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Studies on age determination and growth pattern of the wedge sole *Dicologoglossa cuneata* (Moreau, 1881) in the Spanish waters of the Gulf of Cadiz (southwest Iberian Peninsula)

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ABSTRACT

The wedge sole *Dicologoglossa cuneata* (Moreau, 1881) is a typical coastal soleid which is considered as one of the main target species in the demersal fishery of Spain's southern Atlantic region. This paper presents a study on the growth pattern of wedge sole in the Gulf of Cadiz. Age was determined by observing and analysing whole otoliths (sagittae), thereby obtaining the mean lengths at age for males and females in the year 1993 (from 15-20.9 cm TL and 1-4 years for males; from 15.9-23.6 cm TL and 1-6 years for females). In addition, the growth parameters for both sexes were obtained according to the Von Bertalanffy equation: L_∞ = 24 cm, K = 0.343 and t_0 = −1.384 for males; L_∞ = 27 cm, K = 0.296 and t_0 = −1.520 for females (showing growth differences growth between the sexes). These were compared with results reported by other authors for other areas of the species's distribution range. Through the interpretation of the otolith and its edge, a sequence of annual rapid- and slow-growth rings was observed; otoliths with an opaque edge (rapid growth) showed the highest percentages in the period from May to October. Mean otolith diameters for each of the estimated ages were calculated, as well as the body length/otolith diameter relationship: a = −12.631 and b = 61.033 (r^2 = 0.70).

Key words: *Dicologoglossa cuneata,* wedge sole, age, growth, Gulf of Cadiz, southwest Iberian Peninsula.

RESUMEN

Estudios sobre la determinación de la edad y el modelo de crecimiento de la acedía* Dicologoglossa cuneata *(Moreau, 1881) en las aguas españolas del golfo de Cádiz (suroeste de la península Ibérica)

La acedía Dicologoglossa cuneata *(Moreau, 1881) es un soleido típicamente costero, considerado como una de las especies objetivo de las pesquerías demersales de la región suratlántica ibérica. En este trabajo se estudia el patrón de crecimiento de la acedía del golfo de Cádiz. La determinación de la edad se realizó mediante la lectura de otolitos enteros (*sagitta*), obteniéndose las tallas medias por clase de edad para machos y hembras del año 1993 (entre 15 y 20,9 cm de longitud total y de 1 a 4 años para machos; de 15,9 a 23,6 cm de longitud total y de 1 a 6 años para hembras). Por otra parte, se estimaron los parámetros de crecimiento para ambos sexos según la ecuación de Von Bertalanffy: L_∞ = 24 cm, K = 0,343 y t_0 = −1,384 para machos; L_∞ = 27 cm, K = 0,296 y t_0 = −1,520 para hembras, presentando ambos sexos un crecimiento diferente. Estos resultados se compararon con los obtenidos por otros autores en otras áreas del rango de distribución de la especie. Mediante la interpretación del otolito y su borde, se observa una sucesión anual de anillos de crecimiento lento, formados durante el periodo invernal, y otros de crecimiento rápido, que muestran los porcentajes más altos en el periodo de mayo a octubre. Se calcularon los diámetros de los anillos para cada una de* *las edades estimadas, así como la relación longitud total del pez - diámetro del otolito, obteniéndose una ecuación lineal en la que a = −12,631 y b = 61,033 (r^2 = 0,70).*

Palabras clave: Dicologoglossa cuneata*, acedía, edad, crecimiento, golfo de Cádiz, suroeste de la península Ibérica.*

INTRODUCTION

The wedge sole *Dicologoglossa cuneata* (Moreau, 1881) is a typical coastal soleid inhabiting depths from 10-150 m (exceptionally up to 430 m on the Mauritanian continental slope), and is widely but irregularly distributed on the sandy and sandy-muddy bottoms of temperate-warm waters of the eastern Atlantic, as far as the coasts of southwest Africa, and in the western Mediterranean (Quéro, 1981; Heemstra and Gon, 1986; Quéro, Desoutter and Lagardère, 1986; Bauchot, 1987). In the Gulf of Cadiz, *D. cuneata* occurs along the inner shelf as deep as 115 m. The species is more abundant at the mouth of the Guadalquivir River between depths of 15-30 m, with its optimal coinciding with the principal fishing grounds, which extend from the six nautical miles offshore line to depths of 35-40 m (Jiménez, Sobrino and Ramos, 1998). Most of these fishing grounds have muddy-sandy substrata, with a high abundance of tube-forming polychaete worms (Ramos, Sobrino and Jiménez, 1996), which are a major component in the *D. cuneata* diet.

