NORTH CAROLINA ANADROMOUS FISHERIES MANAGEMENT PROGRAM

by

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Completion Report for Project AFCS-22

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TABLE OF CONTENTS

INTRODUCTION

Anadromous fishes have been important to North Carolina fishermen for many generations. Fisheries in the Albemarle Sound area predate the American Revolution. Table 1 shows clearly that the Albemarle Sound area is the center of North Carolina's anadromous fisheries industry. Combined landings of blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), American shad (Alosa sapidissima), hickory shad (Alosa mediocris), striped bass (Morone saxatilis) and sturgeons (Acipenser sp.) have fluctuated over the years, principally because of fluctuations in river herring landings (blueback herring and alewife). However, the decline from 1969 to the extremely low 1981 level is unprecedented. River herring landings have rebounded somewhat since the low in 1981 to a level in 1985 comparable to 1970-72 (Table 2). 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 bycatches of other fisheries. Work conducted on adult striped bass in North Carolina was accomplished under a separate project (AFC-25 funded by National Marine Fisheries Service) and is not considered in this report.

Study I of Project AFCS-22 is a continuation of anadromous fisheries research and management activities initiated in the Albemarle Sound area during 1971 (Project AFCS-8). The original objectives of this project were to designate spawning and nursery areas, monitor juvenile year class abundance, adult year class composition, to collect catch-effort statistics from the Chowan River herring pound net fishery, and analyze and report on American shad data that have been collected in the Albemarle Sound area during 1972-1983. Another objective was to conduct a survey of blueback herring

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anadromous fish in North Carolina and in the Albemarle Sound area as shown by commercial landings (from published and unpublished data: NMFS, Branch of Statistics, Beaufort, N.C.; N.C. Division of Marine Fisheries, Morehead City; and Zoology Department, N.C. State University at Raleigh).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

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

Table 2. Commercial landings of anadromous fishes in North Carolina, 1965 - 1985 (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

*Preliminary landings subject to revision in Fishery Statistics of the United States larvae and juveniles to evaluate the possible relationship between poor water quality as evidenced by altered phytoplankton community structure and declines in abundance. A separate report on this topic by a contractor is included in this completion report as Study II.

Study III concerns assessment of juvenile striped bass in the Albemarle Sound area and stocking and evaluation of stocking in the major drainage basins of coastal North Carolina.

For many years, Canadian authorities have considered taking advantage of the wide tidal ranges in the Bay of Fundy to generate electricity. Concern over the potential effects of this development on anadromous fishes has resulted in research on possible effects. A contractor's report on river herring tagging in Minas Basin, Canada is included as Study IV.

Because of the decline in landings of river herring, American shad, and hickory shad 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 these resources. Data from this project will be part of the data base for this plan, which is being coordinated by the Atlantic States Marine Fisheries Commission's Interstate Fisheries Management Program.

PROJECT I

ALOSID PROJECT

SECTION I

ALOSID AND STRIPED BASS PROJECTS

by

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ABSTRACT

Juvenile and adult blueback herring (*Alosa aestivalis*), alewife (*A. pseudoharengus*), American shad (*A. sapidissima*), and hickory shad (*A. mediocris*) were monitored in the Albemarle Sound area, N.C., during 1983-1985. Spawning areas for blueback herring and alewife were delineated in the Chowan River and its tributaries during 1983. American shad spawning areas were identified in the Nottoway and Blackwater rivers, Va. in 1984. Juvenile sampling was also conducted in the Currituck Sound area during 1983-84. Juvenile alosids were more abundant during the 1983 sampling period. Catch-effort data for the Chowan River pound net fishery indicated peak catches occurred during weeks 13-18 each year. River herring landings during 1985 were the highest since the early 1970s. Weekly catch data for the Chowan River pound net fishery were combined with age and sex data to estimate the harvest of blueback herring and alewife in the fishery by year class and sex for 1983 and 1984; 23.9 million fish were taken in 1983, while 27.3 million fish were landed in 1984. Age and sex composition data were collected for all four species of *Alosa* from the commercial fisheries in the Albemarle Sound area during 1983-85. American shad were also sampled from the Outer Banks area of North Carolina and the Neuse River, Tar-Pamlico River and Cape Fear River areas.

INTRODUCTION

Fisheries for river herring (blueback herring and alewife), American shad and hickory shad have been important to North Carolina fishermen for many years. The principal commercial gears used to capture these alosids have been pound nets and gill nets in the coastal sounds and tributaries.

The landings of these species have fluctuated over the years, primarily due to variations in river herring landings. From about 1970 through 1981 river herring landings declined. However, since 1982 the landings have increased somewhat, with 1985 landings being similar to 1970-72 (Table 2).

STUDY AREA

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

Blackwater River and and Nottoway River

Ihe Blackwater River and Nottoway River, located in southeastern Virginia, converge near the Virginia/North Carolina border to form the Chowan River. The Blackwater River watershed is entirely in the coastal plain while the Nottoway River watershed lies in the coastal plain as well as the Piedmont (NRCD 1982). The river bottom consists of sand, mud, and detritus. The shoreline consists of wooded swamps, occasional and beaches and bluffs (Smith, 1963) (Figure 2).

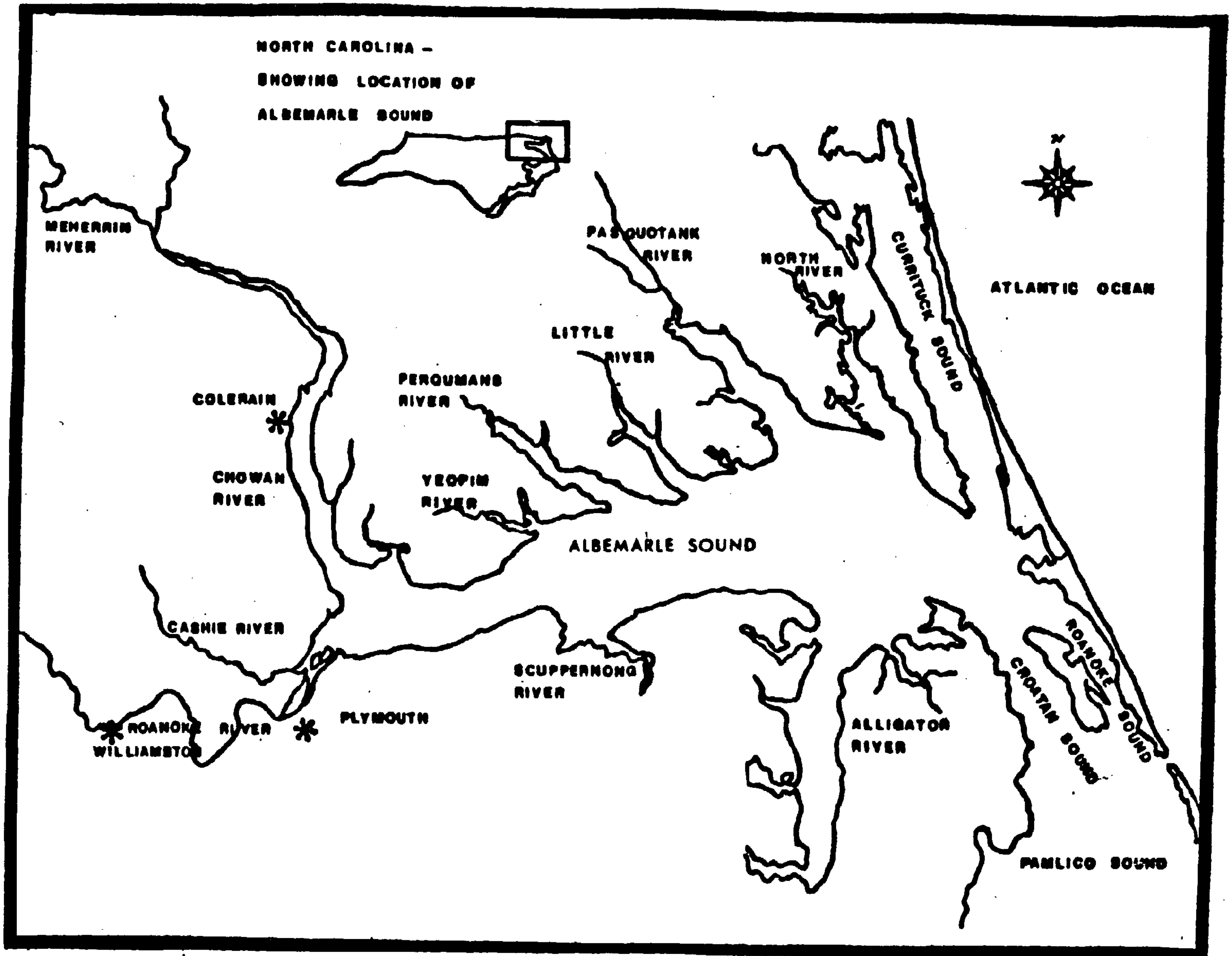


Figure 1. Albemarle Sound area and its tributaries, North Carolina.

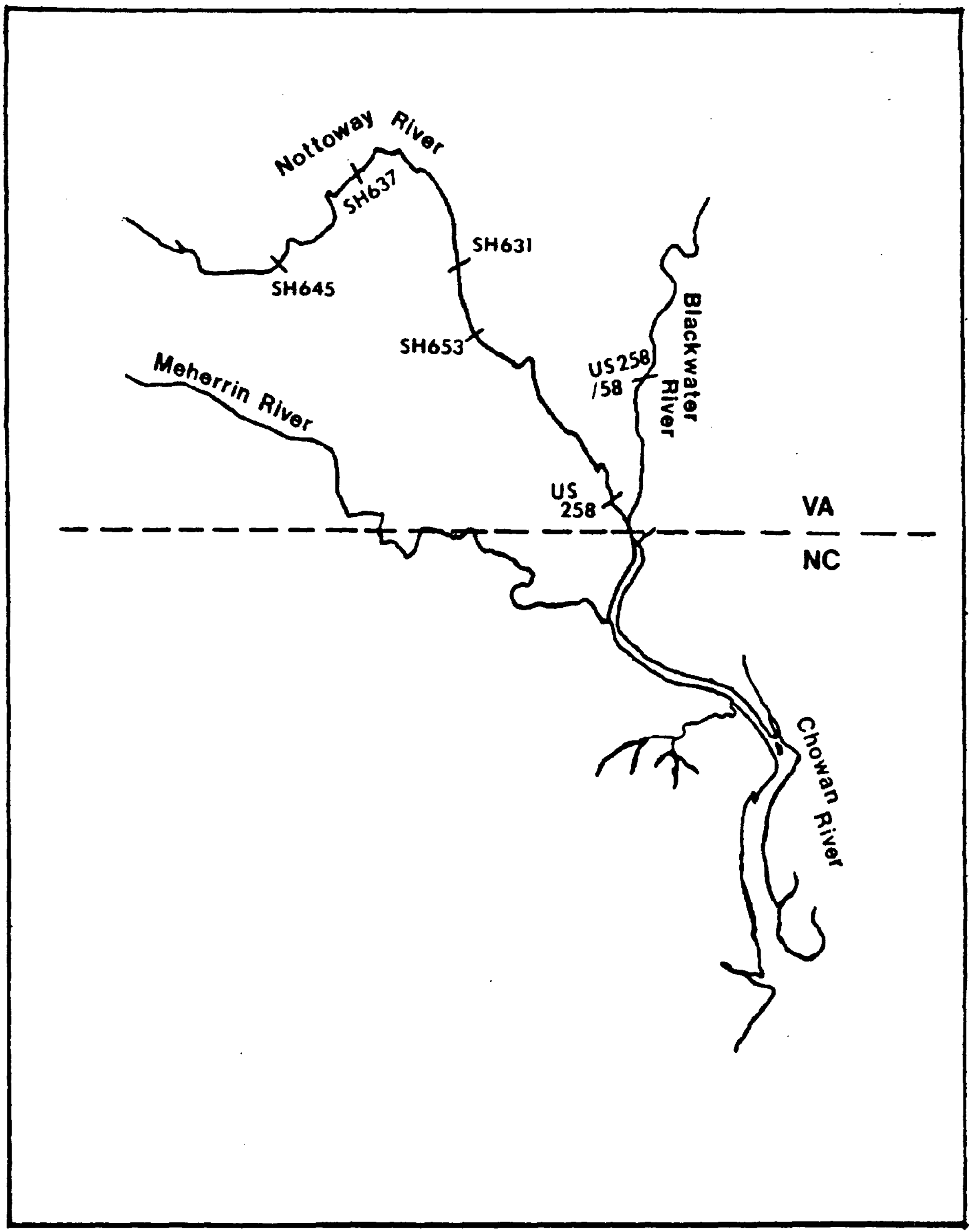


Figure 2. Nottoway River, Blackwater River, and Meherrin River, Virginia.

MATERIAL 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 Meherrin, River (North Carolina and Virginia, and the Blackwater, and Nottoway Rivers, Virginia. All are tributaries of Chowan River.

Monofilament gill nets from 1.52 m (5 ft) - 9.14 m (30 ft) long with stretched mesh ranging from 63.5 mm (2.5 in) to 82.5 mm (3.25 in) were fished in tributaries of the Chowan River (North Carolina portions) during 1983 to determine distribution of adult anadromous fishes. Nets were set for up to 24-hour periods. Captured adult river herring were identified, counted, measured, examined for spawning condition, and scale samples were taken for aging. 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 1983 and 1984 with a 0.5 m plankton net of #00 Nitex mesh with a wide mouth 0.95 jar attached to the cod end. Plankton net samples were taken from bridges and boats, with sample time ranging from 5-15 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.

Albemarle Sound - Nursery Area Survey

In the western Albemarle Sound area, approximately 34 previously established stations were sampled monthly during June-August, October 1983 and June 1984, using a wing trawl, (23 samples) or a seine (11 samples) (Figure 3). During September 1983, 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 4). In July 1984, the number of stations sampled monthly (July-August and October) was reduced to 11 seine stations, previously established. Trawl stations were dropped because the index of relative abundance is determined from seine samples. During September 1984, an additional 15 seine stations were sampled (Figure 4).

The seine stations were sampled with an 18.3 m (60 ft) bag seine with a 6.3 mm (1/4 in) mesh bag. One seine haul was considered one unit-of-effort. All trawl stations were sampled with a 7.9 m (26 ft) head rope wing trawl containing webbing which ranged from 101.6 mm (4 in) stretched mesh in the wings to an 0.125 mm (1/8 in) mesh tail bag (Street et al. 1975). The wing trawl was pulled for 10 min at 1800 revolutions per minute (rpm) by a 5.2 m (17 ft) boat equipped with a 115 horsepower outboard engine or a 7.9 m (26 ft) twin 130 horsepower inboard engine boat at 1000 rpm.

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 Nursery Area Survey

In the Currituck Sound area, 23 previously established stations (18 trawl and 5 seine), were sampled monthly during June-October 1983 (Figure 5). Six

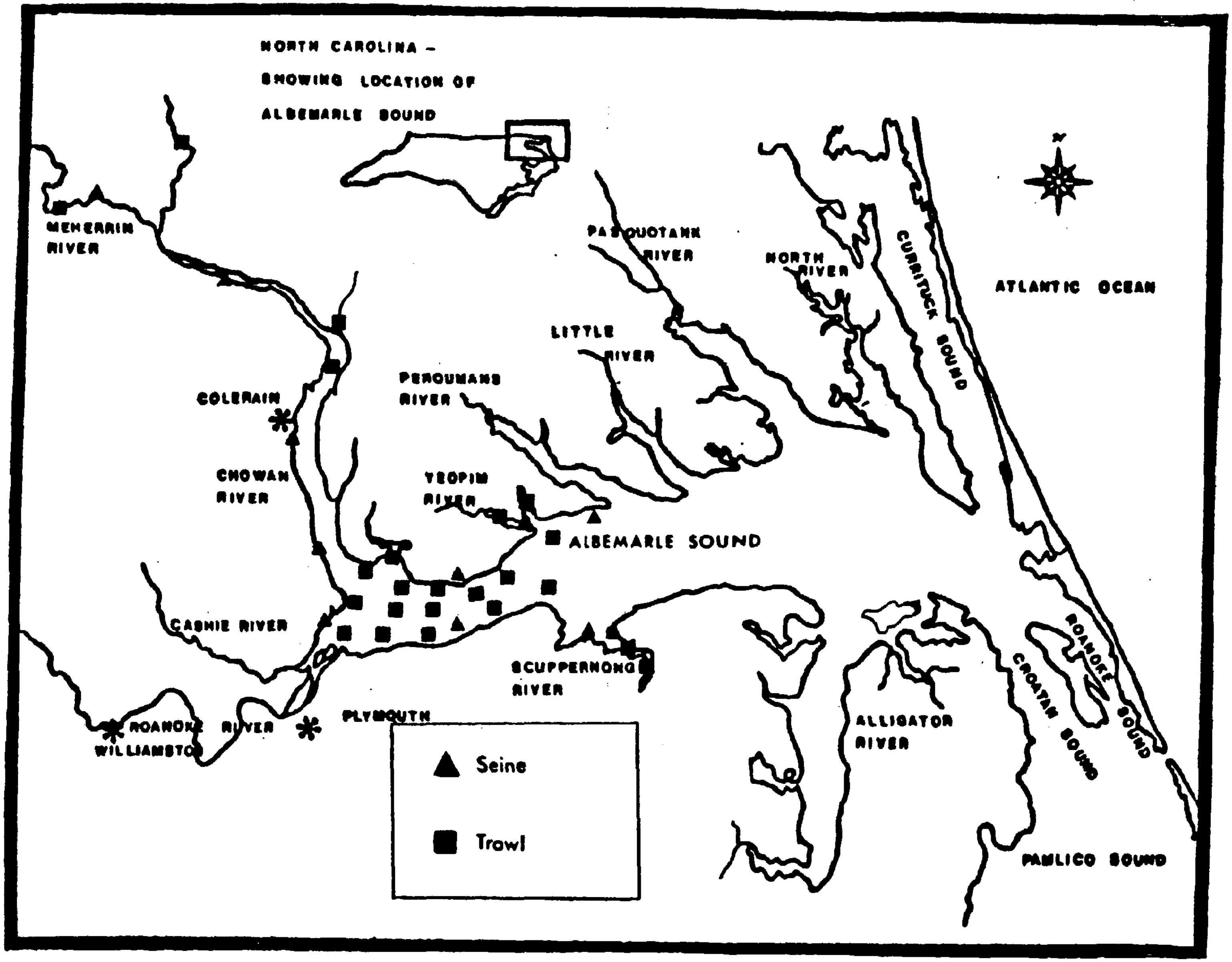


Figure 3. Nursery area sampling sites in the Albemarle Sound area, N. C., during June - October. (Only seine stations sampled July - October 1984.)

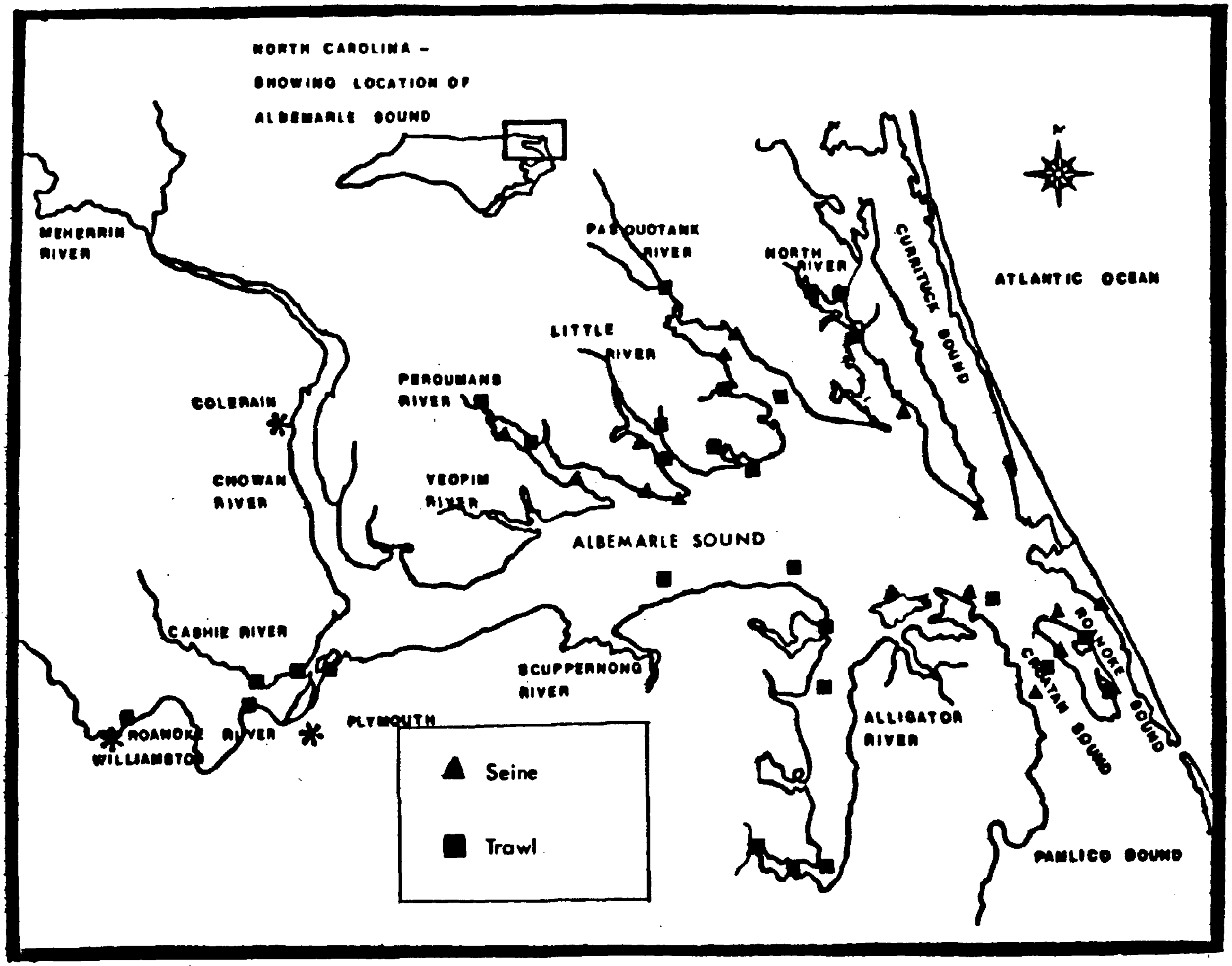


Figure 4. Nursery area sampling sites in Albemarle Sound area, N. C., during September. (Only seine stations sampled in 1984.)

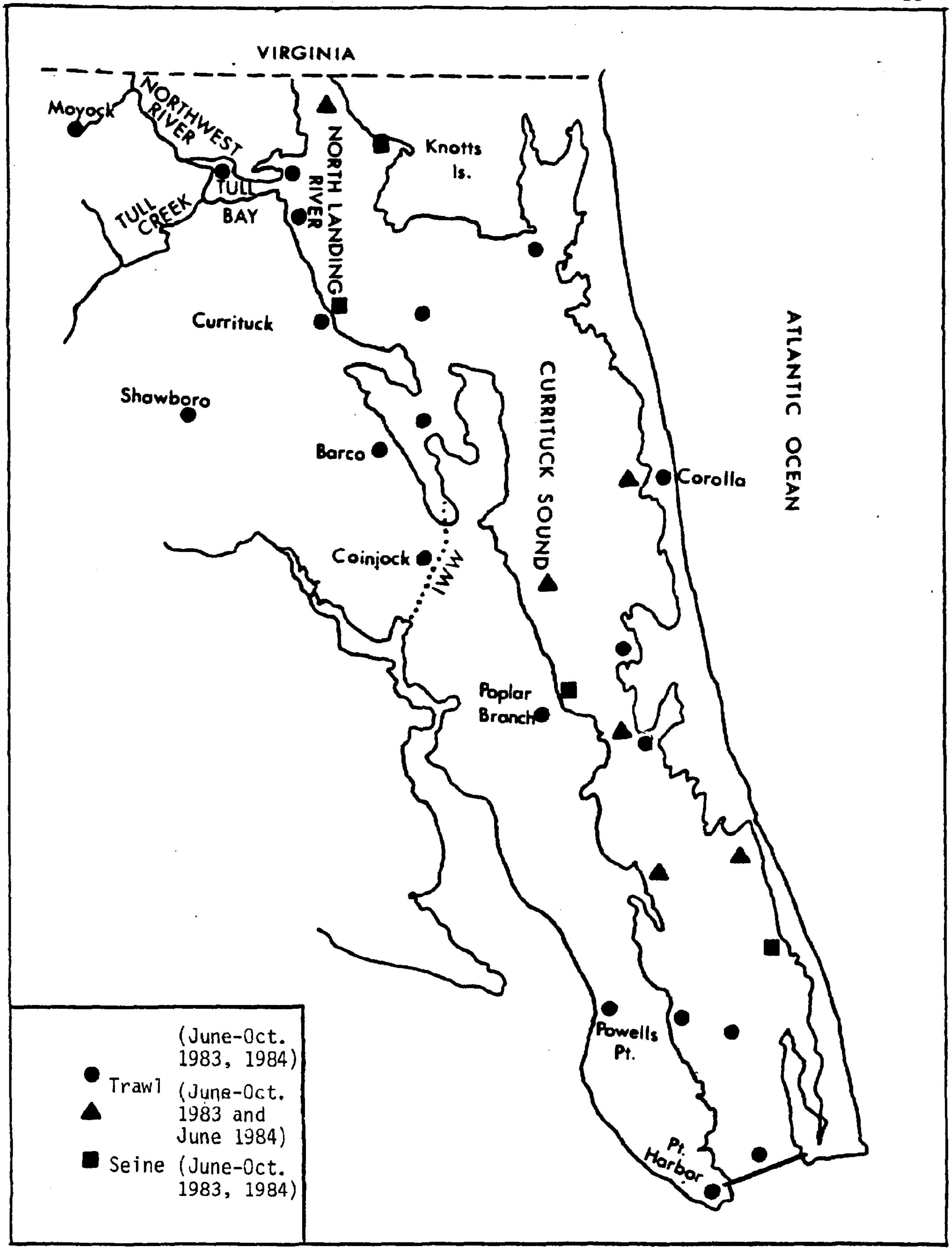


Figure 5. Nursery area sampling sites in Currituck Sound area, N. C., (IWW = Atlantic Intracoastal Waterway).

trawl stations in the southern end of the sound were also sampled monthly during March-May 1983. During 1984, the number of trawl stations sampled monthly (June-October) was reduced to 12, but the 5 seine stations were continued (Figure 5).

Sampling gear consisted of (1) a 6.1 m (20 ft) two-seam flat trawl with 19.2 mm (3/4 in) bar mesh in the body and 6.3 mm (1/4 in) bar mesh in the tail bag, and (2) an 18.3 m (60 ft) bag seine with a 6.3 mm (1/4 in) mesh bag. The flat trawl was towed for 5 min at 1500 revolutions per minute (rpm) by a 5.2 m (17 ft) boat equipped with a 115 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. Salinity sampling continued in the Currituck Sound area through 1983, as described by Winslow et al. (1983) (Figure 6).

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 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 conducted in conjunction with the North Carolina/National Marine Fisheries Service Cooperative Statistics Program.

Each Chowan River blueback herring or alewife for which age, sex, and weight data were available was placed in the appropriate year class for each week sampled during 1983 and 1984. The number of individuals of each year

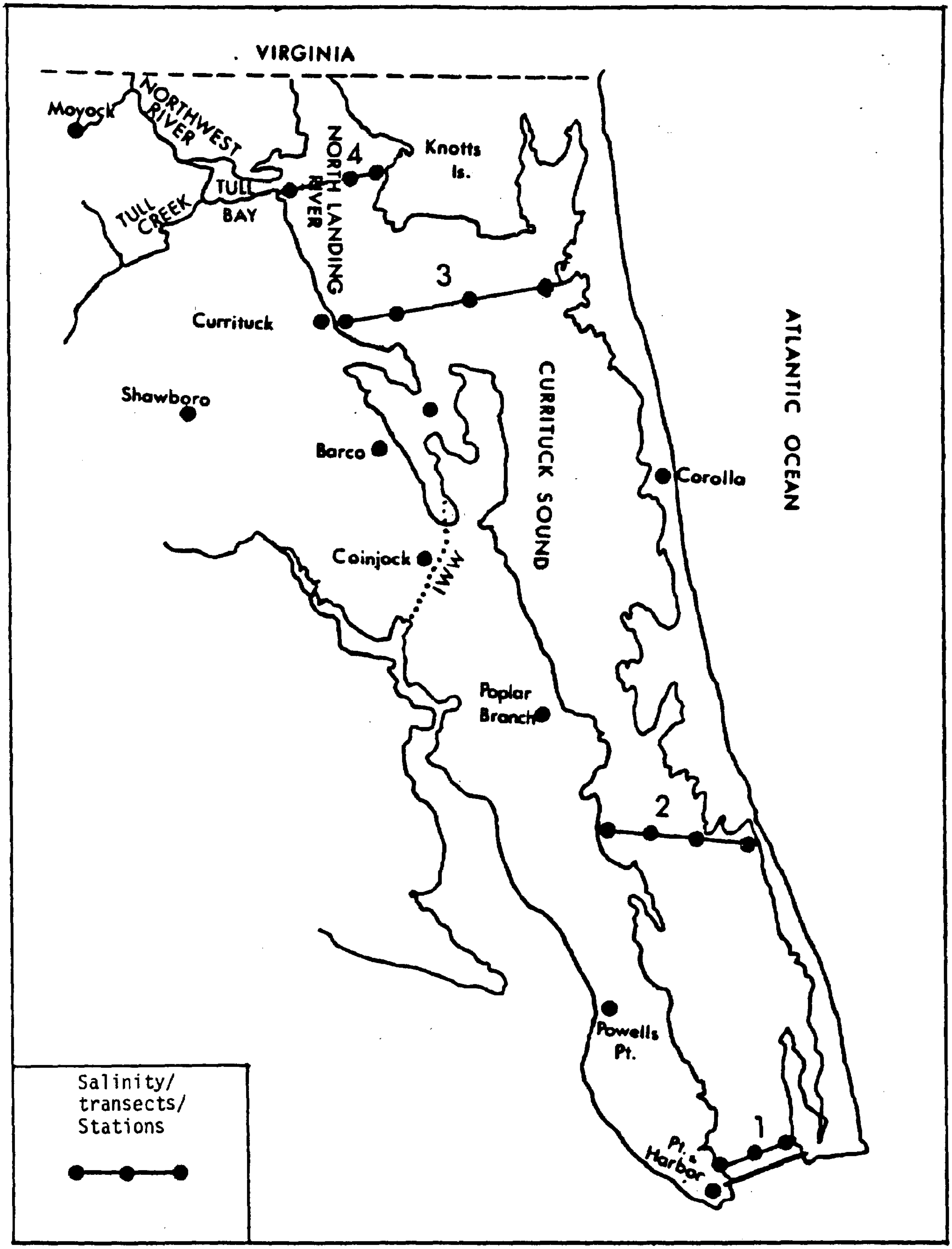


Figure 6. Currituck Sound, N. C., salinity transects
(IWW = Atlantic Intracoastal Waterway).

class was followed weekly through the sampling period. Each species was separated by sex, and weekly mean weight (kg) and percent number and weight (kg) by year class were calculated. The total river herring harvest (pounds) for each week was multiplied by the percent weight (kg) of a year class during that week and divided by the mean weight (kg) of individuals of each sex of that year class for each species, resulting in the number of individuals from each year class.

Adult Sampling

Commercial harvest sampling sites were the same as those reported by Winslow et al. (1983). Data collected at these sites (Figure 7) were assumed to be representative of 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 aging.

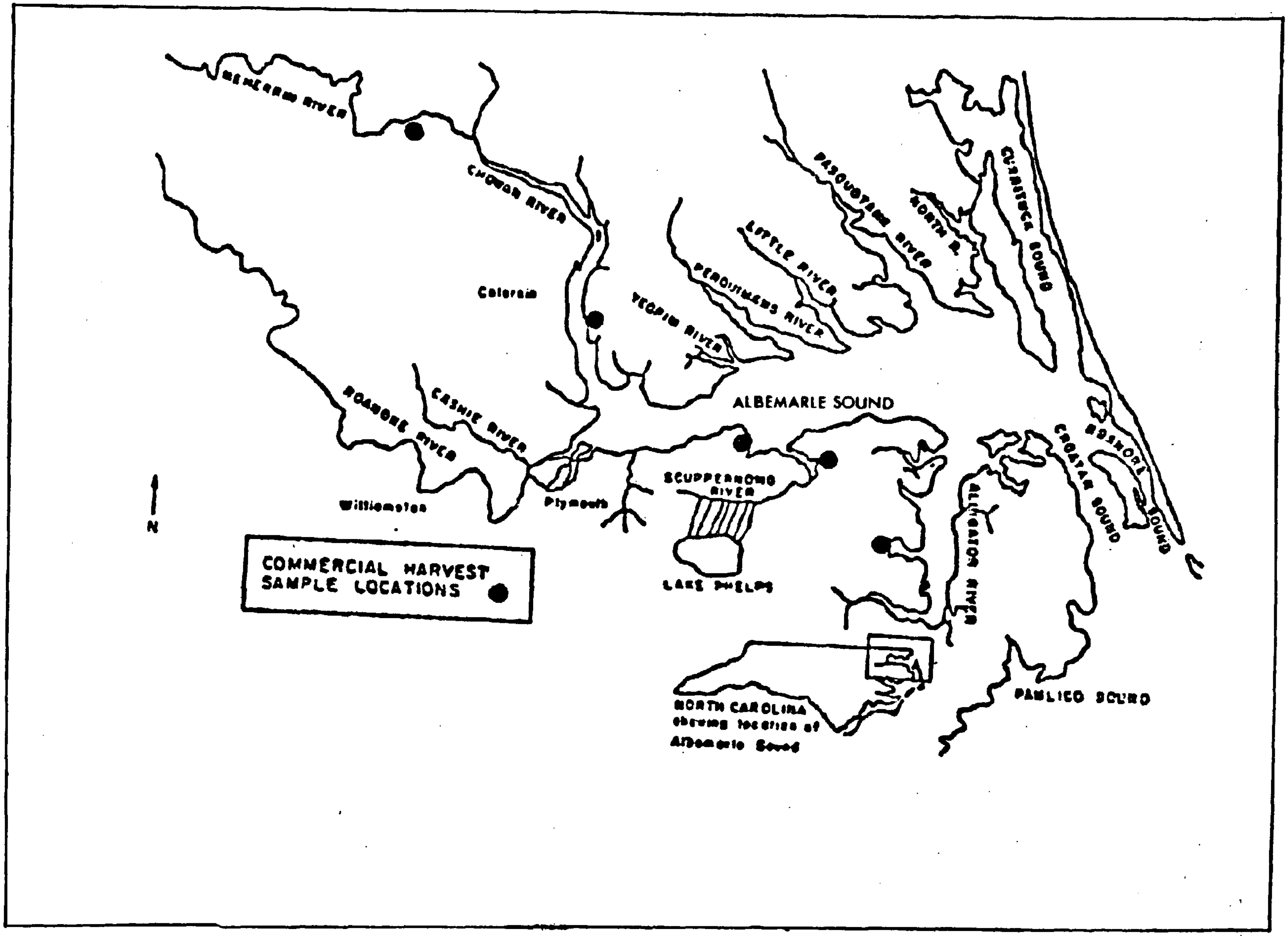


Figure 7. Location of Albemarle Sound, North Carolina commercial harvest sampling sites.

Due to the large number of alosid scale samples taken and the time-consuming process of aging, stratified subsampling for aging was used during this 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.

American Shad Report

Data collected on American shad from 1972-1983 in the Albemarle Sound area was to be analyzed and a report written. Due to the number of errors in coding historic data and errors in past aging, this report will be completed under the new anadromous fish project (AFC-27).

RESULTS AND DISCUSSION

Spawning Area Survey

Chowan River and Tributaries

Locations and times of anadromous fish spawning were determined for the North Carolina portion of the Chowan River and its tributaries during 1983. Table 3 shows the dates of capture, location, number and species of running-ripe females taken by gill nets. The relationship of temperature and time to capture of eggs and larvae are shown in Figure 8. Tables 4 and 5 show the number and general locations of capture of alosid eggs and larvae in the study area. Figure 9 shows the approximate spawning areas of alewife and blueback herring in the Chowan River area as shown by observation of running-ripe females. The approximate spawning area locations for river herring as

Table 3. Observation of running-ripe female river herring in the Chowan River and its tributaries during 1983.

Date	Location	Number of fish	Species
4/06/83	Bennetts Creek - N.C. Highway 37	4	Blueback
4/06/83	Salmon Creek - U.S. Highway 17	3	Blueback
4/06/83	Wiccacon River - N.C. Highway 45	3	Blueback
4/07/83	Dillard Creek - SSR* 1226	1	Alewife
4/07/83	Salmon Creek - U.S. Highway 17	1	Blueback
4/26/83	Dillard Creek - SSR 1226	1	Blueback

*SSR: State Secondary Road

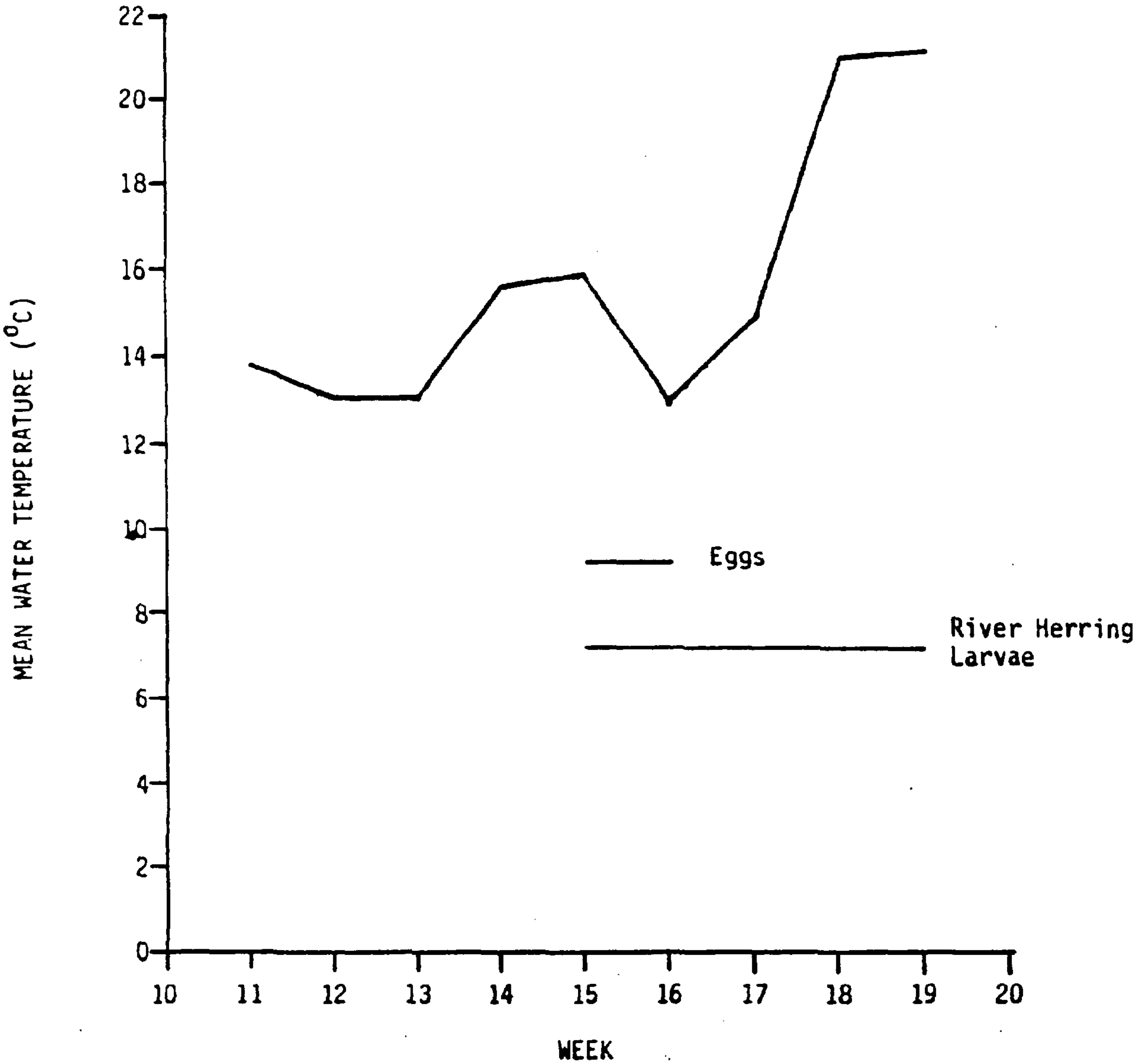


Figure 8. Spawning times and temperatures associated with the capture of river herring eggs and larvae in the Chowan River area, North Carolina, 1983.

Table 4. River herring eggs collected by egg net in Chowan River and its tributaries, 1983.

Date	Location	Number of eggs
4/11/83	Dillard Creek - SSR* 1226	20
4/12/83	Wiccacon River - N.C. Highway 45	100
4/12/83	Dillard Creek - SSR 1226	6
4/13/83	Wiccacon River - N.C. Highway 45	10
4/13/83	Dillard Creek - SSR 1226	84
4/14/83	Trotman Creek - SSR 1100	1
4/18/83	Dillard Creek - SSR 1226	2

*SSR: State Secondary Road

Table 5. River herring larvae collected by egg net in Chowan River and its tributaries, 1983.

Date	Location	Number of larvae
4/11/83	Rockyhock Creek - SSR* 1222	7
4/13/83	Wiccacon River - N.C. Highway 45	3
5/10/83	Island Creek	72
5/10/83	Wiccacon River - N.C. Highway 45	82
5/10/83	Barnes Creek	101
5/10/83	Sarem Creek	246

*SSR: State Secondary Road

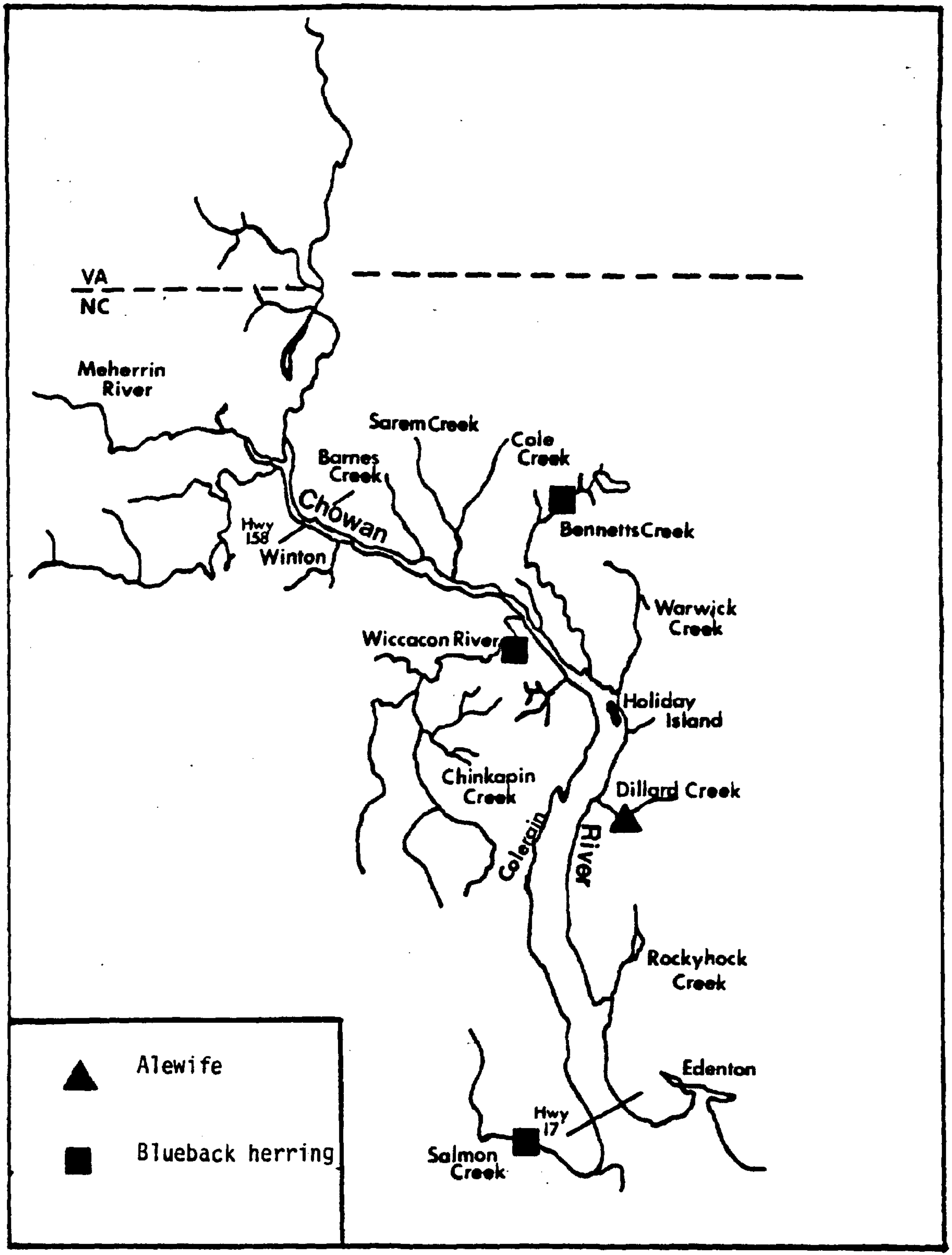


Figure 9. Spawning areas of alewife and blueback herring in Chowan River area, N. C., as shown by observation of running-ripe females during 1983.

indicated by the capture of eggs and larvae are shown in Figure 10. These spawning areas closely agree with those reported by Street et al. (1975) and Johnson et al. (1981) for the Chowan River and its tributaries during 1973 and 1979, respectively.

Scale samples taken from 109 blueback herring and 12 alewife, captured in gill nets during the spawning area survey, were aged. The age and spawning frequency by species is presented in Table 6, for combined locations. Of the blueback herring, 41.3% were virgins, and they ranged in age from 3 to 5 years old. Virgin fish comprised 59.7% of the alewife sampled; ages ranged from 3 to 5 years old. Age and spawning frequency of blueback herring and alewife are shown by location in the Appendix (Appendix Tables 1-7).

Blackwater River and Nottoway River

Locations and times of American shad spawning were determined for the Blackwater River and Nottoway River, Virginia (tributaries of Chowan River) during May 1984. Egg net samples were taken from bridges and/or boats. Figure 11 shows the relationship between mean weekly water temperature and the capture of American shad eggs and larvae. Tables 7 and 8 show the number and general locations of capture of American shad eggs and larvae or the observation of spawning. American shad were observed spawning in the Nottoway River; these areas are shown in Figure 12. Figure 13 shows the approximate spawning areas of American shad in the Blackwater River and Nottoway River areas, Virginia, as evidenced by capture of eggs and/or larvae. These American shad spawning areas closely agree with those reported by Street et al. (1975) for 1973. No American shad eggs or larvae were captured from the Meherrin River area during the 1984 sampling period. However, Winslow, et al. (1983) documented American shad spawning in the Meherrin River during 1980, as evidenced by capture of eggs and larvae.

