AGE, GROWTH AND MORTALITY OF GRAY SNAPPER COLLECTED FROM FLORIDA WATERS

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Abstract: Otoliths and scales of gray snapper, *Lutjanus griseus,* sampled from the Florida headboat fishery were examined to see if they could be used to age the species. Scales were not useful, but sectioned otoliths proved to be excellent for determining age and growth. Rings could be identified and counted on 91% of all otoliths examined, and measurements could be made on 86%. The oldest fish encountered was 21 years; 775 mm TL. Back-calculated lengths at annulus formation ranged from 95 mm for age 1 to 772 mm for age 19. The von Bertalanffy equation describing theoretical growth is $l_t = 890\ (1\text{-}e^{-0.1009(t+0.3161)})$. Gray snapper were fully recruited to the hook and line fishery as 5 to 7 year olds depending on the area. Total instantaneous mortality estimates for fish landed in North Florida (Mayport and Daytona) and South Florida (Pompano, Boynton and Key West) were significantly different. A yield-per-recruit model is presented and should be useful in the future management of the species along the east cost of Florida. The length-weight relationship is $W = 2.4 \times 10^{-8}\ TL^{2.9122}$, where W = weight in kilograms. Length conversions are FL = 3.6476 + 0.9359TL, and SL = 2.7381 + 0.7781TL.

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The objectives of this study were to determine the age and growth of gray snapper in Florida, estimate total instantaneous rates of mortality using catch curves from the recreational headboat fishery and construct a yield per recruit model to demonstrate the effects of different levels of fishing on potential yields. We anticipate that the information presented in this paper will be used by Regional Fishery Management Councils to assist them in preparing management plans for reef fish as provided for under the Fishery Conservation and Management Act of 1976.

The gray snapper, also known as the mangrove snapper, is a tropical marine reef fish which commonly occurs in the western Atlantic from the northern coasts of Florida to Rio de Janeiro. Juveniles are occasionally found as far north as Massachusetts but are not indicative of local, established populations. The habitat is highly variable and includes irregular substrates offshore such as coral reefs, rock outcroppings and shipwrecks. Inshore, the species may be found over smooth bottom usually associated with seagrass beds and mangrove thickets. Larger individuals generally occur offshore, whereas smaller fish are found in estuaries and in shallow coastal waters.

Like other lutjanids, gray snapper are important to both recreational and commercial fisheries because they are game fighters on sporting tackle and are excellent to eat. The species is very popular off South Florida and around the Antilles where it is caught by hook and line, beach seines and fish traps.

Recreational anglers fish for reef fish from headboats or smaller private boats using manual or electric reels, sturdy boat rods, heavy monofilament line and two-hook bottom rigs baited with squid or cut fish (Huntsman 1976). This form of deep water fishing is very popular off Florida where the gray snapper is caught with mutton snapper, *Lutjanus analis,* lane snapper, *L. synagris,* red snapper, *L. campechanus,* and yellowtail snapper, *Ocyurus chrysurus,* as well as representatives of the families Haemulidae, Serranidae and Sparidae. In addition, smaller reef fish including young gray snappers are caught by anglers fishing from piers, jetties, bridges, and the shore.

Two previous studies have been published on the age and growth of gray snapper from south Florida (Croker 1962; Starck and Schroeder 1971). However, both were directed at small (young) fish and data are indequate to calculate growth parameters which may be used to derive harvest strategy models for the fishable stock(s).

Our research was made possible through the combined efforts of the National Marine Fisheries Service, Southeast Fisheries Center's Reef Fish Program (Beaufort Laboratory) and Bioprofiles Task (Panama City Laboratory). Special appreciation is extended to Robert L. Dixon and Harold Brusher who directed field sampling activities along the east coast of Florida and in the Florida Keys, respectively.

METHODS

Gray snapper were sampled from recreational headboats operating out of ports along the east coast of Florida from Jacksonville through the Keys, 1978 - 1981. In addition, 19 young-of-year fish caught in shrimp channel nets were obtained from a commercial fisherman in Beaufort, North Carolina in October, 1980. A total of 1,305 fish was weighed and measured, and otholiths and scales were removed from 659. Weights were recorded in kilograms and total and fork lengths in millimeters. All lengths were later converted to total lengths.

Scales were taken beneath the tip of the posteriorly extended pectoral fin, soaked in a 10% phenol solution, cleaned and dried. Six scales per fish were mounted between 2 glass slides and viewed on an Eberbach projector at about 40× (Mention of product brand names does not mean an endorsement by NMFS, NOAA.). When possible, measurements were made in the anterior field along a line from the focus to the scale margin. Distances in millimeters from the focus to each ring and to the margin were recorded. (Fig. 1a).

