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SPECIES ASSEMBLAGES, DISTRIBUTION, AND ABUNDANCE OF FISHES AND DECAPOD CRUSTACEANS FROM THE WINYAH BAY ESTUARINE SYSTEM, S.C. 1/

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SPECIES ASSEMBLAGES, DISTRIBUTION, AND ABUNDANCE OF FISHES AND DECAPOD CRUSTACEANS FROM THE WINYAH BAY ESTUARINE SYSTEM, S.C.[1/]

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ABSTRACT

Fishes and decapod crustaceans were collected along the salinity gradient in the Winyah Bay estuary, South Carolina with a 6-m otter trawl over a two-year period. A total of 77 species of fishes and 20 decapod crustaceans were collected. Species diversity was greatest at stations in the bay near the mouth.

Seven fish species comprised > 90% of the total number of individuals collected: Stellifer lanceolatus, Micropogonias undulatus, Trinectes maculatus, Ictalurus catus, Cynoscion regalis, Brevoortia tyrannus, and Leiostomus xanthurus. The decapod crustaceans were not as important as the fishes in abundance or biomass. Callinectes sapidus, Penaeus duorarum, P. aztecus, and P. setiferus constituted > 90% of the decapod catch by number.

Most species and individuals were collected in the fall when Trinectes maculatus and Stellifer lanceolatus were abundant and an influx of stenohaline marine transient species occurred. The fall peak in diversity was followed by a sharp decrease in winter when several stenohaline and transient euryhaline species left the estuary. In spring, numbers of species and individuals increased, although stenohaline marine species were still not very abundant and were patchy in their occurrence. In summer, the number of stenohaline marine transients entering Winyah Bay peaked and transient euryhaline species were most abundant.

Juvenile fishes dominated catches in the Winyah Bay system. The suitability of the area as a nursery habitat is probably enhanced by freshwater input. However, density and biomass estimates for fishes and decapods were low compared to other S.C. estuarine systems studied.

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INTRODUCTION

The Winyah Bay estuarine system of South Carolina, which includes the Waccamaw, Peedee, Black, and Sampit Rivers as well as Winyah Bay itself, has experienced rapid industrialization and municipal development over the past decade. As a result, sedimentation, loss of critical habitat, and pollution have lowered water quality in the Winyah Bay system, yet the estuary is still being considered as a site for further development.

Although Winyah Bay is an important habitat for penaeid shrimp, blue crabs, and numerous finfishes, its importance as a nursery area and its fishery potential in terms of abundance of fishes and decapod Crustacea have never been assessed. This paper provides information on the species assemblages, spatial and temporal abundance, and distributional patterns of fishes and decapod crustaceans from the Winyah Bay estuarine system.

STUDY AREA

The Winyah Bay estuarine system is bounded to the north by the Cape Fear River Basin, North Carolina, and to the south by the Santee River Basin of South Carolina (Figure 1). Winyah Bay connects with the Atlantic Ocean and is bounded at the mouth on the north by North Island, an arcuate spit, and on the south by a barrier island (Sand Island) connected to the mainland by an east-west jetty.

The bay itself is about a mile (1.6 km) wide at either end and about four miles (6.4 km) wide at its center. Waters at the seaward end reflect the higher

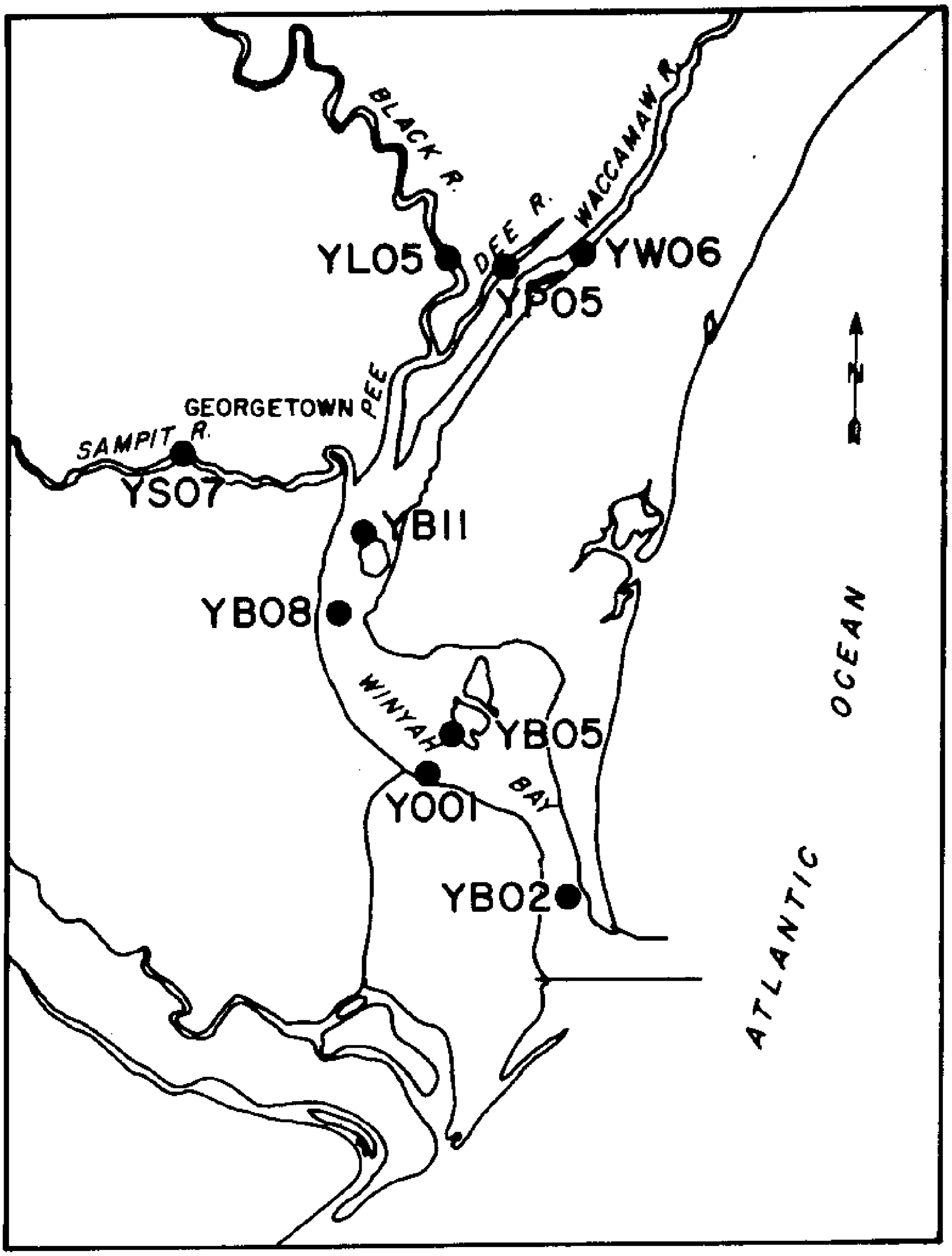

FIGURE 1. STATION LOCATIONS IN THE WINYAH BAY ESTUARINE SYSTEM, S.C.

salinity of the ocean, but upstream, the bay receives considerable freshwater from four major sources:

(1) the Waccamaw River which forms at Lake Waccamaw, N.C., and flows into the Great Peedee River near Georgetown, S.C.,

(2) the Black River which enters the Great Peedee River near Georgetown, S.C.,

(3) the Great Peedee River which receives waters of the Black River and then enters Winyah Bay at Georgetown, S.C., and

(4) the Sampit River which is a short coastal river that lacks a large drainage basin.

About 60% of the freshwater input to Winyah Bay is supplied by the Peedee River (Conservation Foundation[1]). Despite the strong freshwater influence, the Winyah Bay estuarine system may best be classified as partially mixed, although this condition does fluctuate greatly, especially at the extreme ends of the estuary. Conditions at the mouth may range from nearly stratified to partially mixed, while the head of the estuary is either nearly homogeneous or partially mixed, depending on tidal stage (Bloomer, 1973). Fluctuating freshwater input also changes the distance over which saltwater intrusion occurs. During average runoff conditions of about 15,000 cfs (Johnson, 1970), saltwater intrusion, as measured from the river's mouth, reaches mile 2.0 on the Black River and mile 5.0 on the Peedee and Waccamaw Rivers (Bloomer, 1973).

The freshwater influence of the major source rivers also affects the amount of coastal marshlands in the Winyah Bay system. Within this region are 129 km^2 of coastal marshlands, 80% of which are freshwater marshes (Tiner, 1977). Freshwater marshes are located on the northern side of Winyah Bay and along the upper reaches of the Waccamaw, Peedee, and Black Rivers. Brackish marshes

[1]The Conservation Foundation, 1980. Winyah Bay Reconnaissance Study, Summary Report. Washington, D.C. 75 p.

compose 18% of the wetlands, and salt marshes < 1% of Winyah Bay wetlands. Most of the intertidal areas of Winyah Bay, including South Island, North Island, and the shores of the lower reaches of the tributaries to Winyah Bay, consist of salt marsh dominated by saltmarsh cordgrass (*Spartina alterniflora*) (Tiner, 1977).

METHODS AND MATERIALS

Data Collection

We sampled monthly from January 1977 to December 1978 at nine fixed stations located in the channel of Winyah Bay estuary (Figure 1): Y001 (Winyah Bay), YB02 (Buoy N "16"), YB05 (Buoy C "19A"), YB08 (Buoy R "24"), YB11 (Buoy R "30"), YL05 (Black River), YP05 (Peedee River), YS07 (Sampit River), and YW06 (Waccamaw River).

All collections were made with a 6-m (20-ft.) semi-balloon otter trawl of 2.5-cm (1-inch) stretch mesh throughout. A twenty-minute tow was made at each station against flood tide during daylight hours. Tow speed was 1.3 m sec^{-1} (2.5 knots), which resulted in a coverage of 1.5 ± 0.4 km during a tow.

Bottom-water samples were collected with 6-liter capacity Van Dorn bottles 0.3 m above the bottom at each station prior to trawling. Water temperature was read from stem thermometers mounted within the Van Dorn bottles. Salinity was measured in the laboratory with a Beckman RS7B induction salinometer. Dissolved oxygen was determined by the Winkler-Carpenter method (Strickland and Parsons, 1968). Turbidity was determined with a Hach Model 2100A Turbidimeter. Specimens were either processed in the field or preserved in 10% formalin and returned to the laboratory for identification, measuring, and weighing. Specimens were weighed to the nearest 0.1 g and counted. We also recorded measurements (total length for fishes, carapace width for crabs, and total length for shrimp) for all species numbering $\leq$ 50 specimens per tow. At stations where the trawl caught larger numbers of organisms, we subsampled each species in the catch as follows: if $\geq$ 50 to $\leq$ 250 individuals were collected, then a minimum of 50 randomly-selected specimens were measured and weighed; if > 250 to $\leq$ 500 individuals were caught, then 20% of the catch was measured and weighed; when > 500 were caught, 10% of the catch was measured and weighed.

Seasons are consistent with other paper on S.C. estuaries (Wenner et al.[2]): Winter encompases January, February, and March; Spring encompasses April, May, and June; Summer encompasses July, August, and September; and Fall includes October, November, and December.

Data Analysis

Similarity among collections and among species was determined with the Bray-Curtis similarity coefficient (Clifford and Stephenson, 1975), using a log transformation and flexible sorting with $\beta = -0.25$. Prior to calculation of similarity matrices, we reduced the data set by elimination of species which occurred in only one or two collections and by elimation of collections which contained only one species. Separate matrices were then constructed for each season on combined data from the two-year sampling period with collections as entities and species as attributes (normal analysis) and with species as entities and collections as attributes (inverse analysis). Two separate dendrograms were constructed for each season: a dendrogram which indicated association of all collections by season during the two-year sampling period based on their species

[2]Wenner, E.L., M.H. Shealy, Jr. and P.A. Sandifer. Profile of the fish and decapod crustacean community in a South Carolina estuarine system prior to flow alteration. (in press, NOAA Special Scientific Report).

composition, and another which indicated association of all species for each season over the two-year sampling period based on the collections in which they occurred. We then used post-clustering techniques of nodal analysis (Williams and Lambert, 1961; Lambert and Williams, 1962) to examine species and station coincidences, based on patterns of constancy and fidelity.

An index of abundance (Musick and McEachran, 1972; Elliott, 1977) was used to discern spatial and temporal patterns of abundance for dominant species and is expressed as:

$$\text{Index of Abundance} = \frac{1}{n} \sum_{1}^{n} \log_{10} (x + 1)$$

where x = number of individuals of a given species and n = number of collections in a chosen time frame.

We determined biomass and density estimates for fishes and decapod crustaceans from computations of area swept for the 6-m trawl. Estimates of area swept (a) were determined by the following equation given by Roe (1969):

$$a = \frac{K \times M \times (0.6\ H)}{10{,}000\ m^2/\text{hectare}}$$

where K is speed in meters per hour, M is time in hours fished, and H is headrope length in meters (Klima[3]). Roe (1969) assumed an effective swath of about 60% of the headrope length as established by Wathne (1959). The area swept by our 6-m otter trawl was estimated to be 0.72 hectare/tow by this method.

[3]Klima, E.F. 1976. A review of the fishery resources in the western central Atlantic. Western Central Atlantic Fishery Comm. Publ., No. 3.

RESULTS AND DISCUSSION

Hydrographic Parameters

Bottom water temperatures in Winyah Bay estuarine system were fairly uniform from station to station. Seasonal bottom water temperatures fluctuated from a low ($\leq$ 5°C) throughout the study area in February to a high during July 1977 ($\sim$ 30°C) and August 1978 ($\sim$ 29°C) (Figure 2). The most distinct differences in temperature occurred from winter to spring, and from summer to fall. Average temperatures were slightly lower in 1978 than in 1977.

Application of the Venice system of salinity classification (Symposium on the Classification of Brackish Waters, 1958) showed that upriver stations (YL05, YP05, YW06) ranged from limnetic (< 0.5°/oo) to mesohaline (5-18°/oo) depending on season (Figure 3). At these stations, winter and spring salinity conditions were low and stable for both years, whereas highest salinities occurred in summer and fall. Bottom water salinity never exceeded 4°/oo at station YW06 during the sampling period. Salinities at stations YS07 and YB11 ranged from 0.14-11.65°/oo and from 0.06-18.24°/oo, respectively. Bottom water salinities were highest at these stations during the fall and were lowest during winter and spring. Stations YB08, YB05, YO01, and YB02 were highly variable with respect to salinity. Their extremes over the two-year sampling period were: YB08 (0.11-25.87°/oo), YB05 (0.06-28.44°/oo), YO01 (0.14-24.86°/oo), and YB02 (0.71-32.72°/oo). Average salinities at these stations were also highest in fall and lowest in spring.

Average dissolved oxygen concentrations were greatest at all stations in winter and lowest in summer (Table 1). Dissolved oxygen concentrations below

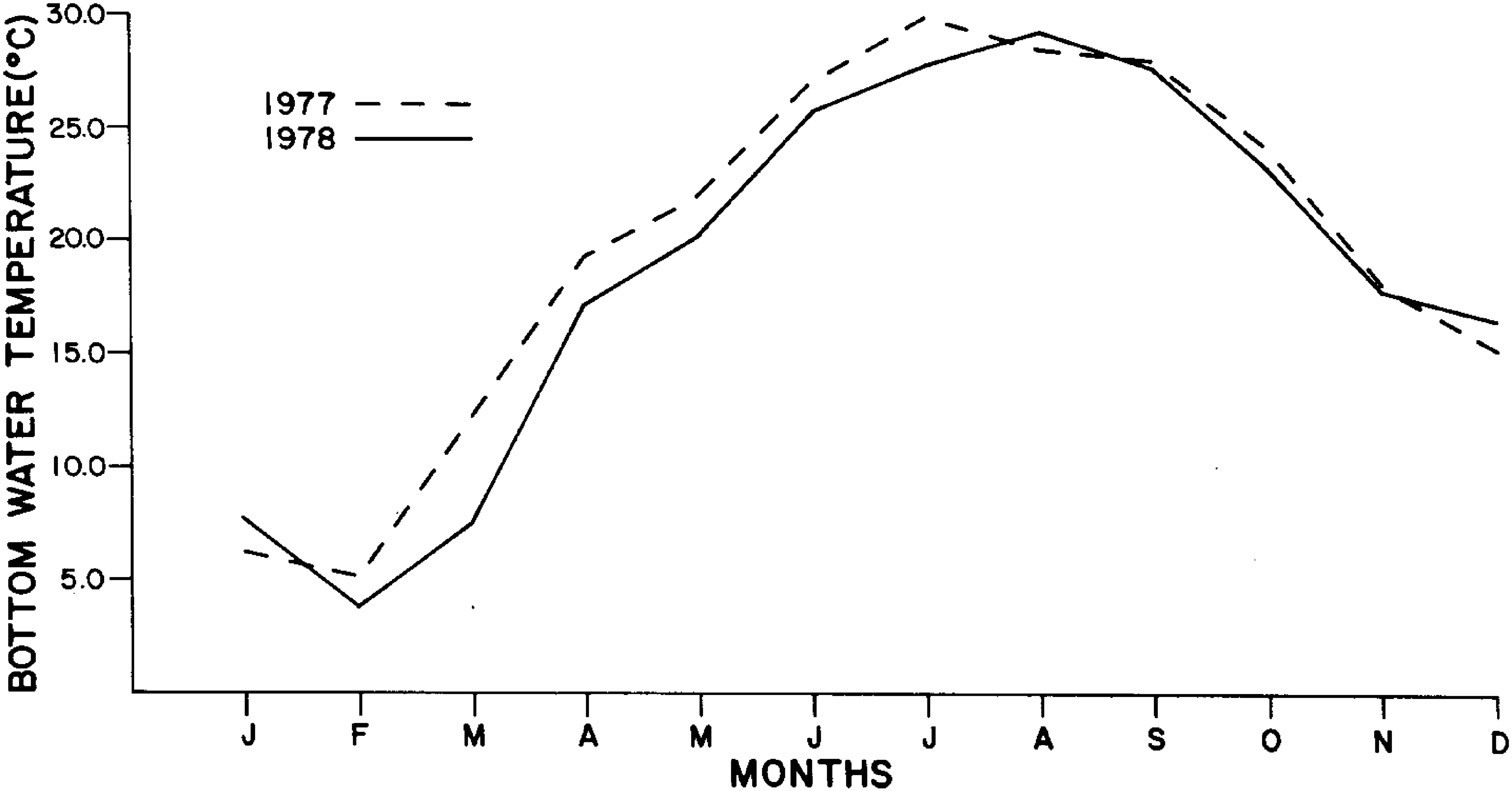

FIGURE 2. MONTHLY FLUCTUATIONS IN BOTTOM TEMPERATURE AT SAMPLING SITES IN THE WINYAH BAY ESTUARINE SYSTEM, 1977 - 1978.

