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Morphologic and Morphometric Study of the Otoliths: *Sagitta*, *Asteriscus* and *Lapillus of Xiphias gladius* (Perciformes: Xiphiidae) in the Mexican Pacific Coast

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ABSTRACT

In the present study morphologic and morphometric analysis of the three pairs of otoliths: *sagittae, asterisci* and *lapilli* of the swordfish *Xiphias gladius* is carried out for the first time. *X. gladius* data were obtained from 2000 to 2002 in nine fishing cruises in two commercial vessels that arrived in Manzanillo, México. As with other billfishes, *sagittae* are characterized by having four bodies: a *rostrum* and *antirostrum* separated by the *excisura major* and a *postrostrum* and *pararostrum* separated by an *excisura minor*; being this a peculiar character observed in these species and in the dolphinfish. The growth of the 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 ventral areas. No statistically significant morphometric differences were observed between the right and left otolith and between sexes of *X. gladius*. Seasonal growth rings could not be observed in the *sagittae*, but were present in some *asterisci*. Results are discussed with those reported by other authors. It is recommended that studies of daily growth increases in one-year organisms or less be carried out. We suggest that a capture quota of this fishery is given to the commercial fishermen.

Introduction

The swordfish *Xiphias gladius* Linnaeus 1758 belongs to the Xiphiidae family. Palko *et al.* (1981) made the following diagnosis: Pelvic fins are absent, scales are absent in adult, one pair of caudal keels. The snout is long and sword shaped, the base of first dorsal fin short and broadly separated from the second dorsal fin. Cosmopolitan in tropical and template waters, present in all the area between 50°N and 3°S. It is an epipelagic species, mainly oceanic, although sometimes it is found in coastal areas. It is a high migratory species, very aggressive and normally solitary. Generally it lives above the thermocline, but can descend to great depths (up to about 800 m). It feeds on a wide variety of fish, crustaceans and squid. It is said that it uses the sword to kill its prey. Its meat is sold locally fresh and refrigerated (Collette 1995).

There are several studies on the biology and dynamics of this species, as that of Beckett (1974) on the life cycle of the swordfish, Govoni *et al.* (2000) on the larvae distribution, Kondritskaya (1970) on larvae in the Channel of Mozambique and Markle (1974) on larvae in the Atlantic Ocean. De la Serna and Alot (1990) studied migratory movements of this species in the Strait of Gibraltar. Gorbunova (1969) studied the feeding of larvae, Scott and Tibbo (1968) the feeding habits of the adults. Mahé *et al.* (2016) studied the form of otoliths to identify different swordfish stocks. Ehrhardt (1992) studied age and growth in the northwestern Atlantic.

However, studies on otoliths of this species are scarce; they were studied by Sun *et al.* (2002), Ovchinnikov (1971), Beckett (1974), Tserpes and Tsimenides (1995).

This study poses the following objectives: a) analyze the morphology of the *sagittae*, *asterisci* and *lapilli.* b) Study the morphometry of the otoliths and its variation between left and right and regarding sex. c) Identify growth marks. d) Compare results with those of other authors.

Studies on otoliths with scanning microscope level provide valuable information for the study of its morphology and the impulse transmission from the otolith to the brain, given the high specialization that for evolutionary process has occurred in these organisms.

Materials and Methods

The swordfish *X. gladius* data were obtained from 2000 to 2002 in nine fishing cruises in two commercial vessels that arrive in Manzanillo, Colima, México. Organisms were captured with long line. Measurements were taken *in situ* for each organism: eye to fork length (EFL, cm) 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 optic capsules, *sagittae* from *sacculus*, *asterisci* from *lagena* and *lapilli* from *utriculus*, and cleaned in water and dried. They were preserved dry in Eppendorf tubes with the number of the organism, capture date, eye to fork length and sex.

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The structure and microstructure of the otoliths were studied with a scanning electronic microscope, from the Institute of Physics of the Universidad Nacional Autónoma de México.

Otoliths were analyzed with a dissecting microscope. The terminology of the Secor *et al.* (1992) glossary was used to describe 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, 2016, 2017) and Espino-Barr *et al.* (2006, 2013, 2015, 2018).

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.

Results

Description of the otoliths of *Xiphias gladius*.

