Reproduction, Age, and Growth of the Whitemouth Croaker *Micropogonias furnieri* (Desmarest 1823) in Trinidad Waters

Sherry C. Manickchand-Heileman
Zoology Department, University of West Indies, St. Augustine, Trinidad, West Indies
Present address: Institute of Marine Affairs, P.O. Box 3160,
Carenage Post Office, Trinidad, West Indies

Julien S. Kenny
Zoology Department, University of West Indies
St. Augustine, Trinidad, West Indies

Abstract.–Reproduction, age, growth, and mortality of the whitemouth croaker *Micropogonias furnieri* in Trinidad, West Indies, were studied. Maturity was attained at 2 years of age for both sexes. Spawning occurred year-round with a peak from February to August. The condition factor varied with the reproductive cycle. The sex ratio was 1:1.3 male:female. Fecundity ranged from 17×10^3 to 37×10^5 eggs for fish measuring 27.6–57.2 cm total length. Relationships between fecundity (F) and total length (TL) in centimeters, and body weight (W) and ovary weight (Wg) in grams, respectively, were: $F = 2 \times 10^{-4} \mathrm{TL}^{5.56}$; $F = 0.81\, \mathrm{W}^{1.88}$, and $F = 22525\,\mathrm{Wg} - 81355$. The length-weight relationship was $\mathrm{W} = 0.037\,\mathrm{TL}^{2.64}$. Age was determined using otoliths and the analysis of length-frequency distributions. The von Bertalanffy growth equations were $L_t = 65.3\,\{1 - \exp[-0.16(t + 1.6)]\}$ for males and $L_t = 82.9\{1 - \exp[-0.13(t + 1.3)]\}$ for females. Total mortality rate was 1.2/year, natural mortality rate 0.4/year, and fishing mortality 0.8/year. Yield-per-recruit analysis showed the whitemouth croaker to be fully exploited in Trinidad.

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The whitemouth croaker *Micropogonias furnieri* (Desmarest 1823) is found in most of the Antilles, and along the southern Caribbean coast and Atlantic coast of South America from Costa Rica to Argentina (Fischer 1978). Important fishing grounds extend from Venezuela to Uruguay. This species is one of the most economically important demersal fish in Trinidad, where it is caught mainly by trawling and bottom longlines. Juvenile croakers also constitute a significant portion of the shrimp bycatch, most of which is discarded at sea.

Relevant studies have been conducted in Brazil and include general biology (Vazzoler 1962); age and growth (Rodrigues 1968); reproduction, population diversification, and growth (Vazzoler 1970, 1971); feeding habits (Tanji 1974); growth and sexual maturation of juveniles (Castello 1982); and reproductive biology (Isaac-Nahum and Vazzoler 1983).

Presented in this paper are some aspects of the biology, including reproduction, growth, mortality, and yield-per-recruit (Y/R) analysis, of the croaker in Trinidad waters.

Materials and methods

Study area

The island of Trinidad lies between lat. 10°2′N and 10°50′N and long. 60°54′ and 61°56′W on the South American Continental Shelf. Wide expanses of flat, muddy, relatively shallow substrate are found in the coastal areas where trawling for demersal fish and penaeid shrimps is carried out. The climate is tropical with a dry season from January to June and a wet season from July to December. Sampling was done in the northwestern waters of Trinidad in depths of 30–60 m.

Methods

Between October 1977 and September 1982, 2314 croakers were obtained by trawling. The vessels were of steel hull, 25–29 m in length, and carrying two side trawls. The opening of the trawl nets ranged from 13.7 to 18 m at the head end while the cod end mesh size was 2.5 cm. The catch was sorted into species and placed in separate baskets, each with a capacity of about 32 kg. Depending on the size of the catch, 2–3 baskets of croaker were taken at random for analysis. Total length (TL) in centimeters, body weight (W) and gonad weight (Wg) in grams, and sex and gonad maturity stage were recorded.

