NOTA

MORPHOMETRIC ANALYSIS OF *SAGITTA* OTOLITH OF *Salilota australis* (GÜNTHER, 1878) (PISCES: MORIDAE) OF THE SOUTHERN PATAGONIAN SHELF, ARGENTINA*

by

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RESUMEN

Análisis morfométrico del otolito *sagitta* de *Salilota australis* (Günther, 1878) (Pisces: Moridae) de la plataforma continental patagónica, Argentina. Se estudió la morfometría del otolito *sagitta* de *Salilota australis*. La variable longitud permitió estimar el largo total de los ejemplares utilizando regresiones potenciales.

SUMMARY

The morphometric parameters of *Salilota australis sagitta* otolith were measured. The length variable allowed to estimate the total length of individuals using potential regressions.

Palabras clave: Morfometría de otolitos, relaciones alométricas, estudios tróficos, Moridae, *Salilota australis*, Océano Atlántico Sudoccidental.
Key words: Otolith morphometry, allometric relations, trophic studies, Moridae, *Salilota australis*, Southwest Atlantic Ocean.

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Tadpole codling (*Salilota australis*, Gadiformes: Moridae) is a demersal fish living exclusively in the southernmost part of South America in both, Pacific and Atlantic Oceans (Wöhler *et al.*, 2001). At present, no different populations were identified within the distribution area. *S. australis* is a demersal-benthonic predator that performs trophic migrations in the water column (Wöhler, 1987; Wöhler *et al.*, 2004). Tadpole codling is consumed by austral predators of commercial interest such as pink cuskeel**,** southern hake, longtail hake and some rays and sharks (Sánchez and Prenski, 1996; Wöhler *et al.,* 2004) thus placing the species in a key position in the austral trophic web. On the other hand, *sagittae* otoliths present in gut content are widely used to identify preys for trophic studies (Ross *et al.*, 2005). Fishery biologists use said methodology as a proxy indicator of fish distribution and to quantify the potential effects of natural predation (Mauco *et al*., 2001; Waessle *et al*., 2003). The objectives of this work were to study the morphometry of *S. australis sagitta* otolith and to analyze potential regressions between fish total length and morphometric variables or *sagittae* weight. Such regressions will allow to estimate the prey size in trophic web studies in the cold-temperate seas of South America.

Sampling surveys were carried out by the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP). Bottom trawling performed on the Argentine marine platform in the 1999, 2006 and 2007 austral summer (December-March) during demersal species survey cruises between 45° S-56° S, at 50-350 m depth, allowed to collect 348 specimens (Figure 1). Fish was discriminated by sex and total length (TL) measured to the nearest mm. Morphometric variables such as length (OL), width (OW) and thickness (OT) of the right *sagitta* otolith of each individual were measured to the nearest 0.01 mm with a digital MAX-CAL NSK calliper (Figure 2). The otolith weight (OWe) was registered to the nearest 0.1 mg with a Mettler Toledo AL204

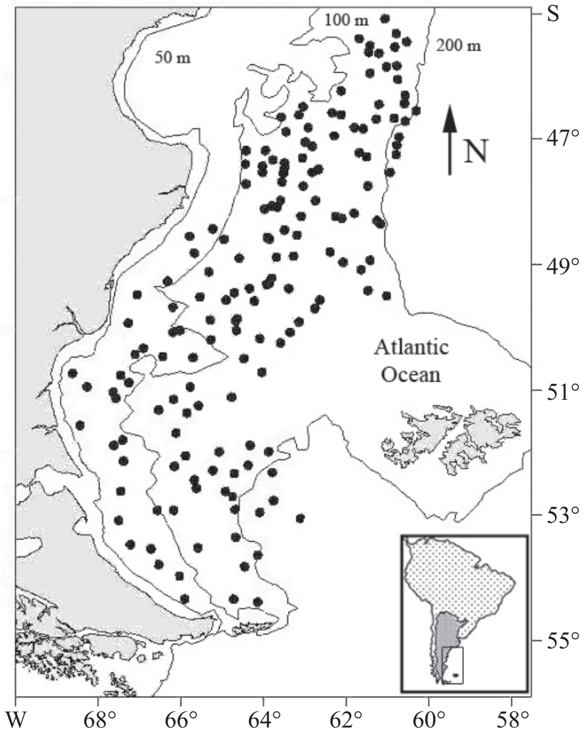

Figure 1. Argentine marine platform area. The black points indicate the sampling sites during the 1999, 2006 and 2007 austral summer cruises.