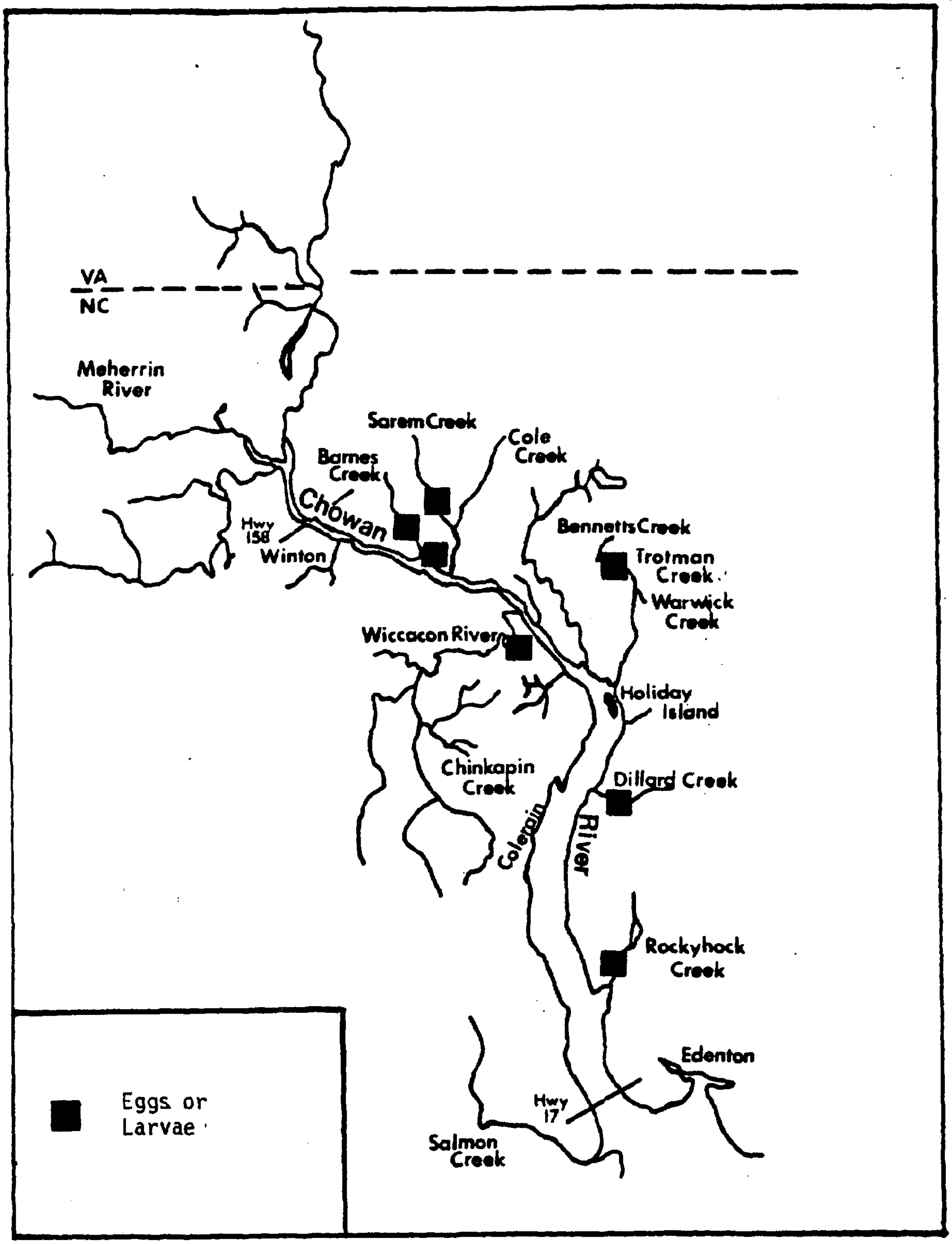


Figure 10. Spawning areas of river herring in Chowan River area, N. C., as shown by capture of river herring eggs and larvae during 1983.

Table 6. Age and spawning frequency of blueback herring and alewife captured by gill nets, during Chowan River spawning area survey, 1983

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	2	0							2	0
IV	23	16							23	16
V	1	3	27	11					28	14
VI			7	5	4	4			11	9
VII					1	2	0	3	1	5
TOTAL	26	19	34	16	5	6	0	3	65	44
Percent by sex	40.0	43.2	52.3	36.4	7.7	13.6	0	6.8		
Percent of sexes combined	41.3		45.9		10.1		2.7			

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	1	0							1	0
IV	26	6							26	6
V	7	3	17	5					24	8
VI			5	1	0	1			5	2
VII										
TOTAL	34	9	22	6	0	1			56	16
Percent by sex	60.7	56.3	39.3	37.5	0	6.2				
Percent of sexes combined	59.7		39.0		1.3					

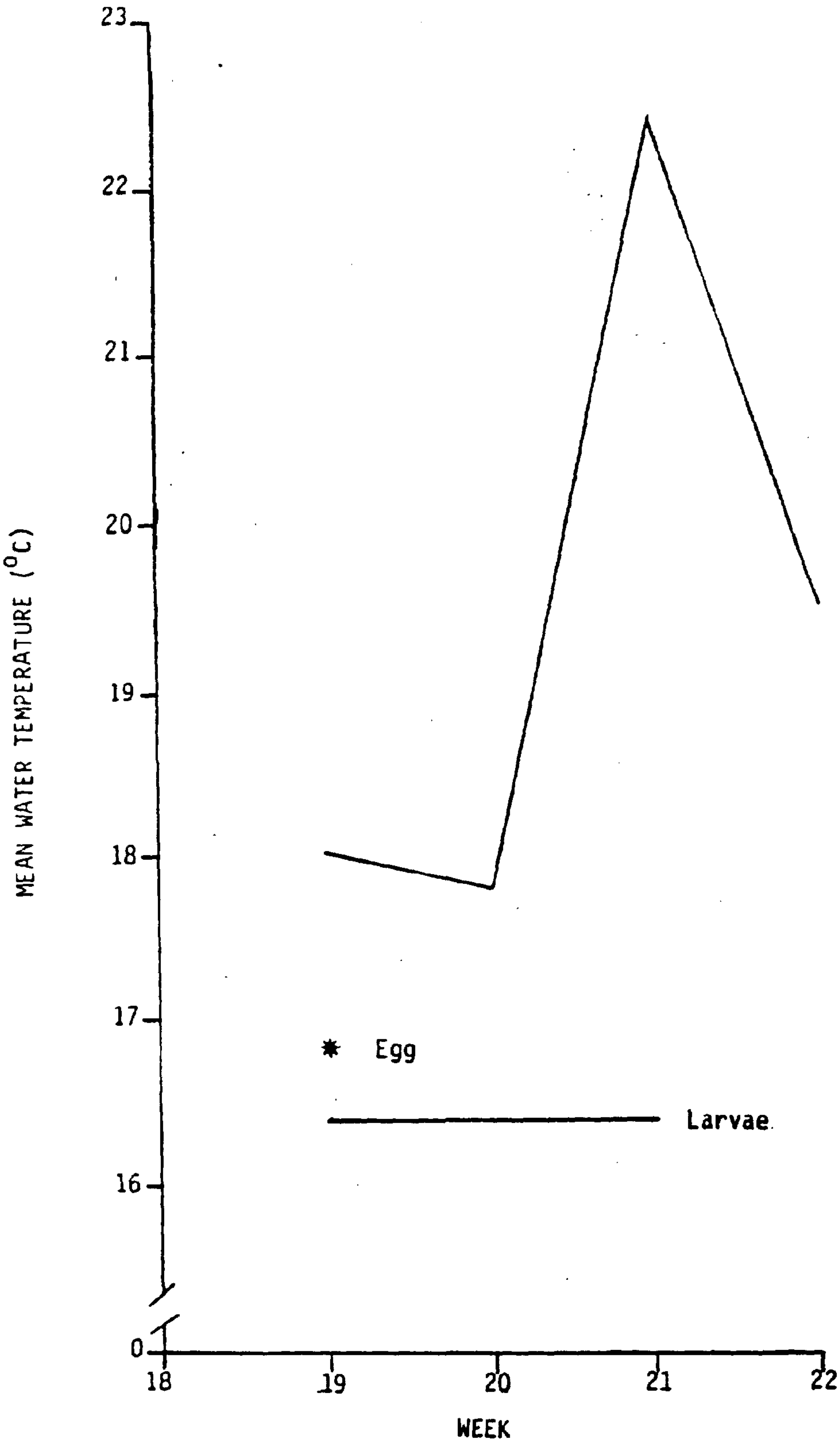


Figure 11. Spawning times and temperatures associated with the capture of American shad eggs and larvae in the Blackwater and Nottoway Rivers, Virginia, 1984.

Table 7. American shad egg collected by egg net sampling in Nottoway River area, Virginia, 1984.

Date	Location	Number of eggs
5/10/84	Nottoway River - Virginia Highway 653	1

Table 8. American shad observed spawning and/or larvae collected by egg net in Blackwater River and Nottoway River areas, Virginia, in 1984.

Date	Location	Number of eggs or spawning observed
5/10/85	Blackwater River - U.S. Highway 258/58	1
5/17/84	Nottoway River - Virginia Highway 631	1
5/22/84	Blackwater River - 5 mi. above mouth	3
5/22/84	Nottoway River - Virginia Highway 637	10
5/22/84	Nottoway River - U.S. Highway 258	2
		Spawning observed
5/22/84	Nottoway River - Virginia Highway 645	Spawning observed
5/22/84	Nottoway River - Virginia Highway 631	Spawning observed
5/22/84	Blackwater River - 400 yds. from mouth	1
5/22/84	Nottoway River - 400 yds. from mouth	2
5/22/84	Nottoway River - 2 mi. above U.S. Highway 258 bridge	2

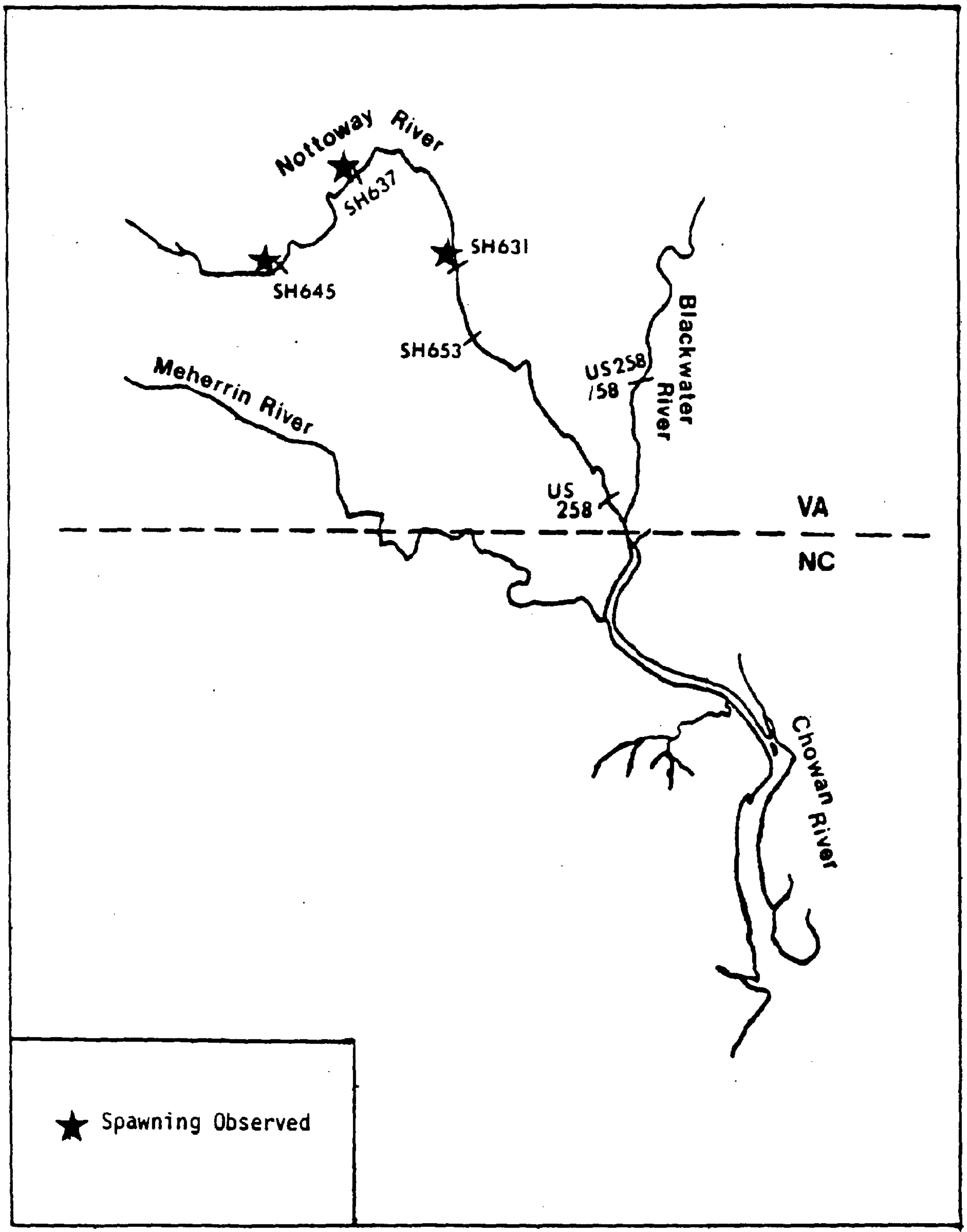


Figure 12. Spawning areas of American shad in Blackwater River and Nottoway River, Virginia, by observation of spawning, 1984.

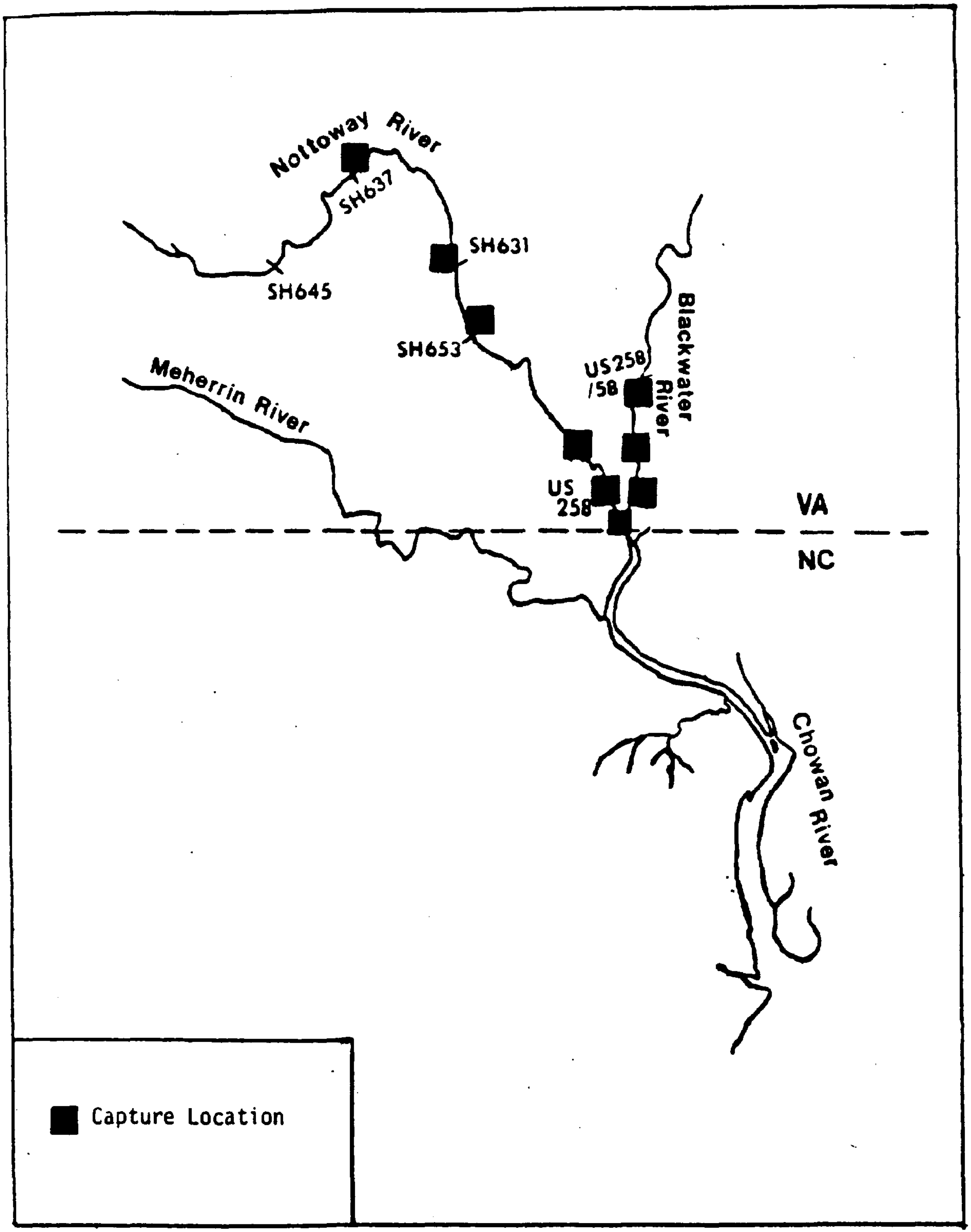


Figure 13. Spawning areas of American shad in the Blackwater River and Nottoway River, Virginia, as shown by capture of eggs and/or larvae, 1984.

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

Nursery Area Survey

Albemarle Sound Area

During June 1983 - October 1984, a total of 15,643 juvenile anadromous fishes were captured in 307 samples in the Albemarle Sound area. The main purpose of sampling was to determine relative abundance of the 1983 and 1984 year classes. Numbers of samples taken by each sampling gear for each year are shown in Table 9. Since so few American shad and hickory shad were taken (14 and 2, respectively), these species will not be considered further in the discussion. Winslow et al. (1983) described several possible reasons why these juveniles are not captured during the sampling period.

As reported by Street et al. (1975), Johnson et al. (1981), and Winslow et al. (1983), the seine proved to be the most effective gear for the capture of juvenile blueback herring during 1983 and 1984. The mean catch-per-unit-of-effort (CPUE) by month for blueback herring, for seine and trawl, is shown in Figure 14.

The seine and wing trawl, during 1983, were found to be basically equal for capture of juvenile alewife. In 1984, the wing trawl, as Street et al. (1975) and Johnson et al. (1981) found, again proved to be the most effective gear for alewife even though trawl samples were taken during only one month (Figure 15).

Nursery Areas

Nursery areas of blueback herring and alewife generally coincided with each other. Again, nursery areas identified during 1972-1976 continued to

Table 9. Number of samples, catch, and catch/effort of juvenile anadromous fishes by trawl and seine in the Albemarle Sound area, North Carolina, 1983 and 1984.

1983

Species	Trawl 145 samples		Seine 69 samples	
	Number	C/E	Number	C/E
Blueback herring	1,429	9.8	12,586	182.4
Alewife	225	1.5	114	1.6
American shad	5	0.03	1	0.01
Hickory shad	2	0.01	0	0
Striped bass	33	0.23	55	0.80
Total	1,694		12,756	

1984

Species	Trawl* 23 samples		Seine 70 samples	
	Number	C/E	Number	C/E
Blueback herring	59	2.6	1,038	14.8
Alewife	50	2.2	38	0.5
American shad	0	0	8	0.1
Hickory shad	0	0	0	0
Striped bass	0	0	0	0
Total	109		1,084	

*Trawl samples were taken only during June 1984.

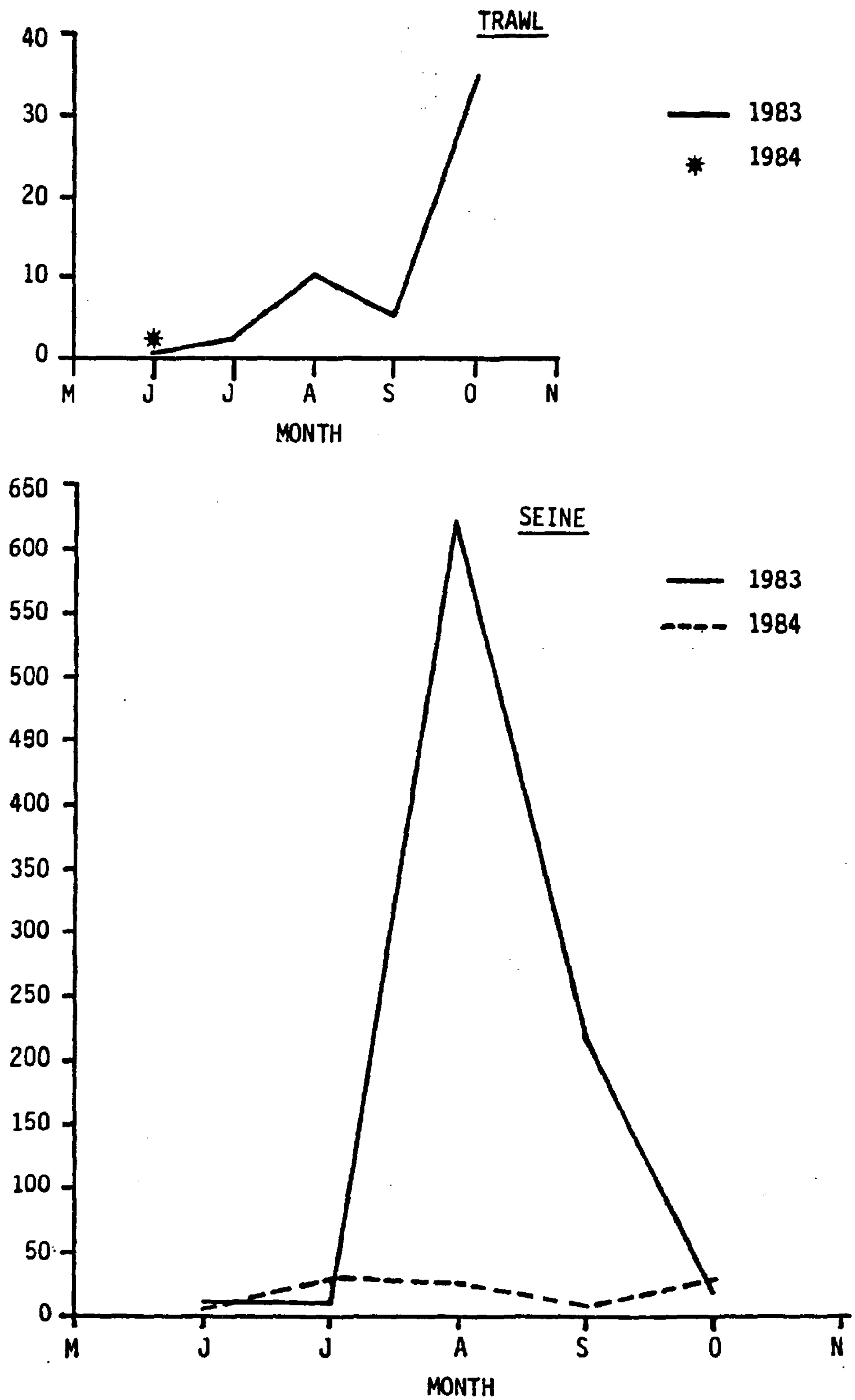


Figure 14. Monthly mean catch-per-unit-of-effort for blueback herring by trawl and seine in the Albemarle Sound area, N. C., 1983-1984

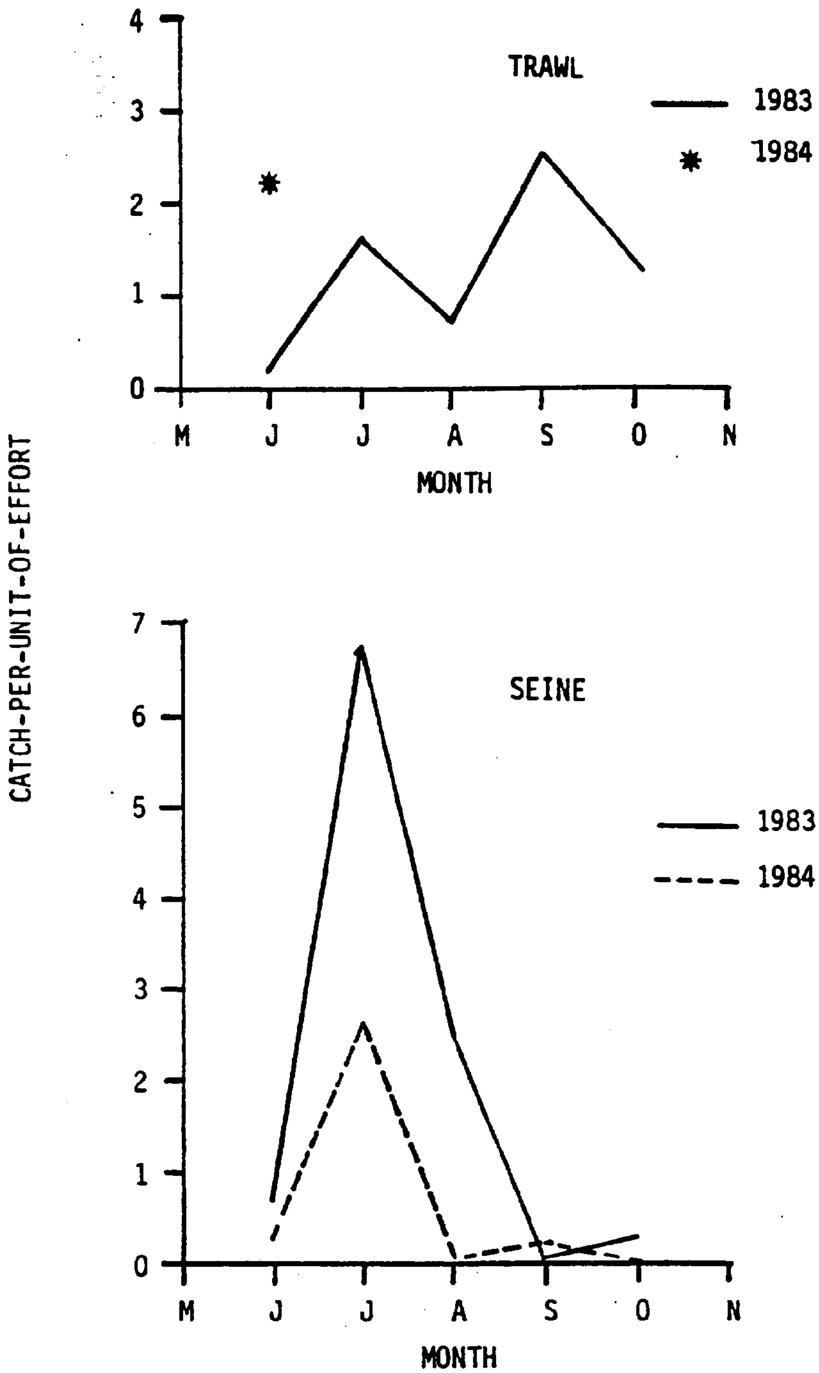


Figure 15. Monthly mean catch-per-unit-of-effort for alewife by trawl and seine in the Albemarle Sound area, N. C., 1983-1984.

yield large numbers of young anadromous fishes (Street et al. 1975, Johnson et al. 1977). Figure 16 shows nursery areas in the Albemarle Sound area. As Street et al. (1975) stated, these nursery areas are vitally important for the maintenance of river herring populations and should remain unaltered and protected from pollution.

Growth

During this project, the 1983 and 1984 year classes of blueback herring and alewife were followed during June - October of each year for growth. Figure 17 shows the mean fork length of juvenile blueback herring and alewife for each month of sampling for each year. These data generally agree with that reported by Street et al.(1975), Johnson et al. (1977, 1981) and Winslow et al. (1983). The mean fork lengths of juvenile blueback herring and alewife are shown for the month of October during 1972-1984 in Figure 18. As reported by Winslow et al. (1983), mean lengths compared with the relative abundance index of juveniles for those years (Figure 19) suggest that growth may be density dependent.

Movement

The movements of the 1983 and 1984 year classes of blueback herring and alewife were virtually the same as those reported by Street et al. (1975), Johnson et al. (1977, 1981), and Winslow et al. (1983).

Relative Abundance

Sampling with seines and trawls, which Street et al. (1975) proved effective, was again used in order to compare results from different samples taken with the same gear. Such data should show changes in juvenile abundance from year to year.

Relative abundance data have been collected on thirteen year classes (1972-1984) of blueback herring and alewife. For comparative purposes, data

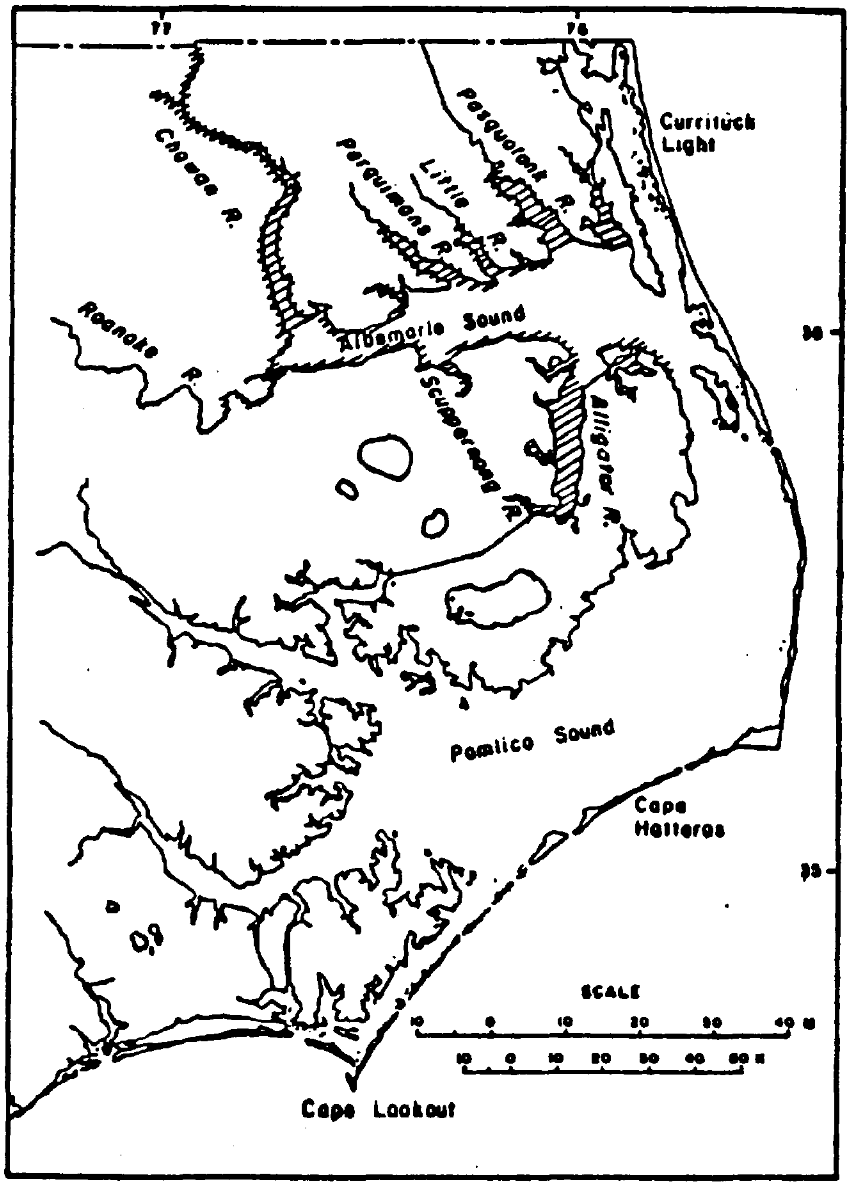


Figure 16. Nursery areas of blueback herring and alewife in Albemarle Sound and tributaries, North Carolina.

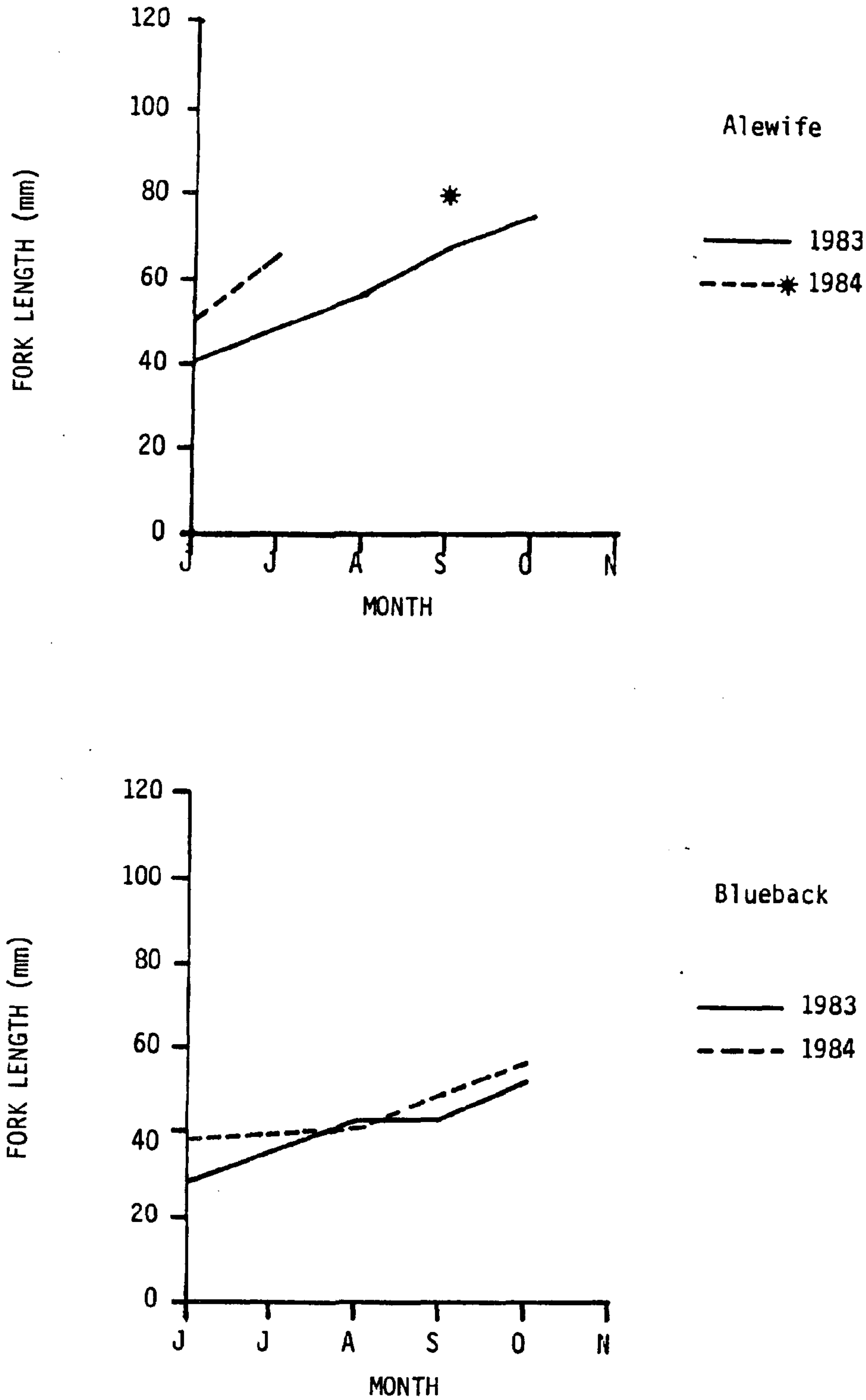


Figure 17. Mean fork length of blueback and alewife by month during 1983-1984.

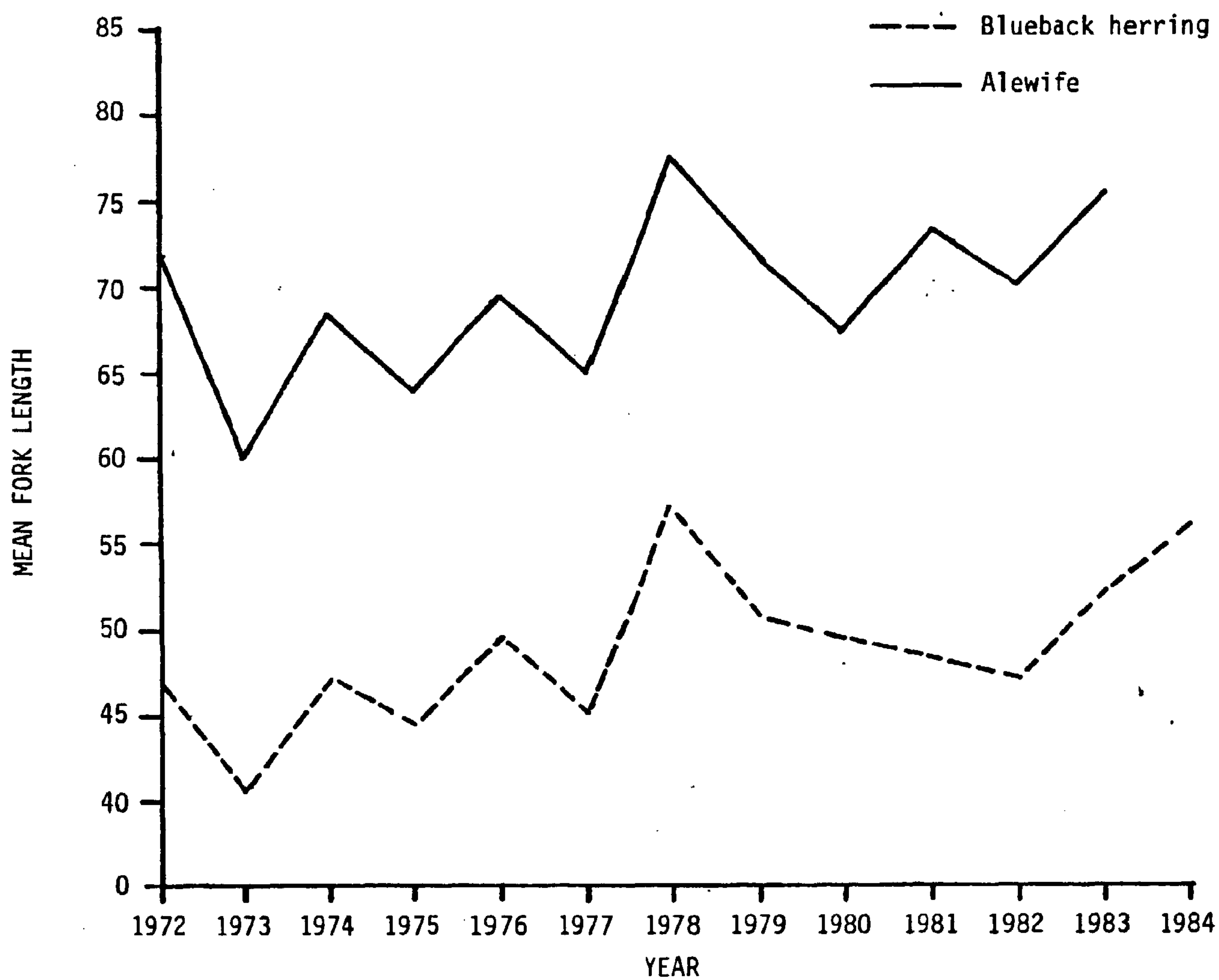


Figure 18. Mean fork length (mm) of juvenile blueback herring and alewife sampled during October of 1972-1984 from the Albemarle Sound area, North Carolina. (No alewife captured during October 1984.)

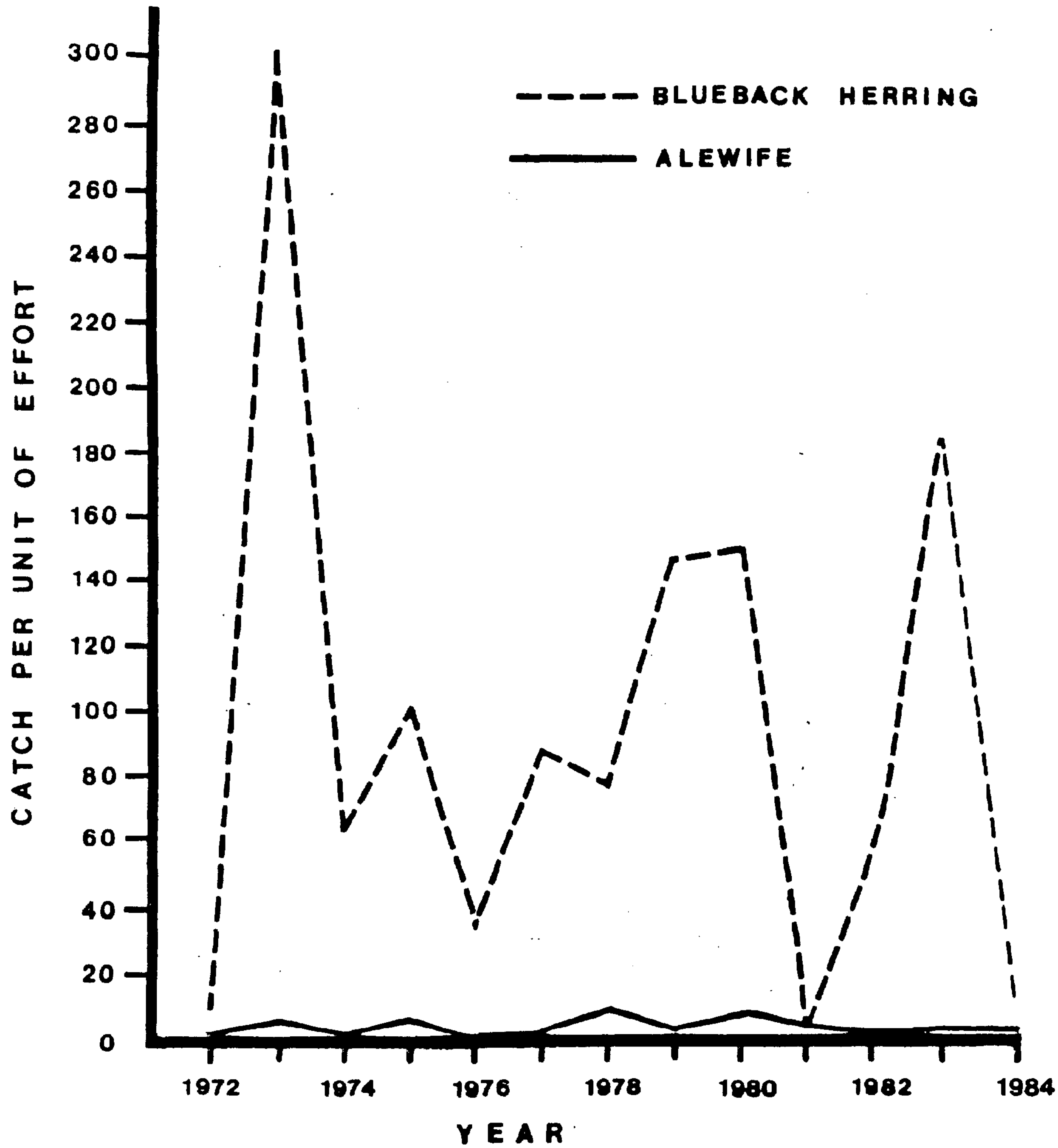


Figure 19. Catch-per-unit-of-effort by seine for blueback herring and alewife 1972-1984 year classes, from Albemarle Sound area, North Carolina.

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) and Johnson et al. (1977, 1981) reported that blueback herring were far more numerous than alewife, and this trend continued in 1983 and 1984. Figure 19 shows the CPUE using data from the monthly seine stations during 1972-1984. The 1983 year class strength for blueback herring was the greatest since 1973, while the 1984 year class was between that of 1972 and 1976.

The CPUE for alewife in the 1983 year class (1.6) was greater than that found in 1982. However, in 1984 the year class strength (0.5) was comparable to that of the 1974, 1976, and 1982 year classes.

Currituck Sound Nursery Area Survey

A total of 233 juvenile river herring were captured in 217 samples from the Currituck Sound area during 1983 and 1984. Blueback herring were more abundant than alewife during each year (Table 10).

The trawl proved to be the most effective capture gear for blueback herring (Figure 20), and alewife (Figure 21). This situation was opposite to that reported by Winslow et al. (1983) for 1982.

Nursery Areas

Those areas found to serve as nursery areas for river herring in the Currituck Sound area during this project closely agree with those reported by Winslow et al. (1983) (Figure 22). However, future sampling in the Currituck Sound may delineate additional nursery areas. It must be stressed that those waters designated as nursery areas are critical for the maintenance of anadromous fish and should be protected from unwise alteration and pollution.

Table 10. Number of samples, catch, and catch-effort of juvenile alosids by trawl and seine in the Currituck Sound area, North Carolina, 1983 and 1984.

1983

Species	Trawl 107 samples Number	Trawl 107 samples C/E	Seine 25 samples Number	Seine 25 samples C/E
Blueback herring	172	1.6	38	1.5
Alewife	11	0.10	0	0
Total	183		38	

1984

Species	Trawl* 60 samples Number	Trawl* 60 samples C/E	Seine 25 samples Number	Seine 25 samples C/E
Blueback herring	9	0.15	2	0.08
Alewife	1	0.02	0	0
Total	10		2	

*Monthly trawl samples reduced during 1984.

