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A Five-Year Study of Seasonal Distribution and Abundance of Fishes and Decapod Crustaceans in the Cooper River and Charleston Harbor, S.C., Prior to Diversion

E. L. Wenner, W. P. Coon III,
M. H. Shealy, Jr., and P. A. Sandifer

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U.S. DEPARTMENT OF COMMERCE
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Malcolm Baldrige, Secretary
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John V. Bryne, Administrator
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ABSTRACT

Fluctuations in the distribution and abundance of fishes and decapod crustaceans collected by a 6 m otter trawl net from the Cooper River-Charleston Harbor estuarine system (South Carolina, USA) were examined over a 5-year sampling period. A total of 101 fish species and 41 decapod crustacean species were collected. Species richness was greatest at stations nearest the harbor mouth. Annual fluctuations in species abundance were apparently related to low bottom-water temperatures which affected year-class strength. Ten species accounted for ~90% of the total number and ~71% of the total biomass of fin fishes collected in the estuary: *Stellifer lanceolatus*, *Anchoa mitchilli*, *Micropogonias undulatus*, *Brevoortia tyrannus*, *Leiostomus xanthurus*, *Symphurus plagiusa*, *Bairdiella chrysoura*, *Cynoscion regalis*, *Urophycis regia*, and *Trinectes maculatus*. The decapod crustaceans *Penaeus setiferus*, *P. aztecus*, *Xiphopenaeus kroyeri*, and *Callinectes sapidus* dominated the fin fishes in abundance but not biomass. They composed ~96% by number and ~97% by weight of the total decapod fauna. The biomass of fishes from this study is lower than values reported for other estuaries along the Atlantic coast of the United States.

The Cooper River-Charleston Harbor estuarine system, an important nursery area for fishes and decapod crustaceans, is characterized by gradual changes in faunal assemblages and considerable overlap in spatial distributional patterns of resident and transient species. Numerically dominant species of fish and decapod crustaceans form assemblages which are spatially and temporally ubiquitous. Resident estuarine species and stenohaline marine species are more restricted in their distribution.

INTRODUCTION

Charleston Harbor and its tributary, the Cooper River, have been subjected to greatly increased man-made alterations since 1942. Prior to that time, the Cooper River was a relatively small coastal plains stream with a watershed of 1.86 million km^2. After construction of Pinopolis Dam across the upper watershed of the Cooper River and creation of Lake Moultrie, input of freshwater to the Cooper River increased, resulting in inundation of marshes and abandoned rice fields. Increased freshwater flow into Charleston Harbor decreased salinity (Zetler 1953) and formed density currents with a predominant upstream bottom flow throughout most of the lower 18 km of the harbor. As a consequence, sediments were trapped within the harbor and shoaling increased considerably (U.S. Army Corps of Engineers[2]). In turn, the shoaling has caused an increase in dredging costs and depletion of available disposal sites within the harbor. Because of this situation, the Army Corps of Engineers will redivert water flow in 1983 from Lake Moultrie into the Santee River system to effect a reduction of flow into the Cooper River.

The proposed rediversion probably will produce significant changes in estuarine habitat as well as in populations of estuarine organisms, such as fishes and decapod crustaceans. To assess possible effects of rediversion on population structure, spawning success, and distribution of these organisms, it is necessary to determine species composition, abundance, and distribution prior to the perturbation. This paper describes fluctuations in these parameters over a 5-yr period for fishes and decapod crustaceans in the Cooper River-Charleston Harbor estuarine system.

STUDY AREA

The Cooper River is classified as a mixohaline system, in which the salt wedge extends along the bottom to Big Island (Station C002) and bottom salinities decrease from about 27‰ at Cummings Point (Station J003) to freshwater at the Tee (Station C001) (Mathews and Shealy 1978) (Fig. 1). Charleston Harbor is a stratified or salt-wedge estuary with saltwater intrusion primarily a function of the tidal range and the amount of freshwater released by the Santee-Cooper Dam. A salinity differential between top and bottom strata of the harbor causes the bottom flow currents to predominate over the bottom ebb currents, with the result that upstream movement of the bottom currents within the saline region of the harbor forms a sediment trap (South Carolina Wildlife and

[1]Marine Resources Research Institute, South Carolina Wildlife & Marine Resources Department, P.O. Box 12559, Charleston, SC 29412.

[2]U.S. Army Corps of Engineers. 1975. Final Environmental Statement: Cooper River Rediversion Project, Charleston Harbor, S.C. U.S. Army Corps of Engineers, Charleston District Office, Charleston, SC 29403. 201 p.

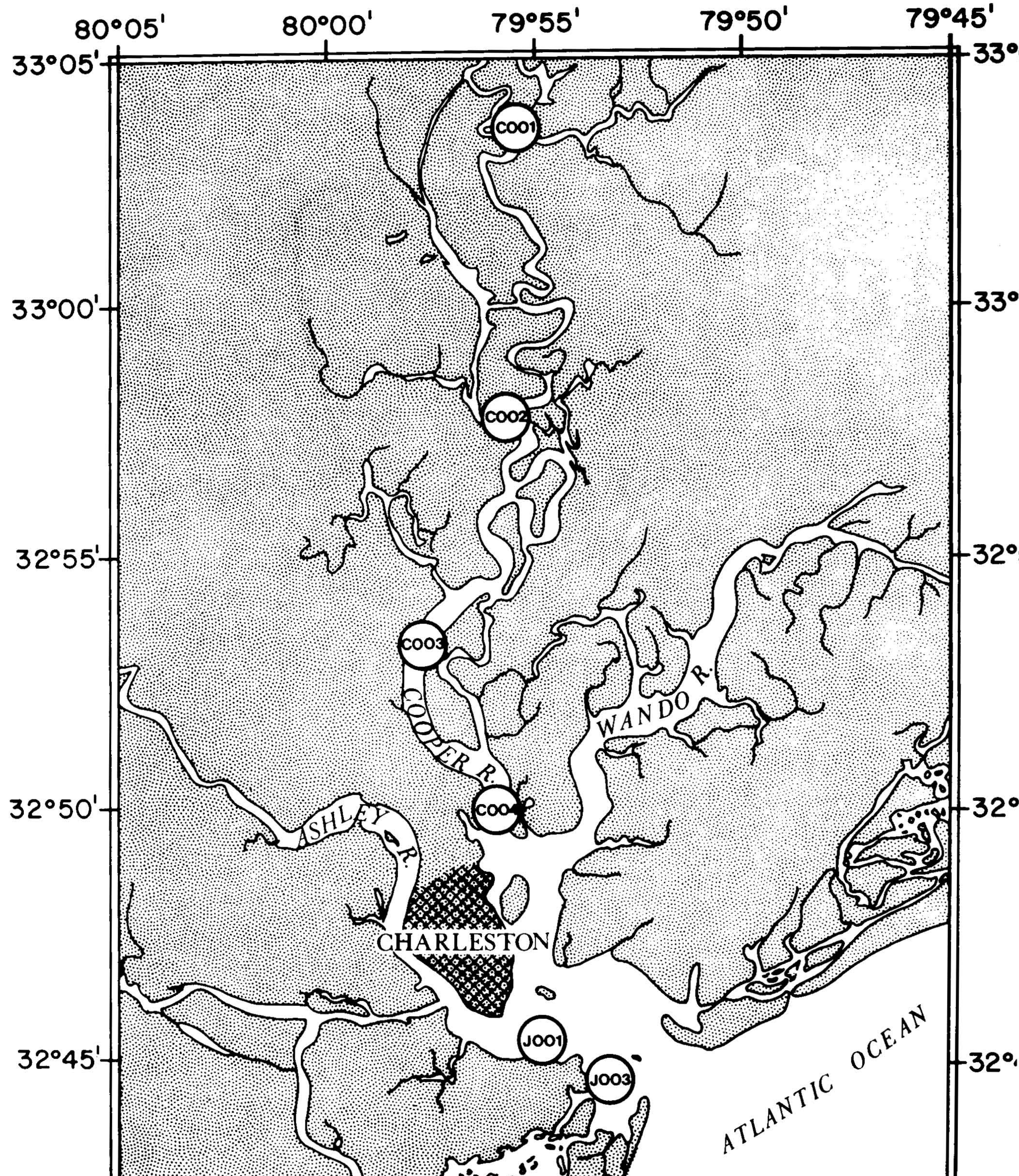


Figure 1. – Locations of six sampling stations in the Charleston Harbor – Cooper River estuary, S.C., during the 5-yr study from February 1973 to December 1977

Marine Resources Department[3]). Extended periods of high river flow in the Cooper River frequently dilute water in Charleston Harbor and even in the vicinity of the harbor mouth (U.S. Army Corps of Engineers, footnote 2).

Coastal marshes cover approximately 20,230 ha in the entire Charleston Harbor system. Of the total marsh area, salt marshes compose about 48%, while freshwater marshes cover approximately 36%, brackish marshes make up 6%, and impoundment areas cover 10% (Tiner 1977). The marshes of the Cooper River reflect strong freshwater inflow, dominated by bulrushes (*Scirpus* sp.), cattail (*Typha* sp.), and giant cordgrass, *Spartina cynosuroides*. Smooth cordgrass, *Spartina alterniflora*, dominates the low salt-marsh habitats and is mixed with black needlerush, *Juncus roemerianus*, in upstream locations where salinity transitions occur (South Carolina Wildlife and Marine Resources Department, footnote 3).

METHODS AND MATERIALS

Data Collection

We sampled six fixed stations in the channel of the Cooper River-Charleston Harbor system (Fig. 1): C001 (The Tee), C002 (Big Island), C003 (North Charleston), C004 (Mouth of Cooper River), J001(Charleston Harbor), and J003 (Cummings Point). Stations extended in a transect from the harbor mouth inland to above permanent freshwater. Each station was sampled once a month during the 5 yr from February 1973 through December 1977, with the following exceptions: C001 was sampled only during 1973 and January 1974 and was discontinued because of untrawlable bottom; a new station, J001, was established in January 1975. In addition, J003 was not sampled until May 1973.

All collections were made with a 6 m (20-ft) semiballoon otter trawl of 2.5 cm (1-in) stretch mesh. This net is particularly selective toward capture of juvenile fishes and is less effective in collection of older, larger fish and highly mobile decapod crustaceans. Twenty-minute tows were made against flood tide during daylight hours at a speed of 1.3 m/s (2.5 kn), resulting in a coverage of 1.5 ± 0.4 km/tow.

