Age, growth and longevity of the gray triggerfish, Balistes capriscus (Tetraodontiformes: Balistidae), from the Southeastern Brazilian Coast

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SUMMARY: Age, growth and longevity of gray triggerfish *Balistes capriscus* from the coast near São Paulo were estimated from first dorsal spine sections of 1,800 fish. The translucent zone was formed during winter (June, July and August) and the reproductive period (December, January, February). The von Bertalanffy growth equations were: FL = 514.9 [$1 - e^{-0.2625 (t + 0.0391)}$] for males, and FL = 504.6 [$1 - e^{-0.2748 (t - 0.0304)}$] for females. The longevity estimated was 11 years old for males and females. The instantaneous mortality rates estimated were 0.26 for males and 0.27 for females. The weight-length relationships for both sexes of gray triggerfish together were Wt = 0.000004 $FL^{3.299}$.

Key words: gray triggerfish, *Balistes capriscus*, age, growth, longevity, Brazil.

INTRODUCTION

High rates of exploitation of Atlantic croaker (*Micropogonias furnieri*) and weakfish (*Cynoscion jamaicensis)* along the southeastern coast of Brazil by the commercial fishing fleet has led to a demand for underutilised species. One of the underutilised species is the gray triggerfish, *Balistes capriscus* (Tetraodontiformes: Balistidae), a demersal species exploited in the state of São Paulo since the 1960s. For many years it was included in the miscellaneous fish category, but in the last 15 years, it has become a very important fishery resource and is currently one of the most commonly-caught commercial species: 4,836.26 tons in 1987 (Bernardes, 1988), 2,742.20 tons in 1992 and 650.59 tons in 1998 (Castro, 2000).

This species occurs in the tropical and temperate zones of the Atlantic, from Nova Scotia (Canada) to Argentina, as well as along the African coast. In Brazil, it is particularly abundant along the coasts of Espírito Santo (20ºS), Rio de Janeiro (22ºS) and São Paulo (24ºS).

Information on age and growth of *Balistes capriscus* using the first dorsal spine is available only from the southern coast of Africa (Caverivière *et al.*, 1981; Ofori-Danson, 1989) and from the northeastern Gulf of Mexico (Johnson and Saloman, 1984), the later also including mortality estimates.

This paper presents the results of an investigation of age and growth of the gray triggerfish from the south coast of the State of São Paulo in Brazil.

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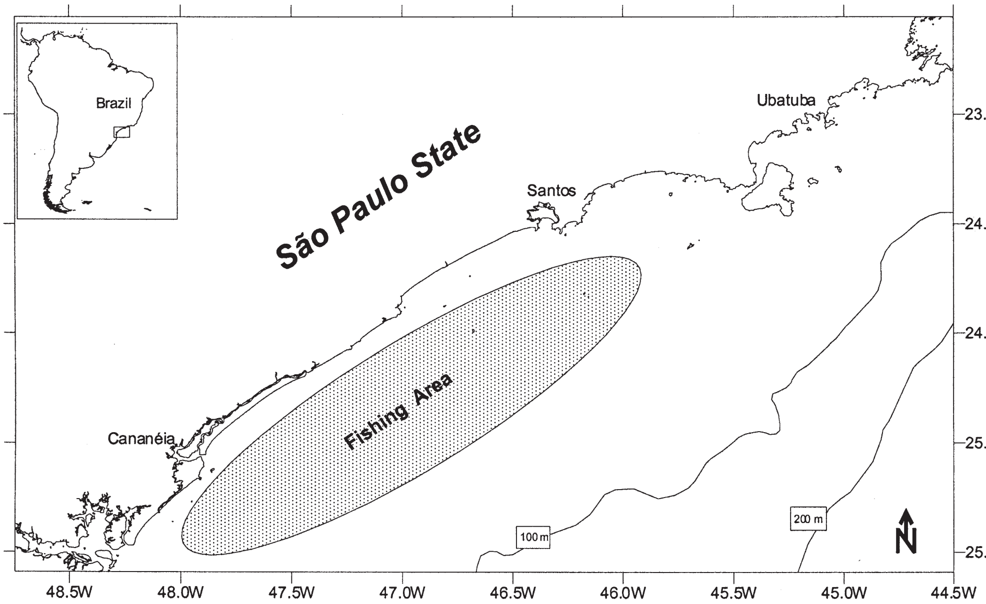

FIG. 1. – Map of São Paulo State south coast showing *B. capriscus* fishing area .

