AGE, GROWTH, AND MORTALITY OF GRAY TRIGGERFISH, *BALISTES CAPRISCUS*, FROM THE NORTHEASTERN GULF OF MEXICO

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ABSTRACT

Age, growth, and mortality of gray triggerfish, *Balistes capriscus*, from the northeastern Gulf of Mexico were estimated from sections of the first dorsal spine of 1,746 fish. The oldest female was estimated to be 12 years old and the oldest male was 13 years old. The von Bertalanffy growth equations, using weighted means, were as follows: males, $l_t = 491.9\ (1 - e^{-0.382(t - 0.227)})$ and females, $l_t = 437.5\ (1 - e^{-0.383(t - 0.150)})$, where l = fork length in millimeters and t = age in years. The mean annual mortality rate as determined by four methods of analyses (based on number of fish at age) ranged from 0.32 to 0.53. The weight-length relationships of gray triggerfish were males, $W = 6.71505 \times 10^{-6}\ L^{3.187}$, and females, $W = 1.3939 \times 10^{-5}\ L^{3.065}$, where W = weight in grams and L = fork length in millimeters.

Exploitation of fish from the northeastern Gulf of Mexico by recreational and commercial fishermen has created a demand for underutilized fish resources. One of the abundant fish resources that is being subjected to exploitation is the gray triggerfish, *Balistes capriscus*. A dramatic increase in demand for this species can be seen in the commercial landings on the west coast of Florida: 7.8 t in 1967 and 26.7 t in 1977 (Anonymous 1967, 1977).

This species is known to occur in the western and eastern Atlantic. In the western Atlantic, its range is from Nova Scotia to Argentina, including the Gulf of Mexico (Briggs 1958; Moore 1967). In the Gulf of Mexico, the gray triggerfish is a primary reef fish inhabiting the area between 12 and 42 m in depth (Smith 1976), except for its first year of life when it is planktonic and associated with *Sargassum* (Dooley 1972).

The harvest of the gray triggerfish in the northeastern Gulf of Mexico and its utilization of reef habitats has created a need to know more about the biology of this species, especially age, growth, and mortality. Age and growth of gray triggerfish, using the first dorsal spine, has been reported only for the southwestern coast of Africa (Anonymous 1980; Caveriviere et al. 1981). This paper reports the results of our investigation on age, growth, and mortality, using the first dorsal spine of gray triggerfish from the northeastern Gulf of Mexico.

METHODS AND MATERIALS

The hook and line fishery for gray triggerfish off Panama City, Fla., was sampled from May 1979 to March 1982. During this period, 2,808 fish were sampled and from each the fork length in millimeters and total weight in grams measured and recorded. The sexes of the fish were also recorded when determinable by gross examination of the gonads. First dorsal spines were available from 1,746 of the 2,808 fish in the collection. Total length (TL), standard length (SL), and fork length (FL) were measured in millimeters from 100 fish to develop length conversion formulas.

The first dorsal spines were processed for examination as follows: 1) removing the first 5 mm of spine shaft above the condyle with a Dremel[2] tool; 2) placing the shaft section on a mounting tag using Lakeside No. 70c thermoplastic cement and sectioning the shaft using the method described by Berry et al. (1977); 3) removing three 0.18 mm thick serial sections from the cement with 50% isopropanol; and 4) mounting the clean sections in 20% Piccolyte cement (20% Piccolyte, 80% xylenes) on glass slides.

Spine cross sections were examined and measured using a closed-circuit television using a 50

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[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Manuscript accepted February 1984.

mm 3.5 macro lens which projected an image of the section on to a monitor screen at 20× magnification. Illumination was by transmitted light. Translucent (light) bands on the cross sections were counted and the distances (in millimeters) from the center of the spine to the distal edge of each band was measured. The spine radius (R) was defined as the maximum distance (in millimeters) from the center of the section (appears as a small hole) to the posterior distal edge (Fig. 1).

