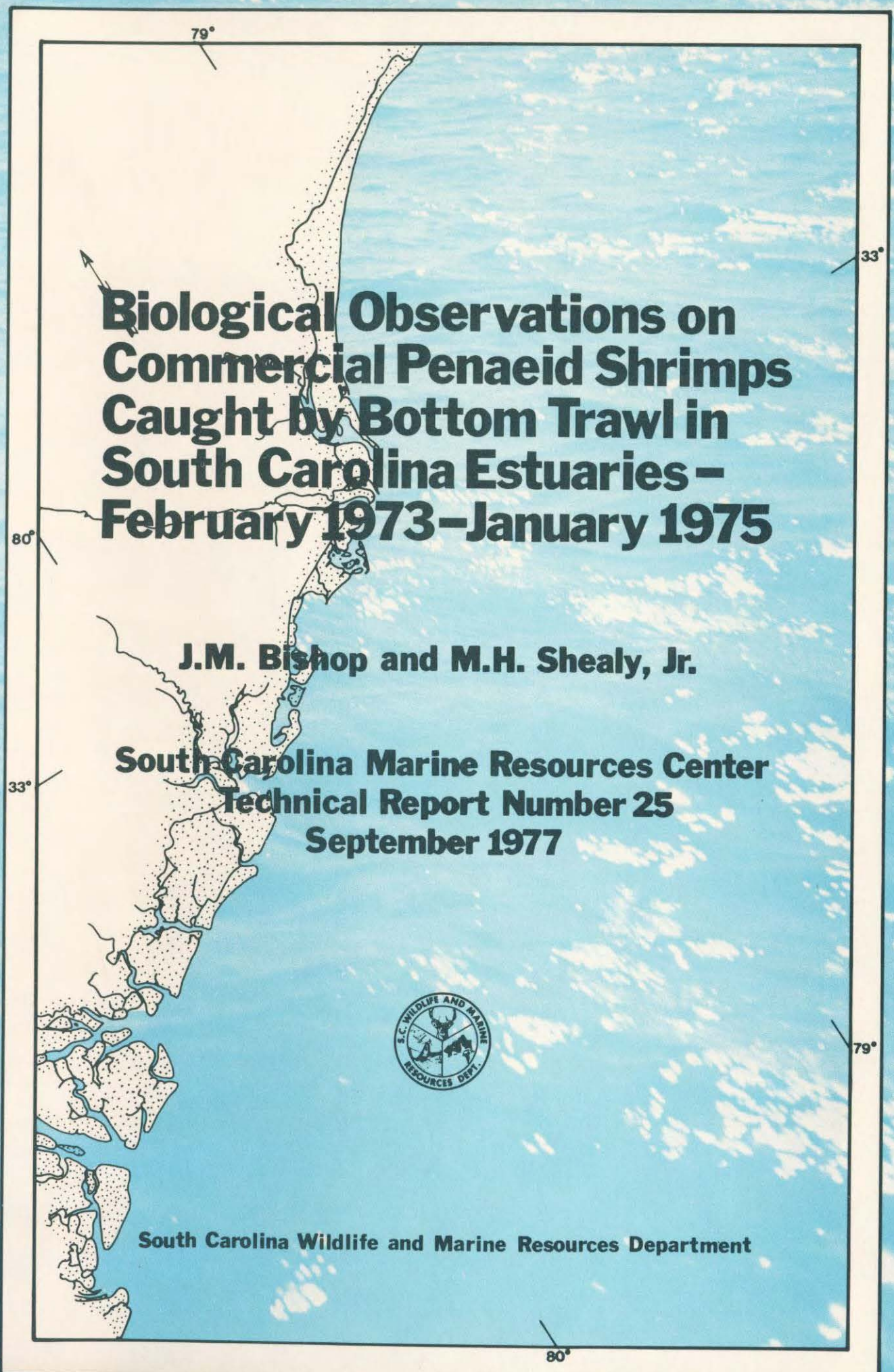

Biological Observations on Commercial Penaeid Shrimps Caught by Bottom Trawl in South Carolina Estuaries – February 1973–January 1975

J.M. Bishop and M.H. Shealy, Jr.

South Carolina Marine Resources Center
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by

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Abstract

White shrimp (Penaeus setiferus), brown shrimp (P. aztecus), and pink shrimp (P. duorarum) comprised 94, 6, and < 0.1% respectively, of the total number of shrimps captured by 6-m otter trawls from February 1973 through January 1975. Twenty minute trawl tows in Charleston Harbor and environs produced a mean of 376 shrimp; trawling north and south of this region produced a mean of only 152 and 94 shrimp per 20-min tow, respectively. White, brown, and pink shrimp were caught in waters with bottom salinities and water temperatures ranging from < 1.0-34.2 °/oo and 8.6-30.5°C, < 1.0-34.0 °/oo and 9.4-31.4°C, and 5.6-34.1 °/oo and 11.0-29.7°C, respectively. No obvious relationships involving length of shoreline, area of open water, area of marsh, or freshwater input were found to explain the observed differences of shrimp populations among estuaries sampled monthly.

White shrimp were caught in all estuaries sampled throughout the year. Young-of-the-year P. setiferus were initially caught in the trawl in July with mean lengths approximating 60 mm, and estimated growth was 1 mm per day. Emigration from the estuaries in the fall was judged to be initiated in September. Maximum numbers of 1,400 white shrimp per tow were obtained in September 1973 in the Cooper River-Charleston Harbor estuary, and mean total lengths were 90-105 mm depending upon the estuary. On the average, white shrimp were found to be half as numerous but twice as large in the North Edisto as in the Cooper River-Charleston Harbor estuary. Mean total lengths approached 130 mm prior to the spring emigration in May. White shrimp were distributed throughout the North Edisto, and as far inland as 33 km in the Cooper River and 35 km in the South Edisto. Mean length of white shrimp caught in salinities < 3 °/oo was 77 mm and gradually increased to 140 mm for those caught in salinities > 33 °/oo.

Brown shrimp were caught in all estuaries sampled and almost exclusively during June, July, and August. Growth rates of P. aztecus were conservatively judged at < 1 mm per day. In June, brown shrimp averaged from 90 to 100 mm total length in 1973 and from 78 to 90 mm in 1974. Maximum numbers of 300 brown shrimp per 20-min tow were obtained in July in the Cooper River-Charleston Harbor estuary. Brown shrimp were distributed throughout the North Edisto, and as far inland as 23 km in the Cooper River and 24 km in the South Edisto. Mean length of brown shrimp caught in salinities < 3 °/oo was 68 mm and gradually increased to 132 mm for those caught in salinities > 33 °/oo.

Pink shrimp were caught in too few numbers to estimate any portion of their estuarine life history. The highest catch of 11 individuals per 20-minute tow was obtained in Bull Bay which is a high-salinity estuary.

Introduction

Since 1965 shrimp have been South Carolina's most valuable fishery (Fishery Statistics of the United States, 1963-1972). From 1965 through 1972, shrimp have accounted for an average of 36% (6.6 million pounds, heads on) of the weight and 68% (6.2 million dollars) of the value of the state's total annual fishery landings, respectively. Despite the economic importance of shrimp to the state, few published data exist on their life histories in South Carolina waters. Lindner and Anderson (1956) studied the monthly size distribution and migration patterns of white shrimp off South Carolina's coast, and Bearden and McKenzie (1972) monitored movements of shrimp tagged in Charleston Harbor. Bearden (1961) reported on penaeid post-larvae in the state's estuaries south of Wadmalaw Island, and Lunz (1958, 1968) studied growth of penaeids in impoundments. Shealy and Miglarese (in preparation) are analyzing the unusually high incidence of microsporidosis in shrimp taken from South Carolina's estuaries. A review of the state's shrimp fishery and a regional management plan are provided by Calder, Eldridge, and Joseph (1974) and Eldridge and Goldstein (1975), respectively.

In February 1973, the Marine Resources Research Institute of the South Carolina Wildlife and Marine Resources Department initiated a major program to survey the biotic and abiotic characteristics of the state's estuaries over a several-year period. This report presents data on the relative abundance, seasonal distribution and length-frequency relationships for the three species of commercial shrimps, Penaeus setiferus (white shrimp), P. aztecus (brown shrimp), and P.

duorarum (pink shrimp), caught by bottom trawl in South Carolina estuaries during the 24-month period from February 1973 through January 1975.

Materials and Methods

Sampling Design

Thirty-three sampling sites were selected in the South Carolina coastal zone (Fig. 1) and divided into two categories, Extensive Phase stations or Intensive Phase stations. The Extensive Phase consisted of sampling 16 stations four times yearly (i.e., during each of the four seasons). These stations were selected to be representative of most of the state's major estuaries and were sampled in April, July, October of 1973; January, April, August, October of 1974; and January of 1975. Locations, mean depths, tidal ranges, bottom salinity and water temperature ranges, and bottom types for these stations are given in Table 1.

The data from the Extensive Phase stations were analyzed according to the station's relative location in the state's coastal region, i.e., northern, central, or southern. The northern region consists of stations in the South Santee River (S001), Winyah and Bull Bays (Y001, B002, B003); the central region, of stations in Inlet Creek (B001), Nowell Creek (W001), Charleston Harbor near Fort Johnson (J001, J002), Ashley River (K001), and the Stono River (F001); and the southern region, of stations in St. Helena Sound (H001-H003), Port Royal Sound (P001-P002), and Calibogue Sound (G001).

The Intensive Phase consisted of monthly sampling of 17 stations; four in the South Edisto estuary (D001-D004), eight in the North Edisto estuary (E001-E008), and four in the Cooper River-Charleston Harbor estuary (C002-C004, J003). Sampling by trawl was conducted at one additional station (The Tee, C001) during the first year in the Cooper River. This station was the most inland (52 river km) on the Cooper River transect. Locations, mean depths, tidal ranges, bottom salinity and water temperature ranges, and bottom types for these stations are given in Table 2.

The stations of the Intensive Phase were chosen to encompass the salinity gradient in each estuary, and each station within an estuary was designated with a letter characteristic of the name or location within the estuary. The stations within an estuary were numbered consecutively such that the lowest number represents the most inland station and the highest number the most seaward.

Trawl Techniques

With the exception of December 1974, all sampling was carried out aboard the Department's R/V ANITA, a 16-m (52-ft) shallow draft vessel rigged as a stern trawler. The R/V CAROLINA PRIDE, a 16-m trawler, was used in December 1974. Twenty-minute tows were made against flood tide during daylight at an engine speed of 750 rpm. This resulted in a speed of about 2.5 knots (1.3 m sec^{-1}), and depending on the wind velocity and tidal currents, 1.5 $\pm$ 0.4 km were covered during a tow. During 25-hr stations of May, July, and November 1974, trawling was conducted day and night midway after each tidal change.

A six-meter (20-ft) semiballoon otter trawl with 2.5-cm (1-inch) stretch mesh was used for all tows. A complete description of the trawl is given by Shealy, Miglarese, and Joseph (1974).

Catch Processing

Specimens collected at each station were either processed immediately on board or preserved in 10% buffered formalin and returned to the laboratory for identification, measuring, weighing, and sex determination. Shrimp were sorted by species and examined immediately for diseases and anomalies. Shrimp were sexed, and their stage of maturity judged either by the presence of joined petasmal endopod for males or by a modification of King's (1948) classification of ovarian development for females. Total length (tip of rostrum to tip of telson) was obtained to the nearest millimeter for each shrimp. Each shrimp was measured if less than 50 individuals of a species were caught in a single tow. If more than 50 individuals were caught, the total catch was weighed and generally a total count was taken (except for very large catches when total numbers were estimated from a subsample). Subsampling was conducted as follows: if >50 to $\leq$250 were captured, a minimum of 50 specimens were individually measured; if >250 to $\leq$500 were caught, a minimum of 20% were measured; and if >500 were caught, a minimum of 10% were measured. Sex ratios of the subsample were biased because equal numbers of males and females were often selected from a large trawl catch. Individual lengths, weights, and sex ratios were obtained from the subsample. A Mettler top-loading Model P-11 electronic balance was used to weigh individual shrimp to the nearest 0.1 g.

Statistical Analyses

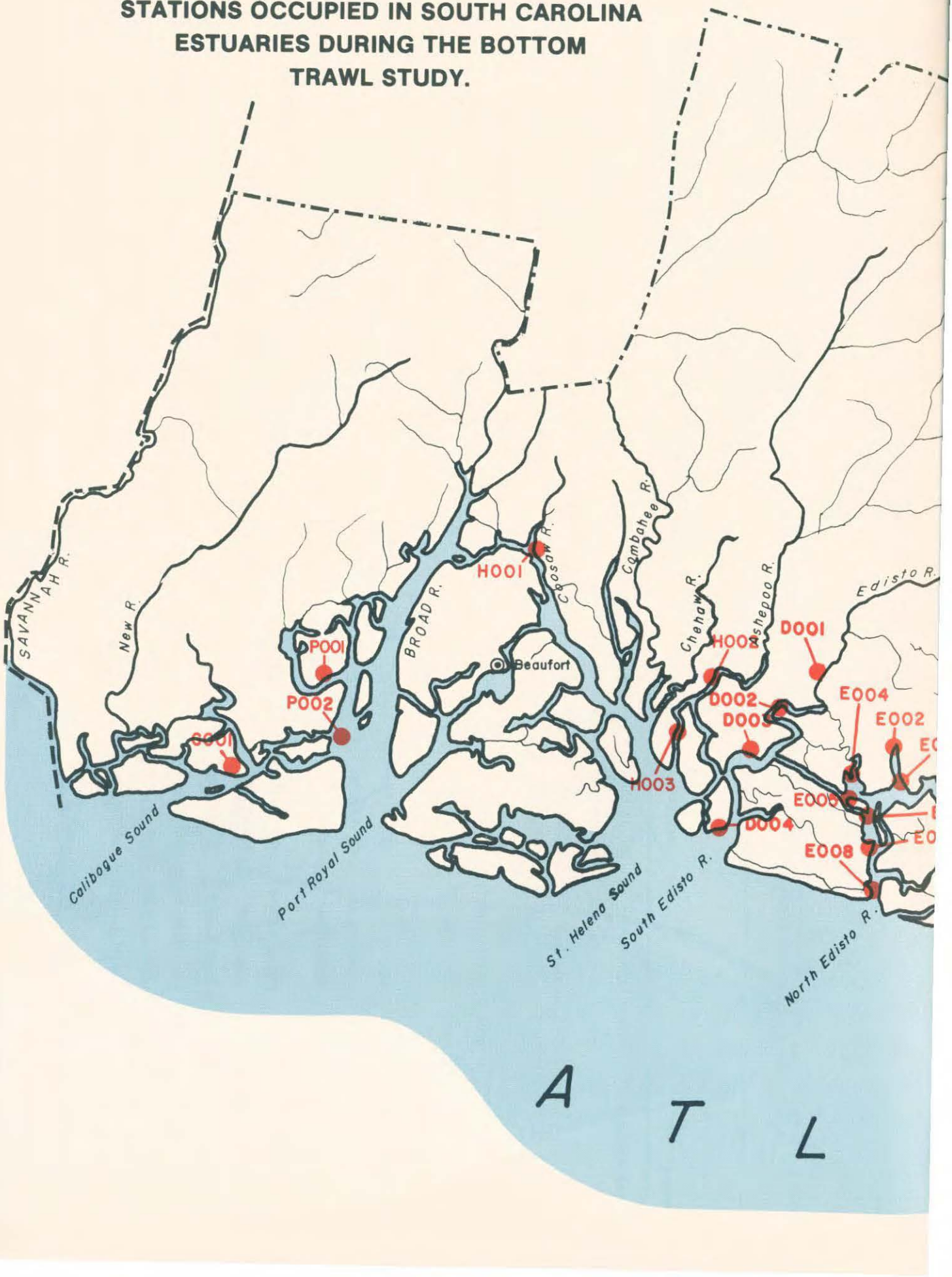
T-test for two sample means (Steel and Torrie 1960) were used to determine if observed differences were significant. Differences were tested for the following: mean size of brown shrimp caught in June-July 1973 vs. June-July 1974; mean number of white shrimp and of brown shrimp caught during flooding vs. ebbing tide and during day vs. night.

Shrimp Catches in Relation to Bottom Salinity and Water Temperature

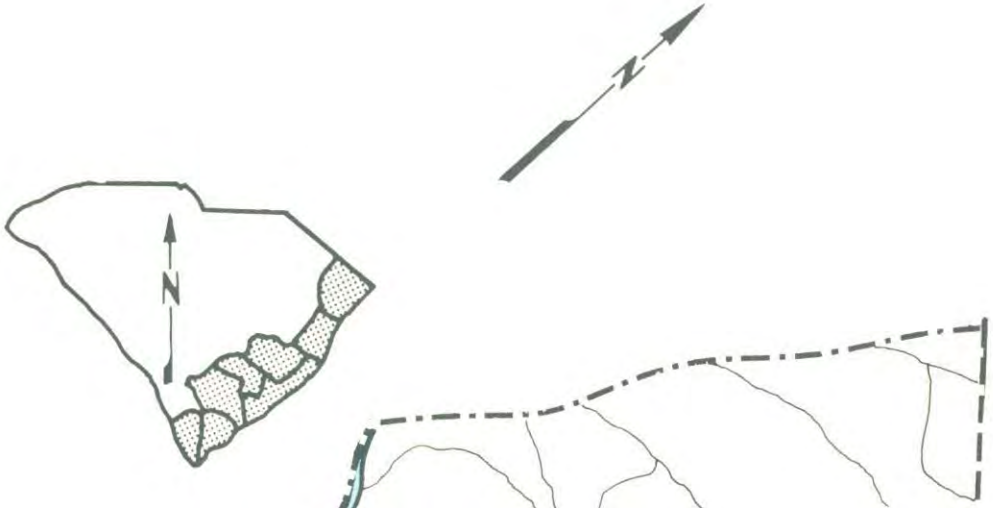
The catch frequency and size of shrimp in relation to salinity and temperature were ascertained by analyzing monthly shrimp catches in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries. The trawl data were standardized by calculating the mean catch per 20-min trawl tow in salinity and temperature increments of 3 °/oo and 3°C, respectively. The standardized catches for the salinity (or temperature) increments were summed, and the percent contribution to the summed total of each standardized catch in 3 °/oo S and 3°C increments was obtained. These percentages and the mean lengths were plotted against increasing salinity and temperature for all shrimp data and also for each season and each estuary. Throughout the remainder of this report, the catch per unit

FIGURE 1.

STATIONS OCCUPIED IN SOUTH CAROLINA ESTUARIES DURING THE BOTTOM TRAWL STUDY.




LAKE
MARION
LAKE
MOULTRIE
SANTEE R.
10
C001
East Branch
Back R.
C002
C003
ASHLEY R.
COOPER R.
C004
WANDO R.
W001
K001
F001
J001
J003
J002
Charleston
B001
B002
B003
Intra-Coastal Waterway
SANTEE R.
SANTEE R.
S001
Y001
Sampit R.
Stono Inlet
Charleston Harbor
Bull Bay
Winyah Bay
A N T I C O


N
N


0
10 Miles
SCALE
Little Pee Dee R.
ack R.
Georgetown
peeDee R.
Waccamaw R.
Intra-Coastal Waterway
Murrells Inlet
Little R.
C E A N

Table 1. Locations and major characteristics of the 16 Extensive Phase stations occupied quarterly in a number of estuaries throughout the South Carolina coastal zone during the 24-month period from February 1973 through January 1975.

Estuary	Station	Latitude	Longitude	Mean Depth (m)	Tidal Range (m) Mean	Tidal Range (m) Spring	Bottom Salinity Range (o/oo)	Bottom Temperature Range (°C)	Bottom Type
Northern Region	Y001 - Winyah Bay	33° 15.6'N	79° 15.4'W	4.0	1.0	1.2	0.1 - 25.9	10.2 - 28.4	mud
	S001 - South Santee	33° 08.8'N	79° 19.2'W	4.0	1.2	1.4	0.4 - 23.1	9.3 - 29.5	sand and clay
	B003 - Bull Bay	32° 55.9'N	79° 36.2'W	5.0	1.5	1.7	31.2 - 34.2	10.4 - 29.5	mud and sand
	B002 - Price Creek	32° 54.2'N	79° 40.7'W	7.9	1.6	1.8	23.4 - 34.2	10.3 - 29.2	sand and shell
Central Region	B001 - Inlet Creek	32° 47.5'N	79° 49.5'W	4.2	1.6	1.8	23.5 - 33.8	12.0 - 27.8	sand and shell
	W001 - Nowell Creek	32° 53.1'N	79° 52.6'W	3.8	1.8	2.1	9.2 - 18.4	11.2 - 29.0	sand and mud
	J001 - Ft. Johnson	32° 45.4'N	79° 55.1'W	7.2	1.6	1.8	10.9 - 25.1	10.8 - 28.0	mud and sand
	J002 - Hog Island	32° 47.1'N	79° 53.2'W	3.1	1.6	1.8	15.7 - 29.0	11.7 - 28.4	mud and silt
	K001 - Ashley River	32° 48.6'N	79° 58.1'W	5.5	1.6	1.9	7.6 - 18.7	11.2 - 29.3	mud
	F001 - Stono River	32° 44.9'N	80° 00.7'W	4.1	1.6	1.8	10.1 - 21.8	11.2 - 29.9	shell and sand
Southern Region	H002 - Ashepoo River	32° 34.0'N	80° 29.9'W	5.3	1.9	2.2	0.2 - 12.3	12.2 - 29.9	sand
	H003 - Rock Creek	32° 30.9'N	80° 27.9'W	5.2	1.9	2.2	12.0 - 25.9	11.8 - 30.5	mud - sand - shell
	H001 - Whale Branch	32° 32.1'N	80° 43.7'W	4.6	2.2	2.5	10.4 - 26.8	12.4 - 31.4	mud - sand - shell
	P002 - Port Royal Sound	32° 16.2'N	80° 43.7'W	4.9	2.1	2.5	24.1 - 31.7	12.0 - 30.0	mud and sand
	P001 - Colleton River	32° 16.2'N	80° 48.5'W	8.3	2.3	2.7	22.3 - 30.7	12.1 - 30.6	mud - sand - clay
	G001 - Calibogue Sound	32° 10.9'N	80° 47.8'W	6.1	2.2	2.5	22.2 - 30.3	12.4 - 30.5	mud - sand - shell

Table 2. Locations and major characteristics of the 17 Intensive Phase stations occupied monthly in the North and South Edisto and Cooper Rivers, South Carolina, during the 24-month period from February 1973 through January 1975.

Estuary	Station	Latitude	Longitude	Mean Depth (m)	Tidal Range (m) Mean	Tidal Range (m) Spring	Bottom Salinity Range (o/oo)	Bottom Temperature Range (°C)	Bottom Type
North Edisto	E001 - Yonges Island	32° 41.2'N	80° 10.4'W	7.6	2.0	2.3	14.0 - 28.7	9.4 - 30.1	sand - shell - mud (hard)
	E002 - Toogoodoo Creek	32° 41.3'N	80° 17.3'W	3.7	1.9	2.3	11.9 - 28.4*	9.5 - 30.4*	sand - shell - mud
	E003 - Bears Bluff	32° 38.8'N	80° 15.7'W	6.7	1.8	2.1	16.4 - 28.9	9.4 - 29.8	sand and shell
	E004 - Dawho River	32° 37.9'N	80° 18.6'W	4.9	1.8	2.1	13.1 - 28.9	9.4 - 30.1	sand
	E005 - Steamboat Creek	32° 36.2'N	80° 17.7'W	6.7	1.7	2.0	15.6 - 31.3	9.4 - 29.9	sand
	E006 - Wadmalaw Island	32° 36.5'N	80° 14.8'W	8.0	1.8	2.1	17.7 - 30.4	9.2 - 29.9	sand
	E007 - Point of Pines	32° 35.9'N	80° 13.5'W	7.3	1.7	2.0	17.8 - 32.1	8.1 - 29.5	mud
	E008 - Deveaux Bank	32° 33.6'N	80° 10.7'W	10.7	1.8	2.1	22.1 - 34.4	8.7 - 29.1	shell and sand
South Edisto	D001 - Snuggedy Swamp	32° 39.7'N	80° 24.8'W	3.0	1.9	2.2	<0.1 - 1.4	7.2 - 28.7	sand
	D002 - Sampson Island	32° 36.3'N	80° 25.4'W	10.0	1.9	2.2	<0.1 - 14.9	7.2 - 29.1	mud and shell
	D003 - Fenwick Island	32° 33.7'N	80° 23.7'W	5.2	1.9	2.2	0.1 - 30.4	6.6 - 29.5*	sand
	D004 - Bay Point	32° 29.7'N	80° 21.2'W	7.5	1.8	2.1	14.2 - 34.0	8.6 - 29.3	sand
Cooper River	C001 - The Tee	33° 04.0'N	79° 55.5'W	10.0	1.2	1.4	<0.1 - 0.5	8.7 - 28.8	mud (hard)
	C002 - Big Island	32° 58.2'N	79° 55.2'W	7.6	1.4	1.7	<0.1 - 18.1	9.1 - 29.3	sand
	C003 - N. Charleston	32° 53.8'N	79° 57.6'W	6.8	1.5	1.8	0.1 - 13.7	11.2 - 29.1	shell and sand
	C004 - Mouth of Cooper	32° 51.1'N	79° 56.0'W	10.2	1.6	1.9	2.0 - 26.2	11.6 - 29.2	mud - sand - shell
	J003 - Cummings Point	32° 44.9'N	79° 51.6'W	9.3	1.5	1.8	21.4 - 32.8	12.2 - 29.4	shell and sand

*Surface reading

effort (cpue) is used to refer to numbers of shrimp caught per 20-min trawl tow, whereas the catch percentages in particular salinity (or temperature) increments are referred to as "percent of the summed cpue."

Hydrographic Analyses

Water samples were collected 0.3 m above the bottom with six-liter capacity Van Dorn bottles at all stations just prior to trawling. Water temperatures were read immediately from stem thermometers internally mounted in the Van Dorn bottles, and salinity was measured in the laboratory with a Beckman RS7B Induction Salinometer.

Results

Salinity and Temperature Conditions

Bottom salinities and water temperatures for stations sampled quarterly statewide are summarized in Tables 3 and 4, respectively. The lowest mean salinities (6 °/oo) were recorded in Winyah Bay (Y001) and the Ashepoo River (H002). The highest mean salinities (>27 °/oo) were recorded for Bull Bay (B003), Price Creek (B002), Inlet Creek (B001), Port Royal Sound (P002), Colleton River (P001), and Calibogue Sound (G001) (Table 3). The lowest and highest mean water temperatures were recorded in January 1975 and July 1973, respectively (Table 4).

Mean monthly salinities for the North and South Edisto and Cooper River-Charleston Harbor estuaries for both years are presented in Fig. 2, and the mean salinity of each station within each estuary is presented in Fig. 3. In both years, the lower salinities were recorded in late winter-early spring, and the higher salinities were recorded in late fall-early winter. The lowest mean salinities (<1-22 °/oo) generally occurred in March and the highest (27-30 °/oo) in November for all three estuaries. Mean salinities for the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries ranged from 3, 22, and <1 °/oo at the uppermost stations to 27, 30, and 29 °/oo at the most seaward stations, respectively (Fig. 3).

In the Cooper River-Charleston Harbor and the South Edisto estuaries, the highest mean temperatures (28-29 °C) were recorded in August, and in the North Edisto (29 °C), in September. The lowest mean temperatures were recorded in January and February in the Cooper River-Charleston Harbor, North Edisto, and the South Edisto estuaries (Fig. 4). Overall mean temperatures were approximately 20-22 °C at all stations in each estuary (Fig. 5).

Species Composition

Statewide. During the two years of this study, 92.5% of the total number of shrimp of the genus Penaeus were P. setiferus (Figs. 6, 7). Most of these were caught during late summer and fall of both years, with the highest catch occurring in October (about 24% of each year's total catch). Brown shrimp accounted for only 5.3% of the total catch from February 1973 through January 1974 (Fig. 6) and for 10.3% of the total catch from February 1974 through January 1975 (Fig. 7). Large numbers of brown shrimp were caught only during June, July, and August. Percentages of pink shrimp were low, never exceeding 0.1% in a given month. Fewer pink shrimp were caught in the winter and spring.

In general, the percentages by weight were similar to the percentages by numbers (Figs. 8, 9). Notable exceptions occurred in July and August 1973 and August 1974. In July and August 1973, white shrimp comprised 6.5 and 14.0% by number, but only 2.6 and 7.6% by weight, respectively, of the total penaeid catch during the first year (Figs. 6, 8). The July 1973 catch of brown shrimp comprised 4.5% by number and 10.2% by weight of the total catch during the first year. The August 1974 catch of white shrimp accounted for 14.7% by numbers, but only 9.2% by weight, of the total catch during the second year.

Differences in abundance and species ratios were observed among the state regions. The central region was the most productive in numbers of shrimp caught (Table 5). On the average the central region yielded about 2.4 times more white shrimp per 20-min tow than the northern region (334.4 vs. 141.1) and 4.3 times more than in the southern region (334.4 vs. 77.9). Brown shrimp were caught nearly four times more often per tow in the central than in the northern region (40.9 vs. 10.3) and 2.6 times more often than in the southern region (40.9 vs. 15.9). In the northern, central, and southern areas, an average of 0.4, 0.7, and 0.1 pink shrimp were caught per tow, respectively (Table 5).

Intensive sampling. Most of the shrimp caught were white shrimp. Brown shrimp made up <1.5% of the first year's penaeid catch in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, but in the second year, they comprised 12.7% of the catch (Figs. 10, 11). The monthly percentages of pink shrimp were always less than 0.1% of that year's total penaeid catch (Figs. 10, 11).

Spatial and Temporal Distribution.

Extensive sampling. Nearly 58% of the 24,308 white shrimp collected during quarterly extensive sampling were taken from three stations (Ashley River, Hog Island, and Fort Johnson) in the central region, and 12% were taken from the South Santee River station (S001). Over 36% of the white shrimp catch was obtained in October 1973, and 14% was obtained in both April and August 1974 (Table 6). Of the 3,056 brown shrimp caught during extensive phase trawling, 53% came from one station, Inlet Creek (B001), in the central region of the coast. Over 11% of the brown shrimp were caught at Calibogue Sound (G001) and also at Rock Creek (H003) in the southern portion of the coast. Seventy-seven percent of the browns were caught in July 1973, and 11% were caught in August 1974 (Table 7).

Only 51 pink shrimp were caught during quarterly statewide sampling and two-thirds of these were caught at one station in Inlet Creek (B001).

Table 3. Bottom salinities (o/oo) of stations sampled quarterly.

Station	1973			1974				1975	Mean Salinity by Station
	Spring (April)	Summer (July)	Fall (Oct.)	Winter (Jan.)	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)	
Northern Region									
Winyah Bay (Y001)	0.0	6.9	25.9	0.9	0.3	1.8	12.3	2.3	6.3
South Santee (S001)	0.1*	12.6	23.1	17.8	4.3*	16.7	15.6	26.0	14.5
Bull Bay (B003)	22.8*	32.1	34.2	33.2	33.2	31.2	32.8	32.7	31.5
Price Creek (B002)	23.4	33.2	34.1	33.4	33.0	30.0	33.4	32.9	31.7
Central Region									
Inlet Creek (B001)	24.6*	30.3	33.8	23.4	28.7	29.5	33.4	29.1	29.1
Nowell Creek (W001)	6.9*	12.2	18.4	11.2	9.2	11.4	16.6	13.4	12.4
Fort Johnson (J001)	10.9	15.4	20.3	25.1	23.3	21.8	21.4	16.2	19.3
Hog Island (J002)	15.7	26.6*	29.0	25.2	15.9*	22.7	25.5	27.6	23.5
Ashley River (K001)	7.6	15.7	18.7	14.2	13.6	12.9	18.7	17.7	14.9
Stono River (F001)	10.5	11.0	21.8	20.6	18.8	10.1	21.3	14.2	16.0
Southern Region									
Ashepoo River (H002)	0.2	0.5	7.7	12.3	3.9	5.6	12.3	11.6	6.8
Rock Creek (H003)	12.0	16.0	23.9	24.1	21.8	21.0	25.5	25.9	21.3
Whale Branch (H001)	10.4	15.6	21.4	25.9	21.8	23.2	22.6	26.8	21.0
Port Royal Sound (P002)	24.1	28.7	29.3	30.9	29.6	30.0	30.0	30.0	29.1
Colleton River (P001)	22.3	25.7	27.6	30.4	29.6	29.4	28.9	30.7	28.1
Calibogue Sound (G001)	22.2	25.4	28.6	28.8	28.5	27.8	29.8	30.3	27.7

* Surface Salinity.

Table 4. Bottom water temperatures (°C) of stations sampled quarterly.

Station	1973			1974				1975
	Spring (April)	Summer (July)	Fall (Oct.)	Winter (Jan.)	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)
Northern Region								
Winyah Bay (Y001)	18.7	28.4	21.0	11.6	18.0	26.3	16.6	10.2
South Santee (S001)	19.8*	29.5	20.2	12.7	21.1*	27.3	15.8	14.1
Bull Bay (B003)	22.0*	29.5	20.0	10.4	20.8	27.5	14.4	10.9
Price Creek (B002)	19.9	29.2	19.6	10.3	21.7	26.8	13.8	10.8
Central Region								
Inlet Creek (B001)	22.0*	27.8	24.4	14.7	17.8	27.8	21.8	12.0
Nowell Creek (W001)	16.8*	29.0	26.1	14.7	18.8	28.8	22.0	11.2
Fort Johnson (J001)	17.8	28.0	26.2	13.2	18.0	27.8	21.8	10.8
Hog Island (J002)	17.6	27.4*	25.9	13.7	21.2*	28.4	21.5	11.7
Ashley River (K001)	18.5	29.3	26.3	14.2	17.6	28.2	21.3	11.2
Stono River (F001)	18.3	29.9	20.6	13.6	17.3	27.5	21.5	11.2
Southern Region								
Ashepoo River (H002)	16.7	29.9	27.0	15.1	21.0	27.2	19.5	12.2
Rock Creek (H003)	15.8	30.5	27.2	15.2	24.8	27.5	20.0	11.8
Whale Branch (H001)	16.8	31.4	28.8	16.6	21.0	27.5	20.6	12.4
Port Royal Sound (P002)	16.6	30.0	27.6	14.1	19.8	28.2	20.4	12.0
Colleton River (P001)	16.9	30.6	28.3	14.7	20.0	28.2	20.9	12.1
Calibogue Sound (G001)	16.2	30.5	27.8	14.3	20.4	27.9	20.1	12.4
Mean Temperature by Season	18.2	29.4	24.8	13.7	20.0	27.7	19.5	11.7

* Surface Temperature.

