

GROWTH IN THE 0-GROUP OF ARGENTINE HAKE (*Merluccius hubbsi*) FROM THE ARGENTINE-URUGUAYAN COMMON FISHING ZONE*

by

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RESUMEN

Crecimiento del grupo de edad 0 de la merluza argentina (*Merluccius hubbsi*) de la Zona Común de Pesca Argentino-Uruguaya. Se realizó un estudio del crecimiento en el grupo de edad 0 de la merluza (*Merluccius hubbsi*) de la Zona Común de Pesca Argentino-Uruguaya. La fecha de desove se retrocalculó, identificando los anillos diarios de crecimiento en los otolitos de ejemplares (14-69 mm LT) capturados en campañas de investigación realizadas en mayo de 1997, mayo de 1998 y junio de 1999. Los incrementos se leyeron bajo microscopio y utilizando el sistema de medición de anillos diarios (RATOC). Los cambios en los anchos de los incrementos muestran un patrón que parece ser similar e independiente de la fecha de nacimiento entre los individuos analizados. Se hallaron altos ajustes de los datos observados y retrocalculados al modelo de Laird-Gompertz. En todas las comparaciones de las curvas de crecimiento se hallaron diferencias significativas entre los coeficientes a partir de los datos observados y retrocalculados. Las tasas de crecimiento estimadas a partir de los datos observados mostraron los valores más altos (ca. 0,54 mm d⁻¹) para las larvas tardías y los mínimos (ca. 0,25 mm d⁻¹) para los juveniles tempranos más grandes. Las épocas de desove retrocalculadas para los tres años se corresponden con la escasa actividad reproductiva de mediados de verano.

SUMMARY

Growth of hake (*Merluccius hubbsi*) in the 0-group from the Argentine-Uruguayan Common Fishing Zone was studied and spawning data were back-calculated by identifying daily growth rings in otoliths of specimens caught during research cruises performed in May 1997, May 1998 and June 1999. Total length (TL) range was 14-69 mm. Increments were read under microscope using an otolith daily ring measurement system (RATOC). Changes in the increment width data present a pattern that seemed to be similar, and independent from birth date of individuals. Data observed and back-calculated showed good accordance with the Laird-Gompertz model. Significant differences between coefficients were found in all comparisons of growth curves for observed and retrocalculated data. Growth rates estimated from observed data showed maximum values (ca. 0.54 mm d⁻¹) at the stage of late larvae and minimum values at the stage of large early juveniles (ca. 0.25 mm d⁻¹). For each year back-calculated hatching dates corresponded to the scarce mid-summer reproductive activity.

Key words: *Merluccius hubbsi*, growth, larvae, juveniles, Southwest Atlantic.

Palabras clave: *Merluccius hubbsi*, crecimiento, larvas, juveniles, Atlántico Sudoccidental.

INTRODUCTION

Merluccius hubbsi, or Argentine hake, is distributed over the Argentine-Uruguayan Common Fishing Zone (AUCFZ) (Figure 1) and the Argentine Sea mainly at 50-800 m depth and mostly concentrated in the region between 35° S and 48° S. The species is the basis of commercial fisheries in Argentine and Uruguayan waters (Bezzi *et al.*, 1995).

In the distribution area north of 41°S, fishing mortality increased from 1986 to 1998 and total and spawning biomasses declined from 1986 to 1999. During that period the cohorts of 1996, 1997 and 1998 were considered as weak ones, but 1999 seemed to be a year of good recruitment (Renzi *et al.*, 2002).

Most early life history studies of *M. hubbsi* focused on egg and larval stages (Ciechomski and Weiss, 1974 a and b; Ciechomski *et al.*, 1975; 1979;

Ehrlich and Ciechomski, 1994), while studies on early juveniles are scarce (Ehrlich, 1998; Ehrlich, 2000).

