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ARTICLE

Morphometric analysis on sagitta, asteriscus and lapillus of Shortnose Mojarra *Diapterus brevirostris* (Teleostei: Gerreidae) in Cuyutlan coastal Lagoon, Colima, Mexico

Análisis morfométrico de la sagitta, el asteriscus y el lapillus de la mojarra malacapa *Diapterus brevirostris* (Teleostei: Gerreidae) de la laguna costera de Cuyutlán, Colima, México

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Resumen.- Se estudiaron la morfología, la morfometría y los anillos de crecimiento de los otolitos: sagitta, asteriscus y lapillus de *Diapterus brevirostris* de la laguna de Cuyutlán, Colima, México. Las muestras se obtuvieron de la captura comercial de abril 2010 a julio 2012. Se analizaron las diferencias entre derecho e izquierdo y entre sexos de los tres pares de otolitos. Las relaciones entre la longitud total del pez y la longitud y anchura del otolito mostraron que estas estructuras pueden utilizarse para determinar la edad en los peces. En todos los casos se observó que el crecimiento en los otolitos es excéntrico con respecto al núcleo. Se identificaron 6 anillos de crecimiento en las sagittae y en los asterisci. Debido a su grosor, estas marcas no se observaron en los lapilli. El crecimiento de las sagittae y los lapilli es mayor en machos que en hembras en el intervalo de clases de tallas de 160 a 320 mm de longitud total. Sin embargo, se observó que el crecimiento de los asterisci es mayor en hembras que en machos en las tallas de 180 a 320 mm.

Palabras clave: Otolitos, anillos de crecimiento, determinación de edad, *Diapterus brevirostris*

Abstract.- Morphology, morphometry and growth rings of the otoliths: sagitta, asteriscus and lapillus of *Diapterus brevirostris* from Cuyutlán Lagoon in Colima, Mexico were studied. The samples were obtained from the commercial catch from April 2010 to July 2012. Right and left and sex differences of the three pairs of otoliths were analyzed. Relations between total length of the fish and length and width of the otolith showed that these structures can be used to determine age in fish. Growth in otoliths is eccentric according to the core in all cases. Six growth rings were identified in sagittae and asterisci. These marks could not be seen in lapilli because of the thickness of this structure. Growth of sagittae and lapilli is faster in males than females of 160 to 320 mm total length. Nonetheless, it was observed that growth in asterisci is faster in females than in males of 160 to 320 mm.

Key words: Otolith, growth rings, age determination, *Diapterus brevirostris*

INTRODUCTION

Shortnose mojarra *Diapterus brevirostris* (Sauvage, 1879) used to be named Peruvian mojarra *D. peruvianus* (Cuvier, 1830) (González-Acosta *et al.* 2007). Its common name, Peruvian mojarra has also been changed for Shortnose mojarra (pers. comm. Héctor Espinosa-Pérez¹). It is distributed in Eastern Pacific from south part of the Gulf of California to Peru. Its habitat is near the shore, on sandy bottoms. Juveniles penetrate brackish coastal lagoons. The species is mainly carnivorous; it consumes small benthic invertebrates and fish, also small amounts of vegetable

mater (Allen & Robertson 1994, Bussing 1995).

This species is an important fishery resource, caught by gill nets and cast nets by artisanal fishers, although it is not the target species. During 2011 its production in Mexico was 62 thousand tons; in the Mexican Pacific coast the production was 62% and Colima registered 345 ton (1% of the Pacific production). The price at the market is of \$30.00 Mexican pesos (\$2.30 US dollar).

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Studies on Gerreidae family taxonomy have been made by Tapia-García & Ayala-Pérez (1996-1997), González-Acosta *et al.* (2005, 2007); distribution patterns of this family have been studied by Martínez-González (1983), Avilés-Torres *et al.* (2001), Halpern (2004), Caballero-Vázquez *et al.* (2005), Castillo-Rivera *et al.* (2005), and Ospina-Arango *et al.* (2008). Álvarez-Pliego (2009) carried out a study on phylogenetic and biographic analysis of the genus *Diapterus*. Jiménez-Rosenberg (2003) studied *D. peruvianus* larvae and Hernández *et al.* (2012) larvae of *Eugerres mexicanus*. Gómez del Prado-Rosas *et al.* (2007) reported parasites trematoda in *Gerres cinereus*.

Aguirre-León & Díaz-Ruíz (2000, 2006) studied length structure, gonadic maturation and feeding habits of *Eugerres plumieri* and *D. rhombeus*.

Rubio *et al.* (2004²) reported data on growth in cages of *D. peruvianus* and *Eucinostomus currani* in Buenaventura Bay, Colombia. Díaz-Murillo (2010) studied otolith sagitta of several Gerreidae species. Age determination of *G. cinereus* was calculated by Álvarez-Hernández (1999) and Jones *et al.* (2010), using length frequency analysis and scales. Herrera-Reveles *et al.* (2012) studied daily growth increments and RNA/DNA ratios in juveniles of *Eucinostomus argenteus* in the Caribbean sea of Venezuela. Chen *et al.* (2007) analyzed mitochondrial DNA in relationships on phylogenetic studies.

Otoliths are hard structures of specialized crystals that are part of the lateral acoustic system of fish. They are immersed in the membranous labyrinth at each side of the brain, and act as equilibrium and audition organs. They are formed mainly by crystalized calcium carbonate inserted in an organic protein mater. Analyses on otoliths composition and physiology on different species have been done by Hickling (1931), Sasaki & Miyata (1955), Carlström (1963), Mugiya (1964, 1966 a, b), Degens *et al.* (1969) and Gallardo-Cabello (1986).

