8 THE FISHERY FOR BROWN SHRIMP (*Penaeus subtilis*) IN FRENCH GUIANA

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8.1 The fishery

The fishery management area covers the waters from the Maroni river in the west to the Oyapock river in the east (Fig. 8.1). The potential surface of the shrimp fishing grounds is approximately 24 000 km^2, from 10 to 60m depth.

For the preservation of the small scale fishery and of traditional fishing activities, a local regulation forbids any trawling inside within the 30m isobath. There is no closure regulation or minimum legal landing size. The minimum authorised mesh size in the cod end is 45mm stretched.

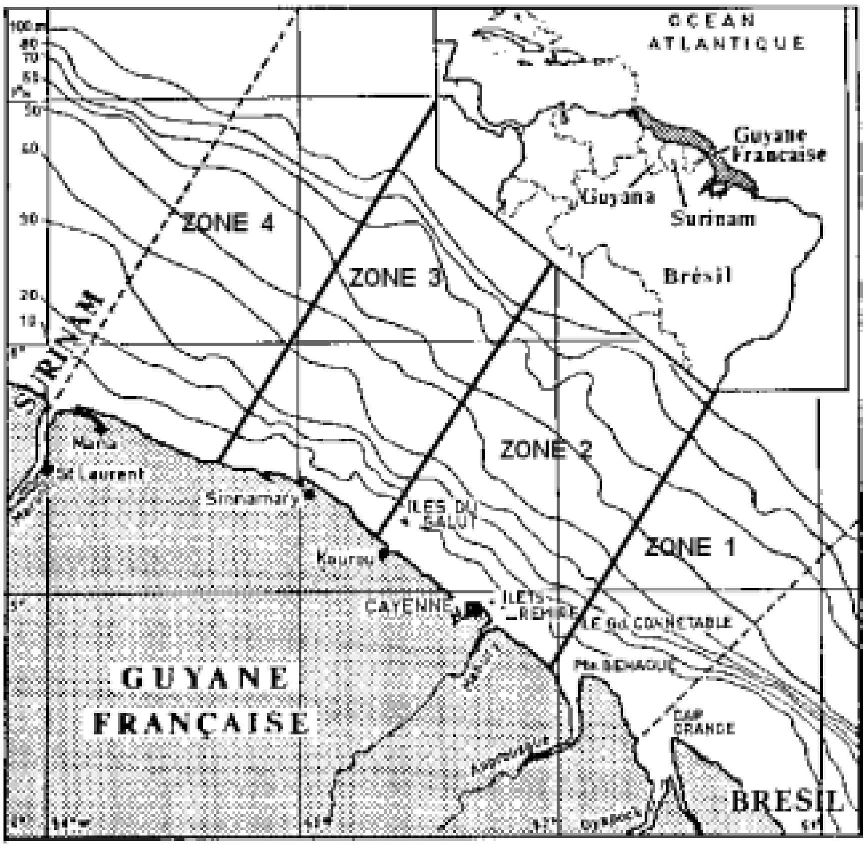

Figure 8.1 Map of the French Guiana fishery, from 30 to 100 meters

Currently shrimp trawlers are exclusively from the EU (all French). They are all licensed, the number of licences being decided by the “prefectoral” authority (Head of the Administration in French Guiana), after a deliberation between fishermen and producers organisations.

It is important to note that in the French Guiana fishery, shrimp companies are French and the crews are from Guyana and Brazil. This situation makes responsible fishing harder, as foreign crews have few social advantages, receive a percentage of the profits from fishing and therefore have a lower regard for the long-term state of the fishery. This can be incompatible with strategies aiming at achieving sustainable exploitation of shrimp resources.

A precautionary TAC of 4 108t decided by European Union covers all species of penaeid shrimps *(Penaeus subtilis* or brown shrimp*, P. brasiliensis* or pink shrimp*, P. notialis, P. schmitti* and *Xiphopenaeus kroyeri* or seabob) caught in the EEZ of French Guiana, of which 4 000t are for the EU and 108t for ACP countries. In the last five years, brown shrimp represented 86-92% and pink shrimp 7-13% of the landings (Table 8.1). The shrimps are landed and sold whole, so all values refer to whole weight or cephalothoracic length.

Table 8.1 French Guiana. Shrimp landings in tonnes over the period 1989-97

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Penaeus subtilis	3512	3618	3117	3660	2833	3854	3684	3755	3667	3785
Penaeus brasiliensis	192	308	209	290	225	299	316	562	310	151
Solenocera acuminata	143	167	84	74	17	107	180	16	73	92
Parapenaeus edwardsianus	41	55	259	150	140	55	33	326	89	167

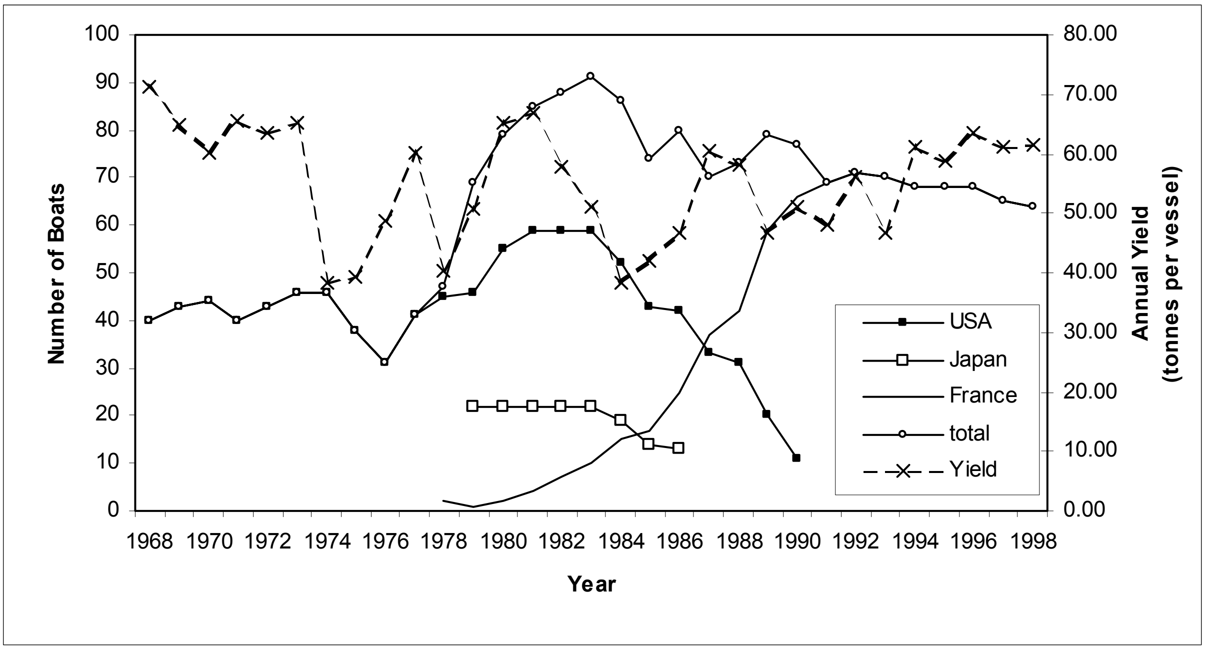

Figure 8.2 The national compositions of the shrimp trawlers and average annual production per vessel

There has been a considerable decrease in the number of boats from 91 vessels in 1983 to 65 in 1998 (Fig. 8.2). That decrease was followed by a recovery in the landings by boat until these reached around 60 tonnes by year. From 1992, the renewal of the fleet was accompanied by an increase in mean numbers of days at sea by boats (Fig. 8.3). According to a local unwritten agreement between companies, the number of licences will decrease over the coming years and aim to reach 60 boats by the beginning of the 21st century.

Two important changes occur on that fishery: the creation of the EEZ in 1978 and the switch to French vessels in 1990 (Fig. 8.2). The last boats, from the USA and Japan, left the fishery at the end of 1990.