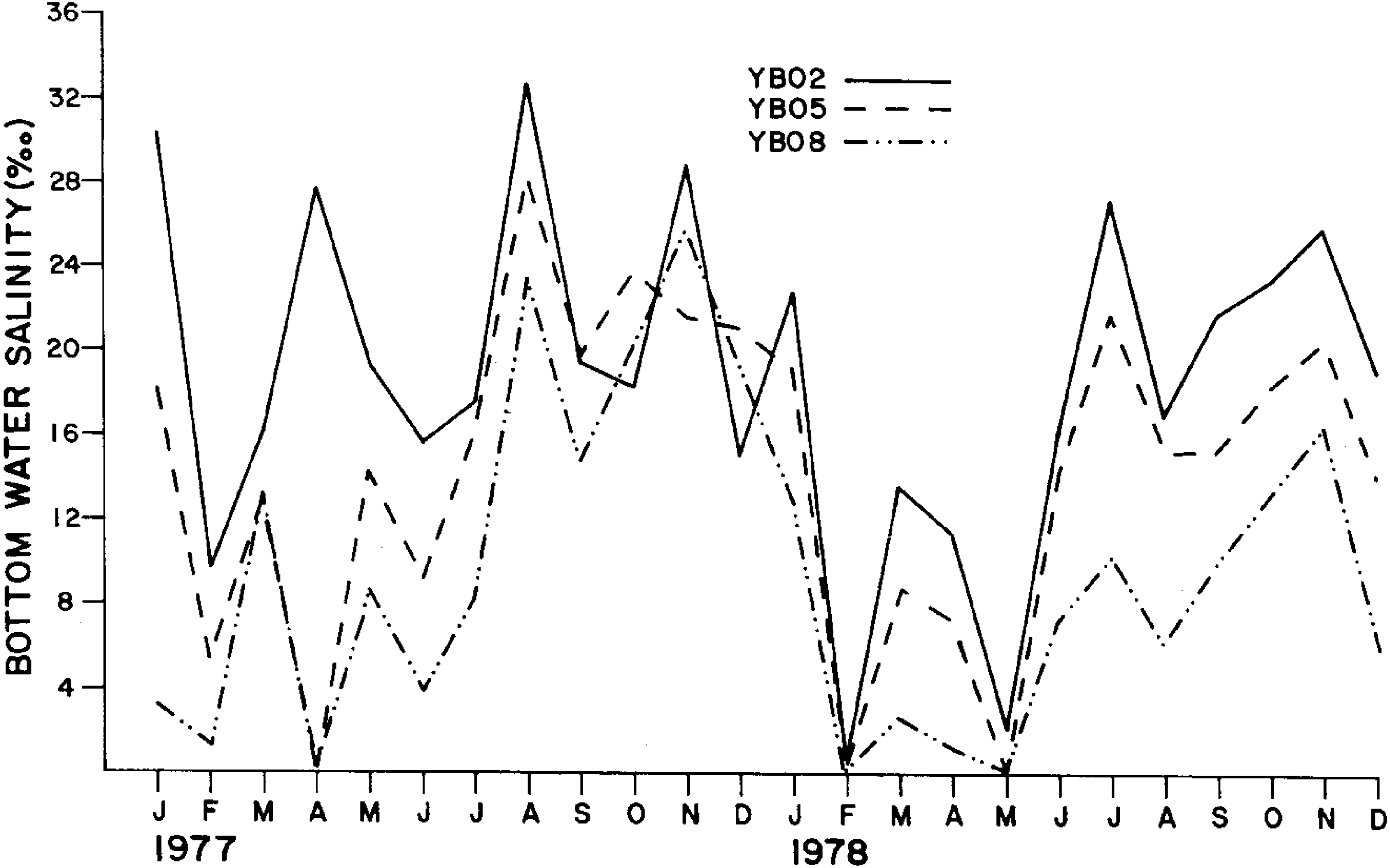

FIGURE 3. Bottom water salinity variations at nine fixed sampling locations in the Winyah Bay estuarine system, 1977 - 1978.

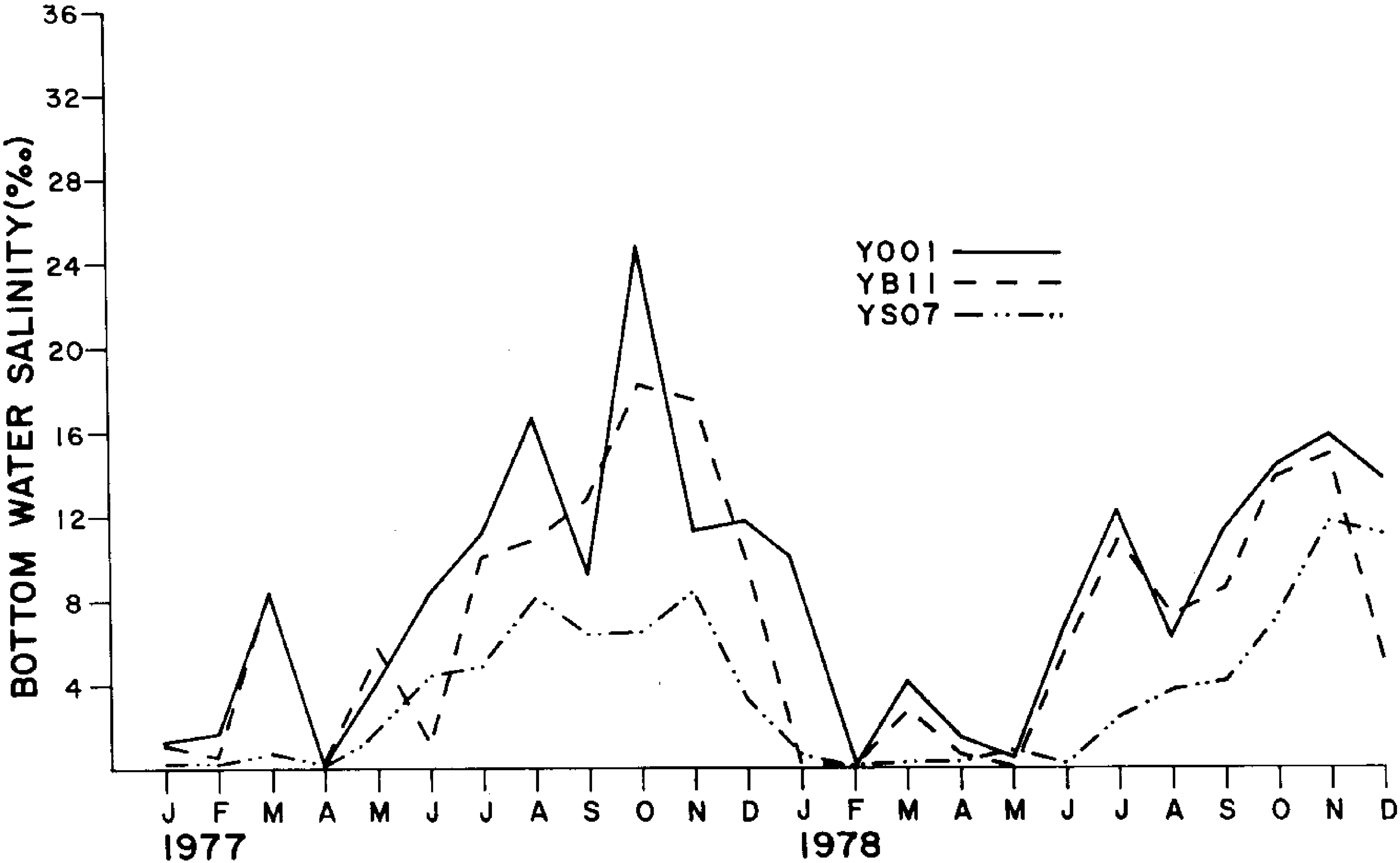

FIGURE 3. (CONTINUED).

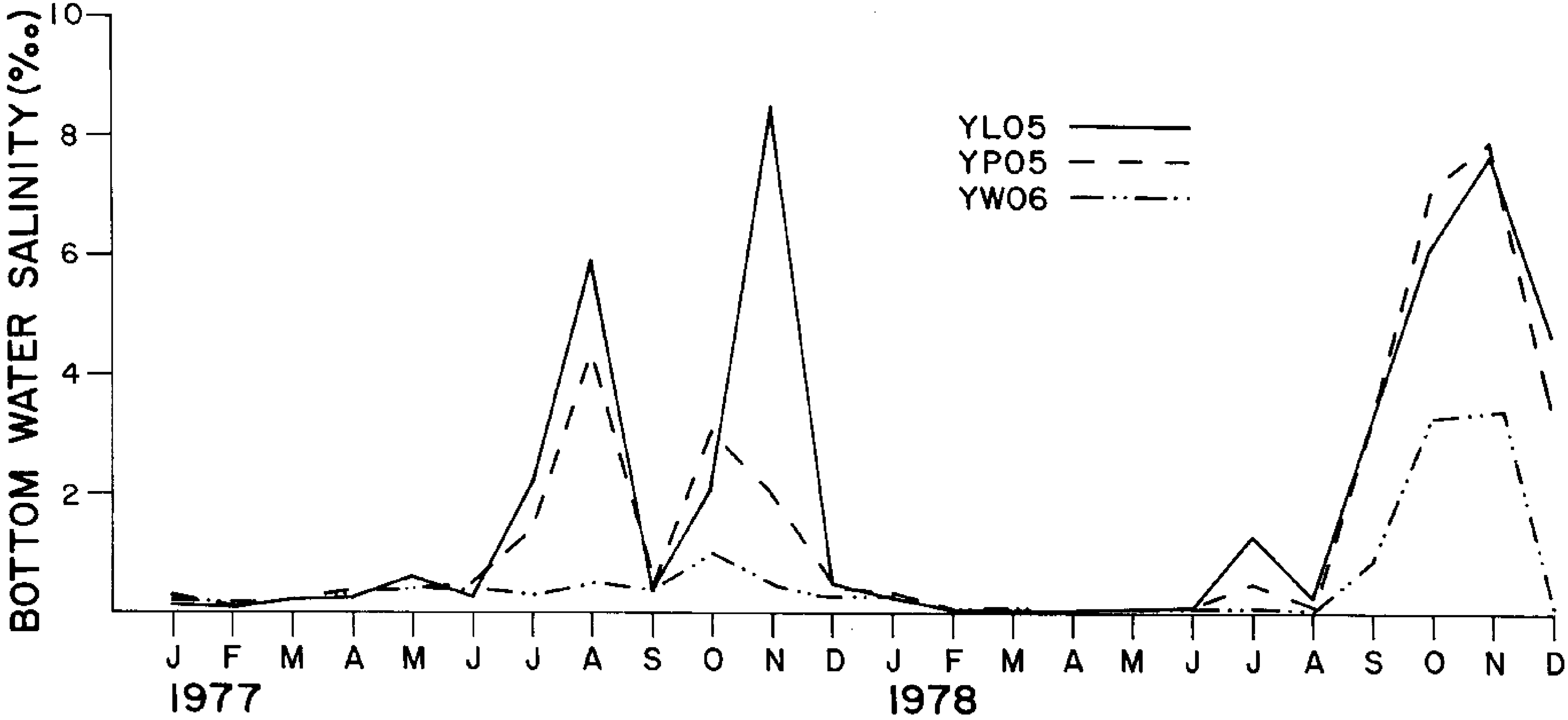

FIGURE 3. (CONTINUED).

TABLE 1. Average depth and dissolved oxygen conditions at stations in the Winyah Bay estuarine system, S.C. from 1977 - 1978.

	YL05		YP05		YW06		YS07		YB11		YB08		Y001		YB05		YB02	
Months	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)	Depth (m)	Dissolved O_2 (mg/l)
1	5.0	10.2	4.0	10.7	8.0	11.0	3.0	10.0	5.5	10.8	6.0	10.2	3.5	10.6	5.5	8.8	6.5	8.5
2	6.0	11.5	5.0	11.6	9.0	11.4	4.0	10.6	4.5	11.6	6.0	12.1	3.5	11.9	4.0	10.3	4.3	11.4
3	5.5	10.1	4.5	10.5	8.0	10.4	4.0	8.7	3.5	10.0	6.0	10.2	3.5	10.1	4.0	10.1	5.0	8.1
4	5.5	6.2	4.5	7.0	7.5	6.8	3.5	6.1	5.0	7.3	5.5	7.4	3.0	7.5	3.0	7.8	4.0	8.1
5	5.5	5.2	4.0	5.6	8.0	6.2	4.0	5.4	5.5	6.1	6.5	6.4	2.5	6.6	4.5	6.6	5.0	6.8
6	5.0	4.2	7.5	3.9	8.0	4.8	3.0	3.9	3.5	5.0	5.5	5.6	2.5	5.6	4.5	5.9	5.5	5.8
7	5.0	4.6	5.0	4.6	7.0	5.0	3.5	3.8	6.0	5.5	5.0	5.5	3.0	5.6	4.0	5.2	2.5	5.4
8	4.5	4.8	4.0	4.4	7.0	4.7	3.5	4.7	3.5	5.5	5.5	5.2	4.0	4.9	4.5	4.8	4.5	5.0
9	5.5	4.2	4.0	4.3	9.0	5.0	5.0	3.8	5.0	5.2	6.0	5.4	2.5	5.4	5.5	5.4	5.0	5.5
10	5.5	6.0	5.0	5.8	8.0	5.7	4.0	5.6	4.0	6.8	4.0	6.3	3.5	6.6	4.0	6.2	4.5	6.6
11	5.5	7.2	5.0	7.1	8.0	6.6	4.0	5.8	4.5	7.4	6.0	7.4	3.0	6.9	4.0	6.8	5.5	7.2
12	4.5	7.3	4.0	7.6	8.5	8.2	3.0	6.9	4.5	7.6	5.5	7.8	3.0	7.6	5.0	7.4	4.0	7.3

4 mg/l were encountered only at stations YS07 and YP05 during late spring and summer.

Diversity and Community Composition

A total of 77 species of fishes were collected from the Winyah Bay system during the 1977-1978 sampling period (Table 2). The length, bottom salinity, and bottom temperature ranges, along with relative abundance of all species collected are found in Appendix I. Of the fishes collected, seven comprised > 90% of the total number of individuals taken during the study period: star drum (Stellifer lanceolatus), Atlantic croaker (Micropogonias undulatus), hogchoker (Trinectes maculatus), white catfish (Ictalurus catus), weakfish (Cynoscion regalis), Atlantic menhaden (Brevoortia tyrannus), and spot (Leiostomus xanthurus). Although S. lanceolatus was the most abundant species collected, constituting 29% of the total fish catch numerically, I. catus contributed most to the total biomass, being about 16% of the total catch by weight.

Twenty identifiable species of decapod crustaceans were collected (Table 3). The decapod crustaceans were neither as abundant nor weighed as much as the fishes. The blue crab, Callinectes sapidus, constituted the greatest portion of the decapod catch numerically and by weight throughout the two-year sampling period. Other dominants included the pink shrimp (Penaeus duorarum), the brown shrimp (P. aztecus), and the white shrimp (P. setiferus), which with the blue crab, constituted > 90% of the decapod catch by number.

Species richness, expressed as number of decapod and fish species, was lowest at station YB08 during both years of sampling (Table 4). Stations YB02, YW06, and YO01 had the richest fish fauna, while more decapod species were caught

TABLE 2. Total number and total biomass (kg) of fishes from 1977 - 1978 in the Winyah Bay estuary. Species are listed in order of abundance and data are pooled over the two-year sampling period.

