NORTH CAROLINA ALOSID FISHERIES MANAGEMENT PROGRAM

by

Sara E. Winslow

North Carolina Department of Natural Resources
and
Community Development

Division of Marine Fisheries
Morehead City, NC 28557

Completion Report for Project AFC-27

May 1989

This project was supported under the Anadromous Fish Conservation Act (PL 89-304, as amended) and funded, in part by the U.S. Department of Commerce, National Marine Fisheries Service, under Project No. AFC-27.

TABLE OF CONTENTS

INTRODUCTION

Anadromous fishes have been important to North Carolina fishermen for many decades. Fisheries in the Albemarle Sound area predate the American Revolution. The principal commercial gears used to capture these alosids have been pound nets and gill nets in the Coastal Sounds and tributaries. Table 1 clearly shows that the Albemarle Sound area is the center of the state's anadromous fisheries industry. Combined landings of blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), American shad (Alosa sapidissima), hickory shad (Alosa mediocris), striped bass (M saxatilis) and sturgeons (Acipenser sp.) have fluctuated over the years, principally due to the fluctuations in river herring landings (blueback herring and alewife). The decline from 1969 to the extremely low 1981 level is unprecedented. River herring landings have rebounded somewhat from the low in 1981 to a level in 1985 comparable to 1970-72. In 1977 and 1988, the lowest river herring landings, respectively were recorded (Table 2). The river herring landings during these years do not necessarily reflect the amount of fish present but reflect the environmental and market conditions. Sturgeon and striped bass landings are included in Tables 1 and 2, so all anadromous species taken in North Carolina's commercial fisheries are shown. Sturgeon landings probably do not reflect the population as these fish are incidental by catches of other fisheries.

Project AFC-27 is a continuation of anadromous fisheries research and management activities initiated in the Albemarle Sound area during 1971 (Project AFC-8). The original objectives of the project were to designate spawning and nursery areas, monitor juvenile year class abundance, adult year class composition, to collect catch-effort statistics form the Chowan River pound net fishery, and analyze and report on American shad data that have been collected in the Albemarle Sound area during 1972-1987.

Since the landings of river herring, American shad and hickory shad declined along the Atlantic Coast, all of the coastal states marine fisheries management agencies have joined together with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service to prepare a Cooperative Management plan for the resources. Data from past

Table 1. Relative importance of anadromous fish in North Carolina and in the Albemarle Sound area as shown by commercial landings (from published and unpublished data: NMFS, Branch of Statistics, Beaufort, NC; NC Division of Marine Fisheries, Morehead City; and Zoology Department, NC State University at Raleigh).

Year	Total edible finfish (lbs)	Anadromous fish (lbs)	Percent anadromous fish	Anadromous fish Albemarle Sound area (lbs)	Percent of anadromous fish from Albemarle Sound
1960	30,470,000	14,308,000	46.9	13,469,000	94.1
1961	30,029,000	13,490,000	44.9	12,766,000	94.7
1962	31,887,000	16,037,000	50.3	15,101,000	94.2
1963	32,348,000	16,864,000	52.1	15,979,000	94.8
1964	24,562,000	9,183,000	37.4	8,402,000	91.5
1965	33,538,000	14,658,000	43.7	13,570,000	92.6
1966	32,567,000	14,130,000	43.4	13,114,000	92.8
1967	40,880,000	21,250,000	51.9	19,678,000	92.6
1968	36,102,000	18,467,000	51.1	17,016,000	92.1
1969	41,099,000	22,282,000	54.2	20,831,000	93.5
1970	29,832,000	14,974,000	50.2	12,475,000	83.3
1971	31,380,000	14,991,000	47.8	13,542,000	90.3
1972	40,731,000	13,190,000	32.4	11,952,000	90.6
1973	41,203,000	10,121,000	24.6	8,594,000	84.9
1974	47,243,000	7,730,000	16.4	6,357,000	82.2
1975	53,681,000	7,570,000	14.1	6,675,000	88.2
1976	53,754,000	7,652,000	14.2	6,931,000	90.6
1977	61,755,000	9,268,307	15.0	9,085,400	98.0
1978*	67,072,000	7,759,418	11.6	7,269,100	93.7
1979*	82,248,000	6,047,481	7.3	5,468,600	90.4
1980*	91,528,000	7,011,745	7.7	6,686,670	95.4
1981*	68,826,000	5,635,341	8.2	5,015,155	88.9
1982*	63,909,000	10,235,974	16.0	9,775,230	95.5
1983*	53,634,000	6,730,714	12.5	6,121,934	91.0
1984*	64,706,000	7,586,407	11.7	7,010,639	92.4
1985*	69,945,000	12,226,923	17.5	11,979,927	98.0
1986*	60,089,000	7,418,490	12.3	7,067,319	95.3
1987*	51,813,000	3,843,751	7.4	3,583,587	93.2
1988*	61,571,596	4,669,266	7.6	4,145,355	88.8

*Preliminary data, subject to revision in Fishery Statistics of the United States.

Table 2. Commercial landings of anadromous fishes in North Carolina, 1965 - 1988 (thousands of pounds).

Year	River herring	American shad	Hickory shad	Striped bass	Sturgeon
1965	12,826	1,069	202	484	77
1966	12,520	701	197	653	59
1967	18,486	777	131	1,817	39
1968	15,525	842	141	1,912	47
1969	19,762	719	101	1,568	132
1970	11,521	953	61	2,318	120
1971	12,722	680	63	1,449	78
1972	11,237	468	69	1,261	154
1973	7,932	321	66	1,752	56
1974	6,237	369	42	1,016	93
1975	5,952	241	29	1,303	44
1976	6,401	167	19	1,038	46
1977	8,524	121	22	572	30
1978*	6,608	402	21	698	32
1979*	5,119	278	32	614	41
1980*	6,219	199	92	477	30
1981*	4,754	352	81	417	31
1982*	9,438	412	25	338	23
1983*	5,868	446	70	361	18
1984*	6,515	585	60	513	45
1985*	11,548	330	41	177	24
1986*	6,814	373	20	189	20
1987*	3,195	327	45	262	13
1988*	4,191	261	92	115	7

*Preliminary landings subject to revision in Fishery Statistics of the United States.

projects as well as this project will be part of the database for this plan, which is being coordinated by the Atlantic States Marine Fisheries Commission's Interstate Fisheries Management Program.

STUDY AREA

The Albemarle Sound area was thoroughly described by Street et al. (1975), and Winslow et al. (1983 and 1985) (Figure 1).

MATERIALS AND METHODS

Spawning Area Survey

The designation of anadromous fish spawning areas was based on the occurrence of one or more of the following criteria: (1) capture or observation of running ripe females, (2) the actual observation of spawning activity, or (3) the capture of eggs and larvae.

Potential river herring spawning areas were sampled in the Pasquotank, Little, Perquimans and Yeopim rivers and their tributaries. All are tributaries of the Albemarle Sound.

Monofilament gill nets from 4.57 m (15 ft) - 9.14 m (30 ft) long with stretched mesh ranging from 57.2 mm (2,25 m) to 82.5 mm (3.25 in) were fished in the above mentioned rivers and their tributaries during 1987 and 1988 to determine distribution of adult river herring. Nets were set for up to 24 hours periods. Captured adult river herring were identified, counted, measured, and examined for spawning conditions. Other species captured were also counted and noted. Surface water temperatures were taken at the time the net was set and picked up.

Eggs and larvae were sampled during 1987 and 1988 with a 0.5 m plankton net of #00 Nitex mesh with a wide mouth 0.95 l jar attached to the cod end. Plankton net samples were taken from bridges, with sample time being 15 minutes. Samples were preserved in 5% formalin and returned to the laboratory where eggs and larvae were sorted, identified, counted, and measured with a binocular microscope fitted with an ocular micrometer. Water chemistry data, including temperatures, dissolved oxygen and pH were recorded for each sample.

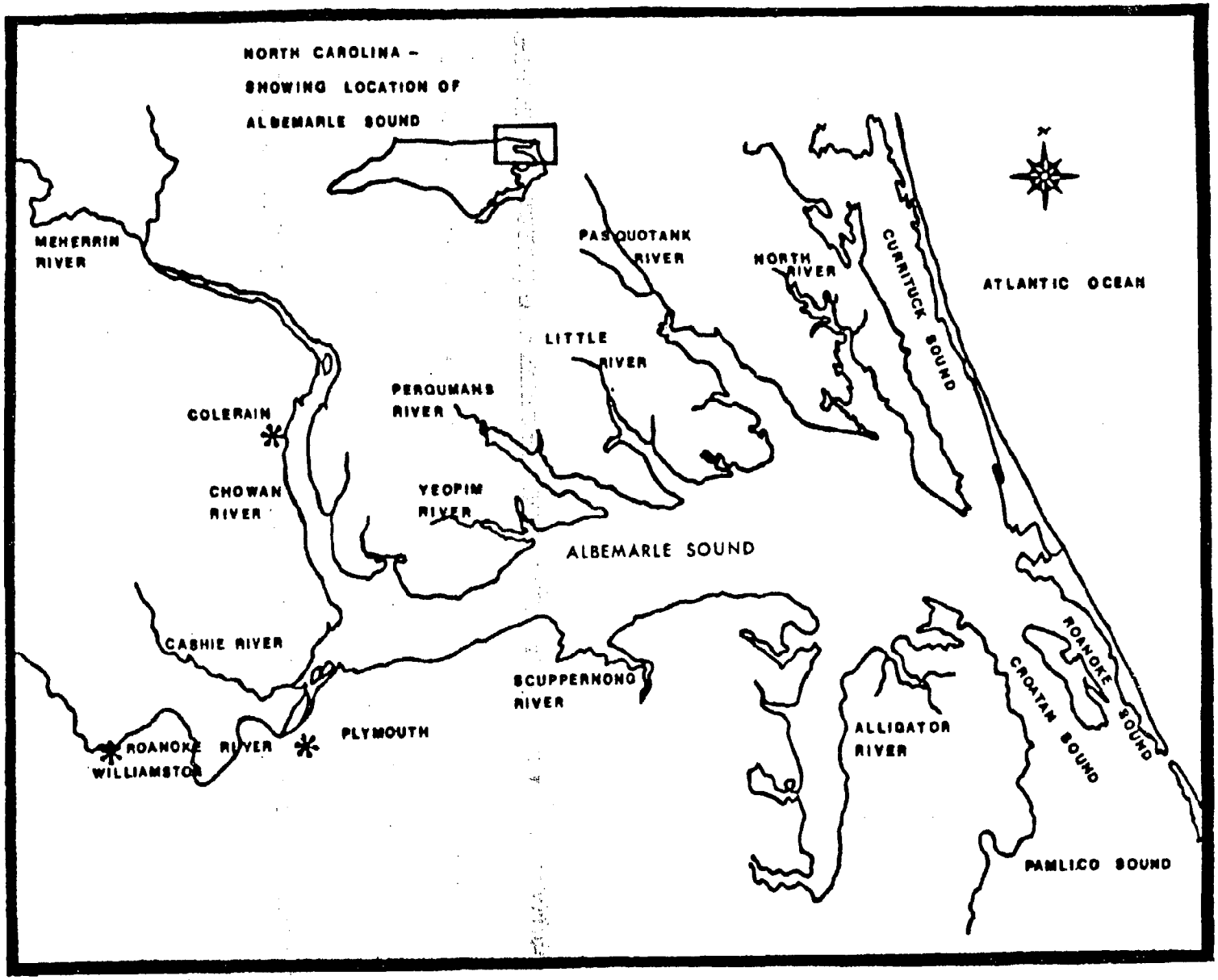


Figure 1. Albemarle Sound area and its tributaries, North Carolina.

Nursery Area Survey

Albemarle Sound Area

Eleven previously established stations were sampled monthly by seine in the western Albemarle Sound area June-November 1986 through 1988 (Figure 2). During September of each year, an additional 14 seine samples were taken throughout the Albemarle Sound area to determine overall distribution and utilization of nursery areas (Figure 2).

The stations were sampled with a 18.5 m (60 ft) bag seine with a 6.3 mm (1/4 in) mesh bag. One seine haul was considered one unit-of-effort.

Samples were sorted to species, and up to 30 individuals of each alosid species present were measured to the nearest millimeter, fork length (mm, FL). Species other than anadromous fishes were also noted, as were environmental parameters such as surface and bottom water temperatures, dissolved oxygen levels and salinities.

Currituck Sound Area

In the Currituck Sound area, 16 previously established stations (1 trawl and 5 seine), were sampled monthly during June-October 1986-1988, to determine juvenile alosid abundance (Figure 3).

Sampling gear consisted of a (1) 6.1 m (20 ft) two seam flat trawl with 19.2 mm (.75 in) bar mesh in the body and 6.3 mm (.25 in) bar mesh in the tail bag, and (2) an 18.3 m (60 ft) bag seine with a 6.3 mm (.25 in) mesh bag. The flat trawl was towed for 5 mm at 1,500 rpm by a 6.7 m (22 ft) boat equipped with a 150 horsepower outboard engine.

All fish species were identified and counted in each sample, with a maximum of 30 fish per species measured at each station. Environmental parameters such as water temperature and salinity were measured at each sample site.

Commercial Harvest Survey

During the fishing season (approximately February-May), weekly pound net landings were obtained by statistics program port samplers from cooperating dealers and fishermen in the Albemarle Sound area. The number of pound nets fished each week was obtained every other week. Weeks were serially numbered beginning with the first full week in

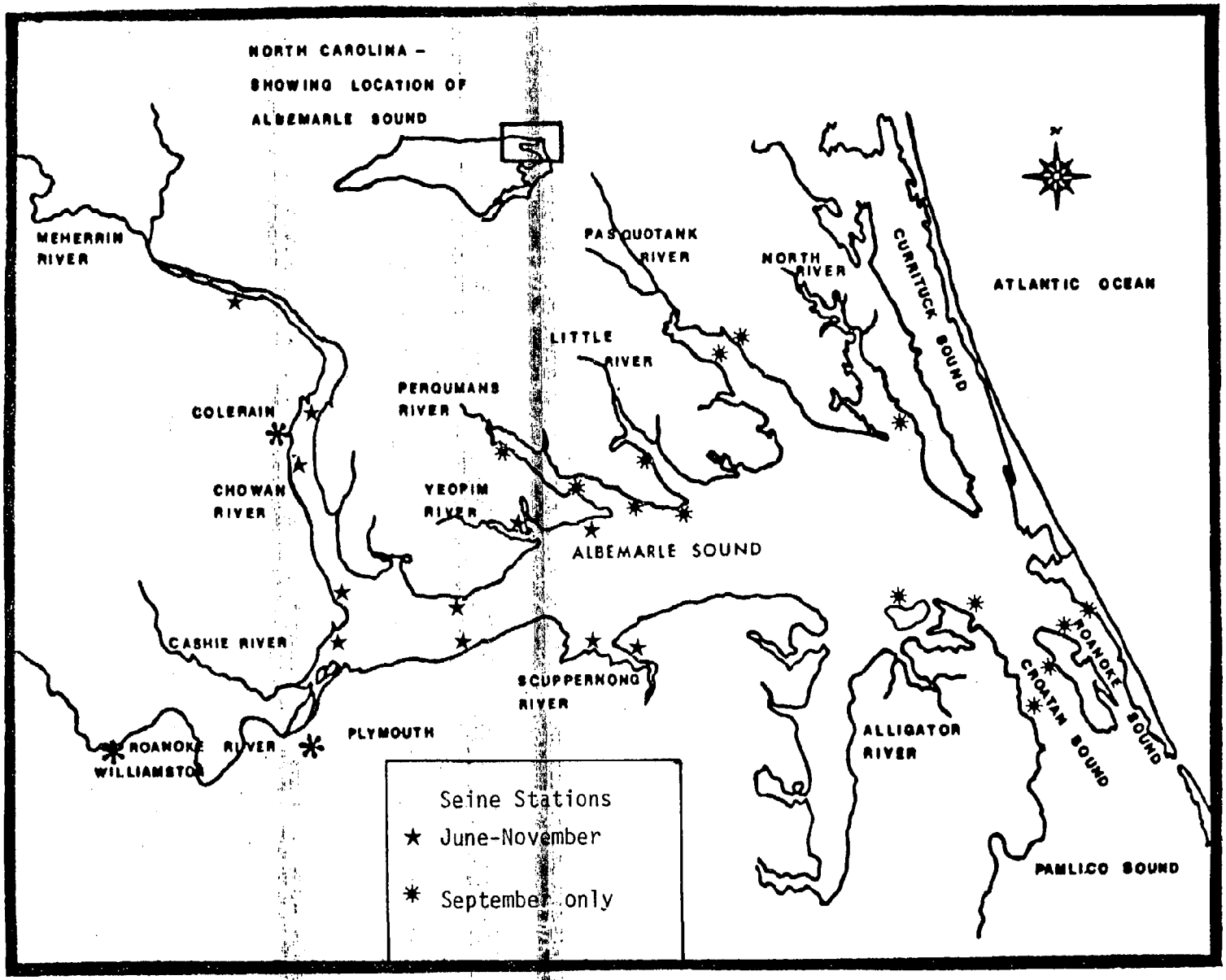


Figure 2. Nursery area sampling sites in the Albemarle Sound area, NC, 1985-1988.

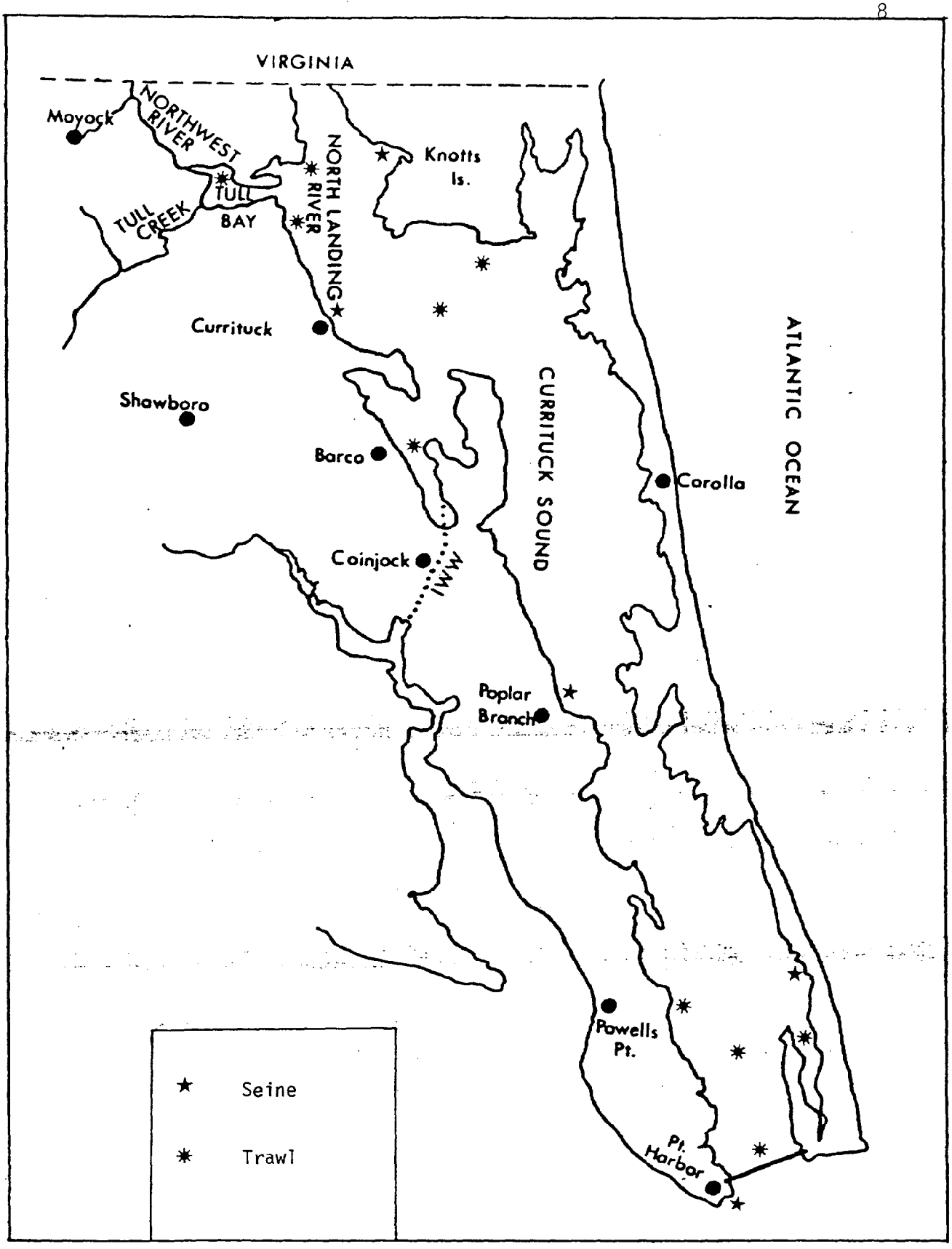


Figure 3. Nursery area sampling sites in Currituck Sound area, NC, 1985-1988. (IWW=Atlantic Intracoastal Waterway.)

January. The catch/effort (kg/pound net week) was calculated for the Chowan River by dividing the total number of kilograms landed by the total weekly number of active pound nets. This work was calculated in conjunction with the North Carolina-NMFS Cooperative Statistics Program.

Adult Sampling

Commercial harvest sampling sites were the same as those reported by Winslow et al. (1985). Data collected at these sites (Figure 4) were assumed to be representative to total commercial landings in the Albemarle Sound area. During February-May of each year, project personnel visited at least three Albemarle Sound area fish dealers weekly to obtain unculled samples of blueback herring, alewife, hickory shad, and American shad. Commercial American shad fisheries were also sampled in the Cape Fear River, Neuse River, Pamlico River, and along the Outer Banks (ocean catch). These samples were taken on an opportunistic basis by Division of Marine Fisheries staff, working in each of those areas. Therefore, the samples may not be entirely representative of the total populations found in each area.

Data from each site was obtained from unculled samples, whenever possible, for determining species composition and sex ratios. In the Albemarle Sound area, up to 30 individuals of each species were examined weekly to determine fork length, sex, and weight. Fork lengths (FL) were measured to the nearest millimeter, and weights were taken in kilograms. Scale samples were taken and processed in the same manner as described by Street et al. (1975). Up to 200 American shad were examined from each of the other areas to determine size (mm, FL) and sex, and scale samples were taken for ageing.

Due to the large number of alosid scales samples taken and the time-consuming process of ageing, stratified subsampling for ageing was used during the project. The techniques used in which modal length groups were subsampled were similar to those developed by Ketchen (1950). Blueback herring and alewife were separated by sex into 10 mm modal size groups. American shad and hickory shad were separated by sex into 25 mm modal size groups. At least half of the scales in each size group were aged if 15 or more samples were present; in those with less than 15, all were aged. The subsamples were expanded to obtain the age composition estimates for each species.

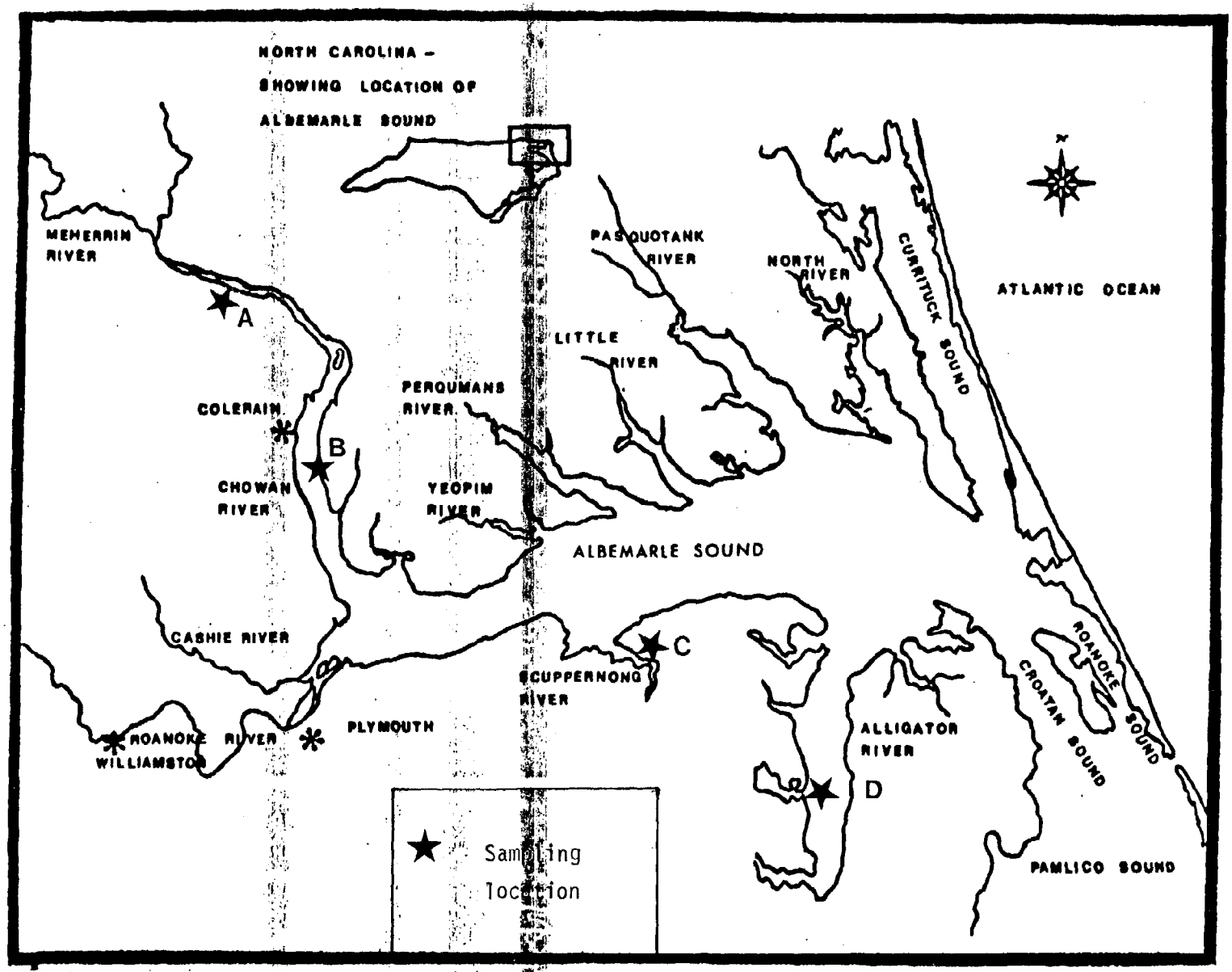


Figure 4. Location of Albemarle Sound area, NC, harvest sampling sites, 1986-1988.

Contribution of Year Class (Number of Individuals) to Harvest

Blueback herring and alewife from the Chowan River for which age, sex, and weight data were available were placed in the appropriate year classes for each week sampled during 1986, 1987, and 1988. The number of individuals of each year class was followed weekly through the sampling period. The number of blueback herring and alewife landed for a week of a particular sex and age class was calculated by multiplying the landings (kg) by the percent weight of the landings made up of that sex and age class divided by the mean weight of that sex for that year class during that week. To obtain the estimated number of individuals the following calculations were performed:

$$\text{Number of individuals landed} = \frac{\text{Landings (kg)} \times \%\ \text{wt of sex + year class}}{\text{wt of sex, of year class}}$$

To obtain % wt of sex, year class

$$\frac{\text{wt of sex of year class}}{\text{wt of all year classes, both sexes}}$$

American Shad Report

Data collected on Albemarle shad from 1972-1987 in the Albemarle Sound area was analyzed and a report written under separate cover.

RESULTS AND DISCUSSION

Spawning Area Survey

Locations and times of river herring spawning were determined for the Pasquotank, Little, Perquimans, Yeopim rivers and their tributaries during the spring, 1987 and 1988.

Pasquotank River and Tributaries

The dates of capture, location, number, and species of running-ripe female taken by gill net from the Pasquotank area are shown in Table 3. All of the running-ripe females were captured in 1987. Table 4 shows the number and general locations of capture of alosid larvae from the study area. The approximate spawning area of blueback herring, as shown by observation of running-ripe females or spawning observed, are shown in Figures 5 and 6. In 1988, no river herring larvae were captured, but

Table 3. Observation of running-ripe female river herring in the Pasquotank River and its tributaries 1987. (None captured in 1988.)

Date	Location	Number of fish	Species
04/09/87	Mill Dam Creek, NC Hwy 343	1	Blueback
04/13/87	Knobbs Creek, US Hwy 17	1	Blueback
04/16/87	Sawyer's Creek, NC Hwy 343	2	Blueback
04/16/87	Sawyer's Creek, SSR* 1200	Spawning observed	Blueback

*SSR: State Secondary Road

Table 4. River herring larvae collected by egg net in Pasquotank River and its tributaries, 1988. (None captured in 1987.)

Date	Location	Number of larvae
05/05/88	Joyce Creek, NC Hwy 343	27
05/05/88	New Begun Creek, NC Hwy 34	2

Table 5. Observation of running-ripe female river herring in the Little River and its tributaries, 1987. (None captured in 1988.)

Date	Location	Number of fish	Species
04/10/87	Little River, US Hwy 17	1	Blueback
04/14/87	Halls Creek, SSR* 1140	1	Blueback

*SSR: State Secondary Road

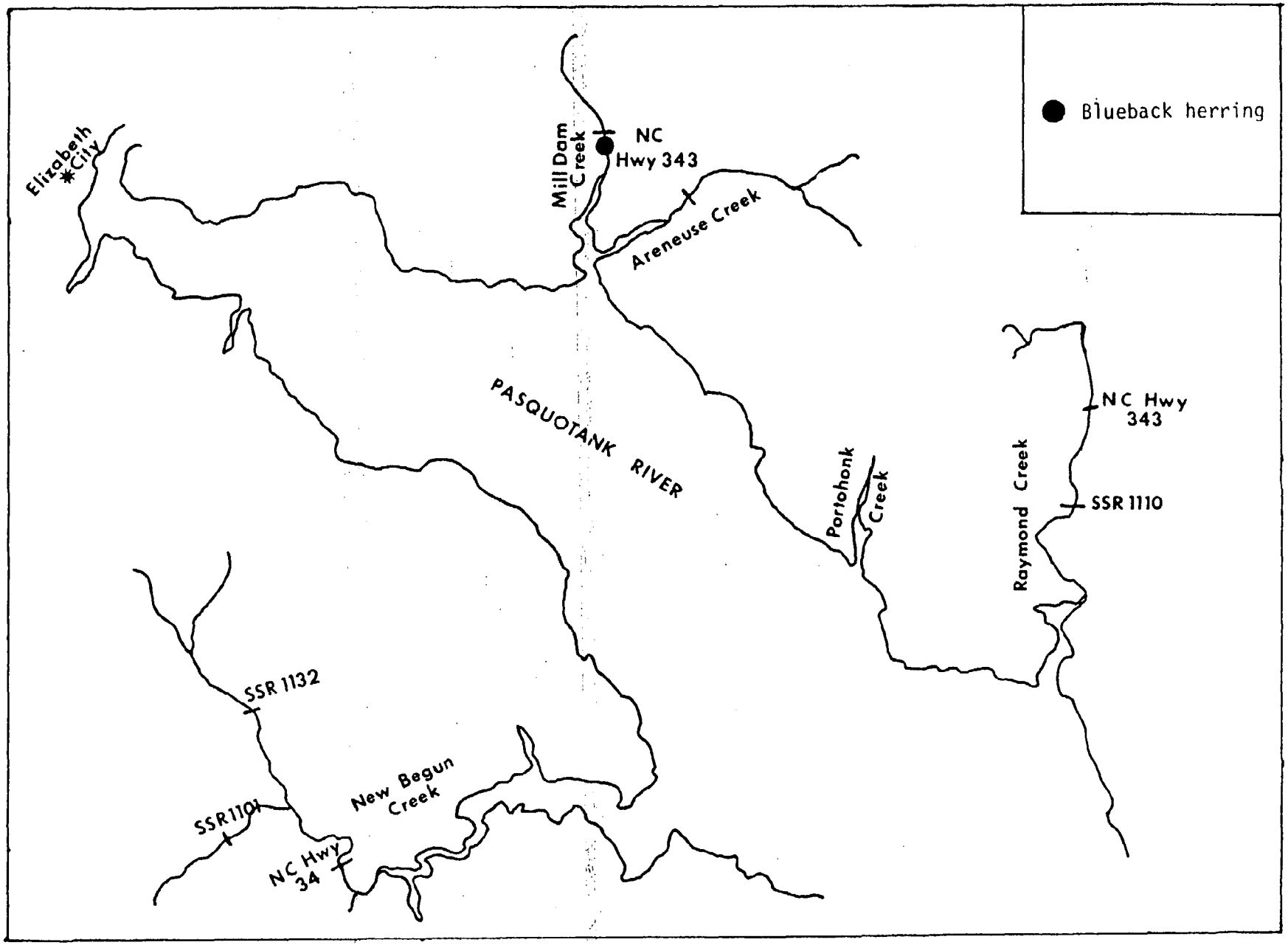


Figure 5. Spawning areas of blueback herring in lower Pasquotank River area, NC, as shown by observation of running-ripe females, 1987. (None captured in 1988.)

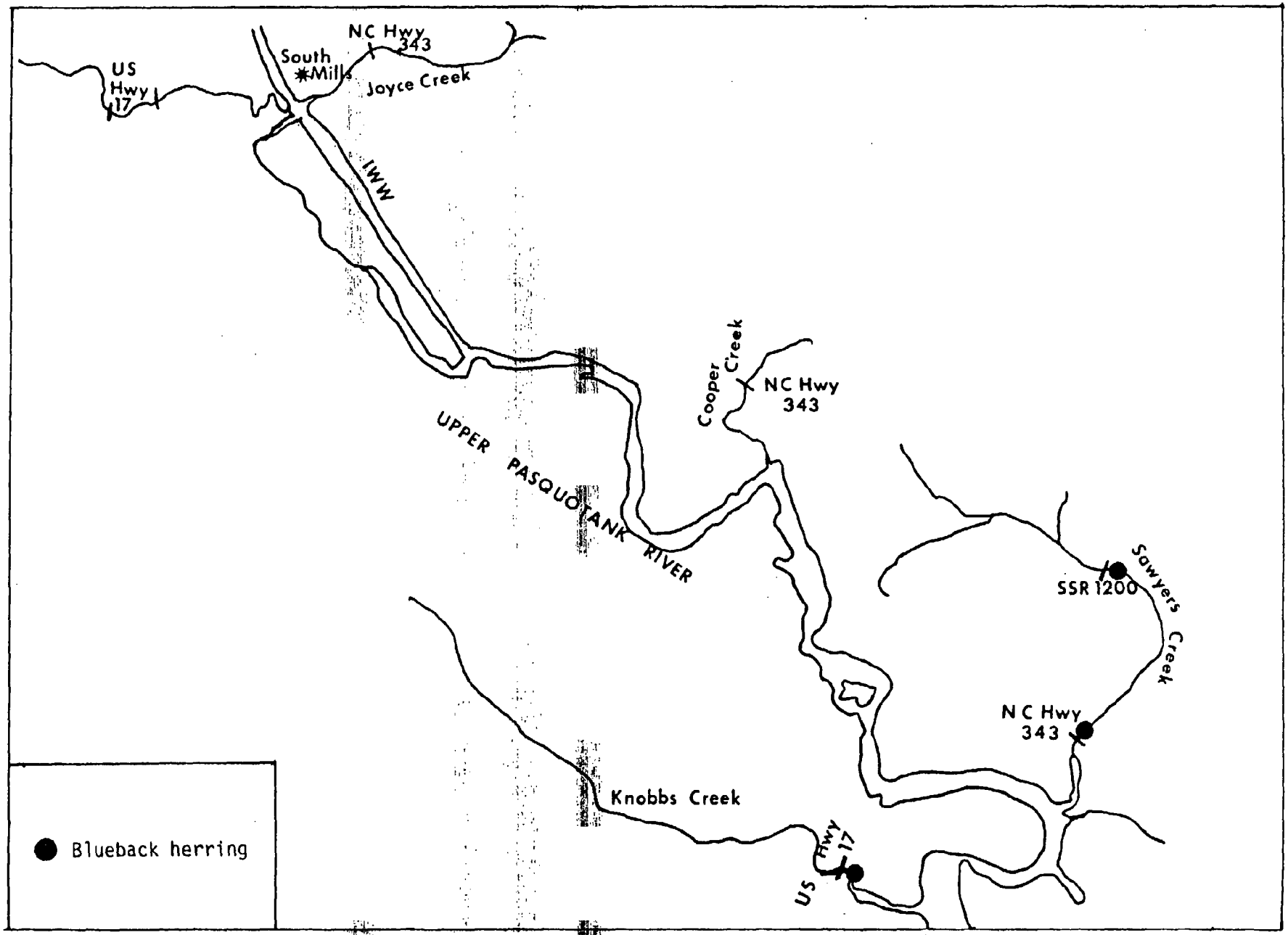


Figure 6. Spawning areas of blueback herring in upper Pasquotank River area, NC, as shown by observation of running-ripe females or spawning activity, 1987. (None captured in 1988.) (IWW=Atlantic Intracoastal waterway).

the approximate spawning location, as indicated in 1987 by capture of larvae, are shown in Figures 7 and 8.

Little River and Tributaries

Locations and times of blueback herring spawning in the Little River area, as indicated by capture of running-ripe females, are given in Table 5. No running-ripe females were captured during the 1988 sampling season. Running-ripe female blueback herring captured in the Little River are shown in Figure 9. No river herring eggs or larvae were captured either year.

Perquimans River and Tributaries

River herring spawning area in the Perquimans River area, as indicated by capture of running-ripe females in 1987 and 1988, are shown in Table 6. One river herring larvae was captured during 1987 in Brights Mill Creek (Table 7); 1988 yielded no larvae. Figures 10 and 11 show the approximate spawning areas of alewife and blueback herring in the Perquimans River area as shown by observation of running-ripe females. The approximate spawning area locations for river herring as indicated by the capture of larvae is presented in Figure 12.

Yeopims River and Tributaries

All observations of running-ripe female blueback herring occurred in 1987 (Table 8). The general location of capture of river herring larvae from the Yeopim River area is shown in Table 9. The approximate spawning locations of blueback herring is presented in Figure 13. River herring spawning area, as indicated by capture of larvae, is shown in Figure 14.

Some of the areas determined by Street et al. (1975) and Johnson et al. (1977) to functions as river herring spawning areas did not do so during this study. The Albemarle area experienced a very wet and cold spring in 1987 (Figure 15). The 1988 season was also variable--the weather was cold; thus, water temperatures fluctuated over a wide range (Figure 16). Due to weather conditions (cold temperature and high water), these may have been an impact on traditional spawning areas. In 1987, as a result of the heavy rains and run-off, dissolved oxygen levels were extremely low in the tributaries to the rivers. The

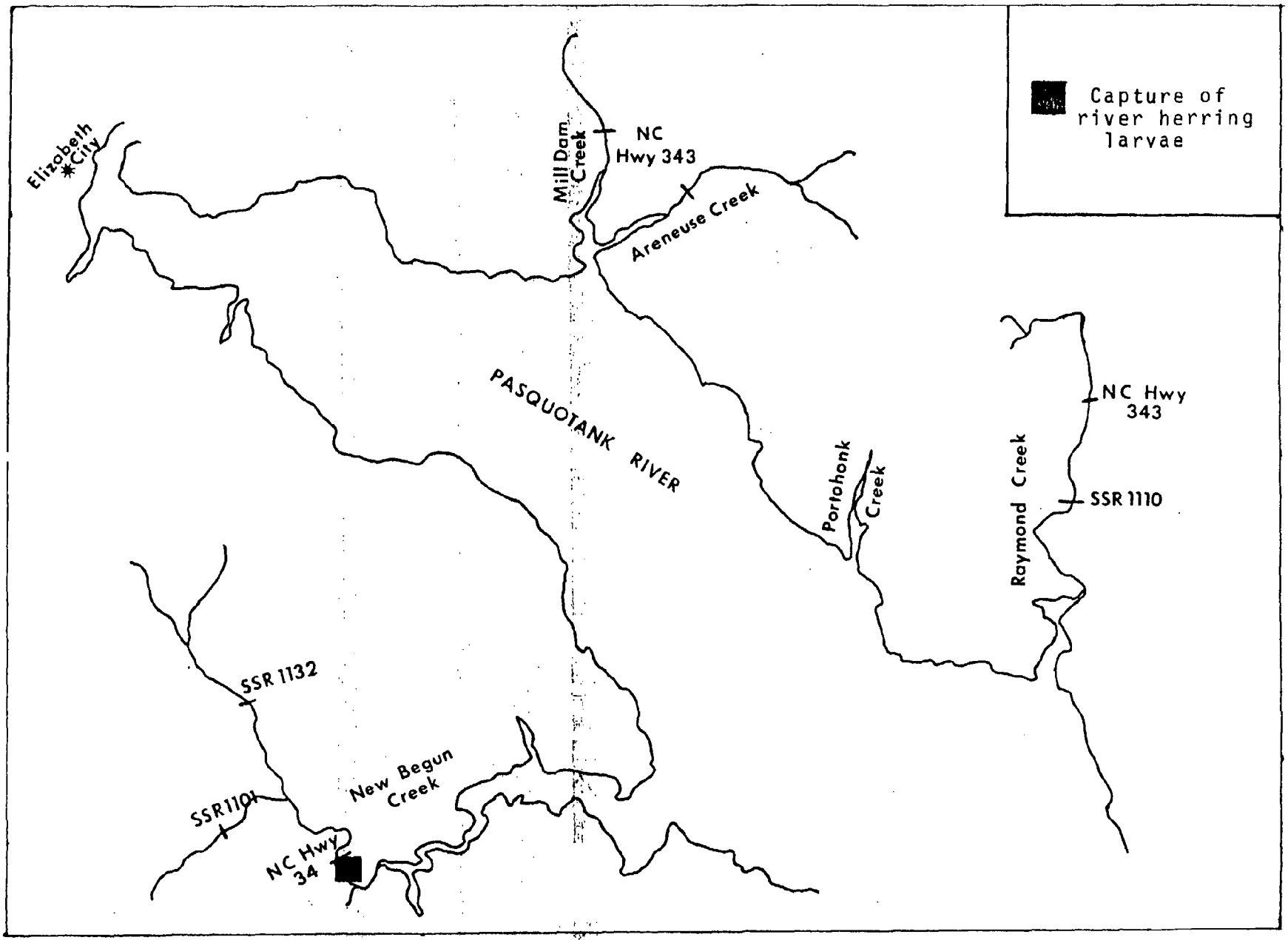


Figure 7. Spawning area of river herring in lower Pasquotank River area, NC, as shown by capture of river herring larvae, 1988. (None captured in 1987.)

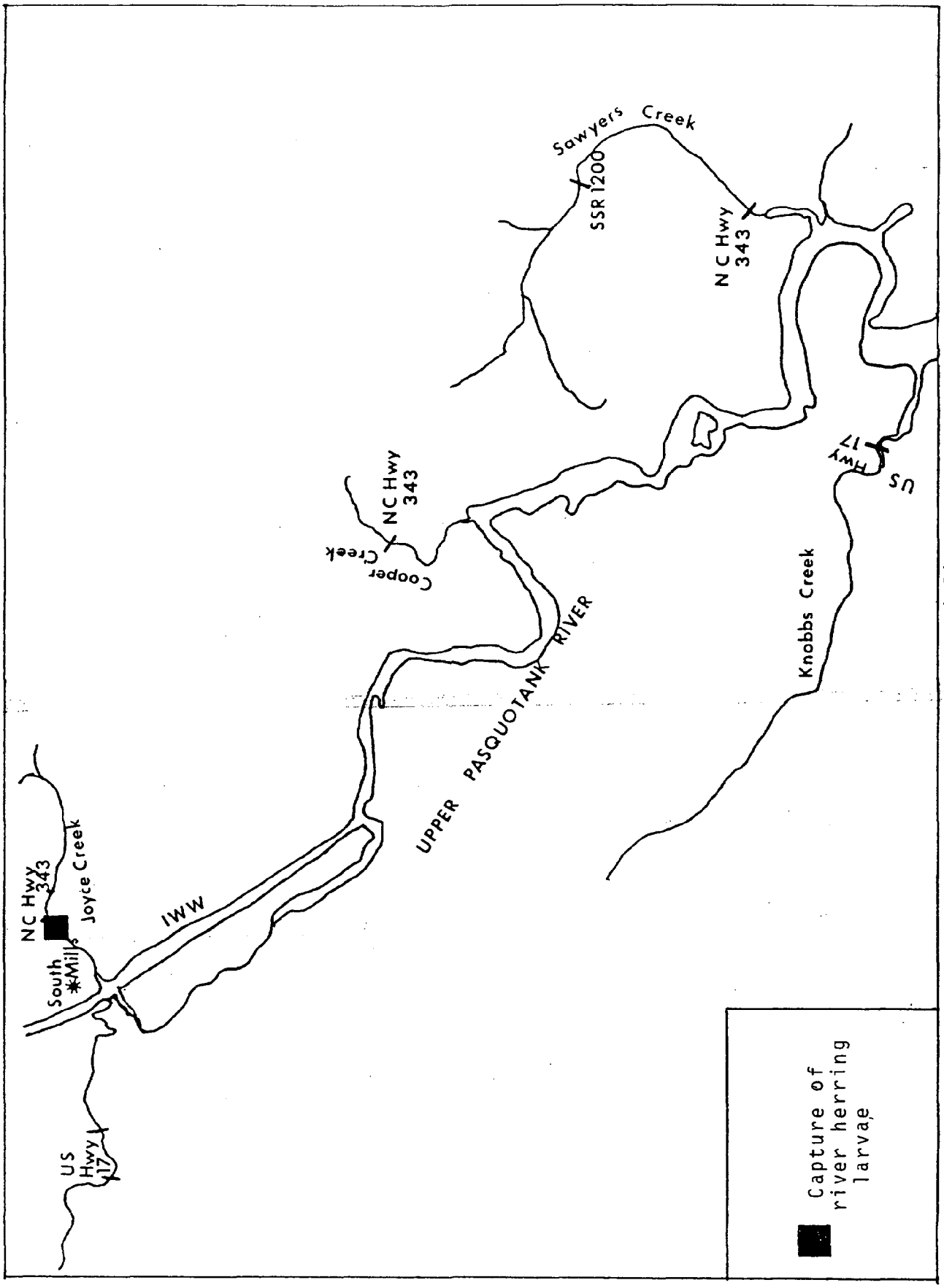


Figure 8. Spawning area of river herring in upper Pasquotank River area, NC, as shown by capture of river herring larvae, 1988. (None captured in 1987.)

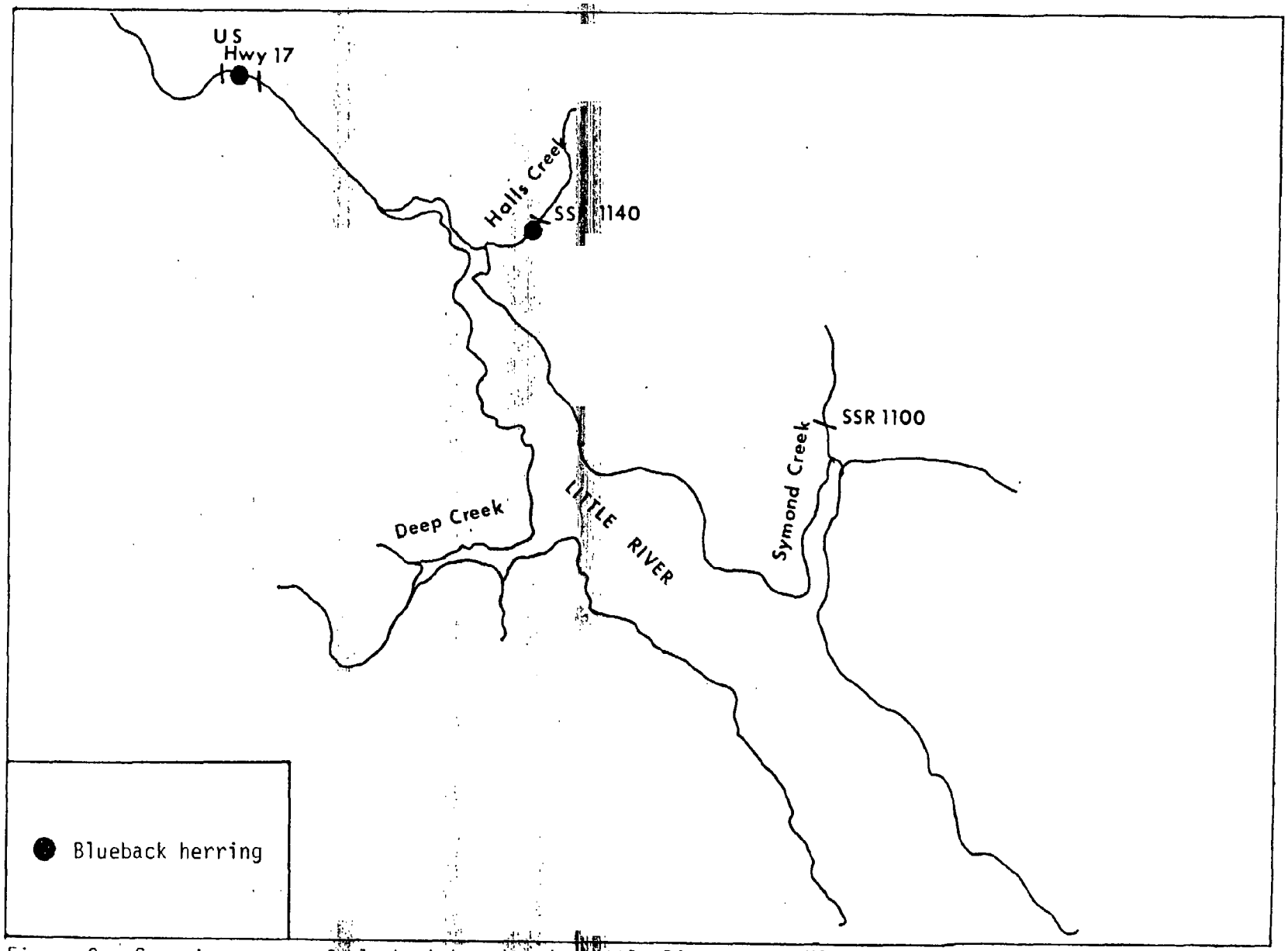


Figure 9. Spawning areas of blueback herring in Little River area, NC, as shown by observation of running-ripe females, 1987. (None captured in 1988.)

Table 6. Observation of running-ripe female river herring in the Perquimans River and its tributaries, 1987 and 1988.

Date	Location	Number of fish	Species
04/02/87	Goodwin Creek, SSR* 1111	1	Alewife
04/09/87	Goodwin Creek, SSR 1111	1	Blueback
04/24/87	Sutton's Creek, SSR 1300	Spawning observed	Blueback
04/04/88	Walter's Creek, Church St. Ext.	1	Blueback
04/06/88	Bright's Mill Creek, US Hwy 17 Business	1	Blueback
04/06/88	Goodwin Creek, SSR 1111	2	Blueback
04/07/88	Bright's Mill Creek, SSR 1220	1	Blueback
04/07/88	Walter's Creek, SSR 1107	1	Blueback
04/28/88	Bright's Mill Creek, SSR 1220	1	Blueback
04/28/88	Goodwin Creek, SSR 1111	1	Blueback

*SSR: State Secondary Road

Table 7. River herring larvae collected by egg net in Perquimans River and its tributaries, 1987. (None captured in 1988.)

Date	Location	Number of larvae
05/06/87	Bright's Mill Creek, US Hwy 17 Business	1

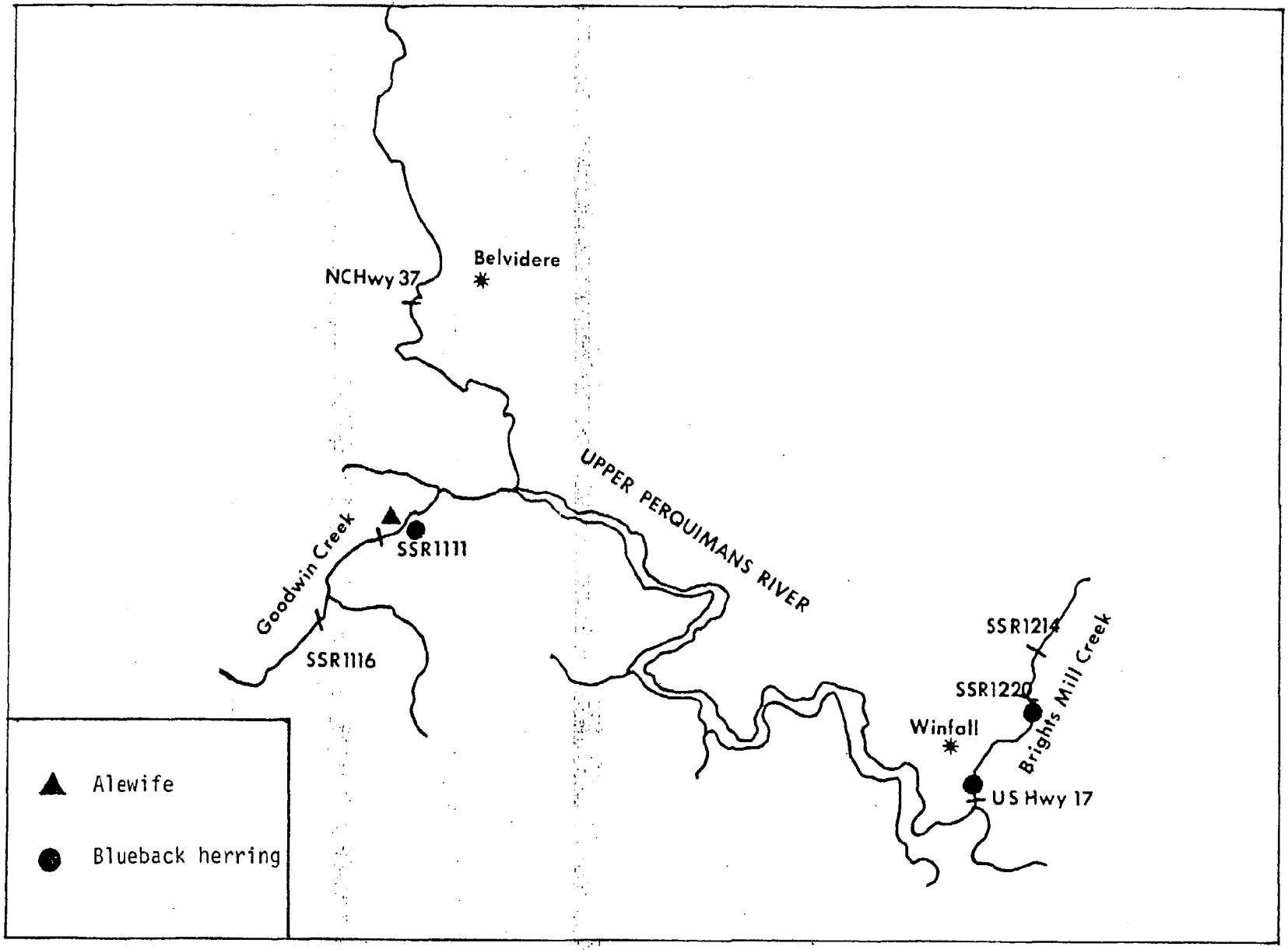


Figure 10. Spawning areas of alewife and blueback herring in upper Perquimans River area, NC, as shown by observation of running-ripe females, 1987 and 1988.

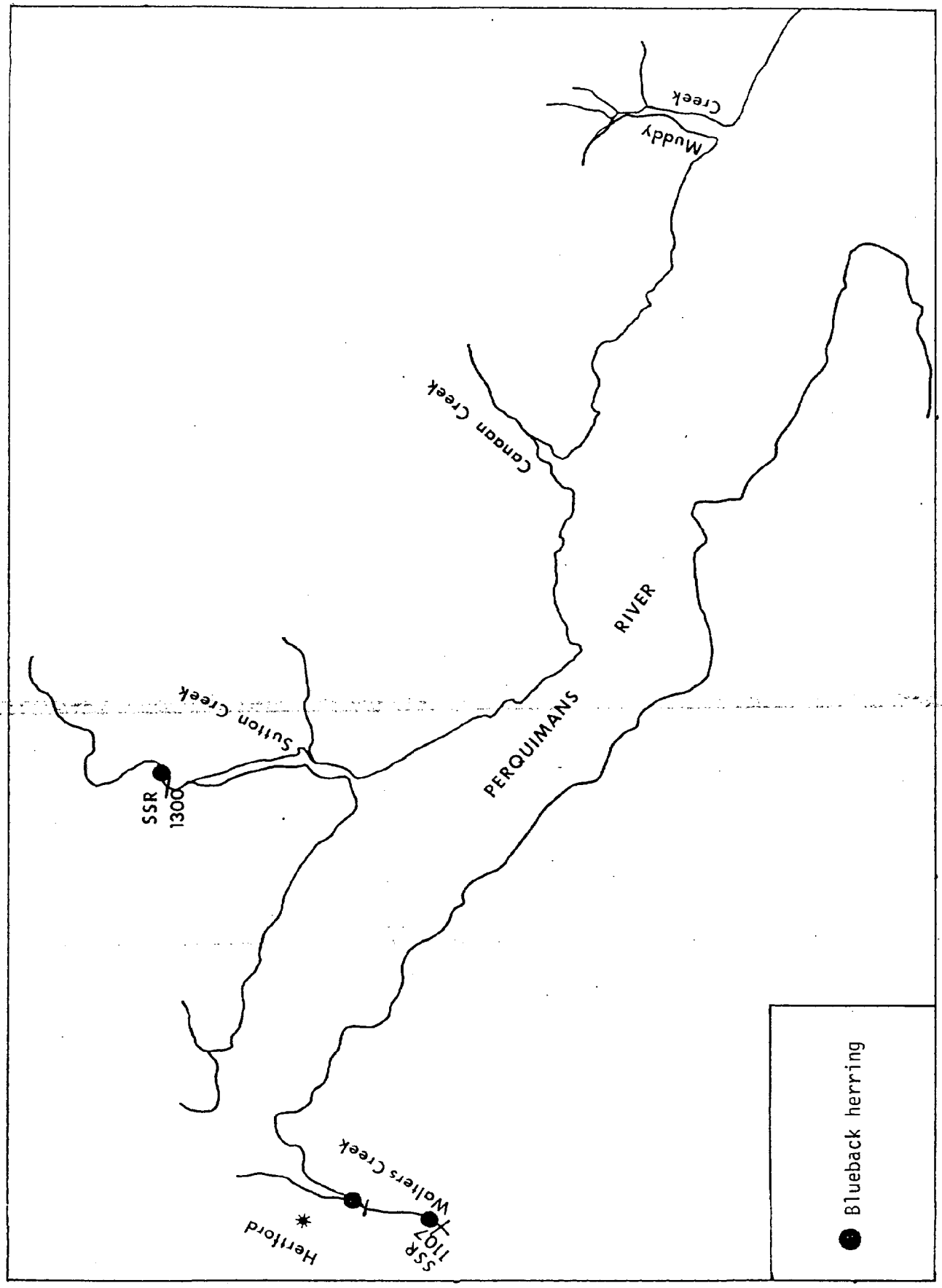


Figure 11. Spawning areas of blueback herring in lower Perquimans River area, NC, as shown by observation of running-ripe females or spawning activity, 1987 and 1988.

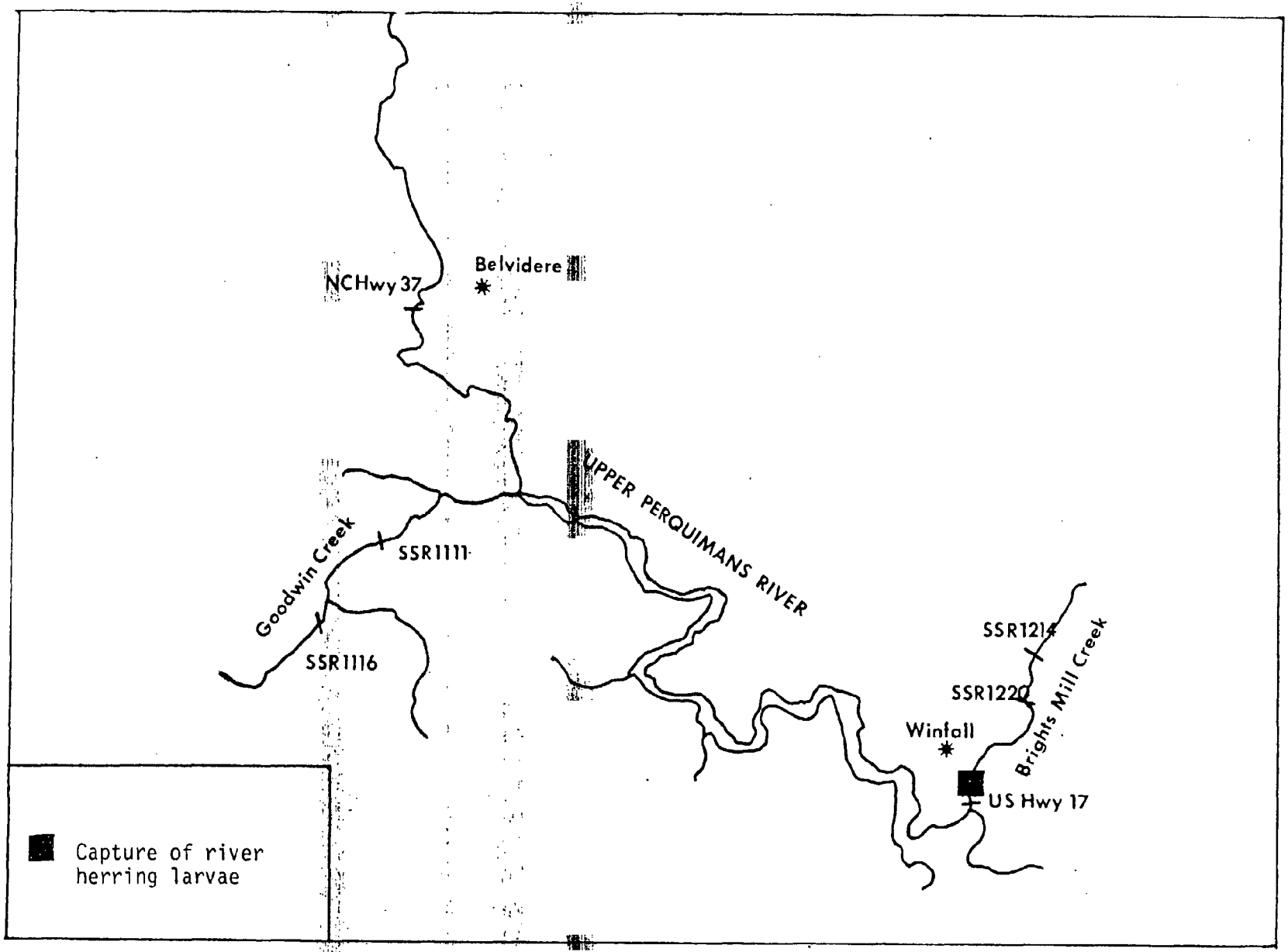


Figure 12. Spawning area of river herring in upper Perquimans River area, NC, as shown by capture of river herring larvae, 1987. (None captured in 1988.)

Table 8. Observation of running-ripe female river herring in the Yeopim River and its tributaries, 1987. (None captured in 1988.)

Date	Location	Number of fish	Species
04/15/87	Bethel Creek, SSR* 1101	1	Blueback
04/24/87	Yeopim Creek, SSR 1347	Spawning observed	Blueback
04/24/87	Burnt Mill Creek, SSR 1343	Spawning observed	Blueback
04/24/87	Middleton Creek, SSR 110	Spawning observed	Blueback

*SSR: State Secondary Road

Table 9. River herring larvae collected by egg net in Yeopim River and its tributaries, 1988. (None captured in 1987.)

Date	Location	Number of larvae
05/09/88	Bethel Creek, SSR*1101	2

SSR: State Secondary Road

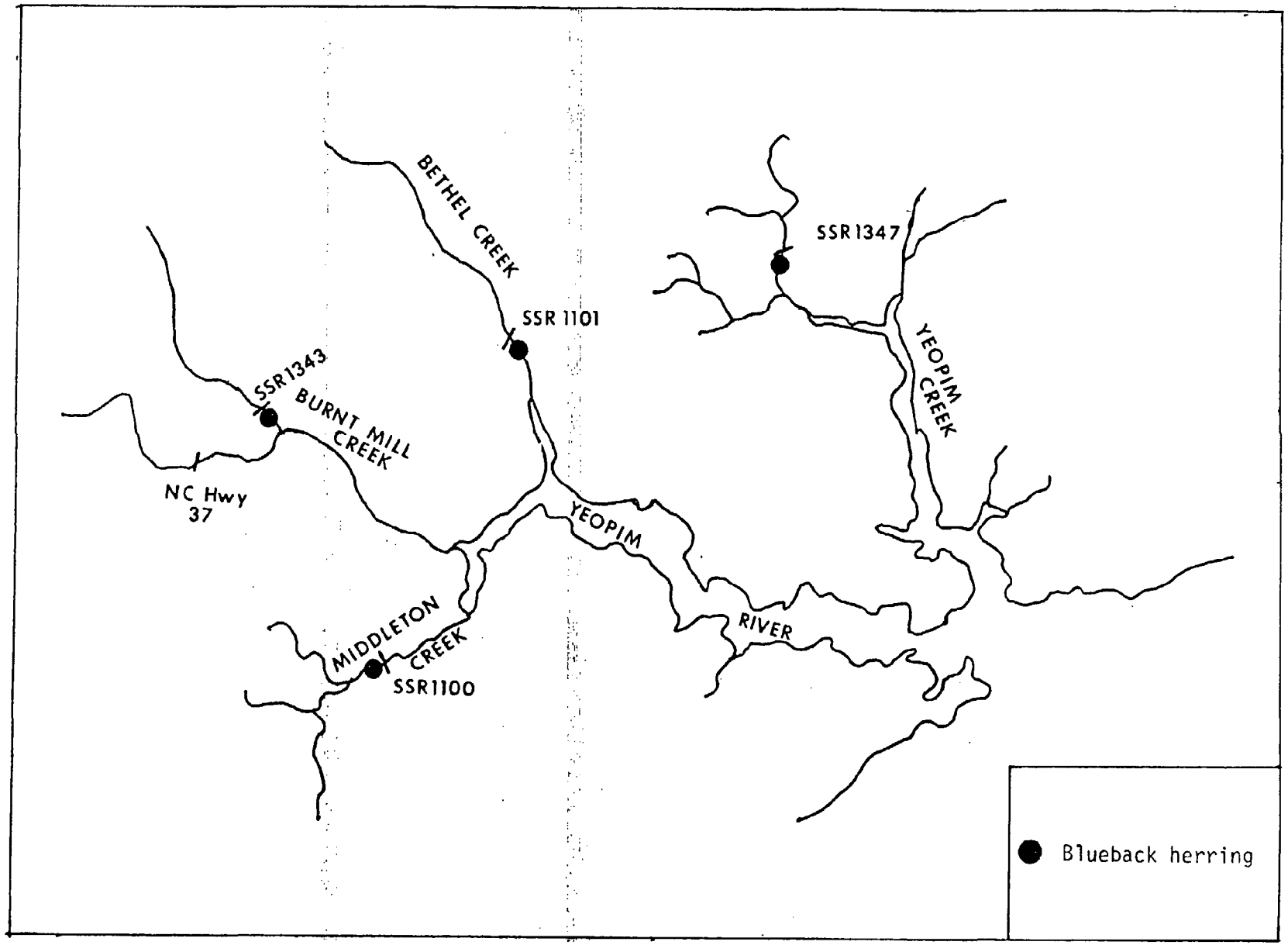


Figure 13. Spawning area of blueback herring in Yeopim River area, NC, as shown by observations of running-ripe females or spawning activity, 1987. (None captured in 1988.)