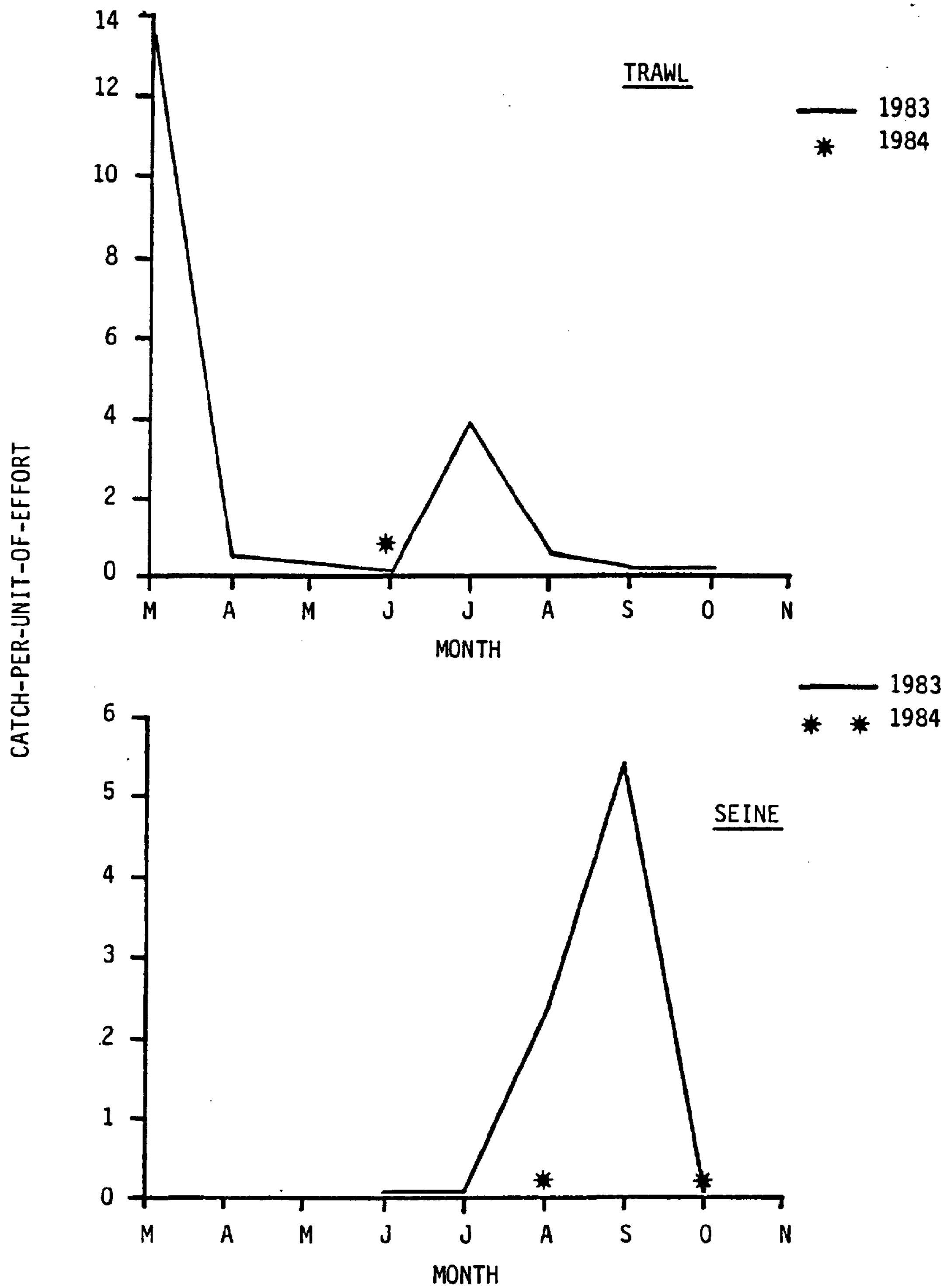


Figure 20. Monthly catch-per-unit-of-effort for blueback herring by trawl and seine in Currituck Sound area, N. C., 1983-1984. (March-May of 1983 only 6 trawl samples per month.)

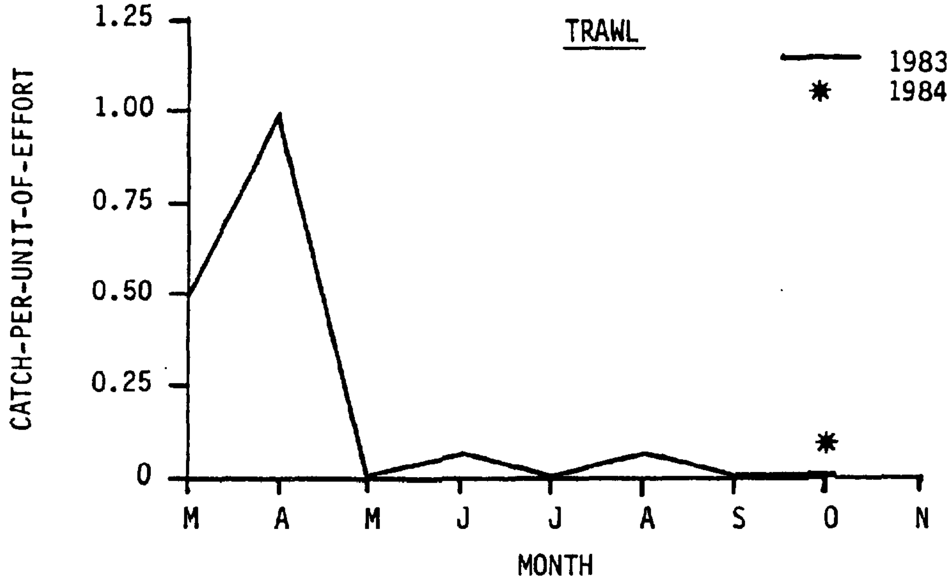


Figure 21. Monthly catch-per-unit-of-effort for alewife by trawl in Currituck Sound area, N. C., 1983-1984. (March-May of 1983 only 6 trawl samples per month.)

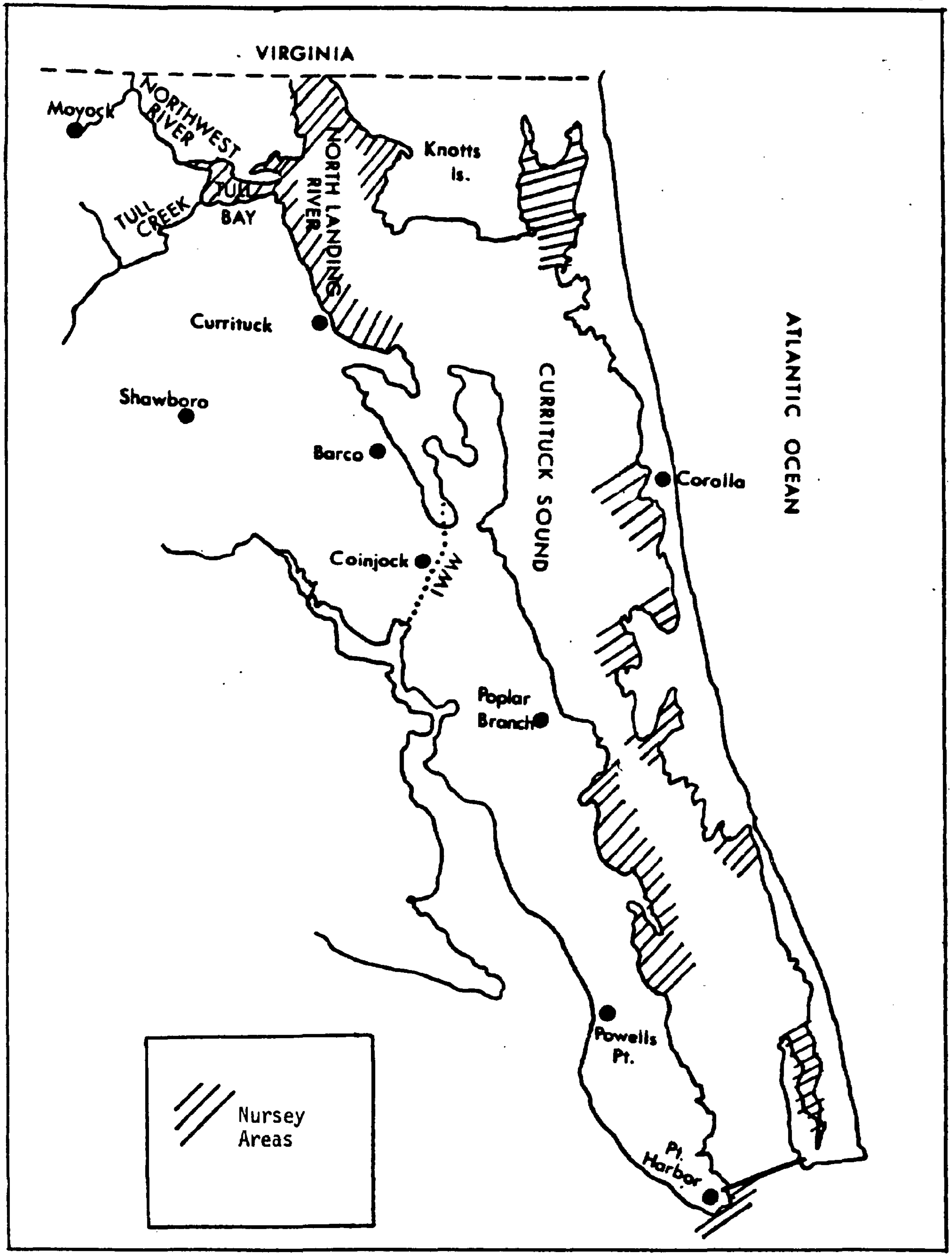


Figure 22. Nursery areas of blueback herring and alewife in Currituck Sound area, N. C. (IWW = Atlantic Intracoastal Waterway).

Growth

Growth of the 1983 and 1984 year classes of blueback herring and alewife from the Currituck Sound area were followed during the project. Figure 23 shows the mean monthly fork length of juvenile blueback herring and alewife. These data generally agree with that found for the Albemarle Sound area during 1983 and 1984.

Movement

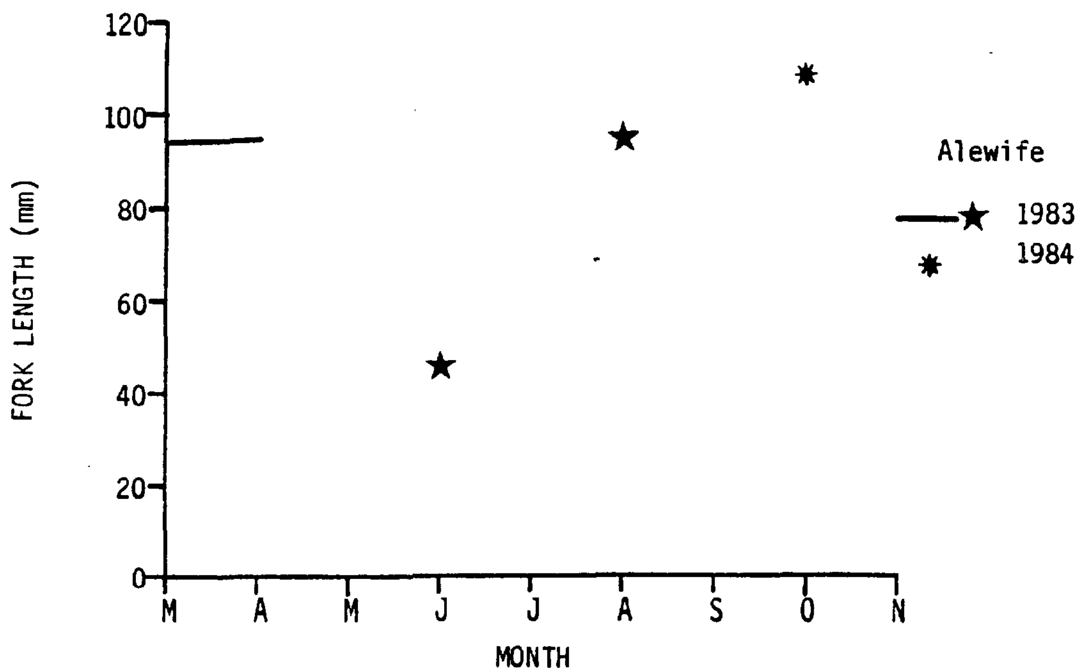
The movements of the 1983 year class of blueback herring and alewife were virtually the same as those reported by Winslow et al. (1983). So few individuals were captured during 1984 that movements could not be defined.

Relative Abundance

The relative abundance of blueback herring from the Currituck Sound area during 1983 (1.5) and 1984 (0.08), with the seine, was lower than that found in 1982. During 1983 and 1984, no juvenile alewife were captured with the seine (Figure 24).

Salinity Sampling

Salinity readings were taken during March - October 1983 at the designated stations. The lower sound stations, closer to Oregon Inlet, had higher salinities. The upper stations, influenced by drainage from North Landing River, Northwest River, and Tull Creek were lower. The eastern and mid-sound stations generally had higher salinities than those to the west. The predominant southerly and southwesterly winds during the summer and early fall months could possibly account for this occurrence by pushing the water toward the east side of the sound. The lack of precipitation is evidenced by the increase in salinity levels during September and October. The mean monthly salinities are shown for each station in Table 11.



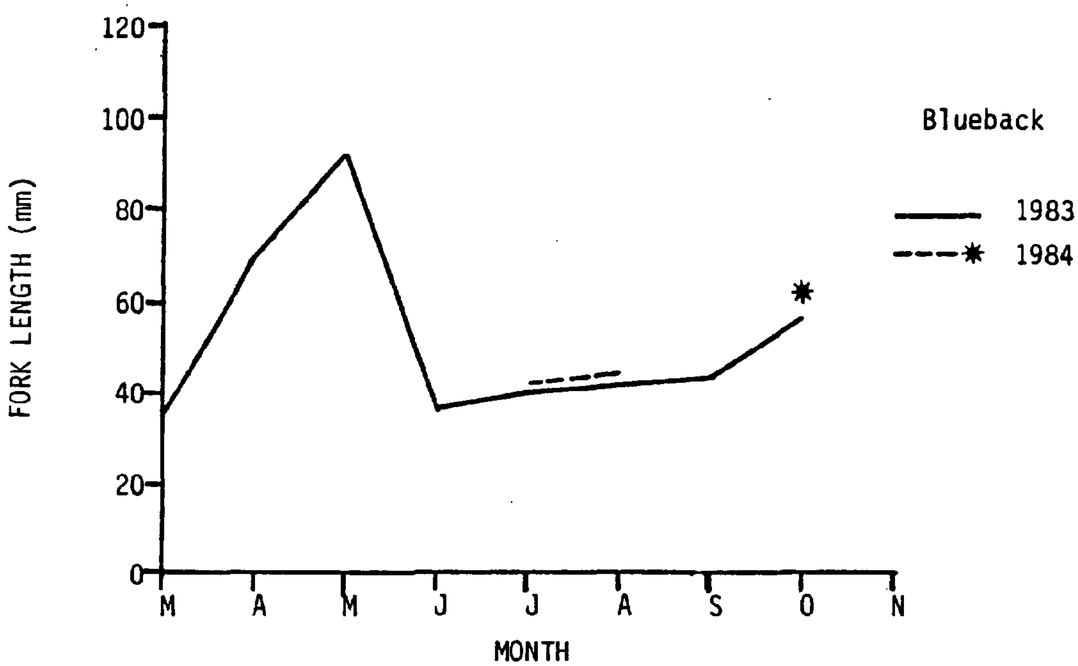


Figure 23. Mean fork lengths of blueback herring and alewife by month for Currituck Sound area, N. C., 1983-1984.

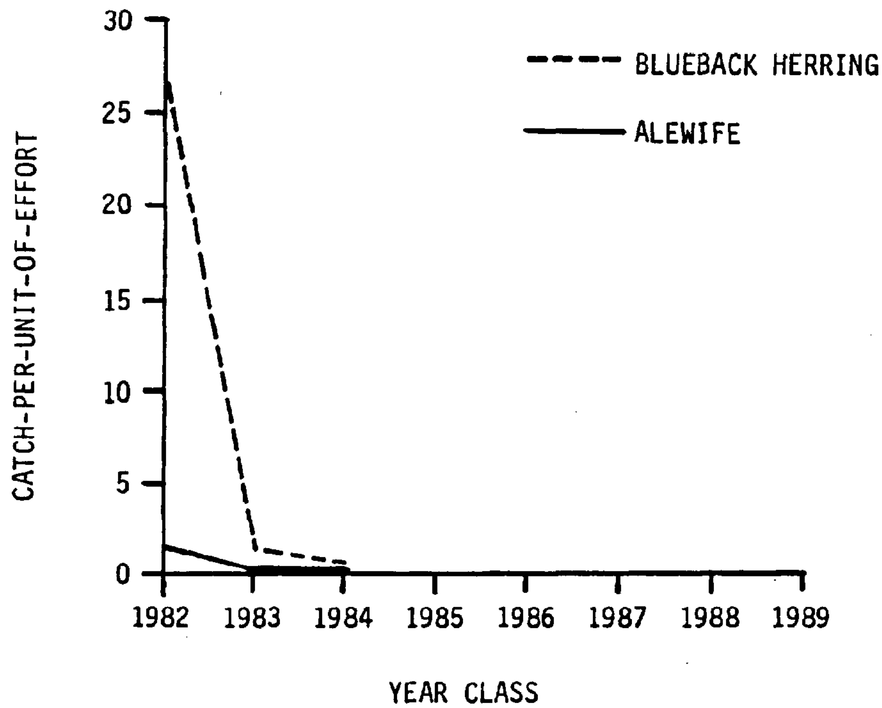


Figure 24. Catch-per-unit-of-effort by seine for blueback herring and alewife, 1982-1984 year classes, for Currituck Sound area, N. C.

Table 11. *Mean monthly salinities from the Currituck Sound area, North Carolina, 1983.*

Month		Transect 1			Transect 2				Transect 3				Transect 4		
		E	MS	W	E	ME	MW	W	E	ME	MW	W	E	M	W
March	Top	0.8	2.1	2.0	No sample taken										
	Bottom	1.8	2.0	2.0											
April	Top	1.0	1.3	0.3	No sample taken										
	Bottom	1.0	1.0	0.8											
May	Top	1.1	1.3	0.8	1.3	1.3	1.2	0.9	0.8	0.9	0.5	0.6	0.5	0.2	0.3
	Bottom	1.2	1.2	0.8	1.3	1.2	1.2	0.9	0.8	0.9	0.6	0.6	0.4	0.2	0.3
June	Top	0.8	0.8	1.2	1.2	1.2	1.1	1.2	1.0	0.9	0.8	0.9	0.7	0.7	0.8
	Bottom	0.8	0.8	1.2	1.2	1.2	1.2	1.3	1.0	1.1	1.1	0.9	0.7	0.8	0.9
July	Top	1.6	1.6	1.7	0.8	0.8	0.8	1.0	1.1	1.2	0.7	1.0	0.9	0.7	0.8
	Bottom	1.7	1.8	1.7	0.8	0.8	0.8	1.1	1.1	1.3	0.8	0.9	1.1	0.7	0.8
August	Top	2.3	2.0	1.8	1.7	1.5	1.4	1.4	1.3	1.1	1.2	1.0	1.1	1.1	0.8
	Bottom	2.2	2.1	1.9	1.7	1.5	1.4	1.4	1.3	1.1	1.2	1.0	1.2	1.1	0.8
September	Top	5.9	6.4	5.7	2.2	2.2	2.4	2.4	1.3	1.3	1.6	1.4	1.5	1.4	1.5
	Bottom	5.5	8.9	7.1	2.2	2.2	2.5	2.2	1.3	1.3	1.6	1.3	1.5	1.4	1.3
October	Top	8.0	10.0	10.0	5.0	5.0	2.0	2.0	1.1	1.1	1.6	1.0	0.5	1.1	0.5
	Bottom	9.2	11.4	10.5	5.0	5.0	2.1	2.1	1.1	1.3	1.8	1.8	0.7	1.3	0.7

Commercial Harvest Survey

The pound net catch-effort statistics for the Chowan River river herring fishery for 1983-1985 are presented in Tables 12-14. During 1983 and 1984, no significant catches of river herring were made prior to week 9 or after week 20. In 1985, no significant catches were made prior to week 8 or after week 19.

The catches of river herring during 1983 and 1984 were lower than that for 1982 (3,354,479 kg) as reported by Winslow et al. (1983). For the three year study period, 1983 total landings (1,964,798 kg) were the lowest. During 1984, the landings increased by 106,271 kg from those in 1983. The river herring landings from the Chowan River pound nets during 1985 were the highest in 14 years, up 1,933,425 kg from 1983 and 1,827,153 kg from 1984 (See Table 2). The relative abundance index for juveniles showed an increase in 1980 (Figure 19), which might account for an increased harvest as fish produced during that year returned to spawn as mature adults. As reported by Winslow et al. (1983), a drought occurred in the Albemarle Sound area in 1981, causing salinity levels in the rivers and tributaries to be high. The relative abundance index in 1981 may not have reflected the numbers of juveniles produced as they may have moved out of the established sampling area due to the higher salinities.

The peak week occurred earlier in 1984 (week 13), than in 1983 (week 18) and 1984 (week 16). The 1985 landings might have been even higher but the market became flooded early and the prices dropped. As a result, the majority of the pound net fishermen began pulling their nets earlier in the season than normal. During the three year period duration of this project, 1985 had the least amount of pound net effort, while 1984 effort was less than 1983.

Table 12. Catch/effort statistics for river herring taken in Chowan River, N.C. pound net fishery, 1983.

	Weekly landings		Effort	Catch per effort	
Week	(kg)	(lb)	(number of pound nets)	(kg)	(lb)
9	884	1,950	283	3.1	6.9
10	5,942	13,099	380	15.6	34.5
11	8,881	19,580	486	18.3	40.3
12	31,135	68,641	486	64.1	141.2
13	20,315	44,787	486	41.8	92.1
14	289,817	638,938	486	596.3	1314.7
15	441,418	973,160	486	908.3	2002.4
16	25,955	57,220	486	53.4	117.7
17	437,468	964,451	486	900.1	1984.5
18	487,392	1,074,516	480	1015.4	2238.6
19	197,991	436,496	200	989.4	2182.5
20	14,797	32,623	150	98.6	217.5
TOTAL	1,961,995	4,325,461*			

*Total Chowan River pound net landings of 4,327,749 lb during 1983 include 2,288 lb taken before and after the sampling period.

Table 13. Catch/effort statistics for river herring taken in Chowan River, N.C. pound net fishery, 1984.

	Weekly landings		Effort	Catch per effort	
Week	(kg)	(lb)	(Number of pound nets)	(kg)	(lb)
9	1,137	2,506	250	4.5	10.0
10	465	1,026	350	1.3	2.9
11	2,395	5,280	480	5.0	11.0
12	11,362	25,049	480	23.7	52.2
13	19,879	43,826	480	41.4	91.3
14	29,465	64,959	480	61.4	135.3
15	72,653	160,172	480	151.4	333.7
16	918,579	2,025,121	480	1913.7	4219.0
17	255,695	563,712	480	532.7	1174.4
18	490,491	1,081,347	480	1021.8	2252.8
19	230,147	507,388	400	575.4	1268.5
20	36,090	79,494	200	180.4	397.4
TOTAL	2,068,358	4,559,880*			

*Total Chowan River pound net landings of 4,561,828 lb during 1984 include 1,978 lb taken before the sampling period.

Table 14. Catch/effort statistics for river herring taken in Chowan River, N.C. pound net fishery, 1985.

Week	Weekly landings (kg)	Weekly landings (lb)	Effort (Number of pound nets)	Catch per effort (kg)	Catch per effort (lb)
8	1,966	4,330	101	19.5	42.9
9	35,306	77,766	196	180.1	396.8
10	65,524	144,326	301	271.7	479.5
11	40,487	89,179	371	109.1	240.4
12	60,824	133,973	421	144.5	318.2
13	1,218,661	2,684,277	421	2894.7	6376.0
14	888,823	1,957,760	421	2111.2	4650.3
15	886,113	1,951,791	421	2104.8	4636.1
16	631,538	1,391,054	421	1500.1	3304.2
17	64,088	141,164	421	152.2	335.3
18	1,925	4,240	171	11.2	24.8
19	2,339	5,152	42	55.7	122.7
Total	3,897,594	8,585,012*			

*Total Chowan River pound net landings of 8,586,394 lb during 1985 include 1,382 lb taken before the sampling period.

River herring year age class composition

The Chowan River age data for 1983 and 1984 was used to calculate the number of individuals in the commercial harvest from each year class by week. The 1985 data will be presented in the next anadromous fish project report. The Chowan River data were used because approximately 85% of the river herring landings usually occur in this system. Thus, it best represents the total population.

The contribution of each year class to the blueback herring harvest from the Chowan River pound net fishery by sex and by week for 1983 are shown in Table 15. The 1979 and 1978 year classes (ages IV and V) dominated the blueback herring harvest, contributing 81.6% of the total. The recruitment of three-year-old fish (1980 year class) was higher than that found in 1981 (Winslow et al. 1983). Table 16 shows the contribution of each year class by sex in summary for 1983.

The 1984 blueback herring data are shown in Table 17. During 1984, the 1980 and 1979 year classes (ages IV and V) were dominate contributing 81.9% to the harvest. The recruitment of three-year-old fish (1981 year class) was slightly higher than that found in 1983. An overall summary of the year classes by sex for 1984 is presented in Table 18.

The alewife year class contributions for 1983 are shown in Table 19. No sample was obtained during week 15. The 1979 and 1978 year classes (ages IV and V) were dominant in the alewife harvest for 1983, contributing 92.7%. There was no significant recruitment of the 1980 year class (three years old), only 2.6%. A summary of year class contribution by sex for alewife in 1983 is shown in Table 20.

Data are shown in Table 21 for alewife contribution of each year class of alewife by sex and by week for 1984. Ages IV and V (1980 and 1979 year

Table 15. Contribution of each year class to the blueback herring harvest from the Chowan River, North Carolina, pound net fishery by sex, by week, 1983.

		Male		Female		
Week number	Year class	Percent	Number of individuals	Percent	Number of individuals	Total number of individuals
11	1980	12.5	5,717	0	0	5,717
	1979	75.0	33,795	100	4,441	38,236
	1978	12.5	5,723	0	0	5,723
12	1980	30.8	53,513	0	0	53,513
	1979	46.1	80,218	33.3	48,571	128,789
	1978	23.1	40,617	66.7	97,368	137,985
13	1980	22.2	22,459	0	0	22,459
	1979	55.6	56,092	25.0	18,107	74,199
	1978	0	0	50.0	36,906	36,906
	1977	22.2	22.873	25.0	18,138	41,011
14	1979	42.8	590,905	40.0	465,156	1,056,061
	1978	28.6	394,151	20.0	237,891	632,042
	1977	28.6	404,364	30.0	352,777	757,141
	1976	0	0	0	0	0
	1975	0	0	10.0	116,832	116,832
15	1980	7.7	179,510	0	0	179,510
	1979	53.8	1,240,875	50.0	1,227,142	2,468,017
	1978	30.8	712,890	50.0	1,225,460	1,938,350
	1977	0	0	0	0	0
	1976	7.7	179,847	0	0	179,847
16	1980	7.8	12,236	0	0	12,236
	1979	46.1	73,885	50.0	59,956	133,841
	1978	46.1	73,107	37.5	45,539	118,646
	1977	0	0	12.5	15,174	15,174
17	1980	7.7	215,088	0		215,088
	1979	69.2	1,863,613	85.7	2,124,382	3,987,995
	1978	15.4	437,468	14.3	354,497	791,965
	1977	7.7	228,124	0	0	228,124
18	1980	15.4	509,887	25.0	727,339	1,237,226
	1979	46.1	1,442,680	25.0	724,585	2,167,269
	1978	30.8	1,002,200	25.0	718,903	1,721,103
	1977	7.7	246,404	25.0	701,844	948,248

Table 15. (continued)

Week number	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
19	1979	75.0	917,747	18.2	177,902	1,094,839
	1978	25.0	299,815	81.8	791,021	1,090,836
20	1979	29.4	30,876	66.7	61,654	92,530
	1978	64.7	65,318	33.3	30,827	96,145
	1977	5.9	6,006	0	0	6,006
TOTAL			11,447,993		10,381,606	21,829,599

Table 16. Contribution of each year class to the blueback herring harvest from the Chowan River, North Carolina, pound net fishery, by sex, for 1983.

Year class	Number of males	Number of females	Total number	Percent of total
1980	998,410	727,339	1,726,749	7.9
1979	6,330,686	4,911,090	11,241,176	51.5
1978	3,031,289	3,538,412	6,569,701	30.1
1977	906,771	1,087,933	1,995,704	9.1
1976	179,837	0	179,837	0.8
1975	0	116,832	116,832	0.5
TOTAL	11,447,993	10,381,606	21,829,599	

Table 17. Contribution of each year class to the blueback herring harvest from the Chowan River, North Carolina, pound net fishery by sex, by week, 1984.

Week number	Year class	Males		Females		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
13	1981	22.2	25,133	0	0	25,133
	1980	33.4	38,515	80.0	85,811	125,326
	1979	33.3	37,074	20.0	81,110	118,184
	1978	11.1	12,650	0	0	12,650
14	1981	7.7	13,826	12.5	17,090	30,916
	1980	53.8	94,092	37.5	51,353	145,445
	1979	30.8	54,743	25.0	35,090	89,833
	1978	7.7	13,703	25.0	34,990	48,693
15	1981	11.1	44,446	0	0	44,446
	1980	55.6	217,959	100	363,265	581,224
	1979	33.3	136,129	0	0	137,129
16	1981	0	0	7.7	367,432	367,432
	1980	100	7,065,933	23.0	1,121,979	8,187,972
	1979	0	0	38.5	1,845,906	1,845,906
	1978	0	0	30.8	1,482,252	1,482,252
17	1981	50.0	918,535	9.1	149,155	1,067,690
	1980	30.0	583,837	63.6	1,022,780	1,606,617
	1979	10.0	188,821	27.3	444,102	632,923
	1978	10.0	189,447	0	0	189,447
18	1981	15.4	564,065	0	0	564,065
	1980	46.1	1,626,166	20.0	551,802	2,177,968
	1979	30.8	1,121,589	80.0	2,234,459	3,356,048
	1978	7.7	269,770	0	0	269,770
19	1981	22.2	383,578	0	0	383,578
	1980	44.5	752,404	11.1	157,815	910,219
	1979	22.2	398,331	77.8	1,150,735	1,549,066
	1978	11.1	191,789	11.1	158,546	350,335
20	1981	7.8	23,294	0	0	23,294
	1980	46.1	146,525	0	0	146,525
	1979	46.1	145,193	100	225,562	370,755
TOTAL			15,257,607		11,581,234	26,838,841

Table 18. Contribution of each year class to the blueback herring harvest from the Chowan River, North Carolina, pound net fishery, by sex, for 1984.

Year	Number of males	Number of females	Total number	Percent of total
1981	1,972,877	533,677	2,506,554	9.3
1980	1,525,491	3,354,805	13,880,296	51.7
1979	2,081,880	6,016,964	8,098,844	30.2
1978	667,359	1,675,788	2,353,147	8.8
TOTAL	15,257,607	11,581,234	26,838,841	

Table 19. Contribution of each year class to the alewife harvest from the Chowan River, North Carolina, pound net fishery by sex, by week, 1983.

Week number	Year class	Male Percent	Male Number of individuals	Female Percent	Female Number of individuals	Total number of individuals
9	1980	37.5	1,880	0	0	1,880
	1979	50.0	2,524	25.0	802	3,326
	1978	12.5	615	50.0	1,609	2,224
	1977	0	0	25.0	803	803
10	1980	37.5	10,171	14.3	3,106	13,277
	1979	37.5	10,002	57.1	12,615	22,617
	1978	6.2	1,679	28.6	6,183	7,862
	1977	18.8	5,093	0	0	5,093
11	1980	11.1	4,662	0	0	4,662
	1979	55.6	23,885	22.2	7,143	31,028
	1978	22.2	9,537	33.3	10,689	20,226
	1977	11.1	4,680	44.5	14,150	18,830
12	1979	42.8	57,175	50.0	59,027	116,202
	1978	42.8	57,210	25.0	29,133	86,343
	1977	14.4	19,304	25.0	29,371	48,675
13	1979	76.9	78,694	50.0	41,184	119,878
	1978	23.1	23,318	50.0	40,195	63,513
14	1979	33.3	413,648	0	0	413,648
	1978	66.7	828,393	0	0	828,393
15	No Sample					
16	1980	25.0	33,222	0	0	33,222
	1979	75.0	99,864	75.0	96,682	196,546
	1978	0	0	0	0	0
	1977	0	0	25.0	24,513	24,513
TOTAL			1,685,556		337,205	2,062,761

Table 20. Contribution of each year class to the alewife harvest from the Chowan River, North Carolina, pound net fishery, by sex, for 1983.

Year class	Number of males	Number of females	Total number	Percent of total
1980	49,934	3,106	53,041	2.6
1979	685,792	217,453	903,245	43.8
1978	920,752	87,805	1,008,561	48.9
1977	29,077	68,837	97,914	4.7
TOTAL	1,685,556	377,205	2,062,761	

Table 21. Contribution of each year class to the alewife harvest from the Chowan River, North Carolina, pound net fishery by sex, by week, 1984.

Week number	Year class	Male		Female		Total number of individuals
		Percent	Number of individuals	Percent	Number of individuals	
11	1980	50.0	4,866	42.9	3,872	8,738
	1979	40.0	3,965	35.7	3,167	7,132
	1978	10.0	976	14.3	1,257	2,233
	1977	0	0	7.1	631	631
12	1980	20.0	8,831	33.3	14,512	23,343
	1979	40.0	18,084	33.3	14,518	32,602
	1978	40.0	18,139	33.4	14,653	32,792
13	1980	60.0	50,994	50.0	36,577	87,571
	1979	40.0	33,960	35.8	26,358	60,318
	1978	0	0	7.1	5,156	5,156
	1977	0	0	7.1	5,179	5,179
14	1981	10.0	13,802	0	0	13,802
	1980	70.0	95,895	61.5	64,936	160,831
	1979	20.0	27,360	7.7	8,103	35,463
	1978	0	0	15.4	16,390	16,390
	1977	0	0	15.4	16,332	16,332
TOTAL			276,872		231,641	508,513

classes) were dominant, contributing 81.9% of the harvest, with very little recruitment of three-year-old fish (1981 year class), 2.7%. The recruitment of three-year-old fish in 1983 and 1984 were very similar. The year class summary for alewife during 1984, by sex, is presented in Table 22.

River herring species composition

Species composition of both alewife and blueback herring (by number) were determined from unculled samples of commercial catches taken in Chowan and Scuppernong rivers during Spring 1983-1985. Weeks were serially numbered as in the commercial harvest survey. Early catches of river herring examined at sampling locations during 1983-1985 were dominated by alewife with blueback becoming the dominant species at approximately mid-season. However, during 1985, 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. The change in species composition at each location occurred between the 12th and 15th weeks during the project (Figures 25-27). These data closely agree with that reported by Street et al. (1975), Johnson et al. (1977, 1981) and Winslow et al. (1983).

Unculled samples taken from the Scuppernong River and Chowan River sites were limited to 30 fish per species, per week, because of time and personnel limits. Species composition for the entire 1983 season, determined from sampling on Scuppernong and Chowan rivers, was 55% blueback herring and 45% alewife. In 1984, the composition was 71.2% blueback herring and 28.8% alewife. During 1985, the species composition was 77.8% for blueback herring and 22.2% alewife. These percentages were obtained 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 most

Table 22. Contribution of each year class to the alewife harvest from the Chowan River, North Carolina, pound net fishery, by sex, for 1984.

Year class	Number of males	Number of females	Total number	Percent of total
1981	13,802	0	13,802	2.7
1980	160,586	119,897	280,483	55.2
1979	83,369	52,146	135,515	26.7
1978	19,115	37,456	56,571	11.1
1977	0	22,142	22,142	4.3
TOTAL	276,872	231,641	508,513	

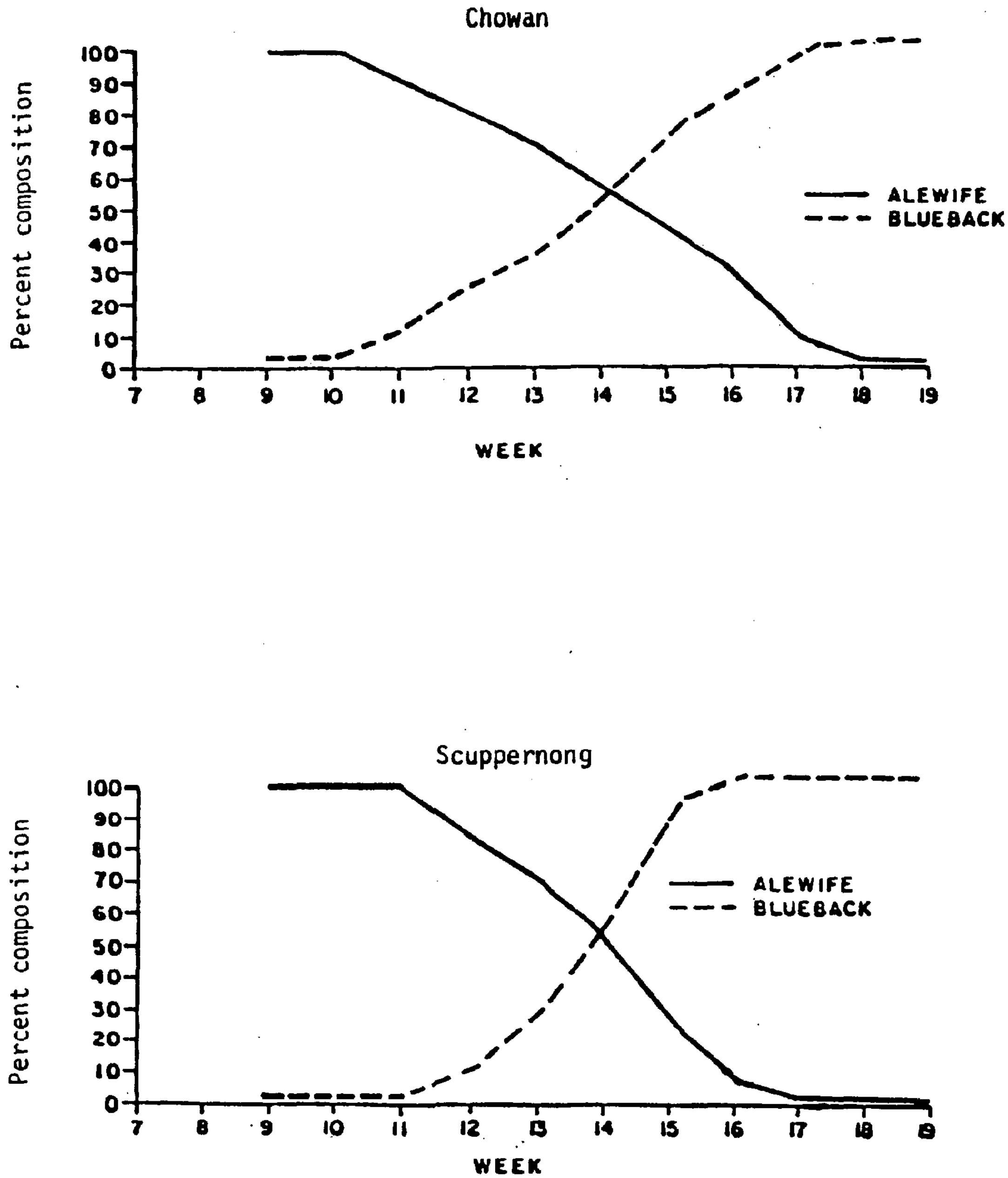
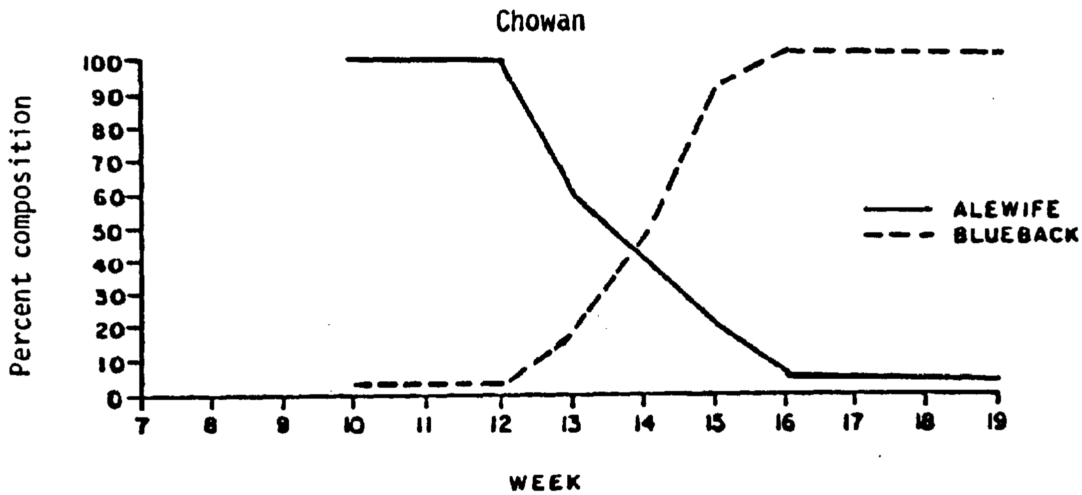


Figure 25. Weekly species composition of the 1983 samples from the Chowan River and Scuppernong River pound net fisheries.



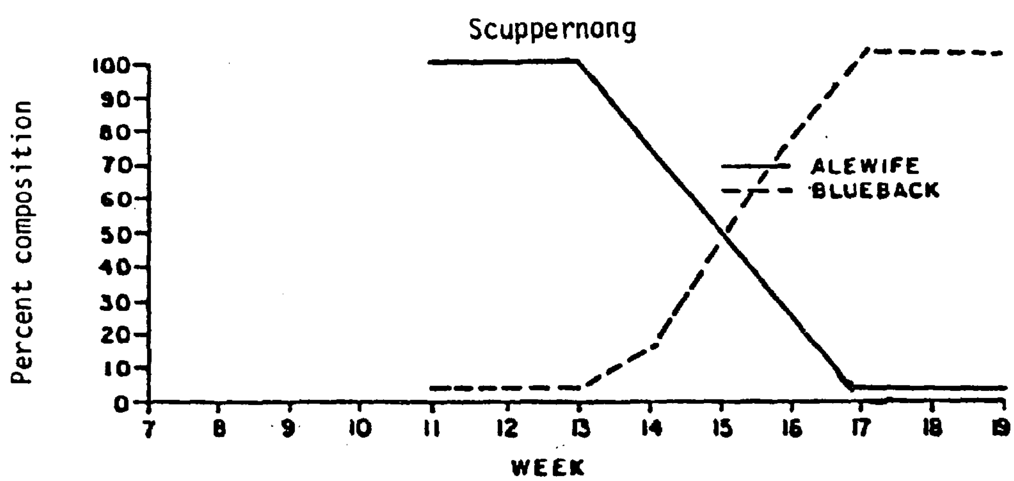
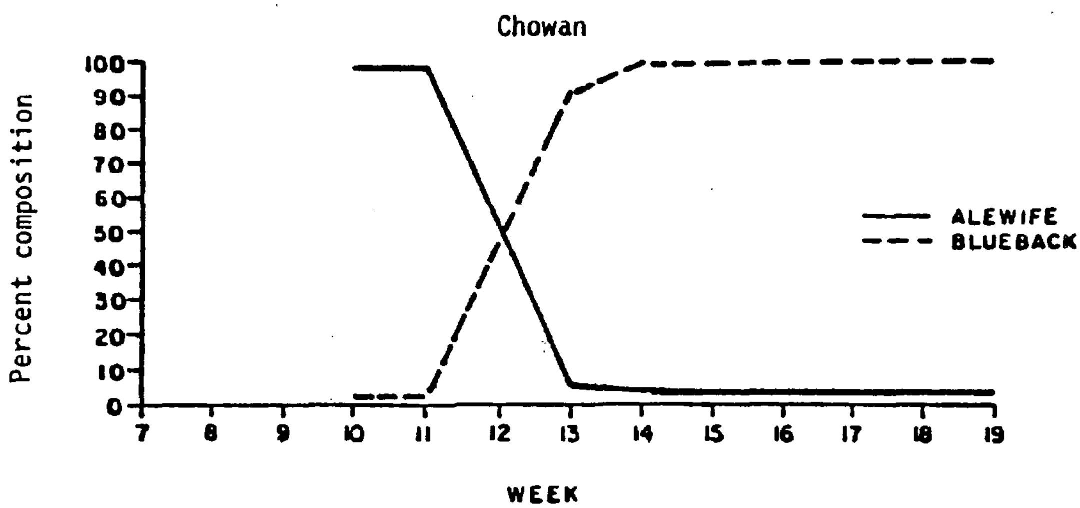


Figure 26. Weekly species composition of the 1984 samples from the Chowan River and Scuppernong River pound net fisheries.



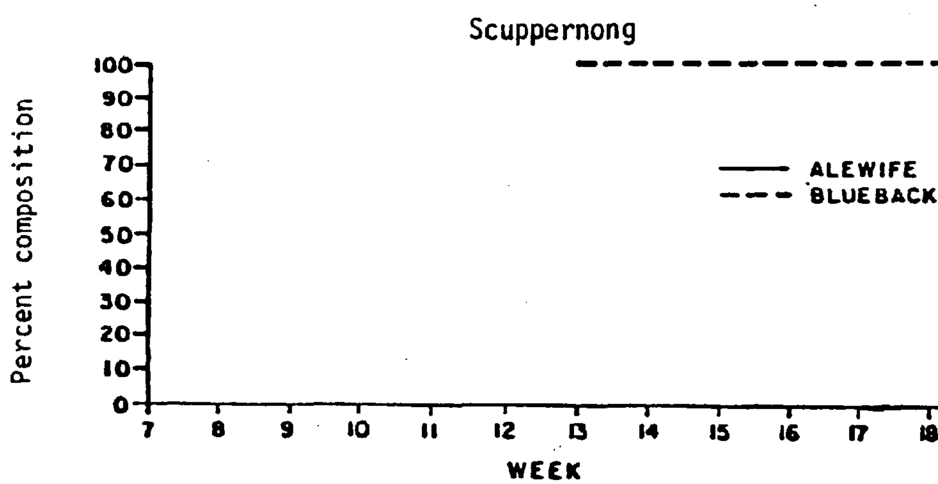


Figure 27. Weekly species composition of the 1985 samples from the Chowan River and Scuppernong River pound net fisheries.

representative of the stocks. These percentages generally agree with percentages reported by Johnson et al. (1981) and Winslow et al. (1983).

Sex Ratios

River herring

Sex ratios were obtained from combined data taken at all sample sites during 1983-1984. Pound nets at these sites are believed to be nonselective. During 1983, the male to female sex ratio was 1.6:1 for blueback herring and 1.5:1 for alewife. Chi-square analysis indicated that the blueback herring and alewife ratios were significantly different at the .05 level from the expected ratio. The 1984 male to female sex ratios were 1.7:1 for blueback herring and 0.99:1 for alewife. Chi-square analysis indicated that the blueback herring ratio was significantly different from 1:1, but the alewife ratio was not significantly different at the .05 level. Combined data for 1983 and 1984 showed a male to female ratio of 1.6:1 for blueback herring and 1.2:1 for alewife. These sex ratios for blueback herring and alewife are similar to those reported by Winslow et al. (1983) for 1980-1982.

American shad

A sex ratio for American shad of 1.3:1 (males to females) was obtained from pooled data from the Albemarle Sound area during 1983. Chi-square analysis indicated that the ratio differed from the theoretically expected ratio (1.1) very significantly (P <.01). In 1984, the male:female ratio was 1.2:1, which was not significantly different at the P <0.01 level. These estimated sex ratios of American shad, however, are biased because the gill nets employed are selective for females (Street et al. 1975). The actual sex ratio for the population is unknown.

