Red grouper (Epinephelus morio) population in Campeche Bank, Gulf of Mexico and different management strategies considering the technological interaction of three fishing fleets

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Red grouper fishery of considerable economic importance in Yucatan Peninsula is being exploited simultaneously by three fleets (sequential) from the coast to the open sea (from shallow to deep water). The size of the fish caught by the fleets is different, though there is some overlapping. From 1970 on, the red grouper population has been estimated by various people with different results; most of the studies did not consider fleet interaction,i.e., the effect of one fleet over the catch of the other two. In this work the red grouper population is estimated considering the catch of the three fleets operating in sequence; cohort analysis of length-frequency is applied to samples of the comercial catch of the three fleets from 1988 to 1990 over the Campeche Bank, Gulf of Mexico. Maximum biological and economic sustained yield are evaluated with Thompson and Bell method and analysis are made of the effect over each fleet catch, of increments of fish mortality due to the operation of the two mexican fisheries. Results show that average population amounts to 513.42 X 10^9 individuals and 147 475 tons. Exploitation level is below the optimal biological and economic levels; the increment on fish mortality by the artisanal fleet would produce the smallest negative effect on the catches of the other two fleets.
Keywords: Red gruper, stock assessment, *Epinephelus morio*, sequential fisheries, technological interactions.

La pesquería de mero es muy importante en la economía de la Península de Yucatán, en esta pesquería participan tres flotas que pescan en áreas secuencialmente diferentes en profundidad. El tamaño de los peces capturados por las flotas es diferente aunque existe cierto sobrelapamiento en las tallas. Desde 1970 hasta la fecha se han relizado varias evaluaciones de la población de mero sujeta a aprovechamiento pesquero, sin embargo los resultados obtenidos son muy diferentes y los estudios no consideran la interacción entre las flotas, i.e., el efecto de la captura de una flota sobre la captura de las otras dos. En este trabajo se aplica un análisis de cohortes por longitudes con datos de las capturas comerciales de las tres flotas que operaron en el Banco de Campeche, Golfo de México durante el período 1988 a 1990. Se utiliza el modelo de Thompson y Bell para evaluar el rendimiento máximo sostenible biológico y económico y se analiza el efecto de aumentos en la mortalidad por pesca debida a las flotas mexicanas. Los resultados indican que la población media en el mar es de 513.42 X 10^9 individuos que pesan 147 475 tons. Los niveles de explotación están por debajo de los niveles óptimos biológico y económico; por otra parte el incremento de la mortalidad por pesca debida a la flota artesanal produce un menor efecto negativo sobre las capturas de las otras dos flotas.
Palabras clave: Mero, *Epinephelus morio*, evaluación de la población, pesquerías secuenciales, interacción tecnológica.

Introduction

Red grouper fishery is an important source of food, labor and foreign currency in the State of Yucatan, Mexico. Three different fleets operating at different depths participate in this fishery, the artisanal or minor, the technified or major, both mexican and the "chernera" cuban fleet; they exploit the red grouper population (*Epinephelus morio*) which inhabit the Campeche Bank in the Gulf of Mexico.

Stock assessment of this population by various people started in the decade of 1970 using surplus and dynamic models; the estimates go from 228 000 (Arreguín-Sánchez 1985) to 60 561 Tons. (Fuentes *et al.*, 1989) and in succesive years with a variation of about 51 000 Tons.

The problem with these stock assessments in Yucatan is that the fishery is sequential in space, implying size selection in the catch. The artisanal fleet operates in shallow water (less than 28 m -15 fath) the technified one between 28 to 56 m (15 to 30 fath) and the cuban fishery between 37 to 56 m (20 to 30 fath); because of this variation in the depth of the fishing ground, the size of the organisms being caught by the different fleets also varies; size of the fishes increases with depth. Stock evaluation

by the dynamic method based on data of one or two fleets will be biased. If population structure is based on the catch of the artisanal fleet there will be overestimation of the instantaneous rate of total mortality (Z) and of the fishing mortality (F), assuming natural mortality (M) constant. The contrary is true if the structure is based in larger fishes. Figure 1 illustrates the size structure of the catches expected from a sequential fishery such as the red grouper. Another related problem is that the catch of one of the fleets may affect the catch of the other two fleets (externalities), this complicates the adoption of the proper management strategy.

