FISHES INHABITING THE OUTER BANKS OFF NORTH CAROLINA: THEIR ORIGIN AND DISPERSAL

By FRANK J. SCHWARTZ [1]

With 2 figures and 2 tables

ABSTRACT. Historical origins, type, and movement of North Carolina's Outer Banks isolated islands and oceanography are reviewed. Fishes inhabiting freshwater ponds located on the islands are compared in relation to species origin, presence on each island, their dispersal within the Outer Banks system, and relationships between islands. Eighteen species frequent the island ponds as follows: Hatteras 12 ponds, 7 species; Ocracoke 2, 7; Portsmouth 33, 13; Core Banks 41, 7; and Shackleford Banks 18, 10. Ocean and lagoonal habitats are also examined as possible sources of the fishes inhabiting the islands. Historical changes in the fish fauna of Mullet Pond (Shackleford Banks) is noted as an example, in the light of constantly natural and man-made changes in island ecologies, of the possible fate of each island's pond fishes.

INTRODUCTION

Most islands located in the Atlantic Ocean are of volcanic origin, exist atop sea mounts, and possess short rivers or no inland standing waters (EDWARDS 1990; PENRITH 1967). Inshore or inland fish faunas of such islands may be endemic, related to nearby continents or a result of continental drift and ocean currents to or from mainland regions (BÖHLKE & CHAPLIN 1968; DIETZ & SCROLL 1970; DOOLEY *et al.* 1985; GON & HEEMSTRA 1990; STERRER 1986). Rarely have marine and freshwater fish faunas of isolated western Atlantic Ocean islands, formed by accretion or frontal progression processes, been examined (LEATHERMAN 1979; MOSLOW & HERON 1979, 1981; OTVOS 1985; PIERCE 1969; PIERCE & COLQUHOUN 1970; SHABICA *et al.* 1983).

This study documents the fishes inhabiting freshwater ponds located on North Carolina's isolated "Outer Banks" continental islands. I also review the origin of the islands, examine dispersal and the relationships between/and adjacent island fish faunas. The possible oceanic and inshore sources of the fishes inhabiting the ponds are discussed. Other factors that affect the islands' ponds and fish faunas are also included.

[1] Institute of Marine Sciences, University of North Carolina, Morehead City, NC 28557 USA

 ISSN 0870-3876

STUDY AREA

The "Outer Bank" islands (DOLAN & LINS 1986) off North Carolina (Hatteras, Ocracoke, Portsmouth Islands, Core Banks, and Shackleford Banks) are the farthest projecting island land masses in the western North Atlantic Ocean. Origin and positioning of the islands have been controversial. The origin probably occurred sometime between the Pleistocene and Holocene. MOSLOW & HERON (1979, 1981) believed the islands were formed over a sand-fill base. PIERCE (1969) and PIERCE & COLQUHOUN (1970) believed that the northern islands were areas built upon material of mainland origin exposed to weathering; while they believed that southern islands were secondary barriers built upon marine sediments. Longshore sand movement southward along Hatteras Island and westward of Cape Hatteras is moving to isolate Shackleford Banks (Fig. 1, lower left corner) and move the entire barrier system and island westward. PIERCE & COLQUHOUN (1970) also established that barrier island system origin and movement was eastward into the Atlantic prior to subsequent movement westward to present island locations. Several East-West barriers have also formed during a progression of spit elongation southward at the rate of 45-98 m/century (MOSLOW & HERON 1979) and landward 1.6-3.6 km during the last 4,000 years (PIERCE & COLQUHOUN 1970). Cape Lookout (Fig. 1) once stood 3-5 km seaward of its present position and Cape Lookout, during the Pleistocene, was situated 25 km NW of its present location (PIERCE & COLQUHOUN 1970).

The present islands were also formed or shaped by 18, of 25 known, inlets. These inlets were once cut across the original barrier, following hurricane or northeast or northwest wind-wave storms, and/or caused overwash of the barrier islands (STICK 1958). Many areas along the present Outer Bank islands are barely above sea level (3 m is usual height, highest is 14 m at Cape Lookout). Maximum island widths range 0.8-2 km (widest 4 km at Cape Hatteras).