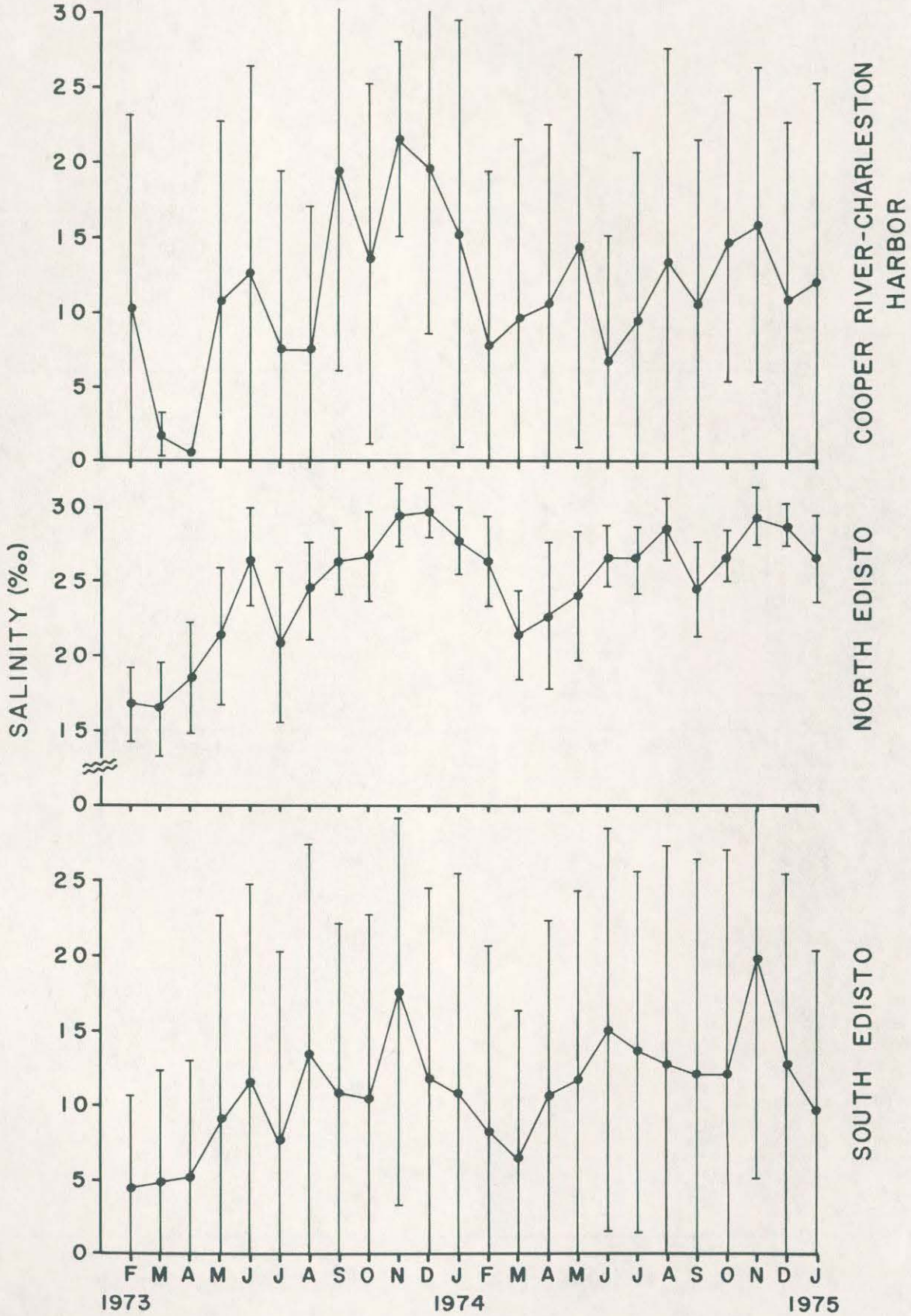


Fig. 2. Mean bottom salinity (± 1 SD) conditions by month in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina from February 1973 through January 1975.

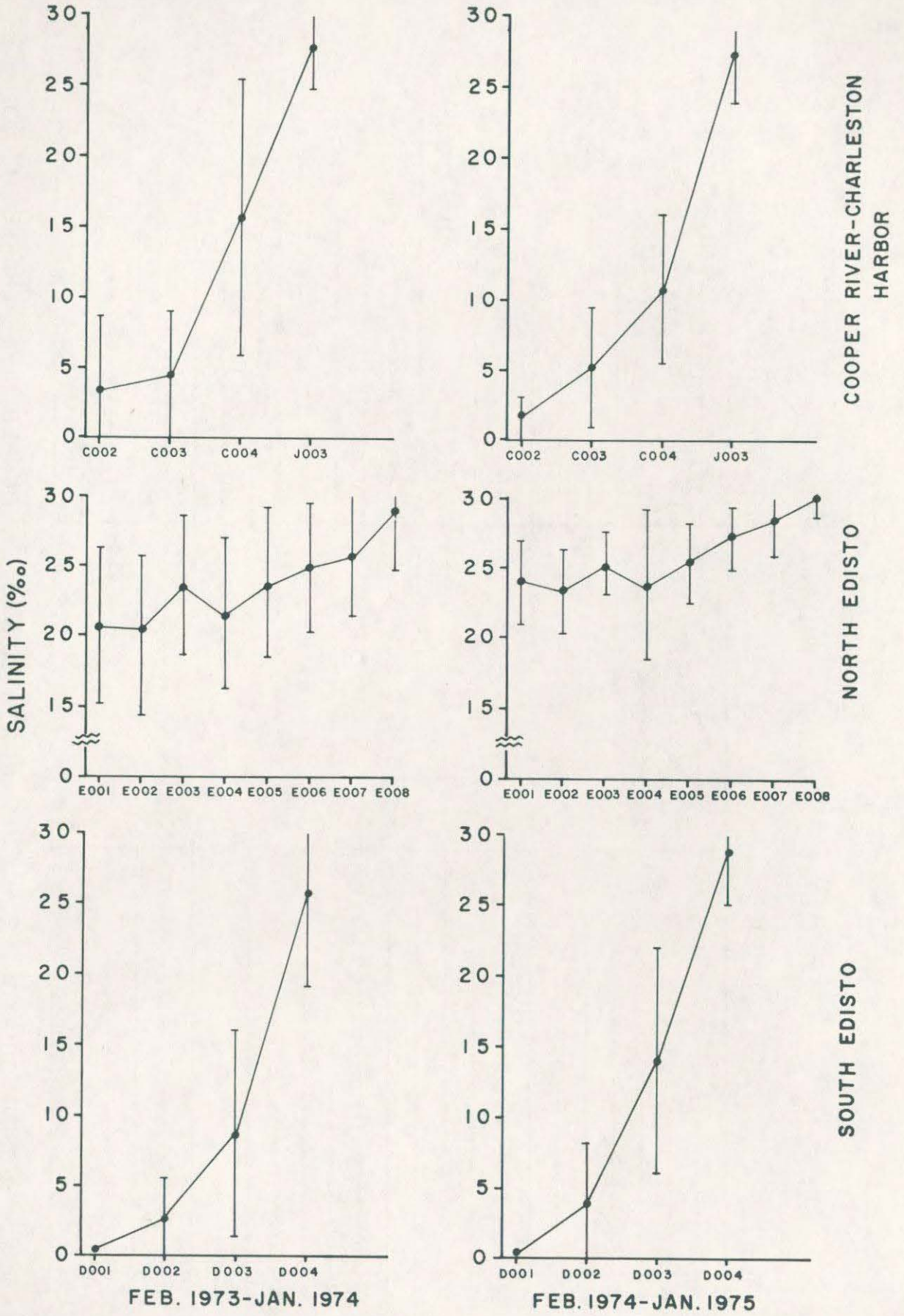


Fig. 3. Mean bottom salinity (± 1 SD) conditions by station in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

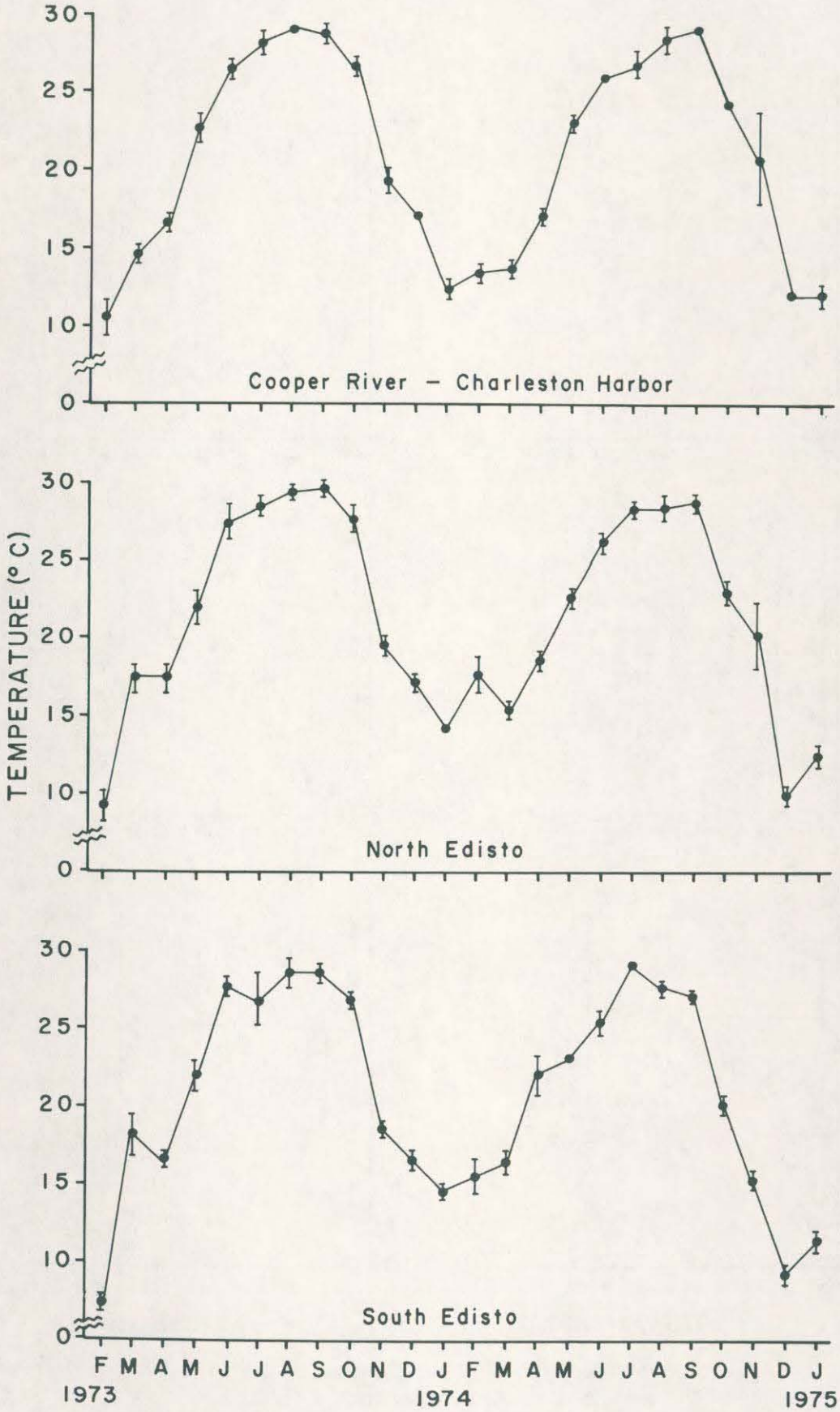


Fig. 4. Mean bottom temperature (± 1 SD) conditions by month in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

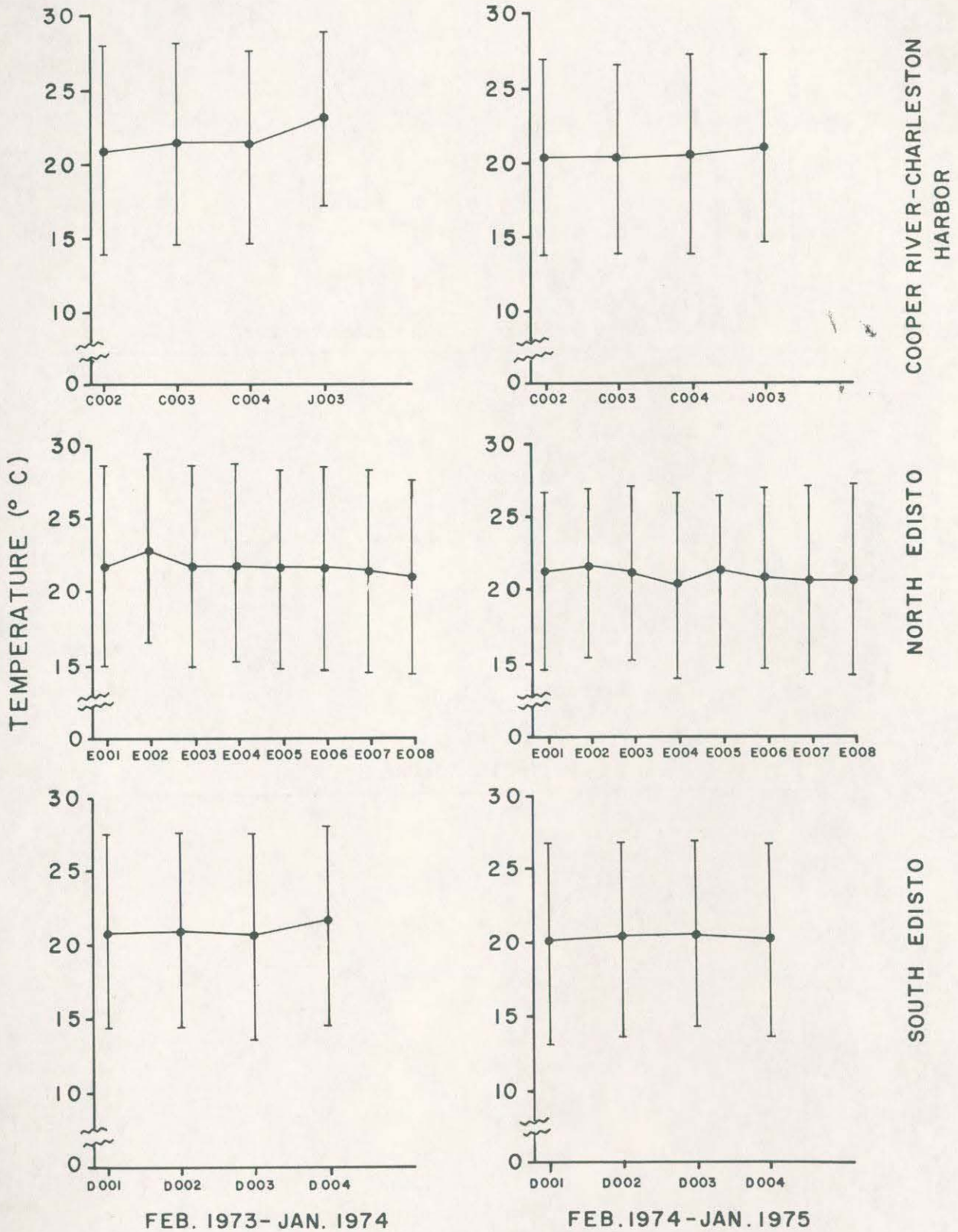


Fig. 5. Mean bottom temperature (± 1 SD) conditions by station in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina from February 1973 through January 1975.

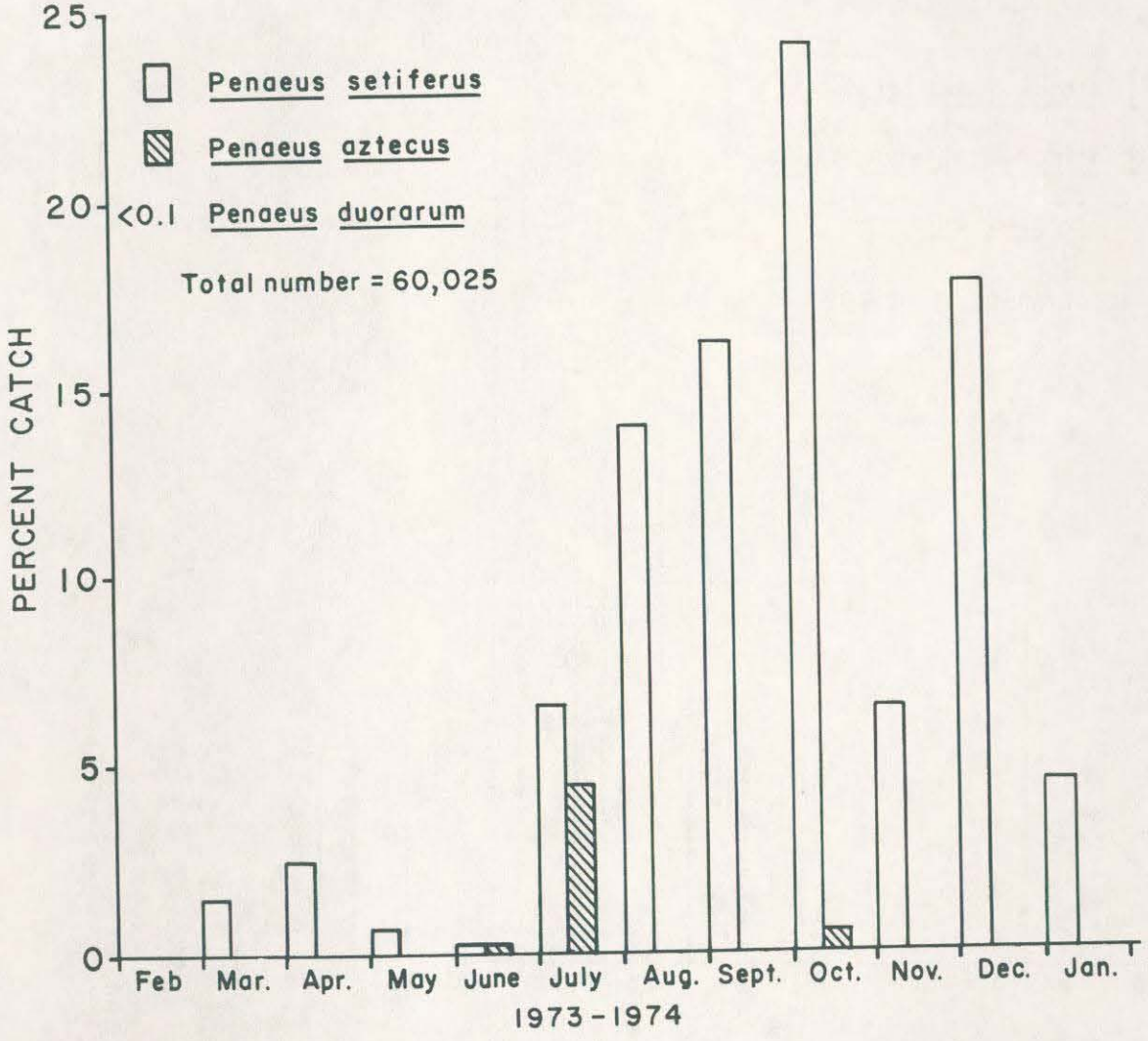


Fig. 6. Penaeid shrimp species composition in South Carolina estuaries (all stations combined) from February 1973 through January 1974.

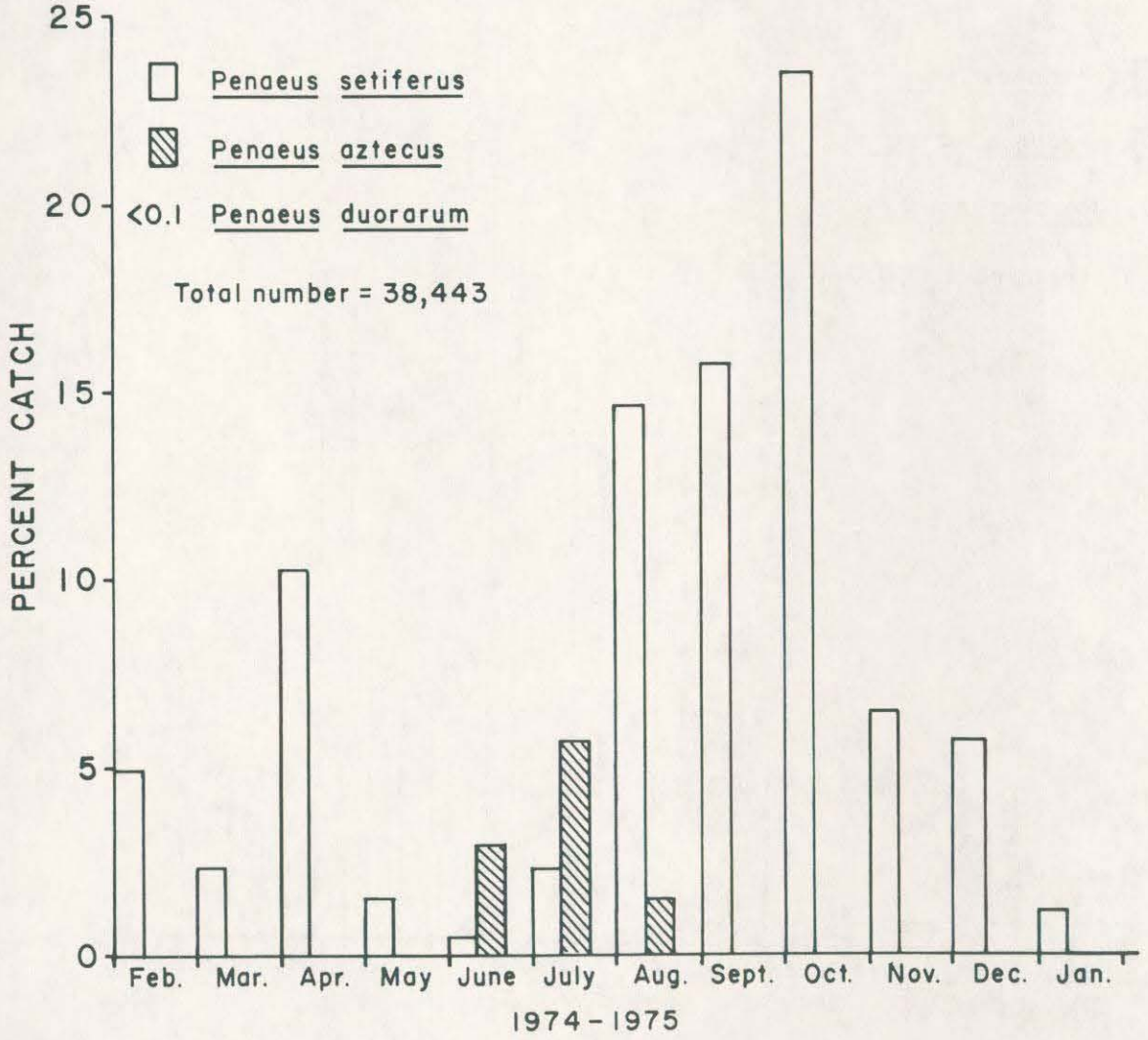


Fig. 7. Penaeid shrimp species composition in South Carolina estuaries (all stations combined) from February 1974 through January 1975.

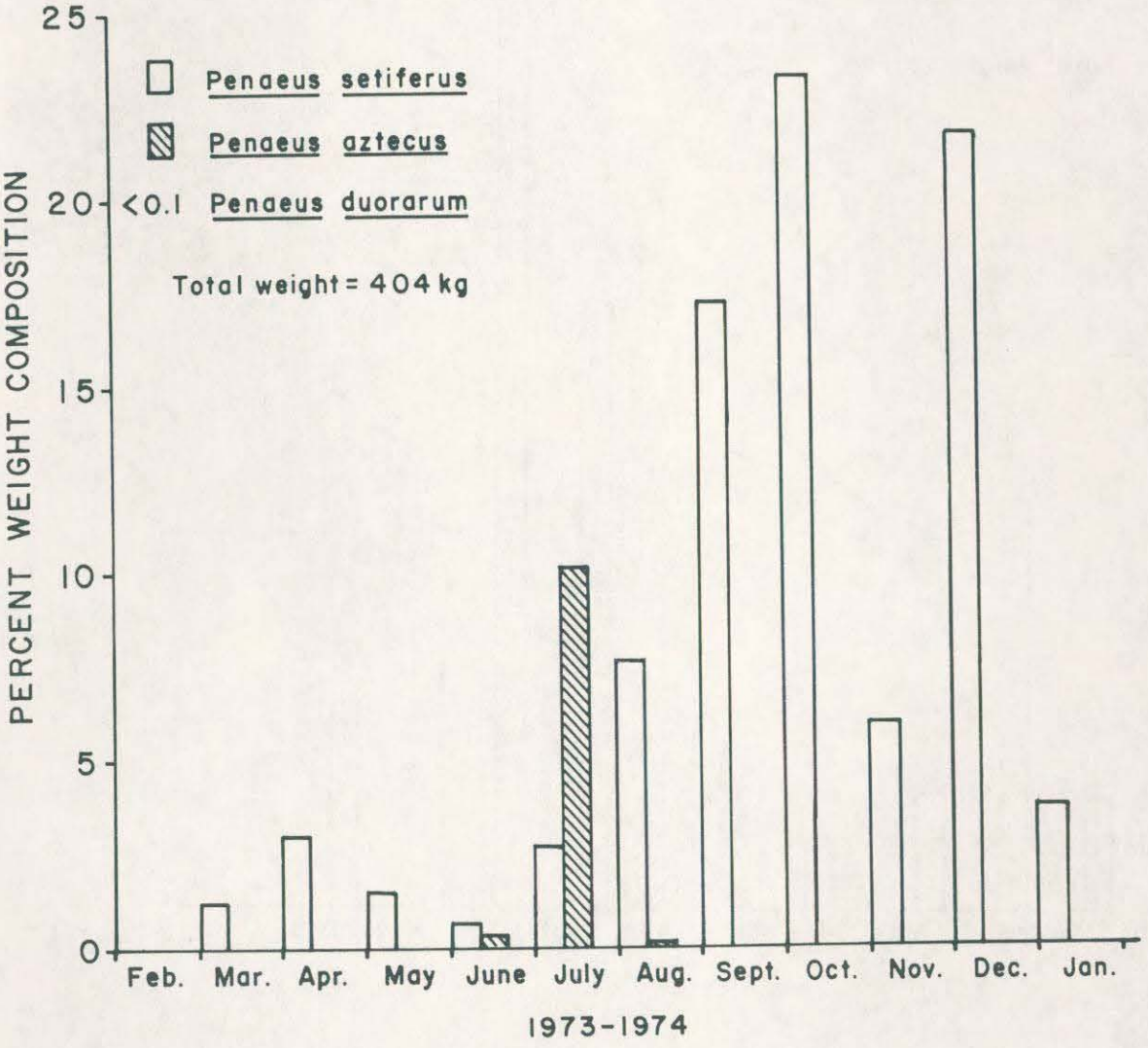


Fig. 8. Penaeid shrimp species composition by weight in South Carolina estuaries (all stations combined) from February 1973 through January 1974.

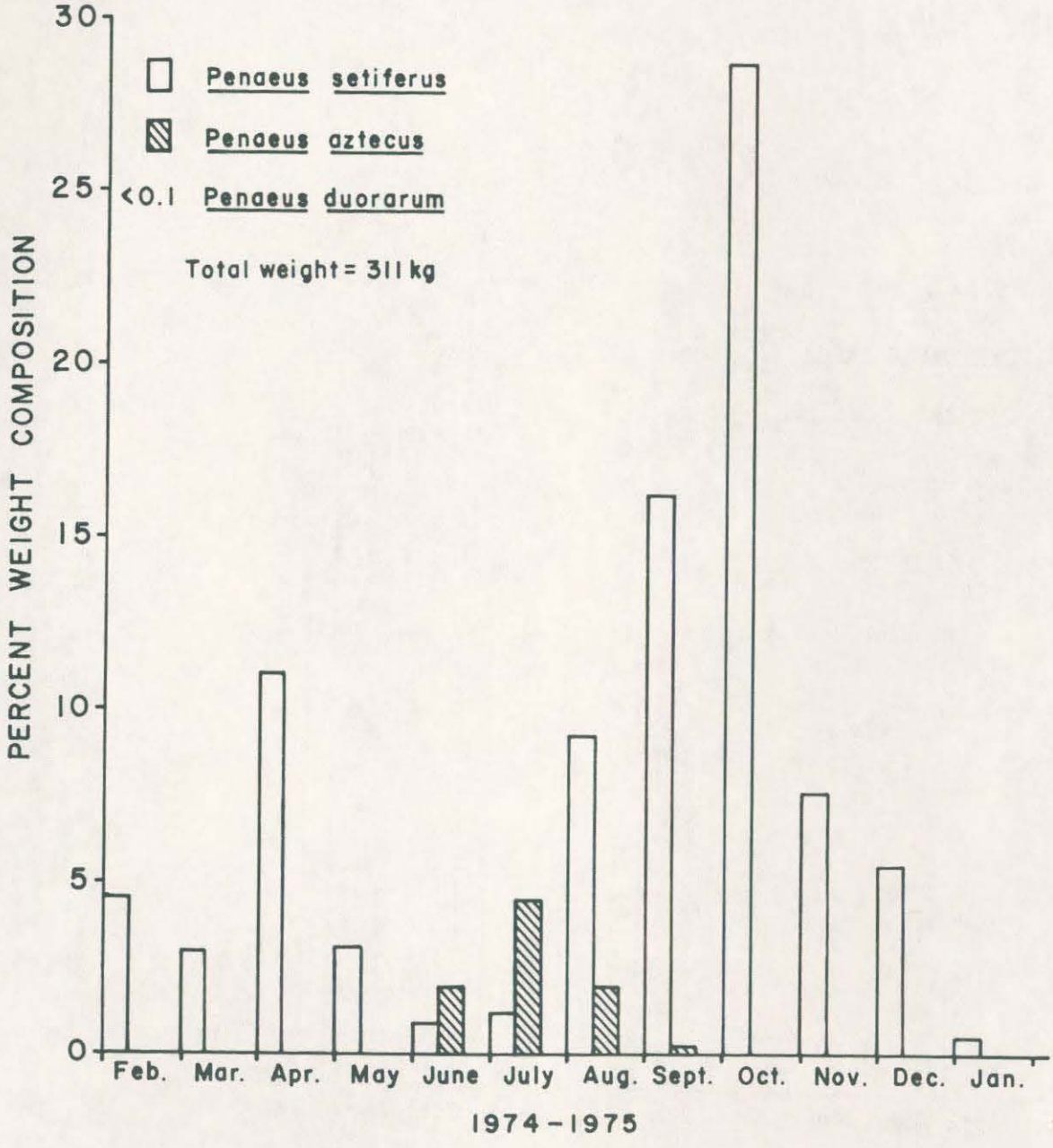


Fig. 9. Penaeid shrimp species composition by weight in South Carolina estuaries (all stations combined) from February 1974 through January 1975.

Table 5. Penaeid shrimp species composition (whites:browns:pinks) based on numerical catch per 20-min trawl tows in each region of the South Carolina coast from February 1973 through January 1975.