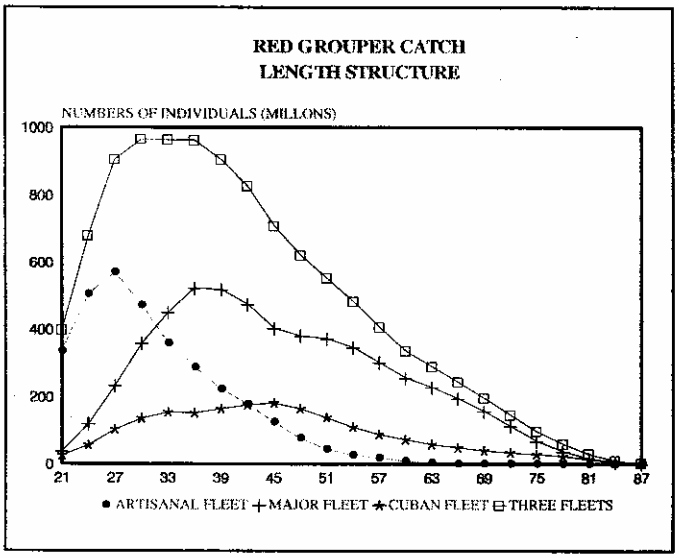

Fig. 1. Size structure of the catches expected in a sequential fishery

This paper deals with a) red grouper stock assessment on the Campeche Bank, using population structure data coming from the three fishing fleets (sequential fishing) using length cohort analysi and b) the biological and economical implications of changes in the fishing mortality of the two mexican fleets.

Methodology

Samples were obtained from the catches of the three commercial fisheries during 1988 to 1990; fish size and frequency were measured so it was possible to have the population structure by fleets. Length class interval was 3 cm between 21 and 90 cm, *table 1* lists the catches of each fleet during the period.

Table 1. Red grouper catch (in tones) by fleet during 1988 to 1990 in Campeche Bank-Gulf of Mexico

YEAR	CUBAN FLEET	MAJOR FLEET	ARTISANAL FLEET
1988	2979	8829	3375
1989	3112	7802	1905
1990	1672	7664	3140

Source: Delegación Federal de Pesca del Estado de Yucatán.

Table 2 shows values of a and *b* obtained by various authors; von Bertalanffy parameters were estimated by Valdés *et al.* (1991) with Ford-Walford technique as modified by Beverton and Holt, and age determined by urohial bone reading.

Table 2. Some estimation of parameters (*a* and *b*) of the length-weight (g-cm) relation of the red grouper *Epinephelus morio*.

PARAMETER		AUTHOR
a	b	
0.0001479	2.58	Muhlia, 1976
0.0000138	3.00	Doi et al., 1981
0.0000024	3.27	Basurto, 1986
0.000015	2.95	Fuentes et al., 1989
0.0129656	3.05	Valdés et al., 1994
0.0000024	3.27	

To estimate the number of individuals for each length-class the following relation was used:

1. $W=aL^b$; W being the weigth in g; L the fork-length in cm; a= 0.01; b= 3.
2. $Lt = 96.2\ (1\ e^{-0.105(t+1.92)})$, t being the age in years and Lt the fork-length in cm at the age t.

Stock assessment was evaluated through cohort-length analysis (Jones 1984, Sparre *et al.* 1990) and the LFSA program (Sparre 1987); the instantaneous rate of natural mortality (M) was 0.271, estimated from Pauly (1980) with a bottom mean temperature of 23.1 °C. Mean length at maturation for the grouper is about 53 centimeters corresponding to an age about 6 years (Mexicano 1990).

After estimating the average number and biomass of the stock the maximum biologic and economic yield was obtained through Thompson and Bell (1934) method. Price on the beach of the grouper was: less than 1.5 Kg = 1.05 US$; 1.5 Kg and greater = 1.65 US dollars. With similar technique it was evaluated the impact on the population and in the economic yield produced by fish mortality changes in the minor and major mexican fleets holding two constant and changing one at a time.

Results

Cohort analysis gave the following results:

Average number of individuals at sea:	513.42×10^9
Average population biomass:	147 475.2813 Tons
Average recruitment:	54.520 X 106 organisms
Biomass recruitment:	2 637 Tons

Maximum sustainable yield (MSY) obtained with a fishing mortality of 3.78 (present one is 1) would be 17 787.59 tons and a mean biomass of 66 891.7 tons. Maximum economic yield (MEY) with a fishing mortality of 2.56 (1.56 times the present one) is of 23.11 millions of US dollars.

Tables 3 and 4 give the catch and value predictions for each fleet when the fishing mortality of the artisanal fleet is changed. If the fishing mortality of the artisanal fleet is increased four times, there will be a 15% reduction of a catches of the other

two fleets, an increase of about 180% in the artisanal one and a total catch value of the three fleets 10% greater than the present level (Fig. 2).