Seaward of the islands the ocean shelf is narrow (10 km off Cape Hatteras), increasing southward to 80 km off Cape Lookout and Shackleford Banks. The Gulf Stream off Cape Hatteras varies between 1-3 km offshore during the summer and 5-15 km during the winter, whereas off Cape Lookout, subject to seasonal winds, it varies between 15-20 km during the summer and 80-100 km during the winter. Shelf substrate at inlets is sandy, mixing with sand or mud along the beaches, changing to sand with increasing depth offshore.

Coastal ocean waters are turbid out to 15 m depths as a result of strong seasonal storm winds and waters pouring out inlets from the Pamlico-Albemarle lagoon that are carried by longshore currents outward. Salinities in these turbid coastal waters are usually 30-32 ppt. Waters seaward of 15 m are green and salinities are 32-34 ppt. Edge of shelf waters are blue, depths are 735 m, and salinities are 34-36 ppt. Southeast or southwest winds, during nine months of the year, influence tide height and sea state and deflect the Gulf Stream shoreward. Whereas, northeast or northwest winter winds for 3-4 months cause rough seas and extra high tides, resulting in extensive beach erosion around each island.

A vast lagoonal system composed of Pamlico and Albemarle Sounds (Fig. 1) extends in a north-south direction for 50-130 km and separates the islands from the mainland to the west. Lagoonal depths range to 7.3 m while most average 5 m. Salinities vary seasonally 0-30 ppt, highest in November and lowest in April following spring rains (SCHWARTZ & CHESTNUT 1973). Strong southwest summer or North-East and northwest winter winds cause turbid year-round lagoonal waters. This mixing condition enhances the status of the lagoon as a nursery area for shrimp, blue crabs, and fishes (ROSS & EPPERLY 1985; WOLFF 1976). The western portion of the lagoon has a muddy substrate, while near the islands it is sandy.

SAMPLING

A host of collections of the ocean waters adjacent to the Outer Banks islands of Hatteras, Ocracoke, Portsmouth, Core Banks, and Shackleford Banks (Fig. 1) have been carried out by state, federal, university, private sources, and the author. SCHWARTZ (1989) summarized the fishes collected by species, habitat, and province origin and noted 685 species inhabiting the ocean to depths of 600 m. Similarly a vast array of samples has characterized the fishes found in the landward Pamlico-Albemarle lagoon (EPPERLY 1984; ROSS & EPPERLY 1985; WOLFF 1976). WOLFF (1976) found 101 marine species frequenting the lagoonal sides of each Outer Bank island.

Ocean and lagoon water sampling was accomplished by using various sized otter trawls (19 mm mesh, 12 m wide), haul seines (15 cm mesh), and pound nets (19 mm mesh) (lagoon waters only). Trawl tows varied in direction and depth sampled.

Seine sampling of the 106 freshwater ponds scattered on Hatteras, Ocracoke, Portsmouth Islands, Core Banks, and Shackleford Banks found they contained a mixture of freshwater and marine origin fishes. Pond distribution was Hatteras 12, Ocracoke 2, Portsmouth 33, 41 throughout Core Banks, Shackleford Banks 18. Knotless nylon seines 3 mm meshed 1.2 x 3 or 1.2 x 7.5 m lengths were employed during oceanside and lagoon beach sampling. One to several seine passes were made in each freshwater island pond until no new species were encountered. Water and air temperatures, salinity, substrate composition, water depth and color, and oxygen content were also noted. All fishes were measured to nearest 0.1 mm standard length, weighed to 0.1 g, preserved in 10% formalin, later 10% isopropyl alcohol, and deposited in the curated Institute of Marine Sciences fish collection at Morehead City, NC. Freshwater was defined as having a 0-0.05 ppt salinity following the convention of the Venis Commission (1958).

RESULTS

While 188 freshwater ponds are located and sampled through-out the Outer Banks

from Virginia to Beaufort Inlet, North Carolina (280 km), only 106 occurred on the isolated study islands (SCHWARTZ 1992). Twenty-nine species of fishes were collected through-out the Outer Banks, 25 of which occurred in mainland ponds from Virginia to the treacherous Oregon Inlet (Fig. 1, Table 1). Eighteen species frequented the island ponds as follows: Hatteras 12 ponds, 7 species; Ocracoke 2, 7; Portsmouth 33, 13; Core Banks 41, 7; and 18, 10 on Shackleford Banks (Table 1). Numbers and weights of the combined catches/island reviewed from north to south were: Hatteras 481 fish (281.5 g weight), Ocracoke 316 (587.4 g), Portsmouth 5,447 (6,237 g), Core Banks 1,163 (1,018.2 g), and Shackleford Banks 4,521 (5,126.8 g), for a total of 11,928 specimens weighing 13,250.7 g.

