6 NORTHERN BRAZIL SHRIMP FISHERIES

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6.1 Description of the fisheries

A description of the Northern Brazil shrimp fisheries, especially of the industrial pink shrimp (*Penaeus subtilis*) fishery, was presented in the previous workshop. The main features of these fisheries can be summarised as follows:

- A main fishing ground is located between the mouth of Parnaíba River and the border of French Guyana, along the coast of the States of Maranhão, Pará and Amapá. The main landing port is located in the city of Belém, State of Pará, where are also found most of the processing plants.
- Fisheries are conducted by artisanal, small scale and industrial vessels and the most important species caught are pink shrimp (*Penaeus subtilis*), white shrimp (*Penaeus schmitti*) and seabob shrimp (*Xiphopenaeus kroyeri*).
- The artisanal fisheries are conducted in estuaries and shallow waters using hand-operated gears from canoes. Small motorised trawlers with a length of 7 to 11m are commonly used to catch seabob shrimp and white shrimp in eastern part of the area.
- In general, the industrial shrimp trawlers have steel hulls and a total length varying from 19 to 25m, similar to the type used in the Gulf of Mexico. Most of the catches are composed of pink shrimp. The number of boats operating is shown in Table 6.1.
- Almost all of the shrimp produced by the industrial fishery is processed as head-off frozen products and a small amount as whole shrimp. The products are exported mainly to the United States of America and Japan.
- Until 1997, the main management measures were: limitation of the number of licensed industrial boats to 250; a closed season from December to January; prohibition of trawling within 10 miles of the coast in Pará and Amapá and 3 miles of the coast in Maranhão.
- From 1994 onwards, the industrial fisheries suffered an economical crisis due to the low catch rates. Many boats stopped their operation and the processing sector was restructured by reducing the number of fish processing plants in Belém to only two. In the last two years, however, catch rates have increased improving the economic performance of the industry.

Following, this report presents a summary of the present situation of the industrial fisheries of *Penaeus subtilis* and the available information on catch and effort data, stock assessment and management of the fisheries, as well the results obtained during the workshop.

Table 6.1 - Landings, fishing effort and CPUE of the industrial pink shrimp fisheries in Northern Brazil, from 1970 to 1998. (Source: CEPNOR / IBAMA)

Year	Landings (kg)		Number of		Days at	CPUE		
	Tails	Whole	Boats	Trips	Sea (DS)	Boat	Trip	DS
1970	169 789	264 871	6	42	987	28298.2	4042.6	172.0
1971	646 485	1 008 517	27	169	3 518	23943.9	3825.4	183.8
1972	264 864	413 188	16	88	1 896	16554.0	3009.8	139.7
1973	1 084 594	1 691 967	28	182	4 550	38735.5	5959.3	238.4
1974	716 625	1 117 935	34	221	5 967	21077.2	3242.6	120.1
1975	495 418	772 852	26	153	4 394	19054.5	3238.0	112.7
1976	871 955	1 360 250	29	248	7 018	30067.4	3515.9	124.2
1977	1 162 124	1 812 913	48	330	9 133	24210.9	3521.6	127.2
1978	1 718 407	2 680 715	50	299	8 502	34368.1	5747.2	202.1
1979	2 063 529	3 219 105	86	493	11 256	23994.5	4185.7	183.3
1980	3 571 165	5 571 017	158	912	23 913	22602.3	3915.8	149.3
1981	4 476 648	6 983 571	150	913	24 684	29844.3	4903.2	181.4
1982	3 770 477	5 881 944	155	807	25 702	24325.7	4672.2	146.7
1983	3 899 217	6 082 779	179	892	27 273	21783.3	4371.3	143.0
1984	5 493 466	8 569 807	254	1 339	40 355	21627.8	4102.7	136.1
1985	5 131 828	8 005 652	287	1 450	49 677	17880.9	3539.2	103.3
1986	4 574 966	7 136 947	256	1 341	46 510	17871.0	3411.6	98.4
1987	6 435 427	10 039 266	246	1 362	46 852	26160.3	4725.0	137.4
1988	6 356 622	9 916 330	228	1 247	39 593	27879.9	5097.5	160.5
1989	4 489 849	7 004 164	242	1 227	39 650	18553.1	3659.2	113.2
1990	3 918 749	6 113 248	256	1 136	36 226	15307.6	3449.6	108.2
1991	4 328 753	6 752 855	243	1 117	36 379	17813.8	3875.3	119.0
1992 (*)	3 888 590	6 066 200	188		30 838			126.1
1993 (*)	5 256 606	8 200 305	218		35 679			147.3
1994 (*)	4 071 472	6 351 497	209		34 261			118.8
1995 (*)	3 922 517	6 119 126	180		29 479			133.1
1996 (*)	3 739 746	5 834 004	163		26 794			139.6
1997 (*)	2 833 543	4 420 327	137		22 444			126.2
1998 (*)	3 473 956	5 419 372	131		21 462			161.9