Bottom-water samples were collected 0.5 m above the bottom with Van Dorn bottles 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. Winter sampling encompassed January-March; spring sampling April-June; summer July-September; and fall October-December.

Specimens collected were either processed in the field or preserved in 10% Formalin and returned to the laboratory for identification, counting, weighing (nearest 0.1 g), and measuring (total length for fishes; carapace width for crabs, measured as distance between tips of lateral spines; and total length for shrimp from tip of rostrum to tip of telson). We recorded size measurements for all species numbering ≤ 50 specimens per tow. At stations where the trawl captured larger numbers of organisms, we subsampled the catch as follows: If ≥ 50 to ≤ 250 individuals were collected, a minimum of 50 randomly selected specimens was measured; if >250 to ≤ 500 individuals were caught, a minimum of 20% was measured; when >500 were caught, a minimum of 10% was measured.

[3]South Carolina Wildlife and Marine Resources Department. 1972. A study of the Charleston Harbor estuary with special reference to deposition of dredged sediments. Unpubl. manuscr., unpaginated. Office of Marine Conservation, Management and Services, P.O. Box 12559, Charleston, SC 29412.

Data Analysis

The degree of similarity among collections and among species was determined using normal and inverse cluster analyses, employing the Bray-Curtis similarity coefficient and "flexible sorting strategy" with the cluster intensity coefficient, β, set at the now standard value of -0.25 (Lance and Williams 1967; Williams 1971; Stephenson et al. 1972; Clifford and Stephenson 1975). Species which occurred in only one or two collections during a sampling period and collections which contained only one species were eliminated from the analyses. Abundances were logarithmically transformed ($\log_{10}[x + 1]$ where x is the number of individuals for a given species) in order to lessen the tendency of extremely abundant species to dominate the similarity matrix (Clifford and Stephenson 1975).

Two dendrograms were generated for each season: 1) A dendrogram which indicated association of all sites by season during the 5-yr sampling period based on faunal similarity, and 2) a dendrogram which indicated association of all species collected each season during the 5-yr sampling period based on the abundance of species at sites where they were collected. Nodal analysis (Williams and Lambert 1961; Lambert and Williams 1962) was subsequently used to examine species group and station coincidences based on patterns of constancy and fidelity (Boesch 1977).

An index of abundance (Musick and McEachran 1972; Elliott 1977) was used to compare numbers and weights of selected dominant species and is expressed as:

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

where x = no. or weight of individuals of a given species in a chosen frame and N = no. of collections in that time frame

We determined biomass and density estimates for fishes and decapod crustaceans from computations of area swept by our trawl gear. Estimates of area swept (a) were determined by the following equation given by Klima[4]:

$$a = \frac{KM(0.6H)}{10{,}000 \text{ m}^2/\text{ha}}$$

where K is speed in meters per hour, M is time in hours fished, and H is headrope length in meters. The constant 0.6 designates an effective swath of about 60% of the headrope length as used by Roe (1969) and established by Wathne (1959). The area swept by our 6 m otter trawl was estimated by this method to be 0.54 ha/tow.

[4]Klima, E. F. 1976. A review of the fishery resources in the western central Atlantic. WECAF Studies No. 3, FAO No. 32975-76, 77 p. Available from UNIPUB, 1180 Avenue of the Americas, New York, NY 10036.

RESULTS

Physicochemical Parameters

Bottom-water temperatures were very similar among all stations with mean temperatures lowest but most variable in February and warmest in July, August, and September. Yearly average temperatures were lowest in 1976 and 1977 (Table 1).

Salinities measured monthly were highly variable at all stations; nonetheless, average salinities were sufficiently different between stations (Table 1) to justify classification of sites according to the Venice system (Anonymous 1958). Station C001 was classified as limnetic because salinity did not exceed 0.5°/oo throughout the year it was sampled. Salinities at stations C002 and C003 ranged from 0.4 to 18.0°/oo, and these stations were characterized as limnetic-mesohaline. We classified station C004 as limnetic-polyhaline based on the salinity range of 0.67-26.2°/oo. Stations J001 (7.5-27.7°/oc) and J003 (19.4-33.3°/oo) had the highest salinities and were classified as mesopolyhaline and polyeuhaline, respectively. Average salinity varied also with season, being lowest in spring and highest in fall (Table 1).

Average dissolved oxygen concentrations were greatest at all stations in January and February and lowest in summer. No relation was apparent between dissolved oxygen concentrations and station or depth. The lowest average concentration measured in the Cooper River was 4.9 mg/l.

Although we did not specifically determine sediment characteristics for our fixed stations in the Cooper River-Charleston Harbor system, Mathews and Shealy (1978) reported the general bottom type to be as follows: C001 (hard-mud), C002 (sand), C003 (shell and sand), C004 (mud-shell-sand), J001 (mud and sand), and J003 (shell and mud).

Table 1.—Average water temperatures and salinities in the Charleston Harbor-Cooper River estuarine system, S.C., 1973-77.

	Environmental factors	
Parameters	Avg. temp. (°C)	Avg. salinity (°/oo)
Year (all stations)		
1973	22.1	12.0
1974	20.2	14.1
1975	21.1	14.5
1976	19.9	15.7
1977	19.8	15.7
Station (all years, 1973-77)		
J003	20.9	27.6
J001	20.7	19.2
C004	19.8	12.6
C003	20.9	5.4
C002	20.5	1.8
C001	18.6	0.07
Season (all stations, 1973-77)		
Fall	19.1	15.6
Winter	11.7	14.5
Spring	21.7	13.7
Summer	28.4	14.9

Community Composition and Richness

A total of 101 species of fishes was collected from the Cooper River-Charleston Harbor system during the 1973-1977 sampling period (Table 2). Length, bottom salinity, and temperature ranges, along with relative abundance of all species collected, are available upon request from the authors. Ten species accounted for 90% of the total number and 71% of the total biomass of fishes collected in this estuarine system: Star drum, *Stellifer lanceolatus*; bay anchovy, *Anchoa mitchilli*; Atlantic croaker, *Micropogonias undulatus*; Atlantic menhaden, *Brevoortia tyrannus*; spot, *Leiostomus xanthurus*; blackcheek tonguefish, *Symphurus plagiusa*; silver perch, *Bairdiella chrysoura*; weakfish, *Cynoscion regalis*; spotted hake, *Urophycis regia*; and hogchoker, *Trinectes maculatus*. *Stellifer lanceolatus* was the most abundant fish collected each year of the study, except in 1977 when *Brevoortia tyrannus* was most abundant.

During the 5-yr sampling period, we collected 44 decapod crustacean species (Table 3). Decapods dominated the fishes numerically but not in biomass. The numerical dominance was due to large numbers of white shrimp, *Penaeus setiferus*, collected in the Cooper River-Charleston Harbor system. This species constituted 83% of the total number and 69% of the total biomass of decapod crustaceans. *Penaeus setiferus* was numerically dominant during each of the 5 yr of our study, except in 1977 when *P. aztecus* was most abundant. These two penaeid shrimps, together with seabob, *Xiphopenaeus kroyeri*, and blue crab, *Callinectes sapidus*, composed about 96% by number and 97% by weight of total decapod fauna collected from the Cooper River-Charleston Harbor estuarine system.

Average numbers of species collected were greatest in 1976 at the higher salinity stations C004, J003, and J001 (Table 4), whereas species richness decreased along the transect of stations upriver. Mean numbers of individuals were greatest at the higher salinity stations (C004, J003, J001). In addition, more individuals were collected in 1975-76 than in 1973-74 and 1977 (Table 5). The fewest individuals were collected in 1977, probably because of prolonged periods of extremely low water temperatures during January and February 1977.

Normal classification analysis showed that collections were not distinctly grouped according to their location along the salinity gradient. During all seasons, collections from stations classified as limnetic and/or mesohaline were faunistically least similar to those from high-salinity sites, but overlap occurred in classification of collections in the mesopolyhaline and polyeuhaline range. Because groups broadly overlapped by stations and were not clearly separated by cluster analysis according to salinity regimes within the estuary, we compared collections from our fixed stations, rather than site groups as determined from cluster analysis, with the species groups listed in Table 6. In this way, seasonal comparisons among stations were facilitated by direct cross-referencing against the species assemblages at each station.

During all seasons, collections from higher salinity stations J003 and J001 were characterized by stenohaline marine species. These included black sea bass, *Centropristis striata*; searobins (*Prionotus* spp.); striped cusk-eel, *Ophidion marginatum*; lady crab, *Ovalipes ocellatus*; seabob, *Xiphopenaeus kroyeri*; swimming crabs (*Portunus* spp.); and hermit crabs, *Pagurus longicarpus* and *Clibanarius vittatus*. In fall, stenohaline marine species (Group B) displayed only moderate to low constancy and fidelity for collections at stations J003 and J001 (Fig. 2), while in winter, many of the same species and other marine transient species were still infrequently encountered but highly faithful to collections from station J003 (Fig. 2). Stenohaline marine species, which

Table 2.--Total numbers and total weights of fish species collected 1973-77 in the Cooper River-Charleston Harbor estuarine system, S.C. Species are listed in order of abundance, and data are pooled over the 5-yr sampling period.

