18 CASE STUDY FOR A MULTI-SPECIES MULTI-FLEET SHARED STOCK FISHERY: PRELIMINARY BIO-ECONOMIC ANALYSIS OF THE TRINIDAD AND TOBAGO / VENEZUELA TRAWL FISHERY

18.1 Description of the Trinidad and Tobago fishery

Based on a trawl vessel census conducted in 1997 by the Fisheries Division of Trinidad, the trawl fleet comprises a total of 126 vessels: 30 artisanal Type I (7 to 10 m with outboard engines) and 66 artisanal Type II vessels (8 to 12 m with inboard diesel engines); 11 semi-industrial Type III vessels (10 to 12 m with inboard diesel engines); and 19 industrial Type IV vessels (17 to 22 m Gulf of Mexico double-rigged vessels) (Fabres *et al*. 1995). All trawlers operate in the Gulf of Paria. In addition, the industrial fleet operates in the Columbus Channel, as well as on the north coast of Trinidad. Up until 1995, 70 artisanal vessels were also permitted to trawl in the Orinoco Delta of Venezuela under an agreement between the two countries.

Five species of shrimp are exploited by the trawlers: *Penaeus subtilis*; *P. schmitti*; *P. notialis*; *P. brasiliensis*; and *Xiphopenaeus kroyeri*. Several species of demersal finfish from families such as Sciaenidae, Serranidae, Haemulidae and Lutjanidae are caught incidentally or may be targeted. Estimated landings of shrimp in 1995 are 994t from the industrial fleet, 134t from the semi-industrial fleet and 688t from the artisanal fleet. Bycatch landings for 1995 are estimated to be 1134t from the industrial fleet, 213t from the semi-industrial and 78t from the artisanal fleet.

18.2 Description of the Venezuela fishery

This fishery comprises two fleets: an industrial fleet and an artisanal fleet. The industrial trawl fleet comprises 88 vessels (mostly metal vessels 24 to 30 m in length) that target shrimp (*P. subtilis* and *P. schmitti*) and finfish of the families Sciaenidae, Carangidae, Haemulidae, Trichiuridae, Lutjanidae, Arridae and Mustelidae. This fleet operates in the southern Gulf of Paria and in front of the Orinoco river delta. Landings of this fleet during 1998 reached 6178t of finfish and 636t of shrimp (436t of *P. subtilis* and 200t of *P. schmitti*). The artisanal fleet of trawlers comprised 28 wooden vessels (8 m in length with outboard engines) and operates in the northern area of the Orinoco river delta. This fleet targets only juvenile *P. schmitti* and during 1998 landed 131t.

18.3 Methods

The bio-economic model incorporates data for all the Trinidad fleets but only the industrial Venezuelan fleet (not the Venezuelan artisanal fleet). The model covers a four-year period. Data were included for 1995 to 1998 for Venezuela and 1995 to July 1996 for Trinidad. The model incorporates four of the shrimp species exploited in the Gulf of Paria-Columbus Channel region: *P. subtilis*; *P. schmitti*; *P. notialis*; and *X. kroyeri*. Data from Venezuela are included for only the first two species since the landings of the latter two are negligible. *P. brasiliensis* was excluded from the model since, although the species is important for the Trinidad industrial fleet, the data are not available. In the case of Venezuela, the landings of *P. brasiliensis* are negligible. Bycatch landed by the Trinidad trawl fleet was taken to be 1.1 times that of the shrimp landed by the fleet, while the bycatch landed by the industrial Venezuelan fleet was taken to be 10.1 times the shrimp landed by that fleet. Two recruitment peaks (February/March and July/August) were assumed for all shrimp species except *X. kroyeri* based on an assessment of *P. schmitti* conducted by Altuve *et al*. (1998), as well as a post larval abundance study conducted by Alio *et al.* (1990). Figure 18.1 illustrates the seasonal recruitment pattern generated by the model. Figure 18.2 illustrates the yield of the four shrimp species estimated by the model over the four-year period and Figure 18.3 the observed and estimated catch of *P. subtilis* over the period.

