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Research Article

Overlap of the reproductive cycle and recruitment of the four main species caught by the purse seine fleet in Brazil

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ABSTRACT: The purse seine fleet in southeastern and southern Brazil has the Brazilian sardine *Sardinella brasiliensis* as the target species, and fishery management is based solely on its life cycle. This study aimed to analyze a possible overlap of the reproductive cycle and recruitment of the main species caught by seine fleet. During the daily program of industrial fishing monitoring in the ports of Itajaí and Navegantes (Santa Catarina) biometrics were performed twice a month at landings between 2000 and 2013 for posterior analysis in laboratory abroad. The samples analyzed did not include part of the reproductive period and the recruitment due to the closed seasons. The size at first maturity (L_{50}) was obtained by adjusting the proportion of adult females to a logistic model. The reproductive period was determined by analyzing gonadosomatic index and proportion of the maturation stages. Recruitment was determined from the length distribution and the ratio of immature throughout the year. L_{50} determined was 18.60 cm for *S. brasiliensis*, 19.58 cm for *Opisthonema oglinum*, 18.48 cm for *Chloroscombrus chrysurus* and 21.22 cm for *Scomber japonicus*. The analyzed species overlapped spawning period between November and April and recruitment in June and July. In the case of directing fishing effort to these non-target species, the possibility of inclusion of these species in closed seasons of target species could ensure a better management and consequently the sustainability of this activity.

Keywords: reproduction, recruitment, Brazilian sardine, purse seine fishery, fishery management, Brazil.

Superposición del ciclo reproductivo y reclutamiento de las cuatro principales especies capturadas por la flota de cerco en Brasil

RESUMEN: La flota de cerco del sureste y sur de Brasil tiene como especie objetivo la sardina-verdadera *Sardinella brasiliensis*, siendo el manejo de esta pesquería basado únicamente en su ciclo de vida. El objetivo del presente trabajo fue analizar la superposición entre el ciclo reproductivo y de reclutamiento de las principales especies capturadas por la flota de cerco. Entre 2000-2013 fueron realizadas biometrías quincenales de cada especie en los desembarques, y colectadas submuestras para analizar en el laboratorio. Las muestras analizadas no incluyeron parte del período reproductivo y del reclutamiento debido a las vedas. El tamaño de primera maduración (L_{50}) fue obtenido por el ajuste de proporción de hembras adultas en un modelo logístico. El periodo de reproducción fue determinado a través del análisis de IGS y de la proporción de las fases de maduración. El reclutamiento fue determinado a partir de la distribución de tallas y de la proporción de inmaduros a lo largo del año. El L_{50} fue de 18,60 cm para *S. brasiliensis*, 19,58 cm para *Opisthonema oglinum*, 18,48 cm para *Chloroscombrus chrysurus* y 21,22 cm para *Scomber japonicus*. Las especies analizadas presentaron superposición de desove en el periodo entre noviembre y abril, y reclutamiento entre junio y julio. En el caso de redirección del esfuerzo hacia las especies no objetivo, debería ser considerada la posibilidad de incluirlas en los periodos de prohibición de captura de la especie objetivo *S.brasiliensis*, asegurando una mejor gestión y, consecuentemente, sostenibilidad de dicha actividad.

Palabras clave: reproducción, reclutamiento, sardina verdadera, pesca de cerco, gestión pesquera, Brasil.

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INTRODUCTION

Brazil is among of the 20 largest fish producers countries, and according to estimates of the Ministry of Fisheries and Aquaculture (MPA) produced more than 1 million tons in 2011 (1,431,974 ton), wherein 38.7% of this total (553,670 ton) originates in marine extractive fishing (MPA, 2013). The fishing ports of Itajaí and Navegantes of Santa Catarina State stands out as the largest marine fish producer, with a total of 121,960 ton landed in 2011 (UNIVALI/CTTMar, 2013). The purse seine fleet employs the largest fishing effort in terms of number of landings, which accounted for 36.1% of the state production between 2000 and 2009 (UNIVALI/CTTMar, 2010). The target species of the purse seine fleet is the Brazilian sardine *Sardinella brasiliensis* (Steindachner, 1879), that comprises the most important marine fishery resources in Brazil. Between 2012 and 2014, landings of this specie have fluctuated around 100,000 ton in Brazil, with Santa Catarina responding for 52,000 ton in 2012 (UNIVALI/ CTTMar, 2013) being the largest produc-tion observed in 15 years.

Brazilian sardine is a marine pelagic clupeid of small port that inhabits Brazilian waters from Cabo de São Tomé (Rio de Janeiro - 22°S) to Cabo de Santa Marta Grande (Santa Catarina - 29°S) in depth up to 100 meters. Species distribution is associated to a complex oceanographic structure mainly characterized by the penetration of the South Atlantic Central Water (SACW) below the Tropical Water (TW) and the Platform Water (PW) on shallow waters of the continental shelf. These intrusions result in a nutrient intake and the formation of a thermocline, especially in late spring and summer, which enhance feeding and survival conditions of juveniles (Matsuura, 1986; Braga & Niencheski, 2006).

The high number of juveniles in the catches and the unstable fluctuations in Brazilian sardine production in the 1970s led the implementation of measures to regulate this activity, such as the minimum size of capture (17 cm) and the establishment of closed seasons, aiming to protect reproduction and recruitment periods of the species (Cergole & Dias-Neto, 2011). Over the past 20 years, closed seasons was implanted in different periods. The current model established in 2009 determined the period from November 1 to February 15 for reproduction and from June 15 to July 31 for the recruitment (Brasil, 2009).

In the 1990s, fluctuations in sardine catches led the purse seine fleet to find alternative resources, such as other pelagic species and demersal fish, which no longer could be considered monospecific (Schwingel & Occhialini, 2007). In terms of production, as well as Brazilian sardine, another pelagic species such as the Atlantic thread herring *Opisthonema oglinum*, Atlantic bumper *Chloroscombrus chrysurus* and chub mackerel *Scomber japonicus* accounted for, respectively 13.2%, 6.0% and 4.5% of the total landings of the purse seine fleet in Santa Catarina between 2000 and 2012 (UNIVALI/CTTMar, 2010, 2013). Among these species, only the Atlantic thread herring and Atlantic bumper have a minimum size of capture and both lack any kind of regulation to limit their capture (Brasil, 2005).

