Carvalho, Felipe M.; Castello, Jorge P.

Argentine anchovy (Engraulis anchoita) stock identification and incipient exploitation in southern Brazil

Latin American Journal of Aquatic Research, vol. 41, núm. 5, noviembre, 2013, pp. 820-827
Pontificia Universidad Católica de Valparaíso
Valparaiso, Chile

Research Article

Argentine anchovy (*Engraulis anchoita*) stock identification and incipient exploitation in southern Brazil

Felipe M. Carvalho[1] & Jorge P. Castello[1]
[1]Institute of Oceanography, Federal University of Rio Grande (FURG)
Rio Grande, RS 96201-900, Brazil

ABSTRACT. The Argentine anchovy (*Engraulis anchoita*) is an essential species in the pelagic ecosystem of the southwest Atlantic Ocean, and a potentially important fishery resource. Exploitation has recently started in southern Brazil, so it requires a better understanding of their structure and population dynamics. This work aims to update the information on the population identification of *E. anchoita*. Parameters such as age and size composition, length-at-age data and other parameters using *sagittae* otoliths were used to compare anchovy of the continental shelf between 20º and 32ºS. The results indicate the existence of different populations in the southeastern and southern regions of Brazil: the *bonaerense* stock in southern Brazil is shared with Argentina and Uruguay and exhibits migratory behavior, while in the southeast there is a population confined to this region and shows different population characteristics. This has implications for the management of this species and should be taken into account by the institutions responsible for the assessment and management of fisheries in Brazil.

Keywords: anchovy, stock identification, fisheries management, Brazil, southwest Atlantic.

Identificación de stocks y explotación incipiente de la anchoíta argentina (*Engraulis anchoita*), en el sur de Brasil

RESUMEN. La anchoíta (*Engraulis anchoita*) es una especie esencial en el ecosistema pelágico del Océano Atlántico sudoccidental, y un recurso pesquero potencial importante. La explotación se ha iniciado recientemente en el sur de Brasil y se requiere una mejor comprensión de su estructura y dinámica poblacional. Este trabajo tiene como objetivo actualizar la información sobre la identificación de la población de *E. anchoita*. Parámetros, como composición por edad y tamaño, longitud por edad y otros parámetros usando los otolitos *sagittae,* se utilizaron para comparar la anchoíta de la plataforma continental, entre 20º y 32ºS. Los resultados indican la existencia de diferentes poblaciones en el sudeste y sur de Brasil: el stock bonaerense en el sur de Brasil se comparte con Argentina y Uruguay y exhibe un comportamiento migratorio, mientras que en el sudeste existe una población confinada a esta región y muestra características poblacionales diferentes. Esto tiene implicancias para el manejo de la especie y debe ser considerado por las instituciones responsables de la evaluación y control de la pesca en Brasil.

Palabras clave: anchoíta, identificación de poblaciones, manejo pesquero, Brasil, Atlántico sudoccidental.

Corresponding author: Jorge P. Castello (docjpc@furg.br)

INTRODUCTION

The Argentine anchovy (*Engraulis anchoita*) is a small pelagic fish occurring from Vitoria, off Brazil (20ºS), to Gulf San Jorge, off Argentina (48ºS). It inhabits the continental shelf waters between depths of 10 and 200 m and at temperatures ranging from 8 to 23ºC (Hansen, 2004; Castello, 2007). The species has a central role in the trophic relations of the pelagic ecosystem: anchovies are secondary consumers near the bottom of the food chain; thereby, they have been considered as essential preys to other fish resources as well as to top predators, such as marine mammals and seabirds (Castello, 2007).

Engraulis is largely distributed in temperate oceans, usually supporting large fisheries (Blaxter & Hunter, 1982). In the Southeast Pacific, the "anchoveta" from Peru and Chile (*E. ringens*) sustains the highest capture of a single species in the world's fisheries, reaching 7.3 million ton in 2010 (FAO, 2012). *Engraulis anchoita* however, is caught at levels below its biological potential with a maximum of 48.000 ton in 2006, most of it captured by the Argentinean fleet.

Hydroacoustic assessments and environmental studies have shown that a sustainable exploitation of anchovy in southern Brazil is viable (Madureira *et al*., 2009). Recent advances (2010) have been made under an agreement between the Brazilian government and the Federal University of Rio Grande (FURG), which includes the rental of a standard purse seiner properly equipped, in order to carry out hauls under pilot-simulated commercial conditions. At this stage of work, anchovy captures are intended for making different products and introduction into school meals so that children come to 'like' the product, and encourage their families to incorporate it into their food regime. This initiative has already taken place in 58 primary schools in the state of Rio Grande do Sul. The introduction of anchovy for human consumption in Brazil may have a higher social and economic impact when compared with the other traditional destinations, as input for fishmeal production (Madureira *et al*., 2009).

