FOOD, GROWTH, MIGRATION, REPRODUCTION, AND ABUNDANCE OF PINFISH, *LAGODON RHOMBOIDES*, AND ATLANTIC CROAKER, *MICROPOGON UNDULATUS*, NEAR PENSACOLA, FLORIDA, 1963–65

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ABSTRACT

The abundance, growth, age composition, food, migration, and reproduction of the two species were studied at two locations for each species from August 1963 to December 1965. The materials comprised 22 fish collections at each station, taken in about 500 hours of trawling.

The stomach contents of 3,577 pinfish and 2,520 Atlantic croakers indicated that pinfish are omnivorous and croakers carnivorous. Principal foods were vegetation, crustaceans, and polychaetes for pinfish and annelids, fish, and arthropods for croakers. Types of food in pinfish stomachs were similar at all sizes and seasons, but the relative amount of each type differed by season and size of fish. Foods in croaker stomachs differed at the two stations but were similar from year to year. The average food volume in the stomachs varied with time of year, location, and fish size. Volumes of food in stomachs of both species decreased when the fish moved from the estuary.

Length-frequency distributions can be used to estimate age in both species. Pinfish, and possibly croakers, form annuli on their scales. Growth of pinfish and Atlantic croaker varied from year to year.

Some fish of both species had developing gonads in the fall of their first year of life and may spawn. Both species migrate offshore in the fall to spawn. The fry and some adults return to the estuary in the winter and spring.

Abundance of pinfish and Atlantic croakers was highest in late spring and early summer. Pinfish at both stations and croakers at one station were less abundant in 1964 than in 1963 or 1965. Yearly differences in abundance of croakers were not large at the other location.

Pinfish, *Lagodon rhomboides*, and Atlantic croaker, *Micropogon undulatus*, are two of the most abundant species of fish in the Pensacola area and other estuaries in the Southeastern States. The life history of pinfish from areas other than Pensacola has been investigated by Reid (1954), Kilby (1955), Caldwell (1957), and others; and that for Atlantic croaker has been studied by Pearson (1928), Hildebrand and Cable (1930), Wallace (1940), Gunter (1945), Haven (1957 and 1959), and others. The purposes of the present study were to investigate the life histories of these species in the Pensacola Estuary and to contribute to the general knowledge of the biology of these fishes.

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DESCRIPTION OF THE STUDY AREA

The "Pensacola Estuary" (so termed for convenience) has an area of about 370 km.^{2}; it encompasses three bays (two of which are shown in fig. 1) and a sound. The estuary supports commercially harvested stocks of fish and shellfish.

Two stations in the lower estuary were selected for study of pinfish. The sandy bottom at both supports a dense growth of grasses—predominantly turtle-grass, *Thalassia testudinum*, and seagrass, *Ruppia maritima*. Station I is on the north side of Santa Rosa Sound across from Sabine Island, site of the Bureau of Commercial Fisheries Biological Field Station, Gulf Breeze, Fla.; station II is on the south side of Pensacola Bay. Average depth at mean low water is 3.0 m. at station I and

