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ANALYSIS OF THE OTOLITHS *SAGITTA*, *ASTERISCUS* AND *LAPILLUS* OF BIGEYE SCAD *SELAR CRUMENOPHTHALMUS* (TELEOSTEI: CARANGIDAE) IN MANZANILLO BAY, MEXICAN CENTRAL PACIFIC

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ABSTRACT

Morphology, morphometry and growth rings of the otoliths: *sagitta*, *asteriscus* and *lapillus* of *Selar crumenophthalmus* in Manzanillo and Santiago bays in Manzanillo, Colima, Mexico were studied. Differences between sexes, as right and left of the three pairs of otoliths were analyzed. In all cases the growth of the otoliths is eccentric to the core. Relationship between fish length and length and/or width of the otoliths showed that these structures are useful in the growth determination. Four growth rings were identified in *sagittae* and *asterisci*. Growth rings could not be observed in *lapilli* because the thickness of this structure prevents the observation by transparency. Growth is bigger in males than females in the case of the *asteriscus* and the *lapillus*, however in the case of the *sagittae*, it is bigger in females than males.

INTRODUCTION

Selar crumenophthalmus (Bloch 1793) is a thin elongated fish, moderately compressed (Fig. 1). Its two big eyes have adipose eyelids protecting most of the eye, except the pupil. Its distribution is circumtropical, in the Indo-Pacific: from East Africa (Smith-Vaniz 1984) to Rapa, north and south Japan and the Hawaiian Islands, south to New Caledonia. Eastern Pacific: Mexico to Peru, including the Galapagos Islands (Chirichigno 1974). Western Atlantic: Nova Scotia, Canada and Bermuda through the Gulf of Mexico and the Caribbean to São Paulo, Brazil (Figueiredo *et al*. 2002). Eastern Atlantic: Cape Verde to southern Angola (Smith-Vaniz *et al*. 1990). Adults prefer clear oceanic waters around islands and clear to neritic waters (Cervigón *et al.* 1992); occasionally they are found in turbid waters (Smith-Vaniz 1995).

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Mundy (2005) describes them as pelagic individuals that travel in compact groups of hundreds of thousands of fish. They are mainly nocturnal, but disperse to feed on small shrimps and benthic invertebrates when inshore; and zooplankton and fish larvae when offshore (Smith-Vaniz 1995, Allen & Ermann 2012). They can reach 170 m deep (FAO 2016). It's a commercial resource that is found in the market fresh, salted or dried (Smith-Vaniz 1995). Its size can reach 70 cm of total length (TL) (Kuiter & Tonozuka 2001). This species is caught on hooks and lines, beach seines trawls, purse seines and traps. The total catch reported by FAO in 1999 was 69 149 t. The countries with the largest catches were Philippines (65 776 t) and Venezuela (3 765 t). In the coast of Colima, Mexico, an annual average of 19.5 t, fluctuating between 1.2 and 62.9 t, were fished from 2000 to 2015. This species is used exclusively as bait in Colima for the fishing of big pelagic with long line and sport fishing of sail fish, marlin and dolphin fish. Its price is one of the cheapest in the fishing, of $5.00 pesos per kg ($0.26 US dollars). Photographs or sketches of the *sagitta* of *S. crumenophthalmus*, mentioning the main parts of this structure have been reported by Cabrera-Mancilla (1989), Rivaton & Bourret (1999) and Mier-Uco (2011). FAO (2016) published generalities of this species including capture statistics in the "Species fact sheets". Ingles & Pauly (1984) published data on this species in Philippines including growth determination through length frequency analysis. A study on feeding habits of *S. crumenophthalmus* was carried out by Roux & Conand (2000) and on the diet composition by López-Peralta & Arcilla (2002). Reproductive biology was studied by Clarke & Privitera (1995) and on general biology in the island of La Reunión by Roos *et al*. (2007). However, there are no data on the growth analysis of the rings on otoliths, useful structures to determine age. The scales of the Carangidae species cannot be used in studies to identify the growth rings, because they are continually replaced by new ones during the fish life cycle, as occurs with *Caranx caballus* and *C. caninus* (Gallardo-Cabello *et al*. 2006, Espino-Barr *et al*. 2006, respectively).

Therefore the present study poses the following objectives:

- Description and analysis of the labyrinth system.
- Morphologic analysis of the *sagittae*, *asterisci* and *lapilli.*
- Morphometric study of the otoliths and its variation regarding age and sex.
- Identification of growth marks.
- Comparison with results by other authors.

Studies on the growth ring identification are necessary to determine the species growth and calculus of the von Bertalanffy growth constants, which allows the composition by age groups of the population to be calculated and continue with the analysis on the population dynamics of the species, such as reproduction, feeding, maximum sustainable yield models, prediction and capture simulation. This information is to achieve a rational management and prevent overexploitation of resources.

