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THE FISHES OF THE SANTA FE RIVER SYSTEM

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THE FISHES OF THE SANTA FE RIVER SYSTEM

THOMAS R. HELLIER, JR.[1]

SYNOPSIS: This paper correlates the fish populations of the Santa Fe River with such physical aspects as its underground channel, substantial subterranean drainage, and low chlorinity. Recorded from the river and its tributaries are 60 species of fishes representing 21 families and 13 orders. Pertinent life history notes are given for many of the species, including one species nearly endemic to the river, *Micropterus notius*.

The derivation of the ichthyofauna is suggested; 25 species comprise an element widespread to the north, 18 to the southeast; 8 species are typically Floridian, and 8 species are from marine waters. Euryhaline species in the Santa Fe are generally restricted to the portion of the river downstream from the underground channel. A new term is proposed, dihaline, to describe those species that maintain breeding populations in both fresh and marine waters.

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[1] The work reported on here was submitted to the Graduate School, University of Florida, in partial fulfillment of the requirements for the Master of Science. The author is now associated with the Department of Biology, Arlington State College, Arlington, Texas. Manuscript received 3 August 1965.—ED.

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Introduction

The Santa Fe River, one of the three major tributaries of the Suwannee, is unique in that it is the only river in Florida that leaves its surface channel and flows underground for a considerable distance before reappearing on the surface. The underground channel of the Santa Fe measures more than 2 miles in length, but can be traced with ease on aerial photographs which mark its subterranean course by a series of sink holes separated by intervening natural bridges (Stubbs, 1941). Many other streams in the limestone regions of Florida disappear underground, but they either reappear within a few hundred yards, or do not return to the surface as the same stream. The long underground section of the Santa Fe divides the river into two distinct portions and forms a possible barrier to upstream migration of some fishes.

Although a number of fish population surveys have been made in North America, none has dealt with a clear-water river like the Santa Fe, in which direct observations of the fishes can be made in the main channel. Furthermore, none has been made on a river that is divided into two portions by a long subterranean channel. In the Southeast the fishes of only two rivers have been reported on with any degree of thoroughness. The Escambia in western Florida was the object of an investigation by Bailey, et al., (1954) and the St. Johns was studied over a 10-year period by McLane (1955). Neither of these studies, however, were in places that afforded a consistent opportunity for direct observation of the fishes, or that presented a possible physical barrier to the ascent of marine invaders.

The present paper with modifications was submitted as a masters thesis to the University of Florida in August, 1957. I wish to thank my advisory committee, John D. Kilby, Chairman, E. S. Ford, and J. N. Yount for guidance during the study. I am indebted to the many students and faculty who assisted in the field work and provided advice, particularly David K. Caldwell and William L. Jennings. J. C. Briggs, and Clark Hubbs were especially helpful in suggesting revisions of the manuscript. My wife, Evelyn, provided encouragement and assistance in all facets of the work.

Description of the River

The Santa Fe River drains the central portion of the upper peninsula of Florida (Fig. 1). It arises in the northeast corner of Alachua County, Florida, from Lake Santa Fe, a typical, oligotrophic, sand-

hill lake bedded in sands of Pleistocene origin. From Lake Santa Fe the river follows the northern Alachua County line westward for approximately 40 miles to O'Leno State Park where it disappears underground through the Santa Fe Sink. The major tributaries of this section of the river are the New River, which forms the boundary between Bradford and Union Counties, and Olustee Creek, which separates Union and Columbia Counties. The watershed area for the Santa Fe above Santa Fe Sink includes the northern portion of Alachua, all of Bradford and Union, southwestern Baker and southeastern Columbia Counties. This area is principally agricultural land and pine flatwoods underlain by the Miocene Hawthorne formation, whose imperviousness encourages drainage into the Santa Fe through small surface streams.

The river itself after leaving Lake Santa Fe flows through Pleistocene sands, which lie on top of the Hawthorne formation, until it reaches a point just west of Station I (see Fig. 1). As might be expected, the depth of the river in this section varies considerably with the amount of rainfall, and often during periods of dry weather no water flows in the river bed for several miles below Lake Santa Fe. The aquatic plants found in this part of the river are generally very sparse and consist principally of figwort (*Hydrotrida caroliniana*), spikerush (*Eleocharis*), water-purslane (*Ludwigia*), water-pennywort (*Hydrocotyle umbellata*), aquatic moss (*Fontinalis*), maidencane (*Panicum hemitomon*), and some floating filamentous algae. Several small streams collect rainwater from the surrounding flatwoods and empty into this portion of the Santa Fe; the water in them is generally more brownish than that of the Santa Fe proper and their emergent vegetation is more extensive.

Just downstream from Station I the Santa Fe cuts down into the Hawthorne as evidenced by outcroppings of this formation along the banks, particularly at the mouth of Olustee Creek. The character of the river changes considerably from this point on to the Santa Fe Sink. It becomes wider and slightly deeper with occasional rapids. The current in the main river channel increases, but more backwater reaches become evident and the aquatic plants change. Tape-grass (*Vallisneria*), naiad (*Najas*), muskgrass (*Chara*) and much attached filamentous algae dominate the areas with current, while cattail (*Typha*) and spatterdock (*Nuphar*) are found along the banks in areas of lessened flow. In the shallow rapids the rocks are covered with aquatic moss (*Fontinalis*), and some figwort (*Hydrotrida caroliniana*) grows in sandy patches between the rocks. The bottom of this por-

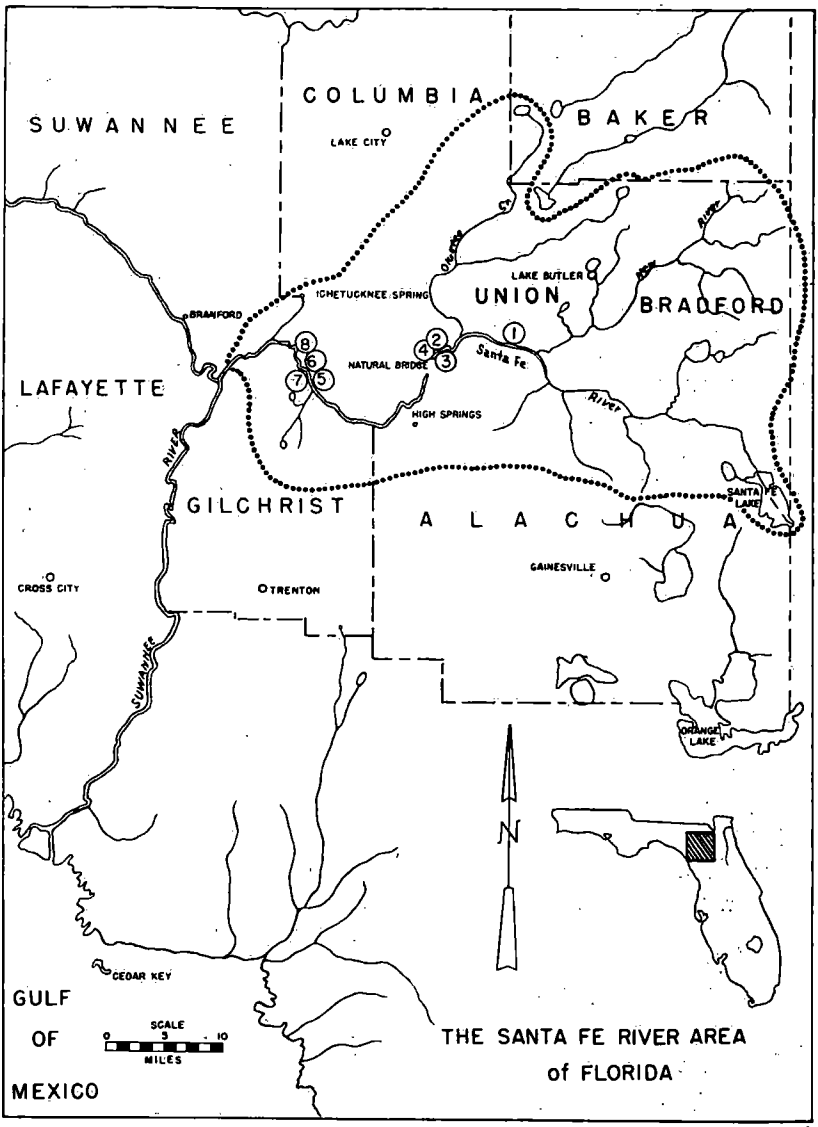

Fig. 1.—The Santa Fe River area of Florida. The dotted line indicates the boundary of the drainage basin and the eight numbered circles show the locations of the regular collecting stations.

tion of the river is still generally sand. The vegetation along the river from Lake Santa Fe to Santa Fe Sink is of a mixed river swamp and low hammock type with bald cypress (*Taxodium distichum*), willow (*Salix longipes*), river birch (*Betula nigra*), water oak (*Quercus nigra*), white bay (*Magnolia virginiana*), titi (*Cyrilla racemiflora*), black gum (*Nyssa sylvatica*), and sweet gum (*Liquidamber styraciflua*) as the dominant trees. Where the river cuts through sand bluffs the mixed river swamp and low hammock type vegetation along its banks is replaced by live oak (*Quercus virginiana*), slash pine (*Pinus elliottii*), and occasionally longleaf pine (*Pinus palustris*). The Santa Fe River east (upstream) of Santa Fe Sink will be referred to as the area "above the natural bridge."

After disappearing into the sink, which penetrates the pervious Ocala Limestone of Eocene origin, the Santa Fe follows an underground course southwesterly for two miles and then reappears as a surface stream. Thereafter it follows the northern boundaries of Alachua and Gilchrist Counties as a surface stream for approximately 30 miles to enter the Suwannee River 9 miles southeast of the town of Branford, Florida. This confluence is about 70 miles upstream from the mouth of the Suwannee on the Gulf of Mexico.

The Santa Fe west of (downstream from) the natural bridge receives most of its drainage from a series of limestone springs. Some of the larger springs emptying into this part of the river are Poe and Lily Springs in Alachua County, Blue Springs in Gilchrist County, and Ichetucknee Springs in Columbia County. The run of Ichetucknee Springs receives the water of several smaller springs, and its average flow of 335 cubic feet per second is the third largest for springs in Florida (Ferguson, *et al.*, 1947). The pervious Ocala Limestone that underlies this last section of the Santa Fe accounts for the large amount of subterranean drainage into the river. This portion of the Santa Fe receives very little surface drainage except during periods of heavy rain. The principal aquatic plants that occur here are: Tape-grass (*Vallisneria*), naiad (*Najas*), muskgrass (*Chara*), water-purslane (*Ludwigia*), *Sagittaria* with narrow strapshaped leaves, aquatic moss (*Fontinalis*), and filamentous algae. Coontail (*Ceratophyllum demersum*) is locally abundant in some of the larger springs and spring runs. The vegetation along the river on its western end is also of a mixed river swamp and low hammock type with the same species of trees dominating as listed before, with the addition of the overcup oak (*Quercus lyrata*) which occurs sporadically in several places. (The aquatic plants are after Eyles and Robertson (1944) and

the trees are after West and Arnold (1956). The above species of plants are referred to in the remainder of this paper by generic name only.) Downstream from the natural bridge the current is generally swift, the water clear except after heavy rains, and the bottom is usually of sand on rock or bare rock. The Santa Fe west of the natural bridge will be referred to as "below the natural bridge."