Season	cpue per South Carolina Coast		
	Northern Region white:brown:pink	Central Region white:brown:pink	Southern Region white:brown:pink
1973			
Spring	58.3: 0.0: 1.0	78.3: 4.8:0.0	47.3: 0.0:0.0
Summer	104.3: 13.0: 0.5	538.3:319.7:1.8	34.0:65.2:0.0
Fall	99.8: 1.8: 0.3	1311.2: 0.2:0.2	103.2:51.2:0.0
1974			
Winter	28.0: 0.0: 0.0	107.0: 0.3:1.0	65.5: 0.3:0.0
Spring	400.3: 0.5: 0.5	222.7: 0.2:1.2	80.0: 0.8:0.2
Summer	175.8: 66.8: 0.5	257.2: 1.8:0.8	201.0:10.0:0.3
Fall	250.5: 0.0: 0.3	137.8: 0.0:1.0	89.2: 0.0:0.2
1975			
Winter	12.0: 0.3: 0.0	23.3: 0.0:0.8	2.8: 0.0:0.0
Mean	141.1: 10.3: 0.4	334.4: 40.9:0.7	77.9:15.9:0.1

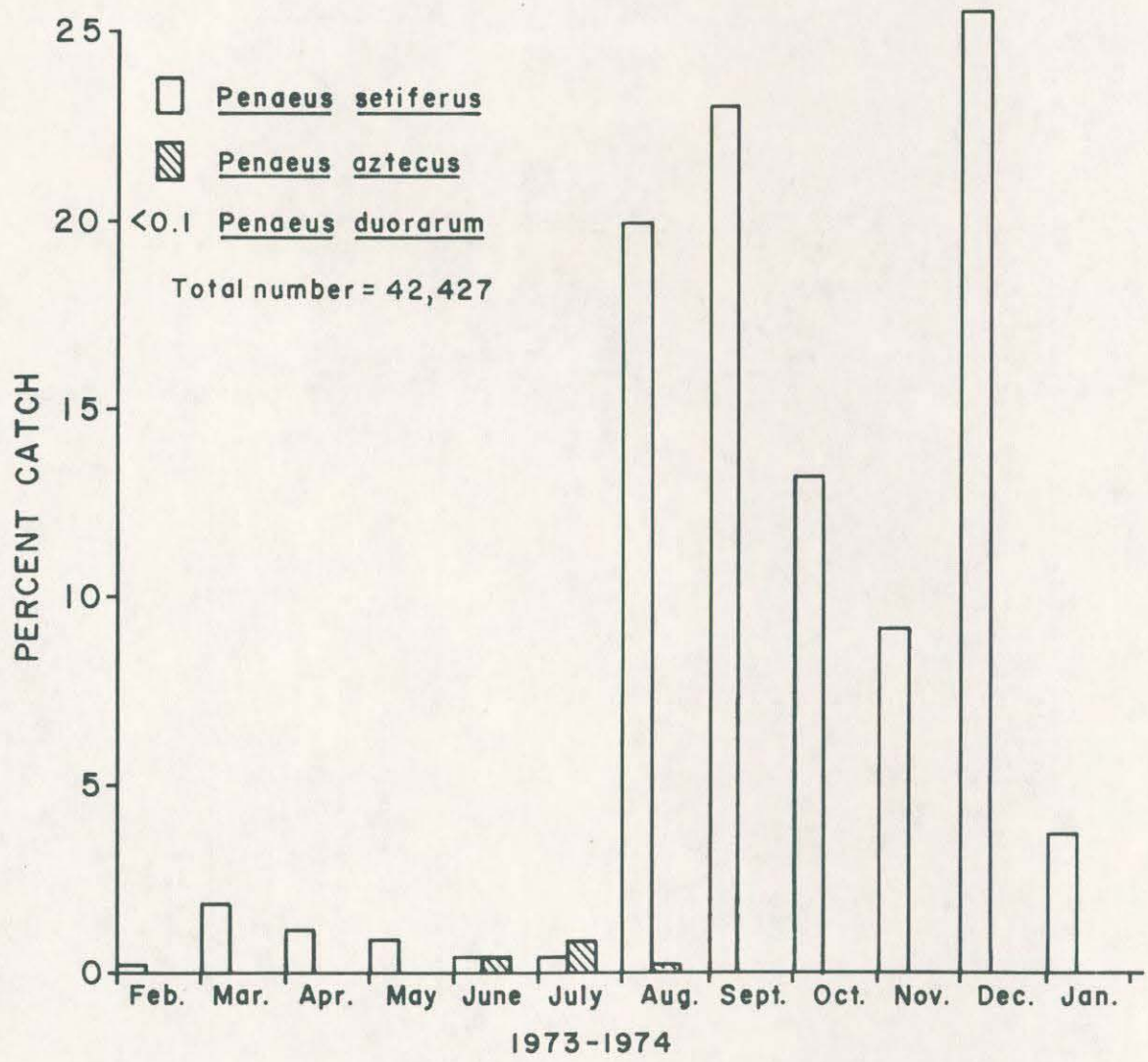


Fig. 10. Penaeid shrimp species composition in Cooper River-Charleston Harbor North Edisto, and South Edisto estuaries from February 1973 through January 1974.

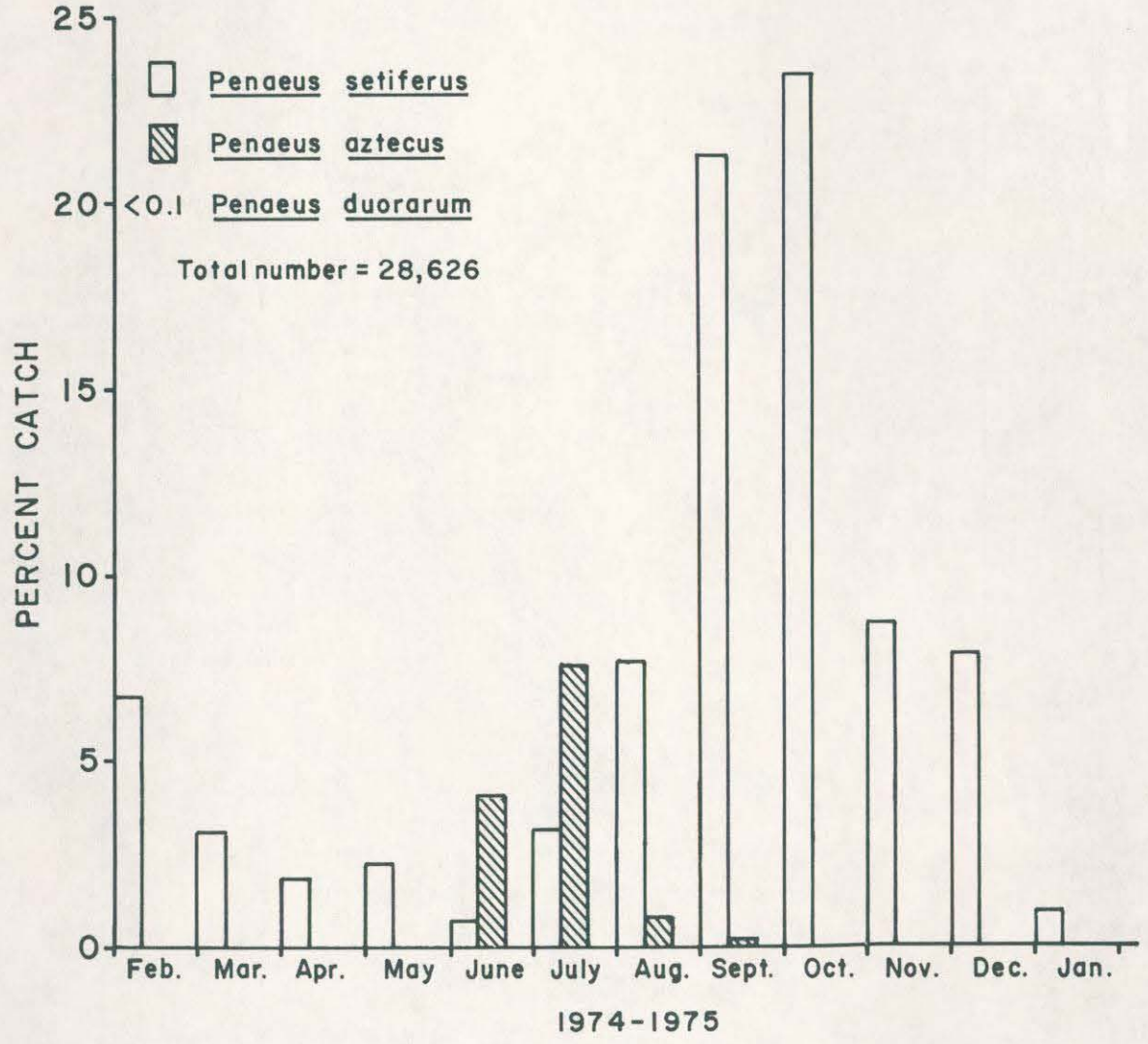


Fig. 11. Penaeid shrimp species composition in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1974 through January 1975.

Table 6. Seasonal numerical abundance of Penaeus setiferus collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Station	1973			1974				1975	Total Catch by Station	Station Contribution to Total Catch (%)
	Spring (April)	Summer (July)	Fall (Oct.)	Winter (Jan.)	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)		
Northern Region										
Winyah Bay (Y001)		137	205	4		218	519		1,083	4.4
South Santee (S001)		113	153	95	1,597	466	471	32	2,927	12.0
Bull Bay (B003)	233	162	36	13	4	19	2	16	485	2.0
Price Creek (B002)		5	5				10		20	0.1
Central Region										
Inlet Creek (B001)	19	87	9	1		163	6		285	1.2
Nowell Creek (W001)	68	641	152		65	295	17		1,238	5.1
Fort Johnson (J001)	285	403	307	161	618	301	411		2,486	10.2
Hog Island (J002)	2	1,576	1,320		4	587	158		3,647	15.0
Ashley River (K001)	48	407	6,019	479	600	179	136	139	8,007	32.9
Stono River (F001)	48	116	60	1	49	18	99	1	392	1.6
Southern Region										
Ashepoo River (H002)			230	155	3	419	115	14	936	3.9
Rock Creek (H003)	38	106		68	88	622	202		1,124	4.6
Whale Branch (H001)	240	97	125	99	10	101	46		718	3.0
Port Royal Sound (P002)				42	116	33		1	192	0.8
Colleton River (P001)			72	8	10	8	22		120	0.5
Calibogue Sound (G001)	6	1	192	21	253	23	150	2	648	2.7
Total Catch by Season	987	3,851	8,885	1,147	3,417	3,452	2,364	205	24,308	
Season Contribution to Total Catch (%)	4.1	15.8	36.6	4.7	14.1	14.2	9.7	0.8		100.0

Table 7. Seasonal numerical abundance of Penaeus aztecus collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Station	1973			1974				1975	Total Catch by Station	Station Contribution to Total Catch (%)
	Spring (April)	Summer (July)	Fall (Oct.)	Winter (Jan.)	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)		
Northern Region										
Winyah Bay(Y001)		19	7		2	5			33	1.1
South Santee (S001)		7				192			199	6.5
Bull Bay (B003)		14				65		1	80	2.6
Price Creek (B002)		12				5			17	0.6
Central Region										
Inlet Creek (B001)	28	1,588	1	2		6			1,625	53.2
Nowell Creek (W001)		10							10	0.3
Fort Johnson (J001)	1	212				5			218	7.1
Hog Island (J002)		95			1				96	3.1
Ashley River (K001)		4							4	0.1
Stono River (F001)		9							9	0.3
Southern Region										
Ashepoo River (H002)			5			6			11	0.4
Rock Creek (H003)		14	302	2	1	25			344	11.3
Whale Branch (H001)		21			1	26			48	1.6
Port Royal Sound (P002)		8			2	1			11	0.4
Colleton River (P001)					1				1	0.0
Calibogue Sound (G001)		348				2			350	11.4
Total Catch by Season	29	2,361	315	4	8	338	0	1	3,056	
Season Contribution to Total Catch (%)	0.9	77.3	10.3	0.1	0.3	11.1	0.0	0.0		100.0

Three stations (Inlet Creek, B001; Price Creek, B002; and Bull Bay, B003) between Charleston Harbor and the South Santee River, accounted for over 90% of the pink shrimp caught during quarterly statewide cruises. Twenty-five percent of the pinks were caught in July 1973 (Table 8).

White and brown shrimp comprised 88.7 and 11.1%, respectively, of the total captured at Extensive Phase stations (Table 9) with pink shrimp accounting for 0.2% of the catch. Stations at which the largest percentage of white shrimp were caught also accounted for the largest percentage for all three species combined. Twenty-nine percent of the total catch (27,415) were taken in the Ashley River (K001) and 13.7% were taken at the Hog Island station (J002). Only 1,944 shrimp were caught at the Inlet Creek station (B001), but 83.6% of these were brown shrimp and 14.7% were whites (Table 9). Penaeid shrimp were most numerous in summer and fall and least abundant in winter 1975 (Table 10).

Intensive sampling. In both the Cooper River-Charleston Harbor and in the South Edisto estuaries, white shrimp were caught further inland during the fall months (Tables 11, 12). The most inland station (C002) in the Cooper River contributed only 10.7% of the total number of white shrimp captured in that estuary, while at the most inland station in the South Edisto estuary (D001), catches of white shrimp comprised <0.1% of the total for that river (Tables 11, 12). No shrimp were caught at The Tee during the first year of trawling, and trawling at this station was discontinued due to high incidence of gear damage by bottom obstructions.

The spatial distribution of white shrimp in North Edisto estuary was not similar to that observed in the Cooper River-Charleston Harbor and South Edisto estuaries (Table 13). Shrimp were caught more often 21 km inland (Yonges's Island, E001) than at the mouth of this estuary (Deveaux Bank). Most of the white shrimp taken from the North Edisto were obtained just inland from the mouth at the Point of Pines station (E007) and the least were taken from the Deveaux Bank station (E008) (Table 13).

Of the 66,819 white shrimp caught during the intensive phase of the study, 62.7% were taken in the first year and 37.3% during the second. In both years, the greatest catches were made from August through December (Table 14). These five months accounted for 91.7% of the first year's catch and 78.6% of the second. Overall, the period August-December 1973 contributed 57.5% of the combined catch of white shrimp, while the same period in 1974 accounted for only 29.4%, reflecting the nearly two-fold difference in total catches for the two years (Table 14).

Brown shrimp were not nearly as abundant as white shrimp and were caught primarily in the summer (Tables 15, 16, 17). No P. aztecus were obtained at the most inland stations during any month in either the Cooper or South Edisto Rivers (Tables 15, 16). Most of the brown shrimp (54%) taken from the Cooper River-Charleston Harbor estuary were obtained from Cumming's Point, the seaward-most station. In 1973, only one P. aztecus was taken at the North Charleston station which is 23 km inland; however, in 1974, 219 brown shrimp were taken at this station. Of those from the South Edisto estuary, 65% were obtained at the Fenwick Island station (14 km inland). Brown shrimp were collected throughout the North Edisto estuary and were most numerous at Yonge's Island, the most inland station (Table 17).

The catches of brown shrimp were far more seasonal than those of white shrimp. Approximately 98% of the total catch of 4,191 brown shrimp was obtained in June, July, and August (Table 18). Nearly 12% of the total intensive catch was colcected in June and July of 1973, and 86% was collected in June, July, and August of 1974 (Table 18).

Pink shrimp were the least frequently captured commercial shrimp. During two years of intensive trawling in the Cooper River-Charleston Harbor and the South Edisto estuaries, a total of six pink shrimp were identified from the catches. Two were captured at the mouth of the Cooper River (station C004) in August 1973, and in the South Edisto, three were taken at Fenwick Island (station D003) in October 1973 and one at Bay Point (station D004) in April 1974. In the North Edisto estuary, however, 37 pink shrimp were taken (Table 19), and fifteen of these were obtained at the Toogoodoo Creek station (Table 19). Of the 43 pink shrimp caught in the monthly, intensive sampling, 18.6% were obtained in October of 1973 and 18.6, 14.0, and 14.0% were collected in March, April, and October of 1974, respectively (Table 20).

During the two years, a total of 71,053 shrimp of the genus Penaeus were caught. Of this total, 42,427 or 59.7% were taken during the first twelve months, and these were virtually all white shrimp (Table 21). In contrast, during the following year, the catch of white shrimp was reduced by about 40% while that of browns increased nearly seven-fold. Thus, brown shrimp accounted for 12.7% of the catch during the second year. Overall, white shrimp comprised 94% and brown shrimp comprised 5.9% of the total catch. The numbers of pink shrimp caught were not greater than 0.1% of the catch (Table 21).

Most of the white shrimp were caught in late summer and fall months, while most brown shrimp were obtained during summer. Over 86% of the total number of white shrimp were taken from August through December, and 92.7% of the brown shrimp were obtained in June and July. Thirty-seven percent (16) of the pink shrimp were caught in March and April (Table 22). The two-year mean number of shrimp caught per tow in the three estuaries was 186.5. The mean numbers of white shrimp captured per tow during the first and second year of the study were 221 and 130, and for brown shrimp 3 and 19, respectively (Table 23).

Higher numbers and biomass of shrimp were collected per tow in the Cooper River-Charleston Harbor than in the other estuaries (Tables 24, 25). Nearly 58% by number and 44% by weight of the catch per tow were taken from this estuary. The North Edisto was found to be the next most productive estuary, accounting for only 27% by numbers, but 42% by weight of the mean catch per tow. Only 15% by numbers and 14% by weight of the catch per 20-min tow were obtained from the South Edisto estuary (Tables 24, 25).

White shrimp were caught in greater numbers per

Table 8. Seasonal numerical abundance of Penaeus duorarum collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Station	1973			1974				1975	Total Catch by Station	Station Contribution to Total Catch (%)
	Spring (April)	Summer (July)	Fall (Oct.)	Winter (Jan.)	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)		
Northern Region										
Winyah Bay (Y001)									0	0.0
South Santee (S001)									0	0.0
Bull Bay (B003)						1	1		2	3.9
Price Creek (B002)	4	2	1		2	1			10	19.6
Central Region										
Inlet Creek (B001)		11	1		6	5	6	5	34	66.6
Nowell Creek (W001)									0	0.0
Fort Johnson (J001)									0	0.0
Hog Island (J002)					1				1	2.0
Ashley River (K001)									0	0.0
Stono River (F001)									0	0.0
Southern Region										
Ashepoo River (H002)						2			2	3.9
Rock Creek (H003)					1				1	2.0
Whale Branch (H001)									0	0.0
Port Royal Sound (P002)									0	0.0
Colleton River (P001)									0	0.0
Calibogue Sound (G001)							1		1	2.0
Total Catch by Season	4	13	2	0	10	9	8	5	51	
Season Contribution to Total Catch (%)	7.8	25.5	3.9	0.0	19.6	17.7	15.7	9.8		100.0

Table 9. Total numerical abundance by species for penaeid shrimps collected by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Station	Penaeus setiferus		Penaeus aztecus		Penaeus duorarum		Total Catch by Station	Station Contribution to Total Catch (%)
	Number	Percent	Number	Percent	Number	Percent		
Northern Region								
Winyah Bay (Y001)	1,083	4.0	33	0.1	0	0.0	1,116	4.1
South Santee (S001)	2,927	10.7	199	0.7	0	0.0	3,126	11.4
Bull Bay (B003)	485	1.8	80	0.3	2	< 0.1	567	2.1
Price Creek (B002)	20	0.1	17	0.1	10	< 0.1	47	0.2
Central Region								
Inlet Creek (B001)	285	1.0	1,625	5.9	34	0.1	1,944	7.1
Nowell Creek (W001)	1,238	4.5	10	< 0.1	0	0.0	1,248	4.6
Fort Johnson (J001)	2,486	9.1	218	0.8	0	0.0	2,704	9.9
Hog Island (J002)	3,647	13.3	96	0.4	1	< 0.1	3,744	13.7
Ashley River (K001)	8,007	29.2	4	< 0.1	0	0.0	8,011	29.2
Stono River (F001)	392	1.4	9	< 0.1	0	0.0	401	1.5
Southern Region								
Ashepoo River (H002)	936	3.4	11	< 0.1	2	< 0.1	949	3.5
Rock Creek (H003)	1,124	4.1	344	1.3	1	< 0.1	1,469	5.4
Whale Branch (H001)	718	2.6	48	0.2	0	0.0	766	2.8
Port Royal Sound (P002)	192	0.7	11	< 0.1	0	0.0	203	0.7
Colleton River (P001)	120	0.4	1	< 0.1	1	< 0.1	122	0.4
Calibogue Sound (G001)	648	2.4	350	1.3	0	0.0	998	3.6
Total Catch by Species	24,308		3,056		51		27,415	
Species Contribution to Total Catch (%)		88.7		11.1		0.2		100.0

Table 10. Seasonal numerical abundance by species for penaeid shrimps collected by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Species	1973			1974				1975	Total Catch by Species and Species Contribution to Total Catch (%)
	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)	Spring (April)	Summer (Aug.)	Fall (Oct.)	Winter (Jan.)	
Penaeus setiferus	987	3,851	8,885	1,147	3,417	3,452	2,364	205	24,308
Percent	3.6	14.0	32.4	4.2	12.5	12.6	8.6	0.8	88.7
Penaeus aztecus	29	2,361	315	4	8	338	0	1	3,056
Percent	0.1	8.6	1.2	< 0.1	< 0.1	1.2	0.0	< 0.1	11.1
Penaeus duorarum	4	13	2	0	10	9	8	5	51
Percent	< 0.1	0.1	< 0.1	0.0	< 0.1	< 0.1	< 0.1	0.2	0.2
Total Catch by Season	1,020	6,225	9,202	1,151	3,435	3,799	2,372	211	27,415
Season Contribution to Total Catch (%)	3.7	22.7	33.6	4.2	12.5	13.9	8.6	0.8	100.0

Table 11. Numerical catch of Penaeus setiferus collected monthly by bottom trawl at four stations in the Cooper River-Charleston Harbor estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward→)					
	Big Island (C002)	North Charleston (C003)	Mouth of Cooper (C004)	Cummings Point (J003)	Total Catch by Month	Monthly Contribution to Total Catch (%)
Distance Inland (km)	33	23	16	0		
1973						
February					0	0.0
March			5		5	< 0.1
April					0	0.0
May			4	7	11	0.1
June					0	0.0
July			50	47	97	0.5
August	2	4,370	831	440	5,643	27.9
September	3	824	1,740	12	2,579	12.7
October	148	2,290	524	257	3,219	15.9
November	2,430	409	157	38	3,034	15.0
December	183	32	5,040		5,255	26.0
1974						
January		4	141	242	387	1.9
Year's Catch by Station	2,766	7,929	8,492	1,043	20,230	
Station Contribution to First Year's Catch (%)	13.7	39.2	42.0	5.2		100.0
1974						
February			14	1,612	1,626	17.2
March			122	387	509	5.4
April			152	83	235	2.5
May		164	331	17	512	5.4
June		32	90	37	159	1.7
July	1	111	144	10	266	2.8
August	74	133		3	210	2.2
September		2,050	277	69	2,396	25.3
October	326	1,600		6	1,932	20.4
November	12	438	483	86	1,019	10.8
December		26	164	242	432	4.6
1975						
January			6	171	177	1.9
Year's Catch by Station	413	4,554	1,783	2,723	9,473	
Station Contribution to Second Years Catch (%)	4.4	48.1	18.8	28.7		100.0
Total Catch by Station	3,179	12,483	10,275	3,766		
Station Contribution to Total Catch (%)	10.7	42.0	34.6	12.7		100.0

Grand Total (All stations and months combined) = 29,703

Table 12. Numerical catch of Penaeus setiferus collected monthly by bottom trawl at four stations in the South Edisto estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward→)					
	Snuggedy Swamp (D001)	Sampson Island (D002)	Fenwick Island (D003)	Bay Point (D004)	Total Catch by Month	Monthly Contribution to Total Catch (%)
Distance Inland (km)	35	24	14	2		
1973						
February				9	9	0.2
March				12	12	0.2
April				14	14	0.3
May			20	3	23	0.5
June				1	1	<0.1
July		1			1	<0.1
August		170	1,026		1,196	23.7
September	1	131	1,000	105	1,237	24.5
October		82	202	63	347	6.9
November		105	78	5	188	3.7
December		210	1,710	3	1,923	38.1
1974						
January			74	26	100	2.0
Year's Catch by Station	1	699	4,110	241	5,051	
Station Contribution to First Year's Catch (%)	<0.1	13.8	81.4	4.8		100.0
1974						
February			18		18	0.6
March				152	152	4.7
April			9	2	11	0.3
May		1	7	4	12	0.4
June				5	5	0.2
July		446	137		583	18.1
August		627	279		906	28.2
September	1	386	163	50	600	18.7
October		77	112	1	190	5.9
November	2	431	23	49	505	15.7
December		2	22	157	181	5.6
1975						
January			51		51	1.6
Year's Catch by Station	3	1,970	821	420	3,214	
Station Contribution to Second Year's Catch (%)	< 0.1	61.3	25.5	13.1		100.0
Total Catch by Station	4	2,669	4,931	661		
Station Contribution to Total Catch (%)	<0.1	32.3	59.7	8.0		100.0

Grand Total (All stations and months combined) = 8,265

Table 13. Numerical catch of Penaeus setiferus collected monthly by bottom trawl at eight stations in the North Edisto estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward →)									
	Yonges Island (E001)	Toogoodoo Creek (E002)	Bears Bluff (E003)	Dawho River (E004)	Steamboat Creek (E005)	Wadmalaw Island (E006)	Point of Pines (E007)	Deveaux Bank (E008)	Total Catch by Month	Monthly Contribution to Total Catch (%)
Distance Inland (km)	21	22	15	16	14	10	6	0		
1973										
February			1		1			27	29	0.2
March	21	6	55	514	139	5	2	5	747	4.5
April	109	124	71	51	74	5	17	1	452	2.7
May	20	164	89	29	6	13	10	2	333	2.0
June	4	1	28	5	27	8	72	12	157	0.9
July	3	49		20					72	0.4
August	117	167	32	485			750	8	1,559	9.4
September	609	1,290	96	1,710	403	714	1,097	17	5,936	35.8
October	263	298	24	400	141	151	640	108	2,025	12.2
November	144	4	5	182	93	84	171		683	4.1
December	546		352	1,360	360	391	543	4	3,556	21.4
1974										
January	10	30	31	181	223	43	346	171	1,035	6.2
Year's Catch by Station	1,846	2,133	784	4,937	1,467	1,414	3,648	355	16,584	
Station Contribution to First Year's Catch (%)	11.1	12.9	4.7	29.8	8.8	8.5	22.0	2.1		100.0
1974										
February	61		1	27	168	17	1	1	276	2.2
March	79	8	61	19	58	9	13	2	249	2.0
April	102			158	20		1		281	2.3
May	21			53	9	7	5	13	108	0.9
June			1	3	1	3		1	9	0.1
July	8		1	38	1	2	2		52	0.4
August	314	8	37	642	23	5	35	2	1,066	8.7
September	319	187	45	195	95	63	2,030	131	3,065	25.0
October	132	901	62	492	120	67	2,730	41	4,545	37.1
November	43	5	91	172	240	272	129	21	973	7.9
December	31		135	18	707	233	318	171	1,613	13.1
1975										
January			10			19		1	30	0.2
Year's Catch by Station	1,110	1,109	444	1,817	1,442	697	5,264	384	12,267	
Station Contribution to Second Year's Catch (%)	9.0	9.0	3.6	14.8	11.8	5.7	42.9	3.1		100.0
Total Catch by Station	2,956	3,242	1,228	6,754	2,909	2,111	8,912	739		
Station Contribution to Total Catch (%)	10.2	11.2	4.3	23.4	10.1	7.3	30.9	2.6		100.0

Grand Total (All stations and months combined) = 28,851

Table 14. Numerical catch of Penaeus setiferus collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Month	Total Catch by Month	Monthly Contribution to Year's Catch (%)	Monthly Contribution to Total Catch (%)
1973			
February	38	0.1	0.1
March	764	1.8	1.1
April	466	1.1	0.7
May	367	0.9	0.5
June	158	0.4	0.2
July	170	0.4	0.3
August	8,398	20.1	12.6
September	9,752	23.3	14.6
October	5,591	13.4	8.4
November	3,905	9.3	5.8
December	10,734	25.6	16.1
1974			
January	1,522	3.6	2.3
	41,865	100.0	
First Year's Total Catch = 41,865			
1974			
February	1,920	7.7	2.9
March	910	3.6	1.4
April	527	2.1	0.8
May	632	2.5	0.9
June	173	0.7	0.3
July	901	3.6	1.3
August	2,182	8.7	3.3
September	6,061	24.3	9.1
October	6,667	26.7	10.0
November	2,497	10.0	3.7
December	2,226	8.9	3.3
1975			
January	258	1.0	0.4
	24,954	100.0	100.0*
Second Year's Total Catch = 24,954			
Grand Total (All stations and months combined) = 66,819			

*Two Year Total (%)

Table 15. Numerical catch of Penaeus aztecus collected monthly by bottom trawl at four stations in the Cooper River-Charleston Harbor estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward→)					
	Big Island (C002)	North Charleston (C003)	Mouth of Cooper (C004)	Cummings Point (J003)	Total Catch by Month	Monthly Contribution to Total Catch (%)
Distance Inland (km)	33	23	16	0		
1973						
February					0	0.0
March					0	0.0
April					0	0.0
May					0	0.0
June		1	6		7	5.3
July			6	102	108	81.2
August			1	15	16	12.0
September					0	0.0
October					0	0.0
November				1	1	0.8
December					0	0.0
1974						
January			1		1	0.8
Year's Catch by Station	0	1	14	118	133	
Station Contribution to First Year's Catch (%)	0.0	0.8	10.5	88.7		100.0
1974						
February			1		1	0.1
March					0	0.0
April					0	0.0
May			4		4	0.2
June		67	500	159	726	39.4
July		152	170	786	1,108	60.2
August				2	2	0.1
September				1	1	0.1
October					0	0.0
November					0	0.0
December					0	0.0
1975						
January					0	0.0
Year's Catch by Station	0	219	675	948	1,842	
Station Contribution to Second Year's Catch (%)	0.0	11.9	36.6	51.5		100.0
Total Catch by Station	0	220	689	1,066		
Station Contribution to Total Catch (%)	0.0	11.1	34.9	54.0		100.0

Grand Total (All stations and months combined) = 1,975

Table 16. Numerical catch of Penaeus aztecus collected monthly by bottom trawl at four stations in the South Edisto estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward→)					
	Snuggedy Swamp (D001)	Sampson Island (D002)	Fenwick Island (D003)	Bay Point (D004)	Total Catch by Month	Monthly Contribution to Total Catch (%)
Distance Inland (km)	35	24	14	2		
1973						
February					0	0.0
March				4	4	23.5
April				2	2	11.8
May			1		1	5.9
June				7	7	41.2
July			1		1	5.9
August					0	0.0
September				1	1	5.9
October					0	0.0
November				1	1	5.9
December					0	0.0
1974						
January					0	0.0
Year's Catch by Station	0	0	2	15	17	
Station Contribution to First Year's Catch (%)	0.0	0.0	11.8	88.2		100.0
1974						
February					0	0.0
March					0	0.0
April					0	0.0
May					0	0.0
June		54	39	17	110	28.1
July		15	223	1	239	61.0
August			2	29	31	7.9
September				12	12	3.1
October					0	0.0
November					0	0.0
December					0	0.0
1975						
January					0	0.0
Year's Catch by Station	0	69	264	59	392	
Station Contribution to Second Year's Catch (%)	0.0	17.6	67.3	15.1		100.0
Total Catch by Station	0	69	266	74		
Station Contribution to Total Catch (%)	0.0	16.9	65.0	18.1		100.0

Grand Total (All stations and months combined) = 409

Table 17. Numerical catch of Penaeus aztecus collected monthly by bottom trawl at eight stations in the North Edisto estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward ⟶)									
Distance Inland (km)	Yonges Island (E001) 21	Toogoodoo Creek (E002) 22	Bears Bluff (E003) 15	Dawho River (E004) 16	Steamboat Creek (E005) 14	Wadmalaw Island (E006) 10	Point of Pines (E007) 6	Deveaux Bank (E008) 0	Total Catch by Month	Monthly Contribution to Total Catch (%)
1973										
February			1						1	0.3
March							1	1	2	0.5
April	7							1	8	2.0
May	1		2		1	3	1		8	2.0
June	77	27	16	3	19			1	143	36.3
July	52	40	20	16	51	13	32		224	56.9
August							4		4	1.0
September		2							2	0.5
October									0	0.0
November									0	0.0
December									0	0.0
1974										
January					2				2	0.5
Year's Catch by Station	137	69	39	19	73	16	38	3	394	
Station Contribution to First Year's Catch (%)	34.8	17.5	9.9	4.8	18.5	4.1	9.6	0.8		100.0
1974										
February									0	0.0
March									0	0.0
April							1		1	0.1
May					7				7	0.5
June	104		112	48	62	16	1	4	347	24.6
July	140		16	223	128	71	135	150	863	61.1
August	100	20	26	2	26	1	16		191	13.5
September				2				2	4	0.3
October									0	0.0
November									0	0.0
December									0	0.0
1975										
January									0	0.0
Year's Catch by Station	344	20	154	275	223	88	153	156	1,413	
Station Contribution to Second Year's Catch (%)	24.3	1.4	10.9	19.5	15.8	6.2	10.8	11.0		100.0
Total Catch by Station	481	89	193	294	296	104	191	159		
Station Contribution to Total Catch (%)	26.6	4.9	10.7	16.3	16.4	5.8	10.6	8.8		100.0

Grand Total (All stations and months combined) = 1,807

Table 18. Numerical catch of Penaeus aztecus collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Month	Total Catch by Month	Monthly Contribution to Year's Catch (%)	Monthly Contribution to Total Catch (%)
1973			
February	1	0.2	< 0.1
March	6	1.1	0.1
April	10	1.8	0.2
May	9	1.7	0.2
June	157	28.9	3.7
July	333	61.2	7.9
August	20	3.7	0.5
September	3	0.6	0.1
October	0	0.0	0.0
November	2	0.4	< 0.1
December	0	0.0	0.0
1974			
January	3	0.6	0.1
	544	100.0	
First Year's Total Catch = 544			
1974			
February	1	< 0.1	< 0.1
March	0	0.0	0.0
April	1	< 0.1	< 0.1
May	11	0.3	0.3
June	1,183	32.4	28.2
July	2,210	60.6	52.7
August	224	6.1	5.3
September	17	0.5	0.4
October	0	0.0	0.0
November	0	0.0	0.0
December	0	0.0	0.0
1975			
January	0	0.0	0.0
	3,647	100.0	100.0*
Second Year's Total Catch = 3,647			
Grand Total (All stations and months combined) = 4,191			

*Two Year Total (%)

Table 19. Numerical catch of Penaeus duorarum collected monthly by bottom trawl at eight stations in the North Edisto estuary, South Carolina, from February 1973 through January 1975.

	Stations (Progressing Seaward →)									
Distance Inland (km)	Yonges Island (E001) 21	Toogoodoo Creek (E002) 22	Bears Bluff (E003) 15	Dawho River (E004) 16	Steamboat Creek (E005) 14	Wadmalaw Island (E006) 10	Point of Pines (E007) 6	Deveaux Bank (E008) 0	Total Catch by Month	Monthly Contribution To Total Catch (%)
1973										
February									0	0.0
March									0	0.0
April	2								2	15.4
May				1					1	7.7
June									0	0.0
July									0	0.0
August					1				1	7.7
September		1						1	2	15.4
October		2						3	5	38.5
November					2				2	15.4
December									0	0.0
1974										
January									0	0.0
Year's Catch by Station	2	3	0	1	3	0	0	4	13	
Station Contribution to First Year's Catch (%)	15.4	23.1	0.0	7.7	23.1	0.0	0.0	30.8		100.0
1974										
February									0	0.0
March		8							8	33.3
April	3			1	1				5	20.8
May	1	1							2	8.3
June									0	0.0
July					1				1	4.2
August			1						1	4.2
September									0	0.0
October	1	3			1			1	6	25.0
November									0	0.0
December			1						1	4.2
1975										
January									0	0.0
Year's Catch by Station	5	12	2	1	3	0	0	1	24	
Station Contribution to Second Year's Catch (%)	20.8	50.0	8.3	4.2	12.5	0.0	0.0	4.2		100.0
Total Catch by Station	7	15	2	2	6	0	0	5	37	
Total Contribution to Catch (%)	18.9	40.5	5.4	5.4	16.2	0.0	0.0	13.5		100.0

Grand Total (All stations and months combined) = 37

Table 20. Numerical catch of Penaeus duorarum collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Month	Total Catch by Month	Monthly Contribution to Year's Catch (%)	Monthly Contribution to Total Catch (%)
1973			
February	0	0.0	0.0
March	0	0.0	0.0
April	2	11.1	4.7
May	1	5.6	2.3
June	0	0.0	0.0
July	0	0.0	0.0
August	3	16.7	7.0
September	2	11.1	4.7
October	8	44.4	18.6
November	2	11.1	4.6
December	0	0.0	0.0
1974			
January	0	0.0	0.0
	18	100.0	
First Year's Total Catch = 18			
1974			
February	0	0.0	0.0
March	8	32.0	18.6
April	6	24.0	14.0
May	2	8.0	4.6
June	0	0.0	0.0
July	1	4.0	2.3
August	1	4.0	2.3
September	0	0.0	0.0
October	6	24.0	14.0
November	0	0.0	0.0
December	1	4.0	2.3
1975			
January	0	0.0	0.0
	25	100.0	100.0*
Second Year's Total Catch = 25			
Grand Total (All stations and months combined) = 43			

*Two Year Total (%)

Table 21. Total numbers and percentages of penaeid shrimps caught by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries during the two-year period from February 1973 through January 1975.

