STOCK ASSESSMENT OF BROWN SHRIMP (*Penaeus subtilis)* IN SURINAME

by

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1. INTRODUCTION

The shrimp fishery started in Suriname in 1958, and developed, together with other fleets based along the Guyana-Brazil shelf, through the mid-1970's, when the maximum number of vessels was reached. Since the establishment of the 200 miles Exclusive Economic Zone by the countries of the region, around 1978, the size of the fleet based in Paramaribo has generally tended to decrease, and fluctuated in the last ten years between 100 and 120 vessels.

More than 95% of the trawlers are foreign owned, and operated by Korean and Japanese fishing companies. With the exception of a few small local operators using their own facilities, all shrimp is landed at two large plants called “Sail” (government owned) and “Sujafi” (private owned, 49% Japanese capital). Three fleets can be distinguished, in accordance with their fishing strategy : a Korean fleet landing at Sail, a Korean fleet landing at Sujafi and the Japanese fleet, also landing at Sujafi. There is no artisanal fishery.

Landings include 2 main species (*Penaeus subtilis* and *P. brasiliensis*) in comparable proportions, and two secondary species (*P. schmitti* and *P. notialis*) representing together less than 5 % of the total landings.

The shrimp fishery is the most important of the country in terms of output value and sustains a very profitable processing and export industry. Efforts have therefore been made, since the eighties, to collect data suitable for assessment of the exploited stocks. Several attempts to understand and assess the resource, and the difficulties that were met, are outlined in the national report included in this volume. It was, among other things, concluded that a priority should be given to studying the recruitment mechanisms of the different shrimp species, since recruitment variations appear to be the major factor directly affecting the performance of the fishery.

The brown shrimp, *Penaeus subtilis*, is caught throughout the region and accounts, depending on the year, for around 60% of the shrimp production in Surinamee. Since only negligible quantities of shrimp are caught by fishing gear other than shrimp trawls, it can be considered that data obtained on the landings by the industrial shrimp fleet correspond, in first approximation, to the total production. This further justifies the selection of the brown shrimp as a priority species for stock assessment.

2. DATA AND METHODS

2.1 Data Available

The larger part of the shrimp is landed head-off at one of the two processing plants mentioned above, where it is sorted into the prevalent count-per-lb commercial categories, in accordance with individual weight. A significant part (10 to 20%) is landed at one of the plants (Sujafi) head-on, already graded, packed, frozen and ready for shipping. The commercial categories used for head-on shrimp differ from those of the head-off products. Monthly Figures on landings by commercial categories have been obtained from the industry since the year 1978, while partial information could be retrieved from different reports at the Fisheries Department for the period 1971-1977. From the information provided be the industry, fishing effort can also be calculated, in number of vessels and number of trips. Partial information on the number of days at sea is also available.

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As the species are not segregated in the processing, the data describe the global landings. Data by species can only be obtained through sampling. As explained in some detail in the national report, a sampling program has been carried out at one of the plants (Sail) from 1985 to 1991, in order to monitor the species, gender and length composition of the landings. The first output of this program is the average species and gender composition of the landings by commercial category for every month, based on samples of each category taken from 8 to 10 vessels (each month).

In a second step, monthly landings by species, gender and length (by 5 mm tail length ranges) are generated, using a set of length frequency distributions for each species/gender inside each commercial category. A single set of distributions has been established for the entire period considered, by combining all measurements taken for a given category over a number of months. These distributions could not be monitored through time, due to lack of staff, and they were assumed to remain sufficiently stable through the period considered. The validity of this assumption needs to be assessed. All calculations and extrapolations have been carried out on spreadsheets (Lotus 123 at the time).

Sampling of the head-off landings at Sujafi has been less intensive, because of practical constraints (distance from the Fisheries Department, lower frequency and total volume of landings). As a result, separate matrices for the two transformations of the landings data from this plant could not be generated. Whether, or to what extent, parameters obtained at Sail could be extrapolated to Sujafi remains to be established. For the time being, however, the Sujafi head-off landings by commercial categories have been broken down by species, gender and 5 mm length range, using the results of the samplings at Sail.

The head-on landings, also from Sujafi, have been re-distributed into corresponding head-off categories, in accordance with their respective number of counts per pound, and added to the head-off landings. Since it is presumed that the species composition of these head-on landings might differ from that of the former, a specific sampling program has been designed to monitor the occurrence of the different species in all head-on categories. This program could not yet be carried out with the required intensity, however, mainly due to the reluctance of the fishing companies to provide samples. Sampling head-on landings means thawing a number of already packed and ready-for-export 2 kg boxes, which involves a loss for the company (thawed head-on shrimp can only be processed, after sampling, as head-off shrimp).

2.2 Analytical Methods

The method used in this study is the length-based cohort analysis, from Jones (1984). A review of this method as well as practical guidelines can be found in Sparre and Venema (1992. The calculations were carried out using a spreadsheet template designed by Ehrhardt and Legault (1996). This spreadshe*et al.*so allows for tuning the analysis in such a way that the length specific fishing mortality rates obtained are in closest possible agreement with the weighed average fishing mortality rate obtained independently, for a similar range of lengths, from for example a catch curve analysis. This approach, called tuned length-based cohort analysis, is further explained in other chapters of this volume dealing with assessment of shrimp.

2.3 Input Parameters

Population parameters necessary to start a length-based cohort analysis include natural mortality rate (M), and growth parameters K and L_∞ In accordance with estimates available in the literature, which are discussed in the meeting report (this volume), the following parameters were adopted by the workshop, and were also used in this analysis :

	Female	**Male**
L_∞ (mm, tail length)	135.5	109.59
K (month^{-1})	0.0885	0.0974
m (month^{-1})	0.146	0.146

3. RESULTS

The outputs of the tuned length cohort analysis are monthly estimates, by size range, of the total and fishing mortalities and of the population size (both in biomass and in number of individuals). These results constitute a powerful data base from which trends can be traced for example in the abundance of recruits, or of spawners, or of any other size component, and relationships can be investigated between these different components, or between their abundance and external parameters, like environmental or fishery-driven parameters. The preliminary analysis hereunder proposes an interpretation of the global trends in fishing mortality, abundance and recruitment, and will be carried further in connection with environmental information, results on other target species of this fishery, more refined data on longer time series and locally determined population dynamics parameters (when they become available).

3.1 Fishing mortalities

The fishing mortalities for both sexes, plotted in Figure 1, follow each other closely. The fishing mortality of males appears to be always substantially lower than that of females. This may be caused, at least partly, by the choice of input parameters. In particular, the same natural mortality (M=0.146) has been assumed for both genders, while some sources suggest that males may bear a higher natural mortality rate than females (Isaac *et al.*, 1992).

For both genders, the average fishing mortality shows, in the entire period considered, a clear annual periodicity where a maximum is reached in the middle of the second half of each year. It then decreases gradually until February, and the minimum values are generally observed between February and April. The annual pattern seems fairly reproducible. In 1989, however, lower levels of fishing mortality were reached in the second half of the year than was the case in other years. The same could be said, to a lesser extent, of the year 1991. The period characterised by lower fishing mortalities, in the first months of the year, was more extended (6 to 7 months) than usual (4 months) in both 1989 and 1991.

There has been no apparent long term change in the mortality levels, and the fishing mortality estimates obtained by this analysis remain always, for both sexes, below the value postulated for the natural mortality.

