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Reproductive condition of *Centropomus robalito* (Perciformes: Centropomidae) in the coastal lagoon of Chautengo, Guerrero, Mexico

Condición reproductiva de *Centropomus robalito* (Perciformes: Centropomidae) en la laguna costera de Chautengo, Guerrero, México

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ABSTRACT

It is important to know the reproductive characteristics of the organisms that are captured for commercialization, *Centropomus robalito*, it is an important coastal species that is commercialized throughout the Mexican Pacific. The objective of this study is to determine some reproductive characteristics of the species, describe the length distribution, know the sexual ratio, and provide information on gonadal development, through microscopic analysis. The organisms were obtained each month from the commercial fishing that takes place in the Chautengo lagoon, Guerrero. The fish were measured, weighed, and the gonads and liver were removed and weighed. The gonads were preserved in neutral formalin and processed for histological analysis to identify the degree of gonadal maturity and sex. 330 organisms were sampled, which presented an average total length of 19.7 cm (± 0.09) and an average total weight of 75.3 g (± 0.79). A greater number of females (61.2 %) were captured than males (38.8 %). The best represented stage of maturity in both sexes was immature. Oocytes has asynchronously development and the cell arrangement in the testis is lobular. A reproductive period of the species was not identified, since the values of the gonadosomatic index and the stages of gonadal maturation did not present a clear trend and significant variation in the sampling year. The growth of the organisms was negative allometric. It is concluded that the commercial capture is directed mainly to immature fish, this does not allow future reproduction; and may also indicate that *C. robalito* is being overexploited

KEY WORDS: Commercial fishing, Asynchronous development, Youths, Gonadal histology, Coastal lagoon.

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RESUMEN

Es importante conocer las características reproductivas de los organismos que son capturados para la comercialización, *Centropomus robalito*, es una especie costera de importancia que se comercializa a lo largo del Pacífico mexicano. El presente estudio tuvo como objetivo determinar algunas características reproductivas de la especie, describir la distribución de la longitud, conocer la proporción sexual, y aportar información sobre el desarrollo gonádico, mediante el análisis microscópico. Los organismos se obtuvieron cada mes de la pesca comercial que se realiza en la laguna de Chautengo, Guerrero. Los peces se midieron, pesaron y se les extrajeron las gónadas y el hígado, los cuales se pesaron. Las gónadas se conservaron en formol neutro y se procesaron para un análisis histológico, e identificar el grado de madurez gonadal y el sexo. Se muestrearon 330 organismos, los cuales presentaron longitud total promedio de 19.7 cm (± 0.09) y peso total promedio de 75.3 g (± 0.79). Se capturó una mayor cantidad de hembras (61.2 %) que de machos (38.8 %). El estadio de madurez mejor representado en ambos sexos fue el inmaduro. Los ovocitos se desarrollan de manera asincrónica y el arreglo celular en el testículo es lobular. No se identificó un periodo reproductivo de la especie, ya que los valores del índice gonadosomático y los estadios de maduración gonadal no presentaron una clara tendencia y variación significativa en el año de muestreo. El crecimiento de los organismos fue alométrico negativo. Se concluye que la captura comercial se dirige principalmente a peces inmaduros, esto no permite la reproducción a futuro; y puede indicar también que *C. robalito* está siendo sobreexplotado.

PALABRAS CLAVE: Pesca comercial, Desarrollo asincrónico, Juveniles, Histología gonadal, Laguna costera.

Introduction

Fish reproduction is a process of great interest, from a basic point of view as well as an application for fisheries biology studies (Gassman *et al*., 2017). Among the most important fishery resources in the Mexican Pacific are snooks (*Centropomus* spp.), due to their size and weight, which make them a high-quality resource (Espino-Barr *et al.,* 2003; 2004; Granados, 2018). In the Pacific states of Nayarit, Sinaloa, and Guerrero, reports indicate a snook production ranging from 100 to 2,450 tons from 2012 to 2021 (CONAPESCA, 2021).

Among the general aspects known about the species of the Centropomidae family is that they are euryhaline fish and can be found in salt, brackish, or freshwater, depending on the season and fish age (Alvarez-Lajonchere & Tsuzuki, 2008). They are considered multiple spawners (iteroparous), as females may release their oocytes several times during summer (Chapman *et al*., 1982), and also since the ovaries contain three or more different groups of oocytes (Peters *et al*., 1998). Snooks are diadromous species, requiring seawater for final maturation and spawning, as well as for embryonic development and early larval stages (Alvarez-Lanjochere & Tsuzuki, 2008). Juvenile snook populations are generally more abundant in coastal lagoons and canals, with moderate slope shores and depths of 1 m or less; compared to other areas with steeper slopes. This is because these sites provide suitable habitat, even at low tide (Peters *et al*., 1998).

One of the most studied Centropomidae species is *C. undecimalis*, which inhabits the Atlantic and Mexican Gulf. In Tabasco state, for this species, the sex ratio has been reported, with males being more abundant, and both sexes exhibiting isometric growth. Males reach sexual maturity earlier than females (Perera-García *et al.,* 2008; 2011).

In the Grijalva-Usumacinta river system in Tabasco, it has been observed that in *C. undecimalis*, juveniles are captured in freshwater environments, while adults spawn in marine environments. Both sexes can inhabit both environments, although individuals that mature in freshwater environments migrate to the sea during the spawning season (Hernández-Vidal *et al.,* 2014).

In southeastern Campeche, *C. undecimalis* also recorded a greater number of males than females, and males also matured earlier than females (Cabello-Chávez, 2011). In the Alvarado Lagoon System, Veracruz state, the reproductive period and length of maturity of *C. undecimalis* and *C. poeyi* females were studied, and a correlation was found between rainfall and the reproductive period only in *C. poeyi* (Lorán-Nuñez *et al*., 2012).