SPECIES	TOTAL NUMBER	PERCENT NUMBER	TOTAL BIOMASS (kg)	PERCENT BIOMASS
Stellifer lanceolatus	11356	29.22	37.399	8.55
Micropogonias undulatus	9706	24.98	60.989	13.94
Trinectes maculatus	7532	19.38	40.254	9.20
Ictalurus catus	3133	8.06	69.156	15.81
Cynoscion regalis	1905	4.90	8.831	2.02
Brevoortia tyrannus	1334	3.43	19.467	4.45
Leiostomus xanthurus	722	1.86	12.576	2.87
Urophycis regia	517	1.33	5.726	1.31
Symphurus plagiusa	421	1.08	4.483	1.02
Anchoa mitchilli	400	1.03	0.866	0.20
Bairdiella chrysoura	333	0.86	8.097	1.85
Paralichthys lethostigma	178	0.46	30.025	6.86
Menticirrhus americanus	118	0.30	1.228	0.28
Prionotus tribulus	106	0.27	0.154	0.04
Paralichthys dentatus	79	0.20	2.302	0.53
Anguilla rostrata	76	0.20	9.499	2.17
Peprilus alepidotus	73	0.19	0.829	0.19
Opsanus tau	71	0.18	17.037	3.89
Morone americana	70	0.18	11.278	2.58
Chaetodipterus faber	70	0.18	0.684	0.16
Prionotus carolinus	59	0.15	0.120	0.03
Morone saxatilis	53	0.14	2.772	0.63
Urophycis floridana	49	0.13	1.112	0.25
Hypsoblennius hentzi	48	0.12	0.336	0.08
Lepisosteus osseus	42	0.11	20.269	4.63
Dasyatis sabina	34	0.09	38.756	8.86
Gobiesox strumosus	32	0.08	0.100	0.02
Ictalurus punctatus	30	0.08	0.720	0.16
Peprilus triacanthus	25	0.06	0.180	0.04
Scophthalmus aquosus	24	0.06	0.148	0.03
Alosa sapidissima	24	0.06	0.209	0.05
Acipenser oxyrhynchus	21	0.05	3.242	0.74
Etropus crossotus	21	0.05	0.100	0.02
Dorosoma petenense	20	0.05	0.106	0.02
Ictalurus nebulosus	17	0.04	3.071	0.70
Citharichthys spilopterus	16	0.04	0.110	0.03
Lepomis microlophus	14	0.04	1.039	0.24
Lagodon rhomboides	14	0.04	0.179	0.04
Pomatomus saltatrix	11	0.03	0.100	0.02
Ancylopsetta quadrocellata	9	0.02	0.034	0.01
Cynoscion nebulosus	9	0.02	0.343	0.08
Mugil cephalus	8	0.02	1.277	0.29
Ophidion marginatum	8	0.02	0.237	0.05
Chloroscombrus chrysurus	7	0.02	0.033	0.01
Bagre marinus	7	0.02	0.095	0.02
Chilomycterus schoepfi	5	0.01	0.054	0.01
Lepomis gulosus	4	0.01	0.553	0.13
Alosa aestivalis	3	0.01	0.168	0.04
Selene vomer	3	0.01	0.013	<0.01
Prionotus evolans	3	0.01	0.004	<0.01
Astroscopus y-graecum	3	0.01	0.067	0.02
Ictalurus platycephalus	3	0.01	0.331	0.08
Cyprinus carpio	2	0.01	7.767	1.78
Gobionellus shufeldri	2	0.01	0.003	<0.01
Hypsoblennius ionthas	2	0.01	0.010	<0.01
Sciaenops ocellata	2	0.01	0.006	<0.01
Pogonias cromis	2	0.01	10.757	2.46
Prionotus scitulus	2	0.01	0.005	<0.01
Monacanthus hispidus	2	0.01	0.002	<0.01
Lutjanus griseus	2	0.01	0.023	0.01
Centropomus sp.	2	0.01	0.001	<0.01
Arius felis	2	0.01	0.215	0.05
Lepomis punctatus	1	<0.01	0.014	<0.01
Myrophis punctatus	1	<0.01	0.064	0.01
Anchoa hepsetus	1	<0.01	0.005	<0.01

Table 2 (continued)

SPECIES	TOTAL NUMBER	PERCENT NUMBER	TOTAL BIOMASS (kg)	PERCENT BIOMASS
Dorosoma cepedianum	1	<0.01	0.395	0.09
Morone chrysops	1	<0.01	0.051	0.01
Archosargus probatocephalus	1	<0.01	0.092	0.02
Centropristis striata	1	<0.01	0.044	0.01
Centropristis philadelphica	1	<0.01	0.035	0.01
Syngnathus fuscus	1	<0.01	0.002	<0.01
Acipenser brevirostrum	1	<0.01	0.715	0.16
Raja eglanteria	1	<0.01	0.265	0.06
Scorpaena calcarata	1	<0.01	0.005	<0.01
Larimus fasciatus	1	<0.01	0.009	<0.01
Ariosoma balearicum	1	<0.01	0.013	<0.01
Lepomis auritus	1	<0.01	0.062	0.01
Micropterus salmoides	1	<0.01	0.153	0.03
Total	38862		437.463	

TABLE 3. Total number and total biomass (kg) of decapod Crustacea from 1977 - 1978 in the Winyah Bay estuary. Species are listed in order of abundance and data are pooled over the two-year sampling period.

SPECIES	TOTAL NUMBER	PERCENT NUMBER	TOTAL BIOMASS (kg)	PERCENT BIOMASS
Callinectes sapidus	4975	39.49	159.572	74.91
Penaeus duorarum	3972	31.53	17.617	8.27
Penaeus aztecus	1745	13.85	19.543	9.17
Penaeus setiferus	822	6.52	12.005	5.64
Palaemonetes vulgaris	450	3.57	0.187	0.09
Callinectes similis	192	1.52	3.126	1.47
Trachypenaeus constrictus	123	0.98	0.086	0.04
Macrobrachium ohione	109	0.87	0.489	0.23
Palaemonetes pugio	66	0.52	0.047	0.02
Panopeus herbstii	52	0.41	0.135	0.06
Rhithropanopeus harrisii	49	0.39	0.037	0.02
Portunus gibbesii	23	0.18	0.065	0.03
Portunus spinimanus	4	0.03	0.030	0.01
Panopeus occidentalis	4	0.03	0.012	0.01
Palaemonetes sp.[a]	3	0.02	0.0	0.0
Ovalipes ocellatus	2	0.02	0.012	0.01
Xiphopenaeus kroyeri	2	0.02	0.005	0.01
Ovalipes stephensoni	1	0.01	0.001	0.01
Alpheus heterochaelis	1	0.01	0.001	0.01
Hexapanopeus angustifrons	1	0.01	0.001	0.01
Callinectes ornatus	1	0.01	0.045	0.02
Xanthidae[a]	1	0.01	0.001	0.01
Callinectes sp.[a]	0	0.0	0.0	0.0
Total	12598		213.017	

[a] Field identification

TABLE 4. Total number of individuals and species of fishes and decapod Crustacea collected at otter-trawl sampling locations in the Winyah Bay estuarine system, S.C. during 1977 and 1978.

SAMPLING SITE	NUMBER OF INDIVIDUALS		NUMBER OF SPECIES		NUMBER OF COLLECTIONS
	FISHES	DECAPODS	FISHES	DECAPODS	
1977					
YB02	2299	2044	33	11	12
YB05	1524	683	27	12	12
YB08	1654	65	11	3	12
YB11	2803	742	25	10	12
YL05	1638	59	21	12	12
YP05	837	69	26	8	12
YS07	1116	1187	21	9	12
YW06	2803	2870	33	11	12
Y001	1546	423	34	10	12
1978					
YB02	4458	492	31	9	12
YB05	1193	511	23	8	12
YB08	2117	89	12	5	12
YB11	2690	657	26	10	12
YL05	1792	159	20	6	12
YP05	1492	202	22	8	12
YS07	1298	742	24	10	12
YW06	3764	972	31	7	12
Y001	3838	632	35	14	12

at stations YB05 and YL05 in 1977 and YO01 in 1978. The number of decapod specimens collected was lowest during both years of sampling at stations YB08, YL05, and YP05. Fewest fish specimens were collected in 1977 at station YP05. Generally, species richness and the logarithmically-transformed number of individuals were lowest during winter and highest in the fall (Figure 4).

The numbers of species of fishes and decapod crustaceans and numbers of decapod crustacean individuals ($\log_e$ transformed) were positively correlated with bottom temperature and salinity and negatively correlated with oxygen and depth (Table 5). The numbers of individual fish, however, were positively correlated with bottom temperature and salinity and negatively correlated only with oxygen.

Although not absolute indicators of stress, species richness (total number of species) and evenness (total number of individuals) are useful in determining nursery potential and productivity of the estuary. In the Winyah Bay estuarine system, those stations characterized by unstable yet generally high salinity conditions (YB02, YO01, YB05, YB11) were the richest in species and supported the most individuals. In contrast, fewest species and individuals were collected at stations on the Black (YL05), Peedee (YP05) and Waccamaw (YW06) Rivers which underwent less drastic salinity changes and exhibited low annual mean salinities. The Sampit River supported a richer fauna than the other distributaries entering Winyah Bay. This higher diversity may be related to the higher overall salinity of the Sampit River. However, all distributaries had a lower salinity and lower species richness than Winyah Bay. Increased diversity of higher salinity waters is a usual occurrence in estuaries and is attributable to the presence of a diverse assemblage of stenohaline marine species and euryhaline species.

Numerical classification analysis showed that collections made at limnetic-oligohaline stations which experienced little fluctuation in salinity (YW06, YL05,

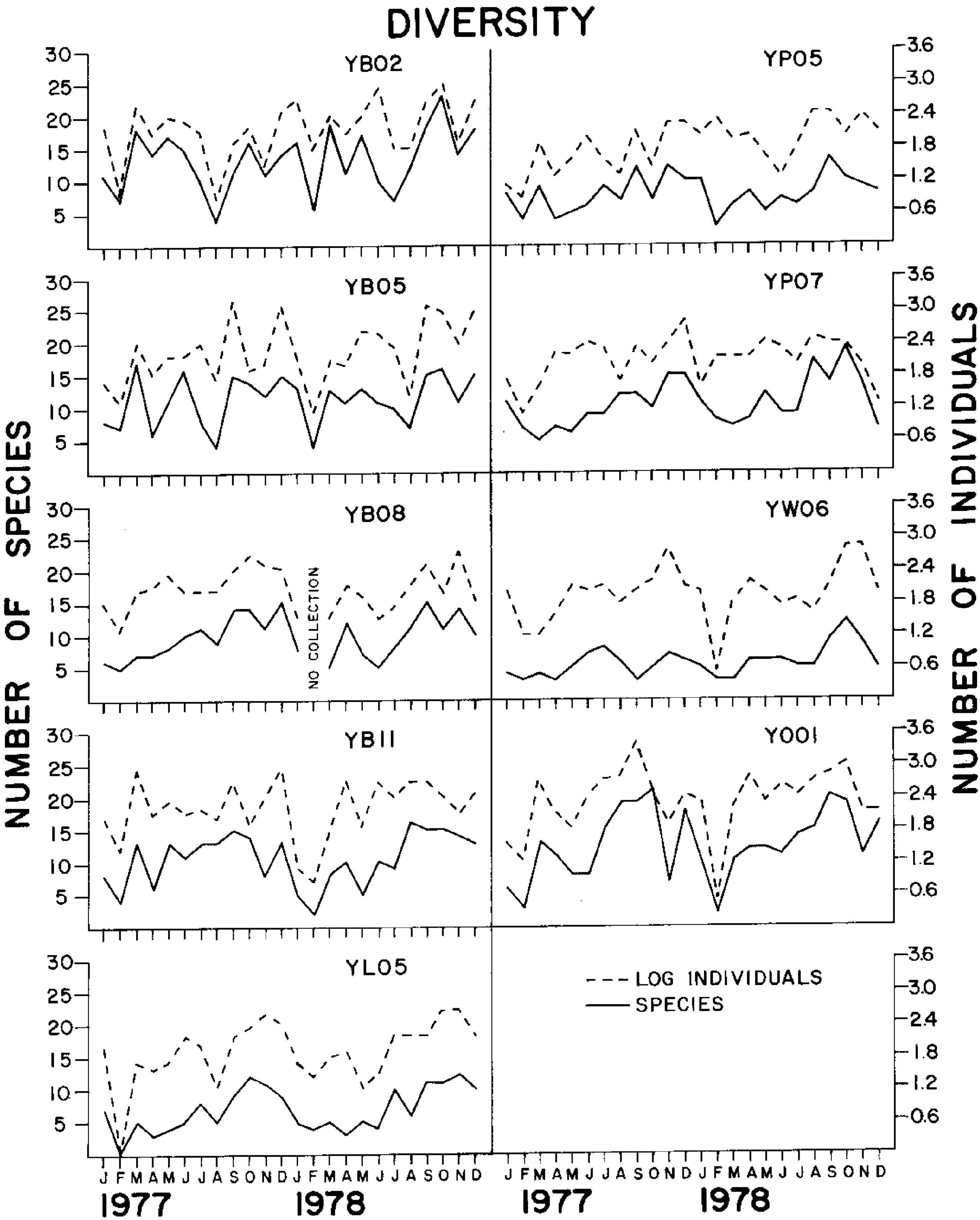

FIGURE 8. Monthly fluctuations in number of species and number of individuals (log transformed) for fishes and decapod crustaceans at sampling sites in the Winyah Bay estuarine system, 1977 - 1978.

TABLE 5. Correlation between numbers of species and $\log_e (x + 1)$ transformed values of number of individuals of fishes and decapods in relation to environmental factors. Data are pooled for the two-year study period. r = Pearson product-moment correlation coefficient; n = number of observations; x = number of individuals.

Environmental Factors	Number of Species				Transformed Number of Individuals			
	Fishes		Decapods		Fishes		Decapods	
	r	n	r	n	r	n	r	n
Bottom Temperature (°C)	0.242**	209	0.279**	194	0.309**	209	0.390**	192
Salinity (°/oo)	0.480**	209	0.442**	194	0.183*	209	0.468**	192
Oxygen (mg/l)	-0.179*	209	-0.254**	194	-0.303**	209	-0.343**	192
Turbidity (FTU)†	0.122	209	0.002	194	0.045	209	0.074	192
Depth (m)	-0.351**	209	-0.194**	194	-0.053	209	-0.283**	192

* Significant ($\rho \neq 0$) at $\alpha = 0.05$

** Significant ($\rho \neq 0$) at $\alpha = 0.01$

† Formazin Trubidity Units

YP05, YS07) were least similar in species composition to collections made at stations (YB02, YB05, YO01, YB08, YB11) which were limnetic-euhaline and experienced wide salinity fluctuations during a season. Site groups formed during cluster analysis did overlap, however, with regard to station location. This overlap was especially noticeable for collections from stations in the meso- polyhaline and poly-euhaline range. Because collections did not clearly cluster according to salinity regimes within the estuary, we compared collections from each fixed station, rather than collection groups as determined from cluster analysis with the species groups resulting from inverse analysis (Table 6). Thus, we made seasonal comparisons of species assemblages among collections from fixed stations (Figures 5-8).

The Winyah Bay estuarine system is similar in species composition to other estuaries of the southeastern United States such as the Cape Fear River, N.C. and Santee System, S.C. which receive considerable freshwater input. These systems are usually dominated by euryhaline species which primarily use the estuary as a nursery ground; however, the success of these species in the estuary is subject to spatial and temporal variation as well as interaction with resident estuarine species and stenohaline marine transients.

The numerically-dominant fishes and decapod crustaceans such as *Ictalurus catus*, *Trinectes maculatus*, *Micropogonias undulatus*, and *Callinectes sapidus* were ubiquitous in the Winyah Bay system. In the fall, these species formed group A and were consistently encountered from collections at stations YO01, YB08, YB11, YL05, YP05, YS07, and YW06 but were not restricted in their distribution to collections from these stations, as shown by low fidelity values (Table 6, Figure 5). Group B consisted of numerically abundant but transient

TABLE 6. Groups formed from seasonal inverse cluster analyses of species of fishes and decapod Crustacea collected in the Winyah Bay estuarine system from 1977-1978.

FALL	WINTER	SPRING	SUMMER
Group A	Group A	Group A	Group A
Callinectes sapidus	*Scophthalmus aquosus*	*Ictalurus catus*	*Cynoscion regalis*
Trinectes maculatus	*Urophycis floridana*	*Trinectes maculatus*	*Penaeus aztecus*
Micropogonias undulatus	*Ancylopsetta quadrocellata*	*Micropogonias undulatus*	*Micropogonias undulatus*
Ictalurus catus	*Palaemonetes vulgaris*	*Callinectes sapidus*	*Callinectes sapidus*
	Panopeus herbstii		*Trinectes maculatus*
	Paralichthys lethostigma		*Ictalurus catus*
	Symphurus plagiusa		
	Gobiesox strumosus		
	Opsanus tau		
	Leiostomus xanthurus		
Group B	Group B	Group B	Group B
Paralichthys lethostigma	*Anchoa mitchilli*	*Anguilla rostrata*	*Stellifer lanceolatus*
Leiostomus xanthurus	*Paralichthys dentatus*	*Lepisosteus osseus*	*Penaeus duorarum*
Symphurus plagiusa	*Palaemonetes pugio*	*Rhithropanopeus harrisii*	*Symphurus plagiusa*
Menticirrhus americanus	*Cynoscion nebulosus*	*Acipenser oxyrhynchus*	*Menticirrhus americanus*
Penaeus duorarum		*Macrobrachium ohione*	*Penaeus setiferus*
Stellifer lanceolatus		*Morone americana*	*Peprilus alepidotus*
Penaeus setiferus		*Morone saxatilis*	*Paralichthys lethostigma*
Cynoscion regalis		*Ictalurus nebulosus*	*Anchoa mitchilli*
Penaeus aztecus			*Leiostomus xanthurus*
Anchoa mitchilli			*Brevoortia tyrannus*
Group C	Group C	Group C	Group C
Hypsoblennius hentzi	*Ictalurus catus*	*Panopeus herbstii*	*Palaemonetes vulgaris*
Gobiesox strumosus	*Trinectes maculatus*	*Gobiesox strumosus*	*Panopeus herbstii*
Panopeus herbstii		*Trachypenaeus constrictus*	*Opsanus tau*
Opsanus tau		*Opsanus tau*	*Trachypenaeus constrictus*
Bairdiella chrysoura		*Dasyatis sabina*	
Trachypenaeus constrictus		*Ophidion marginatum*	
Palaemonetes vulgaris			
Etropus crossotus			
Group D	Group D	Group D	Group D
Chaetodipterus faber	*Callinectes sapidus*	*Bairdiella chrysoura*	*Paralichthys dentatus*
Prionotus tribulus	*Brevoortia tyrannus*	*Scophthalmus aquosus*	*Chaetodipterus faber*
Callinectes similis	*Micropogonias undulatus*	*Cynoscion regalis*	*Callinectes similis*
Paralichthys dentatus	*Stellifer lanceolatus*	*Prionotus tribulus*	*Bagre marinus*
Scophthalmus aquosus	*Urophycis regia*		*Dasyatis sabina*
Citharichthys spilopterus	*Bairdiella chrysoura*		
Dasyatis sabina	*Lagodon rhomboides*		
Portunus gibbesii			
	Group E	Group E	Group E
	Alosa sapidissima	*Urophycis floridana*	*Macrobrachium ohione*
	Mugil cephalus	*Urophycis regia*	*Acipenser oxyrhynchus*
		Stellifer lanceolatus	*Morone americana*
		Symphurus plagiusa	*Morone saxatilis*
		Brevoortia tyrannus	
		Anchoa mitchilli	
		Peprilus tricanthus	
	Group F		
	Rhithropanopeus harrisii		
	Morone americana		
	Morone saxatilis		
	Lepisosteus osseus		
	Anguilla rostrata		
	Dorosoma petenense		

Table 6 (continued)