Additionally, before the spines were sectioned, the anterior-posterior thickness (T) of 200 dorsal spines was measured to the nearest 0.01 mm at the sectioning site.

The type of growth (opaque = dark, translucent = light) of the margin of each section was noted. The sections were read three times.

The relationships of R, T, and body weight to FL and the relationships between TL, SL, and FL were determined by least squares methods following the suggestions of Ricker (1975). A computer program by Abramson (1971) was used to fit weighted back-calculated mean length at age to von Bertalanffy growth curves. The growth equation (von Bertalanffy 1938, 1957) and values were as follows:

$$l_t = l\,(1 - e^{-K(t-t_0)})$$

where l_t = length at age t,
l = asymptotic length,
K = growth coefficient,
t_0 = time when length would theoretically be zero.

Estimates of annual mortality (a), annual survival (s), and instantaneous mortality (i) were developed for the total collection (2,808 fish) (Ricker 1975). Length-frequency data were converted to age-frequency distribution (N_y = number of fish caught in age class y) by applying age-length keys. Ages III through IX of the resultant catch curves were analyzed by the methods of Heincke (1913), Jackson (1939), Robson and Chapman (1961) and by finding the slope (m) of a regression line fitted to $l_n(N_y)$ and y and substituting the equation $a = 1 - e^m$.

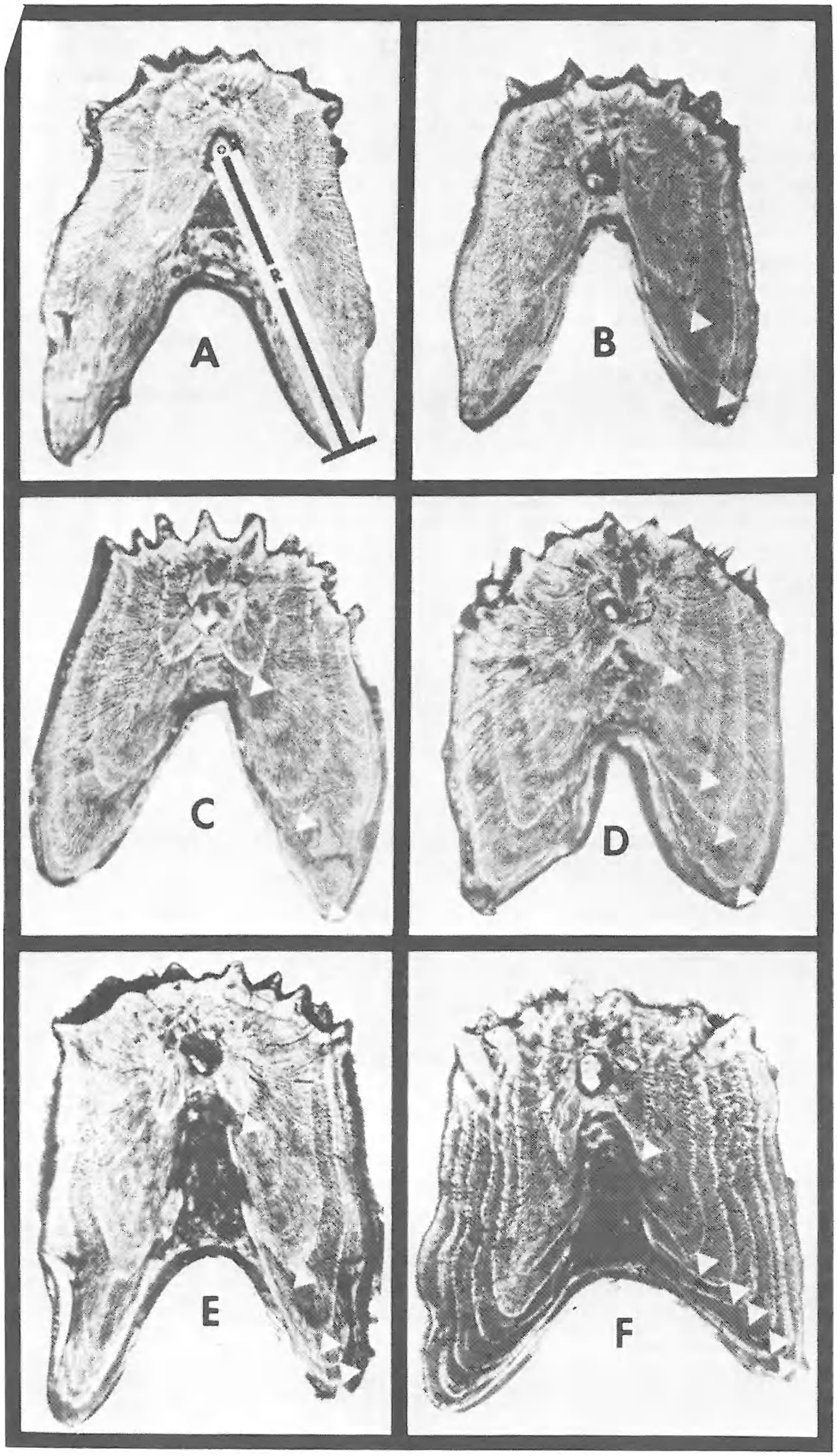
FIGURE 1.—Sections of gray triggerfish first dorsal spines from fish collected off Panama City, Fla. (A) Spine section from a 1-yr-old male (263 mm FL) collected 4 September 1980 with spine radius R labeled. (B) Spine section from a 2-yr-old female (336 mm FL) collected 11 September 1980. (C) A 3-yr-old female (315 mm FL) collected 8 August 1980. (D) A 4-yr-old male (350 mm FL) collected 13 August 1980. (E) A 5-yr-old female (331 mm FL) collected 24 September 1980. (F) A 6-yr-old male (477 mm FL) (seventh mark forming on margin) collected 25 June 1980.

