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Demersal Fish Stock Assessment in Seychelles: An Analysis of a Mothership/Catcher Boat Fishery

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MEES, C.C. 1996. Demersal fish stock assessment in Seychelles: An analysis of a mothership/catcher boat fishery [*Evaluacion de peces demersales en Seychelles: Un analisis de una pesqueria basada en un bote nodriza*], p. 254-265. *In* F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos and D. Pauly (eds.) Biology, fisheries and culture of tropical groupers and snappers. ICLARM Conf. Proc. 48, 449 p.

Abstract

Stock assessments for certain important tropical demersal species are presented, based on the analysis of commercial line fishing data collected from a mothership/catcher boat operation targeting snappers, groupers and emperors in Seychelles waters. Six fishing trips were conducted over the period March 1991 - March 1993 at a number of unexploited or lightly fished banks and sea mounts of varying sizes far from the main centers of population.

Depletion estimates of initial population size (biomass, B_0) are derived from daily information within single fishing voyages at specific locations. An attempt to determine production is presented using biomass estimates from subsequent voyages to the same locations. The limited time spent at any one fishing location and variability in catch rates resulting from changes in fishing depths and target species restrict the number of comparisons of site-specific analyses from the present data, but the method will be of increasing value as more information becomes available. The implications for management purposes are great: inferences may be made regarding the rate of recovery of depleted areas, which is useful in what is essentially a 'hit and run' fishery.

It is suggested that if adequate care is taken to account for variability in catch rates not directly attributable to fishing pressure, the application of this type of analysis to commercial data offers a cheap alternative to intensive fishing experiments during research cruises.

Resumen

La evaluación de recursos de ciertas especies demersales tropicales importantes son presentadas en base al análisis de datos de la pesca comercial con línea colectados de la operación de un bote nodriza orientado a la pesca de pargos, meros, y emperadores en aguas de Seychelles. Seis viajes de pesca fueron efectuados en el período comprendido entre Marzo de 1991 y Marzo de 1993, hacia varios bancos no explotados o ligeramente explotados y varias montañas marinas de tamaño variable, alejadas de los principales centros de población.

Las estimaciones de descuento en el tamaño inicial de la población (biomasa, B_0) fueron derivadas de información diaria dentro de viajes de pesca sencillos a localidades específicas. Se presenta un intento para determinar la producción usando estimaciones de biomasa de viajes subsecuentes a las mismas localidades. La limitada duración de las operaciones de pesca en cualquiera de las localidades, y la variabilidad en las tasas de captura resultantes de los cambios en las profundidades de pesca (especies objetivo) limitaron el número de comparaciones para el análisis de sitios específicos del presente conjunto de datos, pero el método tendrá mayor valor conforme mas cantidad de información vaya

venting gas from an everted stomach (a common misconception exists that this is the gas bladder) by knife puncture. As stated earlier in the discussion, stomach eversion generally occurs as a result of gas bladder rupture. Although venting gas through the stomach may increase a fish's ability to submerge, our results indicate that long-term survival of these fish is unlikely. Further the effect of stomach puncture on survival is not known, particularly given the stress already present from hydrostatic pressure damage. Although all deflation efforts by anglers are not as crude as those described above, it demonstrates that significant angler education would be necessary for proper utilization of these techniques, if it is found that deflation techniques enhance survival for a given species.

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siendo disponible. Las implicaciones para propósitos de manejo son grandes: algunas inferencias pueden ser hechas sobre la tasa de recuperación de las áreas que mostraron decrementos, aspecto que es esencial en una pesquería basada en el éxito de cada operación de pesca.

Se sugiere que si se toma cuidadosamente en cuenta la variabilidad en las tasas de captura que no son atribuibles directamente a la intensidad de pesca, la aplicación de este tipo de análisis de datos comerciales puede ofrecer una alternativa de bajo costo para intensificar experimentos de pesca durante los cruceros de investigación.

Introduction

The large number of fish species and information-intensive requirements of most multi-species stock assessment models (for reviews, see Gulland and Garcia 1984; Kerr and Ryder 1989; Polovina 1992) means that data-collection requirements for adequate stock assessment are beyond the means of many small fishery departments in tropical countries. Depletion methods of stock assessment, however, can be substantially cheaper and more effective than others (Hilborn and Walters 1992). Polovina (1986) applied this approach to data collected during an intensive fishing experiment in the Marianas. Where commercial data can be utilized, substantial cost savings may be gained over the application of experimental fishing during planned research cruises, although at the expense of experimental design.

In this paper stock assessments are based on the analysis of commercial line fishing data collected from a mothership/catcher boat operation targeting snappers, groupers and emperors in Seychelles waters. Mees (1993) estimated the biomass of *Pristipomoides filamentosus* (Valenciennes 1830) from data collected during a single voyage of this vessel. Here, subsequent voyages to a number of locations are presented, and enable estimates of stock production.

The study area

Seychelles consists of four island groups in the western Indian Ocean between 5° and 10°S and 45° and 56°E (Fig. 1). The majority of the population live on the granitic islands Mahé, Praslin and La Digue within the Mahé Plateau, whilst the coralline Amirantes, Providence/Farquhar and Aldabra/Cosmoledo groups are sparsely inhabited.

Demersal fishing effort by the artisanal fleet (mostly wooden vessels, 12 m length or smaller) is largely confined to the Mahé Plateau and its periphery, but in periods of good weather a few vessels may venture to the Amirantes group. The Providence/Farquhar and Aldabra/Cosmoledo groups may be regarded as unfished excepting some exploitation during the 1970s by mothership/catcher boat ventures at the former group. Fishing activity at these locations and at lightly fished banks and sea mounts south of the Mahé Plateau is examined.

Climatic conditions during the southeast trade winds, which average 12 knots, frequently limit fishing activity from the end of May to October. It may also be affected by the northwest monsoon between mid-November and mid-March. During the two inter-monsoon periods light variable winds and frequent calms occur.

Materials and Methods

Between March 1991 and March 1993 an 88.4 m refrigerated cargo ship deployed up to twelve 7 m fiberglass catcher boats during six fishing voyages to remote banks and island groups in the Seychelles. Each voyage lasted between 46 and 71 fishing days (Table 1).

Catcher boats were equipped with echo sounder and compass and usually fished within 10 miles of the mothership. Handlines were used during the first voyage. Electric fishing reels were fitted subsequently although

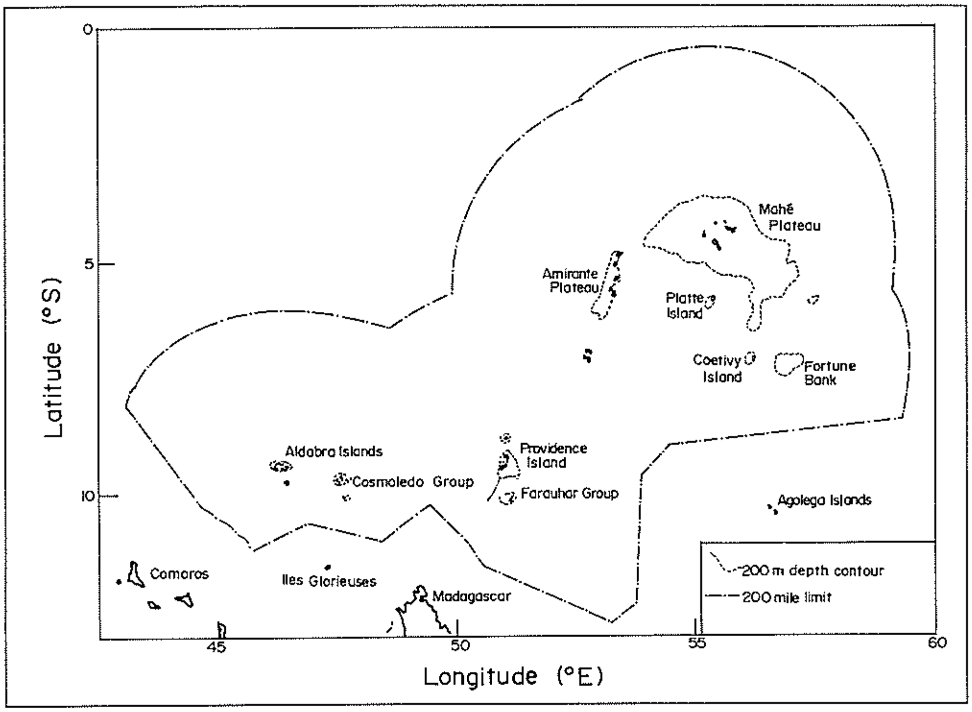

Fig. 1. Seychelles EEZ indicating the fishing locations visited by the mothership catcher vessel: Mahé Plateau, and Banks South of the Plateau, the Amirantes group, Providence/Farquhar group, and Aldabra/Cosmoledo group. [*ZEE de Seychelles indicando las localidades de pesca visitadas por el barco nodriza: Planicie de Mahe, y Bancos del Sur de la Planicie, el grupo Amirantes; el grupo Providence/Farquar y el grupo Aldabra/Cosmoledo.*]

Table 1. Details of the fishing voyages undertaken between March 1991 and March 1993. [*Detalle de los viajes de pesca efectuados entre Marzo de 1991 y Marzo de 1993.*]

Voyage	Fishing dates	Days	Fishing locations	Boat-days
1	03/03/91-02/05/91	70	Mahé Plateau (MP)	169
			Banks south of MP	547
2	23/10/91-16/12/91	54	Mahé Plateau	297
			Banks south of MP	142
			Platte Plateau	4
			Amirantes group	58
			Providence/Farquhar	137
3	08/01/92-12/03/92	64	Mahé Plateau	73
			Banks south of MP	252
			Amirantes group	325
4	11/04/92-27/05/92	46	Providence/Farquhar	501
5	26/10/92-20/12/92	55	Amirantes group	13
			Providence/Farquhar	443
			Aldabra/Cosmoledo	79
6	10/01/93-22/03/93	71	Mahé Plateau	12
			Banks south of MP	60
			Platte Plateau	12
			Saya de Mahla bank	591

frequently a combination of electric reels and hand-lines were used by the crew of three. One trip per boat per day was usual, although occasionally two trips were made.