FALL	WINTER	SPRING	SUMMER
Group E	Group G	Group F	Group F
Anguilla rostrata	*Ictalurus punctatus*	*Leiostomus xanthurus*	*Prionotus tribulus*
Cynoscion nebulosus	*Macrobrachium ohione*	*Penaeus aztecus*	*Chloroscombrus chrysurus*
Rhithropanopeus harrisii	*Acipenser oxyrhynchus*	*Paralichthys dentatus*	*Lepisosteus osseus*
Morone americana		*Paralichthys lethostigma*	*Anguilla rostrata*
Lepisosteus osseus		*Palaemonetes vulgaris*	*Citharichthys spilopterus*
Morone saxatilis		*Palaemonetes pugio*	*Bairdiella chrysoura*
Palaemonetes pugio			*Palaemonetes pugio*
Alosa sapidissima			
Group F			
Brevoortia tyrannus			
Peprilus alepidotus			
Macrobrachium ohione			
Dorosoma petenense			
Acipenser oxyrhynchus			

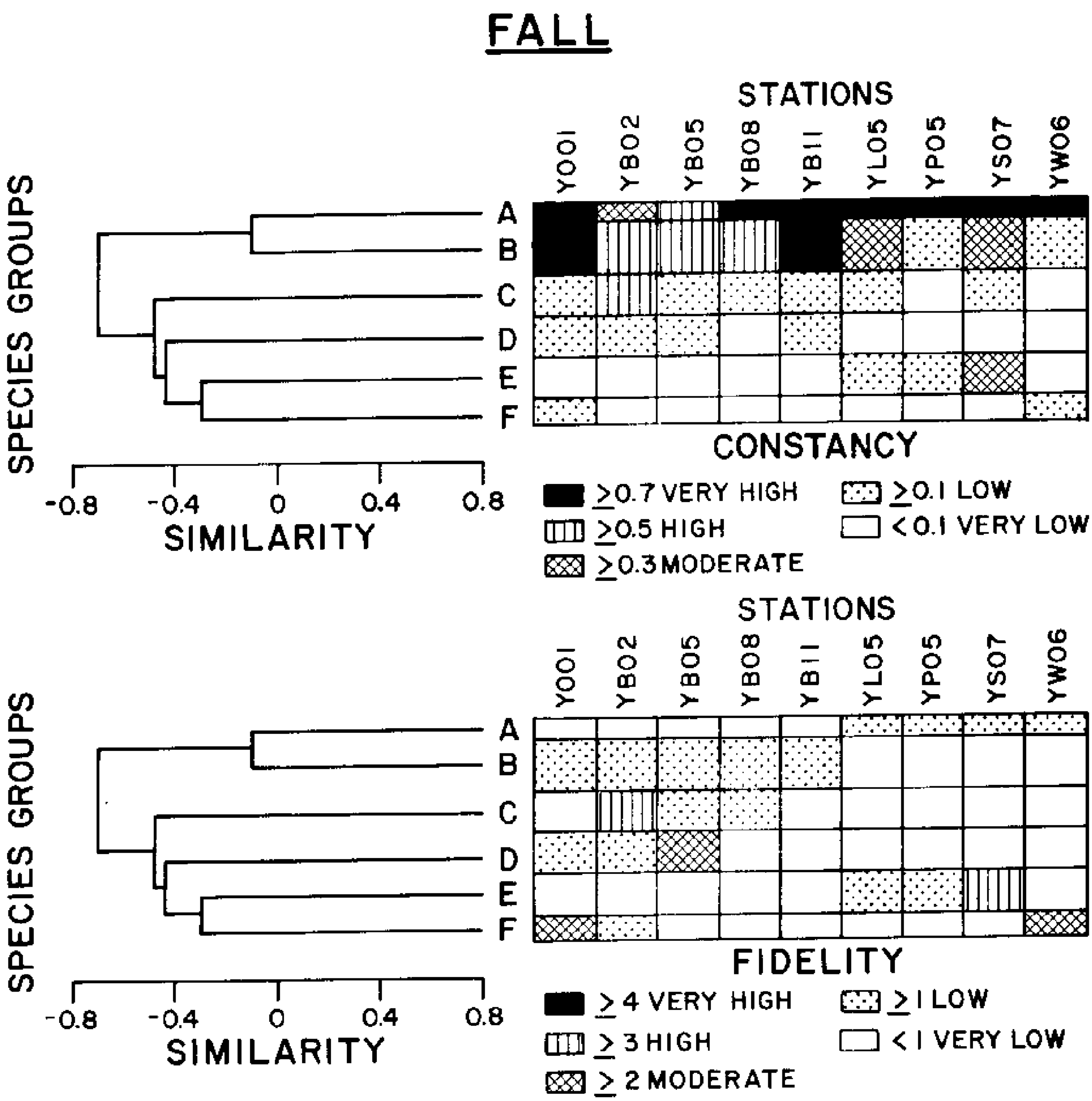

FIGURE 5. Two-way coincidence tables of constancy and fidelity which compare species associations with collections from each station sampled in the Winyah Bay estuarine system for Fall, 1977 - 1978 (years combined). The species groups, designated alphabetically, resulted from cluster analysis of species (dendrogram not shown) collected from the Winyah Bay system. Species comprising these associations are listed in Table 6.

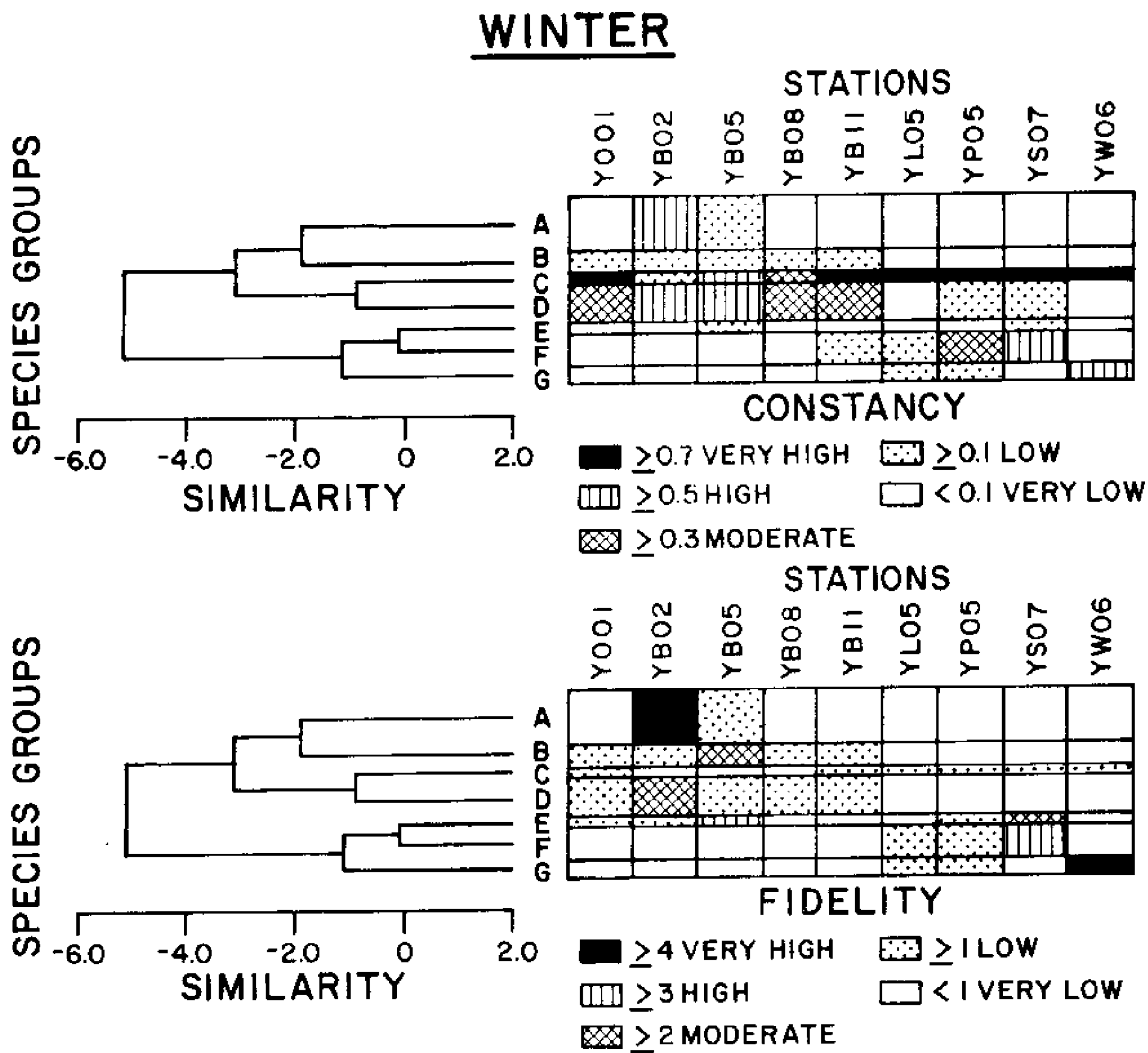

FIGURE 6. Two-way coincidence tables for Winter, 1977 - 1978 (years combined). Other information same as for Figure 5.

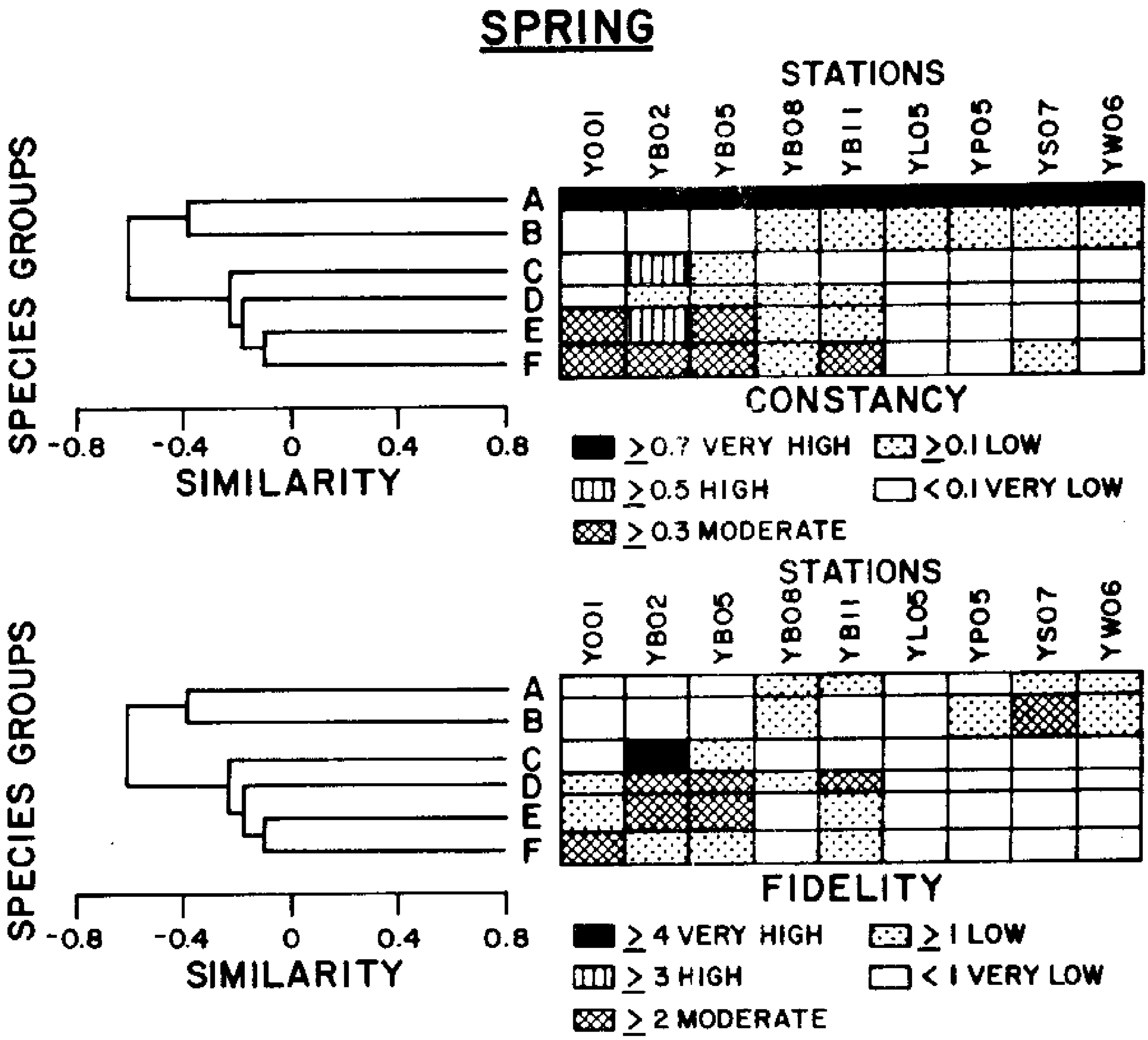

FIGURE 7. TWO-WAY COINCIDENCE TABLES FOR SPRING, 1977 - 1978 (YEARS COMBINED). OTHER INFORMATION SAME AS FOR FIGURE 5.

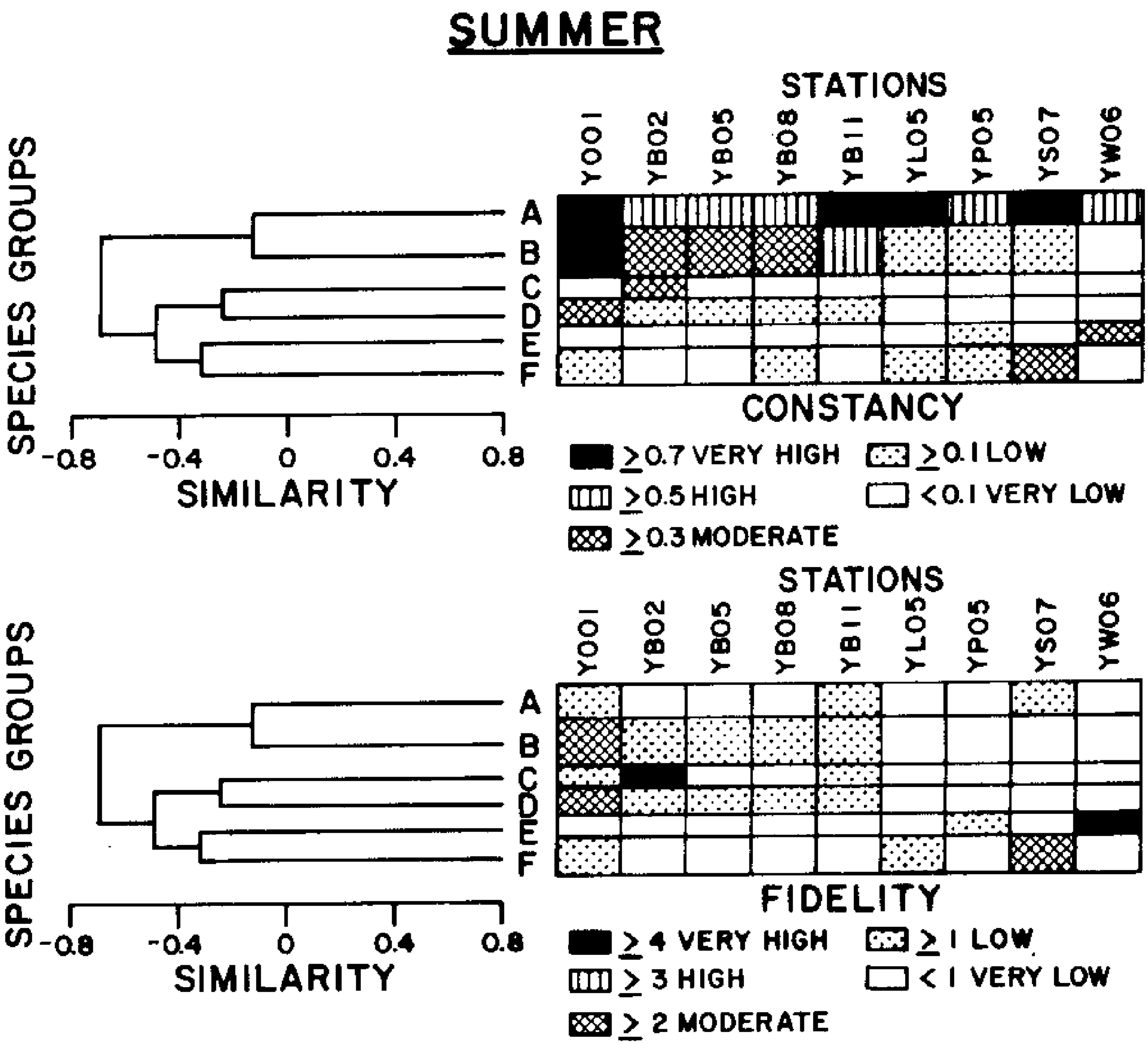

FIGURE 8. Two-way coincidence tables for Summer, 1977 - 1978 (years combined). Other information same as for Figure 5.

species such as sciaenid fishes and penaeid shrimps, which spend only a portion of their life within estuaries. These species were most consistently collected at higher salinity stations and were similar in distribution to group A species. In winter, only group C species consisting of I. catus and T. maculatus were consistently found throughout much of the Winyah Bay system. The numerically-abundant species found in group D (Callinectes sapidus and Micropogonias undulatus) were most consistently collected in samples from stations YB02 and YB05, but they were not restricted to any station (Figure 6). During spring and summer, species in group A were ubiquitous and unrestricted in their distribution (Figures 7 and 8). In summer, group B consisted mostly of transient species which were most consistently encountered at stations YO01 and YB11.

Stenohaline marine assemblages of species were not found further upestuary than station YB11. In fall, group D consisted mostly of stenohaline marine species which were infrequently encountered and not restricted to stations YO01, YB02, YB05, and YB11. In winter, species group A contained stenohaline marine species as well as estuarine transients such as Leiostomus xanthurus and estuarine endemics such as Palaemonetes vulgaris. These species displayed high constancy and very high fidelity for station YB02. Species of group C in spring were similarly distributed. Group E species in spring also were most frequently taken in collections at station YB02 but were not restricted spatially in their distribution. In summer, species in group C were restricted to station YB02, while group D contained species which were infrequently collected from stations YB02-YB11.

