped to be able to work out criteria for determining age of blueback herring.

Our attempt to validate the scale method of determining age of blueback herring is documented in Appendix I, which is an excerpt from a thesis by Beal (1968). Our data strongly suggest that the freshwater zone and the first annulus coincide or are very close together. We have been unable to demonstrate conclusively that this is the case because we have been unsuccessful in our attempts to obtain fish of ages 1 and 2 from the ocean. Our data suggest that most blueback herring mature at age 5, though a few mature at age 4 and some not until age 6. By contrast most alewife mature at age 4.

Catch curves have been plotted for the river herring fisheries of the Rappahannock River (Figs. 1-1 through 1-4) and of the Potomac River (Figs. 1-5 through 1-8). In addition, by combining data

collected under this agreement with additional data collected by VIMS prior to this agreement, we have been able to trace two spawning classes through the fishery in the Potomac River (Figs. 1-9, 1-10). It is noteworthy that the mortality rate of blueback herring was greater in 1967 and in 1968 than in 1965 and 1966. A spawning class contributes significantly to the fishery for four to five years and a few fish survive to spawn as many as six times.

Catch curves of the shad fishery in the Rappahannock River are shown in Figs. 1-11 and 1-12. The catch curve for the York River shad fishery (pound net) in 1968, the single year for which reliable catch records are available, is shown in Fig. 1-13. We have been unsuccessful in obtaining unbiased samples of shad from the Potomac River.

We are unable to construct meaningful catch curves for the fisheries of the York River and James River because we lack catch records to serve as a basis for expansion of our samples. In neither of these rivers were pound nets suitably positioned to serve as sampling sites and as index units of gear with consistency. We obtained samples of fish each week from fyke nets; however, the fishermen kept no record of their catch of river herring, in fact, they usually discarded them and it was with some difficulty that we arranged to obtain samples each week. Lack of an adequate basis of expanding our samples to represent the week-to-week changes in the number of fish comprising the run has prevented our constructing meaningful catch curves for the fisheries in two rivers. Nevertheless, we have examined scales from the samples of fish obtained at weekly intervals and have on hand the data

concerning spawning history and age (Table 1-1). We propose to examine the validity of extrapolating the unknowns from some other data base. Perhaps we will be able to find a useful method of estimating mortality rates in the York and James.

Hickory shad are not caught in sufficient quantity to be sampled economically.

Because recruitment apparently differs from year to year, catch curves such as most of these, which are based on the catch in a single year, are doubtful indicators of mortality rates. As additional data are accumulated in the future, we will be able to trace a single year-class or spawning class through the fishery and thereby arrive at more realistic estimates of mortality rates. At present only Fig. 1-9 and Fig. 1-10 are based on following a single spawning class.

Table 1-1.

Spawning history of Alosa in James River based on weekly samples from one index site per river

Spawning Checks	Alewife ♂	Alewife ♀	Blueback ♂	Blueback ♀	A. Shad ♂	A. Shad ♀
1967						
0	99	42	91	57	31	50
1	112	28	71	17	25	22
2	36	9	35	8	27	26
3	30	6	7	3	13	11
4	6	2	1	0	1	1
5	1	1	0	0	0	0
6	0	0	1	0	0	0
1968						
0	64	64	90	62	5	51
1	72	36	58	7	2	34
2	53	52	54	18	1	26
3	10	26	15	9	4	15
4	8	9	2	2	1	4
5	1	4	1	0	0	0
6	1	0	0	0	0	0
1969						
0	56	26	30	20	20	71
1	65	52	57	19	11	26
2	48	36	45	18	1	10
3	19	28	29	11	1	8
4	2	6	6	5	3	0
5	0	5	0	1	0	1
6	0	1	0	0	0	0

Table 1-1.

Spawning history of Alosa in York River based on weekly samples from one index site per river.

1967

Spawning Checks	Alewife ♂	Alewife ♀	Blueback ♂	Blueback ♀	A. Shad ♂	A. Shad ♀
0	128	70	70	61	49	84
1	69	31	49	27	24	33
2	38	16	50	36	7	14
3	18	27	15	16	4	7
4	7	13	2	5	1	1
5	2	4	0	0	0	2
6	0	1	1	0	0	0

1969

0	43	36	33	23	8	5
1	62	50	34	24	4	5
2	26	62	19	16	4	5
3	9	17	18	10	1	0
4	1	6	6	5	0	0
5	0	0	1	2	0	0
6	0	0	1	1	0	0

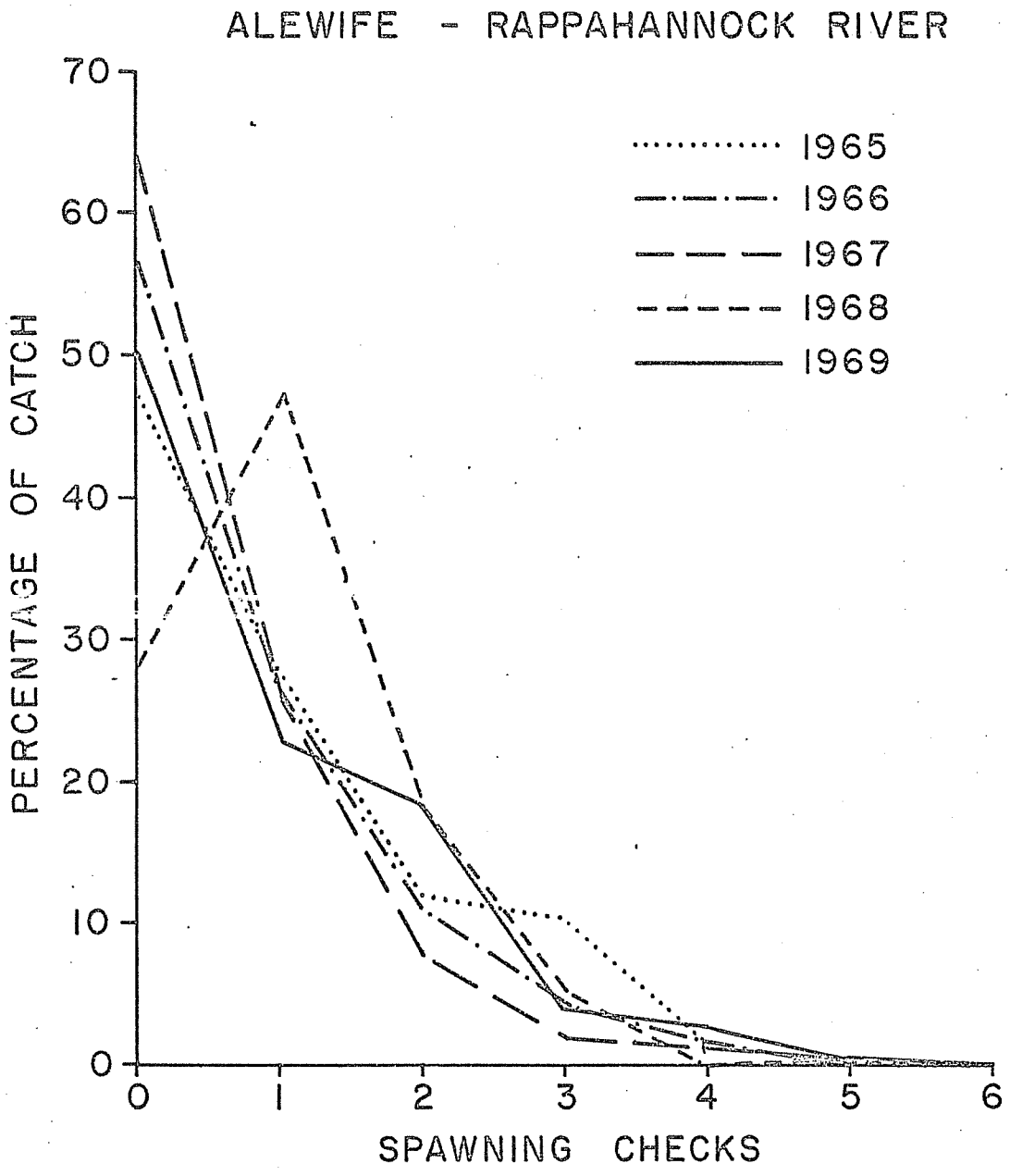

Fig. 1-1. Catch curves of alewife in the Rappahannock River.

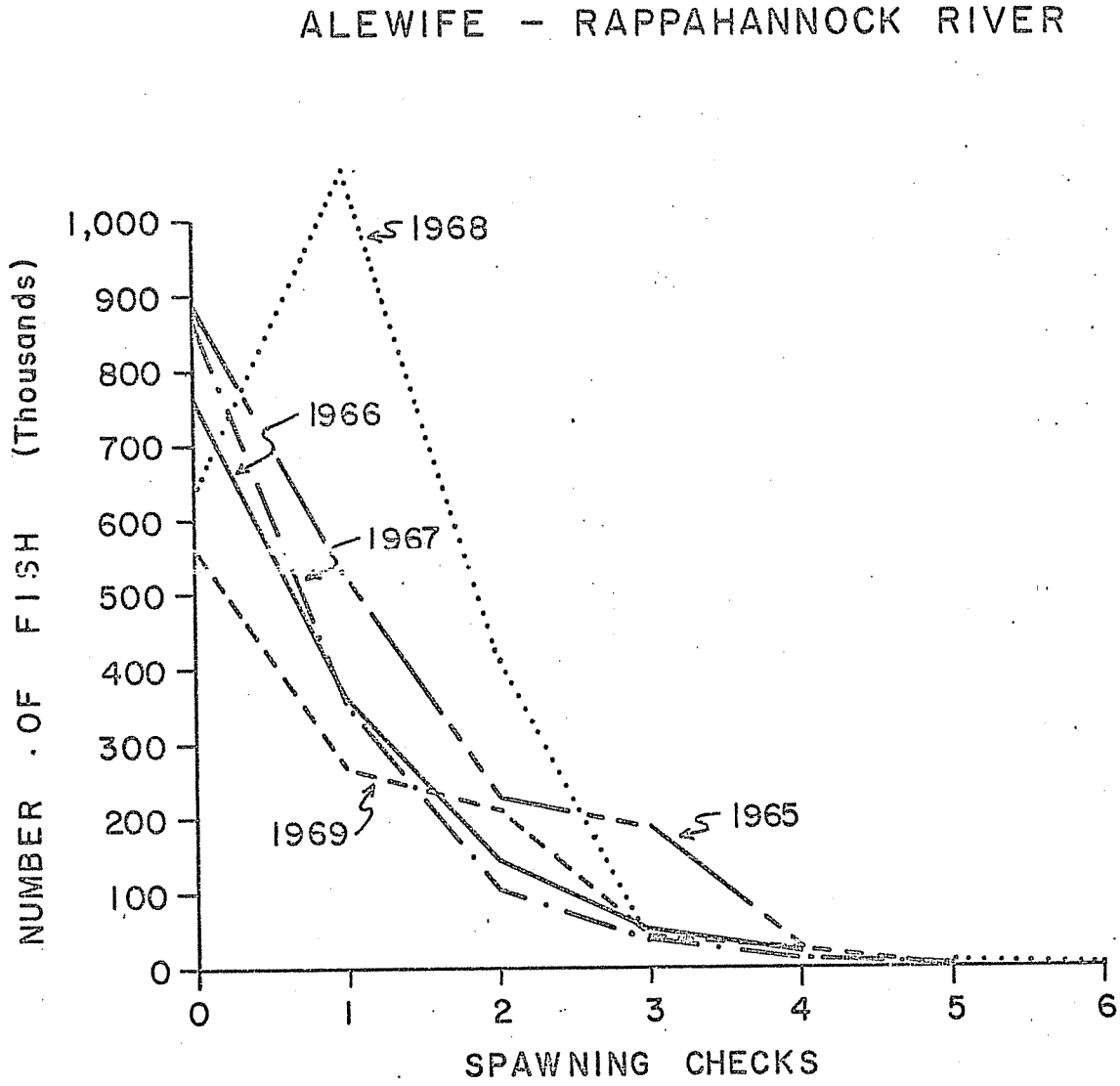

Fig. 1-2. Estimated number of alewife caught in the Rappahannock River.

