

## LARVAL AND JUVENILE GROWTH OF TWO PATAGONIAN SMALL PELAGIC FISHES: *Engraulis anchoita* AND *Sprattus fuegensis*\*

by

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### RESUMEN

**Crecimiento de larvas y juveniles de dos pequeños peces pelágicos patagónicos: *Engraulis anchoita* y *Sprattus fuegensis*.** La anchoíta patagónica (*Engraulis anchoita*) y la sardina fueguina (*Sprattus fuegensis*) constituyen los dos recursos pelágicos más importantes de la Plataforma Patagónica Argentina. Se determinaron la edad y el crecimiento de larvas y juveniles de ambas especies mediante el análisis de incrementos diarios de los otolitos. Se analizaron un total de 404 anchoítas (4,1-33 mm LS) y 157 sardinias (5-41 mm LS). Se ajustó el modelo de crecimiento de Laird-Gompertz a los datos longitud-edad de las anchoítas:  $L(t) = 4,2 \exp(2,28(1 - (-0,034 t)))$ . Según el modelo:  $L_{\infty}$ : 41,06 mm; el punto de inflexión: 15,11 mm y 27 días; y la máxima tasa de crecimiento: 0,51 mm día<sup>-1</sup>. Los datos longitud-edad de larvas y juveniles de sardina fueguina se representaron en dos modelos lineales:  $L(t) = 0,32 t + 7,6$  y  $L(t) = 0,22 t + 6,6$ . Las pendientes representaron las tasas de crecimiento medias, 0,32 y 0,22 mm día<sup>-1</sup> en larvas y juveniles, respectivamente. Las variaciones en longitud-edad entre años se estudiaron mediante el análisis de trayectorias individuales de crecimiento. Se encontraron variaciones en las sardinias fueguinas, no en las anchoítas.

### SUMMARY

Patagonian anchovy (*Engraulis anchoita*) and sprat (*Sprattus fuegensis*) constitute the two most important pelagic resources of the Argentine Patagonian shelf. Age and growth parameters of larvae and juveniles of both species were determined analyzing otoliths daily increments. A total of 404 anchovies (4.1-33 mm SL) and 157 sprats (5-41 mm SL) were analyzed. The Laird-Gompertz growth model was fitted to the length-at-age data of anchovies:  $L(t) = 4.2 \exp(2.28(1 - (-0.034 t)))$ . The parameters of the model were:  $L_{\infty}$ : 41.06 mm; the inflection point: 15.11 mm and 27 days; and the maximum growth rate: 0.51 mm day<sup>-1</sup>. The length-at-age data of sprat larvae and juveniles were represented in two linear models:  $L(t) = 0.32 t + 7.6$ ; and  $L(t) = 0.22 t + 6.6$ . Slopes represented mean growth rates, 0.32 and 0.22 mm

day<sup>-1</sup> for larvae and juveniles, respectively. Variations in length-at-age between years were determined through the analysis of individual growth trajectories. Variations were found in sprats, not in anchovies.

**Key words:** *Engraulis anchoita*, *Sprattus fuegensis*, larvae, juveniles, growth, otoliths.

**Palabras clave:** *Engraulis anchoita*, *Sprattus fuegensis*, larvas, juveniles, crecimiento, otolitos.

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## INTRODUCTION

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Patagonian anchovy (*Engraulis anchoita*) and sprat (*Sprattus fuegensis*) occupy the southernmost habitats of all engraulids and clupeids in the world. Anchovy inhabits the north and middle part of the Patagonian coast (41° S-47° S); sprat distributes in the southern sector (47° S-55° S). Both species constitute the most important pelagic resources of the Argentine Patagonian shelf (Sánchez and Ciechowski, 1995).

The reproductive activity of anchovy in the region that takes place during spring and summer (November through March) has been associated to the tidal thermal front formation in the north and centre of the Patagonia and the thermohaline front of the south of the San Jorge Gulf (Sánchez, 1995; Sánchez *et al.*, 1998). Sprat spawning season also occurs during spring and summer (Sánchez *et al.*, 1995; 1997) and relates to the formation of an oceanographic front (Acha *et al.*, 1999). Two sprat populations off Santa Cruz and around Malvinas Islands were identified on the basis of growth differences (Gru and Cousseau, 1982) and the comparison of meristic and morphometric characters (Cousseau, 1982). In a more recent work, differences were detected in vertical migration and school morphology between the two populations of *Sprattus fuegensis* (Casarsa, 2005).

Events during the early life stages may develop in a critical period when determining the strength of a marine fish year class (Cushing, 1975; Smith, 1985). Small changes in growth rates during larval stages may reduce or extend the duration of stages thus causing serious

effects on recruitment when the mechanisms responsible for high mortality levels operate (Houde, 1989).

Pannella (1971) suggested a daily rate of increments in fishes otoliths. Said increments were recognised in at least 300 species (Secor *et al.*, 1992) and used as an effective tool to estimate fish larvae growth (Campana and Jones, 1992) due to the fact that counts of daily increments allow a direct measurement of length-at-age. The widths of successive increments in an otolith represent the growth history of an individual during the deposition period. The analysis of the sequence of increments widths may lead to elucidate individual growth trajectories (Butler and Nishimoto, 1997; Watanabe and Kuroki, 1997; Watanabe and Nakamura, 1998).

Previous studies on *Engraulis anchoita* larval and juvenile growth were published for the Brazilian stock (Castello and Vasconcellos, 1995; Kitahara and Matsuura, 1995; Ekau, 1998; Castello and Castello, 2003). Sánchez (1995) and Sánchez *et al.*, (1995) established growth parameters for larvae and juveniles of both species in the Patagonia, but the information is only preliminary. There are no previous published works on growth during the larval stages of those species off Patagonia.

The aim of this paper is to determine anchovies and sprats age and growth parameters during larval and juvenile stages through the analysis of the daily deposition microstructure in the *saggita* otoliths. Variations between years were also analyzed.

## MATERIALS AND METHODS

### Sampling

Samples were obtained on board of RVs “Meteor”, “Dimitri Stefanov”, “Capitán Oca Balda” and “Dr. Eduardo L. Holmberg”. Trawls were performed obliquely, integrating the water column from bottom to surface. Four groups of lar-

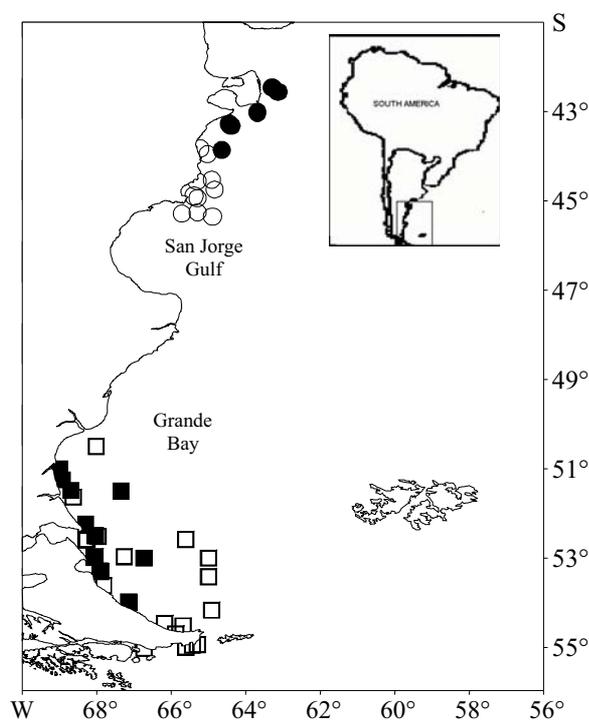


Figure 1. Study area and location of the sampling stations. The symbols indicate the names of the cruises during which specimens were caught. METEOR 89 (●) anchovy larvae; EH-01/95 (○) anchovy juveniles; OB-13/96 (□) sprat larvae; DS-01/92 (■) sprat juveniles.