MATERIALS AND METHODS

From November 2012 to October 2013, 72 organisms of *Selar crumenopthalmus* were taken directly from the commercial captures in Manzanillo and Santiago bays in Manzanillo, Colima, Mexico and taken to the laboratory of the Regional Fishery Research Center (CRIP). Organisms were captured with fixed trap-net, gill net, "robador" (hand line with five hooks), and pound net, to obtain a stratified sample which includes all the age groups and size classes. In the laboratory, data were taken for each organism: total length (TL, cm), standard length (SL, cm), total weight (TW, g), eviscerated weight (EW, g) and sex. *Sagittae*, *asterisci* and *lapilli* were obtained by doing a transversal cut in the organism's skull, removing the brain, and extracting the semi-circular canals (left and right). Otoliths were liberated from the otic capsules: *sacculus*, *lagena* and *utriculus*, cleaned in water and dried. They were preserved dry in Eppendorf tubes, with the number of the organism, capture date, total length and sex. Otoliths were analyzed with a dissecting microscope. The terminology of the Secor *et al.* (1992) glossary was used to describe the labyrinth system and the *sagittae* of this species. In the case of the *asterisci* and *lapilli*, similar concepts were used for their description as in Gallardo-Cabello *et al*. (2006, 2011, 2012, 2014) and Espino-Barr *et al.* (2006, 2013, 2015). Measurements of the length and width of the three pairs of otoliths (right and left) were registered, with the help of a graduated measuring ocular in the microscope. Sample size was corroborated (Daniel 1991). Regressions by least squares were used to calculate the relationship constants of the *sagitta rostrum* length (SL) *vs*. *antirostrum* length (SA) and width (SW). In the case of the *asterisci* and *lapilli* the regression indexes were only used for length (L) *vs.* width (W). The allometric relationships between total length of the fish and the length and width of each otolith were also obtained by least square regression. A one way variance analysis (ANOVA) (Zar 1996) was used to determine if there were morphometric differences between male and female otoliths, and between right and left otolith. Growth ring identification was carried out only on the *sagittae* and *asterisci*, observing the rings by transparency in a stereoscopic microscope, using transmitted light. In the case of the *lapilli*, this wasn't possible because of the thickness of the piece. Average length for each growth ring was calculated.

RESULTS

This is the first time that data on the otoliths of *Selar crumenophthalmus* is published considering the three pairs: *sagittae*, *asterisci* and *lapilli*, therefore this study is completely original and we could not find other researches to compare and discuss our findings.

Fig. 1. Bigeye scad *Selar crumenophthalmus* (Bloch, 1793).

Labyrinth system of Selar crumenopthalmus

The membranous labyrinth is constituted by a tubular system that form the semicircular canals (Fig. 2, 3), which are the anterior vertical canal, the posterior vertical canal and the horizontal canal. These canals present widenings forming chambers containing the otoliths: the *sagitta* is found in the *sacculus*, the *asterisci* in the *lagena,* and the *lapillus* in the *utriculus* (Fig. 2, 3). Each chamber keeping the otoliths presents a liquid called endolymph, in which these structures are immersed (Lagler *et al.* 1962). Otoliths present a structure called *macula* that penetrates in their acoustic canal through the nervous cells called neuromasts (Fig. 2, 3). The macula nurtures the otoliths by means of the calcic carbonate and protein deposits. The macula also shows ramifications of the eighth cranial nerve, which are in charge of sending the impulses produced by vibrations of the otoliths in the endolymph to the brain (Mugiya 1964, 1966a, b). According to Holst *et al.* (1950) and Lowenstein (1957), the *sagittae* and *asterisci* are related to the perception of the sound, gravity and angular acceleration, while the *lapilli* are more related to the fishes' equilibrium.

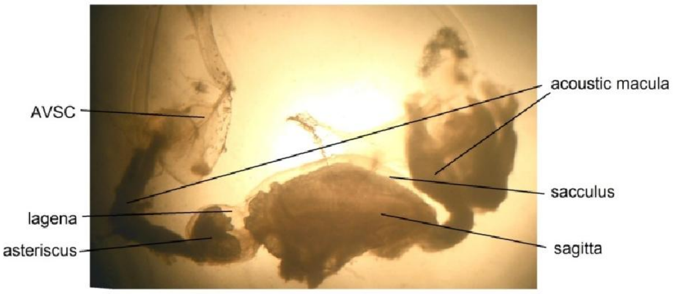


Fig. 2. Section of the membranouss laberinth of an organisms of *Selar crumenopthalmus* (20 cm total length) (enlarged 97.4 times) showing the *sacculus*, which includes the *sagitta*, and the *lagena* with the *asteriscus*; also the acoustic macula is shown penetrating the acoustic channel of each of these otoliths. Fragments semicircular front vertical channel is also shown (AVSC)

