SHALLOW MARSH HABITATS AS PRIMARY NURSERIES FOR FISHES AND SHELLFISH, CAPE FEAR RIVER, NORTH CAROLINA

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ABSTRACT

Seine and rotenone collections taken during 1977 from the upper reaches of tidal creeks and along the marsh fringe in the vicinity of the Cape Fear River, N.C., indicated that these areas serve as primary nursery habitats for postlarval and juvenile fishes and shellfish. Average densities (number/400m^2) for several ocean-spawned species at the peak of postlarval or early juvenile recruitment were high: spot, *Leiostomus xanthurus*, 3,099; Atlantic menhaden, *Brevoortia tyrannus*, 839; striped mullet, *Mugil cephalus*, 711; white mullet, *Mugil curema*, 525; and brown shrimp, *Penaeus aztecus*, 329. Standing crops for the majority of species studied further indicated that lower productivity per unit area occurred in high salinity marshes closest to the ocean. In addition, distribution patterns for several species were significantly correlated with salinity and substrate characteristics or combinations of them and seasonal effects also were evident so that related and potentially competing species were separated temporally.

Community analyses demonstrated that each marsh complex was unique; however, overall similarity for the most abundant species was high. The differences were related to salinity gradients and to the presence of an "edge effect" where marshes closest to the river mouth were species rich due to seasonal invasion by low densities of reef, nearshore, and shelf marine species. Similarly, freshwater fishes invaded brackish marshes during periods of high river flow.

Patterns of distribution of estuarine species have often been correlated with environmental gradients (Remane 1934; Hedgepeth 1957; Gunter 1961; Khlebovich 1969; Gainey and Greenberg 1977) and have also been described in terms of characteristic estuarine zones: marshes, tidal flats, sounds, bays, and channels. Within these areas, organisms are frequently associated with specific habitats; for example, the marshes can be divided into the high marsh and tidal creeks, the latter characterized by soft muds at their headwaters and by more scoured areas downstream. Several properties of the water column also vary in these creeks, being generally more stable near the creek mouth (Hackney et al. 1976), and the presence of food organisms is often correlated with sediment properties so that predators may frequent one area more than another (de Sylva 1975). On the basis of individual tolerances, some species will frequent habitats under a wide range of conditions, while others will be more restricted in their distribution. These tolerances may change with the age of the individual so that a given species may be a member of several different communities during its life cycle.

When the nursery role of estuaries is considered in this framework, it becomes evident that information is lacking on age-specific utilization of estuarine zones. Few investigators have studied the primary nursery areas where the youngest members of many ocean-spawned species first take up residence (Herke 1971; Parker 1971; Purvis[2]). In one such area, the tidal salt marshes, comprehensive sampling efforts have demonstrated that a temporal succession takes place with many species residing in the upper reaches of tidal creeks during their earliest days and then moving gradually downstream as they grow (Herke 1971; Dunham 1972; Purvis see footnote 2). A similar successional pattern occurs in the upper reaches of the Chesapeake Bay (Haven 1957; McHugh 1967; Chao and Musick 1977) and in open bay waters near the heads of estuaries in South Carolina (Bearden 1964), Louisiana (Thomas and Loesch 1970), and Florida (Hansen 1970).

The present study details the composition of the nekton community of several shallow marsh areas, including tidal creeks and marshes adjacent to the river shoals. Consideration is given to the role of these habitats as primary nurseries, and patterns

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[2]Purvis, C. 1976. Nursery area survey of Northern Pamlico Sound and tributaries. Div. Mar. Fish. Rep. (prepared for U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.), 62 p.

Manuscript accepted January 1979.
FISHERY BULLETIN: VOL. 77, NO. 2, 1979.

of distribution of individual species are described. An attempt is also made to correlate these distributions with both biotic and abiotic parameters.

STUDY AREA

All sampling stations were situated within the Cape Fear River, N. C., located at approximately lat. 33° N (Figure 1). The estuary is relatively narrow, averaging only 1.6-3.6 km wide and extending 45 km from the general location of the salt boundary at Wilmington, N.C., to the river mouth at Baldhead Island. A 12 m deep ship channel is maintained from Wilmington to the river entrance, and numerous spoil islands are found adjacent to this channel over its entire length. Tidal velocities in the Cape Fear are high, averaging 1.5 m/s at the river mouth during ebb.

Tidal salt marshes cover approximately 8,900 ha and form the largest contiguous system of this type in North Carolina (U.S. Army Corps of Engineers[3]). Dominant plant species include the smooth cordgrass, *Spartina alterniflora*, and black needle rush, *Juncus roemerianus*, with giant reed grass, *Spartina cyanosuroides*, prevalent upstream at lower salinities. Tidal creeks cover an estimated 648 ha, and shallow open water areas (shoals) between the channel and salt marshes contribute an additional 7,285 ha of suitable nursery habitat.

MATERIALS AND METHODS

Nine stations were established within several major marsh systems and along the river shoals (Figure 1; Table 1). Suitable interior marsh sites could not be located in the middle reaches of the estuary, since the few available creek systems were inaccessible or could not be sampled without great difficulty. Salinities at the chosen sites ranged from 0 to 35‰, and a wide variety of substrata were included, ranging from soft organic ooze, approximately 10-20 cm deep, to sandy areas containing little organic material. Stations were sampled on a monthly basis from January through December 1977 with several exceptions (Table 1). Because of ice cover, the Dutchman and Walden Creek rotenone stations were not sampled in January, and new stations were established at Shellbed Island and Hechtic Creek in February and at Barnards Creek in April.

Two collection methods were employed throughout this study: seining, where footing was satisfactory, and rotenone application (5% emulsifiable Fish-Tox[4]), where softer mud or snags predominated. Before either method was attempted, an area of tidal creek was isolated utilizing large blocking seines. Nets were extended from shore to shore and were anchored with U-shaped lengths of concrete reinforcing rods, especially helpful in pinning the leadline along the contours of the banks on each side of the station (at several sites, one shoreline was always bordered by a bar formation). In addition, a length of heavy chain was affixed to the leadline of each block net to ensure direct contact with the substrate. Initially, 6.5 mm mesh block nets were employed; beginning in April 1977 these were replaced with fine mesh (approximately 1.0 mm) nets capable of retaining the smallest ocean-spawned larvae. The enclosed area then was swept repeatedly with a 7.6 m, 6.5 mm mesh, seine or treated with sufficient rotenone to kill all fish present.

To determine the number of seine sweeps required, a study was conducted in October 1976 when nekton diversity remained near a yearly maximum. After the block nets were set at the Dutchman Creek site, a total of 13 sweeps were taken, and the contents of each sweep kept separate. The results were plotted (Figure 2) as the cumulative number of species, the expected number of species (ENS) (Hurlburt 1971) and the cumulative diversity (H′, Shannon and Weaver 1949). As seen in the figure, little new information was gained after the eighth sweep, i.e., an asymptote was approached. A separate study at Baldhead Creek in September 1977 confirmed these results, and a procedure requiring eight sweeps was instituted at each seine station.[5] In addition, three overlapping sweeps with a 7.6 m, approximately 1.0 mm mesh, seine were taken at each site. These served to capture the smallest fish present, those capable of passing through the 6.5 mm meshes. A preliminary experiment indicated that these seines were capable of significantly reducing the lower size range of key species studied (Table 2).

[3]U.S. Army Corps of Engineers. 1977. Maintenance of Wilmington Harbor, North Carolina. Final environmental statement. U.S. Army Engineers District, Wilmington, N.C., 97 p.

[4]References to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[5]A 50-ft (15.2 m) seine was used on the last sweep, this was the original downstream blocknet.