3.2 Stock Abundance

Stock abundance is reflected by the average numbers of shrimp at sea, and by the corresponding biomass. Figure 2 shows that brown shrimp males consistently had a lower biomass than females. The trends for both genders are very similar, however. Abundance appears to have changed widely from month to month, with maxima situated in the first half of the year. Abundance estimates may increase or decrease, in a matter of a few months, by a factor of 3 or 4. On the other hand, no increasing or decreasing long term trend is observed over the years considered. After a low in 1989, biomass recuperated quickly and was back at its previous level in 1991.

Catch (shown in tonnes) represents a relatively small fraction of the biomass (Figures 3, 12 and 13). This proportion varies following a recurrent annual pattern, with higher values towards the end of the year, corresponding to the higher fishing mortalities. The contribution of males in the catch is about half that of the females, and the proportion of males seems to decrease in the periods when catch and biomass are higher (Figure 3). It is notable that the catch has a very constant relation to the recruitment (Figures 12 and 13), which underscores the role that recruitment may play in the variations in shrimp production.

3.3 Catch per Unit of Effort

The catch per unit of effort (CPUE), expressed in number of individuals caught in an average trip, is given in Figure 4. Maxima are generally observed in the second half of the year, and a second, less conspicuous peak is visible in the first months of most years. The year 1988 exhibits only the main peak (September to November), and no CPUE peak is discerned at all in 1989. The catch per unit of effort for males is lower than for females, and this difference is accentuated in the second half of the year.

Figures 5 and 6 illustrate, respectively for females and males, the relationship between abundance, catch and CPUE, all expressed in numbers. It can be seen that the three curves follow the same evolution, but also that the numbers caught seem to match the changes in the abundance more accurately than does the CPUE. It is useful to mention here that the unit of effort used in the CPUE calculations (number of trips) is not very precise, and that using, for example, the number of days at sea, might lead to a different interpretation. Plotting respectively the numbers caught per trip and the numbers caught against the abundance (Figures 7 and 9 for the females, 8 and 10 for the males) confirms that the catch apparently has a closer relationship to abundance than does the CPUE.

3.4 Recruitment

Recruitment as expressed by the biomass of individuals smaller than 70 mm (females) or 65 mm (males), tail length, is given in Figure 11. For each gender, Figures 12 and 13 compare the recruitment curve with the curve of the biomass and the curve of the catch. All three have very similar patterns, and recruitment seems to follow exactly the biomass, except that the clear biomass peaks translate into lesser conspicuous recruitment peaks, particularly at the beginning of the year. As a result, recruitment appears more or less continuous through the year, with only lows in the middle of certain years (1986, 1988, 1989, 1991).

If the quotient recruitment/biomass is plotted, however, as in Figures 14 and 15, a very clear monomodal recruitment pattern comes forward, with a major peak situated between September and November. Only in the years 1985 and 1989 does this recruitment period appear less predominant (though still clearly visible). This pattern is matched perfectly by another recruitment index, the CPUE of small sizes. Remembering that shrimp is recruited to the trawl fishery from an age of about three months, and that there is a time lag of one to two months between catch and landing time, it follows that the shrimp making up the recruitment peak has been hatched in April - June. These months coincide with the main rainy season in Suriname. This confirms earlier findings on the impact of rainfall on shrimp recruitment in the region (for example Garcia *et al.*, 1984, for French Guiana ; Charlier *et al.*, 1995, for Suriname).

3.5 Fishing Mortality and Fishing Effort

There is no apparent relationship between the fishing effort and the resulting fishing mortality, as demonstrated by the plots in Figures 16 (females) and 17 (males). This translates into, or may be caused by, an important variability of the catchability coefficient (q), which is the quotient between these two variables, from month to month. On the other hand, this coefficient exhibits a seasonal pattern, as higher values are found in the second half of the year (Figure 18), corresponding also to higher values of the fishing mortalities. How all this should be interpreted is not clear at this time. Different elements like the behaviour of the shrimp, the strategy of the fleets, and environmental factors, have to be taken into account. It is interesting to observe that the catchability coefficient seems to be negatively related to the fishing effort (Figures 19 and 20).

3.6 Importance of input parameters

In order to understand the impact of the assumptions made on initial F/Z and other input parameters on the results of the tuned length cohort analysis, several values of F/Z, L_∞ K and M were tested. For this exercise, the average annual length frequency distribution of *P. subtilis* females, for the years 1985-1991, was used. The values tested ranged within the results that have been reported in the literature (Lum Young *et al.*, 1992 ; Charlier, 1995).

The results obtained with varying values of the input parameters are illustrated in Figures 21 to 28. The values given to initial F/Z (in the range 0.1 to 0.7) do not seem to affect the estimated number of survivors (thus the abundance) by size (Figure 25). The fishing mortality estimates obtained by this analysis do not appear to depend very much either on the initial F/Z value (Figure 21). On the contrary, the assumptions made on natural mortality and growth parameters have a significant impact on the results, particularly on the estimated numbers of survivors in the small sizes (Figures 26 to 28). These observations suggest that efforts should be made to verify these parameters in the different countries of the region, in order to obtain more reliable abundance and recruitment estimates. They also underline the need for the countries to cooperate, in common methods and assumptions, and to share the results of their analyses.

4. CONCLUSIONS

a) Length-based cohort analysis offers a way to calculate monthly abundance indices of brown shrimp by size (age), and to quantify recruitment. Preliminary results covering the period January 1985 to December 1991 indicate that abundance varies widely (by a factor 3 to 4) through the year, and in Suriname follows an average annual pattern with maxima at the beginning of the year. Fishing mortality exhibits a very reproducible annual trend with higher values in the second half of the year. In the long term, both variables show notable stability, which would suggest that the level of exploitation, in the period considered, was not excessive.

b) Catch varies in accordance with biomass, which in its turn appears very dependent on recruitment. This confirms that recruitment, and particularly its variability from year to year, is a major factor to be taken into account in the management of the fishery. Understanding the relationship between recruitment and environmental conditions could open the way to yield predictions, and allow for a better adjustment of levels of effort, and economic optimisation.

c) Recruitment to the fishery is year-round, with one conspicuous mode at the time of the year that precisely corresponds to a larval recruitment during the main rainy season in Suriname, from April to June.

d) Catchability was estimated to exhibit seasonal variations, with higher values observed in the periods of maximal fishing mortality, and an apparent negative relationship to fishing effort. The possible impact of a number of factors that may be related to this variability should be investigated.

e) It should be kept in mind that, since the level of fishing effort applied does not appear to be the major factor governing yield, which appears more influenced by abundance fluctuations, economic overexploitation is likely to occur before shrimp stocks become threatened. Economic issues therefore play a particularly important role in the management of shrimp fisheries. On the other hand, shrimp trawling strongly affects the stocks of all fish species included in its by-catch, and the status of these stocks might to some extent constrain shrimp fisheries management.

f) From the considerations above, it is possible to draw some guidelines for future investigations:

- Given their impact on the results of length-based cohort analysis, population parameters, particularly growth, should be investigated based on local data.

- Sampling on a continuous basis is required to keep track of the composition of the landings. An optimised sampling scheme, making the best possible use of available manpower, should be worked out and implemented.

- The current database should be further analysed, in connection with factors of recognised importance, like environmental factors and a more accurate description of fishing effort (including standardisation and integration of technical innovations). The information contained in the seven years 1985-1991 should be sufficient for a reliable extrapolation to other years.