In Venezuela, with regard to *C. undecimalis* and *C. ensiferus*, some reproductive aspects were studied, such as the sex ratio, which varied throughout the sampling year. Males dominated at shorter lengths, while females dominated at longer lengths, suggesting a typical pattern in populations with sequential hermaphroditism. In both species, males matured earlier than females (Gassman *et al.,* 2017). In the case of the Pacific coast of Mexico, specifically in Manzanillo Bay, Colima, it was found that in *C. nigrescens*, females were more abundant than males, and both sexes reached sexual maturity at the same length (Espino-Barr *et al.,* 2017).

Populations of *Centropomus robalito* (Jordan & Gilbert, 1882) are generally more abundant in estuaries and coastal lagoons, where they are considered commercially important (Gallardo-Cabello *et al*., 2018; González-Sansón *et al*., 2014; Violante-González *et al.,* 2011). For *C. robalito* only studies on feeding habits (Flores-Ortega *et al*., 2015; Moreno-Sánchez *et al*., 2015), growth and age (Espino-Barr *et al*., 2019a; Gallardo-Cabello *et al*., 2018; Martínez-Madrigal, 2021), parasite communities (Violante-González *et al*., 2011), otolith description (Espino-Barr *et al*., 2019a; Granados-Amores *et al*., 2020) and some reproductive aspects (Espino-Barr *et al*., 2019b). This work aims to analyze basic aspects of the length structure and some reproductive characteristics of *C. robalito*, which inhabits the Chautengo Lagoon, Guerrero state.

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Material and Methods

The study was conducted in Chautengo Lagoon (16° 35' 13" N to 16° 38' 46" N and 99° 01' 48" W to 99° 10' 48" W), located in Guerrero state. It is a shallow body of water with a maximum depth of 1.9 meters and a surface area of 36 km^2. It receives freshwater input from the Nexpa and Copala rivers and some seasonal streams. The lagoon connects to the sea through a narrow inlet (100 to 200 meters wide) located in the central part of a sandbar, which undergoes a natural process of opening and closing. Typically, the inlet remains open from June to January (the beginning of the rainy season) (Bulit & Díaz-Ávalos, 2009) (Fig. 1).

Analyzed fish were obtained from artisanal fishing, carried out in the first days of the month from January to December 2019. They were captured with gill nets and cast nets with a mesh size of 25, 30, and 40 mm and transferred in coolers to the laboratory of the Facultad de Ecología Marina (UAGro), where the total length (TL, cm), total weight (TW, g), gonads (GW), and liver (LW) were extracted. The gonads were preserved in 10% neutral formalin for several days, rinsed to remove excess formalin, and preserved in 70% alcohol. Subsequently, they were transported to the histology laboratory at DEDSZC, University of Guadalajara, on the south coast of Jalisco. The histological processing involved tissue dehydration with ethyl alcohol, embedding in paraplast, obtaining 5 µm sections, staining with hematoxylin-eosin dyes, and preserving with Canada balsam. They were observed using a microscope (Axiostar, Zeiss) to determine the sex and maturity stage. The diameter of 30 oocytes (µm) from each of the phases found was measured using the Axiovision program (Zeiss). Oocytes were classified based on Lucano-Ramírez *et al*. (2001) and Brown-Peterson *et al*. (2011), while Uribe *et al*. (2014) criteria were considered for the tests.

Sex ratios were calculated for all organisms, monthly and by length class. To determine if there was a deviation from the 1:1 ratio, the Chi-square test (χ^2) was used (Zar, 2010).

The gonadosomatic index was calculated $\left(GSI = \frac{Gw}{TW} \, x \, 100 \; Equation \; 1\right)$, the relative condition factor $\left(CF = \frac{TW}{TL^b} \, x \, 100 \; Equation \; 2\right)$, the hepatosomatic index $\left(HSI = \frac{LW}{TW} \, x \, 100 \; Equation \; 3\right)$, and the length-weight ratio $(W = aL^b \; Equation \; 4)$. The value of b was compared between sexes using Student's t-test (Zar, 2010). Monthly values of temperature and rainfall were obtained from the records of the meteorological station located in the Chautengo Lagoon (0001220) belonging to the National Meteorological Service.

One-way ANOVA was performed to test for differences between the monthly values of gonadosomatic index, condition factor, hepatosomatic index, and diameter oocytes, and if significant values were obtained, the Student-Newman-Keuls (SNK) *post hoc* test was applied to identify homogeneous groups. Spearman's rank correlation analysis (r_s) was performed between gonadosomatic index, condition factor, hepatosomatic index, temperature, and rainfall. STATISTICA v.7.1 (StatSoft 2006) was used for the statistical analyses, and in all cases, a significance level of 0.05 was used.

Results and Discussion

Length distribution

During the sampling year, 330 organisms were obtained, which presented an average total length of 19.7 (± 0.09) cm and an average total weight of 75.3 (± 0.79) g. The average total length of females was 19.8 (± 0.11) cm with a range from 16.7 to 24.1 cm and the average length of males was 19.6 (± 0.15) cm with a range from 17.0 to 24.6 cm. The highest frequencies for females were observed at 18.5 and 19.5 cm and for males, it was at 19.5 cm. In most classes, females were more abundant compared to males. The lowest abundance for both sexes occurred at the smallest (16.5 cm) and largest (23.5 and 24.5 cm) class tags (Fig. 2).

According to Espino-Barr *et al*. (2019b) the females of *C. robalito* in Colima, reach the first sexual maturity at 22.63 cm, suggesting that the obtained organisms for the present work have not yet reached their first sexual maturity; therefore, they did not have the opportunity to reproduce. Therefore, current capture practices could generate problems in the size of *C. robalito* populations in the medium term, if fishing regulation is not considered in this coastal lagoon.

