AN ECOLOGICAL STUDY OF GEORGIA COASTAL FISHES

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ABSTRACT

The distribution of fishes in relation to ecological factors was studied in a Georgia estuary and adjoining beach and coastal plain creek waters to establish fundamental base lines for the ecology of a relatively undisturbed section of the coast. The distributions of 168 fish species were related to nine recognizable habitats, temperature, and salinity. Length frequencies and spawning seasons were determined for most of the trawled species that contributed significantly to fish production in the estuary.

Collecting by a variety of techniques permitted evaluations of types of life cycles, of diversity in the various aquatic habitats, and of distribution patterns within the estuarine complex and adjoining waters. Numbers of species collected in nine aquatic habitats were as follows: beach - 114, lower reach of the estuary - 100, high marsh - 56, upper and middle reaches - 61, oligohaline creek - 40, fresh water - 39, tidal canal - 22, low-salinity tidal pool - 22, high-salinity tidal pool - 37.

Estuaries are highly productive and support important sport and commercial fisheries. A majority of the nation's commercial finfish and shellfish species and many coastal sport fishes utilize the estuarine environment during at least part of their life cycle. Estuaries are important recreational areas, especially for fishing, partly because of their proximity to civilization. Unfortunately, this proximity and lack of pollution controls have resulted in mass degradation of the nation's estuaries through pollution, filling, and dredging. Pre-pollution studies are essential for the precise evaluation of the ecological impact of stresses on estuaries. The normal functioning of estuaries must be understood before scientists can evaluate the effects of various stresses on estuaries. There is an urgent need to determine the significance of coastal habitats to the various life history stages of coastal fishes. The central Georgia coast presents an opportunity to study the ecology of fishes in a relatively undisturbed estuary and establish fundamental base lines for the detection and evaluation of pollution. Aspects of fish ecology that have been selected for examination include (1) distribution of fishes in relation to recognizable habitats, salinity, and temperature, (2) size frequencies and spawning seasons of many abundant species, (3) diversity of fishes in each of nine habitats, and (4) types of life cycles.

Except for the Brunswick and Savannah regions, Georgia estuaries are relatively free of pollution. However, certain Golden Isles along the Georgia coast are being considered for strip mining for titanium and phosphate. A nuclear power plant is under construction on the lower Altamaha River. Recent developments in the estuary studied herein include a kraft paper mill, a shrimp culture farm that may not be completed, and an interstate highway that may alter tidal flushing.

A complete picture of species distributions and size in coastal waters can be obtained only if all major habitat types are examined (Springer and Woodburn, 1960). Extensive trawling and seining were undertaken to achieve this goal. Comparisons with other studies are complicated by the difference in types and numbers of habitats sampled and differences in collecting methods.

There has been little work on the ecology of fishes of the U.S. Atlantic coast between Cape Hatteras, N.C., and northern Florida. Tagatz (1968) surveyed the fishes of St. Johns River,

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Fla. Tagatz and Dudley (1961) studied the seasonality of fishes in four coastal habitats near Beaufort, N.C. In South Carolina, Bearden (1961) published a field guide to the common marine fishes, compiled an unpublished list (1961) of marine fishes, and surveyed the elasmobranchs (Bearden, 1965). Lunz and Schwartz (1970) published an 18-year study of South Carolina coastal fishes.

Anderson (1968) surveyed the fishes caught by shrimp trawling from South Carolina to northeastern Florida from 1931 to 1935. His data are not tabulated here because many species complexes were identified only to genus and his collections were from regions other than the estuary under study. Miller and Jorgenson (1969) studied the seasonal abundance and length frequencies of fishes collected by seining at a beach habitat on St. Simons Island and at two high marsh stations, one near Jekyll Island and one near Meridian, Ga. They also listed the fishes collected at a freshwater station in the Altamaha River. Dahlberg and Heard (1969) surveyed the common elasmobranchs of the Georgia coast. Dahlberg and Odum (1970) demonstrated the trawl diversity of Georgia estuarine fishes collected over 14 months. Dahlberg (1971a)[2] presented an annotated list of the Georgia estuarine and coastal fishes. A section of an unpublished ecological survey (Dahlberg, 1971b)[3] was the basis for this report.

LOCATION AND DESCRIPTIONS OF HABITATS

Composition and diversity of fish species in nine aquatic habitats along the Georgia coast are compared in this study. Salinity, temperature, and some aquatic plants and animals that are characteristic of these habitats are given in Table 1.

[2] Dahlberg, M. D. 1971a. An annotated list of Georgia coastal fishes. *In* An ecological survey of the coastal region of Georgia, p. 255-300. Unpublished report to National Park Service from University of Georgia Institute of Natural Resources, Athens.

[3] Dahlberg, M. D. 1971b. Habitat and diversity of the fishes in North and South Newport Rivers and adjacent waters. *In* An ecological survey of the North and South Newport Rivers and adjacent waters with respect to possible effects of treated kraft mill effluent, p. 36-121. Unpublished report to Georgia Water Quality Control Board from University of Georgia Marine Institute, Sapelo Island.

TABLE 1.—Salinity, temperature, characteristic plants and animals of habitats studied, exclusive of freshwater creek habitat.

Sapelo Island Beach

Salinity—Range was 25.0 to 31.3‰ except when flood waters reduced salinity. Measured at 6.8 to 7.7‰ along south end of beach and 15.2‰ in surf near Big Hole at low tide in April 1970.

Plants—Sea oats *(Uniola paniculata)* are the most conspicuous plant on dunes along the beach.

Invertebrates seined or observed—Ghost crab *(Ocypode quadrata)*, polychaete worm tubes *(Onuphis microcephala,* and *Diopatra cuprea)*, horseshoe crab *(Limulus polyphemus)*, hermit crabs *(Clibanarius vittatus,* and *Pagurus longicarpus)*, gastropods *(Busycon carica,* and *Nassarius)*, sea cucumber *(Thyone briareus)*, sand dollar *(Mellita quinquiesperforata)*, isopod *(Aegothoa oculata)*, white shrimp *(Penaeus setiferus)*, shrimp *(Palaemonetes pugio)*, blue crab *(Callinectes sapidus)*, and squid *(Lolliguncula brevis)*.

Lower Reach of the Estuary - Trawl Stations 1-9, 12-14

Salinity—Averages for these stations ranged from 21.4 to 28.9 ‰ from 1967 to 1970 (Dahlberg et al., 1971, see text footnote 3).

Temperature—Averages for the 12 stations ranged from 8.1° (January) to 31.2°C (August).

Plants—Cord grass *(Spartina alterniflora)* is the dominant plant.

Invertebrates—Commercial species are white shrimp, brown shrimp *(Penaeus aztecus)*, and pink shrimp *(P. duorarum)*, American oyster *(Crassostrea virginica)*, and blue crab. Other common species are too numerous to list here.

High Marsh

Salinity—Generally 15 to 30‰.

Plants—*Spartina alterniflora* and *Juncus roemerianus* are characteristic.

Middle and Upper Reaches

Salinity—Range was 11.7 to 29.0‰ and average was 21.2‰ at lowermost station, trawl station 10. Range was 0.3 to 18.7‰ and average was 5.3‰ at uppermost station (F).

Temperature—Range was 8.3° to 31.7°C and average was 20.9°C at the lowermost station, trawl station 10. Range was 9.0° to 30.0°C and average was 21.5°C at uppermost station, station F.

Aquatic plants—*Spartina alterniflora, Juncus roemerianus,* tall cord grass *(Spartina cynosuroides)*, marsh elder *(Iva frutescens)*, bulrush *(Scirpus robustus)*, primrose-willow *(Jussiaea)*.

TABLE 1.—Continued.

Sapelo Island Beach—Cont.

Semiaquatic invertebrates—*Uca pugnax, Sesarma, U. pugilator.*
Aquatic invertebrates that were seined, in decreasing order of abundance—*Palaemonetes pugio,* white shrimp, blue crab, *Palaemonetes vulgaris,* brown shrimp.

Riceboro Creek in vicinity of U.S. Highway 17 (oligohaline)

Salinity—Range was 0 to 13.6‰ and average was 3.0‰ for 1968-70.
Temperature—Range was 3.5° to 30.5°C and average was 21.2°C for 1968-70.
Aquatic plants—*Spartina alterniflora, Juncus roemerianus,* waterwort *(Elatine americana),* spike-rush *(Eleocharis acicularia), Iva frutescens, Spartina cynosuroides,* saw grass *(Cladium jamaicense),* groundsel-tree *(Baccharus halimifolia),* arrowhead *(Sagittaria),* water hemlock *(Cicuta maculata), Jussiaea* sp., *Scirpus robustus, Scirpus* sp., salt grass *(Distichlis spicata),* mock bishop-weed *(Ptilimnium capillaceum),* sedge *(Cyperus virens),* and beak rush *(Rhynchospora* sp.).
Invertebrates of lower Riceboro Creek, in decreasing order of abundance in net collections—*Palaemonetes pugio,* blue crab, white shrimp, *Rhithropanopeus harrisi,* and brown shrimp. Other invertebrates of lower Riceboro Creek, reported in Heard and Heard (1971)[1] and Heard and Sikora (in press) include crabs *(Uca minax,* and *Sesarma cinereum),* amphipods *(Corophium* sp., *Orchestia grillus, O. uhleri, Gammarus tigrinus, Corophium lacustre,* and *Melita nitida),* isopods *(Cyathura polita, Cassidinidea lunifrons, Munna reynoldsi, Sphaeroma destructor,* and *Ligia exotica),* tanaid *(Leptochelia),* barnacle *(Balanus improvisus),* polychaetes *(Namalycastis abiuma,* and *Nereis succinea),* gastropods *(Littoridinops tenuipes, Hydrobia, Detracia floridana,* and *Melampus bidentatus),* clams *(Cyrenoidea floridana,* and *Polymesoda carolinae).*

Tidal canal

Salinity—Range was 0.3 to 23.2‰.
Temperature—Range was 8.0° in February 1968 to 30.1°C in August 1967.
Aquatic plants—*Iva frutescens, Borrichia frutescens, Spartina alterniflora, Juncus roemerianus,* glasswort *(Salicornia virginica),* and *Distichlis spicata.*
Semiaquatic invertebrates—*Uca minax, U. pugilator,* and *Sesarma* sp.
Aquatic invertebrates seined, listed in decreasing order of abundance—*Palaemonetes pugio,* white shrimp, blue crab, and brown shrimp.

Low-salinity tidal pools

Salinity—Range was 0 to 24.4‰.
Temperature—Range was 7.3° (January 1970) to 28.2°C (September 1969).
Marsh plants—*Spartina alterniflora, Juncus roemerianus, Salicornia virginica, Eleocharis* sp., *Bacopa monnieri,* aster *(Aster tenuifolius), Distichlis spicata, Scirpus* sp., and *Iva frutescens.*
Semiaquatic invertebrates—*Uca minax, U. pugilator,* and *Sesarma* sp.
Aquatic invertebrates—*Palaemonetes pugio,* and blue crab (juvenile).

High-salinity tidal pools

Salinity—Range was 14.7 to 34‰ in "east pools" and 13.1 to 30.3‰ in "west pools."
Temperature—Range was 8°C in January and February to 32°C in July, August, and September.
Marsh plants along road bank—*Iva frutescens, Borrichia frutescens, Baccharus halimifolia, B. angustifolia* - false willow.
Marsh plants occurring below road bank in the marsh—*Spartina alterniflora, Juncus roemerianus, Salicornia virginica, Distichlis spicata, Batis maritima,* and *Aster tenuifolius.*
Semiaquatic invertebrates—*Sesarma* sp., *Uca pugnax, U. pugilator,* and *U. minax* (uncommon).
Aquatic invertebrates seined, listed in decreasing order of abundance—*Palaemonetes pugio,* blue crab, white shrimp, and brown shrimp.

[1] Heard, R. W., Jr., and E. J. Heard. 1971. Notes on the natural history and invertebrate fauna of the Upper North Newport River. *In* An ecological survey of the North and South Newport Rivers and adjacent waters with respect to possible effects of treated kraft mill effluent, p. 234-246. Unpublished report to Georgia Water Quality Control Board from University of Georgia Marine Institute, Sapelo Island.

Figure 1 illustrates the estuarine complex that was studied, with the exception of the freshwater and Sapelo Island stations. Figure 2 gives locations of stations in the upper part of the North Newport River and oligohaline region in relation to the paper mill (station G), creeks, marsh, railroad, highway, and proposed expressway.

An estuary ranges from the oligohaline creeks to the sounds and barrier islands. Ocean beaches are generally not considered as part of the estuary even though the outflow from estuaries, at least in Georgia, affects beaches and offshore areas where the highly turbid and productive estuarine waters are visible to several miles offshore. This study attempts to evaluate the ecological importance of the following seven estuarine habitats and adjoining beach and freshwater habitats to coastal fish populations. The habitat divisions are somewhat arbitrary as they are all interrelated parts of a single aquatic ecosystem along the coast.