Odum (1953) lists the Santa Fe as one of the rivers with the lowest chlorinity in Florida. The chloride content is ten parts per million or less both above and below the natural bridge. Temperatures are generally higher in the summer and lower in the winter above the natural bridge than those below it (Table 1).

TABLE 1. AVERAGE WATER TEMPERATURES FOR STATIONS ABOVE AND BELOW THE NATURAL BRIDGE IN °C

Months	Above Natural Bridge	Below Natural Bridge
January	20.5	22.0
February	17.5	20.5
April	22.0	22.0
May	25.0	25.0
June	27.0	25.5
July	26.5	25.0
August	29.0	25.0
September	28.0	24.0
October	25.0	23.5
November	24.5	23.5
December	21.0	22.5

DESCRIPTIONS OF THE STATIONS

The collecting stations shown on Figure 1 were selected to include the major habitats occurring in the Santa Fe River. The regular stations included locations above and below the natural bridge that were as nearly comparable to each other as possible.

STATION 1. This station is at Cox Bridge where State Highway 241 crosses the Santa Fe. Here the river is a shallow, sand-bottom stream with a moderate current and sparse aquatic vegetation. *Hydrotrida* and *Eleocharis* are the dominant plant genera and cover approximately 10 per cent of the bottom in small mats. An aquatic moss *Fontinalis* covers some of the logs and stones in the river bed. These

three species are the principal submerged plants; the only emergent plant present in any significant amount is *Ludwigia*. The depth of the water varies considerably; no water was flowing in April 1956, but by July the river covered its flood plain at Cox Bridge to a depth of approximately 3 feet.

Fig. 2—Station 1. Santa Fe River at Florida State Highway 241. The water is about two feet deep, slightly above average for the period covered by this study.

STATION 2. The Santa Fe River flows over a series of rapids in O'Leno State Park. The last of these rapids, about 250 yards upstream from the Santa Fe Sink, was selected as Station 2. Here the rapids extend from bank to bank across the river, which is about 12 yards wide. During the present study the depth at this station varied from a few inches to about 3 feet according to rainfall. The heaviest rains and the deepest water occurred in summer. The vegetation is principally of the submerged type; *Najas*, *Vallisneria* and *Chara* occur in patches over the rapids, *Fontinalis* and several green algae grow on many of the submerged stones covering the bottom of the rapids.

STATION 3. In O'Leno State Park 20 yards downstream from Station 2, a slough about 20 yards wide extends approximately 50 yards northeasterly from the Santa Fe; its average depth is 2½ feet. Four major types of aquatic vegetation occur here. The bottom is nearly covered by large beds of *Najas* and *Chara* interspersed with smaller patches of *Vallisneria.* The pleuston is made up of the duckweeds *Lemna minor* and *Spirodela polyrhiza,* the aquatic fern *Azolla caroliniana,* and small patches of green algae, *Spirogyra.* The floating leafed *Nuphar* and the emergent *Typha* occur around the margins of the slough. The bottom of the slough is fine silt on sand except directly under the *Nuphar* where moderate deposits of mud cover the rhizome systems of these plants.

Fig. 3—Station 2. Santa Fe River at O'Leno State Park showing the rapids approximately 250 yards upstream from Santa Fe Sink.

STATION 4. Santa Fe Sink is roughly circular in outline and about 70 yards in diameter. The depth, measured in the center in March 1956, was 105 feet. The sides of the sink slope off very rapidly and the only aquatic plants present in any substantial quantities are the pleuston forms *Lemna, Azolla,* and *Spirodela* which, together with

floating logs, tree branches, leaves and other debris, usually cover the sink's entire surface.

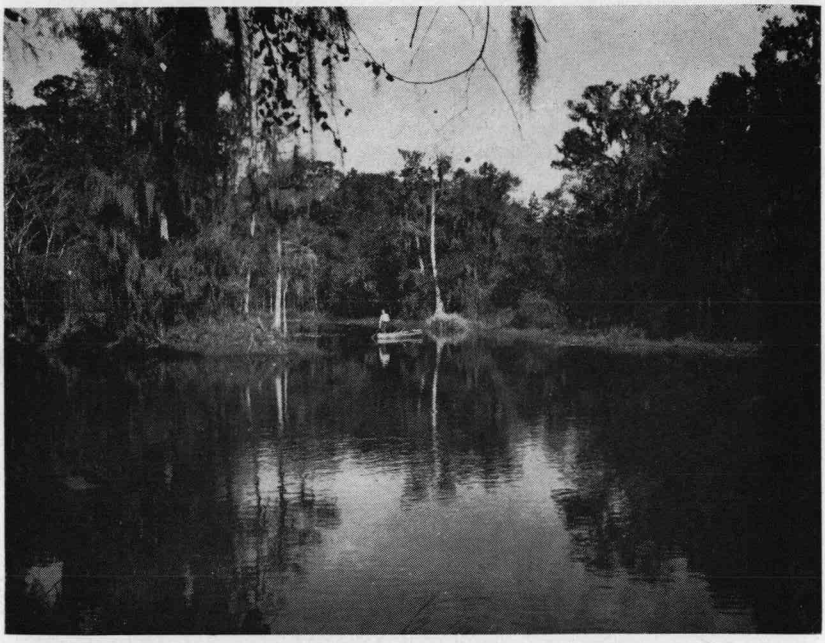

Fig. 4—Station 3. Slough on the Santa Fe River at O'Leno State Park about 200 yards upstream from Santa Fe Sink. The water depth is approximately three feet at the boat in the slough.

STATION 5. This station is ½ mile upstream from Duncan's Landing, Columbia County, at the mouth of a small unnamed spring on the north bank of the river. The bottom is sand and the only vegetation is a submerged moss, *Fontinalis,* attached to the few logs present. The spring and its short run have large beds of *Najas* and *Ludwigia* along the banks.

STATION 6. Station 6 is on the north bank of the Santa Fe River at Duncan's Landing, which is 2½ miles upstream from the confluence of the Ichetucknee and the Santa Fe. The current is much reduced by a curve in the river and by a rock outcrop from which two springs flow. The bottom is silt on sand with an occasional spot of silt on rock. The plants consist of large beds of *Najas, Chara* and *Vallisneria. Lemna* and *Spirogyra* occur in small quantities and *Ludwigia* grows close to and on the bank. The rocks just below the station are

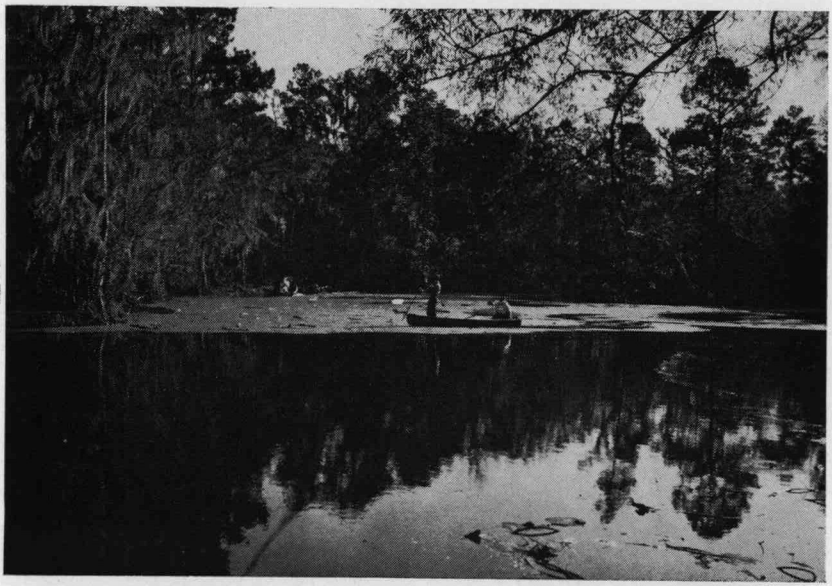

Fig. 5—Station 4. Santa Fe Sink at O'Leno State Park. The material covering the surface is principally *Lemna* and assorted debris.

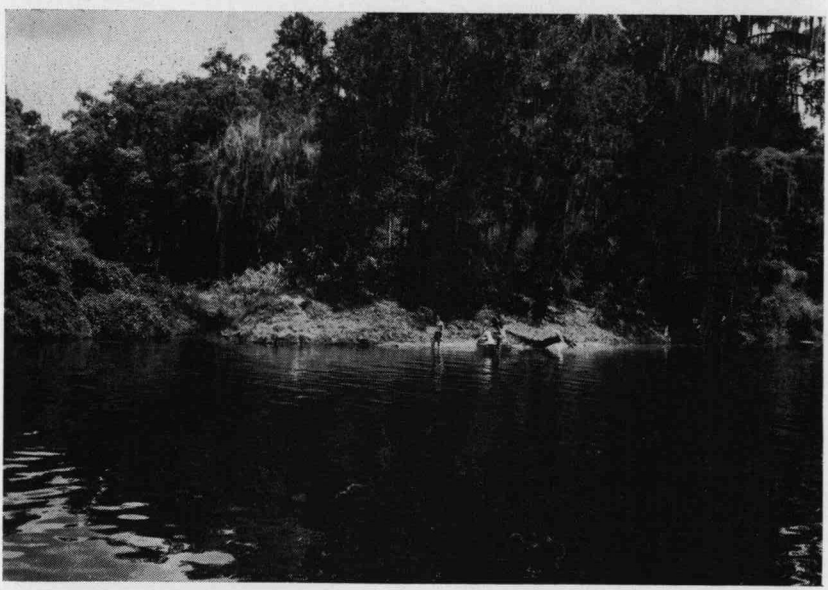

Fig. 6—Station 5. North bank of the Santa Fe River 3 miles upstream from the confluence of the river and Ichetucknee Spring Run. A small unnamed spring run is visible on the left.

covered with *Fontinalis* and filamentous algae. Some *Ceratophyllum* is attached to the rocks in the direct flow of the springs. The depth of the water varies from about 5 feet on the river side to a few inches at the shore.