Species found in the upper reaches of the Winyah Bay estuarine system (stations YL05, YP05, YS07, and YW06) included predominantly freshwater species such as Macrobrachium ohione and Ictalurus punctatus, transients, and catadromous and anadromous species. In fall, species in group E were collected at stations YL05, YP05, and YS07 where they displayed moderate to low constancy with high fidelity to station YS07. In winter, species in groups F and G displayed low to high constancy for stations YB11, YL05, YP05, YS07, and YW06. In addition, group G species were restricted to station YW06. In spring, group B species extended downriver to YB08 but were infrequently encountered and not restricted to any station. Group E species in summer had highest constancy and fidelity at YW06.

Other assemblages defined by our analyses included species which were relatively euryhaline but were generally captured in low numbers and were not restricted to any station location. These assemblages included groups C and F in fall, groups B and E in winter, groups D and F in spring, and group F in summer.

Most species associations were highly seasonal, and species seldom co-occurred within the same assemblage throughout the year (Figure 9); however, there were several species which occurred together year-round. Among these were the estuarine transient species, Micropogonias undulatus with Callinectes sapidus; Leiostomus xanthurus with Paralichthys lethostigma; and Panopeus herbstii and Opsanus tau. Estuarine resident species which co-occurred together or with catadromous or anadromous species year-round included Ictalurus catus with Trinectes maculatus; Lepisosteus osseus with Anguilla rostrata; Morone americana with Morone saxatilis; and Macrobrachium ohione with Acipenser oxyrhynchus.

Our description of community composition for Winyah Bay is applicable for the channel reaches and cannot be extended to include the tidal creeks and near-shore marsh habitat. The importance of tidal salt marshes as a nursery

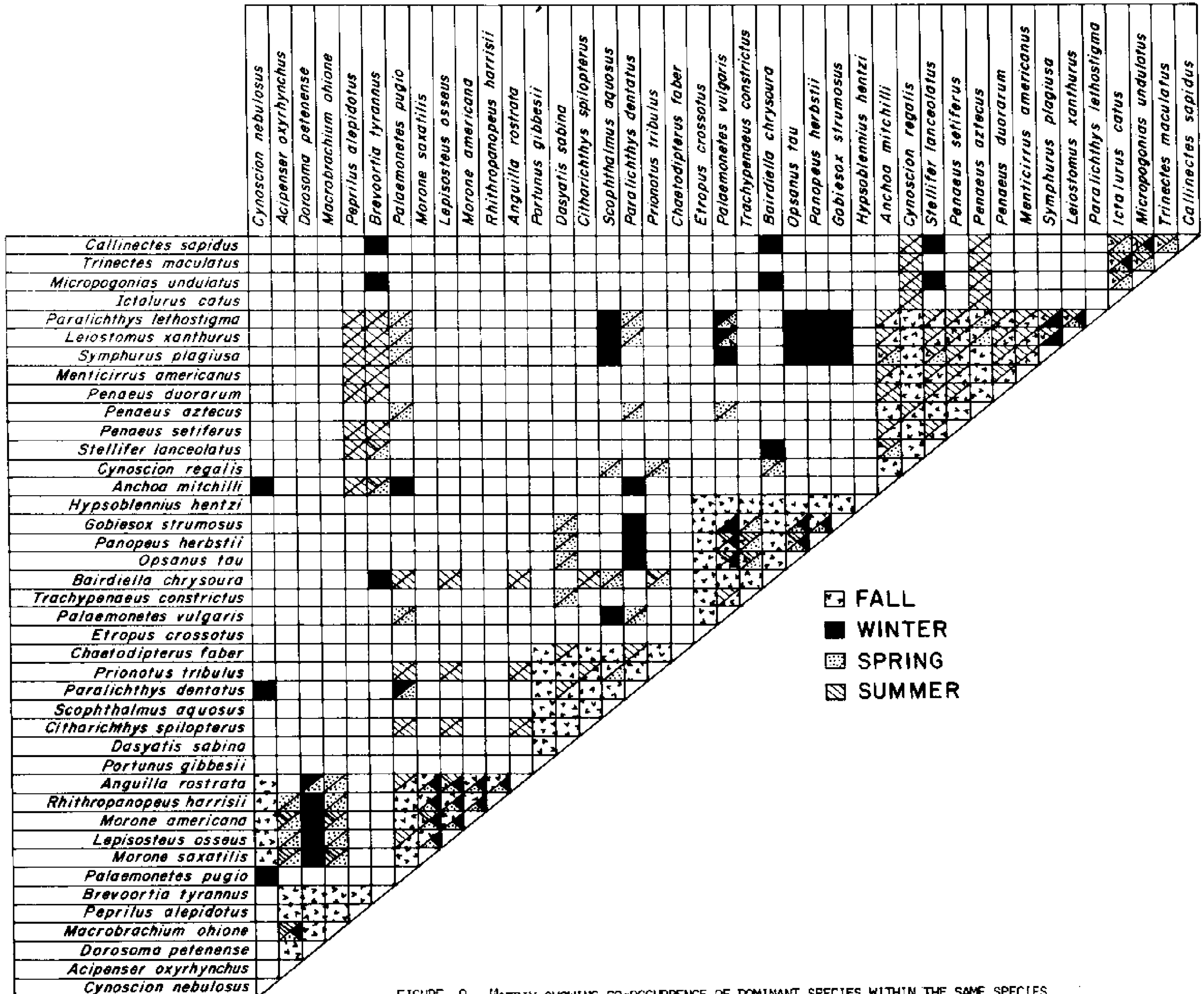

FIGURE 9. MATRIX SHOWING CO-OCCURRENCE OF DOMINANT SPECIES WITHIN THE SAME SPECIES GROUPS RESULTING FROM CLUSTER ANALYSIS OF FALL, WINTER, SPRING, SUMMER DATA FROM TRAWL COLLECTIONS IN THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM. THIS MATRIX INCLUDES ONLY THOSE SPECIES WHICH OCCURRED AT $\geq 10\%$ OF THE COLLECTIONS DURING ANY SEASON.

habitat has been documented for several southeastern estuaries: Cape Fear, N.C. (Weinstein, 1979); North Inlet Estuary, S.C. (Cain and Dean, 1976; Shenker and Dean, 1979; Bozeman and Dean, 1980), and Port Royal Sound, S.C. (Turner and Johnson, 1972). A comparison of the channel communities defined by us with those of shallow marsh habitats in the Cape Fear River, an estuary which undergoes considerable fluctuations in salinity, revealed interesting differences in species composition and abundance patterns. For example, Fundulus heteroclitus, Mugil cephalus, M. curema, and Menidia menidia were the most abundant species reported from tidal creeks by Weinstein (1979). Interestingly, Micropogonias undulatus was absent from marsh shallows of these creeks, and Weinstein (1979) hypothesized that their absence was due to minimum temperatures in the shoal areas during winter recruitment.

In addition to habitat-related differences in species composition and abundance, our survey of the Winyah Bay fishes was biased by our gear which emphasized capture of juveniles. The large amount of coastal marshland and freshwater input which characterizes the Winyah Bay system provides physiological suitability, an abundant food supply, and a refuge from predators, criteria which determine ideal estuarine nursery grounds (Van Engel and Joseph[4]). However, fishes of commercial importance, such as Alosa sapidissima, A. mediocris, and Acipenser oxyrynchus, were not readily vulnerable to our gear and, hence, were not adequately sampled by us.

Temporal and Spatial Distribution of Numerically-Dominant Species

Most of the numerically-abundant fishes and decapod crustaceans were seasonal inhabitants of the estuary and were abundant in specific areas of the

[4]Van Engel, W.A. and E.B. Joseph. 1968. Characterization of coastal and estuarine fish nursery grounds as natural communities. Final Report to U.S. Fish and Wildlife Service. 43 p.

Winyah Bay system.

Star drum, Stellifer lanceolatus, were most numerous from September to January at stations YB02, YB05, YB08, YB11, and Y001 within Winyah Bay (Figure 10). In addition, log-transformed catches of Stellifer were similar during the two-year sampling period, although more individuals were collected in 1978 (Table 7). Length-frequency polygons indicated that small star drum (< 70 mm), which may be new recruits, were prevalent in summer and fall (Figure 11). These fishes may have resulted from summer spawning which occurs along the Atlantic coast from late spring through summer (Welsh and Breder, 1923; Hildebrand and Cable, 1934). Larger, possibly one-year-old fish, were present in winter and spring, along with young-of-the-year. Thus, overlapping in size classes of Stellifer occurred during these seasons.

Atlantic croaker, Micropogonias undulatus, were common throughout the estuary during most of the year, although catches were greatest during May, June, and July (Figure 10). Croaker also appeared to be more numerous at stations YB11 and Y001. Annual catches of croaker did not differ appreciably during the two-year study period (Table 7). The smallest croakers ($\leq$ 60 mm) were present in the Winyah Bay system during fall and winter (Figure 12), suggesting that young croakers may over-winter in the estuary. Similar results were obtained by Van Engel and Joseph[4] for croakers from the Chesapeake Bay system. Modal length of juvenile croakers increased from 70 mm in spring to 90 mm in summer. Although one-year old fish (> 123 mm) were also present in the Winyah Bay system during all seasons, they were not very plentiful in our samples, probably reflecting bias of our sampling gear.

Hogchoker, Trinectes maculatus, were found at all stations during every

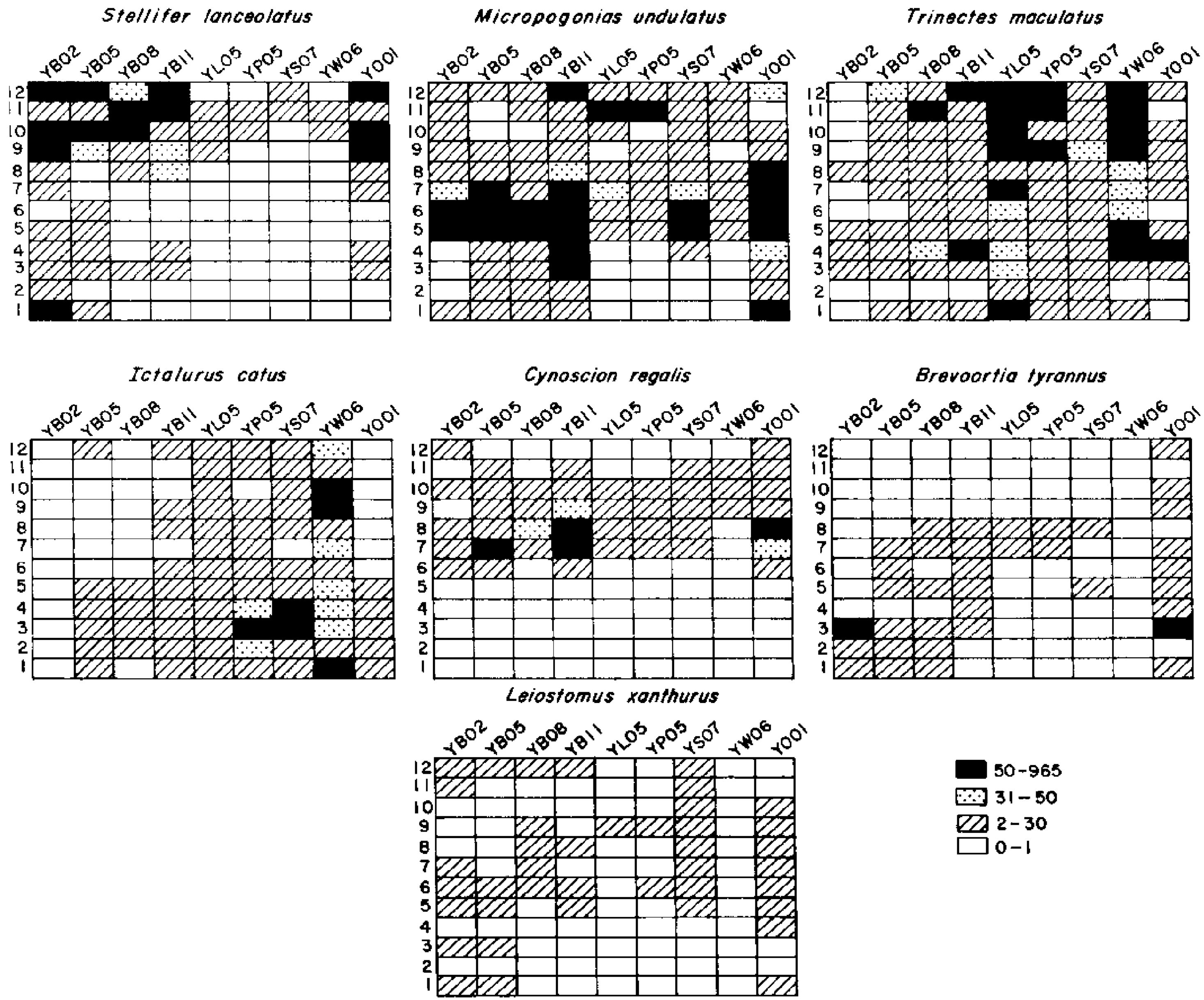

FIGURE 10. INDEX OF RELATIVE ABUNDANCE EXPRESSED AS THE ANTILOG OF THE TRANSFORMED [LOG (x + 1)] MEAN NUMBER OF INDIVIDUALS OF TEN MAJOR FISH SPECIES COLLECTED AT EACH STATION IN THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM ON A MONTHLY BASIS FOR 1977 - 1978. LEGEND INDICATES FOUR ARBITRARY LEVELS OF ABUNDANCE FROM RARE OR ABSENT (0-1) TO MAXIMUM ABUNDANCE (50-965); COLUMNS = STATIONS, ROWS = MONTHS.

TABLE 7. Annual differences between means of logarithmically ($\log_{10}$) transformed counts of the number of individuals for numerically-dominant species of fishes and decapod crustaceans.

Fishes	1977	1978
Stellifer lanceolatus	0.514	0.627
Micropogonias undulatus	0.904	0.978
Trinectes maculatus	0.975	0.959
Ictalurus catus	0.621	0.723
Cynoscion regalis	0.278	0.435
Brevoortia tyrannus	0.245	0.238
Leiostomus xanthurus	0.271	0.247
Decapod Crustaceans		
Callinectes sapidus	0.708	0.871
Penaeus duorarum	0.284	0.398
Penaeus aztecus	0.315	0.350
Penaeus setiferus	0.317	0.158

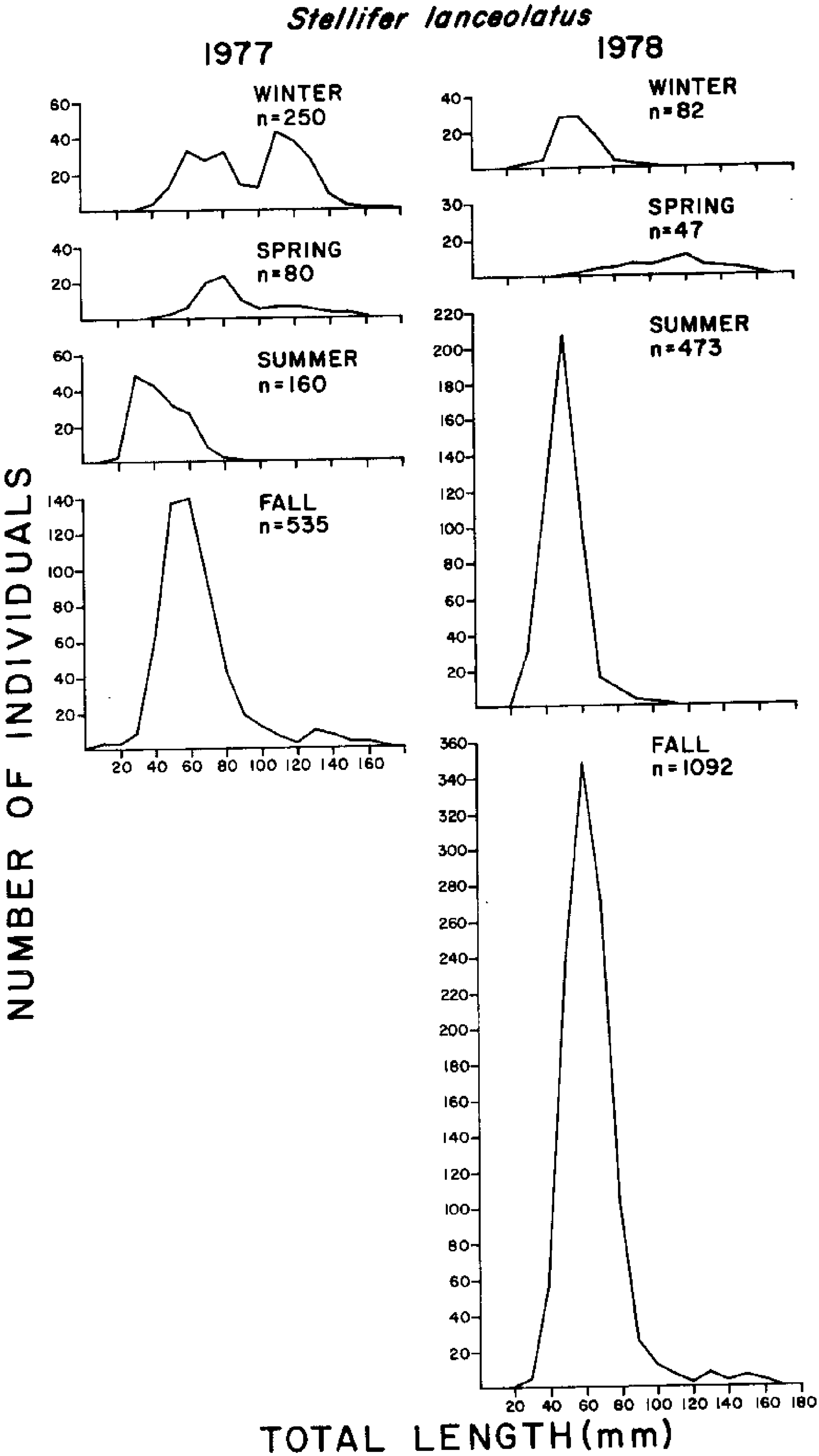

FIGURE 11. Seasonal and annual length-frequency distribution of Stellifer lanceolatus collected from the channel of the Winyah Bay estuarine system.

