ORIGINAL RESEARCH PAPER

Volume-6 | Issue-12 | December-2017 | ISSN No 2277 - 8179 | IF : 4.176 | IC Value : 93.98

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

GROWTH AND REPRODUCTION OF THE ROBALO CENTROPOMUS NIGRESCENS (TELEOSTEI: CENTROPOMIDAE) IN MANZANILLO BAY, MEXICAN CENTRAL PACIFIC

Animal Science

Espino- Barr E* Instituto Nacional De Pesca, Crip- Manzanillo, Playa Ventanas S/n, Colima, Cp 28200, México. *Corresponding Author

Gallardo - Cabello M Instituto De Ciencias Del Mar Y Limnología, Unam, Av. Ciudad Universitaria 3000, Col. Copilco, Cdmx, C.p. 04360, México

Puente-Gómez M Instituto Nacional De Pesca, Crip- Manzanillo, Playa Ventanas S/n, Colima, Cp 28200, México.

Garcia-Boa A Instituto Nacional De Pesca, Crip- Manzanillo, Playa Ventanas S/n, Colima, Cp 28200, México.

ABSTRACT

Specimens of black snook *Centropomus nigrescens* were collected from October 2013 to December 2015. The maximum value of TL was 101.0 cm and the minimum was 11.1 cm, Total weight varied from 5.26 g to 9 810.00 g. Each year a fast growth band and a slow growth band are deposited on the *sagittae* and *asterisci*, equivalent to one year of age. The growth index value of the weight-length equation was positive allometric: b = 3.161 with total weight data and b = 3.15 with eviscerated specimens. Growth parameters obtained by Ford-Walford-Gulland method for total length were: L_∞= 103.55 cm, k = 0.14 years^{-1}, and t_o = 0.00. Growth parameters obtained by convergent iteration process were L_∞ = 103.53 cm, k= 0.14 years^{-1}, t_o= 0.00. The calculated asymptotic total weight was Wt_∞= 9 749 g and the eviscerated asymptotic weight We_∞= 8 863 g. Longevity was of 21.4 years. The proportion of male: female was 1: 1.65. Length of first maturity was L_{25} = 59.00 cm in females and males, and first reproduction length was L_{50} = 76.4 cm in females and L_{50} = 59.0 cm in males. The allometric value of the hepatosomatic index (HSI) relationship was b = 2.95. Maximum values were observed in June, July, November, February, and April. Spawning stage in females and males at 100 % in June and July. The gonadosomatic index (GSI) reached its highest value during June. The gastric repletion index showed higher values during June, July, November, February and April. The higher values of the condition factor are obtained in the months of June, July, October and November. Oocyte diameter was 0.34 mm average, minimum 0.33 mm and maximum 0.39 mm. Fecundity values ranged from 21.7 million to 40.1 million with a mean of 29.1 million oocytes in females of 89 cm to 101 cm. Relative fecundity was of minimum 2 273, maximum of 4 023.6, and average 3 081.7 oocytes per gram of gonad, and per gram of the organism 54 231.9 average (30 237.9 to 90 713.7 oocytes per organism gram).

KEYWORDS

growth parameters, length weight relationship, von Bertalanffy equation, fecundity, relative fecundity, reproduction period, gonadosomatic index, hepatosomatic index, gastric repletion index, condition factor.

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 (Castro-Aguirre, 1978; Allen and Robertson, 1994; Fischer *et al.*, 1995; Nelson *et al*., 2004; Miller *et al*., 2009). *C. nigrescens* in the Pacific is a very little studied species if compared to *C. undecimalis* in the Atlantic, reason why these studies are addressed in the present work.

The present study is the only one considering growth study of *C. nigrescens* based on the analysis of the periodical growth rings in *sagittae* and *asterisci*. According to this, the objectives of this study are: a) to determine the time of formation of the growth rings, b) to obtain the values of the allometric indexes of the weight-length relationship, c) to calculate values of the growth constants of the von Bertalanffy equation, d) to calculate longevity, e) to compare growth parameters of *C. nigrescens* with those of *C. undecimalis* obtained from other authors in the Atlantic Ocean. Similarly, because there are no studies on reproduction of C. nigrescens, it was also determined: sex ratio, average length of sexual maturity (L_{50}) and length of first maturity (L_{25}), analysis of the gonadosomatic index, allometric relationship between liver weight and fish length, analysis of the hepatosomatic index, the gastric repletion index and condition factors according to Fulton (1902), Clark (1928) and Safran (1992). Also, the analysis of total fecundity, relative fecundity, and oocytes diameter were analyzed. Comparisons were made with results obtained with those by other authors of other species of the *Centropomus* genus: *C. undecimalis* and *C. poeyi*.

Fig. 1. Photograph of *Centropomus nigrescens* Günther 1864.