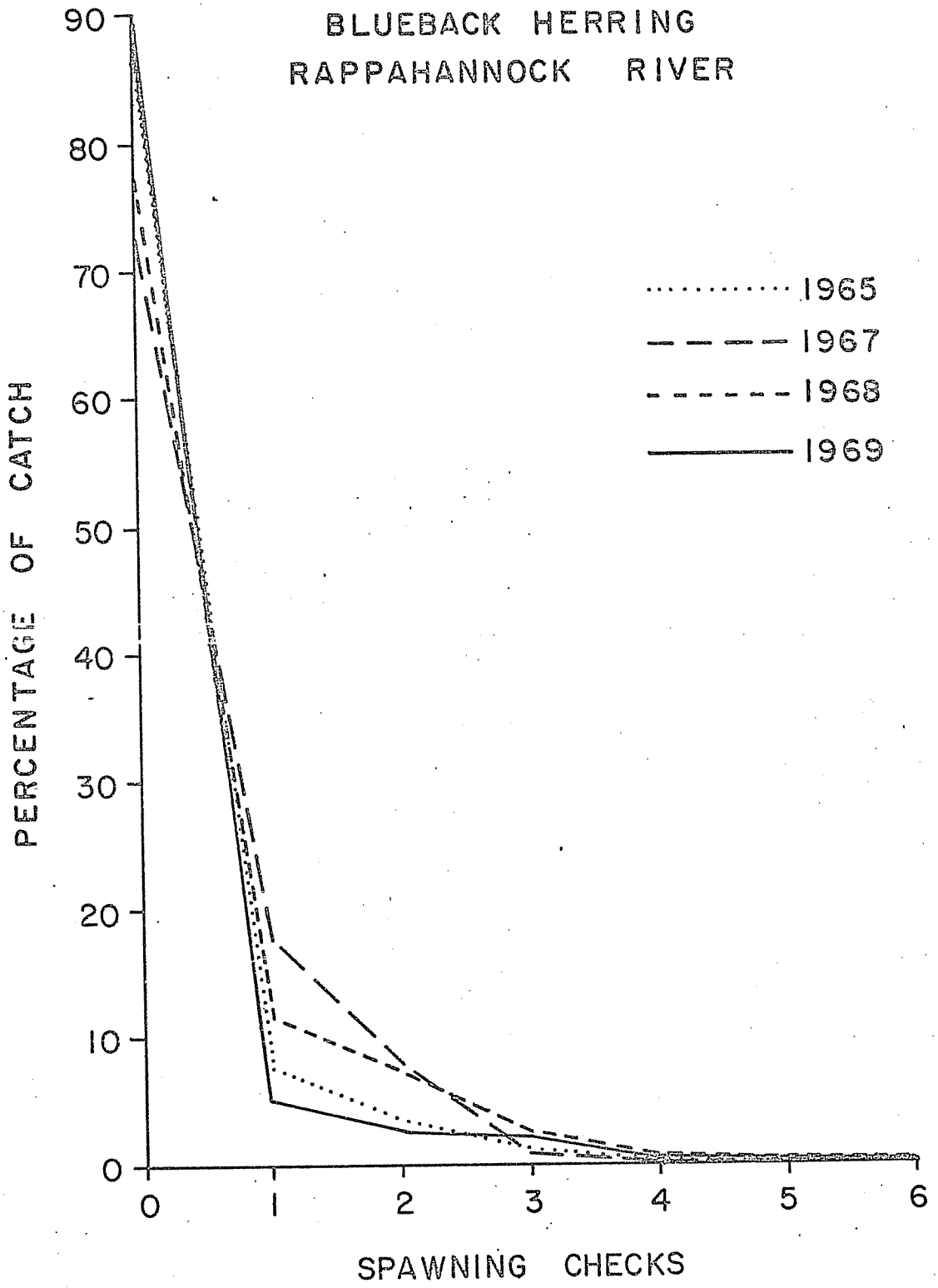

Fig. 1-3. Catch curves of blueback herring in the Rappahannock River.

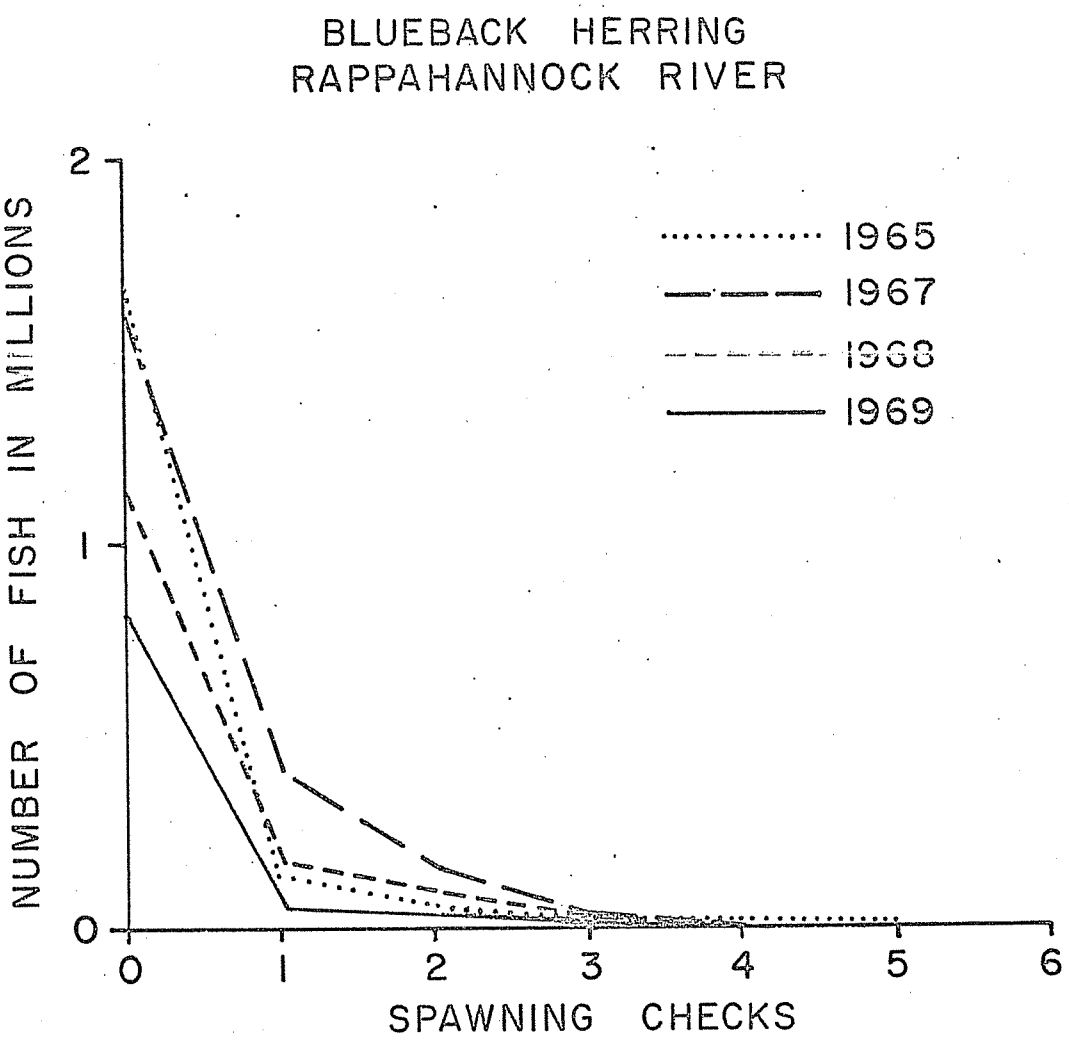

Fig. 1-4. Estimated number of blueback herring caught in the Rappahannock River

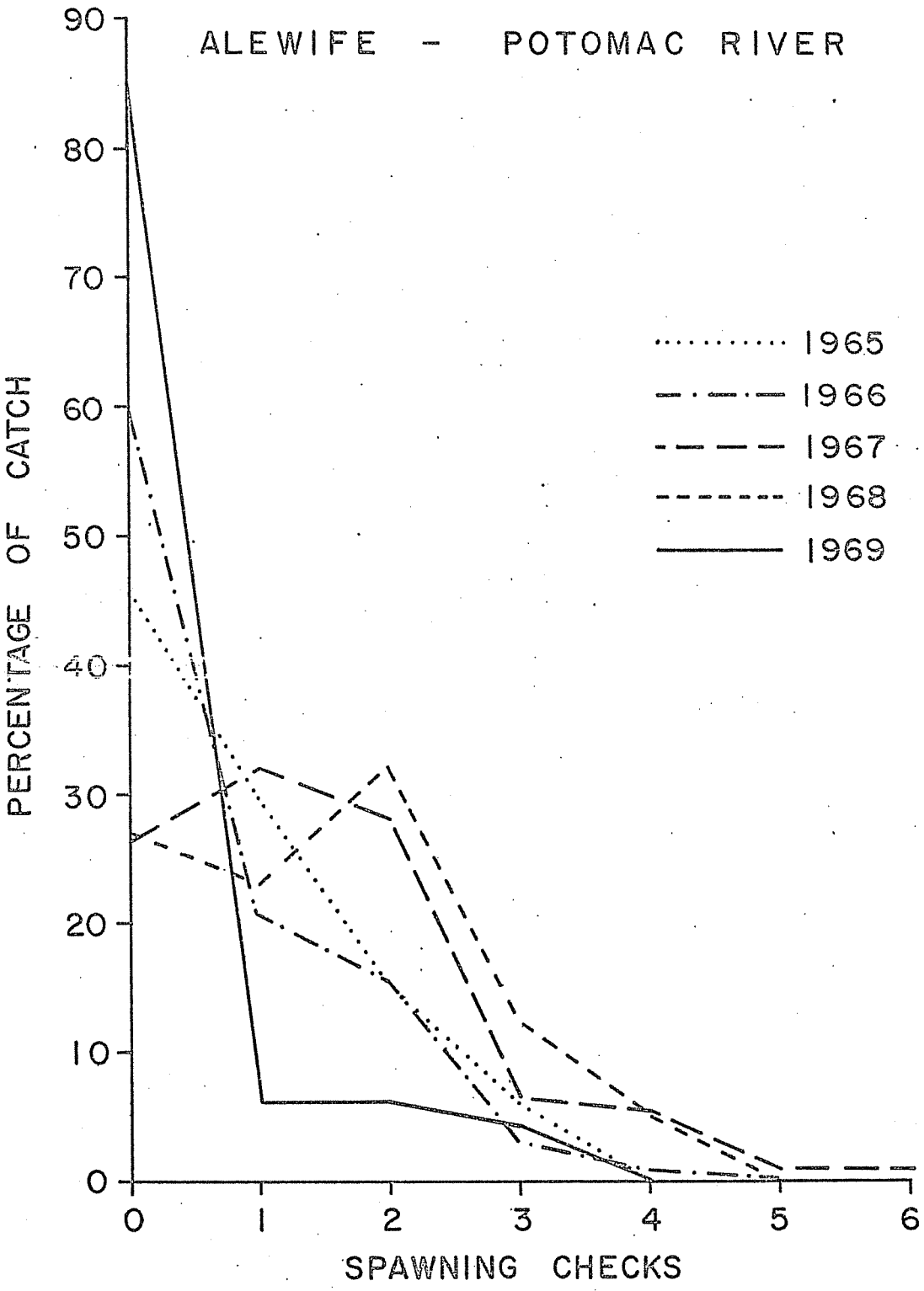

Fig. 1-5. Catch curve of alewife in the Potomac River.

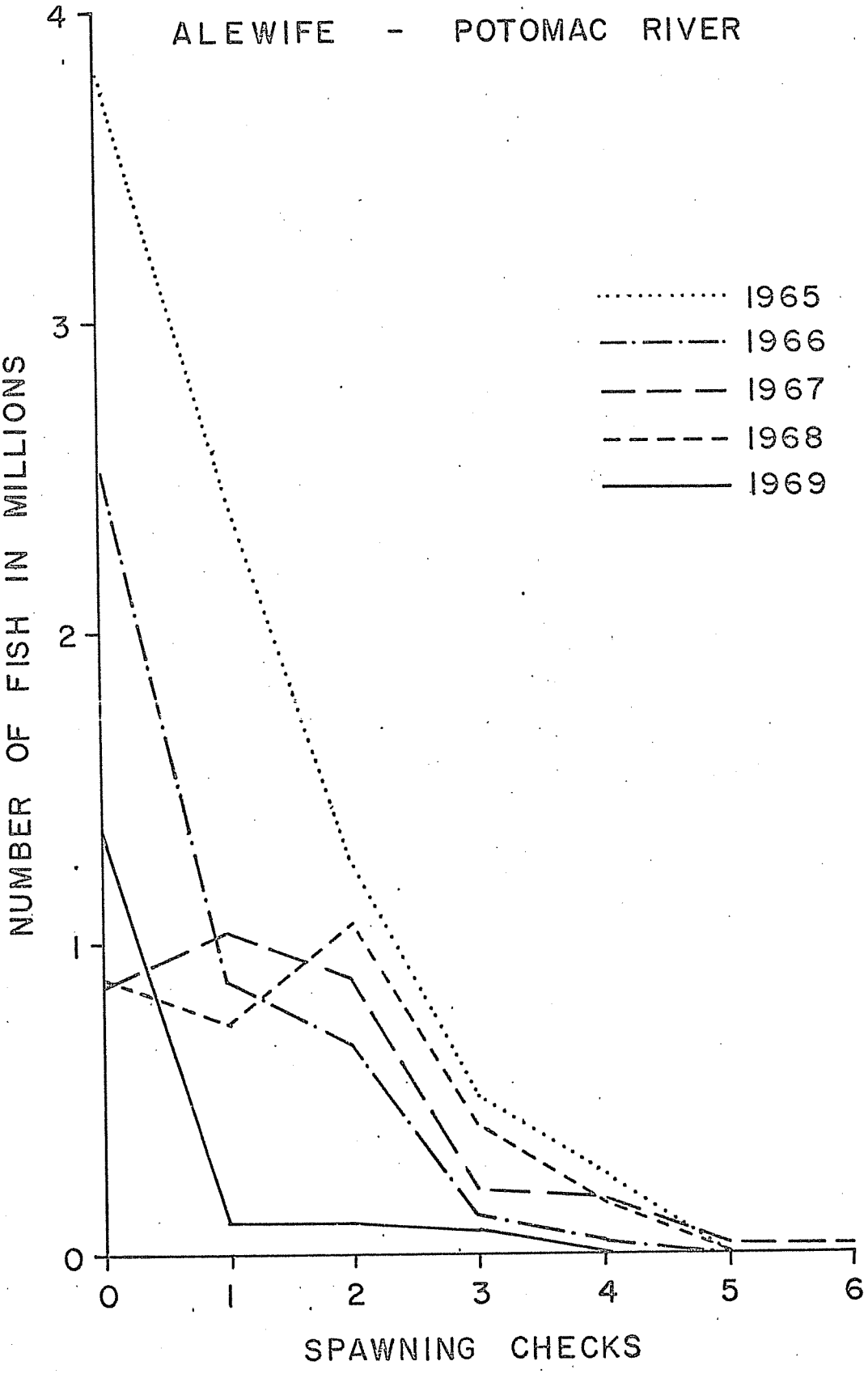

Fig. 1-6. Estimated numbers of alewife caught in the Potomac River in each of several years.