Habitat 1: Sapelo Island Beach (Figure 3).—This station is the ocean beach on Sapelo Island and is known locally as Nannygoat Beach. This beach extends between Dean Creek at the south end and a lagoon (Big Hole) that separates the north end of this beach from Cabretta Island. Most samples were taken in the surf zone near

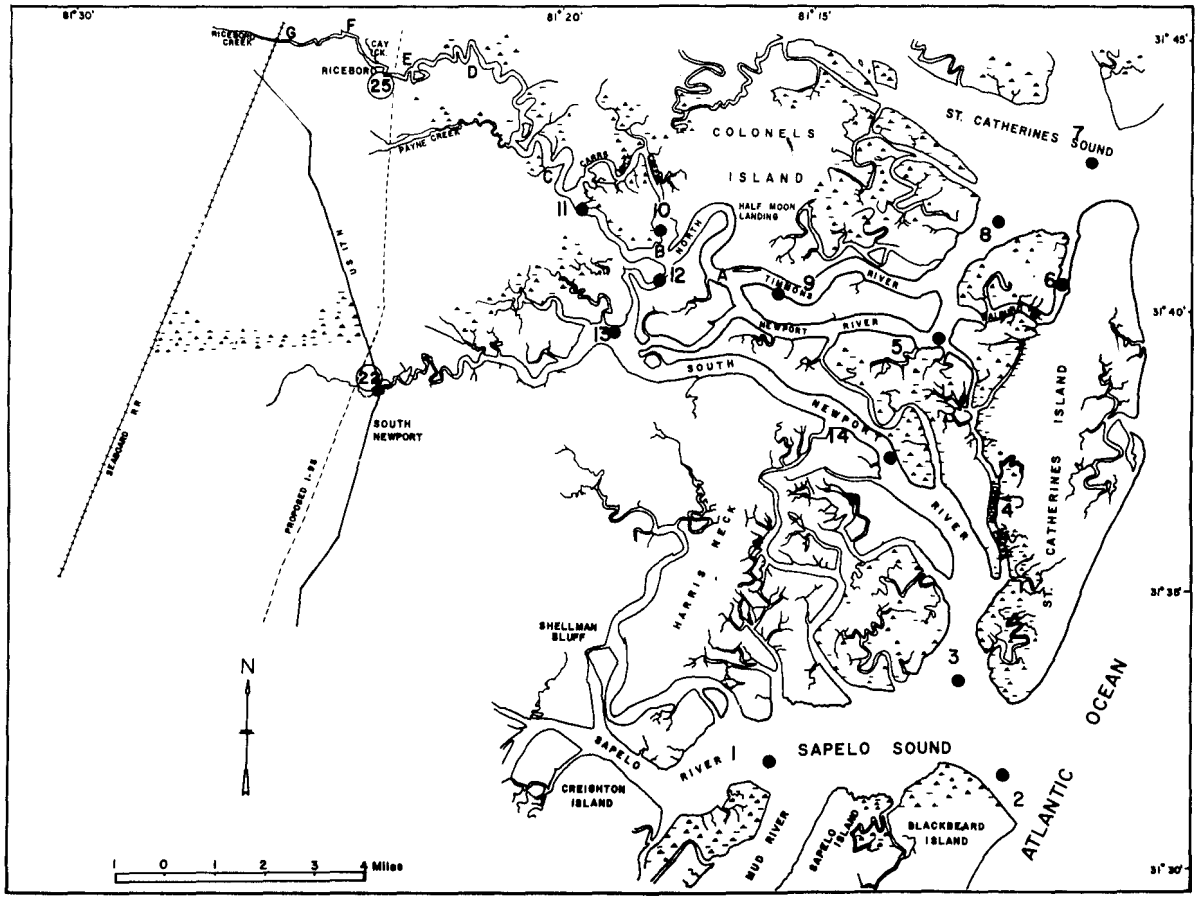

FIGURE 1.—Study area and sampling stations on Georgia Coast except for Sapelo Island and freshwater stations. Numbers 1-14 are trawl stations and associated dots are approximate centers of drags. Letters A-G are stations that were reached with a small boat. Circled numbers are mile points.

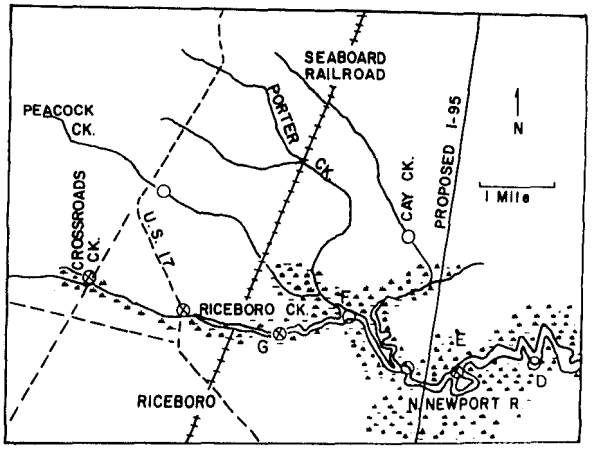

FIGURE 2.—Oligohaline creeks and upper reach of the estuary. Circles are stations sampled for physico-chemical data and circles with an X are fish sampling stations. The Interstate Paper Corp. outfall is at station G. Dashed lines represent highways.

the junction of the road and the beach. Because collecting was generally unproductive in the surf zone at high tide, this station was occupied near low tide. Furthermore, concentrations of fishes in the intertidal sloughs were isolated from the ocean only at low tide.

The continuity of the south end of Sapelo Beach and the lower reach (Doboy Sound) make

FIGURE 3.—View of Sapelo Beach at low tide with Atlantic Ocean and shrimp boat in background and an intertidal slough in center. Fishes become concentrated and trapped in these sloughs at low tide.

it necessary to arbitrarily define the beach habitat to include waters occurring within the wading depth of collectors (about 4 ft). The station is subject to tidal changes—tide ranges from 4.5 to 10.5 ft and has a mean of 6.8 at Sapelo Island (Ragotzkie and Bryson, 1955).

Habitat 2: Lower reach of the estuary. — This habitat includes the sounds and polyhaline river stations. My records for this habitat are based primarily on trawl collections at stations 1-9 and 12-14 (Figure 1). A temperature-salinity diagram (Figure 4) does not indicate any relation between these factors.

Habitat 3: High marsh. — This habitat is the upper section of the littoral zone in the salt marsh. I sampled pools behind high marshes and a tidal ditch in a high marsh but not the high marsh proper. Fishes of this habitat were thoroughly surveyed by Miller and Jorgenson (1969) and are listed in column three of Table 2. Their marsh stations were located near Jekyll Island and near Doboy Sound. The substrate of this habitat is sand and mud that is firm enough to walk on, as opposed to the low marsh which has a soft mud substrate.

Habitat 4: Middle and upper reaches of the estuary (Figures 2 and 5). — The middle reach

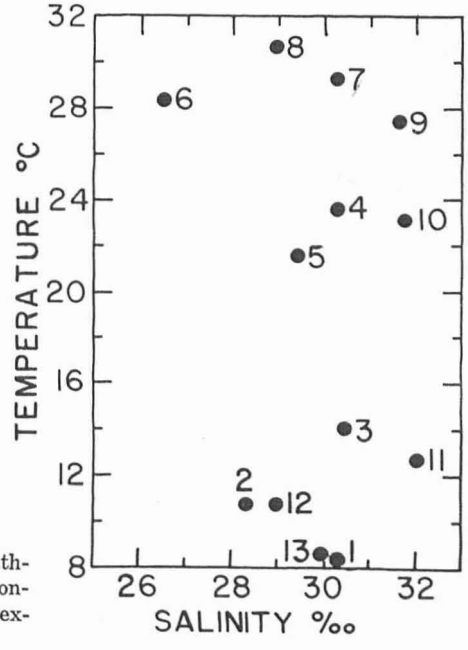

FIGURE 4.—Temperature-salinity diagram for St. Catherines Sound at trawl station 7. Numbers represent consecutive months from January 1968 to January 1969 except 12 is December 1969.

TABLE 2.—Distribution of fishes among the study habitats—1, beach; 2, lower reach; 3, high marsh; 4, middle and upper reaches; 5, oligohaline creek; 6, freshwater creek; 7, tidal canal; 8, low-salinity tidal pool; and 9, high-salinity tidal pool. Names are in phylogenetic order, following Bailey (1970). Parentheses indicate records not taken at regular stations. Boldface indicate record is based on one collection by either the author or Miller and Jorgenson (1969). Asterisk indicates that young of the species are common in the estuary or beach waters. All high marsh records are from Miller and Jorgenson (1969).

Family and species	Habitat								
	1	2	3	4	5	6	7	8	9
Orectolobidae									
Ginglymostoma cirratum	(X)	(X)							
Carcharhinidae									
**Aprionodon isodon*	(X)	(X)							
Carcharhinus acronotus	(X)	(X)							
**Carcharhinus limbatus*	(X)	X							
**Carcharhinus milberti*	(X)	(X)							
Galeocerdo cuvieri	(X)	(X)							
**Negaprion brevirostris*	X	(X)							
Sphyrnidae									
**Sphyrna lewini*	(X)	(X)							
Sphyrna tiburo		X							
Squalidae									
Squalus acanthias		X							
Rhinobatidae									
Rhinobatis lentiginosus		X							
Rajidae									
Raja eglanteria		X							
Dasytidae									
**Dasyatis americana*	(X)	X							
**Dasyatis sabina*	X	X		X					
Dasyatis sayi	(X)	X							
**Gymnura micrura*		X		X					
Myliobatidae									
Rhinoptera bonasus	(X)	(X)							
Lepisosteidae									
Lepisosteus osseus		X		X	X	X			
Lepisosteus platyrhincus						X			
Elopidae									
**Elops saurus*	X		X	X			X	X	X
**Megalops atlantica*	(X)	X					X	X	X
Albulidae									
Albula vulpes	(X)								
Anguillidae									
**Anguilla rostrata*			X		X	X		X	X
Ophichthidae									
Myrophis punctatus	(X)		X		X				
Ophichthus gomesi		X							
Clupidae									
Alosa aestivalis		(X)	X	(X)	(X)	(X)			
Alosa mediocris	(X)	X		(X)	(X)	(X)			
**Alosa sapidissima*		X		X	(X)	(X)			
Brevoortia smithi	X		X				X		X
**Brevoortia tyrannus*	X	X	X	X	X		X	X	X
Dorosoma cepedianum	(X)	(X)	X	X	X	(X)			
**Dorosoma petenense*	X		X				X		
Harengula pensacolae	X	X	X						
**Opisthonema oglinum*	(X)	X	X						
Sardinella anchovia	(X)								

Family and species	Habitat								
	1	2	3	4	5	6	7	8	9
Engraulidae									
Anchoa cubana	(X)								
**Anchoa hepsetus*	X	X	X	X					
Anchoa lyolepis	(X)								
**Anchoa mitchilli*	X	X	X	X	X				X
Esocidae									
Esox americanus					X	X			
Umbridae									
Umbra pygmaea						X			
Synodontidae									
Synodus foetens	(X)	X			X				
Cyprinidae									
Notemigonus crysoleucas					X	X			
Notropis maculatus						X			
Catostomidae									
Erimyzon sucetta						X			
Ictaluridae									
**Ictalurus catus*				X	X	X			
Ictalurus natalis						X			
Noturus gyrinus					X	(X)			
Ariidae									
**Bagre marinus*	(X)	X		X					
**Arius felis*	X	X		X					
Amblyopsidae									
Chologaster cornuta						X			
Aphredoderidae									
Aphredoderus sayanas					X	X			
Batrachoididae									
**Opsanus tau*	X	X		X					
Gobiesocidae									
**Gobiesox strumosus*		X		X					
Antennariidae									
Antennarius radiosus	(X)								
Histrio histrio	(X)								
Gadidae									
**Urophycis floridanus*		X		X					
**Urophycis regius*	(X)	X		X					
Ophidiidae									
Rissola marginata	(X)	X		X					
Belonidae									
Strongylura marina	X	X	X	X					
Cyprinodontidae									
**Cyprinodon variegatus*	X		X				X	X	X
Fundulus chrysotus						X			
**Fundulus confluentus*					X	X		X	
**Fundulus heteroclitus*	X	X	X	X	X		X	X	X
**Fundulus luciae*	(X)		X						
**Fundulus majalis*	X		X				X		X
Fundulus notti						X			

TABLE 2.—Continued.