Figura 1. Área de la plataforma marina argentina. Los puntos negros indican los sitos de muestreo durante las campañas estivales de 1999, 2006 y 2007.

scale. According to fish growth stage data were classified in two groups: Undifferentiated juveniles (Group 1) and males and females (Group 2). Potential regressions ($y = a\ x^b$) between TL and otolith variables OL, OW, OT and OWe and between OL and the rest of the variables (OW, OT and OWe) were calculated. Potential regressions for different groups were statistically compared with slope homogeneity and covariance of linearized potential regression ($\log y = \log a + b \log x$). The relation between OW, OT, and OWe vs. OL (dependent variable) was estimated performing an isometric test on all individuals with no sex or stage discrimination. In the analysis, the slope of linearized potential regressions (b) was tested for isometric growth with statistic t (t

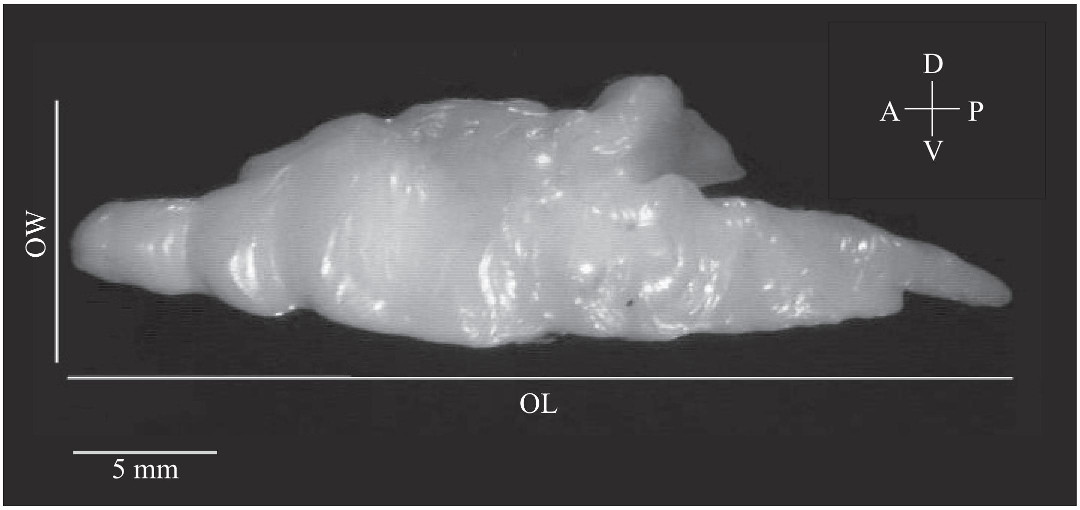

Figure 2: External view of *Salilota australis* right *sagitta* otolith (female 75 cm total length). OL: otolith length, OW: otolith width, OT: otolith thickness in the axis perpendicular to the plane.

Figura 2: Vista de la cara externa del otolito sagitta de Salilota australis (hembra 75 cm longitud total). OL: largo del otolito, OW: ancho del otolito, OT: espesor del otolito en eje perpendicular al plano.

= (b - d) / s_b), where s_b is the standard deviation of b, d: 1 for relations among metric variables and d: 3 for relations between metric and weight variables. The null hypotheses were Ho: b = 1 for the OW, OT vs. OL and Ho: b = 3 for the OWe vs. OL relations.

The 348 individuals examined corresponded to 150 males, 181 females and 17 undifferentiated juveniles. Overall TL ranged 67-800 mm. Individuals 67-150 mm TL of age 0 were classified as undifferentiated juveniles (Group 1) and those 150-800 mm TL of ages 1-16 as males and females (Group 2).

The relation between TL and otolith morphometric variables OL, OW, OT, and OWe were adjusted separately for males and females using potential regressions (Table 1). All regression coefficients were higher than 0.90. For OT and OWe, the slope homogeneity analysis showed significantly different growth rates between males and females; therefore, no general equations could be drawn. For OL and OW vs. TL regressions, neither the slope homogeneity analysis ($p = 0.94$ and 0.39) nor the covariance analysis ($p = 0.57$ and 0.30) revealed significant differences between sexes. Consequently, for the two otolith variables, a general potential equation for individuals of ages 1-16 was obtained and used to compare to undifferentiated juveniles. As regards variance among growth stages, the slope homogeneity analysis of the linearized model for OL and OW in relation to TL showed significant differences ($p < 0.00001$) between groups 1 and 2 (Table 2; Figure 3).