- Similar analyses should be undertaken on the other shrimp species exploited by the trawlers fleets. Data should be collected on different aspects that are important to the management of the fishery, particularly on the economic aspects, and on the by-catch.

5. ACKNOWLEDGEMENTS

The author wishes to express his gratitude and his congratulations to the many Fisheries Department staff members who have been involved in the execution of the shrimp sampling program that has provided the material for this study. The value and usefulness of the resulting data base reflects the great care with which the data have been collected, 364 weeks long. While too many persons have participated to all be cited here, special recognition is deserved by Mrs. Yolanda Babb-Echteld, Ms. Lize Abas, Ms. Maaltie Ori, whose dedication has been unalterable through the full length of the program. The cooperation of the management of the Sail company has been an indispensable condition for the success of the program, that has also always enjoyed the support of successive Heads of the Fisheries Department.

Gratitude is due to FAO and CFRAMP, to the WECAFC Technical Secretary Dr. Kevern Cochrane, and to the consultants Dr. Nelson Ehrhardt and Dr. David Die. The organisation of the recent workshops has given the impulse necessary to effectively achieve the analysis of the data base. The guidance by N. Ehrhardt, particularly in the tuned length cohort analysis, has been more than valuable, and the templates he provided during the workshops have proven to be most practical tools to perform the calculations and start the interpretation of the results of the analyses.

6. REFERENCES

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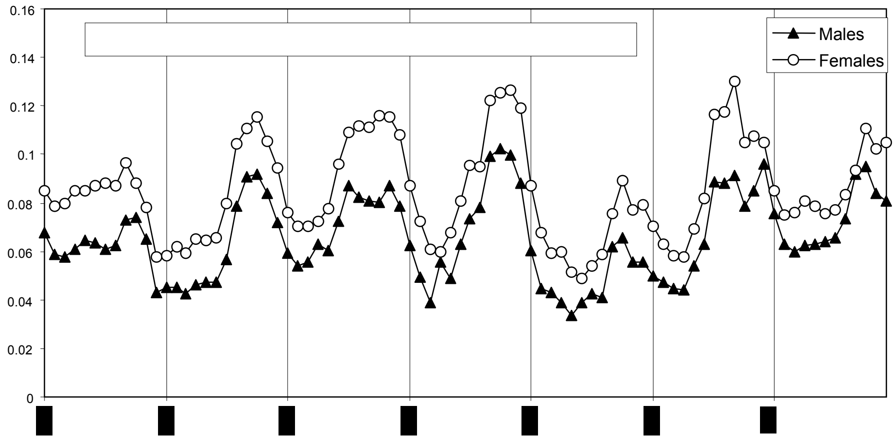

