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Distribution and Relative Abundance of Fishes in Newport River, North Carolina

WILLIAM R. TURNER and GEORGE N. JOHNSON

SEATTLE, WA
September 1973

National Marine Fisheries Service, Special Scientific Report--Fisheries Series

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Distribution and Relative Abundance of Fishes in Newport River, North Carolina

WILLIAM R. TURNER[1] and GEORGE N. JOHNSON[2]

ABSTRACT

Monthly sampling in Newport River during 1970 disclosed a total of 104 species of fishes within the system. Sampling extended from the lower reaches of the estuary upstream into tidal fresh waters, and covered a mid-channel distance of 34.87 km. To sample as wide a range of species as possible, an array of collecting gear was used, i.e., haul seine, surface trawl, bottom trawls (two sizes), and gill nets. In terms of catch per unit of effort the surface trawl was the most successful gear employed, whereas gill nets, the least efficient gear, captured the greatest variety of species.

Most of the species of fishes collected in the system were marine forms. Only 15 essentially freshwater species were collected and 5 of these (longnose gar, gizzard shad, golden shiner, white catfish, and black crappie) showed varying degrees of tolerance for saline waters (0.6-33.7‰).

Relative numbers of fishes in collections by the different gears indicated that seven species made up 97% of the total catch which comprised nearly 129,000 individuals. The dominant species were all marine euryhaline forms that used the estuary as a nursery area, penetrating well upstream into brackish or even tidal fresh waters. Seasonal distribution and abundance of the dominant species, as well as other species collected in substantial numbers, are discussed.

Biomass of fishes in collections by haul seine was estimated at 0.93 g/m^2 for littoral waters of the estuary. Samples collected by other gears did not yield satisfactory estimates of biomass.

INTRODUCTION

In 1970 we initiated a study of the fishes of Newport River to obtain an inventory of species within the system and to determine their seasonal distribution and relative abundance. During the past decade researches in estuarine ecology have been conducted on Newport River near Beaufort, N.C., by the National Marine Fisheries Service, Atlantic Coastal Fisheries Center, to obtain data for construction of a mathematical model describing energy flow within the system and to develop study techniques applicable to estuaries in general. Annual phytoplankton production in Newport River estuary and vicinity was reported by Williams and Murdoch (1966) and Williams (1966). Zooplankton production was estimated by Williams, Murdoch, and Thomas (1968). Williams and Thomas (1967) also estimated the biomass of benthic organisms in a small segment of the estuary. The importance of cord grass, *Spartina alterniflora*, was assessed by Williams and Murdoch (1969), and evaluations of other salt-marsh and rooted aquatic vegetations are currently in progress. Cycling of trace elements in the sediments, waters, and polychaetous worms of the estuary was reported by Cross, Duke, and Willis (1970). To date, however, estimates of the population size and energy requirements of pinfish, *Lagodon rhomboides*, (Angelovic, Hoss, and Thayer, 1969) represent the only published information on fishes in the system. Thus, although parts of the research essential to developing the model are completed, fishes until now have received little

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attention. Our research on the fishes of Newport River in this paper, although not providing the type of quantitative information needed for mathematical modeling, is serving as a guide for ongoing quantitative studies on the biomass and numerical abundance of these fish populations.

DESCRIPTION OF STUDY AREA

Newport River originates on the coastal plains of North Carolina in a swampy area near a group of natural lakes in the Croatan National Forest. The northwest prong (6.08 km long) and the southwest prong (14.02 km long) are the two main tributaries which converge to form the river proper. From the confluence of these two prongs, the river courses eastward for 18.57 km then broadens into the Newport estuary (Fig. 1). The estuary continues eastward then dips south to join the Atlantic Ocean at Beaufort Inlet. From the mouth of the river to its juncture with the ocean, the linear distance along the main channel of the estuary is 19.18 km. The surface area of the estuary has been estimated at 31 km^2 (Cross, Duke, and Willis, 1970); whereas the surface area of the river proper, from the junction of the two prongs to the mouth, is only 0.48 km^2.

The upper section of the river drains hardwood swamps and pine forests which yield downstream to marshlands. The banks are low but steep, and grade sharply into the channel with very little or no littoral area. Channel depths range from 0.6 m, where the river shoals near the mouth, to 4.6 m in the deepest upstream pocket. Mean channel depth was estimated from a series of soundings to be 3.0 m at low tide.

Newport River estuary is generally less than 1.0 m deep at mean low tide, and the shallow

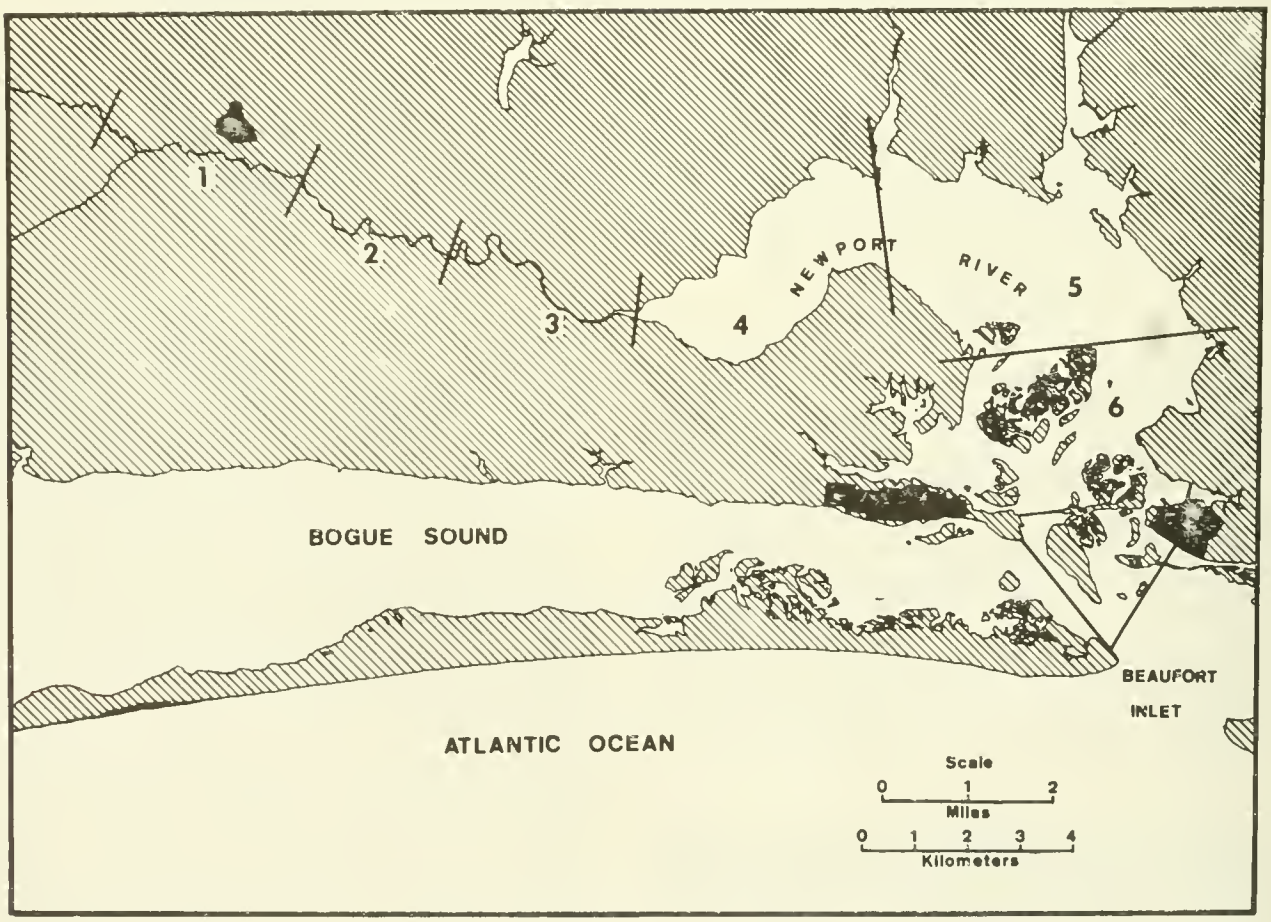

Figure 1.—Zones designated for sampling fishes in Newport River, N.C., during 1970.

waters are well mixed by wind and tidal action. The intracoastal waterway traverses the lower portion of the estuary and forms a connection with Neuse River through Core Creek (Adams Creek Canal). A second connection with the Neuse River is formed by an abandoned canal linking Harlowe Creek to Clubfoot Creek. Exchange of waters with the Neuse River through these canals may have some effect upon the hydrology and species composition of Newport River.