Detailed catch and effort data were recorded for each catcher boat trip by an observer from the Seychelles Fishing Authority. Factors which could potentially affect catch rates and/or species composition were also recorded on the catch and effort log: depth fished, bait type, climatic conditions. These latter data are not available for all voyages and reported details for voyage 4 were considered unreliable. This information is utilized tentatively in interpretation of the results.

Total daily catch and effort data were generated by gear type (lines, reels or both) and location. In order to enable intra-voyage comparisons, relative fishing power was determined for gear type, month and fishing location by application of the following model to standardize fishing effort:

$$U_{tik} = U_{111}\,\alpha_t\,\beta_i\,\gamma_k\,\varepsilon_{tik} \qquad \text{...1)}$$

where U is the catch rate, subscript t refers to time, i to gear type and k to fishing location. U_{111} is the catch rate obtained by the first gear type in the first time period at the first location, α_t is a factor that is the abundance in month t relative to month 1, β_i is the efficiency of gear type i relative to gear type 1, γ_k is the average abundance differential in area k relative to location 1, and ε_{tik} is a factor explaining the deviation between the observed U_{tik} and the expected value for t, i and k (Hilborn and Walters 1992).

Taking the logarithms of both sides of equation 1, a linear statistical model is derived:

$$\begin{aligned}\log(U_{tik}) = {} & \log(U_{111}) + \log(\alpha_t) + \\ & \log(\beta_i) + \log(\gamma_k) + \\ & \log(\varepsilon_{tik}) \qquad \text{...2)}\end{aligned}$$

from which the parameters α, β and γ may be estimated by multiple linear regression.

Fishing effort of the original catcher-boat data was standardized relative to hand-lines and to the month of January. Total daily catch and effort data were recalculated by location. These data were employed in a modification of the Leslie depletion model (Leslie and Davis 1939) in order to determine original biomass at the start of subsequent fishing occasions (B_{01} and B_{02}), as follows:

Since each fishing occasion lasts only a few days, natural mortality, growth, recruitment and immigration will be negligible and may be disregarded. B_{ti}, the biomass remaining on day t of voyage i may be expressed as:

$$\begin{aligned}B_{ti} &= B_{0i} - \sum_{s<t} C_{si} \\ &= B_{0i} - D_{ti} \qquad \text{...3)}\end{aligned}$$

where C_{si} is the catch taken during day s of voyage i, and D_{ti} is the total catch taken on that voyage before day t.

The catch rate U_{ti} on day t of voyage i will be related to the biomass, B_{ti} by:

$$\begin{aligned}U_{ti} &= qB_{ti} + \omega_{ti} \\ &= qB_{0i} - qD_{ti} + \omega_{ti} \qquad \text{...4)}\end{aligned}$$

where q is the catchability, and ω_{ti} explains random variability.

Whilst biomass (B_0) changes between fishing voyages due to mortality, recruitment, growth and immigration, catchability (q) is expected to remain constant. To ensure the same estimate of q for all voyages, and to reduce estimation 'noise' due to short data series, equation (4) may be rewritten enabling simultaneous estimation of q and the B_{0i}'s by multiple regression. First, indicator variables I_{2ti} I_{3ti} .... are defined for all voyages except the first, so that $I_{2ti}=1$ for all data from Voyage 2 and 0 for all other data, $I_{3ti}=1$ for all data from Voyage 3 and 0 for all other data, and so on.

Consider the example of three voyages to one location. Using equation (4) we set for Voyage 1:

$$\begin{aligned} U_{t1} &= qB_{0_1} - qD_{t1} + \omega_{t1} \\ &= qB_{0_1} + I_{2t1}(qB_{0_2} - qB_{0_1}) + \\ &\quad I_{3t1}(qB_{0_3} - qB_{0_1}) - qD_{t1} + \omega_{t1} \end{aligned} \qquad \textbf{...5)}$$

noting that for all observations in Voyage 1, $I_{2t1} = I_{3t1} = 0$.
For Voyage 2, ($I_{2t2}=1$, $I_{3t2}=0$):

$$\begin{aligned} U_{t2} &= qB_{0_2} - qD_{t2} + \omega_{t2} \\ &= qB_{0_1} + I_{2t2}(qB_{0_2} - qB_{0_1}) + \\ &\quad I_{3t2}(qB_{0_3} - qB_{0_1}) - qD_{t2} + \omega_{t2} \end{aligned} \qquad \textbf{...6)}$$

and Voyage 3 ($I_{2t3} = 0$, $I_{3t3} = 1$):

$$\begin{aligned} U_{t3} &= qB_{0_3} - qD_{t3} + \omega_{t3} \\ &= qB_{0_1} + I_{2t3}(qB_{0_2} - qB_{0_1}) + \\ &\quad I_{3t3}(qB_{0_3} - qB_{0_1}) - qD_{t3}) + \omega_{t3} \end{aligned} \qquad \textbf{...7)}$$

This may be written in general form as:

$$U_{ti} = \alpha + \sum_{j=1}^{v} I_{jti}B_j - qD_{ti} + \omega_{ti} \qquad \textbf{...8)}$$

where v is the total number of voyages undertaken,

$$\alpha = qB_{0_1} \qquad \textbf{...9)}$$

$$\beta_j = (qB_{0j} - \alpha) \qquad \textbf{...10)}$$

for j = 1 to v. The variables q, α and β_j may be estimated by multiple linear regression. The biomass at the start of the first voyage may then be estimated from equation (9):

$$\hat{B}_{0_1} = \frac{\alpha}{\hat{q}} \qquad \textbf{...11)}$$

and subsequent voyages for j = 1 to v from equation (10)

$$\hat{B}_{0_j} = \frac{(\alpha + \beta_j)}{\hat{q}} \qquad \textbf{...12)}$$

Production (P) between voyages i and (i+1) to the same location can be estimated from:

$$\hat{P}_{i\rightarrow(i+1)} = \frac{\hat{B}_{0_{i+1}} - (\hat{B}_{0_i} - C_i)}{d_{i\rightarrow(i+1)}} \qquad \textbf{...13)}$$

where C_i is the total catch removed at the end of voyage i, and $d_{i\rightarrow(i+1)}$ is the time interval, in days, between fishing occasions. Production is equivalent to all gains due to growth, recruitment and immigration, less losses due to natural mortality.

Results

Factors applied to standardize the original data by month and gear type are indicated in Table 2. Throughout the six voyages, fishing took place at a total of 31 different banks, sea mounts or islands. At any one location fishing duration varied between 1 and 8 days and the prevalent pattern observed was that of decreasing daily catch rates. Results relate to those locations fished during two or more voyages for greater than one day (Table 3 and Figs. 2a and 2b).

In general, mean catch rates were observed to decrease from one voyage to the next. This was true for small banks and sea mounts, but not for the large banks (Constant Bank). Daily catch rates at Fortune Bank, like Constant Bank, indicated no evidence of depletion between voyages (Fig. 2c). For small banks, exceptions were Bulldog Bank and Sea Mount '25' in the Providence/Farquhar group. During Voyage 4, strong currents depressed catch rates but this was not the case during Voyage 5 to these locations.

Table 2. Parameters derived by multiple linear regression for standardization of fishing effort relative to hand-lines, January and the south-east edge of the Mahé Plateau (MP). [*Parámetros obtenidos de la regresión lineal múltiple para la estandarización del esfuerzo de pesca relativo a líneas de mano, Enero y el borde suroriental de la Planicie Mahe (MP).*]

Parameter	Detail	Value
α_2	February	1.0697
α_3	March	1.5664
α_4	April	1.7115
α_5	May	1.1500
α_6	October	1.9031
α_7	November	1.6164
α_8	December	1.7403
β_2	unknown (gear)	0.0291
β_3	lines and reels	1.0009
β_4	reels only	1.2479
γ_2	Junon Bank	0.9871
γ_3	South Edge MP	1.1702
γ_4	Banks south of MP	1.2525
γ_5	Platte Plateau	0.9407
γ_6	Amirantes	1.5601
γ_7	Providence/Farquhar	2.2391
γ_8	Aldabra/Cosmoledo	1.1974
γ_9	Saya de Mahla Bank	2.4658

After eliminating those locations at which changes in depth and target species were significant (Sea Mount '20', Wizard Reef), only three locations of the original 31 were considered suitable for the present depletion study; namely, Correira Bank, Small Constant Bank and Farquhar (Table 4 and Figs. 2d-2f, respectively). However, Small Constant Bank was also eliminated from the analysis because of inconsistent results which were considered unreliable (only two data points for each of Voyages 2 and 3). This bank was also subject to fishing by other vessels between voyages, so the total catch removed was unknown. Correira Bank was unlikely to have been fished by other vessels and Farquhar had not.

At Correira Bank, no consistently decreasing trend with time occurred for the combined catch rate of all demersal species, but was observed for the target species, *P. filamentosus*. At Farquhar, no trend occurred for individual species but was observed for the combined demersal catch. The biomass preceding each voyage was estimated by regression of standardized catch rate on adjusted cumulative catch for *P. filamentosus* at Correira Bank (Fig. 3, Table 5) and all demersal species at Farquhar

Table 3. Locations visited on two or more voyages for more than one day, and the fishing areas in shallow and intermediate depth strata where available. [*Localidades visitadas en dos o más viajes por más de un día y las áreas de pesca en aguas de profundidad baja e intermedia donde los estratos estuvieron disponibles.*]

Fishing location	Area (km^2) 0-75 m	Length of 100 m contour (km)	Area (km^2) 75-150 m
BANKS SOUTH OF THE MAHE PLATEAU			
Constant Bank	590.0	114.8	28.7
Correira Bank	17.4	33.3	8.3
Fortune Bank	600.0	120.4	30.1
Sea Mount '20'	6.6	11.1	2.7
Small Constant Bank	170.0	55.6	13.8
PROVIDENCE/FARQUHAR			
Bulldog Bank	--	--	--
Farquhar	172.0[a]	--	--
Sea Mount '25'	--	--	--
Wizard Reef	--	--	--

[a] Total area of Farquhar Atoll (UNEP/IUCN 1988) - actual fishing area will be less than this.