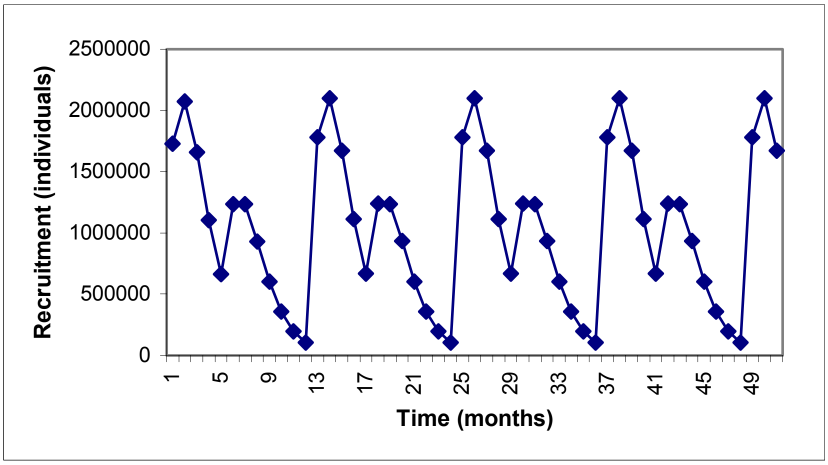

Figure 18.1 Seasonal recruitment pattern for P. schmitti

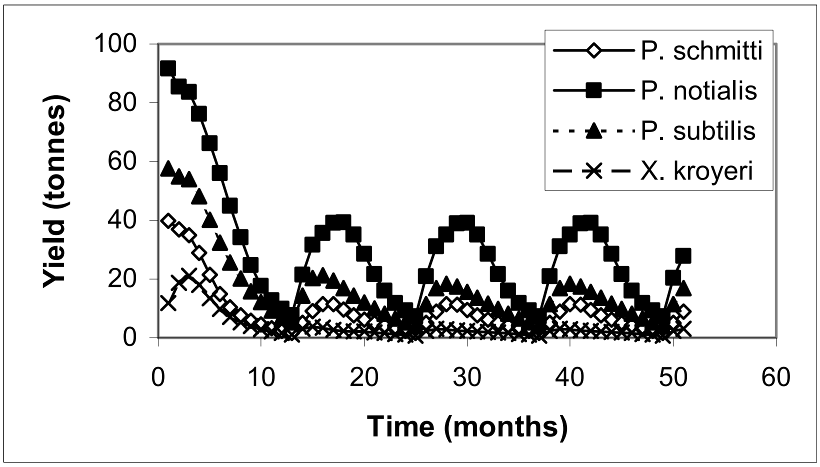

Figure 18.2 Yield of shrimp species estimated by the model over the four year period

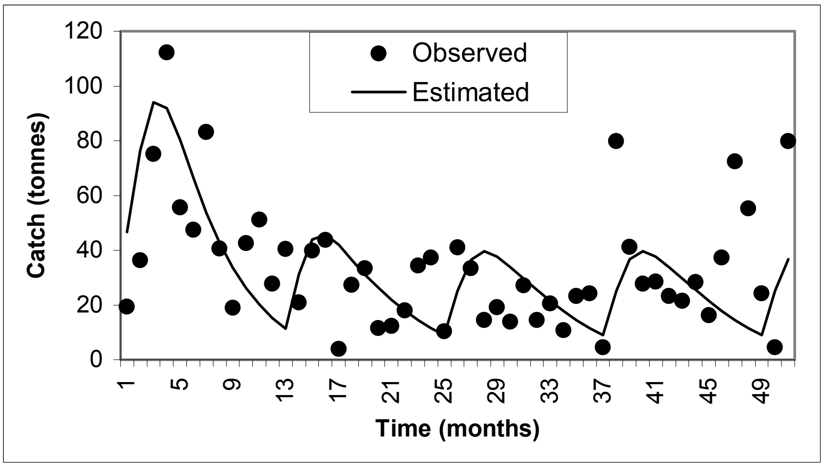

Figure 18.3 Observed and estimated catch of *P.subtilis*

Table 18.1 Input parameters for the bio-economic model of the Trinidad and Tobago (fleet 1) / Venezuela (fleet 2) trawl fisheries

