Mortality and Population Size of the Red Grouper (*Epinephelus morio*) Fishery from the Campeche Bank

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ABSTRACT

The red grouper (*Epinephelus morio*) is the most important demersal fish resource from the Campeche Bank. It supports an international multifleet fishery in which annual yields for the last five years have been about 16,000 metric tons. This is obtained by three fleets, the Cuban and Mexican modern fleets, and an artisanal Mexican fleet. In this contribution, fishing mortality and population size are estimated from annual age structure catch composition data and the amount of fishing applied for a period of 15 years, from 1973 to 1987.

Two scenarios are presented when Virtual Population Analysis (VPA) technique was applied: assuming steady state, and using cohort analysis: For both scenarios a minimization routine was used for selection of the terminal fishing mortality values. Then, time tendencies of fishing patterns and population sizes were compared.

KEY WORDS: red grouper, demersal fishery, VPA, Campeche Bank.

INTRODUCTION

The red grouper (*Epinephelus morio*) is the most important demersal fish resource in the Campeche Bank. Annual yields are around 16,000 metric tons which are caught by three fleets: a modern fleet from Cuba; and in Mexico, a small scale artisanal fleet operates in waters up to 12 fathoms, and a modern fleet which works out to 40 fathoms. Most of the studies from the last years (Seijo, 1986; Arreguín-Sánchez *et al.* (1987a, b), suggest that overfishing may be the cause of declines in grouper populations, although environmental changes resulting in recruitment failures also have been implicated (Arreguín-Sánchez *et al.*, 1990). Although the red grouper is an important fishery in Mexico, oriented mainly to an export market and generating significant employment, information about red grouper population dynamics is scarce. The purpose of this study is to obtain estimates of mortality and population size for a period of fifteen years, from 1973 to 1987.

METHODS AND MATERIALS

Samples were obtained directly from commercial catches of the modern fleet of Mexico which harvests about 70% of the total catches and operates with a high degree of overlap in the fishing grounds with the other fleets. For running VPA, growth parameters were taken from that estimated by Fuentes *et al.*, (1989) were: L = 93.6 cm; K = 0.105 year ; and t_0 = -0.23 year. A value for M = 0. 33 year was taken from Arreguín-Sánchez *et al.* (1987a).

Age structure of catches were obtained through an age-length key to estimate the probability that a fish with a given length corresponded to a given age. This age-length probability key was estimated from results reported by Rodríguez (1984) and Rodríguez y Arreguín-Sánchez (1991).

To obtain estimates of fishing mortality and population size the Virtual Population Analysis (VPA) technique (Gulland, 1965, 1983) was applied, and two separate approaches were considered. The first approach assumed a steady state stock condition where annual catch-at-age data were used. The second approach used the catch-at-age data in a cohort analysis.

The general solution for the VPA equations proposed by Gulland (1965) can be summarized following Murphy-Tomlinson method (Murphy, 1965; Tomlinson (1970) as:

$$N_{(a+1)} = N_{(a)}\, exp^{-(F(a) + M)} \quad (1)$$

$$C_{(a)} = N_{(a)} E_{(a)} \quad (2)$$

$$\text{where } E_{(a)} = \frac{F_{(a)}\,[1\text{-}exp^{-(F(a)+M)}]}{(F_{(a)} + M} = \text{exploitation rate}$$

$N_{(a)}$ = Abundance of a cohort at age a
$F_{(a)}$ = instantaneous rate of fishing mortality at age a
M = instantaneous rate of natural mortality (assumed as constant)
$C_{(a)}$ = catch in numbers of fish at age a
a = index of age (years)

Combining equations (1) and (2), a solution could be presented on the same way to the Murphy-Tomlinson method:

$$\text{Let } R(a) = \frac{C_{(a+1)}}{C_{(a)}}$$

a) For E 0 for some age interval a:

$$\frac{C_{(a+1)}}{C_{(a)}} = \frac{N_{(a+1)}\,E_{(a+1)}}{N_{(a)}\,E_{(a)}} = E_{(a)}\,exp^{Z(a)} = \frac{E_{(a+1)}}{R_{(a)}} \qquad (3a)$$

b) For E = 0 for some age interval:

$$\text{Let } {*R_{(a)}} = \frac{C_{(a+1)}}{C_{(a-1)}}$$

$$= \frac{N_{(a+1)}\,E_{(a+1)}}{N_{(a-1)}\,E_{(a-1)}} = E_{(a-1)}\,exp^{Z(a-1)} = \frac{E_{(a+1)}}{*R_{(a)}} \qquad (3b)$$

The solution requires a value of F_T (where T stands for the last age interval), M, catch-at-age vector $C_{(a)}$, and it was obtained using the algorithm developed by Sánchez *et al.* (this volume) which incorporates error minimization routines (Figure 1) for selection of the F_T value.