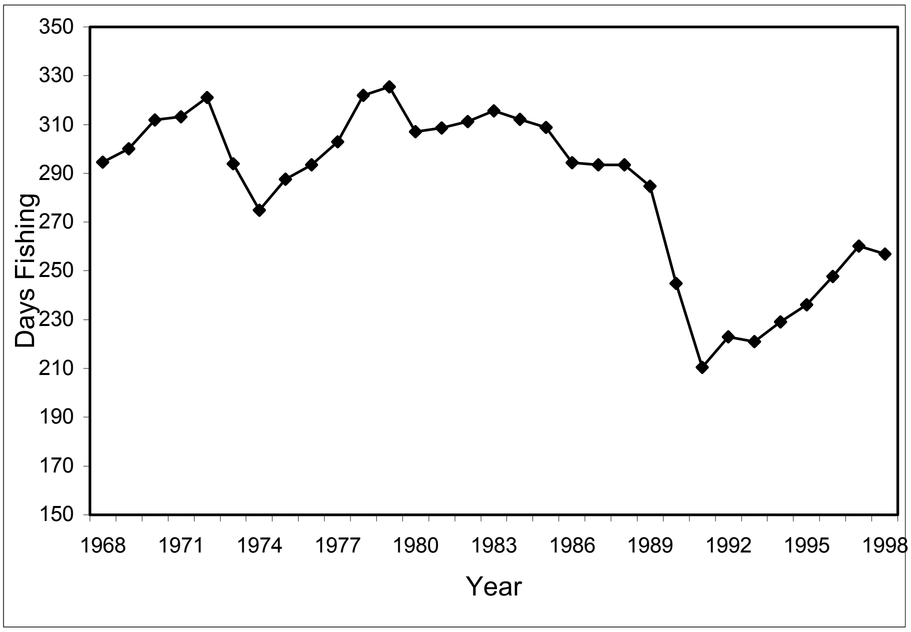

Figure 8.3 Yearly mean numbers of days fishing by boat on the fishery of *Penaeus subtilis*

8.2 Data and biological inputs

Length compositions of the French Guiana production have been obtained by sampling commercial catches since 1985. From 1985 to 1988 catches were made up of a mixture of headed and headless shrimps. Since 1989, all the production is sold headed for the European market.

Due to the numerous problems with fisheries statistics, a preliminary revision of the data for the period 1989-1997 was made at the beginning of 1998. Data on discards are not available.

The biological parameters are given in Table 8.2. All parameters used in the assessments remained unchanged from those of 1997 Workshop in Georgetown.

8.2.1 Comments on the general quality of the inputs

Length frequency data, from 1989 onwards, are available on a monthly basis only from samples of the frozen landings from Cayenne, French Guiana. Sorting by commercial categories takes place at sea and there is no processing after landing.

The sampling procedure is based on the composition of the landings by boats and by companies. Three companies cover 90% of the total production.

Because of insufficient resources, no discard sampling programmes have ever been undertaken. At times, the level of discards may be important, because the size selectivity of the trawl seems to be very low. Preliminary comparisons between length compositions of experimental trawling and sampling on board shrimp trawlers confirm this possibility.

Logbooks give information on the landing composition per day and on the numbers of hours fished per voyage. However, for uncooperative skippers, the number of hours trawled per voyage is also obtained from inquiries amongst companies and fishermen. The results obtained should therefore be considered as best estimates.

Different analyses did not all use the same data. The entire time series 1968-1997 was used for production modelling. Years from 1993 to 1998 were retained for running LCA (Length Cohort Analysis) and TLCA (Tuned Length Cohort Analysis). The data for the most recent period 1989-1998 was retained for running VPA because it covered the period with the most consistent data collection.

In the past, a lot of work has been done on the climatic and economic factors that may affect the mortality and recruitment. However, no one has succeeded in explaining fluctuations in stock size or has been able to predict the landings from recruitment estimates.

These works on ecological themes will be renewed (or finalised) by IRD (or ORSTOM) as part of a workshop of a national programme named PNEC (National Programme for Coastal Ecology) The French Guiana workshop will focus on the equatorial aspects of the general programme.

Table 8.2 Data and monthly input parameters : *Penaeus subtilis* in French Guiana

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Landings in tonnes	3512	3618	3117	3660	2833	3854	3684	3755	3667	3785
Numbers of samples	48	57	115	110	80	81	80	95	81	114
Mean sample numbers of *P.subtilis*	442	375	426	533	339	508	539	432	482	506
Effort in fishing days	22494	18854	14524	15832	15472	15570	16048	16846	16917	16191

Input parameters by month	Value	Source
	Males	
Growth - K (month^{-1})	0.0974	Isaac, Dias-Neto and Damsceno 1992
Growth - L_∞(cephalothoracic length in mm)	41.05	
Natural Mortality (month^{-1})	0.16	
Age at 100% mature	9 months	Dintheer and Rosé 1989
Length/weight relationship: a	0.0016344	
Length/weight relationship: b	2.742832	
	Females	
Growth - K (month^{-1})	0.088	Isaac, Dias-Neto and Damsceno 1992
Growth - L_∞ (cephalothoracic length in mm)	54.8	
Natural Mortality (month^{-1})	0.15	
Age at 100% mature	9 months	Dintheer and Rosé 1989
Length/weight relationship: a	0.0017321	
Length/weight relationship: b	2.716682	

8.2.2 Landings

Pink shrimp (*P.brasiliensis*) makes up a small but significant proportion of the landings (Table 5.2.1). From the beginning of the fishery, except during the Japanese period (Fig 8.2), there was no commercial sorting of brown and pink. From 1985, IFREMER estimates species composition from the sampling programme carried out by its scientific staff.

The landings have been fluctuating around an average of 3500 t yr^{-1}, for all shrimps. The history of the fishery is divided into three parts (see Fig. 8.2 and 8.3):

- 1968-1978, the US period, the fishery was mainly directed to big individuals of *Penaeus subtilis* and *P. brasiliensis*,
- 1979-1990, the beginning of the replacement of the US fleet by French vessels and the presence of a small Japanese fleet.
- By 1992, all vessels were French. Thereafter the numbers of vessels has decreased, but effort per vessel has increased.

Nowadays, the most important issue in this fishery is illegal fishing by unauthorised foreign boats. The level of their catches is unknown. These vessels are probably operating outside of the area fished by French trawlers, especially in depths between 60 and 120m, and targeting *P. brasiliensis*. There is still some doubt whether these illegal catches are high and whether they are catching the same age groups of *P. subtilis* as the legal French Guiana boats. If they are significant, some of the conclusions of the assessment could be incorrect.

Increased landings are made during the months when most rain falls, December to May and then again in September (Fig. 8.4).

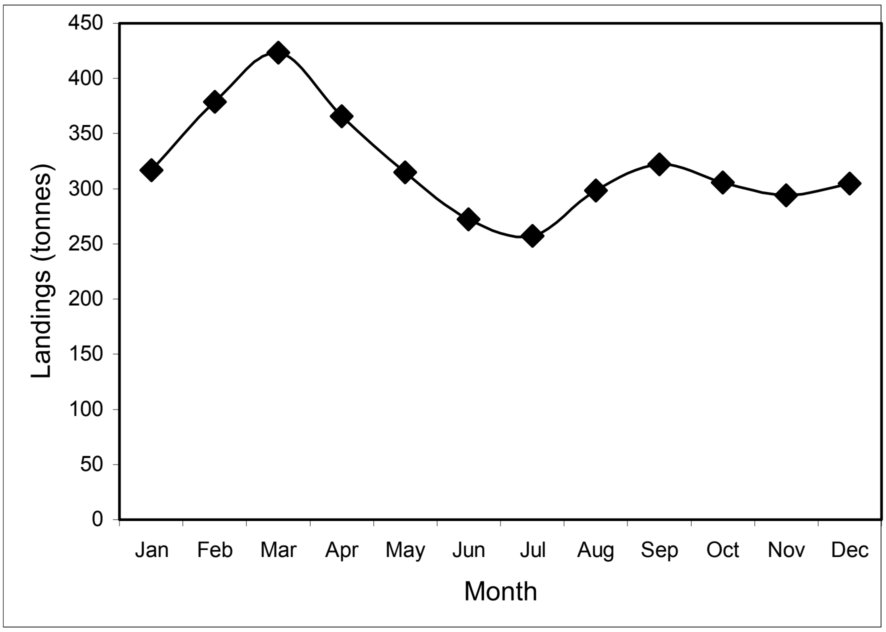

Figure 8.4 Average landings of *P. subtilis* by month on the time series 1985-1998

8.2.3 Effort

From 1968 to 1984, effort data (Table 8.2) correspond to the total effort of shrimp trawlers on all shrimp species. This includes penaeid shrimps and deepwater shrimps (mainly orange shrimp *Solenocera acuminata* and scarlet shrimp *Plesiopenaeus edwardsianus)* caught up to 700m on the slope and edge of the continental shelf. From 1985, the fisheries statistics are split between effort directed at "penaeid shrimps" (brown and pink) and effort directed at deepwater shrimps on the slope and edge of the shelf.