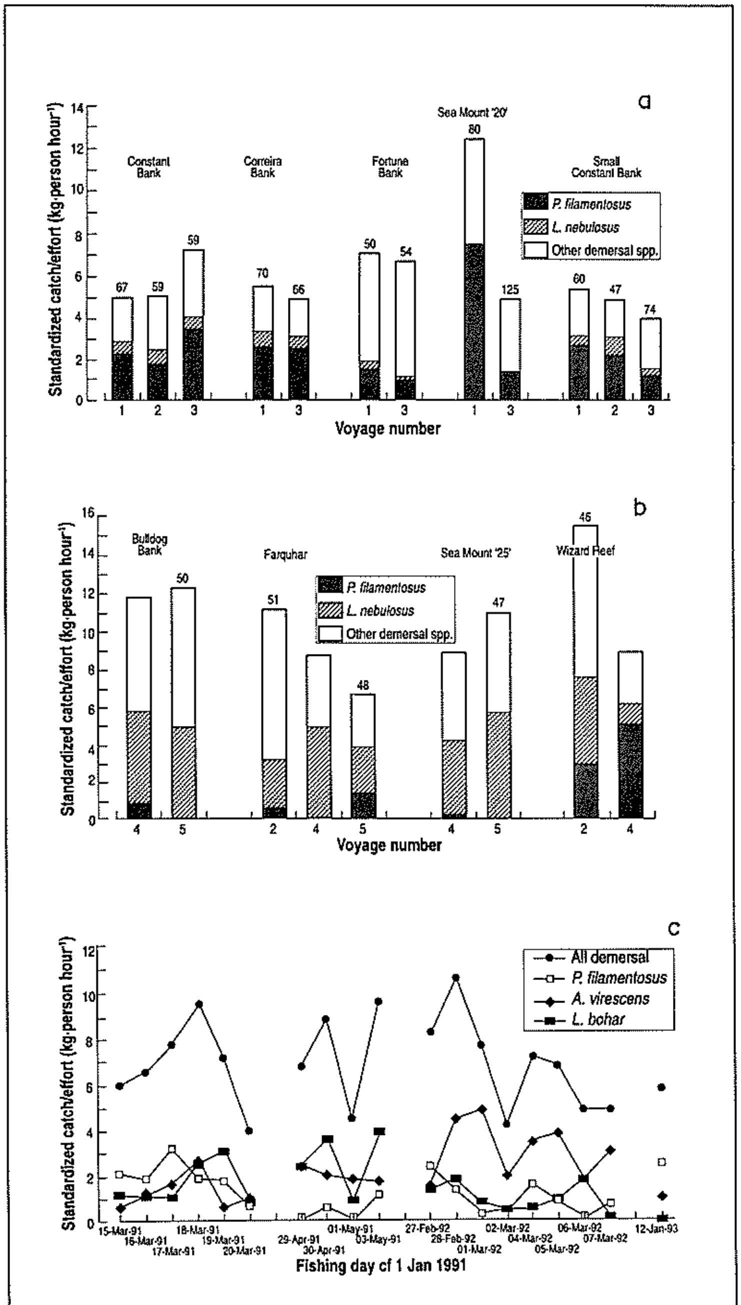

Fig. 2. Mean standardized CPUE (kg/person per hour) by voyage to: a) south of the Mahé Plateau; b) Providence/Farquhar group; c) standardized daily catch rates at Fortune Bank [*CPUE media estandarizada (kg/persona por hora) por viaje en: a) sur de la Planicie Mahé; b) grupo Providence/Farquhar; c) tasas de captura diaria estandarizadas en el Banco Fortuna*] (continued)

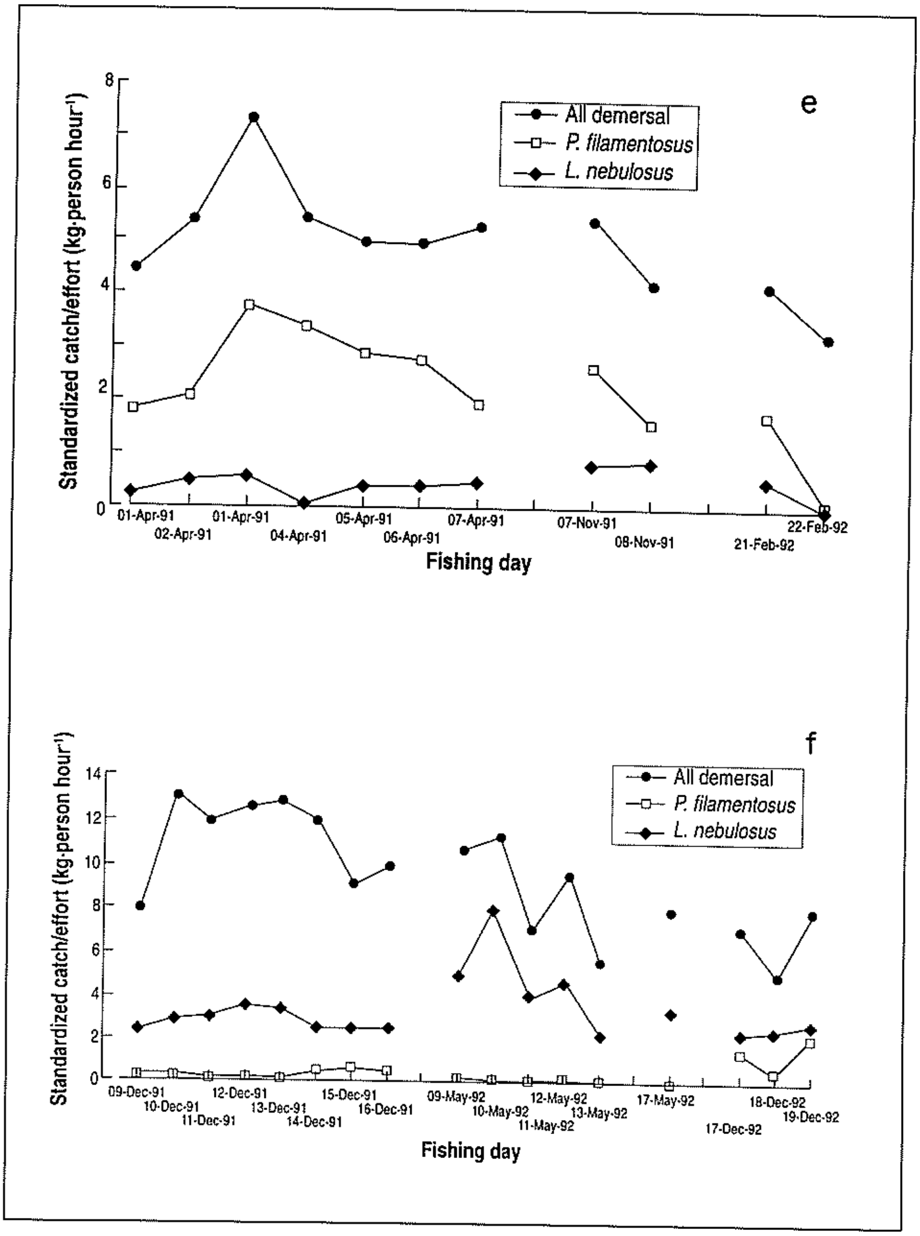

Fig. 2. (continued) d) Correira Bank; e) Small Constant Bank; and f) Farquhar. For Figs. c-f, the x-axis does not represent a linear scale. A break in the line indicates that the mothership moved location (within any voyage) or that the data relate to different voyages. [*d) Banco Correira; e) Banco Small Constant; y f) Farquhar. Para las figuras c-f, el eje-X no representa una escala lineal. Un corte en la línea indica que el bote nodriza se movió de lugar (dentro de un viaje) o que los datos se refieren a diferentes viajes.*]

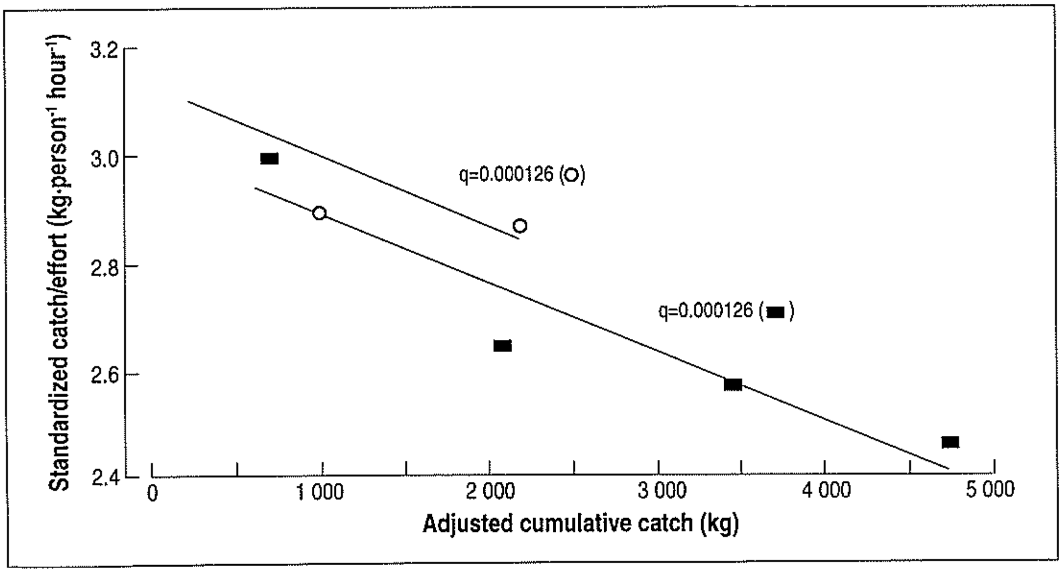

Fig. 3. Depletion of *Pristipomoides filamentosus* at Correira Bank during Voyages 1 and 3. Data for 26 February 1992 were excluded from the analysis since the reported depth was significantly less than on the previous three days and the position had changed. [*Decremento de* **Pristipomoides filamentosus** *en el Banco Correira durante los viajes 1 y 3. Febrero 26 de 1992 fué excluído del análisis porque la profundidad reportada fué significativamente menor que la de los tres días previos y la posición ha cambiado.*]