Figura 1. Área de estudio y posición de las estaciones de muestreo. Los símbolos indican los nombres de las campañas durante las que se capturaron los especímenes. METEOR 89 (●) larvas de anchoíta; EH-01/95 (○) juveniles de anchoíta; OB-13/96 (□) larvas de sardina fueguina; DS-01/92 (■) juveniles de sardina fueguina.

vae and juveniles of both species were defined; the details of each cruise are summarised in Table 1. Hydrologic data were recorded with a self-recording conductivity-temperature-depth (CTD). The sampling stations are shown in Figure 1. Larvae and juveniles were fixed on board in a 96% ethanol solution that was changed several times to assure preservation.

### Laboratory procedures

The standard length of individual larvae and juveniles was measured to the nearest 0.1 mm with an ocular micrometer fitted to a dissecting microscope. The head tissues of specimens were dissolved in a sodium hypochlorite concentrated solution. When both otoliths became visible, they were washed with distilled water. After drying, they were removed using fine dissecting needles and placed onto a glass slide covered with Protexx (transparent mounting medium). If increments were not visible in larvae larger than 10 mm, the otoliths were polished using 12  $\mu\text{m}$ , 9  $\mu\text{m}$  and 3  $\mu\text{m}$  lapping film paper. A total of 404 anchovy larvae and juveniles (4.1–33 mm standard length) and 157 sprat specimens (5–41 mm SL) were analyzed.

The increments were observed under a binocular optical microscope (400 x or 1,000 x) with transmitted light connected to a computer provided with software for image analyses (Kontron program). The identification of the daily deposition pattern was made following the recommendations by Campana (1992) and assumed according to observations of other anchovy and sprat species such as *Engraulis japonicus* (Tsuji and Aoyama, 1984); *E. capensis* (Thomas, 1986); *E. encrasicolus* (Ceremeño *et al.*, 2003) and *Sprattus sprattus* (Alshuth, 1988).

The increments were counted and measured from the nucleus to the outer edge of the otolith along a vector. When the number of increments between right and left otoliths agreed in, at least, 90%, the information obtained from one of them

Table 1. Basic information about research cruises. Names of cruises are indicated in parenthesis; four groups of larvae and juveniles of both species are presented (I-IV).

Tabla 1. Información básica de las campañas de investigación. Los nombres de las campañas se indican entre paréntesis; se presentan cuatro grupos de larvas y juveniles de ambas especies (I-IV).

Ship / cruise	Dates	Collected material	Sampling gear	N
“Meteor” (METOR 89)	5-12 December 1989	Anchovy larvae Group I	Biomoc: 1 m <sup>2</sup> opening and 300 µm mesh size	219
“Dr. Eduardo L. Holmberg” (EH-01/95)	5-20 January 1995	Anchovy juveniles Group II	Methot: 5 m <sup>2</sup> opening and 2,000 µm mesh size	185
“Dimitri Stefanov” (DS-01/92)	28 March-9 April 1992	Sprat juveniles Group III	IKMT: 9 m <sup>2</sup> opening and 2,000 µm mesh size	105
“Capitán Oca Balda” (OB-13/96)	26 November- 3 December 1996	Sprat larvae Group IV	Nackthai: 0.042 m <sup>2</sup> opening and 400 µm mesh size	52

was randomly considered; if the difference was larger, they were discarded. When only one otolith was available, the information was considered.

### Data analysis

Larvae and juveniles age, growth rates and individual growth trajectories were determined counting and measuring *sagitta* otoliths daily increments. Because the length-at-age data of anchovies were approximately S-shaped and showed an asymptotic trend in large juveniles, the Laird-Gompertz model was selected to represent growth (Zweifel and Lasker, 1976). The coefficients were fitted using non-linear least square methods. The model generalized equation was:

$$L(t) = L_0 \exp(G(1 - \exp(-\alpha t)))$$

where:

t: number of otoliths increments;

L(t): standard length at increment t;

L<sub>0</sub>: length at t = 0 (length at first increment deposition);

G = A<sub>0</sub>/α;

A<sub>0</sub>: specific growth rate at t = 0;

α: rate of exponential decay.

The derivative of the Laird-Gompertz equation corresponded to the instantaneous growth rate as a function of size (Sánchez *et al.*, 1999):

$$IGR_{L(t)} = \alpha L(t) (\ln L(t) / L_0 - G)$$

where:

IGR<sub>L(t)</sub> = instant growth rate.

Sprats size-at-increment data were expressed as linear functions of age:

$$L(t) = b(t) + a$$

where:

t: number of otoliths increments;

L(t): standard length at increment t;  
 a: y-axis intercept;  
 b: slope, linear growth rate in mm day<sup>-1</sup>.

The hatching dates of each larvae and juveniles group were determined with back-calculation considering the catch dates, the number of increments and the period during which larvae do not deposit the first increment that was associated to the yolk-sac stage. To compensate that period, Ciechowski and Sánchez (1984) and Alshuth (1988) equations for anchovies and sprats, respectively, were considered.

Plots of standard length against otolith radius were expressed with linear relations in both species. Assuming the existence of linearity at individual level, the past larval sizes were back-calculated according to the biological intercept method (Campana, 1990; Campana and Jones, 1992). The expression used was:

$$SL_i = SL_c + (O_i - O_c) \times (SL_c - SL_0) \times (O_c - O_0)^{-1}$$

where:

SL<sub>0</sub>: larval size at first increment deposition (4.2 mm in anchovies and 7.1 in sprats);

O<sub>0</sub>: otolith radius at first increment deposition;

SL<sub>c</sub>: larval size at catch;

O<sub>c</sub>: otolith radius at catch;

O<sub>i</sub>: otolith radius at increment *i*;

SL<sub>i</sub>: back-calculated larval size at age *i*.

In order to verify the existence of variations in growth between years, the back-calculated past sizes-at-ages of different larvae and juveniles groups were compared using the Mann-Whitney test (Sokal and Rohlf, 1995).