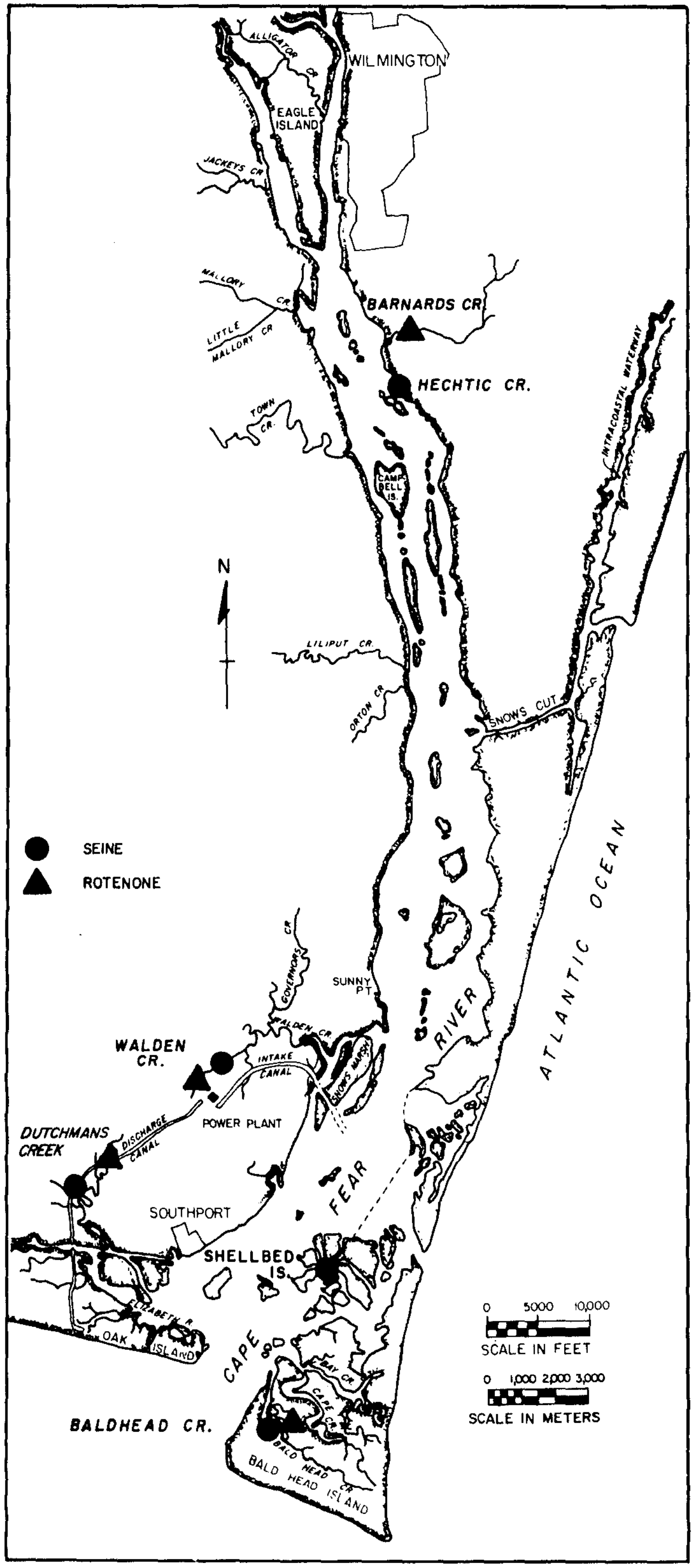

FIGURE 1.—Seine and rotenone sampling sites, Cape Fear River estuary, N.C.

TABLE 1.—Sampling localities and dates for collections of fishes and invertebrates, Cape Fear River estuary, N.C., including physicochemical data. D = approximate distance from river mouth to creek entrance; SD = standard deviation; MPS = median particle size; SC = sorting coefficient.

Station	Location	Sampling schedule	D (km)	Average salinity ±SD	Average temperature ±SD	Sediment parameters: Sand (%) Medium	Sand (%) Fine	Silt-clay	Organics (%)	MPS (mm)	SC (σ_I)	No. of cores
Baldhead Cr.	Tidal											
seine	creek	Jan.-Dec.	0.9	25.7±7.0	21.1±7.6	13	86	1	1.88	0.23	0.65	7
rotenone		Jan.-Dec.	0.9	25.9±6.7	21.3±7.8	34	65	1	1.13	0.34	0.80	6
Shellbed Is.	River											
seine	shoal	Feb.-Dec.	4.6	26.6±5.9	23.1±6.8	7	92	1	0.77	0.23	0.60	3
Dutchman Cr.	Tidal											
seine	creek	Jan.-Dec.	6.6	25.1±6.9	19.9±8.3	10	86	4	2.67	0.21	0.79	7
rotenone		Feb.-Dec.	6.6	18.1±8.7	20.4±8.9	20	66	14	10.42	0.20	1.31	4
Walden Cr.	Tidal											
seine	creek	Jan.-Dec.	9.7	8.6±4.8	21.4±8.1	12	87	1	0.80	0.21	0.59	6
rotenone		Feb.-Dec.	9.7	9.2±5.4	21.2±7.7	12	87	1	0.43	0.25	0.56	3
Hechtic Cr.	River											
seine	shoal	Feb.-Dec.	33.6	6.0±5.5	21.4±9.8	27	66	7	2.30	0.28	1.13	6
Barnards Cr.	Brackish											
rotenone	stream	Apr.-Dec.	33.9	6.1±5.6	22.3±7.6	8	86	6	33.17	0.24	0.72	3

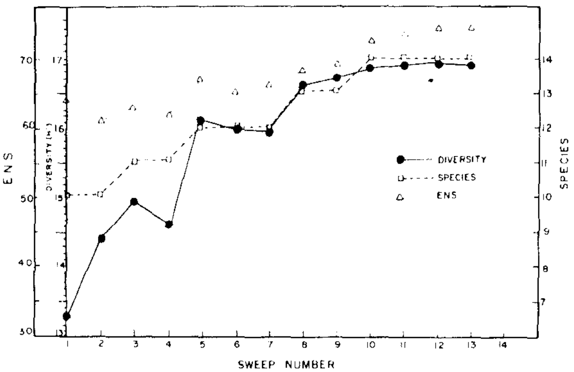

FIGURE 2.—Dutchman Creek, N.C., survey (October 1976) designed to determine the number of seine sweeps required to produce a representative sample. Cumulative number of species (ENS) and Shannon-Weaver diversity (H') are plotted on separate axes.

At rotenone sites, sufficient toxin was introduced to kill all fishes present; this quantity was determined by the presence of certain "indicator" species in the collections, especially killifish (*Fundulus* spp.) and eels (e.g., speckled worm eel, *Myrophis punctatus*; American eel, *Anguilla rostrata*) which are resistant to rotenone and may also burrow in the substrate. Stricken fishes were dipnetted as long as they were visible on the surface, and the downstream block nets were also picked at the end of the survey. During winter, additional rotenone was added to ensure that toxicity remained uniform, and in all months, potassium permanganate ($KMnO_4$) was added downstream to detoxify rotenone carried below the sites. During this study, no attempt was made to account for rotenone losses due to settling.

All collections were initiated near low tide to reduce the effects of current and to sample postlarval fishes that were not swept downstream by tidal flows. To ensure uniformity of water volume between the block nets, staff gauges and landmarks were used to standardize the volume/area sampled. Throughout this paper, all catches will be reported as the number of individuals per 400 m^2, the average surface area of the stations.

Temperature was recorded prior to each collection with a calibrated stick thermometer or temperature mode on a Beckman (model RS 5-3) salinometer; surface salinity was measured with the same instrument. The salinometer was calibrated prior to each monthly sampling trip with a

TABLE 2.—Comparison of length-frequency distributions from 6.5 and 1.0 mm mesh, seine collections, Cape Fear River estuary, N.C. A = 6.5 mm mesh seine, seven sweeps; B = 1.0 mm mesh seine, three sweeps. Lower one-tailed *t*-test; ** = $P<0.01$, ns = not significant. Specimens >28 mm are not included in mean values.

Species		Length (mm): 9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	>28	Total	Mean
Mugil cephalus	A										4	36	37	62	41	20	15	13	7	18	253	21.4
	B											2	5	9	10	1				3	30	21.1 ns
Leiostomus xanthurus	A					1			2	4	20	42	49	24	19	5	2	1		1	170	19.9
	B						1	1	1	7	5	9	6	3							33	18.4 **
Paralichthys spp.	A				1	2		2	2			1									8	14.9
	B	1	1	4	10	9	4	7	3												39	13.0 **

known resistor and periodically checked against salinity standards. Fishes and shellfish were preserved in 10% Formalin and lengths (standard length for fishes, carapace width for crabs, and total length for shrimp) recorded for selected species. Subsampling for lengths was employed when sorted collections contained more than 100 individuals of a given species.

Sediments were collected with a 0.01 m² plug sampler. Three to seven cores, 5 cm deep, were taken at each site, with the actual number at any one location governed by the expected homogeneity of the substratum. Where the bottom was uniform, three evenly spaced cores were taken along a diagonal across the site; where bar formations formed a border of the site, six or seven evenly spaced cores were collected along two transects located parallel to each shore. Cores were processed according to prescribed methods of the American Society for Testing and Materials (American Society for Testing and Materials 1963). Hydrometer analysis was used for the fine fraction, and particle size descriptions were based on the unified scale (U.S. Corps of Engineers 1953).

The degree of similarity among sites was compared with the percent similarity index (PSI) (Whittaker and Fairbanks 1958):

$$\text{PSI} = 100\ \Sigma\ (p_{ia}, p_{ib})$$

where p_{ia} and p_{ib} are the proportion of species i in samples a and b, respectively. Since species with single occurrences (singletons) and taxa not identified to species contributed little to similarity among sites or to an understanding of their role in the community, they were omitted from the analyses. Separate matrices were constructed for pooled monthly data at each site on the basis of station and species affinities (recurring species groups) and clustered by the unweighted pair group-average method (Sneath and Sokal 1973). Data were $\log_{10}$ transformed prior to these analyses to give added emphasis to less common species and decrease the effect of extreme values (Clifford and Stephenson 1975). Three separate dendrograms were constructed—a station association dendrogram in which all nine stations were compared, and a pair of dendrograms which reflected station and species associations for seine sites. Results for the latter comparisons were then cross-referenced by construction of a two-way coincidence table (Clifford and Stephenson 1975).

