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Growth of the Yellowfin Mojarra *Gerres cinereus* off the Pacific Coast of Mexico

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ABSTRACT
This study analyzes for the first time age and growth of *Gerres cinereus* in the coasts of central Mexican Pacific. From April 2010 to November 2011, morphometric data of 427 yellowfin mojarra *Gerres cinereus* were obtained; otoliths and weights of 179 specimens were used to determine age and growth. The growth study entailed two methods: Length frequency analysis and study of sagittae and asterisci otoliths. Both methods identified seven age groups. Growth parameters of von Bertalanffy's equation were determined by Ford-Walford and Gulland methods and an iteration adjustment Solver. Both techniques yielded a high determination coefficient but the Solver method had the better fit: L_∞= 56.43 cm, K = 0.208, t_o= -0.669. Mean size for each age was: Age 1 = 16.57 cm, age 2 = 24.07 cm, age 3 = 30.15 cm, age 4 = 35.09 cm, age 5 = 39.11 cm, age 6 = 42.36 cm and age 7 = 45.01 cm. The allometric index from the weight-length relationship was positive and b = 3.193, the longevity was of 13.73 years. Higher values of L_∞ and smaller of K index were found for specimens of *G. cinereus* in the coasts of Quintana Roo, Mexico and Biscayne Bay in Florida.

Key words: Length frequency distribution, sagittae, asterisci, von Bertalanffy, longevity

INTRODUCTION
The yellowfin mojarra *Gerres cinereus* occurs in the Western Atlantic and Eastern Pacific Oceans from Baja California to Peru. Its habitat is sandy bottoms close to reefs; it also penetrates brackish coastal lagoons. Juveniles form big schools. This species is omnivorous and feeds on vegetable matter, small benthic invertebrates and insects (Allen and Robertson, 1994; Bussing, 1995).

In Mexican waters, *G. cinereus* is fished with gill nets and cast nets, it is registered in official statistics together with other species of the Gerreidae family. In 2011, landings of Gerreidae species decreased to 62,668 t in Mexico from 81,250 t the previous year, of which 63% were obtained off the Pacific coast. Off Colima and Jalisco 8,022 t were captured. Within the artisanal fishery *G. cinereus* represents 1.5% of total weight of 146 species of fish landed. Its price at the beach (when it first arrives to shore) is $ 50.00 Mexican pesos (3.5 US dollar) kg^{-1}.

Age determination studies are necessary to establish population age structure and to understand stock biomass trends and processes. These types of analysis allow comparative studies through time and help determine the influences of environmental fluctuations and/or fishing exploitation (Espino-Barr *et al.*, 2008).

Although the yellowfin mojarra is a commercially important species, studies on its population dynamics are limited. Age and growth studies of this species were only carried out by Alvarez-Hernandez (1999) in the Quintana Roo coasts in Mexico and by Claro and Garcia-Arteaga (2001) off the Cuban shelf. Therefore, this investigation provides, for the first time, data on age and growth of yellowfin mojarra off Colima and Jalisco, analyzing length-frequency data and otoliths. This type of studies has never been done with asterisci of the yellowfin mojarra. These results can be used in fishery models and capture quotas that will help assess and manage this resource.

The objectives of this study are: (1) To analyze *Gerres cinereus* length frequency histograms, (2) Determine time of growth, ring formation in sagittae and asterisci and analyze growth minima and maxima, (3) Calculate von Bertalanffy's growth constants parameters by length frequency analysis data and ring identification in otoliths sagittae and asterisci, (4) Obtain the weight-length relationships (total weight and eviscerated weight) and asymptotic values of weight, (5) Estimate the longevity of *G. cinereus* and (6) Compare results obtained in the present study with those obtained by other authors.