## RESULTS

### Sea surface temperature

Oceanographic data and thermal field characteristics of the area were extensively referred to in previous studies (Sánchez and Ciechowski, 1995; Sánchez *et al.*, 1995; 1997; Sabatini *et al.*, 2001; Sabatini and Martos, 2002). Surface temperature values taken in positive stations of larvae and juveniles of both species fluctuated 12.8 °C-15 °C for METEOR 89 and 13 °C-14 °C for EH-01/95 (anchovy collection). A slight temperature variation between both cruises was observed. Thermal values during the two sprat cruises fluctuated 9 °C-10.2 °C for DS-01/92 and 7.5 °C-9 °C for OB-13/96. Surface temperature was slightly higher in the DS-01/92 cruise. Basically, two thermally distinct areas were defined: Northern Patagonia (warmer) and Southern Patagonia (cooler) that corresponded with the respective nursery grounds of both species.

### Otolith microstructure and growth models

The microstructure was visualized as successive clear and dark bands delimiting each increment (Figure 2). Age, size ranges and hatching periods of different anchovy and sprat groups are summarised in Table 2 and Figure 3.

Length-at-increment data of anchovy larvae and juveniles (groups I and II) adjusted well to the Laird-Gompertz model (Figure 4). The parameters were L<sub>∞</sub>: 41.06 mm, the inflexion point: 15.11 mm and 27 days, and the maximum growth rate: 0.51 mm day<sup>-1</sup>. The first prominent increment deposition was around 4.2 mm SL in anchovy larvae. The value was considered to be a constant in the Laird-Gompertz model.

Due to the fact that length-at-increment data of sprat larvae and juveniles showed different trends, two linear models were fitted to represent

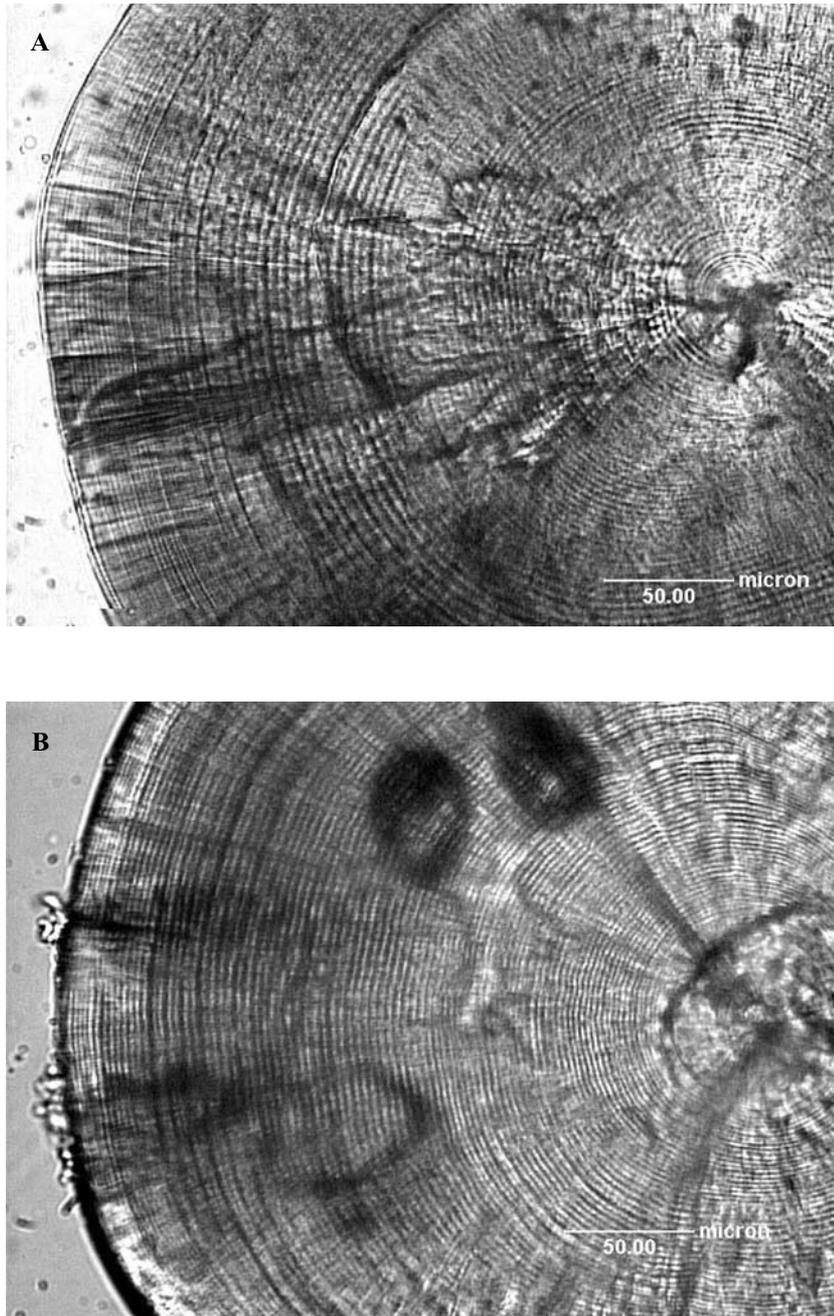


Figure 2. Daily growth increments in *sagitta* otoliths of an *Engraulis anchoita* juvenile (28.5 mm SL) (A) and a *Sprattus fuegensis* juvenile (33 mm SL) (B).

Figura 2. Incrementos diarios en otolitos de un juvenil de *Engraulis anchoita* (28,5 mm LS) (A) y un juvenil de *Sprattus fuegensis* (33 mm LS) (B).

Table 2. Age, sizes and hatching periods of different groups of anchovy (A) and sprat (S).

Tabla 2. Edades, tamaños y períodos de eclosión de diferentes grupos de anchoíta (A) y sardina fueguina (S).

Cruise	Group	Size rank (mm)	Age rank (days)	N	Hatching period
METEOR 89	I A	4.1-13.5	1-25	219	spring 1989
EH-01/95	II A	19-34	30-73	185	spring 1994
DS-01/92	III S	20-41	62-151	105	spring 1991-summer 1992
OB-13/96	IV S	5-20	0-35	52	spring 1996

