POPULATION STRUCTURE OF CAITIPA MOJARRA (*Diapterus rhombeus*) IN AN ESTUARINE SYSTEM OF SOUTHEASTERN BRAZIL*

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ABSTRACT

Santos estuary suffers anthropic influence through various activities, including fisheries. Caitipa mojarra (*Diapterus rhombeus*) is among the exploited resources of the region and, despite its importance, it still has not been well studied. The main goal of this study was to analyze the population structure of this species regarding gonadal development, age and growth. For the analysis of gonadal development, samplings were carried out between November 2008 and August 2011, gathering in total 6,639 individuals. The age and growth parameters were analyzed from a data base of the species, which contained information from samplings from October 2007 to September 2011. Most of the specimens caught (71.93%) was considered juvenile and only 0.68% were spawning. From gonadal maturity, sexual proportion and length classes of the individuals, it could be seen that this species does not spawn within Santos estuary. The growth parameters estimates were L∞ of 262.5 mm, k = 0.24/year and longevity of 12.48 years.

Keywords: Fisheries biology; growth; estuary; fishes; Gerreidae

ESTRUTURA POPULACIONAL DA CARAPEBA (*Diapterus rhombeus*) EM UM SISTEMA ESTUARINO DO SUDESTE DO BRASIL

RESUMO

O estuário de Santos sofre influência antrópica por meio de diversas atividades, incluindo a pesca. A carapeba (*Diapterus rhombeus*) está entre os recursos explorados da região e, apesar de sua importância, ainda não é bem estudada. O objetivo geral desse trabalho foi analisar a estrutura populacional dessa espécie quanto ao desenvolvimento gonadal, idade e crescimento. Para a análise do desenvolvimento gonadal foram utilizadas amostragens realizadas entre novembro de 2008 e agosto de 2011, coletando um total de 6.639 indivíduos. Os parâmetros de idade e crescimento foram analisados a partir de um banco de dados da espécie que continha informações de coletas de outubro de 2007 a agosto de 2011. A maior parte dos espécimes coletados (71,93%) foi considerada juvenil e apenas 0,68% estavam desovando. A partir dos dados de maturação gonadal, de proporção sexual e classes de comprimento dos indivíduos, foi possível observar que essa espécie não desova dentro do estuário de Santos. Os parâmetros de crescimentos foram estimados em L∞ de 262,5 mm, k de 0,24/ano e longevidade de 12,48 anos.

Palavras chave: Biologia pesqueira; crescimento; estuário; peixes; Gerreidae

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INTRODUCTION

Estuaries are essential habitats for various species of commercial, subsistence and recreational importance (BLABER, 1997; PICHLER, 2005; PINHEIRO and JOYEUX, 2007; SOUZA and PETRERE-JR, 2008). Although they may perform similar roles, each estuary has singular biodiversity, hydrodynamic and geomorphological characteristics. In Brazil there is a great heterogeneity of estuaries, especially due to the country's large coastline.

The estuary of Santos, located in the southeastern portion of the Brazilian coast, in the state of São Paulo, presents a similar geomorphology to the Cananéia-Iguape estuarine lagoon system described by MIRANDA *et al.* (2002) and is under a subtropical climate system. This is one of the areas with greatest human impact on the Brazilian coast, mostly due to activities relating to the port (SOUSA *et al.*, 2007), which is the largest in Latin America and extends from the inlet of Santos through the Piaçaguera Channel, already within the estuarine area. Human impact has also been increased by the industrial area of Cubatão and by disorderly expansion of irregular riverside housing. Estuarine artisanal fishing occurs together with this heterogeneity and is still responsible for a good proportion of the income and animal protein intake of these riverside workers (FAGUNDES *et al.*, 2012).

Among the exploited resources of the region is the caitipa mojarra (*Diapterus rhombeus*), one of the main constituents of tropical estuarine environments, as one of the dominant species (AYALA-PEREZ *et al.*, 2001; SPACH *et al.*, 2006; COSTA *et al.*, 2012). It feeds mainly on mollusks, annelids, small crustaceans and algae, but it is also common to find large quantities of sediment in its stomach (MENEZES and FIGUEIREDO, 1980; CHAVES and OTTO, 1998). Despite the importance of this species in the environmental balance of this estuary and in the fisheries that takes place there, *D. rhombeus* has still not been adequately studied in the region, presenting a lack of scientific information in the literature.

