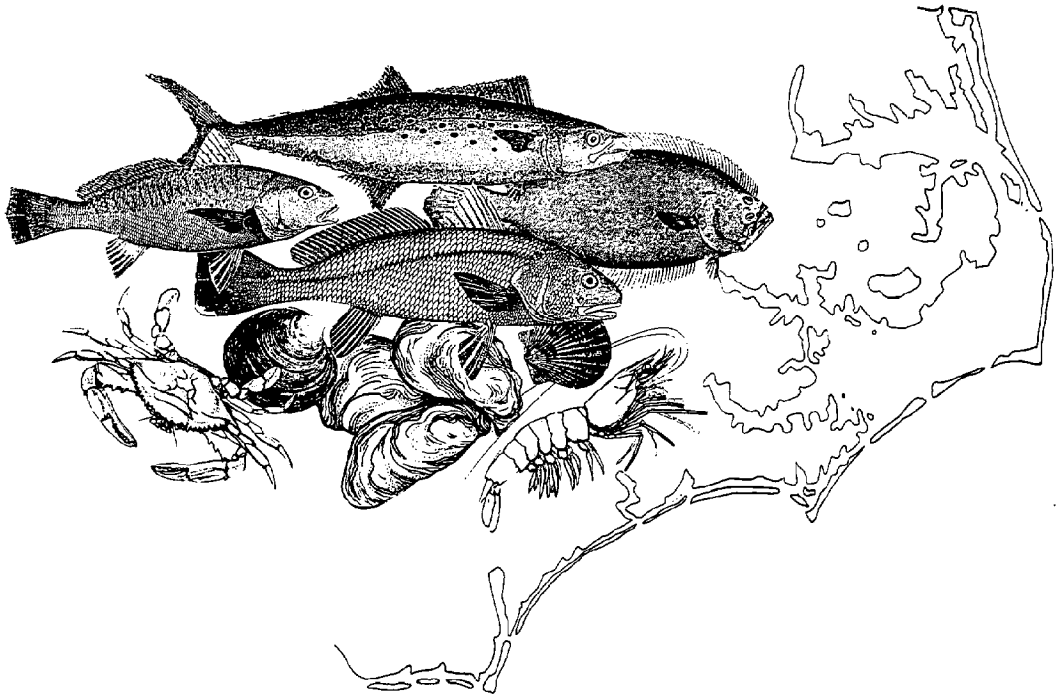
MIGRATION PATTERNS OF AMERICAN SHAD IN THE NEARSHORE OCEAN WATERS OF SOUTHEASTERN NORTH CAROLINA



North Carolina Department of Environment,
Health, and Natural Resources

Division of Marine Fisheries
Morehead City, NC 28557

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MIGRATION PATTERNS OF AMERICAN SHAD IN THE NEARSHORE OCEAN WATERS OF SOUTHEASTERN NORTH CAROLINA

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ABSTRACT

A tagging study of American shad (Alosa sapidissima (Wilson)) utilizing 5 1/2 inch mesh gill nets was conducted in the nearshore ocean waters off Wrightsville Beach, NC. A total of 101 American shad was captured between 18 January 1990 and 8 May 1990. Of those, 98 were tagged with Floy FT-1 dart tags. Returned tags totaled 16, with all returns recaptured south of the tagging site. North Carolina rivers accounted for six returns and South Carolina rivers accounted for four returns. Catch-per-unit-effort (CPUE) was based on a Standard Fishing Unit (SFU) of 100 yd of net at 5.7 yd depth (50 meshes) set for one hour. Daily CPUE's ranged from zero on several dates to a high of 3.50 on 16 March 1990 when 35 American shad were captured and tagged. Temperatures at which American shad were captured ranged from 8.6°C to 19.9°C, with the maximum number of American shad captured at 13.2°C. Regulatory options and recommendations are also discussed.

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INTRODUCTION

The American shad (Alosa sapidissima (Wilson)) fishery was once the most valuable fishery in North Carolina (Alexander 1905). In 1897, American shad landings were almost nine million pounds, which was the highest ever recorded for the state (Townsend 1900). Bowers (1913) reported that North Carolina led all other south Atlantic states with almost 1.3 million fish in 1910. North Carolina landings of American shad have precipitously declined since the early 1900s with overfishing, construction of dams, and pollution generally regarded as the major factors. Johnson (1938) reported that the decline in landings may have also been a result of a decrease in demand for shad from the late 1800s to the 1930s. Despite such obstacles, the American shad fishery still represents a significant industry to commercial and recreational fishermen in North Carolina with landings during 1985-1988 of over 1.25 million pounds with a value of over $740,000 (North Carolina Division of Marine Fisheries data).

American shad are the largest clupeids in the United States. They are anadromous and reported to range from the St. Lawrence River, Canada to the St. John's River, Florida on the western Atlantic coast (Nichols and Massmann 1962). Adult American shad migrate to inland spawning grounds throughout their range along the Atlantic coast. Massmann (1952) reported that spawning invariably takes places in fresh water. Juvenile American shad spend their first summer in the river in which they were spawned and then migrate downstream to the sea in the fall (McDonald 1884; Smith 1896; Smith 1899; Leggett and Whitney 1972). After reaching sexual maturity, they return to fresh water to spawn (LaPointe 1958; Neves and Depres 1979). Sexual maturity is reached by males in 3 to 4 years and by females in 4 to 5 years. Studies by Leggett (1972) showed that American shad in the Connecticut River spent 40 to 100 days in fresh water during spawning migrations. Cornell (1955) reported American shad to remain in North Carolina waters for a few weeks during the spawning period.

American shad exhibit a pronounced latitudinal cline in postspawning survival (Glebe and Leggett 1981; Carscadden and Leggett 1975). Some authors (Leggett 1972; Sykes and Talbot 1959; Chittenden 1975) report North Carolina to be the geographical boundary between semelparous (spawning once) and iteroparous (repeat spawning) populations of American shad, with populations south of

North Carolina being semelparous and populations north of North Carolina being strongly iteroparous. The incidence of repeat spawners enumerated from scale readings was zero in the St. John's River, Florida, compared with 3% for the Neuse River, North Carolina, 27% for the James River, Virginia, 38% for the Connecticut River, Connecticut, 72% for the St. John River, New Brunswick (Leggett and Carscadden 1978) and 85% for the Annapolis River, Nova Scotia (Melvin et al. 1986). Glebe and Leggett (1981) attributed the differences in spawning characteristics to the higher amount of energy expended by American shad to reach southerly spawning grounds.