SCHWARTZ (1989) noted 685 species frequented ocean waters surrounding the islands, 196 in oceanic waters adjacent to each island beach, 116 in lagoon waters (96 were common to both bodies of waters). WOLFF (1976) sampling the lagoonal side of each island collected 106 marine and freshwater fishes. Entry of oceanic fishes into the lagoon was via the numerous inlets: Oregon, Hatteras, Ocracoke, Haulover, Drum, Barden, and Beaufort (Fig. 1).

Of the fishes inhabiting ponds on Hatteras, Ocracoke, Portsmouth Islands, Core Banks, and Shackleford Banks, 14 were found in the Pamlico lagoon while five were of high saline ocean water derivation (Fig. 1). Four of the 18 species inhabiting the study islands were primary freshwater fishes (MYERS 1938) such as: carp, *Cyprinus carpio* LINNAEUS, 1758, and three sunfishes, pumpkinseed, *Lepomis gibbosus* (LINNAEUS, 1758), bluegill *Lepomis macrochirus* RAFINESQUE, 1819, and largemouth bass, *Micropterus salmoides* (LACEPÈDE, 1802) (Table 1). Fourteen were secondary fishes (marine fishes that can adapt to freshwater existence) that inhabit marine waters but can adapt to freshwater (MYERS 1938). As one progresses southward through the islands, pond substrates changed from muddy to sandy on Ocracoke, Portsmouth Islands, Core and Shackleford Banks. Likewise, Hatteras Island from Buxton to Oregon Inlet, Ocracoke, and Portsmouth-Core Banks were subject to frequent ocean overwash, a process that added or replenished the fish faunas of each island's ponds, often annually. This process was vividly demonstrated in Mullet Pond, a pond near the western end of Shackleford Banks (Fig. 1), once 2.6 km, today 0.04 km in extent. Mullet Pond has had its marine oriented fish fauna changed or restricted over an 86 yr period by the waters changing from high salinities to freshwater (Schwartz 1970; Schwartz et al. 1990). Mullet Pond's fish fauna composition changed from 26 species in 1914 to a stable five in 1990: variegated minnow (*Cyprinodon variegatus*) LACEPÈDE 1803, marsh killifish (*Fundulus confluentus*) GOODE AND BEAN, 1879, mummichog (*Fundulus heteroclitus*) (LINNAEUS, 1766), rainwater fish (*Lucania parva*) (BAIRD AND GIRARD, 1855), and mosquitofish (*Gambusia holbrooki*) GIRARD, 1859.

South of Oregon Inlet, seven species of fishes (Fig. 2) have apparently been able to cross the treacherous inlet from the mainland to the north, five species have crossed Hatteras Inlet to inhabit Ocracoke Island while eight passed southward onto the Portsmouth-Core

Banks complex; only seven crossed Barden Inlet to inhabit Shackleford Banks (TABLE 1, Fig. 2). Seven of the fishes found on Hatteras Island also occur on the mainland to the north while only four occupy islands to the south (Fig. 2). Ocracoke Island's seven species relate as follows: Three are common with Hatteras Island to the north, six are similar to mainland species, while five are common with Portsmouth, Core and Shackleford Banks to the south (Fig. 2). Only five of the Portsmouth-Core Banks fishes are common with Ocracoke Island's fauna (to the north), three are similar to Hatteras Island's fauna, 10 are similar to those on Shackleford. Thus, Hatteras Inlet seems to be a barrier separating mainland origin fishes from those inhabiting islands south of the inlet. This can be further seen on examination of size clines of the mosquitofish and variegated minnows as fishes from southern islands are usually larger and heavier than those from northern areas of the banks (SCHWARTZ *et al.* 1990). Likewise, mainland variegated minnows (a species found throughout the Outer Banks islands, Table 1), possess a different morphology, reinforcing the conclusion that northern Outer Banks fishes were of mainland but southern specimens were of marine origin and not the mainland to the west (SCHWARTZ *et al.* 1990).