Billfish *sagittae* are generally characterized by being very small and fragile, therefore their extraction is difficult and if not done carefully, they brake. Figure 1 shows the three pairs of otoliths: *sagittae, asterisci* and *lapilli*, and the measurements taken of length and width.

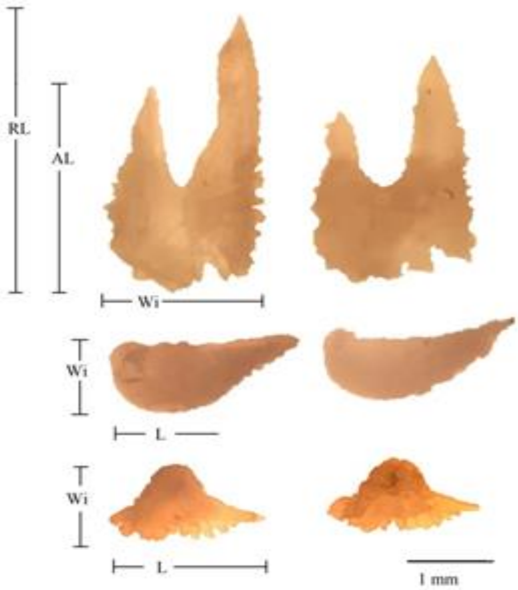

Figure 1. Relationship between the three pairs of otoliths of *Xiphias gladius*, left side are the internal aspect, right side external aspect; RL = *rostrum* length, AL = *antirostrum* length, Wi = width, L = length.

Description of the sagitta.

In figures 1, 3 and 4 it can be appreciated that the *excisura major* divides the otolith in *rostrum* and *antirostrum,* and the *excisura minor* in *postrostrum* and *pararostrum*. The *rostrum* is very elongated and large, simulating an arrow shape structure; the *antirostrum* has a tendency to be rounded. The *postrostrum* shows also an arrow shape structure of a greater thickness than the *rostrum*. The *pararostrum* shows a rounded shaped similar to the *antirostrum*, and the *excisura minor* is very well defined (Figure 3, 4).

Figure 2. Morphologic and morphometric differences in the *sagittae* of *Xiphias gladius* for organisms of different lengths.

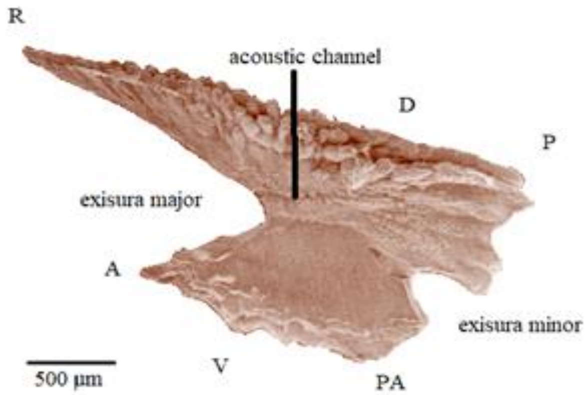

Figure 3. Scanning photograph of the right *sagitta* internal aspect of *Xiphias gladius.* R= *rostrum*, A= *antirostrum*, P= *postrostrum*, PA = *pararostrum*, D= dorsal margin, V= ventral margin.

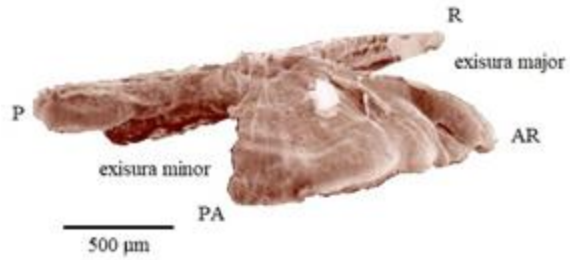

Figure 4. Scanning photograph of the right *sagitta* external aspect of *Xiphias gladius*. R= *rostrum*, A= *antirostrum*, P= *postrostrum*, PA = *pararostrum*, D= dorsal margin, V= ventral margin.

In figure 2 morphologic and morphometric variations are observed in *sagittae* as the organism grows and increments its length. Both, dorsal and ventral margins show great amplitude with a great quantity of denticles that go from the *rostrum* to the *postrostrum* (Figure 5).