Methods

From October 2013 to December 2015, 504 organisms of *C. nigrescens* were taken directly from the commercial captures in Colima and Jalisco States coasts in México and taken to the laboratory of the Regional Fishery Research Center (CRIP). Organisms were captured with gill net, hand line, harpoon 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 (Wt, g), eviscerated weight (We, g) and sex. Gonads (Gi, g), liver (LW,g) and stomach (SW,g) were also weighed, and gonads preserved in 70% alcohol. 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* and *asterisci* otoliths (Gallardo-Cabello *et al*., 2017), and were used to obtain the parameters of the growth equation of von Bertalanffy (1938). The observed values for *sagittae* and *asterisci* were: for age 1 = 13.82 cm, age 2 = 25.79 cm, age 3 = 36.17 cm, age 4 = 45.16 cm, age 5 = 52.95cm, age 6 = 59.70 cm, age 7 = 65.55 cm, age 8 = 70.62 cm, age 9= 75.01 cm, age 10 = 78.82 cm, age 11 = 82.12 cm and age 12 = 84.98 cm of individual total length.

The von Bertalanffy's equation (1938) in the form of $TL = L_\infty [1-e^{-k(t-to)}]$, 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 Wt and eviscerated weight We), TL = total length. A *t- Student* test indicated allometry (Zar, 1996). 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 Wt 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): $\phi' = \log k + 2 \cdot \log L$.

Regarding reproduction analysis, gonads were weight. Sex and gonad maturation were determined *in visu*, on fresh organisms taken to the laboratory the same day they were caught. The stages of sexual maturity were determined using the key described in Espino-Barr *et al*. (2008a). The first spawning TL for males and females was determined by 50% of the accumulative frequency (L_{50}) of stages IV and V of sexual maturation (Sparre and Venema, 1995), and the minimum TL of first spawning (L_{25}) was also recorded to compare with other authors findings (Rodríguez-Gutiérrez, 1992). The minimum TL of first maturation (L_{25}) was also recorded to compare with other author's findings.

The gonadosomatic index (GSI) was calculated according to Rodríguez-Gutiérrez (1992), where gonad weight (GW) is expressed as a function of body weight: $GSI = 100 \cdot GW/TW$ (TW = total weight). As a measure of physical fitness of the fish, we obtained the condition factor $K = (We \cdot TL^{-3}) \cdot 100$ (Clark, 1928), $K = (Wt \cdot TL^{-3}) \cdot 100$ (Fulton, 1902) and $a = Wt \cdot TL^{-b}$ and $a = We \cdot TL^{-b}$ (Safran, 1992). The hepatosomatic index (HSI) was expressed as the percentage of liver weight (LW) with respect to the total weight $HSI = 100 \cdot LW/Wt$ (Rodríguez-Gutiérrez, 1992).

Fecundity (F) and relative fecundity were obtained by the gravimetric method using the wet weight of phase V female gonads of *C. nigrescens*, two subsamples of 0.01 g were obtained of each individual and put in a modified Gilson fluid (Simpson, 1951) to preserve. All oocytes were counted with the help of a stereoscopic microscope and measured with a micrometric ocular. The following expression was used in the calculation: $F = n \cdot Gi/g_i$, where F = fecundity of a sample; *n* = number of oocytes in the subsample; Gi = weight of the gonad (g) and gi = weight of the subsample (g) (Holden and Raitt, 1975).

Results

Biometric relationships.

The maximum value of TL was 101.0 cm and the minimum was 11.1 cm (Table 1). Total weight varied from 5.26 g to 9 810.00 g. The curves that describe the relationship between total and eviscerated weight and length for species and sexes are observed in figure 2.

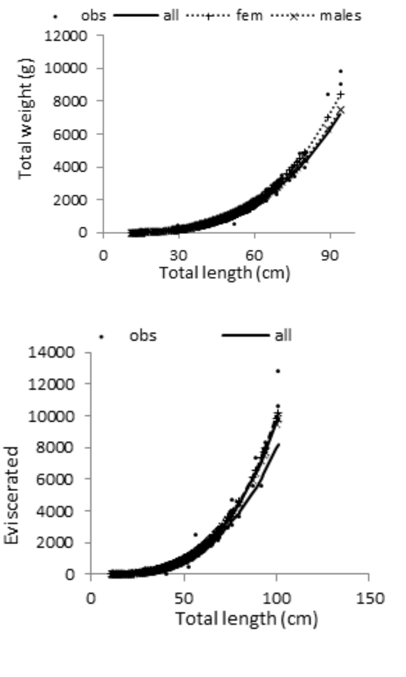

Fig. 2. Observed data (obs) and relationship by potential model for: a) Total weight (g), b) eviscerated weight (g), of the species (all), females (fem) and males (male) of *Centropomus nigrescens*.

Relationships between TL and SL (Table 2) show an isometric values of the allometric growth index for all individuals (b = 1.032), females (b = 1.057), and males (b = 1.059). In the relation of TL *vs* He, growth indexes are isometric for species (b = 1.01) and males (b = 1.06), and for females is positive allometric (b = 1.33). In the relationships between length and weight, that is, total weight (Wt), all values correspond to a positive allometric growth: b = 3.16, 3.32 and 3.13, for the species, females and males, respectively. Also, the same occurs with the eviscerated weight (We), where the allometric growth index is b = 3.15, 3.42, 3.35 for the species (all the organisms), females and males.