The analysis of daily increments in otoliths has been widely applied since Pannella, (1971), including the determination of daily age and hatch date, growth rate, and mortality rate. When these estimates are combined with independent information such as population abundance, oceanographic conditions, and spawning patterns, factors influencing recruitment (i.e. year class strength) can be evaluated.

There are only two studies (Santos and Renzi, 1999; Brown *et al.*, 2004) where daily rings in *M. hubbsi* were identified, and growth rates of individuals younger than a year were estimated. The aim of this work is to study growth of late larvae and early juveniles of *M. hubbsi* from the AUCFZ, by analysing the daily growth of individuals of three years classes: 1997, 1998 and 1999.

MATERIALS AND METHODS

Collection of samples

Late larvae (14-35 mm TL) and early juveniles (36-69 mm TL) (Ehrlich, 1998) were collected in May (1997, 1998) and June (1999) (Table 1) in the AUCFZ during cruises of the R/V's "Dr. E. L. Holmberg" and "Cap. Oca Balda", of INIDEP (National Institute for Fisheries Research and Development) (Figure 1).

Demersal mini trawls (referred to as PILOT, 2.4 m² of net mouth, 25 mm mesh at wing, 10 mm mesh at cod end) were used for sampling.

Table 1. Hake surveys in the Argentine-Uruguayan Common Fishing Zone. n = number of specimens analysed.

Tabla 1. Campañas de investigación en la Zona Común de Pesca Argentino-Uruguaya. n = número de especímenes analizados.

| Survey | H-06/97 | OB-05/98 | H-05/99 |
|--------|-------------|-------------|------------|
| Date | 25-30/05/97 | 22-27/05/98 | 5-11/06/99 |
| n | 58 | 67 | 63 |

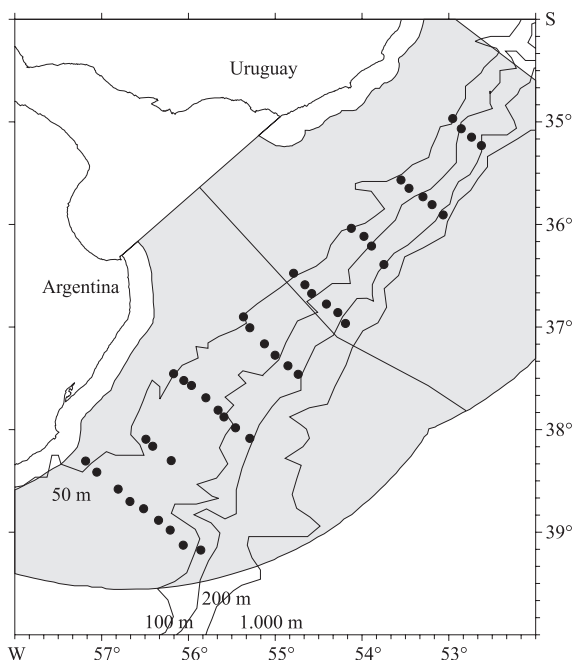


Figure 1. Sampling sites. The Argentine-Uruguayan Common Fishing Zone is shown.

Figura 1. Sitios de muestreo. Se indica la Zona Común de Pesca Argentino-Uruguaya.

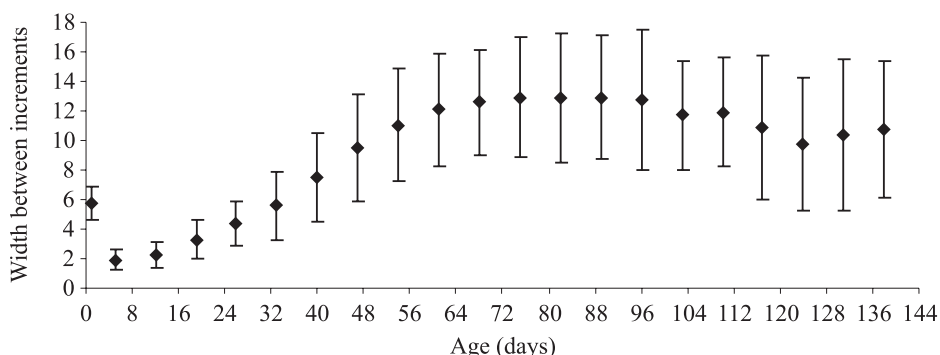


Figure 2. Weekly average of daily width increments (in μm) ($n = 65$). Vertical bars: standard deviations.