Species	Number Total	Number %	Weight Total (kg)	Weight %
Stellifer lanceolatus	22,932	33.33	167.882	18.90
Anchoa mitchilli	9,203	13.38	15.957	1.80
Micropogonias undulatus	7,862	11.43	108.374	12.20
Brevoortia tyrannus	4,848	7.05	82.699	9.31
Leiostomus xanthurus	4,228	6.15	56.200	6.33
Symphurus plagiusa	3,053	4.44	41.633	4.69
Bairdiella chrysoura	3,006	4.37	83.849	9.44
Cynoscion regalis	2,578	3.75	33.005	3.72
Urophycis regia	2,250	3.27	30.091	3.39
Trinectes maculatus	1,996	2.90	15.108	1.70
Ictalurus catus	1,931	2.81	40.623	4.57
Dorosoma petenense	1,060	1.54	5.374	0.60
Alosa aestivalis	513	0.75	1.809	0.20
Menticirrhus americanus	310	0.45	5.057	0.57
Opsanus tau	282	0.41	38.124	4.29
Paralichthys dentatus	250	0.36	9.805	1.10
Peprilus alepidotus	239	0.35	2.730	0.31
Paralichthys lethostigma	215	0.31	39.568	4.45
Peprilus triacanthus	184	0.27	1.730	0.19
Chloroscombrus chrysurus	132	0.19	0.493	0.06
Opisthonema oglinum	128	0.19	0.763	0.09
Etropus crossotus	126	0.18	0.842	0.09
Ictalurus punctatus	124	0.18	1.763	0.20
Prionotus tribulus	108	0.16	0.268	0.03
Anchoa hepsetus	103	0.15	0.818	0.09
Pomatomus saltatrix	91	0.13	2.306	0.26
Anguilla rostrata	74	0.11	9.959	1.12
Centropristis philadelphica	70	0.10	2.945	0.33
Citharichthys spilopterus	63	0.09	0.345	0.04
Chaetodipterus faber	56	0.08	0.617	0.07
Scophthalmus aquosus	54	0.08	0.484	0.05
Ictalurus nebulosus	53	0.08	2.557	0.29
Alosa sapidissima	50	0.07	1.149	0.13
Ancylopsetta quadrocellata	43	0.06	0.709	0.08
Trichiurus lepturus	41	0.06	1.690	0.19
Selene vomer	40	0.06	0.377	0.04
Prionotus evolans	32	0.05	0.216	0.02
Arius felis	32	0.05	2.788	0.31
Urophycis floridana	29	0.04	0.978	0.11
Hypsoblennius hentzi	29	0.04	0.236	0.03
Morone saxatilis	23	0.03	0.154	0.02
Ophidion marginatum	22	0.03	0.433	0.05
Ictalurus furcatus	22	0.03	0.530	0.06
Selene setapinnis	21	0.03	0.096	0.01
Cynoscion nebulosus	21	0.03	1.037	0.12
Lagodon rhomboides	19	0.03	0.692	0.08
Caranx hippos	18	0.03	0.321	0.04
Centropristis striata	15	0.02	0.437	0.05
Urophycis earlli	12	0.02	0.203	0.02
Dasyatis sabina	12	0.02	11.731	1.32
Pogonias cromis	12	0.02	5.000	0.56
Eucinostomus sp.	11	0.02	0.107	0.01
Lepisosteus osseus	10	0.01	17.662	1.99
Alosa mediocris	9	0.01	0.011	0.01
Gobiesox strumosus	9	0.01	0.044	0.01
Scomberomorus maculatus	9	0.01	0.214	0.02
Lutjanus griseus	9	0.01	0.107	0.01
Eucinostomus argenteus	7	0.01	0.062	0.01
Prionotus sp.	7	0.01	0.022	0.01
Prionotus carolinus	7	0.01	0.019	0.01
Menidia menidia	6	0.01	0.025	0.01
Prionotus scitulus	5	0.01	0.038	0.01
Monacanthus hispidus	5	0.01	0.009	0.01
Archosargus probatocephalus	5	0.01	0.156	0.02
Cynoscion nothus	5	0.01	0.035	0.01
Larimus fasciatus	4	0.01	0.027	0.01
Astroscopus y-graecum	4	0.01	0.030	0.01
Mugil curema	4	0.01	0.078	0.01
Cyprinus carpio	4	0.01	18.883	2.13
Synodus foetens	4	0.01	0.187	0.02
Brevoortia smithi	3	0.01	1.297	0.15
Acipenser oxyrhynchus	3	0.01	13.835	1.56
Bagre marinus	3	0.01	0.041	0.01
Chilomycterus antillarum	3	0.01	0.006	0.01
Gobionellus shufeldti	3	0.01	0.006	0.01
Symphurus civitatus	3	0.01	0.026	0.01
Sphoeroides maculatus	3	0.01	0.133	0.01
Perca flavescens	3	0.01	0.024	0.01
Lagocephalus laevigatus	3	0.01	0.106	0.01
Mugil cephalus	3	0.01	0.028	0.01
Gobionellus boleosoma	3	0.01	0.006	0.01
Hypsoblennius ionthas	2	0.01	0.009	0.01
Ictalurus platycephalus	2	0.01	0.335	0.04
Rhinoptera bonasus	2	0.01	-----	----
Dorosoma cepedianum	2	0.01	0.035	0.01
Lepomis punctatus	1	0.01	0.030	0.01
Elops saurus	1	0.01	0.126	0.01
Morone americana	1	0.01	0.010	0.01
Mycteroperca microlepis	1	0.01	0.073	0.01
Gymnura micrura	1	0.01	0.177	0.02
Raja eglanteria	1	0.01	0.671	0.08
Carcharhinus plumbeus	1	0.01	1.046	0.12
Lepomis auritus	1	0.01	0.008	0.01
Ictalurus natalis	1	0.01	0.009	0.01
Ictalurus melas	1	0.01	0.058	0.01
Eleotris pisonis	1	0.01	0.018	0.01
Gobionellus hastatus	1	0.01	0.003	0.01
Sphyraena guachancho	1	0.01	0.001	0.01
Sciaenops ocellatus	1	0.01	0.004	0.01
Menticirrhus littoralis	1	0.01	0.028	0.01
Enneacanthus gloriosus	1	0.01	0.001	0.01
TOTAL	68,796		888.409	

Table 3.--Total numbers and total weights of decapod crustacean species collected 1973-77 in the Cooper River-Charleston Harbor estuarine system, S.C. Species are listed in order of abundance, and data are pooled over the 5-yr sampling period.

	Number		Weight	
Species	Total	%	Total (kg)	%
Penaeus setiferus	80,121	82.62	492.927	69.20
Penaeus aztecus	8,053	8.30	56.757	7.97
Xiphopenaeus kroyeri	2,657	2.74	4.928	0.69
Callinectes sapidus	1,914	1.97	137.936	19.36
Callinectes similis	1,438	1.48	11.029	1.55
Trachypenaeus constrictus	721	0.74	0.912	0.13
Palaemonetes vulgaris	388	0.40	0.199	0.03
Portunus spinimanus	243	0.25	2.308	0.32
Pagurus longicarpus	215	0.22	0.182	0.03
Protunus gibbesii	193	0.20	0.420	0.06
Ovalipes stephensoni	191	0.20	0.646	0.09
Penaeus duorarum	177	0.18	1.256	0.18
Panopeus herbstii	133	0.14	0.358	0.05
Rhithropanopeus harrisii	82	0.08	0.045	0.01
Palaemonetes pugio	82	0.08	0.047	0.01
Clibanarius vittatus	77	0.08	0.054	0.01
Ovalipes ocellatus	69	0.07	0.426	0.06
Macrobrachium ohione	47	0.05	0.165	0.02
Pagurus pollicaris	25	0.03	0.086	0.01
Palaemonetes sp.*	24	0.02	0.014	<0.01
Neopanope sayi	20	0.02	0.019	<0.01
Cancer irroratus	19	0.02	0.248	0.03
Alpheus normanni	11	0.01	0.003	<0.01
Menippe mercenaria	10	0.01	1.066	0.15
Libinia emarginata	10	0.01	0.077	0.01
Libinia dubia	7	0.01	0.019	<0.01
Hexapanopeus angustifrons	7	0.01	0.020	<0.01
Alpheus heterochaelis	6	0.01	0.009	<0.01
Palaemonetes intermedius	5	0.01	0.003	<0.01
Sicyonia laevigata	5	0.01	0.005	<0.01
Panopeus occidentalis	5	0.01	0.005	<0.01
Portunus sp.*	5	0.01	-----	----
Eurypanopeus depressus	4	<0.01	0.004	<0.01
Callinectes ornatus	2	<0.01	0.082	0.01
Exhippolysmata oplophoroides	3	<0.01	0.004	<0.01
Lysmata wurdemanni	1	<0.01	0.002	<0.01
Sicyonia brevirostris	1	<0.01	0.004	<0.01
Hepatus epheliticus	1	<0.01	0.060	0.01
Micropanope sp.	1	<0.01	0.001	<0.01
Libinia sp.*	1	<0.01	0.001	<0.01
Xanthidae*	1	<0.01	-----	----
Penaeus sp.*	1	<0.01	0.001	<0.01
Procambarus clarki	1	<0.01	0.006	<0.01
Callinectes sp.*	1	<0.01	0.001	<0.01
TOTAL	96,978		712,330	

*Field identification or damaged specimen(s).

Table 4.—Average numbers of species of fishes and decapod crustaceans collected 1973-77 at stations in the Cooper River-Charleston Harbor estuarine system, S.C. Numbers in parentheses = standard error of the mean; n = number of samples per year.

	Average numbers of species/station						Grand
Year	C001	C002	C003	C004	J003	J001	Mean
1973	4	6	10	13	12	—	10
	(0.81)	(1.05)	(0.89)	(1.56)	(2.35)	—	
	$n=11$	$n=11$	$n=12$	$n=11$	$n=8$	—	
1974	2	6	9	15	15	—	11
		(0.81)	(1.23)	(2.04	(2.14)	—	
	$n=1$	$n=12$	$n=12$	$n=12$	$n=12$	—	
1975	—	6	11	12	15	16	12
	—	(0.94)	(1.53)	(1.41)	(2.12)	(1.79)	
	—	$n=12$	$n=12$	$n=12$	$n=12$		
1976	—	8	12	18	18	16	14
	—	(0.78)	(1.40)	(1.46)	(1.44)	(1.66)	
	—	$n=12$	$n=12$	$n=12$	$n=12$	$n=12$	
1977	—	9	12	12	13	19	13
	—	(0.75)	(1.38)	(1.79)	(1.77)	(1.27)	
	—	$n=12$	$n=12$	$n=12$	$n=12$	$n=12$	

Table 5.—Average numbers of individual fish and decapod crustaceans collected 1973-77 at stations in the Cooper River-Charleston Harbor estuarine system, S.C. Numbers in parentheses = standard error of the mean; n = number of samples per year.