METHODS

To facilitate the description of fish distribution and the location of hydrological observations, the river was divided into six zones, three in the upper river between the forks and the estuary and three in the lower river or estuary (Fig. 1). The end of navigable waters, at river km 34.87, determined the upstream boundary of Zone 1. Zone boundaries downstream were spaced as evenly as possible and located at points with conspicuous land marks.

A variety of collecting gear was used to sample for a wide range of species in different habitats. A haul seine was used in shallow littoral areas and bottom trawls (two sizes) and a surface trawl in deeper waters. Anchored gill nets, the only stationary gear employed, were fished from surface to bottom in open waters.

Physiography of the system dictated the types of gear fished in each section of the river. The surface trawl (8 stations) and small bottom trawl (4 stations) were fished only in the upper river, while the haul seine (6 stations) and large bottom trawl (5 stations) were fished only in the lower river or estuary. Gill nets were fished in each zone throughout the system (3 stations in the upper river, and 3 regular and 2 alternate stations in the lower river). The surface trawl was limited to fishing in the upper river because of the greater amount of net avoidance encountered in the broader expanse and more transparent waters of the estuary. A larger bottom trawl was used in the estuary than in the upper river to provide a more representative sampling of the larger waters. The larger trawl could not be maneuvered in the narrow confines of the upper river. Steep banks and soft mud bottoms precluded haul seining in the upper river. The total amount of effort expended in each zone during 1970 is summarized in Table 1. Generally, each station was occupied monthly and all samples taken within a 2-week period.

Two bottom trawls of similar construction but of different sizes were used during the surveys. The smaller net was 2.7 m across the headrope and 3.0 m along the footrope, and the larger was 5.8 m across the headrope and 6.1 m along the footrope. A 5-mm diameter chain was fastened along the footrope of each trawl for weighting the bottom line. The trawls were made of 19-mm bar mesh knotted nylon in the body and wings and 6-mm bar mesh in the cod. Otter boards of appropriate size were fastened directly to the ends of the wings. A tickler chain (5-mm diameter), about 0.5 m shorter than the footrope, was suspended between the otter boards to stir the bottom in front of the trawls. Three 8.9-cm diameter floats were attached to the headropes to open the mouths of the trawls. The larger net was towed by a 7.6-m inboard-outboard vessel using two 18.3-m lengths of rope attached to separate warps. The smaller net was towed between two 4.9-m outboard motorboats by two 9.1-m length ropes. The small trawl was towed for 5 min at each station, and the large trawl for 10 min at a station.

The haul seine was 1.2 $\times$ 21.3 m with a 1.2 m^2 center bag. The wings of the seine were 5-mm and the bag was 3-mm (bar measure) woven nylon mesh. The seine was pivoted in a 15.2-m radius around a focal point on the shoreline; one semi-circular sweep covered an area of 363 m^2. One haul was made at each station.

The surface trawl, modified from a net originally described by Massmann, Ladd, and McCutcheon (1952), had a mouth opening 6.7 $\times$ 0.9 m and tapered 6.1 m to the cod end. The wings and body consisted of 6-mm and the tail bag of 3-mm nylon mesh. The trawl was towed downstream between two outboard motorboats for 5 min at each station. A chain attached to the footrope and floats attached to the headrope kept the mouth of the trawl open while under tow.

Experimental gill nets were 2.4 m deep by 38.1 m long and consisted of five equal panels of 2.5-, 3.8-, 5.1-, 6.3-, and 7.6-cm bar mesh monofilament nylon webbing. Additional nets of 1.9-, 3.5-, and 10.2-cm mesh were fished occasionally. The nets were anchored at both ends and fished for a recorded period of time at each station.

Table 1.--Monthly distribution of sampling effort in the Newport River, 1970.

Fishing gear	J	F	M	A	M	J	J	A	S	O	N	D	Total
						Number hauls							
Surface trawl													
Zone 1	2	2	2	2	2	2	2	2	2	2	2	2	24
2	3	3	3	3	3	3	3	3	3	3	3	3	36
3	3	3	3	3	3	3	3	3	3	3	3	3	36
Bottom trawl (3 m)													
Zone 1	1	1	1	1	1	1	1	1	1	1	1	1	12
2	1	1	1	1	1	1	1	1	1	1	1	1	12
3	2	2	2	2	2	2	2	2	2	2	2	2	24
Bottom trawl (6.1 m)													
Zone 4	1	1	1	1	1	1	1	1	1	1	1	1	12
5	2	2	2	2	2	2	2	2	2	2	2	2	24
6	2	2	2	2	2	2	2	2	2	2	2	2	24
Haul seine													
Zone 4	2	2	2	2	2	2	2	2	2	2	2	2	24
5	2	2	2	2	2	2	2	2	2	2	2	2	24
6	2	2	2	2	2	2	2	2	2	2	2	2	24
						Shackle-hours							
Gill nets													
Zone 1	5	1	1	24	16	25	4	5	6	3	5	5	100
2	5	1	1	24	16	3	4	4	4	3	5	5	75
3	6	1	1	24	17	3	4	19	3	3	4	4	89
4	18	1	1	4	1	6	17	5	38	20	17	18	146
5	17	1	1	4	1	7	18	6	74	20	18	19	186
6	55	-	3	6	7	54	55	10	165	53	53	224	685

Fishing effort was expressed in units of shackle-hours (Table 1); one shackle was equivalent to a 7.6-m panel of net.

Fish collections were preserved in 10% Formalin and brought to the laboratory for processing. In catches so large that not all specimens could be preserved, all of the rare species and only samples of the abundant species were taken. A representation of the species collected was preserved in 40% isopropanol and placed in the fish collection at the Center. Processing of fishes included identification, enumeration, and measurement of length (tip of snout to the end of the median caudal ray) and weight. All scientific and common names of fishes referred to in this paper are in compliance with the American Fisheries Society (Bailey, 1970). Water temperature and salinities were measured with a portable induction salinometer during the sampling for fish.

SALINITY AND TEMPERATURE

Salinities in the system ranged from 0.0‰ in the upper river to 33.7‰ in Zone 6 (Table 2). During the summer, salt water penetrated into Zone 1 but during the late winter penetration was only to Zone 4. Salinities were lowest throughout the river during the February-April sampling periods; highest salinities in Zones 3 through 6 were recorded in late summer and early fall, and in Zones 1 and 2 in midsummer. Salinities were most variable in Zone 3, and ranged from 0.0‰ during periods of greatest precipitation (Feb.-Apr.) to 19.3‰ in October. Zone 3, however, was dominated by estuarine waters (>0.6‰ salinity) during most of the year.

Water temperatures (Table 2) were lowest in January, ranging from 6.3° to 6.5°C. Highest temperatures were reached earlier upriver than downriver. The peak temperature was recorded in Zone 1 during July (26.7°C). Peak

temperatures were attained in Zones 2, 3, and 4 during August (27.9°-29.1°C) and in Zones 5 and 6 during September (29.1° and 29.6°C).

FISH DISTRIBUTION AND SALINITY

One hundred and four species of fishes, representing 50 families, were collected during the surveys (Table 3). From 22 to 26 species were taken in each of the three zones in the upper river, while in the lower river numbers of species increased in relation to distance downstream; 53 species were collected from Zone 4, 57 from Zone 5, and 69 from Zone 6. Seventeen species were collected in the upper river exclusively, and 64 species were confined to the lower section of the river; the remaining 23 species ranged over both sections of the river or were found throughout the entire system during some stage of their life cycle.

Thirteen of the 17 species exclusive to the upper river were collected in freshwaters only, 0.0-0.5‰ salinity, while four species (longnose gar, *Lepisosteus osseus;* golden shiner, *Notemigonus crysoleucas*; white catfish, *Ictalurus catus;* and black crappie, *Pomoxis nigromaculatus*) showed a tolerance for low salinity or brackish waters, 0.6-10‰. The longnose gar is a well-known invader of moderate to high salinity waters, but was not taken in the Newport River estuary. Of the 13 species taken only in fresh waters, three are known to occur in saline waters, but their scarcity in the collections reflected a freshwater distributional pattern. They were the anadromous American shad, *Alosa sapidissima*, and white perch, *Morone americana*, and the marsh killifish, *Fundulus confluentus*. Consequently, only 10 species were regarded as strictly freshwater forms.