	February 1973-January 1974			February 1974-January 1975			Species Total	
	Number	Percent of Year's Catch	Percent of Total Catch	Number	Percent of Year's Catch	Percent of Total Catch	Number	Percent
Penaeus setiferus	41,865	98.7	58.9	24,954	87.2	35.1	66,819	94.0
Penaeus aztecus	544	1.3	0.8	3,647	12.7	5.1	4,191	5.9
Penaeus duorarum	18	<0.1	<0.1	25	<0.1	<0.1	43	0.1
Year's Catch	42,427	100.0		28,626	100.0		71,053	
Year's Contribution to Total Catch (%)			59.7			40.3		100.0

Table 22. Combined monthly catches and percentages of penaeid shrimps caught by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Species	February	March	April	May	June	July	August	September	October	November	December	January	Total
Penaèus setiferus													
Number caught	1,958	1,674	993	999	331	1,071	10,580	15,813	12,258	6,402	12,960	1,780	66,819
Percent	2.9	2.5	1.5	1.5	0.5	1.6	15.8	23.7	18.3	9.6	19.4	2.7	100.0
Penaeus aztecus													
Number caught	2	6	11	20	1,340	2,543	244	20	0	2	0	3	4,191
Percent	< 0.1	0.1	0.3	0.5	32.0	60.7	5.8	0.5	0.0	< 0.1	0.0	0.1	100.0
Penaeus duorarum													
Number caught	0	8	8	3	0	1	4	2	14	2	1	0	43
Percent	0.0	18.6	18.6	7.0	0.0	2.3	9.3	4.6	32.6	4.7	2.3	0.0	100.0

Table 23. Mean catch per tow of each species of penaeid shrimp caught by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Species	February 1973-January 1974		February 1974-January 1975		Mean catch per tow	
	Number	Percent	Number	Percent	Number	Percent
Penaeus setiferus	221.5	98.7	130.0	87.2	175.4	94.0
Penaeus aztecus	2.9	1.3	19.0	12.7	11.0	5.9
Penaeus duorarum	0.1	< 0.1	0.1	0.1	0.1	0.1
Total	224.5	100.0	149.1	100.0	186.5	100.0

Table 24. Mean numbers of penaeid shrimp caught per 20-minute bottom trawl tow in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Estuary	February 1973-January 1974		February 1974-January 1975		Years Combined Mean Catch per Tow	
	Number	Percent	Number	Percent	Number	Percent
Cooper River-Charleston Harbor	452.6	61.6	235.7	52.0	340.6	57.6 (54.9)
North Edisto	177.0	24.1	142.7	31.4	159.9	27.1 (25.7)
South Edisto	105.6	14.3	75.2	16.6	90.4 (120.5)*	15.3 (19.4)
Year's Catch	735.2	100.0	453.6	100.0	590.9 (621.0)	100.0

*Values in parenthesis exclude catches and tows at Station D001.

Table 25. Mean biomass of shrimp caught per 20-minute bottom trawl tow in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Estuary	February 1973-January 1974		February 1974-January 1975		Years Combined Mean Catch per Trawl	
	Grams	Percent	Grams	Percent	Grams	Percent
Cooper River-Charleston Harbor	2,063.8	46.4	1,424.7	41.7	1,733.9	44.2 (42.2)
North Edisto	1,660.1	37.3	1,594.5	46.7	1,627.3	41.5 (39.6)
South Edisto	722.3	16.3	397.5	11.6	559.9 (746.2)*	14.3 (18.2)
Year's Catch	4,446.2	100.0	3,416.7	100.0	3,921.1 (4,107.4)	100.0

*Values in parenthesis exclude catches and tows at Station D001.

tow from August through December 1973 than in the remaining months, and during this time, they were caught in greatest numbers per tow in the Cooper River-Charleston Harbor estuary. From April 1974 through January 1975, numbers of white shrimp caught per tow in the Cooper River-Charleston Harbor and the North Edisto were about equal (Fig. 12). Numbers of brown shrimp caught per tow were far greater during the second year, and the number caught per tow was greatest in the Cooper River-Charleston Harbor (Fig. 12). Numbers of pink shrimp caught per tow were low in both years, but more were caught in the North Edisto than in either the Cooper River-Charleston Harbor or the South Edisto estuaries.

The most noticeable change in numbers of shrimp caught per tow between the two years was observed in the Cooper River-Charleston Harbor estuary. During the first year, a mean of 453 shrimp were caught per trawl tow and 99% of these were white shrimp. During the second year, however, a mean of 236 shrimp were caught per tow, but only 84% were white shrimp. Over 16% of the catch per tow during the second year was brown shrimp (Table 26). The year-to-year change was not as obvious in the North and South Edisto estuaries (Table 26).

The mean shrimp catch per 20-min trawl tow differed among estuaries (Table 27). On the average, the number of white shrimp caught per tow in the Cooper River-Charleston Harbor estuary was about twice as great as that captured in the North Edisto estuary and nearly four times as great as that observed in the South Edisto. In contrast, biomass of white shrimp captured per tow was about the same in the Cooper River-Charleston Harbor and North Edisto estuaries, and both were about three times as great as that observed in the South Edisto. Thus, it appears that, overall, white shrimp were only about half as numerous although twice as large in the North Edisto as in the Cooper River-Charleston Harbor estuary. P. setiferus were much less numerous in the South Edisto than in the other two estuaries and were similar in mean size to those taken along the Cooper River-Charleston Harbor transect. Similar trends were observed among brown shrimp; most pink shrimp were collected in the North Edisto estuary (Table 27).

Sex Ratios

During the first two years of the study, most subsamples for sex ratios were biased when large numbers of shrimp were caught. Therefore, sex data from all intensive and extensive stations in which the entire catch was analyzed or when subsampling was unbiased were combined to obtain sex ratios.

More females than males were caught for each species. Females outnumbered males 1.0 to 0.8 for P. setiferus, 1.0 to 0.7 for P. aztecus, and 1.0 to 0.8 for P. duorarum. No consistent trends were noted among the ratios for each species on a monthly basis (Table 28).

Length-frequency Relationships

Extensive sampling. P. setiferus, P. aztecus, and P. duorarum were caught throughout the state regions in the extensive sampling, and obvious length-frequency differences between the sexes were not observed (Tables 29-34). Largest white shrimp were taken in spring and fall, while largest brown and pink shrimp were observed in spring and summer. Mean total lengths of P. setiferus ranged from 70-119 mm (Tables 29, 30); those for P. aztecus, from 65-129 mm (Tables 31, 32); and those for P. duorarum, from 55-130 mm (Tables 33, 34).

Mean total lengths for white and brown shrimp were greatest in the southern region of the South Carolina coast and smallest in the northern region, and in each region, mean lengths for brown shrimp were larger than those for white shrimp (Table 35).

Intensive sampling. Only one "complete" annual cycle for P. setiferus was obtained during the study, i.e., from July 1973 through June 1974 (Tables 36, 37; Fig. 13). Young-of-the-year white shrimp were first detected by bottom trawl in the estuaries in early July of both years. No obvious differences between sizes of males and females were observed for P. setiferus (Tables 36, 37). White shrimp increased in length very rapidly during July-September in the intensively-sampled estuaries in 1973, but only in the North Edisto was their size observed to increase as rapidly in 1974 (Fig. 13). Minimum lengths were recorded in July, while maximum lengths were observed in June and November 1973, and again in May-June and October-November 1974. Maximum mean total lengths of P. setiferus in fall 1973 were greatest in the North Edisto (118 mm) and smallest in the Cooper River-Charleston Harbor (80 mm); similar mean lengths in the South Edisto were intermediate at 102 mm. In the fall of 1974, maximum mean lengths in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries were 94, 122, and 100 mm, respectively. In late spring, maximum mean lengths were approximately the same in all estuaries and approached or exceeded 130 mm. Total lengths of white shrimp averaged about 59 mm in all three estuaries in July 1973, but considerable size differences were noted among these estuaries in July 1974. Mean total lengths in July 1974 for whites in the Cooper River-Charleston Harbor, North Edisto, and South Edisto were 59, 86, and 75 mm, respectively (Fig. 13). These differences among sizes of P. setiferus in the three estuaries persisted to some extent through November 1974. Similar mean length differences were also observed from September through December 1973 (Fig. 13).

Two "complete" annual cycles for P. aztecus were obtained during the study (Tables 38, 39; Fig. 13). Brown shrimp were first detected by trawl in substantial numbers in June. The mean total length of P. aztecus (sexes combined) increased from 96 mm in June to 103 mm in July 1973, and from 83 mm in June to 114 mm in August 1974. In August of both years, just before P. aztecus essentially disappeared from the trawl catches, mean sizes of female P. aztecus were found to be larger than those of males (Tables 38, 39). Differences in mean length of brown shrimp are difficult to assess because of the limited number caught and because they were abundant only in June and July. Where data are available, however, brown shrimp appeared to increase in size at similar rates in all three intensively-sampled estuaries

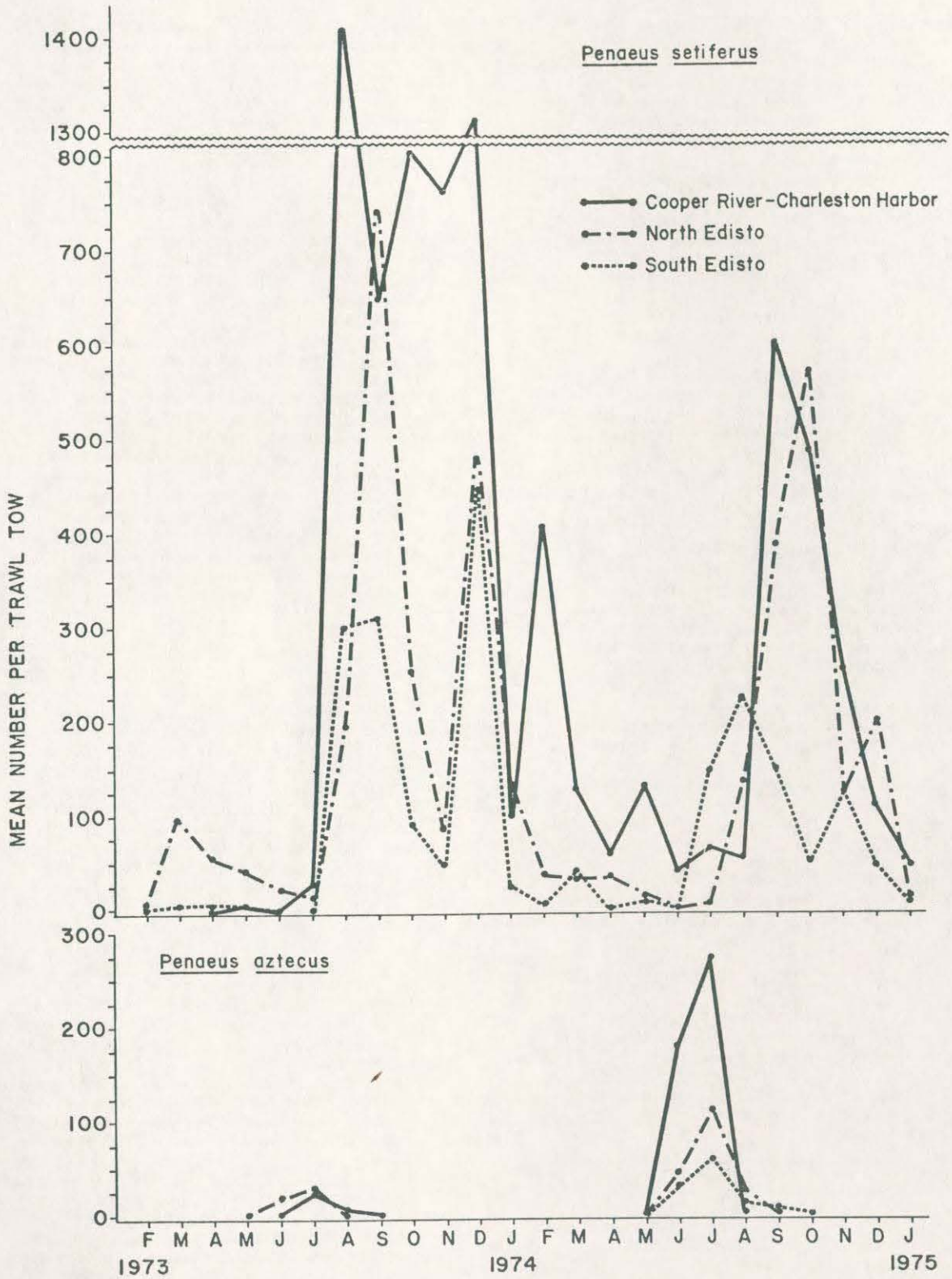


Fig. 12. Numerical catches of Penaeus setiferus and Penaeus aztecus per 20-minute trawl tow in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975. The catch per unit effort for Penaeus duorarum is less than 2 for any given month.

Table 26. Mean catch per tow within the Cooper River - Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, during the two-year period from February 1973 through January 1975.

Estuary and Species	February 1973-January 1974		February 1974-January 1975		Mean Catch per Tow	
	Number	Percent	Number	Percent	Number	Percent
Cooper River-Charleston Harbor						
Penaeus setiferus	449.6	99.3	197.3	83.7	319.4	93.8
Penaeus aztecus	3.0	0.7	38.4	16.3	21.2	6.2
Penaeus duorarum	0.0	0.0	0.0	0.0	0.0	0.0
Year's Catch for Cooper River-Charleston Harbor	452.6	100.0	235.7	100.0	340.6	100.0
North Edisto						
Penaeus setiferus	172.8	97.6	127.8	89.5	150.3	94.0
Penaeus aztecus	4.1	2.3	14.7	10.3	9.4	5.9
Penaeus duorarum	0.1	0.1	0.2	0.2	0.2	0.1
Year's Catch for North Edisto	177.0	100.0	142.7	100.0	159.9	100.0
South Edisto						
Penaeus setiferus	105.2	99.6	67.0	89.1	86.1	95.3
Penaeus aztecus	0.3	0.3	8.2	10.9	4.3	4.7
Penaeus duorarum	0.1	0.1	0.0	0.0	0.0	0.0
Year's Catch for South Edisto	105.6	100.0	75.2	100.0	90.4	100.0

Table 27. Total numbers, biomass (g), and cpue (mean catch per 20-min trawl tow) for penaeid shrimps caught by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries from February 1973 through January 1975.

Species Estuary	Number Caught	Percent of Total	Biomass Caught	Percent of Total	Trawl Tows	Percent of Total	cpue by Numbers	cpue by Biomass	Mean biomass per shrimp
Penaeus setiferus									
Cooper River-Charleston Harbor	29,703	44.4	151,351	30.3	93	24.4	319.4	1,627	5.1
North Edisto	28,851	43.2	296,436	59.4	192	50.4	150.3	1,544	10.3
South Edisto	8,265	12.4	51,158	10.3	96	25.2	86.1	533	6.2
Total	66,819	100.0	498,945	100.0	381	100.0			
Penaeus aztecus									
Cooper River-Charleston Harbor	1,975	47.1	9,889	34.9	93	24.4	21.2	106	5.0
North Edisto	1,807	43.1	15,851	56.0	192	50.4	9.4	83	8.8
South Edisto	409	9.8	2,568	9.1	96	25.2	4.3	27	6.3
Total	4,191	100.0	28,308	100.0	381	100.0			
Penaeus duorarum									
Cooper River-Charleston Harbor	2	4.7	16	7.9	93	24.4	<0.1	<1	8.0
North Edisto	37	86.0	159	78.7	192	50.4	0.2	1	4.3
South Edisto	4	9.3	27	13.4	96	25.2	<0.1	<1	6.8
Total	43	100.0	202	100.0	381	100.0			

Table 28. Sex ratios for penaeid shrimps by species across the South Carolina coastal zone (all 33 stations combined) at monthly intervals during the two-year period from February 1973 through January 1975.

Species		1973 Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1974 Jan.
Penaeus setiferus	M/F	7/2	33/16	18/26	30/22	79/26	313/514	17/18	173/192	331/373	269/266	14/25	213/279
Ratio		3.5	2.1	0.7	1.4	3.0	0.6	0.9	0.9	0.9	1.0	0.6	0.8
Penaeus aztecus	M/F	0	0	16/15	3/1	57/71	117/176	10/9	2/1	6/7	2/0	0	8/0
Ratio		0.0	0.0	1.1	3.0	0.8	0.7	1.1	2.0	0.9	-	0.0	-
Penaeus duorarum	M/F	0	0	10/5	0	0	2/3	0	0/5	2/6	0/2	0	0
Ratio		0.0	0.0	2.0	0.0	0.0	0.7	0.0	-	0.3	-	0.0	0.0

(Table 28 continued next page ...)

Table 28. (Continued.)

Species		1974 Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1975 Jan.
Penaeus setiferus	M/F	125/176	239/264	493/496	153/135	80/86	227/199	1488/2089	1039/1418	1809/2389	989/1508	645/901	186/260
Ratio		0.7	0.9	1.0	1.1	0.9	1.1	0.7	0.7	0.8	0.7	0.7	0.7
Penaeus aztecus	M/F	1/0	0	2/4	6/5	185/302	673/931	190/367	13/4	0	0	0	0
Ratio		-	0.0	0.5	1.2	0.6	0.7	0.5	3.2	0.0	0.0	0.0	0.0
Penaeus duorarum	M/F	0	4/4	6/9	2/2	0	0	4/5	0	4/0	0	1/0	0
Ratio		0.0	1.0	0.7	1.0	0.0	0.0	0.8	0.0	-	0.0	-	0.0

Totals per Species per Two-year Period from February 1973-January 1975.

Penaeus setiferus	M/F	8,970/11,680
Ratio		0.77
Penaeus aztecus	M/F	1,291/1,893
Ratio		0.68
Penaeus duorarum	M/F	35/41
Ratio		0.85

Table 29. Length-frequency distribution for male Penaeus setiferus collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Total Length Interval (mm)	South								Central								North							
	1973			1974				1975	1973			1974				1975	1973			1974				1975
	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.
23 - 27																								
28 - 32																								
33 - 37																								
38 - 42																								
43 - 47						2								1								3		
48 - 52		3				4				9				2				1				4	1	
53 - 57		4	1		1	9				22				9				1				6	1	
58 - 62		8				9				28		3		15		1		9				23		
63 - 67		19	2	1		5				36	4	8		15				4		1		18		
68 - 72	1	22	3	3		13	3	1	1	50	3	12	2	38		1		31				20	3	
73 - 77		12	5	6		16	1	1	1	46	4	17		26	5	5		20		1	1	16	5	3
78 - 82		12	6	21		16	1	1	4	29	10	7	8	28	7	11	2	14		6	3	21	25	1
83 - 87		12	6	15	2	17	3	1	8	28	17	9	3	36	8	13	3	19	1	21	1	12	25	2
88 - 92		2	12	12	1	20	16		19	18	14	12	18	46	18	10	4	13	2	11	14	12	32	3
93 - 97		3	26	24	2	24	15	1	13	14	30	9	27	28	21	6	10	7	8	4	14	9	24	
98 - 102		2	22	15	8	22	29		7	16	24	6	38	45	35	3	11	5	13	2	19	2	32	2
103 - 107		2	29	20	18	19	28		7	17	31	5	30	42	36		4	4	15	2	10	3	18	
108 - 112		1	24	16	28	22	20	2	1	8	26	9	31	49	62	1	2	2	20		11		19	
113 - 117	1		20	6	35	13	22			5	20	5	12	19	37		1		18	1	1	1	6	
118 - 122		1	17	5	34	9	34		1		10	1	13	11	16				12		1		6	
123 - 127	1		9	1	23	4	21		3		5	2	11	2	6			1	7		1		4	
128 - 132			6	1	19	3	19		1		3		4		1				7		1		4	
133 - 137			9		7	2	9		1		3		1		1			1	1				1	
138 - 142			8	1	2		9		1		1								1		1			
143 - 147			6		1		4								1				1					
148 - 152			5				2																	
153 - 157			3																					
158 - 162							1																	
Total Measured by Month	3	103	219	147	181	229	237	7	68	326	205	105	198	412	254	51	37	132	106	49	78	150	206	11
Mean Total Length (mm)	103	74	109	96	117	91	113	89	96	77	101	87	104	90	105	86	97	80	111	88	100	74	96	86

Table 30. Length-frequency distribution for female Penaeus setiferus collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Total Length Interval (mm)	South								Central								North							
	1973			1974				1975	1973			1974				1975	1973			1974				1975
	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.
18 - 22																						1		
23 - 27																								
28 - 32																								
33 - 37						1				2														
38 - 42										7												3		
43 - 47						5				12				4				2				5		
48 - 52			1			6		1		44				6				3				10		
53 - 57		2				17				36				14				8				11		
58 - 62		9	2	1		19	2			48	1	1		22	5	1		12				16		
63 - 67		7	7	1		17	1	2	1	52	6	7		19	1	1		33		1	2	29	1	3
68 - 72		14	4	8		14	2		1	51	8	13		44	9	5		26	1	3		25	5	3
73 - 77		12	9	15	1	25	5	2	3	44	10	25	2	29	13	10	1	27	1	3	1	12	10	2
78 - 82		2	3	22	1	19	7	2	6	32	7	19	3	35	20	7	3	18	1	10	2	8	20	3
83 - 87		2	10	18	2	21	10		10	23	5	21	12	39	19	9	3	12	3	11	9	10	23	6
88 - 92	2		6	26	1	7	13		15	14	13	33	20	48	30	7	3	11	3	14	17	9	35	10
93 - 97			25	21	3	14	13		20	10	18	16	28	32	29	6	7	12	8	14	9	6	24	4
98 - 102			25	29	4	16	23		6	6	16	23	22	38	73	3	6	6	6	2	17	6	33	2
103 - 107	2		36	17	12	15	33		9	7	30	16	21	36	40	1	10	5	21	1	7	5	16	1
108 - 112		2	21	16	23	11	20		3	11	13	11	29	32	38		11	2	19	2	8		18	1
113 - 117		2	29	11	21	13	30				18	7	19	14	23		2		15		2	2	13	1
118 - 122	1		20	7	38	10	26		2	2	17	3	25	10	19		1		11		1	1	6	1
123 - 127	2	1	21	3	15	7	21		5		8	2	18	2	9			2	12				1	
128 - 132			14		18	5	27		5		8		6	2	8				6		1			
133 - 137		1	15	1	13	1	17				9		2	1	1									
138 - 142		2	11	1	7		5				1		1		1				4					
143 - 147		1	5		2		2											1						
148 - 152			1		1		3			1	1				1									
153 - 157			4		1		1								1									
158 - 162			1				1								1									
163 - 167			1																					
168 - 172															1									
173 - 177																								
178 - 182		1																						
Total Measured by Month	7	58	271	197	163	243	262	7	86	402	189	197	208	427	342	50	47	180	111	61	76	159	205	37
Mean Total Length (mm)	109	80	110	95	119	85	112	70	97	69	103	90	106	87	100	83	100	76	111	88	96	71	95	87

Table 31. Length-frequency distribution for male Penaeus aztecus collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Total Length Interval (mm)	South								Central								North							
	1973			1974				1975	1973			1974				1975	1973			1974				1975
	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.
48 - 52						1																		
53 - 57						1																		
58 - 62																						2		
63 - 67			1																1			3		
68 - 72				2		1												1	1			4		
73 - 77						4				2								1				7		
78 - 82									1	3		1						1	1			21		
83 - 87										3												15		
88 - 92						2			1	5		1		1				2			1	16		
93 - 97		1				2				10				2				1			1	5		
98 - 102									3	23												5		
103 - 107		2							2	37												1		
108 - 112		15							2	34				1								7		
113 - 117		20							1	34								3				4		
118 - 122		37				4			2	13								2				4		
123 - 127		20				2				3								1						
128 - 132		6				1			2	3												2		
133 - 137																								
138 - 142																								
143 - 147									1															
Total Measured by Month	0	101	1	2	0	18	0	0	15	170	0	2	0	4	0	0	0	12	3	0	2	96	0	0
Mean Total Length (mm)	-	119	65	70	-	95	-	-	111	107	-	85	-	97	-	-	-	101	72	-	92	89	-	-

Table 32. Length-frequency distribution for female Penaeus aztecus collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Total Length Interval (mm)	South								Central								North							
	1973			1974				1975	1973			1974				1975	1973			1974				1975
	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.
33 - 37										1														
38 - 42										1														
43 - 47																								
48 - 52																						1		
53 - 57										1														
58 - 62										1												2		
63 - 67			1			1				1									1			7		1
68 - 72			1			2												2				6		
73 - 77						3													1			5		
78 - 82						2												2				19		
83 - 87						3				3			1					1	1			16		
88 - 92					1					2				1				1				12		
93 - 97						1			1	2				1				4				11		
98 - 102						1			1	6				1								11		
103 - 107		1				1			1	17				1				4				2		
108 - 112		1								23											1	8		
113 - 117		8			1	2			3	27				2				1				3		
118 - 122		15				3			2	23								2				5		
123 - 127		21				1			1	31								1				5		
128 - 132		25				3			2	20								1				4		
133 - 137		19				2			1	15								2				11		
138 - 142		10				3				9								1				6		
143 - 147		4				1				9								1				4		
148 - 152		1				4												1						
153 - 157																		1				1		
158 - 162										1								1						
Total Measured by Month	0	105	2	0	2	33	0	0	12	193	0	0	1	6	0	0	0	26	3	0	1	139	0	1
Mean Total Length (mm)	-	129	67	-	102	112	-	-	117	119	-	-	85	103	-	-	-	112	75	-	110	99	-	65

Table 33. Length-frequency distribution of male Penaeus duorarum collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Total Length Interval (mm)	South								Central								North							
	1973			1974				1975	1973			1974				1975	1973			1974				1975
	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.
43 - 47														1										
48 - 52																								
53 - 57																							1	
58 - 62														1										
63 - 67										3									1					
68 - 72																								
73 - 77										1														
78 - 82										1				1			1							
83 - 87										1														
88 - 92													1	1										
93 - 97							1						1											
98 - 102																								
103 - 107																								
108 - 112																								
113 - 117																	1							
118 - 122																								
123 - 127																								
128 - 132																					1			
Total Measured by Month	0	0	0	0	0	0	1	0	0	6	0	0	2	4	0	0	2	0	1	0	1	0	1	0
Mean Total Length (mm)	-	-	-	-	-	-	95	-	-	72	-	-	92	69	-	-	97	-	65	-	130	-	55	-

Table 34. Length-frequency distribution for female Penaeus duorarum collected quarterly by bottom trawl at 16 stations across the South Carolina coastal zone from February 1973 through January 1975.

Total Length Interval (mm)	South								Central								North							
	1973			1974				1975	1973			1974				1975	1973			1974				1975
	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Aug.	Oct.	Jan.
63 - 67						1								1								1		
68 - 72										1												1		
73 - 77										1														
78 - 82					1					1						1								
83 - 87													1											
88 - 92																								
93 - 97						1							2			1								
98 - 102																								
103 - 107																1								
108 - 112													1			1	1							
113 - 117													1											
118 - 122																								
123 - 127																								
128 - 132																								
133 - 137																	1							
Total Measured by Month	0	0	0	0	1	2	0	0	0	3	0	0	5	1	0	4	2	0	0	0	0	2	0	0
Mean Total Length (mm)	-	-	-	-	80	80	-	-	-	75	-	-	100	65	-	97	122	-	-	-	-	67	-	-

Table 35. Mean total lengths (mm) for each species of Penaeus in the Northern, Central, and Southern regions of the South Carolina coastal zone (all seasons and stations combined) from February 1973 through January 1975.

Area	Penaeus setiferus	Penaeus aztecus	Penaeus duorarum	Mean Length by Region
Northern	89	96	91	90
Central	91	113	83	93
Southern	102	119	84	104
Mean Length of Each Species	94	110	85	

Table 36. Length-frequency distribution for male Penaeus setiferus collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Total Length Interval (mm)	Month																							
	1973											1974												1975
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
38 - 42						2												2						
43 - 47						5	2											5	9			1		
48 - 52						6	3		1									17	18	1				
53 - 57						9	3	4		1								28	10	5				1
58 - 62						11	18	10	4	4								20	24	6		1		
63 - 67		1				7	39	7	11	9		3						26	31	21	3		5	
68 - 72	1	4				1	63	16	20	15	7	9	3	1				25	20	48	18	7	5	5
73 - 77	2	10	3	1			65	21	18	22	23	7	3	5				38	29	57	48	7	5	6
78 - 82	4	16	2				71	40	30	25	36	33	6	6	1			22	31	51	47	18	27	10
83 - 87	2	20	24			2	72	57	45	30	56	28	4	8	2		1	25	34	49	31	35	46	8
88 - 92		21	41				84	60	52	38	68	58	20	13	4			23	51	68	25	50	39	15
93 - 97		14	30	3			80	83	74	65	110	77	49	27	10	2		7	55	67	32	55	69	11
98 - 102	1	9	24	9			70	87	77	57	112	132	49	43	20	4		6	57	63	45	62	96	10
103 - 107	3	12	14	7			56	85	66	67	94	72	37	41	33	20			47	68	68	48	94	13
108 - 112	2	3	6	20			49	97	51	79	114	47	20	46	45	38	4		26	67	61	86	62	7
113 - 117	1	2	4	10			21	89	42	44	51	28	6	47	39	24	9		18	50	64	53	50	2
118 - 122	1	2		11	6		8	62	25	44	34	15	3	33	31	44	17	1	14	65	78	87	34	1
123 - 127				17	8		6	48	39	19	24	2	1	16	29	30	19	1	5	53	69	50	8	2
128 - 132		1		9	20		2	26	11	33	21	2		4	7	24	14	5		47	62	54	5	
133 - 137	1	1		12	15			20	20	18	7			2	1	17	12			28	40	24	2	
138 - 142				7	10				9	21	5			2		10	2			7	22	21	1	
143 - 147				3	6				13	8	3					2				1	3	8		
148 - 152					1				2	1		1				2				1	1	8		
153 - 157	1							1						1		3					1			
158 - 162				1					1												1			
Total Measured by Month	19	116	148	110	66	43	712	813	611	600	765	514	201	295	222	220	78	251	479	823	719	675	548	91
Mean Total Length (mm)	98	91	94	120	133	57	88	103	102	105	102	98	99	107	112	121	124	73	88	100	108	110	101	93

Table 37. Length-frequency distribution for female Penaeus setiferus collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Total Length Interval (mm)	Month																							
	1973											1974												1975
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
28 - 32						5												3						
33 - 37				1														1						
38 - 42						12												3	2					
43 - 47						22		3	1									10	10					
48 - 52						22	7	6	1	1								18	18	2			1	1
53 - 57						13	23	11	4	5	3		1					21	15	12	1			
58 - 62						14	44	14	9	2	3	1						18	28	16	2	4	6	
63 - 67		1				4	66	19	20	11	5	3		2				19	22	35	7	3	8	8
68 - 72	1	1	7				71	18	15	25	24	7		10				31	27	42	20	11	14	6
73 - 77	2	8	16			1	76	21	25	20	26	12	3	19	1			27	20	49	43	22	26	6
78 - 82	3	13	25			1	87	39	29	29	52	31	10	28	4			16	29	74	37	30	26	9
83 - 87	2	20	35				82	50	41	53	66	43	18	10	8			22	58	58	38	43	44	11
88 - 92	4	17	27	2		2	63	65	43	32	61	58	46	15	10			8	48	72	35	53	53	12
93 - 97	2	9	24	3	2	1	59	60	48	42	68	71	37	23	8			4	51	65	30	48	67	11
98 - 102	1	12	16	4	1	1	55	59	44	48	92	107	58	48	10	4	2	3	50	60	31	67	88	10
103 - 107		2	3	10	4		32	65	40	73	93	74	39	49	13	9			45	58	45	37	81	10
108 - 112		4	3	15	1		24	71	45	63	79	88	22	40	55	23	3		32	65	62	69	67	7
113 - 117		2	1	7			25	66	38	41	56	29	8	42	38	20	4		24	51	59	46	59	1
118 - 122		2		11			7	62	30	36	38	17	2	32	44	30	14		9	65	70	69	33	4
123 - 127		2		8	2		3	38	35	34	37	4	3	21	30	36	19		3	64	50	46	22	
128 - 132				16	4		4	47	22	33	23	2	2	12	11	39	9	2	2	61	65	66	8	
133 - 137				11	9		1	21	29	24	14	1		4	1	17	12	2		21	51	50	3	
138 - 142				5	9			7	17	18	10			1	3	12	13	2		17	34	37	2	
143 - 147				3	16			5	13	20	4			1		5	7	2		6	22	21	2	
148 - 152				5	11			2	4	14	3			1	1	2	1			2	6	7	1	
153 - 157	1			3	4			1	2	7							1				1	5	1	
158 - 162																						1		
163 - 167																						1		
168 - 172									1							1								
Total Measured by Month	16	93	157	104	63	98	729	750	556	631	757	548	249	358	237	198	86	212	493	895	709	737	612	96
Mean Total Length (mm)	90	91	87	122	137	52	83	102	103	106	101	99	98	104	113	124	128	70	87	100	110	111	100	90

