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Species Composition, Distribution, and Relative Abundance of Fishes in the Coastal Habitat off the Southeastern United States

Charles A. Wenner
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U.S. Department of Commerce

NOAA TECHNICAL REPORT NMFS

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National Marine Fisheries Service
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Species Composition, Distribution, and Relative Abundance of Fishes in the Coastal Habitat off the Southeastern United States[1]

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ABSTRACT

Ichthyofauna of the coastal (<10 m depth) habitat of the South Atlantic Bight were investigated between Cape Fear, North Carolina, and the St. John's River, Florida. Trawl collections from four nonconsecutive seasons in the period July 1980 to December 1982 indicated that the fish community is dominated by the family Sciaenidae, particularly juvenile forms. Spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*) were the two most abundant species and dominated catches during all seasons. Atlantic menhaden (*Brevoortia tyrannus*) was also very abundant, but only seasonally (winter and spring) dominant in the catches. Elasmobranch fishes, especially rajiforms and carcharinids, contributed to much of the biomass of fishes collected. Total fish abundance was greatest in winter and lowest in summer and was influenced by the seasonality of Atlantic menhaden and Atlantic croaker in the catches. Biomass was highest in spring and lowest in summer, and was influenced by biomass of spot. Fish density ranged from 321 individuals and 12.2 kg per hectare to 746 individuals and 25.2 kg per hectare. Most species ranged widely throughout the bight, and showed some evidence of seasonal migration. Species assemblages were dominated by ubiquitous year-round residents of the coastal waters of the bight. Diversity (H') was highest in summer, and appeared influenced by the evenness of distribution of individuals among species.

[1]Contribution no. 270 of the South Carolina Marine Resources Center.

Introduction

Investigations of the ichthyofauna of the South Atlantic Bight (SAB, herein defined as the area between Cape Fear, North Carolina [33.9°N] and Cape Canaveral, Florida [28.5°N]) were initiated by the Bureau of Commercial fisheries during exploratory fishing operations off the southeastern U.S. coast. The results of these efforts were summarized by Struhsaker (1969) who presented a generalized habitat scheme based on bottom type and species composition of the fishes. The coastal habitat (0-18 m [0-10 fm]) has a sandy-mud bottom and experiences extensive seasonal temperature and salinity fluctuations relative to other shelf habitats in the region (Struhsaker 1969, Mathews and Pashuk 1977, 1986). Sciaenids are the dominant coastal fishes, and penaeids and portunids are the most abundant decapods (Struhsaker 1969, Wenner and Wenner 1989).

Descriptions of the fish assemblages of the coastal habitat are derived from studies of the bycatch of the penaeid shrimp fishery (Keiser 1976, Anderson and Gehringer 1965, Knowlton 1972). These accounts were concerned with the annual cycle of species composition and relative abundance of the bycatch on a state-by-state basis. This approach, although useful for a general description of the ichthyofauna of the inshore zone, has several limitations. First, since vessels in the fishery use different sized nets, doors, tow times, etc., there is a lack of standardization of the fishing gear. This essentially renders invalid the comparisons of catches from different vessels over a seasonal cycle. It is also difficult to quantify data (in terms of catch/hour) from several vessels that tow differing lengths of time and divide the catch by time towed to obtain catch/hour. This assumes a linear relationship between tow time and catch. Second, shrimp fishermen confine their efforts to discrete areas where penaeid shrimp are most abundant. Locations near estuaries are heavily fished, whereas other areas are very lightly trawled. Thus there was no random sampling, so conclusions drawn from these data are limited. The purpose of this paper is to describe the seasonal species composition, distribution, and relative abundance of coastal fishes in the SAB from regional, standardized otter trawl surveys.

Methods

Surveys

A stratified random sampling design (Grosslein 1969) was used to determine the seasonal distribution and relative abundance of groundfish in coastal waters of the SAB. Thirteen strata were erected in depths of 4.6 to 9.1 m from Cape Fear, North Carolina (33.9°N) to the mouth of the St. John's River, Florida (30.4°N). South of this point to Cape Canaveral, Florida (28.5°N), an additional five strata were delineated with the 5.6-km territorial sea boundary as the offshore boundary (Fig. 1) This change in stratum definition was caused by the steepness of the nearshore shelf in this area. Areas of strata ranged from 7,486 to 31,661 ha ($\bar{x}$ = 17,323 ha).

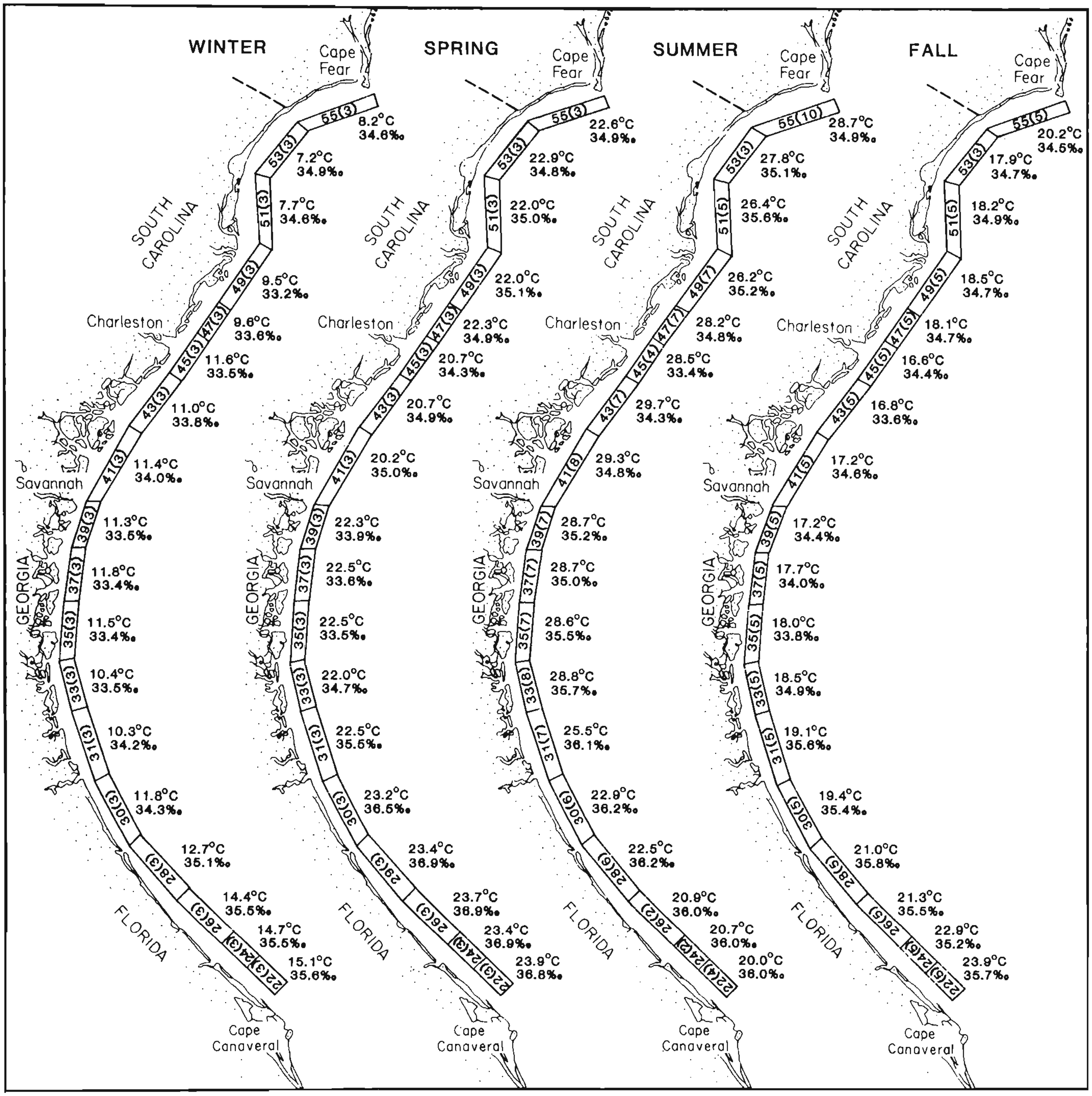

Figure 1

Sampling strata (number in box), number of tows per stratum (number in parentheses in box), bottom temperature, and salinity for each sampling cruise.

At each randomly selected trawl station within a stratum, paired four-seam Gulf of Mexico shrimp trawl nets were towed for 20 min at a speed of 4.4 km/h from either the R/V *Atlantic Sun* (summer, spring, and winter surveys) or the R/V *Lady Lisa* (fall survey). Both vessels were approximately 20 m in length, were formerly involved in the commercial shrimp fishery, and have outriggers that enabled two nets to be fished simultaneously. Characteristics of the fishing gear towed from each outrigger were: 1.5 × 0.8 m wooden and chain doors attached with 61-m bridles to the tow wire; four-seam (12.8-m head rope length, 15.8-m foot rope length) semiballoon trawl net with stretch mesh sizes of 5.1 cm in the wings, 4.4 cm in the body, and 4.1 cm in the cod end attached to the doors. A tickler chain was attached between the doors and adjusted to drag on the bottom 0.6 m in front of the nets. Trawl tows were confined to daylight hours (1 h after sunrise to 1 h before sunset) to eliminate diel changes in availability and vulnerability of groundfish to the trawl gear. At the end of each trawl tow, bottom temperature and salinity samples were taken with a Van Dohrn bottle with an internally mounted stem thermometer. Dates of the survey and sampling effort are in Table 1.

Contents of each net were processed independently. Fishes were sorted to species, counted, weighed to the nearest gram, and either the total catch or a random subsample of very abundant taxa was measured to the nearest cm total length (TL) or fork length (FL).

Table 1
Sampling effort and ratio of the number of possible:actual trawl tows made during each survey in the survey area.

Season	Date	Number of tows	Possible *N* of sample blocks:tows
Winter	7-29 Jan 1982	54	58:1
Spring	28 April-6 June 1981	54	58:1
Summer	15 July-20 Sept 1980	108	29:1
Fall	14 Oct-7 Dec 1982	89	35:1

Biomass and abundance

Catch-per-standard-tow was defined as the combined catch from both trawl nets fished simultaneously at a given stratified random station. The stratified mean catch-per-tow was calculated by the expression (Poole 1974):

$$\bar{y}_{st} = \frac{\sum_{h=1}^{L} N_h \bar{y}_h}{N}$$

where $\bar{y}_{st}$ = stratified mean catch/tow
$\bar{y}_h$ = mean catch/tow in numbers or weight in the h stratum
N = total number of possible sampling units over all strata
N_h = number of possible sampling units in the h stratum.

Frequency distributions of both the number and weight of fish per tow approximated the negative binomial. Data were subjected to a natural logarithmic transformation to standardize the variances and approximate normality. Appropriate parametric tests of significance were employed when the underlying assumptions of the model were met. When these criteria were not met, nonparametric statistical techniques were used.

Minimum biomass and density estimates for trawl-caught groundfish were calculated by the area swept by our trawl gear. The approximation of the area swept was derived from the equation (Roe 1969):

$$a = \frac{(K \cdot M \cdot [0.6H])}{10{,}000 \text{ m}^2/\text{ha}}$$

where a = swept area in hectares
K = speed in meters per hour
M = time in hours fished
H = head rope length in meters.

The result (1.12 ha) was multiplied by two since our standard unit of effort was two nets fished simultaneously. Thus a standard trawl station sampled 2.24 ha.

Community analysis

Species diversity (H') in bits of information per individual was calculated using the Shannon formula (Pielou 1969). The species-richness component of diversity was measured using $D = S\text{-}1/\ln N$, where S is the number of species and N is the number of individuals (Margalef 1968). The evenness component, i.e. the distribution of individuals among species, was measured using $E = H'/H'_{max}$ which is the ratio of the observed diversity (H') of a sample to the maximum H' the sample could have given its number of species (Pielou 1969). Diversity measures were calculated for pooled trawl catches in each stratum during a given survey.

Cluster analysis was used to define assemblages of groundfish and to determine the similarity of strata in species composition and relative abundance of species. Prior to cluster analysis, data from individual trawl tows during a season were pooled by stratum. In effect, this designates a strata with n number of trawl stations occupied during a survey as a single collection. Pooling was done to reduce the data matrix to manageable proportions. Because sampling effort differed among strata, similarity indices for pooled catches for each stratum were calculated on percent standardized data (Boesch 1977). Data were edited before cluster analysis to eliminate species that occurred in less than four strata over the total survey, since these have no discernible distribution pattern and, therefore, contribute no information to the analysis (Boesch 1977). The Bray-Curtis coefficient (Clifford and Stephenson 1975) was used to measure similarity in species composition and relative abundance (percent similarity for standardized data) of collections pooled by stratum and cruise. The Bray-Curtis measure is the most appropriate index to determine percent similarity (Bloom 1981). Normal analysis compared similarities among pooled collections (entities are pooled collections; attributes are the standardized species abundance scores), and inverse analysis compared similarities among the distribution patterns of species (entities are species, attributes are the sites where they occur) (Clifford and Stephenson 1975, Boesch 1977). Entities were classified into groups by using flexible sorting (Lance and Williams 1967), with $\beta = -0.25$. Nodal analysis (Boesch 1977) was used to examine the co-occurrence of species and site groups based on patterns of constancy (frequency of occurrence of members of a particular species group among the collections of a given site group) and fidelity (frequency of species of a species group in a particular site group, relative to other site groups).

Table 2
Top 25 species by numerical abundance for the four seasonal coastal surveys in the South Atlantic Bight, including seasonal rank and percent of catch.

	Total catch		Seasonal rank (% catch)			
Species	Total no.	% catch	Winter	Spring	Summer	Fall
Leiostomus xanthurus	101,062	29.4	2 (29.9)	1 (55.1)	1 (12.6)	3 (12.0)
Micropogonias undulatus	39,165	11.4	3 (22.8)	2 (8.8)	4 (7.6)	16 (1.4)
Brevoortia tyrannus	36,949	10.7	1 (33.0)	8 (1.5)	45 (0.1)	35 (0.1)
Anchoa mitchilli	25,233	7.3	4 (6.0)	4 (6.8)	8 (5.1)	2 (12.4)
Stellifer lanceolatus	16,154	4.7	5 (2.5)	13 (0.9)	3 (8.6)	4 (8.9)
Cynoscion nothus	14,911	4.3	12 (0.3)	19 (0.5)	10 (2.9)	1 (16.8)
Prionotus carolinus	11,601	3.4	51 (<0.1)	3 (7.4)	6 (6.5)	55 (<0.1)
Larimus fasciatus	10,262	3.0	16 (0.2)	10 (1.4)	2 (10.2)	11 (2.0)
Anchoa hepsetus	10,233	3.0	14 (0.2)	16 (0.8)	7 (5.2)	6 (7.6)
Menticirrhus americanus	9,346	2.7	11 (0.4)	14 (0.8)	5 (6.9)	7 (4.4)
Symphurus plagiusa	8,780	2.6	9 (0.5)	7 (1.6)	21 (1.1)	5 (8.4)
Chloroscombrus chrysurus	6,341	1.8	72 (<0.1)	11 (1.3)	9 (4.9)	10 (2.2)
Scophthalmus aquosus	4,477	1.3	26 (<0.1)	5 (2.6)	13 (2.1)	21 (0.6)
Anchoa cubana	4,094	1.2	15 (0.2)	6 (1.8)	14 (1.8)	17 (1.2)
Selene setapinnis	3,910	1.1	72 (<0.1)	44 (<0.1)	11 (2.7)	9 (2.7)
Anchoa lyolepis	3,727	1.1	44 (<0.1)	9 (1.5)	18 (1.3)	13 (1.9)
Trichiurus lepturus	3,580	1.0	25 (0.1)	22 (0.4)	19 (1.3)	8 (3.1)
Cynoscion regalis	3,094	0.9	8 (0.5)	12 (1.0)	23 (0.9)	1 (16.8)
Etropus crossotus	2,901	0.8	13 (0.3)	27 (0.2)	15 (1.8)	14 (1.5)
Opisthonema oglinum	2,823	0.8	10 (0.4)	21 (0.4)	24 (0.9)	12 (1.9)
Trinectes maculatus	2,147	0.6	46 (<0.1)	15 (0.8)	22 (1.0)	20 (0.9)
Centropristis philadelphica	1,857	0.5	30 (<0.1)	35 (0.1)	19 (1.4)	19 (1.0)
Arius felis	1,839	0.5	—	26 (0.2)	12 (2.2)	45 (<0.1)
Citharichthys macrops	1,761	0.5	18 (0.1)	25 (0.2)	16 (1.5)	25 (0.5)
Peprilus triacanthus	1,702	0.5	7 (0.6)	17 (0.6)	35 (0.3)	23 (0.5)
Total *n*	327,949		106,663	91,483	67,701	68,147
Total *N*	344,116		107,045	93,074	72,844	71,153
Percent *n*/*N*	95.3		99.6	98.3	92.9	95.8

Results and discussion

Species composition

The 305 trawl stations from the four seasonal research survey cruises in the SAB collected 344,116 fishes in 147 species (Appendix 1) belonging to 52 families with a total weight of 12,106.7 kg. The Sciaenidae ranked first by both numbers and weight and accounted for 56.5 and 66.5% of the total number and weight, respectively, of fishes taken during all seasons. Spot (*Leiostomus xanthurus*) ranked first in total number and total weight of all species for the four seasons combined, and was first by weight in all seasons (Tables 2 and 3). Although not included in the top 25 numerically dominant species, rajiform elasmobranchs (*Dasyatis centroura*, *D. sayi*, *Rhinoptera bonasus*, *Raja eglanteria*, and *Myliobatis fremenvillei*) and the carcharhinid *Rhizoprionodon terraenovae* were among the 25 most important species by weight because of their large size relative to the juvenile teleosts that dominated by number (Table 3). The 25 most numerous species accounted for 95.3% of the total numbers of fishes for all surveys, whereas the top 25 species by weight composed 90.6% of the total weight. Seven of the top 25 species by numbers and weight were sciaenids, a pattern that was seasonally consistent. Thus, the coastal area of the SAB is largely a sciaenid habitat.

Some seasonal changes were apparent in the dominant species. For example, during the winter survey, Atlantic menhaden (*Brevoortia tyrannus*) was most numerous, accounting for 33.0% of the total catch (Table 2). The total number caught during this season was an order of magnitude higher than during the spring, when *B. tyrannus* was the eighth most numerous species. In the summer and fall Atlantic menhaden did not rank in the top 25 species. Butterfish (*Peprilus triacanthus*), though not as abundant as Atlantic menhaden, showed a similar seasonal pattern of abundance. Silver seatrout (*C. nothus*), striped anchovy (*A. hepsetus*), southern kingfish (*M. americanus*), and weakfish (*C. regalis*) were most abundant in the fall, but ranked low in abundance during other seasons (Table 2).

Table 3
Top 25 species by weight for the four seasonal coastal surveys in the South Atlantic Bight, including seasonal rank and percent of catch.

Species	Total catch: Total weight (kg)	Total catch: % catch	Seasonal rank (% catch): Winter	Spring	Summer	Fall
Leiostomus xanthurus	4,758.66	39.3	1 (40.4)	1 (65.4)	1 (25.0)	1 (19.6)
Micropogonias undulatus	1,736.50	14.3	2 (33.8)	2 (7.3)	2 (13.9)	9 (2.5)
Menticirrhus americanus	608.84	5.0	6 (1.0)	5 (1.6)	3 (9.2)	2 (9.7)
Brevoortia tyrannus	569.92	4.7	3 (16.1)	4 (1.6)	44 (0.5)	38 (0.3)
Symphurus plagiusa	274.70	2.3	10 (0.5)	9 (1.4)	20 (0.8)	6 (6.6)
Dasyatis centroura	271.83	2.2	—	8 (1.5)	—	4 (7.7)
Larimus fasciatus	260.29	2.1	31 (<0.1)	12 (1.0)	5 (7.4)	22 (0.9)
Cynoscion nothus	259.43	2.1	22 (0.1)	18 (0.7)	12 (1.6)	5 (6.7)
Arius felis	251.14	2.1	—	16 (0.7)	4 (8.3)	47 (0.1)
Rhinoptera bonasus	222.64	1.8	—	—	55 (0.1)	3 (7.7)
Raja eglanteria	214.64	1.8	24 (0.1)	6 (1.6)	38 (0.2)	7 (5.3)
Stellifer lanceolatus	211.85	1.7	9 (0.8)	21 (0.5)	6 (3.0)	8 (3.1)
Chloroscombrus chrysurus	165.74	1.4	78 (<0.1)	3 (2.6)	8 (2.5)	37 (0.3)
Cynoscion regalis	162.69	1.3	7 (0.8)	7 (1.5)	16 (1.0)	11 (2.0)
Trichiurus lepturus	125.64	1.0	36 (<0.1)	25 (0.4)	7 (3.0)	19 (1.1)
Synodus foetens	106.22	0.9	38 (<0.1)	23 (0.5)	10 (2.3)	20 (1.0
Prionotus carolinus	104.43	0.9	57 (<0.1)	11 (1.2)	9 (2.4)	70 (<0.1)
Pomatomus saltatrix	100.57	0.8	15 (0.2)	15 (0.7)	25 (0.5)	12 (1.9)
Paralichthys dentatus	94.82	0.8	11 (0.5)	22 (0.5)	13 (1.4)	21 (0.9)
Dasyatis sayi	94.26	0.8	29 (0.1)	17 (0.7)	42 (0.2)	10 (2.2)
Scophthalmus aquosus	83.25	0.7	26 (0.1)	14 (0.8)	14 (1.2)	27 (0.8)
Rhizoprionodon terraenovae	82.48	0.7	—	19 (0.7)	11 (2.2)	61 (<0.1)
Anchoa hepsetus	77.37	0.6	28 (0.1)	31 (0.2)	21 (0.7)	14 (1.7)
Trinectes maculatus	75.04	0.6	50 (<0.1)	13 (0.8)	19 (0.8)	23 (0.8)
Myliobatis fremenvillei	66.53	0.5	—	10 (1.2)	69 (<0.1)	24 (0.8)
Total w	10,969.48		3,097.77	3,338.56	2,468.63	2,619.25
Total W	12,106.70		3,114.26	3,474.21	2,662.67	2,855.58
Percent w/W	90.6		99.5	96.1	92.7	91.7

Biomass and abundance

The stratified mean catch-per-tow for all fishes was highest by number in the winter and lowest in summer (Table 4), and this pattern appeared to be greatly influenced by the seasonality of *Brevoortia tyrannus* and *Micropogonias undulatus* (Table 5). Stratified mean catch per tow by weight was greatest in spring and least in summer. This was due primarily to large catches of *Leiostomus xanthurus*, and increased biomass of *Cynoscion regalis*, *Prionotus carolinus*, and *Chloroscombrus chrysurus* in spring (Table 5). Numerical density estimates ranged from a minimum of 321 to a maximum of 746 fish/hectare, whereas biomass ranged from 12.2 to 25.2 kg/hectare.

Table 4
Seasonal stratified mean catch/tow by numbers and weight, and density estimates based on a swept area of 2.24 hectares during a standard station.

Season	Stratified mean catch tow: *n*	Stratified mean catch tow: kg	Density: *n*/ha	Density: kg/ha
Winter	1,671	51.529	746	23.004
Spring	1.483	56.491	622	25.219
Summer	719	27.355	321	12.212
Fall	793	32.810	354	14.647

Table 5
Stratified mean catch-per-tow and weights (kg) of 15 most numerous species caught during the coastal survey.

	Winter		Spring		Summer		Fall	
Species	*n*	weight	*n*	weight	*n*	weight	*n*	weight
Leiostomus xanthurus	547	21.638	629	34.312	92	7.038	91	6.103
Micropogonias undulatus	422	17.897	118	1.946	60	2.287	10	1.434
Brevoortia tyrannus	394	6.711	32	1.237	1	0.052	1	0.070
Anchoa mitchilli	103	0.146	111	0.219	26	0.024	89	0.112
Stellifer lanceolatus	45	0.398	13	0.280	51	0.650	72	1.046
Cynoscion nothus	8	0.063	9	0.498	22	0.481	143	2.275
Prionotus carolinus	*	0.001	150	0.900	42	0.571	*	0.007
Larimus fasciatus	4	0.029	22	0.778	77	2.091	15	0.270
Anchoa hepsetus	5	0.048	14	0.125	44	0.223	67	0.601
Menticirrhus americanus	8	0.607	13	0.889	43	2.251	33	3.038
Symphurus plagiusa	9	0.235	21	0.700	8	0.226	62	2.012
Chloroscombrus chrysurus	*	**	24	1.765	35	0.584	15	0.090
Scophthalmus aquosus	1	0.035	38	0.459	15	0.347	6	0.262
Anchoa cubana	4	0.004	29	0.058	14	0.016	9	0.017
Selene setapinnis	*	**	1	0.031	24	0.075	21	0.124
Anchoa lyolepis	*	**	27	0.076	16	0.021	14	0.019
Trichiurus lepturus	7	0.245	7	0.245	7	0.568	30	0.379
Cynoscion regalis	11	0.469	14	0.882	4	0.192	10	0.551
Etropus crossotus	5	0.084	4	0.063	13	0.257	12	0.239
Opisthonema oglinum	8	0.051	6	0.145	7	0.116	19	0.224
Trinectes maculatus	*	0.005	15	0.533	7	0.213	7	0.271
Centropristis philadelphica	1	0.020	1	0.055	17	0.384	8	0.332
Arius felis	0	0.000	3	0.413	14	2.275	*	0.036
Citharichthys macrops	2	0.025	3	0.042	11	0.190	3	0.062
Peprilus triacanthus	9	0.333	8	0.134	2	0.066	4	0.089
Other species	78	2.485	171	9.076	46	5.761	73	13.543
Total	1,671	51.529	1,483	56.491	719	27.355	793	32.810

*<1 individual per tow
**<0.001 kg per tow

Leiostomus xanthurus

Spot ranges from the Rio Grande River to Florida in the Gulf of Mexico and from southern Florida to Massachusetts along the Atlantic coast of the United States (Fischer 1978). It is one of the most widely occurring and abundant species of fish in the coastal waters of the SAB (Keiser 1976, Anderson 1968). Spot is an important member of the estuarine fish community in states throughout the region (North Carolina, Weinstein 1979; South Carolina, Wenner et al. 1982; Georgia, Dahlberg 1972). In continental shelf waters it has been reported from the surf zone (Anderson et al. 1977), coastal waters (Keiser 1976, Struhsaker 1969) to depths as great as 110 m (Wenner et al. 1979a).

