PENAEUS SUBTILIS STOCK WITHIN THE ORINOCO AND GULF OF PARIA REGION

by

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1. DEFINITION OF STOCK

Penaeus subtilis is caught throughout the area of influence of the Orinoco and the Amazon rivers. The southeastern limit of significant catches is located offshore of the Brazilian state of Piauí, southeast of the Amazon. The northwestern limit of significant catches is the Gulf of Paria, between Venezuela and Trinidad.

Catches of adult *P. subtilis* are made in offshore waters away from the mouths of the major rivers of the region. There are no catches in front of the mouths of the Amazon or the Orinoco, but there are catches on either side of the mouths within the deltaic influence of both rivers.

The Venezuelan industrial fleet harvests *P. subtilis* in the Gulf of Paria, the Columbus Channel and either side of the mouth of the Orinoco River (statistical areas 10621, 10612, 09614, 09613, 09604, 09601, 08594 and 08593)[28]. The industrial fleet from Trinidad harvests this shrimp in the Gulf of Paria and the Columbus Channel. *P. subtilis* represents[29] 34% of the catches of the Type I artisanal fleet from Trinidad which operates in the Gulf of Paria and 31% of the catches of the Type I artisanal fleet operating in the Special Fishing Area off Venezuela; 2-13% of catches of the Type II artisanal fleet operating in the Gulf of Paria; 27% of the catches from the semi industrial Type III fleet which fishes in the Gulf of Paria and 31-51% of the catches from the Type IV industrial fleet which operates in the Gulf of Paria and the Columbus Channel.

For the purpose of this assessment, we decided to consider the existence of a single stock of *P. subtilis* for the area of the Gulf of Paria and the Orinoco. The limits of this stock are defined by the extent of *P. subtilis* fishing grounds of the Venezuela and Trinidad fleets. These include the Gulf of Paria, the Columbus Channel and the areas offshore of the Orinoco to the eastern limit of the Venezuelan territorial waters (Figure 1). Such a stock definition implies there is a separation between the populations of *P. subtilis* caught in Guyana east of the Oyapock and those caught by Venezuela west of that river (we will refer hereafter to this as assumption I). This assumption (i) has never been tested and should be investigated in the future. Two alternative hypotheses are: (ii) all *P. subtilis* caught from northeastern Brazil to the Gulf of Paria are part of the same stock; and (iii) there are several *P. subtilis* stocks along the coast separated by the mouth of each of the major rivers between the Amazons and the Orinoco.

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[28] Catch locations were determined from data for 1987-1994 found in Table 6 in Marcano *et al.* (1996) and new original data updated by Marcano and Alió for this workshop, with data for 1995 and 1996. The catch by species and by locations are obtained from sample logbooks and observer data .

[29] Table 8 in Fabres *et al*. (1995) shows average species composition of landings for each of the four fleets from Trinidad for 1991 and 1992.

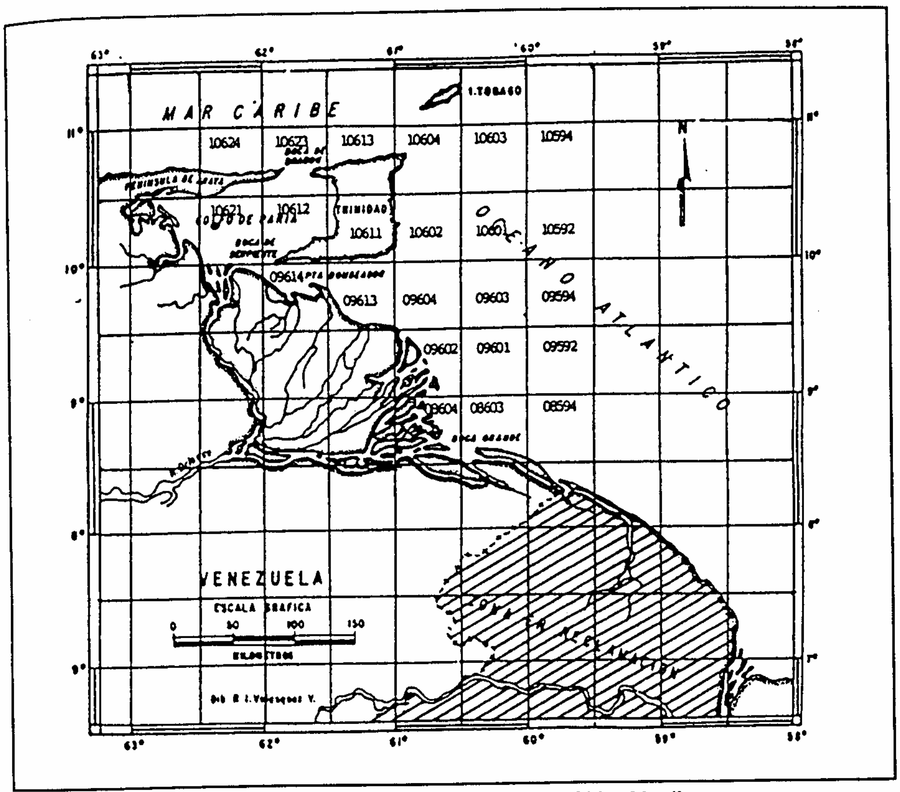

Figure 1: Atlantic zone of Venezuela, divided in fishing squares of 30 x 30 miles.

