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GROWTH OF THE YELLOWFIN SNOOK *Centropomus robalito* (TELEOSTEI: CENTROPOMIDAE) IN CUYUTLAN LAGOON, MEXICAN CENTRAL PACIFIC

Marine Science

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ABSTRACT

Specimens of yellowfin snook *Centropomus robalito* were collected from October 2015 to September 2016, from commercial captures in Cuyutlan lagoon, Colima, Mexico. The maximum value of TL was 34.0 cm and the minimum was 6.50 cm, total weight varied from 2.7 g to 390.00 g. Each year a fast growth band and a slow growth band are deposited on the *sagittae*, equivalent to one year of age. The growth index value of the weight-length equation was positive allometric: b = 3.140 with total weight data and b =3.146 with eviscerated specimens. Growth parameters obtained by Ford-Walford-Gulland method for TL were: $L\infty$= 39.55 cm, k = 0.208 $years^{-1}$, and t_o = - 0.806. The calculated asymptotic total weight was $TW\infty$= 590.1 g and the eviscerated asymptotic weight $EW\infty$= 529.2 g. Longevity value was 13.6 years. Data obtained by other authors were compared with those reported in this study.

KEYWORDS

growth parameters, length weight relationship, von Bertalanffy equation.

INTRODUCTION

The geographic distribution of yellowfin snook *Centropomus robalito* Jordan and Gilbert 1882 goes from Sinaloa State Mexico to Northern Colombia (Allen & Robertson, 1994; Fischer *et al*., 1995). This species lives mostly in coastal lagoons and is fished with hand line and hook, cast net and gill nets. Annual commercial captures go from 1.4 tons to 26.7 tons with an average of 12.8 tons in Colima during the last year (from 2013 to 2017) (SIPESCA, 2017). Its fishery importance is medium in a local scale, it is delivered whole and preserved in ice and its commercial classification is third category; its price is of $40.00 Mexican pesos ($2.00 US dollars).

Cuyutlan lagoon is found in Colima State, Mexico (18°57'-19°01' LN, 104°03'-104°19' LW), it is one of the most important in the coast of Central Mexican Pacific due to its extension, location and environmental conditions; therefore it constitutes a protection zone for reproduction, growth, and feeding of a large number of freshwater, estuarine and marine species.

Studies on growth of this species are scarce; Tovilla-Hernández & Castro-Aguirre (1981) reported data on length frequency analysis of 4 159 organisms collected in Zacapulco, Chiapas, Mexico. Gil-López *et al*. (2010) carried out another length frequency analysisi with this species in the lagunar system of Mar Muerto en Oaxaca and Chiapas, México. Studies that have been tried with scales have not produced the expected results (Tovilla-Hernández & Castro-Aguirre 1981). The present study is the only one considering growth study of *C. robalito* based on the analysis of the periodical growth rings in *sagittae*.

According to this, the objectives of this study are: a) to determine the time of formation of the growth rings, b) obtain the values of the allometric indexes of the weight-length relationship, c) calculate values of the growth constants of the von Bertalanffy equation, d) calculate longevity, e) compare growth parameters of *C. robalito* with those obtained from other authors.

MATERIALS AND METHODS

From October 2015 to September 2016, 335 organisms of *C. robalito* were taken directly from the commercial captures in Cuyutlan lagoon in Colima, Mexico and taken to the laboratory of the Regional Fishery Research Center (CRIP). Organisms were captured with gill net, hand line with hook and cast nets, to obtain a stratified sample which includes all the age groups and size classes.

In the laboratory, data taken from each organism were: total length (TL, cm), standard length (SL, cm), and height (He, cm), total weight (TW, g), eviscerated weight (EW, g) and sex.

To compare the relation and morphometric differences between males and females, a one way variance analysis (ANOVA) was carried out (Zar, 1996).

The time of the growth ring formation was determined, observing whether the borders had slow or fast growth rings. In every case, otoliths were observed by transparency with transmitted light; the hyaline (translucent) zone corresponds to the slow growth band and the opaque zone to the fast growth band, which is in contrast with reflected light (Blacker, 1974).

