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Fishery Analysis of *Centropomus nigrescens*in Central Mexican Pacific

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Abstract:*From October 2013 to December 2015, 504 organisms of Centropomus nigrescens were taken directly from the commercial captures in the coasts of Colima and Jalisco, México. The highest average captures of C. nigrescens in Jalisco, occurred in April, July and December; in Colima it occurred in February, May, October and December. The recruitment length was Lr = 39.0 cm, length of first capture was Lc = 48.00 cm. Differences between sexes were: Lr = 63.8 cm for females and Lr= 48.0 for males, Lc = 76.40 cm for females and Lc = 58.00 cm for males. Total mortality for ages 3 to 15 years was Z = 0.33 and the survival rate was S = 0.72. Natural mortality rate was M = 0.14 and fishing mortality F = 0.19. The exploitation rate was E = 0.576. Increasing fishing mortality from F = 0.19 to F = 0.31 will increment the yield per recruit from 1 554 g to 1 605 grams. The age of 7 years produces the best yields. There is no other analysis of the fishery of C. nigrescens in the Mexican Pacific Ocean with which we could compare results; therefore we used data of the fishery of C. undecimalis, a parallel species in Campeche, the Gulf of Mexico. A ban is suggested during the reproduction season to protect them when they aggregate and are more vulnerable to the fishing gears.*

Key words: *Production, recruitment, first capture rate, total, natural and fishery mortality, exploitation rate, yield per recruit*

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I. Introduction

Members of the Centropomidae family inhabit fresh, brackish and marine waters, they are euryhaline; also these species present protandric sequential hermaphroditism, that is, they develop first as males and then as females. This makes the study of the life cycle much more difficult (Andrade *et al*. 2013, Espino-Barr *et al.* 2017).

The distribution on the black snook*Centropomus nigrescens*is determined by the surrounding salinity and temperature and they can live in waters as cold as 20°C for short periods. They tolerate a broad spectrum of salinity that goes from 0.07 ppm to 58.29 ppm, but prefer fresh water as young males, when they live in rivers, estuaries and coastal lagoons. *C. nigrescens*can live in fresh water with 0.00 ppm salinity (Martínez-Moreno pers. com.). They are very vulnerable to the effects of pollution (Muhlia-Melo*et al.* 1995). They are carnivorous that feed on small fish and crustaceans (Chávez 1963).

In the states of Jalisco and Colima, México, *C. nigrescens* is fished in the small scale fishery with small boats that stay near the coast. Different mesh size (from 6 to 8 inches) gill nets are placed in the surface of the sea up to 12 hours; in the coastal lagoons the mesh size is minimum of 3 inches. *C. nigrescens* is also captured with hand line with one or several hooks with lure or small shrimp as bait. They are also captured by diving with harpoon. The length of the gill nets is from 300 to 400 m long and their height it according to the fishing ground. Sport fishing uses lure and bait, and takes place from shore or trolling. The black snook is one of the fish with the highest commercial value and the current production does not satisfy the national demand.

Commercial catch registers are kept in the Fishing Offices of Puerto Vallarta and Barra de Navidad in Jalisco, and in Manzanillo in the state of Colima.

There are no studies on the fishery of the black snook*C. nigrescens*; Caballero-Chávez (2009, 2012) published data on the fishery of *C. undecimalis* (a parallel species) in the coasts of Campeche, México in the Atlantic Ocean.

In this study the following objectives were raised for the study of the fishery of *C. nigrescens* in the coasts of Jalisco and Colima: analyze annual and monthly captures from 2000 to 2017; calculate recruitment length, and of first capture; determine total, natural and fishing mortality, exploitation index and wellness degree of this fishery, yield per recruit and its simulation changing the age of first capture.

II. Material and Methods

The fishing grounds of the black snook in Manzanillo, Colima, México is located in 103°57'-104°19' W and 18°57'-19°50' N; and in Tomatlán, Jalisco,México in 105º27'-105º33' W and 19º58'-20º05' N (Fig. 1). From October 2013 to December 2015, 504 organisms of *C. nigrescens* were taken directly from the commercial captures in Colima and Jalisco, México, and taken to the laboratory of the Regional Fishery Research Center (CRIP) from the National Institute of Fishery and Aquaculture (INAPESCA). Organisms were captured with gill net, hand line, harpoon and cast nets, to obtain a stratified sample which includes all the age groups and size classes.

