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AGE ANALYSIS OF *CENTROPOMUS NIGRESCENS* BY OTOLITHS *SAGITTA*, *ASTERISCUS* AND *LAPILLUS* IN MEXICAN CENTRAL PACIFIC

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ABSTRACT

Morphology, morphometry and growth rings of the otoliths: *sagitta*, *asteriscus* and *lapillus* of *Centropomus nigrescens* Günther 1864 in Manzanillo and Santiago bays in, 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 width of the otoliths showed that these structures have a negative allometric index. Twelve 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. Data on *sagittae* of *C. undecimalis* were compared with the present results.

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INTRODUCTION

Fish from the Centropomidae family are demersal euryhaline semi-catadromous. Their distribution is determined by salinity and temperature, they can inhabit in water colder than 20°C for short periods. They tolerate a wide spectrum of salinities from 0.07 ppm to 58.29 ppm, but they prefer fresh or brackish waters with a tendency to remain in estuaries, rivers or coastal lagoons. This makes them more prone to the effects of pollution (Muhlia-Melo *et al.*, 1995). They are carnivores that feed on smaller fish and crustaceans (Chávez, 1963). With regard to *Centropomus nigrescens* Günther 1864 (Fig. 1), its distribution is in the Eastern Pacific from southern Baja California, Mexico and mouth of the Gulf of California to northern Colombia.

The maximum length registered is of 123 cm total length (TL) (IGFA 2001), Jiménez-Prado and Béarez (2004) registered a common length of 45 cm TL. In Colima the common size registered by Espino-Barr *et al*. (2003) was 57 cm and maximum 110 cm, and in Jalisco an average size of 44 cm TL and maximum of 110 cm TL (Espino-Barr *et al*., 2004). It is a species with great economic importance, locally and regionally. It is delivered eviscerated, filleted, in ice and its commercial classification is of first category. Its price is of $100.00 Mexican pesos ($5.26 US dollars) to the fisherman, and can go up to $300.00 Mexican pesos ($15.89 US dollars) in the market. It is fished with hand line and fish hook, harpoon by diving, and gill net. It also has importance in the sport fishery, by trolling. Annual commercial captures go from 5 to 40 tons in Colima.

Fig. 1. Black snook *Centropomus nigrescens* Günther, 1864

Studies on *C. nigrescens* are very scarce, Günther-Nonell (1995) studied growth of the juveniles of this species at different salinities in Costa Rica. Muhlia-Melo *et al.* (1995) wrote a general synopsis of *Centropomus*. Sandoval-Castellanos *et al*. (2005) reported information on the genetic differentiation of the *Centropomus* genera of the Mexican Pacific. As comparison *C. undecimalis* has been more studied. Caballero-Chávez (2011) found sizes of *C. undecimalis* of 53.0 to 110.0 cm furcal length in in Campeche, Gulf of México. Lorán-Núñez *et al.* (2012) worked with two species off the coast of Veracruz also in the Gulf of México and found lengths of 24.6.0 cm to 110.0 cm TL in *Centropomus poeyi*, and 27.5 to 120 cm TL *C. undecimalis*. Cabrera-Rodríguez & Amador del Ángel (1998) reported results on their culture in cages. Taylor *et al*. (2000) published data on age and growth, maturity and reversal sex. Perera-García *et al.* (2013) studied *C. undecimalis* in Tabasco, determining age with sectioned *sagittae*. The fishery in the Mexican Atlantic is of several species of snooks, but *C. undecimalis* seems to be the important one. Caballero-Chávez (2009 and 2012) found that they are fished with gill nets in the lagoon and in the ocean. We did not find studies on the age determination of *C. nigrescens*, therefore the following objectives we proposed were: a) Description and analysis of the labyrinth system. b) Morphologic analysis of the *sagittae*, *asterisci* and *lapilli.* c) Morphometric study of the otoliths and its variation regarding age and sex. d) Identification of growth marks. e) 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 October 2013 to December 2015, 504 organisms of *Centropomus nigrescens* were taken directly from the commercial captures in Manzanillo and Santiago bays in Colima, México and taken to the laboratory of the National Institute of Fisheries in Manzanillo (INAPESCA). Organisms were captured with gill net, hand line, harpoon and cast net, to obtain a stratified sample which includes all the age groups and size classes. In the laboratory, data were taken from 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, cleaned in water and dried. They were preserved dry in Eppendorf tubes and plastic containers of 20 ml, with the number of the organism, capture date, total length and sex. Otoliths were analyzed with a dissecting microscope. The glossary terminology of Secor *et al.* (1992) 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 2016) and Espino-Barr *et al.* (2006, 2013, and 2015). Scanning electronic microscope photographs (Hitachi, Mod. SU1510, Hitachi, Japan) were obtained from each otolith, internal and external aspect. Prior, they were mounted on aluminum sample holder, on a two faced carbon tape and coated with a layer of gold of 20 Å for two minutes, in a vaporizer (QUORUN, Mod. Q15RES, Kent, UK).

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 a stereoscopic 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 on *sagittae* and most *asterisci*, observing rings by transparency in a stereoscopic microscope, using transmitted light. In the case of *lapilli* it wasn't possible because this structure didn't show seasonal growth marks. Average length for each growth ring was calculated. The sample sizes were: for *sagitta* 550 individuals, *asteriscus* 527 and *lapillus* 525.

RESULTS

This is the first time that data on otoliths of *Centropomus nigrescens* 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.

