THE BIOLOGY, LIFE HISTORY, AND CULTURE OF THE YELLOW MOJARRA *Petenia kraussii* (Pisces, Cichlidae)

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ABSTRACT

THE BIOLOGY, LIFE HISTORY,

AND CULTURE OF THE YELLOW MOJARRA

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By

Richard A. Powers

Many people in Colombia, South America, suffer from malnutrition and protein deficient diets. One possible solution to these problems is an increase in the amount of available fish protein through the development of pond fish culture. Since little is presently known about the fish of Colombia, their biology and life histories must be investigated before they can be used for fish cultural purposes. The objectives of this investigation were to determine the biology and life history of the yellow mojarra (*Petenia kraussii*), a promising fish for pond culture, and to develop some basic pond cultural techniques for it.

Fish for this investigation were collected from the Cienaga de San Cristobal, a lake near San Cristobal, Colombia. Several ponds were also stocked with fingerling fish to determine their growth rate and the effects that different pond environments had on the growth of the fish.

Yellow mojarra are native to much of northern Colombia and occupy the littoral zones of lakes and the margins of streams. Fish and insects are the principal food of yellow

mojarra, although they also ingest plant material, plankton, and bottom sediments. They are not highly selective in their feeding habits and seem to feed on whatever is most readily available and of suitable size. The digestive rate of yellow mojarra is very rapid, about 50% of ingested material being digested within one hour. The regression equations for the total length-weight and total length-standard length relationships were $\text{Log}_{10} Y = -4.6358 + 2.95530 \text{Log}_{10} X$ and $Y = 6.44962 + 1.28698 X$, respectively. The largest yellow mojarra observed was 280 mm long and weighed 423 grams. Female and male yellow mojarra matured between 12 and 17 cm and 10 and 16 cm, respectively. Females did not spawn until they reached 18 cm total length. In captivity, pairs of yellow mojarra spawned at 30-day intervals. The fecundity regression was: $Y = -3471.04104 + 47.53380 X$, where X is the total length. The average number of eggs per female was 6600. Both parents guard the eggs and young. Yellow mojarra are frequently infected by parasites in the viscera and body cavity (a larval nematode) and in the aqueous humor of the eye (metacercariae of a digenetic trematode). Yellow mojarra are heavily preyed upon by insects, birds, reptiles, and other fish at various times in their life cycle.

Yellow mojarra are easily cultured in tanks, aquaria, or ponds. Pairs of sexually ripe fish spawn naturally and guard the eggs and young. The young must be fed zooplankton. Culture in ponds is the only feasible way of producing large numbers of fingerlings. Yellow mojarra stocked in ponds had an average total length of up to 150 mm in three months and 170 mm in six months. However, the presence of floating aquatic weeds in the ponds lowered the growth rate significantly. Floating aquatic weeds lowered the water temperature, the pH, the dissolved oxygen concentration, and the phytoplankton primary productivity of the ponds. Any one or all of these factors could have lowered the growth rates of the fish. The growth of yellow mojarra was enhanced by the presence of prey fish (*Mollienisia* sp.).

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By

Richard Allen Powers

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way contributes to the development of the fisheries resources of Colombia.

TABLE OF CONTENTS

LIST OF TABLES

TABLE		Page

LIST OF FIGURES

GENERAL INTRODUCTION

This thesis is the result of research carried out while I served as a Peace Corps Volunteer in Colombia, South America, from July, 1971 to December, 1972. I served as a fisheries biologist with the Institute for the Development of the Renewable Natural Resources (INDERENA), Ministry of Agriculture, National Government of Colombia, at the Fish-Culture Center near San Cristobal, in northern Colombia. The chief objective of the program at the San Cristobal Center is the investigation of native fish species in their natural environment and for possible use in pond fish-culture. The goal of this program is the production of fish for human consumption to alleviate the chronic shortage of protein which plagues this region.

Few investigations have been carried out on the fish of Colombia and little is known of their biology, life histories, or ecology. Most of the many species present in Colombia reproduce only in rivers during the annual spawning runs. It is difficult to use these river spawning species for pond culture because the proper facilities for induced spawning and propagation of the eggs, fry, and fingerlings are not available.

The yellow mojarra (Petenia kraussii) was selected as a potentially valuable fish-culture species because: 1) it was one of the few species in Colombia which spawned successfully in lakes and ponds, 2) it appeared to have a fast growth rate, and 3) it was accepted by the people as a good eating fish.

The objectives of this study were to investigate the biology and life history of Petenia kraussii and to apply the results of these investigations to the development of basic pond fish-culture methods for this fish. It is hoped that other investigators in Colombia can use the results of this thesis to further develop the pond culture of the yellow mojarra, to manage natural fisheries, and as a basis for conducting similar investigations on other potentially important fish species. It is through these investigations that the tremendous potential of the fresh-water fisheries resources in Colombia can be developed and maintained for the good of all the people.

STUDY AREA

These investigations were conducted in the Departments of Bolivar and Atlantico, in northern Colombia, South America. The San Cristobal Fish Culture Center is located about one kilometer north of the village of San Cristobal, by the Canal de Dique, in the jurisdiction of the town of Soplaviento; Department of Bolivar. San Cristobal is about 53 kilometers east of the city of Cartagena and 83 kilometers southwest of the city of Barranquilla. San Cristobal is about 10° 28' north of the equator and 75° 5' west of the Greenwich Mean Time Line. It is located on the coastal plain of the Caribbean Sea. The mean elevation above sea level is about 20 meters. The climate of this area is tropical and is characterized by two wet and dry seasons per year. During the wet seasons (September-November and March-June), the cloud cover is intense and usually continuous. Rainfall is almost daily and often very heavy. During the dry seasons, little or no rainfall occurs and the weather is usually very clear and extremely hot. The average annual temperature is 28.5 C, with a range of between 20 and 52 C.

BIOLOGY AND LIFE HISTORY

Introduction

Yellow mojarra (*Petenia kraussii*) for this investigation were collected from the Cienaga de San Cristobal. This is a shallow, marshy lake located about one kilometer north of the town of San Cristobal. This lake is very productive and has an average depth of about one to one and one-half meters and an area of about 20 hectares. The lake is enriched by nutrient run-off from surrounding cattle grazing areas. Floating aquatic plants (*Eichornia crassipes*, *Pistia stratiotes*, and *Typha sp*.) are very abundant. The bottom sediments of the lake consist of about 25% sand and 75% organic muds. The open water areas consist mostly of channels and ponds between the huge growths of cattails, mats of *E. crassipes* and *P. stratiotes*, and dead, partially submerged trees. Dense algal blooms are fairly continuous. The lake level varies by one meter or more between the wet and dry seasons. Some physical and chemical parameters of the lake are given in Table 1.

The yellow mojarra in this lake are subjected to heavy fishing pressure from the inhabitants of the nearby village and consistent catches of large fish are common.

TABLE 1. Physical and chemical parameters of the Cienaga de San Cristobal, San Cristobal, Colombia. November 23, 1972.

Parameter	Station 1		Station 2	
Time	6:30 AM	3:30 PM	6:45 AM	3:45 PM
pH	7.7	8.0	7.7	8.3
Secchi disk (cm)	42	40	49	50
Dissolved oxygen (mg/l)	0.16	8.16	0.24	8.16
Temperature (°C)	29.5	33.0	29.5	32.0
Primary productivity (mg O_2/l/day)[1]	9.45			

[1]Phytoplankton primary productivity only.

General Methods

Five hundred twenty yellow mojarra were collected from the Cienaga de San Cristobal by means of a throw net (stretched mesh size of 4.5 cm) from October 10 to October 18, 1972. These fish were taken to the San Cristobal Fisheries Station where they were measured (nearest mm), weighed (nearest gram), and checked for parasites and the state of gonad development. The stomachs and ripe ovaries were removed and preserved in a 5% formalin solution for later study.

Dissolved oxygen determinations were made by the azide modification of the Winkler method (APHA, 1971). Phytoplankton primary productivity was estimated by the light-dark bottle method using a four-hour incubation period and 250 ml BOD bottles suspended 30 cm beneath the surface. Primary productivity, as used in this thesis, refers only to plytoplankton primary productivity. pH was determined by indicator impregnated pH paper.

Taxonomy and Nomenclature

The yellow mojarra, *Petenia kraussii* (Steindachner, 1879), is a member of the subclass Teleostei, order Perciformes and family Cichlidae (Miles, 1947; Lagler *et al.*, 1962). *Cichlosoma kraussii* (Ragan, 1905), *Chromis dentatus* (Guichenot, 1905), and *Cichlosoma kraussii* (Eigenmann, 1922) are synonyms for *Petenia kraussii*. Common mojarra and anzuelera are other common names of yellow mojarra.

Range

The original range of the yellow mojarra was northern Colombia in the Rio Atrato and the Rio Magdalena and its tributaries as far upstream as Puerto Berrio (Miles, 1947). They are also widely distributed in many of the lakes and connecting waters which make up the vast system of interconnecting waterways which characterizes the Magdalena River in its lower reaches.

The yellow mojarra has been stocked in many ponds and lakes in northern Colombia and has also been used experimentally for fish cultural purposes at Manizales, in central Colombia. It is likely that the yellow mojarra has also been introduced into many other warm areas of Colombia by persons interested in fish culture.

The main factors limiting the range of the yellow mojarra would seem to be: 1) access to the Magdalena River system and 2) water temperatures below an annual average temperature range of about 24 to 28 C.

Distribution in the Study Area

P. kraussii inhabit shallow areas along the margins of lakes, around islands and over reefs. They also inhabit slow moving streams, the margins of the larger rivers, and flooded areas and backwaters of these rivers. Yellow mojarra are usually found in areas of emergent or submerged vegetation, flooded brush and trees, and along the edges of floating aquatic plant mats.

The yellow mojarra is commonly found in association with blue mojarra (Aequidens pulcher), moncholo (Hoplias malabaricus), top minnows (Mollienisia sp.), and various small members of the family Characidae.

The local distribution of yellow mojarra is apparently influenced by water depth, availability of suitable habitat, and sufficient food organisms. Within its range, the yellow mojarra is found in practically every sizable body of water.

Description

The genus Petenia is distinguished from the other genera of the family Cichlidae by its prominent canine teeth and an anal fin with five or six spines and eight or nine soft rays (Miles, 1947). Petenia kraussii has a lateral line with 29 or 30 scales, a dorsal fin with 15 or 16 spines and 10 or 11 soft rays, and large prominent black spots located on the bottom part of the opercula, behind the opercula, below the dorsal fin, and on the caudal peduncle (Dahl, 1971).