In the Spanish waters of the Gulf of Cadiz (figure 1), *D. cuneata* is a target species of the demersal fishery (Anon., 1993; Sobrino *et al.*, 1995). The species is harvested in the study area by both bottom-trawl and artisanal gillnet fleets. Between the years 1993 and 1997, 1693.3 tons of *D. cuneata* (varying between 197.2 tons in 1994 and 533.0 tons in 1997) were landed. About 65 % were landed by the bottom-trawl fleet, while the remainder was caught by the gillnet fishery (figure 2).

The growth of *D. cuneata* has been studied by several authors in other areas (Forest, 1975; Lagardère, 1982; Dinis, 1986; Rousset and Marinaro, 1983). Given the importance of this species and the lack of information available for the study area, we decided to carry out a study on growth and age determination based on whole otoliths (sagittae), to estimate the age structure of the Gulf of Cadiz population. Age determination is essential for effective fisheries management, and the procedures involved in fish growth studies should provide reliable and valid results. We compared our findings with those of other authors for other areas of this species's distribution.

MATERIALS AND METHODS

The biological material analysed came from monthly commercial samples randomly selected from landings of the trawl fleet in Sanlúcar de Barrameda (province of Cadiz). The study period was from February to December 1993. We examined 304 pairs of otoliths (136 males and 168 females) from individuals of total length (TL) range

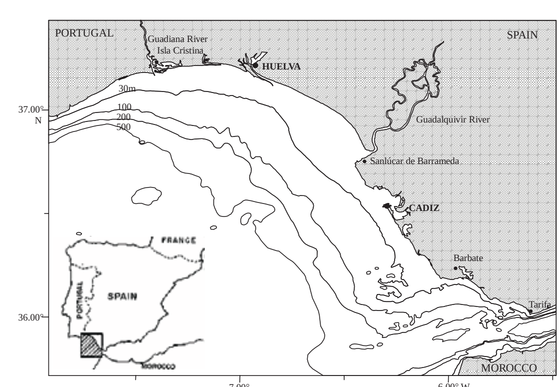
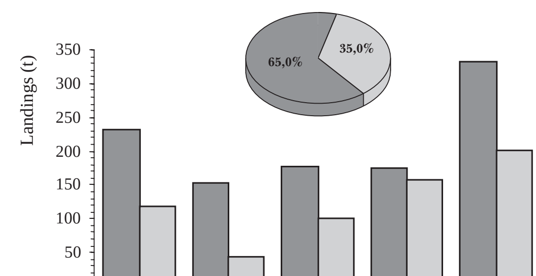


Figure 1. Southern Iberian Atlantic region (Gulf of Cadiz)



	1993	1994	1995	1996	1997
Bottom-trawl	232.4	152.7	178.2	175.6	331.9
Gillnet	117.2	44.5	101.0	158.6	201.1

Figure 2. *Dicologoglossa cuneata.* Landings (t) by fleet type in the Gulf of Cadiz (1993-1997)

13-25 cm. The maximum TL on the landings was 13-23 cm for males, and 13-27 cm for females.

Whole otoliths (sagittae) were dry-stored in paper envelopes for subsequent analysis. To enhance viewing of growth rings, otoliths were immersed in a 40 % aqueous solution of glycerine 2 h prior to being read under reflected light, on a black background (at ×15 magnification). The number of rings and edge type (opaque or hyaline) were recorded. The first of January was assigned as the birth date, following the established procedure for species in the northern hemisphere that spawn between January and April (Morales-Nin, 1987; Jiménez, Sobrino and Ramos, 1998).

The body length/otolith size relationships for the right and left otoliths (figure 3) were fitted to a linear regression of total otolith diameter, both measured in mm. Differences in this relationship between the right and left otoliths were tested with an ANCOVA. In studying the otolith edge, we also noted the evolution of monthly percentages of occurrence of opaque and hyaline edges throughout the duration of the entire sampling period.