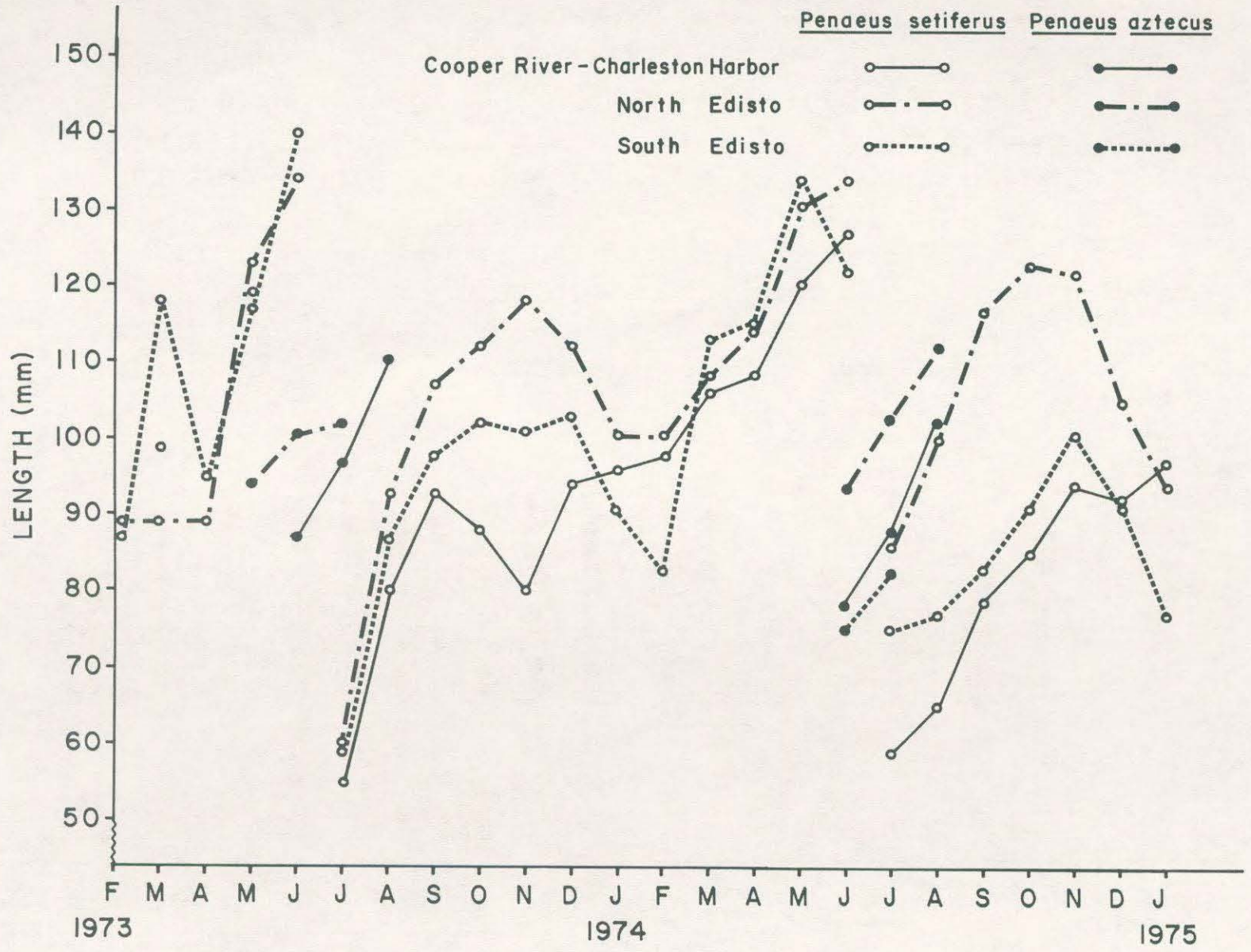


Fig. 13. Mean total lengths of Penaeus setiferus and P. aztecus (both sexes combined) collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Table 38. Length-frequency distribution for male Penaeus aztecus collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Total Length Interval (mm)	Month																							
	1973											1974												1975
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
38 - 42						1											1							
43 - 47						3																		
48 - 52						1	1																	
53 - 57												1					3	1						
58 - 62			1			2		1					1				2	3						
63 - 67						2											16	5						
68 - 72						4		1									22	17						
73 - 77						1											37	26						
78 - 82					4	1											35	66						
83 - 87			2		1							1				1	35	63	2					
88 - 92				1	11	8											39	80	4	1				
93 - 97					24	14	2									3	26	65	3	1				
98 - 102			1	1	12	22	3										19	80	7					
103 - 107				1	5	29	1					2					5	60	13					
108 - 112		1			3	27	2									2	5	40	16					
113 - 117		1			1	13											2	12	6					
118 - 122						8											1	7	6	1				
123 - 127						1												4	1					
128 - 132																								
133 - 137					1																			
138 - 142						1			1															
Total Measured by Month	0	2	4	3	62	138	9	2	1	0	0	4	1	0	0	6	248	529	58	3	0	0	0	0
Mean Total Length (mm)	-	112	82	98	96	101	96	65	140	-	-	87	60	-	-	98	84	93	106	102	-	-	-	-

Table 39. Length-frequency distribution for female Penaeus aztecus collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Total Length Interval (mm)	Month																							
	1973											1974												1975
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
23 - 27																	1							
28 - 32																								
33 - 37																								
38 - 42																	3							
43 - 47						2											2	1						
48 - 52		1															10							
53 - 57						3											8	4						
58 - 62						1											16	12						
63 - 67						1											15	18						
68 - 72			2		1	4											38	16						
73 - 77					1	2											34	22						
78 - 82			1		1	1											46	48	3					
83 - 87					5	2											38	52	2					
88 - 92					11	3	1										45	67	2					
93 - 97			1	1	12	2	1										35	84	2					
98 - 102		1			8	5										1	29	68	10					
103 - 107					10	5	1										20	74	10					
108 - 112					7	13										2	10	75	22					
113 - 117					1	11										2	2	54	19					
118 - 122			1			13	1										7	43	29					
123 - 127					1	8	2										3	26	23	1				
128 - 132						8	1										1	10	17					
133 - 137						3												7	10					
138 - 142						1													3					
143 - 147							1												1					
148 - 152							1																	
Total Measured by Month	0	2	5	1	58	88	9	0	0	0	0	0	0	0	0	5	363	681	153	1	0	0	0	0
Mean Total Length (mm)	-	75	87	95	97	107	121	-	-	-	-	-	-	-	-	110	83	98	117	125	-	-	-	-

(Fig. 13). In June 1973, mean lengths of brown shrimp in the Cooper River-Charleston Harbor and the North Edisto estuaries were 87 and 100 mm, respectively; in June 1974, mean lengths in the Cooper River-Charleston Harbor, North Edisto, and South Edisto were 78, 93, and 75 mm, respectively. A maximum mean total length of 113 mm was obtained in August 1974 in the North Edisto (Fig. 13). As with white shrimp, mean size of brown shrimp in the Cooper River was less than that in North Edisto. Mean size also differed for each year. The mean length (mm) of brown shrimp in June and July was significantly larger in 1973 (100.9, s.e. 0.90, d.f. 345) than that in 1974 (91.7, s.e. 0.38, d.f. 1820) ("t" test, P <0.01).

Too few pink shrimp were caught to meaningfully assess the length-frequency relationship for that species in South Carolina estuaries (Tables 40, 41).

Shrimp Occurrence and Size of Shrimp in Relationship to Bottom Salinity and Temperature

Penaeus setiferus (Linnaeus). A gradual increase in the mean length of P. setiferus from 77 to 136 mm was observed as salinity increased from 0.0-2.9 to 33.0-35.9 °/oo (Fig. 14). The highest percentages of the summed catch per unit effort were obtained in salinities of 3.0-8.9, 12.0-14.9, and 24.0-26.9 °/oo. The percent of the summed cpue in salinities <9.0 °/oo was nearly 31, that in 9.0-20.9 °/oo S was 35, and that in 21.0-29.9 °/oo was 29. Twenty percent of the trawl tows were made in salinities of 0.0-2.9 °/oo, but these accounted for only 10% by numbers of the shrimp catch (Appendix 1). Approximately 10% of the trawl tows were made in waters >29.9 °/oo S and accounted for only 4.5% of the number of P. setiferus caught. Salinities between 23.9 and 30.0 °/oo were trawled most frequently and produced the most shrimp (Appendix 1).

The mean cpue for spring, summer, fall, and winter was 39, 125, 358, and 176, respectively, based on about 95 tows each season (Appendix 1). About 5% of the total 65,994 P. setiferus were caught in the spring, and the cpue was low in all salinities. Shrimp with a mean total length over 100 mm were caught in salinities of 0.0-5.9 and 15.0-29.9 °/oo. Summer catches contributed 18% of the total number of white shrimp captured. The highest percent of the summed cpue for the summer was obtained from waters with salinities <9 °/oo; mean total lengths of these shrimp varied from 69 to 78 mm. The relatively high percent of the summed cpue in waters <3 °/oo S and 3.0-5.9 °/oo was due to single catches; 82 and 69% of the shrimp were caught in single tows, respectively.

Fifty-one percent of the total number of white shrimp were caught during fall (September-November). The highest cpue occurred in waters of 3.0-8.9 and 18.0-23.9 °/oo (Appendix 1). In each case, the high cpue was due to one or two catches. The data for the selected salinity increments are as follows: 3.0-5.9 °/oo, two tows captured 4,340 of a total of 4,681; 6.0-8.9 °/oo, all 1,000 shrimp were caught in one tow; 18.0-20.9 °/oo, one tow caught 2,430 of the 3,460 shrimp; and 21.0-23.9 °/oo, 3,030 of 3,791 shrimp were caught in two tows. Shrimp caught in salinities >23.9 °/oo averaged over 100 mm total length. Twenty-five percent of the total number of white shrimp were caught during the winter months, and 12,000 of these were caught in waters of 24.0-29.9 °/oo S with 36 tows (Appendix 1). Eighteen tows in waters <3.0 °/oo S caught only 26 shrimp. The two highest cpue in the winter were due to single outstanding catches. Ninety-one percent of the 1,883 shrimp caught in 12.0-14.9 °/oo S and 68% of the 7,380 shrimp caught in 24.0-26.9 °/oo S were captured in one tow (Fig. 15, Appendix 1).

The Cooper River-Charleston Harbor, North Edisto and South Edisto estuaries accounted for 44, 44, and 12% of the total number of white shrimp caught in these estuaries, respectively. The mean number of shrimp caught per 20-min trawl tow in each estuary was 314, 153, and 87, respectively (Appendix 2).

In the Cooper River-Charleston Harbor estuary, over 12% of the summed cpue was made in salinities of 3.0 to 5.9 °/oo, and over 25% in salinities of 18.0 to 26.9 °/oo. These high percentages were the results of one or two large catches in the respective salinities. In 3.0-5.9 °/oo, two trawl tows produced nearly 72% of 6,066 shrimp caught in these salinities; in 18.0-20.9 °/oo, one tow captured 73% of 3,322 shrimp; in 21.0-23.9 °/oo, one tow produced 75% of the 2,321 shrimp; and in 24.0-26.9 °/oo, nearly 67% of 7,571 shrimp were from one catch.

In the North Edisto estuary, mean total lengths of shrimp increased rather consistently with increasing salinity, and the highest percentage of the summed cpue, 6.5, occurred in salinities of 27.0-29.9 °/oo (Fig. 16, Appendix 2). Shrimp caught in salinities of 6.0-14.9 °/oo in the South Edisto accounted for nearly 19% of the summed cpue, but this high percent was the result of a few large catches. One thousand of 1,520 shrimp caught in salinities of 6.0-8.9 °/oo and 1,710 of 2,425 shrimp captured in salinities of 12.0-14.9 °/oo, were taken in single tows.

White shrimp were caught in 8.6 to 30.4 °C waters, and the mean length did not consistently change with increasing temperatures (Fig. 17). The largest shrimp (mean total length 121 mm) were caught in 21.0-23.9 °C waters, the smallest (mean total length 90 mm) occurred in 6.0-8.9, 18.0-20.9, and 24.0-26.9 °C waters. In contrast, the percent of the summed cpue did generally increase with increasing temperatures. Water cooler than 15 °C contributed 8.6% of the summed cpue, while waters with temperatures ranging from 15.0 to 30.0 °C yielded 38.1%. Over 53% of the summed cpue was taken in 30.0 to 32.9 °C waters. The high percentage in 30.0-32.9 °C waters was due to three tows during fall (Fig. 18) in the North Edisto estuary (Fig. 19) in which relatively large numbers of shrimp were caught (Appendices 3, 4). The 27.0-29.9 °C waters were trawled 106 times and accounted for 39% of the total 66,819 white shrimp (Appendix 3).

In spring, shrimp were caught in 13.0 to 24.0 °C waters. Mean lengths of shrimp caught in 12.0-14.9 and 21.0-26.9 °C waters were greater than 100 mm, and most of the larger shrimp were caught in May when water temperatures were >21 °C (Fig. 18). The cpue in spring was small. In summer, water temperatures were relatively uniform at all stations.

Table 40. Length-frequency distribution for male Penaeus duorarum collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Total Length Interval (mm)	Month																							
	1973											1974												1975
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
48 - 52														1							1			
53 - 57									1															
58 - 62														1										
63 - 67																							1	
68 - 72														1										
73 - 77									1															
78 - 82																			1					
83 - 87																								
88 - 92																1								
93 - 97															1						1			
98 - 102														1	1									
103 - 107																								
108 - 112							1																	
113 - 117																								
118 - 122															1									
Total Measured by Month	0	0	0	0	0	0	1	0	2	0	0	0	0	4	3	1	0	0	1	0	2	0	1	0
Mean Total Length (mm)	-	-	-	-	-	-	110	-	65	-	-	-	-	70	105	90	-	-	80	-	72	-	65	-

Table 41. Length-frequency distribution for female Penaeus duorarum collected monthly by bottom trawl in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Total Length Interval (mm)	Month																							
	1973											1974												1975
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
58 - 62								1						1										
63 - 67								1	3															
68 - 72									2					1				1						
73 - 77																								
78 - 82							1		1					1	1									
83 - 87										1														
88 - 92																								
93 - 97															1									
98 - 102																								
103 - 107																								
108 - 112														1										
113 - 117																1								
Total Measured by Month	0	0	0	0	0	0	1	2	6	1	0	0	0	4	2	1	0	1	0	0	0	0	0	0
Mean Total Length (mm)	-	-	-	-	-	-	80	62	69	85	-	-	-	80	87	115	-	70	-	-	-	-	-	-

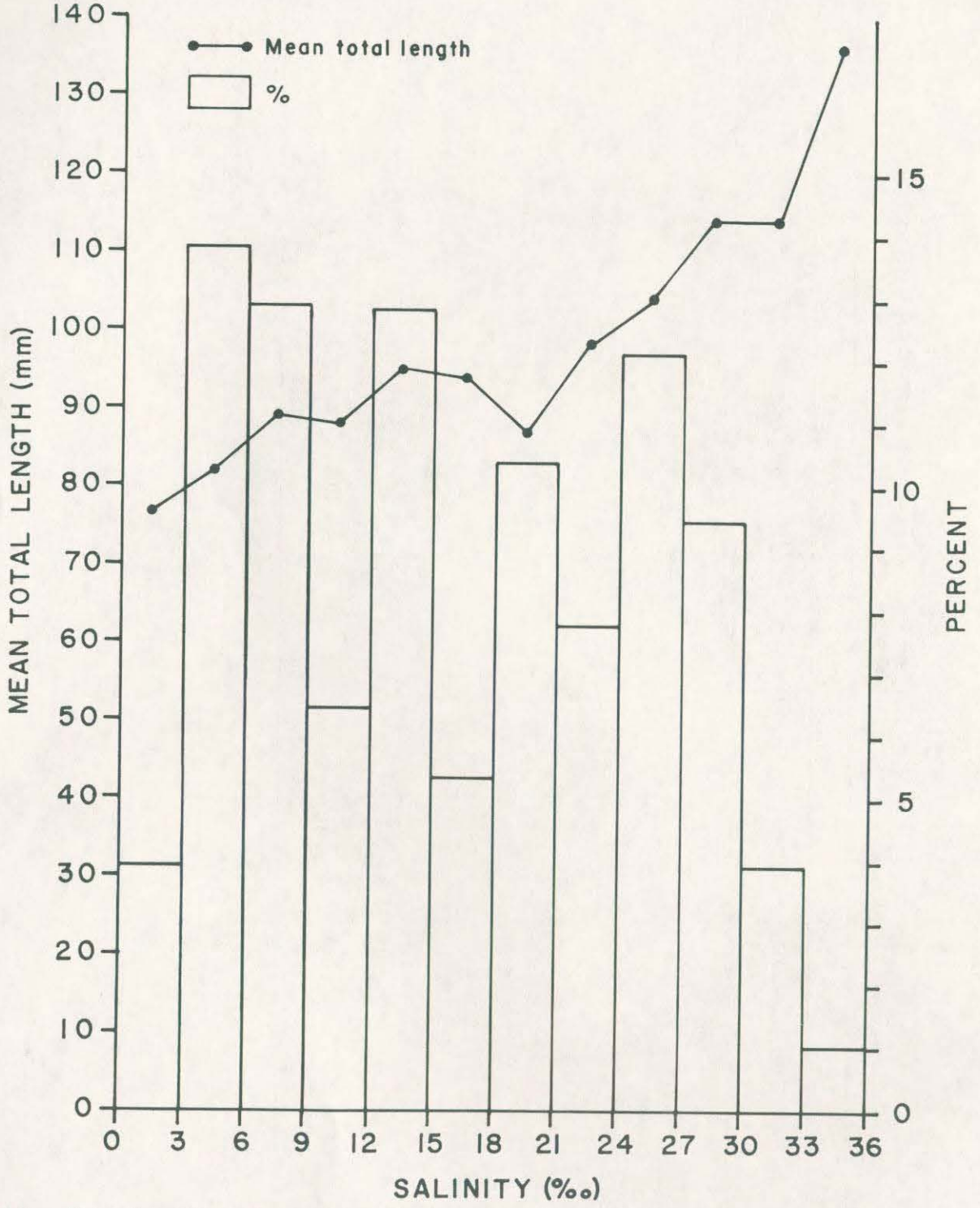


Fig. 14. Mean length and percent of the summed cpue for Penaeus setiferus in relation to bottom salinity in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (estuaries and seasons combined), from February 1973 through January 1975.

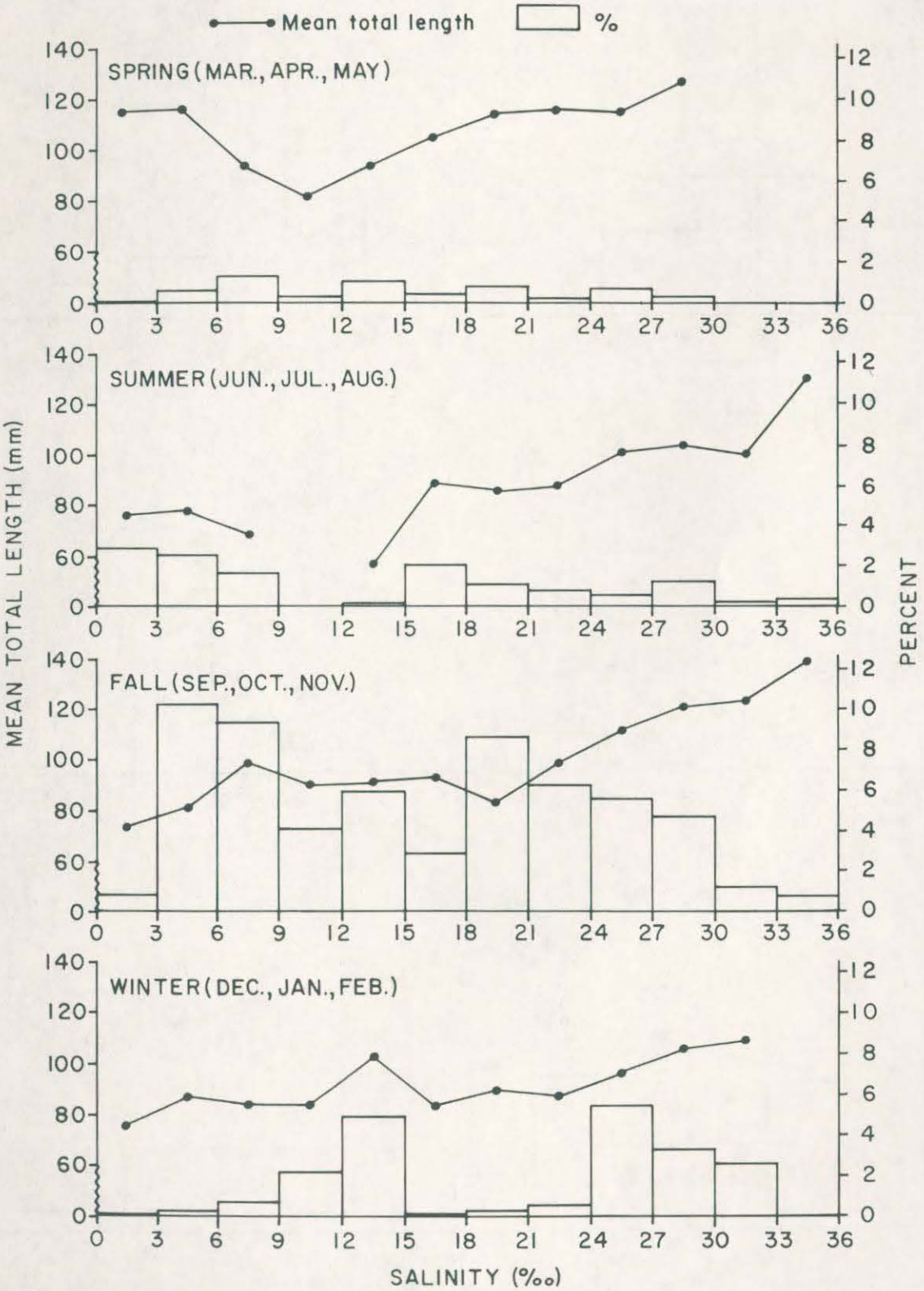


Fig. 15. Mean length and percent of the summed cpue for Penaeus setiferus by season (sum of percents for all seasons equal 100) in relation to bottom salinity in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (estuaries combined), from February 1973 through January 1975.

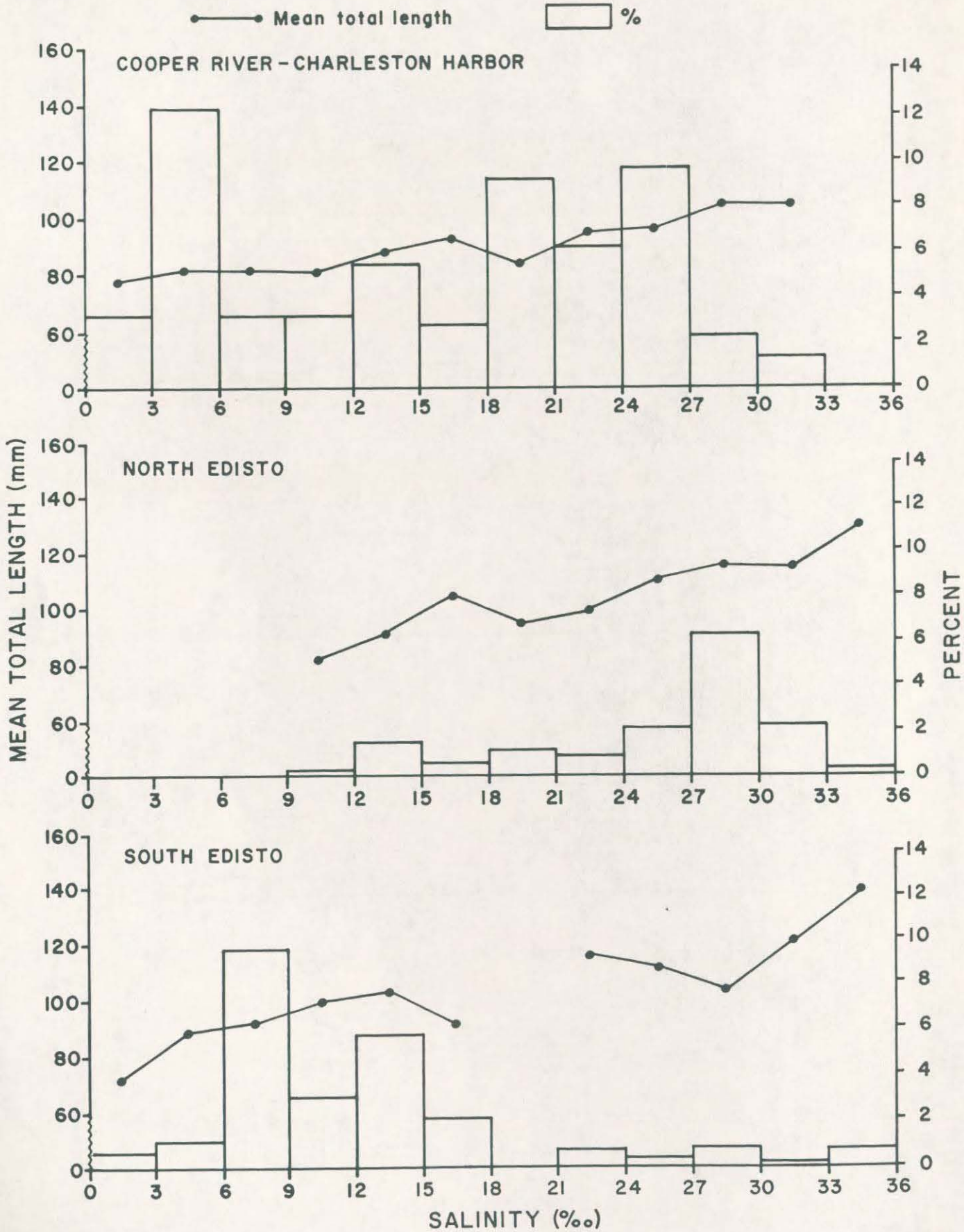


Fig. 16. Mean length and percent of the summed cpue for Penaeus setiferus by estuary (sum of percents for all estuaries equal 100) in relation to bottom salinity in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (seasons combined), from February 1973 through January 1975.

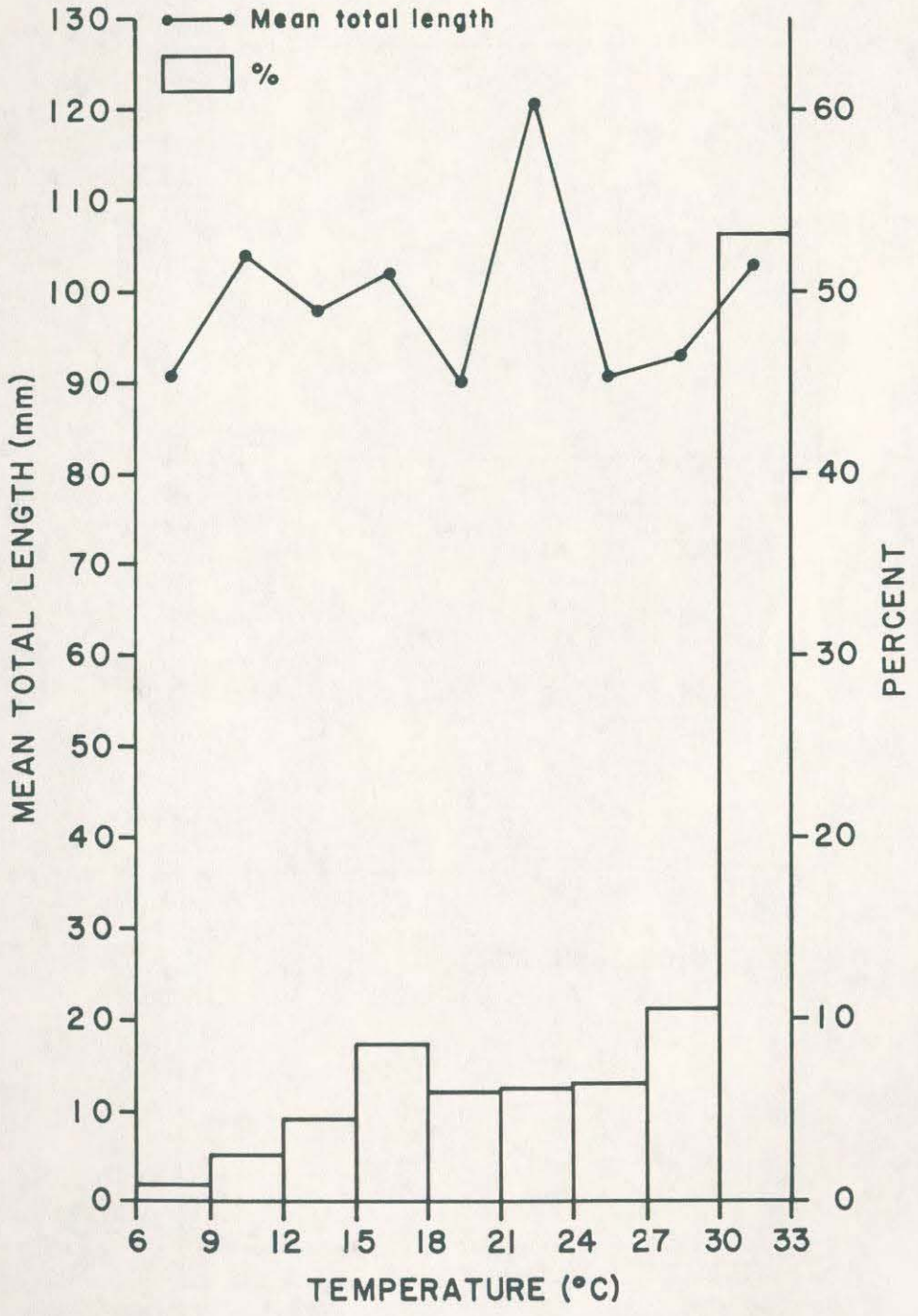


Fig. 17. Mean length and percent of the summed cpue for Penaeus setiferus in relation to bottom temperature in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (estuaries and seasons combined), from February 1973 through January 1975.

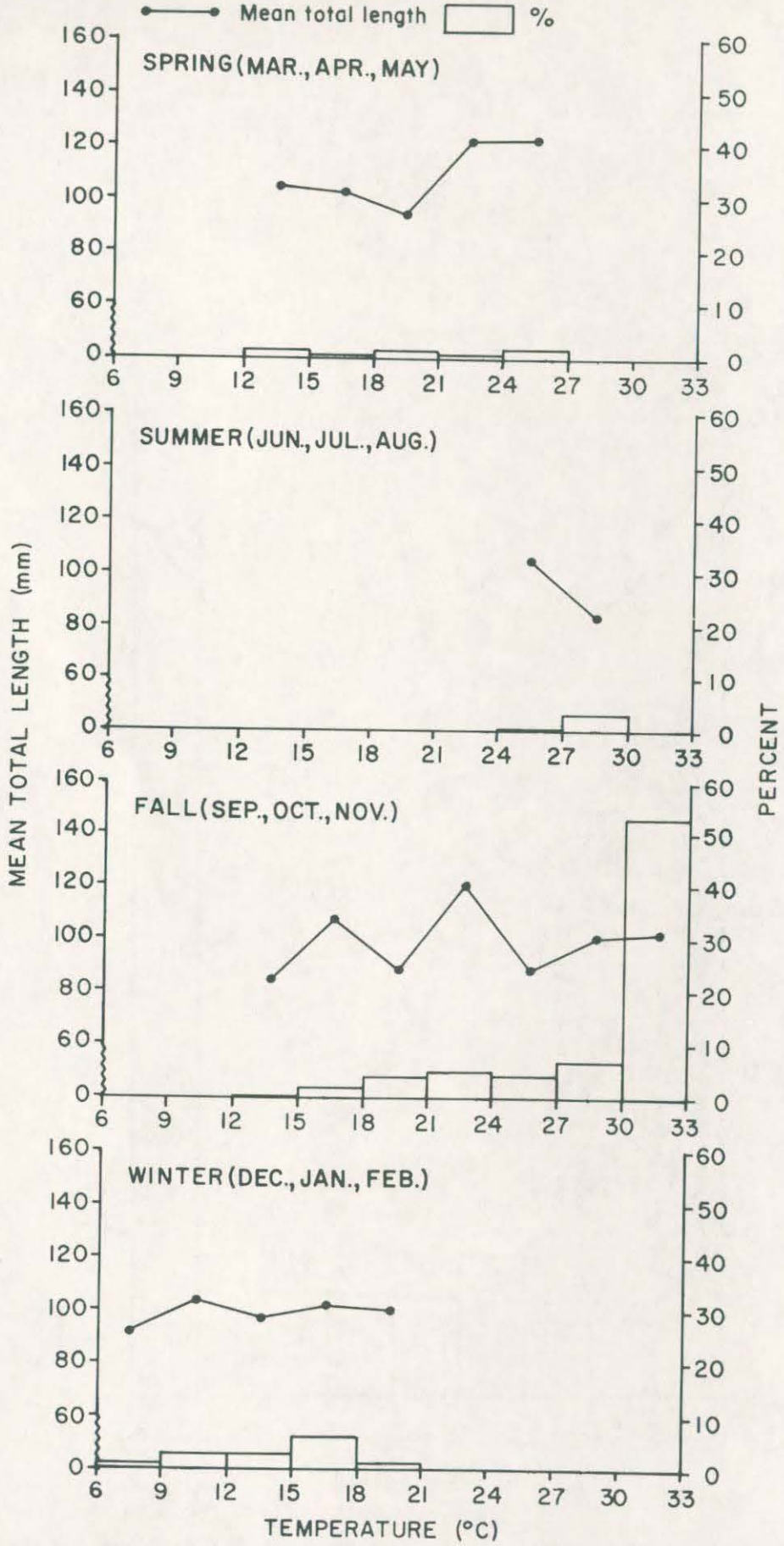


Fig. 18. Mean length and percent of the summed cpue for Penaeus setiferus by season (sum of percents for all seasons equal 100) in relation to bottom temperature in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (estuaries combined), from February 1973 through January 1975.