At the same time, recent and successful experiments proved that anchovy is a good alternative to the Brazilian sardine (*Sardinella brasiliensis*) as a live-bait fish used in the pole-and-live-bait fishery for skipjack tuna (*Katsuwonus pelamis*). Using anchovy as alternative bait has the advantage of releasing the fishing pressure over the sardine stock, which is considered overexploited, if not close to collapse, and therefore a permanent source of conflict between skipjack and sardine fishermen.

Considering these issues, to properly define the stock structure of *E. anchoita* is a necessity. Data analysis suggests the presence of three distinct stocks in the SW Atlantic: the *patagonic* (48º-41ºS), the *bonaerense* (41º-28ºS northern Argentina, Uruguay, and southern Brazil) and another one in the area between 28º and 20ºS, which is known as the Brazilian Southeastern Bight (Castello, 1997). Studies conducted in Brazil and Argentina has dealt with stock identification using different methodologies. Hansen (1994) studied the stock structure using population parameters such as growth rates, size-weight relationships, and length at first maturation to distinguish the *bonaerense* stock from the *patagonic* one. Schwingel (1998), made a comparison of the specie's feeding ecology in the Brazilian Southeastern Bight (BSB) and southern Brazil. He concluded that the main diet item in the BSB region (the copepod *Temora stylifera*) is absent from southern Brazil, which indicates a distinct diet between these regions. Castello & Castello (2002), made advances concerning early life history parameters. Larval growth and length of first feeding were compared between BSB and southern Brazil, finding significant differences.

This work tests the hypothesis proposed by Castello (1997), that BSB and southern Brazil are two distinct anchovy stocks. We present population parameters from BSB, an area on which data are scarce, and compare them with information from the south. We analyzed size and age composition, length-at-age data, and others. These parameters are highly influenced by environmental factors and do not inform about the genetic discreetness of the stocks. Nevertheless, they could be powerful tools for stock identification purposes (Begg, 2004).

MATERIALS AND METHODS

Data from Brazilian Southeastern Bight (BSB) were collected during four acoustic cruises for biomass assessment (ECOSAR project; summers of 2008 and 2010; springs of 2008 and 2009) of the R/V Atlântico Sul on the shelf area between São Tomé Cape (21ºS) and Santa Marta Cape (28ºS). Those cruises surveyed the area for *Sardinella brasiliensis* and other small pelagic species such as the argentine anchovy. Data from southern Brazil were collected under the Anchoita project during the spring of 2010. In all cruises, ecointegration surveys were carried out with an EK-500 scientific echo sounder. A mid-water trawl was used to identify and assess fish species composition detected by the echo sounder.

Analyses were carried out comparing three distinct areas (Fig. 1): southeastern Brazil (SEB), Santa Marta Cape (SMC) and southern Brazil (SB). Data was available for spring and summer seasons in areas SEB and SMC, while information for SB region was only collected during spring. We decided to separate the BSB in two distinct regions, because the Santa Marta Cape area is a transitional zone where anchovies have size and age composition quite different from those of northern locations. Thereby, from now on the BSB will be considered as southeastern Brazil (SEB) and Santa Marta Cape (SMC).

A total of 35 random samples of anchovies were collected in both acoustic cruise series from midwater trawl captures whenever shoals were acoustically identified. The surveys followed a regular rectangular grid with each transect 20 nm apart. Total length distributions were determined and a set of subsamples were frozen on board. Those subsamples were processed on land facilities where length, weight, sexual maturation stage, and otolith (*sagittae*) extractions were performed, for 50 individuals each. Sexual maturation stage was determined after Castello (1997).