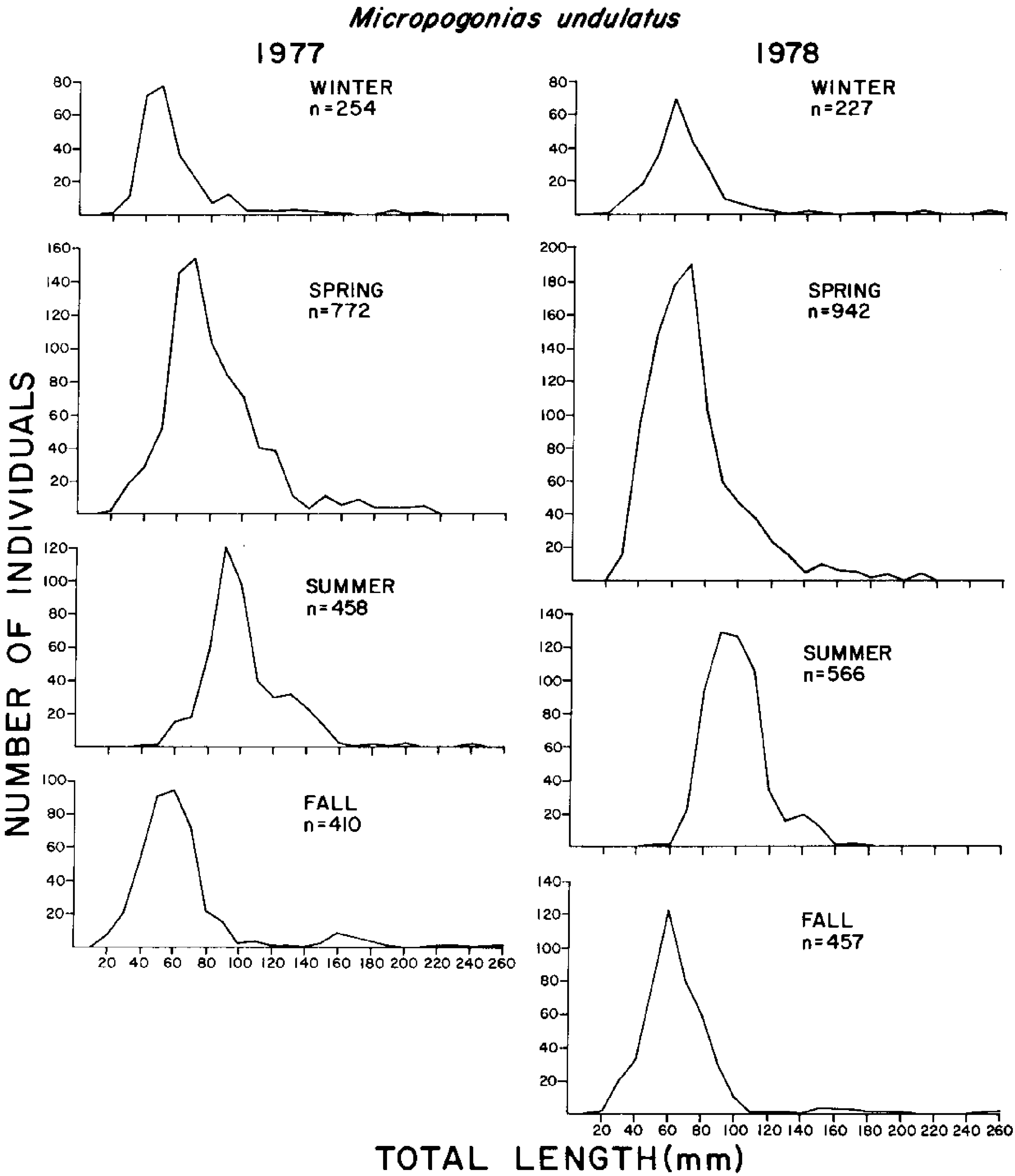

FIGURE 12. SEASONAL AND ANNUAL LENGTH-FREQUENCY DISTRIBUTION OF *MICROPOGONIAS UNDULATUS* COLLECTED FROM THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM.

season of the year; however, hogchokers were most numerous in the upper estuary, especially at stations in the Black (YL05) and Waccamaw (YW06) Rivers and during spring and fall (Figure 10). Catches did not differ appreciably from one year to the next (Table 7). Van Engel and Joseph[4] noted a winter and summer decrease in hogchoker abundance for Chesapeake Bay. They speculated that the decrease in summer was due to emigration of spawning adults, while the winter decrease was related to lessened activity and concentration of the fish in deeper holes. Length-frequency distributions (not shown) indicated that average size of hogchokers was smallest in spring, when we observed a modal peak at 50 mm for both years of study. Sizes of hogchokers increased to a modal length of 60 mm by fall.

Ictalurus catus, which are permanent residents of the estuary, were most plentiful at lower salinity stations, especially YW06 (Figure 10). These catfish also appeared to be most numerous in the spring but decreased in number by summer. Annual catches were stable during the course of study (Table 7). Mean length of catfish were least in spring, but smallest individuals, those < 40 mm, were collected only in summer and fall.

Weakfish, Cynoscion regalis, were not captured in the estuary from January until May. This absence is probably related to a seaward migration from the estuary (Lunz and Schwartz, 1970). Catches of these fishes were greatest at stations within Winyah Bay, especially YO01 and YB11 (Fig. 10). Lunz and Schwartz (1970) noted that seaward migration of weakfish usually begins in late fall in South Carolina, but Shealy et al. (1974) found that weakfish abundance did not markedly decrease until January and proposed that unusually warm temperatures in fall may have influenced their emigration. Catches of weakfish decreased considerably from 1977 with a subsequent decrease in year-class strength in 1978. Small fish (modal length of 40 mm) were present in spring; by summer, the modal length increased to 70 mm, with a subsequent increase to 80-90 mm in fall (Figure 13).

Atlantic menhaden, Brevoortia tyrannus, are pelagic and generally not vulnerable to capture by bottom trawl gear. Therefore, count and distribution estimates are minimal. Menhaden appeared to be most numerous at station Y001 in Winyah Bay (Figure 10). Temporally, catches were greatest in March and annual fluctuations were slight (Table 7). Sizes of menhaden did not differ noticeably among winter, spring, and summer. Scarcity of menhaden in fall collections precluded analysis of length-frequency distributions during that time. Smallest individuals ($\leq$ 40 mm) were collected in spring and summer, while fish > 210 mm were collected only in winter and fall.

Spot, Leiostomus xanthurus, were not very numerous anywhere within the Winyah Bay system, although catches were higher at station Y001 (Figure 10). Most spot were caught during the summer, but fish were present at stations in the estuary during most months of the year. Dawson (1958) noted that spot also occur in the coastal zone from September through November and eventually spawn in offshore waters during the winter. Catches did not differ greatly from one year to the next (Table 7). The smallest fish (modal length 50-60 mm) were present in spring (Figure 14). Fish > 100 mm were probably one year old (Chao and Musick, 1977) and were collected during all seasons but were not abundant.

Blue crab, Callinectes sapidus, were found throughout the Winyah Bay system during all months but catches were greatest from September to December. Their numbers were greatest at stations Y001, YS07, YB08, and YB11 (Figure 15). Catches did not

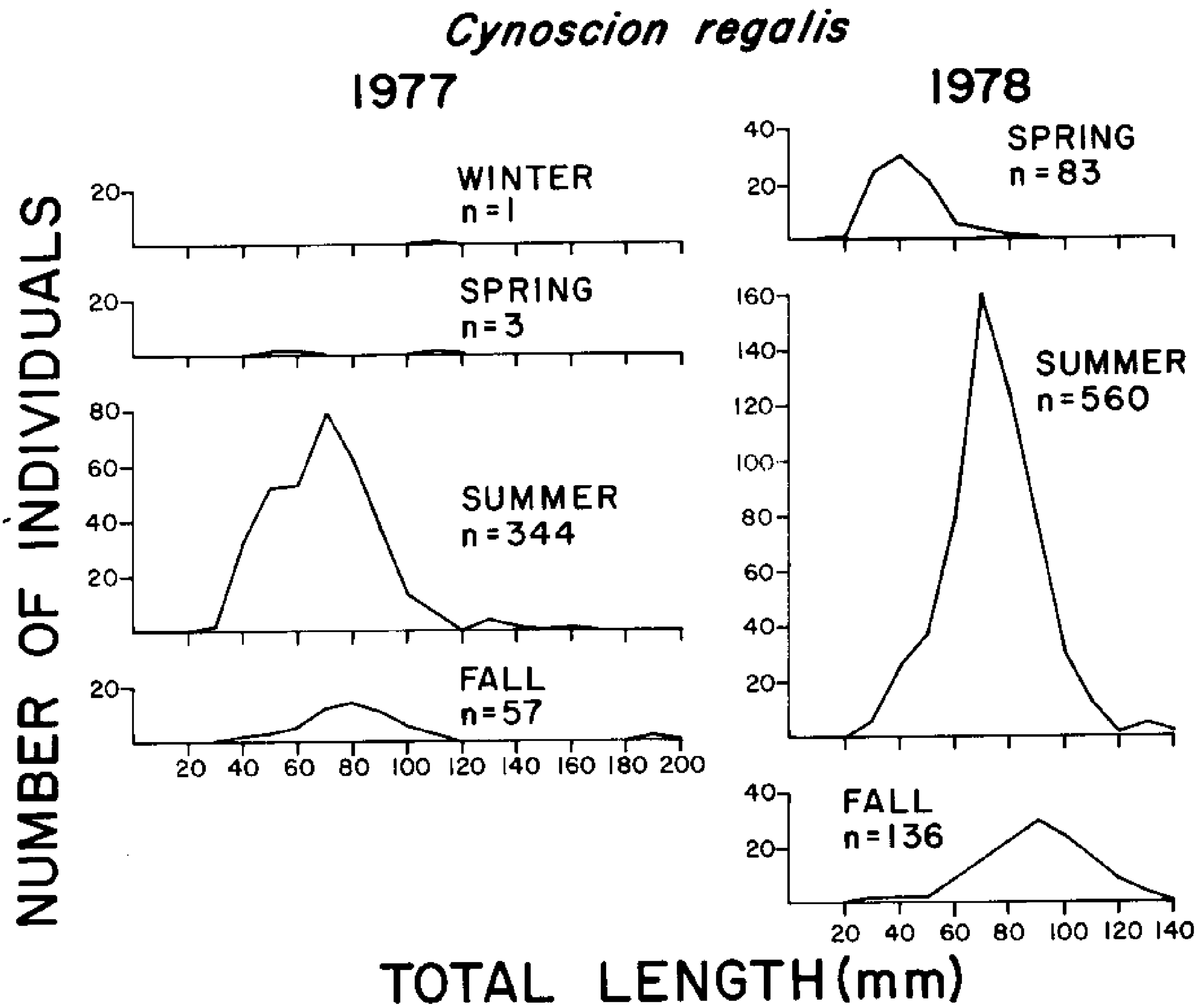

FIGURE 13. SEASONAL AND ANNUAL LENGTH-FREQUENCY DISTRIBUTION OF <u>CYNOSCION REGALIS</u> COLLECTED FROM THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM.

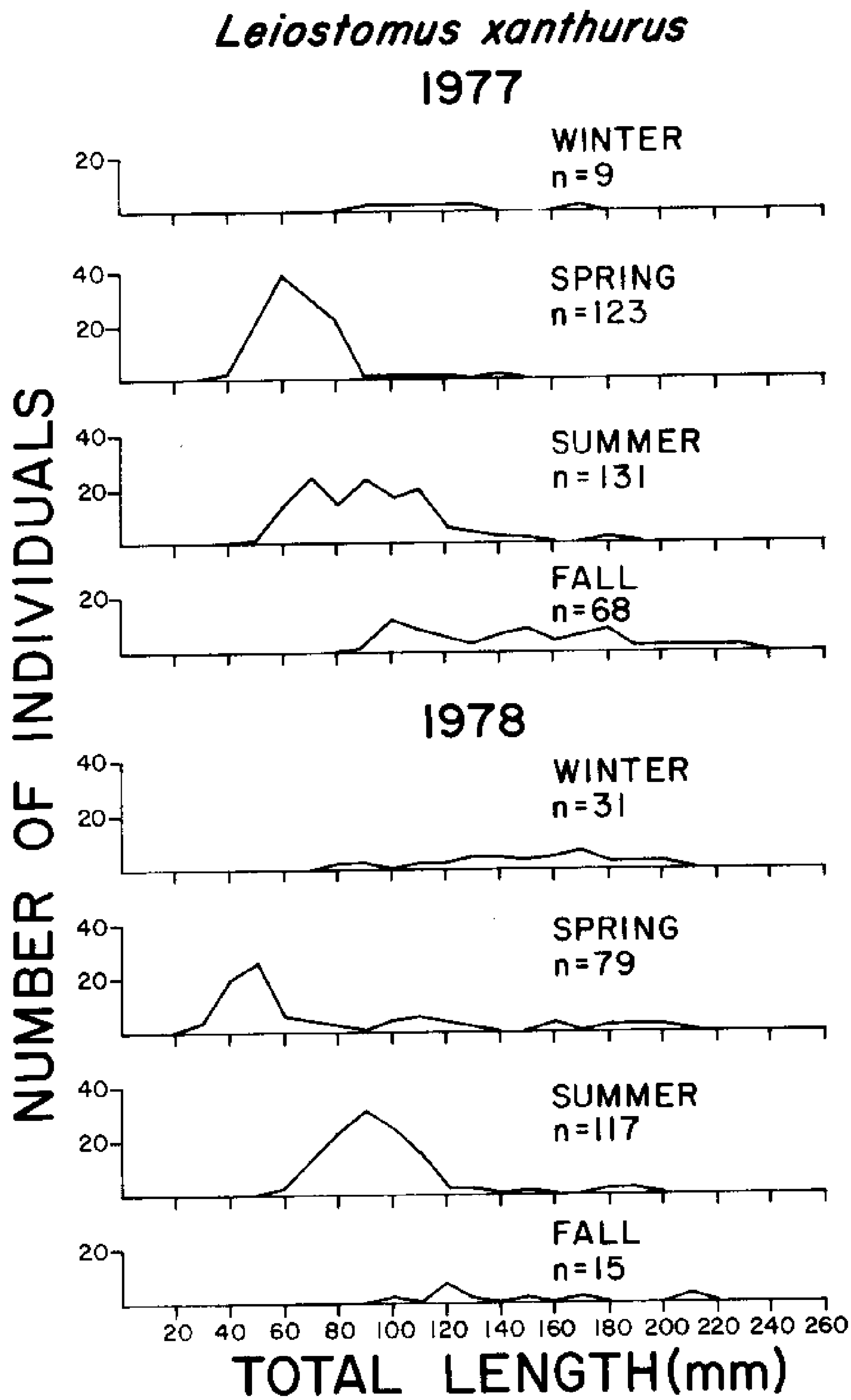

FIGURE 14. SEASONAL AND ANNUAL LENGTH-FREQUENCY DISTRIBUTION OF LEIOSTOMUS XANTHURUS COLLECTED FROM THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM.

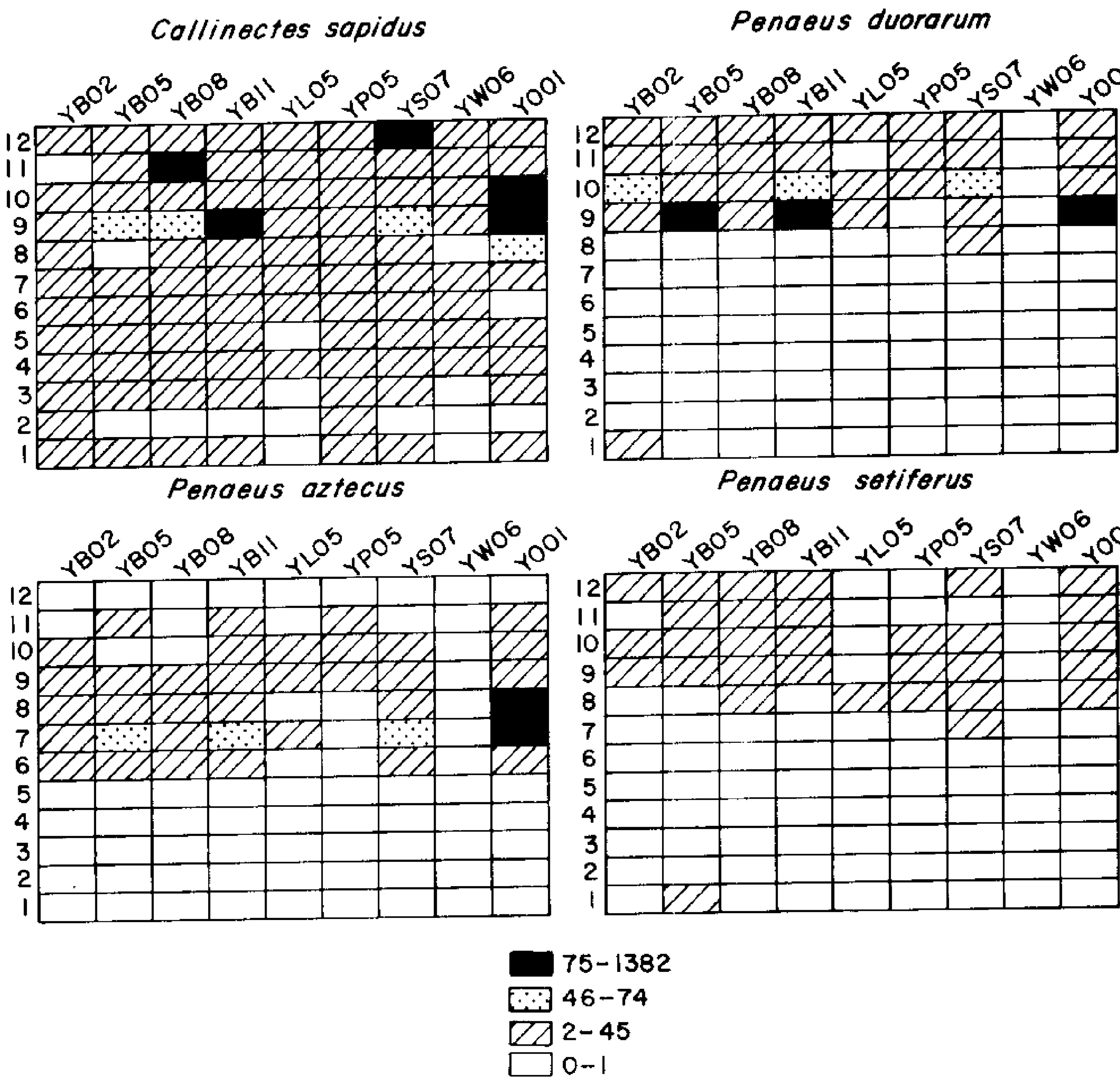

FIGURE 15. ABUNDANCE, EXPRESSED AS THE ANTILOG OF THE TRANSFORMED LOG (X + 1) MEAN NUMBER OF INDIVIDUALS AT EACH STATION EACH MONTH, OF THE FOUR MAJOR SPECIES OF DECAPOD CRUSTACEANS COLLECTED AT EACH STATION MONTHLY IN THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM, 1977 - 1978 (YEARS COMBINED). LEGEND INDICATES FOUR ARBITRARY LEVELS OF ABUNDANCE FROM RARE OR ABSENT (0-1) TO MAXIMUM ABUNDANCE (75-1382).

differ greatly between years. Size-frequency distributions showed that catches consisted of a wide range of blue crabs (Figure 16). Individuals < 40 mm were prevalent in summer and fall.

