Fishery analysis of *Diapterus brevirostris* in the central Mexican Pacific

Análisis de la pesquería de *Diapterus brevirostris* en el Pacífico central mexicano

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Abstract

From April 2010 to July 2012 data and samples on the biology and the fishery of *Diapterus brevirostris* (Teleostei: Gerreidae) were collected in the coasts of Colima and Jalisco. Total catches show fluctuations in the last twenty years in Colima. The catches in Jalisco do not show this species alone, but mixed with other "Mojarras" during the last eleven years. The highest catches in Colima and Jalisco are obtained during summer. First age and length of capture was at 2.04 years and 15.00 cm in Colima and 2.98 years and 19.80 cm in Jalisco. Total mortality was Z = 2.06 in Colima and Z = 1.96 in Jalisco. Natural mortality was M = 0.139 in both cases. Fishing mortality was F = 1.921 in Coli-

Resumen

Durante el periodo de abril de 2010 a julio de 2012 se obtuvieron datos y muestras biológicas de *Diapterus brevirostris* (Teleostei: Gerreidae) en las costas de Colima y Jalisco. Las capturas totales mostraron fuertes fluctuaciones en los últimos 20 años en Colima. En Jalisco, su registro está agregado al rubro de mojarras en los últimos 11 años. Las más altas capturas se obtienen en Colima y Jalisco durante el verano. La edad y talla de la primera captura fue de 2.04 años y 15.00 cm en Colima, 2.98 años y 19.80 cm en Jalisco. La mortalidad total fue Z = 2.06 en Colima y Z = 1.96 en Jalisco. La mortalidad natural fue M = 0.139 en ambos casos. La mortalidad por pesca fue F = 1.921 en Colima y F =

Gallardo-Cabello *et al*. Aia. 2015. 19(1): 77-93
Issn 0188789-0

ma and F = 1.821 in Jalisco, with a survival rate of S = 0.127 in Colima and S = 0.141 in Jalisco. Exploitation rate was E = 0.933 in Colima and E = 0.929 in Jalisco. Yield per recruit was y/r = 106.47 g in Colima and y/r = 107.5 g in Jalisco. Increasing the age of first capture to four years old will get a y/r = 146.5 g for Colima and a y/r= 148.2 g for Jalisco.

Keywords

Capture, mortality, exploitation rate, yield per recruit, shortnose mojarra, *Diapterus brevirostris*.

1.821 en Jalisco, con una tasa de sobrevivencia de S = 0.127 en Colima, y S = 0.141 en Jalisco. La tasa de explotación fue E = 0.933 en Colima y E = 0.929 en Jalisco. El rendimiento por recluta fue y/r = 106.47 g en Colima y y/r = 107.5 g en Jalisco. Incrementando la edad de primera captura a cuatro años de edad se obtendrían rendimientos por recluta de y/r = 146.5 g en Colima y y/r= 148.2 g en Jalisco.

Palabras clave

Captura, mortalidad, tasa de explotación, rendimiento por recluta, malacapa, mojarra de aletas amarillas, *Diapterus brevirostris*.

Introduction

Shortnose Mojarra *Diapterus brevirostris* (Sauvage, 1879) (figure 1) occurs in the Eastern Pacific, tropical, from the western coast of Baja California (Bahia Magdalena, including Gulf of California), to northern Peru (Bussing, 1995). This species used to be named *Diapterus peruvianus*, but its former name was reinstated, after a thorough review (González-Acosta *et al*., 2007). Body is rhomboidal, and laterally compressed, silvery color in fresh specimens, protractile mouth. Its habitat is on sandy bottoms close to reefs; it also penetrates brackish coastal lagoons. Juveniles form big schools. This species is mainly carnivorous, it consumes small benthic invertebrates, insects and fish (Castro-Aguirre, 1978; Allen and Robertson, 1994; Bussing, 1995; Castro-Aguirre *et al*., 1999).

Figure 1
Shortnose Mojarra *Diapterus brevirostris*.