Characteristics of *Centropomus nigrescens*

Table 1 shows general data of the fish. All specimens had an average of TL of 46.39 cm (± 15.44 standard deviation) while separated by sex, the indefinite were 45.73 cm (± 14.58 sd), males 60.00 cm (± 11.96 sd) and females 77.11 cm (± 17.19 sd).

Labyrinth system of Centropomus nigrescens

The canals that form the membranous labyrinth are: the anterior vertical canal, the posterior vertical canal and the horizontal canal (Figs. 2 and 3). The widening of these channels form chambers that contain otoliths: the *sacculus* contains the *sagitta*, *lagena* contains the *asteriscus* and the *utriculus* the *lapillus* (Figs. 1, 2 and 3). The otoliths in each of their chambers are immersed in a liquid called endolymph (Lagler *et al.*, 1962). The acoustic macula (inside each chamber) penetrates the otoliths at the level of the acoustic canal through the neuromas, which are nerve cells (Fig. 1 and 2). Deposition of the calcium carbonate and protein takes place through the macula.

Fig. 2. Section of the membranous labyrinth of an organisms of *Centropomus nigrescens* (80 cm total length) (enlarged 40x times) showing the *sacculus*, which includes the *sagitta*, the *lagena* with the *asteriscus* and the *utriculus* with *lapillus*; also the acoustic macula is shown penetrating the acoustic channel of each of these otoliths. Fragments semicircular front vertical channel is also shown

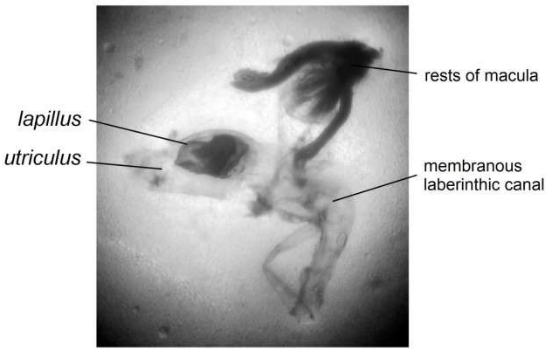

Fig. 3. Section of the membranous labyrinth of an organisms of *Centropomus nigrescens* (80 cm total length) (enlarged 50x times) showing the *utriculus* with *lapillus*, the membranous labyrinth canal and rests of macula

Also in the macula ramifications of the eighth cranial nerve can be observed through which impulse transmission to the brain is carried out, by means of vibration of the otolith suspended in the endolymph (Mugiya, 1964, 1966a, b). *Sagittae* and *asterisci* are related with the sound perception, gravity and angular acceleration, while the *lapilli* are more related to the fishes' equilibrium (Holst *et al.*, 1950; Lowenstein, 1957). The protein of which otoliths are made of presents a high molecular weight and was denominated otoline by Degens *et al*. (1969). Calcium carbonate in its form of aragonite is the other component that forms the otoliths (Lagler *et al*., 1962; Hickling, 1931; Sasaki and Miyata, 1955; Carlström, 1963; Gallardo-Cabello, 1986). The largest otolith is the *sagitta*, it reaches a total length of 20.88 mm, while *asteriscus* 4.20 mm and *lapillus* 3.22 mm in specimens of 80 cm TL (Fig. 4 and 5).

Description of the *sagitta*

It has a rounded *rostrum*, pronounced, oversized, without the presence of an *excisura major* and by consequence without an *antirostrum* (Figs. 5 and 6); nevertheless, to the middle of the otolith a considerable widening is observed preceded by several grooves in the form of notches. The dorsal border is continuous without a great curvature until reaching the *postrostrum* that has a dull appearance and is separated by several lobes, three in most cases. The ventral border also presents lobes from its widening in the middle section of the *sagitta* and on, and later it becomes straight till it reaches the *postrostrum*.

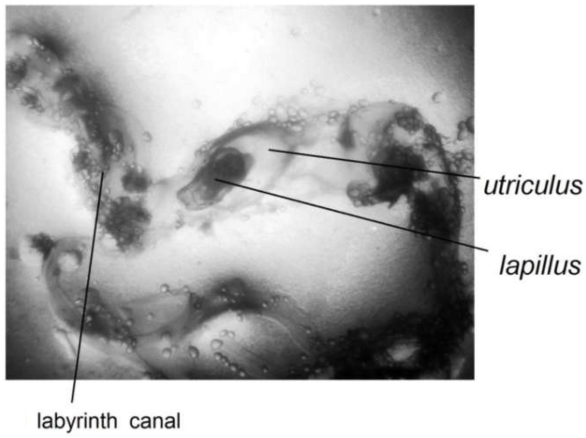

Fig. 4. Section of the membranous labyrinth of *Centropomus nigrescens* (80 cm total length) (enlarged 50x times) showing the *utriculus* with *lapillus* contained, and fragments of the vertical anterior semicircular canal (AVSC) and vertical rear canal (PVSC)

The posterior part of the otolith shows only a *postrostrum*, without an *excisura minor* dividing the *postrostrum* and *pararostrum*. The interior aspect is convex and is covered lengthwise by the acoustic canal, which is very developed and deep, with a notorious differentiation between *ostium* and *cauda* (Fig. 5 and 6). The external aspect is concave; as the organism grows and its age increments, the otolith tends to be more curved and tends to thicken. Growth rings are more clearly observed in the medium part of the *rostrum*, towards the ventral border in the internal aspect and they are seen as dark lines that run the length of the otolith. Average width of the *sagitta* is 1.93 times its average length. No statistic difference was obtained between right and left otoliths ($F'_{0.05\ (2,\ 522=3.859)} = 1.04$). Difference was observed between *sagitta* lengths of females and males ($F'_{0.05\ (2,\ 33\ =\ 4.16)} = 6.024$). In the width of *sagitta*, the difference between males and females was not statistic significant. ($F'_{0.05\ (2,\ 38\ =\ 4.113)} = 3.255$).