MATERIALS AND METHODS

From April 2010 to November 2011, individuals of *G. cinereus* were obtained monthly from the commercial captures of the coastal fishery in Manzanillo, Colima, Mexico (19°00' to 19°02'N and 104°10' to 104°21'W) and in Tomatlán, Jalisco, Mexico (19°58' to 20°04'N and 105°26' to 105°32'W). Total length (TL, cm) and total weight (TW, g) of 427 individuals were measured. Of these, 179 were transported to the fish laboratory of the National Fishery Institute, where TL (cm), standard length (SL, cm), height (He, cm) at the base of the dorsal fin, TW (g) and eviscerated weight (EW, g) and sex were recorded macroscopically for each specimen. Individuals were captured with gillnets of different sizes (2.5-3.0 in, 6.35-7.6 cm) which resulted in the capture of a diversity of different length sizes and age groups.

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

The length frequency distribution was analyzed with the ELEFAN program (Electronic Length frequency Analysis) of the FISAT package (FAO-ICLARM Fish Stock Assessment Tools) (Sparre and Venema, 1995; Gayanilo *et al.*, 2005) to obtain the average length of corresponding to each age group. This method uses a goodness of fit index called Rn (best adjustment measure) on a response surface, where the maximum value indicates the best combination of growth parameters.

Analysis of otoliths: 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 determined by the analysis of the sagittae and asterisci otoliths by Espino-Barr *et al.* (2013) was used to obtain the parameters of Von Bertalanffy (1938) growth equation. The observed values for sagittae and asterisci were: For age 1 = 16.76 cm, age 2 = 22.67 cm, age 3 = 30.00 cm, age 4 = 35.33 cm, age 5 = 39.83 cm, age 6 = 43.25 cm and age 7 = 44.40 cm.

Von Bertalanffy (1938) in the form of $L = L_\infty\ [1-e^{-K(t-to)}]$, was used, where L = length, L_∞ = asymptotic length, K = growth factor and t_o = theoretic length at age 0. The parameters L_∞, K and t_o of Von Bertalanffy (1938) equation were obtained with Ford (1933), Walford (1946) and Gulland (1964) and were adjusted by convergent iterations with Newton´s algorithm with the Solver program in Excel software (Microsoft, 2007). The lowest value of a sum of the squared error determined the best adjustment.

The function $W = a \cdot L^b$ was used, where W = weight, L = length, to obtain the weight-length relationship and 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.

Growth data for length-and weight-length relationships were used to obtain the weight at each age. Weight growth was obtained by substituting TL and L_∞ by TW and W_∞, in the von Bertalanffy (1938) equation. Taylor (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 von Bertalanffy's equation obtained in this study with those from other authors, growth performance index or phi prima test was estimated (Pauly, 1979): $phi' = \log K + 2 \cdot \log L_\infty$.

RESULTS

Biometric relationships: The maximum value of TL was 49.0 cm and the minimum was 14.0 cm, with a difference of 35 cm (Table 1). Total weight varied from 27.0 to 1230 g. Mode was lower than average, in the length cases, that is, in total (TL), standard (SL) and height (He) lengths of the body, implying a data distribution with positive asymmetric trend, also with more values lower than the mode. In the case of weight, the modes are higher than the averages.

Data of the relationships between length, height and weight were highly significant, with $r^2 > 0.90$ ($p < 0.05$) (Table 2). Significant differences between sexes were detected with the analysis of size data ($p < 0.05$), that is, between females and males of total length TL ($F'_{0.05\ (2,\ 163\ =\ 3.898)} = 13.63$). Figure 1 shows the scatter diagram of the relation weight-length, adjusted by the potential model. The slopes of the relationships between lengths (TL, standard length SL and height He) were not statistically different to one; and those between TL and total weight TW and eviscerated weight EW were different to three, positive allometric.