Adult yellow mojarra are usually bright yellow on the ventral side and dark green dorsally. The actual color tends to vary with the environment from pale yellow to black. They have six to nine vertical black bars which tend to merge and form a dark horizontal line along the lateral line. The mouth is protractile.

Fry assume the adult morphology at about one centimeter. Fingerling fish have nine to twelve vertical black bars, which tend to combine into the usual adult number.

The largest yellow mojarra observed during this study was 280 mm total length and weighed 423 grams.

The sex of sexually mature yellow mojarra can be easily distinguished by the shape and color of the genital palpi and by general body shape and form. The males have genital palpi which are elongated and pointed at the apical end. The male genital palpus is usually whitish-clear with traces of red. However, it is more reddish when the male is ready to spawn. The males are generally heavier and longer than the females, but are less robust.

Female yellow mojarra have genital palpi which are short and rounded at the apical end. When the female is ripe and ready to spawn, the genital palpus becomes very inflammed, red, and swollen. The female body form is generally shorter and thicker than the male, with a robust appearance. Gravid females are easily distinguished by the obvious roundness and fullness of their abdomen.

With practice, the sexes can be easily distinguished by the external sexual characteristics in mature fish. Immature fish of total lengths greater than ten centimeters can be sexed with a high degree of accuracy.

Food and Feeding

Methods

The preserved stomachs of the 520 yellow mojarra collected from the Cienaga de San Cristobal in October of 1972, and of 444 yellow mojarra collected from the same site in January through March of 1972, were examined in the laboratory for stomach contents and volume. The stomachs had been preserved in 50-mm size groups of the fish total lengths. Each stomach was cut open and the contents rinsed into a petri dish. The total volume of the stomach contents was then measured in a graduated cylinder accurate to 0.1 ml. The stomach contents were divided into food types: fish, insects, plankton, plants, and miscellaneous. Estimates were then made of the percentage of the total stomach content volume made up by each food type. Taxonomic distinctions of the individual food items were noted whenever possible.

The feeding behavior and periodicity were noted by making extensive observations of yellow mojarra in the field at all times of the day and by observing and photographing the feeding behavior in aquaria.

An experiment was conducted to find the digestive rate of *P. kraussii*. Thirty fish of total lengths between 188 and 265 mm were captured by hook and line and put in a concrete tank with an area of 20 square meters and a depth of 0.5 meters. These fish were fed every morning for one week with pipones (Mollienisia sp.) about two to three centimeters long. The yellow mojarra were then starved for one day. At 7:25 A.M. the following morning, the fish were fed Mollienisia sp. in excess of what they could consume. Five minutes later, the uneaten Mollienisia sp. were removed. Three yellow mojarra were then removed at intervals of 15 or 30 minutes, their stomachs removed and the contents examined to determine how far advanced the digestive process had progressed.

Results

Fish and insects were the most important food types for all size classes of yellow mojarra (Tables 2 and 3). In the smallest size group of fish (33-49 mm), insects were the only food item found. Fish and insects were present in the stomach contents of many of the larger size groups of P. kraussii. However, with the exception of the 100 to 149-mm size group, fish were present in a larger percentage of the stomachs than were insects. By volume, fish and insects also made up the greatest portion of the stomach contents (Table 3). With the exception of the 100 to 149-mm size group (where fish and insect volumes were equal) and the 150 to 199-mm size group, fish made up a greater percentage of the stomach content volume than did insects. The most common prey fish were pipones (Mollienisia sp.), yellow mojarra fry, and small members of the family Characidae. Diptera (Culicidae and Chironomidae) and

TABLE 2. Mean volumes of stomach contents and mean percentages of each food type found in the stomachs of *Petenia kraussii* collected in the Cienaga de San Cristobal.

Size Group (mm)	Mean volume of stomach contents (ml)	Total number fish	Fish with measurable volume	Fish with trace	% fish with empty stomachs	Mean percentage of stomach volume				
						Fish	Insects	Plankton	Plants	Misc.
33-49*	Trace	28	0	7	75.0		100			
50-99	0.18	84	27	15	50.0	74.5	15.9	0.0	2.4	7.1
100-149	0.37	355	27	10	89.6	20.8	13.6	12.4	36.1	17.1
150-199	0.18	65	7	5	81.5	15.8	28.3	5.0	43.3	7.5
200-249	0.42	368	66	38	71.7	44.5	22.1	1.9	16.7	14.7
>250	0.76	64	17	6	64.1	40.0	18.7	0.4	27.8	13.0

*Most of the fish of this size group were 40-49 mm TL.

TABLE 3. Occurrence of food types in the stomach contents of _Petenia kraussii_ collected in the Cienaga de San Cristobal.

Size group (mm)	Number of fish	Percentage of fish with each food type				
		Fish	Insects	Plankton	Plants	Misc.
33-49	7	0.0	100.0	0.0	0.0	0.0
50-99	42	76.2	21.4	0.0	2.4	7.1
100-149	37	36.8	36.8	18.4	55.3	26.3
150-199	12	41.7	50.0	16.7	75.0	16.7
200-249	104	52.4	35.2	1.9	28.6	23.8
>250	23	47.8	34.8	4.4	43.5	8.7

Odonata (Anisoptera and Zygoptera) were the most common insects found in the stomach contents. Hemiptera and Coleoptera were also found occasionally.

Plankton occurred in a relatively large percentage of the stomach contents only in the 100 to 149-mm and 150 to 199-mm size groups of yellow mojarra. The plankton found in the stomachs consisted primarily of Copepoda and Ostracoda.

Plant material occurred in a large percentage of the stomachs of the yellow mojarra over 100 mm total length. Plants also made up a large portion of the volume of the stomach contents of these fish. Higher plants and algae were found in about equal abundance in the stomach contents.

Miscellaneous food items occurred in many of the stomachs of the yellow mojarra in the larger size groups. Sand and detritus made up a large percentage of the miscellaneous materials found. Many fish had large numbers of eggs of P. kraussii in their stomachs. Several small Hirudinea were also found.

The mean volume of the stomach contents ranged from a trace in the 33 to 49 mm fish to 0.76 ml in the fish over 250 mm long (Table 2). With the exception of the 150 to 199-mm size group, the mean volume of the stomach contents increased as the length of the fish increased. A large number of the fish captured had empty stomachs.

The fry of *P. kraussii* begin feeding on plankton (especially Copepoda) at about two to three days after hatching. The prey is selected by sight and the fry make a quick dash at the prey, extend their protractile mouth, and suck the prey in. Older fry and fingerlings feed primarily on insects which are hunted by sight. At about 50 mm, the fingerlings begin feeding on small fish as well as insects.

The adult fish feed by slowly stalking their prey and then making a quick rush with their mouth extended and suck the prey in. If the prey is near the surface of the water, this feeding action is often accompanied by a loud "slurp" or popping noise. Both adults and young were also observed feeding on the bottom by ingesting large quantities of mud or sand. Usually yellow mojarra feed along the edges of and in openings in the floating aquatic vegetation.

The principal feeding times are in the morning for about two hours after sunrise and in the evening for about one and one-half hours before darkness. These feeding times vary with such factors as the season, light intensity, local weather conditions, and the clarity of the water.

The results of the digestive rate investigation show that the digestive rate is very rapid in *Petenia kraussii* (Table 4). After only 15 minutes, the bodies of the prey fish had begun to be broken up and the skin and scales were largely digested. After 30 minutes, the prey fish were 15-20 percent digested. After one hour, the prey fish were

TABLE 4. Time necessary for Petenia kraussii to digest fish prey (Mollienisia sp.).

Fish no.	TL (mm)	Wt. (g)	No. fish eaten	Vol. (ml)	Water temp. (C)	Time after ingest.	% dig.	General state of stomach contents for time group
1	204	154	2	4.0	29	0:15	10	Heads separated, skin
2	220	207	3	2.2			10	beginning to decompose,
3	225	215	0	-			-	scales gone
4	265	336	4	15.0	30	0:30	15	All scales and skin gone,
5	235	237	3	6.0			20	flesh beginning to
6	223	220	3	6.0			20	decompose
7	228	239	4	5.5	30	1:00	50	Only heads recognizable,
8	213	191	8	6.0			50	bodies broken into many
9	204	164	0	-			-	pieces
10	237	261	3	3.5	30	1:15	60	Unrecognizable, bodies
11	236	262	0	-			-	and heads broken up
12	200	159	2	3.5			60	and decomposed
13	228	236	5	5.5	30	1:30	75	Only fluid in stomach,
14	199	155	5	4.5			75	beginning to pass into
15	200	133	2	1.5			75	intestine
16	236	232	6	6.0	30	1:45	80	Only fluid in stomach,
17	230	237	7	4.5			80	passing into intestines
18	220	206	6	5.0			80	
19	260	328	8	9.0	31	2:00	80	Much already in intestine
20	225	211	4	5.5			80	
21	197	149	3	3.5			80	
22	230	220	6	5.0	31	2:30	80	
23	261	286	6	9.0			80	
24	190	132	1	2.5			80	
25	210	179	6	4.5	31	3:00	90	Majority of digested food
26	235	248	4	7.5			90	in intestine, stomach liquid
27	188	123	4	3.5			90	very soapy
28	250	261	4	6.5	31	3:30	90	
29	218	203	8	4.0			90	
30	192	124	0	-			-	

up to 50 percent digested and only the hard parts of the heads were recognizable. One hour and 15 minutes after ingestion, the prey fish were completely unrecognizable and broken into small, partially digested pieces. One hour and 30 minutes after ingestion, the prey fish were almost completely decomposed and liquid material had begun passing into the intestine.

Water temperature during this experiment varied from 29 to 31 C.

Discussion

The principal food items of yellow mojarra are fish and insects. The smaller yellow mojarra (33-49 mm) feed more heavily on insects, while the larger fish feed on both fish and insects in about equal portions. The fact that yellow mojarra feed on their own eggs and fry may be important to their ecology and population dynamics. This author observed no instances of stunted natural populations of yellow mojarra. It is possible that the cannibalistic nature of yellow mojarra serves as a means of controlling its own population. It is likely that a dense population of yellow mojarra would feed very heavily on their own eggs and young and would have a large negative effect on the survival of those young. The survival of the young may well be inversely proportional to the population density of larger fish. Therefore, if a population of yellow mojarra out-grows its food supply, it would be expected that the adults would feed more heavily on the young and the growth of the population would slow or stop until the population density was reduced. Further work in this area needs to be done.

Although P. *kraussii* ingest large quantities of aquatic plants and algae, these plant materials seem to pass through the digestive system in relatively unchanged form. Therefore, it would seem that these plant materials are consumed incidentally to the capture of animal prey. The method yellow mojarra use to capture their prey and the density of the growths of aquatic plants and algae in the Cienaga de San Cristobal would tend to substantiate this explanation.