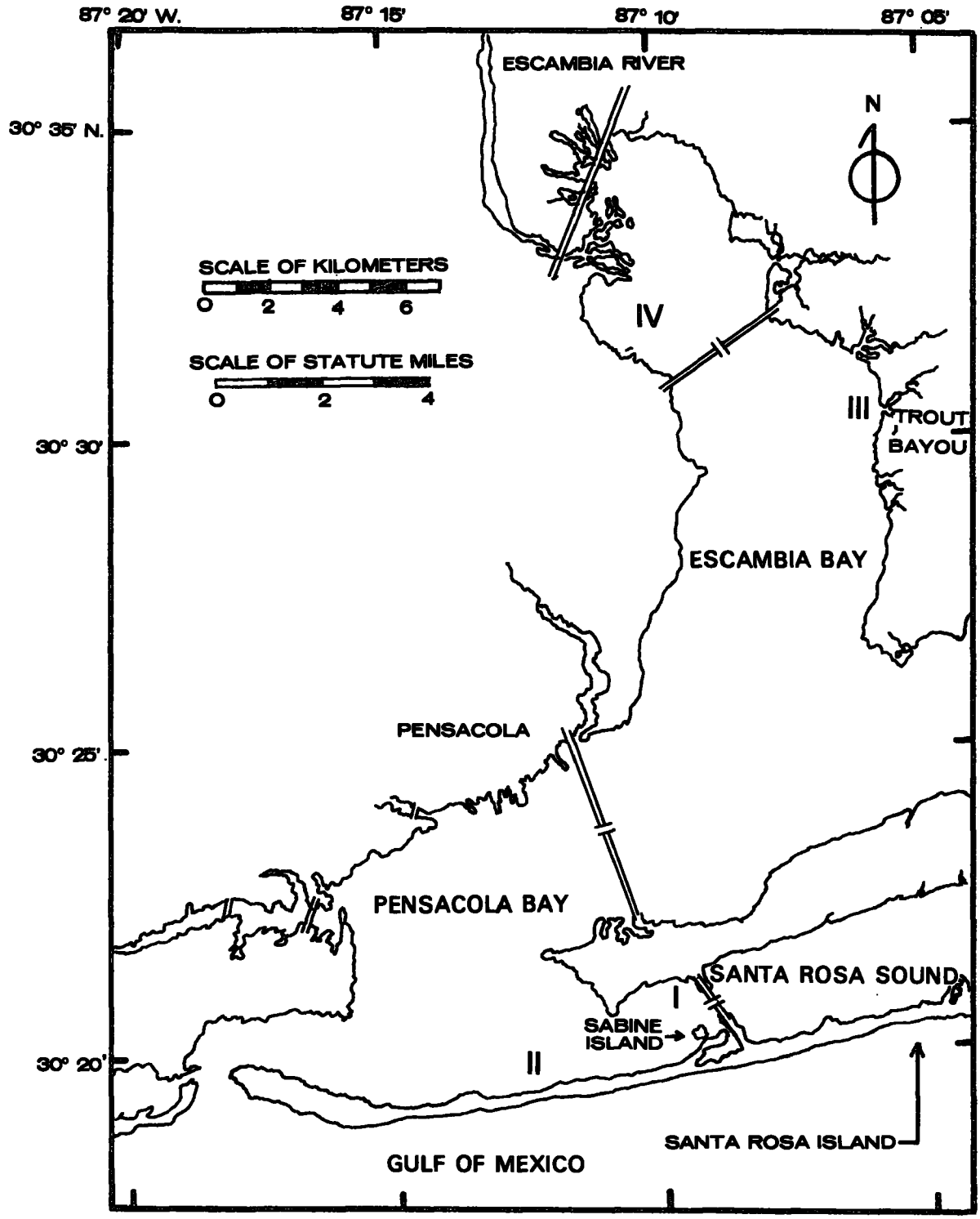

FIGURE 1.—Location of sampling stations in the Pensacola Estuary for pinfish (I and II) and Atlantic croaker (III and IV).

2.5 m. at station II. Salinities at both stations ranged from 4 to 31 p.p.t. and averaged 23 p.p.t. at station I and 24 p.p.t. at station II. Water temperatures were similar at both stations, ranging from 9° to 30° C. and averaging 23° C.

Two locations in the upper estuary were selected for study of Atlantic croakers—station III, off the eastern shore of Escambia Bay, near Trout Bayou, and station IV, off the western shore of the bay. The bottom at both is predominantly mud; attached vegetation is lacking, but station III has isolated oyster reefs. Average depth at mean low water is 2.5 m. at station III and 2.0 m. at station IV. Salinities ranged from 0 to 29 p.p.t., average 15 p.p.t., at station III and from 0 to 27 p.p.t., average 12 p.p.t., at station IV.

MATERIALS AND METHODS

Collections were made with a 5-m. otter trawl of 12-mm. bar mesh. This trawl is the standard "try net" used by commercial shrimpers in Pensacola Bay to find commercial quantities of shrimp. The trawl was pulled behind the 11-m. research vessel *Dolphin* at about 2.5 knots.

All stations were visited 22 times from August 1963 to December 1965; usually 10 trawl hauls (30 minutes) were made at each Atlantic croaker station and 30 hauls (15 minutes) at each pinfish station. Trawling usually began in the middle of the month and lasted 7 days (not necessarily consecutive). The number and duration of hauls were selected to give a reliable estimate of fish abundance. In periods when fish were not abundant the number of trawl samples was reduced to less than half that during periods of abundance.

Treatment of both species after capture was similar. On the boat they were counted, measured to the nearest millimeter of standard length, and whenever possible 50 fish from each 25-mm. size group were preserved in a mixture of 4 percent formaldehyde and sea water of 16 p.p.t. salinity. Fish were slit open to preserve innards (including stomach and gonads). At the laboratory, preserved fish were measured for length and weight (to the nearest millimeter and 0.01 gram) and stomachs and scale samples were removed.

Confidence intervals were computed for the number of fish caught per trawl-haul and on the average length of the fish. Mention of significant differences indicates that confidence intervals, 95 percent confidence coefficient, do not overlap.

Stomach contents of fish captured at the same time were combined by length of the fish—14 to 75 mm. or >75 mm.—and stored in 70 percent ethanol. After identifying and sorting the contents, I blotted them dry and determined their liquid displacement.

Discussion of the volume of stomach contents includes all of the contents but discussion of the composition excludes unidentifiable material; which represented 8.8 percent of the 205.8 ml. of food from 3,577 pinfish stomachs and 25.2 percent of the 58.4 ml. of food from 2,520 Atlantic croaker stomachs. The unidentifiable component of the stomach contents included small particles of inorganic and organic detritus and food digested beyond recognition. Reid (1954) also found large amounts of unidentifiable material in croaker stomachs.

Ages were determined from length-frequency distributions and by examination of scales. The scales were predominantly from fish at the size range where length-frequency distributions indicated a change in age. The scales were taken from the area above the lateral line behind the operculum, stored between sheets of paper, and examined under a monocular microscope. The distances from focus of the scale to the annulus and to the margin of the scale were measured to the nearest 0.1 mm. with an ocular micrometer.

The spawning season extends throughout the winter (about November to March for pinfish and November to February for croakers). In assigning ages to these fish, I used January 1 of the year following the winter of hatching as the first birthday.

I used two methods to study the growth. First, I used the differences in average lengths between consecutive trawling periods to compute the average daily increases in length. Second, I used measurements of scales from yearling pinfish to compute growth increments; increases in length after annulus formation were determined for each sampling date and used to derive daily growth for each season.

To discover movements before spawning, I clipped fins of 26,980 pinfish and 5,269 Atlantic croakers. Fish from different localities were marked differently by removal of either one or both pelvic fins. After the marking, the fish were kept in a tank of circulating water on the boat

until the next trawl-haul was completed, and only fish that seemed healthy were released. The area of release was not fished again for at least 15 minutes. Fish movement could be noted if fish fin-clipped at one station were recaptured at any of the other three stations or at other locations sampled sporadically. I also marked 284 pinfish by attaching an Atkins tag in front of the dorsal fin with nickel wire.

I estimated numbers of eggs in ovaries by measuring the volume of eggs in both ovaries (after most ovarian tissue had been removed) and dividing that value by the average volume of an egg as estimated from measurement of 25 eggs.

PINFISH

Pinfish are one of the dominant animals in the fauna of vegetated areas in the lower Pensacola Estuary. Therefore, I investigated the seasonal and annual change in the food, growth, migration, reproduction, and abundance at two locations from August 1963 to December 1965.

FOOD

Pinfish were omnivorous feeders on the grass flats where stations I and II were located. Gunter (1945) and Reid (1954) on the Gulf of Mexico Coast and Linton (1904) on the east coast of the United States found a large variety of food organisms in pinfish stomachs. I identified 10 phyla of animals and a wide variety of vegetation (including diatoms, filamentous algae, and vascular plants). The type of food varied with season and fish size (table 1), but not by station.