Table 1: Values of lengths and weights of *Gerres cinereus*

Parameters	TL (cm)	SL (cm)	He (cm)	TW (g)	EW (g)
Average	25.920	18.320	8.500	285.000	188.000
Maximum	49.000	34.600	17.500	1,230.000	1,088.000
Minimum	14.000	10.400	04.200	027.000	005.000
Mode	16.000	17.000	05.000	294.000	238.000
SD	08.674	06.091	02.950	300.820	239.201
n	427	427	427	400	179

TL: Total length (cm), SL: Standard length (cm), He: Height (cm), TW: Total weight (g) and EW: Eviscerated weight (g), n: No. of individuals

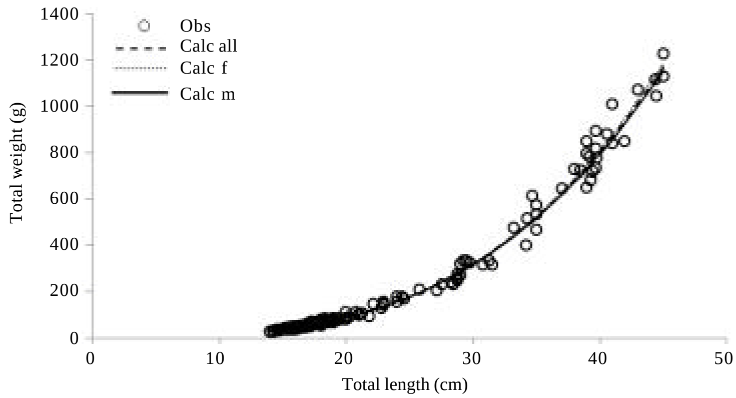

Fig. 1: Observed data and weight-length relationship by potential model calculated for the species (calc all), females (calc f) and males (calc m) for *Gerres cinereus*

Table 2: Morphometric relationships of the variables

Parameters	Species	Females	Males
TL vs SL			
a	0.699	0.704	0.702
b	1.013	1.012	1.010
r^2	0.991	0.993	0.988
F	20,041.000	11,251.000	6,456.800
TL vs He			
a	0.324	0.310	0.353
b	0.993	1.009	0.964
r^2	0.972	0.970	0.970
F	6,109.100	2,703.600	2,637.600
TL vs TW			
a	0.006	0.006	0.007
b	3.193	3.208	3.172
r^2	0.993	0.993	0.993
F	25,410.700	11,175.700	11,365.900
TL vs EW			
a	0.005	0.006	0.005
b	3.203	3.167	3.253
r^2	0.974	0.994	0.928
F	6,298.000	13,339.500	983.900
n	179	85	78

TL: Total length, SL: Standard length, He: Height, TW: Total weight and EW: Eviscerated weight, from *Gerres cinereus*. a: Y intercept, b: Regression coefficient or slope, r^2: Coefficient of determination, F: Statistic test, n: No. of individuals

Time of growth rings formation of the slow and fast growth bands. *Gerres cinereus* showed that a higher percentage of sagittae and asterisci otoliths with fast growth borders occur from August to January while the highest percentage with slow growth bands otoliths in the borders were observed from February to July (n = 179) (Fig. 2).

Analysis of length frequency: Observed values of TL ranged from 14.0 to 49.0 cm; April and November have the smallest individuals and June the largest (Fig. 3). The results of length at each age are shown in Table 3; these values are similar to those obtained by otoliths rings growth

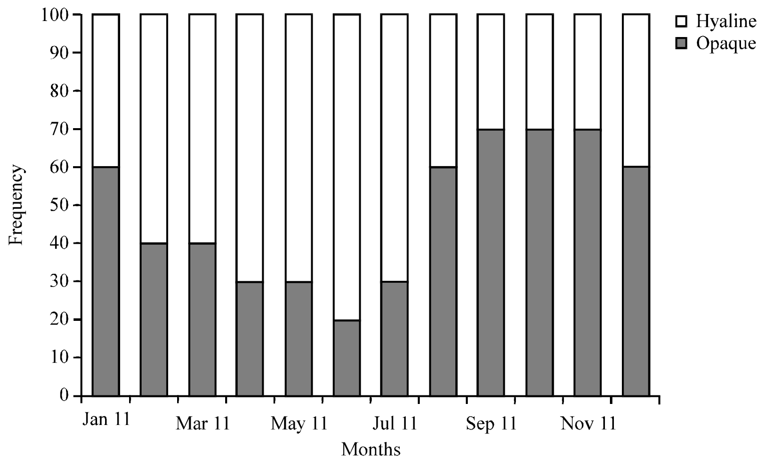

Fig. 2: Monthly frequency of the slow (hyaline) and fast (opaque) growth borders in *G. cinereus* sagittae