Otoliths (sagittae) were removed either by making a cross cut in the cranium with a hacksaw thus exposing the earbones, or by opening the otic bulla with a wood chisel and entering the cranium from under the operculum. The latter technique was used to avoid disfiguring fish which were to be sold. Otoliths were read either whole or after sectioning and were then stored dry in vials or envelopes. Whole otoliths were placed in a blackened-bottom watch glass containing clove oil and were viewed under a dissecting microscope at 20× with the aid of reflected light. Measurements were made from the core to each ring and to the otolith radius (Fig. 1b). The selected field of measurement may very between species. Therefore, before sectioning, respresentative otoliths were examined microscopically to identify the area where rings were most legible and where erosion of the edge was minimal. Otoliths were then aligned and mounted in a chuck to

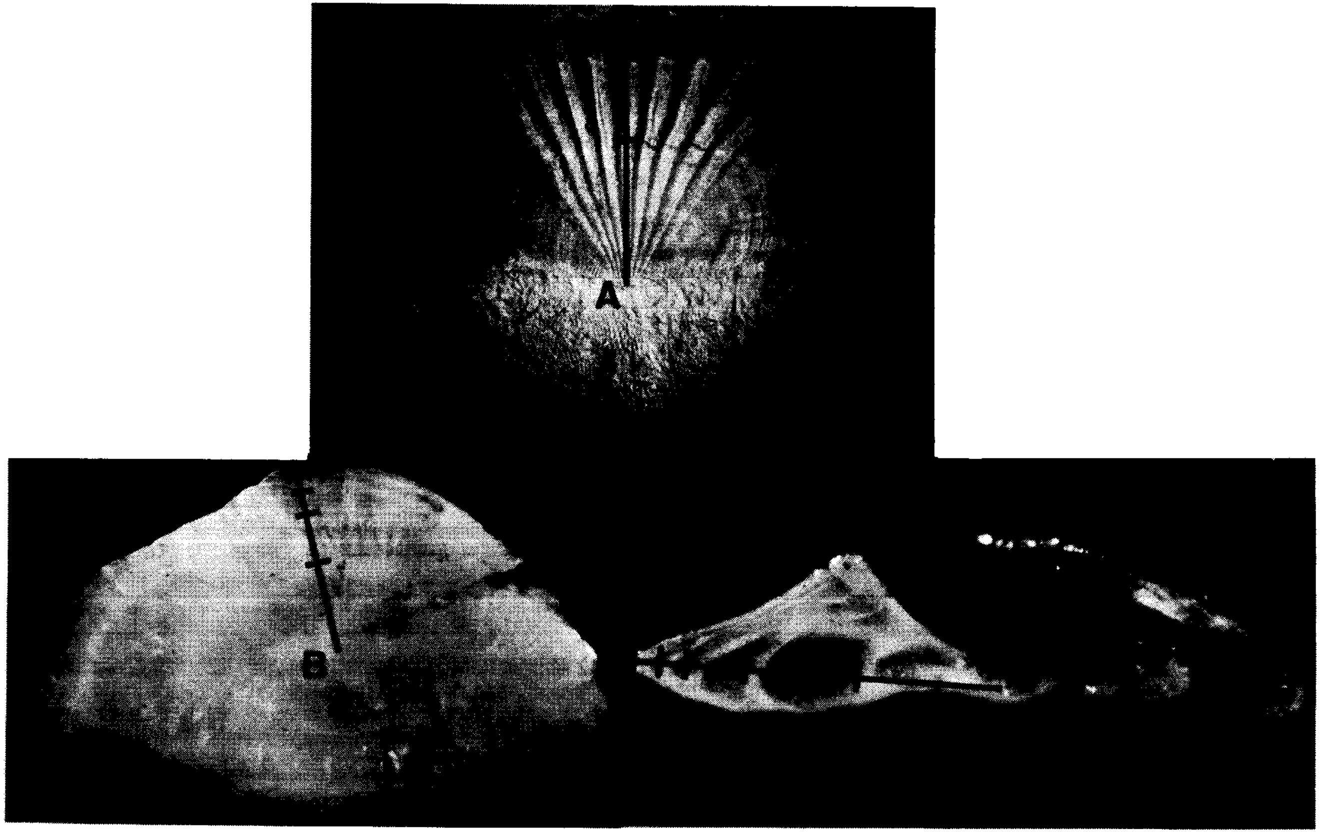

Fig. 1. Scale of gray snapper showing area of measurement (a); whole otolith with area of measurement (b); and sectioned otolith with four annuli and margin measurements (c).

prevent lateral movement, and sectioned with a Buehler Isomet 11 - 1180 low speed saw yielding 3, 0.03-cm sections (Fig. 1c). The sections were read and measured in the same manner as described above for whole otoliths. A detailed discussion of the methods used to prepare and section otholiths is provided by Matheson (1981).