It is not possible to split the total effort between species of penaeid shrimps, because pink shrimp is always a bycatch of brown shrimp. The waters of the French Guiana form the extreme eastern limit of the population of *P. brasiliensis*.

From 1968 to 1989, the estimated effort directed at shrimp is proportional to the number of boats. From 1990 to 1998, after the switch to French vessels was complete, there was an important decrease in total effort, mainly attributable to the old boats bought from US and Japanese companies that left French Guiana (Table 8.1, Fig. 8.3).

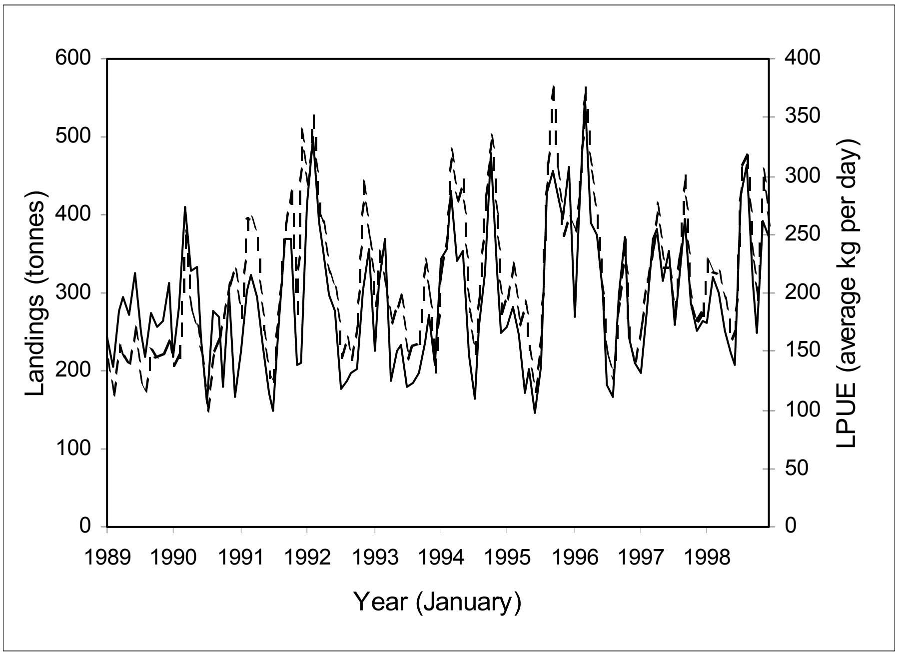

Figure 8.5 Monthly landings (—) and monthly landings per unit effort (---) from 1989 to 1998 of *P. subtilis* in French Guiana

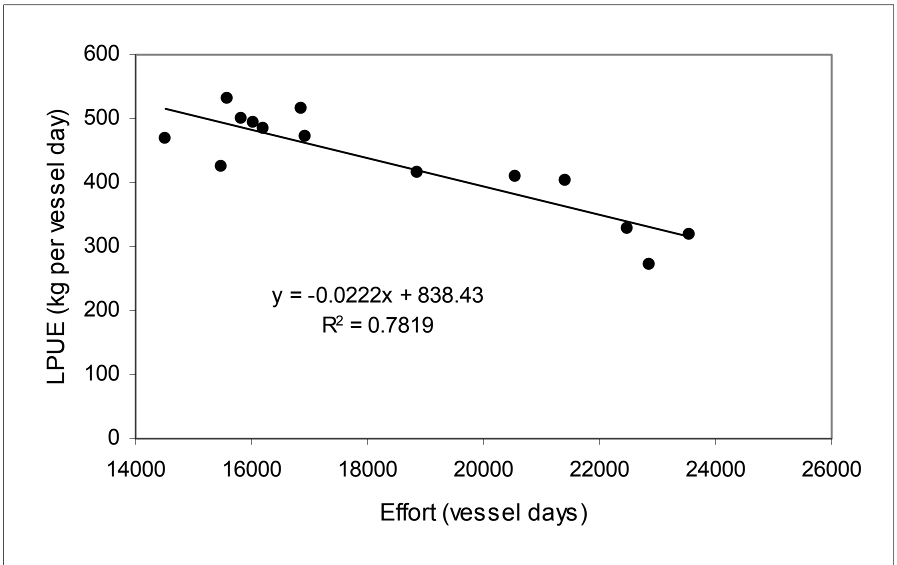

Figure 8.6 Annual effort and LPUE of *P. subtilis* in French Guiana (1985-1998). The significant linear correlation between LPUE and effort indicates a decreasing stock size at higher fishing mortalities

Now, a system of fleet renewal is in place, but avoiding an increase in the total fishing power (total number of kiloWatts). When a company buys 2 shrimp trawlers with financial help from the government, they have to eliminate 3 boats from the fishery. Because of that programme it is likely that the fleet will reach 60 boats at the beginning of the 21st century.

8.2.4 Landings per unit effort

For the period 1997-1998, yields are stable, between 200 and 400 kg day^{-1}. Landings and LPUE for both males and females are usually highest in quarters 1 and 2 (Fig. 8.5). (Since the discards are not sampled at sea, a part of the catch is ignored and for that reason, the term landings per unit effort (LPUE) is preferred over catch per unit effort (CPUE) to emphasise this uncertainty.) There is the usual negative correlation between LPUE and effort (Fig. 8.6). The relationship is not present for monthly data, indicating the relationship is not immediate, but requires the fishery to move towards equilibrium.

8.2.5 Mean sizes

Mean sizes in the landings are presented in Figure 8.7 for *Penaeus subtilis* and *P. brasiliensis*. The mean sizes of males and females of *P. subtilis* in the landings have decreased between 1991 and 1994. That decrease reflects an important change in fishing strategy and is probably due to the switch from the US and Japanese markets to the European market, which prefers the commercial categories containing smaller shrimp. 80% of *P. brasiliensis* landings occur in the size category corresponding to the largest *P. subtilis*.

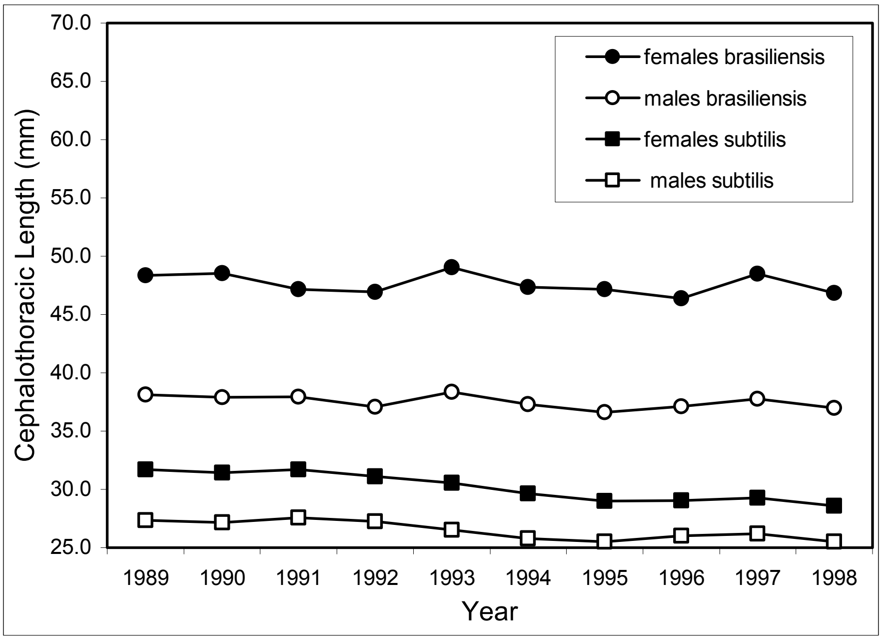

Figure 8.7 Mean cephalothoracic length of landings of *P. subtilis* and *P.brasiliensis*

8.3 Assessments

Two models have been used for stock assessment of *P. subtilis*, the production model and Length Cohort Analysis (Jones 1981). In these analyses, production models were applied to the whole Brazil-Guianas shelf mainly because the shrimp trawlers were from the USA and used to fish the whole area. In the landings, all the species of penaeid shrimps were mixed and the models gave a total figure for MSY. The present precautionary TAC of 4 108 t was calculated with that methodology. Analyses were also undertaken using Length Cohort Analysis in 1988 during a meeting of the WECAFC in Cayenne. Fishing mortalities by length were calculated and a Y/R was estimated.

