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Age and growth of the white croaker *Micropogonias furnieri* (Perciformes: Sciaenidae) in a coastal area of Southeastern Brazilian Bight

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Studies on age and growth of fish populations have direct application in fisheries and contribute for policies of conservation. Our aim was update information on the *Micropogonias furnieri* growth parameters based on *sagittae* otoliths *annulis* readings, and we expected that the studied population from Southeast Brazil can reach more longevity than the reported in the available literature. We examined 286 individuals between August-2010 and July-2011 from Ubatuba Bay, SP. The Total Length ranged 200-480 mm. The determined growth parameters were: Males, L_∞ =523.4mm, k = 0.05×year^{-1}, t_0= -8.78 year; Females L_∞ = 573.5mm, k = 0.06 × year^{-1}, t_0= -7.49 year. The MI and % of edge type evidenced the formation of one ring per year during autumn/winter, coinciding with low temperature and low growth rate. These results differed from those reported for the Vazzoler's Population I (summer), and we detected higher longevity (45-48 years) as compared with the recorded in the available information.

Keywords: Coastal fishes, Growth parameters, Longevity, Marginal increment, Ubatuba.

Estudos de idade e crescimento de peixes têm aplicação direta na biologia pesqueira e contribuem para medidas de conservação. Nosso objetivo foi atualizar informações sobre parâmetros de crescimento de *Micropogonias furnieri* utilizando leitura de anéis etários em otólitos *sagittae*, esperando que a população do Sudeste do Brasil alcance maior longevidade do que o reportado na literatura. Examinamos 286 indivíduos, capturados entre agosto de 2010 e julho de 2011, na Baía de Ubatuba, SP. O comprimento total variou de 200-480 mm. Foram determinados os parâmetros de crescimento: Machos, L_∞ = 523,4 mm, k = 0,05 ano^{-1}, t_0= -8,78 ano; Fêmeas, L_∞= 573,5 mm, k = 0,06 ano^{-1}, t_0= -7,49 ano. O IM e a porcentagem do tipo de borda evidenciaram o padrão de formação anual de anéis no outono/inverno, coincidindo com mais baixas temperaturas e crescimento lento. Estes resultados diferem dos reportados para População I de Vazzoler (verão), e nós detectamos longevidade bem superior (45-48 anos) à descrita anteriormente.

Palavras-chave: Incremento marginal, Longevidade, Parâmetros de crescimento, Peixes costeiros, Ubatuba.

Introduction

Studies on age and growth of fish populations are important because they supply basic information for formulating of conservation policies aiming to exploit these renewable resources. The determination of fish growth parameters contributes to estimate growth rates by age-group and to determine age structure of population (Bagenal, Tesch, 1978; Campana, 2001; Neilson, Campana 2008). The composition and structure of age-classes in a given fish population and the degree of exploitation of these resources are determined by such studies (Longhurst, Pauly, 2007). They also provide information on maximum attainable size, periods of high/low growth rates, size and age structure. Moreover, the informations on population dynamics are important to estimate the amount of fish catches for resources management programs.

The white croaker *Micropogonias furnieri* (Desmarest, 1823) is a fish of the Sciaenidae family that has a large contribution in landings by both industrial and artisanal fisheries performed in the inner continental shelf and in coastal areas, such bays, estuaries and coastal lagoons (Giannini, Paiva Filho, 1990; Vieira, Castello, 1997; Costa, Araújo, 2003). Despite the wide distribution throughout Central and South American Atlantic coast, the highest white croaker landings occur between the Brazilian southeastern (Costa *et al.*, 2014; Mulato *et al.*, 2015) and the north of Argentina coast (Volpedo, Cirelli, 2006). Similarly to most exploited fishery resources, *M. furnieri* is under over-exploitation, as results of poor policies and management of fisheries resources in Brazil, Uruguay and Argentina (MMA-REVIZEE, 2006; Castello, 2007). In the Brazilian coast, landing of *M. furnieri* decreased from 200,000 ton. in 1996 to 70,000 tons. in 2002. In Southern

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Brazil, capture by unit effort (CPUE) estimates changed from 1 ton. per fishing day in 1980 to 0.2 ton. per fishing day in 2002 (Vasconcellos, Haimovici, 2006). Carozza *et al.* (2004) recorded decreases in landings from 60.000 tons in 1995 to 30.000 ton. in 2003, in the Prata River Estuary, a common fishing area for Argentina and Uruguay. Ávila-da-Silva *et al*. (2007) reported that *M. furnieri* is an important artisanal fishery resource of São Paulo State, from which, 47.3% corresponded to gill net catches off Ubatuba coast.

Several studies on the biological parameters of *M. furnieri* suggest a discontinuity of populations/stocks along its geographic distribution area. Vazzoler (1971) was the first to report two populations in South-Southeastern Brazilian coast, one (population I - Southeast) between parallel 23ºS and 29ºS, and the other between 29ºS and 33ºS (Population II - South). This division was confirmed in other studies using immune plasma electrophoretic and electrophoretic patterns of the crystalline proteins (Phan, Vazzoler, 1976; Vazzoler *et al*., 1985; Vazzoler, Phan, 1989). Isaac (1988), in a synopsis of biological data on *M. furnieri,* confirmed Vazzoller populations I and II for Southeastern and Southern Brazil, respectively, and add two more populations, one for the Prata River estuarine region (Population III) and the other for Bahia Blanca (Population IV). Figueroa, Astarloa (1991) and Haimovici, Umpierre (1996) also reported two morphologically differentiated stocks, one in the Bahia Blanca region and the other, with less defined limits encompassing the Prata River estuary and the Uruguayan-Argentinean coastal area. More recently, Vasconcellos *et al.* (2015), studying the genetic structure of *M. furnieri* using nuclear markers, found strong correlation between genetic and geographic distances, identifying three different stocks along the Brazilian coast, the first in the Pará coast, the second between Rio de Janeiro and Santa Catarina State, and the third along the coast of Rio Grande do Sul State, between Torres and Chui.