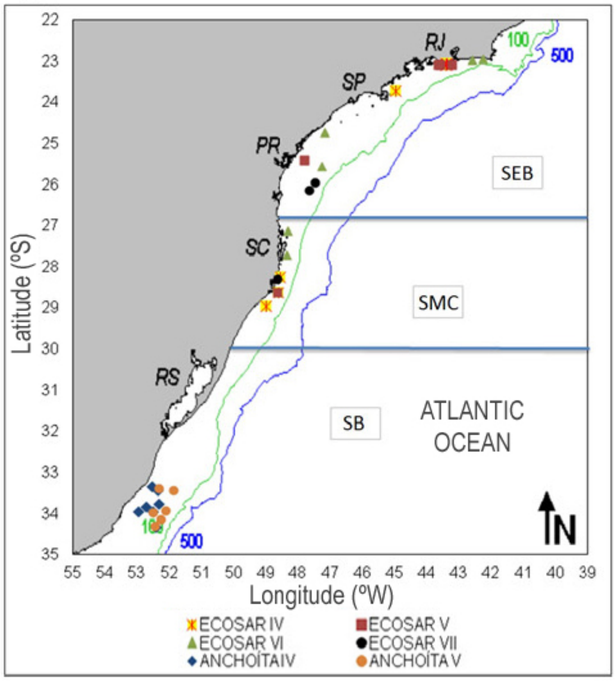

Figure 1. Locations where samples were collected in different cruises.

For age reading, 1,566 otoliths were immersed directly in water using a black bottom and incident lighting. A Moticam® TV camera and software were used to take measurements of total size of the otoliths and first *annulus* width (Fig. 2). Calibration procedures were applied for different scales of magnification used in the microscope. First *annulus* width was obtained as the difference between the nucleus's center and the distal and proximal board of the first hyaline ring.

Anchovy otolith nuclei may present two different appearences when examined under incident lighting. One kind is opaque (Fig. 2), and the other is translucid (Fig. 3). For this kind of nucleus horizontal and vertical measurements were taken.

RESULTS

Summer length compositions (Fig. 4), showed that individuals between 105 and 120 mm were predominant in region SEB while region SMC had larger anchovies with a modal size of 125 mm but also young-of-the-year fish with a 50 mm modal size.

Spring length compositions (Fig. 5), showed that in southeastern Brazil (SEB) only smaller-than-105 mm individuals were found, whereas both at Santa Marta Cape (SMC) and at the southern Brazil (SB) wider size ranges with several modes were caught (65 to 145 mm in the first case; and 45 to 165 mm in the second case).

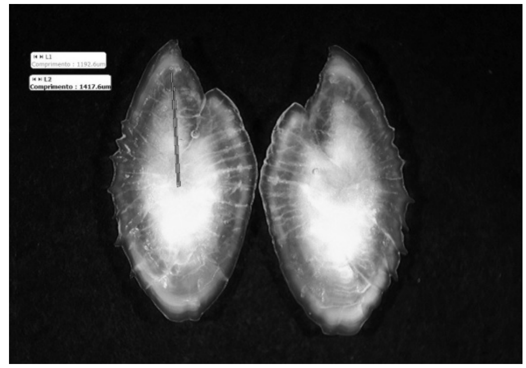

Figure 2. Anchovy otoliths over a black background, under incident light, showing opaque (white) growth zones and hyaline (transparent and grey rings) zones.

Figure 3. Anchovy otolith with a translucid nuclei and the vertical and horizontal axis for measurements.

One-year-old anchovies are the dominant age class in SEB in summer, whereas a more diversified age composition was observed in SMC with anchovies ranging between young-of-the-year (0) and 4 years of age (Fig. 6).

Spring age composition showed a picture similar to that of summer. Catches from the SMC and SB presented 50% of individuals aged 2 or more (Fig. 7), whereas at the SEB one-year-old fish were dominant (80%).

A comparison of mean length-at-age between regions (Table 1), showed a north-to-south *continuum*: fish located in northern regions (SEB and SMC) presented smaller lengths at different ages than those located in SB. The only exceptions were age group 0, in the southern region, which showed a smaller size than in the SEB, and the southernmost age group 1 having an intermediate mean size between SEB and SMC. Growth curves with observed mean lengths, amplitudes and their standard deviations are shown in Fig. 8.

Mean length-at-age for anchovies within the three regions shows high variability as indicated by their

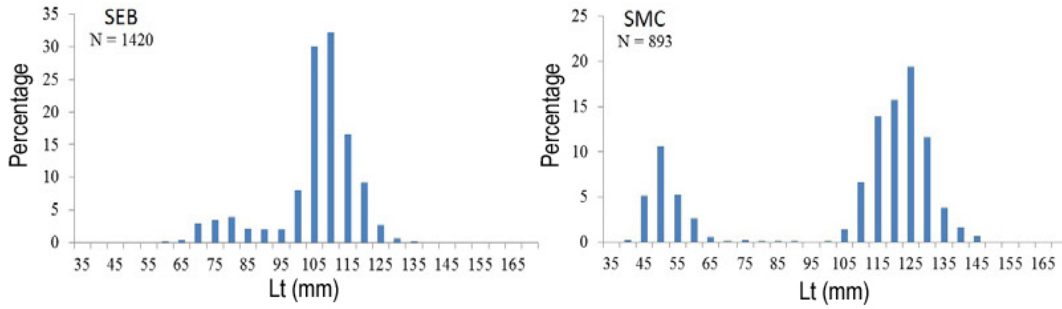

Figure 4. Length distribution in summer, for southeastern Brazil (SEB) and Santa Marta Cape (SMC).