Four maturity stages were recognized macroscopically (following Vazzoler 1971): immature, maturing, mature (ripe), and spent. Mature ovaries were weighed to the nearest gram and preserved in Gilson's fluid (Simpson 1951), and fecundity determined using a volumetric method (Bagenal and Braum 1971). Condition factor (CF) was determined from the formula CF = 100 W/TL^3 (Hile 1936).

Age was determined using otoliths (sagittae) from a total of 252 fish. Longitudinal sections of otoliths were prepared following the technique described by Holden and Raitt (1974). Sections were wet with water and viewed against a black background using reflected light. Distinct alternating broad opaque and narrow translucent rings were present and the latter were assumed to be annuli. Rings were determined to be annual by using the marginal increment technique (e.g., Moe 1969, Turner et al. 1983). Otoliths were reread by the same worker one month after the initial reading and a 90% agreement was found, while a 92% agreement was found with another worker's readings. Marginal increment and otolith radius were measured using an ocular micrometer (1 micrometer unit = 0.05 mm).

Attempts were also made to determine age by analyzing the length-frequency distribution using cumulative probability paper. Total length was plotted against percentage cumulative frequency, resulting in a Cassie curve (Cassie 1954). Age groups were separated using points of inflexion which were chosen by eye. Only fish caught during March–May 1978 were used in this analysis.

The von Bertalanffy (1938) model was used to describe growth:

$$L_t = L_\infty \{1 - \exp[-K(t-t_0)]\}$$

where L_t is length at time t, K is the growth coefficient, L_∞ is the asymptotic length, and t_0 is the hypothetical age at zero length. These parameters were estimated utilizing the Length Based Fish Stock Assessment (LFSA) Package of BASIC computer programs (Sparre 1987).

Total annual mortality rate (Z) was estimated from a length-converted catch curve (Pauly 1984). Natural mortality rate (M) was determined from the empirical relationship derived by Pauly (1980):

$$\log M = 0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634\, T,$$

where T is the mean water temperature which was 26.2°C in this area. Fishing mortality (F) was calculated as the difference between Z and M (Ricker 1975).

Yield per recruit (Y/R) in grams was determined from the model of Beverton and Holt (1957). Analyses were carried out using the LFSA package. The input parameters were W_∞ (determined from the formula $W = a\, L_\infty^b$), K, t_0, M, t_c (age at first capture of 2 years), which was determined by mesh selectivity experiments (Sylvester 1986), and t_r (age at recruitment). Examination of length-frequency distributions of catches indicated that croakers were fully recruited at a total length of 25 cm, or 1 year of age. The average values of K and t_0 for both sexes were used. Y/R analysis was done for a range of M values to determine their effects on conclusions drawn.

Table 1
Percentage of mature male and female croaker by size group in Trinidad waters.

Total length (cm)	Percentage mature	
	Male	Female
22–24	1	4
24–26	6	20
26–28	44	16
28–30	61	17
30–32	67	49
32–34	74	70
34–36	97	85
36–38	97	89
38–40	97	96
40–42	100	100
42–44	100	100
44–46	100	100
46–48	100	100
48–50	100	100
50–52	100	100
52–54	100	100
54–56	—	100
56–58	—	100

Results

Size at maturity

The percentage of mature males and females in each 3-cm size group is shown in Table 1. The size at which 50% of the fish examined were mature was about 28 cm for males and 32 cm for females.

Spawning pattern

Examination of the monthly frequency of croakers in each developmental stage showed the presence of all stages throughout the year (Table 2). A higher percentage of ripe fish was found from February to August, indicating an intensification of spawning during this time.

Sex ratio

The overall sex ratio of 852 croakers was 1:1.3, male: female. This was significantly different from 1:1 (P

Table 2
Monthly percentages of croaker by developmental stage in Trinidad waters.