RESULTS

Contrary to the findings of Croker (1962) and Starck and Schroeder (1971), we found that scales were not useful for aging gray snapper. Over 80% of the scales analyzed in our study were regenerated. Those that were not were thick, often abnormally formed, and rarely possessed a consistent pattern of markings.

Whole otoliths were somewhat more readable than scales, while sectioned otoliths were as legible as any we have seen. Rings were clear, formed around the entire structure, and were therefore easily enumerated and measured. Growth marks could be identified on 91% of all otoliths examined, and measurements could be made on 86% (568 of 659).

The validation process of proving that rings occurring on fish hardparts are true annuli, formed only one time each year, is an important step in any aging study. This is particularly true when the species inhabits tropical waters where water temperatures are relatively stable. However, since Croker and Starck and Schroeder had already aged gray snapper from southern Florida waters, we felt that it was unnecessary to validate our results. This conculsion was based on the knowledge that the above researchers had easy access to young fish (ages 0 - III) throughout the year and could document the time of annulus formation.

Length Conversions

Because fish sampled from the Florida Keys (by Panama City Laboratory personnel) were measured in fork lengths (FL) and data from Croker (1962) and Starck and Schroeder (1971) were presented in FL and standard lengths (SL) respectively, we derived conversion equations so that standardized comparisons of total lengths at ages could be made. The following equations were derived based on random stratified sampling of fish lengths:

$$FL = 3.6474 + 0.9359\ TL,\ N = 95,\ r = 0.995,$$

and

$$SL = 2.7381 + 0.7781\ TL,\ N = 95,\ r = 0.999.$$

Observed Growth

Young-of-year collected in North Carolina in October, 1980 ranged from 80 to 115 mm TL ($\overline{X} = 99.2$ mm). We hypothesize that these individuals were spawned in the late spring and since they were collected in the fall the sizes represent the near maximum lengths they will attain as 0-aged fish. The mean size compares favorably with Croker (1962) and Starck and Schroeder (1971) who recorded 83 and 84 mm TL (converted), respectively, for the sizes at time of the first annulus formation.

Although the mean size increased with added age, there was much variation in lengths for a specific age, especially ages 5 through 8 (Fig. 2). One would expect to find much variation in observed age data, particularly when dates of collection for the different areas were not the same, and because the spawning season of the gray snapper is extended.

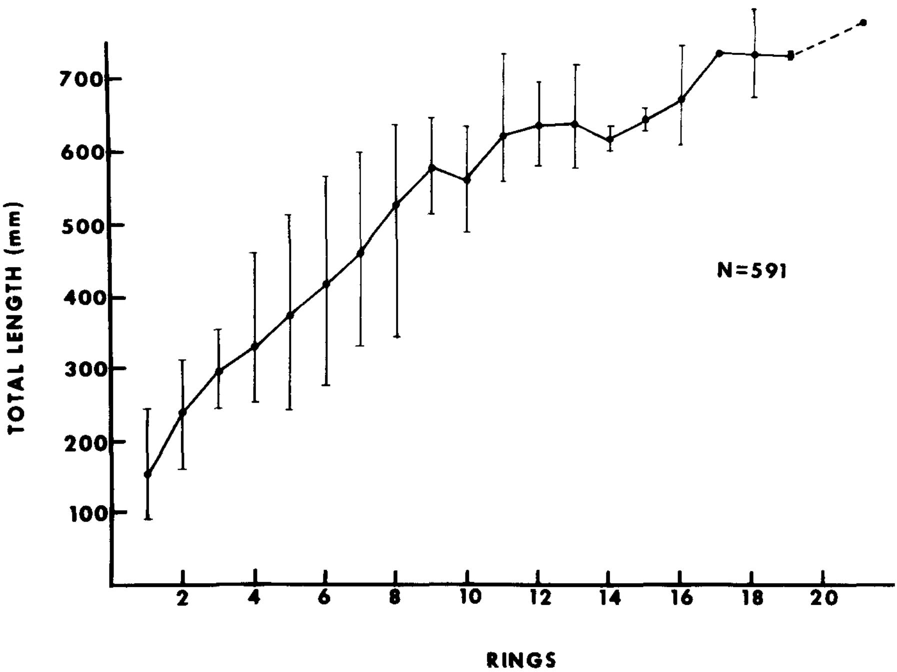

Fig. 2. Observed mean total lengths (mm) and ranges for gray snapper aged by cross-sectioned otholiths.

