Assessment of the fishing effort level in the shrimp fisheries of the Central and Southern Gulf of California

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Abstract

In view of the concern caused by the declining trend in the annual shrimp yield in the Central Gulf of California, an attempt was made to analyze the fishing effort level exerted upon the shrimp stocks of the blue (*Farfantepenaeus stylirostris*) and the brown shrimp (*F. californiensis*) from 1980 to 1991. For this purpose, both Schaefer and Fox production models were applied. The results from these analyses revealed an economic overexploitation condition, and suggested an imperative need to implement as a regulatory measure, the reduction of the catch per unit of effort level (CPUE) to keep the fishery within acceptable bioeconomic margins of a maximum sustainable yield (Ys). This can only be achieved through the adjustment of the fleet size from 481 vessels down to 250 or 275.

Introduction

The economic importance of offshore shrimp production along the Pacific coast of Mexico has experienced significant fluctuations, especially in the central sector of the Gulf of California. Both landings and catch per unit of effort (CPUE) values in this region have shown a drastic decline in recent years. This has given rise to a great deal of concern amongst government authorities and the fishing industry, since no immediate tendency to recovery is expected. According to the annual production statistics for the central Gulf of California, between 1980 and 1991, the total annual shrimp catch fluctuated between 1 600 to 5 500 t and the fishing effort declined 31.4 per cent by the end of this period with only 330 vessels (from the initial 481) operating in the area. In spite of this reduction in effort, the diminishing trend in shrimp yields seems to continue. Shrimp production in this part of the Gulf is mainly sustained by two species of penaeids: the blue shrimp (*Farfantepenaeus stylirostris*) and the brown shrimp (*F. californiensis*). Both species are captured within the boundaries of the inner continental shelf (10 to 100 m) over clay-sandy bottoms (Fig.1). The general biological characteristics and population dynamics of the stocks of these species are well documented in a series of important contributions (Lluch 1975,1982; Rodríguez de la Cruz 1976, 1978, 1981; Galicia and Garcia 1976; Mathews 1976; Ross 1988; Alonso 1989; Quevedo 1990; Sepúlveda 1991, 1999).

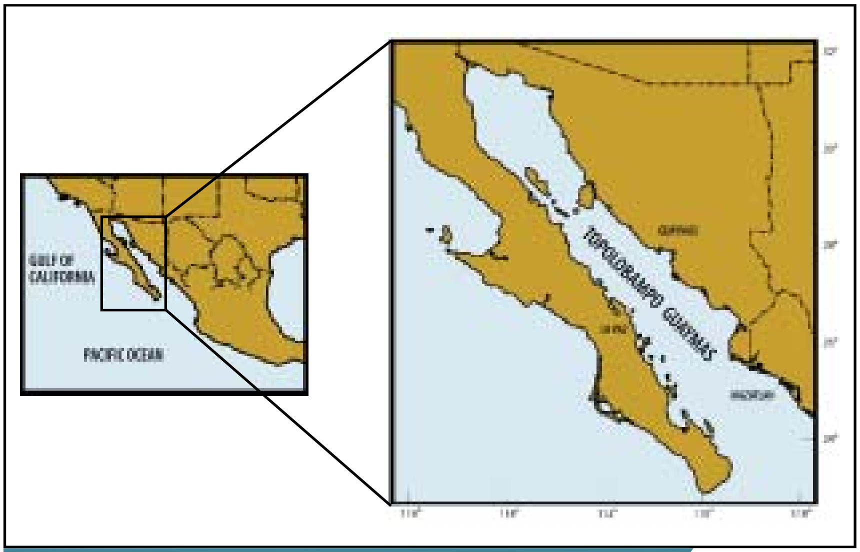

Fig. 1. Fishing areas of the Guaymas' fleet

This study analyzes the fishing effort and yield per vessel of the largest shrimp fishing fleet operating out of the port of Guaymas in NW Mexico in the central and southern sectors of the Gulf of California during the period 1980-91. It is considered vital for this fishery to determine the maximum sustainable yield (Ys) and the optimum fishing effort to assure its sustainable exploitation and adequate management. General criteria for regulatory measures for a reduction of the fleet size to attain equilibrium under the current exploitation levels are also suggested.