Description of the asteriiscus

The form of the *asteriscus* can present high variations in the same individual, for example *figure 7* shows that the right one has a larger area in the dorsal border that does not show in the left. Nevertheless no difference was found between right and left *asteriscus* (F' 0.05 $_{(2,\ 485\ =\ 3.861)}$ = 0.533), but there were between sexes (F' 0.05 $_{(2,\ 33\ =\ 4.16)}$ = 5.316). 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. 7). 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 (Fig 7 b). 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 have numerous indentations. Its average width is 1.57 times its average length.

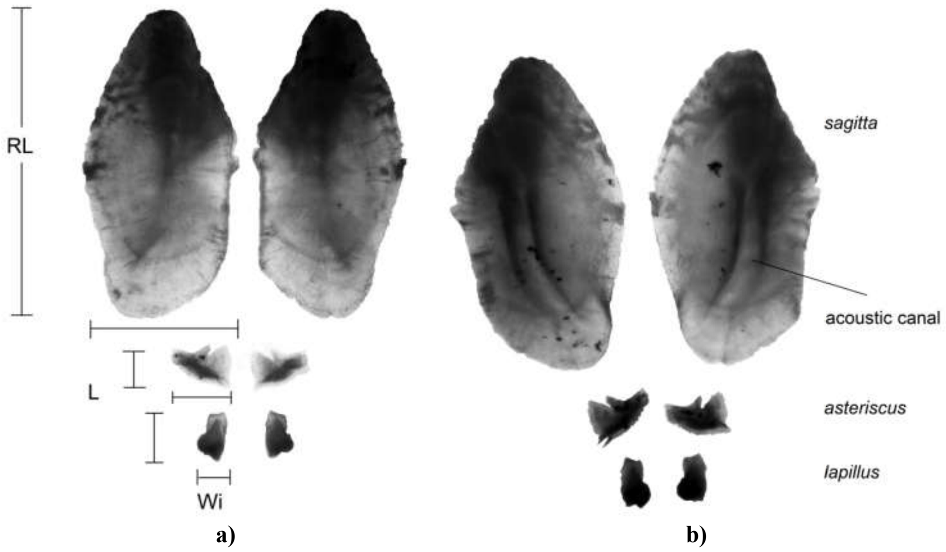

Fig. 5. Relationship between the three pairs of otoliths of *Centropomus nigrescens*: a) external aspect, b) internal aspect. RL = *rostrum* length, Wi = width, L = length

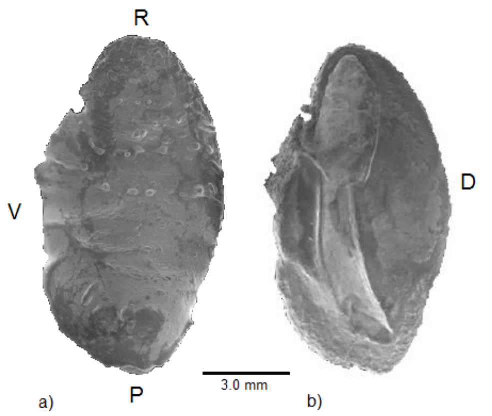

Fig. 6. Scanning photograph of: a) the left *sagitta* external aspect, and b) right internal aspect with acustic canal of *Centropomus nigrescens*. R= *rostrum*, P= *postrostrum*, D= dorsal margin, V= ventral margin

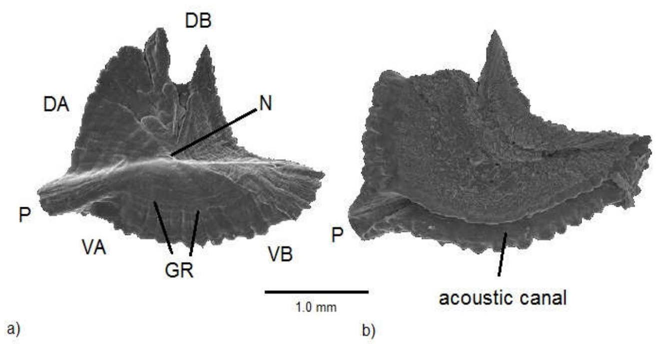

Fig. 7. Scanning photograph of the right and left *asteriscus*, internal and external aspect of *Centropomus nigrescens*: P= projection, N= core or *primordia*, DA = dorsal area, VA = ventral area. GR = growth ring, AC=acoustic canal, DB =dorsal border, VB = ventral border

Figures 7a shows the core or *primordium*, from which the growth bands start to form once the yolk sac of the larvae, is absorbed (Lowenstein, 1957; Degens *et al*., 1969). These growth bands can correspond to different formation periods, they can be daily growth increments, or seasonal rings, or even rings with a different periodicity. Determination of age groups is carried out analyzing the growth rings (Hickling, 1931; Holst *et al*., 1950; Mugiya, 1966 a, b; Gallardo-Cabello, 1986, 2011, and 2014; Espino-Barr *et al*., 2006, 2013, and 2015).

