similar to those of young shad in other rivers along the Atlantic coast (Massmann, 1963; and Walburg, 1956). However, we could not associate the occurrence of terrestrial insects with the wooded upriver areas, as Massmann (1963) did in Virginia, since the entire study area of the Cape Fear River system was wooded.

Blueback herring were not as diversified in their food habits as shad. Planktonic crustaceans and crustacean eggs were the mainstay of their diet. Of the 819 blueback herring stomachs examined, none were empty, even though stomachs generally were not as full as shad stomachs. Apparently young blueback herring fed to some extent throughout the day because all stomachs were relatively full regardless of the time collected. Food items did not differ greatly between rivers. Phytoplankton, larval fish, or gravel were not found in blueback herring stomachs; the lack of gravel suggesting that herring do not feed on bottom organisms. Apparently, blueback herring are much more selective in their food habits than shad.

Young alewives, though not many were examined, had feeding habits similar to blueback herring.

The young clupeids grew at a fast rate in all rivers; however, the growth rate of young shad was greater than that of either blueback herring or alewives. Growth rates for blueback herring and alewives were similar between years and between rivers.

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LIFE HISTORY STUDIES OF THE ALABAMA SHAD, *Alosa alabamae*, IN THE APALACHICOLA RIVER, FLORIDA

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ABSTRACT

Since information on the biology of the Alabama shad, *Alosa alabamae*, of the Gulf coast of the United States is almost nonexistent, a

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study was initiated in February, 1966. Adult shad were collected on their spawning run in the Apalachicola River system, Florida, from February to April. Interpretation of the scale structure indicated that four age classes were represented. A few one-year-old males (average 10.6 inches TL) were in evidence in the latter part of the run. The two-year class consisted mostly of males (average 13.4 inches TL), and small numbers of females (average 14.5 inches TL). Three-year-old fish were most abundant; males (average 14.4 inches TL) and females (average 15.3 inches TL) were found in equal numbers. Small numbers of four-year-olds were taken; most were females (average 16.1 inches TL) and a few were males (average 15.1 inches TL). No specimens more than four years old were collected. Preliminary indications are that one-, two-, and three-year-old males, and two-, and three-year-old females may return to spawn the following year. The adult fish entered the river in mid or late February and attained peak numbers in late April. A gradual ripening of the gonads was observed until the water temperature reached 20°C in late April, at which time spawning took place abruptly. Egg counts in ovaries ranged from 40,000 to 150,000. Food habit studies based on stomach analyses reveal that the adults take little or no food, and that juveniles feed largely on small fishes and aquatic dipterans. Growth and movements of juveniles were followed from June to September. Two distinct size groups of juveniles collected from the lower reaches of the river indicate that spawning takes place in at least two different areas in the drainage system.

INTRODUCTION

The Alabama shad, *Alosa alabamae,* was first noticed ascending river drainages of the Gulf of Mexico around 1850 (Daniel, 1872), and was described as being distinct from the American shad, *Alosa sapidissima,* by Jordan and Evermann in 1896. In contrast to the wealth of information concerning the life history and economic harvest of the Atlantic shad, knowledge of the biology of the Alabama shad is nearly nonexistent. The only references to the shad of the Gulf region have been the original description, scanty information compiled by Hildebrand (1963), and inclusions on lists of species from various river systems.

The Alabama shad has been reported in most of the major drainages along the gulf coast from the Suwannee River in Florida to the Washita River in Arkansas. In Florida, it is the most abundant anadromous fish found on the Gulf coast and occurs in the greatest numbers in the Apalachicola River system.

Because of the lack of information and the potential sport and commercial value of the Alabama shad, a study was launched in January, 1966, to determine the abundance and age composition of the spawning run, fecundity, the location of the spawning grounds, optimum spawning conditions, food, growth, and movements.

DESCRIPTION OF THE AREA

The Apalachicola River, the largest drainage system on the Gulf coast east of Mobile Bay, is bordered by high bluffs of clay and limestone in its upper reaches, dark sloughs and extensive woody banks in its lower reaches, and a vast tidal swamp near its mouth (Figure 1). Formerly its origin was the confluence of the Flint and Chattahoochee rivers near the Florida-Georgia boundary. The completion of the Jim Woodruff Dam at Chattahoochee, Florida, impounded the waters of these two great tributaries and created Lake Seminole; consequently, the Apalachicola River proper takes origin below the dam. Flow in the lower Apalachicola River is increased by numerous smaller streams and rivers; the main tributary is the Chipola River, a clear, fast-flowing stream which originates from springs near Marianna, Florida.