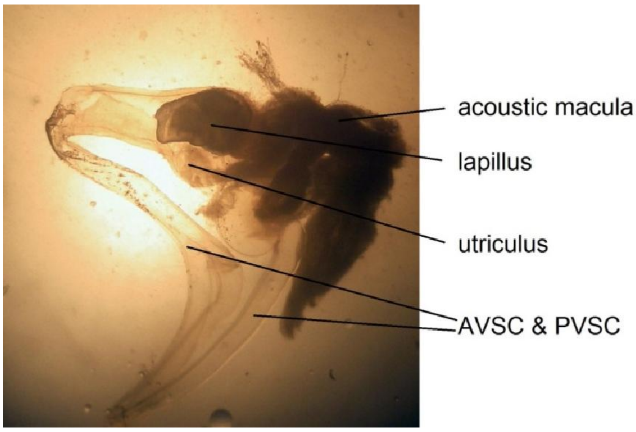
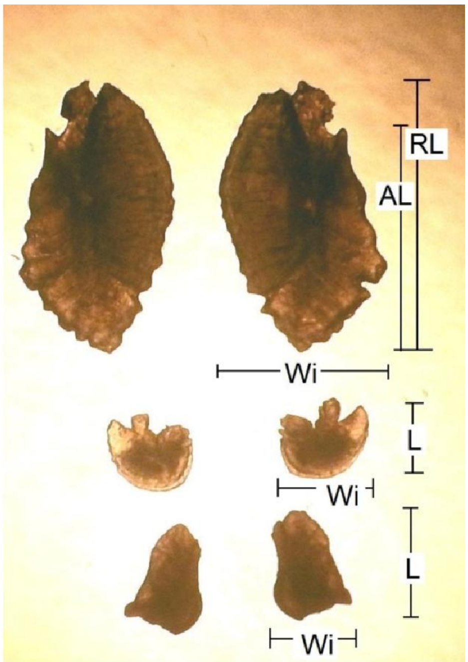


Fig. 3. Section of the membranous laberinth of *Selar crumenopthalmus* (20 cm total length) (enlarged 110.5 times) showing the utriculus with lapillus contained, the acoustic macula is observed penetrating the acoustic channel of the otolith and fragments of the vertical anterior semicircular canal (AVSC) and vertical rear canal (PVSC)

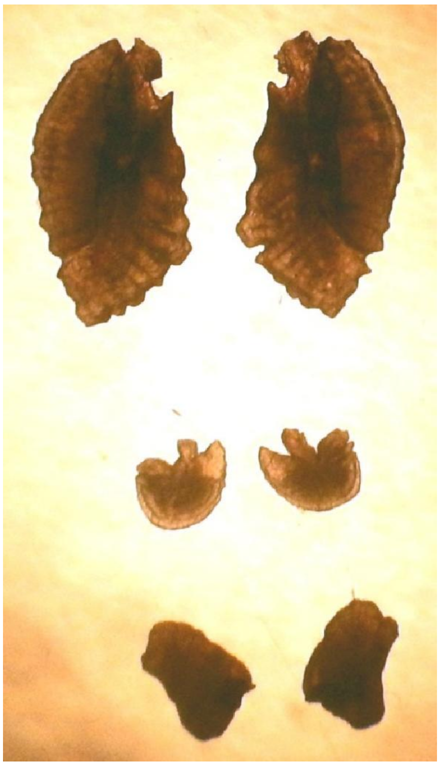
Degens *et al*. (1969) found that the protein in the otoliths has a high molecular weight, and therefore named otolin. The other component in these structures is the calcic carbonate (Lagler *et al*. 1962) of which its polymorphic state in this case is of aragonite (Hickling 1931, Sasaki & Miyata 1955, Carlström 1963, Gallardo-Cabello 1986). The largest otolith in *S. crumenophthalmus* is the *sagitta*, that reaches a total length of 4.22 mm, while *asteriscus* 1.33 mm and *lapillus* 1.63 mm in specimens of 180 mm total length (Fig. 4).

Description of the sagitta

The front shows an excisura major that divides the *sagitta* in rostrum and antirostrum. The first shows a well-defined rounded structure that projects forward towards the excisura major and also separates the anterior part creating a peak or crest (Fig. 5, 6), where the borders of the acoustic canal is formed. The shape of the rostrum varies from one organism to another, in the younger specimens there is little difference, with a blunt anterior part and no differentiated *excisura major*.



a



b

Fig. 4. Relationship between the three pairs of otoliths of *Selar crumenophthalmus*: a) external aspect, b) internal aspect. AL = *antirostrum* length, RL = *rostrum* length, Wi = width, L = length

As the individuals grow (length and weight), their *excisura major* shows more developed, although the *rostrum* is always prominent and the *antirostrum* small. The posterior part of the otolith shows an only *postrostrum*, without an *excisura minor* dividing the *postrostrum* and *pararostrum*. The dorsal and ventral margins are mainly curvilinear and show indentations that vary in number and deepness among different individuals

(Fig. 5, 6); also smaller notches can be presented from the *rostrum* to the *postrostrum*.

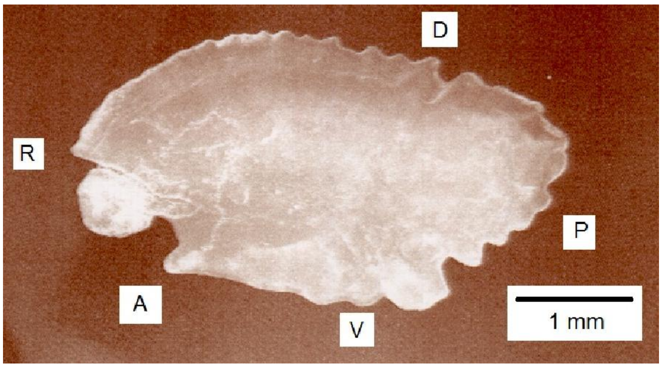


Fig. 5. Scanning photograph of the left *sagitta* external aspect of *Selar crumenophthalmus*. R= *rostrum*, A= *antirostrum*, P= *postrostrum*, D= dorsal margin. V= ventral margin