	Average numbers of individuals/station						Grand
Year	C001	C002	C003	C004	J003	J001	Mean
1973	21	355	867	1,195	456	—	718
	(6.70)	(218.97)	(429.07)	(473.38)	(146.88)	—	
	$n=11$	$n=11$	$n=11$	$n=11$	$n=8$	—	
1974	2	158	541	533	619	—	463
		(45.92)	(209.96)	(94.50)	(180.18)	—	
	$n=1$	$n=12$	$n=12$	$n=12$	$n=12$	—	
1975	—	80	554	519	1,233	1,467	771
	—	(47.58)	(369.91)	(123.91)	(355.84)	(346.78)	
	—	$n=12$	$n=12$	$n=12$	$n=12$	$n=12$	
1976	—	319	715	1,018	688	922	732
	—	(136.55)	(397.20)	(198.60)	(149.82)	(225.80)	
	—	$n=12$	$n=12$	$n=12$	$n=12$	$n=12$	
1977	—	206	263	171	299	503	288
	—	(65.88)	(90.67)	(48.07)	(119.31)	(191.41)	
	—	$n=12$	$n=12$	$n=12$	$n=12$	$n=12$	
Grand mean		223.6	588	687.2	659	964	

Table 6.--Species groups formed from seasonal cluster analyses of fishes and decapod crustaceans collected in the Cooper River-Charleston Harbor estuarine system, S.C., 1973-77.

FALL

Group A

Callinectes sapidus
Symphurus plagiusa
Cynoscion regalis
Bairdiella chrysoura
Anchoa mitchilli
Stellifer lanceolatus
Penaeus setiferus

Group B

Hypsoblennius hentzi
Ophidion marginatum
Prionotus tribulus
Penaeus duorarum
Ovalipes ocellatus
Portunus spinimanus
Pagurus longicarpus
Clibanarius vittatus
Callinectes similis
Menticirrhus americanus
Trachypenaeus constrictus
Portunus gibbesii
Xiphopenaeus kroyeri

Group C

Anchoa hepsetus
Chloroscombrus chrysurus
Selene setapinnis
Peprilus alepidotus
Opisthonema oglinum
Dasyatis sabina
Arius felis
Rhithropanopeus harrisii
Chaetodipterus faber
Penaeus aztecus

Group D

Gobiesox strumosus
Cynoscion nebulosus
Selene vomer
Pomatomus saltatrix

Group E

Palaemonetes vulgaris
Eucinostomus argenteus
Palaemonetes pugio
Caranx hippos
Alosa aestivalis
Dorosoma petenense
Lutjanus griseus

Group F

Paralichthys lethostigma
Anguilla rostrata
Ictalurus furcatus
Eucinostomus sp.
Leiostomus xanthurus
Trinectes maculatus
Ictalurus catus
Etropus crossotus
Centropristis philadelphica
Paralichthys dentatus
Opsanus tau
Menidia menidia
Micropogonias undulatus
Brevoortia tyrannus

WINTER

Group A

Sicyonia laevigata
Libinia dubia
Mugil curema
Neopanope sayi
Alpheus normanni
Libinia emarginata
Prionotus scitulus
Prionotus evolans

Group B

Centropristis striata
Urophycis floridana
Centropristis philadelphica
Callinectes similis
Xiphopenaeus kroyeri
Portunus gibbesii
Portunus spinimanus
Trachypenaeus constrictus
Gobiesox strumosus
Ovalipes ocellatus
Menippe mercenaria
Pagurus pollicaris
Pagurus longicarpus
Menticirrhus americanus
Cancer irroratus
Paralichthys dentatus

Group C

Anchoa mitchilli
Brevoortia tyrannus
Micropogonias undulatus
Bairdiella chrysoura
Dorosoma petenense
Penaeus setiferus
Stellifer lanceolatus
Leiostomus xanthurus
Symphurus plagiusa
Callinectes sapidus
Paralichthys lethostigma
Urophycis regia

Group D

Etropus crossotus
Cynoscion regalis
Hypsoblennius hentzi
Scophthalmus aquosus
Palaemonetes pugio
Lagodon rhomboides
Prionotus tribulus
Alosa aestivalis
Menidia menidia
Clibanarius vittatus
Alosa sapidissima
Ancylopsetta quadrocellata

Group E

Penaeus aztecus
Palaemonetes intermedius
Rhithropanopeus harrisii
Pogonias cromis
Archosargus probatocephalus
Panopeus herbstii
Cynoscion nebulosus
Palaemonetes vulgaris
Opsanus tau

Group F

Ictalurus punctatus
Ictalurus nebulosus
Anguilla rostrata
Macrobrachium ohione
Perca flavescens
Morone saxatilis
Lepisosteus osseus
Alpheus heterochaelis
Ictalurus catus
Trinectes maculatus
Acipenser oxyrhynchus
Ictalurus platycephalus

SPRING

Group A

Stellifer lanceolatus
Penaeus setiferus
Urophycis regia
Trachypenaeus constrictus
Callinectes similis
Brevoortia tyrannus
Peprilus triacanthus
Micropogonias undulatus
Leiostomus xanthurus
Anchoa mitchilli
Callinectes sapidus
Symphurus plagiusa
Trinectes maculatus

Group B

Opsanus tau
Paralichthys dentatus
Penaeus aztecus
Cynoscion regalis
Paralichthys lethostigma
Bairdiella chrysoura
Palaemonetes vulgaris

Group C

Ancylopsetta quadrocellata
Clibanarius vittatus
Pagurus longicarpus
Prionotus tribulus
Penaeus duorarum
Prionotus carolinus

Group D

Dasyatis sabina
Centropristis striata
Arius felis
Citharichthys spilopterus

Group E

Anchoa hepsetus
Ovalipes ocellatus
Trichiurus lepturus

Group F

Dorosoma petenense
Prionotus evolans
Rhithropanopeus harrisii
Palaemonetes pugio
Pomatomus saltatrix
Alosa aestivalis
Lepisosteus osseus
Alosa sapidissima
Urophycis floridana
Anguilla rostrata
Panopeus occidentalis
Scophthalmus aquosus
Prionotus sp.

Group G

Ictalurus punctatus
Macrobrachium ohione
Ictalurus catus

Group H

Ophidion marginatum
Pagurus pollicaris
Ovalipes stephensoni
Portunus spinimanus
Portunus gibbesii
Menticirrhus americanus

SUMMER

Group A

Leiostomus xanthurus
Micropogonias undulatus
Cynoscion regalis
Penaeus aztecus
Anchoa mitchilli
Penaeus setiferus
Callinectus similis
Trachypenaeus constrictus
Stellifer lanceolatus

Group B

Pagurus longicarpus
Portunus gibbesii
Portunus spinimanus
Ophidion marginatum
Pagurus pollicaris
Ovalipes ocellatus

Group C

Arius felis
Centropristis philadelphica
Citharichthys spilopterus
Clibanarius vittatus
Etropus crossotus

Group D

Palaemonetes pugio
Palaemonetes vulgaris
Paralichthys lethostigma
Paralichthys dentatus
Opsanus tau
Callinectes sapidus
Symphurus plagiusa
Trinectes maculatus
Bairdiella chrysoura
Brevoortia tyrannus

Group E

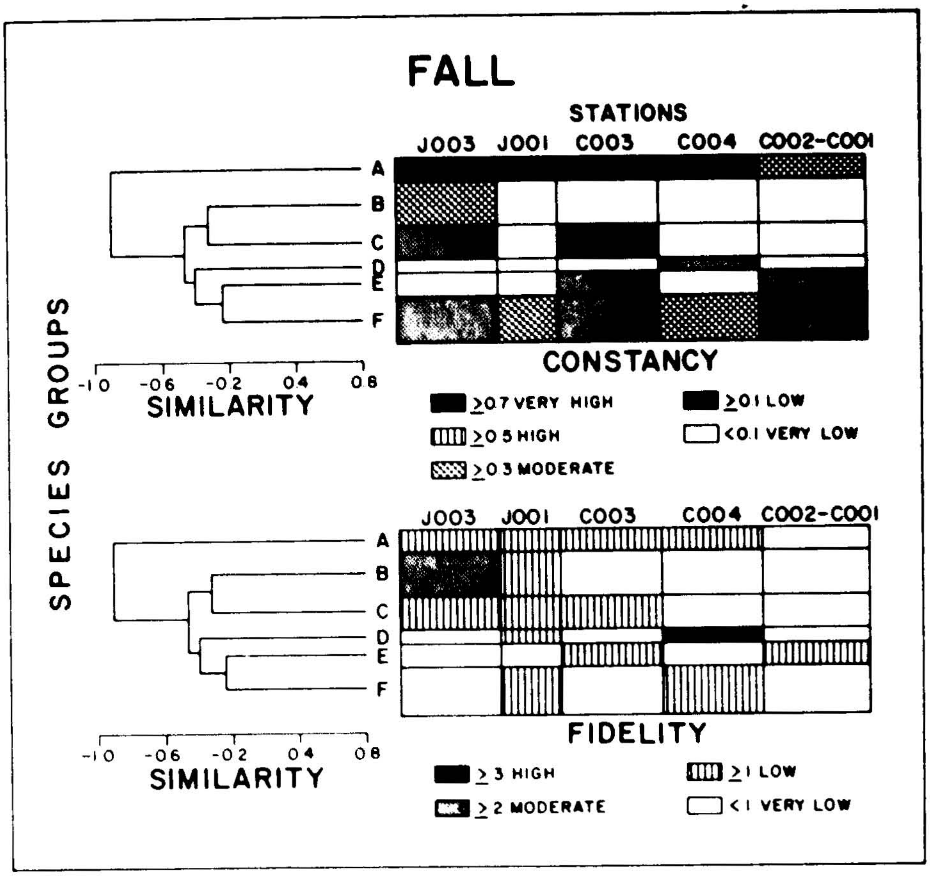
Peprilus alepidotus
Chloroscombrus chrysurus
Opisthonema oglinum
Anchoa hepsetus
Selene setapinnis

Group F

Selene vomer
Trichiurus lepturus
Pomatomus saltatrix
Panopeus herbstii
Prionotus tribulus
Penaeus duorarum
Menticirrhus americanus
Chaetodipterus faber
Neopanope sayi

Group G

Dorosoma petenense
Alosa aestivalis
Morone saxatilis
Peprilus triacanthus
Scomberomorus maculatus
Rhithropanopeus harrisii
Macrobrachium ohione
Ictalurus catus