Otolith readings were performed by two readers at two different times. Thus, a database of four readings and edge characteristics for each otolith was created. Once the readings were completed, length-age keys for both sexes were developed. Mean lengths at age obtained from valid otolith readings (i.e., those in which at least three of the readings coincided) and their standard deviations were calculated by sex, using the midpoint in each size class. Subsequently, mean lengths at age were used to estimate the growth parameters.

The Von Bertalanffy growth model (VBGF), applied according to the method proposed by Beverton and Holt (1957), was fitted to the data to

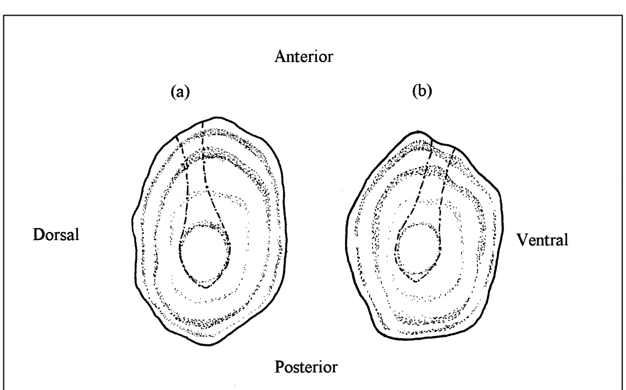


Figure 3. *Dicologoglossa cuneata*. Left (a) and right (b) otoliths

estimate the growth parameters and model the growth pattern. The VBGF is expressed as:

$$L_t = L_\infty \left(1 - e^{-K(t - t_0)}\right) \qquad [1]$$

The L_∞ was constrained by using as the reference length the largest individual of each sex observed in commercial samples. The programme FISHPARM (Saila, Recksiek and Prager, 1988), which uses Marquardt's algorithm (1963) for least squares estimation, was used to fit the VBGF. The growth parameters and curves by sex were obtained and compared with those derived by other authors, with the Munro and Pauly (1983) phi-prime test (ϕ'):

$$\phi' = log_{10}\, k + 2\, log_{10}\, L_\infty \qquad [2]$$

Diameters of annual growth rings were measured by Optical Pattern Recognition System software (OPRS, Biosonics). Only those otoliths for which age reading was considered valid were measured. Measurements for each pair of otoliths were taken, but only when both were in good condition. Differences in otolith ring measurements, relative to location on the fish (left and right) as well as between sexes, were tested with a two-way ANOVA.

RESULTS

Fish length-otolith length relationship

An alternative method which can provide specific and useful information concerning individual growth is the back-calculation. This method reconstructs the size of individuals at a younger age, from growth recorded in their calcified structures (Casselman, 1987). In order to do this, it is necessary to establish a relationship between the linear growth of the otoliths and the fish's size. The results of our ANCOVA analysis indicated that no significant differences exist between otolith diameter (left and right) and fish size (ANCOVA test $p > 0.05$). Therefore, a regression of otolith diameter to total fish length was performed, independently of otolith position (left or right). The results obtained and their corresponding graphic representation are shown in figure 4.

The edge study

Generally, rapid-growth rings (opaque) in otoliths are formed in summer-autumn and slow-growth

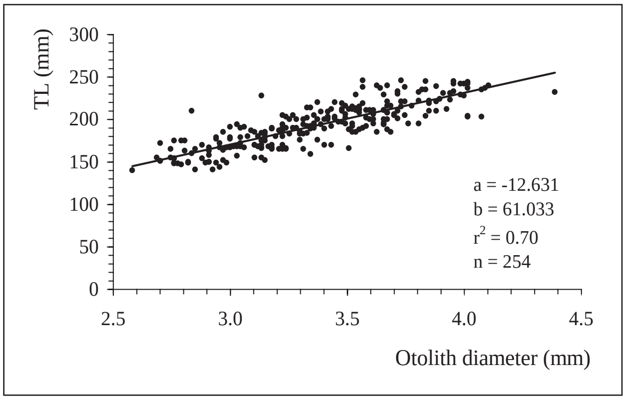


Figure 4. *Dicologoglossa cuneata.* Total length (mm)-otolith diameter (mm) relationship

rings (hyaline) in winter-spring (Morales-Nin, 1987). In our study, the highest percentage of opaque edges was observed during the May to October period, with maximum values in August and September (29.4 % and 50 %, respectively) (figure 5).