Sex ratio

In this work, all individuals were sex-determined by histology. A greater number of females (202) than males (128) were collected, with a ratio of 1:0.63, indicating a significant statistical difference ($\chi^2 = 16.59$, $p < 0.01$). In the analysis of the number of females and males per month, it was observed that in January the ratio was 1:1; although in December the ratio of males was higher than that of females (1.31:1) the difference was not significant ($\chi^2 = 0.53$, $p = 0.47$). In the rest of the months, from February to November, although females dominated, only in April (1:0.36; $\chi^2 = 6.53$, $p < 0.01$) and August (1:0.25; $\chi^2 = 10.80$, $p < 0.01$), the difference in these proportions was significant. Regarding the sex ratio by length class, it was found that at 17.5 cm, males dominated (1:1.25; $\chi^2 = 0.44$, $p = 0.51$) but it was not significant; at 23.5 cm, the ratio was 1:1, and in the rest of the classes, females dominated, but only at 18.5 cm (1:0.51; $\chi^2 = 7.78$, $p = 0.01$) and 20.5 cm (1:0.39; $\chi^2 = 9.98$, $p < 0.01$), the differences were significant.

Similar results with *C. robalito,* where the proportion of females was higher, have been reported in the coastal lagoon of Cuyutlán, Colima. Gallardo-Cabello *et al*. (2018) reported that the number of females was higher than males; in addition, Espino-Barr *et al*. (2019b) found that the ratio of M:H was 1:2.75. Also, Gassman *et al*., (2017) found for *C. ensiferus* in Venezuela a higher ratio of females to males (1.5:1). However, in other Centropomidae species that reach greater length, males dominated over the number of females, as in *C. viridis* (5.5:1, Tapia-Varela *et al*., 2020), and several studies with *C. undecimalis* (2.3:1, Caballero-Chávez, 2001; 2.2:1 and 1:0.16, Perera-García *et al*., 2008, 2011; Gassman *et al*., 2017; 5.5:1, Tapia-Varela *et al*., 2020). The trend observed in several snook species is that males dominate in shorter lengths, while females dominate in longer lengths. This pattern has been supported by the fact that several Centropomid species are protandric hermaphrodites (Peters *et al*., 1998; Taylor *et al*., 2000).

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In addition to sex change, variations in sex ratio could respond to local female aggregations or male migrations (Andrade *et al*., 2013; Gassman *et al*., 2017). Other authors have suggested that differential mortality between sexes, lower longevity, or differential predation may explain the sex imbalance (Vicentini & Araújo, 2003). Another possible explanation is that there may be differences in the growth rate of males and females, which may cause an imbalance in the ratio. The sex that exhibits a faster growth rate will pass the phase of greater vulnerability, and therefore, the predation ratio may decrease for that sex (Vicentini & Araújo, 2003).

Maturity stage

Microscopic analysis of the gonads proved to be an excellent tool for identifying and describing the stages of maturity analyzed in the organisms throughout the sampling year. Immature stage ovaries were recorded during all sampling months, ranging from 65 % in May to 100 % in February-March and from October to December (Fig. 3a). At this stage, the gonads weighed on average 0.29 (± 0.02 g), with values between 0.02 to 0.45 g. The early developmental stage ovary was recorded in January (7%) and from April to July (5% to 24%) (Fig. 3a); ovaries at this stage weighed on average 0.32 (± 0.02 g), with a range from 0.23 to 0.53 g. For the advanced developmental stage, the percentages of occurrence were 4% to 22% from April to September; on average, the gonads weighed 0.38 (± 0.06 g) and ranged from 0.06 to 0.72 g (Fig. 3a). The mature stage ovary was recorded in January (20%), in June and July (11%), and they weighed between 0.50 to 1.40 g and, on average, 0.74 (± 0.14 g) (Fig. 3a).

In the testis, the immature stage weighed an average of 0.22 (± 0.02 g), with an interval of 0.01 to 0.51 g, and was observed throughout the year with percentages of 53 to 100 %; the latter was present in nine months (Fig. 3b). The developing stage was recorded in January with 33 %, April with 13 %, and July with 17 %; the average weight of the testis at this stage was 0.25 (± 0.08 g) and range from 0.05 to 0.59 g (Fig. 3b). Mature stage testes were only recorded in January, represented with 13 %; on average they weighed 0.76 (± 0.17 g) and ranged from 0.59 to 0.94 g (Fig. 3b). In this study, the weight of the testes and ovaries of *C. robalito* was not greater than 1 g, while those reported by Espino-Barr *et al*. (2019b) for this same species, most (except one) on average the weights of the gonads are greater than 1 g.

Recording the percentages of the appearance of maturity stages over time has been used as a means to predict the reproductive period of many fish species (Costa e Silva *et al*., 2021; Espino-Barr *et al*., 2019b; Gassman *et al*., 2017; Lucano-Ramírez *et al*., 2022; Nascimento *et al*., 2022; Perera-García *et al*., 2011). However, for *C. robalito* collected in the Chautengo lagoon, Guerrero, it was not possible to locate a period of reproductive activity with this method, due to the low percentages of gonads recorded from the developing and mature stages (spawning stage gonads were not observed in either sex). However, obtained data is valuable since there was no record of *C. robalito* regarding the characteristics of the gonads from organisms captured for commercialization and/or human consumption.

Gonadosomatic, hepatosomatic, and condition factor indexes

The average monthly values of the gonadosomatic index for females and males did not show significant differences ($F_{11,190}$ = 0.718, *p* = 0.72 and $F_{11,116}$ = 1.013, *p* = 0.44, respectively) throughout the sampling year, for either sex. Monthly mean gonadosomatic index values showed no clear trend across sampling months. In females, gonadosomatic index varied very little with averages from 0.35 (April and May) to 0.55 (July and September). For males, the clearest changes were in the lowest gonadosomatic index values around 0.20 during three months (July, August, and December). It was also found that the monthly mean gonadosomatic index values of females and males were not correlated through the year (r_s = 0.007, *p* = 0.98, n = 12) (Fig. 4). No monthly correlation of female or male gonadosomatic index was found with temperature (r_s = 0.50, *p* = 0.09 n = 12; and r_s = 0.20, *p* = 0.52, n = 12, respectively), nor with rainfall (r_s = 0.54, *p* = 0.06; and r_s = 0.09, *p* = 0.28, n = 12, respectively). No clear annual trend was found in the gonadosomatic index of females and males of *C. robalito* indicating a breeding period. Espino-Barr *et al*. (2019b) define *C. robalito* in Cuyutlán lagoon, Colima, as a period of greatest reproductive activity from June-August, based on gonadosomatic index values (greater than 3).