In spite of the regulative measures established by MPA, purse seine fishery management based solely in the Brazilian sardine life cycle could affect the biological sustainability of the other components of the capture. The understanding of the reproductive cycle and recruitment processes of the main species caught should subsidize a better management model for this fishery. In this sense, this study analyzed a possible overlap of reproduction and recruitment periods of the Brazilian sardine, Atlantic thread herring, Atlantic bumper and chub mackerel, captured in southeastern-southern Brazil between 2000 and 2013 in order to propose a multi-species model management for the purse seine fleet.

MATERIALS AND METHODS

During the daily program of industrial fishing monitoring in the ports of Itajaí and Navegantes (SC) biological samples were obtained between 2000 and 2013 during landings of the purse seine fleet. The samples analyzed did not include part of the reproductive period and the recruitment due to the closed seasons. Biometrics were performed twice a month for the Brazilian sardine (n = 250), and once a month for the Atlantic thread herring (n = 82), Atlantic bumper (n = 35) and chub mackerel (n = 47). In each sample, total length was measured in classes of 0.5 cm in approximately 250 individuals totaling 105,702 specimens measured (Table 1). A subsample of 60 individuals was randomly selected for the analysis of biological attributes, which included 24,749 individuals (Table 1). In the laboratory, individuals were measured in the total length (mm) and body was weighted with 0.01 g accuracy. After the dissection, gonads were weighed (accuracy 0.01 g) and maturity stages were assign based on the macroscopic characteristics, following the scale adapted from Vazzoler (1996), where: immature (I), maturation (II), mature (III) and spawned (IV).

The length of first maturity (L_{50}) for females of all species considered individuals separated into immature (stage I) and adult (stages II, III and IV). A bootstrap resampling method (Crawley, 2005) was applied to

Table 1. Biometry and biological samples of *Sardinella brasiliensis* (SB), *Opisthonema oglinum* (OO), *Chloroscombrus chrysurus* (CC) and *Scomber japonicus* (SJ) captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

Species	Samples	Year														Total
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
SB	Biometry	3,121			3,346	5,068	3,378	5,985	4,839	4,795	7,576	8,428	7,768	5,239	6,685	66,228
	Biological	1,317	4,043	563	494	386	391	1,335	1,126	1,009	1,502	1,795	1,73	1,134	1,472	18,297
OO	Biometry	2,276	923	451	215	691	289	1,215	1,707	1,15	2,104	4,038	2,365	1,024	1,336	19,784
	Biological							60	433	314	452	889	534	240	297	3,219
CC	Biometry				210	228		398	469	1,506	1,593	2,714	790	282	953	9,143
	Biological							112	81	218	426	591	173	44	119	1,764
SJ	Biometry		1,122	162	346	841	488	129	848	1,743	2,111	1,308	492	957		10,547
	Biological					42		41	210	461	354	221	140			1,469
Total	Biometry	5,397	2,045	613	4,117	6,828	4,155	7,727	7,863	9,194	13,384	16,488	11,415	7,502	8,974	105,702
	Biological	1,317	4,043	563	494	428	391	1,548	1,850	2,002	2,734	3,496	2,577	1,418	1,888	24,749

obtain the values of L_{50} and the respective confidence intervals. Maturity data was fit to a logistic regression through the interactive method of least squares to obtain the maturation curve from the formula: $P = 1/[(1 + \exp(\alpha-\beta * Lt)]*100$, where P = proportion of adult and Lt = length class.

The reproductive period was identify by calculating monthly gonadosomatic index (GSI) of females larger than the L_{50}. GSI was obtained by the equation: GSI = (Wgon/(Wt-Wgon))*100 where Wgon = gonad weight and Wt = body weight (Vazzoler, 1996). Median values of GSI and percentiles of 25% and 75% were calculated over the years in order to visualize the dispersion of this index. The proportion of adults during the year was confronted to GSI to better observe reproductive peaks. The months of reproductive activity were those with IGS equal to or greater than 2% and the proportion of adult females equal to or more than 50%.

Recruitment period was identified based on the analysis of monthly length distributions computed and the ratio of immature individuals (stage I) in order to observe the periods with the highest frequency of recruits throughout the year. Recruitment period was associated with the presence of small individuals, as well as immature ratios greater than or equal to 50%.

RESULTS

Length distributions of females used in biological analysis of the Brazilian sardine varied between 4 and 30 cm, with a mode of immature around 19 cm and of adult in 21 cm (Fig. 1). For the Atlantic thread herring, length distribution varied between 10 and 36 cm, whereas for Atlantic bumper, length classes were comprehend values between 14 and 40 cm. In relation the chub mackerel, individuals presented lengths between 19 and 39 cm (Fig. 1).

Length of maturity (L_{50}) obtained was 18.60 cm to the Brazilian sardine, 19.58 cm to Atlantic thread herring, 18.48 cm to the Atlantic bumper and 21.22 cm to the chub mackerel (Fig. 2). Table 2 presents values of L_{50} and respective confidence intervals determined for each species.

The highest GSI values for the Brazilian sardine were recorded between October and April, with median values greater than 4% in February, November and December (Fig. 3, 4). Similarly, the Atlantic thread herring presented the highest GSI values from November to April and the Atlantic bumper between September and May. The chub mackerel showed elevate GSI value (greater than 2%) only in November (Figs. 3, 4). The highest proportions of mature females (stage III) for all species occurred between October and February, mainly in November (Fig. 5). In addition, the first months of the year showed the largest proportion of females in stage IV indicating the spawning season for these species (Fig. 5). Although biological data from the chub mackerel was not as abundant as the other species analyzed, largest GSI values and proportion of mature and spawned females followed the same tendency of the other species occurring between the months of November and April.