Maturity stage	J	F	M	A	M	J	J	A	S	O	N	D
Immature	33	32	23	2	25	48	27	19	–	15	23	37
Maturing	11	34	48	27	40	42	40	32	–	52	58	59
Mature	17	32	20	27	24	10	18	27	–	10	4	3
Spent	39	2	9	44	11	0	15	22	–	23	15	1
N	18	47	141	59	63	42	337	81	–	134	116	80

<0.001). Monthly sex ratios showed a higher proportion of females from March to October and of males from November to February.

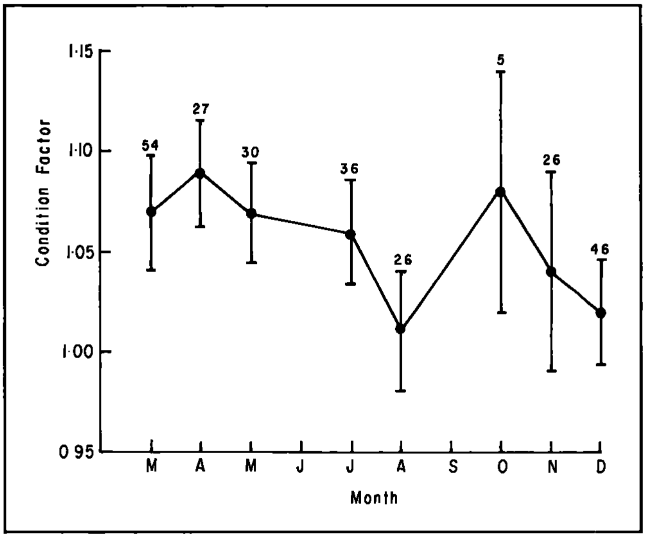

Figure 1
Mean monthly condition factor (±95% CL) of male croaker in Trinidad waters. Number of fish is given for each month.

Fecundity

Fecundity estimates for 24 fish measuring 27.6–57.2 cm ranged from 17×10^3 to 37×10^5 eggs. Mean number of eggs per gram ovary-free body weight was 449 with a standard deviation of 169. Relationships between fecundity and total length, body weight, and ovary weight were described by the following respective regressions:

$$F = 2 \times 10^{-4}\mathrm{TL}^{5.56} \quad (r^2 = 0.90)$$

$$F = 0.81\mathrm{W}^{1.88} \quad (r^2 = 0.89)$$

$$F = 22525\mathrm{Wg} - 81355 \quad (r^2 = 0.99)$$

Length-weight relationship

The length-weight relationship for males was $\mathrm{W} = 0.035\mathrm{TL}^{2.66}$ and for females $\mathrm{W} = 0.030\mathrm{TL}^{2.69}$. Analysis of covariance showed no significant difference between the two sexes ($P>0.05$), therefore the data were pooled and one relationship established: $\mathrm{W} = 0.03\mathrm{TL}^{2.64}$. Asymptotic weight ($W_\infty$) was 3641.6 g.