Species with wide range of geographical distribution (*e.g*., *M. furnieri*) are prone to form different stocks, dictated by eventual ecological barriers along the coast, for example currents, water mass, capes, peninsulas, archipelagos, etc (Francis, 1996). There are some consensus that the "Southeastern Brazilian Bight - SBB" a large sea embayment in South America continent between Cabo Frio (23ºS) and Santa Marta Cape (28º30'S) form special transitional area between tropical and warm temperate regions, that are influenced by water mass of the South Atlantic Convergence Zone - SACS (Mahiques *et al.*, 2010). In this sense, Ubatuba Bay that is located near to the center of this area and that have important fishery landings (Ávila-da-Silva *et al*., 2007), is an interesting site for collecting and evaluate *M. furnieri* biological parameters. Collecting information on a specific area within the range of distribution of a given widely distributed stocks assures that data will not have interference of other possible stocks that are prone to occur near to ecological barriers that favor the formation of other stocks, thus misleading the results.

Several government actions have been done in reference to Ubatuba fishing area, which suggest the great importance of Ubatuba for regional fisheries. Examples of these actions are the shrimp decree (Brazil, Ordinance number 74, 2001) closing catches of this resource, prohibition of fisheries of several Scianenids (*M. furnieri, Cynoscion Guatucupa, Cynoscion virescens* and *Umbrina conosai*) by trawler vessels (Brazil, Ordinance number 43, 2007), the São Paulo State Plano of Coastal Management (São Paulo, Law number 10.019, 1998) and the creation of the Marine Protection Area for the north coast of São Paulo State (São Paulo, Ordinance number 53.525, 2008).

The whitemouth croaker has great importance as an income for local fishermen. This intensively exploited demersal species represented the second largest amount of fishery biomass (1545.6 tons.) for the state of São Paulo fishery landings in 2015, from which, 536.7 tons. are from Ubatuba area (Instituto de Pesca de São Paulo, 2016). Despite its remarkable importance as fishery resource, studies on age and growth of *M. furnieri* in Southeastern Brazil are scarce. Vazzoler (1971) determined age by reading rings in scales of *M. furnieri* Population I (Southeast) and Population II (South) Brazil. However, the used methodology was probably biased since a very low longevity for the Southeast (5 years) and the South (7 years) was reported. Subsequently, Schwingel, Castello (1990) and Cotrina (1998) performed reading of age rings in otoliths from stocks from Southern Brazil and Argentina coast, respectively, and managed to determine a much higher longevity of 38 and 30 years. These differences were probably undestimation of the rings reading in scales compared with more precision of otoliths.

The use of otoliths in studies of age and growth is a scientific breakthrough of great importance to fisheries science and has been successfully employed, as the case of important fishery resources widely distributed, such as the Brazilian codling *Urophycis brasiliensis* (Andrade *et al*., 2004), mapará *Hypophthalmus marginatus* (Cutrim, Batista, 2005), white mullet *Mugil curema* (Santana *et al*., 2009), snowy grouper *Epinephelus niveatus* (Costa *et al*., 2011), lebranche mullet *Mugil liza* (Garbin *et al*., 2014), among others. The high reliability of these calcified structures is attributed to its protection within the auditory capsules, not suffering degeneration as the scales, being also more stable structure and composition over time (Panfili *et al*., 2002), thus providing more accurate information on age and growth studies. In *M. furnieri*, the *sagittae* have been used with great accuracy in studies of age and growth (Schwingel, Castello, 1990; Albuquerque *et al.,* 2009; Borthagaray *et al*., 2011; Braverman *et al*., 2015; Cavole, Haimovici, 2015). This study aimed to determine age and growth parameters of *M. furnieri* from a coastal area in Southeastern Brazilian Bight (Ubatuba Bay), based on year ring readings in *sagittae* otoliths. We intend to update information for the Southeast stocks of *M. furnieri*. We believe that the available literature on growth parameters of *M. furnieri* population in Southeast Brazil (namely, Vazzoler, 1971) underestimated longevity and age for a given size, since the used methodology using scales is less precise than the use of otoliths that offer more accurate results. We also intend to update information on time and periodicity of ring formation. To our knowledge, this is the first study of the kind for this species in southeastern Brazil that was carried out in an area near to center of geographical distribution of this stock where important landings of this fishery resource occur.

Material and methods

Study area. Ubatuba Bay (Fig. 1) is located in the North coast of São Paulo State, Southeastern Brazil (23º23'S-23º28'S and 45º07'W-44º58'W) and has a wide connection with the coastal adjacent area, with a mean depth of 5 m in the inner part of the bay and 10 m in the outer part (Mahiques, 1995). The bay shoreline has several sandy beaches interspersed by reef rocky shores. Streams and creeks drain into the bay giving to the water a mixopolihaline characteristic, low dynamism and a predominant fine and very sediment (Mantelatto, Fransozo, 1999).

This microtidal system has tide range of approximately 1 m (Mahiques *et al*., 2010). Prevailing winds from the northeast and southeast activate currents between the bay and the ocean. A remarkable characteristic of the landscape is the great proximity to the Sea Mountains that extent into the Atlantic Ocean.