Thus, the present study had the objective of carrying out the first assessment of the population structure of *D. rhombeus* in the estuary of Santos, analyzing the patterns of its use of the estuarine environment, so to provide basic and valuable information for management and decision-making issues.

MATERIALS AND METHODS

Samples were gathered between October 2007 and June 2011 with bimonthly periodicity, using several fishing gears in the estuary of Santos, São Paulo (Figure 1). Between October 2007 and August 2008, sampling campaigns were carried out using otter trawl, cast net and gillnet, and through November 2008 to June 2011 samples were done using only cast net and gillnet. The otter trawl was towed for 10 minutes once in every sampling point in which this gear was used. The cast net presented a diameter of 2.5 m, with a knot-to-knot mesh of 20 mm and was applied three times in every sampling point in which this gear was used. The gillnet presented a 70 mm mesh knot-to-knot, 50 m nets, a retention coefficient of 0.60, and was applied with two different submersion periods, depending on the sampling campaign and sampled point: either the gillnet was submerged for a maximum of 10 minutes, or it was submerged for a period of 12 to 18 hours.

Fishery effort and CPUE analyses were not carried out for the present study, since the effort unit for each gear was not determined because this was not part of the aim of the study. Aiming to evaluate possible seasonal differences, the data were distributed quarterly considering the seasons of the southern hemisphere (summer: December, January and February; autumn: March, April and May; winter: June, July and August; and spring: September, October and November). For the analysis of age and growth, the total period (October 2007 to June 2011) was considered. To guarantee an expressive number of individuals per month in this analysis, while reducing bias, an "artificial year" was created by combining all the years of data gathering, compiling the data per month.

After the samplings, the organisms were taken to the laboratory for screening, taxonomic identification and total length (TL) and weight (WT) measurement. From November 2008 until July 2010, the individuals sampled were also subjected to a ventral incision. This enabled the

analysis of stomach vacuity, in order to observe the use made of the estuary as a feeding area, by means of a subjective scale in which "0" represented no stomach content, "1" meant a partially full stomach and "2" a full stomach. Gender was also identified in this stage, as well as gonadal maturity, following the classification developed by VAZZOLER (1996), in which stage "A" the individual is immature, "B" ripening or resting, "C" mature and "D" spent.