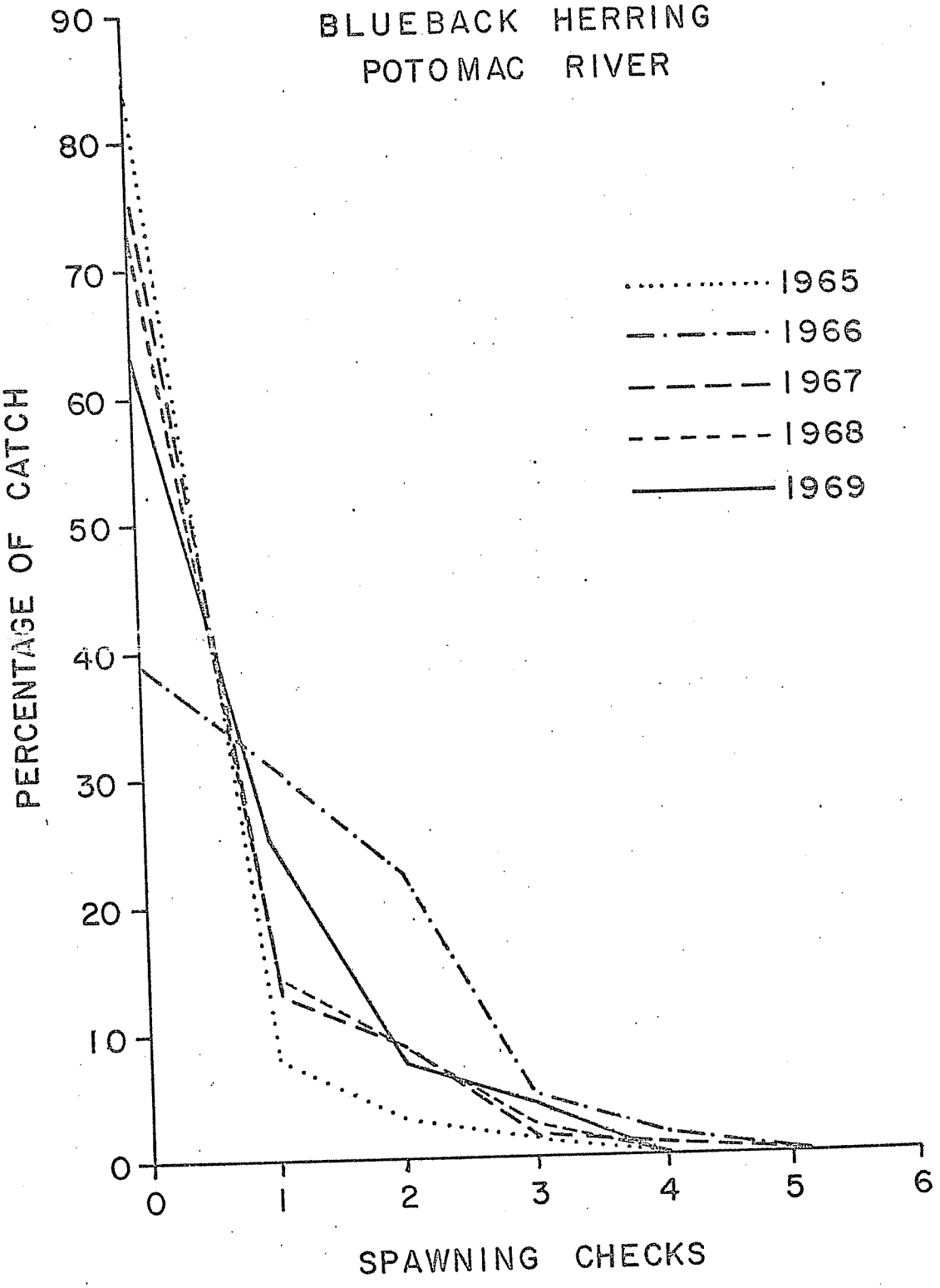

Fig. 1-7. Catch curves of blueback herring in the Potomac River.

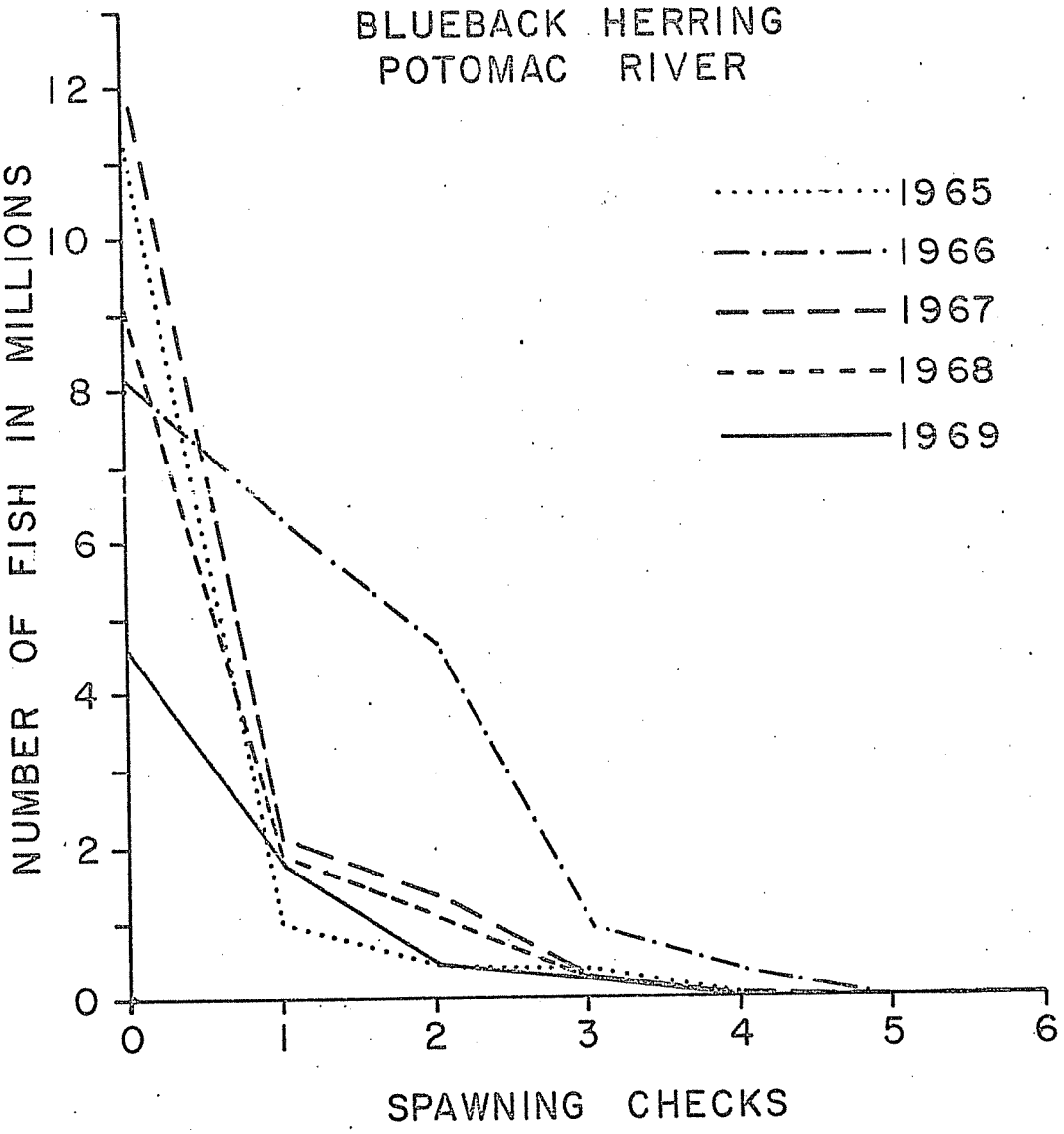

Fig. 1-8. Estimated number of blueback herring caught in the Potomac River in each of several years.

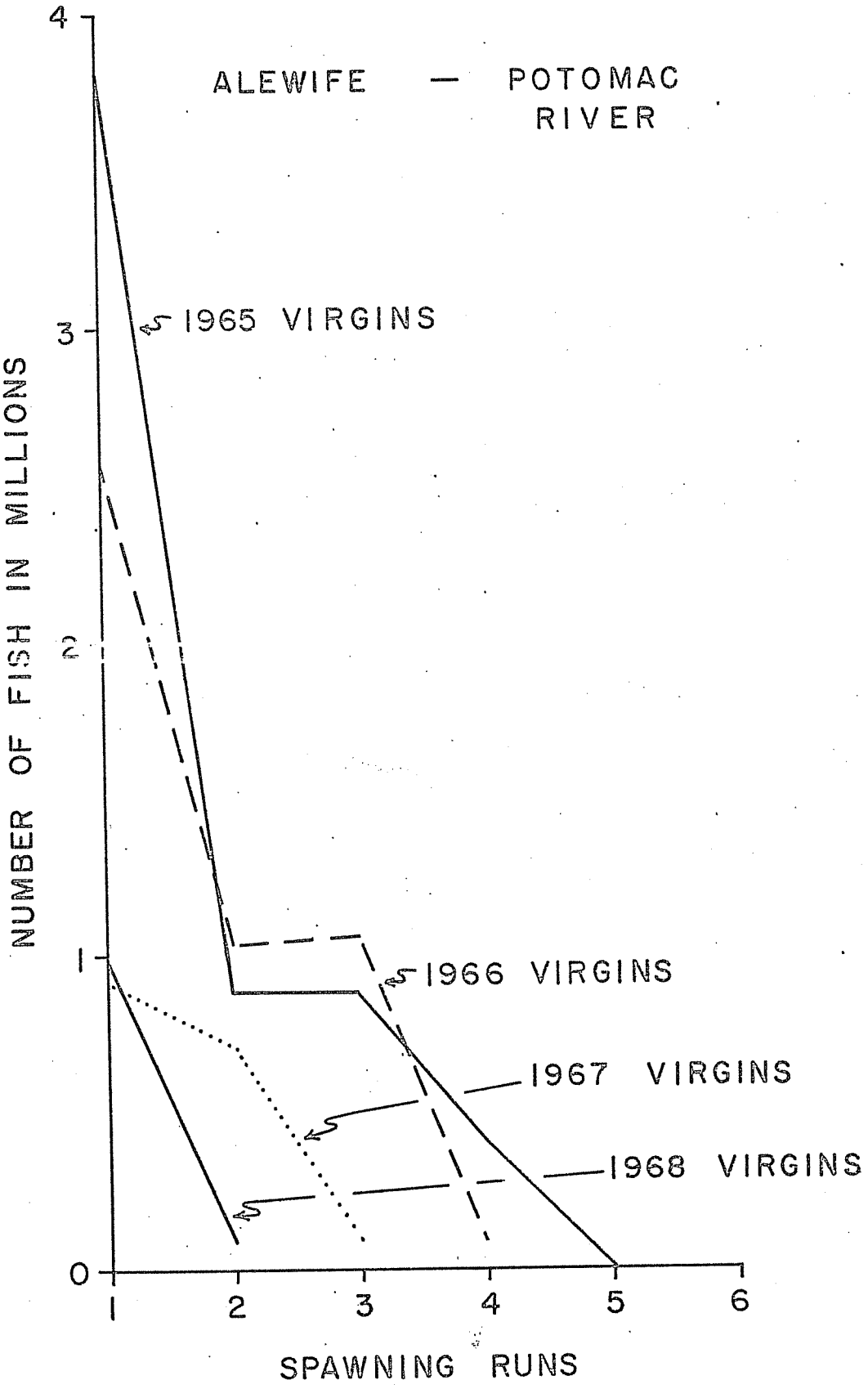

Fig. 1-9. Estimated number of alewife caught from various spawning classes in the Potomac River.

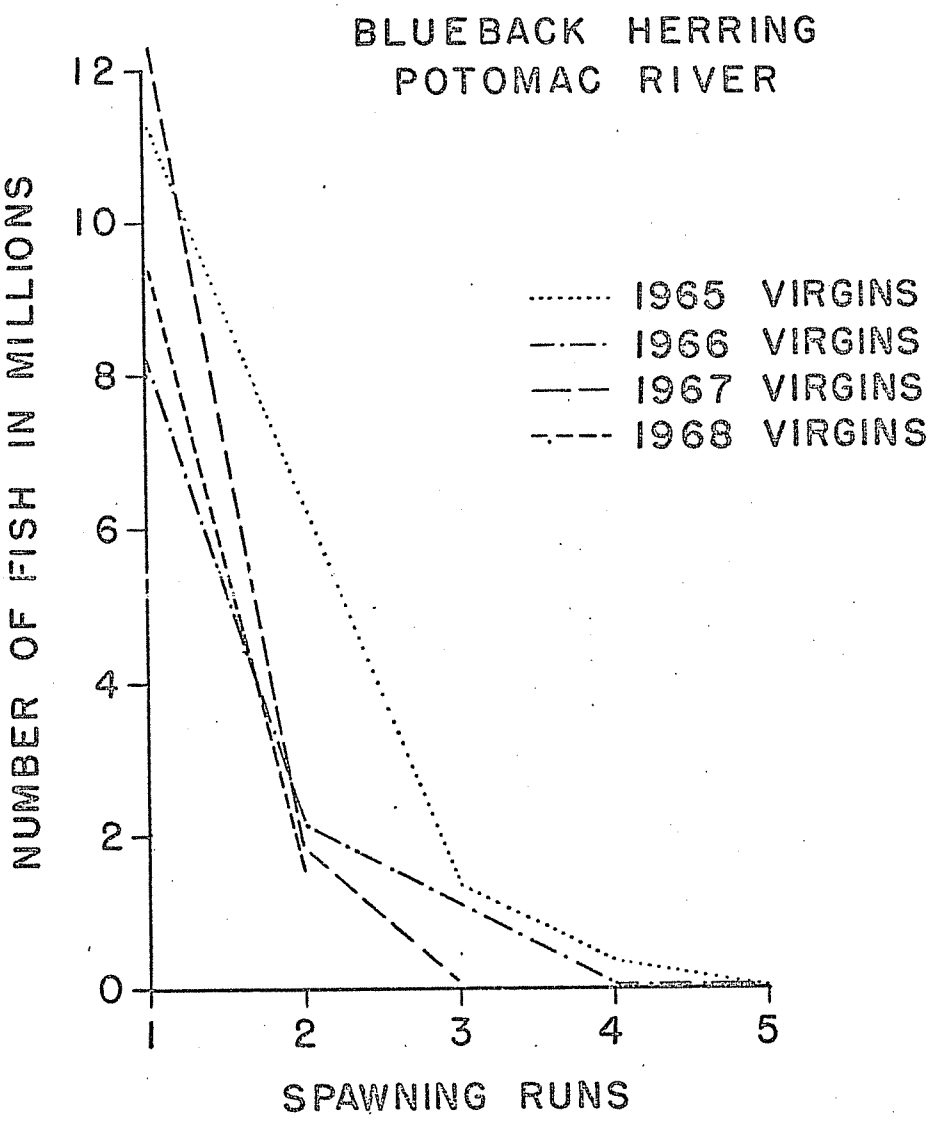

Fig. 1-10. Estimated number of blueback herring caught from various spawning classes in the Potomac River.