From the variety of food items found in the stomachs of the fish, it would appear that they are not highly selective in their feeding habits and feed on whatever is most readily available and of suitable size.

The high percentage of empty stomachs found was probably due to the rapid digestive rate of P. *kraussii*. Although most of the collecting of the fish was done in the early morning and most of the stomachs were preserved within one hour after the capture of the fish, it appears that in many instances the fish had already digested their stomach contents before the stomachs were removed and preserved. Other authors (Windell, 1966; Kionka and Windell, 1972) have found that it takes much longer for bluegill, bass, and rainbow trout to digest 50 percent of the food they ingest than it did for the yellow mojarra in the digestive rate study. It has also been found that the metabolic rate and digestive rate increase with increasing temperatures (Welch, 1952; Molnar *et al.*, 1967). It is probable that the high water temperatures of this study (30 C), which were about 10 C higher than those of the previously mentioned studies, substantially increased the metabolic rate and the digestive rate of the yellow mojarra.

Growth

Methods

The total lengths (mm), standard lengths (mm), and weights (g) of the *P. kraussii* from the Cienaga de San Cristobal were recorded at the time of the capture of the fish. Regression equations were determined for the total length-weight and total length-standard length relationships and an analysis of variance conducted for each regression by means of a computer program modified from Sokal and Rohlf (1969) by Dr. Walter Conley. The condition factors were determined by using the relationship $K_{TL} = Wx10^5/L^3$, where K_{TL} is the condition factor, W is weight in grams, and L is the total length (mm) (Lagler, 1956). Condition factors were calculated at 20-mm total length intervals (90-270 mm) using corresponding weight values calculated from the total length-weight relationship.

Results and Discussion

The regression equation for the total length-weight relationship is Log_{10} Y = -4.6358 + 2.95530 Log_{10} X (Figure 1). The 95% confidence limits on the slope are 2.9306 and 2.9801. An analysis of variance showed the slope of the line to be very highly significant ($p<.001$, Fs = 54,778, df = 1,517).

The regression for the total length-standard length relationship is Y = 6.44962 + 1.28698 X (Figure 2). The 95% confidence limits on the slope are 1.2731 and 1.3009. An analysis of variance showed the slope of the line to be very highly significant ($p<.001$, Fs = 33,038, df = 1, 517). The condition factors for P. kraussii of all total lengths were approximately 1.8 (Table 5). Although there was a slight but steady decrease in condition factors from 90 (K_{TL} = 1.89) to 270 mm (K_{TL} = 1.80), the change was very small.

Reproduction

Methods

The attainment of sexual maturity, the sex ratio, and the fecundity of yellow mojarra were determined from fish collected in the Cienaga de San Cristobal in October, 1972. At the time of collection, gonad development in each fish was noted. Males were classified as immature or mature, depending on the state of development of the testes. Females were classified as immature, mature, ripe, or spent.

FIGURE 1. Total length - weight relationship for *Petenia kraussii* taken from the Cienaga de San Cristobal.

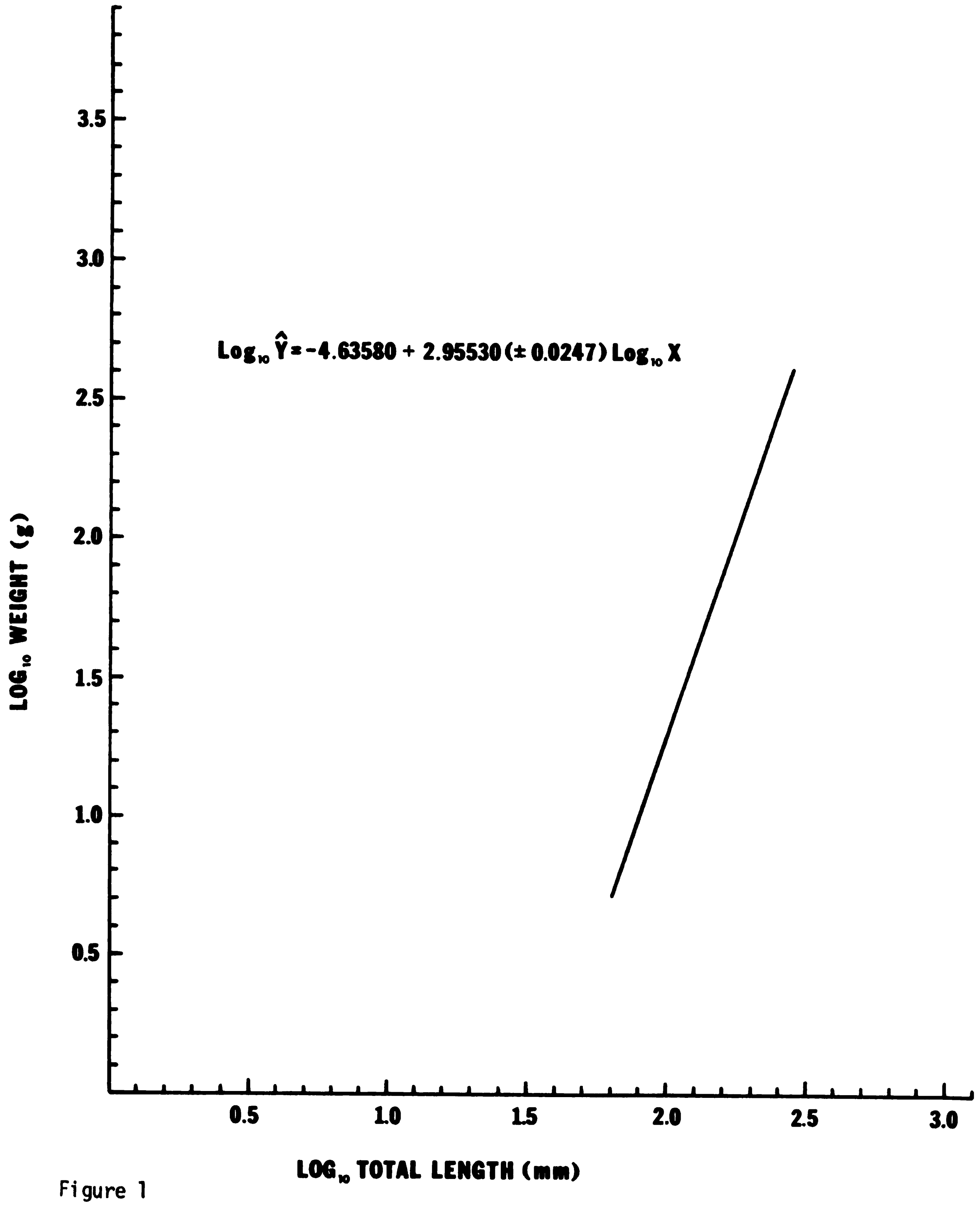

Log₁₀ Ŷ = -4.63580 + 2.95530 (± 0.0247) Log₁₀ X
LOG₁₀ WEIGHT (g)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.5
1.0
1.5
2.0
2.5
3.0
LOG₁₀ TOTAL LENGTH (mm)

Figure 1

FIGURE 2. Total length - standard length relationship for *Petenia kraussii* taken from the Cienaga de San Cristobal.

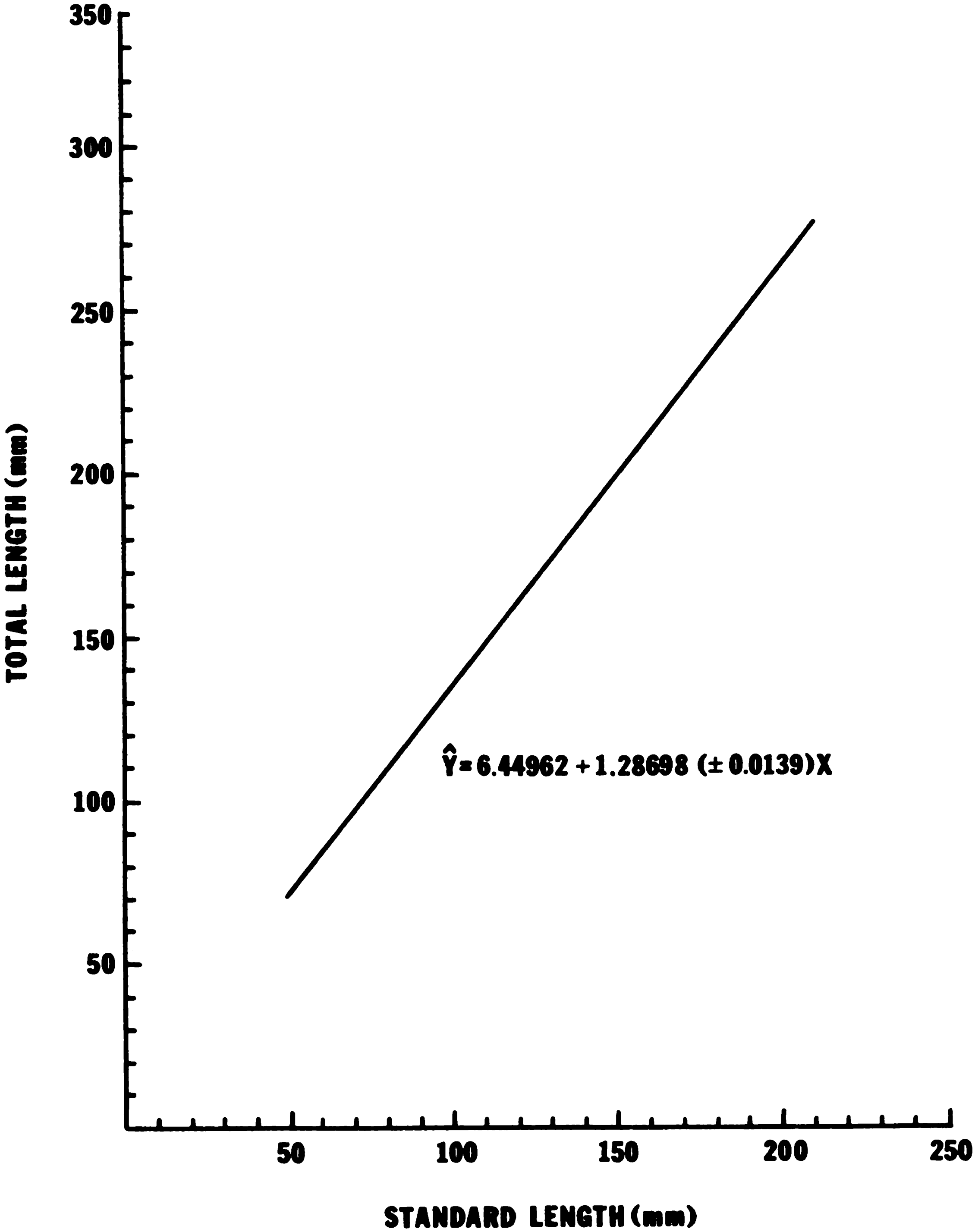

350
300
250
200
150
100
50
TOTAL LENGTH (mm)
Ŷ = 6.44962 + 1.28698 (± 0.0139)X
50
100
150
200
250
STANDARD LENGTH (mm)

Figure 2

TABLE 5. Total lengths at 20-mm intervals, calculated weights from the length-weight relationship, and condition factors for *Petenia kraussii* from the Cienaga de San Cristobal.

