CONCLUSIONS

1. Influent waters from the Nantahala River are warmer in winter and cooler in summer than the other streams flowing into Fontana Reservoir.
2. During the summer, Nantahala River water flows below the warmer Little Tennessee and Tuckaseigee River waters.
3. Two steep temperature gradients meeting the requirements of a thermocline definition were formed in Fontana Reservoir during each annual cycle.
4. No significant variations of alkalinity nor carbon dioxide concentrations were found in the reservoir.
5. Within a mid-water strata of reduced dissolved oxygen concentrations, a highly significant positive correlation was obtained between conductivity and dissolved oxygen concentrations.
6. Anaerobic decomposition of sludge deposits in the Tuckaseigee River arm resulted in the formation of a stratum of anoxic water in the main reservoir.
7. The anoxic water strata was found to reach the penstocks in October at about the time of the fall overturn.
8. At least five percent of the total reservoir capacity is removed from fish productivity by a complete absence of oxygen. The total productivity loss due to low water quality may approach 25 percent.

DISTRIBUTION AND ABUNDANCE OF THE CENTRARCHIDS IN THE RECENT DELTA OF THE MISSISSIPPI RIVER[1]

DUDLEY C. CARVER[2]

ABSTRACT

Distribution and abundance of eight centrarchid fishes were studied on Delta National Wildlife Refuge from August, 1963 through January, 1965.

Gear used to collect the fish included rotenone, gill nets, trammel nets, bag seine, minnow seine and electric shocker. Standing crop samples were conducted using rotenone and block-off nets.

Salinity was a major factor which limited distribution of centrarchids on the refuge. Pond depth and turbidity were also factors affecting distribution and abundance. Oxygen, carbon dioxide, pH and alkalinity were found to be within suitable levels for fishes during sampling periods.

Spotted sunfish had the most diversified distribution of any centrarchid. Largemouth bass preferred the clearer, deeper waters. Warmouth occurred in more turbid waters than other centrarchids.

Centrarchids averaged 32.79 per cent of the total standing crop of fishes in area 1, 23.54 per cent in area 2 and 4.44 per cent in area 3. Centrarchidae represented the second largest family in number of species and first in poundage of fishes occurring on the study area. Redear sunfish, warmouth, spotted sunfish, black crappie and largemouth bass were the most abundant centrarchids in descending order.

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[2] Present address: Louisiana Wild Life and Fisheries Commission, DeRidder, Louisiana 70634.

INTRODUCTION

Ecological factors affecting distribution and abundance of centrarchid fish in estuarine habitats has been much neglected. Several studies have been conducted on centrarchid fish in North Carolina (Louder, 1962 and 1963), but were limited mostly to occurrence and abundance. The largemouth bass sport fishery of Back Bay, Virginia (Wollitz, 1962) was investigated but limited information was given for other members of the Centrarchidae family that occur in this area.

A comprehensive study of the fish populations on Delta National Wildlife Refuge, Plaquemines Parish, Louisiana, was conducted from August, 1963 through January, 1965. This portion of the study deals with the centrarchid fishes. Kelley (1965) reported on the distribution and abundance of other species occurring in the samples.

Delta National Wildlife Refuge lies within the estuarine portion of the Mississippi River and is characterized by shallow mud-bottom ponds, interlaced with distributaries from the Mississippi River. Ponds annually receive flood waters keeping them virtually fresh; however, during late summer and fall saline waters from the Gulf of Mexico invade the ponds and salinity gradually increases.

No previous studies of the fish populations of the refuge have been conducted. This area is expected to undergo changes in flow pattern, water quality, and fish fauna in the years ahead. With an increasing number of people in the Southeastern states seeking additional recreational outlets, information is needed on the present status of fish populations and environment conditions to wisely plan for the protection and management of fish stock in this habitat.

MATERIAL AND METHODS

Collection of Centrarchids

Sampling of centrarchids was on a selected basis. Some ponds were not sampled because of the shallowness of the water and difficulty of getting into certain areas. Gondle, Horseshoe, Major, Horseduck, Sabot and Delta Bend ponds were sampled more extensively because these ponds offered the greatest diversity of habitat on the study area. Fish were sampled periodically with the first collection being conducted August 7, 1963, and the last collection January 29, 1965. Major sampling effort was exerted during the spring and summer months of 1964.

Gear used in collection of the centrarchids included gill net, trammel net, hook and line, minnow seine, bag seine, rotenone, electric shocker and a combination of rotenone and block-off nets.

The largest number of fish were collected with the use of rotenone. Most collections were made as drift samples where the rotenone was pre-mixed with water, dispensed in the sample area with a K-B boat-bailer attached to the foot of an 18-horsepower motor and fish were picked up with a dip net as rotenone drifted through water.