MATERIALS AND METHODS

One hundred forty one adult shad were captured either with an experimental gill net (1½-, 2-, and 2½-inch square mesh), set overnight in the Apalachicola and Chipola rivers, or with a dipnet from the cat-

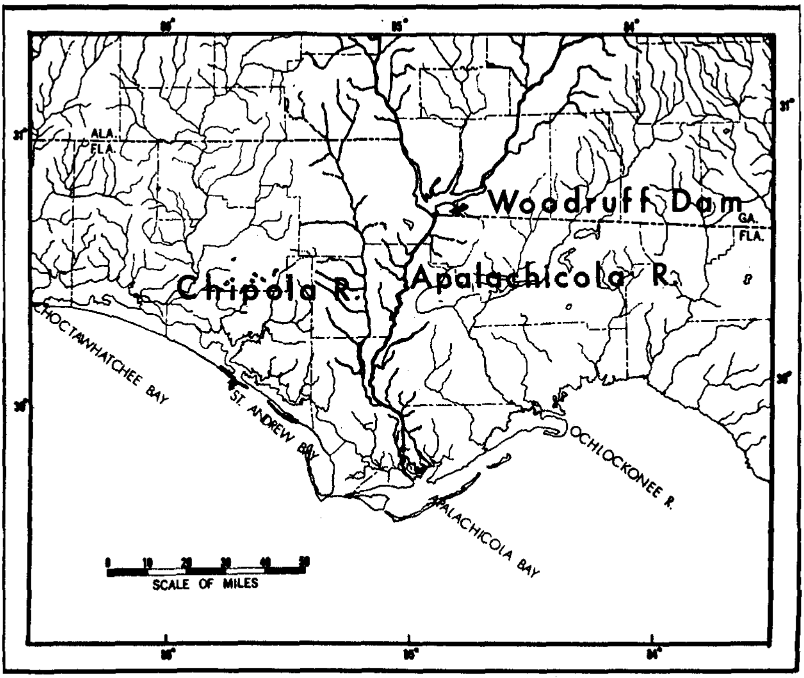

Figure 1. A map of the study area.

walk at the tailrace of Woodruff Dam. Juveniles were seined in shallow water along the banks of the Apalachicola River, or collected with a modified shrimp trawl (Masman, Ladd, and McCutcheon, 1952). Pertinent hydrographic data were noted at the time of each collection.

Adults and juveniles were measured to the nearest 0.1 inch total length (TL), and adults weighed to the nearest ounce.

Gonads from all adults were removed and weighed to the nearest 0.1 gram. The total number of eggs was estimated by using a slight modification of the method employed by Davis (1957).

Stomach contents were analyzed with the aid of a dissecting microscope. With juveniles, each food item was placed in a graduated vial and the amount of water displaced was measured to the nearest 0.1 cc. Identification and nomenclature of the invertebrates was based on Pennak (1953) and Usinger (1956).

Scales were most symmetrical in an area immediately below the lateral line and under the origin of the dorsal fin. Scales were taken from both sides of each fish in this area and stored in vials in a weak formalin solution. Interpretation of the scales was made with the use of a dissecting microscope.

LIFE HISTORY

Abundance and Movements

Shad entered the Apalachicola River in late February and reached peak abundance in mid to late April. Collection data during the spawning run are shown in Table 1. Unsuccessful attempts were made on February 15 and 20 to take shad by setting and drifting a gill net in an area from the mouth of the river to a point approximately seven miles upstream. The first shad, a male, was captured on February 28 in the lower Chipola River, about 50 miles upstream from the mouth of the Apalachicola River. The water temperature at that time was 15°C. Some shad likely entered the river previous to this date, although not

Table 1. Collection data for Alabama Shad in the *Apalachicola River, Florida,* during the 1966 spawning run.

