Present Status of the Red Grouper Fishery of the Campeche Bank

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ABSTRACT

The red grouper (Epinephelus morio) is the most important species in the finfish fishery of the Campeche Bank. The actual level of exploitation by the Yucatan fleet is higher than MSYe (maximum equilibrium yield), estimated to be around 12,000 mt per year. The current level of fishing effort is about 45% higher than that for MSYe. The economic index Income/Cost (I/C) shows a negative balance for the last four fishing seasons. The highest profit could be reached if the fishing effort is reduced by 34% from the MSYe level and 54% of the current level. Although there is overfishing with respect to the MSYe, there is no biological overfishing; that is, the turn-over rate has not yet altered. With these results and the fluctuations of the recruitment rate on yield, the economic profit, and social aspects (employment), the options for the management of the fishery are discussed.

INTRODUCTION

Hook and line fishing is a very important activity on the northern coast of the Yucatan Peninsula. The catches are composed of several species such as red grouper, Epinephelus morio; red snapper, Lutjanus campechanus; mutton snapper, L. analis; gray snapper, L. griseus; "mojarras" (Calamus sp.), and others; the red grouper is the most important species, making up nearly 80% of the total catches in 1981.

Historically, the type of gear used by fishermen has changed little; however, catching power has been increased through the addition of mechanical systems.

This is a fishery which is international in scope, with the participation of fleets from Mexico, Cuba and the United States (Klima, 1976), but in this paper only the Mexican one is analyzed.

The statistical records of catches have shown three phases in the historical development of the fishery (Fig. 1). (1) An initial phase (1956-1966) with a small increase in the fishing effort and catches, (2) A second phase, with considerable decrease in yields in 1967 (near 50%), with a level of fishing effort similar to that of the previous year. However, this situation resulted from an improvement of administrative problems in boat operation. After 1968, the increases in fishing effort and yields were larger than in phase 1, until the fishery reached the Maximum Sustainable Yield (MSY) level in 1974. The third phase is represented by the present situation; the increase of fishing effort has continued, but the yields have decreased below the MSY level.

There are few previous references on this fishery. Solis (1970) gives a description of the red grouper fishery and its operational characteristics. Muhlia (1976), Moreno (1980), and Doi et al. (1981) have provided preliminary estimations of the population dynamics and their parameters, but the results are based on different analysis conditions or assumed values.

ANALYSIS OF THE FISHERY

Unfortunately, there are no reliable statistical records of fishing effort; only capture data are available. Nevertheless, as this traditional fishery is the most important regional fishing activity with participation of almost all fishermen, the capacity of the fleet (year average) was considered an appropriate index of the fishing effort to be applied to the Schaefer model (Schaefer, 1954; 1957) and Walter's procedure to estimate the yield equilibrium curve (Walter, 1975). In addition, Leslie's equation (Ricker, 1975) was used to estimate the catchability coefficient necessary for equilibrium curve computations.

For the economic analysis, the Gordon-Schaefer model (Clark, 1976) was applied in order to compute the Maximum Profitable level, the Income-Cost relationship, and the Maximum Income/Cost (I/C) ratio, using as reference the economic data given by Chavez (1984) for this fishery. Here, the Income (I) was taken as the total catch value; the costs (C), as the exploitation costs, including the fishermen's salaries; and the profits (P), as the difference between Income and Cost (P = I-C).

Using the age, growth and population age structure data for five years from Doi et al. (1981), the stock-recruitment relationship was obtained according to Ricker's model (Ricker, 1954). The recruitment rate was estimated with the α and β values and included in the Schaefer-Walter equilibrium equation (Walter, 1978), to determine changes in population abundance and yields due to recruitment rate variations and its consequences in the management of this fishery.

THE EXPLOITED POPULATION

The Leslie plot (Fig. 2) shows two different conditions for the fishery, given two catchability coefficient values, corresponding to phase 1 and phases 2-3 respectively. The first value of q_1 (1960-67) $= 1.9983 \cdot 10^{-5}$ is almost twice the present value of q_2 (1972-81) $= 1.0374 \cdot 10^{-5}$. It is possible that this difference is due to changes in the fishing power or changes in resource availability, or both.

The equilibrium yield curve was obtained with Walter's procedure, using the previous estimation of the Schaefer curve parameters. The results, given in Table 1, show few differences between parameters and yield curves. Figure 3 portrays the

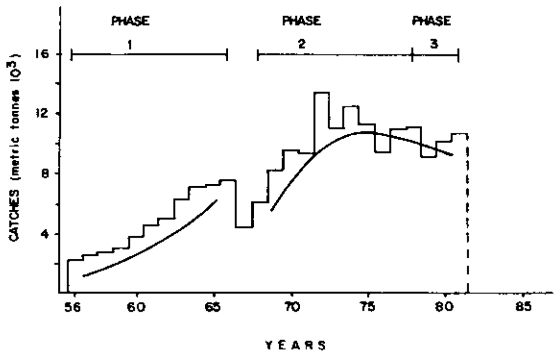

Figure 1. Historical development phases of the red grouper fishery of Campeche Bank.