Studies of the three pairs of otoliths (sagitta, asteriscus and lapillus) have been done on larvae of different species by Barkman (1978), Victor & Brothers (1982), Brothers *et al.* (1983), Solomon *et al.* (1985), Bolz & Lough (1983, 1988), Lagardere (1989), Suthers *et al.* (1989) and David *et al.* (1994), describing its parts and daily growth rings.

Adult fish studies on morphometry related to body length have been carried out by Espino-Barr *et al.* (2006), Gallardo-Cabello *et al.* (2006), Santana-Hernández *et al.* (2008), Granados-Flores *et al.* (2010) and Gallardo-Cabello *et al.* (2011), on diverse species. Study of otoliths can also be useful in the determination of antropogenic contamination (Kamaruzzaman *et al.* 2011).

Otoliths have mostly been used to determine age groups of the stock and growth analysis, one of the fundamental parameters to formulate models on maximum sustainable captures, yield per recruit, predictions and catch simulations (Campana & Neilson 1985, Sparre & Venema 1995, Gallardo-Cabello *et al.* 2003, Mascareña-Osorio *et al.* 2003, Begg *et al.* 2005, Espino-Barr *et al.* 2005, Gallardo-Cabello *et al.* 2007, Espino-Barr *et al.* 2010). These models are used to help regulate the fishery administration to avoid overproduction, capturing organisms that have reproduced at least once and limiting young specimen still sexually immature (Ehrhardt 1981, Stevensen & Campana 1992, Berg *et al.* 2005, Francis *et al.* 2005). Studies on fisheries are of great importance, and should be thoroughly assessed for their sustainability (Eide & Wikan 2010). This is why the analysis of otoliths in age determination is one of the most important bases in population dynamics studies.

This study presents for the first time, a study on morphology and morphometry analysis on otoliths of *Diapterus brevirostris*, and also growth ring identification in the otoliths: sagittae, asterisci and lapilli.

We want to highlight results presented in this study which gives valuable information on phylogenetic and evolutive relations of the species and its ecological niche width. Development of the superior (lapillus) and inferior (sagitta and asteriscus) parts of the internal ear differs in bony fish according to its habitat. Pelagic fish that are fast swimmers require a better tridimensional orientation and present a better developed superior part than demersal fish, where the inferior part has a higher development. Sagitta and asteriscus are related to sound reception, gravity and angular acceleration, while lapillus is associated to equilibrium (Holst *et al.* 1950, Lowenstein 1957, Lagler *et al.* 1962, Gallardo-Cabello 2012³).

²Rubio E, J Loaiza & CJ Moreno. 2004. Crecimiento y sobrevivencia de dos especies de mojarra *Diapterus peruvianus* y *Eucinostomus currani* criadas en jaulas flotantes en la Bahía de Buenaventura. Mem. III Congreso Iberoamericano Virtual de Acuicultura. CIVA. Zaragoza, España. http://www.iip.org.pe/publicaciones/CDs/MEMORIAS_VALIDAS/pdfs/Rubio3.pdf

³Gallardo-Cabello M, E Espino-Barr, A. Garcia-Boa, EG Cabral-Solis & M Puente-Gómez. 2012. Diferencias morfométricas de las sagittae en seis especies de la pesca comercial de Manzanillo, Colima. XIII Congreso Nacional de Ictiología, San Cristóbal de Las Casas, Chiapas 29 octubre a 2 noviembre 2012, p. 31.

Also, the present study shows a detailed description of sagittae of *Diapterus brevirostris* that will allow their identification in stomach contents of its predators, since otoliths are unique to each species and they preserve longer than the soft tissues, even after having passed through the digestive tract of the predators (Le Boeuf & Bonnell 1980, Le Boeuf *et al.* 1983, Gallo-Reynoso & Auriolles-Mendoza 1984, Auriolles 1988). Likewise, otoliths of fish can be recognized in regurgitated and copro material in studies of marine mammals, from which the collection of stomachs is not possible (Laevesteu & Favorite 1981, Bailey & Ainley 1982, Brown & Pierce 1997).

MATERIALS AND METHODS

From April 2010 to July 2012, 401 organisms of *Diapterus brevirostris* were taken directly from the commercial captures of Cuyutlan Lagoon fishery in Manzanillo, Colima, Mexico. Individuals were captured with cast net and gillnet in order to obtain different lengths and age groups. Organisms were taken to the lab to sample: for each individual, total length (TL, mm) and sex were registered.

Sagittae, asterisci and lapilli were obtained through a transverse cut in the ventral cranial cavity, the brain was removed and the left and right semicircular canals were extracted (Fig. 1). Otoliths were separated, cleaned, rinsed with water and stored dry in Eppendorf tubes labeled with number, date, total length and sex.

The structure of otoliths was studied with a dissection microscope (10x). A description of the labyrinth system and sagittae was made with the terminology of the glossary of Secor *et al.* (1992). The same concepts were applied to the description of asterisci and lapilli according to Gallardo-Cabello *et al.* (2006) and Espino-Barr *et al.* (2006).

Data on length and width were registered for each otolith through their observation in a stereoscopic microscope with a graduated ocular lens (10x). Measures were taken on the right and left aspect for the three pairs.