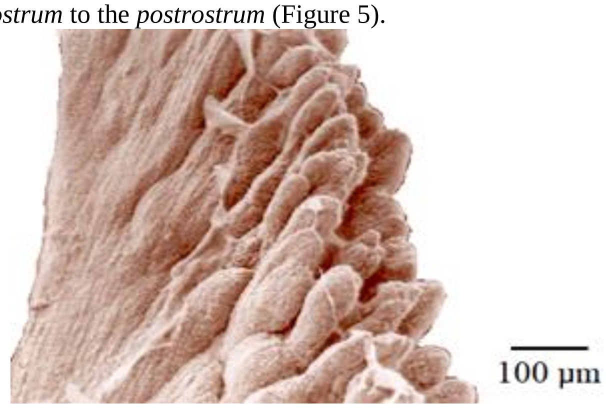

Figure 5. Detail of the ventral margin of the right *sagitta* external aspect of *Xiphias gladius.*

The acoustic canal is very developed, it is wide and deep, and goes along the whole otolith, increasing its width from the anterior part to the posterior, without differentiation on *ostium* and *cauda*. In its base it shows calcic carbonate crystals which enter in contact with the acoustic macula and thus with the ramifications of the eighth cranial nerve, that transmit the impulses to the brain. In between the calcic carbonate crystals, the otolin is distributed forming a reticular structure (Figure 6).

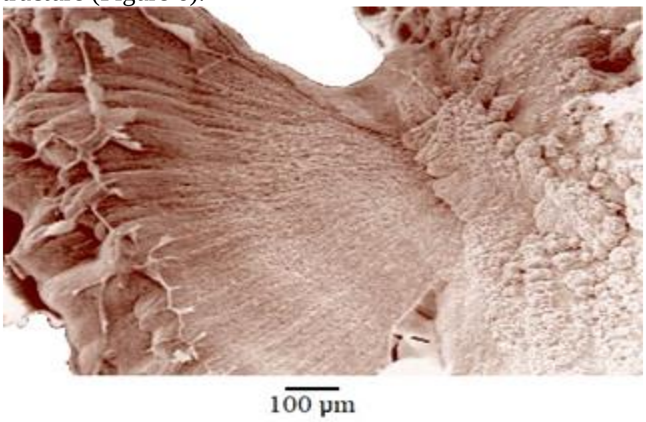

Figure 6. Scanning photograph of the right *sagitta*, internal aspect of *Xiphias gladius* showing the acoustic canal.

The inner face of the *sagitta* is convex while the external face is concave. This aspect increases as the age of the organisms increases, that is, otoliths tend to be more and more curved. According to this, the nucleus of the otolith is eccentric in each plane of the otolith, this is, the *postrostrum* grows more than the *rostrum* and the *pararostrum* more than the *antirostrum*. More material is deposited on the dorsal side than on the ventral side (Figures 1, 2, 3 and 4).

The left and right *sagittae* of the same organism are not equal (Figure 1), but there was no difference between the right and left *sagitta* ($F'_{0.05\ (2,\ 121=3.919)} = 0.046$), nor between females and males ($F'_{0.05\ (2,\ 117\ =\ 3.922)} = 1.051$). The average width of the *sagitta* (SW) is 1.951 times its average length (SL) (Figure 1).

Description of the *asteriscus*.

The *asterisci* can show a great variety of forms between different specimens, but no statistical differences were found between the length of the right and left ($F'_{0.05\ (2,\ 106\ =\ 3.931)} = 0.104$), nor between females and males ($F'_{0.05\ (2,\ 106\ =\ 3.931)} = 0.743$).

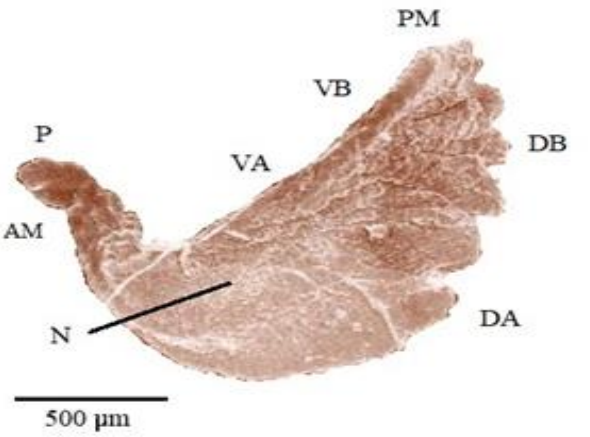

Figure 7. Scanning photograph of the left *asteriscus*, internal aspect of *Xiphias gladus*: P= projection, N= core or *primordia*, DA = dorsal area, VA = ventral area, DB =dorsal border, VB = ventral border, PM = posterior margin, AM = anterior margin.