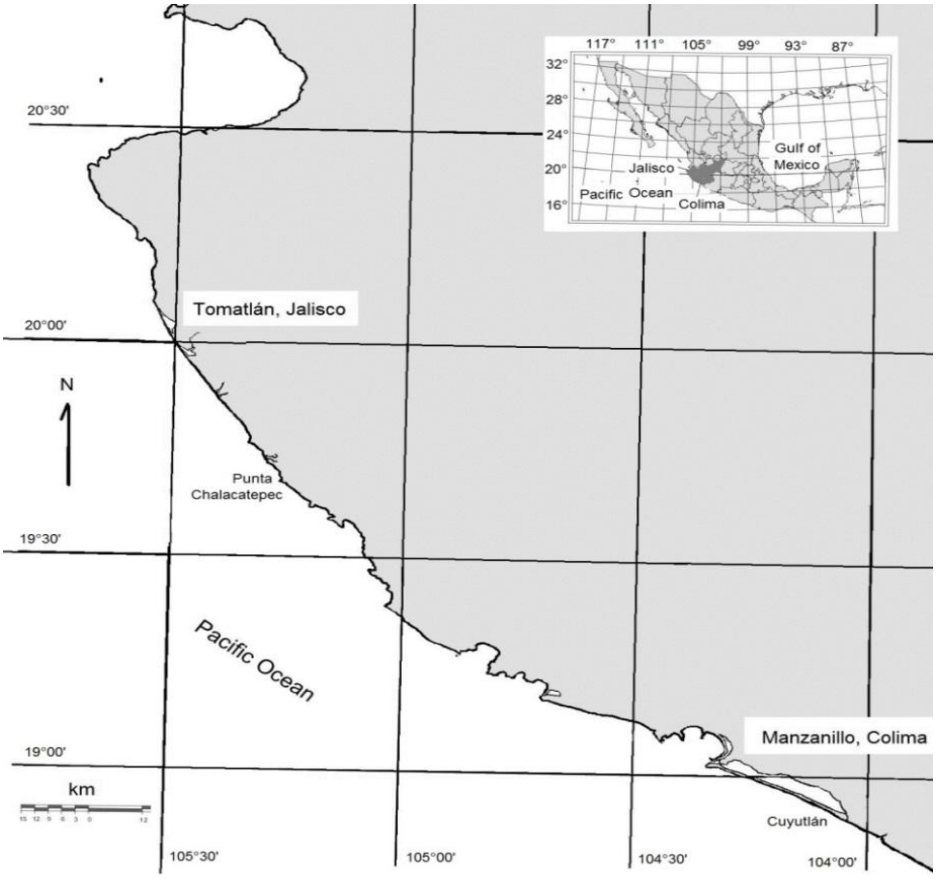


Figure 1. Study area of Colima and Jalisco States, Mexico (INEGI 2000).

In the laboratory, data taken from each organism were: total length (TL, cm), total weight (Wt, g), and eviscerated weight (We, g), and sex.

The results of growth parameters used in this paper were obtained by us and published (Espino-Barr *et al.* 2017). Growth parameters were: L_∞ = 103.55 cm, k = 0.14 and t_o = 0.00 obtained by otoliths reading and Ford-Walford-Gulland methods (Ford 1933, Walford 1946, Gulland 1964). The allometric index from the weight-length relationship was positive *b* = 3.161 with total weight and b = 3.154 with eviscerated weight. Longevity was obtained by Taylor's method (Taylor 1958, 1960): $A_{0.95}$ = 22.27 years.

The source of the capture 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), from 2000 to 2017 (SIPESCA 2017).

Values of individual total length (cm) were used to calculate length at first capture (L_{50} or Lc) and recruitment length (L_{25} or Lr), by means of the accumulated frequency. The logistic function is (Gaertner&Laloe 1986, Sparre&Venema 1995):

$$Hp = \frac{1}{1 + e^{a+b \cdot TL}}$$

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

Linearized catch curve method was used to estimate the total mortality coefficient (Z) by plotting *x* = age groups versus *y* = natural logarithm of the relative abundance of each group (Sparre&Venema 1995).