RESULTS AND DISCUSSION

The relationship expressing changes on standard deviation with age was estimated as::

s.d. = 0.0165 + 25.87 a

These estimates were used to obtain the age-length probability key as:

$$L^T * P = A \qquad (4)$$

where L is the length frequency vector; ^{T} means transpose operation; P is the age-length probability matrix (Table 1); and the A is a transpose age-structured vector. The age-structured catches were estimated for a period involving 1973 to 1987, where 30 ages were represented which were organized to prepare conditions for both scenerios.

Equation (3) as implemented by Sánchez *et al.* (1994) was used to determine the VPA estimates of fishing mortalities for both approaches with annual age structured catches, assuming "steady state" conditions; and following annual cohorts through time.

Under steady state assumptions, F_a values change little with age exhibiting values that range from $F_a = 0.2$ to $F_a = 0.4$ for most ages; the highest estimated values were for ages 3 to 5/6 years, the most abundant ages and composed

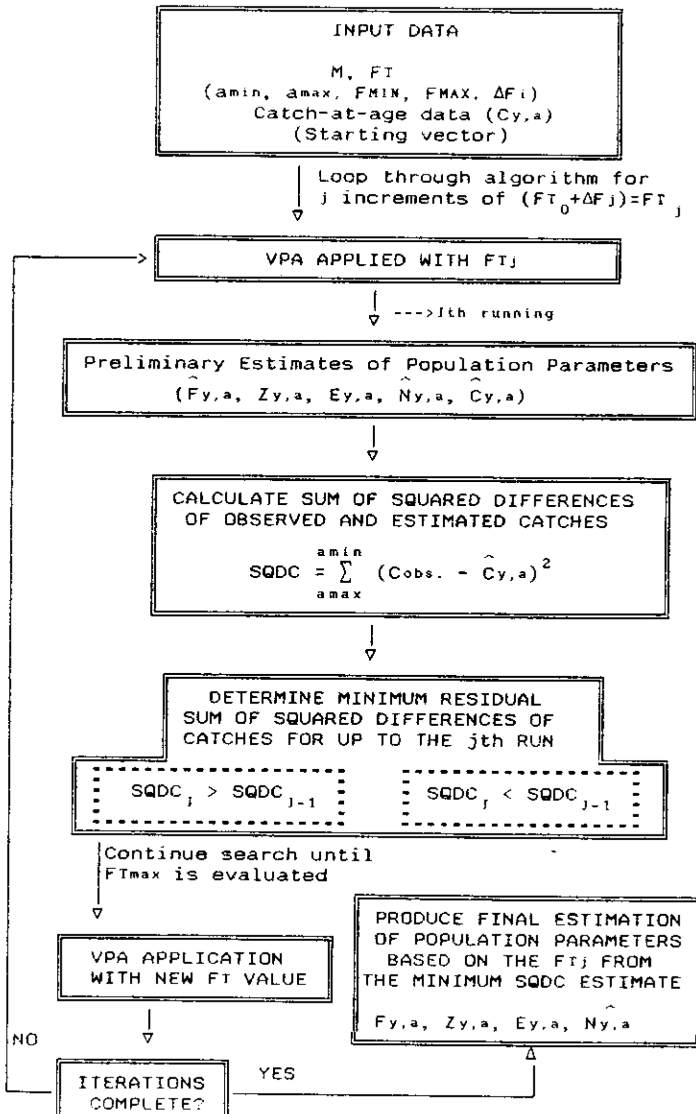

Figure 1. Flowchart showing the algorithm for estimating FT from age composition composition data (taken from Sánchez *et al.*, 1994).

Table 1. Age-length probability key for the red grouper from the Campoeche Bank. Probabilities were estimated by simulation following Cabrera (1991). Growth parameters of the von Bertalanffy equation used were: K = 0.105 (annual); L_∞ = 93.6 cm and t_0 = -0.23 years (Fuentes, 1990).