A pointed projection is shown in the anterior margin dividing the *asteriscus* into two parts, a dorsal area with a larger surface and a ventral area with a smaller area (Figure 7). The anterior margin presents sections that are rectilinear in the zones of the surface and the ventral border, and that extend to the back margin. The dorsal area and the dorsal border show strong irregularities at least in the first part of the *asteriscus*. The posterior margin is curved (Figure 7). The dorsal border of the *asteriscus* presents denticles (Figure 8).

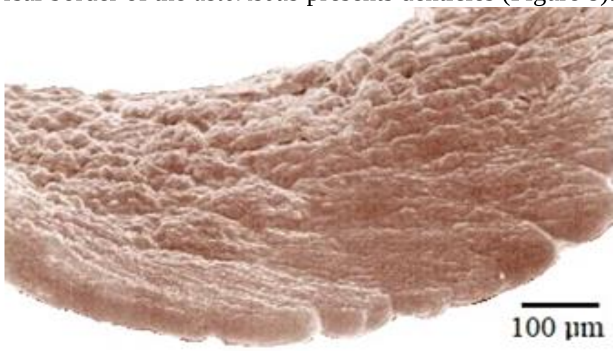

Figure 8. Denticles on the dorsal border of the *asteriscus* of the sword fish *Xiphias gladius*, also growth rings can be observed on the surface, formed by calcic carbonate crystals.

Growth rings are present, with a periodicity lower than the seasonal and can be observed throughout the surface of the *asteriscus* (Figures 8, 9 and 10). The internal aspect of the *asteriscus* is concave and the external convex; this characteristic increases as the organism ages. Small denticles are present in both sides of the *asteriscus* (Figures 8 and 9). The average length of the *asteriscus* (AL) is 2.091 times its average width (AW).

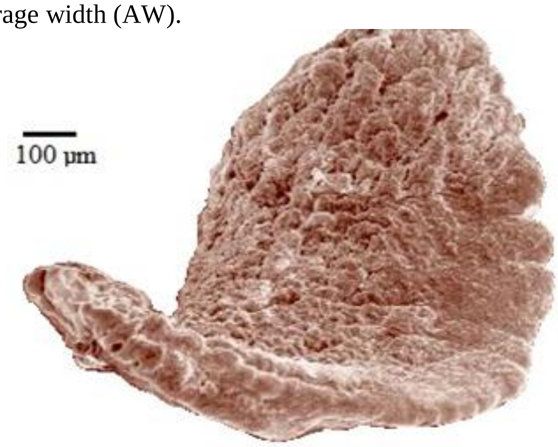

Figure 9. Growth rings on the surface of the *asteriscus* of *Xiphias gladius*; on the dorsal and ventral border denticles can be observed.

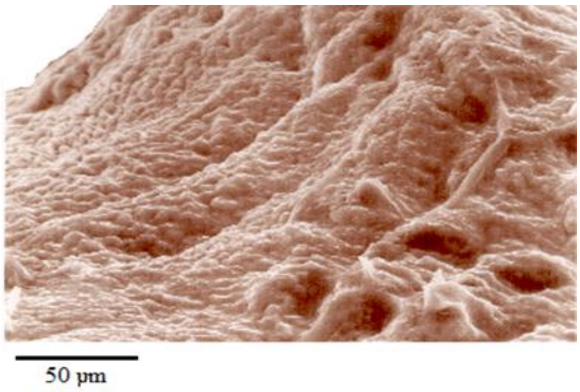

Figure 10. Crystals of calcic carbonate forming growth rings on the *asteriscus* of the swordfish *Xiphias gladius*. In between these crystals the otolin protein is arranged.

Description of the *lapillus*.