Survival rate was obtained by the equation: $S = e^{-Z}$ (Ricker 1948, Ehrhardt 1981). Natural mortality

(M) was estimated using the Taylor's method (Taylor 1958, 1960):
$M = -Ln(1-0.95)/A_{0.95}$,

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

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

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

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.

III. Results

Official data of annual catch for the years 2000 to 2017 in Jalisco and Colima show an inter-annual variation (Fig. 2), being more abundant in 2008, 2010, 2013, 2016-2017 in Jalisco, with a maximum catch of 111.5 t obtained during 2017. In Colima this fishery was abundant during the years of 2005, 2011-2015 with a maximum catch of 85.2 t in 2013. A general trend in Jalisco is positive.

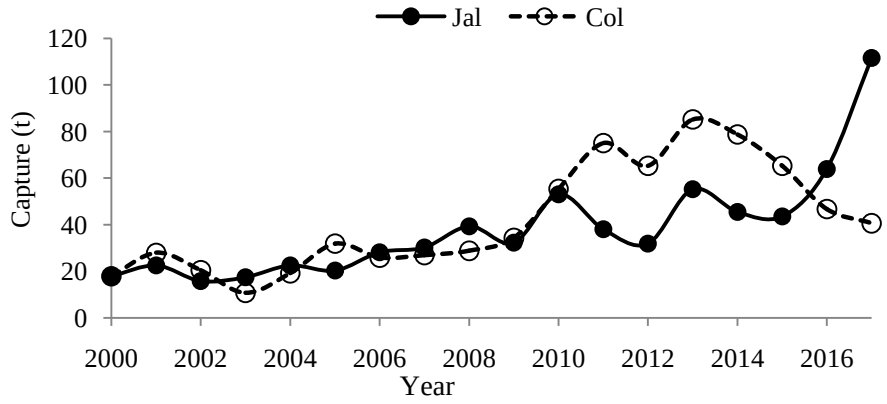


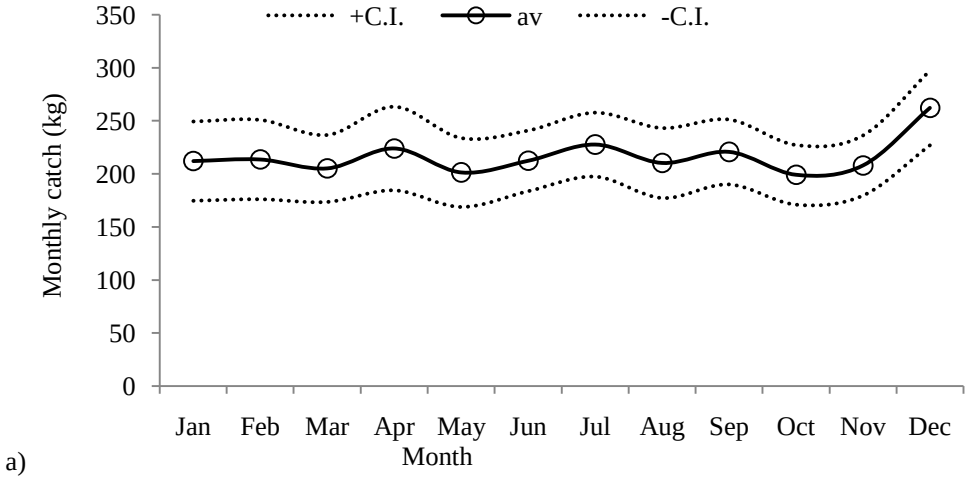
Figure 2. Total catch of *Centropomus nigrescens* in Jalisco and Colima (2000 to 2017), Pacific coast of Mexico (SIPESCA 2017).

Monthly captures in Jalisco show average of 216.26 t (± 269.4 standard error –SE–; ± 32.69 confidence interval –CI–). Higher captures are observed in April, July and December (Fig. 3a). In Colima the monthly average is of 90.0 t (± 109.8 SE, ± 8.14 CI). There is a negative trend from January to July and positive to December (Fig. 3b).