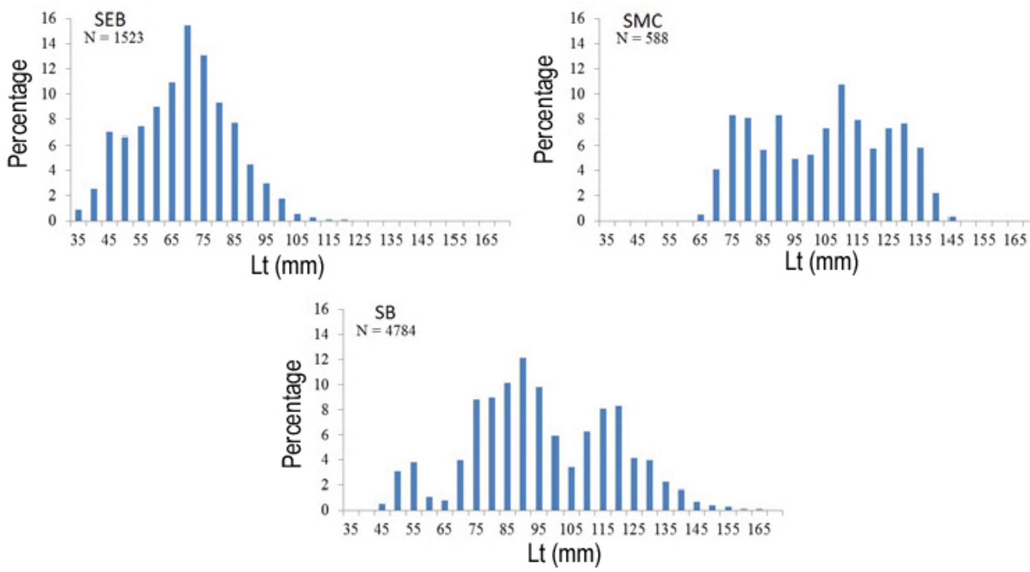

Figure 5. Length distributions in spring time for southeastern Brazil (SEB), Santa Marta Cape (SMC) and southern Brazil (SB).

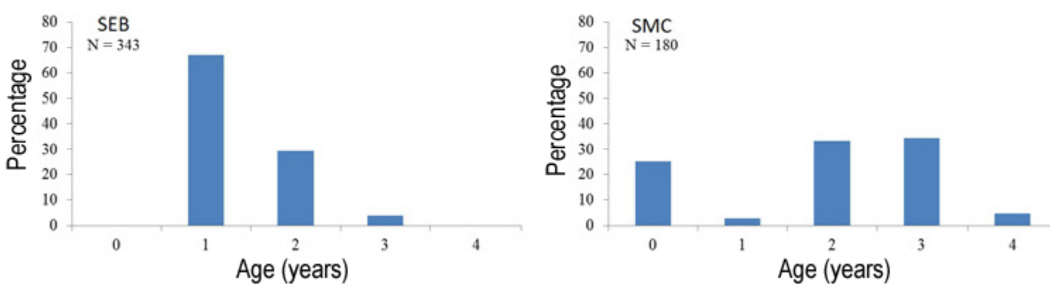

Figure 6. Age composition in southeastern Brazil (SEB) and Santa Marta Cape (SMC) during summer.

standard deviations. Performing growth calculations and fitting a model to these data become a rather imprecise task. Anyway, as seen in Figure 8 the SEB anchovies tend to be smaller with poor growth increments between ages.

Following Castello & Cousseau (1974), linear relationships between otolith size and anchovy total length were fitted for each region (Fig. 9). As expected, correlation coefficients were high and showed little differences between regions. It is noteworthy that an anomaly was found in the southern region, as specimens between 40 and 70 mm Lt seemed to be out of the general trend. Those specimens, all coming from a single sample, were checked for eventual errors and their measurements were confirmed.