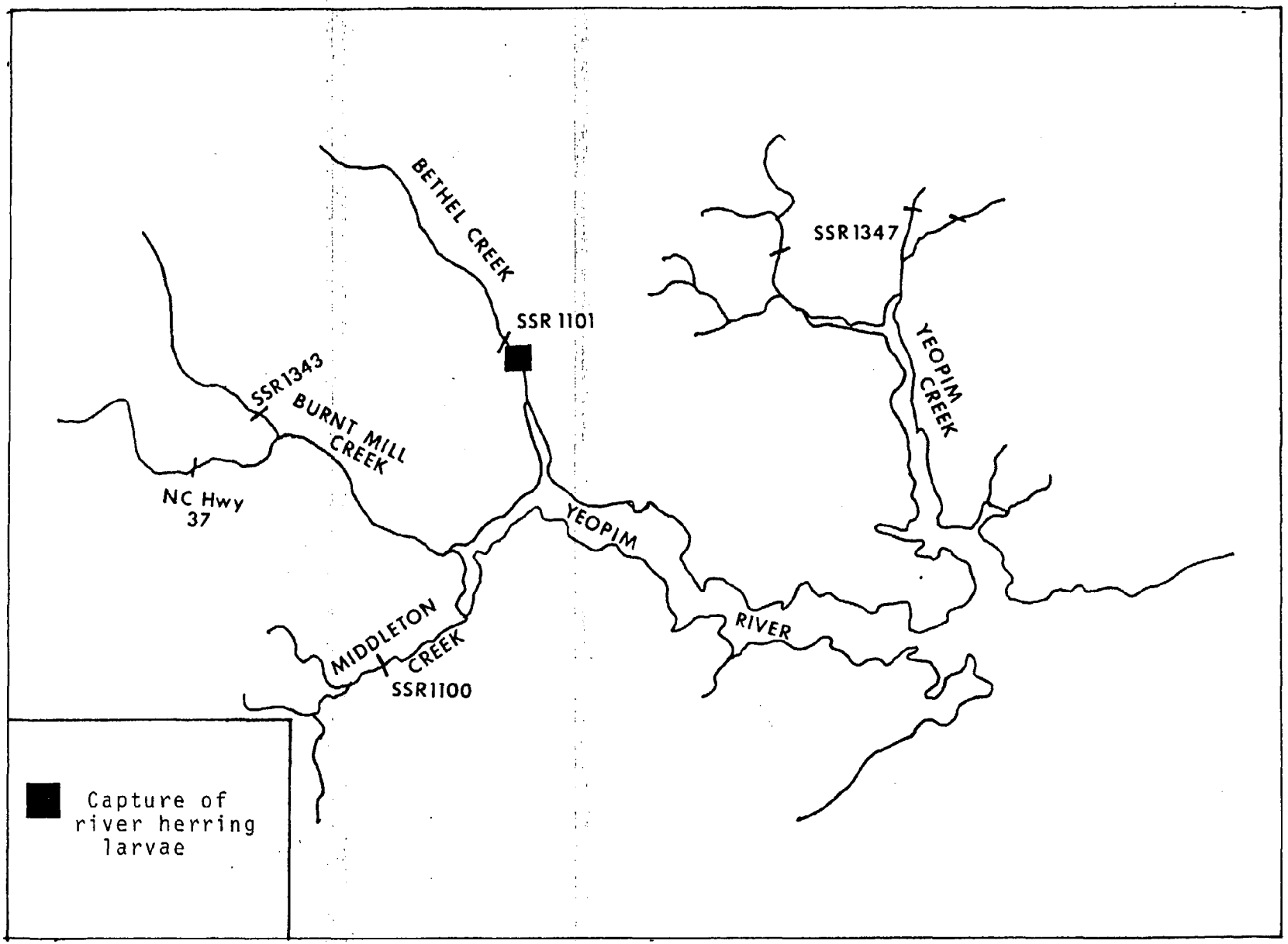


Figure 14. Spawning area of river herring in Yeopim River area, NC, as shown by capture of river herring larvae, 1988. (None captured in 1987.)

dissolved oxygen levels during 1988, were higher than those of 1987, but during week 16 through 19, it was less than optimum (Figure 15 and 16). The low dissolved oxygen levels could have caused eggs and/or larvae to have died. The mean water temperature and dissolved oxygen levels by week, associated with capture of river herring larvae for 1987 and 1988, are shown in Figure 15 and 16, respectively.

Those areas identified as spawning sites are extremely important for the maintenance and preservation of anadromous fish populations and should be protected from alteration and pollution.

Nursery Area Sampling

Albemarle Sound Area

A total of 10,479 juvenile anadromous fishes was captured in 278 seine samples in the Albemarle Sound area, June 1985-October 1988. The major objectives of the sampling was to determine a relative abundance index of the 1985-1988 year classes. The number of individuals and samples taken each year are shown in Table 10.

In 1985, a total of 102 juvenile American shad was captured; the largest number during any previous year. Ninety-three of these individuals were captured at one station during July. Since so few American shad (21) were captured the other years, and no hickory shad, these species will not be considered further in the report. Winslow et al. (1983) described several possible reasons why these juveniles are not captured during the sampling period.

The seine again proved a very effective gear for the capture of juvenile blueback herring during 1985-1988. These data agree with that reported by Street et al. (1975), Johnson et al. (1981) and Winslow et al. (1983 and 1985). The mean catch-per-unit-of-effort (CPUE) by month for blueback herring and alewife, for seine, is shown in Figure 17.

Nursery Area

Nursery areas of blueback herring and alewife generally coincided with each other. Again, nursery areas identified during 1972-1976 continued to yield large numbers of juvenile anadromous fishes (Street et al. 1975, Johnson et al. 1977). Nursery areas in the Albemarle Sound area are shown in Figure 18. These nursery areas are vitally important

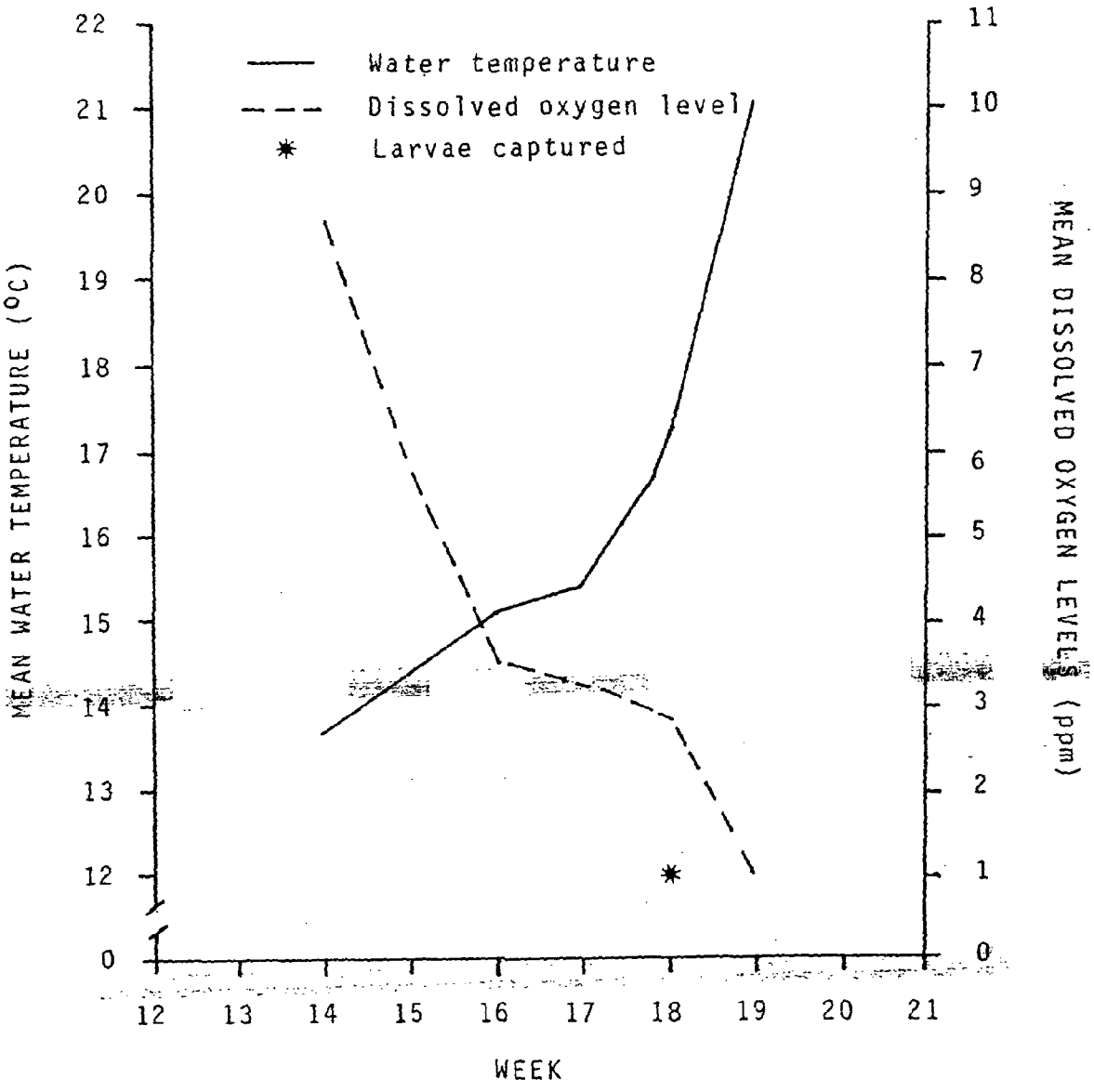


Figure 15. Mean weekly water temperatures and dissolved oxygen levels associated with capture of river herring larvae from spawning area survey, 1987.

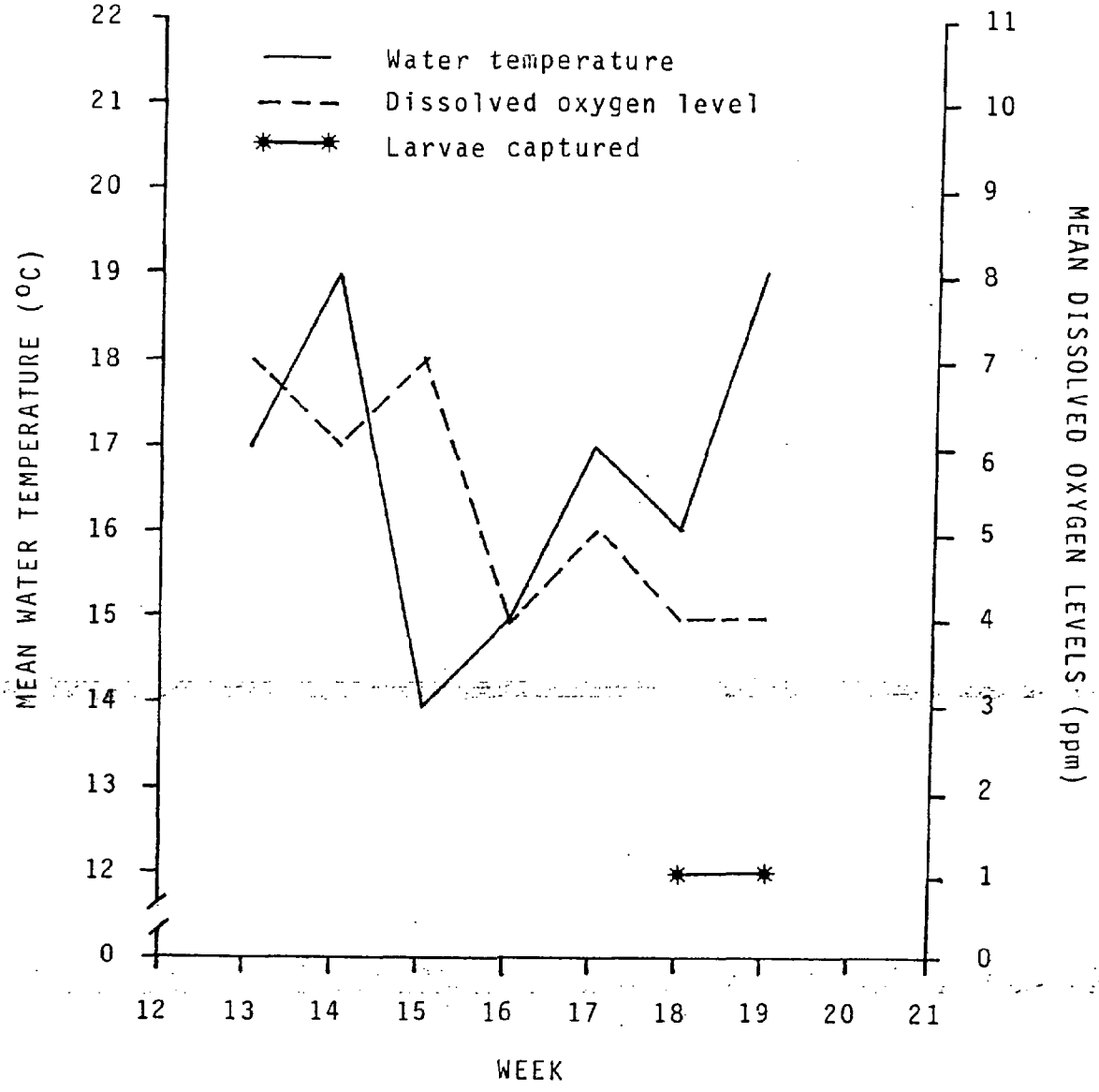


Figure 16. Mean weekly water temperatures and dissolved oxygen levels associated with capture of river herring larvae from spawning area survey, 1988.

Table 10. Number of samples, catch, and catch/effort of juvenile anadromous fishes by seine in the Albemarle Sound area, NC, 1985-1988.

	1985		1986		1987		1988	
	71 samples		69 samples		69 samples		69 samples	
Species	No.	C/E	No.	C/E	No.	C/E	No.	C/E
Blueback herring	7,131	100.4	781	11.3	1,378	19.9	602	8.7
Alewife	201	2.8	127	1.8	0	0	10	0.1
American shad	102	1.4	6	0.1	8	0.1	7	0.1
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	50	0.7	12	0.2	7	0.1	57	0.8
Total	7,484		926		1,393		676	

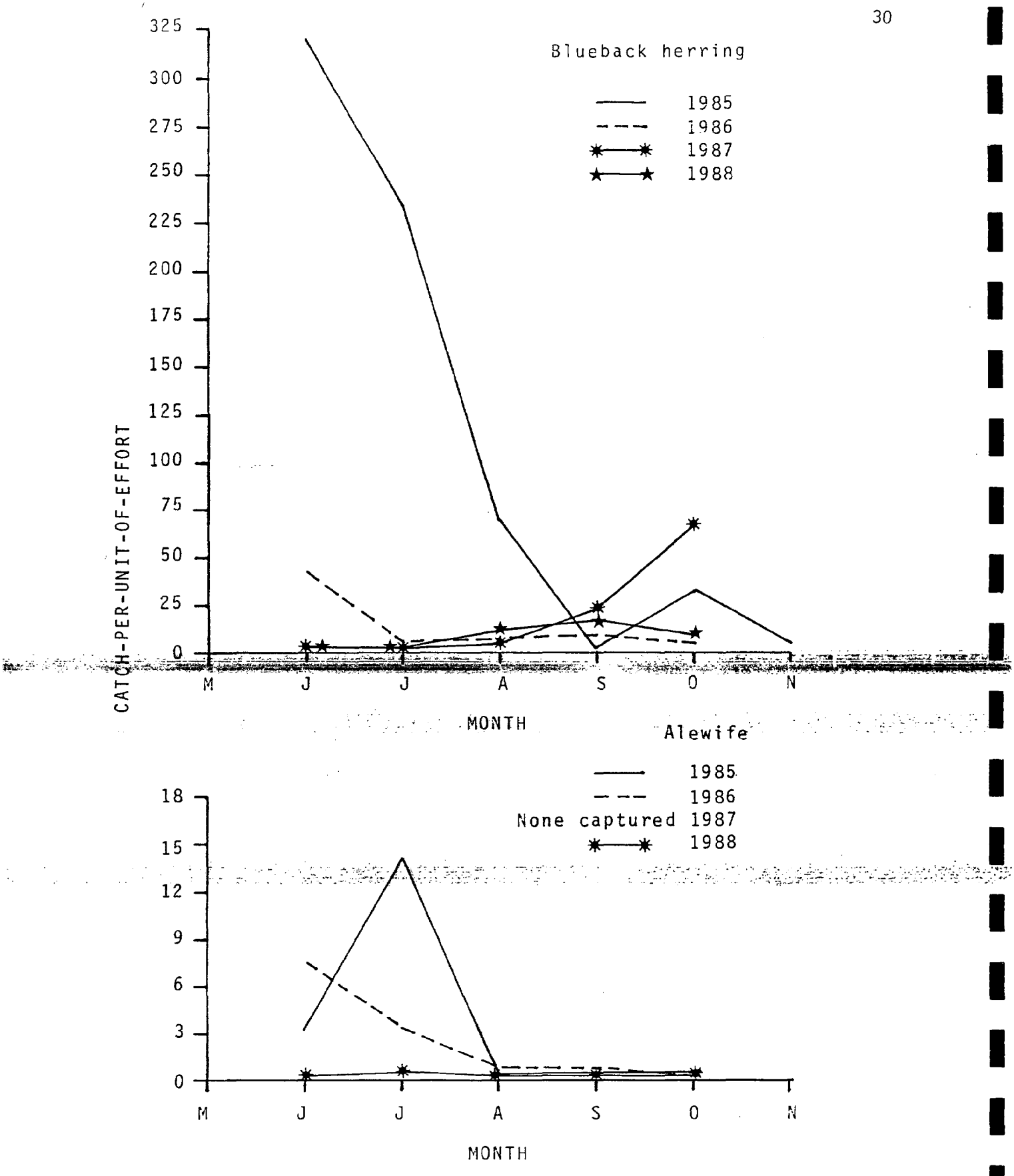


Figure 17. Monthly mean catch-per-unit-of-effort for blueback herring and alewife by seine in the Albemarle Sound area, NC, 1985-1988.

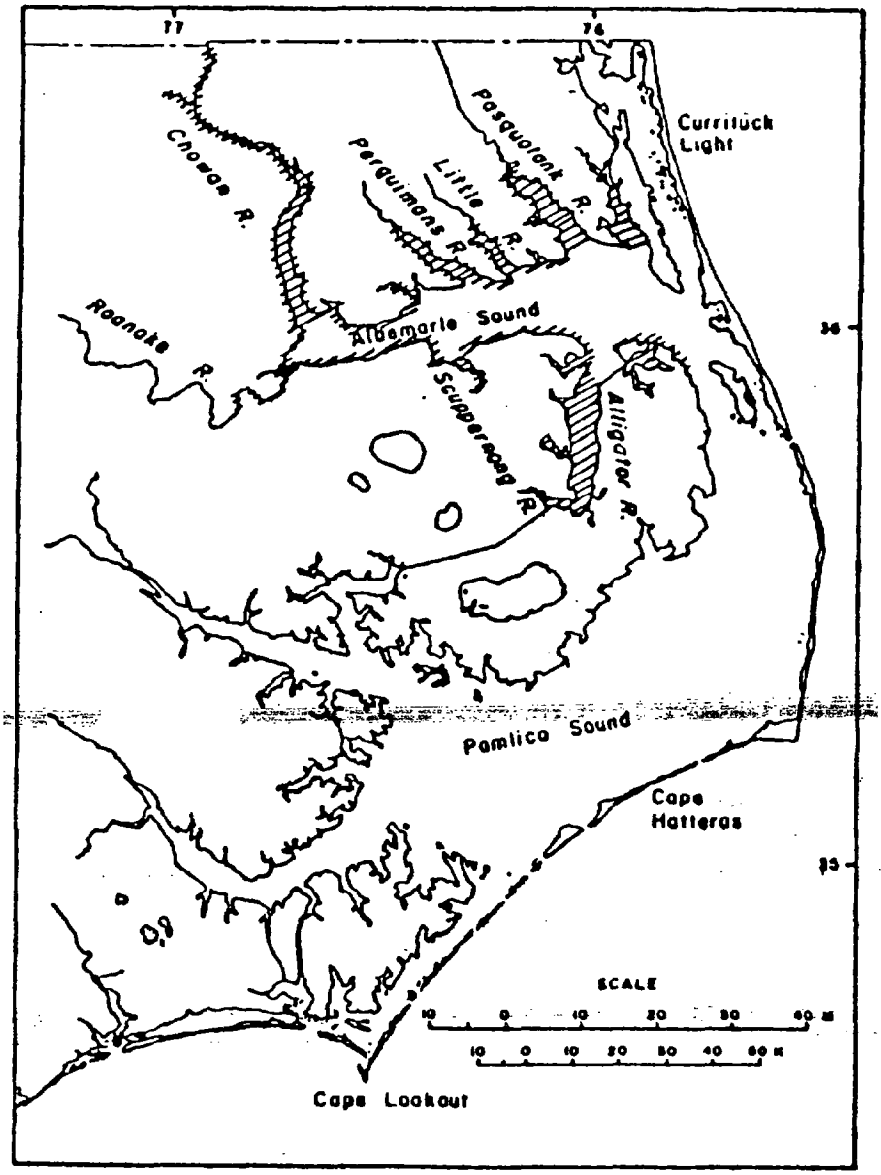


Figure 18. Nursery areas of blueback herring and alewife in Albemarle Sound and tributaries, North Carolina.

for the maintenance of river herring populations and should remain protected and unaltered as stated by Street et al. (1975).

Growth

The 1985-1988 year classes of blueback herring and alewife were followed June-October of each year for growth. The mean fork length of juvenile blueback herring and alewife for each month of sampling, by year, are presented in Figure 19. These data generally agree with that reported by Street et al. (1975), Johnson et al. (1977, 1981) and Winslow et al. (1983,1985). Figure 20 shows the mean fork lengths of juvenile for the month of October during 1972-1988. As reported by Winslow et al. (1983), mean lengths compared with the relative abundance index of juveniles for those years (Figure 21) suggest that growth may be density dependent.

Movement

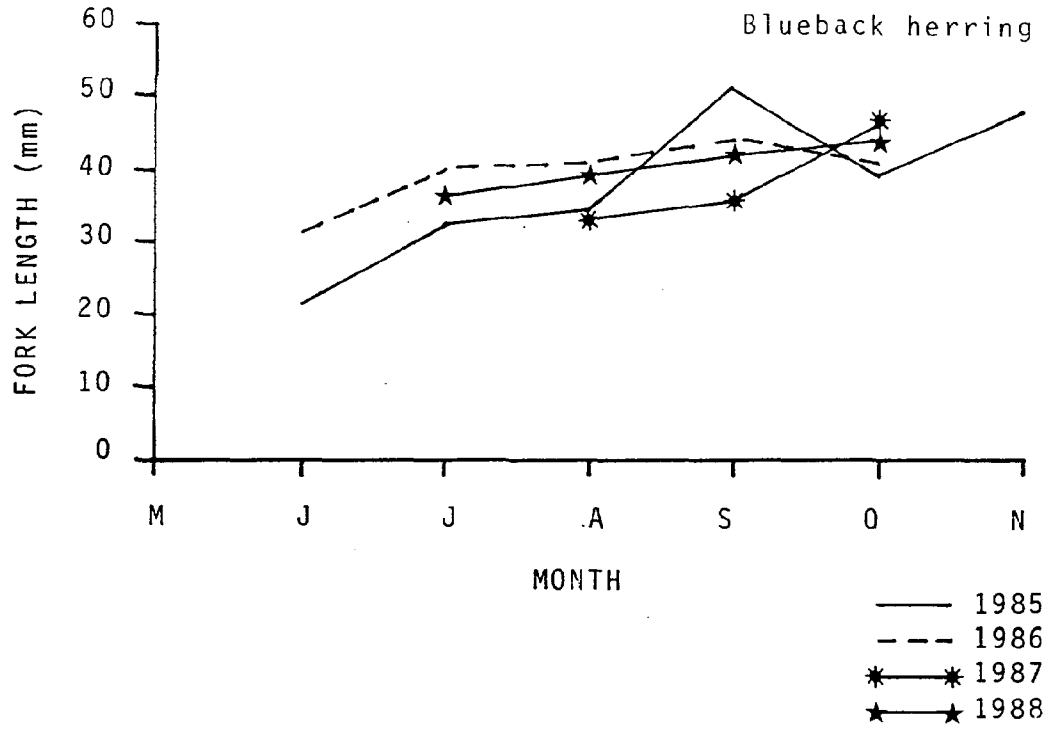
The movements of the 1985, 1986, 1987, and 1988 year classes of blueback herring and alewife were virtually the same as those reported by Street et al. (1973), Johnson et al. (1977, 1981), and Winslow et al. (1983, 1985).

Relative Abundance

Sampling with seines, which Street et al. (1975) proved effective, was again used in order to compare results from difficult samples taken with the same gear. Changes in juvenile abundance from year to year should be apparent from such data.

Relative abundance data have been collected on seventeen year classes (1972-1988) of blueback herring and alewife. For comparative purposes, data are presented on a growth year basis rather than by calendar year; that is,June through December, rather than January through December.

Street et al. (1975) , Johnson et al. (1977, 1981) and Winslow et al. (1983, 1985) reported that blueback herring were far more numerous than alewife, and this trend continued in 1985-1988. The catch-per-unit-of-effort data from the monthly seine stations during 1972-1988 are presented in Figure 21. The 1985 year class strength for blueback herring was comparable to that of 1975 and the highest of the four



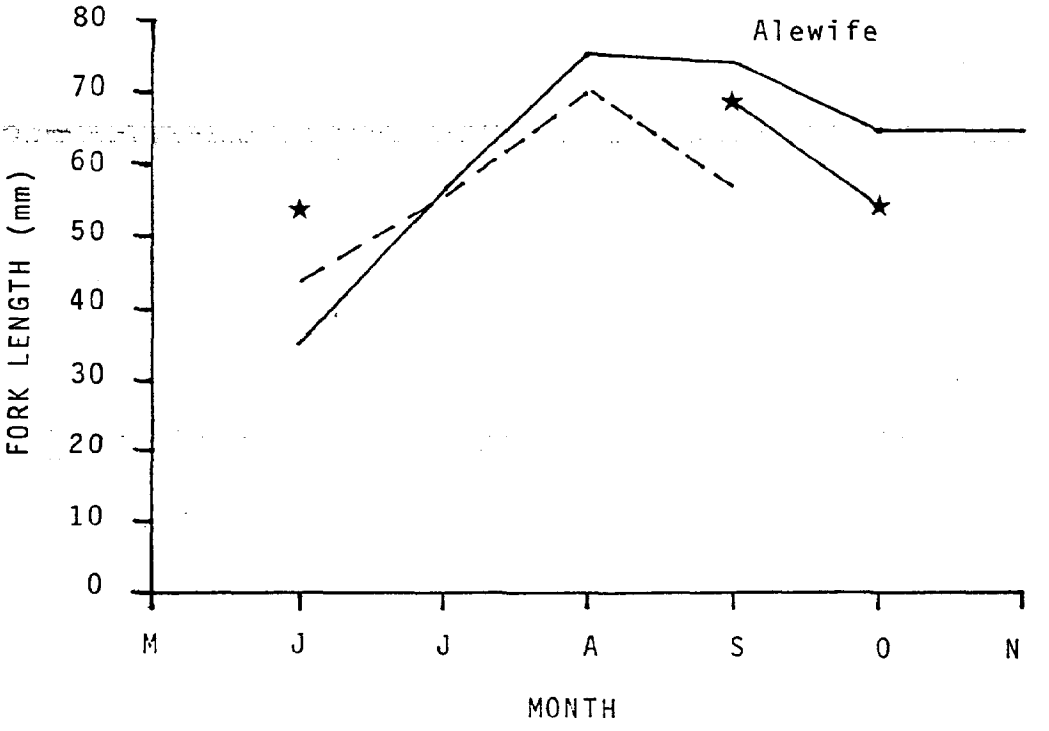


Figure 19. Mean fork length of blueback herring and alewife by from Albemarle Sound area, NC, 1985-1988.

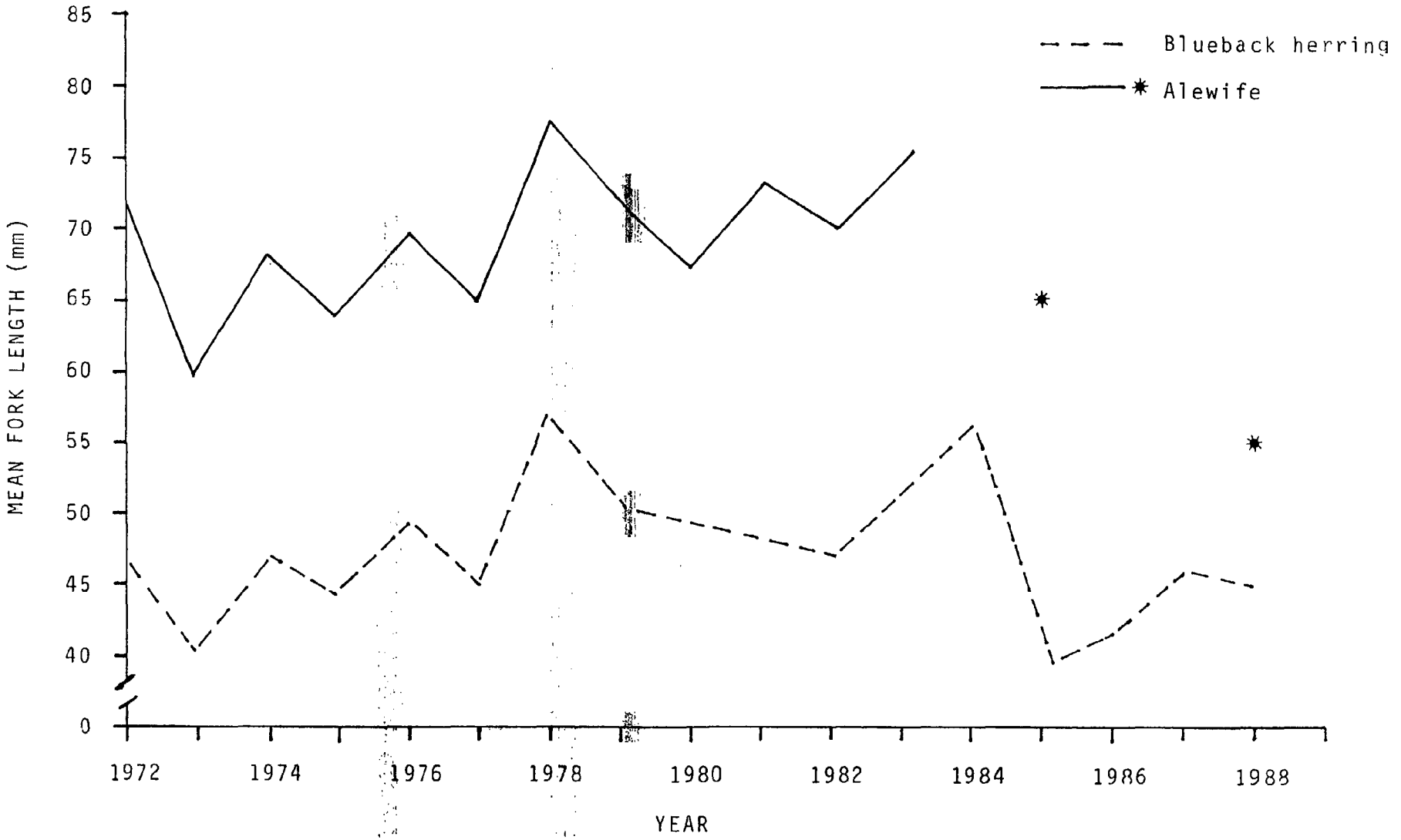


Figure 20. Mean fork length (mm) of juvenile blueback herring and alewife sampled during October 1972-1988 from the Albemarle Sound area, NC. (No alewife captured during October 1984 and 1987.)

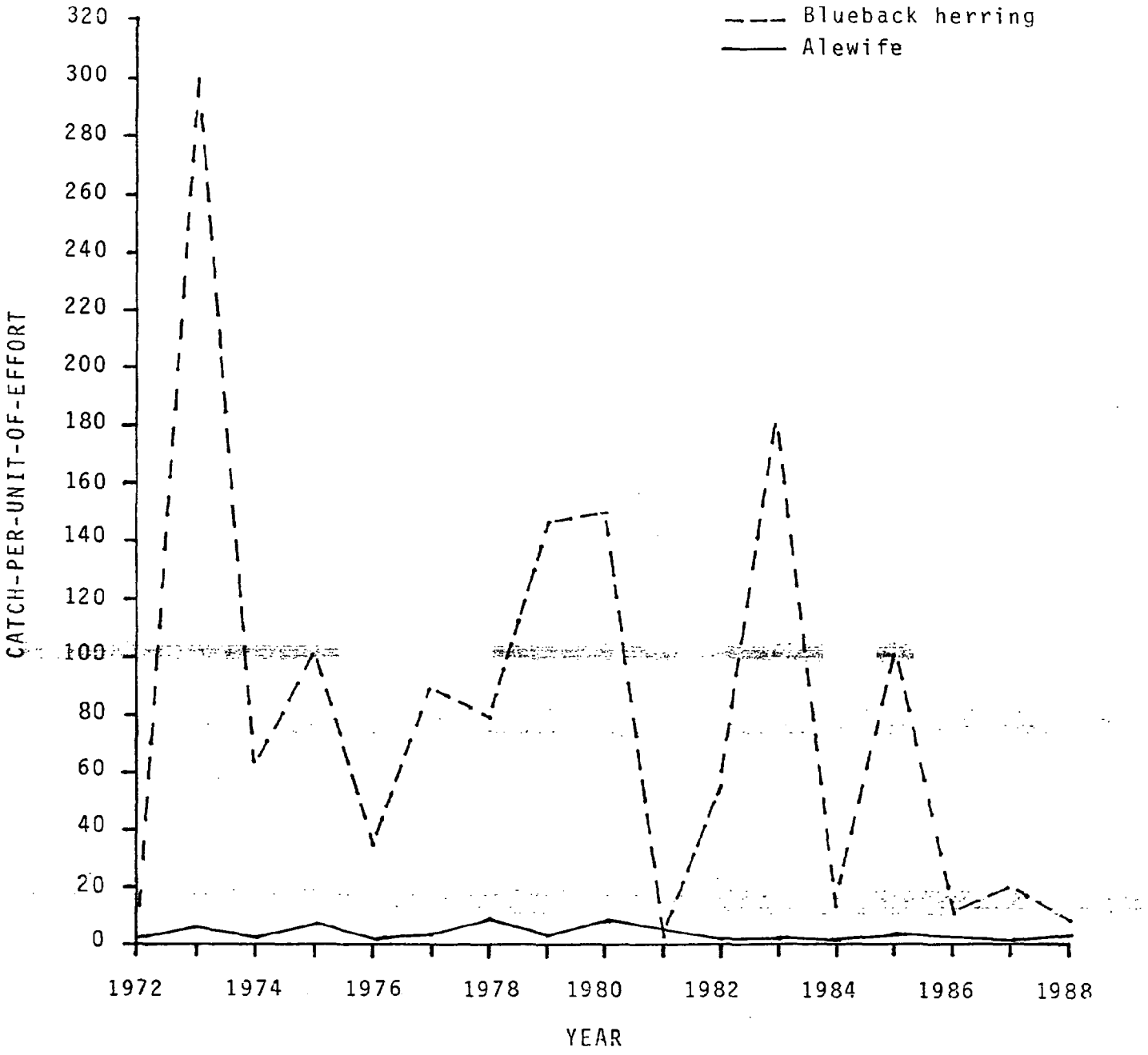


Figure 21. Catch-per-unit-of-effort by seine for blueback herring and alewife 1972-1988 year classes, from Albemarle Sound area, NC.

years included in this report. The 1988 year class strength was higher than that of 1981,but the second lowest on record.

The CPUE for alewife in 1985 was the largest of the 1985-1988 year classes and comparable to that found in 1979. No juvenile alewife were captured in 1987--this is unprecedented. In 1988, the year class strength was comparable to that reported for 1972.

Currituck Sound Area

During June 1985-October 1988, a total of 85 juvenile anadromous fishes was captured in 269 samples. Blueback herring was the most abundant species (Table 11).

The seine proved to be the most effective capture gear for blueback herring (37) and alewife (10). This agrees with Winslow et al. (1983) for 1982, that the seine was the most effective gear. Throughout this project, so few juvenile alosids were captured, monthly and well as total, any comparisons would be difficult. In July 1985, 67 individuals of the four year total (85) were captured.

Nursery Areas

Those areas found to function as nursery areas for juvenile anadromous species in the Currituck Sound area during this project closely agree with those reported by Winslow et al. (1983, 1985) (Figure 22). Additional nursery areas in Currituck Sound area may be delineated with further sampling. Again, it must be stressed that those waters designated as nursery areas are critical for the maintenance of anadromous fish and should be protected.

Growth

Due to so few blueback herring and alewife being captured and the irregular capture rates mean monthly fork lengths of the 1985-1988 year classes could not be followed.

Movement

So few individuals were captured during the project that movements could not be defined.

Table 11. Number of samples, catch, and catch/effort of juvenile anadromous by trawl and seine in the Currituck Sound area, NC, 1985-1988.

Trawl	1985		1986		1987		1988	
	40 samples		40 samples		50 samples		54 samples	
Species	No.	C/E	No.	C/E	No.	C/E	No.	C/E
Blueback herring	26	0.6	1	0.02	0	-	0	-
Alewife	5	0.12	1	0.02	0	-	0	-
Hickory shad	4	0.1	0	-	0	-	0	-
Total	35		2		0		0	

Seine	1985		1986		1987		1988	
	20 samples		20 samples		25 samples		20 samples	
Species	No.	C/E	No.	C/E	No.	C/E	No.	C/E
Blueback herring	27	1.3	1	0.05	0	-	9	0.45
Alewife	10	0.5	0	-	0	-	0	-
Hickory shad	0	-	0	-	0	-	0	-
Striped bass	0	-	0	-	0	-	1	0.05
Total	37		1		0		10	

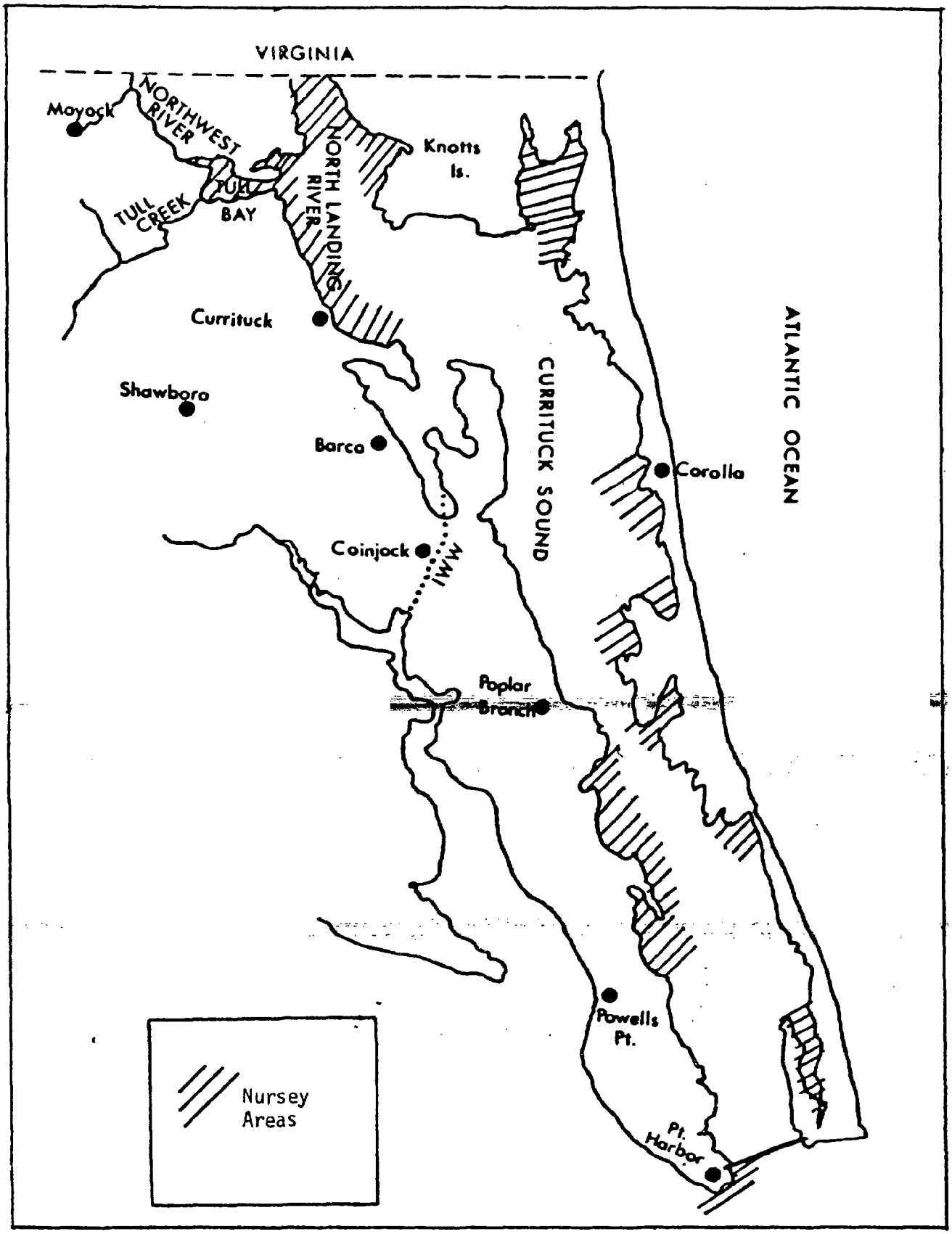


Figure 22. Nursery areas of blueback herring and alewife in Currituck Sound area, NC. (IWW=Atlantic Intracoastal Waterway.)

Relative Abundance

The 1985 relative abundance (1.4) of blueback herring from the Currituck Sound area is comparable to that in 1983 (1.5) with the seine (Figure 23). However, that found for 1986-1988 was even less. During 1985, a CPUE of 0.5 alewife was determined with the seine; no juvenile alewife were captured 1986-1988.

Commercial Harvest Survey

The Chowan River river herring pound net fishery catch-effort statistics for 1986-1988 are presented in Tables 12-14. During 1986, no significant catches of river herring occurred prior to week 9 or after week 20. In 1987 and 1988, no significant catches were made prior to week 10 or after week 10 and 21, respectively.

The catch of river herring during 1986 (2,627,036 kg) was higher than that of 1984 (2,071,070 kg) (Winslow et al. 1985). The 1987 and 1988 total catch of river herring for the Chowan River were the lowest on record, 1,062,469 kg and 1,117,181 kg, respectively. The total catch for 1987 was down 59.6% and 57.5% for 1988 compared to the 1986 catch.

The decrease in the 1986 harvest may have been a result of the fishermen being put on lay days by the dealers. The fishermen reported that there were fish available but no market existed. In 1987, the spring season was characterized by extremely high waters and cold water temperatures. As well, the 1988 season experienced cold weather, thus, low water temperature throughout the season. However, during both years fishermen reported large numbers of fish were present, but remained in the channel portion of the river, thus, not entering the pound nets.

The peak week occurred earlier in 1986 (week 13), then in 1987 (week 19), and 1988 (week 17). During the three year project period, 1987 had the largest amount of effort, while 1988 effort was greater that that for 1986.

Adult Sampling

Species Composition

Weekly river herring and shad sampling for species composition began in mid-February. Weeks were serially numbered as in the commercial harvest survey for consistency.

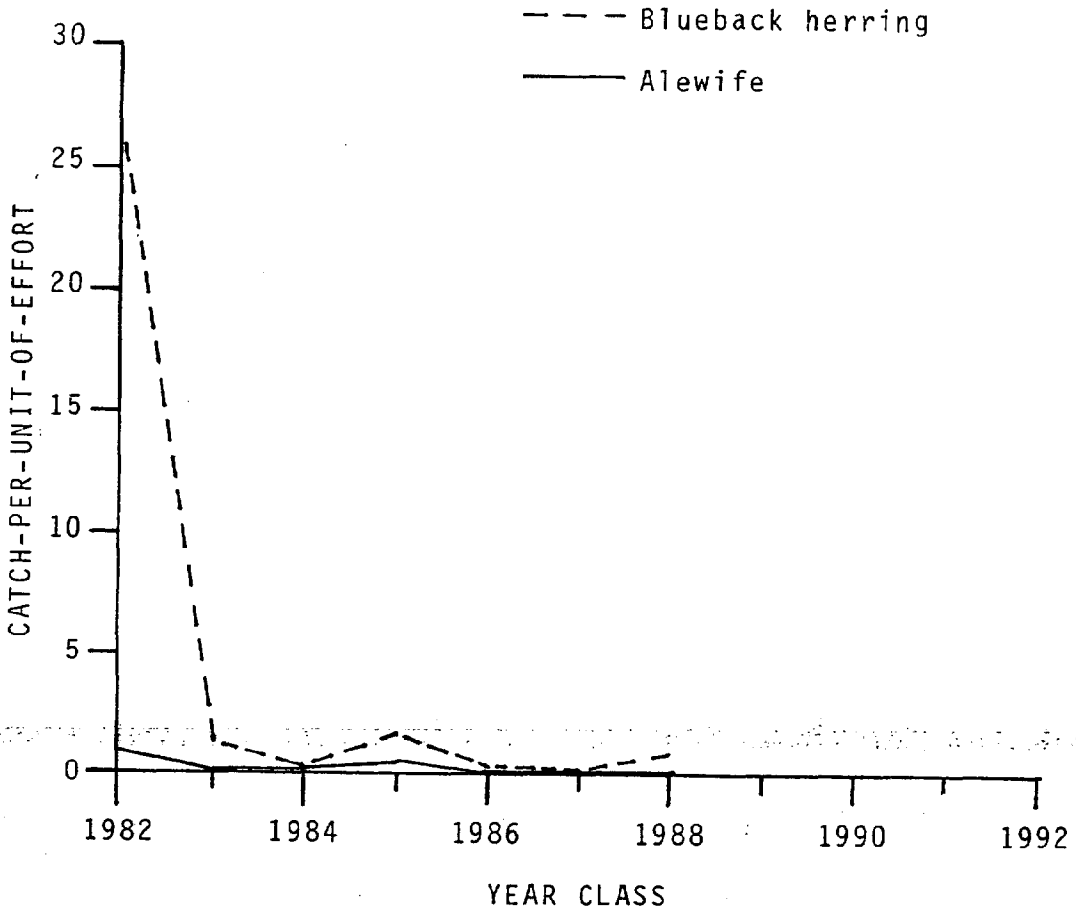


Figure 23. Catch-per-unit-of-effort by seine for blueback herring and alewife, 1982-1988 year classes, for Currituck Sound area, NC.

Table 12. Catch/effort statistics for river herring taken in Chowan River, NC, pound net fishery, 1986.

Week	Weekly landings (kg)	Weekly landings (lb)	Effort (Number of pound nets)	Catch per effort (kg)	Catch per effort (lb)
9	5,432	11,964	104	52.2	115.0
10	6,537	14,398	295	22.1	48.8
11	54,495	120,034	382	142.6	314.2
12	72,129	158,874	451	159.9	352.2
13	697,635	1,536,642	451	1546.8	3407.2
14	689,986	1,519,793	451	1529.9	3369.8
15	381,089	839,403	451	844.9	1861.2
16	202,191	445,355	451	448.3	987.5
17	408,688	900,194	400	1021.7	2250.5
18	101,212	222,934	380	266.3	586.7
19	6,467	14,245	308	20.9	46.2
20	1,135	2,500	117	9.7	21.4
Total	2,626,996	5,786,336*			

* Total Chowan River pound net landings of 5,786,422 lb (2,627,036 kg) during 1986 include 86 lb. taken before the sampling period.

Table 13. Catch/effort statistics for river herring taken in Chowan River, NC, pound net fishery, 1987.

Week	Weekly landings (kg)	(lb)	Effort (Number of pound nets)	Catch per effort (kg)	(lb)
10	3,242	7,141	202	16.0	35.3
11	6,274	13,819	399	15.7	34.6
12	6,832	15,048	501	13.6	30.0
13	8,877	19,554	501	17.7	39.0
14	24,025	52,920	501	47.9	105.6
15	178,959	394,185	501	357.2	786.8
16	254,235	559,989	501	507.4	1,117.7
17	132,395	291,621	501	264.3	582.1
18	26,022	57,318	501	51.9	114.4
19	332,716	732,855	501	664.1	1,462.8
20	84,288	185,658	360	234.1	515.7
Total	1,057,865	2,330,108			

* Total Chowan River pound net landings of 2,340,239 lb (1,062,469 kg) during 1987 include 10,131 lb taken before and after the sampling period.

Table 14. Catch/effort statistics for river herring taken in Chowan River, NC, pound net fishery, 1988.

Week	Weekly landings (kg)	Weekly landings (lb)	Effort (Number of pound nets)	Catch per effort (kg)	Catch per effort (lb)
10	1,575	3,470	223	7.1	15.6
11	1,653	3,640	454	3.6	8.0
12	1,581	3,483	508	3.1	6.9
13	19,809	43,633	508	39.0	85.9
14	214,088	471,559	506	423.1	931.9
15	7,340	16,168	506	14.5	31.9
16	114,320	251,807	506	225.9	497.6
17	369,529	813,940	506	730.3	1,608.6
18	119,496	263,207	467	255.9	563.6
19	188,021	414,144	303	620.5	1,366.8
20	77,237	170,125	101	764.7	1,684.4
21	1,894	4,173	101	18.8	41.3
Total	1,116,543	2,459,349*			

*Total Chowan River pound net landings of 2,460,751 lb (1,117,181 kg) during 1988 include 1,402 lb taken before and after the sampling period.

Commercial harvest sampling sites during the project (Figure 4) differed somewhat for those reported by Winslow et al. (1985). American shad and hickory shad were also sampled during 1986 from nets being fished by division personnel as part of a gill net test project (Henry 1987).

Species composition of both alewife and blueback herring (by number) were determined from unculled samples of commercial catches take in the Chowan and Scuppernong rivers during 1986-1988. Early catches of river herring examined at sampling locations during 1986-1988 were dominated by alewife, with blueback becoming the dominant species at approximately mid-season (Figures 24-26). During 1986, no alewife were sampled in the Scuppernong River. Fishermen in this system were extremely late setting their pound nets, resulting in only blueback herring being captured.

Unculled samples taken from these sites were limited to 30 fish per species, per week, because of time and personnel limits. Species composition for the entire 1986 season, determined from sampling in Scuppernong and Chowan rivers, was 76% blueback herring and 24% alewife. The 1987 season yielded a species composition of 58% blueback and 42% alewife. During 1988, the composition was 64% blueback herring and 36% alewife. These percentages generally agree with percentages reported by Johnson et al. (1981) and Winslow et al. (1983, 1985). The percentages obtained were from the actual number of fish sampled. If the species composition was calculated from the estimated number of individuals in the harvest, the percentages would be significantly different. The percentages obtained from the actual sample is probably representative of the stocks.

Sex Ratios

River Herring

During 1985-1988, sex ratios were obtained from combined data taken of all sample sites. Pound nets in these areas are believed to be non-selective. The male to female sex ratios for blueback herring in 1985 and 1987 were 1.5:1. Chi-square analysis for both years indicated a significant difference from the expected ratio at the .05 level. A sex ratio of 1.1:1 was found for 1986; Chi-square analysis at the .05 level

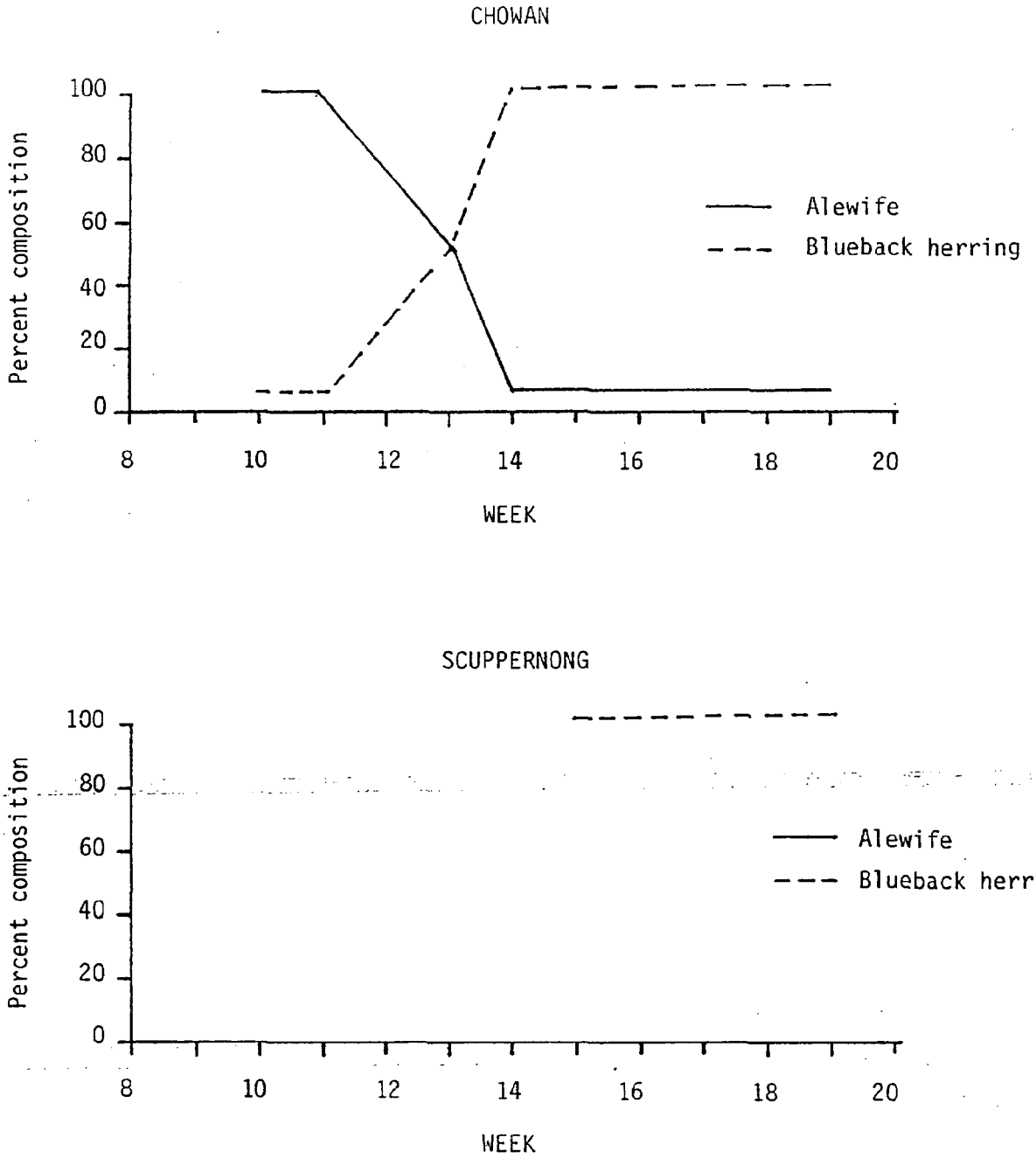


Figure 24. Weekly species composition of the 1986 samples for the Chowan River and Scuppernong River pound net fisheries.

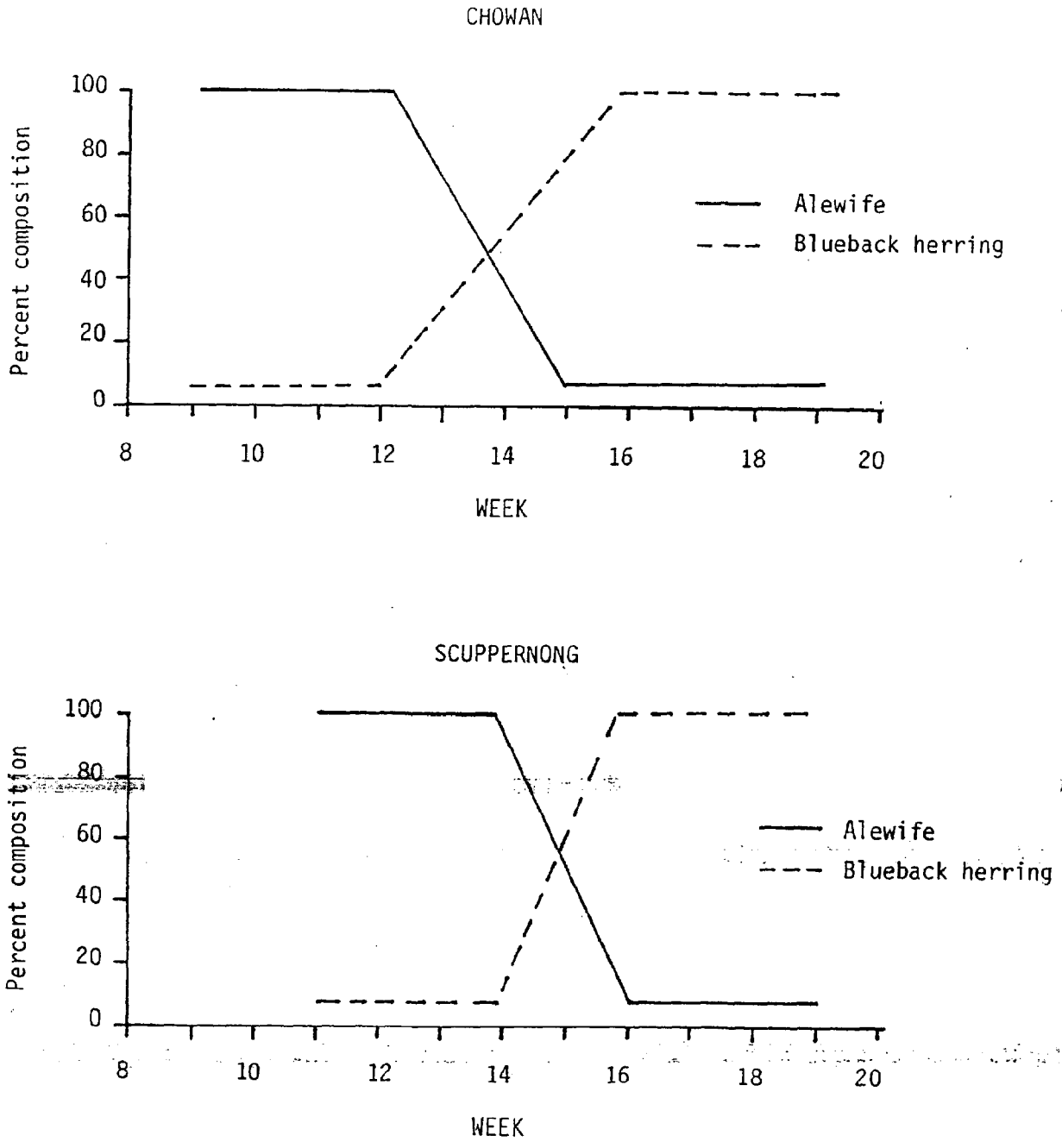


Figure 25. Weekly species composition of the 1987 samples for the Chowan River and Scuppernong River pound net fisheries.

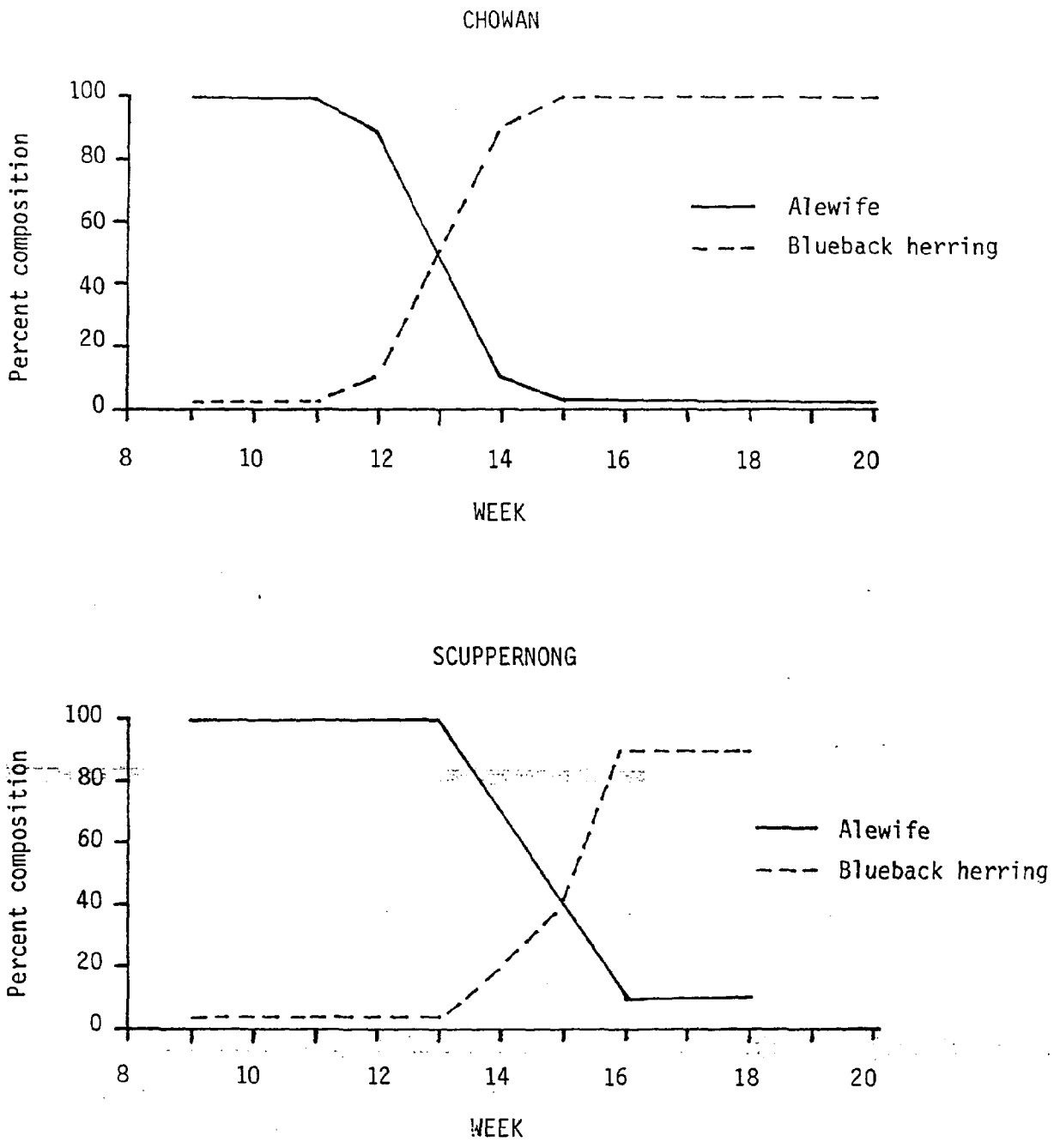


Figure 26. Weekly species composition of the 1988 samples for the Chowan River and Scuppernong River pound net fisheries.

was not significantly different. In 1988, a ratio of 1.9:1, male to female, was obtained. A significant difference from a 1:1 ratio for blueback herring at the .05 confidence level was determined in 1988. The sex ratio of blueback herring obtained for each year are similar to those that would result from the use of the estimated number of individuals data. A set ratio of 1.1:1, male to female, for alewife was obtained in 1985 and 1988. Based on the Chi-square analysis (.05 level), the ratio was very similar to the expected. Sex ratios of 2.7:1 and 2.0:1, were obtained for alewife in 1986 and 1987, respectively; analysis of Chi-square was significantly different for both years at the .05 level. Utilizing the estimated numbers of individual data, the sex ratios differ from the actual obtained but are very similar to the hypothetical ratio.

American Shad

In 1985 and 1988, the American shad male:female ratio from the area was 1.1:1; which was not significantly different at the .05 level. A sex ratio of 2.8:1 was obtained from pooled data from the Albemarle Sound area during 1986. Chi-Square analysis indicated the ratio differed from the theoretically expected ratio (1:1) very significantly (.05 level). The 1987 data yielded a ratio of 1.5:1 male to female. This was found to be significantly different from the expected ratio, utilizing the Chi-square analysis at the .05 confidence level. These data are biased because the gill nets employed are selective for females (Street et al. 1975). The actual sex ratio of the American shad population is unknown.