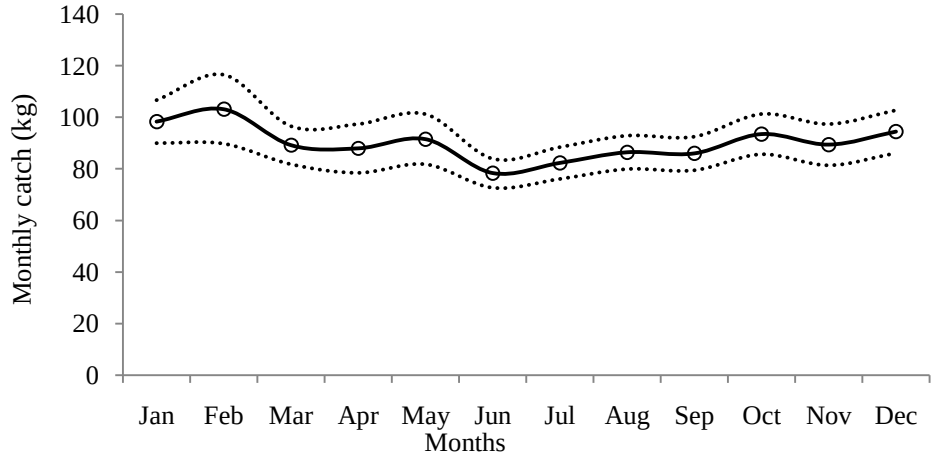
The recruitment length Lr = 39.00 cm that corresponds to an age of 4.25 years and a weight of 450 g. The first capture length (Lc) was 48.0 cm corresponding to an age of 5.32 years and 866 grams (Fig. 4, Table 1). Differences between sexes were found, being the recruitment length Lr = 63.80 cm (7.71years, 2.13 kg) in females, and 48.0 cm (5.32 years, 866 g) in males. The first capture length Lc = 76.40 (10.44 years, 3.76 kg) in females and Lc = 58.0 cm (6.74 years, 1.58 kg) in males (Fig 4).

Figure 5 shows that the length converted catch curve has only the first 2 ages in the ascending section of the curve. Capture starts from age 3 on. The regression equation for the second part of the curve (the negative trend) is: $y = 6.479 \cdot x^{-0.328}$, $r^2 = 0.977$, n = 15 and Z = 0.328.

Natural mortality rate was M = 0.14 therefore fishing mortality was F = 0.19. Value of the calculated exploitation rate was E = 0.576, which is close to E = 0.5 suggested by Gulland (1964) for a healthy fishery (Table 2).



a)



b)

Figure 3. Maximum, average and minimum monthly catch of *Centropomus nigrescens* in a) Jalisco and b) Colima, from 2000 to 2017 (SIPESCA 2017).

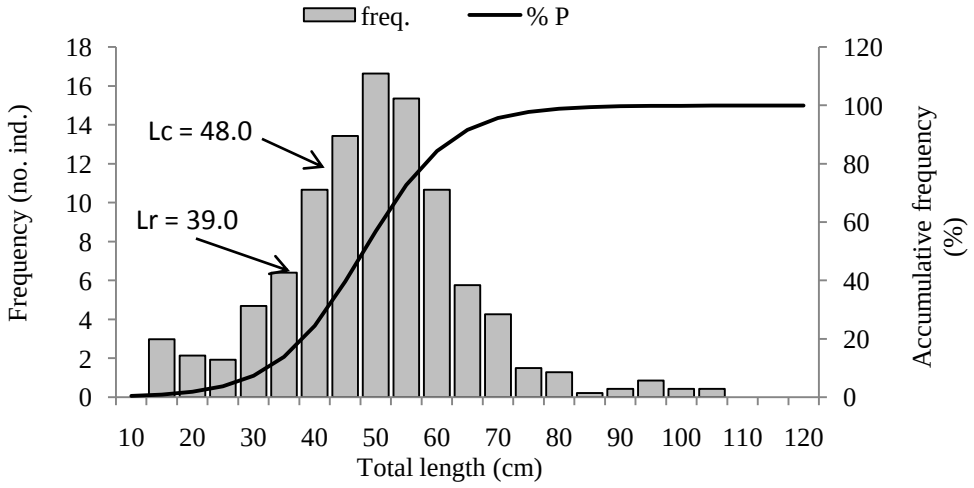


Figure 4. Length frequency distribution, size of first capture (L_{50} or Lc) and recruitment (L_{25} or Lr) of *Centropomus nigrescens*in Colima and Jalisco States, Mexico.