Otolith growth is proportional to total length growth. Therefore, the width of the first *annulus* (first hyaline zone) indicates how much the fish have grown

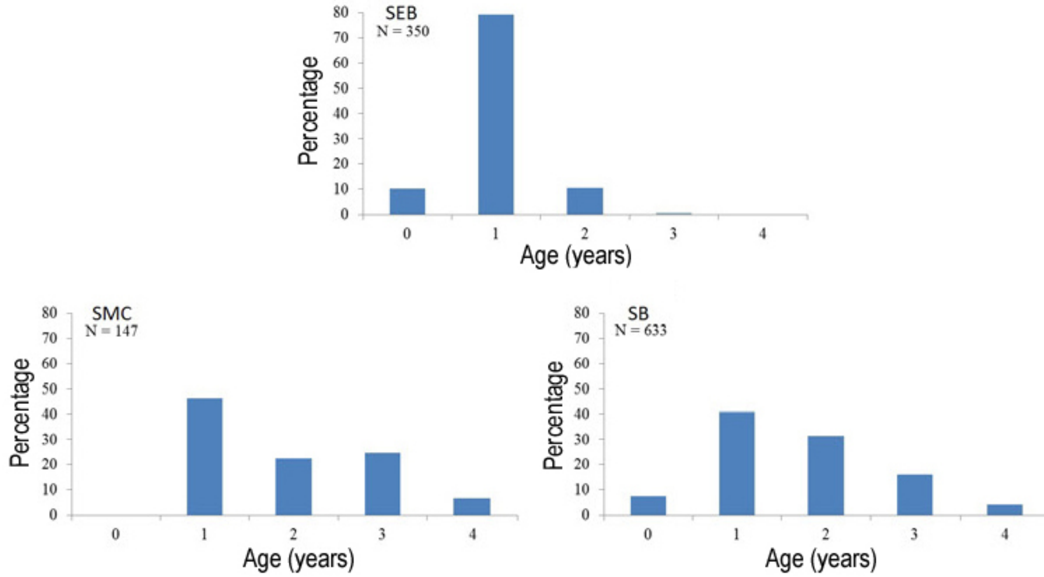

Figure 7. Age composition for southeastern Brazil (SEB), Santa Marta Cape (SMC) and sourthern Brazil (SB) during spring.

Table 1. Mean length (mm), according to age for southeastern Brazil (SEB), Santa Marta Cape (SMC) and sourthern Brazil (SB). N: number, SD: standard deviation.

Age	LT SEB	N	SD	LT SMC	N	SD	LT SB	N	SD
0	72.0	40	11.2	---	---	---	56.2	49	4.2
1	85.2	150	8.8	90.6	68	10.7	88.3	304	11.3
2	93.5	38	9.5	109.5	33	7.5	114.2	173	16.3
3	91.5	2	---	121.7	36	10.6	126.4	84	12.6
4	---	---	---	127.7	10	4.8	137.4	22	8.5

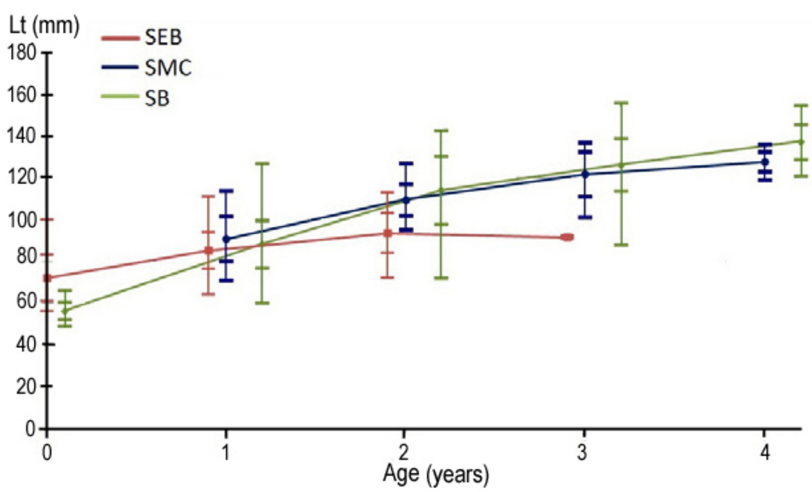

Figure 8. Mean length-at-age data in spring for southeastern Brazil (SEB), Santa Marta Cape (SMC) and sourthern Brazil (SB). External interval represents the amplitude in length; and the inner interval one standard deviation from the mean values.