Thus isolated marine islands should not be neglected for their marine and inland fish faunas should be sampled as ways to learn more about island and its fish origin(s). While secondary fishes might be expected to dominate an island's fauna, they may shed light regarding island origin and eventual fate or both. The effects of natural changes, as in Mullet Pond on Shackleford Banks, can reveal an interesting interplay and effects of natural ecological and habitat changes caused by hurricanes, storms, and tides. Also, the effects of man, through pollution and construction, may have serious effects on an island's faunal long-term existence. In any event, man should try to protect these fragile island habitats at all costs.

ACKNOWLEDGEMENTS

Especial thanks are due OTIS LEWIS, JOE PURIFOY, GLEN SAFRIT, J. CHAPMAN, and P. BERNIER for help in sampling the Outer Banks ponds. Efforts by a host of researchers provided information on the marine fishes known from the area. Superintendents of Cape Hatteras National Seashore Park and Cape Lookout National Park, as well as Pea Island Seashore Park, granted permission to sample the freshwater ponds located on the islands. Information on the origin, movement, and fate of the islands was enhanced by discussions with J. PIERCE of U.S. National Museum and S. Heron of Duke University. L. PRIDDY and R. CARRAWAY of N. C. Dept. Marine Fisheries, provided aerial maps that helped locate island ponds amongst the tall and dense 4 m high stands of poison ivy and live oak and cedar trees. Dr. J. DOOLEY, Adelphi University, reviewed the text and provided helpful comments that strengthened the manuscript. L. WHITE typed the manuscript and R. BARNES developed the figures.

REFERENCES

BÖHLKE, J. E. & C.C.G. CHAPLIN:
1968. Fishes of the Bahamas and Adjacent Tropical Waters. Livingston Publ. Co., Philadelphia, PA. 771 p.

DIETZ, R. S. & W. P. SCROLL:
1970. East Canary Islands as a microcontinent within the Africa-North American continental drift fit. Nature 226:1043-1044.

DOLAN, R. & H. LINS:
1986. The Outer Banks of North Carolina. Prog. Pap. U.S. Geol. Surv. 1177-R. 47 p.

DOOLEY, J. K., J. VAN TASSELL, & A. BRITO:
1985. An annotated checklist of the shorefishes of the Canary Islands. Am. Mus. Novit. No. 2824. 49 p.

EDWARDS, A. J.:
1990. Fish and fisheries of Saint Helena Island. Univ. New Castle Upon Tyne, England. 152 p.

EPPERLY, S. P.:
1984. Fishes of the Pamlico-Albemarle Peninsula, North Carolina; area utilization and potential impacts. Spec. Sci. Rep. 42, N.C. Dept. Nat. Res. Div. Mar. Fish., Morehead City, NC. 129 p.

GON, O. & P. C. HEEMSTRA (EDS.):
1990. Fishes of the Southern Oceans. J. L. B. Smith Inst. Ichthyol., Grahamstown, So. Africa. 465 p.

LEATHERMAN, S. P.:
1979. Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico. Academic Press, NY. 325 p.

MOSLOW, T. F. & S. D. HERON, JR.:
1979. Quarternary evolution of Core Banks, North Carolina: Cape Lookout to New Drum Inlet. p. 211-236 in S. P. Leatherman (ed.), Barrier Islands, Academic Press, NY.

MOSLOW, T. F. & S. D. HERON, JR.:
1981. Holocene depositional history of a microtidal cuspate foreland cape: Cape Lookout, North Carolina. Mar. Geol. **41**:215-270.

MYERS, G. S.:
1938. The freshwater fishes and West Indian zoo-geography. Ann. Rept. Smiths. Inst. Publ. **3451**:339-364 for 1937.

OTVOS, E. G.:
1985. Barrier island genesis - questions of alternatives for the Appalachicola Coast, Northwestern Gulf of Mexico. J. Coastal Res. **1**(3):267-278.

PENRITH, M. J.:
1967. The fishes of Tristan da Cunha, Gough Island, and the Verma seamount. Ann. So. Afr. Mus. **48**(22): 523-548.

PIERCE, J. W.:
1969. Sediment budget along a barrier island chain. Sediment. Geol. 3:5-16.