We found spot to rank first in both numerical abundance and weight (Tables 2 and 3). This species occurred during all surveys throughout the SAB regardless of season (Fig. 2). There was no significant difference in the frequency of occurrence of *L. xanthurus* between seasons at the 95% probability level (χ^2 = 7.02, df = 3); however, maximum catches occurred in spring (51,281 individuals) and minimum catches occurred in fall (8,528). Spot were taken at 89% of the 305 stations made during the four surveys.

The mean catch-per-tow was highest in two strata off Georgia during winter; catches from summer and fall were moderate throughout the region (Fig. 2). The stratified mean catch/tow both in numbers and weight was highest in spring and lowest in the fall (Table 5). Length-frequency distributions indicate that two or possibly three age-classes (Young-of-year, I, II) were present in the SAB (Fig. 3).

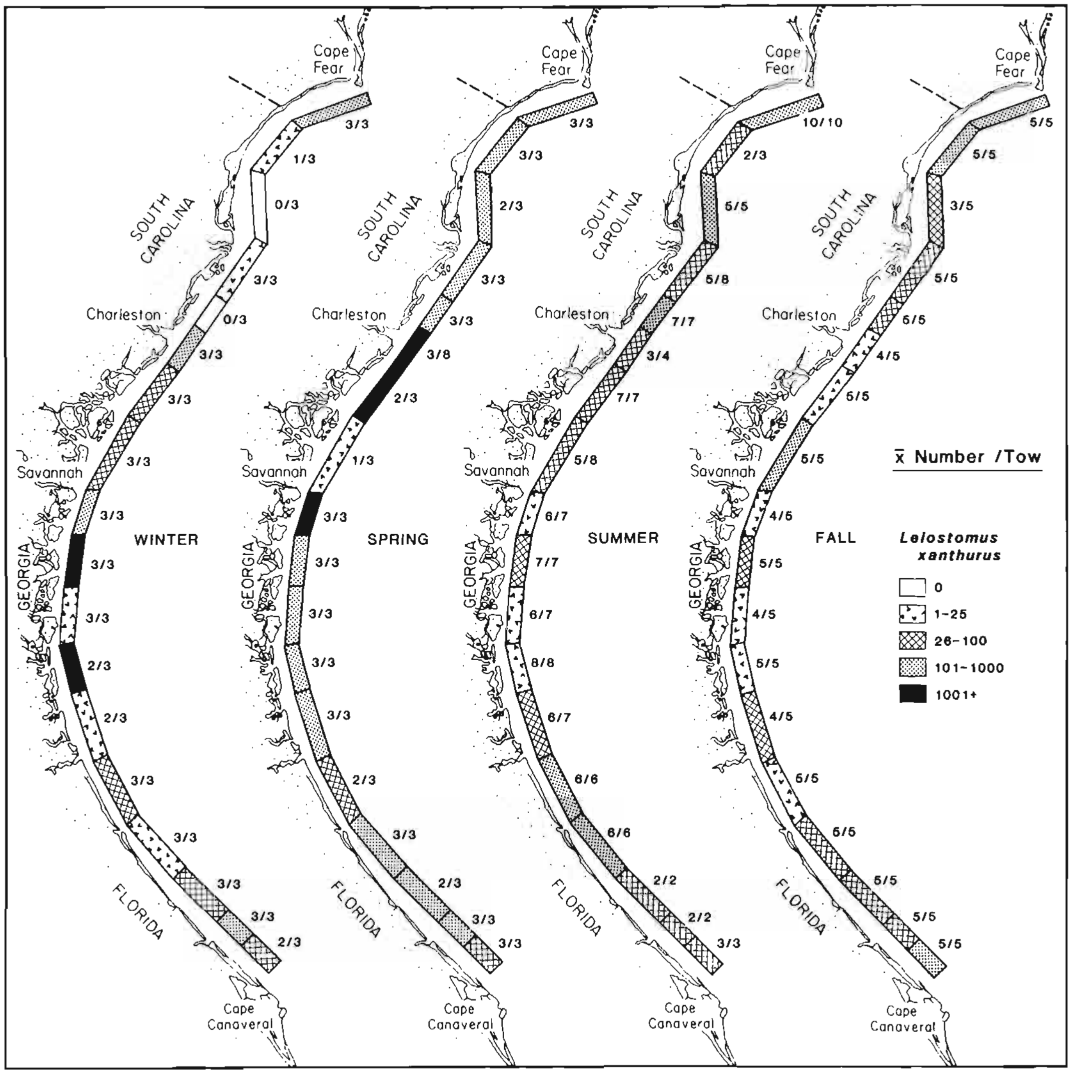

Figure 2
Seasonal catch rates in coastal strata. n/N=no. tows with spot/no. tows in stratum.

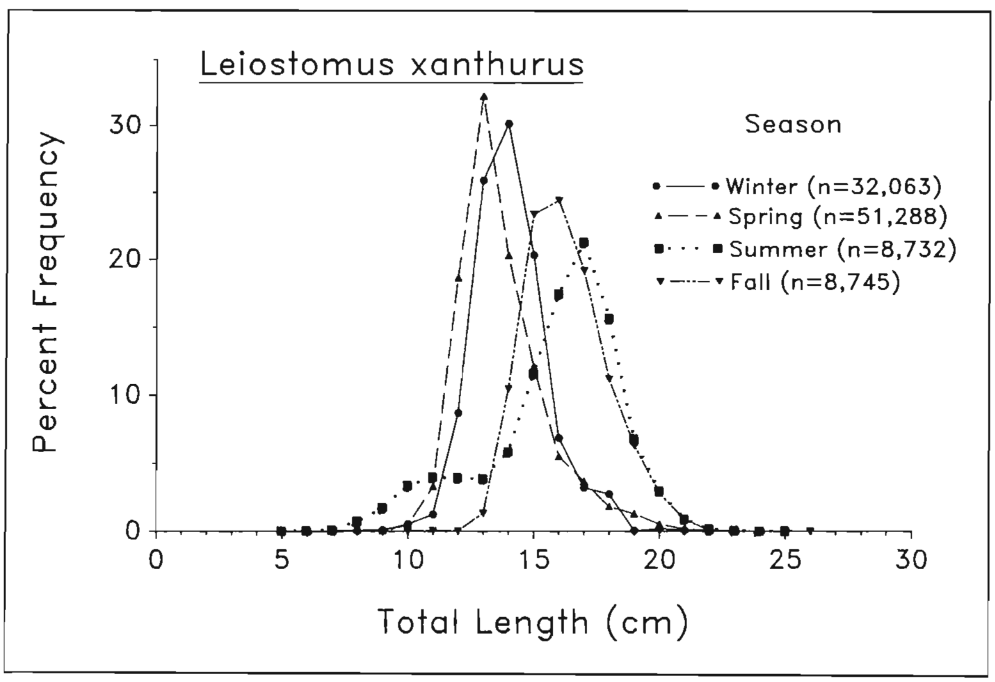

Figure 3
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Atlantic croaker is an abundant sciaenid that occurs in coastal and estuarine waters of the western Atlantic from Argentina to Massachusetts, USA (Fischer 1978). In the coastal and estuarine waters of the SAB, *M. undulatus* is one of the most abundant and widely occurring species of fishes (Wenner et al. 1982, 1984; Dahlberg 1972, Miglarese et al. 1982). Atlantic croaker spawn offshore over an extended period (Middle Atlantic Bight off Chesapeake Bay, fall [Hildebrand and Schroeder 1928]; off North Carolina, September to May [Hildebrand and Cable 1930]; South Carolina, October to January [Bearden 1964]; Gulf of Mexico, September to late March [White and Chittenden 1977]). In continental shelf waters of the SAB, neuston samples in fall (October-November) and winter (February-March) collected larval *M. undulatus* (Powles and Stender 1976). Larvae move from offshore waters into the estuarine nursery grounds of the SAB (Weinstein et al. 1980, Shenker and Dean 1979). Small individuals tend to be found in the upper, lower-salinity reaches of estuaries (Chao and Musick 1977, McGovern and Wenner, in prep.). As *M. undulatus* grows, it moves down estuary so that increased size is correlated with increased salinity (Chao and Musick 1977, Bearden 1964). Atlantic croaker leave the estuaries in the fall (Bearden 1964) and those that have attained sexual maturity move offshore to spawn.

In addition to being an important seasonal component of the estuarine ichthyofauna, *M. undulatus* constitutes a significant part of the coastal fish community of the SAB. The data of Anderson (1968) for catches of Atlantic croaker along the South Atlantic coast indicated marked seasonal changes in the abundance of Atlantic croakers. Catches were very low off all states during late winter and spring, and reached a maximum during late summer and early fall. This pattern is consistent with other accounts from this area (Keiser 1976, Knowlton 1972).

In the present study, *M. undulatus* ranked second by both numerical abundance and weight (Tables 2,3), and composed 11.38% of the total number and 14.34% of the weight of fishes collected. This species occurred in 69% of trawl samples; however, significant differences in the frequencies of occurrence were noted among seasons (χ^2 = 18.37, df = 3, p>0.05). Subsequent analysis showed that *M. undulatus* was taken significantly more frequently in the summer and fall than during the winter and spring (χ^2 = 19.57, df = 1, p>0.05); however, greatest abundance of individuals (24,400) occurred in winter and least abundance in fall (982 individuals). During the winter and spring surveys, *M. undulatus* was taken more often in trawl tows made south of Savannah, Georgia (winter: south 67%, north 45%; spring: south 60%, north 42%) (Fig. 4).

Catch rates of *M. undulatus* in individual strata were more variable both in number and weight during winter and spring than summer and fall. The highest mean catch/tow was found in the winter off southern Georgia (Fig. 4). A single haul in that stratum caught 23,387 Atlantic croaker weighing 1,000 kg. This represented 59.7% of the total number and 57.6% of the total weight of *M. undulatus* taken over all seasons. The stratified mean catch/tow, both in numbers and weight, was highest during winter and lowest during fall (Table 5).

The mean length of *M. undulatus* during the winter survey was 17 cm TL (range 2-28) (Fig. 5). According to White and Chittenden (1977) this probably represented three age-classes. The single small individual (2 cm TL) was a young-of-year (YOY) *M. undulatus*. Generally, YOY Atlantic croakers of this size are found in the estuarine habitat in winter. Age-I fishes appeared to be the most abundant, and less than 1% of the *M. undulatus* were age II using White and Chittenden's (1977) length-at-age data. Spring trawl tows caught a greater number of YOY Atlantic croaker; this decreased the average length to 13 cm TL (range 4-32). Summer *M. undulatus* averaged 17 cm TL (range 6-29), whereas fall fish had a mean length of 18 cm TL (range 11-29). The largest Atlantic croaker was 32 cm TL. It appears that in the SAB, *M. undulatus* has similar population attributes, that is, small size, short life span, and high rates of mortality (White and Chittenden 1977), as do Atlantic croaker from the Gulf of Mexico.

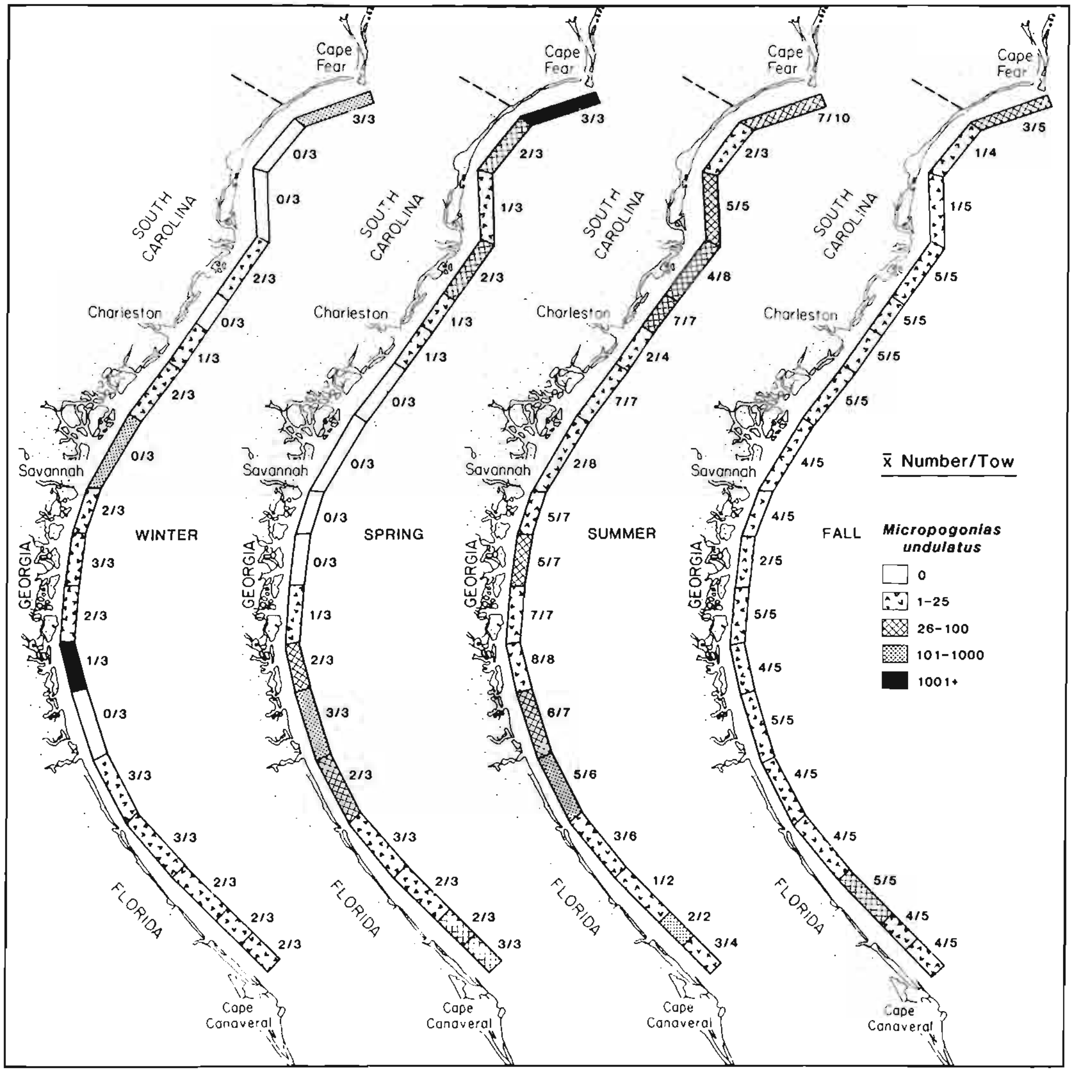

Figure 4
Seasonal catch rates in coastal strata. n/N=no. tows with Atlantic croaker/no. in stratum.

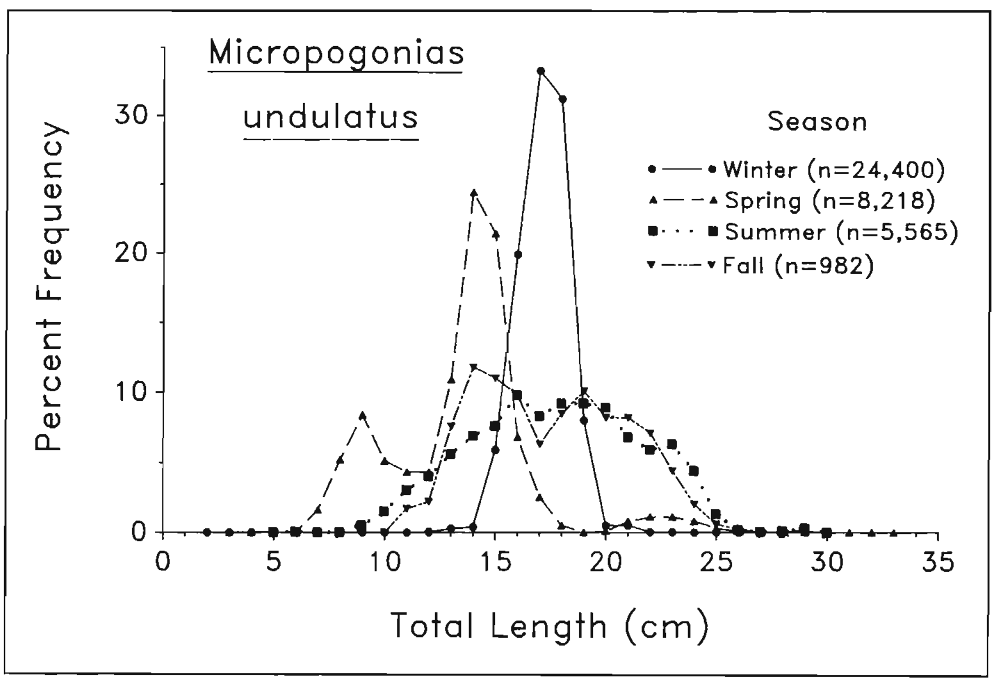

Figure 5
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Brevoortia tyrannus

Atlantic menhaden occurs along the Atlantic coast of North America from Jupiter Inlet, Florida to Nova Scotia (Fischer 1978). This species apparently spawns in most waters over the continental shelf throughout its range with timing dependent on latitude (Nelson et al. 1977). In the SAB, spawning occurs from November to March, whereas in higher latitudes spawning occurs later in the year (May-October off New York and New England; March-April and September-October off the Middle Atlantic States) (Reintjes and Pacheco 1966). Larvae are recruited to estuaries along the coast from Florida to Maine and, following juvenile growth in these estuarine systems, they leave this habitat in the autumn with the onset of cooler water temperatures (Kroger and Guthrie 1973).

Studies of the fishes of the nearshore zone along the southeast coast, as derived from the incidental bycatch of the penaeid shrimp fishery, indicated that Atlantic menhaden were present throughout the year with greatest catch rates in winter months off South Carolina (Keiser 1976). However, in Georgia waters, no period of marked high abundance was apparent (Knowlton 1972). This was in contrast to another study where increased catch rates of *Brevoortia* sp. were observed off Georgia during January, February, and March (Anderson 1968).

In the present study *B. tyrannus* was the third most numerous species in trawl collections (Table 2) and ranked fourth in total weight (Table 3). There were seasonal differences in the relative abundance of Atlantic menhaden. In winter, this species ranked first by number (35,361 individuals) (Table 2). Spring sampling found it to rank eighth, and in the summer and fall, this species was not in the top 25 most numerous species. Lowest catches were in the summer (70 fish).

Atlantic menhaden were found throughout the survey area during all seasons (Fig. 6), but differed significantly in seasonal frequency of occurrence (χ^2 = 42.21, df = 3, p>0.05). This species was taken in 65% of the winter and fall tows, 43% of the spring tows, and only 17% of the summer samples. Over all seasons, 36% of collections yielded *B. tyrannus*. Catch/tow values for individual strata showed that the highest catch rates ($\bar{x}$>1001 individuals/tow) occurred during the winter months off South Carolina and Georgia (Fig. 6). Standardized catches were lighter during the other seasons with summer and fall catches being the least. The stratified mean catch/tow was an order of magnitude higher in winter than in spring, and two orders of magnitude higher than in summer or fall (Table 5).

Atlantic menhaden caught in winter had a modal length of 10 cm FL (range 6-21); only 1.1% of these fish were greater than 12 cm FL (Fig. 7). In spring, the modal length was 13 cm FL (range 7-29) and 1.8% of the *B. tyrannus* were greater than 18 cm FL. The modal length increased to 14 cm FL in summer (range 5-21) and 17 cm FL in fall (range 9-30).

Data from these surveys indicate that YOY Atlantic menhaden are abundant during winter in the coastal habitat of the SAB from Winyah Bay, South Carolina, to northern Florida. It must be pointed out, however, that the gear may not be the most efficient in sampling this species. During winter, we did not observe any surface schools as seen during warmer months in more northerly waters, so the Atlantic menhaden may either school more deeply or the schools are not as compact as during other seasons. The question remains as to the source of large aggregations of Atlantic menhaden off the coast in winter. Do they represent individuals that have left the estuaries of the SAB the previous fall? Are they derived from more northerly estuaries and have migrated around Cape Hatteras as has been suggested by Kroger and Guthrie (1973)? Are they from both areas? Kroger and Guthrie (1973) stated that age-I menhaden (the bulk of Atlantic menhaden captured in winter will be age-I the following spring when the annulus is formed [Kroger et al. 1974]) move northward along the coast with the largest fish going farther north. Since these age-I fish are a significant part of the commercial catch in Chesapeake Bay (J.W. Smith, Beaufort Lab., Southeast Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Beaufort, NC 28516, pers. commun. Sept. 1984), it may be possible to relate the catch-per-unit-effort of YOY Atlantic menhaden along the South Atlantic coast to landings of age-I fish in the Chesapeake Bay the following fishing season. Such a relationship will require a long-term, standardized database, but in view of the magnitude of the fishery and the economic importance of this species, it would be a worthwhile undertaking.

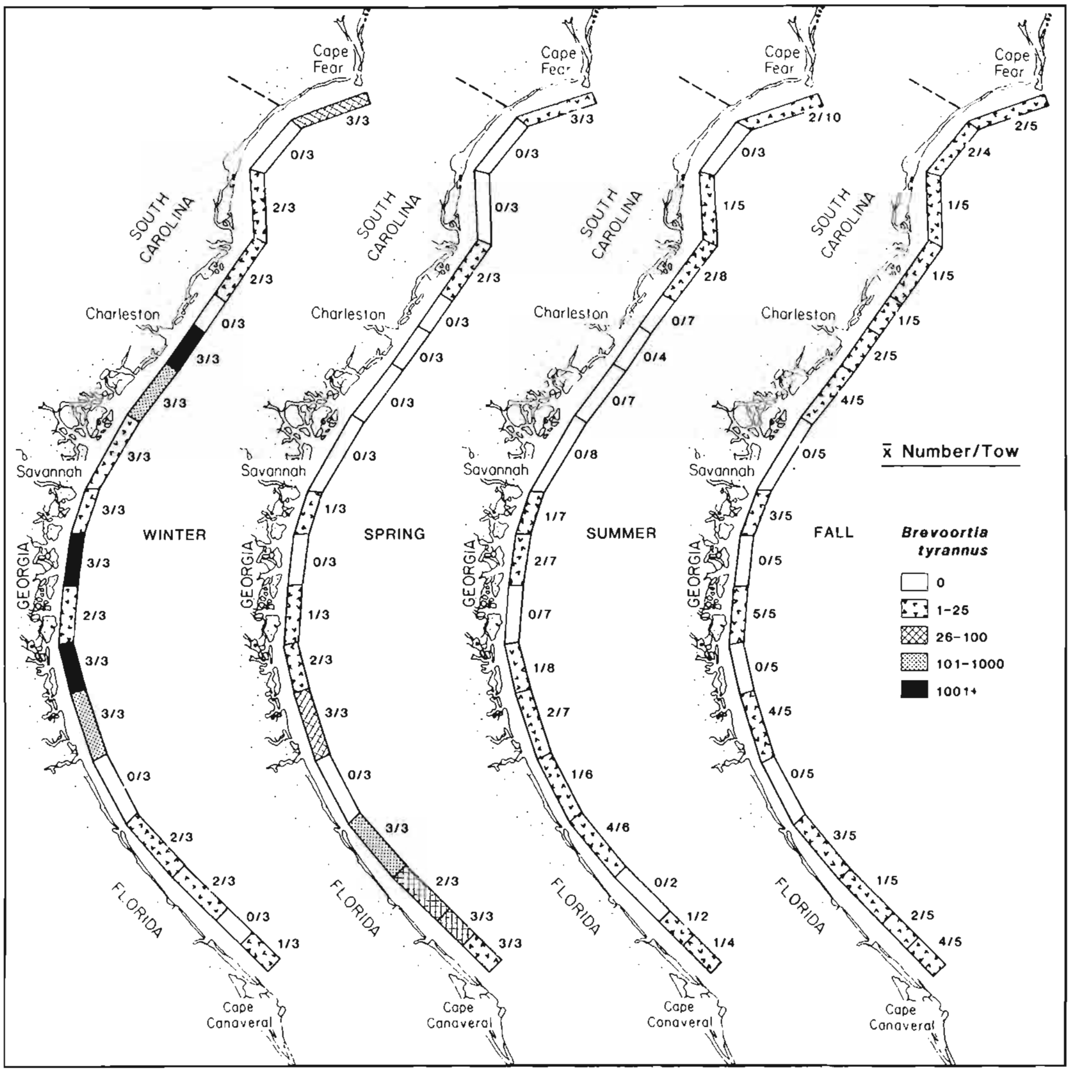

Figure 6
Seasonal catch rates in coastal strata. n/N=no. tows with Atlantic menhaden/no. tows in stratum.