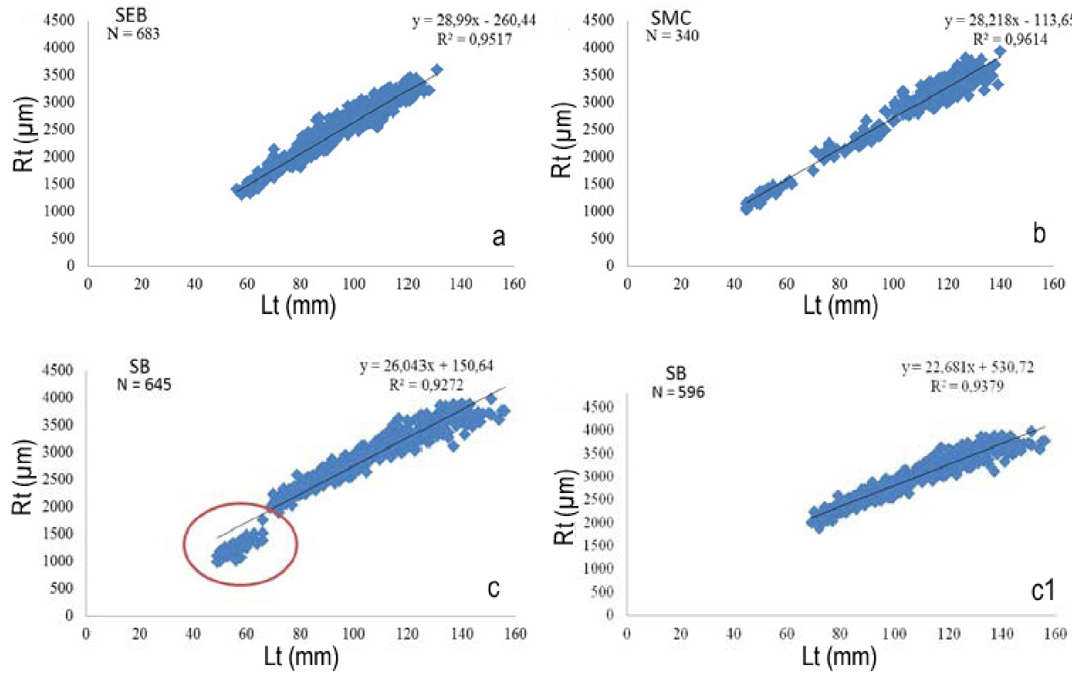

Figure 9. Linear relationship between otolith size (µm), and individual total length (mm), for the three regions. Two graphics are presented for Southern Brazil region (with and without outliers).

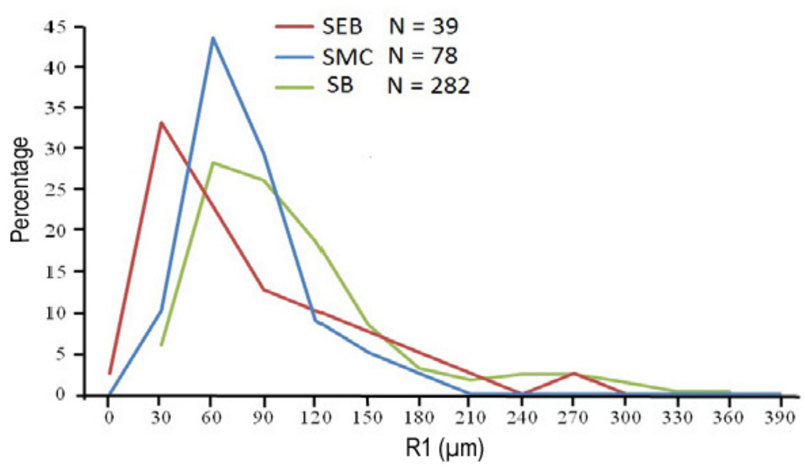

Figure 10. Relative frequency (%) of first *annulus* width in anchovy otoliths for the three regions.

during the first winter of their lives, since growth does not stop during winter in subtropical regions. Frequency distributions of the first hyaline width increments (Fig. 10), showed a clear separation of SEB specimens from those of the other two regions. That is, fish in both southern and Santa Marta regions presented wider first annulus (modes about 60 µm) than those from the SEB (30 µm), probably indicating that environmental conditions for anchovy growth in the SEB winter season are poorer than at higher latitudes.

