Length-weight relationship and condition factor of *Centropomus viridis* (Actinopterygii: Perciforms: *Centropomidae*) in the north coast of Nayarit

Relación longitud-peso y factor de condición de *Centropomus viridis* (Actinopterygii: Perciforms: *Centropomidae*) en la costa norte de Nayarit

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Abstract

This study poses two objectives: to determine whether the growth of females and males of the *C. viridis* is isometric, and whether the commercial fishing changes the condition of snook. The information regarding the length-weight relationship (LWR) is basic for the development of management strategies and conservation of the white snook. The length-weight relationship condition analysis is presented for the snook *C. viridis* fishery in the north coast of Nayarit. A non-experimental, longitudinal aleatory study was performed. Data was obtained during a six-year period (2010-2015). The weight, total length and sex of 2542 organisms were recorded. The LWR of males from 2010 to 2015 indicated negative allometric growth ($p < 0.05$), while the females indicated positive allometric growth ($p < 0.05$). However, the overall analysis LWR for males and females in the whole sampling period (2010-2015) showed negative allometric: b = 2.958 ($p < 0.05$) and r2 = 0.948. Regarding the analysis of condition, results indicated a value of $Kn \geq 1$ in males; females presented a condition lower than 1, which indicated sex-change from male to female. In response to the fishing pressure, the *C. viridis* has readjusted year after year the minimum size of sex switching, generating slight variations of Kn in females of the *C. viridis* in the studied area.

Keywords: White snook, Length-Weight Relationship, allometric growth, *Centropomus viridis*, San Blas, Nayarit.

Resumen

Este estudio plantea dos objetivos: determinar si el crecimiento de hembras y machos de *Centropomus viridis* es isométrico, y si la pesca comercial cambia la condición del róbalo garabato. La información sobre la relación talla-peso (RTP) es básica para el desarrollo de estrategias de manejo y conservación del róbalo. El análisis de relación talla-peso y condición se presenta para la pesquería del robalo *C. viridis* en la costa norte de Nayarit. Se realizó un estudio aleatorio longitudinal no experimental. Los datos se obtuvieron durante un período de seis años (2010-2015). Se registró la talla el peso y el sexo de 2542 organismos. La RTP de los machos de 2010 a 2015 indicó un crecimiento alométrico negativo (p <0.05), mientras que las hembras indicaron un crecimiento alométrico positivo (p <0.05). Sin embargo, el análisis global LWR para machos y hembras en todo el período de muestreo (2010-2015) mostró alometría negativa: b = 2.958 (p <0.05) y r2 = 0.948. Con respecto al análisis de la condición, los resultados indicaron un valor de Kn ≥ 1 en machos; las hembras presentaron una condición inferior a 1, lo que indicaba que el cambio de sexo de hombre a mujer. En respuesta a la presión de pesca, *C. viridis* se ha reajustado año tras año el tamaño mínimo de cambio de sexo, generando ligeras variaciones en Kn de hembras de *C. viridis* en el área estudiada.

Palabras clave : Robalo garabato, Relación Talla Peso, Crecimiento Alometrico, Centropomus viridis, San Blas, Nayarit.

Introduction

In the Mexican Pacific Coast, the family *Centropomidae* is represented by six species of the genus *Centropomus*, locally known as snook (Rivas, 1986). The fishery for this species constitutes one of the most important economic activities of subsistence in the area (Espino, Cruz & Garcia, 2003). The snook fishery in the north coast of Nayarit mainly includes *C. nigrescens*, *C. medius*, *C. robalito* and *C. viridis*; the latter is the most abundant and with the highest commercial value in local and international markets (Labastida-Che, Núñez-Orozco & Oviedo-Piamonte, 2013; Ulloa-Ramírez *et al.*, 2008); despite this, there is a lack of studies containing biological and ecological information for the *Centropomidae* species within the area. Studies concerning the length-weight relationship (LWR) of fish are needed for the evaluation and conservation of the species. Also, this analysis provides information to determine and compare the growth patterns found by sex, season or region (Froese, Tsikliras & Stergiou, 2011; Gaspar, Tobes, Miranda, Leunda & Peláez, 2012). In this study, the LWR and condition factor analyses are presented for *C. viridis* and the snook fishery estuaries of the National Wetlands belonging to the Biosphere Reserve, Nayarit.