Figure 1: Geographical extent of stock of *Penaeus subtilis* defined for the purposes of this assessment as indicated by the distribution of fishing effort

2. DATA

2.1 Catch and Effort Data

Trinidad has collected catch and effort data since the 1960s by using enumerators on selected landing sites for the artisanal and semi-industrial fisheries. These data have been processed for the period 1987 to 1993 to provide estimates of annual effort (Maharaj and Ferreira, 1997). For the period 1987 to 1991, monthly estimates have been obtained as well. In late 1991 early 1992, a logbook program was introduced for the industrial fishery from which an estimate of the annual catch and effort has been produced.

Venezuela has estimated landings and effort by commercial species-group since 1973. These estimates are made from three sources, logbooks, landing reports and, since 1991, from on-board observer data. The accuracy logbook information is highly variable. Landing estimates from landing reports are used to check whether of logbook records are accurate. If the two differ significantly (more than 20%) logbook catch information is discarded, otherwise logbook information is used. Information on effort (duration of each fishing trip) from the log books was always used. Observer data represent less than 5% of the total effort and are used to check the accuracy of the logbook records.

Both logbook and observer data contain information on the statistical location of fishing operations. These data have been summarized by month and statistical area since 1989. The data for 1986 are incomplete because no information was incorporated from the fleet based in Cumaná; only data for Güiria were available.

Table 1: Effort (fishing days), catch of *P. subtilis* (tonnes) and catch per unit of.effort of *P. subtilis* in the Venezuelan industrial fishery

Year	Effort (d-a-s)	Catch (mt)	cpue (kg/day)
1973	8208	1053[3]	128.3
1974	4552	503[3]	110.5
1975	7712	764[3]	99.1
1976	7275	1015[3]	139.5
1977	6956	1527[3]	219.5
1978	4256	598[3]	140.5
1979	4879	612[3]	125.3
1980	5387	553[3]	102.7
1981	6670	644[3]	96.6
1982	6120	611[3]	99.8
1983	5474	429[3]	78.3
1984	3305	471[3]	142.5
1985	3223	336[3]	104.2
1986	4094[30]	797[31]	194.6[32]
1987	6719	539	80.2
1988	7175	536	74.6
1989	8710	563	64.6
1990	13252	920	69.4
1991	13011	983	75.5
1992	9952	673	67.6
1993	12762	656	51.4
1994	8851	402	45.4
1995	9348	515	55.1
1996	6727	270	40.1

Since the logbook and observer program started, Venezuela has obtained data on the species composition of the catch of each commercial species-group. These data have been used to split the commercial catch into catch by species for the period 1987 to the present. This has been done by calculating the average proportion of each species by month and year from all observer trips and from the logbooks available from the whole fleet. These proportions are then used to raise the total monthly catch by species-group (i.e. “brown shrimp” landings) to the catch by species (*P. subtilis*).

2.2 Preparation of Data Sets

It is not possible to estimate precisely the catch of *P. subtilis* for Venezuela in the period of 1973-1985 because there was no observer program from which to estimate the proportion of *P. subtilis* in the catch of brown shrimp. Such proportions are known for the period 1986 to 1996. We conducted a two way analysis of variance of these proportions by year and month. The results indicated that the proportions do change significantly between years but do not change within years. This result suggests that it is appropriate to use an annual proportion but that this proportion is not constant. Examination of the proportions suggests that during the period 1986-1996 the annual proportions of *P. subtilis* varied without a trend and approximated a uniform distribution bounded by .65 and .92 (average 0.755). In subsequent

[30] Estimated from the effort from Güiria divided by 0.45 (average proportion of effort coming from Güiria for 1985-1990).
[31] Estimated from the total effort times the CPUE from Güiria
[32] For the fleet from Güiria only

analyses, 20 random sets of these proportions were used by randomly sampling a uniform distribution (0.65, 0.92) for each year with missing data on species composition. These 20 sets were then multiplied by the catch of brown shrimp for the years 1973-1985. To estimate the catch and effort for 1986, the data from Güiria were raised to the total fleet by using a conversion factor. This conversion factor was estimated by calculating the ratio of effort and the ratio of catch for the two fleets during the period 1985-90. The results are shown in Table 1.

In Trinidad there is only one year of catch and effort data on the industrial fishery. These data are a combination of skipper interviews conducted at the National Fisheries Company (N.F.C.) Limited (the major Type IV vessel landing site) in Port of Spain from April to October 1991. N.F.C. bunkering records were used to estimate the total number of fishing dates for the whole fleet during the period November 1991 to January 1992. For the period April-October 1991, N.F.C. off-loading dates were used as an indication of the number of fishing trips per month. The number of trips was then multiplied by the average trip length for that month (the latter was based on information obtained from the skipper interviews), to give an idea of the total number of fishing days. For the period February to April 1992, a combination of skipper interviews and logbook returns was used to estimate the average trip length per month. This average was then multiplied by the total number of trips for each month (again based on N.F.C. off-loading dates) to calculate the total number of fishing days. The total number of fishing days for the period April 1991 - April 1992 was combined with sample catch per unit of effort from the same logbook and berthing records to estimate total catch of *P. subtilis*.

Total annual shrimp catches and effort (trips, which equate to days) for the Type I, II and III fleets from Trinidad are available for 1983-1993. For those years over the period 1973 to 1996 for which data were not processed, estimates of catch and effort were calculated based on figures for preceding and subsequent years. For those years with missing data prior to 1982 it was assumed that effort was constant and equal to the average of the years with data within the period 1980-85. For years after 1993, effort was assumed constant and equal to the average over the periods 1991-1993. There are also data on the species composition (by weight) in these three fleets for 1991-1994, based on length frequency samplings of shrimp landed by these fleets over the period, with which an average species composition by fleet was estimated. These two data sets were then combined to estimate the catch of *P. subtilis* for each fleet.