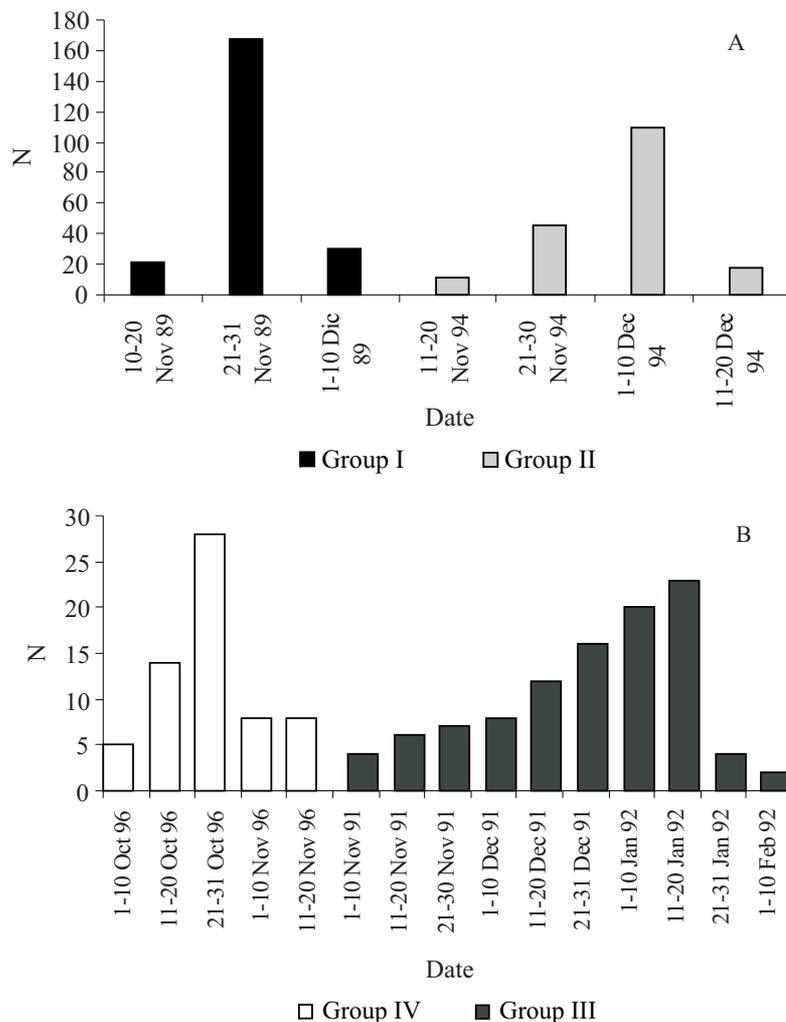


Figure 3. Back-calculated hatching dates corresponding to different groups of anchovy (A) and sprat (B).

Figura 3. Retrocálculo de las fechas de eclosión correspondientes a los distintos grupos de anchoíta (A) y sardina fueguina (B).

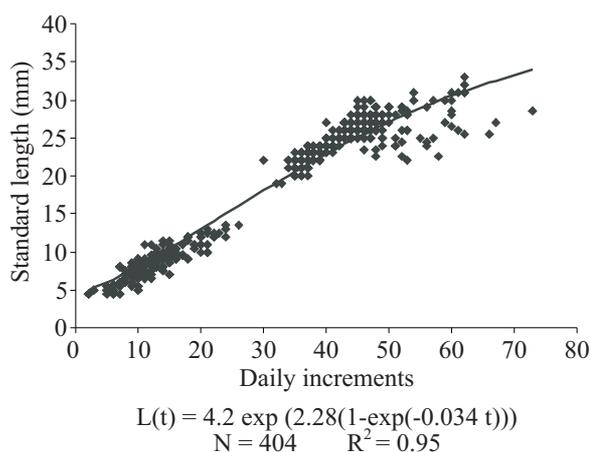


Figure 4. Relation between standard length and number of increments in otoliths of larvae and juveniles of *Engraulis anchoita* fitted to the Laird-Gompertz curve.

Figura 4. Relación entre el largo estándar y el número de incrementos en los otolitos de larvas y juveniles de *Engraulis anchoita* ajustados a la curva de Laird-Gompertz.

the growth of two size groups (Figure 5). It was difficult to identify sprat larval size when the first increment was deposited; therefore, the intercept values of the growth models were considered (6.6 mm and 7.6 mm SL for groups III and IV, respectively). The mean value between both intercepts (7.1 mm) was considered as larval size at sprats first increment deposition.

### Growth rates

Anchovy growth rates obtained deriving the Laird-Gompertz model were represented with a parabola. Values corresponding to 4.9 mm and 15.1 mm larval sizes increased from 0.35 mm day<sup>-1</sup> to 0.51 mm day<sup>-1</sup>. The maximum growth rate value corresponded to the inflexion point of the model. The growth rate decreased from the inflexion point to 0.22 mm day<sup>-1</sup> (33 mm larval size). Sprat linear growth rates of groups III and IV were 0.22 mm day<sup>-1</sup> and 0.32 mm day<sup>-1</sup>, respectively. Growth rates values for both species are represented in Figure 6.

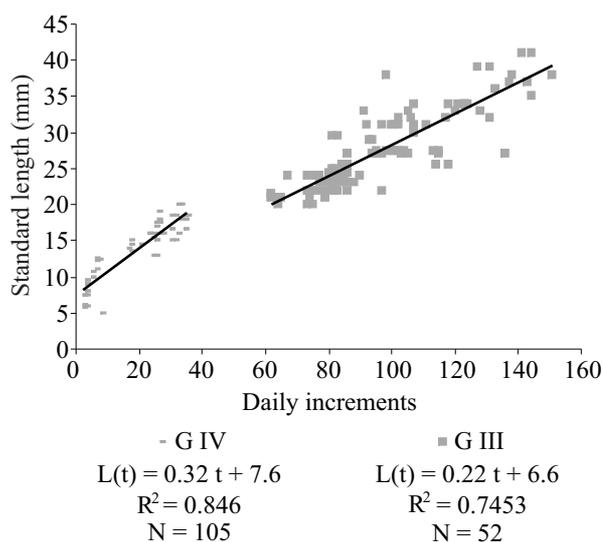


Figure 5. Linear relations between standard length and number of growth increments in otoliths of larvae (G IV) and juveniles (G III) of *Sprattus fuegensis*.

Figura 5. Relaciones lineales entre el largo estándar y el número de incrementos en los otolitos de larvas (G IV) y juveniles (G III) de *Sprattus fuegensis*.

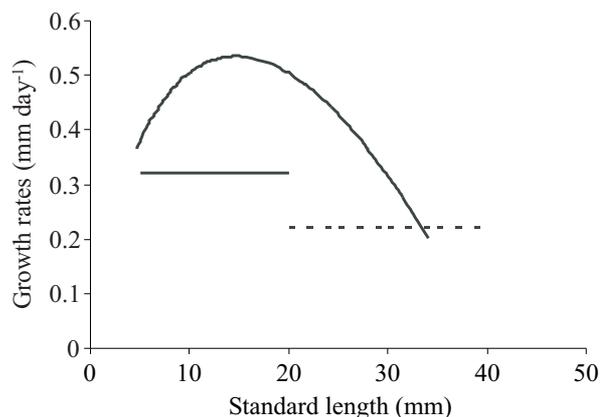


Figure 6. Growth rates of *Engraulis anchoita* (parabola) and *Sprattus fuegensis* (lines). Dotted line: G III; continuous line: G IV.

Figura 6. Tasas de crecimiento de *Engraulis anchoita* (parabola) y *Sprattus fuegensis* (líneas). Línea de puntos: G III; línea continua: G IV).