Date	Male	Female	Total	Gear	Location	Water temperature (Centigrade)
February 15	0	0	0	Set gill net	Mouth Apalachicola River	14°
February 20	0	0	0	Floated gill net	Mouth Apalachicola River	12.5°
February 28	1	0	1	Set gill net	Below Dead Lakes Dam, Chipola River	15°
March 5	1	0	1	Set gill net	Dead Lakes	17°
March 8	4	4	8	Set gill net	Dead Lakes	16°
March 16	12	4	16	Set gill net	Dead Lakes	17°
March 18	12	1	13	Set gill net	Dead Lakes	17.5°
March 25	7	11	18	Set gill net	Dead Lakes	19.5°
March 30	4	8	12	Set gill net	Dead Lakes	18°
April 1	8	11	19	Dip net	Below Woodruff Dam	19°
April 3	3	11	14	Dip net	Below Woodruff Dam	19°
April 8	4	6	10	Dip net	Below Woodruff Dam	19°
April 18	1	6	7	Dip net	Below Woodruff Dam	20°
April 22	5	5	10	Dip net	Below Woodruff Dam	20.5°
April 25	1	4	5	Dip net	Below Woodruff Dam	22°
April 26	2	4	6	Dip net	Below Woodruff Dam	22°
April 30	0	1	1	Dip net	Below Woodruff Dam	23°
Totals	65	76	141			

in large numbers. Survey records in this river by the Florida Game and Freshwater Fish Commission revealed that the earliest collection date for shad in 1954 was February 24, January 26 in 1960, and March 8 in 1961. Water temperatures for these dates were not available for comparison with the present study.

Large numbers of shad were first taken on March 16, 1966, at a water temperature of 17°C. Series of specimens collected from then until April 22 when the water temperature reached 20.5°C. At this time shad became extremely scarce and totally disappeared after April 30 when the water temperature had risen to 22°C.

As with the American shad, males appear to enter the river at earlier dates and at lower water temperatures than the females. Prior to March 25, males outnumbered females in the collections more than three to one. The collections of March 16 and 18 especially show an abundance of males as compared to females. The first collection date on which females outnumbered males was March 25, when the water temperature was 19.5°C. Females were more abundant in every collection after this date. These data concur with those of the Florida Game and Fresh Water Fish Commission: on February 24, 1954; there were 85% males; in 1961 males comprised 74% of the catch prior to February 16.

Age-Class Distribution

The interpretation of scales has long been an important tool employed by fishery biologists in age determination. Reading the scales of American shad has been a difficult problem for fishery research personnel, but was facilitated by Cating (1953) who correlated the number of transverse grooves with the number of annuli. He showed that the number of transverse grooves between successive annuli was reasonably constant from fish to fish. Judy (1961) determined the validity of Cating's method by fin clipping juvenile American shad and then recovering the adult fish of known age when they returned to the spawning grounds. The results of the scale reading were in agreement with the known age established by marking.

In this study, the scales of 141 adult Alabama shad were read employing Cating's method. Although the Alabama shad is considered to be a different species, its habits and morphology are essentially the same as those of the American shad; therefore, the use of this method would seem appropriate. Four age classes were represented (Table 2, Figures 2-5). The majority of fish were three years old. The majority of males

Table 2. Average lengths of Alabama shad from the Apalachicola River, Florida, 1966 by age-class and sex.

Age-class	Sex	Number of Fish	Average total length (inches)
I	M	4	10.6
	F	0	—
II	M	24	13.4
	F	8	14.5
III	M	35	14.4
	F	49	15.3
IV	M	7	15.1
	F	14	16.1

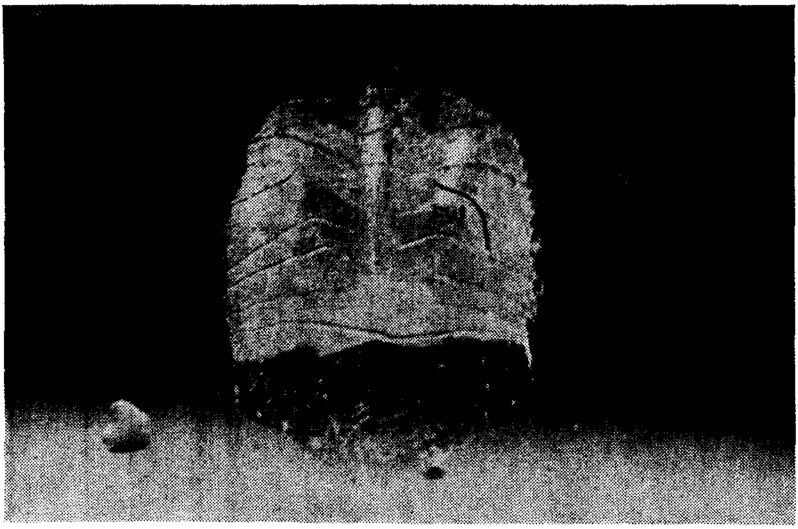

Figure 2. Scale from a one-year-old male, measuring 9.9 inches (TL) and weighing four ounces. FW marks the fresh-water zone.