Hickory Shad

Hickory shad sex ratios were also determined from combined data taken at all sites. A sex ratio of 0.1:1, male to female, was obtained from 1985 and 1988 data. Ratios were also determined in 1986 (0.3:1) and 1987 (0.5:1). Chi-square analysis was highly significant during all years at the .05 confidence level. Again, it should be noted that gill nets are the predominate gear for hickory shad and are selective for females (Street et al. 1975).

Mortality

Survival estimates for 1985-1988 were computed using the Robson and Chapman (1961) method. They showed that estimates of annual rates of survival can be made from the catch curve of a single season if the population is exposed to unbiased fishing gear beyond the age of recruitment and if year class strength and survival rate remain constant from year to year. Assuming these two requirements are met, total annual survival rate(s) of blueback herring, alewife, American shad, and hickory shad, were computed using the formula:

$S = \frac{T}{N+T-1}$ where: $T = N_1+2N_2+3N_3+\ldots+N_t$, N_t=numbers in the t the age group and $N = N_0+N_1+N_2+\ldots N_t$

Total annual mortality rates were calculated as the reciprocal of survival. In this procedure the initial age in the samples (age III - 0) cannot be used since that year class has not fully recruited to the fishery; instead, the data for age IV-0 must be coded to 0, V-1, coded to 1 etc. This will probably make the survival rates lower and mortality rates higher.

Blueback Herring

The total annual mortality estimate for blueback herring during 1985 was 48.7%, the lowest value for the project period. An estimate of 51.1% was determined for 1986, similar to that found in 1980 (53%) (Winslow et al. 1983). During 1987, the blueback herring mortality estimate was 64.5%. Winslow et al. (1983) reported the annual mortality estimate for 1981 was 74%; this agrees with that for 1988.

Alewife

Alewife annual mortality estimates for 1985 through 1988 were 51.7%, 64.7%, 69.6% and 64.4% respectively, for these years. All of these estimates were less than those reported by Winslow et al. (1985) for 1983 (74%) and 1984 (81.3%).

American Shad

Total mortality estimates for American shad were determined for 1985-1988. An estimate of 54.5% was found for 1985. During 1986, total mortality was estimated at 51.7%, while the 1987 estimate was 51.2%. In 1988, the lowest estimate (47.4%) of the project period was obtained. These estimates are similar to those reported by Winslow et al. (1985). The variability of the mortality estimate is probably due to the biased fishing gear.

Hickory Shad

The mortality rate for hickory shad in 1985 was 48.9% and 42.5% for 1986. These estimates are similar to that reported by Winslow et al. (1985) for 1984 (44%). During 1987, the estimate of 65.7% was determined. Total mortality in 1988 (53.0%) was similar to that of 1982 (50.0%) Winslow et al. (1983).

Age and Spawning Class Composition

Age and spawning class composition data for the total commercial harvest and of the commercial harvest in each of the areas sampled during 1985-1988 are presented in Tables 15 through 42. The data presented in these tables are the expanded number for stratified subsampling of each area. These subsampling techniques were the same as those utilized in Winslow et al. (1983, 1985). The 1985-1988 results generally agree with those reported by Street et al. (1975), Johnson et al. (1977, 1981) and Winslow et al. (1983, 1985).

The Scuppernong River fishermen were later than normal setting their pound nets in 1985 and 1986. Thus, the alewife population was not available to sampling. The Alligator River data probably do not adequately represent the river herring population of this system since the fishermen were active only during the early part of the season each year.

Blueback Herring

In 1985, a total of 387 blueback herring scale samples was taken; 250 scale samples were subsampled for age determination. A total of 345 blueback herring scale samples was obtained in 1986; 223 were subsampled for ageing. Two-hundred and ten were subsampled from the 1987 total

(317) for age determination. In 1988, blueback herring scale samples were taken and 203 individuals were subsampled for ageing. For each year, the subsamples were expanded for each modal size group (10 mm groups) to obtain the age of the total sample.

Combined data from all sampling locations showed that males during 1985, 1987 and 1988 ranged from 3 to 7 years old, while in 1986, ages ranged from 3 through 6 years. Female blueback herring in 1985 and 1988 ranged from 4 to 7 years old. In 1986, ages of females were found to be from 4 to 8 years; while in 1987, ages ranged from 3 to 7 years. Age groups 4-6 comprised 97.4% of the males and 96.2% of the females sampled in 1985 (Table 15). These same age groups in 1986 accounted for 93.2% of the males and 94.8% of the females sampled (Table 16). During 1987, 90.6% of the males and 91.3% of the females were in age groups 4-6 (Table 17) Seventy-five percent of the males sampled in 1988 were in age groups 4-6 (Table 18). This percentage is lower than the others found during the project period. It should be noted, however, that approximately 24% of the males sampled were age 3. This was probably a result of the strong year class that was produced in 1985. Females in age groups 4-6 accounted for 98.1% of the sample in 1988 (Table 18). The values found throughout the project period were similar to those reported by Johnson et al. (1981) and Winslow et al. (1983, 1985).

Blueback herring data combined from all sampling locations during 1985-1988 showed spawning populations (sexes combined) comprised of 58.1%, 54.5% 73.8%, and 81.3%, respectively (Tables 15-18). The percentages of virgin fish for the project period are similar to those reported by Johnson et al. (1981) for 1977-1979 and Winslow et al. (1985) for 1983 and 1984. Male and female blueback herring scales had up to two spawning marks 1985-1988. During 1985-1988, only 3.4% 5.8%, 2.2%, and 1.6% respectively, had spawned more than once. These values are higher than those reported by Winslow et al. (1985) for 1983 and 1984, but lower than those reported for 1977-1982 (Johnson et al. 1981, Winslow et al. 1983).

These percentages continue to indicate a lack of older fish in the spawning population. During 1985 (41.9%) and 1986 (45.5%), spawning repetition (sexes combined) increased from that reported by Winslow et al. (1985) for 1983 (32.7%) and 1984 (20.7%). That found for 1987

Table 15. Age and spawning frequency of blueback herring and alewife from the Albemarle Sound, NC, area. Data are combined from all sample sites, 1985 (M=male, F=female).

Blueback herring

Age	Number of times spawned: 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	5	0					5	0
IV	48	13					48	13
V	80	78	67	23			147	101
VI	0	1	25	34	4	2	29	37
VII					1	6	1	6
Total	133	92	92	57	5	8	230	157
Percent by sex	57.8	58.6	50.0	36.3	2.2	5.1		
Percent of sexes combined	58.1		38.5		3.4			

Alewife

Age	Number of times spawned: 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	6	0					6	0
IV	49	29					49	29
V	23	49	41	20			64	69
VI	0	1	18	21	5	1	23	23
VII			0	1	2	4	2	5
Total	78	79	59	42	7	5	144	126
Percent by sex	54.2	62.7	41.0	33.3	4.8	4.0		
Percent of sexes combined	58.2		37.4		4.4			

Table 16. Age and spawning frequency of blueback herring and alewife from the Albemarle Sound, NC, area. Data are combined from all sample sites, 1986 (M=male, F=female).

Blueback herring

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	13	0					13	0
IV	80	33					80	33
V	20	38	49	22			69	60
VI	1	3	22	44	7	5	30	52
VII					0	8	0	8
Total	114	74	71	66	7	13	192	153
Percent by sex	59.4	48.4	37.0	43.1	3.6	8.5		
Percent of sexes combined	54.5		39.7		5.8			

Alewife

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	7	1					7	1
IV	82	19					82	19
V	12	14	37	12			49	26
VI			5	7	2	0	7	7
Total	101	34	42	19	2	0	145	53
Percent by sex	69.6	64.2	29.0	35.8	1.4	0		
Percent of sexes combined	68.2		30.8		1.0			

Table 17. Age and spawning frequency of blueback herring and alewife from the Albemarle Sound, NC, area. Data are combined from all sample sites, 1987 (M=male, F-female).

Blueback herring

Age	Number of times spawned							
	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	16	8					16	8
IV	104	64	1	0			105	64
V	16	26	39	11			55	37
VI			10	14	3	0	13	14
VII			0	1	2	2	2	3
Total	136	98	50	26	5	2	191	126
Percent by sex	71.2	77.8	26.2	20.6	2.6	1.6		
Percent of sexes combined	73.8		24.0		2.2			

Age	Number of times spawned							
	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	28	1					28	1
IV	141	69	4	0			145	69
V	47	35	33	18			80	53
VI	0	1	7	2			7	3
VII					0	1	0	1
Total	216	106	44	20	0	1	260	127
Percent by sex	83.1	83.5	16.9	15.7	0	0.8		
Percent of sexes combined	83.2		16.5		0.3			

Table 18. Age and spawning frequency of blueback herring and alewife from the Albemarle Sound, NC, area. Data are combined from all sample sites, 1988 (M=male, F=female).

Blueback herring

Age	Number of times spawned: 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	51	0					51	0
IV	120	63	4	0			124	63
V	5	13	20	20			25	33
VI			3	6	1	1	4	7
VII					1	2	1	2
Total	176	76	27	26	2	3	205	105
Percent by sex	85.8	72.4	13.2	24.8	1.0	2.8		
Percent of sexes combined	81.3		17.1		1.6			

Alewife

Age	Number of times spawned: 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
II	1	0					1	0
III	27	5					27	5
IV	76	64	9	1			85	65
V	8	29	36	33			44	62
VI			4	15	2	3	6	18
Total	112	98	49	49	2	3	163	150
Percent by sex	68.7	65.3	30.1	32.7	1.2	2.0		
Percent of sexes combined	67.1		31.3		1.6			

(26.2%) was larger than that in 1984. The spawning repetition value has varied considerably over the years in the Albemarle Sound area; however, the 1988 value, 18.7%, is the lowest on record.

Age composition for each of the areas sampled in the commercial harvest surveys during 1985-1988, were similar to those collected for 1972-1984 (Street et al. 1975, Johnson et al. 1977, 1981, and Winslow et al. 1983 and 1985).

The spawning populations (sexes combined) of blueback herring in the Scuppernong River for 1985-1988 was comprised of 56.1%, 65.3% 79.4%, and 82.3% virgin fish, respectively, (Tables 19-22). The highest proportion of virgin fish in the Albemarle Sound area normally occurs from the Scuppernong River. Male blueback herring ranged from 4-7 years old in 1985 and 3-5 years of age in 1988. During 1986 and 1987, males were found from ages 3 through 6. Females ranged from 4 to 7 years in 1985 and 1986. In 1987, females were 3 through 6 years old; while in 1988, the age range was 4-6 years. Age groups 4-6 comprised 96.8% (1985), 93.9% (1986), 88.8% (1987), and 82.3% (1988) of the samples, sexes combined. The percentages found in 1985 and 1986 are similar to those found in 1983 (94.6%) and 1984 (93.9%) (Winslow et al. 1985). In 1985, 12.2% of the fish sampled (sexes combined) from the Scuppernong River were over 5 years of age and 21.0% in 1986. These findings are similar to those reported by Winslow et al. (1983) for 1980 (27.4%) and 1982 (13.4%). The percentage of fish was age 5 in 1987, was 6.5% and 3.9% in 1988; similar to that found in 1984 (4.7%) (Winslow et al. 1985) and prior to 1980 (Street et al. 1975, Johnson et al. 1977, 1981).

The Meherrin River haul seine fishery did not operate during the project period, 1985-1988; thus no data were obtained.

Approximately 85% of the total Albemarle Sound area river herring landings occurs from the Chowan River pound net fishery. Thus, data collected from the Chowan River sampling location should most likely reflect the population parameters of the total river herring run in the Albemarle Sound area (Tables 23-26).

Chowan River data for blueback herring from 1985 showed that 56.2% were virgin fish, sexes combined, and 46.5% in 1986. These proportions are similar to those found in 1980 (46.0%) and 1981 (58.7%) by Winslow et al. (1983). During 1987 and 1988, virgin fish (sexes combined)

Table 19. Age and spawning frequency of blueback herring from the Scuppernong River, NC, pound net fishery, 1985 (M=male, F=female).

Blueback herring

Age	Number of times spawned 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
IV	23	6					23	6
V	30	27	37	13			67	40
VI	0	1	4	8	1	0	5	9
VII					1	4	1	4
TOTAL	53	34	41	21	2	4	96	59
Percent by sex	55.2	57.6	42.7	35.6	2.1	6.8		
Percent of sexes combined	56.1		40.0		3.9			

Table 20. Age and spawning frequency of blueback herring from the Scuppernong River, NC, pound net fishery, 1986 (M=male, F=female).

Blueback herring

Age	Number of times spawned 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	8	0					8	0
IV	48	19					48	19
V	6	14	12	9			18	23
VI	0	1	6	16	4	3	10	20
VII					0	1	0	1
Total	62	34	18	25	4	4	84	63
Percent by sex	73.8	54.0	21.4	39.7	4.8	6.3		
Percent of sexes combined	65.3		29.3		5.4			

Table 21. Age and spawning frequency of blueback herring and alewife from the Scuppernong River, NC, pound net fishery, 1987 (M=male, F=female).

Blueback herring

Age	Number of times spawned: 0		1		Total	
Sex	M	F	M	F	M	F
III	8	4			8	4
IV	32	21			32	21
V	9	11	10	5	19	16
VI			3	4	3	4
Total	49	36	13	9	62	45
Percent by sex	79.0	80.0	21.0	20.0		
Percent of sexes combined	79.4		20.6			

Alewife

Age	Number of times spawned: 0		1		Total	
sex	M	F	M	F	M	F
III	15	1			15	1
IV	21	16	3	0	24	16
V	5	6	11	7	16	13
VI			4	1	4	1
Total	41	23	18	8	59	31
Percent by sex	69.5	74.2	30.5	25.8		
Percent of sexes combined	71.1		28.9			

Table 22. Age and spawning frequency of blueback herring and alewife from the Scuppernong River, NC, pound net fishery, 1988 (M=male, F=female).

Blueback herring

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	9	0					9	0
IV	21	12					21	12
V			2	5			2	5
VI			0	2			0	2
Total	30	12	2	7			32	19
Percent by sex	93.8	63.2	6.2	36.8				
Percent of sexes combined	82.3		17.7					

Alewife

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	7	1					7	1
IV	23	28	5	1			28	29
V	3	12	14	8			17	20
VI			0	3	0	1	0	4
Total	33	41	19	12	0	1	52	54
Percent by sex	63.5	75.9	36.5	22.2	0	1.9		
Percent of sexes combined	69.9		29.2		0.9			

Table 23. Age and spawning frequency of blueback herring and alewife from the Chowan River, NC, pound net fishery, 1985. (M=male, F=female)

Blueback herring

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	5	0					5	0
IV	22	5					22	5
V	48	38	28	10			76	48
VI			21	26	3	2	24	28
VII					0	2	0	2
Total	75	43	49	36	3	4	127	83
Percent by sex	59.0	51.8	38.6	43.4	2.4	4.8		
Percent of sexes combined	56.2		40.5		3.3			

Alewife

Age	Number of times spawned				Total	
	0		1			
Sex	M	F	M	F	M	F
III	4	0			4	0
IV	26	18			26	18
V	15	15	6	4	21	19
VI			1	4	1	4
Total	45	33	7	8	52	41
Percent by sex	86.5	80.5	13.5	19.5		
Percent of sexes combined	83.9		16.1			

Table 24. Age and spawning frequency of blueback herring and alewife from the Chowan River, NC, pound net fishery, 1986 (M=male, F=female).

Blueback herring

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	5	0					5	0
IV	32	14					32	14
V	14	24	37	13			51	37
VI	1	2	16	28	3	2	20	32
VII					0	7	0	7
Total	52	40	53	41	3	9	108	90
Percent by sex	48.2	44.4	49.1	45.6	2.7	10.0		
Percent of sexes combined	46.5		47.5		6.0			

Alewife

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	2	1					2	1
IV	11	6	1	0			12	6
V	5	6	8	7			13	13
VI			2	4			2	4
Total	18	13	11	11			29	24
Percent by sex	62.1	54.2	37.9	45.8				
Percent of sexes combined	58.5		41.5					

Table 25. Age and spawning frequency of blueback herring and alewife from the Chowan River, NC, pound net fishery, 1987 (M=male, F=female).

Blueback herring

Age	Number of times spawned							
	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	8	4					8	4
IV	72	43	1	0			73	43
V	7	15	29	6			36	21
VI			7	10	3	0	10	10
VII			0	1	2	2	2	3
Total	87	62	37	17	5	2	129	81
Percent by sex	67.4	76.5	28.7	21.0	3.9	2.5		
Percent of sexes combined	71.0		25.7		3.3			

Alewife

Age	Number of times spawned							
	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	9	0					9	0
IV	60	30	1	0			61	30
V	13	11	14	6			27	17
VI			1	0			1	0
VII					0	1	0	1
Total	82	41	16	6	0	1	98	48
Percent by sex	83.7	85.4	16.3	12.5	0	2.1		
Percent of sexes combined	84.2		15.1		0.7			

Table 26. Age and spawning frequency of blueback herring and alewife from the Chowan River, NC, pound net fishery, 1988 (M=male, F=female).

Blueback herring

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	36	0					36	0
IV	95	48	4	0			99	48
V	5	13	18	14			23	27
VI			3	4	1	1	4	5
VII					1	2	1	2
Total	136	61	25	18	2	3	163	82
Percent by sex	83.4	74.4	15.3	22.0	1.3	3.6		
Percent sexes combined	80.4		17.6		2.0			

Alewife

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
II	1	0					1	0
III	16	1					16	1
IV	25	13	2	0			27	13
V	3	7	6	0			9	7
VI			3	2	1	1	4	3
Total	45	21	11	2	1	1	57	24
Percent by sex	78.9	87.5	19.3	8.3	1.8	4.2		
Percent sexes combined	81.5		16.0		2.5			

comprised 71.0% and 80.4% of the sample, respectively. The increase in the population of virgin fish in 1987 and 1988 indicated a return to similar levels found in 1977 and 1978 (Johnson et al. 1981). During 1985 and 1986, male blueback herring were found to be 3 to 6 years old (Table 23 and 24). Male bluebacks in 1987 and 1988 ranged in age from 3 to 7 years old (Table 25 and 26). Females in 1985, 1986 and 1988 were ages 4 through 7 years; but in 1987, ages ranged from 3-7 year old (Table 23-26). Age groups 4, 5, and 6 (sexes combined) comprised between 84.0% (1988) and 94.2% (1985) of the samples during the project. These percentages closely agree with those found for 1980-1982 (Winslow et al. 1983) and 1983 and 1984 (Winslow et al. 1985). The Chowan River samples for 1985 and 1987 showed that 3.3% of the fish, sexes combined, had spawned more than once previously. In 1986 6.0% had spawned more than once and 2.0% in 1988. These values are comparable to those found for the Chowan River in 1975-1976 (5%) (Johnson et al. (1977).

As reported by Johnson et al. (1977), fishermen in the Alligator River area concentrated their effort during the early part of the season. Blueback herring samples were obtained from the Alligator River during 1985 (22) and 1988 (14). So few samples were obtained during the project and previous projects that meaningful evaluations of the spawning population cannot be determined. The 1985 data is presented in Table 27 and for 1988 in Table 30.

Alewife

A total of 270 alewife scale samples was taken from the Albemarle Sound area in 1985. One hundred ninety-seven were subsampled for age determination. In 1986, 198 scale samples were obtained and a subsample of 149 were aged. During the 1987 sampling season, 387 alewife scale samples were taken; 287 were subsampled and aged. Throughout the Albemarle area, 313 alewife were sampled in 1988, and a subsample of 243 were aged. The subsamples each year for each modal size group were expanded to obtain the total number sampled.

Combined data from the Albemarle area sampling locations in 1985 showed that male alewife ranged from 3 to 7 years of age, while in 1988 males were 2 to 6 years old (Tables 15 and 18). Males in 1986 and 1987 were found to be from 3 to 6 years old (Tables 16 and 17). Female alewife ages ranged from 4 to 7 years of age in 1985 (Table 15) and 3 to

7 in 1987 (Table 17). During 1986 and 1988 female ages ranged from 3-6 years old (Tables 16 and 18). The alewife harvest was dominated by ages 4-6 in 1985 (95.3%), 1986 (97.5%), 1987 (92.2%), and 1988 (89.5%). These percentages are very similar to those found for 1972-1984 (Street et al. 1975, Johnson et al. 1981, Winslow et al. 1983, 1985).

The alewife spawning population, data combined from all locations, was composed of 58.2% virgins in 1985, 68.2% in 1986, 83.2% in 1987, and 67.1% in 1988 (Tables 15-18). These data closely agree with the 1983 (67.9%) and 1984 (80.6%) values (Winslow et al. 1985). Male and female alewife had up to two spawning marks, 1985 and 1988. In 1986, males had up to two; while in 1987 up to two were found in females. In 1985-1988, of the alewife sampled (sexes combined), 4.4%, 1.0%, 0.3%, and 1.6%, respectively, had spawned more than once. These percentages are similar to those reported for 1981-1984 (Winslow et al. 1983 and 1985).

During 1985 and 1986, no alewife samples were obtained from the Scuppernong River due to fishermen being late in the season setting their nets. Alewife sampled during 1987 showed that both males and females ranged from 3 to 6 years of age (Table 21). During 1988, males ranged from 3 to 5 years; while females were 3 to 6 years (Table 22). Data showed that for 1987 and 1988, 71.1% and 69.9% respectively, (sexes combined) were virgins. These data generally agree with that reported by Winslow et al. (1983) for 1980-82. No alewife were determined to have spawned more than once in 1987 and only 0.9% in 1988. The 1987 and 1988 values tend to agree with those of 1977 and 1978 (Johnson et al. 1981). The amount of effort in the Scuppernong River has decreased over the past decade. Thus, the number of samples has declined and these data may not actually reflect the spawning population of this system.

As previously stated, the Chowan River data probably are the most representative age and spawning class data for the Albemarle Sound area alewife. Male alewife in 1985-1987 ranged in age from 3 to 6 years old and 2 to 6 years in 1988. Female alewife in the Chowan River ranged from 3 to 6 years old in 1986 and 1988. In 1985, females were found to be 4 to 6 years old and 4 to 7 in 1987. Virgin fish comprised 83.9% (sexes combined) of the sample in 1985 (Table 23) and 58.5% in 1986 (Table 24). In 1987, it was determined that 84.2% of the sample and 81.5% in 1988 were virgins (Tables 25 and 26). These data are similar

to those reported by Street et al. (1975), Johnson et al. (1981) and Winslow et al. (1983 and 1985). The percentage of fish that had spawned more than once in 1987 (0.7%) and 1988 (2.5%) were similar to that reported for 1982 (0.5%) and 1983 (2.5%) (Winslow et al. 1983, 1985).

Male alewife sampled from the Alligator River in 1985 ranged from 3 to 7 years in age and 3 to 6 years old in 1986-1988 (Tables 27-30). Females in 1985 were found to be 4 to 7 years old, 1986 and 1987, 4 to 6 years old and in 1988, 3 to 6 years old (Tables 27-30). Virgin alewife, sexes combined, comprised 44.6% of the sample in 1985, 71.2% in 1986, 89.4% in 1987 and in 1988, 55.6%. These findings generally agree with that of 1983 (63.6%) and 1984 (84.5%) percentage of virgins (Winslow et al. 1985). During the project period, 1985-1988, only 6.8%, 1.4%, 0 and 1.5%, respectively, had spawned more than once. Winslow et al. (1985) reported similar findings. Once again, it should be noted that the Alligator River samples may not be truly representative due to the fishery occurring only during the early part of the total river herring season.

American Shad

Albemarle Sound Area

The Albemarle Sound gill net fishery accounts for approximately 95% of the American shad taken from the area; the remainder are captured incidental to the pound net fishery directed for river herring. A total of 446 American shad scale samples were taken in 1985, and 282 scale samples were subsampled for age determination. Two hundred nineteen scales samples were taken throughout the area in 1986; of which 153 were subsampled and aged. In 1987, 440 scales samples were taken and 252 subsampled for ageing. During 1988, a total of 551 American shad were sampled; 317 were subsampled and aged. The subsample was expanded, each sample year, for each modal size group (25 mm group) to obtain the ages of the total sample.

Male American shad ranged in age from 3 to 8 years old in 1985 and 4 to 8 years in 1986-1988 (Tables 31-34). During 1985, females were 4 to 8 years of age, but in 1986-1988 they ranged from 4 to 9 years (Tables 31-34). Age groups 4-6 comprised 90.2%, 84.8%, 89.2% and 88.0%, respectively, of the males in 1985-1988. Females in age groups 5,6, and

Table 27. Age and spawning frequency of blueback herring and alewife from the Alligator River, NC, pound net fishery, 1985 (M=male, F=female).

Blueback herring

Age	Number of times spawned				Total	
	0		1			
Sex	M	F	M	F	M	F
IV	3	2			3	2
V	2	13	2	0	4	13
Total	5	15	2	0	7	15
Percent by sex	71.4	100	28.6	0		
Percent of sexes combined	90.9		9.1			

Alewife

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	2	0					2	0
IV	23	11					23	11
V	8	34	35	16			43	50
VI	0	1	17	17	5	1	22	19
VII			0	1	2	4	2	5
Total	33	46	52	34	7	5	92	85
Percent by sex	35.9	54.1	56.5	40.0	7.6	5.9		
Percent of sexes combined	44.6		48.6		6.8			

Table 28. Age and spawning frequency of alewife from the Alligator River, NC, pound net fishery, 1986 (M=male, F=female).

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	5	0					5	0
IV	71	13					71	13
V	7	8	29	5			36	13
VI			3	3	2	0	5	3
Total	83	21	32	8	2	0	117	29
Percent by sex	70.9	72.4	27.4	27.6	1.7	0		
Percent of sexes combined	71.2		27.4		1.4			

Table 29. Age and spawning frequency of alewife from the Alligator River, NC, pound net fishery, 1987 (M=male, F=female).

Age	Number of times spawned				Total	
	0		1			
Sex	M	F	M	F	M	F
III	4	0			4	0
IV	60	23			60	23
V	29	18	8	5	37	23
VI	0	1	2	1	2	2
Total	93	42	10	6	103	48
Percent by sex	90.3	87.5	9.7	12.5		
Percent of sexes combined	89.4		10.6			

Table 30. Age and spawning frequency of blueback herring and alewife from the Alligator River, NC, pound net fishery, 1988 (M=male, F=female).

	Number of times spawned							
Age	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	6	0					6	0
IV	4	3					4	3
V			0	1			0	1
Total	10	3	0	1			10	4
Percent by sex	100	75.0	0	25.0				
Percent sexes combined	92.9		7.1					

Alewife

	Number of times spawned							
Age	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
III	4	3					4	3
IV	28	23	2	0			30	23
V	2	10	16	25			18	35
VI			1	10	1	1	2	11
Total	34	36	19	35	1	1	54	72
Percent by sex	63.0	50.0	35.2	48.6	1.8	1.4		
Percent sexes combined	55.6		42.9		1.5			

Table 31. Age and spawning frequency of American shad and hickory shad for the Albemarle Sound area, NC, 1985 (M=male, F=female).

American shad

Age	Number of times spawned								Total	
	0		1		2		3			
Sex	M	F	M	F	M	F	M	F	M	F
III	2	0							2	0
IV	44	1							44	1
V	65	41	42	7					107	48
VI	9	48	47	53	6	1			62	102
VII	0	4	4	24	13	27			17	55
VIII					1	3	3	1	4	4
Total	120	94	93	84	20	31	3	1	236	210
Percent by sex	50.8	44.8	39.4	40.0	8.5	14.8	1.3	0.4		
Percent of sexes combined	48.0		39.7		11.4		0.9			

Hickory shad

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
III	4	4					4	4
IV	8	60	0	2			8	62
V	1	71	8	53			9	124
VI			2	33	3	31	5	64
VII					0	6	0	6
Total	13	135	10	88	3	37	26	260
Percent by sex	50.0	51.9	38.5	33.9	11.5	14.2		
Percent of sexes combined	51.7		34.3		14.0			

Table 32. Age and spawning frequency of American shad and hickory shad for the Albemarle Sound area, NC, 1986 (M=male, F=female).

American shad

Age	Number of times spawned								Total	
	0		1		2		3			
Sex	M	F	M	F	M	F	M	F	M	F
IV	17	1							17	1
V	47	7	34	1					81	8
VI	6	5	28	9	2	0			36	14
VII			4	9	18	11			22	20
VIII			0	2	0	8	2	3	2	13
IX							0	1	0	1
Total	70	13	66	21	20	19	2	4	158	57
Percent by sex	44.3	22.9	41.8	36.8	12.7	33.3	1.2	7.0		
Percent of sexes combined	38.6		40.5		18.1		2.8			

Hickory shad

Age	Number of times spawned								Total	
	0		1		2		3			
Sex	M	F	M	F	M	F	M	F	M	F
III	2	0							2	0
IV	15	21							15	0
V	2	41	9	25					10	66
VI			6	24	1	4			7	28
VII			0	1	1	9			1	10
VIII					0	1	0	1	0	2
Total	19	62	14	50	2	14	0	1	35	127
Percent by sex	54.3	48.8	40.0	39.4	5.7	11.0	0	0.8		
Percent of sexes combined	50.0		39.5		9.9		0.6			

Table 33. Age and spawning frequency of American shad and hickory shad for the Albemarle Sound area, NC, 1987 (M=male, F=female).

American shad

Age	Number of times spawned 0		1		2		3		Total	
Sex	M	F	M	F	M	F	M	F	M	F
IV	76	2							76	2
V	53	22	51	10					104	32
VI	9	37	39	36	4	4			52	77
VII	0	4	5	27	20	19			25	50
VIII			0	1	2	14	1	2	3	17
IX							0	1	0	1
Total	138	65	95	74	26	37	1	3	260	179
Percent by sex	53.1	36.3	36.5	41.3	10.0	20.7	0.4	1.7		
Percent of sexes combined	46.2		38.5		14.4		0.9			

Hickory shad

Age	Number of times spawned 0		1		2		3		Total	
Sex	M	F	M	F	M	F	M	F	M	F
III	43	23							43	23
IV	42	115	11	4					53	119
V	4	42	8	26					12	68
VI			2	9	2	8			4	17
VII					0	6	0	2	0	8
Total	89	180	21	39	2	14	0	2	112	235
Percent by sex	79.5	76.6	18.7	16.6	1.8	6.0	0	0.8		
Percent of sexes combined	77.5		17.3		4.6		0.6			

Table 34. Age and spawning frequency of American shad and hickory shad for the Albemarle Sound area, NC, 1988 (M=male, F=female).

American shad

Age	Number of times spawned 0		1		2		3		Total	
Sex	M	F	M	F	M	F	M	F	M	F
IV	36	4							36	4
V	64	34	56	9					120	43
VI	2	28	62	38	36	9			100	75
VII	0	4	4	36	26	54	2	4	32	98
VIII			0	2	0	19	3	16	3	37
IX							0	3	0	3
Total	102	70	122	85	62	82	5	23	291	260
Percent by sex	35.1	27.0	41.9	32.7	21.3	31.5	1.7	8.8		
Percent of sexes combined	31.2		37.6		26.1		5.1			

Hickory shad

Age	Number of times spawned 0		1		2		3		Total	
Sex	M	F	M	F	M	F	M	F	M	F
III	6	8							6	8
IV	11	88	1	7					12	95
V	2	46	5	108	2	4			9	158
VI			0	14	2	29	0	1	2	44
VII					2	7	0	1	2	8
VIII							0	1	0	1
Total	19	142	6	129	6	40	0	3	31	314
Percent by sex	61.2	45.1	19.4	41.1	19.4	12.7	0	1.0		
Percent of sexes combined	46.7		39.1		13.3		0.9			

7 during 1985-1988, made up 97.6%, 73.7% 88.8% and 83.1%, respectively, of the sample. The percentages of these age groups are similar to those reported for 1983 and 1984 (Winslow et al. 1985). The Albemarle Sound area American shad population, sexes combined, was comprised of 48.0% (1985), 38.6% (1986), 46.2% (1987), and 31.2% (1988) virgin fish (Tables 31-34). Data from 1985 showed that 12.3% of the fish sampled (sexes combined) had spawned more than once and 20.9% for 1986. The shad population was comprised of 15.3% (1987) and 31.2% (1988), both sexes, of fish that and spawned more than once. The percentage of repeat spawners from 1985-1988, fell between that reported by Johnson et al. (1977) of 7% and 37.9% as reported by Winslow et al. (1985). These data have generally shown a wide range of year classes in the population.

Outer Banks

During 1985, no American shad samples were obtained from along the Outer Banks. Six samples were taken and aged in 1986 (Table 36). Only 14 samples were taken in 1987 and 3 in 1988. Fish sampled were aged and the information for 1987 (Table 37) and 1988 (Table 38) were reported. Since so few American shad were sampled each year, comparisons with historic data would be inappropriate.

Pamlico River

A total of 192 American shad scale samples was obtained from the Pamlico River area during 1985, and 119 subsampled and aged (Table 35). During 1986, 179 shad scale samples were taken and 111 subsampled for ageing (Table 36). Scale samples (110) were also taken in 1987 and a subsample of 73 were aged (Table 37). In 1986, 119 American shad samples were subsampled and age determined out of a total 198 samples (Table 38). For each year of the project, the subsamples were expanded to obtain the age composition of the total sample.

Male American shad in 1985 and 1988 ranged from 4 to 6 years old, but during 1986 and 1987, the range was from 4 to 7 years. During all years of the project, 1985-1988 females were found to range from 4 to 7 years old. The percentages of virgin fish (sexes combined) during 1985-1988, were 83.9%, 90.0%, 72.2%, and 64.7%, respectively. These percentages of virgin fish are lower than those found for the Pamlico River as reported by Winslow et al. (1983), for 1980 and 1981, but

Table 35. Age and spawning frequency of American shad from the Pamlico River area of NC, 1985 (M=male, F=female).

Pamlico River

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
IV	8	5					8	5
V	25	64	1	5			26	69
VI	10	47	10	12			20	59
VII	0	2	0	1	0	2	0	5
Total	43	118	11	18	0	2	54	138
Percent by sex	79.6	85.5	20.4	13.0	0	1.4		
Percent of sexes combined	83.9		15.1		1.0			

Table 36. Age and spawning frequency of American shad from the Outer Banks area and Pamlico River area of NC, 1986 (M=male, F=female).

Outer Banks

Age	Number of times spawned 0		Total	
sex	M	F	M	F
IV	2	0	2	0
V	0	3	0	3
VI	0	1	0	1
Total	2	4	2	4
Percent by sex	100	100		
Percent of sexes combined	100			

Pamlico River

Age	Number of times spawned 0		1		Total	
Sex	M	F	M	F	M	F
IV	19	11			19	11
V	35	76	7	2	42	78
VI	3	18	1	6	4	24
VII			1	1	1	1
Total	57	105	9	9	66	114
Percent by sex	86.4	91.2	13.6	7.9		
Percent of sexes combined	90.0		10.0			

Table 37. Age and spawning frequency of American shad from the Outer Bank area and Pamlico River area of NC, 1987 (M=male, F=female).

Outer Banks

Age	Number of times spawned							
	0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
IV	5	0					5	0
V	1	2	0	2			1	4
VI			2	1	1	0	3	1
Total	6	2	2	3	1	0	9	5
Percent by sex	66.7	40.0	22.2	60.0	11.1			
Percent of sexes combined	57.1		35.8		7.1			

Pamlico River

Age	Number of times spawned							
	0		1		2		Total	
sex	M	F	M	F	M	F	M	F
IV	5	5					5	5
V	11	35	5	7			16	42
VI	0	19	3	11			3	30
VII	0	3	0	3	1	0	1	6
Total	16	62	8	21	1	0	25	83
Percent by sex	64.0	74.7	32.0	25.3	4.0	0		
Percent of sexes combined	72.2		26.9		0.9			

Table 38. Age and spawning frequency of American shad from the Outer Banks area and Pamlico River area of NC, 1988 (M=male, F-female).

Outer Banks

Age	Number of times spawned 0		1		Total	
Sex	M	F	M	F	M	F
V	0	1	0	0	0	1
VI	0	1	1	0	1	1
Total	0	2	1	0	1	2
Percent by sex	0	100	100	0		
Percent of sexes combined		66.7		33.3		

Pamlico River

Age	Number of times spawned 0		1		2		Total	
Sex	M	F	M	F	M	F	M	F
IV	11	17					11	17
V	29	51	8	27			37	78
VI	2	17	6	26	0	1	8	44
VII	0	1	0	0	0	2	0	3
Total	42	86	14	53	0	3	56	142
Percent by sex	75.0	60.6	25.0	37.3	0	2.1		
Percent of sexes combined		64.7		33.8		1.5		

comparable to those in 1975 (Marshall 1976) and 1983 and 1984 (Winslow et al. 1985).

Neuse River

Scale samples (193) were taken from American shad in the Neuse River for age determination during the spring of 1985. One hundred sixteen were subsampled for ageing. In 1986, 234 scale samples were taken and a subsample of 143 were aged. Only 14 samples were obtained in 1987 and all were aged. A total of 97 scale sample was taken in 1988. Sixty-nine fish were subsampled and the ages determined. For each year that a subsample of the total was taken, the ages were expanded by the appropriate modal size groups to determine the total age of the sample. The ages and spawning frequencies are shown in Tables 39-42 for 1985, 1986, 1987, and 1988, respectively.

Male American shad ranged from 4 to 6 years old in 1985-1986 and 4 and 5 years old during 1987-1988 (Tables 39-42). Female fish ranged from 4 to 7 years of age during 1985 and 1987. However, in 1986 females were 4, 5, and 6 years old, but ages in 1988 ranged from 4 to 8 years old. Data from 1985 for sexes combined showed a population containing 92.2% virgins, while 87.6% was determined in 1986. From the 1987 and 1988 data, the percentage of virgin fish was determined to be 85.7% and 76.6% respectively, sexes combined. These percentages are higher than those reported for 1983 (60.3%) and 1984 (62.7%) (Winslow et al. 1985). The 1985-1988 values are lower than those reported by Winslow et al. (1983) of 100% (1980) and 93.5% (1981).

The overall low proportions of virgin American shad found in the Pamlico River, Neuse River and Cape Fear River area samples are probably a result of the samples being collected in a short period of time. Other possible factors may be naturally low spawning survival or a strong year class moving through the population, as was evidenced in Winslow et al. (1983) by an increased juvenile abundance in these areas.

American shad landings have declined and aroused concern along the east coast. North Carolina landings have fallen steadily from 1,069,000 lb in 1965 to a record low in 1977 of 121,000 lb. Landings since the 1977 low have recovered somewhat during the project period, averaging 318,704 lb per year (Table 2).

Cape Fear River

The Cape Fear River area was sampled during 1985 to obtain scale samples of American shad for age determination. A total of 192 samples was taken and 118 were subsampled and aged (Table 39). In 1986, 128 samples were obtained and 82 subsampled for age determination (Table 40). Ninety-seven samples were taken in 1987 and a subsample of 65 aged (Table 41). Scale samples were obtained from a total of 184 American shad in 1988; of which a subsample of 107 were aged (Table 42). The subsamples each year were expanded to obtain the age composition of the total catch as previously described by Winslow et al. (1985). Male shad in 1985 ranged from 3 to 6 years old; however, in 1986 the range was 4-5 years. In 1987 and 1988, male American shad were 4, 5, and 6 years old. Females in 1985-1987 were 4 through 6 years of age, while the range in 1988 was 4 to 7 years. Virgin fish accounted for 88.5% (1985), 93.6% (1986), 89.7% (1987) and 83.6% (1988) of the sample (sexes combined) during this project. All of the percentages were higher than that determined in 1983 (70.3%), but comparable to that found in 1984 (87.1%) (Winslow et al. 1985).

Hickory Shad

In 1985, 286 hickory shad scale samples were taken from the Albemarle Sound area, and 168 samples were subsampled for age determination (Table 31). During the 1986 spawning season, 162 scale samples were taken (Table 32). One hundred and seven were subsampled and aged. Scale samples (349) were also taken in 1987 and a subsample (208) aged (Table 33). A total of 345 hickory shad scale samples was collected in 1988; of which 196 were subsampled and the age determined (Table 34). The subsample for each year of the project was expanded for each modal size group (25 mm groups) to obtain the age composition of the total sample size.

Male hickory shad ages ranged from 3 to 6 years old in 1985 and 1987, but in 1986 and 1988 from 3 to 7 years old. During 1985 and 1987, ages ranged from 3 to 7 years old for females. Ages of females in 1986 were 5 to 8 years of age, but 3 to 8 years old in 1988. Data from 1985-1988 showed a spawning population (sexes combined) comprised of 51.7%, 50.0%, 77.5%, and 46.7%, respectively, virgin fish. The percent

Table 39. Age and spawning frequency of American shad from the Neuse River area and the Cape Fear River area, NC, 1985 (M=male, F=female).

Neuse River

Age	Number of times spawned					
	0		1		Total	
Sex	M	F	M	F	M	F
IV	39	6			39	6
V	48	64	8	0	56	64
VI	0	21	3	3	3	24
VII			0	1	0	1
Total	87	91	11	4	98	95
Percent by sex	88.8	95.8	11.2	4.2		
Percent of sexes combined	92.2		7.8			

Cape Fear River

Age	Number of times spawned					
	0		1		Total	
Sex	M	F	M	F	M	F
III	2	0			2	0
IV	28	7			28	7
V	35	62	7	4	42	66
VI	9	27	0	11	9	38
Total	74	96	7	15	81	111
Percent by sex	91.4	86.5	8.6	13.5		
Percent of sexes combined	88.5		11.5			

Table 40. Age and spawning frequency of American shad from the Neuse River area and the Cape Fear River area, NC, 1986 (M=male, F=female).

Neuse River

Age	Number of times spawned					
	0		1		Total	
Sex	M	F	M	F	M	F
IV	32	17			32	17
V	43	85	14	5	57	90
VI	3	25	2	8	5	33
Total	78	127	16	13	94	140
Percent by sex	83.0	90.7	17.0	9.3		
Percent of sexes combined	87.6		12.4			

Cape Fear River

Age	Number of times spawned					
	0		1		Total	
Sex	M	F	M	F	M	F
IV	6	15			6	15
V	2	64	1	0	3	64
VI	0	15	0	6	0	21
Total	8	94	1	6	9	100
Percent by sex	88.9	94.0	11.1	6.0		
Percent of sexes combined	93.6		6.4			

Table 41. Age and spawning frequency of American shad from the Neuse River area and the Cape Fear River, NC, 1987 (M=male, F=female).

Neuse River

Age	Number of times spawned									
	0				1				Total	
Sex	M		F		M		F		M	F
IV	1	1			1	1				
V	4	4	1	0	5	4				
VI	0	2			0	2				
VII			0	1	0	1				
Total	5	7	1	1	6	8				
Percent by sex	83.3			87.5		16.7		12.5		
Percent of sexes combined			85.7				14.3			

Cape Fear River

Age	Number of times spawned				Total	
	0		1			
Sex	M	F	M	F	M	F
IV	4	12	0	1	4	13
V	4	57	0	4	4	60
VI	0	11	2	3	2	14
Total	8	79	2	8	10	87
Percent by sex	80.0	90.8	20.0	9.2		
Percent of sexes combined	89.7		10.3			

Table 42. Age and spawning frequency of American shad from the Neuse River area and the Cape Fear River area, NC, 1988 (M=male, F=female).

Neuse River

Age	Number of times spawned						Total	
	0		1		2			
Sex	M	F	M	F	M	F	M	F
IV	21	11					21	11
V	9	28	3	13			12	41
VI	0	3	0	5			0	8
VII							0	0
VIII					0	1	0	1
Total	30	42	3	18	0	1	33	61
Percent by sex	90.9	68.9	9.1	29.5	0	1.6		
Percent of sexes combined	76.6		22.3		1.1			

Cape Fear River

Age	Number of times spawned				Total	
	0		1			
Sex	M	F	M	F	M	F
IV	14	31			14	31
V	16	71	3	8	19	79
VI	0	20	1	12	1	32
VII	0	1	0	6	0	7
Total	30	123	4	26	34	149
Percent by sex	88.2	82.6	11.8	17.4		
Percent of sexes combined	83.6		16.4			

virgin fish during this project are comparable to that reported by Street et al. (1975) for 1972-74 (50% range) and the 75.3% in 1983 (Winslow et al. 1985). The percentage of fish that had spawned more than once previously during the project ranged from 5.2%-14.2%. Johnson et al. (1981) reported similar percentages for hickory shad in 1977-79. These data probably do not accurately represent the hickory shad population due to gill nets being selective for females and the variability of market demand.

Contribution of Year Classes (Number of Individuals) to Harvest

The river herring age data from the Chowan River for 1985-1988 was utilized to calculate the number of individuals in the commercial harvest for each year class by week. These data were used because approximately 85% of the blueback herring and alewife landings usually occur in this system. Thus, it should best represent the total river herring population.

The blueback herring contribution of each year class to the harvest from the Chowan River pound net fishery by sex and by week for 1985 are shown in Table 43. The blueback herring harvest was dominated by the 1980 and 1979 year classes (ages V and VI), contribution 76.2% of the total. A lower percentage (4.0%) of three year old fish (1982 year class) was found in the 1985 harvest than reported by Winslow et al. (1985) for 1983 (7.9%) and 1984 (9.3%). The contribution of each year class by sex in summary for 1985 are represented in Table 44.

The 1986 blueback herring data by week and sex are presented in Table 45. Ages 5 and 6, 1982 and 1981 year classes, dominated the harvest, comprising 74.4%. The overall summary of the year classes by sex are presented in Table 46.

The 1983 and 1982 (age 4 and 5) year classes contributed 73.2% to the harvest in 1987. The weekly contribution of blueback herring by sex is presented in Table 47. An increase in three year olds (1984 year class) (7.0%) was noted, compared to that found in 1985 and 1986. Table 48 shows the year class contribution by sex for the 1987 harvest.

The pound net fishery year class contribution by sex and week for the 1988 season is shown in Table 49. Thirteen percent of the harvest was from the 1985 year class (3 year olds). This has increased

Table 43. Contribution of each year class to the blueback herring harvest for the Chowan River, NC, pound net fishery by sex, by week, 1985.

Week number	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
12	1982	22.2	44,235	-	0	44,235
	1981	11.1	22,118	-	0	22,118
	1980	66.7	131,543	80.0	88,471	220,014
	1979	-	0	20.0	22,118	25,118
13	1982	9.1	418,784	-	0	418,784
	1981	27.3	1,605,338	-	0	1,605,338
	1980	45.4	2,261,433	66.7	1,698,401	3,959,834
	1979	18.2	863,742	33.3	837,568	1,701,310
14	1982	7.1	256,885	-	0	256,885
	1981	35.8	1,323,947	14.3	256,885	1,580,832
	1980	50.0	1,782,141	42.9	784,927	2,567,068
	1979	7.1	256,885	28.5	526,003	782,888
	1978	-	0	14.3	256,885	256,885
15	1981	33.3	889,899	-	0	889,899
	1980	33.4	885,444	55.6	1,491,056	2,376,500
	1979	33.3	852,032	44.4	1,167,599	2,019,631
16	1982	9.1	198,596	-	0	198,596
	1981	9.1	198,596	-	0	198,596
	1980	63.6	1,429,897	77.8	1,390,178	2,820,075
	1979	18.2	410,433	22.2	397,194	807,627
17	1981	-	0	16.7	26,373	26,373
	1980	75.0	158,241	33.3	54,299	212,540
	1979	25.0	52,747	50.0	79,121	131,868
18	1981	7.1	448	18.2	895	1,343
	1980	57.2	3,611	36.4	1,817	5,428
	1979	35.7	2,343	36.4	1,813	4,156
Total			14,049,338		9,082,051	23,131,389

Table 44. Contribution of each year class of the blueback herring harvest from the Chowan River, NC, pound net fishery, by sex, for 1985.

Year class	No. of males	No. of females	Total number	Percent of total
1982	918,500	0	918,500	4.0
1981	4,040,346	284,153	4,324,499	18.7
1980	6,652,310	5,509,149	12,161,459	52.6
1979	2,438,182	3,031,416	5,469,598	23.6
1978	0	257,333	257,333	1.1
Total	14,049,338	9,082,051	23,131,389	

Table 45. Contribution of each year class to the blueback herring harvest for the Chowan River, NC, pound net fishery by sex, by week,1986.

Week number	Year class	Male %	Male Number of individuals	Female %	Female Number individuals	Total number of individuals
12	1983	14.3	50,795	-	-	50,795
	1982	42.9	152,385	100	50,795	203,180
	1981	28.5	100,320	0	0	100,320
	1980	14.3	51,899	0	0	51,899
13	1982	14.3	279,054	20.0	279,054	558,108
	1981	57.1	1,101,529	60.0	849,295	1,950,824
	1980	28.6	558,108	20.0	279,054	837,162
14	1092	25.0	343,277	8.3	171,638	514,915
	1981	50.0	686,553	25.1	506,742	1,193,295
	1980	25.0	343,277	33.3	702,157	1,045,434
	1979	-	-	33.3	700,856	700,856
15	1982	28.6	205,582	38.5	501,107	706,689
	1981	42.8	302,452	15.3	201,928	504,380
	1980	28.6	197,968	38.5	490,521	688,389
	1979	-	-	7.7	98,984	98,984
16	1982	25.0	158,581	14.4	79,290	237,871
	1981	75.0	475,743	42.8	242,827	718,570
	1980			42.8	234,096	234,096
17	1982	-	-	11.2	133,558	133,558
	1981	57.1	524,580	44.4	534,233	1,076,813
	1980	42.9	409,022	44.4	540,303	949,325
18 and 19	No sample					
20	1983	9.1	381	-	-	381
	1982	36.4	1,523	11.1	381	1,904
	1981	36.4	1,549	55.6	1,928	3,477
	1980	18.1	785	33.3	1,143	1,928
Total			5,963,363		6,599,790	12,563,153

Table 46. Contribution of each year class to the blueback herring harvest from the Chowan River, NC, pound net fishery, by sex, for 1986.

Year class	Number of males	Number of females	Total number	Percent of total
1983	51,176	0	51,176	0.4
1982	1,140,402	1,215,823	2,356,225	18.8
1981	3,210,726	2,336,953	5,547,679	44.1
1980	1,561,059	2,247,174	3,808,233	30.3
1979	0	799,840	799,840	6.4
Total	5,963,363	6,599,790	12,563,153	

Table 47. Contribution of each year class to the blueback herring harvest for the Chowan River, NC, pound net fishery, by sex, by week, 1987.

Week number	Year class	Male %	Male Number of individuals	Female %	Female Number of individuals	Total number of individuals
12	1983	28.6	7,402	0	0	7,402
	1982	57.1	14,895	33.3	1,784	16,679
	1981	14.3	3,468	33.3	1,784	5,352
	1980	0	0	33.3	1,784	1,784
13	No sample					
14	1984	9.1	8,580	0	0	8,580
	1983	81.8	79,747	50.0	17,590	97,337
	1982	9.1	8,580	25.0	8,580	17,160
	1981	0	0	25.0	8,580	8,580
15	1984	14.3	53,741	0	0	53,741
	1983	42.8	165,063	75.0	507,185	672,248
	1982	28.6	107,484	16.6	107,484	214,968
	1981	0	0	8.4	53,741	53,741
	1980	14.3	53,741	0	0	53,741
16	1984	14.3	73,905	13.3	147,811	221,716
	1983	57.1	314,098	40.0	464,549	778,647
	1982	14.3	73,905	20.0	221,717	295,622
	1981	14.3	73,905	20.0	229,496	303,401
	1980	0	0	6.7	73,905	73,905
17	1984	0	0	8.3	37,085	37,085
	1983	66.7	211,917	41.8	185,427	397,344
	1982	22.2	74,171	33.3	166,884	241,055
	1981	11.1	37,085	8.3	37,085	74,170
	1980	0	0	8.3	37,085	37,085
18	1983	72.7	88,781	42.8	32,315	121,096
	1982	18.2	10,205	28.6	20,409	30,614
	1982	9.1	10,205	28.6	20,895	31,100
19	1984	7.1	115,526	0	0	115,526
	1983	35.7	587,259	33.3	239,939	827,198
	1982	28.6	477,509	50.0	346,579	824,088
	1981	21.5	353,800	16.7	115,526	469,326
	1980	7.1	115,526	0	0	115,526
Total			3,120,598		3,085,219	6,205,817

Table 48. Contribution of each year class to the blueback herring harvest from the Chowan River, NC, pound net fishery by sex, for 1987.

Year class	Number of males	Number of females	Total number	Percent of total
1984	251,752	184,896	436,648	7.0
1983	1,454,267	1,447,005	2,901,272	46.8
1982	766,749	873,437	1,640,186	26.4
1981	478,563	467,107	945,670	15.2
1980	169,267	112,774	282,041	4.6
Total	3,120,598	3,085,219	6,205,817	

Table 49. Contribution of each year class to the blueback herring harvest for the Chowan River, NC, pound net fishery, by sex, by week 1988.

Week number	Year class	Male %	Male Number of individuals	Female %	Female Number of individuals	Total number of individuals
12	1984	100	9,300	-	0	9,300
13	1985	23.1	16,281	-	0	16,281
	1984	53.8	38,947	33.3	10,854	49,801
	1983	15.4	11,125	50.0	16,567	27,692
	1982	-	0	16.7	5,427	5,427
	1981	7.7	5,427	-	0	5,427
14	1985	8.3	64,098	-	0	64,098
	1984	58.4	448,687	40.0	128,196	576,883
	1983	25.0	189,089	40.0	130,867	319,956
	1982	8.3	64,098	20.0	64,098	128,196
15	1985	30.0	8,582	-	0	8,582
	1984	50.0	14,680	100	17,432	32,112
	1983	-	0	-	0	0
	1982	20.0	5,999	-	0	5,999
16	1985	50.0	285,800	-	0	285,800
	1984	37.5	219,453	100	219,113	438,566
	1983	-	0		0	0
	1982	12.5	71,450		0	71,450
17	1985	14.3	211,165	-	0	211,165
	1984	64.3	930,421	16.7	105,579	1,036,000
	1983	21.4	316,739	50.0	321,766	638,505
	1982	-	0	-	0	0
	1981	-	0	33.3	216,187	216,187
18	1985	11.1	49,583	-	0	49,583
	1984	66.7	297,500	71.4	247,917	545,417
	1983	22.2	102,083	28.6	102,472	204,555
19	1985	33.3	215,242	-	0	215,242
	1984	55.6	338,238	40.0	283,906	622,144
	1983	11.1	69,637	40.0	278,549	348,186
	1982	-	0	20.0	143,143	143,143
20	1985	14.3	40,866	-	0	40,866
	1984	57.1	163,464	28.6	81,732	245,196
	1983	28.6	81,732	57.1	160,910	242,642
	1982	-	0	14.3	40,866	40,866
Total			4,269,686		2,575,581	6,845,267

considerable over the previous three years. It should be noted that the 1985 commercial harvest was the highest since 1972 and the juvenile abundance index was above the average. These two factors probably indicate a strong year class was produced in 1985. During the 1988 season, the year classes 1984 and 1983 accounted for 78.0% of the total Chowan River harvest. An overall summary of the blueback herring year classes by sex for 1988 is presented in Table 50.

Data are shown in Table 51 for alewife contribution of each year class by sex and by week for 1985. Ages IV and V (1981 and 1980 year classes) were dominant, contributing 74.8% of the harvest and good recruitment of the 1982 year class (3 year olds) was noted, 12.5%. The year class summary for alewife during 1985, by sex, is presented in Table 52.

The number of individuals by week and sex for 1986, from the Chowan River pound net fishery are shown in Table 53. The highest percentage of the alewife harvest was comprised of the 1982 and 1981 year classes, contributing 78.8% of the total. Over 12% of the 1986 harvest was accounted for by the 1983 year class as shown in the summary Table 54.

The 1987 alewife harvest was comprised of contributions from the 1980-1984 year classes. These contributions are shown in Table 55 by week and by sex for the 1987 season. The majority of the alewife harvest, 85.3%, was contributed by the 1983 and 1982 year classes. Again in 1987, three year old fish made a considerable contribution (13.4%) to the harvest. Table 56 shows the alewife summary by year class and sex for 1987.

The weekly alewife contribution by year class an sex for the 1988 season is presented in Table 57. Approximately 80% of the total year class contribution in 1988 was made up of the 1984 and 1983 year classes (4 and 5 year olds). A small percentage (0.2%) of two year olds (1986 year class) was in the harvest. The 1985 year class (3 year old) contributed 13.4% to the total alewife harvest in 1988. The percentage of alewife three years old during the project, 1985-1988, were very similar. These percentages of three year old fish are higher than those reported by Winslow et al. (1985) for 1983 (2.6%) and 1984 (2.7%). A summary of year class contribution by sex for alewife in 1988 is shown in Table 58.

Table 50. Contribution of each year class of the blueback herring harvest for the Chowan River, NC, pound net fishery by sex, from 1988.

Year class	Number of males	Number of females	Total number	Percent of total
1985	891,617	-	891,617	13.0
1984	2,460,690	1,094,729	3,555,419	52.0
1983	770,405	1,011,131	1,781,536	26.0
1982	141,547	253,534	395,081	5.8
1981	5,427	216,187	221,614	3.2
Total	4,269,686	2,575,581	6,845,267	

Table 51. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery, by sex, by week 1985.

Week number	Year class	Male %	Male Number of individuals	Female %	Female Number of individuals	Total number of individuals
10	1982	11.1	13,882	-	0	13,882
	1981	33.3	41,647	35.7	70,042	111,689
	1980	55.6	70,105	57.1	109,165	179,270
	1979	-	0	7.2	13,882	13,882
11	1982	-	0	-	0	0
	1981	66.7	50,627	37.6	37,930	88,557
	1980	33.3	24,467	43.7	43,537	68,004
	1979	-	0	18.7	18,750	18,750
12	1982	9.1	16,849	-	0	16,849
	1981	63.6	121,906	75.0	101,093	222,999
	1980	27.3	49,780	25.0	33,697	83,477
13	1981	33.3	1,400,760	50.0	1,400,760	2,801,520
	1980	33.4	1,400,760	50.0	1,400,760	2,801,520
	1979	33.3	1,400,760	-	0	1,400,760
14	1982	50.0	1,388,786	-	0	1,388,786
	1981	-	0	-	0	0
	1980	50.0	1,388,786	100	694,393	2,083,179
Total			7,369,115		3,924,009	11,293,124

Table 52. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery by sex, from 1985.

Year class	Number of males	Number of females	Total number	Percent of total
1982	1,419,517	0	1,419,517	12.5
1981	1,614,940	1,609,825	3,224,765	28.6
1980	2,933,898	2,281,552	5,215,450	46.2
1979	1,400,760	32,632	1,433,392	12.7
Total	7,369,115	3,924,009	11,293,124	

Table 53. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery, by sex, by week 1986.

Week number	Year class	Male %	Male Number of individuals	Female %	Female Number of individuals	Total number of individuals
12	1982	44.4	94,906	8.3	12,021	106,927
	1981	44.4	98,703	75.0	107,621	206,324
	1980	11.2	24,043	16.7	24,676	48,719
13	1983	18.2	380,473	8.3	182,627	563,100
	1982	36.4	743,553	41.7	923,877	1,667,430
	1981	45.4	913,135	33.3	740,120	1,653,255
	1980	-		16.7	365,254	365,254
Total			2,254,813		2,356,196	4,611,009

Table 54. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery by sex, from 1986.

Year class	Number of males	Number of females	Total number	Percent of total
1983	380,473	182,627	563,100	12.2
1982	838,459	935,898	1,774,357	38.5
1981	1,011,838	847,741	1,859,579	40.3
1980	24,043	389,930	413,973	9.0
Total	2,254,813	2,356,196	4,611,009	

Table 55. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery by sex, by week, from 1987.

Year class	Number of males	Number of females	Total number	Percent of total
1984	251,752	184,896	436,648	7.0
1983	1,454,267	1,447,005	2,901,272	46.8
1982	766,749	873,437	1,640,186	26.4
1981	478,563	467,107	945,670	15.2
1980	169,267	112,774	282,041	4.6
Total	3,120,598	3,085,219	6,205,817	

Table 56. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery, by sex for 1987.

Year class	Number of males	Number of females	Total number	Percent of total
1984	26,029	0	26,029	13.4
1983	60,659	56,902	117,561	60.4
1982	14,351	34,069	48,420	24.9
1981	1,490	0	1,490	0.7
1980	0	1,076	1,076	0.6
Total	102,529	92,047	194,576	

Table 57. Contribution of each year class to the alewife harvest from the Chowan River, NC, pound net fishery, by sex, by week 1988.

Week number	Year class	Male %	Male Number of individuals	Female %	Female Number of individuals	Total number of individuals
11	1986	5.0	343	-	0	343
	1985	30.0	2,106	-	0	2,106
	1984	25.0	1,752	80.0	1,355	3,107
	1983	25.0	1,761	20.0	343	2,104
	1982	15.0	1,028	-	0	1,028
12	1985	41.7	1,902	9.1	385	2,287
	1984	50.0	2,268	63.6	2,677	4,945
	1983	-	0	9.1	385	385
	1982	8.3	385	18.2	771	1,156
13	1985	33.3	16,507	-	0	16,507
	1984	33.4	16,966	33.3	16,507	33,473
	1983	33.3	16,941	66.7	33,732	50,673
14	No sample					
15	1984	50.0	9,532	-	0	9,532
	1983	50.0	9,532	50.0	9,532	19,064
	1982	-	0	50.0	9,532	9,532
Total			81,023		75,219	156,242

Table 58. Contribution of each year class of the alewife harvest from the Chowan River, NC, pound net fishery by sex for 1988.

Year class	Number of males	Number of females	Total number	Percent of total
1986	343	0	343	0.2
1985	20,515	385	20,900	13.4
1984	30,518	20,539	51,057	32.7
1983	28,234	43,992	72,226	46.2
1982	1,413	10,303	11,716	7.5
Total	81,023	75,219	156,242	

DEVELOPMENT OF MANAGEMENT AND RESEARCH ALTERNATIVES

The North Carolina river herring fishery is the largest on the Atlantic Coast. The overall status of the fishery could be determined from the condition of the stocks captured and produced in North Carolina. Commercial landings have been on a declining trend since 1970. The 1985 landings were the highest in the past 14 years, but the 1987 landings were the lowest on record (Table 2). Environmental and water conditions may have been the major contributions for the low landings since fishermen stated that a lot of fish were in the system. In the late 1960s and early 1970s the heavy exploitation of the stocks by the foreign offshore fishery attributed to the present poor state of the stocks and the poor reproductive success since that time. Determining water quality has probably contributed to depressed reproductive success in the Albemarle Sound area river herring stocks since reduction of foreign fishing in the mid-1970s.

Discussion

Water quality determination has been experienced in the Albemarle Sound area, especially the Chowan River and western Albemarle Sound as a result of eutrophication and other factors. Though no severe blue-green algae blooms have occurred in late 1980s, severe blooms in the late 1970s and early 1980s may have had adverse effects on the growth and production of juvenile alosids, as well as other species. Everett (1983) reported that preliminary studies conducted on the effects of pulp mill effluent on adult river herring indicated avoidance of the effluent by spawning adults. Toxic effects on juveniles were also indicated. The spring of 1986 was characterized by low river flow and 1988 was a moderate flow year. Fishermen on the Chowan River complained both seasons about the pulp mill effluent remaining in the system for a prolonged period. Thus, the fishermen felt that this was the reason river herring landings were very low (Table 2). Based on Everett's (1983) findings, the pulp mill effluent remaining in the Chowan River for a considerably longer period of time than normal in 1986 and 1988, could have attributed to the low harvest. Rulifson et al. (1986) has reported that river flow controls the development of the zooplankton community in the Roanoke River and Albemarle area. Thus, the coinci-

dence of food with larvae at the appropriate time is related to flow. Therefore, if adequate zooplankton is not produced for whatever reason, starvation of larvae or a reduction in growth may occur. Additional research on avoidance and possible food chain interruption beyond the Division assessment activities are needed to further address these issues.

Criteria need to be established for the designation of alosid spawning and nursery area in the Albemarle Sound and Currituck Sound areas to enable these areas to be protected from alteration and pollution. A considerable portion of the alosid spawning and nursery areas are in inland waters and thus fall under the jurisdiction of the North Carolina Wildlife Resources Commission (WRC). These areas are critical to the preservation of alosids, as well as other species. Some species are at depressed levels and every effort to protect these critical habitats utilized by these species and others should be made.

ACKNOWLEDGEMENTS

Appreciation is extended to all Marine fisheries field personnel who aided in the collection of American shad scale samples. Special appreciation goes to Marine Biologist Lynn T. Henry, Marine Fisheries Technician Stephen Taylor, and Temporary Technician Todd Ball, whose field and laboratory work made this project and report possible. Maury Wolff reviewed the manuscript and provided many valuable suggestions. I also thank D. Willis and D. Tootle for typing the manuscript. Appreciation is extended to the commercial and recreational fishermen and seafood dealers who cooperated with this project.

LITERATURE CITED

Everett, G.
1983. The impact of pulp mill effluent on the Chowan River herring fishery. N.C. Dept. Nat. Res. and Community Develop., Div. Environ. Mgt., Water Qual. Plan. Branch. 18 p.

Henry, L. T.
1987. albemarle Sound gill net study. Compl. Rep., Proj. AFS-23. Nat. Res. and Community Develop., Div. Mar. Fish., Morehead City, NC.

Johnson, H.B., B.F. Holland, Jr., and S.G. Keefe.
1977. Anadromous research program, northern coastal area. Completion Rep. Proj. AFCS-11, N.C. Dept. Nat. and Econ. Res., Div. Mar. Fish. 97 + 40 p.

Johnson, H.B., S.E. Winslow, D.W. Crocker, B.F. Holland, Jr., J.W. Gillikin, and D.L. Taylor.
1981. Part I. North Carolina, p. 1-191. In biology and management of mid-Atlatnic anadromous fishes under extended jurisdiction. N.C. Dept. Nat. Res. and Community Develop., Div. Mar. Fish. (Spec. Sci. Rep. No. 36) and VA Inst. Mar. Sci. (Spec. Rep. No. 236 in Appl. Mar. Sci. and Ocean Eng.), 119 + 204 p.

Ketchen, K.S.
1950. Stratified subsampling for determining age distributions. Trans. Am. Fish. Soc., 79:205-212.

Robson, D.S., and D.G. Chapman.
1961. Catch curves and mortality rates. Trans. Amer. Fish. Soc. 90(2):181-189.