Fig. 7—Station 6. Duncan's Landing on the Santa Fe River 2½ miles upstream from the mouth of Ichetucknee Spring Run. A spring may be seen roiling the surface of the water.

STATION 7. Downstream 30 yards from Duncan's Landing is a small, nearly round depression in the river bed near the north bank of the river. About 10 yards in diameter, the depression slopes off rapidly to a depth of approximately 5½ feet. Here current is insignificant and the only vegetation is *Vallisneria* along the upstream edge of the hole. The bottom and sides of this station are rock, except where the depression is open to the river on the south side. Quantities of dead plant debris float on the surface of this area.

STATION 8. This station is at a broad stretch of rapids 1½ miles above the mouth of the Ichetucknee. Throughout the study water covered these rapids to an average depth of from 2 to 2½ feet. The bottom is rock with patches of sand in the depressions. Many

large beds of *Najas, Sagittaria* and *Vallisneria* occur throughout the rapids. Small patches of *Fontinalis* grow on some of the submerged stones and green, non-filamentous algae cover most of the remaining rocks.

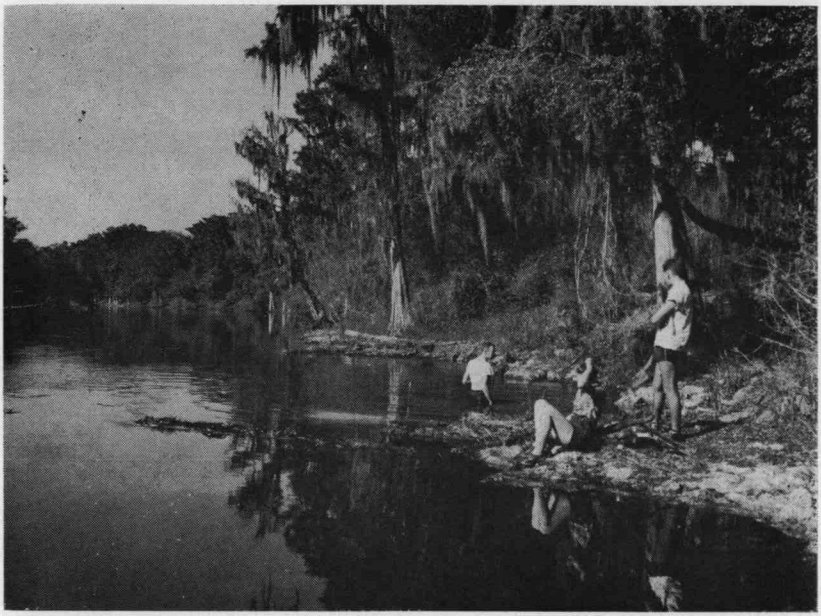

Fig. 8—Station 7. A hole in the river bed just downstream from Duncan's Landing on the Santa Fe River.

Other Stations. Many collections were made at other widely spaced localities in the Santa Fe and its tributaries, but as these places were not visited regularly, they are not numbered. Except those along small, flatwoods streams and in one pond, these other sites generally resembled one of the numbered stations.

Materials and Methods

Collections were made monthly at the eight regular stations and at many other sites along the Santa Fe including representative habitats throughout the drainage basin. Active field work was conducted from June until October 1955, and from January 1956 through January 1957.

Most collections were made with either a 15-foot knit seine with ¼-inch mesh on a 4-foot drop and with a 4-foot bag in the center,

or with an 8-foot common-sense seine also with ¼-inch mesh and a 4-foot drop. Other types of collecting gear occasionally used included gill nets, wire traps, trotlines, hook and line, poison, spears, and explosives. Underwater observations were made with a face mask and scuba gear.

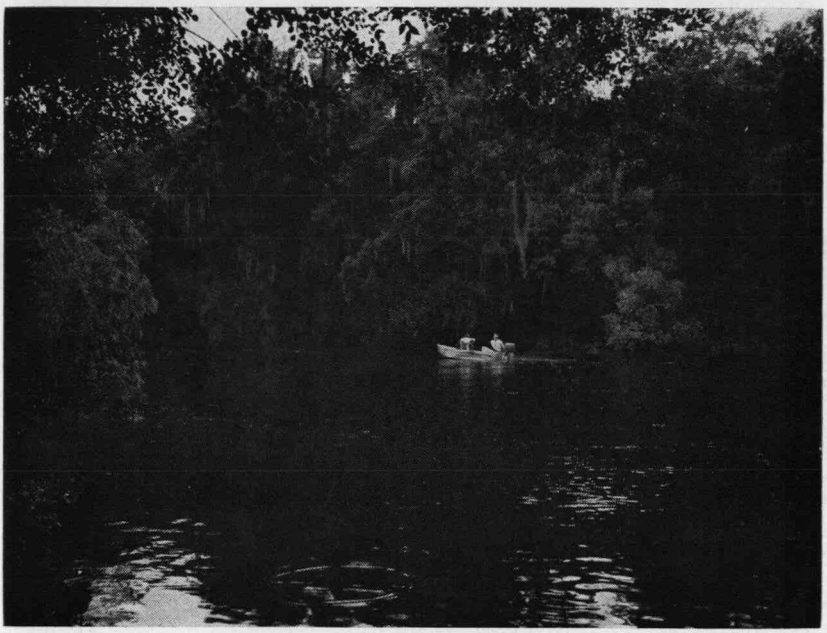

Fig. 9.—Station 8. A broad exposure of rapids in the Santa Fe River one and one-half miles upstream from the junction of Ichetucknee Spring Run with the Santa Fe. The water depth at the boat is approximately 18 inches.

All specimens were preserved in the field in 10 per cent formalin, transferred in the laboratory to 35 per cent isopropanol, and are deposited in the University of Florida collections. Measurements were taken in a straight line to the nearest millimeter, and all length measurements given are standard lengths.

Water samples were analyzed for chlorinity in the laboratory by the Mohr method of silver nitrate titration.

ANNOTATED LIST OF FISHES

The following list of fishes from the Santa Fe River, Florida, encompasses 13 orders, 21 families and 60 species. Tables 4, 5, and 6 are a part of this list, and much of the data, such as specific catches by months and by major habitats both above and below the natural bridge, have been consolidated in the tables for ease of reference and to free the annotated list of these details. The sequence of species and the scientific and common specific names follow Bailey *et al.* (1960).

1. *Acipenser oxyrhynchus desotoi* Vladykov. In the fish collections of the University of Florida is a specimen of the southern sea sturgeon taken from the Santa Fe River at High Springs. No individuals of this species were seen or caught during the study.

2. *Lepisosteus osseus* (Linnaeus). The longnose gar was the largest fish found in the river system. One specimen was collected below the natural bridge in July, and three above it—one each in July, September, and October. Single individuals of this species were observed below the natural bridge on nine occasions in April, May, and July. Invariably they were seen in midstream 1 to 3 feet below the surface. One specimen 54 mm long was collected in July 1955 and one gravid female of 1,016 mm was taken in July 1956.

3. *Lepisosteus platyrhincus* DeKay. The Florida spotted gar is the most abundant gar in peninsular Florida. It occurs in all major freshwater and some brackish habitats, but populations are heaviest in still waters with an abundance of submerged aquatic plants and a rich food supply of small fish (McLane, 1955). Although plentiful in Florida, only 3 individuals were observed in the Santa Fe during the study. Two of these were above the natural bridge in September and one below in July.

4. *Amia calva* Linnaeus. The bowfin is a widespread but seldom abundant fish of quiet waters, especially those with shallows, some cover, and a silty bottom. Places that meet these requirements are more plentiful above than below the natural bridge and, as expected, more individuals were seen above (8) than below it (1).

5. *Alosa alabamae* Jordan and Evermann. The only specimens of this anadromous species found in the Santa Fe were 4 collected at Station 8 in October 1956, which represent a range extension for the species (Berry, 1964). John D. Kilby and J. C. Dickinson, Jr.

(personal communication) collected several dozen Alabama shad from the Santa Fe near Station 8 also in October 1956, but unfortunately the specimens were lost. Thus the species may be locally abundant in the Santa Fe at certain times.

6. *Umbra pygmaea* (DeKay). McLane (1955: 63) records two eastern mudminnows in the University of Florida collections taken in the Santa Fe drainage at Ocean Pond near Olustee, Baker County. The species is rare in Florida, and none were taken during the present study.

7. *Esox americanus* Gmelin. During the study two redfin pickerel were taken above the natural bridge in small, acid tributaries of the Santa Fe. One of these caught in September was a 175 mm female containing ripe ova.

8. *Esox niger* Lesueur. The only chain pickerel taken was a 58 mm individual caught in April 1956 at Station 1.

9. *Hybopsis harperi* (Fowler). The redeye chub is the most abundant vertebrate inhabitant of subterranean waters in Florida and occurs most frequently in springs and their surface runs. Second only to *Lucania goodei* in numbers collected below the natural bridge (1,082 specimens), we collected none above it. The fact that the lower river is fed principally by subterranean streams and the upper portion principally by surface drainage may explain this distribution. It is significant that 39.6 per cent of the fish were taken at Station 7 where a large spring enters the river and another 29.8 per cent from springs or spring runs. Gravid females were caught in January, February, May, June and July. The only specimen under 25 mm collected was a 20 mm fish taken in February.

10. *Notemigonus crysoleucas* (Mitchill). We took 425 golden shiners above the natural bridge and only 9 below it. Though we found them throughout the year and in all habitats examined, 94.3 per cent of the specimens came from under patches of floating *Nuphar* at Station 3. We collected few fingerling or smaller individuals, but took one gravid female of 165 mm in June 1956.

11. *Notropis chalybaeus* (Cope). As McLane (1955) emphasizes, the ironcolored shiner occurs most regularly in small hammock streams that drain pine flatwoods. In the Santa Fe the species is not abundant. All but 2 of the 30 specimens collected were from small flatwoods streams tributary to the river above the natural

bridge, and all were found in association with aquatic vegetation. Males with breeding tubercles were taken in June and July, well within the mid-April to early September breeding season Marshall (1947) reports for the species in Alachua County.

12. *Notropis hypselopterus* (Günther). Over 99 per cent of the 123 sailfin shiners collected were from the headwaters of the Santa Fe where the river has many of the characteristics of a flatwoods stream, including much sandy bottom and a moderate current. Here a collection in September 1955 yielded 65 specimens at a point where the river is almost completely shaded by the hammock type vegetation along the bank. We collected only one specimen below the natural bridge, but in the University of Florida fish collections are several from springs tributary to this part of the river. Collections from July and September contained tuberculate males and gravid females. The single specimen collected in August was a tuberculate male of 39 mm. No sailfin shiners were collected from October through June.