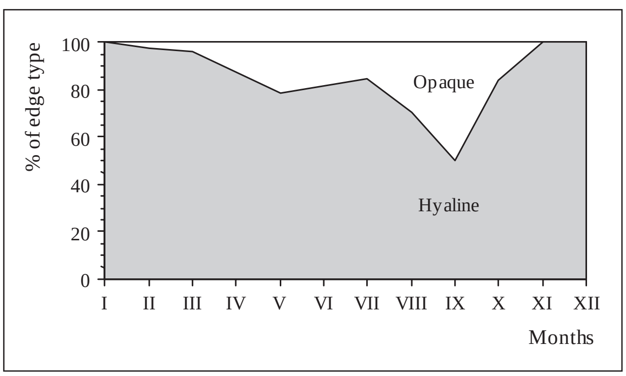


Figure 5. *Dicologoglossa cuneata.* Monthly evolution of the occurrence percentage of edge type in otoliths (1993)

Mean lengths at age

Mean lengths at age by sex were obtained for 1993 (table I). The age range represented was from 1-5 years for females and 1-4 years for males. In females, the mean lengths estimated at each age were always greater than those for males, demonstrating a clear sexual difference in body size.

These results concur with those of other authors who studied *D. cuneata* in other areas of its distributional range. Generally, for both sexes, our data are most similar to those of Forest (1975) and Lagardère (1982) in the Bay of Biscay, especially until the age of 3.

Growth parameters

The growth-in-length parameters for both sexes in the present study, and from studies in other areas, are detailed in table II. With the exception of the data from Dinis (1986), females have greater L_∞ values than the males. In terms of the growth coefficient (K), a diminishing with latitude is apparent for both sexes, with the least value having been reported by Forest (1975) in the Bay of Biscay, and the highest value by Rousset and Marinaro (1983) in Algerian waters.

The Von Bertalanffy growth curves calculated from these parameters are shown in figure 6. For both sexes, it can be seen that from age 3, the values for different authors' data are very similar, especially for females.

Table I. *Dicologoglossa cuneata.* Mean length at age, TL (cm), and standard deviation, SD (cm) in the Gulf of Cadiz and other areas of its distribution range. (M): males; (F): females; (n): number of specimens

Author	Year	Study area	Age	1		2		3		4		5	
			Sex	M	F	M	F	M	F	M	F	M	F
Forest	1975	Bay of Biscay	TL	16.9	17.7	17.9	18.6	18.9	20.5	20.3	21.7	21.2	23.1
			n	32	124	289	867	397	628	296	305	408	38
Lagardère	1982	Bay of Biscay	TL	14.1	14.7	16.8	18.6	18.9	20.7	19.7	22.4	22.5	23.2
			n	44	74	63	130	33	87	11	18	1	5
Rousset and Marinaro	1983	Algeria	TL	12.1	11.3	15.9	16.4	18.4	19.5	20.1	21.5	21.1	22.7
			n	–	–	–	–	–	–	–	–	–	–
Dinis	1986	Tagus estuary	TL	11.8	11.3	16.7	17.5	19.5	20.5	21.5	22.5	22.8	24.1
			n	7	3	61	55	56	77	37	45	13	30
Present work	1993	Gulf of Cadiz	TL	15.0	15.9	18.0	18.9	19.2	20.9	20.9	22.3	–	23.6
			SD	1.14	1.38	1.63	2.02	1.76	1.71	0.85	1.50	–	1.21
			n	13	18	50	46	50	61	13	26	–	7

Table II. *Dicologoglossa cuneata*. Growth parameters and phi-prime test (ϕ') results, by sex and study area

			Males				Females			
Author	Year	Study area	L_∞	K	t_0	ϕ'	L_∞	K	t_0	ϕ'
Forest	1975	Bay of Biscay	25.6	0.203	–3.670	2.12	26.5	0.275	–2.360	2.29
Lagardère	1982	Bay of Biscay	31.0	–	–	–	33.0	–	–	–
Rousset and Marinaro	1983	Algeria	23.7	0.380	–0.880	2.33	24.7	0.470	–0.300	2.46
Dinis	1986	Tagus estuary	27.7	0.283	–0.944	2.34	26.5	0.419	–0.294	2.47
Present work	1993	Gulf of Cadiz	24.0	0.343	–1.384	2.30	27.0	0.296	–1.520	2.33

The phi-prime (ϕ') test estimations (table II) present similar values for both sexes and for different distribution areas, as well. These values range from 2.1 for males in the Bay of Biscay to 2.5 for females from the Tagus estuary and Algeria.