In the present report, four methods have been used for assessing the stock of *Penaeus subtilis* of French Guiana: a production model, a tuned length cohort analysis (TLCA), an untuned length cohort analysis (LCA) and an aged-based VPA.

The use of cohort models is based on the assumption that the stock is made up of monthly micro-cohorts, because spawning and recruitment is continuous throughout the year. This does not exclude the fact that a recruitment peak clearly occurs within the season. All input parameters and outputs, for cohorts analysis, are given on a monthly basis.

- As in the 1998 workshop, we used a biomass dynamics model (Biodyn). All species (brown, pink and seabob) were combined, as in the previous analysis.

- The second method used is a length based analysis (LCA), by sex, (monthly micro-cohorts) according to the method from Ehrhardt and Legault (1996). This method tunes the LCA through a linear model of the catch curve.
- A second LCA, without tuning, using ANALEN (from FAO package), was also used with monthly mean data for each year (1993-1998). Yield per recruit estimates were derived from this analysis as well.
- Finally, age structure was obtained by slicing length compositions into age compositions according to the growth parameters of the species. The age compositions are used to run a classical VPA on ages. A second Y/R is also run using the model of Thompson and Bell.

8.3.1 Production model

An analysis was undertaken using the landings and LPUE data using Biodyn (Punt and Hilborn 1996). Data on catch and effort are available for 1968 to 1998. However, during that time there have been considerable changes in the characteristics of the fishing fleet, which was initially made up mainly of foreign boats, but is now entirely a French fleet.

Several authors have fitted these data from the Brazil-Guianas region to production models. Venaille (1979) and Stevenson (1981) 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 Brazil-Guianas region. Later Ehrhardt (1986) fitted a similar model to the catches of shrimp (all species - tail weight) for the whole region using the number of vessels as a unit of effort. Marcano and Alio (1996) also fitted production models to the shrimp catch (all species - whole weight) and the catch of brown shrimp (whole weight) for the Gulf of Paria and areas east and south of Trinidad.

A biomass dynamic model was initially fitted and applied to the catch of all species and effort data from 1977-1998 using an observation error estimator (Punt and Hilborn 1996). Landings per unit of effort (tonnes per fishing day of whole shrimp) was used as the biomass index.

The predicted CPUE fits the data well and explains the major trends in the historical changes of the catch rate (Fig. 8.8).

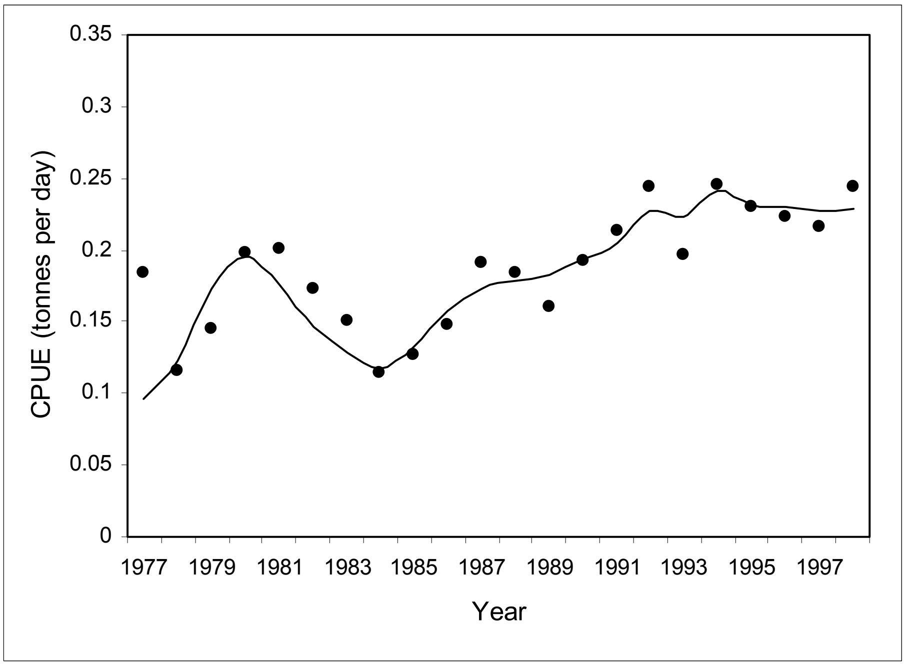

Figure 8.8 Observed and predicted catch per unit effort from biomass dynamic model

The dynamic model was also fitted to the same data set using a process error estimator (Punt and Hilborn 1996) and produced a similar fit to the observation error model. Parameter estimates, however are slightly different and as are the target and limit reference points derived from them (Table 8.3).

Table 8.3 Estimates of parameters (r, K, q) of Schaefer's biomass dynamic model. Also shown are limit reference points (MSY, fishing effort achieving MSY- f_{MSY} and CPUE at MSY- U_{MSY}) and target reference points (catch at 90% of MSY - $C_{0.9MSY}$, CPUE at 90% of MSY - $U_{0.9MSY}$ and fishing effort achieving 90% of MSY - $f_{0.9MSY}$). (Biomass and catch in tonnes, fishing effort in fishing days and CPUE in tonnes per fishing day.)

Parameters		**Limit**		**Target**	
Observation Error Model					
R	**1.11**	**MSY**	**4418**	**$C_{0.9MSY}$**	3976
K	**15858**	**U_{MSY}**	**0.190**	**$U_{0.9MSY}$**	0.257
Q	**0.000024**	**f_{MSY}**	**23164**	**$F_{0.9MSY}$**	15442
Process Error Model					
R	**1.21**	**MSY**	**4422**	**$C_{0.9MSY}$**	3980
K	**14662**	**U_{MSY}**	**0.180**	**$U_{0.9MSY}$**	0.243
Q	**0.000025**	**f_{MSY}**	**24525**	**$f_{0.9MSY}$**	16350

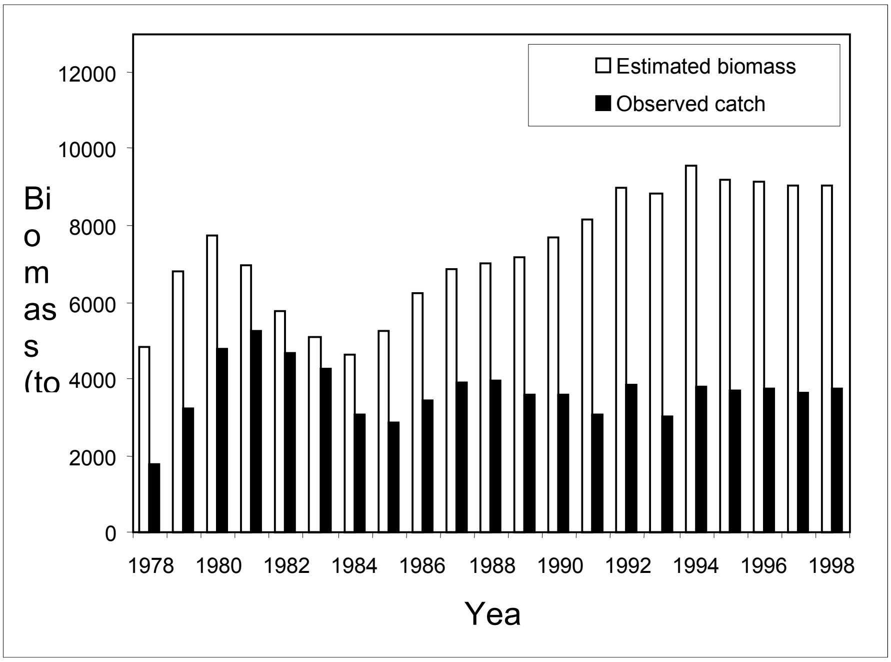

Figure 8.9 Population biomass estimates from biomass dynamic model and observed catch

The model interpreted the changes in LPUE and landings as an increase in biomass of shrimp as effort has decreased since the early 1980s (see also Fig. 8.6). Recently (1996-1998) average annual biomass has been at around 10 000 tonnes, close to 2/3 of the estimated virgin stock biomass of 15 000-16 000 tons. The 1994-1998 effort levels were at around $f_{0.9MSY}$ and therefore close to levels that are recommended under "responsible fishing" principles. The likelihood ratio estimates suggest that MSY estimates and thus catch at 90% of MSY are estimated with sufficient precision to be used in establishing the TAC (Fig. 8.9). Estimated CPUE at 90% of MSY is around 250 kg day^{-1}, close to present catch rates in the fishery. The estimates of MSY and f_{MSY} were similar to those obtained by previous authors (Venaille 1984, Stevenson 1981), which formed the basis for the establishment of the present TAC. The estimated catch at 90% of MSY is close to 4000t consistent with the present TAC of 4108t established for this fishery.