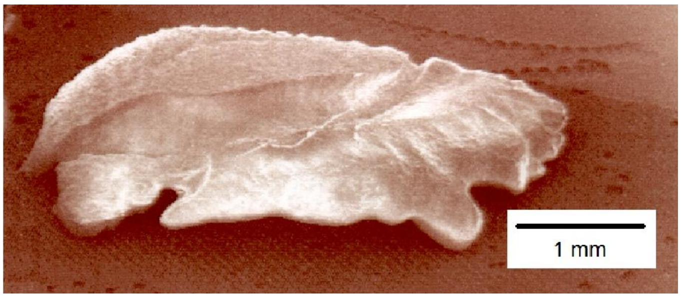


Fig. 6. Scanning photograph of the left *sagitta*, internal aspect of *Selar crumenophthalmus* showing the acoustic canal

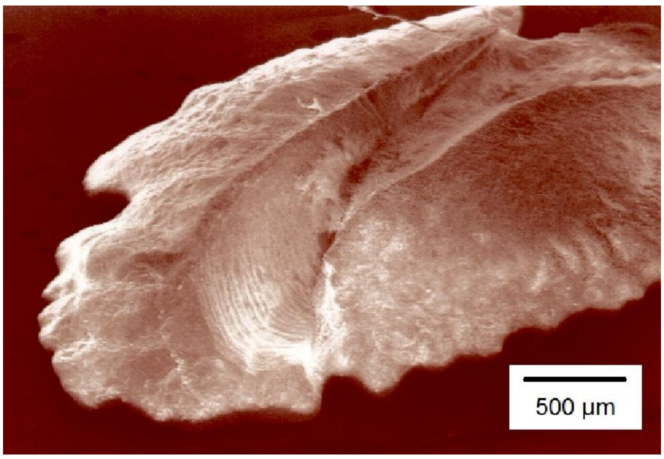


Fig. 7. Scanning photograph of the left *sagitta* internal aspect of *Selar crumenopthalmus* showing in detail the ostium structure of acoustic canal

he interior aspect is convex and is covered length wise by the acoustic canal that presents a differentiation between ostium and cauda (Fig. 6, 7, 8). The base of the acoustic canal is smooth, showing growth rings of a smaller periodicity than seasonal, phenomena that is observed mainly in the ostium part of the acoustic canal; towards the cauda, calcic carbonates of epitaxial growth with different orientation angles can be observed (Fig. 7, 8).

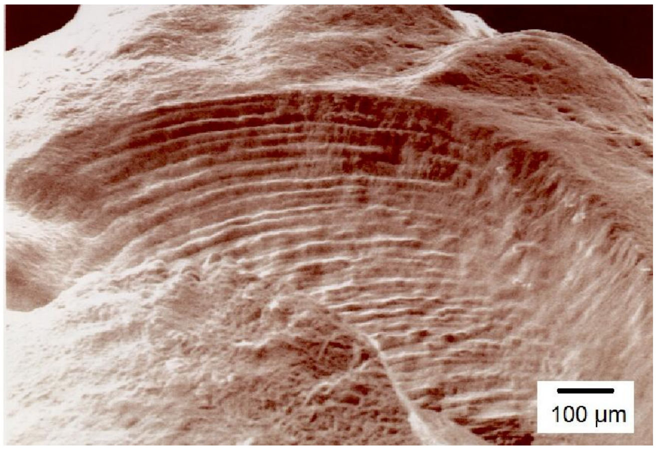


Fig. 8. Scanning photograph of the left *sagitta* internal aspect of *Selar crumenophthalmus* showing the cauda of acoustic canal

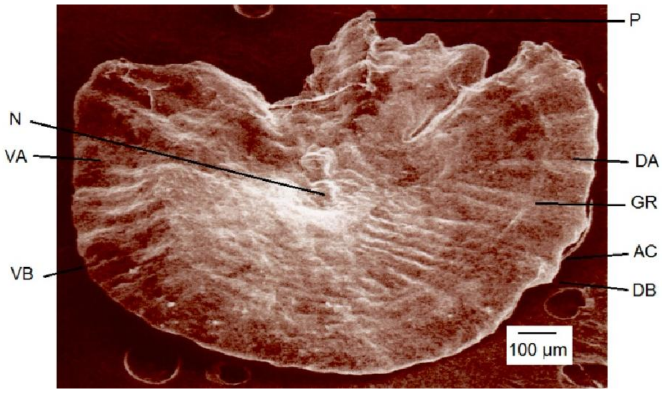
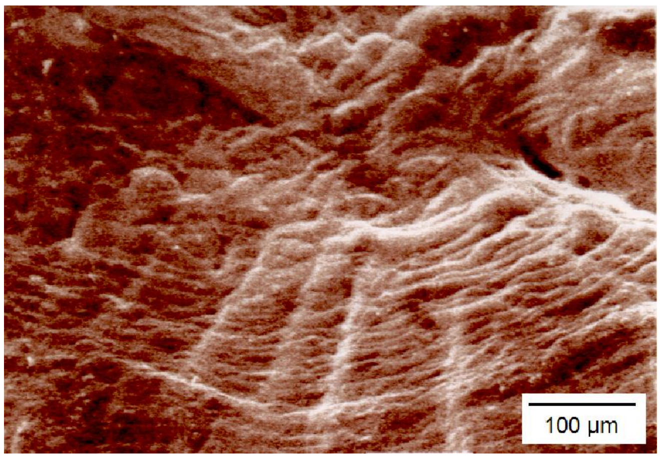