Figura 2. Promedio semanal de los anchos de los incrementos diarios (en μm) ($n = 65$). Barras verticales: desviación estándar.

Specimens were frozen or preserved in ethanol to be processed in the laboratory.

Otolith treatment

Almost 100 specimens of late larvae and early juveniles were sampled in each cruise and sagittae otoliths removed, but some losses during polishing to locate the otolith core yielded a lower number of samples (Table 1). Otoliths were mounted on a glass slide in transparent nail polish. Then they were ground from the internal side using a wet sandpaper of 1,200 grit and lapping film (12 μm , 9 μm , 3 μm mesh) to obtain a clear image from the nucleus to the posterior edge. Otolith daily increments were observed under an optical microscope ($\times 200$ –1,000). The maximum radius, number, and width of each increment were recorded using the otolith daily ring measuring system (RATOC System Engineering Co., Ltd), which is composed of a light microscope, a video camera and monitor, and an image analyser controlled by a computer.

Data analysis

The ratio likelihood test (Fomby *et al.*, 1984) between coefficients of otolith radius and fish total length relationship was performed. A linear model was fitted to the data.

Hatch dates were back-calculated from the age and date of capture.

A daily deposition was assumed since eclosion, and the mean length at the moment of the first ring (L_0) was taken from Brown *et al.* (2002), $L_0 = 2.01$ mm.

Observed and back-calculated data were fitted by the Laird-Gompertz model. Comparison between years was made using maximum likelihood estimation (Aubone and Wöhler, 2000), and so allowing to test each parameter individually and all the parameters together; this method was adapted to analyse the Laird-Gompertz model by Di Marco¹.

In addition, and to compare water temperatures in which hake had been spawning, monthly sea surface temperatures during January, February, March and April were taken from the Climate Data Library of the IRI/LDEO (2002).

RESULTS

Individual growth trajectories

The increment width data, which shows individual growth trajectory, presented a pattern that seemed to be similar and independent of birth date (Figure 2). The initial rings (*ca.* 20 days) were very

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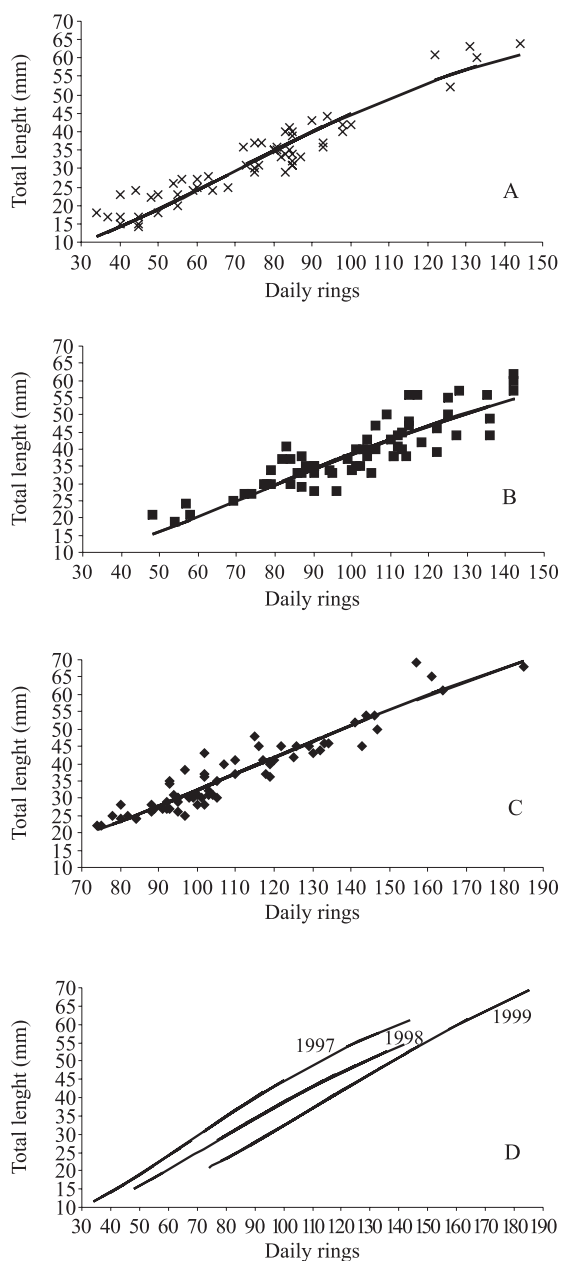