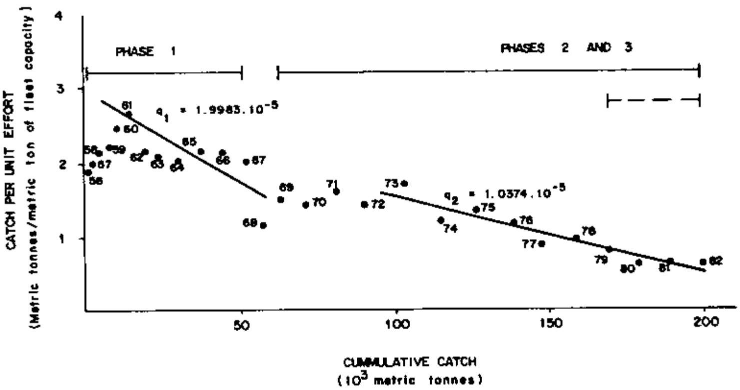

Figure 2. Estimation of the catchability coefficient (q) for the red grouper for the different phases of fishery development.

equilibrium yield curve and the three phases of the fishery. The MSY level under equilibrium conditions (MSYe) was reached in 1974, and the next 7 years included in this analysis are above this level, indicating "overfishing."

In order to determine if this "overfishing" condition is only found above MSYe level, or if the natural turnover rate of the population was altered, the population recovery time was estimated, taking a no-fishing condition as the assumption.

Table 1. Comparison between Schaefer's and Walter's yield curve estimations for the red grouper fishery of Campeche Bank, Mexico

Parameters	Schaefer's Model (average yield curve)	Walter's Procedure (equilibrium yield curve)
MSY (mt)[1)]	11859.4	11880.1
f (mtfc)[2)]	10098	10030
U[3)]	1.17	1.18
a	2.34895	2.3688
b	-1.163×10^{-4}	-1.1181×10^{-4}
r	0.2095	0.2198
B (mt)[1)]	226.4×10^3	228.3×10^3

1) mt = metric tonnes
2) mtfc = metric tonnes of fleet capacity
3) Catch per unit effort
r = Intrinsic population growth rate
B = Population Biomass corresponding to P_∞.

The general population growth equation in absence of fishing

$$\frac{1}{P}\frac{dP}{dt} = r\ 1-(P/P_\infty) \qquad (1)$$

can be solved for P(t) as:

$$P(t) = P_\infty /\ 1 + \ (P/\alpha P_\infty)\ -1\ e^{rt} \qquad (2)$$

where:

P(t) is the population size at time t. Here taken as P/2, corresponding to the MSYe level.

P_∞ is the virgin population size, limited by the environmental carrying capacity.

αP_∞ is the actual population size, where α is the proportionality coefficient.

r is the intrinsic population growth rate.

t is the time, in years.

Then, taking the catch-per-unit effort (U) corresponding to MSYe (Ue) as an abundance index of P(t), Ua (actual population level) as an abundance index to P_∞, and the parameters of the Schaefer-Walter equilibrium curve, the r value and the recovery time of the population was obtained by solving equation (2) for t:

with

$$\gamma = \frac{0.5\ Ua}{Ue} = 0.28 \qquad (3)$$

and then

$$t = 4.5 \text{ years.}$$

The present population size is 0.28 P_∞, lower than 0.5 P_∞, which corresponds to the MSYe level, but in absence of fishing, the population could reach the 0.5 P_∞ size after four years. However, the increments in fishing effort could also produce collapse of the fishery.

The recruitment rate is a parameter used in the Walter's procedure oriented to understand the changes on yields due to recruitment (Walter, 1978). Ricker's model was used to estimate the stock-recruitment relationship, with a recruitment age of tr = 3 years; organisms with ages over 4 years old were considered to be adults. Figure 4 shows the Ricker curve and parameters.