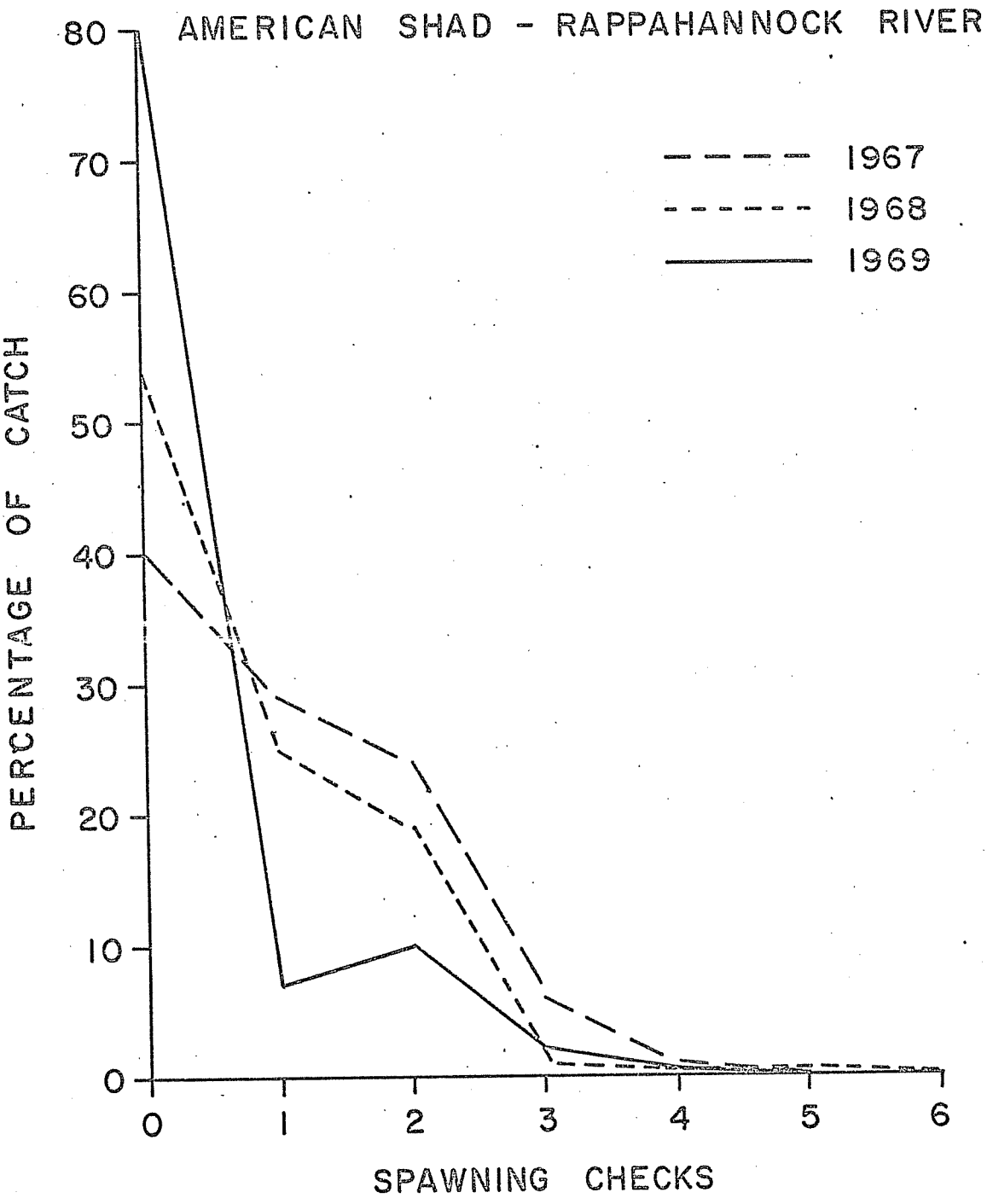

Fig. 1-11. Catch curves of American shad in the Rappahannock River.

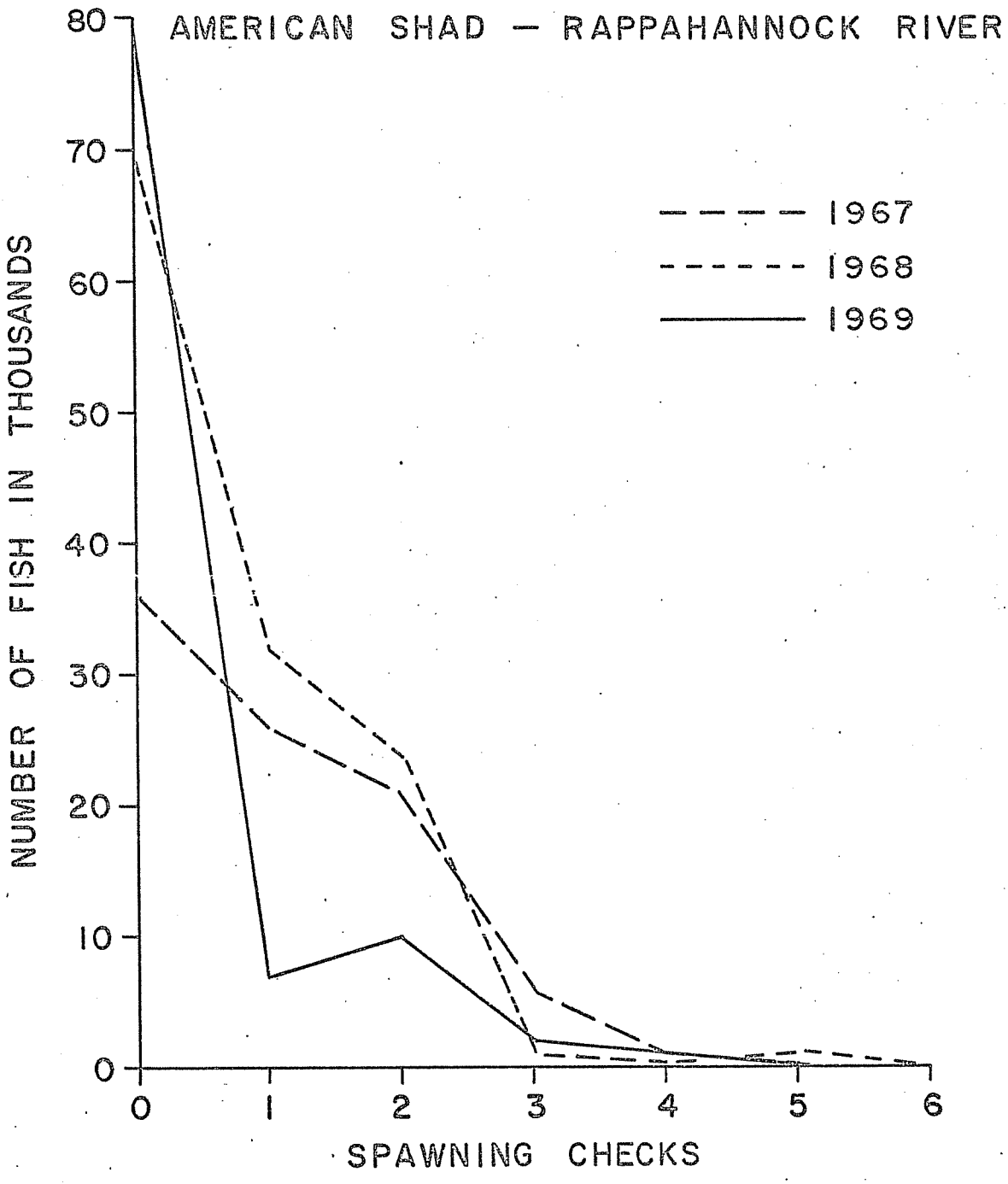

Fig. 1-12. Estimated number of American shad caught in pound nets in the Rappahannock River.

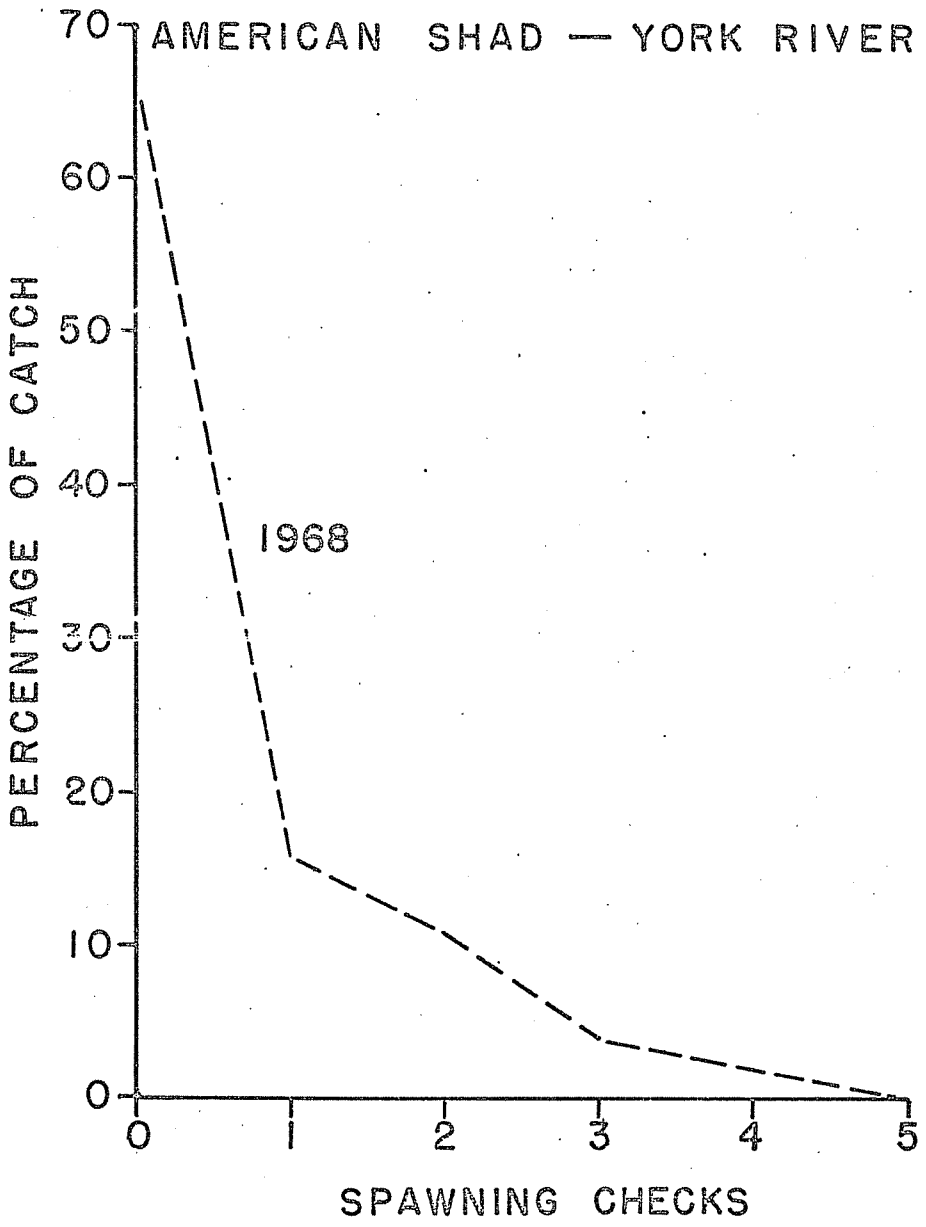

Fig. 1-13. Catch curve of American shad in the York River.

PHASE 2

Catch Per Unit of Effort

The objective was to calculate the catch per unit of effort in each river system. Effort was to be measured by counting pound nets and stake gill nets at monthly intervals from an airplane. Catch was to be measured by obtaining records of the catch from some units of gear in each river. Total catch in each river was to be calculated by multiplying the catch of the index units by the number of units operating in each time period.

We have modified the counting procedure in two respects. We count pound nets fortnightly rather than monthly and count stake gill nets once a season from a small boat rather than from the air. We were unable to count the number of units of gill net comprising a stand from the air and we found that pound nets were set and removed with a frequency that required more frequent counting. Summaries of the counts of pound nets are presented in Fig. 2-1, and of stake gill nets in Table 2-1. Table 2-2 presents the tally of pound nets for each flight in 1970 subdivided by geographic area. Similar detailed tables for other years have been presented in annual progress reports.

Figures 2-2, 2-3, 2-4, and 2-5 summarize the catch each year from the various rivers from which we have been successful in obtaining data. Catch and effort in the pound net fishery on a statewide basis are shown in Fig. 2-6. Fig. 2-7 shows these data from the Potomac

River in addition to those from Virginia. A note of explanation is needed concerning the catch in 1969 as shown in these two figures. CFS No. 5241 reports the statewide total catch to be 30.4 million pounds including the catch in the Potomac River, but Kelly (1969) reports the catch in certain areas of Virginia as follows (in thousands of pounds).

