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Fishery of *Gerres cinereus* in Central Mexican Pacific coast

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From April 2010 to November 2011 data on the biology and the fishery of *Gerres cinereus* (Teleostei: Gerreidae) were collected in the coasts of Colima and Jalisco, in order to help manage its fishery. Although with variations, total catches have increased in the last fifteen years. The highest catches in Colima are obtained during summer (1.9 tons) and in Jalisco during winter and spring (12.2 tons). Age and length of first capture was 1.9 years and 23.8 cm in Colima and 2.3 years and 26.2 cm in Jalisco. Total mortality was Z = 2.44 in Colima and Z = 0.910 in Jalisco. Natural mortality was M = 0.218 in both cases. Fishing mortality was F = 2.222 in Colima and F = 0.692 in Jalisco; survival rate was S = 0.087 for Colima and S = 0.403 for Jalisco. Exploitation rate was E = 0.911 in Colima and E = 0.760 in Jalisco. Yield per recruit was y/r = 260.7 g in Colima and y/r = 315.9 g in Jalisco. Increasing the age of first capture to four years will get a y/r = 383.2 g for Colima and a y/r = 389.0 g for Jalisco. We suggest that the gear's mesh size should be increased to catch bigger and older individuals.
Key words: Capture, mortality, exploitation rate, yield per recruit, *Gerres cinereus.*

Pesquería de *Gerres cinereus* en la costa del Pacífico centro mexicano

Durante el periodo de abril de 2010 a noviembre de 2011 se obtuvieron datos de la pesquería e individuales de *Gerres cinereus* (Teleostei: Gerreidae) en las costas de Colima y Jalisco, con el objeto de sentar las bases para su administración pesquera. Aunque con variaciones, las capturas totales se han incrementado en los últimos quince años. Las mayores capturas se obtuvieron en Colima durante los meses de verano (1.9 t) y en Jalisco durante los meses de invierno y primavera (12.2 t). La edad y la talla de primera captura fueron de 1.9 años y 23.8 cm para Colima y 2.3 años y 26.2 cm para Jalisco. La mortalidad total fue Z = 2.44 en Colima y Z = 0.910 en Jalisco. La mortalidad natural fue M = 0.218 para ambos casos. La mortalidad por pesca fue F = 2.222 en Colima y F = 0.692 en Jalisco. La tasa de supervivencia fue S = 0.087 en Colima y S = 0.403 en Jalisco. El índice de explotación fue E = 0.911 en Colima y E = 0.760 en Jalisco. El rendimiento por recluta fue y/r = 260.7 g en Colima y y/r = 315.9 g en Jalisco. Cuando se incrementa la edad de primera captura a cuatro años se obtienen rendimientos por recluta de y/r = 383.2 g en Colima y un y/r = 389 g en Jalisco. Se recomienda ampliar el tamaño de malla de las redes de captura, lo que incrementará el tamaño y edad de los organismos capturados.
Palabras clave: Captura, mortalidad, tasa de explotación, rendimiento por recluta, *Gerres cinereus.*

Introduction

The Yellowfin Mojarra *Gerres cinereus* (Walbaum 1792) (Fig. 1) occurs in the Western Atlantic and Eastern Pacific. In the Mexican Pacific it is distributed 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 & Robertson 1994, Bussing 1995).

Few studies have analyzed biological aspects of *Gerres cinereus* (Espino-Barr *et al*. 2014), but for the first time aspects of its fishery analysis in the coasts of Colima and Jalisco is shown. Several objectives were followed to compare this fishery in Colima and in Jalisco: *a*) Capture statistics showed the fluctuations of the fishing volumes obtained from the years 1980 to 2013 and

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Fig. 1. Yellowfin Mojarra *Gerres cinereus*.

the changes in production. Also, seasonal variations were analyzed, and those months with the highest catch. *b*) Determination of the age and length of first capture, that give information on the age groups that support most captures and in the case of that these are organisms that have not yet reproduced, can take the population to an overexploitation and extinction danger (Cabral-Solís *et al*. 2007, Espino-Barr *et al*. 2012). *c*) Total mortality was analyzed, considering its both components: natural and fishing mortality, which represent the subtractive factors of the population that make it lower its biomass per unit of time and provides important information on the continuity of the stock in time and space (Stein *et al.* 1975, Gobert 1994, Gray 2002, Gray *et al*. 2005, Clavero *et al.* 2006, Gallardo-Cabello *et al*. 2007, Espino-Barr *et al*. 2008). *d*) Determination of the exploitation index that describes the health level of the population through the balance between natural and fishing mortality (Gulland 1964, Sparre & Venema 1995, Gallardo-Cabello *et al.* 2007, Espino-Barr *et al.* 2012). *e*) Analysis of the values of the yield per recruit, which show the actual values of the fishery and model to obtain the optimum value for the population, so the captures increase without affecting the recruitment mechanism of the species (Beverton & Holt 1957, Hernández-Montaño *et al*. 2006, Cabral-Solís *et al*. 2007, Gallardo-Cabello *et al.* 2007, Espino-Barr *et al*. 2012). The analysis of this information will help improve the fishery assessment, and the differences found in both areas are discussed.