Hickory shad

Hickory shad sex ratios were also obtained from combined data taken at all sites. A sex ratio of 0.04:1 (male:female) was obtained during 1983. Chi-square analysis was highly significant at the $P < 0.01$ level. During 1984, the male to female sex ratio was 0.03:1, which chi-square analysis indicated was highly significant ($P < 0.01$). Again, it should be noted that gill nets are the predominant gear for hickory shad and are selective for females (Street et al. 1975).

Mortality

Survival estimates for 1983 and 1984 were computed using the Robson and Chapman (1961) method. Robson and Chapman (1961) 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:

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

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 1983 was 73.1%, a lower value than that for 1984 (81.2%). These estimates are similar to those for 1981 (74%) and 1983 (72%) as reported by Winslow et al. (1983).

Alewife

Alewife mortality estimates for 1983 and 1984 were 73.7% and 81.3%, respectively. The 1983 and 1984 mortality estimates are similar to those reported by Winslow et al. (1983) for 1981 (72%) and 1982 (78%).

American shad

During 1983, total mortality for American shad was 58.5%, while the 1984 estimate is and 45.5%. These estimates generally agree with those for 1980-1982 (41%, 37%, 50%, respectively, Winslow et al. 1983). The variability of the mortality estimate is probably due to the biased fishing gear.

Hickory shad

Total mortality for hickory shad during 1983 was 73.0% and 43.7% in 1984. The 1983 estimate is within the range of those reported by Johnson et al. (1983) for 1977-1979, 82%, 58% and 72%, respectively. The mortality rates reported by Winslow et al. (1983) for 1981 (41%) and 1982 (42%) agree closely with the 1984 estimate. Again, the variability of the mortality figure is probably due to biased fishing gear.

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 1983 and 1984 are presented in Tables 23 through 36. The data presented in these tables are the expanded figures from stratified subsampling of each area. The subsampling techniques were the same as those described by Winslow et al. (1983).

Table 23. Age and spawning frequency of blueback herring and alewife from Albemarle Sound area, North Carolina.. Data are combined from all sample sites for 1983. (M=Male, F=Female)

Blueback herring

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	24	4							24	4
IV	153	91	7	0					160	91
V	25	26	71	41					96	67
VI			8	15	5	5			13	20
VII					0	3	1	0	1	3
VIII							0	1	0	1
TOTAL	202	121	86	56	5	8	1	1	294	186
Percent by sex	68.7	65.1	29.3	30.1	1.7	4.3	0.3	0.5		
Percent of sexes combined	67.3		29.6		2.7		0.4			

Alewife

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	28	3							28	3
IV	119	81	1	1					120	82
V	26	43	74	24					100	67
VI			14	22	2	3			16	25
VII					0	1			0	1
TOTAL	173	127	89	47	2	4			264	178
Percent by sex	65.5	71.4	33.7	26.4	0.8	2.2				
Percent of sexes combined	67.9		30.8		1.3					

Table 24. Age and spawning frequency of blueback herring and alewife from Albemarle Sound area, North Carolina. Data are combined from all sample sites for 1984. (M=Male, F=Female)

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	32	4							32	4
IV	161	83	2	0					163	83
V	38	34	35	29					73	63
VI			7	14	2	2			9	16
VII							0	0	0	0
VIII							0	1	0	1
TOTAL	231	121	44	43	2	2	0	1	277	167
Percent by sex	83.4	72.5	15.9	25.7	0.7	1.2	0	0.6		
Percent of sexes combined	79.3		19.6		0.9		0.2			

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	3	0							3	0
IV	100	86	1	0					101	86
V	39	50	13	10					52	60
VI			6	13	9	5			15	18
VII			0	1	1	8			1	9
TOTAL	142	136	20	24	10	13			172	173
Percent by sex	82.6	78.6	11.6	13.9	5.8	7.5				
Percent of sexes combined	80.6		12.7		6.7					

Table 25. Age and spawning frequency of blueback herring and alewife from the Scuppernong River pound net fishery, 1983. (M=Male, F=Female)

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	4	1							4	1
IV	47	33							49	33
V	10	8	15	14					25	22
VI			0	7	1	4			1	11
VII					0	3			0	3
TOTAL	61	42	17	21	1	7			79	70
Percent by sex	77.2	60.0	21.5	30.0	1.3	10.0				
Percent of sexes combined	69.1		25.5		5.4					

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	4	1							4	1
IV	5	13							5	13
V	5	11	5	2					10	13
VI			1	4	0	1			1	5
TOTAL	14	25	6	6	0	1			20	32
Percent by sex	70.0	78.1	30.0	18.8	0	3.1				
Percent of sexes combined	75.0		23.1		1.9					

Table 26. Age and spawning frequency of blueback herring and alewife from the Scuppernong River pound net fishery, 1984. (M=Male, F=Female)

Blueback herring

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	8	0							8	0
IV	64	31	2	0					66	31
V	12	10	11	3					23	13
VI			2	3	1	0			3	3
VII							0	0	0	0
VIII							0	1	0	1
TOTAL	84	41	15	6	1	0	0	1	100	48
Percent by sex	84.0	85.4	15.0	12.5	1.0	0	0	2.1		
Percent of sexes combined	84.4		14.2		0.7		0.7			

Alewife

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
IV	14	4	1	0					15	4
V	4	3	3	0					7	3
VI			1	0					1	0
VII					0	1			0	1
TOTAL	18	7	5	0	0	1			23	8
Percent by sex	78.3	87.5	21.7	0	0	12.5				
Percent of sexes combined	80.7		16.1		3.2					

Table 27. Age and spawning frequency of blueback herring and alewife from the Chowan River pound net fishery, 1983. (M=Male, F=Female)

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	19	2							19	2
IV	104	50	4	0					108	50
V	15	16	50	26					65	42
VI			8	7	3	0			11	7
VII							1	0	1	0
VIII							0	1	0	1
TOTAL	138	68	62	33	3	0	1	1	204	102
Percent by sex	67.6	66.7	30.4	32.3	1.5	0	0.5	1.0		
Percent of sexes combined	67.3		31.0		1.0		0.7			

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	19	1							19	1
IV	57	25							57	25
V	2	10	22	5					24	15
VI			5	9	2	2			7	11
TOTAL	78	36	27	14	2	2			107	52
Percent by sex	72.9	69.2	25.2	27.0	1.9	3.8				
Percent of sexes combined	71.7		25.8		2.5					

Table 28. Age and spawning frequency of blueback herring and alewife from the Chowan River pound net fishery, 1984. (M=Male, F=Female)

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	23	4							23	4
IV	68	36							68	36
V	23	19	21	23					44	42
VI			5	11	1	2			6	13
TOTAL	114	59	26	34	1	2			141	95
Percent by sex	80.9	62.1	18.4	35.8	0.7	2.1				
Percent of sexes combined	73.3		25.4		1.3					

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	1	0							1	0
IV	27	42							27	42
V	10	15	6	6					16	21
VI			3	4	4	5			7	9
VII					0	4			0	4
TOTAL	38	57	9	10	4	9			51	76
Percent by sex	74.5	75.0	17.7	13.2	7.8	11.8				
Percent of sexes combined	74.8		15.0		10.2					

Table 29. Age and spawning frequency of blueback herring and alewife from the Alligator River pound net fishery, 1983. (M=Male, F=Female)

Blueback herring

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	1	1							1	1
IV	2	8	1	0					3	8
V		2	6	1					6	3
VI			0	1	1	1			1	2
TOTAL	3	11	7	2	1	!			11	14
Percent by sex	27.3	78.6	63.6	14.3	9.1	7.1				
Percent of sexes combined	56.0		36.0		8.0					

Alewife

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	5	1							5	1
IV	57	43	1	1					58	44
V	19	22	47	17					66	39
VI			8	9					8	9
VII					0	1			0	1
TOTAL	81	66	56	27	0	1			137	94
Percent by sex	59.1	70.2	40.9	28.7	0	1.1				
Percent of sexes combined	63.6		35.9		0.5					

Table 30. Age and spawning frequency of blueback herring and alewife from the Alligator River pound net fishery, 1984. (M=Male, F=Female)

Blueback herring

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	1	0							1	0
IV	29	16							29	16
V	3	5	3	3					6	8
TOTAL	33	21	3	3					36	24
Percent by sex	91.7	87.5	8.3	12.5						
Percent of sexes combined	90.0		10.0							

Alewife

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	2	0							2	0
IV	59	40							59	40
V	25	32	4	4					29	36
VI			2	9	5	0			7	9
VII			0	1	1	3			1	4
TOTAL	86	72	6	14	6	3			98	89
Percent by sex										
Percent of	87.8	80.9	6.1	15.7	6.1	3.4				
sexes combined	84.5		10.7		4.8					

Table 31. Age and spawning frequency of American shad and hickory shad from the Albemarle Sound area, North Carolina, 1983. (M=Male, F=Female)

American shad

	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	5						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 of sexes combined	42.0		44.5		13.9		1.9		0.2			

Hickory shad

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	2	1							2	1
IV	5	123							5	123
V	4	109	1	45					5	154
VI			2	19	0	11			2	30
VII					0	2			0	2
TOTAL	11	233	3	64	0	13			14	310
Percent by sex	78.6	75.2	21.4	20.6	0	4.2				
Percent of sexes combined	75.3		20.7		4.0					

Table 32. Age and spawning frequency of American shad and hickory shad from the Albemarle Sound area, North Carolina, 1984. (M=Male, F=Female)

American shad

	Number of times spawned										Total	
	0		1		2		3		4			
Age	M	F	M	F	M	F	M	F	M	F	M	F
III											0	0
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
VIII					10	35	10	35			20	70
IX					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 of sexes combined	30.6		31.5		26.6		10.9		0.4			

Hickory shad

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	1	0							1	0
IV	0	17							0	17
V	0	34	1	79					1	113
VI			4	104	3	54	0	2	7	158
VII					0	45	0	2	0	47
VIII							0	2	0	2
TOTAL	1	51	5	183	3	99	0	4	9	337
Percent by sex	11.1	15.1	55.6	54.3	33.3	29.4	0	1.2		
Percent of sexes combined	15.0		54.3		29.5		1.2			

Table 33. Age and spawning frequency of American shad from the Pamlico River area and Outer Banks area of North Carolina, 1983. (M=Male, F=Female)

Pamlico River

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	7	0							7	0
V	39	31	7	8					46	39
VI	14	19	27	16	2	0			43	35
VII			4	1	2	1			6	2
TOTAL	60	50	38	25	4	1			102	76
Percent by sex	58.8	65.8	37.3	32.9	3.9	1.3				
Percent of sexes combined	61.8		35.4		2.8					

Outer Banks

	Number of times spawned				
Age	0	1	2	3	Total
V	3				3
VI	4	7			11
VII		2	5	1	8
VIII				2	2
TOTAL	7	9	5	3	24
Percent of total	29.2	37.5	20.8	12.5	

Table 34. Age and spawning frequency of American shad from the Pamlico River area and Outer Banks area of North Carolina, 1984. (M=Male, F=Female)

Pamlico River

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
III	1	0							1	0
IV	26	4							26	4
V	61	39	0	4					61	43
VI	16	38	7	3					23	41
VII			0	1	2	3			2	4
VIII										
TOTAL	104	81	7	8	2	3			113	92
Percent by sex	92.0	88.0	6.2	8.7	1.8	3.3				
Percent of sexes combined	90.3		7.3		2.4					

Outer Banks

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
V	1	1							1	1
VI	0	1	0	3					0	4
VII			0	2	0	3			0	5
TOTAL	1	2	0	5	0	3			1	10
Percent by sex	100	20.0	0	50.0	0	30.0				
Percent of sexes combined	27.3		45.4		27.3					

Table 35. Age and spawning frequency of American shad from the Cape Fear River area and the Neuse River area, North Carolina, 1983. (M=Male, F=Female)

Cape Fear River

	Number of times spawned						Total	
	0		1		2			
Age	M	F	M	F	M	F	M	F
IV	9	2					9	2
V	7	6	4				11	6
VI		2	2	4			2	6
VII			0	1			0	1
TOTAL	16	10	6	5			22	15
Percent by sex	72.7	66.7	27.3	33.3				
Percent of sexes combined	70.3		29.7					

Neuse River

	Number of times spawned						Total	
	0		1		2			
Age	M	F	M	F	M	F	M	F
IV	19	3					19	3
V	40	35	19	3			59	38
VI	12	20	27	20	4	0	43	40
VII			1	4	1	6	2	10
TOTAL	71	58	47	27	5	6	123	91
Percent by sex	57.7	63.7	38.2	28.6	4.1	6.6		
Percent of sexes combined	60.3		34.6		5.1			

Table 36. Age and spawning frequency of American shad from the Cape Fear River area and the Neuse River area, North Carolina, 1984. (M=Male, F=Female)

Cape Fear River

	Number of times spawned						Total	
	0		1		2			
Age	M	F	M	F	M	F	M	F
IV	10	3					10	3
V	18	45	2	4			20	49
VI	2	30	1	5			3	35
VII			0	4			0	4
TOTAL	30	78	3	13			33	91
Percent by sex	90.9	85.7	9.1	14.3				
Percent of sexes combined	87.1		12.9					

Neuse River

	Number of times spawned						Total	
	0		1		2			
Age	M	F	M	F	M	F	M	F
IV	8	0					8	0
V	36	54	13	5			49	59
VI	4	24	15	21	4	0	23	45
VII			1	9	1	6	2	15
TOTAL	48	78	29	35	5	6	82	119
Percent by sex	58.5	65.6	35.4	29.4	6.1	5.0		
Percent of sexes combined	62.7		31.8		5.5			

The 1983 and 1984 results generally agree with those reported by Street et al. (1975), Johnson et al. (1977, 1981) and Winslow et al. (1983).

The Alligator River data probably do not truly represent the river herring population of this system since the fishermen were active only during the early part of the season each year. The fishermen in the Scuppernong River were later than normal setting their pound nets in 1983 and 1984. Thus, the alewife population may not be well represented in the data.

Blueback herring

A total of 480 blueback herring scale samples were taken during 1983; 315 scale samples were subsampled for age determination. The 315 fish subsample was expanded for each modal size group (10 mm groups) to obtain the 480 fish total sample. In 1984, scale samples were taken from 447 blueback herring, with 287 subsampled for aging and the data expanded after aging to reach the total number. During Spring, 1985, 388 fish were sampled for age determination. These scale samples will be subsampled, aged and discussed in the next Albemarle Sound area anadromous fish project report (Project AFC-27).

Combined data from all sampling locations showed that males, in 1983, ranged from 3 to 7 years old, while in 1984, ages ranged between 3 and 6 years. During 1983 and 1984, female blueback herring ranged from 3 to 8 years old. In 1983, age groups 4-6 comprised 91.5% of the males sampled and 95.7% of the females sampled (Table 23). The same age groups made up 88.4% of the male and 97.0% of the female samples in 1984 (Table 24). All of these values are similar to those reported by Johnson et al. (1981) and Winslow et al. (1983), suggesting a continued lack of older fish.

Blueback herring data combined from all sampling locations showed spawning populations comprised of 68.7% virgin males and 65.1% virgin females in 1983 (Table 23). In 1984 the virgin spawning population included 83.4% of the males and 72.5% of the females (Table 24). The percentages of virgin fish for 1983 and 1984 closely agree with those for 1981 and 1982 (Winslow et al. 1983). Male blueback herring scale samples for 1983 had up to three spawning marks, while those in 1984 had a maximum of two. Female blueback herring had up to three spawning marks for both years. Only 0.4% of the fish had spawned more than twice in 1981 and 0.2% during 1984. These values are lower than those found by Johnson et al. (1983) for 1977-1979 (1.0-2.6%) and Winslow et al. (1983) for 1980-1982 (3.0-4.1%). These percentages further indicate a lack of older fish in the spawning population. Spawning repetition (sexes combined) declined from 32.7% in 1983 to 20.7% in 1984. This value has varied considerably over the years in the Albemarle Sound area; however, the value for 1984 is the lowest on record.

Age composition for each of the areas sampled in the commercial harvest surveys during 1983 and 1984 were similar to those collected during 1972-1982 (Street et al. 1975, Johnson et al. 1977, 1981 and Winslow et al. 1983). In the Scuppernong River during 1983 and 1984, the spawning population (sexes combined) was composed of 69.1% and 84.4% virgin fish, respectively (Tables 25 and 26). Blueback herring from the Scuppernong River generally have the highest proportion of virgin fish in the Albemarle Sound area (Street et al. 1975, Johnson et al. 1977, 1981 and Winslow et al. 1983). During 1983 and 1984, male blueback herring ranged from 3 to 6 years in age. Females ranged from 3 to 7 years in 1983, while in 1984, the age range was 4-8 years. Age groups 4, 5, and 6 comprised 94.6% (sexes combined) of the sample in 1983 and 93.9% in 1984. In 1983, 10.1% of the fish sampled (sexes combined) from the Scuppernong River were over 5 years of age; but only 4.7% during 1984. These percentages are lower than those reported by Winslow et al. (1983) for 1980-1982, but closely agree with those reported for the Scuppernong River prior to 1980 (Street et al. 1975; Johnson et al. 1977, 1981).

The haul seine fishery in the Meherrin River did not operate during 1983-1985 due to various reasons, such as flooding. Thus no data were obtained.

Approximately 85% of the total landings of river herring in the Albemarle Sound area come from the pound net fishery on Chowan River. Consequently, data collected from the Chowan River sample site are most likely to reflect population parameters of the total river herring run in the Albemarle Sound area (Tables 27 and 28).

Chowan River data from 1983 showed that 67.3% of the blueback herring were virgin fish, sexes combined (Table 27). During 1984, virgin fish (sexes combined) comprised 73.3% of the sample (Table 28). The proportions of virgin fish found in 1983 and 1984 were considerably higher than those reported by Winslow et al. (1983) for 1980 (46%) and 1981 (58.7%). The 1983-1984 data show a marked increase in the proportion of virgin fish, returning to levels similar to those of 1977 and 1978 (Johnson et al. 1981). During 1983, male blueback herring ranged in age from 3 to 7 years, while females were 3 to 8 years of age. Males and females ranged from 3 to 6 years old in 1984. Age groups 4, 5, and 6 comprised 90.2% of the males and 97.1% of the females sampled in 1983. These same age groups made up 83.7% of the males and 95.8% of the females during 1984. These percentages closely agree with those found during 1980-1982 (Winslow et al. 1983). The Chowan River samples for 1983 showed that 1.7% of the fish, sexes combined, had spawned more than once previously and 1.3% in 1984. These values are much lower than those found in 1980-1982 (Winslow et al. 1983) but comparable to those found in 1975-76 (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 1983 (25) and 1984 (60). So few samples were obtained during this project and previous projects that meaningful evaluations of the spawning population in the Alligator River cannot be made. Data are presented in Table 29 for 1983, and in Table 30 for 1984.

Alewife

A total of 442 alewife scale samples were taken during 1983, of which 313 were sampled for age determination. The subsample was expanded from each modal size group (10 mm groups) to obtain the age composition of the 442 scale sample. In 1984, 354 alewife were sampled for aging; 254 were subsampled and aged. The subsample number was expanded to give the total number sampled. During 1985, 272 alewife were sampled for age determination. Those samples will be subsampled, aged, and presented in the next Albemarle Sound area anadromous fish report (Project AFC-27).

Data combined from all sampling locations in 1983 showed that male alewife ranged from 3 to 6 years of age, while females were 3 to 7 years old (Table 23). Males ranged in age from 3 to 7 years in 1984, and females from 4 to 7 years (Table 24). Age groups 4, 5, and 6 dominated the alewife catches, making up 89.4% of the males and 97.8% of the females in 1983. These same ages comprised 97.7% of the males and 94.8% of the females during 1984. These percentages are very similar to those found during 1977-1982 (Johnson et al. 1981, Winslow et al. 1983).

Alewife data combined from all sampling locations show a spawning population composed of 65.5% virgin males and 71.4% virgin females for 1983 (Table 23). The 1984 spawning population was comprised of 82.6% virgin males and 78.6% virgin females (Table 30). These data closely agree with the

1981-1982 values (Winslow et al. 1983). Male and female alewife observed during this project had up to two spawning marks. In 1983 and 1984, 1.3% and 6.7%, respectively, of the alewife sampled (sexed combined) had spawned more than once. This range is similar to that reported by Winslow et al. (1983) for 1981 (6.5%) and 1982 (1.1%).

Alewife samples from the Scuppernong River during 1983 showed that both males and females ranged from 3 to 6 years of age (Table 25). During 1984, males ranged from 4 to 6 years of age and females from 4 to 7 years (Table 26). Data from 1983 showed that 75% (sexes combined) were virgins, and 80.7% were virgins in 1984. In 1983, only 1.9% of the fish had spawned more than once, but 3.2% had in 1984. These values generally agree with those of 1980-1982 for the Scuppernong River (Winslow et al. 1983). The amount of pound net effort in the Scuppernong River during the past several years has decreased; the fishermen also set their nets later in the season. As a result of these changes, the number of alewife samples has decreased, and these data may not actually reflect the spawning population in the Scuppernong River.

Alewife from the Chowan River ranged in age from 3 to 6 years for both sexes during 1983 (Table 27). Males ranged from 3 to 6 years old and females 4 to 7 years in 1984 (Table 28). Virgin fish comprised 71.7% (sexes combined) of the sample in 1983 and 74.8% in 1984. The data are similar to those reported by Street et al. (1975), Johnson et al. (1981) and Winslow et al. (1983). The proportion of fish that had spawned more than once previously increased from that of 1982 (0.5%, Winslow et al. 1983), to 2.5% in 1983 and 10.2% in 1984. As previously stated, these data are probably the most representative age and spawning class data for Albemarle Sound area alewife.

Samples taken from the Alligator River during 1983 showed that male alewife ranged in age from 3 to 6 years, while females ranged from 3 to 7 years of age (Table 29). During 1984, males were 3 to 7 years old and females were 4 to 7 years old (Table 30). Data showed that 63.6% of the sample in 1983 (sexes combined) were virgins, while 84.5% were virgins in 1984. Only 0.5% of the sample (sexes combined) had spawned more than once in 1983 and 4.8% in 1984. As stated previously, Alligator River data may not be truly representative because the fishery occurs only during the early part of the total river herring season.

American Shad

Albemarle Sound Area

The gill net fishery in Albemarle Sound accounts for approximately 95% of the American shad taken from that area; the remainder are captured incidental to the pound net fishery for river herring.

A total of 640 American Shad scale samples were taken in 1983, and 357 scale samples were subsampled for age determination. In 1984, 676 scale samples were taken, and 379 subsampled for aging. The number of fish subsampled each year was expanded for each modal size group (25 mm groups) to obtain the total number of fish sampled. During 1985, 447 American shad scale samples were taken. These samples will be subsampled, aged and the subsample expanded to obtain the total sample. The 1985 data will be discussed in the next Albemarle Sound area anadromous fish report (Project AFC-27).

American shad males ranged in age from 3 to 8 years old in 1983 and 4 to 8 years in 1984 (Tables 31 and 32). Females were 4 to 9 years of age during 1983 and 5-9 years in 1984 (Tables 31 and 32). Age groups 5 and 6 comprised 85% of the males in 1983 and 73.2% in 1984. Females in age groups 5, 6, and 7 made up 94.9% of the sample in 1983. These same age groups, in 1984, comprised 67.7% of the sample. The American shad population (sexes combined) from the Albemarle Sound area in 1983 and 1984 was comprised of 42.0% and 30.6% virgin fish, respectively (Tables 31 and 32). Data from 1983 showed that 13.5% of the fish sampled (sexes combined) had spawned more than once previously. In 1984, 37.9% had spawned more than once. These percentages of repeat spawners fall between that reported by Johnson et al. (1977) of 7% and 55.5% as reported by Winslow et al. (1983). The data generally show a wide range of year classes in the population.

Pamlico River

A total of 178 American shad scale samples were obtained from the Pamlico River area during 1983. These scale samples were subsampled for age determination (103 fish in the subsample) and expanded to obtain the age composition of the total sample. In 1984, 205 samples were taken, and 121 were subsampled for aging and expanded to reach the total number. During 1985, 193 American shad were sampled from the Pamlico River area. These will be subsampled, aged and reported on in the next Albemarle Sound area anadromous fish report (Project AFC-27).

Male American shad ranged from 4 to 7 years old and females 5 to 7 years old in 1983 (Table 33). In 1984, males were age 3 to 7 years, while females ranged from 4 to 7 years old (Table 34). Fifty-nine percent of American shad males sampled and 65.8% of the females were virgin fish in 1983. The percentage of virgin fish in 1983 is the lowest recorded. The majority of the samples in 1983, however, were obtained within a seven day period which could have biased the data. Virgin fish comprised 92.0% of the males and 88.0% of the females in 1984. These percentages of virgin fish are lower than those found for the Pamlico River area in 1980-81 (Winslow et al. 1983), but comparable to those in 1975 as reported by Marshall (1976).

Outer Banks

Twenty-four scale samples were taken from American shad captured in the Atlantic Ocean along the Outer Banks of North Carolina, in 1983. Sex data was not obtained for these samples. Only 11 American shad were sampled during 1984. All samples for both years were aged, and data are presented in Tables 33 (1983) and 34 (1984). These data generally agree with that reported by Holland and Yelverton (1973) for American shad captured off the Outer Banks in 1971. However, since so few samples were obtained, comparisons would be inappropriate.

Cape Fear River

During 1983, a total of 37 American shad scale samples were taken from the Cape Fear River area. The total sample was aged and data are presented in Table 35. A total of 124 samples were taken during 1984, with 96 subsampled for aging. The 1984 data are shown in Table 36.

Male American shad ranged from 4 to 6 years old, while females were 4 to 7 years old. The male:female sex ratio was 1.4:1 in 1983 and 0.4:1 in 1984. The 1983 ratio closely agrees with those reported by Winslow et al. (1983) for 1978 (1.2:1) and 1980 (1.4:1). However, the ratio in 1984 is probably biased due to the sampling method. Otherwise these data closely agree with those reported by Sholar (1977) and Winslow et al. (1983) for the Cape Fear River.

Neuse River

Scale samples were taken from American shad from the Neuse River area during 1983 and 1984. Two hundred and fourteen samples were taken in 1983, and 132 were subsampled for aging. In 1984, 201 samples were obtained, with 124 subsampled and aged. The subsample was expanded to obtain the total number sampled. The ages and spawning frequencies are shown in Table 35 (1983) and Table 36 (1984).

Male fish ranged from 4 to 7 years of age during both years. However, females in 1983 were 4 to 7 years old, while they were 5 to 7 years old during 1984. These data generally agree with that found by Hawkins (1979, 1980) and Winslow et al. (1983).

The 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 taken in a short period of time naturally low spawning survival, or a strong year class moving through the population, as evidenced by an increased juvenile abundance in these areas (Winslow et al. 1983).

It should be noted that concern has developed because of declining landings of American shad in the south Atlantic states. North Carolina landings have fallen steadily from 1,069,000 lb in 1965 to a low point of 121,000 lb in 1977. Landings have recovered somewhat to 584,843 lb in 1984 (Table 2).

Hickory shad

In 1983, 324 scale samples were taken from hickory shad; 191 scale samples were subsampled for age determination. Scales from a total of 346 hickory shad were taken from the Albemarle Sound area during 1984, and 203 were subsampled for aging. The subsample for each year was expanded in each modal size group (25 mm groups) to obtain the age composition of the total sample. During 1985, a total of 285 hickory shad scale samples were taken from the Albemarle Sound area. The scale samples will be subsampled, aged and the data presented in the next report.

During the project period, males ranged from 3 to 6 years old (Tables 31 and 32). Females were 3 to 7 years of age in 1983, while during 1984, ages were 4 to 8 years (Tables 31 and 32). Data from 1983 for sexes combined showed a population containing 75.3% virgins, while 4.0% had spawned more than once before. The 1984 hickory shad data showed only 15.0% virgin fish (sexes combined), while 30.7% had spawned more than once previously. The percentage of virgin fish in 1983 is similar to that found by Johnson et al. (1981) for 1977-79 (64-85%). However, the percentage found in 1984 is even lower than that of 1982 (21.6%) (Winslow et al. 1983). The 1984 value is the lowest percentage of virgin fish reported for the Albemarle Sound area. This is probably the result of a poor year class (1980-1981) entering the population. It should also be noted that these data may not accurately represent the hickory shad population due to gill nets being selective for females.

DEVELOPMENT OF RESEARCH AND MANAGEMENT ALTERNATIVES

North Carolina has the largest river herring fishery on the Atlantic Coast. The condition of the stocks captured and produced in North Carolina could determine the overall status of the fishery. Landings have been on a declining trend since 1970, with the 1985 landings being the highest in the last 14 years (Table 2). The present poor state of the stocks is attributed to heavy exploitation of the stocks by the foreign offshore fishery in the late 1960s and early 1970s, and poor reproductive success since then. Deteriorating water quality may probably have contributed to reproductive failure of the Albemarle Sound area river herring stocks since reduction of foreign fishing in the mid-1970s.

The Albemarle Sound area, especially the Chowan River and western Albemarle Sound area, has experienced deteriorating water quality as a result of eutrophication and other factors. Severe blue-green algae blooms may have an adverse effect 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. Additional research beyond the stock assessment activities of DMF is needed to address these issues. Criteria need to be established for the designation of alosid nursery areas in the Albemarle Sound and Currituck Sound areas to enable these areas to be protected from alteration and pollution.

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APPENDIX

Appendix Table 1. Age and spawning frequency of blueback herring and alewife captured in Salmon Creek, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	0	5							0	5
V	0	1	3	4					3	5
VI			1	1	1	2			2	3
VII					0	1	0	1	0	2
TOTAL	0	6	4	5	1	3	0	1	5	15

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	1	0							1	0
IV	9	2							9	2
V	1	1	5	4					6	5
VI			1	0					1	0
TOTAL	11	3	6	4					17	7

Appendix Table 2. Age and spawning frequency of blueback herring and alewife captured in Rockyhock Creek, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	3	1							3	1
V			2	0					2	0
VI										
TOTAL	3	1	2	0					5	1

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	1	0							1	0
V	2	1	3	0					5	1
VI			2	1					2	1
TOTAL	3	1	5	1					8	2

Appendix Table 3. Age and spawning frequency of blueback herring and alewife captured in Bennetts Creek, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
IV	3	2							3	2
V	0	1	5	2					5	3
VI			1	2	0	2			1	4
VII					0	1	0	1	0	2
TOTAL	3	3	6	4	0	3	0	1	9	11

Alewife

	Number of times spawned									
	0		1		2		3		Total	
Age	M	F	M	F	M	F	M	F	M	F
IV	2	0							2	0
V									0	0
VI			1	0					1	0
TOTAL	2	0	1	0					3	0

Appendix Table 4. Age and spawning frequency of blueback herring and alewife captured in Catherine Creek, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	3	0							3	0
V			7	1					7	1
VI			2	0	2	0			4	0
VII					1	0	0	1	1	1
TOTAL	3	0	9	1	3	0	0	1	15	2

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	1	1							1	1
V			3	0					3	0
TOTAL	1	1	3	0					4	1

Appendix Table 5. Age and spawning frequency of blueback herring and alewife captured in Dillard Creek, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
III	2	0							2	0
IV	13	6							13	6
V	1	1	9	3					10	4
VI			3	1	1	0			4	1
TOTAL	16	7	12	4	1	0			29	11

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	12	3							12	3
V	3	1	5	0					8	1
VI			1	0					1	0
TOTAL	15	4	6	0					21	4

Appendix Table 6. Age and spawning frequency of blueback herring and alewife captured in Chinkapin Creek, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	1	0							1	0
TOTAL	1	0							1	0

Alewife

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	1	0							1	0
V	1	0	1	1					2	1
VI					0	1			0	1
TOTAL	2	0	1	1	0	1			3	2

Appendix Table 7. Age and spawning frequency of blueback herring and alewife captured in Wiccacon River, North Carolina during spawning area survey, 1983.

Blueback herring

	Number of times spawned								Total	
	0		1		2		3			
Age	M	F	M	F	M	F	M	F	M	F
IV	0	2							0	2
V			1	1					1	1
VI			0	1					0	1
TOTAL	0	2	1	2					1	4

PROJECT II

STRIPED BASS PROJECT

ABSTRACT

Relative abundance of juvenile striped bass was determined in the Albemarle Sound area, North Carolina. Data indicated that natural reproduction was generally unsuccessful, and very poor year classes were produced. A total of 67,433 Phase II striped bass were stocked in Albemarle Sound during December 1983. Of the 2,498 fish that were tagged, 216 were returned during this project. The Cape Fear River was stocked with 56,437 Phase II striped bass during December 1983 and January 1984. Six tags were returned from the 1,395 tagged. During December 1984, 25,000 Phase II striped bass were released in the Pamlico River. A total of 1,000 fish were tagged, and 21 tags were returned. The Albemarle Sound area was stocked with 236,242 Phase II striped bass during December 1984. Of the 6,445 fish that were tagged, 311 were returned during the project. Trawling was conducted in the Croatan Sound and Albemarle Sound areas to capture adult striped bass for tagging; only one was captured. In December 1983, 28,194 Phase II striped bass were released in Lake Mattamuskeet, North Carolina. Nine hundred ninety-three fish were tagged; nine tags have been returned.

INTRODUCTION

Striped bass, (Morone saxatilis) have supported significant fisheries in coastal North Carolina since Colonial times. Historically, commercial and recreational fisheries have been most active in the northern portion of the coast, with year-round fisheries in the Albemarle Sound area and seasonal fisheries elsewhere. Over the last decade, principal commercial gears have been anchor gill nets, pound nets and haul seines in the estuaries and rivers, and beach seines and fish trawls in the ocean (Street and Johnson 1977).

In the past decade striped bass populations have declined along the entire Atlantic Coast (Atlantic States Marine Fisheries Commission 1981). The landings in North Carolina have declined, with the recent catches being the lowest since the 1930s. Despite the decline in landings, the pressures on this resource have increased because of its high market value.

Various aspects of striped bass life history throughout the coastal area of North Carolina have been investigated since the late 1960s under several Anadromous Fish Act (PL89-304) federal aid projects (Street et al. 1975, Johnson et al. 1977, Keefe and Hassler 1981, Harriss 1982). The majority of the work has been concentrated in the Albemarle Sound area.

Dominant year classes have been noted in Albemarle Sound striped bass in 1956, 1959 and 1967 (Hassler et al. 1981). The same report indicated lack of even a strong year class since 1976. Consequently, fewer fish have recruited into the commercial and sport fisheries in recent years. Factors responsible for the lack of dominant year class are believed to be a reduction in egg viability during 1975-80 (Hassler et al. 1981) and poor water quality conditions. Water quality in the Albemarle Sound area has been severely degraded during recent years. Such environmental changes could have detrimental effects on striped bass eggs, larvae, and juveniles (Guier et al. 1980). Poor environmental conditions may be the major factor in the lack of production of a dominant year class.

This investigation is a continuation of striped bass fisheries research and management work initiated in 1971 (juvenile monitoring) and modified in 1980 to also include Phase II stocking and evaluation. Objectives of this project were to stock Phase II striped bass in coastal waters of North Carolina, evaluate the stockings to determine their effects and contribution to the populations and the harvest, monitor juvenile year class abundance of striped in Albemarle Sound, and tag adult striped bass overwintering in the Croatan Sound area, N.C.

The Phase II striped bass stocking program is conducted in cooperation with the U.S. Fish and Wildlife Service under a Cooperative Agreement between the North Carolina Department of Natural Resources and Community Development and the Service .

STUDY AREA

The Albemarle Sound, Cape Fear River, and Pamlico River areas were described by Winslow et al. (1983) (Figure 1).

Lake Mattamuskeet

Lake Mattamuskeet (Figure 2) is the largest natural freshwater lake in North Carolina encompassing an area of 172.8 km^2 (66.7 mi^2) (Heath 1975). Natural drainage was to the north, towards the Alligator River. Depths in the lake average less than 1 m (2.5 ft), and the bottom is predominantly sand except where silt and clays have entered drainage canals (Heath 1975). Since the completion of Lake Landing Canal in 1838, other canals connecting the lake to Pamlico Sound and Alligator River have been dug; drainage is now

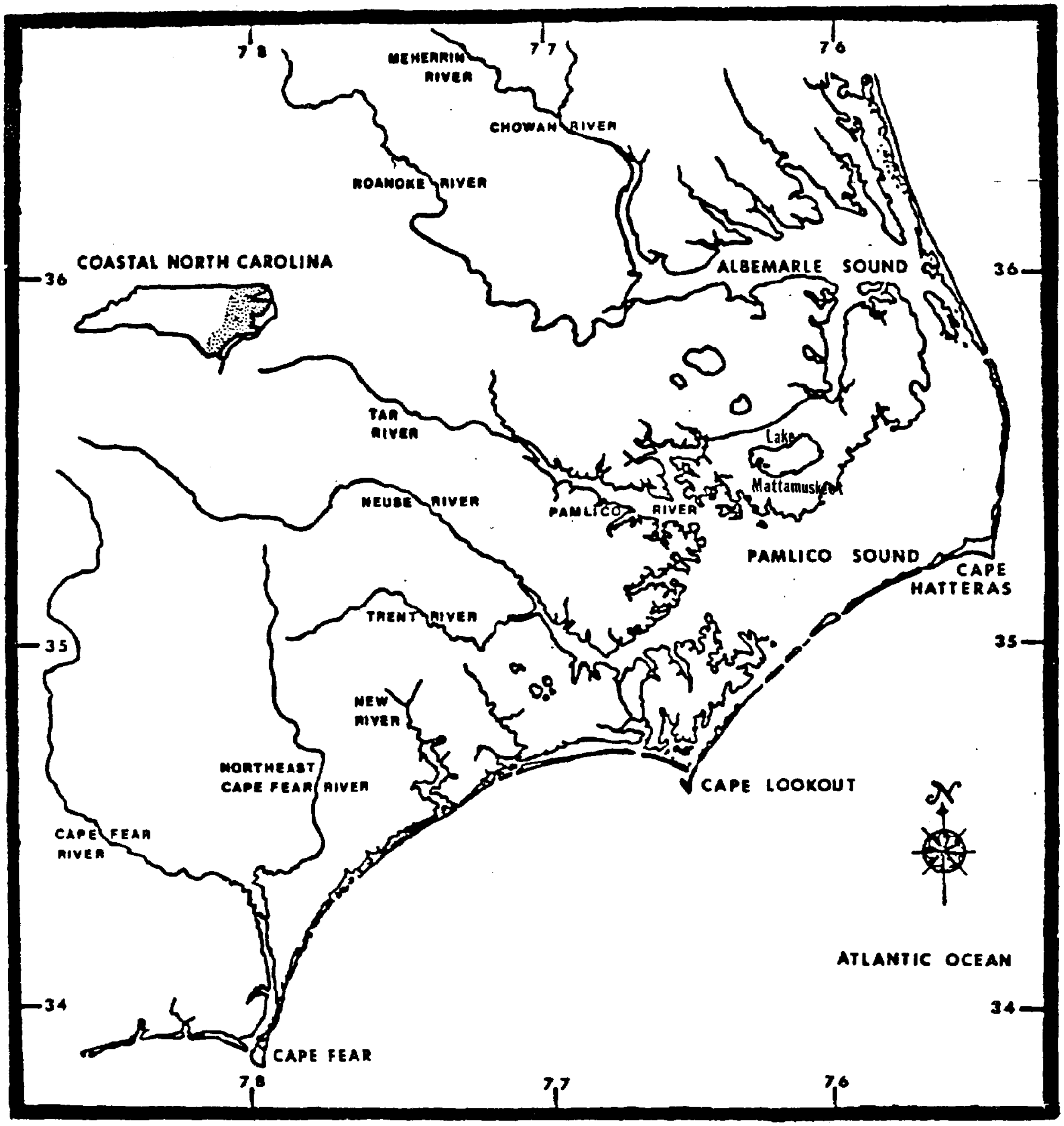

Figure 1. Coastal North Carolina.

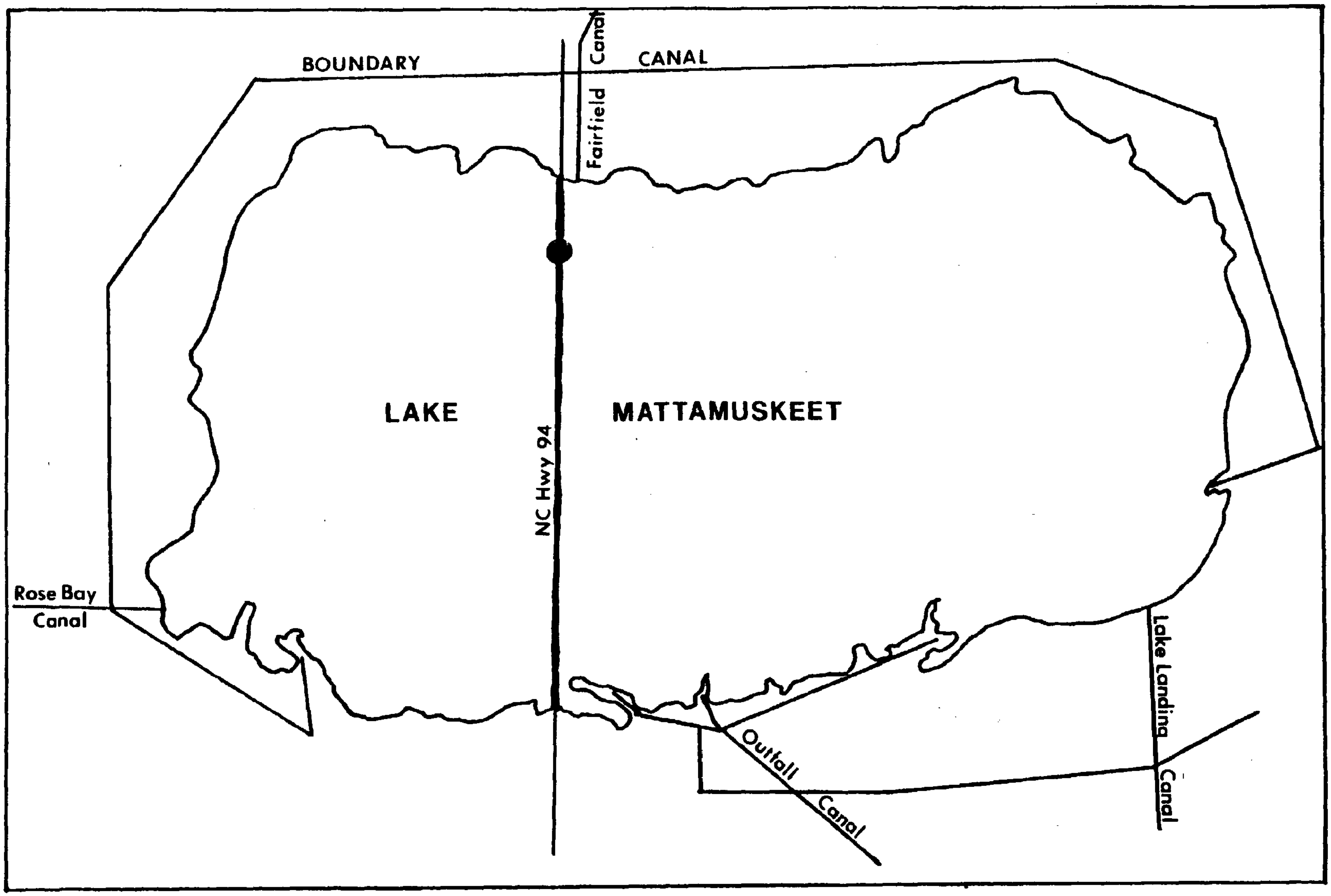

Figure 2. Lake Mattamuskeet, North Carolina.

principally toward Pamlico Sound, to the east and south. In 1913 the lake was drained via an extensive network of canals, ditches and a pumping station in order to form the fertile bottom. In 1933 the ambitious project was abandoned, and in 1934 the lake and adjoining land was purchased to form the Mattamuskeet National Wildlife Refuge.

MATERIAL AND METHODS

Juvenile Striped Bass Sampling

In the western Albemarle Sound area, weekly sampling was conducted at seven established stations during July-October, 1983 (Figure 3). During the same time period in 1984, these stations were sampled bi-weekly. These stations have been sampled since 1955 for relative abundance of young-of-year striped bass by Dr. W. W. Hassler and are described in Hassler et al. (1981). This area has historically functioned as the natural striped bass nursery area in Albemarle Sound. With the deterioration of water quality in western Albemarle Sound, it was suspected that the nursery area may have shifted eastward. Exploratory sampling (26 stations) was conducted during August 1983 in central and eastern Albemarle Sound (Figure 4). Young-of-year striped bass were captured, 12 stations were established and sampled bi-weekly during July-October, 1984 (Figure 5).

All stations were sampled with a 5.49 m (18 ft) head rope, semi-balloon trawl, containing webbing which ranged from 19.05 mm (3/4 in) in the body to a 6.3 mm (1/4 in) cod end. The trawl was pulled for 10-15 min at 1,000 rpm by a 7.9 m (26 ft) boat, with twin 130 horsepower inboard engines.

All striped bass captured were measured to the nearest millimeter, fork length (mm, FL). Other species captured were also noted, as were environmental parameters (water temperature, dissolved oxygen and salinity).