For the Type IV fleet, catch and effort estimates were available for 1991. It was assumed that the effort of the Type IV fleet over the time series 1973 to 1996 mirrored that of the Type III fleet. Based on this assumption, the ratio of the fishing effort of the Type IV fleet to that of the Type III fleet was obtained for 1991 and used with the effort of the Type III fleet to estimate the effort of the Type IV fleet over the time series. Assuming $E_{i,y}$ represents the effort of fleet *i* and year *y* this equates to,

$$E_{iv,y} = \frac{E_{iv,1991}}{E_{iii,1991}} x E_{iii,y}$$

The ratio of the cpue of *P. subtilis* for the Trinidad Type IV fleet to the cpue of the Venezuelan industrial fleet for 1991 and the cpue of the Venezuelan fleet between 1973 and 1996 were used to estimate the cpue of the Type IV fleet from Trinidad.

$$cpue_{iv,y} = \frac{cpue_{iv,1991}}{cpue_{Ven,1991}} x cpue_{Ven,y}$$

The catch of *P. subtilis* for the Type IV fleet was hence calculated using the estimates of effort and cpue.

$$catch_{iv,y} = cpue_{iv,y}\ E_{iv,y}$$

The fishing efforts for the Trinidad Type I, II and III fleets were converted into Type IV units using the relative fishing power of each fleet. This was based on the area trawled by a vessel for a day, that is, speed multiplied by the time trawled multiplied by headrope length. Total fishing effort for the entire

Table 2: Effort (days at sea), catch of *P. subtilis* (tonnes) and catch per unit of effort of *P. subtilis* in the Trinidad - Tobago shirmp fishery. Effort is expressed as Type IV vessels

Year	Catch (mt)	Effort (d-a-s)	cpue (kg/day)
1973	515	1999	257
1974	462	1999	231
1975	428	1999	214
1976	548	1999	274
1977	784	1999	392
1978	551	1999	275
1979	506	1999	253
1980	405	1584	256
1981	494	2036	242
1982	452	1938	233
1983	380	2147	177
1984	604	2453	246
1985	807	4280	189
1986	994	5732	173
1987	908	6338	143
1988	782	5620	139
1989	506	4829	105
1990	771	6234	124
1991	718	5592	128
1992	617	5602	110
1993	520	5155	101
1994	486	4534	107
1995	551	4534	122
1996	453	4534	100

Trinidad fleet was hence calculated in Type IV units (Table 2) which was then combined with the Venezuelan industrial fishing effort. Catches of *P. subtilis* for the Trinidad and Venezuela fleets were also combined and the combined data set was used in the equilibrium and dynamic models (Table 3).

2.3 Environmental Influence on Catches of P. subtilis

It was considered that several environmental variables in the region can influence the recruitment and survival of penaeid shrimps, affecting their biomass level. The yearly shrimp catch would be the result not only of the amount of fishing effort applied by the fleets in the region, but also a consequence of the changing shrimp biomass among different years. The group proposed that, considering the availability of information in the region, the environmental variables to be considered in further analyses should be the river flow of the Orinoco River and wind speed over the Gulf of Paria. Other variables that could influence larval dispersal and recruitment, like the variation in ocean currents, could not be investigated at the moment for lack of information.

Table 3: Combined effort (days at sea), catch of *P. subtilis* (tonnes) and catch per unit of effort of *P. subtilis* for the industrial fleet of Venezuelan and the shrimp fleets of Trinidad – Tobago

Year	Catch (mt)	Effort (d-a-s)	cpue (kg/day)
1973	1568	10207	154
1974	965	6551	147
1975	1193	9711	123
1976	1562	9274	168
1977	2310	8955	258
1978	1149	6255	184
1979	1118	6878	162
1980	959	6971	138
1981	1138	8706	131
1982	1063	8058	132
1983	809	7621	106
1984	1076	5758	187
1985	1143	7503	152
1986	1359	9826	138
1987	1447	13057	111
1988	1318	12795	103
1989	1069	13539	79
1990	1692	19486	87
1991	1701	18603	91
1992	1290	15554	83
1993	1176	17917	66
1994	888	13385	66
1995	1067	13882	77
1996	723	11261	64

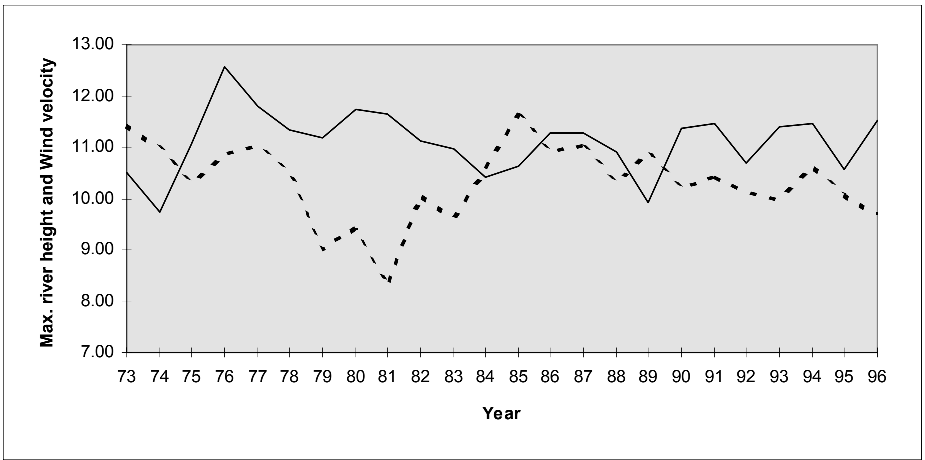

Figure 2: Simultaneous comparison of the trend of environmental variables used in the assessment of *P. subtilis* abundance during the period 1973-96: solid line = Orinoco River maximum heights during August (m above sea level) at Puerto Ordaz, Bolívar State, Venezuela. Dashed line = annual mean wind velocity (km/h) at Piarco Airport, Trinidad - Tobago.