Ring measurements

The mean ring diameters for each otolith (left and right), and by sex, are shown in table III. A two-way ANOVA analysis revealed no significant differences between ring measurements of left and right otoliths. However, there were significant differences for males and females; except for the first ring, the largest ring diameters correspond to females (table IV).

DISCUSSION

Although *D. cuneata* constitutes a species of major commercial importance in the Gulf of Cadiz, there still are gaps in our knowledge of its biology. Several trawl surveys have been carried out, but there is very little information on where juveniles are located in our study area (Jiménez, Sobrino and Ramos, 1998). Thus, the zero age-class is not represented in the present study, because individuals smaller than 13 cm were not found.

Table IV. *Dicologoglossa cuneata*. Results of the two-way ANOVA carried out on the measures of the growth rings. (*): significant difference, $p < 0.05$

Ring	Left/Right	Males/Females
	p	p
D1	0.636	0.078
D2	0.969	0.012*
D3	0.794	0.002*
D4	0.594	0.033*
D5	0.283	–

The pattern of ring formation is clearly apparent in the whole otolith, with one opaque and one translucent (wider) zone being laid down every year. In the first growth zone, a check, which may be related to the process of metamorphosis, occurs frequently. This check is sometimes quite prominent and can be erroneously considered the first annual ring, making interpretation more uncertain.

The classification of edge types is difficult in *D. cuneata* otoliths due to the thinness of this part of the structure. Although hyaline edges are found throughout the year, generally otolith edges are opaque in summer and hyaline or translucent in winter (figure 5).

In the present paper, the results obtained for each sex clearly show differences, with females being larger than males as they become older, a result

Table III. *Dicologoglossa cuneata*. Mean diameters, ∅ (mm) (± SD) of the otolith growth rings by sex

Sex	Males						Females					
Otolith	Left			Right			Left			Right		
	∅ (mm)	SD	n	∅ (mm)	SD	n	∅ (mm)	SD	n	∅ (mm)	SD	n
D1	2.01	0.35	56	1.98	0.30	48	2.05	0.36	67	2.13	0.38	42
D2	2.82	0.23	54	2.83	0.21	46	2.92	0.24	66	2.90	0.28	40
D3	3.27	0.20	37	3.31	0.18	32	3.42	0.24	53	3.37	0.26	32
D4	3.55	0.21	10	3.58	0.18	8	3.72	0.24	32	3.67	0.18	17
D5	–	–	–	–	–	–	3.95	0.12	9	3.86	0.12	4
D6	–	–	–	–	–	–	3.95	0	1	3.83	0	1

of the two sexes' different adult growth rates. Roff (1982) suggested that in flatfish, once males attain the size compatible with successful reproduction, they redirect energy to reproduction and reduce the energy spent searching for food.

Comparing these values with mean lengths at age obtained by other authors in different areas (table I), the results are quite similar after age 2. Best agreement is found with the values estimated by Forest (1975) for the Bay of Biscay populations. The variability of size at age estimated by different authors may be related to different growth conditions throughout the distributional range of wedge sole. However, if this is so, it is difficult to explain why the most similar values are found for stocks from the most distant geographical areas. Alternatively, the discrepancies may be due to inconsistent interpretations of the patterns of ring formation in otoliths.

The phi-prime test (ϕ') estimates provide an indication of estimation reliability, since it has been suggested that phi-prime values are similar for the same species and genera (Bellido *et al.*, 2000). The results obtained in the present study are very similar to those found in other areas of the *D. cuneata* distribution range (table II).

Estimated growth parameters differ by sex (table II). Again, Forest's values (1975) agree closely with those obtained here. However, in our study, the growth rate of males is slightly higher than that of females, and therefore in disagreement with other results. This is probably due to the fact that, contrary to other reports in the literature, the sample of males employed in the present study did not include individuals older than 4 years.