In other snook species, reproductive periods have also been defined using gonadosomatic index values (Costa e Silva et *al*., 2021; Gassman *et al*., 2017; Hernández-Vidal *et al*., 2014; Lorán-Núñez *et al*., 2012; Maldonado-García *et al*., 2005; Nascimento *et al*., 2022; Perera-García *et al*., 2008, 2011). As with the maturity stages, it was not possible to establish a reproductive period in *C. robalito*, mainly since there was no statistically significant variation in the monthly averages that could delimit a reproductive season in this species in the Chautengo lagoon, Guerrero state.

In both sexes, the highest values of the hepatosomatic index occurred during June, July, and August, and the lowest values were recorded in September (the lowest), and from October to December. In both females and males, there was a significant difference ($F_{11,190}$ = 11.35, *p* < 0.01 and $F_{11,116}$ = 11.15, *p* < 0.01, respectively), in the monthly values of the hepatosomatic index. Temporal correlation was found in the hepatosomatic index values of females and males (r_s = 0.867, *p* < 0.01, n = 12) (Fig. 5). Monthly correlation analysis between gonadosomatic index and hepatosomatic index of females and males indicated an inverse relationship (r_s = -0.217, *p* = 0.49, n = 12; r_s = -0.405, *p* = 0.19, n = 12, respectively). However, this relationship was not statistically significant for either sex. In the case of *C. robalito,* Espino-Barr *et al*. (2019b) found that hepatosomatic index was higher one month before spawning (August). Although the authors did not mention it, there might be an inverse relationship between gonadosomatic index and hepatosomatic index, at least during these months. A similar inverse relationship was also observed in *C. medius* (Maldonado-García *et al*., 2005).

In some fish species, high hepatosomatic index values have been found during gonadal development/maturation, while low hepatosomatic index values occur before the peak gonad development. These changes have been interpreted as a decrease in the energy reserves found in the liver in the form of glycogen. These glycogen reserves are transferred to the gonads for use in the reproductive process (Arellano-Martínez *et al*., 2001; Ceballos-Vázquez, 1993; Maddock & Burton, 1999).

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In both sexes of *C. robalito*, the best relative condition was recorded in January (the highest), April, and from June to August, and a clear and sustained decrease was observed from September to December, the latter with the lowest value. Monthly values of this condition factor showed a significant difference in females ($F_{11,190}$ = 14.02, p < 0.01) and males ($F_{11,116}$ = 10.55, p < 0.01). A significant correlation was observed in monthly condition factor values between the two sexes (r_s = 0.874, p < 0.01, n= 12) (Fig. 6). There was no monthly correlation between the condition factor of females and males with temperature (r_s = 0.12, p = 0.40, n = 12; and r_s = 0.13, p = 0.44, n = 12, respectively) nor with rainfall (r_s = 0.04, p = 0.14, n = 12; and r_s = 0.19, p = 0.63, n = 12, respectively).

With the condition factor, the present and future success of a population can be analyzed due to its influence on growth, reproduction, and survival, it is a quantitative parameter that reflects the state of welfare or health of the fish (Mitu *et al*., 2019; Yongo *et al*., 2020). The mean values of condition factor in *C. robalito* were similar in females and males throughout the year, indicating that they have similar conditions. Among fish populations, condition factor tends to vary generally according to factors such as food availability, sex, seasonality, and degree of gonadal development (Froese, 2006).

Microscopic description of the gonads

The ovarian tunic that envelops the entire ovary was distinguished; oocytes in the primary growth phase were found in all stages, however, in the immature stage (Fig. 7a) this phase was the only one observed. Oocytes in the cortical alveolus phase were identified in the early developmental (Fig. 7b), late developmental, and mature stages. In the latter two stages, oocytes in primary vitellogenesis were also distinguished (Fig. 7c), in the mature stage in addition to all the aforementioned phases, oocytes in secondary and tertiary vitellogenesis were also found (Fig. 7d). It could also be observed that oocyte growth increases through each of the developmental stages (Fig. 8); these increases presented a significant difference ($F_{4,477}$ = 1732.30, p < 0.01). The largest diameters were found in the secondary and tertiary vitellogenesis phases. Due to the presence of different phases of oocyte development within the ovary, it is deduced that the oocytes have asynchronous development. This simultaneous presence of several oocyte phases in the same ovary that occurs in *C. robalito* has also been recorded in several snook species such as *C. undecimalis* (Peters *et al*., 1998); *C. medius* (Maldonado-García *et al*., 2005), and *C. parallelus* (Costa e Silva et *al*., 2021), suggesting that these species exhibit long reproductive periods and multiple spawning.

Oocytes with asynchronous development have been reported in *C. medius* (Maldonado-García *et al*., 2005) and in several species that inhabit tropical environments, such as *Lutjanus peru (*Lucano-Ramírez *et al*., 2001), *Lutjanus argentiventris (*Lucano-Ramírez *et al*., 2014) and *Anisotremus interruptus* (Ruiz-Ramírez *et al*., 2012), among others. It has also been found, as in *C. robalito*, that, with the maturation process of the oocytes, these increase in diameter significantly, this aspect has been recorded in several species of marine fish, and the cause of the increase is due to the accumulation of yolk in the cytoplasm (Lucano-Ramírez *et al*., 2001).

