11 ASSESSMENTS OF SHRIMP FISHERIES OF GUYANA

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This report presents the results of the application of length based cohort analysis techniques and age-structured sequential population analysis on three species of penaeid shrimp in the Guyana shrimp fishery. These analyses update the length-based stock assessments of *P. brasiliensis* for the period January 1981 to December 1997 and provide new assessments of *P. notialis* for the period January 1990 through December 1997. *P. subtilis* was previously assessed using length based cohort analysis and in this workshop an age-structured sequential population analysis was applied to data for the period January 1981-December 1997. Similar analyses were performed with *P. brasiliensis* for the same time period. The results of both stock assessments showed a declining trend in abundance and recruitment to the fishery for the species investigated.

11.1 Background

The large penaeid shrimp resources of Guyana are exploited directly by 73 penaeid shrimp trawlers, of which the majority is owned and operated by foreigners and indirectly by 48 locally-owned seabob/finfish vessels (of which 15 were inoperative) of the industrial shrimp trawl fleet. These vessels are mostly of the standard Gulf of Mexico type trawlers and they operate at distances of 40-145 km offshore in waters 18-91 m deep. They range in length from 18.9 to 20.4 m and use jib trawl nets with 4 to 5 cm stretched mesh in the wings and 2.5 to 3.5 cm in the cod-end. The standard Gulf of Mexico type trawlers tow four nets at a time (twin trawling) while the Japanese fleet and most of the local fleet vessels tow two nets at a time. Turtle Excluder Devices (TEDs) are mandatory for the entire shrimp trawl fleet. Most of the local penaeid shrimp vessels switch to seabob/finfishing in the seasons when the penaeid shrimp resources are relatively scarce. A very small, but undetermined, amount of penaeid shrimp are caught at some times of the year by the Chinese seine vessels of the artisanal fleet (Shepherd *et al* 1997).

The majority of the penaeid shrimp trawlers essentially exploit four species of penaeid shrimp *(P. brasiliensis, P. notialis, P. schmitti and P. subtilis),* with finfish, small amounts of squid (*Loligo spp.*) and occasionally lobster (*Panulirus spp.*) as bycatch. The locally owned trawlers primarily exploit the Atlantic seabob (*Xiphopenaeus kroyeri*) and various finfish species (*Macrodon ancylodon, Micropogonias furnieri, Nebris microps, Arius spp.,Cynoscion spp.*), with small quantities of penaeid shrimp being caught as incidental catch (Shepherd *et al*. 1997).

The average total annual production of penaeid shrimp tails has been around 2800t for the period 1980-1985 and 2000t for the period 1986-1990. In more recent years (1990-1996), production has ranged between 1500t and 1900t per annum. This change indicates the possibility of significant changes in the temporal abundance of the shrimp species available to the fleets.

Earlier assessments (Shepherd *et al.* 1999) suggested that the *P. subtilis* stocks were not being overexploited, but there was an overall declining trend in the combined penaeid shrimp catches, which suggested the possibility that one or more of the other large penaeids *(P. brasiliensis, P. notialis* and/or *P. schmitti)* might be exploited at or above MSY. Preliminary assessments of *P. brasiliensis* for the years 1990 to 1997 (Shepherd *et al.* 1998) indicated very high F-values for the species. That was thought to be due to the lateral migration of the species in an easterly direction along the Brazil-Guianas shelf and to very high rates of exploitation of the species. *P. brasiliensis* is the most abundant species in the penaeid shrimp landings of the Guyana shrimp fishery, comprising between 40-60% by weight of the catch. It is marketed frozen, with the most important markets being Japan and the USA.

However, the Japanese fleet, which fished further offshore than the other fleets and targeted *P. brasiliensis* preferentially, ceased operations in November 1996.

11.2 Distribution of the species

Cervigon *et al* (1993) provides a description of the biology of the main shrimp species. The pink-spotted shrimp, *P. brasiliensis* occurs on mud and sandy mud at depths from 3-365m, with the highest levels of abundance occurring at depths ranging from 45-65m. The geographical range extends from North Carolina in the USA, through the Gulf of Mexico, to Rio Grande do Sul in Brazil. This species attains a maximum total length of 25.0 cm in females and 19.1 cm in males.

The southern brown shrimp, *P. subtilis*, is commonly found on mud and sandy mud bottoms at depths from 1-90m and occasionally at depths up to 190m (Fischer 1978). It occurs from the southern coast of the Greater Antilles and Honduras, along the Atlantic coast of Central America and the northern coast of South America, up to the State of Rio de Janeiro in Brazil. *P. subtilis* attains a maximum total length of 20.5 cm in females and 15.2 cm in males and constitutes an estimated 25% of the “pink shrimp” landings in Guyana.