There is a strong suggestion that the differences among the growth parameters obtained in the various studies on *D. cuneata* are due to discrepancies in the ageing methods used. Establishing a standardised and validated method of interpreting otolith structures and ageing criteria for this species will reduce the variability in the age estimates and make it possible to compare growth rates between populations of different areas. For the *D. cuneata* stock exploited in the Gulf of Cadiz, the present study is the first one ever carried out on its growth pattern. However, for the reasons given above, our growth rates must be considered preliminary estimates.

Growth curves for both sexes estimated by different authors present differences, in particular before age 3 (figure 6). For both, males and females, growth curves in the present study are in close agreement with those estimated by Forest (1975). Until age 2, the difference between these growth curves and those presented by Dinis (1986) and Rousset and Marinaro (1983) is about 1 year in the age assigned. Even making allowance for factors

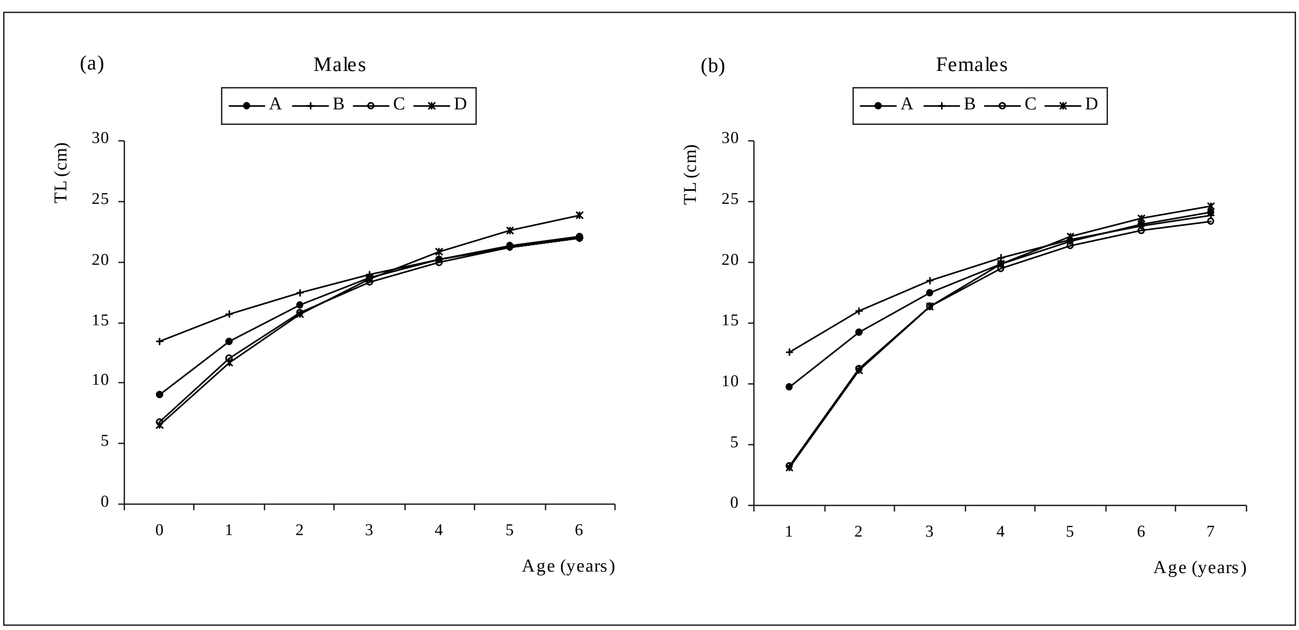


Figure 6. *Dicologoglossa cuneata* growth curves for males (a) and females (b), estimated by different authors in other areas of the species's distribution range (see also table II). (A): present work; (B): Forest, 1975; (C): Rousset and Marinaro, 1983; (D) Dinis, 1986

such as geographic variability or sample size, it seems plausible that the differences between the two sets of curves are due to discrepancies in age determination.

While the comparison of ring diameters in left and right otoliths yielded no significant differences (table III), the diameters of the annual rings in female and male otoliths differ significantly after age 1, with those of females being larger. This is consistent with an estimated wedge sole age of first maturity of 2 years in this area (mean length: 18.2 cm) (Jiménez, Sobrino and Ramos, 1998). This event is probably registered in the otolith and thus, after year 2, females show differences in rings size compared with males (table IV), which also coincides with this species's sexual difference in body size.

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