MATERIALS AND METHODS

Monthly samples (from December 1984 to December 1985, except October 1985) were obtained from commercial pair trawlers operating in waters between 24°S and 25°15'S (Fig. 1). A total of 6,396 individuals were measured (fork length to the nearest millimeter) and 2,582 fish were weighed to the nearest 0.1 grams and sexed; the gonads were weighed and the reproductive condition was assessed. For age determination the first dorsal spine and the first three vertebras were removed, cleaned with water and stored for later analysis.

Transverse sections (180 µm in thickness) of 1,800 individuals were taken directly (without embedding in a polyester resin) from the first dorsal spines above the condyle with a low speed power saw (Fig. 2). the sections were mounted on glass slides and observed in transmitted light using a closed-circuit television (24x magnification). Translucent (light) bands on the spine sections were counted. The distance between the core and the posterior distal edge (spine radius = R_t) and the distance from the core to the distal edge of each translucent band (R_i) were measured (Fig. 3). The relationship between R_t and fork length (FL) was determined by the least squares method. The spine sections were analysed three times by two independent readers and the results were compared.

Whole vertebrae (from 526 fish) were observed under reflected light and the number of zones and type of growth of margin (translucent/opaque) were also recorded. The results of these analyses were used to compare with those obtained from first dorsal spine sections.

Otoliths, which are frequently used for aging fish, were not used because in *B. capriscus* they are very thin, fragile and small (1 to 2 mm). They are difficult to remove, keep and manage, so I avoided using them in this study.

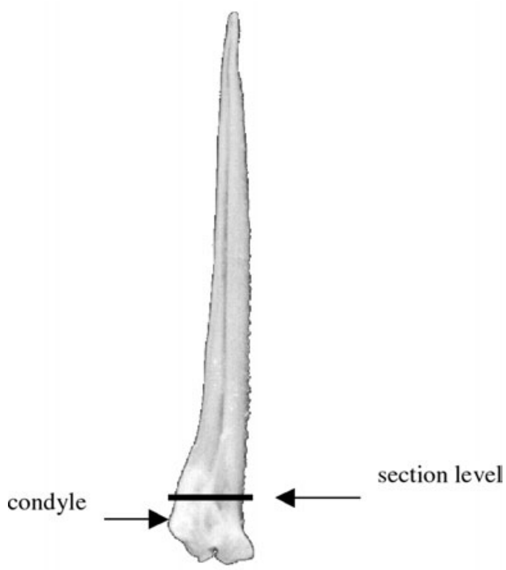

FIG. 2. – Posterior view of first dorsal spine of *Balistes capriscus* showing the condyle and the level of sectioning.