PIERCE, J. W. & D. J. COLQUHOUN:
1970. Holocene evaluation of a portion of the North Carolina coast. Geol. Soc. Am. Bull. **81**: 3693-3714.

ROSS, S. W. & S. P. EPPERLY:
1985. Utilization of shallow estuarine nursery areas by fishes in Pamlico Sound and adjacent tributaries of North Carolina. pp. 207-232. Chp. 10 in A. Yenez-Aranciba (ed.), Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an ecosystem investigation. DR(R) UNAM Press, Mexico.

SCHWARTZ, F. J.:
1970. Fishes and changing ecology of Mullet Pond, a barrier island pond on Shackleford Banks, North Carolina. J. Elisha Mitchell Sci. Soc. **86**(1):31-34.

SCHWARTZ, F. J.:
1989. Zoogeography and ecology of fishes inhabiting North Carolina's marine waters to depths of 600 meters. p. 333-370 in Carolina Coastal Oceanography, R. Y George and A. W. Hulbert (eds.). NOAA-NURP Res. Rep. **89-2**.

SCHWARTZ, F. J.:
1992. Fishes and ecology of freshwater ponds on North Carolina's Outer Banks. p. 93-118 in Barrier Island Ecology of the Mid-Atlantic Coast: A Symposium. Tech. Rept. NPS/SER CAHA/NRTR-93/04, C. Cole and K. Turner (eds.).

SCHWARTZ, F. J. & A. F. CHESTNUT:
1973. Hydrographic Atlas of North Carolina's Estuarine and Sound Waters. UNC Sea Grant **S2-73-12**. 132 p.

SCHWARTZ, F. J., G. SAFRIT, C. JENSEN, & J. PURIFOY:
1990. Stability and persistence of the fishes inhabiting Mullet Pond, Shackleford Banks, North Carolina 1908-1989. J. Elisha Mitchell Sci. Soc. **106**(2):38-50.

SHABICA, S. V., N. B. COFER, & E. W. CAKE, JR. (EDS.):
1983. Proceedings of the Northern Gulf of Mexico Estuaries and Barrier Islands Research Conference, 13-14 June 1983, Biloxi, MS. U.S. Dept. Nat. Res. Park Serv. SE Reg. Off., Atlanta, GA. 191 p.

STERRER, W. (ED.):
1986. Marine Flora and Fauna of Bermuda, A Systematic Guide to the Identification of Marine Organisms. J. Wiley & Co., NY. 742 p.

STICK, D.:
1958. The North Carolina Outer Banks. Univ. N.C. Press, Chapel Hill, NC. 352 p.

VENIS:
Symposium on the Classification of Brackish Waters. 8-14 April 1958. Centro Naz. Studi Talasograf. Consigl. Naz. Richerche XI, Suppl. p. 5-248.

WOLFF, M.:
1976. Nursery Area Survey of the Outer Banks Region. U.S. Dept. Comm. NOAA-NMFS Project **2-222-R**, St. Petersburg, FL. 47 p.