Total Length (mm)	Weight (g)	Condition factor (K_{TL})
90	13.8	1.89
110	24.9	1.87
130	40.8	1.86
150	62.4	1.85
170	90.4	1.84
190	125.5	1.82
210	168.7	1.82
230	220.7	1.81
250	282.4	1.81
270	354.5	1.80

Immature females had ovaries which had not yet begun to develop. Mature females had ovaries which had begun to develop but which were not ripe or spent. Ripe females were mature females that were ready to spawn and had large ovaries containing well developed eggs. Spent females were mature females that had just spawned and had ovaries containing some well developed but unspawned eggs and many small eggs which had not yet begun to develop. The numbers of immature and mature males and females were then grouped in one-centimeter size groups according to their total lengths.

The ratio of males to females was analyzed statistically by means of the Chi-Square test.

The number of eggs in the preserved ovaries of the ripe yellow mojarra females collected in January through March and in October of 1972 were determined by subsampling and the use of a Mettler H 10 TW analytical balance scales accurate to 0.1 mg. This method is similar to the one described by Reed (1971). One hundred eggs were removed from the front and rear of each ovary. The 200 eggs were then blotted dry on paper towels and weighed on the analytical balance to the nearest 0.1 mg. The remaining ovary was then blotted dry and weighed in a similar fashion. The number of eggs was calculated by means of proportions and the 200 eggs removed were added to the calculated number to obtain the total number of eggs in each ovary. Ninety-six (96) ovaries were processed in this manner. A regression of total length to number of eggs was then calculated using a computer program given by Sokal and Rolhf (1969), as modified by Dr. Walter Conley.

The breeding behavior of yellow mojarra was studied in aquaria, tanks, ponds, and in natural lakes by observation of fish which were reproducing.

Results and Discussion

Male P. kraussii began maturing at a shorter total length than females (Table 6). The males began maturing at about 10 cm and the majority (73-80%) were mature between 14 and 16 cm. Females began maturing at about 12 cm and all were mature at 17 cm. Although the females began maturing at 12 cm, they did not spawn before they reached a total length of 18 cm. It can be seen from the percentages of spent females that relatively few of the mature females (6.7-33.3%) were spawning at any given time.

The sex ratio of 276 (55.1%) females and 244 (46.9%) males was found to be highly significant ($p<0.001$, $X^2 = 1.970$, $df = 519$) when tested by means of the Chi-Square test.

The relationship of the number of eggs to total length is expressed by the regression equation $Y = -3471.04104 + 47.53380 X$ (Figure 3). The 95% confidence limits for the slope (b) are 34.4788 and 60.5888. The slope of the regression line was found to be very highly significant ($p<0.001$, $Fs = 50.9286$, $df = 1, 94$) when tested by an

TABLE 6. Numbers of male and female *Petenia kraussii* and percentages of maturity at one-centimenter intervals of total length.

Sex and number		Size group and percentage																		
		<10	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Males (244)	Total no.	4	17	48	41	39	15	5	4	2	4	3	8	7	8	8	13	11	4	3
	% immature	100	76.5	85.4	73.2	64.1	26.7	20.0	-	50.0				14.3						
	% mature	-	23.5	14.6	26.8	35.9	73.3	80.0	100	50.0	100	100	100	85.7	100	100	100	100	100	100
Females (276)	Total no.	4	5	43	58	51	16	6	2	0	6	14	15	18	24	9	3	2	-	-
	% immature	100	100	100	98.3	94.1	87.5	66.7												
	% mature	-	-	-	1.7	5.9	12.5	33.3	100	-	66.7	42.8	46.7	16.7	16.7	-	33.3	50.0	-	-
	% ripe										16.7	50.0	46.6	72.2	70.8	77.8	33.3	50.0	-	-
	% spent										16.7	7.2	6.7	11.1	12.5	22.2	33.3			
	T. % mature[1]				1.7	5.9	12.5	33.3	100	-	100	100	100	100	100	100	100	100		
Total number (520)		8	22	91	99	90	30	11	6	2	10	17	23	25	32	17	16	13	4	3

[1]Includes mature, ripe, and spent females.

FIGURE 3. Total length - egg number relationship (fecundity regression) for *Petenia kraussii* taken from the Cienaga de San Cristobal.

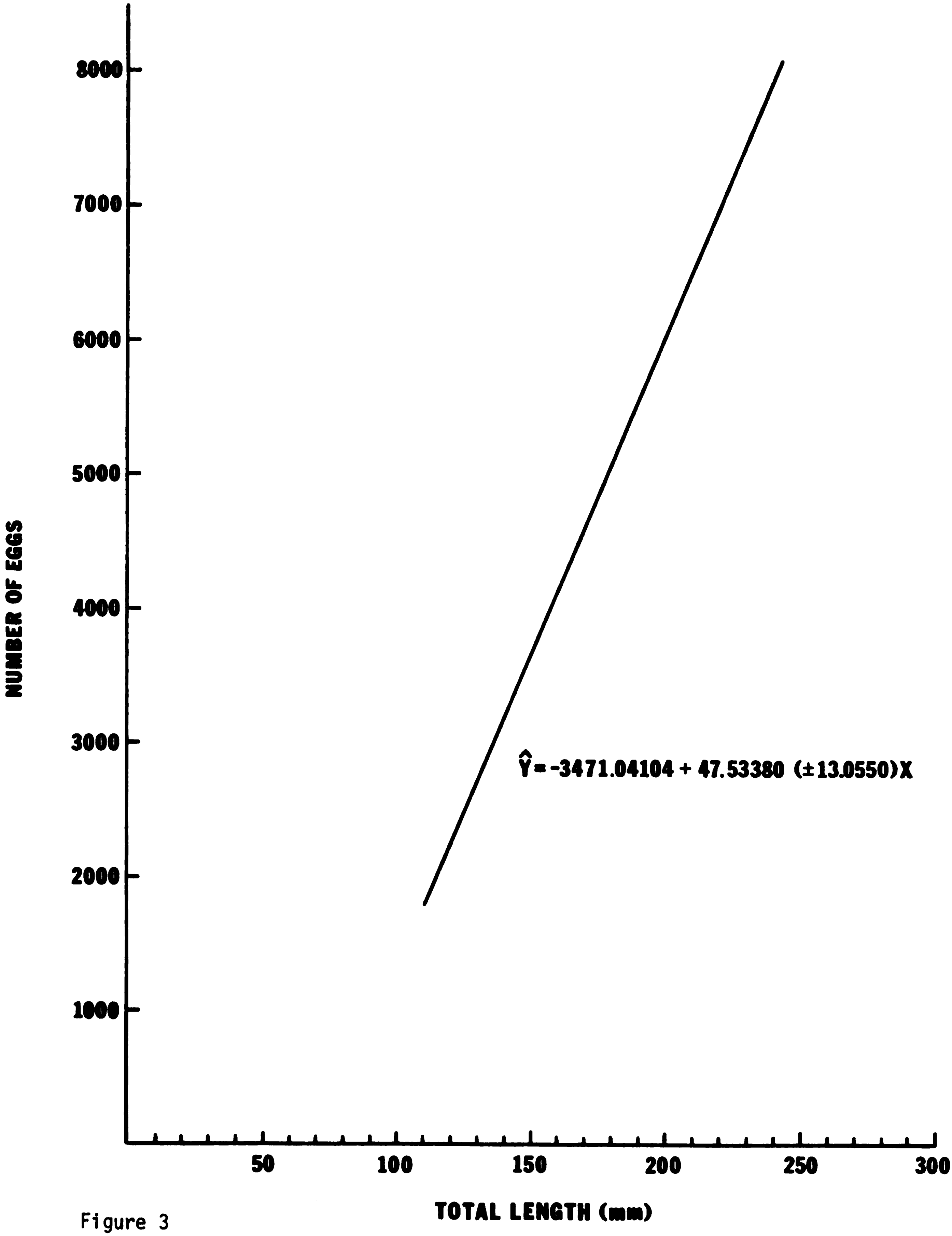

NUMBER OF EGGS
8000
7000
6000
5000
4000
3000
2000
1000
Ŷ = -3471.04104 + 47.53380 (±13.0550)X
50
100
150
200
250
300
TOTAL LENGTH (mm)

Figure 3

analysis of variance. The average number of eggs per female was 6608, with a range from 1200 to 13,037.

The eggs were adhesive, yellow, and oval, with a diameter of 1.5-2.0 mm on the long axis and 1.0-1.2 mm on the short axis.

Yellow mojarra breed in pairs, with the male usually being larger than the female. The male selects a site for the nest, which is usually near shore in 0.5 to 1.0 m of water. Frequently a rock, stick, log, or some other suitable object is chosen as a substrate on which to lay the eggs. The nest site is cleared of organic detritus and other debris by both parents. Courting behavior consists of a series of rushes by the male and female at each other, often accompanied by hitting each other's body with their mouths and occasionally locking jaws.

When spawning begins, the female lays a row of adhesive eggs and the male immediately follows her and fertilizes them. The spawning may continue for one to two hours, with both parents occasionally stopping to rest for short periods. When the spawning is finished, the male assumes the major responsibility for guarding the eggs, although the female usually remains nearby. The parents feed very little while guarding the nest and fry. Snails, insects, and other invertebrates which approach the nest site are either eaten or carried a short distance away in the mouth of the male and expelled. Other fish which approach the nest site are confronted by both parents and

and driven away. As the hatching time of the eggs approaches, both parents intensify their guarding of the nest. The eggs usually hatch in 43 to 48 hours at a temperature of 28 to 30 C (Hurtado, 1971).

The newly hatched larvae remain near the egg cases for a few hours after hatching. The larvae then drop to the bottom and the parents put them in a small area by taking them in their mouths and then expelling them in the desired area. The parents occasionally move all of the young by transporting them in their mouths if the nest site is disturbed. The larvae remain on the bottom for about two days after hatching. During this time, they make vigorous movements with their tails without changing position.