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In the testis, the tunica albuginea was identified, which, as in the ovaries, surrounds or envelops the entire testis. However, in the immature stage, little cellular development was observed (Fig. 9a), in the developing stage, little cellular development was observed in the periphery and the main duct, where the spermatozoa are concentrated (Fig. 9b), and in the mature stage, spermatozoa can be identified within the cysts (Fig. 9c); the cellular arrangement in the testes of *C. robalito* is lobular.

The microscopic description of the gonads helps to assess the degree of gonadal development and to detail their structure. In the case of the testis, it was possible to distinguish the tunica albuginea, the presence or absence of spermatozoa, the amount of interstitial tissue, and the definition of the main duct; these characteristics are distinctive and are associated with the maturity degree of the testis (Grier *et al*., 2009).

Total length-to-total weight ratio

The length-weight relationships of females and males of *C. robalito* indicated that both sexes presented negative allometric growth (b = 2.01 and b = 1.91, respectively; and between these two values there was no statistical difference, $t_{0.05,326} = 0.81$, $p = 0.41$). This means that there is greater growth in length compared to weight (Fig. 10). The negative allometric growth observed in the *C. robalito* in this study may be attributed to the capture of many young organisms, which was confirmed by the histological analysis of the gonads where only a small number of gonads showed some level of maturity. A previous study on *C. robalito* also observed negative allometric growth (Barreto-Figueroa and Solórzano-Barrera, 2006). On the other hand, populations of *C. robalito* from other locations have shown isometric and positive allometric growth (Gallardo-Cabello *et al.,* 2018; González-Sansón *et al.,* 2014; Martínez-Madrigal, 2021). The differences found in this research may be attributed to the fact that several studies analyzed larger fish (27 to 37 cm) compared to those included in this study (16.7 to 24.6 cm).

In the present study, in all *C. robalito* organisms, it was possible to identify the sex due to the lengths presented by the fish and the use of histology in the analysis of the gonads. In turn, Espino-Barr *et al*. (2019b) in Cuyutlán lagoon, Colima, by macroscopic observation of the gonads, recorded 29 (8.7%) undifferentiated organisms (sex was not identified) of *C. robalito* with lengths between 6.5 and 21 cm. Therefore, the advantage of one method over the other in sex identification is clear; however, it is not always probable to apply the histological process.

In this study of *C. robalito*, oocytes with the highest degree of maturation presented an average diameter of 350 μm. Meanwhile, Espino-Barr *et al*. (2019b) also in *C. robalito*, recorded oocytes averaging 270 μm. The difference between these two averages could also be an effect of the method for measuring the diameter, ours was done by histological sections and that of said authors, although they do not mention it, we assume that they used the complete oocyte.

The limited presence of individuals with developing and mature gonads (with none in spawning or spawning) in *C. robalito* during the study period may suggest that the Chautengo Lagoon, Guerrero, primarily serves as an area for the growth and feeding of juveniles. A similar observation was made for *C. undecimalis* in the Tacarigua Lagoon, Venezuela (Gassman *et al.,* 2017). Furthermore, Márquez (1985) notes that this species does not complete its entire reproductive cycle within the lagoon, as it migrates to the open sea for spawning. Additionally, Blewett *et al*. (2009) proposed that some individuals migrate to coastal areas to reproduce and then return to the estuaries.

In this study, it was not possible to estimate the length at maturity of *C. robalito*, due to the reduced number of individuals with gonads in advanced stages of maturation. Also, in *C. undecimalis* the male sample number was so small that they were unable to estimate the average length at maturity in males (Taylor *et al*., 2000). It is worth mentioning that in some snook species, it can be complicated to estimate average length at maturity, as some of these are protandric hermaphrodites (Peters *et al*., 1998).

Given this background, management measures for this species are encouraged to be implemented, such as a net size limitation and the establishment of a minimum capture length. Additional studies in the coastal zone near the Chautengo Lagoon, to investigate reproductive migrations and spawning areas, considering that a marked pattern of fidelity to localities or reproductive areas has been noted in snook species and that these should be considered for the management and integrated management of the spatial structure in the connectivity between spawning sites, larval transport areas, and growth habitats for this species.

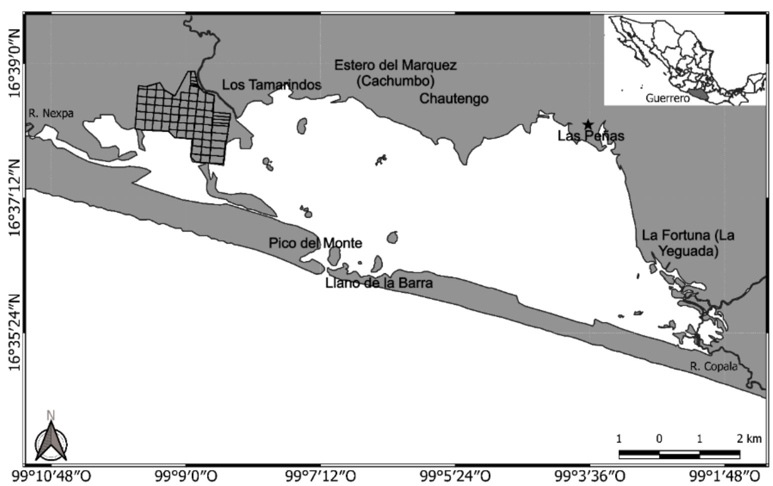

Figure 1. Study area, Chautengo coastal lagoon in Guerrero state, Mexico.