The isometric test performed to compare OW, OT, and OWe vs. OL showed different allometric growth patterns. Otolith width and weight had a negative allometric growth and thickness a positive one (Table 3). Results suggest a larger growth of the dorsoventral axis in relation to the anteroposterior axis and a lower growth of the medium lateral axis in relation to the anteroposterior axis. Likewise, potential regressions calculated comparing OL to the rest of the otolith variables (OW, OT and OWe) were significantly different for males, females and undifferentiated juveniles. Therefore, no general potential regressions were found for the overall size range analyzed.

Table 1. Relation between total length (TL) and otolith length (OL), otolith width (OW), otolith thickness (OT) and otolith weight (OWe) for males and females of Group 2. Sample size (n) and regression coefficient (R^2) are indicated.

Tabla 1. Relación entre longitud total (TL) y longitud del otolito (OL), ancho del otolito (OW), espesor del otolito (OT) y peso del otolito (OWe) para machos y hembras del Grupo 2. Se indican el tamaño de la muestra (n) y el coeficiente de determinación (R^2).

Sex	n	OL vs. TL	R^2	OW vs. TL	R^2	OT vs. TL	R^2	OWe vs. T	R^2
Males	150	$TL = 7.75\ OL^{1.42}$	0.96	$TL = 50.01\ OW^{1.42}$	0.94	$TL = 58.97\ OT^{1.61}$	0.90	$TL = 860.52\ OWe^{0.5}$	0.97
Females	181	$TL = 7.74\ OL^{1.43}$	0.96	$TL = 47.286\ OW^{1.45}$	0.96	$TL = 50.18\ OT^{1.76}$	0.91	$TL = 922.76\ OWe^{0.54}$	0.98

Table 2. Relation between total length (TL) and otolith length (OL), otolith width (OW), otolith thickness (OT) and otolith weight (OWe) for individuals of groups 1 and 2. Sample size (n) and regression coefficient (R^2) are indicated. *Not performed due to significant differences between males and females.

*Tabla 2. Relación entre longitud total (TL) y longitud del otolito (OL), ancho del otolito (OW), espesor del otolito (OT) y peso del otolito (OWe) para los individuos de los grupos 1 y 2. Se indican el tamaño de la muestra (n) y el coeficiente de determinación (R^2). *Diferencia significativa entre machos y hembras del Grupo 2.*

Group	n	OL vs. TL	R^2	OW vs. TL	R^2	OT vs. TL	R^2	OWe vs. TL	R^2
1	17	$TL = 7.759\ OL^{1.40}$	0.74	$TL = 60.835\ OW^{1.13}$	0.57	$TL = 69.09\ OT^{1.08}$	0.74	$TL = 592.4\ OWe^{0.43}$	0.27
2	331	$TL = 7.719\ OL^{1.43}$	0.96	$TL = 48.636\ OW^{1.43}$	0.95	*		*	