Walter (1978) established the yield equation with a specific parameter corresponding to the recruitment rate (γ) as:

$$Y = \frac{qf}{a}\ (r + \gamma\ ) - qf$$

where

$$\gamma = \log_e [\ (R/P) + 1\ ] \qquad (4)$$

and

R = Number of Recruits

P = Population size

or including parameters of Ricker's model

$$\gamma = \log_e[\alpha e^{-\beta P} + 1] \qquad (5)$$

The values obtained for γ from equation (5) were used to estimate the average recruitment rate (γ), and using equation (4) for the five fishing seasons of data considered (Doi et al. 1981), the range of variations of the recruitment rate (γ) was obtained. These values were included in the equilibrium curve as stochastic parameters, showing the range of variations on yields due to recruitment (Fig. 5).

ECONOMIC CONDITION OF THE FISHERY

For the estimation of the economic condition of the fishery, the catch value and the exploitation costs were considered, including the salaries of the fishermen as part of the costs. Boat values were excluded.

The Profit-Cost curve obtained with the Gordon-Schaefer model (Fig. 6) shows that the red grouper fishery has been working at a loss since 1978. However, this condition could perhaps change if the value of the other species captured at the same time are considered. Maximum profit can be reached with a fishing effort of 6,600 mt of fleet capacity; 54.2% below the present condition (1981).

Figure 7 depicts the historical trend of the Income/Cost ratio (I/C). After 1978, the fishery has been below economic equilibrium, thus producing losses. The Gordon-Schaefer model applied to this ratio (Fig. 8) gives an optimum level, I/C = 2.88, which can be reached with a fishing effort of 4,000 mt of fleet capacity.

FISHERY MANAGEMENT

So far we have established that the fishery is working above the MSYe level with a trend towards biological overfishing. However, this condition has not yet been reached; the recovery time of the population to the MSYe level in absence of fishing is four years. The range in variation of the catches due to recruitment is about 7,500 mt below the MSYe level. But, according to the historical development of the fishery (Fig. 3), the largest expected change in two successive years is about 3,500 mt. On the other hand, the economic analysis shows that the fishery is now working at a loss but quite close to economic equilibrium.

Therefore, the priority problems for the exploitation of the red grouper in the next years are as follows:

1) The present population size (0.28 P_∞) is near the critical level (0.25 P_∞), after which collapse is imminent (Arreguin-Sanchez and Chavez, 1985).

2) The recruitment changes produce fluctuations in yields, as

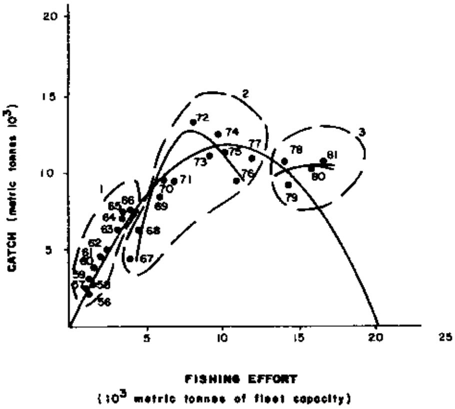

Figure 3. Equilibrium yield curve for the red grouper fishery of Campeche Bank showing the different phases of fishery development.

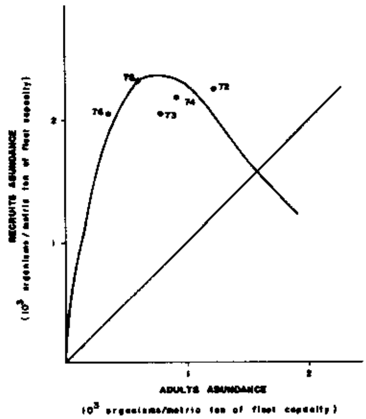

Figure 4. Recruits-Adults relationship according to the Ricker model for the red grouper fishery of Campeche Bank.

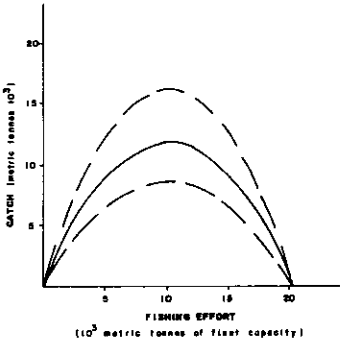

Figure 5. Equilibrium yield curves showing the yield fluctuations due to changes in the recruitment rate for the red grouper of Campeche Bank.

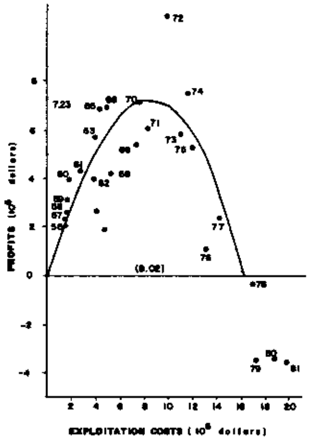

Figure 6. Profit-Cost relationship for the red grouper fishery of Campeche Bank.