Material and Methods

A non-experimental, longitudinal aleatory study was performed. The biological material was evaluated monthly from February 2010 to July, 2015. The material was collected from artisanal and demersal fisheries in the estuaries in the north coast of Nayarit, Boca del Asadero, Nayarit (21° 38' 29.44" N and 105° 25' 38.34" W).
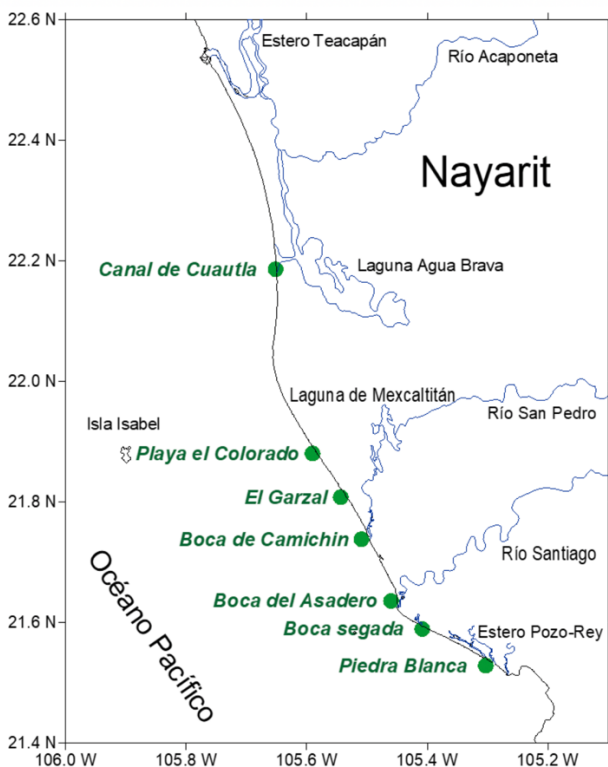

Figure 1. Typical sites of commercial fishing for snook on the north coast of Nayarit.
Source: Authors' own elaboration.

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Sampling was made using commercial gillnets with mesh sizes of 12.7 cm, 15.24 cm and 20.32 cm, and lengths ranging from 1 km to 1.5 km. Nets were used during 12-hour periods (from 16:00 to 04:00) at 13 m and 22 m depth. Total weight (W) from each sampled specimen was obtained to the nearest ± 0.01 g by using a digital balance. Total length (TL) and standard length (SL) were measured using an ichthyometer (± 0.1 mm). Sex was detected by direct gonad observation.

The LWR was determined with the following equation: $W = {_a}L^b$, where W is the total weight, L is the total length (Froese & Pauly, 2000; Le Cren, 1951), a is the interception of logarithm, known as the condition factor of fish, and b is the regression slope, which represents the type of growth. If $b = 3$, then the growth is considered isometric, and when $b \neq 3$, it is considered allometric (Ricker, 1975). This can be negative ($b < 3$) when fish grow more in length, or positive ($b > 3$) when fish grow more in weight (Froese, 2006). To estimate parameter a and b, a timeline of the potential model on aggregate error was considered ($\log_e (w_i) = \log_e (a) + b \log_e (L_i) + e_i$) to stabilize the linearized variables and obtain a better model fit (Ogle, 2013).

A t-Student test was used (IC of 95%) to infer the type of growth by the b parameter (Sokal & Rohlf, 1995). Analyses were performed using R programming language with the statistical routines described by Ogle (2013). The calculation of K is made from the relationship between the weight of the fish and its size, with the intention of describing the condition of each species. The equation that describes this relationship is: $K = 100 * W/L^b$, where K is the condition factor of the fish, W is the weight in grams, L is the size of the fish in mm, b is the value of the isometry ($b = 3$) and 100 is a constant that approaches the value of K to unity; this factor of condition is used in fish that have an isometric growth (Froese 2006; Le Cren, 1951). The relative condition factor was calculated for the species that presented growth of allometric type. Le Cren (1951) proposed this calculated index through the following equation: $Kn = W/a * L^b$. The results of the analysis of the weight relationship of *C. viridis* show an allometric growth, as recommended by Le Cren (1951) and Froese (2006). The relative condition analysis. $Kn = W/a * L^b$ (Le Cren, 1951), it was estimated on a spreadshet.

Results

A total of 2542 organisms were analyzed. The sexual proportion (M:F) was 5.51:1, and the total length varied from 230 mm to 1310 mm (82.13 mm $\pm$ 137.9 mm) (table 1). The male capture registered in the commercial fishing of the snook (*C. viridis*) from 2010 to 2015 in the coast of Nayarit was much higher than in females; the minimum size of registered females in 2010 was 880 mm, and in 2015 it was 670 mm length.