Rulifson, R.A., D.W. Stanley, and J.E. Cooper.
1986. Food and feeding of young striped bass in Roanoke River and western Albemarle Sound, North Carolina, 1984-1985. N.C. Dep. Nat. Res. and Community Develop., Div. Mar. Fish. Compl. Rep. AFS-24.

Street, M.W., P.P. Pate, Jr., B.F. Holland, Jr., and A.B. Powell.
1975. Anadromous fisheries research program, northern coastal region. Compl Rep., Proj. AFCS-8, N.C. Dept. Nat. and Econ. Res., Div. Mar. Fish., 193 + 62 p. + Append.

Winslow, S.E., N.S. Sanderlin, G.W. Judy, J.H. Hawkins, B.F. Holland, Jr., C.A. Fischer, and R.A. Rulifson.
1983. North Carolina anadromous fisheries management program. Compl. Rep., Proj. AFCS-17, N.C. Dept. Nat. Res. and Community Develop., Div. Mar. Fish., 402 p.

Winslow, S.E., S.C. Mozley, and R.A. Rulifson.
1985. North Carolina anadromous fisheries management program. Compl. Rep. Proj. AFCS-22. N.C. Dept. Nat. Res. and Community Develop., Div. Mar. Fish., 207 p.

APPENDIX

STATUS OF THE AMERICAN SHAD, *ALOSA SAPIDISSIMA* (WILSON), IN NORTH CAROLINA

by

Sara E. Winslow

North Carolina Department of Natural Resources
and Community Development

Division of Marine Fisheries
P.O. Box 769
Morehead City, NC 28557

Completion Report for Job 5, Project AFC-27

April 1989

This project was supported under the Anadromous Fish Conservation Act (PL 89-304, as amended) and funded, in part, by the U.S. Department of Commerce, National Marine Fisheries Service, under Project No. AFC-27

TABLE OF CONTENTS

INTRODUCTION

The American shad, Alosa sapidissima (Wilson), has historically supported a significant fishery in North Carolina, as well as in other Atlantic coast states. The native Americans and European colonists who settled along the extensive sounds and rivers found shad to be a valuable food source. Shad which ascended the streams in large numbers during the spring were caught, salted and smoked, and served as an important seasonal food.

Since the late 1800s North Carolina has consistently ranked in the top three states for landings of American shad along the east coast (Walburg and Nichols 1967). The peak reported landings in North Carolina occurred in 1897 at over 4 million kilograms (9 million pounds), but in recent decades the landings have declined significantly (Sholar 1977a, Johnson 1982). An increase in landings was noted in 1981-1984, but these were not significant, even when compared to the landings of the 1960s (Table 1). Landings since the late 1880s, along the entire Atlantic coast of the United States have shown a continued decline (Atlantic States Marine Fisheries Commission 1985). Since the late 1800s, overfishing, construction of dams, and pollution have been blamed for the decline in landings levels (Cheney 1896, Blackford 1916, Roelofs 1951, Talbot 1954, Chittenden 1969, Klauda et al. 1976, and Boreman 1981).

Shad are pursued extensively in the spring, both commercially and recreationally. In recent years, the commercial importance of shad has decreased in some areas, while the species supports an increasingly important recreational fishery in others. Current statewide landings are approximately 94,432 kg (208,000 pounds) annually. This annual poundage decreased from that reported by Johnson (1982), but increased to that which Sholar (1977a) reported (Table 1).

The American shad is anadromous and the largest member of the family Clupeidae in North America. American shad is also known by other common names such as "white shad," "roe shad," and just "shad," and is one of the best-known fishes on the Atlantic coast. The young spend their first summer in nursery areas near their spawning area and migrate to the ocean in the fall. After reaching sexual maturity (3 to 6 years), they return to their natal river to spawn (Cheek 1968). It is

Table 1. American shad landings and value in North Carolina, 1880-1988 (from Chestnut and Davis 1975 and N.C. Division of Marine Fisheries, Morehead City).

Year	Landings X 1000 kg	Landings X 1000 lbs	Value X 1000 $	Year	Landings X 1000 kg	Landings X 1000 lbs	Value X 1000 $
1880	1,462	3,221	330	1957	379	837	209
1887	2,171	4,783	298	1958	223	493	123
1888	2,599	5,725	295	1959	190	419	105
1889	2,452	5,403	280	1960	230	347	127
1890	2,640	5,815	306	1961	305	673	168
1896	4,014	8,843	417	1962	347	765	191
1897	4,069	8,963	363	1963	314	693	168
1902	2,981	6,567	385	1964	290	640	127
1904	1,466	3,230	313	1965	485	1,069	214
1908	1,781	3,924	373	1966	318	701	170
1918	752	1,657	377	1967	352	777	155
1923	1,075	2,370	583	1968	382	842	128
1927	1,083	2,387	475	1969	326	719	137
1928	1,415	3,118	573	1970	432	953	193
1929	868	1,913	350	1971	308	680	117
1930	532	1,172	210	1972	212	468	112
1931	400	883	139	1973	145	321	85
1932	419	925	126	1974	167	369	106
1934	578	1,274	193	1975	109	241	83
1936	497	1,095	177	1976	75	167	65
1937	316	698	106	1977	54	121	55
1938	468	1,032	165	1978	182	402	145
1939	389	859	137	1979	126	278	122
1940	363	801	120	1980	90	199	88
1945	414	912	199	1981	159	351	190
1950	499	1,100	340	1982	187	412	183
1951	564	1,244	300	1983	202	446	187
1952	671	1,479	377	1984	265	585	241
1953	539	1,188	293	1985	149	330	152
1954	656	1,445	258	1986	169	374	229
1955	294	649	160	1987	148	328	215
1956	350	773	193	1988	117	259	149

during this spawning migration that they are susceptible to commercial and recreational fisheries. Fish that escape the fishery and successfully spawn return to the ocean to feed and grow, and may return the following year to spawn (Cheek 1968). However, American shad native to rivers south of North Carolina rarely spawn more than once; the majority of those fish die after spawning (Leggett 1969).

American shad are distributed along the Atlantic coast from the St. Lawrence River, Canada, to the Tomaka River, Florida and are most abundant from Connecticut to North Carolina (Walburg and Nichols 1967). Shad ascend all coastal rivers in North Carolina and are most abundant in Albemarle and Pamlico sounds, Roanoke River, Chowan River, Tar-Pamlico River, Neuse River, Northeast Cape Fear River and Cape Fear River. The fishery throughout the coastal area employs drift gill nets, anchor gill nets, pound nets, haul seines, bow nets, fish wheels, and hook and line (Figure 1).

Considerable research has been conducted on American shad in North Carolina, particularly in the Neuse River (Walburg 1957) and Cape Fear River (Davis and Cheek 1966; Nichols and Louder 1970). Some offshore work was conducted on shad during 1968-1971 (Holland and Yelverton 1973). In the early 1970s, the North Carolina Division of Marine Fisheries began anadromous fish assessments in each of the major coastal sounds and river systems. Data have been collected on spawning areas, nursery areas, juvenile abundance, adult abundance, and age composition of the catch, and the commercial and recreational fisheries for each area. Table 2 provides a list of Division reports concerning American shad.

This report will consolidate and discuss American shad data for the period 1972-1987 for the Albemarle Sound area. The North Carolina Division of Marine Fisheries (DMF) most extensive shad database comes from this area. Data concerning spawning areas, juvenile abundance and growth, nursery areas, year class abundance, and tagging is combined and analyzed to determine stock status and trends for the American shad population spawning in the Albemarle Sound area.

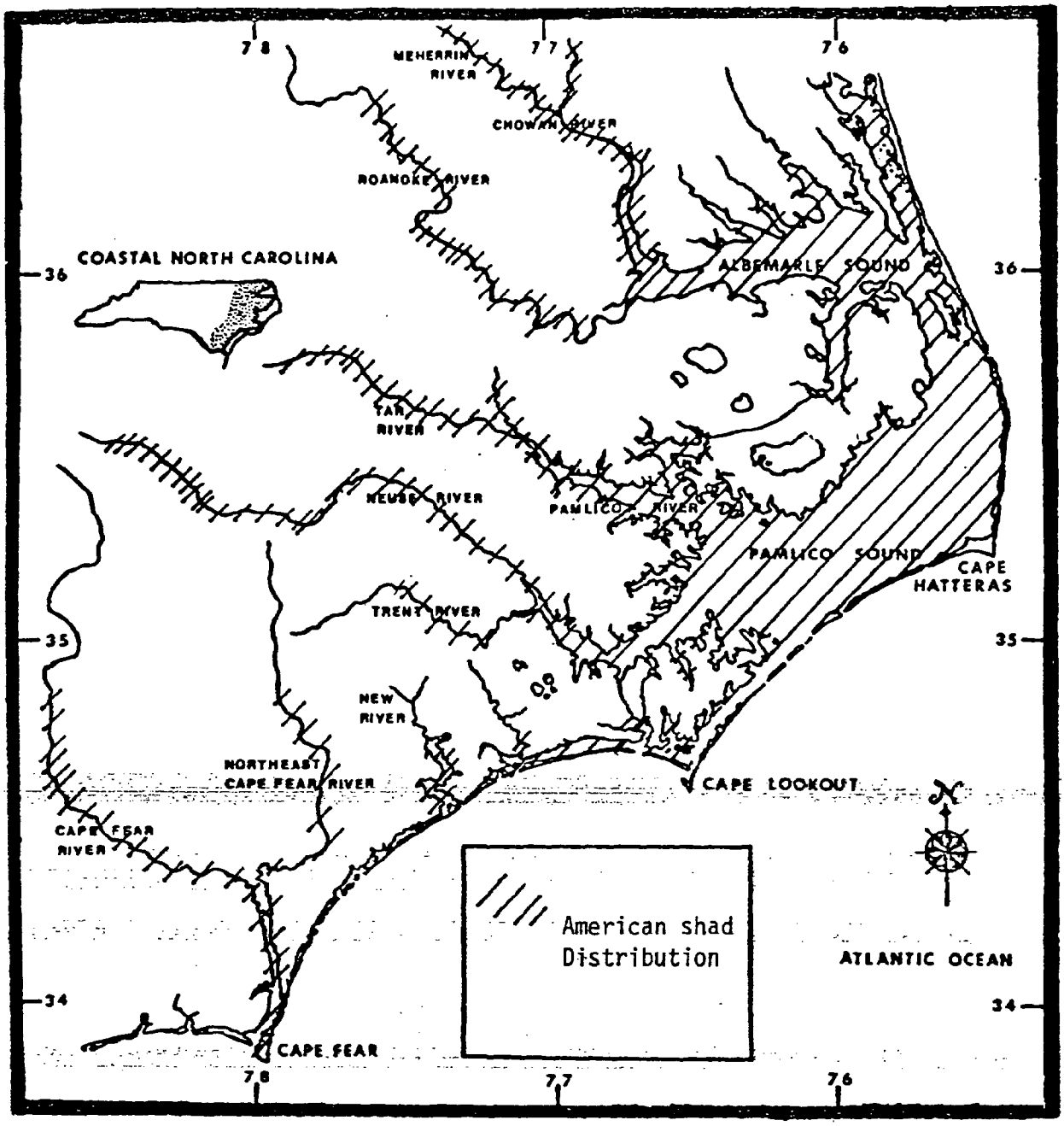


Figure 1. Distribution of American shad in North Carolina.

THE ALBEMARLE SOUND AREA

Albemarle Sound, located in the northeastern portion of North Carolina, is a shallow estuary extending 88.5 km (55 mi) in an east-west direction, averaging 11.3 km (7 mi) wide and 4.9-6.1 m (16-20 ft) deep (Figure 2). Ten rivers drain into the Albemarle Sound, which joins Pamlico Sound through Croatan and Roanoke sounds, and in turn, empties into the Atlantic Ocean via Oregon Inlet. Currituck Sound joins the Albemarle from the northeast. Although the headwaters of the Roanoke River are located in the Appalachian foothills of Virginia, most of the tributaries to the Sound originate in extensive coastal swamps. The Roanoke and Chowan rivers are the principal tributaries, and areas of these rivers are known to function as American shad spawning areas (Street et al. 1975; Johnson et al. 1981; Winslow et al. 1983, 1985).

The Roanoke River is a relatively narrow stream which follows a winding course to its mouth below Plymouth, where it enters western Albemarle Sound. A dam was constructed in 1955 on the river at Roanoke Rapids, NC, 220.6 km (137 mi) from the mouth (Carnes 1965). However, American shad have not been reported above the Scotland Neck bridge at 167.3 km (104 mi) for many years (Baker 1968).

The Chowan River, formed by the junction of the Blackwater and Nottoway rivers near the North Carolina-Virginia border, flows 88.5 km (55 mi) to northwestern Albemarle Sound. The Black River watershed is entirely in the Coastal Plain while the Nottoway River watershed lies in the Coastal Plain as well as the Piedmont (North Carolina Department of Natural Resources and Community Development 1982). The Meherrin River is one of the major tributaries of the Chowan River and originates in the Piedmont area of Virginia. The river follows a southeasterly course after entering North Carolina and meets the Chowan River 65.9 km (41 mi) above the mouth. The North Carolina portions of the Chowan and Meherrin rivers are free of obstructions that may restrict adult shad during their spawning run.

A more detailed description of Albemarle Sound and its tributaries is given by Street et al. (1975) and Winslow et al. (1983, 1985).

Table 2. North Carolina Division of Marine Fisheries anadromous fish projects and reports concerning American shad in North Carolina.

Project	Years	References
AFCS-8 *	1971-1974	Street et al. 1975
AFC-9	1973-1975	Sholar 1975
AFCS-10	1974-1976	Marshall 1976
AFCS-11 *	1974-1976	Johnson et al. 1977
AFCS-12	1975-1977	Sholar 1977b
AFCS-13	1976-1979	Hawkins 1980
AFCS-15	1977-1979	Fischer 1980
AFCS-9 *	1976-1979	Johnson et al. 1981
AFCS-16 *	1980-1983	Winslow et al. 1983
AFCS-22 *	1983-1985	Winslow et al. 1985
AFC-27-1 *	Jul 1985-Jun 1986	Winslow 1987
AFC-27-2 *	Jul 1986-Dec 1987	Winslow 1988
Summary report *		Sholar 1977a
Summary report *		Johnson 1982
Special Scientific Report No. 24	Feb 1968-Jun 1971	Holland and Yelverton 1973

*Denotes reports with data pertaining to Albemarle Sound area, N.C.

THE SHAD FISHERIES

The Albemarle Sound area shad fishery can be divided into two sections: the commercial fishery and the recreational (inland) fishery. Although some of the gears used are employed by both fisheries, they are treated separately because the fisheries are administered by two separate agencies. The commercial fishery is under the jurisdiction of the Division of Marine Fisheries, while the inland section is under the North Carolina Wildlife Resources Commission. These areas are described in North Carolina Fisheries Regulations for Coastal Waters, 1988, (North Carolina Department of Natural Resources and Community Development, Div. Mar. Fish 1988).

There are four principal commercial fishing gears used in the Albemarle Sound area to capture shad: anchor gill nets, stake gill nets, pound nets, and haul seines. These gears are essentially the same as those of the late 1800s (Smith 1907), although the length of these gears has changed somewhat. In 1896, gill nets averaged 18.3 m (20 yds) long and were set in strings of 50 to 500 nets with 133.3 to 139.7 mm (5-1/4 to 5-1/2 in) stretched mesh (Walburg and Nichols 1967). Gill nets now average 3.0 m to 24.4 m (10 to 80 yds) in length, and mesh sizes range from 101.6 to 133.3 mm (4 to 5-1/2 in) stretched mesh.

Pound nets during the late 1800s were set along the shores with 1 to 25 pounds or hearts in each string. Since the 1960s, the majority of the pound nets have been set in the rivers, and the leads seldom exceed 183 m (200 yd) in length. The haul seines that were used to catch shad in 1896 averaged 2275 m (2,500 yd) long, 3.7 - 4.9 m (12 to 16 ft) deep and had a stretched mesh size of 50.8 mm (2 in) in the bunt and 76.2 mm (3 in) in the wings. The haul seines of the 1950s and 60s in the Albemarle area averaged 137.2 m (150 yd) long (Walburg and Nichols 1967).

Gill nets have historically contributed the highest percentage of the landings; since they are fished for the larger roe (female) shad. Several other types of commercial gear are used: bow nets, fyke nets, drift gill nets, and fish wheels. These gears have contributed very little to the total harvest in the Albemarle area. Most of the harvest,

past and present, is handled through dealers in Elizabeth City, Columbia, Manns Harbor, Wanchese, Colerain, and the Chowan County areas (Figure 2) and shipped to northern markets.

The inland fishery gears are composed of bow nets, anchor and drift gill nets, and hook and line. A bow net resembles a large landing net with an oval opening up to 3.0 m (10 ft) in width and 3.7 m (12 ft) in length. Bow nets are usually fished from the bank or from a boat. Drift gill nets are approximately 18.3 -12.2 m (20-40 yd) in length and are fished in coastal rivers by drifting downstream with the current. Some hook and line effort for shad occurs in the upper Roanoke, Chowan, (Nottoway and Blackwater rivers) and Meherrin rivers. Baker (1968) provided an estimate of approximately 3,900 American shad from these areas by these gears in 1966-1967. The shad catches that result from these gears cannot be quantified, but are probably insignificant. Catch from these gears (bow net and hook and line) will not be considered further in this report.

During the late 1970s, an ocean fishery for American shad began to develop along the Outer Banks and in the southern portion of the state. The commercial landings and values for the Atlantic Ocean are shown in Table 3. The major gears are beach haul seines, gill nets, and trawls. The beach haul seine accounted for the majority of the landings 1978, 1981, 1982 and 1984. The landings from gill nets dominated the other years, 1979, 1980, 1983 and 1985-1987. From 1978 to 1985, the areas north of Cape Hatteras, North Carolina, accounted for the majority of the state's ocean shad landings. In 1986, a significant ocean gill net fishery for shad developed in the southern portion of the state off the Cape Fear River. Of the total Atlantic Ocean landings in 1986 and 1987, 87.6% and 94.2% respectively, were taken from this area.

HISTORY OF SHAD FISHERY

There are a number of early records of the shad fishery in the Albemarle Sound area and in some other water bodies in North Carolina (Earll 1887; Skinner 1846; Ward 1882; Yarrow 1874; True 1887). McDonald (1887) reported on the fishery in the Cape Fear River, Neuse River, and Albemarle Sound in 1880. Stevenson (1899) and Cobb (1906) provided the only shad harvest statistics available for individual North Carolina

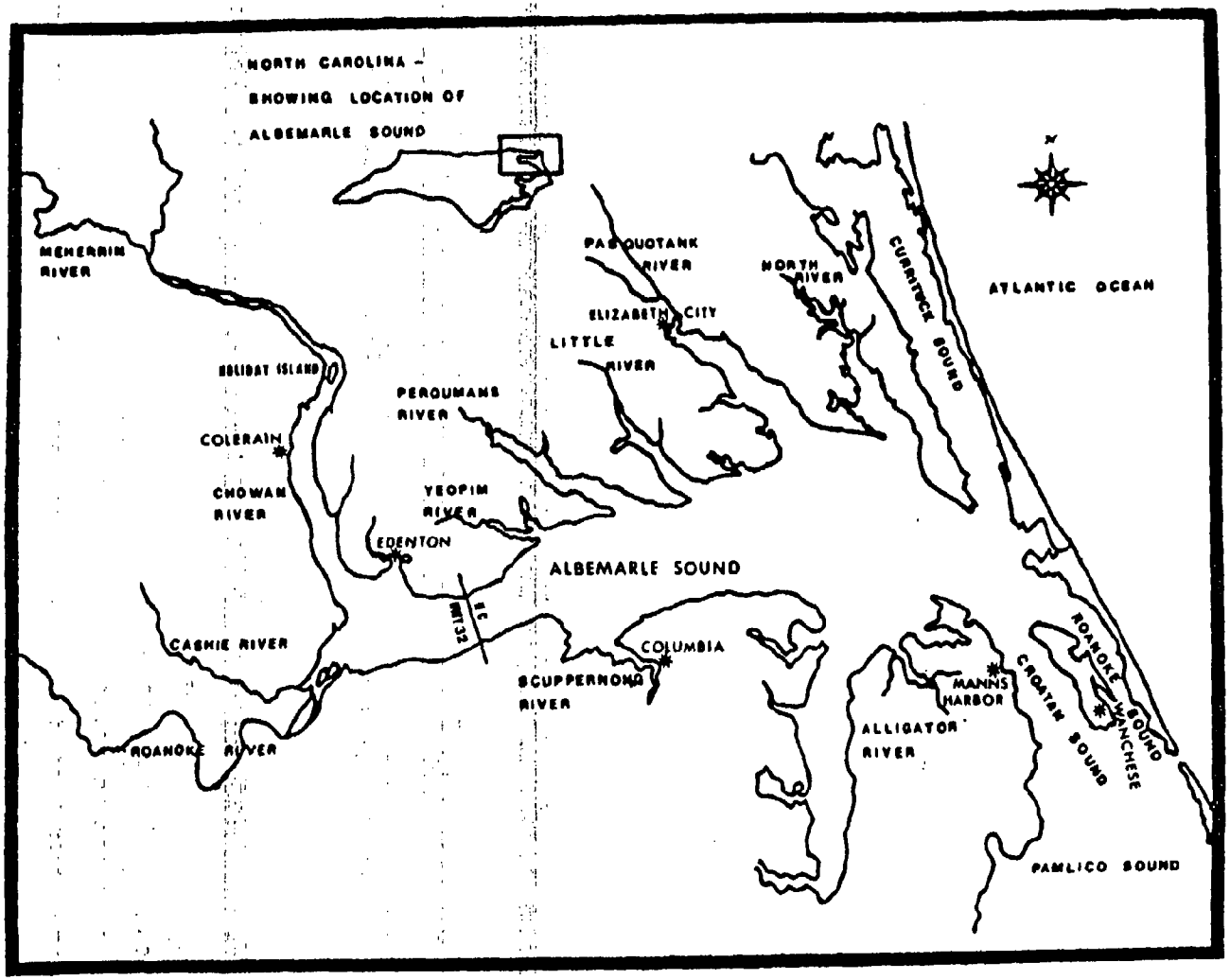


Figure 2. Albemarle Sound area and its tributaries, North Carolina.

water bodies, for 1896 and 1904. Chestnut and Davis (1975) gave a synopsis of American shad landings by gear for the state (1887-1971) and by county (1889-1968).

In 1896, the American shad harvest from the Albemarle Sound was among the most important on the Atlantic coast. Historically, Virginia usually ranked first and North Carolina second (Walburg and Nichols 1967), but by 1960, the landings for the entire state only ranked third along the east coast. Stevenson (1899) reported a harvest of 2,162,998 kg (4,764,314 lb) in 1896 for the Albemarle Sound area. During 1904, Cobb (1906) reported 52,401 kg (115,421 lb) for the same area, a decline of 97.6%. Landings reported by Chestnut and Davis (1975) have fluctuated widely over the years, but show a continued decline since the late 1800s (Table 1). Table 3 shows landings and value of harvest for North Carolina and Albemarle Sound area during 1972-1987. The portion of the harvest contributed by the Albemarle Sound area and its value are also shown. During 1972-1987, landings have averaged about 94,432 kg (208,000 lb), with a range of 54,934-265,590 kg (121,000-585,000 lb).

The shad fisheries of the Albemarle Sound area became important about 1869, with the greatest development coming in the next 25 years (Walburg and Nichols 1967). Until 1860, haul seines were the only gear used and for some years continued to be the principal gear (Cobb 1906). Pound nets were first used in the Albemarle area in 1870 (Cobb 1906). Their popularity grew until 1896, then declined because of cost of the gear and its operations, as well as a decline in harvest (Walburg and Nichols 1967). In the late 1800s and early 1900s, the commercial harvest season normally ran from early February to mid-April. The legal fishing season in 1960 was (1) 1 January-1 May in coastal waters, and (2) 1 January-1 June in inland waters. During this time it was illegal to set gill nets in Albemarle Sound west of the NC Highway 32 bridge, and in Chowan River, from the mouth to Holiday Island (Figure 2). By 1960, nets were set primarily for striped bass and river herring, with shad catches being incidental, due to the continued decline in landings (Walburg and Nichols 1967). The present fishing season is about the same as it was in 1960, although there is no regulated season.

The Roanoke River fishery changed considerably from 1896 to 1960, as the amount of gear fished and catch decreased (Walburg and Nichols

Table 3. Commercial landings, (kg and lbs) and values ($) of American shad in North Carolina, Atlantic Ocean and the Albemarle Sound area, 1972-1987, and percentages contributed by the Atlantic Ocean and the Albemarle Sound area.

Year	Landings						Percent		Value			Percent	
	State total		Atlantic Ocean total		Albemarle Sound area total		Atlantic Ocean	Albemarle Sound area	State total	Atlantic Ocean total	Albemarle Sound area total	Atlantic Ocean	Albemarle Sound area
	lb	kg	lb	kg	lb	kg							
1972	468,484	212,692	-		130,399	59,201	-	27.8	$111,609	$ -	$26,997	-	24.2
1973	321,000	145,734	-		80,770	36,669	-	25.2	85,491	-	22,102	-	25.8
1974	368,833	167,450	-		116,502	52,892	-	31.6	105,668	-	28,531	-	27.0
1975	241,240	109,523	-		87,063	39,527	-	36.1	82,815	-	29,280	-	35.3
1976	167,190	75,904	-		78,301	35,549	-	46.8	65,227	-	30,014	-	46.0
1977	121,022	54,944	-		79,594	36,136	-	65.8	54,764	-	35,234	-	64.3
1978	402,017	182,516	5,000	2,270	158,908	72,144	1.2	39.5	144,986	530	38,233	0.4	26.4
1979	278,070	126,244	25,064	11,379	85,158	38,662	9.0	30.6	121,662	6,915	26,389	5.7	21.7
1980	199,206	90,439	3,943	1,790	68,695	31,188	2.0	34.5	88,112	2,641	21,343	3.0	24.2
1981	351,500	159,581	107,415	48,766	66,732	30,296	30.6	19.0	189,793	48,789	29,330	25.7	15.4
1982	411,852	186,981	63,979	29,046	118,794	53,932	15.5	28.8	183,483	21,524	38,473	11.7	21.0
1983	445,879	202,429	3,788	1,719	216,058	98,090	0.8	48.5	187,360	2,248	80,039	1.2	42.7
1984	584,843	265,519	13,511	6,134	227,308	103,198	2.3	39.0	241,009	3,938	73,151	1.6	30.4
1985	329,639	149,656	3,159	1,434	148,555	67,444	1.0	45.1	152,547	766	54,173	0.5	35.5
1986	373,794	169,702	63,085	28,641	120,367	54,647	16.9	32.2	228,819	28,626	73,152	12.5	32.0
1987	327,646	148,751	39,580	17,969	149,923	68,065	12.2	45.8	215,115	29,194	81,354	13.6	37.8

1967). In 1896, shad fisheries in the Roanoke River were limited to the lower river, from Williamston to the mouth. By 1960, the fishery extended further up the river, to the Scotland Neck bridge (Figure 3). Shad catches were incidental for all gears which were directed at striped bass and river herring. Taylor (1951) stated that pulp mill wastes from upstream probably was the cause of low survival of anadromous fishes, especially shad, in the lower Roanoke River. Regulations adopted by the North Carolina Marine Fisheries Commission in 1983 prohibit the use of gill nets with a stretched mesh length less than 57.2 mm (2-1/4 in) or greater than 76.2 mm (3 in) during 1 April-31 May (North Carolina Department of Natural Resources and Community Development, Div. Mar. Fish. 1983). This regulation was passed to protect striped bass during their spawning run, but it will also permit shad to migrate up the river to spawn.

The Chowan River differed from other areas in 1896, because pound nets and seines were the primary gears used to capture shad, taking 98% of the catch. By the mid-1900s, pound nets and seines were fished primarily for river herring and gill nets for shad. As with all other areas, landings decreased drastically from 1896 to 1960 (Walburg and Nichols 1967).

Since 1896, the areas fished and gears used in the shad fishery have remained essentially unchanged. The extent of fisheries, both the amount of gear and harvest, have declined significantly, and the fishery could not continue if it were wholly dependent on shad (Walburg and Nichols 1967).

EARLY PROPAGATION OF AMERICAN SHAD

To fisheries workers, the fluctuations in landings of the 1800s indicated a problem with the American shad population. Overfishing was thought to be the main factor for the decline in harvest and various solutions were sought. The federal government, in 1873, began artificial propagation of shad at New Bern, North Carolina and striped bass at Weldon, North Carolina. The fry that hatched were released in local waters. In 1877, the state began fish culture operations of its own on the Neuse River at several locations above New Bern (Smith 1907). The shad hatching in 1878 was noteworthy because it was conducted jointly

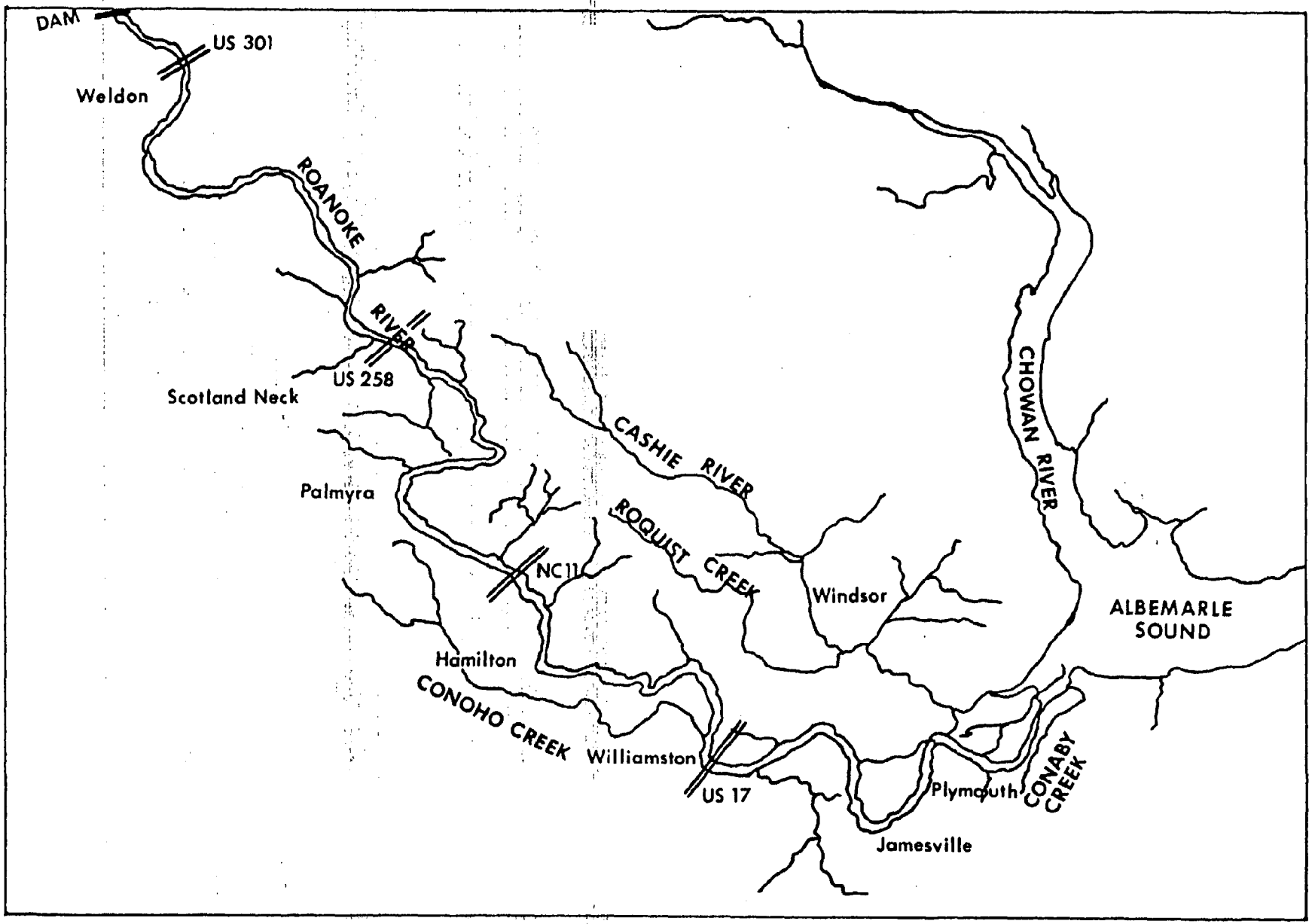


Figure 3. Roanoke River and its tributaries, North Carolina.

with representatives from the U.S. Fish Commission, Virginia, Maryland and North Carolina. The site of the operation was Salmon Creek at the head of Albemarle Sound, and the production was the most successful up to that time: a million fry were produced (Smith 1907). The U.S. government continued shad hatching in 1879 at the mouth of Chowan River, using the steamer LOOKOUT in the work. In 1880 the state constructed a shad hatchery at Avoca and utilized the eggs furnished by the Capehart seine fisheries at Sutton Beach and Scotch Hall. It was in 1881 that the steamer FISH-HAWK was first utilized in shad hatching in Albemarle Sound, and the FISH-HAWK continued in the work for several years. The MacDonald hatching jar was adopted in 1882 with North Carolina being the first state to employ this most important device (Smith 1907). The state continued to operate the hatchery at Avoca until 1884, but in 1885 all culture work ended.

Early results appeared to indicate that stocking of shad fry accomplished its purpose, since landings increased from 1880 to 1897. After that time the harvest declined in spite of continued stocking, and in 1943 the federal government decided artificial propagation as practiced was of little value in maintaining the shad population; consequently, stocking was discontinued (Walburg and Nichols 1967).

NORTH CAROLINA DIVISION OF MARINE FISHERIES AMERICAN SHAD RESEARCH

Data collected by the North Carolina Division of Marine Fisheries between 1972 and 1987 in the Albemarle Sound area will be presented and discussed in the following sections. This work included delineation of spawning areas, juvenile distribution, growth and relative abundance, adult size, sex, age, spawning history, and adult tagging.

MATERIALS AND METHODS

Spawning Area Survey

The designation of American shad spawning areas was based on the occurrence of one or more of the following criteria:

(1) capture or observation of running ripe females;

(2) actual observation of spawning activity; or

(3) the capture of eggs and larvae.

An exploratory sampling approach was used in 1973 to obtain general information on spawning and to define sampling methods. Detailed spawning area surveys were conducted in 1978 in the Roanoke River, 1979 and 1983 in the Chowan River, 1980 in the Meherrin River, and 1984 in the Nottoway and Blackwater rivers. Sampling usually began in March and continued into May. Weeks were serially numbered each year beginning with the first full week of January.

Monofilament gill nets up to 9.15 m (30 ft) long with stretched mesh ranging from 82.5 mm (3-1/4 in) to 127.0 mm (5 in) were fished to determine distribution of American shad. Nets were set for up to 24 hours. Captured fish were identified, counted, and examined for spawning condition.

Eggs were sampled using 0.5 m plankton nets made of #00 Nitex mesh with a wide mouth 0.95 l jar attached to the cod end. Samples were taken from bridges and boats, with sample time ranging from 5 to 15 minutes. Sampling was considered to be qualitative, not quantitative. Thus, all egg net samples were considered as equal units of effort. Samples were preserved in 5% formalin and returned to the laboratory where eggs and larvae were sorted, identified, counted, and measured with a binocular microscope fitted with an ocular micrometer. Water chemistry data, including temperatures, dissolved oxygen, and pH were recorded for each sample.

Nursery Area Sampling

Quantitative determination of year-class strength is a major element in population dynamics. Important long term objectives were to (1) estimate the relationship (if any) between year-class strength and future recruitment and (2) observe the periodicity (if any) of strong year classes.

Preliminary open water trawling was conducted in Albemarle Sound and its major tributaries during November 1971, using a 7.12 m (25 ft) head rope shrimp trawl with 19.0 mm (3/4 in) bar mesh and a 3.0 m (10 ft) X 3.0 m (10 ft) modified Cobb trawl (Street et al. 1975). This net was held open by top and bottom pipes rather than by otter doors as with a shrimp trawl. The Cobb trawl was constructed of 19.0 mm (3/4 in) bar mesh in the body and 6.3 mm (1/4 in) bar mesh in the bag (Appendix

Figure 4). The Cobb trawl proved satisfactory and was adopted as the standard sampling gear. The net was fished for five minutes on the bottom at all stations except one (lower Roanoke River). Because of the many snags, the Roanoke River station was sampled at mid-water. A five minute tow constituted one unit of effort.

Sampling was conducted monthly beginning in January 1972 at 26 open water stations in Albemarle Sound and its major tributaries as a result of the preliminary work. Additional stations were added during April 1972 in Croatan and Roanoke sounds to better cover the higher salinity habitats in the eastern portion of the study area, for a total of 28 samples per month. Sampling was reduced to 15 monthly stations during January-June 1974 (Figure 4).

Preliminary shallow water sampling for juveniles was conducted throughout the Albemarle Sound area during June 1972 with a 1.8 m (6 ft) X 1.8 m (6 ft) modified Cobb trawl (Appendix Figure 2), 18.3 m (60 ft) bag seine and 6.1 m (20 ft) bag seine, all with 6.3 mm (1/4 in) bar mesh. The smaller seine was discarded following the preliminary sampling period because it was ineffective. In addition, bags of 3.2 mm (1/8 in) bar mesh were placed in the larger seines because of escapement through the 6.3 mm (1/4 in) mesh bag.

Trawls were fished on the bottom for 10 minutes where depths were 4 m (14 ft) or less. In areas of greater depth, the trawl was fished for five minutes on the bottom and five minutes near the surface. A 10 minute tow was considered a unit of effort. Seines were pulled in maximum depths of 0.9-1.5 m (3-5 ft) for a distance of approximately 45.7 m (150 ft) at each station, which was considered as one unit of effort for this gear.

From October 1972 through December 1973, 120 trawl samples and 28 seine samples were taken monthly. Sampling was reduced during January-June 1974 to 30 trawl and 25 seine samples per month. Figures 5 and 6 show the location of the nursery area samples during the latter period.

During July 1974-September 1976, approximately 70 previously established stations (Figures 5 and 6), were sampled monthly using seines and trawls, except during the March through April spawning periods. The sampling methods remained the same as those previously described, except for the adoption of an experimental wing trawl (Appendix Figure 3) as a standard sampling device replacing the Cobb

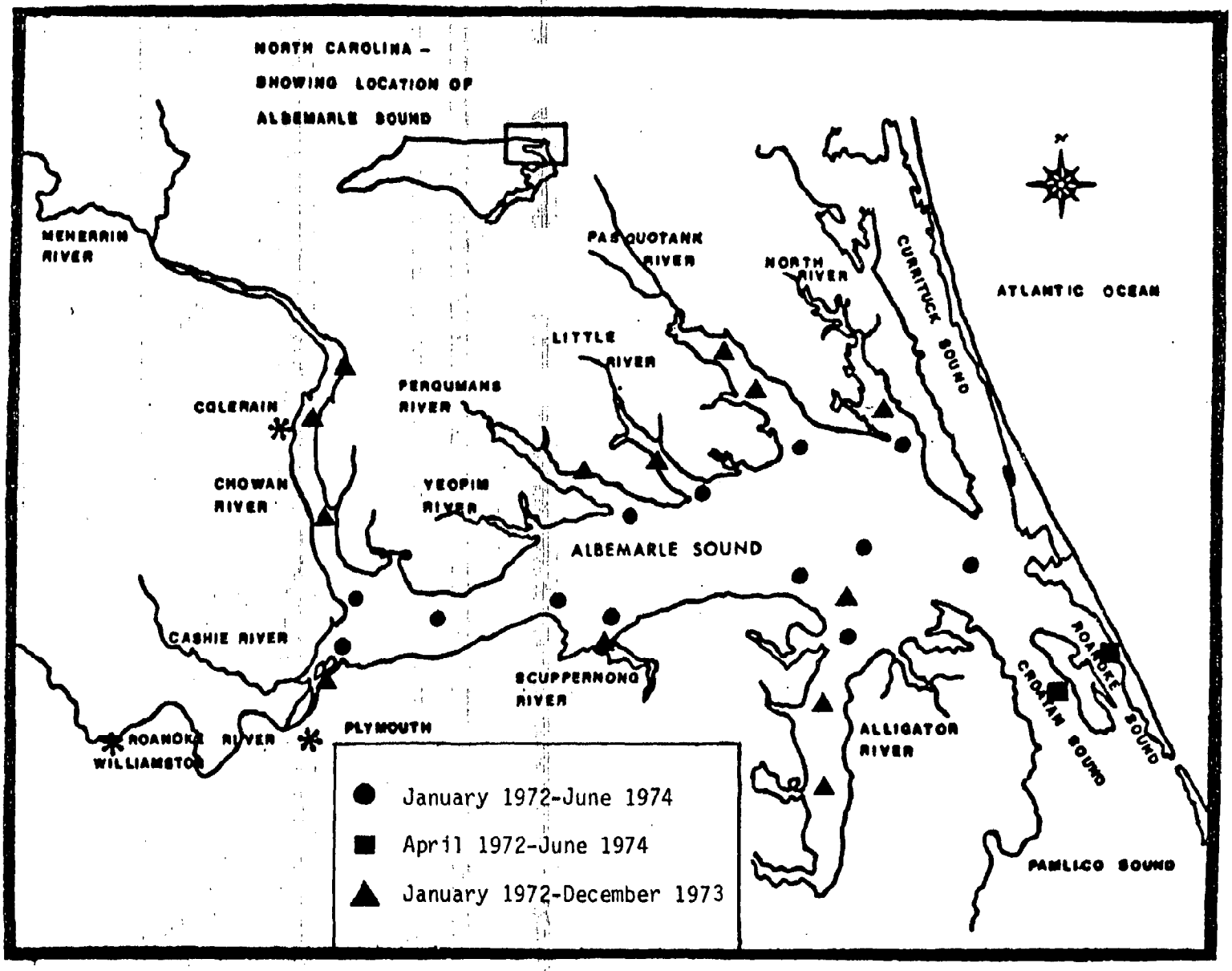


Figure 4. Open water sampling in Albemarle Sound area, N.C., 1972-1974.

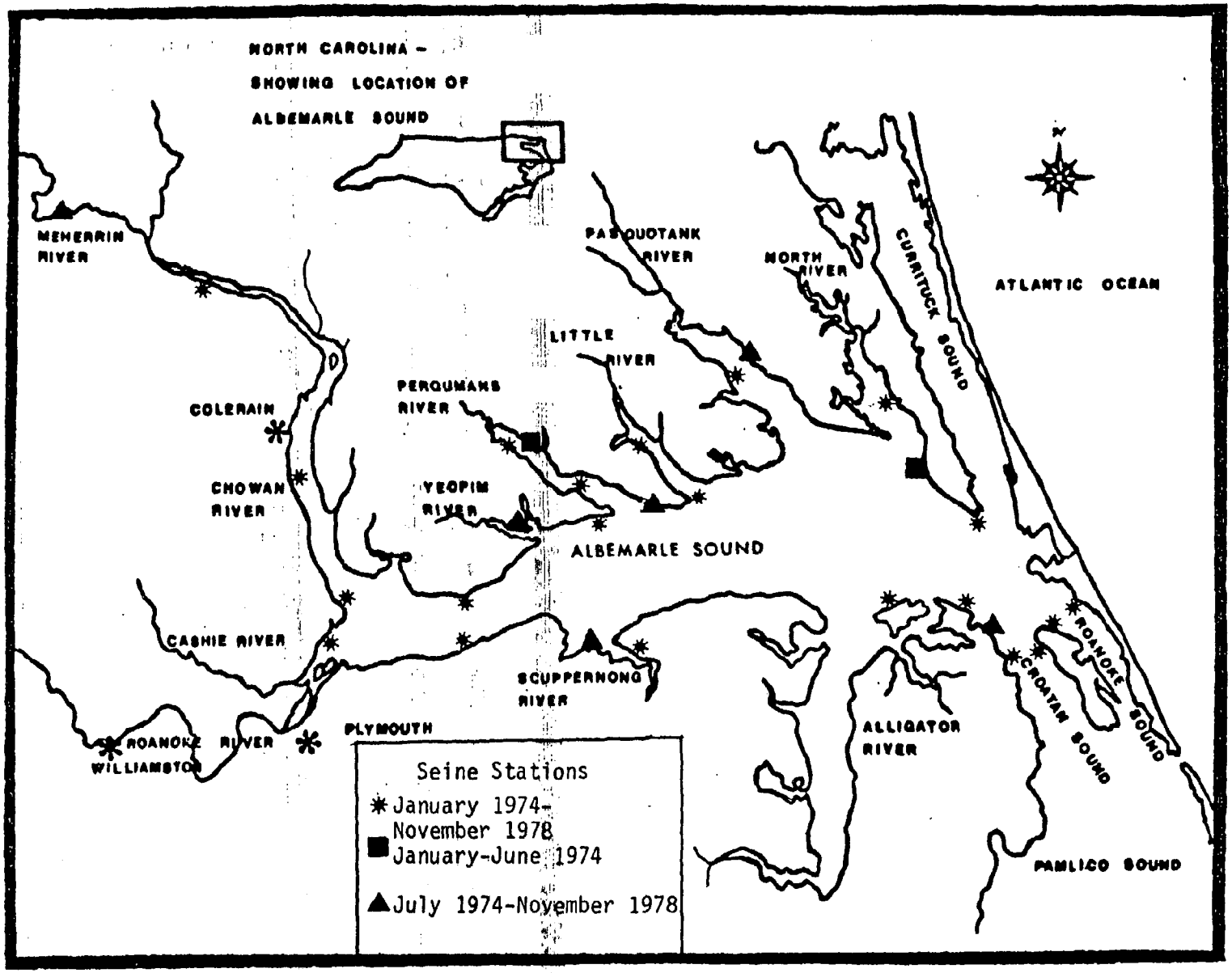


Figure 5. Nursery area seine sampling sites in the Albemarle Sound area, N.C. January 1974-November 1978.

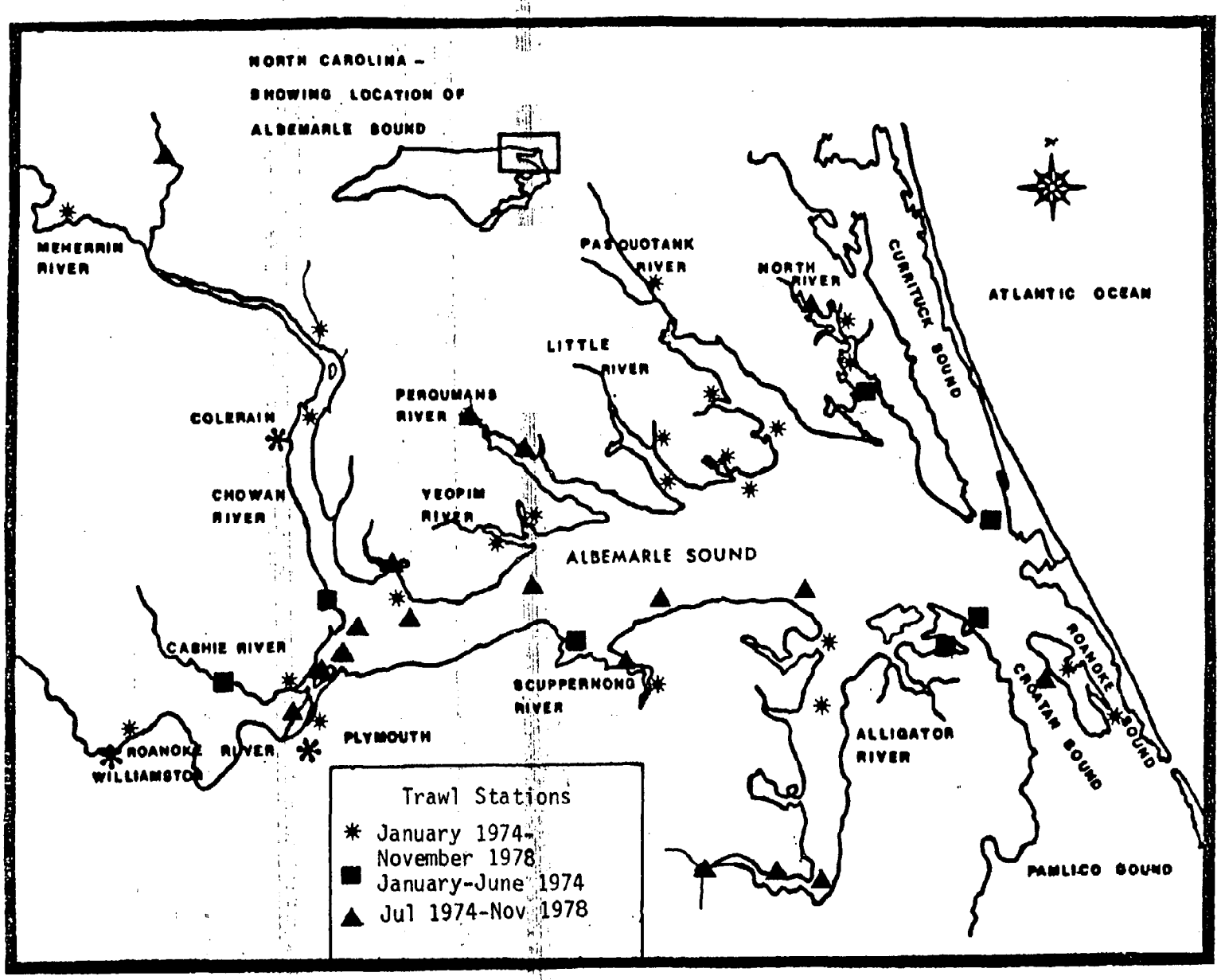


Figure 6. Nursery area sites, with trawls, in the Albemarle Sound area, N.C. January 1974-November 1978.

trawl. The wing trawl had a 7.9 m (26 ft) headrope length, and contained webbing which ranged from 101.6 mm (4 in) stretched mesh in the wings to 3.18 mm (1/8 in) bar mesh in the tail bag. Tow time was 10 minutes, which was considered one unit of effort.

These same stations were sampled monthly by seine or wing trawl during June-December 1977 and 1978. During 1979, the number of stations sampled monthly was reduced to 34 to increase sampling efficiency for all alosids(blueback herring, Alosa aestivalis; alewife, A. pseudoharengus; and hickory shad, A. mediocris; as well as American shad).

From 1979 through 1983, the 34 stations were sampled monthly during June-August and October-November using a wing trawl (23 samples) or a seine (11 samples) (Figure 7). During September, an additional 43 stations (28 trawls and 15 seines), were sampled throughout the Albemarle Sound area to determine distribution and nursery areas of anadromous species (Figure 8).

During June 1984, the 34 stations were sampled. However, in July 1984, the number of stations sampled monthly (June-August and October-November) was reduced to the 11 established seine stations (Figure 7). These stations continued to be sampled during these months, 1985-1987. The stations sampled with the wing trawl were dropped because the seine data have proven more useful, especially for blueback herring. In September 1984-1987, an additional 15 seine stations were sampled (Figure 8).

In the western Albemarle Sound area, weekly sampling was conducted at seven stations during July-October, 1982 and 1983 to establish a relative abundance index for young-of-the-year striped bass (Figure 9). During the same time period in 1984-1987, these stations were sampled bi-weekly. Juvenile American shad were captured during all years except 1985.

These stations were sampled with a 5.49 m (18 ft) head rope, semi-balloon trawl containing webbing which ranged from 19.0 mm (3/4 in) stretched mesh in the body to 6.3 mm (1/4 in) cod end (Appendix Figure 4). Tow time was 15 minutes, which was considered one unit of effort.

Throughout these studies, samples were sorted to species and up to 30 individuals of each alosid species present were measured to the

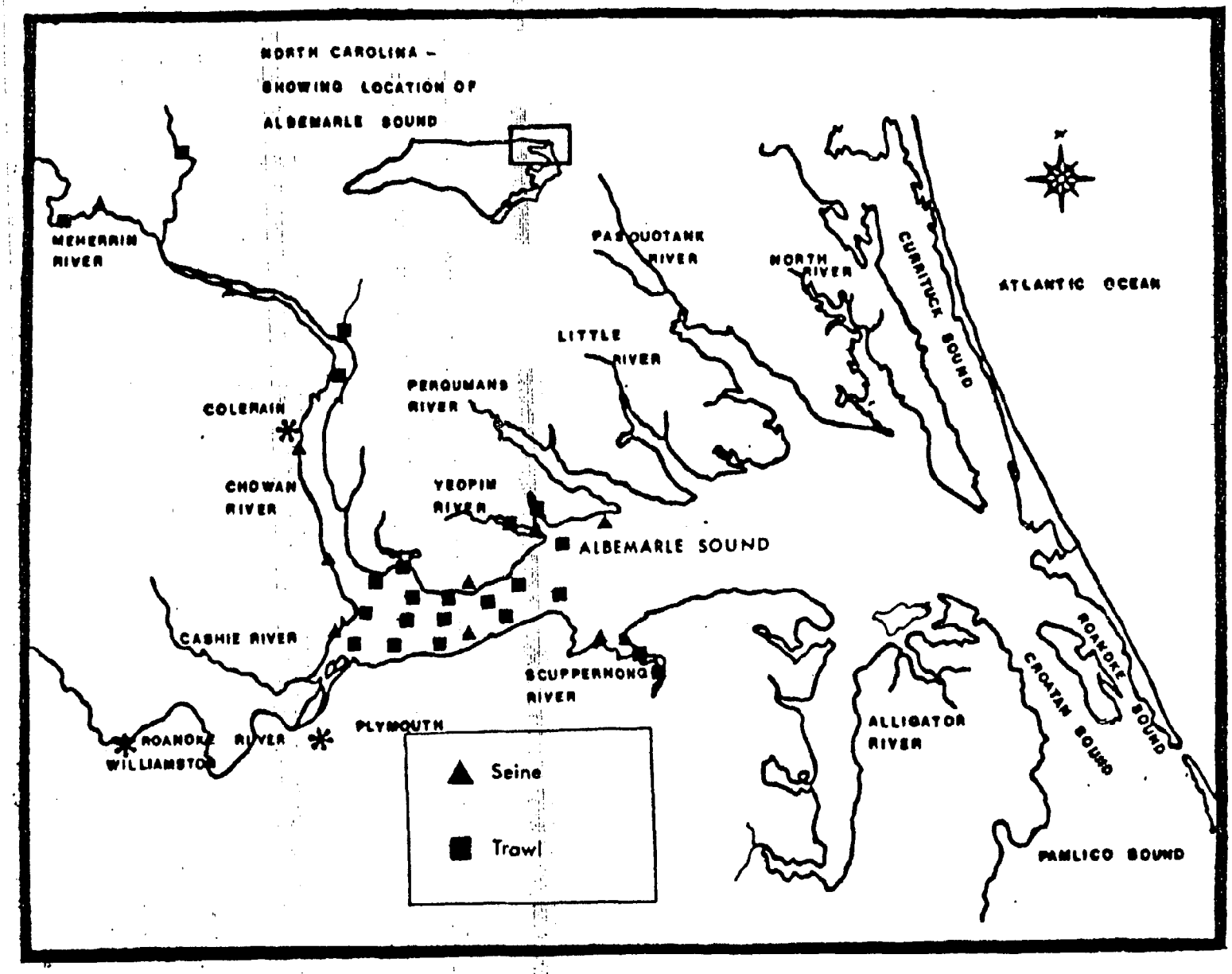


Figure 7. Nursery area sampling sites in Albemarle Sound area, N.C., during June-November, 1979-1983. (Only seine stations sampled July-October 1984-1987.)

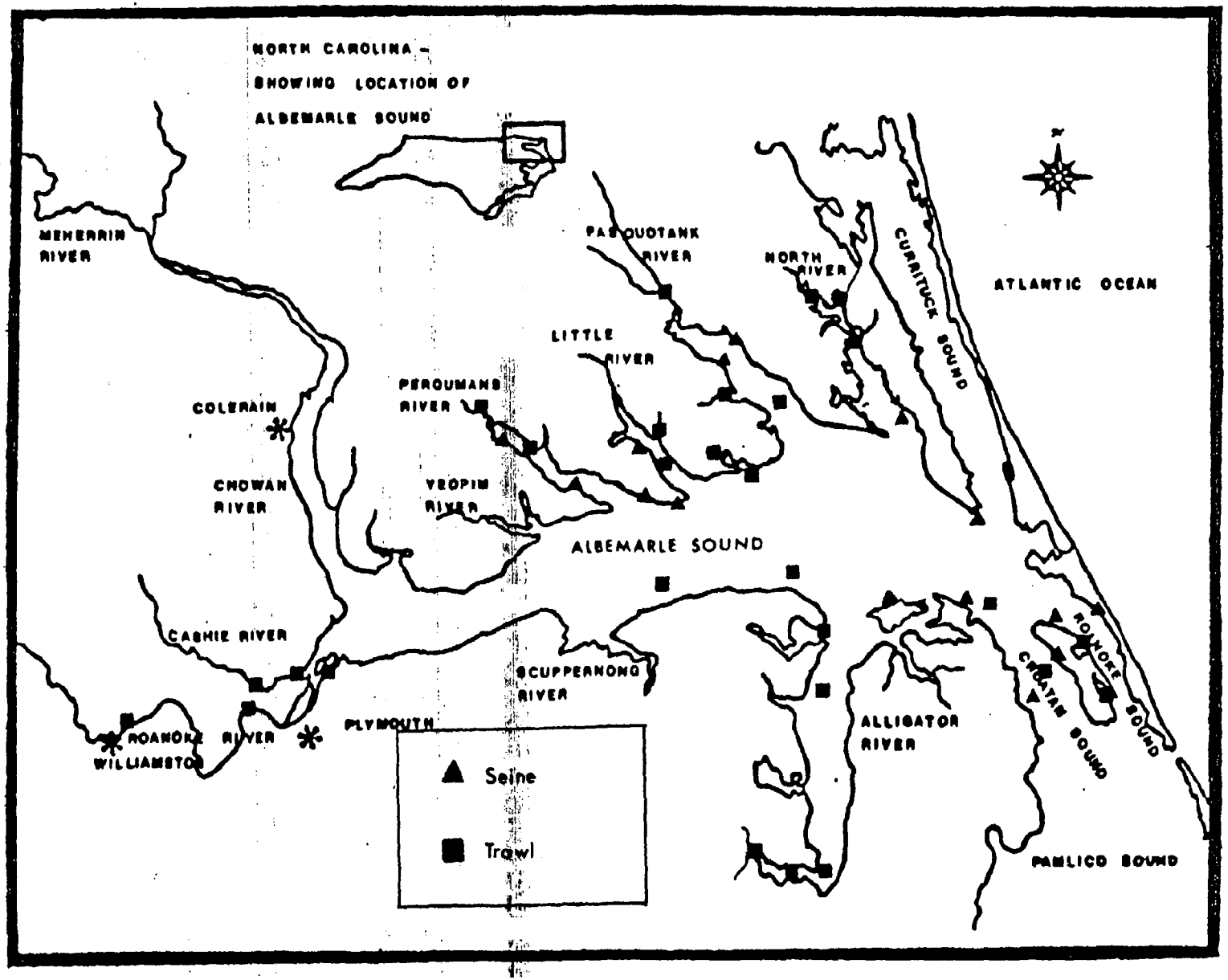


Figure 8. Nursery area sampling sites in Albemarle Sound area, N.C., during September 1979-1983. (Only seine stations sampled in 1984-1987.)

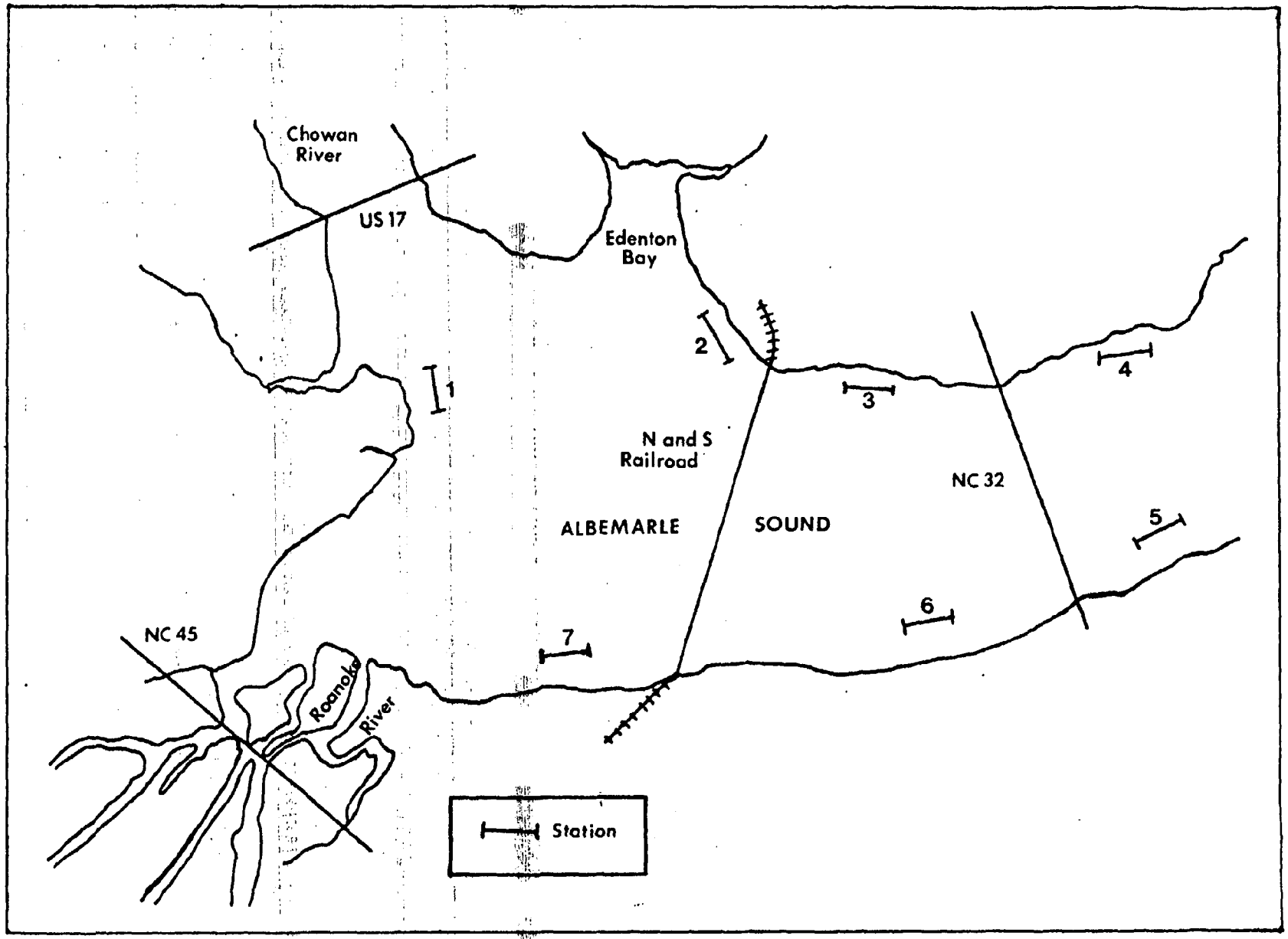


Figure 9. Sampling sites, with 3/4 in semi-balloon trawl in the Albemarle Sound area, N.C., July-October 1983-1987.

nearest millimeter, fork length (mm, FL). Weights in grams (g) were taken prior to January 1973. Species other than anadromous fishes were noted, and environmental parameters, surface and bottom water temperatures, dissolved oxygen levels, and salinities were taken.

Commercial Harvest

During the fishing season (approximately February-May annually), American shad landings data were obtained monthly from cooperating dealers and fishermen in the Albemarle Sound area by statistics program port samplers. This work was conducted as part of the North Carolina/National Marine Fisheries Service Cooperative Statistics Program.

American shad for which age, sex, and weight data were available were placed in the appropriate year class for each month sampled. Individual weights were obtained on American shad during 1972 and 1982-1987. The number of individuals of each year class was followed monthly through the sampling period. Fish were separated by sex, and the monthly mean weight (kg) and percent number and weight by sex, for each year class were calculated. The total American shad harvest (lb converted to kg) for each month was multiplied by the percent weight for each sex of each year class during that month and divided by the mean weight (kg) of individuals of each sex of that year class, to obtain the estimated number of individuals from each year class for each month.

