14 ANALYSIS OF INDUSTRIAL TRAWL AND ARTISANAL FISHERIES OF WHITEMOUTH CROAKER (*Micropogonias furnieri*) OF VENEZUELA AND TRINIDAD AND TOBAGO IN THE GULF OF PARIA AND ORINOCO RIVER DELTA

J.J. Alió, L. Marcano, S. Soomai, T. Phillips, D. Altuve, R. Alvarez, D. Die and K. Cochrane

14.1 Background

The whitemouth croaker, *Micropogonias furnieri*, is one of the important fish species exploited in the Gulf of Paria and the Orinoco River delta by the fleets of Trinidad and Tobago and Venezuela. The Venezuelan fleets landing the species are comprised of 324 artisanal vessels and 88 industrial trawlers. The wooden artisanal vessels are 5-14 m long and propelled by outboard engines. They use multiple gear, 67% operate with gillnets, 64% with longline, 9% with hook and line and 4% with traps. Most vessels (78) in the industrial fleet target shrimp and fish, while 10 vessels use stern gear and only target demersal fish. In Trinidad and Tobago the species is landed by an industrial trawl fleet and an artisanal fleet (comprised of smaller vessels outfitted with trawl or other gear types) which both operate in the Columbus Channel and Gulf of Paria.

The percentage composition of *M. furnieri* in the landings from the industrial and artisanal fleets is similar for both Venezuela and Trinidad and Tobago. In Venezuela, the industrial trawl fleet accounts for 61% of the country's landings of this species while the artisanal fleets land 39%. In Trinidad and Tobago, the industrial fleet (type IV trawlers) accounts for an average of 69% of the country's landings of the species. This is based on a percentage composition by weight for M. furnieri derived from logbook records for 1991-1992 (Maharaj *et al.* 1993). The Trinidad and Tobago artisanal and semi industrial vessels (Types I and II trawlers as well as small vessels outfitted with gillnets, handlines and baited hooks and Type III trawlers respectively) account for the remaining 31% of the landings.

Important changes in the combined fleets' landings of this species have been observed, falling from a yearly average of 2344t in 1988–1993 to less than a 1000t in 1996 (Figs 14.1 and 14.2). The fishing effort of industrial and artisanal fleets in both countries (bi-national fleet) has also shown significant changes in time. With the decrease in effort reported in recent years the stocks seem to be recuperating.

Earlier yield per recruit analyses of the state of the fishery in the region (Manickchand-Heileman and Kenny 1990; Alvarez *et al.* 1998) concluded that *M. furnieri* was fully exploited. During the period 1993-1995, Alvarez *et al.* (1998) estimated the f_{MYR} for the Venezuelan fleet to be in the interval 0.4–0.45 (assuming natural mortality rates between 0.79 and 0.39, respectively). They also estimated that the average fishing mortality was 0.5, showing that the current effort level is slightly above this limit.

In this study we re-evaluate the dynamics of the *M. furnieri* fishery in the Gulf of Paria, by means of biomass dynamic models (Punt and Hillborn 1996), using catch data from the entire bi-national fishery and two indices of abundance (CPUE for Venezuelan industrial trawl fleet and CPUE for the Trinidad and Tobago artisanal fleet). Furthermore, a yield per recruit analysis was made, using estimations on fishing mortality from data collected on board of the Venezuela industrial fleet.