	P. schmitti	*P. notialis*	*P.subtilis*	*X. kroyeri*
Recruitment, R (individuals)	12 000 000	20 000 000	180 000 000	5 000 000
Growth parameter, k (month^{-1})	0.35	0.25	0.0927	0.09
Natural mortality coefficient, M (month^{-1})	0.2	0.2	0.146	0.2
Maximum weight, W_{max} (g)	162.296	145.589	64.932	27.789
Maximum Total length L_{max} (mm)	250	220	176	155
Parameter t_0 of growth equation	0	0	0	0
Discount rate	0.0045	0.0045	0.0045	0.0045
Effort dynamics parameter (fleet 1)	0.000003	0.000003	0.000003	0.000003
Effort dynamics parameter (fleet 2)	0.000003	0.000003	0.000003	0.000003
Average price of species 1 ($ tonne^{-1})	7 400	7 400	3 700	1 380
Unit cost of effort fleet 1 ($ vessel^{-1} day^{-1})	407	407	407	407
Unit cost of effort fleet 2 ($ vessel^{-1} day^{-1})	618	618	618	618
Catchability coefficient fleet 1	0.002	0.000694	0.000694	0.000694
Catchability coefficient fleet 2	0.002	0	0.000694	0.000694
Length 50% retention fleet 1 (mm)	107	107	107	107
Length 75% retention fleet 1 (mm)	121	121	121	121
Selectivity parameter S1 fleet1	3.647	3.647	3.647	3.647
Selectivity parameter S2 fleet 1	0.0341	0.0341	0.0341	0.0341
Area swept fleet 1 (km^2 day^{-1})	1.08	1.08	1.08	1.08
Total area of resource distribution (km^2)	5000	3000	6000	1500
Length 50% retention fleet 2 (mm)	107	107	107	107
Length 75% retention fleet 2 (mm):	121	121	121	121
Selectivity parameter S1 fleet 2	3.647	3.647	3.647	3.647
Selectivity parameter S2 fleet 2	0.0341	0.0341	0.0341	0.0341
Area swept fleet 2 (km^2 month^{-1})	2.1	2.1	2.1	2.1
Parameter "a" of the total length (mm) to total weight (g) relationship	0.00000111	0.00000876	0.0000290	0.00000346
Parameter "b" of the total length (mm) to total weight (g) relationship	3.405	3.0637	2.82789	3.1524
References	Marcano *et al.* 1997	Lum Young *et al.* 1992b	Marcano *et al.* 1997	Lum Young *et al.* 1992b

Table 18.2 Final biomass of *P. subtilis* and present value of rent for the Trinidad and Venezuelan fleets

Total Effort	Effort Trinidad	Effort Venezuela	NPV of TT fleet	NPV of VEN fleet	Joint NPV	Final biomass of *P. subtilis*
(d.a.s)	(d.a.s)	(d.a.s)	(US$)	(US$)	(US$)	(t)
2000	1000	1000	10.1	11.8	21.9	861.8
4000	2000	2000	13.8	17.6	31.4	799.9
6000	3000	3000	16.3	21.5	37.8	744.5
8000	4000	4000	18.1	24.0	42.1	694.9
10000	5000	5000	19.1	25.3	44.4	650.3
12000	6000	6000	19.6	25.8	45.4	610.0
14000	7000	7000	19.7	25.6	45.3	573.6
16000	8000	8000	19.4	24.9	44.3	540.6
18000	9000	9000	18.8	23.8	42.6	510.5
20000	10000	10000	17.9	22.3	40.2	483.1
22000	11000	11000	16.9	20.5	37.4	458.1
24000	12000	12000	15.7	18.6	34.3	435.1
26000	13000	13000	14.4	16.4	30.8	414.1
28000	14000	14000	12.9	14.2	27.1	394.7
30000	15000	15000	11.4	11.8	23.2	376.8
32000	16000	16000	9.8	9.3	19.1	360.2
34000	17000	17000	8.1	6.8	14.9	344.9
36000	18000	18000	6.4	4.2	10.6	330.7
38000	19000	19000	4.7	1.6	6.3	317.5
40000	20000	20000	2.9	-1	1.9	305.2