Description of the *lapillus*

The anterior margin of the *lapillus* is a rounded structure oriented to the front side of the fish (Fig. 8). The dorsal and ventral margins extend toward the rear, forming a broad structure, divided into several lobes by radios (Fig. 8b). 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. The acoustic canal can be observed in the anterior border, this structure 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 1.84 times its average width (Fig. 5). No differences were found between the right and left *lapillus* ($F'_{0.05\ (2,\ 505 = 3.86)} = 0.152$), nor between sexes ($F'_{0.05\ (2,\ 37 = 4.12)} = 4.237$).

Growth of the *sagitta*

The relationship between size classes, *rostrum* length and width of the *sagitta*, for the species as for sexes is observed in Table 3. The *rostrum* growth of the *sagitta* is higher in males than females from 10 to 50 cm TL, but from 160 cm on, it is higher in females than males. Table 4 shows the relationship between the *rostrum* length *vs*. 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 = 0.822 which corresponds to a negative allometric growth, where the *sagitta* grows more lengthwise than widthwise. The determination index for these two series of data is $r^2 = 0.801$, with an ANOVA result of F = 2 206.0. The relationships for sexes were b = 0.943 for females, closer to an isometric index and b = 0.762 for males. The relationship between total fish length, length of the *rostrum* and width of the *sagitta* is shown in Table 5. In all the cases the values obtained for the relationship corresponds to negative allometric indexes. Length of fish *vs rostrum* length is represented by b = 0.736, $r^2 = 0.828$, with an F =2 635.6.

Lower values were obtained dividing by sexes: b= 0.677 for females and b=0.594 for males. Values of the fish length and width of *sagitta*, values of the allometric index were: for all specimens b = 0.688 (r^2 = 0.863, F = 3 594.4), by sex the values were b = 0.663 (females) and b = 0.498 (males). These results show that as the organisms grow in length, *sagittae* decrease in size (length and width).

Growth of the *asteriscus*

Table 6 shows the values of length classes related to the length and width of the *asteriscus* by all individuals and sexes. Similar to the *sagittae*, the growth of the *asteriscus' rostrum* is higher in males than females from 10 to 50 cm TL, nevertheless from 160 cm on, is higher in females than males. Table 7 shows the relationships of the allometric indexes between length and width of the *asteriscus*; for all individuals a value of b = 0.748 (r^2 = 0.575 and F = 710.00) was obtained, which corresponds to a negative allometric growth, that is, the *asteriscus* grows more in width than in length as the fish ages. In the case of females the value of b = 0.998 is very close to an isometric index, that is, that the *asteriscus* growth in length and width in the same proportion. For males the b = 0.461 corresponding a negative allometric index. 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 8. The allometric index value between the fish length and the width of the *asteriscus* for all individuals is b = 0.567 (r^2 = 0.678 and F' =1 123.8), that corresponds to a negative allometric index, where the *asteriscus'* length grows less than the fish length. Similarly, this relationship by sexes shows low values, that is, a negative allometric index: b = 0.558 for females and b = 0.372 for males. In the same way, the relationship between fish length and *asteriscus'* width corresponds to negative allometric indexes, for the species b = 0.549, females b = 0.579 and males b = 0.429, which means that the *asteriscus'* width grows in less proportion to the fish length.

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 9. The *lapilli* of males are of bigger sizes than those of females in length classes from 40 cm to 120 cm of total length. Table 10 shows the values of the allometric indexes for length and width of *lapilli* of the species and by sex. The value of b = 0.577 shows a negative allometric growth index for all the individuals (r^2 = 0.449 and F = 423.5), which means that the *lapillus* grows more lengthwise than in thickness as the fish grows old. On the other hand, sexes show higher values: b = 0.881 for females and b = 1.022 for males, being this last value that of an isometric growth, where the *lapillus* grows in length and width proportionally. Relationships between total length of the fish and length and width of the *lapillus* are observed in Table 11.

Identification of the growth rings

The analysis of the growth rings in *sagittae* and *asterisci* made it possible to identify twelve groups, the results being as follows: ring 1 = 13.82 cm of TL of the fish, ring 2 = 25.79 cm, ring 3 = 36.17 cm, ring 4 = 45.16 cm, ring 5 = 52.95 cm, ring 6 = 59.70 cm, ring 7 = 65.55 cm, ring 8 = 70.62 cm, ring 9 = 75.01 cm, ring 10 = 78.82 cm, ring 11 = 82.12 cm and ring 12 = 84.98 cm. The percentage of the *sagittae* that showed growth rings perfectly defined were 100%. Growth rings were observed with best clarity in the dorsal margin of the base of the *rostrum* of the *sagitta*. These observations were made with a stereoscopic microscope with transmitted light. The same number of rings was observed 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, which ran from the beginning of the dorsal area to the end of the ventral area, very defined and continuous (Fig. 9). Due to its thickness, growth rings in the *lapillus* could not be observed.