Materials and methods

From April 2010 to November 2011, individuals of *G. cinereus* were obtained monthly from the commercial captures from the coastal fishery in Manzanillo, Colima, Mexico (19° 00' to 19° 02' N and 104° 10' to 104° 21' W) and in Tomatlan, Jalisco, Mexico (19° 58' to 20° 04' N and 105° 26' to 105° 32' W) (Fig. 2). Individuals were captured with gillnets of different sizes: 2.5-3.0 inches (6.5-7.62 cm) in Colima and 3.5-4.0 inches (8.89-10.16 cm) in Jalisco, which resulted in the capture of a diversity of different length sizes and age groups. Total length (TL, cm) and weight (TW, g) of 427 individuals were measured. Of these, 179 were transported to the fish laboratory of the Instituto Nacional de Pesca, where total (TL, cm), standard length (SL, cm), total (TW, g) and eviscerated weight (EW, g) and sex were recorded macroscopically for each specimen.

The results of the parameters of the growth analysis obtained by Espino-Barr *et al*. (2014) and Espino-Barr *et al.* (submit) and used in this paper were: L_∞ = 56.4 cm, K = 0.208, t_o = -0.669. Mean size for each age are: age one = 16.6 cm, age two = 24.1, age three = 30.2, age four = 35.1, age five = 39.1 cm, age six = 42.4 cm and age seven = 45.0 cm. The allometric index from the weight-length relationship was positive, b = 3.193, and the Y intercept a = 0.006. Longevity was obtained by Taylor method (1958, 1960) $A_{0.95}$ = 13.73 years (Espino-Barr *et al*. 2014).

The source of information was the Notice of Arrival or Landing Reports (Aviso de Arribo), which is the official statistical information provided by fishers with species name and capture quantities (kg per month), and collected in the Fisheries Bureau (Oficina de Pesca).

Values of individual total length (cm) obtained during monthly samplings (April 2010 to November 2011) were used to calculate length at first capture ($L_{0.5}$) and recruitment length ($L_{0.25}$), by means of the accumulated frequency. The logistic function was described by Gaertner & Laloe (1986) and Sparre & Venema (1995) as follows:

$$H_P = \frac{1}{1 + e^{a+b*Lt}} \qquad \text{Ec. 1}$$

where: H_P = percentage of individuals, a and b are constants. Its logarithmic transformation is: ln 1 (1/Hp-1) = a-b·Lt and the length at which 50% of the population is fished ($L_{0.5}$) is: $L_{0.5}$ = a/b.

Linearized catch curve method was used to estimate the total mortality coefficient (Z) by