Vegetation contributed 40.6 percent of the total volume of identifiable items (including sand) in the stomachs. It was the dominant food in the summer and fall; the amount usually increased in late spring or early summer and decreased in the late fall. Diatoms were most important in fish less than 76 mm. long, and filamentous algae and vascular plants in larger fish.

Crustaceans, polychaetes, and chordates were dominant in pinfish stomachs in the winter and spring. Small pinfish usually contained a higher total number and volume of small crustaceans than large pinfish. The crustaceans were mainly amphipods, copepods, crabs, cyprids, isopods, mysids, and shrimp. Chordates—amphioxus and (secondarily) fish—were most abundant in large fish. Other animals eaten in smaller amounts were brachiopods, bryozoans, chaetognaths, echinoderms, mollusks, and nemerteans.

The mean volume of food in pinfish stomachs was highest during the summer and early fall (table 2). The increase in the volume usually began in May or June for both size groups of fish and came with increase in ingestion of vegetation. The volume decreased in the fall as fish became more carnivorous. In the fall most fish over 90 mm. long leave the estuary. Amounts of food in the stomachs decrease during the spawning season, as is common in many species of fish.

The mean volume of food in pinfish stomachs was generally low and nearly constant from late fall until late spring, except for a short-term increase in February, when large numbers of caprellid amphipods and polychaetes were found in stomachs of small fish.

TABLE 1.—*Percentage of total volume contributed by differen items in pinfish stomachs collected in the lower Pensacola Estuary at stations I and II in different seasons, 1963–65*

Items in stomachs	Fish length class, season, and number of stomachs [1]								
	< 76 mm.				76–173 mm.				All (3577)
	Spring (537)	Summer (887)	Fall (570)	Winter (122)	Spring (184)	Summer (683)	Fall (575)	Winter (19)	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Crustaceans	58.3	2.8	21.7	44.8	8.7	4.6	5.6	24.9	26.9
Polychaetes	17.3	1.0	2.9	43.4	8.0	4.0	4.0	19.4	9.9
Chordates	3.1	1.5	1.1	10.8	12.5	2.0	2.9	31.3	6.6
Vegetation	4.6	87.2	66.5	.9	21.9	66.4	56.6	23.1	40.6
Sand	12.9	6.7	6.6	.0	44.4	18.9	29.5	.2	13.8
Other [2]	3.8	.8	1.2	.1	4.5	4.1	1.4	1.1	2.2

[1] Numbers of stomachs from both stations are shown in parentheses.

[2] Other items include brachiopods, bryozoans, chaetognaths, echinoderms, mollusks, and nemerteans.

TABLE 2.—*Average volume of stomach contents of small and large pinfish collected in the lower Pensacola Estuary at stations I and II in the months of sampling, 1963–65*

Month	Fish length class			
	<76 mm.		76–173 mm.	
	Stomachs Examined	Average contents	Stomachs Examined	Average contents
	No.	*Ml.*	*No.*	*Ml.*
January	32	0.01	1	0.07
February	90	.05	18	.08
March	6	.01	2	.08
April	341	.01	111	.07
May	190	.01	71	.11
June	326	.02	174	.11
July	296	.03	214	.12
August	265	.06	295	.14
September	183	.03	239	.07
October	228	.04	289	.08
November	159	.01	47	.03

AGE AND GROWTH

Pinfish were aged by using length-frequency data and by examination of scales. Length frequencies have been used to age pinfish (Caldwell, 1957) but scales have not. Pinfish from the two stations were of similar lengths; therefore, length-frequency data for the stations were pooled (fig. 2). The bimodal length-frequency distribution indicates at least 2 year-classes of pinfish.

Average length of pinfish at annulus formation, as determined by scale measurements, was similar to the average length of fish measured in early spring. Most of the annuli formed in April of both 1964 and 1965. The percentage of yearling fish that showed an annulus in different months in 1964 and 1965 (data combined) were as follows (number of fish in parentheses): January—12 percent (57); February—13 percent (85); March—0 percent (2); and early May—100 percent (42). Back-calculation of fish lengths showed that the 1963 and 1964 year classes formed a year-mark at average lengths of 61 and 78 mm., respectively. Fish from these year classes were at this size as yearlings in March or April. The average length of fish entering their third year of life was 127 mm. (15 fish) at the time of annulus formation.

The average size of pinfish varied during the different years (table 3). Yearly differences in average size result from a number of factors such as differences in hatching time and growth rate. Standard lengths of fish caught by trawling and seining during the study were 13 to 152 mm.; fish