Family and species	Habitat								
	1	2	3	4	5	6	7	8	9
Cyprinodontidae—Cont.									
Leptolucania ommata						X			
Lucania goodei						X			
Poeciliidae									
**Gambusia affinis*	X		X		X	X	X	X	X
Heterandria formosa			X		X	X			
**Poecilia latipinna*	(X)		X		X		X	X	X
Atherinidae									
**Membras martinica*	X	X	X						
**Menidia beryllina*	X			X	X	X			
**Menidia menidia*	X	X	X	X					X
Syngnathidae									
Hippocampus erectus		X							
**Syngnathus fuscus*	X	X		X	X				
**Syngnathus louisianae*	X	X	X	X	X				X
Centropomidae									
**Centropomus undecimalis*							X	X	X
Serranidae									
Centropristis philadelphica	(X)	X							
Centropristis striata		X		X					
Centrarchidae									
Acantharchus pomotis						X			
Centrarchus macropterus					X	X			
Elassoma evergladei						X			
Elassoma zonatum						X			
Enneacanthus gloriosus						X			
Enneacanthus obesus						X			
Lepomis auritus					X	X			
Lepomis gulosus					X	X			
Lepomis macrochirus					X	X			
Lepomis marginatus						X			
Lepomis punctatus					X	X			
Micropterus salmoides					X	X			
Percidae									
Etheostoma fusiforme						X			
Pomatomidae									
Pomatomus saltatrix	X	X	X	X					
Echeneidae									
Echeneis naucrates	(X)	(X)							
Carangidae									
Caranx hippos	X	(X)	X	X					X
Caranx latus	(X)								
**Chloroscombrus chrysurus*	X	X	X	X					X
**Oligoplites saurus*	X		X	X					X
Selene vomer	X	X							
**Trachinotus carolinus*	X		X						
**Trachinotus falcatus*	X		X						
Trachinotus goodei	(X)								
Vomer setapinnis	(X)								
Lutjanidae									
Lutjanus griseus	(X)	(X)	X					X	X

Family and species	Habitat								
	1	2	3	4	5	6	7	8	9
Gerreidae									
**Diapterus olisthostomus*	X		X		X		X	X	X
**Eucinostomus argenteus*	X	X	X	X	X		X	X	X
Eucinostomus melanopterus					X				
Pomadasyidae									
Orthopristis chrysoptera	(X)	X		X					
Sparidae									
**Archosargus probatocephalus*	(X)	(X)	X						
**Lagodon rhomboides*	(X)	X	X				X	X	X
Sciaenidae									
**Bairdiella chrysura*	X	X	X	X	X		X	X	X
**Cynoscion nebulosus*	(X)	X	X	X					X
**Cynoscion nothus*		X							
**Cynoscion regalis*	X	X	X	X			X		X
**Larimus fasciatus*	X	X							
**Leiostomus xanthurus*	X	X	X	X	X		X	X	X
**Menticirrhus americanus*	X	X	X	X					
**Menticirrhus littoralis*	X	X	X						
**Menticirrhus saxatilis*	X	X	X						
**Micropogon undulatus*	X	X	X	X	X		X		X
**Pogonias cromis*	(X)	X	X				X	X	X
**Sciaenops ocellata*	X	(X)	X				X	X	X
**Stellifer lanceolatus*	X	X		X					
Kyphosidae									
Kyphosus incisor	(X)								
Ephippidae									
**Chaetodipterus faber*	X	X	X	X					
Pomacentridae									
Abudefduf saxatilis	(X)								
Mugilidae									
**Mugil cephalus*	X	(X)	X	X	X		X	X	X
**Mugil curema*	X	(X)	X	X			X	X	X
Sphyraenidae									
Sphyraena guachancho	X								
Sphyraena picudilla	(X)								
Uranoscopidae									
**Astroscopus y-graecum*	X	X	X	X					
Blenniidae									
**Chasmodes bosquianus*	(X)	(X)							
Hypleurochilus geminatus	(X)	X							
**Hypsoblennius hentzi*	(X)	X		X					
Eleotridae									
**Dormitator maculatus*								X	
Gobiidae									
Evorthodus lyricus									(X)
**Gobionellus boleosoma*	X		X						X
Gobionellus hastatus		X							X
**Gobionellus shufeldti*	(X)							X	
Gobionellus smaragdus									X
**Gobiosoma bosci*	X	X	X	X	X				
**Gobiosoma ginsburgi*	(X)	(X)							X
Microgobius thalassinus									X

TABLE 2.—Continued.

Family and species	Habitat								
	1	2	3	4	5	6	7	8	9
Trichiuridae									
Trichiurus lepturus	(X)	X							
Scombridae									
Scomberomorus cavalla	(X)								
Scomberomorus maculatus	X	X							
Stromateidae									
Peprilus alepidotus	X	X		X					
Peprilus triacanthus	(X)	X		X					
Triglidae									
**Prionotus carolinus*	(X)	X							
**Prionotus evolans*	X	X	X	X					
Prionotus salmonicolor		X							
**Prionotus scitulus*	(X)	X		X					
**Prionotus tribulus*	(X)	X		X					
Bothidae									
**Ancylopsetta quadrocellata*		X		X					
Citharichthys spilopterus	(X)	X		X	X				

Family and species	Habitat								
	1	2	3	4	5	6	7	8	9
Bothidae—Cont.									
Etropus crossotus	(X)	X		X					
Paralichthys albigutta	(X)	X							
**Paralichthys dentatus*	X	X		X					
**Paralichthys lethostigma*	X	X	X	X	X				
Paralichthys squamilentus	X								
Scophthalmus aquosus	X	X		X					
Soleidae									
**Trinectes maculatus*	(X)	X		X	X	X			
Cynoglossidae									
**Symphurus plagiusa*	X	X	X	X	X				X
Balistidae									
Monacanthus hispidus	X	X	X	X					
Tetraodontidae									
Sphoeroides maculatus	X	X	X						
Diodontidae									
Chilomycterus schoepfi	X	X	X	X					

includes the North Newport River and lower parts of its tributaries from the lower end of Carrs Neck Creek (trawl station 10) upstream to station C. The upper reach extends from Payne Creek to the mouth of Riceboro Creek (station F). I generally treat these two sections as a unit for convenience.

Because salinity varies so greatly, this section of the estuary only roughly corresponds to the zones recognized by Carriker (1967). He recognized salinity ranges of 5 to 18‰ for the upper reach and 18 to 25‰ for the middle reach.

Habitat 5: Oligohaline creek (Figure 6). — The North Newport River originates at the confluence of Peacock and Riceboro Creeks. Oligohaline sampling stations were located in the oligohaline section of Riceboro Creek (Figure 2). Most fishes were collected in Riceboro Creek at station G and the lower part of Crossroads Creek where it joins Riceboro Creek near the town of Crossroads. Crossroads Creek was recently diverted into Riceboro Creek above the station by the State Highway Department, thus eliminating the station. Salinity and temperature ranges are given in Table 1. A temperature-salinity diagram (Figure 7) indicates that salinity generally increased with rising tide except when fresh water prevailed throughout the tidal cycle. In winter water temperatures were lowest at low tides.

Habitat 6: Freshwater creek. — Seven freshwater or limnetic stations in Coastal Plain creeks, free from the influence of salt water, are called "freshwater stations" in the text. The first six of these stations are in the North Newport River drainage in Liberty County and were sampled on 13 May 1968. The seventh is in the Ogeechee drainage in Chatham County and was occupied on 9 March 1969. Location of these collections are as follows: (1) Upper South Newport River at U.S. Highway 17; (2) Headwaters of Payne Creek on U.S. Highway 17, 2 miles west of Riceboro; (3) Tributary of Riceboro Creek about 2.5 miles north of Crossroads on a county road; (4) Peacock Creek, 2 miles southeast of McIntosh, on dirt road off U.S. Highway 82; (5) Goshen Swamp Creek on U.S. Highway 82, 2 miles south of Flemington; (6) Peacock Creek at Solomon Temple, between

FIGURE 5.—A muddy sand bar exposed at low tide at the mouth of Payne Creek where fishes were seined. *Spartina alterniflora* is visible on the right and the "back marsh" contains *S. alterniflora* and *Juncus roemerianus*. Hammocks and larger islands in this region are bordered by salt marshes and tidal creeks.

FIGURE 6.—Riceboro Creek near high tide at the Seaboard Railroad bridge. A variety of invertebrates are associated with the diverse intertidal flora, roots, and debris found in this oligohaline creek.

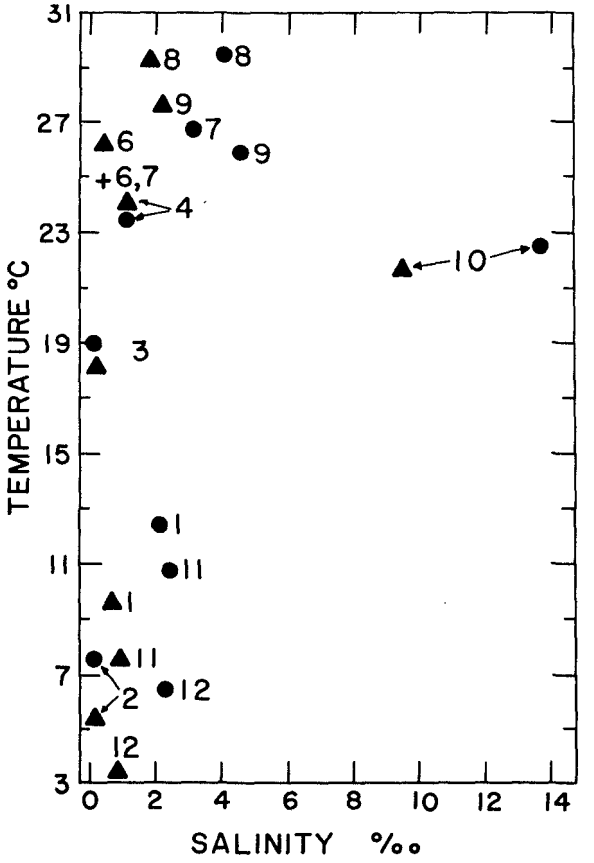

FIGURE 7.—Temperature-salinity diagram for Riceboro Creek at U.S. Highway 17; Numbers 1-4 are months of January through April 1969, and 6-12 are June through December 1968. Circles are high tide readings and triangles are low tide readings. Cross is high tide value for June and low tide value for July.

Midway and McIntosh on dirt road off U.S. Highway 82; (7) Tributary of Ogeechee River at U.S. Highway 17 near the Ogeechee River bridge.

Habitat 7: Tidal canal — This station is a runoff ditch or canal located in the marsh on the west side of Sapelo Island, 3.4 miles north of the Sapelo airport. This ditch is open to a polyhaline river (Mud River) at all tide levels and its mud banks are under several feet of water at high tide. Water depth was 3 to 4 ft at low tide in the deepest section, which was located at the end of a road culvert on the salt marsh side of a road.

Habitat 8: Low-salinity tidal pools — Two small pools located next to the road on the west side of Sapelo Island are treated together in the text. These pools are located 4.1 miles north of the Sapelo airport on the west side of the road. Runoff water flooding through a culvert opening into the lower and larger pools has eroded the bottom to a depth of approximately 5 ft. A higher culvert opening to the upper and smaller pool rarely has runoff water. This pool is 3 to 4 ft deep. At low tide only trickles of water connect the two pools and drain the lower pool through the marsh. Located behind the high marsh, these pools are flooded by Mud River only on high tide.

Habitat 9: High-salinity tidal pools (Figure 8). — These are a series of artificial pools located on the south end of Sapelo Island along a road leading to the Sapelo lighthouse, hence the local name lighthouse ponds. The pools are located behind a high marsh characterized by *Spartina alterniflora* and *Juncus roemerianus*. The pool sampled on the west side of the road is flooded by waters from South End Creek and the Marine Institute's boat basin. Two pools sampled on the east side of the road are connected at high tide and are flooded by waters from Deans Creek. *Palaemonetes pugio* was abundant in seine collection, except during the coldest weeks when the water temperature approached 8°C. At this time the fishes were also scarce or absent, and the relatively sterile and clear water allowed the author to see the bottom of the pools whereas the water was very turbid during other months.

METHODS

I seined shallow estuarine habitats (habitats 1, 5, 7, 8, and 9 and 4 in part) with a 35-ft (10.7-m) seine having ¼-inch (6.35-mm) bar mesh; a 10-ft (3.05-m) version was used in freshwater creeks. For habitat 3 I used the records of Miller and Jorgenson (1969) who collected with 40- and 70-ft (12.2- and 21.4-m) bag seines. Their records for St. Simons Island Beach are included in the list for habitat 1.