Otolith sample size was calculated with the formula described by Daniel (1991), $n = (z \cdot \sigma) / (d \cdot \mu)$. Constants of the relationships of the sagittae were calculated for rostrum length (SL) and width (SW). For asterisci and lapilli the indexes of the constants of the relationship were obtained for length (L) and width (W). Relationships between total length of the fish and all the measures of the three otoliths were also recorded. Regressions were done by the least squares analysis (Mendenhall 1987).

For the evaluation of the relations and the analysis of the possible morphometric differences between the otoliths of males and females, a one way variance analysis (ANOVA) was carried out (Zar 1996).

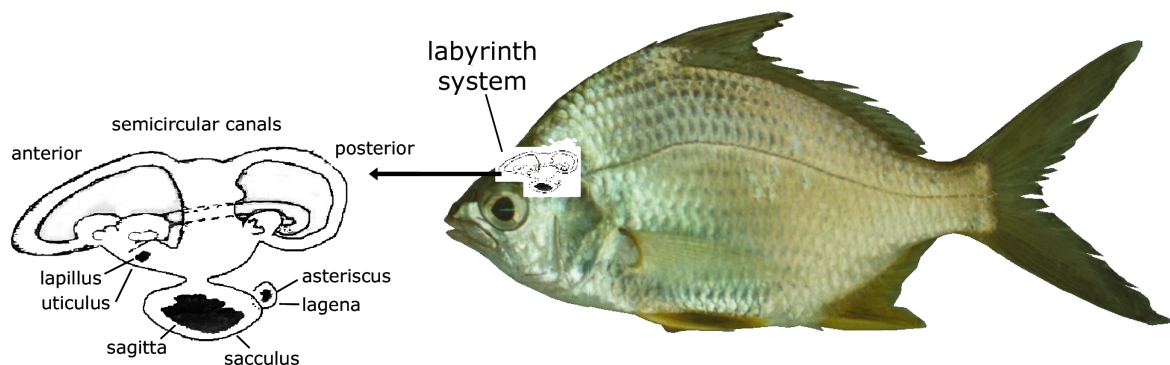


Figure 1. *Diapterus brevirostris* showing the position of the labyrinth system and drawing of the semicircular canals and the 3 otoliths / Posición del sistema laberíntico en *Diapterus brevirostris* y esquema de los canales semicirculares y los 3 otolitos

Growth ring identification was done observing the sagittae and the asterisci in the stereoscopic microscope (1x and 2x) with transmitted light and the average size of each ring was calculated. Rings were validated by observing them all around the structure, by determining marginal increment according to the month of year and relating the number of rings to the size of the fish (Joseph 1962, Heald & Griffiths 1967, Beamish & McFarlane 1983, Jearld 1983, Casselman 1983).

RESULTS

The information on otoliths of *Diapterus brevirostris* is completely original, and no other studies to consult were found to compare and discuss data from this study.

LABYRINTH SYSTEM OF *DIAPTERUS BREVIROSTRIS*

The semicircular canals are a tubular system that forms the membranous labyrinth (Fig. 2); these canals are 3:

anterior vertical canal, posterior vertical canal and horizontal canal. These tubes form chambers containing the otoliths, the lapillus is in the utriculus, the sagitta is in the sacculus (Fig. 2) and the asteriscus is in the lagena (Fig. 2). The otoliths contained in each chamber are immersed in a liquid called endolymph (Lagler *et al.* 1962).

Otoliths are connected with the macula through a type of nerve cells named neuromasts. The macula enters in the acoustic canal of the lapillus, sagitta and asteriscus (Figs. 2 and 3) and nourish the otoliths with the deposition of protein and calcium carbonate.

The largest otolith in *D. brevirostris* is the sagitta, that reaches a total length of 10.17 mm, while asteriscus measures 1.75 mm and lapillus 1.93 mm in specimens of 300 mm total length.