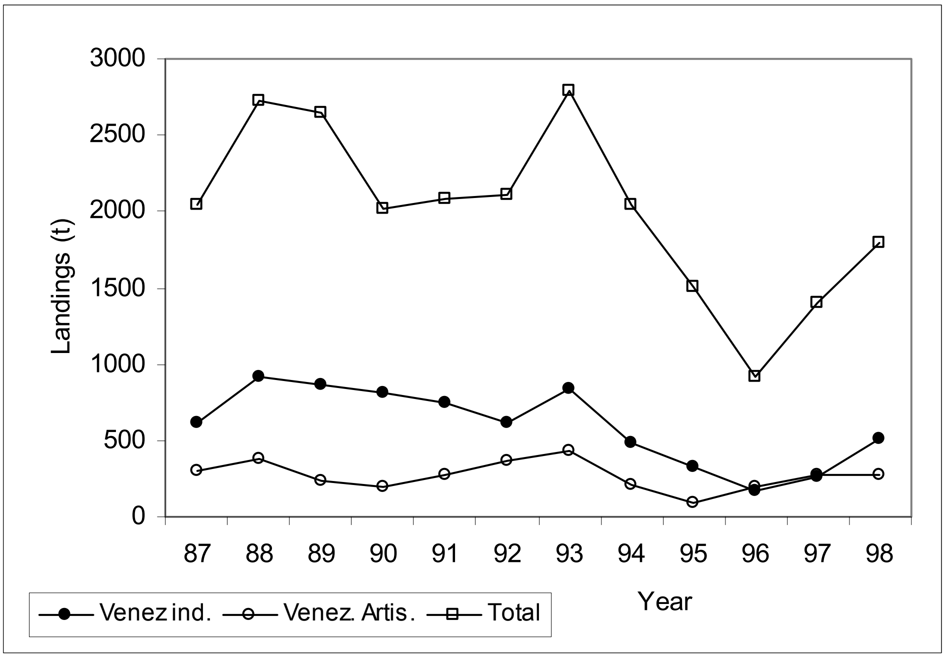

Figure 14.1 Landings of the Venezuelan artisanal and industrial trawl fleets in the Gulf of Paria and Orinoco river delta during the period 1987-1998

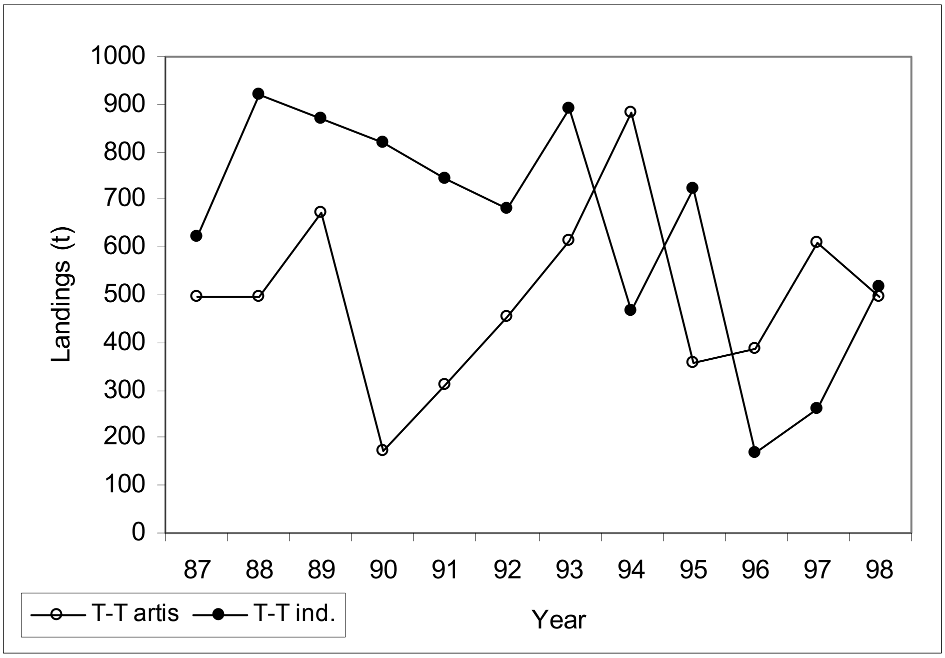

Figure 14.2 Landings of the Trinidad and Tobago artisanal and industrial trawl fleets in the Gulf of Paria during the period 1987-1998

The whitemouth croaker is distributed from the southern Greater Antilles (Caribbean) and along the continental shelf from Costa Rica to Argentina. This demersal species is abundant on the continental shelf of the Guianas and northeastern Venezuela (Cervigón 1993). It inhabits areas of the shelf and estuaries, over muddy and sandy bottoms, down to 60 m depth. It spawns in shallow coastal waters and nursery areas are located in the shallow coastal zones and near the river mouths (Lowe-McConnell 1966; Novoa *et al*. 1998).

14.2 Data sets

Data for the Trinidad and Tobago industrial trawl fleet were available for the period 1992-1995 and were estimated from the catch and effort of a single trawler and extrapolated to the remaining 20 trawlers in the fleet (Table 14.1). Catch data of this fleet for the period 1987-1991 and 1996-1998 were estimated by assuming that the performance of the fleet was similar to the Venezuelan industrial fleet for the respective period (Table 14.2). Information on catch and effort for the artisanal fleet of Trinidad – Tobago was obtained from six different gear types for the period 1989-1997 (Table 14.1). The catches for the period 1987-1988 and 1998 were estimated by the average catch of this fleet for the period 1989-1997 (Table 14.2).