Table 8.4 Sensitivity of the biomass dynamic model parameters and reference points to fixed rate changes in fishing power during the catch/effort time series. Changes are presented as a percentage of the original estimates. Although the parameters are relatively sensitive to changes in fishing power, the reference points are not, which indicates that general management advice based on this model is robust against this effect.

Parameter	**Fishing Power Increase**	
	2%	**5%**
1977	4855	6112
r	4.5%	24.3%
K	-21.8%	-9.2%
MSY	-4.7%	-3.7%
f_{MSY}	-3.3%	4.5%

The analysis assumed the absence of historical changes in fishing power. To test the sensitivity to this assumption, the analyses were repeated assuming fishing power increased by 2% and 5% per year using the observation error estimator. Neither the values of MSY (for 2% and 5% were 4211t and 4255t respectively), nor those of r (1.16, 1.38), values were not sensitive to such changes. Only the values of B_{1977} (4855t, 6112t), f_{MSY} (22400, 24200) and K (12400, 14400) change significantly.

8.3.2 Tuned length cohort analysis

The second method used is a length-based analysis. Data for both males and females was analysed with an LCA on monthly micro-cohorts according to the method from Ehrhardt and Legault (1996) for tuned length-based cohort analysis (TLCA). Due to the large amount of output, the detailed tables of the analysis, month by month for 1993-1998, are not given in this report.

Stock abundance

The tuned length-based cohort analysis (TLCA) performed with F values tuned from length converted catch curves (LCCC) resulted in monthly total population size estimates correlated with the monthly CPUE (Fig. 8.10).

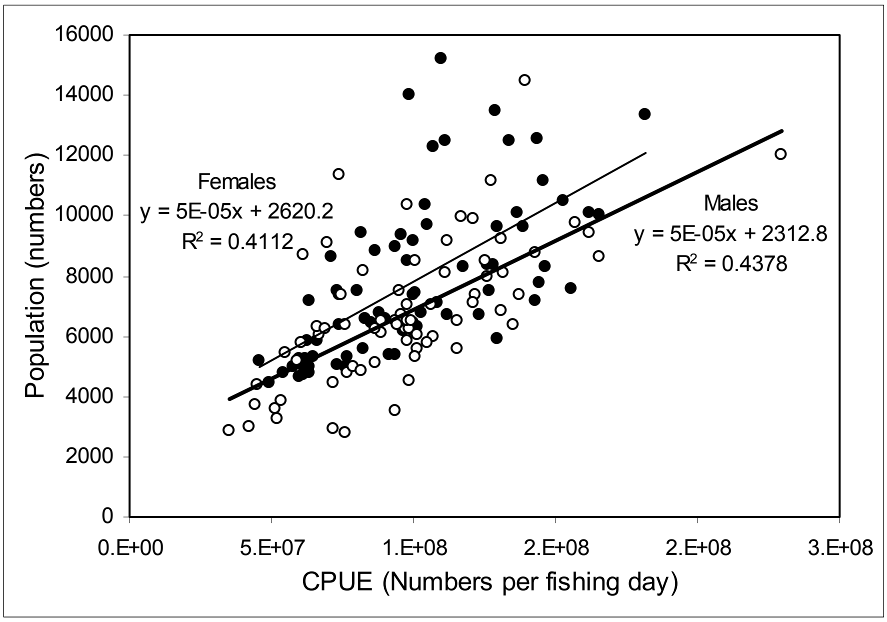

Figure 8.10 Population and CPUE for females (•) and males (o) of *P. subtilis* estimated from TLCA. Data is based on numbers of animals in each month 1993-1998

Stock abundance was estimated as the average abundance in numbers of shrimp in the sea. In the model, the stock abundance is strongly correlated with recruitment (R^2 = 0.92) and with catches (Fig. 8.11). Recruitment drives the population size and also tends to follow the seasonal rainfall pattern with two peaks a year (see also Fig. 8.4).

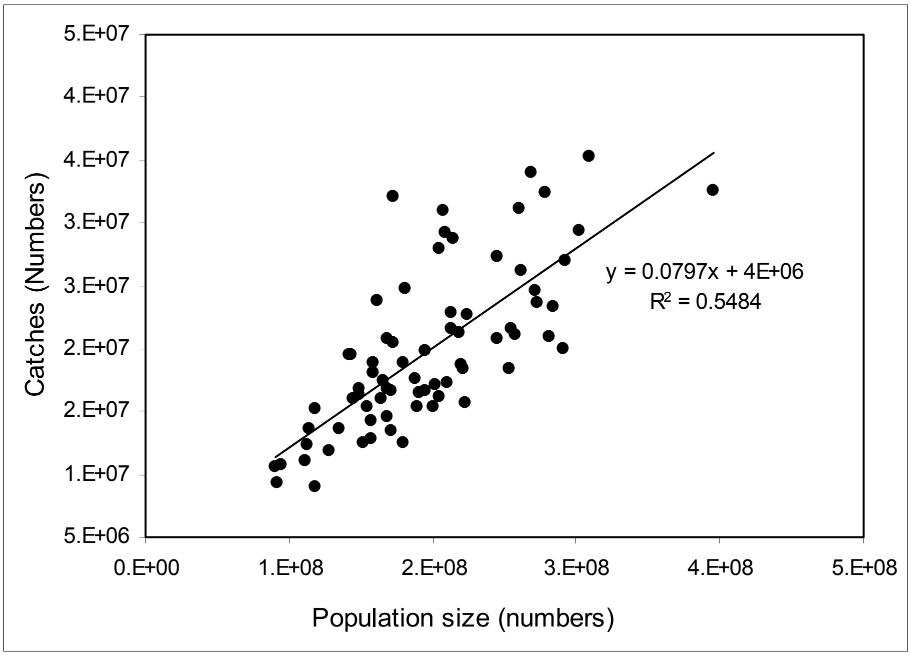

Figure 8.11 Monthly numbers at sea and catches of *P. subtilis* from 1993 to 1998, from TLCA

Fishing mortality estimates

Monthly fishing mortality rates (F) are plotted in Fig. 8.12. In the two last years, fishing mortality appears to be slightly larger in females than in males. In both figures, there is a generally increasing trend in F.

The monthly F-estimates never exceed the levels of natural mortality rate for males (M=0.16 month^{-1}) and females (M=0.15 month^{-1}).

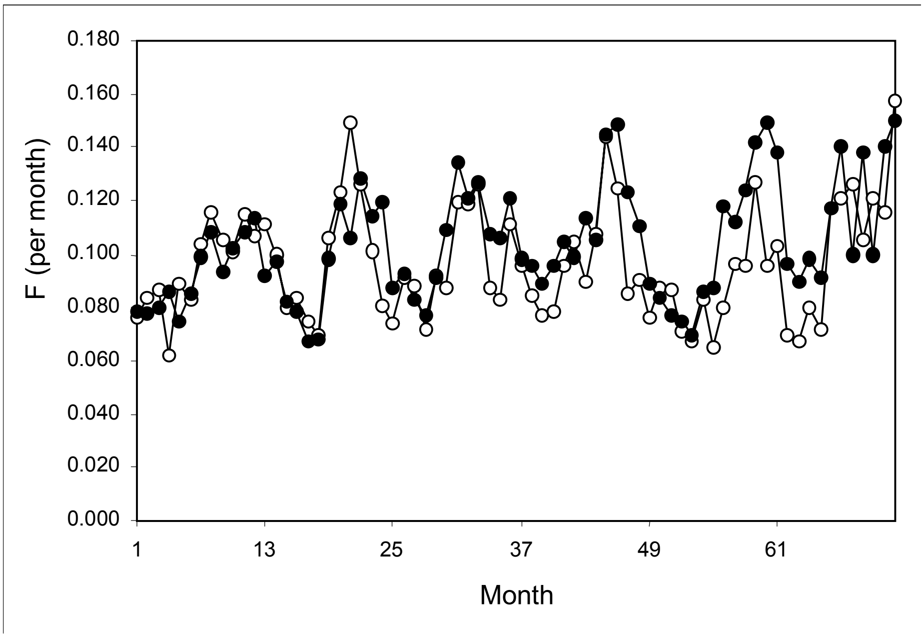

Figure 8.12 Fishing mortality for each month of *P. subtilis* from 1993 to 1998, from TLCA