Penaeid shrimps, Penaeus duorarum, P. aztecus, and P. setiferus, were limited seasonally but not spatially in occurrence. Individuals were caught at every station, except YW06, in the Winyah Bay estuarine system (Figure 15). Both P. duorarum and P. setiferus were most numerous in September and October whereas P. aztecus were most plentiful during the summer months of July and August. All three species were plentiful at stations within Winyah Bay, especially at station Y001. Catches of Penaeus durorarum and P. aztecus were about equal over the two-year study, but fewer P. setiferus were collected in 1978. This decrease may have been influenced by the low winter temperatures observed in February and March 1978. Most Penaeus duorarum collected in the Winyah Bay system were within the size range of 60-90 mm. Sizes of pink shrimp changed very little seasonally (Figure 17); however, total length of brown shrimp, P. aztecus, increased from a modal length of 70 mm in spring to 100 mm in summer (Figure 18). White shrimp, P. setiferus, covered a wide size range during all seasons of occurrence. Seasonal changes in length of P. setiferus were not obvious because of the overlap in sizes of shrimp collected during the fall and summer (Figure 17). Distinguishable bimodal lengths of 80 and 160 mm were noted in Fall 1977, whereas shrimp with modal lengths of 120 and 140 mm were collected in Summer 1977 and Fall 1978, respectively.

The percent of total catch calculated for dominant species was generally not consistent annually or seasonally, except for relative dominance of the catches by Micropogonias undulatus in spring and Stellifer lanceolatus in fall of both

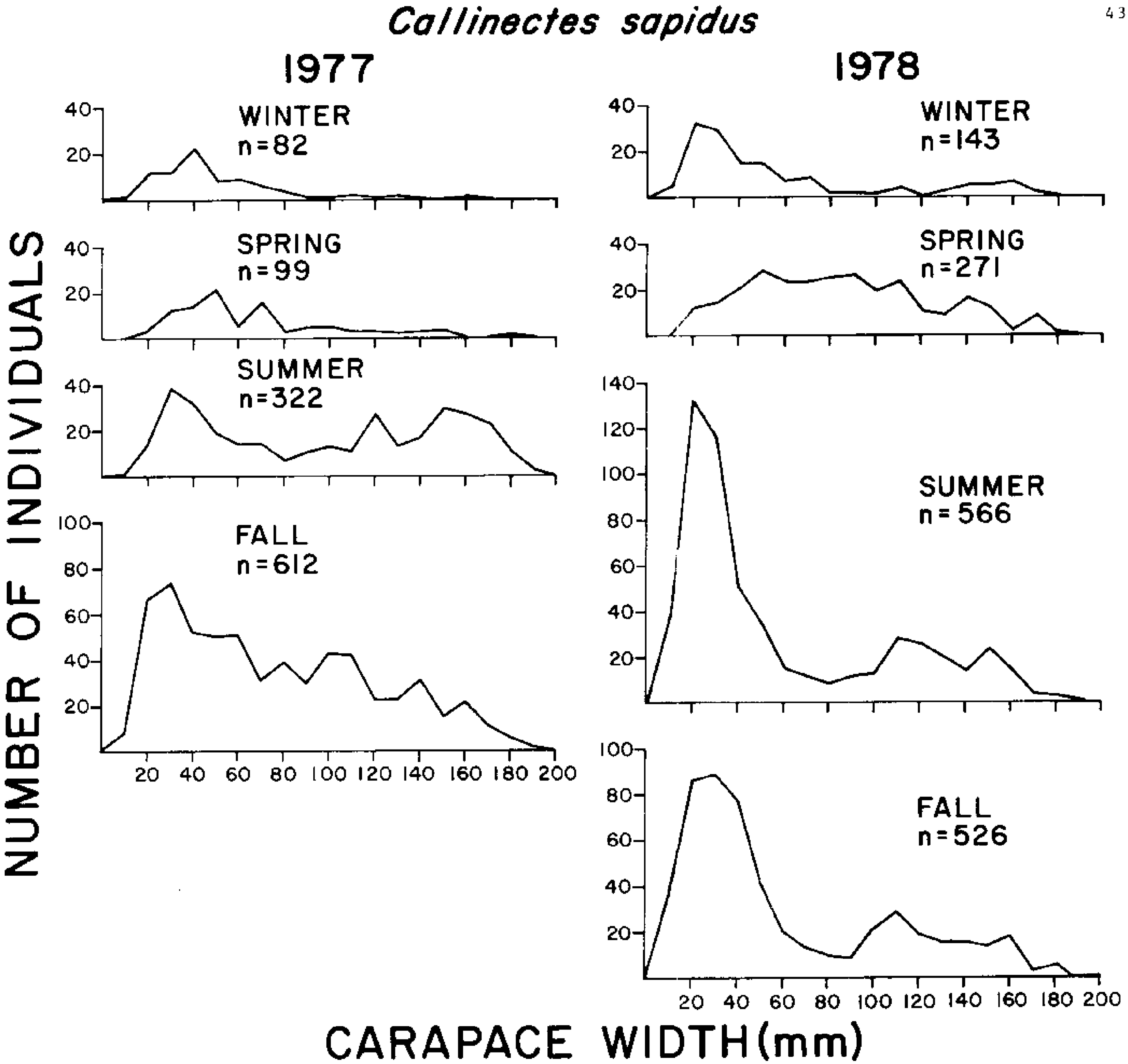

FIGURE 16. SEASONAL AND ANNUAL LENGTH-FREQUENCY DISTRIBUTION OF <u>CALLINECTES SAPIDUS</u> COLLECTED FROM THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM.

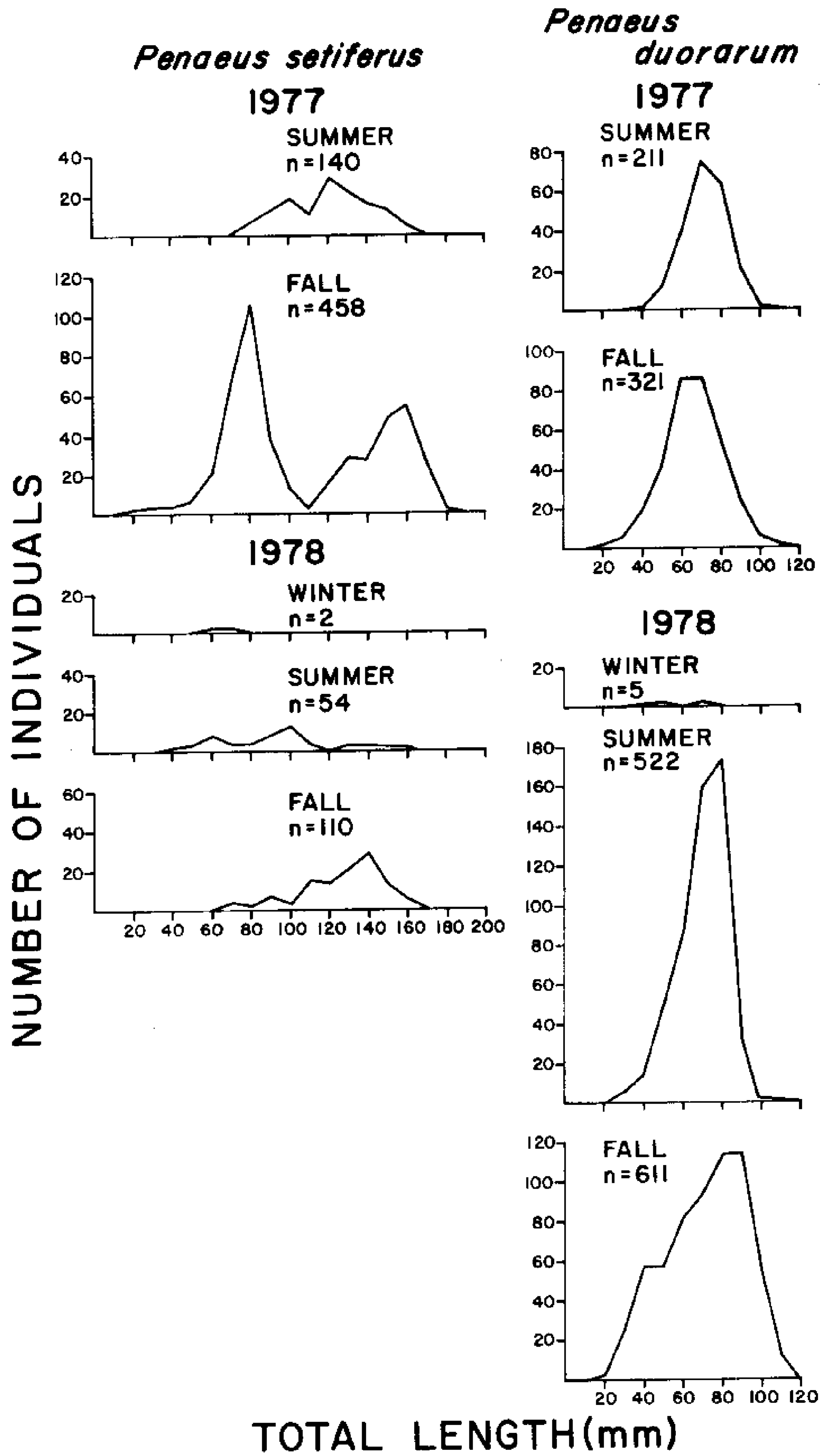

FIGURE 17. SEASONAL AND ANNUAL LENGTH-FREQUENCY DISTRIBUTION OF PENAEUS SETIFERUS AND PENAEUS DUORARUM COLLECTED FROM THE CHANNEL OF THE HINYAH BAY ESTUARINE SYSTEM.

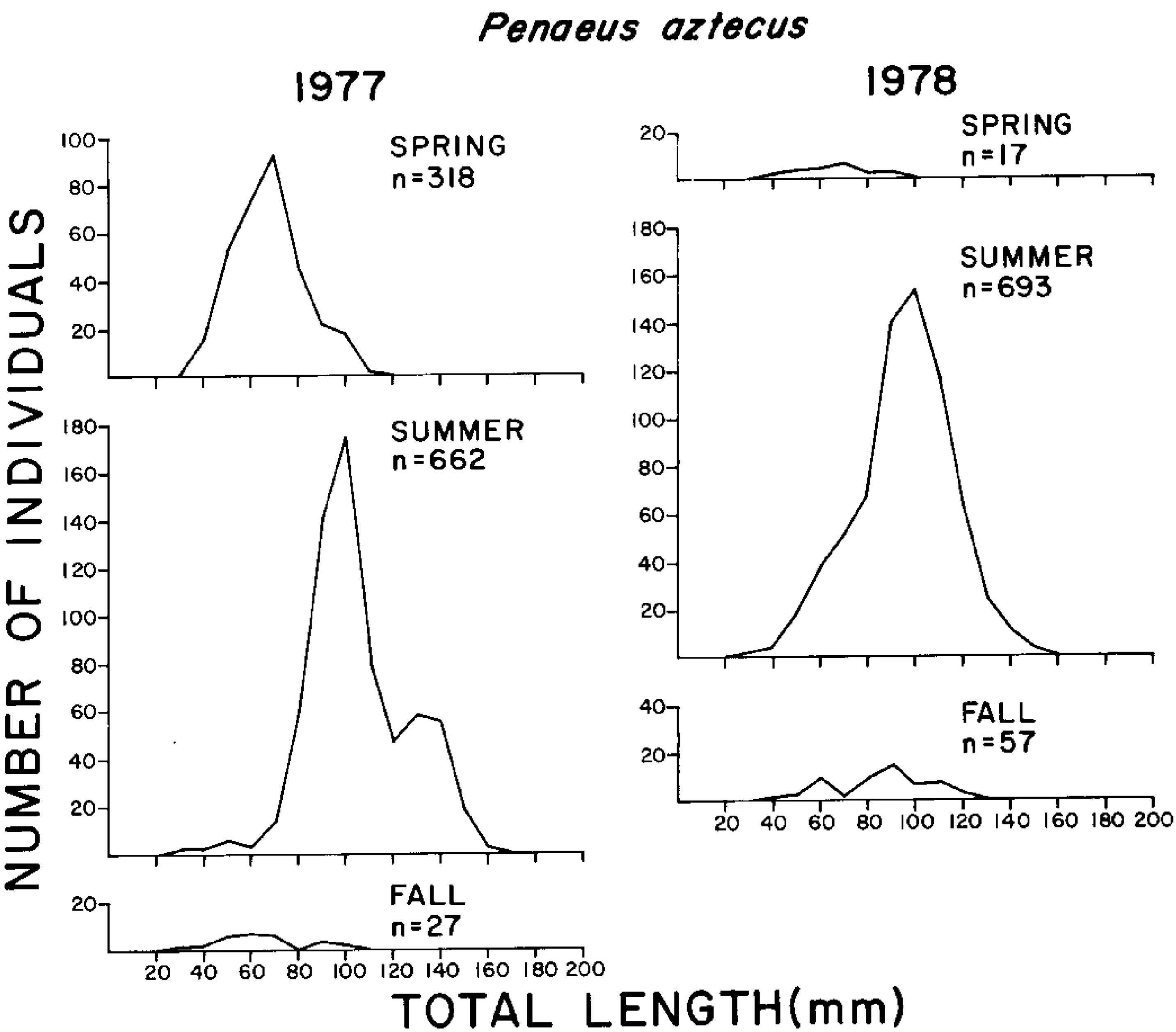

FIGURE 18. SEASONAL AND ANNUAL LENGTH-FREQUENCY DISTRIBUTION OF PENAEUS AZTECUS COLLECTED FROM THE CHANNEL OF THE WINYAH BAY ESTUARINE SYSTEM.

years (Figure 19). Catches in winter were dominated by Brevoortia tyrannus, M. undulatus, and Ictalurus catus. In summer, Penaeus duorarum, Callinectes sapidus, and S. lanceolatus were a major portion of the number of individuals collected.

Spatial and temporal abundance patterns indicated that the numerically-dominant species, except for Ictalurus catus, were most prevalent at stations nearest the mouth of Winyah Bay. In addition, the influx of stenohaline marine species, which were limited physiologically to high salinity waters of Winyah Bay, enhanced the number of species and individuals occurring there.

Biomass and Population Density Estimates

Biomass and population density estimates for fishes were highest at stations YB02 and YB05 during fall and Y001 during summer (Table 8). These high estimates reflected abundance of S. lanceolatus and L. maculatus during fall and of M. undulatus, S. lanceolatus, and C. regalis in summer. Decapod biomass was highest during summer and fall, especially at stations in Winyah Bay itself (Y001 and YB08) and during fall at station YS07 in the Sampit River. These high biomass estimates were due to large catches of blue crabs and brown shrimp during these periods.

Total biomass and density estimates for the Winyah Bay estuarine system during our study period were:

	Biomass (kg/ha)	Density (No./ha)
FISHES	2.77	248.7
DECAPODS	1.36	80.63

These estimates are lower than those reported from other South Carolina estuaries by Wenner et al.[2] and Shealy et al (1974). Lower biomass and density

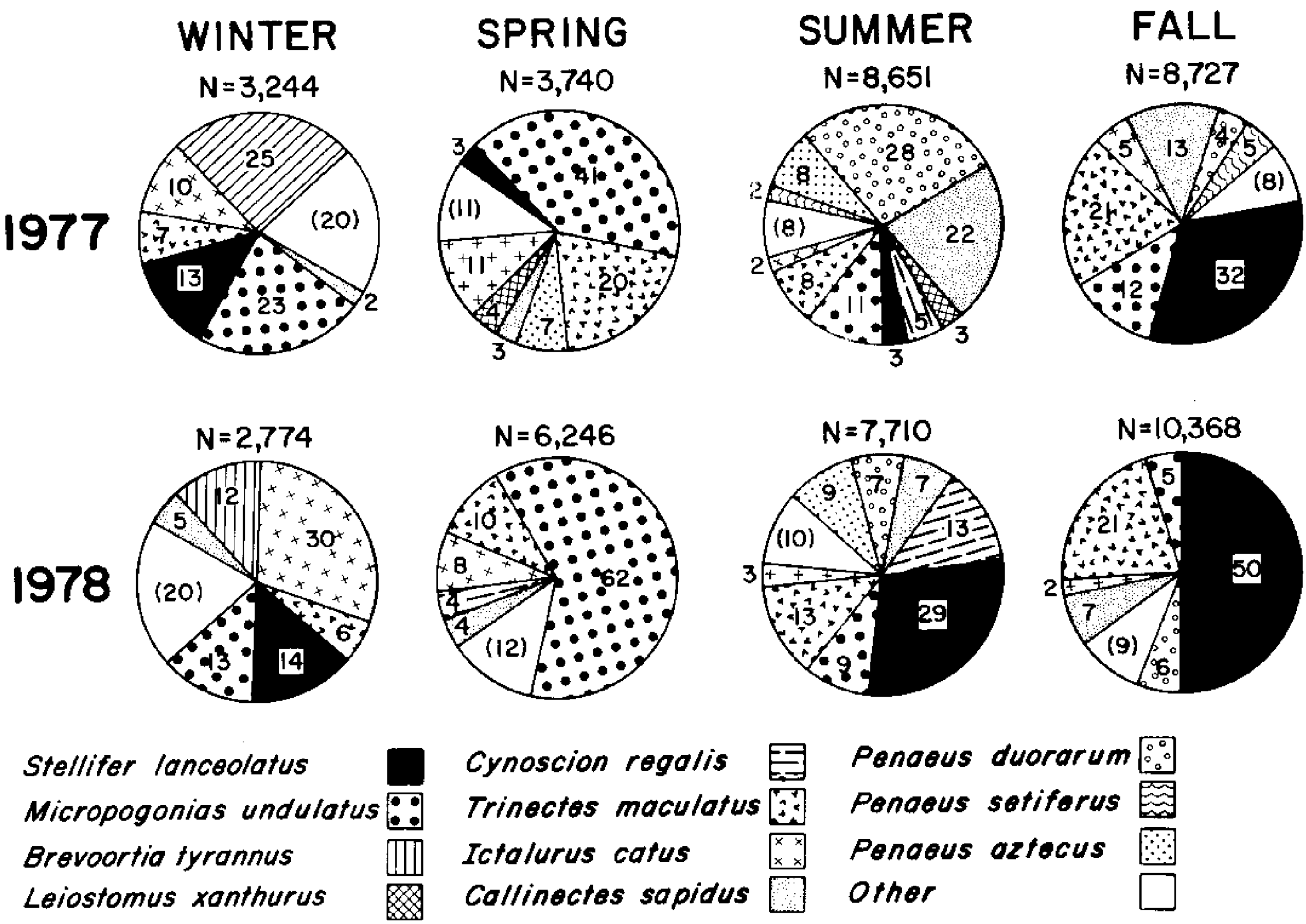

FIGURE 19. SEASONAL AND ANNUAL RELATIVE IMPORTANCE, EXPRESSED AS % OF TOTAL CATCH, FOR MOST COMMON FISHES AND DECAPOD CRUSTACEANS COLLECTED IN THE WINYAH BAY ESTUARINE SYSTEM FOR 1977 AND 1978.