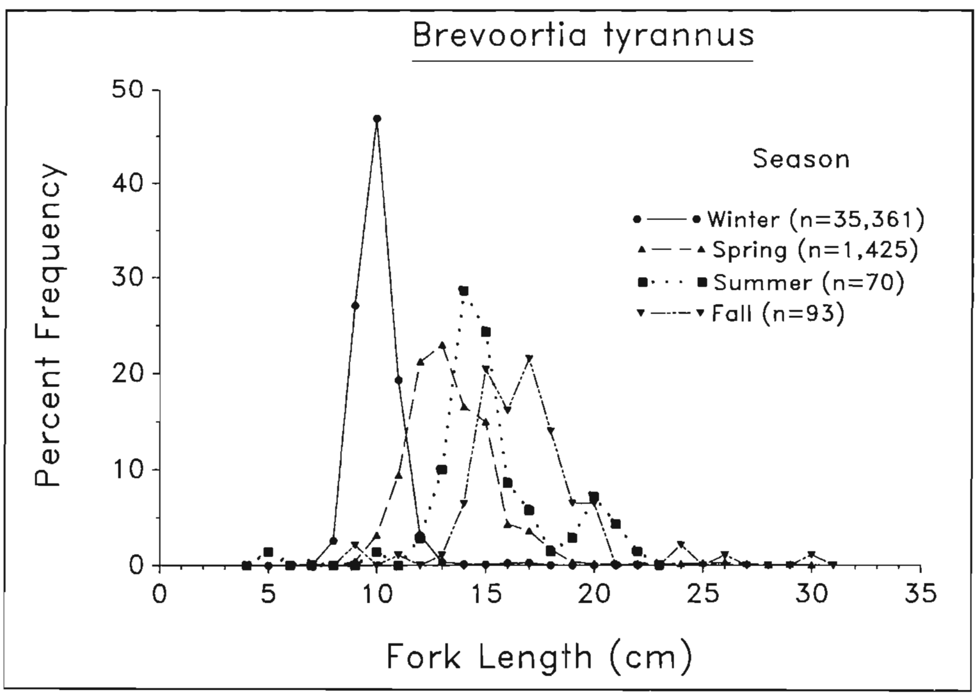

Figure 7
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Anchoa mitchilli

Bay anchovy occurs along the Atlantic coast of the United States from the Gulf of Maine to Florida and throughout the Gulf of Mexico to Yucatan, Mexico (Hildebrand 1963b). Within this geographical range, this species is one of the most ubiquitous and abundant coastal and estuarine species.

In the SAB, *A. mitchilli* has been reported in estuaries of North Carolina (Weinstein 1979), South Carolina (Wenner et al. 1982, 1984; Shenker and Dean 1979), and Georgia (Dahlberg and Odum 1970, Dahlberg 1972). All these studies have indicated that *A. mitchilli* is a ubiquitous and abundant species that occurs over a broad range of substrate types, water depths, temperatures (0.7-32.5°C) and salinities (0.0-36‰). In the coastal waters off South Carolina, Keiser (1976) found *A. mitchilli* to occur in all months. Bay anchovy accounted for 6.22% of the total number of fishes in the bycatch of the South Carolina penaeid shrimp fishery over an annual cycle (Keiser 1976). *Anchoa mitchilli* is apparently a coastal and estuarine species since it was not taken in otter trawl surveys in the open-shelf habitat of the SAB (Wenner et al. 1979a,b,c,d, 1980).

We found *A. mitchilli* to be widely distributed throughout the survey area during all seasons (Fig. 8). Although there was no significant difference at the 95% level in the frequency of occurrence of *A. mitchilli* in trawl tows among seasons ($\chi^2 = 7.436$, df = 3), this species was caught more frequently in tows made during spring and summer than during other seasons in the southern section of the survey area (Fig. 8). Winter catch/tow values were generally high except for the three southernmost strata, where this species was absent. In contrast to the spring when catches were greater in magnitude than winter, those in summer were light. The stratified mean catch/tow was highest in both numbers and weight during the spring and lowest during summer (Table 5).

The smallest *A. mitchilli* (2 cm FL) taken was during the summer survey. Although small bay anchovies may not be fully represented in the samples because of the high probability that many passed through the meshes of the net, the following length-frequencies are presented for illustrative purposes:

Length (cm FL)	Winter 1982	Spring 1981	Summer 1980	Fall 1982
2			6	
3	10		750	22
4	1171	66	1902	2681
5	3178	2497	881	4584
6	1563	3373	134	1458
7	450	857	9	70
8	15	26		1

Modal lengths progressed from a low of 4 cm FL in summer to 6 cm FL in Spring.

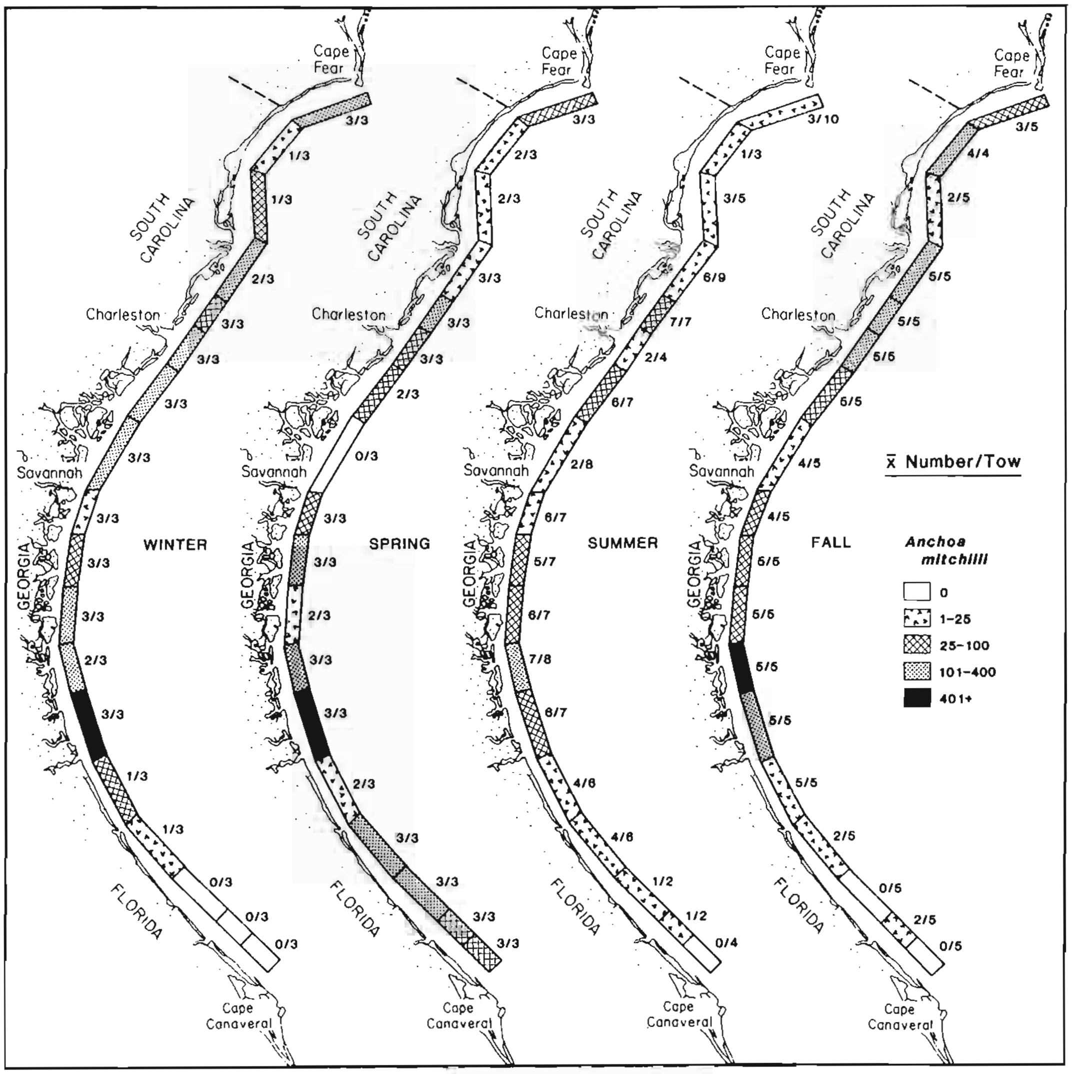

Figure 8
Seasonal catch rates in coastal strata. n/N = no. tows with bay anchovy/no. tows in stratum.

Stellifer lanceolatus

Star drum is one of the most abundant coastal demersal fishes in the SAB (Welsh and Breder 1923). The primary range of this species is from the northern part of the Gulf of Mexico to North Carolina (Fischer 1978) although a specimen was reported along the Virginia coast (Hildebrand and Schroeder 1928). Star drum are common inhabitants of sandy and muddy bottoms along the South Atlantic coast from the surf zone (Anderson et al. 1977) to depths around 13 m (7 fm) (Welsh and Breder 1923). In addition to its importance in the SAB coastal fish community, *S. lanceolatus* has also been found to comprise a significant part of the ichthyofauna of South Carolina (Wenner et al. 1981, 1982) and Georgia estuaries (Dahlberg 1972).

Stellifer lanceolatus ranked fifth in abundance (Table 2) but, because of its relatively small size, twelfth by total weight for all cruises combined (Table 3). Although *S. lanceolatus* were caught throughout the survey area from Cape Fear, North Carolina, to Cape Canaveral, Florida, during all seasons (Fig. 9), marked seasonal differences in its frequency of occurrence in trawl tows were noted. Chi-square analysis showed a significant difference in the frequency of occurrence among seasons ($\chi^2 = 18.81$, df = 1, $p > 0.05$). The greatest frequency was found during the fall survey (80% of 89 tows), and the lowest was during the winter (44% of 54 tows). During the spring and summer surveys, star drum were encountered in 59% of the tows in each season (spring 54, summer 108).

The greatest mean number per tow of *S. lanceolatus* (646 individuals) was found in a stratum off southern Georgia during the winter survey (Fig. 9). The adjacent stratum to the south had a relatively high value, but catches in the remaining strata were very low or zero. During this period, star drum were absent in 7 of the 18 strata sampled. Spring catch rates for individual strata were moderate and increased during the summer months; the abundance and frequencies of occurrence in all strata during the fall tended to be higher than any other survey period. Stratified mean catch-per-tow values were 5.5 times greater for number per tow and 2.6 times greater for weight during the fall (Table 5) than the minimum values found during the spring.

Although the seasonal surveys were not sequential, an ''annual'' cycle of the length composition and an estimate of the age structure can be inferred from length-frequency data. *Stellifer lanceolatus* spawns from late spring through September in the coastal waters of the SAB (Powles and Stender 1978). During the spring survey, this species had a modal TL of 12 cm (range 8-16 cm) (Fig. 10). Young-of-year (YOY) star drum were first vulnerable to the gear during the summer; at this time there were two apparent modes in the length-frequency distribution (8 and 11 cm). Small individuals in both fall and winter surveys suggest continuing recruitment to the gear as would be expected in a species with a protracted (4-5 months) spawning season. This continual recruitment does not readily allow the breakdown of length-frequency distributions into age groups. However, the data suggest that two, or at maximum, three age-classes are present in the coastal waters of the SAB.

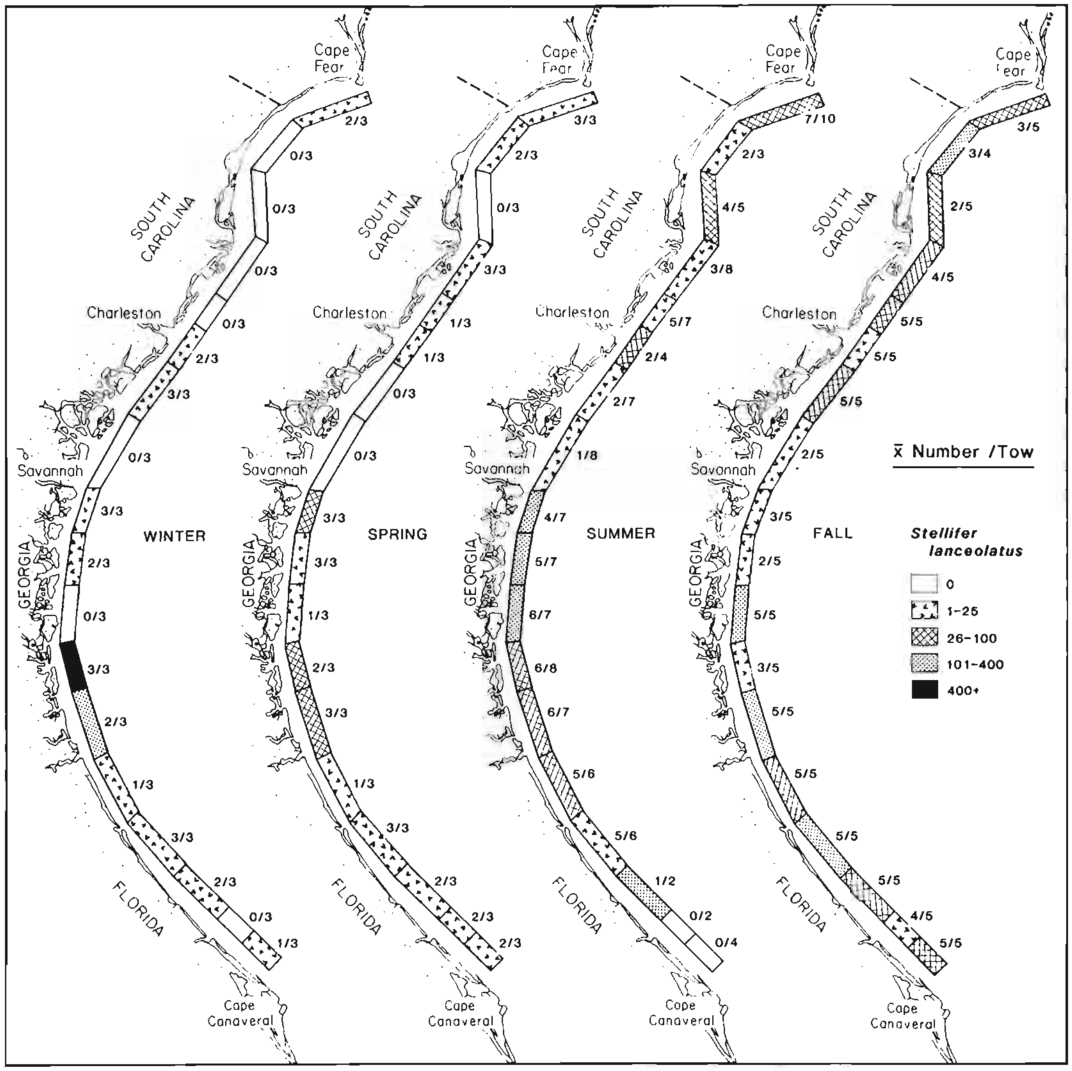

Figure 9
Seasonal catch rates in coastal strata. n/N=no. tows with star drum/no. tows in stratum.

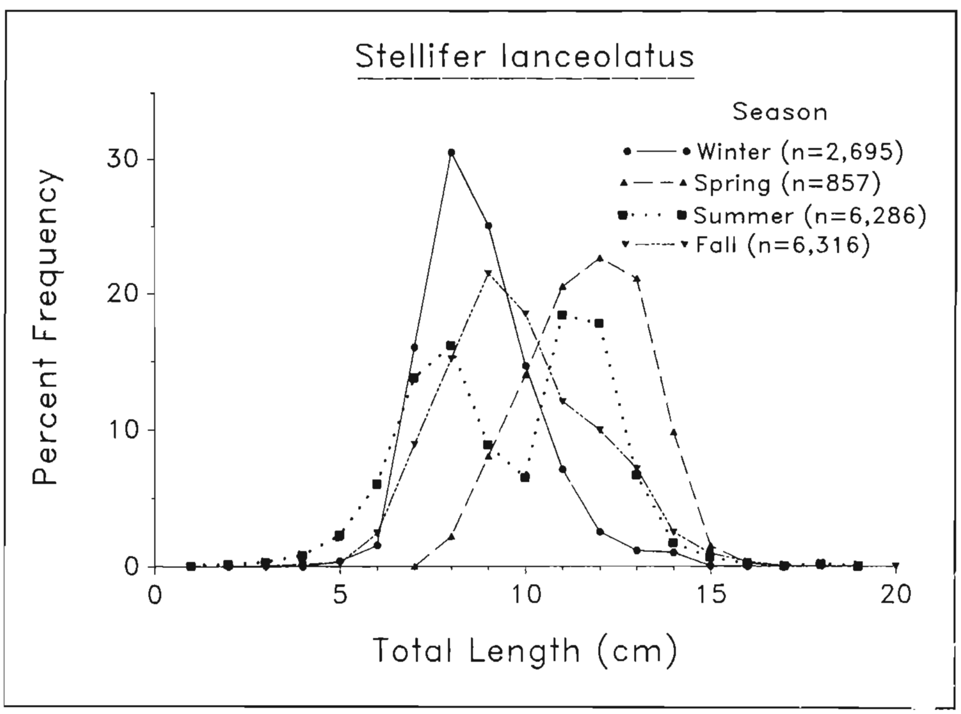

Figure 10
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Cynoscion nothus

Silver seatrout occurs along the northern and eastern Gulf of Mexico and the Atlantic coast of the United States from southern Florida to Chesapeake Bay (Fischer 1978). This species is rarely taken north of Cape Hatteras (Hildebrand and Schroeder 1928), and in contrast to its congeners along the Atlantic coast (*C. regalis* and *C. nebulosus*), *C. nothus* is restricted in its estuarine distribution to the higher salinity areas (Schwartz et al. 1982, Dahlberg 1972). Our present knowledge of the distribution and abundance of *C. nothus* in the SAB results from studies of the bycatch of the penaeid shrimp fishery. Some of this information is suspect, however, because of misidentifications of *C. nothus* and subsequent lumping with *C. regalis*. For example, Knowlton (1972) failed to list *C. nothus* in his study of the bycatch from coastal waters of Georgia, and Keiser (1976) reported it as being absent during May through August 1974 in a similar study from South Carolina. Both of these studies are at variance with other published information and the present study. Anderson (1968) found *C. nothus* to occur throughout the SAB in coastal waters during all seasons. Catch rates were an order of magnitude higher off Florida, where *C. nothus* accounted for 9.6% of the annual fish catch in coastal waters, than off South Carolina and Georgia.

In the present study, *C. nothus* ranked sixth in numerical abundance and eighth by weight (Tables 2, 3). Silver seatrout were taken throughout the SAB during each of the seasonal cruises (Fig. 11); however, differences in the frequency of occurrence in trawl tows were observed. *Cynoscion nothus* was taken at significantly more stations ($\chi^2 = 11.12$, df = 1, $p>0.05$) in fall (74% of 89 tows) than during winter (46% of 54 tows), spring (50% of 54 tows), and summer (58% of 108 tows).

Catch-per-tow values in winter were low in all but two strata off northern Florida (Fig. 11). During spring, values were also low and then increased in summer. The frequency of occurrence in the strata north of Savannah, Georgia, was relatively low during all seasons except fall when both the catch rates and frequency of occurrence reached a maximum. The stratified mean catch-per-tow was highest in the fall and lowest in the winter (Table 5).

Cynoscion nothus taken during the winter survey averaged 9 cm TL (range 6-20); the length-frequency distribution during that season was essentially unimodal (9 cm) (Fig. 12). *Cynoscion nothus* had a larger mean length (16 cm, range 4-29) during spring when the frequency distribution had two distinct modes, 13 and 22 cm. Summer length-frequencies also showed two apparent length groups. Because of the large number of small fishes, the average length decreased to 11 cm (range 4-29). Fall samples lacked larger sized individuals. The largest silver seatrout we collected (one each in spring and summer) were 29 cm TL (24 cm SL) which is slightly larger than the maximum size reported by DeVries and Chittenden (1982) from the Gulf of Mexico but smaller than the maximum size found in Georgia waters (31 cm TL) (Mahood 1974).

Although *C. nothus* has an extended spawning season in the Gulf of Mexico (May through October), two distinct periods of peak reproductive activity were found in May and August-September (DeVries and Chittenden 1982). Mahood (1974) indicated that *C. nothus* spawns during the spring and late summer-early fall off the Georgia coast. Evidence for a spring spawn was based on the occurrence of small *C. nothus* in samples taken at that time, whereas late summer-early fall spawning was determined from gonadal examination and the presence of small individuals in trawl collections from October through January (Mahood 1974). Our data do not allow the definition of specific spawning times throughout the SAB since we collected relatively small fishes during all surveys.

Available information indicates that large *C. nothus* disappear during the winter in the Gulf of Mexico off Texas (DeVries and Chittenden 1982) and along the Georgia coast (Mahood 1974). Our data agree in that fall and winter samples each had only one *C. nothus* greater than 22 cm TL. Three possible explanations for this phenomenon are: (1) During fall and winter, large *C. nothus* are unavailable to the survey gear because of movement from the limits of the survey area, either south of Cape Canaveral, Florida or offshore into deeper water; (2) large *C. nothus* are not vulnerable to the survey gear; (3) large *C. nothus* die in fall and winter. Present information does not allow us to rule out the first possibility. However, seasonal stratified random sampling in offshore waters has collected few *C. nothus* and these were off Florida in depths from 18 to 27 m (Wenner et al. 1979a,b,c,d, 1980). Since large *C. nothus* were taken in the survey gear during spring and summer, trawl avoidance is unlikely. Appearance of some large *C. nothus* in the early spring indicates that not all large fish die off in winter, although DeVries and Chittenden (1982) found that *C. nothus* in the Gulf of Mexico has an annual mortality rate approaching 100%. It cannot be ascertained that there was a combination of factors, that is, movement offshore or mortality, and both factors probably contribute to the rarity of *C. nothus* in the winter.

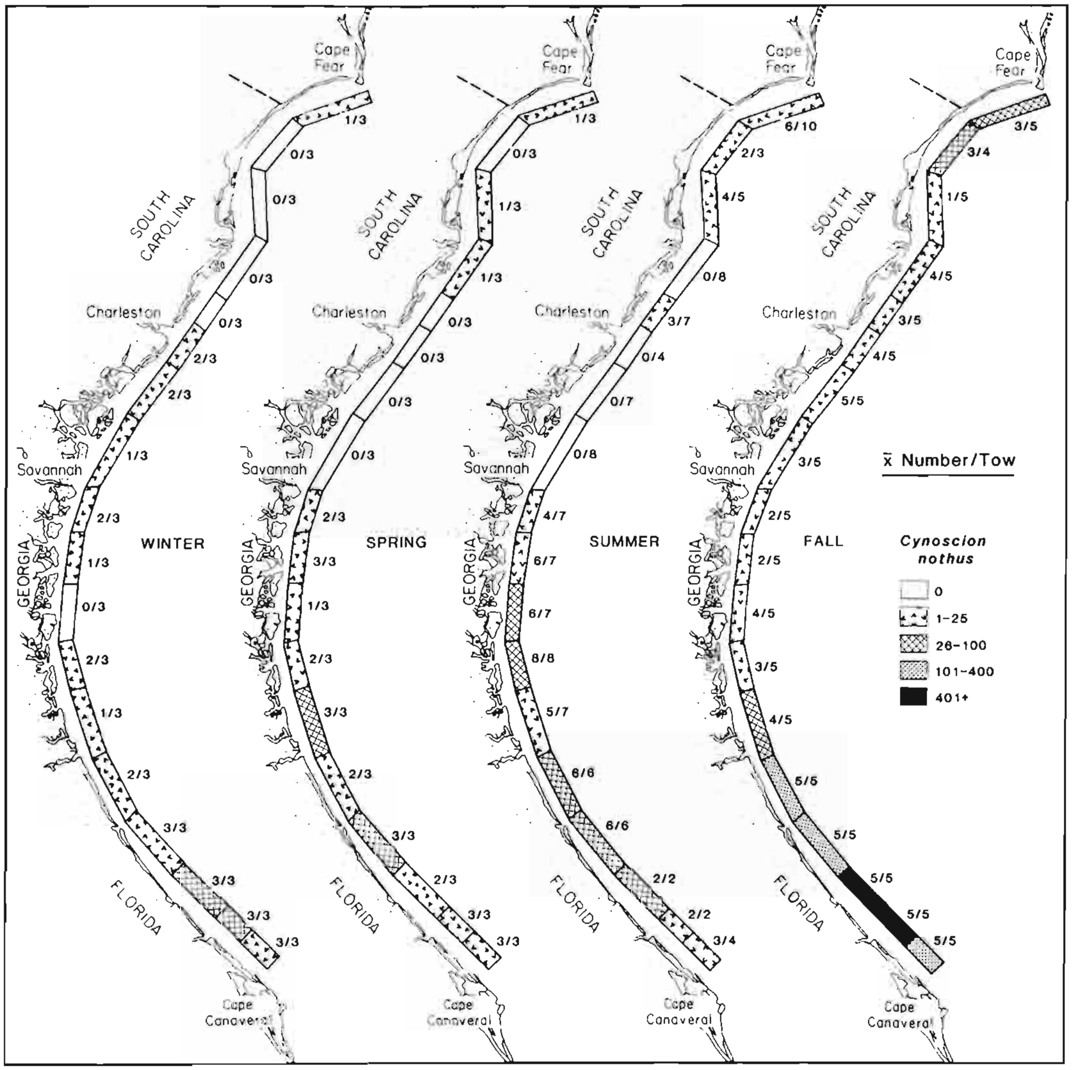

Figure 11
Seasonal catch rates in coastal strata. n/N = no. tows with silver seatrout/no. tows in stratum.