### Growth trajectories

The standard length and otolith radius data corresponding to anchovy larvae and juveniles

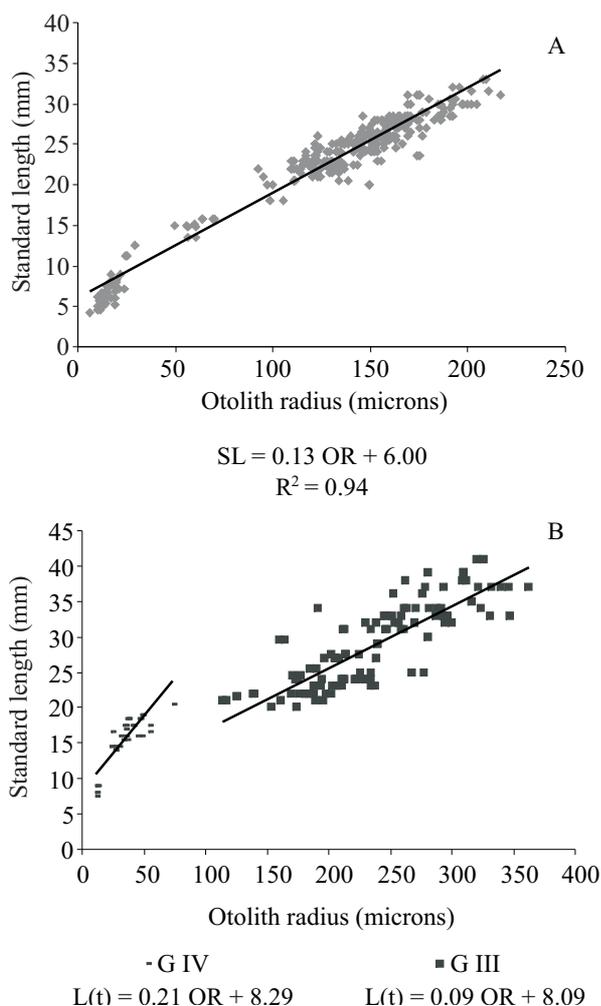


Figure 7. Linear relations between the length and radius of anchovy (A) and sprat (B) otolith. The different groups of sprat (G III and IV) are indicated.

Figura 7. Relaciones lineales entre el largo y el radio del otolito de anchoíta (A) y sardina fueguina (B). Se indican los distintos grupos de sardina fueguina (G III y IV).

(groups I and II) were fitted in a single linear model (Figure 7 A). Plots of standard length and otolith radius were fitted in two linear models for sprat larvae and juveniles (groups IV and III, respectively) (Figure 7 B). Assuming the existence of linearity at individual level, the past sizes at previous ages (individual growth trajectories) were back-calculated.

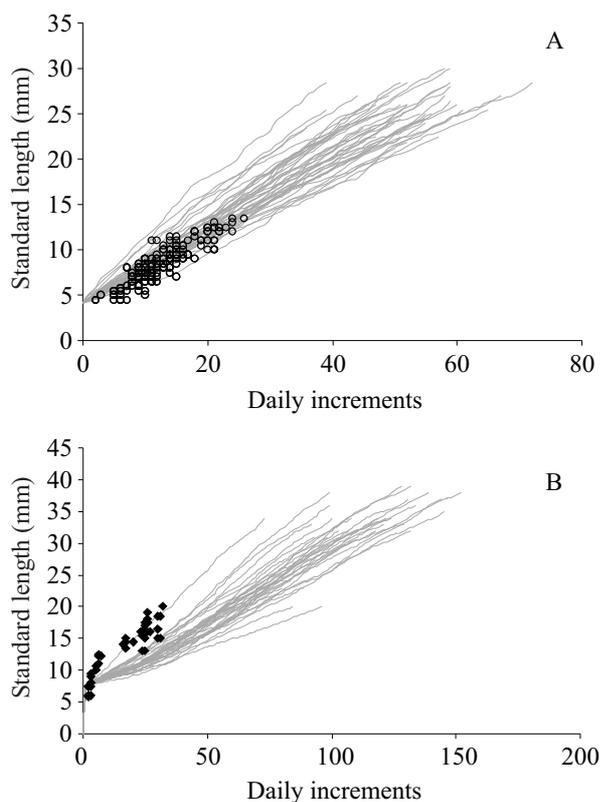


Figure 8. Length-age data of anchovy larvae (A) corresponding to group I (circles) and individual growth trajectories of juveniles corresponding to group II (lines). Length-age data of sprat larvae (B) of group IV (rhombuses) and individual growth trajectories of juveniles of group III (lines).

Figura 8. Datos largo-edad de larvas de anchoíta (A) correspondientes al grupo I (círculos) y trayectorias individuales de crecimiento correspondientes al grupo II (líneas). Datos largo-edad de larvas de sardina fueguina (B) del grupo IV (rombos) y trayectorias individuales de crecimiento de juveniles del grupo III (líneas).

The length-at-age values established for anchovy larvae of group I fell within the back-calculated lengths at the same ages as juveniles of group II (Figure 8 A). As regards sprat (Figure 8 B), it was observed that the length-at-age values established for larvae of group IV were higher than the back-calculated sizes of juveniles of group III at the same ages. The Mann-Whitney test results are summarized in Table 3. It was

Table 3. Mean sizes back-calculated at previous ages of the different groups of anchovy and sprat. Results of the Mann-Witney test. ns: non significant differences; \*: significant differences ( $p < 0.001$ ).

Tabla 3. Tallas medias retrocalculadas a edades previas de los distintos grupos de anchoíta y sardina fueguina. Resultados del test de Mann-Witney. ns: diferencias no significativas; \*: diferencias significativas ( $p < 0,001$ ).

	Mean size (mm)	SD	N	Mean size (mm)	SD	N	Mean size (mm)	SD	N
Anchovy									
		3 d			5 d			8 d	
Group I	5.26 ns	0.43	34	6.02 ns	0.56	28	7.30 ns	0.93	18
Group II	5.38 ns	0.39	41	6.15 ns	0.59	41	7.36 ns	0.88	41
Sprat									
		10 d			15 d			20 d	
Group III	9.21 *	0.52	34	10.03 *	0.81	34	10.92 *	1.09	34
Group IV	10.12 *	2.00	29	11.64 *	2.4	29	12.78 *	1.33	22

observed that the back-calculated lengths of anchovy larvae and juveniles at ages 3, 5 and 8 days corresponding to groups I and II were not significantly different. On the contrary, there were differences in sizes at ages 10, 15 and 20 days between sprat groups III and IV.

## DISCUSSION

Apart from the fact that anchovy and sprat are two distinct species, the highest growth rates obtained for anchovy would be ecologically explained considering that both species inhabit different waters with noticeable differences in temperature and oceanographic characteristics. During the peaks of the largest reproductive activity of both species, Acha *et al.* (1999) registered thermal ranges around 12 °C-16 °C for the North Patagonian coast and 7 °C-8 °C for the South Patagonian shelf.