The North Carolina commercial fisheries for American shad have traditionally been located in estuaries and coastal rivers. Likewise, most studies on American shad in North Carolina have been conducted in estuarine and riverine waters. Holland and Yelverton (1973) conducted the most recent and thorough study on American shad distribution in the oceanic waters of North Carolina. Their capture data suggested that adult American shad were migrating to their spawning grounds as late as March in 1971. Tagging experiments during the study provided little information on migrational patterns because no tags were returned.

In 1985-86, South Carolina conducted a Territorial Sea tagging program involving American shad in their coastal ocean waters. The purpose was to monitor shad stocks and gather information on migrational patterns. Information from the study revealed that all but one of the recaptured tagged fish were caught in rivers south of the tagging sites, suggesting a southern spawning migration pattern of shad in nearshore ocean waters off South Carolina. This finding led to speculation that the developing North Carolina ocean fishery for American shad may be taking South Carolina's spawning stock. This practice of ocean intercept fisheries for American shad is discouraged by the Atlantic States Marine Fisheries Commission's fishery management plan (ASMFC 1985) which encourages each state to fish on its own stocks in or near natal rivers.

The purpose of this study was to determine the migration patterns of American shad in the nearshore ocean waters of southern North Carolina and to ascertain if the developing gill net fishery in that area for American shad may be intercepting South Carolina's spawning stock.

TAGGING SITE

The tagging site, which was a nearshore ocean area off Wrightsville Beach, NC north of Masonboro Inlet (Figure 1), was selected based on success from a study conducted in 1989 (Parker 1989). The location was particularly ideal because of its proximity to Masonboro Inlet and the relatively short boating distance required to reach the site. This situation enabled tagging effort to occur very frequently and to cover long periods. The site was also located north of the Cape Fear River and its tributaries, which is the most southerly of the North Carolina rivers historically known for its "shad run." Most commercial ocean American shad fishing in North Carolina occurs north of the Cape Fear River. Selection of this particular site enabled the study to better assess the extent which North Carolina's ocean American shad fishery may be affecting its own rivers and/or those of more southerly states.

METHODS AND MATERIALS

One hundred yard drift gill nets of 5 1/2 inch stretched mesh were utilized during the study. All nets were 50 meshes (approx. 5.7 yd) in depth and were fished in sets of two tied end to end. This gear has proven to be selective for female American shad, which are the principle target of the fishery. The nets were checked approximately every half hour, or during incidences of high catch, as often as possible. With one exception, tagging effort occurred during daylight hours, and mostly during the morning. This technique was based on findings by Neves and Depres (1979) who reported that day catches of American shad occurred significantly more often ($P < 0.01$) than night catches. All captured American shad were placed in an oval 115 gallon holding tank filled with ambient seawater where they remained until completion of that particular net fishing cycle. They were then transported to an area at least one thousand yards offshore from the drift nets. As quickly as possible, each American shad deemed suitable was measured (fork length (FL), mm), tagged, and released. Also, scales were removed and saved for age determination.

Tags and Tagging Method

Floy FT-1 dart tags were utilized for the study based on their success in a previous study (Melvin et al. 1986). Tags were orange-colored, individually numbered, and printed with the agency return address and a reward notification. Tags were inserted with a canula immediately below the dorsal fin on the left side. Cash rewards of $2 were offered for returned tags.

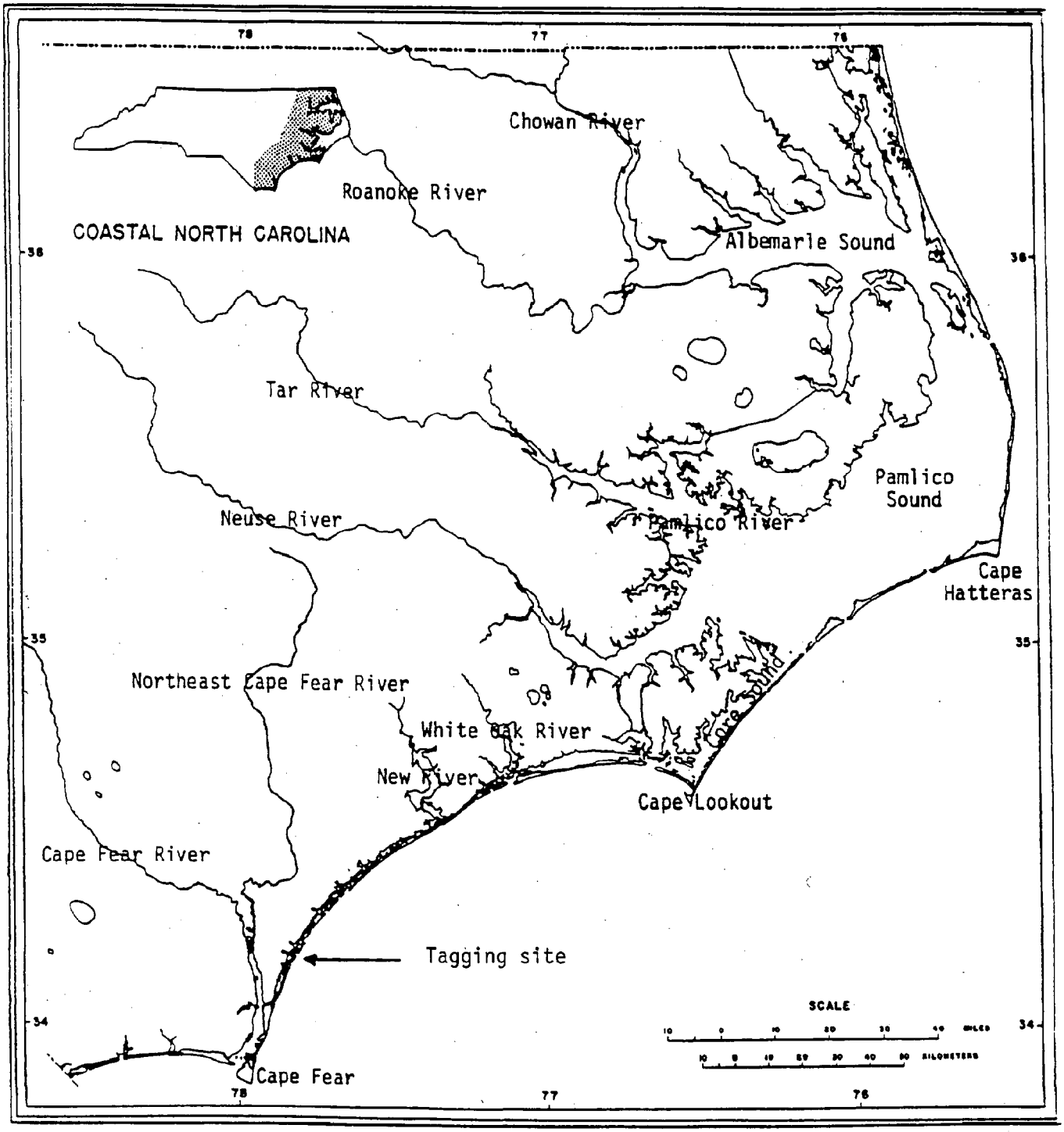

Figure 1. Tagging site of American shad captured in the nearshore ocean off Wrightsville Beach, NC, December 1989 - May 1990.