When the fry swim up, they form a tight school and are guarded by both parents. The fry and parents generally remain near the nest site for a few days and then begin to move about looking for food. The schooling behavior and parental guarding continues until the fry reach a size of about two centimeters, which is usually about 30 days after hatching. The parents then abandon the fry and the school of fry begins to break up into smaller groups. In captivity, the parents usually nest again about two weeks after they abandon the fry.

Parasites and Diseases

Yellow mojarra can be heavily infected by two types of parasites. A larval nematode, probably in the super family Ascaridoidea (Dr. Twohy, Dept. of Microbiology and Pub. Health, Mich. St. Univ.; personal communication), was commonly found burrowing in the viscera, body cavity, liver, and reproductive organs of large mature individuals. Of the 520 fish collected and examined, 144 (27.7%) were found to be infected with this nematode parasite. However, of the 129 fish with total lengths greater than 20 cm, 115 (89.1%) were infected, and of the 391 fish with total lengths less than 20 cm, only 29 (7.4%) were infected. No fish with total lengths of less than 11 cm were infected. It appears that the occurrence of this parasite in yellow mojarra is dependent on the age of the fish, and thus on the length of time that the fish has been exposed to the infectious form of the parasite in the water or in its food. It is likely that the life cycle of this parasite is very complicated and involves an aquatic invertebrate as a first intermediate host and a fish-eating mammal, bird, or reptile as the definitive host (Chandler and Read, 1967).

In many heavily infected fish, damage by the burrowing larvae to the liver, intestines, and gonads was evident. In some cases, much scar tissue had been formed and the viscera were tied together into a single mass. Heavy cases of infection could have adverse effects on the functioning of the organs involved. There was also an adverse cultural and economic effect in that the people preferred to eat those fish which were not infected.

Small white metacercariae of a digenetic trematode were also found in the aqueous humor of the eyes of yellow mojarra. These metacercariae are probably of the family Diplostomatidae (Chandler and Read, 1967). In those fish infected, the number per eye varied from one to as many as 11, with the usual number being two or three. The greatest number found in a single fish with both eyes infected was 19, 11 in one eye and eight in the other. Of the 520 fish examined, 143 (27.3%) were found to have these parasites in one or both eyes. As with the nematode parasites, the incidence of infection was higher in the larger fish. Of the 129 fish with total lengths greater than 20 cm, 45 (34.6%) had one eye infected and 43 (33.1%) had both eyes infected. Of the 390 fish with total lengths less than 20 cm, 50 (12.8%) had one eye infected and 5 (1.3%) had both eyes infected. The smallest fish found with eye grubs was 9.9 cm long. In older fish with high degrees of infection, the lens and aqueous humor of the eye were a whitish-opaque color. Similar damage to the eyes of white suckers, fathead minnows, and rainbow, brown, and brook trout has been reported by Davis (1956). According to Lagler (1956), infections of eye grubs may cause blindness or kill the fish. Loss or impairment of eye sight could have an adverse effect on yellow mojarra because they are predators which feed by sight. The life cycle of this parasite probably has a fish-eating bird as the definitive host and a snail as another intermediate host (Davis, 1956).

In captivity under crowded conditions, yellow mojarra are susceptible to fungus (probably Saprolegnia sp.) and "Ich" (Ichthyopththirius sp.). However, under natural conditions, these diseases do not seem to be important.

Predators

Insects, birds, reptiles, and other fish prey on P. kraussii at times during its life cycle. Coleoptera, Odonata, and Hemiptera (Notonectidae and Belastomatidae) are predators on the fry of yellow mojarra. Fish-eating birds are very abundant in northern Colombia and many species feed heavily on yellow mojarra of all sizes. Concentrations of these birds numbering in the hundreds and feeding in the littoral regions of lakes are common sights. Among the birds observed feeding on yellow mojarra were: herons (Aredeidae), great blue (Ardea herodias), little blue (Florida caerulea), common egret (Casmerodius albus), snowy egret (Leucophoyx thula), striated heron (Butorides striatus), and green heron (B. virescens); osprey (Pandion halinetus), anhinga (Anhinga anhinga); cormorant (Phalacrocorax olivaceus); brown pelican (Pelecanus occidentalis); grebe (Pedicipedidae)- at least two species; and the kingfishers (Alcedinidae)- at least three species (De Schauensee, 1964).

In addition to preying heavily on *P. kraussii*, many of these birds undoubtedly serve as definitive or intermediate hosts for parasites which infect yellow mojarra.

The Central American caiman (*Caiman fuscus*) is very common in regions of northern Colombia and feeds extensively on fish. The American crocodile (*Crocodilus acutus*) also occurs in the area and feeds on fish (Schmidt, 1928). Great damage can be done by these large reptiles to fish populations in ponds.

Many species of fish prey on yellow mojarra. Yellow mojarra adults are very cannibalistic and at times will feed heavily on their own eggs and young. The moncholo (*Hoplias malabaricus*) is a vicious predator which inhabits the littoral zone and feeds heavily on young *P. kraussii*. The blue mojarra (*Aequidens pulcher*) and the aguja (*Ctenolucius hujeta*) feed on the fry of yellow mojarra. The larger predacious fish which at times feed on yellow mojarra include: tarpon (*Tarpon atlanticus*), bagre blanco (*Sorubim lima*), bagre pintado (*Pseudoplatystoma fasciatum*), and eel (*Synbranchus marmoratus*).

Relations to Man

At the present time, there is no organized commercial fishery for yellow mojarra. Some yellow mojarra are caught incidentally by commercial fisherman. These fish are marketed at a relatively cheap price as compared to other commercial species such as the bocachico (*Prochilodus reticulatus magdalenae*).

There is, however, a very large domestic fishery for yellow mojarra. Because it is widespread, abundant, available year around, easily caught, and valued for its flesh, the yellow mojarra is a very important food item in the diets of many rural families. A great share of the domestic fishery is done by children who wade in areas frequented by yellow mojarra and use a short bamboo pole, three to four feet of line, and a hook baited with worms or minnows to catch the fish. The fish are then scaled, eviscerated, salted, and later fried or used in soup. The fish also may be captured using cast nets of a small mesh size (3-4 cm stretched mesh), drag seines, or gill nets (9 cm stretched mesh size). As of now, there seems to be no danger to *P. kraussii* from over-fishing. Its high fecundity, high degree of parental care, numerous spawnings per year, and rapid growth rate seem to offer a good protection against over-fishing. However, as the human population of northern Colombia continues to grow and as the other fish species are depleted, the pressure on the populations of yellow mojarra will increase and it is probable that over-fishing will become a problem and may endanger this valuable source of protein. The introduction of improved fishing methods and gear (especially gill nets) will hasten the development of problems of this kind.

In addition to its value as a source of protein for the people, yellow mojarra could become an important sport fish. As tourism in northern Colombia continues to grow and develop, it is possible that a sport fishery could be developed for many of the fish species present there, including yellow mojarra. Yellow mojarra strike readily on small artificial spoons and spinners (size 0). The best time to fish is usually in the early morning and late evening. On light tackle, yellow mojarra put up a stubborn fight characterized by short runs, dives, and occasional jumps. This author has caught up to 25 fish in an hour, and strikes on every cast were not uncommon.

CULTURE

Propagation

P. kraussii can be easily propagated in aquaria, tanks, or ponds. Regardless of the method to be used, ripe pairs of adult fish should be selected. Females should be 20 to 22 cm total length and should demonstrate a general robustness of the abdomen and a reddish color and swelling of the genital palpi, signifying a ripe condition of the eggs. Males should be slightly larger than the females, should have a slight reddening of the genital palpi, and should extrude milt when a gentle pressure is applied to the abdomen. The adults should be in good physical condition, free of diseases, and free of injuries which could make the fish prone to fungus attacks.

Aquaria and tanks are suitable for producing limited numbers of fry for experimental purposes. For aquarium culture, large aquaria with a surface area of at least one square meter and a depth of 0.5 meters should be used for each pair of fish. The adults should be fed live or dead fish. They should spawn in a few days to one week if ripe adults were selected. If the fish do not spawn in two weeks, a new pair should be selected. The eggs will usually be laid on the bottom of the aquarium, or on a rock, board, or other suitable substrate if it is supplied. The adults guard the eggs until they hatch and the larvae until they swim up. At this point, it is advisable to remove the fry to a larger tank. The fry must be fed on zooplankton. Attempts to feed the fry artificial food have so far failed. Periodic thinning of the fry must be carried out to avoid overcrowding and disease. At a total length of 2.0 to 3.0 cm, the fry are ready to be stocked in ponds.

Tank culture of yellow mojarra is very similar to aquarium culture. Tanks should be filled with water to a depth of 0.5 to 0.75 meters. One pair of ripe adult fish per each 10 or 20 square meters of tank surface area should be placed in the tanks. The eggs will usually be laid on the sides of the tanks. The parents will guard the fry for up to 30 days after they hatch, but it is usually best to remove the adults one or two weeks after the fry hatch to avoid predation on the fry by the adults. The fry can then be left to grow to a stockable size in the tanks. The fry must be fed zooplankton, since sufficient zooplankton is not produced in the tanks.

Pond culture of P. kraussii is the only feasible and economical way to produce large numbers of fingerlings for stocking. Ponds with an area of about 1000 square meters and a depth of about one meter should first be dried to kill as many predacious aquatic insects as possible. Then dried manure should be added and the ponds filled with water to a depth of about 0.8 meters. Approximately 10 pairs of ripe yellow mojarra should then be stocked in each pond. Further work needs to be done to determine the number of pairs of adult fish needed to produce the maximum number of stockable size fingerlings.

About one month after stocking the adults, the fingerlings should reach a stockable size (2.0-3.0 cm). At this time, seining with a fine mesh seine should begin in order to harvest the fingerlings. After about four to six months, the ponds should be drained, the remaining young fish removed, and the adult population adjusted to the original density.

Fry and fingerlings can be transported in large tanks of water or in plastic bags partially filled with water and charged with air or oxygen. The latter method using oxygen under pressure is preferable for transport over long distances. If the density of fish is held to about one gram of fish per 13 cc of water (Ruth and Mortimer, 1965), and the bags are kept cool, the fry and fingerlings should be able to survive trips of more than 48 hours in good condition.

Growth in Ponds

Introduction

The rate of growth is one of the most important aspects of the biology of a fish in determining its suitability for pond culture. The known age method of determining growth was used in this study because other methods were unsuitable. The length-frequency method could not be used because *P. kraussii* reproduce throughout the year and there are no distinct size-age groups. The otolith or scale methods could not be used not only because the proper equipment was not available, but also because annual rings were not formed under the continuous tropical conditions.

The use of the known age method had a further advantage in that the effects on growth of the different physical environments of the study ponds could be determined. Recommendations could then be made as to the type of pond which is most conducive to fast growth of yellow mojarra.