DISCUSSION

In our observations we found that the values of the allometric growth were mainly negative, that is, as the fish grows the length of the *sagittae*, *asterisci* and *lapilli* decrease. Separating the information of the *sagittae* length, better results were obtained in younger specimens from 10 to 30 cm, a b = 0.912, the value closer to the one, representing an allometric growth close to isometry, that is, the fish and its *sagittae* grow proportionally. As the size classes increase, allometric indices decrease and show a trend to a negative allometric, as the case of the 30-50 cm TL with an allometric index of b = 0.742, from 50-70 cm b=0.762 and from 70-90 cm TL b = 0.337. Taylor *et al.* (2000) reported for *Centropomus undecimalis* in the coasts of Florida, both for the east and west coast, that the growth of these organisms reaches the asymptotic very fast, between 6 and 9 years. These authors suggest that the observation of the whole otolith is useful till 10 years, no more. But for organisms of older age, these authors recommend that otoliths should be sectioned to be able to distinguish more rings, being able to find specimens of up to 21 years in *C. undecimalis* marked with ox-tetracycline (OTC). In our study we didn't observe samples of *C. nigrescens* of more than 12 years. Taylor *et al.* (2000) also consider that the gonadic maturation of these organisms is present in very early ages, which can cause a drop in the slope of the growth curve. This phenomenon can be caused because the food is directed mainly to the maturity of the gonads, with a consequent decrease in the calcic carbonate deposition and of the otoline, constituent elements of otoliths (Gallardo-Cabello *et al*., 2006, 2011, 2012, and 2014; Espino-Barr *et al*., 2006, 2013, and 2015). The amplitude of the growth bands in otoliths begins to have a progressive decrease of its width, until there is a moment when these cannot be distinguished from each other, and overlapping phenomena of growth bands are observed which underestimate age (Gallardo-Cabello, 1986). It is also important to point out that the sexual inversion, maturity and spawning aspects, as well as the osmoregulation phenomena in marine and freshwater environments in which these organisms inhabit, must alter the deposition patterns of the calcium carbonate and otoline bands. Although data have been reported that sexual inversion occurs from males to females at a given age, Taylor *et al*. (2000) reported females of one to two years old. The most abundant age groups of males were from 2 to 7 years old and for females from 3 to 8 years. They only found 10 organisms of more than 16 years old. This indicates that there is a very wide range in the phenomena of sexual inversion or protandric hermaphroditism, which complicates even more the sexual inversion phenomena of this species. Similar phenomena of sexual reversion occur in other species, as *Lates calcarifer* from the Latidae family (Davis, 1982; Guiguen, *et al*. 1994).

Table 1. Characteristics of the measures of *Centropomus nigrescens*

	StL (cm)	TL (cm)	Hi (cm)	TW (g)	EW (g)
Average	37.08	46.39	9.00	1 004.2	1 024.9
Maximum	88.00	101.00	25.00	9 810.0	12 820.0
Minimum	7.50	11.10	2.00	5.3	4.4
Sd	12.91	15.44	3.33	1014.6	1281.23
n	504	504	504	489	495

Note: StL = standard length (cm), TL = total length (cm), Hi = maximum height (cm), TW = total weight (g), EW = eviscerated weight (g), Sd = standard deviation, n = number of individuals.

Table 2. Synthetizes the measurements of the otoliths. *Sagittae* are big structures 5x the *asterisci* and 7x the *lapillus*

	TL (cm)	SL (mm)	SW (mm)	AL (mm)	AW (mm)	LL (mm)	LW (mm)
Average	48.1	14.1	7.5	3.1	1.9	2.4	1.4
Maximum	94.0	23.5	11.8	4.5	3.5	4.4	3.1
Minimum	13.2	5.1	2.1	1.2	0.0	1.0	0.7
Sd	12.6	3.0	1.5	0.6	0.5	0.4	0.2
n	631	550	571	535	550	524	525

Note: TL = total length (cm), SL = sagitta length (mm), SW = sagitta width (mm), AL = asteriscus length (mm), AW = asteriscus width (mm), LL = lapillus length (mm), LW = lapillus width (mm), Sd = standard deviation, n = number of individuals.

Table 3. Calculated measures of *rostrum* (SL) and width (SW) of *sagitta* at different size classes of *Centropomus nigrescens*

	All individuals		Females		Males	
Classes (cm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)
10	4.52	2.59	5.02	2.60	5.78	3.60
20	7.53	4.17	8.03	4.11	8.72	5.08
30	10.14	5.51	10.57	5.38	11.10	6.22
40	12.54	6.72	12.85	6.51	13.17	7.18
50	14.77	7.83	14.94	7.55	15.03	8.02
60	16.89	8.87	16.91	8.52	16.76	8.78
70	18.92	9.87	18.77	9.43	18.36	9.48
80	20.88	10.81	20.55	10.31	19.88	10.13
90	22.77	11.73	22.26	11.14	21.32	10.74
100	24.60	12.61	23.90	11.95	22.70	11.32
110	26.39	13.46	25.50	12.73	24.02	11.87
120	28.13	14.29	27.04	13.49	25.30	12.40

Table 4. Relationships between the *rostrum* and width of the *sagitta* of *Centropomus nigrescens*

Sagitta length		a	b	R^2	F'	n
Width	All	0.850	0.822	0.801	2206.0	550
	Females	0.594	0.943	0.917	220.7	22
	Males	1.015	0.762	0.841	47.5	11

Table 5. Relationship between total fish length and *rostrum* length and width of *sagitta* of *Centropomus nigrescens*

Total length (cm)		a	b	R^2	F'	n
SL (mm)	All	0.830	0.736	0.828	2635.6	550
	Females	1.056	0.677	0.753	60.9	22
	Males	1.469	0.594	0.823	42.0	11
SW (mm)	All	0.532	0.688	0.863	3594.4	571
	Females	0.564	0.663	0.757	74.7	26
	Males	1.144	0.498	0.743	28.9	12