Habitat 2 (trawl stations 1-9, 12-14 in Figure 1) and the lower part of habitat 4 (trawl

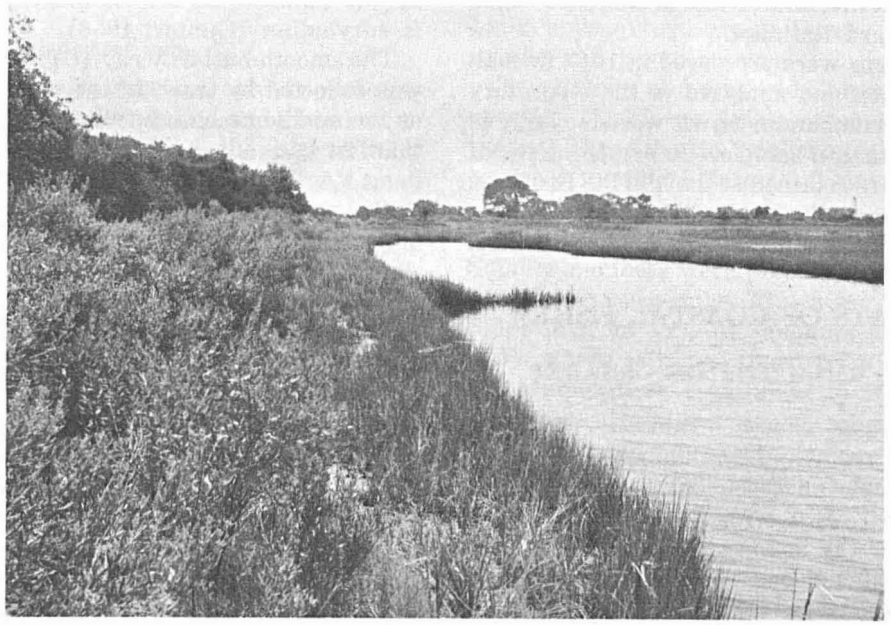

FIGURE 8.—Tidal "borrow pool" on west side of road to lighthouse on Sapelo Island. Zonation of dominant plants along road bank generally from left to right in picture: wax myrtle (*Myrica cerifera*), groundsel-tree (*Baccharus halimifolia*), marsh elder (*Iva frutescens*), and sea ox-eye (*Borrichia frutescens*). *Juncus roemerianus* and *Spartina alterniflora* are dominant along the pool bank. There is an abundance of crabs (*Uca* spp. and *Sesarma* sp.) in both the harder and softer substrates between the pool and the road.

stations 10 and 11) were sampled on RV *Kit Jones* cruises, each station for 15 min with a 20-ft (6.1-m) otter trawl which had 1¼-inch (32-mm) stretched mesh in the bag. Each of the 14 trawl stations was sampled about 37 times from January 1967 through December 1969 except for stations 6, 8, 12, and 13, which were sampled 33 or 34 times and then discontinued. Five trawl samples were lost for various reasons including snags at station 9 on two occasions.

All Sapelo Island habitats (1, 7, 8, and 9) were sampled during all four seasons and about 20 times from April 1967 through February 1970.

Habitat 4 was sampled primarily with a 20-ft (6.1-m) trawl and a 35-ft (10.7-m) seine. The two trawl stations (10 and 11) are the uppermost of the 14 stations sampled with the RV *Kit Jones* from January 1967 through December 1969. Seining stations were sand bars that were exposed only near low tide. Regular stations were at the lower end of Carrs Neck Creek (mile point 10 = 16.1 km) and the mouth of Payne Creek (mile point 15.4 = 24.8 km). These stations were seined approximately monthly from June 1969 to May 1970. In addition 22 collections were made between the upper end of Carrs Neck Creek and mouth of Riceboro Creek with the seine, a cast net, and a 10-ft (3.05-m) trawl towed by an outboard motor boat.

In habitat 5 most fish collections were seined at low tide at a muddy sand bar (station G) between the Seaboard Railroad tracks and the effluent outfall of the Interstate Paper Corp. Trawling (10-ft trawl) was most fruitful in the winter. Seine and dip-net collections were made at the Crossroads station.

A few additional collections were made with a 100-ft (30.5-m) seine in habitat 1, by angling in habitats 1 and 2 (Dahlberg and Heard, 1969),

and by dip net in habitat 8 and in Riceboro Creek at the Seaboard Railroad.

All specimens were preserved in 10% formaldehyde solution and analyzed in the laboratory except when numbers in trawls were too large to retain more than a sample. Representatives of all species were retained at the Marine Institute.

The phylogenetic order and names recommended by Bailey (1970) are followed herein.

HABITATS OF COASTAL FISHES

ORDER SQUALIFORMES - SHARKS

Ten species of sharks (Table 2) were collected in this study and by Dahlberg and Heard (1969). Nearly all specimens, bonnethead excepted, were caught with fishing poles at the beach and in the sounds. Only three sharks were trawled, one each of the spiny dogfish (*Squalus acanthias*), bonnethead (*Sphyrna tiburo*), and the blacktip shark (*Carcharhinus limbatus*).

Most shark species have distinct seasonal migratory patterns. Carcharhinid sharks apparently migrate into the estuary during the warm months as all six were collected from June to September. The spiny dogfish is a cold-water species that migrates into Georgia estuaries during the coldest months (Dahlberg and Heard, 1969); it was collected only in January and February.

ORDER RAJIFORMES - SKATES AND RAYS

The Atlantic guitarfish (*Rhinobatos lentiginosus*) and clearnose skate (*Raja eglanteria*) are most common in the ocean and were not collected farther up the estuary than the sounds. Although the guitarfish was collected only in May and June, the skate was taken throughout the year.

Three stingrays of the genus *Dasyatis* (Table 2) are common in the sounds and shallow waters along the beaches. The Atlantic stingray (*D. sabina*) was the most abundant of the three species taken by trawling and angling. It was commonly trawled in the middle reach of the estuary at salinities as low as 9.9‰. This species is euryhaline (Gunter, 1956).

The smooth butterfly ray (*Gymnura micrura*) was collected by trawl in the estuary as far up as the middle reaches but not at salinities lower than 24.4‰.

ORDER SEMIONOTIFORMES

Lepisosteidae - gars

Two species of *Lepisosteus* were taken in the study area. The Florida gar (*L. platyrhincus*) occurred only at freshwater station 2. The euryhaline longnose gar (*L. osseus*) was abundant and was often seen or trawled in fresh and brackish waters throughout the year. The longnose gar has been collected in the ocean off Georgia.

ORDER ELOPIFORMES

Elopidae - tarpons

Small ladyfish (*Elops saurus*) were common in enclosed waters of tidal pools and the tidal ditch. Only two specimens were collected in open waters, one at Sapelo Beach and one in the upper reach of North Newport River. The ladyfish was common in both the high- and low-salinity pools at a salinity range of 0.1 to 28.7‰. It entered the pools in May and remained until November when the temperature was 19.9°C.

Small tarpon (*Megalops atlantica*) were common in enclosed waters of tidal pools and the tidal ditch, and large tarpon were often hooked by anglers along Sapelo Beach. Young were collected only from July to October at a temperature range of 20.0° to 31.9°C and were more common in the low-salinity pools than the high-salinity pools; the recorded salinity range was 0.1 to 24.8‰. Rickards (1968) found tarpon at Sapelo Island from July to November at salinities of 0.0 to 22.3‰ and temperatures of 16° to 36°C.

Albulidae - bonefishes

Inclusion of the bonefish (*Albula vulpes*) in Table 2 is based on a record from St. Simons Beach (Miller and Jorgenson, 1969).

ORDER ANGUILLIFORMES

Anguillidae - freshwater eels

The catadromous American eel (*Anguilla rostrata*) was widely distributed and abundant in the freshwater habitat and the high-salinity pools, but absent from trawl stations. All small specimens (54-170 mm) occurred in low salinities (0-1.9‰) in the freshwater and oligohaline creeks, and the low-salinity pools. Large specimens (230-470 mm) occurred primarily in saline waters (13.1-30.3‰) but one was collected in fresh water.

Ophichthidae - snake eels

One speckled worm eel (*Myrophis punctatus*) was collected with a dip net in Riceboro Creek under the Seaboard Railroad bridge. The 243-mm specimen was taken at a salinity of 0‰ and temperature of 24°C. Miller and Jorgenson (1969) also reported it from the beach and high marsh habitats.

Three shrimp eels (*Ophichthus gomesi*) were trawled in the lower reach at stations 4, 7, and 9. They probably burrow and easily escape the trawls. I have also seen specimens of the pale-spotted eel (*O. ocellatus*) from the Georgia coast.

ORDER CLUPEIFORMES

Clupeidae - herrings

Three anadromous species of shad (*Alosa*) are listed (Table 2) for the habitats along their migratory route. I collected the American shad (*A. sapidissima*) and hickory shad (*A. mediocris*) only in saline waters. Both of these species and the blueback herring (*A. aestivalis*) spawn in the nearby Altamaha River (Godwin and Adams, 1969).

Young American shad were occasionally collected from the lower reach to the upper reach from December to April. Since the spawning season of the American shad is from March through May in the Altamaha River (Godwin and Adams, 1969), 60- to 114-mm specimens collected from December to March were approximately 1 year old, and a 29-mm shad collected in April was recently spawned. Both age groups were represented in the upper reach but only individuals of age group I were taken in the middle and lower reaches.

Two species and a hybrid of menhaden (*Brevoortia*) (Dahlberg, 1970) occur within the estuary. The Atlantic menhaden (*B. tyrannus*) occurred in eight habitats. Compact schools of adults occurred in the lower reach of the estuary and along the beaches from spring through fall. Smaller numbers were present in the sounds in the winter. Juveniles (29-42 mm) were often collected from June to September in the upper reach where salinity ranged from 0.5 to 16.8‰ and temperature, from 28.4° to 30.8°C. Juveniles were also collected in the oligohaline Riceboro Creek and this species is known to occur in fresh water (Gunter, 1956). Young menhaden (30-99 mm) also occurred in the tidal pools and tidal ditch in May and June.

The yellowfin menhaden (*B. smithi*) was collected in the high-salinity pools, tidal canal, and along the beach. Its absence from trawl collections supports my theory (Dahlberg, 1970) that *B. smithi* is a bay or shallowwater species. The occurrence of this species apparently is restricted by low temperature as it first appeared in May and was present until water temperature decreased to approximately 20°C in November. Its absence after November may result from a southward migration since it is common along Florida in the winter (Dahlberg, 1970).

The hybrid (*B. smithi* × *B. tyrannus*) was the least common of the menhadens. It was collected with *B. smithi* on 5 May 1969 in the tidal canal which had a salinity of 18.8‰ and a temperature of 29°C. Hybrids were collected also along the beach and in the Marine Institute's boat basin at Sapelo Island.

The gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*D. petenense*) are euryhaline species that are important forage fishes in Georgia reservoirs. The gizzard shad is known from the upper reach and the oligohaline creek from two trawl collections made on 19 November 1969. These large gizzard shad (205-220 mm) were collected at water temperatures of 15.5° and 14.1°C, and others were caught in the Marine Institute's boat basin (lower reach habitat) in the summer of 1969.

The occurrence of the threadfin shad at Sapelo Island may have resulted from recent introduction of this species in the Altamaha and Savannah River drainages by the Georgia Game and Fish Commission. Movement to the north through estuarine waters is also possible. This species was taken in water as saline as 29.8‰ and over a temperature range of 26.0° to 30.6°C.

The scaled sardine (*Harengula pensacolae*) and Atlantic thread herring (*Opisthonema oglinum*) were occasionally collected in the higher salinity waters of the beach, lower reach, and high marsh habitats. The Spanish sardine (*Sardinella anchovia*) was reported from St. Simons Beach by Miller and Jorgenson (1969).

Engraulidae - anchovies

Of four species of anchovies known from Georgia, only the striped anchovy (*Anchoa hepsetus*) and bay anchovy (*A. mitchilli*) were common and widely distributed in the estuary. The bay anchovy was one of the most abundant fish species in trawl and seine collections. It was often collected in fresh waters of the oligohaline creek and upper and middle reaches, but was absent from protected waters with low salinity. The bay anchovy was present throughout the year at a temperature range of 7.9° to 32.0°C. The striped anchovy was found in fewer habitats than the bay anchovy, and it occurred only during warmer seasons, May to November, at a temperature range of 15.7° to 30.8°C.

Two tropical species (*A. cubana* and *A. lyolepis*) were collected at St. Simons Beach (Miller and Jorgenson, 1969) but were not collected at Sapelo Beach.

ORDER SALMONIFORMES

Esocidae - pikes

The pickerel (*Esox americanus*) was collected at five freshwater stations. On 16 December 1969, one specimen was trawled in lower Riceboro Creek where the salinity was 0.3‰ and the temperature, 7.4°C.

Umbridae - mudminnows

The little-known eastern mudminnow (*Umbra pygmaea*) was collected at freshwater station 6, the Ogeechee River tributary. This Coastal Plain species is rare in collections from Georgia waters.

ORDER MYCTOPHIFORMES

Synodontidae - lizardfishes

Only one species (*Synodus foetens*) of the lizardfishes ranges inshore in Georgia estuaries. Six specimens were collected by trawls in 1967 and one by a seine in 1969 in the lower and middle reaches from June to November when the salinity was 16.7 to 32.0‰ and temperature was 16.3° to 31.5°C.

ORDER CYPRINIFORMES

Cyprinidae - minnows and carps

Three species of the freshwater cyprinids were collected. Some large carp (*Cyprinus carpio*) were caught in the lower Atlamaha River during the spring and some apparently moved to Doboy Sound and off Sapelo Beach with the flood waters that reduced salinities to 6.8‰ along Sapelo Beach. Three large carp were found dead on Sapelo Beach in April 1970. Some survived in a low-salinity tidal creek that was temporarily dammed on Sapelo Island until June when they were found dead. The alien carp is not known from the North Newport River headwaters.

The golden shiner (*Notemigonus crysoleucas*) was common in the freshwater habitat, and three juveniles (20-24 mm) were collected in the oligohaline creek on 4 September 1969 when the salinity was 0‰ and temperature was 26.4°C. The golden shiner is a common bait and forage fish in Georgia.

The little-known taillight shiner (*Notropis maculatus*) was taken only at freshwater station 4.

