Gayana 81(1): 28-31, 2017.
Short communication
ISSN 0717-652X

Age of Jack mackerel *Trachrus murphyi* (Carangidae) using daily growth rings in sagittae otoliths

Edad de jurel *Trachurus murphyi* (Carangidae) usando incrementos diarios en otolitos sagittae

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ABSTRACT

Growth of Jack mackerel (*Trachurus murphyi*) was estimated using daily growth rings in fish collected in central-south Chile from 2004 to 2011. The von Bertalanffy growth curve at length for both sexes (n=210 individuals) is $FL_t = 75*[1-e^{-0.16(t+0.13)}]$ where FL_t is fork length (cm) at time t (years).

Keywords: age, Chile, daily growth rings, Jack mackerel, sagittae otoliths, *Trachurus murphyi*.

RESUMEN

Se estimó el crecimiento del jurel (*Trachurus murphyi*) usando anillos de crecimiento diario en peces colectados en Chile centro-sur desde 2004 hasta 2011. La curva de crecimiento en longitud de von Bertalanffy para sexos conjuntos (n=210 individuos) es $FL_t = 75*[1-e^{-0,16(t+0,13)}]$ donde LH_t es la longitud horquilla (cm) a tiempo t (años).

Palabras clave: anillos de incremento diario, Chile, edad, jurel, *Trachurus murphyi*.

Trachurus murphyi (Nichols, 1920) is a mid-size pelagic fish species distributed mainly in the South Eastern Pacific Ocean off Ecuador, Peru and Chile (Agafonov 1994). In the 1990s, it was also dispersed along the Subtropical Convergence Zone (35°S to 50°S) in the so-called "Jack mackerel belt" from the Chilean coast to New Zealand (Grechina 1998; Sokolov & Kusnetsov 1994). The peak of annual harvests of *T. murphyi* was 4.40 millions of tones in 1995, which represented 89% of the total harvests in that year considering jointly the Chilean purse seine fleets (north and central-south), the Peruvian purse seine fleet and the offshore mid-water trawling factory fleets. However, total harvests of *T. murphyi* in year 2014 were 395 thousand of tones, only (Table A4.1 in Anonimous, 2014).

Studies on age and growth in species that sustain fisheries are important in stock assessment models and management (Williams et al. 2013) in order to estimate abundance by ages. Besides, natural mortality (M) is an input for stock assessment and is frequently estimatedas a function of the instantaneous coefficient of growth, K (Jensen, 1996; Hoenig 1983; Pauly 1980). The objective of this study was to estimate the parameters of the von Bertalanffy length growth equation for *T. murphyi* using daily growth rings in sagittae otoliths.

Annual growth ring counts in sagittae otoliths have been used to age individuals of *T. murphy I* (Aguayo et al. 1981; Pavez & Saa 1978). But, mean ages for fish with 58 to 60 cm of fork length (FL) ranged from 8 to 16 years (Kochkin 1998). However, determining age in species of *Trachurus* may be complex, since the annual growth rings are difficult to interpret (Araya et al. 2001; Steward & Ferrell 2001; Waldron & Kerstan 2001). Panella (1971) developed a technique to determine age and daily growth rate in sagittae otoliths of *Merluccius bilinearis*. Later, Panella (1974) demonstrated that the annual marks detected in sagittae otoliths of marine species contain 365 daily increments, aproximately. For *T. murphyi*, Araya et al. (2003) validated experimentally the daily frequency of the micro-increments in sagittae otoliths.

210 right sagittae otoliths of *T. murphyi*, from 18 to 60 cm FL, were mounted in polyesther resin. Fish were

collected from year 2004 to 2011 off central Chile. The aim was to follow a cohort during its pass in the fishery.

According to Morales-Nin (1991) and Green et al. (2009), sections in the sagittae otoliths of *T. murphyi* (thickness: 0.5 mm) were obtained and later they were by hand polished (thickness: 0.3 mm).

Daily growth increments in sagittae otoliths were seen under an Olympus CX31-RTSF-2 optical microscope (1000X) as alternately clear and dark concentric rings (Araya et al. 2003). Counts were performed following the radius of the otolith. The density of increments was counted using an ocular reticulate with 100 divisions. Following to Panfili & Morales-Nin (2002), a scanning electron microscope (Center of Spectrometry and Electronic Microscopy, Universidad de Concepción, Chile) was used to observe daily increments.