The fish population of the lower river or estuary was essentially a marine fauna. The only species of freshwater origin collected in the estuary were gizzard shad, *Dorosoma cepedianum*, and the catadromous American eel, *Anguilla*

Table 2.--Mean monthly salinities and temperatures in each zone of the Newport River during periods of actual biological sampling. Lines denote arbitrary divisions of fresh water (0.0-0.5‰) and low (0.6-10‰), moderate (10-25‰), and high (>25‰) salinity.

Month	Zone						Month	Zone					
	1	2	3	4	5	6		1	2	3	4	5	6
	Salinity (o/oo)							Temperature (°C)					
Jan.	0.1	0.2	4.2	22.3	26.2	30.3	Jan.	6.3	6.3	6.5	6.3	6.5	6.5
Feb.	0.0	0.0	0.0	13.7	17.9	22.7	Feb.	7.1	7.5	7.3	9.1	9.3	9.2
Mar.	0.0	0.0	0.0	15.2	16.3	21.5	Mar.	11.7	11.7	12.3	10.1	11.1	11.3
Apr.	0.0	0.0	0.0	8.3	18.7	30.1	Apr.	11.5	12.3	11.9	13.1	13.9	14.3
May	0.1	0.5	3.3	14.2	28.3	25.9	May	24.5	25.5	27.0	22.9	23.2	22.5
June	0.3	0.7	15.0	24.3	27.8	32.1	June	25.3	25.6	26.1	28.7	23.8	23.9
July	0.5	1.1	9.3	22.9	26.7	31.3	July	26.7	26.3	28.7	25.6	27.5	27.9
Aug.	0.4	0.5	1.3	14.4	30.4	33.1	Aug.	26.4	27.9	29.1	29.0	28.3	28.3
Sept.	0.4	0.5	5.0	16.7	31.4	32.9	Sept.	24.5	26.1	26.5	28.6	29.1	29.6
Oct.	0.1	0.6	19.3	27.0	31.0	33.7	Oct.	18.4	19.7	20.9	22.6	21.6	22.5
Nov.	0.1	0.3	8.3	17.3	25.9	30.6	Nov.	14.9	14.7	13.1	13.5	14.1	15.7
Dec.	0.0	0.5	2.2	23.7	29.7	30.6	Dec.	8.5	8.5	8.5	12.9	13.8	13.9

Table 3.--Occurrence of fishes in the Newport River, 1970. Salinity ranges represent extremes measured at times of collection.

Species	Zone						Salinity range
	1	2	3	4	5	6	
Carcharhinidae - requiem sharks							
Carcharhinus milberti, sandbar shark						X	32.6
Rhizoprionodon terraenovae, Atlantic sharpnose shark					X		32.2-32.6
Sphyrnidae - hammerhead sharks							
Sphyrna lewini, scalloped hammerhead				X			24.7
Dasyatidae - stingrays							
Dasyatis sayi, bluntnose stingray					X		19.7-32.5
Myliobatidae - eagle rays							
Rhinoptera bonasus, cownose ray				X	X	X	22.9-32.6
Lepisosteidae - gars							
Lepisosteus osseus, longnose gar	X	X	X				0.0-3.3
Amiidae - bowfins							
Amia calva, bowfin	X						0.2
Elopidae - tarpons							
Elops saurus, ladyfish					X		30.4
Anguillidae - freshwater eels							
Anguilla rostrata, American eel	X		X	X	X		0.2-32.9
Congridae - conger eels							
Conger oceanicus, conger eel						X	30.6
Ophichthidae - snake eels							
Myrophis punctatus, speckled worm eel				X	X	X	23.8-31.2
Clupeidae - herrings							
Alosa aestivalis, blueback herring	X	X	X	X	X		0.4-23.7
Alosa mediocris, hickory shad		X		X			0.8-21.2
Alosa pseudoharengus, alewife				X		X	22.6-29.3
Alosa sapidissima, American shad	X						0.0
Brevoortia tyrannus, Atlantic menhaden	X	X	X	X	X	X	0.1-32.5
Dorosoma cepedianum, gizzard shad	X	X	X	X		X	0.0-28.7
Harengula pensacolae, scaled sardine						X	31.5
Opisthonema oglinum, Atlantic thread herring				X	X	X	19.3-31.0
Engraulidae - anchovies							
Anchoa hepsetus, striped anchovy			X	X	X	X	14.6-33.1
Anchoa mitchilli, bay anchovy	X	X	X	X	X	X	0.2-33.5

Table 3.--Continued.

Species	Zone 1	2	3	4	5	6	Salinity range
Synodontidae - lizardfishes							
Synodus foetens, inshore lizardfish				X	X	X	21.4-32.0
Cyprinidae - minnows and carps							
Notemigonus crysoleucas, golden shiner	X	X	X				0.1-1.4
Ictaluridae - freshwater catfishes							
Ictalurus catus, white catfish	X	X	X				0.0-1.3
Ictalurus natalis, yellow bullhead	X						0.1-0.5
Noturus insignis, margined madtom	X						0.5
Aphredoderidae - pirate perches							
Aphredoderus sayanus, pirate perch	X						0.2
Batrachoididae - toadfishes							
Opsanus tau, oyster toadfish				X	X	X	16.7-29.9
Porichthys porosissimus, Atlantic midshipman					X	X	11.9-28.4
Gadidae - codfishes							
Urophycis regius, spotted hake				X	X	X	9.2-32.6
Exocoetidae - flyingfishes and halfbeaks							
Cypselurus heterurus, Atlantic flyingfish						X	32.3
Hyporhamphus unifasciatus, halfbeak						X	30.9
Belonidae - needlefishes							
Ablennes hians, flat needlefish						X	31.5
Strongylura marina, Atlantic needlefish		X	X	X		X	0.4-32.3
Cyprinodontidae - killifishes							
Cyprinodon variegatus, sheepshead minnow				X	X	X	19.1-33.4
Fundulus confluentus marsh killifish			X				0.2
Fundulus heteroclitus, mummichog			X	X	X	X	0.6-31.4
Fundulus majalis, striped killifish				X	X	X	22.3-33.0
Atherinidae - silversides							
Membras martinica, rough silverside						X	28.1-32.9
Menidia beryllina, tidewater silverside		X	X	X	X	X	0.8-32.9
Menidia menidia, Atlantic silverside		X	X	X	X	X	0.6-31.1

Table 3.--Continued.

Species	Zone 1	2	3	4	5	6	Salinity range
Syngnathidae - pipefishes and seahorses							
Hippocampus erectus, lined seahorse						X	30.6
Syngnathus florida, dusky pipefish					X		18.4
Syngnathus fuscus, northern pipefish					X		17.3-30.0
Syngnathus louisianae, chain pipefish					X	X	12.3-31.3
Percichthyidae - temperate basses							
Morone americana, white perch			X				0.2
Serranidae - sea basses							
Centropristis philadelphica, rock sea bass					X	X	27.4-32.3
Centropristis striata, black sea bass						X	32.0
Epinephelus nigritus, Warsaw grouper				X		X	24.2-28.8
Centrarchiade - sunfishes							
Enneacanthus gloriosus, bluespotted sunfish	X						0.1-0.4
Lepomis gibbosus, pumpkinseed	X	X					0.1-0.3
Lepomis gulosus, warmouth	X						0.0-0.1
Lepomis macrochirus, bluegill	X	X					0.0-0.2
Micropterus salmoides, largemouth bass	X	X					0.0-0.1
Pomoxis nigromaculatus, black crappie	X	X					0.3-1.2
Percidae - perches							
Etheostoma olmstedi, tessellated darter	X						0.2
Pomatomidae - bluefishes							
Pomatomus saltatrix, bluefish		X	X	X	X	X	8.7-32.5
Rachycentridae - cobias							
Rachycentron canadum, cobia					X		28.4
Carangidae - jacks and pompanos							
Caranx hippos, crevalle jack			X	X		X	24.2-30.3
Chloroscombrus chrysurus, Atlantic bumper				X			16.3
Selene vomer, lookdown				X	X	X	20.4-32.3
Trachinotus falcatus, permit						X	31.5
Lutjanidae - snappers							
Lutjanus griseus, gray snapper				X			24.4
Lobotidae - tripletails							
Lobotes surinamensis, tripletail			X				24.4

Table 3.--Continued.