Requested tag return information included tag number, name and address of fisherman, place caught (water body and nearest landmark), date of capture, gear used in capture, and length of fish. Posters advertising the study were placed at local fish markets, boat landings, and other pertinent locations. Posters were also distributed to Atlantic states marine fisheries officials for distribution in their respective states.

Recorded Data

Data from captured American shad included fork length, location, and date. Data monitored and recorded from tagging sites included date, location, surface and bottom temperatures and salinities, water depth, wind speed and direction, gear parameters, and duration (length of time net fished). Pre-tagging mortality of American shad was noted, as well as all other species collected.

Scale Samples

Scales from the left side of the American shad posterior to the pectoral fin were removed and saved in individually numbered envelopes. Scale removal simply involved scraping a dull knife against the fish from rear to front to obtain approximately ten to twenty scales. Scales were used to provide data on age and spawning characteristics of American shad as described by Judy (1961). Scales were cleaned with a 5% NaOH solution and read by use of a microfiche projector.

RESULTS

Tagging took place between December 1989 and May 1990. American shad captures began in late January, peaked during March, and precipitously declined throughout the remainder of the study (Figure 2). A total of 101 American shad was captured and measured. Of those, 98 were considered sufficiently healthy to be tagged. Scales were taken from all captured American shad. All American shad were captured near the bottom of the net which was consistent with findings by Neves and Depres (1979) and Parker (1989). Incidental species captured are listed in Table 1.

Catch-Per-Unit-Effort

Catch-per-unit-effort (CPUE) was based on a Standard Fishing Unit (SFU) of 100 yd of net at 5.7 yd depth (50 meshes) set for one hour. Catch-per-unit-effort was calculated from total catch divided by number of SFU's. Daily CPUE's

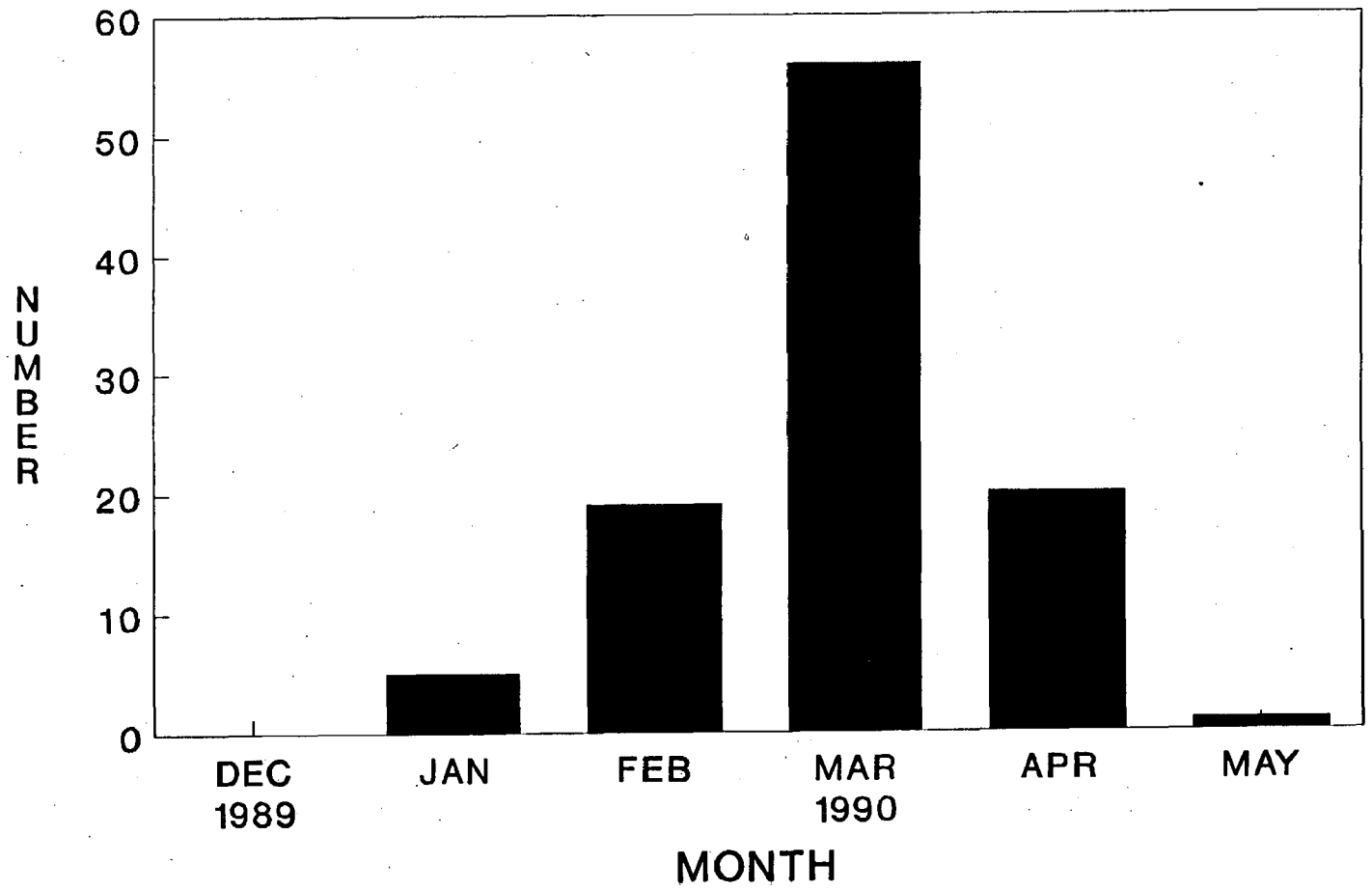

Figure 2. Number of American shad captured by month from the nearshore ocean off Wrightsville Beach, NC, December 1989 - May 1990.

Table 1. Incidental species captured in drift gill nets in the nearshore ocean area off Wrightsville Beach, NC, December 1989 - May 1990.

Scientific name	Common name
Petromyzon marinus	sea lamprey
Mustelus canis	smooth dogfish
Rhizoprionodon terraenovae	Atlantic sharpnose shark
Squalus acanthias	spiny dogfish
Rhinoptera bonasus	cownose ray
Acipenser oxyrhynchus	Atlantic sturgeon
Alosa pseudoharengus	alewife
Brevoortia tyrannus	Atlantic menhaden
Pomatomus saltatrix	bluefish
Echeneis naucrates	sharksucker
Euthynnus alletteratus	little tunny
Callinectes sapidus	blue crab

ranged from zero on several dates to a high of 3.50 on 16 March 1990 (Table 2).