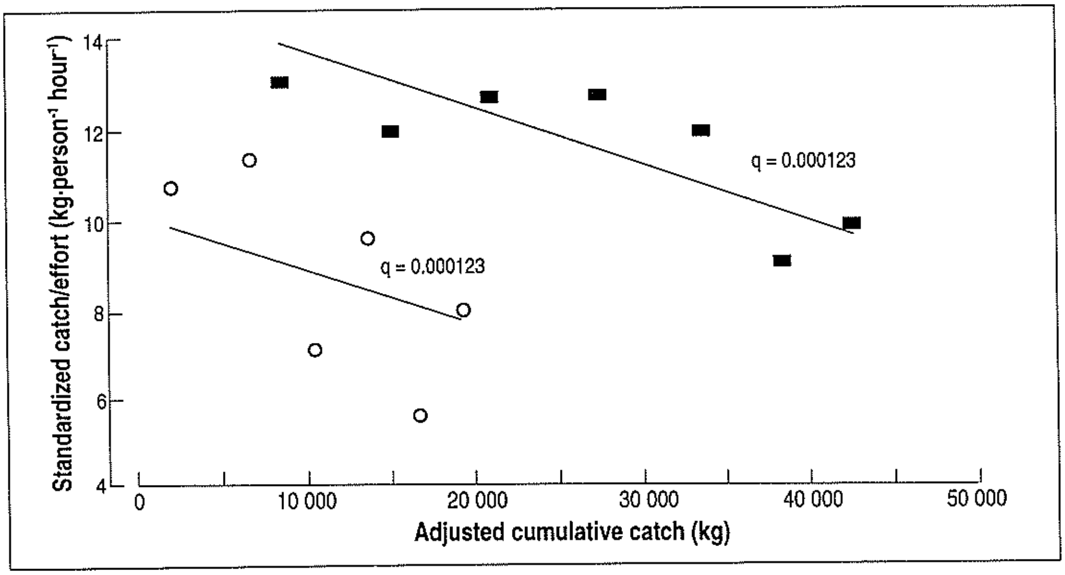

Fig. 4. Depletion of the total demersal species catch at Farquhar during Voyages 3, 4 and 5. Excluded from the analysis were 9 December 1991 and Voyage 5. [*Decremento de la captura total de especies demersales de Farquhar durante los viajes 3, 4 y 5. Diciembre 9 de 1991 fué excluído del análisis.*]

Table 4. Anchoring position of the mothership each day at each of the locations studied showing (*) the days used in the analyses. [*Posición geográfica del barco nodriza cada día de cada una de las localidades estudiadas mostrando los días usados en el análisis (*).*]

Location	Voyage	Dates	Position
Correira Bank	1	24/04/91	06° 29' S 57° 10' E *
Correira Bank	1	25-27/04/91	06° 22' S 57° 05' E *
Correira Bank	1	10/05/91	06° 22' S 57° 05' E
Correira Bank	3	23-25/02/92	06° 21' S 57° 06' E *
Correira Bank	3	26/02/92	06° 30' S 57° 16' E
Small Constant	1	01-07/04/91	06° 03' S 56° 18' E *
Small Constant	2	07-08/11/91	06° 04' S 56° 18' E *
Small Constant	3	21-22/02/92	06° 03' S 56° 17' E *
Farquhar	2	09-16/12/91	10° 08' S 51° 09' E *
Farquhar	4	09-13/05/92	10° 08' S 51° 01' E *
Farquhar	4	17/05/91	10° 05' S 51° 10' E
Farquhar	5	17-18/12/92	10° 08' S 51° 59' E
Farquhar	5	19/12/92	10° 11' S 51° 11' E

Table 5. Regression parameters derived for *Pristipomoides filamentosus* at Correira Bank, and estimates of catchability, biomass, and production between Voyages 1 and 3; all demersal species at Farquhar, and estimated values between Voyages 2 and 4. [*Parámetros de regresión obtenidos para:* Pristipomoides filamentosus *en el Banco de Correira, y estimaciones de capturabilidad, biomasa y producción entre viajes 1 y 3; todas las especies demersales en Farquhar, y valores estimados entre los viajes 2 y 4.*]

Parameter	Correira Bank	Farquhar
No. obs	7	13
R^2	0.9066	0.6724
α	3.017958	14.90345
β_2	0.108966	-4.73422
q	0.000126	0.000123
C_1 (kg)	5426	44788
B_{01} (kg)	23903	121177
B_{02} (kg)	24766	82684
$d_{1\rightarrow 2}$	302	145
$P_{1\rightarrow 2}$ (kg·day^{-1})	20.8	43.4
$P_{1\rightarrow 2}$ (kg·day^{-1}km^{-2})	2.5	0.25

(Fig. 4, Table 5). No attempt was made to partition effort directed at *P. filamentosus* in the case of Correira Bank. This species formed approximately 50% of the catch and at the depth range fished (>70 m) it was the target species. Thus the total effort was assumed to be directed at this species.

In Seychelles, *P. filamentosus* is caught in the depth range 75-150 m (Mees 1993). The net rate of production for *P. filamentosus* at Correira Bank was 2.5 kg day^{-1} km^{-2} of the intermediate depth range (Table 5) or 0.6 kg day^{-1} km^{-1} of the 100 m isobath. For all demersal species at Farquhar, where fishing occurred in the shallow stratum, it was 0.25 kg day^{-1} km^{-2}.

Discussion

Mothership/catcher boat operations exert significant fishing pressure at localized areas over a short time period. At large banks, local depletion may occur during any one voyage (as appeared to be the case during Voyage 3 at Fortune Bank, Fig. 2c) but differences in precise fishing location and the relatively larger standing stock at these locations mean depressed catch rates are not observed between voyages. However, it is apparent that depletion of small isolated areas can be significant, and that catch rates remain depressed from one fishing occasion to the next indicating that insufficient time has elapsed to allow complete recovery.

The rate of recovery, or production, was estimated. At Correira Bank the stock of *P. filamentosus* had fully recovered between Voyages 1 and 3. The production estimate of 2.5 kg km^{-2} day^{-1} equates to 914.6 kg km^{-2}year^{-1} (228.0 kg km^{-1} of the 100 m isobath). Mees (1993) estimated the sustainable yield of this species to be 717 kg km^{-2} year^{-1}. Polovina and Ralston (1986) estimated the total yield of all snappers and groupers within the 200-m isobath in the Marianas to be 300 kg km^{-2} year^{-1} whilst Polovina et al. (1990) gave mean estimates of 380 kg km^{-1} of the 200 m isobath on reefs and 1 460 kg km^{-1} of the 200 m isobath at sea mounts for all species. Given the differences in depth, and the fact that *P. filamentosus* represented approximately 50% of the catch, the estimate of production is of the right order and sufficient to generate the estimated yield for this resource.

Incomplete recovery had occurred at Farquhar between Voyages 2 and 4. Production was estimated to be 0.25 kg day^{-1} km^{-2} in the shallow stratum, which is a rather low value. However, the total area of Farquhar Atoll is an inapropriate value to apply because it is unlikely that fishing actually took place inside the lagoon: this is not permitted, and the maximum depth of the lagoon is 14.6 m, whilst the mean fishing depth was around 50 m. It is most likely that localized depletion of a smaller area occurred. At Farquhar the anchoring positions for Voyages 2 and 4 were 8 nautical miles (nmi) apart. However, the catcher boats fish within a radius of approximately 10 nmi of the mothership and so the same area would have been exploited. Assuming a fished reef area of 10-20 nmi by 0.5-1 nmi (17-69 km^{-2}) the production estimate becomes 2.5-0.62 kg day^{-1} km^{-2}.

Polovina (1986) indicated that the catchability of subordinate species in a multispecies assemblage is inversely related to the abundance of a more dominant species, although this change in catchability may have a time lag associated with it. He also showed that the pooled estimate of abundance for three species representing 90% of the exploitable population was 71% of the estimate derived for these species individually. From this we may conclude the biomass derived for all species at Farquhar may be underestimated on each voyage, but not necessarily the production. At Correira, *P. filamentosus* was dominant in the catch.

Whilst the results presented for *P. filamentosus* are of the correct order and support previous estimates of yield, there are potential sources of bias and error. During each period of fishing the model assumed a 'closed' study population, due to the short time frame involved. Between fishing it was 'open'. Hilborn and Walters (1992) discuss sources of error in estimates based on closed population depletion assessments and suggest that over a short time frame catchability may decline with the removal of the more stupid and/or aggressive fish, increasing q and depressing estimates of B_0. Catchability was assumed to be constant for each fishing occasion although its real value may change within each fishing period in this manner. The time interval between fishing occasions (145 days at Farquhar; 302 at Correira Bank) was considered sufficiently long to negate such a change by the start of the second fishing period. In contrast to this potential bias, q may be underestimated and B_0 overestimated if errors occur in the measurement of the cumulative catch or effort. These are considered to be reliable.

It has been demonstrated that commercial data may be used for depletion estimates of stock size and production. The possible analyses were constrained by lack of replicates which under research conditions would have been contained in the experimental design: particularly depth fished, duplicate fishing trials at certain locations despite low catch rates, longer time series at each location. Nevertheless, for single voyages depletion estimates of stock size were frequently possible (see Mees 1993, for *P. filamentosus* and Mees 1992, for *P. filamentosus* and *L. nebulosus*). For estimating production between voyages it was seen that the number of site specific comparisons was limited. Additionally, depletion estimates of abundance are subject to the bias discussed. Nevertheless, it is argued that despite these limitations, valuable information has been gained at minimal cost, and that this method will be of increasing value as more data become available from future voyages.