Table 3. Rate of change in the total catch (RCTC), and in the catches of the cuban fleet (RCCCF), mexican major (RCCMMF) and mexican artisanal (RCCMAF) as result of increments of the fishing mortality of the artisanal fleet (CAF) in terms of the whole fishery and TOT PROD, the production in ton resulting from each fishing mortality.

CTF	CAF	CAF	RCTC	RCCCF	RCCMMF	RCCAF
1.00	1.00	13339.92	1.00	1.00	1.00	1.00
1.04	1.42	13569.34	1.02	0.97	0.98	1.29
1.09	1.94	13840.02	1.04	0.94	0.95	1.64
1.14	2.47	14094.05	1.06	0.92	0.92	1.97
1.18	2.89	14286.07	1.07	0.89	0.90	2.22
1.28	3.95	14726.33	1.10	0.84	0.85	2.80

Table 4. Rate of change in the total catch value (RCTCV), and in the catches of the cuban fleet (RCCCFV), mexican major (RCMMCV) and mexican artisanal (RCMACV) as result of increments of the fishing mortality of the artisanal fleet (CAF) in terms of the whole fishery and TOT PROD the production in Tons resulting from each fishing mortality, TOT VAL is the production value in millons of mexican pesos resulting form each fishing mortality. 1 Mex $ = 0.003 US Dollar.

CTF	CAF	TOT VAL	RCTCV	RCCCFV	RCMMFCV	RCMAFCV
1.00	1.00	62511.23	1.00	1.00	1.00	1.00
1.04	1.42	63418.95	1.01	0.97	0.97	1.37
1.09	1.94	65443.12	1.03	0.94	0.94	1.81
1.14	2.47	66163.77	1.05	0.91	0.91	2.22
1.19	2.89	66163.77	1.06	0.88	0.89	2.53
1.29	3.95	67768.89	1.09	0.83	0.84	3.25

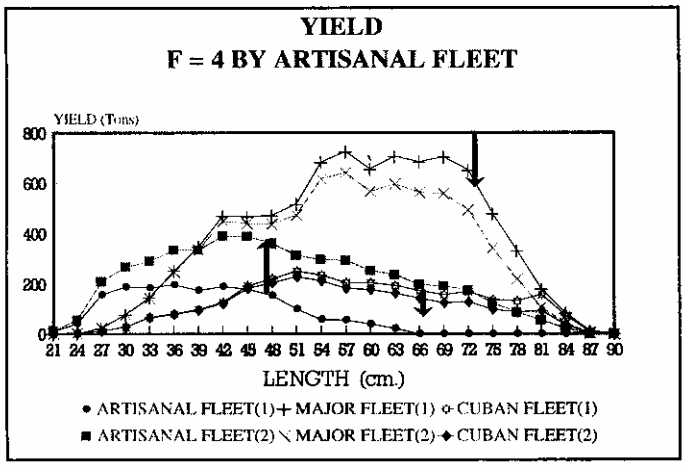

Fig. 2. Yield prediction for each fleet when fish mortality of the artisanal fleet increased

Tables 5 and 6 provide similar information as above, when the fishing mortality of the major mexican fleet is changed; results indicate a greater effect over the total catch, so that increases three times the fishing mortality of the major fleet and produces an increase up to 2.24 times the total catch, implying a decrease of 47% in the cuban fleet and 17% in the artisanal one, while the major fleet will increase its catch in 62% and the total catch in 28% (Fig.3). The above changes in fishing mortality are below the ones needed to reach the MSY and MEY.

Table 5. Rate of change in the total catch (RCTC), and in the catches of the cuban fleet (RCCCF), mexican major (RCCMMF) and mexican artisanal (RCCMAF) as result of increments of the fishing mortality of the major fleet (CMF) in terms of the whole fishery and TOT PROD the production in ton resulting from each fishing mortality.

CTF	CMF	TOT PROD	RCTC	RCCCF	RCCMMF	RCCMAF
1.00	1.0	13339.94	1.00	1.00	1.00	1.00
1.31	1.5	14848.17	1.11	0.93	1.24	0.95
1.62	2.0	15878.88	1.19	0.70	1.41	0.91
1.93	2.5	16590.47	1.24	0.61	1.53	0.87
2.24	3.0	17080.76	1.28	0.53	1.62	0.83

Table 6. Rate of change in the total catch value (RCTCV), and in the catches of the cuban fleet (RCCFCV), mexican major (PCVCFM) and mexican artisanal (RCAFCV) as result of increments of the fishing mortality of the major fleet (CMF) in terms of the whole fishery and TOT PROD TOT the production in Tons resulting from each fishing mortality, TOT VAL is the production value en millons of mexican pesos resulting form each fishing mortality. (1 Mex $= 0.003 US Dollar).