The average length of each growth ring was determined by the analysis of the *sagittae* otoliths (Espino-Barr *et al*., 2018 in press), and were used to obtain the parameters of the growth equation of von Bertalanffy (1938). The observed values of total length of the fish with the analysis of *sagittae* were: for ring 0 = 7.95 cm TL, ring 1 = 14.36 cm, ring 2 = 19.35 cm, ring 3 = 22.42 cm, ring 4 = 25.49 cm, ring 5 =27.54 cm, ring 6 = 29.30 cm, ring 7 = 31.90 cm, ring 8 = no data, ring 9 = 34.0 cm of individual total length.

The von Bertalanffy's equation (1938) in the form of $TL = L[1-e^{-k(t-to)}]$, was used, where TL = total length, L = asymptotic length, k = growth factor, t = time or age, and t_o = theoretic length at age 0. The parameters L, k and t_o of the equation of von Bertalanffy (1938) were obtained with the methods of Ford (1933), Walford (1946) and Gulland (1964), and were adjusted by convergent iterations with Newton´s algorithm, using the solver program in Excel software (Microsoft, 1992). The lowest value of a sum of the squared error determined the best adjustment.

To obtain the weight-length relationship, the function $W = a \cdot TL^b$ was used, where W = weight (for both total weight TW and eviscerated weight EW), TL = total length. The same function was also used to describe TL *vs* SL and He relationships, where the regression coefficient or slope *b* tends to 1, describing an isometric growth with those variables. Data of weight-length relationships were used to obtain the weight at each age. Weight growth was obtained by substituting TL and L by TW and W, in the von Bertalanffy´s equation (1938). Taylor´s equation (1958, 1960) was used to calculate the age limit or longevity (95% of the L): $A_{0.95} = \ln(1-0.95) / k + t_o$.

To compare the growth parameters of the equation of von Bertalanffy obtained in this study with those from other authors, growth performance index or phi prima (phi', ϕ') test was estimated (Pauly, 1979):

$$\phi' = \log k + 2 \cdot \log L_{\infty}$$

RESULTS

Biometric relationships.

The maximum value of TL was 34.0 cm and the minimum was 6.50 cm (Table 1).

According to the proportion of sexes in *figure 1*, it can be observe that most high percentages are of females from 19 cm TL. Juvenile are more abundant from 7 to 11 cm TL. Total weight varied from 2.7 g to 390.0 g. The curves that describe the relationship between total and eviscerated weight and total length for species and sexes are observed in *figure 1*.

Relationships between TL and SL (Table 2) show isometric value of the allometric growth index for all individuals (b = 1.022), for females (b = 1.029), and for males (b = 1.014). In the relation of TL *vs* He, growth indexes are isometric for the species (b = 1.004) and with isometric tendencies for males (b = 0.96); and for females it is a positive allometric value (b = 1.12). In the relationships between length and weight, that is, total weight (TW), all values correspond to a positive allometric growth: b = 3.14, 3.18 and 3.25, for the species, females and males, respectively. Also, the same occurs with the eviscerated weight (EW), where the allometric growth index is b = 3.14, 3.20, 3.26 for the species (all the organisms), females and males.

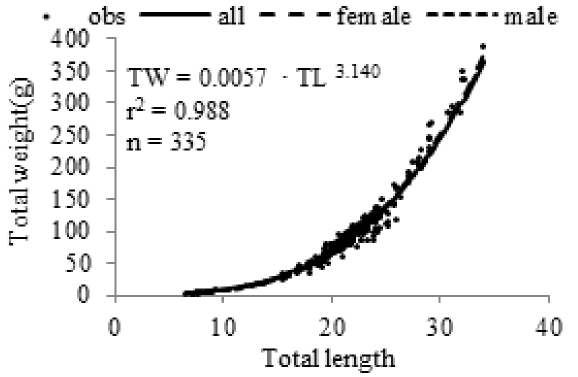
There were statistically significant differences between male and female sizes. ANOVA values were as follows: between standard length (SL) of females and males $F'_{0.05(2,269=3.876)} = 110.923$; between total length (TL) of females and males $F'_{0.05(2,269=3.876)} = 112.638$; between height (He) of females and males $F'_{0.05\ (2,\ 269\ =\ 2.876)} = 98.276$; between total weight (TW) of females and males $F'_{0.05\ (2,\ 269\ =\ 3.876)} = 65.618$, and between eviscerated weight (EW) of females and males $F'_{0.05(2,269=3.876)} = 63.982$.

TABLE 1. Summary of size values of the measured variables: TL=total length, SL= standard length, He= height, TW= total weight and EW=eviscerated weight, from *Centropomus robalito*.