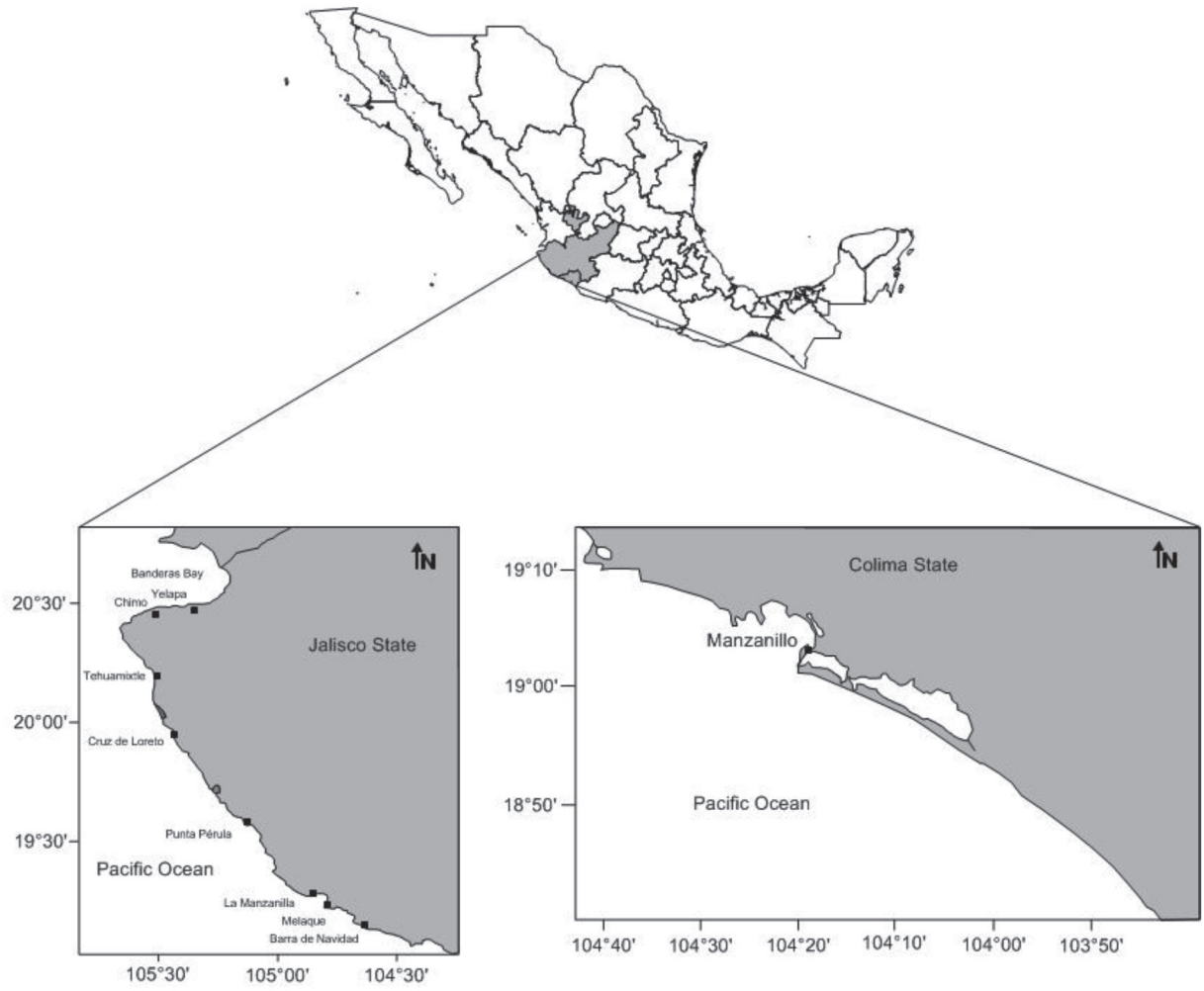

Fig. 2. Study area: coast of Colima and Jalisco.

plotting age groups versus natural logarithm of the relative abundance of each group (Sparre & Venema 1995), where *x* correspond to age groups and *y* to natural logarithm of relative abundance for each age group.

Survival rate was obtained by the equation: $S = e^{-Z}$ (Ricker 1948, Ehrhardt 1981, Sparre & Venema 1995). Natural mortality (M) was estimated using the Taylor's method (1958, 1960): $M = -Ln(1-0.95)/A_{0.95}$, where $A_{0.95}$ is longevity based on the von Bertalanffy growth parameters (von Bertalanffy 1938). Also M was calculated using other methods: Pauly's equation (1980) $Ln\ M = -0.0152 - 0.279 \cdot Ln\ L_\infty + 0.6543 \cdot Ln\ K + 0.463 \cdot Ln\ T$, T = average temperature; Jensen's method (1997) $M = 1.5 \cdot K$; and the indirect method of Hoenig (1983) $Ln\ Z = 1.46 - 1.01 \cdot Ln\ T_{max}$, where at old ages $Z \approx M$, and T_{max} = maximum age.

Exploitation rate was determined as $E = F / Z$ (Sparre & Venema 1995) and the yield per recruit (Beverton & Holt 1957) with the equation:

$$y/r = F * e^{-Mr'} * W_\infty \left(\frac{1}{Z} - \frac{3e^{-Kr'}}{Z+K} + \frac{3e^{-2Kr'}}{Z+2K} - \frac{e^{-3Kr'}}{Z+3K}\right) \qquad \text{Ec. 2}$$

where: y = catch or yield, r = recruit, F = fishing mortality, M = natural mortality, $r' = t_r - t_0$ time between recruitment and the hypothetic t_0, W_∞ = corresponding weight to asymptotic length L_∞, Z = total mortality, and K = growth coefficient.