RESULTS

A positive relationship was found between the growth of the first dorsal spine and FL. The relation between FL and R was as follows: FL = 4.58 $R^{0.951}$ with a correlation coefficient (r) of 0.84. The relation between FL and T was as follows: FL = 24.87 $T^{1.422}$ with r = 0.89. The variation in the two relationships probably resulted from the slight tapering of the spine in the area from which the sections were taken and the effect of sectioning. The FL-R relationship was used for back-calculation of sizes at previous ages. The spine sections possessed distinct dark-light banding patterns (Fig. 1) and the agreement between readings as to the numbers of bands was 98% [Beamish and Fournier's (1981) index of average error was 0.0072]. The translucent (light) band formation occurred during spring and summer (April to October with a peak during June-July), and the mean marginal opaque increment was least during this period of time (Table 1). We thus considered the translucent bands on the first dorsal spines to be annular

TABLE 1.—Percent frequency of dorsal spines with translucent (light) margins and mean marginal measurements of opaque (dark) margins in millimeters for gray triggerfish from northeast Gulf of Mexico, 1979-82.

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Percent of fish with translucent margins	0.00	0.00	0.00	52.27	41.86	56.70	53.59	23.79	2.40	0.90	0.00	0.00
Mean opaque marginal increment for fish												
2 light bands	—	—	1.40	1.24	1.09	0.74	0.82	0.64	1.00	1.70	—	—
3 light bands	—	0.79	0.49	0.59	0.60	0.58	0.56	0.36	0.50	—	—	—
4 light bands	—	0.56	0.47	0.43	0.52	0.48	0.56	0.38	0.60	—	—	—
5 light bands	—	0.44	0.24	0.26	0.06	0.24	0.37	0.037	—	—	—	—
Total number of fish	6	19	83	88	215	194	209	248	250	111	97	13


A
B
C
D
E
F

deposits and suitable for age determination. Lengths varied within age classes and length ranges overlapped between age classes (Tables 2, 3, 4). For example, males with three annuli (translucent bands) ranged from 258 to 537 mm FL and those with four annuli ranged from 250 to 549 mm FL. There was, however, a general trend of increasing modal length with increase in age.