13. *Notropis maculatus* (Hay). I found the red minnow only above the natural bridge and took all the 15 specimens from unvegetated sandy or silty bottomed still water habitats. No one collection contained more than a few individuals; sizes ranged from a minimum of 23 mm in September to a maximum of 45 mm in July, and gravid females were noted in July and in September.

14. *Notropis petersoni* Fowler. The coastal shiner is by far the most widespread cyprinid in the Santa Fe, occurring in all types of habitats above and below the natural bridge. This species was most abundant at Station 7 (28.7 per cent) where it occurred in close association with aquatic vegetation. Observations made with scuba gear indicate that it also occurs commonly in midstream around patches of *Najas, Vallisneria,* and *Chara* as well as over small sandy areas in water up to 20 feet deep. We found this cyprinid frequently in association with *Hybopsis harperi* and the two species are very difficult to distinguish in the field. Tuberculate males and gravid females collected in all months except March, June, and October indicate year-round spawning in the Santa Fe.

15. *Opsopoeodus emiliae* Hay. The pugnose minnow is principally a fish of the still shallows and it occurred both above and below the natural bridge. One collection made in July and two in August from backwaters above the natural bridge contained a total

of 60 specimens ranging from 25 to 41 mm, and all contained gravid females. In the University of Florida fish collections are 4 individuals taken below the natural bridge at Poe Springs.

16. *Erimyzon sucetta* (Lacepede). All but one of the 17 chubsuckers taken, 15 above the natural bridge and 2 below it, were caught at stations having submerged or emergent vegetation. Sizes ranged from a 22 mm individual caught in July to one of 165 mm taken in June.

17. *Minytrema melanops* (Rafinesque). The spotted sucker seems to be more of an open water form than *E. sucetta,* and the Suwannee River drainage is its eastern limit in Florida (Carr and Goin, 1955). We saw 7, 1 in January, 3 in July, and 3 in December, drifting or swimming along the bottom of the river channel at depths up to 15 feet, and collected 8 specimens above the natural bridge and 5 below it. Two taken in Ichetucknee Spring Run during April 1956 were large males (420 and 380 mm) with breeding tubercles on the snout and anal fins. One individual of 33 mm was caught in the river one-half mile north of Louise, Alachua County, in July 1955.

18. *Ictalurus catus* (Linnaeus). Seventeen white catfish were caught on trotlines, 2 below and 15 above the natural bridge; 14 of the latter were taken at Station 4, which furnishes perhaps the best catfish habitat in the Santa Fe. Catfish living in this sink have only to wait for food to be washed downstream to them. Gravid females were collected in June and February. McLane (1955) found young in the St. Johns River during May, June, October, and December which indicates a prolonged breeding season for the species. Our largest catfish from the Santa Fe was 522 mm long and weighed approximately 6 pounds.

19. *Ictalurus natalis* (Lesueur). *I. natalis* was taken principally in the same type of habitat as *I. nebulosus.* However, more yellow cats were caught in small tributary streams (38 per cent) than were bullheads (14 per cent). Our 29 specimens ranged from 16 mm long in September to 156 mm in August.

20. *Ictalurus nebulosus marmoratus* (Lesueur). We found the brown bullhead principally in heavily vegetated areas and around debris. I saw this catfish several times lying under large beds of *Vallisneria* and the masses of debris on the upstream side of tree trunks in the river. The four specimens we caught on trotlines in midstream

over a sand bottom at night show that *I. nebulosus* leaves its concealment to forage after dark.

21. *Ictalurus punctatus* (Rafinesque). Although no channel cat was taken or observed during the present study, Coleman J. Goin informs me that he has caught this species in the Santa Fe River. The University of Florida collections have specimens from Fannin Springs on the Suwannee, but none from the Santa Fe.

22. *Ictalurus* sp. This is an undescribed species to be named elsewhere by Yerger and Relyea. Yerger (personal communication) states that it is more closely related to *Ictalurus catus* than to the flatheads *I. platycephalus* and *I. brunneus*. We caught 27 specimens below the natural bridge ranging in size from 36 mm in December to 155 mm in April. We took none above the natural bridge.

23. *Noturus gyrinus* Mitchill. The tadpole madtom is the most common representative of its family in the Santa Fe, occurring in practically every major habitat above and below the natural bridge. However, it is most plentiful inside large beds of *Najas* along the margins of the river below the natural bridge. We collected gravid females in all months except January, March, May, October, and November and found individuals under 15 mm long in April, June, August, and September. Each of 70 specimens examined was parasitized by Acanthocephala. The largest specimen caught was a heavily parasitized female 79 mm long.

24. *Noturus leptacanthus* (Jordan). The speckled madtom is restricted almost entirely to streams having appreciable currents, some sandy or rocky bottom, and cover in the form of rocks, logs, or other debris. Relatively common in some parts of the Santa Fe, of 132 specimens collected, 75.8 per cent were from the rapids at Stations 2 and 8. Gravid females were found in April, June, July, August, and September. Specimens under 20 mm were collected in August and September; no specimens were taken in March or May. Of 50 fish examined, 32 had Acanthocephala parasites.

25. *Anguilla rostrata* (Lesueur). I caught one specimen of this well known catadromous eel above the natural bridge and 12 below it. The smallest was one 122 mm long taken in December. The digestive tracts showed crayfish remains in all specimens collected.

26. *Strongylura marina* (Walbaum). The needlefish maintains breeding populations both in coastal marine and in the fresh waters

of Florida, and is thus completely euryhaline. It is a surface form usually found where little or no current flows, but in spring runs and in some rivers it feeds actively over bars where currents are sometimes swift. Found only below the natural bridge, needlefish were seen most often swimming at the surface in small schools of up to 8 or 10 individuals. Only 3 specimens were collected. One was taken at dusk in a common sense seine over a bed of *Vallisneria,* and two were taken at night in a 15-foot bag seine close to the springs at Station 6. Sight records indicate the species is more abundant in the Santa Fe during the spring and summer than at other seasons.

27. *Fundulus chrysotus* (Günther). One golden topminnow was collected below the natural bridge and 54 above it. Fish in breeding condition were found in July, August and September.

28. *Fundulus cingulatus* Valenciennes. Four collections, one in June, two in August, and one in September, all from above the natural bridge, contained a total of 35 banded topminnows. These fish were found on the surface in shallow marginal water over a sandy bottom and in close association with emergent vegetation. August and September collections contained adults in breeding condition.

29. *Fundulus notti* (Agassiz). Except for its occurrence in quiet waters of calcareous streams, this species is practically restricted to clear sandhill lakes. Six of the collections above the natural bridge yielded a total of 22 specimens, and two collections below it one specimen each. As elsewhere the starhead topminnow in the Santa Fe is a surface water form. When pursued with nets it sometimes retreats into stands of emergent vegetation, but I have never seen it seek the protection of deep water. The largest and smallest specimens taken were both from July collections, and measured 74 and 16 mm respectively. Gravid females were found June and July.

30. *Fundulus seminolis* Girard. The seminole killifish we found only below the natural bridge, where 188 specimens were collected. Sizes ranged from 18 to 122 mm. The most common habitat of this species in the river was over sandy bottom around patches of vegetation, principally *Vallisneria* and *Najas.* Unlike most other species of *Fundulus,* this killifish was never seen on the surface for any length of time, but usually from near the bottom up to half way to the surface. Again unlike most other fresh water *Fundulus* in Florida,

F. seminolis frequently occurs in loosely organized schools of from 30 to 40 individuals, particularly in the spring and early summer. Gravid females were taken in April only. Ova examined in one female varied from approximately 0.75 to 2.0 mm in diameter. Of 50 specimens examined, 45 were found parasitized by Acanthocephala.

31. *Jordanella floridae* Goode and Bean. The flagfish is most abundant in Florida in roadside ditches and in similar natural situations. I collected a single specimen 22 mm long in June 1955 from shallow water over a sandy bottom below the natural bridge.

32. *Leptolucania ommata* (Jordan). The pygmy killifish inhabits shallow, quiet waters sufficiently vegetated to provide either surface or bottom cover. I took 8 of these fish from the Santa Fe, all from one small flatwoods stream near the headwaters. The fish were near the bank in shallows with *Hydrotrida, Ludwigia,* and *Sphagnum* on the bottom. Three gravid females were found in a July collection and the smallest individual (13 mm) was taken in September.

33. *Lucania goodei* Jordan. The bluefin killifish was by far the most common cyprinidontid encountered, with 560 specimens collected above the natural bridge and 1,343 below it. Although found in every habitat, it occurred most frequently in and around beds of *Najas, Chara,* and *Vallisneria.* These fish, together with *Syngnathus scovelli* and *Noturus gyrinus,* were often found deep in the center of the beds of vegetation. Females with ripe ova were taken in every month and fish under 20 mm in all months except January and May. One specimen collected in April was heavily parasitized by metacercaria of the fluke *Clinostomum marginatum.*

34. *Gambusia affinis holbrooki* Girard. The mosquitofish was one of the more abundant fish in the river with 966 specimens collected above and 400 below the natural bridge. A shallow-water, marginal dweller found generally in association with emergent vegetation and filamentous algae, the species may also be found in small tributary streams, springs, and flood plain ponds where it is often very numerous. One such small pond when poisoned yielded only *G. affinis holbrooki, Elassoma zonatum* and *Heterandria formosa.* Females containing eyed embryos were collected in every month, but a much lower percentage of these ripe females was found from November through February than during the rest of the year. A large disparity

occurs in the sex ratio of this species in the Santa Fe; of 500 individuals examined 78.6 per cent were females.

35. *Heterandria formosa* Agassiz. The least killifish is rather widely distributed in the Santa Fe; 97 specimens were taken below and 177 above the natural bridge. It not only occupies the same type of habitat as *Gambusia affinis holbrooki* but its breeding season is also similar. The largest specimen collected was a female 30 mm long.

36. *Mollienesia latipinna* Lesueur. The sailfin mollie is euryhaline in Florida and has breeding populations in coastal, estuarine, and strictly fresh waters far inland. Maximum populations occur in shallow, marginal situations, especially those with vegetative cover or other type of protection from predation. In the Santa Fe, it is a shallow water, marginal form found almost exclusively in small backwaters with little or no current, some filamentous algae and small amounts of *Lemna* on the surface, and a bottom of sand or rock overlain by silt. We collected 721 specimens below the natural bridge and none above it. Mollies have a prolonged breeding season. Ova were present in February specimens and females containing eyed embryos were found from April through September. No March collections contained *Mollienesia*. A disproportionate sex ratio existed; of 709 specimens examined 72.2 per cent were females. Although these fish were normally found near or at the surface, they invariably retreated toward the bottom when disturbed.