Electric shocking proved to be the most efficient method per man-hour effort for collecting fish. Its use was limited to water with salinity less than 0.20 ppt. The apparatus consisted of boom electrodes mounted on front of a flat-bottom boat. Electric current was generated by a gasoline driven, 60-cycle, Homelite generator rated at 115/230 volts AC and 20.8/13 amperes AC. Best results were obtained by operating the shocker parallel with, and as close to, shore or roseau cane (*Phragmites communis*) as possible.

Standing Crop Procedure

In order to better evaluate the centrarchid fishes in waters of the refuge, two ¼-acre and twenty-six ½-acre block-off net and rotenone combination samples were made between July 11, 1964, and January 29, 1965.

The block-off net used for taking fish population samples was of the type described by Lambou (1959). Samples were made on a selected basis in different types of habitat over the refuge. Sample areas were rectangular to include as much variation in the sample as possible.

Ursic and McClurkin (1958), working with sample plots to measure vegetation, stated a rectangular plot is more efficient than square or circular plots because it tends to include a better representation of local variation in the vegetation. This sampling principle was applied in this study. Samples were made by placing nets as close to the shores or clumps of roseau cane as possible, with the long sides of the rectangle extending into deeper and more open water. One-half acre samples proved to be more efficient than ¼-acre samples. More ½-acre samples could be made than one-acre samples, thereby allowing better coverage of the study area. Rotenone was applied at a concentration of 1 ppm.

Fish were picked up as they surfaced and the sample area was observed until clear of all fish. Block-off nets remained in place for approximately four to five additional hours, then bloated fish were removed.

Lambou and Geagan (1961) left nets overnight in waters of northern Louisiana and picked up bloated fish the second day in order to insure greater accuracy. This procedure was impractical in this study for the following reasons: blue crabs (*Callinectes spadius*) consumed dead and dying fish and did considerable damage to the nets, large numbers of alligator gar (*Lepisosteus spatula*) and spotted gar (*Lepisosteus oculatus*) were attracted to the dead fish and also damaged the net. Gulls (*Larus* sp.) and shore birds also picked up the smaller dead fish.

All data from the block-off net samples are reported on a per-acre basis.

Limnological Methods

The following factors were measured during the course of study: temperature, salinity, dissolved oxygen, carbon dioxide, total alkalinity, pH and turbidity.

During the first two months of field work the temperature was taken with a centigrade thermometer and salinity was determined using the Mohr Method. For the remainder of the study, temperature and salinity were determined with a Solu Bridge Conductivity Meter. Conductivity readings taken with the instrument were converted to ppt salinity.

Dissolved oxygen, carbon dioxide, total alkalinity and pH were not determined until the summer months of 1964. All of these tests were determined by standard chemical field methods. Oxygen determinations were made with the Alsterberg (sodium azide) modification of the Winkler Method.

Turbidity was determined with the aid of a Secchi disk.

RESULTS AND DISCUSSION

Standing Crop Analyses

To estimate the centrarchid populations of Delta National Wildlife Refuge, 28 standing crop samples were made in most major ponds during the summer of 1964 and January, 1965. Kelley (1965) lists poundage per acre of the other fish that occurred in the standing crop samples.

The study area was divided into three areas for reporting standing crop analyses; area 1, ponds south of Octave Pass, area 2, ponds between Octave Pass and Main Pass; and area 3, ponds north of Main Pass. An average of 31.13 pounds per acre of centrarchid fishes were captured in area 1. The poundage ranged from 75.40 pounds per acre in Gondle Pond (Table I) to 2.69 pounds per acre in Mann Outside Pond. Centrarchids averaged 32.79 per cent of the total standing crop of fishes in area 1.

An average of 14.29 pounds per acre of centrarchids was captured in area 2. Poundage ranged from 43.65 pounds per acre in Horseduck Pond (Table II) to 0.00 pounds per acre in Delta Bend. Centrarchids averaged 23.54 per cent of the total standing crop of fishes in area 2.

The average for centrarchid fishes in area 3 was 2.12 pounds per acre. Poundage in this area ranged from 8.40 pounds per acre for

TABLE I. STANDING CROP OF CENTRARCHID FISHES IN GONDLE AND HORSESHOE PONDS LOCATED SOUTH OF OCTAVE PASS, DELTA NATIONAL WILDLIFE REFUGE, 1964-1965. ASTERISK INDICATES ABSENCE OF A SPECIES FROM SAMPLE.