Acknowledgements

The author is grateful to Mahé Pêche Ltd. and Seychelles Fishing Authority (SFA) for permission to publish these data, collected and compiled by SFA observers and computer staff under an SFA-funded demersal fisheries project. The author was financed through the British Overseas Development Administration Fish Management Science Programme. Mark Bravington of MRAG Ltd. helped significantly with the statistical treatment of data and development of the biomass model. Professor John Beddington and Julie Rossouw critically reviewed the text.

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Abundance and Distribution of Snappers and Groupers Targeted by the Artisanal Medium Range Fishery off Northeastern Venezuela (1981-1992)

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MENDOZA, J.J. and A. LÁREZ. 1996. Abundance and distribution of snappers and groupers targeted by the artisanal medium range fishery off northeastern Venezuela (1981 to 1992) [*Abundancia y distribución, pargos y meros por la pesquería artesanal de media altura del noreste de Venezuela de 1981 a 1992*], p. 266-276. *In* F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos and D. Pauly (eds.) Biology, fisheries and culture of tropical groupers and snappers. ICLARM Conf. Proc. 48, 449 p.

Abstract

Changes in catch-per-unit effort (CPUE) for the main species (red snapper [*Lutjanus purpureus*], yellowedge grouper [*Epinephelus flavolimbatus*], and vermilion snapper [*Rhomboplites aurorubens*]) exploited by the medium-range artisanal fishery in northeastern Venezuela are analyzed for 1981 to 1992. The study is based on data obtained from interviews and landing controls. Vessels operate within the area between 7°N 58°W and 12°N 67°W, in the waters of Venezuela and Guyana and those of neighboring island countries. Fishing gears used are manually operated hooks-and-lines and longlines. The analysis is presented for the aforementioned area and three subareas: the Atlantic (east of Trinidad and Orinoco Delta), eastern Margarita (including northern Trinidad) and western Margarita. Handline effort is directed mainly to red snapper (45% of total handline catches) while longline effort is directed to grouper (59% of total longline catches). Species abundance varies from one subarea to another: red snappers are dominant in the Atlantic subarea, groupers in the east and west of Margarita Island and vermilion snappers are present mainly East of Margarita. For the general area, red snapper handline CPUE (kg/handline per fishing day) shows a 40% reduction for the study period. However, this decrease is particularly pronounced in the Atlantic subarea (approx. 60%). Grouper longline CPUE (kg/hook per fishing day) shows a stronger reduction (50%) for the whole area, the decline in abundance being stronger east of Margarita. Vermilion snapper handline CPUE shows the strongest reduction East of Margarita. Finally the strong seasonality of CPUE is discussed, as well as possible implications of overall results regarding stock structure in the study area.

Resumen

En este trabajo se analizan los cambios en la CPUE para las principales especies: pargo colorado (Lutjanus purpureus), *mero fraile* (Epinephelus flavolimbatus) *y el pargo cunaro* (Rhomboplites aurorubens), *explotadas por la pesquería artesanal de media altura del noreste de Venezuela para el período 1981 a 1992. El estudio está basado en datos obtenidos de entrevistas y controles de descargas. Los botes operan dentro de un área entre 7°N 58°W y 12°N 67°W, comprendiendo aguas territoriales de Venezuela y Esequibo (Guyana) y aquellas en las islas de los países vecinos. Las artes de pesca usadas son líneas de mano y palangres operados manualmente. El análisis es efectuado para el área arriba mencionada y 3 subáreas: Atlántico (este de Trinidad y Delta del Orinoco), este de Margarita (incluyendo el norte de Trinidad) y el oeste de Margarita. El esfuerzo de líneas de mano es dirigido principalmente al pargo colorado (45% de las capturas totales de línea de mano), mientras que el esfuerzo con palangres es dirigido al mero (59% de las capturas totales con palangre). La abundancia de especies varía de una subárea a otra: el pargo colorado es dominante en la subárea del Atlántico, el mero al este y oeste de Isla Margarita y el pargo cunaro esta presente principalmente al este de Margarita. Para el área general, la CPUE de las líneas de mano (kg/línea/días de pesca) mostró un 40% de reducción para el período de estudio, sin embargo este decremento es particularmente pronunciado en la subárea del Atlántico (aprox. 60%). La CPUE del mero con palangre (kg/no. de anzuelos/días de pesca) mostró una fuerte reducción (50%) para toda el área, siendo la declinación de la abundancia más fuerte al este de Margarita. Finalmente una fuerte estacionalidad de la CPUE es discutida así como las posibles implicaciones de los resultados globales en relación a la estructura de la población en el área de estudio.*

Introduction

The northeastern Venezuela artisanal snapper-grouper fishery is an important regional socioeconomic activity. The fleet is traditionally divided into two components: the long range fishery operating in waters of the Guianas Plateau (Guyana, Surinam, French Guiana and, to a lesser degree, Brazil) and the medium-range fishery operating in Venezuelan waters and those of neighboring island countries (Trinidad & Tobago and Grenada). Fishing gear consists of manually operated hook-and-line and longlines. These multispecies fisheries are directed mainly toward red snappers (*Lutjanus purpureus*), yellowedge groupers (*Epinephelus flavolimbatus*) and, to a lesser degree, vermilion snappers (*Rhomboplites aurorubens*) (see Cuellar et al., this vol.).

Despite their importance, the analysis of these fisheries has received limited attention. Statistics of catch and effort for the long-range fleet and medium-range fleet have been analyzed for 1983-1984 (Celaya and González 1988; Gonzalez 1990). Furthermore, Anon. (1990) presented estimates of catch and number of boats for 1983-1989 for both fleets. Other studies have been directed towards biological aspects of red snapper, such as growth (González 1990) and reproduction (Lugo 1986) in northeastern Venezuela. Previously, exploratory fishing results in the late sixties and early seventies were reported by Kawaguchi (1974).

In this study we present an analysis of available data on changes in apparent abundance for the medium-range fleet for 1981-1992.

Materials and Methods

The basic data consist of information obtained from interviews and landing controls on a per trip basis. Each trip provides observations on days at sea, days fishing, area fished, fishing gear, number of hooks (longlines) or number of handlines, average depth in area fished, catch per species and value of catch. Over 12 000 fishing trips were analyzed for the study period with an average of about 90 trips per month.

The area considered (Fig. 1) is included within 7°N 58°W at the mouths of the

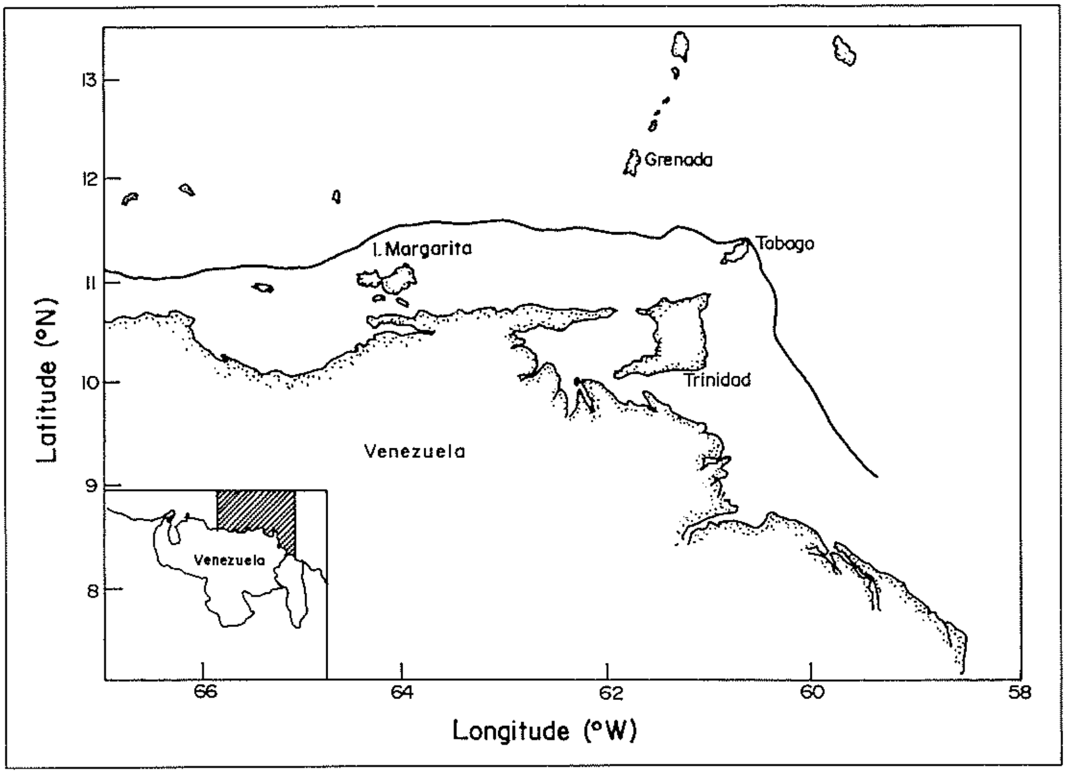

Fig. 1. Fishing area of the northeastern Venezuelan medium-range snapper-grouper artisanal fishery. [***Area de pesca de la pesquería artesanal de media altura de meros y pargos del Noreste de Venezuela.***]

Essequibo river and 12°N 67°W, north of the Los Roques archipelago in the Venezuelan central marine province. This area was further subdivided into three subareas with distinct hydrological regimes: Atlantic (7°N 58°W; 12°N 61°W), eastern Margarita (10°N 61°W; 12°N 64°W) and western Margarita (10°N 64°W; 12°N 67°W). The Atlantic subarea is dominated by the influence of the Orinoco and other important rivers including the Esequibo and the Demerara. The eastern Margarita subarea has a mixed regime of wind-induced upwelling (November through May) and riverine influence (mainly from the Orinoco). In the western subarea upwelling events and riverine input are of relatively minor importance.

Catch per species and fishing effort were used to compute monthly CPUE values per fishing gear and four geographical strata (total area and three subareas). The fishing effort units retained were number of hooks x fishing days for longliners and number of lines x fishing days for handliners.