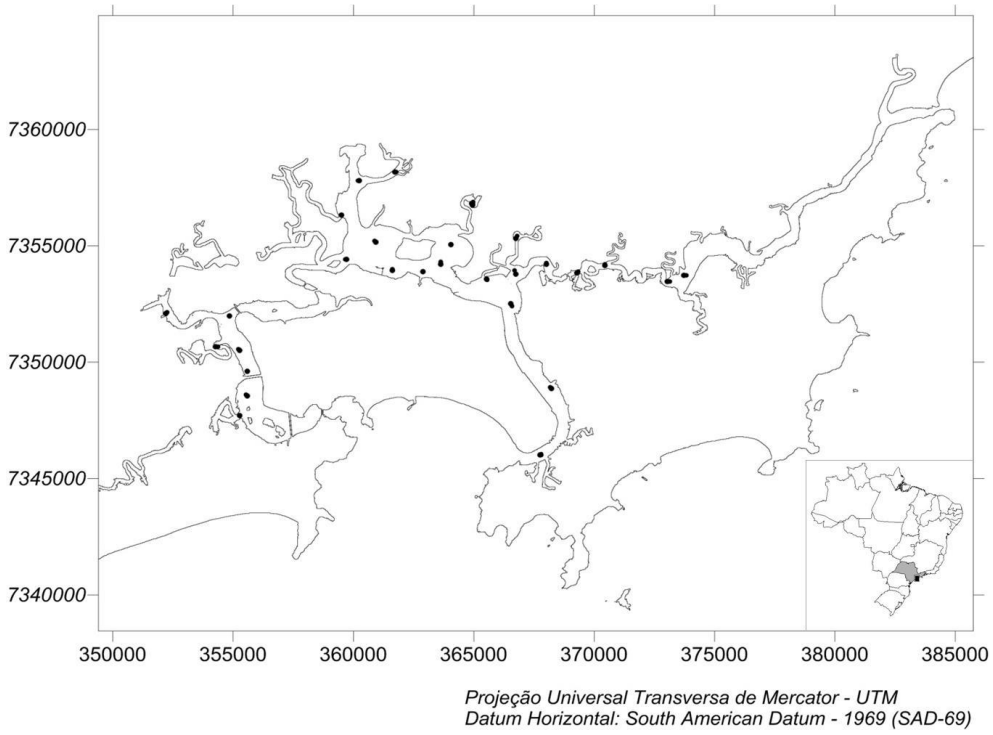

Figure 1. Sampling points in the Santos estuary.

Length variations were evaluated according to the season. The distribution was represented by histograms and the significance of the differences was evaluated by means of the Kruskal-Wallis test, followed by a nonparametric multiple comparison test (ZAR, 1996). The length-weight relationship was described by means of the power model ($WT = aLT^b$), where *a* represents the linear coefficient of the equation, while *b* is the angular coefficient, also called the allometric coefficient, which can be used to observe isometry (b = 3), positive allometry (b>3) and negative allometry (b<3) in the population's growth (SILVA-JÚNIOR *et al.*, 2007). The model was fitted using the nonlinear least-squares iterative weighted method and the determination coefficient (r^2) was calculated, taking into consideration the residual sum, degree of freedom and variance of the dependent variable (SOUZA and ÁVILA-DA-SILVA, 2010). The significance of the difference in the coefficients of the length-weight relationship between the genders was assessed using covariance analysis (ANCOVA) and a Scheffé posteriori test (HUITEMA, 1980; ZAR, 1996).

The gender composition was described in terms of the relative numbers of males and females per season and in the total sample. Differences were evaluated using the chi-square test, χ^2 (ZAR, 1996; VAZZOLER, 1996). The condition factor ($k = WT/TL^b$) was also calculated (*b* means the angular coefficient of the weight and length relationship). This parameter allows the observation of periods of lower intake of food and spawning (FROESE, 2006). The Kruskal-Wallis test was carried out to evaluate possible statistical differences of the mean k among seasons and genders.

Age and growth were assessed through the indirect method, which is based on the observed length frequencies of the population in question throughout a certain period of time. The data were analyzed using the ELEFAN I (Electronic Length Frequency Analysis) routine in the FiSAT II software, version 1.2.0 (PAULY, 1987). The growth curve within this routine is a seasonally oscillatory version of the generalized von Bertalanffy equation (VBGF), with another growth constant (*D*), a factor that expresses the amplitude of the growth oscillations (C), and the time of beginning of the sinusoidal growth oscillation (t_s). However, considering the environmental conditions to which *D. rhombeus* is subjected in the region, meaning the small seasonal variations of temperature and constant availability of food throughout the year, the species' growth was considered non-oscillatory. Thus, those variables regarding the oscillation of growth were suppressed in the estimates, i.e., applying the general von Bertalanffy equation:

$$L_t = L_\infty (1 - e^{-K(t-t_0)})$$

where L_t is the predicted length at age *t*, $L\infty$ is the asymptotic length, *K* is a growth constant and t_o is the age of the fish when its length is equal to zero (hypothetical value).

All statistical analyses were conducted in the R environment (R DEVELOPMENT CORE TEAM, 2010).

RESULTS

Diapterus rhombeus was present in all sampling campaigns. To avoid the effect of fishery selectivity, the absolute number of total catches (n = 6,654) was roughly evaluated as relative catches (number of catches by tows) by fishing gear and by season to verify possible patterns which was demonstrated the presence of the species in all seasons in the estuary (Table 1).

Table 1. Catches in numbers and relative catches (catches in number by tows) by fishing gear and season.