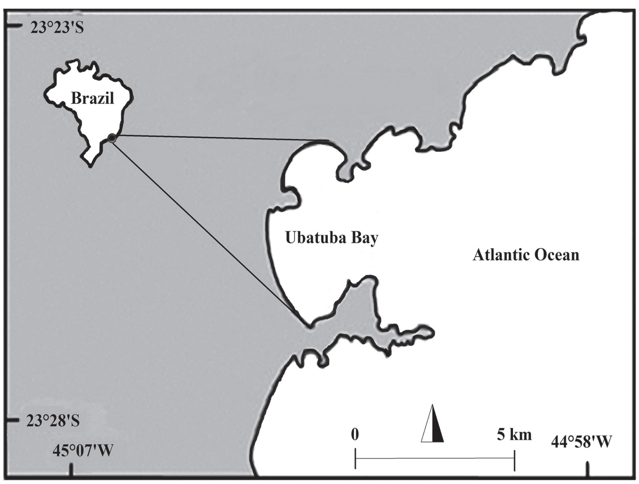

Fig. 1. Study area, Ubatuba Bay in north coast of São Paulo State. Area of artisanal fisheries captures shaded (modified from Santos *et al*., 2015).

Collection and data treatment. A total of 286 individuals (101 females and 185 males), with total length ranging from 200 to 480 mm for females, and 200 to 450 mm for males, collected fortnightly by gill nets (stretched mesh 10-12 cm), between August 2010 and July 2011 was examined.

To test whether the ring formation is related to changes in water temperature or reproductive events, water temperature measurements were taken throughout the year, in the same places and times when the fish were collected. We measured water temperature near to the bottom at each site where the nets were deployed.

All fish specimens were supplied by the artisanal fisheries that are practiced in the Ubatuba Bay. These fisheries cover approximately an area of 10 km^2 in the outer bay zone and are carried out by small boats and canoes measuring approximately 10 m long. The nets used in these fisheries were 60 m long, 5 m height, with mesh size of 11 cm between opposite knots, and were setup at dusk and retrieved in the following morning. Fortnightly fish catches were performed between August 2010 and July 2011.

All fish were identified according to Menezes, Figueiredo (1980), measured to Total Length (in mm) and the sex was attributed based on the macroscopic scale of Vazzoler (1996). Voucher specimens were deposited into the ichthyological collection of the Laboratório de Ecologia de Peixes of the Universidade Federal Rural do Rio de Janeiro (LEP-UFRRJ), under the following catalogue numbers: LEP-UFRRJ 1597; LEP-UFRRJ 1598; LEP-UFRRJ 1599, three individuals in each catalogue number.

The pair of otoliths *sagittae* was removed from the auditive capsules, washed and dried. The otholits height (Ho), length (Lo) and weight (Wo) were measured to assess the relative growth. The Huxley (1993) model was used for males and females in separate and for the grouped sexes. A paired t-test using otolith measurements was performed to ascertain left-right differences (α =0.05%). As no difference was found, we choose to use consistently the right otolith.

After that, the otoliths were mounted in liquid crystal resin before cutting, ensuring the integrity of the structure, and then the block was sectioned directly on a metallographic sharper. The otoliths nucleus was marked for increased precision cuts. Transversal otolith sections were obtained using a low speed metallographic saw Buehler Isomet. For each otolith, we cut two to four sections of approximately 0.6 mm, and choose the one that best illustrate the core of the otolith. The choose section from each otolith was glued on glass slides with adhesive cyanoacrylate and then sanded with water sandpaper number 1200.Transversal otolith sections were examined three times under a stereomicroscope applying reflected light by one reader, without giving any information about size, sex of the fish or sampling period.

To identify and count the age rings, we took photographs using a digital camera (Sony- Optical Steady Shot / DSC-W570) coupled to a trinocular stereoscopic microscope (Quimis T3.15A), which was connected to a PC monitor / HDTV (Samsung Sync Master T22A300) improving the focus to capture the images. We use an magnification of 1.3 in the stereomicroscopy (with ocular magnification × 10) with transmitted light and 2× zoom the camera. The images (Fig. 2) were captured and subsequently analyzed with the help of ImageJ version 1.47.

Data analysis. The period of ring formation was assessed by the percent of edge pattern (translucent/opaque) and marginal increment index. A translucent band (Tr - a narrow region of clear aspect, related to lower growth rates, intercalated with an opaque band - Op - a wide region related to faster growth rates) was considered as one ring (Green *et al*., 2009). According to Fonteles Filho (2011), the translucent areas are age rings, and correspond to the period of slow growth, being composed of a higher proportion of calcium and a lower proportion of organic matter. This implies that there is during the year a pair of band formation, one clear and the other dark. The character (translucent or opaque) of the otolith edge was noted to calculate the relative percentage of type of edge. The otolith radius (Ro) and ring radius (Ra) were measured from the nucleus to the edge of the otolith and from the nucleus to the end of the opaque band at scale of 1 mm, using the program Image J v. 1.47. Measurements of each otolith were performed parallel to the acoustic groove axis, and were used to determine the marginal increment index.