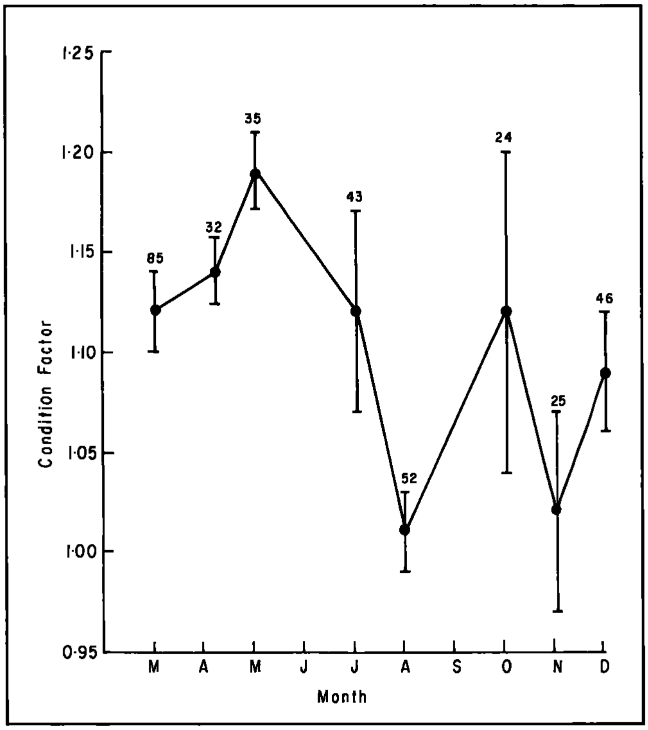

Figure 2
Mean monthly condition factor (±95% CL) of female croaker in Trinidad waters. Number of fish is given for each month.

Condition factor

Monthly variation in condition factor for males and females is shown in Figures 1 and 2, respectively. The condition factor was lowest in August for both sexes while it was highest in April for males and in May for females.

Age and growth

Mean marginal increments were lowest from May to August, indicating that annulus formation occurred during this period (Fig. 3). Fish length was directly proportional to, and highly correlated with, otolith radius (R): $\mathrm{TL} = 12.0 + 32.7\mathrm{R}$, ($r^2 = 0.94$). Otolith reading showed the presence of six age groups for males and seven for females, while analysis of length-frequency

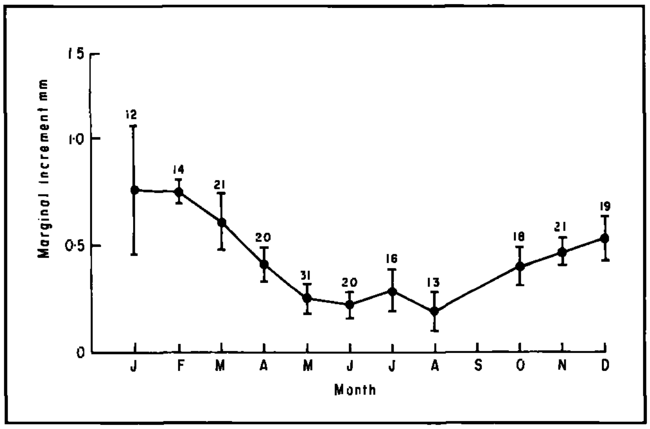

Figure 3
Mean monthly marginal increment (±95% CL) of otoliths of the croaker in Trinidad waters. Number of fish is given for each month.

distribution of combined sexes showed six age groups (Fig. 4). There was close correspondence in lengths at respective ages found by the two methods (Table 3). Based on the above, use of otoliths for age determination of the croaker is considered to be valid. A preliminary plot of the observed length at age revealed that growth of the croaker could be adequately described by the von Bertalanffy equation. Growth parameters showed that females achieved a greater asymptotic length, but grew at a slower rate than males. In Table 4 these parameters are compared with those found for different populations of croaker in Brazil.

Mortality

Total mortality rate (Z) which was the slope of the descending part of the length-converted catch curve in Figure 5 was 1.2/year ($r^2 = 0.96$, $P<0.05$). The 95% confidence limits for Z were 0.91 and 1.49. Natural mortality rate (M) was 0.4/year, and fishing mortality rate (F) was 0.8/year.

Yield per recruit

At the present level of F and t_c, Y/R is already at the maximum of 175 g (Fig. 6). Increasing F results in a decrease in Y/R. Increasing t_c to 3 years results in a Y/R of 181 g at the same level of F. At values of M of 0.1, 0.2, and 0.3 the croaker is overexploited at the corresponding levels of F (Fig. 7), while at M of 0.4 and 0.5 it is fully exploited. At low M values the yield curves are domed with peaks at low F values, while at higher M values they are relatively flat.