Fishing Gear / Season	Trawl		Gillnet		Cast net	
	Catches in numbers	Relative catches	Catches in numbers	Relative catches	Catches in numbers	Relative catches
Spring	882	40.09	598	23.00	28	2.55
Summer	708	23.60	728	26.96	41	3.42
Autumn	1,410	32.79	525	13.82	1	1.00
Winter	1,420	41.76	306	10.20	6	1.50

The total length (TL) of 6,639 specimens ranged from 46 to 250 mm throughout the sampling period, with 74.3% of the sample composed by juveniles (less than 150 mm TL). The mean values of the total lengths were 136.81 mm in the summer, 125.31 mm in autumn, 119.57 mm during winter, and 142.69 mm in spring. With the exception of summer, the other seasons showed a bimodal pattern for the length distribution (Figure 2), and significant differences were observed among the total lengths throughout all seasons (p<0.05) (Table 2). Smaller individuals, which were related to recruitment, were observed during the whole year but in higher numbers during the winter (81.0% of the sample) and lower in spring (58.3%).

The sampled individuals weighed a total of 235,667 g, ranging from 1 to 173 g and with a mean value of 35.44 g (standard deviation: ± 20.15 g). The length-weight relationship did not show any significant differences in the angular (b) and linear (a) coefficients between genders (ANCOVA: p_b = 0.92 and p_a = 0.36), so the data were gathered for both genders in a single fitted curve with the following parameters: a = 1.48 x 10^{-5} ± 0.54 x 10^{-5}, b = 2,984 ± 0.073, r^2 = 0.996 (Figure 3).