(*) Estimations based on data of Pará/Amapá, subject to revision

6.2 Trends in catch and effort

When the fishing agreement between Brazil and USA expired in 1978, the national fleet size reached a peak in 1987/1988, landing about 6 400 t tails. Thereafter catches fluctuated, between 5 257 t in 1993 and 2 640 t in 1997. In general however, there has been decreasing trend in the landings, although a slight recuperation is observed in 1998, with a total catch of 3 018 t (Table 6.1 and Fig. 6.1 and 6.2).

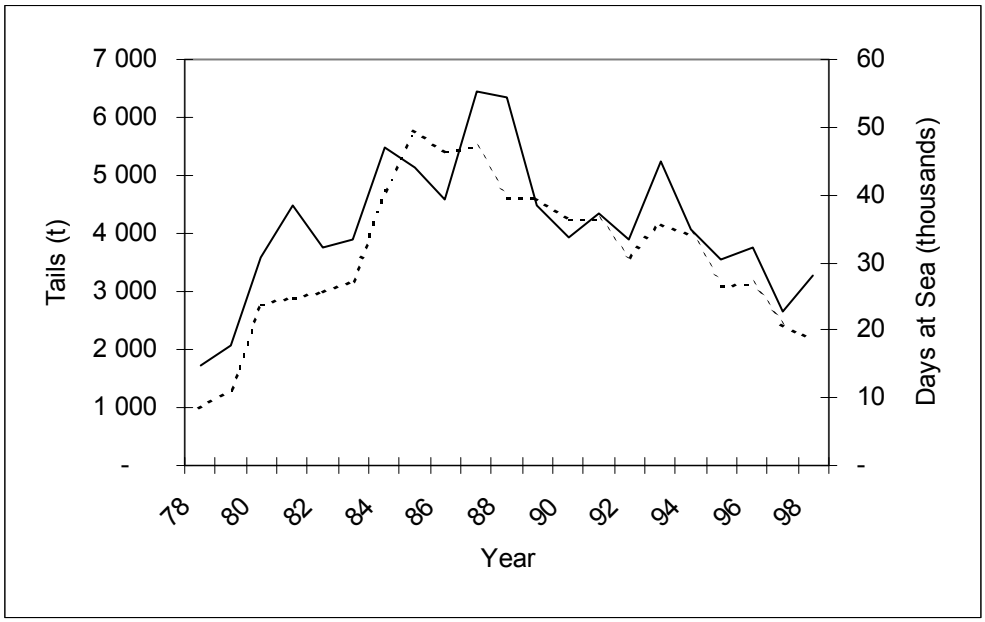

Figure 6.1 Northern Brasil fishery, catch (—) and effort (---) of *P. subtilis*

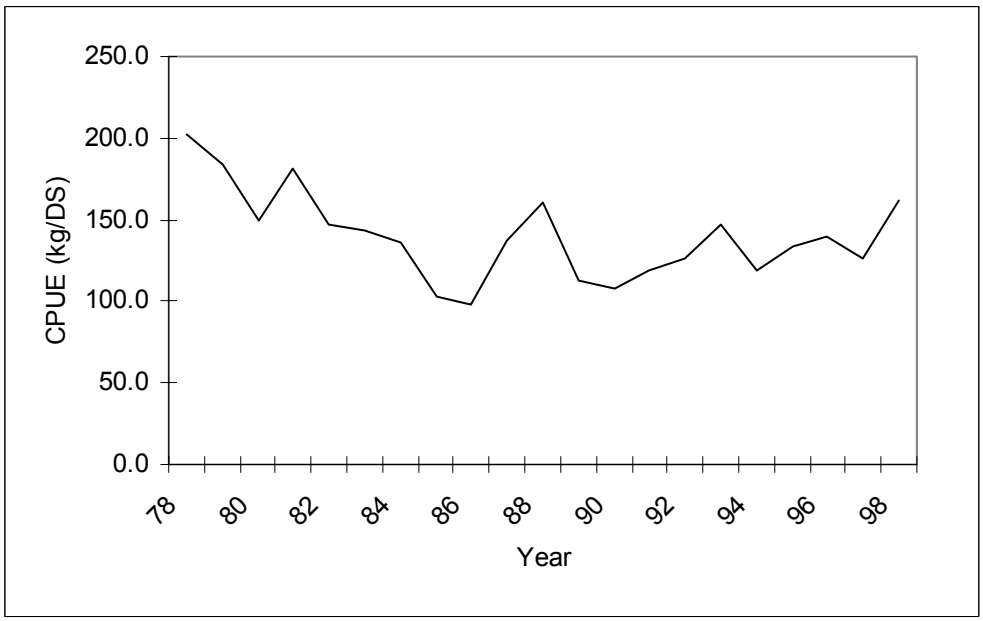

Figure 6.2 Northern Brasil fishery, CPUE of *P. subtilis*

The fishing effort, measured as number of days at sea (DS), increased continuously until 1985, when it reached 49 667 DS. In the following years, effort has gradually decreased to

20 312 DS in 1998. Although landings are correlated with fishing effort (R^2=0.74, df=19), much of the variation is unexplained (Fig. 6.1).

The catch (landings) per unit of effort, here defined as the amount of tails in kilograms per day at sea (kg DS^{-1}), has decreased with the increase of the fishing effort. So the recuperation of the CPUE between 1988 and 1998 (Fig. 6.2) could be a consequence of the reduction of the fishing effort over those years.

6.3 Population dynamics and stock assessment

Sudepe (1985), Sudepe (1986), Isaac *et al.* (1992), Vieira *et al*. (1977) are some of the main studies conducted on the dynamics and assessment of the stock of pink shrimp from the Northern coast of Brazil. There follows the main results of these studies.