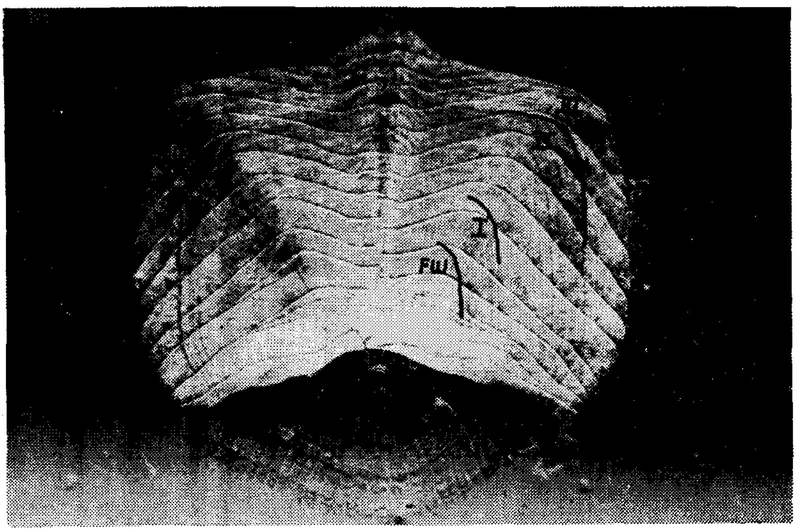

Figure 3. Scale from a three-year-old female measuring 15.3 inches (TL) and weighing two pounds. FW marks the fresh-water zone and Roman numerals I through III indicate the annuli.

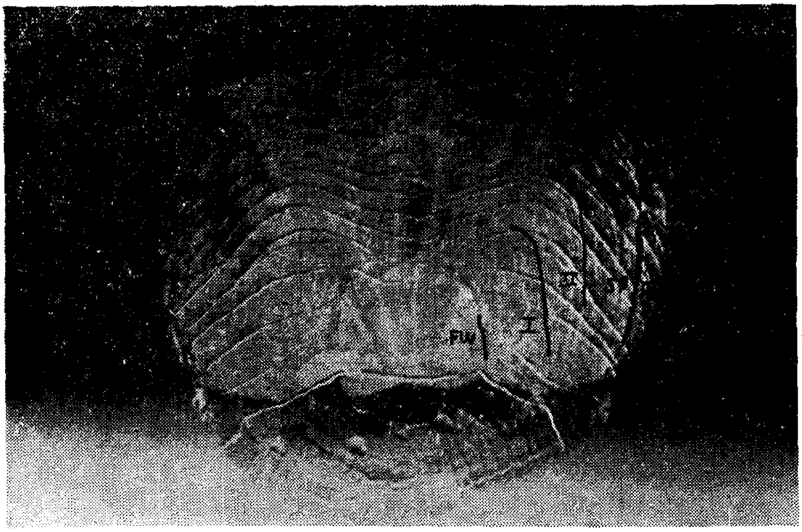

Figure 4. Scale from a four-year-old female measuring 16.8 inches (TL) and weighing one pound 13 ounces. FW marks the fresh-water zone and Roman numerals I, II, and IV indicate annuli. SP indicates a spawning mark and is the third annulus.

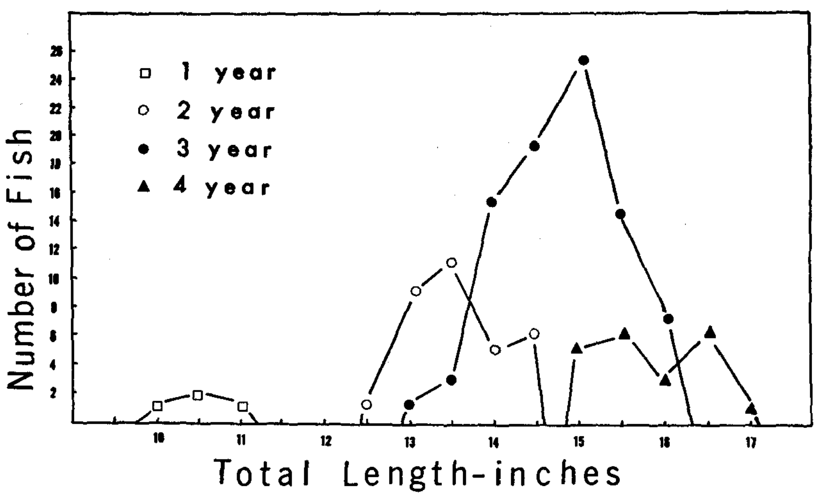

Figure 5. Age frequency graph of Alabama shad from the Apalachicola River, Florida, 1966.

were two and three years old, while the majority of females were three and four years old. No specimens over four years old were collected.