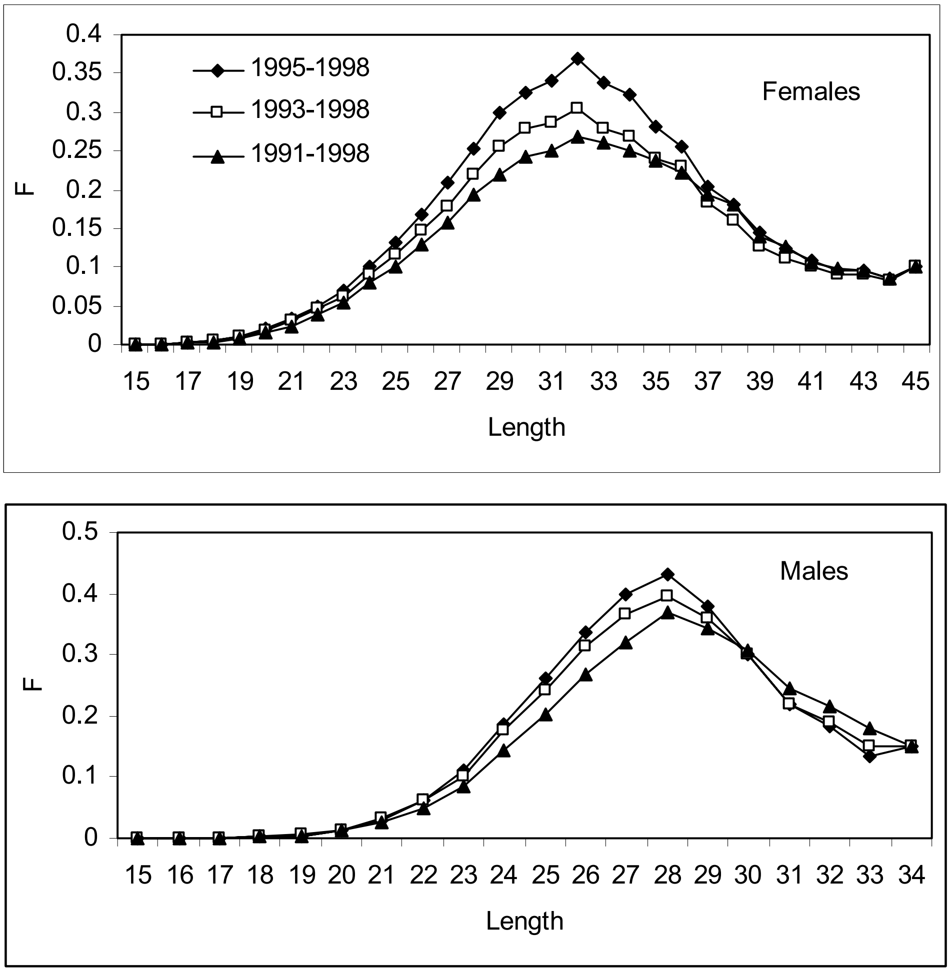

Figure 8.13 *P. subtilis*: F by length showing size selectivity over the years, from LCA

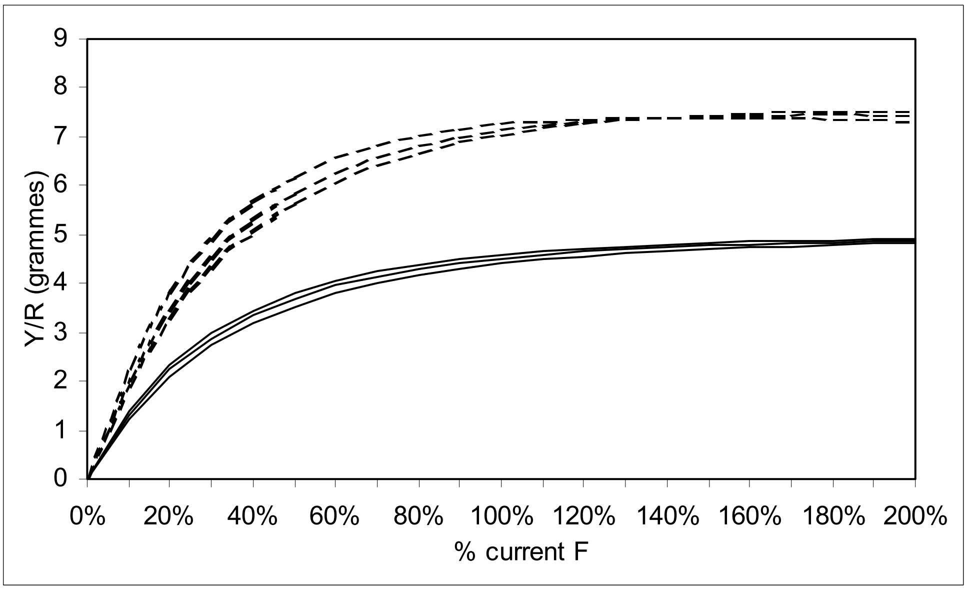

Figure 8.14 Yield per recruit for *Penaeus subtilis* females (---) and males (—), from LCA for each of the three periods, 1995-98, 1993-98 and 1991-98

Analysis of the catchability coefficient indicate that q is may be related to fishing effort through a negative power function (R^2=0.13 and R^2=0.18 for males and females respectively, 70 df). On the other hand, catchability has changed significantly within seasons as well intra-annually. There was no significant correlation between fishing mortality and fishing effort.

8.3.3 Length cohort analysis without tuning

The second set of LCA were run on the yearly average length compositions, on a monthly basis, for each sex, from 1993 to 1997. During the period 1991-1998 there is an increase in F by length for both males and females (Fig. 8.13), which corresponds to a progressive change in the strategy of shrimp trawlers to target the small and medium size shrimps that are very in high demand on the European market.

There are no real differences between Y/R curves estimated by the LCA for the 5 years investigated *(*Fig. 8.14). Selectivity seems relatively constant (Fig. 8.13) and the current Y/R is below the maximum of the yield curve (F_{max}).

8.3.4 Age-based assessment

The monthly length distributions (1989-1998) were split into 12 nominal age-groups (plus-group at age 16) for males and 13 nominal age-groups (plus-group at age 17) for females, using an age slicing program (CEFAS, Lowestoft, UK package containing slicing, tuning and VPA software). The VPA assessments were performed by using the tuning from the same package. Extended survivors analysis was carried out and tuning to fishing effort was performed using the default options proposed in the program and catchability for all ages was assumed to be independent of stock size. The tuning of the VPA was run on the years 1993 to 1998, for which the fishery has recovered close to a new equilibrium with 70 boats and a total effort of 15500 days fishing (Fig. 8.2). From 1989 to 1997, the mean F of ages 7-14 for females and 7-13 for males has increased (Fig. 8.15). It has fluctuated around 0.3, but peaks at 0.6 can be seen in 1996, 1997 and 1998. The estimated F's show considerable variation within the year. There is no correlation between mean F and the mean monthly effort for females for ages 7-14 (R^2=0.04, df=118) or males (R^2=0.00, df=118).

The sex ratio in the recruitment estimates given by the VPA varies between 0.49 and 0.51 females with a mean of 0.496.This is consistent with the biology of this species.