Materials and methods

The information analyzed in this paper was obtained from two main sources:

the records of catch reported by the shrimp fleet based in Guaymas and the shrimp landing statistics compiled by the Instituto Nacional de la Pesca (INP) for the period 1980-91. The landing data included monthly catches and the fishing effort was estimated from the number of trips and vessels operating per month in the central and southern sectors of the Gulf of California during the period. Additionally, landing data (lbs) from the shrimp processing plants was transformed into kilograms or tonnes.

The Schaefer (1954) production model was applied for both species. This model assumes a linear relationship between the capture per unit of effort and the applied unit of effort. The shrimp trawlers with major operation autonomy, storage capacity and engine-power were used as reference in order to standardize the fishing effort. We followed for this purpose, the procedure suggested by Alonso (1989). The estimated parameters were:

Y_s = maximum sustainable yield

f_{opt} = optimum effort required for Y_s

U_s = capture per unit of effort $C/_f$

U_{max} = capture per unit of effort max

$Y_e = U\infty f^{-bf2}$

$$f_{opt} = \frac{U\infty}{2b}$$

$$Y_s = \frac{U\infty^2}{4b}$$

The Fox (1970) model was run to establish the exponential relationship between the catch per unit of effort and the effectiveness applied annually during the period 1980-91. The number of vessels participating in the shrimp fishery was considered as the total effort unit applied. Once the original data were transformed, the following parameters were estimated:

$Y_s = f U_\infty E^{-bf}$

The values of b and f were estimated from the exponential regression $y = ae^{-bf}$.

Where the intercept is expressed as
$\ln = U_\infty - 1 \therefore U_\infty = E^a$
in which (a) is the intercept and (b) is the slope of the regression.

$$f_{opt} = \frac{1\infty}{b} \; ; \; Y_s = \frac{U\infty}{Eb} \; ; \; U_{opt} = \frac{U\infty}{E}$$

After the four basic parameters derived from the Schaefer and Fox models were calculated, a time series analysis was then conducted for the shrimp fishery in the central and southern Gulf of California for the period 1980-91.

Results and discussion

Schaefer production model

The application of Schaefer's model to the shrimp fishery statistics for the period 1980-91 from the Gulf of California revealed that the optimum effort (f_{opt}) for the fleet operating during that period involved 275 vessels, with a maximum sustainable yield (Ys) of 907.5 t, which would roughly correspond to an annual yield of 6.81 t per vessel. Based on these results, one may infer that the shrimp fleet was operating with efficiency. However, when the CPUE values for the period were analyzed, there were significant indications that the level of exploitation slightly exceeded the maximum sustainable yield.

This was corroborated by the results obtained from the regression applied to the observed and estimated CPUE values for each fishing season (Figs. 2 and 3). According to this analysis, for nearly 80 per cent of the fishing season the shrimp fleet maintained operating levels well above its maximum sustainable yield (Ys).

Fox production model

The Fox Production Model is used to measure the level of exploitation of the shrimp population. The units of fishery effort that can be used may be either the number of vessels or the effective fishery days. In this case, the former was used. This model is meant to optimize exploited fish populations.

The results generated from the Fox model (Table 1) appear to substantiate our assumption that the shrimp fleet in the Gulf of California was over exploiting the fishery from 1980 to 1991 (Fig. 4). The average f value estimated for the period of study indicated that the optimum fleet size was exceeded by approximately 33 per cent or 122 vessels, i.e., the fishing effort was more than one-third over its optimum level during that period.

Projection of the relationship between observed and estimated yield

In order to estimate the shrimp production levels and the fleet performance, the estimated optimum effort derived from the two theoretical