For any month j, two different CPUE were estimated per gear:

1) $CPUE_j = \Sigma C_i / \Sigma f_i$ for i individual fishing trips, referred to as CPUE1.
2) $CPUE_j = 1/n \, \Sigma(C_i/f_i)$ for i individual fishing trips and n total trips sampled, referred to as CPUE2.

The ratio CPUE1/CPUE2 is considered to be an index of effort concentration on a per trip basis.

Annual CPUE per species and gear for both indices was estimated as the average of monthly values for each year. Additionally, the seasonal component was determined from the average CPUE for each month over the 12-year study period for red snappers and yellowedge groupers for both gears.

Results

The analysis of relative catch composition per gear allowed us to establish that handline fishing effort is mainly directed towards red snapper (45% of total catches sampled) and that yellowedge grouper is the target species in the longline fishery (approximately 59% of total catches sampled). Vermilion snapper is also caught by both gears but in a higher proportion by handlines (about 17% of total catches sampled).

Figs. 2-4 show the yearly trend for handline CPUEs per species in the total area. It is clear that red snapper CPUE is significantly higher than for other species. All species show a marked decline in abundance during the period, especially red snapper and yellowedge grouper. Vermilion snapper CPUE has apparently stabilized at about 2.5 kg/hook per fishing day in recent years. Both indices (CPUE1 and CPUE2) show similar trends for all species.

Figs. 2 and 3 show, for the whole area, yearly changes in longline CPUE for red snappers and yellowedge groupers. CPUE values are significantly higher in the case of yellowedge groupers. The decreasing trend over the period is especially marked in the case of this species. Red snappers show a strong reduction in apparent abundance between 1981 and 1982, but afterwards the declining trend is relatively moderate. Curiously, CPUE2 values for groupers are almost always higher than CPUE1 estimates, as opposed to red snappers, which do not present any significant difference regarding both indices. It would thus appear that longline effort is not well concentrated on yellowedge grouper.

The analysis of red snapper handline CPUE per subarea (Fig. 5) indicates that overall abundance is much higher in the Atlantic subarea, despite a continuously decreasing trend in apparent abundance. The subareas east and west of Margarita island show relative stability at similar levels of CPUE for this species between 1985 and 1992. Yellowedge grouper handline abundance is higher in the subareas east and, especially, west of Margarita (Fig. 6). Notwithstanding large interannual fluctuations in the western sector, it would appear that trends in abundance differ between the Atlantic subarea and the subareas east and west of Margarita. Vermilion snapper (Fig. 4) abundance is higher in the eastern Margarita sector, though this subarea shows a strong reduction in CPUE from 1983 onwards. Although strong variations occur, the other subareas show relative stability of CPUE over the study period.

Longline red snapper CPUE (Fig. 5) shows a marked decrease in the Atlantic sector and to a lesser degree west of Margarita, while apparent abundance east of Margarita has remained stable over the last six years of the series. Overall abundance was much higher in the Atlantic subarea at the beginning of the period, though present levels are similar for the three subareas considered. If we exempt the last four years of the study period in the subarea east of Margarita, yellowedge grouper longline CPUE (Fig. 6) does not show a sharp declining trend over the study period for the different sectors.

Figs. 2 and 3 show average monthly handline CPUE per subarea for red snappers and groupers from 1981 through 1992. Apparent abundance of red snapper tends to be low at the beginning and end of the average year, especially in the Atlantic and eastern Margarita subareas. On the other hand, yellowedge grouper shows a clear trend towards higher CPUE values in the first and last months. Average monthly longline red snapper CPUE (Fig. 2) differs from handline observations, except for the

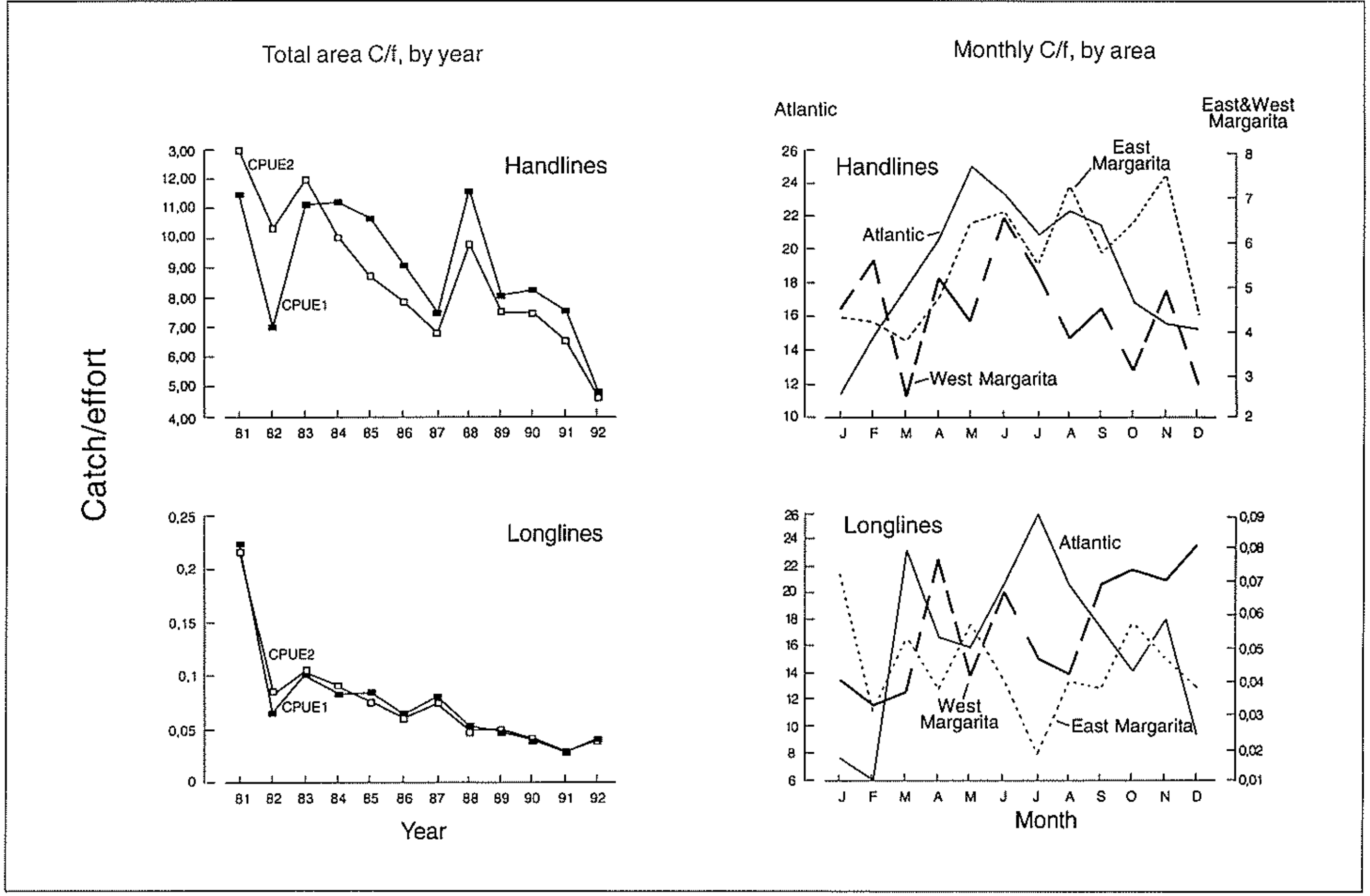

Fig. 2. Average annual red snapper (*Lutjanus purpureus*) CPUE (CPUE1 = $\Sigma C_i/\Sigma f_i$ and CPUE2 = $1/n\Sigma(C_i/f_i)$ for i individual fishing trips and n total trips sampled) by handlines (kg/line per day) and longlines (kg/hook per day) in all areas, and average monthly (1981-1992) red snapper CPUE by subarea. [*Promedio anual de la CPUE (CPUE1 = $\Sigma C_i/\Sigma f_i$ and CPUE2 = $1/n\Sigma(C_i/f_i)$ para i viajes de pesca y n número total de viajes) del pargo colorado* (Lutjanus purpureus) *por líneas de mano (kg/línea por día) y palangres (kg/anzuelo por día) en todo el área y promedio mensual (1981-1992) de la CPUE del pargo colorado por subáreas.*]