The gray triggerfish is a moderately long-lived species. The oldest male was estimated to be 13 yr old (544 mm FL) and the oldest female was 12 yr old (561 mm FL).

The back-calculated and empirical sizes at age are presented in Tables 5, 6, and 7. The average mean back-calculated length at age for males was slightly (5-50 mm FL) larger than that for females at age 1-9, after which the females were larger. Only three fish were collected that were older than 9 yr; thus the reversal of the trend is probably an artifact caused by few samples.

The von Bertalanffy growth parameters varied slightly between males, females, and all fish. The von Bertalanffy equations were:

$$\text{males } l_t = 491.9(1 - e^{-0.382(t-0.227)}),$$

$$\text{females } l_t = 437.5(1 - e^{-0.383(t-0.150)}),$$

$$\text{all fish } l_t = 466.0(1 - e^{-0.382(t-0.189)}).$$

TABLE 2.—Length composition, in percent, of male gray triggerfish by age groups from northeast Gulf of Mexico, 1979-82.

Length group (FL mm)	Age in years										Total number of fish
	0	1	2	3	4	5	6	7	8	9	
150-199	50.00	50.00									2
200-249		50.00	50.00								18
250-299		14.46	44.58	36.14	3.62	1.20					135
300-349		0.66	26.32	42.10	25.66	2.63	1.97	0.66			307
350-399			9.26	35.80	32.72	18.52	3.70				339
400-449			1.48	18.52	29.62	25.19	15.56	5.93	3.70		233
450-499			11.02	12.24	26.53	29.59	16.34	9.18	4.08	1.02	155
500-549				3.30	27.47	30.77	27.47	8.79	1.10		121
550 and larger						66.67	8.33	16.67		8.33	24
Total	1	23	184	371	339	229	117	47	19	4	1,334

TABLE 3.—Length composition, in percent, of female gray triggerfish by age groups from northeast Gulf of Mexico, 1979-82.

Length group (FL mm)	Age in years												Total number of fish
	1	2	3	4	5	6	7	8	9	10	11	12	
200-249	41.67	33.33	25.00										19
250-299	5.04	42.86	33.61	15.97	0.84	1.68							207
300-349	0.47	14.08	44.61	26.29	7.98	4.69	1.41	0.47					453
350-399		4.64	23.84	35.76	23.18	10.60	1.98						304
400-449			15.38	27.69	21.54	18.46	9.23	3.08	4.62				122
450-499		2.63	7.89	21.06	28.95	26.32	7.89		5.26				74
500-549			4.55	22.73	22.73	18.18	9.09	9.09	13.63				40
550 and larger				20.00	40.00	20.00						20.00	9
Total	20	175	374	321	168	107	35	10	17	0	0	1	1,228

TABLE 4.—Length composition, in percent, of gray triggerfish (all fish) by age groups from northeast Gulf of Mexico, 1979-82.

Length group (FL mm)	Age in years														Total number of fish
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
150-199	50.00	50.00													2
200-249		47.83	39.13	13.04											32
250-299		9.13	42.47	35.16	11.42	0.91	0.91								365
300-349		0.47	18.27	41.69	26.93	7.72	3.75	0.94	0.23						848
350-399			7.12	31.05	34.47	19.09	6.84	1.43							691
400-449			0.90	16.59	28.70	25.11	16.59	7.17	3.14	1.38	0.45				418
450-499			1.36	10.20	26.53	28.57	19.73	8.84	2.73	2.04					244
500-549				4.23	27.37	28.20	24.79	8.36	2.58	4.37				0.10	172
550 and larger					5.00	50.00	15.00	10.00	5.00	10.00			5.00		36
Total	1	53	373	805	737	445	249	92	29	22	1	0	1	1	2,808

The weight-length relationships for gray triggerfish computed for the equation $W = aL^b$, where W is weight in grams and L is FL in millimeters, were as follows:

males $W = 6.7105 \times 10^{-6} L^{3.187}$, $r = 0.97$, $n = 169$,

females $W = 1.393 \times 10^{-5} L^{3.065}$, $r = 0.93$, $n = 167$,

TABLE 5.—Back-calculated fork lengths (mm) at age for male gray triggerfish from the northeastern Gulf of Mexico, 1979-82.