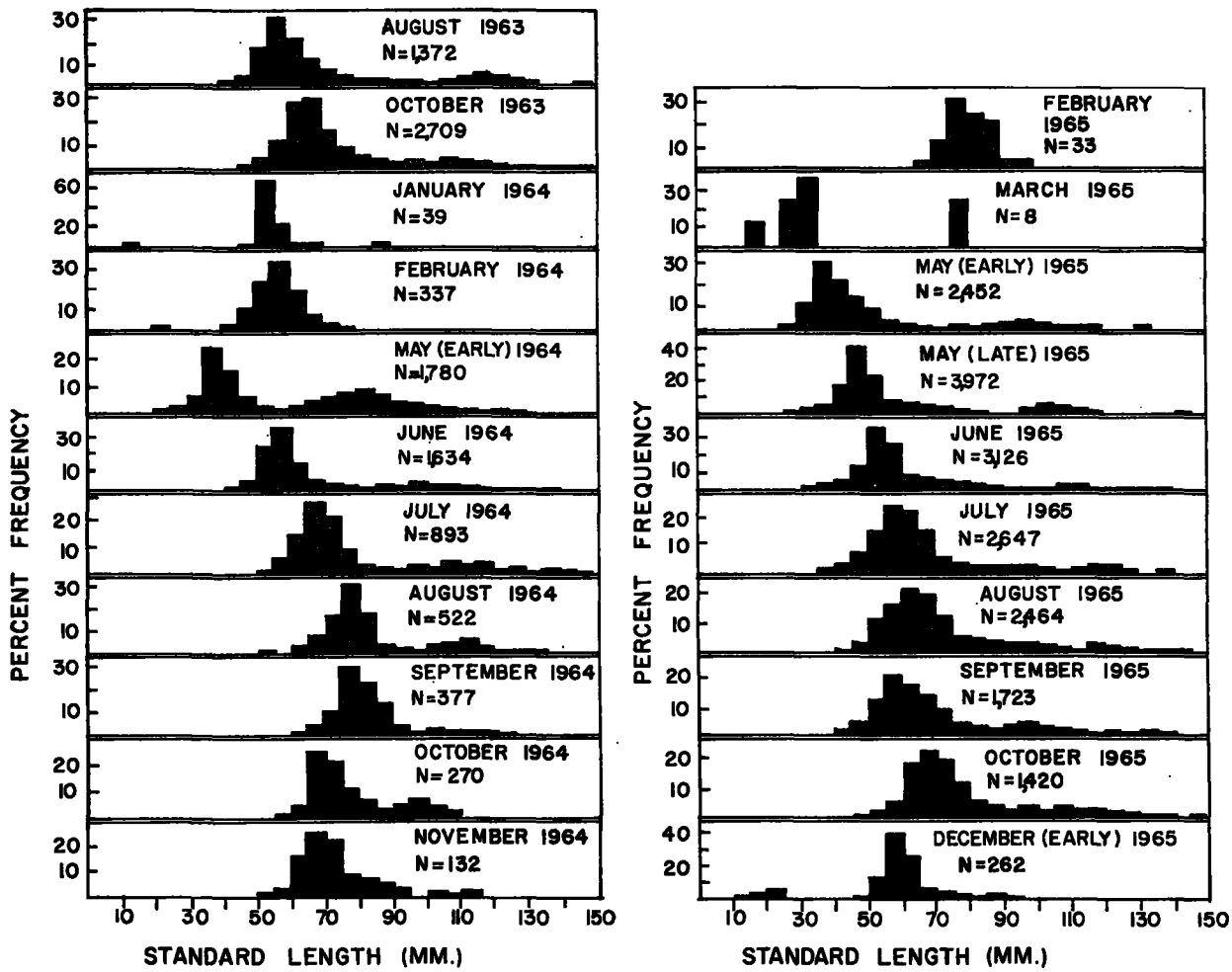

FIGURE 2.—Length-frequency distribution of pinfish caught in the lower Pensacola Estuary at stations I and II, 1963–65.

TABLE 3.—*Standard lengths of pinfish of age-groups 0, I, and II in the lower Pensacola Estuary at stations I and II, 1963–65*

Date	Age-group 0			Age-group I			Age-group II		
	Fish	Length		Fish	Length		Fish	Length	
		Average	Range		Average	Range		Average	Range
1963	*Number*	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*
August 30–September 6	1,316	60	44–102	56	118	105–145	0		
October 29–November 1	2,642	67	47–107	67	117	107–145	0		
1964									
January 10–15	1	14		38	47	43–83	0		
February 28–March 3	1	22		336	56	43– 79	0		
May 12–14	1,008	39	21– 60	771	82	61–123	1	128	
June 29–July 1	1,567	57	42– 79	65	100	81–130	2	132	129–136
August 3–5	829	68	52– 93	62	109	91–140	2	136	136–137
August 31–September 2	438	76	50– 94	84	115	96–133	0		
September 28–30	352	80	60–101	25	112	102–128	0		
October 30–November 3	270	77	59–109	0			0		
November 23–25	132	72	53–110	0			0		
1965									
January 12	1	30		0			0		
March 3	0			33	81	69– 97	0		
March 29	6	28	19– 32	2	78	77– 79	0		
May 6–12	2,369	42	25– 60	82	96	76–116	1	134	
June 1–3	3,917	48	28– 78	53	102	77–111	2	137	136–138
June 25–29	3,098	54	33– 94	21	112	97–130	7	136	131–143
August 2–4	2,623	59	35–105	22	118	113–125	2	136	135–136
August 30–September 1	2,414	64	42–109	49	120	110–137	1	141	
September 22–24	1,706	68	45–110	17	123	113–139	0		
October 25–27	1,383	71	49–116	37	121	112–146	0		
December 6–8	8	20	14– 22	254	60	47– 92	0		

caught at the sampling stations were 14 to 146 mm. long.[1]

Pinfish growth rates computed from changes in lengths between consecutive trawling periods varied with age group and season. Daily increase in length averaged 0.19 mm. for 0-group pinfish and 0.12 mm. for yearlings. Growth of both age groups slowed as the seasons progressed from spring to winter. Daily increase in length of 0-group pinfish averaged 0.32 mm. in the spring, 0.23 mm. in summer, and 0.01 mm. in fall; yearling pinfish averaged 0.32 mm. in the spring, 0.21 mm. in summer, −0.04 mm. in fall, and −0.02 mm. in winter. Caldwell (1957) also observed maximum growth in the spring and negligible growth in the fall and winter.

Annual growth rate of yearling pinfish, estimated from increase in length after annulus formation, was closely similar to that based on increase in measured lengths, but seasonal growth rates determined by the two methods differed. Annual increase in length computed from scale measurements averaged 0.14 mm. per day, and seasonal increases averaged 0.12 mm. per day in the spring, 0.14 mm. in the summer, 0.20 mm. in the fall, and 0.09 mm. in the winter.

[1] Standard length = 0.85 fork length or 0.78 total length on the basis of measurements of 100 fish, 44 to 101 mm. long.