Data on catch and effort from the Venezuelan industrial trawl fleets were available for the period 1987-1998; those on catch from the Venezuelan artisanal fleet were only available for the period 1987-1996. The data on catch for the latter fleet for the period 1997-1998 were approximated by the average catch of that fleet during the period 1987-1996 (Table 14.2).

Since the bi-national artisanal fleet operating with six different fishing gears (trawl nets, gillnets, hook and line, etc.) and two industrial trawl fleets are targeting *M. furnieri* in the study area, the general effort applied by all fleets was estimated in industrial trawl units (days at sea or d-a-s). It was calculated by dividing the yearly total catch by the cpue of the Venezuelan industrial trawlers (Table 14.2).

Monthly information on size structure of *M. furnieri* (both sexes combined) was recorded in Venezuela by observers on board and from samples measured in the FONAIAP laboratory in Cumaná, during the period Jun – Nov. 1993 and Feb., Mar., May, Aug. and Nov. 1994. \

Table 14.1 *Micropogonias furnieri* catch and effort information from the Trinidad – Tobago artisanal and industrial fleets operating in the Gulf of Paria

	Artisanal (type I, II and III trawlers + 5 other gears)			Industrial (Type IV vessels)		
Year	**Catch (t)**	**Effort (trips*)**	**CPUE (kg/trip)**	**Catch (t)**	**Effort (d-a-s**)**	**CPUE (kg/d-a-s)**
89	671	219391	3.10			
90	173	88937	1.95			
91	312	216937	1.44			
92	454	282826	1.61	1284	4043	318
93	614	377610	1.63	1684	3870	435
94	882	322044	2.74	878	4845	181
95	358	135324	2.65	1367	4355	314
96	388	155803	2.49			
97	608	211893	2.87			

* - Trips are equivalent to days
** - d-a-s represents days at sea

Table 14.2. ***Micropogonias furnieri*** **catch and effort information from the Venezuelan artisanal (VA) and industrial fleet (VI) and from the Trinidad and Tobago artisanal (TA) and industrial fleet (TI), operating in the Gulf of Paria during the period 1987-98. The Venezuelan industrial fleet also operates in the Orinoco river delta. Effort information corresponds to the Venezuelan industrial fleet. Total effort (all fleets) was estimated as total catch/Venezuelan industrial CPUE**

Year	Catch VI	Catch VA	Catch TA	Catch TI	Total catch	Effort VI	VI CPUE	Total effort all fleets
	(t)	(t)	(t)	(t)	(t)	(d-a-s)	(kg/d-a-s)	(d-a-s)
87	620	305	496**	620***	2041	6719	92.3	22121
88	922	382	496**	922***	2722	7175	128.5	21185
89	870	240	671	870***	2651	8710	99.9	26540
90	818	203	173	818***	2012	13252	61.7	32601
91	745	282	312	745***	2084	13011	57.3	36389
92	611	363	454	680	2109	9952	61.4	34353
93	840	437	614	893	2784	12762	65.8	42296
94	488	210	882	465	2045	8851	55.1	37097
95	324	95	358	724	1502	9348	34.7	43329
96	166	195	388	166***	916	6727	24.7	37102
97	261	270*	608	261***	1400	6952	37.5	37300
98	516	270*	496**	516***	1798	8669	59.5	30207

*, Approximated by the average catch during the period 1987-96
**, Approximated by the average of the T-T artisanal fleet for the period 1989-97.
***, Approximated by the value of the catch from the Venezuelan industrial fleet for the same year

14.3 Biomass dynamics stock assessment

14.3.1 Method

Due to the lack of information on size structure from most of the fleets in the study area, the population dynamics of the resource was modeled using biomass dynamics model, assuming observation error was dominant (Punt and Hillborn 1996). The population model used was:

$$B_{y+1} = B_y + rB_y\left(1 - \frac{B_y}{B_\infty}\right) - C_y$$

$$I_y = qB_y\, e^{\eta_y}$$

where B_y = the biomass in year y, r = the intrinsic growth rate parameter, B_∞ = the average unexploited equilibrium biomass, C_y = the catch in year y, I_y = the biomass index

(CPUE in this case), q = the catchability coefficient and η_y = the log normally distributed observation error.

