Estimate of Growth Rate and Length of Stay in a Marsh Nursery of Juvenile Atlantic Croaker, Micropogon undulatus (Linnaeus), "Sandblasted" with Fluorescent Pigments[1]

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ABSTRACT

Atlantic croaker constitute over half the industrial bottomfish landings from the Gulf of Mexico. Most length frequency studies indicate their mean standard length at 1 year of age does not exceed 130 mm but two recent papers dispute this.

Project objectives were to determine juvenile croaker growth rates in the marsh and how long they remain there. About 90,000 croaker, from 10 to 40 mm standard length, were "sandblasted" with fluorescent pigment, and released, as they entered a marsh nursery. Recapture attempts were by trawling in the nursery and trapping at the outlet.

Sixty definitely marked croaker were recaptured. These meager returns suggest individual croaker remain in the marsh only 1 to 4 months and grow about 14 mm per month. Croaker in industrial bottomfish landings generally range from 80 to 160mm; thus most may be less than 12 months old. Also, turnover rate of croaker using the marsh may be high enough to make the industry dependent on maintenance of a viable marsh nursery.

INTRODUCTION

The Louisiana Cooperative Fishery Unit has carried on ecological studies of both fresh and salt water fishes and crustaceans since its inception in 1963. In the past 10 years, Unit-supported studies of estuarine-dependent fishes and crustaceans have resulted in at least 20 scientific publications and M.S. theses. Much of this work has been in shallow, brackish marsh areas rather than in the open-water bay and nearshore areas more commonly studied. These marshes are an aquatic environment that has received scant study by fishery scientists until recently.

It might be expected that some new hypotheses concerning fishery biology would be formulated as a result of the Unit's experience in a hitherto neglected environment. This occurred when Herke (1971) concluded that his

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work in the marsh indicated some serious errors in previous beliefs concerning the life history of several species, and that much previous biological work should be re-evaluated from a new viewpoint. A number of interrelated hypotheses were advanced by Herke (1971); these were too numerous to begin testing simultaneously in a single study, so it was decided that certain "key" hypotheses should be tested first. Since the various hypotheses were interrelated, proof or disproof of these key hypotheses would tend to support or weaken the remaining ones.

Two of the key hypotheses were (1) juveniles of several fish species found along the Northern Gulf of Mexico grow at a much faster rate than past studies indicate, and (2) juveniles of these species respond (by emigration) to the interaction of seemingly minor changes in environmental factors. Our paper today describes a preliminary test of the first hypothesis but also utilizes some of the information gathered in a test of the second.

Our objectives in this study were to determine juvenile Atlantic croaker, *Micropogon undulatus,* growth rates in the marsh and how long they remained there.

The croaker was the species selected for use in testing the two key hypotheses because (1) much of the reasoning upon which the hypotheses were based was developed through analysis of croaker data, (2) there are many previous croaker studies available for comparison, (3) juvenile croaker are abundant and easily obtained and (4) croaker in our area constitute more than half of the industrial bottomfish landings (Roithmayr, 1965a, b).

Atlantic croaker growth rates have previously been determined mostly by length frequency data taken from trawl and seine samples. Interpretation of these data may be confounded as a result of emigration of the larger juveniles from inland bays and estuaries toward the ocean (Nelson, 1969; Herke, 1971). Most studies in the Gulf of Mexico region indicate croaker grow to standard lengths of about 80 to 130 mm during their first year of life. However, Avault, et al. (1969) noted a mean length of 172 mm for their pond-reared croaker and Herke felt a modal length of 200 mm 12 months after hatching was a conservative estimate.

Little success has been noted regarding the tagging, marking or finclipping of croaker. Haven (1957) and Hansen (1970) had poor recapture success after clipping croaker pelvic fins. Modest success was recorded with disc tags (Wallace, 1941) and Petersen tags (Haven, 1959) on croaker. Latapie (1968) evaluated five types of tags on croaker and found extremely poor retention after 5 months. The primary purpose of most previous studies was to determine croaker movement.