MIGRATION AND REPRODUCTION

Limited data on estuarine movements of pinfish were obtained from recaptures of fin-clipped or tagged fish. Of 26,980 pinfish fin-clipped, 234 (0.87 percent) were recaptured at the area of original capture during the trawling period in which they were released and only 47 (0.17 percent) were recovered 1 month or more after marking. There could be several reasons for the low recapture rates. The proportion of the population marked was small, the marking mortality was high, or unmarked fish from other areas were moving in. Of the 47 fish recovered 1 month or more after marking, 39 were caught at the station of release, and eight had moved either from station I to station II or from station II to station I (five did so in the 3 principal months of the spawning migration—August, September, and October). Of 284 pinfish tagged in April 1964, two were recaptured—one in July about 125 m. from where it was tagged and the other in October about 3 km. closer to the mouth of the bay.

On the basis of results of trawling and seining, I believe that most pinfish remain over the grass flats where they live in the spring until they migrate out of the estuary in late summer and fall. Most appear to move very little in the summer, but a few may wander over the grass flats. Fish

may congregate in response to abundance or scarcity of food during this time but schools are not formed.

At the start of the spawning migration into the Gulf of Mexico, however, the pinfish school in large numbers. These schools seem to consist of fish of the same age. Large numbers of pinfish captured in Chesapeake Bay in October, as noted by Hildebrand and Schroeder (1927), probably were schools of seaward migrants. Aggregations of pinfish have also been seen in the Gulf of Mexico (Springer, 1957). In the late winter and spring, I have observed schools of pinfish in Santa Rosa Sound, Fla., that were probably returning from the Gulf of Mexico. Most of these fish were in their second year of life. Few fish live to reenter the estuary in their third year.

The stage of gonad development before migration varied. In most years, maturation of gonads probably takes place during the migration or while the fish are at or near the offshore spawning site. In October 1965, when most fish over 80 mm. were mature enough to permit determination of sex, the gonads ranged from the late stage 1 to the late stage 3 of Homans and Vladykov (1954)—gonads growing in size; yellow, opaque eggs microscopic to visible, and testes pinkish to flesh-colored or white and slightly distended. None had gonads that would produce milt or eggs when pressed (stage 4 or 5). Because the examination of scales showed that most fish under about 110 mm. were in their first year of life, it is likely that some 0-group fish and all yearling pinfish spawn.

Eight pinfish 111 to 152 mm. long had ovaries with eggs that were mature enough for counting; eggs in smaller fish were too small to count accurately. The diameters of eggs were 0.09 to 0.66 mm. (average 0.38) and the estimated numbers of eggs were 7,700 to 39,200 (average 21,600). Caldwell (1957) examined a pinfish 157 mm. long which had an estimated 90,000 eggs that averaged about 0.5 mm. in diameter.

ABUNDANCE AT THE SAMPLING STATIONS

Pinfish are present in moderate numbers in the deeper parts of Pensacola Bay in the summer; they are most abundant in the southern part of the estuary in extensive flats covered with turtle grass. Reid (1954) and Kilby (1955) also observed that pinfish were most numerous in vegetation along the Gulf Coast of Florida. Pinfish are distributed unevenly on the flats, as they tend to aggregate in response to the environment—concentrations of food especially attract them.

Despite the wide confidence limits on the average number of fish caught, seasonal trends are clearly evident (table 4). Because the periods of maximum and minimum abundance, and monthly changes in

TABLE 4.—*Pinfish caught per 15-minute trawl-haul in the lower Pensacola Estuary, 1963–65* [1]

Date	Station I			Station II			Averages both stations
	Average	Confidence interval 95 percent	Range	Average	Confidence interval 95 percent	Range	
1963	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
August 30–September 6	312	183–441	5–791	66	21–112	6–219	214
October 29–November 1	66	35–96	0–253	59	48–70	9–145	62
1964							
January 10–15	1	0–3	0–23	[2] 0	[2] 0–0	0–1	1
February 28–March 3	4	1–7	0–40	8	0–16	0–111	6
May 12–14	19	11–28	0–97	40	26–54	2–136	30
June 29–July 1	63	11–114	1–521	110	65–155	1–412	86
August 3–5	11	4–18	0–77	19	10–28	0–95	15
August 31–September 2	14	9–19	0–45	4	3–5	0–10	9
September 28–30	10	6–14	0–40	3	1–4	0–20	6
October 30–November 3	6	3–10	0–33	3	1–4	0–9	4
November 23–25	4	1–7	0–43	1	0–1	0–4	2
1965							
January 12	0			[2] 0	0–1	0–1	[2] 0
March 3	1	0–2	0–2	6	0–18	1–23	3
March 29	1	0–4	0–5	[2] 0	0–1	0–1	1
May 6–12	58	32–84	0–208	29	12–47	0–214	44
June 1–3	120	82–157	0–299	80	49–112	0–326	100
June 25–29	142	98–186	4–409	231	177–286	3–541	186
August 2–4	99	61–138	3–325	144	75–212	0–776	122
August 30–September 1	40	26–52	1–123	92	52–132	0–469	66
September 22–24	22	15–29	1–83	68	45–92	0–218	45
October 25–27	19	13–26	0–71	30	18–41	0–137	25
December 6–8	8	3–12	0–51	2	1–2	0–6	5

[1] 30 trawl-hauls were made at each station on each visit, with the following exceptions (number of hauls in parentheses): Aug. 30–Sept. 6, 1963—station I (15), station II (10); Jan. 12, Mar. 3, and Mar. 29, 1965—each station (5).

[2] Less than 0.5.

abundance, were similar from year to year, I assume that average catch gives a reasonably good estimate of general abundance.

Pinfish young (O-group) and older migrants returning to the estuary began to arrive on the grass flats at both stations in late November and early December. Trawling did not capture young fish in numbers indicative of their actual abundance but seining caught large numbers of them near both stations. The migration continued until the population had reached a maximum by late June. The month that young first appear seems to depend on conditions offshore, because salinity and temperature changes in the estuary show no relation to the time of migration. Progressively fewer fish were captured after June because of natural mortality and emigration.