Fig. 9. Scanning photograph of the right *asteriscus*, external aspect of *Selar crumenophthalmus*: P= projection, N= core or primordia, DA = dorsal area, VA = ventral area. GR = growth ring, AC=acoustic canal, DB =dorsal border, VB = ventral border



The external aspect is concave, as the organism grows and its age increments, the otolith tends to be more curved and increments its thickness. Growth rings are more clearly observed in the medium part of the *sagitta*, towards the dorsal border in the external aspect and they are seen as dark lines that run the length of the otolith. Average width of the sagitta is 1.80 times its average length. No difference between right and left otoliths were obtained ($F'_{0.05\ (2,\ 69=3.98)} = 0.039$), nor between females and males ($F'_{0.05\ (2,\ 40=4.091)} = 0.015$).

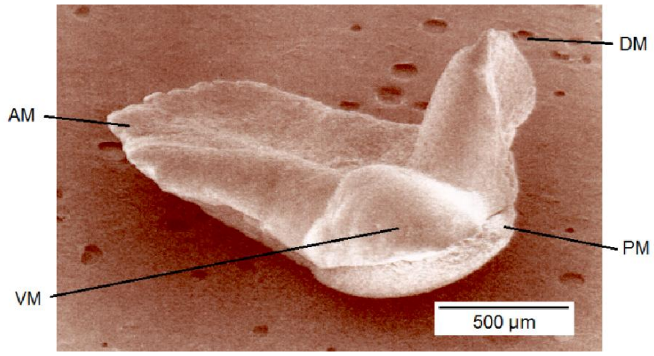


Fig. 11. Scanning photograph of the right *lapillus*, internal aspect of *Selar crumenophthalmus*: AM = anterior margin, PM = posterior margin, DM = dorsal margin and VM = ventral margin

The anterior margin of the asteriscus consists of two parts divided by a blunt projection, nominated as the dorsal area that exhibits a bigger surface and a ventral area of smaller surface (Fig. 9). The anterior margin shows sections that can be rounded or rectilinear towards the ventral of dorsal borders. The *asteriscus* presents an acoustic canal that divides this structure in two parts; the first presents a bigger radius and therefore a larger surface on the external aspect, and a smaller radius and surface in the inner aspect. The internal aspect of the asteriscus is concave, while the external aspect is convex; this curvature is accentuated as the fish ages. The *asteriscus*' borders can have small indentations or be quite smooth. Its average width is 1.22 times its average length. Figures 9 and 10 show the core or primordium, from which the growth bands start to form as soon as the yolk sac of the larvae is absorbed

Saggita

Table 1. Calculated measures of *rostrum* (SL), *antirostrum* (SA) and width (SW) of *sagitta* at different size classes of *Selar crumenophthalmus*

	Both sexes			females			males		
Classes (mm)	SL (mm)	SA (mm)	SW (mm)	SL (mm)	SA (mm)	SW (mm)	SL (mm)	SL (mm)	SW (mm)
130	3.18	2.80	1.65	3.24	2.43	1.58	3.18	2.59	1.63
140	3.39	2.94	1.78	3.44	2.61	1.71	3.39	2.75	1.76
150	3.60	3.08	1.91	3.65	2.79	1.84	3.59	2.91	1.90
160	3.81	3.22	2.04	3.85	2.97	1.98	3.80	3.07	2.03
170	4.01	3.35	2.17	4.05	3.16	2.11	4.00	3.23	2.17
180	4.22	3.48	2.31	4.25	3.34	2.25	4.20	3.38	2.31
190	4.42	3.61	2.44	4.45	3.52	2.38	4.40	3.53	2.45
200	4.62	3.74	2.57	4.64	3.70	2.52	4.60	3.68	2.59
210	4.82	3.86	2.70	4.83	3.88	2.66	4.80	3.83	2.72
220	5.02	3.98	2.83	5.03	4.06	2.79	4.99	3.98	2.86
230	5.21	4.10	2.96	5.22	4.24	2.93	5.19	4.13	3.00
240	5.41	4.22	3.09	5.41	4.42	3.07	5.38	4.28	3.15

Table 2. Relationships between the rostrum and antirostrum and width of the *sagitta* of *Selar crumenophthalmus*

Rostrum	sex	a	b	*n*	r^2	F
Antirostrum	both	1.159	0.765	71	0.789	262.333
Width		0.447	1.142		0.887	551.425
Antirostrum	females	0.782	1.015	17	0.723	42.818
Width		0.355	1.283		0.863	101.896
Antirostrum	males	0.828	0.978	24	0.853	134.253
Width		0.510	1.068		0.696	53.643

Tabla 3. Relationship between total fish length and rostrum length (SL), antirostrum (SA) and width (SW) of *sagitta* of *Selar crumenophthalmus*

Total length (mm)		a	b	n	r^2	F
SL (mm)	Both	0.047	0.866	71	0.939	1 069.290
	Females	0.055	0.837	17	0.758	51.092
	Males	0.048	0.860	24	0.777	80.980
SA (mm)	Both	0.107	0.67	71	0.758	219.904
	Females	0.021	0.976	17	0.739	46.238
	Males	0.049	0.816	24	0.619	38.374
SW (mm)	Both	0.011	1.021	71	0.907	686.734
	Females	0.008	1.086	17	0.757	50.724
	Males	0.009	1.075	24	0.751	70.496