P. subtilis has two peaks in spawning, the first from March to July and the second from September to October. The mean size of first maturation for 50% of the individuals is 110 mm and the mean size at which 50% of the individuals begin to spawn ($L_{50\%}$) is 140mm.

Recruitment to the open sea seems to occur with greater intensity during two distinct periods: from December to May and from July to August. The first is more evident and is when the higher catch rates are observed in the fishery. The time spent by juveniles to move from the nursery areas to the sea was estimated to be two or three months.

Table 6.2 The main population parameters of *P.subtilis*, estimated by Isaac *et al* (1992)

	M ($year^{-1}$)	L_∞ (total mm)	K ($year^{-1}$)
Males	1.920	177	1.17
Females	1.752	217	1.06

Table 6.3 Results from previous production model based stock assessments. The CPUE reference indicates the fleet used as reference to standardise the overall CPUE

	Model Applied	MSY (whole)	f_{MSY} (DS)	CPUE at MSY (kg/DS)	CPUE reference fleet
Sudepe 1985	Fox	8 400	51 000	165	Brazilian fleet
Sudepe 1985	Fox	7 300	32 000	228	Mean of all fleets
Sudepe 1986	Fox	7 900	44 886	176	Fleet of Pará
Isaac *et al*. 1992	Fox	8 499	52 436	162	Fleet of Pará
	Schaefer	9 016	72 298	125	Fleet of Pará

Estimations of maximum sustainable yield of *P. subtilis* in northern Brazil have been done using production models (Sudepe 1985, Sudepe 1986 and Isaac *et al*, 1992). In all cases, a standard CPUE was calculated dividing the total catch by a CPUE of reference.

As can be noted, the MSY varies from 7 300 and 9 016 t whole weight and the annual f_{MSY} from 32 000 to 72 298 days at sea. The large variation in f_{MSY} results in a correspondent variation in CPUE (see Table 6.3).