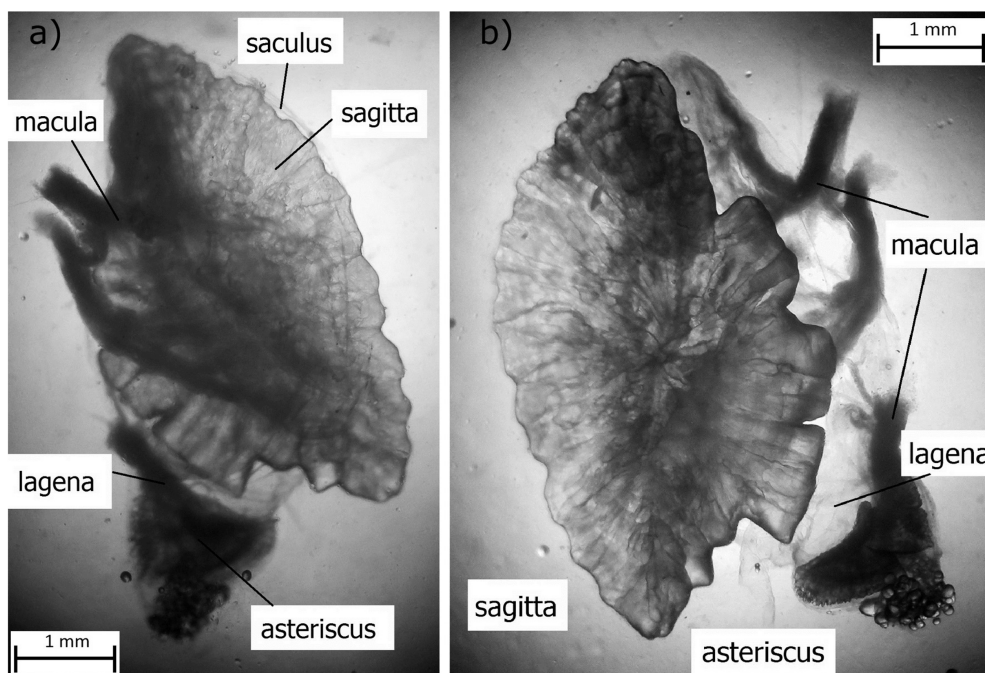


Figure 2. Section of the membranous labyrinth of an individual of *Diapterus brevirostris* (200 mm of total length, increased 12.4 times), showing the sagitta included in the sacculus, the asteriscus in the lagena with sections of the macula, a) internal aspect, b) external aspect / Sección de la membrana del laberinto de un individuo de *Diapterus brevirostris* (de 200 mm de longitud total, incremento de 12,4 veces), que muestra la sagitta dentro del sacculus, el asteriscus en la lagena y secciones de la mácula, a) cara interna, b) cara externa

**DESCRIPTION OF THE OTOLITHS OF SHORTNOSE MOJARRA
*DIAPTERUS BREVIROSTRIS***

DESCRIPTION OF THE SAGITTA

A prominent rostrum is present in the anterior margin of the sagitta, it does not have an excisura major and therefore no antirostrum (Figs. 2 and 3). As the fish ages, the shape of the sagitta varies and lengthens. Its form can vary in the right and left sagittae of the same specimen and can also be totally different between individuals.

The posterior section of the sagitta shows a rounded postrostrum that tends to lengthen as age increases. There is not excisura minor and therefore no parastrostrum (Figs. 2 and 3).

The dorsal margin shows at the beginning a notch, followed by a projected stepped structure which increased its size as the fish ages. The profile of the dorsal margin also shows many irregularities, similar to denticles that extend from the rostrum to the postrostrum. The ventral side shows some irregularities such as indentations but

it tends to be rectilinear from the upper part of the otolith to more than the middle part of the postrostrum.

Sagitta's internal aspect is convex, feature that increases with age; the acoustic channel goes all long the otolith surface (Fig. 3) increasing its width from the rostrum to the postrostrum. The acoustic channel is not divided into the cauda and the ostium.

The external aspect of the sagitta is concave, slightly thicker in the middle part of the sagitta than in the extremes of the otolith (Fig. 2). Growth rings appear more clearly in an area that goes from the middle part of the sagitta to the postrostrum, they can be seen as dark lines following the shape of the otolith. Average width of the sagitta is 1.83 times its average length.

There was no statistical difference found between sizes of right and left sagitta ($F'_{0.05(2, 109)} = 3.929$) = 0.034); also between otolith sizes of males and females ($F'_{0.05(2, 39)} = 4.098$) = 0.292).

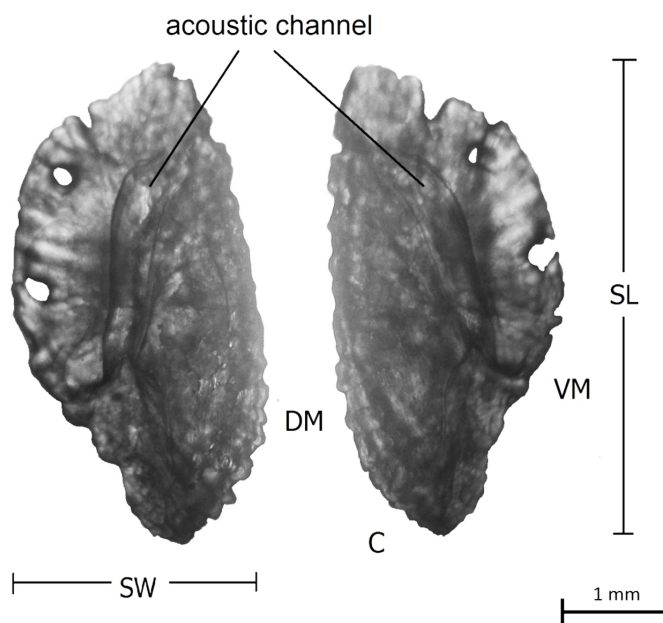


Figure 3. Internal side of the right and left sagitta of *Diapterus brevirostris* showing the acoustic channel, SL= rostrum length, C= postrostrum, DM= dorsal margin, VM= ventral margin, SW= otolith width / Cara interna de la sagitta derecha e izquierda de *Diapterus brevirostris*, se muestra el canal acústico, SL= longitud del rostrum, C= postrostrum, DM= margen dorsal, VM= margen ventral, SW= ancho del otolito

DESCRIPTION OF THE ASTERICUS

The shape of the asterisci did not show differences between right and left, as in the sagittae but can vary between specimens (Fig. 4). Sizes between sexes did not have statistical difference ($F'_{0.05(2, 38) = 4.105} = 2.505$), and also between right and left there was no statistical difference found ($F'_{0.05(2, 99) = 3.934} = 0.206$).

The asteriscus is divided in its anterior margin by a blunt projection in two areas: a dorsal area with a larger surface than the ventral area (Fig. 4). The anterior margin has sections that can be rectilinear from the dorsal to the ventral margins.

The posterior margin is curved and shows a very big and characteristic notch that interrupt the continuity of the posterior margin (Fig. 4). This margin presents a groove all long the dorsal and ventral margin, which divides the otolith in two parts: the first side has a larger sized radius in the external aspect (posterior external margin) interrupted by the notch and the second has a shorter sized radius that forms the posterior internal margin (Fig. 4).