	1969	1968
Hampton Roads	279.5	763.5
Lower Northern Neck	6,242.1	11,671.1
Lower Eastern Shore	37.5	0.0
Total	6,559.1	12,434.6

If the catch in these selected areas in 1969 is presumed to bear the same proportional relationship to the total statewide catch as it did in 1968, then the catch in 1969 approximated 17 million pounds. We have used this approximation in view of the fact that the catch in the Potomac River was reported to be about 4 million pounds less in 1969 than in 1968. The areas from which Kelly obtained records apparently experienced a decline of nearly 6 million pounds. In order for the statewide total to have declined only 2 million pounds, the catch in areas other than the Potomac River, lower Northern Neck, Hampton Roads, and lower Eastern Shore would have had to increase by 8 million. Fishing effort declined generally over the state and our observations of the fishery and conversations with fishermen in the areas in question indicated no increase in catch of the magnitude of 8 million pounds. In fact, most fishermen indicated that their catches had declined, a few said theirs had held stable. Therefore, we use 17 million pounds as a rough approximation of the total catch in 1969 until such time as those who are familiar with the methods of

collecting the two sets of statistics reevaluate them in the light of the apparent discrepancy. We stress that 17 million is an arbitrarily selected estimate and is subject to change.

The statewide catch in 1970 was near 10 million pounds. The precipitous decline in the river herring fishery appears largely attributable to the harvest at sea by foreign vessels, primarily those of the Soviet Union. The domestic fishery was characterized by relative stability until the late sixties when a precipitous decline coincided with the inception of the Russian fishery on river herring in the Middle Atlantic Bight (Fig. 2-8). The trend of the catch of river herring and shad in the most recent four years is shown in Figure 2-2 for the Potomac River and Figure 2-3 for the Rappahannock River. The apparent decline in the catch of shad in the Rappahannock is considered below in the discussion of the catch in 1970.

Estimates of the Catch in 1970

Pound nets in the Rappahannock River above RA-10 caught an estimated 465,000 pounds of river herring (363,123 pounds of alewife and 103,244 pounds of blueback herring) and about 58,000 pounds of shad in the period March 5-May 8 (Table 2-3). In a comparable period in 1969 the catch was somewhat greater. The catch of alewife in 1970 was estimated to be 43% of that in 1969, the blueback catch 27% and shad 22%.

The estimated catch of shad by stake gill nets in the Rappahannock River did not change appreciably from that in 1969, being 193,000 pounds in 1969 and 210,000 in 1970 (Table 2-4). Our estimate of the pound net catch, being based on 16% of the units of gear is probably

less reliable than the estimate of the gill net catch, which is based on records from 36% of the units of gear. We are seeking additional records of pound net catches to improve our estimate.

Stake gill nets took an estimated 87,226 pounds of hickory shad, nearly twice the quantity caught in 1969.

In the York River, stake gill nets caught an estimated 159,000 pounds of shad and 2,750 pounds of hickory shad (Table 2-5). This estimate is based on records of about 75% of the units of gear. The catch of buck American shad and of hickory shad was undoubtedly greater than the landings. The market for these was again poor and fishermen discarded many at the net.

Pound nets in neither the York River nor the James River were suitably positioned to serve as indices of the runs of river herring and shad.

Stake gill nets in the James River took an estimated 1,962,000 pounds of shad between March 1 and May 5 (Table 2-6) up from 1,569,000 pounds in 1969. Gear selectivity and weak markets are reflected by the catch of only 343,000 pounds of buck American shad. The estimate of the catch in the James River is based on records from 14% of the units of gear.

Preliminary catch figures obtained from the Potomac River Fisheries Commission indicate that the river herring fishery recovered somewhat from the low of 1969 but that the shad catch declined (Table 2-7). Our samples of the river herring catch indicate that the catch of alewife continued to decline, but that the catch of blueback herring was twice that of 1969.

Table 2-1

Number of Stake Gill Nets Fishing in Virginia River Systems 1967-1970 and Catch of Roe Shad per Net per Season

River System	Year			
	1967	1968	1969	1970
York	90	86	94	71
James	-	95	83	65
Rappahannock	-	144	120	94
	Catch/Net/Season			
York	2,234	2,375	1,796	2,077
James	-	-	17,289	24,912
Rappahannock	-	964	1,340	1,410

Table 2-2. Number of pound nets in Chesapeake Bay and tributaries, spring 1970.

Area	2-17-70	3-2-70	3-17-70	3-31-70	4-16-70	5-7-70	5-19-70	6-2-70	6-18-70
James	0	1	2	2	1	1	1	0	2
York River	0	1	3	7	7	7	7	7	7
Rappahannock River	0	13	43	47	50	51	32	13	7
Potomac River	0	4	10	22	47	58	51	49	8
Cape Henry to Willoughby Point	1	8	9	7	8	8	8	8	6
Old Point to Tue Marsh Point	0	6	12	11	11	11	11	6	2
Back River	0	3	6	6	8	8	6	6	1
Poquoson River	1	1	1	1	0	0	0	0	0
York Spit	0	0	3	3	4	6	7	7	7
Mobjack Bay	0	1	3	4	5	5	6	5	3
New Point to Stingray Point	1	5	16	23	27	31	28	23	20
Piankatank River	0	0	1	3	3	3	3	2	1
Windmill Point to South Point	7	13	22	24	35	33	33	23	9
Great Wicomico River	0	0	1	2	2	2	2	2	2
Eastern Shore-N. Hungar Creek	0	0	0	0	0	0	0	0	0
Eastern Shore-S. Hungar Creek	0	0	1	1	5	14	20	19	16
Total	10	56	133	163	213	238	215	170	91

Table 2-3. Catch by pound nets in the Upper Rappahannock River, 1970*

Date	Ave. No. of Nets	No. Days Fished	Shad				River Herring			
			Roe		Buck		Alewife		Blueback	
			Ave. Catch Index Nets	Estimated Total Catch	Ave. Catch Index Nets	Estimated Total Catch	Ave. Catch Index Nets	Estimated Total Catch	Per Cent	Pounds	Per Cent	Pounds
March 5-15	28	5	3.7	518	7.9	1,106	482	67,490	100	67,480	0	0
March 16-31	45	8	18.7	6,732	34.3	12,348	623	224,280	91	204,095	9	20,185
April 1-15	49	8	32.5	12,740	41.2	16,150	318	124,656	63	78,533	37	46,123
April 16-31	51	6	13.8	4,223	10.2	3,121	64	19,584	53	10,380	47	9,204
May 1-8	51	4	3.9	796	1.4	286	144	29,376	9	2,644	91	26,732
Total				25,009		33,011		465,376		363,132		102,244

*Only nets between RA-10 and RA-55 were sampled to represent fish assumed to spawn in the Rappahannock River system.
Estimated total catch of shad 58,020.

Table 2-4. Catch by stake gill nets in the Rappahannock River, 1970

		Roe Shad	Buck Shad	Hickory Shad
March	10	297	437	-
	11	186	609	-
	12	372	-	-
	13	362	684	14
	14	1,479	2,460	23
	15	-	-	-
	16	612	1,554	57
	17	1,070	1,381	70
	18	236	329	90
	19	888	1,395	-
	20	981	1,675	204
	21	1,442	2,985	51
	22	-	-	-
	23	2,202	3,566	440
	24	4,514	4,289	272
	25	3,795	3,605	795
	26	3,351	2,685	623
	27	2,465	2,320	1,060
	28	3,394	3,204	1,779
	29	-	-	-
	30	1,765	2,996	2,356
	31	4,180	2,930	2,255
April	1	2,245	1,522	3,283
	2	4,443	2,323	3,143
	3	2,603	2,599	4,812
	4	7,194	3,474	4,427
	5	-	-	-
	6	5,352	3,265	6,129
	7	11,367	3,870	2,574
	8	4,446	2,538	4,525
	9	7,085	2,252	2,782
	10	4,346	1,930	5,137
	11	2,542	1,006	1,808
	12	4,747	1,840	6,856
	13	6,992	1 446	2,853
	14	3,229	1,135	4,575
	15	3,267	53	226
	16	6,838	1,790	5,485
	17	3,623	870	3,684
	18	2,911	1,600	2,739
	19	-	-	-
	20	7,822	1,368	4,117
	21	3,555	1,457	1,192

Table 2-4. continued

	Roe Shad	Buck Shad	Hickory Shad
April 22	2,730	870	637
23	715	472	1,151
24	501	136	801
25	-	199	957
26	-	-	-
27	213	-	2,087
28	80	266	306
29	27	385	346
30	80	292	505
Total	132,544	78,062	87,226

Table 2-5. Catch by stake gill nets in the York River, 1970

	Roe Shad	Buck Shad	Hickory Shad
March 10	598	750	-
11	625	375	-
12	625	625	-
13	250	625	-
14	-	-	-
15	500	-	-
16	375	875	-
17	125	125	-
18	250	125	-
19	250	125	-
20	-	-	-
21	1,250	1,500	-
22	5,000	4,000	-
23	3,568	1,375	-
24	333	-	-
25	2,813	1,125	125
26	2,375	-	375
27	-	-	250
28	-	-	-
29	6,375	-	250
30	7,625	-	775
31	1,750	-	245
April 1	2,000	-	355
2	1,150	-	125
3	-	-	-
4	-	-	-
5	13,450	-	250
6	14,750	-	-
7	5,350	-	-
8	8,450	-	-
9	7,375	-	-
10	-	-	-
11	20,750	-	-
12	-	-	-
13	13,750	-	-
14	6,750	-	-
15	3,375	-	-
16	3,750	-	-
17	-	-	-
18	4,250	-	-
19	-	-	-
20	4,500	-	-

Table 2-5. continued

	Roe Shad	Buck Shad	Hickory Shad
April 21	1,500	-	-
22	750	-	-
23	625	-	-
24	275	-	-
Total	147,487	11,625	2,750

Table 2-6. Catch by stake gill nets in the James River, 1970

		Roe Shad	Buck Shad	Hickory Shad
March	1	-	-	-
	2	-	-	-
	3	-	-	-
	4	390	1,105	-
	5	-	-	-
	6	1,560	5,038	-
	7	1,690	5,395	-
	8	-	-	-
	9	10,616	20,584	-
	10	7,887	20,952	-
	11	7,085	12,979	-
	12	8,274	16,250	-
	13	11,592	17,030	-
	14	7,129	12,393	-
	15	3,337	7,995	-
	16	6,132	6,002	-
	17	4,984	5,959	-
	18	10,400	8,890	-
	19	6,175	8,689	-
	20	6,955	11,375	-
	21	11,944	27,511	-
	22	18,433	23,934	-
	23	29,023	26,195	-
	24	52,000	36,498	-
	25	19,500	14,237	-
	26	12,968	9,750	-
	27	21,288	14,625	-
	28	16,949	8,954	-
	29	16,559	-	-
	30	21,613	13,813	-
	31	16,185	4,875	-
April	1	24,001	-	-
	2	-	-	-
	3	17,225	-	-
	4	44,200	-	-
	5	21,617	-	-
	6	22,831	3,250	-
	7	16,315	-	-
	8	24,619	4,875	-
	9	26,731	-	-
	10	39,894	8,125	-

Table 2-6. continued

		Roe Shad	Buck Shad	Hickory Shad
April	11	47,125	-	-
	12	45,256	-	-
	13	58,663	-	-
	14	52,352	-	-
	15	30,324	-	-
	16	23,826	-	-
	17	38,057	-	-
	18	36,086	-	-
	19	36,822	-	-
	20	31,407	-	-
	21	14,729	-	-
	22	31,190	-	-
	23	33,898	-	-
	24	147,875	-	-
	25	44,295	-	-
	26	49,385	-	-
	27	42,237	-	-
	28	65,000	-	-
	29	52,000	-	-
	30	45,500	-	-
May	1	32,500	-	-
	2	49,075	-	-
	3	23,725	-	-
	4	13,065	-	-
	5	6,825	-	-
Total		1,619,318	343,041	0

Table 2-7. Total Alosa catch by month in Potomac River in 1970

	Roe Shad	Buck Shad		Herring: Alewife	Herring: Blueback
March	2,610	9,238		25,691	51,458
April	73,027	35,201		199,264	2,291,537
May	34,512	12,438		247,221	3,284,505
June	1,003	2,153		981	48,045
Total	111,152	59,030		473,157	5,675,545
		170,182			6,148,702