Description of the asteriscus

The form of the *asterisci* can vary from one individual to the next, but these differences are minimum compared to those in *sagittae* (Fig. 4). No difference were found between right and left asteriscus ($F'\ 0.05_{(2,\ 64\ =\ 3.99)} = 0.066$), nor between sexes ($F'\ 0.05_{(2,\ 37 = 4.105)} = 2.817$)

(Lowenstein 1957, Degens *et al.* 1969). The growth bands around the core show different growth patterns that can be from daily growth increments to seasonal rings or another periodicity. Through analysis of these growth rings age groups can be determined (Hickling 1931, Holst *et al.* 1950, Mugiya 1966 a, b, Gallardo-Cabello, 1986, Espino-Barr *et al.* 2006).

Description of the lapillus

The anterior margin of the *lapillus* is a rounded structure oriented to the front side of the fish (Fig. 11). The dorsal and ventral margins extend toward the rear, forming a broad structure with the shape of a fan, divided into several lobes by radios. The dorsal margin is significantly longer than the ventral and mostly rectilinear, while the ventral border shows dentitions. The inner aspect of the *lapillus* is concave and its curvature increments with age. In the posterior border the acoustic channel is observed throughout the fan-shaped structure which comes into contact with the acoustic macula. The external aspect of the *lapillus* is convex. The surfaces of the external and inner face are smooth. Average length of the *lapillus* is 1.33 times its average width (Fig. 4).No differences were found between the right and left lapillus ($F'_{0.05\,(2,\,70\,=\,3.98)} = 0.039$), nor between sexes ($F'_{0.05\,(2,\,41\,=\,4.085)} = 3.185$). Between total length of females and males there was no significant difference ($F'_{0.05\,(2,\,40\,=\,4.085)} = 0.327$). *Morphometric analysis of otoliths of Selar crumenophthalmus.* The calculated sample sizes are: for *sagitta* 72 individuals, *asteriscus* 65 and *lapillus* 71.

sagitta is higher in females than males. Nevertheless, differences between sexes are not statistically significant. Table 2 shows the relationship between the rostrum length *vs*. antirostrum length and width of the sagitta, both for species and for each sex. The relationship between the rostrum length and width of the sagitta is expressed by the value of the exponent b = 1.142 which corresponds to a positive allometric growth, where the sagitta grows slightly more widthwise than lengthwise. The determination index for these two series of data is $r^2 = 0.887$, with an ANOVA result of F = 551.425. On the other hand, the relationship between the length of the rostrum and antirostrum shows a value of b = 0.765 for the species (both sexes and indeterminate), which corresponds to a negative allometric growth, with values of $r^2 = 0.789$, and an ANOVA result of F= 262.333, which means that, as the fish grows, the length of the antirostrum diminishes. Nevertheless, if we analyze these values according to sexes, the obtained values are of a positive allometric growth, b = 1.015 for females, and a very close value to isometry for males b = 0.978. The relationship between total fish length and the length of the *rostrum* and *antirostrum*, as well as the width of the sagitta is shown in Table 3.

Asteriscus

Table 4. Calculated measures of length (AL) and width (AW) of the *asteriscus* at different size classes of *Selar crumenophthalmus*

	Both sexes		females		males	
Classes (mm)	AL (mm)	AW (mm)	AL (mm)	AW (mm)	AL (mm)	AW (mm)
130	0.91	0.99	0.99	0.92	1.04	1.02
140	0.99	1.03	1.06	0.97	1.11	1.05
150	1.08	1.06	1.14	1.02	1.18	1.08
160	1.16	1.10	1.21	1.07	1.26	1.11
170	1.24	1.13	1.29	1.11	1.33	1.13
180	1.33	1.16	1.36	1.16	1.40	1.15
190	1.41	1.19	1.44	1.21	1.47	1.18
200	1.50	1.22	1.51	1.25	1.54	1.20
210	1.59	1.25	1.59	1.30	1.61	1.22
220	1.68	1.28	1.66	1.34	1.69	1.24
230	1.76	1.31	1.74	1.39	1.76	1.26
240	1.85	1.34	1.82	1.43	1.83	1.28

Table 5. Relationships between the length (AL) and width (AW) of the *asteriscus* of *Selar crumenophthalmus*

AL vs AW	a	b	r^2	F	n
Both sexes	1.154	1.074	0.363	37.534	65
Females	1.313	0.686	0.288	7.073	16
Males	1.451	0.513	0.197	6.405	23

Table 6. Relationship between total fish length and *asteriscus* length (AL) and width (AW) of *Selar crumenophthalmus*

Total length (mm)		a	b	n	r^2	F
AL (mm)	Both	0.095	0.482	65	0.471	58.031
	Females	0.027	0.727	16	0.523	17.438
	Males	0.169	0.370	23	0.095	3.316
AW (mm)	Both	0.003	1.159	65	0.893	534.381
	Females	0.008	0.995	16	0.723	40.195
	Males	0.012	0.921	23	0.740	63.683