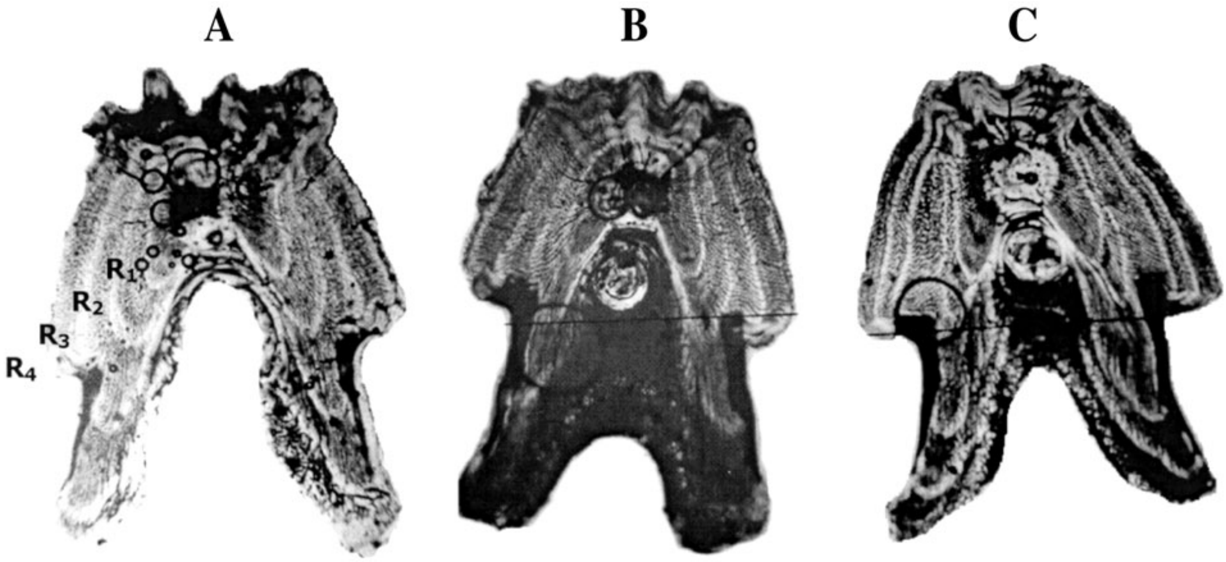

FIG. 3. – Section of gray triggerfish first dorsal spine. A, spime section from a 2-year-old fish, collected in January 1985 (hyaline edge); B, spine section from a 2.2-year-old fish, collected in March 1985 (opaque edge); C, spine section from a 2.4-year-old fish, collected in May 1985 (opaque edge)

The periodicity of the growth zone formation was estimated through the monthly frequency of translucent edges. The validation of age was based on the analysis of marginal increment, that is, the distance separating the last translucent growth mark from the edge of the spine (Cadwallader, 1978).

The size of each fish was back-calculated for all ages on dorsal spine sections using the Frasser-Lee method (Bagenal and Tesch, 1978). The back-calculated mean length at age was used to calculate the growth curve and to determine the growth parameters of the Bertalanffy model (1938). The parameters of this growth equation (k, L_∞ and t_0) were estimated as suggested in Walford (1946) and Ford (1933). Estimates of longevity and instantaneous natural mortality rate were calculated by Taylor's equation (Taylor, 1960) as follows:

$$A_{(0.95)} = [2.9957/k] + t_0 \, ,$$

for the longevity, and

$$M = - [\ln (1 - P) / A_{(0.95)}] \, ,$$

for instantaneous mortality, where

$$P = FL / L_\infty = 0.95.$$

The relationship between total body weight and fork length for males, females and both sexes pooled were estimated.

RESULTS

Length composition

The fork length (FL) of 6,396 fish landed by the commercial fleet ranged from 111 mm to 410 mm. The catch was composed mainly of fish between 160 to 230 mm FL. There were very few specimens that measured less than 150 mm (N=52) and more than 350 mm (N=24). The mean fork length observed for 814 males was 216.4 mm (153 mm < FL< 347 mm) and for 1,240 females it was 203.5 mm (139 mm < FL< 334 mm).

Length-frequency distribution (Fig. 4) showed basically two distinct groups from December 1984 to December 1985: the first group consisted of pre-adults (<200 mm FL) in the second year of life, and the second group was formed by older fishes aged mainly 2 to 4 years. About 46% of the catches were composed by immature fishes, a fork length at first maturity being 169 mm for females and 200 mm for males (Bernardes and Dias, 2000). The smallest specimens (110-130 mm FL) appeared from January to March, possibly indicating the benthic recruitment of juveniles in this period.

Age estimation

The first dorsal spine transverse sections showed a distinct translucent-opaque banding pattern of deposition. The growth zones were distin-