Partial correlations were calculated with physicochemical data and monthly abundances for selected species (Fisher 1973). The latter were based on sufficient sampling densities (taken as at least 10 individuals collected among all sites in any given month) and served to reduce the effect of zero catches in the data. Prior to the analyses, abundance data were $\log_{10}$ transformed in order to stabilize variances (Winsor and Clark 1940).

RESULTS

Physicochemical Parameters

Among the seine sites, two distinct salinity patterns were observed (Table 1); high salinity stations (Baldhead and Dutchman Creeks and Shellbed Island) generally ranged above 15‰, while Hechtic Creek (well upriver) and Walden Creek (part of a fairly extensive freshwater drainage basin) ranged downwards from this value. Seasonal patterns also were evident, with salinity depressions occurring in the spring, especially in March and April, and again during the fall. Although the pattern for rotenone stations was not as distinct as that for seine sites, results were similar, with the exception of the Dutchman Creek station (located at the headwaters of this creek system) which reflected local runoff.

Sediment characteristics (Table 1) represent means for all cores taken at each site. Fine sands (1.25-3.75 ϕ) were the major component of the sediment at all stations averaging 80%, with slightly coarser material (−1.0 to 1.25 ϕ) contributing 20% or more of the bottom particle composition at the Dutchman and Baldhead Creek rotenone sites and at the Hechtic Creek seine site. In general, silts and clays (>3.75 ϕ) were minor components of the substratum at stations located in the Baldhead Island complex, although this percentage increased in Dutchman Creek, with a maximum (14%) at the rotenone site. Both upriver stations, Hechtic and Barnards Creeks, also contained more silts and clay. Organic fractions were similarly distributed, with the lowest station mean recorded for the well-scoured Walden Creek system. Dutchman Creek and upriver sites generally had sediments with high organic content, with a maximum at Barnards Creek of 33.17%.

Sorting coefficients (σ_I) were calculated (Table 1) for each site according to the methods of Folk (1974). Sediments were poorly sorted at the Dutchman Creek rotenone station, located at the headwaters of the marsh creek where flows were minimal throughout the tidal cycle, and at Hechtic Creek which also "dead-ends" a short distance upstream. Median particle size, computed as the geometric mean for all core samples collected at the site, generally fell within a narrow range, with the exception of the Baldhead Creek rotenone station where larger particles were associated with the medium sand fraction. The percentage of this fraction was considerably greater (34%) than at other localities.

Interstation Comparisons

Species richness was greatest at the Baldhead Creek stations, closest to the ocean entrance, while the total number of individuals captured varied among sites (Table 3). The low catch at Barnards Creek is reflected in the reduced sampling effort at this station which was first sampled in April. Catches at Walden Creek were similar to those at Baldhead Island, although fewer taxa were collected. On a seasonal basis, peak total abundance occurred mainly in the winter and early spring, coincident with the presence of winter-spawned species, primarily spot, *Leiostomus xanthurus*; Atlantic menhaden, *Brevoortia tyrannus*; mullets, *Mugil* spp.; and flounders, *Paralichthys* spp.

Differences in relative numbers of species in monthly collections were tested with the Wilcoxon signed rank test (Table 4). Seine and rotenone stations were treated separately, and in comparisons involving Barnards Creek, only the months April to December were used. Among seine stations, Baldhead Creek yielded greater numbers of species than all sites except Hechtic Creek, while the Baldhead Creek rotenone site produced significantly more species than other rotenone stations. The upriver sites, Hechtic and Barnards Creeks, were also richer in species than either Dutchman or Walden Creek, but did not yield more species than the station at Shellbed Island.

The most abundant species (collectively composing 0.5% or more of the total number of individuals) were essentially similar among stations (Table 5), differing only in their order of abundance. For example, *Leiostomus xanthurus*; mummichog, *Fundulus heteroclitus*; and striped mullet, *Mugil cephalus*, were ubiquitous, and *Brevoortia tyrannus*; white mullet, *M. curema*; and Atlantic silverside, *Menidia menidia*, nearly so. Other abundant species seemed more closely associated with specific habitats; the striped killifish, *F. majalis*, for example, was restricted mainly to high salinity areas, while the Atlantic croaker, *Micropogonias undulatus*, and hogchoker, *Trinectes maculatus*, were collected more frequently in brackish water with bottoms high in organic matter. It should be emphasized that seine and rotenone methods used here differed somewhat with respect to gear efficiency and selectivity (Weinstein and Davis in prep.) and, in addition, invertebrates such as brown shrimp, *Penaeus aztecus*, and blue crab, *Callinectes sapidus*, were not considered to be sampled quantitatively with rotenone. These species, however, were common at all seine sites except Shellbed Island.

The effects of the extreme cold in January and February 1977 along the eastern seaboard were reflected in the data with severely reduced catches of organisms in these months. Although catches might have been expected to be higher at this time of year, ice covered the headwaters of several marsh creeks, and water temperatures in the shallows hovered between 0° and 2° C. These tempera-

TABLE 3.—Total number of individuals and species collected at seine and rotenone sampling sites, Cape Fear River estuary, N.C.

Sampling site	No. of individuals	No. of species	Sample size
Baldhead Creek:			
Seine	15,320	52	12
Rotenone	12,259	58	11
Shellbed Island:			
Seine	23,611	43	11
Dutchman Creek:			
Seine	25,964	36	12
Rotenone	36,750	30	11
Walden Creek:			
Seine	14,929	35	12
Rotenone	18,183	37	11
Hechtic Creek:			
Seine	23,113	44	11
Barnards Creek:			
Rotenone	8,063	39	9

TABLE 4.—Species richness comparisons among seine and rotenone stations, Cape Fear River estuary, N.C. The test statistic is the Wilcoxon signed rank test. * = significant at $\alpha = 0.05$; ns = not significant.

Seine station	Baldhead Creek	Shellbed Island	Dutchman Creek	Walden Creek	Hechtic Creek
Baldhead Creek	—	*	*	*	ns
Shellbed Island		—	ns	ns	ns
Dutchman Creek			—	ns	*
Walden Creek				—	*
Hechtic Creek					—

Rotenone station	Baldhead Creek	Dutchman Creek	Walden Creek	Barnards Creek
Baldhead Creek	—	*	*	*
Dutchman Creek		—	ns	*
Walden Creek			—	*
Barnards Creek				—

TABLE 5.—Pooled species abundance for all collections at seine and rotenone sites in the Cape Fear River estuary, N.C., listed in order of abundance. Only species composing 0.5% of the total number of individuals and their corresponding percentages are shown. Barnards Creek was not collected until April 1977.