The anterior margin of the *lapillus* tends to be rounded and is disposed toward the front of the fish (Figures 11 and 12). In the central part of this otolith, the dorsal and ventral margin form a fan-like structure, being the dorsal border much longer than the ventral. In this fan-like structure the acoustic macula is arranged to transmit the vibrating movements of this otolith in the *utriculus* to the brain, by means of the eighth cranial nerve. Also the acoustic macula participates in the growth of the otolith by depositing calcium carbonate and otolin.

The internal aspect of the *lapillus* is concave and the external convex; these characters increase with age as the otoliths become more and more curved as the fish ages. This otolith is divided into several lobes by radius (Figure 13), showing growth rings with periodicities lower than the seasonal (Figure 14). No difference between the right and left *lapilli* were found ($F'_{0.05\ (2,\ 121=3.919)} = 0.016$), nor between females and males ($F'_{0.05\ (2,\ 116\ =\ 3.923)} = 0.540$). Average length of the *lapillus* (LL) is 1.596 times its average width (LW).

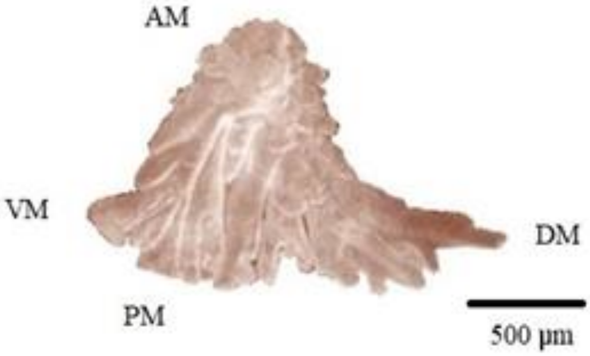

Figure 11. Scanning photograph of the right *lapillus*, external aspect of *Xiphias gladius*: AM = anterior margin, PM = posterior margin, DM = dorsal margin and VM = ventral margin.

Figure 12. Scanning photograph of the left *lapillus* external aspect *Xiphias gladius.*

Figure 13. Lobes and rays in the posterior border of the *lapillus* of *Xiphias gladius.*

Figure 14. Growth rings of smaller periodicity than seasonal in the *lapillus* of *Xiphias gladius.* In between the crystals of calcic carbonate the otolin is arranged.

Morphometric analysis of otoliths of *Xiphias gladius*

Growth of the sagitta. Table 1 shows the relation between *rostrum*, *antirostrum* and width of *sagitta* and the length classes for the species and sexes. Growth of the *rostrum* of *sagitta* is bigger in females at lengths of 100 cm to 130 cm. From 140 cm on, the *rostrum*'s length is bigger in males than in females. In all cases the *rostrum* has a longer size than the *antirostrum*.

The relationship between length of *rostrum* and length of *antirostrum* of *sagitta* is expressed by the exponent value b = 0.642 (Table 2), which shows a negative allometric growth. This indicates that the *rostrum* tends to enlarge as fish ages. In the case of females, results show the same tendency and the relationship between *rostrum* and *antirostrum* is b = 0.449.

On the other hand, in the case of the males, the value of the allometric index is b = 0.965, which shows a tendency to a positive allometry.

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

	Both sexes			Females			Males		
Classes (cm)	SL (mm)	SA (mm)	SW (mm)	SL (mm)	SA (mm)	SW (mm)	SL (mm)	SL (mm)	SW (mm)
100	2.29	1.32	1.21	2.33	1.28	1.17	2.26	1.40	1.26
110	2.41	1.41	1.26	2.44	1.36	1.23	2.39	1.50	1.31
120	2.53	1.49	1.32	2.54	1.45	1.29	2.52	1.59	1.36
130	2.64	1.58	1.37	2.65	1.53	1.35	2.64	1.68	1.41
140	2.75	1.66	1.42	2.74	1.61	1.40	2.76	1.77	1.46
150	2.85	1.74	1.46	2.84	1.68	1.45	2.88	1.85	1.51
160	2.95	1.81	1.51	2.93	1.76	1.50	2.99	1.94	1.55
170	3.05	1.89	1.55	3.02	1.83	1.55	3.10	2.02	1.59
180	3.14	1.97	1.59	3.10	1.91	1.59	3.21	2.10	1.64
190	3.24	2.04	1.63	3.19	1.98	1.64	3.31	2.18	1.68
200	3.33	2.11	1.67	3.27	2.05	1.68	3.41	2.25	1.72
210	3.41	2.18	1.71	3.35	2.12	1.73	3.51	2.33	1.75