Figure 3. Late larvae and early juveniles standard length on daily ring data for each year, and Laird-Gompertz growth curves fitted to each year of data (A: 1997, B: 1998, C: 1999, D: Laird Gompertz curves corresponding to each year).

Figura 3. Anillos diarios según la longitud de larvas tardías y juveniles tempranos y curva de crecimiento de Laird-Gompertz ajustada para los datos de cada año (A: 1997, B: 1998, C: 1999, D: curvas de Laird Gompertz correspondientes a cada año).

thin (except the first one), and then they increased in width up to almost day 70. The maximum growth was maintained for a period of almost 25 days and after that it slowed down to almost day 125 when it increased again.

Comparative study

No significant differences between coefficients of total length and maximum otolith ratio were found in 1997-1998 and 1998-1999, as they were, considering 1997-1999 (Table 2 A). The relationships were expressed by a linear regression for each year (Table 2 B).

Table 2. Fish length/otolith radius relationship. A) Parameters of the linear model. B) Comparison of coefficients. (a: intercept; b: slope; se: standard error of estimate).

Tabla 2. Relación largo del pez/radio del otolito. A) Parámetros del modelo lineal. B) Comparación de los coeficientes. (a: ordenada al origen; b: pendiente; se: error estándar de estimación).

| A | | | | | |
|------|----------------|----|--------|--------|-------|
| Year | r ² | n | a | b | se |
| 1997 | 0.954 | 46 | 28.542 | 229.32 | 2.429 |
| 1998 | 0.947 | 65 | 27.705 | 210.03 | 2.364 |
| 1999 | 0.976 | 45 | 27.103 | 172.56 | 1.919 |

| B | | | |
|-----------|-----------------|--------|----|
| Year | F | P | |
| 1997-1998 | 0.8452 (2,107) | 0.5685 | ns |
| 1997-1999 | 47.492 (2,870) | 0.0000 | ** |
| 1998-1999 | 2.0938 (2, 106) | 0.1283 | ns |

Observed and back-calculated data showed a good fit of the Laird-Gompertz model (Figure 3 and Table 3).

Growth rates estimated from the 1997 data showed maximum values (*ca.* 0.54 mm d⁻¹) at the stage of late larvae and minimum values at the stage of large early juveniles (*ca.* 0.25 mm d⁻¹) (Figure 4 A). Back-calculated growth rates were observed to increase at lengths from 2.2 mm (L₀) to 30 mm (0.56 mm d⁻¹) and began to decrease at

