Ciencia Pesquera (2012) 20(1): 77-88

Aspects of *Scomberomorus sierra* fishery from the coast of Colima, México

Elaine Espino-Barr[*], Rubí Anadely Nava-Ortega[**], Manuel Gallardo-Cabello[***], Esther Guadalupe Cabral-Solís[*], Marcos Puente-Gómez[*] & Arturo García-Boa[*]

During 2003 data and samples on the fishery and the biology of *Scomberomorus sierra* (Perciformes: Scombridae) were collected. This fishery has two periods of maximum catch in the coast of Colima: from January to April and from November to December. Monthly captures are from 2 kg (45 kg average ±63 std.d.) to 1 340 kg (190 kg average ±219 std.d.). Catch per unit of effort is between one and 14 kg per trip during autumn and winter, plus other 37 commercial species that were captured incidentally. First length of capture of *S. sierra* was L_{50} = 48 cm, which corresponds to an age of three years. Total mortality was Z = 0.7660, natural mortality was M = 0.1997 and fishing mortality F = 0.5663. Survival rate was S = 0.4649; exploitation rate was E = 0.739, which is a high value for a healthy fishery. Yield per recruit was y/r = 0.694 grams. Increasing the age of first capture to 5.5 years could allow an increment of effort four times, which would result in a higher capture without negative consequences to the stock.
Key words: Mortality, exploitation rate, yield per recruit, *Scomberomorus sierra.*

Aspectos de la pesquería de *Scomberomorus sierra* de la costa de Colima, México

Durante 2003 se recabaron datos de la pesquería y muestras biológicas de *Scomberomorus sierra* (Perciformes: Scombridae). La pesquería presenta dos periodos de máximas capturas en las costas de Colima: de enero a abril y de noviembre a diciembre. Los valores mensuales de captura van de 2 kg (en promedio 45 kg±63 d.e.) a 1 340 kg (en promedio 190 kg±219 d.e.). La captura por unidad de esfuerzo es de entre uno y 14 kg por viaje durante otoño e invierno, además de otras 37 especies comerciales que se capturan incidentalmente. La talla de primera captura fue de L_{50} = 48 cm que corresponde a una edad de tres años. La mortalidad total fue Z = 0.7660, la natural M = 0.1997 y la mortalidad por pesca fue F = 0.5663. La tasa de sobrevivencia fue S = 0.4649; la tasa de explotación E = 0.739, elevado para una pesquería saludable. El análisis de rendimiento por recluta fue de y/r = 0.694 gramos. Si se incrementa la edad de primera captura a 5.5 años, se podría incrementar el esfuerzo hasta cuatro veces, que resultaría en mayores capturas sin consecuencias negativas para el *stock*.
Palabras clave: Mortalidad, tasa de explotación, rendimiento por recluta, *Scomberomorus sierra.*

Introduction

Scomberomorus sierra Jordan & Starks, 1895 (Fig. 1) is an epipelagic neritic species. It is distributed from South California to Perú, including the Galápagos Islands. It forms schools and feeds on anchovies and sardines, and it is known to spawn near the continental shelf. Its major capture occurs in México, and is fished by sport and commercial fishers (Fischer *et al*., 1995).

Analysis of catch statistics can show trends and fluctuations, and help describe characteristics of a fishery. Catch per unit effort (CPUE) helps analyze these tendencies and explains diverse behaviors of the fishery. The third variable in fisheries is fishing effort referred to as the only variable that can be managed and which has been shown to have a linear relationship with the catch rate (in certain ranges of effort) (Sparre & Venema, 1995).

The unit of effort described by González-Becerril *et al.* (2000) for artisanal fisheries off the coast of Colima is: a trip on a boat, in a span of one day (eight to 12 hours), with one to four anglers or one gill net; *S. sierra* fishery uses

[*] Centro Regional de Investigación Pesquera - Manzanillo, Instituto Nacional de Pesca, SAGARPA, Playa Ventanas s/n, Col. Villa Florida, Manzanillo, Colima. *elespino@gmail.com*
[**] Centro Regional de Investigación Pesquera - Bahía de Banderas, Instituto Nacional de Pesca, SAGARPA. Tortuga 1, la Cruz de Huanacaxtle, Nayarit, 63732.
[***] Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México.

Fig. 1. Pacific sierra *Scomberomorus sierra*.

both: trolling or gillnets. Therefore, *CPUE* is the amount obtained in kilograms per trip. This average value represents an abundance index and resource distribution, which can be analyzed regularly, monthly, seasonally or yearly and compared between capture sites.

The total mortality study, considering its two components of natural and fishing mortality, helps understand the subtraction process of organisms of the population, that depend on its addition (growth and recruitment). The balance between these factors (addition and subtraction) allows stocks to continue in time and space (Stein *et al*., 1975; Gobert, 1994; Gray, 2002; Albaret & Laë, 2003; Gray *et al*., 2005; Clavero *et al*., 2006; Gallardo-Cabello *et al*., 2007; Espino-Barr *et al*., 2008). A large increase in fishing mortality, for example, can endanger the fishing stock or even endanger the species to extinction. The maximum catch that can be achieved by maintaining the balance of the population, without breaking the recruitment product of reproduction is what is known as maximum sustainable yield (Beverton & Holt, 1957). It is therefore of great importance to assess the natural and fishing mortality in order to calculate exploitation rates, that can be applied to obtain the optimum yield per recruit and a rational fisheries management (Hernández-Montaño & Meléndez-Galicia, 2003[1]; Espino-Barr *et al*., 2006; Hernández-Montaño *et al.*, 2006; Cabral-Solís *et al*., 2007).

The present study analyses catch, effort and catch per unit effort data; also total mortality with its natural and fishing mortalities, exploitation rate and yield per recruit analysis, to establish a better basis for managing the fishery of the Pacific sierra *S. sierra* in Colima, México.

Materials and methods

The study zone is the coast of Colima, between 18°40'-19°10' N and 103°50'-104°40' W (Fig. 2), where coastal fishers profit from the marine resources they catch.