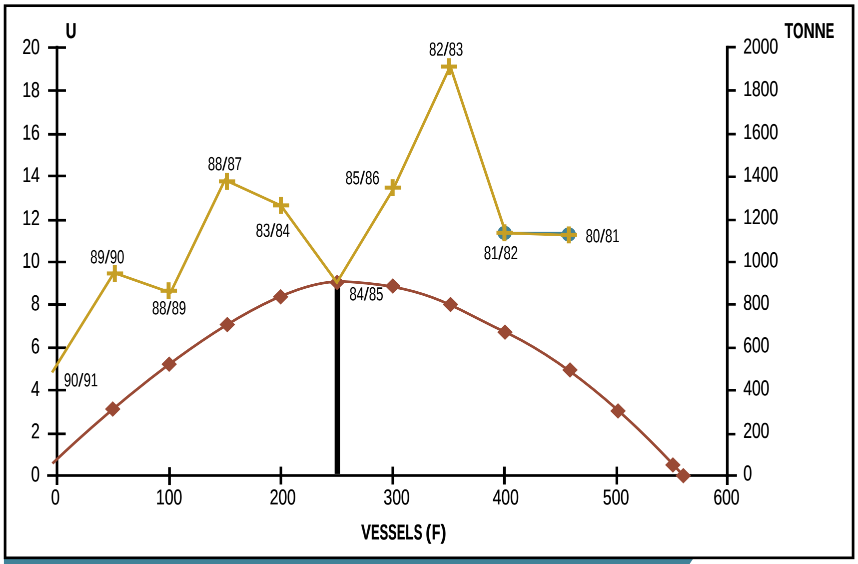

Fig. 2. Guaymas fleet, period 1980-91. *F. stylirostris* and *F. californiensis*

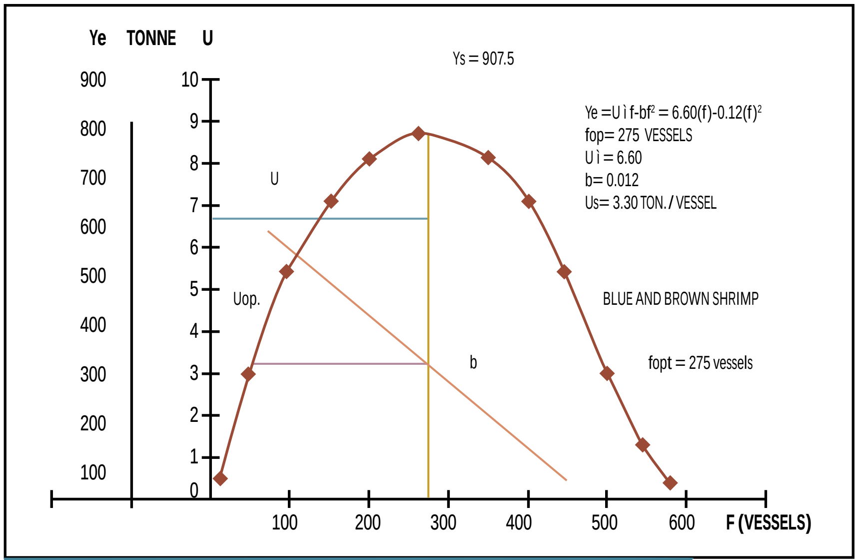

Fig. 3. Schaefer's model

Table 1. Equations and values obtained from the Fox model

		Values	Equation
a	Intersection of the exponential regression	3.381	U∞ = E^a
b	Slope of the exponential regression	0.0040	b = slope
Y_s	Maximum Sustainable Yield	313 t	Y_s = U∞ / bE
f_{opt}	Optimum Effort	250 vessels	$f_{opt} = 1/b$

Table 2. Main parameters obtained from the Schaefer and Fox models

	Y_s	U_{max}	f_{opt}	U_{opt}
Schaefer model	907.5	6.80	275 vessels	3.30 t/vessels
Fox model	313	1.24	250 vessels	--

fishing models (Schaefer f_{opt}=275 vessels; Fox f_{opt}=275 vessels) was used to estimate the magnitude of annual yield increment from 1980 to 1991, maintaining a fixed Ys of 5.39 t/vessel (Table 2).

The data in Table 3 were obtained from the differential between real and estimated yields according to the f_{opt} of each model, thus obtaining the respective ΔC/f that represents the increment of the catch per unit of effort for each model.

A review of the annual shrimp yield over the period 1980-91 indicates four distinct periods. The first corresponds to the years 1980-82 and is characterized by an intensification of fishing effort accompanied by a high shrimp production of 11 to 12 t/vessel. The second period 1982-84 coincided with a surface temperature disturbance in the Gulf of California, associated with the ENSO phenomena, which apparently promotes a rapid growth rate in tropical species. During this period Lluch and Magallon (1991) recorded shrimp yields of 13.2 to 16.2 t/vessel.