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 nigrescens.*

	TL	SL	Het	TW	EW
Species					
Average	46.39	37.08	9.00	1004.2	1024.8
Maximum	101.00	88.00	25.00	9810.0	12820.0
Minimum	11.10	7.50	2.00	5.3	4.4
Standard deviation	15.44	12.91	3.33	1014.6	1281.2
n	504	504	504	489	495
females					
Average	77.11	63.28	16.69	4268.0	4971.9
Maximum	101.00	88.00	25.00	9810.0	12820.0
Minimum	37.00	29.40	7.30	445.0	395.0
Standard deviation	17.19	14.95	5.35	2870.0	3656.2
n	20	20	20	14	19
males					
Average	59.96	48.76	12.08	1889.6	1959.3
Maximum	79.80	66.50	16.50	4728.0	4674.0
Minimum	41.60	33.00	9.00	620.0	534.0
Standard deviation	11.33	9.78	2.58	1157.79	1309.7
n	13	13	13	12	13
indeterminated					
Average	45.73	36.49	8.76	970.3	904.0
Maximum	75.00	62.00	16.00	3993.0	3570.0
Minimum	11.10	7.50	2.00	5.3	4.7
Standard deviation	14.58	12.10	2.89	724.3	658.7
n	370	370	370	370	362

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

	Species	Females	Males
	TL *vs* SL		
R^2	0.994	0.991	0.994
F	84556.604	2136.949	1916.468
a	0.692	0.640	0.637
b	1.037	1.057	1.059
	TL *vs* He		
a	0.186	0.051	0.156
b	1.01	1.33	1.06
R^2	0.972	0.949	0.903
F	17483.688	357.376	113.266
	TL *vs* Wt		
a	0.0042	0.0023	0.0049
b	3.1608	3.3260	3.1356
R^2	0.989	0.972	0.977
F	43085	458	467
	TL *vs* We		
a	0.00	0.00	0.00
b	3.15	3.42	3.35
R^2	0.96	0.98	0.97
F	11000.46	1022.61	453.10
n	504	20	13

Note: a = Y intercept, b = regression coefficient or slope, r^2 = coefficient of determination, F = statistic test.

Differences of the length and weight values between males and females were statistically significant. ANOVA values were as follows: between standard length (SL) of females and males $F'_{0.05\ (2,\ 32\ =\ 4.159)}$ = 9.541; between total length (TL) of females and males $F'_{0.05\ (2,\ 32\ =\ 4.159)}$ = 10.037; between height (He) of females and males $F'_{0.05(2,32=4.159)}$ = 8.307; between total weight (Wt) of females and males $F'_{0.05\ (2,\ 25\ =\ 4.259)}$ = 7.201, and between eviscerated weight (We) of females and males $F'_{0.05(2,31=4.171)}$ =8.046.

Time of growth rings formation.

The fast and slow growth bands of *C. nigrescens* 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. 3).

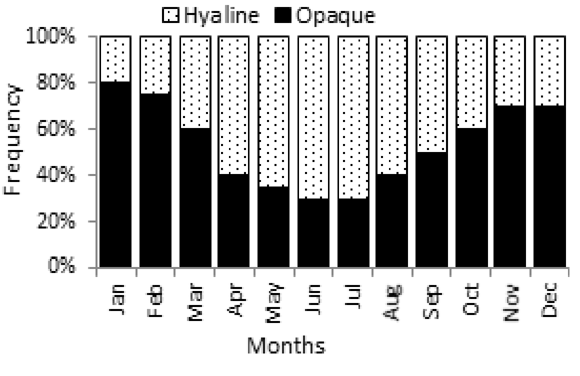

Fig. 3. Monthly frequency of the slow (hyaline) and fast (opaque) growth borders in the *sagittae* of *Centropomus nigrescens*.

Analysis of otoliths.

The *sagittae* and *asterisci* otoliths allowed the identification of twelve age groups. Growth parameters obtained by Ford-Walford-Gulland methods for TL were: L_∞ = 103.55 cm, k = 0.14 years^{-1}, and t_o = 0.00. Growth parameters adjusted by solver iteration process were L_∞ = 103.53 cm, k = 0.14 years^{-1}, t_o = 0.00 (Table 3).