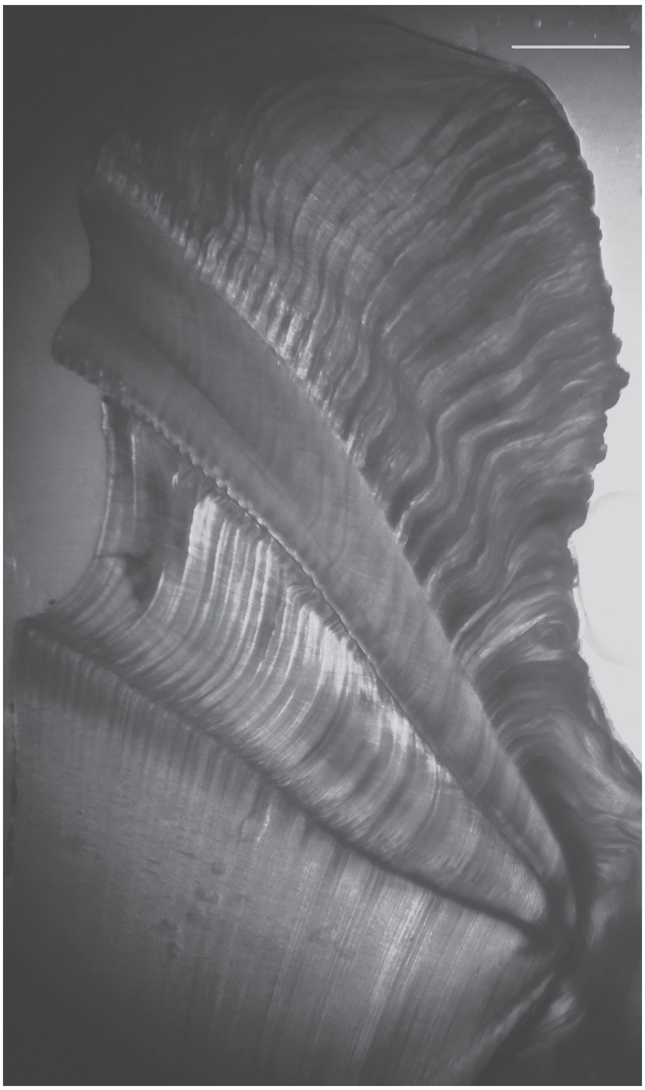

Fig. 2. Photo of a sliced otolith showing the core and the rings formed by the opaque and translucent bands. Scale of 1mm is shown.

Three rings readings were performed for each otolith for the same reader. After this procedure, we performed the consistency analyses among the readings for a given lamina, using the Average Percent Error (APE) (Beamish, Fournier, 1981),

$$APE = \frac{100}{n}\sum_{i=1}^{n}\left[\frac{1}{r_i}\sum_{j=1}^{r_i}\frac{|a_{ij-}a_i|}{\bar{a}_i}\right]$$

where: n = number of otoliths; r_i = number of readings for each otolith i; a_{ij} = the number of rings in otolith *j* in reading *i*; a_i = average age calculated for the otolith i.

The Coefficient of Variation (CV) proposed by Chang (1982) was used to assess the reliability of the ring measurements estimated by the APE, considering the ratio between the standard deviation and the mean of readings taken for each otolith:

$$CV = \frac{100}{n}\left[\sum_{i=1}^{n}\left(\frac{sd_i}{\bar{a}_i}\right)\right]$$

where, Sd_i is the standard deviation of the ages attributed to otolith I and a is the mean of readings.

Percentage of edge pattern and marginal increment were calculated with data from the samples over time in order to validate the time and periodicity of ring formation. The percentage of edge was compared among the months using the difference proportion t-test. The marginal increment index (MI), is the ratio of calcium carbonate deposited on the otolith edge over time. Based on their lowest value of MI, the time of age ring formation was determined, using the following equation proposed by Mio (1961):

$$MI = (RO - Rmax) / Ro$$

where, Ro is the otolith radius and Rmax is the outermost ring mark.

The age composition of the specimens was distributed in ten size-classes of 29 mm interval, in an age-growth table by separate sexes. The von Bertalanffy growth model (VBGM) (von Bertalanffy, 1938) was fitted to age data using Solver in Microsoft Excel for the observed lengths at age, for males and females separately and for pooled sexes, using the equation:

$$La = L_\infty [1 - e^{-k(t - to)}]$$

Where: *La* is the predicted mean length at age a, L_∞ is the maximum theoretical mean length, *K* is the growth coefficient and t_0 is the theoretical age at length zero.

Initial estimation of growth parameters were obtained by the Ford-Walford method (Walford, 1946). The obtained parameters were tested by the ordinary least square through the iterative SOLVER method, the minima variance method MINIVAR and by the empiric Pauly (1979) formulae. Then, we choose the method that better fitted to the von Bertalanffy curve.

The longevity ($A_{0.95}$) represents the time required for a body reaches 95% of its capacity to grow in length and was calculated according to method of Taylor (1958), using the growth parameters obtained from adjustment of von Bertalanffy curve as: $A_{0.95} = (2.996/K) + t_0$ **,** where t_0 is the theoretical time at length zero.

We used the growth performance index ($\varphi' = log_{10}\, k + 2 * log_{10}\, L_\infty$) developed by Munro, Pauly (1983) to assess the adjustment of the growth parameters between males and females.

Results

The left and right otolith measurements did not present any differences ($p > 0.05$ for Lo, Ho and Wo), allowing the use of any of them, therefore, we chose the right. Relative growth (Lt × Lo, Lt × Ho) had negative allometry ($p < 0.001$), suggesting decreasing in the otolith length compared with fish body length as they get larger size (Fig. 3).