Immature individuals (stage I) of the Brazilian sardine occurred mainly between June and September, reaching over 80% in July (Fig. 6). A similar pattern was observed for the Atlantic thread herring and Atlantic bumper, where the number of immature was dominant in June and July. The chub mackerel presented the highest proportion of immature individuals was observed in April, with values around

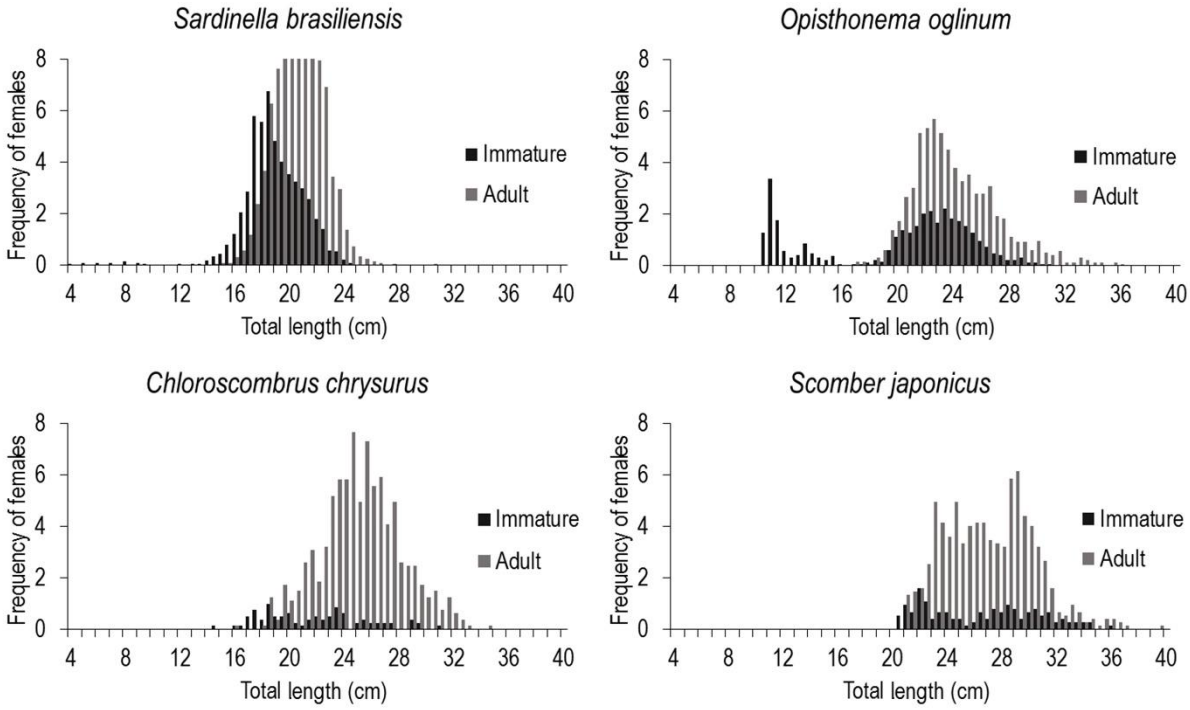

Figure 1. Length distribution of females of *Sardinella brasiliensis*, *Opisthonema oglinum*, *Chloroscombrus chrysurus* and *Scomber japonicus* captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013 analyzed in laboratory.

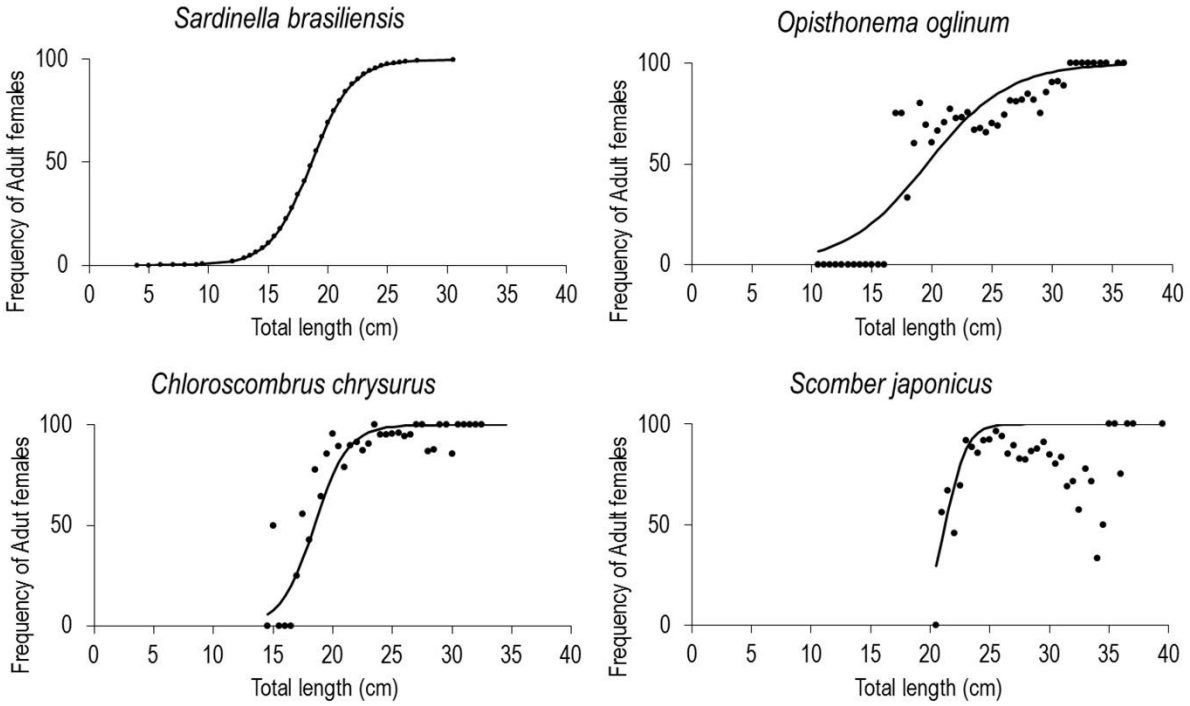

Figure 2. Length of maturity (L_{50}) and the logistic model fit to females of *Sardinella brasiliensis*, *Opisthonema oglinum*, *Chloroscombrus chrysurus* and *Scomber japonicus* captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

Table 2. Length of maturity (L50) and confidence interval of this parameter obtained from resampling to the females of *Sardinella brasiliensis*, *Opisthonema oglinum*, *Chloroscombrus chrysurus* and *Scomber japonicus* captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

Species	Confidence interval of L_{50} (cm)		
	2.5%	50%	97.5%
Sardinella brasiliensis	18.19	18.60	18.92
Opisthonema oglinum	18.78	19.58	20.52
Chloroscombrus chrysurus	18.13	18.48	18.80
Scomber japonicus	20.85	21.22	21.48

80%. Except for the chub mackerel, the presence of juveniles was more intense during June and July (Fig. 6).