As mentioned before, the nucleus of anchovy otoliths may present two different aspects when examined under incident lighting. One kind is opaque (*i.e.*, it reflects light) and the other is translucid or hyaline in the center. In the first case there is a denser protein matrix; in the second case, the protein matrix and the associated deposition of aragonite are looser, thus allowing light trasmission. This is related condition to life conditions during the first anchovy growth period. As seen in Table 2, there is a clear north-to-south trend in the percentage of hyaline nucleus during the spring season.

Table 2. Relative frequency (%) of hyaline (translucid) nucleus in anchovy otoliths for summer and spring.

	SEB summer	SMC summer	SEB spring	SMC spring	SB spring
%	36.0	38.5	64.9	42.2	21.8

DISCUSSION

Anchovy age structure in the SEB is distinct from the other regions. A massive presence of 1-year-old fish and a poor presence of older fish suggest shorter life expectancy. The southern region presents a more diversified age composition with older individuals up to age 4. Differences in age and size composition among regions may be evidence of a distinct recruitment pattern between them (Begg, 2004). This is crucial information for stock separation. It is noteworthy that the parameters obtained in this work reflect an almost virginal condition, since there is currently no full commercial exploitation in Brazilian waters. Therefore, present age composition is an indication of life expectancy and natural mortality rate. Only two individuals aged 3 were found as anchovy occurring in the SEB faces higher natural mortality. Although *E. anchoita* is considered to have a short life cycle, it is common to find elder individuals in southern regions (up to age 8 off Patagonia; Hansen, 2004). The high length-at-age variability for anchovies in all regions is probably a consequence of the presence of multiple cohorts, as the argentine anchovy is a known multiple spawner (Castello, 1997). In spite of high variability, individuals caught in the SEB show consistently lower mean lengths than the others, reflecting poor growing conditions in that region. Nevertheless, a long reproductive season is evidenced by the presence of eggs and larvae in the plankton (Weiss, 1976, 1977) along the year, which could also explain the high length-at-age variability.

Length-at-age data showed a higher growth rate in southern Brazil (SB) when compared with Santa Marta (SMC) and southeastern Brazil (SEB). This may be interpreted as the result of higher levels of first and secondary production in the southern region (Castello *et al.*, 1997). In this regard, the Santa Marta region may present an intermediate condition and the SEB region should be considered as the poorest one. The same conclusion could be extracted from the graphic presenting the relationship between otolith and individual growth (Fig. 10). If wider increments mean higher fish growth, then the same pattern is evident. The linear correlation between otolith and individual growth is consistent (Fig. 9), and the anomaly presented in Figure 8c may represent specific conditions faced by those juveniles, since all those young-of-the-year were collected in a single sample. It is interesting to notice that those individuals were responsible for the only case when inferior length-at-age data corresponded to the southern region instead of the SEB region. This fact should be further investigated with more samples of juveniles collected nearby during the cruise.

The high proportion of hyaline otolith nuclei during spring suggests that the SEB may be a poor nursery and feeding ground for anchovies at that time of the year. We interpret this fact as an indication of non-optimum conditions for the development of anchovies in their early life stages. Because fish in this region may not find enough food availability and ideal physical conditions at those stages, there would be lower deposition of protein matrix and aragonite in their otoliths. Nevertheless, the percentage of hyaline nuclei at the SEB region is even lower during summer, a season when primary productivity is higher due to the Central South Atlantic Water upwelling in that region (Matsuura, 1998). This condition is also reflected on the recruitment and life cycle of the Brazilian sardine, *Sardinella brasiliensis* (Cergole *et al.*, 2002).

We believe that the collection and analysis of this kind of parameters has a good cost-benefit relationship, and it is usually the first step or method to be applied in stock identification (Begg, 2004). This method does not provide definite information about genetic discreteness of stocks but presents phenotypic expressions of the interactions between genotypic and environmental influences, indicating geographically or reproductively isolated stocks (Ihssen *et al.*, 1981). As initial steps are taken, in order to develop commercial fishery off southern Brazil (Madureira *et al.*, 2009), the results presented in this work are helpful in pointing out the southern region, as the most favorable fishing ground, since industrial exploitation of this resource would require a minimum size of 110 mm TL. Larger sizes are practically absent from the SEB region.

We consider that these results show the existence of a different unit stock of anchovy in the SEB region. Distinct age and size compositions and length-at-age data were the best features we have obtained to corroborate Castello's hypothesis (1997). Anchovy in the Santa Marta region should be considered as a part of the *bonaerense* stock given the similarities of the parameters between that region and southern Brazil.