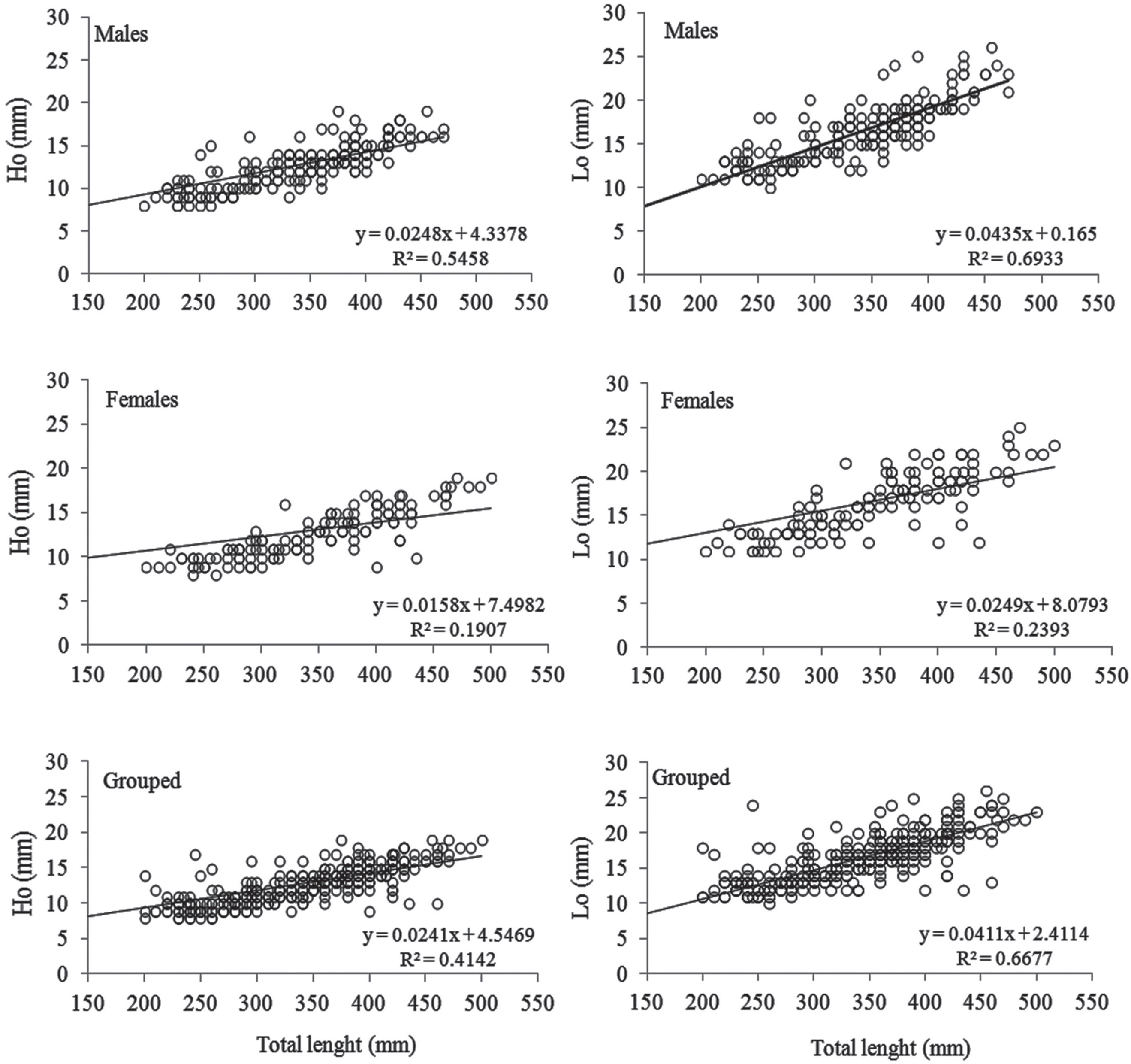

Fig. 3. Relative growth of otoliths parameters (Length and Height) against Total Length of *Micropogonias furnieri*.

Period and frequency of rings formation. The relative percentage of edge type (Fig. 4a) in sections of otoliths showed that the translucent edges were recorded throughout the year, with the highest incidences in the winter/spring (August to October - 2010) and autumn/winter (May-July 2011). Marginal Increment (MI) calculated (Fig. 4b) showed the lowest value in the autumn/winter, suggesting that the rings formation occur in May to July. Water temperature ranged from 19.7 °C to 26 °C (Fig. 4c) throughout the year, with the lowest values in the winter.

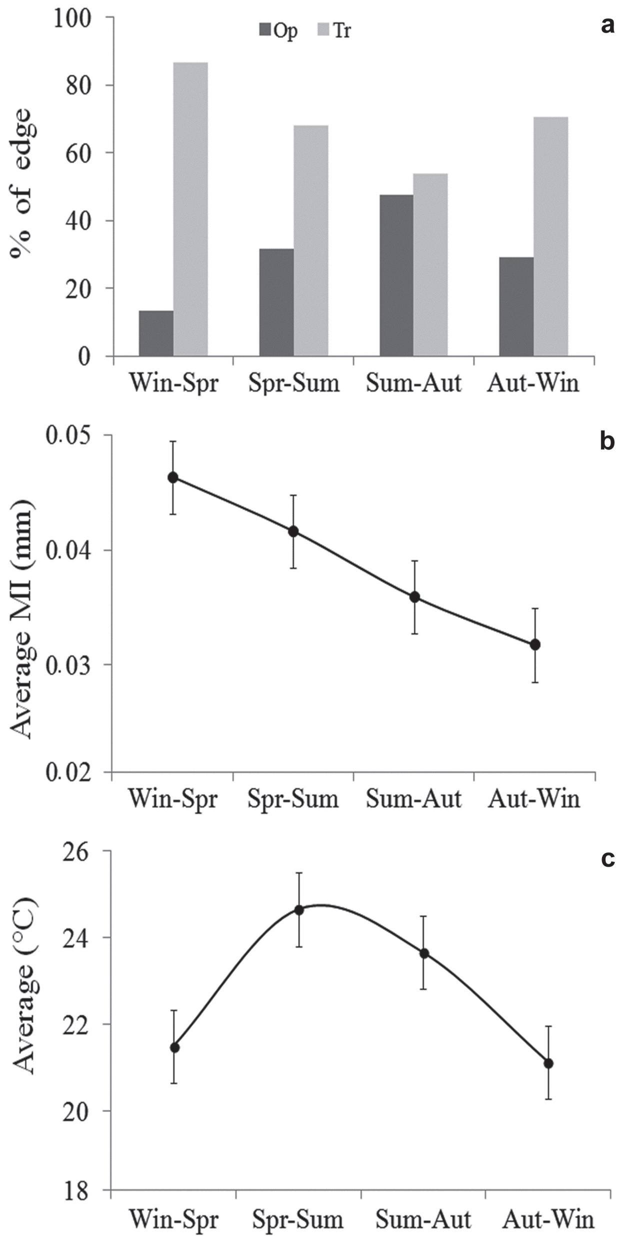

Fig. 4. a. Percent of seasonal frequency of opaque (OP, gray) and translucent (TR, white) edges in *sagittae* otoliths of *Micropogonias furnieri*; **b.** Seasonal average marginal increment (MI, mm) and confidence limits obtained in *sagittae* otoliths of *M. furnieri*; **c.** Average water temperature and confidence limits in waters for Ubatuba Bay.