37. *Syngnathus scovelli* (Evermann and Kendall). The gulf pipefish is another of the few completely euryhaline fishes in Florida, maintaining breeding populations in strictly fresh water as well as in the highly saline waters along the coast. In fresh waters it is usually found in the densely vegetated littoral zone of clear streams and rivers. We collected no pipefish above the natural bridge, but took 108 below it in heavy beds of vegetation, principally *Najas*, along the margins of the river and in the spring runs. Gravid females occurred in samples from every month except March, June, October, and December. Males with embryos in the brood pouch were taken from April through September and in January and February. A count of the embryos in the pouches of 19 males gave an average of 12.2 per pouch, which seems abnormally low. McLane (1955) reported an average of 29.5 per pouch in 66 males from the St. Johns River, and 44.7 per pouch in 48 males from Cedar Key, Florida.

S. scovelli probably breeds throughout the year in the Santa Fe River as it does in the St. Johns.

38. *Aphredoderus sayanus* (Gilliams). Pirate perch were well distributed and associated with aquatic vegetation of all types. In October 1956 we collected 53 specimens with poison over a clean sand bottom at Station 8; the fish were in a hole approximately 35 feet deep and relatively free of current. During some seven hours of underwater observations at all seasons in this hole with scuba gear no *Aphredoderus* were seen; possibly they were hidden in small concavities and crevices along the sheer rock walls of the hole. Very few pirate perch were collected with seines anywhere, but poisoning the same areas with rotenone often produced large numbers. These fish, together with *Noturus gyrinus, Noturus leptacanthus,* and the gars, were the last species the poison affected. Females with ripe eggs were found in February, April, and December. The length-frequency data in Table 2 indicate a late winter breeding season. Over 95 per cent of the fish examined were heavily parasitized by *Acanthocephala;* 14 specimens also had small leeches attached to the membranes of the caudal and dorsal fins.

39. *Centrarchus macropterus* (Lacepede). I collected one flier 64 mm in length in September 1956, from the Santa Fe north of Louise, Alachua County. The river at this point resembles a small flatwoods stream with a sand bottom and moderate current. Another Santa Fe specimen in the University of Florida collections was taken approximately 2 miles upstream from Louise.

40. *Chaenobryttus gulosus* (Cuvier). The warmouth was most abundant above the natural bridge where 50 of the 56 specimens were collected, ranging in length from 16 mm to 140 mm, both taken in August. The habitat preference of *Chaenobryttus* is markedly restricted in the Santa Fe; 92.3 per cent of the specimens were taken from heavily vegetated still waters over either a mud or silt bottom. One collection containing 20 specimens was taken from a small flood plain pond 4 by 5 yards in extent and 2 feet deep next to the river at Worthington Springs, Union County. This pond was completely devoid of vegetation, and had a mud bottom. Judging from the surrounding terrain it is flooded periodically, which might account for the presence of warmouth.

41. *Elassoma evergladei* Jordan. In the University of Florida collections are seven specimens of the Everglades pygmy sunfish

TABLE 2. LENGTH-FREQUENCY DISTRIBUTION OF 272 *Aphredoderus sayanus* FROM THE SANTA FE RIVER

Size Groups (in mm)	Jan	Feb	April	May	June	July	Aug	Sep	Oct	Nov	Dec
11-15			2								
16-20			1								
21-25			1								
26-30			1		1	2	1				
31-35					2	2	3		1		
36-40		1		1		8	1	12	4		1
41-45		3	1	2		2	2	15	4	2	4
46-50		4		1			1	22	15		10
51-55	2	1		1		1	1	15	12	7	15
56-60						2		9	5	8	11
61-65	3					1		4	5		5
66-70	2					1		5	6	2	6
71-75								1	1		4
76-80											2
81-85											
96-90							1				
Totals	7	9	6	5	3	19	10	83	53	19	58

taken in Hatchet Creek, 10 miles north of Gainesville and 9 miles west of Waldo, and one taken in the Santa Fe 7 miles northwest of Waldo by Carter R. Gilbert in November 1961. I did not find the species during my study.

42. *Elassoma okefenokee* Bohlke. Bohlke (1956) states this species lives under overhanging plants in slow-moving, acid streams, in essentially the same habitat as *Leptolucania ommata.* Of 66 fish collected, 32 were from heavily vegetated areas in slow-moving tributary streams and 33 were collected at Station 3. Only one specimen was taken below the natural bridge. The Okefenokee pygmy sunfish was collected only in March, July, September, and November. The smallest fish (10 mm) was taken in September, the largest (24 mm) in November. Gravid females were found in July.

43. *Elassoma zonatum* Jordan. Most of the banded pygmy sunfish (77.8 per cent) were collected from heavily vegetated areas below the natural bridge. These fish were usually found in beds of *Vallisneria, Najas,* and *Chara,* occasionally in patches of *Ludwigia.* The specimens ranged in length from 29 mm in November to 15 mm in July. Females with fully developed ova were taken in February and April. Of the 45 fish collected, 25 had approximately 20 Acanthocephala in the coelomic cavity per fish.

44. *Enneacanthus gloriosus* (Holbrook). All the 172 specimens collected were from above the natural bridge. The smallest individual was 14 mm long, taken in July, and the largest 51 mm, was caught in September. We collected 57 specimens in a vegetation-free flood plain pond with mud bottom near Worthington Springs. Gravid females were found in August and September.

45. *Enneacanthus obesus* (Girard). The University of Florida collections have one specimen of the banded sunfish Carter R. Gilbert collected in Hatchet Creek 10 miles north of Gainesville and 9 miles west of Waldo in April 1961. I did not find the species during my study.

46. *Lepomis auritus* (Linnaeus). The redbreast is by far the commonest centrarchid in the Santa Fe. Although we found it in all types of habitats, it was most abundant in sand bottom creeks (41.5 per cent) and in heavily vegetated sloughs (37.4 per cent). The young preferred shallow vegetated zones in still water but were also found in heavily vegetated tributary streams. Gravid females

were collected in April, June, and July. From June through January we took 59 specimens under 20 mm, 51 of them in June, July, and August. Redbreasts were seen guarding redds in April. Though this fish has a prolonged spawning season in the Santa Fe, a pronounced breeding peak occurs in late spring and early summer.

47. *Lepomis macrochirus purpurescens* Cope. The young and adult bluegills show decided differences in habitat preference in the Santa Fe. Young specimens under 50 mm were taken principally in heavily vegetated still waters. Large individuals were collected and observed in more open waters. Seven adult bluegills were taken at Station 8 in July, and one collection in August made by dynamiting under a large fallen tree yielded 10 adult specimens. The presence of fish under 20 mm in collections from July and November indicates a prolonged breeding season. The largest specimen was taken in July and measured 163 mm.

48. *Lepomis marginatus* (Holbrook). Carter R. Gilbert collected 24 dollar sunfish in the Santa Fe 7 miles northwest of Waldo and 2 in Hatchet Creek 9 miles west of Waldo in November 1961. I did not take the species during my study.

49. *Lepomis microlophus* (Günther). The redear sunfish is primarily a fish of the open waters of larger rivers, springs and lakes. The 244 specimens collected, 211 from above and 33 from below the natural bridge, ranged in size from 16 mm in June, July and November to 220 mm in December. The relative numbers of fish caught above and below the natural bridge may be misleading because 163 were taken in five unusually large collections at Station 3. Underwater observations below the natural bridge showed redear sunfish much more plentiful than the 33 fish collected there would indicate. Adult redears are by far the most common sunfish in the deeper, unvegetated areas at midstream, so numerous in fact that it was impossible to keep exact records of them while swimming downstream on prolonged observations. Short samplings made by swimming across the river and back gave some definite figures on redear abundance; in each of three such short trips at Station 7 in July, November, and April, we counted no less than two and as many as seven large redear sunfish near the middle of the river. These large fish are difficult to collect. When we tried to spear some with an underwater gun, they proved so wary of the diver that we took only one specimen in this manner. Young redears were found most frequently in

vegetated shallow waters and were relatively easy to collect with a seine.

McLane (1955) reports the peak spawning season for the St. Johns is in June and July. The 16 mm specimens in our collections from June, July, and November suggest some spawning probably occurs earlier and later in the Santa Fe.

50. *Lepomis punctatus punctatus* (Valenciennes). This was the only member of its genus collected in greater numbers below (233) than above (123) the natural bridge. We found the spotted sunfish in all types of habitats in the Santa Fe, but it was most abundant in some of the deep holes below the natural bridge, where 42 per cent of the specimens were collected. Fishing with a hook and line with bread for bait at Blue Springs, Gilchrist County, in January 1956, I caught both bluegills and spotted sunfish on the sandy bottom of the boil area, but when I threw my hook over the edge of the rock crevice from which the spring issues, I caught only spotted sunfish. The spotted sunfish was also common in and around dense beds of aquatic vegetation at Stations 3 and 4 (41.4 per cent). No large numbers of small *L. punctatus* were ever taken in a single collection, as often happened with other sunfish. Carr (1947) found that small spotted sunfish tend to disperse soon after leaving the redd. Females with ripe ova were collected in February and from April through September. Caldwell *et al.* (1957) report that this species breeds throughout the year in Silver Springs, Marion County, Florida. Specimens under 20 mm in length were collected in June, August, and September, the smallest (14 mm) in August. The largest specimen was one measuring 232 mm taken in June.

51. *Micropterus notius* Bailey and Hubbs. The Suwannee bass, a relict form in northern Florida, is the most generalized species in the genus *Micropterus* (Bailey and Hubbs, 1949). Known only from swift-flowing rivers in Florida, it is represented by relatively few specimens in collections. During this study we collected 223 specimens and observed several hundred others during diving operations.

Although we took *M. notius* and *M. salmoides floridanus* regularly in the same seine hauls, the two species occurred most frequently in distinctly different habitats. Underwater observations and our catches in the Santa Fe showed *M. notius* to be essentially a fish of rapid waters and *M. salmoides floridanus* one of quieter reaches. In rapids we caught 21 per cent of the total number of *M. notius* and only 1.2 per cent of *M. salmoides floridanus*. Above the natural

TABLE 3. LENGTH-FREQUENCY DISTRIBUTION OF 223 *Micropterus notius* FROM THE SANTA FE RIVER

Size Groups (in mm)	Jan	Feb	Mar	April	June	July	Aug	Sep	Oct	Nov	Dec
10-19				4							
20-29					8	5	1				
30-39				1	10	17	6	4			
40-49					2	14	7	8	1	2	
50-59						4	2	5	15	10	14
60-69	1		2			3	1	2	4	5	8
70-79	1	2		2				2	1	2	4
80-89	1							2	1		
90-99	2	1		2							
100-109	2									1	
110-119	1										1
120-129				1				1	2		
130-139	1						1	2			
140-149									2		2
150-159						1			1		
160-169							1		1		
170-179					1						
180-189											
190-199											
200-209	1										
210-219		3		1	2						
220-229					2				1		
230-239								1			1
Totals	10	6	2	11	25	44	19	27	29	20	30

bridge where rapids are not a dominant feature, only 58 *M. notius* were present in catches that produced 334 *M. salmoides floridanus*. Below the natural bridge where rapids and swift channels occur frequently, the ratio was 164 *notius* to 107 *salmoides*. The length-frequency data in Table 3 strongly indicate a spring spawning season. In April 1956 one individual was observed guarding a redd constructed on a clear sand bottom in approximately 2 feet of water. The redd itself was indistinguishable from those constructed by *M. salmoides floridanus*.