Table 2. Relationships between the *rostrum* and *antirostrum* and width of the *sagitta* of *Xiphias gladius.*

***Sagitta* length (mm)**	**sex**	**a**	**b**	**n**	**r^2**	**F**
Antirostrum	Both	0.899	0.642	122	0.400	81.550
Width		0.937	0.428	116	0.392	75.291
Antirostrum	Females	1.102	0.449	76	0.234	23.958
Width		1.041	0.343	73	0.284	29.517
Antirostrum	Males	0.664	0.965	42	0.754	126.694
Width		0.798	0.583	39	0.678	81.135

The relationship between *rostrum*'s length and *sagitta*'s width shows higher values of negative allometric growth, that is, the *sagitta* tends to enlarge more in length than width with a significant negative allometric growth index of b = 0.428 in all the individuals, b = 0.343 in females and b = 0.583 in males (Table 2). This sharp progressive decline of the width of the *sagitta* shows that the *rostrum* and *antirostrum* tend to close as a pincer or wrench in which the acoustic canal comes in more contact with the ramifications of the eighth cranial nerve, increasing this way the impulse transmission.

These results also indicate that the growth of *sagitta* is eccentric to the core. As the fish grows old and ages, the *postrostrum* grows more than the *rostrum* (Figure 2). The dorsal edge grows more than the ventral, and a larger amount of material accumulates on the inner side than the external aspect of the *sagitta*.

The relationship between eye-fork length and length and width of *sagitta* is shown in Table 3. The highest value of the allometric index relating fish eye-fork length to *rostrum* length is b = 0.595 in males, smaller values are found for the species (all specimens) and females, b = 0.537 and b = 0.491, respectively. In the case of fish eye-fork length and *antirostrum* length, a negative allometric growth index was observed for all organisms: b = 0.680, which means that this structure does not grow directly proportional to fish's eye-fork length, lower values were calculated for males and females, where b = 0.683. The higher values between eye-fork length of the fish and *sagitta*'s width were in females b = 0.521, and that for the species: b = 0.469, and b = 0.449 for males.

In all cases, values show that there is not a direct proportionality between *rostrum* length, *antirostrum* length, and *sagitta* width and fish length, showing that this structure is not adequate to describe the growth of the organism. Although the F values of the ANOVA were high, that does not mean that there is a significant correlation between these structures in each case.

Table 3. Relationship between eye-fork fish length fish and *rostrum* length (SL), *antirostrum* (SA) and width (SW) of *sagitta* of *Xiphias gladius.*

Fish length (cm)		**a**	**b**	**r^2**	**F**	**n**
SL (mm)	Both	0.194	0.537	0.281	48.688	123
	Females	0.243	0.491	0.145	13.853	77
	Males	0.146	0.595	0.497	41.576	42
SA (mm)	Both	0.057	0.680	0.440	104.550	133
	Females	0.055	0.683	0.365	48.771	84
	Males	0.060	0.683	0.543	52.069	44
SW (mm)	Both	0.139	0.469	0.484	118.100	126
	Females	0.107	0.521	0.447	64.760	80
	Males	0.159	0.449	0.596	60.040	41

Growth of the asteriscus. The relationship between fish length and length and width of *asteriscus* is shown in Table 4. The length of the *asterisci* is larger in females of the length classes from 100 cm to 110 cm; and at 120 mm are the same. From 130 cm on, the length is bigger in males than in females.

The relationship between the length and width of the *asterisci* (Table 5) is described for the species by the allometric index b = 0.727 (r^2 = 0.562, F' = 138.234); higher values were obtained for males b = 0.797 and smaller for females b = 0.628. These results show a tendency to a negative allometric growth in which the increase in width is bigger than in length. Growth of *asteriscus* is eccentric to the core; its anterior border grows more than the posterior border and the dorsal margin grows more than the ventral margin.