Length distributions of the Brazilian sardine obtained from biometrics during landings varied between 10 and 27 cm (Fig. 7). Modal value was approximately 20 cm from February to April, ranging between 18 and 21 cm in the rest of the year, showing a bimodal pattern occasionally. Total length of the Atlantic thread herring varied between 13 and 35 cm (Fig. 7). Despite the occurrence of two modes in January (20 and 28 cm), this pattern was not homogenous during the year, with modal length varying from 20 and 24 cm between February and September, with a group of small size individuals identified in November. The length range of the Atlantic bumper varied between 14 and 40 cm (Fig. 7), presenting a bimodal pattern throughout the year. From January to June, modal length presented a shift from 19 to 29 cm and an entry of small sized individuals was identified in April. From July to September, new entries of small individuals were recorded. In the case of the chub mackerel lengths were recorded between 15 and 39 cm (Fig. 7) with bimodal display observed throughout the year (23 and 31 cm). In the months when a single mode was recorded such events was associated with the presence of small sized individuals (17 cm), as seen in November and December (Fig. 7).

DISCUSSION

The observed length of maturity (L_{50}) calculated for the Brazilian sardine was 2 cm higher than the previous L_{50} established by Vazzoler (1961). This may be related to density dependent factors, such as environmental conditions or even to sampling biases during the capture due to a recent demand of the fishing industry to capture larger individuals. In addition, the L_{50} of 17 cm defined by Vazzoler (1961) has been established for over 50 years, what is time enough for a r-strategist like the Brazilian sardine to introduce changes in population structure, leading to variations in size at first maturity (Rose *et al.*, 2001; Silva *et al.*, 2006).

In the case of the Atlantic thread herring, L_{50} was similar to that determined by Feltrim & Schwingel (2005 - 19.2 cm), for the same study area. However, these values were higher from those found in other areas of species distribution, like south Mexico (Garcia-Abad *et al.*, 1998 - 13.5 cm) and the Caribbean Sea (Manickchand-Heileman & Hubbard, 1992 - 15 cm). These differences showed that the L_{50} can vary significantly in species distributed through widely latitudinal areas. For the Atlantic bumper, the L_{50} determined was higher than the values observed in the same area by Masumoto & Cergole (2005 - 15.4 cm) and Haimovici *et al.* (2006 - 15.3 cm). However, these authors calculate the L_{50} for grouped sexes, unlike the present study that analyzed exclusively females. The L_{50} estimated for the chub mackerel was similar to 20.4 cm found for females in the Adriatic Sea (Kec & Zorica, 2000). Considering estimates of L_{50} with grouped sexes, the values were lower than the present study, as recorded by Cengiz (2012 - 18 cm) to Turkey and Kec & Zorica (2000 - 18.3 cm).

Regarding the breeding period, a higher repro-ductive activity was observed for the Brazilian sardine between spring and early autumn (November-April). Until then, studies for this species indicate the occurrence of spawning in late spring and summer (Matsuura, 1977; Isaac-Nahum *et al.*, 1988; Jablonski & Legey, 2004). Extended spawning seasons, as observed in this study, are common warm water species, in which juveniles are subjected to different environmental conditions and distinct vulnerabilities that could provide a greater number of breeding opportunities under favorable environmental condi-tions, what could also increase recruitment success (James *et al.*, 2003; Lowerre-Barbieri *et al.*, 2011). The spawning activity observed for the chub mackerel only in November may be related to the smaller number of samples, a fact that made it difficult to identify the reproductive period. However, other studies confirm that the spawning of the species occurs mainly in the warmer months of the year (Kec & Zorica, 2000; Cengiz, 2012). For the Atlantic thread herring, Houde (1977), Garcia-Abad *et al.* (1998) and Feltrim & Schwingel (2005) identified spawning activity between spring and summer, which corroborate the present study. A long reproductive period was also recorded for the Atlantic bumper (Katsuragawa & Matsuura, 1992) in the same area of the present study and for Sánchez-Ramírez & Flores-Coto (1998) in Mexico, which found larvae throughout the year, with a peak in the summer.