Table 4: Environmental information used in the assessments of the *P. subtilis* fishery in the Gulf of Paria and delta of the Orinoco River : annual mean wind velocity at Piarco Airport, Port of Spain (Trinidad - Tobago Meteorological Service); Orinoco River maximum height (recorded each year during August) at Puerto Ordaz, Bolívar State, Venezuela (Venezuela - Instituto Nacional de Canalizaciones)

Year	Wind velocity (annual mean) (km/h)	Orinoco max. height (m.a.s.l.)
1973	11.44	10.51
1974	11.00	9.74
1975	10.30	11.05
1976	10.86	12.58
1977	11.03	11.79
1978	10.50	11.33
1979	8.99	11.19
1980	9.44	11.75
1981	8.27	11.64
1982	10.07	11.12
1983	9.61	10.96
1984	10.58	10.41
1985	11.66	10.63
1986	10.92	11.28
1987	11.04	11.28
1988	10.29	10.92
1989	10.92	9.93
1990	10.19	11.36
1991	10.41	11.47
1992	10.13	10.69
1993	9.98	11.4
1994	10.63	11.47
1995	10.07	10.57
1996	9.72	11.52

An estimate of shrimp abundance in the region, independent of the fishing effort, was obtained by calculating the residuals from the surplus production model (Fox, 1970) relating catch and effort for 1973 to 1996.

Data on mean monthly wind velocity were available for the station located at Piarco Airport (Port of Spain, Trinidad and Tobago Meteorological Service) during the period 1973-96 (Figure 2; Table 4).

2.4 Previous assessments

There have been several previous attempts to use production models to estimate the maximum sustainable yield for different areas within the Guianas - Brazil region. Dintheer and Le Gall (1988) cite the estimates of Venaille (1979) and Stevenson (1981) which both fitted production models to effort in number of fishing days and catch of shrimp (all species - whole weight) for French Guiana and for the whole Guianas - Brazil region. Later Ehrhardt (1986) fitted a similar model to the whole region catches of shrimp (all species - tail weight) by using the number of vessels as a unit of effort.

Young *et al*. (1992) conducted a preliminary assessment of the artisanal fishery from Trinidad that takes place in the “Special fishing area” within Venezuelan waters contiguous to the Columbus Channel. The Thompson and Bell type assessment conducted suggests that the number of trawlers engaged in fishing during 1991 was appropriate for this fishery and any increases in effort would not produce enough increases in yield to offset the additional costs of such investment.

Marcano *et al.*(1996) also fitted production models to the shrimp catch (all species - whole weight) and the catch (whole weight) of brown shrimp for the Atlantic region (Gulf of Paria and areas east and south of Trinidad). They concluded that presently the traditional trawling fishing grounds of Venezuela are being exploited intensively, although the effort has decreased progressively during the last three years. They estimated that the effort level applied to the bottom resources, and mainly upon the shrimp resources, is beyond that required to achieve the Maximum Sustainable Yield (MSY), with the exception of the resources in the Atlantic zone where the effort is still below that required to reach the MSY.

All the above authors used the traditional equilibrium models of Schaefer (1954) and Fox (1970). It was one of the objectives of this workshop to make use of dynamic production models to see whether they were more useful than equilibrium methods to explain catch and effort dynamics for the stocks of the region. Details on the types of dynamic models used during the workshop can be seen in the manual of the BIODYN software package (Punt and Hilborn, 1996). Only the models found in BIODYN and the model by Schnute (1977) were used during the workshop. The Schnute (1977) model was applied to other data sets from the region but not to the Trinidad-Venezuela data. The environmental data became available and had to be analyzed after the workshop had ended. These results of the CLIMPROD (Freon *et al*, 1993) analyses using equilibrium models and environmental variables are included here.

3. DATA ANALYSIS

Using the combined time series of catch and an index of relative abundance, it was possible to apply production models to derive estimates for a number of the quantities which can be used in the formulation of management advice. These quantities include the current biomass, the virgin biomass (pre-exploitation biomass - K), the intrinsic rate of growth (r), the maximum sustainable yield (MSY), and the level of fishing effort at which MSY is achieved (f MSY). The quality of the estimates obtained from the models depends on how well they fit the data and model assumptions. Three types of production models were applied, equilibrium, dynamic and equilibrium with environmental influence.

The equilibrium model was applied to catch per unit of effort (cpue) data as an index of abundance, in order to generate values of MSY and f_{MSY} for each of a 1973-96 time series and a 1983-96 time series. There is greater confidence in the latter series because the data set for the Trinidad-Tobago trawl fishery requires fewer data interpolations. Best fit was determined by minimizing the sum of squares (SSQ) values. This method will always provide estimates of MSY and f_{MSY} even when the fit to the data is poor because effort (fy) appears in both the dependent and the independent variables. This method is also based on the assumption that the population is in equilibrium and that the rate of change of biomass is zero so that $B_{y+1}=B_y$.