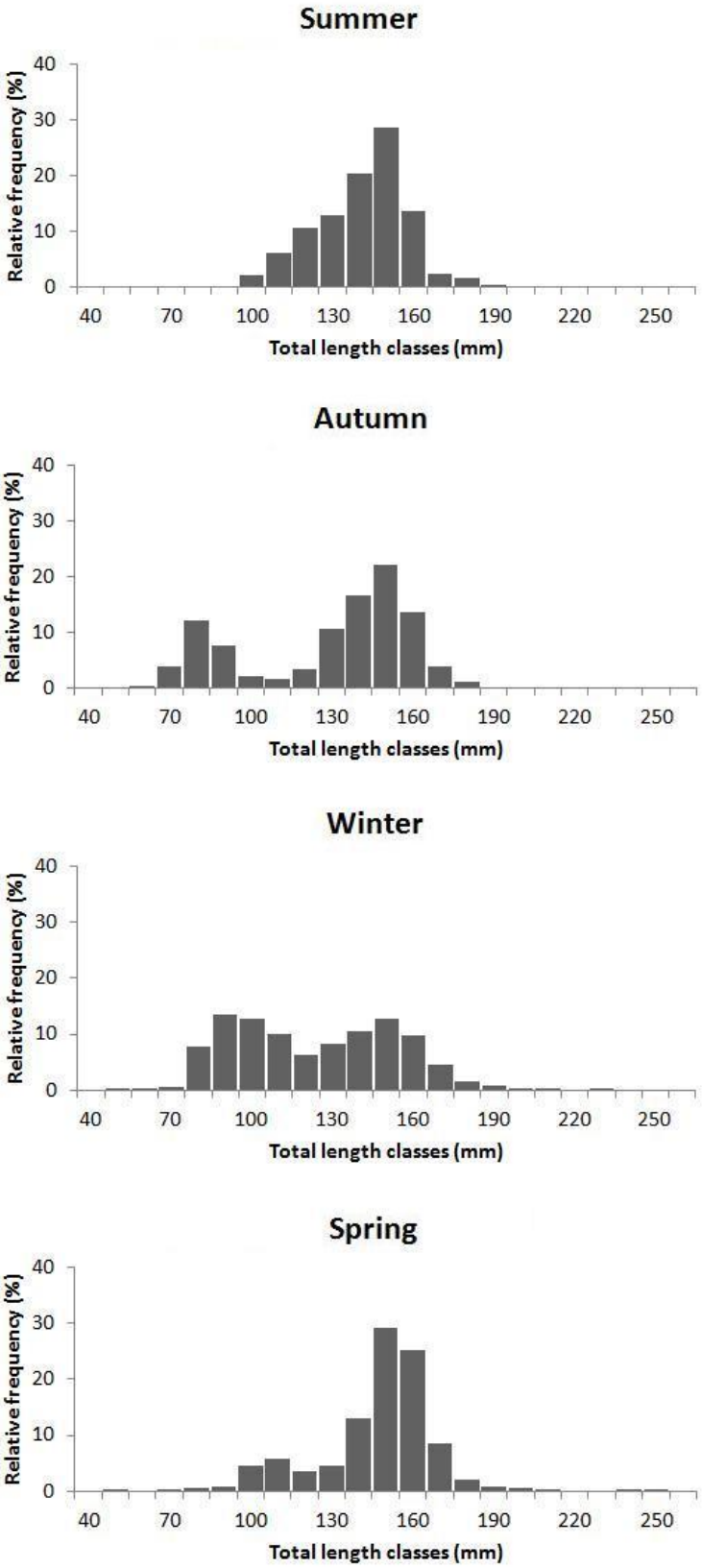

Figure 2. Seasonal total length distribution of *Diapterus rhombeus* from the Santos estuary.

Table 2. Multiple comparison test between seasons for total length after carrying out the Kruskal-Wallis test (p = 0.05) for *Diapterus rhombeus* from the Santos estuary.

Comparisons	Observed difference	Critical difference	Difference
Summer-Autumn	524.9023	174.8627	True
Summer-Winter	948.7991	179.1840	True
Summer-Spring	669.8377	185.3618	True
Autumn-Winter	423.8968	167.3715	True
Autumn-Spring	1,194.7400	173.9693	True
Winter-Spring	1,618.6368	178.3123	True

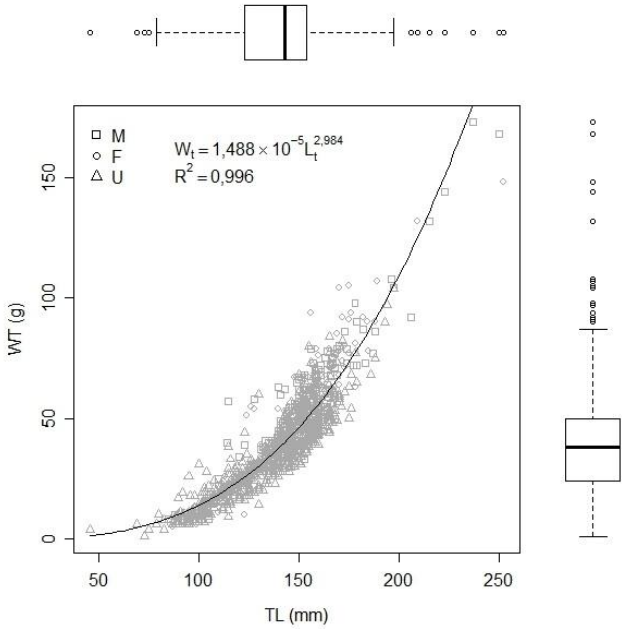

Figure 3. Length-weight relationship and boxplot of the length and weight for grouped genders of *Diapterus rhombeus* gathered in the Santos estuary. (M = male, F = female, U = undetermined).

No statistical differences were observed between genders and seasons for *D. rhombeus* during the sampling period (Table 3).

Table 3. Numbers of specimens by gender and season of *Diapterus rhombeus* and the significance level of the χ^2 test from the Santos estuary (F = female; M = male).

Season	F	M	p
Summer	239	348	0.063
Autumn	392	471	0.360
Winter	89	113	0.234
Spring	422	404	0.827
Total	1,142	1,336	0.433

The gonadal assessment indicated that juveniles (stages A and B) predominated in the sample (71.93%). Specimens in the spawning stage were the least frequent (0.68%). The degree of maturity for each season showed a high abundance of developing females during autumn (stage B with almost 65%). For males, the greatest abundance of immature individuals was during spring, while mature ones were more abundant in the summer (Figure 4). The mean condition factor for each season was higher during summer for both genders. Otherwise, smaller values were observed for females in autumn and in spring than for males (Figure 5). The Kruskal-Wallis test showed statistical differences for seasons (p<0.001) and also for genders (p<0.001). The

finding of stomach vacuity indicated that most individuals were not feeding when they were gathered (63.23%), though the emptiness of the specimens' stomachs could be due to regurgitation, because of the stress of being captured.