The present study gives, for the first time, information on the fishery characteristics of *D. brevirostris* in the shores of Colima and Jalisco. The main objectives were:

a) Analysis of the capture statistics from 1980 to 2013 in Colima and from 1992 to 2000 in Jalisco, considering also monthly variations.

b) Determination of the age and length of first capture, trying to know which age groups support most captures and if they have reproduced at least once. The capture of organisms that have not reproduced at least once can endanger a stock by breaking the regulation mechanisms, and omit recruitment; therefore the fishery should be on the adult organisms, from at least two years old (Gallardo-Cabello *et al*., 2007; Espino-Barr *et al*., 2008).

c) Calculation of the total mortality index by means of the catch curves analysis, for those age groups that have completely recruited to the fishing gear, and analyzing the descending side of the curve. With these results, data on fishing mortality can be obtained by subtracting from the total mortality, the natural mortality obtained by Taylor's method, based on the species longevity (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) The determination of the exploitation rate E, which describes the balance between natural and fishing mortality, and is used to describe the population health. Gulland (1964) established that the E index should be 0.5 or near this value, so that the population is in optimum conditions and overfishing is avoided (Sparre and Venema, 1995; Gallardo-Cabello *et al.*, 2007; Espino-Barr *et al.*, 2012).

e) Calculation of the yield per recruit values to establish the population exploitation state, according to the fishing mortality values and the minimum catch lengths, trying to avoid overfishing, by extracting organisms that have not yet reproduced and stopping the inflow of recruits (Beverton and Holt, 1957; Hernández-Montaño *et al*., 2006; Cabral-Solís *et al*., 2007; Gallardo-Cabello *et al.*, 2007; Espino-Barr *et al*., 2012).

This information will help with basic data to assess the fishery of this resource and design corresponding rules.

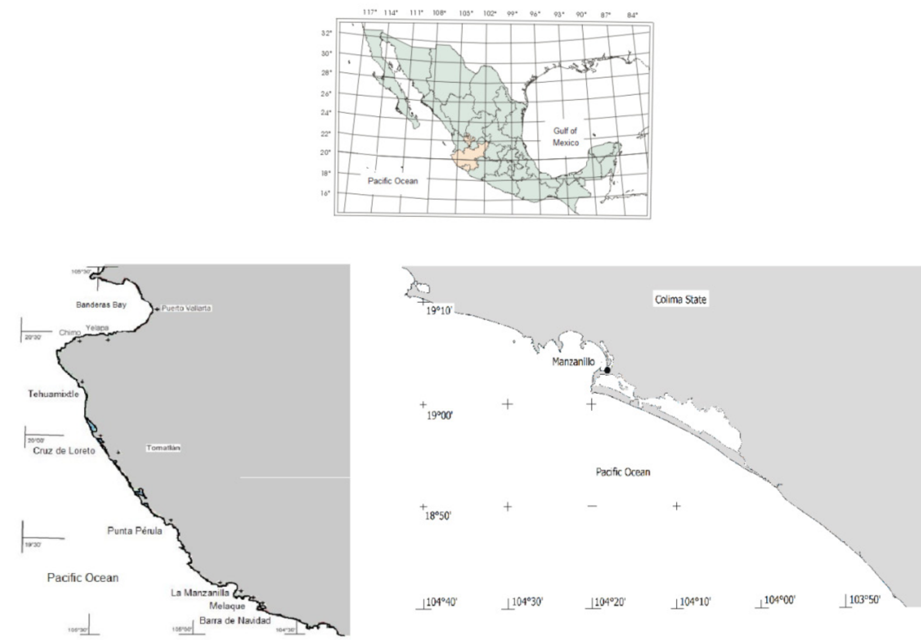
Materials and methods

From April 2010 to July 2012, data on 1,886 individuals of *D. brevirostris* were obtained monthly from the commercial captures of the artisanal 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) (Fig. 2). Total length (TL, cm) and weight (TW, g) of 1,886 individuals were measured. Of these, 394 were transported to the fish laboratory of the National Fishery Institute, where total (TL, cm) and total weight (TW, g) were registered and sex recorded macroscopically for each specimen, for other studies. Authors made the sampling work to be sure that the species is correct.