The generalized von Bertalanffy equation of individual length growth is

$$FL_t = FL_\infty * \left[1 - e^{-K(t-t_0)}\right]$$

where FL_∞ (cm) is the theoretical maximum length or asimptotic length, K (year^{-1}) is the instantaneous coefficient of growth, t_0 (years) is the theoretical time at length 0, and t is time (years). For species of *Trachurus* the fork length (FL) is used. Parameters were estimated with the software R (R Development Core Team. "R: A language and environment for statistical computing". R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org. 2004). In order to estimate better the parameter K and to avoid bias, FL_∞ was estimated according to Taylor (1962 *fide* Pauly, 1983), who communicated that the oldest fish of a stock grow to reach about 95 percent asymptotic length. The largest individuals of *T. murphyi* sampled on board of industrial purse seine vessels operating off central Chile, in the period 2004-2011, had 71 cm FL. So, it was assumed that 71 cm FL represents 95% of FL_∞, which means that FL_∞ is ~ 75 cm FL.

The smallest daily increments in otolith were those close to the center (Fig. 1). The width of daily increments in the border of an otolith was 1.36 µm in one fih of 51 cm FL, but near the border the width was 1.84 µm (Fig. 2). The parameters of the von Bertalanffy length growth equation in *T. murphyi* are shown in Table 1 and the growth curve in Fig. 3.

Historically, the read of annual rings in entire otoliths has been used to determine the age in adults of *T. murphyi*, but considerable variations has been found. K values in this species have ranged from 0.07 year^{-1} (Castillo & Arrizaga 1987) to 0.14 year^{-1} (Kaiser 1973), likely due to the preparation technique used, difficulties in interpretation criteria of annual rings, and confusion with double and/or false rings. However, Cubillos and Arancibia (1994) informed K = 0.138 year^{-1} using the Wetherall (1986) method with 10 years of length-frequency data. Later, Cubillos and Grechina (1998) informed K = 0.144 year^{-1} using the modal progression analysis seasonally from 1987 to 1992. Comparatively, in the present study K = 0.16 year^{-1}, which is close similar to K = 0.155 year^{-1} informed by Dioses (2013) with samples off Peru. Indirectly, with the present study are validated the Dioses' (2013) results, who had used correctly the technique of annual rings.

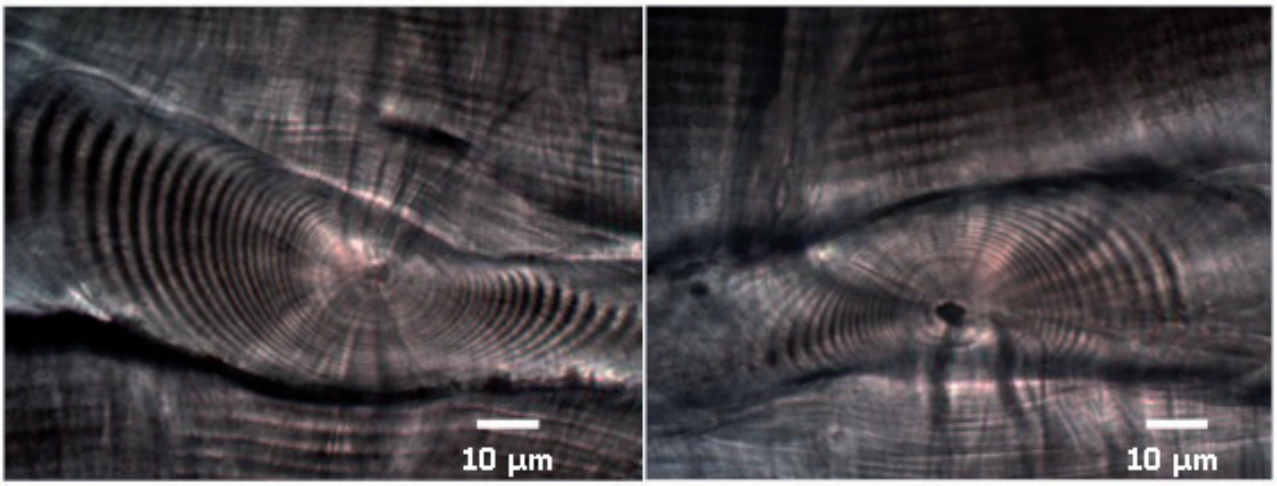

Figure 1. Optical microscope photographs (1000X) showing the center of sagittae otoliths in individuals of *T. murphyi* of 18 cm (left) and 41 cm (right) of fork length. / Fotografía en microscopio óptico (1000X) muestra el centro del otolito sagittae en individuos de *T. murphyi* de 18 cm (izquierda) y 41 cm (derecho) de longitud horquilla.