Location/species	No.	%	Location/species	No.	%	Location/species	No.	%
Seine:			*Mugil curema*	83	0.6	*Trinectes maculatus*	92	1.1
Baldhead Creek:			*Menidia beryllina*	82	0.6	*Penaeus duorarum*	79	1.0
Anchoa mitchilli	4,330	28.2	*P. setiferus*	70	0.5	*Citharichthys spilopterus*	54	0.7
Leiostomus xanthurus	3,918	25.5	Shellbed Island:			*Gobionellus* sp.	52	0.6
Mugil curema	1,668	10.9	*A. mitchilli*	8,927	37.8	*Syngnathus louisianae*	42	0.5
Menidia menidia	1,510	9.8	*M. menidia*	8,758	37.1	Dutchman Creek:		
Fundulus heteroclitus	938	6.1	*Leiostomus xanthurus*	3,023	12.8	*L. xanthurus*	12,436	33.7
Penaeus duorarum	657	4.3	*F. heteroclitus*	730	3.1	*F. heteroclitus*	9,278	25.1
F. majalis	541	3.5	*Mugil cephalus*	525	2.2	*Mugil curema*	8,546	23.2
Brevoortia tyrannus	287	1.9	*E. argenteus*	450	1.9	*M. cephalus*	3,713	10.1
P. aztecus	266	1.7	*M. curema*	354	1.5	*B. tyrannus*	909	2.5
Mugil cephalus	263	1.7	*A. hepsetus*	295	1.2	*Lagodon rhomboides*	677	1.8
Callinectes sapidus	162	1.1	*B. chrysura*	115	0.5	*Elops saurus*	273	0.7
Gobiosoma bosci	114	0.7	Hechtic Creek:			*Menidia menidia*	242	0.7
Bairdella chrysura	108	0.7	*Brevoortia tyrannus*	7,967	34.4	Walden Creek:		
Eucinostomus argenteus	106	0.7	*L. xanthurus*	7,953	34.4	*Leiostomus xanthurus*	11,093	61.0
C. similis	91	0.6	*M. cephalus*	3,009	13.0	*B. tyrannus*	2,531	13.9
Lagodon rhomboides	70	0.5	*P. aztecus*	1,199	5.2	*F. heteroclitus*	910	5.0
Dutchman Creek:			*A. mitchilli*	660	2.9	*Mugil cephalus*	733	4.0
Leiostomus xanthurus	8,534	32.8	*F. heteroclitus*	590	2.6	*Lagodon rhomboides*	708	3.9
M. cephalus	4,160	16.0	*C. sapidus*	265	1.1	*M. curema*	677	3.7
F. heteroclitus	3,056	11.7	*P. duorarum*	247	1.1	*Eucinostomus argenteus*	329	1.8
M. curema	2,582	9.9	*M. curema*	199	0.9	*Menidia menidia*	318	1.8
Menidia menidia	2,510	9.6	*Menidia beryllina*	199	0.9	*M. beryllina*	241	1.3
Brevoortia tyrannus	1,387	5.3	*P. setiferus*	171	0.7	*Paralichthys* spp.	142	0.8
C. sapidus	938	3.6	*Bairdiella chrysura*	160	0.7	*Bairdiella chrysura*	88	0.5
F. majalis	824	3.2	*Micropogonias undulatus*	122	0.5	Barnards Creek:		
P. aztecus	741	2.8				*F. heteroclitus*	2,996	24.4
Bairdiella chrysura	502	1.9	Rotenone:			*Leiostomus xanthurus*	2,750	22.4
E. argenteus	231	0.9	Baldhead Creek:			*M. menidia*	2,486	20.2
A. mitchilli	151	0.6	*L. xanthurus*	1,969	24.2	*Mugil curema*	855	7.0
P. setiferus	132	0.5	*Brevoortia tyrannus*	1,260	15.5	*Lagodon rhomboides*	519	4.2
Walden Creek:			*Mugil cephalus*	1,181	14.5	*Mugil cephalus*	406	3.3
L. xanthurus	7,410	49.6	*F. heteroclitus*	799	9.8	*G. boleosoma*	373	3.0
Brevoortia tyrannus	1,666	11.1	*Micropogonias undulatus*	446	5.5	*B. chrysura*	343	2.8
F. heteroclitus	1,240	8.3	*A. mitchilli*	373	4.6	*Gobiosoma bosci*	223	1.8
P. aztecus	1,217	8.1	*Symphurus plagiusa*	334	4.1	*Anchoa mitchilli*	211	1.7
A. mitchilli	1,050	7.0	*Paralichthys* spp.	250	3.1	*Eucinostomus argenteus*	205	1.7
Mugil cephalus	780	5.2	*Gobionellus boleosoma*	213	2.6	*Brevoortia tyrannus*	158	1.3
E. argenteus	304	2.0	*Anguilla rostrata*	209	2.6	*Paralichthys* spp.	123	1.0
C. sapidus	284	1.9	*C. sapidus*	179	2.2	*F. majalis*	85	0.7
Lagodon rhomboides	192	1.3	*Gambusia affinis*	134	1.6	*Penaeus duorarum*	69	0.6
Menidia menidia	175	1.2	*Penaeus aztecus*	117	1.4	*Symphurus plagiusa*	64	0.5
Bairdiella chrysura	112	0.7	*Paralichthys lethostigma*	100	1.2	*Orthopristis chrysoptera*	56	0.5
P. duorarum	101	0.7						

tures might be fatal to the young of many species, especially since they were prolonged (Gunter and Hildebrand 1951; June and Chamberlain 1959; Massman and Pachecho 1960; Joseph 1972).

Seasonality and Growth

In the Cape Fear estuary tidal marshes, peak seasonal abundance (Figure 3) for young commercially and recreationally important species was always associated with the recruitment of postlarvae or early juveniles into the area and subsequent decreases in numbers were due to mortality and/or emigration from the primary nurseries. Although very few postlarval *Micropogonias undulatus* were captured in early 1977, recruitment was improved at the beginning of the 1977-78 larval year, with densities in November 1977 at upriver sites reaching a mean of 31 individuals/400 m^2 (Figure 3, upper left). Concentrations of this species in the river mainstem were much higher than in the marshes (Hodson[6]). Red drum, *Sciaenops ocellata*, were captured in relatively low numbers in the fall although their density approached 34 individuals/400 m^2 in the Dutchman Creek collections in October. *Leiostomus xanthurus* postlarvae dominated the sciaenid catches with average densities in March of 3,099 individuals/400 m^2.

Except during the cold period in early 1977, *Mugil cephalus* were fairly common throughout the estuary (Figure 3, lower left), with primary recruitment of early juveniles occurring in March and April. *Mugil curema*, however, displayed a

[6]R. G. Hodson, Director, Cape Fear Estuarine Laboratory, North Carolina State University, Southport, N.C., pers. commun. July 1978.

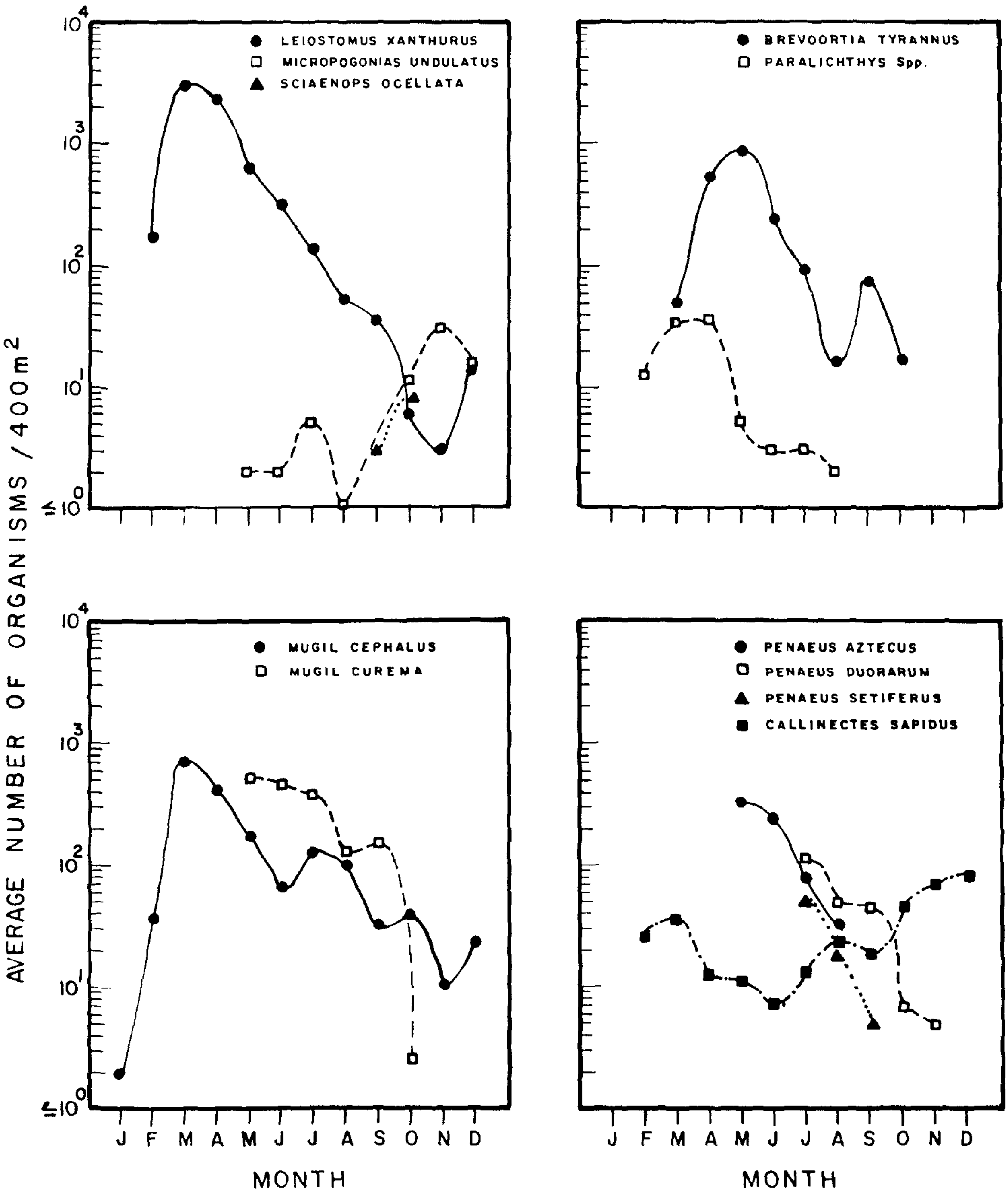

FIGURE 3.—Seasonality for selected estuary species in the Cape Fear River, N.C., 1977.

more distinct seasonal presence in the Cape Fear estuary, with young arriving in May and emigrating nearly completely from the estuary in late fall. The more southerly distribution of this species (Anderson 1957; Moore 1974; Richards and Castagna 1976), perhaps related to temperature tolerance, may be responsible for this pattern.

Other winter-spawned species also were common in the Cape Fear. Flounders of the genus *Paralichthys* were most abundant in March and April when postlarvae first entered the marshes (Figure 3, upper right). *Brevoortia tyrannus* reached peak densities in April and May and were fairly abundant throughout summer and early fall, then they generally migrated out of the shallows in October when temperatures decreased markedly. The pooled data for the Atlantic menhaden, however, do not indicate the large monthly variation observed for catches of this species. In a given creek, densities varied over more than an order of magnitude between months, and peaks of abundance were not coincident among marshes. The only consistent pattern exhibited by the Atlantic menhaden was their generally greater association as postlarvae and early juveniles with intermediate to lower salinities. Except for their brief stay in brackish-water marshes as juveniles, Atlantic menhaden did not seem to establish long-term residency in any area, but instead tended to range throughout the lower salinity portions of the estuary, especially the river mainstem. Their mode of feeding may have contributed to this phenomenon (June and Chamberlain 1959; Jefferies 1975; Durbin and Durbin 1975).