	Weight in Pounds Per Acre								
	Gondle				Horseshoe				
Fishes	7/22/64	7/23/64	7/24/64	1/29/65	8/10/64	8/11/64	8/12/64	8/13/64	1/26/65
Largemouth bass	0.06	12.20	*	3.80	*	8.60	*	4.40	*
Black crappie	5.80	5.00	0.04	15.60	3.40	4.94	5.20	0.64	11.00
White crappie	*	*	*	*	1.03	*	*	*	*
Bluegill	1.48	4.00	0.45	2.20	4.20	9.80	3.00	6.00	*
Warmouth	16.60	15.20	0.09	11.60	6.20	12.20	4.40	2.00	11.80
Redear sunfish	15.80	31.20	7.20	32.80	6.40	11.80	4.60	5.00	1.80
Spotted sunfish	3.50	2.20	*	9.40	6.60	8.20	0.50	1.40	16.00
Orangespotted sunfish	*	*	*	*	*	*	*	*	*
Total pounds centrarchids	43.24	69.80	7.78	75.40	27.83	55.54	17.70	19.44	40.60
Total pounds all other fish	55.16	122.58	68.49	8.53	17.43	125.48	241.12	82.13	38.32
Grand total	98.40	192.38	76.27	83.93	45.26	181.02	258.82	101.57	78.92
Mean of centrarchids				49.06					32.22
Standard error ($s_{\bar{x}}$)				3.92					8.19

TABLE II. STANDING CROP OF CENTRARCHID FISHES IN HORSEDUCK AND SABOT PONDS LOCATED BETWEEN OCTAVE PASS AND MAIN PASS, DELTA NATIONAL WILDLIFE REFUGE, 1964-1965. ASTERISK INDICATES ABSENCE OF A SPECIES FROM SAMPLE.

	Weight in Pounds Per Acre								
	Horseduck					Sabot			
Fishes	7/11/64	7/27/64	7/28/64	8/24/64	1/25/65	7/14/64	8/5/64	8/6/64	1/24/65
Largemouth bass	5.80	0.12	*	9.04	*	*	1.96	*	*
Black crappie	*	*	1.57	0.84	*	2.00	0.34	0.20	1.53
White crappie	*	*	*	*	*	*	0.05	*	*
Bluegill	2.22	2.20	3.22	0.96	1.80	0.30	*	*	*
Warmouth	1.62	2.40	2.60	4.60	2.60	0.14	*	*	*
Redear sunfish	32.00	15.40	14.40	2.00	3.40	1.42	1.79	*	0.50
Spotted sunfish	2.01	0.38	0.59	0.13	0.10	0.18	0.34	0.02	0.09
Orangespotted sunfish	*	*	*	*	*	*	*	*	*
Total pounds centrarchids	43.65	20.50	22.38	17.57	7.90	4.04	4.48	0.22	2.12
Total pounds all other fish	23.98	24.58	17.18	18.30	25.60	32.61	213.31	76.90	49.46
Grand total	67.63	45.08	39.56	35.87	33.50	36.65	217.79	77.12	51.58
Mean of centrarchids					22.40				2.72
Standard error ($s_{\bar{x}}$)					5.87				0.98

location 89° 16′ 25″ W, 29° 15′ 37″ N to 0.00 pounds per acre for location 89° 16′ 30″ W, 29° 15′ 20″ N. Centrarchid fishes comprised 4.44 per cent of the total standing crop of fishes for this area (Table III).

An analysis of variance was computed (Snedecor, 1956) to test the null hypothesis of the difference between standing crops of centrarchids in Gondle, Horseshoe and Horseduck Ponds. A calculated "F-value" of 1.92 with two and 11 degrees of freedom was not significant at the .05 lavel of probability. An additional analysis of variance was computed to test the null hypothesis of the difference between standing crops of centrarchid fishes in Gondle, Horseshoe, Horseduck and Sabot Ponds. A calculated "F-value" of 4.64 for three and 14 degrees of freedom was significant at the .05 level of probability.

Largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), redear (*Lepomis microlophus*), and warmouth (*Chaenobryttus gulosus*) averaged 4.02, 6.61, 2.03, 21.75 and 10.87 pounds per acre, respectively in Gondle Pond. All centrarchid species collected in standing crop samples in Gondle Pond averaged 45.05 per cent of the total poundage for all fishes in the standing crop samples. Largemouth bass, black crappie, bluegill, redear and warmouth averaged 2.60, 5.03, 4.60, 5.92 and 7.32 pounds, respectively, for Horseshoe Pond. All centrarchid species taken in standing crop samples in Horseshoe Pond averaged 33.92 per cent of the total poundage for all fishes. The average poundages per acre for largemouth bass, black crappie, bluegill, redear and warmouth in Horseduck Pond were 2.99, 0.48, 2.08, 13.44 and 2.76, respectively. All centrarchid species taken in standing crop samples from Horseduck Pond comprised 52.54 per cent of the total poundage of all fish.