As in the American shad, transverse grooves apparently develop as growth increments, and the number between successive annuli is quite constant in Alabama shad; six to nine in one-year-old fish, nine to 12 in two-year-olds, 12 to 15 in three-year-olds, and 15 or more in the four-year-olds.

Indications are that the Alabama shad attains sexual maturity at an earlier age and at a smaller size than the American shad. Walburg (1960) showed that for American shad in the St. Johns River in Florida, the majority of males and females were four years old, and a large percentage of females were five years and older. Small numbers of three-year-olds were present and only one two-year-old male was collected. Studies of the American shad in the northern part of its range have shown that the most prevalent year classes may be even older than those in the St. Johns (Leim, 1925; Lehman, 1953). From these data, it can be seen that the Alabama shad in the Apalachicola drainage generally mature one year earlier than the American shad in the St. Johns.

Spawning Repetition

Walburg (1960) revealed that a lack of spawning marks on the scales of the American shad in the St. Johns River indicated that a mass mortality must occur after the first spawning. Other studies have shown that American shad found in streams south of Cape Hatteras also suffer a heavy mortality after spawning (Sykes, 1956; Walburg, 1956). The present studies on Alabama shad indicate that a mortality also occurs, but not necessarily after the first spawning. Spawning marks have been found on two-, three-, and four-year-old males, and on three-, and four-year-old females. The number and percentage of fish that spawned previously are shown in Table 3 according to age-class and sex. The absence of fish more than four years old in the Apalachicola drainage indicates that a mortality takes place after spawning, but no dead fish could be found in the spawning or downstream areas. Sighting or recovery of dead fish is improbable, however, due to the turbid waters and steep banks, the rapid sinking of dead shad, and the abundance of predator species in the spawning area.

Table 3. Numbers and percentages of Alabama shad from the Apalachicola River, Florida, 1966, which had previously spawned.

			Previously spawned	
Age-class	Sex	Total number	Number	Percentage
I	M	4	0	—
	F	0	0	—
II	M	24	2	8
	F	8	0	—
III	M	35	16	46
	F	49	22	45
IV	M	7	2	29
	F	14	8	57

Length-Weight Relationship

The relationship between length and weight was computed from a sample of 120 fish (60 males and 60 females). The range in total length was from 9.9 to 16.8 inches, with an average of 14.6 inches. The range in weight was from four ounces to two pounds six ounces, with an average of one pound six ounces. The length-weight relationship is shown in Figure 6 and is described by the equation Log W = −2.8312 + 3.5657

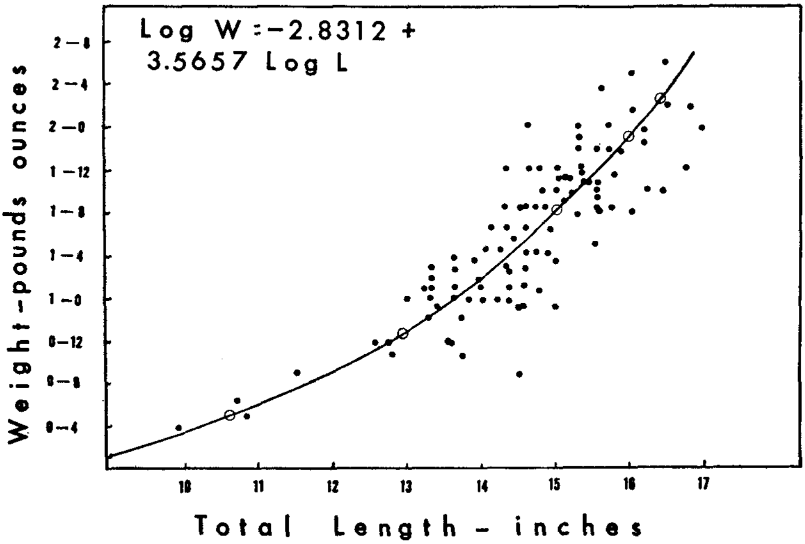

Figure 6. Relationship between body weight and total length in Alabama shad from the Apalachicola River, Florida, 1966.