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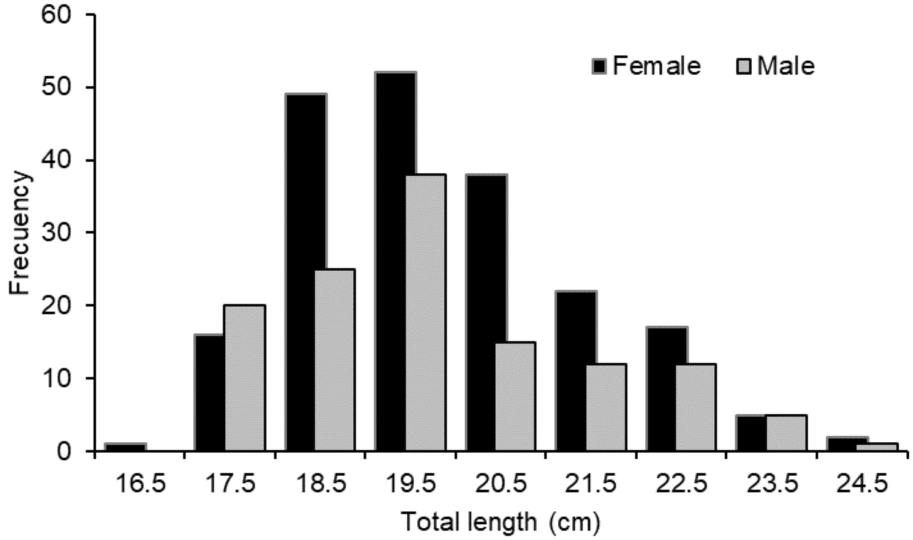

Figure 2. Frequency distribution of total length of females and males of *Centropomus robalito*, from January to December 2019 in the coastal lagoon of Chautengo, Guerrero state, Mexico.

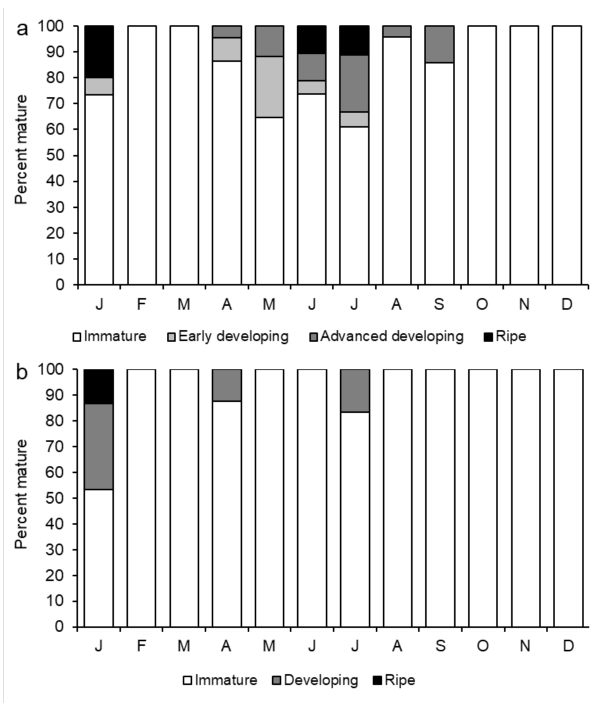

Figure 3. Monthly percentage of gonadal maturity stages of females (a) and males (b) of *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero, Mexico.

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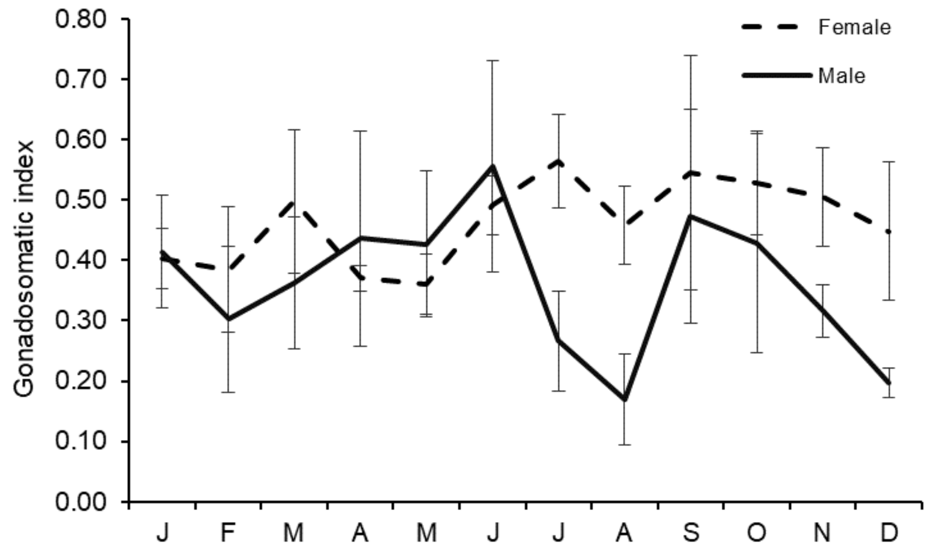

Figure 4. Monthly variation of the gonadosomatic index of females and males of *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero, Mexico.

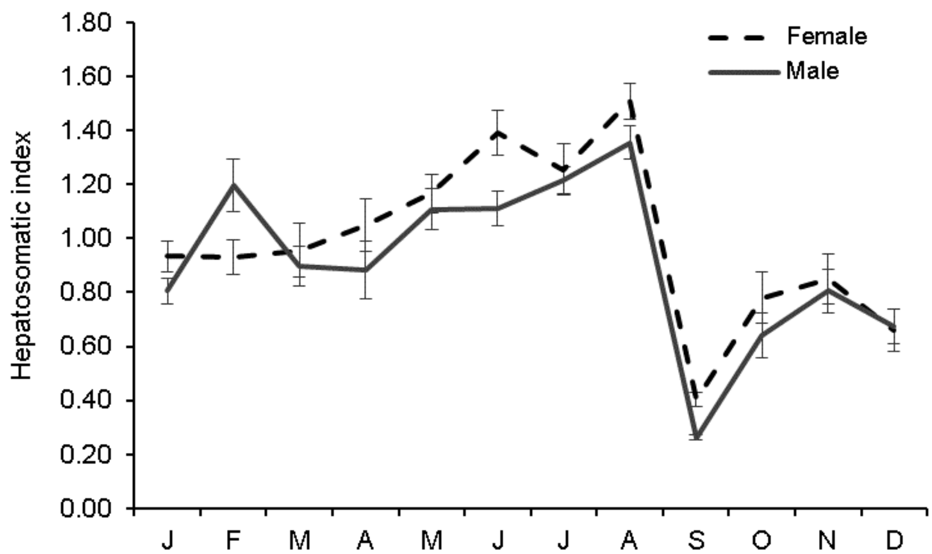

Figure 5. Monthly variation of the hepatosomatic index of females and males of *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero, Mexico.