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 nigrescens.*

k =		**0.14**	**0.14**			
L_∞ =		103.53	103.55			
to =		0	0			
Objective value					6.88	0.00
	obs	**solver**	**F-W**	**Growth rate**	**SSE (solver)**	**SSE F-W**
0	0.00	0.00	0.00		0.00	0.00
1	13.82	13.53	13.81	13.81	0.09	0.00
2	25.79	25.28	25.79	11.97	0.26	0.00
3	36.17	35.51	36.16	10.37	0.44	0.00
4	45.16	44.39	45.15	8.99	0.59	0.00
5	52.95	52.12	52.94	7.79	0.69	0.00
6	59.70	58.84	59.69	6.75	0.75	0.00
7	65.55	64.67	65.54	5.85	0.77	0.00
8	70.62	69.75	70.61	5.07	0.76	0.00
9	75.01	74.16	75.01	4.39	0.72	0.00
10	78.82	78.00	78.82	3.81	0.67	0.00
11	82.12	81.34	82.12	3.30	0.61	0.00
12	84.98	84.23	84.97	2.86	0.55	0.00
13		86.76	87.45	2.48		
14		88.95	89.60	2.15		

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 shows the growth curve of *C. nigrescens* 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 = 0.00, and that of the observed data and the resulting of solver process was SSE = 6.88. Growth from 1 age to 2 was 13.81 cm, from age 2 to age 3 was 11.97 cm, from age 3 - 4 was 10.37 cm, from ages 4 - 5 was 8.99 cm, from ages 5 - 6 was 7.79 cm, from age 6 - 7 was 6.75 cm, from ages 7 to 8 was 5.85 cm, from ages 8 to 9 was 5.07 cm, from age 9 to 10 was 4.39 cm, from 10 to 11 was 3.81 cm, from 11 to 12 was 3.30 cm, from 12 to 13 was 2.86 cm, from 13 to 14, was 2.48 cm, and from 13 to 14 the increment rate was 2.15 cm.

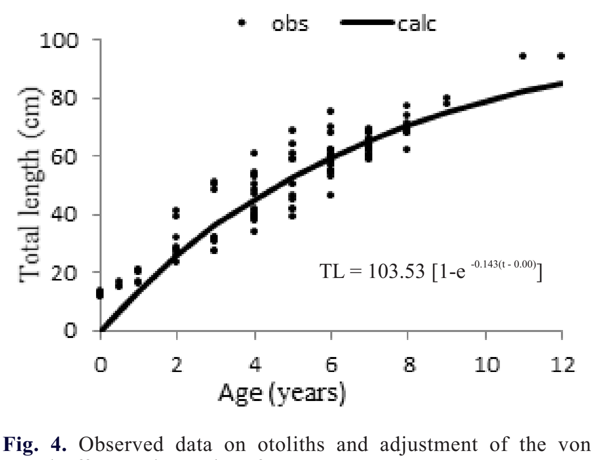

Fig. 4. Observed data on otoliths and adjustment of the von Bertalanffy'growth equation of *Centropomus nigrescens.*

Growth in weight.

The growth index value of the weight-length equation was positive allometric: b = 3.161 with total weight data and b = 3.15 with eviscerated specimens (Table 2).

Theoretical growth in weight.

Values of calculated Wt and We have a slow growth during the first year of age, starting at 16.74 g and 15.43 g (Table 4, Fig. 5). After age 2 there is a very fast growth rate. The calculated asymptotic total weight was Wt_∞ = 9 749 g and the eviscerated asymptotic weight We_∞ = 8 863 g.

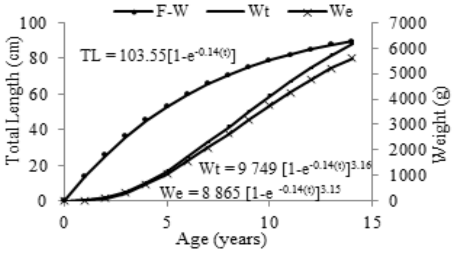

Fig. 5. Von Bertalanffy's growth curve in length and weight for *Centropomus nigrescens*: TL =total length, Wt = total weight, We = eviscerated weight.

Table 4. Values of total length (TL, cm), total (Wt, g) and eviscerated weight (We, g) for each age group (years) of *Centropomus nigrescens*.

age	TL (cm)	Wt (g)	We (g)
0	0.00	0.00	0.00
1	13.81	16.74	15.43
2	25.79	120.39	110.49
3	36.16	350.55	321.01
4	45.15	707.22	646.66
5	52.94	1,169.69	1,068.39
6	59.69	1,709.36	1,560.07
7	65.54	2,297.15	2,095.21
8	70.61	2,907.16	2,650.28
9	75.01	3,518.28	3,206.11
10	78.82	4,114.36	3,748.06
11	82.12	4,683.82	4,265.65
12	84.97	5,219.00	4,751.97
13	87.45	5,715.37	5,202.91
14	89.60	6,170.82	5,616.62

Longevity (Age $A_{0.95}$).

C. nigrescens reached 95% of its infinite length L in 21.4 years.

Reproduction

Gonads can be differentiated macroscopically, except for the virgin individuals who have never spawned and are just beginning their development. Fifty oocytes were measured and diameters were 0.33 mm minimum and maximum 0.39 mm. Fecundity values ranged from 21 771 288 to 40 075 427 with a mean of 29 072 680 oocytes in females of 89 cm to 101 cm. Relative fecundity was from minimum 2 273 to maximum 4 023.6 and an average of 3 081.7 oocytes per individuals Wt. The number of oocytes per gram of gonad was from 30 237.9 to 90 713.7, average 54 231.9. Sample size of sexed individuals was of 33 organisms of *C. nigrescens,* of which 20 (5.0%) were females, and 13 (3.2%) males, and 370 (91.8%) undetermined. The proportion of male: female was 1: 1.65.