Log L, based on the method devised by Beckman (1948) for evaluating this relationship.

As might be expected, examination of the data revealed length and weight differences between the sexes. Females were longer and heavier than males in every age class. Males ranged from 9.9 to 15.8 inches TL (average 13.8), and weighed from four ounces to one pound 11 ounces (average one pound two ounces). Females measured from 14.3 to 16.8 inches TL (average 15.4) and ranged in weight from 10 ounces to two pounds six ounces (average one pound 10 ounces).

Fecundity

The fecundity of Alabama shad was calculated from ovaries taken from 31 adult females collected between March 8 and April 8. The females ranged from two to four years old, measured from 14.5 to 16.8 inches TL, and weighed from one pound six ounces to two pounds six ounces. The ovaries were removed from each fish and weighed to the nearest 0.1 gram. They were then stored in small bottles in a 10% formalin solution. The method used to determine the number of ova was based on that devised by Lehman (1953) and modified by Davis (1957). In the present study, instead of employing the mean of two 1 gram samples from each ovary, the number of eggs in a 1 gram sample from only one of the ovaries was counted and multiplied by the weight of the ovaries to give an estimation of the number of eggs.

Calculations revealed that female shad in the Apalachicola drainage produced between 46,400 and 149,450 eggs (Table 4). The relationship between the number of eggs and total length of the female is shown in Figure 7. Complete counts were made of the actual number of eggs in two females; these were 6% and 8% higher than the calculated number.

Table 4. Fecundity of 31 Alabama shad from the Apalachicola River, Florida, 1966.

Total length of fish (inches)	Weight of fish (pounds-ounces)	Weight of ovaries (grams)	Calculated number of eggs
14.5	1-8	61.4	55,260
14.8	1-6	111.0	88,880
14.8	1-12	107.6	107,600
14.8	1-6	64.5	64,500
14.8	1-9	73.5	80,850
15.0	1-10	60.0	66,600
15.0	1-12	87.6	87,600
15.3	1-9	80.6	83,420
15.3	1-10	61.8	70,300
15.3	1-12	65.2	68,450
15.3	1-12	78.5	78,500
15.3	1-14	148.0	103,600
15.3	1-15	114.5	114,500
15.4	1-10	135.4	81,240
15.5	1-6	46.4	46,400
15.5	1-10	109.1	98,190
15.5	1-10	79.0	71,100
15.8	1-11	123.0	117,110
15.8	2-4	146.0	116,800
16.0	1-8	90.6	99,660
16.0	1-13	129.8	149,450
16.0	2-2	131.1	131,100
16.0	2-5	146.5	131,850
16.3	1-10	129.8	129,800
16.3	2-0	117.7	135,450
16.3	2-1	127.5	112,860
16.4	1-10	71.3	85,560
16.5	2-2	93.7	93,700
16.8	1-13	90.7	99,770
16.8	2-0	125.4	125,400
16.8	2-2	125.7	113,130

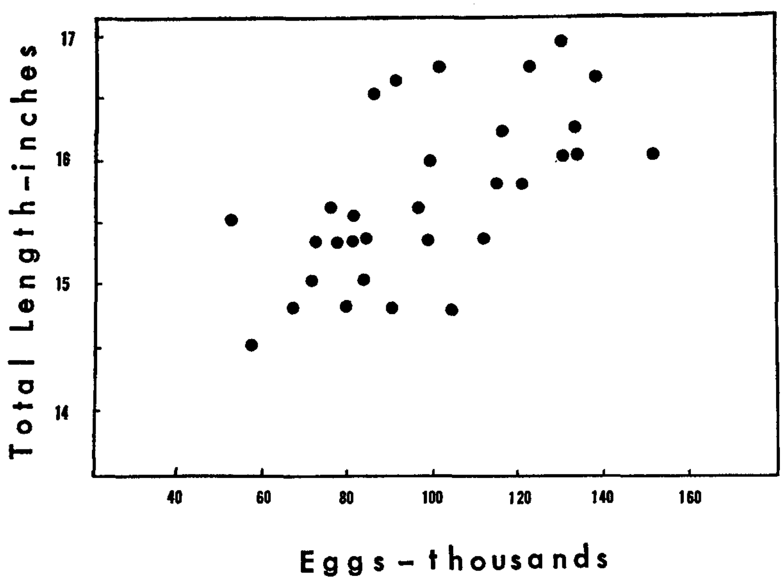

Figure 7. Relationship of egg production to body length in Alabama shad from the Apalachicola River, Florida, 1966.