Results

Official data of annual catch for the years 1980 to 2013 in Colima show an interannual variation (Fig. 3), being more abundant in 1980, 1984, 1989, 1994, 1998, 2002, 2007, 2009 and 2011. Maximum catch of 37 tons was obtained during 1980. In other years the maximum catch ranked from 6 to 25.6 tons.

In the case of Jalisco data were obtained from 1992 to 2013. From 1992 to 2002 the capture was lower than 100 tons, but from 2003 to 2013 values increased, reaching maximum values during 2003, 2004, 2006, 2008 and 2012, ranking from 181 to 312 tons (Fig. 3).

Monthly average captures in Colima were from 0.56 tons in December to 1.37 tons in June. The lowest value was of 0.01 tons in June of 1991 and the highest was 6.8 tons in September 2008 (Fig. 4a). In the case of Jalisco, monthly averages were from 5.8 tons in December to 12.2 tons in March. The lowest value obtained was 0.48 tons in June of 1993 and the highest was 57.6 tons in February of 2004 (Fig. 4b).

The recruitment length ($L_{0.25}$) and the length of first capture ($L_{0.5}$) of *G. cinereus* in both States were different: in Colima these sizes were $L_{0.25}$ = 22.4 cm and $L_{0.5}$ = 23.8 cm, and in Jalisco were $L_{0.25}$ = 24.0 cm and $L_{0.5}$ = 26.2 cm, which correspond to organisms between ages one and two (Table 1, Fig. 5).

Table 1
First capture and recruit lengths, weight and age of *Gerres cinereus* in Colima and Jalisco, Mexico

	Length (cm)	*Weight (g)*	*Age (years)*
		Colima	
$L_{0.25}$	22.40	122.8	1.75
$L_{0.5}$	23.80	149.1	1.95
		Jalisco	
$L_{0.25}$	24.00	153.2	1.98
$L_{0.5}$	26.20	202.7	2.32

An ascendant slope from ages one to 3.3 years for data from Colima and one to 3.96 years in Jalisco is shown in the catch curves of *G. cinereus*. The right descendant side corresponds to ages with a complete recruitment to the fishing gears (Fig. 6). The regression equations calculated to obtain the slopes were for Colima: $y = 13.886 - 2.44x$, $r^2 = 0.842$, $n = 9$ and Jalisco: $y = 10.679 - 0.91x$, $r^2 = 0.963$, $n = 12$. Total mortality of *G. cinereus* at ages between 3.3 and five years was 2.44 in Colima and the survival rate was $S = 0.087$. In the Jalisco case total mortality for ages from 3.96 to 12 years was $Z = 0.91$ and the survival rate $S = 0.403$ (Table 2).

Results on natural mortality varied from one method to the other: Taylor's method gave $M = 0.218$; Pauly's method gave $M = 0.522$; with Jensen's method $M = 0.312$; and with Hoenig's

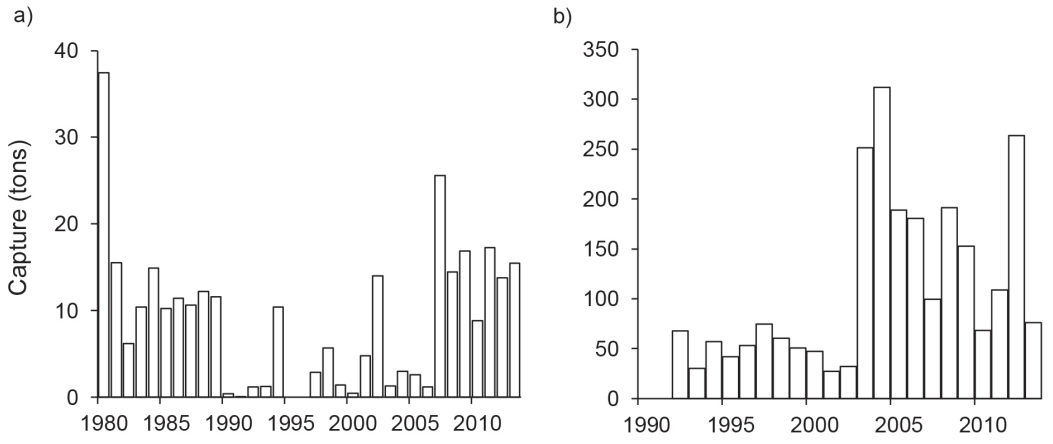

Fig. 3. Total catch of *Gerres cinereus* in *a*) Colima (1980 to 2013) and *b*) Jalisco (1992 to 2013), Pacific coast of Mexico.