The third period spanned the years 1984-87 (Fig. 5). In this period, the CPUE fluctuated between 8.5 t/vessel during the 1984-1985 season and 13.8 t/vessel in 1987-1988. It is interesting to note that though the fishing effort remained stable, an increase in production per vessel occurred (> 10 t/vessel) towards the end of this period. This condition can be attributed to several factors that may involve a possible high recruitment to the parental stocks favored by local environmental conditions (temperature and precipitation) that promoted spawning and growth (Del Valle 1987; Sepúlveda 1991).

The fourth period, identified here as critical and disturbing, extended from 1987 to 1991. In this period shrimp yields diminished from 10 t/vessel (87/88) to 4.8 t/vessel (90/91) (Fig 5). This could have been due to the excessive fishing effort (>350 vessels) exerted upon the shrimp stocks in the Central Gulf of California. However, one cannot dismiss the deleterious effect on recruitment of extraction of the wild shrimp post-larvae from nursery grounds to stock aquaculture ponds. This is a common practice in the region that deserves further study.

Levels of exploitation

The total shrimp production recorded during the period of study (1980-91) amounted to 44 777 t with an estimated annual yield per vessel of 4 070 t. In this fishery, 366 vessels are involved and their estimated capture per unit of effort (C/f) was 10.88 t. Applying the theoretical optimum effort derived from the Schaefer and Fox models, projections of optimum fishing effort were (Fig. 6, Table 4).

Conclusions

The estimated levels of fishing effort to which the shrimp stocks in the central Gulf of California (1 378 km²⁾ are subjected indicate an economic over-exploitation caused by the activity of 366 to 375 vessels. According to our analysis, a reduction of the fleet size to between 250 to 275 fishing boats could increase the capture per unit of effort (Ac/f) as much as 3.91 t/vessel (if the Schaefer projection is accepted) or 5.39 t/vessel (if the Fox model is accepted). In the first instance, the increment in C/f would amount to an annual yield/vessel of 14.8 t or 36 per cent,

Table 3. Observed and estimated shrimp yields from 1980 to 1991

Year	C/f Observed t / vessel	∆C/f t / vessel	C / f $_{Opt}$ (275 vessel)	∆C/f increment	C / f $_{Opt}$ (250 vessel)
80-81	11.34	8.6	19.84	10.4	21.82
81-82	11.25	4.8	16.05	6.4	17.65
82-83	16.20	3.9	20.15	5.9	22.17
83-84	13.60	5.3	18.94	7.2	20.84
84-85	8.65	1.9	10.65	3.0	11.71
85-86	11.89	3.1	15.04	4.6	16.54
86-87	13.84	4.3	18.18	6.1	20.00
87-88	10.49	3.8	14.34	5.3	15.78
88-89	8.49	3.0	11.39	4.1	12.64
89-90	9.16	3.2	12.34	4.4	13.57
90-91	4.80	0.97	5.77	1.5	6.35

∆C/f = Increment catch per unit effort; C/f = Catch per unit effort; C/f opt = Optimum catch per unit