In the present study, some bias could be observed in the fit of the von Bertalanffy length growth curve in *T. murphyi* (Fig. 3), with observed data above the fitted curve for fish of 5 years old and older, and below the curve for fish younger than 5 years. Coincidently, old individuals of *T. murphyi* were more frequently caught by the factory purse seine vessels that were operating far from the Chilean Economic Exclusive Zone (EEZ), from 31°S to 46°S and westwards, where fish are larger and older than within the Chilean EEZ. Then, likely two cohorts of *T. murphyi* have been combined in Fig. 3. However, in any case the results of the present study are invalid with this likely bias.

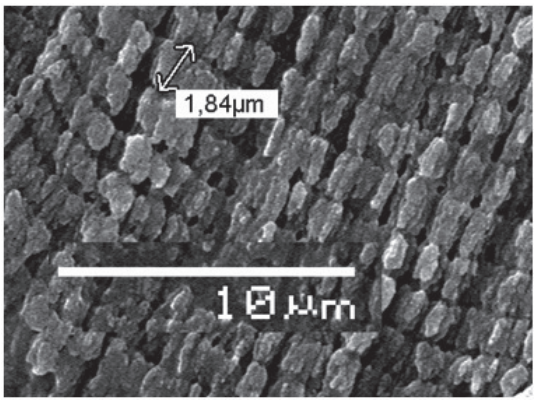

Figure 2. Daily ring width of 1.84 µm near the border in scanning electron micrographs for a fish of 51 cm of fork length. / Ancho de un microincemento diario cercano al borde 1.84 µm para un pez de 1 cm de longitud horquilla, micrografía electrónica de barrido.

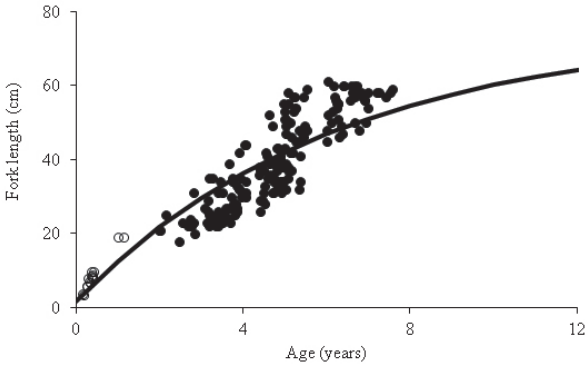

Figure 3. Fit of the von Bertalanffy length growth curve in *T. murphyi.* Solid dots: observed data (central Chile; n=210 otholits); open dots: Peruvian data from Anonimous (2014; n=17 otholits). / Ajuste del crecimiento de von Bertalanffy en longitud a *T. murphyi*. Puntos sólidos: datos observados (Chile central; n=210 otolitos); puntos achurados: datos anonimos estimados en Perú (2014; n=17).

Table 1. Length growth parameters of the von Bertalanffy equation estimated for *T. murphyi. /* Parámetros de crecimiento en longitud de la ecuación de von Bertalanffy estimada para *T. murphyi.*

Parameters	Value	Standard Error	t-value	95% confidence limits		P >|t|
FL_∞ (cm)	75.0	10.1	7.4	55.0	95.01	0.00
K ($year^{-1}$)	0.16	0.04	4.26	0.09	0.23	0.00
t_0(years)	-0.13	0.17	-2.73	-0.47	0.22	0.01

ACKNOWLEDGEMENTS

L.C. thanks to Insituto de Investigación Pesquera (INPESCA) for the otolith samples, to CONICYT due to the a grant for M.Sc. studies, and to Postgraduate Division at the Universidad de Concepción due to a scholarship to carry out my studies.

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Recibido: 28.04.2017
Aceptado: 30.05.2017