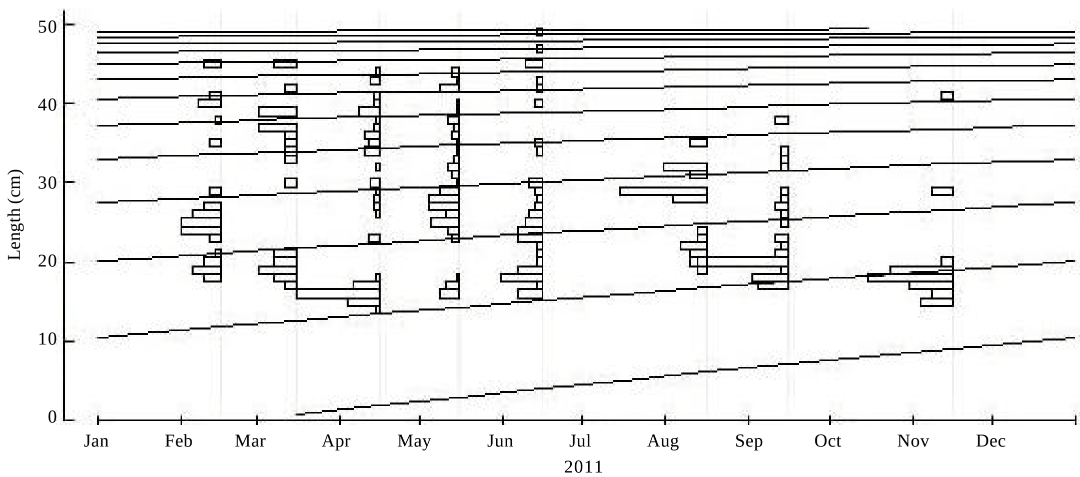

Fig. 3: Length frequency and growth curve of *Gerres cinerus* by ELEFAN method

Table 3: Observed and calculated values of total length (cm) and total (TW) and eviscerated (EW) weight (g) for each age group (years) of *Gerres cinereus*

Parameters		ELEFAN		F-W-G		Solver
L_8		51.150		56.430		56.430
K		0.270		0.203		0.208
t_o		-0.534		-0.669		-0.669
Age (years)	Observed (cm, sd)	ELEFAN (cm)	F-W-G (cm)	Solver (cm)	TW (g)	EW (g)
1	16.76 (±1.552)	17.35	16.22	16.57	47	40
2	22.67 (±1.631)	25.34	23.60	24.07	155	133
3	30.00 (±0.416)	31.45	29.64	30.15	317	274
4	35.33 (±1.568)	36.11	34.56	35.09	515	445
5	39.83 (±1.164)	39.67	38.58	39.11	728	629
6	43.25 (±0.727)	42.39	41.86	42.36	940	813
7	44.40	44.46	44.53	45.01	1,141	987
8		46.04	46.72	47.16	1,324	1,146
9		47.25	48.50	48.90	1,486	1,288