Jackson (1959) developed a marking system using a sandblast gun to embed fluorescent pigment granules under fish epidermis. Phinney (1966) further refined this marking system with his salmonid work. Survival and growth of centrarchids after use of Jackson's system were said to be normal (Ware, 1968). Andrews (1972) found cyprinid movement and behavior apparently unaffected after application of fluorescent pigments. He also noted extremely low marking and handling mortalities. Hennick and Tyler (1970) tested sandblasted fluorescent pigments on emergent salmon fry and found mortalities to differ significantly with various marking pressures, the lowest pressure being safest with little noted sacrifice of pigment retention.

STUDY AREA

The study area was in a coastal marsh at Rockefeller Wildlife Refuge, Grand Chenier, Louisiana. Approximately 2,000 hectares of marsh were encompassed by man-made levees and a natural beach ridge (Fig. 1). A single channel normally controlled tidal movements inland from two water control structures (weirs). These weirs were constructed to maintain water levels in the marsh, primarily to enhance vegetative growth for waterfowl utilization. Only rarely were marsh levels so low that the weirs actually stopped water movements. Since weir crests were about 15 cm below the marsh ground surface, daily high tides usually exceeded crest level. However, especially in winter, there was a tendency for weirs to maintain high water levels inland from them. Therefore high tides in some cases did not result in inflow.

Several extremely high non-storm tides flowed directly over the beach ridge and levee into the marsh during the study. These unusual tides were the major exception to the channel's role as sole regulator of tidal exchanges; levee leaks played a minor role in tidal exchange.

Wiregrass, *Spartina patens,* was the dominant emergent plant species in this marsh. Also present were oystergrass, *Spartina alterniflora;* saltmarsh grass, *Distichlis spicata;* sea oxeye, *Borrichia frutescens;* hogcane, *Spartina cynosu-*

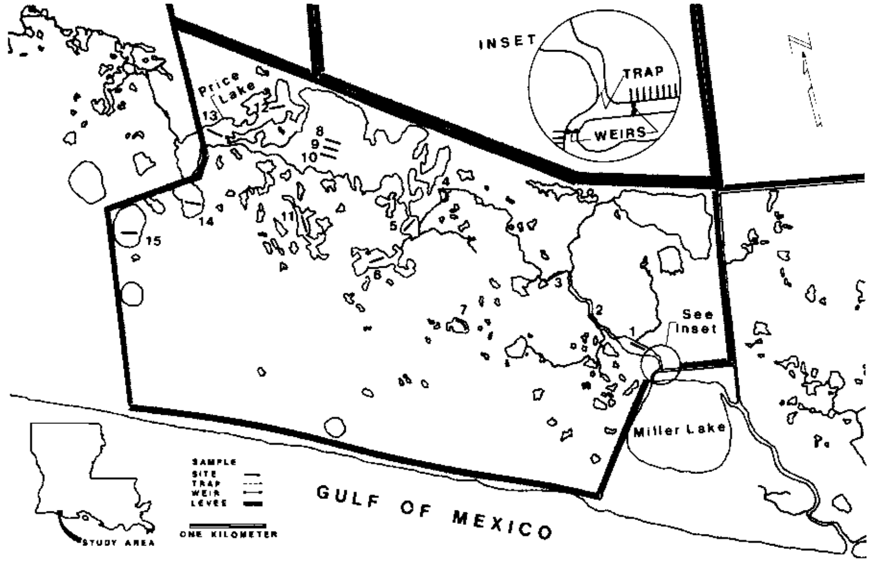

Fig. 1. Trap and trawl sites in the study area.

roides; roseau cane, *Phragmites communis;* leafy three-cornered grass, *Scirpus robustus;* and spikerush, *Juncus* sp.