Discussion

Several similarities exist in the reproductive biology of the whitemouth croaker throughout its geographical range. Early maturity and year-round spawning have

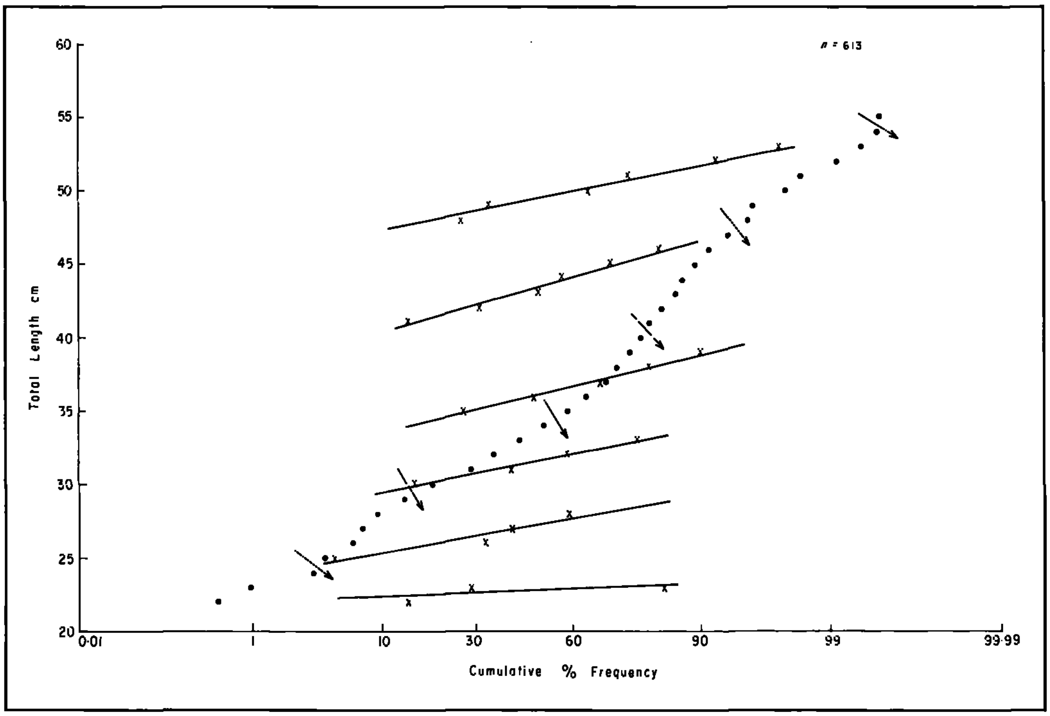

Figure 4
Cumulative percentage length-frequency curve (dotted line) and separation into six age groups (straight lines) for the croaker in Trinidad waters. Arrows indicate inflexion points chosen by eye.

Table 3
Mean length at age determined from otolith sections and length-frequency distribution of the croaker in Trinidad waters.

	Otoliths (TL ± SD)				Length-frequency distribution
Age group	Male	*N*	Female	*N*	(±SD)
I	22.0 ± 1.92	26	21.6 ± 2.09	23	22.3 ± 0.35
II	28.3 ± 1.85	21	29.4 ± 2.71	34	27.3 ± 1.65
III	33.6 ± 1.49	14	34.2 ± 1.89	18	31.6 ± 1.65
IV	38.5 ± 2.36	29	40.5 ± 1.98	30	36.2 ± 2.05
V	42.5 ± 1.83	10	47.5 ± 2.94	12	43.5 ± 2.45
VI	45.6 ± 2.79	10	51.6 ± 2.90	14	49.5 ± 1.70
VII	— —	—	53.5 ± 3.25	11	— —

Table 4
von Bertalanffy growth parameters of the croaker in Trinidad and Brazil waters.