Age group	Mean length ± 1SD at capture	N	Average back-calculated FL at age												
			1	2	3	4	5	6	7	8	9	10	11	12	13
I	250.0 ± 29.0	18	137.7												
II	313.4 ± 41.8	99	123.9	248.0											
III	357.4 ± 55.8	192	119.2	243.0	319.6										
IV	407.8 ± 66.6	186	124.1	244.2	322.8	376.3									
V	450.6 ± 56.2	134	128.2	245.1	324.7	381.8	427.0								
VI	461.9 ± 56.0	72	132.2	245.3	309.7	364.3	409.8	443.2							
VII	474.5 ± 51.5	28	126.3	231.8	301.2	350.7	390.7	430.5	458.7						
VIII	462.5 ± 27.4	10	134.0	236.5	307.4	344.3	372.8	399.5	429.7	448.6					
IX	511.5 ± 78.5	2	165.8	293.1	323.0	362.0	389.8	424.7	468.7	489.9	504.0				
XIII	544.0 ± —	1	91.0	308.5	395.0	452.7	461.5	479.0	492.1	496.5	500.8	509.5	513.8	526.8	535.4
Weighted mean			124.9	244.3	319.6	373.7	415.5	436.2	452.9	458.7	502.9	509.5	513.8	526.8	535.4
± 1SD			± 41.0	± 49.4	± 55.5	± 60.9	± 60.1	± 56.8	± 48.6	± 32.3	± 54.5	—	—	—	—
N			742	724	625	433	247	113	41	13	3	1	1	1	1
Annual increment			124.9	119.4	75.3	54.1	41.8	20.7	16.7	5.8	44.2	6.6	4.3	13.0	8.6

TABLE 6.—Back-calculated fork lengths (mm) at age for female gray triggerfish from the northeastern Gulf of Mexico, 1979-82.

Age group	Mean length ± 1SD at capture	N	Average back-calculated FL at age											
			1	2	3	4	5	6	7	8	9	10	11	12
I	259.0 ± 34.0	12	155.6											
II	300.4 ± 35.2	93	120.1	241.4										
III	330.8 ± 46.2	187	117.0	227.8	298.3									
IV	360.1 ± 57.5	161	117.9	226.3	292.4	335.6								
V	398.5 ± 64.0	85	128.2	226.5	291.7	340.7	378.5							
VI	402.5 ± 63.6	55	113.5	218.4	276.0	320.1	357.5	387.1						
VII	419.8 ± 73.6	16	124.9	205.3	260.9	307.2	345.9	379.0	405.1					
VIII	448.8 ± 79.6	5	109.0	193.3	262.3	305.7	342.4	376.8	415.1	437.4				
IX	457.8 ± 71.2	10	101.8	208.1	264.8	306.9	340.2	373.7	402.5	431.0	447.9			
XII	561.0 ± —	1	121.2	258.2	390.4	463.2	481.2	494.6	516.8	525.7	534.6	547.8	552.2	556.6
Weighted mean			119.4	227.3	291.1	332.0	366.1	384.7	409.3	438.9	455.8	547.8	552.2	556.6
± 1SD			± 37.8	± 43.1	± 45.1	± 53.3	± 61.1	± 62.4	± 70.0	± 71.4	± 73.6	—	—	—
N			625	613	520	333	172	87	32	16	11	1	1	1
Annual increment			119.4	107.9	63.8	40.9	34.1	18.6	24.6	29.6	16.9	92.0	4.4	4.4

TABLE 7.—Back-calculated fork lengths (mm) at age for all gray triggerfish collected from the northeastern Gulf of Mexico, 1979-82.