Table 1. First capture and recruit lengths, weight and age of *Centropomus nigrescens*in Colima and Jalisco States, Mexico.

	Length *	Length (cm)	Weight (g)	Age (years)
All individuals	Lc (L_{50})	48.00	866.3	5.32
	Lr (L_{25})	39.00	449.4	4.25
Females	Lc (L_{50})	76.40	3 764.5	10.44
	Lr (L_{25})	63.80	2 129.5	7.71
Males	Lc (L_{50})	58.00	1 575.6	6.74
	Lr (L_{25})	48.00	866.3	5.32
Undefined	Lc (L_{50})	49.30	942.6	5.49
	Lr (L_{25})	39.00	449.4	4.25

*: Lc = first capure length; Lr = recruitment length

Table 2. Population parameters of *Centropomus nigrescens* in Colima and Jalisco States, Mexico.

Parameter	Value
L_∞ (cm)	103.53
k ($year^{-1}$)	0.140
t_o	0.0
Z ($year^{-1}$)	0.328
M ($year^{-1}$)	0.140
F ($year^{-1}$)	0.188
S	0.719
Longevity (years)	22.27
Survival %	71.89
Total mortality (%)	28.11
If Z =	100.00
dead by fishing	57.58
dead by natural causes	42.42
E = F/Z	0.576

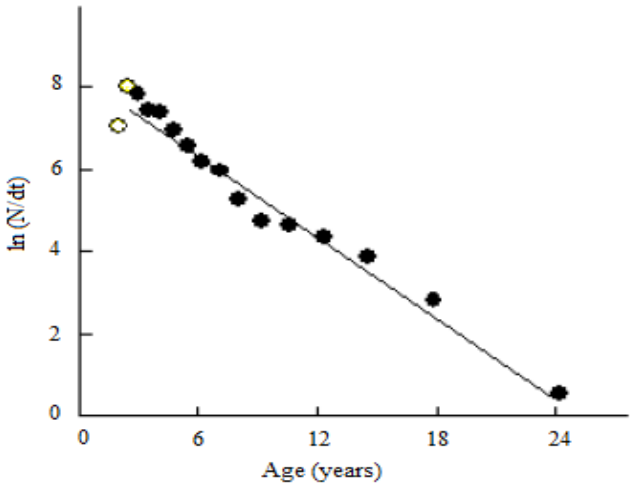


Figure 5. Length-converted catch curve of *Centropomus nigrescens*in Colima and Jalisco States, México.

Table 3 shows the parameter values used in the model of yield per recruit (y/r) of Beverton& Holt (1957). The calculated values of the actual yield were y/r = 1 553.6 g with a value of current fishingmortality F = 0.19 equivalent to organisms of 5 years of age. The highest values that could be obtained without changing the fishing method would be increasing the fishing mortality to F = 0.31 (Figs. 6, 7) to obtain a y/r = 1 605.0 grams.

Table 3. Parameters and values of yield per recruit model of *Centropomus nigrescens*in Colima and Jalisco States, México.

Parameter	Value
k ($year^{-1}$)	0.140
M ($year^{-1}$)	0.140
Tc (year)	5.32
Tr (year)	4.25
t_0	0.0
Wmax (g)	9 837.2

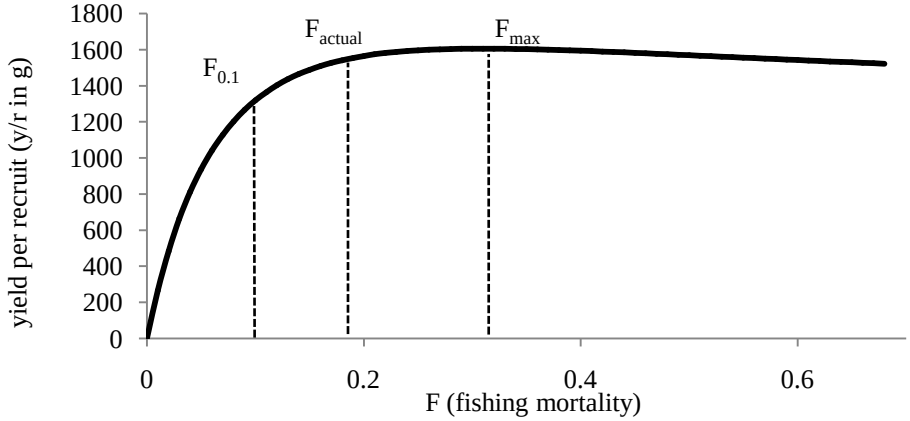


Figure 6. Yield per recruit curve of *Centropomus nigrescens* in Colima and Jalisco States, México at present fishing mortality.