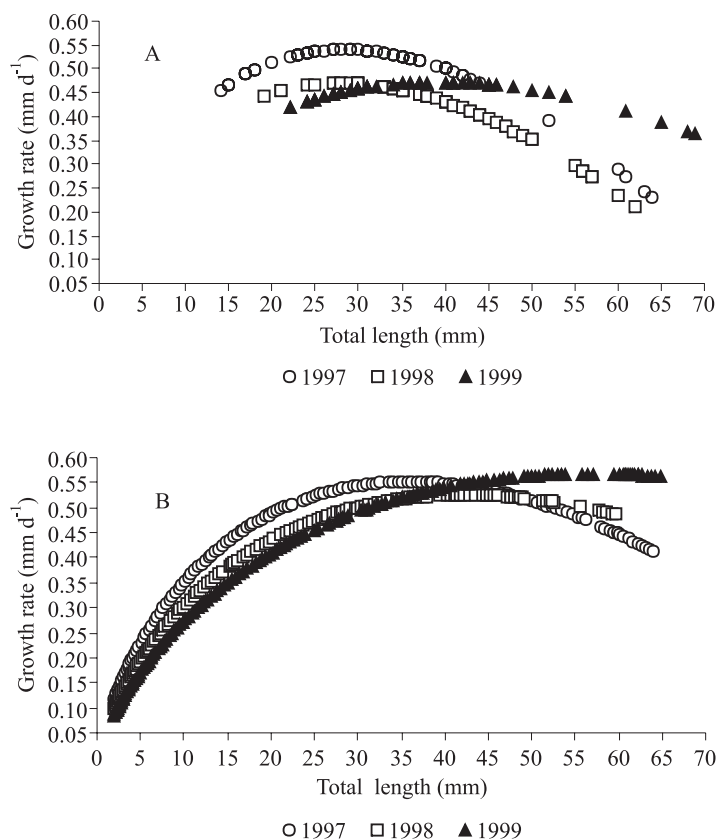


Figure 4. Observed (A) and back-calculated (B) growth rate derived from the model on total length data for each year.
 Figura 4. Tasa de crecimiento derivada del modelo observada (A) y retrocalculada (B) de acuerdo a los datos de longitud total para cada año.

lengths *ca.* 41 mm to 65 mm (0.40 mm d⁻¹) (Figure 4 B).

From the 1998 data growth rates reached their maximum values at a length of 24 mm and began to decline at 30 mm (Figure 4 A). They were lower than in 1997 in all the size ranges sampled. Back-calculated growth rates derived from the model resulted in increasing rates (0.52 mm d⁻¹) up to 40 mm and a slight decrease beyond 46 mm (Figure 4 B).

Considering 1999, growth rates derived from the model were the highest (0.47 mm d⁻¹) between 34 and 47 mm, whereas back-calculated growth rates reached the maximum at 52 mm and were similar up to 65 mm (Figure 4 A and B). Comparing with the other two years, growth in

Table 3. Laird-Gompertz growth model parameters from observed (A) and back-calculated data (B).

Tabla 3. Parámetros del modelo de crecimiento de Laird-Gompertz a partir de datos observados (A) y retrocalculados (B).

| A | | | |
|------|----------------|------|-------|
| Year | r ² | k | G |
| 1997 | 0.99 | 3.60 | 0.019 |
| 1998 | 0.78 | 3.60 | 0.017 |
| 1999 | 0.89 | 3.97 | 0.012 |
| B | | | |
| Year | r ² | k | G |
| 1997 | 0.89 | 3.90 | 0.015 |
| 1998 | 0.99 | 4.05 | 0.012 |
| 1999 | 0.99 | 4.34 | 0.010 |

Table 4. Growth parameters estimations, standard error (SE), coefficient of variation (CV), and lower and upper limit of variation for observed data per year.

Tabla 4. Estimaciones de los parámetros de crecimiento, error estándar (SE), coeficiente de variación (CV) y límite inferior y superior de variación de los datos observados para cada año.

| Year | k | G | CI (95%) | | | | | | | |
|------|-------|-------|----------|-------|--------|-------|-------------|-------|-------------|-------|
| | | | SE | | CV (%) | | Lower limit | | Upper limit | |
| | | | k | G | k | G | k | G | k | G |
| 1997 | 3.648 | 0.019 | 0.067 | 0.001 | 1.842 | 4.960 | 3.514 | 0.017 | 3.783 | 0.021 |
| 1998 | 3.615 | 0.017 | 0.091 | 0.001 | 2.518 | 7.225 | 3.433 | 0.015 | 3.796 | 0.020 |
| 1999 | 3.974 | 0.012 | 0.080 | 0.001 | 2.020 | 4.657 | 3.813 | 0.011 | 4.134 | 0.013 |

Table 5. Growth parameter estimations, standard error (SE), coefficient of variation (CV), and lower and upper limit of variation for back-calculated data per year.