It is recognized that for tropical shrimp species, annual cpue is not always a good index of abundance. Therefore dynamic models were applied using both catch and cpue as indices of abundance for the period 1973-96. We assumed most errors were related to the data and not the model and therefore used the observation error estimation model as described in Punt and Hilborn (1996). To estimate the parameters of the biomass dynamic model, initial values must be assigned to all parameters. B_I, the initial biomass, was assumed to be greater than the average catch of the fishery; K, the carrying capacity, was assumed to be approximately $1.5B_I$. The intrinsic growth rate of the stock, r, was assumed to be high for shrimp and was assumed to be between 1 and 2. Given these initial parameter values, the algorithm in EXCEL’s Solver was used to minimize the logarithm of the ratio between observed and predicted abundance indices.

The software CLIMPROD assumes that the exploited population is in equilibrium, but the catchability or the abundance of the resource is affected by environmental parameters. In the case of the population of *P. subtilis* exploited in the Gulf of Paria and the Orinoco delta, we hypothesize that the variation in annual mean wind velocity and river height may affect the abundance of the shrimp resource. There is some similarity between the trends of the two environmental variables and the residuals of the equilibrium production model for the stock of *P. subtilis* exploited in the Gulf of Paria

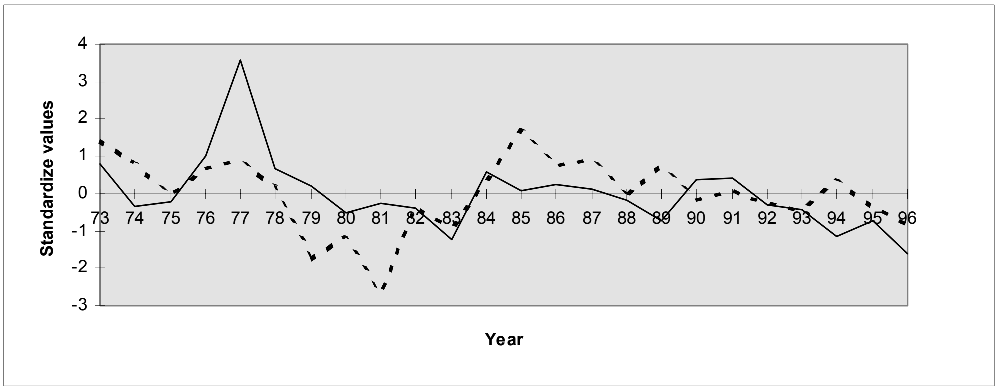

Figure 3: Trend in the standardized values of the fishery of *P. subtilis* (residuals of the surplus production model) (continuous line) and annual mean wind velocity at the Gulf of Paria (Piarco Airport; Trinidad - Tobago) (dashed line), during the period 1973-96.

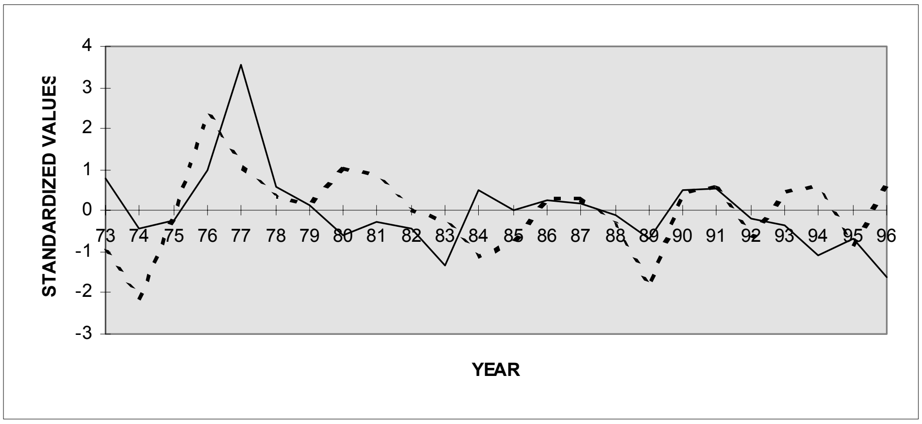

Figure 4: Trend in the standardized values of the fishery of *P. subtilis* (residuals of the surplus production model) (continuous line) and maximum height of the Orinoco River (recorded during August) at the Puerto Ordaz, Bolivar State, Venezuela (dashed line), during the period 1973-96.

and the Orinoco delta (Figure 3 and 4). Neither wind nor river height are, however, significantly correlated to the residuals of the equilibrium model. The largest correlation is between mean annual wind velocity and the residuals of the surplus production models (r=0.38, n=24). Given this correlation, wind velocity was incorporated through CLIMPROD in a multiplicative way into a surplus production model of the Fox (1970) form:

$$\text{cpue} = a^{v} e^{bf}$$

where a and b are the two parameters to be estimated, V is the environmental variable and f the effort. The variation in the height of the Orinoco River was not consistently correlated with shrimp abundance in the time series and was not used in the analyses (Figure 4).

4. RESULTS

Equilibrium models were also fitted using the software CLIMPROD because it provides a jackknife routine to estimate the standard deviation of the model parameters (Table 5). The Fox (1970) exponential model of cpue vs. effort was used in the equilibrium model fits because of the apparent curvilinear relationship between these two variables observed in the fishery under study (Figure 5).