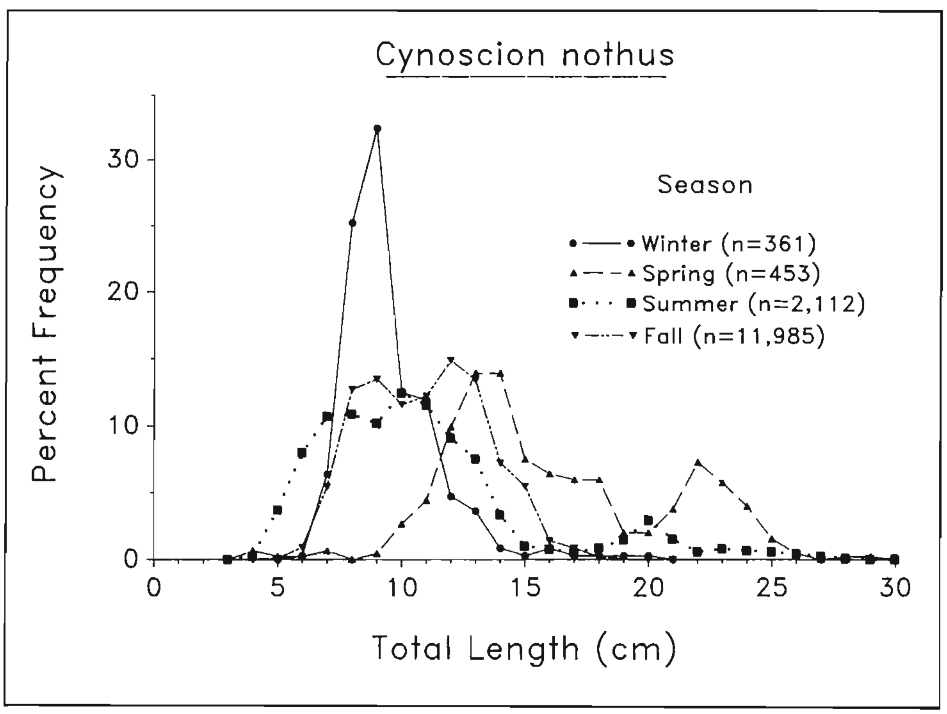

Figure 12
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Prionotus carolinus

Northern sea robin has been reported from the Bay of Fundy to South Carolina (Fritzsche 1978). It is generally found in coastal and shelf waters, although it is taken, sometimes in large numbers, in estuaries such as the Chesapeake Bay (Hildebrand and Schroeder 1928). In the present study, *P. carolinus* was the seventh most numerous species accounting for 3.37% of the catch (Table 2); it ranked seventeenth by weight (Table 3). Although *P. carolinus* was taken during each of the cruises (Fig. 13), there was a significant difference in the frequency of occurrence between seasons (χ^2 = 103.36, df = 3, p>0.05). Northern sea robin was infrequent in winter (7% of tows) and fall (9%) of the trawl samples, whereas in spring and summer it occurred at 70 and 63% of the stations, respectively.

The mean catch/tow was very low in the strata where *P. carolinus* occurred during winter (Fig. 13). The highest catch rates were found during the spring in strata from Savannah, Georgia, north to Cape Romain, South Carolina. Catches declined somewhat in summer, and in fall this species was only encountered in the most northerly strata in small numbers. Length-frequency distributions (Fig. 14) indicated that there are possibly two age-classes (YOY and age-1) in the coastal habitat.

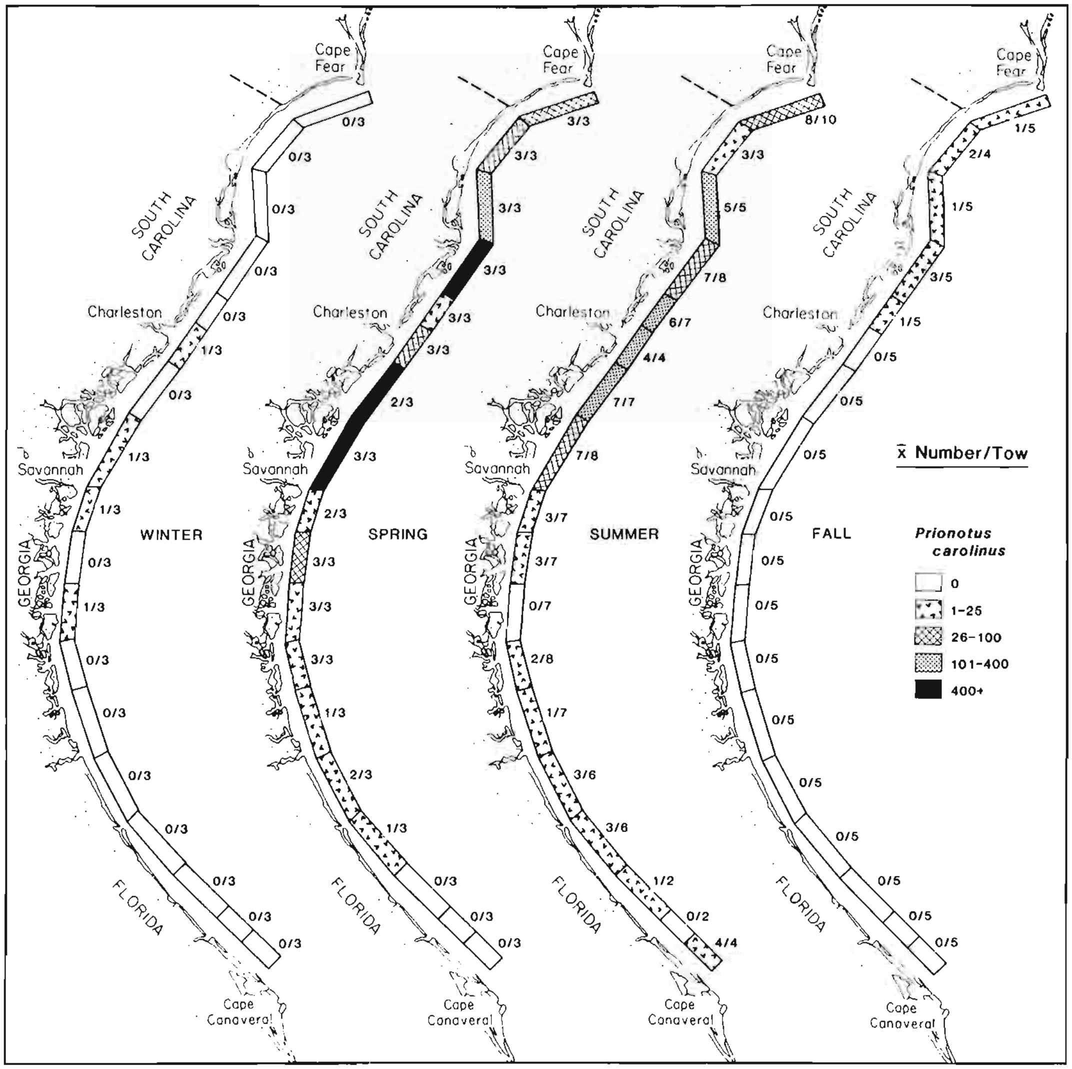

Figure 13
Seasonal catch rates in coastal strata. n/N=no. tows with northern sea robin/no. tows in stratum.

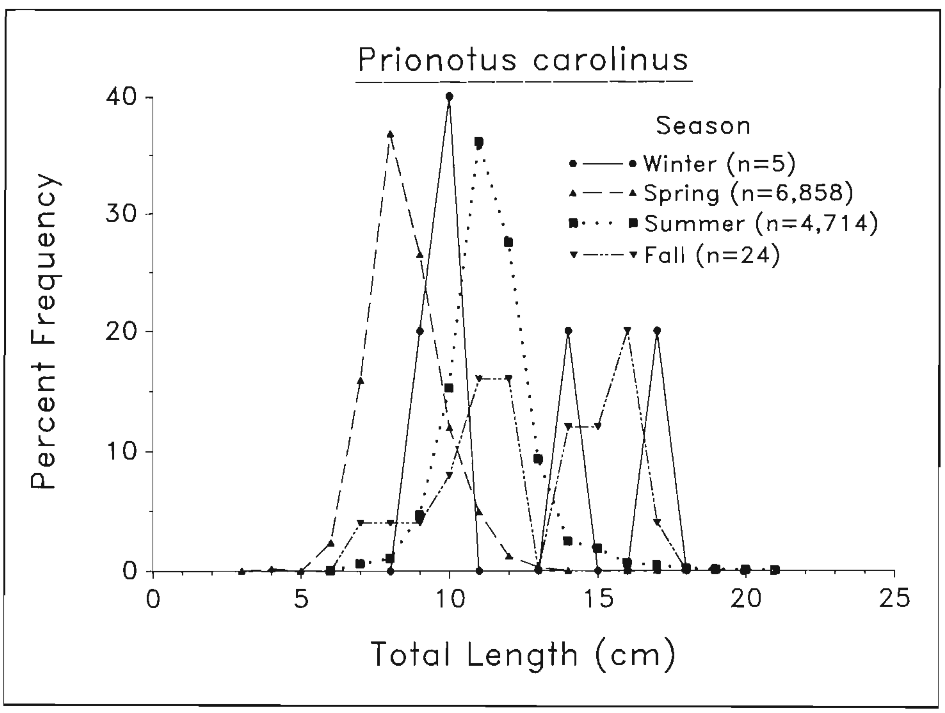

Figure 14
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Banded drum is a common coastal sciaenid that occurs on sandy-muddy bottom along the South Atlantic coast (Welsh and Breder 1923). Although banded drum are occasionally caught north of Cape Hatteras (Hildebrand and Schroeder 1928), the primary range of the species is from North Carolina south along the Atlantic coast to south Florida and throughout the northern Gulf of Mexico (Fischer 1978). *Larimus fasciatus* has been taken in salinities ranging from fresh to oceanic waters (Schwartz et al. 1982); however, when encountered in estuaries along the South Atlantic coast, it occurred most frequently in the polyhaline and euhaline reaches of estuaries (Wenner et al. 1981, Shealy et al. 1974). In the coastal waters of the SAB, banded drum have been taken from the surf zone (Anderson et al. 1977) to 19 m (Wilk and Silverman 1976). In this region, however, the maximum abundance and frequency of occurrence were in depths less than 15 m as shown by data from the bycatch of the penaeid shrimp fishery. It comprised 1.9% of the discarded weight in South Carolina (Keiser 1976), 3.2% of the weight in Georgia (Knowlton 1972), and 1.6% of the number of fishes in Florida's bycatch (Anderson 1968).

Plankton tows in the SAB during April-May and August-September collected small larvae of *L. fasciatus* (Powles and Stender 1978). Presently it is unknown whether this represents two spawning events (spring, fall) as is the case for banded drum in the Gulf of Mexico (Standard and Chittenden 1984) or is part of an extended spawning season from May to October (Hildebrand and Cable 1934) along the South Atlantic coast.

Larimus fasciatus ranked eighth in numerical abundance and seventh by weight for fishes taken in the coastal habitat of the SAB during the four seasonal cruises (Tables 2, 3). This species occurred throughout the survey area during all sampling periods (Fig. 15); however, the frequency of occurrence in trawl tows was significantly different between seasons (χ^2 = 18.89, df = 3, p>0.05). Seasonal comparisons showed that *L. fasciatus* occurred at significantly fewer stations in winter than in spring (χ^2 = 5.44, df = 1, p>0.05), summer (χ^2 = 11.33, df = 1, p>0.05) and fall (χ^2 = 17.22, df = 1, p>0.05). Frequencies from seasons other than winter were not significantly different from one another (χ^2 = 1.57, df = 2). During those seasons, *L. fasciatus* was taken in 74.5% of the 251 collections.

Data indicated that banded drum were displaced to the southern part of the survey area by the lower winter water temperatures in the higher latitudes. Their frequency of occurrence in trawl tows south of Savannah, Georgia (approx. 32°N) was significantly greater than in the northern region (χ^2 = 15.21, df = 1, p>0.05). *Larimus fasciatus* became more widely distributed in the SAB as temperatures increased in the spring (Fig. 15). Maximum catch rates of banded drum were always along the coast of Florida regardless of the season. The stratified mean catch/tow, both in numbers and weight, was lowest in the winter and highest during the summer survey (Table 5).

Although the seasonal surveys were not sequential, it is possible to trace modes in the length-frequency distribution through an "annual" cycle to estimate the age and longevity of *L. fasciatus* in the SAB. Because of the limited sample size in winter collections, only a single mode of 7 cm TL can be inferred from the data (Fig. 16). This can be traced through the other seasons (spring, 9 cm TL; summer, 10 cm TL; fall, 13 cm TL). Interpretation of this is that the 7-cm winter peak represents the modal length of young-of-year banded drum that were spawned during the previous spring and summer. During the period between winter and spring, they increased 2 cm TL in modal length and we estimate that they are approximately age-I by summer. The second summer mode (17 cm TL) probably represents age-II fish; the possibility of older age-classes cannot be clearly inferred from the data. It appears that possibly three age-classes of *L. fasciatus* are in the SAB. These estimates of the length-at-age are in close agreement with von Bertalanffy predicted length-at-age for this species in the northwestern Gulf of Mexico (I = 13 cm TL; II = 18 cm TL) (Standard and Chittenden 1984). Ross (1978, cited in Standard and Chittenden 1984) obtained the following length-at-age values for *L. fasciatus* collected off North Carolina: I = 153; II = 188; III = 209 mm TL; these are comparable to our estimates.

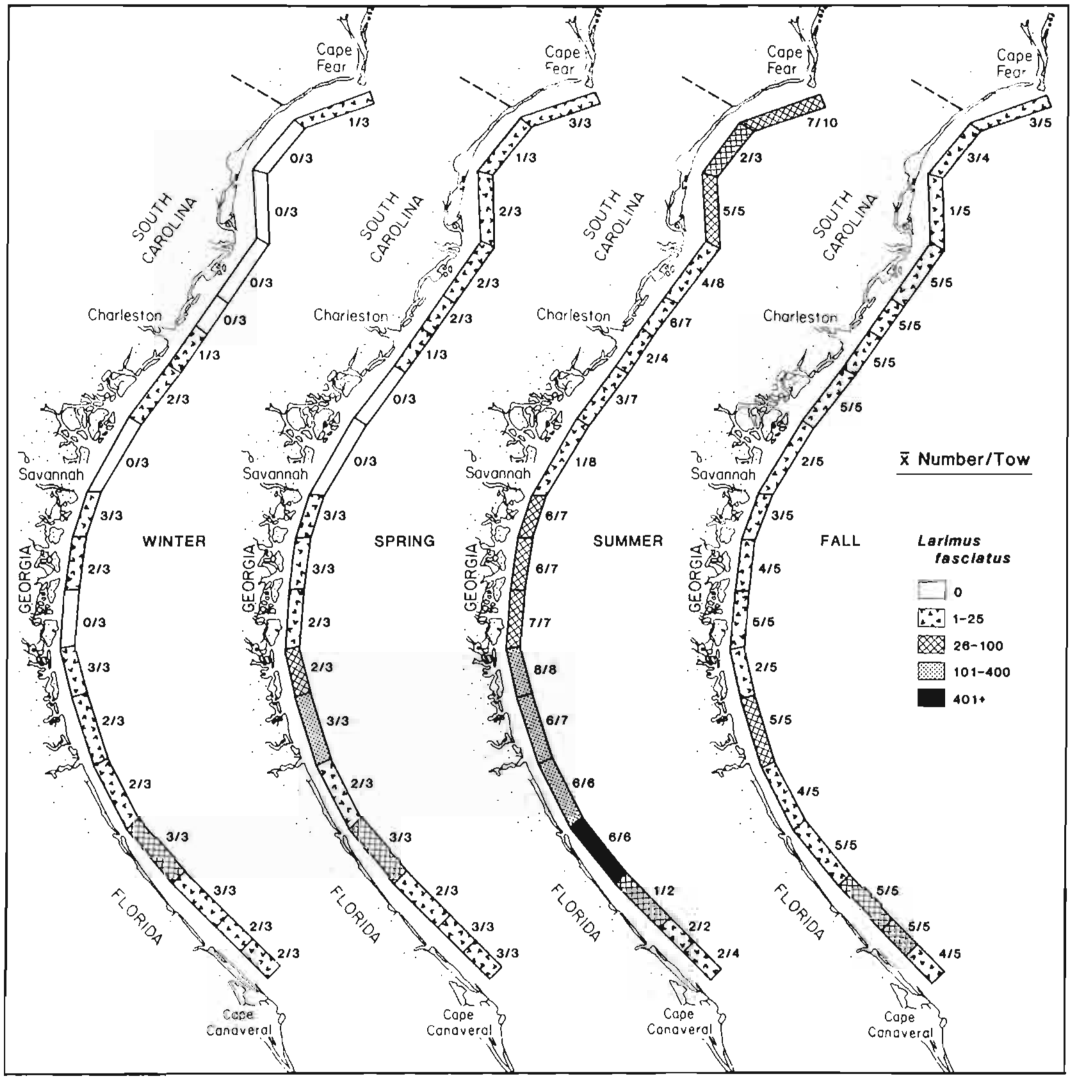

Figure 15
Seasonal catch rates in coastal strata. n/N = no. tows with banded drum/no. tows in stratum.

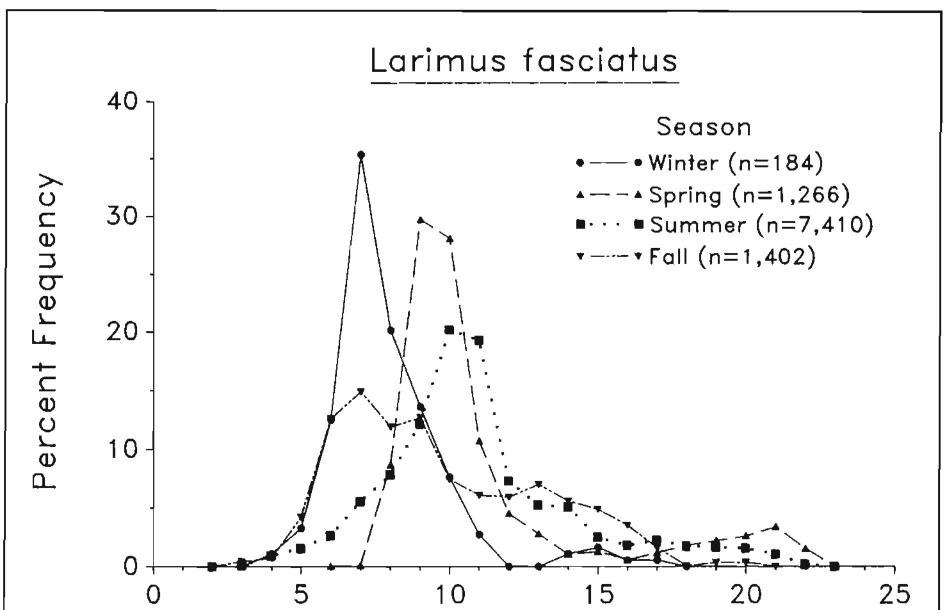

Figure 16
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Chloroscombrus chrysurus

Atlantic bumper is a schooling species found along the Atlantic coast of North and South America from Massachusetts to Uruguay, in Bermuda, and possibly throughout the West Indies (Fischer 1978). In the north central Gulf of Mexico, *C. chrysurus* is most abundant in depths from 2 to 18 m, and catch rates decline with increasing depth (Klima 1971). Atlantic bumper are generally rare beyond the 91-m (50-fm) curve, although it was taken to the 1830-m (1000-fm) curve (Klima 1971). *Chloroscombrus chrysurus* has been found in both the high-salinity portions of gradient estuaries (Wenner et al. 1982, Anderson 1968, Dahlberg 1972) and in euhaline estuaries (Cain and Dean 1976), but greatest abundances have been reported from coastal waters of the SAB, primarily as a bycatch species of the penaeid shrimp fishery (Keiser 1976). Juvenile Atlantic bumper (20-54 mm SL) have been taken in the surf zone off South Carolina during summer (Anderson et al. 1977) to offshore waters of the SAB (Wenner et al. 1980). Small, pelagic juveniles (18-33 mm SL) have been found commensally with sea nettles (*Chrysoura quinquecirrha*) and *Stomolophus meleagris* during July, August, and October in the northern Gulf of Mexico (Phillips et al. 1969). Anderson(1968) found this species to be abundant in the SAB during exploratory surveys of the coastal habitat. Highest catch rates of Atlantic bumper were during the summer months off South Carolina, late summer-early fall off Georgia, and fall-early winter off Florida (Anderson 1968).

During the present investigation, Atlantic bumper ranked twelfth in numerical abundance and thirteenth by weight (Tables 2, 3). This species occurred at 60% of stations made during all seasons; however, there was a marked difference in occurrences. During the winter survey, only a single individual was taken, and it occurred at the southernmost station (Fig. 17). The spring, summer, and fall surveys found *C. chrysurus* to be widespread throughout the SAB. No significant difference was found in the frequency of occurrence among these three seasons ($\chi^2 = 2.382$, df = 2), when Atlantic bumper were taken at 73% of 251 stations.

During the spring and summer, maximum catch rates were in the strata off Georgia and Florida (Fig. 17). Atlantic bumper were widespread throughout the SAB in fall with the highest mean catch/tow in the two most southern strata. The stratified mean catch/tow by number was highest during the summer survey and lowest during fall (excluding the extremely low value for winter) (Table 5). The spring survey had the highest value for biomass/tow.

Examination of length-frequency distributions of the three surveys that caught fish showed that spring sizes were unimodal with a mean length of 17 cm FL (range 13-26) (Fig. 18). Summer trawl tows had two modal length groups (6 and 17 cm FL) whereas fall fish had a single modal length (7 cm FL). Atlantic bumper probably spawn in spring and summer along the southeastern coast of the United States (Fischer 1978), and fish in the smaller modal length group are probably YOY Atlantic bumper. The larger mode probably represents age I+ fish. This interpretation of the ages is tentative, however, until age determination using the analysis of hard parts is conducted.