Fifteen 200-m otter trawl sample sites were established in the study area. Station 1 was located nearest the Gulf in a wide, shallow section of the tidal channel. Stations 2 and 3 were located in narrower and deeper portions of the tidal channel. These three stations were in the passageway by which fish entered and exited the marsh. The tidal channel upstream to Station 3 was at least 6-7 m wide and about 60 cm deep. Soon after passing Station 3, the channel narrowed to approximately 2-3 m and was about 40 cm deep. It meandered for nearly 2 km before reaching the small pond containing Station 4. Beyond Station 4, the remaining stations were located in large lakes. These were generally shallow and of uniform depth. For instance, Stations 8, 9, and 10 averaged about 52 cm deep throughout the study period; water level fluctuations at these three stations resulted in a range from 36 to 78 cm. Although Figure 1 shows the relatively permanent bodies of water, a number of smaller, shallower ponds are not included. During drier parts of the study period some of these ponds, as well as Stations 6, 7 and 11, either dried up or became isolated from tidal exchange following water level declines.

MATERIALS AND METHODS

Galvanized hardware cloth (6.2 mm mesh) deflecting screens were placed diagonally across the tidal channel and fish traps were installed at both ends of the screen system. A removable trap box was installed at the incoming end while a permanent trap was operated at the outgoing end (Fig. 2). These traps were designed to catch immigrating and emigrating fishes, respectively.

The incoming trap was kept in place only during marking periods so organisms could immigrate past the trap system at all other times. High numbers of postlarval and juvenile croaker could be collected at this trap during most winter incoming tides. Tidal movements over the weirs were unpredictable and sporadic, however, so the number of croaker available for marking with any particular color varied considerably. Few croaker were trapped during days when no incoming tides were noted. The outgoing trap was not installed until all marking was completed.

On days when large numbers of croaker were captured in the incoming trap, they were placed into floating minnow graders (Crescent Mfg. Co., Ft. Worth, TX), and sorted to obtain a desirable marking-size range. Grader grill sizes were picked before each marking period to accommodate the most abundant size class of croaker. The sorter system primarily eliminated extreme sizes from each "wave" of incoming croaker.

Fish grading was a relatively simple matter during the first three marking periods (blue, red, and green), since immigrating croaker size was uniform and small. Fish were removed from the incoming trap and placed into a single minnow grader held inside a larger floating basket of 3.2 mm mesh. Croaker (and other trapped species) then attempted to swim through both the grader grill and the holding basket mesh. Those fish which exited the minnow grader but could