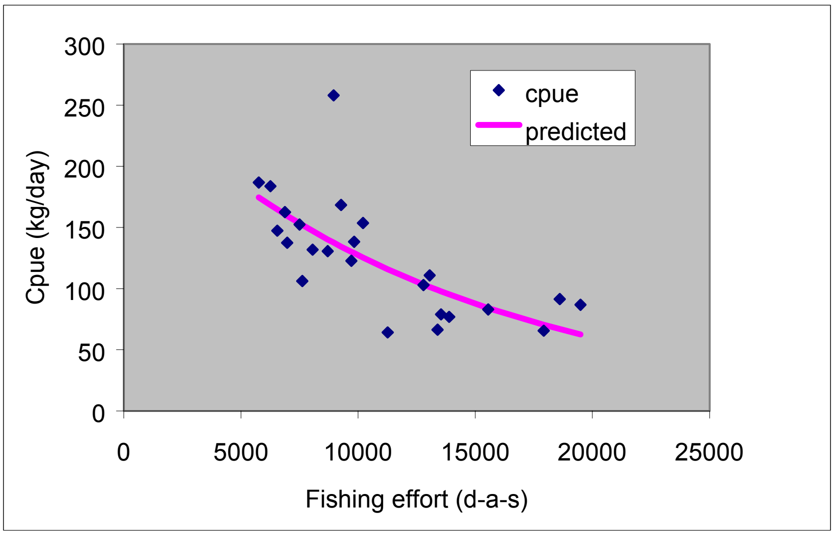

Figure 5: Observed cpue vs fishing effort relationship and fit from Fox equilibrium production model of MSY for this equilibrium model was around 1300 mt, corresponding to a f_{MSY} close to 13,000 days-at-sea

Table 5: Description of models and estimated value of the parameters. Estimates of the standard deviation (SD) were calculated only for the equilibrium models using a jacknife procedure.

Equilibrium models

Model	Data Series	a	SDa	b	SDb	Correlation coefficient
Fox	1973-96	0.2686	0.0304	-7.47*10^-5	1.11*10^-5	0.71
cpue = ae^{bf}	1983-96	0.2682	0.0603	-7.82*10^-5	2.01*10^-5	0.82
	1973-96*	0.2556	0.0305	-7.43*10^-5	1.27*10^-5	0.83
Fox + Envir.	1973-96	0.0267	0.0032	-7.67*10^-5	1.13*10^-5	0.75
cpue = aV_e^{bf}	1973-96*	0.0254	0.0031	-7.66*10^-5	1.27*10^-5	0.85

Dynamic models

Index of abundance	Data Series	r	K	B_I	q	Correlation coefficient
Catch	1973-96	1.42	3760	2507	0.79*	0.75
cpue	1978-96, 1984-96	1.13	4414	4414	0.042	0.95

* The value actually refers to the fishing mortality (F)

The data for 1977 showed a large increase in the catch, compared with the rest of the series. The fit of the model was severely affected by the inclusion (r^2=50%) or not (r^2=69%) of the values for that year in the analyses. The estimate sea (d-a-s) (Table 6). These estimates do not change appreciably if the data for 1977 are included or not in the analyses. When a shorter data series is used (1983-96), for which there is greater confidence on the quality of the information, the estimates for MSY and f_{MSY} are smaller, 1261 mt and 12,787 d-a-s, respectively.

Table 6: Results of fitting the different models to the combined effort and catch data from the Venezuela and Trinidad and Tobago trawl fleets exploiting *P. subtilis* in the Gulf of Paria and Columbus Channel

Model	Data Series	Fit (r^2 %)	f_{MSY} (d-a-s)	f_{MSY} Interval (Mean±SE) (d-a-s)	MSY (t)	MSY interval (Mean±SE) (t)
Equilibrium	1973-96	54	13 394	13 000 - 13 813	1324	1254 - 1396
Fox	1983-96	66	12 787	11 966 - 13 731	1261	1110 - 1436
	1973-96[33]	69	13 452	12 988 - 13 949	1315	1191 - 1349
Equilibrium	1973-96	56	13 038	12 656 - 13 444	1321	1005 - 1580
Fox + Envir.[34]	1973-96[12]	72	13 062	12 624 - 13 532	1262	954 - 1520
Dynamic Schaefer Index: Catch	1973-96	51	-[35]	-	1330	-
Index cpue	1978-96[36]	90	13 415	-	1245	-

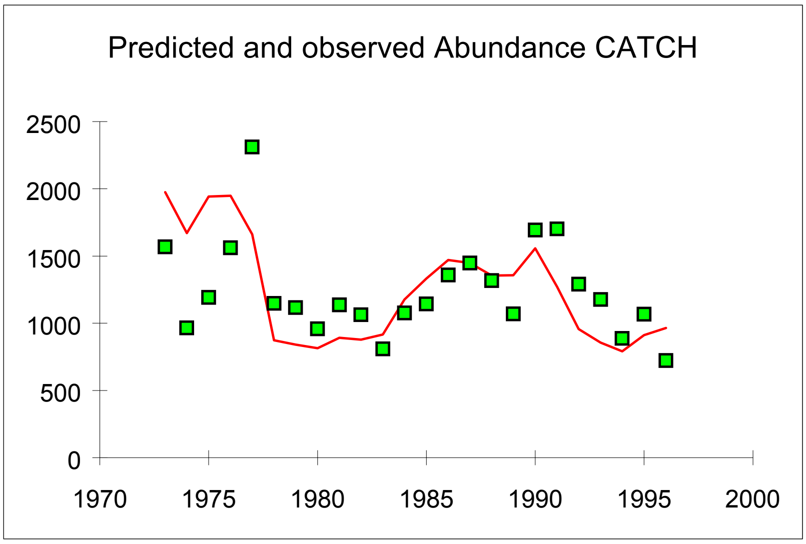

Figure 6: Observed and predicted catch (tonnes) for the biomass dynamic model, Schaefer type. Catch was used as an abundance index

[33] For these series, the data from 1977 were considered outliers and were eliminated from the analysis for comparative purposes

[34] Values for MSY and f_{MSY} were calculated based on the mean annual wind velocity at Piarco Airport, Trinidad - Tobago (10.3 km/h). Intervals were estimated using the extreme values of the coefficients according to the S.E. and the extreme recorded annual mean values for wind velocity at that locality (8.3 and 11.7 km/h).