As two biomass indices were used in this case, two separate q's were estimated. The model used information on total catch for the entire fishery and two indices of abundance, the monthly CPUE values of the Venezuelan industrial trawl fishery during the period 1987-1998 and the CPUE for the artisanal fleet of Trinidad and Tobago during the period 1989-1997.

Because of the uncertainty on the actual value of the instantaneous rate of increase (r) of the species, the parameter was constrained to vary in the range 0.2 to 0.5. The Excel 97 Solver Add-in was used to fit the unexploited stock size (B_∞), initial biomass at the beginning of the exploitation (B_0) and catchability for both fleets (q Venezuela and q Trinidad and Tobago), that minimized the sum of squares between the log-expected and log-observed values of both yearly indices of abundance. The results of the model provided estimates for the Maximum Sustainable Yield (MSY) and the effort at which the MSY can be obtained (f_{MSY}).

14.3.2 Results

The biomass dynamics model was initially run without constraints, allowing Solver to estimate the instantaneous growth rate parameter "r". As the estimated value of r was considered too high for this species, the model was re-run with fixed values of r. The estimate for the MSY varied from 1036 t to 1639 t when the instantaneous rate of increase of the population was allowed to vary from 0.2 to 0.5, respectively (Table 14.3, Fig. 14.3). The estimated effort level that would allow the MSY for the corresponding values of r varied between 19500 and 23700 d-a-s. The catchability coefficients estimated for the Venezuelan fleets (0.005 to 0.011) were much larger than those estimated for the fleets from Trinidad and Tobago (9.15 10^{-5}; Table 14.3) and vary appreciably with the r value. In contrast, the catchability coefficient of the Trinidad and Tobago fleets was very stable for the different values of r.

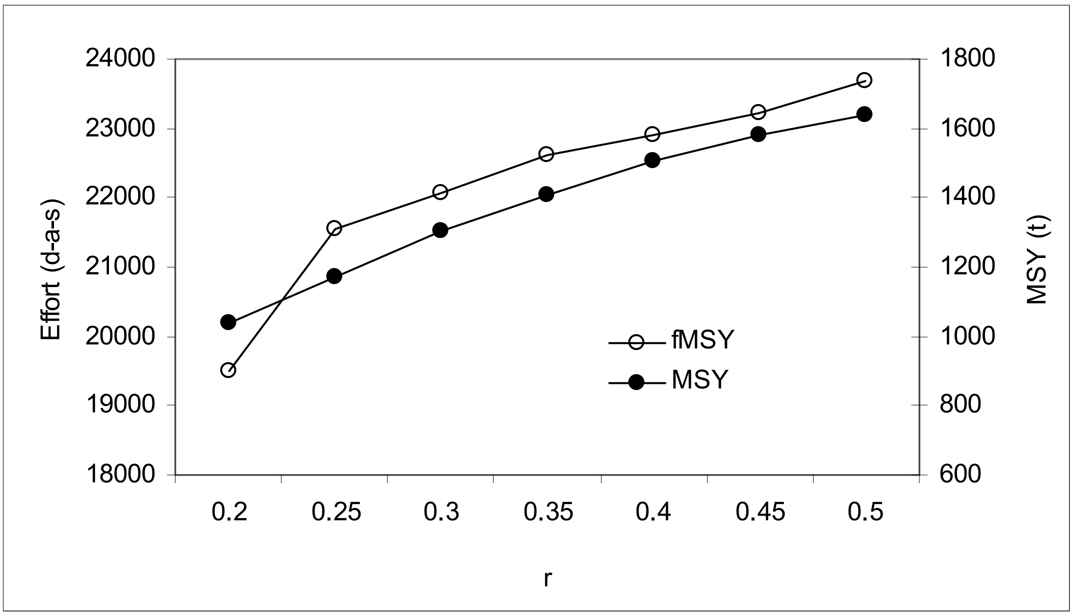

Figure 14.3 Estimated MSY and f_{MSY} for the fishery of *M. furnieri* in the Gulf of Paria and the Orinoco river delta, as a function of the instantaneous growth rate value