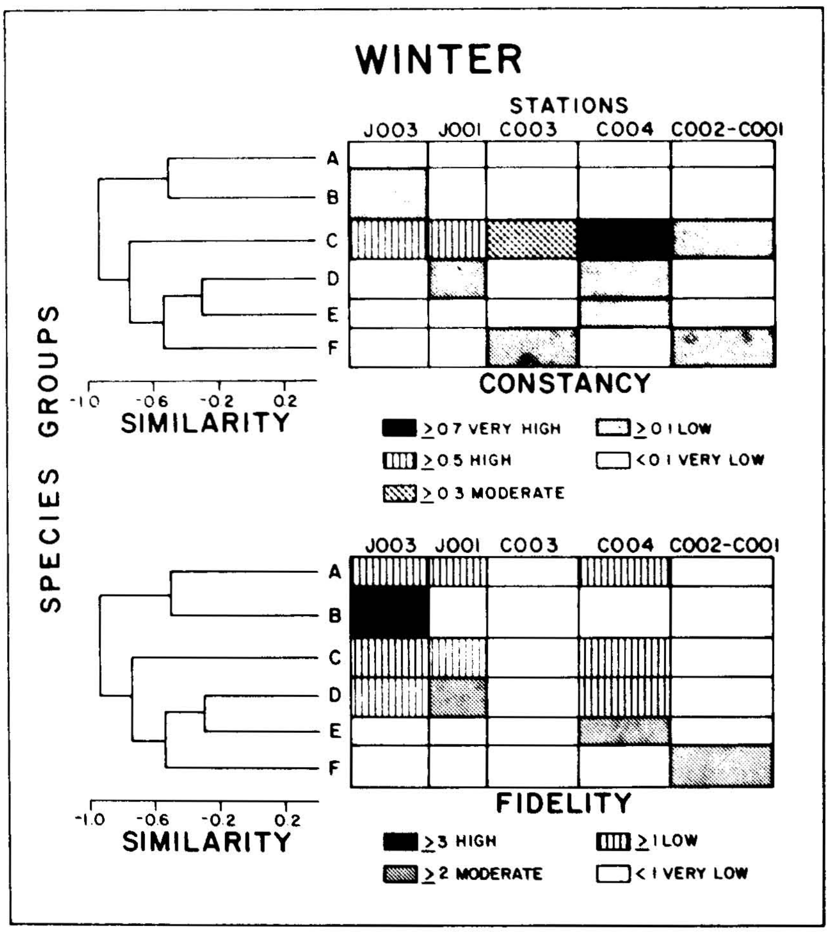
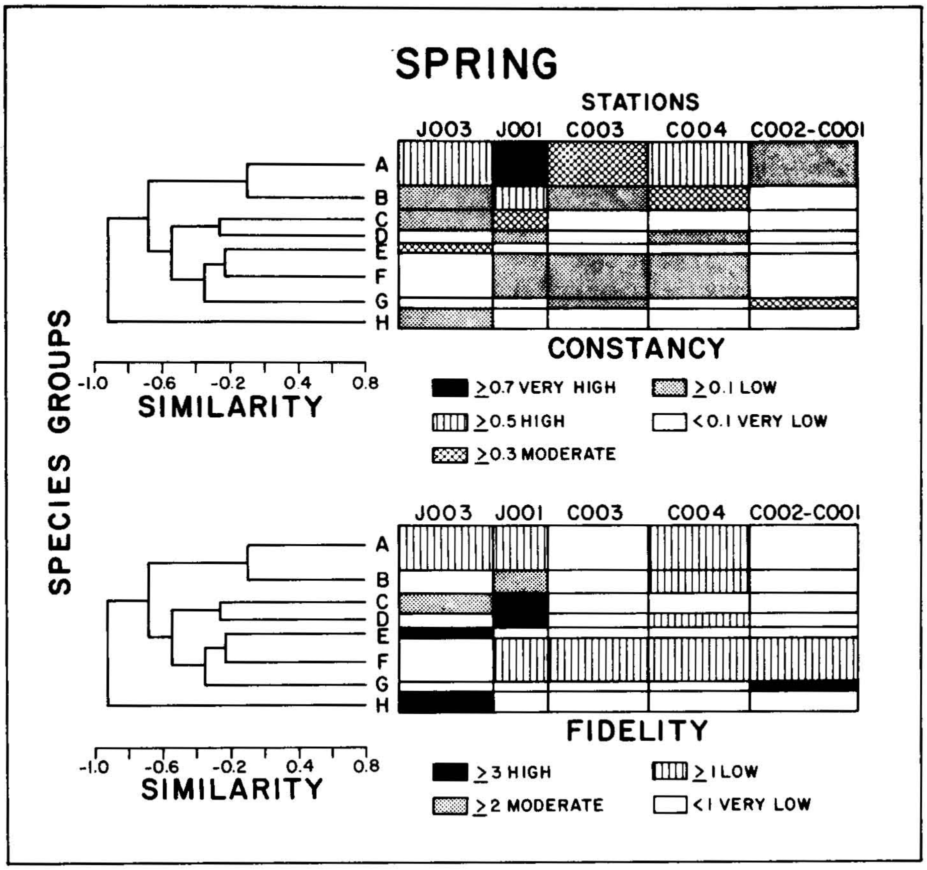
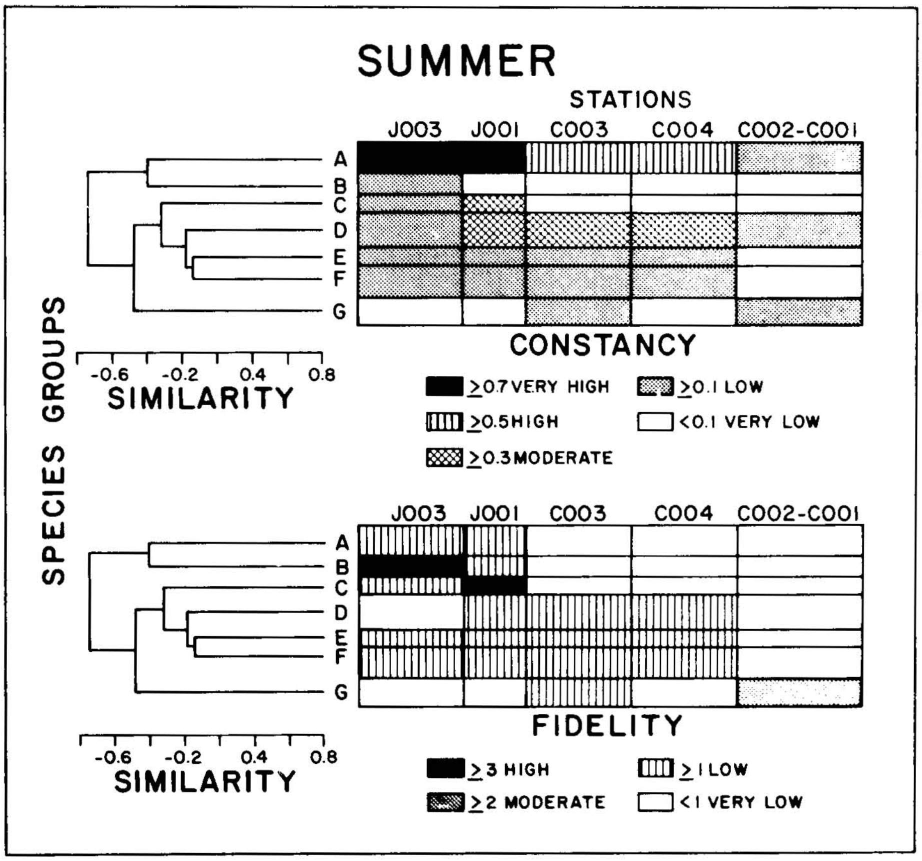


Figure 2.—Two-way coincidence tables of constancy and fidelity which compare species associations among sampling stations in the Cooper River-Charleston Harbor for fa winter, spring, and summer collections, 1973-77. See Table 6 for species group lists.


SPRING
STATIONS
J003 J001 C003 C004 C002-C001
A
B
C
D
E
F
G
H
CONSTANCY
SPECIES GROUPS
-1.0 -0.6 -0.2 0.4 0.8
SIMILARITY
≥0.7 VERY HIGH
≥0.5 HIGH
≥0.3 MODERATE
≥0.1 LOW
<0.1 VERY LOW
J003 J001 C003 C004 C002-C001
FIDELITY
≥3 HIGH
≥2 MODERATE
≥1 LOW
<1 VERY LOW


SUMMER
STATIONS
J003 J001 C003 C004 C002-C001
A
B
C
D
E
F
G
CONSTANCY
SPECIES GROUPS
-0.6 -0.2 0.4 0.8
SIMILARITY
≥0.7 VERY HIGH
≥0.5 HIGH
≥0.3 MODERATE
≥0.1 LOW
<0.1 VERY LOW
J003 J001 C003 C004 C002-C001
FIDELITY
≥3 HIGH
≥2 MODERATE
≥1 LOW
<1 VERY LOW

were restricted in spring to collections at higher salinity stations but displayed only moderate to low constancy there, composed assemblages C, D, E, and H (Fig. 2). Species in these groups included fourspot flounder, *Ancylopsetta quadrocellata*; searobins (*Prionotus* spp.); black sea bass, *Centropristis striata*; lady crabs, *Ovalipes ocellatus* and *O. stephensoni*; Atlantic cutlassfish, *Trichiurus lepturus*; and striped cusk-eel, *Ophidion marginatum*. Many of the same species composed groups B and C from our cluster analysis of summer data and were restricted but infrequently encountered at collections from stations J003 and J001 (Fig. 2).

The only species restricted to samples from the lowest salinity stations (C001, C002) formed group G in spring (Fig. 2). However, the resident estuarine species, *Ictalurus punctatus*, *I. catus*, and *Macrobrachium ohione*, which composed this group displayed only moderate constancy for collections from these low-salinity stations.

Ubiquitous species were present during all seasons in the Cooper River-Charleston Harbor estuarine system. These species included the numerically dominant fishes and decapod crustaceans. Although their penetration extended as far upriver as stations C002-C001, species in these assemblages were generally most constant in collections from stations J003, J001, and C004. In the fall, members of groups A and F were encountered at all stations; but only members of group A were consistently collected, as denoted by their very high constancy, at collections from stations J003, J001, C004, and C003 (Fig. 2). In our analysis of winter collections, only members of group C were eurytopic in station location. Species in this group were consistently represented in collections at stations J003, J001, and C004, but they were not restricted to these stations (Fig. 2). Members of group A in spring were generally found at all sites but were most consistently encountered at stations J003, J001, and C004 (Fig. 2). Our analysis of summer data showed that euryhaline species of Group A were consistently present in collections from stations J003, J001, C004, and C003.

Other assemblages defined by our analysis included species tolerant of a wide salinity range and not restricted to any station location, but generally of low density. Included in these groups were anadromous species, *Alosa aestivalis* and *A. sapidissima*; the American eel, *Anguilla rostrata*; and the caridean shrimps, *Palaemonetes pugio* and *P. vulgaris*.