Individuals were captured with gillnets of different sizes: 2.50-3.00 inches (6.50-7.62 cm) in Colima and 3.50-4.00 inches (8.89-10.16 cm) in Jalisco, which resulted in the capture of an ample range of different length sizes and age groups.

The results of the parameters of the growth analysis obtained by Gallardo-Cabello *et al*. (2014) and used in this study were: $L_\infty = 48.61$ cm, $K = 0.135$, $t_o = -0.696$. Mean size for each age group are: age one = 9.97 cm, age two = 14.86, age three = 19.13, age four = 22.87, age five = 26.12 cm, and age six = 28.97 cm. The allometric index from the weight-length relationship was isometric, b = 2.997. Longevity was obtained by Taylor method (1958, 1960) $A_{0.95} = 21.5$ years (Gallardo-Cabello *et al*., 2014).

Figure 2
Study area: coast of Colima and Jalisco.



The information source used for the catch analysis was: Notice of Arrival (Aviso de Arribo), which is the official statistical information provided by fishers with species common 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 sampling trips (April 2010 to July 2012) 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 and Laloe, 1986; Sparre and Venema, 1995):

$$H_P = \frac{1}{1+e^{a+b*Lt}}$$

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 plotting age groups versus natural logarithm of the relative abundance of each group (Sparre and Venema, 1995), where *x* corresponds to each group of age, and *y* to natural logarithm of relative abundance for each age group. Regression equations were obtained by least squares and a 95% confidence interval of the descending slope *b* parameter was calculated (Zar, 1996).

Survival rate was obtained by the equation: $S = e^{-Z}$ (Ricker, 1948; Ehrhardt, 1981; Sparre and Venema, 1995). Natural mortality (M) was estimated by using Taylor's method (1958, 1960):

$$M = -Ln(1-0.95)/A_{0.95}$$

Where: $A_{0.95}$ = longevity based on the von Bertalanffy growth parameters (1938).

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

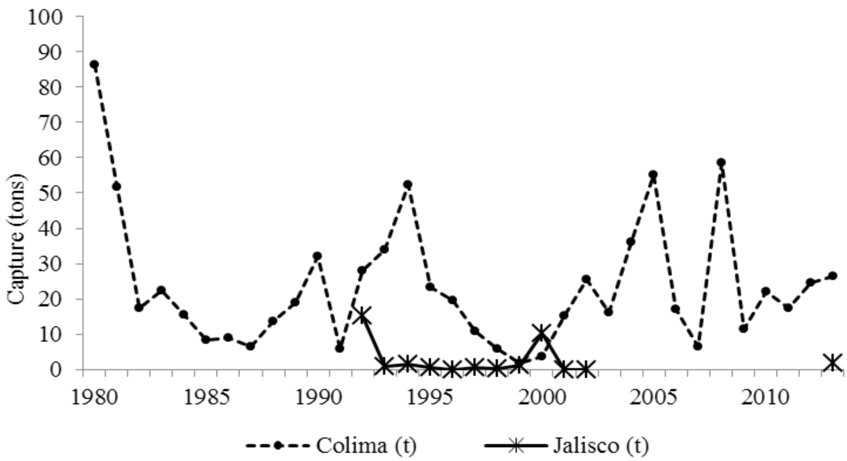
$$y/r = F * e^{-Mr'} * W_{\infty} \left(\frac{1}{Z} - \frac{3e^{-Kr'}}{Z+K} + \frac{3e^{-2Kr'}}{Z+2K} - \frac{e^{-3Kr'}}{Z+3K}\right)$$

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 coast show that the volume varied widely during this period (figure 3), being more abundant in 1980, 1981, 1990, 1994, 2002, 2005, 2008 and 2013. Maximum catch was in 1980, when 86.30 tons were caught. In other years the maximum catch ranked from 25.60 to 58.50 tons.