ADULT SAMPLING

Commercial harvest sampling sites for American shad have varied over the years (Figure 10). Nine locations were sampled during 1972 (A-I); J and K were added in 1973 and E was dropped. In 1974, samples were taken only at A, F, I and K. Sampling locations F and K were eliminated and L added during 1975. In 1976, A, I and L were sampled, but I was dropped in 1977. From 1978 through 1987, only two locations (A and C) have been utilized. Data collected at these sites were assumed to be representative of the total commercial American shad landings in the Albemarle Sound area. During February-May of each year,

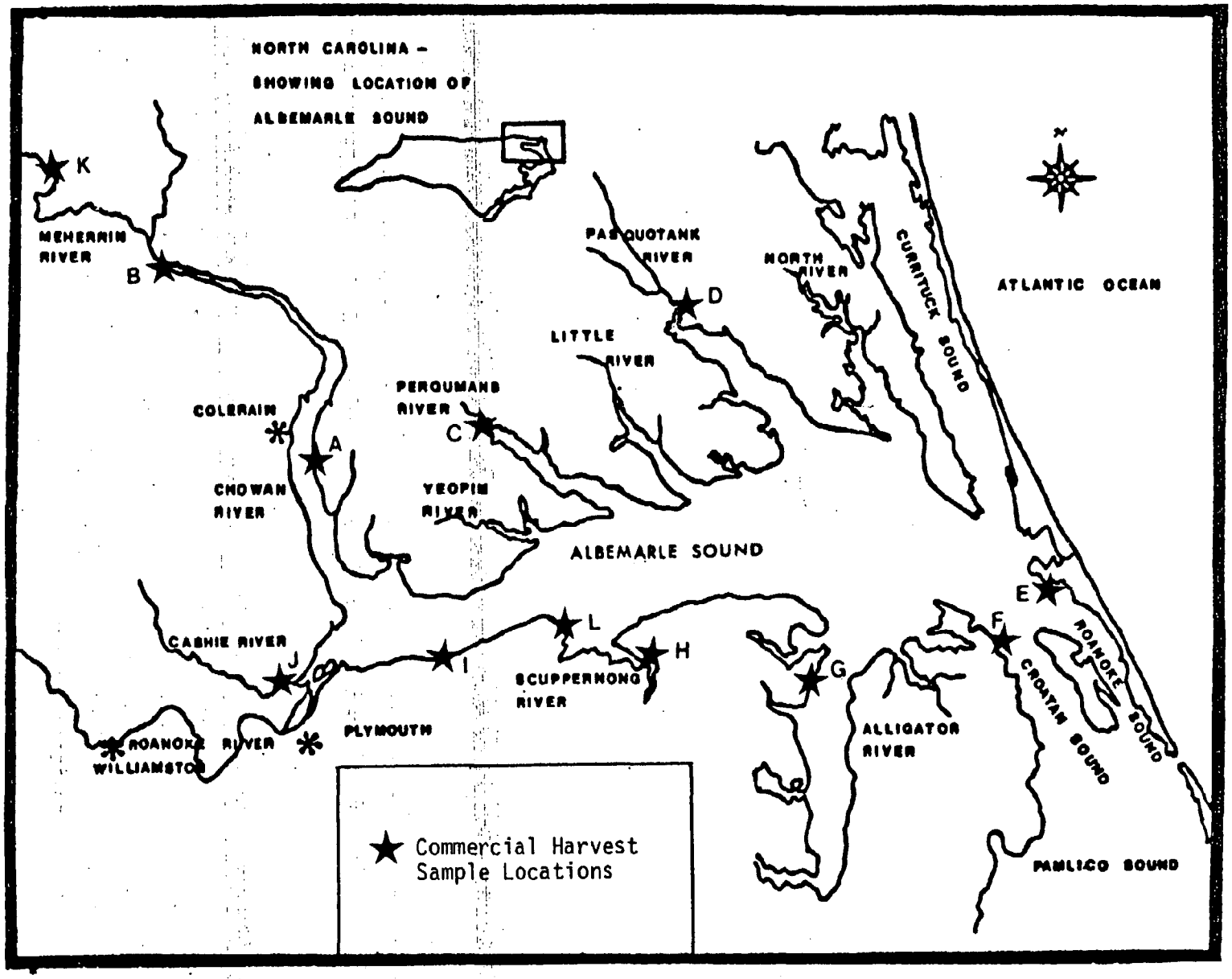


Figure 10. Location of American shad commercial harvest sampling sites in Albemarle Sound area, N.C. 1972-1987.

or until catches dropped to a level which did not warrant sampling, project personnel visited the various sites weekly to obtain samples.

Whenever possible, data from each site were obtained from unculled samples to determine sex composition and sex ratios. If an unculled sample was not available, data were recorded from as many fish as possible without interruption of normal operations of the fishermen and dealers. During 1972-1978, sample sizes often varied with the number of fish available, but normally did not exceed 100 fish per site per week. Up to 30 individuals were examined from each location, each week, during 1979-1987.

Sex was determined and fork lengths (FL) were measured to the nearest millimeter for each fish sampled throughout the period covered. Individual weights in kilograms were taken only during 1972 and 1982-1987. Scale samples were taken from the left side below the insertion of the dorsal fin and just above the mid-line as described by Rothschild (1963) and Marcy (1969).

Age determination was based on Cating (1953) and Judy (1961). At least four of the most legible scales from each fish were read using a binocular microscope, Eberbach projector, or a microfiche reader. For the majority of the project, 1972-1982, two independent readings were made of scales for each fish, and if readings were not in agreement, the fish was deleted from the sample. Following the method of Cating (1953), it was assumed that each fish had completed a full year's growth at the time of capture; thus, the scale edge was counted as a year mark.

Stratified sub-sampling for ageing was used during 1981-1987, due to the large number of American shad scale samples taken in the Albemarle Sound area and the time-consuming process of aging. The technique used, in which modal length groups were sub-sampled, was similar to that developed by Ketchen (1950). Shad were separated by sex into 25 mm modal size groups. If 15 or more samples were present, at least half of the scales in each size group were aged; in those with less than 15, all were aged. The sub-samples were expanded to obtain the age composition estimates for American shad.

Weight-Length Relationship

Linear regression modeling (Ricker 1975) was conducted on 1972 and 1981-1986 data to determine weight length relations. Both sexes were analyzed separately due to variation in weight at a given length.

Mortality

Total mortality (Z) was calculated by catch curve analysis (Gulland 1985; Ricker 1975). The slope (sign changed) of the descending arm of curve, log scale, equals Z. Sexes were analyzed separately and for ages after full recruitment. Full recruitment was assumed to be at age 5 and 6 for males and females, respectively. The validity of these estimates depends on the assumptions that the data are from a random sample, survival is uniform with age and time, and recruitment is constant (Ricker 1975). For comparison, total mortality was also calculated by the mean age method (Ricker 1975). Mean age after full recruitment, age structure of landings, juvenile index, and landings trends were reviewed to evaluate changes in Z.

Tagging

American shad were tagged at two pound nets in Croatan Sound during February-April, 1974 and February-March 1975. All fish were tagged with Floy FD-68B anchor tags on the left side just below the anterior portion of the dorsal fin. The tag was anchored securely in the pterygiophores supporting the dorsal fin. Only those fish which appeared vigorous and healthy were tagged and released. Tag number, date, location, water temperature, and salinity data were recorded for each fish tagged.

Rewards of $1, $5, $10, or $25 were offered for returned tags. The program was widely publicized by posters, news releases and visits to fish houses by DMF personnel.

RESULTS AND DISCUSSION

Spawning Area Sampling

The data collected between 1973 and 1984 by the Division of Marine Fisheries on American shad spawning areas indicates spawning occurred only in Roanoke, Meherrin, Chowan, Nottoway, and Blackwater rivers.

The physical characteristics of the spawning grounds for American shad vary somewhat between systems. Shad may spawn anywhere within a given spawning area, but prefer the shallow flats comprised of sand, gravel or a combination of both which border the rivers (Davis et al. 1970; Mansuetti and Kolb 1953; Bigelow and Welch 1925; Smith 1907; and Walburg and Nichols 1967). Water conditions may vary from clear to very turbid, water depths from 1 m (3 ft) to 9.1 m (30 ft) and temperatures may range from 8-26°C (Walburg and Nichols 1967).

Shad eggs are non-adhesive and slightly heavier than water, so they gradually sink where they are carried along by currents (Ulrich et al. 1979). Sufficient water current is required to keep the eggs suspended in the water column for successful development (Scholar 1977a, and Cheek 1968). This requirement may explain why American shad spawning was found only in these rivers, all of which have relatively strong currents compared to other rivers tributary to Albemarle Sound.

Historically, running-ripe female shad have been captured by seines and gill nets fished in the extreme western Albemarle Sound, an area without strong river currents. The numbers of spawning shad in this location were sufficient to warrant the initiation of shad-hatching operations at Avoca Plantation, at the mouth of Salmon Creek, in 1878 (Worth 1879) and to continue the hatching operation at the Edenton National Fish Hatchery until World War II. Apparently, the wind, which blows almost constantly in this area, creates sufficient current for the eggs to develop (Street et al. 1975). Davis et al. (1970) reported that shad appear to spawn in larger tributaries to some extent. American shad spawning in the western sound has not been documented since the Division began work in the Albemarle Sound area.

All American shad spawning areas have been documented either by capture of eggs and/or larvae or observation of spawning. The spawning surveys were conducted to determine spawning areas for all anadromous fishes, except for the Nottoway and Blackwater rivers during 1984, which were sampled specifically for American shad. During the various surveys, no running-ripe female shad were captured in gill nets. American shad eggs and larvae were identified using Leim (1924) and Mansuetti and Hardy (1967) as references. The various spawning area surveys will be discussed by river system.

Roanoke River

Only one egg was collected in 1973. During 1978, no eggs were captured, but 54 larvae were taken (Table 4). Table 5 shows the number and location of capture of American shad larvae in 1978. The relationship of temperature and time to catches of eggs and larvae is shown in Figure 11, for 1973 and 1978. For both years, the egg and larvae were captured during week 17. The mean water temperature in 1973 was higher (21°C) than that of 1978 (16°C) during week 17. Leim (1924) considered that a temperature of "about 12°C is necessary before much spawning activity would be displayed." Walburg and Nichols (1967) reported that shad spawn at water temperatures from 18°C to 26°C, but usually between 14°C and 21°C.

Figure 12 shows the approximate spawning area locations for American shad as indicated by field sampling during 1973 and 1978. The areas of capture were virtually the same. Baker (1968) reported that shad ascended the Roanoke River to the same point (U.S. 258 bridge) indicated by our data. Walburg and Nichols (1967) reported the same range. From these data it is assumed that all suitable areas below the highest point of capture serve as spawning areas.

Chowan River

No American shad eggs and/or larvae were captured in 1973 or 1983. Only four larvae were captured during the survey in 1979 (Table 4). The number of larvae and general locations of capture are presented in Table 6. Figure 13 shows the relationship of mean water temperature for the three years and time to capture of larvae. As with the Roanoke River, larvae were captured during week 17 in 1979. However, the mean water temperature in the Chowan River during 1979 was lower (14°C) than that found in the Roanoke River during 1973 or 1978. The approximate spawning locations for American shad as indicated by capture of larvae in 1979 is shown in Figure 14.

Meherrin River

One American shad egg was taken in 1973 at the U.S. Highway 301 bridge in Virginia. However, in 1980, seven larvae were captured (no eggs) from the North Carolina portion of the river (Figure 15). Table 7 shows the number and general locations for capture of egg and larvae in

Table 4. American shad eggs and larvae collected by egg nets in the Albemarle Sound area, North Carolina, 1973-1984.

Water body	Year	Number of eggs	Number of larvae
Roanoke River	1973	1	0
	1978	0	54
Chowan River	1973	0	0
	1979	0	4
	1983	0	0
Meherrin River	1973	1	0
	1980	0	7
Nottoway River	1973	5	1
	1984	1	17
Blackwater River	1984	0	5
		—	—
Total		8	88

Table 5. Locations of American shad larvae collected by egg net in the Roanoke River area, North Carolina in 1978.

Date	Location	Number of larvae
04/24/78	Roanoke River U.S. 258 bridge	3
04/25/78	Roanoke River (Conoho Creek)50 below N.C. 125 bridge	50
04/25/78	Roanoke River (Conine Creek) below U.S. 17 bridge	1
Total		54

Table 6. Locations of American shad larvae collected by egg net in Chowan River area, North Carolina in 1979.

Date	Location	Number of larvae
05/07/79	Chowan River (Spikes Creek)	1
05/07/79	Chowan River (Cole Creek)	3
Total		4

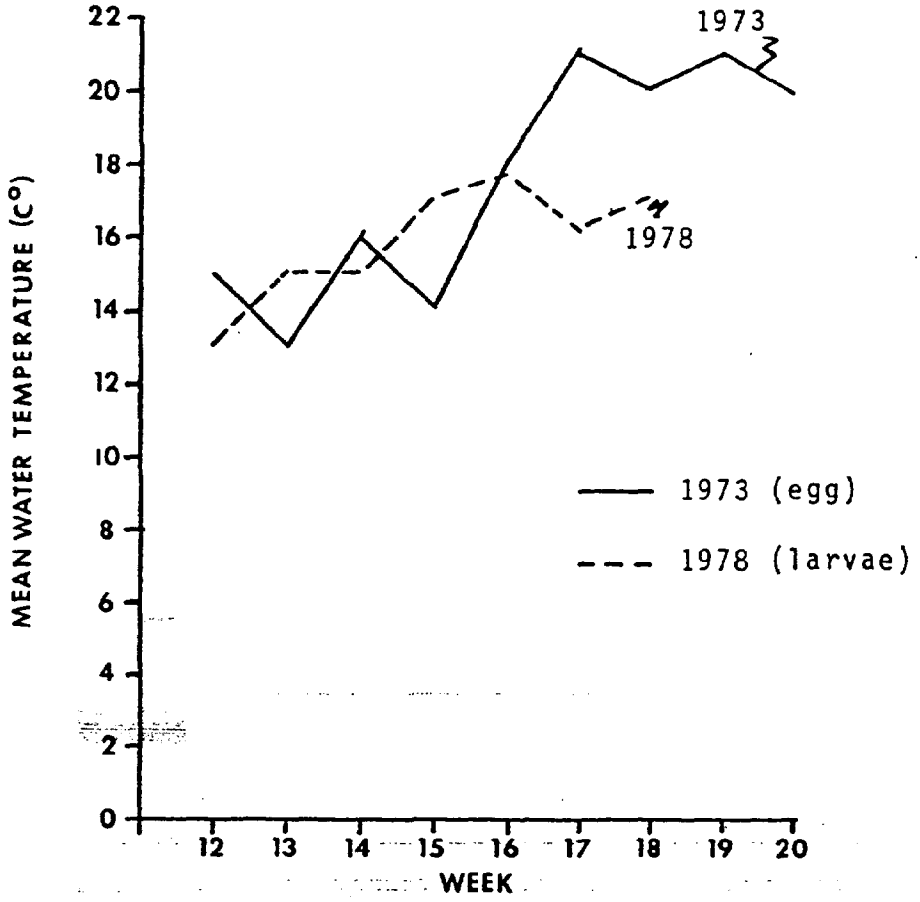


Figure 11. Spawning times and temperatures associated with the capture of American shad eggs and larvae in the Roanoke River area, N.C., 1973 and 1978.

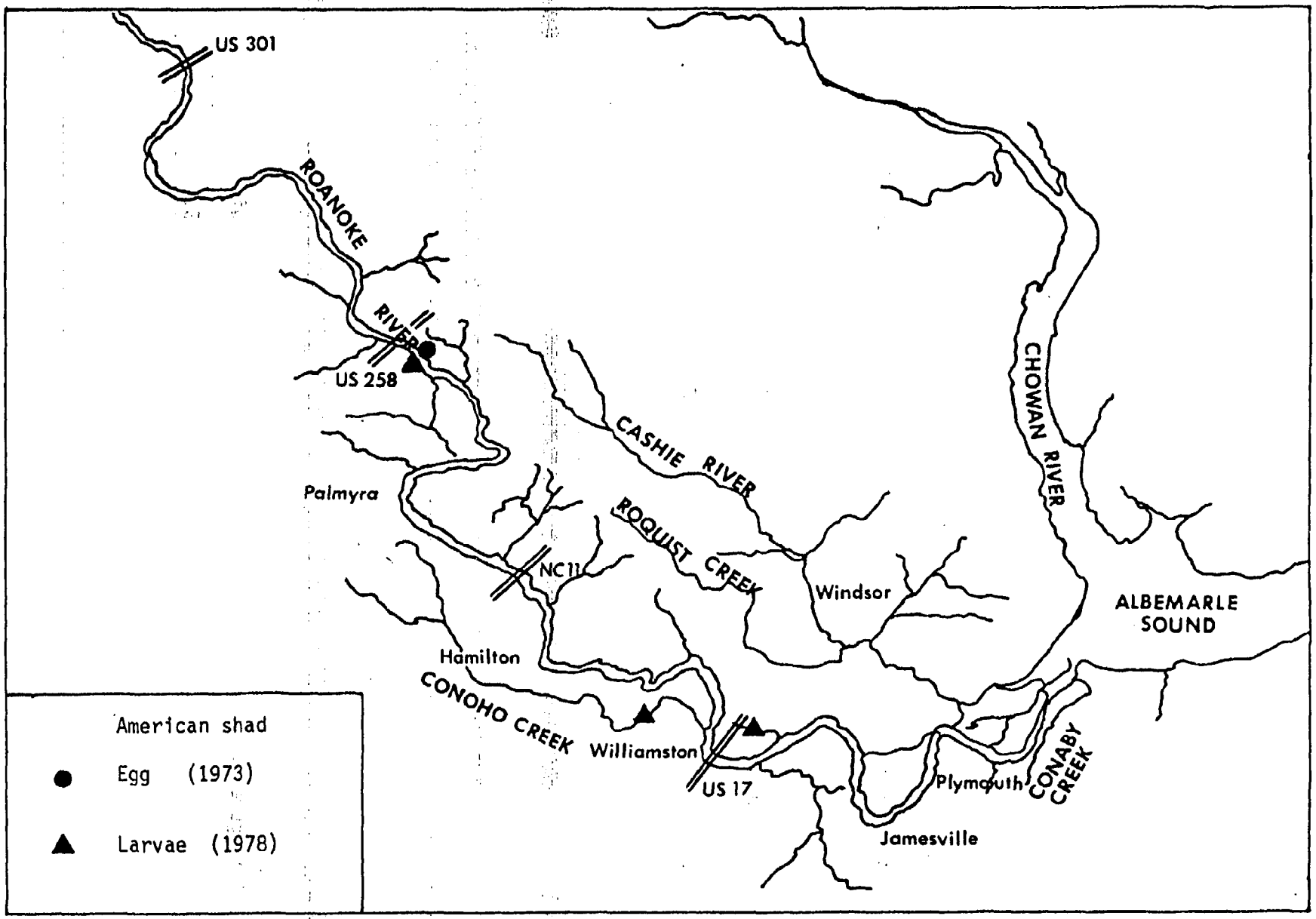


Figure 12. Spawning areas of American shad in Roanoke River area, N.C., as shown by capture of an egg and larvae, 1973 and 1978.

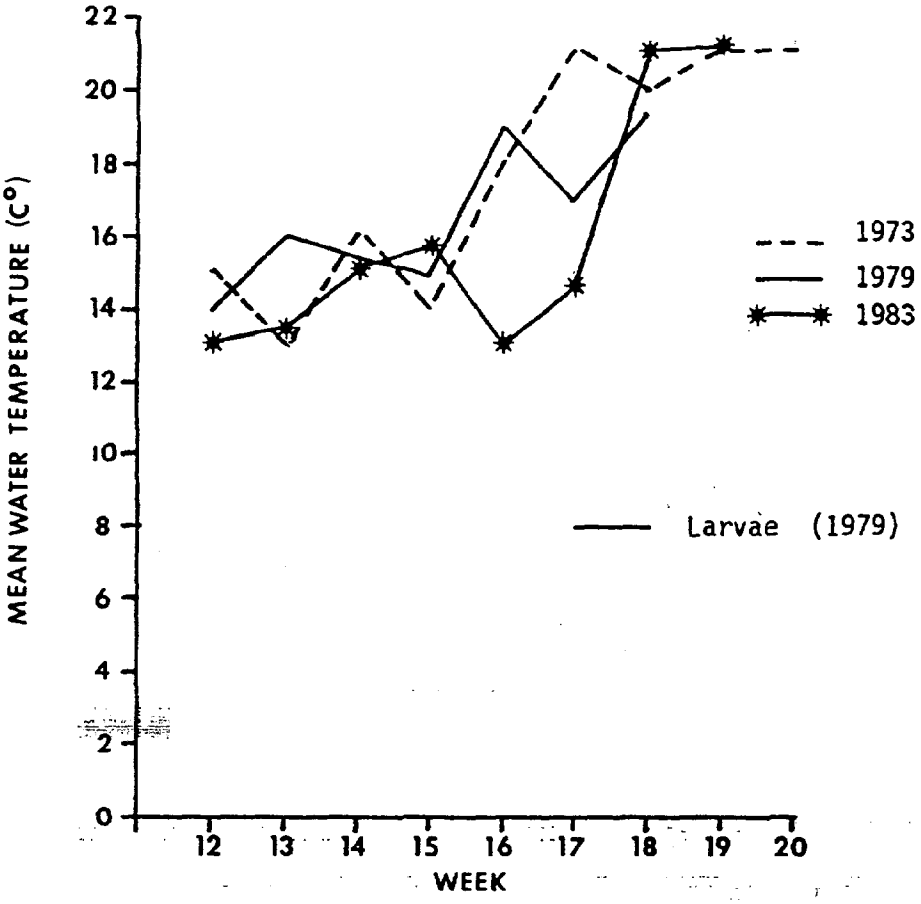


Figure 13. Spawning times and temperatures associated with the capture of American shad larvae in the Chowan River area, N.C., 1973, 1979 and 1983.

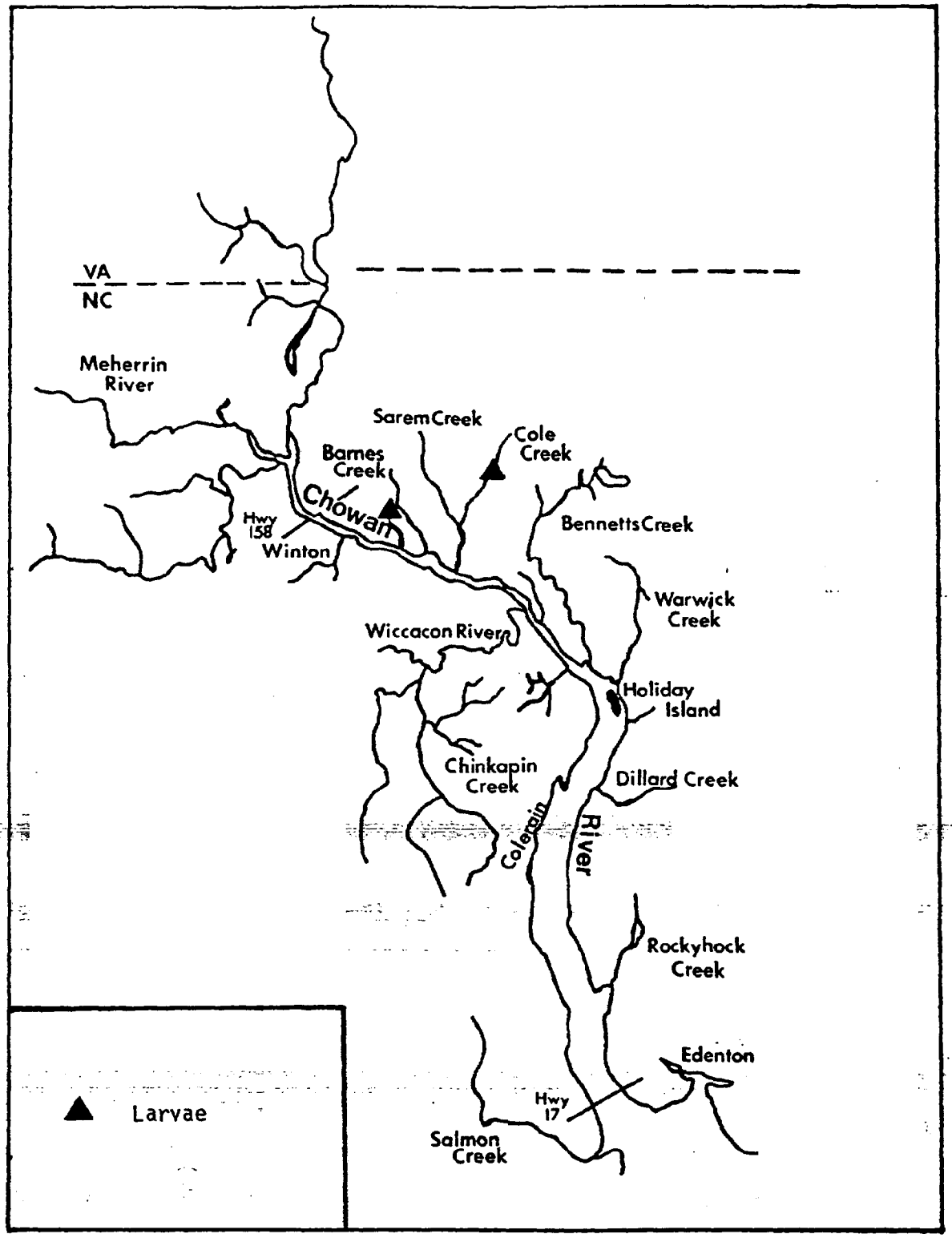


Figure 14. Spawning areas of American shad in Chowan River area, N.C., as shown by capture of larvae, 1979.

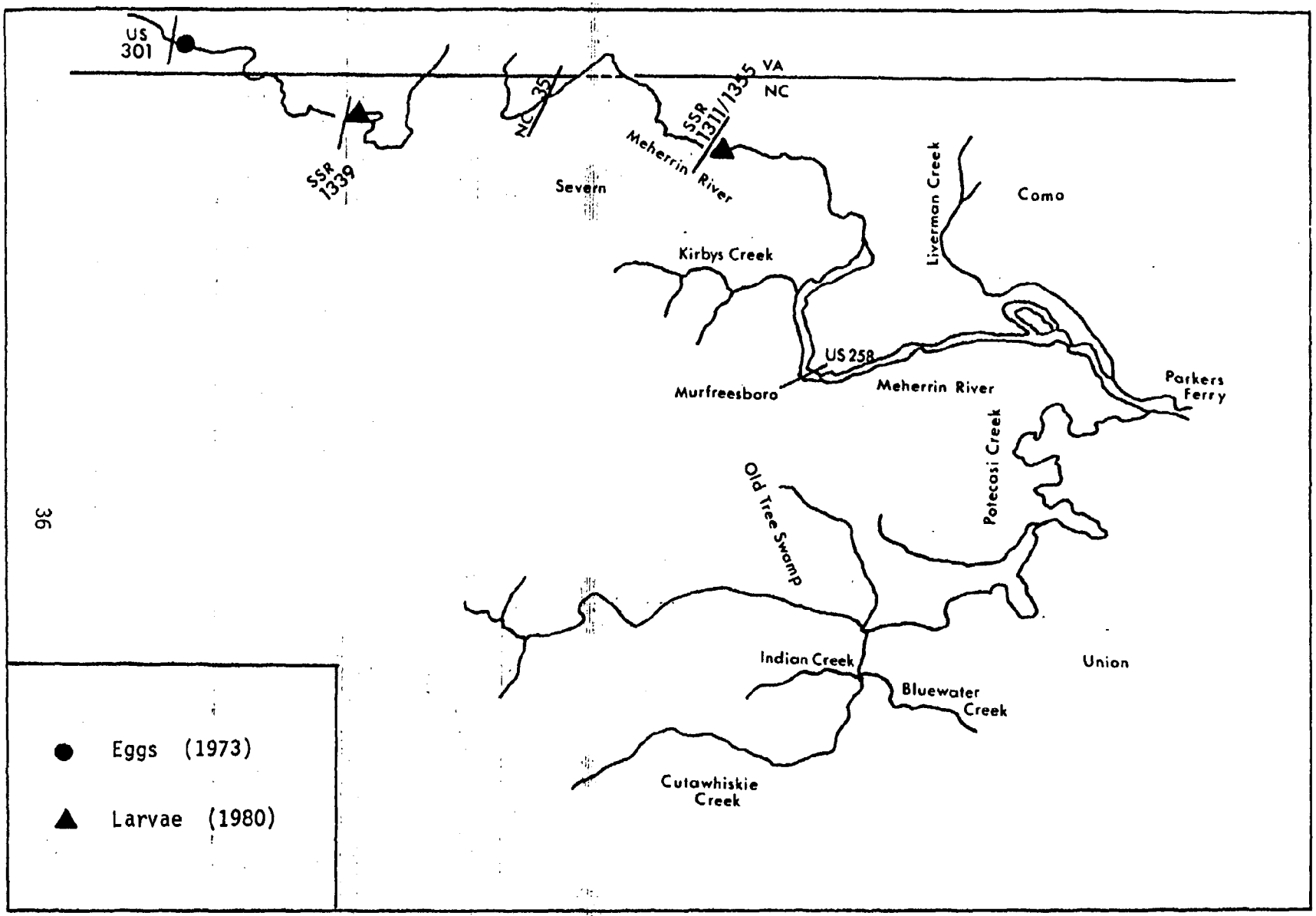


Figure 15. Spawning areas of American shad in Meherrin River, as shown by capture of eggs and larvae, 1973 and 1980.

Table 7. Locations of American shad egg and larvae collected by egg net in the Meherrin River area, North Carolina and Virginia in 1973 and 1980.

Date	Location	Number of eggs	Number of larvae
05/30/73	Meherrin River U.S. 301 bridge	1	0
04/23/80	Meherrin River SSR* 1311 and 1355 bridge	0	4
04/23/80	Meherrin River SSR 1339 bridge	0	2
05/02/80	Meherrin River SSR 1311 and 1355 bridge	0	1
Total		1	7

* SSR: State Secondary Road

Table 8. Location of American shad eggs collected by egg net sampling in the Nottoway River area, Virginia, in 1973 and 1984.

Date	Location	Number of eggs
05/08/73	Nottoway River - Virginia Highway 653 bridge	1
05/15/73	Nottoway River - Virginia Highway 684 bridge	1
05/15/73	Nottoway River - Virginia Highway 40 bridge	2
05/15/73	Nottoway River - Virginia Highway 645 bridge	1
05/10/84	Nottoway River - Virginia Highway 653 bridge	1
Total		6

1973 and 1980. The relationship of temperature and time to the collection of the egg and larvae in the Meherrin River area during 1973 and 1980 are shown in Figure 16. For both years, all captures occurred from weeks 16 through 18. The data collected in 1973 and 1980 shows that American shad ascend the Meherrin River into Virginia (U.S. Highway 301), which is further than Walburg and Nichols (1967) and Baker (1968) reported (Figure 15).

Nottoway and Blackwater Rivers

During the 1973 sampling on the Nottoway River, five eggs and one larvae were captured (Tables 4, 8 and 9). The 1984 sampling produced one egg and 17 larvae from the same general area (Tables 8 and 9). American shad were observed spawning in the Nottoway River (Table 9). In addition, American shad larvae were captured in the Blackwater River (Table 9) which was not documented as an American shad spawning area during the 1973 survey (Street et al. 1975) The relationship of mean water temperature and time to capture of eggs and larvae during 1973 and 1984 is shown in Figure 17. Sampling in 1984 began later (week 19) than previous surveys.

Figure 18 shows the approximate spawning areas of American shad in the Nottoway River (1973 and 1984) and the Blackwater River (1984) areas, Virginia, as indicated by capture of eggs, and/or larvae, and/or observation of spawning activity. The 1973 and 1984 data disagree with that of Walburg and Nichols (1967) and Baker (1968). Both of these reports indicated that shad ascend only to the mouth of Nottoway River. Conversations with local fishermen in 1973 and 1984 indicated that a significant recreational fishery exists on the Nottoway River for shad utilizing fly rods. Fishing occurred over a 50-mile stretch of the river upstream from Courtland, Virginia.

Water temperature is probably the primary factor that triggers American shad spawning, but photo period, flow velocity, and water turbidity also exert some influence (Leggett and Whitney 1972). Sholar (1977a) reported that peak spawning occurred at water temperatures near 20°C in North Carolina. The spawning times as indicated by capture of eggs and larvae and water temperatures associated with American shad spawning in other North Carolina rivers generally agrees with that found for the tributaries of Albemarle Sound. Mansuetti and Kolb (1953),

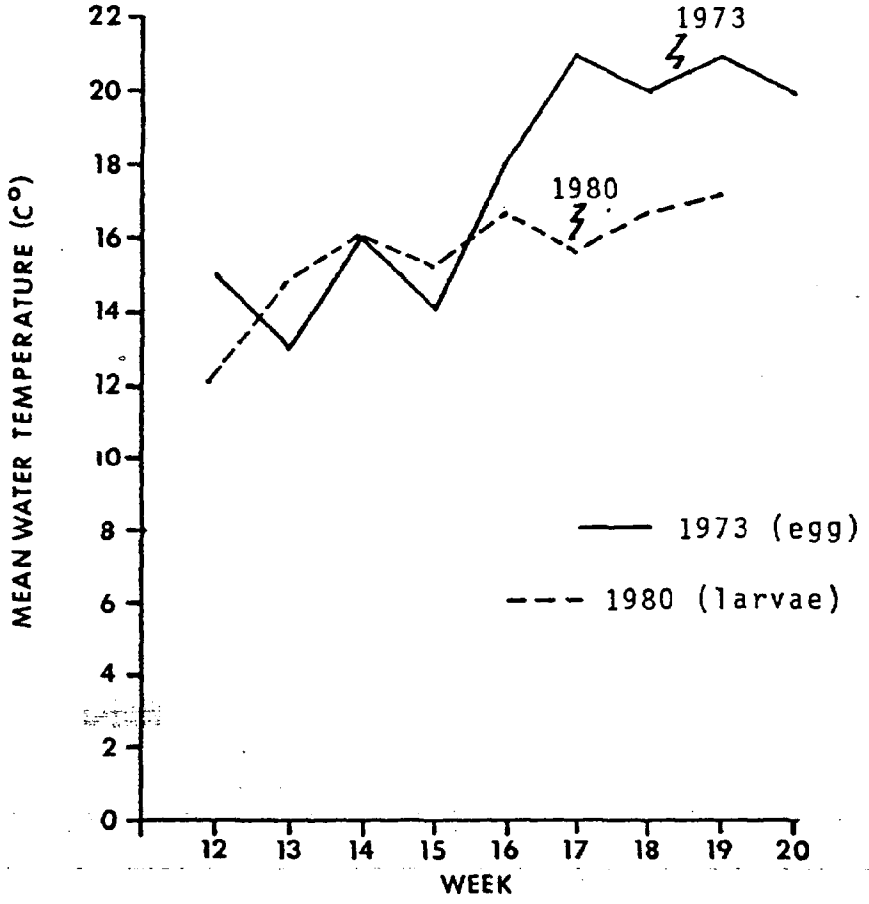


Figure 16. Spawning times and temperature associated with the capture of American shad larvae and an egg in the Meherrin River area, 1973 and 1980.

Table 9. Locations of American shad spawning observations and/or larval collections by egg net in the Blackwater River and Nottoway River areas, Virginia, in 1973 and 1984.

Date	Location	Number of larvae or spawning observed
05/15/73	Nottoway River - VA Rte 626 bridge	1
05/10/84	Blackwater River - US Rte 258/58 bridge	1
05/17/84	Nottoway River - VA Rte 631 bridge	1
05/22/84	Blackwater River - 5 mi above mouth	3
05/22/84	Nottoway River - VA Rte 637 bridge	10
05/22/84	Nottoway River - US Rte 258 bridge	2 and Spawning observed
05/22/84	Nottoway River - VA Rte 645 bridge	Spawning observed
05/22/84	Nottoway River - VA Rte 631 bridge	Spawning observed
05/22/84	Blackwater River - 400 yds above mouth	1
05/22/84	Nottoway River - 400 yds above mouth	2
05/22/84	Nottoway River - 2 mi above US Rte 258 bridge	2

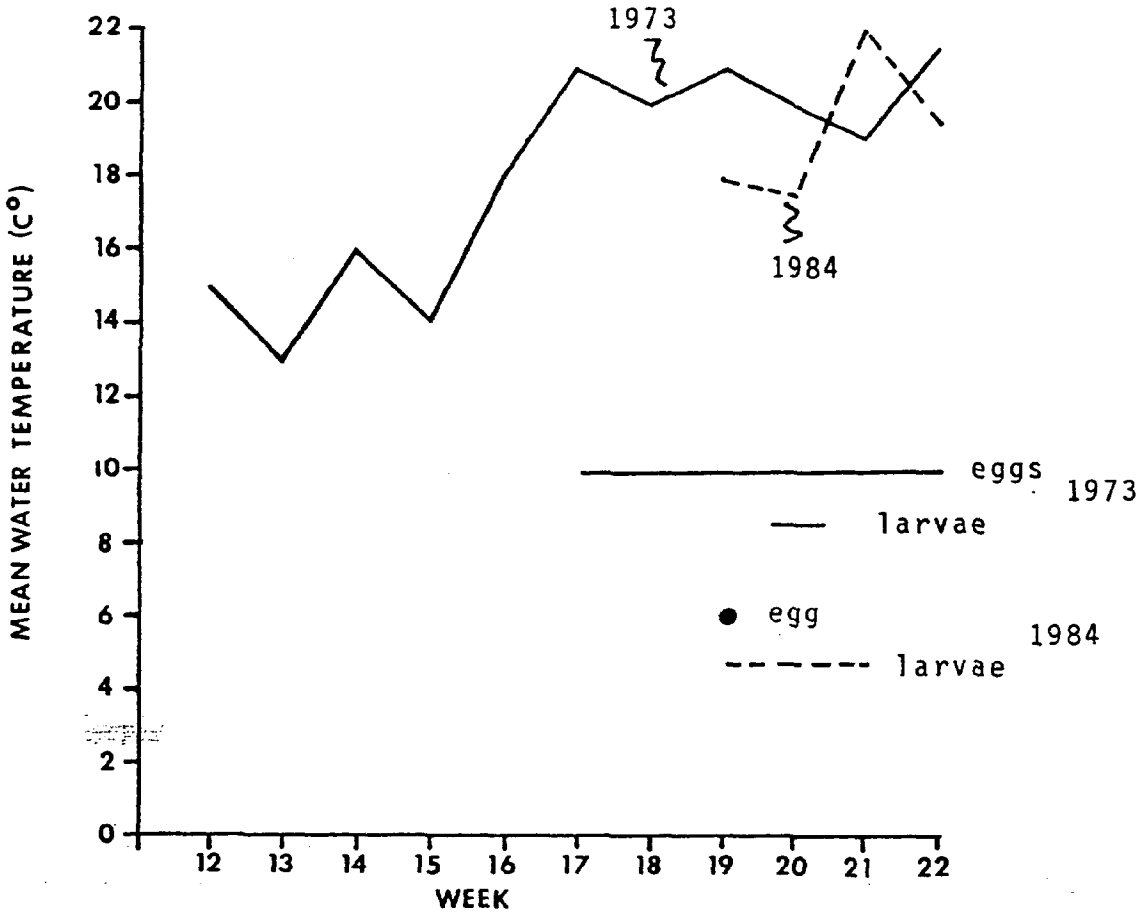


Figure 17. Spawning times and temperatures associated with the capture of American shad eggs and larvae in the Nottoway and Blackwater rivers Virginia, 1973 and 1984.

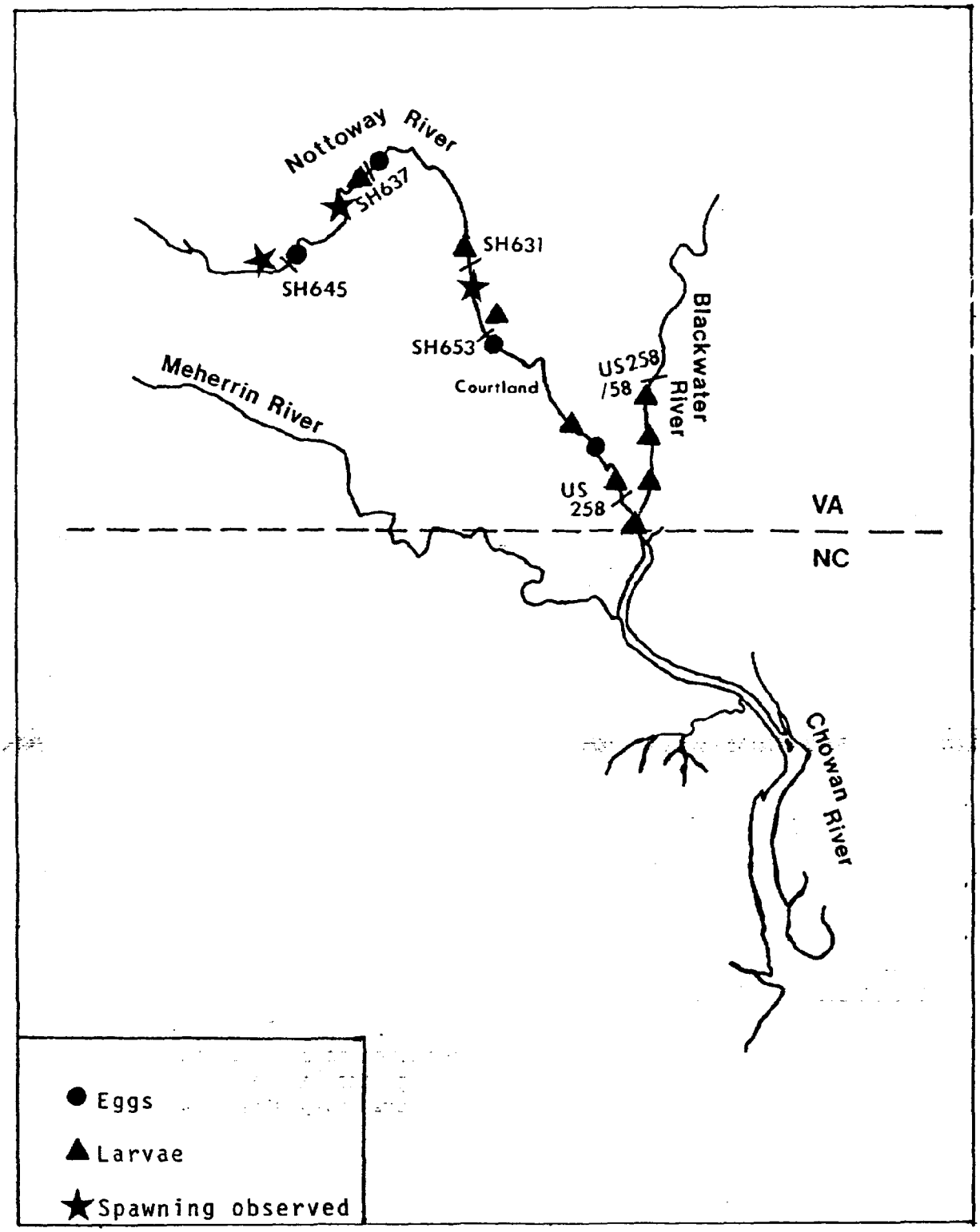


Figure 18. Spawning areas of American shad in the Nottoway and Blackwater rivers, Virginia.

Cheek (1968), and Ulrich et al. (1979) reported that spawning takes place between sundown and midnight. However, shad were observed spawning in the Nottoway River during the middle of the day.

The areas that are documented to function as spawning grounds need to be protected from alteration and pollution to help ensure maintenance of the population. The Albemarle Sound shad fishery appears to depend principally on fish spawned in the Roanoke and Nottoway rivers. Further development of these areas should consider potential effects on maintenance of the American shad population and fishery.

NURSERY AREA SAMPLING

A total of 320 juvenile American shad was captured in 7,562 samples in the Albemarle Sound area during 1972-1987 (Table 10). One of the major objectives of sampling was to determine a relative abundance index for each year class. However, so few shad were captured each year that an abundance index could not be determined. There are several possible explanations: (1) the Albemarle Sound area does not appear to produce the number of juvenile shad that the Cape Fear River, Neuse River, and Tar-Pamlico River produce (Sholar 1977b); or (2) the low number of juveniles captured indicates that nursery areas may not have been sampled or (3) the gears used were not effective for the capture of these juveniles. The explanations presented in 2 and 3 are probably valid and the juveniles that were captured were probably taken while migrating from nursery areas in the upper tributaries. Landings data (Table 3) indicate that the Albemarle Sound area produces about one-third of the annual landings, suggesting greater production than indicated by our sampling.

The number of samples, catch, and catch/effort for juvenile American shad by the various gears in the Albemarle Sound area for 1972-1987 are shown in Table 10. Overall, the seine proved to be the most effective gear; 261 juveniles were caught (CPUE 0.13). In 1985, the highest year since the studies began, 102 juveniles were caught, yielding a CPUE 1.44. Twenty-seven juveniles were taken with the semi-balloon trawl, for a CPUE of 0.06. Hassler (1974) and Hassler and Taylor (1984) reported no juvenile American shad being captured at the same stations utilizing the same gear in 1982-1984 (Figure 9). The

Table 10. Numbers of samples, catch, and catch/effort for juvenile American shad by various gears in the Albemarle Sound area, North Carolina, 1972-1987.

Year	Seine			Cobb trawls			Wing trawls			Semi-balloon trawl			Total	
	No. of individuals	No. of samples	C/E	No. of individuals	No. of samples	C/E	No. of individuals	No. of samples	C/E	No. of individuals	No. of samples	C/E	Individuals	Samples
1972	3	259	0.01	0	1661	0	0	0	0	0	0	0	3	1920
1973	10	332	0.30	0	1146	0	0	0	0	0	0	0	10	1478
1974	3	179	0.02	0	268	0	1	253	0.003	0	0	0	4	700
1975	9	156	0.06	0	0	0	0	276	0	0	0	0	9	432
1976	0	156	0	0	0	0	2	299	0.006	0	0	0	2	455
1977	21	130	0.16	0	0	0	0	249	0	0	0	0	21	379
1978	16	155	0.10	0	0	0	10	296	0.03	0	0	0	26	451
1979	14	52	0.27	0	0	0	0	113	0	0	0	0	14	165
1980	32	81	0.40	0	0	0	10	168	0.06	0	0	0	42	249
1981	3	69	0.04	0	0	0	4	145	0.03	0	0	0	7	214
1982	25	68	0.37	0	0	0	0	122	0	0	70	0	25	260
1983	1	69	0.01	0	0	0	5	145	0.03	6	112	0.05	12	326
1984	8	70	0.11	0	0	0	0	23	0	8	49	0.16	16	142
1985	102	71	1.44	0	0	0	0	0	0	0	56	0	102	127
1986	6	69	0.09	0	0	0	0	0	0	2	63	0.03	8	132
1987	8	69	0.11	0	0	0	0	0	0	11	63	0.17	19	132
Total	261	1985	0.13	0	3075	0	32	2089	0.01	27	413	0.06	320	7562

number of individuals, samples, and catch-effort for juvenile American shad from 1955-1984 as reported by Hassler et al. (1981), Hassler (1984) and Hassler and Taylor (1984) are shown in Table 11. The number of individuals captured has varied over the years (0-63), agreeing with the Division data that an abundance index could not be determined. A total of 32 individuals were captured using the wing trawl (CPUE 0.01). No juvenile American shad were taken with the Cobb trawls (large or small). The relative abundance indices for juvenile American shad by gear and year are shown in Figure 19. Because of the low numbers of juveniles captured and the probability that actual nursery areas were not well sampled, the relative abundance indices shown in Tables 10 and 11 and Figure 19 should be used with great caution or not at all.

Nursery Area

Although relatively few juvenile shad have been collected (261), tentative nursery areas can be delineated in the Albemarle Sound area. These areas generally coincide with those of blueback herring and alewife (Figure 20). Sampling in additional areas is needed to definitely map American shad nursery areas in the Albemarle Sound region. As Street et al. (1975) stated, these nursery areas are vitally important for the maintenance of the population and should remain unaltered and protected from pollution.

Movement

Juvenile American shad have been found throughout the Albemarle Sound area. The shad appeared more abundant over sand or gravel bottom, similar to the reports by Walburg and Nichols (1967) and Hawkins (1980). However, this apparent preference may have been due to gear and/or sampling locations. Seine sampling is limited to sand or gravel beaches where the gear can be most effectively used.

Juvenile shad have been taken in the Albemarle Sound area from February through December; overall, July accounted for the largest number of individuals (136), but 93 of the total was captured in 1985. September has accounted rather consistently over the years for a number (91) of individuals (Table 12).

Table 11. Number of samples, catch, and catch/effort for juvenile American shad by semi-balloon trawl in the Albemarle Sound area, North Carolina 1955-1984. (Hassler, Hill and Brown 1981, Hassler 1984, and Hassler and Taylor 1984).

	Semi-balloon trawl		
Year	Number of individuals	Number of samples	C/E
1955	0	37	0
1956	0	45	0
1957	0	57	0
1958	16	40	0.40
1959	0	51	0
1960	0	54	0
1961	1	61	0.02
1962	0	44	0
1963	12	45	0.27
1964	0	44	0
1965	4	49	0.08
1966	0	52	0
1967	26	33	0.78
1968	0	49	0
1969	0	49	0
1970	7	49	0.14
1971	0	49	0
1972	0	56	0
1973	0	56	0
1974	2	56	0.04
1975	1	56	0.02
1976	0	56	0
1977	0	54	0
1978	0	54	0
1979	63	49	1.29
1980	2	56	0.07
1981	0	56	0
1982	0	49	0
1983	0	56	0
1984	0	56	0
Total	134	1,518	0.09

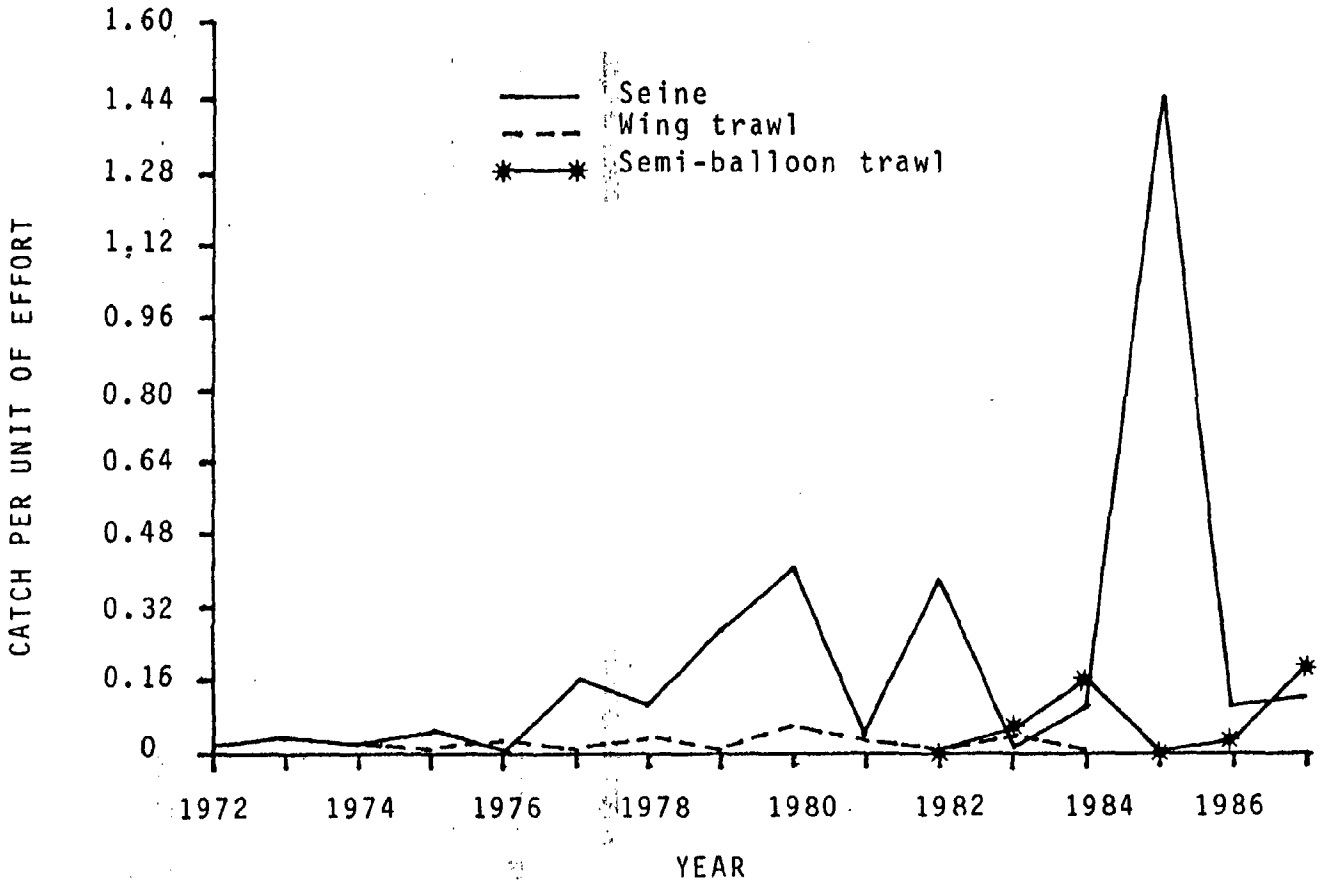


Figure 19. Catch-per-unit-of-effort by gears for American shad, 1972-1987 year classes, for the Albemarle Sound area, North Carolina, from Division sampling.

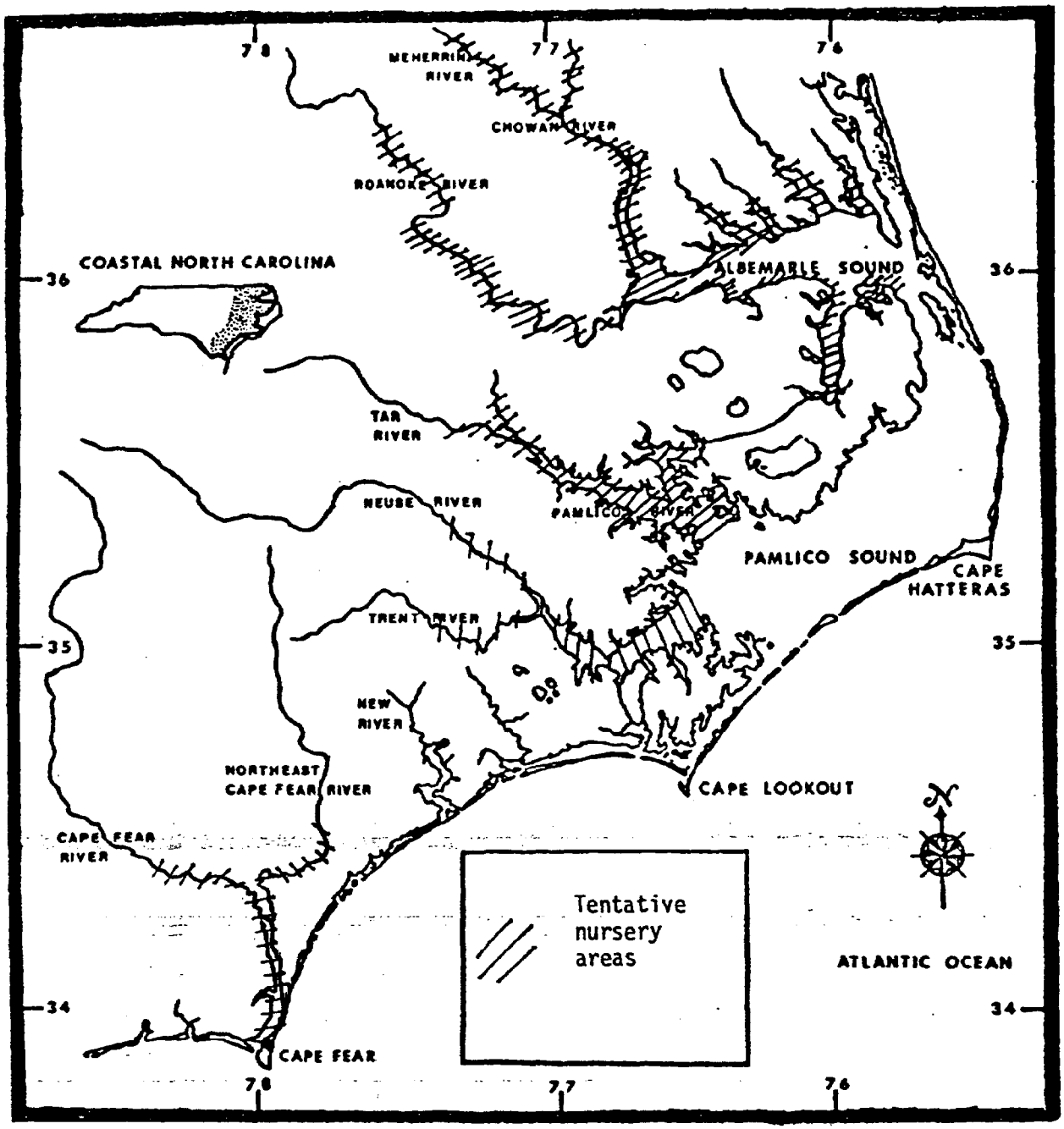


Figure 20. Tentative nursery areas of American shad in Albemarle Sound and tributaries, North Carolina.

Table 12. Number by month, mean fork length and length range (mm) of juvenile American shad taken in Albemarle Sound area, North Carolina, 1972-1987.

	January			February			March			April			May			June		
	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)
1972		-			-			-			-						-	
1973		-			-	141		-		1	-	105				4	37	33-40
1974		-			-			-	94	2	110	106-115						
1975		-			-			*			*			*			-	
1976		-			*			*			*			*			-	
1977		*			*			*			*			*			-	
1978		*			*			*			*			-			-	
1979		*			*			*			*			*			*	
1980		*			*			*			*			*		8	45	40-51
1981		*			*			*			*			*		1	-	100
1982		*			*			*			*			*			-	
1983		*			*			*			*			*			-	
1984		*			*			*			*			*			-	
1985		*			*			*			*			*				
1986		*			*			*			*			*				
1987		*			*			*			*			*				
Total	0						1			3			0			13		

(continued)

Table 12. (continued).

	July			August			September			October			November			December			
	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	No.	Mean FL	Length range (mm)	Total No.
1972		-			-			-		3	90.3	70-101							3
1973		-		1	-	81	1	-	58		-			-		2	96	95-97	10
1974		-			-			-		1	-	111		-			-		4
1975		-			-		9	88	74-140		-			-			-		9
1976		-			-		2	101	100-102		-			-			-		2
1977		-			-		21	67	60-81		-			-			-		21
1978	3	57	50-62	2	80	77-83	20	75	55-96	1	-	95		-			*		26
1979	3	67	62-70	3	63	59-69	8	62	55-68		-			*			*		14
1980	25	52	39-67	9	60	50-86		-			-			-			*		42
1981	3	47	40-54		-		3	85	83-86		-			*			*		7
1982		-		21	63	50-75	4	63	48-75		-			-			*		25
1983	1	-	81	3	92	84-105	3	85	61-100	5	89	73-125		*			*		12
1984	6	77	54-86	2	91	85-98	7	82	66-115	1	-	92		*			*		16
1985	93	67.2	45-90	1	-	72	1	-	79	7	79.6	73-95		*			*		102
1986		-		2	76	67-85	1	-	77	5	84.0	71-103		*			*		8
1987	2	67.0	62-72	5	92.6	88-101	11	97.2	73-121	1	-	93		*			*		19
Total	136			49			91			24			2			0			320

-Denotes samples taken, no catch.

*Denotes no samples.

Studies indicate that American shad remained in fresh and brackish waters until October or November, when they migrated to the ocean (LaPointe 1958; Talbot and Sykes 1958; Godwin and Adams 1969). Sholar (1975) and Hawkins (1980) noted decreased catches of juvenile shad during October for the Cape Fear River and Neuse River, respectively. Decreased catches were also noted in the Albemarle Sound area during October (Table 12).

Godwin and Adams (1969) in Georgia found evidence of size-related movement. Sampling produced no evidence of this type movement in the Albemarle Sound area. The mean length of American shad increased steadily from month to month from combined data (1972-1987), showing no sign of leveling off. These data agree with that for the Neuse River as reported by Hawkins (1980).

Most juvenile shad migrate to coastal waters by their first winter. Chittenden and Westman (1967), Leggett and Whitney (1972), Neves and Depres (1979) and Boreman (1981) noted a coincidence between peak down river movement of juvenile shad and a decline in water temperature below 15.1°C. This was also evident from the Albemarle Sound data. The few fish that were taken during the winter months were captured in the lower sound, probably utilizing the region as a wintering area. Spitsbergen and Wolff (1974) reported the capture of juvenile shad in lower Neuse River area during March. These fish were evidently using the lower estuarine waters to over winter. Oceanic sampling conducted by the R/V DAN MOORE indicated that juvenile shad migrated from the nursery areas as late as February (Holland and Yelverton 1973).

Growth

American shad from the Albemarle Sound area exhibited rapid steady growth. Juvenile shad during June-October, 1972-1987, ranged from 37 to 125 mm FL. These sizes are slightly larger than those found by Walburg (1956) and Hawkins (1980) in the Neuse River. Mean fork lengths and standard deviation by month are presented (Figure 21) for those years in which juvenile American shad were caught consistently during June-October (1978-1987). High growth rates were reported for shad from the Altamaha River, GA (Godwin and Adams 1969), Cape Fear River (Fischer 1980), and Neuse River (Hawkins 1980). Hildebrand and Schroeder (1928) also documented the fast growth of shad in the Potomac River, VA,

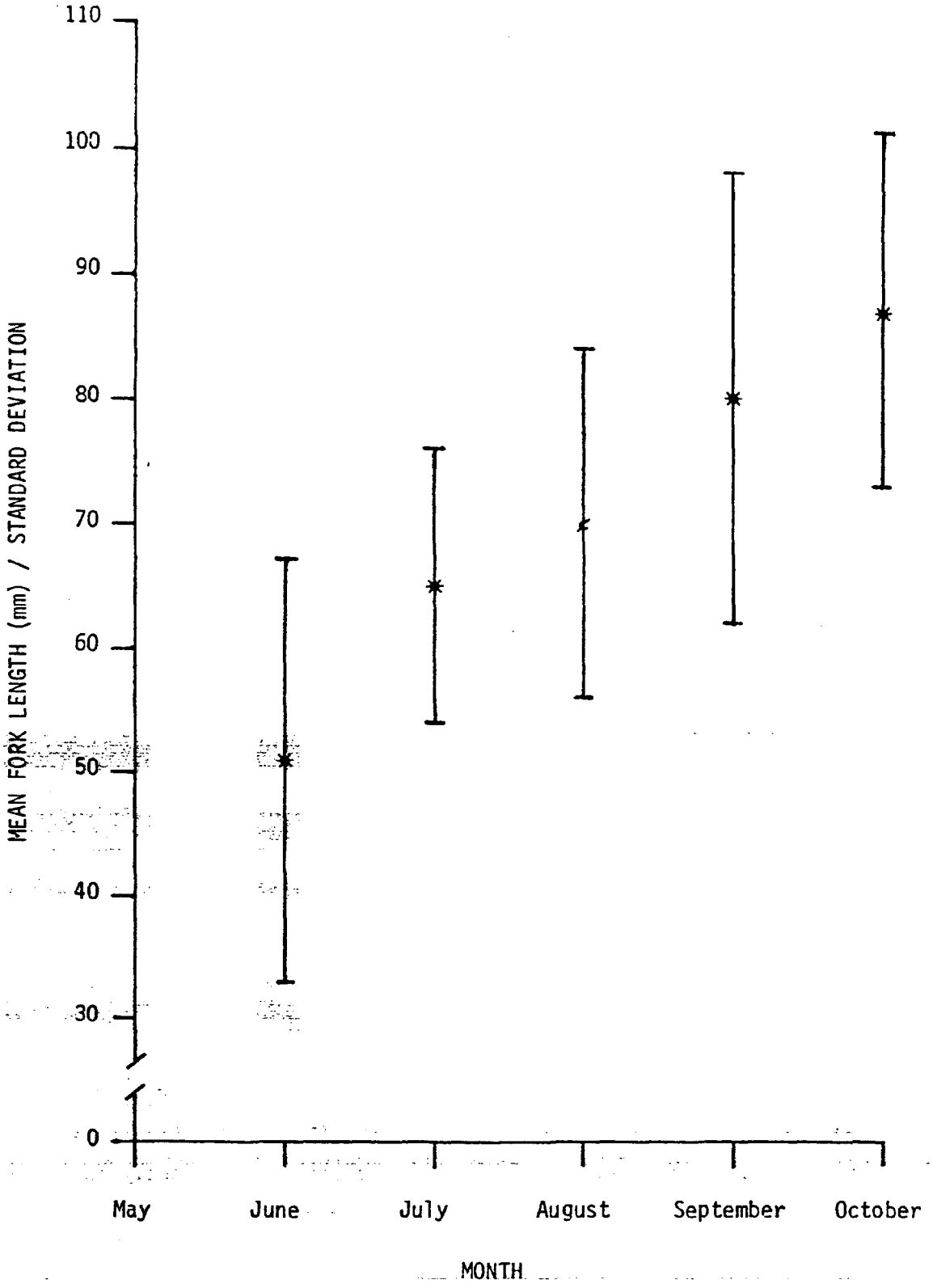


Figure 21. Mean fork length (mm) and standard duration of American shad by month from the Albemarle Sound area, North Carolina. (Data combined 1978-1987).

reaching an average length of 47 mm during the first half of July, 66.5 mm by the last half of August, and 70 mm by the last half of October. The mean lengths found in Albemarle Sound area are very similar to those of the Potomac River, VA.

COMMERCIAL HARVEST SURVEY

American shad landings and values for North Carolina and the Albemarle Sound area are presented in Table 3 for 1972-1987. Landings and values have fluctuated considerably during these 16 years. The decline in North Carolina landings has been more dramatic than that in Virginia or South Carolina, but has not resulted in stocks reaching the low levels observed in Maryland (Atlantic States Marine Fisheries Commission 1985). The Atlantic coast landings, by state, are shown in Table 1 of the Appendix for 1880-1985.

Walburg and Nichols (1967) stated that the Neuse River was the most important shad stream between the St. John River, FL and the James River, VA in 1896. However, Hawkins (1980) reported that American shad landings for 1972-1979 from the Neuse River area accounted for an average of 14.5% of the total North Carolina shad catch. Comparing this average with that of the Albemarle Sound area for the same time period, the Albemarle area has contributed an average of 64% of the state total. This is significantly more than the Neuse River. These proportions may be somewhat misleading, for fish from outside these areas are sometimes sold to area fish dealers; however, shad from Albemarle Sound are also sold to dealers in other areas. Therefore, these landings are the best estimate of commercial catch available.

For the 1972-1987 time period, the lowest state landings were reported in 1977--54,943 kg (121,022 lb). However, the Albemarle Sound area in 1977 contributed the highest percentage (65.8%) to the state total than in any other year, between 1972-1987. The lowest total reported in the Albemarle area, occurred in 1981 (30,296 kg, or 66,732 lb), but the state total was above the 16 year average (153,003 kg, or 337,013 lb). Winslow et al. (1983) reported the lowest river herring landings on record in 1981 for the Albemarle Sound area.

The North Carolina Division of Environmental Management has collected data on river flow and the concentration levels of pulp

mill effluent discharged into the Chowan River in Virginia, just north of the North Carolina-Virginia border for several years. During years with normal river flow (i.e. 1979-1980), the pulp mill effluent is out of the river prior to spawning runs. However, in 1981 flow was low and the effluent remained in the river considerably longer (Winslow et al. 1983). Everett (1983) therefore concluded that in the spring 1981, the high concentrations of pulp mill effluent in the river probably interfered with the normal river herring migratory pattern. This may also have affected American shad movement resulting in the decrease in landings.

Total state and Albemarle Sound area landings increased significantly during 1983 and 1984. Albemarle area landings were higher than any reported during the previous 13 years (Figure 22). American shad landings in 1985-1987 declined for the state and Albemarle area compared to that of 1984. In 1986 the state total was above the 153,003 kg (337,013 lb) average (1972-1987), but the Albemarle area total was below its average (54,852 kg, or 120,820 lb). During 1985 and 1987, the reverse situation occurred (Table 3 and Figure 22).