Several information sources were used for the catch analysis:

a) Statistical yearbook: official catch values of the sierra were obtained from 1980 to 2008 in Colima and other states; they were plotted to observe the trend or periodicity (SAGARPA, 2003).
b) Notice of arrival (aviso de arribo): official statistical information provided by fishers with species name and capture quantities (kg) (data from the Fisheries Bureau, Oficina de Pesca).
c) Catch per unit effort (CPUE): a series of data from sierra's catch per fishing trip (2001 to 2005) was obtained from the fishery-biological sampling made by the CRIP-Manzanillo. This value is the amount of catch obtained per trip and its value serves as an abundance index, because it is independent of the total catch and effort or fishing trips (González-Becerril *et al*., 2000).
d) From January 2003 to March 2004, organisms of *S. sierra* were monthly obtained from the commercial captures of the coastal fishery in Colima, México (in total 464), and taken to the lab, where total (TL) and standard length (SL), height (He), total (TW) and eviscerated weight (EW) and sex were registered for each

1. HERNÁNDEZ-MONTAÑO D & C Meléndez-Galicia. 2003. Análisis de la pesquería de sierra *Scomberomorus sierra* de la costa de Michoacán, México. *Memorias del II Foro Científico de Pesca Ribereña.* Colima, Col. del 20 al 22 de octubre de 2003. pp: 20-21.

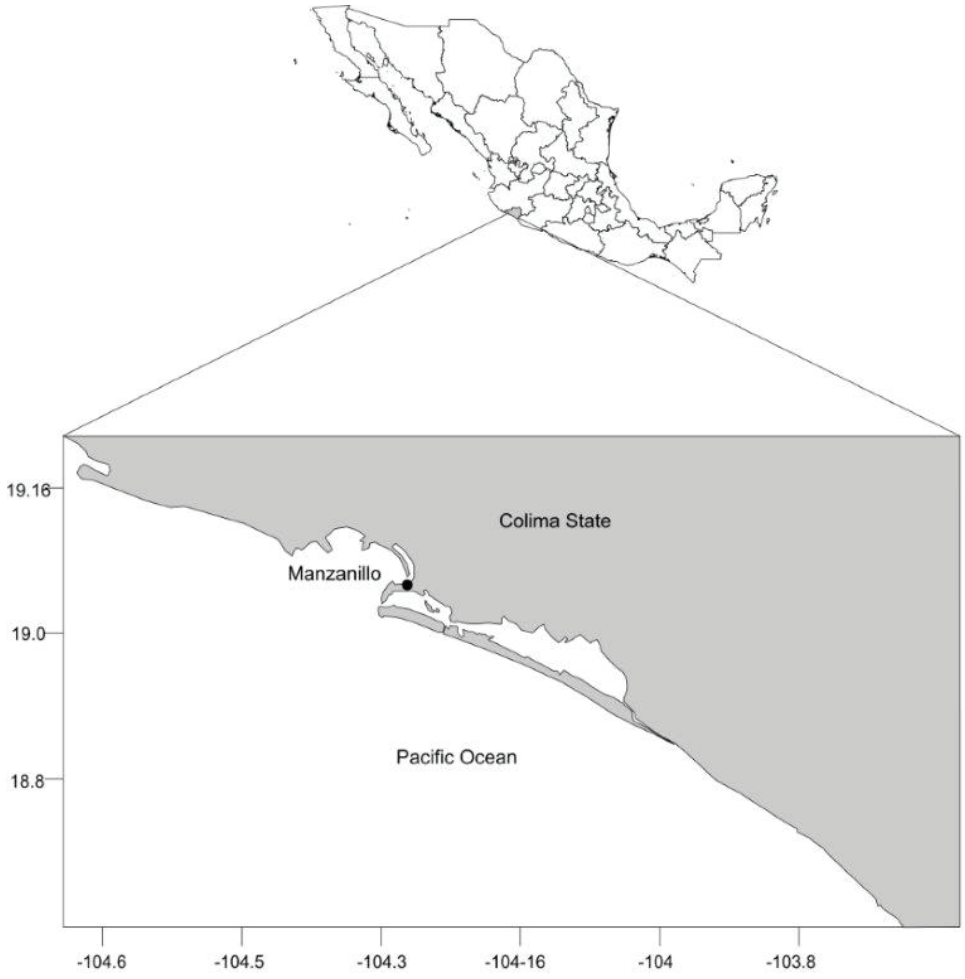

Fig. 2. Study area: coast of Colima, México (taken from INEGI, 1997).

organism. Total length and weight from 972 organisms were taken directly throughout the year at the collection area (where fishers arrive with their product). Individuals were captured with hand lines, troll and gillnet in order to obtain different lengths and age groups.

Age determination was carried out by length frequency analysis and study of sagittae. Both methods presented five age groups. The length frequency distribution was analyzed with the ELEFAN program of the FISAT package (Gayanilo *et al*., 1993) to obtain the average length of the polimodal curves corresponding to each age group.

Average length of growth rings determined by otoliths *sagittae* and *asterisci* analysis by Gallardo-Cabello *et al*. (2011) were used to obtain the constants of von Bertalanffy's (1938) growth equation. Observed values were: for age one = 19.20 cm; age two = 35.14 cm; age three = 45.80 cm; age four = 56.20 cm and age five = 64.51 cm. 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 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). There were no differences in growth between males and females (Gallardo-Cabello *et al*., 2011).

Growth constants of von Bertalanffy's equation were determined by Ford-Walford and Gulland methods and an iteration adjustment with the "solver" application; both techniques presented a high adjustment between observed and calculated data (sum of square error), but the second one was better; the results obtained were:

L_∞ = 99.54 cm, K = 0.205, t_o = -0.060. Mean size for each age are: age zero = 1.22 cm, age one = 19.47 cm, age two = 34.33, age three = 46.43, age four = 56.29 and age five = 64.32 cm. The allometric index from the weight-length relationship was isometric, b = 3.031. Longevity was obtained by Taylor's method (1958, 1960) $A_{0.95}$ = 15 years (Nava-Ortega *et al.*, 2011, in press).