Catostomidae - suckers

The lake chubsucker (*Erimyzon sucetta*) was collected at freshwater stations 1, 4, and 6.

ORDER SILURIFORMES

Ictaluridae - freshwater catfishes

Three species of freshwater catfishes were collected. The yellow bullhead (*Ictalurus natalis*) was common in freshwater stations. A 16-mm tadpole madtom (*Noturus gyrinus*) wandered downstream from its typical freshwater habitat to the Crossroads station where the salinity was 1.9‰. The white catfish (*I. catus*) ranged down the estuary to the middle reach (trawl stations 10 and 11) when the salinity was reduced to 11.7 and 9.2‰ and temperatures were 11.1° and 10.8°C, in January and February. White catfish were seined and trawled (10-ft trawl) on nine occasions in the oligohaline creek at salinities less than 1‰ and at a temperature range of 7.4° to 28.4°C. Large samples including specimens over a length range of 40 to 300 mm, trawled in January and February 1970, suggest that large numbers of white catfish moved into the oligohaline creek when temperatures were 8.6° and 10.0°C. The low temperatures could also reduce their mobility and ability to avoid the trawl.

Ariidae - sea catfishes

The sea catfish (*Arius felis*) and gafftopsail (*Bagre marinus*) were most abundant in the lower reach of the estuary but also occurred in the middle reach and beach habitats. Most of the sea catfish (*Arius*) migrated to the ocean in the late autumn and winter and returned to the estuary and beaches in the spring (Table 3). Males orally incubated the marble-sized eggs in June and July. Young with and without yolk sacs were incubated in August until they were 42 mm long or longer. Young lost the yolk sac when they were 37 to 40 mm long. The gafftopsail also is an oral incubator, but none of the few adults collected contained eggs or young. This species is common in the warm months but scarce in the winter.

ORDER PERCOPSIFORMES

Amblyopsidae - cavefishes

The rare swampfish (*Chologaster cornuta*) was collected at freshwater station 7.

TABLE 3.—Length-frequency distribution of the sea catfish, *Arius felis*, collected with a trawl, 1967. There was no June collection.

Length	Apr.	May	July	Aug.	Sept.	Oct.	Nov.
mm							
25-30				4			
31-35				31			
36-40				104	4		
41-45				123	19		
46-50				90	65		
51-55				45	93	8	
56-60				10	72	26	
61-65				2	55	92	1
66-70	1				11	92	2
71-75	1	3		1	3	51	
76-80	3	3			3	22	
81-85	3	5					
86-90	2	24					
91-100		27	2		1		
101-110		7	20				
111-120		1	53		2		
121-130	1		37	16			
131-140		7	7	16	1		
141-150		7	1	3			
151-160		10	8	2			
161-170		2	13	3			
171-180		10	7	8			
181-190		11	3	6			
191-200		11	9	6	1		
200-210		9	5	3			
211-220		5	6	2			
221-230		3	1	2			
231-240		3	2				
241-250		3					
251-260		2					
261-280		2					

Aphredoderidae - pirate perches

The pirate perch (*Aphredoderus sayanus*) was collected at freshwater stations 3, 4, 5, and 7, and one specimen was taken in fresh water in the oligohaline creek.

ORDER BATRACHOIDIFORMES

Batrachoididae - toadfishes

The oyster toadfish (*Opsanus tau*) was often collected in small numbers in trawls in the lower and middle reaches of the estuary throughout the year. This toadfish is sometimes seen in oyster reefs, and one specimen was found in a fouling community on the underside of a floating dock. The collection of only one specimen in the beach habitat can be attributed to the lack of cover. Salinity ranged from 12.4 to 32.0‰ and temperature, from 28.4° to 30.8°C.

ORDER GOBIESOCIFORMES

Gobiesocidae - clingfishes

The habitats of the small skilletfish (*Gobiesox strumosus*) are similar to those of toadfish. It is usually associated with oyster reefs or bottoms that provide cover, especially shell bottoms. The skilletfish occurred in small numbers in the lower and middle reaches throughout the year.

ORDER LOPHIFORMES

Antennariidae - frogfishes

Two species of frogfishes (Table 2) collected at St. Simons Beach (Miller and Jorgenson, 1969) are stragglers from offshore. The sargassumfish (*Histrio histrio*) is often associated with sargassum weed, which drifts onto Sapelo Beach.

ORDER GADIFORMES

Gadidae - codfishes

The southern hake (*Urophycis floridanus*) and spotted hake (*U. regius*) were common in the trawl collections in the lower and middle reaches from January to May. These southern representatives of a group that inhabit cold water first entered the estuary when the temperature was 8.2° to 10.1°C in January, and they remained until it rose to 24.3° to 24.6°C. Salinity and temperature ranges were 12.4 to 30.6‰ and 9.0° to 24.6°C for *U. floridanus*, and 14.5 to 31.1‰ and 8.2° to 24.3°C for *U. regius*. Miller and Jorgenson (1969) also reported four *U. regius* from St. Simons Beach.

Ophidiidae - cusk-eels

This family is represented by one species, the striped cusk-eel (*Rissola marginata*), in Georgia estuaries. Small numbers of this burrowing species were collected throughout the year by trawling in the lower and middle reaches at salinities of 11.6 to 32.6‰ and temperatures of 8.0° to 30.0°C.

ORDER ATHERINIFORMES

Belonidae - needlefishes

Several needlefishes range to the Georgia coast, but only the Atlantic needlefish (*Strongylura marina*) is common in Georgia estuaries. It is occasionally seen around docks in the lower and middle reaches and specimens were seined at the beach, high marsh, and middle reach habitats. Specimens (52-315 mm) were collected from May to October at 22.9° to 30.9°C.

Cyprinodonidae - killifishes

These small fishes are found almost entirely in shallowwater habitats. The euryhaline sheepshead minnow (*Cyprinodon variegatus*) was present throughout the year at salinity and temperature ranges of 0.8 to 34.0‰ and 7.9° to 31.9°C in the tidal pools, beach, high marsh, and tidal canal habitats.

The golden topminnow (*Fundulus chrysotus*) was collected at freshwater stations 3 and 5.

The marsh killifish (*F. confluentus*) occurred at freshwater station 1 and at Crossroads but was common only at an artesian well and in the low-salinity tidal pool where it occurred throughout the year. Recorded salinity and temperature ranges were 0 to 24.4‰ and 7.8° to 29.3°C.

The mummichog (*F. heteroclitus*) occurred at all the habitats except the freshwater habitat. Although it is a shallowwater species, two collections were made at trawl stations (10 and 12) that were close to the marsh. The mummichog was common at most seine stations but was rare along the beach. Recorded salinity and temperature ranges were 0 to 34‰ and 7.8° to 32.2°C.

The southernmost record of the spotfin killifish (*F. luciae*) was reported by Miller and Jorgenson (1969).

The striped killifish (*F. majalis*) was present at the Sapelo Beach throughout the year, but was scarce during the coldest months. It was also common in the high marsh and high-salinity tidal pools, and uncommon in the tidal ditch. The striped killifish was not taken at sand bars in the middle reach although it was col-

lected at low salinities. Salinity and temperature ranges were 6.8 to 34.0‰ and 7.0° to 32.2°C.

The last three cyprinodonts listed on Table 2 are freshwater species characteristic of the Coastal Plain. The bluefin killifish (*Lucania goodei*) is also common in fresh water on Sapelo Island.

Poecilidae - livebearers

The euryhaline mosquitofish (*Gambusia affinis*) occurred at seven habitats and was abundant at the freshwater, oligohaline creek, and low-salinity tidal pool stations. It was collected on the beach only when the salinity was 6.8‰, but it was not uncommon at higher salinities. Salinity and temperature ranges were 0 to 34‰ and 7.3° to 30.7°C.

The least killifish (*Heterandria formosa*) is a freshwater species that occasionally wanders into estuarine waters. The highest salinity record was 4.0‰.

The sailfin molly (*Poecilia latipinna*) was common in the shallow protected waters of the tidal pools, tidal ditch, and an artesian well on Sapelo Island. It occasionally occurred in the high marsh, beach, and oligohaline creek habitats. Temperature and salinity ranges were 7.3° to 32.2°C and 0 to 34‰.

Atherinidae - silversides

The rough silverside (*Membras martinica*) was common at the beach and high marsh habitats. It was attracted to artificial lights at night and collected in large numbers with a dip net in the lower reach. Because of their pelagic nature and small size, only one was collected in a trawl.

The Atlantic silverside (*Menidia menidia*) was found in the four high salinity habitats and in the middle and upper reaches of the estuary. This silverside was common only at high salinities, but it occurred at a sand bar in the middle reach when the salinity was 0.9‰ on 4 September 1969. Although collected at a temperature range of 7.0° to 31.5°C, this silverside left the sand bars of the middle and upper reaches at temperatures below 12°C.

The tidewater silverside (*Menidia beryllina*) was common in the freshwater and oligohaline creek habitats at salinities of 0 to 7.9‰. It ranged to the middle reach when the salinity was 0.1‰. One was collected at Sapelo Beach when the salinity was 6.8 to 7.7‰; this was the only occasion the two species of *Menidia* were collected together although their habitats and salinity tolerances overlap.

ORDER GASTEROSTEIFORMES

Syngnathidae - pipefishes and seahorses

One lined seahorse (*Hippocampus erectus*) was collected by trawl in Johnson Creek (station 4) in May 1969 at a salinity of 27.1‰ and a temperature of 22.3°C. The northern pipefish (*Syngnathus fuscus*) was taken sporadically by trawl and seine throughout the year. It occurred in four habitats at a salinity range of 0 to 31.3‰.

The chain pipefish (*Syngnathus louisianae*) was uncommon in all six habitats where it was found. It was taken by trawl and seine throughout the year, but was less common than the northern pipefish. The chain pipefish was collected only 12 times and at a salinity range of 0.7 to 31.6‰.

ORDER PERCIFORMES

Centropomidae - snooks

The snook (*Centropomus undecimalis*) was represented by young (23-81 mm) collected in protected waters of the tidal pools and tidal ditch. These were collected from June to November at salinity and temperature ranges of 0 to 22.1‰ and 23.0° to 28.6°C. Linton and Rickards (1965) collected 64 juveniles (24.1-74.9 mm long) at Sapelo Island in 1963 and 1964. Their low temperature record of 18°C occurred in November.

Serranidae - sea basses

Of the diverse serranids found on the Georgia coast, only two species range inshore to the estuary. Young of the black sea bass (*Centropristis striata*) and rock sea bass (*C. philadelphica*)

were collected throughout the year in the lower reach, mostly over shell bottoms at trawl stations 3 to 6.

Centrarchidae - sunfishes

Twelve centrarchids (Table 2) were common in the creeks of the Coastal Plain. Six species (*Centrarchus macropterus, Lepomis auritus, L. gulosus, L. macrochirus, L. punctatus,* and *Micropterus salmoides*) were also collected in the oligohaline creek. Although sunfishes have marked tolerance for salinity (Bailey, Winn, and Smith, 1954), none of these were found at a salinity above 0.5‰.

Percidae - perches

The swamp darter (*Etheostoma fusiforme barratti*) was collected only at freshwater stations 3, 4, and 5.

Pomatomidae - bluefishes

The bluefish (*Pomatomus saltatrix*) is often caught by anglers in the beach and lower reach habitats but was rarely taken in this study. Only four young (115-196 mm) were collected, one in each season of the year.

Echeneidae - remoras

A sharksucker (*Echeneis naucrates*) is recorded for the lower reach and beach habitats since one was attached to a lemon shark that was caught from the beach in Doboy Sound (Dahlberg and Heard, 1969).

Carangidae - jacks and pompanos

Nine species of carangids occurred primarily in the beach and lower reach habitats. The horseeye jack (*Caranx latus*) is represented by four specimens from St. Simons Beach (Miller and Jorgenson, 1969). The crevalle jack (*C. hippos*) was occasionally caught by anglers in the lower reach of the estuary and a few juveniles were seined as far up the estuary as the upper reach when the salinity was 10.8‰. Five small specimens (24-77 mm) were collected in the summer and autumn.

The Atlantic bumper (*Chloroscombrus chrysurus*) and leatherjacket (*Oligoplites saurus*) were mostly caught at the high-salinity stations. The lowest salinity recorded for the leatherjacket was 16.8‰. Both occupied shallow waters and the bumper was also caught in trawls.

The lookdown (*Selene vomer*) and Atlantic moonfish (*Vomer setapinnis*) were found in the beach habitat generally from May to November. Lookdowns were occasionally trawled in the sounds.

Young of the commercially important Florida pompano (*Trachinotus carolinus*) and young permit (*T. falcatus*) were common in the beach habitat and occasionally wandered to the high marsh. Young pompano were present from spring to autumn. The palometa (*T. goodei*) was present in summer and autumn at St. Simons Beach (Miller and Jorgenson, 1969), and the permit followed the same pattern at Sapelo Beach.

Lutjanidae - snappers

The gray snapper (*Lutjanus griseus*) spawns offshore, and the young have occasionally been collected in the beach, high marsh, and tidal pools habitats. This primarily tropical species was collected from August to November. The lowest salinity recorded for this species was 13.1‰.