This study indicates that the fecundity of the Alabama shad is considerably less than that for the American shad in the St. Johns River where Walburg (1960) found that egg production ranged from 277,000 to 659,000. This might be expected, however, because of maturation at an earlier age and a smaller size for Alabama shad. The St. Johns population seemed to be the most prolific of any of the American shad stocks. Lehman (1953) indicated that egg production in Hudson River shad ranged between 116,000 and 468,000 eggs. Lehman's figures are closer to those calculated for Alabama shad in the present study if one takes into consideration the older age and greater size for the shad of the Hudson.

Spawning

Efforts to locate the spawning grounds of the shad in the Apalachicola River revealed that large numbers spawned below the Woodruff Dam at Chattahoochee, Florida. It is not known what effect the building of the dam had on stocks of Alabama shad which formerly could reach the headwaters of the Chattahoochee and Flint rivers to spawn. However, the area below the dam seems quite suitable for shad with a sand and gravel bottom and moderate current. Table 1 shows that most shad were taken between March 8 and April 18 and that they became scarce after April 22 when the water temperature rose to 22°C. Field observations revealed that on April 18 eggs could be freely stripped from the females when the water temperature reached 20°C. Three of six females taken on the same date were partially spent. Although few specimens were collected because of damaged gear, shad were more abundant on that date than at any other time. Subsequent collections (April 22, 25, and 26) at water temperatures ranging from 20.5°C to 22°C included females that were completely or partially spent. Shad were noticeably scarce on those dates. The last fish, a spent female, was taken on April 30 with the water temperature at 23°C. No adult shad were seen or captured after this date. Table 5 gives the date, average weight of the ovaries, and water temperature.

Table 5. Changes in average weight of ovaries with changes in water temperature.

Date	Average weight of ovaries (grams)	Average weight of fish (pounds-ounces)	Water temperature (Centigrade)
March 8	90.2	1-12	16°
March 25	78.9	1-11	19.5°
March 30	84.9	1-11	18°
April 1	117.3	1-13	19°
April 8	109.8	1-10	19°
April 18	71.5	1- 4	20°

It shows that the average weight of the ovaries was at its greatest at a water temperature of 19°C and decreased considerably when the temperature reached 20°C. This tends to support the data from the field notes and indicates that Alabama shad in the Apalachicola River apparently spawn rather abruptly and immediately die or leave the area.

Food Habits — Adults

Stomach analyses were made on 100 adult shad. As with most anadromous fish on their spawning run, Alabama shad take little or no food. Unidentifiable insect remains and detritus were found in only two of the 100 fish examined. An unidentifiable green slime coated the stomachs of 21 fish. Interviews with fishermen in the Dead Lakes region of the Chipola River revealed that Alabama shad can be lured and caught on unbaited silver hooks. The extent of this sport fishery for shad is limited, however, as most local fishermen prefer to fish for bass and bream.

Growth and Movements — Juveniles

Immediately after the abrupt disappearance of adults from the spawning area, efforts were made to collect eggs and developing larvae. After two weeks of negative results, the use of a plankton net was abandoned. On May 26, large numbers of juvenile shad were taken with a minnow seine along the banks of the river below the Woodruff Dam. Periodic collections were made in the area until the juveniles disappeared about July 1. Numbers and sizes of juveniles collected are shown in table 6.

Table 6. Collections of juvenile Alabama shad spawned at the Woodruff Dam area, Apalachicola River, Florida.

Date	Number	Average total length *and range in inches*	*Location*
May 26	50	1.8 (1.1 - 2.4)	Below Woodruff Dam
June 6	4	2.1 (1.6 - 2.4)	Below Woodruff Dam
June 21	47	2.6 (1.7 - 3.7)	Below Woodruff Dam
September 2	5	4.5 (4.2 - 4.7)	40 miles from mouth
September 13	5	5.2 (5.0 - 5.5)	15 miles from mouth

After the disappearance of the juveniles from the Woodruff Dam area, collecting operations were transferred to the lower reaches of the Apalachicola River. Juveniles were collected at several stations, from the mouth of the Chipola River (approximately 50 miles from the Gulf) to a point only two miles upstream from the mouth of the Apalachicola River.