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 & Venema, 1995), where *x* corresponds to groups of age 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 by using Taylor's method (1960): $M = -Ln(1-0.95)/A_{0.95}$, where $A_{0.95}$ is longevity based on the von Bertalanffy growth parameters (1938).

Exploitation rate was determined as $E = F \cdot Z^{-1}$ (Sparre & Venema, 1995) and the yield per recruit (Beverton & Holt, 1957) with the equation:

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

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; K = growth coefficient.

Results

Official data of annual catch for years 1956 to 2008, in Colima, the Pacific coast and nationwide show that the captures of *S. sierra* in Colima varied widely during this period (Fig. 3), being more abundant during 1956, 1962, 1990 and 2004 when it reached 200 tons. Maximum catch was in 1980, when 400 tons were caught. In recent years 2005-2007, the trend is downward. Pacific values have a positive trend with fluctuations similar to the capture in Colima.

A comparative of captures by coastal states during 2003 shows that *S. sierra* was 2% of the total catch in the Mexican Pacific coast (Fig. 4), higher catches were in Sonora and Sinaloa, although national fisheries statistics do not distinguish species, and Sonora's catch records include also *Scomberomorus concolor* (Lockington, 1879), up to 90% in some years (Montemayor-López & Cisneros-Mata, 2000).

Daily individual catches in Colima during 2003 are from minimum two to 1 340 kg. Monthly averages go from 45 kg (±63 std.d.) to 190 kg (±219 std.d.), maximum captures are from January to April and from November to December; minimum in September and October (Fig. 5).

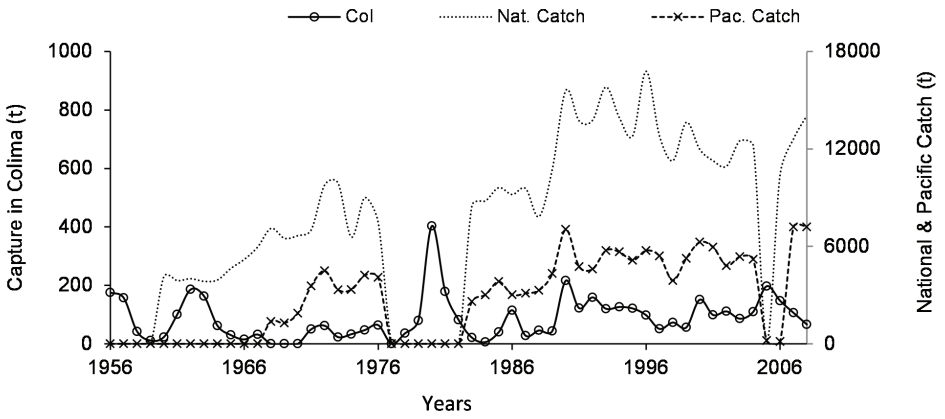

Fig. 3. Total catch of *Scomberomorus sierra*, comparative in both coasts of México, Pacific coast and Colima, from 1956 to 2008.

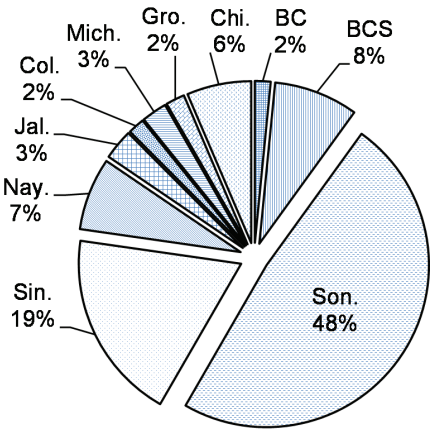

Fig. 4. Proportional catch of Pacific sierra *Scomberomorus sierra* per state on the Mexican Pacific coast during 2003.

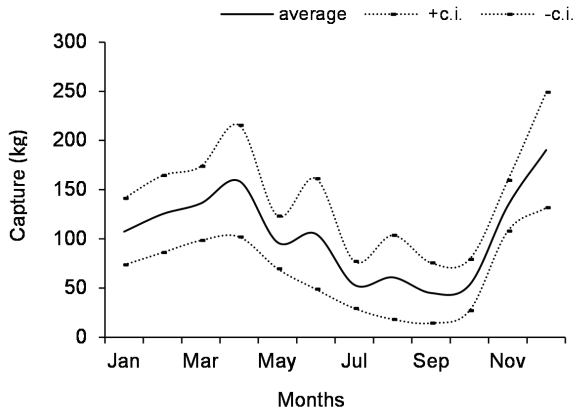

Fig. 5. Pacific sierra's monthly catch in Colima, México during 2003.

Figure 6 shows that *CPUE* of *S. sierra* varied from one to 14 kg per trip during autumn and winter, it means that between 2% and 75% of the total catch per trip is of *S. sierra*; in those trips between one and 32 kg are of other commercial species. Other commercial species caught with "sierra" are listed in *table 1*.

Sierra's range of sizes was from 25 to 97 cm *TL*. Average size = 50.5 cm (±10.4 std.d) and mode = 46 cm. Size at first capture (Ltc) was L_{50} = 48 cm corresponding to fishes of three years old (Fig. 7).

An ascendant slope from zero to three years of age is shown in the catch curve of *S. sierra* (Fig. 8). The right descending side corresponds to ages whose recruitment to fishing gears was complete. Total mortality rate value for age groups 3.2 to eight years was obtained by interpolation. The regression equation calculated to obtain the slope is: $y = 6.135 - 0.766\,x$, $R^2 = 0.8456$; $n = 16$. Total mortality value for *S. sierra* for ages between 3.2 and eight years was Z = 0.766 and the survival rate was S = 0.4649 (Table 2).

Natural mortality rate of *S. sierra* was M = 0.1997, therefore fishing mortality was F = 0.5663, more than two times higher than the first. Value of the calculated exploitation rate was E = 0.739, higher than E = 0.5 suggested by Gulland (1964) to be a healthy fishery.