Salinity

The Mississippi River is in varying stages of flood for approximately eight months of the year (Elliott, 1932); therefore, salt concentrations on the study area are relatively low. Salinity increases in both ponds and passes from spring to fall and as distances increase from Cubits Gap toward the gulf (Tables IV and V).

With decreasing flow of the Mississippi River in early spring, higher salinities were noted near the bottom of the passes. Because salt water is more dense than fresh water, a time lapse was noted between the increase in salinities in the passes and an increase in the ponds.

Access canals are dug through the natural levees into the marsh by oil companies to conduct drilling and pipe laying operations on the refuge. Delta National Wildlife Refuge has a commitment from oil operators to plug and maintain all cuts through the levees. This helps prevent salt water intrusion into many of the ponds when salinity increases in the passes. Several of the plugs are breached by high river stages in the spring, but are usually repaired by the oil companies prior to high salinity conditions in the passes which usually occur in the fall. Two sources of oil well brine discharge from pumping stations on Romere and Octave Passes revealed only localized (50 feet) salinity changes.

The area north of Main Pass had the highest salinities throughout the entire study (Tables IV and V). This area is more accessible to the waters of the Gulf of Mexico because of its geographic position and prevailing southeasterly winds in the area. Portions of the refuge south of Main Pass are open only on the east side. This area is not as severely affected by salinity because river flow and prevailing southeasterly winds tend to hold back the gulf waters.

Hurricane Hilda occurred in October, 1964 and the study area was checked shortly thereafter for increased salinity and adverse affects on the fish populations. The area north of Main Pass had the greatest increase in salinity (Tables IV and V). Certain areas north of Main Pass and the upper portion of Delta Bend reached 43 per cent sea water concentration at this time. Other areas showed variable salinity changes with the area south of Raphael Pass being the least affected. Changes in fish distribution were not evident.

TABLE III. STANDING CROP OF CENTRARCHID FISHES IN PONDS LOCATED NORTH OF MAIN PASS, DELTA NATIONAL WILDLIFE REFUGE, 1964-1965. ASTERISK INDICATES ABSENCES OF A SPECIES FROM SAMPLE.

	Weight in Pounds Per Acre			
	89° 16′ 30″ W 29° 15′ 20″ N		89° 16′ 25″ W 29° 16′ 37″ N	89° 15′ 40″ W 29° 17′ 26″ N
Fishes	8/19/64	1/23/65	8/20/64	1/22/65
Largemouth bass	*	*	5.20	*
White crappie	*	*	*	*
Black crappie	*	*	2.50	0.08
Bluegill	*	*	*	*
Redear	*	*	*	*
Warmouth	*	*	*	*
Spotted sunfish	*	*	0.70	*
Orangespotted sunfish	*	*	*	*
Total pounds centrarchids	0.00	0.00	8.40	0.08
Total pounds all other fish	9.20	1.22	47.48	121.80
Grand total	9.20	1.22	55.88	121.88
Mean of centrarchids		0.00		
Standard error ($s_{\bar{x}}$)		0.00		

TABLE IV. AVERAGE MONTHLY SALINITY OF PONDS, AREAS 1 THROUGH 3, IN ORDER OF INCREASING DISTANCE FROM CUBITS GAP.

	Salinity ppt											
	1963			1964								1965
Ponds	Aug.	Sept.	Nov.	Jan.	Mar.	May	June	July	Aug.	Sept.	Oct.	Jan.
				Area 1 (South of Octave Pass)								
Mann Outside	2.08	—	—	—	—	—	.29	—	—	1.32	—	.70
Horseshoe	—	—	—	—	—	—	.07	—	.18	—	1.35	1.07
Gondle	1.07	—	3.80	2.85	.38	.07	.09	.12	—	—	1.03	1.19
Flatboat Inside	1.82	—	—	—	—	—	.18	—	—	1.12	—	.38
				Area 2 (Between Octave and Main Pass)								
Horseduck	—	—	—	—	.21	—	.16	.25	.21	—	1.60	1.60
John Johnson	—	—	—	—	—	—	.17	—	—	—	—	—
Major Inside	2.20	—	5.20	4.00	.12	.10	.17	.17	—	—	2.80	—
Adolph	—	—	—	—	—	—	.13	—	—	—	—	—
Sabot	—	—	6.20	5.00	.15	.11	.15	.14	.82	—	9.40	.94
Delta Bend	1.95	3.51	—	—	.16	—	—	—	2.00	—	—	.50
				Area 3 (North of Main Pass)								
89° 16′ 30″ W												
29° 15′ 20″ N	—	7.15	—	7.50	—	—	—	—	.34	—	3.40	.29
Lake	—	—	—	5.00	—	—	—	—	1.72	—	—	—
Bennies	—	4.78	6.80	—	—	—	—	—	—	—	—	—
Willow Outside	—	5.20	6.80	—	—	—	—	—	—	—	—	—

TABLE V. AVERAGE MONTHLY BOTTOM SALINITY OF PASSES, AREAS 1 THROUGH 3, IN ORDER OF INCREASING DISTANCE FROM CUBITS GAP.