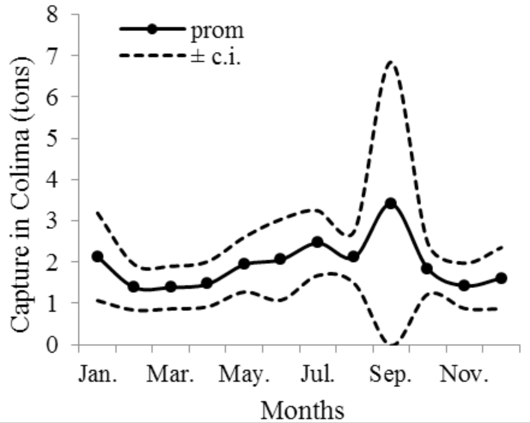
Figure 3
Total catch of *Diapterus brevirostris* in Colima and Jalisco, Pacific coast of Mexico. Colima from 1980 to 2013 and Jalisco from 1992 to 2013.



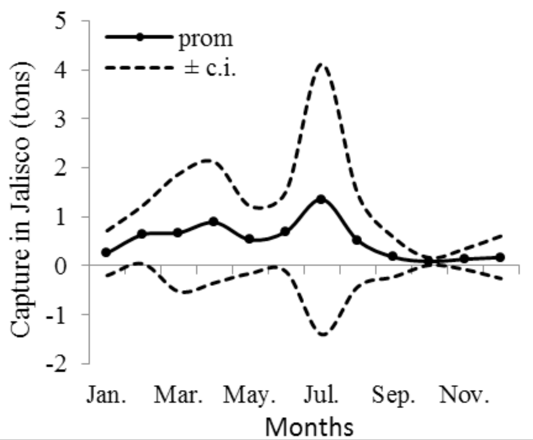
In the case of Jalisco data were obtained from 1992 to 2000. From 2001 to 2012 the capture was not registered until 2013. In 1992 the capture was of 15.30 tons and 10.10 tons in 2000. Values were very low for the other years, inferior to 2.00 tons (figure 3). There are no official data on fishing effort or catch per unit of effort. *D. brevirostris* capture is part of a multispecific fishery.

Monthly average captures in Colima, are from 1.40 tons in February, March, and November to 3.40 tons in September (figure 4a). In the case of Jalisco, monthly averages go from 0.10 tons in October and November to 1.40 tons in July (figure 4b).

Figure 4
Diapterus brevirostris monthly catch in a) Colima and b) Jalisco, from 1992 to 2013.



a)



b)

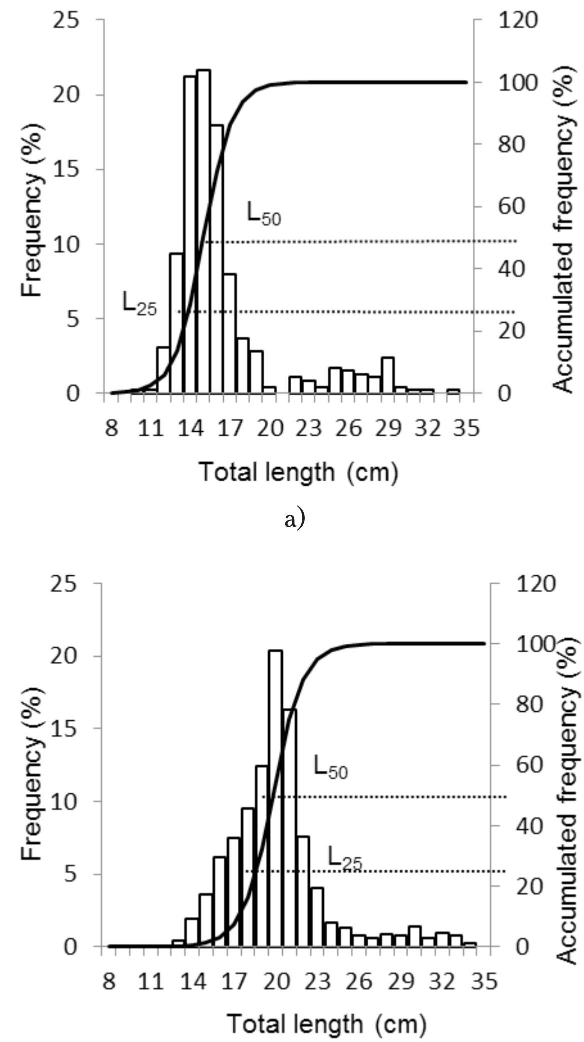
The recruitment length ($L_{0.25}$) and the length of first capture ($L_{0.5}$) of *Diapterus brevirostris* in both States were different: in Colima this size was $L_{0.25}$ = 13.8 cm and $L_{0.5}$ = 15.0 cm, and in Jalisco were $L_{0.25}$ =18.0 cm and $L_{0.5}$ = 19.8 cm, which correspond to fish between ages one and two (table 1, figure 5).