In table 1, the LWR was analyzed in the male population with a value of $b \leq 3$ and indicated a negative allometric growth ($p < 0.05$). And the LWR value ($b \geq 3$) in females indicated a positive allometric growth ($p < 0.05$). However, the overall analysis of the LWR for males and females in the whole sampling period (2010-2015) determined a negative allometric growth: $b = 2.958$ ($p < 0.05$) and $r^2 = 0.948$.

Table 1. The length-weight relationship parameters of *Centropomus viridis* in the north coast of Nayarit.

Year	Sex	N	Total length [mm] Range	Total length [mm] Mean ± SD	Total weight [g] Range	Total weight [g] Mean ± SD	a	SE of a	b	SE of b	r²	t-test	C.F. Kn	A
2010	F	61	880-1310	1066 ± 84.7	6200-16000	10490 ± 1900	0.000671	0.0002221	2.073	0.071	0.935	*	0.95	-
2010	M	218	230-970	696 ± 154.7	400-6500	2950 ± 1640	0.000028	0.000004	2.697	0.039	0.957	*	1	-
2011	F	114	780-1310	1026 ± 104.9	3300-11000	7320 ± 3080	0.000009	0.000003	2.99	0.086	0.911	*	1	-
2011	M	783	230-1020	787 ± 118	800-4260	4267 ± 1122	0.000021	0.000002	2.764	0.022	0.953	*	1.01	-
2012	F	101	770-1270	989 ± 102.4	4000-23500	8010 ± 2640	0.000011	0.0000049	2.925	0.096	0.903	*	1.01	-
2012	M	694	440-940	815 ± 73.3	700-6800	4000 ± 1062	0.000007	0.000001	3.01	0.032	0.927	*	1.04	+
2013	F	27	720-1190	981 ± 112.4	2400-14500	7570 ± 2980	0.000002	0.0000015	3.331	0.196	0.92	*	0.82	+
2013	M	131	330-940	796 ± 112.1	200-6200	3620 ± 1280	0.000002	0.0000005	3.27	0.051	0.97	*	1.04	+
2014	F	32	810-1220	1013.7 ± 110.1	4000-16000	9187 ± 3321	0.000003	0.0000018	3.246	0.146	0.941	*	1.07	+
2014	M	105	460-970	722 ± 132.5	620-6000	3131 ± 1540	0.000011	0.0000048	2.904	0.192	0.944	*	1.02	-
2015	F	46	670-1200	946.6 ± 106.7	2800-12000	6423 ± 1863	0.000064	0.0000349	2.525	0.12	0.907	*	0.96	-
2015	M	230	490-990	825 ± 942	800-6800	4224 ± 1154	0.000047	0.0000123	2.578	0.06	0.891	*	1	-
10~15	F	381	670-1310	1002.6 ± 109.4	2400-21000	8.676 ± 3.066	0.000005	0.0000011	3.112	0.048	0.904	*	0.98	+
10~15	M	2161	230-1020	788.4 ± 115.1	200-7000	3.878 ± 1.372	0.000018	0.0000011	2.804	0.014	0.941	*	1.02	-
10~15	A	2542	230-1310	821.3 ± 137.9	200-21000	4.615 ± 2.456	0.000009	0.0000005	2.958	0.013	0.948	*	1.03	-

Source: Authors' own elaboration.
N = Sample size; a = Proportionality coefficients (intercept); SE of Standard error a = Confidence limits for a; b = Allometry coefficient (slope); SE of b = Standard error for b; r² = Coefficient of determination and t-tester (*) = $p < 0.05$.

The relative condition factor (Kn) covering both sexes was ≥ 1, and the males presented a $Kn \geq 1$, while the analysis for the female population indicated a $Kn \leq 1$, respectively.