Figure 1: Monthly fishing mortalities, *P. subtilis*, Suriname, 1985-1991

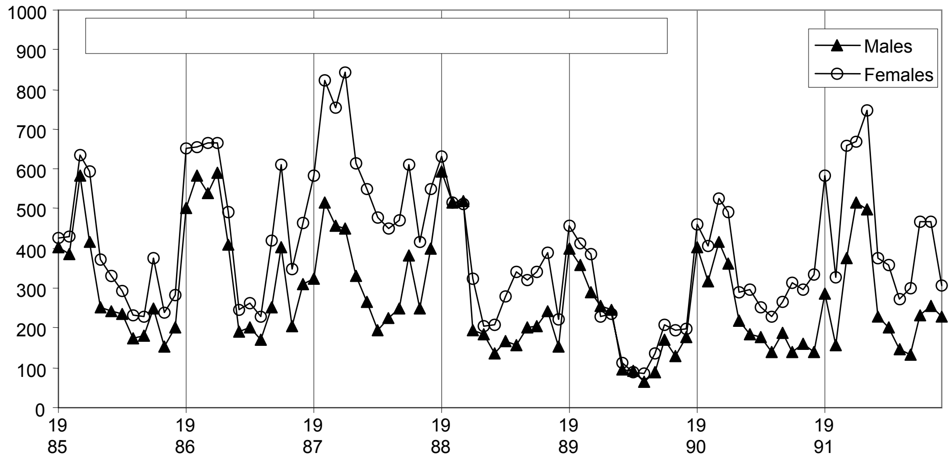

Figure 2: Monthly average biomass, *P. subtilis*, Suriname, 1985-1991

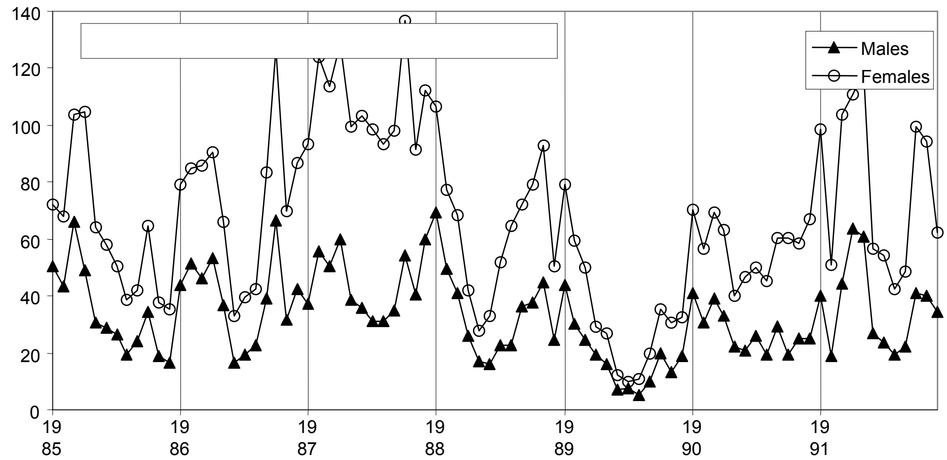

Figure 3: Monthly catch, *P. subtilis*, Suriname, 1985-1991

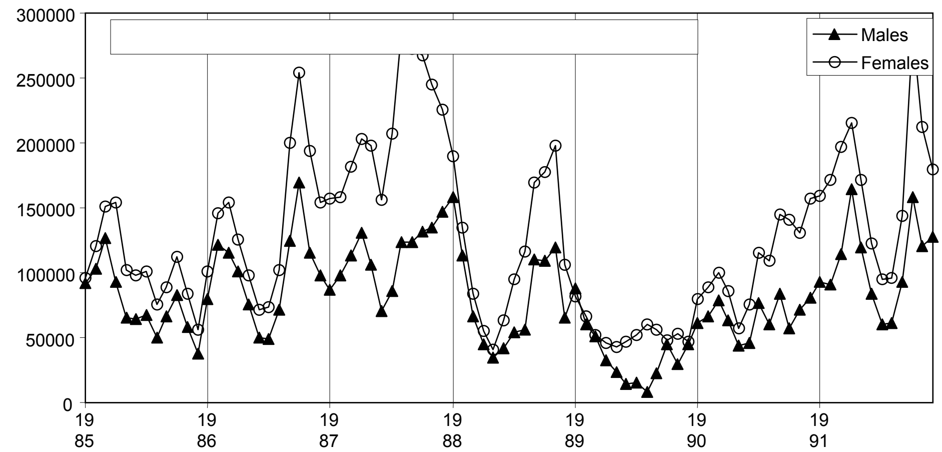

Figure 4: Monthly cpue (# caught/trip), *P. subtilis*, Suriname, 1985-1991

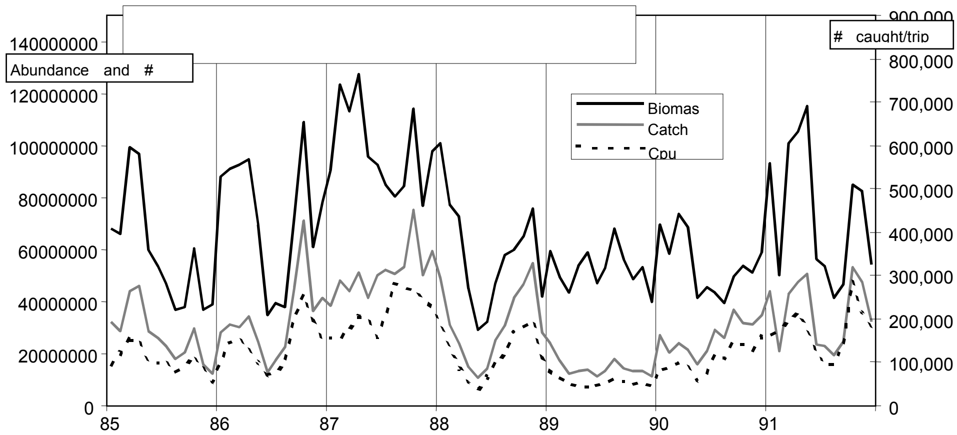

Figure 5: Monthly abundance, catch and cpue in numbers, *P. subtilis* female, Suriname, 1985-1991

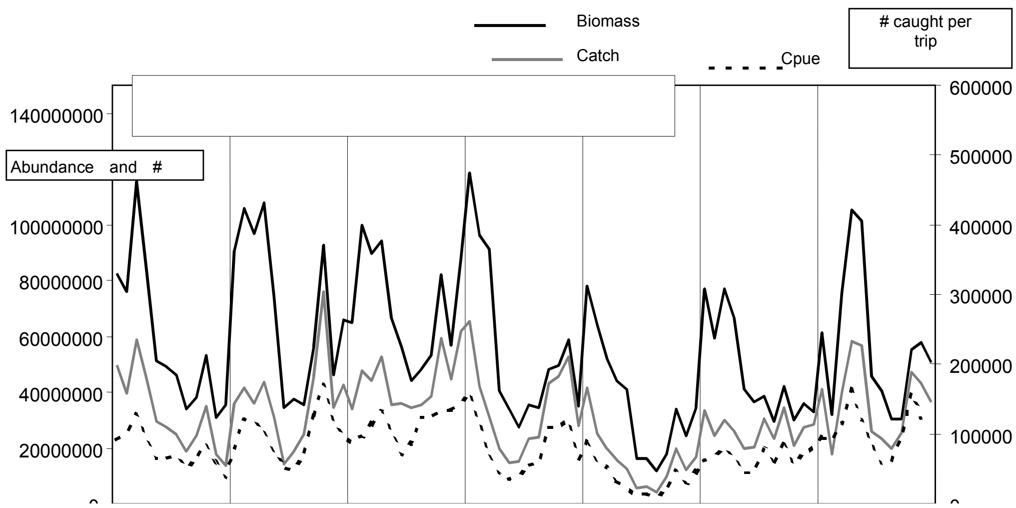

Figure 6: Monthly abundance, catch and cpue in numbers, *P. subtilis* male, Suriname, 1985-1991

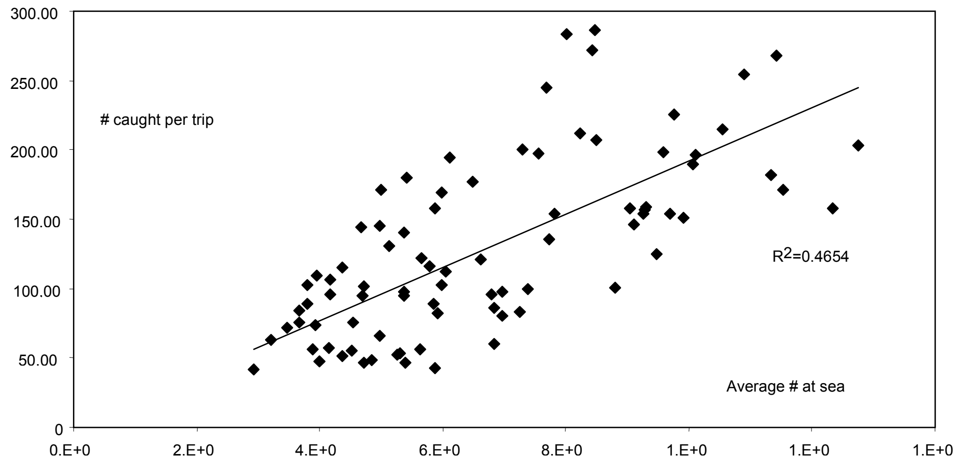

Figure 7: Cpue (# caught/trip) vs abundance, *P. subtilis*, female, Suriname, 1985-1991

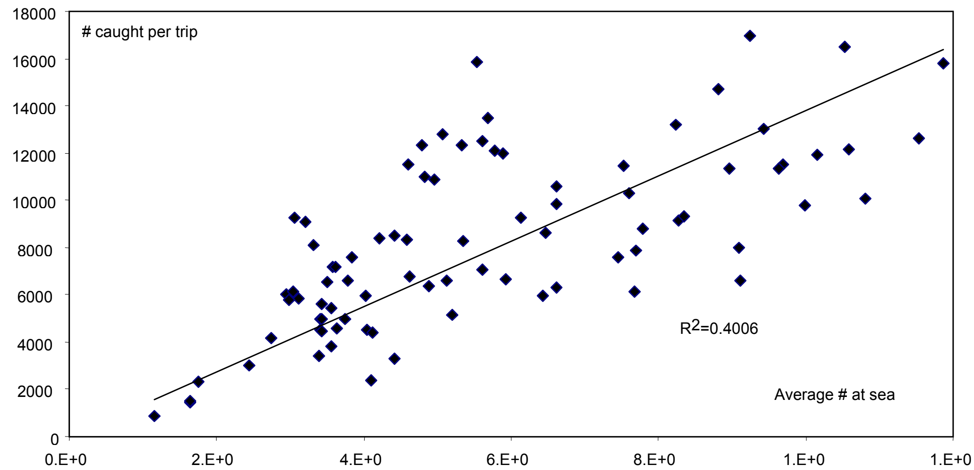

Figure 8: Cpue (# caught/trip) vs abundance, *P. subtilis,* male, Suriname, 1985-1991

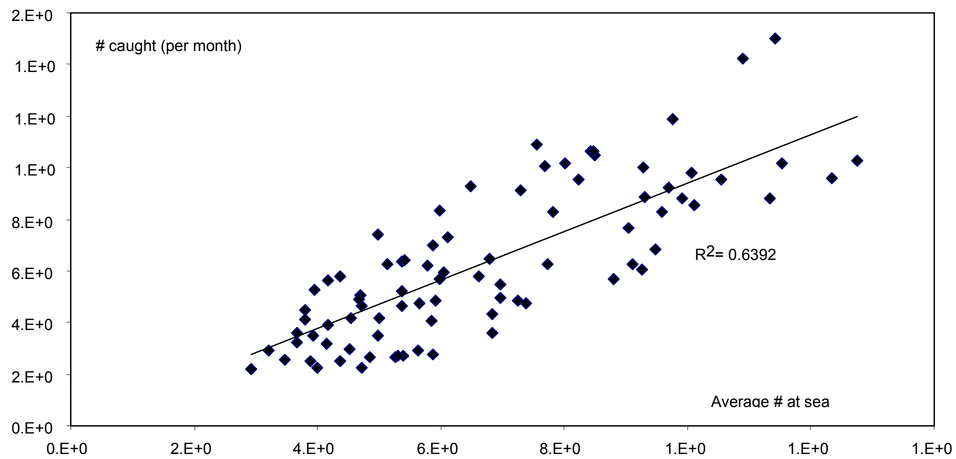

Figure 9: Catch in numbers vs abundance, *P. subtilis,* female, Suriname, 1985-1991