Table 1
Length, weight and age at first capture and recruitment of *Diapterus brevirostris* in Colima and Jalisco, Mexico.

	Length (cm)	Weight (g)	Age (years)
	Colima		
$L_{0.25}$	13.8	34.64	1.78
$L_{0.5}$	15.00	40.4	2.04
	Jalisco		
$L_{0.25}$	18.00	76.4	2.73
$L_{0.5}$	19.80	89.74	2.98

An ascendant slope from ages 2.40 to 3.43 years for Colima and 3.00 to 4.62 years for Jalisco is shown in the length frequency catch curves of *D. brevirostris*. The right descendant side corresponds to those ages whose recruitment to the fishing gears were complete (figure 6). The regression equations calculated to obtain the slopes were for Colima: $y = 12.64 - 2.01x$ ($CI_Z = 1.18 – 2.89$) ($R^2 = 0.794$, n= 10), and in Jalisco: $y = 16.00 - 1.96\ x$ ($CI_Z = 1.531 – 2.390$) ($R^2 = 0.965$, n = 7). Total mortality of *D. brevirostris* at ages between 3.65 and 5.74 years was Z = 2.06 in Colima and its survival rate was S = 0.127. In the Jalisco case total mortality for ages from 4.89 to 7.42 years was Z = 1.96 and the survival rate S = 0.141 (table 2).

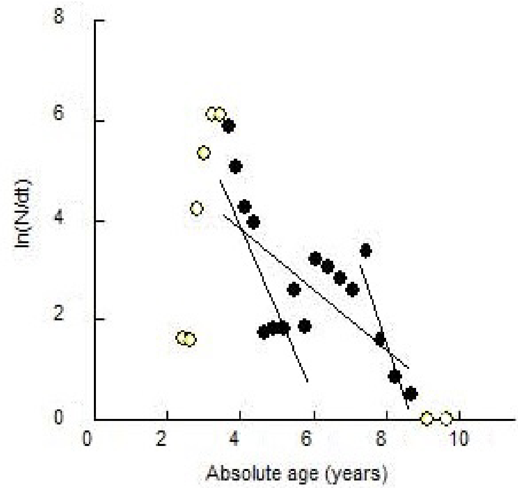
Figure 5
Length distribution and size of first capture: a) Colima, b) Jalisco.



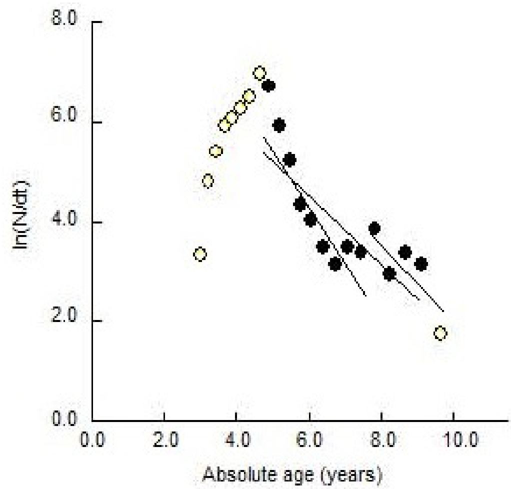
a)

b)

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



a)



b)

Table 2
Calculated parameters of the population dynamics of *Diapterus brevirostris* in Colima and Jalisco, Mexico.