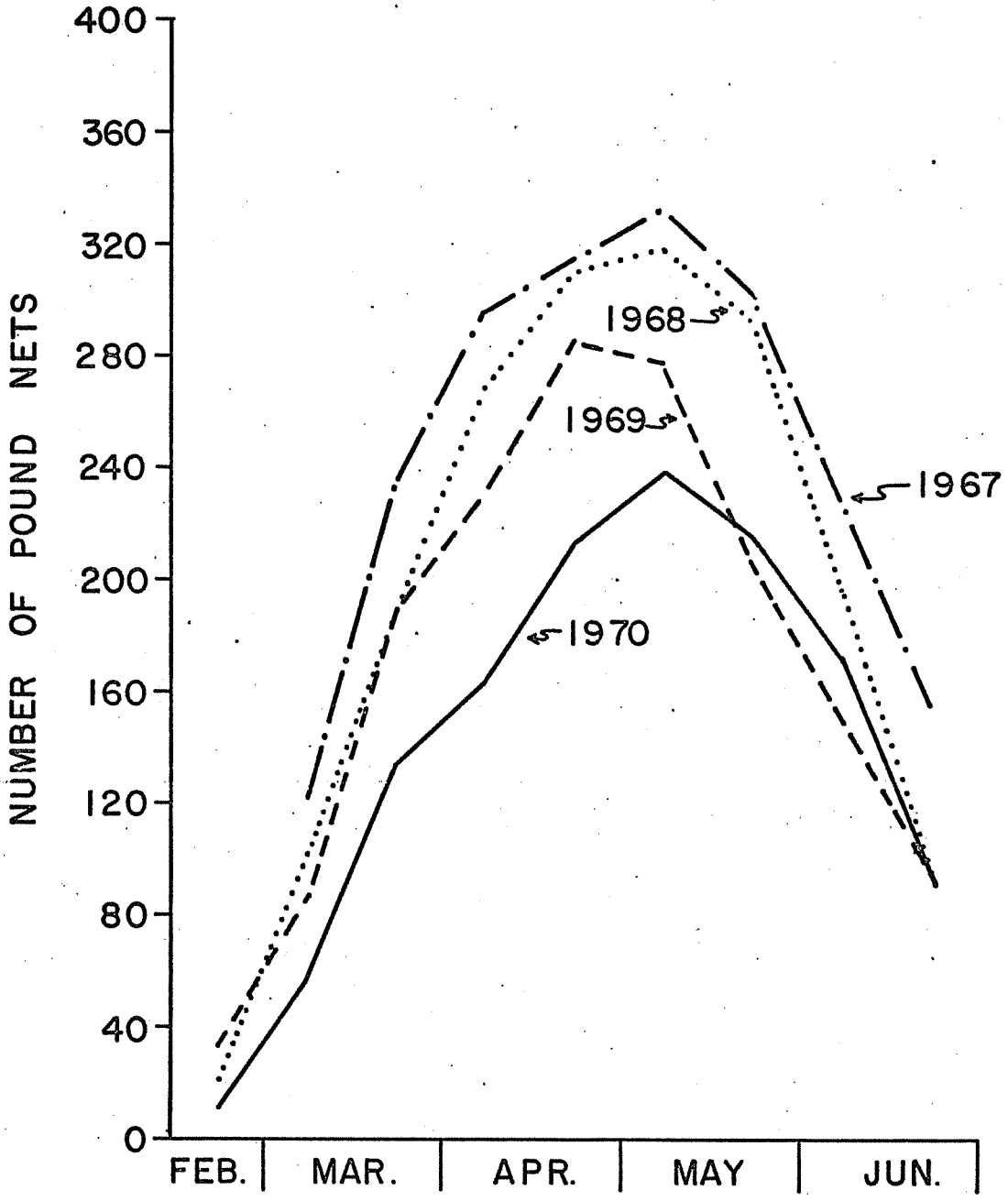

Fig. 2-1. Number of pound nets in lower Chesapeake Bay and its tributaries.

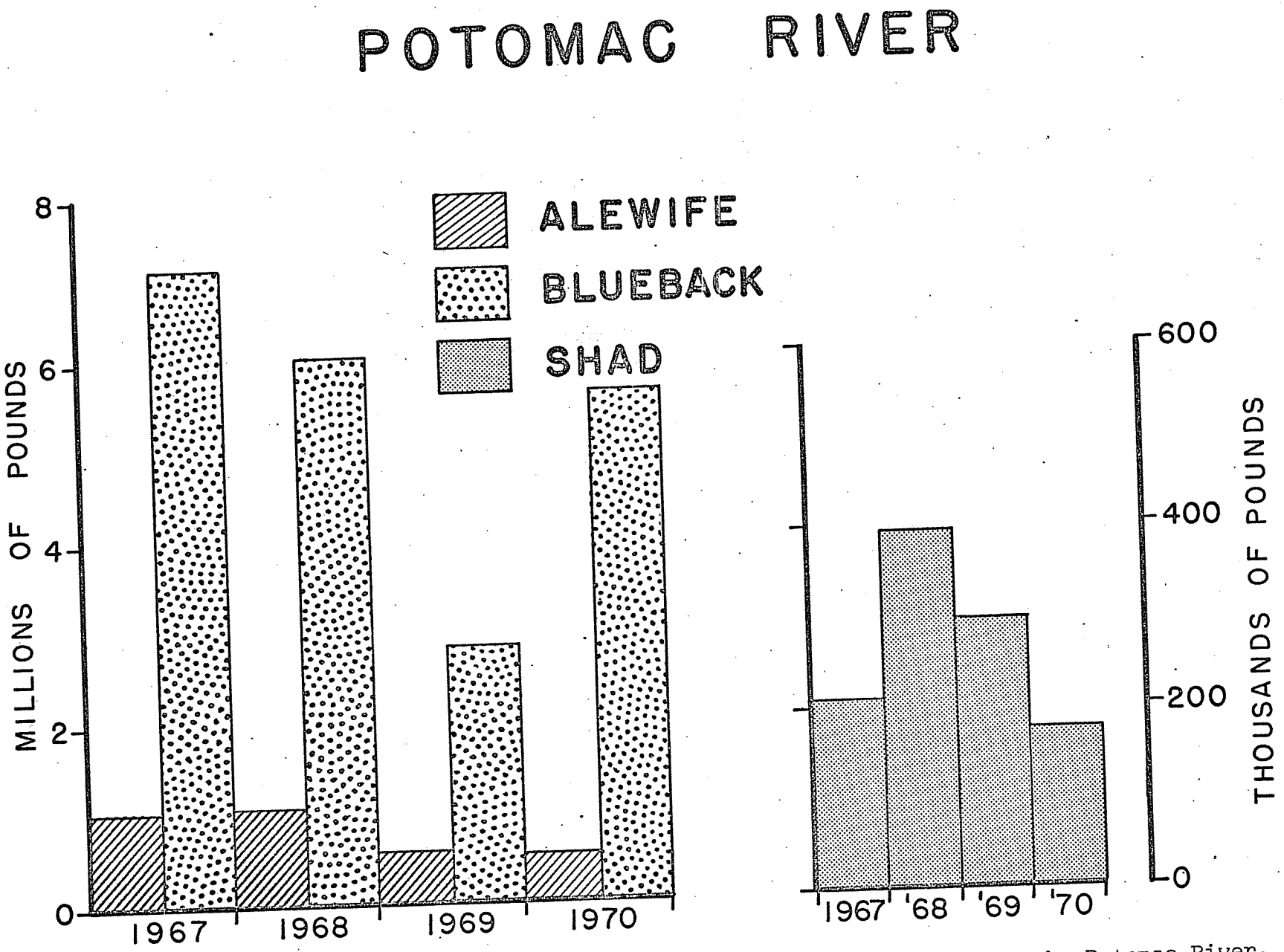

Fig. 2-2. Landings of Alosa spp. in Virginia from the Potomac River.

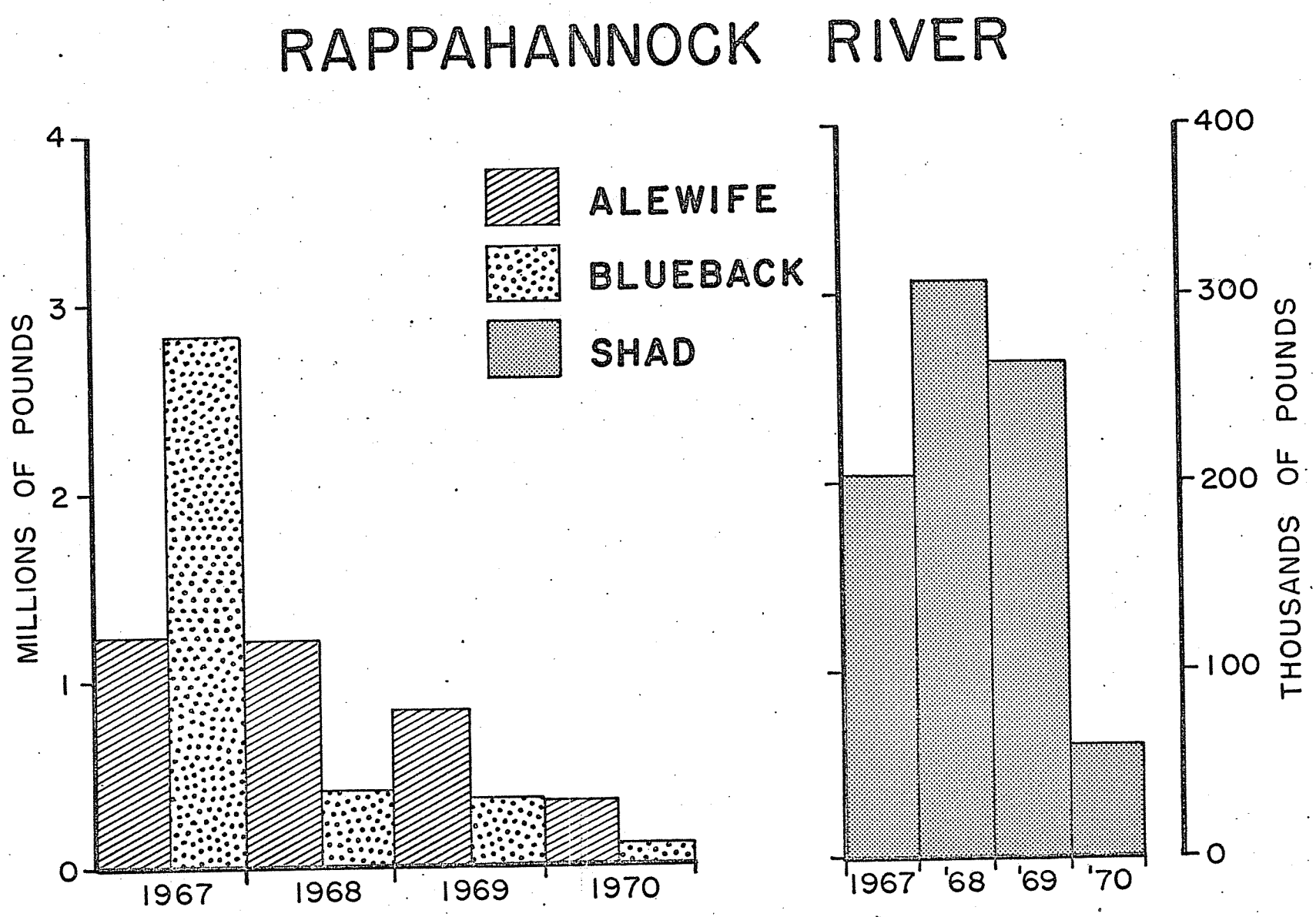

Fig. 2-3. Estimated catch of Alosa spp. by pound net from the Rappahannock River.

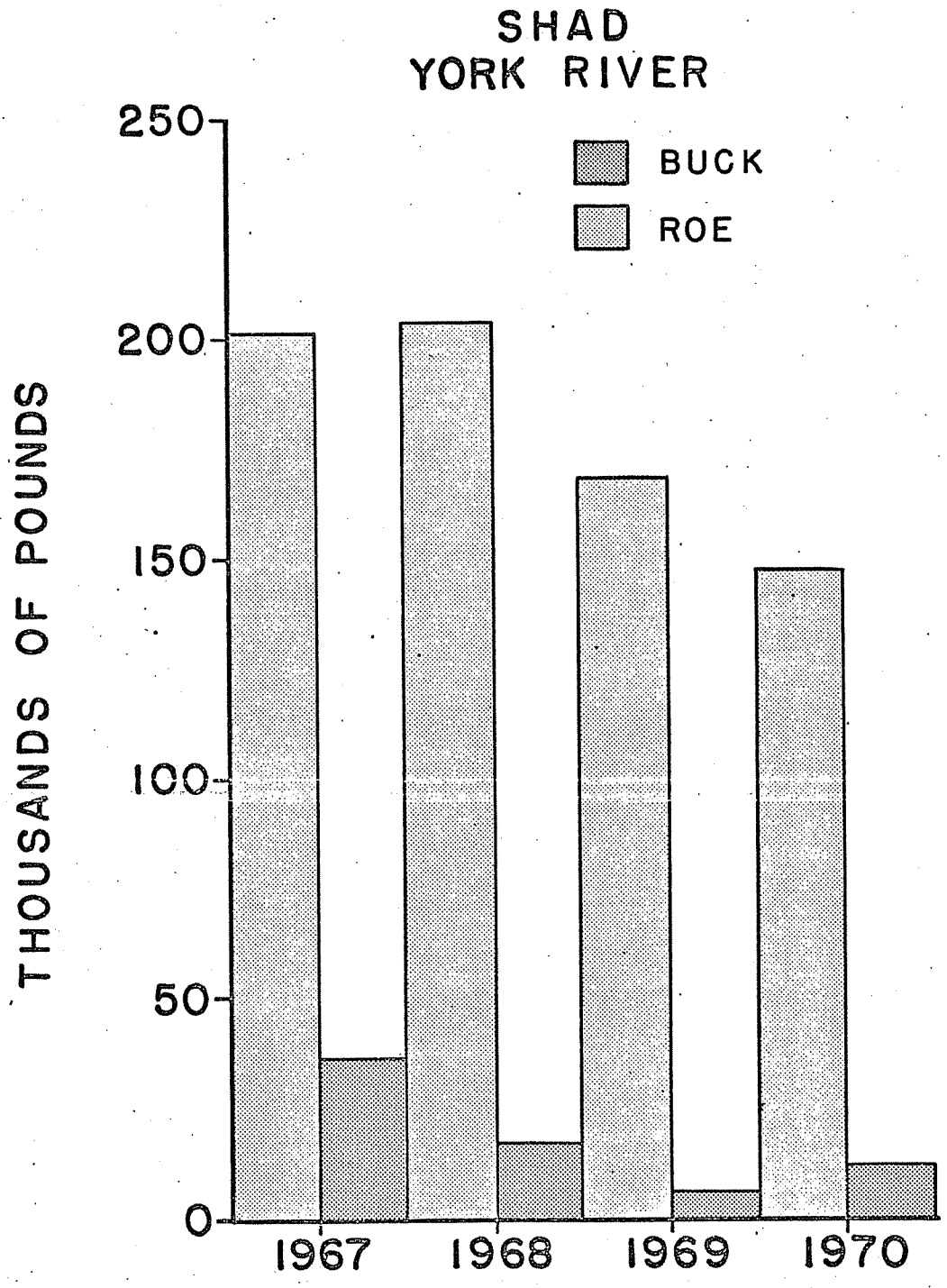

Fig. 2-4. Estimated catch of American shad by stake gill nets in the York River.