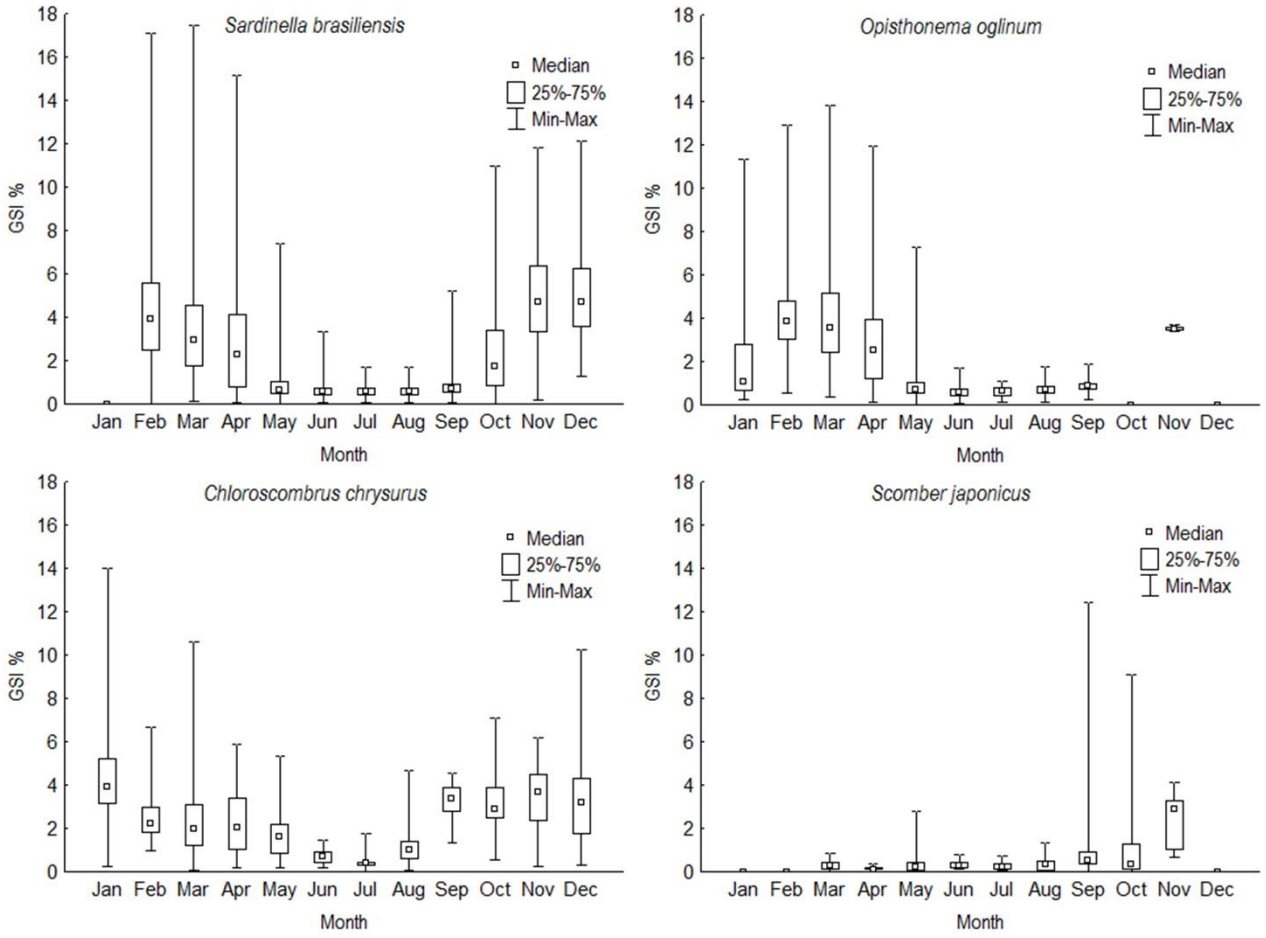

Figure 3. Median, percentil of 25% and 75% and minimum and maximum GSI values calculated per month for females of *Sardinella brasiliensis*, *Opisthonema oglinum*, *Chloroscombrus chrysurus* and *Scomber japonicus* captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

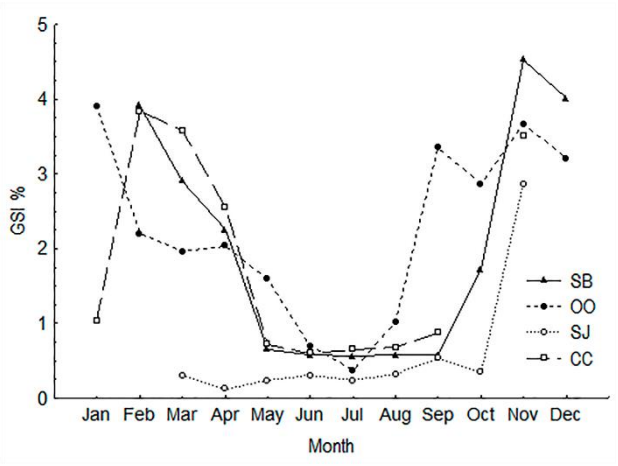

Figure 4. Median GSI values calculated per month for females of *Sardinella brasiliensis* (SB), *Opisthonema oglinum* (OO), *Chloroscombrus chrysurus* (CC) and *Scomber japonicus* (SJ) captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

Between 2000 and 2013, the Brazilian sardine presented a recruitment period between June and September, what was similar to that described by Matsuura (1977). For the Atlantic thread herring recruitment occurred in the same period, however, the results also showed the presence of small individuals in November. To the coast of Mexico, García-Abad *et al.* (1998) identified a recruitment period from June to October. In the case of the Atlantic bumper, Cunha *et al.* (2000) observed higher proportion of juveniles in May and June in northeastern Brazil, a similar result found in the present study, despite latitudinal differences. Although a high proportion of immature observed in June and July, length distributions revealed the entry of smaller individuals were present in the catch in different months of the year, indicating long recruitment period for the Atlantic bumper. Recruitment period for the chub mackerel was not as clear as in other species, however, the presence of smaller individuals in catches (17-19 cm) during November and

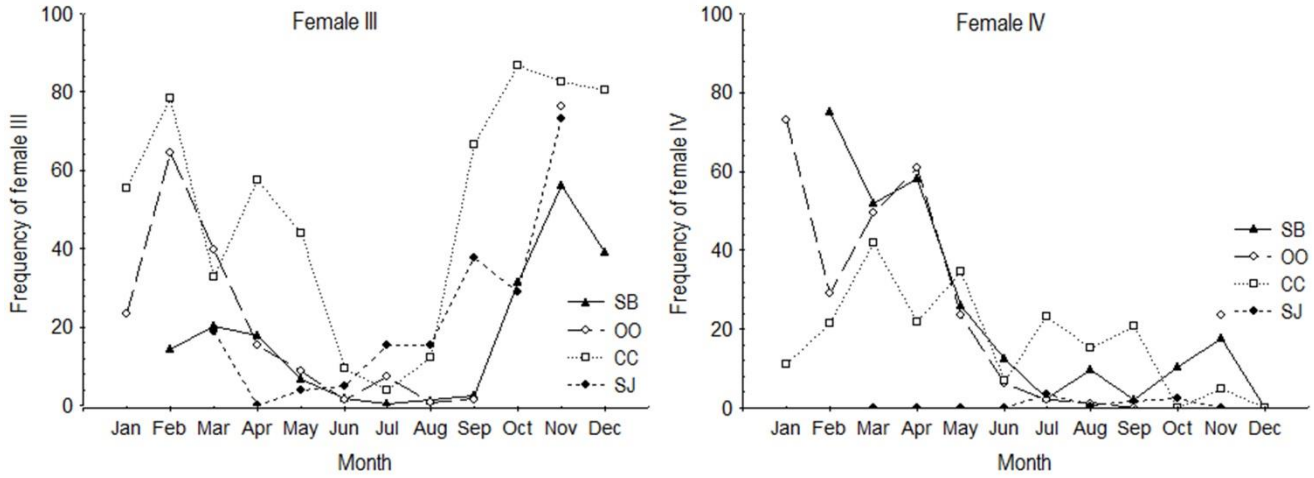

Figure 5. Number of females in stages III and IV of gonadal maturity for females of *Sardinella brasiliensis* (SB), *Opisthonema oglinum* (OO), *Chloroscombrus chrysurus* (CC) and *Scomber japonicus* (SJ) captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