All three species of commercial shrimps (Figure 3, lower right) exhibited distinct seasonal presence: *Penaeus aztecus* was recruited to the marshes as early as May, and white, *P. setiferus*, and pink, *P. duorarum*, shrimp were first captured in July. For all three species, peak densities were recorded during the month of first appearances, and young adults emigrated from the shallow marshes during the fall, especially after October. *Callinectes sapidus* (Figure 3, lower right) generally were abundant in all months, with a peak of recruitment in November and December. Apparently, the absence of early juveniles in January and February 1977 catches reflected heavy mortality or emigration due to the extreme cold in these months.

Length-frequency data for abundant 0 year class fishes and brown shrimp indicated that most of these species resided in tidal creeks at relatively small sizes and grew rapidly after April (Table 6). The smaller increments of growth occurring prior to this month for winter-spawned species resulted from the effects of low temperatures and the masking effect of continued recruitment through March. Extended recruitment periods created a similar "lag" in growth for species spawned in other seasons.

Standing Crops at Peak Recruitment

Patterns of distribution for selected species at the peak of postlarval recruitment are shown in Table 7; in all cases, more than 1 mo was averaged since a plateau was indicated in the data. Catches generally were lower at Baldhead Island stations (including Shellbed Island) for most dominant fishes, suggesting the inability of these marshes to support as much juvenile production per unit area as other Cape Fear marshes or perhaps indicating greater predation pressure in this area. *Leiostomus xanthurus* was relatively evenly distributed although catches of this species and those of *Mugil cephalus* and *M. curema* were lower at Baldhead Island; *M. curema* also was captured in reduced numbers at low salinity sites. In addition, both species of mullet were collected where the substrate contained high levels of organic matter.

Atlantic menhaden postlarvae and early juveniles (17-32 mm) predominated upriver at brackish salinities and also were abundant in Walden and Dutchman Creeks. Although salinity was relatively low in Dutchman Creek in April (11.5 and 12.6‰ at the rotenone and seine sites, respectively) the high catch of menhaden in May at the seine site (742 individuals/400 m^2) occurred at a time when salinity (35‰) was at a yearly maximum. Interestingly, the majority of these fish were of a different age-class (probably yearlings, 50-109 mm) than were the postlarvae and early juveniles that predominated in the April and May collections at other stations. These individuals may have already completed their early developmental period in brackish waters (June and Chamberlain 1959) and were moving freely throughout the Cape Fear estuary. They also apparently made forays into the Walden Creek system, and in other months contributed to the patchiness at all stations described previously.

Penaeid shrimp were an important component of the marsh nekton community during the late spring and summer months. Maximum densities

TABLE 6.—Length data for 0 year class individuals of selected species, Cape Fear River estuary, N.C., all station collections combined. — = data were not available.

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Leiostomus xanthurus:												
Mean length	14.3	19.5	22.4	24.6	33.4	41.3	43.8	49.1	58.4	68.6	89.8	109.4
Range	13-16	13-25	14-30	12-41	16-60	21-69	29-71	36-73	38-98	48-109	54-162	63-174
Sample size	3	412	1,969	1,778	1,275	709	524	373	376	193	41	35
Brevoortia tyrannus:												
Mean length	—	—	27.7	27.0	31.9	33.3	47.3	37.2	52.3	56.8	68.0	67.3
Range	—	—	22-31	17-32	24-44	20-46	37-60	41-43	32-64	43-69	42-86	50-82
Sample size	0	0	300	674	693	306	146	5	54	57	3	3
Mugil cephalus:												
Mean length	21.0	21.9	22.8	25.6	36.0	45.8	62.1	62.3	69.3	76.1	83.6	78.5
Range	19-22	18-28	16-29	17-37	24-62	28-67	35-92	37-94	40-113	48-131	49-118	55-127
Sample size	4	235	1,025	853	816	403	553	382	277	355	149	372
M. curema:												
Mean length	—	—	—	—	25.8	37.0	56.3	61.6	63.1	70.5	75.1	—
Range	—	—	—	—	15-38	21-60	18-87	18-90	18-121	17-135	25-114	—
Sample size	0	0	0	0	718	751	665	392	327	67	71	0
Sciaenops ocellata:												
Mean length	—	—	—	—	—	—	—	14.3	17.5	24.8	39.5	33.5
Range	—	—	—	—	—	—	—	13-15	5-30	12-40	23-47	23-48
Sample size	0	0	0	0	0	0	0	3	39	80	13	10
Paralichthys spp.[1]:												
Mean length	—	13.1	15.4	17.6	—	—	—	—	—	—	—	—
Range	—	9-19	12-21	10-30	—	—	—	—	—	—	—	—
Sample size	0	68	100	169	0	0	0	0	0	0	0	0
Anchoa mitchilli:												
Mean length	—	—	—	—	—	17.3	20.2	21.0	22.3	22.2	26.5	24.6
Range	—	—	—	—	—	8-23	10-35	10-34	11-53	15-53	17-61	19-48
Sample size	0	0	0	0	0	473	540	391	844	715	447	85
Penaeus aztecus[2]:												
Mean length	—	—	—	—	37.7	70.1	88.6	97.6	—	—	—	—
Range	—	—	—	—	18-64	24-113	30-130	24-127	—	—	—	—
Sample size	0	0	0	0	663	421	370	169	0	0	0	0

[1]Probably mostly *Paralichthys lethostigma* which was abundant at upriver stations: 0 year class identified to species after April.
[2]*Penaeus* sp. was collected down to 11 mm TL in May, probably *P. aztecus*.

TABLE 7.—Relative densities (mean number of individuals/400 m^2) for selected species at the peak of postlarval and early juvenile recruitment in the Cape Fear River estuary, N.C. Rotenone collection data are not presented for shrimp, *Penaeus* spp.

Species	Peak recruitment months	Baldhead Creek		Shellbed Island	Dutchman Creek		Walden Creek		Hechtic Creek	Barnards Creek
		Seine	Rotenone	Seine	Seine	Rotenone	Seine	Rotenone	Seine	Rotenone
Leiostomus xanthurus	Mar.-Apr.	1,781	972	1,259	3,474	4,520	2,721	4,043	3,762	[1]1,510
Brevoortia tyrannus	Apr.-May	110	16	24	373	439	505	153	3,821	618
Mugil cephalus	Mar.-Apr.	80	109	172	1,788	970	209	24	909	803
M. curema	May-June	712	179	148	979	2,251	21	73	71	0
Penaeus aztecus	May-June	113	—	0	257	—	525	—	538	—
P. duorarum	July-Aug.	266	—	14	2	—	31	—	92	—
P. setiferus	July-Aug.	0	—	0	60	—	26	—	85	—

[1]April data only.

of brown shrimp occurred at Hechtic and Walden Creeks. Except for a single individual in August, none were collected at Shellbed Island, and catches were also low at the Baldhead Creek site. The presence of shrimp in high densities in Walden Creek is of interest since the organic (detrital) content of the substratum is the lowest of any of the Cape Fear stations. Except for one tributary where nearby construction activities have added large quantities of fine sediments, this creek is well scoured almost its entire length. White shrimp (*P. setiferus*) were most abundant at Hechtic and Dutchman Creeks, where the sediment contained considerable quantities of organic matter and were absent from the high salinity stations in Baldhead Creek and Shellbed Island. On the other hand, pink shrimp reached maximum abundance in Baldhead Creek, while intermediate numbers were also collected at Hechtic Creek.

Community Patterns

Numerical classification analysis was employed to detect underlying patterns among marsh nekton communities (Figure 4). Two primary station clusters were discerned by this procedure, a group consisting of the Baldhead Island sites (i.e., Baldhead Creek seine and rotenone stations and Shellbed Island) and a second group composed of the Walden and Hechtic Creeks and the Dutchman Creek seine station. The latter cluster was joined by the Walden and Dutchman Creek rotenone sta-

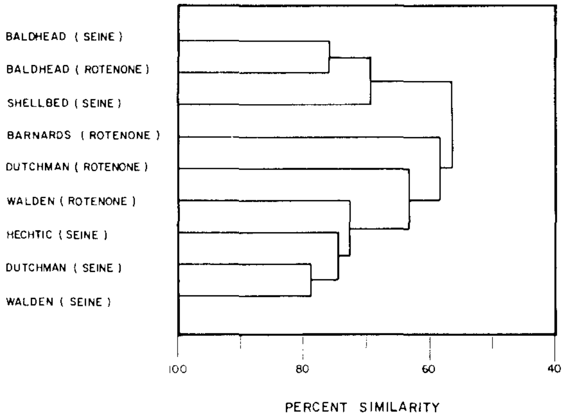

FIGURE 4.—Similarities among all stations collected from February to December 1977 in the Cape Fear River estuary, N.C. Associations in dendogram are based on pooled monthly collections. Sampling was not initiated at Barnards Creek, N.C., until April.

tions and by the Barnards Creek site which exhibited the lowest overall degree of association. Although the physicochemical factors at the Barnards Creek site differed in some respects from those of other stations (particularly with respect to percent organics, Table 1), it should be emphasized that this station was not collected until April and, therefore, did not reflect a large portion of winter recruitment. Since the rotenone stations were not collected uniformly throughout the year, they were omitted from further analysis. Data for individual species, however, are used to support conclusions drawn from seine studies.