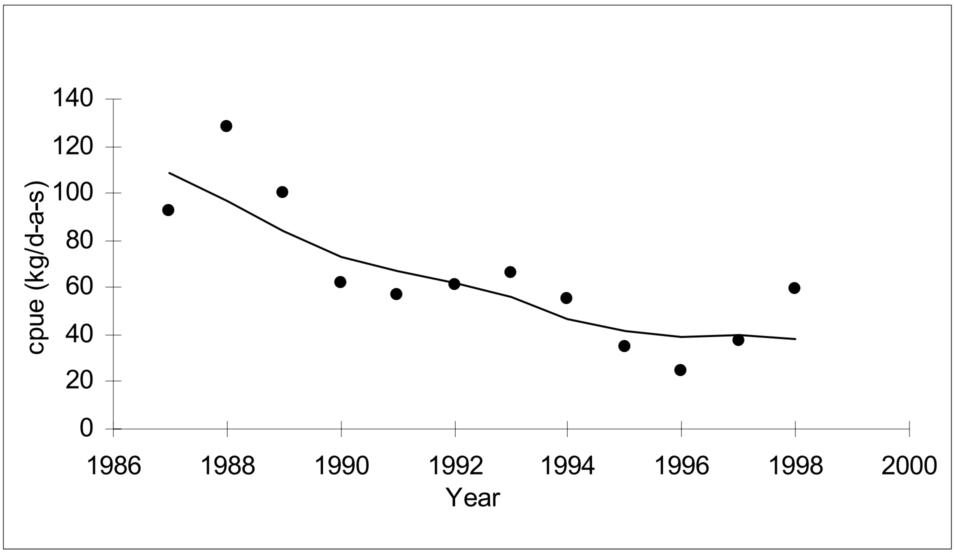

Figure 14.4 Predicted (—) and observed (•)CPUE for the Venezuelan fleet of *M. furnieri* in the Gulf of Paria and the Orinoco river delta

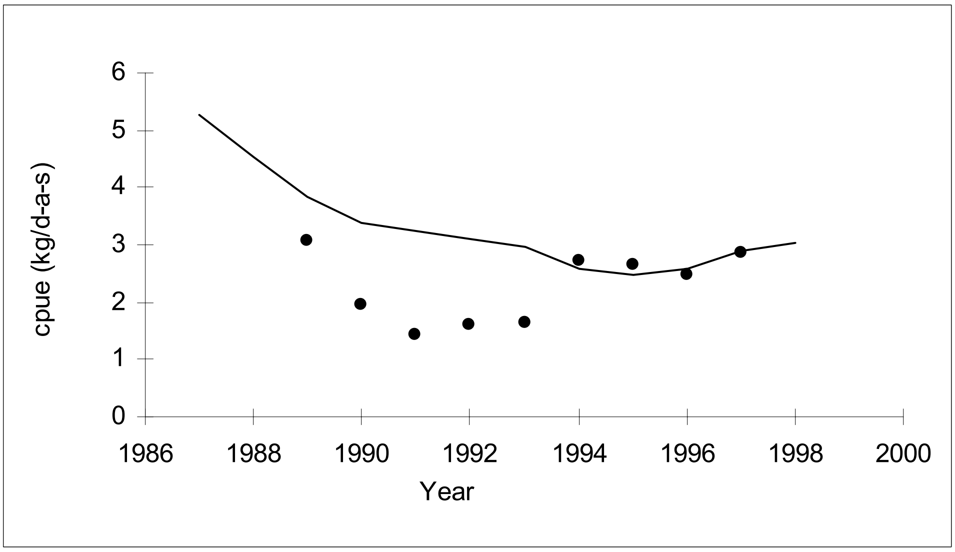

Figure 14.5 Predicted (—) and observed (•) for the Trinidad and Tobago fleet of *M. furnieri* in the Gulf of Paria

The carrying capacity (B_∞) for the estuarine ecosystem of the Gulf of Paria was estimated at 13000t to 21000t, depending on the r value. The value for the biomass at the starting moment of the simulation maintained values below B_∞ for r values between 0.3 and 0.5. For smaller values of r, the optimization routine could only find a solution with B_i being equal to B_∞, which is unrealistic as the fishery had been in existence for many years prior to 1987. In all simulations the observed catch would be an average of 21% of the available biomass per year.