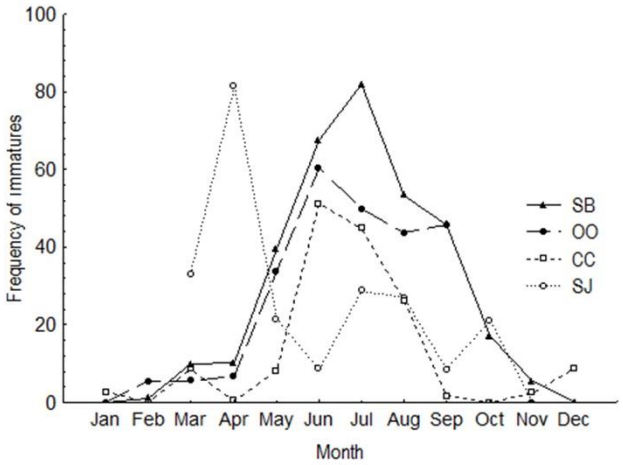

Figure 6. Monthly number of immature individuals (stage I), including males and females of *Sardinella brasiliensis* (SB), *Opisthonema oglinum*(OO), *Chloroscombrus chrysurus* (CC) and *Scomber japonicus* (SJ) captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

December, corroborate the observations of Perrotta (1992) in Argentina. Although the higher proportion of immature was only observed in April, the literature showed the occurrence of these individuals throughout the year for different areas of the Atlantic (Gluyas-Millan & Muñoz-Gómez, 1993; Perrotta, 1992). In addition, the small number of chub mackerel samples may have limited the identification of the recruitment period.

Length distribution analysis identified the occurrence of two size groups for the Brazilian sardine throughout the year. According Saccardo & Rossi-Wongtschowski (1991) this species reaches an age up to 4 years and the predominant class of 1 year in the catches when individuals are higher than 15 cm. The Atlantic thread herring has a similar length distribution pattern, however, individuals of 2 years predominate in catches varying between 16-17 cm long (Feltrim & Schwingel, 2005). The other species have different sizes groups during the year, a fact associated with longer life cycles, and therefore larger number of age classes in the samples. For the Atlantic bumper, Masumoto & Cergole (2005) observed individuals up to 7 years old and for the chub mackerel, Simãozinho (2011) identified individuals up to 5 years in the catches.

In general, studied species have overlapped recruitment and reproductive periods. According to Vazzoler (1996) and Lowerre-Barbieri *et al.* (2011) reproduction occurs if suitable conditions for fertilization and offspring survival are met. Similarly, according to the hypothesis of the Fundamental Triad of Bakun (1996), the enrichment of the water column, the concentration of planktonic prey and subsequent retention processes and the transport of larvae are decisive factors in the recruitment success. Matsuura (1998) and Gigliotti *et al.* (2010) argue that intrusions of cold, nutrient enriched waters, such as ACAS, can provide the necessary conditions for to the reproductive success of Brazilian sardine. Studied species showed a strong relationship to the same environmental conditions that are favorable to reproduction and recruitment.

The temporal similarity of reproduction and recruitment periods, the Atlantic thread herring, Atlantic bumper and chub mackerel could be benefit by closed seasons of the Brazilian sardine. Moreover, these species does not represent targets of continuous fishing