Fishery may develop in south Brazil, as anchovies represent a good alternative in that area. Fish production in the country, and the introduction of a new fish product in the Brazilian market, may significantly enhance with a sustainable exploitation of that species. On the other hand, a precautionary management approach is necessary in Southeastern Brazil, considering the inferior age and size composition of the stock inhabiting this area, its higher natural mortality, and the apparent lack of migratory behavior.

REFERENCES

Begg, G. 2004. Life history parameters. In: S. Cadrin, K. Friedland & J. Waldman (eds.). Stock identification methods, application in fishery science. Oxford: Elsevier Academic Press, London, pp. 119-150.

Blaxter, J.H.S. & J.R. Hunter. 1982. The biology of the clupeoid fishes. Adv. Mar. Biol., 20: 194 pp.

Castello, J.P. 1997. A anchoíta (*Engraulis anchoita*, Engraulididae, Pisces) no sul do Brasil. Doctoral Thesis, Programa de Pós-Graduação em Oceanografia Biológica, Universidade Federal do Rio Grande, FURG, Rio Grande, 84 pp.

Castello, J.P. 2007. Síntese sobre a anchoíta (*Engraulis anchoita*) no sul do Brasil. In: M. Haimovici (Org.). A prospecção pesqueira e abundância de estoques marinhos no Brasil nas décadas de 1960 a 1990: levantamento de dados e avaliação crítica. Brasília: MMA/SMCQ, pp. 197-218.

Castello, L. & J.P. Castello. 2002. Anchovy stocks (*Engraulis anchoita*) and larval growth in the SW Atlantic. Fish. Res., 59: 409-421.

Castello, J.P. & M.B. Cousseau. 1974. Investigaciones sobre edad en juveniles de anchoíta. Physis, Sec. A, Buenos Aires, 33(86): 59-74.

Castello, J.P., M. Haimovici, C. Odebrecht & C.M. Vooren. 1997. The continental shelf and slope. In: U. Seeliger, C. Odebrecht & J.P. Castello (eds.). Subtropical convergence environments: the coast and sea in the southwestern Atlantic. Springer, New York, pp. 171-179.

Received: 10 October 2012; Accepted: 20 August 2013

Cergole, M.C., S.A. Saccardo & C.L.D.B. Wongtschowski. 2002. Stock assessment of the Brazilian sardine, *Sardinella brasiliensis*, of the southeastern coast of Brazil. Sci. Mar., 55(3-4): 597-610.

Food and Agriculture Organization (FAO). 2012. Statistics and Information Service of the Fisheries and Aquaculture Department. FAO yearbook. Fish. Aquat. Statistics. 2008. Rome, 72 pp.

Hansen, J.E. 1994. Diferencias entre parámetros vitales de las poblaciones bonaerense y patagonica de anchoita argentina. Rev. Invest. Des. Pesq., 9: 11-24.

Hansen, J.E. 2004. Anchoíta (*Engraulis anchoita*). El mar argentino y sus recursos pesqueros. In: E.E. Boschi (ed.). Publicaciones especiales INIDEP, Mar del Plata, pp. 101-115.

Ihssen, P.E., H.E. Booke, J.M. Casselman, J.M. McGlade, N.R. Payne & F.M. Utter. 1981. Stock identification: materials and methods. Can. J. Fish. Aquat. Sci., 38: 1838-1855.

Madureira, L.S.P., J.P. Castello, C. Prentice-Hernández, M.I. Queiroz, M.L. Espírito Santo, W.H. Ruiz, P.R. Abdallah, J.E. Hansen, M.I Bertolotti, E. Manca, M.I. Yeannes, N. Avdalov & F. Amorín. 2009. Current and potential alternative food uses of the Argentine anchoita (*Engraulis anchoita*) in Argentina, Uruguay and Brazil. In: M.R. Hasan & M. Halwart (eds.). Fish as feed inputs for aquaculture: practices, sustainability and implications. FAO Fish. Aquacult. Techn. Pap., No. 518: 269-287.

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

Schwingel, P.R. 1998. Feeding ecology of *Engraulis anchoita* (Hubbs & Marini, 1935) in Brazilian waters (22º to 34ºS). Doctoral Thesis in Science, Faculty of Biology, Federal University of Hamburg, Hamburg, 204 pp.

Weiss, G. & J.A. Souza. 1976. Contribuição ao conhecimento do ictioplâncton marinho da plataforma sul do Brasil. Atlântica, 1(1/2): 7-26.

Weiss, G. & J.A. Souza. 1977. Desova invernal de *Engraulis anchoita* na costa sul do Brasil em 1970 e 1976. Atlântica, 2(2): 5-24.