Pinfish abundance changed from year to year. If catch in August (a month fished in each of 3 years) is used as an indicator of yearly changes in abundance, pinfish were significantly less plentiful in 1964 than in 1963 or 1965. Pinfish were most numerous at station I in 1963 and at station II in 1965. The number of fish caught in the winters of 1963–64 and 1964–65 did not differ from November to February at station I and November through April at station II.

The numbers of fish caught at the two stations at each sampling time were similar, differing significantly only in August and September of each of the 3 years. This period marks the start of migration out of the estuary; significant changes in abundance might, therefore, be expected if the fish left one station earlier than the other.

ATLANTIC CROAKER

Atlantic croakers are one of the dominant fish in the upper Pensacola Estuary. Therefore, I investigated seasonal and annual change in the food, growth, migration, reproduction, and abundance at two locations from August 1963 to December 1965.

FOOD

Atlantic croakers are carnivorous (table 5). The animal food in the present collections included five phyla and numerous species. Vegetation and sediments in some stomachs were probably taken incidentally while fish were capturing animal food.

TABLE 5.—*Percentage of total volume contributed by different items in Atlantic croaker stomachs collected in the upper Pensacola Estuary at stations III and IV in different seasons, 1963–65*

Items in stomachs	Fish length class, season, and number of stomachs [1]								
	<76 mm.				76–173 mm.				All lengths (2,520)
	Spring (488)	Summer (222)	Fall (63)	Winter (230)	Spring (317)	Summer (981)	Fall (162)	Winter (7)	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Arthropods	25.8	3.2	4.1	20.6	26.5	28.0	7.0	8.1	14.3
Mollusks	2.3	3.3	.0	.1	8.4	9.2	1.7	.0	3.5
Annelids	43.4	74.2	92.6	51.6	26.4	40.0	66.9	89.5	61.5
Nemerteans	.6	1.4	.0	.0	.1	.2	.3	.0	.3
Fish	19.9	11.9	.9	27.1	35.1	17.0	17.3	.0	15.9
Vegetation	1.5	1.5	.0	.2	1.8	4.3	4.2	1.3	2.0
Sediments	6.5	4.5	2.4	.4	1.7	1.3	2.6	1.1	2.5

[1] Numbers of stomachs from both stations are shown in parentheses.

Annelids were the major food except in large fish in the spring, when fish were dominant. Pearson (1928), who collected along the Gulf Coast, and Roelofs (1954), on the Atlantic Coast, found that annelids were dominant and that the other foods listed in table 5 were present in the stomachs of young croakers.

Fish were most common in Atlantic croakers over 75 mm. long. At station III, fish were most plentiful in stomachs in the spring and summer. At station IV, fish were most abundant in the winter in croakers less than 76 mm. long and in the spring in croakers over 75 mm.

Arthropods, chiefly crustaceans, were most plentiful in small fish in the winter and spring and in large fish in the spring and summer. The most important crustaceans were copepods, amphipods, isopods, mysids, shrimp, and crabs; larger forms were most common in stomachs of large fish. Insects—mainly tendipedids, dytiscids, and anisopterans—made up 67 percent of the arthropods in stomachs collected at station IV after heavy runoff in the spring.

Mollusks and nemerteans were minor constituents in the stomachs of Atlantic croakers. Mollusks were most plentiful in stomachs of large fish in the spring and summer.

The volume of food in croaker stomachs was greatest in the winter and spring; average for 768 fish under 76 mm. long was 0.02 ml. and for 324 fish over 75 mm. long, 0.04 ml. Food volumes decreased in the summer and fall; for 285 fish less than 76 mm. long the average volume was 0.01 ml. in both summer and fall, and for fish longer than

75 mm., the average was 0.03 ml. in the summer (981 fish) and 0.01 ml. in the fall (162 fish).

AGE AND GROWTH

I determined the age of Atlantic croakers by using length-frequency data. Fish from the two stations were of similar lengths, except for some segregation by size according to salinity (see next paragraph). Length-frequency data for the stations were, therefore, pooled (fig. 3). The data indicated that only 18 of 19,107 croakers (less than 0.1 percent) were in their second year of life.

Scales may be suitable for age determination of Atlantic croakers from the study area, but this method was unacceptable for Lake Pontchartrain fish (Suttkus, 1955). In the Pensacola Estuary, 6 of 201 Atlantic croakers had what may have been an annulus on their scales. The age of fish as indicated by scales conformed to that indicated by length-frequency data.

Changes in the size distribution of Atlantic croakers within this estuary occur when the larger fish move to areas of higher salinity. A faster growth rate in more saline waters would accentuate this size difference. In June 1964, 620 croakers averaged 70 mm. at station IV, and 1,290 averaged 76 mm. long at station III; in collections 8 and 12 miles below station III, 283 fish averaged about 94 mm. Length differences were still apparent in July. Average lengths were 90 mm. at station IV (149 fish), 91 mm. at station III (742 fish), and 98 mm. 12 miles below station III (155 fish).

The average size of Atlantic croakers varied during the different years (table 6) as a result of differences in hatching time and growth rate. In 1965, fish arrived in the estuary earlier than in 1964;