CTF	CMF	TOT VAL	RCTCV	RCCFCV	RCMMFCV	RCAFCV
1.00	1.0	62511.35	1.00	1.00	1.00	1.00
1.31	1.5	68200.24	1.09	0.81	1.21	0.95
1.62	2.0	71558.81	1.14	0.67	1.34	0.90
1.98	2.5	71558.81	1.17	0.57	1.42	0.86
2.24	3.0	74316.57	1.19	0.49	1.48	0.82

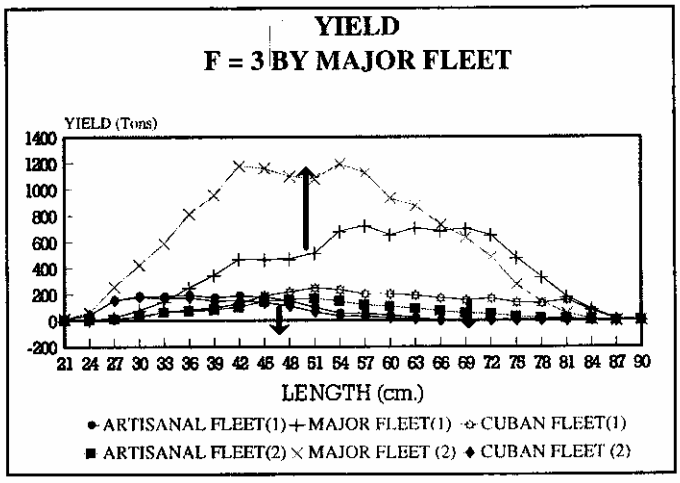

Fig. 3. Yield prediction for each fleet when the fishing mortality of major fleet is increased

In this regard it is of interest to show the results obtained by various authors: Doi *et al.* (1981) gives a biomass average of 138 000 for 1972-1976; Fuentes and Contreras (1986) report 156 039 Arreguín et al. (1987a) 35.22 and 18.97 millions of individuals using age and length cohort analysis respectively.

The most recent one within the Mexican-Cuba agreement gives 79 000 t.

Discussion

As it can be seen, the differences in the mean biomass amount to thousands of *tones.*; the causes can be related to the various methods employed, sampling variability (different places and times) and to the values of the parameters (natural mortality and growth). With the exception of the last evaluation (1991) the above methods used the population structure of one or two of the three fleets, generating a bias in the evaluation of total mortality Z.

Natural mortality affects greatly stock assessment. Two values of M has been estimated in this work; one after Pauly (1980) which relates M with the average bottom temperature and growth parameters, and the other after Rikhter and Efanov which relates M with maturation age. Although both M estimations are punctually different' it is likely that this is not the case when intervals are considered.

As for von Bertalanff's parameters, in view of the great variability in growth of the red grouper, the direct approach of age determination was used because it is considered more reliable.

Though the growth parameters and natural mortality used in this work differed from the 1991 evaluation, the main difference lies in the way that the numbers of individual length classes were estimated; in this case it was done for each catch fleet and added together.

The evaluation of the maximum sustainable yield (MSY). is an important result During the last few years it has been stressed that red grouper is being overexploited or almost (Arreguín *et al.* 1987b). The result of this work shows that it is possible to duplicate the fishing mortality withougt reaching the MSY; of course this is valid if the explotation does not affect the recruitment levels assumed constant by Thompson and Bell (1934).

The advantage of this analysis is the use of biomass and catch prediction for each length class to estimate the maximun catch (inflection point in the parabola).

As a management strategy it is recommended to adopt the fishing mortality for the maximum economic yield; the results indicate that this level of fishing mortality can be reached increasing 1.5 times the present value.

Conclusions

It can be concluded that:

1. The red grouper population is being exploited at a rate below the optimum biological and economic levels.
2. Fishing mortality increased by any of the three fleets will reduce the catch of the other two; however, if the increment is on the artisanal fleet, the negative effect on the other two will be smaller.
3. It is important to study natural mortality of the red grouper in the Campeche Bank to strenghten growth studies based on aquaculture essays. Moreover it is necessary to analize the fishery based on cost data of the three fleets.

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