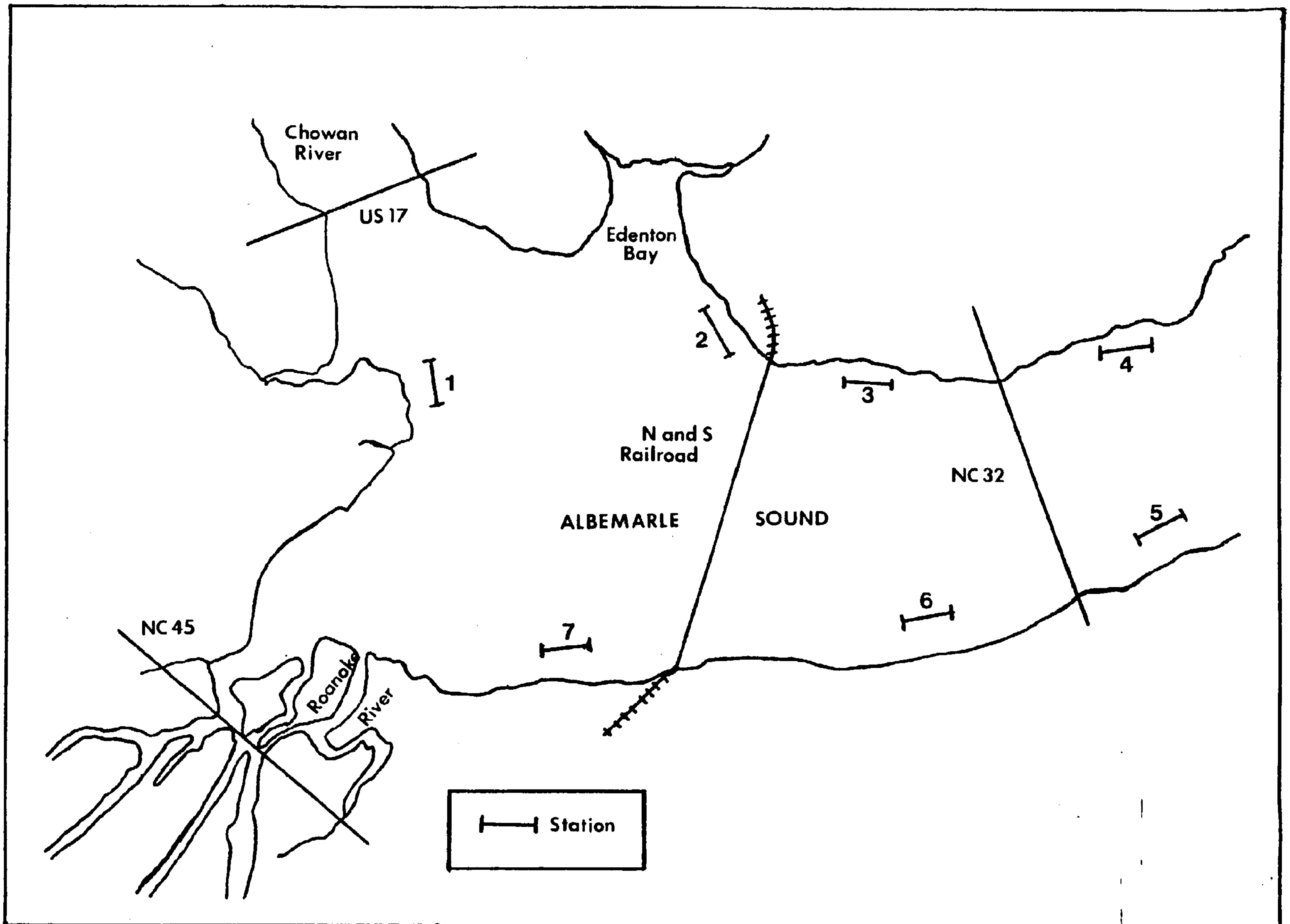

Figure 3. Station locations for young-of-year striped bass sampling in western Albemarle Sound area, North Carolina, 1983-1984.

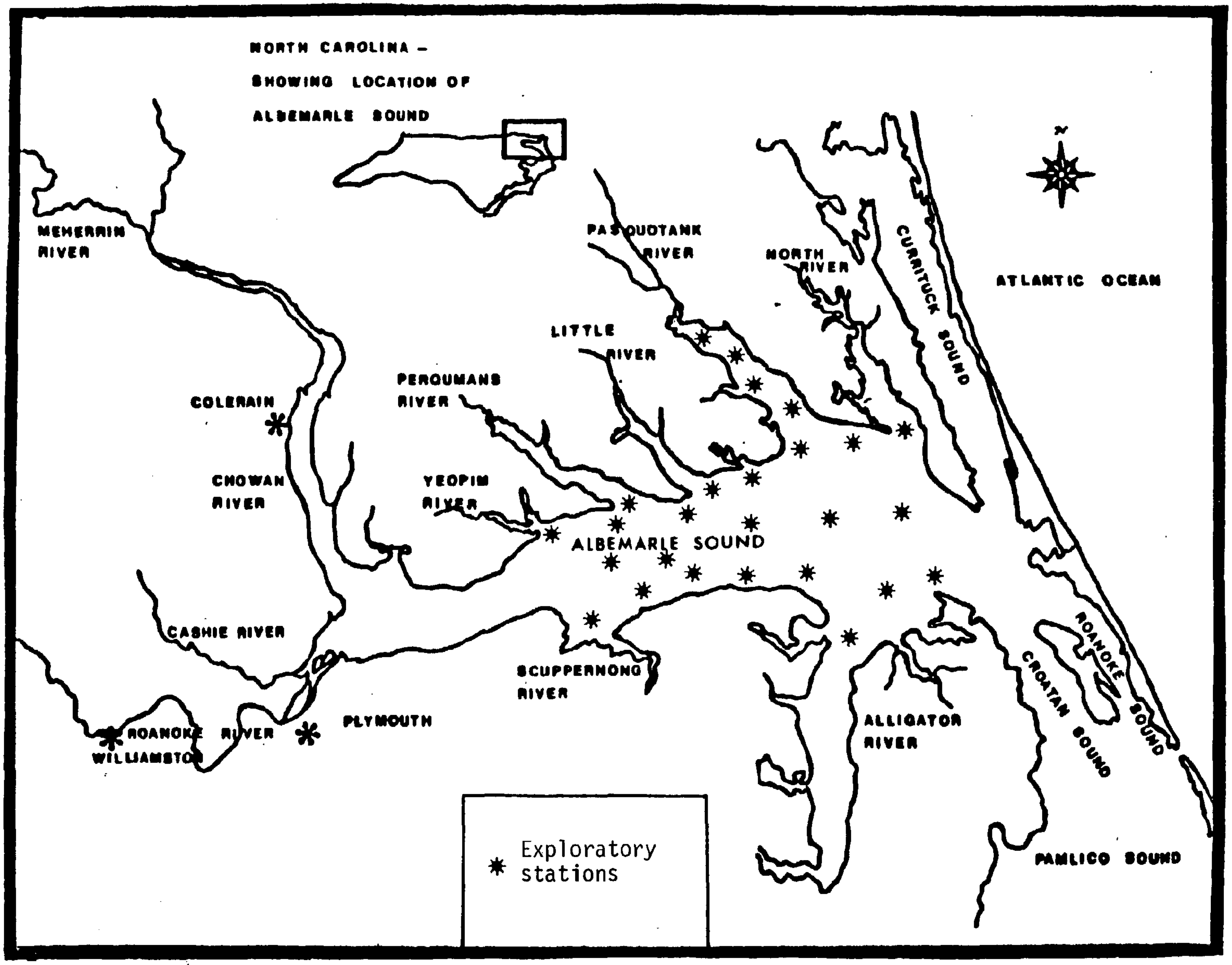

Figure 4. Locations of exploratory stations sampled for young-of-year striped bass in central and eastern Albemarle Sound, North Carolina,1983.

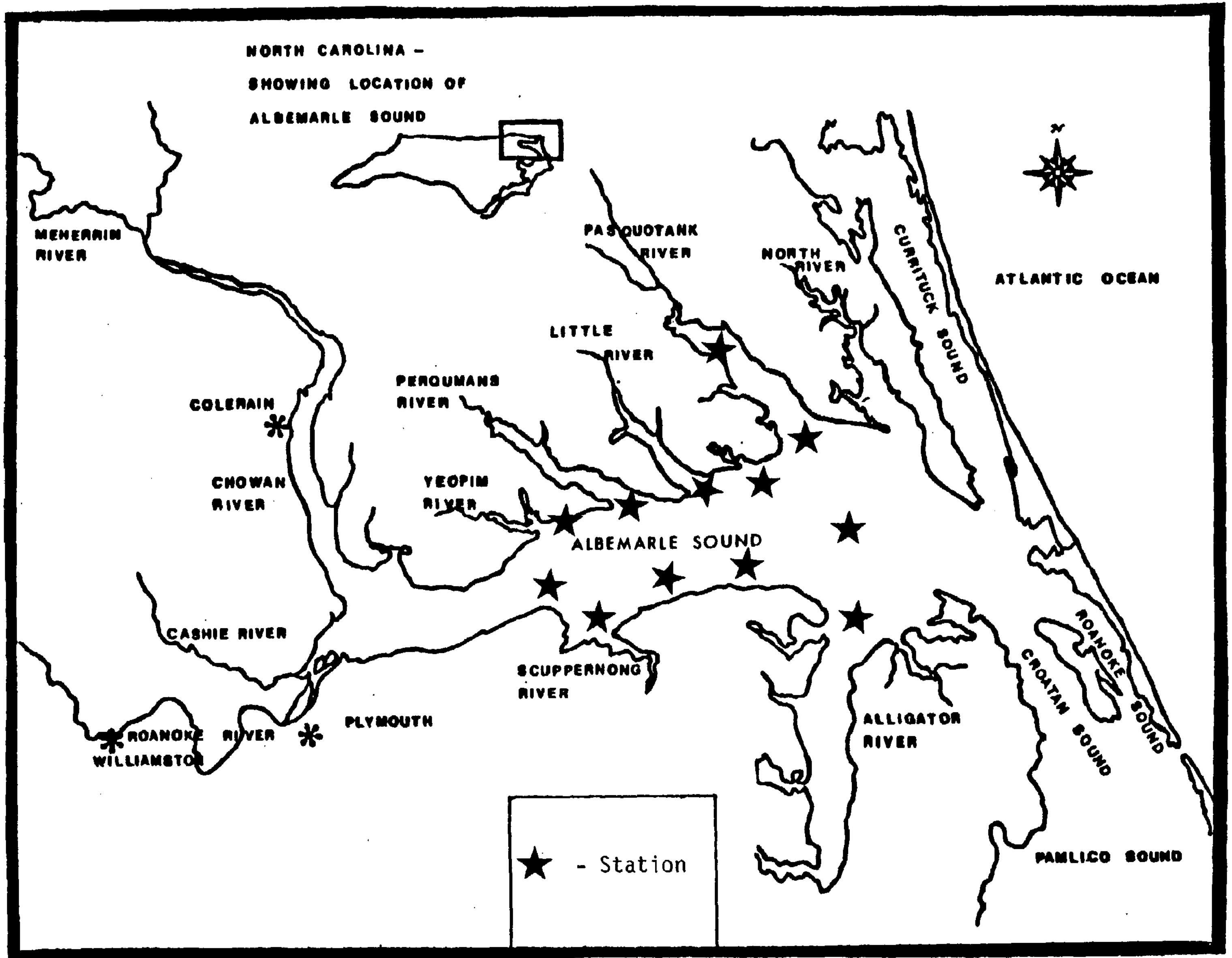

Figure 5. Station locations for young-of-year striped bass sampling in central and eastern Albemarle Sound area, North Carolina, 1984.

Catch/effort was determined to establish an index of abundance for the 1983 and 1984 year classes.

Phase II Striped Bass Stocking and Evaluation

Phase II striped bass from various spawning areas were obtained from U.S. Fish and Wildlife Service fish hatcheries located in North Carolina during 1983 and 1984, and also in Georgia, Alabama and Florida in 1984.

Brood fish from various spawning areas were artifically spawned and the larvae reared using the techniques of Bonn et al. (1976). The fish were harvested from the ponds in late fall or winter at approximately 102-254 mm (4-10 in) TL. The Phase II fish were transported to tanks in the holding house for inventory and tagging. Those fish not selected for tagging were transported to the appropriate stocking locations.

Prior to stocking, a portion of the fish were tagged with cinch-up spaghetti tags to determine time at large, distribution, migration, utilization, mortality, and contribution to the fishery in each area stocked. These tags were approximately 123 mm (5 in) long. The Phase II fish were retrieved from the tanks in the holding house and placed on pieces of water-saturated foam rubber. The tags were loaded in the canula and the canula inserted through the back of the fish just under the soft dorsal. The canula was removed leaving the tag in the fish; the end was cinched up and the excess cut off. The average tagging rate was approximately two hundred fish per hour.

The tagged fish were put in another holding tank and treated with a 3% salt solution. Tagged fish were held two to seven days prior to stocking to establish short term tagging mortality rates. The Phase II striped bass were loaded on a U.S. Fish and Wildlife Service tank truck and transported to the appropriate stocking location.

The stocking and tagging programs were widely publicized. Rewards were offered for the return of the tags and the following information about the recapture: date, location, and type of gear. Out of each 100 tags there were five $5.00, five $10.00, two $25.00 and 88 $1.00 randomly-assigned rewards.

Phase II striped bass were released in the Cape Fear River in 1983, Pamlico River in 1984 and Albemarle Sound both years (Figure 6).

Adult Striped Bass Tagging

During December-January, 1983-84 and 1984-85, sampling was conducted in the Croatan Sound and eastern Albemarle sound areas in order to capture adult striped bass (Figure 7). This area was known to serve as overwintering grounds for striped bass (Street et al. 1975). The sampling gear consisted of 9.1 m (30 ft) and 13.1 m (43 ft) wing trawls. Tow times ranged from 15-30 minutes.

Up to 500 striped bass were to be tagged with dart tags and released. Age, sex, and size data were to be obtained from 10% of the striped bass captured. Environmental data were collected each fishing day.

Rewards of $1.00-$25.00 were to be paid for the return of tags and information on recapture location, data and gear. The program was to be publicized by news releases and reward posters.

Lake Mattamuskeet Striped Bass Stocking, Tagging and Evaluation

During December 1983, approximately 30,000 Phase II striped bass were stocked in Lake Mattamuskeet, North Carolina, by the U.S. Fish and Wildlife Service (Figure 2). Up to 1,000 of these fish were to be tagged with Carlin disc tags prior to stocking. The tagging procedures were the same as those described by Winslow et al. (1983).

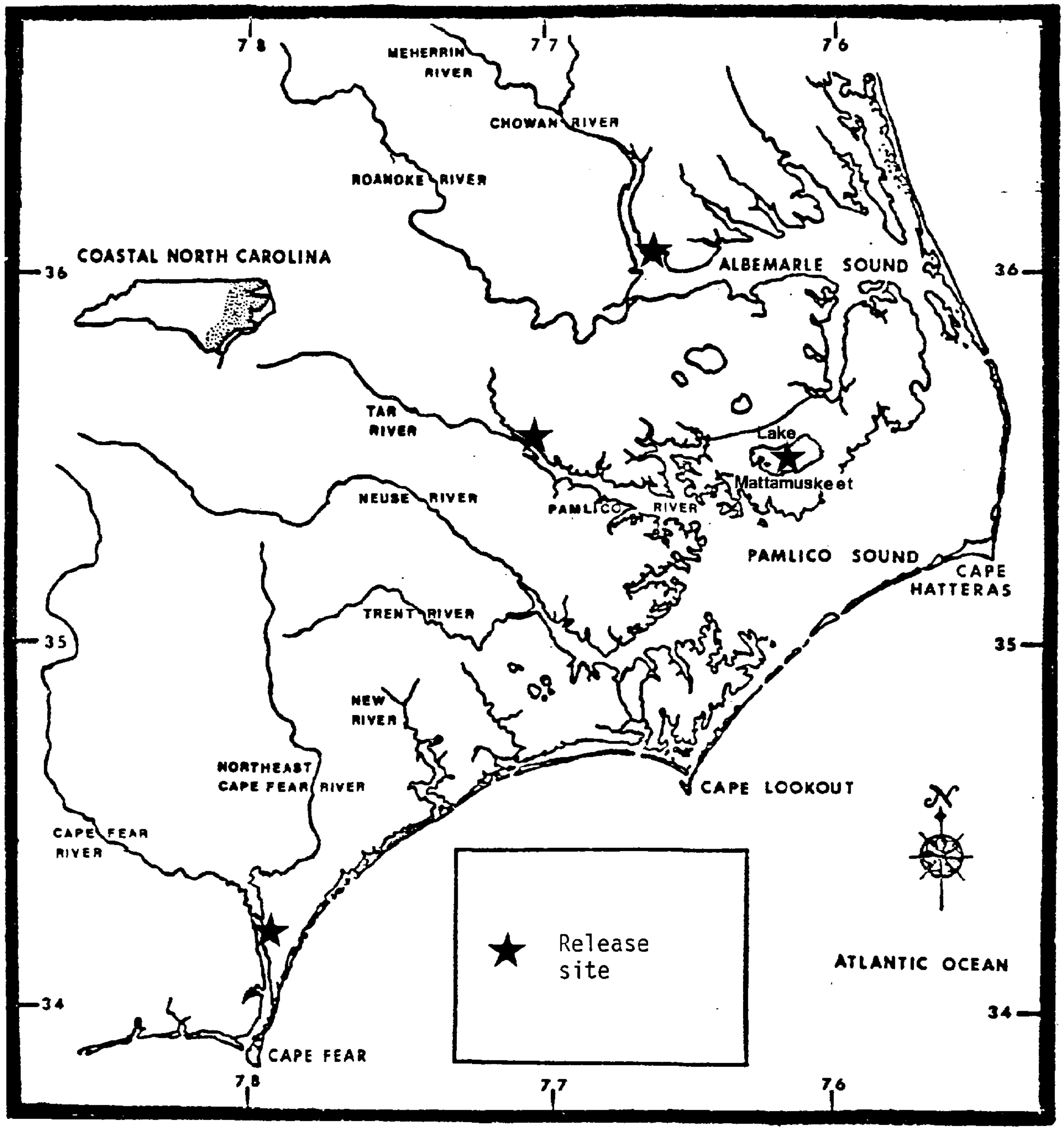

Figure 6. Release sites of Phase II striped bass, 1983-1984.

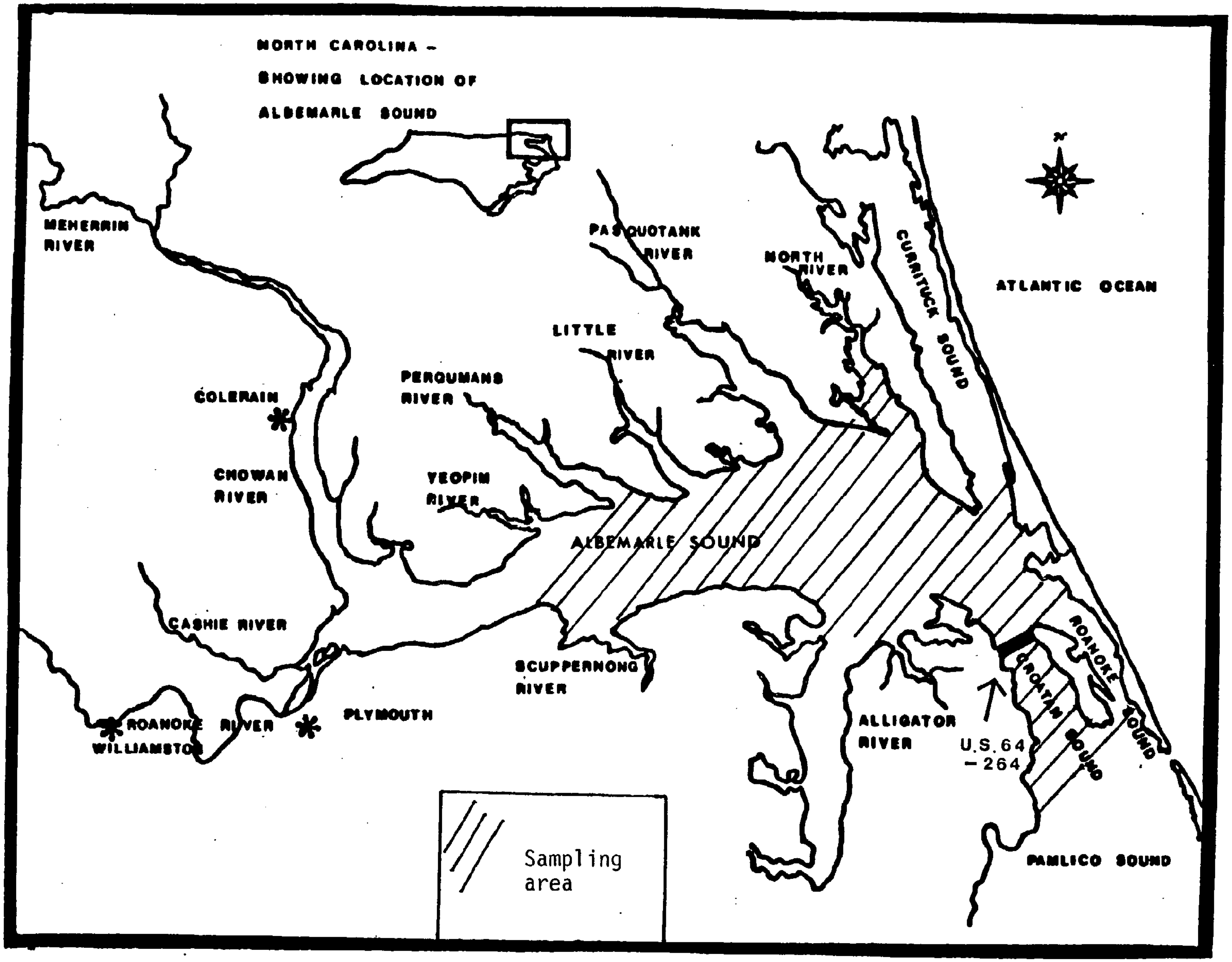

Figure 7. Sampling area for adult striped bass tagging December 1983, 1984 and 1985.

The stocking and tagging program was publicized. Rewards were offered for the return of the tags and information on where and when the fish were captured. From each 100 tags there were five $5.00, five $10.00, two $25.00 and 88 $1.00 randomly-assigned rewards.

RESULTS AND DISCUSSION

Juvenile Striped Bass Sampling

During July-October 1983, a total of 112 trawl samples were taken in the western Albemarle Sound area (Figure 3), and 40 young-of-the-year striped bass were captured. The 1983 catch/effort was 0.36. Table 1 shows the date and number of young-of-year striped bass captured by station during 1983. The 1983 relative abundance falls far below the 26-year mean of 6.81 as reported by Hassler et al. (1981), for 1956-1980. In 1984 (July-October), 49 samples were taken, and no striped bass were captured. Based on data presented in Hassler et al. (1981), Hassler and Taylor (1984), and Hassler (pers. comm.) for 1956-1984, striped bass were captured every year. Thus, the results in 1984 are unprecedented.

In August 1983, 26 exploratory samples were taken in central and eastern Albemarle Sound (Figure 4). A total of 39 young-of-year striped bass were captured, resulting in a CPUE of 1.5. Based on these exploratory samples, 12 stations were established and are shown in Figure 5. A total of 84 samples were taken in 1984, with only one week sampled in August and September due to engine breakdowns and weather. Twelve young-of-year striped bass were captured all in August, for a catch/effort of 0.14.

Young-of-year fish may have been utilizing this area in previous years, but sampling was not conducted in these areas. It is possible, that because

Table 1. Number of young-of-year striped bass captured by semi-balloon trawl in western Albemarle Sound, North Carolina, by station, July-October 1983.

	Station Number							
Date	1	2	3	4	5	6	7	Total
July and August - No catch								
09/02/83	0	0	0	1	0	0	0	1
09/12/83	0	0	0	0	0	0	1	1
09/26/83	0	2	0	0	0	0	1	3
10/13/83	1	3	7	0	4	1	1	17
10/20/83	3	1	7	0	2	0	4	17
10/27/83	1	0	0	0	0	0	0	1
TOTAL	5	6	14	1	6	1	7	40

of water quality deterioration in the western sound, the nursery area has shifted eastward. The catch/effort from the central and eastern areas cannot be used for comparison with past data from the western area. However, since regular sampling has now been implemented in these areas, comparisons in the future may be possible.

Phase II Striped Bass Stocking and Evaluation

Edenton Bay/Albemarle Sound 1983

During December 1983, 67,433 Phase II striped bass from the Edenton National Fish Hatchery were released in Edenton Bay, a tributary of Albemarle sound. On 16 December 1983, 2,493 of these fish were tagged and released at the same location (Figure 8). This area is known to function as the natural striped bass nursery area (Street et al. 1975, Johnson et al. 1977) Tagging mortality for this stocking was 0.28% for a 72 hr time period.

As of 30 June 1985, 216 tags (8.7%) had been returned. Gill nets were the predominant type of recapture gear (98.1%) with the remainder taken by rod and reel (Table 2). The mesh sizes and directed fisheries remained the same as reported by Winslow and Johnson (1984). Early returns occurred when the tag became entangled in gill nets. Returns are shown by calendar quarter for the 1983 Edenton Bay stocking in Table 3.

The majority of these fish attained legal size, 305 mm (12 in) TL, during August-October 1984 and recruited into the striped bass fishery. Of the 216 tags returned, only 11.6% have occurred since reaching legal size.

Recapture locations are shown in Figures 8 through 15. The movements of the pre-recruits were very similar to those for 1981 and 1983 (January) stocking (Winslow and Johnson 1984). That is, striped bass remained in the eastern portion of Albemarle Sound, especially along the southeastern

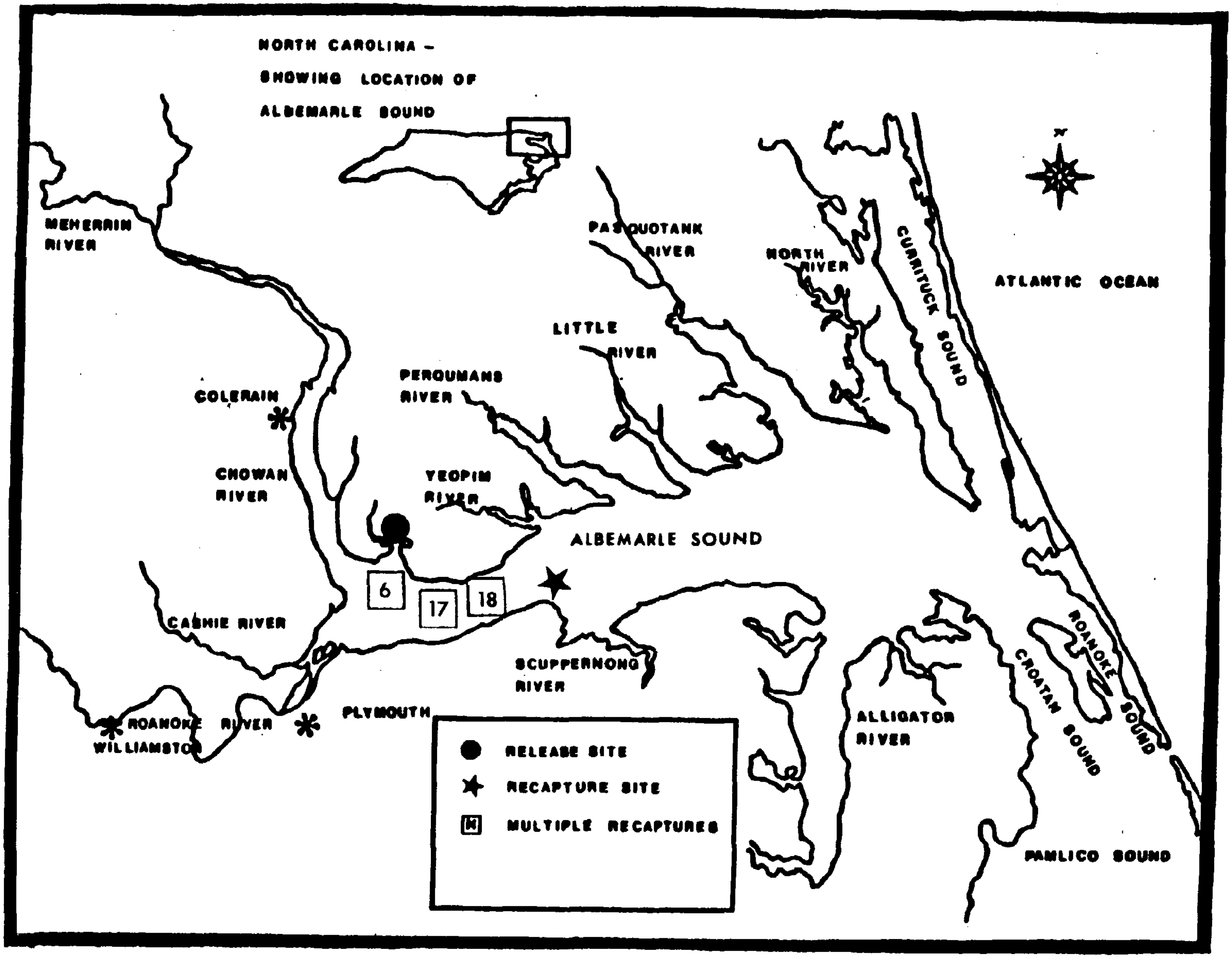

Figure 8. Recapture locations of Phase II striped bass, Edenton Bay stocking, 1983 (December 1983, 42 returned)

Table 2. Gear used to recapture striped bass in North Carolina coastal waters December 1983 - December 1984.

Recapture gear	Edenton Bay 1983		Cape Fear River 1984		Pamlico River 1984		Albemarle Sound 1984		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Gill net	212	98.1	5	83.3	19	90.4	308	99.1	544	98.2
Rod and reel	4	1.9	0	0	1	4.8	2	0.6	7	1.3
Pound net	0	0	0	0	0	0	1	0.3	1	0.2
Trawl	0	0	1	16.7	1	4.8	0	0	2	0.3
TOTAL	216		6		21		311		554	

Table 3. Phase II striped bass tag return summary by quarter from Edenton Bay stocking, 1983.

Quarter	Number returned	Days at large mean	Days at large range	Distance from release site (miles) mean	Distance from release site (miles) range
December 1983	42	10.5	5-14	6.9	2- 15
January-March 1984	128	45.3	16-104	9.3	2- 38
April-June 1984	16	88.1	107-189	26.6	6- 45
July-September 1984	4	246.2	204-284	40.7	16- 79
October-December 1984	14	348.8	301-373	42.5	14-173
January-March 1985	11	431.7	386-470	27.9	10- 42
April-June 1985	1	490	-	44	-
TOTAL	216				

Table 4. Phase II striped bass tag return summary by quarter from Cape Fear River stocking, 1984.

Quarter	Number returned	Days at large mean	Days at large range	Distance from release site (miles) mean	Distance from release site (miles) range
January-March 1984	6	7.3	3-45	2.7	1.7
TOTAL	6				

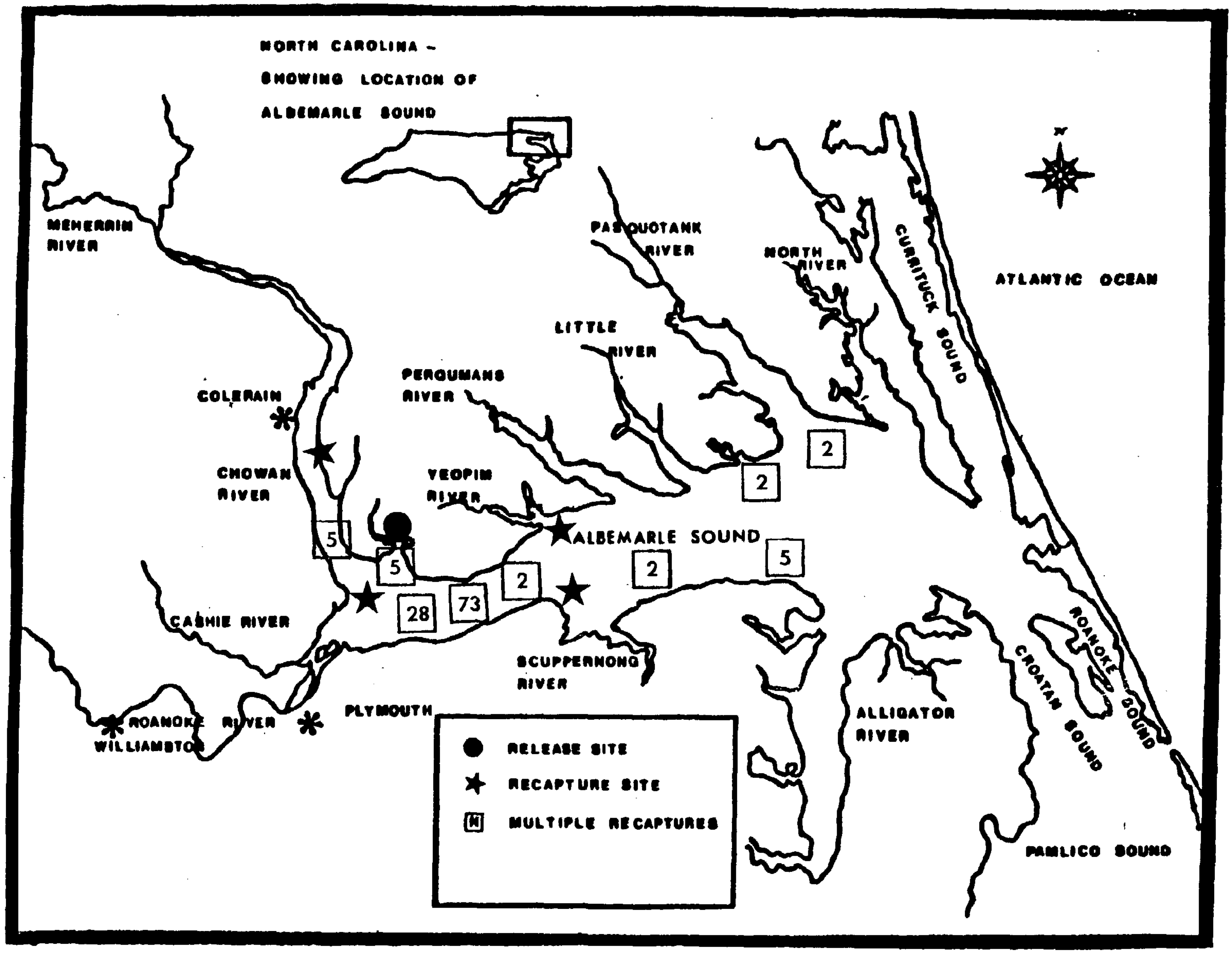

Figure 9. Recapture locations of Phase II striped bass, Edenton Bay stocking, 1983 (January - March 1984, 128 returned).

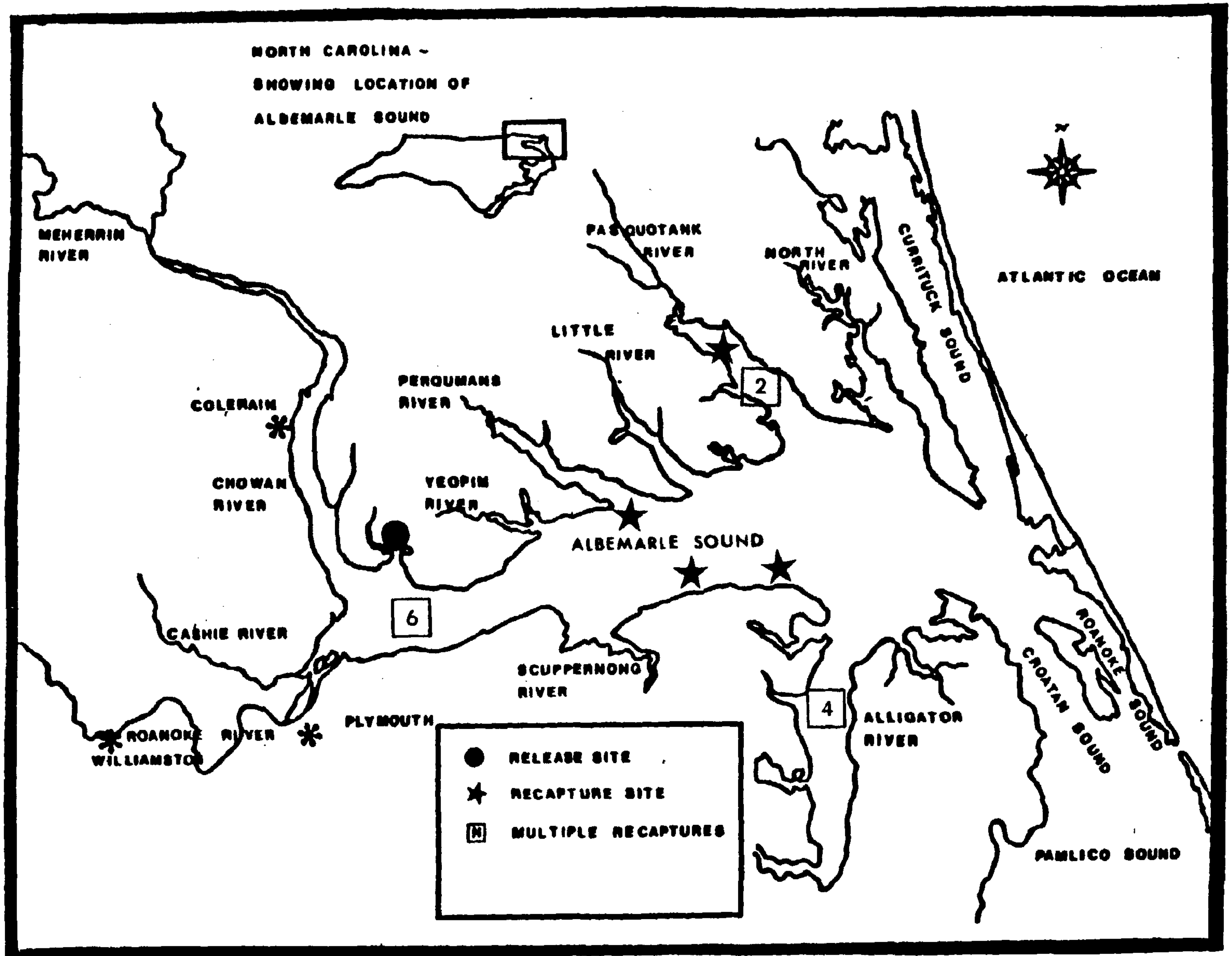

Figure 10. Recapture locations of Phase II striped bass, Edenton Bay stocking, 1983 (April - June 1984, 16 returned).

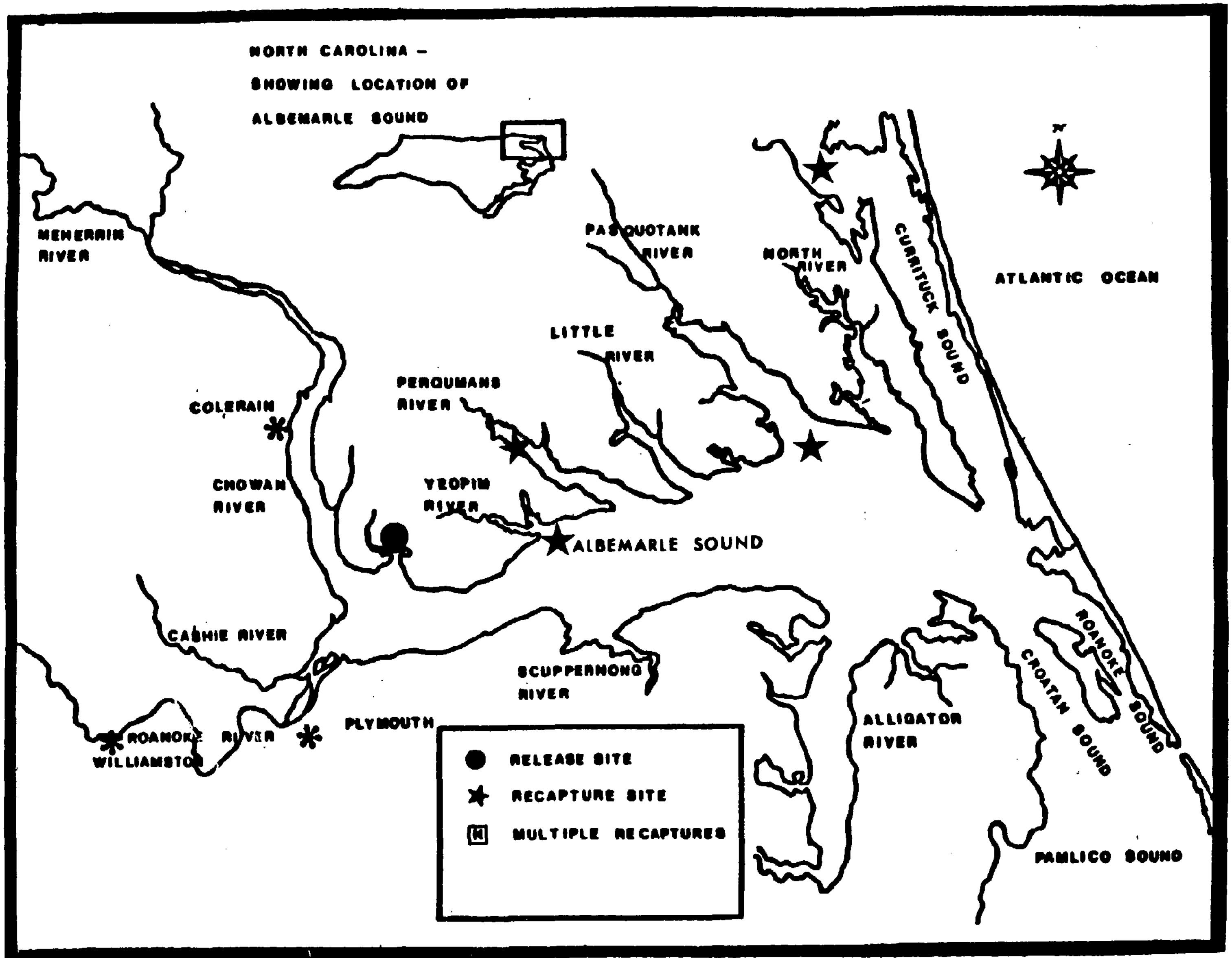

Figure 11. Recapture locations of Phase II striped bass, Edenton Bay stocking, 1983 (July - September 1984, 4 returned).

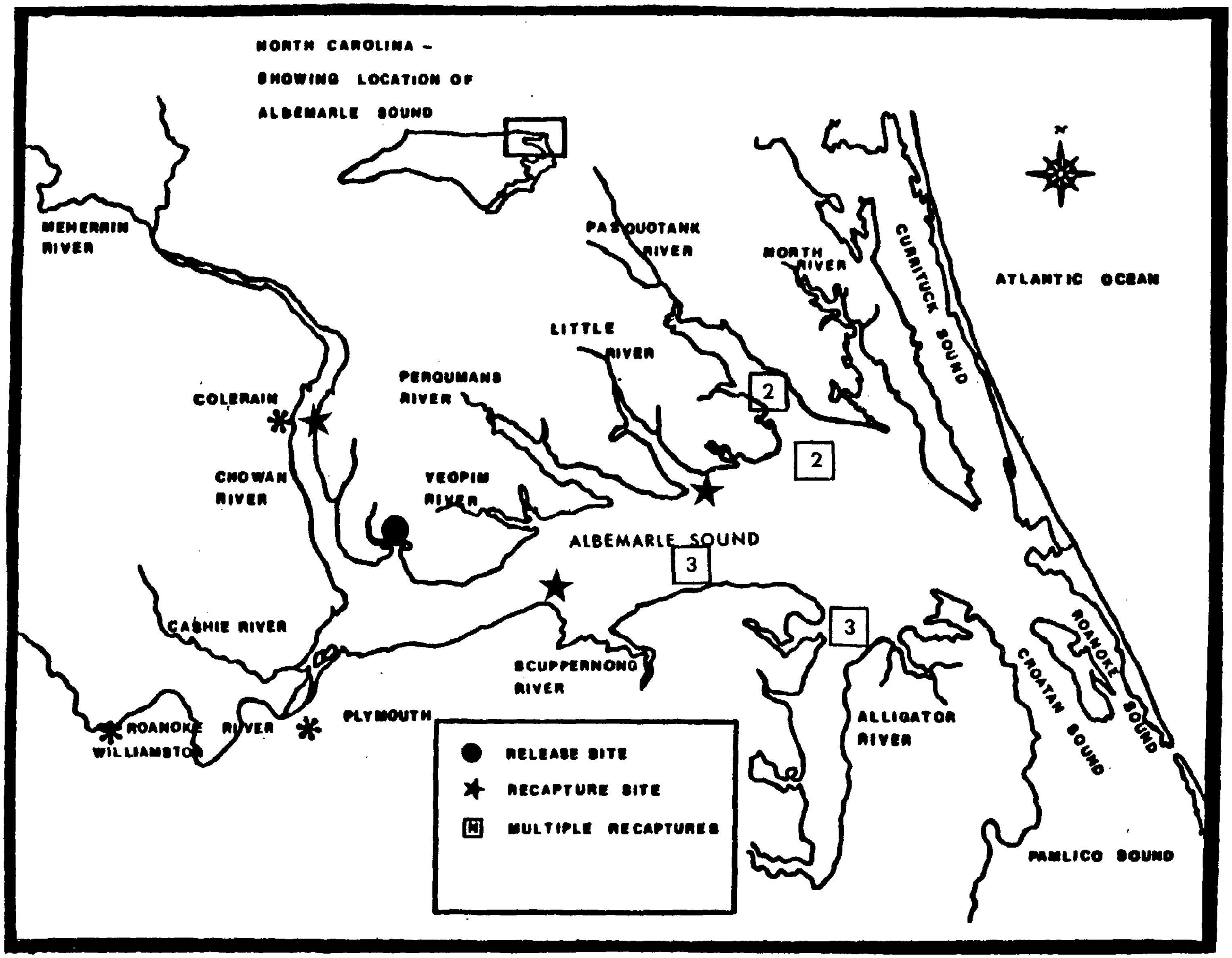

Figure 12. Recapture locations of Phase II striped bass within North Carolina, Edenton Bay stocking, 1983 (October - December 1984, 13 returned).

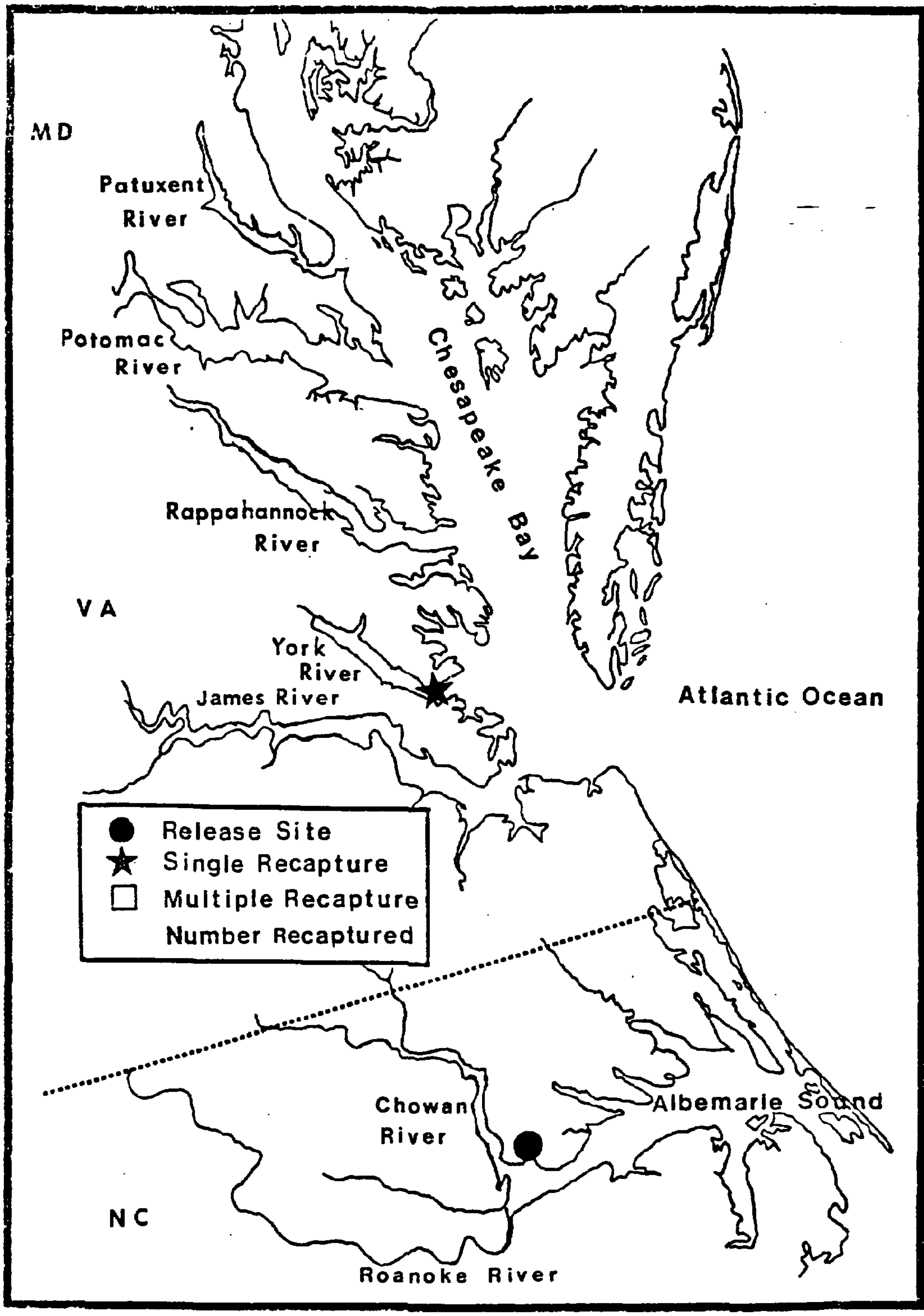

Figure 13. Recapture locations of Phase II striped bass outside North Carolina, Edenton Bay stocking, 1983 (October - December 1984, 1 returned).