Species	Zone 1	2	3	4	5	6	Salinity range
Gerreidae - mojarras							
Eucinostomus argenteus, spotfin mojarra						X	35.3
Eucinostomus gula, silver jenny				X	X	X	23.4-31.6
Pomadasyidae - grunts							
Orthopristis chrysoptera, pigfish				X	X	X	21.4-32.1
Sparidae - porgies							
Archosargus probatocephalus, sheepshead					X	X	28.5-31.3
Lagodon rhomboides, pinfish			X	X	X	X	0.8-33.6
Sciaenidae - drums							
Bairdiella chrysura, silver perch			X	X	X	X	9.0-30.7
Cynoscion nebulosus, spotted seatrout			X	X	X	X	7.8-32.4
Cynoscion regalis, weakfish				X	X	X	9.4-30.2
Leiostomus xanthurus, spot		X	X	X	X	X	0.6-33.2
Menticirrhus americanus, southern kingfish				X			27.1
Menticirrhus saxatilis, northern kingfish				X	X	X	24.3-32.7
Micropogon undulatus, Atlantic croaker	X	X	X	X	X	X	0.8-31.2
Pogonias cromis, black drum				X	X	X	19.4-33.4
Ephippidae - spadefishes							
Chaetodipterus faber, Atlantic spadefish					X	X	27.4-29.2
Mugilidae - mullets							
Mugil cephalus, striped mullet	X	X	X	X	X	X	0.3-31.5
Sphyraenidae, barracudas							
Sphyraena barracuda, great barracuda						X	31.1
Gobiidae - gobies							
Gobionellus boleosoma, darter goby				X		X	17.4-26.9
Gobionellus hastatus, sharptail goby						X	28.4
Gobionellus shufeldti, freshwater goby		X		X	X		0.1-29.3
Microgobius thalassinus, green goby				X	X		19.0-24.3
Trichiuridae, cutlassfishes							
Trichiurus lepturus, Atlantic cutlassfish					X		21.3-29.9
Scombridae - mackerels and tunas							
Scomberomorus maculatus, Spanish mackerel				X	X	X	24.5-31.7

Table 3.--Continued.

Species	Zone 1	2	3	4	5	6	Salinity range
Stromateidae - butterfishes							
Peprilus alepidotus, harvestfish				X			8.7-9.4
Peprilus triacanthus, butterfish				X	X	X	22.6-30.3
Triglidae - searobins							
Prionotus carolinus, northern searobin					X	X	29.2-32.8
Prionotus evolans, striped searobin					X	X	24.1-30.2
Prionotus scitulus, leopard searobin						X	29.3
Prionotus tribulus, bighead searobin				X		X	23.5-28.4
Bothidae - lefteye flounders							
Ancylopsetta quadrocellata, ocellated flounder					X	X	24.9-28.3
Citharichthys spilopterus, bay whiff				X		X	22.5-28.5
Etropus crossotus, fringed flounder				X	X	X	20.6-31.3
Paralichthys albigutta, Gulf flounder						X	30.2-34.5
Paralichthys dentatus, summer flounder			X	X	X	X	3.1-32.9
Paralichthys lethostigma, southern flounder	X	X	X	X	X	X	0.6-33.4
Scopthalmus aquosus, windowpane					X	X	23.2-29.9
Soleidae - soles							
Trinectes maculatus, hogchoker	X	X	X	X	X	X	0.1-30.4
Cynoglossidae - tonguefishes							
Symphurus plagiusa, blackcheek tonguefish				X	X	X	4.7-29.4
Balistidae - triggerfishes and filefishes							
Monacanthus hispidus, planehead filefish					X	X	9.4-30.2
Tetraodontidae - puffers							
Sphoeroides maculatus, northern puffer					X	X	28.3-30.2
Diodontidae - porcupinefishes							
Chilomycterus schoepfi, striped burrfish					X	X	29.1-31.5

rostrata. On the other hand, 12 of the marine forms were considered as euryhaline and penetrated into tidal fresh waters of the upper river. Seven other marine species were taken in waters within the low salinity range (0.6-10‰); four were collected from brackish waters of the upper river and three from the low salinity waters (8.3‰) encountered in Zone 4 of the lower river during the April sampling period.

Eighty-six different species were collected in moderate to high salinity waters (i.e., over 10‰) of the estuary. Twenty-six of these species gave evidence of preferring high salinity since they were collected only from waters greater than 25‰. Six of these species, however, have been recorded from fresh waters by other workers (Gunter, 1956; Gunter and Hall, 1963) and are therefore considered euryhaline: these species are ladyfish, *Elops saurus*; rough silverside, *Membras martinica*; spotfin mojarra, *Eucinostomus argenteus*; sheepshead, *Archosargus probatocephalus;* sharptail goby, *Gobionellus hastatus;* and northern puffer, *Sphoeroides maculatus*.

RELATIVE ABUNDANCE

A total of nearly 129,000 fishes were collected from Newport River in 1970. Moveable gear (trawls and haul seine) accounted for 98% of the total catch, and stationary gear (anchored gill nets) the remainder. Gill nets were fished for 1,281 shackle-hours over the 12-month period, whereas the actual fishing time for all other gears was estimated at 28.5 hr. The surface trawl netted 66% of the total catch and was the most successful gear employed in terms of catch per unit of effort, 884 fish per haul. The haul seine took 19% of the total catch and 335 fish per haul, the large bottom trawl 13% of the total catch and 284 fish per haul, and the small bottom trawl less than 1% of the total catch and 23 fish per haul. Gill nets were the least effective of the various gears, yielding only 1.4 fish per shackle-hour.

A general picture of the utilization of each zone and of the different habitats within the system can be derived from the relative abundance of species in the catches by various gears. Species representing at least 1% of the total catch for the year by any gear were considered dominant forms.

Table 4.--Relative abundance of the principal fishes taken by surface trawl and bottom trawl in upper Newport River, 1970.

	Catch per haul in Zone			Composition of total catch
	1	2	3	
	Surface trawl			Percent
Brevoortia tyrannus	7	138	1,758	80.6
Anchoa mitchilli	17	24	369	17.1
	Bottom trawl			Percent
Leiostomus xanthurus	-	1	17	39.1
Micropogon undulatus	1	5	6	19.6
Trinectes maculatus	1	1	7	17.5
Ictalurus catus	1	1	2	7.3
Lagodon rhomboides	-	-	3	6.3
Anchoa mitchilli	-	-	1	2.3

Although surface trawls captured 29 species in the upper river, two species made up nearly 98% of the catch (Table 4). Atlantic menhaden (*Brevoortia tyrannus*), predominantly young of the year, was the most abundant species and was followed by bay anchovy (*Anchoa mitchilli*). Both of these species, marine euryhaline fishes, moved upstream into Zone 1, but their numbers decreased in a direct relation to distance upstream. Golden shiner ranked next in abundance, but made up less than 1% of the total catch.

Twenty-six species were taken in the upper river by bottom trawl, but the seven dominant species constituted 94% of the catch. Spot (*Leiostomus xanthurus*) was the predominant species in the samples, and was followed in order of decreasing abundance by Atlantic croaker (*Micropogon undulatus*), hogchoker (*Trinectes maculatus*), white catfish, pinfish, bay anchovy, and pirate perch (*Aphredoderus sayanus*). Atlantic croaker and hogchoker occurred as far upstream as Zone 1, but were more numerous downstream. Spot was taken as far upstream as Zone 2, but was more abundant in Zone 3. White catfish was distributed rather evenly throughout the upper river, while the other

freshwater species, pirate perch, was found only in Zone 1. Pinfish and bay anchovy were collected in Zone 3 only. Of the nine predominant fishes in samples from the upper river, six were marine euryhaline species and three were freshwater species.

Four of the 58 species in samples collected by bottom trawling in the lower river comprised 95% of the catch (Table 5). Spot was again the most abundant species and was followed successively by bay anchovy, pinfish, and Atlantic croaker. All of the latter were also among the dominant species of the upper river. Spot was most numerous in Zone 6, bay anchovy in Zone 4, pinfish in Zone 6, and Atlantic croaker in Zone 5. Pinfish and Atlantic croaker were sparse in Zones 4 and 6, respectively.