Area	Sex	L_∞	K	t_0	Structure	Author
Brazil (33–29°S)	F	69.33	0.149	−2.79	scales	Vazzoler 1971
	M	89.57	0.076	−4.64		
Brazil (29–23°S)	F	60.10	0.219	−2.08	scales	Vazzoler 1971
	M	82.90	0.106	−2.97		
Brazil (4°S)	F	67.60	0.18	−0.42	scales	Rodrigues 1968
	M	68.60	0.18	−0.52		
Trinidad	F	82.90	0.13	−0.13	otoliths	This study
	M	65.30	0.16	−0.16		

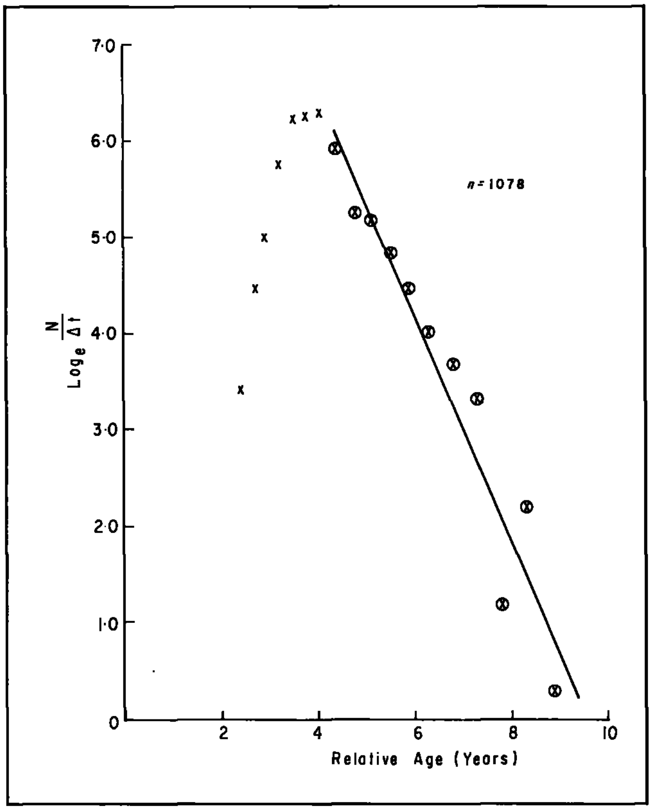

Figure 5
Length-converted catch curve of the croaker in Trinidad waters. (⊗) points used to find Z; (x) ascending part of curve, not used in analysis.

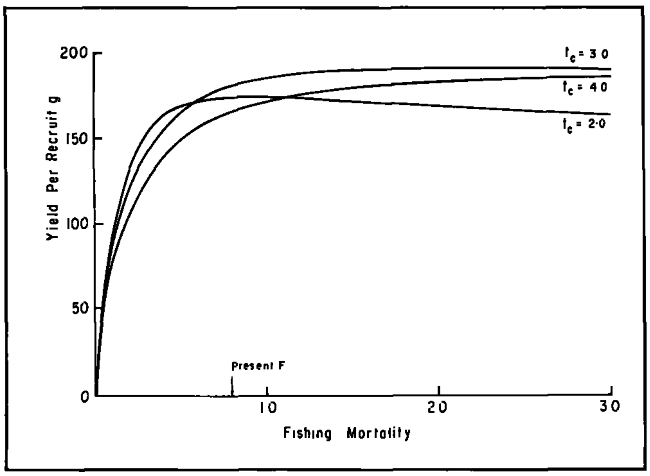

Figure 6
Yield per recruit (g) of croaker in Trinidad waters against fishing mortality for age at first capture of 2, 3, and 4 years.