Age and Length Composition

Based on scale readings, the age composition of the captured American shad was 4.3% four-year-olds, 53.3% five-year-olds and 42.4% six-year-olds (Table 3). There were no repeat spawners. Size ranged from 434 mm to 546 mm (Figure 3), with an average length of 496 mm. Mean fork length (mm) and length ranges by age group are shown in Table 4.

Tag Return Data

Of the total number (98) of fish tagged, sixteen were recaptured (Table 5). Of those, six were recaptured in the Cape Fear, Northeast Cape Fear, and Black rivers of North Carolina. All three rivers are near the tagging area and have historical gill net fisheries for American shad. There were also six fish recaptured in the Atlantic Ocean off North Carolina and four fish were recaptured in South Carolina rivers. All American shad recaptured were taken south of the tagging site (Figure 4). The average distance traveled was 82 miles, with the farthest travel being 370 miles (Still Creek, Savannah River, SC). The average number of days at large was 10.2 with a range of 1 to 47 days out.

Environmental Parameters

Temperatures at which American shad were captured ranged from 8.6°C to 19.9°C, with the maximum number of American shad caught at 13.2°C. Salinity during the sampling period ranged from 33.9 to 36.0 parts per thousand (Table 6). Water depth at the tagging site was an average of 6.0 meters.

DISCUSSION AND CONCLUSIONS

Age and Size Data

Data analysis on age and size of American shad is limited due to the type of fishing gear and mesh size selected for the study. The use of a single mesh size of 5 1/2 inch stretched mesh obviously diminishes the chances of capturing all sizes of American shad while favoring the capture of adult roe female shad. It was selected for the study because it was the preferred mesh size of commercial shad fishermen, who were the primary source of recapture data. The use of other size meshes would have likely resulted in fewer recaptures, thus

Table 2. Comparisons of daily standard fishing units, total catch and catch-per-unit-effort for American shad in the nearshore ocean off Wrightsville Beach, NC, December 1989 - May 1990.

Date	Standard fishing units	Total catch (number)	CPUE
12 Dec 89	4	0	-
18 Dec 89	4	0	-
21 Dec 89	4	0	-
4 Jan 90	4	0	-
10 Jan 90	6	0	-
12 Jan 90	4	0	-
17 Jan 90	6	0	-
18 Jan 90	40*	1	0.025
23 Jan 90	4	0	-
26 Jan 90	7	4	0.571
30 Jan 90	4	0	-
2 Feb 90	4	0	-
5 Feb 90	4	1	0.025
7 Feb 90	8	0	-
9 Feb 90	4	0	-
12 Feb 90	4	0	-
14 Feb 90	4	6	1.500
16 Feb 90	4	8	2.000
19 Feb 90	4	0	-
20 Feb 90	3	1	0.333
21 Feb 90	5	3	0.600
2 Mar 90	4	0	-
6 Mar 90	8	3	0.375
8 Mar 90	2	1	0.500
14 Mar 90	8	1	0.125
16 Mar 90	10	35	3.500
19 Mar 90	8	5	0.625
23 Mar 90	4	7	1.750
26 Mar 90	4	2	0.500
28 Mar 90	2	0	-
3 Apr 90	4	1	0.250
4 Apr 90	5	3	0.600
5 Apr 90	5	1	0.200
6 Apr 90	6	0	-
9 Apr 90	4	0	-
10 Apr 90	5	1	0.200
12 Apr 90	6	4	0.667
16 Apr 90	5	4	0.800
17 Apr 90	4	0	-
20 Apr 90	4	7	1.750
23 Apr 90	4	0	-
27 Apr 90	4	1	0.250
2 May 90	4	0	-
4 May 90	2	0	-
8 May 90	4	1	0.250

* Overnight sampling effort.

Table 3. Number and percent of American shad captured by age in the nearshore ocean area off Wrightsville Beach, NC, December 1989 - May 1990.

Age (yr)	Number	Percent
IV	4	4.3
V	49	53.3
VI	39	42.4

Table 4. Mean fork length (mm), standard deviation, and length ranges (mm) by age for American shad captured in the nearshore ocean off Wrightsville Beach, NC, December 1989 - May 1990.

Age (yr)	Number	Mean (mm)	±	S.D. (mm)	Min. (mm)	Max. (mm)
IV	4	450		14	434	467
V	49	488		18	450	520
VI	39	510		16	475	546