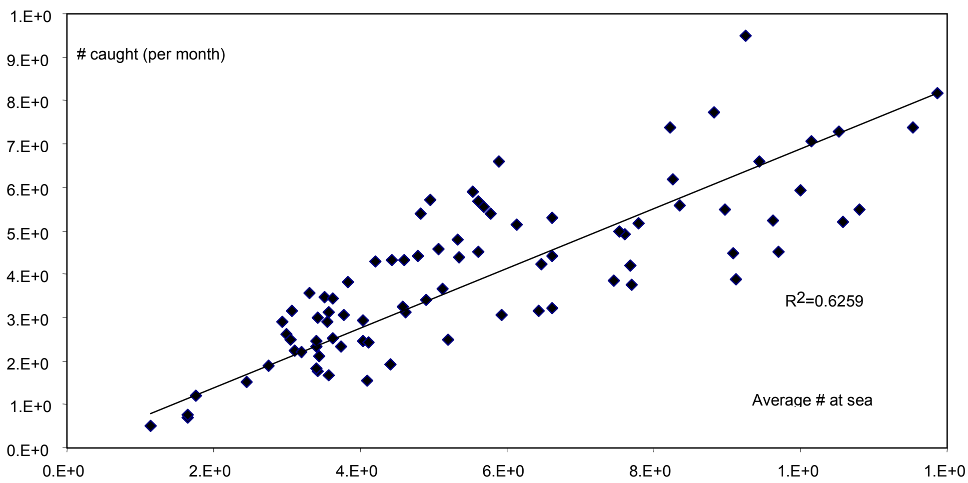

Figure 10: Catch in numbers vs abundance, *P. subtilis,* male, Suriname, 1985-1991

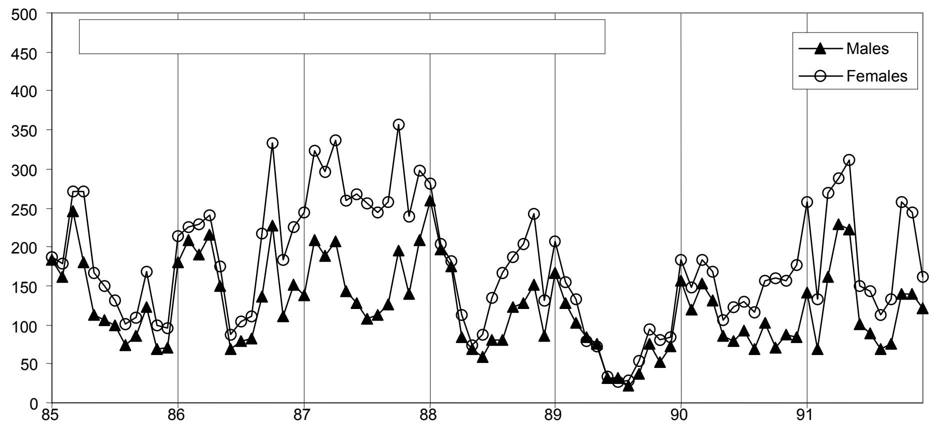

Figure 11: Monthly recruitment, *P. subtilis,* female, Suriname, 1985-1991

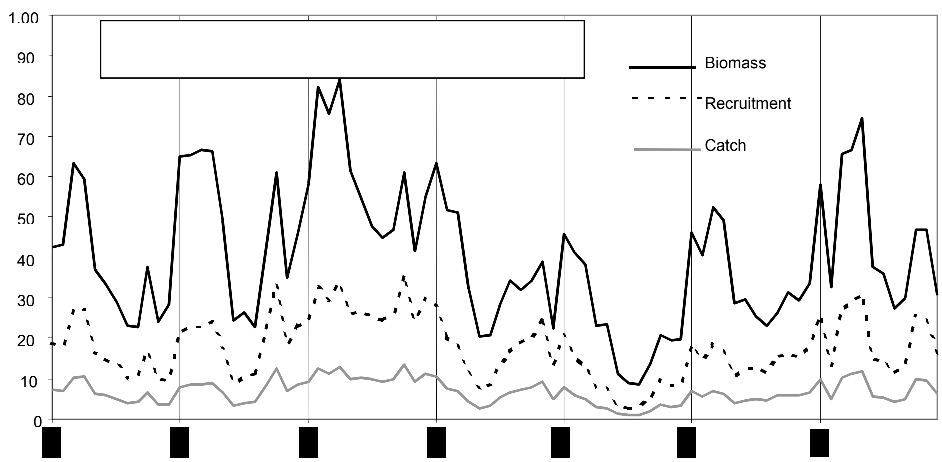

Figure 12: Monthly biomass, recruitment and catch (tonnes), *P. subtilis,* female, Suriname, 1985-1991

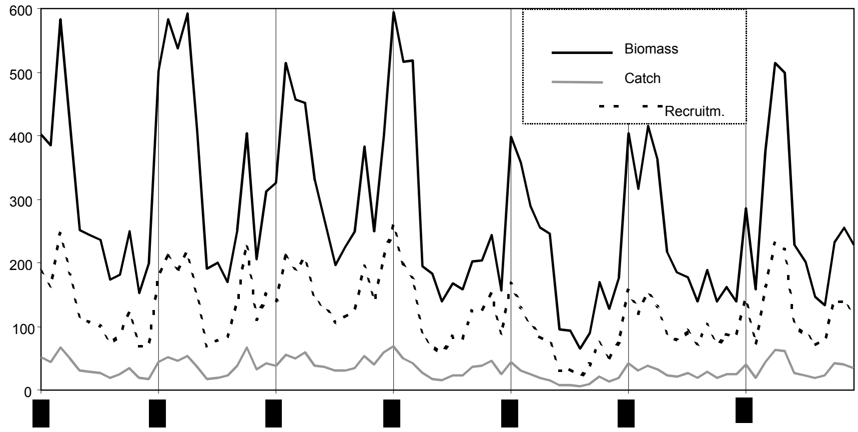

Figure 13: Monthly biomass, recruitment and catch (tonnes), *P. subtilis,* male, Suriname, 1985-1991