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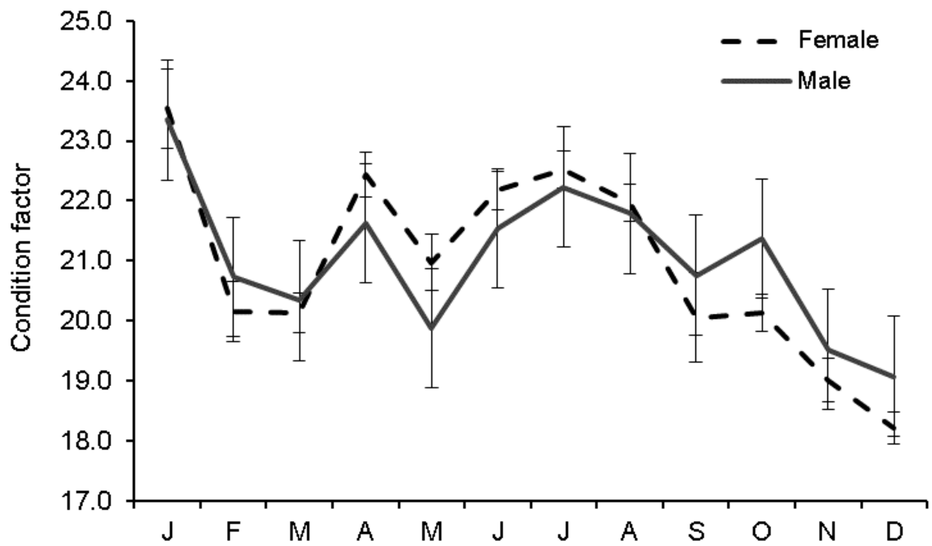

Figure 6. Monthly variation of the relative condition factor of female and male of *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero, Mexico.

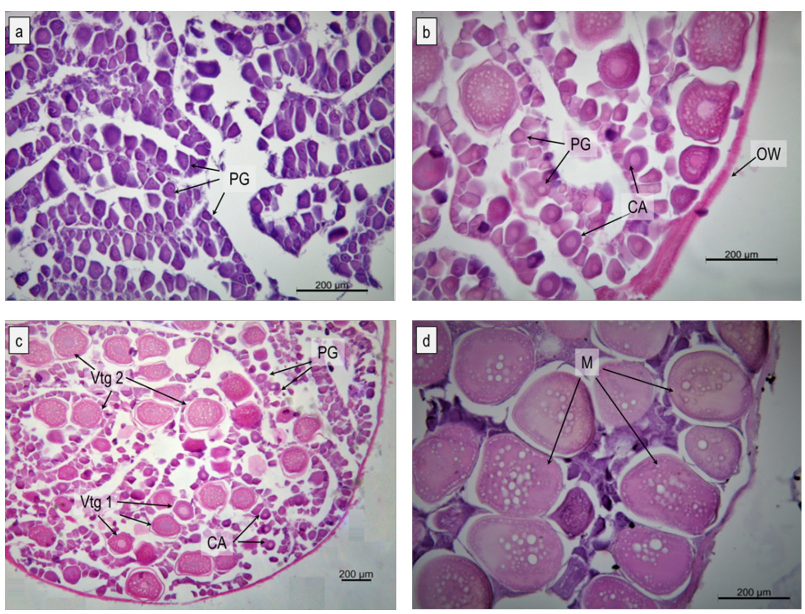

Figure 7. Microscopy of gonadal maturity stages of female *Centropomus robalito* in the coastal lagoon of Chautengo, Guerrero, Mexico.

a) Immature stage, b) early developmental, c) advanced developmental, d) mature stage, OW= ovarian tunica, PG= primary growing oocytes, CA= cortical alveoli, Vtg 1 primary vitellogenesis, Vtg 2= secondary vitellogenesis, M= mature. Hematoxylin-eosin stain. Scale 200 µm.

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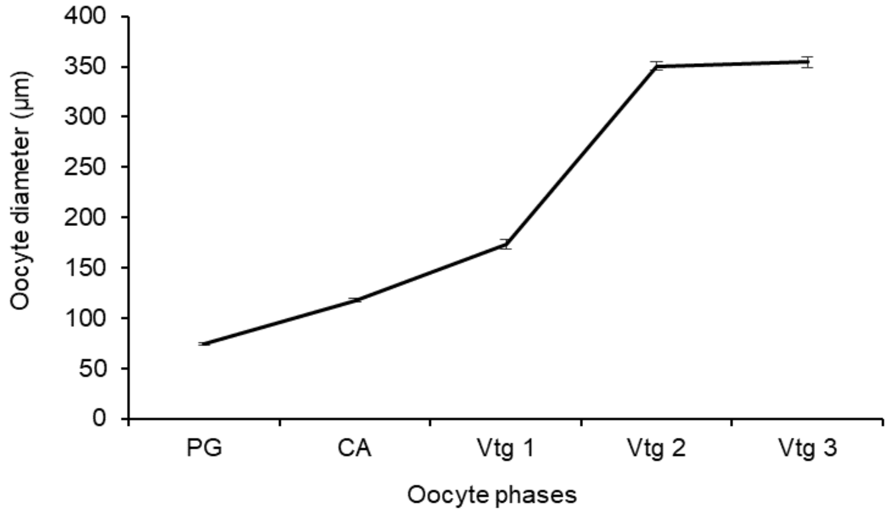

Figure 8. Average diameter of oocytes in each of the developmental stages of *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero, Mexico.