Monthly variations of the relative frequency of gonad maturity showed that phase V or spawning stage was in females and males at 100% at June and July.

Length of first maturity was L_{25} = 59.00 cm for all the organisms, corresponding to a Wt = 1 661.7 g and an age of 6.89 years. First reproduction length was L_{50} =76.4 cm (4 216.0 g and 10.43 years) in females, and L_{50} = 59.0 cm (1 749.4 g and 6.89 years) in males.

The gonadosomatic index (GSI) reached its highest value in June. Other months that reached high values were July, September, October and December. GSI values decreased during the months of February, April, May and August (Table 5). The allometric relationship of the hepatosomatic index (HSI) obtained in the present study was LW = 0.00007 $TL^{2.95}$ (r^2 = 0.872). The allometric index *b* indicates that the liver weight (LW) increments in a lower proportion than cubic, in terms of its length, which results in a negative allometric growth of the fish, decreasing its fatty reserves as it ages. HSI variations are shown in Table 5, maximum values are observed in June, July, November, February, and April.

Variations in the gastric repletion index (GRI) (Table 5) show higher values during June, July, November, February and April. Table 5 shows the values of the condition factor; the higher values are obtained in the months of June, July, October and November for Fulton and Clark, and June with Safran's indexes.

Table 5. Monthly values of the relative condition factor by methods of Safran (1992), Fulton (1902) and Clark (1928), and the indexes of gonadosomatic, gastric repletion and hepatosomatic, for total (Wt) and eviscerated weight (We) of *Centropomus nigrescens.*

Month	Safran	Fulton	Clark	GSI-TW	GSI-EW	GRI-TW	GRI-EW	HSI-TW	HSI-EW
Jan	0.400	0.744	0.676			1.235	0.723	1.344	0.788
Feb	0.405	0.760	0.700	0.081	0.087	1.467	0.669	1.595	0.728
Mar	0.416	0.764	0.604	0.258	0.280	1.361	0.891	1.491	0.965
Apr	0.443	0.764	0.779	0.137	0.149	1.435	0.829	1.526	0.910
May	0.412	0.774	0.719	0.134	2.544	0.983	0.620	1.096	0.690
Jun	0.575	1.189	1.024	3.332	3.872	1.893	1.720	2.211	1.994
Jul	0.433	0.789	0.763	0.628	0.679	2.072	0.691	2.217	0.742
Aug	0.419	0.775	0.755	0.113	0.122	1.231	0.708	1.319	0.756
Sep	0.424	0.778	0.710	0.604	2.105	1.355	0.840	1.499	0.927
Oct	0.428	0.810	0.723	0.454	0.378	1.307	0.811	1.435	0.885
Nov	0.439	0.804	0.729			1.464	0.822	1.621	0.909
Dec	0.395	0.723	0.659	0.424	0.472	1.303	0.912	1.444	1.003

Table 6. Growth parameters of the von Bertalanffy equation for *Centropomus nigrescens* and other species of the same genera reported by different authors (ϕ' values were calculated by us).

	East Florida, USA[2]	West, Florida, USA	Barra Bosque, Tabasco, Gulf of México[3]	Barra San Pedro, Tabasco, Gulf of México[3]	San Pedro, Tabasco, Gulf of México [3]	Tres Brazos, Tabasco, Gulf of México[3]	Chiapas, Southern Mexican Pacific[1]	Jalisco and Colima,Central Mexican Pacific
species	*C. undecimalis*	*C. undecimalis*	*C. undecimalis*	*C. undecimalis*	*C. undecimalis*	*C. undecimalis*	*C. viridis*	*C. nigrescens*
L_∞	98.93	94.73	109.21	94.56	97.15	83.77	80	103.53
k	0.235	0.175	0.21	0.27	0.17	0.26	0.57	0.14
to	-0.0976	-1.352	0.57	0.48	1.32	0.49	-0.218	0
ϕ'	3.36	3.20	3.40	3.38	3.21	3.26	3.56	3.18
0	2.24	19.96	-13.89	-13.08	-24.44	-11.38	9.35	0.00
1	22.49	31.96	9.43	12.39	-5.43	10.40	40.04	13.53
2	38.50	42.04	28.33	31.83	10.61	27.20	57.40	25.28
3	51.16	50.50	43.65	46.67	24.14	40.15	67.22	35.51
4	61.16	57.60	56.07	58.00	35.55	50.14	72.77	44.39
5	69.07	63.56	66.13	66.65	45.18	57.84	75.91	52.12
6	75.32	68.56	74.29	73.26	53.31	63.78	77.69	58.84
7	80.27	72.77	80.91	78.30	60.16	68.35	78.69	64.67
8	84.18	76.29	86.27	82.15	65.94	71.88	79.26	69.75
9	87.27	79.25	90.61	85.08	70.82	74.60	79.58	74.16
10	89.71	81.74	94.14	87.33	74.94	76.70	79.76	78.00
11	91.64	83.82	96.99	89.04	78.41	78.32	79.87	81.34
12	93.17	85.57	99.31	90.34	81.34	79.57	79.92	84.23
13	94.37	87.04	101.18	91.34	83.81	80.53	79.96	86.76
14	95.33	88.28	102.70	92.10	85.90	81.27	79.98	88.95

Note: Parameters from: [1]Taylor *et al*. (2000), [2]Perera-García *et al*. (2013), [3]Labastida-Ché *et al*. (2013), [4]this study.