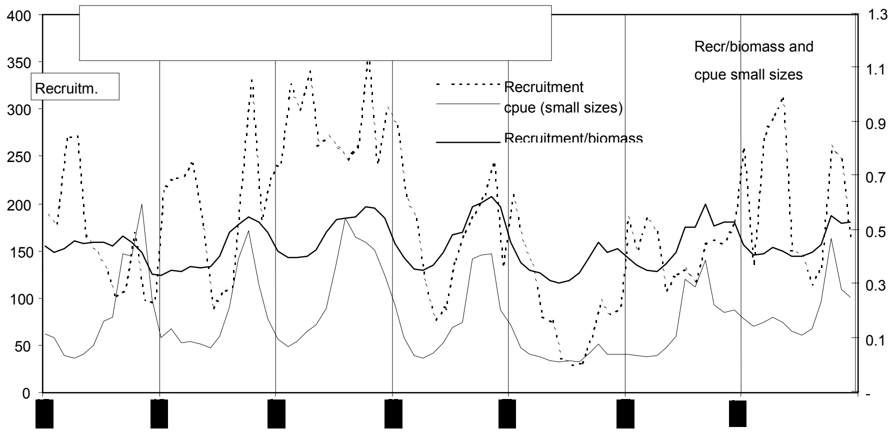

Figure 14: Monthly recruitment and recruitment indicators, *P. subtilis,* female, Suriname, 1985-1991

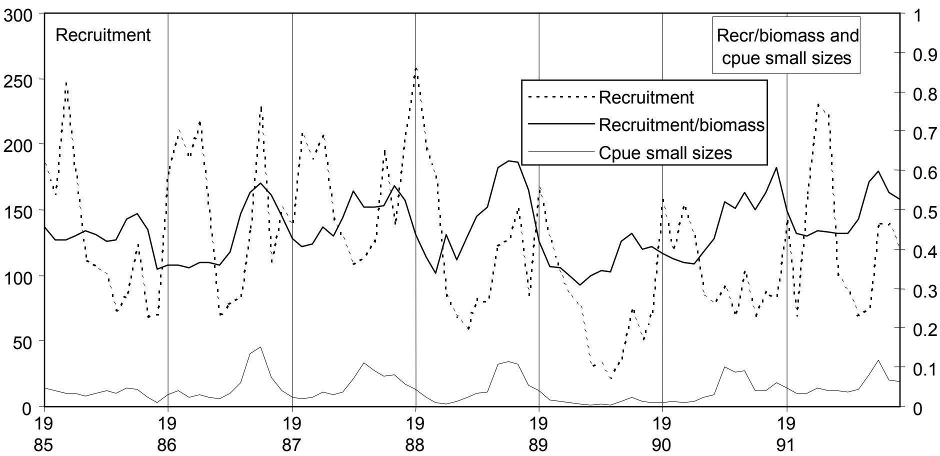

Figure 15: Monthly recruitment and recruitment indicators, *P. subtilis,* male, Suriname, 1985-1991

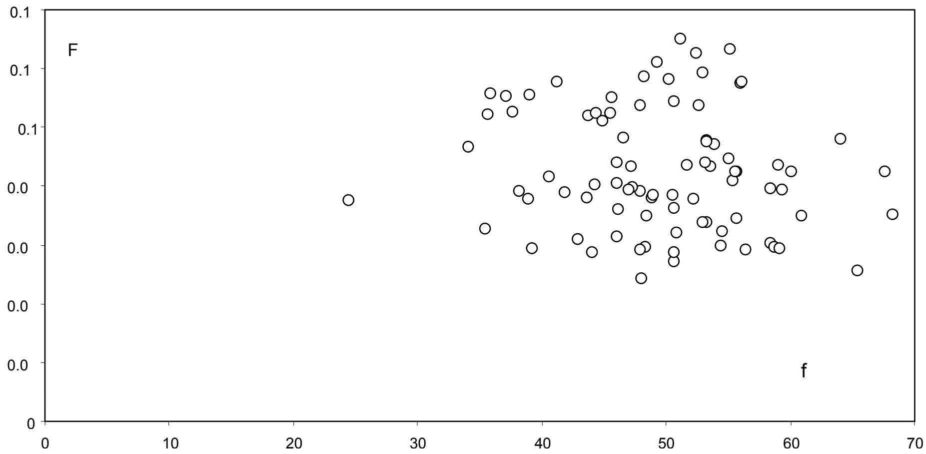

Figure 16: Fishing mortality vs effort (# trips), *P. subtilis,* female, Suriname, 1985-1991

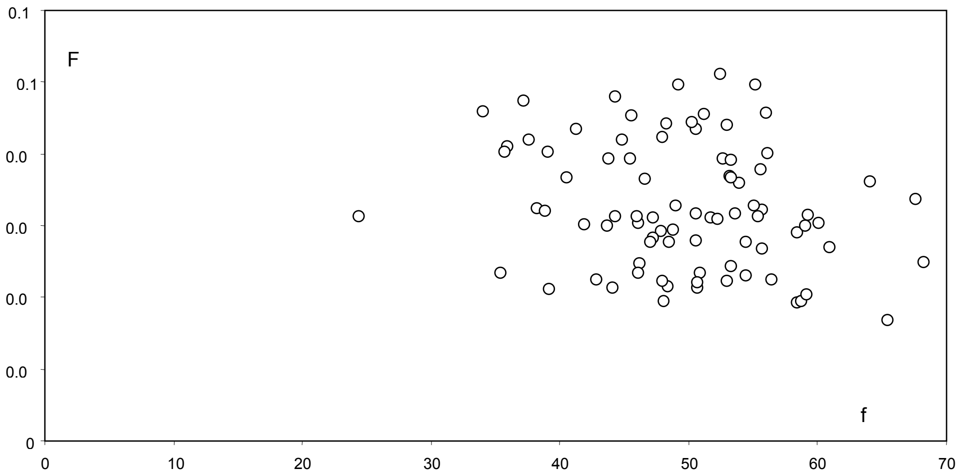

Figure 17: Fishing mortality vs effort (# trips), *P. subtilis,* male, Suriname, 1985-1991