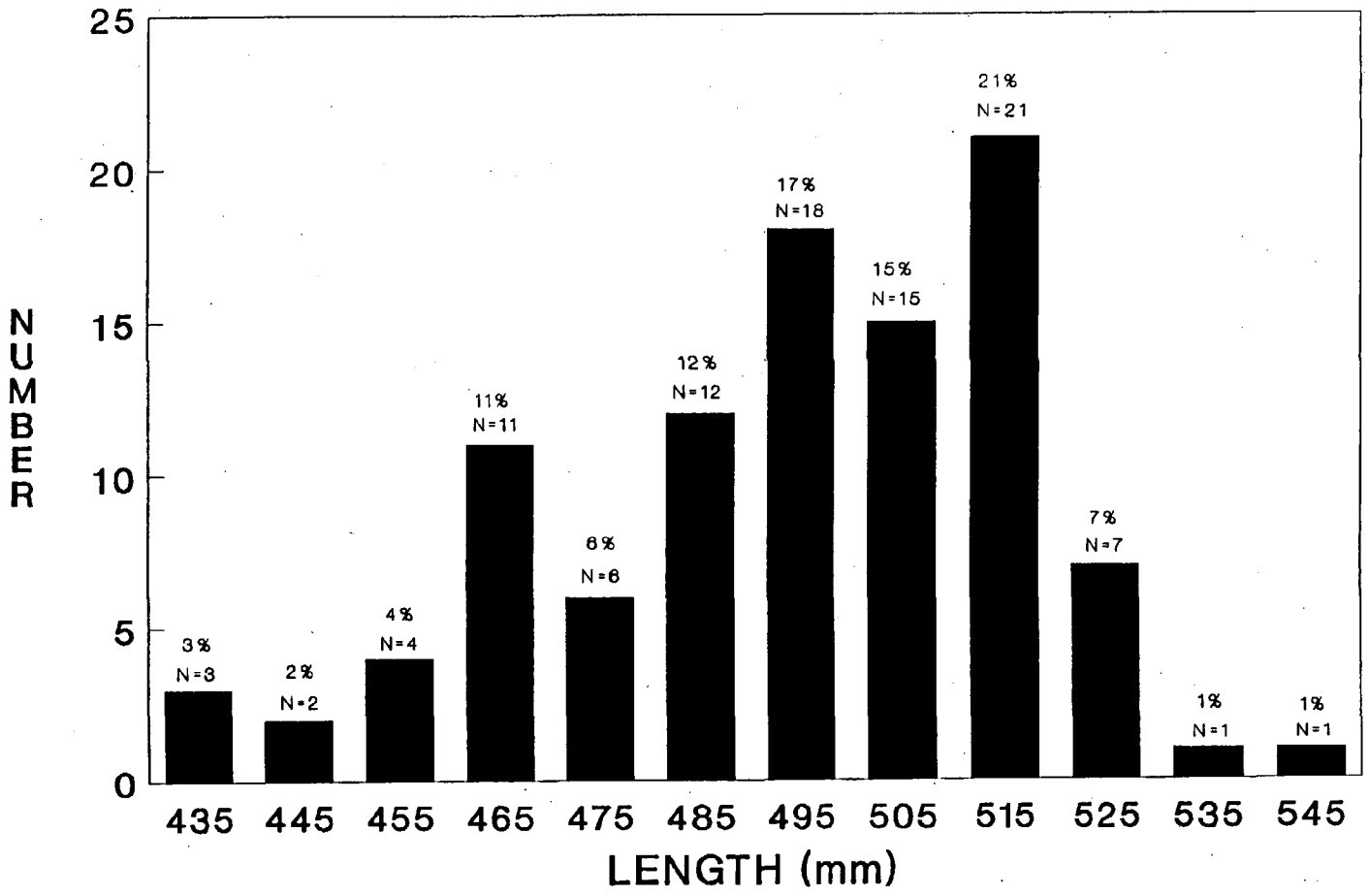

Figure 3. Number and percent of American shad captured by length from the nearshore ocean off Wrightsville Beach, NC, December 1989 - May 1990.

Table 5. Recapture locations, dates tagged and recaptured, distance from release site, and days at large for American shad tagged and released in the nearshore ocean off Wrightsville Beach, NC, 1990.

Recapture location	Date tagged	Date recaptured	Distance from site (miles)	Days at large
Baldhead Island, NC	26 Jan 90	27 Jan 90	25	1
Waccamaw River, SC	14 Feb 90	14 Feb 90	99	28
Carolina Beach, NC	16 Feb 90	18 Feb 90	13	2
Carolina Beach, NC	16 Mar 90	18 Mar 90	13	2
NE Cape Fear River, NC	16 Mar 90	28 Mar 90	88	12
Carolina Beach, NC	16 Mar 90	18 Mar 90	13	2
Black River, NC	16 Mar 90	21 Mar 90	92	5
Cape Fear River, NC	16 Mar 90	22 Mar 90	100	6
Cape Fear River, NC	16 Mar 90	30 Mar 90	58	14
Black River, SC	16 Mar 90	21 Mar 90	160	5
Black River, NC	23 Mar 90	27 Mar 90	92	4
Savannah River (Still Cr.), SC	23 Mar 90	8 May 90	370	47
Baldhead Island, NC	4 Apr 90	5 Apr 90	25	1
Waccamaw River, SC	4 Apr 90	10 Apr 90	119	6
Baldhead Island, NC	10 Apr 90	11 Apr 90	25	1
Black River, NC	12 Apr 90	4 May 90	104	22

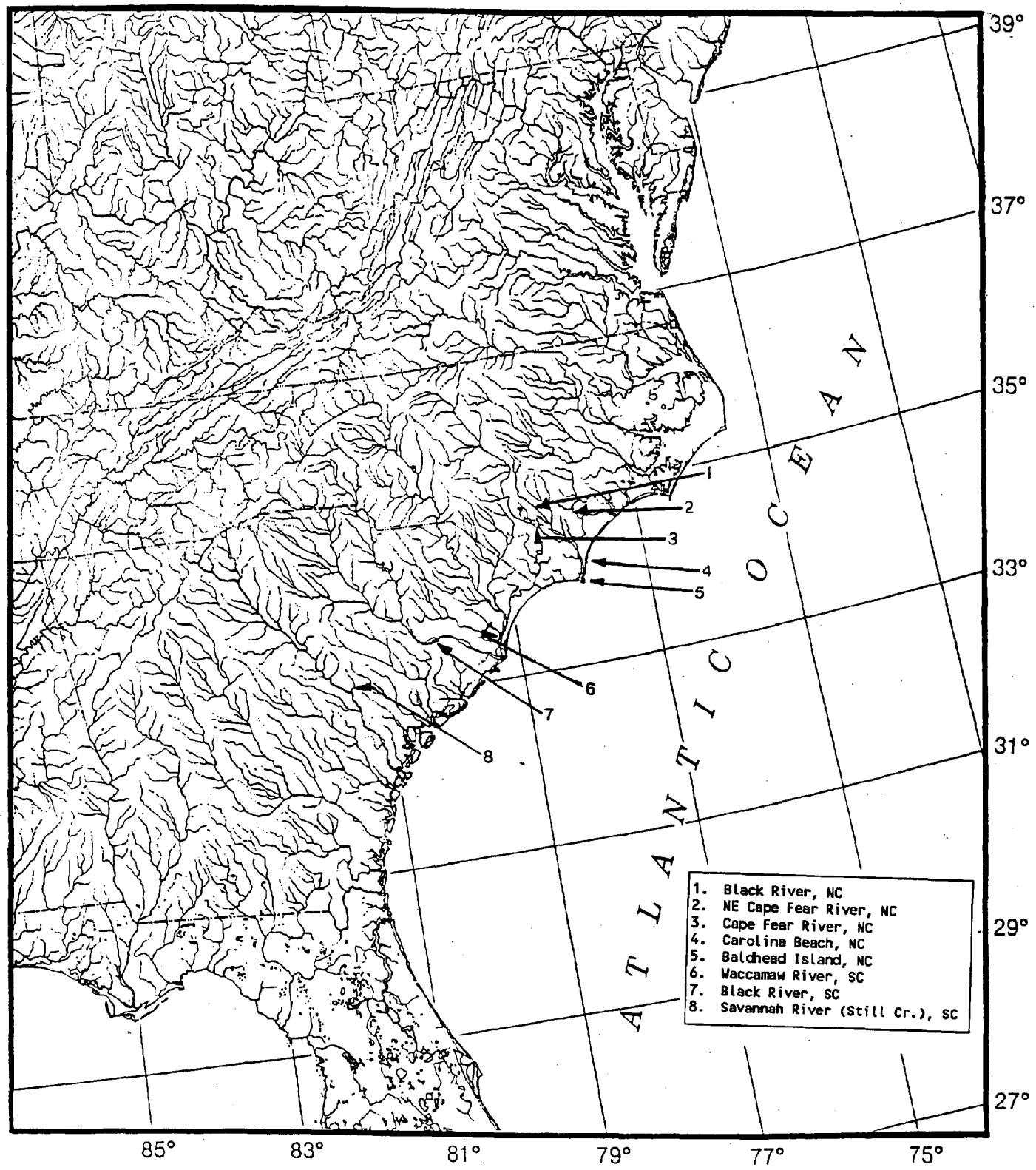

Figure 4. Recapture sites for American shad tagged in the nearshore ocean off Wrightsville Beach, NC, 1990.