The external aspect of the otolith is convex and the internal aspect is concave, this curvature of the otolith increases as the fish ages. The asteriscus shows small

indentations in both aspects (Fig. 4). Its average width is 1.6 times its average length.

DESCRIPTION OF THE LAPILLUS

The lapillus shows an anterior margin which is pointed and oriented toward the front of the fish. Dorsal and ventral margins run from the anterior margin to the central part of the otolith developing a fan-shaped structure. The ventral margin is rectilinear and smaller and the dorsal edge of this structure is notably larger and rounded (Fig. 5). The inner lapillus surface is concave, its curvature increases with age, in the fan shaped structure the otolith is divided in several lobes by radios (Fig. 5b). A sulcus is present in the posterior border which enters in contact with the acoustic macula, it extends all along the dorsal and ventral margins. The outer aspect of the lapillus is convex; their dorsal and ventral margins are smooth (Fig. 5a). Average length of the lapillus is 1.02 times its average width.

The analysis of variance did not show statistical differences between sexes ($F'_{0.05(2, 37) = 4.113} = 0.503$), nor between right and left ($F'_{0.05(2, 117) = 3.923} = 0.046$).

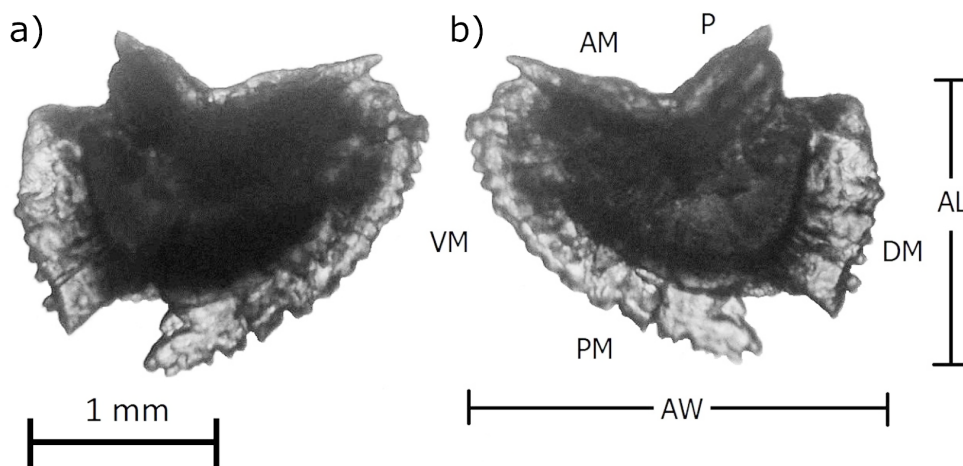


Figure 4. Asteriscus of *Diapterus brevisrostris*: a) external and b) internal aspect. AM= anterior margin, PM= posterior margin, DM= dorsal margin and VM= ventral margin, AL= length, AW= width / Asteriscus de *Diapterus brevisrostris*: a) cara externa b) cara interna. AM= margen anterior, PM= margen posterior, DM= margen dorsal y VM= margen ventral, AL= largo, AW= ancho

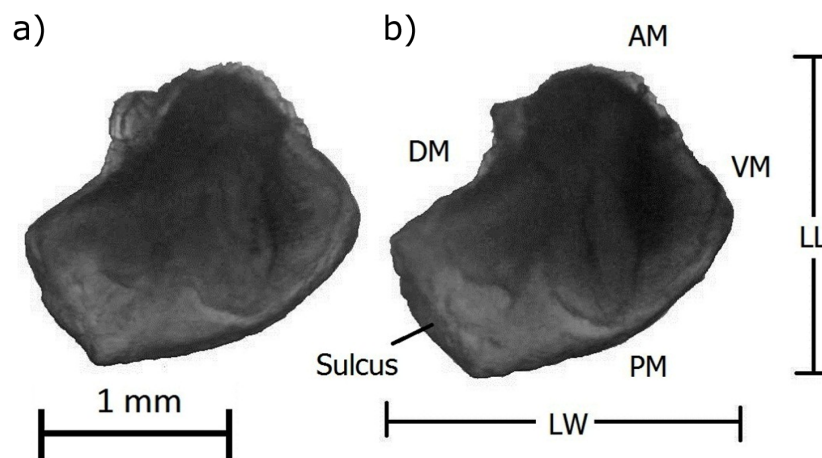


Figure 5. Lapillus of *Diapterus brevisrostris*: a) external and b) internal aspect. AM= anterior margin, PM= posterior margin, DM= dorsal margin and VM= ventral margin, LL= length, LW= width / Lapillus de *Diapterus brevisrostris*: a) cara externa y b) cara interna. AM= margen anterior, PM= margen posterior, DM= margen dorsal y VM= margen ventral, LL= largo, LW= ancho

MORPHOMETRIC ANALYSIS OF OTOLITHS OF *DIAPTERUS BREVIROSTRIS*

GROWTH OF THE SAGITTA

Table 1 shows the relation between the length classes of fish, rostrum and width of sagitta, for the species and sexes. Growth of the rostrum of sagitta are bigger in males from 160 to 320 mm.