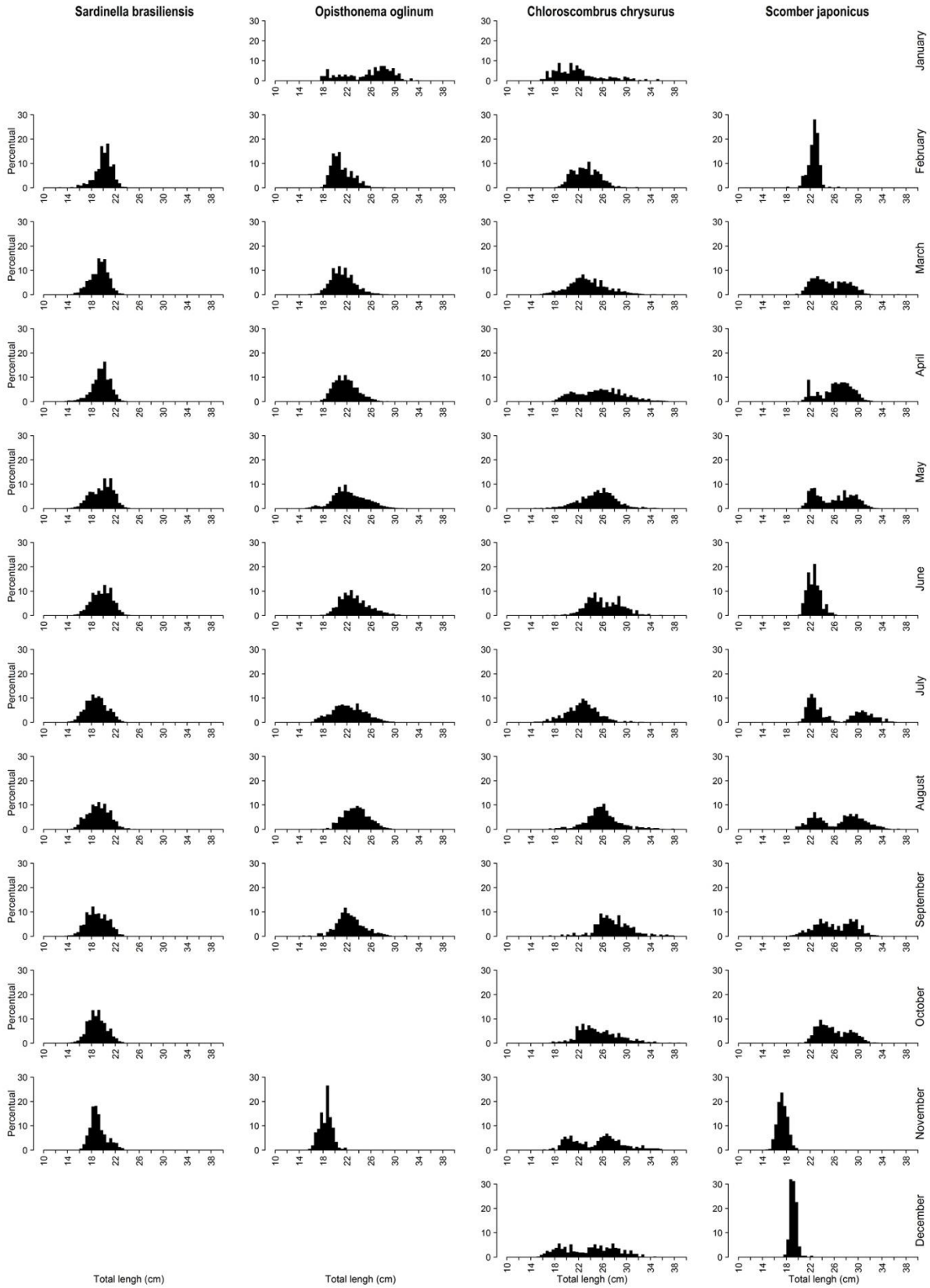

Figure 7. Montly length distribution of *Sardinella brasiliensis*, *Opisthonema oglinum*, *Chloroscombrus chrysurus* and *Scomber japonicus* measured during biometrics in the ports of Itajaí and Navegantes between 2000 and 2013 captured by the purse seine fleet in southeastern and southern Brazil between 2000 and 2013.

throughout the year, being associated with low availability of the Brazilian sardine or during closed seasons of the target species. It must be considered that much of the purse seine fleet currently does not operate during the closed seasons of the Brazilian sardine, reducing the fishing effort on other species in an important period of life cycle. In the case of directing fishing effort to these non-target species, the possibility of inclusion in closed seasons should be evaluated first. In relation to management measures, a review of minimum size of catches could also be evaluated, as this study revealed some differences from the sizes of maturity previously established. At the same time, L_{50} should be continuously monitored, since this parameter varies over time and could also be used as an indicator of stock status (Tsikliras & Stergiou, 2014). On the other hand, the sampled period did not include part of the reproductive period and the recruitment due to the closed seasons. This fact may affect the results, because another species than *S. brasiliensis* could have smaller reproductive/spawning season that were even not sampled. In addition, to estimate the L_{50} is necessary to sample the whole species distribution area and all phases of its life cycle, however, commercial fishing concentrates in areas of high abundance of the target species and catch larger individuals of the population, mostly because of the minimum size of 17 cm determined by law. This insertion of lots of large individuals in the samples may have an influence on L_{50}, that unlike other studies used a broader range of individual lengths.

It is evident that fishery management based solely on the target species life cycle may endanger the biological sustainability of other species component of the capture. In this sense, management of the purse seine fishery in the southeastern and southern Brazil, including reproductive and recruitment data of the main species caught, can ensure a better management and consequently the sustainability of this activity.

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REFERENCES

Bakun, A. 1996. Patterns in the ocean: ocean processes and marine population dynamics. University of California Sea Grant, San Diego, California, 323 pp.

Braga, E.S. & L.F.H. Niencheski. 2006. Composição das massas de água e seus potenciais produtivos na área entre o Cabo de São Tomé (RJ) e o Chuí (RS). In: C.L.D.B. Rossi-Wongtschowski & L.S.P. Madureira (org.). O ambiente oceanográfico da Plataforma Continental e do Talude na região Sudeste-Sul do Brasil. Editora da Universidade de São Paulo, São Paulo, pp.161-218.

Brasil. 2005. Instrução Normativa MMA N°53, de 22 de novembro de 2005. Estabelece o tamanho mínimo de captura de espécies marinhas e estuarinas do litoral sudeste e sul do Brasil. Diário Oficial da União, Brasília, Nº225, 24 de novembro de 2005: 87.

Brasil. 2009. Instrução Normativa N°15, de 21 de maio de 2009. Estabelece os períodos de defeso para a pesca da sardinha-verdadeira (*Sardinella brasiliensis*). Diário Oficial da União, Brasília, Nº96, 22 de maio de 2009: 81.

Cengiz, O. 2012. Age, growth, mortality and reproduction of the chub mackerel (*Scomber japonicus* Houttuyn, 1782) from Saros Bay (northern Aegean Sea, Turkey).Turk. J. Fish Aquat. Sci., 12: 799-809.

Cergole, M.C. & J. Dias-Neto. 2011. Plano de gestão para o uso sustentável da sardinha-verdadeira *Sardinella brasiliensis* no Brasil. Ibama, Brasília, 180 pp.

Crawley, M.J. 2005. Statistics: an introduction using R. John Wiley, London, 327 pp.

Cunha, F.E.A., C.V. Feitosa, J.E.P. Freitas & C. Monteiro-Neto. 2000. Biologia e biometria da palombeta, *Chloroscombrus chrysurus* (Linnaeus, 1766) (Teleostei: Carangidae), em Fortaleza, Ceará, Brasil. Arq. Ciên. Mar., 33: 143-148.

Feltrim, M.C. & P.R. Schwingel. 2005. *Opisthonema oglinum* (Lesueur, 1818). In: M.C. Cergole, A.O. Ávila-da-Silva & C.L.D.B. Rossi- Wongtschowsky (eds.). Análise das principais pescarias comerciais da região Sudeste-Sul do Brasil: dinâmica populacional das espécies em explotação. Série Doc. Revizee/Score Sul, São Paulo, pp. 112-115.

García-Abad, M.C., A. Yáñez-Arancibia, P. Sánchez-GiI& M. Tapia-García. 1998. Distribución, abundancia y reproducción de *Opisthonema oglinum* (Pisces: Clupeidae) em la plataforma continental del sur del Golfo de México. Rev. Biol. Trop., 46(2): 257-266.

Gigliotti, E.S., D.F.M. Gherardi, E.T. Paes, R.B. Souza & M. Katsuragawa, 2010. Spatial analysis of egg distribution and geographic changes in the spawning habitat of the brazilian sardine *Sardinella brasiliensis*. J. Fish Biol., 77: 2248–2267.

Gluyas-Millán, M.G. & V.M. Muñoz-Gómez. 1993. Composición por tallas y edades de la macarela *Scomber japonicus* de Bahía Vizcaino, México. Invest. Mar. CICIMAR, 8(1): 33-38.

Haimovici, M., C.L.D.B. Rossi-Wongtschowski, M.C. Cergole, L.S.P. Madureira & A. Bernardes. 2006. Recursos pesqueiros da costa sudeste-sul. In: REVIZEE, Relatório executivo - Avaliação do potencial sustentável de recursos vivos na Zona Econômica Exclusiva. MMA, Brasília, pp. 217-254.