Gerreidae - mojarras

Three species of mojarras, Irish pompano (*Diapterus olisthostomus*), spotfin mojarra (*Eucinostomus argenteus*), and flagfin mojarra (*E. melanopterus*), were collected. The flagfin mojarra was represented in one collection that contained all three species. This unusual collection was at a sand bar in the oligohaline creek on 22 October 1969 when the salinity was 0.7‰ and the temperature was 24°C. The Irish pompano was represented by juveniles collected at six shallowwater habitats. They occurred from July to November at salinities and temperatures of 0.7 to 31.3‰ and 19.4° to 31.8°C.

The spotfin mojarra was collected in seven habitats by seining and was the only mojarra collected (twice) by trawling. This species was

taken from July to November at salinities and temperatures of 0.7 to 31.3‰ and 12.7° to 31.1°C. Dr. C. L. Hubbs identified this species in two collections from Sapelo Beach and Riceboro Creek, and I believe that neither of the closely related species, *E. gula* or *E. jonesii*, occurred in my collections.

Pomadasyidae - grunts

The primarily tropical grunts are represented by the pigfish (*Orthopristis chrysoptera*) in Georgia estuaries. The pigfish was trawled in the lower and middle reaches from June to December and was also collected at the beach. A minimum salinity of 15.4‰ was recorded.

Sparidae - porgies

The sheepshead (*Archosargus probatocephalus*) provides an important sport fishery around docks in the lower reaches and also occurred in the high marsh and beach habitats. The small pinfin (*Lagodon rhomboides*) was rare but widespread (six habitats). Small pinfish (20-87 mm) were present from May to September, and most were collected in the intertidal pools.

Sciaenidae - drums

This is the most important family of fishes in Georgia estuaries to sport fishermen. Sciaenids are the most numerous fishes in terms of numbers available to trawls (Anderson, 1968), and probably most abundant in terms of biomass in trawl collections.

Silver perch (*Bairdiella chrysura*) occupied a variety (8) of habitats. Adults were common only in trawl collections in the lower and middle reaches. The silver perch spawned primarily in April and May (Table 4). The smallest specimens were collected in the lower reach and high-salinity pools in May and June. Two age groups (Table 4) were distinct from May to July. Young grew rapidly from May to October in a wide variety of habitats. They apparently use the whole estuary and also the beach waters as a "nursery ground." Salinity and temperature ranges for this species were 1.3 to 34.1‰ and 7.5° to 32°C.

The spotted seatrout (*Cynoscion nebulosus*) are among the most important estuarine fishes to Georgia anglers. They were occasionally trawled in small numbers in the lower and middle

TABLE 4.—Length-frequency distribution of the silver perch, *Bairdiella chrysura*, collected by trawling and seining, 1967-68.

Length	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
mm												
16-20			3									
21-25			13	6								
26-30			92	6								
31-35			20	14	10							
36-40				8	46							
41-45				1	85	2						
46-50				1	85	8						
51-55				3	66	9	2					
56-60					43	10		1				
61-65					34	15	4	5				
66-70					8	9	7	15		1		
71-75					4	6	7	35	1	2		
76-80						4	13	48	3	2		2
81-85	1		2			4	14	64	5	4	3	5
86-90			1	2		1	14	65	6	5	3	4
91-95	3	7	2	1			6	60	6	4	10	4
96-100	2	1	9	2	1		3	52	4	13	9	1
101-105	1	8	20	5				36	2	8	5	
106-110	4		6	3	1			14			1	1
111-115	2		7		1			4			2	
116-120	1		1		2			1		1		
121-125											1	
126-130											1	
131-135					1							
136-140					1							

TABLE 5.—Length-frequency distribution of weakfish, *Cynoscion regalis*, collected by trawling, 1967-68. None were collected in March.

Length	Jan.	Feb.	Apr.	May	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
mm											
11-20				4	2		2				
21-30				7	42	25	18				
31-40				27	93	66	18	6			
41-50				12	150	55	7	24			
51-60				1	122	24	5	30			
61-70	1				151	17	5	50	1	1	
71-80	1				157	16	9	61	3		
81-90	1			1	141	21	4	66	18	1	
91-100	1				122	28	1	36	24	4	2
101-110	5	1	2	1	95	29		22	18	7	
111-120	1			4	50	41	5	14	5	1	
121-130	1	1	2	11	18	35		9	2	3	1
131-140		1		7	13	25		8	1		
141-150			2	16	6	10		3		1	
151-160				9		4		1			
161-170				3		1					
171-180				1	4	1					
181-190					1						
191-200					1	1					
201-210								1			
211-220								1			
221-230											
231-240		1									

reaches throughout the year. They were rarely seined in shallowwater habitats although many are caught with fishing poles along the beaches and salt marshes. Spotted seatrout are known to spawn in and spend their whole life in the estuary (Tabb, 1966). Juveniles were found as far up the estuary as the upper reach at a salinity of 0.5‰.

During 1967-69, silver seatrout (*Cynoscion nothus*) entered the lower reach of the estuary in May and stayed until July or August.

Weakfish (*Cynoscion regalis*) apparently spawned from April to August (Table 5). With the exception of May samples, age groups are difficult to recognize because of the protracted spawning season. Young weakfish were collected in six habitats. Adults and young were abundant only in trawl collections in the lower and middle reaches. Although most abundant in high-salinity waters, young weakfish occurred at salinities as low as 6.6‰ in the upper reach. Weakfish were conspicuously scarce in the cold months, December to April.

The banded drum (*Larimus fasciatus*) was occasionally collected in the lower reach throughout the year and was collected three times along the beach. It was restricted to high salinities, 22.0 to 34.1‰.

Length frequencies of the spot (*Leiostomus xanthurus*) were based on trawl and seine collections (Table 6). Adults were common in deeper waters and juveniles dispersed to eight shallowwater and deepwater habitats. Young spot (11-85 mm) were among the most numerous fishes of the oligohaline creek where they were collected seven times from April to July at a salinity range of 0.2 to 3.1‰. Young were also common in the tidal pools and tidal ditch. Seine collections indicated that the spot spawned primarily from January to April. Two age groups were distinct from February to May.

The three species of kingfishes (*Menticirrhus*) have marked similarities and differences in their ecologies. All three occurred in the beach and lower reach habitats and were rare in the high marsh. Young southern kingfish (*M. americanus*) were also taken in the middle and upper reaches. It is the only kingfish that was found in low salinities. Four juveniles (19-36 mm) were collected in the upper reach in July and August at salinities of 1.5 to 7.9‰, much lower than the low-salinity limits observed by Gunter (1961).

Seining along Sapelo Beach took young southern kingfish that had been spawned primarily from April to August (Table 7). Young and

TABLE 6.—Length-frequency distribution of the spot, *Leiostomus xanthurus*, collected by seine, 1967-69 (in parentheses) and by trawl in 1967. None were collected in September.

Length	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Oct.	Nov.	Dec.
mm											
11-15		(2)	(3)		(3)						
16-20		(10)	(14)		(2)						
21-25		(6)	(30)	(4)	(1)						
26-30			(12)	(3)	(1)						
31-35				(2)	(6)	(4)					
36-40			(1)	(4)	1 (10)						
41-45				(2)	3 (11)	(2)	(7)				
46-50				(1)	2 (10)		(5)				
51-55				(1)	3 (9)	(3)	2 (9)	(2)			
56-60				(5)	2 (9)	(3)	5 (13)				
61-65				(4)	(5)		6 (6)	(1)			
66-70	4	2			(3)	(3)	7 (3)	1			
71-75	11	10			(1)	(1)	4 (3)				
76-80	12	14			2 (1)	2 (3)	5		3		
81-85	17	12	4		(2)		2 (1)				
86-90	18	14	3				2	1	2 (1)		
91-95	14	18	1	2	2			2			
96-100	19	16	3		4		2	2			1
101-105	23	18	9	2	4		1	2			1
106-110	14	7	7	4	7		1	2			
111-115	21	8	7	2	8			2			
116-120	13	8	11		12		1				
121-125	9	8	7	3	9		1				
126-130	10	5	9	2	10		2	1			
131-135	5	5	10	5	9		2			2	1
136-140	1	2	5	2	9		2				1
141-145	2		4	3	9		5	1		1	1
146-150	2	1		1	4		6			2	3
151-155							7			1	
156-160					1					1	2
161-165					1		2			1	1
166-170							1				

adults also occupied the lower and middle reaches. Although generally common, adults were rare in March and April apparently because they migrate to the ocean where they spawn in offshore waters (Bearden, 1963).

Gulf kingfish (*M. littoralis*) spawned primarily from April to September, judging from 18- to 22-m specimens that were taken along the beach from May to October. The Gulf kingfish was common only along the beach from May to November in my collections.

The northern kingfish (*M. saxatilis*) was the least common of the kingfishes. Young (17-50 mm) occurred along the beach in April and May, and five larger specimens (58-140 mm) were trawled in the lower reach from May to August.

The Atlantic croaker (*Micropogon undalatus*) somewhat resembles the spot (*Leiostomus xanthurus*) in population size and distribution in the estuary. Table 8 indicates that croakers spawned primarily from September to April. Bearden (1964) found that in South Carolina croakers spawned almost entirely in the ocean, and larvae were found from October through May. Young croakers (16-80 mm) were collected in seven habitats, including six shallow-water habitats, at salinities down to 2.7‰. Unlike spots, young croakers were not abundant in shallow water and they did not occur in fresh water. Adult croakers were common in trawl catches in the lower and middle reaches, especially May through August when they were not spawning. The population decline in autumn

TABLE 7.—Length-frequency distribution of the southern kingfish, *Menticirrhus americanus*, collected at Sapelo Beach by seine, 1967-68 (parentheses) and by trawls, 1967.

Length	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
mm												
11-15					1 (4)				(2)			
16-20					1 (33)	(1)	2 (2)	(1)	1 (15)			
21-25					1 (48)	(13)	2 (1)	1 (1)	4 (23)			
26-30					(14)	(24)	19 (14)	21 (2)	11 (7)			
31-35					(2)	(45)	38 (28)	49 (2)	12 (3)	(1)		
36-40						(19)	48 (33)	41	11	6 (2)	1	
41-45					1	(2)	30 (11)	30	5	18	1	
46-50							39 (3)	26	9 (1)	27		
51-55					(1)		15 (1)	28	6	21	2	1
56-60					(2)		15 (2)	29	9	17	3	1
61-65	1				(1)		14	20	8	14	5	1
66-70		2			(1)		15 (3)	21	7	11	3	4
71-75	1	2					16 (2)	12	4	10	8	7
76-80	4	3					19	12	4	7	7	13
81-85	2	6	1				18	16	10	9	6	5
86-90	3	12		1			13	4	4	14	7	4
91-95	4	7					11	9	2	10	6	3
96-100	4	13					7	10	2	5	6	5
101-105	4	6					11	6	2	11	5	2
106-110	1	8	1				1	6	1	6		4
111-115	1	5			2			2	2	10	4	4
116-120	1	6	1		2			1	1	4	5	2
121-125	1	2					1		1	6		1
126-130	1	5			2			1	2	4	2	2
131-135	2				3			2				4
136-140	2	1		1	3		1					1
141-150	3	1	1		4		1	1		3	2	2
151-160	2	1	1		2		2	1		5	2	
161-170	1						2				1	1
171-180	2						2	1				
181-190		1					1	1	1			2
191-200		1			2		3					
201-210	1						1					1
211-220									1			1
221-230										2		1
241-250		1										1

was the result of seaward migration for spawning. Bearden (1964) found ripe croakers 3 to 30 miles offshore. Correlation of movements with spawning is complicated by the protracted (8 months) spawning period.

Large black drums (*Pogonias cromis*) are occasionally caught by fishermen in the lower reach. I collected only a few black drums, all small (19-130 mm), mostly in the high-salinity pools.

The red drum (*Sciaenops ocellata*) is one of the most popular estuarine sport fishes because of its large size and abundance in the beach and lower reach habitats. The red drum was taken in only six seine collections and no trawl collections. The smallest (36 and 37 mm) specimens occurred in November.

The star drum (*Stellifer lanceolatus*) was the most abundant species in the lower reach habitat in 1967 (Dahlberg and Odum, 1970) and also in estuaries near Brunswick in 1933-35 (Anderson, 1968). It is a small species and may account for less biomass than the spot or croaker. Young of the year, apparently spawned from May or June to September (Dahlberg and Odum, 1970), accounted for most of the numbers.

TABLE 8.—Length-frequency distribution of the Atlantic croaker, *Micropogon undulatus*, 1967 and January and February 1968. Most were collected with a trawl. Seine and cast net collections are indicated by parentheses.