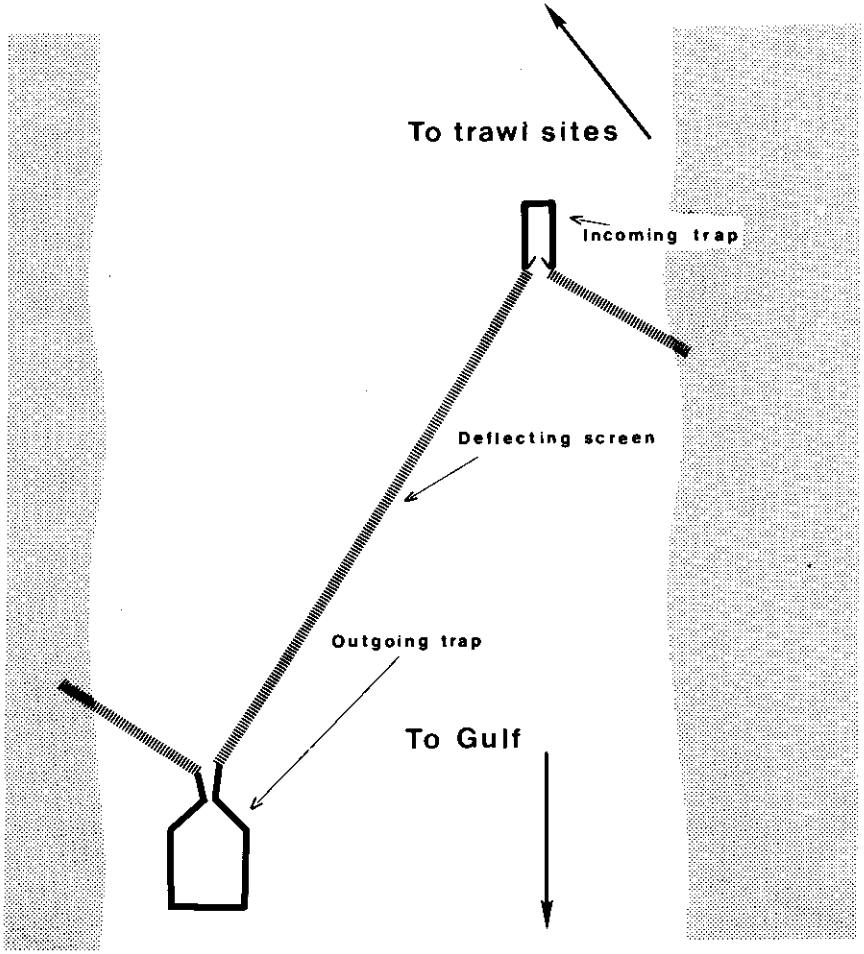

Fig. 2. Trap system. Incoming trap was installed only during marking periods.

not penetrate the holding basket mesh were an "ideal" marking size (i.e., within a 10-mm length range).

The croaker separation process for the last three colors (yellow, orange and pink) required an extra step because of greater croaker size variation during those marking periods. Fish captured in the incoming trap were first placed into a grader free-floating in the channel. Fish not able to pass through this grader grill after 15 minutes were then placed into a second grader having a slightly greater grill width. This grader floated inside the 3.2 mm mesh holding basket. Croaker not able to swim through the grill openings of the second grader were released into the channel. The croaker remaining in the holding basket were a suitable length for marking.

Croaker were marked with fluorescent pigments (Jeffrey mill grind, Day-Glo Corp., Cleveland, OH) which were embedded under the epidermis with a sandblast at 70-95 lb/in^2. A frame covered with polyethylene insect screen was folded over the fish to hold them while they were marked on both sides. Croaker were released into incoming tides after approximate numbers were noted.

Several samples were taken each day during a marking period. These were combined to determine the size range and median length of fish marked during that period. Table 1 includes marking size ranges (all in standard lengths, as are all other fish measurements in this paper unless otherwise noted), grader grill clearances used for croaker sorting, marking pressures and approximate total numbers marked for each particular color.

Mortality and/or retention tests were performed while blue, red, green and yellow pigments were being applied. During these tests croaker were held either in styrofoam containers or in channel-held floating hardware cloth baskets. Croaker kept in these containers were checked for survival at 12 or 24 hour intervals for as long as 7 days. After termination of these test periods those fish still alive were preserved in 10% formalin and later searched for fluorescent pigments.

In addition to those marked with fluorescent pigments, 894 croaker from 33 to 100 mm long were marked with tiny plastic tags (Floy Tag, FTF-69 Fingerling Tag) and released in 4 areas: incoming trap (Fig. 2), plus trawl stations 5, 12 and 14 (Fig. 1).

After marking was completed the outgoing trap was checked daily for emigrating croaker. All recaptured fish were placed under a long-wave ultraviolet lamp and searched for fluorescent pigments. Those fish which retained detectable pigments were measured to the nearest mm and preserved in 10% formalin. Growth rates were computed by linear regression methods using the Julian calendar date of each croaker recapture as the independent variable and the length of that croaker at recapture as the dependent variable. Time-lengths spent in the marsh were calculated by comparing recapture dates with the date of the appropriate marking period.

Croaker taken in the otter trawl samples were preserved and later examined under an ultraviolet light. With few exceptions, samples were taken weekly between 9 December 1972 and 3 August 1973. An airboat was used to pull a trawl having a mouth about 7 m wide and bar mesh of about 15 mm. The posterior of the trawl was fitted with an exterior sock of 3.4 m mouth circumference and 3.2 mm knitted nylon mesh effective on croaker as small as 10 mm.