Determination of age and growth parameter. Considering the three averaged readings, we recorded individuals from 0 to 20 years in Ubatuba Bay. Males and females were represented in virtually all age and size classes (Tab. 1).

The Average Percentage Error index (APE) between the three readings was 5.47% with coefficient of variation of 7.48%. The growth parameters estimated for the von Bertalanffy curve were, Males: L_∞= 523.4 mm, *k*= 0.05 year^{-1}, t_0= -8.78; Females: L_∞= 573.5 mm, *k*= 0.06 year^{-1}, t_0= -7.49; Grouped sexes: L_∞= 531.5 mm, *k*= 0.05×year^{-1}, t_0= -8.84 year. The adjusted growth curves for males and females are shown in Fig. 5.

The longevity was 48 years for males and 45 years for females. The growth performance index (*φ'*) for males and females were very close (2.55 for males and 2.68 for females), showing that the set of estimated parameters differ little from each other.

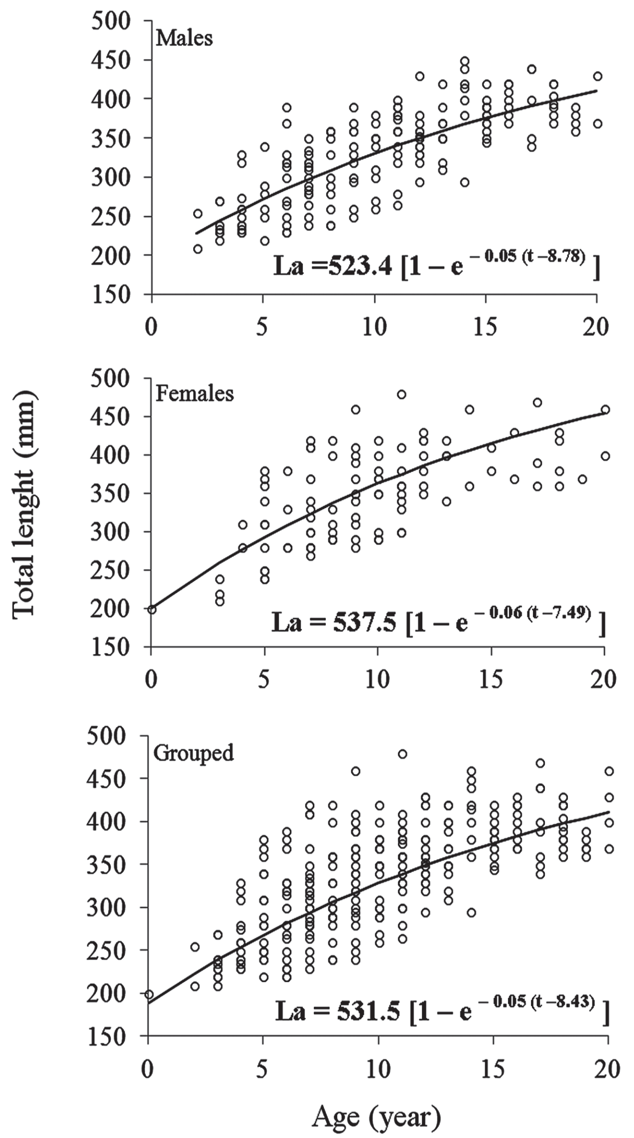

Fig. 5. Growth curves adjusted according to von Bertalanffy models for *Micropogonias furnieri.*

Tab. 1. Age-length distribution for Males and Famales of *Micropogonias furnieri* obtained from ring-count of the otoliths.

Males																						
Age (years)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	%
TL (mm)																						
200-229			1	2		1	2			1												3.8
230-259			1	6	9	1	6	2	2	1		1			2							16.8
260-289				2	3	2	2	5	2	1	2	2										11.4
290-319						1	2	4	2	2	2		1	1	1	1	1					9.7
320-349					2	1	4	4	1	3	1	3	5	1		1		1				14.6
350-379							1	1	4	3	4	4	5	5		4	1	1	1	2	1	20.0
380-409							1			1	1	6	1	1	2	6	3	1	4	2		15.7
410-439													1	1	2	1	3		2		1	5.9
440-469															2			2				2.2
>470																						
Total																						100
Females																						
Age (years)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	%
TL (mm)																						
200-229	1			2																		2.97
230-259				1		4				1			1									6.93
260-289					1	1	2	4	1													8.91
290-319					1	2		2	5	2	3	2										16.8
320-349						1	1	3	1	2		2		1								10.9
350-379						2		1		2	4	3	2		1		1	1	1	1		18.8
380-409						1	1		1	2	2	1	2	2		1		1	1		1	15.8
410-439								3	1	1	1	1	3	1		1	1	2				14.9
440-469										1					1						1	2.97
>470																		1				0.99
Total																						100

Discussion

In this study, we found that the ring formation of *M. furnieri* in Southeast Brazil occurs in Autumn/Winter (May to July), as indicated by the lowest value of the marginal increment index (MI), when we found the highest occurrence of translucent edges, which are indicators of the slow growing season. These findings are not in agreement with Vazzoler (1971) who, using scales, reported the summer as the period of formation of the ring. The advantage of the otoliths in studies of age and growth was also reported by Haimovici, Reis (1984) that highlight a tendency to read a lesser number of rings using scales compared with otoliths, especially in individuals of 5 years or more. They found that changes in otoliths zones (opaque/translucent) is clear even in older specimens. Thue *et al*. (1982), who determined the maximum age of eight years using reading of age rings in scales, also confirmed this trend underestimate the age for *Centropomus undecimalis* in Florida. Posteriorly, Taylor *et al.* (2000) using otoliths found a maximum age for 21 years for this species in Mexico Gulf, confirming the trend for finding a higher number of rings in otoliths.