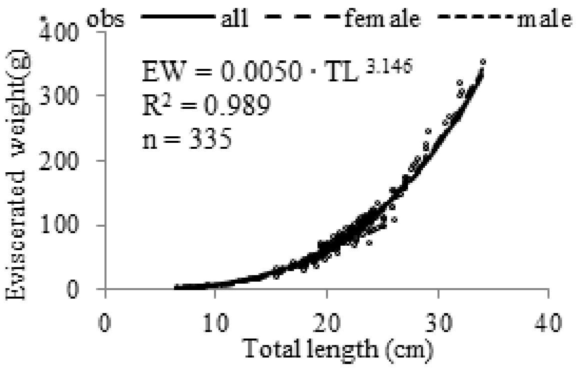
	SL	TL	He	TW	EW
all					
n	335	335	335	334	335
average	15.90	20.78	4.78	91.3	82.7
maximum	27.00	34.00	8.00	390.0	353.0
minimum	5.00	6.50	1.60	2.7	2.5
SD	3.696	4.686	1.160	59.222	53.734
females					
n	198	198	198	198	198
average	17.70	23.04	5.34	116.8	105.8
maximum	27.00	34.00	8.00	390.0	353.0
minimum	12.00	15.60	3.20	28.0	26.0
SD	2.478	3.044	0.859	59.772	54.354
males					
n	72	72	72	72	72
average	14.23	18.69	4.23	57.5	52.5
maximum	20.00	26.20	6.00	154.0	143.0
minimum	9.50	12.50	3.00	15.0	13.0
SD	2.161	2.796	0.657	27.809	25.555
juveniles or indeterminated					
n	64	64	64	63	64
average	12.19	16.07	3.69	49.5	44.8
maximum	18.00	24.48	5.90	116.0	104.0
minimum	5.00	6.50	1.60	2.7	2.5
SD	4.523	5.908	1.351	37.569	33.883

Time of growth rings formation.

The fast and slow growth bands of *C. robalito* showed that a higher percentage of *sagittae* and *asterisci* otoliths with fast growth borders (opaque) were observed from September to February, while the highest percentage with slow growth bands (hyaline) in the borders occur from March to August (Fig. 2).



a)



b)

Figure 1. Observed data and relationship by potential model for: a) Total weight (g), b) Eviscerated weight (g), of the species (all), females and males of *Centropomus robalito*.

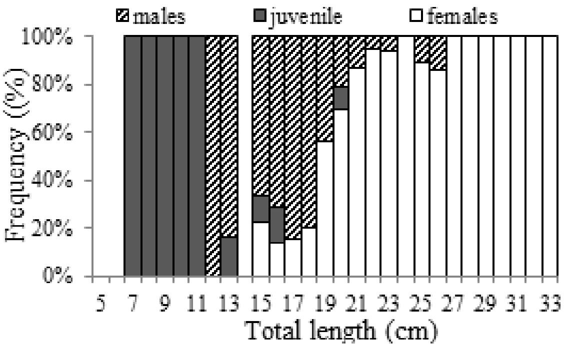


Figure 2. Total length frequency of *Centropomus robalito* by sexes.

Analysis of otoliths.

The *sagittal* otoliths allowed the identification of nine age groups. Growth parameters obtained by Ford-Walford-Gulland methods for TL were: L = 39.55 cm, k = 0.208 years^{-1}, and t_o = -0.806. Growth parameters adjusted by solver iteration process were L = 33.85 cm, k = 0.364 years^{-1}, t_o = 0.00 (Table 3).

TABLE 2. Morphometric relationships of the variables: TL = total length, SL = standard length, He = height, TW = total weight and EW = eviscerated weight, from *Centropomus robalito*.

	all	female	male
TL vs SL			
r^2	0.994	0.971	0.981
F	52064	6519	3738
a	0.715	0.700	0.731
b	1.022	1.029	1.014
n	335	198	72
TL vs He			
r^2	0.959	0.846	0.892

F	7812	1080	590
a	0.227	0.158	0.254
b	1.004	1.120	0.960
n	335	198	72
TL vs TW			
r^2	0.988	0.946	0.964
F	26575	3484	1890
a	0.006	0.005	0.004
b	3.140	3.182	3.251
n	334	198	72
TL vs EW			
r^2	0.989	0.955	0.963
F	29650	4165	1871
a	0.005	0.004	0.003
b	3.146	3.206	3.262
n	335	198	72

Note: a = Y intercept, b = regression coefficient or slope, r2 = coefficient of determination, F = statistic test.