The pink shrimp, *P. notialis*, is commonly found on mud and sandy mud bottoms. The species is present at depths from 1-90m, with fishable populations occurring between 27 and 82m. The geographical range extends from Cuba to the Virgin Islands and from Quintana Roo, Mexico, to Cabo Frio, Brazil. *P. notialis* constitutes an estimated 35 % of the “pink” shrimp landings in Guyana.

11.3 Biological data

Frequency and average weight for each length and sex class of *P. brasiliensis, P. notialis and P. subtilis* for the months October 1996 to September 1997 from commercial size categories landed in Georgetown were used to reconstruct monthly length frequency distributions of the total landings reported from the fishery. The statistical procedures to collect the above data, as well as the overall length frequency estimation procedures were explained in the Reports of the First and Second CFRAMP/FAO/DANIDA (1997 and 1998) Workshops on the Assessment of the Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf (FAO 1997b, FAO 1999a and FAO 1999b).

Table 11.1 Growth and mortality parameters used for the different shrimp species

Growth Parameters	*P. brasiliensis*		*P. notialis*		*P. subtilis*	
	Females	Males	Females	Males	Females	Males
L_∞ (mm tail)	153	137	149	115	136	109.6
K (month^{-1})	0.15	0.15	0.2268	0.248	0.088	0.097
M (month^{-1})	0.20	0.20	0.20	0.20	0.146	0.163

Growth parameters (Table 11.1) were obtained from a review of the existing literature on the species and region. However, information on *P. notialis* was missing for the Brazil-Guianas region, therefore, an average was used of the parameter values available from Cuba. This average was obtained after a pre-analysis of the various estimates available. This was accomplished by plotting L_∞ vs K independently for females and males and from those plots outliers were identified. Those outliers were excluded from the computation of the averages.

11.4 Catch and effort data

Monthly penaeid shrimp landings from January 1981 to December 1998 in pounds of tails per commercial size category are available. Statistics on the number of landings or its equivalent to fishing trips are available from 1986-1997. The monthly number of vessels that actively operated in the fishery, thus providing fishing effort in number of vessels, is available from 1986. The number of days fishing per trip is available for the period 1990-1996. The average number of days per trip seems to be constant at about 30 days. Thus, the total number of days fished per month was estimated as the product of the number of trips in a month by the 30-day average per trip. All this information was used to reconstruct length frequencies in the landings and to develop the indices of relative abundance necessary to calibrate some of the age-based stock assessment methods used in these analyses.

11.5 Stock assessment methods

The generalized length-based crustacean stock assessment algorithm of Ehrhardt and Legault (1996) and a calibrated age-based sequential population analysis algorithm developed for the assessment of shrimp stocks were used in this study.

Sequential population analysis (SPA) determines the populations as they ought to have been in order to have produced the catches obtained and requires catches at age in numbers of individuals. Sequential population analysis used here is based on Pope's approximation of the Baranov catch equation:

$$N_{t+1} = N_t e^{-M} - C_t e^{-M/2}$$

Successive backward or forward calculations are done for each cohort. Once natural mortality is fixed, the model only requires the final or initial population sizes. These start or end populations are estimated by fitting the model to CPUE data.

11.6 Results and discussion

The following results from the stock assessments are preliminary, but give an indication of the general states of the stocks. Further work is required on improving the data sources and assessments.

In general, the results of the TLCAs for both *P. brasiliensis* and *P. notialis* showed clear trends of decreasing abundance for both females and males for the time period studied. The TLCAs for *P. brasiliensis* were re-done for the entire period 1981-1997, using refined estimates of the growth parameters L_∞, K and M.

11.6.1 P. brasiliensis

Two very different methods were used to generate estimates of abundance; one was length cohort analysis and the other was sequential population analysis. In both methods, similar trends were observed both in the seasonal variability and the overall historic pattern of abundance. There is a general downward trend in abundance for both females and males, with the downward trend becoming much more significant in the 1990s. One of the major aspects of *P. brasiliensis* abundance is the loss of the recruitment peaks in both females and males in the 1990s, with the trend being more significant in females. SPA seems to slightly overestimate abundance of the females, but in the males, the estimates are strikingly similar to those obtained from the TLCAs. There is a slight smoothing behaviour of SPAs, which may be due to the way age frequencies are obtained from the length frequencies through the growth equation. This effect should be further researched and could be one of the tasks for the interim period.