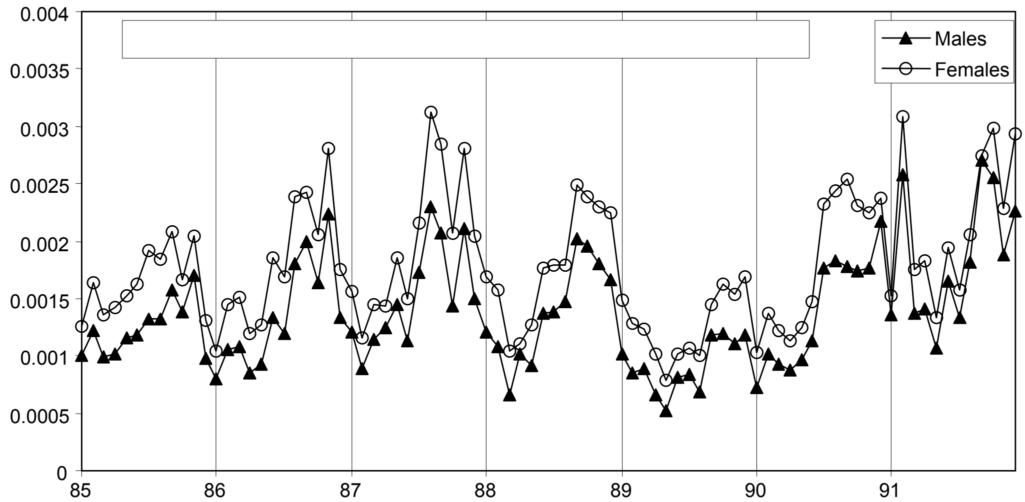

Figure 18: Monthly catchability coefficient, *P. subtilis,* Suriname, 1985-1991

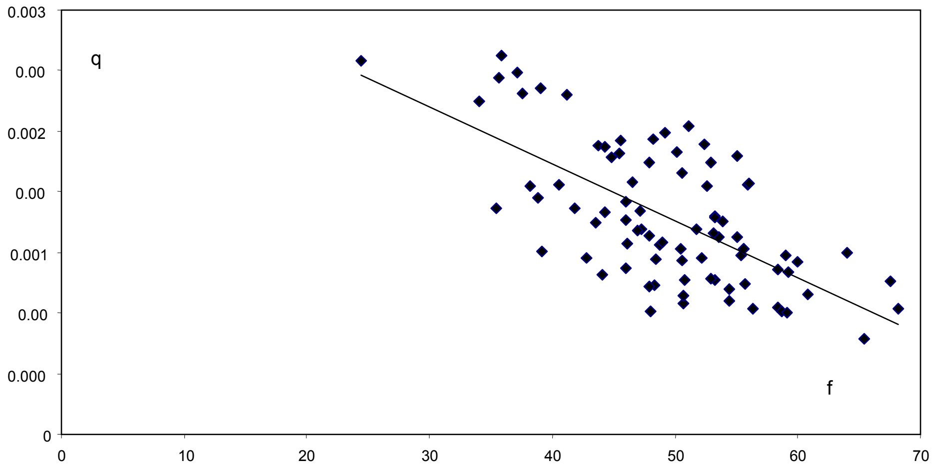

Figure 19: Catchability coefficient vs fishing effort, *P. subtilis,* female, Suriname, 1985-1991

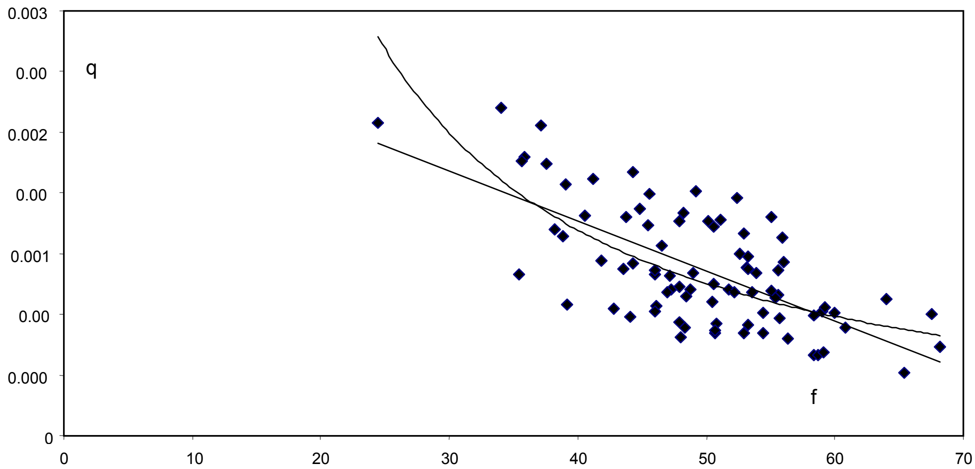

Figure 20: Catchability coefficient vs fishing effort, *P. subtilis,* male, Suriname, 1985-1991

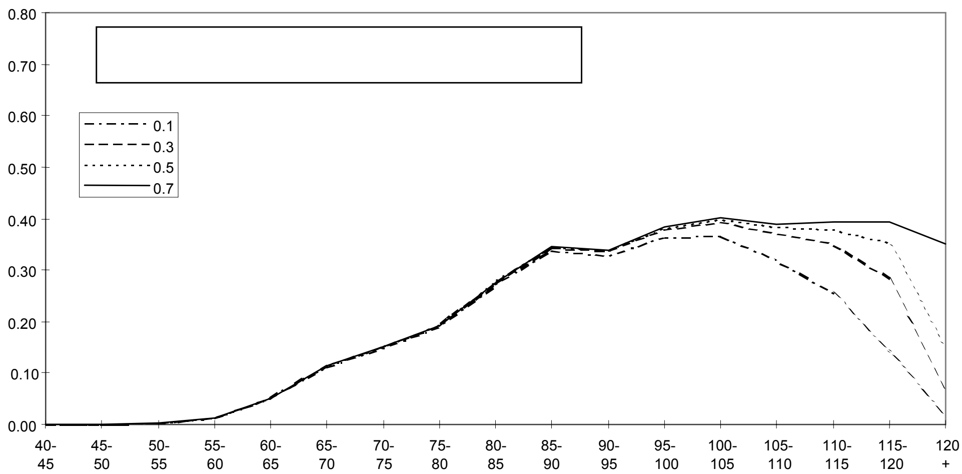

Figure 21: Impact of initial F/Z on fishing mortality by size, *P. subtilis,* female, Suriname, average 1985-1991

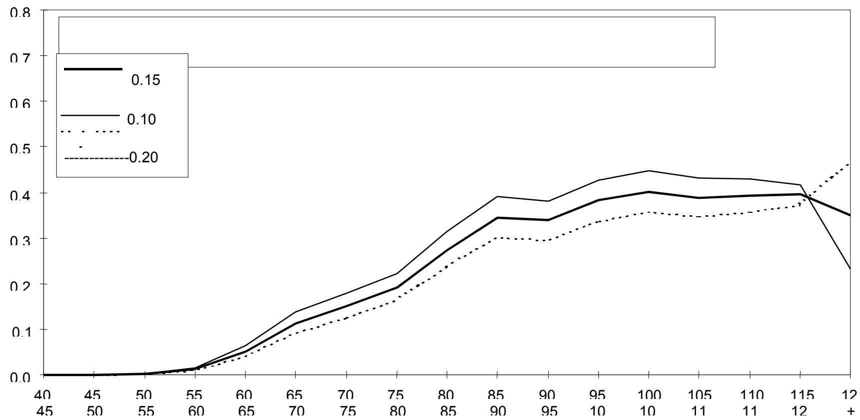

Figure 22: Impact of assumed natural mortality on estimated fishing mortality by size, *P. subtilis,* female, Suriname, average 1985-1991

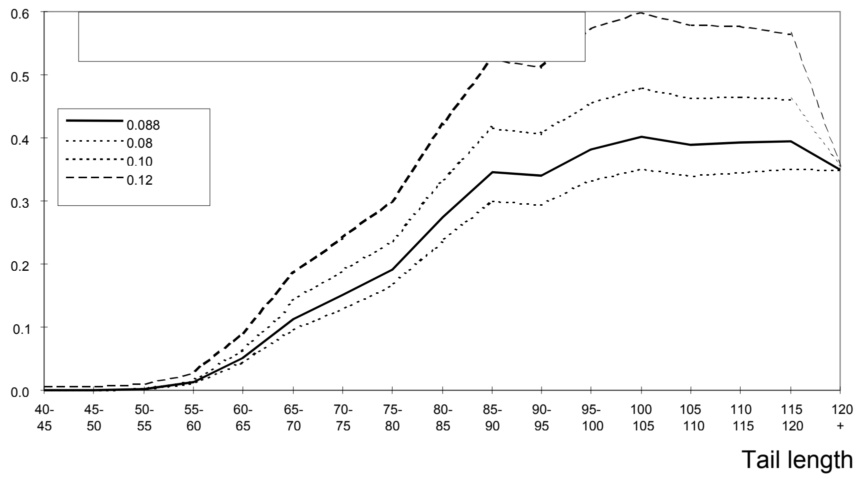

Figure 23: Impact of assumed K on estimated fishing mortality estimates by size, *P. subtilis,* female, Suriname, average 1985-1991