Table 1. Calculated measures of rostrum (SL) and width (SW) of sagitta at different size classes of *Diapterus brevisrostris* (n= 394) / Medidas calculadas del rostrum (SL) y ancho (SW) del otolito sagitta a diferentes clases de longitud de *Diapterus brevisrostris* (n= 394)

Classes (mm)	n	Both sexes		Females		Males	
		SL (mm)	SW (mm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)
80		2.84	2.45	2.83	2.40	2.81	2.52
100	1	3.51	2.81	3.51	2.77	3.49	2.89
120	14	4.19	3.15	4.18	3.11	4.17	3.22
140	140	4.85	3.47	4.84	3.43	4.84	3.54
160	179	5.52	3.77	5.50	3.74	5.51	3.83
180	43	6.17	4.06	6.16	4.03	6.17	4.11
200	11	6.83	4.34	6.81	4.31	6.84	4.39
220	2	7.49	4.60	7.46	4.58	7.50	4.64
240	3	8.14	4.86	8.11	4.84	8.16	4.90
260		8.79	5.11	8.76	5.09	8.82	5.14
280		9.43	5.35	9.40	5.34	9.48	5.37
300	1	10.08	5.59	10.05	5.58	10.14	5.60
320		10.72	5.82	10.69	5.81	10.79	5.82

The relationship between length and width of sagitta is expressed by the exponent value $b = 0.642$, which shows a tendency to a negative allometric growth ($n = 107$, $R^2 = 0.818$, $F' = 460.60$), although the dorsal margin of the sagittae increase the width of the otolith. The results show that the sagitta tends to enlarge as fish grow, because most of the individuals used in this study belong to the 150 mm class of total length. In the case of sexes, results keep a similar trend and the relations of males are $b = 0.606$ ($n = 29$, $R^2 = 0.671$, $F' = 57.00$), and females $b = 0.656$ ($n = 43$, $R^2 = 0.847$, $F' = 276.25$). The results show that the growth of sagitta is eccentric to the core, that means that when the fish ages, the dorsal edge grows more than the ventral edge, the postrostrum grows more than the rostrum and a larger amount of material accumulates on the inner side than the external aspect of sagitta.

The relationship between fish length and length and width of sagitta is shown in Table 2. The higher value of the allometric index relating fish length to rostrum's length is for the males with a value of $b = 0.970$, smaller values are found for the species and females, $b = 0.959$ and $b = 0.958$, respectively. On the other hand, the higher value of the relation between fish length and rostrum width is for the females with a value of $b = 0.637$ ($b = 0.625$ for species and $b = 0.604$ for males). In all cases, values show that there is a direct proportionality between fish length and sagitta length and width; for that reason sagittae are

adequate to describe the growth of the organism. In each case, high values of the ANOVA's F' show a strong significance among the structures analyzed. Values of allometric growth rates are below one, due to the difficulty of relating very small structures (mm) with values of total fish length, expressed in centimeters.

Table 2. Relationship between total fish length and rostrum length (SL) and width (SW) of sagitta of *Diapterus brevirostris* / Relaciones entre el largo total del pez y el largo del rostrum (SL) y el ancho (SW) de la sagitta de *Diapterus brevirostris*

Total length (mm)		a	b	n	R ²	F'
SL (mm)	Both	0.042	0.959	109	0.903	991.14
	Females	0.043	0.958	41	0.968	1199.60
	Males	0.040	0.970	31	0.743	86.58
SW (mm)	Both	0.159	0.625	107	0.827	501.65
	Females	0.147	0.637	42	0.868	263.93
	Males	0.179	0.604	30	0.798	110.83

a= origin ordinate of relation, b= slope of relation, n= number of individuals, R²= determination index of relation, F'= Fischer relation index.

GROWTH OF THE ASTERICUS

The relationship between fish length and length and width of asteriscus is shown in Table 3. In all cases growth length of asteriscus is higher in females than males from lengths of 180 mm on.

The relationship between the length and width of the otolith is described by the females allometric index $b=1.039$ ($n=92$, $R^2=0.880$, $F'=212.31$) with values for species ($b=0.944$, $n=92$, $R^2=0.736$, $F'=251.20$), and males, the latter having a small value of the allometric index of $b=0.877$ ($n=27$, $R^2=0.417$, $F'=17.88$). These results show a trend to an isometric growth in which the increase in width is equal to length, but the asteriscus' growth is eccentric to the core. The dorsal margin grows more than the ventral margin and its anterior border grows more than the posterior border.

Table 4 shows the relationship between fish's total length and length and width of asteriscus. The allometric index value closest to one is for females $b=0.909$ for fish total length and asteriscus width, and $b=0.780$ for fish total length and asteriscus length. Similar values were found for the species: $b=0.750$ and $b=0.872$ for fish total

Table 3. Measures of length (AL) and width (AW) of asteriscus at different length classes of *Diapterus brevirostris* (n= 394) / Medidas del largo (AL) y ancho (AW) del asteriscus a diferentes clases de longitud de *Diapterus brevirostris* (n= 394)

Classes (mm)	Both sexes		Females		Males	
	AL (mm)	AW (mm)	AL (mm)	AW (mm)	AL (mm)	AW (mm)
80	0.65	0.89	0.64	0.87	0.74	0.97
100	0.77	1.09	0.76	1.07	0.84	1.15
120	0.88	1.27	0.87	1.26	0.93	1.32
140	0.99	1.46	0.98	1.45	1.02	1.48
160	1.10	1.64	1.09	1.64	1.10	1.64
180	1.20	1.81	1.20	1.83	1.18	1.79
200	1.30	1.99	1.30	2.01	1.26	1.94
220	1.39	2.16	1.40	2.19	1.33	2.09
240	1.49	2.33	1.50	2.37	1.40	2.23
260	1.58	2.50	1.59	2.55	1.46	2.37
280	1.67	2.66	1.69	2.73	1.53	2.51
300	1.76	2.83	1.78	2.90	1.59	2.65
320	1.84	2.99	1.87	3.08	1.65	2.78

length and asteriscus length and width, respectively. Smaller values were found for males $b=0.582$ and $b=0.762$ for fish total length and asteriscus length and width respectively. Values of the ANOVA's F' show a correlation between the structures analyzed in each case, with a tendency to a direct proportionality between fish length and asteriscus width and length, which allows age group determination based on the number of growth rings in asteriscus to be valid for *D. brevirostris*.