LENGTH (cm)	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12
6	1.000											
8	1.000											
10	0.970	0.030										
12	0.959	0.041										
14	0.849	0.151										
16	0.408	0.575	0.018									
18	0.084	0.871	0.045									
20	0.031	0.823	0.146									
22		0.632	0.309	0.049	0.010							
24		0.516	0.403	0.065	0.015							
26		0.234	0.554	0.201	0.010							
28		0.073	0.623	0.246	0.037	0.010	0.010					
30		0.039	0.464	0.364	0.112	0.020						
32		0.018	0.452	0.375	0.129	0.018	0.009					
34			0.218	0.464	0.215	0.076		0.026				
36			0.125	0.428	0.256	0.147	0.011	0.022	0.012			
38			0.050	0.410	0.340	0.146	0.028	0.018		0.009		
40			0.008	0.217	0.407	0.164	0.117	0.053	0.018	0.008	0.008	
42			0.008	0.109	0.333	0.258	0.162	0.097	0.032			
44				0.055	0.370	0.218	0.190	0.063	0.024	0.016		0.008
46				0.068	0.172	0.297	0.182	0.122	0.104	0.011	0.011	0.014
48				0.036	0.141	0.248	0.210	0.120	0.111	0.078	0.020	
50				0.010	0.076	0.204	0.278	0.175	0.079	0.069	0.017	0.030
52					0.021	0.184	0.204	0.257	0.100	0.071	0.021	0.042
54					0.013	0.127	0.179	0.203	0.140	0.083	0.070	0.045
56						0.067	0.104	0.151	0.208	0.103	0.098	0.036
58					0.005	0.018	0.138	0.121	0.156	0.105	0.126	0.058
60					0.004	0.036	0.060	0.116	0.080	0.136	0.064	0.076
62						0.005	0.032	0.079	0.138	0.166	0.102	0.100
64						0.004	0.008	0.061	0.081	0.122	0.142	0.081
66							0.019	0.038	0.099	0.088	0.084	0.103
68						0.004	0.007	0.018	0.091	0.084	0.090	0.086
70						0.003		0.013	0.017	0.054	0.104	0.077
72								0.003	0.028	0.024	0.068	0.082
74								0.003	0.006	0.029	0.051	0.090
76									0.006	0.040	0.043	0.059
78								0.003			0.040	0.049
80										0.020	0.019	0.039
82										0.009	0.009	0.019
84										0.003	0.015	0.018
86										0.006		0.007
88												0.008
90												
92												0.004
94												0.005
96												
98												
100												

mainly of females. Similar values were found for all fifteen years. For other ages, F_a values were $F_a = 0.2$ (Table 2).

Results from the cohort analysis also suggest that the red grouper population is relatively stable despite the historical level of exploitation and changes in abundance. Figure 2 shows cohort trends with time for generations recruited from 1973 to 1978, and Figure 3 shows the population trends for 1979 to 1983. Cohorts declining with time show a similar slope (total mortality rate) for most of these years. Although changes in the magnitude of number of fishes were obvious, the most important ones were well identified since 1980 to 1987. Estimates obtained from VPA and cohort analysis are shown in Table 3.

Exploitation patterns exhibit similar trends for all the cohorts analyzed, with highest F_a values for those ages which were more abundant. This aspect suggests catch probability is dependent of population abundance. The exploitation patterns for 1973 to 1978 were quite similar for all cohorts (Figure 2a). The exploitation patterns for 1979 to 1983 cohorts, suggest important changes for 1979 where the fishing mortality pattern showed a different tendency (Figure 2b). These changes were assumed to be as consequence of environment perturbation and not due to overfishing. Arreguín-Sánchez *et al.* (1990) mentioned a dramatic decrease in recruitment in 1980 due to high mortalities on the early development stages probably linked to the oil industry catastrophe in the Campeche Bank in 1979, which induced at the same time a change in regional fishing strategies for most of the fisheries.

Although changes in population abundance could have been caused by recruitment variability, it is important to note the decline in red grouper populations after 1980, despite a consistent fishery effort. Similarity of cohort's tendency suggests that population stability could be assumed as a general criteria for the fishery, although a decrement in population abundance was obvious.

In conclusion, annual trends of exploitation detected through the VPA based on catch-at-age data (independently if "steady state" were assumed for the analysis, or if cohort analysis was performed) suggest this fishery has been operating under the last fifteen years without evidence of overfishing.

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Table 2. Fishing mortality estimates from VPA and cohort analysis for the red grouper (*Epinephelus morio*) from the Campeche Bank, for 1973 to 1987. Data correspond to modern fleet of Mexico. Column heading indicates the year where the cohort is incorporated within the catches.