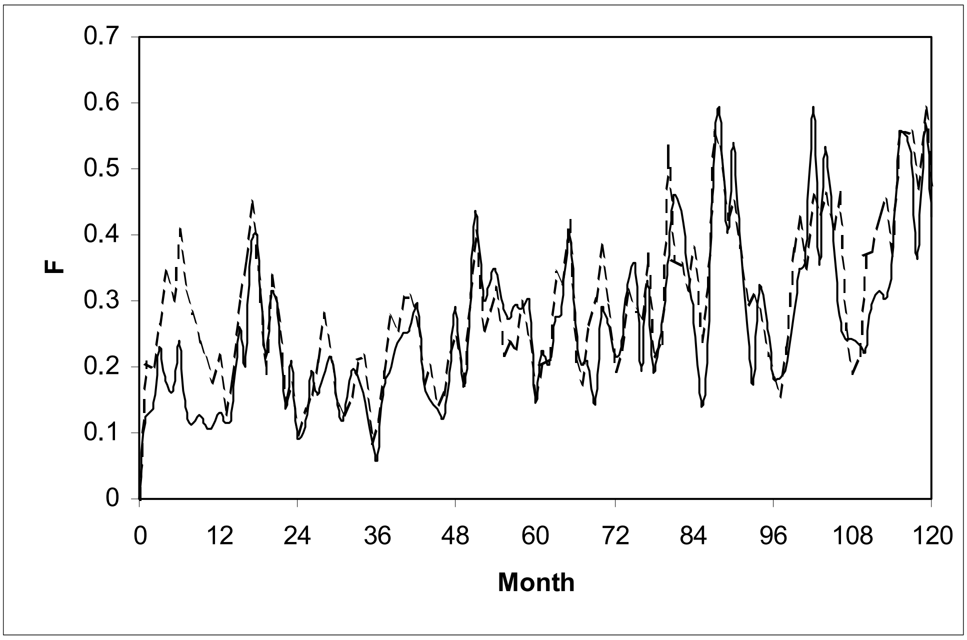

Figure 8.15 Monthly F for females (---), mean for ages 7-14 and males (—), mean of ages 7-13, of *P. subtilis* in French Guiana (1989 -1998), from VPA

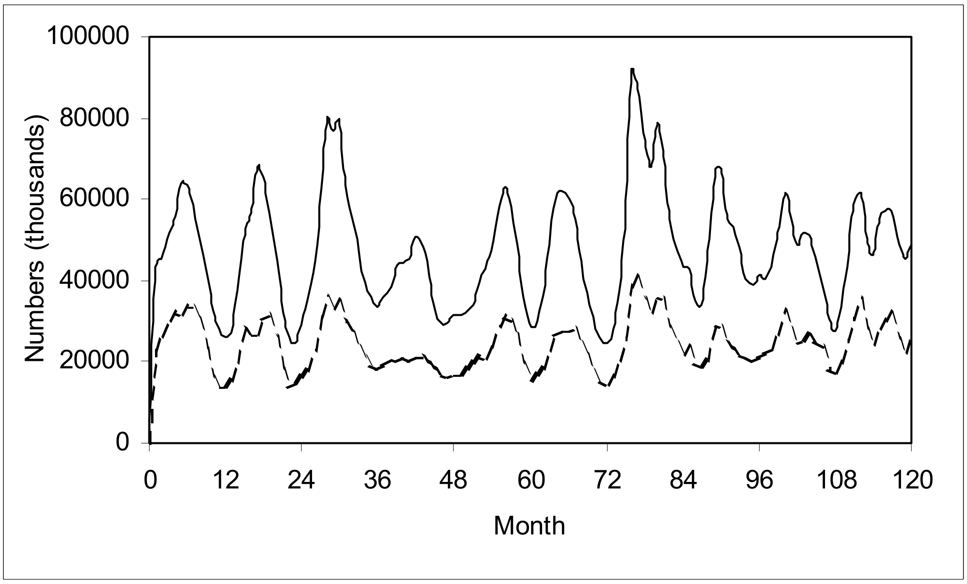

Figure 8.16 Monthly numbers (in thousands) of total (—) and female (---) recruits for *P. subtilis* from 1989 to 1998, from VPA

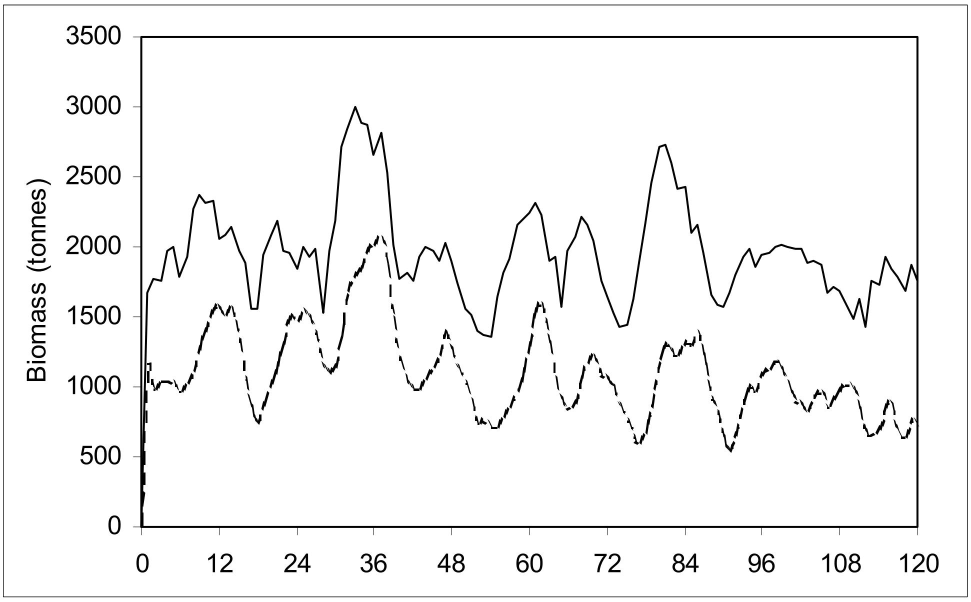

Figure 8.17 Total biomass (—) and biomass of spawners (---) of *P. subtilis* by month from 1989 to 1998, from VPA

Recruitment occurs all throughout the year with a maximum of intensity in the middle of the year (Fig. 8.16). The variations in monthly biomass follow those of the recruitment (Fig. 8.17). Although female spawning stock biomass has been slightly decreasing over the period, reflecting the overall decrease in total biomass, the model suggests recruitment has not decreased. Hence, recruitment may be independent of the level of the female SSB over the range of population change.

Recruitment is strongly correlated with the estimate of total biomass 4 months later (R^2=0.48), implying the population size is driven to a large extent by recruitment. However, there is no significant relationship between recruitment and SSB, although there is a small positive correlation after a 6 month delay (R=0.03, df = 114). After spawning, the early life cycle of brown shrimp (larva, post larva) lasts 4 months spent on the coastal muddy grounds. The recruits to the fishery are thought to be juveniles of an age of 5 to 6 months.

There is no significant correlation between landings and population biomass (R^2=0.04, df = 118) and landings per unit effort and population biomass (R^2=0.04, df = 118). If this is correct, then an important assumption of the biomass dynamics model will be incorrect. It is not clear yet which analysis is more correct.

The results of the yield per recruit analyses are more pessimistic for females, F_{max} being 87.7% of the current F (Fig. 8.18). In both cases $F_{0.1}$ is around 30% of the current F.

8.4 General comments on quality of assessment

The growth parameters, for both sexes, remain one of the main sources of uncertainty in these assessments (Table 8.5). Other sources of uncertainty are related to the estimation of fishing effort and the annual length compositions of the catches. Fishing effort should be investigated. The number of hours fished may not be an accurate estimate of the present level of effective fishing effort, as there have been improvements in fishing efficiency and a target shift towards small shrimp.