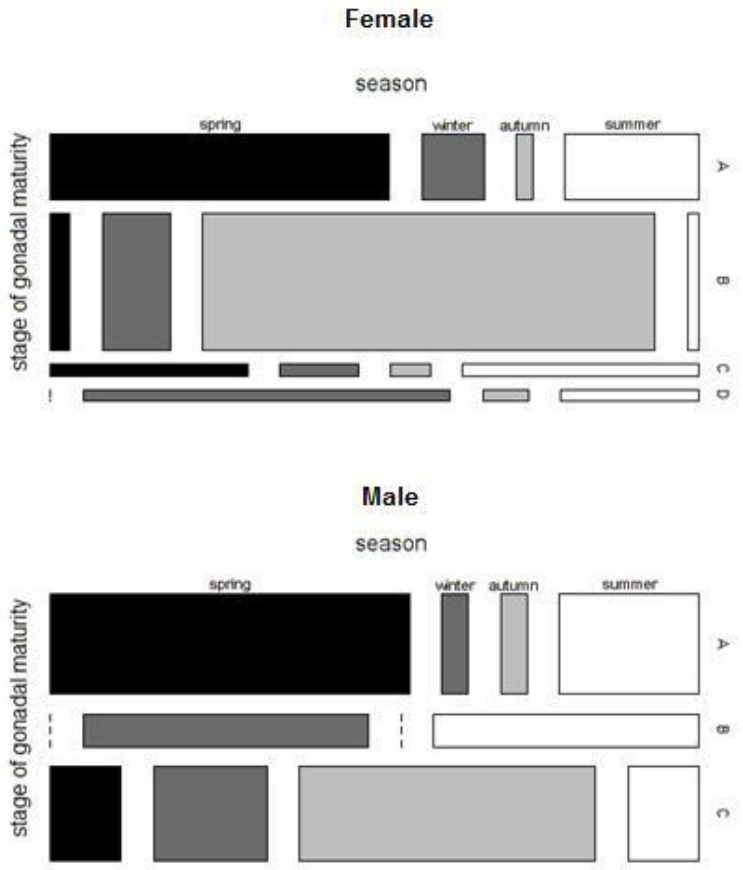

Figure 4. Gonadal maturity of *Diapterus rhombeus* gathered in the Santos estuary (A = immature, B = ripening or resting, C = mature and D = spent).

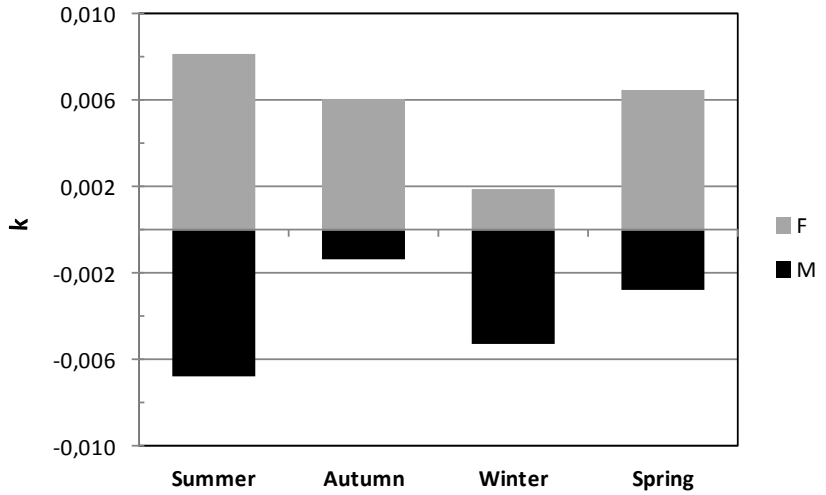

Figure 5. Mean condition factor (k) for each season and gender of *Diapterus rhombeus* gathered in the Santos estuary.