Growth of the sagitta

The relationship between size classes, rostrum length, antirostrum length and width of the sagitta, for the species as for sexes is observed in Table 1. The rostrum growth of the

Higher values of the allometric index were obtained between total fish length and the width of the sagitta, which for both the species and sexes were values of 1.021, 1.086 and 1.075, respectively, very close to the unit which expresses an isometric growth coefficient, that is, both fish and sagittae grow proportionally. This confirms that this structure is adequate to describe the growth lengthwise of this species. Values of the determination index were r^2 = 0.907, = 0.757 and =0.751, respectively. The ANOVA results were F = 686.734, = 50.724 and = 70.495, respectively and show a high correlation between these two length measures. The values of the allometric indexes obtained for the other measures between total length and lengths of the *rostrum* and *antirostrum*, show a tendency to the isometry. Values fluctuated from r^2 = 0.67 (total length and antirostrum length), to r^2 = 0.976 (total length and antirostrum length of females).

Growth of the asteriscus

Table 4 shows the values of the length and width of the *asteriscus* by all individuals and sexes, related to length classes. *Asteriscus*' length is larger in males than in females, although this difference is not statistically different. Table 5 shows the relationships of the allometric indexes between length and width of the asteriscus; for all individuals a value of b= 1.074 (r^2 = 0.363 and F = 37.534) was obtained, which corresponds to an isometric growth, that is, the asteriscus grows similarly in length and width throughout the different age groups.

Lapillus

The relationship between the total length of the fish and the length and width of the *asteriscus* for all the individuals as for sexes are shown in Table 6. The allometric index value between the fish length and the width of the asteriscus for all individuals is b = 1.159 (r^2 = 0.893 and F' = 534.381), with a clear tendency to a positive isometry, where the asteriscus' width grows slightly more than the fish length. Nevertheless this relationship by sexes shows a lower value and close to isometry: b = 0.995 for females (r^2 = 0.723 and F' = 40.195), and b = 0.921 for males (r^2 = 0.740 and F' = 63.683), that is, the *asteriscus* grows proportionally, enabling the determination of age through this structure as valid for *S. crumenophthalmus*. In the case of the relationship between the length of the fish and length of the *asteriscus*, it was observed that the values of the *b* index had a trend to negative allometry, due to the big variations of the blunt structure, that produces a strong slant in the *asteriscus* length determination.

Growth of the lapillus

The relationships between length and width of the *lapillus* for the species (all individuals) and each sex, for each age class are shown in Table 7. The *lapilli* of males are of bigger sizes than those of females in length classes from 130 to 220 mm of total length. Table 8 shows the values of the allometric indexes for length and width of *lapilli* of the species and by sex. The value of b = 0.857 shows a negative allometric growth index for all the individuals (r^2 = 0.585 and F = 99.699), which means that the *lapillus* grows more lengthwise than in thickness as the fish grows old. Relationships between total length of the fish and length and width of the *lapillus* are observed in Table 9 for all the individuals as for each sex. The value of b = 0.965 (r^2 = 0.912 and F = 724.597) corresponding

Table 7. Calculated measures of length (LL) and width (LW) of the *lapillus* at different size classes of *Selar crumenophthalmus*

	Both sexes		females		males	
Classes (mm)	LL (mm)	LW (mm)	LL (mm)	LW (mm)	LL (mm)	LW (mm)
130	1.19	0.95	1.07	1.22	1.35	1.04
140	1.28	1.01	1.17	1.25	1.42	1.09
150	1.37	1.07	1.27	1.27	1.50	1.15
160	1.46	1.13	1.36	1.28	1.57	1.20
170	1.54	1.18	1.46	1.30	1.64	1.25
180	1.63	1.24	1.56	1.32	1.72	1.31
190	1.72	1.30	1.66	1.34	1.79	1.36
200	1.81	1.36	1.76	1.35	1.86	1.41
210	1.89	1.41	1.86	1.37	1.93	1.45
220	1.98	1.47	1.97	1.38	2.00	1.50
230	2.07	1.52	2.07	1.40	2.06	1.55
240	2.15	1.58	2.17	1.41	2.13	1.60

Table 8. Relationships between the length (LL) and width (LW) of the *lapillus* of *Selar crumenophthalmus*

LL *vs.* LW	a	b	r^2	F'	n
Both sexes	0.817	0.857	0.585	99.699	71
Females	1.079	0.386	0.123	3.395	18
Males	0.895	0.740	0.426	18.072	24

Table 9. Relationship between total fish length and *lapillus* length (LL) and width (LW) of *Selar crumenophthalmus*

Total length (mm)		a	b	n	r^2	F'
LL (mm)	Both	0.011	0.965	71	0.912	724.597
	Females	0.004	1.149	18	0.754	53.208
	Males	0.035	0.749	24	0.701	54.885
LW (mm)	Both	0.017	0.827	71	0.532	80.683
	Females	0.402	0.229	18	-0.024	0.596
	Males	0.034	0.702	24	0.495	23.519

to the total length of the fish and length of the *lapillus* for all individuals (the species) shows a growth close to isometry, which defines that growth of this structure is proportional to the growth of the fish, therefore the *lapillus* could be also used to determine the age of the fish.