Table 6. Water temperature, salinity and number of American shad captured by date in the nearshore ocean area off Wrightsville Beach, NC, 1989-90.

Date	Temperature (°C)		Salinity (ppt)		No. of shad captured
	Surface	Bottom	Surface	Bottom	
12 Dec 89	11.1	10.5	35.1	34.7	0
18 Dec 89	11.0	10.9	35.2	35.7	0
21 Dec 89	10.9	10.8	35.0	35.4	0
4 Jan 90	7.5	7.4	35.8	35.4	0
10 Jan 90	7.4	7.5	36.0	36.0	0
12 Jan 90	7.6	7.6	35.3	35.4	0
17 Jan 90	8.6	8.6	34.2	34.7	0
18 Jan 90	8.8	8.6	34.6	35.1	1
23 Jan 90	10.1	10.2	35.3	35.4	0
26 Jan 90	10.2	10.2	35.4	35.5	4
30 Jan 90	10.0	10.0	35.2	35.3	0
2 Feb 90	11.1	10.6	34.8	34.8	0
5 Feb 90	10.5	10.4	34.6	35.5	1
7 Feb 90	11.1	10.7	35.4	35.4	0
9 Feb 90	11.6	11.0	35.0	35.1	0
12 Feb 90	11.2	11.3	34.8	34.8	0
14 Feb 90	11.6	11.4	34.9	34.9	6
16 Feb 90	11.7	11.5	35.0	35.1	8
19 Feb 90	12.2	12.0	34.7	34.7	0
20 Feb 90	12.2	12.1	34.9	34.9	1
21 Feb 90	11.4	11.5	35.1	34.9	3
2 Mar 90	11.5	11.1	34.7	35.0	0
6 Mar 90	11.8	11.9	34.6	34.3	3
8 Mar 90	11.0	11.0	34.7	34.9	1
14 Mar 90	12.5	11.8	34.9	35.0	1
16 Mar 90	14.1	13.2	33.9	34.8	35
19 Mar 90	13.7	13.1	35.0	35.1	5
23 Mar 90	14.0	13.9	34.9	35.0	7
26 Mar 90	14.7	14.7	34.9	34.9	2
28 Mar 90	13.7	13.8	35.4	35.2	0
3 Apr 90	14.5	14.5	35.0	35.2	1
4 Apr 90	14.0	14.0	35.2	35.0	3
5 Apr 90	14.4	14.2	35.0	35.2	1
6 Apr 90	14.5	14.8	35.3	35.3	0
9 Apr 90	14.6	14.4	35.0	34.8	0
10 Apr 90	15.3	15.2	35.0	35.1	1
12 Apr 90	14.8	14.9	34.7	35.1	4
16 Apr 90	16.3	15.9	34.9	34.9	4
17 Apr 90	17.9	17.2	34.9	34.9	0
20 Apr 90	15.8	15.9	35.0	35.0	7
23 Apr 90	17.4	17.3	34.7	35.0	0
27 Apr 90	18.5	18.4	34.8	35.0	1
2 May 90	20.5	19.9	34.6	34.9	0
4 May 90	22.6	21.0	35.1	35.0	0
8 May 90	19.8	19.9	35.6	35.5	1

defeating the primary purpose of the study. However, since collection methods were virtually the same, comparisons can be made between age and length data from this study and those of a study (Parker 1989) conducted in the same vicinity a year earlier (Figure 5). Data from this study showed an increase in mean length of shad of approximately 12 mm from 484 mm to 496 mm. When lengths between the two studies were compared, a significant difference was found (d.f.=192, t=-4.0, and $P<0.0001$). The age composition between studies also varied with this study yielding a higher percentage of older fish (Table 7). Changes in age and length of fish can signify the effects of fishing on a population or differences in year-class strength. Ricker (1958) reported that increased fishing reduced mean age over a period of years while entry of a weak year-class into a fishery increased the mean age, length, and weight. Other factors (disease, parasites, predation, etc.) being negligible, increases in mean length and age of American shad from 1989 to 1990 are probably due to differences in year-class strength.

The sex of American shad captured was influenced by gear type and mesh size. Weinrich et al. (1988) reported that gill nets bias the length range and sex ratios of captured adult shad. The sex composition of American shad captured during this study was not positively determined because of time and health restraints on the fish and difficulty in visual sex identification. Therefore, the sex variable was not used in data analysis. However, it was assumed that most or all of the American shad tagged during this study were female based on the bias of the mesh size toward capture of females and the fact that all recaptures and all untagged American shad were positively identified as female.

Migrational Characteristics

As most studies suggest, American shad migration appears to be influenced by water temperature. McDonald (1884) reported that American shad occupy a specific thermal range and migrate within that range along the coast into and up rivers. Leggett and Whitney (1972) also proposed that the oceanic distribution of American shad was temperature-controlled and quantified the temperature regime that shad occupy as between 13° and 18° C. This offshore temperature regime was disputed by Neves and Depres (1979) on the basis that it was established from inshore data and extrapolated to include offshore distribution. They proposed that near-bottom temperatures between 3° and 15°