Table 6. Calculated measures of length (AL) and width (AW) of the *asteriscus* at different size classes of *Centropomus nigrescens*

	All individuals		Females		Males	
Classes (cm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)
10	1.29	0.85	1.25	0.85	1.77	1.09
20	1.92	1.25	1.85	1.26	2.29	1.46
30	2.41	1.56	2.31	1.60	2.66	1.74
40	2.84	1.83	2.72	1.89	2.96	1.97
50	3.22	2.07	3.08	2.15	3.21	2.17
60	3.57	2.29	3.41	2.39	3.44	2.34
70	3.90	2.49	3.71	2.61	3.64	2.51
80	4.20	2.68	4.00	2.82	3.83	2.65
90	4.49	2.86	4.27	3.02	4.00	2.79
100	4.77	3.03	4.53	3.21	4.16	2.92
110	5.03	3.19	4.78	3.39	4.31	3.04
120	5.29	3.34	5.01	3.56	4.45	3.16

Table 7. Relationships between the length (AL) and width (AW) of the *asteriscus* of *Centropomus nigrescens*

AL vs AW	a	b	R^2	F'	n
All	0.854	0.748	0.575	710.0	527
Females	0.704	0.998	0.692	42.8	21
Males	1.342	0.461	0.388	6.3	12

Table 8. Relationship between total fish length and *asteriscus* length (AL) and width (AW) of *Centropomus nigrescens*

Total length (mm)		a	b	R^2	F'	n
AL (mm)	All	0.351	0.567	0.678	1123.8	535
	Females	0.347	0.558	0.731	51.6	21
	Males	0.751	0.372	0.397	6.6	12
AW (mm)	All	0.241	0.549	0.657	1006.5	528
	Females	0.223	0.579	0.549	23.1	21
	Males	0.405	0.429	0.335	5.0	12

Table 9. Calculated measures of length (LL) and width (LW) of the *lapillus* at different size classes of *Centropomus nigrescens*

	Both sexes		Females		Males	
Classes (cm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)	SL (mm)	SW (mm)
10	0.94	0.68	1.01	0.69	0.90	0.43
20	1.42	0.93	1.48	0.95	1.42	0.72
30	1.80	1.12	1.84	1.16	1.84	0.98
40	2.14	1.28	2.15	1.32	2.22	1.22
50	2.44	1.41	2.43	1.47	2.57	1.45
60	2.71	1.53	2.68	1.61	2.89	1.66
70	2.97	1.65	2.92	1.73	3.19	1.86
80	3.22	1.75	3.13	1.84	3.48	2.06
90	3.45	1.84	3.34	1.95	3.75	2.25
100	3.67	1.93	3.54	2.05	4.02	2.44
110	3.88	2.02	3.73	2.14	4.28	2.62
120	4.09	2.10	3.91	2.23	4.52	2.80

Table 10. Relationships between the length (LL) and width (LW) of the *lapillus* of *Centropomus nigrescens*

LL vs. LW	a	b	R^2	F'	n
All	0.838	0.577	0.449	423.5	522
Females	0.676	0.881	0.377	13.3	24
Males	0.560	1.022	0.586	14.2	12

Table 11. Relationship between total fish length and *lapillus* length (LL) and width (LW) of *Centropomus nigrescens*

Total length (cm)		a	b	R^2	F'	n
LL (mm)	All	0.242	0.591	0.726	1385.5	524
	Females	0.290	0.544	0.708	55.7	25
	Males	0.203	0.648	0.815	44.2	12
LW (mm)	All	0.242	0.451	0.574	706.0	525
	Females	0.231	0.474	0.261	7.8	24
	Males	0.076	0.753	0.619	16.2	12

Taylor *et al.* (2000) considered that the scales were very difficult to interpret and his results were inconsistent in *C. undecimalis*. Labastida-Che *et al.* (2013) determined age in *Centropomus viridis* in the Chantuto-Panzacola lagoon system, Chiapas, using the length frequency analysis. The average length for each age differs greatly from those obtained in the present study. They determined longevity of 6 years. If values are calculated to obtain age groups of 8 to 10 years, the resulting values are similar to those of this study. Perera-García *et al.* (2013) found ages of 2 to 17 years by sectioning sagittae. They considered (as we did) that the metabolic energy during the reproductive season is deviated to the somatic growth, appearing in the sagittae as fast growth or opaque, thinner and the slow growth as hyalines and more wide.

As no other studies on age determination on otoliths of *C. nigrescens* were found, we were forced to make comparisons with *C. undecimalis* from the Atlantic. This species reaches sizes larger than *C. nigrescens* in the Central Mexican Pacific. The maximum ages found by Taylor *et al*. (2000) in *C. undecimalis* were of 21 years old and 17 in the coasts of Tabasco (Gulf of Mexico) by Perera-García *et al*. (2013). In our case the highest age found was of 12 years.

Conclusion

The identification of growth rings was carried out in *sagittae* and some *asterisci*. In the case of *lapilli*, marks were not recognized due to the thickness of the otolith. No statistically significant morphometric differences were observed between the right and left otolith, but between sexes there were differences in the case of the sagittae and asterisci. 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 borders and ventral areas. The relationship between total length of the fish and length and width of the three pairs of otoliths showed a negative allometric growth. Twelve growth rings were identified on *sagittae* and *asteriscus*, nevertheless the time of formation of these rings will have to be evaluated.