Table 3 shows the parameter values used in the model of yield per recruit (y/r). The calculated value was y/r = 694 g, with the value of current fishing mortality F = 0.5663. The highest

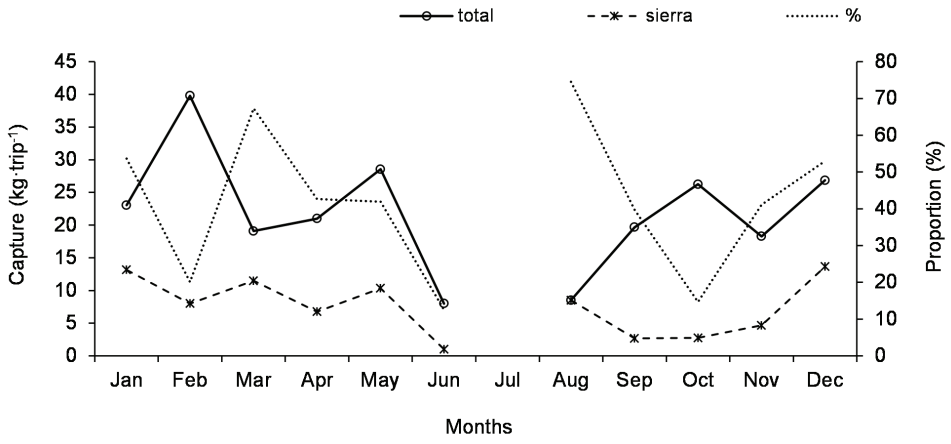

Fig. 6. Monthly total and sierra's catch per unit effort and its proportion during 2003 in Colima, México.

Table 1
Commercial species captured incidentally with Pacific sierra *Scomberomorus sierra*

No.	*Common name (in English)*	*Common name (in Spanish)*	*Scientific name*	*Family*	*%*
1	Pacific sierra	Sierra	*Scomberomorus sierra*	Scombridae	100.00
2	Pacific crevalle jack	Jurel	*Caranx caninus*	Carangidae	22.25
3	Pacific red snapper	Huachinango	*Lutjanus peru*	Lutjanidae	16.45
4	California needlefish	Agujón	*Strongylura exilis*	Belonidae	10.90
5	Spotted rose snapper	Pargo lunarejo	*Lutjanus guttatus*	Lutjanidae	10.11
6	Panamic grunt	Burro	*Pomadasys panamensis*	Haemulidae	7.84
7	spottail grunt	Rasposa	*Haemulon maculicauda*	Haemulidae	6.66
8	Mexican barracuda	Buzo	*Sphyraena ensis*	Sphyraenidae	6.15
9	Green jack	Cocinero	*Caranx caballus*	Carangidae	6.04
10	Panamic flounder	Lenguado	*Cyclopsetta panamensis*	Paralichthyidae	5.80
11	Black skipjack	Barrilete	*Euthynnus lineatus*	Scombridae	4.39
12	Giant hawkfish	Tigre	*Cirrhitus rivulatus*	Cirrhitidae	4.31
13	Flag cabrilla	Cabrilla	*Epinephelus labriformis*	Serranidae	4.23
14	Milkfish	Sábalo	*Chanos chanos*	Chanidae	3.14
15	Surf croaker	Curvina	*Umbrina xanti*	Sciaenidae	1.96
16	California butterfly ray	Raya mariposa	*Gymnura marmorata*	Gymnuridae	1.88
17	Peruvian mojarra	Malacapa	*Diapterus peruvianus*	Gerreidae	1.57
18	Whipper snapper	Pargo colmillón	*Lutjanus jordani*	Lutjanidae	1.57
19	Rainbow runner	Albacora	*Elagatis bipinnulata*	Carangidae	1.10
20	Blackblotch pompano	Pámpano	*Trachinotus kennedyi*	Carangidae	1.02
21	Finescale triggerfish	Puerco	*Balistes polylepis*	Balistidae	0.94
22	African pompano	Pámpano caballo	*Alectis ciliaris*	Carangidae	0.94
23	Golden trevally	Chocho	*Gnathanodon speciosus*	Carangidae	0.94
24	Almaco jack	Medregal	*Seriola rivoliana*	Carangidae	0.86
25	Gafftopsail pompano	Palmilla	*Trachinotus rhodopus*	Carangidae	0.78
26	Dolphinfish	Dorado	*Coryphaena hippurus*	Coryphaenidae	0.78
27	Machete	Chile	*Elops affinis*	Elopidae	0.78
28	Bigeye trevally	Ojo de perra	*Caranx sexfasciatus*	Carangidae	0.71
29	Bullseye puffer	Botete	*Sphoeroides annulatus*	Tetraodontidae	0.71
30	Black snook	Robalo	*Centropomus nigrescens*	Centropomidae	0.63
31	Cortez grunt	Ronco chano	*Haemulon flaviguttatum*	Haemulidae	0.47
32	Pacific dog snapper	Pargo mulato	*Lutjanus novemfasciatus*	Lutjanidae	0.20
33	Gulf coney	Baqueta	*Epinephelus acanthistius*	Serranidae	0.16
34	Pacific mutton hamlet	Cabrilla rosada	*Alphestes immaculatus*	Serranidae	0.16
35	Spotted cabrilla	Pintillo	*Epinephelus analogus*	Serranidae	0.16
36	Pacific creolefish	Viejita	*Paranthias colonus*	Serranidae	0.16
37	Yellowfin surgeonfish	Cirujano	*Acanthurus xanthopterus*	Acanthuridae	0.08

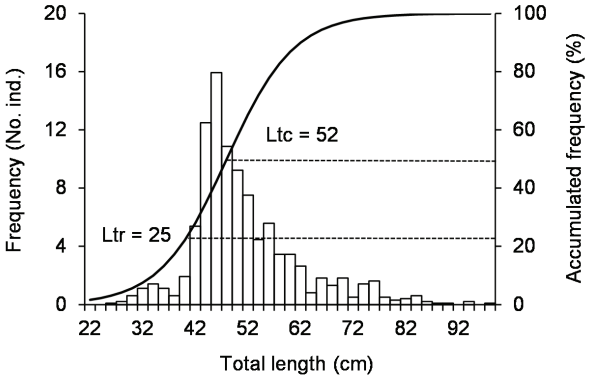

Fig. 7. Length distribution and size of first capture L_{50}.