Gill nets, pound nets and haul seines have historically been the principal commercial fishing gears in the Albemarle Sound area, as well as the entire state for American shad (Walburg and Nichols 1967). Landings for 1972-1987 from the Albemarle Sound area and North Carolina are shown in Table 13 and 14 by year and gear. Since 1896, gill nets normally have accounted for the largest percentage of the landings annually in the Albemarle area and North Carolina (Stevenson 1899, Walburg and Nichols 1967). Gill nets were the dominant gear for Albemarle Sound area landings during 11 years and pound nets were the dominant gear the other five years. Landings by haul seines have continued to decline since the 1890s, but the use of this gear also has declined. The overall data for the Albemarle area for these 16 years indicates that gill nets have accounted for 64.6%, pound nets 33.3%, haul seines 2.2% and other gears 0.01% of the harvest.

Gill nets (anchor and drift) have contributed the highest percentage of American shad to the state landings for 15 of the past 16 years (Table 14). Only in 1977, did pound net catches dominate the state's landings. Overall for this time period, commercial gears contributed the following to the harvest: 65.7% were taken by anchor

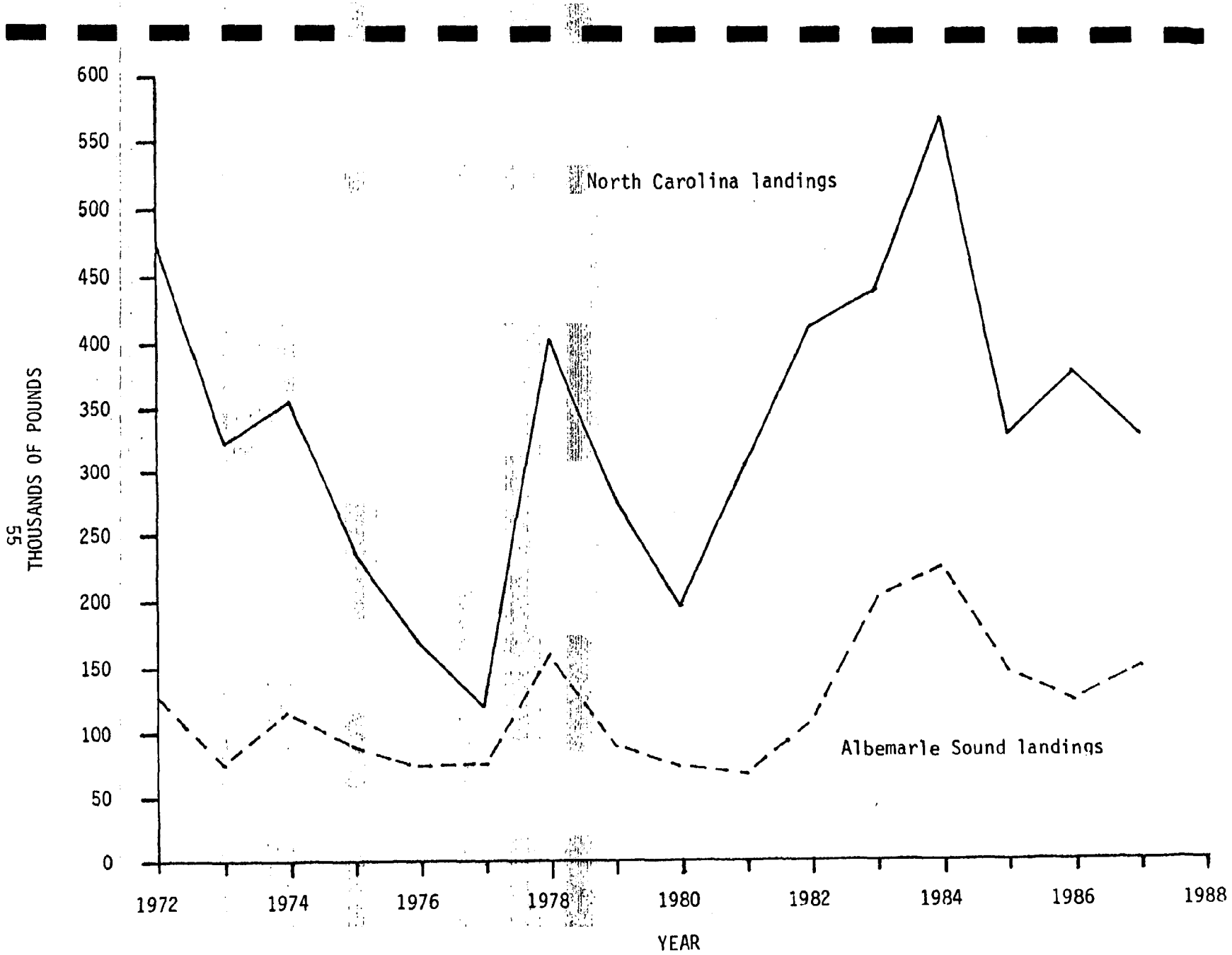


Figure 22. American shad landings for North Carolina and the Albemarle Sound area, 1972-1987.

Table 13. American shad landings by gear and percent from the Albemarle Sound area, 1972-1987.

Year	Albemarle Sound area landings (lb)	Albemarle Sound Area Totals: Anchor gill net Pounds	%	Pound net Pounds	%	Haul seine Pounds	%	Other Pounds	%
1972	130,399	59,721	45.8	70,678	54.2	-	-	-	-
1973	80,770	19,518	24.2	61,252	75.8	-	-	-	-
1974	116,502	68,537	58.8	43,493	37.3	4,472	3.9	-	-
1975	87,063	18,037	20.7	68,088	78.2	938	1.1	-	-
1976	78,301	35,774	45.7	36,215	46.2	6,312	8.1	-	-
1977	79,594	19,083	24.0	60,267	75.7	-	-	244	0.3
1978	158,908	122,367	77.0	36,541	23.0	-	-	-	-
1979	85,158	63,173	74.2	19,805	23.2	2,180	2.6	-	-
1980	68,395	36,880	53.7	30,785	44.8	1,030	1.5	-	-
1981	66,732	49,750	74.6	16,354	24.5	628	0.9	-	-
1982	118,794	91,628	77.1	26,223	22.1	943	0.8	-	-
1983	216,058	172,667	80.0	28,811	13.3	14,580	6.7	-	-
1984	227,308	197,354	86.8	22,546	10.0	6,408	3.2	-	-
1985	148,555	78,209	52.6	67,097	45.2	3,249	2.2	-	-
1986	120,367	83,124	69.1	37,243	30.9	-	-	-	-
1987	149,923	132,961	88.7	16,962	11.3	-	-	-	-
Total	1,933,127	1,248,783	64.6	642,360	33.2	41,740	2.2	244	<0.1

Table 14. American shad landings by gear and percent for North Carolina, 1972-1987.

	North Carolina Totals													
	N.C. total landings	Anchor gill net		Pound net		Drift gill net		Haul seine		Trawls		Other	
Year		Pounds	%	Pounds	%	Pounds	%	Pounds	%	Pounds	%	Pounds	%
1972	468,484	240,973	51.4	160,543	34.3	66,968	14.3	-	-	-	-	-	-
1973	321,000	173,150	54.0	118,730	37.0	29,120	9.0	-	-	-	-	-	-
1974	368,833	210,387	57.0	133,755	36.3	20,219	5.5	4,472	1.2	-	-	-	-
1975	241,240	103,145	42.8	114,208	47.3	22,949	9.5	938	0.4	-	-	-	-
1976	167,190	109,241	65.3	44,349	26.5	7,288	4.3	6,312	3.9	-	-	-	-
1977	121,022	38,644	32.0	63,438	52.4	16,121	13.3	2,575	2.1	-	-	244	0.2
1978	402,017	321,253	79.9	44,639	11.1	28,962	7.2	7,163	1.8	-	-	-	-
1979	278,070	203,947	73.3	26,030	9.4	45,758	16.4	2,180	0.8	155	<0.01	-	-
1980	199,206	97,776	49.1	47,935	24.1	45,486	22.8	5,867	2.9	2,142	1.1	-	-
1981	351,500	189,218	53.8	26,583	7.6	53,011	15.1	80,984	23.0	1,704	0.5	-	-
1982	411,852	259,472	63.0	29,790	7.2	77,934	19.0	44,640	10.8	16	<0.1	-	-
1983	445,879	331,068	74.3	33,574	7.5	65,728	14.7	15,255	3.4	254	<0.1	-	-
1984	584,843	436,906	74.7	58,660	10.0	68,911	11.8	14,179	2.4	4,038	0.7	2,149	0.4
1985	329,639	240,371	73.0	67,247	20.4	14,164	4.3	3,434	1.0	799	0.2	3,624	1.1
1986	373,794	295,261	79.0	37,495	10.0	37,048	9.9	3,956	1.0	34	<0.01	-	-
1987	327,646	292,433	89.3	19,079	5.8	13,813	4.2	1,992	0.6	329	0.1	-	-
Total	5,392,215	3,543,245	65.7	1,026,055	19.0	613,480	11.4	193,947	3.6	9,471	0.2	6,017	0.01

anchor gill nets; 19.0% pound nets; 11.4% drift gill nets; 3.6% haul seine; 0.1% trawls; and 0.05% by other gears.

American Shad Year/Age Class Composition

The Albemarle Sound area age data for 1972 and 1982-1987 (years when individual weights were taken) was used to calculate the number of individuals in the commercial harvest from each year class by month. The contribution of each year class to the American shad harvest by sex and month for these years are presented in Appendix Tables 2-8. The summary by sex of the year classes represented in the 1972 and 1982-1987 fishery is shown in Table 15.

The 1972 fishery was represented by year classes 1969-1963 (ages 3-9). Males contributed to year classes 1969-1964 with the 1967 year class (age 5) dominating the male harvest (53.8%). Females were dominated by the 1966 year class (age 6), making up 51.7 %, but was represented by 1968-1963 year classes. The 1967 and 1966 year classes (age 5 and 6) clearly dominated the harvest, accounting for 84.1%, sexes combined.

The year classes 1979-1974 were represented in the 1982 male sample, with the 1977 year class (age 5) comprising 45.7% of the males. The 1976 year class (age 6) dominated the females 40.4%, with the 1979-1973 year classes represented. Age classes 1977 and 1976 (age 5 and 6) represented the majority of the fish in the fishery (64.0%)

Year classes 1980-1974 were represented in the fishery during 1983. The 1978 year class (age 5) composed 52.2% of the males, but males contributed to the 1980-1975 year classes. Females were dominated by the 1977 year class (age 6), 38.0%. Year classes 1978 and 1977 accounted for 74.0% of the fish.

The 1984 fishery was composed of fish from the 1980-1975 year classes. Forty-two percent of the males were from the 1979 year class (age 5). Females were dominated by the 1977 year class (age 7), contributing 32.9%. Age classes 5 and 6 (year classes 1979 and 1978) dominated, amounting to 53.2% of the fishery.

The 1982-1977 year classes were represented in the fishery, 1985. Males were found to contribute to all year classes, but the 1980 year class age (5) accounted for the highest percentage (46.4%). The 1979

Table 15. Contribution of each year class to the American shad harvest for the Albemarle Sound area, N.C., commercial fishery, by sex 1972 and 1982-1987.

Year class	Fishing Year 1972 Number	1972 Percent	1982 Number	1982 Percent	1983 Number	1983 Percent	1984 Number	1984 Percent	1985 Number	1985 Percent	1986 Number	1986 Percent	1987 Number	1987 Percent
Male														
1964	40	0.3												
1965	345	2.3												
1966	3,113	20.8												
1967	8,045	53.8												
1968	3,135	21.0												
1969	271	1.8												
1970														
1971														
1972														
1973														
1974			83	0.4										
1975			821	3.7	387	1.2								
1976			4,725	21.0	1,457	4.5	2,252	7.7						
1977			10,233	45.7	8,918	27.4	4,777	16.2	481	2.6				
1978			6,299	28.1	16,961	52.2	8,273	28.1	1,700	9.3	385	1.6		
1979			248	1.1	4,589	14.1	12,387	42.1	4,836	26.6	2,730	11.3	425	2.5
1980					193	0.6	1,733	5.9	8,435	46.4	5,261	21.8	3,412	19.8
1981									2,581	14.2	12,341	51.1	4,044	23.4
1982									162	0.9	3,420	14.2	9,385	54.3
1983														
Female														
1963	40	0.2												
1964	21	0.1												
1965	1,375	8.3												
1966	8,550	51.7												
1967	5,948	36.0												
1968	609	3.7												
1969														
1970														
1971														
1972														
1973			83	0.6										
1974			425	3.2	193	0.8								
1975			3,958	29.8	838	3.6	2,543	8.7						
1976			5,368	40.4	5,782	24.9	6,512	22.2						
1977			2,507	18.9	8,822	38.0	9,636	32.9	322	1.7	134	1.2		
1978			770	5.8	6,549	28.2	7,347	25.1	4,818	24.6	2,524	23.3	218	1.0
1979			167	1.3	1,049	4.5	3,238	11.1	9,500	48.6	4,290	39.6	1,687	8.1
1980									4,758	24.3	2,428	22.4	5,574	27.0
1981									162	0.8	1,328	12.3	8,790	42.4
1982											134	1.2	4,165	20.1
1983													283	1.4

year class (age 6) dominated the female portion, composing 48.6% of the total. Females were represented by 1981-1977 year classes.

Males were represented in the 1982-1978 year classes, with the 1981 year class accounting for 51.1% of the total, during 1986. The 1979 year class (age 6) dominated the females (39.6%), but females were represented by 1982-1977 year classes. Overall, the 1981 and 1980 year classes contributed 61.1%.

During 1987, the males were dominated by the 1982 year class (age 5), representing 37.6%. Year classes of males were 1983-1979. The 1981 year class (age 6) accounted for 42.4% of the females. Year classes 1982 and 1981 accounted for 57.8% of the fish.

It is evident from this data that March and April are the principle months of the shad fishery in the Albemarle area, as it has been historically. The contribution of the year classes over the months is spread out. For these years that the number of individuals have been calculated, there does not appear to be any relationship between time period (months) and age of the fish. It is obvious that 5 and 6 year olds contribute the major portions of the harvest. The percentage of 5 and 6 year old fish in the harvest has varied somewhat during these years, from a high in 1972 of 81.4% to a low in 1984 of 53.2%.

ADULT SAMPLING

Size, Age, and Spawning Class

American shad were sampled from the commercial harvest each spring in the Albemarle Sound area. A total of 4,118 scale samples was found suitable for age determination from 1972-1980. As described in the methods, sub-sampling for aging began in 1981. Scale samples from 2,073 shad were aged and expanded following Ketchen (1950) to obtain the total number of fish samples (3,638) during 1981-1987.

The annual age-size composition for 1972-1987 is shown in Tables 9-24 in the Appendix. Most shad populations on the Atlantic coast are comprised primarily of age classes 4 through 7 (Rulifson et al. 1982). The Albemarle Sound data generally agrees with the literature, except for the 1979 data. The large number of old virgin fish is questionable and differs significantly from the other years. Unfortunately, the scale samples for 1979 were destroyed and could not be re-read.

Therefore, this data will not be included in the combined age table or in the discussion. The combined age and spawning frequency for American shad from the Albemarle Sound area, 1972-1978 and 1980-1987 is presented in Table 16.

Ages ranged from two to eight years for males and four to nine years for females (Table 17). The mean ages from 1972-1987 ranged from 4.0 to 5.8 years for males and 4.8 to 6.5 years for females. The mean low occurred in 1974 and the high in 1981 for both sexes. Mean age of males for all years was 5.0 years and females 5.6 years. Age groups four and five comprised 68.6% of the male sample (Table 17); similar to that found in the York River, VA. (75%) in 1957 (Nichols and Massmann 1963). The percentage of males age 4 and 5 in the Albemarle area is lower than that reported for the Pamlico River, 89.5%, (Marshall 1976), Cape Fear River, 93%, (Sholar 1977b) and the Neuse River, 85%, (Hawkins 1980), but higher than that found in Virginia rivers in 1978 and 1979, 37.8% and 33.7%, respectively (Johnson et al. 1978 and Loesch et al. 1981). Males in age group three contributed only 1.5% to the fishery, probably due to the size selectivity of gill nets. Walburg (1957) reported similar results from the Neuse River.

Females were predominately five and six years old, comprising 66.6% of the sample (Table 17). Nichols and Massmann (1963) reported a much lower percentage (39.5%) for the York River, VA., during 1957-1959. The percentage of five and six-year-old females in these age groups is similar to that reported by Walburg (1957) for the Neuse River (72%), but differs from that of the Pamlico River (77%) (Marshall 1976), Cape Fear River (86%) (Sholar 1977b) and Neuse River (92%) (Hawkins 1980). The modal age for spawning in the Albemarle Sound area appears to be five years old. This agrees with that found by Loesch et al. (1979) for Virginia in 1977. Since samples were from the gill net fishery, which is size selective, it is possibly biased.

Age groups five through seven years old, sexes combined, accounted for 77.2% of the sample (Table 17). Similar percentages (80.6%) were reported from offshore North Carolina (Holland and Yelverton 1973) and on the Delaware and Connecticut rivers (Walburg and Nichols 1967).

The percent contribution of each year class of American shad from the Albemarle Sound area commercial harvest 1972-1987 is shown in Table

Table 16. Age and spawning frequency for American shad from the Albemarle Sound area, N.C. Combined data 1972-1978 and 1980-1987 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
II	1	0									1	0
III	64	0									64	0
IV	966	164	30	2							996	166
V	1,260	822	630	164	10	8					1,900	994
VI	214	558	415	334	228	128	3	3			860	1,023
VII	5	28	37	144	224	289	48	49	2	0	316	510
VIII	1	2	0	4	16	91	63	128	7	26	87	251
IX					0	2	0	46	0	35	0	83
Total	2,511	1,574	1,112	648	478	518	114	226	9	61	4,224	3,027
Percent of total	59.5	52.0	26.3	21.4	11.3	17.1	2.7	7.5	0.2	2.0		
Percent sexes combined	56.3		24.3		13.7		4.7		1.0			

Table 17. American shad number, percent, mean length range, mean weight, range at age, by, sex from the Albemarle Sound area, N.C. commercial catch, 1972-1978 and 1980-1987 (M = male, F = female).

Age	Number		Percent of total by sex		Percent sexes combined	Fork length (mm)				Weight (kg)*			
						Mean		Range		Mean		Range	
	M	F	M	F		M	F	M	F	M	F	M	F
II	1	0	<0.1	-	<0.1	375		-	-	-	-	-	-
III	64	0	1.5	-	0.9	366	-	325-426	-	0.82	-	0.50-1.39	-
IV	996	166	23.6	5.5	16.0	400	438	238-497	340-520	1.09	1.69	0.46-2.25	0.69-2.80
V	1,900	994	45.0	32.9	39.9	422	468	256-520	275-591	1.28	2.00	0.51-2.35	0.59-3.17
VI	860	1,023	20.3	33.8	26.0	433	485	316-548	380-574	1.43	2.02	0.66-2.76	0.62-3.35
VII	316	510	7.5	16.8	11.4	438	487	380-544	353-560	1.46	2.25	0.90-2.81	0.68-3.58
VIII	87	251	2.1	8.3	4.7	456	494	347-553	397-560	1.78	2.37	1.21-3.01	1.02-3.24
IX	0	83	-	2.7	1.1	-	510	-	457-595	-	2.54	-	1.84-3.23
Total	4,224	3,027											

* Weights were taken during 1972 and 1981-1987.

18. This data generally agrees that with reported from Virginia rivers, 1977-1983 (Loesch et al. 1977, 1981; Johnson et al. 1978; Loesch and Kriete 1980, 1981, 1982, 1983).

Spawning history indicated that most males spawned first at age four and females at age five, agreeing with that reported by Walburg (1957) and LaPointe (1958). The proportion of repeat spawners in a population increases with increased latitude. Virtually all shad south of Cape Hatteras die after spawning, while the percentage of repeat spawners in rivers north increases (Leggett 1969; Chittenden 1975; Leggett and Carscaddan 1978). Of the American shad sampled in the Albemarle Sound area, 19.4% were repeat spawners. This percentage fluctuates annually, from a low of 0.2% (1977) to a high of 57.9% (1981). The percentage of repeat spawners for the Potomac River, VA, was 17% (Walburg and Sykes 1957) and 23% for the York River, VA., (Nichols and Massmann 1962). The percentage found for the Albemarle Sound area is considerably higher than the 3% and 7.4% reported for the Neuse River by Walburg (1957), and Hawkins (1980), respectively, but comparable to the 18.6% found by Hassler and Pate (personal communication) in 1971. Virgin males composed 59.5% of the data and females 52.0%, sexes combined virgin fish accounted for 56.3% of the sample.

Mean lengths of Albemarle Sound area American shad were compared with those of other investigations in North Carolina (Table 19) and along the Atlantic coast (Table 20). Mean size at age is similar for all North Carolina studies. Growth differs between northern and southern rivers as well as between sexes. Length increases with age of shad greater in the north than south (Walburg and Nichols 1967). Since females grow faster than males, females are considerably larger at all ages. The Albemarle Sound data generally agrees with these findings.

Sex Ratio

Sex ratios of American shad populations are difficult to determine due to collection techniques and commercial practices of harvesting and marketing. Fishermen utilize large mesh gill nets to select for the larger females because of their higher value (price per pound) compared to males, especially if the females are "roe" shad (Rulifson and Huish 1982). Examining the ageing data on an annual basis, sex ratios have

Table 18. Percentage contribution of each year class of American shad harvest 1972-1987.

	Year class	Fishing Year 1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Male	1963																
	1964	0.4															
	1965	3.8	0.6														
	1966	18.4	2.0														
	1967	54.8	6.4	1.0	0.6												
	1968	19.2	25.4	-	1.2												
	1969	3.4	56.4	17.1	9.1	0.7											
	1970		9.2	72.9	46.1	12.0											
	1971			9.0	42.4	53.1	11.8	0.3	1.0								
	1972				-	34.2	65.2	13.7	4.7	4.7							
	1973				0.6		23.0	66.0	21.8	19.2							
	1974							18.9	40.3	22.5	8.7	0.5					
	1975							1.1	29.5	41.8	20.3	4.1	0.5				
	1976								2.7	11.8	40.2	22.7	4.9	5.5			
	1977										29.8	45.9	29.7	15.0	1.7		
	1978										1.0	26.8	55.3	28.1	7.2	1.2	
	1979												9.3	45.1	26.3	13.9	1.2
	1980												0.3	6.3	45.3	22.8	9.6
	1981														18.6	51.3	20.0
	1982														0.9	10.8	40.0
	1983															29.2	
Female	1963	0.5															
	1964	0.9															
	1965	9.0	0.3														
	1966	44.6	2.3														
	1967	38.7	45.0	0.7	0.7												
	1968	6.3	39.8	8.0	2.8	0.4											
	1969		12.6	58.4	23.6	1.3											
	1970			32.9	57.9	23.8	2.3		0.5								
	1971				15.0	67.1	41.5	3.9	2.4	4.4							
	1972					7.4	55.0	38.0	16.9	21.3							
	1973						2.2	53.7	46.4	36.8	18.0	1.0					
	1974							4.4	30.9	27.9	42.1	4.7	0.4				
	1975								2.9	9.6	23.2	30.8	2.6	9.7			
	1976										12.3	39.7	24.5	22.6			
	1977										4.4	21.0	41.7	32.9	1.9	1.7	
	1978											2.8	28.6	26.1	26.2	22.8	0.6
	1979												2.2	8.7	48.6	35.1	9.5
	1980														22.8	24.6	27.9
	1981														0.5	14.1	43.0
	1982															1.7	17.9
	1983																1.1

* Ages reported for 1979 are highly questioned.

Table 19. Age and mean fork length (mm) of American shad from various areas of North Carolina.

Age	2		3		4		5		6		7		8		9	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Location																
Albemarle Sound	375	-	366	-	400	438	422	468	433	485	438	487	456	494	-	510
Northeast Cape Fear River[1]					392	436	430	462	460	510	-	517				
Neuse River[2]			370	-	401	428	418	460	435	482	455	502	-	547		
Pamlico Sound and River[3]			334	-	415	445	437	481	456	494	470	489	485	522		
Offshore North Carolina[4]					459		451		458		467		486		488	

[1]Sholar, 1977b

[2]Hawkins, 1980

[3]Marshall, 1976

[4]Holland and Yelverton, 1973 (sexes combined)

Table 20. Age and mean fork length (mm) of American shad from Albemarle Sound compared to investigations in other areas.

Age	1		2		3		4		5		6		7		8		9	
Sex / Location	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Albemarle Sound, NC			375	-	366	-	400	438	422	468	433	485	438	487	456	494	-	510
St. Johns River, FL[2]					367	403	386	415	409	442	-	450						
Neuse River, NC[1]	178	183	287	295	368	376	422	429	-	472	-	513						
York River, VA[2]					335		379	411	398	432	407	445	-	494	-	458		
Delaware River, NJ*[3]	193	209	307	321	380	404	435	464	466	511	482	538	491	553	-	558		
Connecticut River, CT[2]					397		432	458	453	474	469	501	480	507	483	524		
St. John River, NB[2],CAN							406	430	428	445	436	452	439	465	-	471		

*Based on back calcuation from scales.

[1]LaPointe, 1958; calculated fork lengths in inches converted to mm.

[2]Leggett, 1969.

[3]DBFWMC, 1981.

varied from 1.12:1 males to females, to 2.7:1. The overall sex ratio from the aged individuals yields 1.39:1 male:female; however, if all sex data is analyzed, a sex ratio of 0.92:1 is obtained. As previously stated, this is a biased size selective fishery and these ratios probably do not reflect the true population. Walburg and Nichols (1967) and Cheek (1968) reported that during the freshwater migration the sex ratios vary, with the early part of the run dominated by males and the latter part of the run approximately equal or slightly dominated by females.

Length Frequency

The length frequency distributions for male and female American shad from the commercial fishery in the Albemarle Sound area, 1972-1987, are presented in Figure 23. The annual length frequencies are shown in Figures 5-16 in the Appendix. Male shad ranged in length from 238 mm to 562 mm FL, and in weight from 0.46 kg to 3.01 kg. Females ranged in length from 279 mm to 595 mm FL, and in weight from 0.59 kg to 3.58 kg. Male shad dominated sizes 350-425 mm, and females 450-525 mm FL. Females were consistently of larger modal lengths than males, agreeing with historical data. The length ranges for both sexes of shad in the Albemarle Sound area exceeded the lower and upper ends of the ranges found for the Blackwater River, Cape Fear River, Northeast Cape Fear River, Neuse River, and the Tar-Pamlico River (Winslow et al. 1983).

Weight-Length Relationship

Males and females were analyzed separately due to variation in weight at a given length (Table 21) in the linear regression model. The overall fork length-weight relationship by sex is shown in Figure 24. The regression model for all years combined accounts for 78% of the variability for males and 75% for females. Coefficient of determination is the proportion of the variability in the dependent variable (weight) that is accounted for by the independent variable length.

Insufficient numbers of spent American shad were available to accurately calculate a length-weight regression for post spawning fish. Weight loss by the small number of spent females sampled were considerably higher percentage-wise, than females of other species. Losses of 30 to 45% were not uncommon (Street et al. 1975, Leggett 1969).

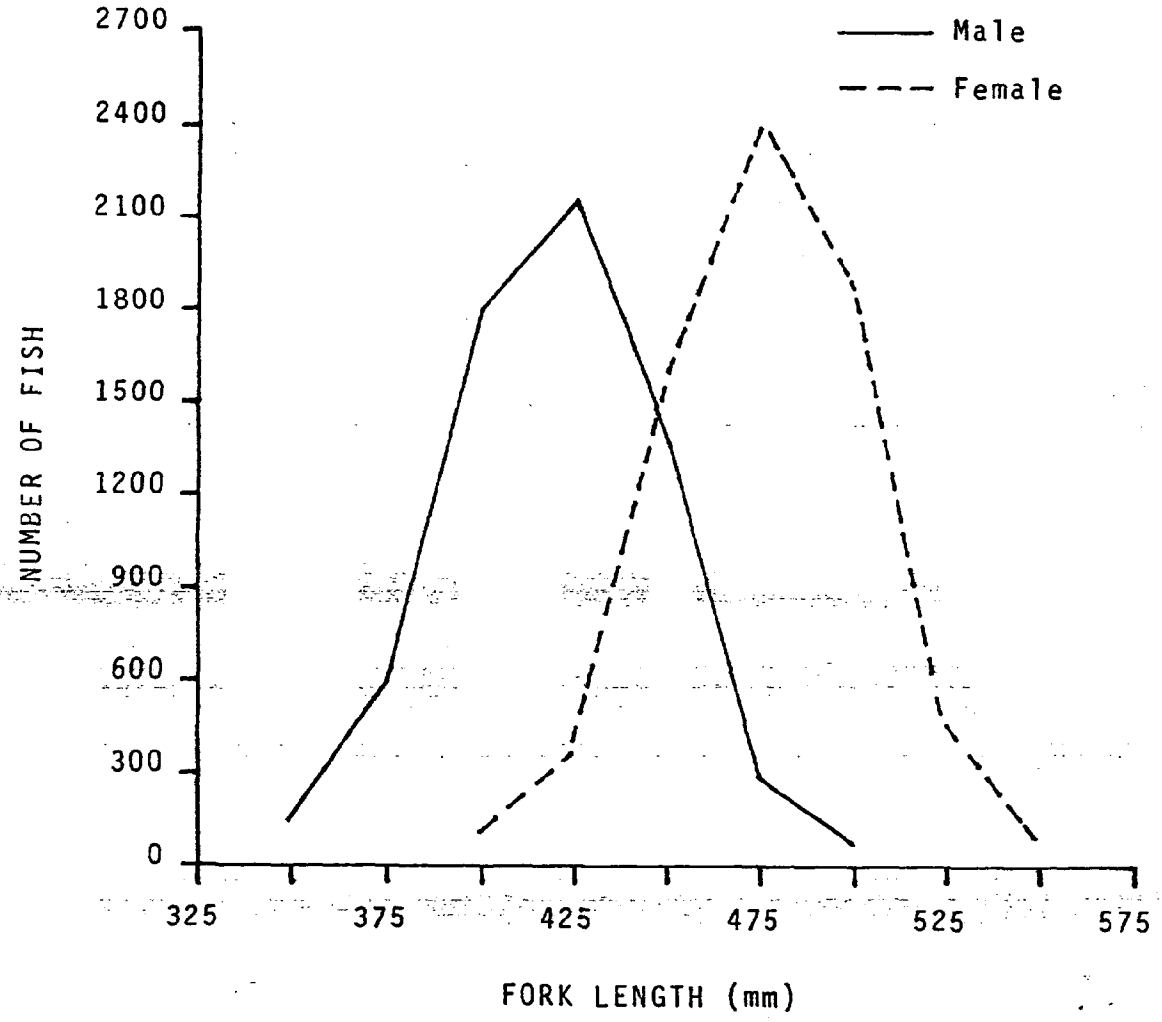


Figure 23. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, N.C., 1972-1987.

Table 21. Weight-length regressions for American shad, where log 10 weight (kg) = a+b log 10 length (mm) and r^2 = coefficient of determination from the Albemarle Sound area, NC.

	Male			Female		
Year	a	b	r^2	a	b	r^2
1972	-9.61	3.70	0.80	-7.32	2.85	0.68
1981	-7.85	3.02	0.79	-7.53	2.92	0.77
1982	-7.78	2.99	0.76	-8.67	3.34	0.82
1983	-8.46	3.26	0.73	-6.97	2.71	0.57
1984	-8.82	3.39	0.86	-7.76	3.01	0.72
1985	-9.17	3.51	0.75	-8.42	3.25	0.80
1986	-7.40	2.86	0.69	-7.17	2.79	0.60
All years combined	-8.68	3.34	0.78	-8.07	3.13	0.75

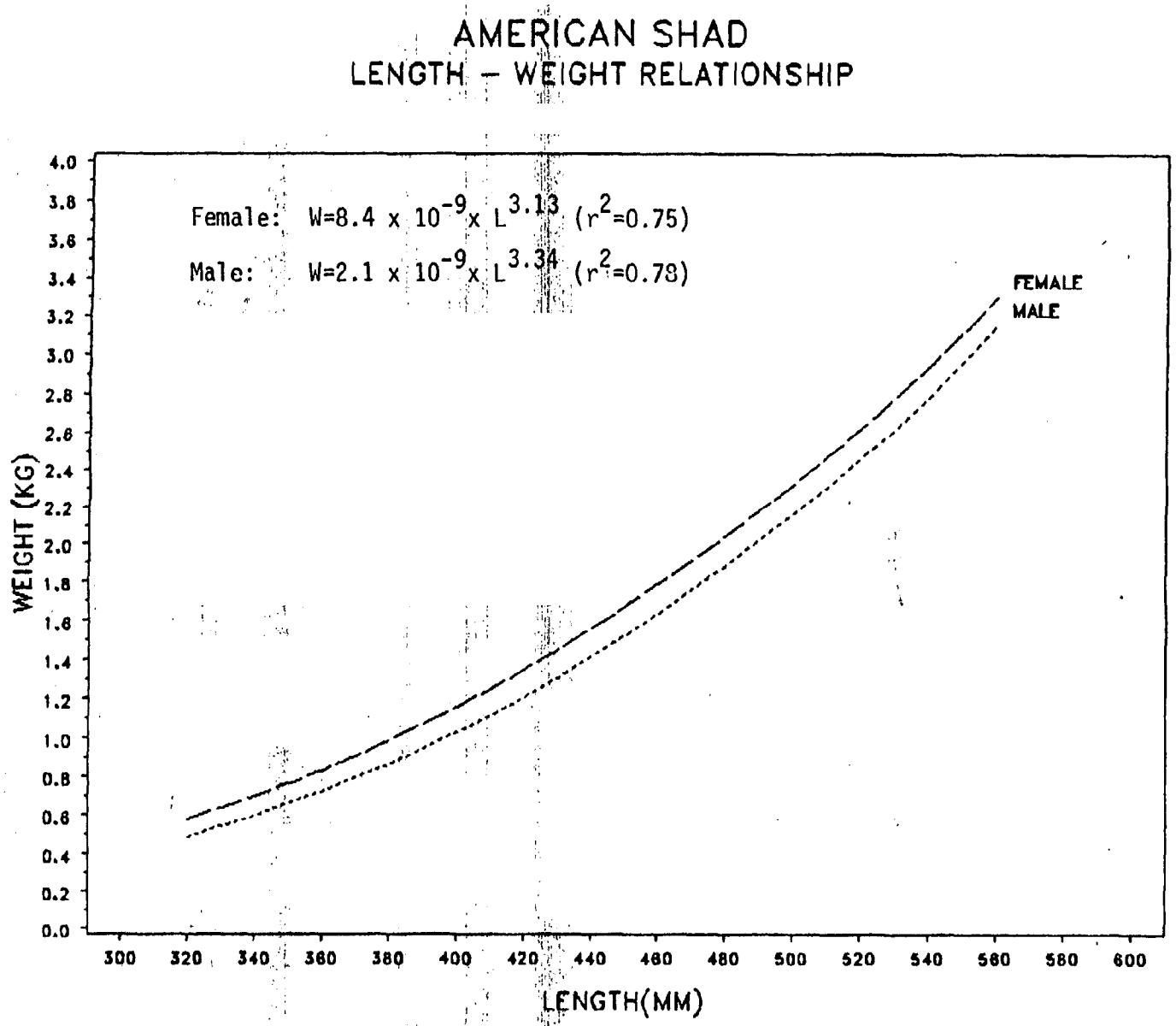


Figure 24. Fork length-weight relationship (linear) for male and female American shad, 1972 and 1981-1986 combined.

Mortality

Total mortality for males derived from catch curve analysis ranged from 0.4 in 1981 to 2.6 in 1978 and from 0.6 in 1981 and 1984 to 2.7 in 1977 for females (Table 22). Female mortality estimates during 1977, 1978, and 1981 and male mortality estimates for 1974 and 1977 were calculated with less than ideal methods due to only two age classes being present after recruitment. Estimates before 1979 appear reliable with flat descending arms on the catch curves (Mean r^2=0.97). Other fishery statistics remained relatively constant during this period including mean age after recruitment (Table 23), landings, except 1978, (Figure 22), and age structure. The mortality estimates calculated from the mean age methods were similar to catch curve estimates.

Total mortality estimates were lower during 1980-1986 than during the 1970s (Table 22). The descending arm of the catch curves was less flat (mean r^2=0.92) than during the 1970s, indicating a change in effort or recruitment. The increase in landings (Figure 22), increase in the juvenile index for year class 1975-1980 (Figure 19), decrease in total mortality, increase in mean age after full recruitment (Figure 25), and the increase in the number of older fish in the landings after 1980 (Figures 26 and 27) indicate an increase in recruitment.

TAGGING

Efforts at two pound nets located in southern Croatan Sound from 28 February through 30 April 1974 and 15 February through 31 March 1975 resulted in the release of 115 tagged American shad. Table 24 summarizes the number of American shad tagged each month and the percent recaptures during the same time period. A total of nine fish have been recaptured, yielding a return rate of 7.8%. During 1974, 49 shad were tagged and six returned (12.2%), while 66 were tagged in 1975 and three returned (4.5%). Gill nets accounted for 7 (77.8%) of the returns, with pound nets contributing the remainder (2)(Table 25).

The recapture locations are shown in Figures 28 and 29 for American shad tagged in 1974 and 1975. Of the six returned during 1974, four were recaptured near the tagging site, while the other two were from central Albemarle Sound. One of the three shad recaptured in 1975 was taken from the Pee Dee River, SC after traveling approximately 360 miles

Table 22. Total mortality (Z) for American shad in Albemarle Sound area, 1972-1986.

	Total mortality (Z)			
	Males		Females	
	Catch curve method	Mean age method	Catch curve method	Mean age method
1972	1.6	1.3	1.6	1.7
1973	1.2	1.4	2.4	2.4
1974	1.4*	-	1.8	1.9
1975	1.5	1.7	1.8	1.7
1976	2.5	2.0	1.9	2.6
1977	1.4*	1.8	2.7*	2.8
1978	2.6	1.9	2.3*	2.5
1979	-	-	-	-
1980	0.7	0.8	1.1	1.7
1981	0.4	0.6	0.6*	0.4
1982	1.3	1.1	1.3	1.0
1983	1.4	1.1	1.4	1.1
1984	0.6	0.8	0.6	0.6
1985	1.1	1.0	1.4	1.2
1986	1.0	0.9	1.4	0.6

* Estimates from only 2 age classes

Table 23. Mean age of American shad after full recruitement*.

Year	Mean age	
	Females	Males
1972	6.21	5.37
1973	6.10	5.34
1974	6.17	5.00
1975	6.23	5.23
1976	6.08	5.16
1977	6.06	5.29
1978	6.09	5.17
1979	-	-
1980	7.02	5.85
1981	6.80	6.09
1982	6.59	5.47
1983	6.47	5.49
1984	7.20	5.86
1985	6.42	5.57
1986	7.08	5.63

* Assumed full recruitment at age 5 and 6 for males and females, respectively.

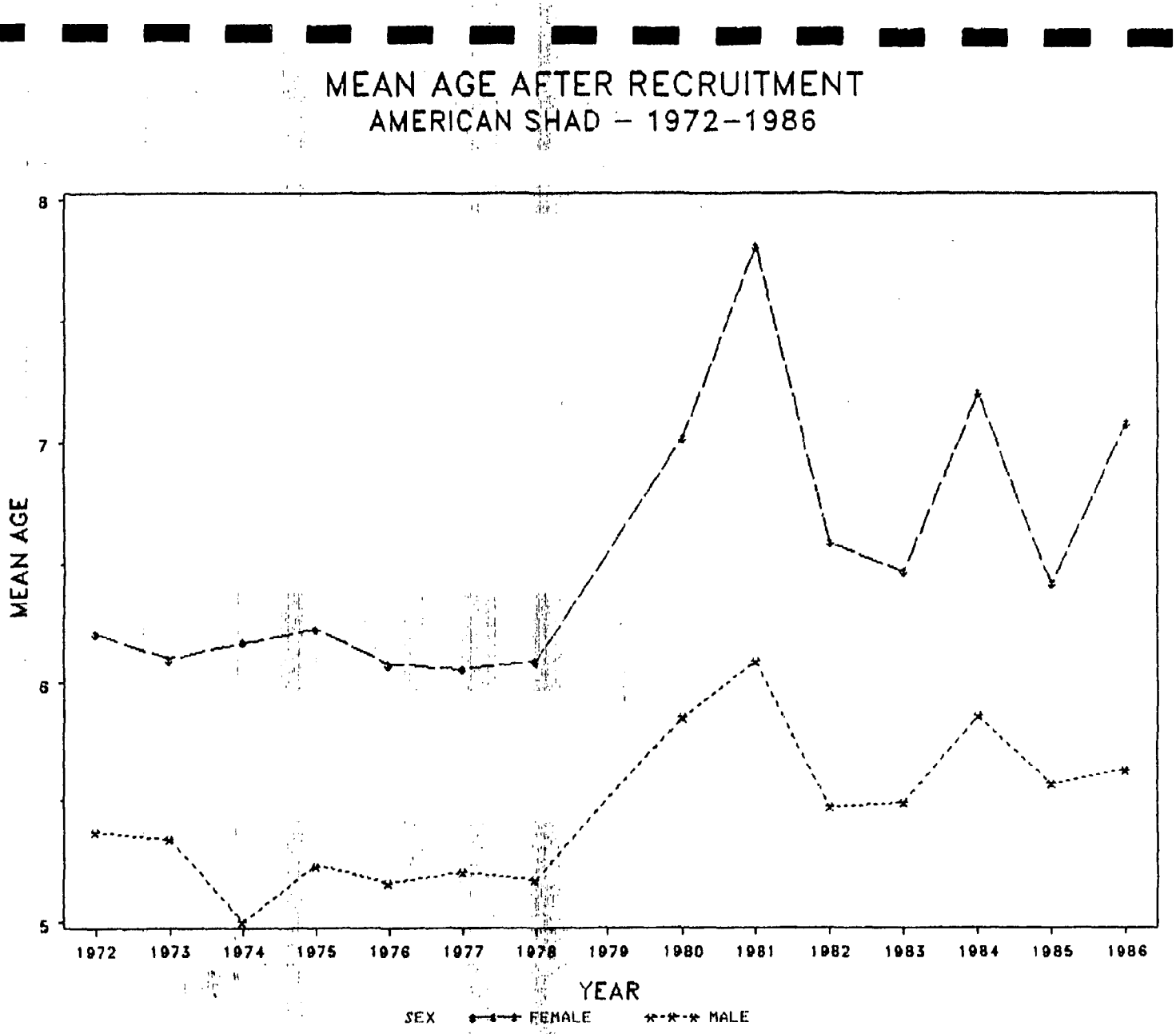


Figure 25. Mean age after recruitment in to the Albemarle Sound area, N.C. commercial fishery, 1972-1986.

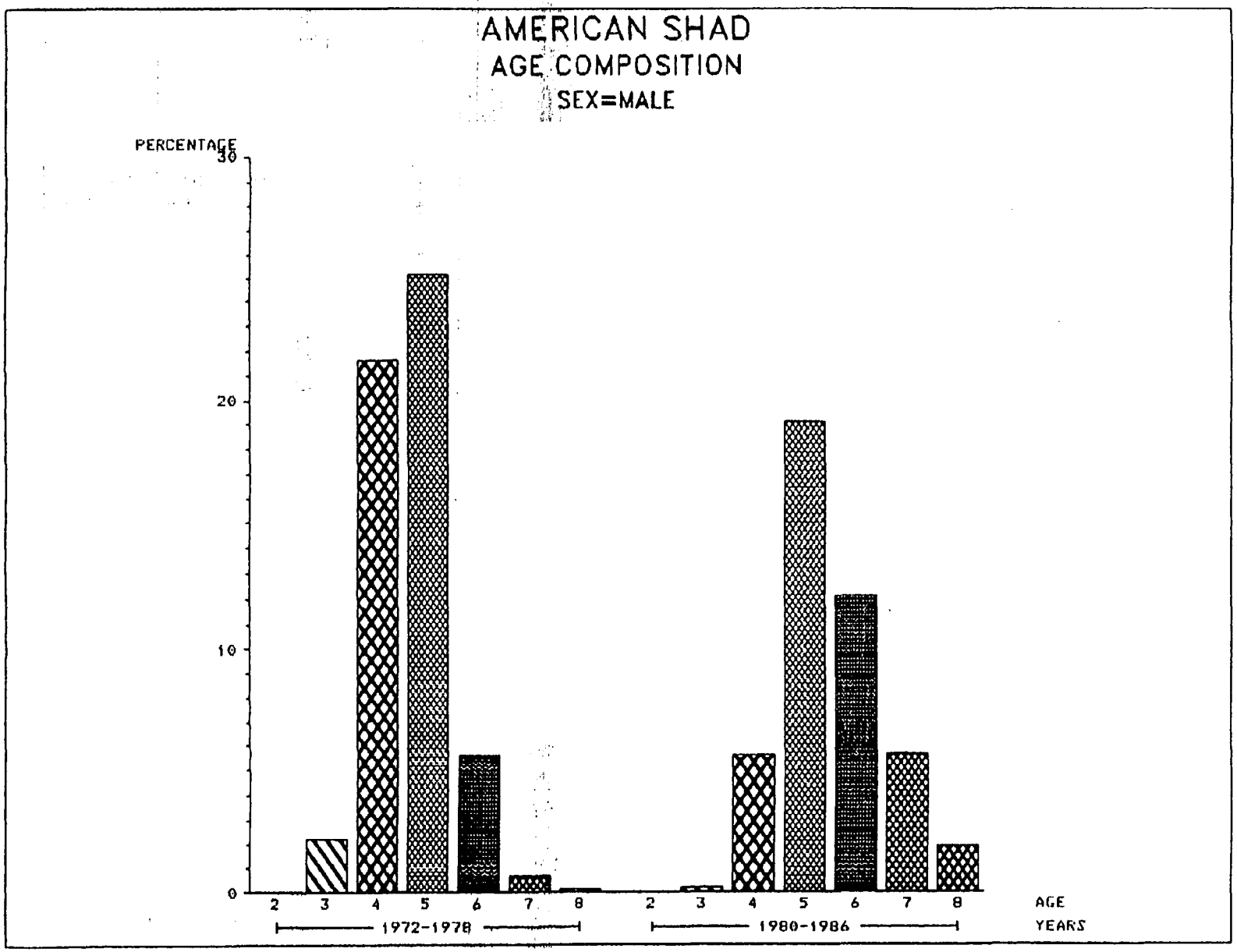


Figure 26. Age composition of male American shad from the Albemarle Sound area, N.C. commercial fishery.

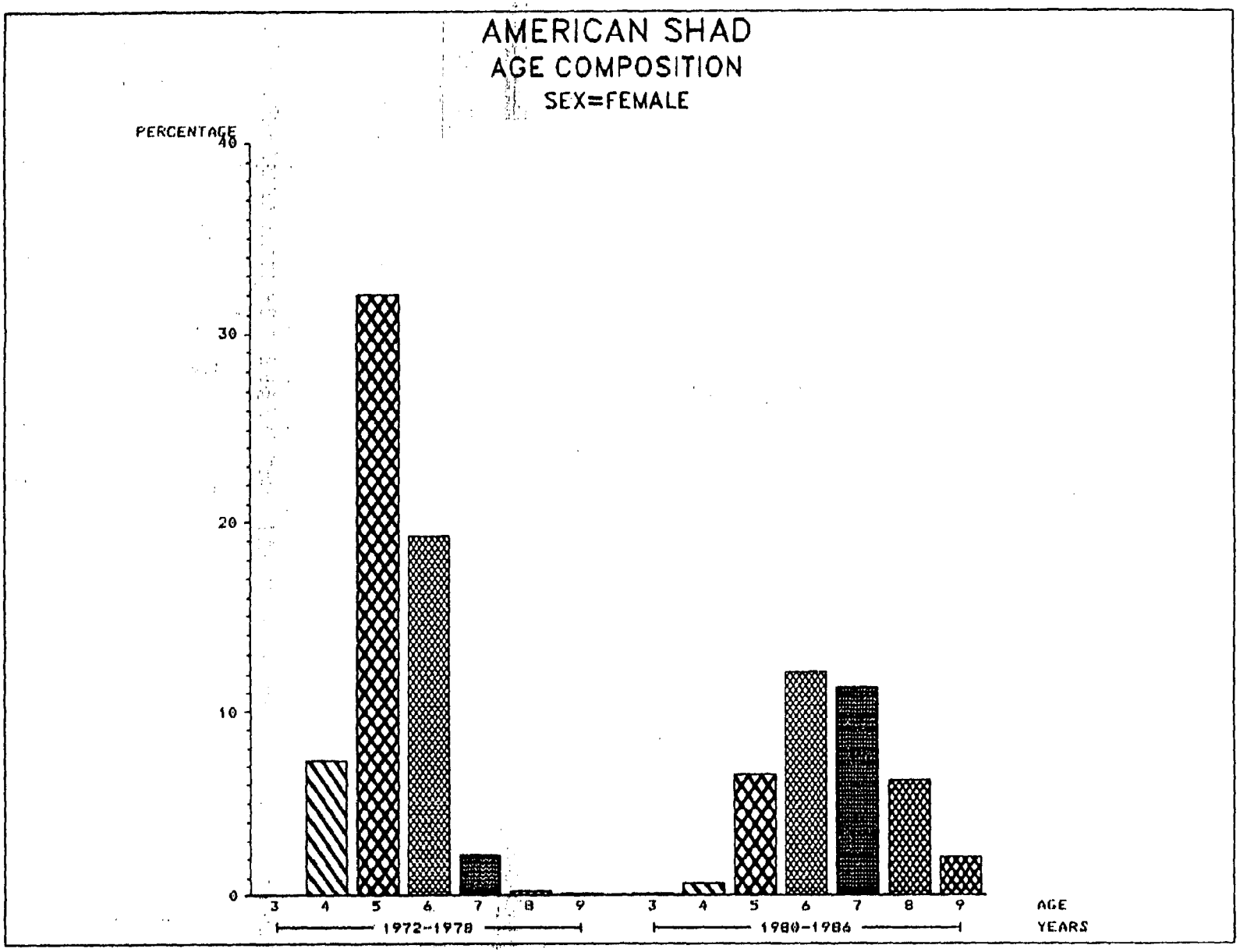


Figure 27. Age composition of female American shad from the Albemarle Sound area, N.C. commercial fishery.

Table 24. Summary of American shad tagged in Croatan Sound by year and month, 1974 and 1975.

Year	February		March		April		Total		
	Number Tagged	Number recaptured	Number tagged	Number recaptured	Number tagged	Number recaptured	Number tagged	Number recaptured	Percent
1974	1	0	19	1	29	5	49	6	12.2
1975	9	0	21	2	36	1	66	3	4.5
Total	10	0	40	3	65	6	115	9	7.8

Table 25. Gear used to recapture American shad tagged in Croatan Sound, during 1974 and 1975.

Year	Pound net		Gill net		Total	
	Number	Percent	Number	Percent	Number	Percent
1974	2	100	4	57.1	6	66.7
1975	0	-	3	42.9	3	33.3
Total	2	22.2	7	77.8	9	

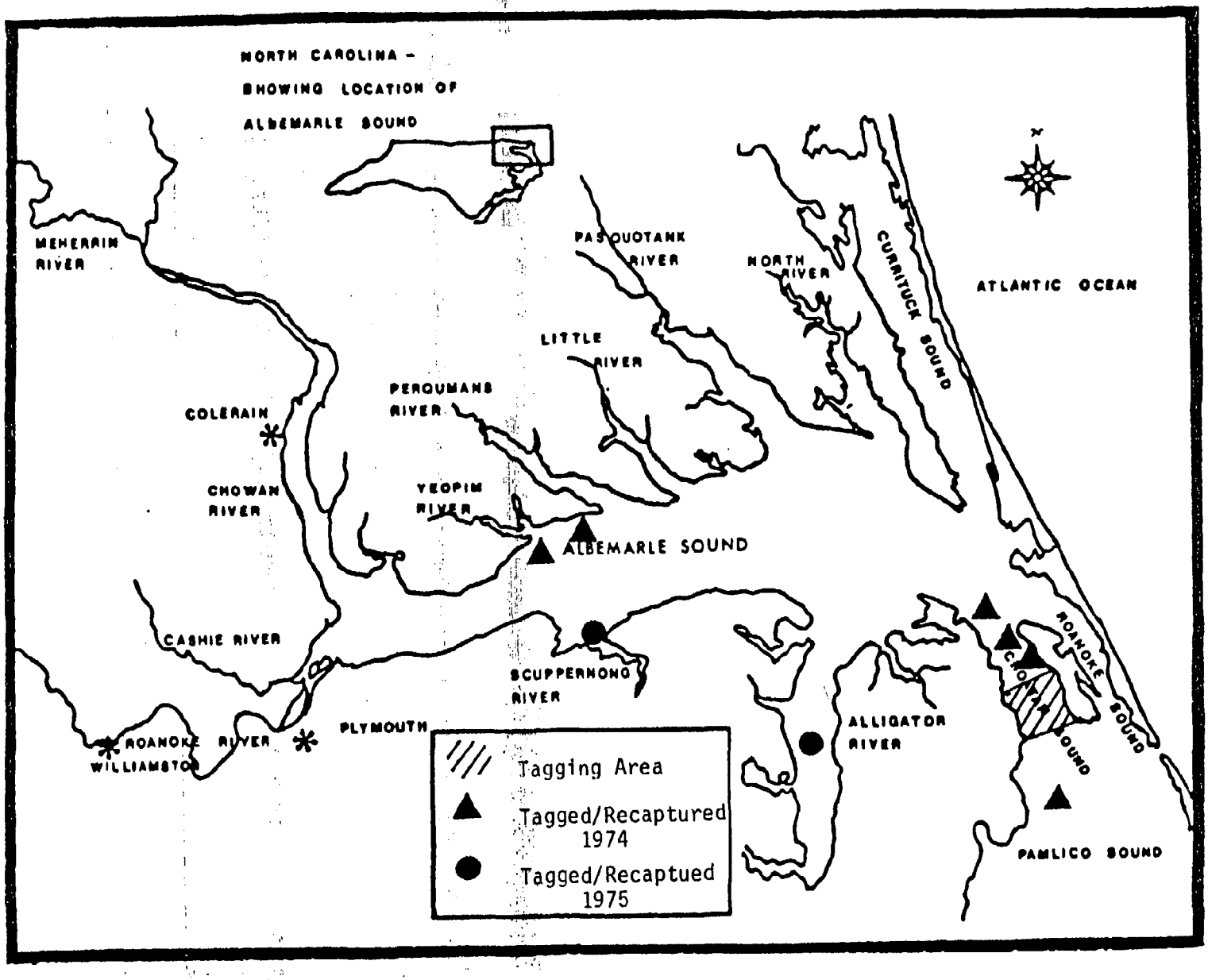


Figure 28. Recapture sites for American shad tagged from pound nets in Croatan Sound, N.C., February-April 1974 and February-March 1975.

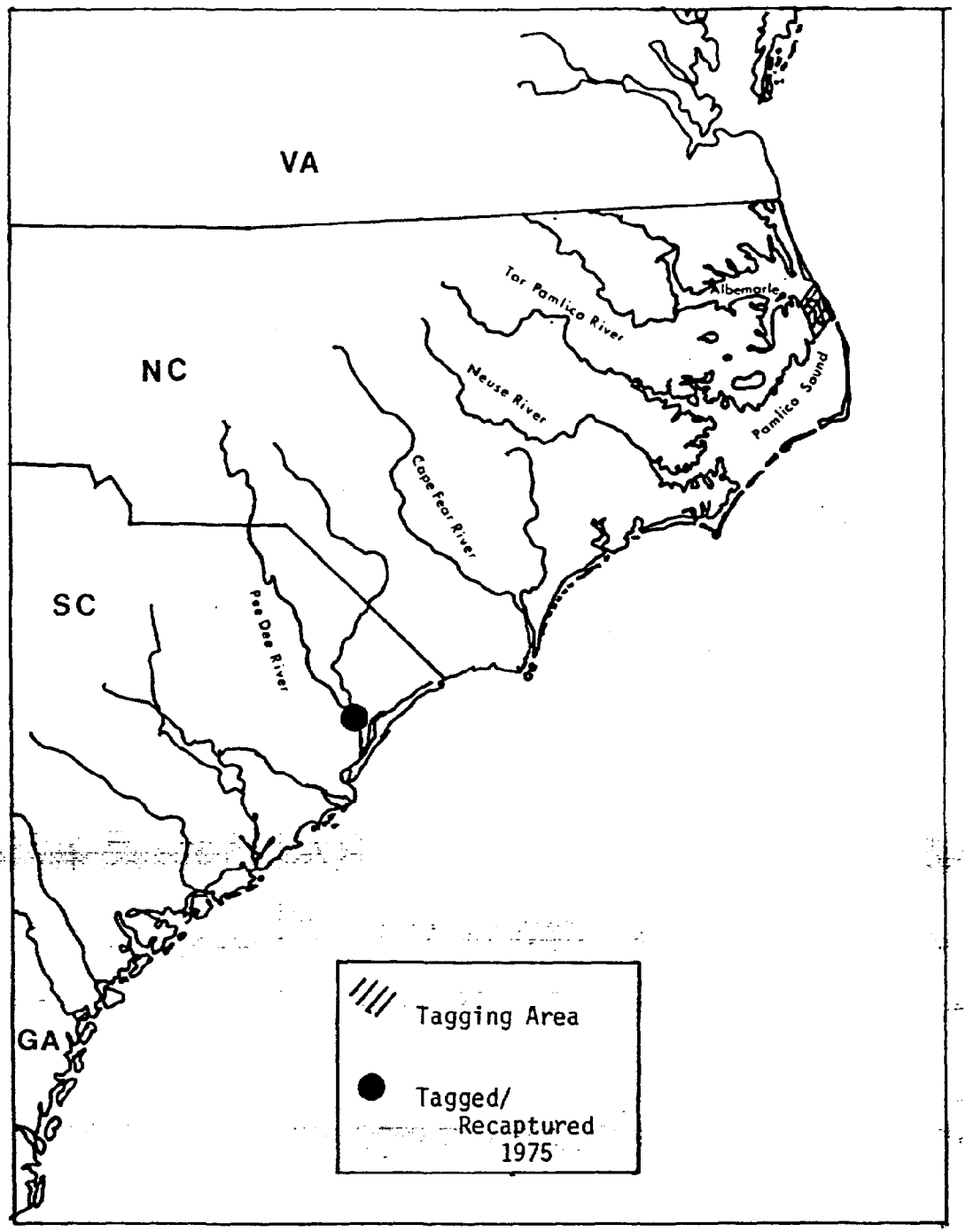


Figure 29. Recapture site outside Albemarle Sound area, N.C., for American shad tagged from pound nets in Croatan Sound, N.C., February-March 1975.

in only 29 days. Whether the southward movement was a reaction to tagging trauma or represented the natural migration of this fish cannot be determined. The other two fish recaptured in 1975 were from the Albemarle area. All of these recaptures came soon after tagging (29 days maximum). Considering the amount of fishing effort expanded throughout Albemarle Sound and its tributaries, it is puzzling that no shad were recaptured late in the season or near the spawning grounds.

The Division conducted offshore anadromous tagging on the R/V DAN MOORE 1968-1971. A total of 308 American shad were captured and tagged with Floy FT-2 dart tags. All of these fish were captured between Chesapeake Bay entrance and Wimble Shoals (Holland and Yelverton, 1973). No tags have been returned from the R/V DAN MOORE tagging. The number of American shad tagged and recaptured were insufficient to show any pattern of movement. All of the fish recaptured, except for one each in 1974 and 1975, showed movement up into the system. This was similar to that found by Hawkins (1980) for the Neuse River.

Scarratt and Dadswell (1983) have conducted extensive summer tagging projects on American shad recently in the Bay of Fundy, Canada. The widespread distribution of recaptures demonstrates that shad from all river systems along the east coast intermix in the Bay of Fundy. The return data confirms the seasonal movement patterns hypothesized by Talbot and Sykes (1958) and Leggett and Whitney (1972). That is, after spawning, adult fish migrate to the Gulf of Maine and remain in that area throughout the summer and into the fall. A southward migration begins in mid-fall, with over wintering occurring in the mid-Atlantic area.

American shad tagged in the Bay of Fundy have been returned from North Carolina, from both offshore and inshore waters (Scarratt and Dadswell 1983). No shad tagged in North Carolina have been returned from the northern areas. This is probably a result of so few fish being tagged.

FACTORS AFFECTING DECLINE IN ABUNDANCE

The American shad run in Albemarle Sound area, as well as the rest of North Carolina, are greatly reduced from what they were during the 19th century. State landings have fallen precipitously from a peak of 4,086,000 kg (9 million pounds) in 1897 to a low of 54,935 kg (121,022 pounds) in 1977. However, shad landings are considered to be inaccurate due to the decrease in the number of true commercial fishermen in recent years. A large quantity of shad are caught in North Carolina by recreational fishermen using commercial gear. These fish are kept for personal consumption or are "peddled" to friends. In either case, the shad never enter the official statistics. The lack of catch-effort data for the fishery also prohibits a true picture of the shad resource. Even with these inadequacies, the trend is the same; fewer fish are being caught each year. Currently there are insufficient data to determine the actual cause or causes for the decline.

Taylor (1951) found that shad showed signs of "depletion" or biological scarcity in North Carolina. He stated, "shad is probably at a permanent biological disadvantage and may never be as abundant or migrate as in former years." The decline of shad in North Carolina has been attributed to pollution (industrial, pesticides, siltation), dams, and overfishing. These same factors have been suggested for the entire Atlantic coast (Roelofs 1951, Mansuetti and Kolb 1952, Walburg and Nichols 1967). While these factors may have contributed to historical declines in landings, their role in the last 20 years has generally not been clearly delineated. Roelofs (1951) considered siltation and dams to be the major factors in the decline of shad in North Carolina. In the Albemarle Sound area, only one dam exists on a tributary within the state. The dam was built in 1955 on the Roanoke River at Roanoke Rapids, NC.

In recent decades the Albemarle Sound and its tributaries have experienced deterioration of water quality which has been considered to have impacted the alosid stocks. However, the impact is not as clearly defined as that of the Delaware River (Atlantic States Marine Fisheries Commission 1985). Several factors resulting from poor water quality may be involved in preventing recovery: (1) blue green algae blooms possibly smothering larvae or producing toxins; (2) low dissolved

oxygen levels resulting from blooms; (3) food chain interruption may be eliminating preferred food items; and/or (4) migration patterns of spawning adults may be altered during low flow years when pulp mill effluent is highly concentrated in the lower tributaries to western Albemarle Sound. While these indirect findings suggest a potential pollution effect, it has not been vigorously established.

Similarly, pollution of nearly all estuarine waters along the east coast has certainly increased over the last 20 years due to all aspects of development on the watersheds. The general degradation of water quality is a coast-wide problem. During the past 20 years, sewage discharge has decreased significantly with the construction of sewage plants. This decrease in organic enrichment would benefit water quality conditions; however, it would not result in a reduction of other types of pollutant discharges (Atlantic States Marine Fisheries Commission 1985). Boreman (1981) reported that dams and pollution are two stresses that have been blamed for stock reduction; however, more subtle stresses may have gone undetected.

Other investigations have determined overfishing to be the major cause for the decline of shad in the Chesapeake Bay area and Hudson River. Talbot (1956) statistically determined excessive fishing pressure to be the major factor affecting shad runs in the Hudson River. Nesbit (1939) stated "the decline in shad production in Maryland, Virginia, and North Carolina is the result of overfishing." Roelofs (1951) concluded that overfishing was very unlikely in North Carolina and, at that time, unproven. Goodyear (1977) suggested that the observed decline in landings may have been caused by increased exploitation, but more likely caused by reduced ability of stocks to withstand additional stress, i.e. reduction in the stock's "compensatory reserve."

Currently, no proof exists to explain the drastic reduction of shad in North Carolina over the years. Possibly the combined effects of these factors, singly or collectively, could be acting on the population to account partially for the decline. Undoubtedly, pollution and migration barriers have taken their toll, but excessive harvest, although unproven, probably has had a significant role. When the effects of each of these factors are combined with high post-spawning

mortality, the overall result is a seriously depleted shad resource. Mansuetti and Kolb (1953) suggested the existence of some type of natural biological cycle within the population, but no evidence has been presented to substantiate their view.

RECOMMENDATIONS

The North Carolina and Albemarle Sound area shad resources, despite slight increased landings during the last few years, continue to be depressed. American shad and civilization are not compatible and it is doubtful they can ever be restored to the status of the late 19th century. Changes have occurred in the spawning and nursery areas as a result of the encroachment of man, from being reduced in some areas to complete elimination in others. Rivers and sound environments have been altered physically as well as chemically.

The data collected in North Carolina on American shad has been beneficial in many aspects. Data has been utilized in the joint ventures agreements with foreign fishing interest. The information available on American shad in North Carolina has proven useful in the development of an east coast shad and river herring plan coordinated by the Atlantic States Marine Fisheries Commission. The knowledge of areas utilized by American shad as spawning and nursery areas has proven beneficial in the curtailment of development in those areas. These areas need to be protected from degredation. In the future, if North Carolina decides to develop an American shad state management plan, all of this data will be available for the plan.

Current anadromous studies in the Albemarle area do not yield sufficient information to evaluate the reason for the decline. One of the major deficiencies is a lack of catch-effort data. Once catch and effort statistics have been obtained for several years, studies can proceed to determine population sizes and factors responsible for fluctuations in abundance, and appropriate management measures could be developed. In addition, information on harvest and utilization is desperately needed; without it the shad population can never be adequately evaluated. The Atlantic States Marine Fisheries Commission shad and river herring plan is beginning to address these data needs.

Action needs to be taken to reduce or eliminate pollution of the waters and habitat destruction. With basic biological data and reliable

harvest data, there is no reason why the American shad population in the Albemarle Sound area, as well as North Carolina, cannot again support a viable fishery.