There was a generally stable trend in fishing mortality rates up to the late 1980s (1989), but starting in the 1990s, there is a general increase in fishing mortality for both females and males. The average estimate of fishing mortality for the last year of the study is 0.3 $month^{-1}$ (3.6 $year^{-1}$), while the natural mortality rate (M) for the year is 0.2 $month^{-1}$ (2.4 $year^{-1}$). That seems to indicate a very significant difference between the natural mortality adopted and the overall annual fishing mortality rate. These high F-values may not be purely due to fishing mortality, but a fraction may be due to emigration out of the Guiana shelf area. Tagging and recapture studies could reveal whether those conclusions are valid or not, but such studies would have to be done within a regional context. However, there seems to be a general excess of fishing mortality on those stocks.

11.6.2 P. notialis

Assessments for *P. notialis* were done for the period 1990-1997, using TLCAs only, as time did not permit the SPA analyses. A slight decrease in abundance was observed in the males, but not in the females. It is not clear if that decrease is a local effect or if it is a continuing trend from the 1980s; the years 1980-1989 would be analysed in the interim period before the next workshop. There is clearly defined seasonality in the stocks.

Fishing mortality rates for *P. notialis* were found to be stable during the 1990s, with average F-values being slightly higher in the females than in the males. In general, the fishing mortality rates to which the stocks are subjected are the same as the natural mortality rates applied to the stocks. That seems to imply that the stocks are fully exploited.

11.6.3 P. subtilis

Estimates of abundance for *P. subtilis* were derived from both length cohort analysis and sequential population analysis. The two methods generated remarkable similarities both in the seasonal trends and in the long-range historic trends, despite the methodologies and data used. It can be concluded that starting in 1989/1990, a significant downward trend in abundance was observed for this species, very similar to that seen in *P. brasiliensis*.

Fishing mortality rates for *P. subtilis* were generally very stable and the seasonality is more or less the same; there is however a slight increase in fishing mortality in the late 1990s, especially among the females. The average F-values for the late 1990s have reached the value of the natural mortality rate (1.80 $year^{-1}$), which seems to suggest that the *P. subtilis* stocks are fully exploited.

It is also thought that there may be other factors that are contributing to the decreasing trends in abundance of the penaeid shrimp stocks. In earlier assessments (Shepherd *et al*. 1999) suggested that possible correlations between environmental variables, such as rainfall and river discharge and trends in abundance of *P. subtilis* in the Guyana shrimp fishery should be investigated. Similar attempts should be made to examine correlations, if any, between those environmental variables and trends in abundance of *P. brasiliensis* and *P. notialis*.

The growth parameters L_∞, K and M used in the analyses were obtained from the literature. It is known that the initial estimates of F from the length-converted catch curves (LCCC) are very sensitive to the values of the input growth parameters used. Those initial estimates of F from the LCCC analyses would have in turn influenced the values of F/Z used as tuning indices in the length cohort analyses. While the values used were obtained from the region, it could be that those animals have different growth curves, thus efforts should be made to generate growth parameters for the shrimp stocks in the Guyana EEZ using available length frequency and weight at size data. Those should presumably refine the analyses and make them more robust.

11.7 Conclusions

(i) The three shrimp species analysed show a status of full exploitation for *P. notialis* and *P. subtilis* and overexploitation for *P. brasiliensis* based on the estimates of fishing mortality relative to natural mortality. It is recommended that the levels of fishing effort in the penaeid shrimp and seabob fisheries be monitored very carefully.

(ii) There is a general downward trend in the abundance of *P. subtilis* and *P. brasiliensis*, however, those trends are more conspicuous during the late 1980s and throughout the 1990s. It is not clear what is the origin of such trends, but they may be due to a combination of sustained environmental changes and exploitation.

(iii) There are some clear indications of potential relationships between the environment and recruitment in all three species. Lack of time prevented the completion of those analyses.

11.8 Recommendations

(i) There should be a regional review of the growth and mortality parameters. Existing information may allow such comparative analyses to improve the statistical quality of the parameters.

(ii) The comparative analyses of the stock assessment algorithms should be continued and the methods expanded to include environmental variables. Trends in recruitment and abundance especially should be correlated with environmental variables.

(iii) Analyses should be done for the seabob fishery taking into account the interactions with the penaeid shrimp fishery (multi-species / multi-fleet analyses).

(iv) The *P. notialis* assessments should be continued to include the earlier years of the historic database (1981-1989) and sequential population analyses subsequently done for the species.

(v) Special attention should be paid to the exploitation trends observed in the fisheries as the fishing mortality rates are at or beyond the levels of full exploitation.

(vi) All aspects of the stock assessment work carried out to date should be critically reviewed, especially with regards to checking the database.