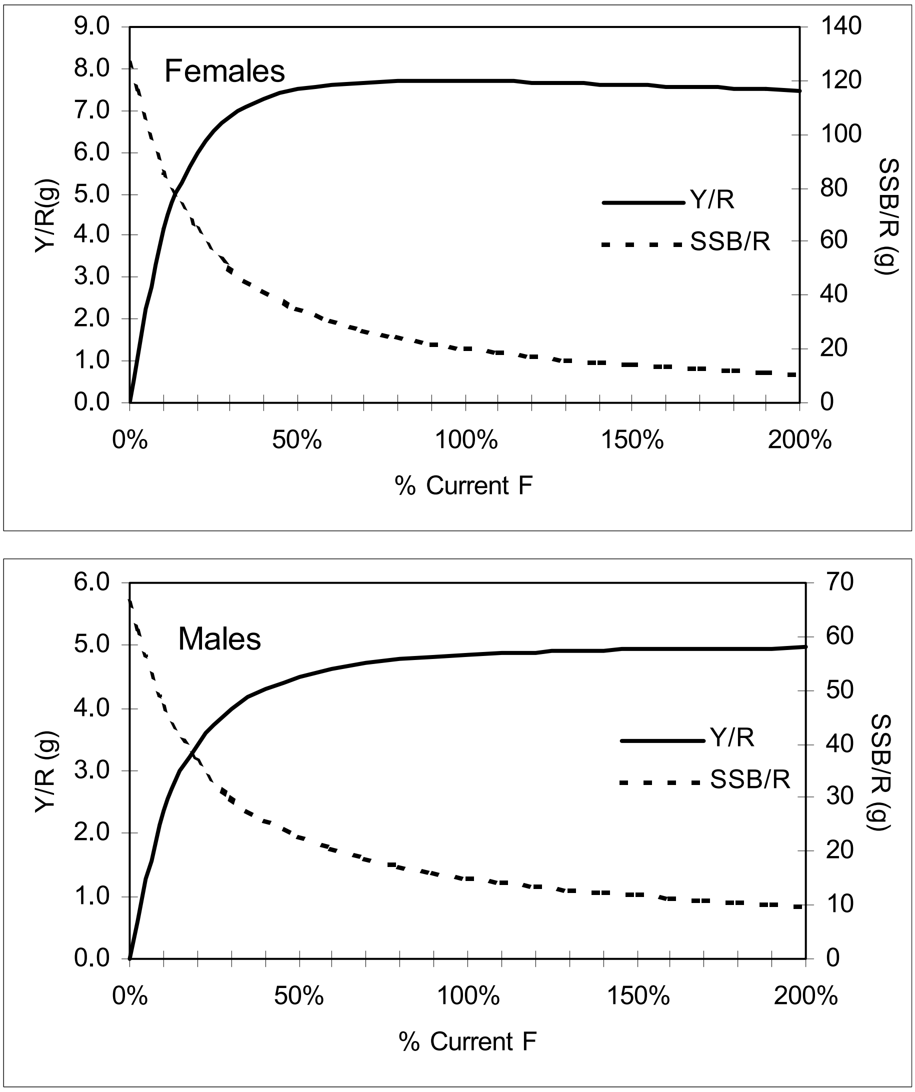

Figure 8.18 Yield per recruit and spawning stock biomass per recruit for *P. subtilis*, based on VPA and Thompson and Bell method

Table 8.5 For the monthly growth parameters, there were two sets of parameters. For the workshop, the values estimated for Brazil were used as all the assessments done during the workshop were preliminary and consistent growth parameters allowed easier comparisons of results. However, there is a wide variation in possible growth rates.

P. subtilis		**K (month^{-1})**	**L_∞ (cephalothorax mm)**
Isaac, Dias Neto and Damsceno (1992)	females	0.088	54.8
	males	0.0974	41.05
Dintheer and Le Gall (1988)*	females	0.190	52.07
	males	0.155	40.07

* Dintheer Ch., Le Gall J-Y., Analyse et modélisation des composantes biologiques de la pêcherie crevettière de Guyane Française, Internal report DRV-88.026/RH-CAYENNE.

8.4.1 Comparisons between assessment results

Fishing mortality

The peak in F does not occur at the same period in the year for VPA and TLCA. The maximum for TLCA being at the end of the year and at the beginning of the following year, during the dry season.

F values generated by the VPA have no consistent monthly trends and are subject to wide variations. The fishing mortality fluctuations are similar to that of recruitment.

In both VPA and TLCA, there is no relation between F and effort. In 1989 and 1990, high levels of F occurred because at that moment shrimp trawlers formerly belonging to companies from the USA and Japan were still present on the fishery. At the end of 1990, ten boats left the fishery and in 1991 the fleet was reduced to 69 boats.

Catchability

In both cases the catchability matches very well the variations of F. The monthly effort variations are low and the decrease of effort gradual from 1991 to recent years, so effort is unable to explain these changes in F.

No change in catchability can be seen in the results from the TLCA. The time series used for the analysis is probably too short.

With the VPA, there is a constant increase in catchability, from 1989 to 1995. In 1996, a new trend started in the fishery. Financial help was given by the EU for the marketing of shrimps. These subsidies resulted probably in an increase in the fishing mortality of juvenile shrimps. There is now an advantage for companies to aim for quantity rather than quality of the product. However, the assessment of changes in catchability is uncertain until a reliable relationship has been established between effort and fishing mortality.

Biomass

The TLCA monthly abundance shows a correlation with the seasonal rainfall pattern, which is less evident for VPA. TLCA biomass estimates are also correlated with landings for both males and females, whereas no correlation was evident with the VPA estimates. The VPA does suggest a slightly decreasing trend in total and spawner biomass, but not recruitment.

Recruitment

From both analyses it is clear that recruitment takes place throughout the year. For TLCA, the estimates of numbers of recruits suggest two maxima a year whereas for VPA, there is only one mode, usually in the middle of the year (Fig. 8.16). There is no statistically significant correlation between the biomass of females spawners and the total numbers of recruits, suggesting there is no simple linear relationship between stock and recruitment.

8.5 Management considerations

The results suggest that the stock is not over-exploited. The production model shows that the estimated catch, 90% of the MSY, is consistent with the present TAC of 4108 tonnes established for this fishery. The trends of SSB and recruitment for both males and females, as given by the age and the tuned length based assessments, show that there is no immediate reason for concern about negative effects of fishing upon recruitment levels. The length-based assessments confirm that fishing mortality is moderate and presents no evidence of overfishing.

In the last few years, according to the VPA, there is a decreasing trend in biomass for both males and females (Fig. 8.16 and 8.17). That decrease could be related to the increase in F on younger individuals as observed from 1995 onwards (Fig. 8.15). However, there is a contradiction between the results from the production model and of the VPA. The production model shows recovering trends in total biomass (Fig. 8.6), whereas the VPA indicates decreasing ones. The second pattern is consistent with an increase in F which cannot be explained only by an increase of small individuals in the landings. As mentioned above, illegal fishing by foreign boats could be a major reason for the increasing uncontrolled trends in F and decreasing trends in biomass. In 1996, 1997 and 1998, a Korean fleet of shrimp trawlers, based in Paramaribo was very active in the western part of the French Guiana fishery. These activities were stopped at the beginning of 1999 with the boarding of two vessels.

8.6 Conclusions

This report presents a comprehensive and comparative stock assessment study for *Penaeus subtilis* in French Guiana. The whole set of the assessments is now available because in recent years important improvements have been made to the fishery statistics. However, the results presented in this report are still of a preliminary nature and should be corroborated in the future.

The greatest problem with the current analysis is the lack of data on discards of juveniles. If estimates of discards were available that might lead to better indices of recruitment and make the VPA more reliable.

The estimation of biological parameters also remains a problem. The growth parameters were derived from Brazilian analyses. They could be improved if they were revised using catch samples from French Guiana.

It is also very important to consider the limitations and advantages of different models. The TLCA generated credible results. The average female and male stock abundance estimates followed trends in seasonal relative abundance estimated with external sources of information (catch and effort data). The brown shrimp, *P. subtilis*, appears to be a stable resource, following natural seasonal fluctuations during the time period covered by this study. Fishing mortality for both males and females appears to be driven by the timing of fishing and the availability of shrimp during those times.

The VPA provides a different result and suggests that F and q increased between 1996 and 1998, something not reflected by the TLCA analysis. More than improvements in technology, it is likely that the marketing subsidies given by the EU have had a decisive influence on the fishing strategy of shrimp companies. However, it is difficult to compare the levels of monthly fishing mortality. In TLCA the values of F apply to a length class, whereas for VPA, F refers to an age class.

Stock abundance during the 10 years analysed does not present significant decreasing or increasing trends other than the natural seasonal trends. *P. subtilis* is a resource that shows a rather remarkable constant abundance at least throughout the study period. This suggests that, while results remain uncertain in many regards, urgent management action to prevent overfishing is not required.

Several recommendations for further research emerge from this study, among these are:

1. To standardise fishing effort series;
2. To test the significance of seasonal changes in the biological condition of female and male *P. subtilis*;
3. To re-estimate growth parameters with the local biological data;
4. To analyse recruitment trends including any evaluation of discards, environmental parameters that could enhance the understanding of recruitment variability; and
5. To research the dynamics of changes in catchability.