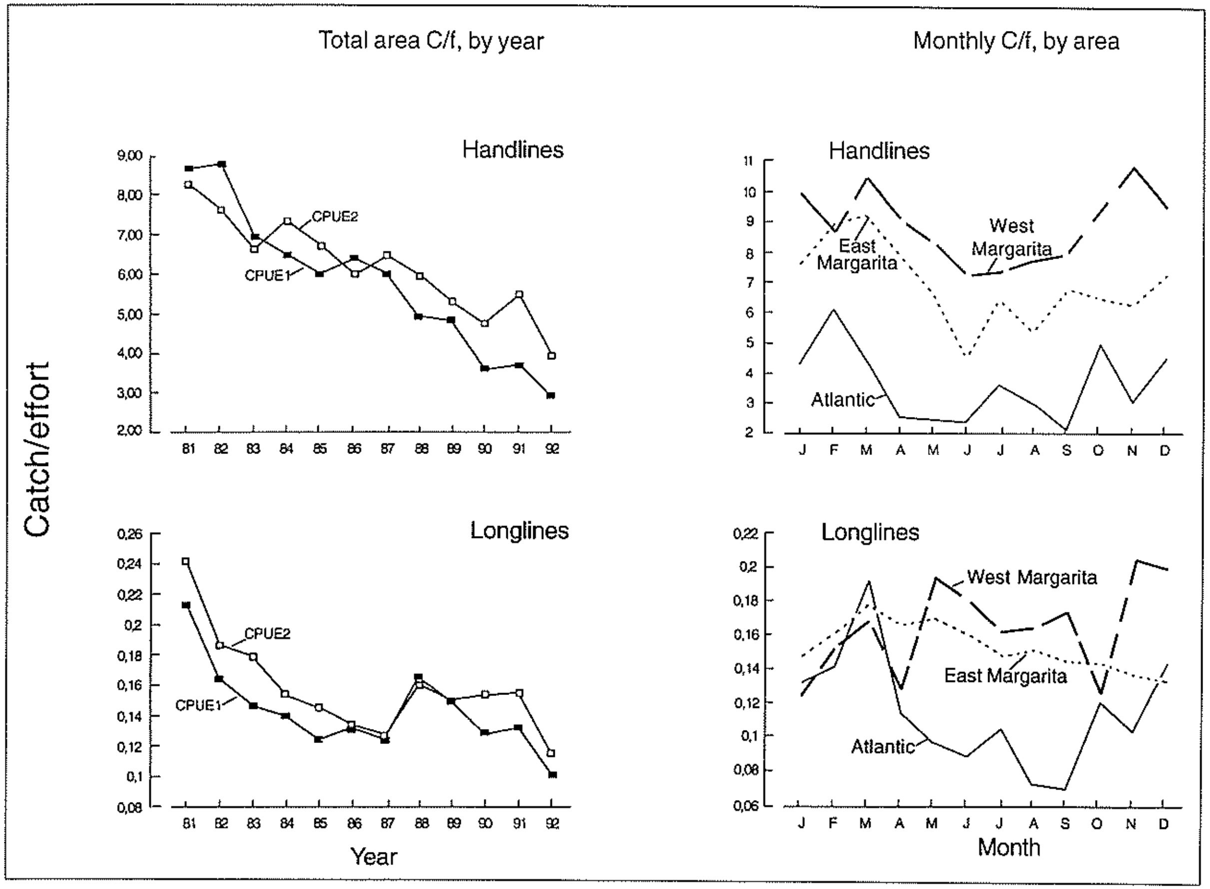

Fig. 3. Average annual yellowedge grouper (*Epinephelus flavolimbatus*) CPUE (CPUE1 = $\Sigma C_i/\Sigma f_i$ and CPUE2 = $1/n\Sigma(C_i/f_i)$ for i individual fishing trips and n total trips sampled) by handlines (kg/line per day) and longlines (kg/hook per day) in all areas, and average monthly (1981-1992) yellowedge grouper CPUE by subarea. [*Promedio anual de la CPUE (CPUE1= SCi/Sfi y CPUE2= 1/n S Ci/fi) para i viajes de pesca y n número total de viajes) del mero fraile* (Epinephelus flavolimbatus) *por líneas de mano (kg/línea por día) y palangres (kg/anzuelo por día) en todo el área y promedio mensual (1981-1992) de la CPUE del mero fraile colorado por subáreas.*]

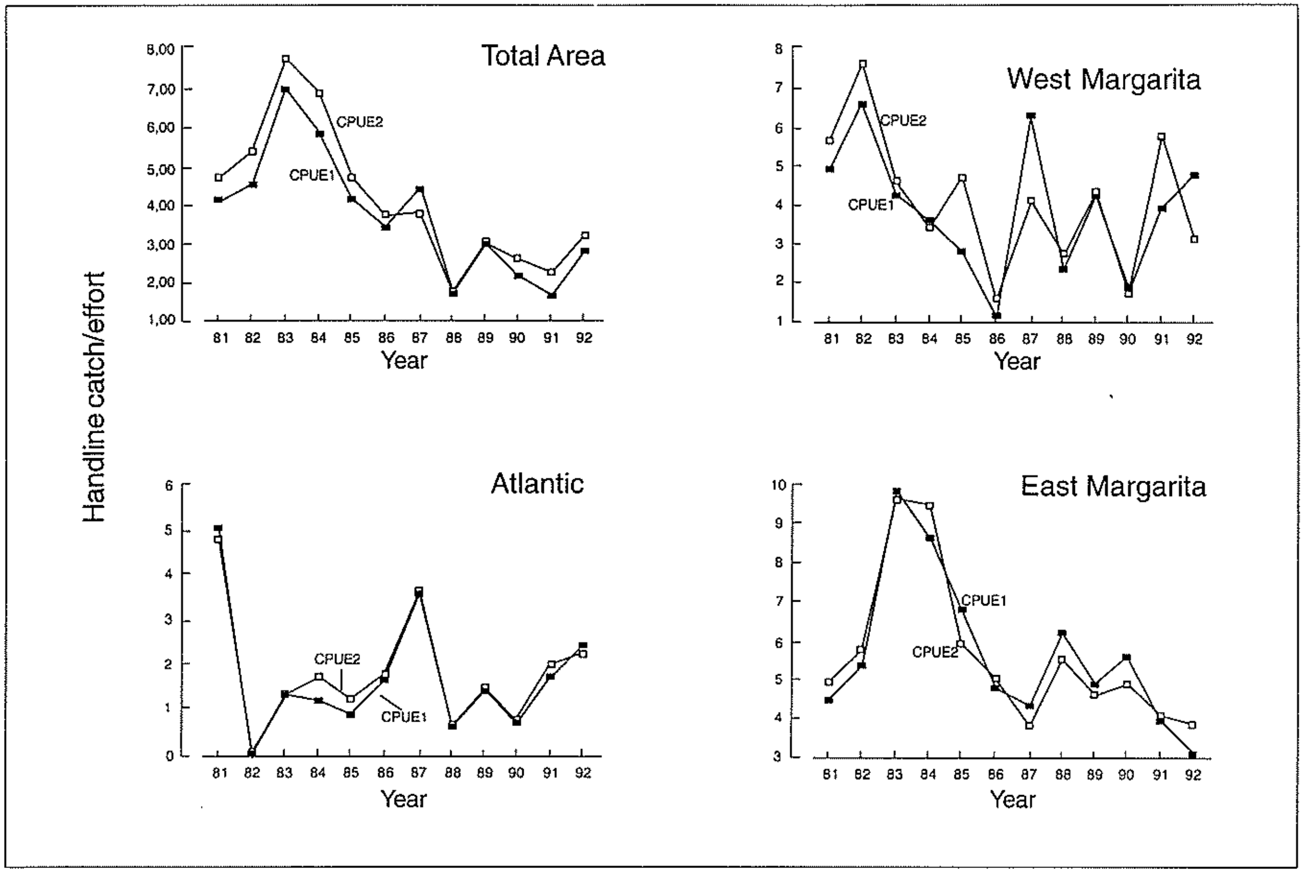

Fig. 4. Average annual vermilion snapper (*Rhomboplites aurorubens*) CPUE (CPUE1 = $\Sigma C_i/\Sigma f_i$ and CPUE2 = $1/n\Sigma(C_i/f_i)$ for i individual fishing trips and n total trips sampled) by handline (kg/line per day) in all areas. [*Promedio anual de la CPUE (CPUE1=SCi/Sfi y CPUE2= 1/n (S Ci/fi) para I viajes de pesca y n número total de viajes) del cunaro* (Rhomboplites aurorubens) *por líneas de mano (kg/línea por día) en todas las áreas.*]

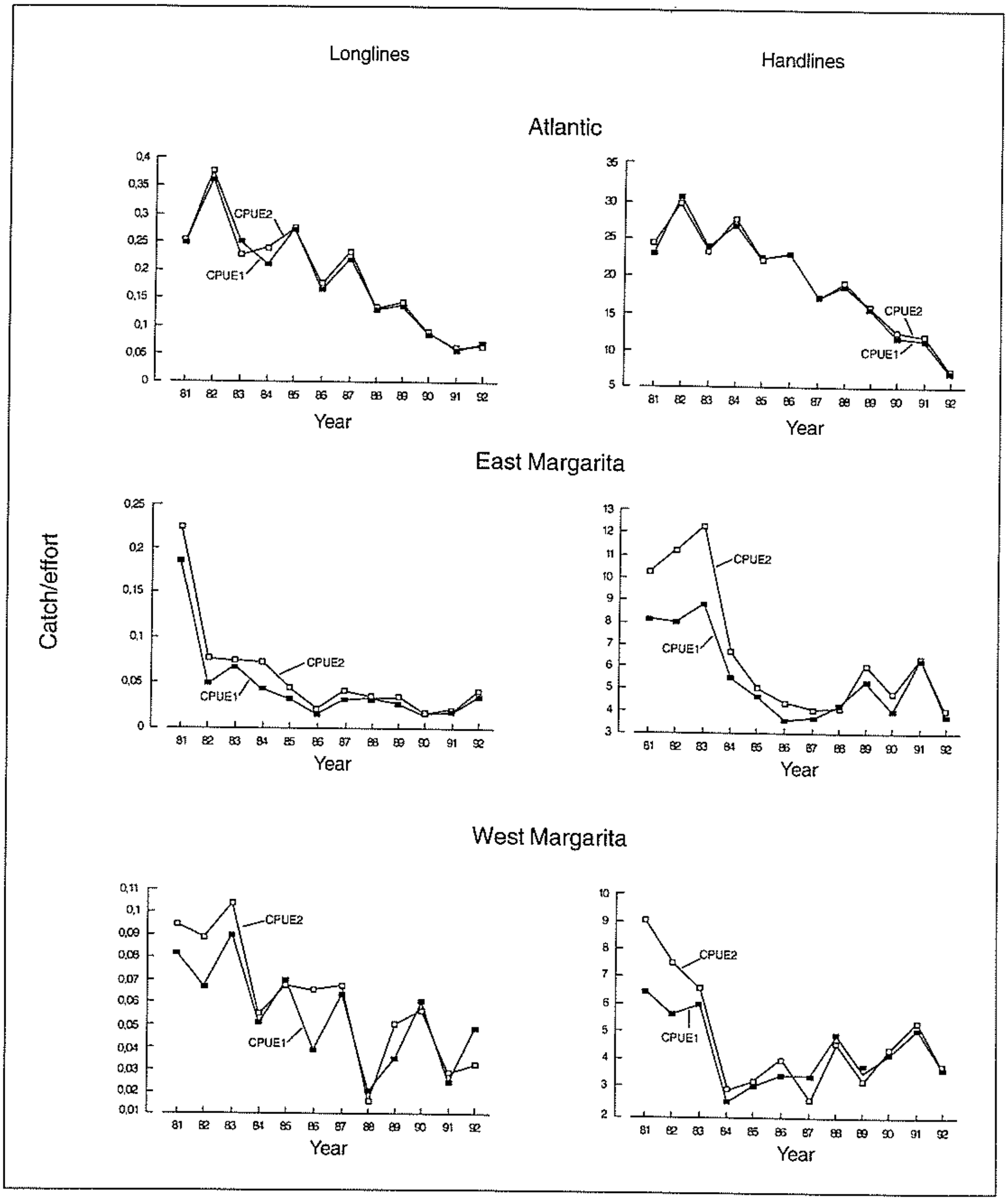

Fig. 5. Average annual red snapper (*Lutjanus purpureus*) CPUE by handlines (kg/line per day) and longlines (kg/hook per day) by subarea (CPUE1 = $\Sigma C_i/\Sigma f_i$ and CPUE2 = $1/n\Sigma(C_i/f_i)$ for i individual fishing trips and n total trips sampled). [*Promedio anual de la CPUE del pargo colorado* (Lutjanus purpureus) *por líneas de mano (kg/línea por día) y palangres (kg/anzuelo por día) por subáreas (CPUE1=SCI/Sfl y CPUE2= 1/n (S CI/fl) para i viajes de pesca y n número total de viajes).*]