	Salinity ppt											
	1963			1964								1965
Passes	Aug.	Sept.	Nov.	Jan.	Mar.	May	June	July	Aug.	Sept.	Oct.	Jan.
			Area 1 (South of Octave Pass)									
Raphael at Gondle Pond	—	3.30	—	2.20	.17	—	—	—	—	—	10.70	
Adolph Clark	—	—	—	—	—	—	.23	—	—	—	2.28	
			Area 2 (Between Octave and Main Pass)									
Canal adjoining Adolph Pond	—	—	—	—	—	—	.09	—	—	1.00	1.80	—
Octave, Spanish Is. to Bienvenue	1.82	—	—	2.20	.08	—	—	.08	—	—	10.70	—
Gaspar at Delta Bend	—	6.89	15.30	—	.09	.09	—	.08	1.90	—	15.20	—
Snow Goose	—	5.85	—	—	.17	—	—	.09	—	—	—	—
Gaspar at Grants	—	—	9.40	—	—	—	6.20	—	—	—	—	—
Gaspar at gulf	2.89	—	—	.11	—	—	—	—	—	—	9.40	—
			Area 3 (North of and including Main Pass)									
29° 16′ 25″ W 29° 16′ 37″ N	—	—	—	6.50	—	—	—	—	1.32	—	—	1.20
Main at East Fork	5.20	3.40	6.20	—	—	—	—	—	—	—	—	.17
East Fork, Cal. Co. Hq.	—	4.94	—	6.80	—	—	.09	—	1.32	—	11.30	.19
East Fork, Cal. Co. pump sta.	—	—	3.40	9.40	—	—	7.80	—	1.86	—	15.20	.20
Long Island Bayou	—	—	—	6.20	—	—	—	—	1.70	—	5.60	—
89° 15′ 40″ W 29° 17′ 26″ N	—	9.75	—	7.60	—	—	2.00	—	—	—	—	.94
Main at Grants canal	—	6.80	—	—	—	—	—	—	—	—	10.60	—

Normal tides in the area are small (Holle, 1952) and have only slight effects on salinity. These effects could be noted daily, especially in the passes.

Turbidity

Turbidity on the area varied considerably throughout the entire study. Deeper ponds became less turbid in the summer months with decreased flow of the Mississippi River. Turbidity within ponds also decreased in areas of heavy growths of coontail (*Ceratophyllum demersum*) and water milfoil (*Myriophyllum* sp.). Heavy silt deposition was noted on the leaves of these plants.

Wave action had definite effects on the turbidity of many ponds. These waves are small because of their short fetch, but are sufficient to stir up the soft bottom sediments in shallow ponds, thereby increasing turbidity.

Turbidity in the passes fluctuated upward in spring and early summer months when water levels of the Mississippi River began to rise. In the fall and winter months the passes cleared with increased salinity, especially at their distal ends.

Temperature

Water temperature in ponds and passes varied with the season of the year. The average pond water temperatures for three months in 1963 were August, 30.8°; September, 31.5°; and November, 21.1°C. The lowest average monthly pond water temperature in 1964 was 15.3° in January. The highest monthly water temperature in 1964 occurred in September, with an average of 31.3°. Extreme temperatures in ponds for 1964 ranged from 13.4° in late January to 33.9° in mid-June. The average temperature in ponds for the period June, 1964 through September, 1964 was 30.7°. The average pond temperature during January, 1956 was 15.2°. Extreme temperatures in ponds for January, 1965 were 11.1° to 17.8°. The average monthly temperatures of the passes were less than the average monthly pond temperatures except in August and September.

During the summer and fall, surface and bottom water temperatures on the same day were relatively equal in the ponds over the refuge.