It was immediately apparent that these juveniles were noticeably smaller (average TL 2.2 inches) than the last series of juveniles (average TL 2.6 inches) taken at the Woodruff Dam six weeks earlier (Tables 7 and 6). One possible explanation was that these fish had been spawned in the Chipola River. Subsequent attempts to collect juveniles in the Apalachicola River upstream from the mouth of the Chipola River were unsuccessful; no collections were made in the Chipola River. Since no data are available on spawning dates of the shad nor water temperatures in the Chipola River, this hypothesis of their origin remains unproven.

Table 7. Collections of juvenile Alabama shad from the lower Apalachicola River, Florida, presumably spawned in the Chipola River.

Date	Number	Average total length and range in inches	Location
August 4	107	2.2 (1.6 - 3.2)	7 - 17 miles from mouth
August 24	89	2.5 (1.8 - 3.7)	2 - 15 miles from mouth
September 2	72	2.6 (1.8 - 3.6)	2 - 50 miles from mouth
September 13	75	2.7 (1.9 - 4.1)	2 - 15 miles from mouth

On September 2 five juveniles (average TL 4.5 inches) were captured in a downriver area where no other shad were taken. These were so much larger than any of the other shad collected that day, that it is felt they were probably hatched at the Woodruff dam area. On September 13 another lot of these larger juveniles (average TL 5.2 inches) was taken in an area farther downstream than the previous group. It is felt that the reason these larger juveniles did not appear in the earlier downriver collections was that they probably had not yet made their way downstream from Woodruff Dam. Because these fish were obviously not of the same stock as the majority of the downriver fish, and since they were approximately the size of the projected growth for Woodruff Dam juveniles, they have been included in Table 6.

Food Habits — Juveniles

An analysis of food eaten by juveniles in two different areas of the river is shown in Table 8. Comparison of the two groups reveals that the

Table 8. Food habits of young Alabama shad from two areas in the Apalachicola River as revealed by stomach analyses, summer 1966.

Location	Woodruff Dam area		Lower river	
Size range, TL (inches)	1.1 - 3.7		1.6 - 5.5	
No. of stomachs	101		273	
Total volume of food (cc)	11.45		8.2	
Mean average volume (cc)	0.12		0.03	
Food item	Percent volume	Number of occurrences	Percent volume	Number of occurrences
Cladocera	2	12	—	—
Coleoptera	3	4	—	—
Copepoda	8	43	—	—
Diptera	34	78	38	217
Pisces	35	46	12	18
Trichoptera	3	6	Trace	2
Unidentifiable	11		44	
Miscellaneous:	4		6	
Annelida		1		—
Arachnida		—		6
Hemiptera		—		3
Hymenoptera		2		7
Isoptera		4		—
Odonata		—		4
Orthoptera		—		2
Plant matter		—		2

juveniles in the Woodruff Dam region contained greater mean volume of food per stomach than the downriver fish, and fed to a greater extent on fishes. The large numbers of juvenile threadfin and gizzard shad, *Dorosoma petenese* and *D. cepedianum,* which were spawned just after the Alabama shad, provided abundant forage for these fish. The table also reveals that the food in the Woodruff Dam area was more varied than in the downriver area. By far, the greatest amount of food taken from the stomachs of the downriver fish was the remains of larval, pupal, and adult dipterans. It is believed that the greater variety of food and availability of other forage fishes may have contributed to the fast growth of juvenile shad in the Woodruff Dam area as compared to the group of smaller juveniles which has been assumed to have been spawned in the Chipola River.

Massmann (1963) showed that the summer food of juvenile American shad in Virginia waters was predominantly Hemiptera and Ephemeroptera, with Diptera and fish remains comprising only a small portion of the diet. Since juvenile Alabama shad in the Apalachicola feed mostly on fish and Diptera, it appears that these young fish are opportunists and feed largely on whatever is available. This view is supported by Walburg (1957) who examined the stomach contents of juvenile Atlantic shad from the St. Johns River to the Connecticut River. He concluded that the diet of juvenile shad is quite diversified and varies from river to river.

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COST ANALYSES OF SPORT FISHING IN COMMERCIAL CATFISH PONDS

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ABSTRACT

Fishermen were interviewed as they fished for catfish and largemouth bass in pond S-1 (22 acres) and pond S-7 (2.5 acres) of the Auburn University Fisheries Research Unit to determine selected expenditures per trip. From September 15 to December