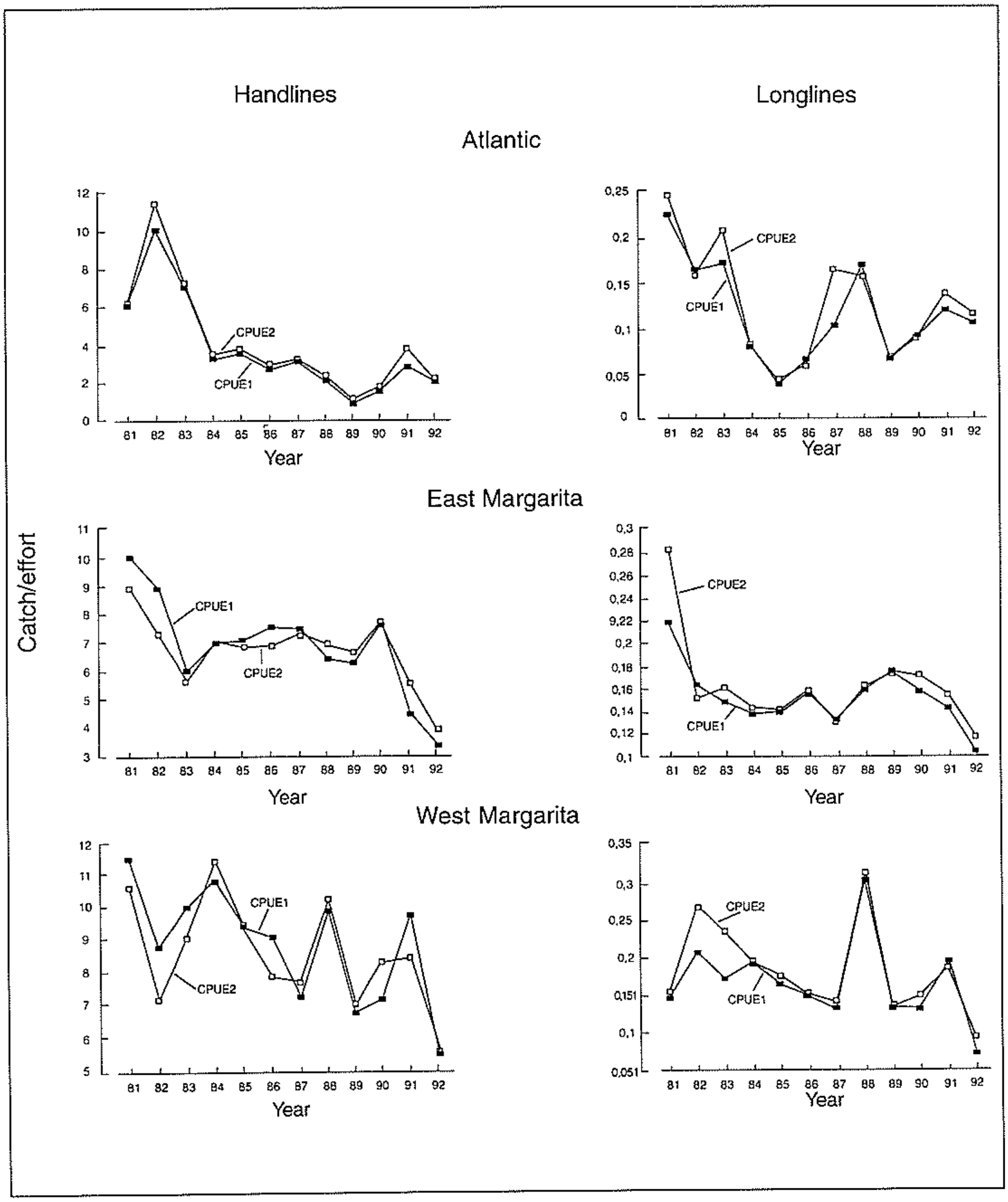

Fig. 6. Average annual yellowedge grouper (*Epinephelus flavolimbatus*) CPUE by handlines (kg/line per day) and longlines (kg/hook per day) by subarea (CPUE1 = $\Sigma C_i/\Sigma f_i$ and CPUE2 = $1/n\Sigma(C_i/f_i)$ for i individual fishing trips and n total trips sampled). [*Promedio anual de la CPUE del mero fraile* (Epinephelus flavolimbatus) *por líneas de mano (kg/línea por día) y palangres (kg/anzuelo por día) por subáreas CPUE1=SCi/Sfi y CPUE2= 1/n (S Ci/fi) para i viajes de pesca y n número total de viajes).*]

Atlantic sector. In east and west Margarita, higher values are observed in the first and second semesters, respectively. For yellowedge grouper longline CPUE (Fig. 3) only the Atlantic subarea presents monthly variations similar to the ones observed for handlines, and monthly fluctuations east and west of Margarita are much less pronounced.

Discussion

Economic policies developed by the Venezuelan government during the period 1983-1988 favored a large increase in number of boats and consequently fishing effort in several national fisheries. The northeastern Venezuelan snapper-grouper fleet increased from an estimated 341 boats in 1983 to 961 boats in 1989, of which approximately 50% participated in the medium range fishery (Anon. 1990).

Estimates of total catch for the latter fishery were only available for the years 1988 and 1989, in which a reduction from 6 331 t to 3 659 t was observed (Anon. 1990). Current work will try to reconstruct longer catch series in order to obtain a more precise picture of the response of these resources to exploitation. In any case, the analysis of CPUE data for the period 1981-1992 indicates that overall apparent abundance has decreased markedly for the main exploited species. This is particularly evident in the case of red snapper, yellowedge grouper and vermilion snapper handline CPUE for the total area, in which relative declines over the study period have been greater than 50%. Longline yellowedge grouper CPUE and, to a lesser degree, red snapper longline CPUE, present a similar trend. The image obtained from this analysis suggests that these resources are heavily exploited and that measures should be adopted to reduce fishing effort.

However, the additional information obtained from the geographical stratification of catch and effort data may imply that more than one unit stock exists for each species in the fishing area. Red snappers are more abundant in the Atlantic subarea where reduction of CPUE for both gears shows a pronounced and continous trend, as opposed to the western subareas where abundance is lower and CPUE estimates have remained relatively stable in the last seven years of the series. In this case we may be dealing with at least two separate stocks; an Atlantic stock associated with the Guianas Plateau and what may be called a southeastern Caribbean stock (northeastern Venezuela and northern Trinidad). A similar situation may exist for yellowedge grouper: the species is more abundant in the western subareas and its CPUE series resemble each other more than those from the Atlantic subarea. Following the same line of thought, trends in abundance of vermilion snapper would indicate that three different unit stocks may be present (Fig. 4). However, this species is a secondary target in the handline fishery and trends in CPUE may not adequately reflect changes in population abundance.

The relation between the two CPUE estimates indicates that handline effort is somewhat concentrated on red snapper, relative to longline effort, which is more dispersed. Snappers and groupers are generally more abundant on "hard bottoms" and rocky outcrops over the continental shelf and slope edge (Kawaguchi 1974). Experienced medium-range artisanal fishers use visual reference points to locate hard bottom grounds and, once within them, they employ a leaded wire or a fishfinder to determine the nature of the substrate. A preliminary assessment of our data showed that fishing occurs mainly in 60-240 m depth with higher red snapper catches obtained in less than 160 m, while yellowedge groupers were more abundant in deeper waters. This difference in depth distribution and higher mobility to avoid ground where "strikes" are not satisfactory, may explain why handliners are able to concentrate fishing effort on red snappers.

Seasonal changes in apparent abundance are not easily interpreted in this fishery. Red snapper handline CPUE peaks during the months from April to September, which corresponds with low apparent abundance for yellowedge grouper. This pattern is present in longline CPUE only in the Atlantic sector. Longline CPUE in other subareas does not present a well-defined seasonal pattern. Numerous factors related to fish behavior, environment, recruitment and fishing strategy and tactics may determine the observed changes in the handline fishery. We think, however, that changes in local densities associated with reproductive behavior may be a major determinant factor. Snappers (Thompson and Munro 1983a) and groupers (Thompson and Munro 1983b; Robertson 1991) have been reported to form spawning aggregations. *Lutjanus purpureus* is known to have a protracted spawning period extending from April to September. Even though we are not aware of specific studies on *Epinephelus flavolimbatus*, information presented for the Caribbean (Thompson and Munro 1983b; Robertson 1991) indicates that several serranid species spawn in the first and last months of the year. These observations are consistent with our results regarding handline CPUE for both species and, to a lesser degree, for that on longlines.

Acknowledgements

We wish to thank Mr. José Silva from the Departamento de Biología Pesquera, Instituto Oceanográfico, Universidad de Oriente, for his assistance in data processing.

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