Tabla 5. Estimaciones de los parámetros de crecimiento, error estándar (SE), coeficiente de variación (CV) y límite inferior y superior de variación de los datos retrocalculados para cada año.

| Year | k | G | CI (95%) | | | | | | | |
|------|--------|--------|----------|--------|--------|--------|-------------|--------|-------------|--------|
| | | | SE | | CV (%) | | Lower limit | | Upper limit | |
| | | | k | G | k | G | k | G | k | G |
| 1997 | 3.8795 | 0.0154 | 0.0096 | 0.0001 | 0.2465 | 0.6655 | 3.8606 | 0.0152 | 3.8984 | 0.0156 |
| 1998 | 4.0468 | 0.0124 | 0.0248 | 0.0002 | 0.6139 | 1.3634 | 3.9977 | 0.0121 | 4.0960 | 0.0128 |
| 1999 | 4.3414 | 0.0100 | 0.0276 | 0.0001 | 0.6364 | 1.3427 | 4.2868 | 0.0097 | 4.3959 | 0.0103 |

1999 showed the lowest rates in almost all the size ranges studied, but larger juveniles exhibited the highest.

Significant differences between coefficients were found in all comparison of growth curves (1997-1998; 1998-1999; 1997-1999) for observed and retrocalculated data when both parameters were compared together (Tables 4 and 5). However, when comparison of 1997-1998 years of observed data was performed for each parameter individually, no significant differences were found, which means that one parameter alone does not explain the differences between those years (Table 6 and 7).

Hatch date estimation

Hatching dates were back-calculated for each year (Figure 5). In 1997 we obtained the

smallest larvae, so an autumn spawning could have been registered but the bulk of the larval corresponded to mid February mid March (late summer). In 1998 most of the individuals seemed to have been born by the end of January and during February. In 1999 the majority of survivors were from late summer. It is important to consider that the hatch date distribution is biased by mortality.

Comparing sea surface temperature in the spawning periods among the three years (Table 8), January of 1997 and March of 1999 were the warmest, the first with a low hatch frequency and the second with a high one. On the other hand, the coldest March (1997) presented also a high number of births (Figure 6). It is evident from this description that more data from each year are needed to make a statistic test which may allow us to reach a conclusion.