RESULTS

A total of 60 previously marked croaker were recaptured at 5 different sites; incoming trap, outgoing trap, and trawl Stations 1, 2, and 3. The three trawl sites were about 0.5, 1.0 and 1.8 km up the channel from the traps. Croaker were occasionally found at these sites less than 48 hours after they were marked in the trap area. Several pigment-impregnated croaker were recaptured 4 months after marking completion. Table 2 gives a breakdown of croaker size at time and

Table 1. Marking Period Information. Length Ranges (overall and 95%) and Median Lengths Were Determined after the Sorting Process

Color	Marking period	Length in millimeters: Overall range	95% range*	Median§	Grader bar clearance (mm)	Spray pressure (lb/in^2)	Total marked
Blue	11–12 Nov	12–18 (n=30)	12–17	14	4.06	70	2,125
Red	18 Dec	9–22 (n=363)	10–14	12	4.06	70	32,400
Green	4–5 Jan	12–24 (n=274)	13–21	16	4.32	75	24,600
Yellow	13–19 Feb	14–33 (n=536)	17–27	22	4.06 & 5.59#	85	17,400
Orange	28 Feb–4 Mar	26–48 (n=138)	31–44	37	5.59 & 7.11#	95	5,550
Pink	13–19 Mar	24–44 (n=351)	27–40	33	5.59 & 6.86#	90	9,650

*95% of all the croaker in the samples taken during a marking period were within this range.

§Median of overall length range.

#Two graders used in separation process.

Table 2. Recapture Data from the Five Recovery Sites

Date	Color	Size (mm)	Station	Date	Color	Size (mm)	Station
Jan				Apr			
6	Green	16,16,16,16,17,18,20	#1	1	Pink	44	Out. trap
6	Green	14	#3	7	Red	62	Out. trap
17	Red	26	In. trap	14	Pink	38	Out. trap
25	Green	22	#2	16	Red	67	Out. trap
Feb				26	Red	58	#1
8	Red	28	In. trap	29	Pink	63	Out. trap
8	Green	25	In. trap	May			
Mar				2	Yellow	48	Out. trap
1	Yellow	27,28,31	#1	9	Yellow	63	Out. trap
1	Yellow	29,33,37	#2	15	Yellow	67	Out. trap
5	Yellow	43	In. trap	15	Pink	66	Out. trap
5	Orange	26,26,29	In. trap	16	Yellow	73,77	Out. trap
9	Yellow	48	In. trap	17	Pink	67	Out. trap
15	Yellow	38	#1	18	Pink	54,55	#1
15	Pink	29,33	#1	19	Yellow	66	Out. trap
15	Yellow	29,30,31,33,33	#2	24	Pink	63	Out. trap
15	Pink	34,34	#2	Jun			
15	Yellow	34	#3	8	Yellow	88	Out. trap
15	Pink	30,31,33	#3	12	Yellow	77	Out. trap
19	Orange	30	In. trap	14	Yellow	77,83	Out. trap
23	Yellow	50	#3				

place of recapture. The most successful pigment was yellow, with 26 returns, followed by pink (15), red (5), green (10, but only 2 after 48 hours), orange (4) and blue (0).

Yellow fluorescent pigment was sandblasted onto approximately 17,000 croaker from 13 through 19 February. Yellow-marked croaker growth rates (as well as all other growth rates plotted) were analyzed as linear because low return rates and the short recovery period tended to obscure any possible curvilinear relationship between growth and time. The regression equation for yellow-marked croaker ($Y=0.4878X + 1.29$; $r^2=0.90$) indicates a growth rate of 0.49 mm/day and nearly 15 mm/month for croaker entering the marsh in mid-February (Fig. 3A). The initial recovery was by otter trawl on 1 March, when 6 yellow-marked croaker were found. The 10 "yellow" croaker recovered in May and June were all taken in the outgoing trap. The final recovery date for this color was 14 June, suggesting a maximum nursery utilization period of 4 months.