The oldest fish we examined had 21 rings and measured 775 mm TL. A fish 849 mm TL was reported by a sampler, but we were unable to verify the species identification or match aging structures with the field data.

Back-Calculated Growth

Lengths by age for all years and areas combined were back-calculated from otolith radius-fish length regression. The equation was derived by plotting projected otolith radius on total fish length. Since a majority of the measurements occurred between a relatively narrow size range because of fishing gear selectivity, we subsampled fish length measurements after first grouping them into 25-mm size intervals. The equation was log TL = 0.4588 + 1.3414 (log OR); r = 0.9748 and N = 135, or $TL = 1.5822\ OR^{1.3414}$, where TL = total fish length in mm, and OR = otolith radius in micrometer units. We substituted the means of the distances from the focus to each annulus for OR in the above equation, calculated the mean length of gray snapper at the time of each annulus formation, and then calculated mean growth increment for each year (Table 1).

Growth increments for the 1st 2 years are about equal (95 and 103 mm). It is unusual that the 2nd year's growth appears to exceed that of the 1st. Other researchers have found a similar pattern (Table 2). We believe that our values resulted from an under estimate of the 1st annulus which often appeared as a relatively wide, poorly defined band. Gray snapper continue to grow at a relatively fast rate for the next 2 years (ages 3 and 4), but afterwards annual growth begins to level off and generally declines (Table 1). Mean increment values for ages 14 to 19 are of doubtful accuracy because of small sample sizes and because annuli of older fish are extremely close together and therefore difficult to measure precisely. For these older fish tenths of micrometer units become important, and are almost impossible to measure.

Theoretical Growth

The von Bertalanffy equation, $l_t = L_\infty(1-e^{-K(t-t_o)})$, was selected to describe the theoretical growth of gray snapper. The curve was fitted to back-calculated data (Everhart, Eipper and Youngs 1975; Ricker 1975). The growth parameters $L\infty$ and K were initially obtained by fitting a Walford (1946) line: $l_{t+1} = L\infty(1-k) + kl_t$, where l_t = total fish length at age t, k = slope of the Walford line, and L_∞ = maximum length. The equation for our data is $l_{t+1} = 93.9681 + 0.8901\ l_t$, r = 0.9991. The slope (k) is equal to e^{-k}, thus K = -ln 0.8901 or 0.1164. A preliminary value of 855.5 for $L\infty$ was obtained by solving the equation:

$$L_\infty = \frac{\text{y intercept}}{(1-k)}.$$

These estimates of K and $L\infty$ look reasonable to us. However, to check the accuracy of our estimates of the 2 growth parameters, we plotted $l_n\ (L\infty - l_t)$ against t; the straightness of the line is dependent upon the value of L_∞. By using trial values of L_∞ at 10-mm intervals which bracketed the preliminary value obtained, we were able to determine that the best $L\infty$, the one with the straightest line, occurred for 890 mm (Fig. 3). The K derived from this equation, 0.1009, and y intercept, 6.7593 were used to solve for t_o:

$$t_o = \frac{\text{y intercept of natural log line} - ln\ 890}{K} = -\ 0.3161.$$

This technique of deriving von Beralanffy growth parameters is discussed by Everhart, Eipper and Youngs (1975:76) and is illustrated by Ricker (1975:226). Thus, our theoretical growth equation for gray snapper is

$$l_t = 890\ (1\text{-}e^{-0.1009(t\ +\ 0.3161)}).$$

Specific age-length values are presented in Table 3.

Table 1. Calculated total lengths of gray snapper aged by otoliths.