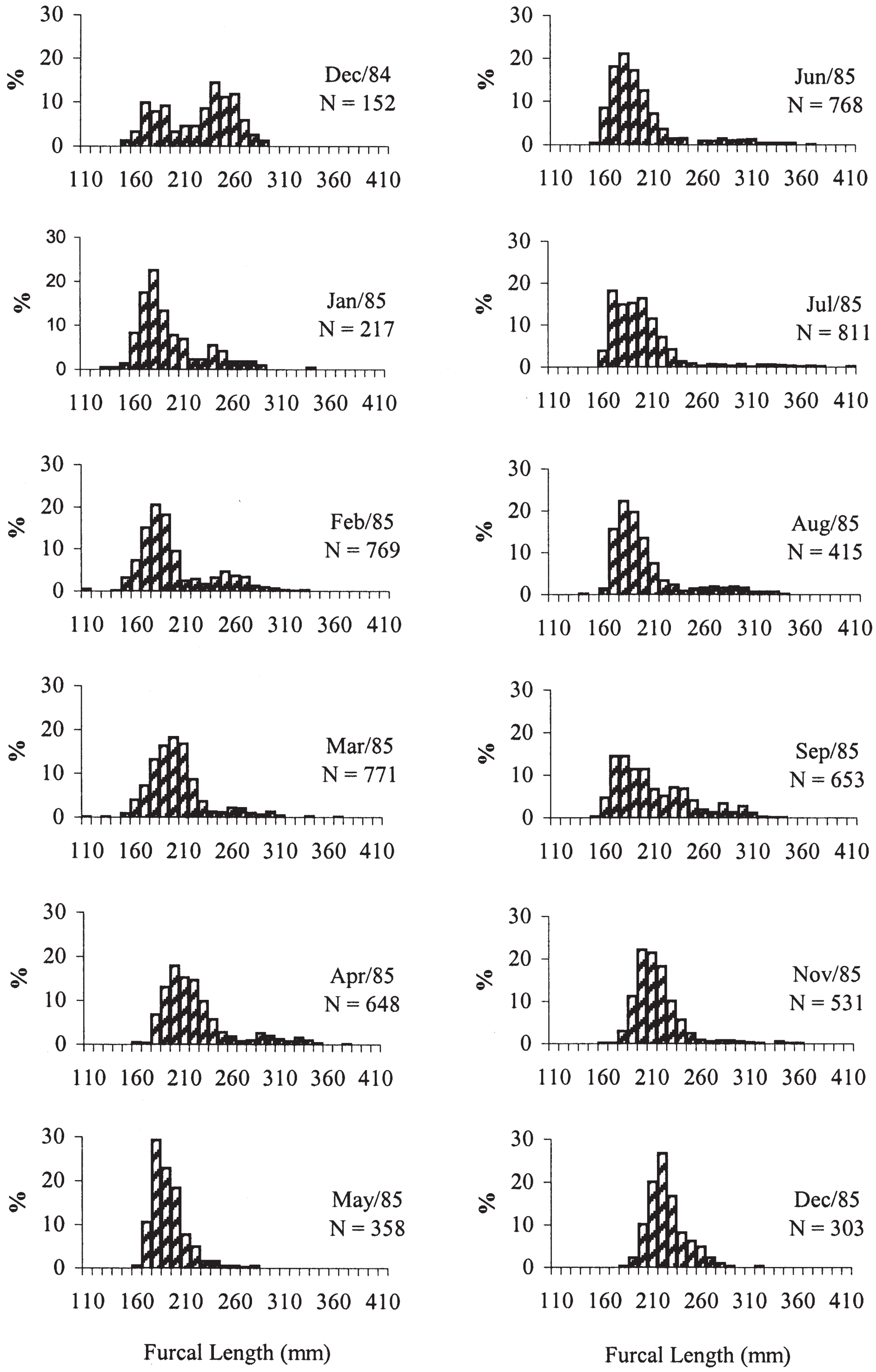

FIG. 4. – Length-frequency histograms of *Balistes capriscus* caught by commercial fleet at São Paulo coast, between December 1984 and December 1985 (percentage of number).

guishable in the upper anterior portion of the spine section. The core is small and located slightly upward in relation to the center of the spine (Fig. 3). The narrow translucent marks (*annuli*) are slow growth zones and the wide opaque bands correspond to fast growth zone. The portion between the core and the first zone was not very distinct. The interpretation of this portion is quite difficult due to the fact that it corresponds to the first year of growth and is probably highly influenced by environmental conditions and food availability during this stage.

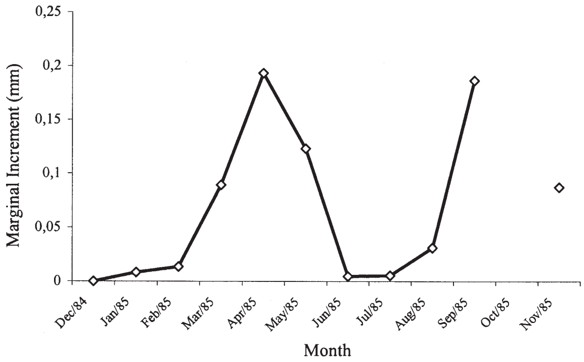

FIG. 5. – Marginal increment by month for *Balistes capriscus* captured off São Paulo (N = 274).

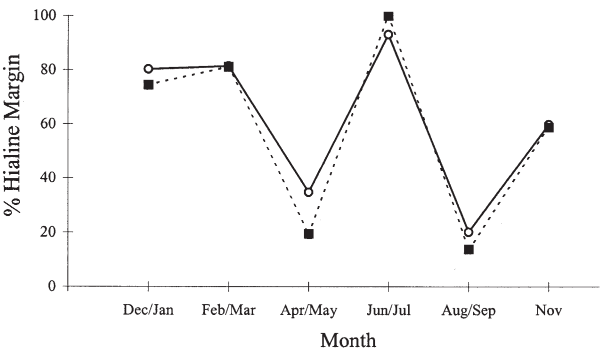

FIG. 6. – Seasonal variation of percentage of hialine margin on dorsal spine and vertebrae of *Balistes capriscus*, captured off São Paulo.