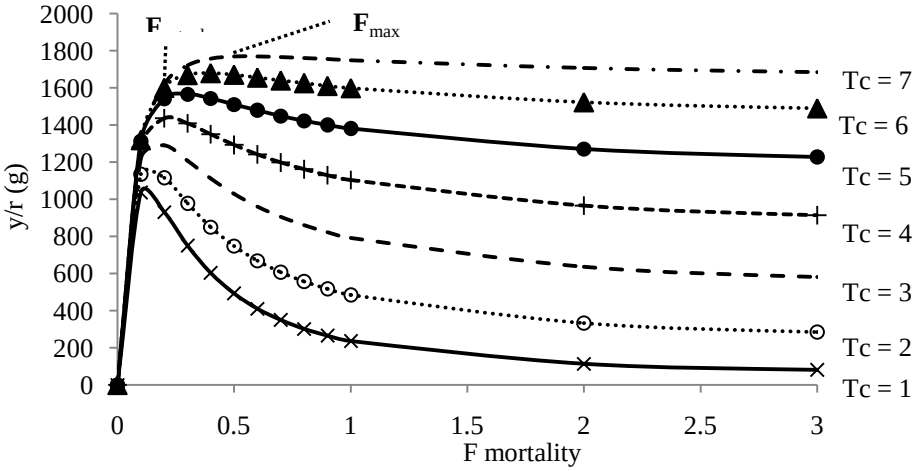


Figure 7. Yield per recruit simulation with different ages of first capture of *Centropomus nigrescens* in Colima and Jalisco, México.

Simulating different scenarios of the fishing activity, the method to obtain the highest yield would be to fish organisms of age 7 (1 721 g) and older (Fig. 7).

In relation to the proportion of catches of *C. nigrescens* in the Mexican Pacific, figure 8 shows differences in each State: Nayarit has a higher register of the species (34%), followed by Sinaloa (14%), Oaxaca (10%), Colima (5%), Jalisco, Michoacán (4%) and Baja California Sur (1%).

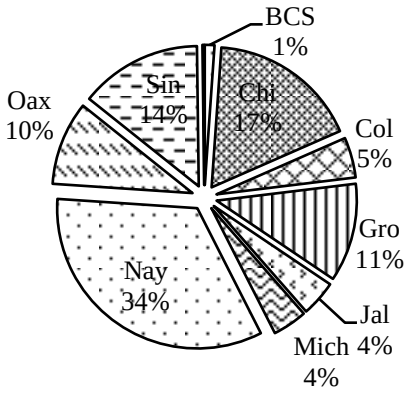


Figure 8. Capture proportion of *Centropomus nigrescens* in the States of the Mexican Pacific: BCS = Baja California Sur, Chi = Chiapas, Col = Colima, Gro = Guerrero, Jal = Jalisco, Mich = Michoacán, Nay = Nayarit, Oax = Oaxaca, Sin = Sinaloa (SIPESCA 2017).

IV. Discussion

The fishery of the black snook*Centropomus nigrescens* takes place in the coastal line and coastal lagoons of all the states of the Mexican Pacific. In the northern states the captures are very sporadic. This study is of the states of Jalisco and Colima, central Mexican Pacific.

Maximum monthly captures obtained in Jalisco in the period of 2000 to 2017 occur in December and April, months with high demand for fish. Another value of high capture is July, which coincides with massive spawning season and therefore higher presence of males and females during reproduction, who aggregate and are more vulnerable to fishing mortality F (Espino-Barr *et al.* 2017). These values descend during the months of March, May, August and October.In the case of the fishing in Colima's coast, most captures are during the months of February, May, October and December, and the lower in June and July (Fig. 3b).In both sites the captures increase in December probably because there is more demand of the fish due to the vacation in Christmas, New Year and Easter holydays.Caballero-Chávez (2012) found that the maximum captures of *C. undecimalis* in the coasts of Campeche were in May and October.