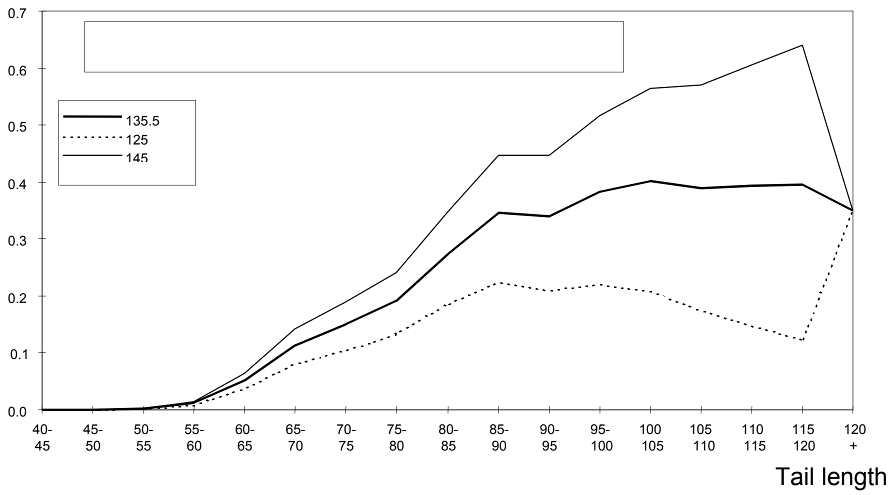

Figure 24: Impact of assumed L_∞ on estimated fishing mortality estimates by size, *P. subtilis,* female, Suriname, average 1985-1991

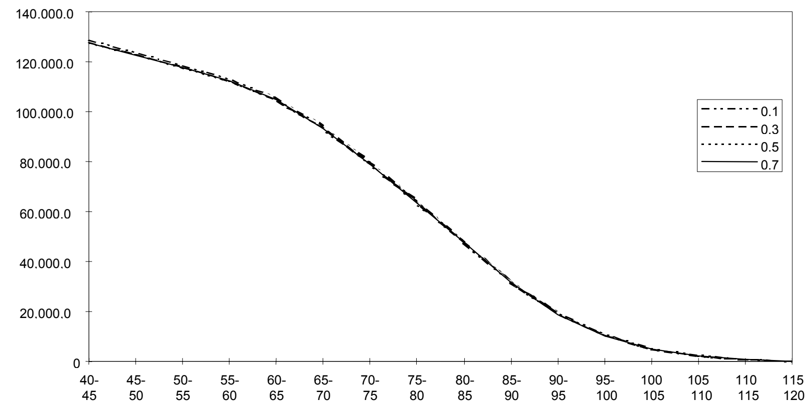

Figure 25: Impact of initial F/Z on abundance estimates by size, *P. subtilis,* female, Suriname, average 1985-1991

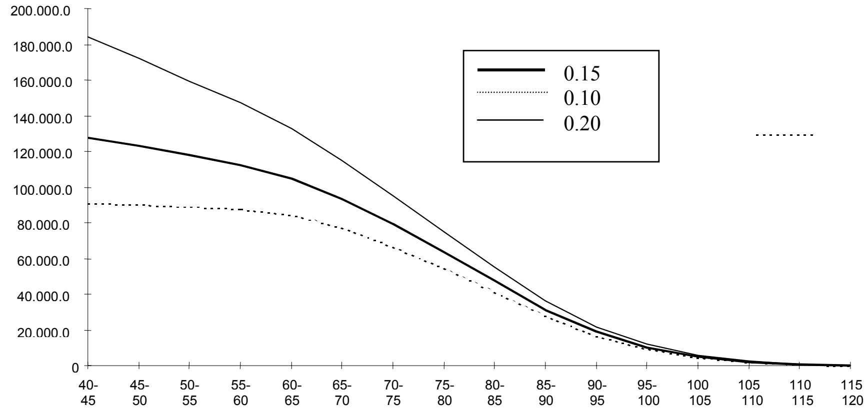

Figure 26: Impact of assumed natural mortality on abundance estimates by size, *P. subtilis,* female, Suriname, average 1985-1991

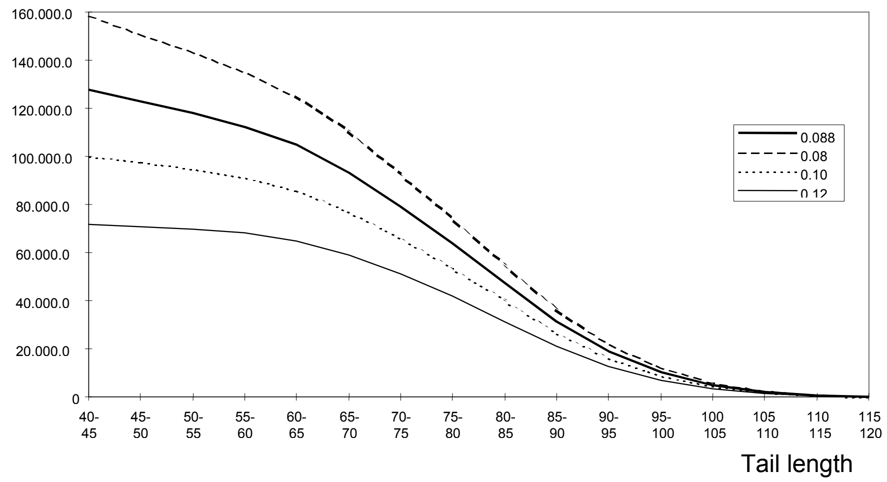

Figure 27: Impact of assumed K on abundance estimates by size, *P. subtilis,* female, Suriname, average 1985-1991

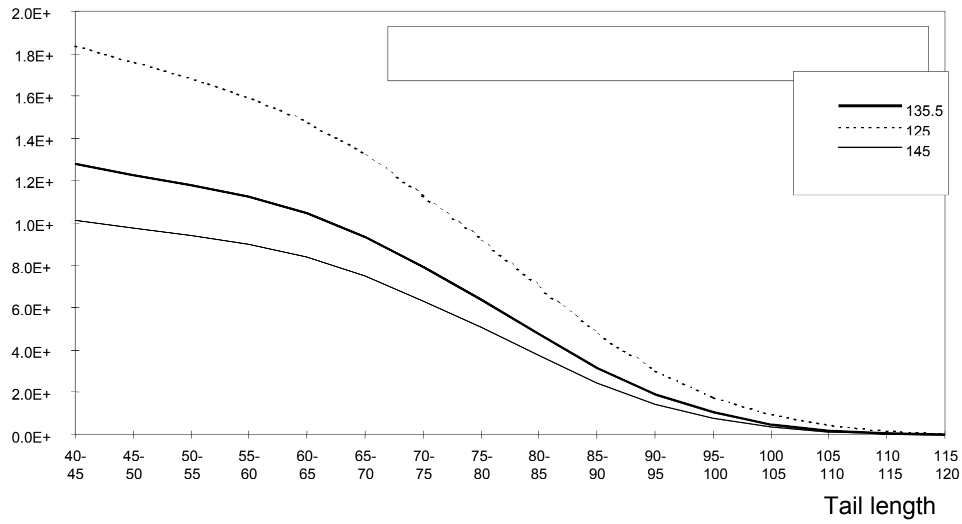

Figure 28: Impact of assumed L_∞ on abundance estimates by size, *P. subtilis,* female, Suriname, average 1985-1991