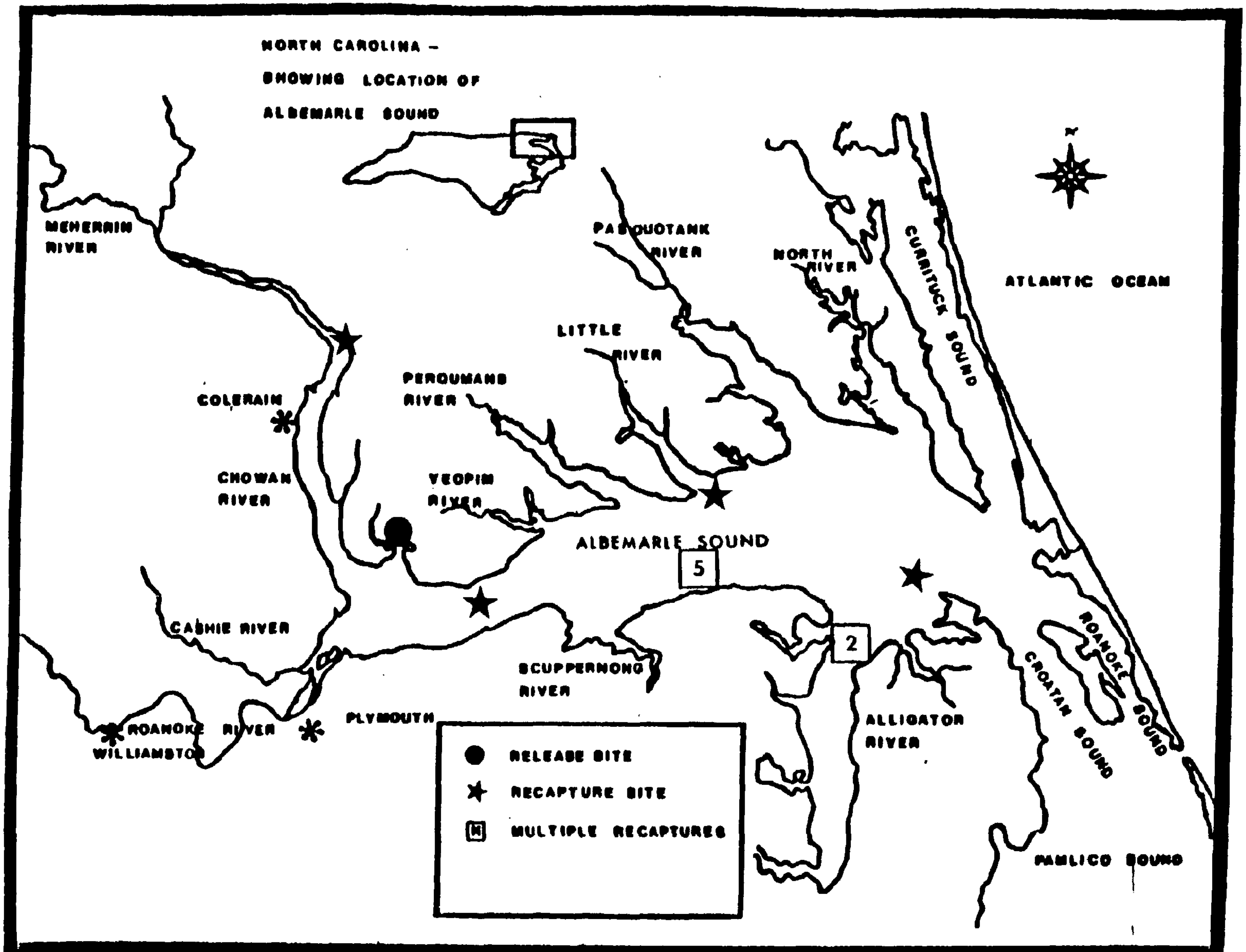

Figure 14. Recapture locations of Phase II striped bass, Edenton Bay stocking, 1983 January - March 1985, 11 returned).

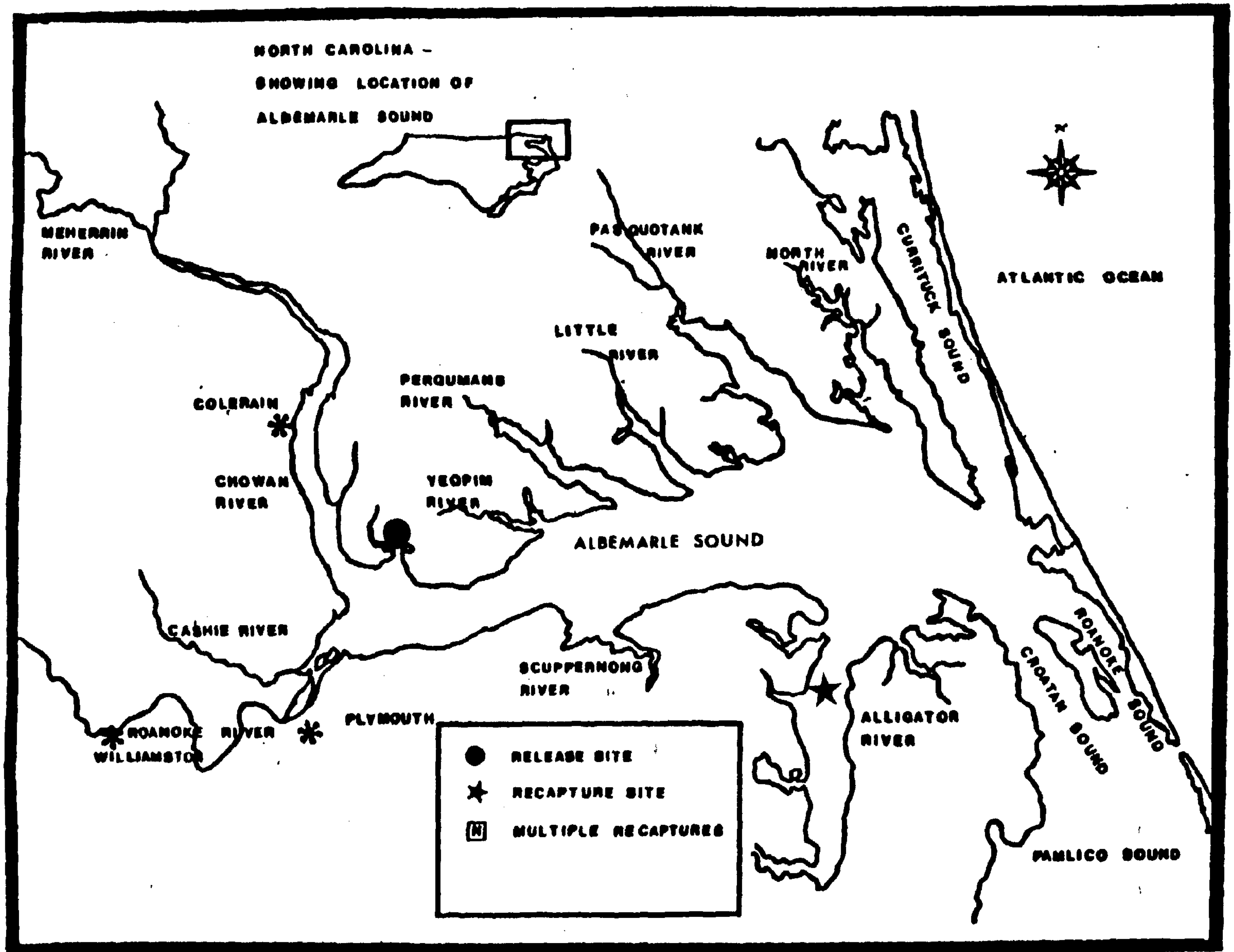

Figure 15. Recapture locations of Phase II striped bass, Edenton Bay stocking, 1983 (April - June 1985, 1 returned).

shore of the Sound and in the Alligator River area during the winter months (Figure 12). During the early spring, the fish began moving toward the western portion of the Sound (Figure 14). It is anticipated that as winter returns, the majority of the returns will once again come from the eastern Sound area.

The largest fish recaptured thus far was taken in November 1984; it measured 381 mm (15 in.) and weighed 1.02 kg (2.25 lb). This fish was at large 345 days and was recaptured in the York River, Virginia, approximately 173 miles from the release site (Figure 13). This was the only return from outside the Albemarle Sound area.

These fish have contributed to the commercial harvest and males will be sexually mature in the spring of 1986, possibly contributing to the spawning population.

Cape Fear River - 1984

The Cape Fear River at Wilmington, North Carolina, was stocked with 56,437 Phase II striped bass, from U. S. Fish and Wildlife Service fish hatcheries at McKinney Lake, North Carolina and Millen, Georgia during December 1983 and January 1984. Of the total, 1,395 were tagged with yellow cinch-up tags and released on 17 January 1984 (Figure 16). As reported by Sholar (1977) and Fischer (1979), this area serves as a natural striped bass nursery area. These fish were held for a 24 hr time period prior to stocking to establish the short term mortality rate, 0.36%.

As of 30 June 1985, six tags (0.4%) had been returned. All of these occurred during January-March 1984 (Table 4). Of these returns, 83.3% were taken by gill nets and 16.7% by trawls (Table 2). The recaptures from gill nets occurred when the tag became entangled in the mesh. The low number of tag returns could be a result of the striped bass regulations as described by

Winslow and Johnson (1984), and the low amount of fishing effort. The trawl return was from routine sampling conducted by personnel of Carolina Power and Light Company, Brunswick Steam Electric Plant.

The recapture locations are shown in Figure 16 for the 1984 Cape Fear River stocking. The areas in which these fish were recaptured are quite similar to those reported by Winslow and Johnson (1984) for the 1980 Cape Fear River stocking.

Pamlico River - 1984

During December 1984, 25,000 Phase II striped bass from Edenton and McKinney Lake National Fish Hatcheries, North Carolina, were stocked in the Pamlico River at Washington, North Carolina. On 20 December 1984, an additional 1,000 tagged fish were released (Figure 17). These fish were released in the natural striped bass nursery area as described by Marshall (1976) and Hawkins (1979). These fish were held for 24 hr to establish the short term mortality rate; there were no mortalities.

As of 30 June 1985, 21 tags (2.1%) had been returned. Gill nets were the predominant type of recapture gear (90.4%); 4.8% were captured by rod and reel and the same amount by trawl (Table 2). Similar to the previous stockings, early returns resulted mostly from the tag becoming entangled in gill nets. The returns are shown by calendar quarter for the Pamlico River stocking in Table 5.

Recapture locations are shown in Figures 17 and 18. These early returns closely agree with those reported by Winslow and Johnson (1984) for the Pamlico River stocking in 1983. The majority of the returns, 85.7%, have occurred between Washington and the mouth of Pamlico River (Figure 17 and 18).

These Phase II fish should recruit into the fishery during the fall of 1985.

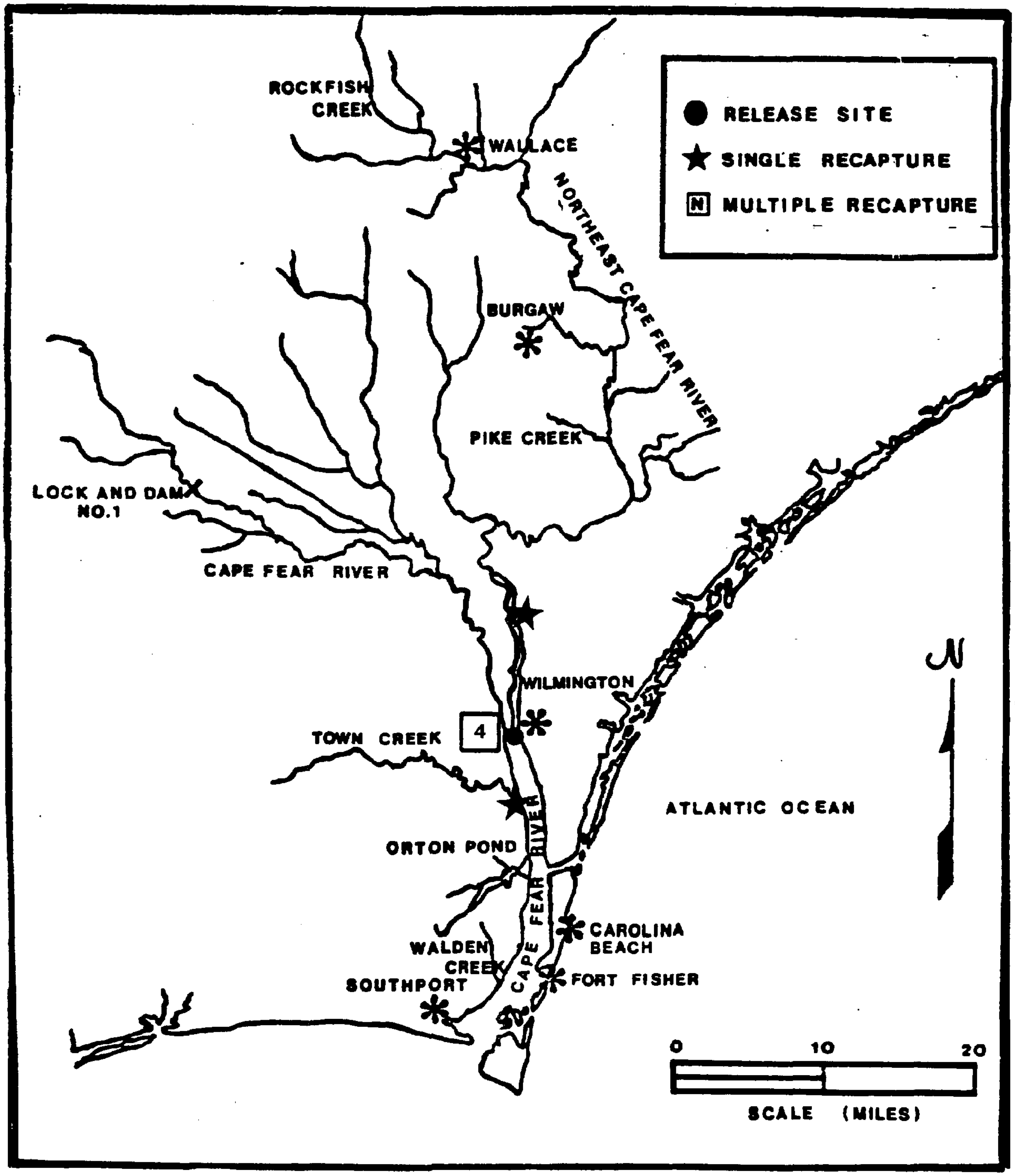

Figure 16. Recapture locations of Phase II striped bass, Cape Fear River stocking, 1984 (January - March 1984, 6 returned).

Table 5. Phase II striped bass tag return summary by quarter from Pamlico River stocking, 1984.

Quarter	Number returned	Days at large		Distance from release site (miles)	
		mean	range	mean	range
January-March 1985	17	62.2	43-97	10.7	1-48
April-June 1985	4	130.0	118-151	8.2	3-23
TOTAL	21				

Table 6. Phase II striped bass tag return summary by quarter from Albemarle Sound area stocking, December 1984.

Quarter	Number returned	Days at large		Distance from release site (miles)	
		mean	range	mean	range
December 1984	73	8.5	2- 25	7.7	2-27
January-March 1985	198	55.7	14-108	14.8	2-52
April-June 1985	40	118.2	102-166	31.3	7-56
TOTAL	311				

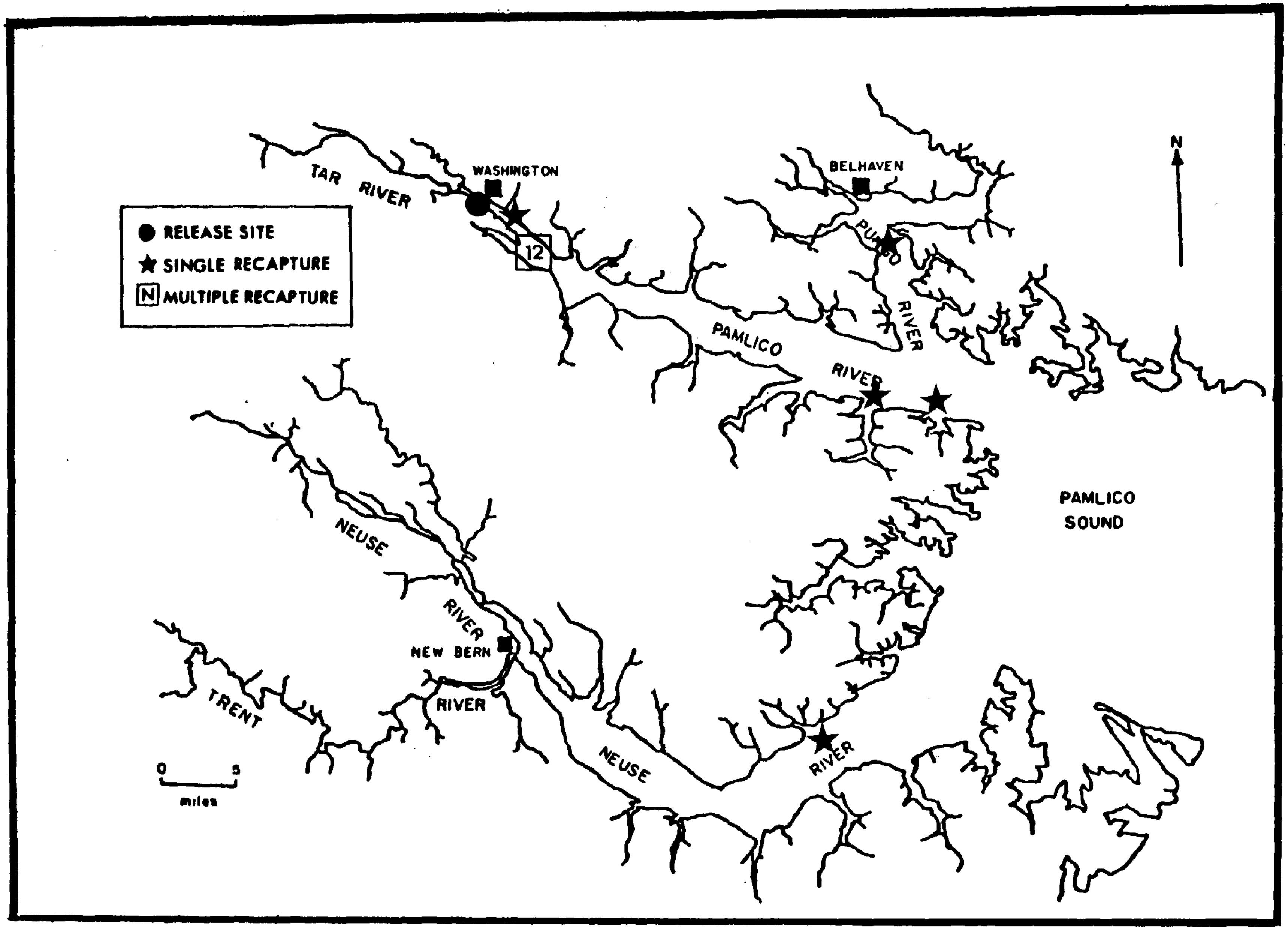

Figure 17. Recapture locations of Phase II striped bass, Pamlico River stocking, 1984 (January - March 1985, 17 returned).

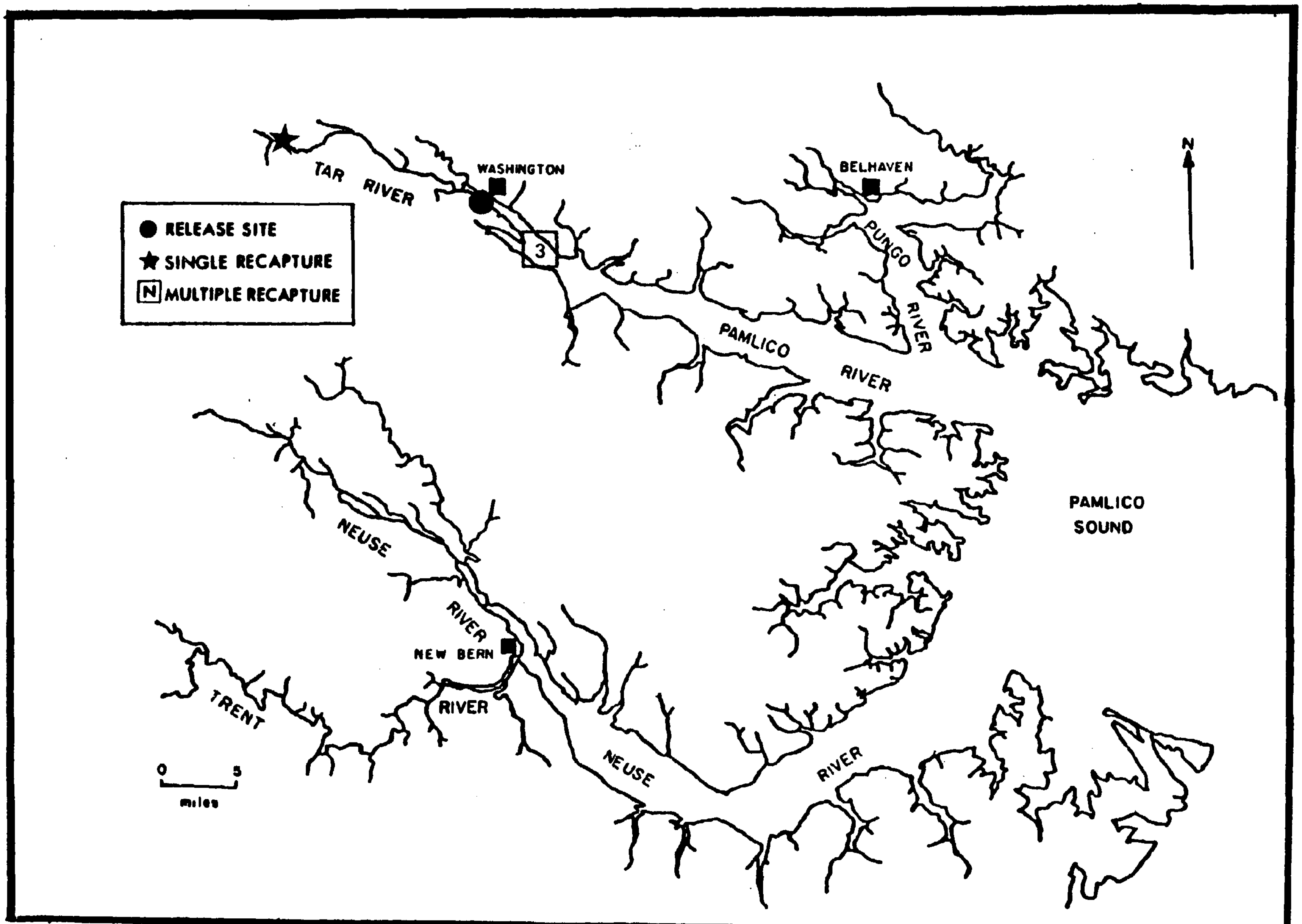

Figure 18. Recapture locations of Phase II striped bass, Pamlico River stocking, 1984 (April - June 1985, 4 returned).

Albemarle Sound Area - 1984

A total of 236,242 Phase II striped bass were released in the Albemarle Sound area during December, 1984. These fish were obtained from U. S. Fish and Wildlife Service National Fish Hatcheries in North Carolina, Georgia, Alabama and Florida. Of the total, 6,445 fish were tagged with cinch-up tags and released during 5-20 December 1984 at two locations in the Albemarle Sound area (Figure 19). All of these fish were released in the natural striped bass nursery area (Street et al. 1975). The overall tagging mortality rate was 0.8%, which is very low considering the distance that many of these fish were transported for stocking.

As of 30 June 1985, 311 tags (4.8%) had been returned. Gill nets continue to be the predominant recapture gear (99.1%), with the tags becoming entangled in the mesh. Rod and reel has accounted for 0.6% of the returns and pound nets 0.3% (Table 2). The number of returns and mean days and miles traveled by quarter are shown in Table 6.

Figures 19-21 show the recapture locations by quarter. All tags returned thus far have been from Albemarle Sound and its tributaries. The areas from which these returns came are very similar to those from previous stockings during 1981 and 1983 (Winslow and Johnson 1984).

These fish will obtain legal size by late fall and recruit into the fishery.

Adult Striped Bass Tagging

During 13-29 December 1983, a total of six 30 minute sets (180 min total tow time) were made in the Croatan Sound area, from approximately 3.2 km south of the U.S. 64-264 bridge to a point off Mashoes Creek, approximately 12.9 km north of the bridge (Figure 7). Trawling was restricted almost entirely in

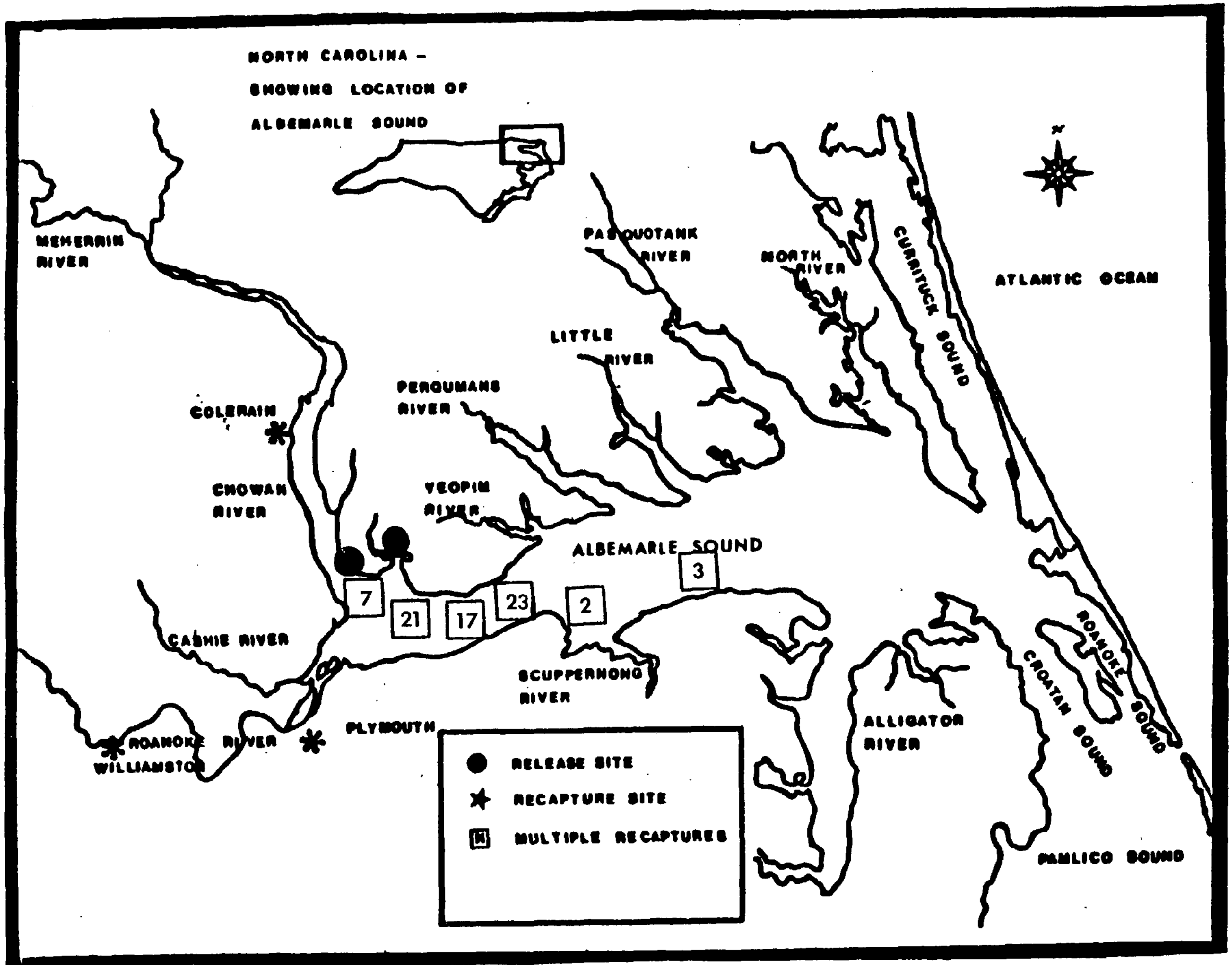

Figure 19. Recapture locations of Phase II striped bass, Albemarle Sound area stocking, 1984 (December 1984, 73 returned).

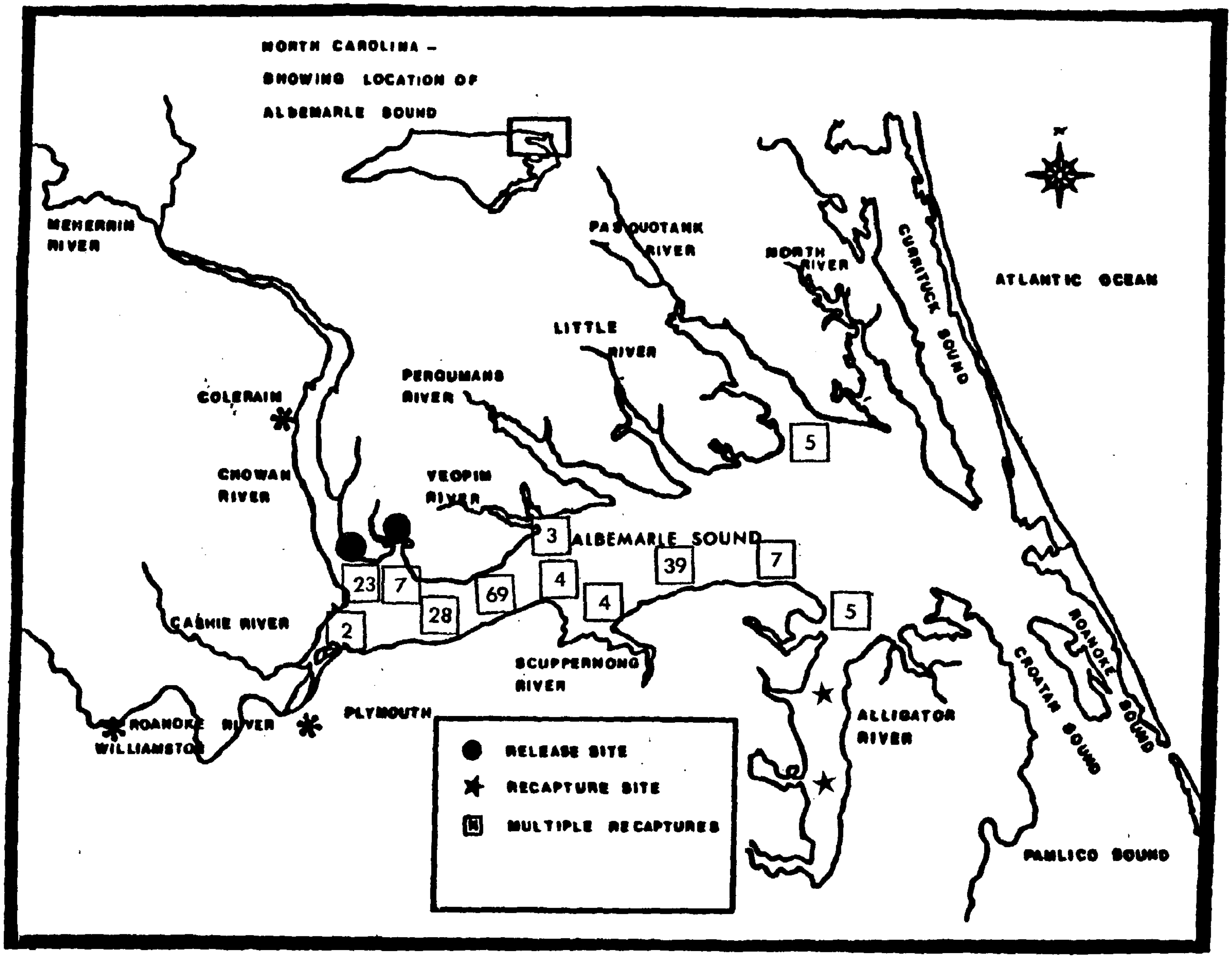

Figure 20. Recapture locations of Phase II striped bass, Albemarle Sound area stocking, 1984 (January - March 1985, 198 returned).

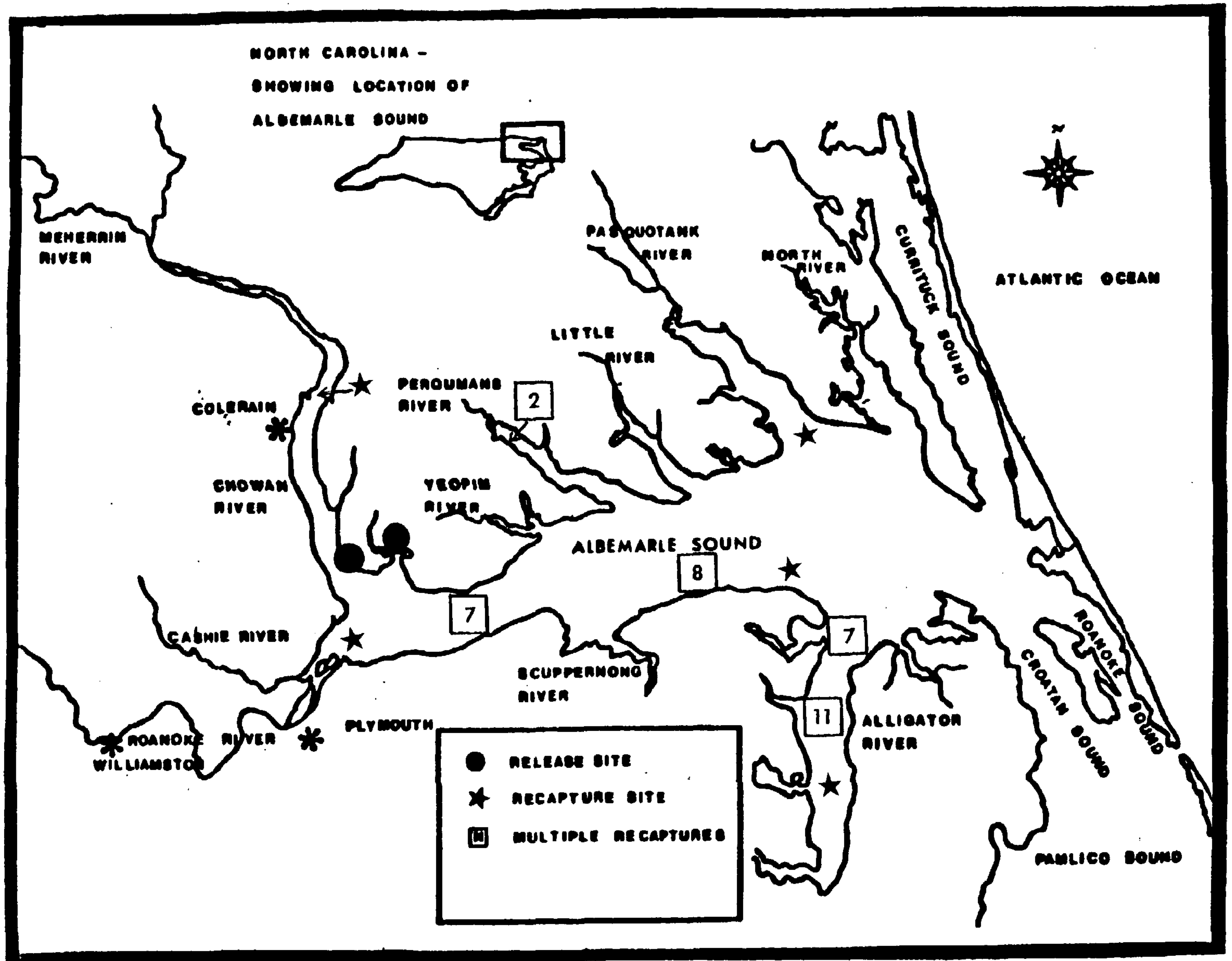

Figure 21. Recapture locations of Phase II striped bass, Albemarle Sound area stocking, 1984 (April - June 1985, 40 returned).

the main channel of the Sound, due to the large number of stakes scattered throughout the area. Additional trawling was conducted between 4 December 1984 and 14 January 1985 in the Croatan Sound, Albemarle Sound (west to Laurel Point), and North River (Figure 7). Thirty-four 15-30 minute sets were made with a total towing time of 14.25 hr. Day and night sampling was conducted. Water depths ranged from 3 m to 7m.

No striped bass were captured in the trawl samples during 1983. In 1984, one striped bass was captured, tagged and released in Indian Town Creek, a tributary to North River, on 12 December. This striped bass was 406 mm (16 in) FL.

Lake Mattsmuskeet Stocking, Tagging and Evaluation

During December 1983, a total of 28,194 Phase II striped bass from the Edenton National Fish Hatchery were released in Lake Mattamuskeet. On 15 December 1983, 993 striped bass were tagged with Carlin disc tags and released (Figure 22).

A total of 9 tags (0.9%) have been returned since the stocking. The returns by quarter are shown in Table 7. Eight of the tag returns have come from within Lake Mattamuskeet, and all were captured by hook and line. The greatest concentration of tag returns (4) has come from the western end of the lake, near Rose Bay Canal (Figure 23). In April 1985, one return came from a gill net in Pamlico Sound between Far Creek and Long Shoal River (Figure 24). The U. S. Fish and Wildlife Service has stocked Lake Mattamuskeet for 7 years with striped bass (E. Atstupenas - personal communication). It was suspected that these fish moved out of the lake through the extensive canal systems. The return from Pamlico Sound indicates that some movement out of the lake does occur.

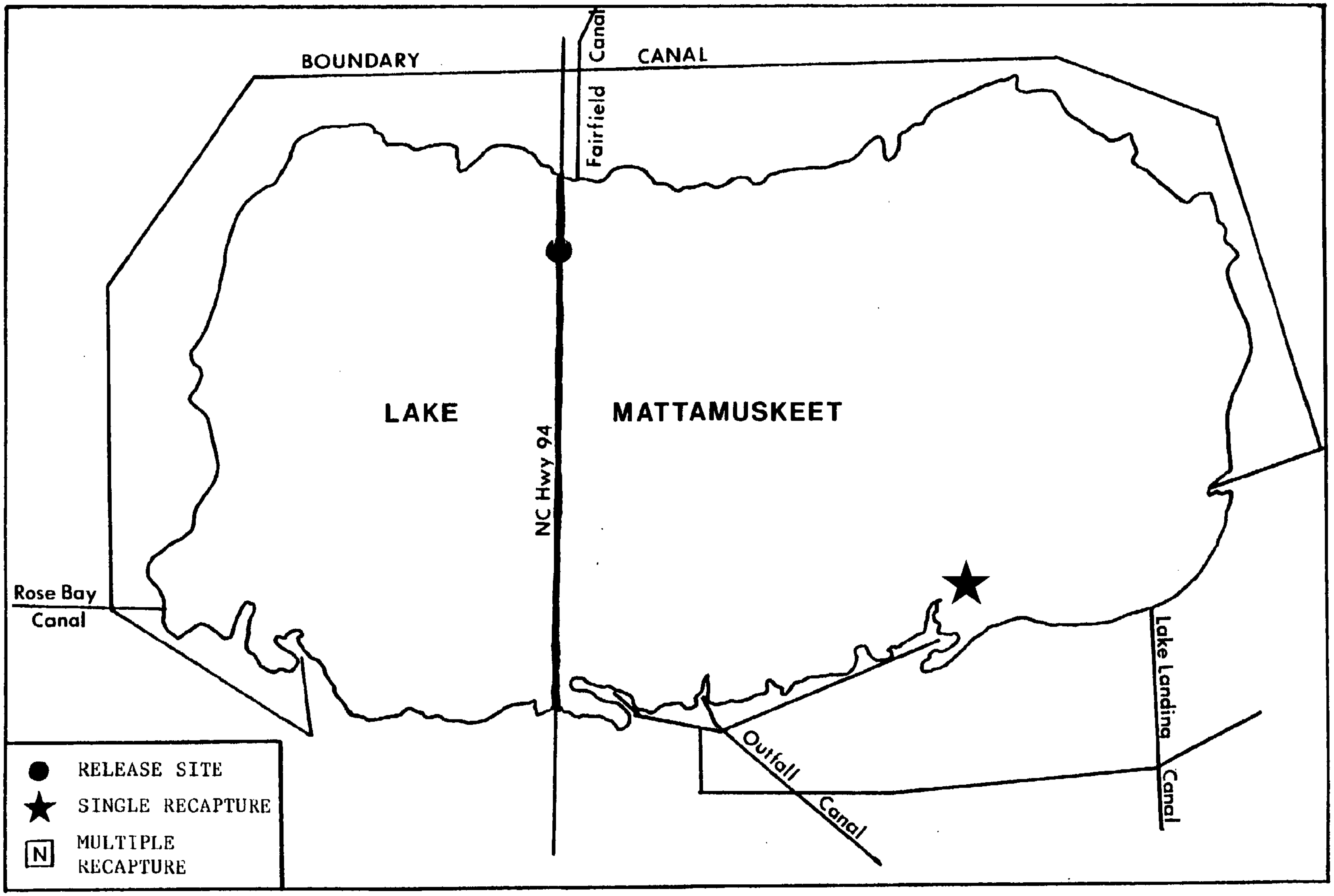

Figure 22. Recapture location of Phase II striped bass, Lake Mattamuskeet stocking, 1983 (January - March 1984, 1 returned).

Table 7. Phase II striped bass tag return summary by quarter from Lake Mattamuskeet area stocking, 1983.

Quarter	Number returned	Days at large		Distance from release site (miles)	
		mean	range	mean	range
January-March 1984	1	93	-	8	-
April-June 1984	7	132.9	119-142	4.6	1-13
April-June 1985	1	482	-	24	
TOTAL	9				

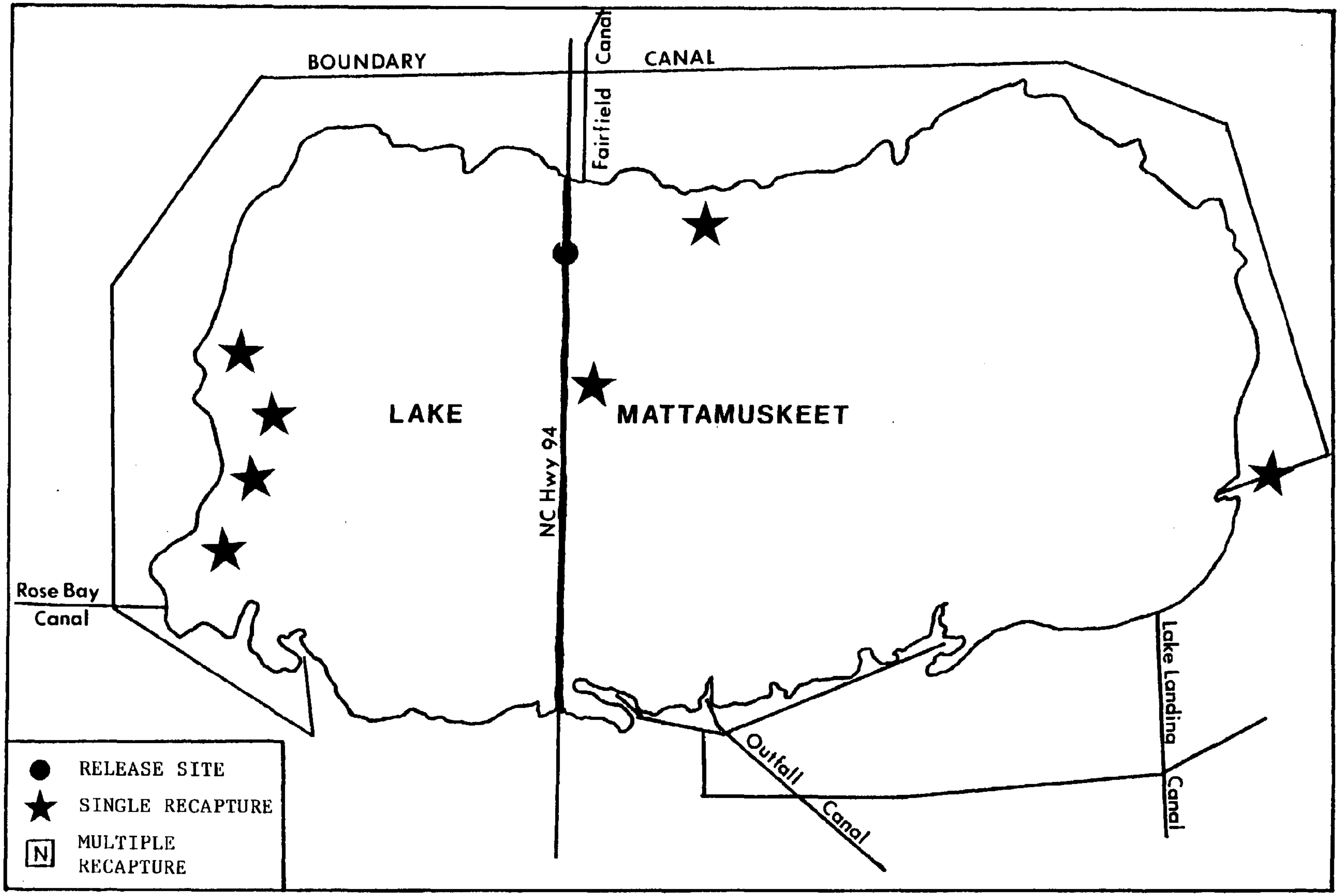

Figure 23. Recapture locations of Phase II striped bass, Lake Mattamuskeet stocking, 1983. (April - June 1984 , 7 returned).