52. *Micropterus salmoides floridanus* (Lesueur). This bass and *M. notius* are the most common large predatory fish in the Santa Fe. Adult largemouth bass occur in every major habitat but are most abundant where submerged trees and other debris provide cover. Bass were found in every series of observations we made, at all depths and in currents of every magnitude in the river. Small individuals were most often collected and observed in sand bottom shallows and in sparse patches of *Ludwigia, Vallisneria, Najas,* and *Chara*. Specimens under 25 mm were taken from April through August and one gravid female 208 mm long, was collected in April. Bass were observed guarding redds in April and June at Station 1 and immediately upstream from Station 2. Carr (1942) describes the construction of redds for this species. The ones observed in this study were on a clear sand bottom free of vegetation in 2 to 3 feet of water.

53. *Pomoxis nigromaculatus* (Lesueur). Black crappie are not common in the Santa Fe. Six specimens taken above the natural bridge were the only ones seen.

54. *Etheostoma edwini* (Hubbs and Cannon). This darter, as its describers (1935) note, frequents swift, clear, vegetated streams. Of the 54 brown darters we collected, 42 per cent were from rapids. We took 68.5 per cent of the total below the natural bridge, where the most suitable habitat exists. As females with ripe ova were taken in January, February, April, June, July, September, and December, these fish evidently breed throughout the year in the Santa Fe.

55. *Etheostoma fusiforme barratti* (Holbrook). The 38 swamp darters we collected, 29 above and 9 below the natural bridge, ranged in size from 48 mm in July to 26 mm in August. No collections con-

taining this species were made in January, May, or October. Adults with breeding tubercles and ripe gonads were collected in February and March. Of the 38 fish examined 9 contained Acanthocephala in the coelomic cavity.

56. *Percina nigrofasciata* (Agassiz). Although we collected 82 blackbanded darters above and 9 below the natural bridge, the relative numbers are not at all indicative of the species actual abundance, as its major habitat below the natural bridge precludes successful collecting. Principally bottom dwellers, these fish may be seen plentifully in the current of the main river bed resting on the bottom behind rocks and pieces of debris. We counted approximately 50 individuals while swimming once across the river and back at Station 6 in July. Every longer sampling showed these darters plentiful in their favored habitat. Above the natural bridge we found the species principally in the shallow rapids at Station 2 (26.4 per cent) and on the sand bottom in the main current at Station 1 (33.0 per cent). The smallest specimen (24 mm) was collected in April and the largest (73 mm) in September. Adults in breeding condition were found in February and April and from July through October. No collections made in January, March, May, November, or December contained *Percina*.

57. *Eucinostomus* sp. David K. Caldwell and I saw several mojarras in April and May at Station 6. As our attempts to collect these fish were unsuccessful, no positive identification could be made. McLane (1955), Carr and Goin (1955), and Herald and Strickland (1949) list *Eucinostomus argenteus* Baird and Girard as occurring in Florida fresh water rivers, and most probably the fish we saw were of this species.

58. *Mugil cephalus* Linnaeus. Although the striped mullet is principally a fish of marine lagoons, estuaries, and other coastal shallows, it frequently invades fresh waters. Many mullet were observed below the natural bridge in all months except September, October, and November; no mullet were taken or seen above it. These marine invaders may be present throughout the year, but they do not become plentiful until early winter. They were common in the river from February through August. Local fisherman catch large numbers on hook and line using small wads of *Spirogyra* or earthworms for bait. No small specimens were taken or seen during this study, and the adults collected showed little gonadal development.

59. *Labidesthes sicculus vanhyningi* Bean and Reid. The brook silversides is distinctly a surface form, and often occurs in small schools. We found it very abundant above the natural bridge at Stations 1 and 3 (76.9 per cent of the fish collected) and less so in the small tributary streams (7.9 per cent of the total). It was not very common below the natural bridge, but could be found there in springs and a few other places where the current was weak. Over 95 per cent of the specimens were collected from areas of very slowly flowing or still water. The species has an extended breeding season in the Santa Fe. Females with ripe gonads were taken from February through April and from June through September; no specimens were collected in May. The smallest specimen collected was one of 12 mm in June 1956. No other individuals under 20 mm were collected.

60. *Trinectes maculatus* (Bloch and Schneider). We collected 143 hogchokers on clean sandy bottom below the natural bridge and found none above it. Our fish ranged in length from 22 mm in May to 65 mm in July. We collected specimens under 25 mm in April, May, July, and November. We noted no gonadal development in any of our specimens, and it is improbable that this fish spawns in the Santa Fe. Mansueti and Pauly (1956) give 111 mm standard length as the minimum size of sexually mature individuals in the Patuxent River, Maryland.

DISCUSSION

The fish fauna of the Santa Fe is a diversified one characterized by a large number of species of wide ecological differences. However, the bulk of this fauna is made up of relatively few species well adapted to the principal types of habitat available in the river, reflecting the fact that a few habitats are quite extensive while many others are restricted in extent.

Several marine species occur in the Santa Fe, where two of them maintain breeding populations. In view of the extremely low salinities (10 parts per million maximum) and the distance from the Gulf of Mexico (approximately 70 miles), this marine invasion of euryhaline fish is remarkable.

The natural bridge is a more effective barrier to upstream migration than to downstream. Many fish, fry, and eggs may be carried under it by the current, but any upstream migration through the underground channel must be active, not passive.

General Fish Fauna

The fish fauna of the Santa Fe may be divided into three major groups on the basis of distribution above and below the natural bridge.

The first and largest of these three groups is the one including those fishes that occur both above and below the natural bridge. The species in this group may be further subdivided into those that are principally stream forms, those that are found most often in still water, and those that can adapt to either situation. Generally the stream forms are found wherever the current is a significant feature. Those that occur most often in streams are *Lepisosteus osseus, Minytrema melanops, Noturus leptacanthus, Lepomis auritus, Lepomis punctatus punctatus, Micropterus notius, Etheostoma edwini,* and *Percina nigrofasciata.*

Notropis hypselopterus, Leptolucania ommata, Elassoma okefenokee, Elassoma zonatum and *Enneacanthus gloriosus* are also principally stream forms, but they are found most often in small streams where the current is not so evident.

The still-water forms found both above and below the natural bridge are *Lepisosteus platyrhincus, Amia calva, Opsopoeodus emiliae, Erimyzon sucetta, Fundulus chrysotus, Fundulus notti, Chaenobryttus gulosus, Etheostoma fusiforme barratti,* and *Labidesthes sicculus vanhyningi.*

Those fishes found commonly in both lakes and streams are *Notemigonus crysoleucas, Notropis petersoni, Ictalurus catus, Ictalurus nebulosus, Noturus gyrinus, Lucania goodei, Gambusia affinis holbrooki, Heterandria formosa, Aphredoderus sayanus, Lepomis macrochirus purpurescens,* and *Micropterus salmoides floridanus.* One catadromous species, *Anguilla rostrata,* occurs both above and below the natural bridge, and is the only euryhaline form found above it.

The second major group of fishes includes the species found only above the natural bridge. These fishes, all either lake or small stream forms, are *Esox americanus, Esox niger, Notropis chalybeus, Notropis maculatus, Fundulus cingulatus, Centrarchus macropterus,* and *Pomoxis nigromaculatus.* All these species occur very infrequently even in suitable habitat above the natural bridge, and probably they also occur infrequently below it. However, during the period covered by the study, the water level of the river was very low and suitable habitat for these fishes was almost non-existent. One other species recorded from above the natural bridge, *Umbra*

pygmaea, is known in Florida only from a few localities and is probably very rare in the Santa Fe drainage.

The last group includes the fishes found only below the natural bridge. These can be subdivided into the primary freshwater forms *Hybopsis harperi, Ictalurus* sp., *Fundulus seminolis,* and *Jordanella floridae;* and the euryhaline *Strongylura marina, Mollienesia latipinna, Syngnathus scovelli, Mugil cephalus,* and *Trinectes maculatus.*

Hybopsis harperi, one of the few vertebrates known from the subterranean waters of Florida, also occurs in surface waters with considerable subterranean drainage, which is the general situation below but not above the natural bridge. *Ictalurus* sp. is known in Florida to inhabit deep, rocky holes in swift, clear water, a habitat found in the Santa Fe only below the natural bridge. Possibly the natural bridge acts as a barrier to the upstream migration of *Fundulus seminolis,* which is not known from subterranean waters. Only one specimen of *Jordanella* was taken during the entire study; probably this species, usually found in roadside ditches, strayed accidentally into the Santa Fe.

Of the euryhaline species, *Alosa alabamae,* the only anadromous species found in the river, was seen only in October. Although at times relatively abundant, this fish probably does not play a significant role in the overall ecology of the Santa Fe. The sturgeon and the mojarra are probably only accidental and sporadic visitors. *Trinectes maculatus* also is probably only a visitor; it was found only below the natural bridge where it was rather abundant, but no large or very small specimens were encountered. Present knowledge indicates the sea as the species' place of reproduction as well as the habitation of most of the population. Though *Mugil cephalus* forms a very conspicuous part of the Santa Fe fish fauna, as no evidence of breeding can be found and the species apparently leaves the river during the fall months, this mullet must also be called a euryhaline visitor.

Strongylura marina was found moderately plentiful, but no evidence was obtained to indicate that it maintains a breeding population in the river. As this species spawns in the St. Johns River system and maintains heavy populations in some of the larger lakes in that drainage (McLane, 1955) possibly the needlefish may spawn in the Santa Fe.

Mollienesia latipinna and *Syngnathus scovelli* were abundant below the natural bridge. That both species maintain breeding populations in the river is proved by the presence in the collections of

adults in breeding condition and of fry. No term is currently available to distinguish fishes that maintain breeding populations in both fresh and marine waters from other euryhaline types. For such species the writer proposes the term "dihaline".