Thirty-seven species were represented in samples from littoral waters of the estuary, and seven of these accounted for 96% of the catch by haul seine. These samples consisted principally of young-of-the-year fishes. Young spot predominated in these samples. Atlantic silverside (*Menidia menidia*) and young striped mullet (*Mugil cephalus*) ranked next in importance but were each less than a third as numerous as spot. Bay anchovy and postlarval Atlantic menhaden ranked next and were followed by postlarval pinfish and rough silverside. Unlike the adults, young spot were most abundant in the upper reaches of the estuary indicating an upstream movement similar to that of Atlantic menhaden. Both species of atherinids, Atlantic and rough silversides, were most numerous in the lower reaches of the system. The distribution of bay anchovy and pinfish in littoral waters paralleled their distribution in samples from benthic waters.

Table 5.--Relative abundance of the principal fishes taken by bottom trawl and haul seine in lower Newport River, 1970.

Species	Catch per haul in Zone			Composition of total catch
	4	5	6	
	Bottom trawl			Percent
Leiostomus xanthurus	74	107	129	38.4
Anchoa mitchilli	281	61	65	37.5
Lagodon rhomboides	2	24	45	9.9
Micropogon undulatus	31	45	2	8.8
	Haul seine			Percent
Leiostomus xanthurus	273	129	116	51.5
Menidia menidia	41	40	89	16.9
Mugil cephalus	50	37	63	14.9
Anchoa mitchilli	25	9	11	4.5
Brevoortia tyrannus	25	16	1	4.2
Lagodon rhomboides	5	4	11	2.0
Membras martinica	-	-	19	1.9

Gill nets, fished in open waters throughout the river, took a slightly greater variety of fishes than any other gear, 59 different species. Because of their selectivity, however, gill nets sampled only the moderate-to-large-sized fishes. Eight species composed about 93% of the total catch by gill nets (Table 6). Atlantic menhaden (chiefly yearling fish) was by far the dominant species in the open waters. Yearling menhaden were especially abundant in catches in the estuary but small numbers were taken upstream into Zone 2. Juvenile and adult pinfish ranked second in abundance and occurred only in samples from the estuary. Spot was the third most abundant species and was captured as far upstream as Zone 2, but in smaller numbers than in the estuary. Longnose gar ranked next in abundance and was limited to samples from the upper river. This species appeared the most abundant of the large freshwater fishes. Bluefish (*Pomatomus saltatrix*), mostly yearlings, also were taken in large numbers in the estuary; young-of-the-year bluefish were taken by surface trawl in the upper river but in relatively smaller numbers. Gizzard shad were gillnetted throughout the system, but were most abundant in the upper river. Atlantic thread herring (*Opisthonema oglinum*) and Atlantic croaker were taken only in the estuary, the former species being most abundant in the upper reaches and the latter species in the lower reaches.

The seven dominant fishes in the combined collections by various gears were Atlantic menhaden, bay anchovy, spot, Atlantic silverside, striped mullet, pinfish, and Atlantic croaker—all marine euryhaline species. The first five species accounted for 93% of the total catch and

Table 6.--Relative abundance of the principal fishes taken by gill nets in the Newport River, 1970.

Species	Catch per 100 shackle-hours in Zone--						Percent of total catch
	1	2	3	4	5	6	
Brevoortia tyrannus	-	1.3	1.1	173.3	198.4	34.2	54.9
Lagodon rhomboides	-	-	-	24.7	55.4	15.3	12.8
Leiostomus xanthurus	-	2.7	2.2	5.5	6.5	34.2	6.9
Lepisosteus osseus	9.0	25.3	14.6	-	-	-	6.6
Pomatomus saltatrix	-	-	-	12.3	17.2	12.7	5.7
Dorosoma cepedianum	2.0	9.3	7.9	0.7	-	1.0	2.8
Opisthonema oglinum	-	-	-	9.6	1.1	0.3	1.5
Micropogon undulatus	-	-	-	0.7	3.2	6.3	1.4

the next two, 4%. Although the remaining 97 species each contributed less than 1% of the total catch, some nevertheless were taken in considerable numbers. The three next most common species were golden shiner, rough silverside, and tidewater silverside (*Menidia beryllina*); only one freshwater species, golden shiner, ranked among the 10 most numerous fishes. Other species occurring in substantial numbers were blueback herring (*Alosa aestivalis*), hogchoker, and bluefish. Because of their abundance, all of these species are important components of the estuary (Zones 2 through 6).

SEASONAL DISTRIBUTION OF MAJOR SPECIES

Numerically, the fish population within the river system was of course dominated by small fishes and larvae and juveniles of larger species. All of the dominant species used the system as a nursery area and three of the estuarine species, bay anchovy, Atlantic silverside, and tidewater silverside, apparently resided within the system throughout their lives. The capacity to which most of the dominant species utilized the system was inferred from their seasonal and areal distribution, sizes, and numbers in the collections.

Atlantic Menhaden

Samples collected by haul seine in the estuary and surface trawl in the upper river best describe the cyclic distribution of menhaden within the system (Table 7). Menhaden spawn off the North Carolina coast from November to March (Higham and Nicholson, 1964). Larvae enter the estuary, transform into juveniles and usually remain most of their first year of life. Larval and postlarval menhaden were first taken in the estuary in February. By March some fishes attained juvenile proportions (about 35 mm in length), and many had moved into the upper portion of the river. Salinity was 0‰ throughout the upper river at the time of menhaden influx into that area. Menhaden moved well upstream and into Zone 1 by May and remained until August. Peak numbers were encountered in May and June and most of the population was centered in Zone 3. During these two months the population of young menhaden in the system was spread along a very wide salinity gradient, ranging from a mean of 0.1‰ in Zone 1 to a mean of 28.3‰ in Zone 5. After July the number of menhaden in collections diminished abruptly. By August the juveniles had emigrated from Zones 1 and 2, but some remained in Zone 3 at the mouth of the river until November. After departing from the upper river,

Table 7.--Monthly distribution and length range (mm in parentheses) of young-of-the-year Atlantic menhaden in samples collected by haul seine in the lower river and surface trawl in the upper river.

Month	Zone						Total number
	6	5	4	3	2	1	
Jan.	-	-	-	-	-	-	0
Feb.	4 (23-27)	1 (31)	8 (22-31)	-	-	-	13
Mar.	-	326 (22-34)	420 (22-37)	2,287 (24-35)	4 (24-26)	-	3,037
Apr.	34 (26-30)	18 (24-35)	84 (26-35)	808 (24-34)	-	-	944
May	-	2 (25-28)	3 (25-27)	31,276 (22-48)	183 (25-34)	1 (28)	31,465
June	-	12 (35-62)	50 (41-57)	20,191 (29-52)	4,397 (29-42)	161 (33-45)	24,811
July	-	-	16 (34-61)	8,190 (37-78)	388 (32-73)	4 (29-32)	8,598
Aug.	-	-	-	2 (62-67)	-	-	2
Sept.	-	-	-	486 (61-95)	-	-	486
Oct.	-	-	-	32 (65-115)	-	-	32
Mov.	-	-	-	-	-	-	0
Dec.	-	-	-	-	-	-	0

juveniles probably stayed in open waters of the estuary and thus were not available to seining efforts in the littoral areas. The majority of these young menhaden left the estuary and returned to the ocean as waters began to cool. Some lingered in the system for a greater period of time, however, as attested by the catches of yearlings in gill nets throughout the year.

Bay Anchovy

Bay anchovy was distributed throughout the system and occurred in collections each month (Table 8). They were taken in the upper portion of the river from June through December. Small anchovies entered the catches in June, indicating that spawning began in May. Young fishes persisted in the catches during the remainder of the year, suggesting a prolonged breeding season extending well into fall. The bay anchovy was most numerous from July-October with a peak of abundance in September suggesting that spawning intensity was greatest in mid-summer.

Spot

Postlarval spot were first collected in the estuary during February and appeared in samples from the upper river, Zone 3, in March (Table 9). During April they occurred as far upstream as Zone 2 in waters that were completely fresh at the time of sampling. By July young spot had emigrated from the upper river, but young-of-the-year were taken from the estuary through October.