Observed age	N	Mean calculated total length at time of annulus formation.																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	13	88.5																		
2	23	91.3	199.2																	
3	47	97.3	192.7	272.5																
4	159	86.9	188.3	263.9	323.2															
5	82	95.3	196.4	270.8	326.3	370.4														
6	104	95.8	199.3	275.9	328.8	371.8	409.8													
7	57	97.0	200.7	276.8	332.7	374.7	412.7	449.9												
8	33	90.4	201.6	282.4	342.6	386.7	426.8	466.0	500.6											
9	15	90.4	205.9	284.8	346.2	393.9	438.3	476.9	514.5	548.0										
10	5	109.9	203.8	283.2	333.5	380.7	427.7	468.7	501.6	531.2	555.6									
11	5	101.2	211.1	283.2	336.8	379.0	422.4	463.3	497.9	531.2	563.1	591.7								
12	4	91.0	186.4	265.0	333.5	388.4	445.4	490.5	525.1	557.9	591.2	622.6	649.4							
13	4	100.0	211.8	290.7	337.6	384.1	427.7	463.3	499.7	529.8	565.0	588.8	615.8	637.2						
14	2	91.0	193.6	280.8	354.4	401.4	440.9	476.9	518.2	546.1	574.5	603.2	627.4	647.0	666.7					
15	6	100.0	199.6	279.4	328.0	371.3	407.2	442.5	484.4	518.2	549.3	584.0	611.2	634.0	658.5	679.8				
16	4	92.5	193.6	278.8	335.6	379.8	418.9	456.6	495.1	536.8	574.5	600.8	627.4	654.3	679.0	699.0	724.1			
17	-																			
18	4	100.0	202.7	268.9	327.3	371.3	410.1	452.1	490.5	525.1	567.4	596.0	634.7	666.7	688.0	709.0	734.2	752.0	772.4	
19	1	93.9	172.3	253.4	333.5	384.1	418.9	472.4	508.9	536.8	565.0	584.0	612.9	632.3	661.7	681.5	701.5	721.6	741.8	772.4
Number of calculations		568	555	532	485	326	244	140	83	50	35	30	25	21	17	15	9	5	5	1
Weighted means		95.1	197.6	275.7	334.7	381.3	423.6	464.9	503.3	536.1	567.3	596.4	625.5	645.3	671.0	692.3	719.9	736.8	757.1	772.4
Increments		95.1	102.5	78.1	59.0	46.6	42.3	41.3	38.4	32.8	31.2	29.1	29.1	19.8	25.7	21.3	27.6	16.9	20.3	15.3

Table 2. Comparison of 3 sources of back-calculated length at age data.

Age	Total length (mm)		
	This study	Croker (1962)	Starck and Schroeder (1971)
1	95	83	84
2	198	188	155
3	276	254	216
4	335	311	278
5	381	372	320
6	424	457	365
7	465	483	413
8	503		474
9	536		520

Theoretical growth parameters were also calculated by the Marquardt method utilized by Nelson (1980). The values of L_∞ (893 mm), K(0.0982), and t_0 (−0.4820) derived were extremely close to the parameters calculated by our iteration method.

Length-Weight Relationship

To calculate the relationship of fish weight to total fish length, we arranged lengths in order of smallest to largest and stratified them by 100-mm intervals. All fish <200 mm and >700 mm were selected because there were few of them. Random subsamples were taken from each of the other 100-mm intervals so that $N \geq 100$. The length (TL) – weight (kg) equation for gray snapper is

$$W = 2.4 \times 10^{-8}\, TL^{2.9122};\ N = 119 \text{ and } r = 0.9967.$$

Mortality Estimates

Mortality estimates may be obtained after fish have been aged and if the size or age distrubution in the catch is known. Gray snapper were not fully recruited to the headboat fishery until at least age 5 and sometimes as late as age 7. Annual total mortality estimates from catch curves, therefore, were based on fish age 5 or older. If the $\log_e$ of the age frequency in the catch is plotted on age, the slope of the linear descending right limb of the curve estimates the mean instantaneous total mortlity (Z). To calculate mortality rates, we first needed to assign ages to the unaged fish whose lengths had been recorded. We grouped fish of known age by 25-mm length intervals, calculated the percentage of fish of each observed age in each group and used these percentages to estimate the number of fish of each age for the unaged group (Ricker 1975). We estimatd annual total instantaneous mortality rates (Z) by area using the regression method (Beverton and Holt 1957).

When we analyzed length frequency data from headboat landings by area we discovered drastic differences. Fish from the more southern ports along Florida's east coast were much smaller than gray snapper caught farther north (Fig. 4). This difference presented a problem when the data were compared by geographic area. Therefore, for the purpose of this paper we used length frequency data for all years