[35] Since it is assumed that the biomass of the resource is not related to the effort level, this parameter is not calculated

[36] Fit was made manually because the optimization procedure Solver of Excel would always converge to a straight line.

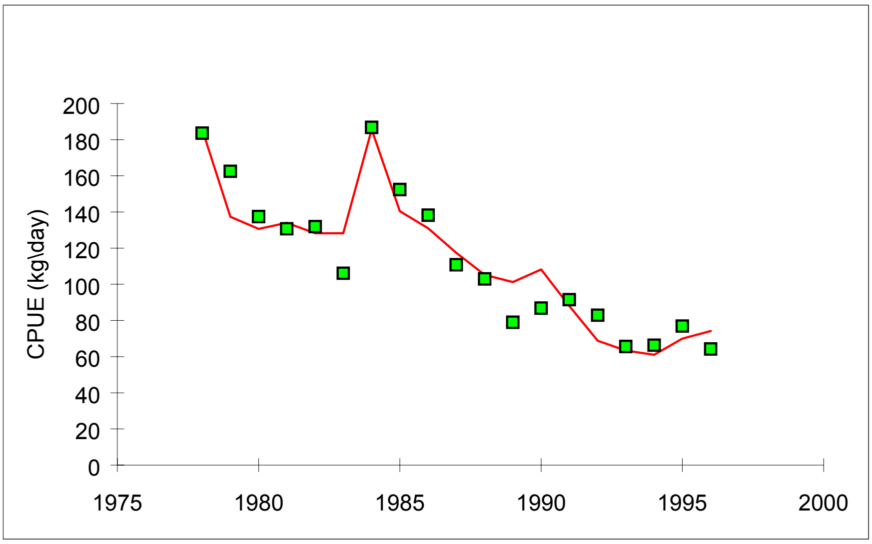

Figure 7: Observed and predicted cpue for biomass dynamic model Schaefer type, cpue was used as an abundance index.

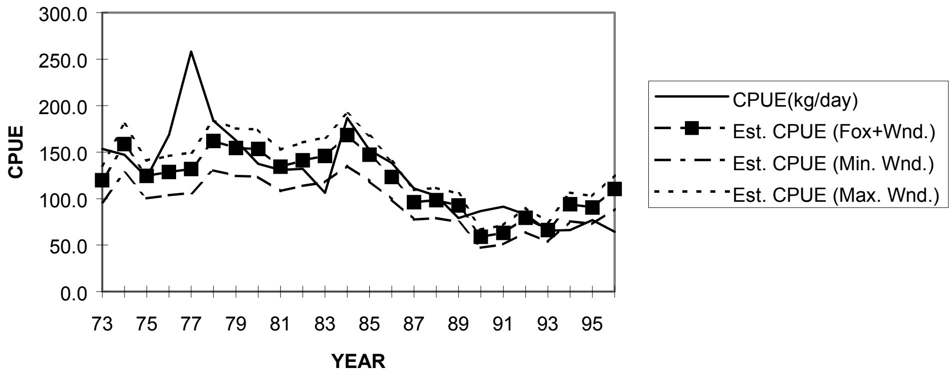

Figure 8: Observed (continuous line) and predicted (dashed lines) cpue vs. time, from Fox equilibrium production model incorporating multiplicatively an environmental variable (annual mean wind velocity). The curve is bounded by estimations of cpue when the environmental variable reaches the minimum and maximum mean year values in the region

During the work with dynamic models, it was observed that the Solver procedure of EXCEL, used in the software BIODYN to optimize the fit of the model, required that initial parameter values were provided in the vicinity of the final result. Often convergence was slow or not achieved. In one case (using data for 1973-96 with cpue as an index of abundance), Solver would always converge to a set of parameters predicting constant cpue.

The estimate of MSY from the dynamic model, using catch as an index of abundance for the entire time series (1973-1996), was 1330 mt, which is in close proximity to the estimate from the equilibrium models (Figure 6 and Table 6). No estimate of f_{MSY} can be obtained with this model.

Dynamic model fits obtained when using cpue as an index of abundance for the entire time series did not converge to a plausible solution. This is the result of the unusual trend in cpue which seems to be monotonically decreasing except for increases in 1976-77 and 1984. The normal biomass model cannot explain such large increases in cpue. Good fits were, however, obtained by restricting the time series to either 1978-1996 or 1984-1996 (Figure 7). The biomass models used for 1978-1996 and 1984-1996 were constrained such that the biomass in 1978 and 1984 was equal to the carrying capacity of the stock, K. The models thus contained only three parameters and yet produced the best fits of all the models used. The estimated MSY obtained using these data were 1245 mt and the f_{MSY} was 13 415 days at sea. Although the software BIODYN used in the evaluation of the dynamic models provides means to calculate the variance of the estimated parameters, this routine was not used during the analyses due to problems in the application of the software.

The incorporation of the environmental variable in a multiplicative way to the equilibrium surplus production model, allowed the fit (r^2) to improve from 50% (using the equilibrium model alone) to 56%. The additive model is recommended when there is a large variability in the cpue values when the resource is over-exploited, which is not the case in the present population. For these reasons, the additive model was not evaluated. When the data for 1977 are excluded from the analyses, the fit of the model (r^2) rises from 56% to 72%; however, again, the new estimations for MSY and f_{MSY} are very close in both cases (Table 6).