Of the 60 species found in the Santa Fe, 43 species were taken above and 42 species below the natural bridge. This practically even distribution in species numbers suggests that approximately the same number of ecological niches for fishes occur in each end of the river.

Above the natural bridge 18 species made up approximately 90 per cent of the population as shown by numbers collected and per cent of total catch (Table 4). Below the natural bridge 13 species contributed over 90 per cent of the individuals collected (Table 5). Four of the species concerned, *Micropterus notius; Lepomis m. purpurescens, Lepomis microlophus* and *Percina nigrofasciata,* were actually more abundant than the percentages indicate. Repeated direct observations confirmed that the catches did not reflect their abundance accurately.

The difference between the upper and lower portions of the river apparently is not in the number of different habitats available, but in the relative extent of these habitats. Thus it is concluded that, although both segments of the Santa Fe are about evenly endowed with types of habitats, more of the habitats above the natural bridge are more extensive than those below it, where a few principal habitats are very extended and the remainder quite restricted.

Derivation of the Ichthyofauna

The ichthyofauna of the Santa Fe may be divided into the following groups according to their area of derivation as based on known ranges given chiefly by Briggs (1958), and Carr and Goin (1955).

1. A northern element composed of fishes widespread to the northward and reaching their southern limit in Florida. These species are:

Lepisosteus osseus
Amia calva
Umbra pygmaea
Esox americanus
Esox niger
Notemigonus crysoleucas
Notropis chalybeus
Opsopoeodus emiliae
Erimyzon sucetta
Minytrema melanops
Ictalurus catus
Ictalurus natalis

Ictalurus nebulosus marmoratus
Ictalurus punctatus
Noturus gyrinus
Gambusia affinis holbrooki
Aphredoderus sayanus
Centrarchus macropterus
Chaenobryttus gulosus
Elassoma zonatum
Enneacanthus gloriosus
Enneacanthus obesus
Lepomis auritus
Pomoxis nigromaculatus
Etheostoma fusiforme barratti

2. A southeastern element composed of fishes widespread in the southeastern U.S. These are:

Lepisosteus platyrhincus
Notropis hypselopterus
Notropis maculatus
Notropis petersoni
Noturus leptacanthus
Fundulus chrysotus
Fundulus cingulatus
Fundulus notti
Heterandria formosa
Elassoma evergladei
Elassoma okefenokee
Lepomis macrochirus purpurescens
Lepomis marginatus
Lepomis microlophus
Lepomis punctatus punctatus
Etheostoma edwini
Percina nigrofasciata
Labidesthes sicculus vanhyningi

3. A typically Floridian element subdivided further into the following three groups:

a. Fishes typically Floridian but not exclusively so.

Hybopsis harperi
Ictalurus sp.
Jordanella floridae

b. Species endemic to Florida.

Fundulus seminolis
Leptolucania ommata
Lucania goodei
Micropterus salmoides floridanus

c. Species nearly endemic to the Santa Fe Drainage.

Micropterus notius

4. An element derived from marine waters.

Acipenser oxyrhynchus desotoi
Alosa alabamae
Anguilla rostrata
Strongylura marina
Mollienesia latipinna
Syngnathus scovelli
Mugil cephalus
Trinectes maculatus

It is interesting to note that of the dominant species in the Santa Fe, 9 are from the southeastern fauna, 7 from the northern, 4 from the typically Floridian and 1 from marine waters.

The following species that were not collected during the present study might be expected to occur in the Santa Fe on the basis of their known ranges:

Dorosoma cepedianum
Dorosoma petenense
Notropis cummingsae
Notropis leesdi
Notropis texanus
Notropis welaka
Acantharchus pomotis

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TABLE 4. DISTRIBUTION OF MONTHLY CATCHES ABOVE THE NATURAL BRIDGE*

Number of Collections	Jan 2	Feb 4	Mar 1	April 4	June 5	July 8	Aug 5	Sep 9	Oct 2	Nov 2	Dec 3	Total Number Specimens	Per Cent Total Catch
Gambusia affinis holbrooki	—	12	15	69	81	219	314	211	—	43	2	966	17.0
Lepomis auritus	2	29	18	82	149	134	188	271	—	55	4	932	16.4
Labidesthes sicculus vanhyningi	2	64	—	58	31	59	192	113	—	63	56	638	11.2
Lucania goodei	—	2	98	48	96	73	77	123	—	42	1	560	9.9
Notemigonus crysoleucas	—	2	—	4	276	38	61	17	—	18	9	425	7.5
Micropterus salmoides floridanus	1	2	2	75	113	63	39	30	—	2	6	333	5.9
Lepomis microlophus	3	—	9	12	100	1	6	35	—	26	19	211	3.7
Heterandria formosa	1	—	—	4	12	15	114	31	—	—	—	177	3.1
Enneacanthus gloriosus	—	1	—	—	—	93	2	74	—	2	—	172	3.0
Notropis petersoni	1	16	—	28	—	59	—	65	—	1	2	172	3.0
Lepomis macrochirus purpurescens	2	1	—	5	—	11	7	29	—	62	20	137	2.4
Lepomis punctatus punctatus	1	1	12	5	14	11	2	65	—	5	7	123	2.2

* Species are arranged by relative abundance in collections.

TABLE 4—*Continued*

Number of Collections	Jan 2	Feb 4	Mar 1	April 4	June 5	July 8	Aug 5	Sep 9	Oct 2	Nov 2	Dec 3	Total Number Specimens	Per Cent Total Catch
Notropis hypselopterus	—	—	—	—	—	15	—	107	—	—	—	122	2.2
Percina nigrofasciata	—	1	—	27	6	9	7	32	—	—	—	82	1.4
Noturus leptacanthus	—	1	—	41	2	6	3	13	—	—	6	72	1.3
Elassoma okefenokee	—	—	1	—	—	23	—	9	—	32	—	65	1.1
Opsopoeodus emiliae	—	—	—	—	—	12	48	—	—	—	—	60	1.1
Micropterus notius	—	7	2	4	21	9	10	5	—	—	—	58	1.0
Fundulus chrysotus	—	—	—	1	—	4	6	43	—	—	—	54	1.0
Chaenobryttus gulosus	2	2	—	3	—	2	3	31	—	5	2	50	.9
Noturus gyrinus	—	4	—	2	—	—	8	28	—	1	1	44	.6
Fundulus cingulatus	—	—	—	—	1	—	3	31	—	—	—	35	.6
Aphredoderus sayanus	—	8	—	1	3	7	5	4	—	1	1	30	.5
Notropis chalybeus	—	—	—	—	2	7	—	—	—	21	—	30	.5
Etheostoma fusiforme barratti	—	3	5	—	1	5	8	5	—	2	—	29	.5
Fundulus notti	—	—	—	—	2	8	—	—	—	12	—	22	.4
Etheostoma edwini	—	1	—	2	4	—	—	2	—	2	6	17	.3
Ictalurus catus	—	5	—	—	1	—	—	—	—	4	5	15	.3

TABLE 4—*Continued*

Number of Collections	Jan 2	Feb 4	Mar 1	April 4	June 5	July 8	Aug 5	Sep 9	Oct 2	Nov 2	Dec 3	Total Number Specimens	Per Cent Total Catch
Notropis maculatus	—	1	—	—	—	4	1	6	—	3	—	15	.3
Erimyzon sucetta	—	—	—	—	—	2	—	8	—	2	1	13	.3
Ictalurus natalis	—	—	—	—	—	—	1	11	—	—	—	12	.2
Elassoma zonatum	—	—	—	—	—	—	—	9	—	—	—	9	.2
Ictalurus nebulosus marmoratus	—	—	—	—	1	—	3	4	—	—	—	8	.1
Leptolucania ommata	—	—	—	—	—	4	—	3	—	1	—	8	.1
Minytrema melanops	—	1	—	2	4	1	—	—	—	—	—	8	.1
Pomoxis nigromaculatus	1	—	—	—	1	—	—	1	—	2	1	6	.1
Lepisosteus osseus	—	—	—	—	—	1	—	1	1	—	—	3	—
Amia calva	1	—	—	—	—	—	—	—	1	—	—	2	—
Esox americanus	—	—	—	—	—	1	—	1	—	—	—	2	—
Lepisosteus platyrhincus	—	—	—	—	—	—	—	2	—	—	—	2	—
Anguilla rostrata	—	—	—	—	—	—	—	—	—	—	1	1	—
Centrarchus macropterus	—	—	—	—	—	—	—	1	—	—	—	1	—
Total specimens	17	164	162	474	921	896	1108	1421	2	407	150	5722	

TABLE 5. DISTRIBUTION OF MONTHLY CATCHES BELOW THE NATURAL BRIDGE*

Number of Collections	Jan 4	Feb 4	Mar 1	April 4	May 1	June 4	July 12	Aug 4	Sep 3	Oct 3	Nov 3	Dec 3	Total Number Speci-mens	Per Cent Total Catch
Lucania goodei	22	87	—	102	4	36	316	126	137	25	120	368	1343	20.7
Hybopsis harperi	92	52	—	—	13	18	367	106	102	—	146	186	1082	16.7
Mollienesia latipinna	8	35	—	153	42	15	117	10	24	—	85	232	721	11.1
Notropis petersoni	12	24	—	204	—	—	21	19	144	35	61	23	543	8.4
Noturus gyrinus	9	6	—	7	2	10	25	25	94	10	132	82	402	6.2
Gambusia affinis holbrooki	13	26	—	39	2	40	103	43	29	2	49	54	400	6.2
Aphredoderus sayanus	7	1	—	5	—	—	12	4	77	53	25	58	242	3.7
Lepomis punctatus punctatus	11	5	—	12	2	8	20	33	33	23	65	21	233	3.4
Lepomis auritus	23	7	—	3	3	15	45	11	12	32	31	9	191	2.9
Fundulus seminolis	6	3	—	49	—	—	57	8	15	2	40	8	188	2.9
Syngnathus scovelli	9	3	—	5	16	1	53	39	18	9	23	4	180	2.8
Micropterus notius	10	3	—	4	—	3	34	9	17	36	18	30	164	2.5
Trinectes maculatus	—	—	—	5	43	—	55	6	—	3	31	—	143	2.2
Micropterus salmoides floridanus	4	1	—	12	3	—	53	6	18	5	21	2	125	1.9

*Species arranged by relative abundance in collections.