Methods

Private cattle watering ponds in the departments of Atlantico and Bolivar were selected for use in the growth investigation. The names, locations, and some physical and chemical characteristics of these ponds are given in Table 7. The incompleteness of these data is due to the lack of sufficient materials to conduct thorough investigations in all of the ponds. The mean maximum and minimum temperatures were determined by placing maximum-minimum thermometers in the ponds approximately 15 cm below the surface and obtaining daily readings over a one to two-week period. The ponds were all underlain by similar soil types.

TABLE 7. Names, locations, and physical and chemical parameters of the ponds used in the growth investigation of Petenia kraussii.

Pond	Department	Area (m^2)	Mean depth (m)	% plant cover	pH range	Temperature (C)				Dissolved oxygen (mg/l)		Primary Productivity[1] (mg O_2/l)		
						Max.	Min.	Mean max.	Mean min.	Min.	Max.	Gross/ hr.	Net/ day	Resp./ hr.
A. Turbaco 2	Bolivar	1000	1.0	0	6.5-7.3	32.0	26.0			8.82	14.40	0.42	3.60	0.06
B. Loma Grande 1	Atlantico	1200	1.0	0-40	6.3-7.0	32.2	24.4	31.7	25.6	3.31	9.68			
C. Loma Grande 2	Atlantico	1200	1.0	0-40	6.3-7.7	32.5	26.0	34.6	27.7	0.48	5.76			
D. Turbaco 1	Bolivar	1500	1.0	100	6.5-7.0	28.0	26.0			1.00	1.28	0.23	-1.08	0.16
E. Santa Rosa 3	Bolivar	10000	1.5	0	6.3-7.3	36.1	26.0	33.3	28.9	7.14	9.71			
F. Santa Rosa 4	Bolivar	2000	1.5	90	6.5-7.3	33.3	26.0	31.1	27.8	6.61	9.71			
G. La Fe 1	Atlantico	1200	1.2	0	5.5-5.9	39.0	23.0				8.69			
H. La Fe 2	Atlantico	1200	1.0	0	5.3-5.7	37.0	24.0				10.42			

[1]Phytoplankton primary productivity only.

Ponds A, B, C, D, E, and F were stocked in December of 1971 at a rate of 200 fingerlings per 1000 square meters of pond surface area. The fingerlings stocked were hatched and raised at the San Cristobal Fisheries Station. The mean total lengths and numbers of fingerlings stocked in each pond are given in Table 8. All of the ponds except pond E contained large populations of prey fish (Mollienisia sp. and Characidae). Pond E contained a large population of Tilipia mossambica and few prey fish. All of the ponds were constructed by damming a natural ravine and were filled by run-off water. Fluctuations in water level occurred between the wet and dry seasons.

Samples of yellow mojarra were obtained from each pond at monthly intervals to determine growth. The fish were captured with seines or throw nets and held in tanks until the sample was complete. The total length of each fish was then measured to the nearest millimeter and the weight to the nearest gram. Their general physical condition was noted, the females were checked for sexual maturity, and the fish were returned to the ponds. An attempt was made to capture at least 20 fish from each pond for each monthly sample. Occasionally, however, it was impossible to capture 20 fish due to weed growths, equipment failures, and other problems.

Ponds G and H were stocked with 200 fingerlings per 1000 square meters in June, 1972. These two ponds were naturally very acid (pH of 5.3-5.9) and had no natural

TABLE 8. Growth of <u>Petenia kraussii</u> in ponds giving mean total length ($\bar{X}$) in millimeters, standard error ($S_{\bar{X}}$), sample size (n), and coefficient of variation (CV) for each month elapsed from stocking time[1].

	Elapsed time (months)																						
	At stocking		Two				Three				Four				Five				Six				
Pond	X	n[1]	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV
A	21	200	4	133			10	150	±5.4	11.3	10	156	±1.8	3.7	No Sample				12	174	±3.2	6.4
B	26	243	20	136	±2.1	6.8	20	141	±2.9	9.2	34	146	±2.7	10.7	17	149	±3.4	9.5	21	148	±2.7	8.4
C	26	243	12	104	±4.2	14.1	20	120	±2.7	10.3	21	136	±2.1	6.9	11	146	±1.4	3.2	No Sample			
D	21	300	14	48			15	57			62	63	±4.0	49.6	22	85	±6.7	36.8	20	77	±9.4	54.6
E	23	2000	20	62			15	76	±1.7	8.6	5	86	±5.7	14.9	15	85	±1.4	6.3	21	99	±1.6	7.5
F	23	400	7	58			18	73	±5.8	40.0	20	93	±7.9	38.0	12	108	±10.1	32.4	20	103	±7.9	34.2
G	45	212	20	86	±1.9	10.2	20	99	1.4	6.3	20	104	±1.1	4.6	20	112	±2.0	7.8				
H	45	212	20	72	±1.2	7.7	20	75	1.4	8.4	20	77	±1.1	6.2	20	83	±1.3	7.0				

[1]Ponds A-F stocked December 14, 1971, and ponds G and H stocked June 16, 1972. All ponds stocked at a rate of 200 fish per 1000 m^2 of pond surface area.

populations of fish. Approximately 200 adult *Mollienisia sp.* were stocked in pond G at the same time as the yellow mojarra fingerlings.

In the course of this investigation, it became evident that the presence of floating aquatic plants (water lettuce, *Pistia stratiotes*, and water hyacinth, *Eichornia crassipes*) which covered a large percentage of a pond's surface area affected the chemical and physical characteristics of the pond and the growth of the yellow mojarra. To determine what changes in the physical and chemical characteristics of a pond might be caused by the presence of floating aquatic weeds, an experiment was conducted using several tanks at the San Cristobal Fisheries Station. Three concrete tanks (5 m x 4 m x 1 m) were cleaned and filled to a depth of 0.85 meters with water pumped from the Canal de Dique on October 24, 1972. The water had a pH of 5.9 and a Secchi Disk reading of 15 cm. Water lettuce (*Pistia stratiotes*) was then placed in two of the tanks. The surface of one tank was completely covered and the surface of a second tank was divided into two equal sections by means of a heavy wire and one section was covered. The third tank had no water lettuce. A maximum-minimum thermometer was placed in the center of each tank at mid-depth (40 cm). A fourth maximum-minimum thermometer was placed on a stake next to the tanks to obtain air temperatures. The maximum and minimum daily temperatures were recorded each morning. Periodically, Secchi Disk, pH, and dissolved oxygen readings were taken. Several phytoplankton primary productivity tests using the light-dark bottle method with four-hour incubation periods were conducted. The tanks were drained on December 2, 1972 and the fish which were introduced as larvae with the water were counted, weighed, and identified.

Results

The average growth rates of the P. kraussii stocked in the six ponds in December, 1971 were high in three of the ponds (A, B and C) and lower in the other three ponds (D, E and F) (Tables 8 and 9, Figure 4). The average growth rate of the yellow mojarra was highest in pond A. The fish in ponds B and C grew at only slightly lower rates. In all three of the above ponds, most of the fish reached what was considered to be a usable size by the local human population only three months after they were stocked.

The growth of the yellow mojarra was lowest in pond D (Tables 8 and 9, Figure 4). The fish stocked in ponds E and F achieved growth rates very similar to that of the yellow mojarra stocked in pond D. Very few of the fish in ponds D, E and F had reached a usable size six months after they were stocked.

An analysis of variance of the means of the total lengths of the fish from all six ponds gave a statistically significant difference ($p<0.001$) for each monthly

TABLE 9. Growth of *Petenia kraussii* in ponds giving mean weight ($\bar{X}$) in grams, standard error ($S_{\bar{X}}$), sample size (n), and coefficient of variation (CV) for each month elapsed from stocking time[1].

	Elapsed time (months)																					
	At stocking		Two				Three				Four				Five				Six			
Pond	$\bar{X}$	n	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV	n	$\bar{X}$	$S_{\bar{X}}$	CV
A	0.1	200	4	42			10	63	±6.5	32.5	10	65	±2.4	11.7		No Sample			12	97	±5.0	17.8
B	0.2	243	20	50	±2.2	19.2	20	50	±2.8	25.8	34	54	±2.7	29.1	17	56	±3.8	27.8	21	54	±2.9	25.0
C	0.2	243	12	21	±2.3	39.3	20	31	±2.4	14.4	21	48	±2.3	20.9	11	52	±2.0	12.8		No Sample		
D	0.1	300	14	2.4			15	3.6			62	8.0	±1.7	172.7	22	13.2	±3.1	109.8	20	17	±6.6	180.0
E	0.2	2000	20	3.4			15	7.7	±0.5	26.9	5	10	±2.0	43.5	15	10	±0.5	19.1	21	16	±0.8	21.3
F	0.2	400	7	3.4			18	8.4	±2.0	101.1	20	14	±3.5	115.6	12	26.8	±8.2	106.7	20	23	±4.4	84.6
G	1.6	212	20	14	±0.9	30.7	20	16	±0.6	18.0	20	19	±0.6	13.1	20	25	±1.0	18.8				
H	1.6	212	20	7	±0.3	22.2	20	7	±0.4	24.0	20	8.2	±0.3	14.1	20	10.7	±0.4	16.4				

[1] Ponds A-F stocked December 14, 1971, and ponds G and H stocked June 16, 1972. All ponds stocked at a rate of 200 fish per 1000 m^2 of pond surface area.

FIGURE 4. Growth (mean total length) of *Petenia kraussii* stocked in ponds in the departments of Bolivar and Atlantico, Colombia.