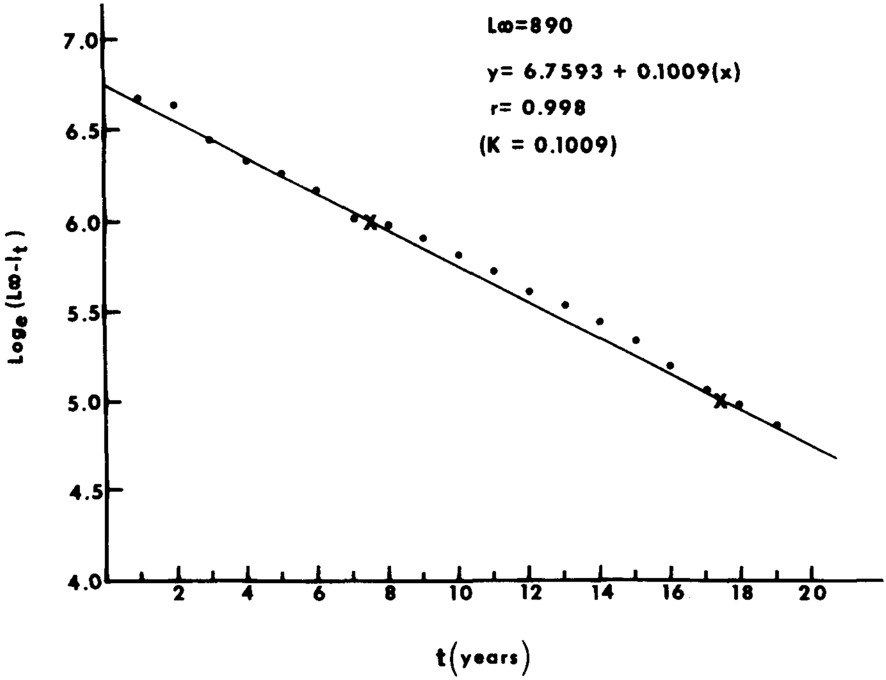

Fig. 3. Plot of Log_e (L_∞ − l_t) against age that best fits the back-calculated growth data of gray snapper.

combined for the east coast where sampling of landings had been more spatially and temporally representative. Two geographic areas were compared: North Florida (Mayport and Daytona), and South Florida (Pompano, Boynton and Key West).

Gray snapper were fully recruited to the headboat hook and line fishery at age 5 in South Florida and age 7 in North Florida (Fig. 5). For South Florida, the estimated instantaneous mortality rate was calculated using only ages 5 through 14 years since very few fish older than 14 were sampled. The mortality rate for North Florida was determind by using ages 7 through 14. As expected the mortality rate was higher for South Florida (0.60) than for North Florida (0.39). We believe the difference results from a much greater fishing pressure in South Florida.

Yield-Per-Recruit Model

Estimates of productivity or yield are a prerequisite for proper management of marine fish species. Since stock size-recruitment relationships and extended annual catch and effort statistics are not presently available for gray snapper, we utilized a yield-per-recruit model which allows calculation of a surface expressing yield-per-recruit as a function of recruitment age and fishing mortality (Beverton and Holt 1957). Yield-per-recruit is defined as the ratio of total weight (kg) of fish that could be taken from a cohort divided by the number of individuals of that cohort

Table 3. Comparison of observed, calculated and theoretical growth data.

Age	Observed	Back-calculated	Theoretical
1	151.1	95.1	110.7
2	238.8	197.6	185.5
3	298.4	275.7	253.1
4	331.0	334.7	314.3
5	379.2	381.3	369.4
6	419.4	423.6	419.5
7	466.5	464.9	464.6
8	530.0	503.3	505.4
9	580.8	536.1	542.4
10	560.6	567.3	575.7
11	622.6	596.4	605.9
12	637.7	625.5	637.1
13	638.8	645.3	657.8
14	618.5	671.0	680.0
15	643.2	692.3	700.2
16	670.8	719.9	718.4
17	735.0	736.8	734.9
18	733.8	757.1	749.8
19	731.5	772.4	763.3
20			775.5
21	775.0		786.4

which entered the fishing grounds. Parameter estimate requirements were minimal yet allowed an analysis of the relationships between fishing mortality, recruitment age, and yield.

The yield model for gray snapper was constructed according to the techniques outlined by Huntsman, Manooch, Massey, and Grimes (unpbl. ms., Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, N.C. 28516-9722). Instantaneous natural mortality (M) and growth parameters such as L_∞, W_∞, and K shaped the response surface, while instantaneous fishing mortality (F) and age at recruitment to the fishery (T_r) were independent variables that fixed yield.

The growth parameters K, L_∞, and t_0 were derived from the von Bertalanffy equation, and W_∞ was calculated using the L_∞ value in the length-weight relationship. Maximum age attained by gray snapper and maximum age in the fishery were determined from the aging work.

Instantaneous natural mortality was calculated by using the multiple regression method described by Pauly (1980), which was based on the relationship of M to annual mean water temperature (°C), K, and L_∞. M for gray snapper was 0.22.

Instantaneous total mortality (Z) is equal to instantaneous natural mortality (M) plus intantaneous fishing mortalilty (F) (Ricker 1975). Estimates of Z in North Florida and South Florida were 0.39 and 0.60, respectively, and M for gray snapper is estimated at 0.22. Therefore, the present estimate of F in North Florida is 0.17 compared to 0.38 in South Florida.