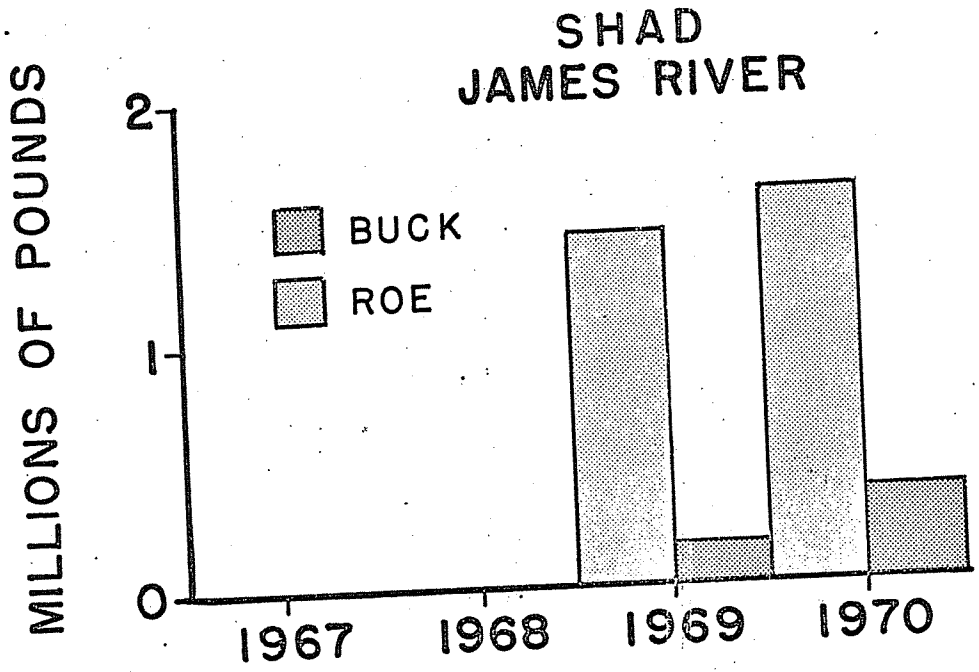

Fig. 2-5. Estimated catch of American shad by stake gill nets in the James River (records not available in 1967 and 1968).

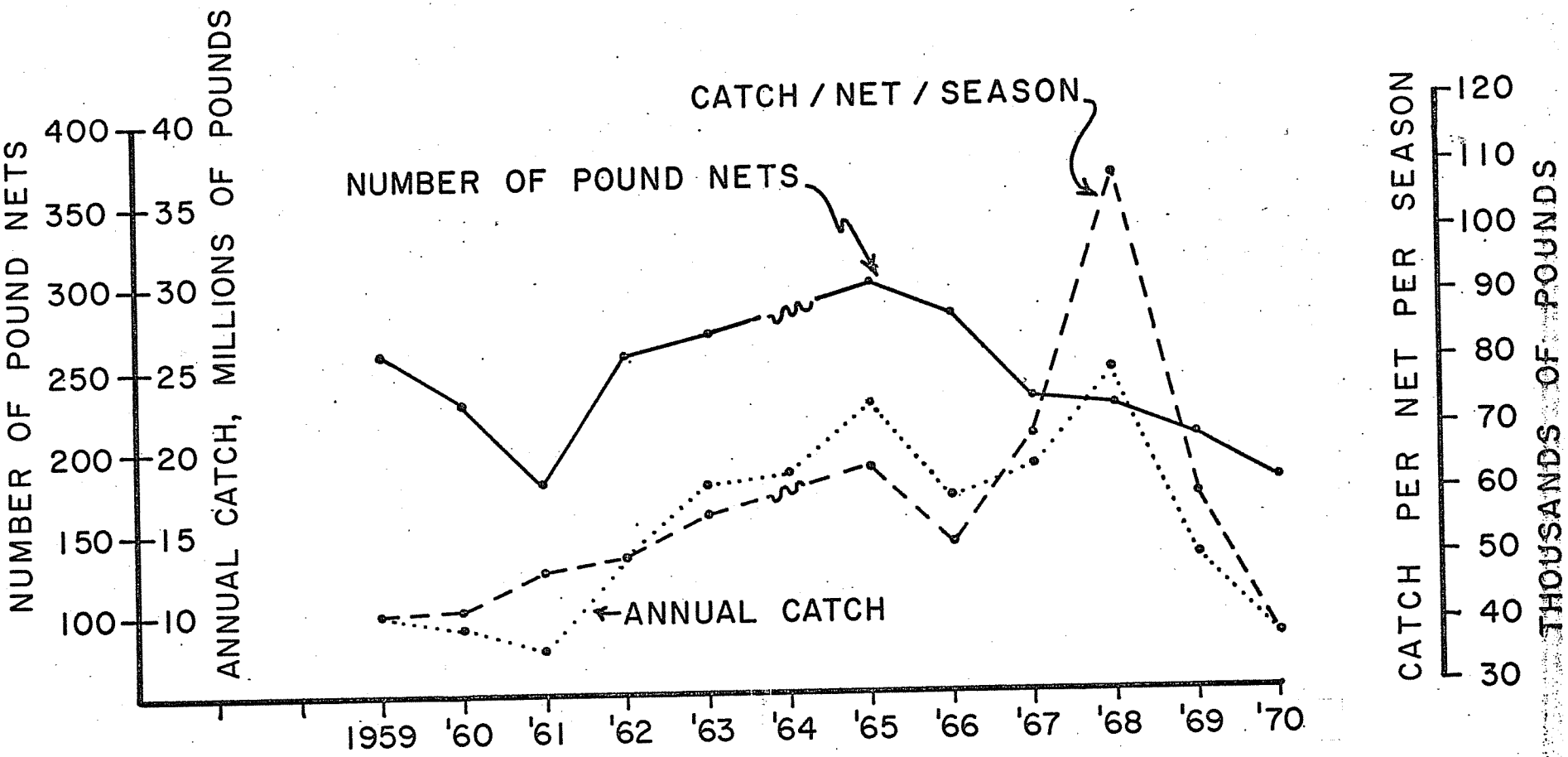

Fig. 2-6. Fishing effort and catch rate in the river herring fishery of Virginia exclusive of the Potomac River.

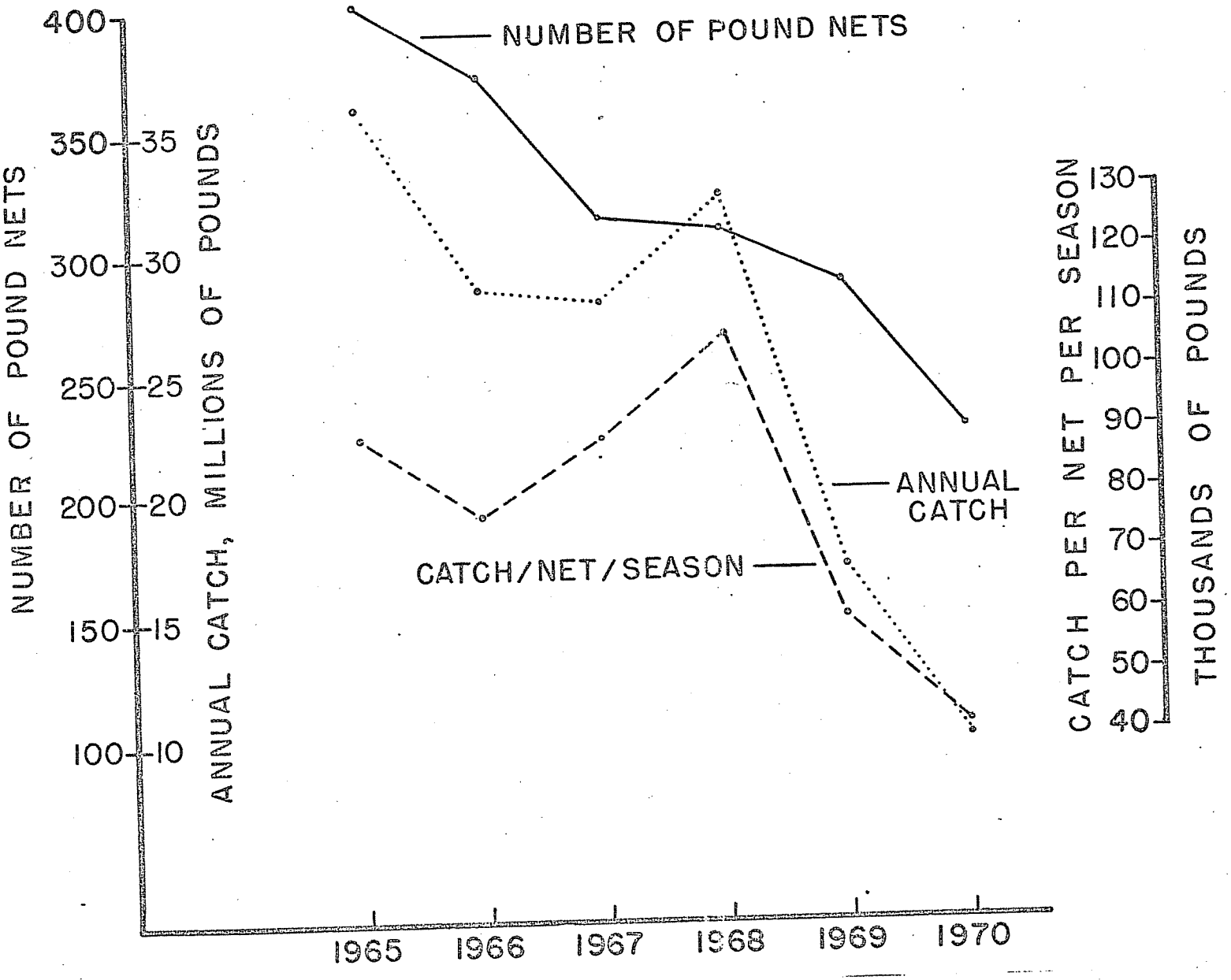

Fig. 2-7. Fishing effort and catch rate in the river herring fishery of Virginia and the Potomac River.

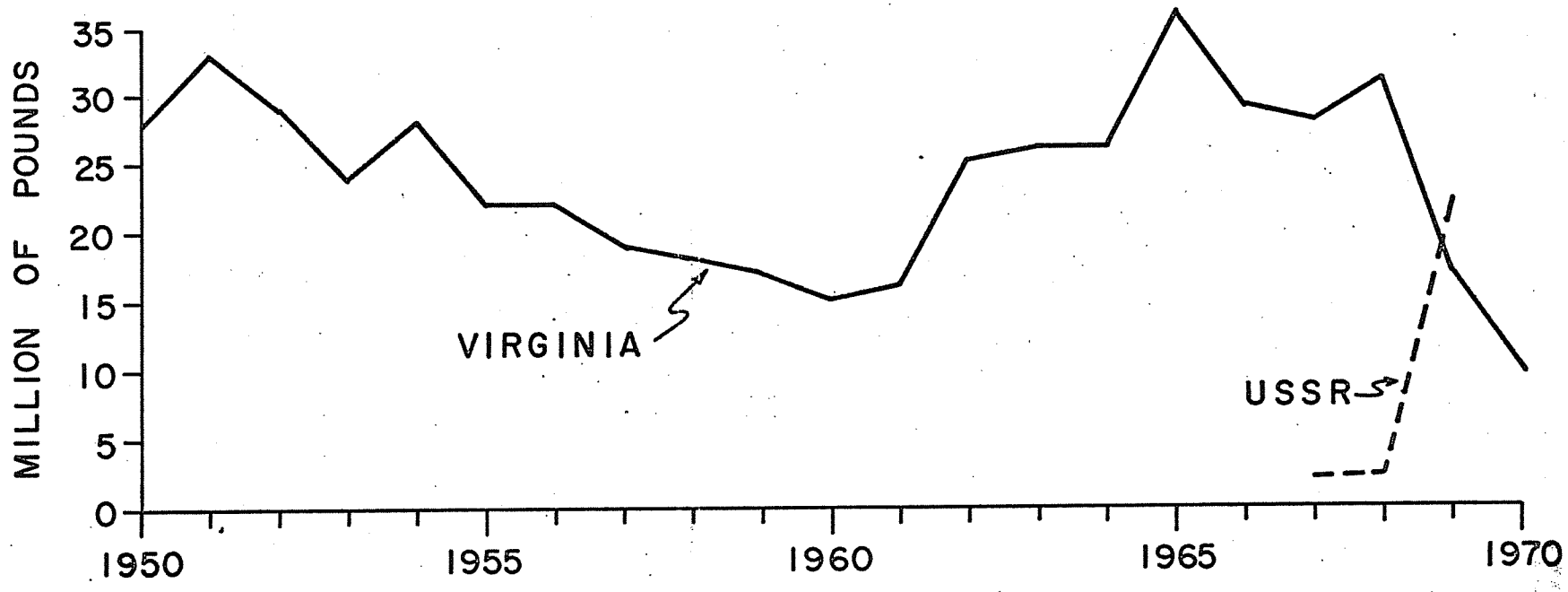

Fig. 2-8. Landings of river herring in Virginia (lower Chesapeake Bay and tributaries) and by USSR from the Middle Atlantic Bight.

PHASE 3

Location of Spawning Sites and Nurseries

The objective was to delimit the geographic extent of spawning sites and nurseries of fishes of the genus Alosa. To accomplish this objective field parties sampled each tidal tributary stream of each river system. The mainstream was also sampled at frequent intervals throughout its length. Sampling gears used were gill nets, seines, fyke nets, and plankton nets. If ripe adults were caught the site of capture was assumed to serve as a spawning area. The same assumption was made if eggs or larvae were taken in the plankton nets. At least two visits and frequently more were needed to confirm whether or not a tributary or site in the mainstream served as a spawning area.