Temporal and Spatial Distributions

Patterns of distribution for the most abundant species of fishes at each station for each month of collection are shown in Figure 3, and fluctuations in their abundance over the 5-yr sampling period are shown in Figure 4. Length-frequency plots which were generated for selected species are not shown but are available from the authors upon request.

Stellifer lanceolatus, Star drum.—Star drum were most abundant at higher salinity stations C004, J001, and J003, whereas catches were negligible at stations farther upriver (C001, C002) (Fig. 3A). This species displayed seasonality in its abundance, with most individuals collected October through May. Catches of *S. lanceolatus* also underwent considerable annual variation and were greatest during the years 1974-76 (Fig. 4A). Length-frequency polygons for star drum over the 5-yr sampling period suggested a consistent influx of small fish (<80 mm TL) into the population during summer with recruitment continuing into fall. Frequencies of these small fish were lower during winter and spring. Our results are consistent with those of Welsh and Breder (1923), Dahlberg and Odum (1970), and Shealy et al. (1974), who also noted that recruitment of young fish first occurred during summer after late-spring and early-summer spawning.

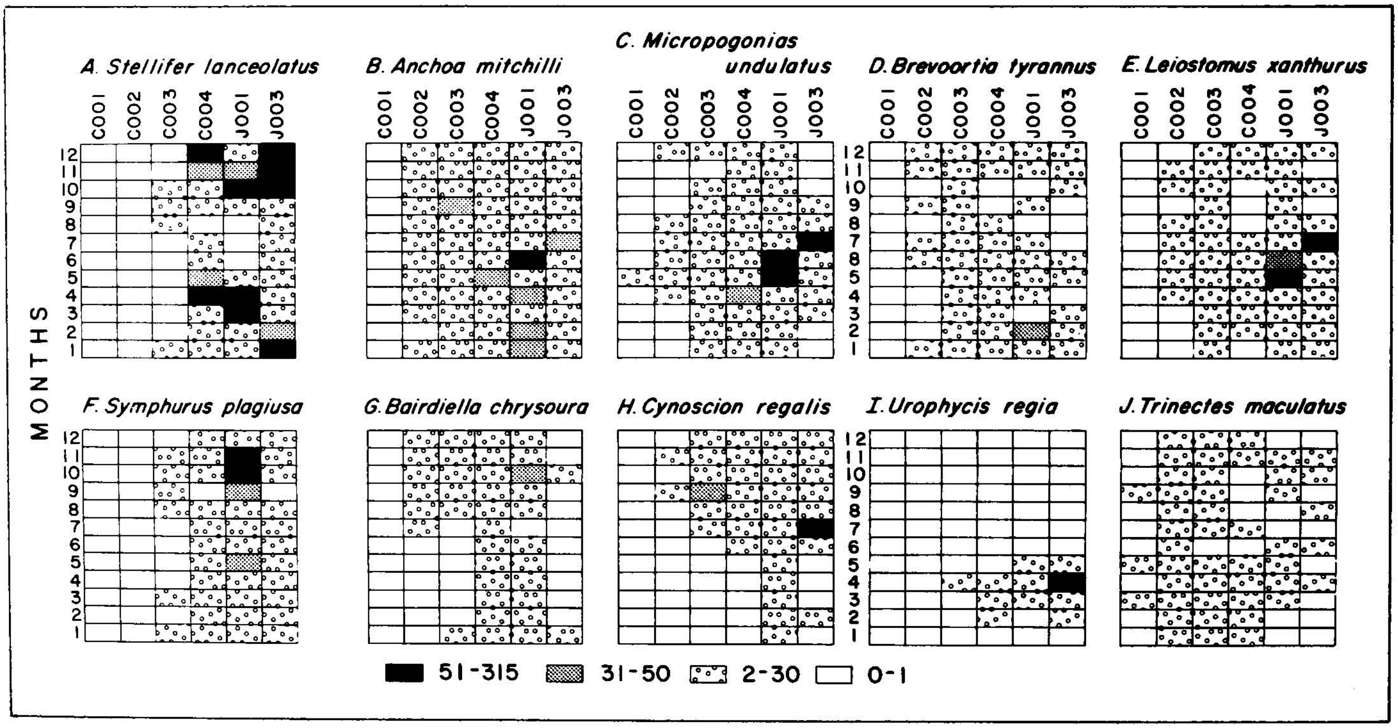


Figure 3.—Abundance, expressed as the antilog of the transformed [$\log_{10}(x + 1)$] mean number of individuals, of 10 major fish species collected monthly in the channel of the Cooper River—Charleston Harbor estuarine system, 1973-77. Legend indicates four arbitrary levels of abundance, from rare or absent (0-1) to maximum abundance (51-315).

Anchoa mitchilli, Bay anchovy.—*Anchoa mitchilli* were collected at all stations in the Cooper River-Charleston Harbor system, except for the most limnetic station (C001) (Fig. 3B). Bay anchovy were most abundant at station J001. Monthly fluctuations in abundance indicated that little, if any, seasonality was associated with catches of bay anchovy, but catches did undergo annual fluctuations, being highest during 1974-76 (Fig. 4B).

Micropogonias undulatus, Atlantic croaker.—Atlantic croaker were collected at all stations in the Cooper River-Charleston Harbor system, but abundances were greatest from April through July at higher salinity stations, particularly those located near the mouth (J001, J003) (Fig. 3C). Annual variation in catches of croaker was small, with little fluctuation about the grand mean (Fig. 4C). Length-frequency distributions indicated that most estuarine croaker available to our trawls were <120 mm TL throughout the year. Although these smaller fish predominated in spring and summer catches, they were also present during other seasons, but in fewer numbers. Newly recruited fish (<30 mm TL) generally appeared first in fall and continued to appear in the population during winter and spring. The continued presence of small croaker during spring in South Carolina may reflect the slow growth of fish spawned in late winter or early spring (Chao and Musick 1977). By summer, few croaker <45 mm were collected from the Cooper River-Charleston Harbor system, and modal groups were in the 75-90 mm range. Although 1-yr-old fish (108-285 mm, from Chao and Musick 1977) were infrequently caught, probably due to gear avoidance (Wenner et al. 1982), their numbers were fewer in summer. Migration of yearling croaker from the estuarine environment during summer has been reported in the York River, Virginia (Chao and Musick 1977), and late summer and early fall in South Carolina (Bearden 1964) and Florida (Hansen 1969).

Brevoortia tyrannus, Atlantic menhaden.—Atlantic menhaden were collected at every station except for C001, the station farthest upriver (Fig. 3D). Menhaden displayed little change in abundance by month but were most consistently present in November, December, January, and June. Annual catches fluctuated moderately about the grand mean and were greatest in 1977 (Fig. 4D).

Leiostomus xanthurus, Spot.—Spot exhibited a distributional pattern similar to that of Atlantic croaker, being most abundant at stations J001 and J003 near the mouth. Spot also were most abundant during May-July (Fig. 3E). Annual catches of spot steadily increased over the 5-yr sampling period (Fig. 4E). The average size of spot was greatest in fall and winter. Length-frequency distributions indicated that spring and summer catches of spot were dominated by fishes in the 60-80 mm size range. Our data support results of other studies in South Carolina (Dawson 1958; Shealy et al. 1974), North Carolina (Hildebrand and Cable 1930), and the lower Chesapeake Bay (Hildebrand and Schroeder 1928; Chao and Musick 1977), which found that young-of-the-year spot first entered the estuary in April.

Symphurus plagiusa, Blackcheek tonguefish.—*Symphurus plagiusa* were most abundant in higher salinity areas of the Cooper River-Charleston Harbor system, although the species did penetrate into limnetic-mesohaline areas of the estuaries at station C003 (Fig. 3F). Over the 5-yr sampling period, abundance of *S. plagiusa* was greatest in October and November; however, annual catches showed a consistent increase from 1973 to 1976 with a slight decrease in 1977 (Fig. 4F).

Bairdiella chrysoura, Silver perch.—Silver perch were collected at all stations except C001; and their abundance increased at stations downriver, especially at C004 and J001

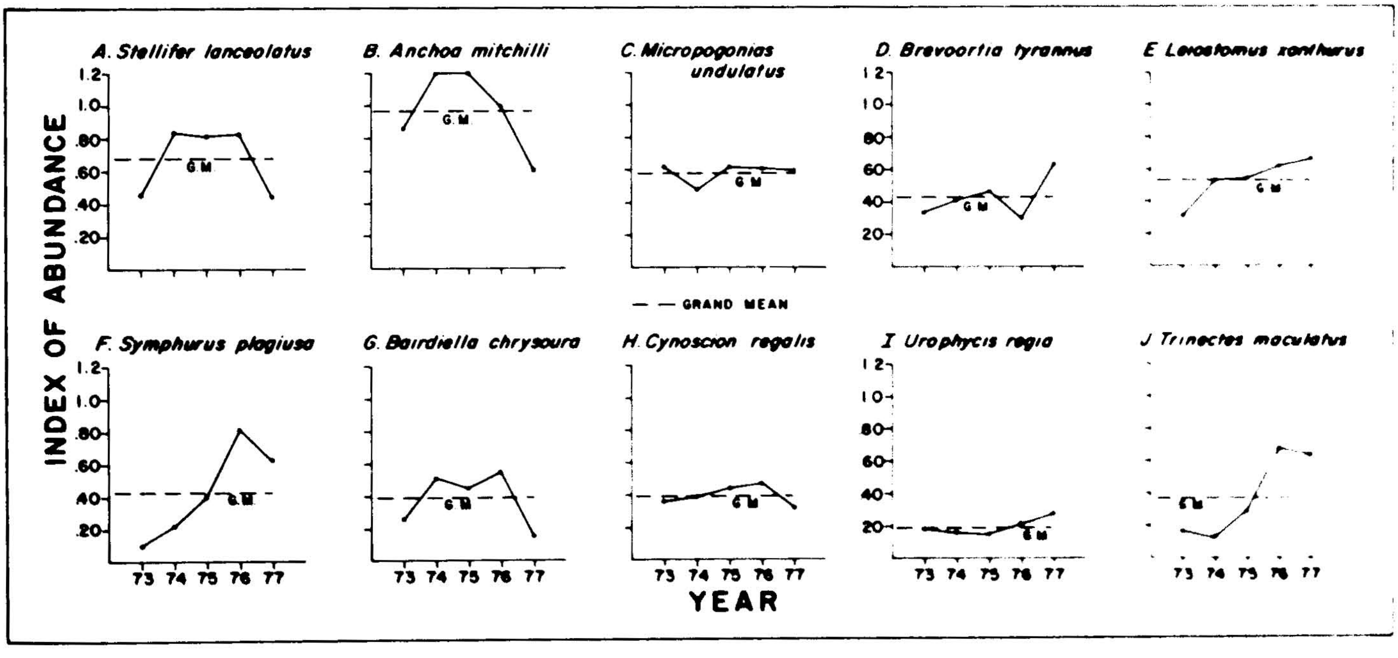


Figure 4.—Annual variation in the transformed $[\log_e (x + 1)]$ mean number of individuals of 10 major fish species collected in the Cooper River-Charleston Harbor estuarine system, 1973-77.