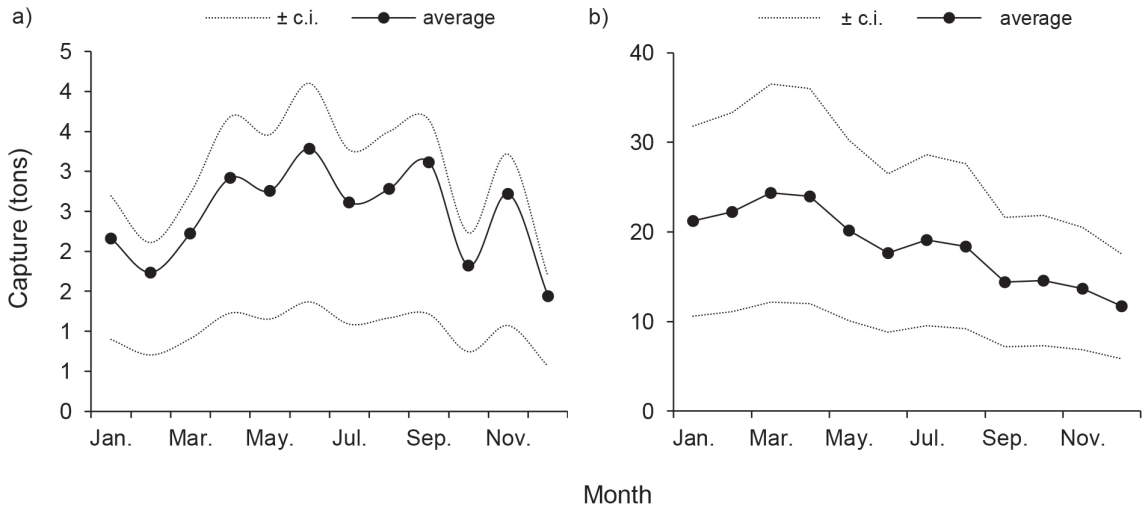

Fig. 4. *Gerres cinereus* monthly catch in *a*) Colima and *b*) Jalisco, from 1992 to 2013 (c.i. = confidence interval).

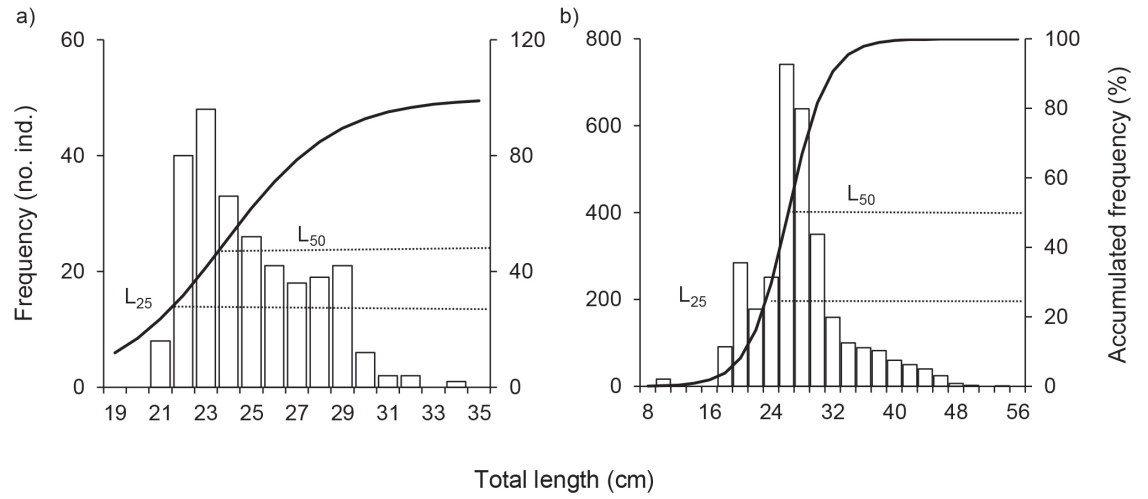

Fig. 5. Length distribution and size of first capture: *a*) Colima, *b*) Jalisco.

method M = 0.305. The present study used Taylor's method, because it was the lowest.