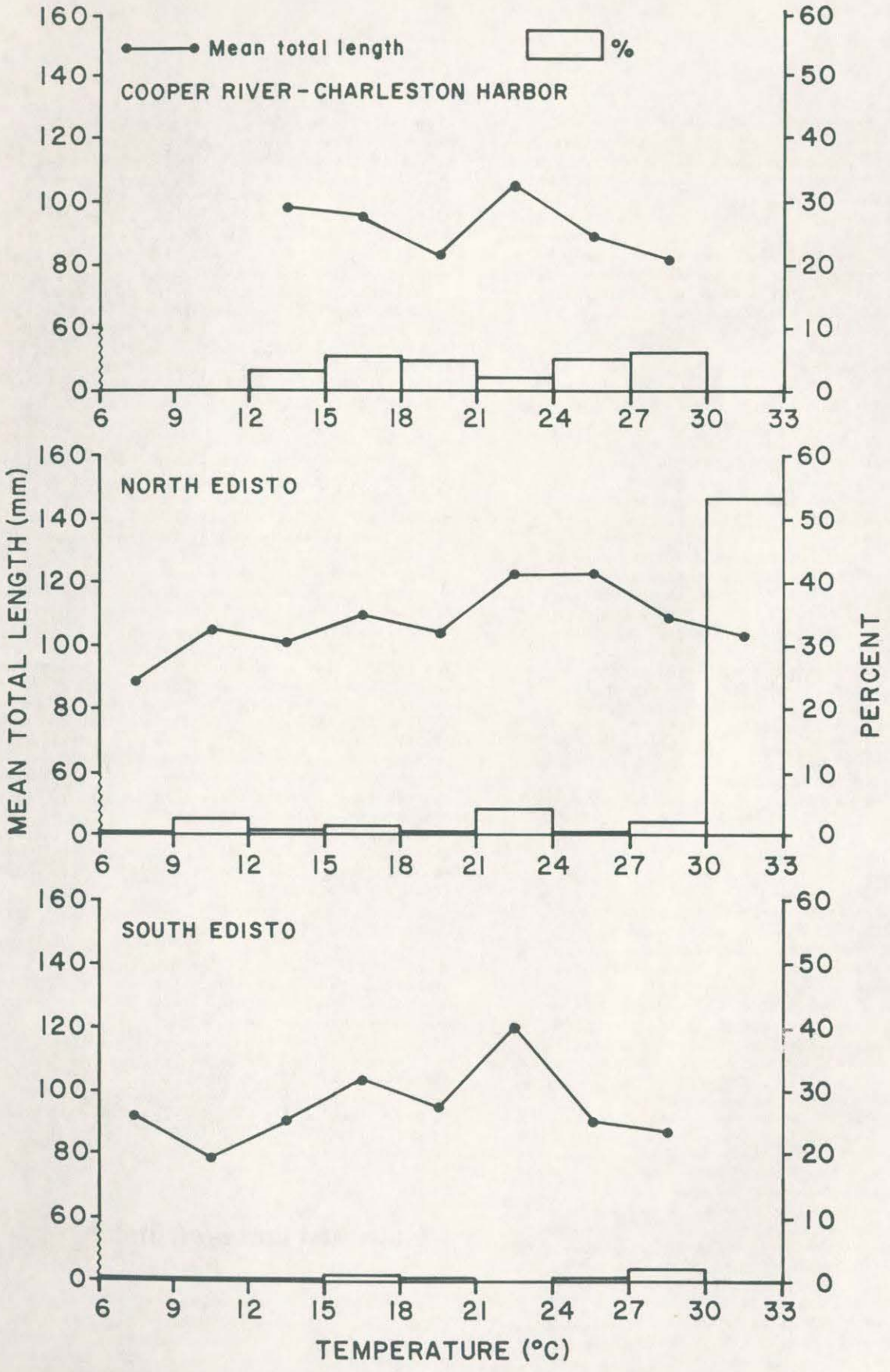


Fig. 19. Mean length and percent of the summed cpue for Penaeus setiferus by estuary (sum of percents for all estuaries equal 100) in relation to bottom temperature in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (seasons combined), from February 1973 through January 1975.

Nearly all the shrimp (97%) caught during the summer were taken in 27.0-29.9 °C waters; mean total length was 83 mm. In fall, water temperatures varied considerably and shrimp were captured at water tempertures ranging from 14.0 to 30.4 °C. Mean lengths ranged from 83 to 121 mm. In winter, shrimp were caught in waters ranging from 8.6 to 19.0 °C and averaged about 100 mm total length (Fig. 18, Appendix 3). Of the 16,698 white shrimp captured during winter months, 64.3% were taken in December 1973 when water temperatures averaged 16.9 °C. In January and December 1974, and January 1975, water temperatures averaged 13.7, 10.2, and 12.2 °C, respectively, and only 9.1, 13.3, and 1.5% of the numerical winter catch was taken. Mean salinities during these months did not change more than 2 °/oo and approximated 20 °/oo.

No shrimp were caught at water temperatures <12.4 or >29.0 °C in the Cooper River-Charleston Harbor estuary. In the North Edisto estuary, shrimp were caught in 8.7 to 30.4 °C waters. Catches per unit effort were generally low in all waters except those of 30.0-32.9 °C which have been discussed previously. In the South Edisto estuary, shrimp were caught in waters with temperatures ranging from 8.6 to 29.5 °C. Mean total lengths of shrimp generally increased with temperature to 24 °C in the North and the South Edisto estuaries and thereafter declined somewhat. A similar trend was not obvious in the Cooper River-Charleston Harbor estuary (Fig. 19, Appendix 4).

Penaeus aztecus Ives. The mean length for brown shrimp caught at salinities <3 °/oo was 68 mm and increased to 132 mm for shrimp taken in salinities >33 °/oo (Fig. 20). Sixteen, five, and 47% of the total intensive catch of 4,191 shrimp were captured in salinities of 3.0-5.9, 6.0-8.9, and 24.0-26.9 °/oo, respectively, and these catches represent 22, 23, and 23% of the summed cpue. Twenty percent of the tows occurred in salinities <3 °/oo and produced only 2% of the numerical catch, and 28% of the trawl tows occurred in salinities >26.9 °/oo and produced only 13% of the numerical catch (Appendix 5).

The mean number of brown shrimp caught per 20-min trawl tow throughout the two-year study was 11, and during the spring, summer, fall, and winter, the catches per tow averaged 0.4, 43, 0.2, and <0.1, respectively (Appendix 5). The data are not graphed seasonally because 4,127 (98.5%) of the total 4,191 brown shrimp were caught in June, July, and August, and a graph of the summer catch would be nearly identical to Fig. 20. During the summer, the highest cpue were 134, 74, and 90 shrimp in 3.0-5.9, 6.0-8.9, and 24.0-26.9 °/oo S, respectively (Appendix 5). In each case, the high cpue resulted from one or two large catches. Few brown shrimp were caught in salinities <3 o/oo even though 22% of the trawl tows during the summer were made in such salinities (Appendix 5).

The total number of brown shrimp caught in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries was 1,974, 1,807, and 410, respectively. The mean number caught per 20-min trawl tow in each estuary was 21, 10, and 4, respectively (Appendix 6). In the Cooper River-Charleston Harbor, the highest percent of the summed cpue occurred in salinities of 3.0-5.9, 6.0-8.9, and 24.0-26.9 °/oo (Fig. 21). The numbers of shrimp caught in these salinities represent 16.0, 3.6, and 21.2% of the total catch, and 22, 17, and 18% of the summed cpue (Appendix 6). Mean total lengths of shrimp caught in 3.0-8.9 and 24.0-26.9 °/oo were about 80 and 92 mm, respectively.

In the North Edisto estuary the highest percent of the summed cpue occurred in salinities of 12.0-14.9 and 24.0-32.9 °/oo. The percent of the total number of brown shrimp caught and the percent of the summed cpue in these salinities are the following: 12.0-14.9 °/oo, 2.2 and 3.1; 24.0-26.9 °/oo, 25.9 and 4.6; 27.0-29.9 °/oo, 7.3 and 3.2; 30.0-32.9 °/oo, 4.1 and 2.3 (Appendix 6). Mean total lengths varied between 83 and 113 mm (Fig. 21).

Catches were scattered throughout the various salinities in the South Edisto estuary (Fig. 21). The highest percent of the summed cpue occurred in salinities of 6.0-8.9, 15.0-17.9, and 18.0-20.9 °/oo. The numbers of shrimp caught in these salinities represent only 1.7, 5.5, and 0.9% of the total catch, but 6, 7, and 4% of the summed cpue (Fig. 21, Appendix 6). Mean lengths of shrimp taken in salinities <21 °/oo were smaller than those captured in waters of salinities >24 °/oo.

Brown shrimp were caught in waters ranging from 9.4 to 30.4 °C. Mean length did not consistently change with increasing temperature (Fig. 22). The largest shrimp (mean total length 116 mm) were caught in 18.0-21.9 °C waters, and the smallest (mean total length 52 mm), in 9.0-11.9 °C waters. Ninety-eight percent of the summed cpue in relation to temperature occurred in 24.0-29.9 °C waters. This high percentage was due to summer catches (Appendix 7). Brown shrimp were caught in the North Edisto in waters with temperatures ranging from 9.4 to 30.4 °C. No shrimp were caught in waters <12 or >30 °C in the Cooper River-Charleston Harbor or the South Edisto estuaries (Fig. 23, Appendix 8).

Tidal and Diurnal Sampling

Catches of white shrimp were not found to be greatly influenced by tide stage nor were obvious diurnal differences found (Tables 42-44). Brown shrimp catches were much larger on flood (233.0, s.e. 99.7, d.f. 8) than ebb tide (61.7, s.e. 18.2, d.f. 5) and larger during the day (178.8, s.e. 86.6, d.f. 9) than night (135.0, s.e. 86.7, d.f. 4), but these differences were not found to be significant ("t" test, $P < 0.05$) (Tables 42-44). Too few pink shrimp were caught to determine the effects of tide and light (Tables 42-44).

Discussion and Conclusions

General Considerations

South Carolina estuaries are generally of two types: those with source waters originating well above the fall line and those with source waters originating below the fall line. The former, such as the Cooper River-Charleston Harbor and the South Edisto Edisto estuaries, are subject to spring

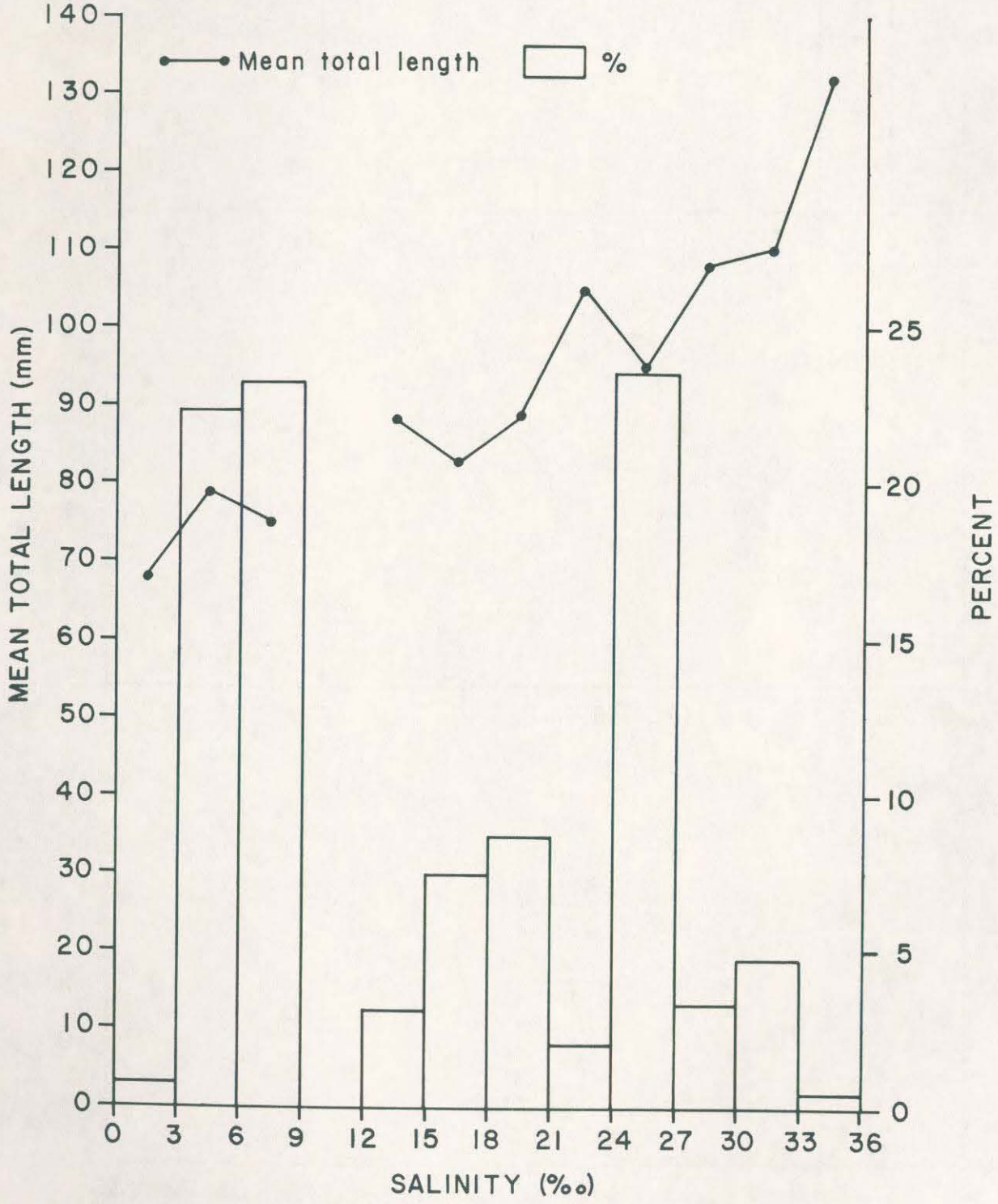


Fig. 20. Mean length and percent of the summed cpue for Penaeus aztecus in relation to bottom salinity in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (estuaries and seasons combined), from February 1973 through January 1975.

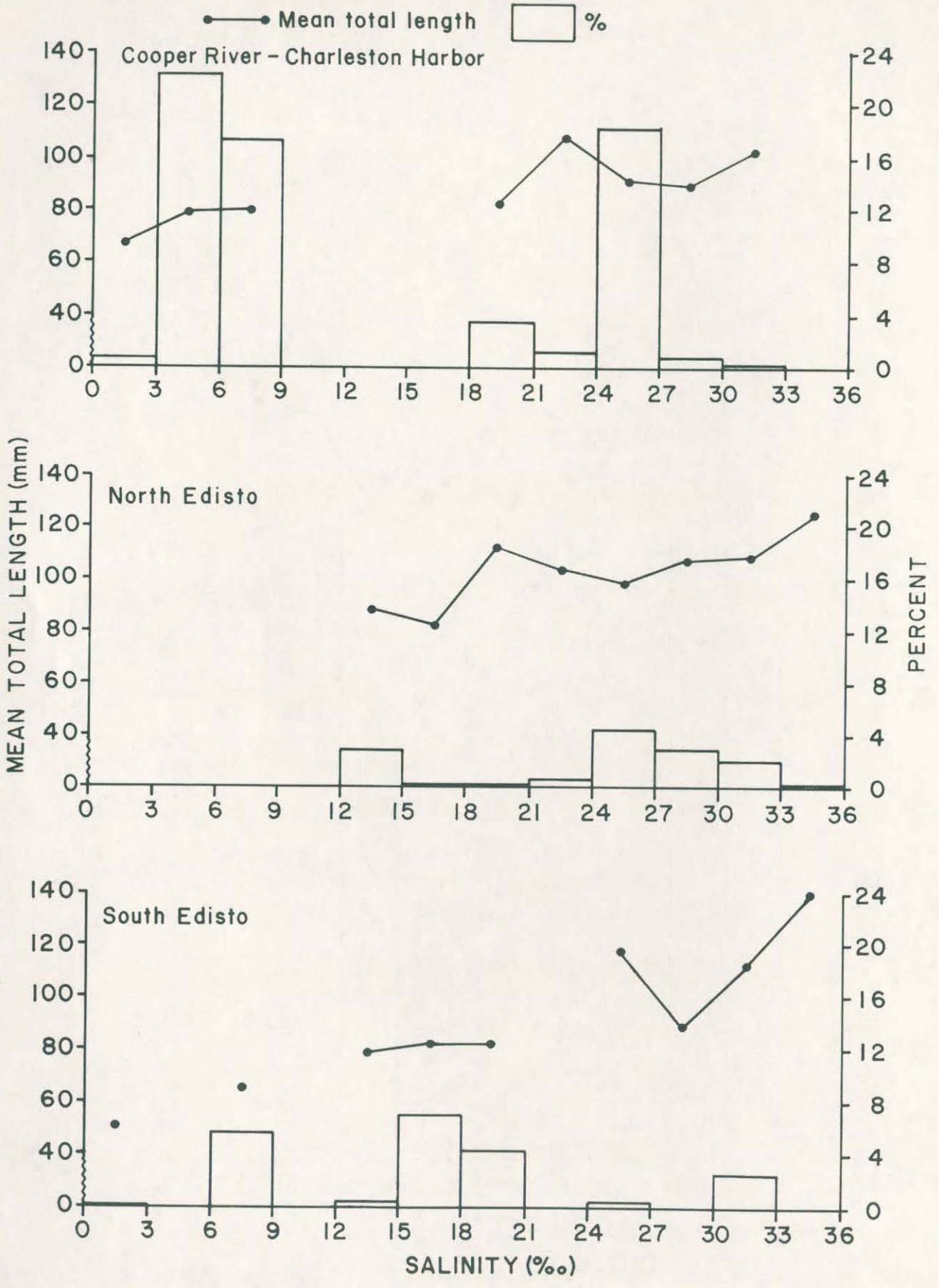


Fig. 21. Mean length and percent of the summed cpue for Penaeus aztecus by estuary (sum of percents for all estuaries equal 100) in relation to bottom salinity in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (seasons combined), from February 1973 through January 1975.

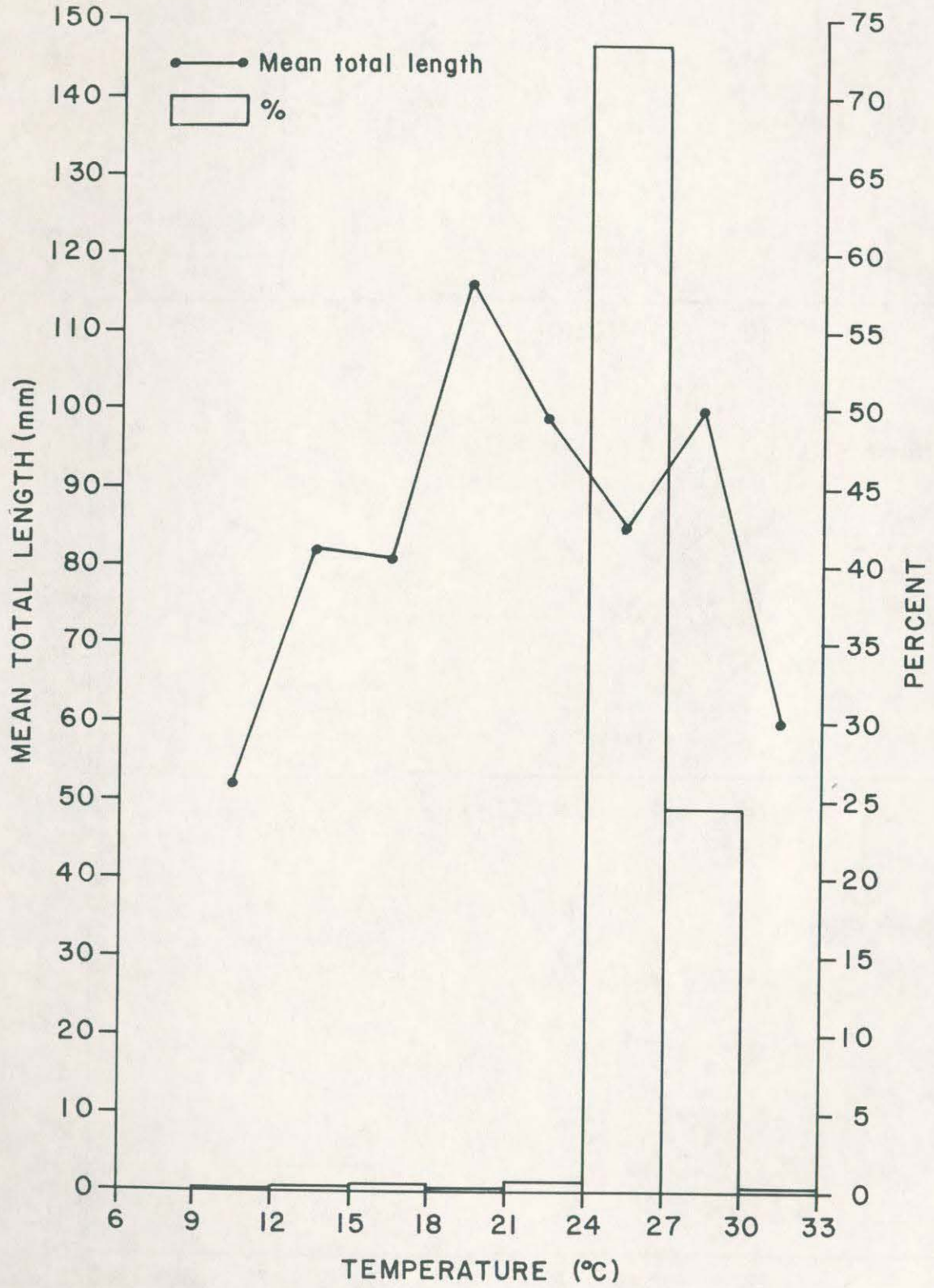


Fig. 22. Mean length and percent of the summed cpue for Penaeus aztecus in relation to bottom temperature in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina (estuaries and seasons combined), from February 1973 through January 1975.

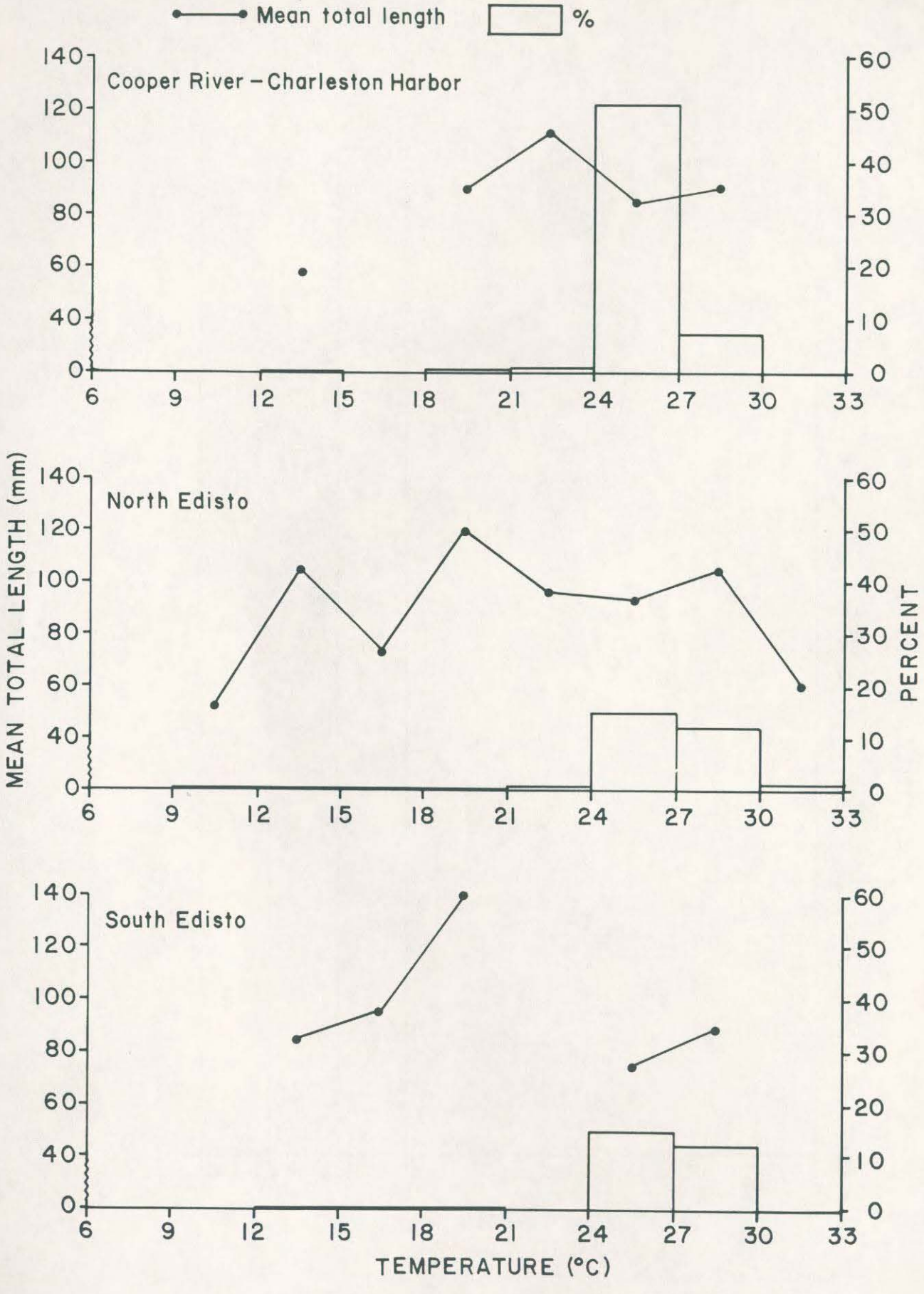


Fig. 23. Mean length and percent of the summed cpue for Penaeus aztecus by estuary (sum of percents for all estuaries equal 100) in relation to bottom temperature in the Cooper River-Charleston Harbor, North Edisto and South Edisto estuaries, South Carolina (seasons combined), from February 1973 through January 1975.

Table 42. Numbers and biomass (g) of shrimp caught by bottom trawl every six hours during 25-hour stations in the Cooper River-Charleston Harbor (Station J001), North Edisto (Station E007), and South Edisto (Station D003) estuaries, South Carolina.

Date	Estuary	Light Conditions	Tide Stage	Penaeus setiferus		Penaeus aztecus		Penaeus duorarum	
				Number	Biomass	Number	Biomass	Number	Biomass
13 May 1974	C. H.*	Light	Flood	0	0	0	0	0	0
13 May 1974	C. H.	Light	Ebb	36	113	0	0	0	0
13 May 1974	C. H.	Dark	Flood	27	567	0	0	0	0
14 May 1974	C. H.	Dark	Ebb	56	1,021	0	0	0	0
14 May 1974	C. H.	Light	Flood	95	1,588	0	0	0	0
01 July 1974	C. H.	Light	Flood	1	16	29	200	0	0
01 July 1974	C. H.	Dark	Ebb	2	8	110	794	2	4
02 July 1974	C. H.	Dark	Flood	10	85	474	2,722	1	2
02 July 1974	C. H.	Light	Ebb	5	57	63	283	0	0
02 July 1974	C. H.	Light	Flood	5	3	939	5,443	1	1
04 Nov. 1974	C. H.	Light	Flood	163	1,701	0	0	0	0
04 Nov. 1974	C. H.	Light	Ebb	301	3,742	0	0	0	0
04 Nov. 1974	C. H.	Dark	Flood	340	1,105	0	0	0	0
05 Nov. 1974	C. H.	Dark	Ebb	352	4,082	0	0	0	0
05 Nov. 1974	C. H.	Light	Flood	219	2,722	0	0	0	0
01 May 1974	N. E.*	Light	Flood	5	124	0	0	0	0
01 May 1974	N. E.	Dark	Ebb	2	12	0	0	2	10
02 May 1974	N. E.	Dark	Flood	9	227	0	0	0	0
02 May 1974	N. E.	Light	Ebb	0	0	0	0	0	0
02 May 1974	N. E.	Light	Flood	8	78	0	0	3	14
09 July 1974	N. E.	Light	Flood	2	45	135	1,446	0	0
09 July 1974	N. E.	Light	Ebb	3	No Data	105	1,247	0	0
09 July 1974	N. E.	Light	Flood	0	0	103	1,134	0	0
10 July 1974	N. E.	Dark	Ebb	0	0	12	85	0	0
10 July 1974	N. E.	Light	Flood	0	0	71	567	0	0
12 Nov. 1974	N. E.	Light	Flood	129	2,268	0	0	0	0
12 Nov. 1974	N. E.	Dark	Ebb	56	1,021	0	0	0	0
13 Nov. 1974	N. E.	Dark	Flood	56	879	0	0	0	0
13 Nov. 1974	N. E.	Light	Ebb	14	113	0	0	0	0
13 Nov. 1974	N. E.	Light	Flood	73	1,361	0	0	0	0
06 May 1974	S. E.*	Light	Flood	7	133	0	0	0	0
06 May 1974	S. E.	Dark	Ebb	36	794	0	0	1	3
07 May 1974	S. E.	Dark	Flood	35	500	0	0	0	0
07 May 1974	S. E.	Light	Ebb	17	227	0	0	0	0
07 May 1974	S. E.	Light	Flood	32	454	0	0	0	0
11 July 1974	S. E.	Light	Flood	137	595	223	1,134	0	0
11 July 1974	S. E.	Light	Ebb	18	25	6	11	0	0
11 July 1974	S. E.	Dark	Flood	4	12	9	40	0	0
12 July 1974	S. E.	Dark	Ebb	40	227	74	456	0	0
12 July 1974	S. E.	Light	Flood	61	340	114	850	0	0
14 Nov. 1974	S. E.	Light	Flood	23	340	0	0	0	0
14 Nov. 1974	S. E.	Light	Ebb	102	1,247	0	0	0	0
14 Nov. 1974	S. E.	Dark	Flood	74	907	0	0	0	0
15 Nov. 1974	S. E.	Dark	Ebb	118	1,247	0	0	0	0
15 Nov. 1974	S. E.	Dark	Flood	67	822	0	0	0	0

*C. H. = Charleston Harbor; N. E. = North Edisto; S. E. = South Edisto

Table 43. Mean number of penaeid shrimp caught per tow by bottom trawl during flood and ebb tide. Tows made every six hours during quarterly 25-hour stations in the Cooper River-Charleston Harbor (Station J001), North Edisto (Station E007), and South Edisto (Station D003) estuaries, South Carolina.

Species and Tide	Number Caught	Number Tows	CPUE
Penaeus setiferus			
Maximum Flooding Tide	1,582	27	58.6
Maximum Ebbing Tide	1,158	18	64.3
Penaeus aztecus			
Maximum Flooding Tide	2,097	9*	233.0
Maximum Ebbing Tide	370	6*	61.7
Penaeus duorarum			
Maximum Flooding Tide	5	27	0.2
Maximum Ebbing Tide	5	18	0.3

*July 1974 tows only

Table 44. Mean number of penaeid shrimp caught per tow by bottom trawl during daylight and dark. Tows made every six hours during quarterly 25-hour stations in the Cooper River-Charleston Harbor (Station J001), North Edisto (Station E007), and South Edisto (Station D003) estuaries, South Carolina.

Species and Light Conditions	Number Caught	Number Tows	CPUE
Penaeus setiferus			
Light	1,456	27	56.0
Dark	1,284	18	67.6
Penaeus aztecus			
Light	1,788	10	178.8
Dark	679	5	135.8
Penaeus duorarum			
Light	4	27	0.2
Dark	6	18	0.3

*July 1974 tows only

freshets and floods and receive heavy sediment loads. The latter, such as the North Edisto estuary, rarely experience large variations in freshwater discharge and receive little sediment.

The Cooper River-Charleston Harbor estuary is a mixohaline estuary (Venice system 1959) and receives drainage waters from not only the Cooper River but also waters diverted from the Santee River via the Santee-Cooper impoundment (Lake Moultrie). The Cooper River system bisects the South Carolina coastal zone, and, therefore, geographically provides a reference for comparison with other estuaries across the state. The Cooper River-Charleston Harbor estuary was selected for intensive study not only for its geographic location, but for a number of other reasons. The river is experiencing continuously increasing pressure from extensive port and industrial development, and the U. S. Army Corps of Engineers have plans to redivert freshwater from the Cooper River back to the Santee River to alleviate heavy silting in Charleston Harbor. Charleston Harbor is not open to commercial shrimping, so the shrimp population in the estuary should be little affected by commercial shrimping pressures. The fauna of the Cooper River-Charleston Harbor includes not only penaeid shrimp, but also (1) diverse marine species in open water at the mouth of Charleston Harbor, (2) an estuarine community in the extensive and often fluctuating zone of intermediate salinities, and (3) a zone above the permanent freshwater line, typified by an ictalurid-clupeid-anguillid ichthyofauna and submergent aquatic plants dominated by Anacharis canadensis Michaux (waterweed) and Ceratophyllum demersum (coontail). Species of fish commonly caught by trawls include Stellifer lanceolatus (star drum), Micropogon undulatus (Atlantic croaker), Anchoa mitchilli (bay anchovy), Brevoortia tyrannus (Atlantic menhaden), and seasonally, Urophycis regius (spotted hake) (Shealy, Miglarese, and Joseph 1974).