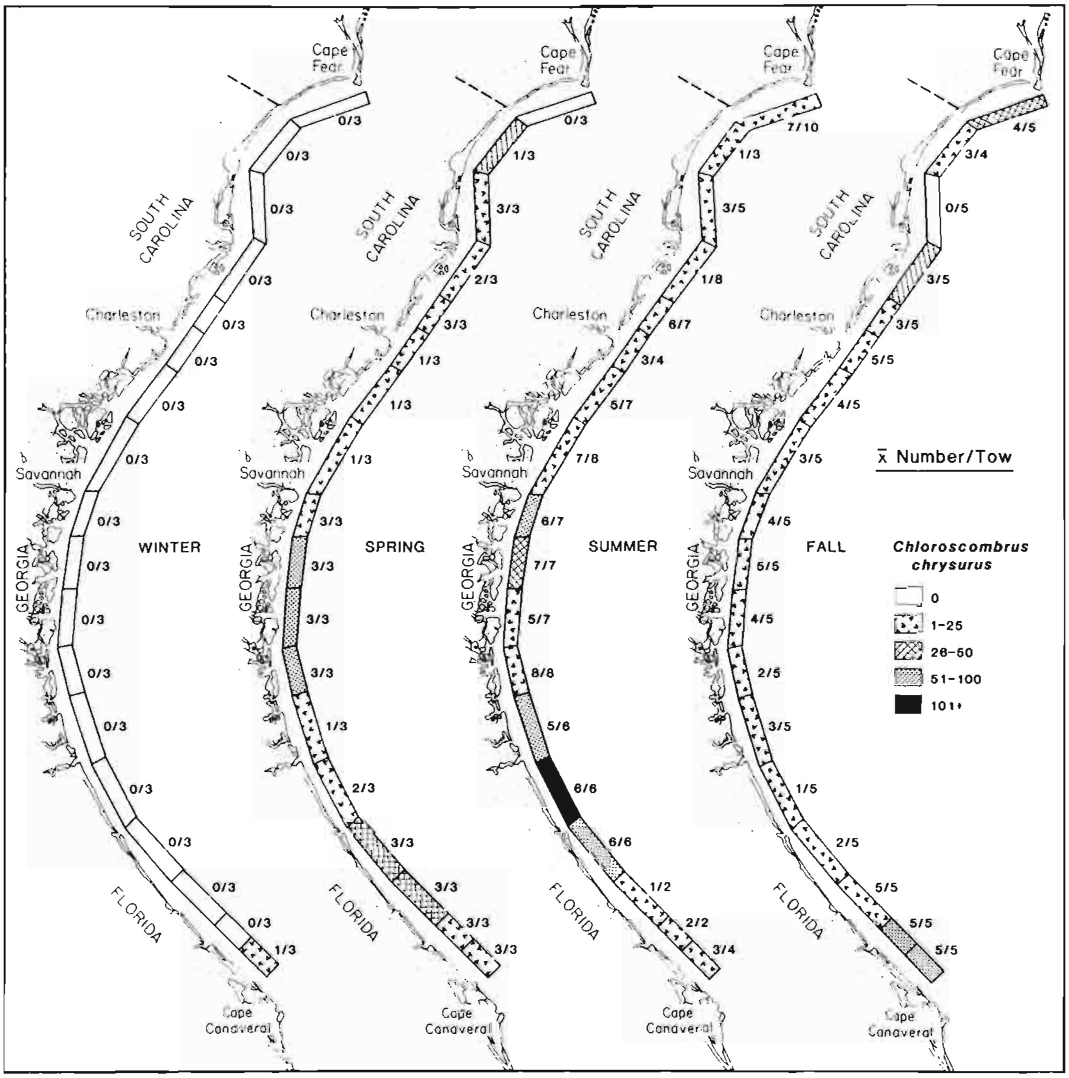

Figure 17
Seasonal catch rates in coastal strata. n/N=no. tows with Atlantic bumper/no. tows in stratum.

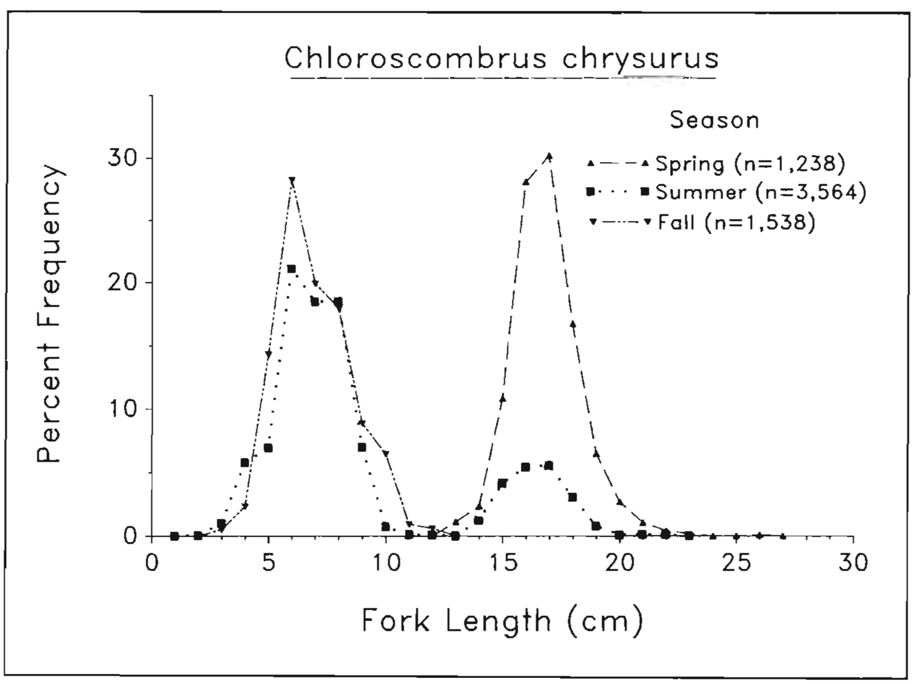

Figure 18
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Windowpane have been reported from the Atlantic coast of North America from the Gulf of St. Lawrence to Florida (Gutherz 1967). In the SAB, a few *S. aquosus* were taken occasionally in otter trawl tows in the open-shelf habitat in depths of 9-22 m (Wenner et al. 1979a,b,c,d, 1980). However, most accounts indicated that *S. aquosus* were shallow-water residents along the South Atlantic coast. Keiser (1976) found small numbers in all months but November and December in the bycatch of the penaeid shrimp fishery off South Carolina. Exploratory trawling along the Georgia coast caught *S. aquosus* during every month with highest catch rates of 13 and 26 fish per hour in early spring (Anderson 1968). Although reports have indicated that *S. aquosus* was primarily a coastal bothid, it was collected in the high-salinity portions of estuaries in North Carolina (Weinstein 1979), South Carolina (Wenner et al. 1982), and Georgia (Dahlberg 1972). A single report indicated that *S. aquosus* ranged from freshwater to oceanic salinity (Schwartz et al. 1982); however, this species has been found almost exclusively at high salinities.

Scophthalmus aquosus was more abundant during the present study then was found in the literature. This species was the thirteenth most numerous fish for all four surveys, but because of its small size, it was less important by weight (Tables 2, 3). *Scophthalmus aquosus* was taken in 57% of the 305 trawl samples and there was a significant difference in the frequency of occurrence between seasons (χ^2 = 30.308, df = 3, p>0.05). It had the following frequencies of occurrence: winter 26% (N = 54); spring 80% (N = 54); summer 62% (N = 108); fall 56% (N = 89). When the survey area was divided into northern and southern sections at Savannah, Georgia, and the presence-absence data were pooled for each area over the four seasons, there was a significant difference in the frequency of occurrence between areas (χ^2 = 46.001, df = 1, p>0.05). *Scophthalmus aquosus* was taken significantly more frequently in the northern (78% of 139 tows) than in the southern area (39% of 166 tows) of the SAB.

Mean catch/tow values for individual strata were very low during the winter survey (Fig. 19). Spring sampling showed reasonably consistent and large values in the strata north of Savannah, Georgia. This was followed by a general decline in mean values for strata in summer and fall. The stratified mean number/tow ranged from a high of 38 individuals in spring to a low of 1 in winter (Table 5). These two seasons also had the highest and lowest kg/tow values (Table 5).

Length-frequency distributions showed two apparent modes in winter (5 and 15 cm TL) (Fig. 20). During the following seasons, the smaller mode progressed to 9 cm TL in spring, 11 cm TL in summer, and 15 cm TL in fall. The large mode was not discernible in other seasons; however, fishes from 16 to 20 cm TL were present in spring and a few individuals greater than 20 cm TL were found in fall. Comparisons of these length-frequency distributions of *S. aquosus* with length-age information from southern New England indicated this species attains a much larger size in the northern part of its range. Age determinations by otoliths in fishes from southern New England (Moore 1947) gave the following length-at-age (cm TL) values: I, 6.3; II, 11.7; III, 19.4; IV, 24.7; V, 27.7; VI, 29.6; VII, 31.5. In southern New England, male *S. aquosus* matured at age-III whereas some females were mature at age-III and all were mature at age-IV (Moore 1947). Data from the present study indicated that *S. aquosus* was not as long-lived and reached a smaller maximum size in the SAB than individuals north of Cape Hatteras.

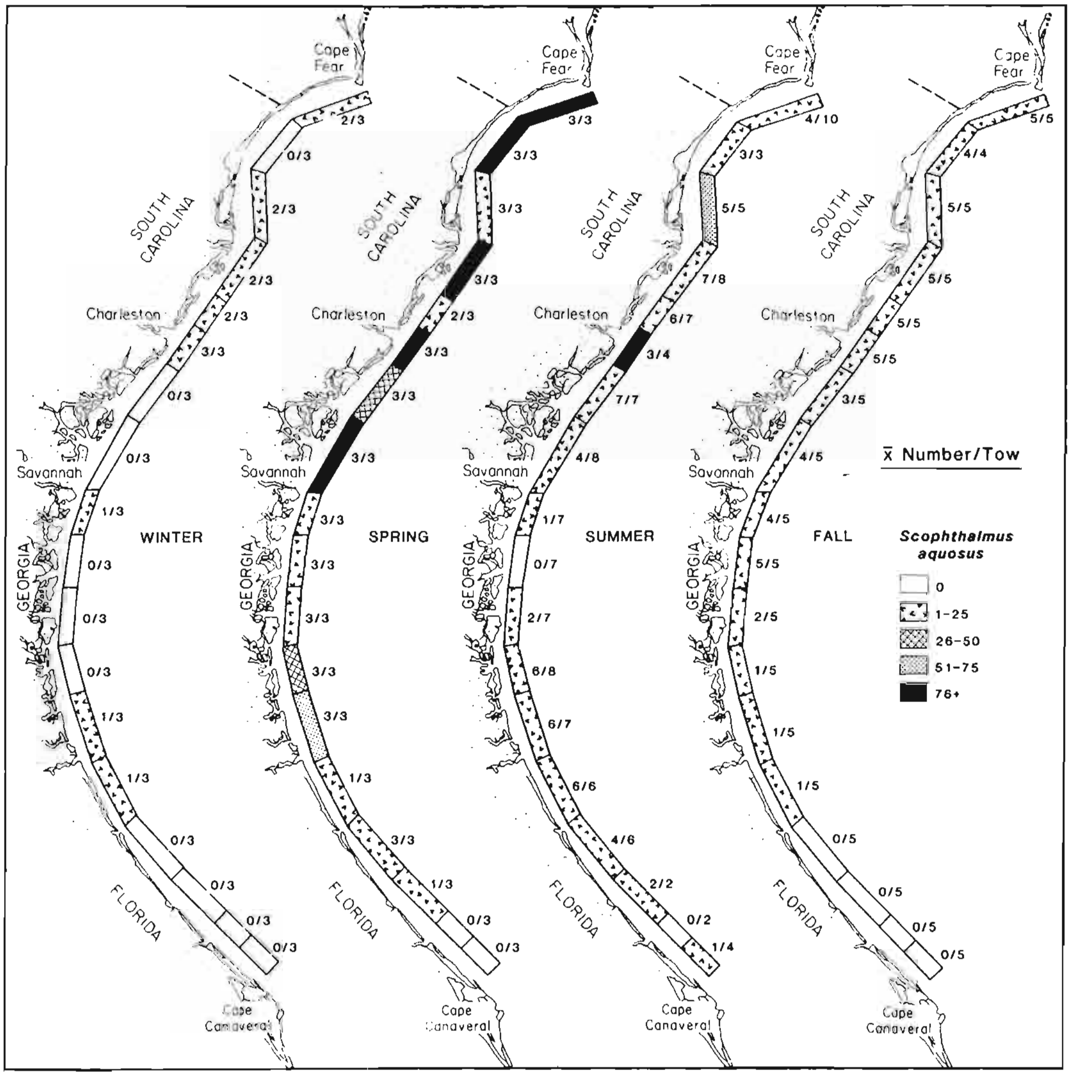

Figure 19
Seasonal catch rates in coastal strata. n/N=no. tows with windowpane/no. tows in stratum.

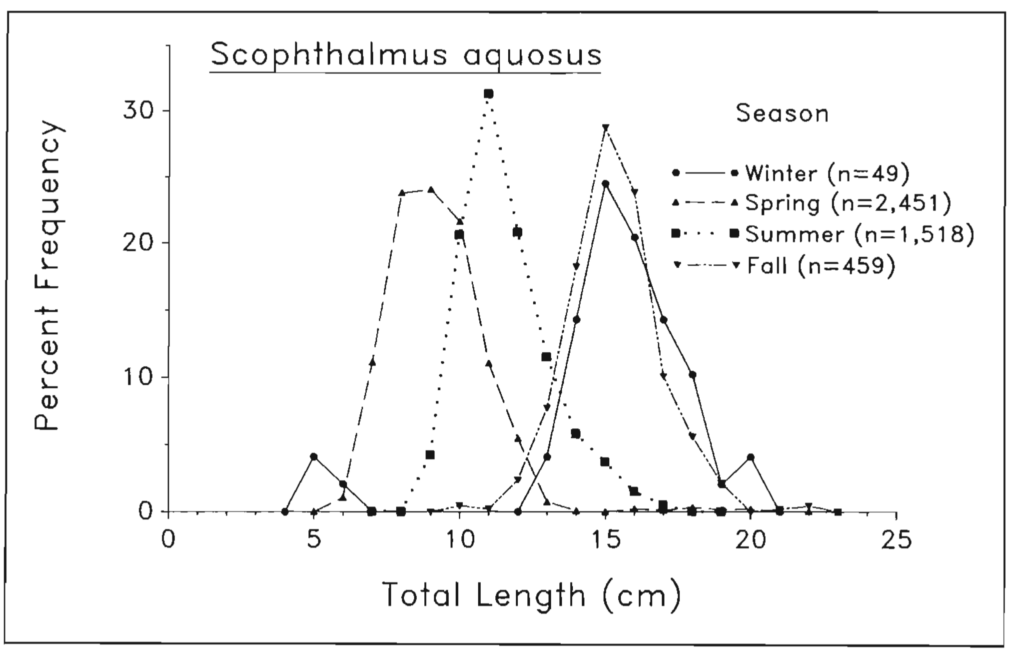

Figure 20
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Striped anchovy occurs along the Atlantic coast from Nova Scotia to Florida, throughout the Gulf of Mexico, and along the South American coast to Uruguay (Hildebrand 1963b, Whitehead et al. 1988). In Chesapeake Bay, Hildebrand and Schroeder (1928) found *A. hepsetus* to be abundant during warmer months in the southern part of the bay. Striped anchovies were year-round residents in estuaries and coastal waters of North Carolina (Schwartz et al. 1982), and have been taken in estuaries of Georgia during warmer months of May to November (15.7-30.8°C) (Dahlberg 1972). In the coastal waters of the SAB, *A. hepsetus* was the ninth most numerous species of fishes, comprising 2.65%, in the incidental bycatch of the penaeid shrimp fishery off South Carolina (Keiser 1976).

In the present study, we found *A. hepsetus* to be the ninth most numerous species for all four surveys combined (Table 2). Because of the small size of the striped anchovy, it ranked only 23rd by weight (Table 3). During the spring, summer, and fall surveys, *A. hepsetus* was found throughout the SAB, but in winter this species was taken only in trawl tows off the Florida coast (Fig. 21). *Anchoa hepsetus* was in 65% of the 305 trawl samples; however, there was a significant difference in its frequency of occurrence between seasons (χ^2 = 47.94, df = 3, p>0.05). Striped anchovies were in only 24% of the winter tows, whereas in spring, summer, and fall they occurred at 74, 72, and 75% of the stations, respectively.

In winter, the mean catch/tow of *A. hepsetus* was low for all strata except for one off central Florida (Fig. 21). Spring samples showed that striped anchovies had spread throughout the Bight with catches being generally low, except off northern and central South Carolina and southern Georgia. Summer and fall values were highest in the southern part of the survey area. The stratified mean catch/tow was highest in the fall for both numbers and weight and lowest in winter (Table 5).

The length composition of *A. hepsetus* from the surveys was:

Fork length (cm)	Winter	Spring	Summer	Fall
3			21	29
4			97	557
5		47	255	324
6		50	627	13
7	3	8	980	1
8		8	795	83
9	60	196	539	1332
10	132	306	382	2071
11	38	106	112	739
12	13	28	10	262
13			1	31
14				
15			1	

From these data, it appears that *A. hepsetus* may live 1+ years.

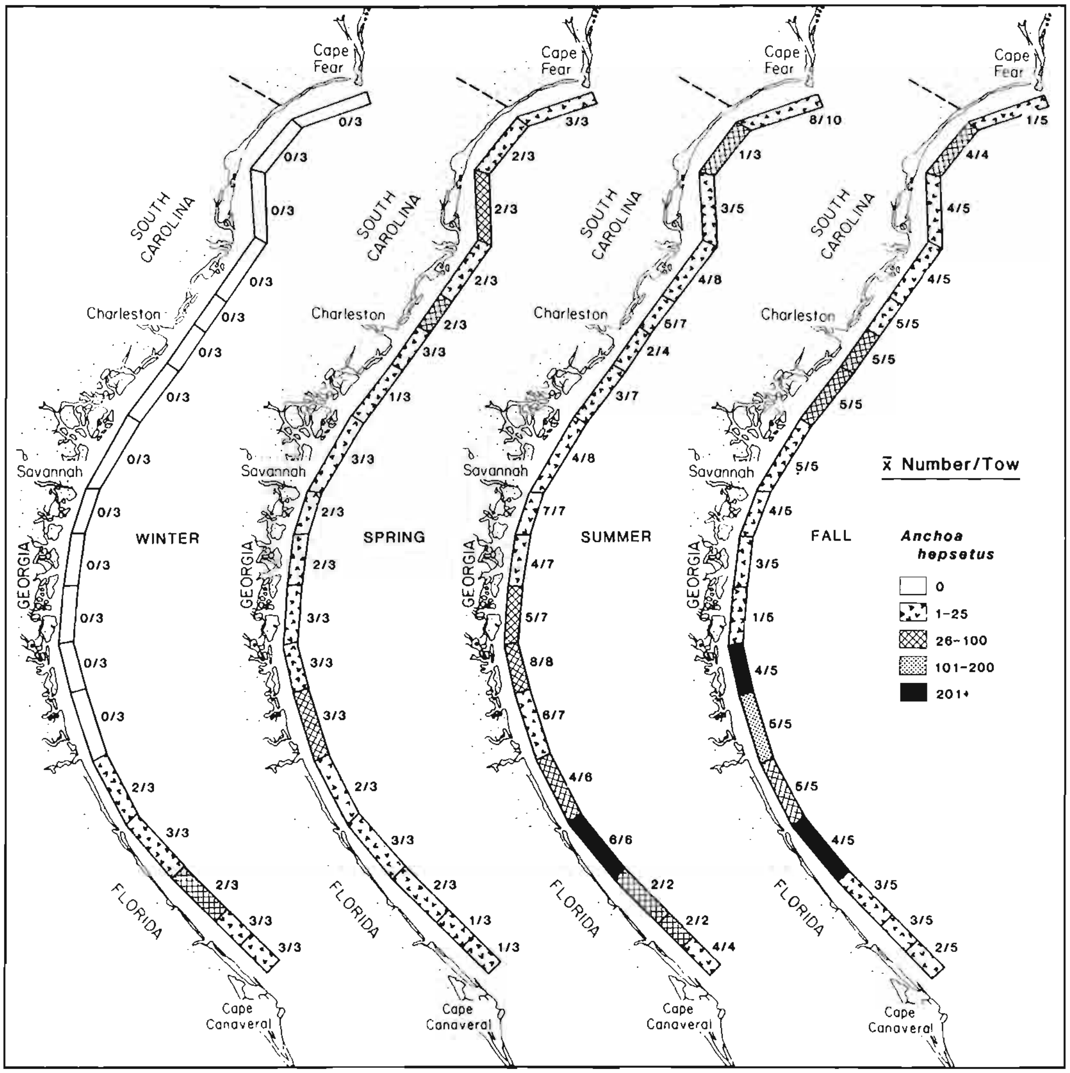

Figure 21
Seasonal catch rates in coastal strata. n/N = no. tows with striped anchovy/no. tows in stratum.

Menticirrhus americanus

Southern kingfish ranges from New York to Texas and is the most abundant of three species of the genus occurring in nearshore waters of the SAB from Cape Fear, North Carolina, to Cape Canaveral, Florida (Hildebrand and Cable 1934, Bearden 1963, Dahlberg 1972). *Menticirrhus americanus* is a demersal species that occurs over a wide variety of substrates ranging from mud to sandy-mud mixtures. Adults prefer sand bottoms of ocean beaches and the mouths of large coastal sounds (Bearden 1963). Southern kingfish are purported to make seasonal movements from the estuarine and nearshore oceanic waters (<9 m) to deeper offshore waters when water temperatures dropped below 10°C (Bearden 1963), yet otter trawl surveys have failed to document this event (Wenner et al. 1979b). A protracted spawning season extends from April to September, and juvenile growth rates are rapid (Hildebrand and Cable 1934, Bearden 1963).

Menticirrhus americanus occurred from Cape Fear, North Carolina, to Cape Canaveral, Florida, during each of the seasonal surveys (Fig. 22). However, a highly significant ($p<0.01$) seasonal difference in the frequency of occurrence in trawl tows was found ($\chi^2 = 35.43$, df = 3). Frequency of occurrence was highest during summer and fall when *M. americanus* was found in 93 of 108 and 87 of 89 trawl collections, respectively. In winter, southern kingfish were encountered in 32 of 54 tows, and the spring survey found this species in 41 of 54 tows. Southern kingfish ranked tenth in numerical abundance overall and third by weight for the survey (Tables 2, 3).

Winter abundance, as indicated by the mean catch/tow was greatest toward the south (Fig. 22). In winter, the transformed values (ln [number + 1]) of the mean catch/tow were significantly correlated with the mean bottom temperatures of the strata ($r = 0.611$, $p<0.05$, df = 16). During spring, southern kingfish spread throughout the Bight and reached their greatest frequency of occurrence and abundance in fall trawl tows.

The stratified mean catch/tow by number was lowest in the winter and highest in the summer (Table 5) when its value was five times greater than the winter minimum. Larger, heavier *M. americanus* were captured in fall, thus making this season first by weight.

Menticirrhus americanus moves from high-salinity estuaries and coastal waters of the northern parts of the SAB to the central Atlantic coast of Florida during winter. A four-year average of commercial landings for "king whiting" (mostly *M. americanus*) in the Cape Canaveral area showed that 88% of the 112,084 kg landed on average were made between November and February (Anderson and Gehringer 1965). Maximum landings occurred at the height of the shrimp season and coincided with increased effort. Fisheries independent data from 1933-1935 showed lowest catches in the spring (2-3 fish/hour), moderate summer (40-274 fish/hour) and winter catches (50-188 fish/hour), and maximum catches in the fall (44-680 fish/hour) off central Florida (Anderson and Gehringer 1965, see Table 9). The recent increase in Florida landings probably resulted from increased winter effort in the penaeid shrimp fishery along the Florida coast coupled with the "concentrating" effect of seasonal hydrographic conditions.

Although *M. americanus* was a year-round, shallow-water resident of the SAB, seasonal changes in abundance were readily apparent. Bearden (1963) obtained the lowest catch/tow in southern South Carolina estuaries and coastal stations from January through April; maximum values were from August through November. We observed the same seasonal changes in abundance with few *M. americanus* captured north of Savannah, Georgia, during winter. Since abundance was correlated with temperature, it appears that most fishes move into warmer waters with the cooling of coastal water in winter. It was assumed that during this period of cold water temperatures, *M. americanus* moves offshore to deeper, warmer water (Bearden 1963). This does not appear to be the case since this species was encountered in only 14% of the stratified random trawl tows ($N = 35$) in deeper water during winter months (Wenner et al. 1979b). We also failed to observe any seasonal trend in the frequency of occurrence, and all captures were in depths from 9 to 20 m, mostly along the coast.

Seasonal length-frequency distributions indicated that two age-classes, in addition to young-of-the-year fish, were present in the catches, based on age data from Smith and Wenner (1985) (Fig. 23).