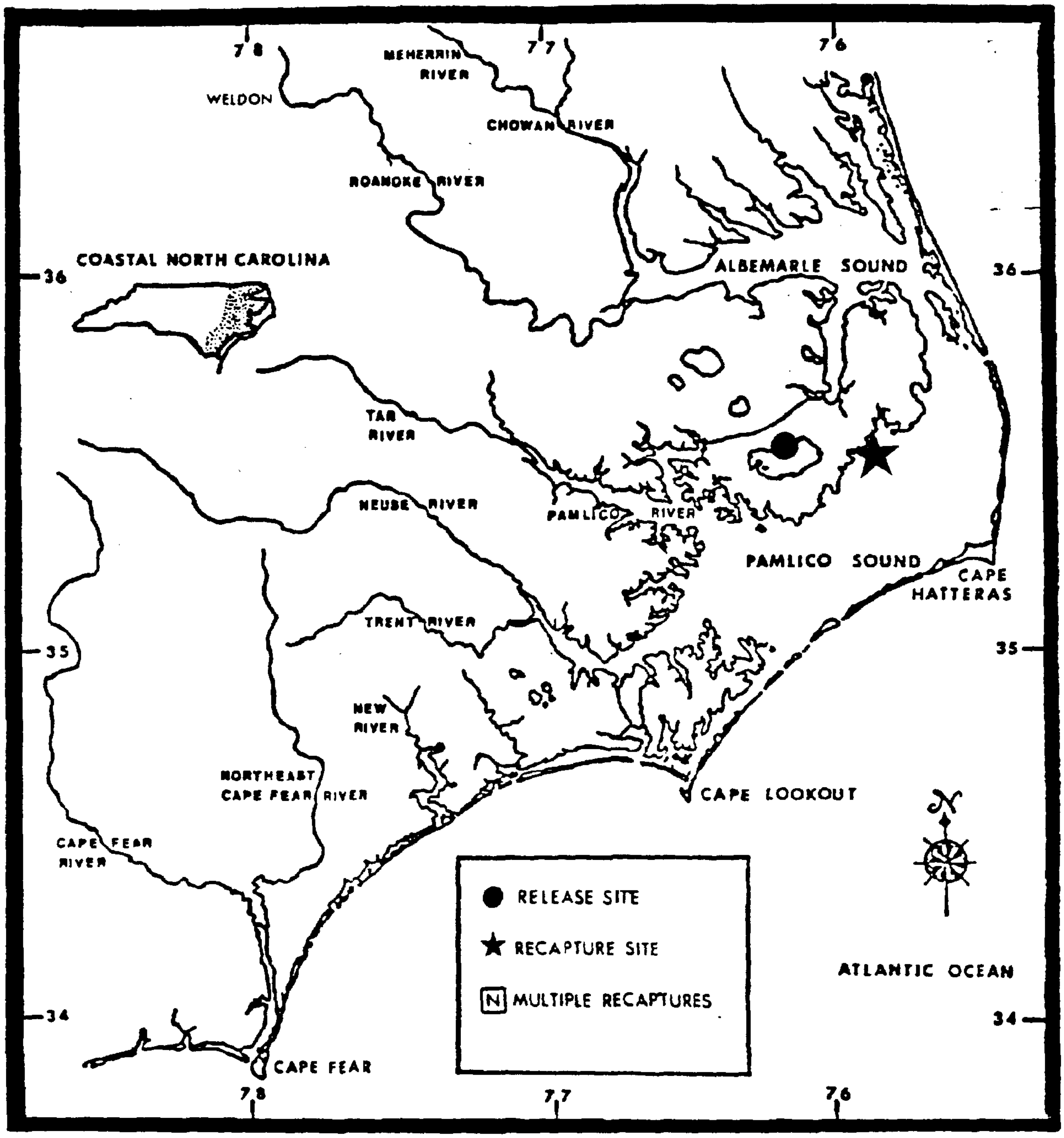

Figure 24. Recapture location of Phase II striped bass, Lake Mattamuskeet 1983 (April - June 1985, 1 returned).

MANAGEMENT IMPLICATIONS

Striped bass landings in North Carolina have declined during the past decade, as well as along the entire Atlantic Cost. The present poor state of the stocks is attributed to lack of a dominant or even strong year class being produced. Causes for this situation are not fully understood, but probably include poor egg viability, degraded water quality and heavy fishing pressure applied to a declining population.

The recent striped bass regulations passed by the North Carolina Marine Fisheries Commission (June 1985) will aid in relieving some of the pressure on the stock, but will certainly not solve the basic problems. These regulations provide for a greatly reduced commercial season, increased minimum size, sport fish creel limit, maintenance of the ocean closure, and elimination of bycatch. Other agencies must address the environmental issues.

The results of the Phase II stocking programs have shown that stocking can be used as a management tool. The data indicate that the stocked fish have contributed to the harvest of both recreational and commercial fishermen, as well as augmenting the spawning population. Tagging of a portion of Phase II fish stocked may also provide data for determining exploitation rates and at least survival to first spawning. These stocking programs may help sustain a striped bass population during low levels of abundance, but probably cannot be used to restore the population to self-sustaining levels in the face of heavy fishing pressures prior to sexual maturity and poor environmental conditions.

The new regulations and stocking programs will aid in sustaining a minimal population, but even short term recovery will not be possible until a strong year class is established, and long-term recovery cannot be expected until environmental conditions are improved.

ACKNOWLEDGEMENTS

Appreciation is extended to all Marine Fisheries field personnel who aided in the collection of striped bass tags. Special appreciation goes to — Marine Fisheries Technician Robert C. Harriss, Jr. and Marine Biologist Lynn T. Henry who assisted in the tagging and field work on this project. Elliot Atstupenas, Manager of the Edenton National Fish Hatchery, managers of the Millen, Warm Springs and Carbon Hill National Fish Hatcheries and their staffs reared the fish, harvested the ponds, and stocked the fish at designated sites. This project would not have been possible without their full support, for which I am most grateful. Michael W. Street, Harrel B. Johnson and Lynn T. Henry reviewed the manuscript and provided many helpful suggestions. Fisheries Management Section secretaries Frances Burke and Dee Willis typed the report. I thank the many commercial and recreational fishermen and dealers throughout North Carolina who returned tags.

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SECTION II

ZOOPLANKTON AND DIETS OF JUVENILE BLUEBACK HERRING IN THE CHOWAN RIVER AND ALBEMARLE SOUND, 1982-1983

by

Samuel C. Mozley

ABSTRACT

A study of zooplankton, and young-of-year juvenile blueback herring sizes and diets was conducted in the lower Chowan River (1982-1983) and also western Albemarle Sound (1983). The project was designed to determine the likelihood that cyanobacterial (= blue-green algal) blooms were reducing the fish's forage base. Specifically, the hypothesis was that blooms inhibited populations of zooplankton on which juvenile herring feed. No evidence was found to support this hypothesis. On the contrary, the fortuitous occurrence of low algal biomasses and percentage cyanobacteria in the first year followed by high levels in the second showed that zooplankton were actually more abundant, and fish had more prey in their stomachs and reached larger body weights when blooms were worse. The data base was too small to draw good conclusions about alternative hypotheses, but there were suggestions that river flow controlled both bloom intensity and forage base by flushing algae and zooplankton from the system in high flow periods.

The Chowan River had much lower zooplankton densities than have been reported for the James River immediately to the north. Chowan herring correspondingly showed a tendency to feed on sediment-associated prey such as benthic cladocerans and chironomid larvae, unlike any previously reported population. They also fed more on rotifers and were much less selective among the zooplankton prey in the Chowan than in the James. The controls of fish-forage interactions, and the roles these interactions play in year class recruitment, proved too complex to determine at the level of the present study.

This first study of zooplankton in a freshwater estuary suffering from cyanobacterial blooms gave results not entirely consistent with those reported from laboratory and pond studies. Copepods (including naupliar larvae), and particularly the calanoid <u>Eurytemora</u>, were able to maintain community dominance in the presence of high cyanobacterial biomass and of fish which are at least capable of feeding as size-selective, visual predators.

INTRODUCTION

It has been suggested that the low landings of post-spawning blueback herring in the Chowan-Albemarle system, which have persisted despite restrictions on offshore fishing for adults, are due to poor water quality conditions, primarily cyanobacterial (= blue-green algal) blooms in Chowan nursery areas (Street and Johnson 1982). In particular, early spring blooms in upstream nursery areas were thought to smother larvae (loc. cit.). In a proposal to do the present research, I put forward another idea, that cyanobacterial dominance could also be suppressing the populations of zooplankton forage organisms in the lower nursery areas where juvenile herring spend the peak bloom period of summer and early autumn (cf. Rulifson, et al. 1982). The resulting reduction in forage base might cause slow growth and low survival of the juveniles. The North Carolina Division of Marine Fisheries (NCDMF) provided financial support and sampling services for a preliminary test of this idea. Cyanobacterial biomass was to be compared with forage organism densities and composition, and the importance of various forage organisms (zooplankton prey) to juvenile herring was to be determined by analysis of fish stomach contents in the lower Chowan River during two successive summers. As it happened, light blooms developed briefly in May and again in August of the first year (1982), but severe blooms persisted from June into October the second year, providing a good contrast of conditions during the study.

Results of a 1982 study (see Methods and Materials) were consistent with the original hypothesis. Zooplankton densities were low throughout the summer, and then-anecdotal reports of cyanobacterial blooms in August appeared to correspond to a shift toward smaller zooplankton types (especially Bosminidae cladocerans). Similar size shifts have been observed in a study of lake plankton, and were attributed to the clogging of filter-feeding appendages of the larger zooplankton by filaments of the blooming algae (Webster and Peters 1978). Young-of-year herring sizes in the Chowan in summer 1982 were smaller than for summer periods in the James (Burbidge 1874) and Cape Fear (Rulifson, et al. 1982) Rivers. Moreover, August 1982 Chowan fish stomachs contained many algal colonies, and it appeared that the algae were interfering with normal feeding on animal prey. Partly because of the indications of effects, the current project with NCDMF was initiated in April 1983. Zooplankton samples collected through the winter of 1982-83 in the Chowan were analyzed and supplemented with collections in the Chowan, and after June in Albemarle Sound, through 1983. However, no algal or flow information has been assembled here for comparisons with Albemarle Sound data. The combination of data from the earlier project with those from the present one in this report enabled direct comparison of two years with strongly differing bloom conditions.

This report primarily addresses the question of whether the much larger cyanobacterial biomass in the Chowan in 1983 again produced effects of the type expected, i.e., reduced densities and mean sizes of forage organisms and relatively small fish sizes. It also provides the first description of zooplankton composition, density dynamics, and distribution in a North Carolina freshwater estuary affected by algal blooms.

METHODS AND MATERIALS

Data on river flows and measures of algal concentration and composition in the Chowan were taken directly from a North Carolina Division of Environmental Management report (NCDEM 1984).

Zooplankton samples were collected with Schindler- Patalas traps with mesh openings .07 mm wide (#20) in attached nets. In June, July and mid-August 1982, an older, handmade trap with a volume of 36.4 liters was used. In June and early July 1982, seven volumes were pooled to form single samples of about 255 liters. This was done by lowering the trap until submersed, raising so that the doors closed and its contents drained out through the net, then lowering again in repetition. The bottom door covered the net port as the trap was lowered, preventing washout of previously trapped plankton. Sample sizes were still quite small, so in late July the number of pooled volumes was increased to 14, about 510 liters. Then in late August a commercially produced Schindler-Patalas trap (volume 30.4 liters) was substituted and the 14 pooled volumes (about 425 liters) were continued for the rest of the study. Only one sample was taken from each station on each date, since the intent was to describe the overall dynamics of lower Chowan zooplankton, not to document local patterns within the river.

This report incorporates earlier work conducted under a North Carolina Department of Natural Resources and Community Development contract (No. C-1317, May 24 - December 31, 1982) with the University of North Carolina Water Resources Research Institute. In that project samples collected June through September 1982 included seven sites: Bennett's Creek mouth, both shores and midchannel at the level of Colerain-Arrowhead Beach (Fig. 1, Stations 1-3), and both shores and midchannel at the level of Mt.Gould Beach-Harris Landing (Fig. 1, Stations 4-6). The two midchannel sites were sampled at two depths, surface and 5 m; station depth was normally about 7 m. Then after September the Bennett's Creek site was omitted due to consistently very low zooplankton densities (no data reported here), and only surface samples were collected at midchannel sites (Table 1).

Zooplankton samples analyzed under the present contract were collected at least monthly in the Chowan River from January through November, and in Albemarle Sound from June through October, 1983 (Tables 1 and 2, Fig. 1). More samples were collected from December 1983 through July 1984, but those from December, June and July were not sent to the laboratory until August 1984 and could not be analyzed within remaining time. Samples collected from January through May 1984 reached the laboratory in June 1984, but were not analyzed because of their low priority and the need to devote remaining funds to data reduction. Their low value was due mainly to the absence of juvenile herring from the Chowan during this period. As shown below, zooplankton samples in the previous winter-early spring were severely limited by typically high flows in those seasons.

In the laboratory, zooplankton samples were poured into counting trays and enumerated by major taxonomic categories (see below). When many more than 200 animals occurred in a sample, a Folsom Plankton Sample Splitter was used to subsample down to about this number of animals for actual counting. Sample or subsample counts were converted to number per cubic meter by appropriate multiplication factors.

Fish were collected by NCDMF field crews, usually with beach seines. Dates and sites of samples are shown in Tables 1 and 2. Juvenile clupeids were put on ice immediately, then preserved in formalin and tranported to

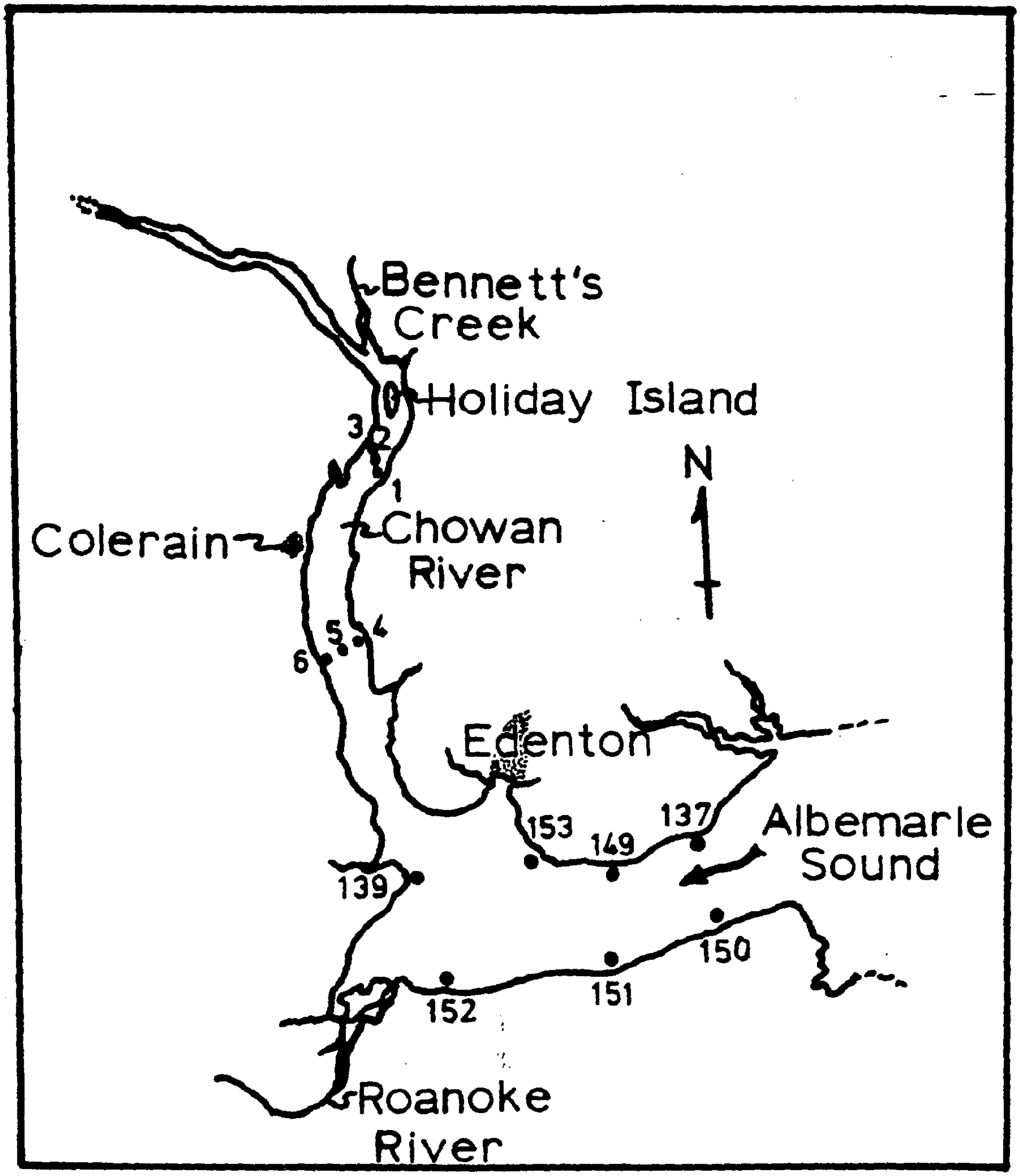

Figure 1. Station locations in the Chowan River and Albemarle Sound, N.C., for 1982-83 collections of zooplankton and juvenile blueback herring.

Table 1. Dates and stations sampled in the Chowan River, N.C., 1982-83. Locations of stations 1-6 are shown in Fig. 1.

Date		Zooplankton						Date	Fish					
		1	2	3	4	5	6		1	2	3	4	5	6
1982	6/3	x	x	x	x	x	x	6/24	x					
	7/5	x	x	x	x	x	x							
	7/26	x	x	x	x	x	x	7/28	x		(*)			x
	8/16	x	x	x	x	x	x	8/9	x					x
	8/23	x	x	x	x	x	x	8/23	x					x
	9/7	x	x	x	x	x	x	9/7						x
	10/27	x	x	x	x	x	x							
	11/23	x	x	x	x	x	x							
	12/20	x	x	x	x	x	x							
1983	1/24	x	x	x	x	x	x							
	2/28	x	x	x	x	x	x							
	3/30	x	x	x	x	x	x							
	4/26	x	x	x	x	x	x							
	5/18	x	x	x	x	x	x							
	6/7	x	x	x	x	x	x							
	6/28	x					x							
	7/11	x	x	x	x	x	x	7/11	x				x	x
	7/26	x					x	7/26	x					
	8/9	x	x	x	x	x	x	8/9	x					x
	8/26	x					x							
	9/6	x	x	x	x	x	x	9/6	x				x	x
	10/24	x						10/24						x
	11/8	x	x	x	x	x	x							

* Chowanoke Shores; only sampled once.

Table 2. Dates and stations sampled in Albemarle Sound in 1983. Station locations are shown in Fig. 1.

Date	Zooplankton							Fish						
	137	139	149	150	151	152	153	137	139	149	150	151	152	153
6/6		x				x	x							
6/28	x		x	x	x									
7/13	x	x	x	x	x	x	x		x		x		x	x
7/27		x				x			x				x	
8/12	x	x	x	x	x	x	x		x					
8/25	x	x	x	x	x	x	x		x		x	x		x
9/7	x	x	x			x		x	x	x				
10/20		x				x			x					

Raleigh. In my laboratory, they were measured for standard length and formalin-wet-weight. Stomachs were removed, ranked according to a "gut fullness index" (0 = empty, 4 = full, 5 = distended) and contents enumerated in the same way as zooplankton samples. Although fish collections were more localized and less frequent than for plankton, it was assumed that all-site zooplankton averages were the best representation of the forage conditions experienced by the actively pelagic, schooling juvenile fish. All fish were collected in the middle of the day.

The Ivlev electivity index (cf. Burbidge 1974) was applied to fish stomach and zooplankton data to detect seasonal feeding preferences for major categories of prey.

$$E = \frac{(\%\ \text{item in fish}) - (\%\ \text{item in plankton})}{(\%\ \text{item in fish}) + (\%\ \text{item in plankton})}$$

The index ranges from + 1.0 (item occurred only in fish) to - 1.0 (item occurred only in plankton). Species were pooled into major categories partly because index reliability was poor when a taxon was rare in both plankton and fish collections. Averaging the index values over available sampling dates provided a measure of year-to-year and river-sound differences, as well as of within-year variability.

RESULTS

Prey Taxonomy and Analytical Categories

Most effort was concentrated on crustacean zooplankton in the groups Copepoda and Cladocera, for these were expected to be the primary forage base (Burbidge 1974) and the most likely to be affected by phytoplankton composition. Individual specimens were identified as far as possible using keys in Edmondson (1959) and Pennak (1978), but in sample processing taxonomic detail was limited mainly to copepod families (nauplii of all copepods groups combined in a separate category), and cladoceran and rotifer genera. Some species were easily distinguished, and when they dominated counts for their genus, that is noted in Tables 3 and 4. Most

Table 3. Crustaceans identified from plankton samples and fish stomachs in the Chowan River and western Albemarle Sound, N.C., 1982-1983. (A = abundant and frequent; F = frequent but less abundant; E = erratically abundant; O = occasionally present in moderate numbers, not frequent; R = rare).

Copepoda
- Canthocamptidae (Harpacticoida)
  - *Bryocamptus* R (in fish)
  - *Mesochra* O
- Cyclopidae
  - *Cyclops varicans rubellus* Lillj. R?
  - *C. vernalis* Fisch. F
  - *Ergasilus chatauquaensis* Fellows F
  - *Ectocyclops phaleratus* Koch *
  - *Macrocyclops fuscus* (Jurine) *
  - *Orthocyclops modestus* (Herrick) *
  - *Paracyclops fimbriatus poppei* (Rehb.) *
- Diaptomidae (Calanoida)
  - *Diaptomus reighardi* March R?
- Temoridae (Calanoida)
  - *Eurytemora affinis* (Poppe) A

Ostracoda (not identified) F (in fish)

Amphipoda (not identified) R (in fish)

Cumacea (*Almyracuma*) R (in fish)

Cladocera
- Bosminidae
  - *Bosmina longirostris* (O.F. Mueller) A
  - *Bosminopsis dietersi* Richard A

Cladocera, continued
- Chydoridae
  - *Alona quadrangularis* (O.F. Mueller) R
  - *A. rectangula* Sars F
  - *Alonella* sp. R (in fish)
  - *Alonopsis elongata* Sars F
  - *Camptocercus rectirostris* Schoedl. R
  - *Chydorus globosus* Baird F
  - *C. sphaericus* (O.F. Mueller) F
  - *Leydigia acanthocercoides* (Fisch.) R
  - *Monospilus dispar* Sars O (in fish)
- Daphnidae
  - *Ceriodaphnia reticulata* (Jurine) O
  - *Daphnia ambigua* Scourfield R
  - *D. parvula* Fordyce R
  - *Scapholeberis kingi* Sars R
- Holopedidae
  - *Holopedium amazonicum* Stingl. E
- Leptodoridae
  - *Leptodora kindtii* (Focke) E
- Macrothricidae
  - *Ilyocryptus spinifer* Herrick F
- Sididae
  - *Diaphanosoma brachyurum* (Lieven) E
  - *D. leuchtenbergianum* Fisch. R
  - *Sida crystallina* (O.F. Mueller) F

* Eucyclopinae, not routinely identified to species. A

Table 4. Other animals identified from plankton samples and fish stomachs in the Chowan River and Albemarle Sound, N.C., 1982-1983. For code A, F, E, O, R, see Table 3.

- Rotatoria
  - Asplanchnidae
    - Asplanchna sp. F
  - Brachionidae
    - Keratella sp. A *
    - Lepadella sp. F *
    - Notholca sp. R
  - Conochilidae
    - Conochilus sp. E
  - Lecanidae
    - Monostyla sp. R
  - Synchaetidae
    - Ploesoma sp. F *
    - Polyarthra sp. O
  - Testudinellidae
    - Filinia sp. R
    - Trochosphaera sp. R
  - Trichocercidae
    - Trichocerca sp. F
- Turbellaria (unidentified) R
- Nematoda (unidentified) R
- Acari (unidentified) F
- Pelecypoda
  - Unionidae (glochidia) F in fish
  - bivalve veliger larvae (Rangia or Corbicula) O in plankton
  - Sphaeriidae (Pisidium) R
- Insecta
  - Diptera
    - Chaoboridae
      - Chaoborus punctipennis (Say) (eggs, larvae, pupae, adults) E in fish
    - Chironomidae (larvae, pupae, adults; > 11 species) O in fish
    - Simuliidae (unidentified) R
  - Ephemeroptera (unidentified) F in fish
  - Hemiptera (unidentified) R in fish
  - Megaloptera (unidentified) R in fish
  - Odonata (unidentified) R in fish
  - Protura (unidentified) R in fish
  - Trichoptera (Unidentified) R in fish
- Oligochaeta
  - Aeolosomatidae
    - Aeolosoma leidyi Cragin R
  - Naididae (unidentified) R in fish
  - Tubificidae (unidentified) R in fish

* noted in fish; rotifers were infrequently identified to genus in fish diets.

individuals of *Cyclops* examined closely proved to be *C. vernalis*, and most Calanoida were *Eurytemora*. Distinctions among the four genera of Eucyclopinae and the two species of *Chydorus* were not made often enough to determine which species were most abundant. For analysis, data were pooled still further to family for Daphnidae, and the genera *Sida* and *Ilyocryptus* were combined with Chydoridae into the category "Benthic Cladocera". Although quantitative estimates of rotifers in both plankton and fish were begun in 1983, the data for these and Nematoda have not been analyzed. Most nematodes and some rotifers were small enough to pass through the net used on the plankton traps, and were underestimated to an unknown degree. Except for Chironomidae (all genera pooled), insects were combined with mollusks, annelids, Acari (mites), peracaridan crustaceans and fish eggs as a miscellaneous category because they were generally rare and encountered only in fish stomachs. A full list of taxa identified from the Chowan and Albemarle samples is provided in Tables 3 and 4.

Phytoplankton Data

Data on algal biomass, density and composition near the water surface were collected at least monthly from seven stations in the lower Chowan River in both 1982 and 1983 by NCDEM's Water Quality Section (NCDEM 1984). The composition data are reprinted from their table for station no. 2053632 in mid-river at Colerain (near # 2 in Fig. 1 and Table 1), and monthly averages for biomass and cell concentrations are reprinted from a table of lower Chowan River stations (Table 5). Monthly chlorophyll concentrations were taken from a station near Colerain (Figure 12 of the NCDEM 1984 report). Since the data were very similar every month of both years at the station near Edenhouse, the Colerain site is probably representative of the entire river between Holiday Island and the Sound.

Weather patterns contrasted strongly between the two years. According to NCDEM (1984), relatively lower rainfall and runoff in spring 1982 enabled earlier phytoplankton development, with a peak in April. But a series of high summer flows kept algal biomass comparatively moderate through the summer and autumn. The early dominance of cyanobacteria in May

Table 5. Selected algal data from the Colerain station, Chowan River, 1982-83 (taken from NCDEM 1984).

Month	Chl-a(ug/l)[1]		Cells/ul		Biomass(mg/l)		% Cyanobacteria[2]			
	1982	1983	1982	1983	1982	1983	Day	1982	Day	1983
Jan	0.8	1.0	0.5	<0.1	0.4	0.2	5	0	17	0
							20	0		
Feb	0.8	1.0	0.2	<0.1	0.5	0.1	2	0	28	0
Mar	1.6	1.0	0.6	0.1	1.9	0.1	1	0	14	0
Apr	11.2	1.0	7.8	0.2	10.5	0.2	13	0	26	0
May	27.2	1.6	3.2	1.8	3.7	1.8	10	16.5	18	0
							24	86.2		
Jun	16.0	6.4	1.2	0.7	2.4	2.0	7	0	7	54.0
							14	0		
Jul	63.5	68.8	2.8	13.8	4.6	11.5	5	0	11	89.7
							19	0		
Aug	56.0	37.6	1.8	4.1	5.1	6.6	3	9.1	9	69.2
							16	0		
							30	16.6		
Sep	13.6	36.0	1.5	6.3	1.5	14.1	27	0	6	54.3
Oct	2.4	7.0	2.6	2.3	2.7	3.0	27	0	18	0
									19	31.8
Nov	2.4	6.5	0.2	2.1	1.3	2.7	8	0	8	29.4
Dec	3.0	1.0	2.0	0.1	3.1	0.2	6	0	13	0

1) Estimated from graph in report.

2) Sum of %'s of biomass due to dominant species of Anabaena, Microcystis (= Anacystis), and Aphanizomenon. Dominance was defined as contributing at least 5% of total biomass.

was eliminated by higher flows in early June and recurred only briefly and less intensely in August. In 1983, high runoff from a wet spring kept chlorophyll and biomass concentrations low until June or July, but then a dry summer allowed build-up of higher biomass, mostly higher chlorophyll and much greater dominance of cyanobacteria through November (Table 5). More than 50% of phytoplankton biomass was contributed by nuisance-blooming blue-greens in June, July, August and September of 1983, but only during late May in 1982. Therefore, any negative interactions between cyanobacteria and zooplankton populations should have been much more severe in 1983, especially during summer months.

Zooplankton Density

Densities of all taxa except rotifers were combined as a crude estimate of the magnitude of the forage base for juvenile herring. Variations in density among stations on any given date were high, as shown by coefficients of station variation that were rarely less than 60% and frequently over 100% (Table 6). In 1982, densities in the Chowan were scarcely above 2 per liter ($2/l = 2000/m^3$) throughout the summer. But in 1983, densities varied widely from month to month with 2/l a virtual minimum. Maxima above 8/l were common, indicating a much richer forage base in 1983. Albemarle Sound zooplankton densities in 1983 were much less variable and usually lower than densities in the Chowan River.

Zooplankton densities through summer of 1983 in the Chowan often appeared to vary inversely with river flow, similarly to algal biomass (cf. NCDEM 1984). But while densities in summer 1982 fell slightly following flow peaks in mid-July and mid-August, they fell even lower and remained there during continually declining flows in late August and September (Table 6). In 1983, densities increased sharply just after the mid-May low flow (unlike algae), but fell again during a flow peak in late May and early June. Another sharp increase developed as very low flows (including some reverse or upstream net flows) prevailed in the second half of July through early September. Flow records in the NCDEM 1984 report end then, so it is not possible to interpret zooplankton density changes just after that time, but the strong declines suggest a flow increase.

Table 6. Density of animals (excluding rotifers) in zooplankton samples from the Chowan River and Albemarle Sound, N.C., in 1982 and 1983. (C.V. = coefficient of variation. Mean and S.E. in numbers per cubic meter, rounded to three significant figures.)

Date	Chowan River			Date	Albemarle Sound		
	Mean	S.E.	C.V.		Mean	S.E.	C.V.
1982							
6/3	1,540	398	63				
7/5	2,250	916	100				
7/26	1,120	280	62				
8/16	2,360	1,740	181				
8/23	873	256	72				
9/7	779	134	42				
10/27	1,060	314	73				
11/23	630	191	75				
12/20	242	48	49				
1983							
1/24	68	18	65				
2/28	140	64	112				
3/30	420	118	69				
4/26	683	375	135				
5/18	13,300	5,760	107				
6/7	3,580	655	45	6/6	2,140	1,510	122
6/28	2,960	2,670	128	6/27	2,970	921	62
7/11	1,920	523	67	7/13	3,650	1,260	91
7/26	7,570	2,990	56	7/27	2,440	501	29
8/9	14,800	6,620	109	8/12	3,020	647	57
8/26	8,340	2,850	48	8/25	4,310	1,150	70
9/6	8,620	2,610	74	9/7	2,700	700	52
10/3	196	37	26	- - -	- - -	- - -	- - -
10/24	137	(N = 1)		10/20	576	510	125
11/8	8,570	2,200	63	- - -	- - -	- - -	- - -

There was no evidence of any effect of cyanobacterial dominance on zooplankton densities. Total arthropod plankton (i.e., excluding rotifers) were sparse during the summer of 1982 when blue-greens were comparatively unimportant. In the summer of 1983 the widely fluctuating and often relatively high zooplankton densities in the Chowan bore no close temporal relationship to cyanobacterial proportions of phytoplankton biomass. A peak in May developed at relatively low chlorophyll levels when few cyanobacteria were present (cf. Table 5), but other peaks corresponded to high blue-green proportions in August and September, 1983 (Table 6).

Zooplankton Composition

Nauplii (larvae of copepods), Bosminidae (2 species), calanoid copepod juveniles + adults, *Diaphanosoma*, and cyclopoid juveniles + adults were the only taxa contributing at least 5% over an entire year or season (Tables 7 and 8). Nauplii were generally the group with the highest relative density, bosminids next and calanoids third. Bosminids were particularly important in the Chowan during high zooplankton densities in 1983, once during a blue-green bloom (August), but also at a time of low total algal biomass (May; Table 7).

Benthic cladocerans were dominant in the Chowan River during winter when flows were high and total densities low (Table 7). *Diaphanosoma* and *Holopedium* were among the dominants in June or July of both years at moderately low flows. Bosminids and cyclopoids seemed to do best in mid-to-late summer. Nauplii were dominant in Albemarle Sound more often than in the Chowan during these periods (Table 8). Overall, patterns in Chowan zooplankton composition did not correspond closely to total algal biomass or the proportion of cyanobacteria, but displayed broadly similar seasonal patterns in both years.

Daytime Depth Distribution of Zooplankton

The representativeness of surface samples for zooplankton densities was tested using the data from summer 1982 at midchannel stations (#'s 2

Table 7. Percentage of numbers in dominant zooplankton taxa in the Chowan River, N.C., by date and for yearly sampling periods, combining all stations. (Only taxa contributing at least 5% to totals, excluding rotifers and rare taxa, are shown. Codes for taxonomic group names may be deduced from Table 3.)

Date	Naupl	Bosmn	Calan	Cyclp	Dphns	BenCl	Holpd	Leptd	Daphn
1982									
6/3	55	7	19	7	8	-	-	-	-
7/5	35	-	18	16	26	-	-	-	-
7/26	77	12	-	-	6	-	-	-	-
8/16	71	16	-	7	-	-	-	-	-
8/23	17	53	10	11	7	-	-	-	-
9/7	17	47	17	14	-	-	-	-	-
10/27	40	18	17	23	-	-	-	-	-
11/23	33	48	12	6	-	-	-	-	-
12/20	14	30	37	6	-	6	-	-	-
YEAR	50	19	11	10	7	-	-	-	-
1983									
1/24	46	14	18	10	-	10	-	-	-
2/28	9	16	6	-	-	62	-	-	-
3/30	25	8	17	-	-	41	-	-	-
4/26	7	19	9	-	-	44	-	-	10
5/18	10	70	14	5	-	-	-	-	-
6/7	-	6	8	-	-	-	80	-	-
6/28	80	-	8	-	-	-	-	-	-
7/11	27	8	20	5	17	-	9	11	-
7/26	81	7	-	-	-	-	-	-	-
8/9	13	57	12	-	11	-	-	-	-
8/26	85	6	-	-	-	-	-	-	-
9/6	34	46	-	14	-	-	-	-	-
10/3	43	25	5	21	-	-	-	-	-
10/24	60	6	23	11	-	-	-	-	-
11/8	97	-	-	-	-	-	-	-	-
YEAR	44	33	8	-	-	-	-	-	-

Table 8. Percentage of numbers in dominant zooplankton taxa in Albemarle Sound, N.C., in 1983 by date and for the entire sampling period, combining all stations. (Only taxa contributing at least 5% to totals, excluding rotifers and rare taxa, are shown. Codes for taxonomic groups may be deduced from Table 3.)

Date	Naupl	Bosmn	Calan	Dphns	Hrpct	Holpd
6/6	45	11	20	-	-	22
6/27	82	6	7	-	-	-
7/13	44	39	-	8	-	-
7/27	45	48	-	-	-	-
8/12	72	12	-	9	-	-
8/25	54	19	14	8	-	-
9/7	82	9	-	-	-	-
10/20	72	-	16	-	9	-
YEAR	62	21	8	5	-	-

and 5) as replicates. Each major group's density was transformed by y = log(x + 1) and transformed means were compared for each of the six sampling dates separately. A significant probability that the depths were different (p < .05) was obtained for only three taxa, once each. Cyclopoid copepods were more abundant at 5 m than at 1 m on 7/26, and *Diaphanosoma* and benthic cladocerans showed the same trend on 9/7. In addition, *Diaphanosoma* was different at p < .10 in June and July. This proportion of significant differences is about what might be expected by chance (3 of 71 comparisons, 4%). While this test was certainly not very powerful, vertical stratification of zooplankton communities did not appear to be well-developed in the Chowan.

Fish Size and Rations

Nearly all the the juvenile clupeids collected for this study were young-of-year blueback herring (*Alosa aestivalis*). The few alewives (*A. pseudoharengus*) and year 1+ fish were insufficient for analysis and therefore excluded. All fish were sampled by seining (or rarely, midwater trawling) at four sites in the Chowan River and six sites in Albemarle Sound, and no one site was represented by an adequate number of fish more than three times in one year. Sample sizes in June 1982, late July 1983 (one fish each) and October 1983 were quite small. Therefore, the data can not support a detailed analysis of seasonal or locational size comparisons as would be required for a comparison of growth rates between summers or areas. Furthermore, the decreases (note low standard errors) in standard length from June to July 1982 in the Chowan and from July to August 1983 in Albemarle Sound indicate that the samples were biased representations of the population (Table 9).

However, the samples show substantially higher mean individual fish weights (formalin wet weight) in August and September 1983 than in the same months of 1982. These seem accurate, and probably reflect the larger forage base as zooplankton density in the second year. Still greater mean weights in Albemarle Sound are consistent with the expectation that juvenile herring move downstream to overwintering habitats in the brackish waters of the Sound as they grow (cf. Rulifson, et al. 1982).

Table 9. Size and condition of young-of-year blueback herring and ration summary in the Chowan River 1982-83 and Albemarle Sound 1983, averaged across all fish from each date, regardless of collection site within area. The exception is number of prey per fish, for which statistics (SE, N) refer to variation among stations rather than individual fish.

Date	Stand Lnth (mm) X (SE, N)	Form Wet Wt (g) X (SE, N)	Gut Fullness * X (SE, N)	No. Prey / Fish X (SE , N)
Chowan River 1982				
6/24	27.4 (2.8, 5)	N. D.	1.80 (0.58, 5)	3.7 (- , 1)
7/28	24.6 (0.7, 30)	N. D.	1.60 (0.16, 30)	0.3 (- , 1)
8/9	35.6 (0.4, 53)	0.48 (0.02, 45)	3.00 (0.10, 52)	31.2 (8.4, 2)
8/23	35.9 (0.4, 56)	0.45 (0.02, 55)	2.48 (0.12, 56)	6.4 (0.2, 2)
9/7	37.6 (0.9, 18)	0.57 (0.06, 18)	3.28 (0.19, 18)	83.0 (- , 1)
Chowan River 1983				
7/11	23.7 (1.0, 30)	0.12 (0.02, 15)	2.57 (0.20, 30)	62.6 (- , 1)
8/9	39.1 (0.7, 28)	0.85 (0.04, 27)	2.85 (0.10, 27)	17.6 (- , 1)
9/6	39.5 (0.6, 65)	0.86 (0.04, 66)	3.18 (0.10, 66)	381.0 (345.0, 3)
10/24	49.3 (1.2, 9)	1.42 (0.10, 9)	2.28 (0.38, 9)	217.0 (- , 1)
Albemarle Sound 1983				
7/13	37.1 (0.9, 18)	0.74 (0.05, 18)	3.31 (0.24, 16)	70.6 (22.6, 3)
7/27	43.0 (0.7, 38)	1.14 (0.06, 38)	2.47 (0.16, 36)	20.8 (5.7, 2)
8/12	39.8 (0.6, 29)	0.87 (0.04, 30)	2.80 (0.12, 30)	19.0 (- , 1)
8/25	42.1 (0.5, 49)	1.03 (0.04, 49)	4.21 (0.16, 48)	102.6 (41.4, 2)
9/7	42.5 (0.8, 20)	1.02 (0.06, 20)	2.43 (0.12, 20)	30.8 (- , 1)

* 0 = empty; 4 = full; 5 = distended.

Stomach fullness estimates were made as an indication of whether fish were finding enough food (Table 9). Values for this index show that stomachs were less than half full in the Chowan in June and July 1982, but well over half full at all other times. Numbers of prey items per stomach were also low during this early period. Analysis of the apparently full stomachs in August 1982 showed that much of the material was gelatinous colonies of Anabaena and Microcystis, and that the few prey present were mostly small-bodied bosminids. This reflected both the dominance of bosminids at that time of low total zooplankton densities, and the somewhat higher cyanobacterial biomass during August. But in 1983, there were many more items per stomach without much change in stomach fullness, and algae were only rarely noted as a major diet constituent despite higher algal biomasses and the continuous dominance of Anabaena. The implication is that higher prey densities in 1983, resulting perhaps from low summer flows, may have enhanced feeding success and produced larger sizes of juvenile herring in 1983.

Fish Feeding Electivity

The electivity index reflects the relative abundance of a given item in the fish's diet relative to its proportion in the plankton. One must assume that the plankton were sampled in an unbiased manner, and in the normal feeding habitat of the fish. A discrepancy would indicate either discrimination among potential prey by the fish, called selective feeding, or use of a foraging habitat other than the surface plankton environment. Blueback juveniles in this system often showed a positive electivity for prey which are usually associated with the sediments, such as benthic cladocerans, ostracods and chironomid larvae (Table 10). Among planktonic prey, fish in the Chowan River appeared to elect against the largest taxa (Leptodora, Holopedium if sheath is included), and to be indifferent to smaller or middle-sized items such as Daphnidae, Bosminidae, Cyclopidae and Calanoida. The very smallest crustacean zooplankton, nauplii, were strongly under-captured (negatively elected). This was not entirely a matter of size, because the small rotifers Keratella, Lepadella, and Ploesoma (data not reported in detail here) were abundant in stomachs

Table 10. Means (Standard Errors) of Ivlev Electivity Indices for major diet items and areas, across all dates within each year. (* signifies that 95% confidence limits do not include 0.)

Taxonomic Group	Chowan 1982			Chowan 1983			Albemarle 1983		
	X	SE		X	SE		X	SE	
Calanoida	+0.06	(0.40)		-0.56	(0.24)		+0.85	(0.05)	*
Cyclopoida	-0.55	(0.26)		-0.46	(0.32)		+0.21	(0.25)	
Harpacticoida	-0.24	(0.47)		-0.22	(0.15)		-0.13	(0.57)	
Nauplii	-0.96	(0.04)	*	-0.92	(0.03)	*	+0.11	(0.59)	
Bosminidae	-0.11	(0.37)		-0.12	(0.35)		-0.24	(0.49)	
<u>Diaphanosoma</u>	-0.29	(0.36)		-0.28	(0.46)		+0.61	(0.08)	*
Daphnidae	0	(1)		+0.02	(0.51)		+0.88	(0.12)	*
<u>Leptodora</u>	-0.76	(0.16)	*	-0.58	(0.25)		N. D.		
<u>Holopedium</u>	-0.94	(0.03)	*	-0.52	(0.25)		-1.00	(0)	*
Benthic Cladocera	+0.68	(0.26)	*	+0.86	(0.08)	*	+0.56	(0.23)	
Ostracoda	+0.67	(0.19)	*	+0.35	(0.29)		+1.00	(0)	*
Chironomidae Larvae	+0.84	(0.13)	*	+0.95	(0.01)	*	+0.87	(0.12)	*
Chironomidae Pupae	+1.00	(0)	*	+0.20	(0.37)		+1.00	(0)	*
Rotatoria #	N. D.			+0.20	(0.37)		-1.00	(0)	*

Index overestimated electivity, since some rotifers of the kinds eaten by juvenile bluebacks were small enough to pass through zooplankton nets.

from most 1983 samples, icluding fish over 40 mm in standard length. In Albemarle Sound where fish tended to be slightly larger, there was stronger positive electivity for Calanoida, Diaphanosoma, and Daphnidae and less preference for benthic cladocerans (primarily small Chydorus species).

DISCUSSION

The most remarkable finding here was that densities of larger zooplankton were positively correlated, in a general way, with proportion of cyanobacteria in phytoplankton biomass. Both plankton groups were probably limited in part by the flushing effects of high flows, and biomass or numbers tended to increase at low flows due to the longer development times possible.

A second surprise was the remarkably low zooplankton densities in this very productive system compared to the James River, the only really comparable data available (Burbidge 1974). There, densities in the broad, tidal freshwater reaches ranged from about 50 up to 200 animals per liter through most of the summer and fall, and over 90% were crustaceans. Crustacean densities in the Chowan, even in 1983, never exceeded 15/l. Rotifers (not reported here) added another 30 - 50/l to Chowan zooplankton densities during the late summer of 1983, and Chowan herring ate many, but rotifers were never important in either plankton or fish diets in the James. This contrasting pattern of overall low densities combined with the greater success of small-bodied nauplii and rotifers and strong-swimming copepods in the Chowan suggests that filter-feeding predators, possibly blueback herring juveniles, are controlling the zooplankton community.

Plankton traps used for this study may have undersampled the zooplankton to some degree. Recent trials in ponds (Mozley, unpublished data) have shown that the lower door of the commercial Schindler-Patalas trap does not always close completely when the trap is lifted out of the water, so part of the volume escapes without draining through the net. Discrepancies from this source in ponds were as high as 40% of total density. But even if sampling estimates from the Chowan were 50% too low, crustacean zooplankton densities would still rank well below James River estimates in both years.

Reduced herring sizes in the Chowan, particularly in 1982, can be understood as a response to a poor forage base. Feeding electivity showed that true zooplankton were rarely selected by Chowan juvenile herring, but Burbidge (1974) found consistently strong electivity for calanoid copepods (Eurytemora, also common in the Chowan). Instead, Chowan herring concentrated on epibenthic forms with occasional indications of indiscriminate pump-filtering of zooplankton (high bosminid or rotifer numbers and cyanobacterial colonies in diets) in late summer. The shift to benthic prey at low availabilities of forage organisms was noted for alewife juveniles by Vigerstad and Cobb (1978). But Domermuth and Reed (1980) provide evidence that blueback juveniles feed only near the surface, and suggest that benthic prey items are not taken unless they migrate above bottom. Chowan data indicate that blueback, like alewives, will turn to alternative feeding habitats when planktonic prey densities are too low.