Table 4. Relationship between total fish length and length (AL) and width (AW) of the asteriscus of *Diapterus brevirostris* / Relaciones entre el largo total del pez y el largo (AL) y ancho (AW) del asteriscus de *Diapterus brevirostris*

Total length (mm)		a	b	n	R ²	F'
AL (mm)	Both sexes	0.024	0.750	92	0.778	315.76
	Females	0.021	0.780	31	0.865	186.41
	Males	0.057	0.582	27	0.714	62.41
AW (mm)	Both sexes	0.020	0.872	92	0.870	602.67
	Females	0.016	0.909	31	0.957	649.38
	Males	0.034	0.762	27	0.664	49.39

a= origin ordinate of relation, b= slope of relation, n= number of individuals, R²= determination index of relation, F'= Fischer index of relation

GROWTH OF THE LAPILLUS

Table 5 shows the relationship between fish length and length and width of lapillus. As in sagitta, the fastest growth of lapillus occurs in males from 160 to 320 mm.

The best relationship between the length and width of lapillus is described by the species allometric index $b=0.766$ ($n=118$, $R^2=0.739$, $F'=328.86$), smaller indexes were found for males: $b=0.721$ ($n=37$, $R^2=0.702$, $F'=82.45$), and females $b=0.705$ ($n=39$, $R^2=0.741$, $F'=105.77$). These values represent a trend to a negative allometric growth, in which lapillus grows more in length than in width. Lapillus growth is eccentric to the core, which means, the anterior and ventral margins show a higher deposition of growth materials than the posterior and dorsal margins.

The relationship between fish length and the length and width of the lapillus is shown in Table 6. The higher value of the allometric index for fish total length and lapillus length was found for males with a value of $b=0.537$, smaller indexes were found for the species and females: $b=0.516$ and $b=0.509$, respectively. Similar values were found for fish total length and lapillus width: $b=0.489$ for males, $b=0.459$ for species and $b=0.400$ for females. These values suggest a trend toward direct proportionality between fish length and lapillus that validates identification of growth rings in this structure of *D. brevirostris*.

Table 5. Measures of length (LL) and width (LW) of lapillus at different length classes of *Diapterus brevirostris* (n= 394) / Medidas del largo (LL) y ancho (LW) del lapillus a diferentes clases de longitudes de *Diapterus brevirostris* (n= 394)

Classes (mm)	Both sexes		Females		Males	
	AL (mm)	AW (mm)	AL (mm)	AW (mm)	AL (mm)	AW (mm)
80	0.98	1.02	0.98	1.08	0.97	1.00
100	1.10	1.13	1.10	1.18	1.09	1.12
120	1.20	1.23	1.21	1.27	1.21	1.22
140	1.30	1.32	1.31	1.35	1.31	1.31
160	1.40	1.41	1.40	1.42	1.41	1.40
180	1.48	1.49	1.48	1.49	1.50	1.49
200	1.57	1.56	1.57	1.55	1.59	1.57
220	1.65	1.63	1.64	1.61	1.67	1.64
240	1.72	1.70	1.72	1.67	1.75	1.71
260	1.79	1.76	1.79	1.72	1.83	1.78
280	1.86	1.82	1.86	1.78	1.90	1.85
300	1.93	1.88	1.92	1.82	1.97	1.91
320	2.00	1.94	1.99	1.87	2.04	1.97

IDENTIFICATION OF GROWTH RINGS

It was possible to identify 6 growth rings through the analysis of sagittae and asterisci of *D. brevirostris* (Table 7). Growth rings were identified in all sagittae (100%). The deposition of growth material is higher in a region on the dorsal margin that runs from the middle part of the otolith to the postrostrum, for this reason growth rings can be easily appreciated in this part of the sagittae (Fig. 3).

Table 6. Relationship between total fish length and length (LL) and width (LW) of the lapillus of *Diapterus brevirostris* / Relaciones entre el largo total del pez y el largo (LL) y ancho (LW) del lapillus de *Diapterus brevirostris*

Total length (mm)		a	b	n	R ²	F'
LL (mm)	Both sexes	0.102	0.516	118	0.755	357.73
	Females	0.106	0.509	39	0.848	207.12
	Males	0.093	0.537	37	0.678	73.59
LW (mm)	Both sexes	0.137	0.459	118	0.753	353.92
	Females	0.187	0.400	39	0.781	132.32
	Males	0.117	0.489	37	0.759	110.52

a= origin ordinate of relation, b= slope of relation, n= number of individuals, R²= determination index of relation, F'= Fischer index of relation

In asterisci, growth rings run from the dorsal to the ventral margin on the outer side of the otolith they look as dark concentric lines (Fig. 4). In 70% percent of asterisci the same number of rings were observed as in sagittae, in the remaining 30% growth rings were not clearly identified as growth rings.

Growth rings identification by transmitted light transparency was very difficult in lapilli because of the thickness of this structure.