Discussion

In the six years of sampling, the size of the females of *C. viridis* 21 cm. The plasticity of the hermaphroditism, sequential protandric that the snook present sex-changing from male to female (Álvarez-Lajonchère & Tsuzuki, 2008; Molloy, Goodwin, Côté, Gage & Reynolds, 2007; Taylor, Whittington, Grier & Crabtree, 2000;). Has permitted the snook *C. viridis* the minimum size of females on average 35 mm per year. the minimum size of women in 2010 was 880 mm, and by 2015 the minimum size was 670 mm. As an adaptation adjustment strategy to balance the proportion M/F. In accordance to Birkeland & Dayton (2005); Munday, Buston & Warner (2006); Molloy *et al.* (2007); Chiba, Yoshino, Kanaiwa, Kawajiri & Goshima (2012) and Benvenuto, Coscia, Chopelet, Sala-Bozano & Mariani (2017),predicts that plasticity does not act as a buffer against the evolutionary pressure of selective fishing. optimal age (size) at sex-change is attained when the average of males and females becomes equal. Despite the fact that *C. viridis* has reduced the minimum size of sex change, it has not been able to reach the optimum size of sex change, which balances the M: F ratio. predict that plasticity of the sex-change in the hermaphrodical species does not act as a buffer to the evolutional pressure in the selective fishing even though the readjustment of the first size from the sex-change has not been able to make the *C. viridis* balance the proportion of sexes.

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In this research, a maximum length of 131 cm for *C. viridis* was recorded, which is 11 cm longer than the previous length reported for this species (Robertson & Allen, 2008). The type of growth has not varied in accordance to the year of sampling and sex, presenting both positive and negative allometric growth. Previous studies based on the standard length (sizes < 94 cm) mention that the growth for *C. viridis* is isometric (Labastida-Che *et al.*, 2013). An allometric growth has been reported for other species of snook in the Mexican Pacific, such as *C. robalito* (Nieto-Navarro, Zetina-Rejon & Arreguin-Sanchez, 2010) and *C. nigrescens* (Sandoval-Huerta, Madrigal-Guridi, Domínguez-Domínguez, Ruiz-Campos & Gonzalez-Acosta, 2015), and in the Mexican Atlantic for *C. Parallelus* (Zarza, Berruecos, Vásquez & Álvarez, 2006), *C. pectinatus* (Benavides & Brenes-Rodríguez, 2010), *C. undecimalis* and *C. ensiferus* (Gassman, López & Padrón, 2017). The latter resulted similar to this study, where males presented negative and females positive allometry.

The snooks are estuarine-dependent, which is why it is not possible finding them in the surroundings of islands or fishing them ordinarily in the open sea (Camacho & Gadea, 2005). However, the snook are mixohaline species that migrate from salty marine environments to other water masses presenting lower salinity concentrations during their ontogenetic development (Castro-Aguirre, 1999); the type of growth of the individuals analyzed herein could have been affected by reproductive migrations and size structure. Results from an experimental culture of *C. parallelus* and *C. undecimalis* at different salinity concentrations (0 ups, 15 ups, 25 ups and 35 ups) indicated that, in freshwater conditions, isometric growth was obtained for both species, while allometric growth was reached as the salinity concentration increased (Zarza *et al.*, 2006). Chaves & Bortolan (2013) determined that in cultured *C. parallelus* females presented positive allometric growth at salinities of 35 ups, whereas males showed negative allometric growth in salinity conditions of 0 ups.

Regarding the condition factor, Le Cren (1951) noted that values of *Kn* < 1 indicate that the environment is not suitable for growth or that the population can easily be affected by external factors such as overfishing. The condition factor in the overall analysis for females was 0.98 < 1, this may indicate that a fishing effort could be generating slight variations, changing the condition of the *C. viridis* population in the studied area.

Conclusion

It is probable that the male population of *C. viridis* remained in estuarine areas until the first sexual maturity, reaching the neritic zone in the reproductive period and prevailing in the marine environment after becoming female, this would explain the negative allometric growth in males, contrary to the one found in females.

In conclusion, the sex change of the withe snook works as a bio-indicator of the stress generated by the fishing effort in the sexual proportion, it is probable that the high indexes of mortality by the selective fishing not premeditated of males has induced alterations in the proportion M:F. The could affect the reproductive natural process and sex-change from male to female of the snook. In response to the fishing pressure the *C. viridis* has readjusted year after year the minimum size of sex switching, generating slight variations of Kn in females of the *C. viridis* in the studied area.

Facing a reality that implies a limited knowledge of the biological-reproductive aspects, fishing and ecologic of the *C. viridis* in the north coast of Nayarit. It is highly recommended to evaluate the population dynamics, age and growth, sex-change and the selectivity of the fishing arts. This is meant to establish

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mechanisms that could allow the development of a sustainable management plan and the conservation of *C. viridis* and species associated to fishery of snook in the mexican Pacific.

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