The hydrography of the North Patagonian coast (anchovy habitat) is characterized by the presence of a tidal thermal front during spring

and summer. The front separates homogenized coastal waters from stratified waters in the vertical plane (Glorioso, 1987). The high biologic production, represented by phytoplankton blooms, is associated to the high levels of nitrate availability (Carreto and Benavides, 1990); the large copepods aggregations (Ramírez *et al.*, 1990) are distinctive of the system.

In the Argentinean shelf off Southern Patagonia (sprat habitat) frontal structures produced by tide dynamics were identified (Glorioso and Flather, 1995). Nevertheless, the most important structure found is the hydrologic front that develops as a consequence of cooler waters that move from the Magellan Strait northward to encounter warmer waters of the continental shelf in the Grande Bay. Divergence processes and the consequent upwellings originate in the area (Sánchez *et al.*, 1995). High nitrate concentrations related to the maximum phytoplankton production during spring-summer (Sánchez and Ciechowski, 1995) and high values of zooplankton biomass were identified (Ciechowski and Sánchez, 1983; Sabatini and Álvarez Colombo, 2001).

The comparison of growth rates calculated in this work with the values other authors obtained for *Engraulis anchoita* and *Sprattus sprattus* are represented in Table 4. In general, values were estimated deriving the length-age models established by different authors. No extrapolation was made outside the observation ranks. Anchovy growth rate values were quite similar to the ones obtained by Sánchez *et al.* (1999) for larvae that originate in the Buenos Aires shelf and, in general, lower than the values calculated by Castello and Vasconcellos (1995), Kitahara and Matsuura (1995) and Ekau (1998). The thermal influence would be associated to that phenomenon. *E. anchoita* growth rate values obtained in this work were quite similar to those registered by Castello and Castello (2003) for larvae that originate in the Brazilian Southeastern Bight. Results could not be explained on the basis of the thermal influence. Other mechanisms such as differences between stocks would be involved. The growth rate values obtained for *Sprattus fuegensis* seemed to be lower (or situated in the inferior limit) than those Munk (1993), Ré and Gonçalves (1993) and Dulcic (1998) registered for *S. sprattus* larvae. As regards *S. sprattus* juveniles (0.48-0.69 mm day<sup>-1</sup>), Baumann *et al.* (2006) found higher growth rates back-calculated 25 days after the first feeding; the authors related the phenomenon to the concept of enhanced survival probabilities of individuals that grow faster. Although the two sprat species are distinct, the temperature factor would account for such differences.

A crucial point in back-calculation is the mean size at the first increment deposition (SL<sub>0</sub>). It was observed that, in general, clupeids first deposition begins when exogenous feeding occurs (Brothers *et al.*, 1976; Maillet and Checkley, 1990; Ré and Gonçalves, 1993). Castello and Castello (2003) found a positive correlation between SL<sub>0</sub> and sea-surface temperature. The different L<sub>0</sub> values several authors registered for anchovy larvae varied from 2.7 to 6.51 SL mm (Table 4). The value con-

sidered in this work (4.2 mm) was identical to the ones Sánchez *et al.* (1999) obtained for *E. anchoita* and Methot and Kramer (1979) for *E. mordax*. Sprat mean larval size at first ring deposition was around 6.6-7.6 SL mm probably as a result of an earlier increments deposition. Limitations in optical microscopy did not allow to identify the rings.

Three facts led to detect similar growth in anchovy larvae and juveniles: 1) the fitting of length-age data corresponding to different years (1989 and 1995) in a single Laird-Gompertz model, 2) the fitting of the length-otolith radius in a unique linear model, 3) the analysis of growth trajectories. The absence of larval growth variations between years could be attributed to the birth of both groups of anchovies the same season (spring) of different years (see Table 2). Sea surface temperature was quite similar both years (12.8 °C-15 °C for 1989 and 13 °C-14 °C for 1995). Based on a study performed with samples obtained during 15 years, Martos (2000) concluded that during the frontal system formation (spring), minimal oscillations in temperature were recorded in the different integrating sectors (homogenous, transition and stratified areas). The seasonal thermal stability would make anchovy larval growth similar in spring of different years.

Three factors allowed to evidence a differential growth in sprat larvae and juveniles: 1) the fitting of length-age data corresponding to different years (1992 and 1996) in two different linear models, 2) the fitting of the length-otolith radius in two distinct linear models also, and 3) the analysis of growth trajectories.

Each of those sprat groups (III and IV) hatched at different times of the reproductive season (Table 2) with larger sizes for the specimens hatched first (Table 3). From these observations the following question arises: Are differences in back-calculated sizes a consequence of growth fluctuations that occur within the same spawning season? The hypothesis could not be certainly affirmed due to the fact that samples were col-

Table 4. Estimates of growth rates of *Engraulis anchoita*, *Sprattus fuegensis* and *Sprattus sprattus*. Several growth rates were calculated deriving the theoretical models proposed by the authors. Others are expressed as rank of values. Thermal values, when available, are represented. From Castello and Vasconcellos (1995) (a), non mentioned Laird-Gompertz model (b), with back-calculation procedures (c).  
 Tabla 4. Estimaciones de tasas de crecimiento de *Engraulis anchoita*, *Sprattus fuegensis* y *Sprattus sprattus*. Varias tasas de crecimiento se calcularon por derivación de los modelos teóricos propuestos por los autores. Otras se expresan como rango de valores. Se representan valores de temperatura, cuando estuvieron disponibles. De Castello y Vasconcellos (1995) (a), modelo de Laird-Gompertz no mencionado (b), con métodos de retrocálculo (c).

Species	Temperature (°C)	Larval/ juvenil size (mm)	Growth rate (mm day) <sup>-1</sup>	Adjusted model	Source of information
<i>Engraulis anchoita</i>	12-15	10 20 30	0.48 0.49 0.32	$L(t) = 4.2 \exp(2.28(1 - (-0.034 t)))$	this work
	20 (a)	10 20 30	0.41 0.78 1.14	$L(t) = 6.19 \exp(17.08(1 - (0.0025 t)))$	Kitahara and Matsuura (1995)
	15	10	0.42	$L(t) = 4.2 \exp(2.77(1 - (-0.022 t)))$	Sánchez <i>et al.</i> (1999)
	20	10 20 30	0.44 0.61 0.68	$L(t) = 5.19 \exp(2.95(1 - (-0.019 t)))$	Castello and Vasconcellos (1995)
	22-25	10 15 20	0.49 0.42 0.26	$L(t) = 6.51 \exp(1.37(1 - (-0.052 t)))$	Castello and Castello (2003)
	18-22	10 20 30	0.74 0.91 0.86	$L(t) = 2.72 \exp(3.102(1 - (-0.041 t)))$	Ekau (1998)
<i>Sprattus fuegensis</i>	7.5-9	6-20	0.32	$L(t) = 7.6 + 0.32 t$	this work
	9-10.2	20-41	0.22	$L(t) = 6.6 + 0.22 t$	this work
<i>Sprattus sprattus</i>	-	10 20	0.63 0.32	$L(t) = 6.74 \exp(1.33(1 - (-0.067 t)))$	Dulcic (1998)
	12-19	70-100	0.48-0.69	(c)	Baumann <i>et al.</i> (2006)
	11-16	12	0.32-0.47	(b)	Munk (1993)
	11-13.5	4-20	0.42	$L(t) = 5.49 + 0.42 t$	Valenzuela and Vargas (2002)
	11.25-13.3	7.5-20	0.41	$L(t) = 7.8 + 0.41 t$	Ré and Gonçalves (1993)