Age group	Mean length ± 1SD at capture	N	Average back-calculated FL at age												
			1	2	3	4	5	6	7	8	9	10	11	12	13
I	259.3 ± 29.7	34	140.9												
II	308.6 ± 42.3	210	121.7	247.4											
III	343.9 ± 52.1	424	118.0	235.4	308.9										
IV	384.0 ± 66.1	398	122.0	235.3	307.3	356.1									
V	425.8 ± 70.7	243	128.1	236.6	309.1	361.8	403.9								
VI	434.7 ± 67.1	141	123.9	232.6	295.0	346.0	386.6	417.7							
VII	541.0 ± 64.6	49	123.6	221.0	286.7	334.8	373.2	409.0	435.7						
VIII	464.8 ± 54.2	16	134.2	227.1	296.3	335.3	372.2	401.3	432.6	452.2					
IX	478.1 ± 72.3	14	117.4	233.5	282.6	324.1	354.4	388.8	420.1	448.4	468.6				
X	439.0 ± —	1	108.3	204.0	251.5	274.8	286.3	309.2	331.9	354.9	384.1	420.8			
XII	561.0 ± —	1	212.2	258.2	390.4	463.2	481.2	494.6	516.8	525.7	534.6	547.8	552.2	556.6	
XIII	544.0 ± —	1	91.9	308.4	395.0	452.7	461.5	479.0	492.1	496.5	500.8	509.5	513.8	526.7	535.4
Weighted mean			112.8	236.5	305.8	354.1	392.9	412.9	432.8	451.2	460.4	492.7	533.0	541.7	535.4
± 1SD			± 40.0	± 47.8	± 52.6	± 61.0	± 65.9	± 66.0	± 64.0	± 61.8	± 72.0	± 65.1	± 27.2	± 21.1	—
N			1,523	1,498	1,288	864	466	223	82	33	17	3	2	2	1
Annual increment			112.8	123.7	69.3	48.3	38.8	20.0	19.9	18.4	9.2	32.3	40.3	8.7	−6.3

all fish $W = 2.146 \times 10^{-5} L^{2.992}$, $r = 0.96$, $n = 175$.

Conversions between different length measures were linear and expressed as follows:

FL vs. TL: FL = 29.704 + 0.774 TL, r = 0.97, n = 100,

FL vs. SL: FL = 22.823 + 1.171 SL, r = 0.99, n = 100,

TL vs. SL: TL = 9.666 + 1.446 SL, r = 0.96, n = 100.

Estimates of mortality (a, s, and i) varied slightly between estimation methods (Table 8). Full recruitment to the fishery was considered to be at 3 yr for both sexes. Estimates of a were between 0.32 and 0.53 with i between 0.39 and 0.75 (Table 8).

TABLE 8.—Estimated annual mortality (a), annual survival (s), and instantaneous mortality (i) by estimation technique for gray triggerfish from the northeastern Gulf of Mexico, 1979-82.

	Estimation technique			
	Heincke (1913)	Jackson (1939)	Robson and Chapman (1961)	Regression analysis
Males				
a	0.33	0.32	0.44	0.53
s	0.67	0.67	0.56	0.47
i	0.40	0.39	0.57	0.75
Females				
a	0.36	0.32	0.45	0.47
s	0.64	0.68	0.55	0.53
i	0.45	0.38	0.59	0.64
All fish				
a	0.34	0.33	0.44	0.49
s	0.66	0.64	0.56	0.51
i	0.41	0.40	0.58	0.67

DISCUSSION

The variation in length at age and overlays of length ranges between ages found in gray triggerfish is not unusual in fish from southeastern U.S. waters. Many species such as king mackerel, *Scomberomorus cavalla*; Spanish mackerel, *S. maculatus*; red grouper, *Epinephelus morio*; sailfish, *Istiophorus platypterus*; and black sea bass, *Centropristis striata*, have large variations in size within age groups (Beaumariage 1973; Powell 1975; Moe 1969; Jolley 1977; Waltz et al. 1979).