Even though the incorporation of the environmental variables to the equilibrium model improved the fit, the increase was modest and could not be appreciated in the figure when the models with and without the environmental variable are compared (Table 6, Figure 8). An advantage of considering environmental information in the model is the possibility to asses variations in the catch level when the environmental variable under consideration changes (Figure 8).

5. DISCUSSION

According to the knowledge on shrimp resources in this and other regions of the world, several assumptions can be proposed to explain the observed trends in catch and cpue of *P. subtilis.* Depending on the assumptions proposed we used different models to fit the data and obtain estimates of parameters like MSY and f_{MSY}.

A common assumption is that the biomass of the shrimp resource is in equilibrium among different years and that changes in catch are due to random variations in the abundance and the catchability of the resources. This strong assumption leads to models which are probably overly simplistic representations of the dynamics of the stock and which produce inferences that should only be taken as broad indicators of stock productivity. Analyses of data from Trinidad and Venezuela with an equilibrium model indicate that shrimp resources in the area were overexploited for the period 1990-1993. The model predicts that catches can again reach the MSY level, estimated at 1300 t (in the range of 1100 to 1400 t), if effort is slightly increased from the 1996 level to around 14,000 days. The model's interpretation of the low catches in 1994 and 1995 (when effort was close to f_{MSY}) is that these low catches are the result of random (environmental) variation.

The same sorts of results are obtained with the equilibrium model that incorporates environmental information. The only difference is that this model predicts that changes in MSY can be expected as the wind strength changes from year to year. More specifically a higher catch should be expected during windy years. Unless there are long periods of several years with light or strong winds the advice that can be generated with this model is no different than that produced by the equilibrium model alone. According to both models, the fishery can be managed through the control of the fishing effort by adjusting effort to the f_{MSY}. As soon as effort is adjusted to f_{MSY} the fishery should, on average, produce MSY. However, modern practice is to set efforts or the target catch at a level below MSY, eg. f_{01} to reduce the risk of over-exploitation.

If we are not prepared to assume that the biomass of shrimp resources is in equilibrium, then we must use the results obtained from the dynamic models. Depending on the index of abundance used to describe the changes in the biomass of these resources, different interpretations on the status of stocks can be obtained and thus different management strategies recommended.

Assuming that catch is a better indicator of the abundance of shrimp resources in a region is the same as accepting that total landings will reflect changes in the biomass independent of the level of fishing effort applied. This means that fishermen are expected to retrieve a similar proportion of the shrimp resource every year, regardless of the level of effort, thus making the fishing mortality F approximately constant among years. Under this scenario cpue and catchability are expected to be inversely linearly related within the range of fishing effort experienced by the stock.

The dynamic model applied to catch data from Trinidad and Venezuela must be interpreted as indicating that for the period since 1973 around 79% of the biomass was removed by the fleet each year. Fluctuations in catch were related to random (environmental) variation and the MSY for the stock is 1,330 mt. The model is based on the assumption that effort controls have no consequence in the landings of the fishery. It must be noted that these conclusions only apply as long as effort is within the observed range of values (6,000- 19,0000 d-a-s). Again, like the equilibrium model, this model concludes that low catches since 1994 were due to unfavorable environmental condition.

Assuming that cpue is a better indicator of shrimp abundance equates to acknowledging that fishing effort determines the amount of catch that can be extracted from the stock, which is an assumption generally accepted in other fisheries. When a dynamic model was applied to cpue data it produced a similar estimate of MSY, 1,330 mt, as the previous models. The estimate of f_{MSY} is of the same order of magnitude (13,415 d-a-s) as the ones obtained previously. This model suggests that twice during the history of the fishery (1978 and 1984) the shrimp stock grew to its carrying capacity. A possible hypothesis to explain this is that during those two years there was exceptionally high recruitment due to favorable environmental conditions. This model also suggests that fishing impacts the stock by reducing its biomass.

In addition to the differences in the f_{MSY} and MSY estimates, this dynamic model implies a very different state of the population than the previous ones. This dynamic model suggests that biomass since 1994 has been below the level of B_{MSY} as a direct result of over-fishing during 1990-93. In order to reach the biomass level that will produce the MSY, the stock must be allowed to rebuild. Although effort has been below f_{MSY} since 1994, the effort reduction has not been enough to allow the stock to rebuild. Rebuilding can only be achieved by maintaining levels of effort that are sufficiently below f_{MSY} for a few more years. Once the stock has rebuilt, then fishing effort can be allowed to increase gradually to f_{MSY}.

Because of the paucity of catch and effort data for some of the fishing fleets of Trinidad and Tobago, the group had to make a number of assumptions about the relationship between catch and effort trends in the different components of the fishery. It is not known how close this dataset approximates reality. Every effort should be made either to test those assumptions or fill the gaps in the dataset.

This group believes that in the absence of better information it is not possible to discern unequivocally which of the four models used is the most appropriate to represent shrimp stocks in the region. All models, however, suggest that MSY is around 1,300 mt but disagree on the mechanism required to achieve MSY. This group believes that the dynamic models are a more appropriate choice to provide advice because they are more precautionary than equilibrium models. It is impossible to choose between the two dynamic models on the basis of the quality of the fit, thus a choice must be made on other criteria. Again, the model that uses cpue as an index of abundance is more precautionary and more consistent with current understanding of fishery dynamics than the one using catch and therefore should be favored. On this basis we recommend that fishing effort is not allowed to increase beyond 1996 levels and that landings and cpue are monitored to see any evidence of stock rebuilding. If the stock does not rebuild and cpue does not increase, then further controls on fishing effort may be necessary.

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