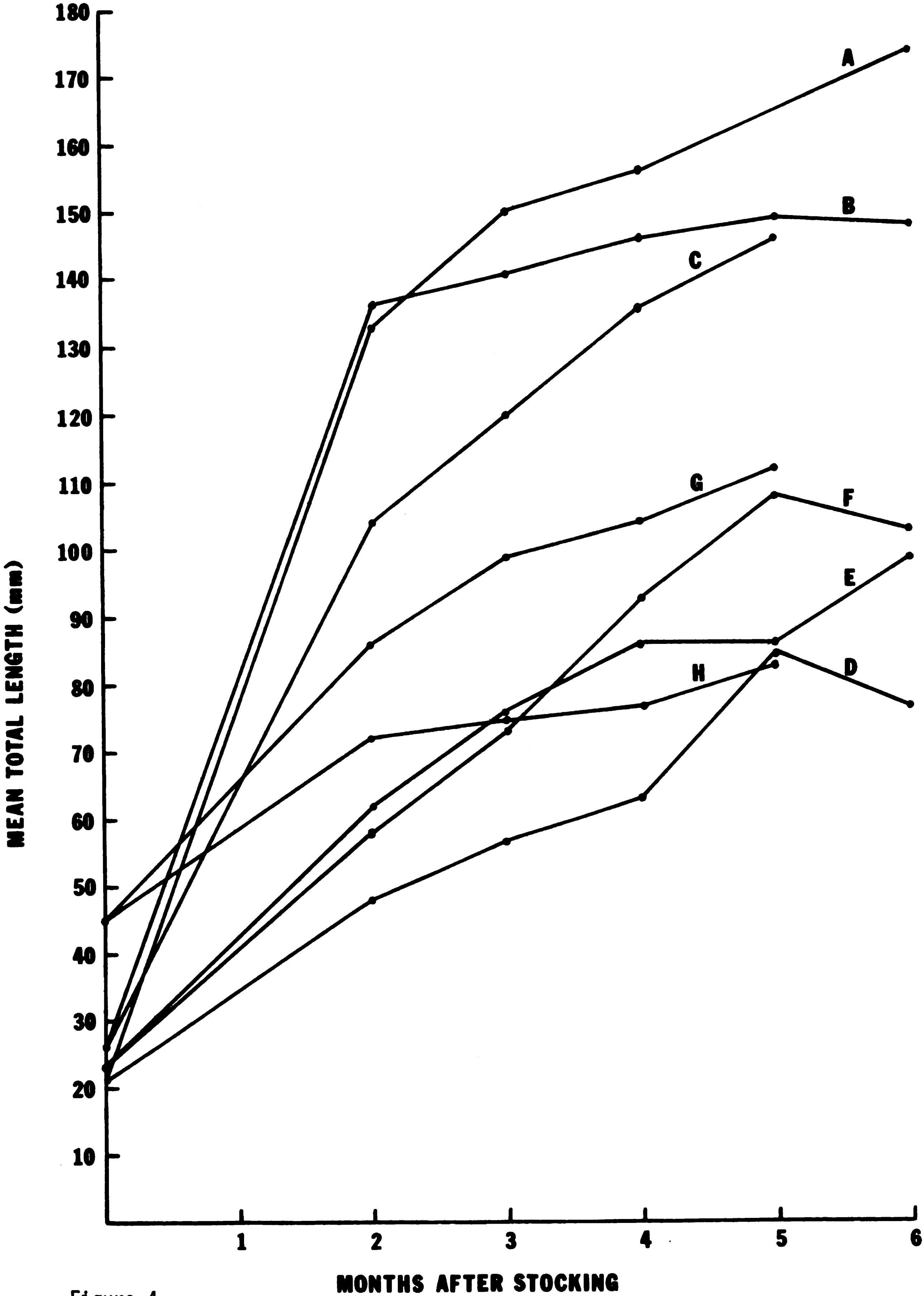

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
MEAN TOTAL LENGTH (mm)
A
B
C
G
F
E
H
D
1
2
3
4
5
6
MONTHS AFTER STOCKING

Figure 4

sample. A Ducan's Multiple Range Test revealed that at the 0.01 level of probability, the means of the total lengths of the yellow mojarra in the three ponds where high growth occurred (A, B and C) were all significantly greater than the means of the total lengths of the fish from the ponds where low growth occurred (D, E and F).

According to Sokal and Rohlf (1969), coefficients of variation (CV) can be used to compare the amount of variation in populations having different means. Coefficients of variation will be used in this thesis to compare the amounts of variation in the mean total lengths of the populations of yellow mojarra in the ponds. A high CV of the mean total length would indicate a wide range of total lengths of the individual fish in the sample. The coefficients of variation of the mean TL of the fish from the ponds in which high growth rates occurred were much less than the coefficients of variation of the mean TL of the fish from the ponds where low growth rates occurred for each month for which samples were taken (Table 8). The fish of pond E, which had a low growth rate and a low CV of mean TL, were the only exception to the above statement.

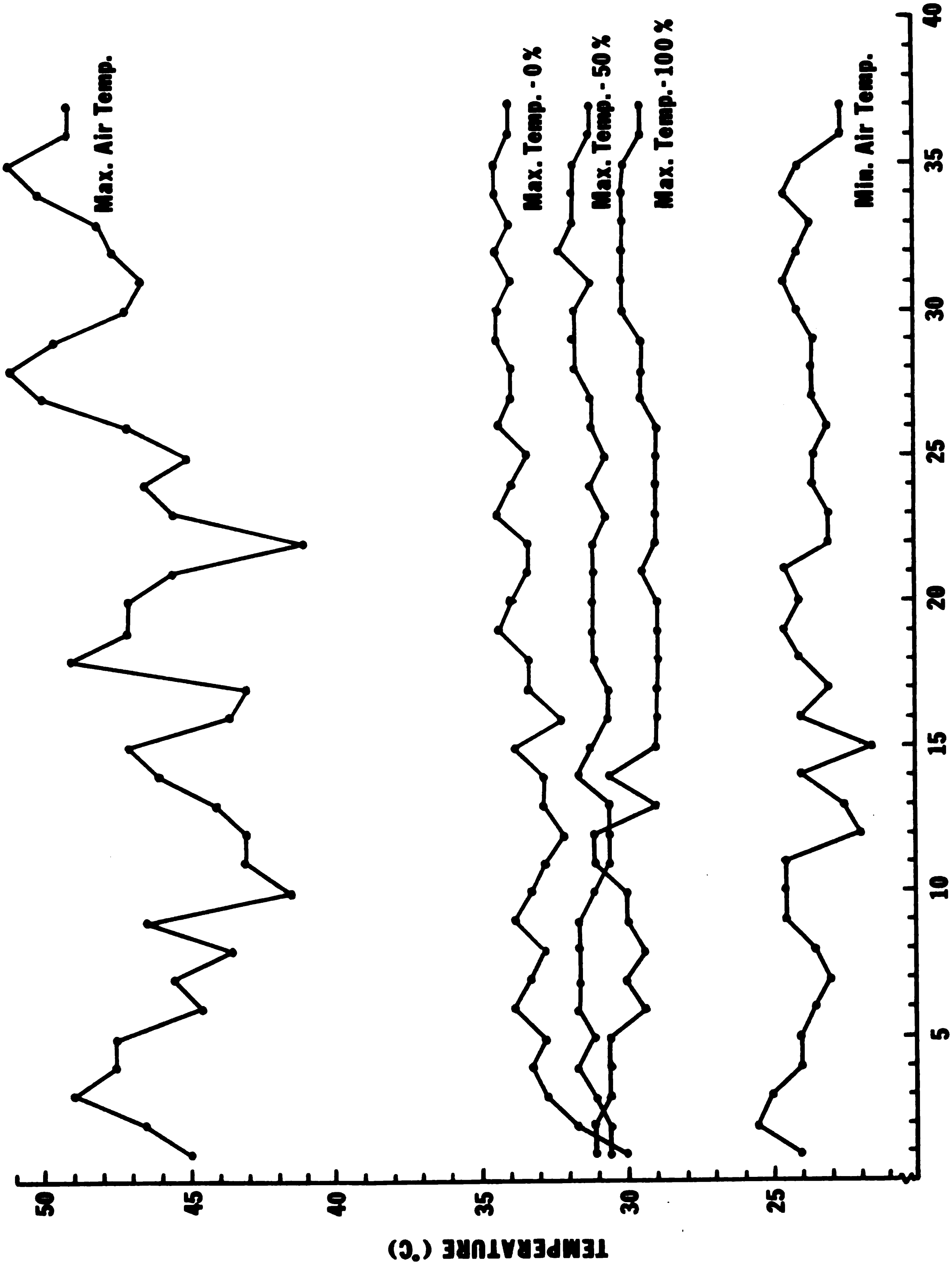
The growth of the yellow mojarra in the acidic ponds (G and H) was much lower than in the more alkaline ponds (A, B and C). The coefficients of variation of the mean total lengths were low for each month. The growth of the yellow mojarra in pond G, which was stocked with forage fish, was significantly greater ($p<0.001$) than the growth of the fish stocked in pond H, which had no forage fish.

Approximately 15 days after the initiation of the tank experiments at the San Cristobal Center, the water temperatures reached an equilibrium (Figure 5). The maximum water temperature in the tank having no water lettuce was much more responsive to daily fluctuations of the air temperature than was the water temperature in the tanks having water lettuce. The maximum temperature in the tank with no water lettuce was generally 2 to 3 C greater than the tank having 50 percent of its surface covered and 3 to 5 C greater than the tank which had 100 percent of its surface covered.

The water in the tanks with water lettuce cleared much more rapidly than did the water in the tank with no water lettuce, as evidenced by Secchi Disk readings (Table 10). The plants adsorbed great quantities of suspended solids to their root systems.

The pH and dissolved oxygen concentrations of the water were consistently lower in those tanks with water lettuce than in the tank with no water lettuce (Table 10). The phytoplankton gross primary productivity (mg O_2/l/hr) of the tank with 100 percent of its surface covered was much less than the tank with no water lettuce. The respiration in the tank with water lettuce was much higher than that of the tank with no water lettuce. In the primary

FIGURE 5. Daily maximum and minimum air temperatures and maximum water temperatures in experimental tanks having 0, 50, and 100% of their surface area covered by water lettuce (*Pistia stratiotes*).



Max. Air Temp.
Max. Temp. - 0%
Max. Temp. - 50%
Max. Temp. - 100%
Min. Air Temp.
TEMPERATURE (°C)
50
45
40
35
30
25
DAYS AFTER FILLING
5
10
15
20
25
30
35
40

Figure 5

TABLE 10. Effects of water lettuce (*Pistia stratiotes*) on water quality in experimental tanks[1].

Parameter	Percentage plant cover	Date (1972)									
		October		November							
		25	29	1	3	5	11	13	16*	22*	30*
pH	0	5.9		6.5				7.0	6.8-7.3	6.8-7.3	7.0-7.3
	50	5.9		5.9				5.7	5.9-6.2	5.9-6.2	5.9-6.2
	100	5.9		5.9				5.7	5.7-5.9	5.7-5.8	5.7-5.8
Secchi Disk (cm)	0	15	24	47	67	64**	85**	**	**	**	**
	50	15	33	85**	**	**	**	**	**	**	**
	100	15	85**	**	**	**	**	**	**	**	**
Dissolved oxygen (mg/l)	0								9.8-10.6	7.8-9.2	
	50									1.1-4.8	
	100								0.8-0.5	0.4-2.0	
Phytoplankton primary productivity											
Gross (mg O_2/l/hr.)	0								0.21	0.31	
	50								-	-	
	100								0.01	-0.08	
Respiration (mg O_2/l/hr.)	0								0.02	0.21	
	50								-	-	
	100								0.12	0.07	
Net (mg O_2/l/hr.)	0								1.95	-1.44	
	50								-	-	
	100								-2.16	-1.17	
Fish harvested (no. species-total no.)	0										6-159
	50										10-126
	100										4-26

[1]Tanks: 4x5x1 meter.
*Readings taken at 7:30 A.M. and 4:00 P.M.
**Total depth of tank.

productivity test conducted on November 16, 1972, the net primary productivity of the tank without water lettuce was 1.95 mg O_2/l/day, while that of the tank completely covered by water lettuce was -2.16. In the productivity test conducted November 22, 1972, both tanks had negative net daily primary productivities. However, the tank with no water lettuce had extensive growths of bacteria on its walls and suspended in the water, which may have invalidated the results.