Identification of the growth rings

The analysis of the growth rings in *sagittae* and *asterisci* made it possible to identify four groups, the results being as follows: ring 1 = 140 mm, ring 2 = 192 mm, ring 3 = 216mm and ring 4 = 232 mm. The percentage of the *sagittae* that showed growth rings perfectly defined were 100%. Growth rings were observed with best clarity from the dorsal margin in the base of the rostrum to the base of the *posrostrum* in the *sagitta*. The same number of rings was observed in in 75% of the *asterisci*, only in 25% of individuals the growth rings could not be identified. Growth rings were observed with good clarity on the external aspect and run from the beginning of the dorsal area to the end of the ventral area, very defined and continuous (Fig. 9). Due to the thickness of the lapillus, rings were not able to be observed by transparency and transmitted light.

DISCUSSION

During the first age groups the excisura major of the sagitta of *S. crumenophthalmus* is less prominent and occasionally nonexistent, unlike other members of the Carangidae family, as *Caranx caballus* (Gallardo-Cabello *et al*. 2006) and *C. caninus* (Espino-Barr *et al.* 2006), where the excisura major is well developed in the first age groups. In *C. caninus* (Espino-Barr *et al.* 2006) an opposite phenomena occurs as to *S. crumenophthalmus*: as the organism grows old, excisura major tends to disappear and the otolith division in rostrum and antirostrum cannot be observed. It was not observed that the form of the sagittae in *S. crumenophthalmus* varies in the same organism, that is, that the right sagitta is different of the left, as occurs in *C. caballus* and *C. caninus* (Gallardo-Cabello *et al*., 2006 and Espino-Barr et al., 2006), respectively. The rounded structure formed in the rostrum of the sagitta of *S. crumenophthalmus* is a distinctive feature not observed in any other sagitta of the Carangidae family or other of the bony fish group. The *asterisci* form of this studied species is very similar to the one in *C. caballus* (Gallardo-Cabello *et al*. 2006) and *C. caninus* (Espino-Barr *et al.* 2006).

The surfaces of the external and internal aspects of the lapilli in *C. caballus* (Gallardo-Cabello *et al.* 2006) and *C. caninus* (Espino-Barr *et al.* 2006) exhibit a large number of crystal growth patterns of different sizes and orientations, phenomena not present in *S. crumenophthalmus.* In the analysis of the relationship between the rostrum and antirostrum length, it was observed that in the younger age groups the growth index was negative allometric and as the fish grows, the dimensions of the excisura major increases and therefore there is a better definition of the rostrum and antirostrum. The best values of the allometric index of the relationship between the total length of the fish and the length and width of the sagitta were obtained between the total length of the fish and the otoliths width, because the width measurements of the sagitta are much more consistent and do not present as many variations and biases, as the case of the rostrum and antirostrum, where can come to present as "blunt tips" or very long ones, resulting in a high variation of data. As fish ages, the *sagitta* tends to be wider and the size of the excisura major increases, so the growth of this structure is eccentric to the core; the dorsal border grows more than the ventral, and the rostrum more than the posrostrum. The isometric growth index between the length and width of the *asteriscus* shows that the form of this structure maintains throughout the different age groups and length classes. The growth of the *asteriscus* is eccentric to the core, and it grows more towards the dorsal margin than the ventral and the anterior border more than the posterior. The lapillus is an otolith that tends to lengthen as the fish grows, changing its form. This phenomenon was observed also in *C. caballus* (Gallardo-Cabello *et al.* 2006). The lapillus growth is eccentric to the core; it grows more in the anterior border than the posterior and more to the dorsal margin than the ventral. A greater amount of material is deposited in the anterior margin than in the posterior, therefore its thickness tends to diminish as its body size increases.

It is important to develop techniques to reduce the surface of the lapilli to a degree in which it is possible to observe the growth rings by transparency with transmitted light. Published studies of Cabrera-Mancilla (1989), Rivaton & Bourret (1999) and Mier-Uco (2011) show diagrams and photographs of the sagitta, they mention a few parts of this structure, but none of the cases give information on the growth rings that could help establish some comparison with the results obtained in this study. Ingles & Pauly (1984) reported two age groups for this species in Manila Bay, Philippines, determined by means of the analysis of length frequency, which correspond to age 1 = 22 cm and age 2 = 32 cm. these values are higher than those found in our study, nevertheless in this study we found four marks of growth in otoliths.

Conclusions

The identification of growth rings was carried out in sagittae and asterisci. In the case of lapilli, marks were not recognized due to the thickness of the otolith that enabled the observation by transparency. No statistically significant morphometric differences were observed between the right and left otolith and between sexes. The growth of these three pairs of otoliths is eccentric to the core; a larger quantity of material is deposited in the dorsal areas and borders, in relation to the borders and ventral areas. The relationship between the total length of the fish and the length and width of the three pairs of otoliths showed that these structures are suitable to determine the age of this species. Four growth rings were identified on sagittae and asterisci, nevertheless the time of formation of these rings will have to be evaluated. Growth of asterisci and lapilli is higher in males than females. Growth in sagittae is higher in females than in males.

Recommendations

Studies to identify growth rings in this species should continue, in order to detect changes in the average size for each growth ring which may represent overfishing and reduced the size of first capture. The time of growth ring formation has to be evaluated to consider them as annual age groups and conduct studies on the growth of this species, calculating the von Bertalanffy growth constants and compare these results with those obtained by other authors.

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