Limit reference points (LRPs) were established for two performance variables, namely the standing biomass of *P. subtilis* (the dominant species taken by both fleets) at the end of the four-year period and the present value of rent of the Trinidadian and Venezuelan fleets. The limit reference points specified were 0.25 of the virgin biomass (B_{max}) of *P. subtilis* (i.e. 481t) and 0.5 of the Maximum Economic Yield (MEY) for the two fleets (i.e. US$8.8 million for Trinidad and US$14.3 million for Venezuela). The former LRP, 0.25 B_{max}, was calculated using the formula $B_{max} = CPUE_{max}/q$. $CPUE_{max}$ was taken as that of *P. subtilis* (0.226 t/fishing day) in 1977 from the Venezuelan industrial fleet (Marcano *et al*. 1997) and q as the catchability coefficient (generated by the bio-economic model for the Venezuelan fleet) of *P. subtilis* at age 18 months (0.00012) when the individuals are fully recruited. The LRP 0.25 Bmax (481t) obtained using data from Venezuela, as detailed above, was more conservative and thus used over 0.25 B_{max} (340 tonnes) obtained from Trinidad data. The limit reference point, 0.5 MEY, was determined for the entire Trinidad fleet and the Venezuelan industrial fleet separately where the MEY was derived from the bio-economic model.

Natural mortality (M) was identified as a parameter representing a major source of uncertainty and hence the M for each of the four species was allowed to vary randomly while running Monte Carlo with varying levels of fishing effort for each fleet. The levels of effort used for the analysis were 5 000 to 20 000 days per fleet at 2 500-day intervals, or 10 000 to

40 000 days for both fleets combined. The objective here was to observe the performance variables (final biomass of *P. subtilis* and the present value of rent of the Trinidadian and Venezuelan fleets) and the probabilities of exceeding the LRPs at various levels of fishing effort. The optimum effort at which the present value of rent of the fishery (Trinidad and Venezuelan fleets combined) is maximized was then determined for the two fleets. One constraint here was that the fishing effort of each fleet be at least 5 000 days.

The bio-economic parameter sets used to model the dynamics of the Trinidad – Venezuela shrimp fishery are presented in Table 18.1.

18.4 Results

Table 18.2 provides the net present value of the rent for the Trinidad and Venezuela fleets as well as the final biomass of *P. subtilis* at the end of the four-year period for a range of fishing efforts: 1 000 to 20 000 days at sea (d.a.s.) per fleet at 1 000-day intervals. The probability of the performance variables exceeding the limit reference points (0.25 B_{max} and 0.5 MEY) is given in Table 18.3 for a range of fishing efforts: 5 000 to 20 000 d.a.s. per fleet at 2 500-day intervals.

Table 18.3 Probability of exceeding LRPs, 0.25 B_{max} *P. subtilis* and 0.5 MEY of the Trinidad and Venezuelan fleets

Total Effort	Effort TT	Effort Venezuela	Probability of Exceeding LRP			
(d.a.s)	(d.a.s)	(d.a.s)	0.25 B_{max} *P. subtilis*	Profits at 0.5 MEY TT	Profits at 0.5 MEY VE	Profits at 0.5 Joint MEY
10000	5000	5000	2.0	0.0	1.0	0.0
15000	7500	7500	15.0	0.0	1.0	0.0
20000	10000	10000	49.0	0.0	8.0	0.0
25000	12500	12500	88.0	4.0	35.0	14.0
30000	15000	15000	96.0	27.0	60.0	46.0
35000	17500	17500	100.0	56.0	85.0	82.0
40000	20000	20000	100.0	92.0	100.0	98.0

Figure 18.4 illustrates that as the fishing effort increases the final biomass of *P. subtilis* decreases such that the LRP of 481t is achieved at approximately 10 000 d.a.s. per fleet which is not much greater than the current effort of 17 523 d.a.s. for both fleets (taken as that from 1995 being 8 175 days (in Type IV units) for the Trinidad fleet and 9 348 days for the Venezuelan fleet – see arrows on figures). Figure 18.5 shows that as the total effort of the two fleets increases, the probability of exceeding 0.25 B_{max} increases, with the probability being 39% at the current level of effort. At the current effort, the final biomass was estimated at approximately 512t.