A total of 6,639 individuals were considered for the evaluation of the species' age and growth in the "artificial year". The VBGF terms were consistent with the biology of the species. The value of the asymptotic length ($L\infty$) was 262.5 mm, k was 0.24/year and the longevity ($t_{0.95}$) was of 12.48 years (Figure 6).

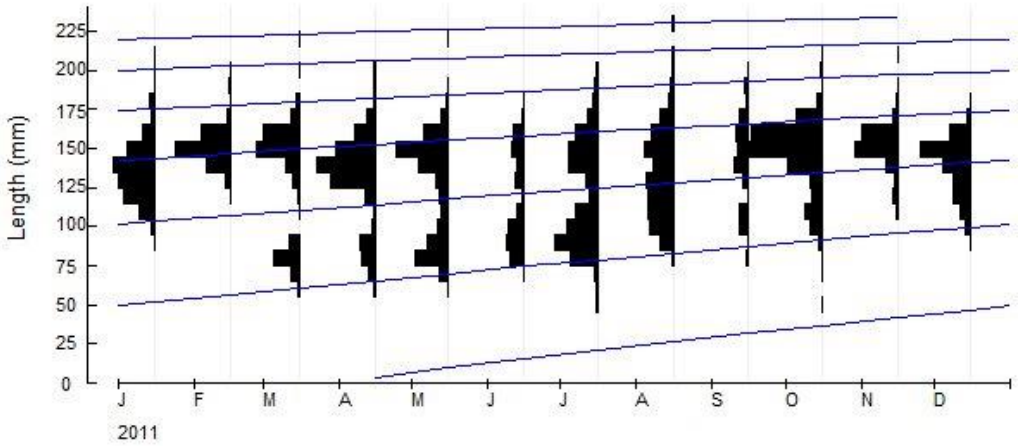

Figure 6. Growth lines of *Diapterus rhombeus* gathered in the Santos estuary.

DISCUSSION

The present estuary can be classified as a medium sized open estuary with a semidiurnal tidal regime, according to BLABER (2002). Thus, this estuary is under the influence of tidal variations, and presents a particular vocation for the construction of ports and harbours, leading to the development of cities and industrial sites. These intrinsic characteristics undoubtedly have a substantial influence on the organisms that inhabit this estuary, either as a resident or as part of their life cycle.

Although the temperature variations in a subtropical environment, such as the focus of the present study, are less pronounced than in temperate environments, there are still seasonal variations that may influence ecological processes. Moreover, BLABER (2002) states that daily and seasonal fluctuations of salinity and an array of other factors even in tropical and subtropical estuaries, where physical-chemical phenomena are still unclear in many aspects, can determine which species are found and influence their role in the ecosystem.

The lowest abundance of specimens was observed during summer and spring, which were the seasons when the largest (250 mm) and heaviest (173 g) individuals were caught, respectively, corroborating with CHAVES and OTTO (1998) and PICHLER (2005), who evaluated the ichthyofauna of a Brazilian southern estuary. Moreover, CHAVES and OTTO (1998) considered winter to be the season of greatest abundance and summer was correlated to the species' growth within the mangroves, contradicting the present study. Differences are possibly due to the physical, geomorphological and climate features of the environments, which influence directly on the life cycle of the organisms that inhabit these locations, as well as methodological differences and variations in the sample size and population strata that was analyzed in each case.

FAGUNDES *et al.* (2007) observed a length range of 148 to 400 mm (median of 238 mm) for the species in beach seine fisheries in Santos Bay, with larger individuals during spring (October and November). Considering that the literature indicates that *D. rhombeus* carries out a migration towards deeper waters to spawn (MENEZES and FIGUEIREDO, 1980; CHAVES and OTTO, 1998; AYALA-PEREZ *et al.*, 2001), it is possible that these larger specimens were spawning in the coastal region, while the estuarine region presents a larger quantity of juvenile and maturing specimens. Other findings in the present study indicate that the species does not spawn within the Santos estuary: a low

frequency of mature (C) and spent (D) females in the estuary; and a smaller presence of adults during the spring, period in which the migration to deeper water probably begins, extending throughout summer as well, since *D. rhombeus* is a partial spawning species.