lected in different years. If the phenomenon is assumed, variations could be related to food availability. Sabatini *et al.* (2001) analyzed the zooplankton of the austral Patagonian shelf during fall and spring the same year (1996) and concluded that zooplankton biomass, abundance of individuals and number of species were larger in spring. Faster growth of sprat born in spring could be related to food potential. Future studies with in situ observations on food availability and plankton concentration will be necessary to detect the causes of *Sprattus fuegensis* differential larval growth. Working with herring larvae, Jones (1985) also found that larvae hatched earlier grew faster. Another mechanism to be considered relates to endogenous causes. Marteinsdottir and Steinarson (1998) detected a positive correlation between the sizes of eggs and growth rates of *Gadus morhua* larvae.

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### ACKNOWLEDGEMENTS

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The authors would like to express their gratitude to the captains, officers and crew of RVs "Dr. Eduardo L. Holmberg", "Capitán Oca Balda" and "Dimitri Stefanov" for their participation in the collection of samples.

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### REFERENCES

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- ACHA, E.M., PÁJARO, M., & SÁNCHEZ, R.P. 1999. The reproductive response of clupeoid to diferent physical scenarios. Three study cases in the Southwest Atlantic. ICES Council Meeting Papers. Estocolmo, K: 12.
- ALSHUTH, S. 1988. Daily growth increments on otoliths of sprat (*Sprattus sprattus* L.) larvae. Meeresforsch. Rap. Mar. Res., 32: 23-29.
- BAUMANN, H., HINRICHSEN, H.H., VOSS, R., STEPPUTTIS, D., GRYGIEL, W., CLAUSEN, L.W. & TEMMING, A. 2006. Linking growth to environmental histories in central Baltic young of the year sprat, *Sprattus sprattus*: an approach based on otolith microstructure analysis and hydrodynamic modelling. Fish. Oceanogr., 15 (6): 465-476.
- BROTHERS, E.B., MATHEWS, C.P. & LASKER, R. 1976. Daily growth increments in otoliths from larval and adult fishes. Fish. Bull., U.S., 74: 1-8.
- BUTLER, J. & NISHIMOTO, R.N. 1997. Growth and cohort dynamics of larval Pacific hake (*Merluccius productus*). CalCOFI Rep., 38: 63-68.
- CAMPANA, S.E. 1990. How reliable are growth back-calculations based on otoliths? Can. J. Fish. Aquat. Sci., 47: 2219-2227.
- CAMPANA, S.E. 1992. Measurement and interpretation of the microstructure of fish otoliths. In: STEVENSON, D.K. & CAMPANA S.E. (Eds.). Otolith microstructure examination and analysis. Can. Spec. Publ. Fish. Aquat. Sci., 117: 59-71.
- CAMPANA, S.E. & JONES, C.M. 1992. Analysis of otolith microstructure data. In: STEVENSON, D.K. & CAMPANA S.E. (Eds.). Otolith microstructure examination and analysis. Can. Spec. Publ. Fish. Aquat. Sci., 117: 73-100.
- CARRETO, J.I. & BENAVIDES, H.R. 1990. Phytoplankton. Synopsis on the reproductive biology and early life history of *Engraulis anchoita*, and related environmental conditions in Argentine waters. In: Second IOC Workshop on Sardine/Anchovy Recruitment Proyect (SARP) in the Southwest Atlantic. IOC Worksh. Rep., 65 (V): 2-4.
- CASARSA, L. 2005. Morfología y comportamiento de los cardúmenes de sardina fueguina (*Sprattus fuegensis*) en dos sectores característicos del Atlántico Sudoccidental. Seminario de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, 29 pp.
- CASTELLO, L. & CASTELLO, J.P. 2003. Anchovy

- stock (*Engraulis anchoita*) and larval growth in the SW Atlantic. *Fish. Res.*, 59 (3): 409-421.
- CASTELLO, J.P. & VASCONCELLOS, M.C. 1995. Growth rate of anchovy (*Engraulis anchoita*) larvae caught off Cape Santa Marta Grande (Brazil). *Arch. Fish. Mar. Res.*, 42 (3): 263-281.
- CEREMEÑO, P., URIARTE, A., DE MURGÍA, M. & MORALES-NIN, B. 2003. Validation of daily increment formation in otoliths of juvenile and adult European anchovy. *J. Fish. Biol.*, 62: 679-691.
- CIECHOMSKI, J.D. DE & SÁNCHEZ, R.P. 1983. Relationship between ichthyoplankton abundance and associated zooplankton biomass in the shelf waters off Argentina. *Biol. Ocean.*, 3 (1): 77-101.
- CIECHOMSKI, J.D. DE & SÁNCHEZ, R.P. 1984. Field estimates of embryonic mortality of Southwest Atlantic anchovy *Engraulis anchoita*. *Meeresforsch. Rap. Mar. Res.*, 30 (3): 172-187.
- COUSSEAU, M.B. 1982. Revisión taxonómica y análisis de los caracteres morfométricos y merísticos de la sardina fueguina (*Sprattus fuegensis*), Jenyns, 1842 (Pisces, Clupeidae). *Rev. Invest. Desarr. Pesq.*, 3: 77-94.
- CUSHING, D.H. 1975. *Marine Ecology and Fisheries*. Cambridge University Press, Cambridge, 278 pp.
- DULCIC, J. 1998. Larval growth of sprat, *Sprattus sprattus phalericus*, larvae in the Northern Adriatic. *Fish. Res.*, 36 (2, 3): 117-126.
- EKAU, W. 1998. Comparative growth analysis of *Engraulis anchoita* larvae from southern Brazil. *Arch. Fish. Mar. Res.*, 46 (1): 1-17.
- GLORIOSO, P.D. 1987. Temperature distribution related to shelf-sea fronts on the Patagonian Shelf. *Cont. Shelf Res.*, 7 (1): 27-34.
- GLORIOSO, P.D. & FLATHER, R. 1995. A barotropic model of the currents off SE South America. *J. Geoph. Res.*, 100 (C7): 13427-13440.
- GRU, D.L. & COUSSEAU, M.B. 1982. Estudio de edad y crecimiento de la sardina fueguina (*Sprattus fuegensis*) de las costas de la provincia de Santa Cruz e Islas Malvinas. *Rev. Invest. Desarr. Pesq.*, 3: 51-58.
- HOUDE, E.D. 1989. Subtleties and episodes in the early life of fishes. *J. Fish. Biol.*, 35 (A): 29-38.
- JONES, C. 1985. Within season differences in growth of larval Atlantic herring, *Clupea harengus harengus*. *Fish. Bull.*, 83 (3) 289-298.
- KITAHARA, E.M. & MATSUURA, Y. 1995. Growth and mortality estimate of the southwest Atlantic anchovy *Engraulis anchoita* larvae from Cape Santa Marta Grande in southern Brazil. *Arch. Fish. Mar. Res.*, 42 (3): 251-262.
- MAILLET, G.L. & CHECKLEY, D.M. 1990. Effects of starvation on the frequency of formation of growth increments in sagittae of laboratory-reared Atlantic menhaden *Brevoortia tyrannus* larvae. *Fish. Bull.*, U.S., 88 (1): 155-165.
- MARTEINSDOTTIR, G. & STEINARSSON, A. 1998. Maternal influence on the size and viability of Iceland cod *Gadus morhua* eggs and larvae. *J. Fish. Biol.*, 52: 1241-1258.
- MARTOS, P. 2000. Características del campo térmico en la plataforma patagónica entre 42 y 45° LS. *Inf. Téc. Int. DNI-INIDEP* 27, 13 pp.
- METHOT, R.D. & KRAMER, D. 1979. Growth of northern anchovy, *Engraulis mordax*, larvae in the sea. *Fish. Bull.*, U.S., 77: 413-423.
- MUNK, P. 1993. Differential growth of larval sprat *Sprattus sprattus* across a tidal front in the eastern North Sea. *Mar. Ecol. Prog. Ser.*, 99: 17-27.
- PANNELLA, G. 1971. Fish otoliths: daily growth layers and periodical patterns. *Science*, 173: 1124-1127.
- RAMÍREZ, F.C., MIANZAN, H.W., SANTOS, B. & VIÑAS, M.D. 1990. Zooplankton. Synopsis on the reproductive biology and early life history of *Engraulis anchoita*, and related environmental conditions in Argentine waters. In: *Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the South-*