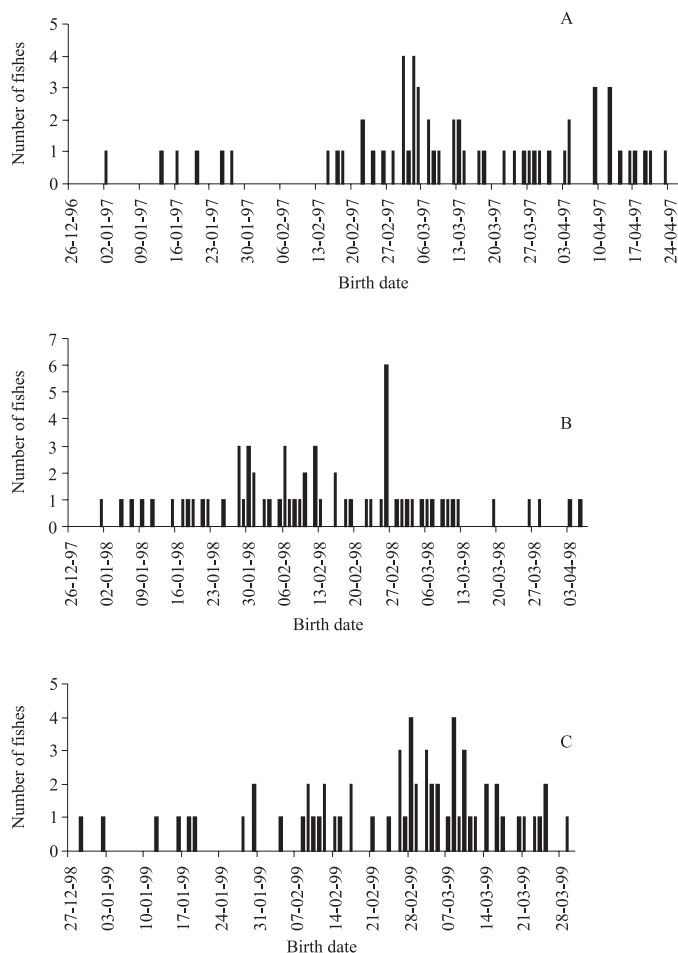


Figure 5. Back-calculated spawn dates for 1997 (A), 1998 (B) and 1999 (C).
 Figura 5. Fechas de desove retrocalculadas para 1997 (A), 1998 (B) y 1999 (C).

DISCUSSION

Hake presents a Patagonian reproductive area in summer (stock south of 41° S) and a northern one between 34° S and 39° S (stock north of 41° S), with spawning peaks during autumn and winter (Ehrlich and Ciechomski, 1994; Ehrlich, 2000). Because of the timing of the research cruises analysed here, most of the studied individuals corresponded to the scarce reproductive activity of ending summer, and were born in February and March (Figure 5).

The bulk of the pre-recruits examined in this

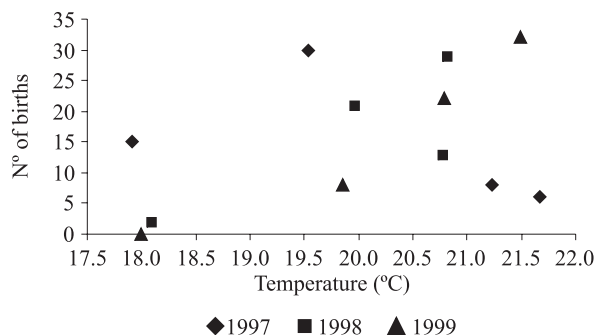


Figure 6. Sea surface temperature versus back-calculated number of births.

Figura 6. Temperatura de superficie del agua de mar versus número de nacimientos retrocalculados.

Table 6. Comparison of parameters of Laird-Gompertz model by maximum likelihood of observed data between years 1997-1998, 1997-1999, and 1998-1999.

Tabla 6. Comparación de los parámetros del modelo de Laird-Gompertz por máxima verosimilitud de los datos observados entre los años 1997-1998, 1997-1999 y 1998-1999.

| Years | H ₀ : k1=k2; G1=G2 | | H ₀ : k1=k2 | | H ₀ : G1=G2 | |
|-----------|-------------------------------|---------|------------------------|---------|------------------------|---------|
| | chi ² | P | chi ² | P | chi ² | P |
| 1997-1998 | 30.77 | 0.00001 | 0.09 | 0.7627 | 1.42 | 0.2337 |
| 1997-1999 | 126.37 | 0.00001 | 45.43 | 0.00001 | 60.60 | 0.00001 |
| 1998-1999 | 54.03 | 0.00001 | 8.59 | 0.0034 | 5.77 | 0.0163 |

Table 7. Comparison of parameters of Laird-Gompertz model by maximum likelihood of back-calculated data between years 1997-1998, 1997-1999 and 1998-1999.