Table 2
Summary of parameters of *Scomberomorus sierra* in Colima, México

Parameter	*Value*
L_∞	99.54
K	0.205
t_0	-0.060
Z	0.7660
M	0.1997
F	0.5663
S	0.4649
Longevity	14.553
Survival %	46.30
Total mortality %	53.70
If Z =	100
Die by fishing	74.06
Die naturally	25.94
E = F/Z	0.739

Table 3
Initial parameters for the yield per recruit model of Beverton and Holt (1957)

Parameter	*Value*
K ($years^{-1}$)	0.205
M ($years^{-1}$)	0.1997
Tc (years)	3.5
Tr (years)	1.4
Wmax (g)	5 687.2

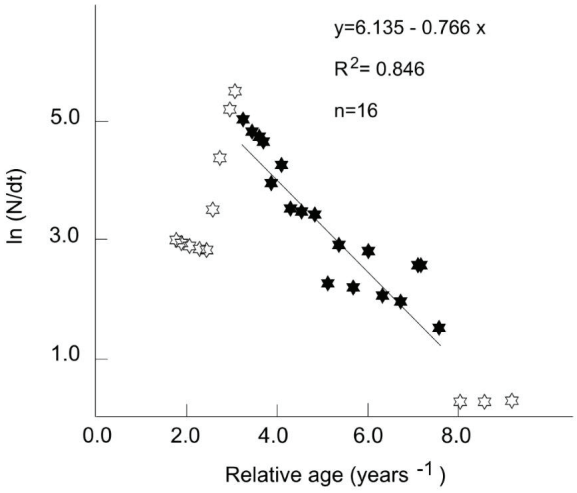

Fig. 8. Length-converted catch curve.

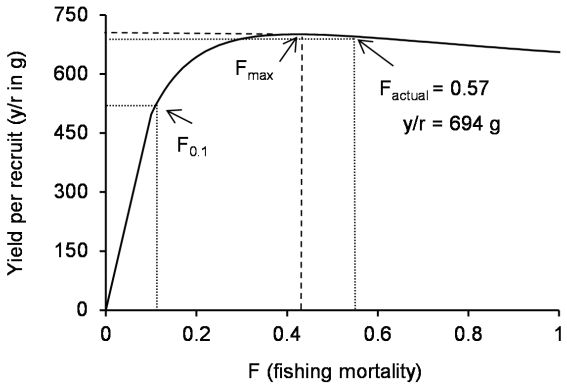

Fig. 9. Yield per recruit of *Scomberomorus sierra* in the central coast of Mexican Pacific.

value that can be obtained without changing the fishing method is by reducing the fishing mortality to F = 0.42 (Fig. 9), and that is y/r = 700 grams.

A simulation of *y/r* changing values of age at first capture (Tc) and different values of fishing mortality (*F*) shows that the actual value of Tc = 3.5 years corresponds to y/r = 694 g. On the other hand, if this age is increased to Tc = 5.5 years of age, *y/r* quotient increases conveniently to 787 g (Fig. 10).

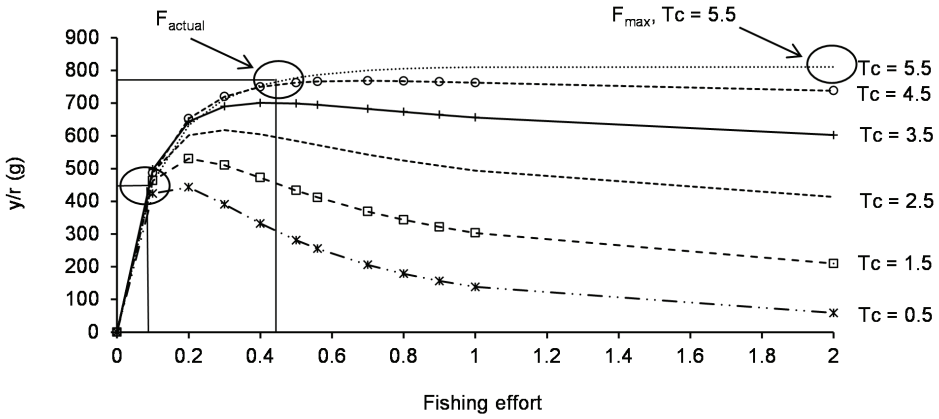

Fig. 10. Yield per recruit simulation, varying the age of first capture for *Scomberomorus sierra*.

Discussion

Despite its low proportion in the catch, *S. sierra* is an important resource: it can reach a price of between $ 40 and $ 60.00 Mexican pesos (Nava-Ortega, 2008) and can be fished up to 40 kg per day, which gives a good income to the fisher in the high seasons.

Monthly catches of *S. sierra* in Colima during 2003 reached their maximum values during autumn and winter. Chávez (1986) and Hernández-Montaño & Meléndez-Galicia (2003[1]) found similar periods of maximum capture: February-March and September-November in the coast of Colima and Michoacán. Likewise, in the coast of Sinaloa, Márquez-Millán (1972) found two periods of maximum catch that relate to migratory movements of the population: north during the summer and south in winter (probably to reproduce, feed or get away from cold water). Espino-Barr *et al*. (1990) found the period of highest catch of Pacific sierra between March and May.

CPUE makes a fishery important, popular or abandoned. Sierra's fishery is traditionally popular, even though it doesn't produce a high income throughout the year. What makes it important is that during its season it captures sierra in high quantities, plus other species, that are incidental, but are also commercialized, rising the economic value of the capture.

Effort in this and other coastal fisheries cannot be considered constant; it is subject to many variables (environmental, social, political and economic, in addition to fishing) and depending on the years and seasons (Espino-Barr *et al*., 2008).