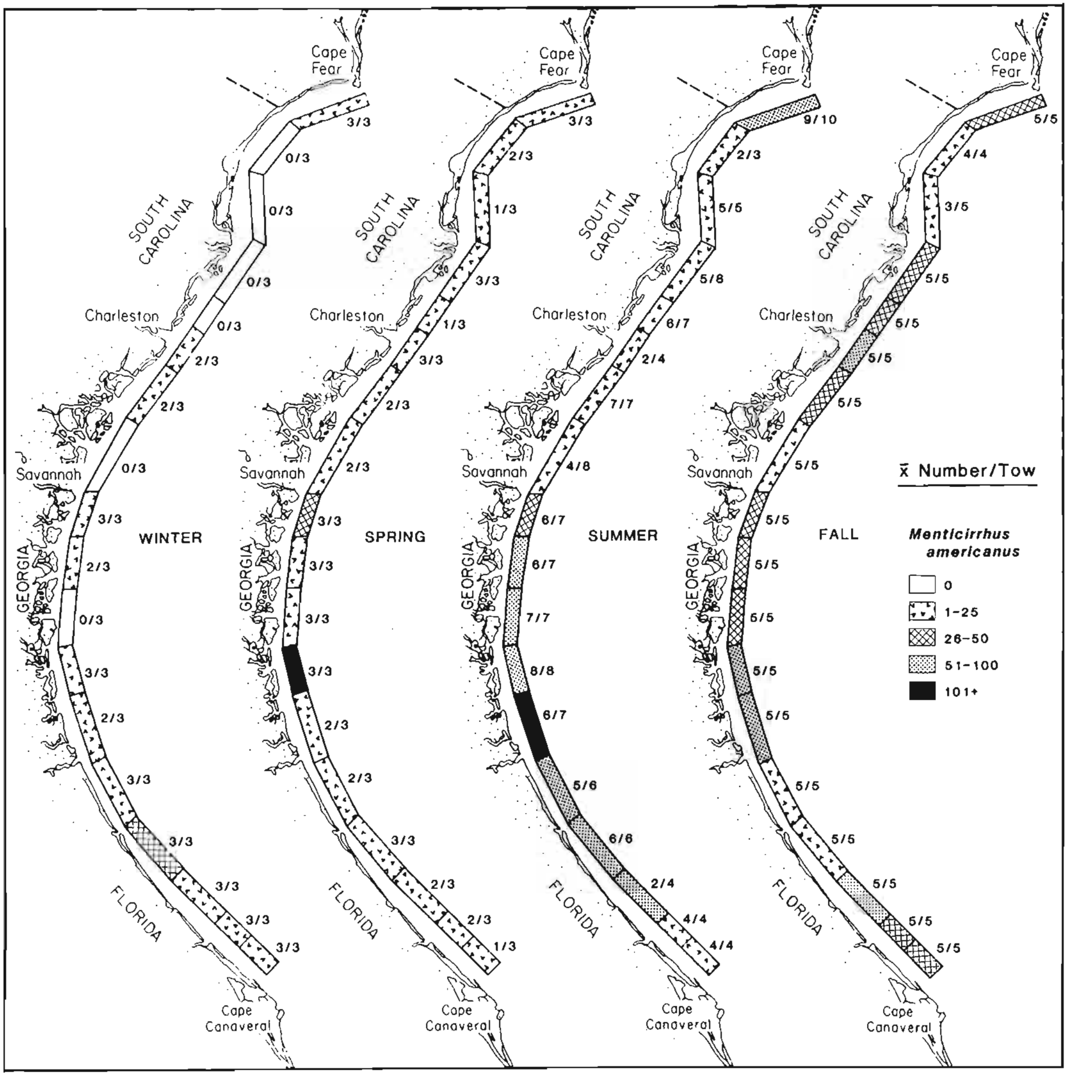

Figure 22
Seasonal catch rates in coastal strata. n/N=no. tows with southern kingfish/no. tows in stratum.

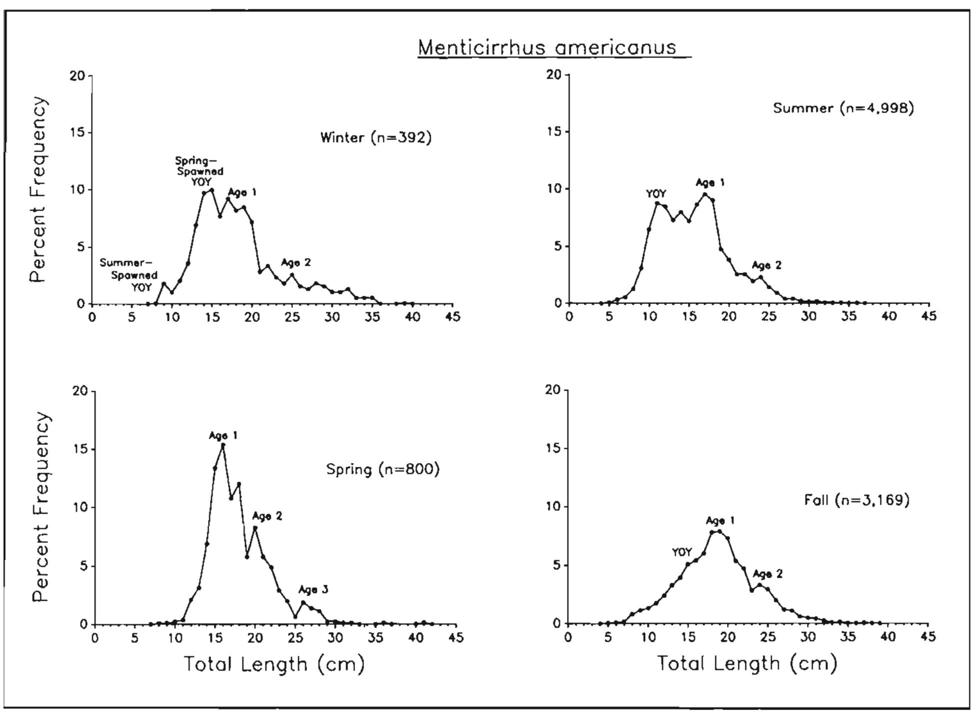

Figure 23
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Symphurus plagiusa

Blackcheek tonguefish is found along the Atlantic and Gulf coasts of the United States, the Bahamas, and in the Greater Antilles (Fischer 1978). It is the most common species of *Symphurus* on the Atlantic and Gulf coasts of the United States in inshore waters (Ginsburg 1951). *Symphurus plagiusa* is the most euryhaline of the Atlantic cynoglossids, being found from freshwater in estuaries (Schwartz et al. 1982) to hypersaline waters in Florida (Roessler 1970).

Along the southeastern coast of the United States, *S. plagiusa* has been reported from the estuaries of North Carolina (Tagatz and Dudley 1961, Schwartz et al. 1982), South Carolina (Wenner et al. 1982) and Georgia (Dahlberg 1972). In nearshore waters off South Carolina, *S. plagiusa* was most abundant December-April and composed 2.05% of the total number of fishes in the bycatch of the penaeid shrimp fishery (Keiser 1976). In the Gulf of Mexico and Middle Atlantic Bight, this species spawns during spring and summer (Topp and Hoff 1972, Olney and Grant 1976).

In the present study, *S. plagiusa* was the eleventh most numerous species and ranked fifth by weight (Tables 2, 3). This species was found at 78% of stations from all cruises, and there was a significant difference in the frequency of occurrence of *S. plagiusa* between seasons ($\chi^2 = 41.998$, df = 3, $p > 0.05$). It occurred less frequently during winter (48% of all tows) than in spring (85%), summer (76%), or fall (94%). Seasonal samples found *S. plagiusa* to be widespread throughout the survey area (Fig. 24). Catch-per-tow values by stratum were generally low in winter, with maximum catches off southern South Carolina and central Georgia (Fig. 24). During spring, mean values were lowest in southern strata and highest off the northern Georgia coast. Summer catches were relatively consistent throughout the SAB, and catches in fall were highest in the more northern strata.

The length composition of the trawl-caught *S. plagiusa* was consistent from season to season, with means of 14-15 cm TL (Fig. 25). The smallest individual was 5 cm TL from the summer, whereas the largest specimens were 21 cm TL from the fall. The fact that fish less than 10 cm TL were rare in the samples indicated that either *S. plagiusa* inhabit a different habitat as juveniles or they are not recruited to the fishing gear until 10 cm TL.

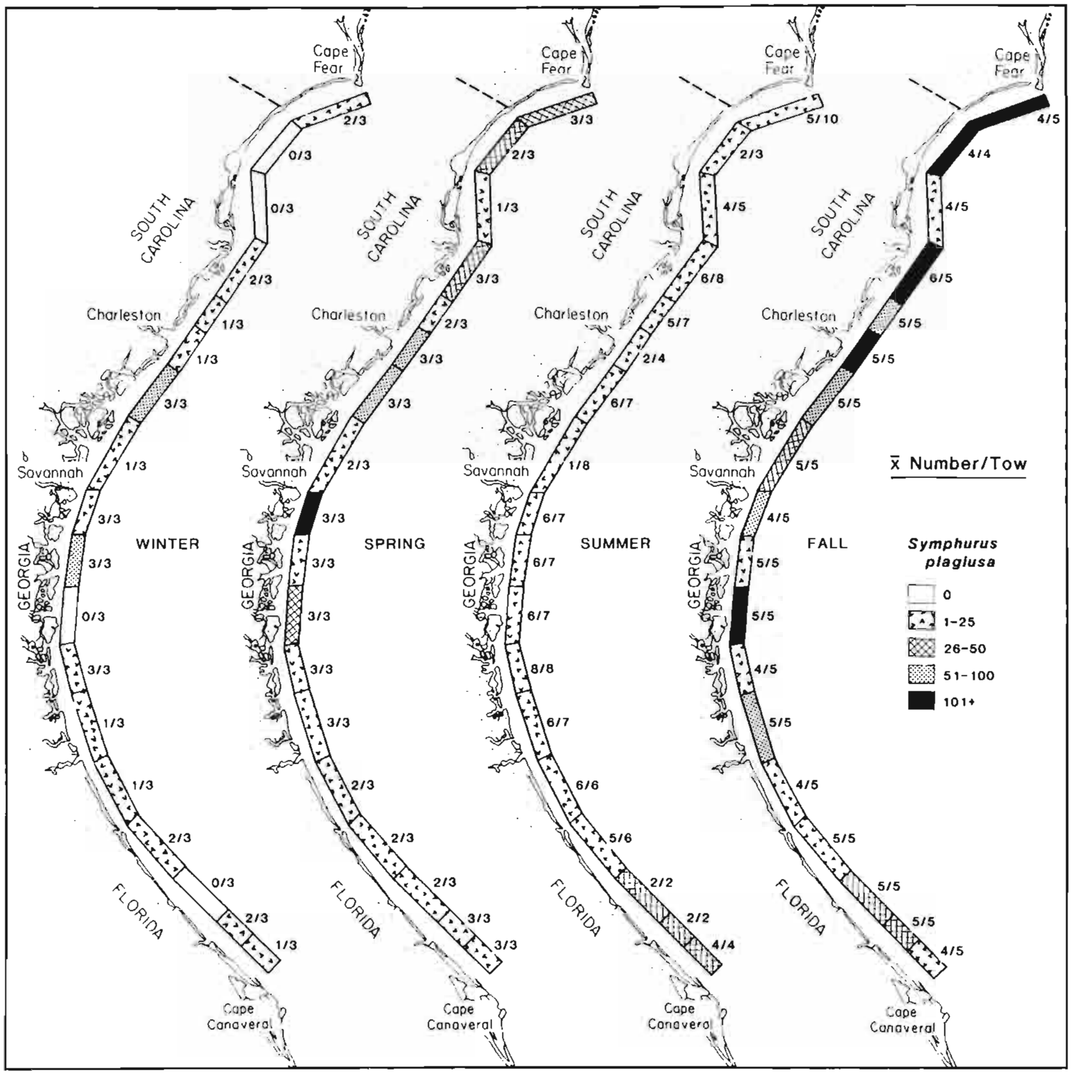

Figure 24
Seasonal catch rates in coastal strata. n/N = no. tows with blackcheek tonguefish/ no. tows in stratum.

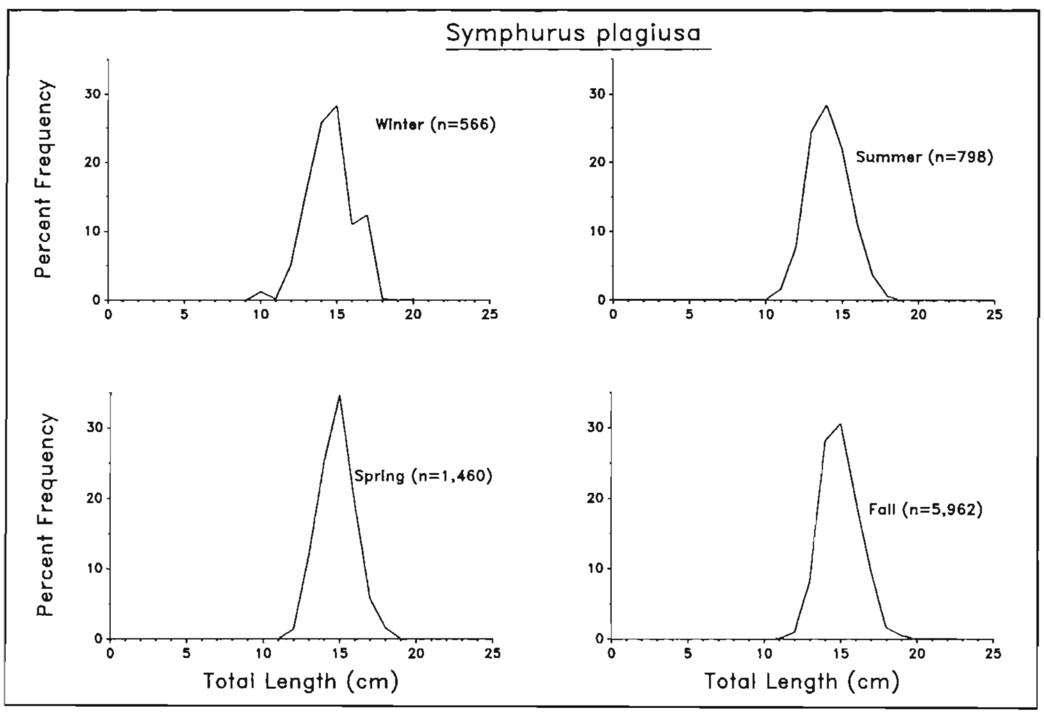

Figure 25
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Opisthonema oglinum

Atlantic thread herring is a pelagic clupeid that occurs primarily in coastal waters from the Gulf of Maine to Brazil (Fischer 1978). Occasionally this species will form dense nearsurface schools that are harvested by the same purse seine nets as those used in the menhaden fishery (Fuss et al. 1969). In the eastern Gulf of Mexico, gill net catches of *O. oglinum* were highest between 27 and 29°C in coastal waters less then 18.3 m deep (Kinnear and Fuss 1971). Along the South Atlantic coast, thread herring was reported as a ubiquitous, transient species that occurred over a broad range of temperature (0.7-31.0°C) and salinity (0.5-36‰) in the Cape Fear River estuary of southern North Carolina (Schwartz et al. 1982). In the coastal waters of South Carolina, *O. oglinum* was collected in the surf zone (Anderson et al. 1977) to locations as far as 20 km offshore (Wenner et al. 1979d). These latter few specimens were taken incidentally to demersal species in bottom trawl samples. *Opisthonema oglinum* was found during all seasons in the bycatch of fishes of the South Carolina penaeid shrimp fishery (Keiser 1976), and Dahlberg (1972) occasionally collected *O. oglinum* in the higher-salinity waters of lower estuaries and ocean beaches along the Georgia coast. Small numbers were reported throughout the year in the bycatch from inventories of the penaeid shrimp resource in coastal and estuarine areas of Georgia and Florida (Anderson 1968).

During the present study, *O. oglinum* ranked 20th in numerical abundance but only 34th by weight, since they were generally small fishes that contributed only 0.36% to the total catch.

Opisthonema oglinum was taken in 105 of the trawl tows made during the survey. Although this species was encountered throughout the study area, seasonal differences in the frequencies of occurrence and distribution patterns were apparent (Fig. 26). There was a significant difference in the frequency of occurrence between seasons ($\chi^2 = 28.70$, df = 3, $p>0.05$). *Opisthonema oglinum* occurred in significantly fewer trawl tows during winter than in spring ($\chi^2 = 17.00$, df = 1, $p>0.05$), summer ($\chi^2 = 23.88$, df = 1, $p>0.05$) or fall ($\chi^2 = 4.01$, df = 1, $p>0.05$). Frequencies of occurrence in spring and summer collections were not significantly different ($\chi^2 = 0.18$, df = 1), whereas both of these seasons had significantly greater frequencies than during the fall (spring-fall $\chi^2 = 4.64$, df = 1, $p>0.05$; summer-fall $\chi^2 = 9.17$, df = 1, $p>0.05$).

Seasonal catches indicated that during the winter months the distribution of *O. oglinum* was restricted primarily to the coastal waters off Florida (Fig. 26). With the onset of spring, thread herring dispersed throughout the Bight; however, catch rates and frequency of occurrence were still greater in the southern strata. In summer, *O. oglinum* was fairly ubiquitous throughout the survey area. With the cooling of the coastal waters in fall, this species migrated to the south. The seasonal changes in this species' distribution pattern inferred from trawl catches is supported by additional evidence from tagging studies. Pristas and Cheek (1972) tagged fish off Beaufort, North Carolina, during September and recoveries showed that by November these individuals had migrated south 592 km to the coastal waters off northern Florida.

The stratified mean catch/tow (in number) was lowest in the spring and highest in the fall (Table 5). The fall value was highest because of elevated catch rates in the southern part of the survey area during this season.

Opisthonema oglinum has a protracted spawning season (April-September) in the eastern Gulf of Mexico (Houde 1977). A more restricted period was reported off Beaufort, North Carolina (Hildebrand 1963a). Initial estimates of length-at-age for *O. oglinum* from commercial purse catches in the eastern Gulf of Mexico were: age-I 146 mm FL; age-II 149 mm FL. Estimates of age-III were considered unreliable because of the small sample size (Fuss et al. 1969). The methodology was not validated and sampling was biased by the gear. We did not age or document the reproductive biology of this species during this study; however, some very tentative inferences can be made about these aspects of the natural history of *O. oglinum* from the seasonal length-frequencies of the trawl catches.

The length composition of the fish caught during the winter survey had one apparent mode (8 cm FL, Fig. 27). Two modes (10 cm FL and 14 cm FL) were observed during spring, and summer samples had smaller fish (4-6 cm FL) that were absent during other seasons. These small fish were probably the result of a spring spawning event in the SAB and represented the size of first recruitment to the fishing gear. The fall survey had length frequencies with modes at 8 cm FL and 15 cm FL, and lengths in winter trawl tows were also bimodal (8 and 15 cm FL). We interpret these data as indicating that during the spring, age-I fish ranged in length between 9 and 13 cm FL, while age-II were from 13 to 16 cm FL. The smaller fish taken during the summer survey were young-of-year. Further estimates from these data could be misleading because of the nature of the distribution in the larger length classes and the possibility of size-related changes in migratory patterns and vulnerability to the gear.

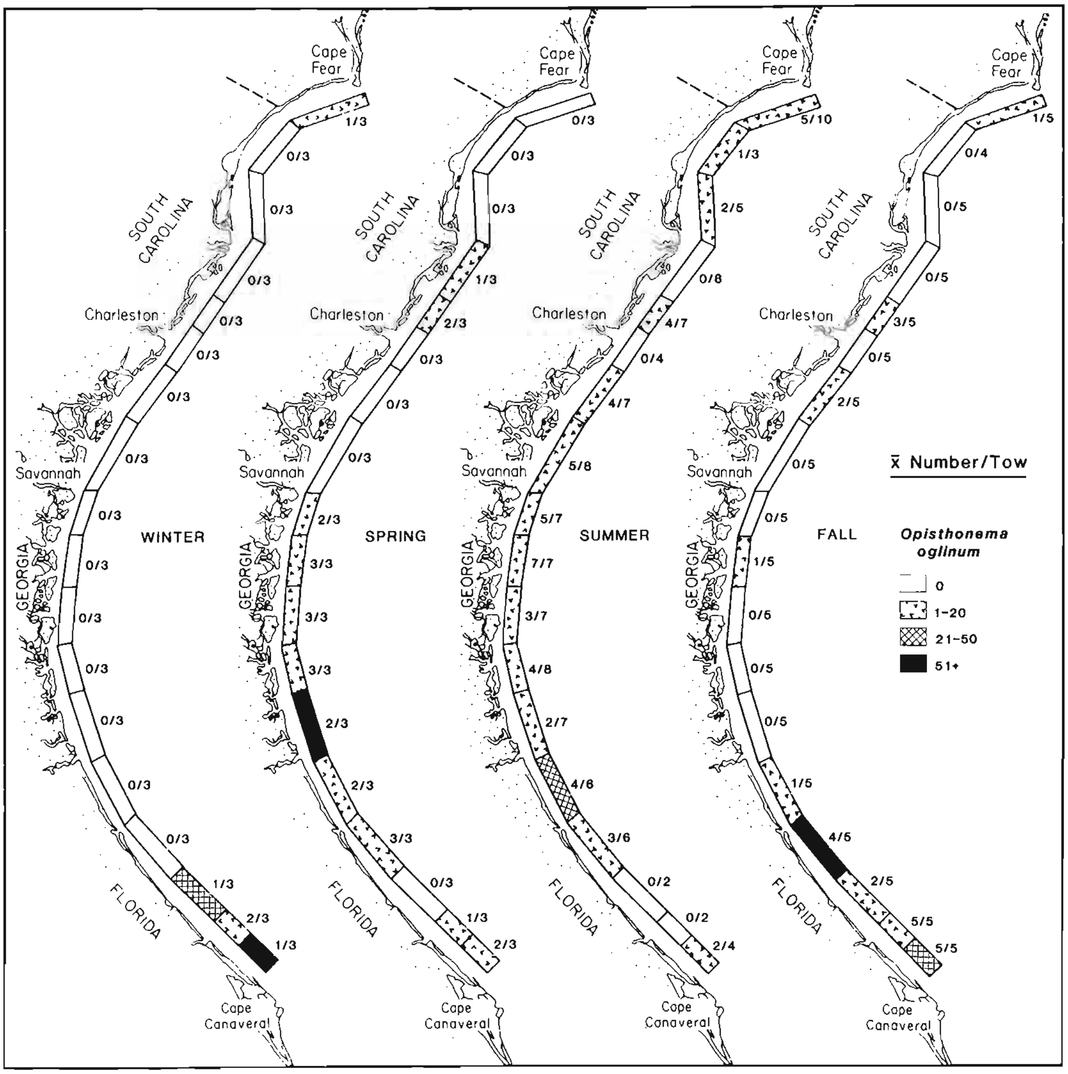

Figure 26
Seasonal catch rates in coastal strata. n/N=no. tows with Atlantic thread herring/ no. tows in stratum.

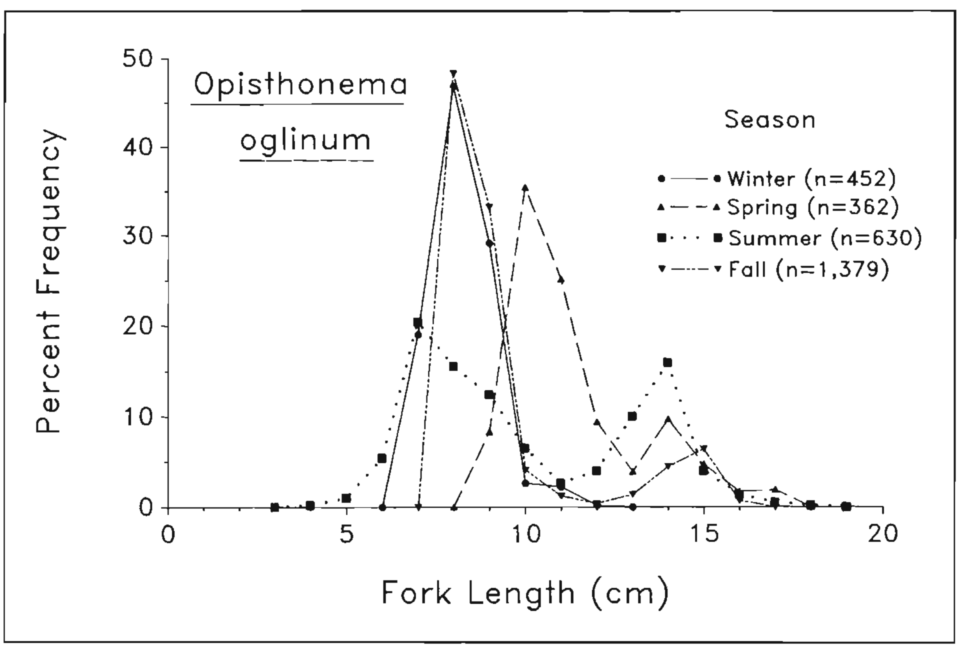

Figure 27
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Bluefish is a pelagic schooling species of commercial and recreational importance that occurs throughout the Gulf of Mexico, along northern Cuba, Bermuda, and the Atlantic coast of the United States to Nova Scotia (Fischer 1978). This species is also found along the eastern coast of South America, in the eastern Atlantic and Mediterranean Sea, and in the Indo-West Pacific (Fischer 1978). Along the Atlantic coast of the United States, bluefish are highly migratory. A generalized movement pattern has emerged from ichthyoplankton and tagging studies, but specific movements from all areas are unknown. This is especially true for juvenile bluefish from the coastal and estuarine habitats of the SAB. The seasonal movements of adult fishes (north in spring, south in fall) are well documented (Lund and Maltezos 1970, Wilk 1977, Kendall and Walford 1979). During fall, cooling of waters on the continental shelf in the northern part of the species range along the eastern U.S. stimulates the movement of adult bluefish to warmer waters offshore and south (Lund and Maltezos 1970). Some individuals migrate to waters off southeastern Florida (Wilk 1977), whereas others from southern New England apparently move southeast to the warmer waters of the upper continental slope in the vicinity of Hudson's Canyon where they have been taken in otter trawl gear (Lund and Maltezos 1970, Bigelow and Schroeder 1953). In the spring, bluefish migrate from shelf waters off southeastern Florida to higher latitudes (Wilk 1977).