Oxygen and Carbon Dioxide

Oxygen and carbon dioxide determinations were made in various pond locations from July 23, 1964, through September 3, 1964, to include shallow water, open water and waters having dense aquatic vegetation. Dissolved oxygen and carbon dioxide were determined in the early part of the day usually just after dawn. Determinations were also made on consecutive days when heavy cloud cover persisted. Dissolved oxygen ranged from near saturation to 2.0 ppm. The 2.0 ppm oxygen determination occurred in waters where dense aquatic vegetation was growing. Adjacent waters of the same ponds were sampled and found to contain 4.0 to 6.0 ppm dissolved oxygen. Similar findings occurred in other ponds supporting dense aquatic vegetation. Although many ponds are shallow and contain dense growths of aquatic vegetation, sufficient wave action mixes the surrounding open water to supply substantial amounts of dissolved oxygen to support fish. Free carbon dioxide for this period ranged from 0.0 to 15.0 ppm.

Total Alkalinity and pH

Total alkalinity and pH determinations were made from July, 1964 through January, 1965. Total alkalinities did not vary greatly over the study area. The range of total alkalinity in Gondle Pond, which is fresher, was 111.0 to 191.0 ppm; and in Sabot Pond, which is influenced more by saline waters, it ranged from 105.0 to 145.0 ppm. It was noted that the carbonates were absent or lower in the fresher ponds and increased in areas influenced by saline waters.

Measurements of pH were higher in the area north of Main Pass and ranged from 8.0 to 8.6. In fresh water ponds south of Main Pass pH measurements ranged from 7.2 to 8.4. Geagan (1962) reported higher

pH values in the more saline marsh area of Lake Borgne, Louisiana than in the fresher ponds.

DISTRIBUTION AND ABUNDANCE

Largemouth Bass

Largemouth bass distribution was limited primarily to two localized areas: the southeast portion of the refuge which included Gondle, Horseshoe, and Mann Outside Ponds, and the central western portion which included Major Inside, Horseduck, Adolph and John Johnson Ponds. Largemouth bass were collected on single occasions in Flatboat Pond, the northern portion of Delta Bend and from a dead-end canal adjacent to Buras Bayou. Largemouth bass were collected on two separate occasions in Sabot Pond. Sampling operations were conducted extensively in many other ponds, passes, and canals of the refuge but largemouth bass were not observed.

Depth of ponds appears to be one of the factors having the greatest influence on the distribution of largemouth bass. Gondle, Horseshoe and Horseduck Ponds are the deepest ponds on the refuge. Average depth of Gondle and Horseduck was approximately three feet and the average depth of Horseshoe Pond was approximately five feet. Largemouth bass are well established in these ponds and apparently move into favorable niches in ponds nearby.

Several bass were collected in turbid waters and turbidity did not appear to be a major limiting factor. Salinity increases in the ponds and passes in proximity to and connected with the Gulf of Mexico did affect distribution. The ponds in which the bass were localized are fresher throughout the year and receive large amounts of fresh water annually during periods of high water stages of the Mississippi River. Limited bass habitat in the area north of Main Pass consists of a few shallow ponds, passes and man-made canals. The fact that these passes and canals become more saline (Table V) in the fall and winter in this area could explain why bass are found only occasionally in this area. Largemouth bass were collected in salinities that ranged from 0.04 ppt in Horseshoe Pond in June, 1964 to 4.10 ppt in Major Inside Pond in January, 1965. The single bass collected north of Main Pass was in a salinity of 1.32 ppt. Tebo and McCoy (1964) obtained information from stream survey work on the downstream sections of the Neuse River in North Carolina concerning the distribution of various species of fish in relation to the concentration of sea water. Largemouth bass were present in areas where sea water concentration ranged from 0 to 29 per cent. Occurrence of largemouth bass dropped sharply in areas having more than 10 per cent sea water and were found in samples taken from areas that had more than 15 per cent sea water. Salinity in the area north of Main Pass reached 43 per cent sea water in October and the one bass taken in this area was in 3.8 per cent sea water in August, 1964. When compared to information of Tebo and McCoy (1964) salinity definitely appears to limit the distribution of bass in this area. Bass were collected in limited numbers in Major Inside Pond in January, 1964 when waters reached 11.7 per cent sea concentration. Collections of bass increased in this pond in the spring and summer months. Salinity appears to have some seasonal effect on bass in this area and compares favorably with information given by Tebo and McCoy (1964).

Considering the entire refuge, largemouth bass was not an abundant fish. Average percentage of the total standing crop computed for bass was low when compared with other centrarchids. Greatest abundance of bass was in Gondle and Horseshoe Ponds. Observations made while conducting electric shocking operations revealed this fish to be more abundant in these ponds than standing crop figures indicate. As example, 16 bass (9.3 to 18.1 inches total length) were collected in Horseshoe Pond on June 4, 1964, in approximately 30 minutes shocking time and 300 yards distance along the edge of roseau cane. Fifteen bass were collected in Gondle Pond (8.8 to 16.3 inches total length) in the same approximate time and distance. These fish were also collected along the edge of roseau cane.