AGE	C73	C74	C75	C76	C77	78	C79	C80	C81	C82	C83
1	0.10			0.10	0.10	0.10		0.10	0.10	0.10	0.10
2	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.10	0.10	0.10
3	0.15	0.15	0.15	0.15	0.10	0.15	0.50	0.25	0.20	0.30	0.45
4	0.25	0.25	0.20	0.15	0.15	0.70	0.40	0.30	0.45	0.75	0.25
5	0.20	0.20	0.20	0.15	0.70	0.40	0.30	0.50	0.75	0.25	0.48
6	0.15	0.15	0.15	0.70	0.35	0.30	0.45	0.70	0.25	0.37	
7	0.15	0.15	0.70	0.30	0.25	0.40	0.50	0.25	0.55		
8	0.15	0.70	0.35	0.25	0.40	0.60	0.25	0.54			
9	0.70	0.30	0.20	0.35	0.45	0.30	0.27				
10	0.30	0.20	0.30	0.40	0.25	0.47					
11	0.20	0.30	0.40	0.30	0.27						
12	0.30	0.35	0.30	0.36							
13	0.35	0.30	0.47								
14	0.35	0.41									
15	0.38										

Table 3. Population size of the red grouper from the Campeche Bank, estimated through VPA and cohort analysis for the 1973 to 1987 period. Column headings correspond to the year in which cohorts were incorporated within the catches. Estimates are in millions of fish.

AGE	C73	C74	C75	C76	C77	C78	C79	C80	C81	C82	C83
1	15.481			11.508	11.126	11.612		7.475	6.430	5.989	4.577
2	13.994	12.587	10.820	10.320	9.852	9.844	9.842	6.285	5.443	4.996	3.822
3	12.182	10.777	9.203	8.665	8.094	7.948	7.581	4.637	4.249	3.885	2.762
4	9.115	7.558	6.675	6.331	6.064	5.824	3.673	2.854	2.898	2.277	1.376
5	6.024	5.214	4.739	4.423	4.222	2.361	1.978	1.724	1.491	0.867	0.900
6	4.074	3.834	3.399	3.007	1.693	1.304	1.162	0.868	0.572	0.556	
7	2.973	2.734	2.364	1.223	0.998	0.794	0.623	0.356	0.370		
8	2.210	1.942	0.975	0.735	0.645	0.428	0.315	0.227			
9	1.573	0.781	0.582	0.476	0.357	0.187	0.213				
10	0.623	0.461	0.377	0.272	0.192	0.115					
11	0.379	0.311	0.222	0.143	0.125						
12	0.262	0.199	0.126	0.088							
13	0.166	0.112	0.074								
14	0.093	0.067									
15	0.054										