Roughly 9,000 croaker were marked with pink flourescent pigment from 13 through 19 March (Table 1). Fewer recoveries (15) were made with this color than yellow. Of these 15 recoveries, 7 were trawled within 48 hours of the marking period. For the eight later recoveries, the regression equation for pink-marked croaker ($Y=0.4155X + 4.00$; $r^2=0.56$) indicates that croaker entering the

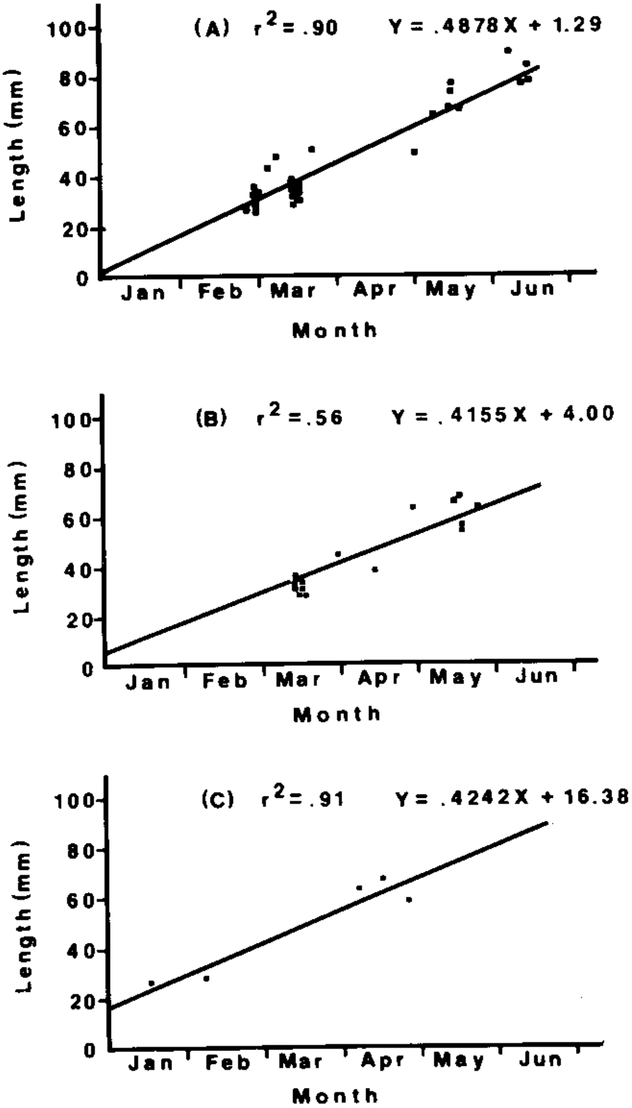

Fig. 3. Growth rates calculated from croaker bearing (A) yellow, (B) pink and (C) red fluorescent pigments.

marsh in mid-March grew about 0.42 mm/day or 12.6 mm/month (Fig. 3B). Recapture of emigrating croaker at the outgoing trap indicated a nursery period of 1-2 months.

Only 5 of the approximately 33,000 croaker marked with red pigment were recovered. Their small marking size (median = 12 mm) during the 8-hour marking period of 18 December may have contributed to this low return rate. The regression equation ($Y=0.4242X + 16.38$; $r^2=0.91$) for these sparse returns suggests a growth rate of 0.42 mm/day or 12.6 mm/month (Fig. 3C). "Red" croaker were recaptured from 17 January to 26 April; a maximum nursery period of 4.3 months is suggested by these returns.

An intergroup regression analysis was performed on yellow, pink and red returns. The pooled regression equation became $Y=0.4741X + 3.97$, indicating that croaker growth from December 1972 to June 1973 averaged 0.47 mm/day or 14.2 mm/month. Only Avault, et al. (1969) and Herke (1971) have suggested higher growth rates than those found in this study. Growth rates found by these and other researchers are shown in Table 3.