Black Crappie

Black crappie were distributed in almost identical areas to the largemouth bass. This species was collected most often in surrounding ponds from the same two localized areas: the southeast portion and the central western portion of the refuge. Black crappie were also well established in the area north of Main Pass. On June 26, 1964, several young-of-the-year black crappie were collected north of Main Pass in a salinity of 2.00 ppt. Several adult black crappie, total lengths up to 9.6 inches, were collected in waters having salinities of 1.32 ppt. This area reached 43 per cent sea water concentration in October, 1964. This salinity would limit reproduction of largemouth bass and bluegill (Tebo and McCoy, 1964); however, this salinity level does not appear to be limiting the reproduction of black crappie. Louder (1963) gives the occurrence of black crappie in Cape Fear River and its tributaries in North Carolina in salinities up to 4.7 ppt, but this species was much more abundant in the fresher headwaters of the river.

Turbidity was greater in canals and passes, but did not appear to limit black crappie distribution. Trautman (1957) stated that black crappie seemed to be less tolerant to silty waters than the white crappie in Ohio. Several black crappie were collected in the ponds although black crappie were more numerous in the deeper waters of the canals. The greatest numbers of black crappie found in ponds were in Gondle, Horseshoe and Horseduck Ponds. The presence of greater numbers of black crappie in these ponds further substantiates the preference of black crappie for the deeper waters.

Black crappie is not an abundant centrarchid in Delta National Wildlife Refuge. Based on standing crop analyses, black crappie are most abundant in Gondle and Horseshoe Ponds, but no standing crop samples were made in the deeper canals due to sampling gear limitations. Observations made during rotenone sampling and electric shocking operations in the canals indicate black crappie to be more abundant in these areas than the ponds.

White Crappie

White crappie (*Pomoxis annularis*) were collected on six occasions. In all samples where this species was found black crappie also occurred. Six white crappie were young-of-the-year (2.8 to 5.2 inches total length) and three were adults (7.2 to 9.9 inches total length). Since only limited numbers of white crappie were collected and distribution was sporadic, no definite pattern was demonstrated.

The highest salinity in which white crappie were collected was 1.32 ppt. The area was located north of Main Pass in a canal east of Buras Bayou. Waters in this general vicinity reached 43 per cent sea water concentration in October, 1964. Salinity probably limits this species more than any other factor. White crappie have not been reported in previous collections of fish in estuarine habitats along the Louisiana coast. Hoenke (1964) did not list either the white or black crappie as occurring in the marsh between Lake Borgne and Chandeleur Sound east of New Orleans, Louisiana. Gunter and Shell (1958) did not list the white or black crappie as occurring in the lower Mermentau River basin. Turnage (1964) lists both the white and black crappie occurring in Lake Palourde, Louisiana, which is located 30 miles by water from the Gulf of Mexico. This lake is influenced by brackish water at certain times during the summer months. Kendeigh (1961) states the white crappie is more often found in small rivers and creeks than the black crappie.

Bluegill

Distribution of the bluegill closely parallels that exhibited by largemouth bass. South of Octave Pass, bluegill occurred only in Gondle, Horseshoe and Flatboat Ponds. This fish was widely distributed in ponds between Octave Pass and Main Pass. Bluegill were collected in most sampling operations in Major Inside and Horseduck Ponds. This fish also occurred in four ponds, John Johnson, Death, Adolph and Major Outside, which are in the vicinity of Horseduck and Major Inside Ponds.

Bluegill were collected on two occasions in the southern portion of Sabot Pond, but were not found in the waters of Delta Bend.

One bluegill, 2.5 inches total length, was collected in a dead-end canal north of Main Pass in a salinity of 2.00 ppt. This area had its highest salinities during fall months. Bluegill could have entered this area during a period of higher and fresher water conditions and become isolated.

Salinity appears to be the major factor limiting the distribution of bluegill. Bioassay studies by Tebo and McCoy (1964) showed that approximately 10 to 12 per cent sea water was the maximum concentration in which bluegill could successfully reproduce.

Bluegill were not an abundant species when compared to other *Lepomis* sp. that occurred on the refuge. Greatest numbers of bluegill occurred in Horseshoe Pond (Table I).

Redear

Distribution of redear was confined to ponds south of Main and Octave Passes. Redear were well established in Horseduck, Major Inside, Adolph, Horseshoe and Gondle Ponds. These fish were collected on several occasions in shallow ponds, especially Flatboat and Sabot Ponds. Pond depth and turbidity did not appear to be limiting factors on redear distribution.