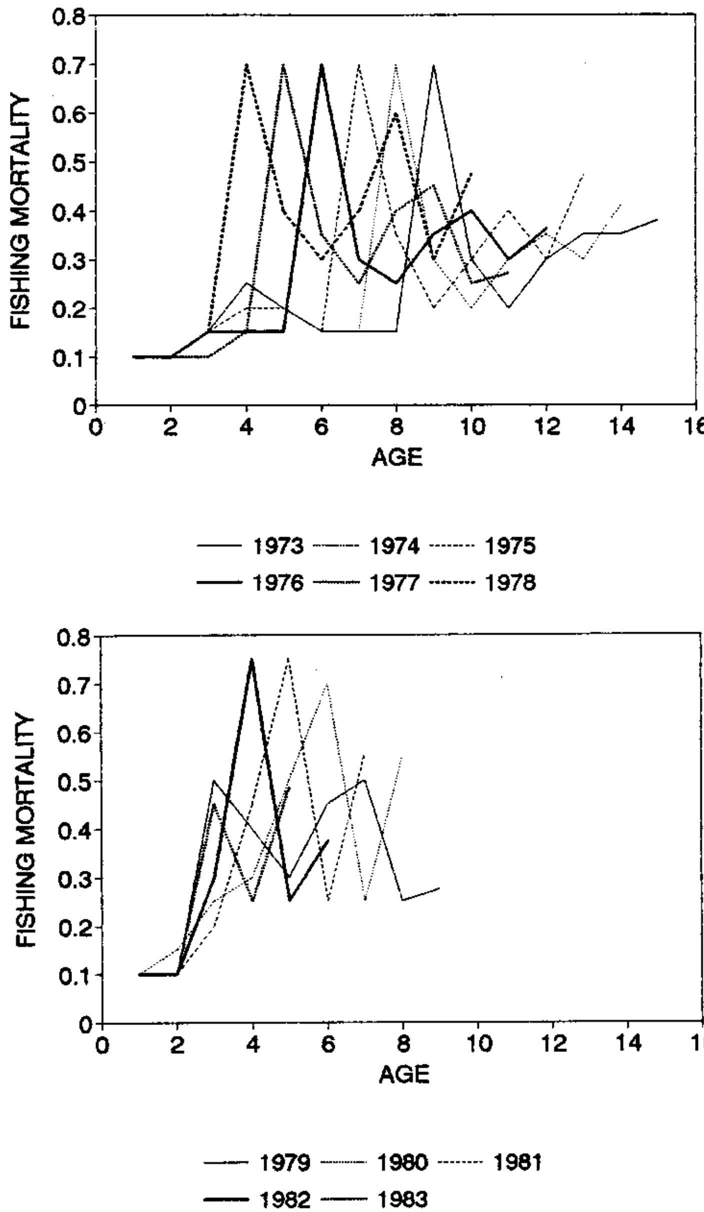

Figure 2. Fishing mortality patterns with age estimated using VPA and cohort analysis. Years indicate the time when a given cohort was incorporated to the fishery; A) 1973 – 1978 and B) 1979 – 1983.

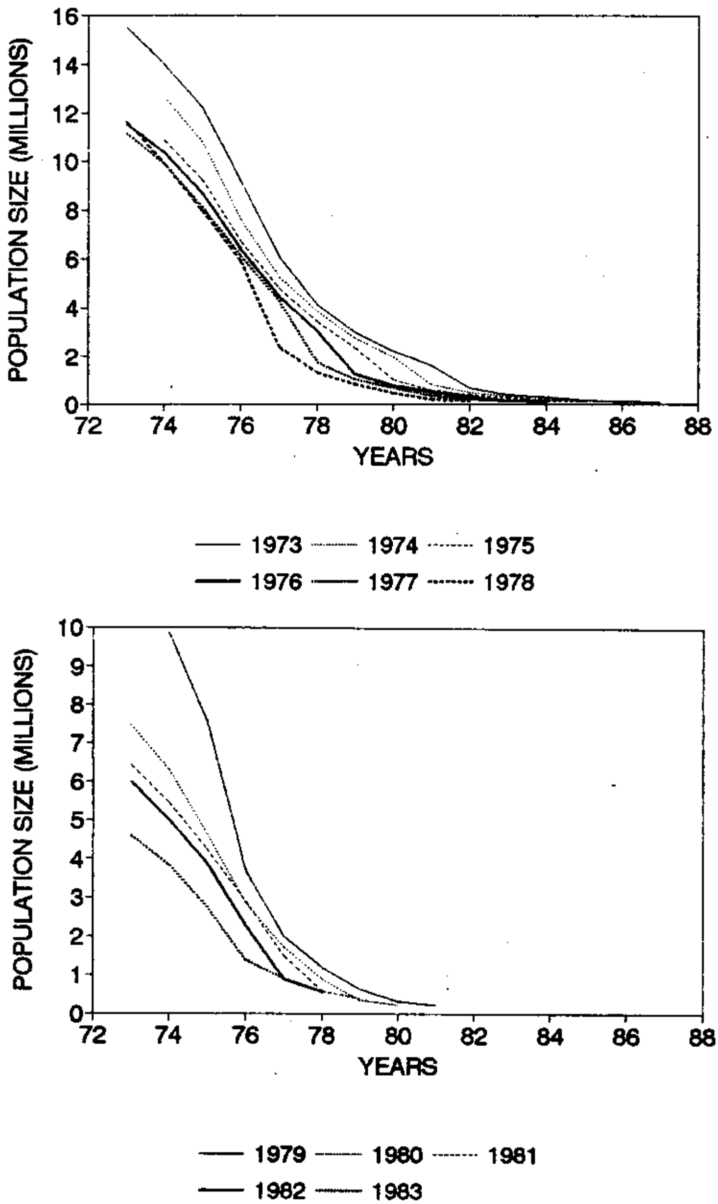

Figure 3. Changes in population size with time estimated through the VPA and cohort analysis. Each line represents the change in cohort abundance for cohorts incorporated in the fishery in the specified year; A) 1973 – 1978 and B) 1979 – 1983.

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