According to ELLIOTT *et al.* (2007) the species of the Gerreidae family are classified in the larger class of marine migrants and, more specifically, within the sub-class of marine estuarine dependent species. This classification was based on the fact that species from this family spend a large part of their juvenile stage within the estuary, but are also found along the coast where they spawn, which is in agreement with the findings of the present study. Moreover, these species make use of the selective tidal stream transport for entry and retention within estuary, as reported by ELLIOTT *et al.* (2007). Thus, it is reasonable to state that *D. rhombeus* depends on the estuary to complete its life cycle, but the species does not inhabit the environment throughout its whole life, considering that larger individuals occur in the adjacent coastal waters (GRAÇA-LOPES *et al.*, 2002; FAGUNDES *et al.*, 2007; SOUZA *et al.*, 2007). In addition, the length and weight data analyses of the present study suggested a pattern of species migration towards the sea during spring and summer, and an entrance of recruits beginning in autumn, at an estimated relative age of slightly over 1 year.

The calculated allometric coefficient was close to 3, thus indicating isometric growth, in accordance with the data of MUTO *et al.* (2000) and JOYEUX *et al.* (2008) in the State of São Paulo, but lower than COSTA *et al.* (2012), AYALA-PEREZ *et al.* (2001), SILVA-JÚNIOR *et al.* (2007) and JOYEUX *et al.* (2008) for other localities, possibly because of incorporating distinct population strata, from either more coastal or more inland regions. FROESE (2006) affirms that small specimens have different weight-length relationships and, therefore, condition factors, to larger specimens.

The highest estimate for the mean condition factor during the summer coincided with the highest occurrence of the maturity stage D (spent). This scenario reflects the preparation of the individuals towards reproduction, with an increase in mass due to gonadal development. CHAVES and OTTO (1998) found a higher condition factor during winter months, while the lowest value was found in spring, not following the same pattern as the present study. COSTA *et al.* (2012) identified the condition factor of spring as the start of the reproductive process for the same species at Sepetiba Bay, Rio de Janeiro.

The smallest size classes were recorded during autumn-winter, corroborating with the hypothesis that recruitment occurs from autumn onwards. Therefore, it can be inferred that individuals occupied the estuarine environment for growth and maturation during the whole year, leaving the estuary about two years later for the first spawning, when the individuals are around 150 mm in total length. COSTA *et al.* (2012) identified two cohorts, which may be the same case for the Santos estuary, where one cohort migrates to sea during spring and the second one, during summer. It was not possible to infer about the entrance of the second cohort.

Regarding the age and growth analysis, the value of k estimated in the present study (0.24/year) represents a relatively low growth rate, suggesting that this population of *D. rhombeus* requires more time to reach $L\infty$, since k determines the speed at which a fish reaches its $L\infty$. Growth parameters can differ between different stocks or even cohorts according to, for example, environmental conditions (SPARRE and VENEMA, 1997). AYALA-PEREZ *et al.* (2001), studying the same species in Mexico and using the same calculation routine, found a smaller value of $L\infty$ of 204 mm, and a higher value of k (0.74/year). ETCHEVERS (1978), in Venezuela, also found $L\infty$ of 204 mm, though k was 0.67. For COSTA *et al.* (2012) the growth parameters were $L\infty$ of 358 mm and k of 0.57/year. Not only do these studies consider distinct regions, but the sample sizes and possibly the population strata that were analyzed do not correspond to those of the present study.

CONCLUSION

The caitipa mojarra *D. rhombeus* is an important component of the ichthyofauna of the estuary of Santos considering its high abundance and role as a fisheries resource. Its spawning most

likely occurs in adjacent coastal waters, but the estuary is paramount for its development and maturation. The age and growth analysis showed a relatively low growth rate for the species, which is in agreement with the high L∞ value obtained from the observed population.

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