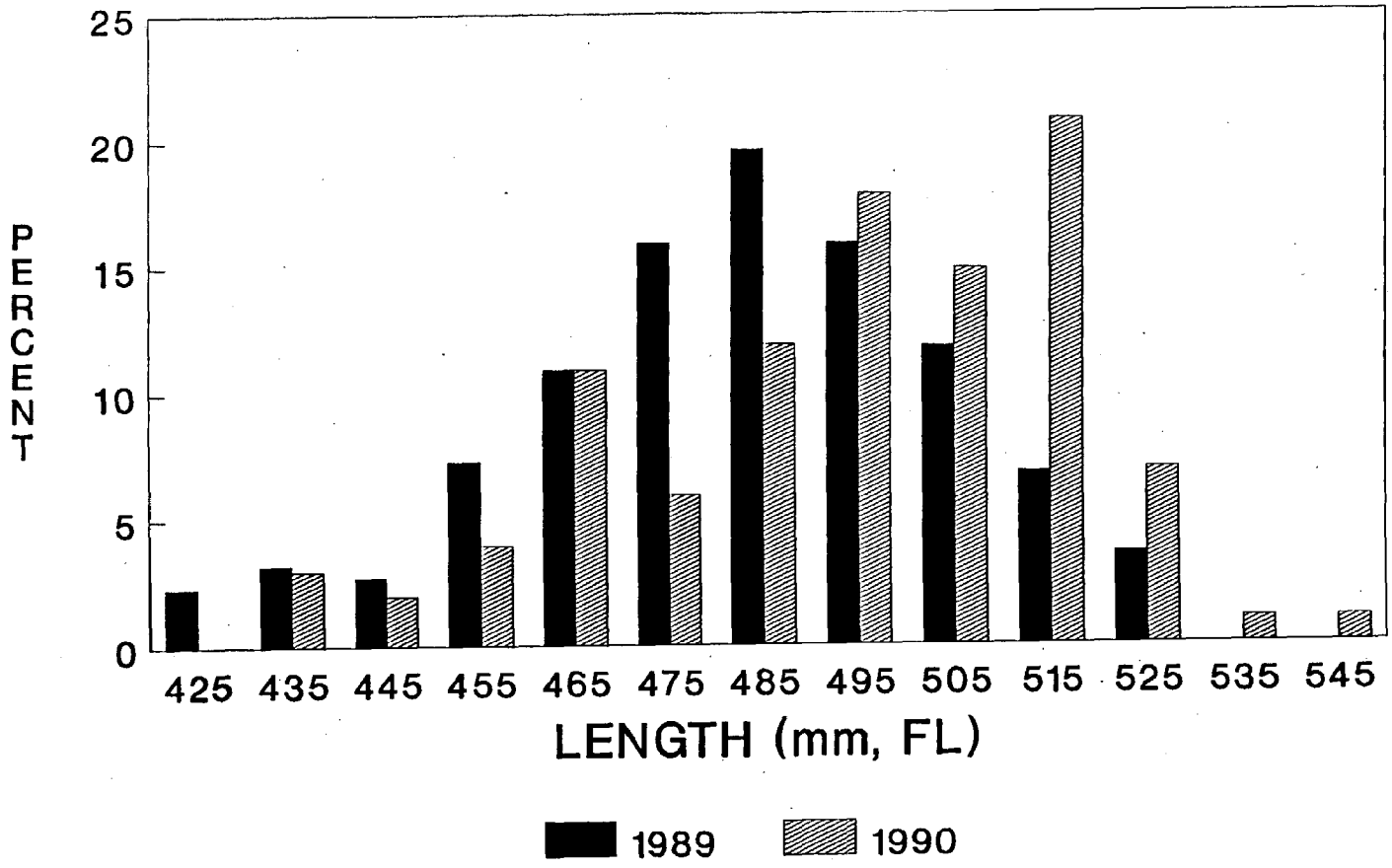

Figure 5. Length-frequencies of American shad from the nearshore ocean off southeastern North Carolina, 1989 and 1990.

Table 7. Comparisons of age composition of American shad captured in near-shore ocean waters off Wrightsville Beach, NC in 1989 and 1990.

Age (yr)	1989		1990	
	Number	Percent	Number	Percent
IV	32	15.6	4	4.3
V	157	76.6	49	53.3
VI	16	7.8	39	42.4

Table 8. Total American shad landings and ocean caught Amnerican shad landings for North Carolina in pounds and dollars by year, 1985 - 1989 (from DMF data).

Year	Total landings		Ocean landings	
	Pounds	Value	Pounds	Value
1985	329,639	$152,547	3,159	$ 766
1986	373,794	228,819	63,086	28,626
1987	327,646	215,115	39,580	28,875
1988	283,050	171,962	50,088	40,844
1989	323,396	214,896	38,548	34,309
Total	2,668,604	$983,359	194,461	$133,420
% of total	100%	100%	7.3%	13.5%

C provide a better basis for predicting American shad distribution in offshore waters. Their collections were made in the ocean at depths between 27 m and 366 m extending from Nova Scotia to Cape Hatteras.

Data from this study were collected in nearshore ocean waters, approximately 6 m in depth. American shad were captured within a bottom temperature range of 8.6° to 19.9° C. The peak period of capture occurred at a bottom temperature of 13.2° C (Figure 6). The temperature ranges from this study more closely resembled those established by Leggett and Whitney (1972), who recorded water temperatures when American shad first entered Atlantic coast rivers. The higher temperature range established from inshore waters by Leggett and Whitney (1972) and from nearshore waters by this study may reflect physiological changes in prespawning adults resulting in higher temperature tolerances as they become sexually "ripe."

Distances travelled (up to 370 miles) from the tagging site by some American shad suggest that fish were not necessarily occupying the nearshore waters of the tagging site because of its proximity to natal rivers and streams, but possibly because of its location along their migratory route. Neves and Depres (1979) hypothesized that south Atlantic American shad migrate within a narrow coastal corridor between the coast and the Gulf Stream to reach southern rivers. Information from this study support their hypothesis.

This study clearly reveals that American shad captured in nearshore ocean waters off southeastern North Carolina exhibit a pronounced southerly migrational pattern. All tag returns were reported captured south of the tagging site with four recaptures in South Carolina. Although most tag returns were from North Carolina waters, the study confirms that the ocean gill net fishery in North Carolina is, to some extent, intercepting the stocks of more southerly states. If North Carolina is to comply with the ASMFC policy of fishing only on its own stock, then some restrictions on ocean shad fishing are probably necessary.

Regulatory Options

Closed Fishery - According to DMF data, the North Carolina ocean fishery for shad has produced less than 200,000 pounds of American shad at a value of