Approximately 33,000 croaker were sandblasted with the other three colors (green, orange and blue). Because of low return rates, neither growth rates nor nursery periods were calculated for croaker marked with these three pigments. About 25,000 croaker received green pigments on 4 and 5 January, but only 2 green recoveries were made after 6 January. About 6,000 croaker were marked with orange pigment from 28 February to 4 March. The increase of spraying pressure to 95 lb/in^2 seemed to stress croaker considerably. Many were belly-up and alive after 24 hours but dead after 48 hours. Only 4 orange-marked croaker were recaptured; all were taken within 14 days of the last marking date for that color. Andrews (1972) stated that blue fluorescent pigment is difficult to detect under an ultraviolet light. For this reason it was decided to use blue pigment through the initial marking period of 11 and 12 November; during this time methods for separating and marking large numbers of fish were being tested. Only 2,000 fish were marked with blue pigment and none were recovered. Also, none of the 894 croaker marked with FTF-69 plastic tags were recaptured.

Trawling was continued through 3 August, although few croaker were captured after 29 June. The outgoing trap was operated daily through mid-July; recovery efforts there were discontinued when trawl catches indicated the vast majority of croaker had migrated seaward.

DISCUSSION

Relatively few croaker were trawled at inland stations 4-15 compared to channel stations 1-3 during almost any given week, especially prior to early March. Therefore few previously-marked croaker could have been expected from the non-channel stations, as the rate of pigmented fish recapture was approximately 1 fish per 2,000 examined at sites which yielded returns. Otter trawls performed at the channel stations may have captured relatively larger numbers of croaker because the "dilution effect" of the larger inland marsh lakes made fish at stations 4-15 much less susceptible to capture.

Another reason for the apparently low utilization of marsh stations 4-15 by croaker may have been the nature of the 7-km system of waterways, weired tidal channels and rivulets connecting the Gulf with the inland lakes. Possibly croaker migrations were stymied by strong tidal currents in these channels, and instead of directly proceeding deep into the marsh they simply maintained themselves in these channels for a period of time. Data from the incoming trap suggests that

Table 3. First Year Croaker Growth Rates from Previous Research Efforts Prorated to Monthly and Daily Growth Increments in Millimeters. Except for Herke (1971) and Hoese (1973) all Previous Estimates Were Originally Given as Total Length/Year

Study	Area	Total length per year	Standard length (TL x 0.8)/year	SL growth per month	SL growth per day
Welsh and Breder (1923)	New Jersey and Cape Canaveral Bight, FL	150	120	10	0.33
Higgins and Pearson (1928)	Pamlico Sound, NC	180	144	12	0.40
Pearson (1929)	Texas	150	120	10	0.33
Hildebrand and Cable (1930)	Beaufort, NC	143.4	114.7	9.6	0.32
Suttkus (1955)	Lake Pontchartrain, LA				
	1953	145.5	116.4	9.7	0.32
	1954	104.7	83.8	7.0	0.23
Haven (1957)	Virginia	175-180	140-144	11.7-12.0	0.39-0.40
Roithmayr (1965a)	Northern Gulf	120	96	8.0	0.27
Avault, et al. (1969)	Grand Chenier, LA (pond)	215	172	14.3	0.48
Nelson (1969)	Mobile Bay, AL	117	93.6	7.8	0.26
Hansen (1970)	Pensacola, FL				
	1964	108.0	86.4	7.2	0.24
	1965	129.6	103.7	8.6	0.29
Herke (1971)	Louisiana marsh	—	200	16.7	0.56
Parker (1971)	Lake Borgne, LA	162.9	130.3	10.8	0.36
	Galveston Bay, TX				
	1963-64	140.9	112.7	9.4	0.31
	1964-65	143.2	114.5	9.5	0.32
Wagner (1973)	Caminada Bay, LA	140-150	112-120	9.3-10.0	0.31-0.33
Hoese (1973)	Georgia	—	150	12.5	0.42
This investigation	Grand Chenier, LA	—	—	14.1	0.47

croaker either may have followed tidal movements up and down the channels or remained channel residents. Biweekly samples taken at this trap during the study period included nine marked croaker attempting to reenter the marsh. Several of these fish had been marked at the trap area 2 months prior to recapture (Table 2).