Our gray triggerfish growth rates are similar to growth information from the Gulf of Mexico, but not information from Africa. Beaumariage (1969) reported growth rates for three tagged fish (250, 270, and 332 mm TL) from the northeastern Gulf of Mexico. His fish grew at a rate of 187.2, 153.6, and 51.6 mm/yr. If one considers Beaumariage's fish to be 2, 2, and 3 yr old, respectively, then his growth increments are similar to ours (Table 7). Gray triggerfish age and growth have been reported from southwestern Africa (Ivory Coast-Ghana-Togo area) by Anonymous (1980). We took the information in Anonymous' figure 11 and converted it to mean length at capture per age which gave the following approximate values: age I, 148 mm; age II, 203 mm; values are about 100 mm less than ours for each age (Table 7). Caveriviere et al. (1981) provided comprehensive information on the age and growth of gray triggerfish off Senegal and the Ivory Coast. Two hypotheses with regard to band formation were suggested: A) one band per year, and B) two bands per year. The sizes (FL) at age (in years) for Senegal fish by hypotheses were age I, 153 mm for hypothesis A, 90 mm for B; age II, 231 mm for A, 170 mm for B; age III, 285 mm for A, 238 mm for B; age IV, 322 mm for A, 290 mm for B; age V, 348 mm for A, 324 mm for B. Sizes at age of our Gulf of Mexico fishes (Table 7) were larger after the first year than predicted by both of the above hypotheses for Senegal fish. The sizes at age for Ivory Coast fish were smaller than both the Senegal and the Gulf of Mexico fish using the hypothesis of one band formed per year. These differences may be the result of different environments, biology, methods of capture, or aging. Anonymous (1980) suggested that the African fish have a seasonal offshore migration to avoid the cold coastal water (during the third quarter of the year) which is the result of upwelling. Gulf of Mexico fish are not known to have migratory habits, and thus might not be subject to the energy expense such movements incur. More information on the life histories and environments of these groups of gray triggerfish is needed to explain the observed variations.

The K values (growth coefficient) of gray triggerfish varied between 0.382 and 0.383. These values were similar to, but higher (about 0.1) than, those reported for other demersal marine fish from the southeastern United States (see Manooch 1982 and Pauly 1978 for a listing of values). The K values estimated for gray triggerfish may be high because of the low asymptotic lengths that were found. Additional investigation of the larger and older fish is needed to evaluate the growth coefficients of this species. The estimates of mortality (Table 8) were similar to those of demersal marine fish such as the white grunt, *Haemulon plumieri*, where a = 0.37-0.51 and the red porgy, *Pagrus pagrus*, where a = 0.32-0.55 (Manooch 1976; Manooch and Huntsman 1977) that inhabit similar habitats. The mortality rates for gray triggerfish probably reflected the exploitation level on this species in the northeast Gulf of Mexico. Nelson and Manooch (1982) reported similar values (i = 0.39-0.50) for red snapper, *Lutjanus campechanus*, from the Carolinas and Florida coasts where the fishing pressure is light to medium and much higher values (i = 0.78-0.94) from the fishery off Louisiana where the commercial fishing pressure is high. The effect of fishing on gray triggerfish populations were therefore assumed to be similar to the effects of fishing on these other reef fish resources.

ACKNOWLEDGMENTS

We thank H. F. Horton, Oregon State University, Corvallis, Oreg.; E. D. Prince, National Marine Fisheries Service, Southeast Fisheries Center, Miami, Fla.; and R. S. Nelson, National Marine Fisheries Service, Southeast Fisheries Center, Beaufort, N.C., for their valuable criticisms of the manuscript.

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