Recently a comprehensive stock assessment of the pink shrimp resources in the Northern Region of Brazil was done (Ehrhardt 1998, in press). In this paper, a tuned length-based cohort analysis was applied, using estimations of monthly catches and length frequency samples. The main conclusions of this study can be summarised as follows:

- The recruitment abundance follows trends in seasonal rainfall, which is consistent with the general dynamics of the environment and of the species.
- Landings in this fishery appear to be driven by levels of seasonal abundance while catch per unit of fishing effort reflects at best a weak correlation with stock abundance.
- Under the levels of fishing effort observed during the study period, it appears that the fleet is able to catch biomass that is a function of the abundance and not of the amount of effort deployed.
- Catch per unit of fishing effort is related to the way the available catchable biomass was distributed among fishing effort units. This conclusion was also supported by a decreasing trend in seasonal catchability as seasonal fishing effort increased.
- The constancy of the average seasonal F estimates observed in males and females (estimated as the slope of the line relating catch and average stock abundance), underlies the lack of relationship between F and fishing effort. However, under high levels of fishing effort, the amount of catch retrieved from the stock is proportional to stock size. This conclusion is significant when considering the economic consequences of open access policies or when dimensioning optimum fleet size for this fishery.
- The levels of exploitation observed during the study period appear well within the expected fishing mortality levels inflicted on an annual species exhibiting high natural mortality rates. In effect, the seasonal fishing mortality rates never exceeded the monthly natural mortality rates assigned to the species and sex.

The study also presented the following recommendation for future work:

- The analyses were based on biological data from a single year (1980), consisting of sex ratios and tail weight frequency distributions by commercial size categories. These data were used to reconstruct tail length frequencies in the years included in the study. It is recommended that a search for similar historical biological data be made to test whether changes in the biological condition of the shrimp have occurred through time, or if significant differences are observed between data sets. If this data set does not exist, then it is recommended that new data be collected.
- The analysis in the study used a stock assessment algorithm under equilibrium conditions to estimate abundance and fishing mortality. It is recommended that the results obtained here are tested against age-based stock assessment algorithms so as to include the dynamic linkages that might exist among monthly cohorts.
- Further analysis on biomass production from cohort analysis should be attempted and compared with results based on biomass dynamic models. In this way, some of the important non-linear relationships between CPUE and average stock abundance and between catchability and fishing effort may be elucidated.
- The results of the analyses indicate the need to integrate economic data and economic analysis into the assessment of the *P. subtilis* fishery in the Northern Region. This is an important step to be taken in the future given findings in this report.

On the other hand, during the 1998 workshop, biomass dynamics models were applied to assess the stocks and the following preliminary results were obtained:

- The recruitment pattern follows the monthly rainfall pattern and presents high interannual fluctuations;
- The maximum sustainable yield was estimated in about 4 400 t and the optimal fishing effort in 31 000 days of sea (Table 6.4).

Table 6.4 Results from the biomass dynamic model fitted to the catch and effort data in the 1998 workshop. Limit and target reference points are given

Parameters		Limits		Targets	
r	1.10	**MSY**	4 906 903	$C_{0.9msy}$	4 416 213
K	17 843 284	f_{MSY}	46 737	$F_{0.9msy}$	31 158
B_{1991}	12 104 549				
q	0.000012	**SSQ**	0.41	$CPUE_{0.9msy}$	141.3

6.4 Stock assessments

The following assessments were conducted at this workshop. Results presented are preliminary as there is an on-going unfinished task in improving the basic data. The results are summarised and update previous analyses.

6.4.1 Cohort analysis

During the present workshop, the data for the period of 1995 to 1998 were used in a tuned length-based cohort analysis. The methodology applied is same described in Ehrhardt *et al* (in press), except that weight frequency samples were converted to length frequency samples using a length-weight relationship estimated by Rocha and Barbosa (1977).