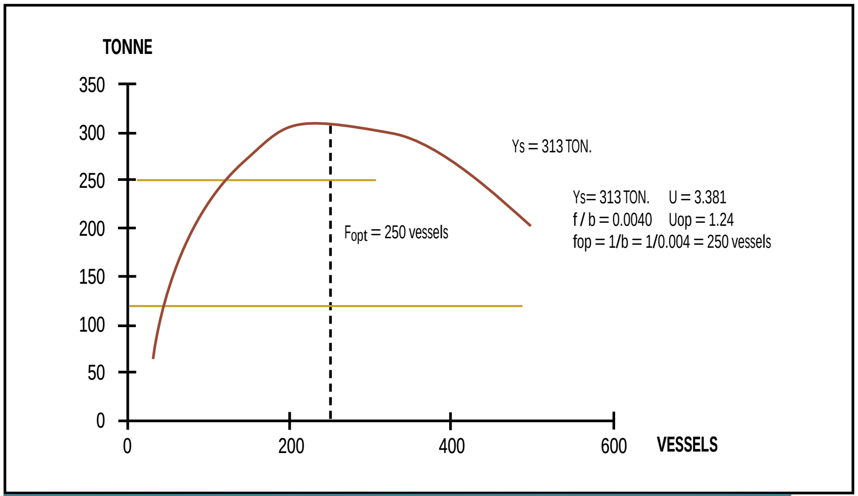

Fig. 4. Fox Production Model for the period 1980-91 Guaymas, Sonora, Mexico

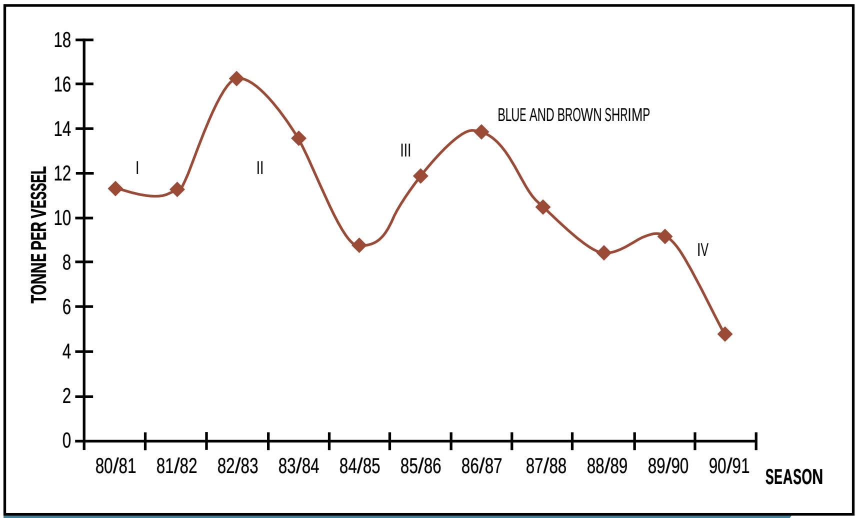

Fig. 5. Shrimp yield of the Guaymas fleet

while in the latter the increment is of 16.7 t or 49 per cent.

The proposed fleet size reduction would not only achieve maximum sustainable yields without reaching over-exploitation limits, but would also serve to attain major economic benefits in terms of ship cost operation. A recommendation of this kind acquires more relevance in light of the severe setbacks in shrimp production recorded during the fishing seasons of 1995-96 and 1998-99 in the southern Gulf of California. During these seasons, the fishing effort fluctuated between 370 to 390 vessels with a 25 per cent reduction in the average annual shrimp yield (4 000 t).

Thus the bioeconomical fishery models must be related to the exhaustive knowledge of the life cycle of the coastal penaeids and their close relation to the applied effort to the resources that are studied (García and Le Reste, 1986).

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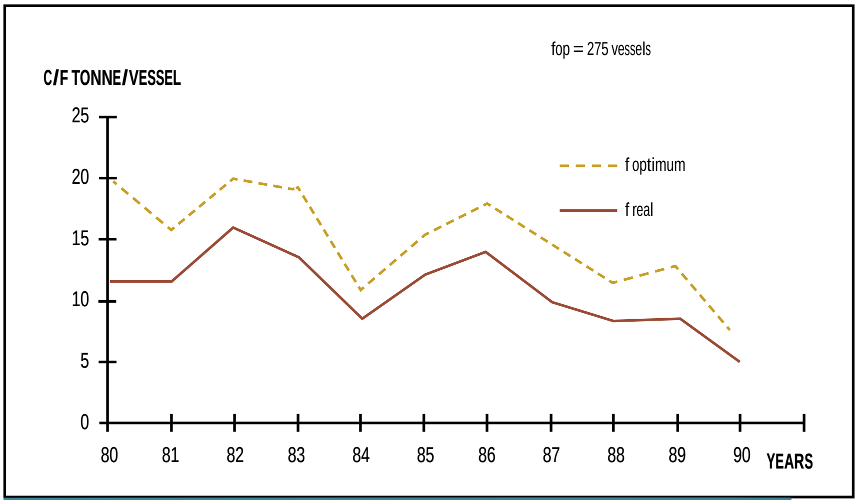

Fig. 6. Protection of relation yield - effort (optimum and real) (Schaefer)

Table 4. Theoretical increases in shrimp yield obtained by assuming different fleet reductions

Level of exploitation (no. vessels)	C/f	∆C/f
366l	10.88	-
275	14.79	3.91
250	16.27	5.30
200	20.53	6.62

∆C/f = Increment catch per unit effort; C/f = Catch per unit effort

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