The North Edisto estuary is a high-salinity estuary, characteristically mixo-polyhaline (Venice system 1959); it receives no major freshwater inflow, and intermediate salinities are common (Fig. 3). Stations were selected to represent areas in both the main trunk of the estuary and the tributaries (Fig. 1). This estuary is relatively pristine and contains large shrimp nursery grounds and many oyster leases. The penaeid shrimp populations in the North Edisto are accompanied by a diverse benthic fish community which tends to be dominated by sciaenids and engraulids. The most common species of fish captured by trawls include, in order of decreasing numerical abundance, Stellifer lanceolatus (star drum), Anchoa mitchilli (bay anchovy), Leiostomus xanthurus (spot), Micropogon undulatus (Atlantic croaker), Cynoscion regalis (weakfish), and Urophycis regius (spotted hake) (Shealy, Miglarese, and Joseph 1974).

The South Edisto estuary has minor connections with the North Edisto (Fig. 1), but unlike the North Edisto, it receives runoff from a comparatively large drainage basin. As a result the South Edisto is a mixohaline estuary with the inland half characteristically mixo-mesohaline and the seaward half, mixo-polyhaline (Venice system 1959). Stations were selected to represent the entire salinity gradient from the estuary's mouth to above the permanent freshwater line (Figs. 1, 3). The South Edisto is a nursery ground for blue crabs, shrimp, and coastal migrant fishes. Species of fish commonly caught by trawls include Stellifer lanceolatus (star drum), Micropogon undulatus (Atlantic croaker), Ictalurus catus (white catfish), Anchoa mitchilli (bay anchovy), and Chloroscombrus chrysurus (Atlantic bumper) (Shealy, Miglarese, and Joseph 1974).

The Edisto estuaries were selected for intensive study because they have been less affected by man's activities than many of the other major estuaries in South Carolina. Therefore, the data should be representative of shrimp populations in an unpolluted coastal ecosystem and will assist in establishing baseline conditions prior to possible industrialization and urbanization. Trawling during this initial study was restricted to flood stage during daylight hours in order to minimize the number of variables influencing the catch data. All shrimp data presented in this report were collected by semi-balloon otter trawl. Therefore, the data are representative of the shrimp's vulnerability to capture by the trawl. Young shrimp may actually occupy the estuaries from several weeks to several months prior to their regular appearance in the trawl catches.

The stations were selected to be representative of that estuary's fauna as much as possible, and we believe that all the stations were relatively unbiased in selecting for or against a specific species. Obviously, typically freshwater species would not be expected to be taken at high salinity stations and vice versa.

Several additional points should be considered. While the majority of the South Carolina coastal zone was sampled in the extensive phase of the study, no stations were sampled above Winyah Bay (Y001). Also these results are limited to a two-year period during which meteorological conditions at times fluctuated atypically. Just prior to the start of monthly sampling in February 1973, South Carolina coastal counties recorded the heaviest snowfalls experienced for the past several decades. Subsequent freshwater runoff during the spring along with heavy rains in early summer (June), undoubtedly influenced estuarine hydrography and, in turn, possibly the distribution and movements of penaeid populations during the first six months of the study. During the 1973-1974 winter, unusually mild temperatures prevailed. Thus, the results may not reflect in every case the "normal" length-frequency, relative abundance, and distribution patterns generally exhibited by penaeid shrimp populations in South Carolina estuaries. For this and other reasons, these studies are being continued over a number of additional annual cycles.

Penaeus setiferus (Linnaeus)

Nearly 67,000 white shrimp weighing a total of 500 kg were caught in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries during the two-year study. Of these, 5, 18, 52, and 25% by numbers were caught in the spring, summer, fall, and winter, respectively. The seasonal percent catch is a reflection of the shrimp's life cycle. White shrimp were judged by

Lindner and Anderson (1956) to spawn from May into September in South Carolina waters. Immigration of the postlarvae occur from late spring through September with peaks in June, July, and August (Bearden 1961; Charles Boardman, personal communication, 22 August 1975). In the estuaries, juvenile shrimp increase rapidly in size, and most egress from the estuaries during the fall months (September-November) as subadults. The exact trigger for this emigration is unknown, but it probably includes a combination of factors. Idyll (1957) stated that temperature is responsible, but Lindner and Anderson (1956) reported that the offshore migration of P. setiferus in Louisiana cannot be temperature-related because movement occurs well in advance of any appreciable drop in temperature. They suggested that the offshore movement is related to the shrimp's "approach of adulthood and spawning," and that it is accelerated by lowering temperatures. Joyce (1965) stated that size alone or stage of maturation appears responsible for the emigration and that lowering temperatures hasten the offshore movement.

The number of shrimp in South Carolina estuaries during the winter appears to be dependent upon the severity of the winters; relatively high numbers remain in the estuaries during mild winters. Williams (1960) found that low temperatures (~8.8 °C) interfered with the osmoregulatory abilities of P. aztecus and P. duorarum, and Gunter et al. (1974) stated that P. varians, P. aztecus, P. duorarum, and Leander serratus tolerate low salinities better at high temperatures. The same appears to be true for P. setiferus in South Carolina estuaries and probably is at least partially responsible for the shrimp's overwintering patterns.

The relationships of salinity and/or temperature to the growth and distribution of shrimp has been the subject of many papers (Copeland and Bechtel 1974; Gunter et al. 1964; Gunter and Hildebrand 1954; Harris 1974; Panikkar 1951, 1969; St. Amant et al. 1966; Williams 1965; Zein-Eldin and Griffith 1969). Viosca (1920) first implied a relationship between salinity and size of P. setiferus. Weymouth et al. (1933) mention this relationship more directly, and Gunter (1961) discusses the size of estuarine organisms in general with respect to salinity. Our findings agree with their statements that the smaller shrimp are found at lower salinities and that larger shrimp are found in higher salinities (Fig. 14). More recently Gunter et al. (1964) discussed the salinity preferences on the commercial shrimp (genus Penaeus). They presented data which showed that juvenile white shrimp ranging in total length from "15 to 100 mm and longer" are most abundant in waters of salinities less than 10 °/oo in Alabama and Texas Bays and stated that salinity per se was responsible for the observed distribution. In Caminada Bay, Louisiana, Crowe (1975) obtained results for P. setiferus similar to those of Gunter et al. (1964). The data presented in this report do not necessarily support findings of Gunter et al. (1964). During our two-year study, only 22% of the catch of P. setiferus was obtained in salinities <9 °/oo even though waters in this salinity range received nearly 28% of the trawling effort. White shrimp were abundant in the North Edisto estuary, with an average catch of 153 shrimp per tow (Appendix 2), yet salinities were never recorded at the 0.5-10 °/oo "optimum" of these other investigators. We obtained a fairly even percentage distribution of the summed cpue in relation to salinity: the percent of the summed cpue below 9 °/oo was 31; from 9-20.9 °/oo, 35; and from 21-29.9 °/oo, 29 (see Fig. 14). Thus white shrimp in South Carolina do not necessarily show a preference for salinities <10 °/oo, and therefore, "salinity per se" does not seem to be the primary factor governing their distribution as suggested by Gunter et al. (1964) for P. setiferus in northern Gulf of Mexico waters.

Gunter et al. (1964) did not give the mean sizes of shrimp caught in various salinity ranges, but the shrimp caught in our study are probably larger. This may partially account for the apparent discrepancy because smaller shrimp are more numerous than larger ones. In our study, only 1.3% of the 16,000 shrimp measured were <53 mm total length.

Our sampling was restricted to open waters, and open waters as well as nearshore areas were sampled by investigators mentioned in the report by Gunter et al. Loesch (1965) found "Thousands of whites in a band no more than 6 ft. wide along edge from 0 - 12" deep" in Mobile Bay, Alabama, and obtained length modes of less than 25 mm by sampling the edge with a minnow seine. No modal lengths of less than 70 mm were obtained from his open water stations in Mobile Bay (Loesch 1965). In Georgia, modal lengths of the first new-crop white shrimp caught by seine in the upper creeks and marshes was 33 mm, but that of the initial white shrimp caught by trawl in the rivers and sounds was 78 mm. These shrimp were first captured by seine in June and by trawl in July (Harris 1974). Williams (1955) observed that numbers of juvenile shrimp in Core Sound, North Carolina, are enormous on the sand and clay shoals vegetated with Diplanthera wrightii and Zostera marina, but that on unvegetated shoals and in the deeper portions of the sound, the numbers of juvenile shrimp are almost nonexistent. Giles and Zamora (1974) found juvenile P. setiferus (51-70 mm total length) to significantly prefer a substrate of Spartina alterniflora "planted in an upright position" to one of shell and sand, and suggested that this preference may serve as a defense against predation and be related to food availability. George (1974) reported that 10-15 mm Metapenaeus monoceros primarily ingest planktonic crustaceans, that 15-50 mm shrimp primarily consume detritus, and that animal matter was the most important component of the diet for shrimp greater than 50 mm. Thus it appears that small white shrimp (15-70 mm) primarily occupy the shallow edges of the estuaries where cover and preferred foods are available. This would account for the paucity of small shrimp in our samples because only 3.1% of our trawl tows were made in waters less than 3 m deep and none were made in waters of less than one meter.

Differences between Gunter et al. and our findings should not be due to our gear biasly undersampling small shrimp or lack of sampling in low salinity waters. The otter trawl used in our

study had one-inch stretch mesh (trawls mentioned in the paper by Gunter et al. had 0.25, 1.5, and 1.75 inch stretch mesh) and on several occasions captured literally thousands of grass shrimp (Palaemonetes sp.) ranging in total length from 20-35 mm. This indicates that our trawl should have been at least as effective in catching small penaeid shrimp as trawls used to catch shrimp analyzed by Gunter et al. (1964). About 28% of our total monthly trawl effort occurred in waters of <10 °/oo S.

If our data are analyzed as percent of the summed cpue in relation to season (Fig. 15), then salinity, percent of the summed cpue, and size are observed to have an interrelationship which gives credence to the statement by Gunter et al. that white shrimp "select" salinities <10 °/oo. During summer, the small, newly recruited white shrimp were found in salinities <9 °/oo (Fig. 15). As the season progressed into fall, new-crop white shrimp were still being recruited and high cpue were obtained in salinities <9 °/oo, but cpue were high in salinities >9 °/oo also. Thus, it appears that the younger shrimp primarily occupy the lesser salinities as suggested by Gunter (1961), and as they grow, move to higher salinities. The cpue was high in nearly all salinities between 3 and 30 °/oo in fall when the white shrimp are at their peak abundance in the estuary. In summary, the distribution of white shrimp in South Carolina estuaries does not appear to be affected by salinity per se, but rather by a combination of factors including salinity, season, geographic area, and shrimp size.

Weymouth et al. (1933) were first to clearly state that generally larger shrimp were obtained from the higher salinities. Gunter (1945, 1950) also noticed this relation. More recently, Brusher and Ogren (1976) suggested that the more nearly oceanic conditions of lower St. Andrews Bay, Florida, may "induce" shrimps of the genus Penaeus to remain in the estuary for longer periods of time. Consequently, shrimp in St. Andrews Bay grow to a larger size compared to shrimp in other estuaries of the northern Gulf (Brusher and Ogren 1976). The high salinities of the North Edisto estuary appear to provide a favorable environment for the larger white shrimp (Fig. 13). The mean total length of shrimp from the North Edisto was 110 mm, while that of shrimp from the Cooper River-Charleston Harbor and the South Edisto was 88 and 93 mm, respectively. Mean size during periods of emigration was also larger for white shrimp in the North Edisto (Fig. 13). Whether the larger size of white shrimp in the North Edisto is due to fast growth or a longer estuarine residence time as suggested by Brusher and Ogren (1976) is unknown, but high salinity is believed to be an influence.

That P. setiferus is eurythermal is well supported by the data (Fig. 17). The largest numbers of shrimp, 12,779 and 25,997, were caught in waters with temperature ranges of 15.0-17.9 and 27.0-29.9 °C, respectively (Appendix 3). These maxima are a reflection of the timing of the shrimp's life cycle and the warm December in 1973.

Postlarval white shrimp enter the estuaries in late spring-early summer and exit as subadults during fall. Therefore, it was expected that the largest numbers of white shrimp would be caught at the time the waters were warmest. This was found to be true (Fig. 18). Variations in water temperature throughout the estuaries during any sampling period were small (Fig. 4); therefore, the shrimp had a limited "choice" of temperatures at any given time. This was most obvious in the summer (Fig. 18) when temperature for June, July, and August 1973 and 1974, varied only 25.0 to 29.8 °C. About 97% of the summer-caught shrimp were obtained in 27.0-29.9 °C waters, but this temperature range was recorded for only 72% of the trawl tows (Appendix 3). Therefore, shrimp may prefer the higher temperature waters or may be more available to the trawl at higher temperatures.

The movement of shrimp in the fall to offshore waters is hastened by decreasing temperatures (Joyce 1965). This movement, in part, may be due to osmoregulatory problems that shrimp experience in reduced salinities at low temperatures (see Williams 1960). The cpue were greater in the higher temperature waters in the fall (Appendix 3) and relatively high at all salinities (Appendix 1). In winter, however, the cpue were relatively high only in the warmer waters (>12.0 °C) and in salinities of 9-15 °/oo and 24 °/oo (Appendices 1, 3). Panikkar (1951) cites evidence of estuarine organisms "preferring" high salinities during winter conditions.

The mean lengths of shrimp show no consistent trend with increasing temperatures (Fig. 17). The largest shrimp, 121 mm mean total length, were caught in 21.0-23.9 °C waters and accounted for 9.5% of all P. setiferus caught during intensive sampling. Shrimp of this size were caught in the fall and spring (Fig. 13). In the spring, when estuary waters begin to warm, the large shrimp apparently move from offshore waters into the estuary as reported in Viosca (1920) and Williams (1955), or the population of overwintering shrimp grow to subadult size. Whether the major portion of the large spring-caught shrimp are derived from the overwintering population or from an immigrating offshore population is unknown.

Growth of white shrimp was rapid during summer of 1973. From July to August, mean length increases were 25, 34, and 27 mm for shrimp in the Cooper River-Charleston Harbor, North Edisto, and South Edisto, respectively. Thus, the per day length increase for shrimp in all three estuaries was about one mm day $^{-1}$. Emigration, recruitment of small shrimp, and decreased growth rates of the larger shrimp probably account for the smaller increases in mean length increases after September 1973 (Fig. 13).

The maximum apparent growth rate for white shrimp in South Carolina estuaries, about 30 mm month $^{-1}$, compares favorably with estimated growth rates from other areas. On the Texas coast, Gunter (1950) estimated that white shrimp grew at rates of 25 to 40 mm month $^{-1}$. Loesch (1965) estimated monthly growth rates in Mobile Bay, Alabama, to be 12-27 mm during winter and 18-31 mm in summer. He stated, however, that very young shrimp may grow to 65 mm in one month during summer. Along the northeast coast of Florida, Johnson and Fielding (1956) obtained growth rates

of 50 mm in 24 days in extensive culture pond conditions, and Joyce (1965) estimated that wild juvenile whites grow an average of 35 mm month $^{-1}$. Williams (1955) estimated growth rates of white shrimp in North Carolina to be about 36 mm month^{-1} in the summer.

Over 20,000 white shrimp were sexed during the study, and sex ratios favored female shrimp (Table 28). Of the total, 11,680 or 57% were females (Table 28). Pullen and Trent (1969) found that 55% of the white shrimp emigrating from Galveston Bay, Texas, were females, but this was not a significant difference. Harris (1974) found that in June, 70% of the trawl-caught P. setiferus in creeks and sounds were females. Farfante (1969) observed considerable variation of sex ratios around 1:1 and has examined catches comprised entirely of a single sex. Therefore, this sex ratio is not considered unusual.

White shrimp are generally considered diurnal animals (Farfante 1969, Joyce 1965), but diel data from 25-hr stations do not show this to be true (Table 44). In fact, more white shrimp were caught per tow during night than day. Wickham and Minkler (1975) observed white shrimp in aquaria, and after the first day, found them to be active at all times regardless of the light regime. Clark and Caillouet (1975), however, caught significantly more white shrimp during the day than at night. Dugas (1975) obtained no consistent day-night catch trends for P. setiferus in Vermillion Bay, Louisiana, but Joyce (1965) caught 85% of 8,480 white shrimp during the day with equal day and night sampling in inshore waters. At Joyce's offshore stations, only 57.6% of the white shrimp were caught during daylight.

White shrimp were most abundant in the central region of the South Carolina coast (Table 5). Mean cpue for the northern, central, and southern regions were 141, 334, and 78 shrimp, respectively. The Cooper River-Charleston Harbor estuary is in the central region, and the North and South Edisto estuaries are between the central and southern regions. In the Cooper River-Charleston Harbor, over 319 white shrimp were caught per tow (Table 26), and in the North and South Edisto estuaries, an average of 129 shrimp were caught. Thus it appears that the most productive estuarine areas of the state for white shrimp may be the central region with productivity decreasing both south and north of this region.

Overall, the general biology of the white shrimp in South Carolina waters was found to differ little from that of white shrimp in Louisiana (Gaidry and White 1973), northeast Florida (Joyce 1965), Georgia (Harris 1974), or North Carolina (Williams 1955).

Penaeus aztecus Ives

Postlarval brown shrimp first begin entering the estuaries in South Carolina in January with maximum numbers occurring in February and March (Bearden 1961; Charles Boardman, personal communication, 03 October 1975). Juvenile brown shrimp were first caught in the trawl in substantial numbers in June. Nearly 93% of the 4,191 brown shrimp caught in the estuaries intensively sampled were caught in June and July, and 6% of the total were caught in August 1974 (Tables 18, 22). Assuming that the majority of the brown shrimp captured in June first entered the estuary in mid-February, then mean growth rates can be inferred. Postlarval brown shrimp range in length from 9-12 mm (Bearden 1961) and the mean length of the June-caught brown shrimp was 96 mm in 1973 and 84 mm in 1974. Thus, the mean inferred growth rates from mid-February to the end of May are 0.8 and 0.7 mm day $^{-1}$ for 1973 and 1974, respectively. The mean length increase during June 1973 was 0.2 mm day $^{-1}$ and those for June and July 1974 were 0.6 and 0.4 mm day $^{-1}$, respectively. The lower rates of length increases in June and July were probably due to emigration of the larger individuals so that while the length of the overall population is increasing, the rate of the increase appears to be depressed.

Other field investigations have obtained higher growth rates. Loesch (1965) sampled the shrimp population in all areas of Mobile Bay, Alabama, by several methods and caught brown shrimp as small as 15 mm without the use of a plankton net. He estimated juvenile browns (20 mm total length) to grow 1.7 mm day^{-1} in spring, and juvenile and subadults to grow about 0.8 - 1.4 mm day^{-1} during summer. St. Amant et al. (1966) suggested that juvenile brown shrimp grow less than 1.0 mm day^{-1} when water temperatures are less than 25 °C. Their highest estimated growth rate was 2.5 mm day^{-1}, and they found no obvious growth in waters less than 16 °C. Ringo (1965) estimated in Galveston Bay, Texas, that juvenile browns grew less than 0.1 mm day^{-1} when water temperatures were less than 20 °C, but that growth increased to 1.7 mm day^{-1} when water temperatures exceeded 20 °C. A maximum growth of 3.3 mm day^{-1} was attained when water temperature reached 25 °C. White (1975) reported a growth rate of 1.3 mm day^{-1} for P. aztecus in Barataria Bay, Louisiana, but found this rate to be much less during years of low salinities, i.e., less than 12 °/oo. An increase in total length of 1.7 and 1.4 mm day^{-1} was obtained by Williams (1955) and McCoy (1968), respectively, for P. aztecus in North Carolina estuaries. Rose et al. (1975) estimated summer growth of juvenile brown shrimp (25-90 mm total length) to be 1.3 mm day^{-1} and that for subadults (90-140 mm total length) to be 0.5 mm day^{-1} in a Louisiana salt-marsh impoundment in which predator and competitor control was practiced.

The somewhat lower growth rate estimated for P. aztecus in South Carolina probably results from the methods used to infer growth. In this study, the estuaries were sampled at the beginning of each month, and the juvenile brown shrimp could have occupied the trawl sites for as long as four weeks before detection in the first week of June. Also mean lengths were used to obtain growth rates rather than the length increases of the largest individuals caught, a procedure used in some other studies (Ringo 1965, Williams 1955). Therefore, it is believed that a growth rate of 0.7-0.8 mm day^{-1} for brown shrimp in South Carolina is a conservative estimate.

Sex ratios favored female shrimp (Table 28). Renfro and Brusher (1963) and Joyce (1965) obtained a 1:1 ratio for P. aztecus in offshore waters. In inshore waters, however, Joyce

obtained a male:female ratio of 0.81:1.00. Of the 3,184 brown shrimp which were sexed in this study, 60% were females.

Brown shrimp are reported to be nocturnally active (Farfante 1969; Wickham and Minkler 1975; Williams 1958, 1965). Because of this behavior, brown shrimp are fished primarily at night on the Gulf coast (Gunter 1950; Viosca 1957), but this is not necessarily so off the South Carolina coast (Richard K. Keiser, Jr. personal communication, 30 October 1975). In North Carolina, McCoy (1972) readily caught brown shrimp in the early morning daylight hours. Differences between our diurnal and nocturnal trawl catches for brown shrimp are not conclusive. On a catch per unit effort basis, only 43% of the browns were caught during night sampling (Table 44), but brown shrimp were caught only during three of the 25-hr stations (Table 42). In a 24-hr period in Vermilion Bay, Louisiana, 90% of 324 P. aztecus were caught at night (Dugas 1975). In northeast Florida, Joyce (1965) sampled the inshore and offshore waters equally during the day and night. Day samples accounted for 71% of 1,648 brown shrimp caught inshore and 51.2% of 1,221 shrimp caught offshore. Springer and Bullis (1952) found that in the deeper offshore waters, the day-night catch differences for brown shrimp were not as well defined as in shallower waters. Clark and Caillouet (1975) found no significant day-night catch differences in turbid waters of a Texas estuary.

In this survey, nearly four times as many shrimp were caught during maximum flood tide than maximum ebb tide during around-the-clock sampling (Table 43), but the data are far from conclusive because of the small sample size (Table 42).

A relationship between mean total length of P. aztecus and salinity was obtained (Fig. 20); however, the percentages of shrimp caught within various salinities were not equal. Over 47% of the shrimp (mean length 95 mm) were caught in waters of 24.0-26.9 °/oo S, and 16% (mean total length 79 mm) were caught in waters of 3.0-5.9 °/oo S. Gunter (1950) and Williams (1955) found an "apparent positive correlation" between size and salinity for P. aztecus. Parker (1970) did not report such a relationship, but his Figs. 4 and 5 (size distribution of P. aztecus and salinity distributions) show that the smaller shrimp were found in the lower salinity waters and that the larger shrimp were found in the higher salinity waters of Galveston Bay, Texas in 1963. Loesch (1965) found brown shrimp to be smaller at his inshore and nearshore stations than those at the bay stations and states that waters offshore (i.e., those in Mobile Bay) were usually more saline than the most shoreward stations.

Juvenile brown shrimp reportedly "prefer" salinities between 10 and 20 °/oo (Gunter et al. 1964). The data that they present show that more shrimp were caught per haul within these salinities than in other salinities. In Caminada Bay, Louisiana, Crowe (1975) caught a mean of 14.5, 44.5, and 78.5 juvenile P. aztecus per tow in salinities of 0-10, 11-20, and 21-30 °/oo, respectively. Below 9.0 °/oo S, we caught 968 shrimp in 105 tows; in 9.0-20.9 °/oo, 611 shrimp were caught in 75 tows; and in 21.0-29.9 °/oo, 2,376 shrimp were caught in 160 tows, for a mean of 9.2, 8.1, and 14.8 brown shrimp per tow, respectively. Even with the increased salinity range of 9.0 to nearly 21 °/oo, as opposed to 10-20 °/oo, our catch per tow was smallest in the "preferred" salinity range cited by others. In fact, the highest percent of the summed cpue was obtained in salinities below 9.0 °/oo, i.e., 46.4. This high percentage was due, however, to two trawl tows in which relatively high numbers of shrimp were caught. Fifty-seven percent of the 4,191 brown shrimp were caught with 42% of the trawl tows in salinities of 21.0 to 29.9 °/oo, so these salinities appear to be the most preferred by brown shrimp in South Carolina waters. Therefore, our data and those of Crowe (1975) do not necessarily support the conclusion of Gunter et al. (1964) that juvenile P. aztecus prefer waters of 10-20 °/oo. Our findings may, in part, be the result of the sampling gear and the estuaries sampled. Salinities in the North Edisto, where 50% of the intensively-sampled stations were located, were seldom less than 20 °/oo (Figs. 2, 3). Also, no trawl tows were made in waters of less than two meters in depth, and the edges of the estuaries were not sampled with seines or push nets. This probably accounts for the paucity of small shrimp (<50 mm total length) caught during the two-year study.

The distribution of brown shrimp in South Carolina estuaries indicate that smaller shrimp are found in the lower salinities when lower salinities are available. In the Cooper River-Charleston Harbor and the South Edisto estuaries, shrimp less than 80 mm total length were collected in 3.0-8.9 °/oo S; but in the North Edisto, the smallest shrimp (80-90 mm total length) were collected at salinities from 12.0-17.9 o/oo (Fig. 21). Both the Cooper and the South Edisto Rivers produce salinity gradients from freshwater to nearly full strength seawater. The North Edisto, however, has no significant freshwater input, and only twice were salinities recorded below 14 °/oo. Therefore, large areas of lower salinities were not available to the juvenile in the North Edisto estuary, but this did not appear to affect their growth or survival. Hoese (1960) concluded that juvenile P. aztecus can populate areas of high salinity if other environmental factors are ideal, and Zein-Eldin and Griffith (1969) state that juvenile penaeids are found throughout Texas estuaries from nearly freshwater to hypersalinity. Zein-Eldin's (1963) laboratory experiments on the effects of salinity on P. aztecus at 23-25 °C led her to conclude that low salinity was not a requirement for growth and survival, i.e., she obtained equal growth and 90-100% survival for postlarvae held in 2-40 °/oo for 30 days. Examining data collected from 1962 to 1972 in the Barataria Bay area of Louisiana, Barrett and Gillespie (1973) concluded that the salinity optimum is about 19 °/oo.

Only 544 brown shrimp were caught in 1973, and mean lengths were about the same in all three estuaries. In 1974, over 3,600 brown shrimp were caught and the mean total lengths of shrimp from the North Edisto, South Edisto, and Cooper River-Charleston Harbor estuaries were 103, 82, and 84 mm, respectively. The higher salinity waters in

the North Edisto estuary possibly create an environment more favorable for large shrimp (see Brusher and Ogren 1976). No evidence was found for shrimp growing larger in the North Edisto because of a longer residence time. Over 13% of the brown shrimp taken in the North Edisto were caught in August 1974; in the South Edisto and the Cooper River-Charleston Harbor estuaries, comparable August catches were 8 and 0.1%, respectively. The mean size of brown shrimp in the North Edisto in 1974 was 103 mm and that for browns without the August data was 100 mm. Therefore the higher August catch of brown shrimp is not responsible for the larger mean size of brown shrimp from the North Edisto.

The fact that brown shrimp were numerous in August in the North Edisto estuary may be due to lack of competition from white shrimp or that in high salinities, brown shrimp are more competitive than whites. Whatever the reason, brown shrimp, like whites, appear to attain a larger size in the North Edisto estuary.

Population density of brown shrimp within each estuary was never as high as that for white shrimp and does not appear to be a major factor influencing size of brown shrimp. Other studies have reported a relationship between shrimp densities and mean size. Parker (1970) found P. aztecus as small as 41 to 55 mm total length in the Gulf near Galveston Bay, Texas, in 1963 when shrimp populations were large in Bay waters. The following year when shrimp populations were smaller, emigration did not begin until shrimp reached a minimum size of 86 mm. Idyll, Iversen, and Yokel (1966) found an inverse relationship between numbers and size of emigrating P. duorarum in 1963-1964.

Water temperature (25-29.8 °C) in which 98% of the brown shrimp were captured was favorable for their growth and osmoregulation. Zein-Eldin and Griffith (1969) state that growth of P. aztecus is more strongly influenced by temperature at the same salinity than by salinity at similar temperatures. Their statement is supported by field as well as laboratory investigations. Maximum growth rates in the laboratory at 25 °/oo S were 1.1 mm day^{-1} at 25 °C and 1.4 mm day^{-1} at 32 °C. Almost no growth was observed at any salinity at 11 °C (Zein-Eldin and Aldrich 1965). Williams (1960) found that P. aztecus osmoregulatory abilities were impaired at 8.8 °C.

Brown shrimp were not found to be uniformly distributed over the coastal regions of South Carolina. An average tow in the northern, central, and southern regions of the coast produced 10, 41, and 16 shrimp, respectively (Table 5). In the Cooper River-Charleston Harbor, North Edisto, and the South Edisto estuaries, a mean of 21, 9, and 4 brown shrimp, respectively, were caught per tow (Table 26). The paucity of brown shrimp caught per tow is due to the fact that large numbers of shrimp are available to the trawl only two months of the year (Table 22). Thus, in the extensive, quarterly sampling, sizeable catches of brown shrimp could be expected in one-fourth of the trawl tows, and in the intensive sampling, in one-sixth of the trawl tows.

Penaeus duorarum Burkenroad

In South Carolina, pink shrimp are captured only occasionally. During the two years of this study, a total of 94 P. duorarum were caught in 508 trawl tows for a cpue of 0.18. Gunter et al. (1964) consider P. duorarum to be more halophyllic than either P. setiferus or P. aztecus, and our data do not contradict their statement.

Over 66% of the pink shrimp caught during the quarterly statewide sampling came from the station at Inlet Creek (B001). Salinities at this station averaged nearly 30 °/oo and were never less than 23 °/oo (Table 3). Over 86% of the pink shrimp taken from the three intensively-sampled estuaries were caught in the high-salinity North Edisto estuary (Fig. 3). The nearest pink shrimp fishery to South Carolina is in North Carolina, where pink shrimp replace the white shrimp as the prominent species fished in the fall (Williams 1955).

Estuarine Catches in Relation to Commercial Catches

The catch data used for comparisons were standardized as much as possible by comparing total catch data from the intensive phase of the Estuarine Survey (Cooper River-Charleston Harbor, North Edisto, and South Edisto catches) to commercial landings data from the central portion of the South Carolina coast, i.e., Charleston County. Charleston Harbor and North Edisto estuaries are wholly within, and the South Edisto River is the southern boundry of, Charleston County.

The penaeid catch of the Estuarine Survey reflected the year-to-year change in volume of the combined commercial catch of white and brown shrimp and that of white shrimp alone. The 1973 penaeid catch comprise 52-53% of the 1973-1974 total, and the 1973 catch of white shrimp accounts for 54.5% of the 1973-1974 total (Table 45). The Estuarine Survey catch did not reflect the year-to-year difference in commercial catch of brown shrimp. In 1973 and 1974, brown shrimp comprise 23 and 31% of the commercial landings, and 2.0 and 9.2% of the Estuarine Survey catch, respectively. The 1973:1974 brown shrimp ratio is 1.0:1.2 for the commercial landings, and that for the Estuarine Survey (intensive phase) is 1.0:4.2. Because the Estuarine Survey catches of brown shrimp were not indicative of the commercial catches, the ratio of browns to whites is not proportional. The brown:white shrimp ratio for the 1973-1974 South Carolina commercial landings (Charleston County) is 1.0:2.7, and that for the Estuarine Survey is 1.0:17.6.

Brown shrimp were caught by the Estuarine Survey almost exclusively in June and July in the estuaries and by the commercial fishery offshore from June through August (unpublished data, Statistics Section, South Carolina Marine Resources Division). If the brown shrimp catches during June and July in the intensively-sampled estuaries are compared with those of the July and August commercial catches (Table 46), then the ratios are equal. The brown:white shrimp ratio in the June-July 1973 and 1974 penaeid catches in the intensively-sampled estuaries is 1.0:0.4, while that of the July-August 1973 and 1974 commercial penaeid catches is 1.0:0.4. Thus, there appears to be a month lag between the estuarine penaeid catches and the offshore commercial landings. It is

Table 45. Landings (kg) of Penaeus setiferus and Penaeus aztecus from the South Carolina commercial fishery and from the intensively-investigated estuaries from February 1973 through January 1975.

	February 1973 through January 1974	February 1974 through January 1975	Two-year Catch for Each Species
Cooper River-Charleston Harbor, North Edisto, and South Edisto			
Penaeus setiferus	271.8	227.2	499.0
Penaeus aztecus	5.4	22.9	28.3
Total Catch for Year	277.2	250.1	
South Carolina Commercial Landings *			
Penaeus setiferus	1,460,078.4	1,223,309.5	2,683,387.9
Penaeus aztecus	452,180.0	554,209.4	1,006,389.4
Total Catch for Year	1,912,258.4	1,777,518.9	

* Landings of shrimp in January 1974 and January 1975 were zero, so catches are representative of calendar year.

Table 46. Landings (kg) of Penaeus setiferus and Penaeus aztecus from the South Carolina commercial shrimp fishery in July and August of 1973 and 1974 and from the intensively-sampled estuaries in June and July of 1973 and 1974.

	Penaeus setiferus	Penaeus aztecus	Two-month Catch for Year
Cooper River-Charleston Harbor, North Edisto, and South Edisto			
June-July 1973	3.1	4.6	7.7
June-July 1974	6.6	19.8	26.4
Species Total Catch	9.7	24.4	34.1
South Carolina Commercial Landings			
July-August 1973	164,065.0	340,436.4	504,501.4
July-August 1974	159,845.8	486,896.9	646,742.7
Species Total Catch	323,910.8	827,333.3	1,151,244.1

assumed that both brown and white shrimp are equally vulnerable to the trawl both inshore and offshore, and that the trawls used in this study and those used by the commercial fishermen are equally selective.

Several circumstances may account for the observed differences between the composition of the species landed in the intensively-sampled estuaries and the commercial fishery. White shrimp were numerous in the estuaries in nearly all months and are more typical of estuarine fauna than are brown shrimp. The white-shrimp catch ratios, however, were similar between the Estuarine Survey and the commercial landings, so it is believed that the estuarine white shrimp catches were indicative of the true population. Brown shrimp were caught in the estuaries almost exclusively during June and July. Commercial offshore landings of brown shrimp began as early as June and tapered off in August-September (South Carolina Landings), so they were fished commercially for about four months. It is believed, therefore, that trawling in the estuaries undersampled brown shrimp populations. The commercial penaeid catch is probably a more accurate representation of the species abundance in South Carolina waters.