Houde, E. 1977. Abundance and potential yield of the Atlantic thread herring, *Opisthonema oglinum*, and aspects of its early life history in the eastern Gulf of Mexico. Fish. Bull., 75(3): 493-512.

Isaac-Nahum, V.J., R.D. Cardoso, G. Servo & C.L.D.B. Rossi-Wongtschowski. 1988. Aspects of the spawning biology of the brazilian sardine, *Sardinella brasiliensis* (Steindacher, 1879), (Clupeidae). J. Fish Biol., 32: 383-396.

Jablonski, S. & L.F.L. Legey. 2004. Quantifying environmental effects on the recruitment of brazilian sardine (*Sardinella brasiliensis*), 1977-1993. Sci. Mar., 68(3): 385-398.

James, A., J.W. Pitchford & J. Brindley. 2003. The relationship between plankton blooms, the hatching of fish larvae, and recruitment. Ecol. Modell., 160: 77-90.

Katsuragawa, M. & Y. Matsuura. 1992. Distribution and abundance of carangid larvae in the southeastern Brazilian Bight during 1975-1981. Bolm. Inst. Oceanogr., São Paulo, 40(1/2): 55-78.

Kec, V.C. & B. Zorica. 2000. The reproductive traits of *Scomber japonicus* (Houttuyn, 1782) in the Eastern Adriatic Sea. J. Appl. Ichthyol., 28: 15-21.

Lowerre-Barbieri, S.K., K. Ganias, F. Saborido-Rey, H. Murua & J.R. Hunter, 2011. Reproductive timing in marine fishes: variability, temporal scales, and methods. Mar. Coast. Fish., 3: 71-91.

Manickchand-Heileman, S.C. & R.H. Hubbard.1992. A preliminar survey of the clupeoid fishes in Trinidad, West Indies, and their use in live bait fishing. Proc. Annu. Gulf. Caribb. Fish. Inst., 41: 403-415.

Masumoto, C. & M.C. Cergole. 2005. *Chloroscombrus chrysurus* (Linnaeus, 1766). In: M.C. Cergole, A.O. Ávila-da-Silva & C.L.D.B. Rossi- Wongtschowsky (eds.). Análise das principais pescarias comerciais da região Sudeste-Sul do Brasil: dinâmica populacional das espécies em explotação. Série Doc. Revizee/Score Sul, São Paulo, pp. 35-39.

Matsuura, Y. 1977. O ciclo de vida da sardinha-verdadeira (Introdução à oceanografia pesqueira). Publ. Esp. Inst. Oceanogr., São Paulo, 4: 146 pp.

Matsuura, Y. 1986. Contribuição ao estudo da estrutura oceanográfica da região sudeste entre Cabo Frio (RJ) e Cabo de Santa Marta Grande (SC). Ciên. Cult., 38(8): 1439-1450.

Matsuura, Y. 1998. Brazilian sardine (*Sardinella brasiliensis*) spawing in the southeast Brazilian Bight over period 1976-1993. Ver. Bras. Oceanogr., 46(1): 33-43.

Ministério da Pesca e Aquicultura (MPA). 2013. Boletim Estatístico da Pesca e Aquicultura - Brasil - 2011. Ministério da Pesca e Aquicultura, Brasília, 60 pp.

Perrotta, R. G. 1992. Growth of mackerel (*Scomber japonicus* Houttuyn, 1782) from the Buenos Aires-north patagonian region (Argentine Sea). Sci. Mar., 56(1): 7-16.

Rose, K.A, J.H. Cowan, K.O. Winemiller, R.A. Myers & R. Hilborn, 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish Fish., 2: 293-327.

Saccardo, S.A. & C.L.D.B. Rossi-Wongtschowski. 1991. Biologia e avaliação do estoque da sardinha *Sardinella brasiliensis*: uma compilação. Atlântica, Rio Grande, 13(1): 21-28.

Sánchez-Ramírez, M. & C. Flores-Coto. 1998. Growth and mortality of larval Atlantic bumper *Chloroscombrus chrysurus* (Pisces: carangidae) in the southern Gulf of Mexico. Bull. Mar. Sci., 63(2): 295-303.

Schwingel, P.R. & D.S. Occhialini. 2007. Descrição e dinâmica de traineiras no porto de Itajaí (SC) entre 1997 e 1999. In: C.L.D.B. Rossi-Wongtschowski, R.A. Bernardes & M.C. Cergole (eds.). Dinâmica das frotas pesqueiras comerciais da região Sudeste-Sul do Brasil. Série Doc. Revizee/Score Sul, São Paulo, pp. 218-247.

Silva, A., M.B. Santos, B. Caneco, G. Pestana, C. Porteiro, P. Carrera & Y. Stratoudakis. 2006. Temporal and geographic variability of sardine maturity at length in the north-eastern Atlantic and the western Mediterranean. J. Mar. Sci., 63: 663-676.

Simãozinho, P.F. 2011. Idade e crescimento da cavalinha (*Scomber japonicus* Houttuyn, 1782) capturada pela frota de cerco no sudeste e sul do Brasil. Monografia de Graduação. Universidade do Vale do Itajaí, 32 pp.

Tsikliras, A.C. & K.I. Stergiou. 2014. Size at maturity of Mediterraneam marine fishes. Rev. Fish Bio. Fish., 24: 219-268.

UNIVALI/CTTMar. 2010. Boletim estatístico da pesca industrial de Santa Catarina - Ano 2009 e Panorama 2000-2009. Universidade do Vale do Itajaí, Centro de Ciências Tecnológicas da Terra e do Mar, Itajaí, SC, 97 pp.

UNIVALI/CTTMar. 2013. Boletim estatístico da pesca industrial de Santa Catarina - Ano 2012. Universidade do Vale do Itajaí, Centro de Ciências Tecnológicas da Terra e do Mar, Itajaí, SC, 13(1): 66 pp.

Vazzoler, A.E.A.M. 1961. Sobre a primeira maturação sexual e destruição de peixes imaturos. Pub. Inst. Oceanogr., São Paulo, 161: 38 pp.

Vazzoler, A.E.A.M. 1996. Biologia da reprodução de peixes teleósteos: teoria e prática. EDUEM, São Paulo, 169 pp.

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