Natural mortality rate of *G. cinereus* was M = 0.218, for both cases, Colima and Jalisco, therefore fishing mortality was F = 2.222 for Colima and F = 0.692 for Jalisco. Values of calculated exploitation rate were E = 0.9107 for Colima and E = 0.7604 for Jalisco, higher in both cases than E = 0.5 suggested by Gulland (1964) to be a healthy fishery (Table 2).

Table 3 shows the parameter values used in the model of yield per recruit (y/r). The calculated values were for Colima y/r = 260.7g with a value of current fishing mortality F = 2.222, while for Jalisco were y/r = 315.9 g for F = 0.690. The highest values that could be obtained without changing the fishing method would be reducing the fishing mortality to F = 0.38 (Fig. 7) and obtaining y/r = 331.10 in both cases.

A simulation of y/r changing values of age at first capture (Tc) and different values of fishing mortality (F) shows that for Colima the actual value Tc = 1.95 years correspond to y/r = 260.7 g, if this age is increased to Tc = 4 years then y/r = 383.2 g. In the case of Jalisco the actual value of Tc = 2.32 years corresponds to y/r = 316 g; if this age is increased to Tc = 4 years, then y/r = 389 g (Fig. 8).

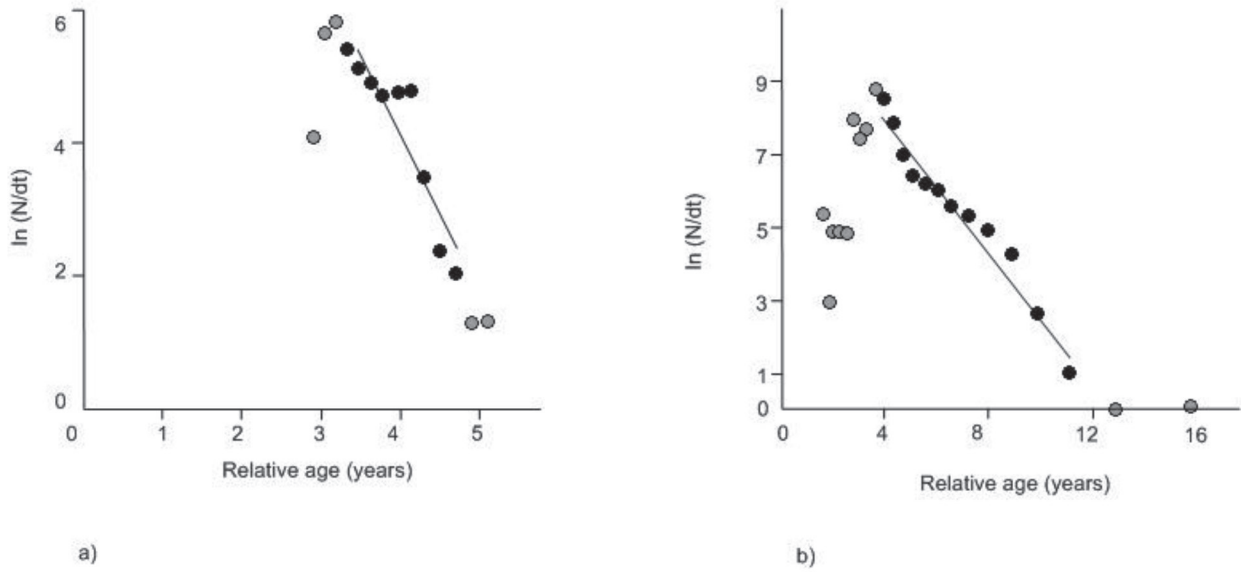

Fig. 6. Length-converted catch curves: *a*) Colima; *b*) Jalisco.

Table 2
Population parameters of *Gerres cinereus* in Colima and Jalisco, Mexico

Parameter	*Colima*	*Jalisco*
L_∞	56.43	56.43
k	0.208	0.208
t_o	-0.669	-0.669
z	2.440	0.910
m	0.218	0.218
f	2.222	0.692
s	0.087	0.403
longevity (years)	13.73	13.73
Survival %	8.72	40.25
Total mortality %	91.28	59.75
If Z =	100.00	100.00
dead by fishing	91.07	76.04
dead by natural causes	8.93	23.96
e = f/z	0.9107	0.7604

Tabla 3
Parameters and values of Beverton & Holt (1957) yield per recruit model

Parameter	*Value*
K (years $^{-1}$)	0.208
M (years $^{-1}$)	0.218
Tc	2.320
Tr	1.980
Wmax (g)	2 348.100

Note: Tc = age of first capture; Tr = age of recruitment.