Ichthyoplankton surveys have found two distinct periods and areas of peak reproduction of bluefish along the Atlantic coast. South of Cape Hatteras, N.C. (approx. 35°N), major concentrations of larval *P. saltatrix* were found inside the 183-m (100-fm) curve from 33°N to 34°N during May (Kendall and Walford 1979) and offshore of the continental shelf north of 32° in April and May (Collins and Stender 1987). Powles and Stender (1976) and Collins and Stender (1987) found larval *P. saltatrix* east of the 100-fm curve in the SAB in significant numbers during May. In the Middle Atlantic Bight, maximum larval abundance was found in midshelf waters from 38°N to 40°N during August (Kendall and Walford 1979). It should be noted, however, that spawning activity as demonstrated by the presence of larvae occurs winter, spring, and autumn (Powles and Stender 1976, Kendall and Walford 1979, Collins and Stender 1987) in the South Atlantic and June through September in the Middle Atlantic Bight (Kendall and Walford 1979).

With the exception of the schools of adult fishes that occur around artificial reefs and jetties during early spring, the bluefish found in the coastal habitat of the SAB are juveniles. Kendall and Walford (1979) present a generalized scheme of recruitment pathways of larval and juvenile bluefish into estuarine nursery areas, but there is an obvious lack of information on juvenile bluefish in the nursery areas of the SAB. Larval bluefish are primarily neustonic and have a life-cycle involving spawning in warm, saline, offshore waters and movement to cooler, less saline, nearshore waters (Powles 1981, Kendall and Walford 1979). Powles (1981) found the smallest larval bluefish nearest the 180-m contour in the SAB, and Collins and Stender (1987) reported maximum abundance of larvae ≤4 mm over the outer continental shelf. Larval size increases with proximity to shore (Powles 1981, Collins and Stender 1987). Collins and Stender (1987) suggested that a southerly flowing countercurrent (Bumpus 1973) may provide a mechanism for movement of larvae to nearshore waters within the SAB.

Along the South Atlantic coast, *P. saltatrix* has been found from the surf zone (Anderson et al. 1977) to offshore waters at the outer continental shelf (37-55 m) (Wenner unpubl. data). This species occurs in all estuarine systems of the area from the Cape Fear River estuary in North Carolina (Schwartz et al. 1982), South Carolina (Wenner et al. 1982), and Georgia (Mahood et al. 1974a,b,c). Bluefish have been found in the bycatch of the commercial shrimp fishery off South Carolina (Keiser 1976), Georgia (Knowlton 1972), and Florida (Anderson and Gehringer 1965). In South Carolina coastal waters, young bluefish accounted for 0.49% and 0.89% of the number and weight, respectively, of fishes in the bycatch over a 14-month period (Keiser 1976). Seventy-seven percent of the total number and 65.7% of the weight were found during June, July, and August (Keiser 1976). Only six specimens weighing 0.3 kg were collected from December to May (Keiser 1976). In Georgia, *P. saltatrix* was a minor constituent of the bycatch, comprising <0.1 (July) to 2.5% (November) of the total weight of the bycatch of fishes (Knowlton 1972). Catch rates were 0 or very low (<0.1 kg/h) from December to April. Bluefish were taken in trawl tows during all months in estuarine systems of Georgia (Mahood et al. 1974a,b,c). Largest catches occurred in April, May, and June; these accounted for 55% of the total weight of bluefish taken during the annual survey.

In the present study, bluefish ranked 30th by numerical abundance (980 individuals, 0.28% of the catch) and 18th by weight (Table 3) for the four surveys. Forty-one percent of the 305 total trawl collections caught bluefish. Sampling showed seasonal changes in the distribution, frequency of occurrence, and abundance in the SAB. Bluefish were in only a single trawl haul (southern South Carolina) along the coast of the Carolinas during winter (Fig. 28), but were more abundant in strata to the south. During the other seasons, this species was widely distributed throughout the Bight. There was a significant difference in the frequency of occurrence of bluefish between seasons (χ^2 = 19.91, df = 3, p>0.05). Winter sampling found *P. saltatrix* in significantly fewer trawl collections (11 of 54) than spring (33 of 54; χ^2 = 18.56, df = 1, p>0.05), summer (40 of 108; χ^2 = 4.63, df = 1, p>0.05), or fall tows (40 of 89; χ^2 = 7.57, df = 1, p>0.05). Seasonal values of the stratified mean catch-per-tow for bluefish were:

Season	$\bar{y}_{st}$ no.	$\bar{y}_{st}$ kg
Winter	3.7	0.15
Spring	4.4	0.43
Summer	1.5	0.14
Fall	3.5	0.47

Although bluefish may forage throughout the water column, they are primarily a strong-swimming pelagic species (Wilk 1977). The present study reports the catches of a four-seam, demersal shrimp trawl net. Therefore, these catch rates with their means should be considered relative.

Although the seasonal surveys were not sequential, it is possible to follow the length composition of bluefish in the coastal habitat of the SAB over an ''annual cycle'' (Fig. 29). Wilk (1977) presented the following mean-length-at-age estimates for *P. saltatrix* aged by scales: I 21 cm FL; II 35 cm FL; III 41 cm FL. He determined that the annulus was laid down during spring by marginal increment analysis. Based on this information, bluefish collected during the winter survey ($\bar{x}$ FL = 16 cm; mode = 15 cm; range 12-23 cm) were young-of-year (YOY) probably spawned during the late winter or spring (Powles and Stender 1976, Kendall and Walford 1979, Collins and Stender 1987). The spring survey collected some small individuals (7-10 cm FL) that may have resulted from the fall spawn in the SAB (Kendall and Walford 1979). The overall mean length was 19 cm FL (mode 18 cm; range 7-31 cm), and according to Wilk (1977) these were almost 1 year-old, i.e., the first annulus was about to be laid down. Bluefish from the summer survey had a large length range (12-33 cm FL; $\bar{x}$ 18 cm) and were probably YOY and age-I fish. Fall fish averaged 21 cm FL (range 9-30 cm), and these were probably YOY and age-I fish as in the summer collections.

From these data, it appears that the coastal waters of the SAB provide habitat for a significant number of YOY and age-I bluefish. In addition, personal observations indicate that bluefish of sizes similar to those captured in the coastal surveys inhabit the estuaries of South Carolina during the warmer months of the year. The relative abundance of larger fish (ages II and older) during the year does not reflect the abundance of juvenile bluefish in South Carolina waters. This strongly suggests that with increased length and age, bluefish that utilized both the estuaries and coastal waters of the SAB as ''nursery areas'' joined the bulk of the larger fish that have large seasonal migrations along the Atlantic coast. The relative contribution of this ''stock'' to the western Atlantic population has not been documented and in most cases it is ignored (Wilk 1977). However, estuaries in coastal South Carolina and Georgia are extensive, and bluefish from these areas may make a significant contribution to the harvest in northern waters as they mature.

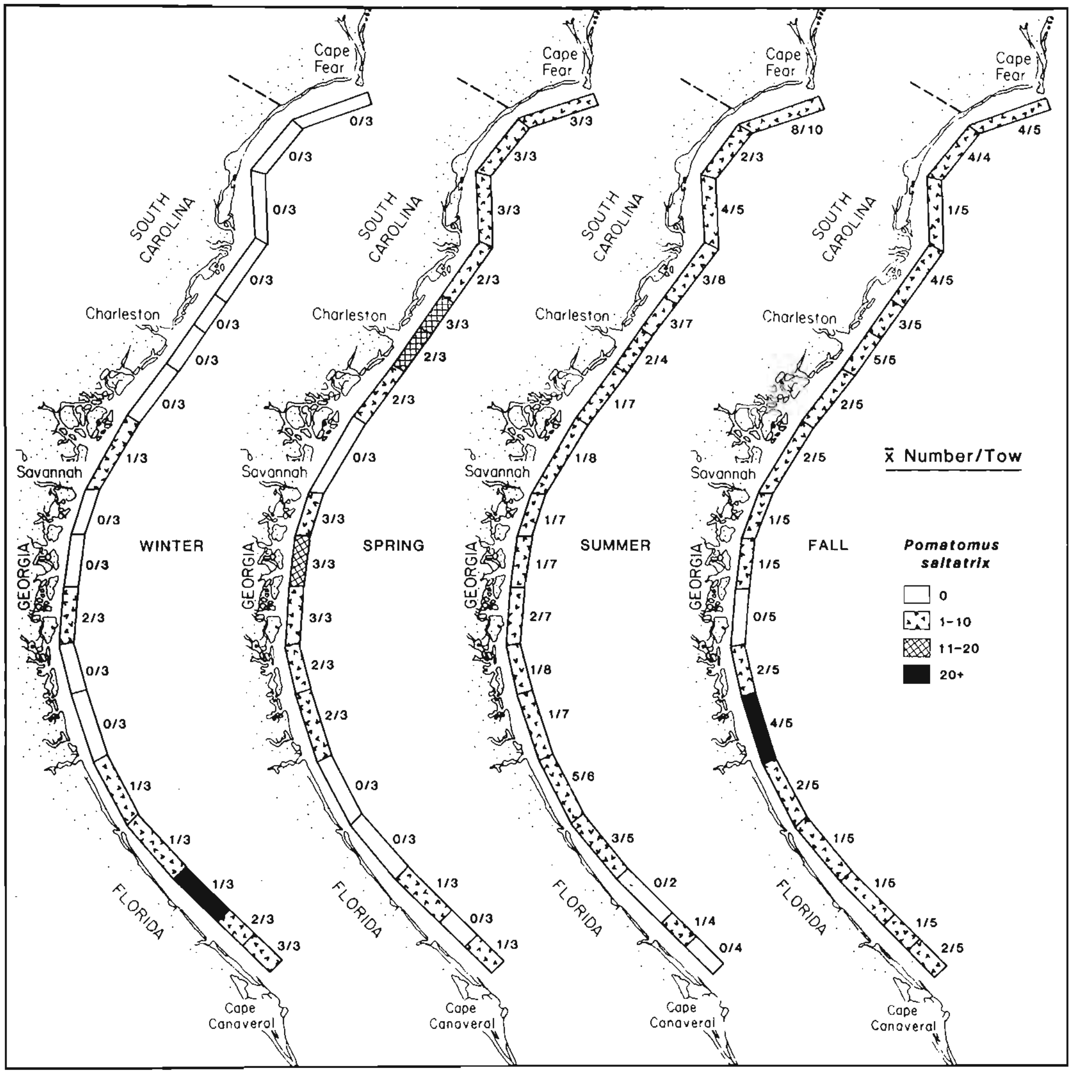

Figure 28
Seasonal catch rates in coastal strata. n/N=no. tows with bluefish/no. tows in stratum.

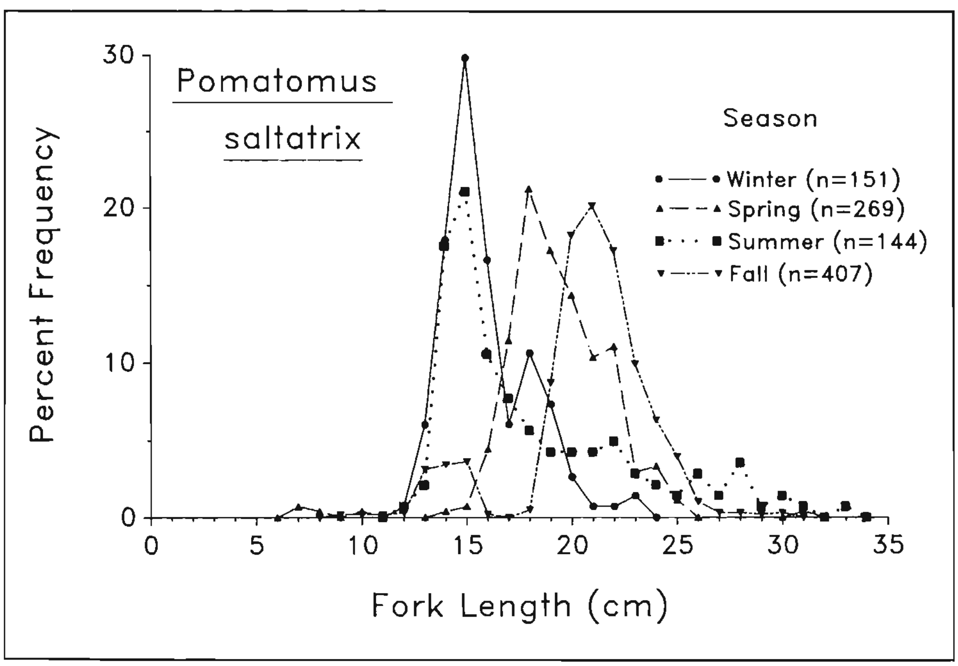

Figure 29
Seasonal length-frequency distribution in South Atlantic Bight coastal waters.

Community analysis

Normal cluster analysis formed 11 groups of sites, and clusters primarily reflected the similarity of species composition within the season of collection. Geographic area appeared to have a secondary influence on the cluster results (Fig. 30). Group 1 consisted mainly of collections from North Carolina through Georgia. Many of these entities were united because they consisted of trawl collections off Georgia in spring. Northerly stations that were sampled in summer and fall also occurred in this group, perhaps indicating seasonal migration of similar species between these regions. Collections in Groups 2 and 3 consisted of stations off South Carolina that were sampled in all seasons except winter. Most of these stations were sampled in spring and summer. Collections in Groups 4 and 5 were all made in fall, and most were from South Carolina and Florida waters. Group 6 stations were primarily from northern Florida and southern Georgia in summer. Group 7 stations were primarily southern stations sampled in spring and fall. Station Group 8 included collections from Florida in winter and South Carolina in summer and fall, indicating occurrence of similar species in these relatively widely separated geographic areas during different times of the year. Group 9 consisted of stations that were located throughout the SAB during the cooler seasons of winter and spring. Group 10 comprised stations from Florida and Georgia sampled during the warmer seasons, and Group 11 comprised mainly stations from Georgia and South Carolina waters sampled in winter.

Inverse cluster analysis formed 14 groups of species with similar distributions (Table 6, Fig. 31), some of which showed high constancy at several site groups (Fig. 32). In general, however, fidelity values were low, indicating broad latitudinal distribution of species groups over the four seasons. Species in Group A were small, benthic species that were found most often off Florida and Georgia, generally during the warmer seasons. Group A species were most frequent at stations in site Group 10 (Florida and Georgia in summer and fall), and showed moderate fidelity to that site group.

Group B included some schooling species (*S. vomer*, *S. maculatus*, *S. aculeatus*, *R. terraenovae*). These species were frequently taken from site Group 3, spring and summer collections off South Carolina. Collins and Wenner (1988) found increased abundance of *S. maculatus* in trawl catches in the South Atlantic Bight in summer, and clustering of Group B species may reflect the abundance of newly recruited juveniles to coastal waters of the Bight. Large numbers of other Group B species, such as *S. aculeatus*, *R. terraenovae*, and *P. carolinus*, occur in shallower waters in summer (Fritzsche 1978, Sedberry and Van Dolah 1984, Parsons 1983), reflecting seasonal migration and recruitment in these species. Group B species showed low fidelity to all site groups. Group C species showed high fidelity to site Group 11 (winter stations off South Carolina and Georgia). *Squalus acanthias*, a member of Group C, is commonly found in coastal waters of the southeast only in winter (Struhsaker 1969), as are migrating American shad (Leggett and Whitney 1972, Van Dolah, et al. 1987).

Species Groups D,J,K,L,M, and N comprised species that appeared to be ubiquitous, year-round residents of coastal waters, based on within-group uniformity of constancy levels and a concomitant low fidelity for all site groups. Species in Group D were relatively rare species that showed low constancy to all site groups, whereas Groups J-N were frequently taken (i.e., high in constancy) at most site groups. These groups included very abundant species such as those in Group L, which demonstrated very high constancy at all site groups, as well as other species collected throughout the Bight. Species in Groups J and M were high in constancy at all site groups except Group 11, which were mainly winter stations off South Carolina and Georgia. Many of these species were sciaenids known to migrate to offshore waters and to the south in winter (Chao and Musick 1977) as well as other species known to have similar winter movements. It is noteworthy that spotted hake, *U. regia*, occurred in Group J. Based on reported seasonal offshore-inshore migrations for this species, it should occur relatively frequently in coastal waters in winter (Sikora et al. 1972, Burr and Schwartz 1986). Apparently spotted hake had moved farther inshore into high-salinity estuaries during the winter sampling period. January movement into estuaries is well-documented for spotted hake (Barans 1972, Sikora et al. 1972, Burr and Schwartz 1986). Species in Group N were high to very high in constancy at all site groups with the exception of Group 5 that consisted of all fall collections off Florida.

Groups E through I, unlike many other species groups, demonstrated moderate to high fidelity for at least one site group. Species in Group E were moderately faithful to site groups from summer and fall southern strata (Georgia and Florida). Group F species were moderately faithful to sites from South Carolina in spring and summer. Group G consisted mainly of elasmobranch species that were relatively rare in collections, but occurred frequently in fall samples (site Groups 4 and 5), probably reflecting coastal migratory patterns exhibited in many coastal elasmobranch species (Smith and Merriner 1986). The occurrence of many species of large elasmobranchs to the exclusion of most small teleosts has been noted previously, and may indicate competition between the two groups or avoidance of predation by the smaller teleosts (Longhurst 1969). Species Groups H and I were also frequently taken in fall samples (site Groups 4 and 5).

Highest diversity (H') was in summer (Fig. 33), and H' diversity values appeared to be more influenced by the evenness of distribution of individuals among species (Fig. 34) than by species richness (Fig. 35). The overwhelming dominance of spot (Table 2), which was at least one order of magnitude more abundant than all other species, contributed to the low evenness values, and low H' values often coincided with high abundances of spot. Lowest values of H' were found in winter and spring when evenness and, particularly in winter, species richness values were low. Low diversity values in winter probably reflect migration offshore

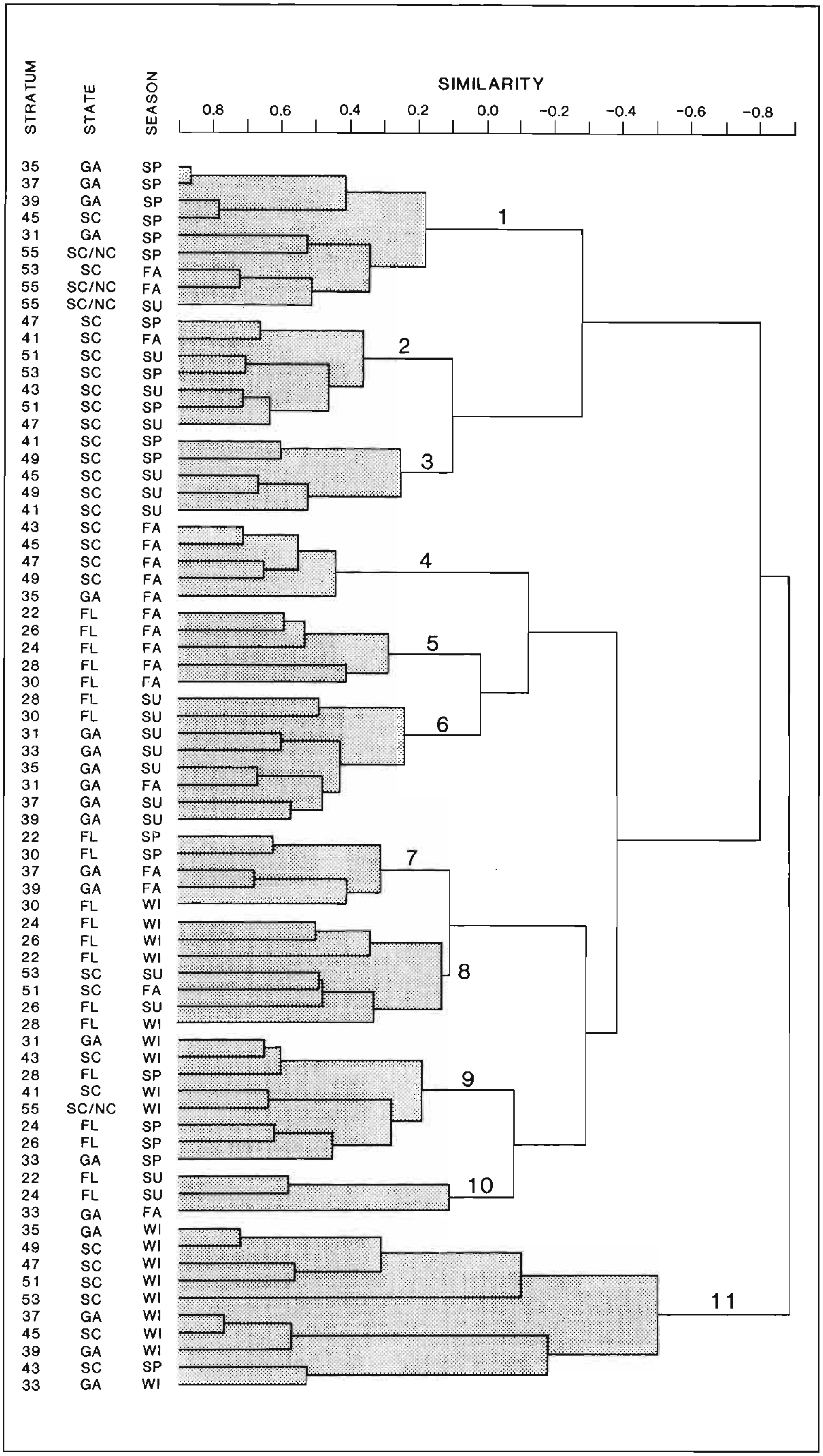

Figure 30
Dendrogram depicting normal cluster analysis of trawl collections pooled by stratum within season. Strata numbers correspond to those in Figure 1.

Table 6
Species groups resulting from inverse cluster analysis of trawl data by season, pooled by stratum.

Group A
Eucinostomus argenteus
Eucinostomus gula
Syacium papillosum
Etropus cyclosquamus
Centropristis striata

Group B
Selene vomer
Chilomycterus schoepfi
Citharichthys spilopterus
Scomberomorus maculatus
Stenotomus aculeatus
Rhizoprionodon terraenovae
Prionotus evolans
Ancylopsetta quadrocellata
Paralichthys dentatus

Group C
Squalus acanthias
Clupea harengus
Menticirrhus saxatilis
Alosa sapidissima

Group D
Trachurus lathami
Urophycis floridana
Diplectrum formosum
Decapterus punctatus
Hippocampus erectus
Dasyatis sayi
Urophycis earlli
Hypsoblennius hentzi
Etrumeus teres

Group E
Narcine brasiliensis
Paralichthys albigutta
Porichthys plectrodon
Sphyrna tiburo
Caranx hippos
Caranx crysos
Paralichthys squamilentus
Sphyrna lewini
Trachinotus carolinus

Group F
Monacanthus hispidus
Syngnathus louisianae
Scomberomorus cavalla
Ophidion marginatum
Rhinobatus lentiginosus
Astroscopus y-graecum

Group G
Dasyatis americana
Gymnura micrura
Myliobatis freminvillei
Dasyatis centroura
Ophidion grayi
Scorpaena calcarata
Rhinoptera bonasus

Group H
Sphyraena guachancho
Menticirrhus littoralis
Harengula jaguana
Sardinella aurita
Anchoa sp.
Lagodon rhomboides

Group I
Etropus microstomus
Menidia menidia
Mustelus canis
Syngnathus fuscus
Paralichthys lethostigma
Membras martinica
Sphoeroides maculatus
Dasyatis sabina
Ogcocephalus rostellum

Group J
Cynoscion regalis
Trinectes maculatus
Peprilus triacanthus
Pomatomus saltatrix
Raja eglantaria
Prionotus tribulus
Bairdiella chrysoura
Urophycis regia

Group K
Centropristis philadelphica
Peprilus alepidotus
Prionotus salmonicolor
Prionotus scitulus
Orthopristis chrysoptera
Citharichthys macrops
Etropus crossotus
Synodus foetens
Arius felis
Chaetodipterus faber

Group L
Leiostomus xanthurus
Micropogonias undulatus
Brevoortia tyrannus

Group M
Larimus fasciatus
Menticirrhus americanus
Chloroscombrus chrysurus
Selene setapinnis
Opisthonema oglinum
Trichiurus lepturus
Anchoa hepsetus
Stellifer lanceolatus
Cynoscion nothus

Group N
Anchoa lyolepis
Anchoa cubana
Prionotus carolinus
Scophthalmus aquosus
Symphurus plagiusa
Anchoa mitchilli

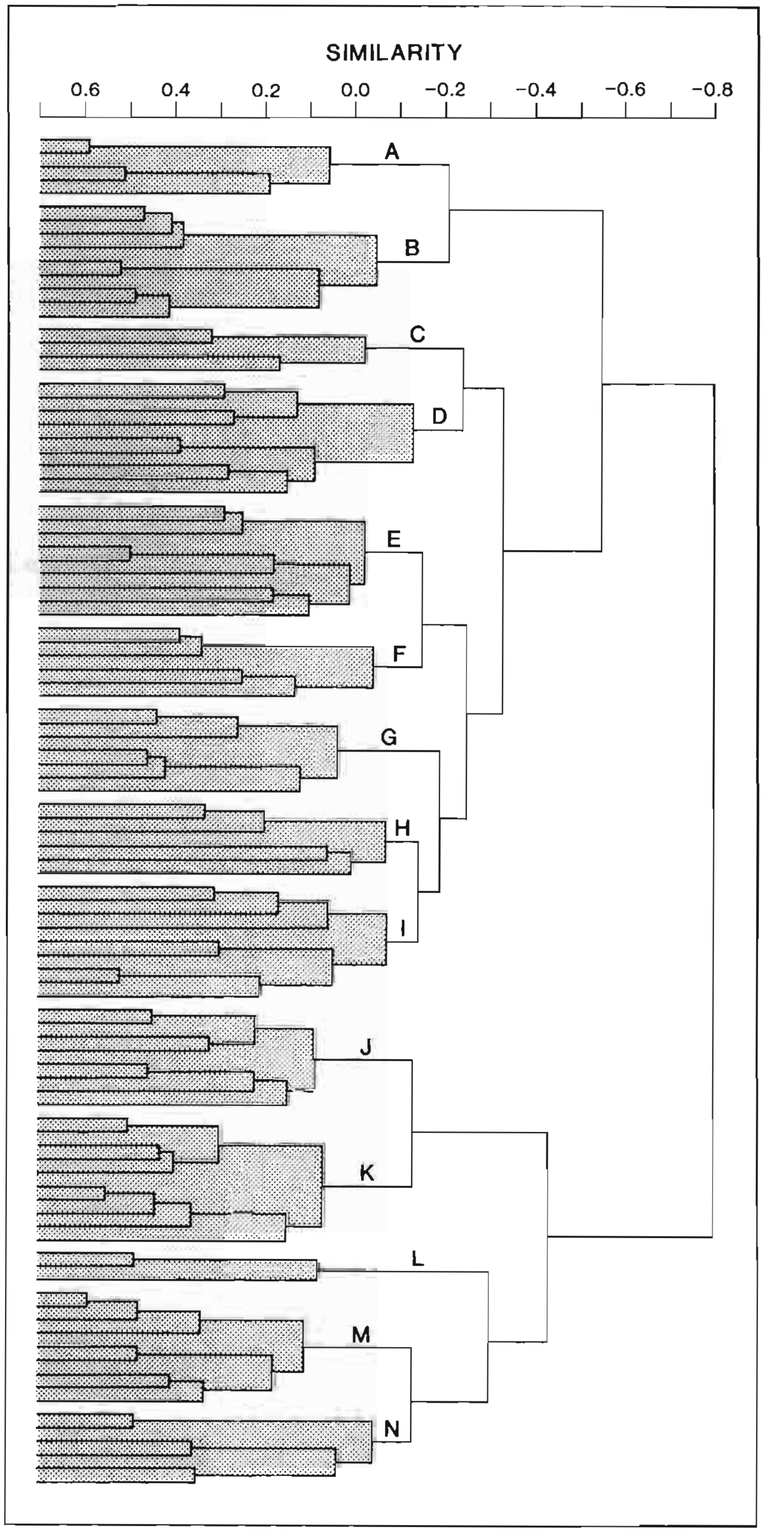

Figure 31
Dendrogram depicting inverse cluster analysis of trawl collections pooled by stratum within season. Species groups correspond to those in Table 6.