Nurseries were delimited by sampling monthly at 5-mile intervals from the mouth of each river to the fall line. Sites of capture of juveniles were assumed to be parts of the nursery. Sampling gears used were otter trawls, beach seines, surface trawls, and a modified Cobb midwater trawl. The Cobb trawl proved to be the most effective sampling gear. The Cobb trawl was fished from the R/V Langley, a 100 ton converted ferry. The extensive sampling necessary to delimit spawning areas and nurseries occupied a four man field party from the onset of the spawning season in the spring until the juveniles departed in the fall. One river system was examined each year.

Spawning Areas

River herring and shad spawn in water less saline than one ppt and usually in fresh water. Our data indicate that river herring spawn in the upper reaches of nearly all tributary streams which empty into the mainstream above the mean transition zone between fresh and salt water. Also many river herring spawn in the tidal freshwater portion of the mainstream.

American shad, as indicated by capture location of running-ripe spawners, prefer spawning on shallow-water flats of the tidal freshwater section of the mainstream. Apparently shad also spawn to some extent in the tributary streams since shad larvae and young juveniles were found in the upper reaches of tributaries shortly after the spawning period.

Hickory shad were also found in running-ripe and spent condition in tributary streams and in the mainstream. These shad appear to run as far as possible up the main stream to spawn below the first insurmountable barrier encountered. Hickory shad in spawning condition were taken below the dam on the Rappahannock River at Fredericksburg; at Walkers Dam on the Chickahominy River; and below the first dam at Richmond on the James River. Spawning hickory shad were also captured along with river herring in several tributary streams in these rivers.

Alewife, hickory shad, and American shad enter Chesapeake Bay about the same time during early spring. Alewife have been reported in the York-Mattaponi-Pamunkey river system in December and January,

although the earliest capture of alewife during our study was in early February in the James River system when surface water temperature was 4.9°C. Alewife were found in spawning condition in tributary streams until the middle of May with the height of spawning occurring during the latter part of April when surface water temperatures ranged from 16.0 to 21.5°C.

Hickory shad have been reported by commercial fishermen in the James River in early February; however, the earliest capture of hickory shad recorded by our field crews was in the York River system (Holts Creek) on March 28 when surface water temperature was 10°C. These fish were found on the spawning grounds with partially spent gonads until late May when surface water temperature was 21.5°C. Not enough of these shad were taken to determine a peak spawning period.

American shad enter Chesapeake Bay in March with the height of the spawning migration coming in April. The earliest capture of adult shad by our field crews was on March 27 in the Pamunkey River (P30) when surface water temperature was 10°C. Shad were found in the spawning areas until late May when water temperature was 19.3°C.

Blueback herring usually do not appear in the rivers until April and remain until late May and early June. Most blueback spawning occurs during May when water temperature ranges from 18 to 24°C.

In all species of Alosa the males are generally more numerous than the females throughout the spawning season; they also appear in the rivers earlier and stay later.

For each river system tributaries known to serve as spawning areas and those which probably so serve are cataloged in Tables 3-1, 3-2, 3-3, and 3-4. The tributaries indicated as spawning areas are

so designated because our field crews found in these areas running ripe or spent adult fish, eggs, or larvae. Tributaries entering the tidal freshwater portion of the mainstream but too small to enter by skiff or so shallow as to preclude efficient use of our collecting gear are designated as probable spawning areas providing they were neither severely polluted nor had any physical barriers to entry by fish. Tributaries which serve as spawning areas also serve as nurseries.

Of the four river systems inventoried the Potomac River system with 61,000 acres, including tributaries from both Virginia and Maryland, had the largest area of suitable spawning and nursery grounds for Alosa (Table 3-5). We examined only those tributaries in Virginia. The James River (Table 3-6) ranks second with 41,000 acres, the Rappahannock River system (Table 3-7) third with 16,000 acres, and the York-Pamunkey-Mattaponi River system (Table 3-8) fourth with 11,000 acres. Only the two major branches of the York River system serve as nurseries; the York River proper is too saline. The general locality of the spawning areas and nurseries is shown in Fig. 3-1. Details of monthly distribution of juveniles have been presented in annual progress reports and are not repeated here.

Nursery of the James River

Distribution of juveniles was determined monthly to complete the description of the annual pattern. Distribution during the early months of 1969 was reported in the Annual Progress Report for the period ending September 30, 1969.

The distribution of juveniles in October of 1969 (Tables 3-9, 3-10, 3-11) was similar to that of September 1969 with reference to location of the fish. The difference between the two months is that nearly twice as many fish were taken during October as were caught during September. The increase in numbers in the mainstream suggests that the juveniles are moving out of the tributaries into the mainstream in preparation for their seaward exodus. In November slightly fewer fish were caught, and they were further downstream than in October. By December considerably fewer fish were found in the river and the majority were in the lower river apparently on their way to sea. By the end of December seaward migration was virtually complete. Figure 3-2 shows distribution of juveniles with relation to mean monthly water temperatures. Trawl surveys run through the fall and early spring indicate that a few juvenile Alosa remain in the lower James River and apparently move upstream with the adult spawners and later follow them out to sea.

In order to determine amount of year-to-year variation trawl surveys were continued throughout the nursery season in 1970 (Tables 3-12, 3-13, 3-14). Longitudinal distribution of juveniles was similar in the two years; however, far more fish were found in 1970 than in 1969.

Using identical procedures and equal effort in the two years, we captured seven times as many juveniles in 1970 and in 1969.

Table 3-1
Spawning Areas of *Alosa* in Potomac River System

Tributary	Miles Above Mouth (nautical)	Length (nautical miles)	Gradient (ft./mile)	Acreage	Spawning Confirmed	Spawning Probable
Accokeek Creek	59	15.18	18.5	280.3	X	
Accotink Creek	80	13.11	13.0	21.1	X	
Aquia Creek	60	19.32	10.4	1730.6	X	
Broad Creek	86	-	-	327.0		X
Chickamuxen Creek	68	-	-	279.7		X
Chopawamsic Creek	66	6.90	14.5	327.0	X	
Chotank Creek	50	5.52	10.9	81.9	X	
Cuckhold Creek	37	-	-	375.7		X
Deep Creek	40	-	-	- a	X	
Dogue Creek	81	10.35	16.4	158.7	X	
Farm Creek	73	3.45	20.3	49.3	X	
Four Mile Run	93	-	-	- a	X	
Gambo Creek	41	3.45	5.8	53.8	X	
Goldman Creek	39	-	-	- a		X
Gunston Cove	80	-	-	- b		X
Hunting Creek	90	4.83	16.6	72.3	c	
Kanes Creek	74	2.76	39.9	78.7	X	
Little Hunting Creek	84	4.49	11.1	116.5	X	
Marumsco Creek	73	2.07	4.8	35.2	X	
Massey Creek	74	2.76	32.6	81.1	X	
Mattawoman Creek	73	-	-	1513.0		X
Mattox Creek	35	9.66	14.5	700.8	X	
Monroe Creek	36	7.59	7.9	- a		X
Nanjemoy Creek	52	-	-	2406.4		X
Neabsco Creek	72	11.04	22.6	231.0	X	
Occoquan Creek	74	6.90	11.6	503.2	X	
Oxon Creek	91	-	-	103.0		X
Piccowaxen Creek	43	-	-	144.6		X
Piscataway Creek	87	-	-	777.6		X
Pohick Creek	80	16.56	18.7	28.2	X	
Pomonkey Creek	77	-	-	79.4		X
Popes Creek	33	6.90	17.4	349.4	X	
Port Tobacco River	47	-	-	1723.5		X
Potomac Creek	59	13.80	11.6	1413.1	X	
Powells Creek	71	8.97	40.1	119.0	X	
Quantico Creek	69	11.73	23.9	611.8	X	
Rosier Creek	39	5.52	7.3	287.4	X	
Swan Creek	86	-	-	58.2		X
Upper Machodoc Creek	40	19.32	8.3	1153.3	X	
Williams Creek	40	4.14	9.7	93.4	X	

a Areas too small to measure
b Area incorporated with mainstream acreage
c No spawning due to pollution

Table 3-2
Spawning Areas of Alosa in Rappahannock River System

Tributary	Miles Above Mouth (nautical)	Length (nautical miles)	Gradient (ft./mile)	Acreage	Spawning Confirmed	Spawning Probable
Balls Creek	34	1.73	23.1	- a		X
Birchwood Run	79	-	-	-		X
Bridge Creek	44	3.10	0	81.3		X
Broad Creek	42	4.49	26.7	58.7		X
Brockenbrough Creek	48	4.83	24.8	- a	X	
Cat Point Creek	39	19.32	5.7	36.7	X	
Cones Creek	61	-	-	-a		X
Corbins Neck Creek	81	-	-	-a		X
Deep Run	93	-	-	-a		X
Doctors Creek	40	-	-	-a		X
Dogue Run	77	-	-	-a		X
Elmwood Creek	56	6.21	25.8	11.0		X
Fall Run	91	-	-	-a		X
Farmers Hall Creek	44	5.52	18.1	22.0	X	
ngoteague Creek	66	-	-	-		X
Goat Island Thorofare	72	-	-	63.4		X
Goldenmale Creek	68	13.11	15.3	6.4	X	
Guycatic Run	68	6.21	19.3	7.3		X
Hazel Run	94	-	-	-a		X
Haskins Creek	37	12.42	8.1	79.4	X	
Hongh Creek	78	-	-	-a		X
Jetts Creek	62	4.83	29.0	26.9	X	
Jones Top Creek	75	1.38	7.3	11.0	X	
Jugs Creek	34	4.14	24.2	-a		X
Keys Run	77	-	-	-a		X
Lamb Creek	79	-	-	-		X
Lewis Creek	42	-	-	76.8		X
Little Carters Creek	35	6.21	3.2	89.0	X	
Little Totuskey Creek	32	4.14	24.1	25.7	X	
Massaponax Creek	89	-	-	-a		X
McGuire Creek	36	2.42	-	35.2		X
Mill Creek	35	-	-	-a		X
Mill Creek	67	-	-	44.2		X
Millbank Creek	69	2.76	29.0	15.4	X	
Millers Pond Creek	67	-	-	-a		X
Mt. Airy Mill Pond	39	-	-	-a		X
Mt. Landing Creek	39	9.66	12.4	47.7	X	
Mount Swamp	73	4.83	41.4	-a		X
Muddy Creek	85	5.52	12.7	-a	X	
nzatico Bay	65	-	-	-b		X

Table 3-2 (cont'd)

Tributary	Miles Above Mouth	Length	Gradient	Acreage	Spawning Confirmed	Spawning Probable
Occupacia Creek	44	13.11	6.9	267.9	X	
Pecks Creek	33	3.45	17.4	- a		X
Peedee Creek	49	5.52	25.4	55.1	X	
Piscataway Creek	35	15.2	6.6	308.5	X	
Portobago Bay	64	-	-	- b		X
Richardson Creek	31	6.90	14.5	18.4	X	
Rock Creek	73	-	-	- a		X
Skinker Creek	79	-	-	- a		X
Sluice Creek	43	3.45	14.5	18.4	X	
Tobacco Creek	63	4.83	20.7	18.4	X	
Totuskey Creek	32	16.56	7.3	414.7	X	
Troy Creek	57	-	-	- a		X
Ware Creek	82	-	-	- a		X
Waterview Creek	41	4.14	24.2	22.0	X	
White Marsh Creek	76	-	-	- a		X
Wilna Creek	44	-	-	- a		X

a Areas too small to measure
b Areas incorporated with mainstream acreage

Table 3-3
Spawning Areas of Alosa in York River System

Tributary	Miles From Mouth	Length (nautical miles)	Gradient (ft./mile)	Acreage	Spawning Confirmed	Spawning Probable
Pamunkey						
Bell Thorofare	50	1.3	0	39.2	X	
Big Creek	52	3.0	26.7	18.4	X	
Broad Creek	62	.75	0	46.7		X
Clapper Creek	65	.75	0	10.5		X
Clayborne Creek	56	1.0	0	18.4		X
Cohoke Creek	47	8.5	14.1	11.0	X	
Consaic Marsh	41	-	-	26.2	X	
Cumberland Thorofare	47	1.5	0	65.3	X	
Harrison Creek	56	5.5	14.6	23.1		X
Holts Creek	47	3.0	13.3	47.7	X	
Jacks Creek	58	8.5	14.1	44.0	X	
Macon Creek	58	2.0	60.0	51.2	X	
Manquin Creek	69	4.6	26.1	3.7		X
Matadequin Creek	62	3.0	26.7	7.8	X	
Meadow Creek	68	-	-	-	X	
Mill Creek	28	2.0	0	22.0	X	
[illegible] 11 Creek	41	-	-	7.8	X	
Montague Creek	61	4.0	20.0	7.3		X
Polkwest Creek	58	-	-	41.8		X
Sweet Hall Marsh	40	-	-	26.2		X
Whitehouse Creek	53	3.0	13.3	58.2	X	
Mattaponi						
Aylett Mill Creek	59	-	-	-a	X	
Beulah Creek	67	-	-	-a		X
Brooks Creek	46	3.0	40.0	3.7	X	
Burnt Mill Creek	30	7.5	16.0	33.0	X	
Chapel Creek	65	-	-	-a		X
Coons Creek	64	-	-	-a		X
Corbin Creek	31	2.75	0	18.4	X	
Courthouse Creek	43	4.25	23.5	7.3	X	
Custis Mill Creek	39	-	-	-a	X	
Garnetts Creek	49	-	-	-a	X	
Grass Creek	41	2.75	29.0	-a	X	
Heartquake Creek	36	5.5	14.6	11.0	X	
London Swamp	56	2.8	42.9	-a		X
Madison Creek	48	2.0	60.0	-a		X
Mantapike Creek	47	3.5	34.3	3.7	X	
Mill Creek	38	2.75	29.8	11.0	X	
Walkerton Creek	53	4.0	30.0	14.7	X	

a Areas too small to measure