Figure 18.6 indicates that the joint net present value reaches a maximum of approximately US$45.4 million (US$25.8 million for Venezuela and US$19.6 million for Trinidad) at approximately 6 000 d.a.s. per fleet. The rent for the Venezuelan fleet is eliminated by a fishing effort of that fleet of 20 000 days. Figure 18.7 shows that the risk of exceeding the limit reference point of 0.5 MEY increases fairly rapidly with increasing effort from about 10 000 days for the Venezuelan fleet and beyond 12 500 days for the Trinidad fleet. At the current level of effort, the net present value of rent was estimated at approximately US$24.7 million for Venezuela and US$18.5 million for Trinidad, with a 5% probability that profits will be less than 0.5 MEY for the Venezuelan fleet and no risk of exceeding this LRP in the case of the Trinidad fleet as well as for both fleets combined.

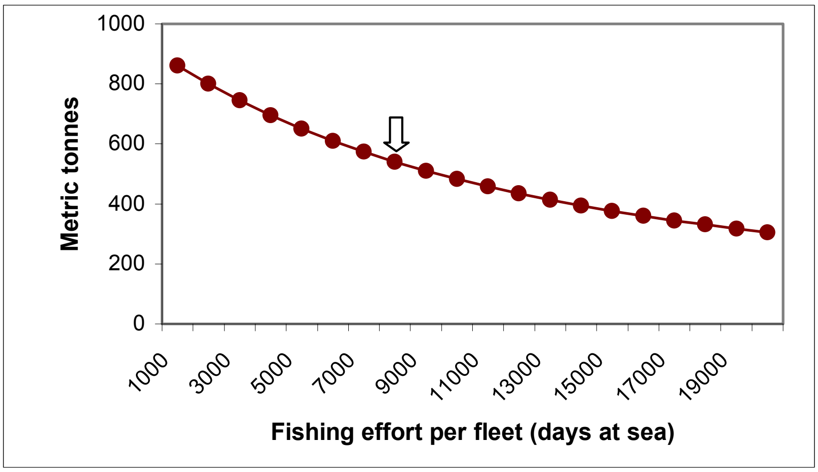

Figure 18.4 Final biomass of *P. subtilis* at the end of the four year period. The arrow marks the current effort