The bulk of 1982-1983 data from the Chowan-Albemarle system contradict any hypothesis that cyanobacterial blooms have reduced the forage base for juvenile blueback. They do suggest that the forage base is poor, and that juvenile fish do not grow as well as in other Atlantic estuaries, so the bluebacks must seek alternate and probably less suitable prey in the Chowan River. While zooplankton densities may be limited generally by flushing effects of high flows, part of the explanation for low zooplankton and poor fish growth may be that food chain controls are working mostly in the direction opposite to that of the original hypothesis. That is, recruitment of blueback in the Chowan exceeds the carrying capacity of zooplankton prey populations and juvenile fish overcrop their food supply. The fact that Leptodora and Holopedium, which seem to be avoided by herring, are rather common in this system (Tables 7 and 8) is consistent with this idea.

This explanation begs the question of how the Chowan-Albemarle fishery remained so productive until the recent past, if the main limiting factor was sufficient prey to support growth and survival of juveniles. A clearer resolution of the relationship between frequent failures of herring runs in the Chowan and the survival and growth of juveniles on the nursery grounds will require more quantitative estimates of density, size structure and survival of juvenile fish, as well as controlled experiments to determine whether prey densities are important for juvenile fish survival and subsequent recruitment to marine populations. This study has laid to rest the notion that cyanobacterial blooms have large negative effects on prey densities, but does not rule out toxic, growth-suppressing, or other direct effects of the blooms on juvenile herring.

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Appreciation is expressed to field personnel who collected the present samples, Sara Winslow (NCDMF) and Lynn Henry (NCDEM), and to the NCDEM, who added zooplankton collections to their routine sampling program in the Chowan River. Technical assistants who analyzed samples in the laboratory, in descending order of contribution, were Richard Diehl, Joseph Staton, Diane Moody and Thomas J. Miller.

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SECTION III

TAGGING STUDIES OF RIVER HERRING (*Alosa aestivalis* and *A. pseudoharengus*) IN BAY OF FUNDY, NOVA SCOTIA, CANADA

by

Roger A. Rulifson

ABSTRACT

River herring (Alosa pseudoharengus and A. aestivalis) are a commercially-important fishery resource in North Carolina. Stocks have been declining in recent years due, in part, to a once-unrestricted offshore fishery by foreign trawlers and water quality problems in North Carolina estuaries. A new potential threat to southern U.S. fisheries may be the development of tidal power in Canadian maritime provinces. To address this concern, 3,584 river herring in Minas Basin and Cobequid Bay, Nova Scotia, were marked with tags bearing North Carolina and Canadian return addresses to determine migration patterns and rivers of origin. From 1 June to 15 August 1983, river herring were captured by gillnet, weir, and midwater trawl in Cobequid Bay, and by weir only in Minas Basin. Nine tagged fish were recaptured by commercial fishermen and other researchers, providing a return rate of 0.25%. In 1983, one tagged alewife released from a weir in Cobequid Bay was recaptured by gillnet in the bay three days later. In May 1984, eight tagged alewives were recaptured within Cobequid Bay in the Avon estuary, Nova Scotia -- seven in the Gaspereau River and one in the Avon River. These fish were recaptured 290 to 346 days after tagging, coinciding with the spring spawning run of alewife in Nova Scotia Rivers. No tagged blueback herring were recaptured. Seven of the eight fish recaptured in 1984 were released from a weir in Cobequid Bay within a twenty-day period (26 June to 16 July 1983). The lack of tag returns from fish released before and after the twenty-day period suggested that more than one alewife population was present. This hypothesis was supported by examination of gonadal maturation and stock discrimination studies using meristic and morphometric criteria. Based on evidence presented in this study and on the life history similarities between shad and river herring, it is possible that river herring stocks from North Carolina and other Atlantic coastal states may migrate to Canadian waters during their life cycles.

INTRODUCTION

Along the east coast of the United States and Canada, alewife (Alosa pseudoharengus) and blueback herring (A. aestivalis) are important species for commercial and recreational fisheries. Alewife and blueback herring are similar in appearance and are marketed together as "river herring" in the U.S. and as "gaspereau" in Canada. Every Atlantic coast state except Georgia has a commercial river herring fishery (Street 1970). Along the eastern seaboard, blueback herring range from Cape Breton, Nova Scotia, to northern Florida (Scott and Crossman 1973). Alewife occur from Newfoundland (Winters et al. 1973) to South Carolina (Berry 1964). Little is known about the biology and migration patterns of anadromous river herring after they leave freshwater. The social, economic, and historical significance of anadromous river herring in southern Atlantic coast states was reviewed by Rulifson et al. (1982).

In North Carolina, alewife and blueback herring are the most abundant anadromous fish species and support important commercial fisheries. In 1981, North Carolina fishermen landed 4,754,000 pounds of river herring valued at $317,000 (Rulifson et al. 1982). Pound nets produce about 95% of the total river herring catch in the state (McCoy 1976). Peak catches of the inshore fishery generally occur during the latter half of April, which coincide with the spawning peak of blueback herring. Most fish caught in the inshore fishery are spent adult fish from several year classes emigrating from the upstream spawning areas. The offshore fishery depends primarily on sexually-immature fish (McCoy 1976). Greatest abundance of river herring occurs in Albemarle Sound; populations are comprised of 70% blueback herring and 30% alewife in the Chowan and Scuppernong Rivers (Pate 1974).

In recent years, river herring stocks in North Carolina have declined drastically due to several factors. The offshore trawl fishery, initiated primarily by foreign countries in 1967, may have contributed to stock decline in the 1970's (McCoy 1976). Research by the North Carolina Division of Marine Fisheries led to severe restrictions on high seas catches of river herring by foreign vessels (Street 1980). In 1979, river herring catches were the lowest on record, which may have been related to water quality problems in the Chowan River and Albemarle Sound (Street 1980).

A new potential threat to river herring stocks may be tidal power development in Canadian Maritime Provinces, which has raised questions in southern U.S. states about potential effects on southern fisheries. This concern has been underscored by Canadian researchers, who confirmed that American shad (Alosa sapidissima) from U.S. rivers (from as far south as Florida) migrate to the Bay of Fundy, Canada, to feed during summer (Dadswell et al. 1983). In every year since 1979, shad tagged in Minas Basin, Nova Scotia, and Cumberland Basin, New Brunswick, have been recaptured in western Albemarle Sound and other North Carolina sounds and tributaries (Dadswell et al. 1984). Other highly migratory fish species from southern waters may also spend a portion of their life cycles residing in Canadian waters (M.J. Dadswell and R.A. Rulifson, unpubl. data). Limited evidence from previous tagging studies of river herring (B.M. Jessop, Canadian Department of Fisheries and Oceans, pers. comm.; M.W. Street, NC Division of Marine Fisheries, pers. comm.) suggest that alewife and blueback herring may perform extensive migrations, perhaps in a manner similar to American shad. Thus, the large Canadian assemblage of river herring found each summer in the upper Bay of Fundy could possibly contain North Carolina, and other Atlantic coastal, river herring stocks. In view of the precipitous decline of many river herring and shad stocks during this century, interstate and international management of migratory fish stocks must become increasingly important.

This study was designed to examine the ocean migratory patterns and rivers of origin of the large numbers of river herring that congregate in the upper Bay of Fundy during summer. The research was conducted through an international effort by the North Carolina Division of Marine Fisheries, Canadian Department of Fisheries and Oceans, and Unity College in Maine.

STUDY AREA

The study was conducted in the Bay of Fundy, which lies between the state of Maine and the province of New Brunswick to the west and Nova Scotia to the east (Figure 1). The two large arms (Chignecto Bay and Minas Basin) comprising the upper Bay are macrotidal estuaries. Changes in water depth between high and low tides average 10 to 12 m, and greatest differences exceed 16 m on spring tides in Minas Basin (Daborn 1983). These tides are among the largest in the world, making Cumberland Basin (New Brunswick) and Minas Basin (Nova Scotia) excellent sites for tidal power development (Baker 1983). Tides in the basins are semi-diurnal and asymmetrical with a periodicity of 12.4 hours. Flood and ebb currents in Minas Channel commonly reach eight knots, causing strong vertical mixing and high levels of turbidity in Cobequid Bay (Daborn 1983).

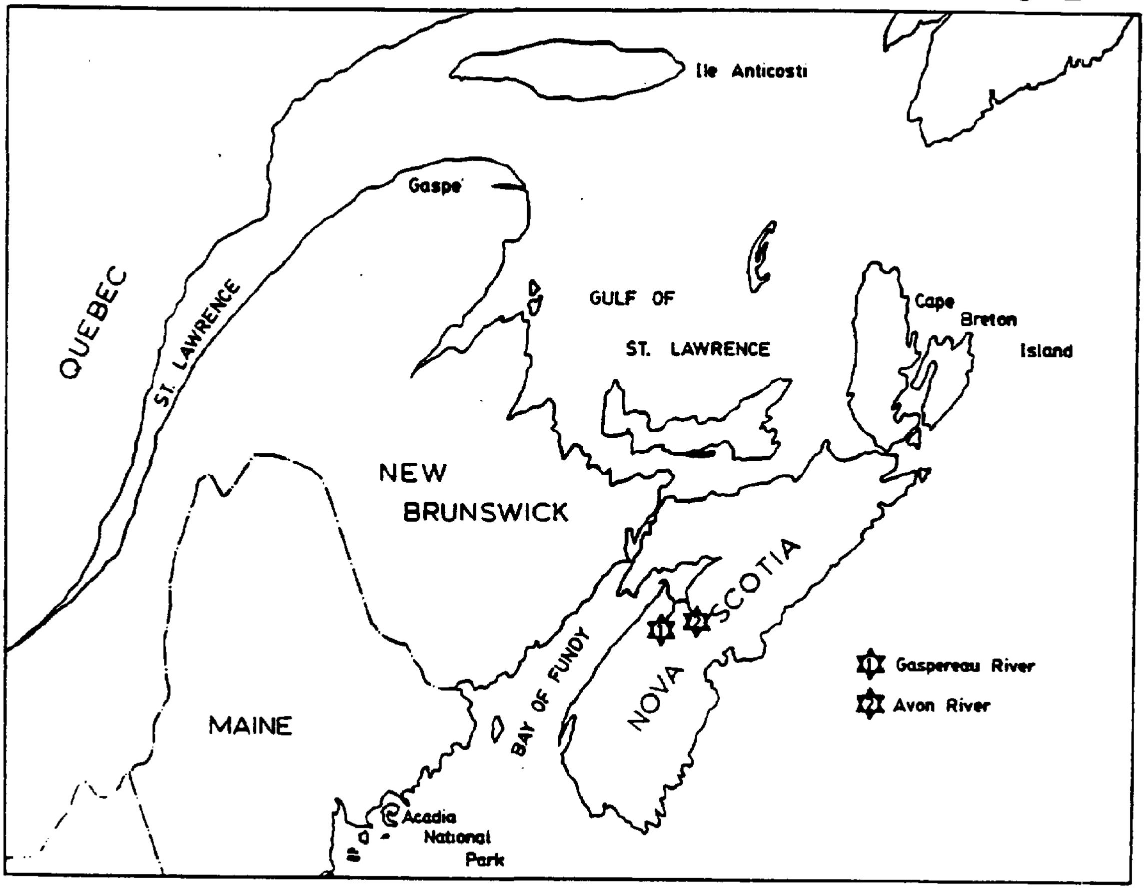


Figure 1. The Bay of Fundy relative to New England and the Canadian maritime provinces.

Slack water ranges from 15 to 30 minutes, allowing little time for surface waters to clear of suspended sediment. Large expanses of intertidal mudflats are exposed at low tide, making boat access to basin waters from the shore impossible at most locations. Daytime heating of exposed mudflats causes water temperatures in the basins to be warmer than those in the lower Bay of Fundy (Dadswell et al. 1984).

METHODS

From 1 June to 15 August 1983, river herring were collected in Minas Basin and Cobequid Bay, Nova Scotia, using commercial weirs, drift gill nets, and midwater trawls. River herring were marked with Floy FD-68B anchor tags bearing individual identification numbers and a return address to either the North Carolina Division of Marine Fisheries in Morehead City, or to the Canadian Department of Fisheries and Oceans in Halifax, Nova Scotia.

Drift gill net activities were centered near Great Village, Nova Scotia (Figure 2). Access to Cobequid Bay waters was limited by boat to approximately two hours before and two hours after high tide. Gill nets, each constructed of multifilament nylon mesh 100 m long and 6 m deep, were set in gangs of mixed mesh sizes in conjunction with the continuation of the American shad tagging project described by Dadswell et al. (1983). Nets were attached to 7-m Eastporter boats in the tidal stream in or near the frontal zone (Bowman and Iverson 1978). Usually two sets were made for up to one hour, the first during the approaching slack high tide and the other just after slack high tide. These high-water drifts occurred primarily over areas of mudflats exposed at low tide. Starting points, set duration, and direction of drift were determined by tide type (spring or neap) and phase (flood or ebb).

Commercial fishing weirs were used to collect and mark river herring during low tide. Harold's weir was located in Cobequid Bay near Economy Point approximately 1 km from the high tide line (Figure 2). At high tide the weir was covered by 5 to 7 m of water. At low water during spring tides, the weir was about 1 km from the low-water mark. At low water during neap tides, portions of the weir remained flooded and access sometimes was impossible. The 500-m long weir was constructed in the shape of a horseshoe with 3-m long wood stakes driven into the tide flat to a depth of approximately 1 m. The weir was positioned so that the tips of the weir "wings" faced the shore, and the "heart" or "throat" of the weir was located in the center of the weir farthest from

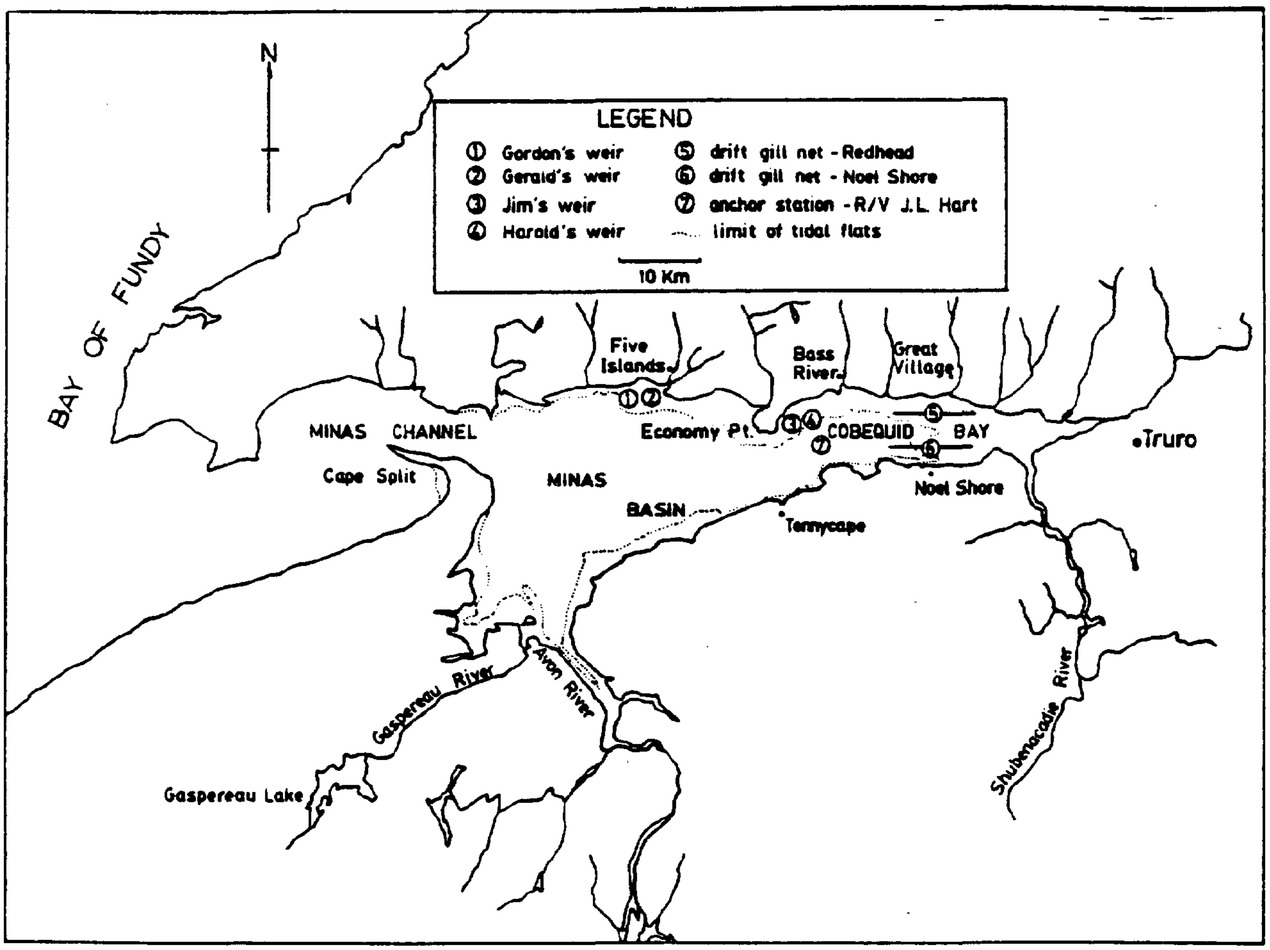


Figure 2. River herring collection sites in Minas Basin and Cobequid Bay, Nova Scotia.

shore. Brush was woven between the stakes to form the wings, and small-mesh net, brush, and stones were used in fabricating the weir heart. Harold's weir held very little water at low tide, which is common for the area, so most fish were tagged and thrown into the ebbing waters. Gerald's weir, the second weir rented for the study, was located in Minas Basin near Five Islands approximately 1.3 km from the high tide line (Figure 2). The weir was approximately 800 m long and fabricated of netting and brush along its full length. Gerald's weir held water at low tide; thus, tagged fish were kept inside until the rising tide flooded the weir, allowing the fish to escape.

River herring also were collected by trawl during a 48-hour study conducted between Economy Point and Tennycape (Figure 2). From 29 June to 1 July, a large midwater trawl was used for one-hour sets from the stern of the Canadian research vessel J.L. Hart at two-hour intervals. River herring were examined for tags, marked, and released.

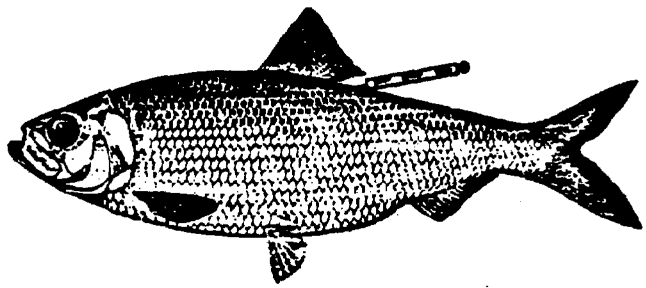
Posters offering monetary rewards (U.S. $2.00) for the return of recaptured fish were distributed to all Atlantic coastal states through the Atlantic States Marine Fisheries Commission and to Canadian maritime provinces by the Canadian Department of Fisheries and Oceans (Figure 3). Also, the poster was reproduced and published in the July 1983 issue of National Fisherman, a trade magazine for commercial fishermen.

Subsamples of fish captured in weirs and gillnets were examined to determine meristic and morphometric characters (Ricker 1971) to assist in identifying stock components of river herring utilizing Minas Basin. Standard length (SL), total length (TL), snout-to-anal length (SNL), body depth (BD), and eye length (EL) were measured while specimens were still fresh. Fish were preserved by freezing; the remainder of the morphometric data were obtained on thawed specimens. Measurements of the fin bases, fin rays, snout, maxillary, head, eye, and interorbital width were taken to the nearest 0.1 mm using Vernier calipers. Vertebral counts were obtained by removing the tissue from the spinal column. Gill raker counts were taken from the first arch of the left gill raker. Sex and gonadal maturation were determined using criteria established by Kesteven (1960) and Nikolsky (1963) for classifying stages of maturity in fishes (see Ricker 1971).

$2.00 REWARD

FOR
TAGGED RIVER HERRING

ALEWIFE (GASPEREAU) AND BLUEBACK HERRING HAVE BEEN MARKED WITH YELLOW PLASTIC TAGS BELONGING TO THE NORTH CAROLINA DIVISION OF MARINE FISHERIES AND THE CANADIAN DEPARTMENT OF FISHERIES AND OCEANS TO OBTAIN INFORMATION ON MIGRATION PATTERNS AND DISTRIBUTION.



TO CLAIM THE $2.00 REWARD AND FIND OUT WHEN AND WHERE THE FISH WAS TAGGED -

PLEASE RETURN THE TAG TO THE APPROPRIATE ADDRESS BELOW AND INCLUDE THE FOLLOWING INFORMATION:

NORTH CAROLINA TAG	CANADIAN TAG
DEPT. NER MRHD. CITY NC REWARD A xxxxxx	DFO BOX 550,HALIFAX,N.S. 0xxxx
N.C. Division of Marine Fisheries P.O. Box 769 Morehead City, NC 28557 USA	Department of Fisheries and Oceans P.O. Box 550 Halifax, NS B3J 2S7 Canada
Tag number................ Date caught............... Place caught.............. .... Gear used.................	Tag number................. Date caught................ Place caught............... .... Gear used..................
Your name................. Address................... City...................... State or Province......... Zip or postal code........	Your name.................. Address.................... City....................... State or Province.......... Zip or postal code.........

Figure 3. Reward poster for tagged river herring.

RESULTS AND DISCUSSION

During summer 1983, a total of 3,584 alewife and blueback herring were marked with Floy tags and released in Minas Basin and Cobequid Bay, Nova Scotia (Table 1). The greatest number (58%) of fish were released from Harold's weir; an additional 25% of marked fish were released from Gerald's weir (Figure 2). The number of fish marked from weirs was a function of the number of fish caught, which depended on the time at which low tide occurred (before or after dusk and dawn), and the number of personnel and equipment available on that date. The remainder of fish tagged (17%) were collected by gillnet or midwater trawl and released in Cobequid Bay.

Estimates of tag losses were obtained by recovering individual unattached tags from the substrate of the weirs on the following daytime low tide. Minimum tag loss by fish released from the weirs averaged 4% (SD = 3.9) and ranged from 0.1 to 11.0%. Recovery time of unsecured tags averaged 2.2 days (SD = 3.6) and longest time to recovery was 17 days. Maximum rate of tag loss and long-term tag retention estimates were not possible with data obtained by this study.

Of the 3,584 river herring marked and released in 1983, nine tags were returned by commercial fishermen and other researchers, which provided a tag return rate of 0.25%. All recaptured fish were alewives; no blueback herring tags were returned. With the exception of one fish, all recaptured alewives were released from the Cobequid Bay (Harold's) weir within a twenty-day period (26 June to 16 July 1983) and recaptured in the Avon estuary in May 1984 (Table 2). These fish remained at large an average of 325 days and were recaptured 290 to 346 days after tagging, coinciding with the spring spawning run of alewives in Nova Scotia rivers (Table 2). Seven of these fish were recaptured in the Gaspereau River, Nova Scotia, which contains a large spawning population of "gaspereau", or alewife (Figure 1). One alewife was recaptured by drift gillnet in the Avon River. Both rivers discharge into the Avon Estuary (Figure 2).

Tag return rates were recalculated based on the numbers of fish released from each site and by date of release. From 1 June to 25 June, only 2% of all marked fish were released and none were recaptured. During the twenty-day period between 26 June and 16 July, 56% of all marked fish were released; nine fish were recaptured for a return rate of 0.45%. The remaining 42% of marked fish were released between 17 July and 15 August, and none were recaptured. On a release-site basis, 58% of the marked fish were released from the Cobequid Bay

Table 1. Number of river herring (alewife and blueback herring) marked with Floy FD-68B anchor tags and released in Minas Basin and Cobequid Bay, Nova Scotia, during 1983. Asterisk (*) indicates tagging dates from which marked fish were recaptured and tags returned by fishermen.

	STATION				
DATE	2 (Gerald's)	4 (Harolds's)	5 (Redhead)	6 (Noel Shore)	7 (J.L. Hart)
6-14	7			15	
6-16	28	1			
6-17	11				
6-18	11				
6-26		13*	1		
6-27	1	88*	108*		
6-28	3	141*	64		
6-29		18	1		93
6-30	7	104*			196
7-1					77
7-2	34				
7-4	2	99			
7-11		124*	45		
7-12		166	7		
7-13		11			
7-15		167			
7-16		439*			
7-18		201			
7-19		150	3		
7-20	43				

Table 1. Continued

DATE	STATION 2 (Gerald's)	4 (Harold's)	5 (Redhead)	6 (Noel Shore)	7 (J.L. Hart)
7-26		103			
7-27	24	159			
7-28	187	93			
7-29	311		3		
8-4	84				
8-5	141				
Totals	894	2077	232	15	366

Total marked = 3,584

Table 2. Recapture information of alewifes marked with Floy FD-68B anchor tags and released in Cobequid Bay, Nova Scotia, during 1983. Release locations as in Figure 1; recapture locations depicted in Figure 2.

Tag	Release			Recapture			Days at
Number	Agency	Date	Location	Date	Location	Method of Capture	Large
00089	DFO	6-26-83	4	6-29-83	Off Bass R. Lighthouse	Drift Gillnet	4
00261	DFO	6-27-83	5	5-3-84	Avon R.	Drift Gillnet	311
A-28063	NCDMF	6-27-83	4	5-11-84	Gaspereau R.	Unknown	319
A-28198	NCDMF	6-28-84	5	5-??-84	Gaspereau R.	Unknown	308-338?
A-28529	NCDMF	6-30-83	4	5-31-84	Gaspereau R.	Unknown	336
A-28664	NCDMF	7-11-83	4	5-$$-84	Gaspereau R.	Unknown	295-325?
A-29612	NCDMF	7-16-83	4	5-27-84	Gaspereau R.	White Rock Fishway	346
A-29617	NCDMF	7-16-84	4	5-??-84	Gaspereau R.	Unknown	290-320?
A-29700	NCDMF	7-16-84	4	5-??-84	Gaspereau R.	Unknown	290-320?

weir and eight were recaptured for a tag return rate of 0.38%. An additional 6.4% of the marked fish were released in Cobequid Bay off Redhead Bluff; one fish was recaptured for a 0.43% tag return rate. The remaining 35.7% of marked fish were released from the Minas Basin weir (25%), the Canadian research vessel J.L. Hart (10%), and off Noel Shore (0.4%); only one fish from these groups (Minas Basin weir) was recaptured.

These tag return patterns suggest that the large numbers of river herring present in Minas Basin and Cobequid Bay are comprised of fish from several stocks and not from one stock, which was believed previously. Additional data in support of this hypothesis were available by examination of (1) catch patterns in gillnets and weirs, (2) alewife gonadal development, and (3) meristic and morphometric characters.

Patterns of river herring catches in weirs and gillnets suggest that the large numbers of river herring in Minas Basin and Cobequid Bay during summer are actually comprised of several stocks moving into and out of the region in discrete groups, a pattern similar to that of American shad (Dadswell et al. 1984). Gillnet catches of river herring in Cobequid Bay during 1983 exhibited several peaks in alewife abundance (Figure 4). Blueback herring increased in abundance throughout the summer. After mid-August, river herring were not caught in the upper reaches of the Bay of Fundy, but catches increased in the lower bay near Passamaquoddy Bay in the fall (M.J. Dadswell, unpubl. data). Unequal distribution of river herring in Minas Basin and Cobequid Bay also were evident in weir catches collected on the same tides (Table 1).

The hypothesis that more than one river herring stock was present in Fundy waters is supported by the examination of gonadal development of the alewives subsampled during tagging operations. Gonads examined from adult alewife (245 to 292 mm TL) retained from gillnets in Cobequid Bay (off Redhead Bluff) indicated that females were in various stages of gonadal maturity (Table 3). No immature (stage I) females were caught, probably because of gear selectivity favoring larger fish. Most of the ovaries examined (80 to 85% of 30 fish) were in the resting stage (II) or initial stages of maturation (III). Some females (15 to 20%) had ovaries that were mature (stage IV) or in a reproductive state (V); none were in spent (VI) condition. Male alewife (245 to 280 mm TL) testes were either in the resting stage (II, 67%) or the initial stage of maturation (III, 33%). No males in spawning condition (IV or V) were observed in Cobequid Bay gillnet catches. Thus, the range of gonadal development in females (resting stage to spawning condition) and the lack of range of male gonadal maturity

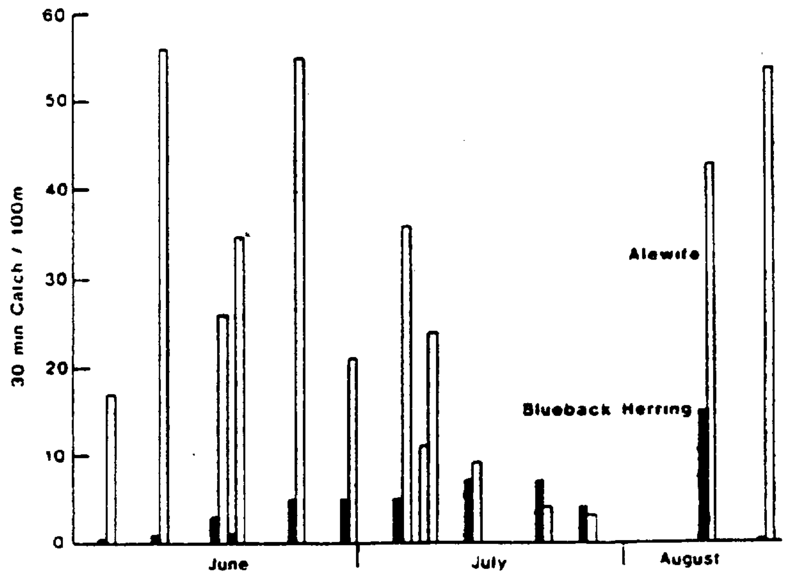


Figure 4. Capture rate of alewife and blueback herring in a 6.2 cm stretched mesh drift gillnet in Cobequid Bay, Nova Scotia, during 1983 (from Dadswell et al. 1984).

Table 3. Stage of gonadal maturity of alewife captured in Minas Basin and Cobequid Bay, Nova Scotia, during 1983. Values represent percentage of the population at each stage of maturity.

		MALES						FEMALES					
Date	Location	N	I	II	III	IV	V	N	I	II	III	IV	V
6-15	Redhead	6		67	33			20		70	15	10	5
6-16	Gerald's							3	67	33			
6-18	Gerald's	5	100					8	50	50			
	Harold's	5	40	40	20			16	12	44	25	19	
6-27	Redhead	3		67	33			10		20	60	10	10
7-12	Harold's	3	67	33				8	12	76	12		

Males:

I. Immature - testes small, transparent.
II. Resting Stage - testes translucent, grey-red.
III. Maturation - testes change from transparent to pale rose.

Females:

I. Immature - eggs invisible to naked eye, ovaries transparent.
II. Resting stage - Ovaries translucent, grey-red; eggs not distinguishable to naked eye.
III. Maturation - Ovaries red to orange-red; eggs clearly visible to naked eye.
IV. Maturity (gravid) - Ovaries fill ventral cavity; eggs completely round, some ripe.
V. Reproduction (spawning condition) - Eggs extrude in response to light pressure on belly.

suggest that more than one alewife stock were present, and intermixing, in Cobequid Bay waters during June 1983.

Alewife stocks may intermix in Cobequid Bay for indefinite periods, but probably arrive and exit from Minas Basin in large schools of discrete populations, a pattern similar to that described for shad by Dadswell et al. (1983). Subsamples of alewife collected simultaneously from two locations showed significant differences between the two groups in gonadal development and meristic and morphological characters. Ovaries of females collected from the Cobequid Bay (Gerald's) weir on 18 June were either immature (50%) or in a resting condition (50%); Minas Basin females collected on the same night ranged from immature (12%) to gravid (19%) (Table 3). No spawning or spent females were present in either group. No significant difference of the fork length-age relationship between the two groups was evident, but females in the Cobequid Bay weir averaged older (2.7 years) than Minas Basin females (1.1 years). A t-test indicated significant differences in morphological characters between the two female groups, which included variables LRP ($P<.001$), LRA ($P<.01$), LRV ($P<.01$), and SNL ($P<.02$) (Table 4). Morphometric differences at the $P<.10$ level included body depth (BD), interorbital width (IOW), and dorsal longest ray (LRD). The only meristic character that differed significantly ($P<.001$) between female groups was the average number of caudal fin rays (Table 4), a character that may be highly variable within the same population (G.D. Melvin, St. Andrews Biol. Station, pers. comm.). Differences in gonadal maturity and morphology between male alewife collected 18 June from the two locations were less distinct than those for females. Cobequid bay males averaged larger (243.4 mm TL) than those from Minas Basin (203.8 mm TL) (Table 5); fewer immature fish (40%) were present in the former compared to the latter (100%) (Table 3). Interorbital width was the only morphometric character significantly different between the two populations at $P<.05$. However, differences in FLA, LRP, and LRV between male groups were observed at $P<.10$. None of the meristic characters differed significantly between the two male groups.

Few identification studies of river herring stocks utilizing meristic and morphometric traits have been reported in the literature, but comparisons of data collected in Fundy waters to other studies suggest that the technique may define discrete stocks, at least on a regional basis. Scott and Crossman (1973) presented ranges of these traits for Canadian alewife (sexes combined) but did not include mean values or numbers of fish examined. Morphometric measurements of the present study that fell outside the ranges reported by Scott and Crossman

Table 4. Meristic and morphometric measurements of female alewife collected from Gerald's weir (Minas Basin) and Harold's weir (Cobequid Bay) on 18 June, 1983.

Character	Proportional Relationship	Gerald's Weir			Harold's Weir		
		N	Ave.	Range	N	Ave.	Range
Morphometric							
Total Length (TL)	TL (mm)	8	207.12	163-250	16	266.19	187-319
Snout to Anal Length (SAL)	SAL (%TL)	8	58.61	57.47-61.60	16	58.35	56.75-59.64
Body Depth (BD)	BD (%TL)	8	23.14	21.56-25.56	16	24.22	22.55-26.19
Eye Length (EL)	EL (%HL)	7	26.72	25.86-28.53	16	26.76	24.79-30.94
Fin Length-Dorsal (FLD)	FLD (%TL)	8	12.61	11.78-13.57	16	12.77	11.17-13.79
Fin Length-Anal (FLA)	FLA (%TL)	8	12.60	11.24-13.66	16	12.10	10.67-13.44
Longest Ray-Dorsal (LRD)	LRD (%TL)	8	12.71	11.76-13.53	16	13.17	12.23-14.06
Longest Ray-Anal (LRA)	LRA (%TL)	8	5.17	4.62-5.77	16	5.82	5.14- 7.11
Longest Ray-Pectoral (LRP)	LRP (%TL)	8	13.71	12.78-15.03	16	14.62	13.92-15.61
Longest Ray-Ventral (LRV)	LRV (%TL)	8	9.65	8.90-10.27	16	10.26	9.43-10.90
Head Length (HL)	HL (%TL)	7	18.88	18.52-19.37	16	18.62	17.17-19.69
Snout Length (SNL)	SNL (%HL)	7	29.34	28.65-30.57	16	31.01	28.45-33.25
Head Width (HW)	HW (%HL)	7	39.62	37.15-42.06	16	42.18	29.16-51.55
Interorbital Width (IOW)	IOW (%HL)	7	25.52	23.04-32.48	16	28.84	21.33-35.04
Maxillary Length (ML)	ML (%HL)	6	47.69	44.86-50.49	16	48.73	44.42-51.44

Table 4. (Continued)

Character	Proportional Relationship	Gerald's Weir			Harold's Weir		
		N	Ave.	Range	N	Ave.	Range
Meristic							
Number of Rays -							
Left Pectoral (LP)	Count	8	15.25	15-16	16	15.50	15-16
Right Pectoral (RP)	Count	8	15.12	15-16	16	15.38	15-16
Left Ventral (LV)	Count	8	9	9	16	9	9
Right Ventral (RV)	Count	8	9	9	16	9	9
Dorsal (D)	Count	8	15.62	15-17	16	15.56	14-16
Anal (A)	Count	8	17.50	17-19	16	17.69	17-18
Caudal (C)	Count	7	22.57	20-25	15	21.40	20-23
Left Gill Raker -							
Upper (GRU)	Count	4	20.25	17-23	14	21.21	19-23
Lower (GRL)	Count	4	37.5	34-40	14	38.21	32-44
Total (GRT)	Count	4	57.75	51-63	14	59.43	56-66
Scutes -							
Preventral (AS)	Count	8	19.62	18-20	15	19.53	19-20
Postventral (PST)	Count	8	14.75	13-16	15	15.00	14-16
Vertebrae (VT)	Count	7	48.14	47-49	16	48.94	47-51

Table 5. Meristic and morphometric measurements of male alewife collected from Gerald's weir (Minas Basin) and Harold's weir (Cobequid Bay) on 18 June, 1983.

Character	Proportional Relationship	Gerald's Weir			Harold's Weir		
		N	Ave.	Range	N	Ave.	Range
Morphometric							
Total Length (TL)	TL (mm)	5	203.8	195-212	5	243.4	185-315
Snout to Anal Length (SAL)	SAL (%TL)	5	58.95	56.92-60.38	5	59.18	57.21-60.70
Body Depth (BD)	BD (%TL)	5	23.45	22.89-24.39	5	23.41	21.62-24.90
Eye Length (EL)	EL (%HL)	5	25.99	22.52-27.46	5	27.44	24.36-28.96
Fin Length-Dorsal (FLD)	FLD (%TL)	5	12.48	11.04-13.88	5	12.88	11.63-14.86
Fin Length-Anal (FLA)	FLA (%TL)	5	12.73	11.74-13.71	5	11.67	10.16-12.49
Longest Ray-Dorsal (LRD)	LRD (%TL)	4	12.65	12.34-13.27	5	12.88	11.12-14.48
Longest Ray-Anal (LRA)	LRA (%TL)	5	5.07	4.73-5.66	5	5.50	4.28- 6.48
Longest Ray-Pectoral (LRP)	LRP (%TL)	5	13.58	12.99-14.03	5	14.66	13.30-16.51
Longest Ray-Ventral (LRV)	LRV (%TL)	5	9.33	8.73-9.71	4	9.98	9.30-10.41
Head Length (HL)	HL (%TL)	5	19.17	18.83-19.44	5	18.83	18.05-19.81
Snout Length (SNL)	SNL (%HL)	5	29.26	26.22-31.93	5	32.44	28.44-39.62
Head Width (HW)	HW (%HL)	5	38.99	36.25-41.09	5	41.12	36.07-45.04
Interorbital Width (IOW)	IOW (%HL)	5	27.16	23.91-31.13	5	32.91	27.56-36.21
Maxillary Length (ML)	ML (%HL)	5	49.62	46.79-52.07	5	48.05	30.39-63.11

Table 5. (Continued)

Character	Proportional Relationship	Gerald's Weir			Harold's Weir		
		N	Ave.	Range	N	Ave.	Range
<u>Meristic</u>							
Number of Rays -							
Left Pectoral (LP)	Count	5	15.2	15-16	5	15.2	15-16
Right Pectoral (RP)	Count	5	15.0	14-16	5	15.4	15-16
Left Ventral (LV)	Count	5	9.0	9	5	9.2	9-10
Right Ventral (RV)	Count	5	9.0	9	5	9.0	9
Dorsal (D)	Count	5	15.4	13-17	5	16.4	15-19
Anal (A)	Count	5	17.4	16-18	5	17.2	16-19
Caudal (C)	Count	4	21.75	21-22	5	21.8	21-23
Left Gill Raker -							
Upper (GRV)	Count	5	20.4	19-22	5	22.6	19-27
Lower (GRL)	Count	5	37.4	36-39	5	37.8	33-45
Total (GRT)	Count	5	57.8	55-61	5	60.4	52-72
Scutes -							
Preventral (AS)	Count	5	19.6	19-20	5	20.0	19-21
Postventral (PST)	Count	5	14.4	14-15	5	14.8	14-15
Vertebrae (VT)	Count	5	34.0	33-35	5	34.8	34-35

included body depth, dorsal fin length, anal fin length, head length, and interorbital width (Table 6). Meristic differences were evident in the number of left and right ventral fin rays. Data from the current study compared to values reported for Chesapeake Bay fish by Hildebrand and Schroeder (1928) suggest differences in snout length, interorbital width, and total scute count (Table 7). Between-area comparisons of spawning alewives and blueback herring in the Saint John River, New Brunswick, indicated significant differences in meristic characters within species (Messieh 1977).

Alewife and blueback herring are closely related to American shad and exhibit similarities in freshwater life history patterns (Rulifson et al. 1982). However, very little is known about river herring life histories in the marine environment. River herring enter ocean waters after spawning and are caught by trawlers offshore (Neves 1981). Thus, the possibility that river herring stocks may migrate offshore, perhaps for long distances, is not surprising. American shad migration studies conducted in the upper Bay of Fundy by Dadswell et al. (1983) confirm many of the ocean migration patterns proposed by Leggett and Whitney (1972) and refined by Neves and Dupres (1979), and also pinpoint rivers of origin for discrete shad stocks utilizing Bay of Fundy waters. An extensive ocean tagging program conducted by the North Carolina Division of Marine Fisheries offshore North Carolina failed to produce any recaptured river herring (M.W. Street, pers. comm.). In New Brunswick, a large tagging program was conducted on alewife spawning in the St. John River; two were recaptured by trawler offshore Rhode Island (B.M. Jessop, pers. comm.). Therefore, based on evidence presented in this study and on the life history similarities between shad and river herring, it is possible that river herring stocks from North Carolina and other southern states may migrate to Canadian waters during their life cycles.

Table 6. Comparisons of meristic and morphometric characters of alewife from Canadian waters (Scott and Crossman 1973) and Bay of Fundy waters (present study). Data are for sexes combined; blanks indicate no information available.

Character	Proportional Relationship	Scott and Crossman (1973)			Present Study		
		N	Ave.	Range	N	Ave.	Range
Morphometric							
Total Length (TL)	TL				89	252.36	145-326
Snout to Anal Length (SAL)	SAL (%TL)				89	58.59	55.51-61.60
Body Depth (BD)	BD (%TL)			17.8-21.7	89	23.67	19.74-26.91
Eye Length (EL)	EL (%HL)			26.1-32.0	75	26.58	21.08-30.94
Fin Length - Dorsal (FLD)	FLD (% TL)			13.6-17.7	89	12.69	10.21-14.89
Fin Length - Anal (FLA)	FLA (% TL)			10.3-12.0	89	12.11	9.60-13.98
Longest Ray - Dorsal (LRD)	LRD (% TL)				88	12.84	9.95-14.48
Longest Ray - Anal (LRA)	LRA (% TL)				89	5.58	4.28- 7.11
Longest Ray - Pectoral (LRP)	LRP (% TL)			13.0-16.6	89	14.35	11.75-16.51
Longest Ray - Ventral (LRV)	LRV (% TL)			8.2-11.6	88	9.94	8.73-11.45
Head Length (HL)	HL (% TL)			20.3-23.7	88	18.72	17.17-21.33
Snout Length (SNL)	SNL (% HL)			26.9-35.7	88	30.61	21.59-39.62
Head Width (HW)	HW (% HL)				88	33.81	29.16-51.55
Interorbital Width (IOW)	IOW (% HL)			15.7-21.6	87	28.40	21.33-36.21
Maxillary Length (ML)	ML (% HL)				87	48.81	30.39-63.11

Table 6. (Continued)

Character	Proportional Relationship	Scott and Crossman (1973) N	Ave.	Range	Present Study N	Ave.	Range
Meristic							
Number of Rays							
Left Pectoral (LP)	Count			14-16	89	15.2	14-17
Right Pectoral (RP)	Count			14-16	89	15.2	14-17
Left Ventral (LV)	Count			10	89	9.01	9-10
Right Ventral (RV)	Count			10	89	9.01	9-10
Dorsal (D)	Count			12-16 (13-14)	89	15.93	13-19
Anal (A)	Count			15-19 (17-18)	89	17.73	16-21
Caudal (C)	Count				83	24.76	19-30
Left Gill Raker -							
Upper (GRV)	Count				74	21.38	14-24
Lower (GRL)	Count			38-43	74	38.094	27-45
Total (GRT)	Count				74	59.42	41-66
Scutes							
Preventral (AS)	Count			17-21 (19-20)	88	19.56	18-21
Postventral (PST)	Count			13-16 (14-15)	88	14.62	13-16
Vertebrae (VT)	Count			48-50	86	48.65	46-51

Table 7. Comparisons of meristic and morphometric characters of alewife from Chesapeake Bay waters (Hildebrand and Schroeder 1928) and Bay of Fundy waters (present study). Data are for sexes combined; dash (-) indicates no information available.

Character	Proportional Relationship	Hildebrand and Schroeder (1928)			Present Study		
		N	Average	Range	N	Average	Range
Morphometric							
Body Depth (BD)	SL/BD	22	3.23	2.80-4.15	89	3.40	3.00-4.13
Eye Length (EL)	HL/EL	22	3.12	2.60-4.15	76	3.73	3.23-4.74
Longest Ray - Pectoral (LRP)	HL/LRP	22	-	1.20-2.00	89	1.29	1.14-1.49
Head Length (HL)	SL/HL	22	-	2.90-4.30	89	4.24	3.67-4.65
Snout Length (SNL)	HL/SNL	22	-	3.50-5.00	89	3.26	2.52-4.26
Interorbital Width (IOW)	HL/IOW	22	-	4.00-6.45	88	3.54	2.76-3.69
Maxillary Length (ML)	HL/ML	22	-	2.00-2.65	89	2.02	1.58-3.29
Meristic							
Number of Rays -							
Dorsal	Count	22	16-17	15-19	89	15.93	13-19
Anal	Count	22	-	17-21	89	17.73	16-21
Lower Gill Raker	Count		-	33-40	74	38.04	27-45
		(for fish 158-284 mm SL)			(for fish 136-260 mm SL)		
Scutes -							
Preventral	Count		-	19-22	88	19.56	18-21
Postventral	Count		-	11-15	88	14.62	13-16
Total	Count		-	30-35	86	48.65	46-51

RECOMMENDATIONS

Additional, more extensive, studies are required to confirm the migration of river herring stocks from U.S. coastal waters to Canada, especially Bay of Fundy waters. Meristic and morphometric studies of several spawning populations of river herring collected from rivers near the ends of the biological range (e.g., rivers in New Brunswick and North Carolina) will indicate if these characters can be used for population discrimination studies. An intensive ocean tagging program conducted in the Bay of Fundy region (20,000 fish in one season), combined with efforts to inform commercial fishermen in the U.S. and Canada of the study, could result in a tag return rate high enough to determine migration patterns. These studies should be conducted as soon as possible so that state and federal management plans for river herring currently being developed can utilize the information.

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