Salinity appeared to prevent this fish from inhabiting the area north of Main Pass, which reached its highest salinities (Tables IV and V) in the fall and early winter months. The highest salinity in which redear were collected in numbers was 4.1 ppt in Major Inside Pond on January 27, 1964. Geagan (1962) found redear sunfish in abundance in Lake Borgne, Louisiana, from February, 1961 through April, 1961 in salinities ranging from 2.6 ppt to 6.7 ppt.

Based on standing crop analyses (Tables I, II and III) the redear sunfish was the most abundant centrarchid occurring in waters of the refuge. Redear comprised the highest average poundage and percentage of all centrarchid occurring in waters of the refuge. Redear comprised the highest average poundage and percentage of all centrarchids in Gondle, Horseshoe, Mann Outside and Horseduck Ponds.

Warmouth

Distribution patterns of warmouth were almost identical to those exhibited by the redear sunfish. It occurred more frequently in samples than the redear. The only noted difference was that warmouth occupied a greater number of the shallow ponds. Warmouth occurrence in these shallow ponds, which were more turbid, indicates this fish was more adapted to turbid water habits. Larimore (1957) found the warmouth most frequently and in greater abundance in muddy or turbid waters in Illinois.

Salinty also prevented the warmouth from occupying the more saline waters north of Main Pass. The highest salinity in which warmouth were collected was 4.1 ppt in Major Inside Pond on January 27, 1964.

Based entirely on standing crop analyses (Tables I and II), warmouth was the second most abundant fish occurring in waters of the refuge. Louder (1963) lists warmouth as being one of the numerically dominant species in the lower Cape Fear River of North Carolina. Louder (1962) states the warmouth was the most widely distributed game fish of the Lumber River watershed of North Carolina.

Spotted Sunfish

The spotted sunfish occupied the most diversified habitats of any centrarchid occurring in water of the refuge (Tables I through III). This species was well distributed in both shallow and deep ponds. Spotted sunfish demonstrated no preference in relation to salinity, turbidity or depth in this study.

Spotted sunfish occurred more often in the area north of Main Pass than did other centrarchids. This area had only limited occurrence of other centrarchids due to higher salinities in the fall and winter.

Geagan (1962) lists spotted sunfish as being abundant in Lake Borgne, east of New Orleans, Louisiana. Spotted sunfish abundance on the delta study area varied (Tables I through III). In the majority of ponds in which they were collected, spotted sunfish ranked third in pounds per acre of the total standing crop of centrarchids.

Orangespotted Sunfish

This fish exhibited the most seasonal occurrence of all centrarchids. They were first collected in Gondle Pond on March 27, 1964, and the last collection of this species occurred on June 12, 1964, in Mann Pond. Only 23 orangespotted sunfish were collected during the entire study period. Ten fish collected on March 27, 1964, in Gondle Pond ranged from 1.7 to 4.3 inches total length. Maximum total length for orangespotted sunfish collected was 5.8 inches. Orangespotted sunfish were also collected in Major Inside Pond.

Orangespotted sunfish were not collected in salinities exceeding 0.74 ppt. These fish may have moved into the study area from the Mississippi River during spring rises. Apparently they were either removed by predation or found cover in the roseau cane where collections could not be made.

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SPORT FISHERY STATISTICS FROM THE INLAND WATERS OF NORTH CAROLINA

FREDERIC F. FISH
Federal Aid Coordinator (DJ)

Division of Inland Fisheries
North Carolina Wildlife Resources Commission
Raleigh, North Carolina
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ABSTRACT

Data obtained from 28,454 Wildlife Protector interviews during the course of routine license and creel checks between April 1, 1964 and March 31, 1965 supported the following estimates respecting the "rod-and-reel" sport fishery in the Inland Waters of North Carolina:

Respecting Angler Numbers:

Licensed — 404,878 (53%)
Unlicensed — 357,335 (47%)

Respecting Choice of Gear:

By licensed anglers: cane pole 32%; casting rod 49%; fly rod 9%
By unlicensed anglers: cane pole 64%; casting rod 26%; fly rod 4%
All anglers: cane pole 47%; casting rod 38%; fly rod 7%

Respecting Choice of Baits:

By licensed anglers: natural 63%; artificial 22%
By unlicensed anglers: natural 98%; artificial 1%
By all anglers: natural 80%; artificial 12%
(Balance indicates both baits used on same trip)

Respecting Catches:

The percentage of the estimated Statewide harvest from Inland Waters by "rod-and-reel": sunfishes 44.0%; crappie 19.1%; white perch 12.6%; catfishes 10.0%; largemouth bass 3.6%; mountain trout 3.5%; all others combined 7.2%