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

	Both sexes		**Females**		**Males**	
Classes (cm)	**AL (mm)**	**AW (mm)**	**AL (mm)**	**AW (mm)**	**AL (mm)**	**AW (mm)**
100	1.29	0.62	1.31	0.62	1.27	0.64
110	1.36	0.65	1.38	0.65	1.35	0.67
120	1.43	0.68	1.44	0.69	1.44	0.70
130	1.49	0.71	1.49	0.72	1.51	0.73
140	1.55	0.74	1.55	0.74	1.59	0.76
150	1.62	0.77	1.60	0.77	1.67	0.79
160	1.68	0.80	1.65	0.80	1.74	0.82
170	1.73	0.83	1.70	0.82	1.81	0.85
180	1.79	0.85	1.75	0.85	1.88	0.88
190	1.85	0.88	1.80	0.87	1.95	0.90
200	1.90	0.91	1.84	0.90	2.02	0.93
210	1.95	0.93	1.89	0.92	2.09	0.95

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

AL vs AW	**a**	**b**	**n**	**r^2**	**F**
all	0.544	0.728	108	0.562	138.234
females	0.575	0.629	69	0.435	53.358
males	0.528	0.797	35	0.743	99.077

Table 6 shows the relationship between eye-fork length of fish and length and width of *asteriscus*. The highest allometric index value was for males b = 0.671, and eye-fork length of fish and *asteriscus* length. These indexes decrease for the species b = 0.562, and females b = 0.489. In the case of the relationship between eye-fork length and *asteriscus* width, the specie shows the highest value b = 0.553, decreasing for the males b = 0544 and females b= 0.527.

Table 6. Relationship between eye-fork fish length and *asteriscus* length (AL) and width (AW) of *Xiphias gladius*.

Fish length (cm)	**sex**	**a**	**b**	**r^2**	**F**	**n**
AL (mm)	Both	0.097	0.562	0.384	67.753	108
	Females	0.138	0.489	0.274	26.675	69
	Males	0.058	0.671	0.523	38.282	35
AW (mm)	Both	0.048	0.553	0.396	74.968	114
	Females	0.055	0.527	0.356	41.361	74
	Males	0.052	0.544	0.402	24.541	36

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

	Both sexes		**females**		**Males**	
Classes (cm)	**LL (mm)**	**LW (mm)**	**LL (mm)**	**LW (mm)**	**LL (mm)**	**LW (mm)**
100	1.34	0.89	1.32	0.85	1.34	0.95
110	1.41	0.92	1.39	0.89	1.42	0.97
120	1.47	0.95	1.45	0.93	1.49	0.98
130	1.53	0.98	1.51	0.96	1.55	0.99
140	1.59	1.01	1.57	1.00	1.62	1.00
150	1.65	1.03	1.63	1.03	1.68	1.02
160	1.70	1.05	1.68	1.07	1.74	1.03
170	1.76	1.08	1.74	1.10	1.80	1.04
180	1.81	1.10	1.79	1.13	1.86	1.05
190	1.86	1.12	1.84	1.16	1.92	1.05
200	1.91	1.14	1.89	1.19	1.97	1.06
210	1.95	1.16	1.94	1.22	2.03	1.07

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

LL vs LW	a	b	n	r^2	F
all	0.838	0.420	123	0.339	63.510
female	0.800	0.542	83	0.481	77.127
male	0.899	0.236	35	0.132	6.189

The relationship between the length and width of *lapillus* (Table 8) show very low values, the highest allometric index b = 0.542 was for the females, b = 0.420 for the specie, and b = 0.236 for males. These values represent negative allometric growth, in which *lapillus* grows more in length than in width (Figure 12). *Lapillus* growth is eccentric to the core, but the anterior and ventral margins show a higher deposition of growth materials than the posterior and dorsal margins.

Table 9. Relationship between eye-fork fish length and *lapillus* length (LL) and width (LW) of *Xiphias gladius.*

Fish length (cm)	sex	a	b	r^2	F	n
LL (mm)	Both	0.132	0.504	0.237	38.963	123
	Females	0.123	0.516	0.228	25.221	83
	Males	0.104	0.556	0.260	12.925	35
LW (mm)	Both	0.175	0.354	0.228	37.026	123
	Females	0.090	0.486	0.343	43.733	83
	Males	0.456	0.160	0.038	2.335	35

The relationship between fish eye-fork length, and the length and width of the *lapillus* is shown in Table 9. The highest value of the allometric index for the eye-fork length of fish and *lapillus* length was found for males with a value of b = 0.556, smaller indexes were found for the females and species: b = 0516 and b = 0.504, respectively. The higher value of the relationship between fish eye-fork length and *lapillus* width, corresponds to females b = 0.486, and lower values were found in the species b= 0.354 and in males b= 0.160.