TABLE 5—*Continued*

Number of Collections	Jan 4	Feb 4	Mar 1	April 4	May 1	June 4	July 12	Aug 4	Sep 3	Oct 3	Nov 3	Dec 3	Total Number Specimens	Per Cent Total Catch
Labidesthes sicculus vanhyningi	1	—	19	—	—	—	61	1	9	3	8	—	102	1.6
Heterandria formosa	1	3	—	23	1	21	11	3	2	—	8	24	97	1.5
Noturus leptacanthus	2	—	—	—	—	—	2	11	4	14	18	9	60	.9
Etheostoma edwini	5	—	—	—	1	1	6	1	2	7	14	—	37	.6
Elassoma zonatum	—	10	—	4	—	1	9	—	—	—	9	3	36	.6
Lepomis macrochirus purpurescens	3	2	—	—	—	3	12	10	—	3	2	1	36	.6
Lepomis microlophus	—	3	—	7	—	—	8	—	2	3	4	6	33	.5
Ictalurus sp.	2	—	—	—	—	—	—	3	5	1	—	16	27	.4
Ictalurus nebulosus marmoratus	—	—	—	—	—	—	5	3	2	2	1	7	20	.3
Ictalurus natalis	—	—	—	—	—	2	2	1	11	—	—	1	17	.2
Anguilla rostrata	—	1	—	1	2	—	3	—	—	1	1	3	12	.2
Etheostoma fusiforme barratti	—	—	—	4	—	—	2	—	—	—	1	2	9	.1
Notemigonus crysoleucas	—	—	—	—	—	—	9	—	—	—	—	—	9	.1

TABLE 5—*Continued*

Number of Collections	Jan. 4	Feb 4	Mar 1	April 4	May 1	June 4	July 12	Aug 4	Sep 3	Oct 3	Nov 3	Dec 3	Total Number Speci-mens	Per Cent Total Catch
Percina nigrofasciata	—	—	—	1	—	—	—	1	1	6	—	—	9	.1
Alosa alabamae	—	—	—	—	—	—	—	—	—	6	—	—	6	.1
Chaenobryttus gulosus	—	5	—	—	—	—	—	1	—	—	—	—	6	.1
Minytrema melanops	—	—	—	2	—	—	—	—	—	1	1	1	5	.1
Strongylura marina	—	—	—	3	—	—	—	—	—	—	—	—	3	—
Erimyzon sucettta	—	—	—	—	—	—	—	—	—	—	1	1	2	—
Fundulus notti	—	—	—	—	—	—	2	—	—	—	—	—	2	—
Ictalurus catus	—	—	—	—	—	—	—	—	—	—	2	—	2	—
Mugil cephalus	—	1	—	—	1	—	—	—	—	—	—	—	2	—
Elassoma okefenokee	—	—	—	—	—	—	—	—	1	—	—	—	1	—
Fundulus chrysotus	—	—	—	—	—	—	1	—	—	—	—	—	1	—
Jordanella floridae	—	—	—	—	—	1	—	—	—	—	—	—	1	—
Lepisosteus osseus	—	—	—	—	—	—	1	—	—	—	—	—	1	—
Notropis hypselopterus	—	—	—	—	—	—	—	1	—	—	—	—	1	—
Total specimens	240	278	19	645	135	175	1412	481	759	282	917	1151	6494	

TABLE 6. DISTRIBUTION OF FISHES BY STATIONS SHOWING TOTALS COLLECTED AND PERCENTAGES TAKEN AT EACH STATION ABOVE AND BELOW THE NATURAL BRIDGE

		Above Natural Bridge						Below Natural Bridge				
Species	Total No.	Sta 2	Sta 3	Sta 1	Sta 4	Other[1]	Percentage Above	Sta 8	Sta 6	Sta 5	Sta 7	Other[2]	Percentage Below
Alosa alabamae	6	—	—	—	—	—	0	100.0	—	—	—	—	100.0
Amia calva	2	—	—	—	50.0	50.0	100.0	—	—	—	—	—	0
Anguilla rostrata	13	—	—	—	7.7	—	7.7	38.5	30.8	—	23.0	—	92.3
Aphredoderus sayanus	272	.3	3.7	3.7	—	2.6	11.0	2.2	38.0	1.4	40.4	7.1	89.0
Centrarchus macropterus	1	—	—	—	—	100.0	100.0	—	—	—	—	—	0
Chaenobryttus gulosus	56	—	28.7	7.1	—	53.5	89.3	—	10.7	—	—	—	10.7
Elassoma okefenokee	66	—	50.0	—	—	48.5	98.5	—	—	—	—	1.5	1.5
Elassoma zonatum	45	—	2.2	—	—	17.8	20.0	2.2	66.7	—	—	11.1	80.0
Enneacanthus gloriosus	172	—	11.6	.58	—	98.3	100.0	—	—	—	—	—	0
Erimyzon sucetta	15	—	5.9	—	—	82.3	88.2	—	5.9	—	—	5.9	11.8
Esox americanus	2	—	—	—	—	100.0	100.0	—	—	—	—	—	0
Esox niger	1	—	—	100.0	—	—	100.0	—	—	—	—	—	0
Etheostoma fusiforme barratti	38	—	34.2	28.9	—	13.2	76.3	—	18.4	5.3	—	—	23.7
Etheostoma edwini	54	29.6	—	—	—	—	31.5	13.0	13.0	—	22.2	20.3	68.5
Fundulus chrysotus	55	—	5.5	5.5	—	87.2	97.2	—	1.8	—	—	—	1.8
Fundulus cingulatus	35	—	2.9	5.7	—	91.4	100.0	—	—	—	—	—	0
Fundulus notti	24	—	—	8.3	—	83.3	91.6	—	4.2	—	—	4.2	8.4
Fundulus seminolis	188	—	—	—	—	—	0	4.2	70.7	—	9.0	16.0	100.0
Gambusia affinis holbrooki	1366	.08	13.0	17.8	—	38.7	69.5	.3	22.4	1.5	—	6.3	30.5

[1] Tributary streams and flood plain ponds.

[2] Springs, spring runs, and river sites other than the stations.

TABLE 6—*Continued*

Species	Total No.	Above Natural Bridge						Below Natural Bridge					
		Sta 2	Sta 3	Sta 1	Sta 4	Other[1]	Percentage Above	Sta 8	Sta 6	Sta 5	Sta 7	Other[2]	Percentage Below
Heterandria formosa	274	.4	7.3	7.7	—	49.6	64.6	—	25.5	6.6	—	2.9	35.4
Hybopsis harperi	1082	—	—	—	—	—	0	7.6	39.6	.2	22.8	29.8	100.0
Ictalurus catus	17	5.9	—	—	82.3	—	88.2	—	—	—	5.9	5.9	11.8
Ictalurus natalis	29	—	—	3.4	—	37.9	41.4	—	51.7	—	—	6.9	58.6
Ictalurus nebulosus marmoratus	28	—	3.6	10.7	—	14.3	29.0	—	35.7	3.6	32.1	—	71.0
Ictalurus sp.	27	—	—	—	—	—	0	—	3.7	—	88.9	7.4	100.0
Jordanella floridae	1	—	—	—	—	—	0	—	—	—	—	100.0	100.0
Labidesthes sicculus vanhyningi	740	4.0	44.0	30.9	—	7.2	86.1	.5	10.5	1.9	—	1.0	13.9
Lepisosteus osseus	4	—	25.0	—	—	50.0	75.0	—	25.0	—	—	—	25.0
Lepisosteus platyrhincus	2	—	—	—	—	100.0	100.0	—	—	—	—	—	0
Lepomis auritus	1123	.8	31.2	37.8	—	13.3	83.0	1.7	6.2	3.7	3.6	1.9	17.0
Lepomis macrochirus purpurescens	173	—	67.6	5.1	—	6.4	79.2	6.9	8.1	4.1	1.7	—	20.8
Lepomis microlophus	244	—	85.2	.4	—	.8	86.4	—	4.1	—	7.0	2.5	13.6
Lepomis punctatus punctatus	356	.8	24.7	2.5	—	6.5	34.6	1.4	15.7	4.8	42.4	1.1	65.4
Leptolucania ommata	8	—	—	—	—	100.0	100.0	—	—	—	—	—	0
Lucania goodei	1903	.6	22.0	1.4	—	5.5	29.4	2.6	36.9	1.0	—	30.9	70.6
Micropterus notius	222	.9	15.8	6.8	—	2.7	26.2	19.8	25.7	4.9	—	23.4	73.8

TABLE 6—*Continued*

Species	Total No.	Above Natural Bridge						Below Natural Bridge					
		Sta 2	Sta 3	Sta 1	Sta 4	Other[1]	Percentage Above	Sta 8	Sta 6	Sta 5	Sta 7	Other[2]	Percentage Below
Micropterus salmoides floridanus	458	.5	37.8	27.3	—	9.3	74.9	1.6	14.4	.7	2.0	6.4	25.1
Minytrema melanops	13	7.7	46.1	—	—	7.7	61.5	7.7	7.7	—	7.7	15.4	38.5
Mollienesia latipinna	721	—	—	—	—	—	0	—	58.1	3.0	—	38.9	100.0
Mugil cephalus	2	—	—	—	—	—	0	50.0	50.0	—	—	—	100.0
Notemigonus crysoleucas	434	.7	94.3	—	—	3.0	98.0	—	2.0	—	—	—	2.0
Notropis chalybeus	30	6.6	—	—	—	93.4	100.0	—	—	—	—	—	0
Notropis hypselopterus	123	—	—	—	—	99.2	99.2	—	.8	—	—	—	.8
Notropis maculatus	15	—	40.0	6.7	—	53.3	100.0	—	—	—	—	—	0
Notropis petersoni	715	1.3	7.3	1.0	—	14.5	24.0	5.0	28.7	2.4	13.8	26.0	76.0
Noturus gyrinus	446	1.8	.2	1.5	—	6.3	9.9	3.4	32.5	—	—	54.3	90.1
Noturus leptacanthus	132	41.7	3.0	1.5	—	8.3	54.5	34.1	9.1	.8	—	1.5	45.5
Opsopoeodus emiliae	60	—	20.0	75.0	—	5.0	100.0	—	—	—	—	—	0
Percina nigrofasciata	91	26.4	2.2	33.0	—	28.6	90.1	—	—	3.3	—	6.6	9.9
Pomoxis nigromaculatus	6	—	83.3	—	—	16.7	100.0	—	—	—	—	—	0
Strongylura marina	3	—	—	—	—	—	0	—	66.6	—	—	33.3	100.0
Syngnathus scovelli	180	—	—	—	—	—	0	26.2	69.0	1.2	—	3.6	100.0
Trinectes maculatus	143	—	—	—	—	—	0	8.4	64.3	27.3	—	—	100.0

Contributions to the BULLETIN OF THE FLORIDA STATE MUSEUM may be in any field of biology. Manuscripts dealing with natural history or systematic problems involving the southeastern United States or the Caribbean area are solicited especially.

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