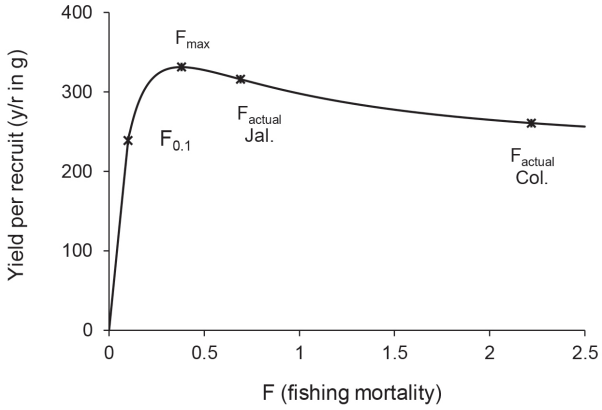

Fig. 7. Actual yield per recruit of *Gerres cinereus* in the coastal fisheries of Jalisco and Colima.

Discussion

Even though the Yellowfin Mojarra fishery does not represent high captures, it is an important protein source for the coastal communities of Colima and Jalisco. Its cost can reach $30.00 pesos per kg (one to two dollars per kilogram), and therefore is available to an important number of people, because of its low cost. It is consumed almost directly and mainly locally; it does not go through industrial process.

Total catch of this species has increased in the last years, since 2002 in the case of Jalisco and since 2005 in Colima. The highest catch in Jalisco was of 312 tons, and in Colima of 37 tons.

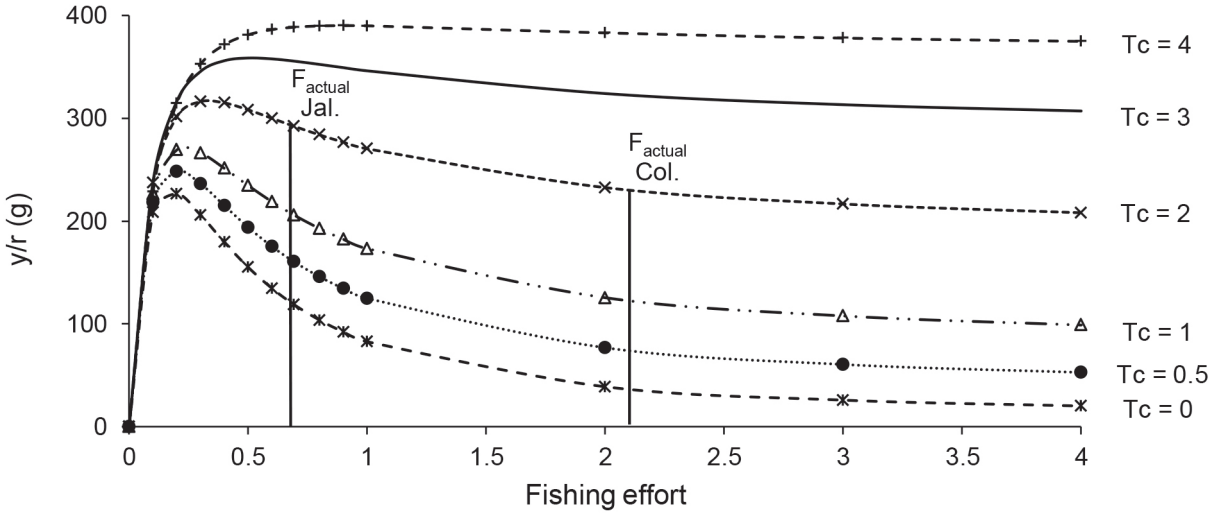

Fig. 8. Simulation of yield per recruit simulation with different ages of first capture of *Gerres cinereus*.

This difference can be related, among other reasons, to the coastal length of each State: Jalisco is 350 km long and Colima 157 km; but also because of the fishing activity, which is with gears of different mesh sizes: in Jalisco a bigger mesh is used (3.5-4.0 inches, 8.89-10.16 cm), and in Colima of 2.5-3.0 inches (6.5-7.62 cm).

In Colima the highest captures are obtained between April and September, this is, during spring and summer, reducing in autumn and winter. In the coasts of Jalisco, the highest captures are obtained from January to August, which is winter, spring and first part of summer, declining during part of summer and autumn.