Table 8.--Monthly distribution and length range (mm in parentheses) of bay anchovy collected in samples from all gears combined in the upper and lower river.

Month	Zone						Total number
	6	5	4	3	2	1	
Jan.	-	9 (36-45)	4 (45-53)	1 (50)	-	-	14
Feb.	2 (34-35)	10 (55-61)	548 (37-55)	-	-	-	560
Mar.	19 (43-57)	319 (42-83)	176 (38-82)	4 (33-78)	-	-	518
Apr.	89 (43-82)	87 (47-81)	9 (53-73)	-	-	-	185
May	26 (45-78)	194 (53-69)	22 (58-70)	21 (38-73)	-	-	263
June	39 (48-65)	186 (17-65)	87 (17-68)	-	-	1 (25)	312
July	12 (43-64)	333 (18-72)	413 (22-82)	945 (19-72)	61 (21-31)	398 (25-35)	2,162
Aug.	693 (37-63)	278 (47-72)	368 (24-72)	276 (22-46)	-	-	1,615
Sept.	224 (31-77)	224 (33-53)	1,415 (19-100)	10,102 (18-50)	9 (32-46)	-	11,974
Oct.	678 (41-61)	-	696 (40-55)	1,711 (25-53)	764 (23-42)	1 (87)	3,850
Nov.	2 (28-32)	25 (41-61)	250 (41-62)	220 (22-42)	6 (26-37)	-	503
Dec.	39 (40-69)	19 (30-62)	-	33 (26-67)	13 (37-68)	-	104

Adult spot containing well-developed roe were taken from gill nets in Zone 6 during October. They apparently left the estuary after October and moved offshore to spawn. The cyclic distribution of spot paralleled that of Atlantic menhaden, the chief differences being that spot attained peak abundance in the catches during March and did not move upstream to as great an extent as menhaden. Disparity in peaks of abundance of these two species probably reflects the high vulnerability of juvenile menhaden to the surface trawl.

Atlantic Silverside

This species was also widely distributed in the system and occurred in samples throughout the year (Table 10). Although Atlantic silverside has been recorded from fresh waters on many occasions, the species was never taken in Zone 1 and was collected only in limited numbers in Zone 2. Collections indicated that spawning occurred in April and May, and the species reached peak abundance in the collections in June.

Striped Mullet

Postlarval striped mullet first appeared in samples from the estuary in November and were taken in Zone 3 in December (Table 11). The species apparently spawns over an extensive period as larvae persisted in samples through April.

Table 9.--Monthly distribution and length range (mm in parentheses) of young-of-the-year spot in samples collected by haul seine in the lower river and bottom trawl in the upper river.

Month	Zone						Total number
	6	5	4	3	2	1	
Jan.	-	-	-	-	-	-	0
Feb.	266 (11-22)	269 (12-23)	1,418 (12-22)	-	-	-	1,953
Mar.	1,842 (16-31)	1,904 (19-27)	3,168 (14-26)	335 (14-24)	-	-	7,249
Apr.	710 (20-29)	655 (18-32)	2,185 (20-33)	22 (31-48)	11 (31-44)	-	3,583
May	59 (17-51)	391 (21-47)	190 (12-50)	-	-	-	640
June	27 (41-49)	55 (16-73)	70 (48-64)	1 (59)	-	-	153
July	-	5 (70-83)	6 (60-101)	-	-	-	11
Aug.	6 (88-106)	1 (93)	4 (82-88)	-	-	-	11
Sept.	6 (97-106)	-	5 (96-118)	-	-	-	11
Oct.	1 (112)	5 (95-110)	1 (120)	-	-	-	7
Nov.	-	-	-	-	-	-	0
Dec.	-	-	-	-	-	-	0

Striped mullet penetrated well upstream and was taken in Zone 1 in July.

Pinfish

Postlarval pinfish (11 mm) first appeared in the estuary in November and small specimens (<18 mm) persisted in the samples from the lower river until early May. This suggests a prolonged spawning period, probably from October to April, coincident with the Atlantic menhaden and striped mullet spawning seasons in this area. Spawning occurs offshore.

Atlantic Croaker

An insufficient number of young-of-the-year croaker was collected to accurately infer spawning time in this area; however, there is evidence of spawning off the South Carolina coast from October to January (Bearden, 1964). Most of the croakers taken in Newport River were yearlings and adults collected by bottom trawls and gill nets. The species occurred throughout the system.

Bluefish

The majority of bluefish collected were yearling fish taken by gill nets from the lower river. Small numbers of young-of-the-year, however, were collected by surface trawl in the upper river. Yearling bluefish were taken in Zone 6 from March-December, in Zone 5 from April-November, and in Zone 4 from May-November. Young-of-the-year (45-72 mm) occurred sporadically in collections from the upper river in May, July, and October. They moved upstream into Zone 2

in July, but were more abundant in Zone 3. A winter spawning offshore was indicated by size and time of appearance of young fish in the collections. The absence of bluefish in collections with the bottom trawls was probably indicative of their habitat preferences and in no way reflected population size.

Blueback Herring

Blueback herring were taken in Zones 1-5. and young-of-the-year (22 mm) were first encountered in collections from Zone 1 in June. Young-of-the-year remained in the upper river until December and were taken with adult fish in Zones 4 and 5 as late as February. The mean length of young blueback herring was 23 mm in June, 40 mm in August, 51 mm in September, 59 mm in October, 71 mm in November, 71 mm in December, and 81 mm in February.

Other Abundant Species

Data on the other abundant species mentioned above were too incomplete to draw definite conclusions regarding spawning times and migrational patterns. Golden shiner, the only freshwater fish among the dominant species, was collected in the upper river throughout the year and was far more numerous in Zones 1 and 2 than in Zone 3. Young-of-the-year (22 mm) were first collected in June, indicating that spawning occurred in spring. Tidewater silverside was taken in Zones 2-6 and was most abundant in

Table 10.--Monthly distribution and length range (mm in parentheses) of Atlantic silverside in samples collected by haul seine and surface trawl.

Month	Zone						Total number
	6	5	4	3	2	1	
Jan.	2 (70-75)	188 (45-102)	14 (31-90)	2 (42-55)	-	-	206
Feb.	1 (65)	285 (66-110)	46 (53-103)	-	-	-	332
Mar.	88 (48-100)	58 (53-104)	211 (47-105)	2 (47-77)	-	-	359
Apr.	11 (70-105)	9 (73-94)	56 (50-108)	1 (68)	-	-	77
May	39 (72-110)	8 (80-100)	128 (21-102)	7 (41-62)	6 (52-54)	-	188
June	906 (24-81)	613 (23-40)	328 (25-47)	1 (31)	2 (47-58)	-	1,850
July	-	4 (40-82)	110 (23-60)	36 (37-39)	2 (54-63)	-	152
Aug.	375 (45-60)	7 (35-54)	12 (48-60)	2 (34-41)	-	-	396
Sept.	9 (66-74)	-	186 (46-72)	5 (43-69)	6 (34-47)	-	206
Oct.	582 (65-78)	4 (60-75)	7 (65-71)	131 (42-85)	-	-	724
Nov.	274 (72-103)	-	4 (41-62)	111 (51-95)	-	-	389
Dec.	242 (61-93)	40 (58-91)	1 (41)	159 (41-89)	3 (53-54)	-	445

Table 11.--Monthly distribution and length range (mm in parentheses) of young-of-the-year striped mullet in samples collected by haul seine and surface trawl.

Month	Zone						Total number
	6	5	4	3	2	1	
Jan.	24 (21-24)	3 (21-27)	17 (25-29)	-	-	-	44
Feb.	31 (21-27)	97 (22-31)	1,434 (16-33)	-	-	-	1,562
Mar.	497 (19-34)	31 (22-33)	141 (25-28)	-	-	-	669
Apr.	967 (21-34)	784 (21-38)	136 (22-34)	11 (19-27)	-	-	1,898
May	-	-	2 (30-34)	-	-	-	2
June	-	10 (34-39)	-	-	1 (52)	-	11
July	-	1 (78)	6 (83-104)	15 (45-97)	4 (55-70)	1 (84)	27
Aug.	8 (91-123)	2 (104-108)	3 (40-107)	2 (72-87)	-	-	15
Sept.	4 (107-123)	4 (96-134)	41 (59-126)	1 (84)	-	-	50
Oct.	-	11 (82-118)	4 (101-133)	14 (92-114)	1 (118)	-	30
Nov.	1 (80)	3 (21-80)	11 (88-120)	5 (86-106)	-	-	20
Dec.	15 (114-131)	-	13 (20-102)	110 (22-83)	-	-	138

collections from Zone 5, while rough silverside was restricted to collections from Zone 6. No young-of-the-year of either species occurred in the collections. Hogchoker occurred throughout the system, but the sizes of specimens in collections did not provide any information on spawning and movement. The smallest hogchoker (19 mm) was collected from Zone 5 in August.