Of the 1,800 sections examined 83.5% were readable. The agreement between the two readers on the spines was 78.6%. The oldest fish were the most difficult to interpret. The analysis of the marginal increments by month for fish with 3 annuli on dorsal spine has shown that the *annuli* are laid down twice a year, during the summer (December to February), and winter (June to August) (Fig. 5). These results confirm that *Balistes capriscus* has two growth cycles per year.

The time of translucent and opaque zones formation was confirmed by observation of the marginal zone type of dorsal spine and vertebrae over the year (Fig. 6). The translucent zone formation occurred during winter (June to August) and summer (December to March) which corresponds to the spawning season. The opaque zone formation occurred during the months of April and May, and from September to November.

January first was considered the fish birthday in order to attribute an annual scale of time to the growth zones. Thus, a fish captured in January showing four narrow and four wide zones on first dorsal spine and on vertebrae is 2 years old. The first narrow zone represents the first winter, the second narrow zone represents biological recruitment (changing of habitat and diet = 1 year old), the third narrow zone represents the second winter and the fourth narrow zone represents spawning period (2 years old). The largest fish aged (347 mm FL, captured in July-85) presented 9 *annuli* on both the first dorsal spine and vertebrae, corresponding to 4,5 years. The smallest fish aged (139 mm FL, captured in February-85) presented 2 *annuli*, corresponding to 1 year of life.

Growth and longevity

A positive relationship was found between fork length (FL) and radius of dorsal spine (R_t) and it was represented by the following equation:

$$FL = -26.9350 + 101.8125\, R_t \; (r^2 = 0.88;\ n = 363),$$
for males;
$$FL = -26.2179 + 100.8140\, R_t \; (r^2 = 0.89;\ n = 369),$$
for females.

The mean back-calculated fork lengths at age of males and females are presented in Table 1.

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

$$\text{males} \;:\; FL = 514.9\,[1 - e^{-0.2625\,(t + 0.0391)}]\,;$$
$$\text{females} \;:\; FL = 504.6\,[1 - e^{-0.2748\,(t - 0.0304)}]\,;$$
$$\text{all fish} \;:\; FL = 509.5\,[1 - e^{-0.2687\,(t + 0.0049)}]\,.$$

The growth curves for gray triggerfish male and female are presented in Figure 7.

The weight-length relationship was represented by the following equations:

males: $W_t = 0.000005\, FL^{3.265}$, ($r^2 = 0.97$; n = 814);
females: $W_t = 0.000003\, FL^{3.340}$, ($r^2 = 0.96$; n = 1,240);
both: $W_t = 0.000004\, FL^{3.299}$, ($r^2 = 0.96$; n = 2,054).

TABLE 1. – Back-calculated fork lengths (mm) of males and females of *Balistes capriscus*, from the southeastern coast of Brazil; n: number of fish specimes; σ: standard deviation.

age	male	n	σ	female	n	σ	both sexes
1	93.4	347	15.1485	93.5	211	13.6259	93.5
2	178	291	18.9621	180.1	182	21.6300	179.1
3	247.4	68	23.0023	246.6	46	24.7012	247
4	310.4	9	6.6008	312.7	7	14.6154	311.5
5	346.5	4	0.5	347	2	-	346.7

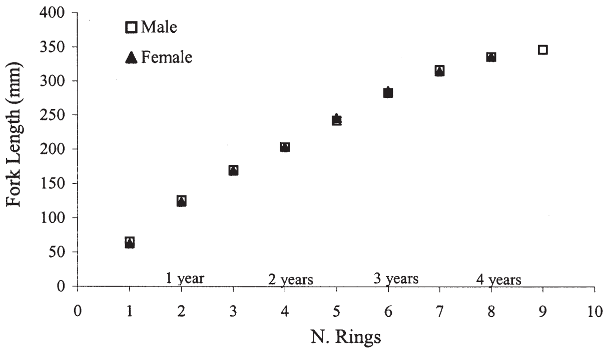

FIG. 7. – Growth curve of *Balistes capriscus* (male and female) from São Paulo coast, based on back-calculated fork length.