There are important differences of lengths and ages of first captures. While in Colima it occurs at the age of 1.95 years and a length of 23.80 cm, in Jalisco it occurs at the age of 2.32 years and a length of 26.20 cm, which is related with the mesh size of the gill nets. These nets have a mesh size of 2 inches (5.08 cm) in Colima and of 4 inches (10.16 cm) in Jalisco.

In both cases (Colima and Jalisco), the lengths of first capture were higher than the first maturity length $L_{0.25}$ = 15.80 cm in males and 16.50 cm in females, and the length of first reproduction $L_{0.5}$ = 16.40 cm in males and 20.20 cm in females, both in their first year of age. According to this, the captured organisms have reproduced at least once, which ensures the population recruitment.

Total mortality of *G. cinereus* in Colima was higher than that found in Jalisco. In Colima, of every 100 fish of *G. cinereus*, 91 die by fishing pressure and nine of natural mortality, that is, predation, sickness and old age. Instead, in Jalisco of every 100 fish, 76 die by fishing pressure and 24 by natural mortality. This is related to the length and age of first capture, which in Colima occurs at 23.80 cm and an age of 1.95 years, and in Jalisco at a length higher than 26.20 cm and an age of 2.32 years. This means that the recruitment is higher in Jalisco and young organisms have better possibilities to reproduce, while in Colima individuals are caught younger.

Natural mortality was obtained by several methods, which were proposed by different authors based on theories. Some of these have been used largely. The results vary according to the method, and we recommended one result. With the Taylor method, the value of M was smaller, which implies that F is higher. This species is fished continually without any regulation, which suggests that a high F is a better assumption.

Table 4 shows the natural mortality values of *G. cinereus* in different localities, it is observed that the values of this species in Quintana Roo (Álvarez-Hernández 1999) and Cuba (Claro & García-Arteaga 2001) are higher than those reported in this study. It is important to note, that according to Taylor (1958, 1960), as the value of the K index increments, the values of infinitum length and the longevity diminish, and therefore the natural mortality increases. This means that the fish can reach faster the value of asymptotic

length, live fewer years and increases its natural mortality due to predation. Taylor (1958, 1960) also mentions that at lower latitude and increase of temperature, augments the value of K index and natural mortality. We observed that at the increase of latitude and temperature, the value if the K index went from 0.208 in Colima and Jalisco to 0.341 in Quintana Roo (Álvarez-Hernández 1999) and 0.65 in the coasts of Cuba (Claro & García-Arteaga 2001), with the same increase in the values of natural mortality.

Table 4
Natural mortality and growth parameters of the von Bertalanffy equation for *Gerres cinereus* reported by different authors (M, longevity and ϕ' values were calculated by us)

	This study 2011	*Álvarez-Hernández (1999)*	*Claro & Garcia-Arteaga (2001)*
Area	Colima, Mexico	Quintana Roo, Mexico	Cuba
Method	Otoliths	Length frequency and scales	Length frequency
L_∞ (cm)	56.43	36.00	28.00
k	0.208	0.341	0.650
t_o	-0.669	-1.030	0.000
Longevity (years)	13.73	7.78	4.61
m	0.218	0.385	0.650
ϕ'	2.822	2.646	2.707

The longevity of this species in Quintana Roo is practically half of that reached in the coast of Colima and Jalisco, and a third of that presented in Cuba.

Gulland (1964) established that the optimum exploitation rate occurs when $F = M$, that is, $E = 0.5$, which means that 50% of the biomass of the population is being fished. In the case of Colima, this exploitation rate is very high: $E = 0.911$, and fairly high in Jalisco $E = 0.760$. Because of these high values, the fishing mortality can be reduced by using gillnets with larger mesh sizes, to allow the lengths and first capture age to increase from 1.95 years in Colima and 2.32 years in Jalisco, to four years in both cases, with which the fishery yields would increase and the stock would be protected allowing a higher recruitment by increasing the ages and reproduction periods.

It is important to note that the population of *G. cinereus* in the coasts of Jalisco is healthier than that of Colima: in the first case captures are higher, lengths and first capture ages are higher en the exploitation rate E closer to $E = 0.5$.

In this study we suggest that the mesh size should be enlarged to increase the sizes of *G. cinereus,* which would also allow the intensification of the fishing effort, protecting the stocks of a possible overexploitation.

Conclusions

The fishery of *Gerres cinereus* is healthier in the coasts of Jalisco than those of Colima. An increase in the mesh sizes to four inches (10.16 cm) would increase the recruitment and the yield per recruit of the fishery.

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