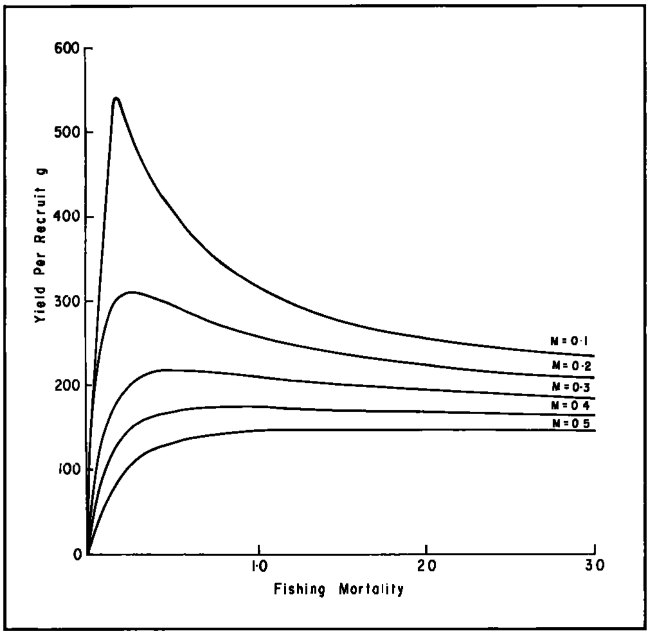

Figure 7
Yield per recruit (g) of croaker in Trinidad waters against fishing mortality for natural mortality rates of 0.1, 0.2, 0.3, 0.4, and 0.5 per year.

also been recorded in Brazil (Vazzoler 1962, 1971; Castello 1982; Isaac-Nahum and Vazzoler 1983), and in Guyana (Lowe-McConnell 1966).

Other workers have been successful in determining the age of tropical and subtropical sciaenids using otoliths (e.g., Bayagbona 1969, Villyamar 1972, Pannella 1974, Barger 1985). Annulus formation coincides with both the period of peak spawning and the wet season when salinity decreases due to river run-off. A similar pattern occurs in other species of tropical sciaenids (e.g., Rao 1966, Le Guen 1971). The annulus in immature croaker is probably formed in the wet season of the year following their year of birth. Use of the Cassie method had two disadvantags: the subjectivity in choosing the inflexion points and the crowding of older age groups into the upper part of the cumulative frequency curve. However, the close agreement of results obtained by both methods validates the use of otoliths for age determination of the croaker.

The higher value of K for males than for females suggests a higher mortality rate for the former (Beverton and Holt 1959). This could also account for the presence of only six age groups for males and the predominance of females in the population.

The variation in growth between Trinidad and Brazil indicates that the croaker does not present a uniform population in this region. According to Vazzoler (1971) geographical differences in growth characteristics of this species are due to genotypical and ecological factors such as salinity and temperature.

Estimation of mortality rates from length-converted catch curves is subject to several assumptions, the most important of which is that of constant recruitment (Ricker 1975). Examination of length-frequency distributions indicated that the modal length in the catch was similar for all years of sampling (33.0–34.9 cm), and no particularly strong or weak year class was apparent. Another assumption is that of constant fishing effort, which did not change appreciably during the period of sampling, as indicated by the number of active vessels. Since only fully recruited age groups were used in this analysis, Z was assumed to be constant over these ages. Trawling was considered to be a random method of sampling for older, fully recruited age groups, and the sample was assumed to be representative of that part of the population which was used to compute Z. Violation of these assumptions often results in non-linear right limbs of catch curves (Ricker 1975). However, the linear right limb of the catch curve in this study and the significant regression suggest that the estimate of Z is acceptable.

All of the conditions, except that of isometric growth, accompanying the Beverton and Holt model are assumed to exist for the croaker. The assumption of isometric growth, when growth is in fact allometric, leads to incorrect estimates of yield (Paulik and Gales 1964). However, the absolute levels of these estimates are not of as much interest as the differences in yield that result from varying t_c and/or F. The relative error in such differences, when using an incorrect b, tends to be much less than that in the absolute levels (Ricker 1975).

Locally, fishing is the major cause of mortality of the croaker. At the present t_c and the level of F the maximum sustainable Y/R is already being obtained, and any increase in F would result in overexploitation. Increasing t_c to 3 years may not be economically worthwhile since the resulting increase in Y/R is only 6 g. Such a move however, would protect 2-year-old fish that are spawning for the first time. Because of the flattening of the yield curves at high F values, the effect of overexploitation on yield is small. However, the effects of overexploitation on recruitment is unknown, and requires future study.

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