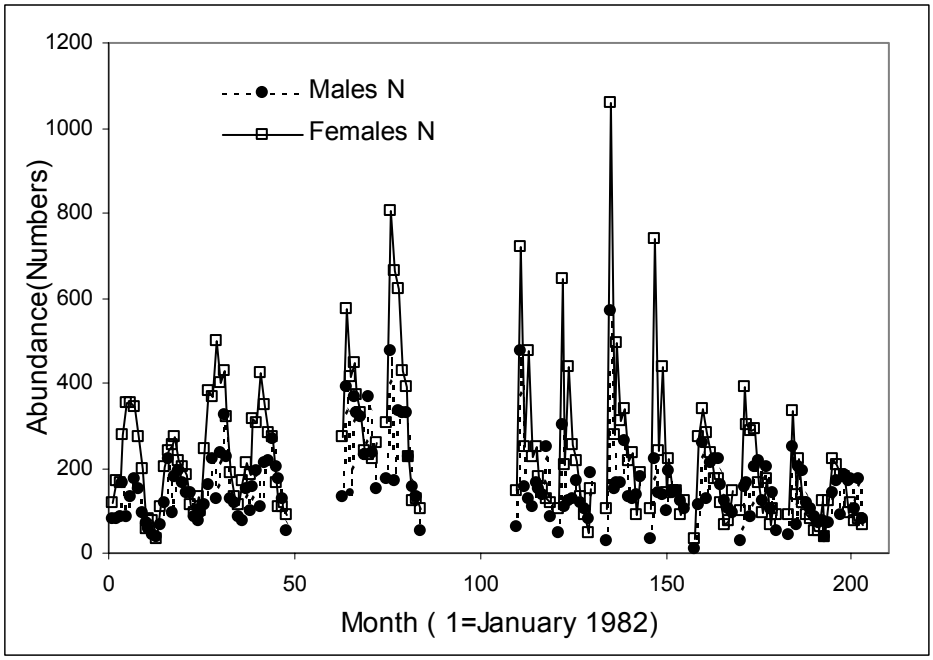

Figure 6.3 Average abundance of *P. subtilis* estimated for each month from a tuned length-based cohort analysis

The results found were similar to the ones found by Ehrhardt *et al* (1998) and allow the same conclusions to be drawn. However, the abundance of the stock from the period 1995-96 (months 156-168), now incorporated into the analysis, was very low (Fig. 6.3). As no reason could be found for this, it is possible the data may be biased. Only after a critical revision of the data, that is presently being carried out and a new analysis it will be possible to have reliable results.

6.4.2 Biomass dynamic models

The analysis previously carried out using biomass dynamic models was also updated, with the incorporation of the data for the period of 1995-98. The results were similar to the 1998 workshop results. They are not compatible with the cohort analysis results for this latter period, according to the Table 6.5.

Table 6.5 Results from fitting the biomass dynamic model updating the results of the 1998 workshop (Table 6.4). Limit and target reference points are given

Parameters		Limit		Targets	
r	0.80	**MSY**	4 712 891	$\mathbf{C_{0.9msy}}$	4 241 602
K	23 694 951	$\mathbf{f_{MSY}}$	45 850	$\mathbf{F_{0.9msy}}$	30 567
$\mathbf{B_{1991}}$	17 904 004				
q	0.00000868	**SSQ**	0.35	$\mathbf{CPUE_{0.9msy}}$	138.8

6.5 Management

The present management measures for the shrimp fishery in North region of Brazil are directed mainly at the control of fishing effort and protection of the recruitment. Until 1997, the management measures for this fishery were:

- Limitation of the number of licensed vessels to 250;
- A closed season from December to January;
- Prohibition of trawl fisheries in coastal zone up to of 10 miles in Amapá and Pará and up to 3 miles in Maranhão.

In 1997, after negotiations with the shrimp fishery industry, the set of measures was temporarily modified to the following:

- Limitation of the number of licensed vessels to 185;
- Close the fishery in the area between latitudes 00°20' N and 01°10' N and longitudes 47°00' W and 47°55' W;
- A total annual allowed catch (TAC) of 4600 t;
- Prohibition of trawl fisheries in the coastal zone up to of 10 miles in Amapá, Pará and Maranhão.

6.6 Research programme

A research programme for shrimp is being carried out in the State of Pará, by the Fisheries Research Center of the North of Brazil (CEPNOR) and consists of biological sampling and collection of data on catch and effort. The programme covers both industrial and artisanal fisheries. The research intends to obtain grants to study the whole life cycle of the species.

The sampling of the industrial fishery consists of the collection of monthly data on species, sex and tail length of 100 specimens within each commercial category. Samples of juveniles are obtained at three different places in the estuaries of the eastern coast of Pará. In each location, about 300 specimens are caught with fixed frame trawls operated by hand. The sample is taken to the laboratory for analysis. Information on species, sex, total length, tail

length, total weight and tail weight are obtained. During the sampling, information on salinity, temperature, moon phase and duration of the trawl are also recorded.

Recently, a joint sampling programme aboard industrial vessels has been established. It consists of the separation of all the shrimp catch of one trawl, every 15 days on a trip, or whenever the boat moves to another fishing ground. This programme involves ten vessel captains. The latitude and longitude of the trawl is also recorded. At landing, the sample is weighed and data on species, sex, gonad maturation stage, total length, tail length, total weight and tail weight is obtained from a 10% sub-sample.

The catch and effort data are obtained from the processing reports at the shrimp processors. Information on the name of the boat, date of departure and arrival, total catches and weight of processed products per commercial category are recorded.