Discussion

Data of the relationships between length, height and weight (Table 2) show a higher tendency to positive allometry in females than males with exception of TL *vs* SL which is little higher in 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, except TL *vs* SL, which is barely higher in 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 females, 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* and *asterisci*, allowing the use of this structure to estimate the age of *C. nigrescens* 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, 2008b, 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 t_0, reducing it to 0.00. 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 present 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 by other authors (Table 6) it can be observed that there are no any studies on *C. nigrescens*, the comparisons presented below were made with *C. viridis* in the state of Chiapas, Pacific Ocean and *C. undecimalis* in Florida and Tabasco State in the Atlantic Ocean.

Labastida-Ché *et al*. (2013) found very high values of the catabolic index k = 0.57, probably because their study was carried out in the coastal lagoons where the snook or robalo organisms are mainly juvenile with an accelerated growth during their first development stages. Nevertheless they report a L_∞ = 80 .0 cm, similar to that reported by Perera-Garcia *et al*. (2013) in the area of Tres Brazas, Tabasco for *C. undecimalis*. Also, Labastida-Ché *et al.* (2013) study is based in length frequency analysis, which can be biased compared to that obtained with otoliths (Taylor *et al*. 2000).

The highest value of L_∞ obtained in *C. undecimales* by Perera-Garcia *et al*. (2013) in Barra Bosque was L_∞ = 109.21 cm. Values of L_∞ found in Barra de san Pedro and San Pablo L_∞ = 94.56 cm and L_∞ = 97.15 cm, respectively are similar to those found by Taylor *et al.* (2000) in the east coast of Florida, L_∞ = 98.93 and in the west coast of L_∞ = 94.73 cm. Values of the *k* index found in the west coast of Florida and the locality of San Pedro, Tabasco are the same k = 0.17. In our case we found a value of L_∞ = 103.53 cm, lower to that reported by García-Perera *et al*. (2013) in Barra Bosque and higher than the rest of the localities. The k index value found in this study k = 0.14 is the lowest reported for this genera. Nevertheless we can consider that our data are similar to those reported for *C. undecimalis*, which fall into a range where the ϕ' value falls into an intermediate position.

In relation to the period of the massive spawning, authors that have studied *C. undecimalis* report July as the month of more reproductive activity (Chávez 1963, Carvajal 1975, Caballero-Chávez 2011, Lorán-Nuñez *et al.* 2012, Perera-García *et al.* 2013). Taylor *et al.* (2000) reported the highest reproductive activity of *C. undecimalis* from September to November in the coasts of Florida. Chávez (1963), Fuentes (1973), Carvajal (1975) and Lorán-Núñez *et al*. (2012) also report July as the month of highest reproductive activity for *C. poeyi*.

During July the greatest activity of rainfall is carried out, which produces a migration of most organisms of *Centropomus* inside the coastal lagoon, as mature males to swim towards the ocean where they meet mature females (Lorán-Núñez *et al*., 2012), and reproduce. Sexual inversion can take place in males little after spawning (Taylor *et al*., 2000).

According to authors that have studied *C. undecimalis*, sex proportion is males: females 2.3:11 (Caballero-Chávez 2011); Perera-García *et al*. (2013) found 1: 0.68 in the coast of the Gulf of Mexico and 1: 0.16 in the lagoons; Taylor *et al.* (2000) found 1.6: 1.0. In all cases males are more abundant than females. Nevertheless, in our case, we found a higher proportion of females (1:1.65), but even more immature.

Caballero-Chávez (2011) reported a first mature length of 82.6 cm in females and 76.1 in males; Perera-García *et al.* (2013) reported a length of 60.0 cm in females and 80.0 cm in males, with an age of 5.5 and 8.5 years, respectively. Lorán-Núñez *et al*. (2012) found a first mature length of 81.6 cm. In relation to fecundity, Caballero-Chávez (2011) reported between 549 208 and 10 467 556 oocytes in *C. undecimalis*, a very lower number than what we found, of 22 to 40 million oocytes in *C. nigrescens*.