The size at first capture reported by Espino-Barr *et al*. (1990) was 32.7 cm, which is lower than the one found in this study, due perhaps to changes in the fishing gears, which could not be verified. Other data were not found for this species.

Espino-Barr (2000) analyzed the average length of different species because the theory that their decline is an indicator of fishing pressure (which is related to fishing gear). Maximum lengths found in Colima's Pacific sierra were 66.50 cm by Espino-Barr *et al*. (1990), 71.0 cm by Espino-Barr & García-Boa (1999[2]) and in this paper, 82.30 cm. Although the length frequency distribution for this population shows a wide range of sizes, that could indicate nowadays a healthy stock or at least at no risk, it also suggests that the organisms captured are sexually immature subadults (Nava-Ortega, 2008).

Natural mortality rate *M* and growth parameters of other species of the *Scomberomorus* genera are shown in *table 4*. Maximum values of *M* are from *S. plurilineatus* Fourmanoir, 1966 in South Africa: M = 0.722 (Chale-Matsau *et al*., 1999), and *S. maculatus* (Mitchill, 1815) in Veracruz, Gulf of México, M = 0.609 (Mendizábal y Oriza, 1987). On the other hand, smaller values were from *S. cavalla* (Cuvier, 1829) in

2. ESPINO-BARR E & A García-Boa. 1999. La pesca artesanal de la sierra *Scomberomorus sierra* en la costa de Colima. Informe de Investigación (Documento interno). INP, CRIP-Manzanillo, 29p.

Table 4
Natural mortality rate and growth parameters of other species of the *Scomberomorus* genera

Author	*Country*	*Zone*	*Species*	*Method*	L_∞	*K*	*longevity*	*M*	*fi*	*T (°C)*
Devaraj (1981)	India	Palk Bay & Gulf of Mannar	*S. guttatus*	TL	128.00	0.180	16	0.185	3.470	13
Devaraj (1981)	India	Palk Bay & Gulf of Mannar	*S. commerson*	TL	208.00	0.183	16	0.185	3.899	
Edwards *et al.* (1985)	Yemen	Gulf of Aden	*S. commerson*	FL	230.00	0.120	25	0.120	3.803	29
Chale-Matsau *et al*. (1999)	South Africa	KwaZulu-Natal	*S. plurilineatus*	FL	93.50	0.583	4	0.722	3.707	25
de León & Guardiola (1986)	Cuba	Southeast Zone	*S. regalis*	FL	66.50	0.220	11	0.268	2.988	27
Sturm (1978)	Trinidad & Tobago	Caribean	*S. maculatus*	FL	73.00	0.290	10	0.306	3.189	27
Mendizábal y Oriza (1987)	Gulf of México	Veracruz, México	*S. maculatus*	Direct	58.28	0.648	5	0.609	3.343	
Carneiro-Ximenes *et al.* (1978)	Brasil	Ceará State	*S. cavalla*	FL	125.00	0.180	15	0.202	3.449	
González-Ramos (1993)	Veracruz, México	Gulf of México	*S. cavalla*	Direct and indirect	166.73	0.120	25	0.119	3.523	
Valle *et al*. (1997)	Cuba	Gulf of México	*S. cavalla*	FL	101.00	0.190	13	0.225	3.287	
Aguilar-Salazar *et al.* (1991)	Yucatán, México	Yucalpetén	*S. cavalla*	Indirect (ELEFAN)	117.00	0.230	13	0.235	3.498	
Aguilar-Salazar *et al*. (1991)	Quintana Roo, México	Holbox	*S. cavalla*	Indirect (ELEFAN)	155.00	0.250	12	0.256	3.779	
Montemayor-López & Cisneros-Mata (2000)	México	Gulf of California	*S. concolor*	LF	71.60	0.360	8	0.361	3.266	22
Valdovinos-Jacobo *et al.* (2006*)	México	Gulf of California	*S. concolor*	otoliths	67.70	0.230	13	0.235	3.023	
Espino-Barr *et al*. (1990)	México	Colima	*S. sierra*	TL	80.70	0.360	8	0.361	3.370	27
Aguirre-Villaseñor *et al.* (2006)	México	Gulf of California, Mazatlán	*S. sierra*	LF	108.30	0.150	20	0.150	3.245	
This paper	México	Central Mexican Pacific	*S. sierra*	TL	99.54	0.205	15	0.197	3.308	27

* VALDOVINOS-JACOBO LA, C Quiñónez-Velázquez & G Montemayor-López. 2006. Edad y crecimiento de la sierra del Golfo *Scomberomorus concolor* (Lackington, 1879) en el Golfo de California. *Memoria del II Foro Científico de Pesca Ribereña,* pp: 39-40.

Veracruz, Gulf of México, M = 0.119 (González-Ramos, 1993) and *Scomberomorus commerson* (Lacépède, 1800) in the Gulf of Aden, Yemen, M = 0.120 (Edwards *et al.,* 1985).

Values of mortality rate (Z and M) for *S. sierra* in Colima at ages between 3.2 and 8 years were $Z = 0.766$ and $M = 0.1997$, lower than $Z = 1.908$ and $M = 0.361$, obtained by Espino-Barr *et al.* (1990) more than ten years ago, but higher than those calculated by Aguirre-Villaseñor *et al.* (2006) in Mazatlán, Sinaloa, México. This means that in Colima, in one year 53.70% die

and 46.30% survive. From these values, 74.06% die by fishing and 25.94% naturally, therefore *S. sierra* could be considered as an overfished resource. However, Z value could be reduced by decreasing the fishing intensity, thereby protecting the population from overexploitation and subsequently increasing the fishery yield, since growth and recruitment will raise abundance and biomass (sizes and weights) of the population, in each age group.

Besides, differences between mortality values are related to the K index (growth index). It was observed that M is directly proportional to K index and inversely proportional to L_∞ and longevity.