Penaeid Shrimp Productivity in South Carolina Estuaries

Of the three estuaries sampled monthly, the Cooper River-Charleston Harbor estuary was found to yield more shrimp per unit area in both number and biomass (Tables 24, 25). Nearly twice as many shrimp by numbers were caught in the Cooper River-Charleston Harbor as in the next most productive estuary, the North Edisto. The South Edisto was the least productive of the three, but its mean catch per trawl tow should not be as low as that in Table 24, i.e., 90. During the two years of sampling in the South Edisto, salinities recorded at the most inland station (D001) were never above 1 ^{o}/oo and only four shrimp were caught. Because of the low catch and consistently low salinities, data from this station are not considered to be indicative of shrimp populations in the estuary. Therefore, a catch-per-unit-effort for the South Edisto should be based upon data from the three seaward-most stations only. This results in a mean catch per trawl tow in the South Edisto of 121 shrimp.

The exact function that estuaries serve in the production and perpetuation of the shrimp is unknown, but it is believed that estuaries are essential for major shrimp resources (Kutkuhn 1966). Postlarval and young juvenile shrimp can survive and grow in full strength seawater (Hoese 1960, Zein-Eldin 1963), but commercial landings of shrimp are largest in states with large estuarine areas (St. Amant 1973). Within these estuarine areas, production of shrimp varies annually and geographically and man's alterations in the estuary are known to affect distribution of shrimp. Burkenroad (1934) noted that the "perifluvial area investigated seems to support a more concentrated population than the coast to east or westward does." We obtained highest numbers of shrimp per trawl tow in the Cooper River-Charleston Harbor estuary (Table 26). Mock (1967) and Trent et al. (1976) found higher concentrations of shrimp in or nearer areas of unaltered marsh or estuary than in adjacent altered areas. Thus, there seem to be conditions which are favorable to higher shrimp concentrations and production.

Shrimp are known consumers of detritus (Darnell 1958, Eldred et al. 1961, George 1974, Williams 1955), and most of the detritus in estuaries is produced in adjacent marshes (Teal 1962, Day et al. 1973). Salt marshes are among the most productive natural areas on Earth (Odum 1971) and the nutrient input from rivers is partly responsible for the high productivity (see Gunter 1967, Ho and Barrett 1975). Thus large areas of marsh and estuary with substantial land runoff are conducive for good shrimp production. Also important, however, is the amount of the marsh-open water interaction, i.e., the length of shoreline. Kutkuhn (1966) reported that it is the shoreline zone and transitional marsh area that are sought by the young shrimp during the earliest stages of their estuarine existence. Loesch's (1965) findings substantiate Kutkuhn's statement.

In an attempt to explain the observed differences among catches in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, selected characters of each estuary were assessed and compared within and between estuaries. The amount of freshwater input, area of surrounding marsh, area of open water, and the length of the shoreline for each estuary were compiled from maps of the Environmental Evaluation Section, Office of Conservation and Management of the South Carolina Wildlife and Marine Resources Department (Table 47). The length of shoreline and the area of open water and marsh of each estuary were measured from the mouth of the estuary to the upper limit of brackish marsh. Brackish marsh is considered as that marsh in which Juncus roemerianus, Scripus robustus, and (or) Spartina cynosuroides are the dominate vegetation. The shoreline, open water, and marsh acreage of the Ashley and Wando Rivers were included with the data for the Cooper River-Charleston Harbor estuary.

The area of marsh and open water are greatest for the Cooper River-Charleston Harbor, but the North Edisto's shoreline is about 180 km longer than that of the Cooper River-Charleston Harbor estuary. Extensive mudflats exist in the North Edisto at low tide, and the effective shoreline may be somewhat less than the 792 km value given in Table 47.

No obvious relationships between the amount of shrimp caught per trawl tow and the ratios of the areas of brackish marsh to saltmarsh, total marsh to open water, total marsh to length of shoreline, area of open water to length of shoreline, or area of open water plus total marsh to length of shoreline were found. Ratios of the area of brackish marsh, salt marsh, total marsh, open water, and open water plus total marsh between the Cooper River-Charleston Harbor estuary and the North Edisto or South Edisto estuaries also showed no consistent relationship with the shrimp catch (Table 48).

Adding to the complexities is the fact that all three of the intensively sampled estuaries differ from one another. The Cooper River-

Table 47. Area of marsh and open water, length of shoreline, and river-flow for the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina.

Estuary	$(km)^2$					km	m^3/s
	Brackish Marsh	Salt Marsh	Total Marsh	Open Water	Open Water and Total Marsh	Shoreline	River-flow*
Cooper River-Charleston Harbor	13.3	86.2	99.4	88.4	187.8	612.6	14,766
North Edisto	6.9	72.9	79.8	69.4	149.2	791.9	---
South Edisto	19.1	47.5	66.6	30.1	96.7	304.4	2,843

*Monthly mean from February 1973 through January 1975.

Table 48. Ratios of abiotic factors for the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina. TM = total marsh, OW = open water, SL = shoreline.

Estuary	Brackish Marsh / Salt Marsh	TM / OW	TM / SL	OW / SL	OW + TM / SL	SL + OW / TM
Cooper River-Charleston Harbor	0.154	1.125	0.162	0.144	0.301	7.051
North Edisto	0.094	1.149	0.101	0.088	0.188	10.797
South Edisto	0.402	2.215	0.219	0.099	0.318	5.021

Estuary Ratio	Brackish Marsh	Salt Marsh	Total Marsh	Open Water	Open Water plus Total Marsh
Cooper River-Charleston Harbor / North Edisto	1.4	1.2	1.2	1.3	1.2
Cooper River-Charleston Harbor / South Edisto	0.5	1.8	1.4	2.9	1.9

Charleston Harbor estuary and the South Edisto estuary both have substantial freshwater input. Two major man-made lakes (Lakes Marion and Moultrie), as well as a U. S. Navy Base, are located on the Cooper River, and the City of Charleston is situated at the confluence of the Ashley and Cooper Rivers. The North Edisto receives little freshwater input, and no municipalities are located nearby. The effects of these factors on shrimp production are unknown and may be impossible to assess.

The Cooper River-Charleston Harbor and the North Edisto estuaries have approximately the same amount of marsh, open water, and shoreline (Table 47) but the freshwater input differs greatly. If freshwater input alone were responsible, then there should not have been more shrimp in the North Edisto (on a cpue basis) than in the South Edisto as was observed. So the observed shrimp densities probably result from several direct and indirect complex interactions. Thus it may be that if the North Edisto received a substantial amount of freshwater, it would be more productive; or if Charleston Harbor received less freshwater, its shrimp production might decrease.

Literature Cited

Barrett, B. B., and M. C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. Louisiana Wild Life and Fisheries Commission; Oysters, Water Bottoms and Seafoods Division, Technical Bulletin No. 9. 28 p.

Bearden, C. M. 1961. Notes on postlarvae of commercial shrimp (Penaeus) in South Carolina. Contribution from Bears Bluff Laboratory No. 33. 8 p.

Bearden, C. M., and M. D. McKenzie. 1972. Results of a pilot shrimp tagging project using internal anchor tags. Transactions of the American Fisheries Society 101: 358-362.

Brusher, H. A., and L. H. Ogren. 1976. Distribution, abundance, and size of penaeid shrimps in the St. Andrew Bay system, Florida. Fishery Bulletin 74: 158-166.

Burkenroad, M. D. 1934. The Penaeidea of Louisiana with a discussion of their world relationships. Bulletin of the American Museum of Natural History 68: 61-143.

Calder, D. R., P. J. Eldridge, and E. B. Joseph (ed.). 1974. The shrimp fishery of the southeastern United States: a management planning profile. South Carolina Marine Resources Center, Technical Report No. 5. 229 p.

Clark, S. H., and C. W. Caillouet. 1975. Diel fluctuations in catches of juvenile brown and white shrimp in a Texas estuarine canal. Contributions in Marine Science 19: 119-124.

Copeland, B. J., and T. J. Bechtel. 1974. Some environmental limits of six Gulf coast estuarine organisms. Contributions in Marine Science 18: 169-204.

Costello, T. J., and D. M. Allen. 1970. Synopsis of biological data on the pink shrimp Penaeus duorarum duorarum Burkenroad, 1939. FAO Fisheries Report 57: 1499-1537.

Crowe, A. L. 1975. Population dynamics of two species of commercial shrimp in Caminada Bay, Louisiana. Proceedings of Louisiana Academy of Sciences 38: 86-91.

Darnell, R. M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publications of the Institute of Marine Science, University of Texas 5: 353-416.

Day, J. W., Jr., W. G. Smith, P. R. Wagner, and W. C. Stowe. 1973. Community structure and carbon budget of a salt marsh and shallow bay estuarine system in Louisiana. Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana. 80 p.

Dugas, R. J. 1975. Variation in day-night trawl catches in Vermilion Bay, Louisiana. Louisiana Wildlife and Fisheries Commission; Oysters, Water Bottoms, and Seafoods Division, Technical Bulletin No. 14. 13 p.

Eldred, B., R. M. Ingle, K. D. Woodburn, R. F. Hutton, and H. Jones. 1961. Biological observations on the commercial shrimp, Penaeus duorarum Burkenroad, in Florida waters. Florida State Board of Conservation, Marine Laboratory. Professional Paper Series No. 3. 139 p.

Eldridge, P. J., and Steven A. Goldstein (ed.). 1975. The shrimp fishery of the South Atlantic United States: a regional management plan. South Carolina Marine Resources Center, Technical Report No. 8. 66 p.

Farfante, Isabel P. 1969. Western Atlantic shrimps of the genus Penaeus. Fishery Bulletin 67: 461-591.

Fishery Statistics of the U. S. 1963-1974. National Marine Fisheries Service, NOAA, Department of Commerce. U. S. Government Printing Office, Washington, D. C.

Gaidry, W. J., III, and C. J. White. 1973. Investigations of commercially important penaeid shrimp in Louisiana estuaries. Louisiana Wild Life and Fisheries Commission; Oysters, Water Bottoms, Sea Foods Division, Technical Bulletin No. 8. 154 p.

George, M. J. 1974. Indian Journal of Fisheries. (In press.) - cited in Qasim, S. Z., and D. C. V. Easterson. 1974. Energy conversion in the shrimp, Metapenaeus monoceros (Fabricius), fed on detritus. Indian Journal of Marine Science 3: 131-134.

Giles, J. H., and G. Zamora. 1973. Cover as a fac-

tor in habitat selection by juvenile brown (Penaeus aztecus) and white (P. setiferus) shrimp. Transactions of American Fisheries Society 102: 144-145.

Gunter, Gordon. 1945. Studies on marine fishes of Texas. Publications of the Institute of Marine Science, University of Texas 1(1): 1-190.

Gunter, Gordon. 1950. Seasonal population changes and distributions as related to salinity, of certain invertebrates of the Texas coast, including the commercial shrimp. Publications of the Institute of Marine Science, University of Texas 1(2): 7-51.

Gunter, Gordon. 1961. Some relations of estuarine organisms to salinity. Limnology and Oceanography 6: 182-190.

Gunter, Gordon. 1967. Some relationships of estuaries to the fisheries of the Gulf of Mexico, p. 621-638. In G. H. Lauff (ed.) Estuaries. AAAS Publication No. 83. Washington, D. C.

Gunter, Gordon, B. S. Ballard, and A. Venkataramiah. 1974. A review of salinity problems of organisms in United States coastal areas subject to the effects of engineering works. Gulf Research Reports 4: 380-475.

Gunter, Gordon, J. Y. Christmas, and R. Killebrew. 1964. Some relations of salinity to population distributions of motile estuarine organisms, with special reference to penaeid shrimp. Ecology 45: 181-185.

Gunter, Gordon, and H. H. Hildebrand. 1954. The relation of total rainfall of the state and catch of marine shrimp (Penaeus setiferus) in Texas waters. Bulletin of Marine Science of the Gulf and Caribbean 4: 95-103.

Harris, C. D. 1974. Observations on the white shrimp (Penaeus setiferus) in Georgia. Georgia Department of Natural Resources, Game and Fish Division, Coastal Fisheries Office. Contribution Series No. 27. 54 p.

Ho, C. L., and B. B. Barrett. 1975. Distribution of nutrients in Louisiana's coastal waters influenced by the Mississippi River. Louisiana Wildlife and Fisheries Commission; Oysters, Water Bottoms, and Seafoods Division, Technical Bulletin No. 17. 39 p.

Hoese, H. D. 1960. Juvenile penaeid shrimp in the shallow Gulf of Mexico. Ecology 41: 592-593.

Idyll, C. P. 1957. The commercial shrimp industry of Florida. Florida State Board of Conservation, Marine Laboratory. Educational Series No. 6. 30 p.

Idyll, C. P., E. S. Iversen, and B. Yokel. 1966. Abundance of juvenile pink shrimp on the Everglades National Park nursery grounds, p. 19-20. Annual Report of the Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas, fiscal year 1965. U. S. Fish and Wildlife Service, Circular No. 246.

Johnson, M. C., and J. R. Fielding. 1956. Propagation of the white shrimp, Penaeus setiferus (Linn.), in captivity. Tulane Studies in Zoology 4: 173-190.

Joyce, E. A., Jr. 1965. The commercial shrimps of the northeast coast of Florida. Florida Board of Conservation, Marine Laboratory. Professional Papers Series No. 6. 224 p.

King, J. E. 1948. A study of the reproductive organs of the common marine shrimp, Penaeus setiferus (Linnaeus). Biological Bulletin 94: 244-262.

Kutkuhn, J. H. 1966. The role of estuaries in the development and perpetuation of commercial shrimp resources, p. 16-36. In R. F. Smith, A. H. Swartz, and W. H. Massmann (ed.). A Symposium on Estuarine Fisheries. American Fisheries Society Special Publications No. 3.

Lindner, M. J., and W. W. Anderson. 1956. Growth, migrations, spawning and size distribution of shrimp Penaeus setiferus. Fishery Bulletin of the Fish and Wildlife Service 56: 553-645.

Loesch, H. 1965. Distribution and growth of penaeid shrimp in Mobile Bay, Alabama. Publications of the Institute of Marine Science, University of Texas 10: 41-58.

Lunz, G. Robert. 1958. Pond cultivation of shrimp in South Carolina. Proceedings of the Gulf and Caribbean Fisheries Institute 10: 44-48.

Lunz, G. Robert. 1968. Farming the salt marsh, p. 172-177. In J. D. Newsom (ed.) Proceedings of Marsh and Estuary Management Symposium. Division of Continuing Education, Louisiana State University, Baton Rouge.

McCoy, E. G. 1968. Migration, growth and mortality of North Carolina pink and brown penaeid shrimps. North Carolina Department of Conservation and Development, Division of Commercial and Sports Fisheries. Special Scientific Report No. 15. 26 p.

McCoy, E. G. 1972. Dynamics of North Carolina commercial shrimp populations. North Carolina Department of Conservation and Development, Division of Commercial and Sports Fisheries. Special Scientific Report No. 21. 53 p.

Mock, C. 1967. Natural and altered estuarine habitats of penaeid shrimp. Proceedings of the Gulf and Caribbean Fisheries Institute 19: 86-98.

Odum, E. P. 1971. Fundamentals of ecology. W. B. Saunders Company, Philadelphia. 574 p.

Panikkar, N. K. 1951. Physiological aspects of adaptation to estuarine conditions. Proceed-

ings of the Indo-Pacific Fisheries Council 2: 168-175.

Panikkar, N. K. 1969. Osmotic behaviour of shrimps and prawns in relation to their biology and culture. FAO Fisheries Report 57: 527-538.

Parker, J. C. 1970. Distribution of juvenile brown shrimp (Penaeus aztecus Ives) in Galveston Bay, Texas, as related to certain hydrographic features and salinity. Contributions in Marine Science 15: 1-12.

Pullen, E. J., and W. Lee Trent. 1969. White shrimp emigration in relation to size, sex, temperature, and salinity. FAO Fisheries Report 57: 1001-1014.

Renfro, W. C., and H. A. Brusher. 1963. Spawning populations, p. 13-17. In Fishery Research, Biological Laboratory, Galveston, Texas, fiscal year 1962. U. S. Fish and Wildlife Service, Circular No. 161.

Ringo, Robert D. 1965. Dispersion and growth of young brown shrimp, p. 68-70. In Fishery Research, Biological Laboratory, Galveston, Texas, fiscal year 1964. U. S. Fish and Wildlife Service, Circular No. 230.

Rose, C. D., A. H. Harris, and B. Wilson. 1975. Extensive culture of penaeid shrimp in Louisiana salt-marsh impoundments. Transactions of the American Fisheries Society 104: 296-307.

St. Amant, L. S., J. G. Broom, and T. B. Ford. 1966. Studies of the brown shrimp, Penaeus aztecus, in Barataria Bay, Louisiana, 1962-1965. Proceedings of the Gulf and Caribbean Fisheries Institute 18: 1-17.

St. Amant, L. S. 1973. Shellfish and crustacean productivity in marshes and estuaries, p. 151-161. In R. H. Chabreck (ed.), Proceedings of the Coastal Marsh and Estuary Management Symposium, Louisiana State University, Baton Rouge.

Shealy, M. H., Jr., J. V. Miglarese, and E. B. Joseph. 1974. Bottom fishes of South Carolina estuaries -- relative abundance, seasonal distribution, and length-frequency relationships. South Carolina Marine Resources Center, Technical Report No. 6. 189 p.

South Carolina Landings. 1973-1975. National Marine Fisheries Service, NOAA, Department of Commerce. Washington, D. C.

Springer, S., and H. R. Bullis, Jr. 1952. Exploratory shrimp fishing in the Gulf of Mexico, 1950-1951. U. S. Fish and Wildlife Service, Fisheries Leaflet 406. 34 p.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481 p.

Teal, J. M. 1962. Energy flow in the salt marsh ecosystem of Georgia. Ecology 43: 614-624.

Trent, L., E. J. Pullen, and R. Proctor. 1976. Abundance of macrocrustaceans in a natural marsh and a marsh altered by dredging, bulkheading, and filling. Fishery Bulletin 74: 195-200.

Venice system. 1959. Final resolution, p. 243-245. In symposium on the classification of brackish waters. Archivio di Oceanografia e Limnologia XI. Supplement.

Viosca, Percy, Jr. 1920. Report of the biologist, p. 120-130. Louisiana Department of Conservation, Fourth Biennial Report 1918-1920.

Viosca, Percy, Jr. 1957. The Louisiana shrimp story. Louisiana Wild Life and Fisheries Commission, Wildlife Education Bulletin No. 40. 16 p.

Weymouth, F. W., M. J. Lindner, and W. W. Anderson. 1933. Preliminary report on the life history of the common shrimp Penaeus setiferus (Linn.). Bulletin of the Bureau of Fisheries 48: 1-26.

White, Charles J. 1975. Effects of 1973 river flood water on brown shrimp in Louisiana estuaries. Louisiana Wildlife and Fisheries Commission; Oysters, Water Bottoms, and Seafoods Division, Technical Bulleton No. 16. 24 p.

Wickham, D. A., and F. C. Minkler, III. 1975. Laboratory observations on daily patterns of burrowing and locomotor activity of pink shrimp, Penaeus duorarum, brown shrimp, Penaeus aztecus, and white shrimp, Penaeus setiferus. Contributions in Marine Science 19: 21-35.

Williams, A. B. 1955. A contribution to the life histories of commercial shrimps (Penaeidae) in North Carolina. Bulletin of Marine Science of the Gulf and Caribbean 5: 116-146.

Williams, A. B. 1958. Substrates as a factor in shrimp distribution. Limnology and Oceanography 3: 283-290.

Williams, A. B. 1960. The influence of temperature on osmotic regulation in two species of estuarine shrimps (Penaeus). Biological Bulletin 119: 560-571.

Williams, A. B. 1965. Marine decapod crustaceans of the Carolinas. Fishery Bulletin 65: 1-298.

Zein-Eldin, Zoula P. 1963. Effect of salinity on growth of postlarval penaeid shrimp. Biological Bulletin 125: 188-196.

Zein-Eldin, Zoula P., and D. V. Aldrich. 1965. Growth and survival of postlarval Penaeus aztecus under controlled conditions of temperature and salinity. Biological Bulletin 129: 199-216.

Zein-Eldin, Zoula P., and G. W. Griffith. 1969. An appraisal of the effects of salinity and temperature on growth and survival of postlarval penaeids. FAO Fisheries Report 57: 1015-1026.

Appendix 1. Number of Penaeus setiferus caught seasonally and number of trawl tows within each salinity increment (3°/oo) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Season	Salinity Increments												Season Total	Two Year Total
	0.00-2.99	3.00-5.99	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99	33.00-35.99		
Spring (Mar, Apr, May)														
Number Caught	1	189	274	6	874	830	622	313	429	128	0	0	3,666	
Number Tows	26	4	2	1	6	14	10	13	9	9	0	0	94	
cpue	0.04	47.25	137.00	6.00	145.67	59.29	62.20	24.08	47.67	14.22	-	-		
Mean cpue = 39.00														
Summer (Jun, Jul, Aug)														
Number Caught	5,327	1,198	557	0	52	1,462	689	590	934	1,110	51	12	11,982	
Number Tows	21	5	3	0	4	4	6	7	22	14	9	1	96	
cpue	253.67	239.60	185.67	-	13.00	365.50	114.83	84.29	42.45	79.29	5.67	12.00		
Mean cpue = 124.81														
Fall (Sep, Oct, Nov)														
Number Caught	827	4,681	1,000	584	3,153	483	3460	3,791	7,052	7,637	926	54	33,648	
Number Tows	11	5	1	3	7	1	4	6	15	25	14	2	94	
cpue	75.18	936.20	1,000.00	194.67	450.43	483.00	865.00	631.83	470.13	305.48	66.14	27.00		
Mean cpue = 357.96														
Winter (Dec, Jan, Feb)														
Number Caught	26	299	74	215	1,883	29	28	202	7,380	4,620	1,942	0	16,698	
Number Tows	18	8	1	2	5	6	2	4	16	20	13	0	95	
cpue	1.44	37.38	74.00	107.50	376.60	4.83	14.00	50.50	461.25	231.00	149.38	-		
Mean cpue = 175.77														
Total														
Number Caught	6,181	6,367	1,905	805	5,962	2,804	4,799	4,896	15,795	13,495	2,919	66		65,994
Number Tows	76	22	7	6	22	25	22	30	62	68	36	3		379
cpue	81.33	289.41	272.14	134.17	271.00	112.16	218.14	163.20	254.76	198.46	81.08	22.00		
Mean cpue = 174.13														

Appendix 2. Number of Penaeus setiferus caught and number of trawl tows within each salinity increment (3°/oo) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Estuary	Salinity Increments												Estuary Total	Two Year Total
	0.00-2.99	3.00-5.99	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99	33.00-35.99		
Cooper River-Charleston Harbor														
Number Caught	4,703	6,066	385	492	2,615	489	3,322	2,321	7,571	572	343	0	28,879	
Number Tows	32	15	3	3	7	2	5	3	10	7	5	0	92	
cpue	146.97	404.40	128.33	164.00	373.57	244.50	664.40	773.67	757.10	81.71	68.60	-		
Mean cpue = 313.90														
North Edisto														
Number Caught	0	0	0	6	922	809	1,477	2,316	8,146	12,692	2,471	12	28,851	
Number Tows	0	0	0	1	9	15	16	24	49	53	21	1	189	
cpue	-	-	-	6.00	102.44	53.93	92.31	96.50	166.24	239.47	117.67	12.00		
Mean cpue = 152.65														
South Edisto														
Number Caught	1,478	301	1,520	307	2,425	1,506	0	259	78	231	105	54	8,264	
Number Tows	44	7	4	2	6	8	1	3	3	8	7	2	95	
cpue	33.59	43.00	380.00	153.50	404.17	188.25	0.00	86.33	26.00	28.88	15.00	27.00		
Mean cpue = 86.99														
Total														
Number Caught	6,181	6,367	1,905	805	5,962	2,804	4,799	4,896	15,795	13,495	2,919	66		65,994
Number Tows	76	22	7	6	22	25	22	30	62	68	36	3		379
cpue	81.33	289.41	272.14	134.17	271.00	112.16	218,14	163.20	254.76	198.46	81.08	22.00		
Mean cpue = 174.13														

Appendix 3. Number of Penaeus setiferus caught seasonally and number of trawl tows within each temperature increment (3°C) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Season	Temperature Increments									Season Total	Two Year Total
	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99		
Spring (Mar, Apr, May)											
Number Caught	0	0	516	1,194	948	844	164	0	0	3,666	
Number Tows	0	0	7	37	17	32	1	0	0	94	
cpue	-	-	73.71	32.27	55.76	26.38	164.00	-	-		
Mean cpue = 39.00											
Summer (Jun, Jul, Aug)											
Number Caught	0	0	0	0	0	0	356	11,626	0	11,982	
Number Tows	0	0	0	0	0	0	27	68	0	95	
cpue	-	-	-	-	-	-	13.19	170.97	-		
Mean cpue = 126.13											
Fall (Sep, Oct, Nov)											
Number Caught	0	0	2	804	5,071	5,500	5,116	14,371	3,609	34,473	
Number Tows	0	0	1	5	24	14	11	38	3	96	
cpue	-	-	2.00	160.80	211.29	329.86	465.09	378.18	1,203.00		
Mean cpue = 359.09											
Winter (Dec, Jan, Feb)											
Number Caught	193	1,690	3,787	10,781	247	0	0	0	0	16,698	
Number Tows	8	26	33	23	5	0	0	0	0	95	
cpue	24.13	65.00	114.76	468.74	49.40	-	-	-	-		
Mean cpue = 175.77											
Total											
Number Caught	193	1,690	4,305	12,779	6,266	6,344	5,636	25,997	3,609		66,819
Number Tows	8	26	41	65	46	46	39	106	3		380
cpue	24.13	65.00	105.00	196.60	136.22	137.91	144.51	245.25	1,203.00		
Mean cpue = 175.84											

Appendix 4. Number of Penaeus setiferus caught and number of trawl tows within each temperature increment (3°C) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Estuary	Temperature Increments									Estuary Total	Two Year Total
	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99		
Cooper River-Charleston Harbor											
Number Caught	0	0	3,136	5,490	3,967	849	5,044	11,217	0	29,703	
Number Tows	0	7	18	12	7	9	17	23	0	93	
cpue	-	0.00	174.22	457.50	566.71	94.33	296.71	487.70	-		
Mean cpue = 319.39											
North Edisto											
Number Caught	27	1,615	1,067	4,667	1,921	5,449	341	10,155	3,609	28,851	
Number Tows	2	14	17	32	27	27	13	57	3	192	
cpue	13.50	115.36	62.76	145.84	71.15	201.81	26.23	178.16	1,203.00		
Mean cpue = 150.27											
South Edisto											
Number Caught	166	75	102	2,622	378	46	251	4,625	0	8,265	
Number Tows	6	5	6	21	12	10	9	26	0	95	
cpue	27.67	15.00	17.00	124.86	31.50	4.60	27.89	177.88	-		
Mean cpue = 87.00											
Total											
Number Caught	193	1,690	4,305	12,779	6,266	6,344	5,636	25,997	3,609		66,819
Number Tows	8	26	41	65	46	46	39	106	3		380
cpue	24.13	65.00	105.00	196.60	136.22	137.91	144.51	245.25	1,203.00		
Mean cpue = 175.84											

Appendix 5. Number of Penaeus aztecus caught seasonally and number of trawl tows within each salinity increment (3°/oo) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Season	Salinity Increments												Season Total	Two Year Total
	0.00-2.99	3.00-5.99	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99	33.00-35.99		
Spring (Mar, Apr, May)														
Number Caught	0	0	0	0	0	16	5	4	10	1	0	0	36	
Number Tows	26	4	2	1	6	14	10	13	9	9	0	0	94	
cpue	0.00	0.00	0.00	0.00	0.00	1.14	0.50	0.31	1.11	0.11	-	-		
Mean cpue = 0.38														
Summer (Jun, Jul, Aug)														
Number Caught	75	670	221	0	93	241	255	75	1,970	307	219	1	4,127	
Number Tows	21	5	3	0	4	4	6	7	22	14	9	1	96	
cpue	3.57	134.00	73.67	-	23.25	60.25	42.50	10.71	89.55	21.93	24.33	1.00		
Mean cpue = 42.99														
Fall (Sep, Oct, Nov)														
Number Caught	0	0	1	0	0	0	0	4	0	1	14	1	21	
Number Tows	11	5	1	3	7	1	4	6	15	25	14	2	94	
cpue	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.67	0.00	0.04	1.00	0.50		
Mean cpue = 0.22														
Winter (Dec, Jan, Feb)														
Number Caught	0	1	0	0	0	0	1	1	2	0	1	0	6	
Number Tows	18	8	1	2	5	6	2	4	16	20	13	0	95	
cpue	0.00	0.12	0.00	0.00	0.00	0.00	0.50	0.25	0.12	0.00	0.08	-		
Mean cpue = 0.06														
Total														
Number Caught	75	671	222	0	93	257	261	84	1,983	309	234	2		4,191
Number Tows	76	22	7	6	22	25	22	30	62	68	36	3		379
cpue	0.99	30.50	31.71	0.00	4.23	10.28	11.86	2.80	31.98	4.54	6.50	0.67		
Mean cpue = 11.06														

.dix 6. Number of Penaeus aztecus caught and number of trawl tows within each salinity increment (3°/oo) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Estuary	Salinity Increments												Estuary Total	Two Year Total
	0.00-2.99	3.00-5.99	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99	33.00-35.99		
Cooper River-Charleston Harbor														
Number Caught	74	671	152	0	0	0	169	16	889	1	2	0	1,974	
Number Tows	32	15	3	3	7	2	5	3	10	7	5	0	92	
cpue	2.31	44.73	50.67	0.00	0.00	0.00	33.80	5.33	88.90	0.14	0.40	-		
Mean cpue = 21.46														
North Edisto														
Number Caught	0	0	0	0	92	26	53	68	1,087	307	173	1	1,807	
Number Tows	0	0	0	1	9	15	16	24	49	53	21	1	189	
cpue	-	-	-	0.00	10.22	1.73	3.31	2.83	22.18	5.79	8.24	1.00		
Mean cpue = 9.56														
South Edisto														
Number Caught	1	0	70	0	1	231	39	0	7	1	59	1	410	
Number Tows	44	7	4	2	6	8	1	3	3	8	7	2	95	
cpue	0.02	0.00	17.50	0.00	0.17	28.88	39.00	0.00	2.33	0.13	8.43	0.50		
Mean cpue = 4.32														
Total														
Number Caught	75	671	222	0	93	257	261	84	1,983	309	234	2		4,191
Number Tows	76	22	7	6	22	25	22	30	62	68	36	3		379
cpue	0.99	30.50	31.71	0.00	4.23	10.28	11.86	2.80	31.98	4.54	6.50	0.67		
Mean cpue = 11.06														

Appendix 7. Number of Penaeus aztecus caught seasonally and number of trawl tows within each temperature increment (3°C) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Season	Temperature Increments									Season Total	Two Year Total
	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99		
Spring (Mar, Apr, May)											
Number Caught	0	0	0	16	1	19	0	0	0	36	
Number Tows	0	0	7	37	17	32	1	0	0	94	
cpue	-	-	0.00	0.43	0.06	0.59	0.00	-	-		
Mean cpue = 0.38											
Summer (Jun, Jul, Aug)											
Number Caught	0	0	0	0	0	0	2,166	1,960	0	4,126	
Number Tows	0	0	0	0	0	0	27	68	0	95	
cpue	-	-	-	-	-	-	80.22	28.82	-		
Mean cpue = 43.43											
Fall (Sep, Oct, Nov)											
Number Caught	0	0	0	0	2	0	0	17	2	21	
Number Tows	0	0	1	5	24	14	11	38	3	96	
cpue	-	-	0.00	0.00	0.08	0.00	0.00	0.45	0.67		
Mean cpue = 0.22											
Winter (Dec, Jan, Feb)											
Number Caught	0	1	5	0	0	0	0	0	0	6	
Number Tows	8	26	33	23	5	0	0	0	0	95	
cpue	0.00	0.04	0.15	0.00	0.00	-	-	-	-		
Mean cpue = 0.06											
Total											
Number Caught	0	1	5	16	3	19	2,166	1,978	2		4,190
Number Tows	8	26	41	65	46	46	39	106	3		380
cpue	0.00	0.04	0.12	0.25	0.07	0.41	55.54	18.66	0.67		
Mean cpue = 11.03											

Appendix 8. Number of Penaeus aztecus caught and number of trawl tows within each temperature increment (3°C) in the Cooper River-Charleston Harbor, North Edisto, and South Edisto estuaries, South Carolina, from February 1973 through January 1975.

Estuary	Temperature Increments									Estuary Total	Two Year Total
	6.00-8.99	9.00-11.99	12.00-14.99	15.00-17.99	18.00-20.99	21.00-23.99	24.00-26.99	27.00-29.99	30.00-32.99		
Cooper River-Charleston Harbor											
Number Caught	0	0	2	0	1	4	1,671	296	0	1,974	
Number Tows	0	7	18	12	7	9	17	23	0	93	
cpue	-	0.00	0.11	0.00	0.14	0.44	98.29	12.87	-		
Mean cpue = 21.23											
North Edisto											
Number Caught	0	1	2	10	1	15	385	1,391	2	1,807	
Number Tows	2	14	17	32	27	27	13	57	3	192	
cpue	0.00	0.07	0.12	0.32	0.04	0.56	29.62	24.40	0.67		
Mean cpue = 9.41											
South Edisto											
Number Caught	0	0	1	6	1	0	110	291	0	409	
Number Tows	6	5	6	21	12	10	9	26	0	95	
cpue	0.00	0.00	0.17	0.29	0.08	0.00	12.22	11.19	-		
Mean cpue = 4.31											
Total											
Number Caught	0	1	5	16	3	19	2,166	1,978	2		4,190
Number Tows	8	26	41	65	46	46	39	106	3		380
cpue	0.00	0.04	0.12	0.25	0.07	0.41	55.54	18.66	0.67		
Mean cpue = 11.03											