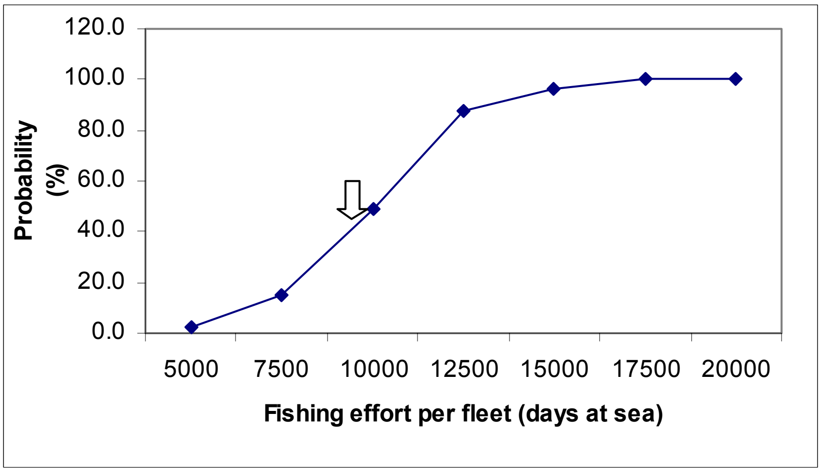

Figure 18.5 Risk of exceeding LRP: 0.25 Bmax of *P. subtilis*

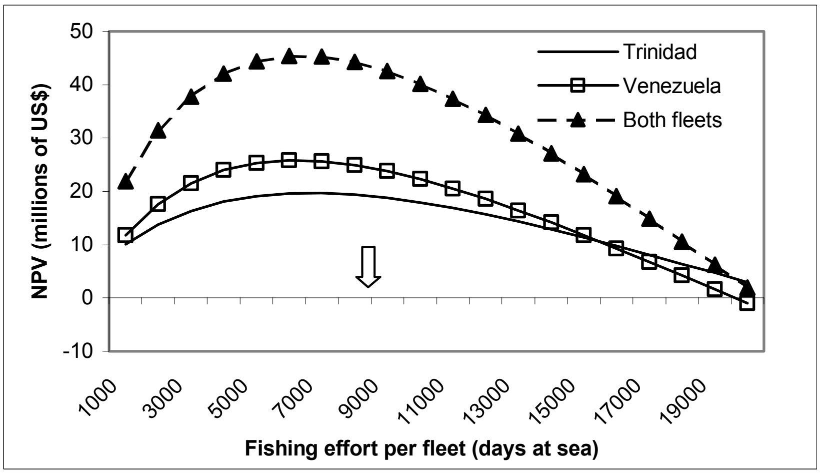

Figure 18.6 Present value of rent of the Trinidad and Tobago / Venezuela trawl fishery

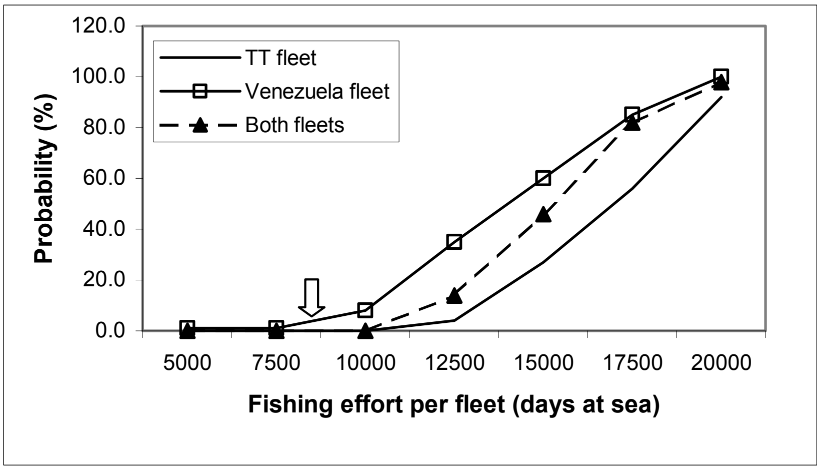

Figure 18.7 Risk of exceeding LRP 0.5 MEY

The optimum effort at which the MEY of US$46.1 million (US$28.5 million for Venezuela and US$17.6 million for Trinidad) for the shared fishery is attained is estimated to be 5 000 days for the Trinidad fleet and 7 697 days for the Venezuelan fleet. At this level of effort, the final biomass of *P. subtilis* is estimated to be approximately 584t, with a 1% risk of exceeding 0.25 B_{max}.

18.5 Conclusions

The preliminary bio-economic analysis conducted reveals that the fishing effort of both the Trinidad and Venezuelan fleets should not be increased beyond the current level. In addition, the optimum allocation of fishing effort between the two fleets which would yield maximum profits to this shared fishery is 61% of the current effort of the Trinidad fleet and 82% of the current effort of the Venezuelan fleet.

18.6 Recommendations for future research

This analysis must be considered to be preliminary. The input parameters to the model need to be refined. With regard to the Trinidad industrial fleet in particular, in the absence of a formal system of data collection for these trawlers, landings and effort data used are very rough estimates. It should be noted that while an estimate of 994t shrimp was used in this analysis for 1995, an estimate of 1000t was obtained from logbook records for this fleet for 1991, compared to an estimate of 423t for 1995 based on personal communication with the President of the Trinidad and Tobago Trawler Owners Association. A logbook programme will be implemented for this fleet in the near future. In addition, the costs should be determined as a function of yield, effort and number of boats in accordance with Sparre and Willmann (1993). Recruitment should also be represented as an stochastic function, with a probability distribution that approximates that of environmental factors that could affect this process, such as mean Orinoco river discharge or maximum yearly wind speed in the Gulf of Paria (Alió *et al*. 1999b).