The t-test indicated a significant difference ($t = 8.797$; $P < 0.05$) between the weight-length relationship for males and females, males being heavier than females.

The longevity estimated for *Balistes capriscus* was 11 years old for males and females and the natural mortality rate (M) was 0.26 for males and 0.27 for females.

DISCUSSION

The age and growth of the gray triggerfish have been reported from southwestern Africa by Caveriviére *et al*. (1981) and by Ofori-Danson (1989), and from the northeastern Gulf of Mexico by Johnson and Saloman (1984). Johnson and Saloman (1984) determined that the translucent zone formation of *Balistes capriscus* from the Gulf of Mexico, occurred during spring and summer (from April to October with a peak during June-July). In Senegal and the Ivory Coast, Caverivière *et al.* (1981) stated that the translucent zone was only visible after the second year of life. They suggested two hypotheses regarding zone formation: A) one mark per year, or B) two marks per year. The fork lengths at age for the Gulf of Mexico fishes were larger after the first year than predicted by both of hypothesis for Senegal fish. The fork lengths at age for Ivory Coast fish were smaller than Senegal and the Gulf of Mexico fishes using the hypothesis of one zone formed per year.

Comparing to data from other localities, *Balistes capriscus* from our coast were smaller in length at age than those from the Ghana coast and Gulf of Mexico and larger than those from the Senegal coast. These differences may be the result of different environments, methods of capture or higher fishing mortality rates. Table 2 shows the results of different authors.

The period of fast growth for gray triggerfish from São Paulo coast, reflected by the deposition of an opaque zone, corresponds to the months of April and May and the period of September to November. On the other hand, the translucent zone, corresponding to the period of slow growth, appears from June to August (winter) and from December to February (summer). The factors that might be involved in translucent ring formation on the structures of *Balistes capriscus* in this case are a decrease in temperature and food supply during winter and the reproduction during summer. For the African *Balistes capriscus* the formation of a translucent zone in the summer is approximately equivalent to the beginning of gonadal maturity and the decrease in growth rates would be linked to the spawning period (Caverivière *et al.*, 1981). The African fish have a seasonal offshore migration to avoid cold coastal water, which is the result of upwelling (Anonymous, 1980, *In*: Johnson and Saloman, 1984).

It seems that the first translucent zone of our *Balistes capriscus* from the Brazilian coast, is deposited in the first winter (0.5 years old, about 60-70 mm FL) and the second translucent zone is deposited during summer (1 year old, 90-120 mm FL) due to changes of diet and habitat (pelagic to demersal). Dooley (1972, *In:* Johnson and Saloman, 1984) reported that the gray triggerfish is planktonic and associated with *Sargassum* during the first year of life, and after this period inhabitis the benthic area between 12 and 42 m in depth (Smith, 1976, In*:* Johnson and Saloman, 1984).

Balistes capriscus was considered a moderately long-lived species by Johnson and Saloman

TABLE 2. – Mean fork length (mm) at age and von Bertalanffy growth parameters (k, L_∞ and t_0) for *Balistes capriscus*, estimated by (1) this study; (2) Caverivière *et al.*, 1981; (3) Ofori-Danson, 1989; (4) Johnson and Saloman, 1984.

Age	São Paulo (1) Fork length	Senegal (2) Fork length	Ghana (3) Fork length	Gulf of Mexico (4) Fork length
I	94.8	90	144	124.1
II	182	170	230	232.7
III	250.8	238	292	306.8
IV	305	290	330	357.3
V	347.7	324		391.8
k	0.23	0.3058	0.43	0.38
L_∞	506	407	408	466
t_0	-0.13	-3.4	—	-0.189

(1984). These authors estimated that the oldest male gray triggerfish from the Gulf of Mexico was 13 years old at 544 mm FL and the oldest female was 12 years old (561 mm FL). Our estimates were similar (11 years old for males and females). However, our results indicated differences in asymptotic fork lengths (514.9 mm for males and 504.6 mm for females) compared to those from the Gulf of Mexico. I observed lower growth rates (k = 0.27) than those obtained from the Gulf of Mexico (0.38) and Africa (0.30). The differences between the estimated and reported k-values might be due to different environmental conditions affecting growth. The analysis of the W_t-FL relationship of *Balistes* showed significant differences between sexes. The exponent *b* of this relation (3.265 - males and 3.340 - females) showed that the growth is allometric.

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