According to Gulland (1964) the exploitation rate $E = 0.5$ means that 50% of the biomass is being fished, then optimum exploitation value is when $F = M$. Therefore, if the value of the exploitation rate $E = 0.739$ is considered high, it means that a great number of fish in reproductive age is being extracted, which are the recruitment providers of the organisms of the subsequent years, and are being fished as sub adults that have not reached their first reproduction.

Fishing mortality $F = 0.5663$ was lower than $F = 1.7$ reported by Espino-Barr *et al*. (1990). This result indicates that after years of constant fishing, the stock still maintains as a commercially important resource, and that variations are due to other factors that are not controlled by the increase or decrease of fishing rates.

Fishing gears used in the artisanal fishery of sierra are variable; fishers build them like handcrafts according to their experience. They test them throughout the fishing years, applying small improvements, adjustments, but maintain more or less the same principal characteristics. Yield per recruit showed that if *S. sierra* is fished at the same size successively as nowadays, biomass and catch could diminish; *y*/*r* could diminish if fishing mortality increases by fishing effort. On the other hand, fishing effort could increase and obtain higher values of *y*/*r,* if the age of first capture is modified higher than $Tc = 5.5$ years and $F = 2$, then *y*/*r* could augment to 810 grams.

Acknowledgements

We want to thank the fishers who kindly proportionate the study specimens and from whom we always learn something new on each species we study. We owe Daniel Hernández-Montaño special thanks for helping us with the use of Beverton & Holt's model of the yield per recruit. To the referees that provided helpful comments and suggestions on the manuscript.

References

AGUILAR-SALAZAR F, S Salas-Márquez, MA Cabrera-Vázquez & JD Martínez-Aguilar. 1991. Crecimiento y mortalidad del carito *Scomberomorus cavalla* en la zona de la costa norte de la península de Yucatán. *Ciencia Pesquera* 8: 71-82.

AGUIRRE-VILLASEÑOR H, E Morales-Bojórquez, RE Morán-Angulo, J Madrid-Vera & MC Valdez-Pineda. 2006. Indicadores biológicos de la pesquería de sierra (*Scomberomorus sierra*) al sur del Golfo de California, México. *Ciencias Marinas* 32(3): 471-484.

ALBARET JJ & R Laë. 2003. Impact of fishing on fish assemblages in tropical lagoons: the example of the Ebrie lagoon, West Africa. *Aquatic Living Resources* 16(1): 1-9.

BEVERTON RJH & SJ Holt. 1957. On the dynamics of exploited fish population. Fishery Investigations. Ministry of Agriculture, Fisheries and Food. Great Britain. *Series II Vol. XIX*. 19: 533p.

BLACKER RW. 1974. Recent advances in otolith studies. *In*: R. Harden-Jones (ed.). *Sea Fisheries Research*. Elek Science, London, pp: 67-90.

CABRAL-SOLÍS EG, E Espino-Barr, M Gallardo-Cabello & AL Ibáñez-Aguirre. 2007. Fishing impact on *Mugil curema* stock of multispecies gill net fishery in a tropical lagoon, Colima, México. *Journal of Fisheries and Aquatic Science* 2(3): 235-242.

CARNEIRO-XIMENES MO, M Ferreira & AA Fonteles-Filho. 1978. Idade e crescimento da cavala, *Scomberomorus cavalla* (Cuvier), no Estado do Ceará (Brasil). *Arquivos de Ciencias do Mar* 8(1-2): 73-81.

CHALE-MATSAU JR, A Govender & LE Beckley. 1999. Age and growth of the queen mackerel *Scomberomorus plurilineatus* from KwaZulu-Natal, South Africa. *Fisheries Research* 44(2): 121-127.

CHÁVEZ RJE. 1986. Análisis preliminar biológico-pesquero de la sierra, *Scomberomorus sierra* Jordan y Starks, 1895, en la bahía de Manzanillo, Colima. Tesis de Licenciatura, ENEP-Iztacala, UNAM. 52p.

CLAVERO M, F Blanco-Garrido & J Prenda. 2006. Monitoring small fish populations in streams: A comparison of four passive methods. *Fisheries Research* 78(2-3): 243-251.

DE LEÓN ME & M Guardiola. 1986. Estudio actual de las pesquerías de sierra y afines en la zona suroriental de Cuba. *Revista Cubana de Investigación Pesquera* 12(3/4): 794-813.

DEVARAJ M. 1981. Age and growth of three species of seerfishes *Scomberomorus commerson*, *S. guttatus* and *S. lineolatus*. *Indian Journal Fisheries* 28(1/2): 104-127.

EDWARDS RRC, A Bakhader & S Shaher. 1985. Growth, mortality, age composition and fishery yields of fish from the Gulf of Aden. *Journal of Fish Biology* 27: 13-21.

EHRHARDT N. 1981. *Curso sobre métodos en dinámica de poblaciones*. 1a. Parte. Estimación de parámetros poblacionales. México, D.F. 150p.

ESPINO-BARR E, M Cruz-Romero & A García-Boa. 1990. Biología pesquera de tres especies de la familia Scombridae en el litoral de Colima, México. *In*: M Dailey & H Bertsch (eds.). *Memorias del VIII Simposium de Biología Marina*. Ensenada, México, pp: 65-74.

ESPINO-BARR E. 2000. Criterios biológicos para la administración de la pesca multiespecífica artesanal en la costa de Colima, México. Tesis de Doctorado, Facultad de Veterinaria, Universidad de Colima, México. 120p.

ESPINO-BARR E, M Gallardo-Cabello, EG Cabral-Solís, A García-Boa & M Puente-Gómez. 2006. Aspectos biológico pesqueros del jurel *Caranx caninus* Günther, 1868, en la costa de Colima. *In*: MC Jiménez-Quiroz & E Espino-Barr (eds.). *Los recursos pesqueros y acuícolas de Jalisco, Colima y Michoacán*. INP, SAGARPA, pp: 494-503.