Conclusions

- The maximum value of TL was 101.0 cm and the minimum was 11.1 cm, total weight varied from 5.26 g to 9 810.00 g.
- Each year a fast and a slow growth band are deposited on the *sagittae* and *asterisci* of *C. nigrescens*, equivalent to one year of age.
- The growth index value of the weight-length equation was positive allometric: b = 3.161 with total weight data and b =3.154 with eviscerated specimens.
- Growth parameters obtained by Ford-Walford-Gulland method for TL were: L_∞= 103.55 cm, k = 0.14 years^{-1}, and t_o= 0.00. Growth parameters obtained by Solver iteration process were L_∞ = 103.53 cm, k= 0.143 years^{-1}, t_o= 0.00.
- The calculated asymptotic total weight was Wt_∞= 9 749 g and the eviscerated asymptotic weight We_∞ = 8 863 g.
- Longevity value was 21.4 years.
- The proportion of male: female was 1: 1.65.
- Length of first maturity was L_{25} = 59.00 cm in females and males corresponding an age of 6.89 years.
- First reproduction length was L_{50} =76.4 cm in females and L_{50} = 59.0 cm in males corresponding to an age of 10.43 years and 6.89 years, respectively.
- The allometric relationship of the hepatosomatic index (HSI) obtained in the present study was LW = 0.00007 $TL^{2.95}$ (r^2= 0.872). Maximum values were observed in June, July, November, February and April.
- Spawning season was observed in females and males in June and July.
- The gonadosomatic index (GSI) reached its highest value during June.
- The gastric repletion index (GRI) showed higher values during June, July, November, February and April. The higher values of the condition factor were obtained in June, July, October and November.
- Oocyte diameter was 0.33 mm, minimum 0.33 mm and maximum 0.39 mm.
- Fecundity values ranged from 21 771 288 to 40 075 427 with a mean of 29 072 680. oocytes in females of 89 cm to 101 cm. Minimum relative fecundity was of 2 273 oocytes per gonad gram, maximum 4 023.6, and an average of 3 081.7 oocytes per gonad gram. Oocytes per organism gram was of minimum 30 237.9, maximum 90 713.7, and average 54 231.9.

Recommendations

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

It is important not to fish these organisms inside the coastal lagoons where the juveniles and smaller organisms are found, to prevent their capture, but adults that have reproduced at least once.

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. nigrescens*; the disappearance and/or contamination of mangroves elevates the natural mortality indexes of a great number of marine organisms.

Studies on *C. nigrescens*' reproduction should expand by histologic analysis of gonads, which will allow us to continue with the knowledge we have about oogenesis and spermatogenesis of this species. Also reach a better understanding of the sexual inversion phenomena, and obtain a higher number of data on fecundity of this species.