- west Atlantic. IOC Workshop, Rep. 65, Anexo V: 4-6.
- RÉ, P. & CONÇALVES, E. 1993. Growth of sprat, *Sprattus sprattus*, larvae in the German Bight (North Sea) as inferred by otolith microstructure. Mar. Ecol. Prog. Ser., 96: 139-145.
- SABATINI, M.E. & ÁLVAREZ COLOMBO, G.L. 2001. Seasonal pattern of zooplankton in the Argentinian shelf off Southern Patagonia (45°-55° S). Sci. Mar., 65 (1): 21-31.
- SABATINI, M. & MARTOS, P. 2002. Mesozooplankton features in a frontal area off northern Patagonia (Argentina) during spring 1995 and 1998. Sci. Mar., 66 (3): 215-232.
- SABATINI, M.E., GIMÉNEZ, J. & ROCCO, V. 2001. Características del zooplancton del área costera de la plataforma patagónica austral (Argentina). Bol. Inst. Esp. Oceanogr., 17 (3, 4): 7-13.
- SÁNCHEZ, R.P. 1995. Patrones de distribución espacio-temporales de los estadios embrionarios y larvales de *Engraulis anchoita* (Hubbs & Marini, 1935) a micro y macroescala. Su relación con la supervivencia y el reclutamiento. Tesis de Doctorado, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, 630 pp.
- SÁNCHEZ, R.P. & CIECHOMSKI, J.D. DE. 1995. Spawning and nursery grounds of pelagic fish species in the sea-shelf off Argentina and adjacent areas. Sci. Mar., 59 (3,4): 455-478.
- SÁNCHEZ, R.P., ALHEIT, J., MARTOS, P. & PÁJARO, M. 1998. The spawning and early life of *Engraulis anchoita* in the tidal fronts off Patagonia. ICES Council Meeting Papers. Cascais, R: 1.
- SÁNCHEZ, R.P., CIECHOMSKI, J.D. DE, LASTA, C.A. & GUERRERO, R.A. 1999. A drift study of vertical distribution and mortality of *Engraulis anchoita* eggs and larvae. Rev. Invest. Desarr. Pesq., 12: 51-75.
- SÁNCHEZ, R.P., REMESLO, A., MADIROLAS, A. & CIECHOMSKI, J. 1995. Distribution and abundance of postlarvae and juveniles of the Patagonian sprat, *Sprattus fuegensis* and related hidrographic conditions. Fish. Res., 23: 47-81.
- SÁNCHEZ, R.P., MADIROLAS, A.O., RETA, R., PÁJARO, M., EHRLICH, M.D., ÁLVAREZ COLOMBO, G.L. & MACCHI, G.J. 1997. The reproductive biology of the patagonian sprat (*Sprattus fuegensis*): Several facts and still some speculations. ICES Council Meeting Papers. Baltimore, HH: 22.
- SECOR, D.H., DEAN, J.M., & LABAN, E.H. 1992. Otolith removal and preparation for microstructure examination. Can. J. Fish. Aquat. Sci., 117: 19-57.
- SMITH, P.E. 1985. Year-class strength and survival of 0-group clupeoids. Can. J. Fish. Aquat. Sci., 42 (1): 69-82.
- SOKAL, R.R. & ROHLF, F.J. 1995. Biometry. The principles and practice of statistics in biological research. Freeman, New York, 887 pp.
- THOMAS, R.M. 1986. Growth of larval pelagic fish in the South-East Atlantic from daily otolith rings in 1982/83 and 1983/84. S. Afr. J. Mar. Sci., 4: 61-77.
- TSUJI, S. & AOYAMA, T. 1984. Daily growth increments in otoliths of Japanese anchovy larvae *Engraulis japonicus*. Bull. Japan. Soc. Sci. Fish., 50: 1105-1108.
- VALENZUELA, G.S. & VARGAS, C.A. 2002. Comparative larval growth rate of *Sprattus sprattus* in relation to physical and biological oceanographic features in the North Sea. Arch. Fish. Mar. Res., 49 (3): 213-230.
- WATANABE, Y. & KUROKI, T. 1997. Asymptotic growth trajectories of larval sardine (*Sardinops melanosticus*) in the coastal waters off western Japan. Mar. Biol., 127: 369-378.
- WATANABE, Y. & NAKAMURA, M. 1998. Growth trajectory of the larval Japanese sardine *Sardinops melanosticus* transported into the Pacific coastal waters off central Japan. Fish. Bull., 96: 900-907.
- ZWEIFEL, J.R. & LASKER, R. 1976. Prehatch and

posthatch growth of fishes - A general model.  
Fish. Bull., U.S., 74: 609-621.

*Recibido: 05-10-2007*  
*Aceptado: 27-03-2009*