Annual ring formation for *M. furnieri* in Ubatuba Bay may be associated with a combination of low winter temperature and energetic expenditure directed to gonad maturation. The time of ring formation coincides with the higher values of IGS (Santos *et al*., 2015), indicating high reproductive activity, however, the temperature also seems to be associated with this event, since it is possible to observe age rings in sexually active individuals immature (L_{50} 321 mm for males, L_{50} 341 mm for females, Santos *et al*., 2015), indicating that rings may occur independently of the reproductive event. In several species, adults individuals spawning causes low growth rate, and the formation of translucent rings (Morales-Nin, 1987). Schwingel, Castello (1990) found the occurrence of a single annual peak for the two types of edges, confirming the annual formation of a ring for *M. furnieri* in the Rio Grande do Sul coast, where the formation of translucent edges occurred from February to May. Haimovici, Reis (1984) reported that *Umbrina canosai* Berg, 1895 form one annual ring during the winter, and that this event is associated to reproductive activity, lower feeding activity and low water temperature. They also reported that spawning did not seem to be a determinant factor for ring formation, since they found rings in sexually immature individuals. Moreover, Cotrina (1998) reported that the fast growth coincides with the end of the reproductive season and intense feeding activity.

This study is the first detailed growth analysis of *M. furnieri* in Southeastern Brazilian coast based in otolith rings counting that is a satisfactory method for the assessment the species age and growth. It was determined in this study that the growth rate (k = 0.05×year^{-1}) was similar between the sexes, which is not in accordance with Vazzoler (1971), who described a comparatively higher growth rate for males (k = 0.11×year^{-1}) and females (k = 0.22×year^{-1}) (Tab. 2). Vazzoler (1971) reported that in Southeastern Brazil, *M. furnieri* has a higher growth rate, reaching smaller sizes and ages in comparison with the individuals of the South of Brazil. These differences were associated with the known water temperature difference between these two environments, which directly influence the metabolic activities of the fish.

The growth rate (k) for *M. furnieri* found in this study was relatively lower compared to the values reported in the literature for this species in other regions. Lack of individuals in size smaller than 200 mm Lt can be associated to such differences, because the juvenile individuals present a high growth rate, due to the low energy consumption (Fonteles Filho, 2011). This trend was confirmed for the marine catfish *Genidens genidens* in the Açu Lagoon, with the adults canalizing high energy budget to metabolic process associated to reproductive activities (Oliveira, Novelli, 2005).

The maximum theoretical length for females (L_∞= 573.5 mm) was slight lower than those reported by Vazzoler (1971) from Southeastern populations (L_∞ = 601mm), although the values for males (L_∞ = 822 mm) were comparatively higher than our findings (L_∞ = 523.4 mm). Carneiro *et al*. (2005) reported a L_∞= 961.5 mm for grouped sexes, but expressed some concerns in such high estimate because of only one specimen caught with Lt = 900 mm. The relatively low L_∞ values and other growth parameters in our findings compared to other studies may be attributed to a particular eco-phase of this species in the Ubatuba Bay, that could be comprised by individuals in a given size range. Additionally, the selectivity of the fisheries equipment (*e.g*., mesh size of gill nets) may also catch a comparatively narrow range of the size population. According to Haimovici, Reis (1984), the highest size reach by females after gonadal maturation is an adaptation to increase total fecundity, thus assuring the reproductive success by spawning a large number of oocytes.

Our t_0 values were lower than those found for Southeastern Brazil in the literature consulted (Tab. 2). According to King (1995), when t_0 is positive, the growth is slow in the early life period compared with the adult phase, occurring the opposite when t_0 is negative. Our low t_0 values suggest fast growth in the early first years, followed by a much slower growth in the large-sized individuals. In agreement with our findings, Carozza *et al.* (2000) reported that *M. furnieri* has fast growth in the first four year of life, reaching approximately 60% of maximum total length. In the early life phases, metabolism processes are increased by the high capacity of gills uptake oxygen in waters. Demand by oxygen increase by assimilation gill capacity decreases as the fish grow, thus decreasing growth rates. Pauly (1979) reported that the main reason for fishes convert the absorbed food in new tissues is because of the reduction of superficial gill areas, with the amount of absorbed oxygen for the body synthesis is enough only for organism maintenance.

Tab. 2. Growth parameters for *Micropogonias furnieri* along its distribution area.

L_∞ (mm)	K	t_0	φ'	Sex	Region	Source
340.0	0.44	0.36	2.71	Grouped	Colombian caribbean	Mozo *et al.* (2006)
686.0	0.18	0.52	2.93	Male	Ceará	Rodrigues (1968)
676.0	0.18	0.42	2.92	Female		
829.0	0.11	-2.97	2.88	Male	Southeast	Vazzoler (1971)
601.0	0.22	-2.08	2.90	Female		
961.5	0.08	-0.99	2.87	Grouped	Southeast	Carneiro *et al.* (2005)
507.0	0.25	-0.59	2.81	Grouped	Southeast + South	Vazzoler (1962)
621.0	0.12	-0.39	2.67	Grouped	Southeast+ South	
507.0	0.25	0.14	2.81	Grouped	South	Vazzoler (1962)
895.7	0.08	-4.64	2.81	Male	South	Vazzoler (1971)
693.3	0.15	-2.79	2.86	Female		
488.7	0.17	-2.80	2.61	Male	South	Schwingel, Castello (1990)
577.4	0.15	-2.76	2.70	Female		
302.0	0.19	-2.12	2.24	Grouped	Uruguay	Borthagaray *et al.* (2011)
499.8	0.34	-0.37	2.93	Male	Argentina/Uruguay	Ehrhardt *et al.* (1977)
536.9	0.28	-0.50	2.91	Female		
440.9	0.32	-1.01	2.79	Grouped	Argentina	Carozza *et al.* (2000)
523.4	0.05	-8.78	2.55	Male	Ubatuba (Southeast Brazil)	Present study
573.5	0.06	-7.49	2.68	Female		
531.7	0.05	-8.84	2.17	Grouped		