DISCUSSION

Six age groups were identified in the sagittae and asterisci; it is important to evaluate the growth period of time of each ring to refer them to each age group. With this information growth studies are carried out which render in the growth constants of von Bertalanffy's equation, which are used to formulate future models in maximum sustainable yield and catch predictions. This allows an adequate management of the fishery, avoiding its overfishing.

The relationship between the fish length and the length and width of the three pairs of otoliths showed that these structures are adequate to determine age of the species

Table 7. Number of rings on sagittae and asteriscus and average length of *Diapterus brevirostris* and data from other species of the Gerreidae family (mm) / Número de anillos en las sagittae y los asteriscus, y el largo promedio de *Diapterus brevirostris* y datos de otras especies de la familia Gerreidae (mm)

	Colima	Costa Rica	Colima and Jalisco	Colombia		Japan	Campeche
	<i>Diapterus brevirostris</i> ¹	<i>Diapterus peruvianus</i> ² (<i>brevirostris</i>)	<i>Gerres cinereus</i> ³	<i>Eugerres plumieri</i> ⁴		<i>Gerres oyena</i> ⁵	<i>Diapterus rhombeus</i> ⁶
				Males	Females		
1	100	81	167.6	143	148	102.9	199.8
2	150	112	226.7	156	163	119.8	202.0
3	190	172	300.0	168	177	134.0	203.1
4	230	226	353.3	179	190	145.8	203.5
5	260	251	398.3	186	206	155.6	203.8
6	290		432.5			163.9	203.9
7			444.0			170.7	204.0
8						176.5	204.0

¹this study, ²Cabrera-Peña *et al.* (1996), ³Espino-Bar *et al.* (2014), ⁴Olaya-Nieto & Appeldoorn (2004), ⁵Kanak & Tachihara (2006), ⁶Ayala-Pérez *et al.* (2001)

and that they are equivalent of their growth, both the otoliths and the fish. The growth ring identifications were done with the analysis of the sagittae and asterisci. In the case of the lapilli, due to its shape and thickness, this identification could not be done by transparency, therefore a future technique should be carried out by cutting and polishing to a level at which the rings can be observed. In fact, during the larvae stage, the three pairs of otoliths show a discoid structure, where the daily growth rings are observed, and as time goes by to the adult stage, the otoliths grow in length and thickness. In the case of the lapilli, this growth prevents the observation of seasonal growth rings in the lapilli (Victor & Brothers 1982, Brothers *et al.* 1983).

Also worth mentioning, during the growth process, as the fish ages, the deposition of the calcium carbonate and otoline vary, being increasingly erratic and eccentric to the core, so that a greater amount of material is deposited in the postrostrum than in the rostrum, and the dorsal margin of the sagitta grows more than the ventral border. All this means that the otoliths grow increasingly curved as the fish ages, and identifying the latter growth rings is more difficult.

The number of studied otoliths varies depending on whether it is the sagitta, asteriscus or lapillus, due to the difficulty of extraction. Often sagittae are broken because of its large size and the cut made on the base of the skull. Other occasions the semicircular canals tear during the extraction and the lapilli are lost. During the liberation and cleaning of the otoliths from the sacculus, lagena or utriculus, otoliths can break, as it occurs mainly with asterisci. Therefore the otolith extraction has to be done very carefully from each of the chambers.

The 3 pairs of otoliths show morphologic differences between right and left and by sexes, but this difference was not statistically significant. Growth of sagittae and lapilli is higher in males than females from 160 to 320 mm. Growth in asterisci is higher in females than in males from 180 to 320 mm.

Cabrera-Peña *et al.* (1996) calculated age growth rings of *D. peruvianus* (= *D. brevirostris*) in the coastal lagoons of rivers Damas and Palo Alto in Costa Rica by length frequency analysis; they found 5 growth rings with a medium length similar to those found in the present paper (Table 7).

Medium length at each age or growth rings were obtained by different authors for different members of

the Gerreidae family (Table 7). Kanak & Tachihara (2006) found small lengths for each age group for *Gerres oyena* in Okinawa Island in Japan. Also, Romero & González (1986) reported small sizes for each age in *Eugerres plumieri* for both cases: males and females. Ayala-Pérez *et al.* (2001) found small sizes at each age for *D. rhombeus* in the Lagoon of Terminos, Campeche, Mexico. López-Martínez *et al.* (2011) reported for *Eucinostomus currani* in the Gulf of California small sizes: 114 mm for 0.9 years, 137 mm for 1.2 years, 156 mm for 1.6 years and 180 mm for 2.2 years.

Data on number of growth rings found in the present paper are bigger in relationship of those mentioned above, but *D. brevirostris* reached smaller sizes than those reported for *G. cinereus* in the coast of Colima and Jalisco (Espino-Barr *et al.* 2014).

According to Chávez-Comparán & Hammann (1989), *D. brevirostris* and *G. cinereus* in the Cuyutlan Lagoon in Colima State, are considered to be both omnivorous but *G. cinereus* feeds principally upon benthic invertebrates while *D. peruvianus* (= *D. brevirostris*) also feeds on planktonic preys, which means that this species has a wider range of food spectrum of preys in its diet. These food habits help both species reduce the degree of competition between them.

A higher number of growth rings of *D. brevirostris* were found in Cuyutlán Lagoon, Colima, than in Costa Rica coasts. This can be explained by Taylor's theory (1958, 1960), who establishes that organisms of the same species are less long-lived and present fewer age groups as they locate closer to the equator, its longevity diminishes the same as the latitude.

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