A two-way coincidence table (Table 8) was prepared for seine data collected from February to December 1977 by first clustering the matrix for seine station associations and comparing these with a dendrogram for species associations. In this way, comparisons among stations was facilitated by direct cross-referencing against the characteristics species associations at each site. The five seine stations fell into two clusters at the 65% similarity level, designated A and B in the table. Twelve species association clusters were recognized at this same level. Clearly, several subcategories of marsh communities may be distinguished for the Cape Fear region, although the marshes also share many commonalities, as indicated in Figure 4 by the generally high similarity values among station clusters (>55%).

Members of Group III (Table 8) were generally ubiquitous, with most difference being reflected in relative numbers. *Leiostomus xanthurus*, *Mugil cephalus*, and *Brevoortia tyrannus*, for example, were more prevalent at Hechtic, Walden, and Dutchman Creeks, while the bay anchovy, *Anchoa mitchilli*, and *Menidia menidia* dominated at Baldhead Island stations. Species groups I, IV, and X were characterized by the lower salinities at Hechtic and Walden Creeks and included species present in relatively higher densities, such as the tidewater silverside, *M. beryllina*, and species normally associated with lower salinities, such as gizzard shad, *Dorosoma cepedianum*; mosquitofish, *Gambusia affinis*; *Anguilla rostrata*; and juvenile *Micropogonias undulatus*. Two freshwater fishes, the bluegill, *Lepomis macrochirus*, and golden shiner, *Notemigonus crysoleucas*, also were captured at these sites. In rotenone collections, by comparison, tidewater silverside were absent from Baldhead Creek collections and only six specimens were captured at Dutchman Creek. In Walden Creek, this species was a relativley abundant member of the community, contributing 1.3% of the total number of individuals (Table 5). At Barnards Creek, however, only 15 individuals were captured. Several other species were also more abundant in low salinity rotenone collections, postlarval and juvenile *M. undulatus* (9-83 mm), for example, were the fifth most abundant species captured in Barnards Creek samples, and *A. rostrata* and *G. affinis* contributed 2.6 and 1.6% of the total number of individuals, respectively (Table 5).

The Baldhead Creek and Shellbed Island sites form a complex that is influenced by the nearby marine environment. Groups VII, VIII, and IX included many species associated with intermediate to higher salinities and probably also reflected additional parameters such as the substratum composition and proximity to the ocean entrance. Several stenohaline marine species were collected only at these locations. These included rough silverside, *Membras martinica*; several species of searobins, *Prionotus* spp.; windowpane flounder, *Scopthalmus aquosus*; summer flounder, *Paralichthys dentatus*; fringed flounder, *Etropus crossotus*; gag, *Mycteroperca microlepis*; southern blue crab, *Callinectes similis*; inshore lizardfish, *Synodus foetens*; and pigfish, *Orthopristis chrysoptera*. Except for *Scopthalmus aquosus* and *E. crossotus*, these species were also recorded in low to intermediate densities from Baldhead Creek rotenone collections (e.g., pigfish ranked 17th in abundance out of a total of 61 taxa collected). Members of the genus *Prionotus* were not

TABLE 8.—Two-way coincidence table comparing dendograms for station and species associations in the Cape Fear River estuary, N.C., February-December 1977. The two station clusters, designated A and B, are cross-referenced against 12 species clusters derived from previous calculations. Dendrograms are not shown.

B			A			
Dutchman Creek	Walden Creek	Hechtic Creek	Shellbed Island	Baldhead Creek	Species	
	2				*Notemigonus crysoleucas*	I
	3				*Morone saxatilis*	
	10				*Alosa aestivalis*	
1	1				*Trinectes maculatus*	II
2	1	2		5	*Cynoscion nebulosus*	III
2	26	16	3	1	*Stronglyura marina*	
741	1,217	1,199	1	266	*Penaeus aztecus*	
2,510	175	57	8,758	1,510	*Menidia menidia*	
231	304	6	405	106	*Eucinostomus argenteus*	
824	50	7	46	541	*Fundulus majalis*	
2,582	83	199	354	1,668	*Mugil curema*	
67	101	247	31	657	*Penaeus duorarum*	
24	192	89	55	70	*Lagodon rhomboides*	
1,387	1,666	7,967	71	287	*Brevoortia tyrannus*	
938	284	265	41	162	*Calinectes sapidus*	
4,160	780	3,009	525	263	*Mugil cephalus*	
502	112	160	115	108	*Bairdiella chrysura*	
3,056	1,240	590	730	938	*Fundulus heteroclitus*	
8,534	7,410	7,953	3,023	3,918	*Leiostomus xanthurus*	
1	29	14	19	48	*Paralichthys* spp.	
151	1,050	660	8,927	4,330	*Anchoa mitchilli*	
1	21	13			*Gambusia affinis*	IV
1	6	10			*Dorosoma cepedianum*	
1	82	199			*Menidia beryllina*	
4	3	122	3		*Micropogonias undulatus*	
3	3	8	2		*Caranx hippos*	
2	1	3	2		*Pomatomus saltatrix*	
6	2	49		1	*Anguilla rostrata*	
27	4	22		2	*Elops saurus*	
132	70	171			*Penaeus setiferus*	
1		15		32	*Syngnathus louisianae*	V
1	1	9		9	*Gobionellus boleosoma*	
		13	3	114	*Gobiosoma bosci*	
		20	1	7	*Lutjanus griseus*	
		2	5		*Citharichthys spilopterus*	VI
		2	4		*Caranx latus*	
			21		*Membras martinica*	VII
			3		*Citharichthys macrops*	
1	2	2	27	48	*Symphurus plagiusa*	VIII
	1	2	5	16	*Monacanthus hispidus*	
		1	1	1	*Myrophis punctatus*	
	1		9	3	*Paralichthys dentatus*	
			5	2	*Mycteroperca microlepis*	
			2	1	*Etropus crossotus*	
			295	11	*Anchoa hepsetus*	
			3	1	*Scophthalmus aquosus*	
			3	1	*Prionotus carolinus*	
	1		9	18	*Synodus foetens*	
			34	91	*Callinectes similis*	
			19	29	*Orthopristis chrysoptera*	
			1	2	*Prionotus scitulus*	
			3	10	*Priontus tribulus*	
				4	*Opsanus tau*	IX
				21	*Syngnathus fuscus*	
				3	*Prionotus evolans*	
				2	*Lutjanus synagris*	
				5	*Astroscopus y-graecum*	
			1	15	*Gobiosoma ginsburgi*	
		2			*Lepomis macrochirus*	X
		2			*Lucania parva*	
		2			*Evorthodus lyricus*	
2		1		1	*Chaetodipterus faber*	XI
62		1		2	*Sciaenops ocellata*	
3					*Pogonias cromis*	XII
3					*Gobionellus hastatus*	
2					*Trachinotus falcatus*	

recorded from low salinity sites with the exception of the two very small, unidentified species from Walden Creek in August (salinity 18.3‰). Also absent from low salinity rotenone collections were *S. aquosus*, *E. crossotus*, and *P. dentatus*; on the other hand, the southern flounder, *P. lethostigma*, was common at low salinity stations and was the 14th most abundant species at Barnards Creek, composing 1.2% of the total captured. A winter visitor to the estuary, striped cusk-eel, *Rissola marginata*, was present in Baldhead Creek rotenone collections; a total of 15 specimens were captured during February-April, and a single specimen was also captured at the seine site. At least three estuarine species with a previously reported preference for higher salinities were collected in larger numbers at Baldhead Island stations, the Atlantic silverside (Johnson 1975), striped killifish (Griffith 1974), and blackcheek tonguefish, *Symphurus plagiusa* (Gunter 1945; Reid 1954), which also was taken in substantial numbers in Dutchman Creek.

The affiliation of Dutchman Creek presents an interesting case among marshes. Recent construction activities nearby have effectively reduced the input of freshwater to this orginally brackish water creek (Birkhead[7]). Thus, apparently in the process of change, Dutchman Creek retains both original similarities to Walden Creek, and "newer" associations with higher salinity marshes (e.g., for the Atlantic silverside and white mullet).