TABLE 8. Average biomass (kg/ha) and density (no./ha) of fishes and decapod crustaceans in the Winyah Bay estuarine system by station and season.

	STATION																	
	YB02		YB05		YB08		YB11		YL05		YP05		YS07		YW06		YO01	
	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha
Fishes																		
Fall	6.39	[illegible]	4.85	793.75	2.28	297.92	2.60	377.55	3.68	456.02	2.09	175.46	2.16	95.14	2.80	538.88	2.46	382.18
Winter	4.73	261.28	4.07	130.32	1.24	55.78	3.10	237.27	1.26	69.21	1.02	112.50	3.54	94.67	0.61	70.60	4.18	223.15
Spring	5.70	373.84	2.94	287.96	2.20	137.04	2.59	376.85	0.56	88.88	0.97	78.93	2.22	231.71	0.94	131.71	2.28	376.39
Summer	1.37	145.60	1.94	352.08	6.11	138.19	3.11	279.86	1.61	179.86	3.28	172.22	2.73	137.27	1.23	131.71	5.89	538.43
Decapods																		
Fall	0.91	87.73	1.87	97.22	5.02	145.83	1.29	87.73	0.38	31.02	0.69	36.34	6.11	234.26	0.30	14.12	3.01	145.83
Winter	0.67	41.61	0.28	10.18	0.06	7.17	0.01	3.00	0.00	1.15	0.00	3.703	0.07	5.09	0.00	3.93	0.13	12.03
Spring	1.55	49.54	0.33	25.46	0.69	19.21	0.41	18.29	0.04	3.24	0.09	2.77	0.86	60.65	0.08	13.88	0.60	35.18
Summer	0.86	54.16	4.31	454.16	6.52	105.32	2.47	214.81	0.24	15.04	1.22	20.14	2.86	146.53	0.07	5.55	5.77	696.30

estimates for Winyah Bay may reflect mortality of Penaeus setiferus and other estuarine species during the extremely cold winters of 1977 and 1978. In addition, salt marsh acreage is much less in Winyah than in other major S.C. estuarine systems and may affect the total number of individuals which can be supported in the food web.

CONCLUSIONS

Most species and individuals of fishes and decapod crustaceans were collected in fall when catches of Trinectes maculatus and Stellifer lanceolatus were large, and an influx of stenohaline marine transients moved into Winyah Bay. These stenohaline species were broadly distributed throughout Winyah Bay waters during fall. The general abundance of resident estuarine species and Penaeus spp. was reflected by an increase in biomass and density estimates in fall.

The fall peak in diversity was followed by a sharp decrease in winter, which was caused by the exodus of several stenohaline and euryhaline transient species, such as Chaetodipterus faber, Prionotus tribulus, Dasyatis sabina, Menticirrhus americanus, Penaeus duorarum, Penaeus setiferus, Penaeus aztecus, and Cynoscion regalis. Those stenohaline marine species which were present in the estuary during winter were usually caught at stations near the mouth of the bay. The total catches of fishes and decapod crustaceans, as well as biomass and density, were also lowest in winter.

In spring, numbers of species and individuals increased, although stenohaline marine species were still not very abundant and were patchy in their occurrence throughout Winyah Bay. Trawl catches were dominated by Micropogonias undulatus and Trinectes maculatus.

The diversity and number of individuals increased from spring to late summer, with the exception of August 1977. In summer, the number of stenohaline marine transients entering Winyah Bay peaked and transient euryhaline species such as M. undulatus, Cynoscion regalis, and Penaeus spp. were most abundant.

Although the status of Winyah Bay fisheries is dependent on the extent and type of future development on and around the Bay and its distributaries, we cannot presently distinguish any aspect of the estuarine fish and decapod community which would indicate a stressed system. Like the Santee and Cooper River estuarine systems, Winyah Bay appears significant as a nursery area and supports a relatively rich fauna near its mouth. The Winyah system supports resident populations as well as stenohaline marine species and euryhaline transients which utilize the estuary during a portion of their life cycle.

The future development plans for the Winyah Bay system deserve serious consideration to insure that the estuary does not deteriorate. Factors which affect water quality within the Winyah Bay system, such as increases in turbidity, reduction in dissolved oxygen levels, and resuspension of pollutants previously entrapped through adsorption to or absorption by bottom sediments, could substantially affect fish and invertebrate communities (Conservation Foundation[1]).

This paper has addressed some of the basic biological, physical and chemical characteristics of the Winyah Bay estuary, the seasonal changes in these characteristics, and how they interact. The study was designed initially to gather and analyze baseline data and was not structured to assess impact of development projects which have been proposed, e.g. an oil refinery, riverside industrial park, and expansion of the port facilities at Georgetown. In order to detect and possibly remedy any detrimental effects to fishes and decapods which might result from these developments in the Winyah Bay estuarine system, it is necessary to describe the community in terms of its structure, its members, and their temporal and spatial relationships. The present paper represents a contribution toward that goal. While not designed to specifically assess impacts of an oil refinery, these base-line results could be used, to some extent, to compare with future studies which will be necessary once any of the proposed Winyah Bay development projects are implemented. Only then can the stability and flexibility of the Winyah Bay estuarine ecosystem be assessed.

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APPENDIX I. Total length, bottom salinity, and temperature ranges, and relative abundance by station for fish and decapod crustacean species captured by 6-m trawl in the Winyah Bay estuarine system, South Carolina from 1977 - 1978. Legend: [o] ≤ 1; [+] 2-50; [*] 51-100; [A] > 100

Species	Total Length Range (mm)	Bottom Salinity Range(°/oo)	Bottom Temperature Range (°C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	YO01
FISHES												
Raja eglanteria	375.0	21.98	23.40	o								
Dasyatis sabina	395.0-975.0	2.06-25.92	17.90-28.30	o	o	o			o			o
Acipenser brevirostrum	498.0	0.11	19.40			o						
Acipenser oxyrhynchus	23.0-965.0	0.05- 7.16	3.20-30.00			o		o	o		o	
Lepisosteus osseus	111.0-755.0	0.05-11.36	4.00-29.90				o	o	o	o		o
Anguilla rostrata	48.0-660.0	0.03-25.87	5.80-29.20		o	o	o	o	o	+		o
Myrophis punctatus	404.0	0.06	4.80		o							
Alosa sapidissima	29.0-208.0	0.06-23.91	5.10-28.80	o	o	o			o	o		o
Brevoortia tyrannus	31.0-241.0	0.29-30.39	5.10-29.90	+	+	+	+	o	o	o		+
Anchoa hepsetus	30.0-125.0	28.44	28.0		o							
Anchoa mitchilli	19.0- 90.0	0.31-32.72	5.80-29.40	o	+	+		o	o	o	o	+
Lepomis punctatus	90.0	0.20	12.10						o			
Ictalurus catus	15.0-460.0	0.03-21.08	3.00-30.90	o	+	+	+	+	+	+	+	+

Appendix I (continued

Species	Total Length Range (mm)	Bottom Salinity Range (^{o}/oo)	Bottom Temperature Range ($^{\circ}$C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	YO01
Arius felis	75.0-283.0	14.40-18.47	22.00-23.50	o								o
Bagre marinus	83.0-147.0	7.40-16.60	27.90-29.50				o					o
Opsanus tau	42.0-345.0	0.29-28.96	4.60-29.20	+	o							o
Gobiesox strumosus	44.0- 71.0	2.07-30.39	7.60-28.30	o		o						
Urophycis floridana	69.0-215.0	0.64-27.60	7.60-21.70	+			o					
Urophycis regia	51.0-197.0	0.14-27.60	6.20-21.80	+	+	o	+			o		+
Ophidion marginatum	155.0-190.0	8.60-27.60	11.00-28.30	o	o	o						o
Gobionellus shufeldti	57.0- 65.0	0.16- 0.34	5.00- 6.50					o	o			
Morone americana	75.0-385.0	0.03-11.65	3.80-30.80					o	o	+	o	
Morone saxatilis	35.0-382.0	0.03-11.65	3.00-28.40				o	o	o	o	o	
Centropristis philadelphica	136.0	15.15	15.20	o								
Centropristis striata	148.0	22.74	11.00	o								
Dorosoma cepedianum	358.0	6.40	28.90							o		
Syngnathus fuscus	77.0	13.95	16.50									o
Lutjanus griseus	88.0-105.0	3.41-18.47	17.90-22.00	o							o	
Morone chrysops	158.0	3.41-18.47	17.90-22.00						o			

Appendix I (continued)

Species	Total Length Range (mm)	Bottom Salinity Range (°/oo)	Bottom Temperature Range (°C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	YO01
Chloroscombrus chrysurus	45.0-123.0	7.40-14.40	23.50-29.10			o	o					o
Archosargus probatocephalus	165.0	19.09	16.30	o								
Lagodon rhomboides	82.0-112.0	8.00-16.40	7.60-12.80	o	o	o	o					o
Bairdiella chysoura	46.0-200.0	0.41-30.39	7.00-30.90	+	o	o	o	o	o	o	o	o
Cynoscion nebulosus	131.0-195.0	8.00-25.87	8.00-18.20		o	o	o					o
Cynoscion regalis	23.0-378.0	0.47-28.44	12.80-30.90	+	+	+	+	o	+	+	o	+
Larimus fasciatus	89.0	16.40	12.50	o								
Leiostomus xanthurus	33.0-267.0	0.14-32.72	7.60-30.80	+	o	+	+	o	o	+		+
Menticirrhus americanus	47.0-176.0	5.37-25.87	15.00-29.60	o	o	o	o					+
Micropogonias undulatus	19.0-350.0	0.05-30.39	5.10-30.90	*	*	+	Δ	+	+	+	+	*
Pogonias cromis	49.3- 88.2	0.29-18.47	19.70-22.00	o	o							
Stellifer lanceolatus	15.0-170.0	0.29-30.39	4.60-29.90	Δ	Δ	*	+	+	o	o	+	*
Chaetodipterus faber	27.0-136.0	7.77-24.86	17.90-29.70	o	+	o	o	o				o
Hypsoblennius hentzi	42.0-104.0	15.15-25.92	11.00-28.30	+	o							
Hypsoblennius ionthas	59.0- 88.0	15.60-27.60	17.50-27.30	o								

Appendix I (continued)

Species	Total Length Range (mm)	Bottom Salinity Range(°/oo)	Bottom Temperature Range (°C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	Y001
Peprilus alepidotus	27.0-120.0	6.35-27.14	15.20-29.70	o	o	o	o					o
Peprilus tricanthus	50.0-110.0	5.88-19.94	21.70-29.50	o	o	o	o					o
Astroscopus y-graecum	43.0-127.0	8.47-18.24	24.40-27.40				o					o
Mugil cephalus	102.0-328.0	0.06- 5.32	4.00- 7.60		o					o		o
Scorpaena calcarata	56.0	25.92	18.00	o								
Prionotus carolinus	34.0- 82.0	9.13-16.60	27.30-28.00	+	o							o
Prionotus evolans	38.0- 52.0	14.95-19.94	21.70-22.00	o	o							
Prionotus scitulus	55.0- 66.0	0.29- 2.07	19.70-20.40	o	o							
Prionotus tribulus	27.0- 86.0	5.88-24.86	12.50-28.80	o	o	o	o			o		+
Ancylopsetta quadrocellata	51.0- 78.0	8.40-16.40	7.40-12.50	o	o		o					
Etropus crossotus	49.0-125.0	5.37-25.87	15.70-23.60	o	o	o	o	o				o
Paralichthys dentatus	47.0-340.0	0.36-24.86	7.00-29.20	o	o	o	o	o	o	o		o
Paralichthys lethostigma	65.0-534.0	0.06-30.39	4.80-30.90	o	o	o	o	o	o	o	o	+
Scophthalmus aquosus	35.0-140.0	0.64-24.86	7.60-27.90	o	o	o	o					o
Trinectes maculatus	20.0-186.0	0.03-32.72	3.00-30.90	o	+	+	+	*	+	+	*	+

Appendix I (continued)

Species	Total Length Range (mm)	Bottom Salinity Range (°/oo)	Bottom Temperature Range (°C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	YO01
Symphurus plagiusa	36.0-195.0	1.46-30.39	5.20-29.70	o	+	+	+	*	+	+	*	+
Monacanthus hispidus	18.0- 38.0	6.99-14.22	24.90-26.20		o							o
Ictalurus platycephalus	156.0-246.0	.20	12.20					o				
Ictalurus nebulosus	86.0-380.0	0.03- 0.51	3.80-30.00					o	o		o	
Ictalurus punctatus	42.0-285.0	0.04- 3.23	4.00-27.90					o	o	o	o	
Dorosoma petenense	63.0-130.0	0.20-19.27	5.0 -15.80		o	o		o	o	o	o	o
Ariosoma balearicum	207.0	0.71	4.60	o								
Alosa aestivalis	25.0-286.0	0.48- 5.32	5.10-20.40		o							o
Sciaenops ocellata	59.0- 80.0	3.46- 8.92	7.40-15.70		o					o		
Citharichthys spilopterus	53.0-115.0	3.71-24.86	23.30-29.10		o	o	o					o
Pomatomus saltatrix	68.0-175.0	6.35- 6.99	26.20-29.10			o				o		o
Selene vomer	55.0- 71.0	10.28-12.07	28.20-28.40			o						o
Cyprinus carpio	575.0-730.0	1.40- 4.42	28.20-30.80						o			
Lepomis microlophus	95.0-191.0	0.36- 0.66	6.00- 7.60						o	o		
Lepomis auritus	141.0	0.66	7.60							o		

Appendix I (continued)

Species	Total Length Range (mm)	Bottom Salinity Range ($^{o}/oo$)	Bottom Temperature Range (°C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	YO01
Micropterus salmoides	220.0	0.66	7.60							o		
Lepomis gulosus	123.0-218.0	0.20-11.16	6.00-28.20						o	o		
Chilomycterus schoepfi	37.0-58.0	16.60	28.00									o
DECAPOD CRUSTACEANS												
Penaeus aztecus	34.0-164.0	1.31-28.44	17.50-29.90	+	+	+	+	o	o	+	o	+
Penaeus duorarum	22.0-117.0	2.06-28.96	11.00-29.60	+	*	+	+	o	+	+	o	*
Penaeus setiferus	27.0-180.0	0.46-28.96	9.50-29.90	+	+	+	+	o	o	+		+
Trachypenaeus constrictus	25.0- 75.0	0.46-28.96	12.50-29.60	+	o	o	o	o	o	o		o
Palaemonetes pugio	22.0- 43.0	0.23- 8.92	4.60-30.90	o	o	o	o	o	o	o		o
Palaemonetes vulgaris	15.0- 41.0	0.29-30.39	4.60-29.50	+	+	o	o	o	o	+		+
Alpheus heterochaelis	40.0	19.09	16.30	o								
Ovalipes stephensoni	18.0	19.94	21.70	o								
Portunus gibbesii	22.0- 60.0	10.00-25.87	16.60-29.60	o	o	o	o					
Portunus spinimanus	40.0-52.0	19.09-21.98	16.30-23.40	o								

Appendix I (continued)

Species	Total Length Range (mm)	Bottom Salinity Range($^{o}/oo$)	Bottom Temperature Range (°C)	YB02	YB05	YB08	YB11	YL05	YP05	YS07	YW06	YO01
Callinectes sapidus	10.0-200.0	0.03-30.39	4.80-30.90	+	+	+	+	+	+	*	+	*
Panopeus herbstii	8.0- 33.0	2.07-30.39	7.60-29.50		o	o						o
Panopeus occidentalis	15.0- 30.0	0.48-14.05	7.60-20.40	o				o				
Callinectes similis	21.0-106.0	0.48-32.72	15.80-29.20	o		o	o	o				
Callinectes ornatus	112.0	19.96	27.80		o							
Xiphopenaeus kroyeri	58.0	20.55-24.86	24.10-25.00			o						o
Macrobrachium ohione	40.0-106.0	0.05-12.07	5.30-30.80			o	o	o	o	o		o
Rhithropanopeus harrisii	6.0- 20.0	0.03-19.28	4.00-29.90			o	o	o	o	o	o	o
Hexapanopeus angustifrons	14.0	10.0	29.60				o					
Ovalipes ocellatus	33.0	8.55	18.50							o		