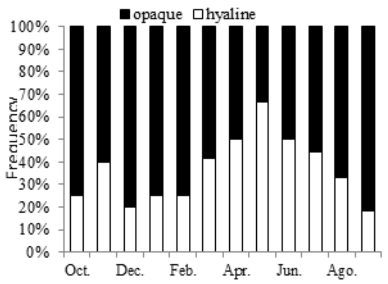


Figure 3. Monthly frequency of the slow (hyaline) and fast (opaque) growth borders in the *Centropomus robalito* sagittae.

TABLE 3. Observed and calculated values of total length (TL, cm) and total (TW, g) and eviscerated weight (EW, g) for each age group (years) of *Centropomus robalito*.

	L_∞	39.55	33.85		
	k	0.208	0.364	Objective value	
	to	-0.806	0	12.063	86.726
Age (years)	obs	calc F-W	solver	SSE F-W-G	SSE solver
0	7.95	6.12	0.000	3.365	63.206
1	14.36	12.41	10.337	3.814	16.167
2	19.35	17.51	17.518	3.379	3.357
3	22.42	21.66	22.505	0.582	0.007
4	25.49	25.02	25.970	0.221	0.226
5	27.54	27.76	28.376	0.047	0.699
6	29.30	29.98	30.048	0.457	0.559
7	31.90	31.78	31.209	0.015	0.478
8		33.24	32.015		
9	34.00	34.43	32.575	0.183	2.030
10		35.39	32.964		
11		36.18	33.234		
12		36.81	33.422		

Note: obs = observed values, calc = calculated values, F-W-G = Ford-Walford and Gulland method to obtain parameters, SSE =sum of squares error.

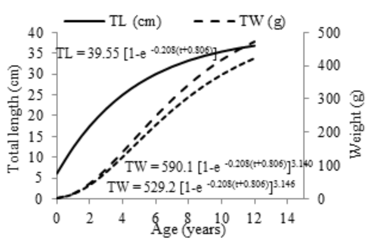


Figure 4. Von Bertalanffy's growth curve in length and weight for *Centropomus robalito:* TL =total length, TW = total weight, EW = eviscerated weight.

Figure 4 shows the growth curve of *C. robalito* according to von Bertalanffy's method. Ford-Walford and Gulland methods gave a better fit of the calculated equation to the observed data of otoliths readings, than solver's method. The sum of square errors (SSE) between observed and calculated data by Ford-Walford and Gulland was SSE = 0.183, and that of the observed data and the resulting of solver process was SSE = 2.030. Growth from 0 age to 1 was 6.65 cm, from age 1 to age 2 was 5.63 cm, from age 2 - 3 was 4.76 cm, from ages 3 - 4 was 4.03 cm, from ages 4 - 5 was 3.41 cm, from age 5 - 6 was 2.88 cm, from ages 6 to 7 was 2.44 cm, from ages 7 to 8 was 2.06 cm, from age 8 to 9 was 1.74 cm.

Growth in weight.
The growth index value of the weight-length equation was positive allometric: b = 3.140 with total weight data and b = 3.146 with eviscerated specimens (Table 2).

Theoretical growth in weight.
Values of calculated TW and EW have a slow growth during the first year of age, starting at 16.74 g and 15.43 g (Table 4, Fig. 4). After age 2 there is a very fast growth rate. The calculated asymptotic total weight was TW= 590.1 g and the eviscerated asymptotic weight EW= 529.2 g.

Longevity (Age $A_{0.95}$).
C. robalito reached 95% of its infinite length TL in 13.6 years.

TABLE 4. Values of total length (TL, cm), total (TW, g) and eviscerated weight (EW, g) for each age group (years) of *Centropomus robalito.*

Age	TL (cm)	TW (g)	EW (g)
0	6.12	1.7	1.5
1	12.41	15.5	13.8
2	17.51	45.7	40.8
3	21.66	89.1	79.6
4	25.02	140.2	125.4
5	27.76	194.1	173.7
6	29.98	247.1	221.3
7	31.78	296.8	265.8
8	33.24	341.9	306.3
9	34.43	381.7	342.0
10	35.39	416.3	373.1
11	36.17	445.9	399.7
12	36.81	471.0	422.2

DISCUSSION

Data of the relationships between length, height and weight (Table 2) show that the relationship between TL *vs* He is isometric for the species, positive allometric for females and negative allometric for males. In the case of the relationships between total and eviscerated weight and total length, a positive allometric growth is observed for the species and for both sexes, although it was much higher in males, that is, organisms grow faster in weight than in length as they grow older.