ACKNOWLEDGEMENTS

Appreciation is extended to all Marine Fisheries personnel who aided in the collection of American shad data. Special appreciation goes to Paul Phalen who provided valuable computer assistance and review of the manuscript. Dr. Joseph Loesch and Dr. Linda Mercer reviewed the manuscript and provided many valuable suggestions. A special thanks also goes to Maury Wolff who has reviewed many stages of the report and made valuable recommendations. I also thank Dee Willis and Diana Tootle for typing the numerous stages of the manuscript. Appreciation is extended to the commercial and recreational fishermen and seafood dealers who cooperated with this project.

LITERATURE CITED

Atlantic States Marine Fisheries Commission.
1985. Fishery management plan for the anadromous alosid stock of the eastern United States: American shad, hickory shad, alewife, and black herring: Phase II in interstate management planning for migratory alosids of the Atlantic coast. Washington, DC. XVIII + 347 p.

Baker, W.D.
1968. A reconnaissance of anadromous fish runs into the inland fishing waters of North Carolina. Compl. Rep. for Proj. AFS-3. NC Wildl. Resour. Comm., 33 p.

Bigelow, H.B., and W. Welsh.
1925. Fishes of the Gulf of Maine. U.S. Bull. Bur. Fish. 40 (1):110-113.

Blackford, C.M.
1916. The shad - a national problem. Trans. Am. Fish. Soc. 46(1):5-14.

Boreman, J.
1981. American shad stocks along the Atlantic coast. Nat. Mar. Fish. Serv., Northeast Fish. Cntr., Woods Hole Lab., Woods Hole, MA. Lab. Ref. Doc. No. 81-40.

Carnes, W. C.
1965. Survey and classification of the Roanoke River watershed, North Carolina. Final Rep. for Proj. F-14-R, Job 1-Q. N C. Wildl. Resour. Comm., Raleigh., 17 p.

Cating, J.P.
1953. Determining age of Atlantic shad from their scales. U.S. Fish and Wildl Serv., Fish. Bull. 85(54):187-199.

Cheek, R.P.
1968. The American shad. U.S. Fish Wildl. Serv., Fish. Leaflet 614, 13 p.

Cheney, A.N.
1896. Shad of the Hudson River. Annu. Rep. Comm. Fish., Game, and For. N.Y. 1895:125-134.

Chestnut, A.F., and H.S. Davis.
1975. Synopsis of marine fisheries of North Carolina, Part 1. Univ. of North Carolina Sea Grant Program, Pub. No. UNC-SG-75-12, 426 p.

Chittenden, M.E.
1969. Life History and ecology of the American shad, Alosa sapidissima, in the Delaware River. Ph.D. Thesis, Rutgers Univ. 458 p.

Chittenden, M.E.
1975. Dynamics of American shad, Alosa sapidissima, runs in the Delaware River. U.S. Nat. Mar. Fish. Serv. Fish. Bull. 73:487-493.

Chittenden, M.E., and J.R. Westman.
1967. Highlights of the life history of American shad in the Delaware River. Presented at the public hearing on water quality for the Delaware River at Trenton, New Jersey, January 26, 1967, held by the Delaware River Basin Comm.

Cobb, J.N.
1906. Investigations relative to the shad fisheries of North Carolina. NC Geo. Surv., Economic Paper no. 12, 39 p.

Davis, J.R., and R.P. Cheek.
1966. Distribution, food habits, and growth of young clupeids, Cape Fear River system, North Carolina. Proc. 20th Ann. Conf. Southeast Assoc. Game Comm., p. 250-260.

Davis, J.R., B.J. Fontenot, C.E. Hoenke, A.M. Williams, and J.S. Hughes.
1970. Ecological factors affecting anadromous fishes of Lake Pontchartrain and its tributaries. La. Wildl. Fish. Comm., Fish. Bull. No. 9, 63 p.

Delaware, Basin Fish and Wildlife Management Cooperative.
1981. A manuscript plan for the American shad (Alosa sapidissima) in the Delaware River basin.

Delaware Basin Fish and Wildlife Management Cooperative.
1981. A management plan for the American shad (Alosa sapidissima) in the Delaware River basin.

Earll, R.E.
1887. North Carolina and its fisheries, p. 475-497. In G.B. Goode [ed.]. The fisheries and fishery industries of the United States, section 2, pt. 12. U.S. Commissioner of Fish and Fisheries, Washington, DC.

Everett, G.
1983. The Impact of pulp mill effluent on the Chowan River herring fishery. NC Dept. Nat. Resour. and Community Develop., Div. Environ. Mgmt., Water Qual. Plan. Branch, 18 p.

Fischer, C.A.
1980. Anadromous fisheries research program-Cape Fear River systems, Phase II. Compl. Rep., Proj. AFCS-15, NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 65 p.

Godwin, W.F., and J.G. Adams.
1969. Young clupeids of the Atlamaha River, Georgia. Ga. Game Fish. Comm., Mar. Fish. Div. Contrib. Ser. 15, 30 p.

Goodwin, C.P.
1977. Assessing the impact of power plant mortality in the compensatory reserve of fish populations. P. 186-195 in W. Van Winkle (ed.) Assessing the effects of power plant-induced mortality in Fish Populations. Permagamn Press, N.Y.

Gulland, J.A.
1985. Fish Stock Assessment: A manual of basic methods. John Wiley and Sons. New York. 223 p.

Hassler, W. W.
1984. Status and abundance of striped bass, Morone saxatilis, in the Roanoke River and Albemarle Sound, NC, 1977-1981. Compl. Rep., Proj. AFS-14. NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 40 p.

Hassler, W.W., N.L. Hill, and J.T. Brown.
1981. Status and abundance of striped bass, Morone saxatilis, in the Roanoke River and Albemarle Sound, NC, 1956-1980. NC Dept. Nat Resour. and Community Develop., Div. Mar. Fish., Spec. Sci. Rep. No. 38, 156 p.

Hassler, W.W., and S.D. Taylor.
1984. The Status, abundance, and exploitation of striped bass in the Roanoke River and Albemarle Sound, NC, 1982, 1983. Compl. Rep., Proj. AFC-19, NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 67 p. + App.

Hawkins, J.H.
1980. Investigations of anadromous fishes of the Neuse River, NC. NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., Spec. Sci. Rep. No. 34, 111 p.

Hildebrand, S.F., and W.C. Schroeder.
1928. Fishes of Chesapeake Bay. U.S. Bur. Fish., Bull. 43 (Pt.1)., 366 p.

Holland, B.F., Jr., and G.F. Yelverton.
1973. Distribution and biological studies of anadromous fishes offshore NC. NC Dept. Nat. Econ. Resour. Spec. Sci. Rep. 24, 132 p.

Johnson, H.B.
1982. Status of American shad in NC. NC Div. Mar. Fish., Elizabeth City, NC.

Johnson, H.B., B.F. Holland, Jr., and S.G. Keefe.
1977. Anadromous fisheries research program, northern coastal area. NC Div. Mar. Fish., Compl. Rep., Proj. AFCS-11, 97 + 40 p.

Johnson, H.B., D.W. Crocker, B.F. Holland, Jr., J.W. Gillikin, D.L. Taylor, M.W. Street, J.G. Loesch, W.H. Kriete, Jr., and J.G. Travelstead.
1978. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. NC-VA AFCS 9-2. NC Div. Mar. Fish. and VIMS, 175 p.

Johnson, H.B., S.E. Winslow, D.W. Crocker, B,F, Holland, Jr. J.W. Gillikin, and D.L. Taylor (NC) and J.G. Loesch, W.H. Kriete, Jr. J.G. Travelstead, E.J. Foell and M.A. Hennigar.
1981. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. NC. Dept. Nat. Resour. and Community Develop., Div. Mar. Fish. and VA Inst. Mar. Sci., Spec. Sci. Rep. No. 36, 204 p.

Judy, M.H.
1961. Validity of age determination from scales of marked American shad. U.S. Fish Wildl. Serv., Fish. Bull. 61:161-70.

Ketchen, K.S.
1950. Stratified subsampling for determining age distributions. Trans. Am. Fish. Soc., 79:205-212.

Klauda, R.J., M. Nittel, and K.P. Campbell.
1976. The commercial fishery for American shad in the Hudson River: fishing effort and stock abundance trends. p. 107-134 in Proceedings of a workshop on American shad. U.S. Fish and Wildl. Serv., Nat. Mar. Fish. Ser.

LaPointe, D.F.
1958. Age and growth of the American shad from three Atlantic coast rivers. Trans: Am. Fish. Soc. 87:139-150.

Leggett, W.C.
1969. Studies on the reproductive biology of the American shad, (Alosa sapidissima) (Wilson). A comparison of populations from four rivers on the Atlantic seaboard. Ph.D. Thesis, McGill Univ., Montreal. 125 p.

Leggett, W.C., and J.E. Carscadden.
1978. Latitudinal variation in reproductive characteristics of American shad (Alosa sapidissima): evidence for populations specific life history strategies in fish. J. Fish. Resour. Board Can. 35(11):1469-1478.

Leggett, W.C., and R.R. Whitney.
1972. Water temperature and the migrations of American shad. Fish. Bull. 70(3):659-670.

Leim, A.H.
1924. The life history of the shad (Alosa sapidissima) (Wilson) with special reference to the factors limiting its abundance. Fish. Resour. Bd. Canada, Contr. to Can. Biol. 2(11):163-284.

Loesch, J.G., and W.H. Kriete, Jr.
1980. Anadromous fisheries research program, VA. Annu. Rep., Anad. Fish Proj., 1980. VA Inst. of Mar. Sci., School of Mar. Sci., Coll. of William and Mary, Gloucester Point, VA.

Loesch, J.G., and W.H. Kriete, Jr.
1981. Anadromous fisheries research, VA. Annu. Rep. 1981. Nat. Mar. Fish. Ser. Proj. No. AFC 10-2. VA Inst. of Mar. Sci., School of Mar. Sci., Coll. of William and Mary, Gloucester Point, VA, 74 p.

Loesch, J.G., and W.H. Kriete, Jr.
1982. Anadromous fisheries research, Virginia. Annu. Rep. 1982. Nat. Mar. Fish. Ser. Proj. No. AFC 10-3. VA Inst. of Mar. Sci., School of Mar. Sci., Coll. of William and Mary, Gloucester Point, VA, 55 p.

Loesch, J.G., and W.H. Kriete, Jr.
1983. Anadromous fisheries research, VA. Compl. Rep. Anadromous Fish Proj. 1979-1983. VA Inst. of Mar. Sci., Coll. of William and Mary, Gloucester Point, VA. Proj. No. AFC 10-1 to 10-4.

Loesch, J.G., and W.H. Kriete, Jr., H.B. Johnson, B.F. Holland, and M.W. Street.
1977. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. Proj. NU. NC-VA AFCS 9-1, Proj. Rep. 1977, 183 p.

Loesch, J.G., and W.H. Kriete, Jr., J.G. Travelstead, E.J. Foell and M.A. Hennigar.
1981. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. Part II: VA Compl. Rep. 1977-1979. Nat. Mar. Fish. Serv. Proj. No. AFCS 9-1 to 9-3. VA Inst. of Mar. Sci., Gloucester Point, VA, 204 p.

Mansuetti, A.J., and J.D. Hardy, Jr.
1967. Development of fishes of the Chesapeake Bay Region, and atlas of egg, larval, and juvenile stages, Part I. Nat. Resour. Inst., Univ., Maryland, 202 p.

Mansuetti, A.J., and H. Kolb.
1953. A historical review of the shad fisheries of North America. Md. Dep. Resour. Educ. Publ. 97, 292 p.

Marcy, B.C., Jr.
1969. Age determination from scales of Alosa pseudoharengus (Wilson) and Alosa aestivalis (Mitchell) in Connecticut waters. Trans. Am. Fish. Soc. 98:622-630.

Marcy, B.C., Jr.
1976. Early life history studies of American shad in the lower Connecticut River and the effects of the Connecticut Yankee plant. P. 141-168 in D. Merriman and L.K. Thorpe (eds.), The Connecticut River ecological study; the impact of a nuclear power plant. Amer. Fish. Soc. Monogr. No. 1.

Marshall, M.D.
1976. Anadromous fisheries research program Tar River, Pamlico River, and North Pamlico Sound. Compl. Rep. for Proj. AFCS-10. NC Dept. of Nat. and Eco. Resour., Div. Mar. Fish., 90 p.

McDonald, M.
1887. The rivers and sounds of North Carolina, p. 625-637. In G.B. Goode [ed.] The fisheries and fishery industries of the U.S., Sec. 5, pt. 12. U.S. Comm. of Fish and Fish., Washington, DC.

Nesbit, R.A.
1939. How shad can be brought back in Chesapeake Bay and NC. Memo Rep., U.S. Bur. of Fish., (84052):7-1.

Neves, R.J., and L. Depres.
1979. The oceanic migration of American shad, Alosa sapidissma, along the Atlantic coast. NOAA Fish. Bull. 77(1):199-212.

Nichols, P.R., and D.E. Louder.
1970. Upstream passage of anadromous fish through navigation locks and use of the stream for spawning and nursery habitat, Cape Fear River, NC, 1962-1966. U.S. Fish Wildl. Serv., Cir. 352, 12 p.

Nichols, P.R., and W.H. Massman.
1963. Abundance, age, and fecundity of shad, York River, VA., 1953-1959. U.S. Fish and Wildl. Serv., Fish Bull. 63:179-187.

NC Dept. of Natural Resources and Community Development, Division of Environmental Management.
1982. Chowan River water quality management plan. Ral., NC.

NC Dept. of Natural Resource and Community Developmental, Division of Marine Fisheries.
1983. NC fisheries regulations for Coastal Waters, 1987. NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish.

NC Dept. of Natural Resource and Community Developmental, Division of Marine Fisheries.
1987. NC fisheries regulations for Coastal Waters, 1987. NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish.

Public Service Electric and Gas Company.
1982. American shad (Alosa sapidissima): A synthesis of information on natural history, with reference to occurrence in the Delaware River and Estuary and involvement with the Salem Nuclear Generating Station. Feb. 1982. Salem Nuclear Gen. Stat. 316 (b) Demonstration Append III. Newark, N.J.

Ricker, W.E.
1975. Computations and interpretations of biological statistics of fish populations. Bull. Fish. Resour. Board Can. 191:382 p.

Roelofs, E.W.
1951. The edible finfishes of NC. In H.F. Taylor (ed.), Survey of Mar. Fish. of NC. Univ. of NC Press, Chapel Hill.

Rothschild, B.J.
1963. A critique of the scale method for determining the ages of the alewife, Alosa pseudoharengus (Wilson). Trans. Am. Fish. Soc., 92(4):409-413.

Rulifson, R.A., M.T. Huish, and R.W. Thoesen.
1982. Anadromous fish in the southeastern U.S. and recommendation for development of a management plan. U.S. Fish and Wildl. Serv., Fish. Resour., Reg. 4 Atlanta, GA. 525 p.

Scarratt, D.J., and M.J. Dadswell.
1983. New approaches to tidal power. Fish. and Env. Sci., Dept. Fish. and Oceans, Biol. Station, St. Andrews, New Brunswick, Canada.

Sholar, T.M.
1975. Anadromous fisheries survey of the New and White Oak River Systems. NC Div. Mar. Fish., Compl. Rep. Oct. 73-June 75, Proj. AFC-9, 54 p.

Sholar, T.M.
1977. Anadromous fisheries research program, Cape Fear River System, Phase I. Progress report for Proj. AFCS-12. NC Dept. of Nat. and Eco. Resour., Div. Mar. Fish., 60 p.

Sholar, T.M.
1977a. Status of American shad in NC, pp. 17-32. In: Proceedings of a workshop on American shad, 14-16 Dec. 1976, Amherst, MA.

Skinner, J.B.
1846. Letters on the subject of the Albemarle fisheries. NC Public Doc., 1846-47, 8 p.

Smith, H.M.
1907. The fishes of North Carolina. NC Geol. Econ. Surv. 2, 453 p.

Spitsbergen, D.L., and M. Wolff.
1974. Survey of nursery areas in western Pamlico Sound, NC, Compl. Rep., Div. Comm. Sport Fish., 80 p.

Stevenson, C.H.
1899. The Shad fisheries of the Atlantic Coast of the U.S. U.S. Comm. Fish Rep. (1898)24:101-269.

Street, M.W., P.P. Pate, Jr., B.F. Holland, and A.B. Powell.
1975. Anadromous fisheries research program, northern coastal region, NC. Final Rep. for Proj. AFCS-8, NC Dept. of Nat. and Eco. Resour., Div. Mar. Fish., 210 p.

Talbot, G.B.
1954. Shad in the Hudson. New York State Cons. 8(5):17-19.

Talbot, G.B.
1956. Conservation of an east coast shad fishery. Proc. Gulf Carib. Fish. Inst., 8th Annu. Sess.:92-99.

Talbot, G.B., and J.E. Sykes.
1957. Atlantic coast migrations of American shad. Fish Bull. 142:473-490.

Taylor, H.F.
1951. Survey of marine fisheries of NC. Univ. NC Press, Chapel Hill, 555 p.

True, F.W.
1887. The pound-net fisheries of the Atlantic states, p. 595-610. In G.B. Goode [ed.] The fisheries and fishery industries of the U.S., Sec. 5, pt. 11. U.S. Comm. of Fish and Fish., Washington, DC.

Ulrich, G., N. Chipley, J.W. McCord, and D. Cupka.
1979. Development of fishery management plans for selected anadromous fishes in South Carolina/Georgia. Spec. Sci. Rep. No. 14, Mar. Resour. Cntr., S.C. Wildl. Mar. Res. Dept., 135 p.

Walburg, C.H.
1956. Commercial and sport shad fisheries of the Edisto River, SC. U.S. Fish Wildl. Serv. Spec. Sci. Rep. - Fish. No. 187, 9 p.

Walburg, C.H.
1957. Neuse River shad investigations, 1953, U.S. Fish Wildl. Serv., Spec. Sci. Rep. - Fish. 206, 13 p.

Walburg, C.H., and P.R. Nichols.
1967. Biology and management of the American shad and the status of fisheries, Atlantic coast of the U.S., 1960. U.S. Fish Wildl. Serv., Spec. Sci. Rep. - Fish. 550, 100 p.

Ward, E.L.C.
1882. Fisheries and fish-hatching in NC. At home and abroad, 3(5):309-313.

Winslow, S.E.
1987. North Carolina alosid fisheries management program. Ann. Prog. Rep., Proj. AFC-27, NC Dept. Nat. Res and Community Develop. Div. Mar. Fish., 37 p.

Winslow, S.E.
1988. North Carolina alosid fisheries management program. Ann. Prog., Rep., Proj. AFC-27-2, NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 57 p.

Winslow, S.E., N.S. Sanderlin, G.W. Judy, J.H. Hawkins, B.F. Holland, Jr. C.A. Fischer, and R.A. Rulifson.
1983. North Carolina anadromous fisheries management program. Compl. Rep., Proj. AFCS-17. NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 402 p.

Winslow, S.E., S.C. Mozley, and R.A. Rulifson.
1985. North Carolina anadromous fisheries management program. Compl. Rep.. Proj. AFCS-22, NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 207 p.

Worth, S.G.
1879. Fish culture in North Carolina [Appended to] L.L. Polk. Rep. of the Commissioner of Agriculture for 1877-78. General Assembly of NC, 1879. Public Doc. No. 8 26 p.

Yarrow, H.C.
1874. Report of a reconnaissance of the shad-rivers south of the Potomac. U.S. Commissioner of Fish and Fisheries, Rep. for 1872-73, pt. 2, p. 396-402.

APPENDIX
FIGURES

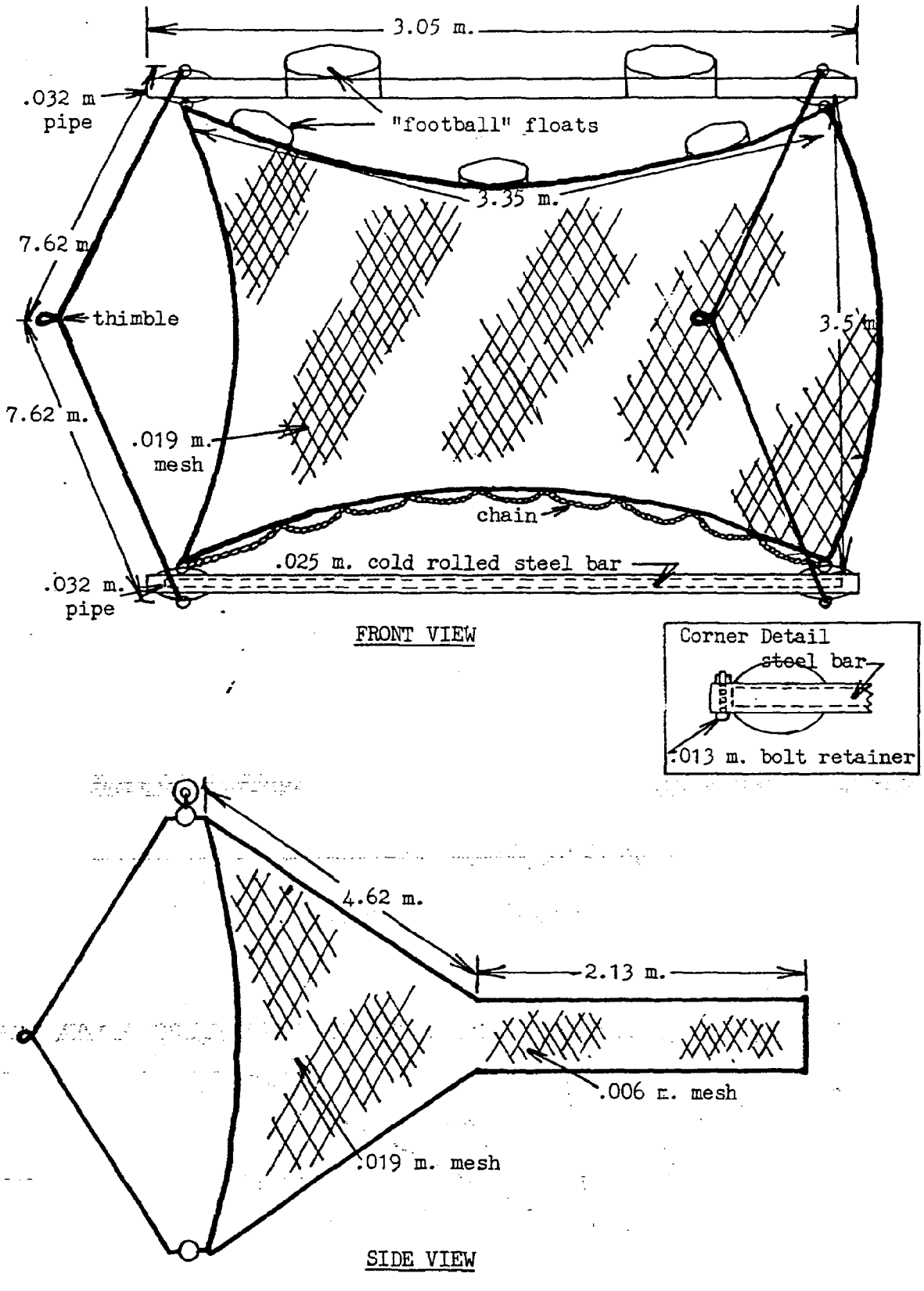


Figure 1. Large modified cobb trawl.

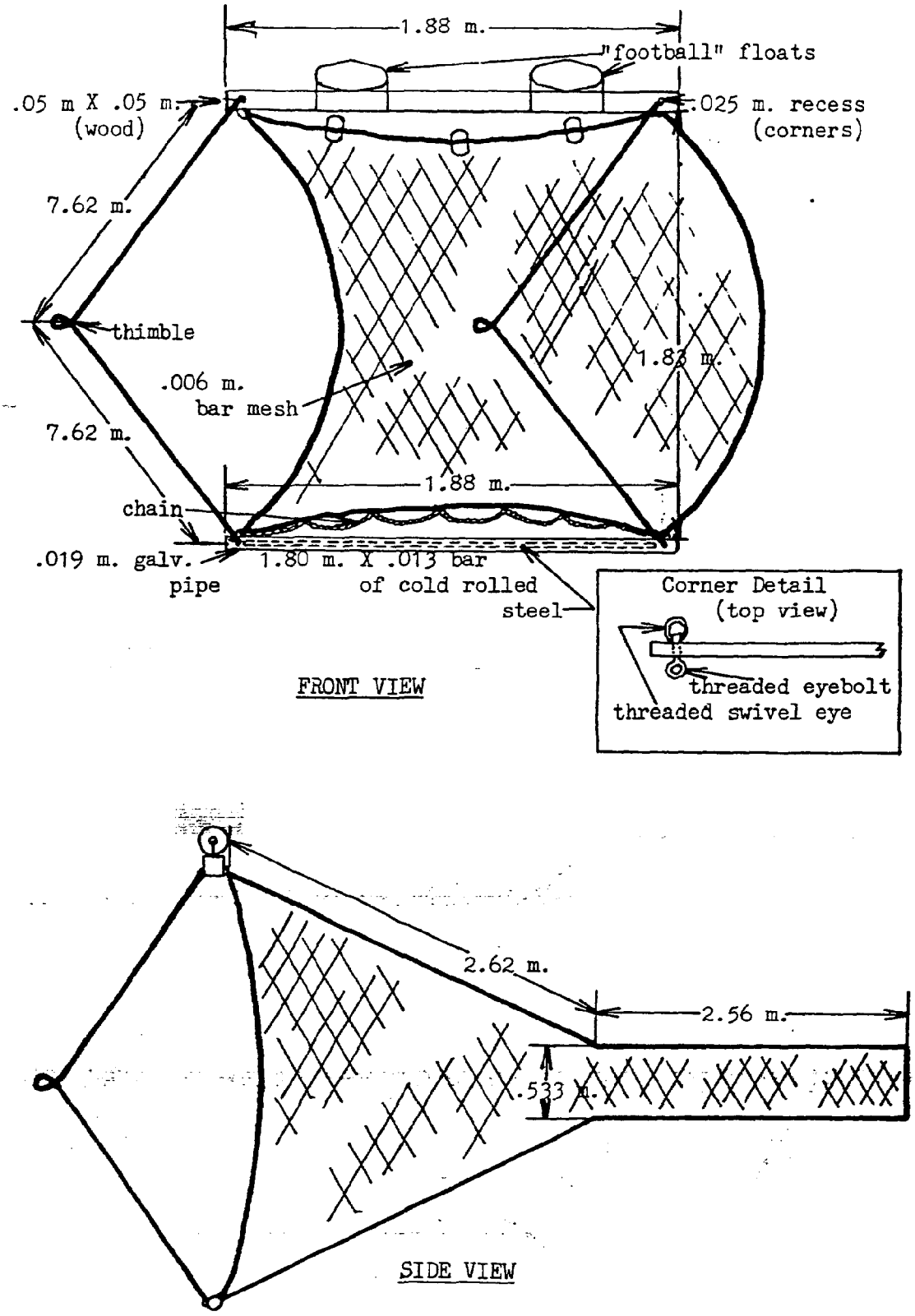


Figure 2. Small modified cobb trawl.

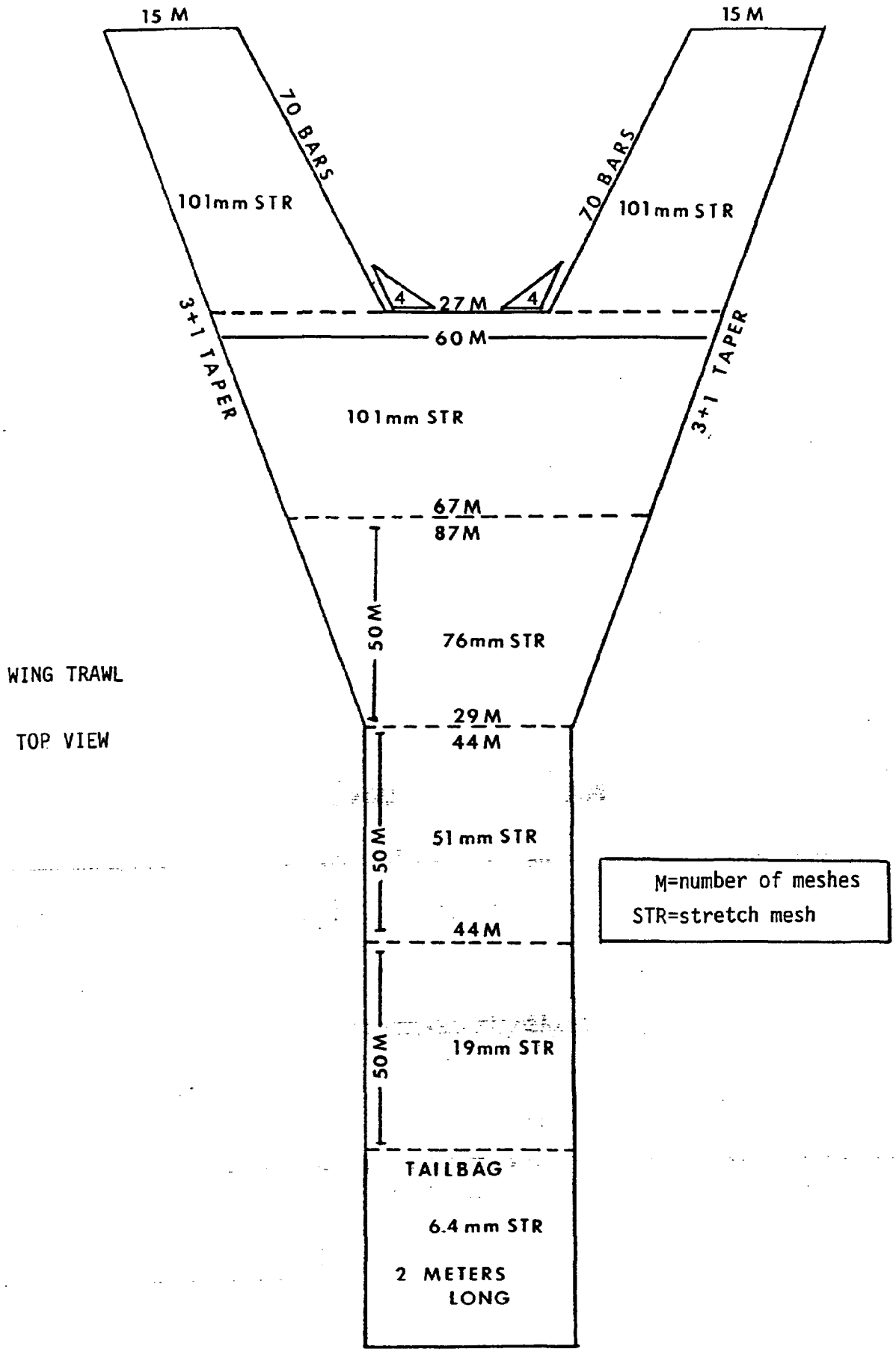


Figure 3. Diagram of wing trawl, adopted for juvenile sampling July 1974.

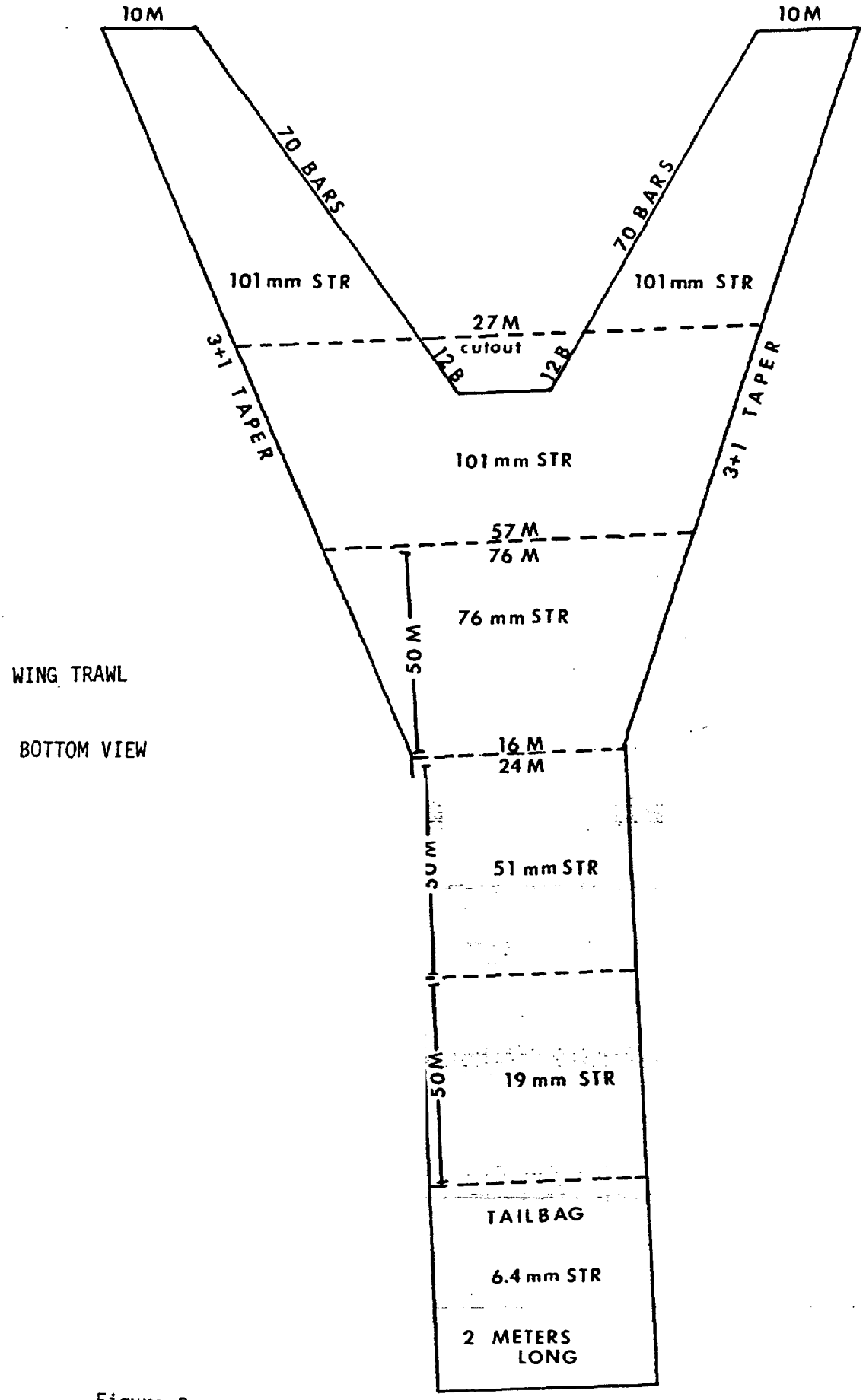


Figure 3. Continued

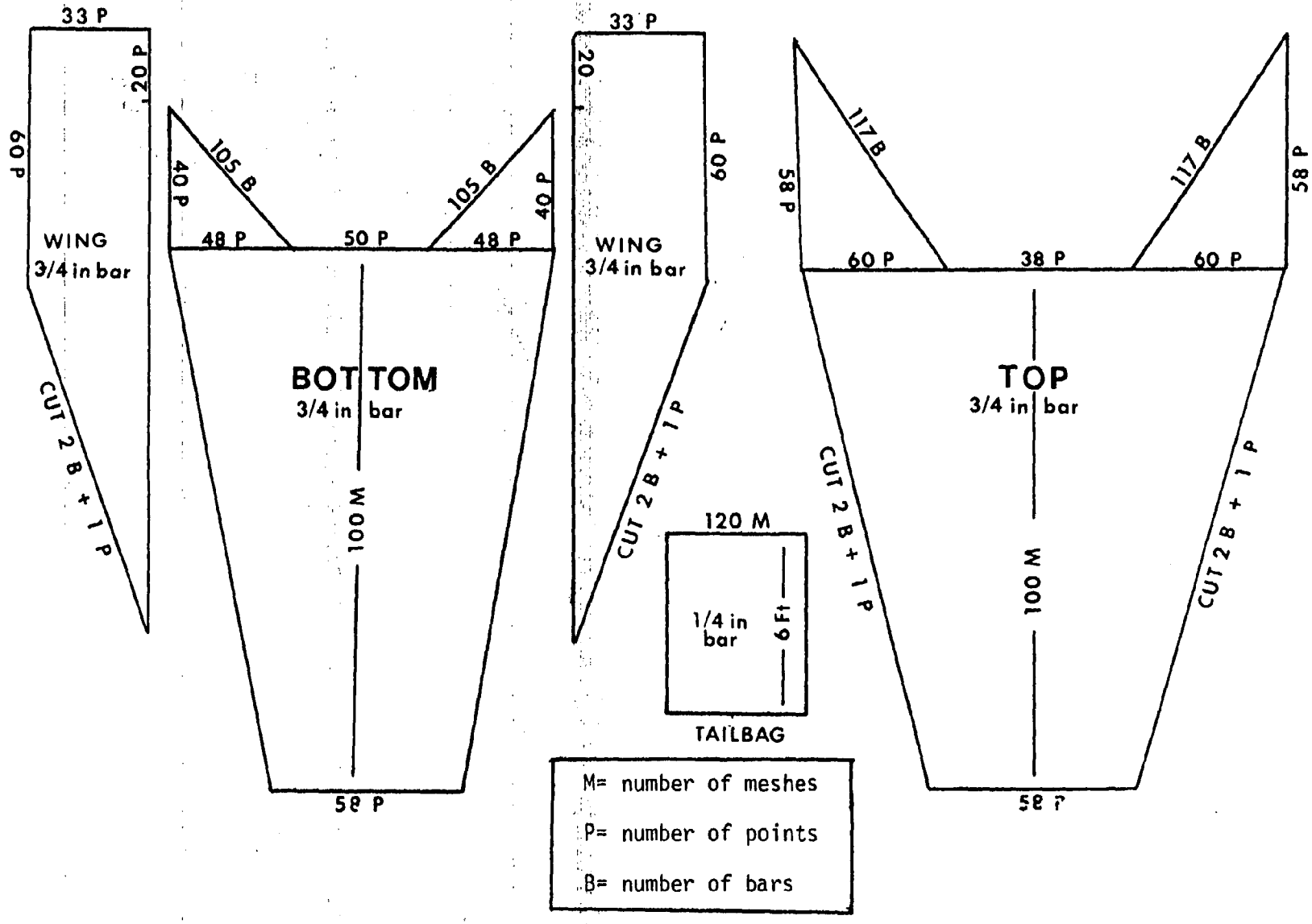


Figure 4. Diagram of 18 ft semi-balloon trawl used during July-October 1982-1987.

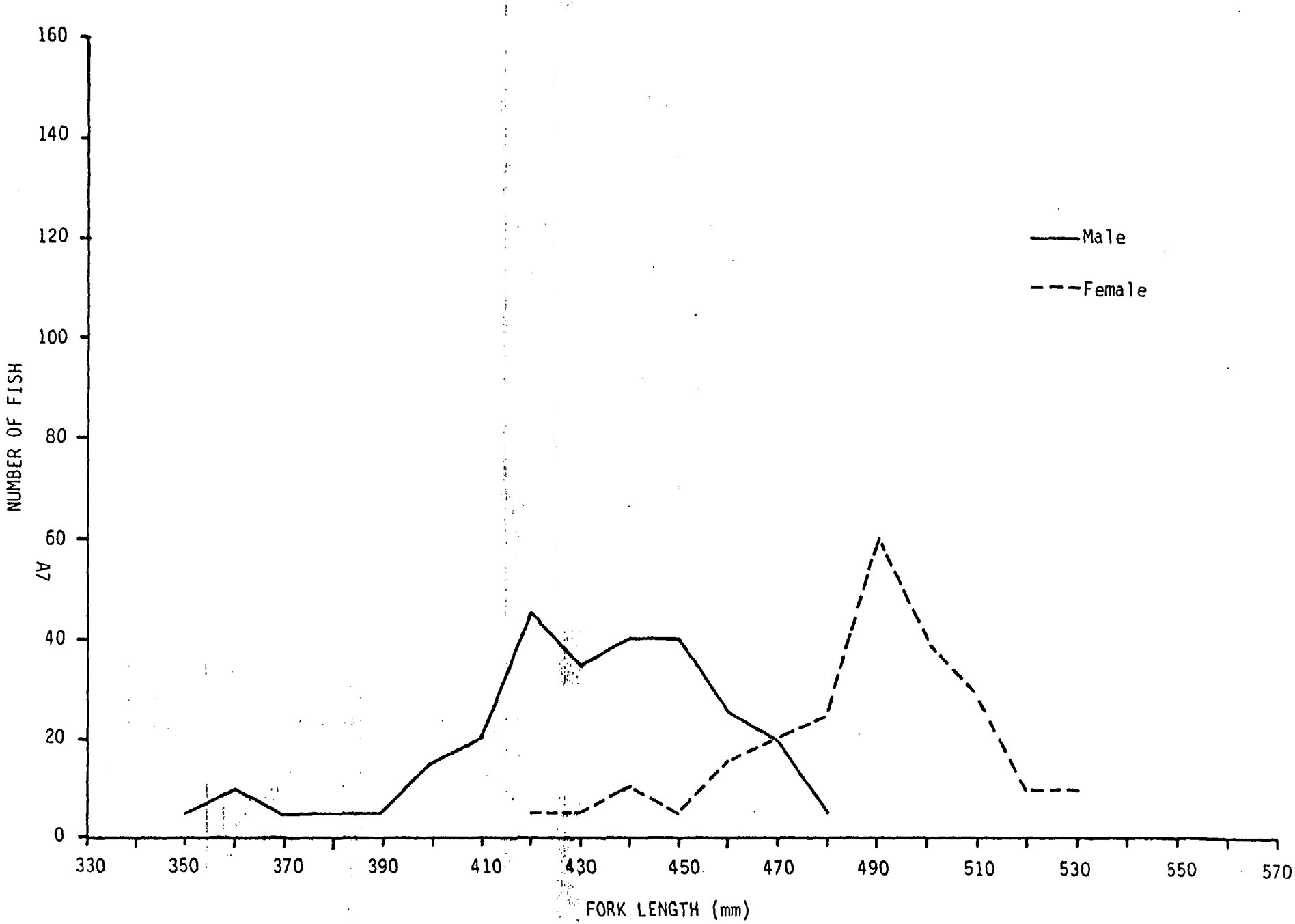


Figure 5. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1972.

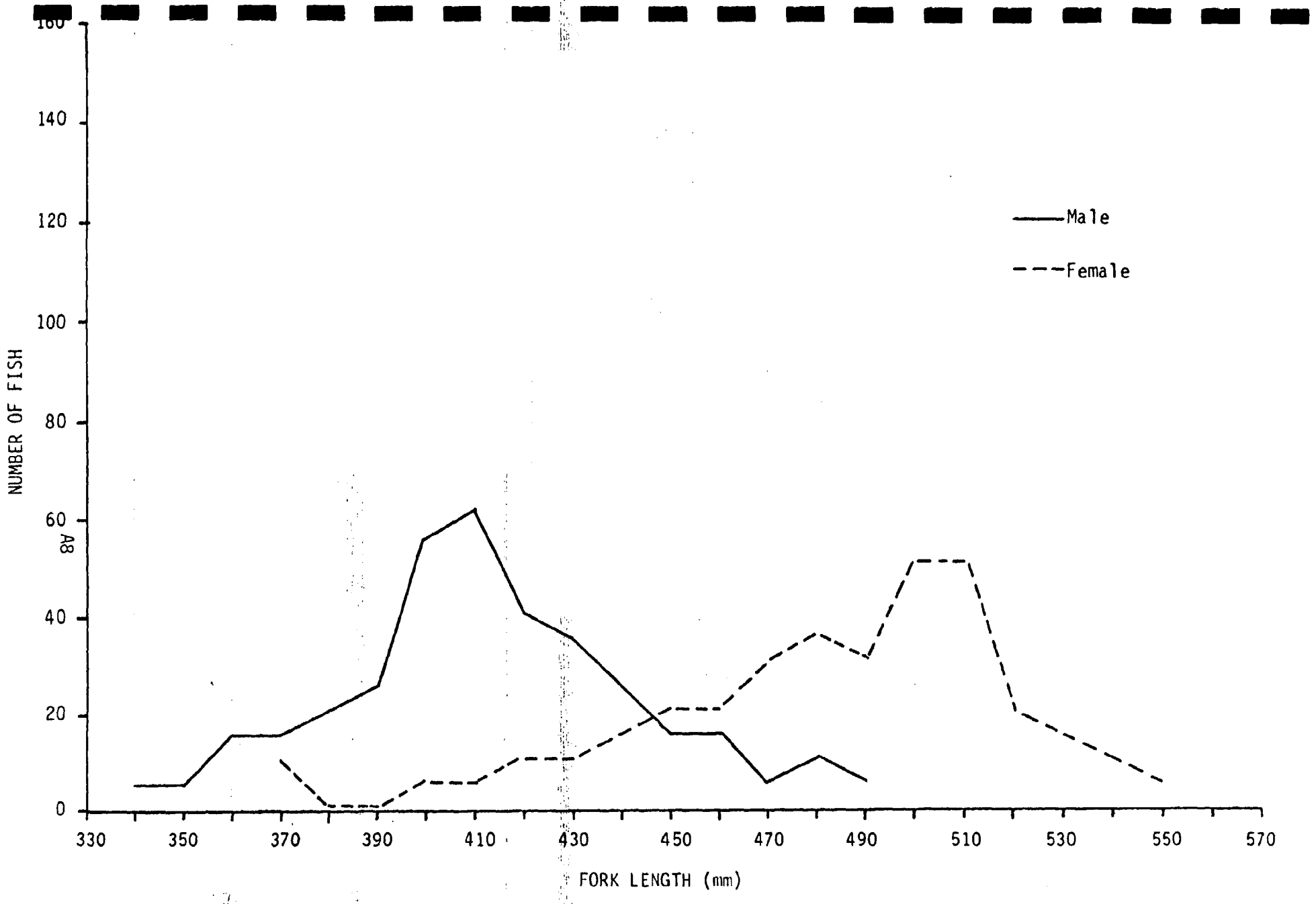


Figure 6. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1973.

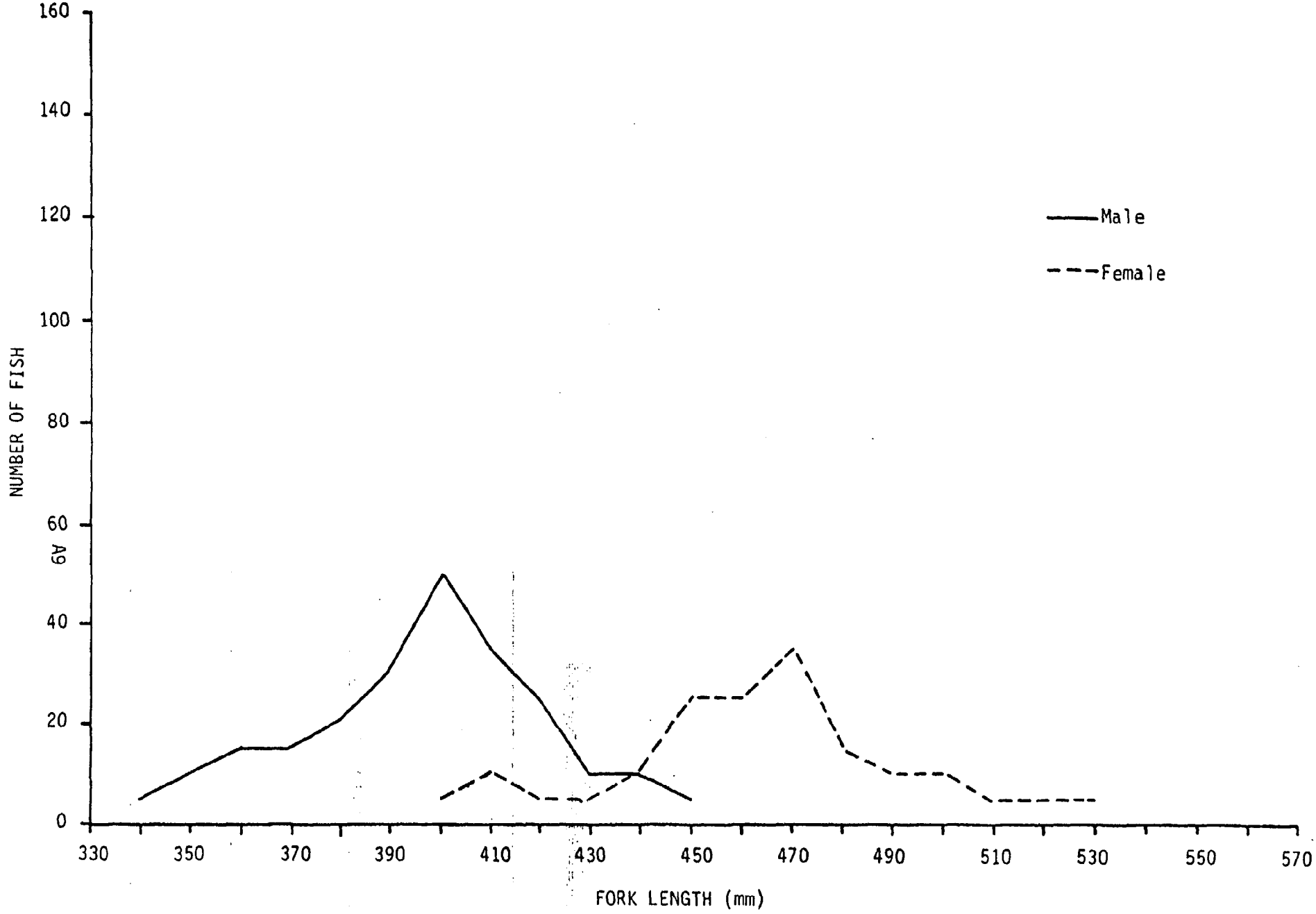


Figure 7. Fork length frequency of American shad for commercial fishery of the Albemarle Sound area, North Carolina, 1974.

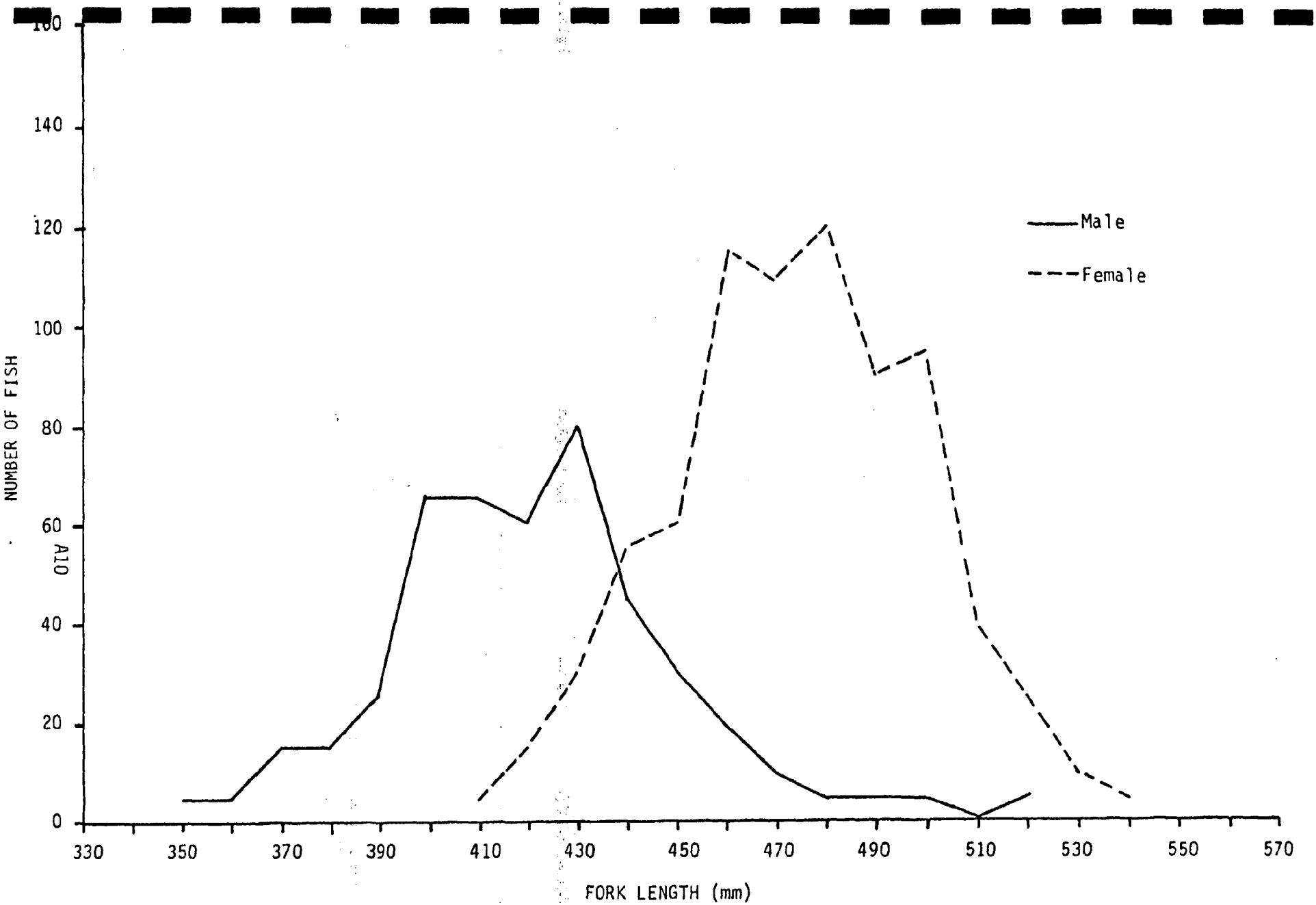


Figure 8. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1975.

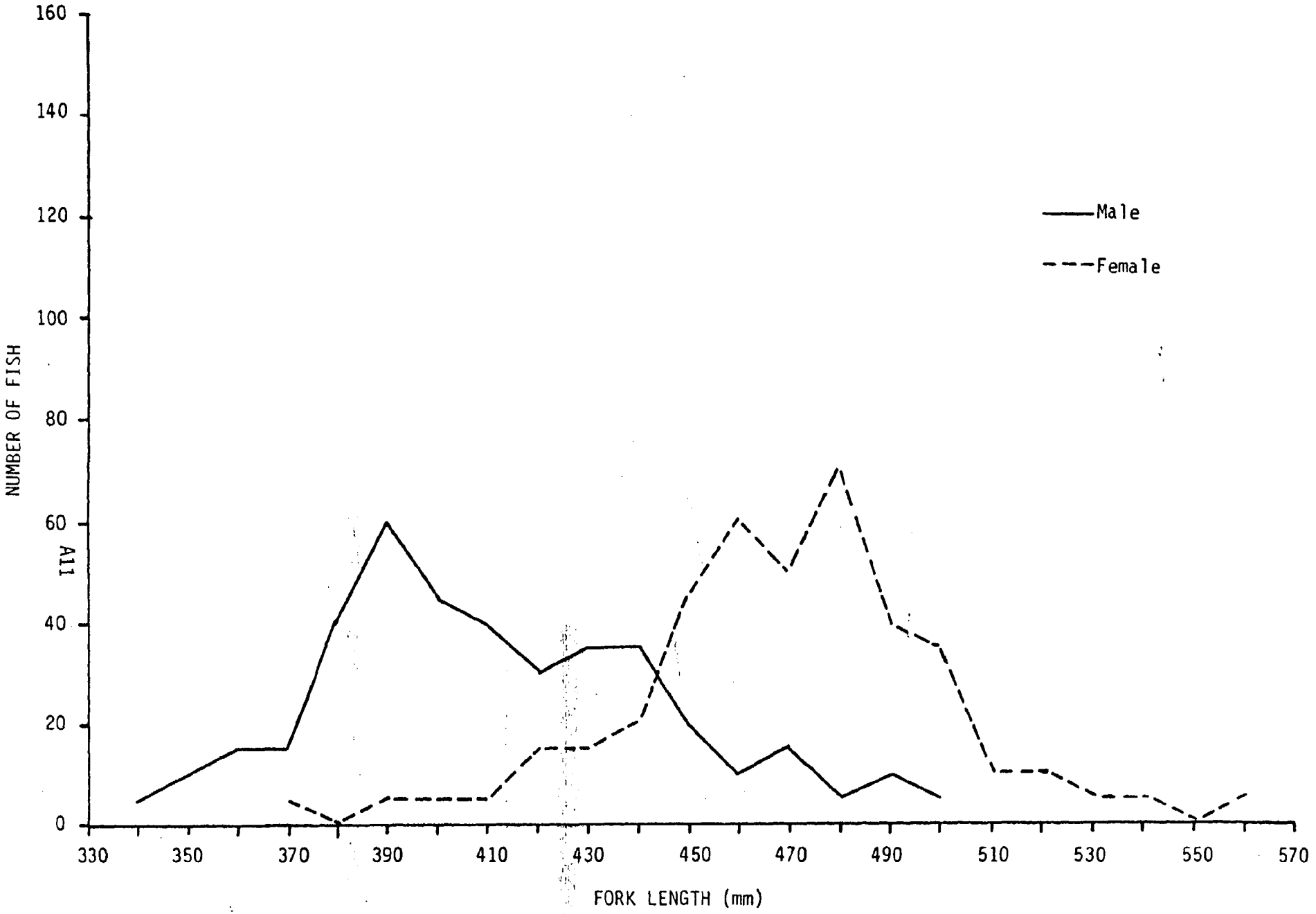


Figure 9. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1976.

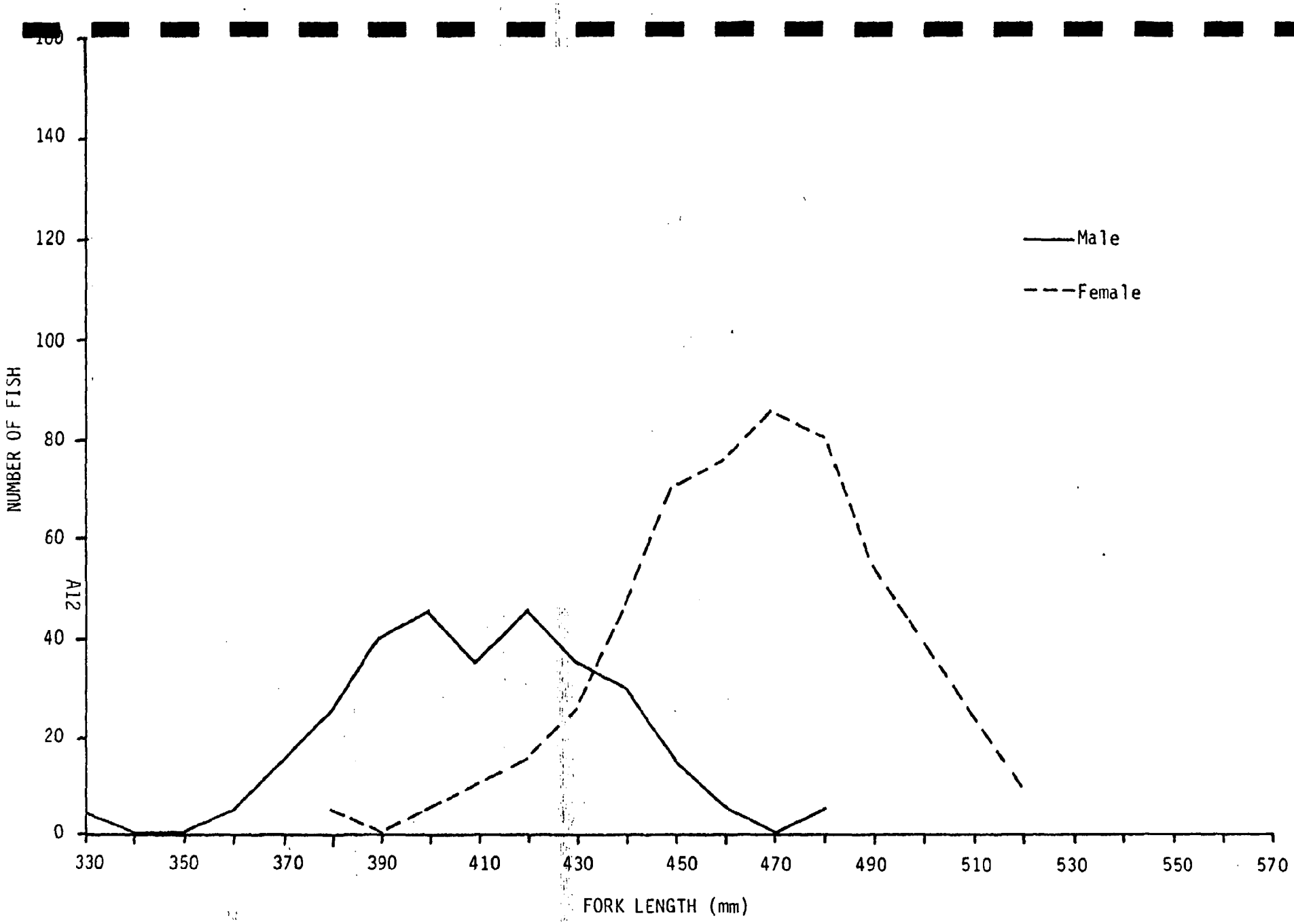


Figure 10. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1977.

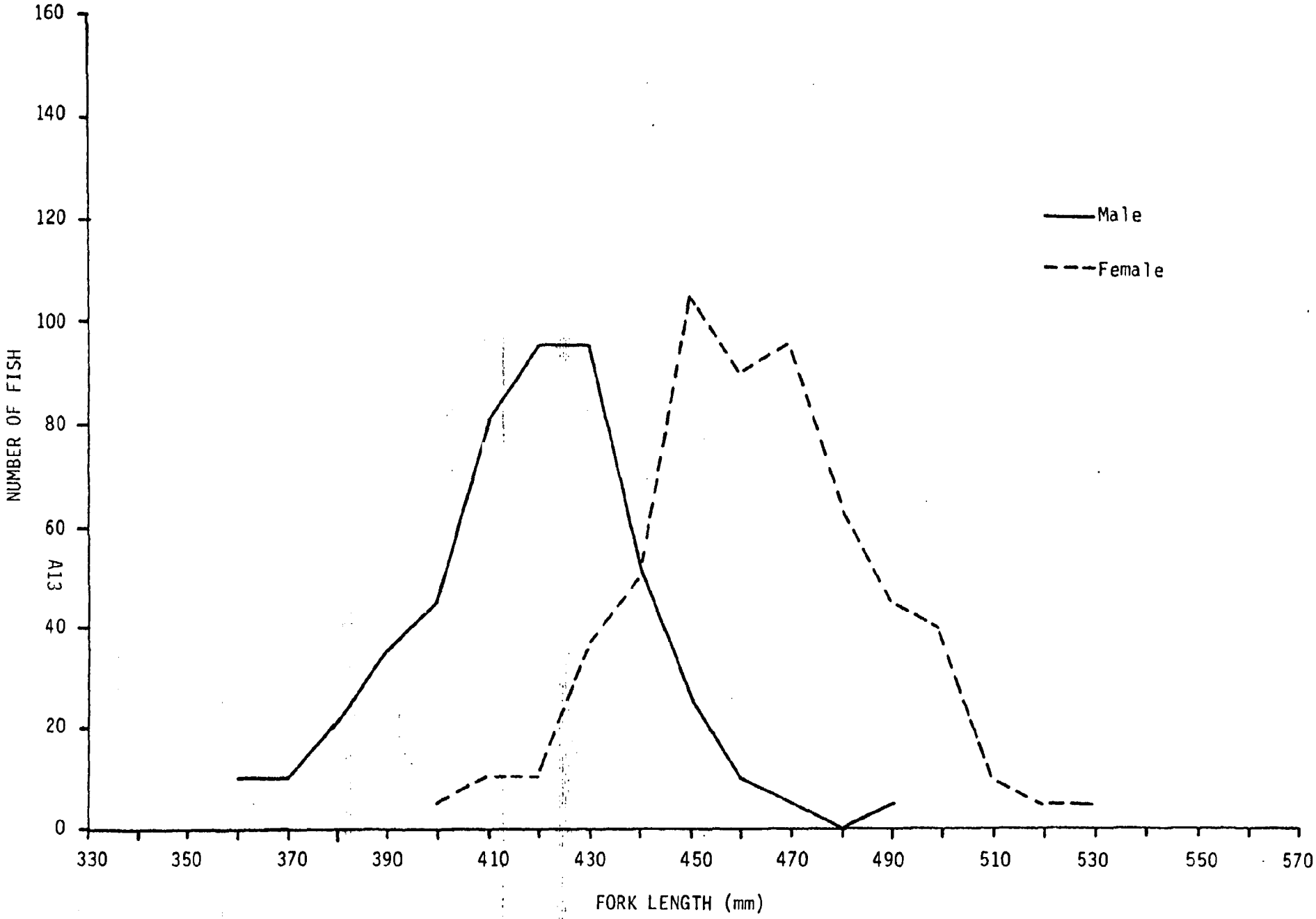


Figure 11. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1978.