	Colima	Jalisco
Parameter	Values	
L_∞	48.61	48.61
K	0.135	0.135
t_o	-0.696	-0.696
Z	2.06	1.96
M	0.139	0.139
F	1.921	1.821
S	0.127	0.141
Longevity (years)	21.49	21.49
Survival %	12.75	14.09
Total mortality %	87.25	85.91
If Z =	100.00	100.00
Dead by fishing	93.25	92.91
Dead by natural Causes	6.75	7.09
E = F/Z	0.9325	0.9291

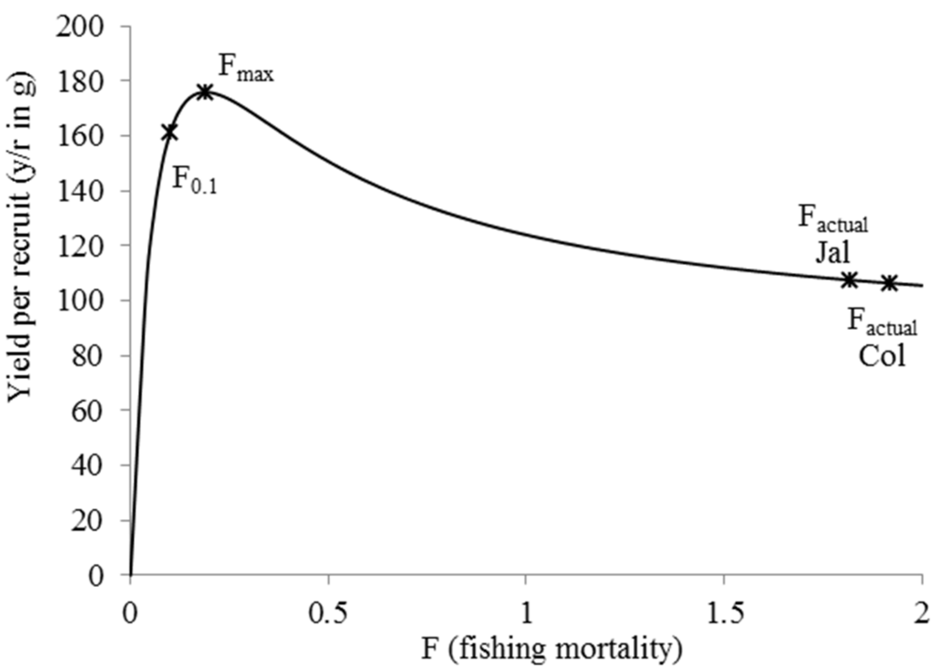
Natural mortality rate of *D. brevirostris* was M = 0.319, for both cases, Colima and Jalisco, therefore fishing mortality was F = 1.921 in Colima and F = 1.821 in Jalisco. Values of calculated exploitation rate were E= 0.9325 in Colima and E = 0.9291 in Jalisco, higher in both cases than E = 0.5 suggested 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 = 106.4.7g with a value of current fishing mortality F= 1.921, while for Jalisco were y/r= 107.5 g for F = 1.821. The highest values that could be obtained without changing the fishing method would be reducing the fishing mortality to F = 0.19 (figure 7) and obtaining y/r = 175.9 g in both cases.

Table 3
Parameters and values of Beverton and Holt (1957) yield per recruit model for *Diapterus brevirostris* in Colima and Jalisco.