Tabla 7 Comparación de los parámetros del modelo de Laird-Gompertz por máxima verosimilitud de los datos retrocalculados entre los años 1997-1998, 1997-1999 y 1998-1999.

| Years | H ₀ : k1=k2; G1=G2 | | H ₀ : k1=k2 | | H ₀ : G1=G2 | |
|-----------|-------------------------------|-------------|------------------------|-------------|------------------------|-------------|
| | chi ² | P | chi ² | P | chi ² | P |
| 1997-1998 | 589.50 | 9.8012E-129 | 47.67 | 5.05337E-12 | 174.29 | 8.56556E-40 |
| 1997-1999 | 848.61 | 5.3166E-185 | 232.59 | 1.62223E-52 | 425.82 | 1.32308E-94 |
| 1998-1999 | 321.43 | 1.59549E-70 | 55.83 | 7.88713E-14 | 105.56 | 9.18994E-25 |

Table 8. Mean sea surface temperature (°C) during back-calculated hatch periods (standard deviations indicated between brackets).

Tabla 8. Temperatura media de la superficie del mar (°C) durante los periodos de desove retrocalculados (entre paréntesis se indica la desviación estándar).

| Year | January | February | March | April |
|------|--------------|--------------|--------------|--------------|
| 1997 | 21.67 (1.95) | 21.23 (2.08) | 19.54 (2.17) | 17.91 (2.30) |
| 1998 | 19.97 (1.66) | 20.82 (1.54) | 20.77 (1.31) | 18.10 (1.45) |
| 1999 | 19.85 (1.87) | 20.79 (1.65) | 21.50 (1.91) | 17.99 (1.82) |

work were distributed between 50 m and 100 m south of 37° S and between 50 m and 150 m north of that latitude, as shelf becomes narrower (Ehrlich, 2000). In 1997 length frequency distribution showed the mode around 34-36 mm, in 1998 the mode was at 40 mm and in 1999 pre-recruits were dominated by late larvae (Machinandiarena *et al.*, 2003).

Analysing otolith growth Campana and Neilson (1985) stated that changes in the width increments are generally related to phases in larval and juvenile life. In addition Gutiérrez and

Morales-Nin (1986), studying growth of *Dicentrarchus labrax* larvae, identified three phases of growth data series each corresponding to a stage of development. In this study, changes in the increment width that could be considered as phases (Figure 2) were also found. This pattern differed relatively little within any given year, suggesting that individuals shared some common growth history. Based on these preliminary observations, Buratti (2003) studied in detail the *M. hubbsi sagittae* otoliths microstructure. He concluded that the progressive increase in the width

of increments from the nucleus until the edge of the primordium, represents the pelagic life of the larvae, the gradual transition to the demersal habit and the end of the metamorphosis. The whole process is completed, in average, in 65 days when the larvae reach *ca.* 30 mm. Ehrlich (1998) stated that *M. hubbsi* larvae begin to settle on the bottom when they reach 20 mm length, staying there during daylight and migrating to mid water at night as the adults do. The second phase of growth, when it slows down and increases again, is not clear yet and will be considered in a future study.

Temperature may act on the thickness of daily increments as a result of its effect on metabolism (Marshall and Parker, 1982). We used width between rings as a measure of growth based on the high correlations found between otolith radius and fish length (Table 2).

Early larvae had the lowest growth rates (<0.30 mm d⁻¹, from back-calculated values) in the three years studied. Brown *et al.* (2002) found similar growth in *M. hubbsi* early larvae from the southern stock unit. Back-estimated growth rates of young larvae (≤ 20 days) showed that growth was similar among years (Figure 4 B) as Butler and Nishimoto (1997) found for *M. productus*.

In this research work, results for juvenile growth rates were similar to those of Hollowed (1992) for *M. productus*, derived from length-frequency data, and lower than those of Woodbury *et al.* (1995). Larger juveniles showed similar growth in 1997 and 1998 but the highest growth rates corresponded to 1999, a year for which a strong year class was assessed (Renzi *et al.*, 2002) even though the rest of other growth rates estimated for this year were the lowest.

Although there could be some potential sources of error in otolith microstructure examination, like using over or underground preparations, the resolution of light microscopy for increments less than 2 μm apart (Neilson, 1992), and the assumed bias in back-calculation (Campana, 1990), it is considered that useful information was obtained from daily growth which will help for

understanding the recruitment process of the hake population in the area.

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