The observed and predicted CPUE values follow a similar pattern with a steady declining trend and recuperation at the end of the time series. The fit appears to be better for the Venezuelan fleet (Fig. 14.4 and 14.5). The approximation of predicted to the observed cpue values could be improved with higher r values, but r beyond 0.5 were considered unrealistic.

Table 14.3. Sensitivity of results of biomass dynamics model simulation with error associated in the data, for the Trinidad and Tobago – Venezuela fisheries of *M. furnieri*, when changing the instantaneous growth rate (r) parameter

Parameter	Instantaneous growth rate (r)						
	0.2	**0.25**	**0.3**	**0.35**	**0.4**	**0.45**	**0.5**
B_∞ (t)	20728	18730	17368	16104	15048	14056	13111
B_i (t)	20728	18730	15903	13932	12192	10985	10138
q (Venezuela)	0.00512	0.00580	0.00679	0.00774	0.00874	0.00969	0.01056
q (Trinidad - Tobago)	$9.51\ 10^{-05}$	$9.51\ 10^{-05}$	$9.51\ 10^{-05}$	$9.51\ 10^{-05}$	$9.51\ 10^{-05}$	$3.32\ 10^{-03}$	$9.51\ 10^{-05}$
MSY (t)	1036	1171	1303	1409	1505	1581	1639
f_{MSY} (d-a-s)	19514	21539	22079	22622	22892	23219	23681

14.4 Yield per recruit stock assessment

14.4.1 Method

With the available information on monthly size structure of the species from the Venezuelan trawl fleet, the Bhattacharya method was employed to estimate modes and their movement over time to estimate growth. Furthermore, the variation in monthly fishing mortality (F) was estimated by means of linearized catch curve analyses (using the algorithm of Ehrhardt and Legault 1996). Average F values were weighted by the size of the monthly samples. The paucity of data and the short series of months for which the data on size structure was available prevented the use of virtual population analyses.

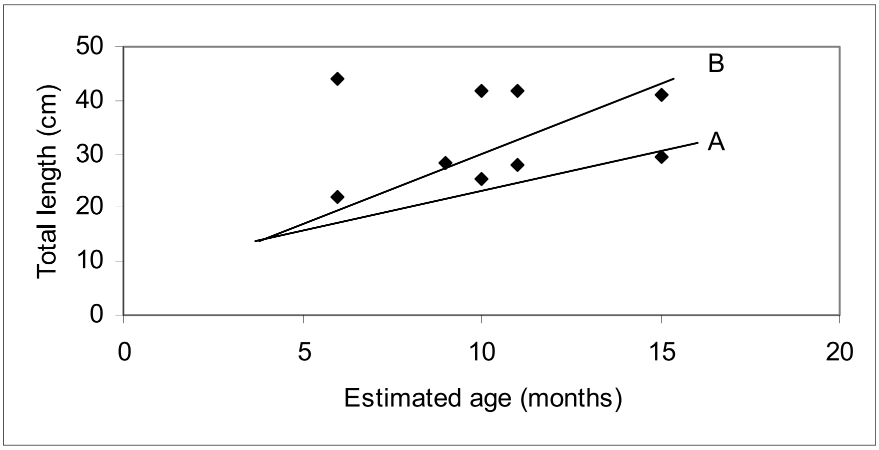

Figure 14.6 Estimated age for *M. furnieri*. K value would depend on the assumed trajectory of growth (0.13 with option A and 0.6 with option B)

14.4.2 Results

The number of modes observed for any month in the Bhattacharya analyses varied between 4 and 6. The progression of modes was unclear. Approximating the position of modes with ages (Fig. 14.6), it was estimated that the parameters of the von Bertalanffy growth equation could have the following values: L_∞ = 70 cm; K = 0.6 and t_0 = -0.13. However, depending on the position of the growth curve, the value of K probably lies between 0.13 and 0.6.

Since observed sizes were already larger than 70 cm, it was decided that the following analyses about fishing mortality were to be performed using estimates of K and L_∞ from the literature (L_∞ = 83 cm and K = 0.13 $year^{-1}$; Manickchand-Heileman and Kenny 1990). The monthly linearized catch curve analyses resulted in values for the fishing mortality (F) between 0.4 and 3.2, depending on the value of K used in the analyses (Table 14.4)). With the preferred value from the literature of K = 0.13, the estimated average annual value of F was 0.47.