(Fig. 3G). Although silver perch were present in the Cooper River-Charleston Harbor system throughout the year, abundance of the species was greatest from August through January. Annual catches decreased in 1977 (Fig. 4G). The presence of silver perch throughout the year in estuaries of South Carolina (Shealy et al. 1974; Wenner et al. 1982) differs from the seasonal pattern observed in Chesapeake Bay. Chao and Musick (1977) noted that most silver perch leave the York River estuary of Virginia by November. They collected no silver perch from January to March and suggested that the year-round presence of the species in estuaries south of Chesapeake Bay may be due to the higher salinity or temperature of those waters.

Cynoscion regalis, Weakfish.—Weakfish were collected at all stations except C001 and were most abundant during summer (Fig. 3H). Annual catches were fairly constant with little variation about the grand mean (Fig. 4H). The average length of weakfish did not differ markedly by season, but length-frequency distributions showed that the modal length for spring catches was usually smaller than for other seasons. This reduction in size is probably caused by increasing numbers of young-of-the-year weakfish, newly recruited from the May-August spawning period (Lunz and Schwartz 1970).

Urophycis regia, Spotted hake.—Spotted hake displayed the most seasonality in its distribution and abundance, being collected from February to May only (Fig. 3I). Their absence from South Carolina estuaries during the rest of the year is attributed to offshore migration to deeper water during warmer months (Hildebrand and Cable 1938). Spotted hake were collected at the most seaward stations, with maximum abundance occurring at the mouth of the estuary. Little variation in annual catches of spotted hake was present in our samples (Fig. 4I).

Trinectes maculatus, Hogchoker.—*Trinectes maculatus* were collected sometime during the year at every station in the Cooper River-Charleston Harbor system. Hogchoker were most consistently abundant at stations upriver (C002 and C003) and displayed no apparent seasonality in abundance (Fig. 3J). Annual catches of hogchoker increased over the 5-yr sampling period and were greatest in 1976 and 1977 (Fig. 4J).

Penaeus setiferus, White shrimp.—Catches of white shrimp were seasonal with most individuals occurring late summer through fall. White shrimp were also most numerous at the downriver stations (Fig. 5A). Length-frequency distributions indicated that young-of-the-year white shrimp were present in the Cooper River-Charleston Harbor system during summer and fall. Most shrimp collected during these seasons were <80 mm TL, except in 1977 when a few shrimp >120 mm TL were collected in summer and fall. The absence of young-of-the-year shrimp in 1977 is also reflected in the annual catch data for that year when a marked decrease in abundance of white shrimp occurred (Fig. 6A). Modal lengths of white shrimp generally increased during spring to >100 mm TL. The larger size of shrimp during spring is attributable to shoreward migration of large shrimp from offshore waters (Williams 1955) or to the growth of overwintering shrimp to subadult size (Bishop and Shealy 1977).

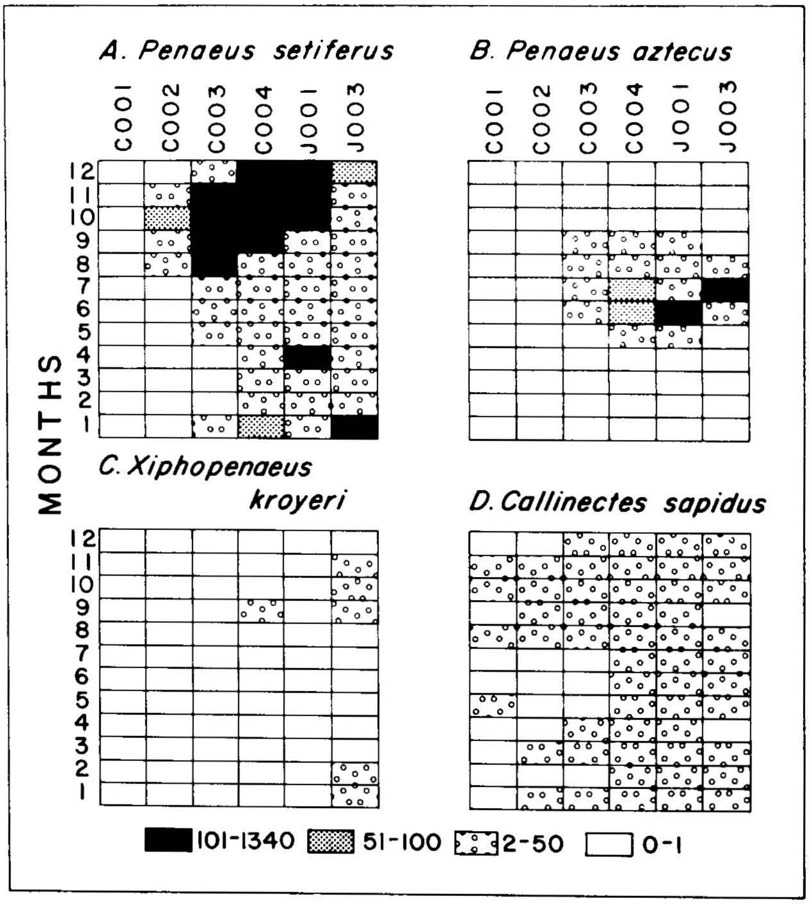


Figure 5.—Abundance, expressed as the antilog of the transformed [$\log_{10}(x + 1)$] mean number of individuals at each station each month, of four major species of decapod crustaceans collected in the channel of the Cooper River-Charleston Harbor estuarine system, 1973-77. Legend indicates four arbitrary levels of abundance, from rare or absent (0-1) to maximum abundance (101-1,340).

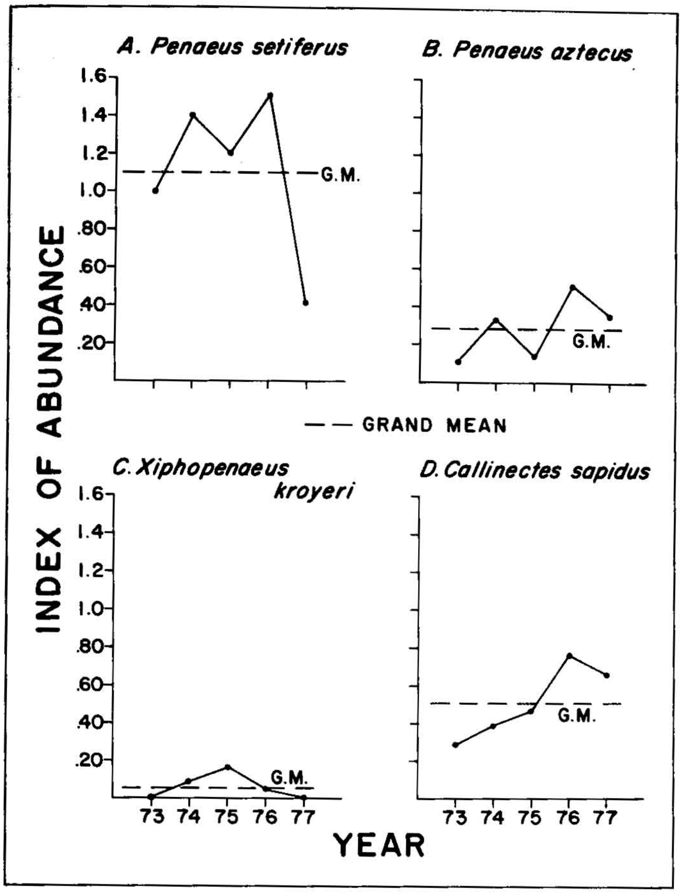


Figure 6.—Annual variation in the transformed [$\log_{10}(x + 1)$] mean number of individuals of four major decapod crustacean species collected in the Cooper River-Charleston Harbor estuarine system, 1973-77.

Penaeus aztecus, Brown shrimp.—Brown shrimp were highly seasonal in their occurrence within the Cooper River-Charleston Harbor estuarine system. They were collected May to September and were most abundant during June and July at higher salinity stations (Fig. 5B). Annual catch rates were variable and highest in 1974 and 1976 (Fig. 6B). Juvenile brown shrimp entered the estuary in spring, remained through the summer, and were almost totally absent from fall and winter collections. This seasonal abundance pattern has also been noted in other South Carolina estuaries (Bishop and Shealy 1977), although the absence of brown shrimp from these estuaries during winter is probably due to gear bias for larger-sized shrimp (Wenner et al. 1982).

Xiphopenaeus kroyeri, Seabob.—Seabob were limited to higher salinity areas of the estuary during fall and winter (Fig. 5C). Annual catches were low, and no seabob were collected in 1973 and 1977 (Fig. 6C). Although *X. kroyeri* occurs in the lower portion of estuaries, it is most commonly encountered in the near offshore coastal zone (Gunter 1950).

Callinectes sapidus, Blue crab.—Blue crab were collected throughout the Cooper River-Charleston Harbor system, but occurred year-round only at stations C004 and J001 (Fig. 5D). Crab were also least abundant at stations upriver. Annual catches increased over the 5-yr sampling period except for a slight decline in 1977 (Fig. 6D). Size-frequency distributions of blue crab covered a wide range of sizes from 10 to 100 mm carapace width with small crab (< 60 mm CW) present during all seasons. Average sizes of blue crab were generally larger in spring and summer.

Biomass Estimates

Biomass and density for fishes were greatest at higher salinity stations J001 and C004 during winter and spring (Table 7). Increased values during these time periods were coincident with the increased dominance of catches by *Stellifer lanceolatus*, *Brevoortia tyrannus*, and *Micropogonias undulatus*. Decapod biomass and density were greatest at station J001 in Charleston Harbor and during fall and summer for all stations combined. These seasonal peaks coincided with periods when young-of-the-year shrimp became vulnerable to our trawl gear.