DISCUSSION

Tidal Creeks as Nurseries

Due partly to sampling difficulties, the nursery role of tidal salt marshes, especially the shallow upper reaches of tidal creeks, has seldom been investigated (Herke 1971; Copeland and Bechtel 1974; Cain and Dean 1976). Nevertheless, it is this very habitat that has been defined by Purvis (see footnote 2) and others (Kilby 1955; Herke 1971; Dahlberg 1972) as one of the primary nursery zones where initial postlarval development takes place. Populations of marine-spawned species in the areas Purvis studied in Pamlico Sound, N.C., (low salinity, shallow tributaries with mud or mud-grass bottoms) were uniformly of very early juveniles. In the past, several investigators have pointed to the relationship between the size of organisms in an area and salinity as an indicator of the primary nursery grounds (Gunter 1945, 1961, 1967; Herke 1971; Dahlberg 1972; Copeland and Bechtel 1974). Others, however, have noted that the size-salinity relationship is not a simple one, and that interactions with food supplies, substratum characteristics, and other physicochemical factors dictate preferred zones for nursery utilization (Kilby 1955; Reid 1957; Simmons 1957; Dawson 1958; Reid and Hoese 1958; McHugh 1967; Parker 1971).

Results of my study demonstrate that shallow tidal creeks and marsh shoals of the Cape Fear River estuary harbor dense populations of postlarvae of several marine-spawned species. Field observations showed that young fishes and shellfish were actively seeking the creek headwaters, that in effect, the marshes fill up backwards during recruitment. Postlarval spot, *Mugil* spp., *Paralichthys* spp., red drum, and other species accumulated in great numbers in the upper reaches of the creeks and gradually decreased in densities downstream. Ichthyoplankton tows in the mouths and a short distance upstream in these same creeks yielded much lower concentrations of postlarvae than collections closer to the headwaters (Hodson see footnote 6). Although the gear deployed in these surveys differed, recent studies of gear efficiency indicated that the methods are reasonably similar (Weinstein and Davis in prep.). The period of residency in these habitats is apparently lengthy; winter recruits of several species were abundant throughout the summer (Figure 3); and a mass exodus did not seem to take place until the following fall. Other studies have shown, however, that larger members of the population tend to move downstream as they grow, leaving behind slower growing individuals and newer recruits (Herke 1971: Dunham 1972; Purvis see footnote 2).

Parallel conclusions on the comparative richness of shallow marsh habitats were reached by Marshall (1976). Employing similar sampling techniques, including the use of 1 mm mesh seines, he reported densities of spot, *Mugil* spp., Atlantic menhaden, and brown shrimp in two marsh areas altered by ditching for mosquito control to exceed $0.1/m^2$. Standing crops of most species in the natural creeks and ditches he studied were among the highest ever reported for small estuarine nekton. A survey of the literature

[7]W. Birkhead, Associate, Cape Fear Estuarine Laboratory, North Carolina State University, Southport, N.C., pers. commun. April 1978.

by Marshall (1976) supported this observation, even higher densities for total nekton were noted in the studies of Turner and Johnson (1974) in South Carolina tidal marshes. However, Marshall cautioned that the efficiency and selectivity of gear used to study various estuarine areas may, in part, be responsible for some of the differences seen among areas. Average densities in my study for the same species listed by Marshall all exceeded 0.1 organism/m^2 except for brown shrimp. When seine data alone were considered for this species, however, densities of 0.1/m^2 were recorded.

The utilization of the marsh shallows does not, however, hold for all postlarvae that inhabit the Cape Fear region. Atlantic croaker, for example, occurred primarily in the deeper water of the river from the vicinity of the salt boundary through the mesohaline zone. As postlarvae, this species was noticeably absent in the downstream marshes and densities generally were low at upstream stations. The Atlantic croaker was not listed among the 10 most abundant species captured in each of two marsh areas near Beaufort, N.C., by Marshall (1976), nor was it among the 10 most abundant species collected in six tidal creeks located near Port Royal Sound, S.C. (Turner and Johnson 1974). In my study, only one specimen of the 1976-77 year class was collected before May, when juveniles (27-35 mm) appeared at low salinity stations. In the early stages of recruitment for the 1977-78 year class, however, low densities of postlarval and early juvenile croaker (9-19 mm) were collected, principally at Hechtic and Barnards Creeks. Haven (1957) and Wallace (1940) observed a similar distribution in the Chesapeake Bay, and for most Atlantic and Gulf coast estuaries containing deeper channels, this relationship seems to hold (Welsh and Breder 1923; Suttkus 1955; Nelson 1969). However, the Atlantic croaker also utilizes the marsh shallows extensively in some of the Gulf states, including Louisiana, Texas, and Mississippi (Herke 1971; Parker 1971; Arnoldi et al. 1974; Yakupzack et al. 1977). In the Cape Fear region, where there are extensive marshes, the Atlantic croaker is simply absent. Perhaps minimum temperatures during winter recruitment in the Cape Fear and other middle Atlantic coast estuaries are limiting for this species (Joseph 1972). Another species that seems to prefer open waters is the Atlantic menhaden, which was captured in lower numbers in the interior marshes than on the river shoals and in the ship channel (Hodson see footnote 6). Since postlarvae feed primarily on zooplankton (Thayer et al. 1974) which are found in higher concentrations out in the estuary (Jefferies 1975), this preference for open waters is not surprising.

These observations lead to conjecture as to the mechanisms that may reduce potential competition among the early life stages of species with similar food requirements (Thayer et al. 1974; Kjelson et al. 1975). The results of recent studies (May 1974; Thayer et al. 1974; Lasker 1975; Houde 1977; Laurence 1977) suggested that food supplies are potentially limiting in estuaries and nearshore areas and that critical densities of food items were required at several larval developmental stages. If species were undergoing diffuse competition (MacArthur 1972), they might, therefore, benefit from behavioral patterns that resulted in temporal and/or spatial segregation on the nursery grounds. There are apparently two major nursery areas in the Cape Fear estuary: the interior marshes, including the shallow marsh fringe, and the river mainstem at the head of the estuary. Related or potentially competitive species, by utilizing either one of these zones, may remain spatially segregated.

Seasonal presence also may enhance survival of many species; the data showed this clearly for white and striped mullet and for penaeid shrimp although local variables within each major nursery zone also influenced patterns of distribution for these groups. For example, white and pink shrimp were recruited at similar times of the year, yet they separated within the marsh zones on the basis of salinity. White mullet were much more abundant at high salinities in areas with sediments containing considerable quantities of organic matter; striped mullet were distributed throughout the estuary although they, too, were most abundant where sediments contained a high level of organics.

Salinity preferences for several dominant species are treated statistically in Table 9. Although consistent relationships appeared in the data, monthly values reflected local variations in freshwater flow. In September, for example, heavy rainfall in the vicinity of Dutchman Creek depressed salinities 16‰ below the previous collection date. The resident population of white mullet apparently remained in the area and catches were high (1,112 individuals/400 m^2 at the rotenone site). Along with lower catches for this species elsewhere in the system, this observation suggests

TABLE 9.—Partial correlations (given temperature) of species abundance with salinity in the Cape Fear River estuary, N.C. Collections with <10 individuals of a given species in any month were omitted from the calculations. N.C. = >10 individuals collected. **P<.01.

Species	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Pooled	χ^2	df
Leiostomus xanthurus	-0.449	-0.808	-0.582	0.176	-0.237	-0.493	-0.783	-0.751	-0.210	-0.449	0.577	-0.409**	13.870	10
Menidia menidia	.387	.983	.747	.856	.799	.546	.673	.676	.722	.799	.732	.777**	10.244	10
M. beryllina	-.509	N.C.	N.C.	N.C.	-.547	-.604	-.719	-.755	-.469	-.820	-.855	-.693**	2.705	7
Mugil cephalus	.525	-.132	.080	-.637	-.501	-.118	-.304	-.769	.374	-.418	.060	-.291	8.312	10
M. curema	N.C.	N.C.	N.C.	.769	.757	.627	.624	.067	.252	N.C.	N.C.	.560**	3.783	5
Symphurus plagiusa	N.C.	N.C.	N.C.	N.C.	N.C.	-.018	-.217	-.068	-.625	.523	N.C.	-.092	4.428	4
Brevoortia tyrannus	N.C.	-.001	-.735	-.570	-.555	-.274	-.334	.537	-.110	N.C.	N.C.	-.426**	3.243	7
Fundulus heteroclitus	-.293	-.397	.269	-.675	.438	.343	.441	.094	.169	.043	.082	.060	7.622	10
F. majalis	.665	.669	.887	.514	.700	.544	.600	.873	.453	.460	.654	.673**	4.827	10
Micropogonias undulatus	N.C.	N.C.	N.C.	-.765	-.724	-.781	N.C.	N.C.	-.580	-.648	-.576	-.688**	0.732	5
Bairdiella chrysura	N.C.	N.C.	N.C.	N.C.	.146	.015	.518	.628	N.C.	N.C.	N.C.	.353	1.761	3
Anchoa mitchilli	N.C.	N.C.	N.C.	.449	.537	-.271	-.084	.109	-.058	.030	.242	.130	3.090	7
A. hepsetus	N.C.	N.C.	N.C.	N.C.	.355	.324	.542	.585	N.C.	N.C.	N.C.	.459	0.421	3
Lagodon rhomboides	-.111	-.474	-.032	-.099	-.162	-.289	.384	-.290	-.332	N.C.	.857	-.003	11.804	9
Sample size (stations)	7	8	9	9	9	9	9	9	9	9	9			

[1]χ^2 values are based on tests of equality among correlations of the 11 monthly collections; none were significant; therefore, all individual correlation values were pooled.

a lack of correlation of distribution with salinity. This effect occurred in other months for other species and is consistent with the patterns of distribution of estuarine organisms and their ability to withstand wide ranges of salinity, at least over the short term. What is important, however, is that during the course of residency in the marshes, the presence of several species was significantly correlated with salinity. Gunter (1961) draws a similar conclusion by stating that correlation is not necessarily with a given salinity but rather with the gradient as a whole.