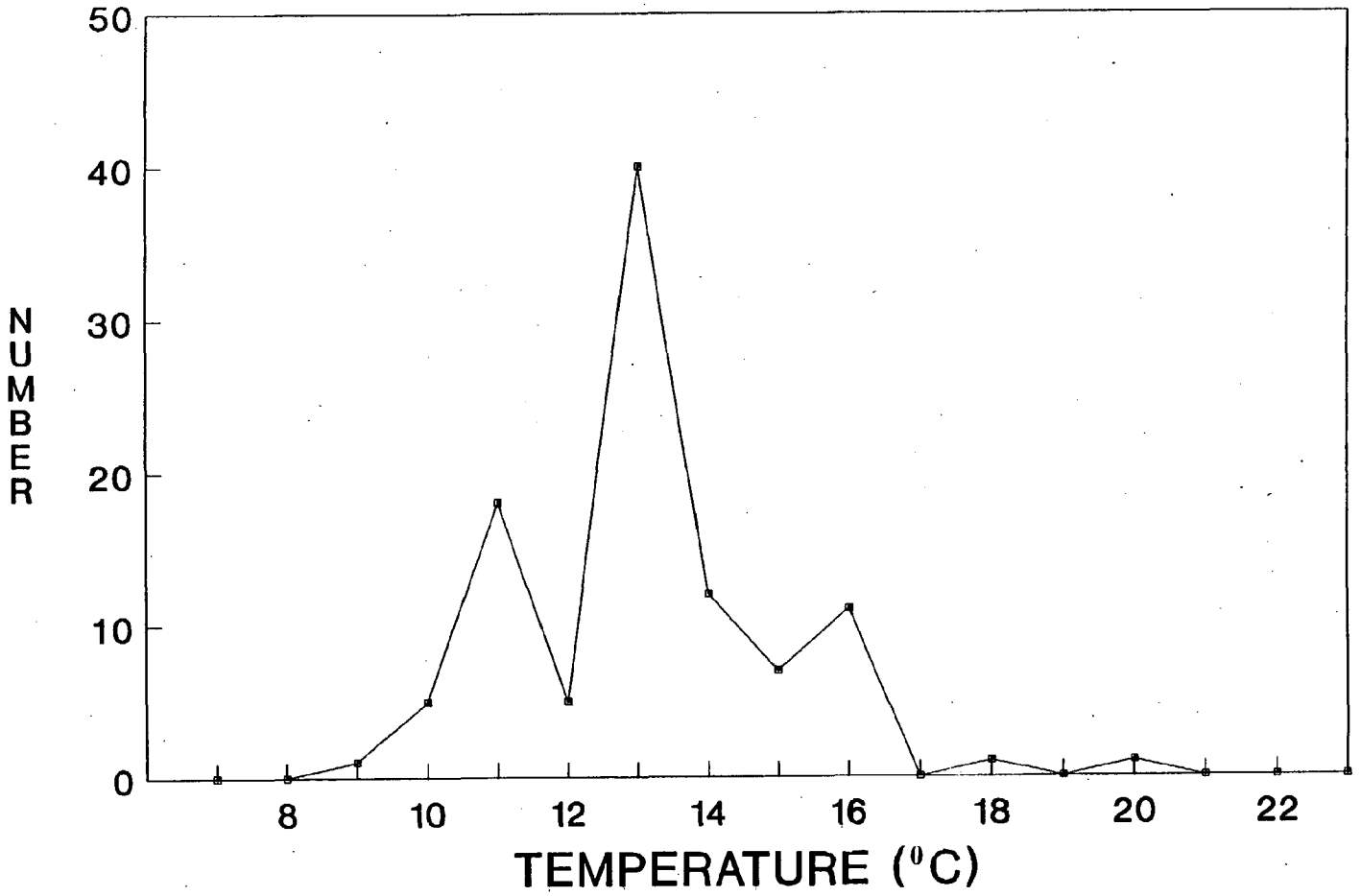

Figure 6. Relationship of water temperature and number of American shad captured in the nearshore ocean off Wrightsville Beach, NC, December 1989 - May 1990.

approximately $133,000 from 1985 through 1989. This figure represents 7.3% of the total poundage and 13.5% of the total value of American shad landed in North Carolina during the same period (Table 8). The slightly higher values for American shad captured in the ocean typically reflect the prices of ocean shad which are captured earlier in the season when the market demand has not yet been affected by catches from inshore commercial fishermen. Considering the relatively low poundage of American shad landed from the ocean, the low number of ocean fishermen, and the seasonal nature of the fishery, one regulatory option is to close the ocean fishery for American shad. This strategy would affect a small number of commercial fishermen while maintaining most of the state's (>92%) total landings. However, the same line of reasoning could be used to justify the continuance of ocean shad fishing since its impact has already been determined to be relatively small while at the same time yielding a higher price per pound. Inasmuch as the major purpose of a closed fishery for American shad would be to discontinue the intercepting of other state's American shad stock, the argument for a closed fishery is further weakened by the fact that the majority of tag returns were from North Carolina waters.

Delayed Season - One of the aims of this study was to determine if the majority of American shad captured earlier in the season were destined to more southerly rivers. This would present a management option of a delayed opening of ocean shad fishing and thus allow American shad with fidelity to rivers in states south of North Carolina to escape capture. However, findings in support of the hypothesis were inconclusive. Three of the first four recaptures (27 January 1990 to 18 March 1990) were reported in ocean waters off North Carolina, south of the tagging site and prior to reaching a major river. Therefore, the destination of those fish could not be determined. The fourth return was from Waccamaw River, SC. Therefore, a number of possibilities exist as to the destination of the earliest tagged American shad since a confirmation could be attained on only one of the returns. American shad tagged on the comparatively late dates of 23 March 1990 and 4 April 1990 and recaptured in Savannah River (Still Creek), SC and Waccamaw River, SC respectively, suggest that certainly not all of the more southerly bound American shad migrate earlier. This point basically renders ineffective the option of a delayed shad season.

Landings Quotas - This option would involve limiting the number of American shad taken from ocean waters. It would not necessarily eliminate the interception of other state's stock but might reduce the impact of North Carolina's ocean shad fishery. Disadvantages include the allowance of some interceptions through continued ocean fishing, problems in establishing quota type (per day, per season, per boat, per area, etc.), likely enforcement difficulties, and difficulty in accurately assessing the extent of this option's effect on reducing interceptions.

Reduced Fishing Effort - Reduced fishing effort basically affords the same advantages and disadvantages as the option for landings quotas. It would probably involve limiting ocean American shad fishing to a certain number of days per week, hours per day, and/or establishing an ocean shad season. Implementation should at least allow some migrating shad to escape capture during periods of non-harvest and should reduce the impact of North Carolina's ocean shad fishery. However, the success or failure of reduced fishing effort would be very difficult to assess. This action would likely bring protest from North Carolina's ocean shad fishermen and result in little or no cooperation if not strictly enforced. Both landings quotas and reduced fishing effort present a number of enforcement problems which may make each option impractical to implement.

Recommendation - Implementation of any of the above options would involve significant rule changes and/or enforcement difficulties based on mostly speculative data. Furthermore, advantages gained from enacting any of the options may be too vague and/or slight to warrant such action. The most practical course of action may involve monitoring South Carolina for any significant decline in American shad landings while also monitoring North Carolina for significant increases in ocean landings of American shad. Increases in either should result in implementation of one of the aforementioned options which could be selected based on the severity of the divergence in landings. Annual review of South Carolina's total American shad landings and North Carolina's ocean and total American shad landings is recommended to serve as an indication of whether or not regulatory action in North Carolina is warranted.

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