Copies of FAO publications can be requested from:
Sales and Marketing Group
Information Division
FAO
Viale delle Terme di Caracalla
00100 Rome, Italy
E-mail: publications-sales@fao.org
Fax: (+39) 06 57053360
WESTERN CENTRAL ATLANTIC FISHERY COMMISSION

REPORT OF THE THIRD WORKSHOP ON THE ASSESSMENT OF SHRIMP AND GROUNDFISH FISHERIES ON THE BRAZIL-GUIANAS SHELF

Belém, Brazil, 24 May - 10 June 1999

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2000
This document was prepared by the Food and Agriculture Organization of the United Nations (FAO), which organized the third Stock Assessment Workshop on the Shrimp and Groundfish Fisheries on the Brazil-Guiana Shelf in Brazil from 24 May to 10 June 1999. The Workshop was organized and funded through the FISHCODE Project in collaboration with the CARICOM Fisheries Resource Assessment and Management Program (CFRAMP), funded by the Canadian International Development Agency (CIDA). The work was accomplished under the guidance and with support of FAO/Western Central Atlantic Fishery Commission.

The FISHCODE Project (GCP/INT/648/NOR), that is funded by Norway, aims at improving the quality of scientific advice for fisheries management and a major involvement of all stakeholders. This Workshop was a follow-up to two similar workshops jointly organized and funded by CFRAMP and the FAO/DANIDA Project GCP/INT/575/DEN “Training in fish stock assessment and fishery research planning”.

This document is a follow-up to FAO Fisheries Report 600, which contains the documents prepared at the second workshop held in Port-of-Spain, Trinidad and Tobago from 7 to 18 April 1997. It assembles the reports prepared before and during the third Workshop held in Belém on the marine shrimp and groundfish fisheries and their management of northern Brazil, French Guiana, Guyana, Suriname, Trinidad and Tobago and eastern Venezuela. It includes national reports and papers on methodology presented at the Workshop and stock assessment papers on shrimp and groundfish resources and their management prepared during the Workshop. Sections 18 and 19 deal with the bio-economics of shrimp fisheries of the Brazil–Guiana shelf and in particular with seasonality, risk and uncertainty.

Section 20 contains a report on a meeting where the results of assessments were presented to the fisheries managers and recommendations were drafted for follow-up activities, including national workshops to discuss the results of the assessments made in Belém with all stakeholders in each country. Such follow-up meetings already did take place in 2000 and reports were issued as Field Reports of the FISHCODE Project in the languages used at those meetings (Dutch, English, French, Portuguese and Spanish).

This document, a contribution of the FISHCODE Project, has been edited by Paul Medley, in close cooperation with the various authors, as well as Kevern Cochrane and Siebren Venema.

A report of the fourth regional Workshop in this series, was in October 2000 in Cumaná, Venezuela, will be issued soon by the FISHCODE Project, also as a FAO Fisheries Report.

Siebren C. Venema
Project Manager FISHCODE
GCP/INT/648/NOR
ABSTRACT

This document assembles the reports on the marine shrimp and groundfish fisheries of northern Brazil, French Guiana, Guyana, Suriname, Trinidad and Tobago and eastern Venezuela prepared for and during the third Workshop on the Assessment of Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf, held in Belém, Brazil, from 24 May to 10 June 1999.

Section 2 includes papers dealing with overviews of important shrimp and groundfish resources and their fisheries. Section 3 deals with fisheries management practices in the area in the context of the Code of Conduct for Responsible Fisheries. Sections 4 and 5 contain papers on stock assessment methodology applicable in the region.

Sections 6 to 18 deal with national or sub-regional assessments of selected shrimp and groundfish fisheries. Section 17 also deals with the bio-economics of shrimp fisheries in general and in particular with seasonality, risk and uncertainty.

Section 19 is a report of a task group on snapper fisheries of the Brazil-Guianas Shelf, it includes a discussion on future management measures.

Section 20 contains a report on a meeting where the results of assessments were presented to the fisheries managers and recommendations were drafted for follow-up activities.