References

1. Allen GR, Robertson DR. (1994). Peces del Pacífico Oriental Tropical. CONABIO, Agrupación Sierra Madre y CEMEX, 327 pp.
2. Blacker RW. (1974). Recent advances in otolith studies. In: Harden-Jones E (ed). Sea Fisheries Research. pp. 67-90. Elek Science, London.
3. Caballero-Chávez V. (2011). Reproducción y fecundidad de robalo blanco (Centropomus undecimalis) en el suroeste de Campeche. Ciencia Pesquera 19(1): 35-44.
4. Carvajal RJ. (1975). Contribución al conocimiento de la biología de los robalos Centropomus undecimalis y C. poeyi en la Laguna de Términos, Campeche, México. Bol. Inst. Oceanogr. Univ. Oriente 14(1): 51-70.
5. Castro-Aguirre JL. (1978). Catálogo sistemático de los peces marinos que penetran a las aguas continentales de México, con aspectos zoogeográficos y ecológicos. Depto. Pesca. INP. Serie Científica 19., 298p.
6. 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.
7. Clark F. (1928). The weight-length relationship of the Californian sardine (Sardina coerulea) at San Pedro. Fish. Bull. U.S. 12: 22-44.
8. 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.
9. Espino-Barr E, González Vega A, Santana Hernández H, González Vega H. (2008a). Manual de biología pesquera. Universidad Autónoma de Nayarit, ISBN 968-833-076-0, 168p.
10. Espino-Barr E, Gallardo-Cabello M, Cabral Solís EG, Garcia-Boa A, Puente-Gómez M. (2008b). Growth of the Pacific jack Caranx caninus (Pisces: Carangidae) from the coast of Colima, México. Rev. Biol. Trop. 56(1): 171-179.
11. Espino-Barr E, Gallardo-Cabello M, Granados-Flores K, Cabral-Solís EG, Garcia-Boa A, Puente-Gómez M. (2010). Growth analysis Microlepidotus brevipinnis (Steindachner 1869) (Pisces: Haemulidae) from the coast of Jalisco, México. Journal of Fisheries and Aquatic Science 5(4): 293-303.
12. Espino-Barr E, Gallardo-Cabello M, Garcia-Boa A, Puente-Gómez M. (2015). Growth analysis of Mugil cephalus (Percoidei: Mugilidae) in Mexican Central Pacific. Global Journal of Fisheries and Aquaculture. Science Research Journals 3(6): 238-246.
13. Espino-Barr E, Gallardo-Cabello M, Puente-Gómez M, Garcia-Boa A. (2016). Growth of the Bigeye Scad Selar crumenophthalmus (Teleostei: Carangidae) in Manzanillo Bay, Mexican Central Pacific. J Mar Biol Oceanogr 5:3. doi: 10.4172/2324-8661.1000160
14. Fischer W, Krupp F, Schneides W, Sommer C, Carpenter KE, Niem UH (ed.). (1995). Guía FAO para la identificación de especies para los fines de la pesca. Pacífico Centro Oriental. Vertebrados Vols. II y III, Roma, FAO, pp 644-1813.
15. Ford E. (1933). An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. Journal of the Marine Biological Association of the United Kingdom 19: 305-384.
16. Fuentes CDF. (1973). Contribución al conocimiento de la biología del robalo prieto (Pisces, Centropomus poeyi Chávez) en el parea de Alvarado, Veracruz, México. Rev. Soc. Mex. Hist. Nat. 34: 369-421.
17. Fulton T. (1902). Rates of growth of sea-fishes. Sci. Invest Fish. Div. Scot. Rept.21-3720.
18. Gallardo-Cabello M, Espino-Barr E, 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 caballus (Pisces: Carangidae) in the coast of Colima, Mexico. International Journal of Zoological Research 2(1): 34-47.
19. Gallardo-Cabello M, Espino-Barr E, Garcia-Boa A, Cabral-Solís EG, Puente-Gómez M. (2007). Study of the growth of the green jack Caranx caballus Günther 1868, in the coast of Colima, México. Journal of Fisheries and Aquatic Science 2(2): 131-139.
20. 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. DOI: 10.3923/jfas.2011.390.403.
21. Gallardo-Cabello M, Espino-Barr E, Puente-Gómez M, Garcia-Boa A. (2017). Age analysis of Centropomus nigrescens by otoliths sagitta, asteriscus and lapillus in Mexican Central Pacific. International Journal of Development Research 7(11): 6499-16507.
22. Gulland JA. (1964). Manual of methods of fish population analysis. FAO Fisheries Technical Paper, 40: 1-60.
23. Holden MJ, Raitt DFS. (1975). Manual de Ciencia Pesquera. Parte 2.- Métodos para investigar los recursos y su aplicación. ONU/FAO. Doc. Tec. sobre pesca, No. 115. rev. 1. 207p.
24. 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.
25. Lorán-Nuñez RM, Martínez-Isunza FR, Valdez-Guzmán AJ, Garduño-Dionate M, Martínez-Lorán ER. 2012. Reproducción y madurez sexual de robalo prieto (Centropomus poeyi) y robalo blanco (C. undecimalis) en el Sistema Lagunar de Alvarado, Veracruz (2005-2007). Ciencia Pesquera 20(1): 49-64.
26. Microsoft. (1992). Manual de usuario. Referencia de funciones. Microsoft Excel Versión 4.0 para Windows, 702 pp. Microsoft Corporation USA, Redmond.
27. Miller RR, Minckley WL, Norris SM, Hall Gach M, Schmitter-Soto JJ. 2009. Peces dulceacuícolas de México. CONABIO, México. 559 p.
28. 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 acuacultural acerca de los robalos del género Centropomus en México. Programa de Evaluación de Recursos Naturales del Centro de Inbestigaciones Biológicas del Noroeste, SC. 51 p.
29. Nava-Ortega RA, Espino-Barr E, Gallardo-Cabello M, Garcia-Boa A, Puente-Gómez M, Cabral-Solís EG. (2012). Growth analysis of the Pacific sierra Scomberomorus sierra in Colima, México. Revista de Biología Marina y Oceanografía 47(2): 273-281.
30. Nelson JS, Crossman EJ, Espinosa-Pérez H, Findley LT, Gilbert CR, Lea RN, Williams JD. (2004). Common and scientific names of fishes from the United States, Canada and Mexico. 6th edition. American Fisheries Society. Special Publication 29
31. Pauly D. (1979). Theory and management of tropical multispecies stocks: a review with emphasis on the Southeast Asian demersal fisheries. ICLARM Studies Reviews 1: 1-35.
32. 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.
33. Rodríguez-Gutiérrez M. (1992). Técnicas de evaluación cuantitativa de la madurez gonádica en peces. AGT Ed., 79 p.
34. Safran P. 1992. Theoretical analysis of the weight-length relationship in fish juveniles. Mar. Biol. 112: 545-551.
35. Simpson AC. (1951). The fecundity of the plaice. Fishery Investigations, London, Serie 2, 18(5): 1-27.
36. Sparre P, Venema SC. (1995). Introducción a la evaluación de recursos pesqueros tropicales. Parte 1 - Manual. FAO Doc. Tec. de Pesca 306/1, Roma, 420 p.
37. Taylor CC. (1958). Cod growth and temperature. J. Conseil 23(3): 366-370.
38. Taylor CC. (1960). Temperature, growth and mortality – the Pacific cockle. J. Conseil 26(1): 117-124.
39. 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.
40. von Bertalanffy L. (1938). A quantitative theory of organic growth (inquiries on growth laws). Human Biology 10(2): 181-213.
41. Walford LA. (1946). A new graphic method of describing the growth of animals. The Biological Bulletin 90(2): 141-147.
42. Zar JH. (1996). Biostatistical analysis. 3rd ed. Prentice Hall. USA. 662 p.