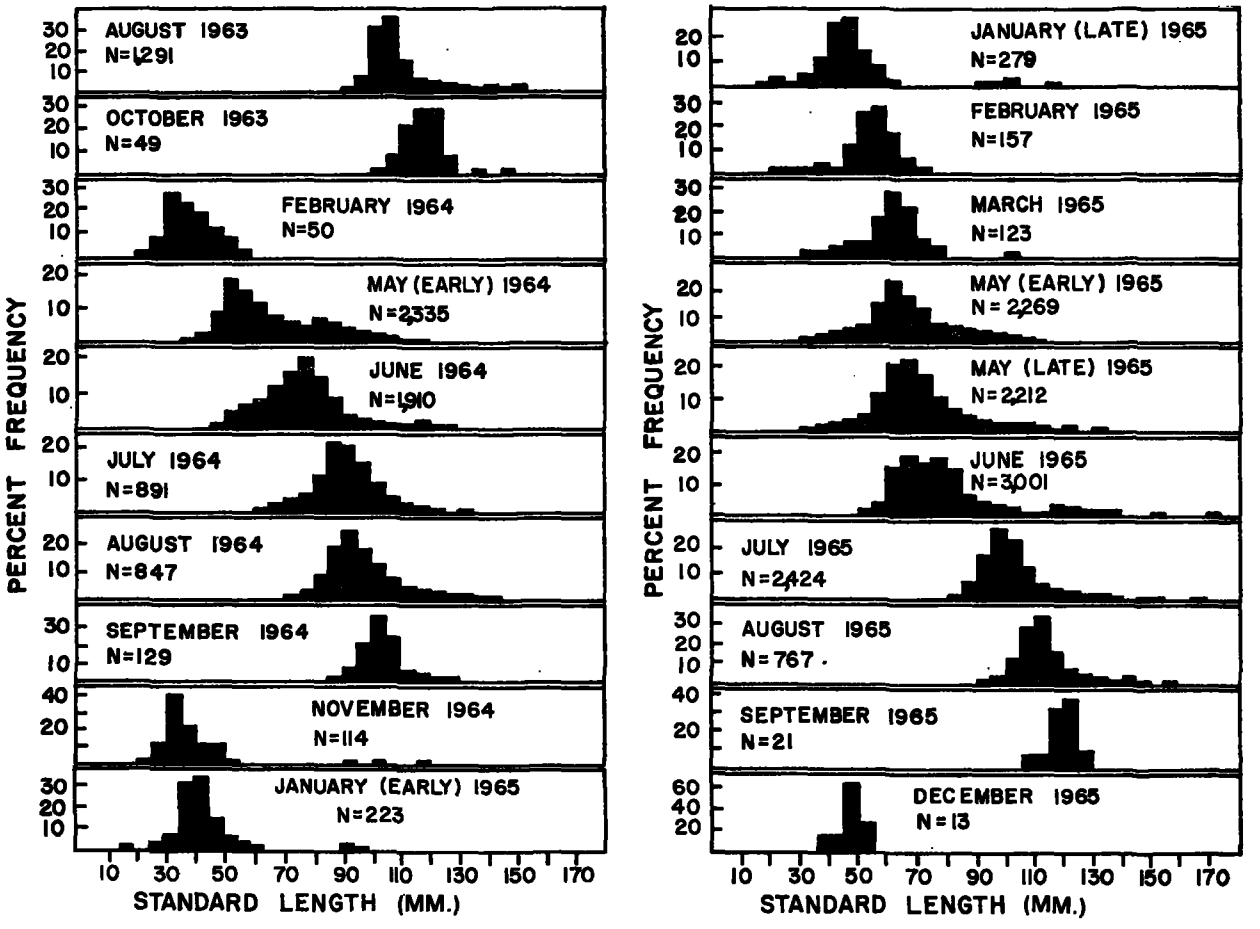

FIGURE 3.—Length-frequency distribution of Atlantic croakers caught in the upper Pensacola Estuary at stations III and IV, 1963–65.

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TABLE 6.—*Standard lengths of Atlantic croakers of age-groups O and I in the upper Pensacola Estuary at stations III and IV, 1963–65*

Date	Age-group O			Age-group I		
		Length			Length	
	Fish	Average	Range	Fish	Average	Range
1963	*Number*	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*
August 22–29	1,291	107	91–152	0		
October 21–24	49	117	103–146	0		
1964						
January 6–14	2	32	24– 40	0		
February 24–27	50	38	20– 55	0		
May 5–11	2,335	65	35–117	0		
June 22–25	1,909	75	45–128	1	166	
July 27–30	891	91	61–131	0		
August 24–27	847	94	70–140	0		
September 21–24	139	102	86–125	0		
October 26–29	0			0		
December 8–10	111	35	24– 50	3	105	94–118
1965						
January 5–7	220	41	17– 60	3	93	91– 96
January 26–28	274	45	15– 64	5	102	94–118
February 23–March 2	157	54	21– 74	0		
March 23–31	122	61	30– 79	1	112	
May 3–7	2,269	67	34–113	0		
May 25–28	2,211	68	34–123	1	132	
June 21–24	2,999	74	51–136	2	163	153–173
July 26–30	2,422	99	68–151	2	164	161–168
August 24–27	767	111	93–155	0		
September 20–21	21	118	106–129	0		
December 1–2	13	47	38– 53	0		

therefore, they were larger in the winter, and from January through August grew at a faster rate (0.30 mm. per day in 1964, 0.36 mm. per day in 1965) so that in August they averaged 17 mm. longer than in 1964. Growth was greatest in the spring in 1964 and in the summer in 1965, and maximum growth was in July in both years (0.60 mm. per day).

MIGRATION AND REPRODUCTION

Migrations of Atlantic croakers are extensive. In December and January the young begin to enter the estuary from spawning grounds in the Gulf of Mexico and move to areas of low salinity. Haven (1957) noted that these fish move up the estuary in the salt-water "wedge" near the bottom. Two days of trawling (February 10–11, 1964) at all depths near the mouth of the Pensacola Estuary, however, caught no young croakers.

Atlantic croakers of age-group O appeared earlier and were more abundant at station IV in the years when estuarine water temperatures were relatively high in November and December. The average temperatures in November–December were: 1963—14.0° C., 1965—16.4° C., and 1964—19.2° C. In the winter of 1963–64 the first young-of-the-year croakers were caught in early January. In the winter of 1964–65 and 1965–66 they appeared in late November and early December (in the greater numbers in the winter of 1964–65). Young fish appeared first and in greatest abundance in areas of low salinity (station IV). They moved to areas of higher salinity as they grew and appeared in the lower estuary (stations I and II) in late spring. Fish caught at stations I and II were never as small as fish captured in the upper estuary near the beginning of the fry migrations.