The names and addresses of the various authors can be obtained from the section headings and the list of participants in Section 22.

There is an extensive list of references in Section 21.
# TABLE OF CONTENTS

1 INTRODUCTION .......................................................................................................................... 1

2 BACKGROUND TO THE SHRIMP AND GROUNDFISH FISHERIES OF THE REGION .... 4

2.1 Brazil ....................................................................................................................................... 4
2.2 French Guiana .......................................................................................................................... 5
2.3 Suriname ................................................................................................................................ 5
2.4 Guyana ................................................................................................................................... 7
2.5 Venezuela ................................................................................................................................. 8
2.6 Trinidad and Tobago ................................................................................................................ 9
2.7 Jamaica .................................................................................................................................... 9

3 EXISTING APPROACHES TO FISHERIES MANAGEMENT IN THE BRAZIL-GUIANAS SHELF .................................................................................................................. 11

3.1 Legal framework ..................................................................................................................... 11
3.2 Regional Cooperation .......................................................................................................... 13
3.3 Precautionary approach to fisheries ................................................................................... 13
3.4 National fisheries legislation ............................................................................................... 14
3.5 Institutional structure .......................................................................................................... 16
3.6 Current management goals ................................................................................................. 21
3.7 Fishery management issues ............................................................................................... 21
3.8 Current management regulations ....................................................................................... 22
3.9 Regional approach to management .................................................................................... 30

4 BIOMASS DYNAMIC MODELS................................................................................................ 32

5 DEVELOPMENT OF A MULTISPECIES-MULTIGEAR PER-RECRUIT MODEL THAT INCORPORATES PARAMETER VARIABILITY .............................................................................. 33

5.1 Introduction ........................................................................................................................... 33
5.2 The development of a multispecies-multifishery per-recruit model .................................. 33
5.3 Calculation of biological reference points ......................................................................... 36
5.4 Incorporating variability into the assessment framework ................................................ 36

6 NORTHERN BRAZIL SHRIMP FISHERIES ........................................................................ 37

6.1 Description of the fisheries ................................................................................................. 37
6.2 Trends in catch and effort ................................................................................................. 39
6.3 Population dynamics and stock assessment .................................................................... 40
6.4 Stock assessments .......................................................................................................... 42
6.5 Management .................................................................................................................... 43
6.6 Research programme ....................................................................................................... 43

7 ASPECTS OF FISHING FOR SNAPPER (*Lutjanus purpureus*) ON THE NORTH COAST OF BRAZIL .................................................................................................................. 45

7.1 Background ....................................................................................................................... 45
8 THE FISHERY FOR BROWN SHRIMP (Penaeus subtilis) IN FRENCH GUIANA ................... 54
  8.1 The fishery ................................................................................................................ ......... 54
  8.2 Data and biological inputs ................................................................................................. 56
  8.3 Assessments ................................................................................................................ ...... 60
  8.4 General comments on quality of assessment ................................................................. 68
  8.5 Management considerations .............................................................................................. 70
  8.6 Conclusions ....................................................................................................................... 71

9 RED SNAPPER (Lutjanus purpureus) FISHERY IN FRENCH GUIANA ......................... 72
  9.1 Introduction ......................................................................................................................... 72
  9.2 Data and biological inputs ................................................................................................. 75
  9.3 Assessments ................................................................................................................ ...... 77
  9.4 Stock - recruitment and yield per recruit ........................................................................... 84
  9.5 Discussion and management considerations ....................................................................... 86

10 SHRIMP AND FINFISH FISHERIES IN SURINAME ....................................................... 87
  10.1 General background ......................................................................................................... 87
  10.2 Collection of data for stock assessment ............................................................................ 87
  10.3 Shrimp fishery ................................................................................................................... 88
  10.4 Seabob Fishery ................................................................................................................ 94
  10.5 Finfish fisheries ................................................................................................................ 94