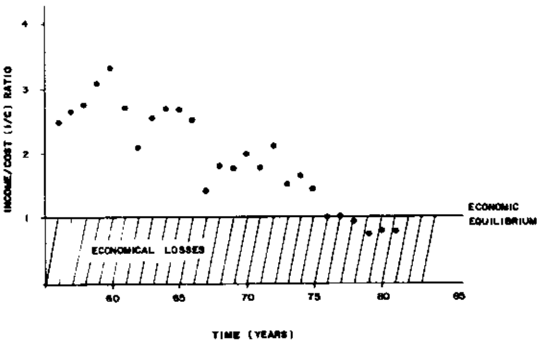

Figure 7. Historical variations of the Income/Cost (I/C) ratio for the red grouper fishery of Campeche Bank.

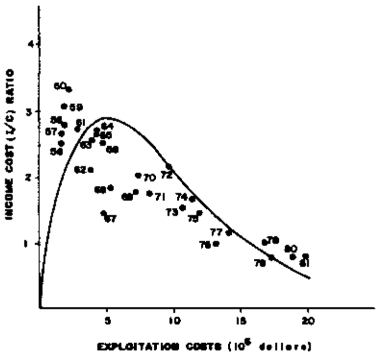

Figure 8. Estimation of the optimum Income/Cost (I/C) ratio for the red grouper fishery of Campeche Bank.

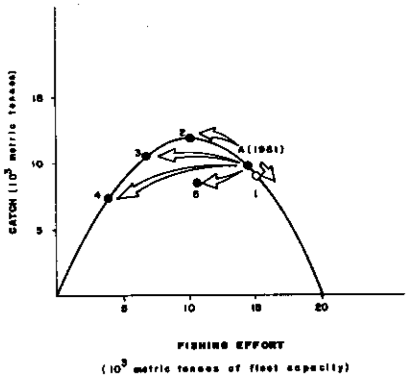

Figure 9. Alternatives for management of the red grouper fishery of Campeche Bank.

Table 2. Management Alternatives for the Red Grouper Fishery of Campeche Bank, Mexico

*	MANAGEMENT OPTIONS	CATCH (mt)	FISHING EFFORT (mtfc)	EMPLOYMENT a)	% OF CHANGE FROM A: effort	% OF CHANGE FROM A: catch	POPULATION LEVEL
A	TO MAINTAIN THE ACTUAL LEVEL OF EXPLOITATION. This implies stopping increases in fishing effort.	9600	14,400	CURRENT LEVEL	-	-	0.28P
1	FREE ACCESS. This implies taking no management action and to let the fishery continue as now with the fishery moving towards over-fishing and population collapse.	8960	15,000	INCREASE	+ 4.2	- 6.9	0.25P b)
2	TOWARDS MSYe. Regulation of the fishery to maintain it at levels of fishing effort such that the fluctuations in recruitment have no negative effect on the population	12000	10,000	DECREASE	-30.6	+23.5	0.5P
3	TOWARDS MAXIMUM PROFIT	10500	6,600	DECREASE	-54.2	+ 9.0	0.67P
4	TOWARDS MAXIMUM LEVEL OF THE INCOME/COST (I/C) RATIO	7600	4,000	DECREASE	-72.2	-21.1	0.80P
5	GUARANTEE RENT OF EXPLOITATION WITH MINIMUM RECRUITMENT LEVEL	11800	10,500	DECREASE	-27.1	23.2	0.47P

* Symbols correspond to those used in Fig. 9.
mt Metric tonnes
mtfc Metric tonnes of fleet capacity
a) Only refer to employment in the exploitation phase, not to post-catch phase
b) This population size correspond to the critical exploitation level after which the turnover rate is altered (Arreguín-Sánchez y Chávez, 1985)
c) Taking P_∞ as virgin population

well as a combination of low recruitment levels in two or more successive years. Increases in fishing effort and the current population size could result in biological overfishing, with the obvious socio-economic consequences.

3) The economic analysis of the fishery shows a negative balance if only the red grouper is considered. If the other species are considered, economic conditions could change perhaps to a positive value, but always near economic equilibrium. If the conditions mentioned in 2) above pertain, then the fishery situation will be more dangerous, especially to fishermen as our analysis only deals with the exploitation phase (including fishermen's salaries). With a great reduction in catches, both profits and salaries decrease. However, the additional value gained in the post-catch phase (due to management and industrialization) could maintain the exploitation as an economically productive activity attractive to fishermen.

Given the conditions mentioned, some fishery management alternatives are provided in Table 2 and displayed in Figure 9. Of these alternatives, the recommendation is to stop the increase in the fishing effort.

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