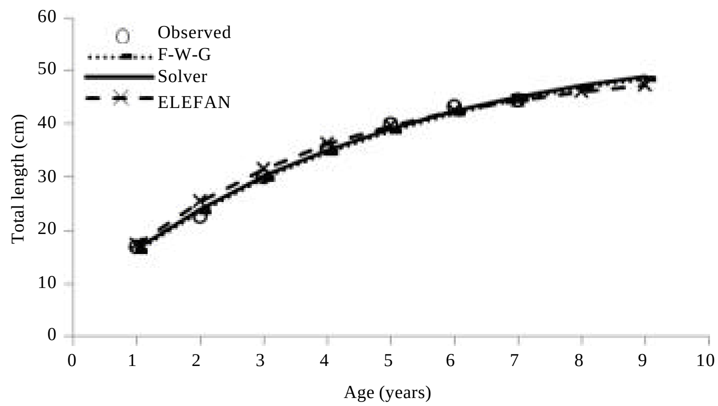

Fig. 4: Von Bertalanffy's (1938) growth curve in length for *Gerres cinereus* by Ford-Walford-Gulland (F-W-G) with otolith readings, solver and by length frequency with elefan methods for *Gerres cinereus*

analysis. Observed TL for each age obtained with ELEFAN's method showed higher values from ages one to four and lower values for ages five to seven. Growth parameters for TL were: L_∞ = 51.15 cm, K = 0.270 years^{-1} and t_o= -0.534. The Sum of Square Errors (SSE) between observed values from otoliths and data obtained by ELEFAN was SSE = 11.018.

Analysis of otoliths: Analysis of the sagittae and asterisci otoliths allowed the identification of 7 age groups. Growth parameters obtained by Ford-Walford-Gulland method for TL were: L_∞ = 56.43 cm, K = 0.203 years^{-1}, t_o= -0.669. Growth parameters obtained by Solver iteration process were very similar: L_∞ = 56.43 cm, K= 0.208 years^{-1}, t_o= -0.669. Growth from one age to the next was 16.57 cm from age 0 to age 1, 7.50 cm from age 1 to age 2, 6.09 cm from ages 2 to 3, 4.94 cm from ages 3 to 4, 4.01 cm from ages 4 to 5, 3.26 cm from ages 5 to 6 and 2.65 from age 6 to age 7. Figure 4 shows the growth curve of *G. cinerus* according to von Bertalanffy's method.

The Solver iterative process gave a better fit of the calculated equation to observed data of otoliths readings, than Ford-Walford and Gulland methods. The Sum of Square Errors (SSE) between observed and calculated data by Ford-Walford and Gulland was SSE = 5.418 and that of the observed data and the resulting of Solver process was SSE = 3.749.

Growth in weight: The growth index value of the weight-length equation was positive allometric: b = 3.193 with total weight data and b = 3.203 with eviscerated specimens (Table 2). The allometric growth index b was slightly higher for eviscerated weight, because data do not come from the same organisms in all cases.

Theoretical growth in weight: Values of calculated Total Weight (TW) and Eviscerated Weight (EW) have a slow growth during the first years of age, starting at 47 g and 40 g (Table 3, Fig. 5). After age 3 there is a very fast growth rate that starts to slow down after age 5. The calculated asymptotic total weight was Wt_∞ = 2 348.1 g and the eviscerated asymptotic weight EW_∞= 2 037.3 g.

Longevity (Age $A_{0.95}$). *G. cinereus* reached 95% of its infinite length L_∞ in 13.73 years.

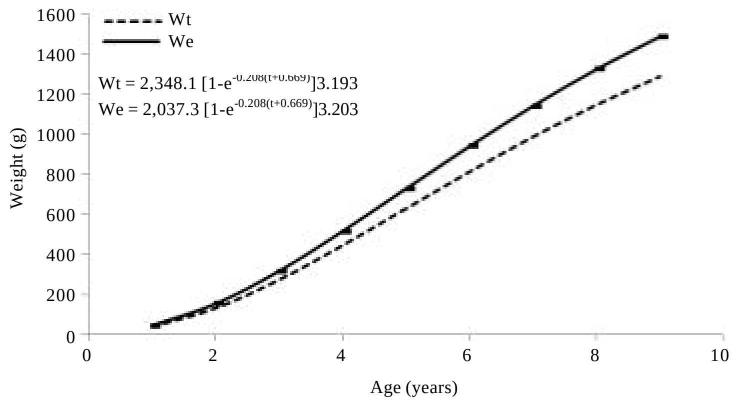

Fig. 5: Von Bertalanffy's (1938) growth curve in total and eviscerated weight for *Gerres cinereus*

DISCUSSION

Data of the relationships between length, height and weight (Table 1) show a higher tendency to positive allometry in females than males, except between total length and eviscerated weight, where the higher trend is of the males. It is possible that this is a result of the gonadic maturity of females which increase their weight. Females mature at 20.6 cm TL and 1.5 years old and males at one year of age and 16.4 cm TL (Espino-Barr *et al*., 2013).