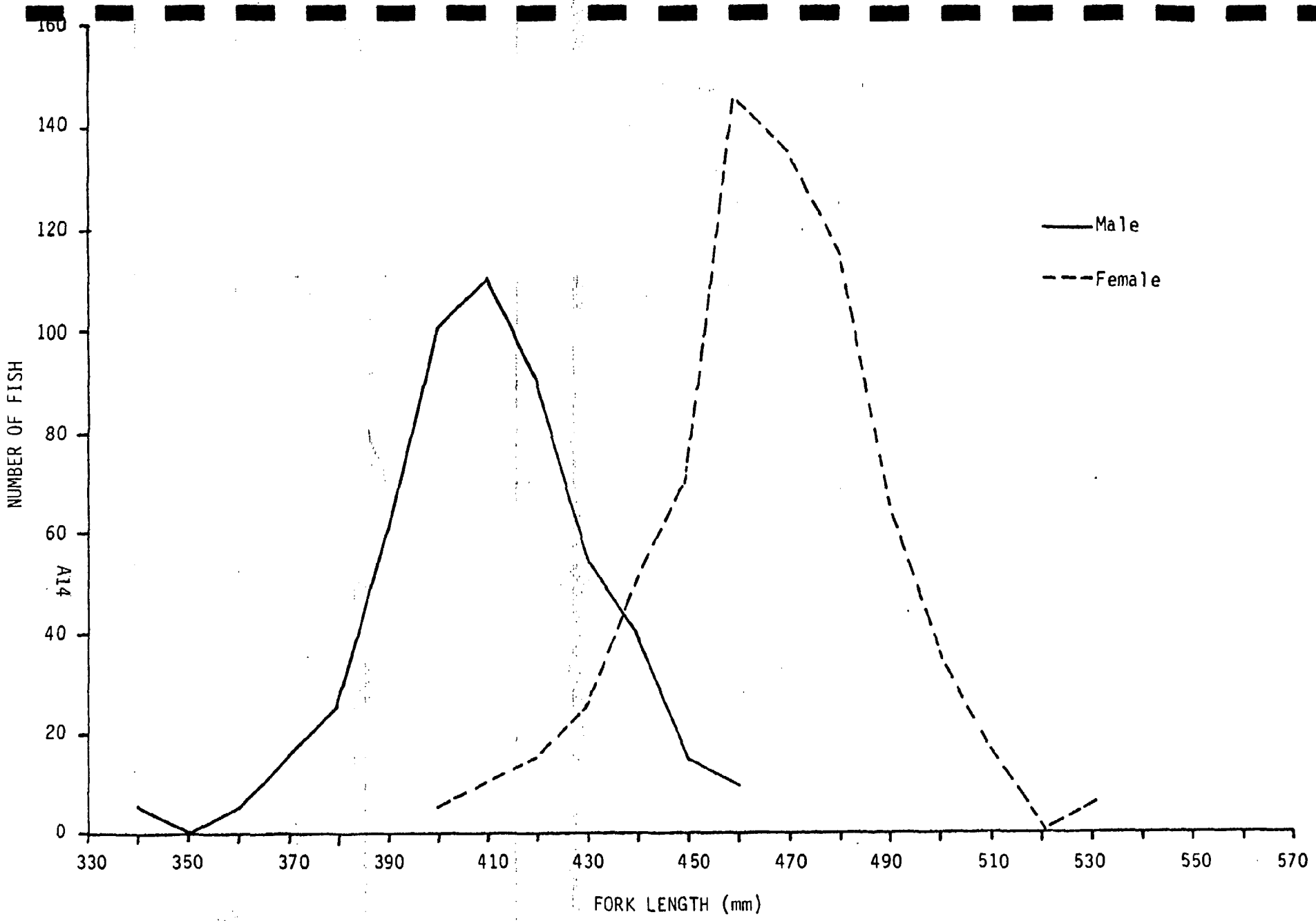


Figure 12. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1979.

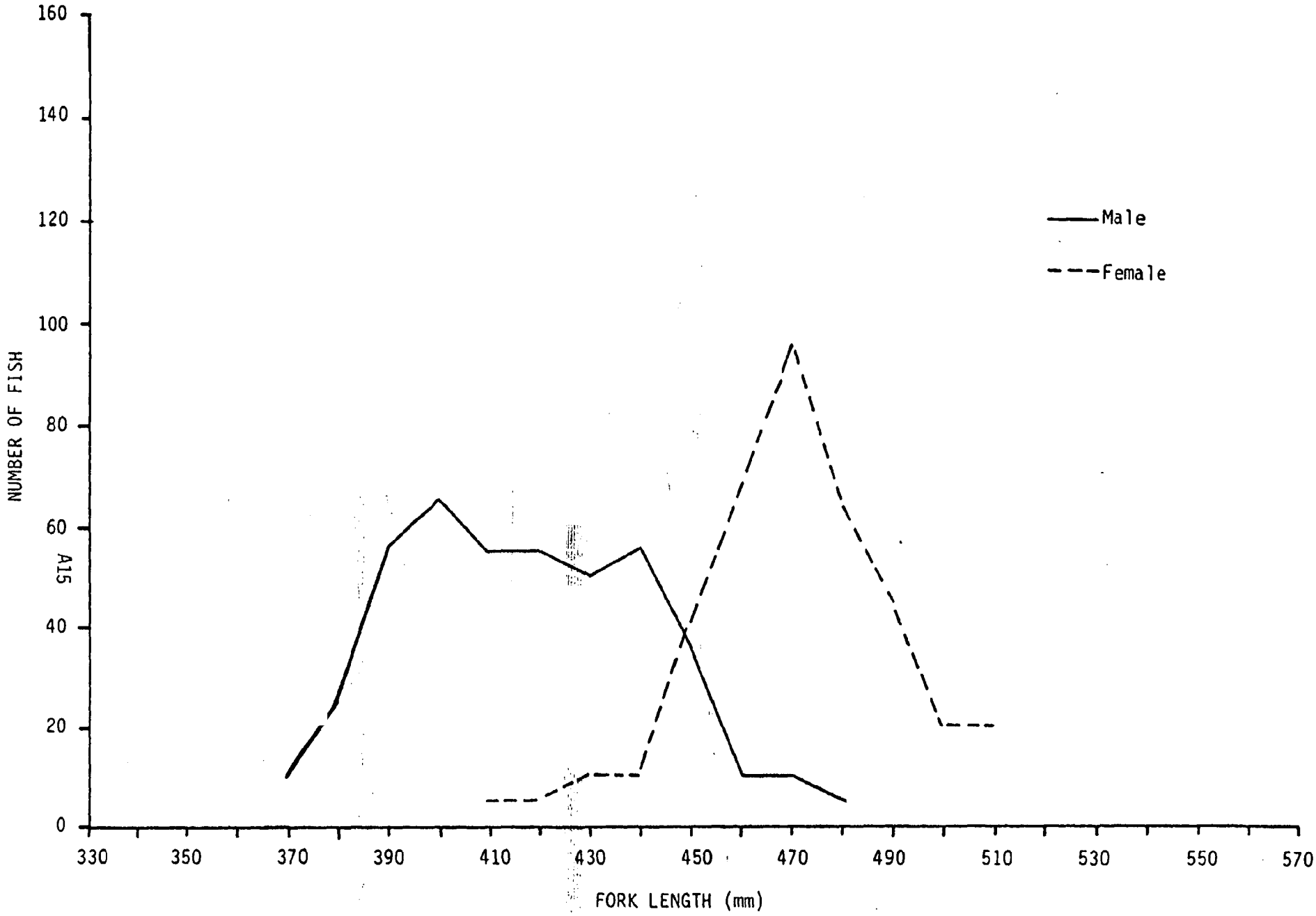


Figure 13. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1980.

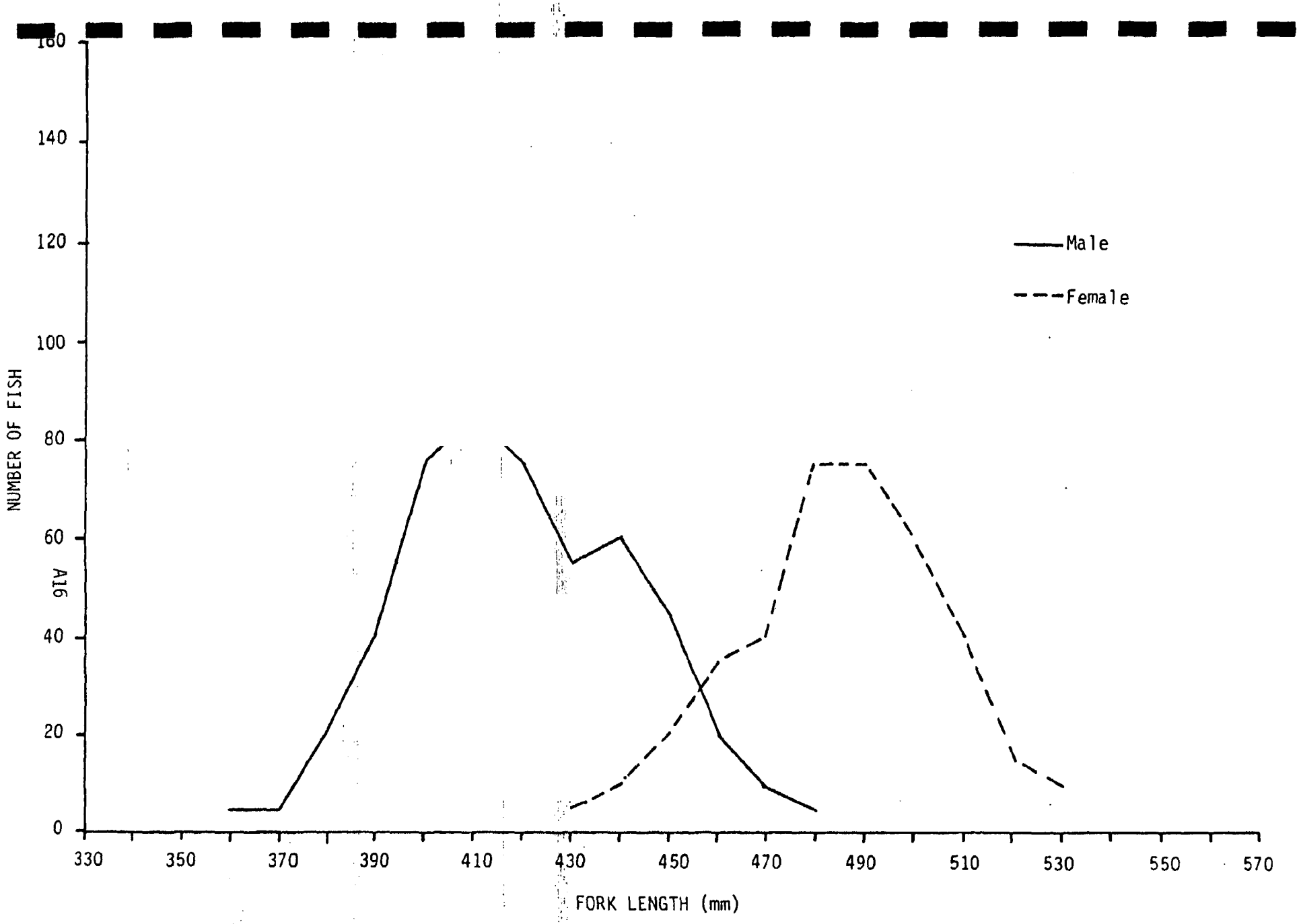


Figure 14. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1981.

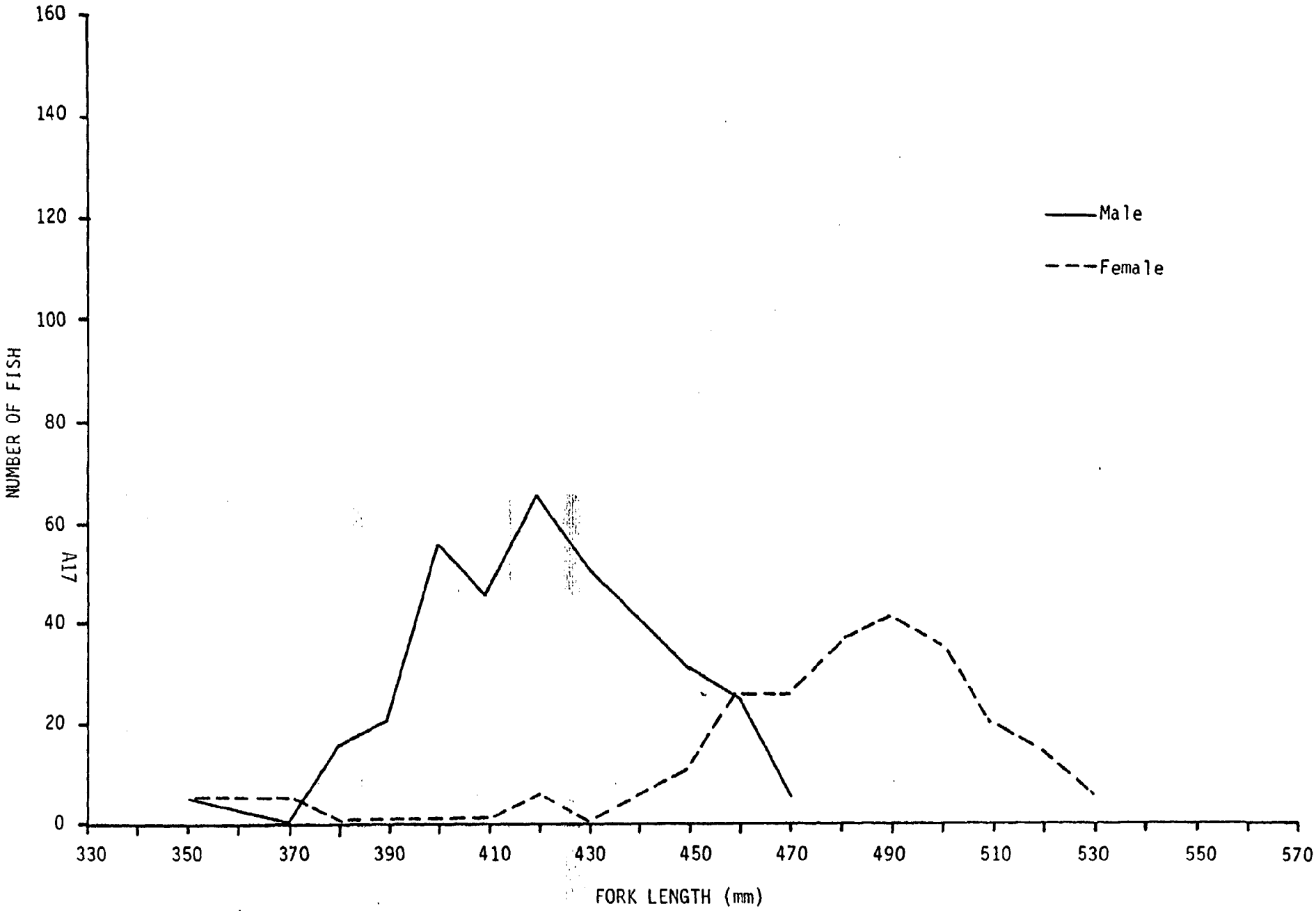


Figure 15. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina 1982.

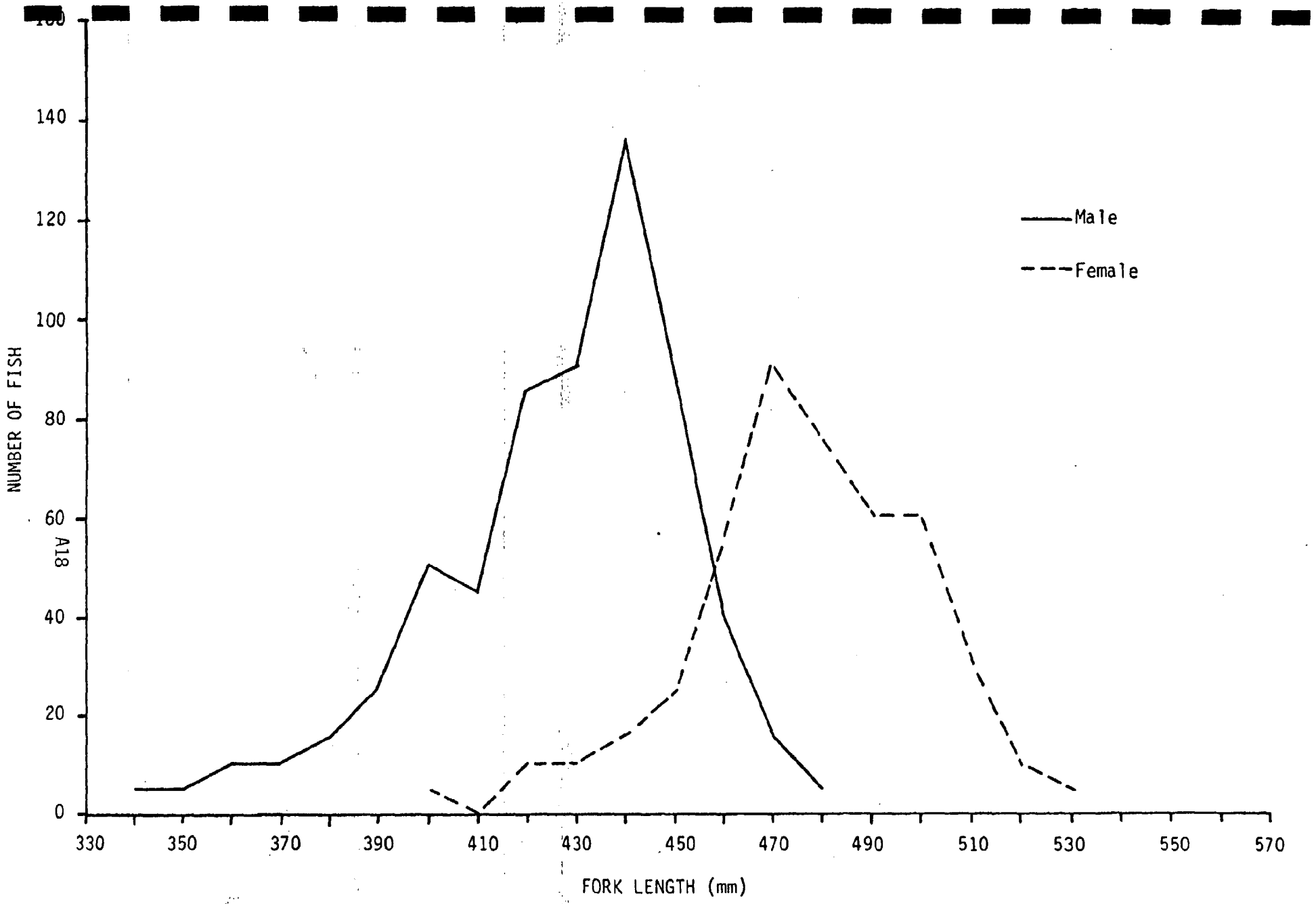


Figure 16. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1983.

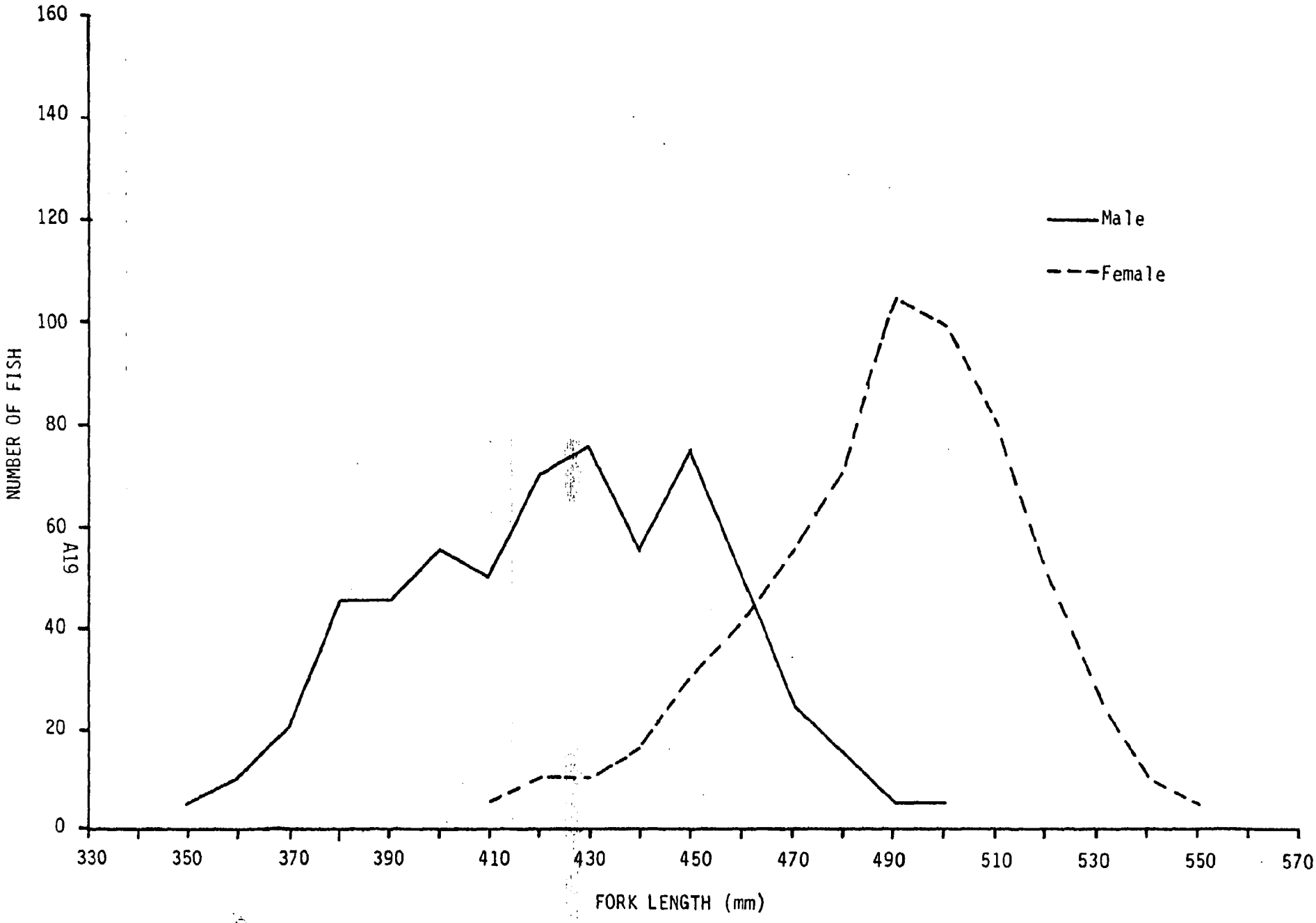


Figure 17. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1984.

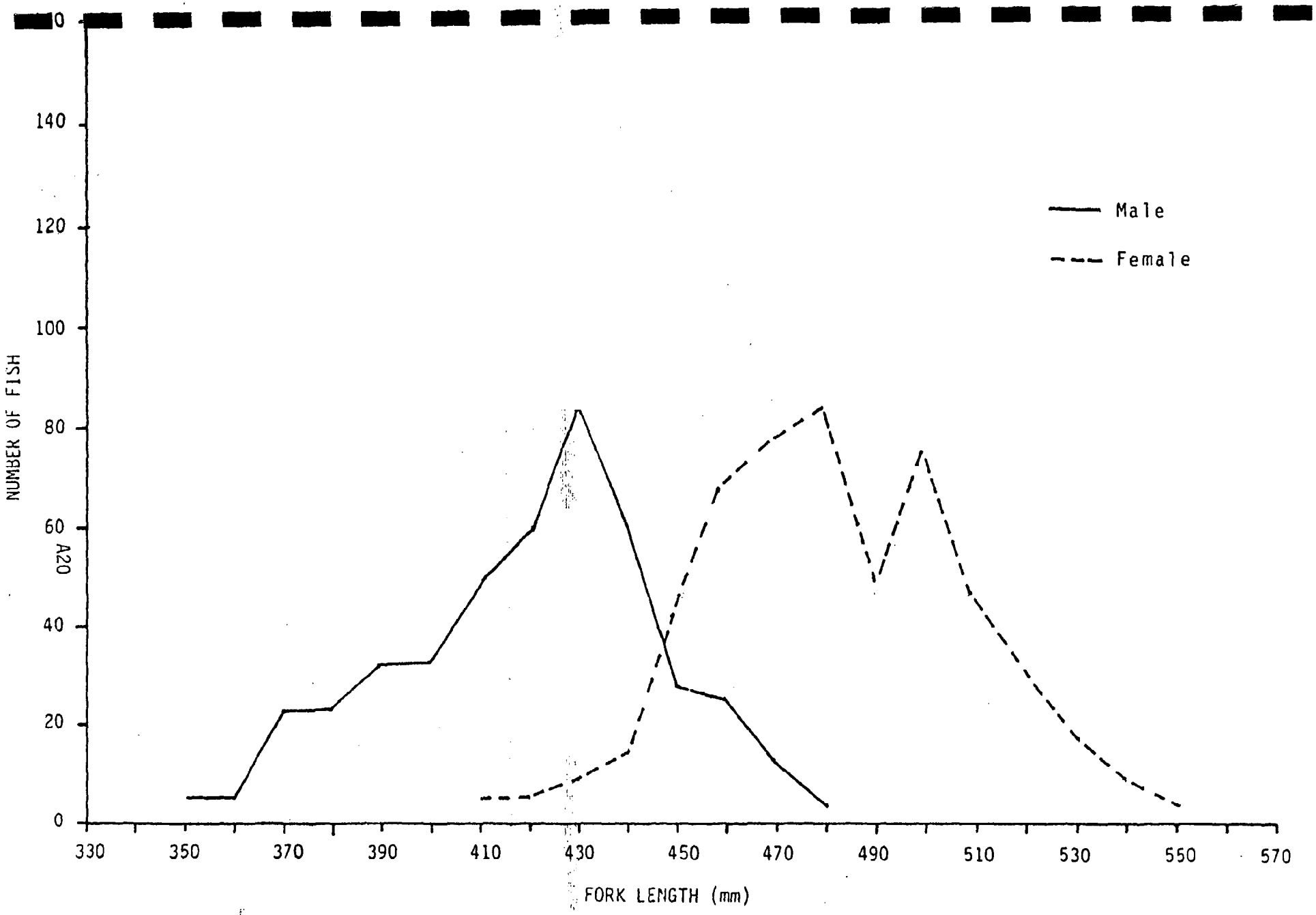


Figure 18. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1985.

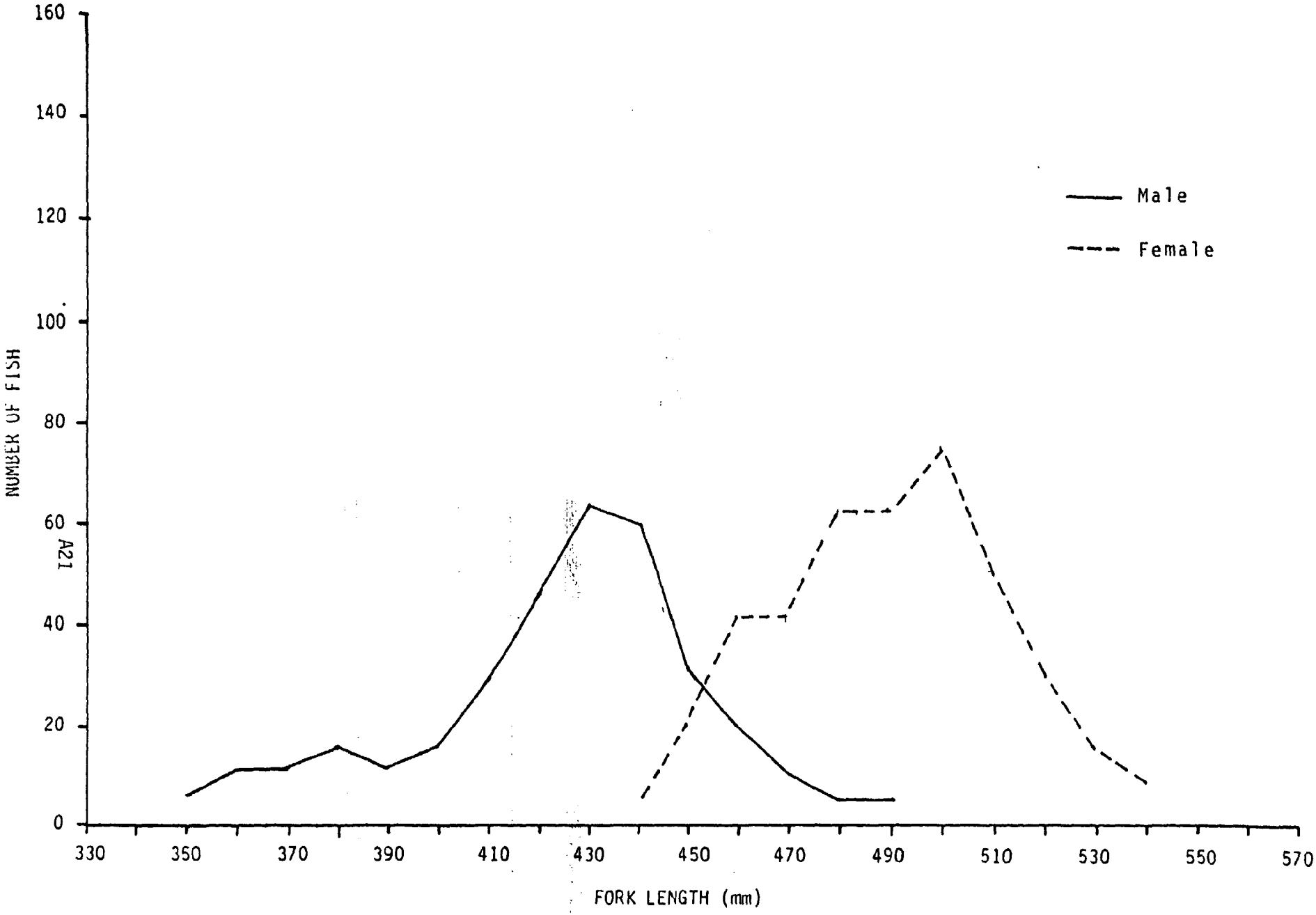


Figure 19. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1986.

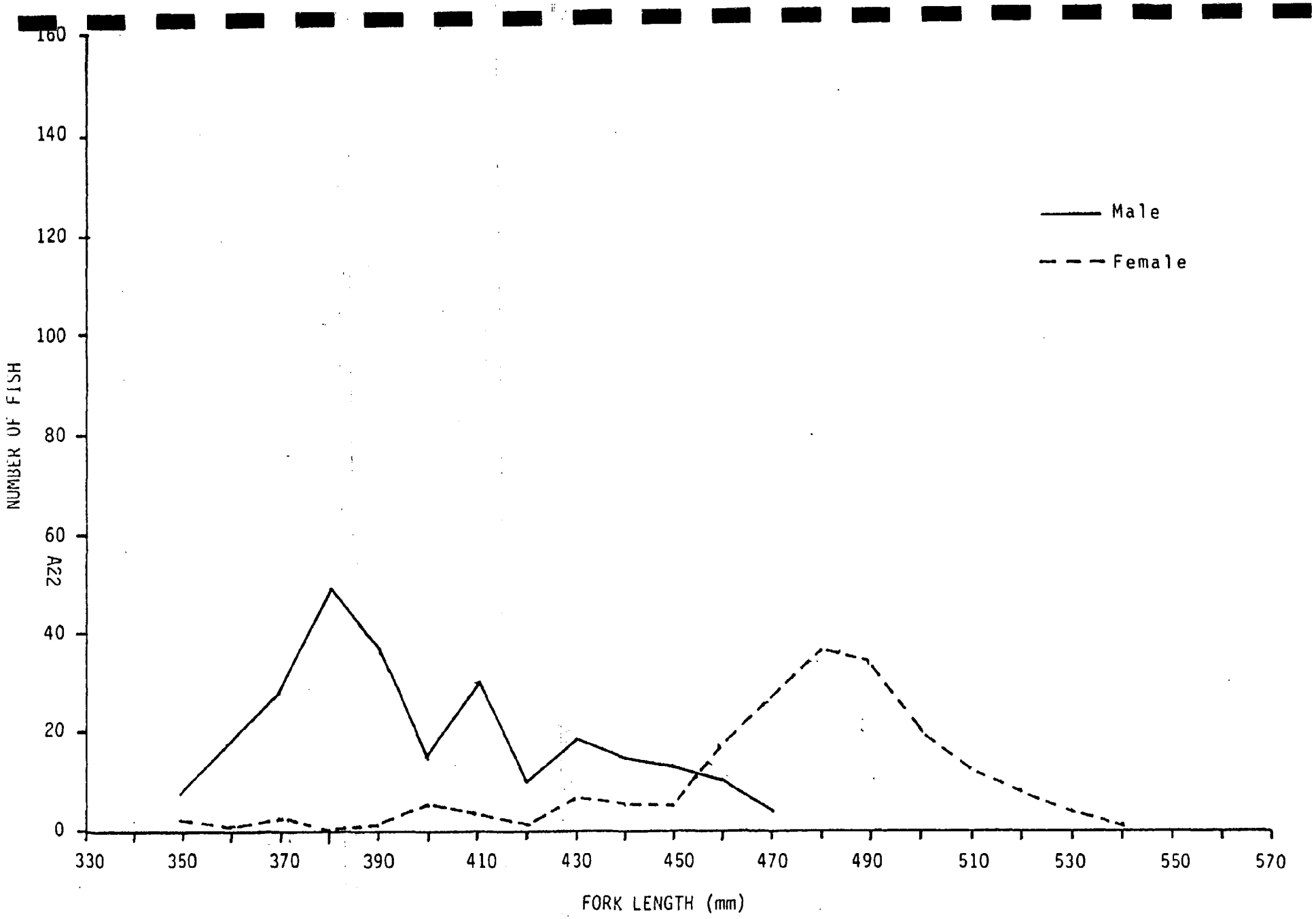


Figure 20. Fork length frequency of American shad from commercial fishery of the Albemarle Sound area, North Carolina, 1987.

APPENDIX
TABLES

Table 1. American shad catch (in thousands of pounds) per state and total Atlantic coast for years of available data. Data 1880-1960 from Walburg and Nichols(1967); 1961-1979 from U.S. Dept. of Commerce Fishery Statistics of the U.S. (from PS E&G, 1982); 1980-1985 from Boreman (1981) and/or state fisheries agencies (ASFMC 1985); where no number appears information was lacking.

Year	FL	GA	SC	NC	VA	MD	DE	PA	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1880		252	208	3,221	3,172	3,774	1,050	559	750	2,734						18,068
1887		255	366	4,783	3,815	4,041	1,270	1,424	6,495	3,586	337	17	133			29,630
1888		263	433	5,725	7,057	4,868	1,389	1,387	6,523		282	17	260		1,096	33,397
1889		356	577	5,403			1,498	2,753	10,424	4,332	196	17	234		839	
1890		400	563	5,815	7,266	7,128	1,797	2,898	10,623	3,777	120					
1896	1,299	537	672	8,843	11,171	5,541	1,993	2,501	13,910	2,201	261	53	114		1,404	50,499
1897	1,011	788	506	8,963	11,529	5,800	1,621	2,007	13,001	1,884	256					
1901					6,972	3,111	1,368	2,983	14,031	3,432	434				731	
1902	1,819	1,029	434	6,567							480	31	21		849	
1904				3,230	7,320	2,912	951	836	4,338	498	603				1,259	
1908	2,833	1,333	464	3,942	7,314	3,937	870	593	3,004	360	122	4	389		770	25,935
1909					6,030	3,253					122				980	
1915					4,714	1,455					148					
1918	964	101	167	1,657							241					
1920					7,294	1,867					176					
1921					6,909	1,807	87	19	168	116	72					
1923	503	134	184	2,370							46					
1925					6,104	1,260					146					
1927	348	187	182	2,387							120					
1928	691	317	320	3,118							199	6	31		110	
1929	701	472	260	1,913	7,977	1,549	94	22	342	164	318	15	92	0	36	13,955
1930	880	275	214	1,172	6,183	998	54	5	224	167	54	4	54	0	89	10,373
1931	621	132	152	883	7,291	1,196	39	7	257	357	75	18	150	0	158	11,336
1932	546	288	123	925	4,848	1,667	16	2	224	401	70	8	46	0	108	9,272
1933					4,817	1,374	22	2	458	352	133	11	63	0	179	
1934	782	232	209	1,274	4,105	885					525					
1935					2,883	800	25	10	818	476	403	6	306	0	13	
1936	282	236	177	1,095	1,615	570					385					
1937	288	193	138	698	3,086	405	20	13	3,340	1,021	383	5	48	0	9	9,647
1938	229	98	59	1,032	3,607	600	14	14	2,492	1,072	427	10	54	0	12	9,720
1939	254	75	42	859	3,559	624	44	11	2,699	1,370	409	28	85	0	8	10,075

Table 1. Continued

Year	FL	GA	SC	NC	VA	MD	DE	PA	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1940	344	150	50	801	2,811	446	31	10	3,365	1,382	360	54	95	0	65	9,964
1941	256				2,126	534					438			0	48	
1942	323				2,430	725	14	7	4,826		373	1	33	0	161	
1943	666						24	0	3,348	2,245	553	2	114	0	272	
1944	811				4,665	711	41	0	4,314	2,130	747	4	20	0	441	
1945	842	222	89	912	5,299	617	133	0	2,917	2,850	772	2	29	0	15	14,699
1946	837				3,599	719		0		1,744	1,146	3	10	0	1,107	
1947	625				4,086	868	68	0	1,547	1,267	793	2	52	0	304	
1948	515				3,206	1,004	53	0	1,853	1,393	622	2	34	0	3	
1949	284				2,801	1,083	57	0	1,407	900	471	3	11	0	5	
1950	298	180	73	1,100	3,031	1,443	102	0	1,072	628	264	2	28	0	2	8,223
1951	336	206	96	1,244	3,295	1,554	110	0	682	462	338	6	72	0	76	8,477
1952	203	243	136	1,479	4,007	1,636	65	0	1,402	773	474	5	48	0	50	10,521
1953		214	110	1,188	3,054	1,448	60	0	679	491	360	4	40	0	27	7,799
1954		180	196	1,445	3,169	1,501	55	0	826	707	295	2	9	0	2	8,668
1955	508	158	88	649	3,500	1,464	12	0	1,326	615	210	5	37	0	7	8,599
1956	376	168	116	773	3,191	2,092	12	0	1,316	704	197	1	724	0	2	9,672
1957	361	247	80	837	2,918	2,356	3	0	1,384	627	329	5	2,214	0	8	11,369
1958	589	319	71	493	2,254	1,900	59	0	964	644	456	2	425	0	10	8,186
1959	540	391	80	419	1,774	1,481	28	0	1,026	672	401	3	1,383	0	2	8,200
1960	511	534	162	702	1,386	1,336	42	0	694	472	421	3	658	0	(1)	8,134
1961	425	404	110	673	1,329	1,815	90	0	633	303	463	4	80	0	0	6,329
1962	760	527	115	765	2,220	1,575	118	0	480	243	456	7	7	0	(1)	7,274
1963	590	331	120	693	2,312	827	100	0	442	202	301	2	22	0	0	5,942
1964	613	134	120	640	2,651	890	150	0	430	141	278	3	39	0	0	6,269
1965	758	376	176	1,069	2,955	1,343	110	0	392	133	352	4	24	0	0	7,692
1966	530	386	119	701	2,431	1,133	56	0	242	81	242	23	12	0	2	5,959
1967	319	334	132	777	2,138	867	26	0	248	113	240	5	509	0	(1)	5,709
1968	531	569	110	842	2,550	958	12	9	241	126	212	2	2	0	2	6,157
1969	390	618	177	719	2,248	1,292	18	0	188	136	190	6	5	0	0	5,987
1970	218	532	148	953	4,112	1,039	13	0	195	106	173	12	1	0	0	7,502
1971	253	420	99	680	1,520	953	8	0	141	73	241	42	0	0	0	4,430
1972	120	344	159	468	2,057	957	9	0	263	103	249	14	1	0	0	4,744
1973	99	239	26	321	2,436	597	8	0	143	157	258	2	1	0	0	4,287
1974	100	162	24	369	1,569	220	8	0	122	164	247	7	3	0	(1)	2,996

Table 1. Continued

Year	FL	GA	SC	NC	VA	MD	DE	PA	NJ	NY	CT	RI	MA	NH	ME	Total Atlantic Coast
1975	33	182	62	241	1,137	184	19	0	122	196	165	6	2	0	35	2,384
1976	28	93	32	167	896	110	36	0	100	186	393	3	0	2	15	2,058
1977	97*	118	80	121	1,469	78		0	198	217	302	1	(1)	3	22	2,706
1978	131	238	305	402	1,235	93	70	0	242	309	266	1	(1)	3	25	3,261
1979	95*	268	197	278	993	18	95	0	149	438*	207	1	3	2	18	2,895
1980	141*	188	217	199	973	23	94	0	293	1,249*	312	2	2	0	28	3,618
1981	170*	196	317	352	499	-	191	0	264	541*	439	33			91	2,625
1982	145*	198	398	412	585	-	350	0	391	383*	373	79			26	3,076
1983	78*	210	331*	444	564	-	233	0	233	448*	4447	23			41	2,773
1984	214		492		991	-		0	293	601	399	36			33	
1985	220															

(1) denotes less than 500 lbs

* from A. Kahle, NYSDEC, November 1984.

Table 2. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1972.

Month	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
February	1968	38.5	173	10.0	35	208
	1967	53.8	245	60.0	209	454
	1966	7.7	35	30.0	105	140
March	1968	11.6	610	7.1	365	975
	1967	58.2	3,058	39.0	1,983	5,041
	1966	23.2	1,213	42.1	2,147	3,360
	1965	6.2	324	11.1	568	892
	1964	0.8	40	-	-	40
	1963	0	-	0.7	40	40
April	1969	2.3	199	-	-	199
	1968	25.0	2,193	1.9	199	2,392
	1967	52.3	4,473	33.3	3,581	8,054
	1966	20.4	1,793	57.4	6,164	7,957
	1965	-	-	7.4	797	797
May	1969	12.3	72	-	-	72
	1968	26.3	154	2.9	10	164
	1967	45.6	269	50.0	175	444
	1966	12.3	72	38.2	134	206
	1965	3.5	21	2.9	10	31
	1964	-	-	5.8	21	21
Total			14,944		16,543	31,487

Table 3. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1982.

Month	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
February	1978	15.8	195	0	0	195
	1977	42.1	524	18.8	196	720
	1976	31.6	392	31.2	327	719
	1975	10.5	131	31.2	327	458
	1974	0	0	18.8	196	196
March	1978	32.6	4,527	5.5	437	4,964
	1977	46.3	6,414	16.4	1,314	7,728
	1976	17.9	2,480	49.1	3,959	6,439
	1975	3.2	440	27.2	2,195	2,635
	1974	0	0	1.8	146	146
April	1979	4.1	248	4.4	167	415
	1978	26.0	1,577	8.9	333	1,910
	1977	39.7	2,414	26.7	997	3,411
	1976	24.7	1,493	28.9	1,082	2,575
	1975	4.1	250	26.7	997	1,247
	1974	1.4	83	2.2	83	166
	1973	0	0	2.2	83	83
May	1977	66.7	881	0	0	881
	1976	33.3	360	0	0	360
	1975	0	0	100	439	439
Total			22,409		13,278	35,687

Table 4. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1983.

Month	Year class	Males		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
February	1979	20.0	696	5.0	174	870
	1978	55.0	1,912	6.1	174	2,086
	1977	20.0	695	41.9	1,042	1,737
	1976	5.0	174	47.0	1,043	1,217
March	1980	1.1	193	0	0	193
	1979	19.1	3,466	5.6	579	4,045
	1978	52.2	9,433	28.3	2,900	12,333
	1977	22.3	4,050	30.2	3,093	7,143
	1976	3.2	578	26.4	2,703	3,281
	1975	2.1	387	7.5	773	1,160
	1974	0	0	2.0	193	193
April	1979	3.2	296	3.4	296	592
	1978	50.7	4,897	32.8	2,821	7,718
	1977	41.8	3,713	43.1	3,705	7,418
	1976	5.1	443	20.7	1,774	2,217
May	1979	8.3	131	0	0	131
	1978	45.8	719	33.4	654	1,373
	1977	29.2	460	50.0	982	1,442
	1976	16.7	262	13.3	262	524
	1975	0	0	3.3	65	65
Total			32,505		23,233	55,738

Table 5. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1984.

		Male		Female		
Month	Year class	Percent	Number of individuals	Percent	Number of individuals	Total number of individuals
February	1980	15.0	505	0	0	505
	1979	45.0	1,519	0	0	1,519
	1978	25.0	845	33.3	169	1,014
	1977	15.0	506	33.3	169	675
	1976	0	0	33.3	169	169
March	1980	5.6	622	0	0	622
	1979	48.3	5,386	8.8	750	6,136
	1978	33.7	3,743	17.6	1,502	5,245
	1977	9.0	997	29.5	2,499	3,496
	1976	3.4	375	32.3	2,742	3,117
	1975	0	0	11.8	1,002	1,002
April	1980	2.6	342	0	0	342
	1979	37.2	4,953	13.4	2,224	7,177
	1978	25.6	3,421	27.8	4,620	8,041
	1977	20.5	2,745	30.9	5,118	7,863
	1976	14.1	1,877	18.6	3,072	4,949
	1975	0	0	9.3	1,541	1,541
May	1980	16.7	264	0	0	264
	1979	33.3	529	7.1	264	793
	1978	16.7	264	28.6	1,056	1,320
	1977	33.3	529	50.0	1,850	2,379
	1976	0	0	14.3	529	529
Total			29,422		29,276	58,698

Table 6. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1985.

Month	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
February	1980	33.3	531	33.3	88	619
	1979	61.1	972	66.7	177	1,149
	1978	5.6	88	-	0	88
March	1982	1.8	162	-	0	162
	1981	14.0	1,297	1.3	162	1,459
	1980	47.4	4,382	30.4	3,872	8,254
	1979	24.5	2,265	45.5	5,818	8,083
	1978	10.5	972	21.5	2,744	3,716
	1977	1.8	162	1.3	162	324
April	1981	17.4	1,284	-	0	1,284
	1980	47.8	3,522	12.2	798	4,320
	1979	21.7	1,599	53.7	3,505	5,104
	1978	8.7	640	31.7	2,074	2,714
	1977	4.3	319	2.4	160	479
Total			18,195		19,560	37,755

Table 7. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1986.

Month	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
February	1981	36.8	1,048	11.2	149	1,197
	1980	36.8	1,043	22.2	298	1,341
	1979	21.1	596	22.2	299	895
	1978	5.3	149	44.4	596	745
March	1982	14.8	2,134	-	0	2,134
	1981	47.5	6,877	17.2	1,179	8,056
	1980	21.3	3,066	31.1	2,130	5,196
	1979	14.8	2,134	34.5	2,359	4,493
	1978	1.6	236	17.2	1,180	1,416
April	1982	14.3	614	-	0	614
	1981	71.4	3,068	-	0	3,068
	1980	14.3	614	-	0	614
	1979	-	0	66.7	1,230	1,230
	1978	-	0	33.3	614	614
May	1982	26.3	672	16.6	134	806
	1981	52.6	1,348	-	0	1,348
	1980	21.1	538	-	0	538
	1979	-	0	50.0	402	402
	1978	-	0	16.7	134	134
	1977	-	0	16.7	134	134
Total			24,137		10,838	34,975

Table 8. Contribution of each year class to the American shad harvest from the Albemarle Sound area, North Carolina, commercial fishery, by sex, by month, 1987.

Month	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
February	1983	31.3	313	-	0	313
	1982	31.3	313	18.2	249	562
	1981	31.3	312	50.0	688	1,000
	1980	6.1	62	9.1	124	186
	1979	-	0	22.7	312	312
March	1983	37.8	3,689	-	0	3,689
	1982	33.3	3,278	13.2	1,091	4,369
	1981	17.8	1,740	44.7	3,713	5,453
	1980	11.1	1,093	26.3	2,183	3,276
	1979	-	0	13.2	1,091	1,091
	1978	-	0	2.6	218	218
April	1983	22.8	2,261	4.2	283	2,544
	1982	44.3	4,395	20.8	1,418	5,813
	1981	20.0	1,992	33.3	2,279	4,271
	1980	8.6	850	37.5	2,564	3,414
	1979	4.3	425	4.2	284	709
May	1983	33.4	1,407	-	0	1,407
	1982	33.3	1,399	33.3	1,407	2,806
	1981	-	0	50.0	2,110	2,110
	1980	33.3	1,407	16.7	703	2,110
Total			24,936		20,717	45,653

Table 9. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1972 (M = male, F = female).

Age / Sex	Number of times spawned: 0 M	0 F	1 M	1 F	2 M	2 F	3 M	3 F	4 M	4 F	Total M	Total F
III	8	0									8	0
IV	43	13	3	1							46	14
V	81	57	46	22	4	7					131	86
VI	18	63	15	16	9	17	2	3			44	99
VII	1	6	3	3	2	4	2	7	1	0	9	20
VIII	0	1			0	1			1	0	1	2
IX					0	1					0	1
Total	151	140	67	42	15	30	4	10	2		239	222
Percent by sex	63.2	63.1	28.0	18.9	6.3	13.5	1.7	4.5	0.8			
Percent sexes combined	63.1		23.6		9.8		3.1		0.4			

Age	Total number M	Total number F	Percent of sample M	Percent of sample F	Mean length (mm) M	Mean length (mm) F	Length range (mm) M	Length range (mm) F	Mean weight (kg) M	Mean weight (kg) F	Weight range (kg) M	Weight range (kg) F
III	8	0	3.4	-	361	-	340-389	-	0.66	-	0.50-0.99	-
IV	46	14	19.2	6.3	408	446	342-487	375-487	1.10	1.65	0.50-1.80	0.86-2.15
V	131	86	54.8	38.7	420	471	358-448	405-520	1.43	2.00	0.71-2.35	1.06-2.70
VI	44	99	18.4	44.6	449	495	400-492	435-536	1.59	2.32	1.11-2.04	1.45-3.35
VII	9	20	3.8	9.0	459	504	436-484	481-560	1.60	2.44	1.10-2.17	1.41-3.40
VIII	1	2	0.4	0.9	476	509	476	491-527	1.95	2.69	1.95	2.66-2.73
IX	0	1	-	0.5	-	571	-	571	-	2.42	-	2.42
Total	239	222										

Table 10. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1973 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
III	32	0									32	0
IV	178	38	17	0							195	38
V	57	112	28	8	3	0					88	120
VI	16	111	2	21	3	4	1	0			22	136
VII	1	1	0	2	0	1	5	3	1	0	7	7
VIII	0	1							2	0	2	1
Total	284	263	47	31	6	5	6	3	3		346	302
Percent by sex	82.1	87.1	13.6	10.3	1.7	1.7	1.7	0.9	0.9			
Percent sexes combined	84.4		12.0		1.7		1.4		0.5			

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
III	32	0	9.2	-	365	-	339-390	-
IV	195	38	56.4	12.6	402	421	315-474	361-480
V	88	120	25.4	39.8	432	474	388-500	373-540
VI	22	136	6.4	45.0	467	504	425-516	437-551
VII	7	7	2.0	2.3	469	522	448-486	449-558
VIII	2	1	0.6	0.3	452	510	444-460	510
Total	346	302						

Table 11. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1974 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
III	18										18	0
IV	142	49	3	0							145	49
V	28	83	6	3	0	1					34	87
VI	0	9	0	3	0	0					0	12
VII	1	0			1	1					2	1
Total	189	141	9	6	1	2					199	149
Percent by sex	95.0	94.6	4.5	4.1	0.5	1.3						
Percent sexes combined	94.8		4.3		0.9							

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
III	18	0	9.0	-	365	-	342-426	-
IV	145	49	72.9	32.9	397	436	340-448	391-475
V	34	87	17.1	58.4	423	473	375-462	415-535
VI	0	12	-	8.0	-	502	-	468-545
VII	2	1	1.0	0.7	555	556	555	556
Total	199	149						

Table 12. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1975 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
II	1	0									1	0
III	0	0									0	0
IV	67	20	3	1							70	21
V	42	61	33	20	1	0					76	81
VI	5	19	10	9	0	5					15	33
VII	0	0	0	1	2	2	0	1			2	4
VIII	1	0			0	1					1	1
Total	116	100	46	31	3	8	0	1			165	140
Percent by sex	70.3	71.4	27.9	22.1	1.8	5.8	-	0.7				
Percent sexes combined	70.8		25.3		3.6		0.3					

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
II	1	0	0.6	-	375	-	375	-
III	0	0	-	-	-	-	-	-
IV	70	21	42.4	15.0	408	447	345-497	399-490
V	76	81	46.1	57.9	429	479	345-520	405-546
VI	15	33	9.1	23.6	456	497	380-521	420-546
VII	2	4	1.2	2.8	467	500	450-485	440-530
VIII	1	1	0.6	0.7	469	455	469	455
Total	165	140						

Table 13. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1976 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	100	17	3	0							103	17
V	107	134	51	21	2	0					160	155
VI	8	11	12	16	16	28					36	55
VII	0	1	0	0	0	1	2	1			2	3
VIII			0	1							0	1
Total	215	163	66	38	18	29	2	1			301	231
Percent by sex	71.4	70.6	21.9	16.4	6.0	12.6	0.7	0.4				
Percent sexes combined	71.0		19.5		8.8		0.7					

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
IV	103	17	34.2	7.4	389	417	338-490	375-460
V	160	155	53.1	57.1	420	463	350-518	370-522
VI	36	55	12.0	23.8	445	479	388-518	422-561
VII	2	3	0.7	1.3	463	497	432-495	447-560
VIII	0	1	-	0.4	-	511	-	511
Total	301	231						

Table 14. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1977 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	53	2									53	2
V	140	89	10	5							150	94
VI	19	66	8	5							27	71
VII	0	1	0	2	0	1					0	4
Total	212	158	18	12	0	1					230	171
Percent by sex	92.2	92.4	7.8	7.0	0	0.6						
Percent sexes combined	92.3		7.5		0.2							

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
IV	53	2	23.0	1.2	381	422	290-446	384-460
V	150	94	65.2	55.0	411	456	256-470	375-510
VI	27	71	11.8	41.5	429	481	387-463	430-526
VII	0	4	-	2.3	-	492	-	460-511
Total	230	171						

Table 15. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1978 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
III	3	0									3	0
IV	53	9	1	0							54	9
V	180	109	8	1							188	110
VI	30	71	9	7							39	78
VII	0	5	0	3	1	0					1	8
Total	266	194	18	11	1	0					285	205
Percent by sex	93.3	94.6	6.3	5.4	0.4	0						
Percent sexes combined	93.9		5.9		0.2							

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
III	3	0	1.1	-	370	-	354-415	-
IV	54	9	18.9	4.4	402	433	300-495	380-471
V	188	110	66.0	53.7	420	459	358-496	402-530
VI	39	78	13.7	38.0	437	476	393-490	415-526
VII	1	8	0.3	3.9	480	496	480	444-532
Total	285	205						

Table 16. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1979 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	8	0									8	0
V	79	6	9	0							88	6
VI	93	61	25	3	2	0					120	64
VII	56	90	6	6	2	0	1	0			65	96
VIII	13	29	1	6							14	35
IX	3	5									3	5
X	0	1									0	1
Total	252	192	41	15	4	0	1	0			298	207
Percent by sex	84.6	92.8	13.8	7.2	1.3	-	0.3	-				
Percent sexes combined	87.9		11.1		0.8		0.2					

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
IV	8	0	2.7	0	402	-	343-445	-
V	88	6	29.5	2.9	408	462	345-490	279-506
VI	120	64	40.3	30.9	414	477	336-510	380-515
VII	65	96	21.8	46.4	424	468	387-497	405-530
VIII	14	35	4.7	16.9	431	480	393-455	455-513
IX	3	5	1.0	2.4	442	467	414-470	457-483
X	0	1	-	0.5	-	483	-	483
Total	298	207						

Table 17. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1980 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	35	0									35	0
V	77	11	47	2							124	13
VI	8	22	31	14	28	2					67	38
VII	0	2	5	6	43	40	9	2			57	50
VIII					1	11	13	18			14	29
IX								5	0	1	0	6
Total	120	35	83	22	72	53	22	25	0	1	297	135
Percent by sex	40.4	25.7	28.0	16.2	24.2	39.0	7.4	18.4	0	0.7		
Percent sexes combined	35.8		24.2		29.0		10.8		0.2			

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)	
Age	M	F	M	F	M	F	M	F
IV	35	0	11.8	-	392	-	358-432	-
V	124	13	41.8	9.6	410	453	324-470	354-492
VI	67	38	22.5	27.9	426	472	380-485	407-519
VII	57	50	19.2	36.8	432	480	387-481	445-521
VIII	14	29	4.7	21.3	446	482	417-493	454-512
IX	0	6	-	4.4	-	495	-	462-510
Total	297	136						

Table 18. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1981 (M = male, F = female).

Age	Number of times spawned										Total	
	0		1		2		3		4			
	M	F	M	F	M	F	M	F	M	F	M	F
IV	4	0									4	0
V	103	6	20	4							123	10
VI	60	8	36	14	70	6					166	28
VII	2	3	8	2	54	42	20	6			84	53
VIII					2	18	32	56	2	22	36	96
IX							0	13	0	28	0	41
Total	169	17	64	20	126	66	52	75	2	50	413	228
Percent by sex	40.9	7.5	15.5	8.8	30.5	28.9	12.6	32.9	0.5	21.9		
Percent sexes combined	29.0		13.1		30.0		19.8		8.1			

Age	Total number		Percent of sample		Mean fork length (mm)		Length range (mm)		Mean weight (kg)		Weight range (kg)	
	M	F	M	F	M	F	M	F	M	F	M	F
IV	4	0	1.0	-	399	-	340-422	-	0.97	-	0.86-1.09	-
V	123	10	29.8	4.4	413	466	353-472	415-505	1.03	1.49	0.66-1.48	.99-1.90
VI	166	28	40.2	12.3	424	488	381-482	426-548	1.18	2.03	0.66-1.88	1.60-2.75
VII	84	43	20.3	23.2	427	485	393-454	445-532	1.21	2.03	0.90-1.54	1.59-2.76
VIII	36	96	8.7	42.1	454	491	423-504	445-521	1.61	2.23	1.21-2.52	1.65-2.67
IX	0	41	-	18.0	-	506	-	480-558	-	2.42	-	1.84-2.98
Total	413	228										

Table 19. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1982 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	97	6									97	6
V	56	11	110	34							166	45
VI	0	6	28	26	54	53					82	85
VII					8	39	7	27			15	66
VIII							0	6	2	4	2	10
IX									0	2	0	2
Total	153	23	138	60	62	92	7	33	2	6	362	214
Percent by sex	42.3	10.7	38.1	28.0	17.1	43.1	1.9	15.4	0.6	2.8		
Percent sexes combined	30.6		34.3		26.7		7.0		1.4			

	Total number		Percent of sample		Mean fork length (mm)		Length range (mm)		Mean weight (kg)		Weight range (kg)	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	97	6	26.8	2.8	402	426	330-448	345-484	1.03	1.38	0.46-1.47	0.69-1.90
V	166	45	45.9	21.0	417	450	320-460	332-527	1.16	1.61	0.52-1.73	0.59-2.58
VI	82	85	22.7	39.7	442	472	400-489	372-527	1.38	1.96	0.52-2.12	0.62-2.82
VII	15	66	4.1	30.8	453	475	428-487	353-535	1.44	2.01	0.61-2.81	0.68-2.84
VIII	2	10	0.5	4.7	396	477	347-445	397-525	-.46	2.04	0.32-0.61	1.02-2.51
IX	0	2	0	1.0	-	500	-	500	-	2.50	-	2.50
Total	362	214										

Table 20. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1983 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
III	1	0									1	0
IV	34	6									34	6
V	127	58	76	20							203	78
VI	11	32	78	77	20	5					109	114
VII			2	32	15	33	1	2			18	67
VIII							2	7			2	7
IX									0	1	0	1
Total	173	96	156	129	35	38	3	9	0	1	367	273
Percent by sex	47.1	35.2	42.5	47.2	9.6	13.9	0.8	3.3	0	0.4		
Percent sexes combined	42.0		44.5		11.4		1.9		0.2			

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)		Mean weight(kg)		Weight range(kg)	
Age	M	F	M	F	M	F	M	F	M	F	M	F
III	1	0	0.3	-	383	-	383	-	0.84	-	0.84	-
IV	34	6	9.3	2.2	396	432	334-457	400-471	1.01	1.49	0.62-1.55	1.10-2.00
V	203	78	55.3	28.6	425	460	345-487	328-518	1.28	1.90	0.51-2.06	0.90-2.88
VI	109	114	29.7	41.7	442	480	396-548	400-531	1.51	2.08	0.84-2.76	1.09-2.71
VII	18	67	4.9	24.5	461	495	417-544	460-551	1.63	2.27	1.30-2.14	1.47-2.80
VIII	2	7	0.5	2.6	530	524	508-553	505-555	2.42	2.73	2.35-2.52	2.30-3.15
IX	0	1	-	0.4	-	556	-	556	-	3.16	-	3.16
Total	367	273										

Table 21. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, commercial fishery, 1984 (M = male, F = female).

	Number of times spawned											
	0		1		2		3		4		Total	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	23	0									23	0
V	97	21	68	6							165	27
VI	15	50	72	28	16	3					103	81
VII	0	1	6	33	47	68	2	0			55	102
IX					10	35	10	35			20	70
X					0	1	0	26	0	3	0	30
Total	135	72	146	67	73	107	12	61	0	3	366	310
Percent by sex	36.9	23.2	39.9	21.6	19.9	34.5	3.3	19.7	0	1.0		
Percent sexes combined	30.6		31.5		26.6		10.9		0.4			

	Total number		Percent of sample		Mean fork length(mm)		Length range(mm)		Mean weight(kg)		Weight range(kg)	
Age	M	F	M	F	M	F	M	F	M	F	M	F
IV	23	0	6.3	-	408	-	350-482	-	1.18	-	0.60-1.96	-
V	165	27	45.1	8.7	4.9	474	332-491	408-528	1.26	2.02	0.60-2.13	1.09-2.90
VI	103	81	28.1	26.1	436	489	316-505	415-548	1.45	2.07	0.70-2.40	1.14-2.95
VII	55	102	15.0	32.9	443	492	380-498	426-550	1.52	2.22	0.95-2.21	1.07-3.00
VIII	20	70	5.5	22.6	474	506	441-501	426-555	1.98	2.40	1.54-3.01	1.18-3.24
IX	0	30	-	9.7	-	517	-	485-545	-	2.68	-	2.11-3.23
Total	366	310										

Table 22. Age, spawning frequency, size and age composition of American shad from Albemarle Sound area, N.C. commercial fishery, 1985. (M = male, F = female).

Age	Number of times spawned									
	0		1		2		3		Total	
Sex	M	F	M	F	M	F	M	F	M	F
III	2	0							2	0
IV	44	1							44	1
V	65	41	42	7					107	48
VI	9	48	47	53	6	1			62	102
VII	0	4	4	24	13	27			17	55
VIII					1	3	3	1	4	4
Total	120	94	93	84	20	31	3	1	236	210
Percent by sex	50.8	44.8	39.4	40.0	8.5	14.8	1.3	0.4		
Percent sexes combined	48.0		39.7		11.4		0.9			

Age	Total number		Percent of sample		Mean fork length (mm)		Length range (mm)		Mean weight (kg)		Weight range (kg)	
	M	F	M	F	M	F	M	F	M	F	M	F
III	2	0	0.9	-	367	-	356-378		0.79		0.73-0.86	
IV	44	1	18.6	0.5	400	-	350-457	424	1.10	-	0.51-2.25	1.29
V	107	48	45.3	22.8	423	475	363-498	398-591	1.25	2.01	0.53-2.15	0.83-2.99
VI	62	102	26.3	48.6	438	486	382-493	416-574	1.44	2.16	0.66-2.04	1.17-3.28
VII	17	55	7.2	26.2	447	509	413-481	453-560	1.46	2.47	1.10-2.00	1.49-3.58
VIII	4	4	1.7	1.9	473	517	464-488	512-525	1.81	2.54	1.78-1.84	2.31-2.91
Total	236	210										

Table 23. Age, spawning frequency size and age composition of American shad from Albemarle Sound area, N.C. commercial fishery, 1986. (M = male, F = female).

Age / Sex	Number of times spawned: 0 M	0 F	1 M	1 F	2 M	2 F	3 M	3 F	Total M	Total F
IV	17	1							17	1
V	47	7	34	1					81	8
VI	6	5	28	9	2	0			36	14
VII			4	9	18	11			22	20
VIII			0	2	0	8	2	3	2	13
IX							0	1	0	1
Total	70	13	66	21	20	19	2	4	158	57
Percent by sex	44.3	22.9	41.8	36.8	12.7	33.3	1.2	7.0		
Percent sexes combined	38.6		40.5		18.1		2.8			

Age	Total number M	Total number F	Percent of sample M	Percent of sample F	Mean fork length (mm) M	Mean fork length (mm) F	Length range(mm) M	Length range(mm) F	Mean weight(kg) M	Mean weight(kg) F	Weight range(kg) M	Weight range(kg) F
IV	17	1	10.8	1.7	404	-	331-470	415	1.14	-	0.54-1.81	0.82
V	81	8	51.3	14.1	429	486	326-492	409-545	1.36	2.17	0.61-2.18	1.10-3.17
VI	36	14	22.8	24.6	438	501	390-494	425-547	1.40	2.37	0.92-2.15	1.28-3.07
VII	22	20	13.9	35.1	443	488	410-487	385-545	1.47	2.29	1.07-1.96	1.55-3.28
VIII	2	13	1.2	22.8	498	512	400-590	480-558	2.19	2.62	1.52-3.10	2.28-3.15
IX	0	1	-	1.7	-	-	-	514	-	-	-	2.06
Total	158	57										

Table 24. Age, spawning frequency size and age composition of American shad from Albemarle Sound area, N.C. commercial fishery, 1987. (M = male, F = female).

Age	Number of times spawned								Total	
	0		1		2		3			
Sex	M	F	M	F	M	F	M	F	M	F
IV	76	2							76	2
V	53	22	51	10					104	32
VI	9	37	39	36	4	4			52	77
VII	0	4	5	27	20	19			25	50
VIII			0	1	2	14	1	2	3	17
IX							0	1	0	1
Total	138	65	95	74	26	37	1	3	260	179
Percent by sex	53.1	36.3	36.5	41.3	10.0	20.7	0.4	1.7		
Percent sexes combined	46.2		38.5		14.4		0.9			

Age	Total number		Percent of sample		Mean fork length (mm)		Length range(mm)		Mean weight(kg)		Weight range(kg)	
	M	F	M	F	M	F	M	F	M	F	M	F
IV	76	2	29.2	1.1	374	398	315-418	396-400	0.83	1.01	0.54-1.22	1.00-1.03
V	104	32	40.0	17.9	398	451	360-461	375-492	0.98	1.62	0.62-1.61	0.78-2.22
VI	52	77	20.0	43.0	427	483	390-470	414-521	1.27	1.99	0.91-1.74	1.22-2.57
VII	25	50	9.6	27.9	447	477	427-476	450-540	2.00	1.34	0.96-1.68	1.70-2.88
VIII	3	17	1.2	9.5	474	458	444-505	468-534	2.34	1.78	1.34-2.22	1.98-2.83
IX	0	1	-	0.6	-	-	-	467	-	-	-	1.86
Total	260	179										