Our mean total biomass and density estimates for all seasons and stations sampled in the Cooper River-Charleston Harbor system over the 5-yr study period were:

	Biomass (kg/ha)	*Density (no./ha)*
Fishes	6.04	471
Decapods	4.98	678

These estimates are comparable to those obtained by Wenner et al. (1982) for estuarine portions of the Santee River system of South Carolina and by Shealy et al. (1974) for estuarine portions of the Cooper River-Charleston Harbor and Edisto River systems.

Table 7.—Average seasonal biomass (kg/ha) and density (no./ha) of fishes and decapod crustaceans collected at stations in the Cooper River-Charleston Harbor estuarine system, S.C., 1973-77.

	Average biomass and density/station										Grand mean	
	C002		C003		C004		J001		J003			
Season	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./kg	kg/ha	no./ha	kg/ha	no./ha	kg/ha	no./ha
					Fishes							
Fall	3.62	166	2.63	202	7.55	592	11.03	542	4.30	888	5.37	472
Winter	3.53	175	3.78	258	16.48	621	14.52	976	6.52	558	8.60	480
Spring	1.75	428	5.25	242	13.94	763	11.99	1,071	6.06	636	7.45	589
Summer	0.86	97	2.44	289	2.49	252	5.30	602	4.59	593	2.95	346
					Decapods							
Fall	1.57	521	6.71	1,122	9.35	1,380	15.60	1,993	6.68	915	7.31	1,116
Winter	0.05	8	0.22	17	0.77	143	2.03	314	6.40	931	1.74	260
Spring	0.06	10	0.53	58	5.10	376	17.80	1,270	2.27	287	4.26	339
Summer	0.90	221	12.20	2,078	5.26	928	12.10	1,288	3.18	338	6.28	943

DISCUSSION

The Cooper River-Charleston Harbor estuarine system is characterized as mixohaline with gradual changes in faunal assemblages. The most striking differences in species composition occurred between those stations located at or near the mouth of the estuary and those located far upriver. The fish and decapod crustacean species assemblages associated with these two areas were primarily composed of stenohaline marine species and low-salinity resident estuarine species, respectively. Nevertheless, euryhaline species, which extended from the mouth of the estuary into brackish waters, were the dominant faunal component throughout the estuary as a whole. Except for a few freshwater species, resident estuarine species (e.g., *Trinectes maculatus*, *Anchoa mitchilli*, *Palaemonetes pugio*, *Ictalurus catus*) were found throughout the system, their distributions often overlapping with those of species derived from the marine environment. This distributional pattern is similar to that described by Weinstein et al. (1980) who noted considerable overlap in distributional patterns of resident fishes and stenohaline marine transients in the Cape Fear River, N.C.

The observed overlapping spatial distributional patterns of resident and transient fishes and decapod crustaceans can be related to salinity regimes within the estuary and to the physiological tolerances of component estuarine species to these regimes. In comparison with estuaries of the Middle Atlantic states, such as Chesapeake Bay, South Carolina estuaries are narrower, deeper, and shorter in length (Mathews and Shealy 1978). The physiography of estuaries (Pritchard 1954), in addition to other factors such as runoff, tidal action, and current velocity (Mathews and Shealy 1978), affect vertical mixing and, consequently, determine salinity regimes as well. The combined effect of these factors in South Carolina estuaries is a compression of the isohalines, with resultant overlap in the distributional patterns of many estuarine species. Ultimately, however, it is the physiological tolerances of component estuarine species which really determine their distribution. The spatial limits of freshwater species are maintained through physiological constraints, while other resident estuarine species are able to tolerate a wider range of salinity and apparently are not limited by competition and predation to the lower reaches of the estuary (Weinstein et al. 1980). Physiological tolerances are also important in determining the upestuary limits of species which are numerically dominant in the Cooper River-Charleston Harbor system. For the most part, these species were unable to penetrate into areas where the isohalines were $\leq 0.5‰$ and were generally most abundant at stations in the mesopolyhaline zone.

The overlapping spatial distributions of many resident estuarine, stenohaline marine, and numerically dominant euryhaline species in the Cooper River-Charleston Harbor system are reflected in the greater species richness and abundance of individuals at stations in the mesopolyhaline zone. Assemblages at these stations were comparatively diverse, consisting of some resident estuarine and euryhaline species and many stenohaline marine species. Seasonal peaks in species diversity are largely attributable to those stenohaline marine transients which occur sporadically in low densities throughout the lower reaches of the Cooper River-Charleston Harbor system. Biological interactions such as predation and competition for space and food can also contribute to species diversity and richness. Weinstein et al. (1980) noted that increased predation pressure probably enhanced species diversity in downstream marsh areas of the Cape Fear River, N.C., by preventing dominant competitors from monopolizing the major food and space resource. An alternative explanation is that enough food may be present in the lower reaches of the river to support a high diversity of species. Euryhaline species such as the sciaenids were numerically dominant in the Cooper River-Charleston Harbor system and were most abundant at downriver stations. Juvenile sciaenids feed opportunistically on a variety of infaunal and demersal species (Chao and Musick 1977). Their successful coexistence in higher salinity areas with stenohaline marine and other estuarine species may be attributed to utilization of food resources from different levels of the water column and to the abundant food resources of the estuarine system. In this case, food would not be a limiting resource and intrafamilial or interspecific competition would not be as important a factor (Chao and Musick 1977).

Temporal distributional patterns were another important aspect of the fish and decapod community of the Cooper River-Charleston Harbor system. Temporal changes in species associations and abundance were related primarily to fluctuations in abiotic variables. Bottom-water temperature in the channel of the estuarine system exerted a substantial influence on the abundance of species collected. The most noticeable decreases in abundance of fishes and decapods coincided with annual minimum temperatures, especially those experienced during the extremely harsh winter of 1977. These seasonal trends in abundance were especially evident for the sciaenid fishes and penaeid shrimps. For those species which may overwinter in the estuary, such as *Micropogonias undulatus* and *Penaeus* spp., extremely low winter temperatures can destroy an entire year-class (Massmann 1971; Farmer et al. 1977). Thus, temperature-related mortalities, as well as emigration of juveniles, probably contributed to the low abundance and biomass observed at that time. Similar explanations were suggested by Weinstein (1979) for decreased abundance of *Penaeus* spp. in the Cape Fear River, N.C.

Seasonal differences in species assemblages reflected changes in abundance as well as exclusion of some species from the estuary during part of the year. However, most species remained in the estuary throughout the year, while their abundances changed seasonally. Nevertheless, while faunal affinities varied throughout the year, as indicated by cluster analysis, the species composition of the estuarine system as a whole was not altered appreciably. Temporal fluctuations in abundance appear to be a means through which more species are able to utilize the estuary simultaneously by a reduction in densities and competition for food and space.

The importance of abiotic factors in determining the distributional patterns of estuarine biota has elicited concern about the effects of rediversion on the integrity of species assemblages and, more importantly, on interspecific balance (Shealy and Bishop 1979). A restriction of freshwater inflow will probably cause salinities to be higher and, consequently, modify the existing salinity gradient. Additional consequences of a decrease in flow rate might include a decrease in nutrient and detritus influx, lowering of the water table, reduction in water turbidity, alteration of estuarine circulation, and reduction in the ability of organisms to withstand stresses of normal drought periods (Heald 1970; Keiser and Aldrich 1976). These alterations, should they occur in the Cooper River-Charleston

Harbor estuary, will undoubtedly affect the suitability of the estuary as a nurseryground.

A reduction of freshwater inflow will eventually increase the homeohalinity of this estuarine system. A displacement of the current mesopolyhaline zone further upstream will affect the distribution and abundance of larval and juvenile fishes and shrimps. Upestuary marshes are critical areas for early developmental stages of fishes and shellfish (Weinstein 1979). The inflow of freshwater, which currently inundates marshes and abandoned rice fields in the Cooper River-Charleston Harbor estuarine system is more important in maintaining upestuary marsh habitat suitable for fishes and decapod crustaceans. After rediversion, much of this habitat, currently subject to overflow, will no longer be available as a nursery due to lowered water levels and higher salinities (U.S. Army Corps of Engineers footnote 2). A substantial reduction in nursery habitat could affect the entire estuarine foodweb. Estuarine salt marshes are highly productive, being dominated by cordgrass (*Spartina*) which ultimately provides a source of food to organisms in the estuarine system (Massmann 1971). Thus, the nursery functions of estuaries are closely related to the viability of plant communities. Alteration of areas which supply much plant detritus may lower the numbers of detritus-algae consumers which, in turn, will eventually limit subsequent trophic levels. This may be particularly troubling from an economic point of view because the abundance of commercially valuable penaeid shrimp is directly related to the absolute area and type of estuarine-intertidal vegetation (Turner 1977).

The habitat of stenohaline marine species may not be affected deleteriously by rediversion. In fact, these species will probably penetrate even farther upriver than they currently do. Because numbers of species and individuals of fishes and decapod crustaceans are now higher in more saline reaches of the river, species diversity of areas in the Cooper River-Charleston Harbor which are currently lower in salinity could be increased by rediversion. Increases in diversity probably will be attributed to higher numbers of stenohaline marine species rather than euryhaline or resident estuarine species; however, many estuarine species, whether resident or transient, are living near the limit of their physiological tolerance of temperature or salinity, so further alteration of the environment may exclude some species permanently (Odum 1970).

In addition to changes in diversity, the species assemblages as we have defined them by station location will probably be altered following rediversion. Whether this alteration will entail a mere shifting of assemblages upriver or the introduction of completely different groupings of species will depend on the effects of rediversion on competition and predation. Food resources can be limiting in estuaries (Lasker 1975; Houde 1978; Laurence 1977). If habitat is lessened and the opportunity for spatial segregation becomes minimal, then seasonality and other forms of temporal segregation may be the only means of reducing competition among species with similar food requirements (Weinstein 1979). Seasonality, which includes differences in spawning periods as well as density-independent factors such as temperature, dissolved oxygen, and nutrient inputs, may mitigate any changes in competition or predation (Enright 1976) precipitated by man-made perturbations. In turn, the adverse effects of rediversion on the estuarine biota may be neither drastic nor irreversible, although this remains to be seen.

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