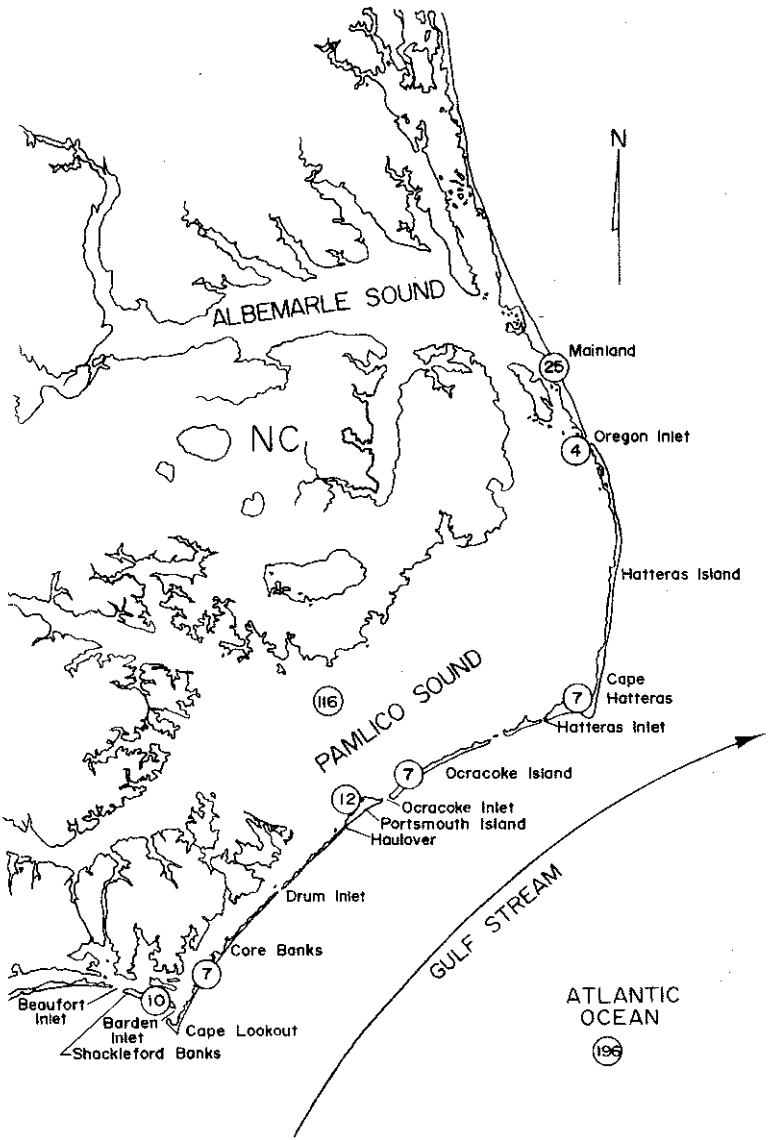

Figure 1 - Fishes, circled numbers, frequenting Outer Banks freshwater island ponds and surrounding lagoon or ocean waters.

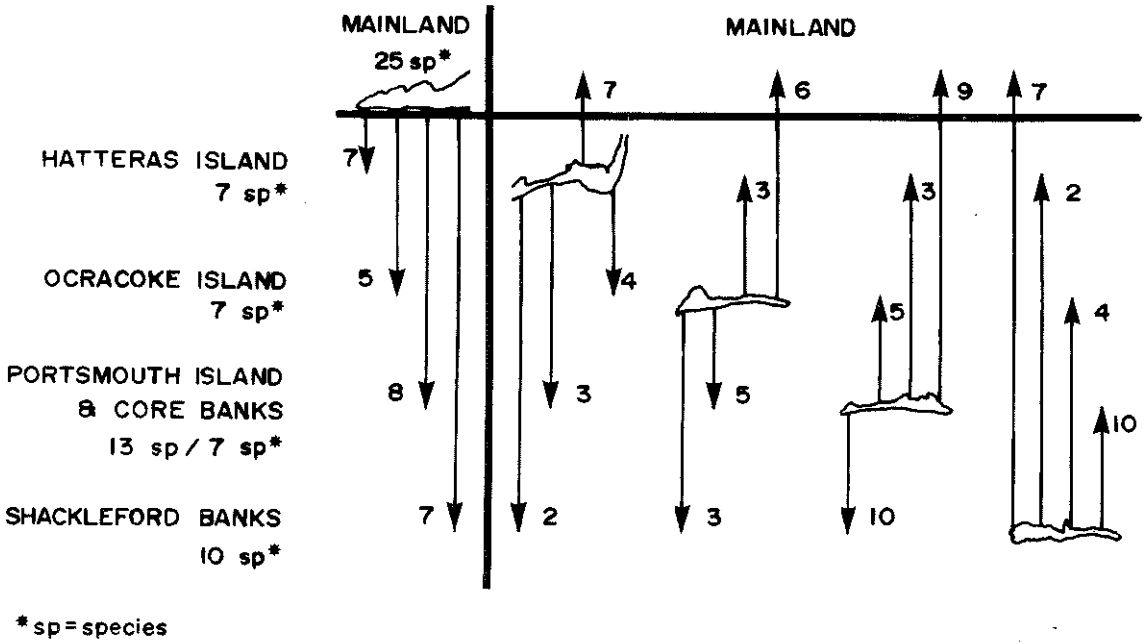

Figure 2 - Interrelationships of the species of fishes occurring on and between each North Carolina Outer Bank Island to that of the mainland.

TABLE I

Outer Banks pond regions, from north to South, frequented by each species captured by seine or trawl.