Table 14.4. *Micropogonias furnieri*. Estimates of F using linearized catch curve analyses on samples from the Venezuelan industrial trawl fleet operating in the Gulf of Paria and Orinoco River delta. Maximum total length (L_∞) was assumed 83cm and natural mortality (M) 0.4 (after Manickchand-Heileman and Kenny 1990)

Year	Period	F				Sample Sizes
		K=0.13	K = 0.2	K = 0.4	K = 0.6	
93	Jun	0.27	0.64	1.67	2.7	841
	Jul	0.23	0.56	1.52	2.49	207
	Aug	0.04	0.22	0.84	1.46	103
	Sep	0.92	1.62	3.65	5.67	664
	Oct	0.52	1.01	2.43	3.8	880
	Nov	0.63	1.19	2.78	4.37	525
94	Feb	0.56	1.08	2.56	4.05	264
	Mar	0.56	1.08	2.56	4.05	547
	May		0.01	0.42	0.84	357
	Aug	0.55	1.06	2.52	3.98	121
	Nov	0.07	0.32	1.03	1.75	239
	TOTAL					4748
Weighted average*		0.42	0.65	1.98	3.21	
Standard error		0.004	0.007	0.013	0.02	
95% Conf. Interv.		0.41 - 0.43	0.63 - 0.66	1.96 - 2.0	3.17 - 3.25	

* F values were LOG_{10} transformed before average calculations

The yield per recruit analysis of the *M. furinieri* fishery (Fig. 14.7) was carried out using the parameters indicated in Table 14.5. This analysis suggests a current effort leading to a fishing mortality (F) value of 0.47 assuming a K value of 0.13 and an F value of 3.54 with a K value of 0.6 (Table 14.6). At an F value of 0.4 (with a K value of 0.13), a recommended minimum of 40% spawners biomass will be removed and this is very close to the current F value. The $F_{40\%SBR}$ value would increase to 0.51 (with a K value of 0.6), when the current F value increases to 3.54.

Table 14.5 Parameters used in the yield per recruit analysis of the fishery of *M. furnieri* in the Gulf of Paria and Orinoco river delta. The parameters "a" and "b" correspond to the length–weight relationship; M is the natural mortality (after Manickhand - Heileman and Kenny 1990)

Parameter	Used in this study
L_∞	83 cm
K	0.13 mo^{-1}
to	-0.13 mo
a	0.03
b	2.64
M	0.4