Several reasons could account for the low return rate (60 out of about 90,000) of fluorescent-marked croaker. High mortality rates, whether marking-induced, marking-related or natural, may have decimated large numbers of fish. Post-marking mortalities were noted after use of blue, red, green and yellow pigments. Mortalities were notably higher than those discussed in Ware (1968) or Phinney and Matthews (1969). Blue-marked croaker suffered 25% mortalities at 24 hours (n=30) red 10.5% at 24 hours (n=84), green 3.6% at 12 hours (n=274), yellow 19.4% at 48 hours (one basket, n=67) and 5.5% at 7 days (another holding basket, n=241). Strong currents during orange and pink pigment application periods ruined mortality tests for those two colors.

Retention of fluorescent pigments by croaker may have been low, thus reducing the recovery rate. Retention checks made after 48 hours and 7 days (on fish in separate holding facilities) during the yellow marking period yielded percentages of 100 (n=67) and 12.2 (n=241) respectively.

Ware (1968) noted that after 9 months fluorescent marks on bass were reduced to a few widely scattered granules or one or two small clusters. We found a similar reduction of granules after a shorter period (1 week to 4 months); granules on marked croaker were generally confined to the opercular area and to the tissues around the eyes. No appreciable loss of color brilliance was noted with granules retained by croaker for 4 months.

Marking pressures were raised from 85 to 95 lb/in^2 after the yellow 7-day retention check, as it was suspected that low pressures may not have embedded pigment granules properly. Retention rates, however, could not be checked for subsequent colors because of high mortalities for channel-held fish. These high mortalities may have been partially induced by the pressure increase.

Trap system breakdowns were commonplace: blue crabs, *Callinectes sapidus*, frequently tore gaping holes in the outgoing trap; strong incoming tides (especially in April) occasionally pushed over or washed away some deflecting screen sections; tidal flow scoured sediments from below the deflecting screens; after April, an attached phaeophyte weighted down and ruined some screen sections. All of these factors may have allowed significant numbers of marked croaker to escape recapture. Still other croaker probably emigrated directly to the Gulf over the beach ridge during periods of unusually high tides.

In conclusion, our estimate of juvenile croaker growth rate (0.47 mm/day or 14.2 mm/month) is higher than estimates by most previous workers. If this rate were maintained from hatching until age 12 months, length would fall about 30 mm short of Herke's (1971) estimate of 200 mm at 1 year of age. However, our estimate for croaker does support his "key" hypothesis that juveniles of several fish species found along the Northern Gulf of Mexico grow at a much faster rate than past studies indicate. Croaker 80 to 160 mm long are a major component of industrial bottomfish landings (Roithmayr 1965b). If our growth rate estimates are correct, the fishery is dependent on an annual crop.

In addition, it appears that in our study, individual croaker remained in the particular marsh studied for only 1-4 months. This suggests that several croaker "populations" may utilize coastal marshes during the course of the year, because our estimated nursery periods for any particular color were much shorter than the total length of time croaker were observed in the marsh (October through June). Therefore, the marsh nursery may contribute more to the industrial bottomfish fishery than is apparent from samples of the standing crop. Herke (1971) stated that the marsh seems to be the primary nursery for Atlantic croaker; our study supports his statement. The croaker fishery may be dependent on maintenence of a viable marsh nursery.

We recaptured relatively few marked fish, all below 90 mm and taken mostly during the cooler part of the year. Consequently our estimates and conclusions should be considered tentative. The project will be repeated this coming year with assistance from the LSU Sea Grant Program. Experience gained during this past year should help increase our returns of marked fish.

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