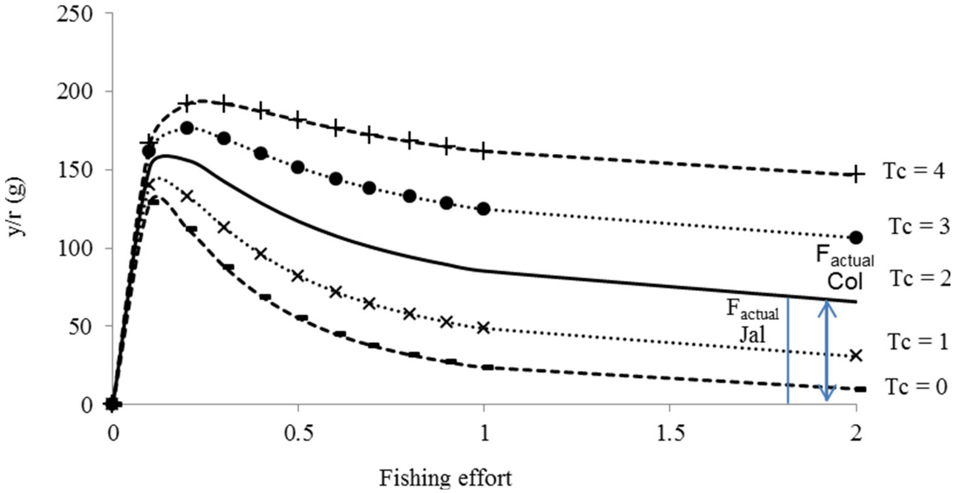
Parameter	Value
K (years -1)	0.135
M (years -1)	0.139
Tc	2.976
Tr	2.73
Wmax (g)	1,470.653

Figure 7
Yield per recruit of *Diapterus peruvianus* in the coastal fisheries of Jalisco and Colima



A simulation of y/r changing values of age at first capture (Tc) and different values of fishing mortality (F) shows that in Colima the actual value Tc = 2.976 years corresponds to y/r= 89.74 g; if this age is increased to Tc = 4 years, y/r = 146.5 g. In the case of Jalisco, the actual value Tc = 2.976 years corresponds to y/r= 108.5 g; if this age is increased to Tc = 4 years, y/r = 148.2 g (figure 8).

Figure 8
Simulation of yield per recruit simulation with different ages of first capture of *Diapterus brevirostris*.



Discussion

The Shortnose Mojarra fishery does not represent high captures, but it is valued by the coastal communities of Colima and Jalisco for its low price protein source and its good taste. Its cost can reach $30.00 pesos · kg^{-1} (one to two dollars per kilogram). It is consumed directly and mainly locally, without industrial process. In the case of Colima, the catch does not show a positive trend, but there are fluctuations that extend throughout the years. In the case of Jalisco, there are no statistical registers from 2001 to 2012 (in 2013, 1.78 tons), which is because *D. brevirostris* catches are registered with a common name of "mojarras" and include several species.

In Colima, the highest captures are obtained during September; this is, during summer, reducing in autumn and winter. In the coasts of Jalisco, the highest captures are obtained in July, which is summer declining during 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.

Total mortality of *D. brevirostris* in Colima is very similar to that found in Jalisco. In Colima and Jalisco, of every 100 fish of *D. brevirostris*, 93 die by fishing pressure and seven of natural mortality, that is, predation, sickness and old age. These results are referred to the individuals of *D. brevirostris* from the Cuyutlán Lagoon in Colima and of those in Tomatlán, Jalisco, which are of smaller sizes than those captured in the coastal seaside.

Organisms of this species stay in the lagoons till the approximate age of 5.74 years old in Cuyutlán, Colima and 7.42 years old in Tomatlán, Jalisco, and migrate to open sea after. According to this, outside the lagoons bigger sizes and ages are caught by the commercial fishery. Figure 6 a) and b) show the catch curves for all the organisms, that is, those in the lagoons, as those in the sea.

Their regression equations were: in Colima y = 6.51 - 0.63x (the confidence interval of Z, CI_Z = 0.268 - 0.997) (R^2 = 0.477, n=17); in Jalisco y = 8.79 - 0.69x (CI_Z = 0.35 – 1.03) (R^2 = 0.648, n = 13). Total mortality of *D. brevirostris* at ages between 3.65 and 8.65 years was Z = 0.63 in Colima and the survival rate was S = 0.53.

In the Jalisco case total mortality for ages from 4.89 to 9.6 years was Z = 0.69 and the survival rate S = 0.502. This means that for each 100 individuals, 77.94 die through fishing and 22.06 of natural mortality in Colima; in Jalisco of every 100 Shortnose Mojarras, 79.86 die by fishing and 20.14 by natural causes.