Of 5,269 fin-clipped Atlantic croakers only 6 (0.1 percent) were recaptured, and only 2 of these had been marked at least 1 month before recapture. None had left the area of marking.

The migration of Atlantic croakers out of the estuary begins in late summer and ends before November. All fish probably leave the estuary; no croakers have been captured after the period of gulfward migration until the newly hatched fish enter the estuary.

Pearson (1928), Suttkus (1955), and Roithmayr (1965) found that, along the Gulf Coast, Atlantic croakers spawn at the end of their second year of life. In the Pensacola Estuary, most croakers had developing gonads in the fall of their first year of life. Most females and males examined had well-developed gonads (stage 2 or 3 of Homans and Vladykov, 1954). Although it is possible that the developing eggs are retained, these croakers may spawn in their first year of life.

Ovaries of 18 croakers, 101 to 145 mm. long,

caught in the fall of 1963, near the end of their first year of life, had an average of 41,200 eggs. The diameter of eggs was 0.02 to 0.72 mm. and averaged 0.34 mm. Hildebrand and Cable (1930) indicated that a mature egg probably has a diameter less than 1 mm. The eggs in the large yellow ovaries had fat globules.

ABUNDANCE AT THE SAMPLING STATIONS

Atlantic croakers are most abundant in low-salinity areas in the Pensacola Estuary. Young (O-group) enter the estuary in the winter and spring and move out in the fall. Fish in the estuary are rarely more than 10 months old.

Monthly changes in abundance (table 7) are caused primarily by migrations and, to a lesser extent, by natural mortality. In the winter young croakers move rapidly from the Gulf to the upper estuary; catches were largest at the station of lowest salinity. The number of fish increases to a maximum in May or June. Yearly differences in abundance were small at station III but croakers were most numerous at station IV in 1965.

SUMMARY

Life histories of pinfish and Atlantic croaker in the Pensacola Estuary were studied from August 1963 to December 1965. Their food, growth, age composition, migrations, reproduction, and abundance were studied from fish collected at intervals of about 1 month for 2½ years. Each species was sampled 22 times at each of two stations.

Feeding, migrations, and other aspects of the biology of pinfish from the Pensacola Estuary change seasonally. They spawn in the Gulf of Mexico in winter. Young and adults enter the estuary in the winter and spring where they congregate on grass flats and feed primarily on animals—crustaceans, polychaetes, and chordates—and attain maximum abundance in June. From June until the fall migration pinfish apparently move only short distances over the grass flats and are primarily herbivores. The amount of food in the stomachs is at its highest level at this time. The gonads of all fish except the smaller ones in their first year of life begin to develop in the fall; ovaries contain about 22,000 developing eggs. The maturing pinfish school and leave the estuary in the fall. Food of the remaining fish includes fewer plants, and the amount of food in their stomachs decreases. Usually pinfish form the first annulus on their scales in April of their second year of life.

The life history of Atlantic croakers from this area is similar to that of pinfish. Croakers spawn in the Gulf of Mexico in the late fall and winter,

TABLE 7.—*Atlantic croakers caught per 30-minute trawl-haul in the upper Pensacola Estuary at stations III and IV, 1963–65*[1]

Date	Station III			Station IV			Average both stations
	Average	Confidence interval 95%	Range	Average	Confidence interval 95%	Range	
1963	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
August 22–29	107	63–150	25–229	22	18– 27	11– 34	64
October 21–24	3	2– 5	0– 8	2	1– 2	1– 2	2
1964							
January 6–14	[2]0	[2]0– 0	0– 1	[2]0	[2]0– 0	0– 1	[2]0
February 24–27	0			5	0– 10	0– 16	2
May 5–11	280	218–342	202–463	9	7– 12	5– 16	144
June 22–25	228	81–375	11–527	62	37– 87	19–100	145
July 27–30	74	54– 94	27–110	13	9– 21	5– 26	44
August 24–27	48	21– 74	1–134	41	28– 54	13– 74	44
September 21–24	11	3– 18	1– 26	2	1– 4	0– 7	6
October 26–29	0			0			0
December 8–10	0			11	1– 22	0– 38	8
1965							
January 5–7	1	0– 5	0– 3	22	8– 36	3– 66	17
January 26–28	1	0– 1	0– 1	28	6– 50	0– 77	20
February 23–March 2	2	0– 4	1– 3	15	0– 33	0– 83	12
March 22–31	6	3– 8	2– 14	6	1– 12	0– 26	6
May 3–7	85	43–127	3–172	174	128–220	89–320	130
May 25–28	102	80–124	67–172	495	349–642	135–801	298
June 21–24	221	145–297	67–436	332	284–380	239–408	276
July 26–30	93	17–170	1–378	149	87–212	76–353	121
August 24–27	27	18– 36	10– 47	50	35– 65	17– 85	38
September 20–21	4	0– 8	0– 8	0			2
December 1–2	0			3	0– 10	0– 13	2

[1] 10 trawl-hauls were made at each station per month with the following exceptions (number of hauls in parentheses): Station III, 1964—Dec. 8–10 (3); 1965—Jan. 6 (3), Jan. 28 (4), Mar. 2 (3), Sept. 21 (5), and Dec. 2 (2); Station IV, 1965—Sept. 20 (5), and Dec. 1–2 (5).

[2] Less than 0.5.

and the young move rapidly to the upper estuary; adults rarely reenter the estuary. The young arrive earlier and are more abundant in the winter of years of high water temperatures in November and December but maximum abundance, reached in May or June, seems to be unrelated to water temperatures. The volume of food in the stomachs of croakers is greatest during the first few months after their arrival in the upper estuary. While in the estuary they feed primarily on animals; polychaetes are the dominant food of all sizes of fish. Mollusks, large crustaceans, and fish are eaten in greater amounts as croakers become larger. As croakers grow, the larger individuals move down the estuary causing a stratification by size along the salinity gradient. Migration to the Gulf and gonadal development begin in the late summer and fall. Ovaries of fish in their first year of life contain about 40,000 eggs.

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