The Average Percent Error (APE) and the Coefficient of Variation (CV) also contributed to age determination of the individuals. These two indices can vary from zero to 100%, but for more reliable data Campana (2001) recommends that for a good consistency of the readings, the CV should not exceed the 7.5% threshold. The age composition described in the present study (up to 20 years, size 200 to 480 mm Tl) is different from the description of Cotrina, Lasta (1986) that found individuals between 0 and 30 years, with size range of 50- 600 mm Tl in the Argentina-Uruguay coast. Schwingel, Castello (1990) found individuals with 2 to 38 years, in size range 160 to 650 mm for the Southern Brazilian coast. In the Trinidad Island, fishes from 1 to 7 years were recorded in size range from 216 to 535 mm for females, and from 1 to 6 years in size range from 220 to 456 mm for males (Manickchand-Heileman, Kenny, 1990). Our results corroborate the available findings, even though we have no individuals smaller than 200 mm Tl.

In the present study, we excluded the six first rings in each otolith, thus following the recommended procedure by Cavole, Haimovici (2015) that consider the first rings as "checks". They also reported that the first rings are in fact daily rings increments instead of *annuli* rings. According to Albuquerque *et. al.* (2009), the first otolith daily ring is deposited two or three days after hatch. Cavole, Haimovici (2015) reported the *M. furnieri* spent the first year in the Patos Lagoon Estuary, when they reach 195 mm Tl or in the coastal adjacent area where they reach an average of 205 mm Tl. These findings are in accordance of our results (≈200 mm at the end of the first year), thus eliminating the possibility of misleading our age-length estimates. Castello (1986) described an excessive slow growth for *M. furnieri* in the Patos Lagoon based on scales rings after consider up to five rings as *annuli* formation. Some years later, Cabral (2002) did not succeed in validate the findings of Castelo (1986) and raised doubts on the annual formation of those rings. For Albuquerque *et al*. (2012), the inclusion of checks as *annuli* rings results in overestimation of *M. furnieri* age in the Patos Lagoon estuary by both, Castello (1986) and Cabral (2002). For the range of considered ages, the radius average of large fishes did not tend to decrease because the higher age can be too far from the maximum age found. Likewise, in our study, the average rings radius did not show a decreasing trend in the distance between the rings in older individuals, possibly because the higher age is too far from the maximum age found.

Estimation of the fish length at each age using rings reading in calcified structures such otoliths (*e.g*., back-calculation methods) requires to assess the length as function of the structure rings radius (Cutrim, Batista, 2005). For *M. furnieri* stocks in Southeast Brazil the average lengths back-calculated did not show a clear pattern, resulting in weak adjust considering the high individual variability in otolith size, *i.e*, fishes of a given size have a wide variability in otoliths size. The high data dispersion precluded the use of back-calculation. Stevenson, Campana (1992) also raised some concerns on the use of back-calculation using otoliths rings readings because of some logistic and theoretical restriction, which is also in agreement with other studies (*e.g*., Campana, Neilson, 1985; Bradford, Geen, 1987; Secor, Dean, 1989). A major constraint to most back-calculation procedures is the assumption that the fish-otolith relationship is not only linear, but does not vary systematically with the growth rate of the fish. The degree of error can be substantial in some cases, and appears to explain many reported cases of Lee's Phenomenon. This occur when the back-calculated average length decreases with increase ages, that is, does not follow the expected pattern of increasing length with higher ages (Francis, 1990).

The longevity obtained of 48 years for males and 45 years for females is directly associated with the comparatively low values of t_0 and k, found for both sexes. These are acceptable and reasonable findings, considering that there are records of individuals with 38 years (Schwingel, Castello, 1990) and that L_∞ reported in the literature exceeds 900 mm (Carneiro *et al*., 2005). *M. furnieri* stocks from southeast Brazilian coast have a higher longevity compared with other sciaenids such as the Argentine croaker *Umbrina canosai* (22 years) (Haimovici, Reis, 1984), the striped weakfish *Cynoscion striatus* (15 years) (Vieira, Haimovici, 1993) and the king weakfish *Macrodon ancylodon* (16 years) (Carneiro, Castro, 2005).

The growth performance index (φ') takes the natural relationship between the maximum theoretical length and the growth coefficient into consideration (Munro, Pauly, 1983). Slightly between-sexes differences in φ' were found, with these values being similar to the available information (Tab. 2). Munro, Pauly (1983) use this index to compare growth between fish and invertebrates whose growth could be described by the von Bertalanffy equation. Between-sex differences can be assigned to local characteristic of each habitat/system and aspects relative to productivity (primary and secondary), population densities and metabolic features for each species. Differences in growth parameters for a given population between different areas are common, such these values are dependent on the examined size structure and size class ranges. In this study, we compared our results mainly with those of Vazzoler (1971) and Carneiro *et al.* (2005) because both studies are from *M. furnieri* stocks from Southeastern Brazil. In addition to the expected differences associated with size structure and size class intervals, we can also attribute differences to the different methodologies employed in each study.

Overall, our results are coherent with the available information confirming the annual periodicity for ring formation, but differed in relation to the period of formation that was autumn/winter instead of summer. Our expected higher longevity for Southeast stocks of *M. furnieri* was confirmed in this study. We attribute these findings to the use of otoliths rings readings which is a more reliable methodology compared with scales or the indirect estimations. We believe that this contribution is an update on age and growth parameters for this very important fishery resource in Southeastern Brazil that should be considered by environmental managers to elaborate conservation plans. In the future, the results presented here may serve as a basis for other studies on age and growth of fish using otoliths, where the influence of feed rate on the formation of age rings can also be tested.

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