Considering only the older organisms taken from the sea, regression lines are: y = 16.2 - 1.8x (CI_Z = 0.51 - 3.11) (R^2 = 0.867, n=5) in Colima; and y = 10.817 – 0.90 (CI_Z = -0.248 - 2.045) (R^2 = 0.674, n = 5). So, of every 100 organisms in Colima, 92 die by fishing and nine by natural mortality; in Jalisco, of every 100 individuals, 85 are fished and 15 die of natural mortality.

According to this, total mortality in the lagoons is higher and reduces in older individuals in open sea. The coastal lagoons represent a smaller surface, where a higher concentration of organisms can exist, which have a higher growth rate due to a higher feeding dynamic, because of the material from rivers which increment food availability to the different categories of the feed web, and its lower salinity and higher concentrations of dissolved oxygen, which favor the growth of fish (Nikolsky, 1963; Margalef, 1980). Also the lagoons present a higher number of fishers and smaller mesh sizes in their gears: gillnets and cast-nets, all which increases the catches and present a higher mortality rate, compared to the open sea zones.

The length and age of first capture, occurs in Colima at 15.0 cm and an age of 2.04 years, and in Jalisco at a length higher than 19.8 cm and an age of 2.98 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.

Table 4 shows the natural mortality values of *D. brevirostris* in different localities, it is observed that the values of this species in Costa Rica (Cabrera-Peña *et al.*, 1996) 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, those of the infinitum length and longevity diminish, and therefore the natural mortality increases. This means that the fish can reach the value of asymptotic length faster, live fewer years and increase its natural mortality due to predation. Taylor (1958, 1960) also mentions that at lower latitude and increase of temperature, the value of K index and natural mortality increases. We observed that at the increase of latitude and temperature, the value if the K index went from 0.135 in Colima and Jalisco to K = 0.268 in Costa Rica (Cabrera-Peña *et al.*, 1996, Allen method) and K = 0.293 (Cabrera-Peña *et al.*, 1996, Tomlinson and Abramson method) with the same increase in the values of natural mortality.

Table 4
Growth parameters of the von Bertalanffy equation for *Diapterus brevirostris* obtained by different authors (longevity, natural mortality and ϕ' values were calculated by us).

	This paper	Cabrera-Peña *et al.*	Cabrera-Peña *et al.*
Year	2011	1996	1996
Area	Colima, México	Costa Rica	Costa Rica
Method	otoliths	Allen	Tomlinson and Abramson
L_∞ (cm)	48.61	31.9	32.3
K	0.135	0.268	0.293
t_o	-0.696	0.046	0.042
Longevity (years)	21.5	11.1	10.2
M	0.139	0.267	0.292
ϕ'	2.504	2.436	2.485

The natural mortality values of this species in Costa Rica are practically half of that reached in the coast of Colima and Jalisco.

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 high: E = 0.779, similar to that obtained for Jalisco E = 0.799. Considering only data of the lagoons, this index increases to E= 0.933 in Colima and E = 0.929 in Jalisco. With data obtained of individuals from the ocean side, E= 0.923 in Colima (similar to those in lagoons), and E = 0.846 in Jalisco, lower than in Colima, but still higher than that calculated for the total sample.

Because of these high values, the fishing mortality can be reduced by using gillnets with larger mesh size, to allow the lengths and first capture age to increase from 2.4 years in Colima and 3.0 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 *D. brevirostris* in the coasts of Jalisco is healthier than in Colima: in the first case captures are higher, lengths and first capture ages are higher and the exploitation rate E closer to E = 0.5.

Conclusions

The mesh size of the gillnet to fish *Diapterus brevirostris* should be enlarged to at least 4 inches (10.15 cm), which will allow an increase of the captures in weight, and protect the population of a possible overexploitation.

Acknowledgements

The authors wish to thank the fishermen who kindly proportionate the samples and always teach us something new on each species we study.

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Recibido: Octubre 15, 2014
Inicio de arbitraje: Noviembre 10, 2014
Dictamen para los autores: Enero 22, 2015
Aceptado: Febrero 27, 2015

Título: *Desenrollo*
Autor: Adoración Palma (2manoS)
Técnica: mixta (bolígrafo sobre monotipia en papel)
Año: 2014
Medidas: 10x30 cm