Each year a band of fast and slow growth are deposited on the otoliths *sagittae* allowing the use of this structure to estimate the age of *C. robalito* and its growth. This has also been observed in Carangidae species, where scales are not present, as *Caranx caballus*, *C. caninus* and *Selar crumenophthalmus,* or other species, as *Scomberomorus sierra* (Gallardo-Cabello *et al*., 2006, 2007, 2011, Espino-Barr *et al.,* 2006, 2008, 2016, Nava-Ortega *et al*. 2012), allowing a good assessment of ageing, not always possible with scales.

In this study the Ford-Walford-Gulland presented better results of adjustment or fitness from the calculated to the observed values, showing a lower value of the sum of square error. The Newton algorithm method in solver (Microsoft 1992) overestimated the *k* value and underestimated L_∞ providing a lower value than the maximum average length sampled. We consider that the F-W-G method presented a better fit whenever samples contain a larger number of biases and this method is less sensitive than solver. Similar results were observed in analysis of *Mugil cephalus* growth in the same area (Espino-Barr *et al.,* 2015) and *Selar crumenophthalmus* (Espino-Barr *et al*., 2016).

According to the different fishing methods, organisms come from different samples. These fishing gears can capture any species of fish present in the area, depending on currents, sea temperatures, seasons, vulnerability to fishing gears and the presence of other species as prey, predators or competitors (Espino-Barr *et al*., 2010; Gallardo-Cabello *et al*., 2011).

Related to the growth parameters calculations done in this study, and those provided by other authors (Table 5), it is observed that the higher value obtained for L_∞ is reported in the present analysis as L_∞ = 39.55 cm, decreasing to L_∞ = 38.80 cm in the lagoon of Chiapas (Tovilla-Hernández & Castro-Aguirre 1981), and even more in the lagoon system of Mar Muerto between Oaxaca and Chiapas to L_∞ = 37.60 (Gil-López *et al.*, 2010).

Table 5. Growth parameters and average lengths of each age group of *Centropomus robalito* by different authors: a) this study, b) values reported by Tovilla-Hernández & Castro-Aguirre (1981), c) Gil-López *et al*. (2010) calculated by us.

L_∞	39.55	38.80	37.60
k	0.208	2.223	0.490
t_o	-0.806	2.420	0.310
ϕ'	2.513	3.525	2.841
Age	TL (cm) a)	TL (cm) b)	TL (cm) c)
0	6.12	2.4199	-6.17
1	12.41	9.823	10.79
2	17.51	16.42	21.17
3	21.66	21.83	27.54
4	25.02	25.71	31.43
5	27.76	27.99	33.82
6	29.98	31.31	35.29
7	31.78		36.18
8	33.24		36.73
9	34.43		37.07

It is observed that the values of k index tend to increase as the L_∞ decreases, as is observed in the results of Gil-López *et al.* (2010) to a value of k = 0.49 and L_∞ = 37.60.

The ϕ' value obtained in the present study occupies an intermediate position with respect to the other two.

CONCLUSIONS

The maximum value of TL was 34.0 cm and the minimum was 6.50 cm, total weight varied from 2.7 g to 390.00 g.

Each year a fast and a slow growth band are deposited on the *sagittae* of *C. robalito*, equivalent to one year of age.

The growth index value of the weight-length equation was positive allometric: b = 3.140 with total weight data and b =3.146 with eviscerated specimens.

Growth parameters obtained by Ford-Walford-Gulland method for TL were: L= 39.55 cm, k = 0.208 years^{-1}, and t_o= - 0.806.

The calculated asymptotic total weight was TW = 590.1 g and the eviscerated asymptotic weight EW= 529.2 g.
Longevity value was 13.6 years.

RECOMMENDATIONS

Studies on biology and population dynamics of *C. robalito* should continue, to establish a norm that regulates its capture and prevents overexploitation.

It is very important to stop the cutting of the mangroves, as these habitats in the coastal lagoons are spawning areas and nurseries to a great quantity of species of fishes including *C. robalito*; the disappearance and/or contamination of mangroves elevates the natural mortality indexes of a great number of marine organisms.

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