SPECIES	REGION					
	VA/ Oregon Inlet	Hatteras Island	Ocracoke Island	Portsmouth Island	Core Banks	Shackleford Banks
Gambusia holbrooki GIRARD, 1859	x	x	x	x	x	x
Lucania parva (BAIRD & GIRARD, 1855)	x	x	x	x	x	x
Cyprinodon variegatus LACEPÈDE, 1803	x		x	x	x	x
Anguilla rostrata (LESUEUR, 1817)	x	x	x	x		
Menidia beryllina (COPE, 1866)	x		x	x		
Fundulus confluentus GOODE & BEAN, 1879	x		x	x		
Fundulus heteroclitus (LINNAEUS, 1766)			x	x		
Mugil cephalus LINNAEUS, 1758	x			x		x
Leiostomus xanthurus LACEPÈDE, 1802	x			x		x
Elops saurus LINNAEUS, 1766	x		x			
Cyprinus carpio LINNAEUS, 1758	x	x				
Lepomis gibbosus (LINNAEUS, 1758)	x	x				
Lepomis macrochirus RAFINESQUE, 1819	x	x				
Micropterus salmoides (LACEPÈDE, 1802)	x	x				
Centrarchus macropterus (LACEPÈDE, 1801)	x					
Enneacanthus gloriosus (HOLBROOK, 1855)	x					
Lepomis auritus (LINNAEUS, 1758)	x					
Pomoxis nigromaculatus (LESUEUR, 1829)	x					
Fundulus diaphanus (LESUEUR, 1817)	x					
Morone americana (GMELIN, 1789)	x					
Ameiurus nebulosus (LESUEUR, 1819)	x					
Notemigonus crysoleucas (MITCHILL, 1814)	x					
Dorosoma cepedianum (LESUEUR, 1818)	x					
Lepisosteus osseus (LINNAEUS, 1758)	x					
Esox americanus GMELIN, 1788	x					
Fundulus luciae (BAIRD, 1855)				x		x
Fundulus majalis (WALBAUM, 1792)				x	x	x
Menidia menidia (LINNAEUS, 1766)				x	x	
Brevoortia tyrannus (LATROBE, 1802)						x

TABLE 2

List of 27 species of fishes known from Mullet Pond, Shackleford Banks, collected or reported by various researchers 1914-1989.
Table from SCHWARTZ *et al*. 1990.

	Collectors										
	Hilde brand*	Schwartz									
	Stras- burg*										
	1914										
	16, 25, 30	1/07/59	6/08/69	30/05/76 6/06/76	21/04/82	12/04/84	21/05/85	3/06/87 30/06/87	30/06/88	6/5,3/6, 26/07/89	Total [5]
Elops saurus	√										
Brevoortia tyranus	√										
Opisthonema oglinum	√										
Anchoa eurystole [1]	√										
Anchoa hepsetus	√										
Opsanus tau	√										
Cyprinodon variegatus	√	422	77	64	356	260	68	223	288	206	1.964
Fundulus confluentus	√		11		10		289	291	53	44	698
Fundulus heteroclitus	√				53		3	209	3	12	280
Fundulus luciae [4]	√				1						1
Fundulus majalis	√										
Lucania parva [2, 3]	√	72	70	45	139	226	177	79	203	81	1.092
Gambusia holbrooki	√	125	513	374	692	183	319	252	382	129	2.969
Urophycis earlli	**										
Urophycis regia	√										
Menidia beryllina	√										
Menidia menidia	√										
Strongylura marina	√										
Mugil cephalus	√										
Mugil curema	√										
Echeneis naucrates	√										
Eucinostomus gula	√										
Ctenogobius stigmaticus	√										
Gobiosoma bosci	√										
Orthoprises chrysoptera	√										
Lagodon rhomboides	√										
Leiostomus: xanthurus	√										
TOTAL		619	671	483	1.251	669	856	1.054	929	472	7.004

* Unpublished.

** One about UNC 3050 was captured.

[1] Also recorded by RADCLIFFE (1914).

[2] Also recorded by KUNTZ (1916).

[3] Also recorded by TAGATZ and DUDLEY (1961).

[4] Also recorded by HILDEBRAND (1941).

[5] Total specimens collected only by SCHWARTZ 1969-1989.