Other Fishes

In addition to the above major species, many other marine fishes utilized the system as a nursery area. Most notable among these were speckled worm eel (*Myrophis punctatus*), inshore lizardfish (*Synodus foetens*), spotted hake (*Urophycis regius*), Atlantic needlefish (*Strongylura marina*), mummichog (*Fundulus heteroclitus*), rock sea bass (*Centropristis philadelphica*), black sea bass (*C. striata*), Warsaw grouper (*Epinephelus nigritus*), crevalle jack (*Caranx hippos*), Atlantic bumper (*Chloroscombrus chrysurus*), lookdown (*Selene vomer*), gray snapper (*Lutjanus griseus*), silver perch (*Bairdiella chrysura*), spotted seatrout (*Cynoscion nebulosus*), weakfish (*C. regalis*), black drum (*Pogonias cromis*), Atlantic cutlassfish (*Trichiurus lepturus*), spanish mackerel (*Scomberomorus maculatus*), bay whiff (*Citharichthys spilopterus*), fringed flounder (*Etropus crossotus*), summer flounder (*Paralichthys dentatus*), southern flounder (*P. lethostigma*), black-

cheek tonguefish (*Symphurus plagiusa*), and planehead filefish (*Monocanthus hispidus*).

Continued sampling through July 1971 added only seven species not collected during 1970. These were chain pickerel (*Esox niger*), mosquitofish (*Gambusia affinis*), and redear sunfish (*Lepomis microlophus*) from the upper river; smooth butterfly ray (*Gymnura micrura*), banded rudderfish (*Seriola zonata*), red drum (*Sciaenops ocellata*), and feather blenny (*Hypsoblennius hentzi*) from the lower river.

NOTABLE OCCURRENCES

Carcharhinus milberti, sandbar shark

Two specimens were taken in Zone 6 during September; they were 1,205 and 1,315 mm long. The water temperature was 28.7°C and the salinity 32.6‰ at the collection site. According to Radcliffe (1916), the sandbar shark is rare in the Beaufort region. Occasional specimens have been taken in the bight of Cape Lookout, and two specimens (622 and 654 mm in length) were recorded from Newport River in May 1914.

Sphyrna lewini, scalloped hammerhead

One specimen, 470 mm long, was taken in Zone 4 during June; water temperature was 28.7°C and salinity 24.7‰ at the collection locality. This species ranges northward to New Jersey (Casey, 1964), but to our knowledge has not been recorded from inshore waters in North Carolina.

Alosa sapidissima, American shad

Although apparently once abundant in the Beaufort region (Yarrow, 1874), the American shad has not been since recorded from the upper reaches of Newport River. That the species remains scarce was attested by the collection of a single adult female (461 mm long) in Zone 1 during April. Water temperature and salinity was 11.2°C and 0.0‰, respectively, at the time of collection. Tagatz and Dudley (1961) found the species abundant in the interconnected but larger Neuse River.

Harengula pensacolae, scaled sardine

Scaled sardine are not abundant along the North Carolina coast, and the northern range extremity recorded is Pasquotank River at Elizabeth City, N.C. (Fowler, 1945). One male (146 mm) and one female (148 mm) approaching spawning condition were collected in Zone 6 during late May when water temperature was 21.1°C and salinity 31.5‰ at the sampling site. The most advanced eggs ranged from 1.20 to 1.47 mm and the average diameter was 1.30 mm. Yolk diameters ranged from 0.93 to 1.20 mm, and the perivitteline space was 0.16 to 0.36 mm in width. A single oil globule was present and ranged from 0.07 to 0.13 mm in diameter.

Cypselurus heterurus, Atlantic flyingfish

The type of this species was collected at Beaufort (Smith, 1907), and other specimens have since been collected offshore (Fowler, 1945). One specimen, a 231-mm female, was taken in Zone 6 during June. Water temperature was 24.3°C and salinity 32.3‰ at the time of collection.

Ablennes hians, flat needlefish

Although only one flat needlefish was taken during our survey, several other specimens were collected during subsidiary studies. This species is apparently not uncommon in the lower reaches of Newport River estuary, however, its occurrence in the Beaufort region has not been recently documented. The specimen was collected in Zone 6 during July when the water temperature was 21.1°C and the salinity 31.5‰.

Epinephelus nigritus, Warsaw grouper

Two young-of-the-year Warsaw grouper were collected in Newport River estuary; a 57-mm specimen was taken from Zone 6 in July (water temperature 29.7°C, salinity 28.8‰) and a 19-mm specimen was taken from Zone 4 in August (water temperature 29.5°C, salinity 24.2‰). Adults are taken regularly in the offshore fishery, and the species apparently uses the estuary as a nursery area.

Lutjanus griseus, gray snapper

One young-of-the-year gray snapper (88 mm) was collected from Zone 4 in September. The water temperature was 28.6°C and the salinity 24.4‰ at the time of collection. Smith (1907) first recorded the species at Beaufort, and Gudger (1913) captured a small specimen at Cape Lookout. Tagatz and Dudley (1961) collected two specimens, 21 and 22 mm, along Atlantic Beach in September. Our inshore record indicates that this species uses estuaries in North Carolina as nursery area.

Lobotes surinamensis, tripletail

This species was previously reported from Beaufort Harbor (Smith, 1907) and from Beaufort Inlet (Fowler, 1945), but our studies indicated that the tripletail utilized the entire estuary of Newport River. Specimens ranging up to 345 mm were collected from Zone 4 in September (temperature 28.6°C, salinity 24.4‰) and October (temperature 25.7°C, salinity 24.4‰).

Eucinostomus argenteus, spotfin mojarra

Forty-one spotfin mojarras (22-75 mm) were collected from Zone 6 in October when the water temperature was 24.1°C. Although this species invades fresh waters in Florida (Carr and Goin, 1959), in our collections they were confined to higher salinities (35.3‰) in the lower reaches of the estuary.

ANNUAL VARIATION

Bottom-trawl data (Donald E. Hoss and Curtis W. Lewis, National Marine Fisheries Service, Beaufort, N.C., unpublished data) collected at monthly intervals in Zones 2-6 for the 2 years preceeding our study differed markedly in relative abundances of species. Much the same species, however, dominated the catches all 3 years (Table 12). Only nine species contributed 1% or more to the annual catches in the upper river. The seven species that contributed 1% or more to the total catch in 1970 comprised 96.7% of the catch in the upper river that year, 89.7% of the catch in 1969, and 92.2% of the catch in 1968. Only five species contributed 1% or more to the annual catches in the lower river. The four species that contributed at least 1% to the total catch in 1970 comprised 94.6% of the catch in the lower river that year, 84.5% of the catch in 1969, and 95.9% of the catch in 1968.

BIOMASS OF FISHES

The wide variety of sampling gear employed during the fish inventory studies identified the dominant species, their habitat preferences, relative abundances, and distributions within the river system. Only the haul seine, however, provided satisfactory estimates of biomass because the area sampled by the seine was known and could be replicated with little variability, and because the littoral regions in which the haul seine was used are frequented chiefly by young or small fishes that are readily susceptible to capture.