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 reduce 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. Analysis of the reproduction of C. nigrescens has to be carried out in order to know the proportion of sexes, hermaphroditism, fecundity, and lengths and season at which the phenomena of sexual inversion might take place, and reproduction zones. Also the analysis of feeding, hepatosomatic index, condition factor, relationships of length weight per sex, by season, months and different year are important. These studies would help have a better comprehension of the age and growth phenomena.

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REFERENCES

Caballero-Núñez V. 2009. Fishery of common snook *Centropomus undecimalis* in Campeche. Ciencia Pesquera 17(2): 77-86.

Caballero-Núñez V. 2011. Reproduction and fecundity of common snook *Centropomus undecimalis* in southwest of Campeche. Ciencia Pesquera 19(1): 35-46.

Caballero-Núñez V. 2012. Common snook *Centropomus undecimalis* fishery evaluation in Ciudad del Carmen, Campeche. Ciencia Pesquera 20(2): 35-42.

Cabrera-Rodríguez P, Amador del Ángel LE. 1998. Crecimiento del robalo blanco *Centropomus undecimalis* (Bloch, 1729) en jaulas fijas en la Laguna del Pom, Campeche, México. Proceedings of the 50th Gulf and

Carlström D. 1963. A crystallographic study of vertebrate otoliths. Biol. Bull. Mar. Biol. Lab, Woods Hole, 125, pp. 441-463.

Chávez H 1963. Contribución al conocimiento de la biología de los robalos chucumite y constantino (*Centropomus* spp.) del estado de Veracruz (Pisces: Centropomidae). Ciencia Mex. 22: 141-161.

Daniel WW 1991. Biostatistics: A Base for the Health Sicence's Analysis. Noriega-Limusa, Mexico, 667 p.

Davis TLO 1982. Maturity and sexuality in barramundi, Lates calcarfer (Bloch), in the Northern Territory and south-eastern Gulf of Carpetaria. *Aust. J. Mar. Freshwater Res*., 33: 529-545.

Degens ET, Deuser WG, Haedrich RL 1969. Molecular structure and composition of fish otoliths. *Mar. Biol*., 2(2): 105-113.

Espino-Barr E, Cabral-Solís EG, Garcia-Boa A, Puente-Gómez M 2004. Especies marinas con valor comercial de la costa de Jalisco, México. SAGARPA – INP, México, 145 p.

Espino-Barr E, Cruz-Romero M, Garcia-Boa A. 2003. Peces marinos con valor comercial de la costa de Colima, México. CONABIO INP, México. 125 p.

Espino-Barr E, Gallardo-Cabello M, Cabral-Solís EG, Garcia-Boa A, Puente-Gómez M 2015. Analysis of the otoliths *sagitta*, *asteriscus* and *lapillus* of Yellowfin Mojarra *Gerres cinereus* (Perciformes: Gerreidae) in the coast of Colima and Jalisco, Mexico. *Open Journal of Ocean and Coastal Sciences,* 2(1): 18-33.

Espino-Barr E, Gallardo-Cabello M, Cabral-Solís EG, Puente-Gómez M, Garcia-Boa A. 2013. Otoliths analysis of *Mugil curema* (Pisces: Mugilidae) in Cuyutlan Lagoon, Mexico. Avances de Investigación Agropecuaria 17(1): 35-64.

Espino-Barr E, Gallardo-Cabello M, Garcia-Boa A, Cabral-Solís EG, Puente-Gómez M. 2006. Morphologic and morphometric analysis and growth rings identification of otoliths: *sagitta*, *asteriscus* and *lapillus* of *Caranx caninus* (Pisces: Carangidae) in the coast of Colima, Mexico. *Journal of Fisheries and Aquatic Science,* 1(2): 157-170.

Gallardo-Cabello M. 1986. Estudio de la ultraestructura del otolito "sagitta" de la brótola *Phycis blennoides* (Brunnich 1768) en el Mediterráneo occidental (Pisces: Gadidae). An. Inst. Cienc. del Mar. y Limnol. UNAM, México 13(2): 197-206.

Gallardo-Cabello M, E Espino-Barr, A Garcia-Boa, EG Cabral-Solís, M Puente-Gómez 2006. Morphologic and morphometric analysis and growth rings identification of otoliths: *sagitta*, *asteriscus* and *lapillus* of *Caranx caballus* (Pisces: Carangidae) in the coast of Colima, Mexico. *International Journal of Zoological Research* ,2(1): 34-47.

Gallardo-Cabello M, Espino-Barr E, Cabral-Solís EG, Garcia-Boa A, Puente-Gómez M 2014. Morphometric analysis on *sagitta*, *asteriscus* and *lapillus* of Shortnose Mojarra *Diapterus brevirostris* (Teleostei: Gerreidae) in Cuyutlan coastal Lagoon, Colima, Mexico. Revista de Biología Marina y Oceanografía 49(2): 209–223.

Gallardo-Cabello M, Espino-Barr E, Cabral-Solís EG, Puente-Gómez M, Garcia-Boa A 2012. Study of the otoliths of *Mugil cephalus* (Pisces: Mugilidae) in Mexican Central Pacific. *Journal of Fisheries and Aquatic Science*, 7(6): 346-363.

Gallardo-Cabello M, Espino-Barr E, Garcia-Boa A, Puente-Gómez M. 2016. Analysis of the otoliths *sagitta*, *asteriscus* and *lapillus* of bigeye scad *Selar crumenophthalmus* (Teleostei: Carangidae) in Manzanillo Bay, Mexican Central Pacific. *International Journal of Development Research,* 6(9): 9541-9550.