Of the species tested (Table 9), striped mullet; blackcheek tonguefish; mummichogs; silver perch, *Bairdiella chrysura*; pinfish, *Lagodon rhomboides*; bay anchovy; and striped anchovy, *A. hepsetus*, were distributed independently of salinity. In several instances, a considerable portion of the variance associated with abundance data was explained by salinity alone; this was true for the Atlantic and tidewater silversides and for the striped killifish and Atlantic croaker. Although other r values were significant (P<0.01) it is obvious that factors other than salinity were contributing to patterns of distribution.

Substrate characteristics have been shown to influence invertebrate populations and the structure of fish communities (Mills 1975). In this study, the distribution of several species also appeared influenced by properties of the sediment (Table 10). The abundance of *Menidia menidia* and *M. beryllina* was negatively correlated with percent organics, and the former species displayed a similar relationship with sorting coefficient. This is not at all surprising in light of their mode of feeding and the presence of currents which probably act to carry food items through the area. On the other hand, young striped mullet which relies heavily on detritus in its diet (Odum 1968) was expected to display a positive association with percent organics, but this did not occur with respect to all creeks concerned. If Barnards Creek was omitted from the calculations, however, the relationship became highly significant. The extremely high organic content of Barnards Creek sediments probably is indicative of highly reducing conditions, and may, in fact, have contributed to the low total fish catch in this creek.

TABLE 10.—Partial correlations (given salinity) of species abundances with several sediment parameters in the Cape Fear River estuary, N.C. Collections with <10 individuals of a given species in any month were omitted from the calculations. Values in parentheses do not include Barnards Creek. ** = P<.01.

Species	Percent organics	Sorting coefficient	Fine sand
Menidia menidia	-0.410**	-0.468**	0.234
M. beryllina	-.655**	-.123	-.009
Mugil cephalus	.065 (.562**)	.588**	.364
M. curema	-.136 (.743**)	.620**	-.399**
Symphurus plagiusa	.628**	-.326	.210
Micropogonias undulatus	.553**	.366	-.193
Fundulus heteroclitus	.297	.565**	-.353**
Anchoa mitchilli	.031	-.310	.511**

Two other species exhibited a positive relationship with percent organics, the blackcheek tonguefish and the Atlantic croaker. The blackcheek tonguefish commonly is associated with muddy bottoms and high salinity (Gunter 1945; Kilby 1955) although salinity did not seem to play a role in governing its distribution in the Cape Fear region (Table 7). Darnell (1958) has described the feeding preference of young croaker for organic matter and since this species tends to accumulate toward the headwaters of many systems (where deposition is greatest), this result may have been expected.

Thus, both spatial and seasonal programming seem to play an integral role in habitat partitioning among ocean-spawned recruits utilizing Cape Fear estuary primary nurseries. Whether or not this partitioning results in enhanced survival of otherwise competing species remains an area for fruitful research.

Community Composition

Each marsh community in the Cape Fear estuary displayed several unique characteristics. In addition to seasonal differences in species richness, abundance relationships varied among marsh complexes (Tables 5, 8). Although some species appeared in relatively low numbers, they only occurred in certain areas or were much more abundant in a specific marsh complex. The Atlantic croaker, southern flounder, mosquitofish, and the seasonal capture of freshwater species including white catfish, *Ictalurus catus*, bluegill, golden shiner, *Notemigonus crysoleucas*, and largemouth bass, *Micropterus salmoides*, were associated with low salinity sites (Walden, Hechtic, and Barnards Creeks). More abundant members of these communities also seemed to display a preference for lower salinities including tidewater silverside and 0 year class Atlantic manhaden (see also Table 9).

Two groups apparently set the high salinity marshes apart from other areas. Several species, usually associated with estuaries during the early part of their life cycle, were restricted mainly to the polyhaline zone. Pigfish, white mullet, red drum, and southern blue crab were in this category and along with two permanent marsh residents, Atlantic silverside and striped killifish were much more abundant or were only captured at high salinities.

The predominance of sandy areas near Baldhead Island, in combination with higher salinity, attracted several species—e.g., the windowpane, rough silverside, spotted whiff, *Citharichthys macrops*, inshore lizardfish, and bighead sea robin, *Prionotus tribulus*—were in this group.

The proximity of the Baldhead Island marsh to the ocean entrance also provided suitable conditions for invasion by several stenohaline species not usually associated with estuaries. Many of these species were seasonal visitors to the area and their general rarety suggests that the marsh is not a primary nursery habitat. Young sergeant major, *Abudefduf saxatilis*; great barracuda, *Sphyraena barracuda*; Atlantic spadefish, *Chaetodipterus faber*; lookdown, *Selene vomer*; lane snapper, *Lutjanus synagris*; gag, and others are seldom collected in marshes and, in fact, would probably be classified as reef species. McHugh (1967) has described these species as adventitious invaders of the estuary.

The majority of community dominants captured in this study were transient in the marshes, being resident for only part of their life cycle. The only permanent residents which were dominant members of the marsh community were mummichog, striped killifish, and Atlantic silversides. Thus, energy flow at higher trophic levels is predominantly through those species that utilize the marsh nurseries in the first year of life. Although larger individuals of these species probably make feeding forays into the upper tidal creeks, their importance in these areas is not known.

Not surprisingly then, species richness was greatest in areas (Baldhead Island and upriver) influenced by the marine and freshwater biotas. It is tempting to relate higher species diversity to more stable physicochemical conditions existing at these sites, yet as indicated in Table 1, salinity and temperature variations were generally similar at all stations. A more plausible explanation of these phenomena may lie in what has been described as an "edge effect" (Odum 1971). Thus, Baldhead Island forms a mixing zone for estuarine, shelf, and reef faunas as evidenced by the seasonal invasion of the latter forms. Similarly, Barnards and Hechtic Creeks are influenced by fresh and brackish faunas at various times of the year.

It is a remarkable observation that if all the transient members of the shallow marsh community were removed, that the remaining, permanent estuarine residents would form a community distinguished by the paucity of its members (Emery and Stevenson 1957). The importance of the link, or continuum, between the estuary and the nearshore marine environment and the energy transfers therein, is highlighted by this observation. It seems obvious that the functional integrity of the estuarine ecosystem is as much dependent on the marine fish community as the members of that community are dependent on the estuary for part of their life cycle. Continued productivity, within the estuary and marine environment for certain species important to man may indeed, depend on the continued health of this relationship.

CONCLUSIONS

Shallow marsh habitats are demonstrably critical areas for the earliest developmental stages of fishes and shellfish. Postlarvae of most species important to man were found to reside in immense numbers at the headwaters of shallow tributary creeks and along the marsh fringe at the rivers edge. With few exceptions these species were the community dominants at all study sites.

Salinity seemed to play an important role in governing spatial distributions of many species and to a lesser extent substratum characteristics interacted with salinity to restrict certain species to a narrow range of habitats. Based partly on these observations, a hypothesis has been established whereby seasonal programming and spatial distributions mediated by salinity and substratum preferences (and probably other factors) may serve to reduce competition among species recruited to the estuary throughout the year.

Similarly, these and other physicochemical parameters, which affect individual tolerances, create unique conditions in each marsh complex that affects the composition of the nekton community. Species richness was highest in the marshes closest to the ocean entrance where higher salinities allowed seasonal invasion by marine forms otherwise unable to reside in the estuary. An apparently similar phenomenon, more limited in extent, occurred at the head of the estuary for freshwater species. Despite the seasonal progression of species, it is apparent that marsh communities in the Cape Fear are highly structured and are able to maintain a specific identity throughout the year.

ACKNOWLEDGMENTS

I am grateful to J. P. Lawler of the Lawler, Matusky & Skelly (LMS) Engineers and W. T. Hogarth of the Carolina Power and Light Co. for the opportunity to conduct these studies. I am also grateful to the biotechnicians of LMS, in particular, R. Beatty, R. Davis, L. Gerry, J. Hecht, W. Pollard, and P. Woodard for their conscientious efforts in the field and laboratory; the quality of their work added measurably to the success of this study. Several individuals have provided constructive criticism of the manuscript including K. L. Heck, J. P. Lawler, G. W. Thayer, R. L. Wyman, and two anonymous reviewers. S. Weiss contributed significantly with his expertise in statistics, and J. Berkun, B. McKenna, and S. Kaufman provided editorial and typing assistance. This program was funded by the Carolina Power and Light Co.

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