The average age of recruitment to the fishery (T_r) was estimated by analyzing length-frequency data to determine the minimum length (mm) when gray snapper

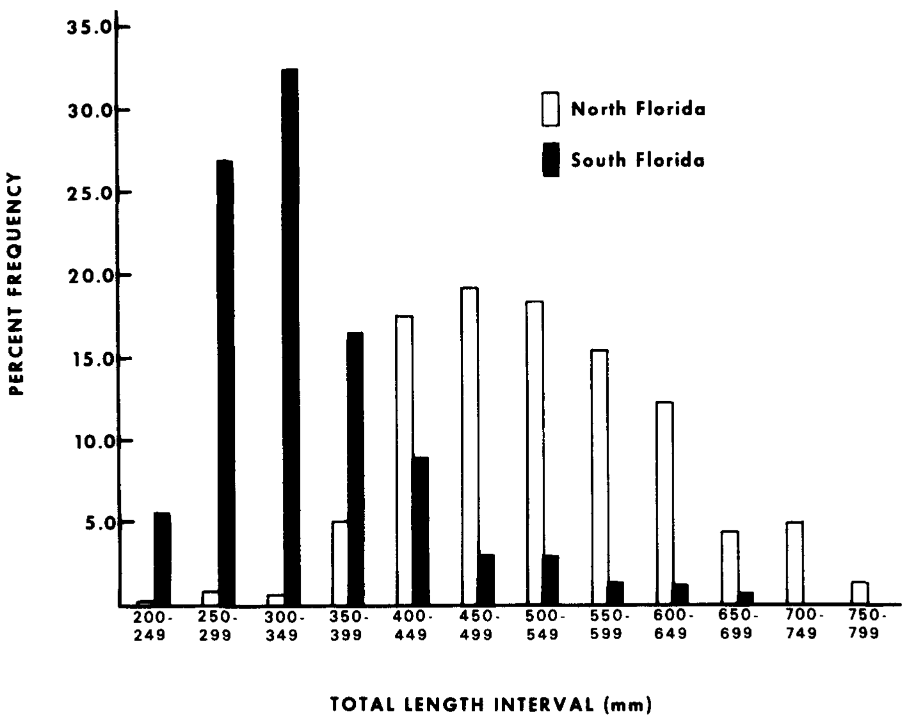

Fig. 4. Length-frequency data for gray snapper caught by headboats in North Florida (N=532) and South Florida (N=434).

become fully susceptible to the hook and line gear in the headboat fishery. Probabilities were calculated based on a normal distribution of the chances that a fish of given age would achieve the minimum length. These probabilities were then used to calculate a weighted mean age at first capture: 6.4 years in North Florida, and 3.9 years in South Florida.

The yield model for gray snapper (Fig. 6) suggests that North Florida headboats are harvesting approximately 71% of the potential yield at current levels of T_r (6.4 years) and F (0.17). Assuming that fishing effort and F are proportional, a 20% increase in yield may be achieved if effort increases 50% and T_r remains constant.

South Florida headboats are harvesting about 79% of the maximum yield, given a current T_r of 3.9 years and F equal to 0.38 (Fig. 6). However, increased effort at current T_r will actually cause a decrease in yield to headboats operating in South Florida. If T_r is allowed to increase to 4.5 years and F remains constant, a 20% increase in yield can be obtained.

Management of gray snapper on the Atlantic coast of Florida should recognize the apparent differences between North Florida and South Florida gray snapper stocks. Gray snapper caught by headboats in South Florida are much younger and have a mortality rate that is half again that in North Florida. It also appears that