PG= primary growth, CA= cortical alveoli, Vtg1= primary vitellogenesis, Vtg 2= secondary vitellogenesis, Vtg 3= tertiary vitellogenesis.

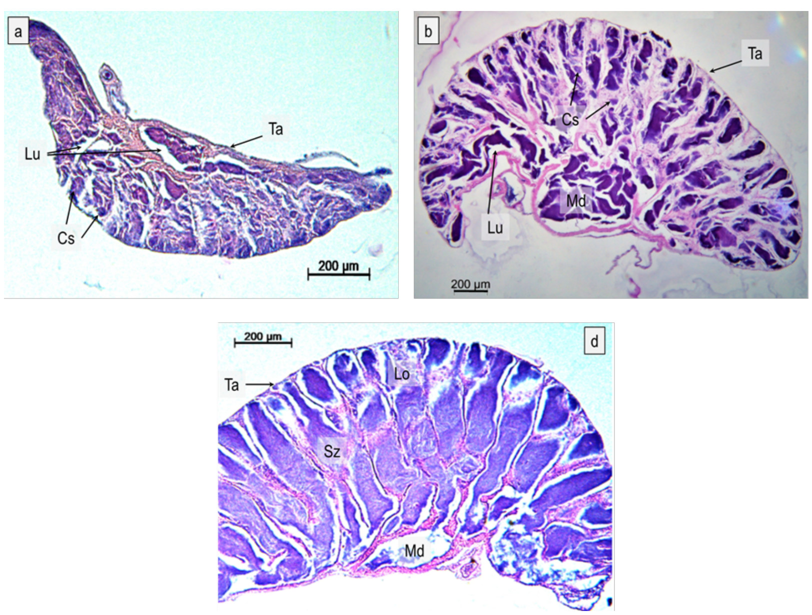

Figure 9. Microscopy of gonadal maturity stages of male *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero state, Mexico.

a) immature stage, b) developmental, c) mature stage, Ta= tunica albuginea, Lu= lumen, Lo= lobules, Cs= cysto, Sz= spermatozoa, Md= main duct. Hematoxylin-eosin stain. Scale 200 µm.

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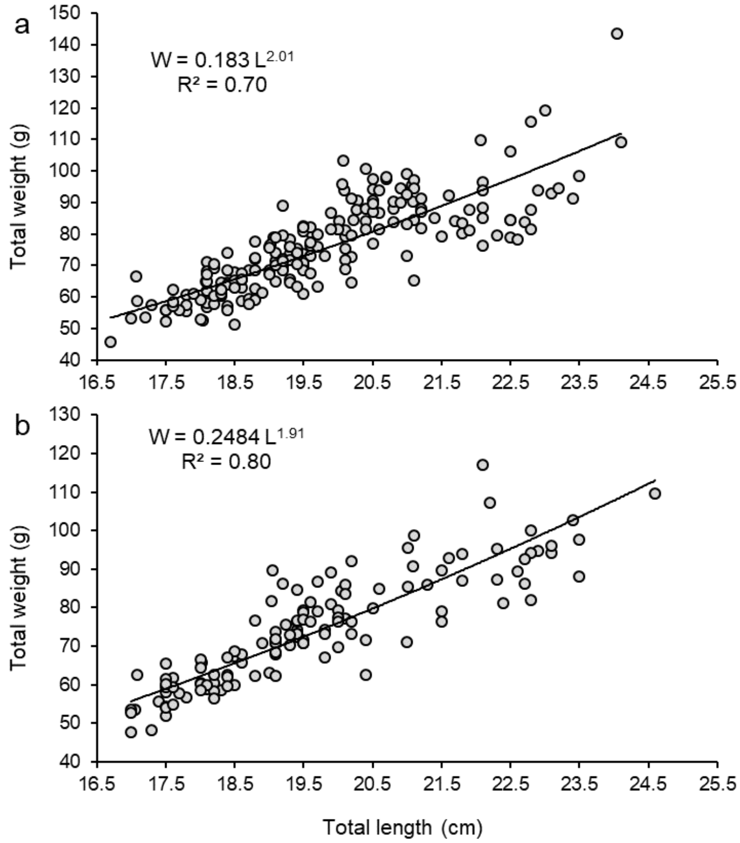

Figure 10. Length-weight relationship of females (a) and males (b) of *Centropomus robalito*, in the coastal lagoon of Chautengo, Guerrero state, Mexico.

Conclusions

The reproductive condition and biological-reproductive variables presented by most individuals of *C. robalito* suggest that reproductive events do not occur in the Chautengo Lagoon and that they use this water body as a juvenile rearing site. Histological analysis of the gonads of *C. robalito* indicated that it is a dioecious species. This is the first study on the Pacific coast using the histological technique of gonads to evaluate the reproductive status of *C. robalito*. Long-term studies of reproduction and population dynamics of *C. robalito* both within and in the vicinity of the lagoon are recommended, in addition to restricting the use of fishing gear that catches individuals smaller than 23 cm Lt thus preventing the catch volume from being limited in the future.

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Author contribution

Conceptualization, LRG, ZCC. Methodology development, LRG, ZCC, RRS; Software management, LRG, ZCC, RRS, VGJ; Experimental validation, LRG, RRS, VGJ; Analysis of results, LRG, ZCC, RRS, VGJ; Data management, LRG, ZCC, RRS, VGJ; Manuscript writing and preparation, LRG, RRS; Drafting, revising, and editing, LRG, ZCC, RRS, VGJ; Project manager, LRG; Fund acquisition, LRG, ZCC.

All authors of this manuscript have read and accepted the final version of the manuscript.

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Ethical statements

The study does not require ethical approval, since the organisms come from commercial fisheries.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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