In the case of the relationships between total weight and total length, a positive allometric growth is observed, for the species and for both sexes, this is, the 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 age of *G. cinereus* and its growth. This has also been found in other tropical species, where scales are not present (Gallardo-Cabello *et al*., 2006, 2007, 2011; Espino-Barr *et al*., 2006, 2008), allowing a good assessment of ageing, not always possible with scales.

The values obtained with the length frequency analysis were similar (although overestimated) to those found by the identification of growth rings in the sagittae and asterisci which render age determination of *G. cinereus* valid with both methods and validating each other (Joseph, 1962). The differences emerged are because of the methods used: A direct and an indirect approach.

Organisms utilized to study fishery dynamics come from partially biased samples, due to the catching methods which consist on gillnets and castnets. With these methods the capture is multispecific that change in their proportions depending on the time of year, temperatures, currents (Espino-Barr *et al*., 2010; Gallardo-Cabello *et al*., 2011).

In this kind of studies it is impossible to obtain samples that are not biased if they are obtained from the commercial fishery, where the gears select the catch of a few age groups. Nonetheless, these study samples are representative of this population, because they fulfill the sample size in all the age groups, all represented and the periodicity is of a year.

Analysis using catch per unit of effort have to be done and also growth fishery parameters must be applied to analyze the state of health of the species in the central Mexican Pacific coast.

Related to the growth parameters calculations done by other authors, Claro and Garcia-Arteaga (2001) studied *G. cinereus* in the Cuban shelf and found a very high value of the

Table 4: Growth parameters of the von Bertalanffy (1938) equation for *Gerres cinereus* reported by different authors (longevity and ϕ' values were calculated by us)

Parameters	This study	Alvarez-Hernandez	Claro and Garcia-Arteaga
Year	2011	1999	2001
Area	Colima, México	Quintana Roo, México	Cuba
Method	otoliths	Length frequency and scales	Length frequency
L_∞ (cm)	56.43	36	28.00
K	0.208	0.341	0.650
t_0	-0.669	-1.03	0
Longevity (years)	13.73	7.78	4.61
ϕ'	2.822	2.646	2.707

L_∞: Asymptotic length, K: Growth factor, t_0: Theoretic length at age 0, ϕ': Growth performance index

index K = 0.65 and therefore, a low asymptotic length L_∞= 28.00 cm; because of this K value, the species would reach L_∞ very fast and would have a longevity of maximum age of 4.61 years (Table 4).

In the southern coast of Quintana Roo (Alvarez-Hernandez, 1999) analyzed with length frequency and growth rings on scales. He found K = 0.341 and L_∞ = 36 cm which would give a longevity or maximum age of 7.78 years. These results show that (Alvarez-Hernandez, 1999) only used three age groups to evaluate the growth parameters which means that his analysis corresponds to the first part of the curve of von Bertalanffy and the catabolic index is higher than the real. Had this author used organisms of a higher age, he would have found lower values of K and higher L_∞ but the highest studied age is of three years that corresponds to a length of 26.90 cm (Table 4).

The differences found in the values of the growth parameters of the von Bertalanffy equation are determined by the environmental conditions such as latitude, temperature, salinity, among other (Taylor, 1958; 1960). The pressure of the fishing activity has also an influence: If there is overfishing, the older age groups will disappear (Espino-Barr *et al*., 2010; Gallardo-Cabello *et al*., 2011).

CONCLUSION

Growth ring analysis on sagittae and asterisci are the best method to determine age in *Gerres cinereus*.

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