When the tanks were drained, 159 fingerling fish of six species were recovered from the tank with no water lettuce, 126 fish of 10 species from the tank with 50 percent coverage, and 26 fish of four species from the tank with 100 percent coverage (Table 10).

Discussion

The growth of the *P. kraussii* in the six ponds which were stocked in December, 1971, clearly falls into two groups; poor (D, E and F) and good (A, B and C) growth. The fingerlings stocked were from the same stock of adult fish, abundant food was present in all ponds except pond E, and all of the fish populations were healthy. Therefore, some physical and/or chemical parameters of the ponds or the pond water must have influenced the growth rate of the yellow mojarra. Ponds A, B and C had little or no floating aquatic plants while ponds D and F had 90 to 100 percent of their surface area covered by aquatic plants. Furthermore, the yellow mojarra in ponds A, B and C had low coefficients of variation for their mean total lengths, while those in ponds D and F had high coefficients of variation. It appears that the floating aquatic plants which covered ponds D and F lowered the growth rate of the yellow mojarra stocked in them.

Pond E, in which the yellow mojarra had poor growth but a low CV and which had no plant cover, fits into neither category and will be discussed separately.

Since yellow mojarra are predators which feed primarily by eyesight, the floating plants could have directly affected them by lowering the light penetration to such an extent that it became impossible for them to locate sufficient quantities of food. Furthermore, the roots of these plants provide places of refuge for forage fish and insects and could reduce the ability of yellow mojarra to capture food. Lynch et al. (1947) found that forage fish are protected by water hyacinth to such an extent that often the larger predators are unable to use these fish for food.

Indirectly, the floating plants could have affected the water quality which in turn affected the growth rate of the yellow mojarra. The pH, dissolved oxygen, temperature, and phytoplankton primary productivity were all lower in the ponds with floating plants than in the ponds without floating plants. The results of the investigation using tanks with and without floating plants confirms that the differences in the above mentioned factors were due to the floating plants and not to other causes. Similar differences in water quality between lakes with and without water hyacinth mats were found by Lynch <u>et al</u>. (1947). Any one or a combination of the above parameters could affect fish growth.

The pH of the pond water could be lowered by the formation of humic acids when the plants decompose or the plants might directly lower the pH. It is possible that the roots of the plants act as ion exchange sites and cause a reduction in the pH of the water. This could also explain the adsorption of the suspended solids to the roots. The pH could limit the growth of the fish indirectly by affecting the availability of nutrients for primary production (Matida, 1967; Wolny, 1967; Golterman, 1967). A pH lower than that normally encountered by a fish in its normal environment often results in lowered growth rates long before any lethal effects are observed (Loyd, 1968; Beamish, 1972). The reduced growth rate in ponds G and H, which were extremely acid but had no floating aquatic plants, seems to confirm that a low pH can reduce the growth rate of fish.

The water temperature in the ponds with floating plants was lowered by the shading effect of the plants. Water temperature is the parameter which is perhaps most likely to affect fish growth, since it directly affects the metabolic rate of fish. The difference found in the tank experiment of up to 5 C in maximum daily water temperatures between tanks with and without floating plants could significantly affect the metabolic rate of fish. The temperatures found in the individual ponds at any given point in time were generally higher in those ponds with no floating plants. The temperature differences are not obvious in Table 7 because they are masked by the overlapping ranges and the limited data.

Since yellow mojarra inhabit the shallow littoral zone and have adapted to the high water temperature found there, it is possible that reductions in water temperature below some critical level could reduce growth substantially. Gribanov _et al_. (1968) found that carp in the USSR had a minimum critical water temperature of 22 C, below which growth was greatly reduced. Backiel and Stegman (1968) found that carp had a preferred range of temperatures within which they had the greatest appetite and maximum growth rate. Warren and Davis (1968) found in laboratory studies that fish have a temperature at which food is used most efficiently for growth and that the efficiency is lowered by any deviation from that temperature. They also found that temperature can influence the food consumption and metabolic rate of fish either physiologically or behaviorally, and can subsequently affect the growth rate.

Dissolved oxygen concentrations in the pond water were probably lowered by decomposition of plant material, impediment of oxygen exchange through the surface film, and impediment of phytoplankton photosynthesis by shading. Similar phenomena were observed by Lynch _et_ _al_. (1947) in lakes in the Gulf States of the southern United States; in addition they found that water hyacinth and water lettuce can remove oxygen directly from the water to support their respiratory requirements. Many authors have reported that a drop in dissolved oxygen below some critical level reduces the appetite, efficiency of utilization of food, and subsequently the growth rate of fish (Fisher, 1963; Adelman and Smith, 1970; Herrmann _et_ _al_., 1962).

The phytoplankton primary productivity of the ponds could be reduced by the great reduction of light intensity and by the uptake of nutrients by the floating plants (Lynch _et_ _al_., 1947). A reduction in primary production reduces the amount of food available at the higher stages of the food chain. Goodyear _et_ _al_. (1972) found that fish production (mosquito fish) in microcosms increased with increasing values of net and gross productivity, as measured by dissolved oxygen methods.

Further effects of thick mats of floating aquatic plants which could reduce fish growth and production include: reduced populations of aquatic invertebrates because of low dissolved oxygen and the destruction of submerged aquatic plants which provide refuge to these organisms, filling of the pond with detritus, ruining spawning sites, and reduction of plankton populations (Lynch _et_ _al_., 1947).

Although the mean values for the total lengths and weights of the fish in ponds D and F were low, there was a great range in the individual values, as indicated by the high coefficients of variation. Approximately 20 percent of the fish in each pond population grew to a size comparable to that of the fish in the ponds where good growth was achieved. It would seem that those fish which grew to a relatively large size were able to adapt to the conditions which restricted the growth of the majority of the fish. Selective breeding of those fish which grow well in ponds covered by floating plants could lead to a strain of *P. kraussii* which could grow well under the adverse conditions created by the plants.

The yellow mojarra in Pond E, although they did not grow well, had a low CV and were not under the stresses created by floating plants. Whereas, in ponds D and F the stresses produced by the plants affected the fish unequally and some were able to adapt to the conditions and grow well, the fish in pond E were apparently all affected equally by the factors that reduced their growth rate and none of them could adapt to it. The large population of tilapia (*Tilapia mossambica*) in pond E may have affected the growth of the yellow mojarra through competition.

An investigation of the tilapia population in pond E resulted in the capture of 113 individuals, all of which were sexually mature. Of these fish, 102 (90%) had zooplankton as the only food item in their stomachs and 11 (10%) had empty stomachs. The tilapia in pond E exhibited physical characteristics typical of a stunted population such as a predominance of small fish, large heads in relation to body size, and sexually mature individuals which were very small. Hida (1962) stated that under conditions of proper food, temperature, and space, male T. mossambica should average about 30 cm TL and females about 22 cm. The largest male and female fish captured in pond E had total lengths of 19.5 and 17.5 cm respectively. The average total lengths for males and females were 17.0 and 13.4 cm respectively. The pond owners also stated that shortly after the tilapia were stocked many large fish were captured, but that in recent years only small fish had been captured. It appears that the stunted tilapia, by feeding on the zooplankton, competed directly with the prey fish and with the small yellow mojarra. It is also possible that the tilapia preyed on the forage fish and the small yellow mojarra (Bhimachar and Tripathi, 1967). A reduced forage fish population would lower the amount of food available to the larger yellow mojarra and could reduce their growth. The tilapia fry probably would not be a good source of food for the yellow mojarra because the fry return to their mother's mouth at the approach of danger (Uchida and King, 1962). Weatherly (1963) found that the intensity of competition is density dependent and that the essential consequences of competition for food among fish are lowered growth rates. Therefore, it seems likely that the low growth of the yellow mojarra in pond E was the result of direct and indirect competition with the large tilapia population for the limited food supply.

The growth of *P. kraussii* is much enhanced by the presence of forage fish. The yellow mojarra stocked in pond G, which contained forage fish, grew at a much faster rate than those stocked in pond H, which contained no forage fish.

Conclusions and Recommendations

P. kraussii grow much faster in ponds with little or no floating aquatic vegetation, although small amounts of floating vegetation may enhance the growth rate of fish by providing diversification of the environment and increased food production (Philipose, 1968; Walquist, 1969). Floating aquatic plants would, however, probably present greater problems in trying to control their spread than would be justified by the small increase in production. Other authors have recommended that fish ponds be kept free of higher plants (Philipose, 1968; Walquist, 1969).

Yellow mojarra grow much faster when forage fish are available. If forage fish are not present in ponds which are to be stocked with yellow mojarra, they should be stocked before or with the yellow mojarra.

The use of Tilapia mossambica for fish culture in Colombia should be stopped and their spread controlled if possible, since they apparently compete with P. kraussii and since nothing is known of their effects on the other fresh-water and estuarine fish and invertebrates of Colombia. The damage that this fish could cause to the fish and invertebrate fauna of Colombia is enormous. If tilapia damage or destroy native fish and invertebrate populations, the Colombian economy would suffer greatly because of decreases in: 1) fisheries related jobs, 2) the amount of usable fish protein available, and 3) badly needed foreign currency derived from shrimp export.

Yellow mojarra, because of their relatively high position in the food chain, probably do not offer the high rates of production that could be achieved with other species of fish which are native to Colombia and which are omnivores (Pimelodus clarius) or detritus feeders (Prochilodus reticulatus). However, because of its fast growth, ability to breed in lentic conditions, acceptance as a fine food fish, easy catchability, and piscivorous habits, the yellow mojarra definitely has a place in future pond fish culture in Colombia. In intensive pond culture of mixed species of fish, the yellow mojarra would be of value in controlling small fish which usually enter a pond and which compete with other species. In farm ponds, the yellow mojarra could provide a family with an easily obtainable, cheap and continuous supply of fish protein with which to supplement their diet.

Further work needs to be done with the yellow mojarra in the following areas: 1) stocking rate of adults in brood ponds, 2) stocking rate of fingerlings in growth ponds, 3) mixed species culture, 4) fertilization of ponds and 5) artificial feeding.

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