Length	1967											1968	
	Jan.	Feb.	Mar.	Apr.	May	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
mm													
16-20											(5)		(1)
21-25					1					(1)	(9)		
26-30					3				1		(6)		
31-35					1				2		(6)		
36-40					2				2	2	(1)		
41-45					3				1	2	2		
46-50		1			10				1		4		1
51-55		2			17	1	1	1		1	1	1	
56-60	1		1		7	1	1	1					2
61-65		2		2	8	5			5			1	1
66-70				1	20	7			11				1
71-75		1		4	17	6			2				
76-80	2	2	1	1	23	13			5	1			
81-85	1			2	25	12	2		8	1	1		1
86-90			1	1	8	18			3	2	2	1	3
91-95			3		7	43	3		5	1	3	3	1
96-100				1	7	47	7		1			2	1
101-105					4	70	6				1	1	
106-110						81	10						4
111-115		1				74	13			1		1	5
116-120		2	1			50	9				2	1	4
121-125	1	1		1		41	10			1		1	1
126-130	1	2				16	5					2	1
131-135		2			1	4	4		1		1		2
136-140						3	3					1	
141-145						3		1					
146-150							1						
151-170								1	1				

Most star drum left the estuary during the cold months.

Kyphosidae and Pomacentridae

These two families were represented only by stragglers from offshore (Table 2). They were collected at St. Simons Beach (Miller and Jorgenson, 1969).

Ephippidae - spadefishes

Small Atlantic spadefishes (*Chaetodipterus faber*) were common in trawls in the lower and middle reaches from June to October at a temperature range of 20.1° to 32.0°C. They were uncommon in shallowwater habitats and were not collected at salinities below 9.9‰.

Mugilidae - mullets

Striped mullet (*Mugil cephalus*) and white mullet (*M. curema*) were widespread and abundant in the estuary. Both species generally occupied shallow water near the surface. The striped mullet was collected in eight shallow-water habitats, and it often enters inland rivers. The white mullet occupied the same estuarine habitats with the exception of the oligohaline creek. This difference may be attributed to salinity preferences since the white mullet was taken at salinities down to 5.0‰ and the striped mullet was often collected at salinities below 0.5‰.

The striped mullet was common or abundant in all the habitats in which it occupied. The white mullet was common in the beach and high-salinity pool habitats. The striped mullet apparently has a greater temperature tolerance since it was collected throughout the year at a temperature range of 7.0° to 31.7°C. The white mullet was absent from collections from January through March and occurred at a temperature range of 15.0° to 32.2°C.

Length frequencies indicated that the striped mullet spawned from September through April and the white mullet from March through September, with some overlap in March, April, and September.

Sphyraenidae - barracudas

Young of two species of barracudas occurred in the beach habitat. One guaguanche (*Sphyraena guachancho*) was collected at Sapelo Beach in October 1967. Three southern sennets (*S. picudilla*) were collected at St. Simons Island Beach in May (Miller and Jorgenson, 1969).

Uranoscopidae - stargazers

The southern stargazer (*Astroscopus y-graecum*) was occasionally trawled in the lower and middle reaches. Young were seined along the beach and in the upper and middle reaches at salinities as low as 12.5‰.

Blennidae - combtooth blennies

Three species of blennies (Table 2) are commonly associated with oyster reefs or patches of oyster shells in the lower reaches of the estuary. The feather blenny (*Hypsoblennius hentzi*) was occasionally trawled in the lower and middle reaches and one crested blenny (*Hypleurochilus geminatus*) was trawled in the lower reach. All three species occasionally occurred along the beach (Miller and Jorgenson, 1969) generally in association with shell or debris.

My data suggest that the feather blenny occurred primarily in deep water in the cold months and that they migrated to the oyster reefs in the warm months where they rear their eggs inside of gaping oyster shells. Three male striped blennies (*Chasmodes bosquianus*), 58 to 64 mm, were rearing embryos inside of gaping oyster shells on 24 April 1970 and 19 May 1970 when water temperature was 27° to 27.5°C.

Eleotridae - sleepers

The fat sleeper (*Dormitator maculatus*) was collected only in the low-salinity tidal pools from May through November in 1967.

Gobiidae - gobies

The lyre goby (*Evorthodus lyricus*) was collected once in the high-salinity pools previous to my collections. All four species of *Gobionellus* were rarely encountered. The darter goby (*G. boleosoma*) was collected three times in the high-salinity tidal pools and was rarely found in the beach or high marsh habitats. Only five specimens of the sharptail goby (*G. hastatus*) were collected—three in trawls, one in the Marine Institute's boat basin, and one in the high-salinity pools. This goby was found only in September 1967 and November 1969.

The freshwater goby (*G. shufeldti*) occurred in the low-salinity tidal pools from May 1967 to February 1968. This goby was also reported in the high-salinity waters of St. Simons Beach and in fresh water of Altamaha River (Miller and Jorgenson, 1969).

The emerald goby (*G. smaragdus*) and green goby (*Microgobius thalassinus*) are two little-known species that were collected only in the high-salinity tidal pools. The former occurred there only in September and November and the latter only in May and November.

Two species of scaleless gobies (*Gobiosoma*) were most abundant in oyster reefs and patches of oyster shells where they laid their eggs inside gaping oyster shells during the warm months. The naked goby (*G. bosci*) occurred in six habitats in addition to oyster reefs and was the most abundant goby in the estuary. It was collected by hand in gaping oyster shells and by seining, and three were trawled. The salinity range was from fresh water to 30.8‰. Only juveniles (18-22 mm) were found at salinities of less than 2‰.

The seaboard goby (*Gobiosoma ginsburgi*) was not collected at regular stations except for specimens from the lower reach that were taken from the stomachs of hakes (*Urophycis*). Males were found rearing embryos inside of gaping oyster shells. On 4 March 1969, a large number of seaboard gobies and a few naked gobies were found in burrows in an eroding clay bank at Sapelo Island Beach.

Trichiuridae - cutlassfishes

The Atlantic cutlassfish (*Trichiurus lepturus*) was occasionally trawled throughout the year in the lower reach but was rare along the beach.

Scombridae - mackerels and tunas

King and spanish mackerels are often caught offshore by sport fishermen during the warm months. Young Spanish mackerel (*Scomberomorus maculatus*) occasionally ranged into the high marsh, beach, and lower reach habitats, but they were rarely collected by seine or trawl because of their speed. One king mackerel (*S. cavalla*) was also collected along the beach (Miller and Jorgenson, 1969).

Stromateidae - butterfishes

The butterfish (*Peprilus triacanthus*) and harvestfish (*Peprilus alepidotus*) are primarily marine fishes that occasionally occur in trawl catches in the middle and lower reaches and in beach seine hauls. They have a wide temperature tolerance as they were collected throughout the year. Butterfish did not occur at salinities below 19.5‰ and harvestfish below 22.8‰.

Triglidae - searobins

Four species of searobins (*Prionotus carolinus, P. evolans, P. scitulus,* and *P. tribulus*) were present in trawl collections in the lower reach throughout the year, and all but *P. carolinus* were trawled in the middle reach. Three of these, excluding *P. evolans,* were occasionally taken in the beach habitat (Miller and Jorgenson, 1969). A salinity of 15.3‰ for *P. evolans* was the lowest I found occupied by searobins. One *P. salmonicolor* was collected in Sapelo Sound.

ORDER PLEURONECTIFORMES

Bothidae - lefteye flounders

The lefteye flounders were represented by eight species that were found only in habitats 1 to 5 (Table 2). Species of *Paralichthys* reach a large size and two of them are important sport and commercial fishes whereas the four other bothids are small. The ocellated flounder (*Ancylopsetta quadrocellata*) and windowpane (*Scophthalmus aquosus*) migrated into the lower and middle reaches during the winter and spring, December or January to May. Water temperature ranges were 8.0° to 26.0°C for the ocellated flounder and 8.8° to 25.7° for the windowpane. These species were seasonally replaced by the bay whiff (*Citharichthys spilopterus*), which was occasionally trawled in the lower and middle reaches from May to October at a temperature range of 26.0° to 31.5°C. Stragglers also occurred in the beach and oligohaline creek habitats.

The fringed flounder (*Etropus crossotus*) was common in trawls in the lower reach throughout the year. There are records from the beach habitat, and a 16-mm specimen was seined in the upper reach when the salinity was 0.5‰.

Two species of *Paralichthys* occur primarily offshore and rarely move inshore. The gulf flounder (*P. albigutta*) was trawled only three times. The broad flounder (*P. squamilentus*) was represented by only one juvenile from the beach habitat.

The summer flounder (*P. dentatus*) and southern flounder (*P. lethostigma*) enter the commercial and sport fisheries of the coast. The summer flounder was most abundant in the lower reach and was rarely trawled in the middle reach. The southern flounder was much more abundant at the middle reach stations than in the lower reach. Its tolerance or preference for lower salinities was also demonstrated by its distribution up the estuary to Riceboro Creek where it was often collected in fresh water.

Soleidae - soles

The hogchoker (*Trinectes maculatus*) is a marine or brackish-water fish that often spends considerable time and travels considerable distances in fresh water. It was common from the lower reach to the freshwater habitat. The hogchoker was present throughout the year in Riceboro Creek where the water was usually fresh.

Cynoglossidae - tonguefishes

The blackcheek tonguefish (*Symphurus plagiusa*) was rarely collected outside of the lower and middle reaches where it was one of the most

abundant species. A low-salinity record of 0.7‰ was obtained from Riceboro Creek.

ORDER TETRAODONTIFORMES

Three marine species (in three families) in this order were represented mostly by small numbers of juveniles. Nearly all specimens were collected in the lower reach and beach habitats. One planehead filefish (*Monacanthus hispidus*) was recorded for a low salinity of 11.8‰. The planehead filefish was in the estuary from April to September at 21.8° to 31.3°C. The northern puffer (*Sphoeroides maculatus*) and striped burrfish (*Chilomycterus schoepfi*) were in the estuary from April to November or December when the temperature was reduced to approximately 11° to 16°C.

LIFE CYCLES OF ESTUARINE SPECIES

Many fishes found in estuaries follow the marine-estuarine life cycle pattern described by Gunter (1967). They spawn in the ocean and the young enter the estuarine and beach waters where the salinity is reduced. The estuary apparently provides them with a nursery ground that is rich in food and a refuge from certain predators, diseases, and parasites that do not thrive in the rigors of highly variable salinities and temperatures. Young of coastal species often have greater tolerance to reduced salinities than adults (Gunter, 1961). Young Atlantic menhaden even require low salinities for development (June and Chamberlin, 1959). Gunter (1967) noted: "The preponderant macroorganisms, both in numbers of species and individuals, are mostly motile species which undergo the general type of life history described above. In southern waters these are the mullet (*Mugil*), menhaden, croakers (sciaenids), shrimp and crabs. Vast numbers of these animals may be found in estuaries at one time or another and in general the very smallest sizes are found in the lower salinities." Some species that spawn in high-salinity waters but were represented predominantly by young in two low-salinity estuarine habitats (oligohaline creek and low-salinity tidal pools) included the spot, striped mullet, hogchoker, southern flounder, ladyfish, tarpon, and snook. The Atlantic menhaden, silver perch, and Atlantic croaker were euryhaline and represented in the upper reach primarily by young.

Since estuaries are being destroyed by pollution, dredging, and filling, it is important to recognize which species are found in estuaries as adults or young. Dependence of the young of marine species on the estuaries is the basis of the nursery ground concept (Gunter, 1967). I expand the nursery ground concept to include all species that are commonly represented by young (defined herein as sexually immature) in estuaries, whether they were spawned in the ocean, estuary, or fresh water.

A total of 168 species is listed for coastal waters (Table 2). The number of species recorded for the estuary is 136 when the numbers of species found only in the freshwater habitat (17) and only along the beach (15) are excluded. The beach and estuary are treated as a single complex here because of their similar fish species compositions. The estuary and beach complex functions as a nursery ground to various degrees for 78 species. Some young sharks and rays that were commonly caught by angling (Dahlberg and Heard, 1969) are included in the compilation. Two species that spawn in fresh water, the anadromous American shad and the white catfish, are also included. The family Sciaenidae includes 13 species that have young dependent on the rich estuarine waters. These sciaenids are the most important group of sport fishes on the Georgia coast and they are potentially important commercial fishes. Atlantic menhaden that are reared in the estuaries are caught offshore in large numbers with purse seines. Vitally important in the food chain are forage species such as the bay anchovy, Atlantic silverside, and rough silverside.

Some organisms that are indigenous to bay or estuarine waters, or at least normally complete their life cycle in these waters, include certain "copepods and planktonic species," several species of molluscs including the American oyster, certain gobioid and cyprinodontid fishes, and a palaemonid shrimp (Gunter, 1967). I have not found fish species that are restricted by salinity tolerances to estuarine waters throughout their

life cycle, but many normally complete their life cycle in the estuary. Some species that typically pass their complete life cycle in the estuary, at least in Georgia estuaries, include those species I later consider to be characteristic of the oyster reefs and certain cyprinodontid fishes such as the marsh killifish, spotfin killifish, and mummichog. The spotted seatrout possibly belongs to this category but adults are common along the beach at times and northern populations migrate offshore in the winter (Tabb, 1966).

There are species that typically complete their life cycle in the ocean or fresh water that are either regular or accidental visitors to the estuary. Another life cycle pattern is exhibited by the anadromous shads (*Alosa*) which spawn in Georgia rivers, including the Altamaha River (Godwin and Adams, 1969). The American eel is the only catadromous species in the estuary.