Discussion

The size of the otoliths is very small and fragile, for that reason they are very difficult to extract, manage and analyze. The sagitta of an individual of *X. gladius* of 170 cm eye-fork long measures 3.05 mm, the *asteriscus* 1.73mm and the *lapillus* 1.76 mm.

No periodical growth rings were observed on the *sagittae* of *Xiphias gladius* as described for sailfish, the striped marlin or blue marlin by Radtke (1983), who located them on the dorsal and ventral borders of the otoliths (Radtke and Dean 1981). Or those observed in the sagittae of *M. nigricans* in Kona, Hawaii, reported by Hill *et al.* (1989). However, growth rings were observed in the *asterisci* of *X. gladius* whose periodicity need to be analyzed (Figures 8, 9, 10).

Observation and interpretation of daily growth increments in dolphinfish *Coryphaena hippurus* by Solano *et al*. (2015) made the study of age and growth in organisms that have not yet reached one year of age possible. To do this, the *sagittae* were polished at the nucleus level and the counts of daily growth increments observed towards the periphery.

Likewise, daily growth increases in swordfish *X. gladius* larvae have also been observed by Megalofonou *et al.* (1995) in the Mediterranean Sea, Sun *et al.* (2002) in Taipei, Taiwan, Govoni *et al.* (2003) in the North Atlantic and Groison *et al.* (2004) in Australia.

The difficulty of obtaining organisms of less than one year of age makes the study of the daily growth increases in these organisms not easy. Also, it is very difficult to polish otoliths of swordfish *X. gladius* due to its very small size and enormous fragility, since it is very easy for these to split in their middle part where the acoustic canal is located. *Asterisci* are also very fragile due to the thinness of the structure.

Sun *et al*. 2002 reported data on the age determination of juvenile swordfish using otoliths and concluded, together with other authors, that these structures are not adequate to determine the age of this species (Ovchinnikov 1971, Beckett 1974, Tserpes and Tsimenides 1995).

Recent studies carried out by several authors have resolved to combine analysis of daily growth increments on otoliths in juvenile specimens of *X. gladius* and complete them with the analysis of growth rings identification in samples of cut anal spines of adult organisms (Esteves *et al*. 1995). This is the case of Sun *et al.* (2002), who determined age and growth of *X. gladius* in Taiwanese waters, by growth rings in transversal cuts of the first anal fin. In other cases age groups were determined through the analysis of the growth rings of this fin in the coast of Chile (Chong and Aguayo 2009) and in the Mediterranean Sea (Akiol and Ceyhan 2013).

In some cases, estimates of age and growth of *X. gladius* have been made using the length frequency analysis through the use of the ELEFAN method (Varghese *et al*. 2013).

The analysis of the relationship between otolith length and that of the fish, revealed in all cases a negative allometric growth index, much lower than the unit, which establishes that otolith growth is not proportional to that of the fish, and cannot be used as structures to determine the age of organisms.

Morphometric differences between the right and left otoliths for the three pairs were not statistically significant. In the same way, differences in otolith sizes were not statistically significant between sexes.

Conclusions

The otoliths of *Xiphias gladius* are structures with which age cannot be determined in organisms, because the growth of the otolith is not proportional to the fish.

Growth rings were observed in *asterisci* of *Xiphias gladius* but the periodicity was not determined.

No statistical significant morphometric differences were observed between the right and left otolith and between sexes.

Recommendations

It is very important to continue studies of the otoliths of *Xiphias gladius* to increase the amount of information on the morphometry and morphology of these structures. This will also help understand the form and function, as its capacity to transmit impulses from the different cavities where they are included (*sacculus*, *lagena* and *utriculus*) to the brain, by the eighth cranial nerve.

It is important to analyze the abundance of this species in the Mexican Pacific, with the objective to establish capture quotas for its commercial fishing as sport fishing.

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