Average biomass (wet weight) of fishes in the littoral waters of the estuary was estimated as 0.93 g/m^2 for the entire year of sampling (Table 13). Monthly averages of biomass did not appear related to the migrations of species, but varied erratically and ranged from 0.46 to 1.83 g/m^2. Peak catches occurred in March, August, September, and November. Atlantic silverside made up 39.0% of the total biomass in littoral waters and was followed by striped

Table 12.--Species composition of catches with bottom trawls in the upper (Zones 2-3) and lower (Zones 4-6) Newport River, 1968-1970.[1]

Species	1968		1969		1970	
	%	(Rank)	%	(Rank)	%	(Rank)
			Upper River			
Micropogon undulatus	49.9	(1)	45.9	(1)	20.1	(2)
Trinectes maculatus	30.1	(2)	23.4	(2)	18.2	(3)
Ictalurus catus	6.2	(3)	8.7	(3)	6.3	(5)
Leiostomus xanthurus	3.3	(4)	2.5	(7)	41.9	(1)
Anchoa mitchilli	2.7	(5)	6.2	(5)	2.5	(6)
Symphurus plagiusa	1.7	(6)	7.1	(4)	--	
Bairdiella chrysura	1.1	(7)	--		--	
Brevoortia tyrannus			3.0	(6)	1.0	(7)
Lagodon rhomboides					6.7	(4)
Totals	95.0		96.8		96.7	
			Lower River			
Micropogon undulatus	35.5	(1)	12.6	(2)	8.8	(4)
Leiostomus xanthurus	28.5	(2)	59.0	(1)	38.4	(1)
Lagodon rhomboides	25.7	(3)	9.6	(4)	9.9	(3)
Anchoa mitchilli	6.2	(4)	3.3	(5)	37.5	(2)
Brevoortia tyrannus	1.1	(5)	9.7	(3)	--	
Totals	97.0		94.2		94.6	

[1]All stations were occupied with the 3-m trawl except in 1970 when the 6.1-m trawl was used in the lower river.

mullet, 17.4%; spot, 15.0%; and pinfish, 6.5%. The remaining 20% of the biomass was made up of a mixture of 33 other species.

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LITERATURE CITED

ANGELOVIC, J. W., D. E. HOSS, and G. W. THAYER.
1969. Energy requirements of pinfish, *Lagodon rhomboides*, in the Newport River estuary, N.C. [Abstract.] Assoc. Southeast. Biol. 16(2):42.

BAILEY, R. M. (chairman).
1970. A list of common and scientific names of fishes from the United States and Canada. 3d ed. Am. Fish. Soc., Spec. Publ. 6, 150 p.

BEARDEN, C. M.
1964. Distribution and abundance of Atlantic croaker, *Micropogon undulatus*, in South Carolina. Contrib. Bears Bluff Lab. No. 40, 23 p.

CARR, A., and C. J. GOIN.
1959. Guide to the reptiles, amphibians, and freshwater fishes of Florida. 2d ed. Univ. Fla. Press, Gainesville, 341 p.

Table 13.--Biomass (g/m^2) of fishes collected from littoral waters of Newport River, 1970.

Month	Zone			Mean
	4	5	6	
January	1.29	1.43	0.04	0.92
February	0.82	3.35	0.08	1.42
March	7.48	1.61	1.90	3.66
April	1.64	0.94	1.18	1.25
May	2.98	0.85	1.47	1.77
June	2.04	0.87	1.42	1.44
July	2.53	0.25	0.23	1.00
August	2.12	1.71	5.00	2.94
September	3.36	0.96	2.36	2.23
October	0.70	1.38	2.52	1.53
November	0.63	0.92	5.49	2.35
December	0.44	0.49	4.18	1.70
Totals	26.03	14.76	25.87	22.22
Means	2.17	1.23	2.16	1.85

CASEY, J. G.
1964. Anglers' guide to sharks of the northeastern United States, Maine to Chesapeake Bay. Bur. Sport Fish. Wildl., Circ. 179, 32 p.

CROSS, F. A., T. W. DUKE, and J. N. WILLIS.
1970. Biogeochemistry of trace elements in a coastal plain estuary: distribution of manganese, iron, and zinc in sediments, water, and polychaetous worms. Chesapeake Sci. 11:221-234.

FOWLER, H. W.
1945. A study of the fishes of the southern Piedmont and Coastal Plain. Acad. Nat. Sci. Phila., Monogr. 7, 408 p., 313 Fig.

GUDGER, E. W.
1913. Natural history notes on some Beaufort, N.C., fishes, 1910-11. No. III. Fishes new or little known on the coast of North Carolina. Collected by Mr. Russell J. Coles. J. Elisha Mitchell Sci. Soc. 28:157-172.

GUNTER, G.
1956. A revised list of euryhaline fishes of North and Middle America. Am. Midl. Nat. 56:345-354.

GUNTER, G., and G. E. HALL.
1963. Additions to the list of euryhaline fishes of North America. Copeia 1963:596-597.

HIGHAM, J. R., and W. R. NICHOLSON.
1964. Sexual maturation and spawning of Atlantic menhaden. U.S. Fish Wildl. Serv., Fish. Bull. 63:255-271.

MASSMANN, W. H., E. C. LADD, and H N. McCUTCHEON.
1952. A surface trawl for sampling young fishes in tidal rivers. Trans. 17th North Am. Wildl. Conf. p. 386-392.

RADCLIFFE, L.
1916. The sharks and rays of Beaufort, North Carolina. Bull. [U.S.] Bur. Fish. 34:239-284.

SMITH, H. M.
1907. The fishes of North Carolina. N.C. Geol. Econ. Surv. Vol. 2, 453 p. E. M. Uzzell and Co., Raleigh.

TAGATZ, M. E., and D. L. DUDLEY.
1961. Seasonal occurrence of marine fishes in four shore habitats near Beaufort, N.C., 1957-60. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 390, 19 p.

WILLIAMS, R. B.
1966. Annual phytoplanktonic production in a system of shallow temperate estuaries. *In* H. Barnes (editor), Some contemporary studies in marine science, p. 699-716. George Allen & Unwin Ltd., Lond.

WILLIAMS, R. B., and M. B. MURDOCH.
1966. Phytoplankton production and chlorophyll concentration in the Beaufort Channel, North Carolina. Limnol. Oceanogr. 11:73-82.
1969. The potential importance of *Spartina alterniflora* in conveying zinc, manganese, and iron into estuarine food chains. *In* D. J. Nelson and F. C. Evans (editors), Symposium on Radioecology, p. 431-439. Proc. Second Natl. Symp., Ann Arbor, Mich., May 15-17, 1967.
WILLIAMS, R. B., M. A. MURDOCH, and L. K. THOMAS.
1968. Standing crop and importance of zooplankton in a system of shallow estuaries. Chesapeake Sci. 9:42-51.
WILLIAMS, R. B., and L. K. THOMAS.
1967. The standing crop of benthic animals in a North Carolina estuarine area. J. Elisha Mitchell Sci. Soc. 83:135-139.
YARROW, H. C.
1874. Notes on the shad as observed at Beaufort Harbor, North Carolina, and vicinity. U.S. Comm. Fish Fish., Part II, Rep. Comm. 1872 and 1873, p. 452-456.

636 Oil pollution on Wake Island from the tanker *R. C. Stoner*. By Rginald M. Gooding. May 1971, iii + 12 pp., 8 figs., 2 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 25 cents.

637 Occurrence of larval, juvenile, and mature crabs in the vicinity of Beaufort Inlet, North Carolina. By Donnie L. Dudley and Mayo H. Judy. August 1971, iii + 10 pp., 1 fig., 5 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 25 cents.

638 Length-weight relations of haddock from commercial landings in New England, 1931-55. By Bradford E. Brown and Richard C. Hennemuth. August 1971, v + 13 pp., 16 fig., 6 tables, 10 appendix A tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 25 cents.

639 A hydrographic survey of the Galveston Bay system, Texas 1963-66. By E. J. Pullen, W. L. Trent, and G. B. Adams. October 1971, v + 13 pp., 15 figs., 12 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 30 cents.

640 Annotated bibliography on the fishing industry and biology of the blue crab, *Callinectes sapidus*. By Marlin E. Tagatz and Ann Bowman Hall. August 1971, 94 pp. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.00.

641 Use of threadfin shad, *Dorosoma petenense*, as live bait during experimental pole-and-line fishing for skipjack tuna, *Katsuwonus pelamis*, in Hawaii. By Robert T. B. Iversen. August 1971, iii + 10 pp., 3 figs., 7 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 25 cents.

642 Atlantic menhaden *Brevoortia tyrannus* resource and fishery—analysis of decline. By Kenneth A. Henry. August 1971, v + 32 pp., 40 figs., 5 appendix figs., 3 tables, 2 appendix tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 45 cents.

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