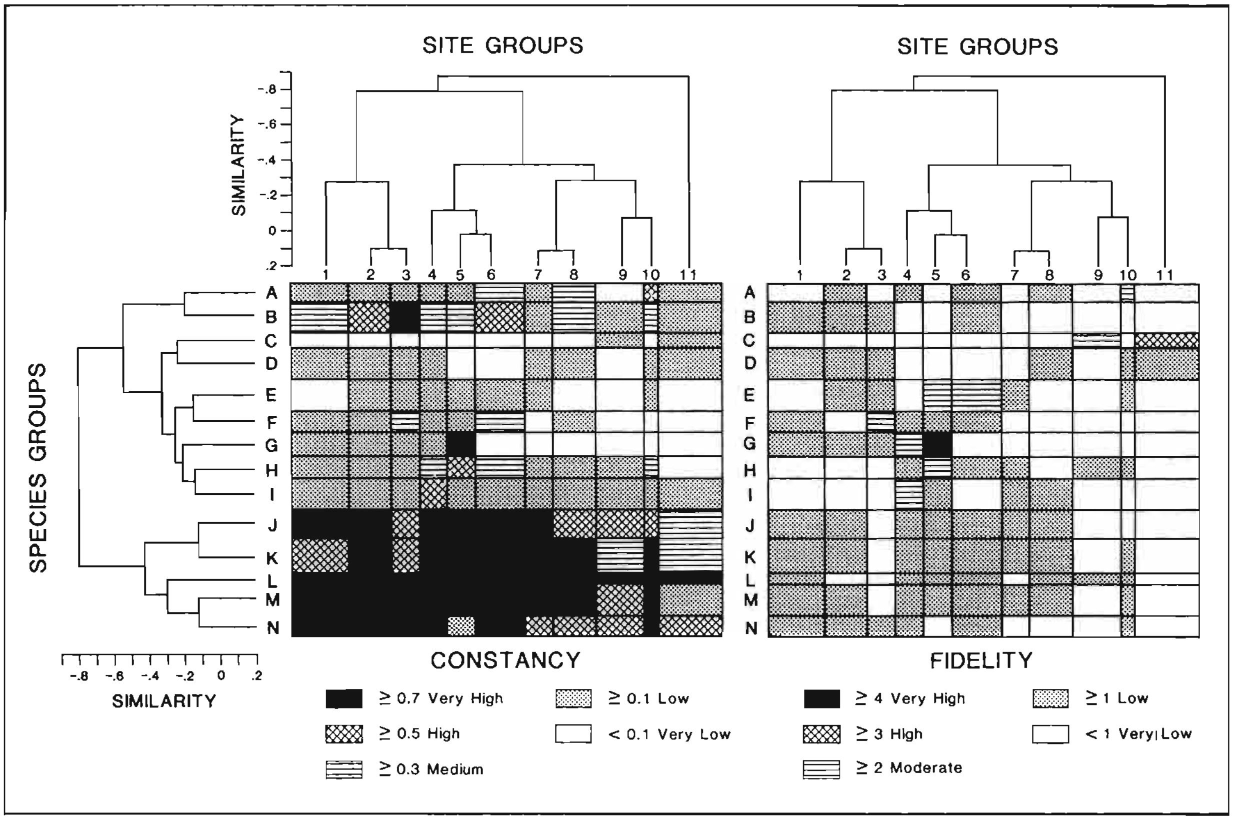

Figure 32
Normal and inverse cluster hierarchies and nodal constancy and fidelity diagrams for trawl collections pooled by stratum within season.

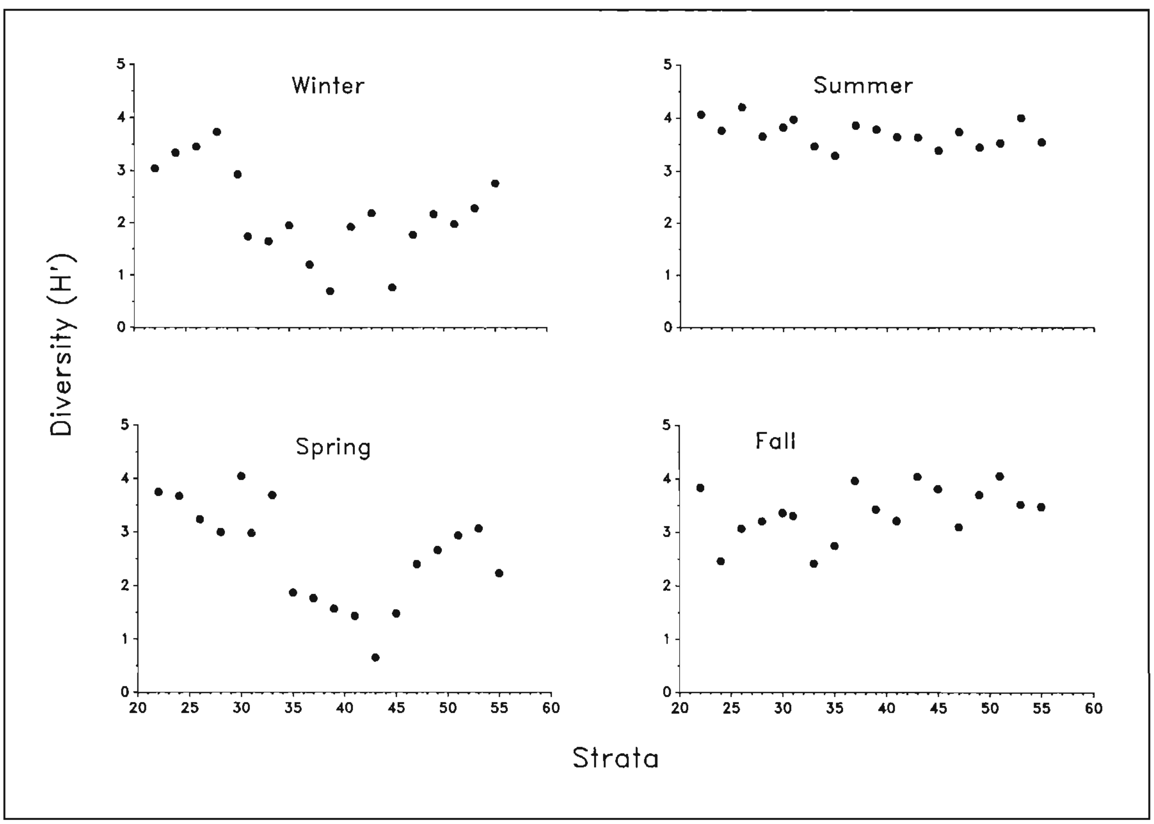

Figure 33
***H′* diversity values for collections pooled by stratum within season. Strata numbers correspond to those in Figure 1.**

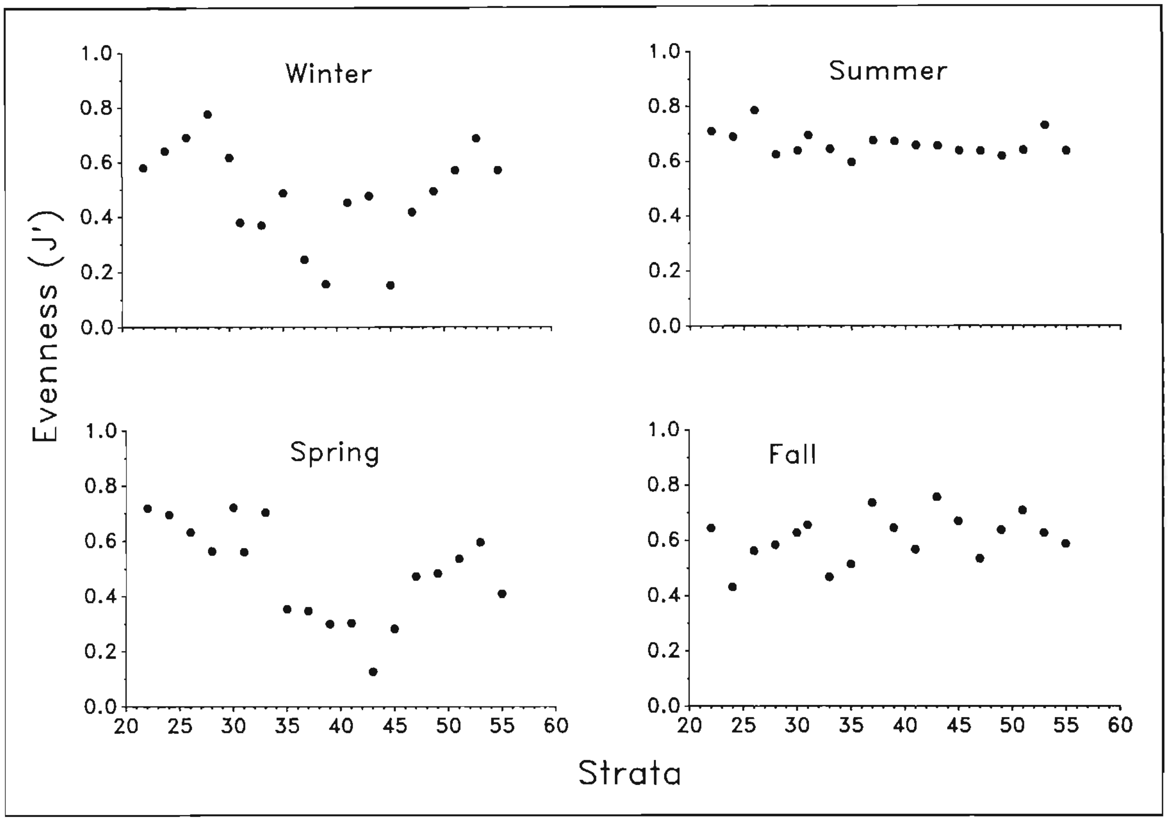

Figure 34
J' evenness values for collections pooled by stratum within season. Strata numbers correspond to those in Figure 1.

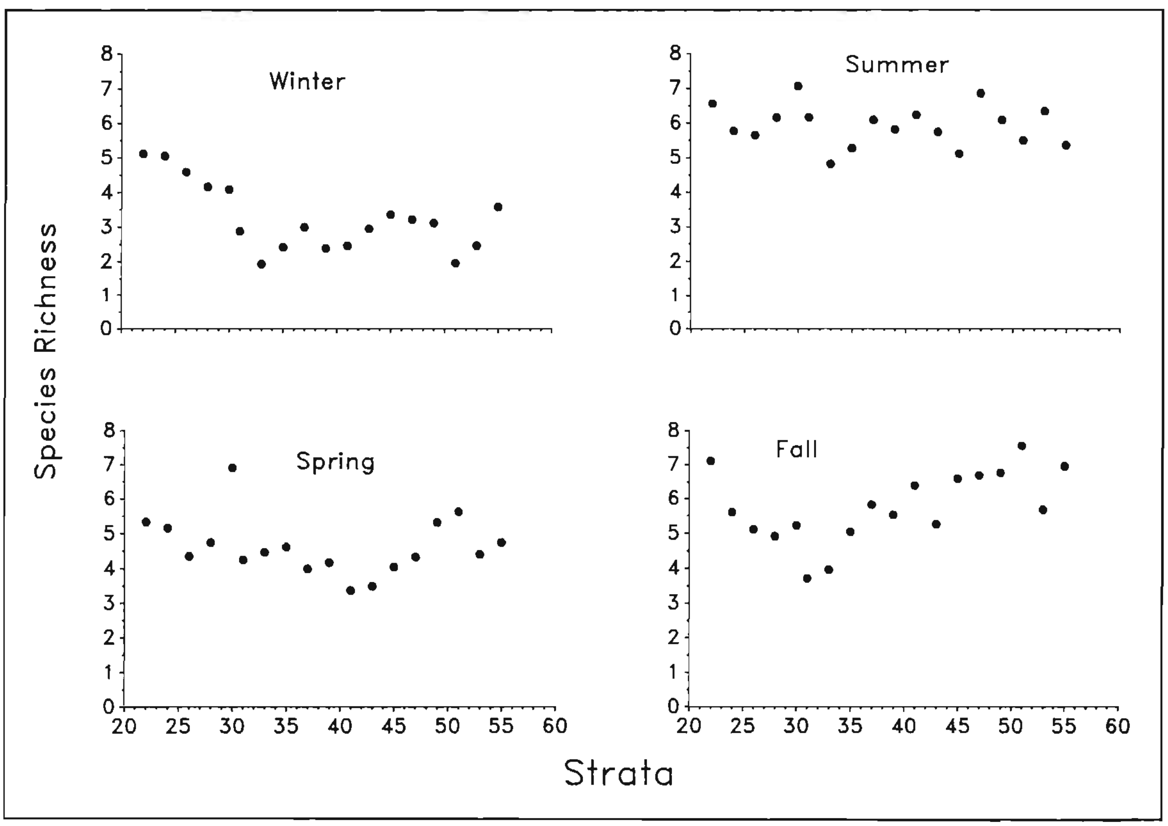

Figure 35
Species richness values for collections pooled by stratum within season. Strata numbers correspond to those in Figure 1.

or to the south of the study area of many species found in coastal waters during warmer seasons, and an overwhelming dominance (62.9% of all individuals) of the fauna by only two species, spot and Atlantic menhaden (Table 2). In spring, the fauna was largely dominated by spot (55.1% of all individuals); evenness and, therefore, H' values were low. In summer and fall, the two most abundant species comprised only 22.8% and 29.2% of the total individuals, respectively, and there was greater evenness of distribution of individuals among species, in addition to greater species richness.

There was considerable variation in diversity among collections within seasons and strata. Diversity values were similar in range to those reported from other habitats in the SAB (Sedberry and Van Dolah 1984, Wenner 1983).

In conclusion, the coastal habitat of the South Atlantic Bight supports a fish fauna dominated by the family Sciaenidae, with many other highly migratory species of fishes. Many of the genera of sciaenids, as well as other genera, are typical of those found in coastal soft-bottom habitats in other parts of the subtropical and temperate Atlantic (Lowe and Longhurst 1961, Lowe 1962, Longhurst 1969). Families, genera, and many species that form the coastal fish community in the SAB are identical to those found in similar habitats in the Gulf of Mexico, off South America and the Atlantic coast of Africa (Longhurst 1969), and familial composition is similar to that found in soft-bottom estuarine-influenced coastal habitats in other oceans (Longhurst 1969). Patterns of biomass, abundance, and community structure reflect the seasonal migration patterns of the dominant species, as well as recruitment of juveniles to the coastal nursery area.

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Appendix 1

Seasonal presence-absence of species and families of fishes collected during the coastal survey. Plus sign (+) indicates presence.

Family Species	Winter	Spring	Summer	Fall
CARCHARHINIDAE				
Carcharhinus acronotus		+	+	
Carcharinus limbatus			+	
Mustelus canis	+	+		+
Rhizoprionodon terraenovae		+	+	+
SPHYRNIDAE				
Sphyraena lewini		+	+	+
Sphyraena tiburo	+	+	+	+
SQUALIDAE				
Squalus acanthias	+			
RHINOBATIDAE				
Rhinobatos lentiginosus		+	+	+
TORPEDINIDAE				
Narcine brasiliensis	+		+	+
RAJIDAE				
Raja eglanteria	+	+	+	+
DASAYATIDAE				
Dasyatis americana	+	+	+	+
Dasyatis centroura		+		+
Dasyatis sabina	+	+	+	+
Dasyatis sayi	+	+	+	+
Gymnura micrura		+	+	+
MYLIOBATIDAE				
Myliobatis freminvillei		+	+	+
Rhinoptera bonasus			+	+
ELOPIDAE				
Elops saurus			+	
OPHICHTHIDAE				
Ophichthus ocellatus				+
CLUPEIDAE				
Alosa mediocris	+			
Alosa sapidissima	+			
Brevooria tyrannus	+	+	+	+
Clupea harengus	+			
Dorosoma cepedianum			+	
Etrumeus teres		+		
Harengula jaguana	+	+	+	+
Opisthonema oglinum	+	+	+	+
Sardinella aurita		+	+	+
ENGRAULIDAE				
Anchoa cubana	+	+	+	+
Anchoa hepsetus	+	+	+	+
Anchoa lyolepis	+	+	+	+
Anchoa mitchilli	+	+	+	+
Engraulis eurystole				+
SYNODONTIDAE				
Synodus foetens	+	+	+	+
ARIIDAE				
Arius felis		+	+	+
Bagre marinus		+	+	
BATRACHOIDIDAE				
Opsanus pardus		+	+	+
Opsanus tau			+	
Porichthys plectrodon		+	+	+

Family Species	Winter	Spring	Summer	Fall
GOBIESCOCIDAE				
Gobiesox strumosus	+			
OGCOCEPHALIDAE				
Ogcocephalus corniger				+
Ogcocephalus cubifrons				+
Ogcocephalus rostellum	+		+	+
GADIDAE				
Urophycis earlli	+	+	+	+
Urophycis floridana		+		
Urophycis regia	+	+		+
OPHIDIIDAE				
Ophidion beani				+
Ophidion grayi				+
Ophidion holbrooki				+
Ophidion marginatum	+	+	+	+
EXOCOETIDAE				
Hyporhamphus unifasciatus			+	+
ATHERINIDAE				
Membras martinica				+
Menidia menidia	+			+
SYNGHATHIDAE				
Hippocampus erectus	+	+	+	+
Sygnathus fuscus	+			+
Sygnathus louisianae	+	+	+	+
Sygnathus pelagicus	+			
PERCICHTHYIDAE				
Morone americana				+
SERRANIDAE				
Centropristis ocyurus			+	
Centropristis philadeliphica	+	+	+	+
Centropristis striata	+	+	+	+
Diplectrum formosum		+	+	
Serraniculus pumilio		+	+	
PRIACANTHIDAE				
Priacanthus arenatus				+
POMATOMIDAE				
Pomatomus saltatrix	+	+	+	+
RACHYCENTRIDAE				
Rachycentron canadum		+	+	
ECHENEIDAE				
Echeneis naucrates			+	
CARANGIDAE				
Alectis ciliaris			+	
Caranx crysos		+	+	+
Caranx hippos		+	+	+
Chloroscombrus chrysurus	+	+	+	+
Decapterus punctatus		+	+	
Selene setapinnis	+	+	+	+
Selene vomer	+		+	+
Trachinotus carolinus			+	+
Trachurus lathami		+	+	
LUTJANIDAE				
Lutjanus analis				+
Lutjanus synagris				+

Appendix 1 (Continued)

Family Species	Winter	Spring	Summer	Fall
GERREIDAE				
Eucinostomus argenteus			+	+
Eucinostomus gula	+		+	+
HAEMULIDAE				
Orthopristis chrysoptera	+	+	+	+
SPARIDAE				
Archosargus probatocephalus				+
Calamus leucosteus			+	
Diplodus holbrooki				+
Lagodon rhomboides	+	+	+	+
Stenotomus aculeatus		+	+	+
SCIAENIDAE				
Bairdiella chrysoura	+	+	+	+
Cynoscion nebulosus	+			
Cynoscion nothus	+	+	+	+
Cynoscion regalis	+	+	+	+
Larimus fasciatus	+	+	+	+
Leiostomus xanthurus	+	+	+	+
Menticirrhus americanus	+	+	+	+
Menticirrhus littoralis	+	+	+	+
Menticirrhus saxatilis	+		+	+
Micropogonias undulatus	+	+	+	+
Pareques acuminatus			+	
Stellifer lanceolatus	+	+	+	+
Umbrina coroides			+	+
MULLIDAE				
Upeneus parvus		+		
EPHIPPIDAE				
Chaetodipterus faber	+	+	+	+
LABRIDAE				
Hemipteronotus novacula		+		
Tautoga onitis		+		+
SPHYRAENIDAE				
Sphyraena guachancho		+	+	+
URANOSCOPIDAE				
Astroscopus y-graecum		+	+	+
BLENNIIDAE				
Hypleurochilus geminatus			+	+
Hypsoblennius hentzi	+	+	+	+
GOBIIDAE				
Gobiosoma bosci				+
Gobiosoma ginsburgi			+	
TRICHIURIDAE				
Trichiurus lepturus	+	+	+	+
SCOMBRIDAE				
Scomberomorus cavalla			+	+
Scomberomorus maculatus		+	+	+
STROMATEIDAE				
Peprilus alepidotus	+	+	+	+
Petrilus triancanthus	+	+	+	+
SCORPAENIDAE				
Scorpaena agassizi	+			
Scorpaena brasiliensis	+			+
Scorpaena calcarata			+	+
Scorpaena plumieri				+
TRIGLIDAE				
Prionotus carolinus	+	+	+	+
Prionotus evolans	+	+	+	+
Prionotus ophryas	+			+
Prionotus salmonicolor	+	+	+	+
Prionotus scitulus	+	+	+	+
Prionotus tribulus	+	+	+	+
BOTHIDAE				
Ancylopsetta quadrocellata	+	+	+	+
Citharichthys macrops	+	+	+	+
Citharichthys spilopterus	+	+	+	+
Etropus crossotus	+	+	+	+
Etropus sp. A	+	+		+
Etropus microstomus	+		+	+
Paralichthys albigutta		+	+	+
Paralichthys dentatus	+	+	+	+
Paralichthys lethostigma	+	+	+	+
Paralichthys squamilentus		+	+	
Scopthalmus aquosus	+	+	+	+
Syacium gunteri			+	
Syacium papillosum	+	+	+	+
SOLEIDAE				
Gymnachirus melas	+	+		+
Trinectes maculatus	+	+	+	+
CYNOGLOSSIDAE				
Symphurus plagiusa	+	+	+	+
BALISTIDAE				
Aluterus schoepfi			+	+
Balistes capriscus			+	
Monacanthus hispidus	+	+	+	+
TETERAODONTIDAE				
Lagocephalus laevigatus			+	
Sphoeroides maculatus		+	+	+
DIODONTIDAE				
Chilomycterus antillarum			+	
Chilomycterus schoepfi		+	+	+