DIVERSITY OF COASTAL HABITATS

Diversity of habitats is considered here in order to determine the importance of the various habitats to the fish community and also to explore the possible relationship of diversity and stability. A simple index, number of species, is used here in a comparison of habitats (Table 9). To be objective, I define stragglers as those species that are represented by only one collection in a habitat. Further studies would be needed to confidently ascertain which species are naturally rare in their preferred habitats. Discounting stragglers removes a large percentage of the accidental species and makes diversity comparison more meaningful. These diversity values are only roughly comparable because of the differences in sampling effort and gear.

TABLE 9.—Number of species recorded for nine Georgia coastal habitats. To eliminate the influence of stragglers, species recorded (collected or seen) once in the estuary are subtracted from total.

Habitat	Number of species	Species recorded once	Species recorded more than once
1. Beach	114	19	95
2. Lower reach	100	4	96
3. High marsh	56	17	39
4. Middle and upper reaches	61	12	49
5. Oligohaline creek	40	21	19
6. Freshwater creek	39	0	39
7. Tidal canal	22	7	15
8. Low-salinity tidal pool	22	4	18
9. High-salinity tidal pool	37	7	30

The beach habitat produced the highest diversity—114 or 95 species if stragglers are discounted. A high diversity of clupeids, carangids, sciaenids, and bothids accounted for 36 species. Tagatz and Dudley (1961) recorded only 40 fish species from a Beaufort, N.C., beach. Gunter (1958) recorded 44 species from Texas beach station, and Springer and Woodburn (1960) recorded 48 from a beach near Tampa Bay. The latter consider the beach notable for harboring few species compared to other coastal habitats. A low diversity would be expected because the beach offers little niche variety or cover. The higher diversity I report may be attributed to several factors. A large number of species that are typical of other marine and estuarine habitats are occasionally found along the beach. Another factor is the inclusion of eight shark species that were caught while fishing from the beach. A third factor is that Miller and Jorgenson (1969) sampled more extensively than in other studies noted herein. They found 98 species at St. Simons Beach; this total includes 38 species which did not occur at Sapelo Beach.

Species that I consider to be eurythermal in the estuary were collected in both winter and summer and usually in all four seasons, but not necessarily every month. Species that are eurythermal in the beach habitat include the rough silverside (Miller and Jorgenson, 1969), Atlantic silverside, striped killifish, bay anchovy, and striped mullet. Some species that were abundant only in the warm months include the bumper, pompano, white mullet, southern kingfish, and gulf kingfish. Numbers of species and individuals were considerably reduced during the cold months.

The lower reach ranked high in diversity. Most of its 100 species were caught in trawls but seven shark records are based on Dahlberg and Heard (1969). Since only four species are ranked as stragglers, diversity of the characteristic species is similar to the beach habitat. Trawl collections in the region of Cedar Key, Fla., yielded only 63 species (Reid, 1954). This

lower diversity is partially the result of less sampling effort.

Dahlberg and Odum (1970) noted the abundance of species at the 14 trawl stations over the first 14 months of this study. We found that the most numerous species for the first 12 months of the study were star drum (15,209 individuals), weakfish (2,454), blackcheek tonguefish (2,193), sea catfish (1,681), southern kingfish (1,345), silver perch (1,133), bay anchovy (1,090), spot (1,004), Atlantic croaker (896), and spotted hake (467). In shrimp trawl catches in an estuary near Brunswick, 1931-35, Anderson (1968) found the following order of decreasing abundance: star drum, Atlantic croaker, spot, fringed flounder, weakfish, sea catfish, anchovy species, gafftopsail catfish, and kingfish species. In both studies the star drum was the most abundant species. Certain differences (e.g., tonguefish, silver perch, fringed flounder, gafftopsail catfish) may be related to spatial or temporal changes in populations, size of trawl, and mesh size.

Miller and Jorgenson (1969) recorded 56 species, including 39 collected more than once, for the high marsh habitat. Species that were eurythermal in the high marsh also were characteristic of the beach habitat. However, they found the mummichog to be more abundant than the striped killifish in the marsh.

Collections with trawls and seines both contributed heavily to the high diversity (61) of the upper and middle reaches. Some of the species trawled in the middle reach may not occur in the lower salinity upper reach. Species that were eurythermal in the middle reach and common in trawl catches in the middle reach include the Atlantic stingray, bay anchovy, silver perch, spot, southern kingfish, Atlantic croaker, hogchoker, blackcheek tonguefish, and oyster toadfish. Species that were common in trawl catches only during the warm months include the sea catfish, weakfish, star drum, and Atlantic spadefish. Species that were common in trawl catches only during the cold months include the two hake species, spotted seatrout, ocellated flounder, and southern flounder.

Gunter (1967) and others have pointed out that young of marine species are predominant in brackish water. Young fishes that I consider to be eurythermal in the shallow waters (collected by seine, 10-ft trawl, and cast net) of the upper and middle reaches include the Atlantic menhaden, silver perch, spot, southern kingfish, croaker, striped mullet, white mullet, southern flounder, hogchoker, and blackcheek tonguefish. The longnose gar, striped anchovy, bay anchovy, mummichog, tidewater silverside, Atlantic silverside, northern pipefish, and chain pipefish were also characteristic of this region.

The oligohaline section of Riceboro Creek has a low diversity (40 species) especially when the stragglers (21 species) are considered. Tagatz and Dudley (1961) recorded 38 species including 12 freshwater species at an oligohaline station in the Neuse River, N.C. Fishes of the oligohaline creek include 15 freshwater species, 20 euryhaline marine species, 4 anadromous species (*Alosa* and *Dorosoma*), and 1 catadromous species (*Anguilla*). Populations of *Dorosoma* species that occur in saline waters can be considered anadromous as Bailey et al. (1954) have done, but these are primarily freshwater species, at least in Georgia. Characteristic species of the oligohaline creek include the longnose gar, bay anchovy, white catfish, mummichog, mosquitofish, tidewater silverside, bluegill, striped mullet, hogchoker, southern flounder, and spot.

Numbers of fish species decrease up the estuary until the stable freshwater habitat is reached. Most of the 39 species recorded for the freshwater habitat are freshwater species that are characteristic of Coastal Plain waters. Others are migratory or euryhaline marine species, including the anadromous shads (*Alosa*), catadromous American eel, tidewater silverside, northern pipefish, and hogchoker. Fishermen report catching the anadromous striped bass (*Morone saxatilis*) in Riceboro Creek but we have no records.

Miller and Jorgenson (1969) reported 48 species from a freshwater station in the lower Altamaha River. In addition to species that I report, they recorded some marine species, freshwater fishes that usually occur in large rivers and reservoirs, and others that are probably absent from the North Newport River drainage.

The tidal canal and low-salinity tidal pools are

quite similar in diversity and location but some interesting differences exist. The canal is more open to high-salinity water and to the marsh. Larger individuals of some species, such as the striped mullet, silver perch, and spot, entered the canal but not the more isolated pools. The pools contained small species and small individuals of large species. Species characteristic of both habitats include the ladyfish, tarpon, sheepshead minnow, mummichog, mosquitofish, sailfin molly, snook, striped mullet, white mullet, and spot. Species that were restricted to the pools include the marsh killifish, fat sleeper, and freshwater goby.

The greater diversity (37) of the high-salinity tidal pools, compared to the low-salinity pools, is probably related to their higher salinity and greater accessibility from habitats of high diversity (beach and lower reach). As noted previously, salinities and temperatures were similar in the two series of high-salinity pools on the east and west sides of the road to the Sapelo Island lighthouse. Conspicuous faunal differences in the two series of pools may be related to water depth. In the shallow pools of the east side there were large numbers of cyprinodontiform fishes (including the sailfin molly, mummichog, sheepshead minnow, mosquitofish, and striped killifish) and spotfin mojarra. These were all found in much smaller numbers in the deep pool on the west side of the road. The deep pool produced larger numbers of young silver perch, young spot, and gobies. The sharptail goby, emerald goby, and green goby were not found in the shallow pool. Large numbers of striped mullet, white mullet, ladyfish, and bay anchovy were found in the shallow and deep pools.

These semi-isolated tidal pools of estuaries have received little attention in ichthyological studies although they are nursery grounds for many species. Kilby (1955) compared "inner pools" and "outer pools" for two regions on the Florida Gulf coast. He found a higher diversity (36 and 26 species) in the outer pools than in the lower salinity inner pools (19 and 28 species). He did not find significantly more species in open water as I have, because of differences in collecting methods.

The ecological stability of a habitat is generally related to its species diversity. Therefore, it would appear that the low-salinity habitats, tidal pools, and tidal canals would be more vulnerable to pollution than the other habitats. This suggests that locating factories or developments on lower reach or beach habitats would be less likely to damage the fish populations. However, other factors must be considered. For example, the beaches are especially sensitive to development because removal of the stabilizing beach plants results in rapid erosion.

ADDITIONAL COASTAL HABITATS

I consider the oyster habitat to include the oyster reefs of the lower reach and smaller patches of oysters in tidal creeks. The oyster habitat was located near the low tide level and was sampled by hand. Fishes that remain within the interstices between oysters at low tide I consider characteristic. In general order of decreasing abundance, these are: naked goby, feather blenny, skilletfish, seaboard goby, striped blenny, oyster toadfish, and crested blenny. The mummichog was often observed swimming in the vicinity of oysters. At high tide a number of sciaenids migrate to submerged oyster reefs where they provide good fishing. The naked goby, feather blenny, mummichog, and oyster toadfish (one specimen) were also associated with the fouling community on the underside of floating docks in the lower reach.

Few species occur in strictly freshwater habitat on Sapelo Island. Collections were made in a pond at the Marine Institute and ditches at artesian wells. The largemouth bass and bluegill were introduced and are well established in ponds. There are specimens in the University of Georgia Fish Collection of the yellow bullhead and warmouth that were collected on Sapelo Island. These species probably were introduced. Five species that were common in a ditch at an artesian well, locally called Flora Bottom, are the mosquitofish, sailfin molly, marsh killifish, least killifish, and bluefin killifish (*Lucania goodei*). Of these, the first three are euryhaline. The least killifish and bluefin killifish may be native to Sapelo Island, or they could have dis-

persed across the estuary from the mainland since salinities are sometimes reduced to brackish in the estuary.

The stabilization pond of the Interstate Paper Corp. at Riceboro provided a unique study habitat. Fishes were collected on 12 August 1969, 14 April 1970, 2 June 1970, and 6 July 1970. Fishes that were intentionally introduced in 1968 and 1969 and subsequently collected by seining include the largemouth bass, bluegill, and warmouth. Personnel of the paper company also collected adults of the following introduced species: brown bullhead (*Ictalurus nebulosus*) and redear sunfish (*Lepomis microlophus*). I collected four specimens that appeared to be hybrids of the bluegill and redear sunfish. Golden shiners are native to the area but since they were not collected until June and July 1970, they may have been introduced by fishermen. Native species include the mosquitofish, which was abundant, and the least killifish, which was represented by one specimen. I collected juveniles of warmouth, sunfish, mosquitofish, golden shiner, and bass that were spawned in the pond.

DISTRIBUTION PATTERNS OF COASTAL FISHES

The 168 coastal fish species exhibit a variety of distribution patterns in relation to the described habitats. The 86 species that were restricted to one or two habitats included large numbers of (1) freshwater species, (2) elasmobranchs and teleosts that were primarily marine and stenohaline, and (3) rare species. The 30 species that occupied three habitats included only one elasmobranch (*D. sabina*), three freshwater species, and some uncommon and stenohaline species. The large number of species in these categories indicates that a majority of the coastal species occupy only a relatively small number of the coastal habitats. However, the low diversity estuarine habitats (habitats 5, 7, 8, and 9) may be widespread and important nursery grounds to estuarine species that are important as sport, commercial, or forage fishes, e.g., tarpon, anadromous shads, Atlantic menhaden, white catfish, tidewater silverside, silver perch, spotted sea trout, weakfish, spot, Atlantic croaker, striped and white mullets, and southern flounder.

Euryhaline species were defined as species that occur in both fresh water and pure seawater (Gunter, 1956). Although many of the species studied are euryhaline, none were found in all nine habitats. Six species occurred in all habitats except the freshwater habitat, and all of these sometimes occur in fresh water. These widely adapted species are the Atlantic menhaden, mummichog, spotfin mojarra, silver perch, spot, and striped mullet. The mosquitofish, croaker, and white mullet occurred at seven habitats. The mosquitofish was absent from the deepwater habitats. The white mullet and croaker were absent only from low-salinity habitats.

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Mrs. Joyce Swanberg identified representative plants using Radford, Ahles, and Bell (1968) but she used Muenscher (1944) to identify *Elatine*. G. C. Miller identified *Prionotus pectoralis*, now a synonym of *P. salmonicolor*. Dr. C. L. Hubbs identified some *Diapterus olisthostomus*, *Eucinostomus argenteus*, and *E. melanopterus*; Dr. E. Herald, some *Syngnathus fuscus* and *S. louisianae*; Dr. C. R. Gilbert, *Evorthodus lyricus*; and R. W. Heard, Jr., many invertebrates.

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