First capture length of Lc = 48.0 cm corresponds to an age of 5.32 years for the whole sample (females, males and juveniles). Females presented aLc = 76.4 cm (age 10.44 years) and males a Lc = 58.00 cm (age 6.74 years). On the other hand, first maturity age for all the organisms is L_{25} = 59.0 cm for the entire sample which corresponds to an age of 6.89 years and a weight of 1 662 g (Espino-Barr *et al.* 2017).These differences mean that the captured organisms might not have reproduced at least once which would reduce the recruitment of the young, and would expose the population to overexploitation.

Total mortality of the *C. nigrescens* shows that 28.1% of the organisms die and 71.9% survives. For every 100 organisms that die, 57.6 individuals die because of fishing mortality and 42.4 of natural causes, which are predation, sickness and senescence. These results mean that the recruitment to the fishing gear and to the fishing zone takes place from the age group 3 and till the age of 24 years (Table 2).

Caballero-Chávez (2012) found higher mortality values for *C. undecimalis* in the coasts of Campeche (in the Gulf of Mexico), these values were Z = 1.15, F = 0.84 and M = 0.31.Gulland (1964) suggests that the fishing mortality should be at the most F = 0.1 to maintain a healthy population. Nevertheless the maximum yield is obtained in our study with an F = 0.31 (1 605 g). If the first capture age is increased to 7 years (instead of 5), the yield per recruit increases and even the fishing mortality could be increased.

Caballero-Chávez (2012) calculated a maximum sustainable yield for *C. undecimalis* in the coasts of Campeche of 479.8 t to 537.5 t, with an optimum effort of between 15 866 and 18 792.3 trips. Also, she considers that the resource is overfished since 2001. The highest exploitation occurs in young organisms with an F = 1.61 and an exploitation rate of E = 0.84. The maximum yield per recruit would be obtained catching adult organisms with lengths of 60.00 cm and bigger.

In relation to the proportion of catches of *C. nigrescens* in the Mexican Pacific, Nayarit has a higher presence of this species because of the large area of coastal lagoons; the same happens in Oaxaca. All the states have coastal lagoons, but not in the same proportion and with the characteristics needed by this species. Register of the species in Nayarit is of 34%, followed by Sinaloa (14%), Oaxaca (10%), Colima (5%), Jalisco, Michoacán (4%) and Baja California Sur (1%). Sonora and Baja California showed sporadic captures in very few years, maybe because warm currents carrying tropical fish reached these northern latitudes.

V. Conclusion

- The highest average captures of *C. nigrescens* in Jalisco, occur in April, July and December; in Colima, during February, May, October and December.
- The recruitment length was Lr = 39.0 cm and the length of first capture Lc = 48.00 cm. Differences between sexes were: Lr = 63.8 cm and Lc = 76.40 cm for females and Lr= 48.0 cm and Lc = 58 cm for males.
- Total mortality for ages 3 to 15 years was Z = 0.328 and the survival rate was S = 0.719.
- Natural mortality rate was M = 0.140. Fishing mortality was F = 0.188.
- The exploitation rate was E = 0.576.
- Increasing fishing mortality from F = 0.19 to F = 0.31 will increment the yield per recruit from 1 554 g to 1605 grams.
- Captures of organisms of age 7 produce the best yields.

VI. Recommendations

The capture of this species intensifies during the rainy season, period in which the organisms reproduce and are the most vulnerable to the capture because of their aggregations;therefore we suggested that a ban should be established. This way young organisms that have not yet completed their cycle and adults that are carrying out the reproduction would be protected during this time.

However, this measure did not yield results in the past. Caballero-Chávez (2003, 2012) suggested a ban for *C. undecimalis* in the coasts of Campeche that included 10 days of every month from June to August: 5 days before and 5 days after full moon. But the fishers did not respect these measures.

It is important to point out that research on population dynamics of *C. nigrescens*must continue with the purpose of having more information of this species that allows managers to design measures on the sustainable use and protection of this resource.

Finally, we want to recommend avoiding damage to the mangroves because they are spawning and nursery areas for many fish species whose survival depends on the health status of these ecosystems.*C. nigrescens* uses mangrove areas when fingerlings and young ages.

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