Gallardo-Cabello M, Espino-Barr E, Nava-Ortega RA, Garcia-Boa A, Cabral-Solís EG, Puente-Gómez M. 2011. Analysis of the otoliths of *sagitta*, *asteriscus* and *lapillus* of Pacific sierra *Scomberomorus sierra* (Pisces: Scombridae) in the coast of Colima México. *Journal of Fisheries and Aquatic Science*, 6(4): 390-403.

Guiguen Y, Cauty C, Fostier A, Fuchs J, Jalabert B. 1994. Reproductive cycle and sex inversión of the seabass, *Lates calcarifer*, reared in sea cages in French Polynesia: histological and morphological description. *Environ. Biol. Fishes,* 39: 231-247.

Günther-Nonell J 1995. Growth of Pacific snook (*Centropomus nigrescens*) juveniles at different salinities. Uniciencia 12: 35-38.

Hickling CF 1931. The structure of the otolith of the hake. *Q. Jl. Microsc. Sc*i. 74: 547−561.

Holst E, Kaiser H, Schoen L, Roebig G, Göldner G 1950). Die Arbeitsweise de Statolithenapparates bei Fischen. *Zeitschrift für verglaichende Physiologie*, 32: 60−120.

IGFA 2001. Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, USA.

Ingles J, Pauly D. 1984. An atlas of the growth, mortality and recruitment of Philippine fishes. ICLARM Technical Reports 13, Philippines, 130 p.

Jiménez-Prado P, Béarez P. 2004. Peces marinos del Ecuador continental / Marine fishes of continental Ecuador. SIMBIOE/NAZCA/IFEA.

Labastida-Ché A, Núñez-Orozco AL, Oviedo-Piamonte JA 2013. Aspectos del robalo hocicudo *Centropomus viridis*, en el sistema lagunar Chantuto-Panzacola, Chiapas, México. Ciencia Pesquera 21(2): 21-28.

Lagler KF, Bardach JE, Miller RR. 1962. Ichthyology. The University of Michigan, John Wiley and Sons, USA, 491 p.

Lorán-Núñez RM, Martínez-Isunza FR, Valdez-Guzmán AJ, Garduño-Dionante M, Martínez-Lorán ER. 2012. Reproduction and sexual maturity of Mexican snook (*Centropomus poeyi*) and common snook (*C. undecimalis*) in the Alvarado Lagoon System, Veracruz (2005-2007). Ciencia Pesquera 20(1): 49-64.

Lowenstein O. 1957. The sense organs, the acusticolateralis system. In: Brown ME (Ed.) The physiology of fishes. Academic Press. N.Y., pp 155-186.

Mugiya Y 1964. Calcification in fish and shell-fish Seasonal occurrence of a pre-albumin fraction in the otolith fluid of some fish corresponding to the perio of opaque zone formation in their otoliths. *Bull. Jap. Soc. Scient. Fish*, 30: 445-467.

Mugiya Y. 1966 a. Calcification in fish and shell-fish. A study on paper electophoretic patterns of the acid mucopolysaccharides and Pas-positive materials in the otolith fluid of some fish. *Bull. Jap. Soc. Scient. Fish*, 32: 117-129.

Mugiya Y 1966 b. Calcification in fish and shell-fish Seasonal change in calcium and magnesium concentration of the otolith fluid in some fish with special reference to the zone formation of their otolith. *Bull. Jap. Soc. Scient. Fish*, 32: 549-557.

Muhlia-Melo A, Arvizu-Martínez J, Rodríguez-Romero J, Guerrero-Tortolero D, Gutiérrez-Sánchez FJ, Muhlia-Almazán A. 1995. Sinopsis de información biológica, pesquera y acuacultral acerca de los robalos del género *Centropomus* en México. Programa de Evaluación de Recursos Naturales del Centro de Investigaciones Biológicos del Noreste, S.C. La Paz, B.C.S. Volumen Especial, 52 p.

Perera-García MA, Mendoza-Carranza M, Contreras-Sánchez W. 2013. Comparative age and growth of common snook *Centropomus undecimalis* (Pisces: Centropomidae) from coastal and riverine areas in Southern Mexico. *Rev. Biol. Trop*., 61(2): 807-819.

Sandoval-Castellanos E, Uribe-Alcocer M, Díaz-Jaimes P 2005. Diferenciación genética poblacional en robalos (Pisces: Centropomidae) del Pacífico mexicano. *Rev. Int. Contam. Ambient*., 21(1): 35-41.

Sasaki H, Miyata J. 1955. Experimentelle Studien über Otolithen. *Zeitschr. Rhinol. Otol*., 34: 740-748.

Secor BW, Dean JM, Laban EH. 1992. Otolith removal and preparation for microstructural examination. In: Stevenson DK, Campana SE (Eds.) Otolith microstructure examination and analysi*s. Canadian Special Publication of Fisheries and Aquatic Sciences*, 117, pp 19-57.

Taylor RG, Whittington JA, Grier HJ, Crabtree RE 2000. Age, growth, maturation, and protandric sex reversal in common snook, *Centropomus undecimalis*, from the east and west coasts of South Florida. *Fish. Bull*., 98: 612-624.

Zar JH 1996. Biostatistical analysis. 3rd ed. Prentice Hall. USA., 662 p.

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