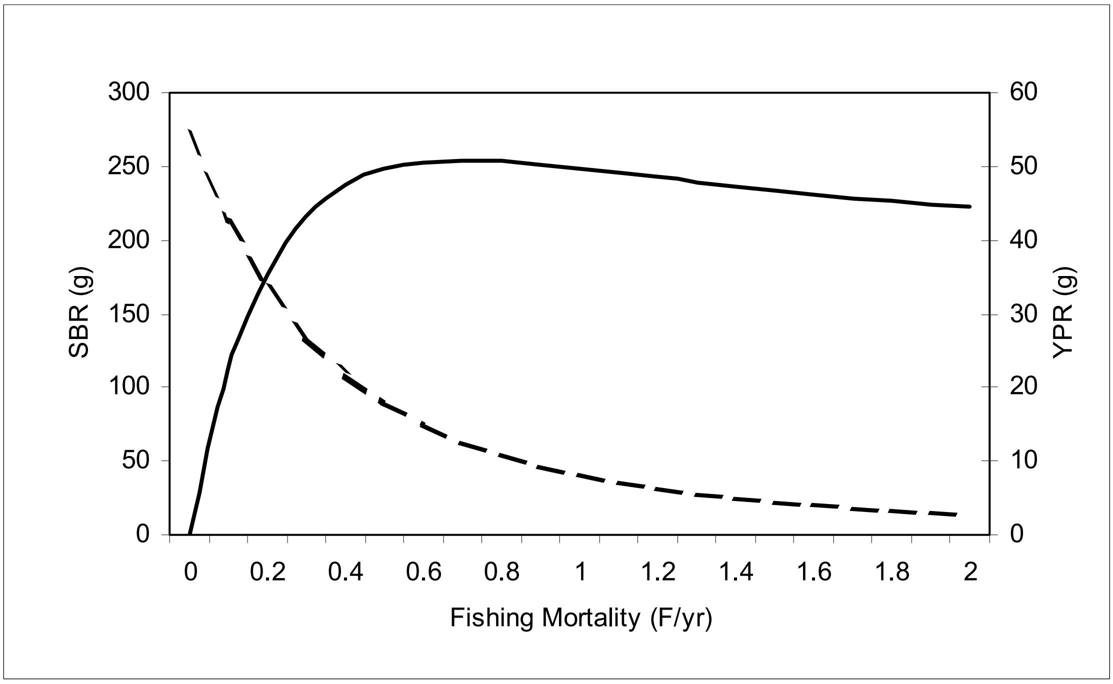

Figure 14.7 Curves of per recruit analysis for the fishery of *M. furnieri* in the Gulf of Paria and Orinoco river delta with a K value of 0.13 $year^{-1}$ and L_∞ = 83 cm

Table 14.6. *Micropogonias furnieri*. Yield and biomass per recruit analyses (Y/R and B/R) on samples from the Venezuelan industrial trawl fleet operating in the Gulf of Paria and Orinoco River delta. Symbols: K = exponential parameter of the von Bertalanffy growth equation; F = fishing mortality; SBR = biomass of spawners

	K			
	0.13	**0.2**	**0.4**	**0.6**
Current F	0.47	0.92	2.23	3.54
F 40% SBR	0.4	0.42	0.47	0.51
SBR virgin (g)	273	584	1450	2009
SBR 40% (g)	109	234	580	803
% SBR at current F	35	18	6	3.5
Y/R 40% SBR (g)	47	109	321	504
Y/R F current (g)	49	119	372	638

14.5 Discussion

Results agree with previous estimates on the level of exploitation of the *M. furnieri* fishery in the region. The use of the surplus production biodynamic model suggested that the Maximum Sustainable Yield of the species in the region is about 1500 t (1300 to 1600 t). This level of exploitation was surpassed several times between 1987 to 1993 and a subsequent decline was recorded in the landings of all fleets of the region. The reduction of the effort after 1993, followed by landings below the MSY level observed in the fishery until 1996, may explain the recuperation in stock number as observed in the landings after this year. The MSY was surpassed again in 1998, when approximately 1800t were landed. If the increasing trend in effort continues, another decline in the landings can be expected in the near future.

Comparison of the results of the biomass dynamic model with the estimated values of F from the linearized catch curve analysis suggests that a lower value of the growth coefficient, K, is closer to the true value. When a value for the growth coefficient (K) of 0.13 was used in the linearized catch curve analysis, the estimated mean value of F was 0.42 $year^{-1}$ (Table 14.4), which is close to the F value (0.47 $year^{-1}$; Table 14.6) estimated by per recruit analysis to result in a surviving spawners biomass of 40%.

It is difficult to obtain from the simulation models a clear idea about the value of the effort that should be maintained in the fishery. The values obtained from the simulations reflect the estimations made for an array of fisheries with very different characteristics. Probably a good approach towards establishing a proper level of effort would be to determine the effort each of the fisheries was making in a critical year (1997 in this case, when stocks recuperated; see Fig 14.1) and to maintain such level in the near future.

It is suggested that effort should not be allowed to increase beyond current levels of exploitation and further it is recommended that the level of effort should be maintained below that observed in 1997. The open access management strategy that has been typically applied to artisanal fisheries in the past, should therefore be replaced by a limited effort regime if future declines in the fisheries are to be avoided.

In the evaluation of *M. furnieri*, migration of the species presents a problem since individuals at different size ranges may be targeted by various fleets in a region. Unless data is available from all active fisheries, it would be difficult to obtain an accurate value for the fishing mortality since reductions in biomass from an area due to migration may be interpreted as being a consequence of a mortality process. In the Gulf of Paria a series of fleets belonging to the bordering countries in the region have been fishing for several decades. However, only since the late 1980s have data on catch and effort and, more recently, on size been gathered, mainly in the Venezuelan side of the Gulf. The availability of data on landings size structure in the Trinidad side of the Gulf is therefore necessary to provide an improved assessment of the current state of the fishery. Alternatively, a series of surveys testing density and size structure on the areas where the different stages of *M. furnieri* distribute in the Gulf may be a faster and less expensive way to estimate the status of the stocks. Such surveys would also provide information on other important fish species in the region.