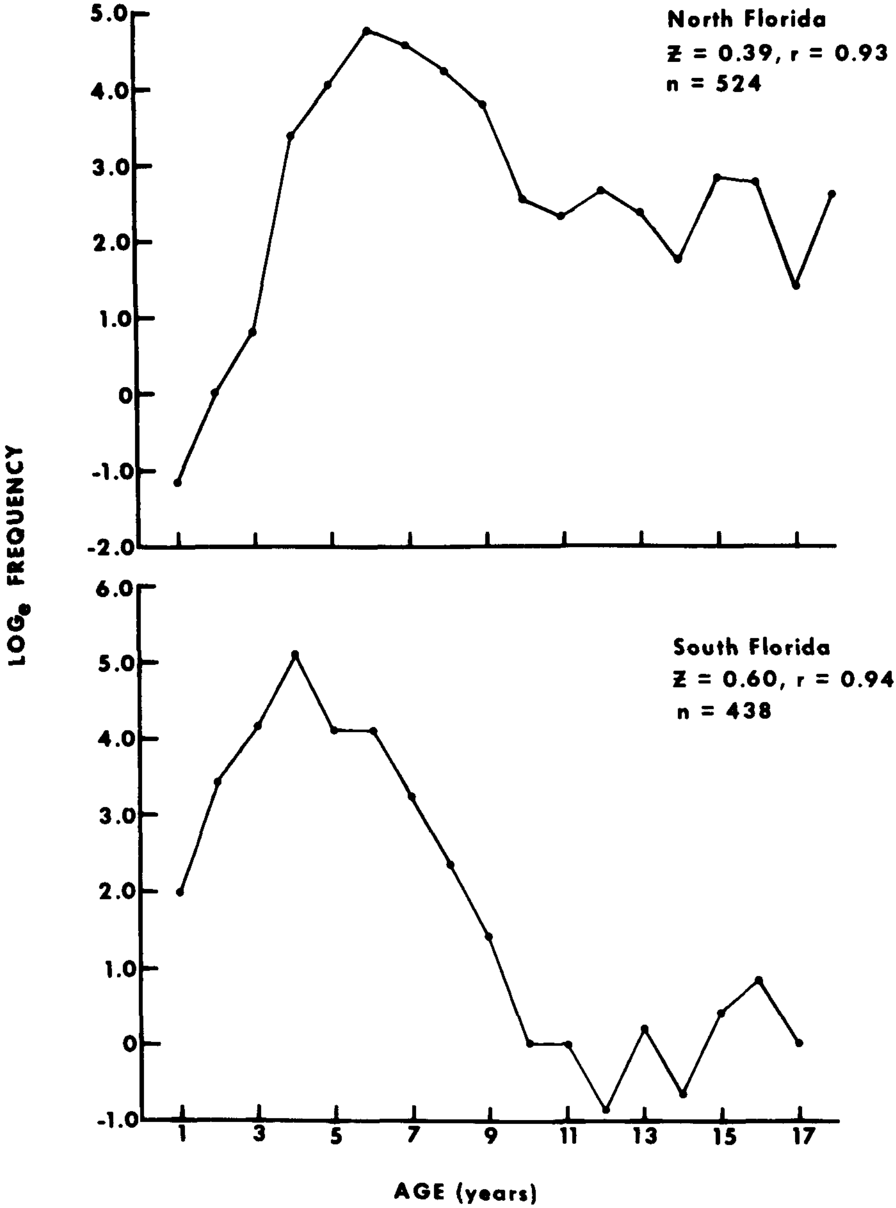

Fig. 5. Catch curves for gray snapper based on length-frequency data from headboats.

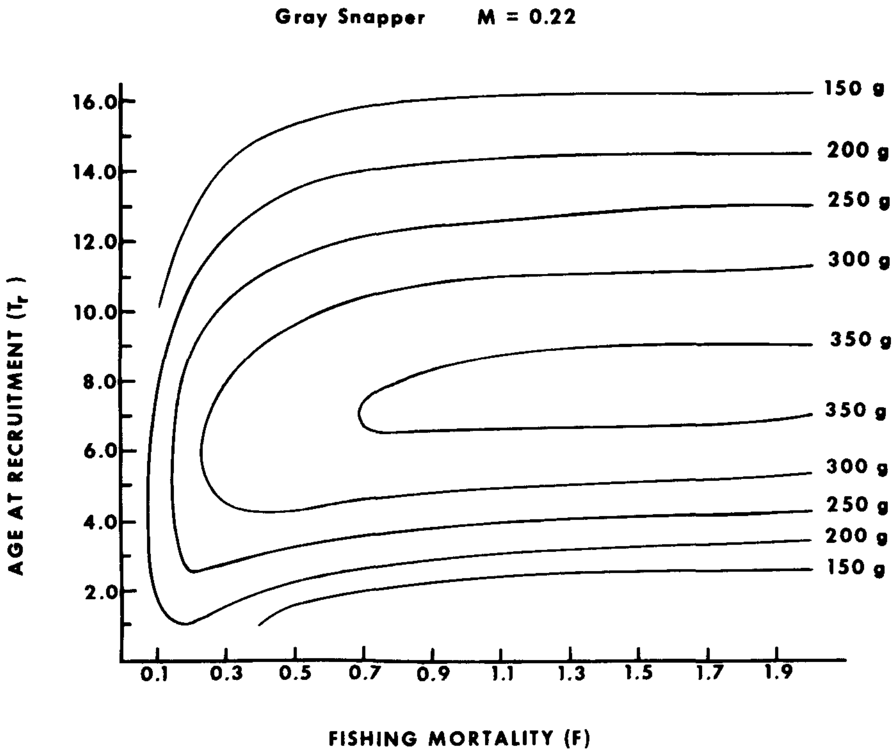

Fig. 6. Yield-per-recruit model for gray snapper, M = 0.22. North Florida T_r = 6.4 years, F = 0.17. South Florida T_r = 3.9 years, F = 0.38.

the age at recruitment of gray snapper harvested in South Florida will have to increase if any additional yield is to be realized in this area by headboat fishermen.

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