ESPINO-BARR E, M Gallardo-Cabello, EG Cabral Solís, A García-Boa & M Puente-Gómez. 2008. Growth of the Pacific jack *Caranx caninus* (Pisces: Carangidae) from the coast of Colima, México. *Revista de Biología Tropical* 56(1): 171-179.

FISCHER W, F Krupp, W Schneides, C Sommer, KE Carpenter & UH Niem. 1995. *Guía FAO para la identificación de especies para los fines de la pesca. Pacífico Centro Oriental.* Vol. III, pp: 1537-1538.

GALLARDO-CABELLO M, E Espino-Barr, A García-Boa, EG Cabral-Solís & M Puente-Gómez. 2007. Study of the growth of the green jack *Caranx caballus* Günther 1868, in the coast of Colima, México. *Journal of Fisheries and Aquatic Science* 2(2): 131-139.

GALLARDO-CABELLO M, E Espino-Barr, RA Nava-Ortega, A García-Boa, EG Cabral-Solís & M Puente-Gómez. 2011. Analysis of the otoliths of *sagitta*, *asteriscus* and *lapillus* of Pacific sierra *Scomberomorus sierra* (Pisces: Scombridae) in the coast of Colima, México. *Journal of Fisheries and Aquatic Science* 6(4): 390-403.

GAYANILO FC, P Sparre & D Pauly. 1993. The FISAT user's guide. FAO computarized information. *Series Fisheries* No. 99. Draft. ICLARM, Philippines. 70p.

GOBERT B. 1994. Size structures of demersal catches in a multispecies multigear tropical fishery. *Fisheries Research* 19(1-2): 87-104.

GONZÁLEZ-RAMOS O. 1993. Determinación de edad y crecimiento del peto *Scomberomorus cavalla* (Cuvier), en costas del estado de Veracruz. Tesis de Licenciatura. ENEP-Iztacala, UNAM. 82p.

GONZÁLEZ-BECERRIL A, E Espino-Barr, M Cruz-Romero & A Ruíz-Luna. 2000. Determinación de la unidad de esfuerzo de pesca en una pesquería artesanal ribereña en Manzanillo, Colima, México. *Ciencias Marinas* 26(1): 113-124.

GRAY CA. 2002. Management implications of discarding in an estuarine multi-species gill net fishery. *Fisheries Research* 56(2): 177-192.

GRAY CA, DD Johnson, MK Broadhurst & DJ Young. 2005. Seasonal, spatial and gear-related influences on relationships between retained and discarded catches in a multi-

species gillnet fishery. *Fisheries Research* 75(1-3): 56-72.

GULLAND JA. 1964. Manual of methods of fish population analysis. *FAO Fishery Technical Paper* 40. 60p.

HERNÁNDEZ-MONTAÑO D, C Meléndez-Galicia & A Arellano-Torres. 2006. Evaluación pesquera del huachinango *Lutjanus peru* en la costa de Michoacán. *In*: MC Jiménez-Quiroz & E Espino-Barr (eds.). *Los recursos pesqueros y acuícolas de Jalisco, Colima y Michoacán*. INP, SAGARPA, pp: 477-484.

INEGI. 1997. Mapa digital de Colima. Sistemas Nacionales Estadísticos y de Información Geográfica. http//.www.inegi.gob.mx

MÁRQUEZ-MILLÁN R. 1972. Sierra del Pacífico. Unidades de producción. Departamento de Pesca, Instituto Nacional de la Pesca. *Serie Científica* 3: 1-10.

MENDIZÁBAL Y ORIZA D. 1987. Análisis preliminar del estado de la población de sierra *Scomberomorus maculatus* (Mitchill) del Golfo de México. (Periodo 1973-1976). Tesis de Licenciatura. Facultad de Ciencias, UNAM. 127p.

MONTEMAYOR-LÓPEZ G & MA Cisneros-Mata. 2000. La sierra del Golfo de California. 259-274. *In*: MA Cisneros-Mata, LF Beléndez Moreno, E Zárate Becerra, MT Gaspar Dillanes, LC López González, C Saucedo Ruíz & J Tovar Ávila. (eds.). *Sustentabilidad y pesca responsable en México. Evaluación y manejo 1999-2000*. INP- SEMARNAP. 1047p.

NAVA-ORTEGA RA. 2008. Criterios para la modificación de la luz de malla para optimizar la pesca de *Scomberomorus sierra* (Jordan y Starks, 1895), en el estado de Colima. Tesis de Maestría en Ciencias, Facultad de Ciencias Marinas, Universidad de Colima. 81p.

RICKER WE. 1948. *Methods of estimating vital statistics of fish population.* Indiana University Publisher Science Series 15: 1-101.

SAGARPA. 2003. *Anuario estadístico de pesca 2002*. Comisión Nacional de Acuacultura y Pesca, Secretaría de Agricultura, Ganadería, Pesca y Alimentación. 266p.

SPARRE P & SC Venema. 1995. *Introducción a la evaluación de recursos pesqueros tropicales*. Parte 1-Manual. *FAO Documento Tecnico de Pesca* 306/1, Roma. 420p.

STEIN RA, JO Mecom & B Ivanovic. 1975. Commercial exploitation of fish stocks in Skadar Lake, Yugoslavia, 1947-1973. *Biological Conservation* 8(1): 1-18.

STURM MG. 1978. Aspects of the biology of *Scomberomorus maculatus* (Mitchill) in Trinidad. *Journal of Fish Biology* 13(2): 155-172.

TAYLOR CC. 1958. Cod growth and temperature. *Journal du Conseil* 23(3): 366-370.

TAYLOR CC. 1960. Temperature, growth and mortality-the Pacific cockle. *Journal du Conseil* 26(1): 117-124.

VALLE SV, JP García-Arteaga & R Claro. 1997. Growth parameters of marine fishes in Cuban waters. *Naga ICLARM Quaterly* 20(1): 34-37.

VON BERTALANFFY L. 1938. A quantitative theory of organic growth (inquiries on growth laws. II). *Human Biology* 10(2): 181-213.

Recibido: 6 de julio de 2011.
Aceptado: 12 de octubre de 2011.