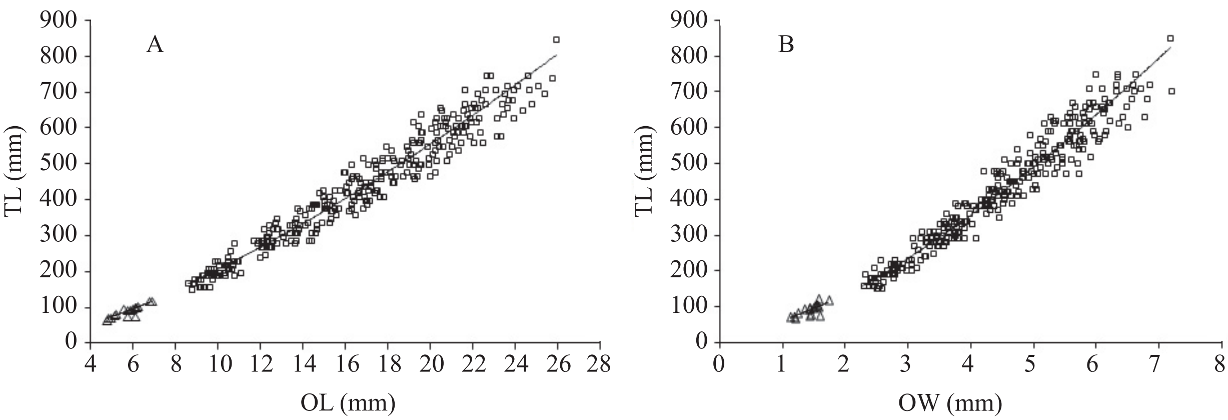

Figure 3. Potential relation between total length (TL) and otolith length (OL) (A) and otolith width (OW) (B) for Group 1 (triangles) and Group 2 (squares) with no differentiation between sexes. The lines show potential regressions for each data group.

Figura 3. Relación potencial entre longitud total (TL) y largo del otolito (OL) (A) y ancho del otolito (OW) (B) para el Grupo 1 (triángulos) y el Grupo 2 (cuadrados) sin diferenciar entre sexos. Las líneas muestran las regresiones potenciales para cada grupo de datos.

Table 3. Results of the isometric test among otolith variables [otolith width (OW), otolith thickness (OT) and otolith weight (OWe)] and otolith length (OL) (dependent variable) with no group discrimination. b: linear regression slope among logarithms of the variables, S_b: standard deviation of b, $t_{(n-2)}$: statistical distribution of student with n-2 freedom degrees and α 0.05, p: probability.

Tabla 3. Resultados del test de isometría entre las variables del otolito [ancho del otolito (OW), espesor del otolito (OT) peso del otolito (OWe)] y longitud del otolito (OL) (variable dependiente) sin discriminación de grupo. b: pendiente de las regresiones lineales entre los logaritmos de las variables, s_b: desviación estándar de b, $t_{(n-2)}$: estadístico de una distribución de student con n-2 grados de libertad y α 0,05, p: probabilidad.

	b	s_b	$t_{(n-2)}$	p
OL vs. OW	0.9591	0.0107	3.8011	0.0002
OL vs. OT	1.1198	0.0165	7.2518	<0.001
OL vs. OWe	0.3590	0.0031	851.935	<0.001

In general, the morphometry of *sagittae* in relation to fish length and sex varies with the species considered. The statistical analysis performed in this study suggests that for *S. australis* the increase of otolith thickness and weight as compared to fish total length is higher in females, probably on account of the differential somatic growth of the species (Cassia, 2006). On the other hand, the relation found between otolith length and width and fish total length did not show any significant differences related to sex. Therefore, the two morphometric variables allow to estimate *S. australis* length using the potential regressions given in Table 2. Based on the results obtained, Hunt (1992) described a uniform pattern in the relation between otolith length and width vs. fish total length for males and females of *Sebastes marinus* (Linnaeus, 1758), a species that shows differential growth. Moreover, studies on *Prionotus nudigula* (Ginsburg, 1950) that presents the same growth features revealed non significant sex-related differences in otolith wide vs. fish total length (Volpedo and Thompson, 1996).

The variance in growth stages of tadpole codling otolith length and width vs. fish total length may be due to changes in diet. Ross (1978) studied leopard sea robin feeding pattern and found that a rapid increase in jaw size and intestinal length preceded a switch to larger preys, which suggests a change in the feeding strategy to maximize energy intake. The study on *S. australis* of the Argentine shelf by Arkhipkin *et al*. (2001) revealed that small fish fed mainly on gammarid amphipods and that large fish did on *Patagonotothen* spp. These changes in diet could be associated to *S. australis* trophic migrations in the water column (Wöhler, 1987; Wöhler *et al*., 2004; Cassia, 2006). Pérez Comas (1980) described a migration pattern in which individuals up to 200 mm total length lived basically in the pelagic stratum, mid-size adults had greater vertical migrations and larger specimens tended to remain close to the bottom.

The estimate of otolith length derived from other variables such as thickness or width is a useful tool to perform diet studies when the otolith is broken or partially eroded. However, the research showed no general potential regression for the entire size range to describe the increase of otolith width, thickness, and weight in relation to length. Hence, it is necessary to obtain complete *S. australis* otoliths to estimate fish total length to, thus, contribute to trophic web studies in the cold-temperate seas of South America.

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