11 ASSESSMENTS OF SHRIMP FISHERIES OF GUYANA .................................................. 105
  11.1 Background ...................................................................................................................... 105
  11.2 Distribution of the species ............................................................................................... 106
  11.3 Biological data .................................................................................................................. 106
  11.4 Catch and effort data ....................................................................................................... 107
  11.5 Stock assessment methods ............................................................................................. 107
  11.6 Results and discussion .................................................................................................... 107
  11.7 Conclusions .................................................................................................................... 109
  11.8 Recommendations ......................................................................................................... 109

12 ASSESSMENTS OF FISHERIES IN GUYANA FOR BANGAMARY (Macrodon ancylodon)
  AND BUTTERFISH (Nebris microps) ............................................................................... 110
  12.1 Introduction ..................................................................................................................... 110
  12.2 Biology ........................................................................................................................... 111
  12.3 Data used for the assessment ........................................................................................ 112
  12.4 Estimation of $L_\infty$ and K parameters ......................................................................... 113
  12.5 Gear selectivity .............................................................................................................. 114
  12.6 Catch Curve Analysis (Ehrhardt and Legault 1996) ..................................................... 116
  12.7 Catch per unit of effort (CPUE) trends ........................................................................... 119
  12.8 Multifishery-multispecies per-recruit modelling (Booth 1999) .................................... 120
  12.9 Discussion ...................................................................................................................... 122
1 INTRODUCTION

The 1999 workshop formed part of a series of workshops, which began with the Third FAO/WECAFC Workshop on the biological and economic modelling of the shrimp resources of the Brazil – Guianas Shelf, held in Paramaribo, Suriname, 22 – 25 June 1992, which was attended by representatives from Brazil, French Guiana, Guyana, Suriname, Trinidad and Tobago, Venezuela and FAO. The conclusions and recommendations from that meeting included the following:

- The need for improvement in data collection systems in most countries including initiating the collection of biological, social and economic data required for bio-economic modelling;
- The shrimp industry in collaboration with governments should take a pro-active approach with regards to management and conservation of secondary stocks (finfish bycatch, turtles, marine mammals, etc.), including studies relating to bycatch reduction, rather than reacting to outside impositions, which may have disruptive effects on the industry;
- Sufficient time should be allocated for bio-economic analyses of one or two shrimp fisheries of the region during the next Workshop and countries should evaluate the impacts of various management strategies applied in the region;
- A harmonised approach to management of the shrimp fisheries in the region should start by acknowledging the common objectives, such as protection of nurseries, regulating effort, etc.;
- That it would be desirable to establish a Scientific Advisory Committee for the Management of the Shrimp Fisheries in the Brazil – Guianas region (SAC);
- That a collaborative working relationship should be established with the Shrimp and Groundfish Assessment Unit of CFRAMP, which will be based in Trinidad and Tobago.

These recommendations were followed up at the subsequent Joint Meeting of the CFRAMP Shrimp and Groundfish Subproject Specification Workshop and Fourth WECAFC Ad hoc Shrimp and Groundfish Working Group of the Guianas – Brazil Shelf, held in Trinidad and Tobago, 8 – 12 January 1996, which was attended by representatives from Belize, Cuba, French Guiana, Guyana, Jamaica, Suriname, Trinidad and Tobago, Venezuela, CFRAMP and FAO. This meeting re-examined the earlier recommendations and explored approaches to implementing the revised recommendations. Participants considered the following actions to have the highest priority:

- Rigorous analysis of the available fisheries data in the countries and region to assess the status of the shrimp and groundfish stocks, which would lead to:
  - Identifying the optimal data requirements for the countries of the region;
  - Facilitating the development of national and regional management scenarios to inform decision makers as to the options available to them and the importance of rigorous resource management;
  - Training personnel from the region in the field, in data collection and analysis;
  - Facilitating greater cooperation between the countries of the region in the experimental development, design and testing of shrimp gear to minimise undesirable bycatch.

Acting directly on the recommendations of the 1996 Joint Meeting, the First CFRAMP/FAO/DANIDA Stock Assessment Workshop on the Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf, was held in Trinidad and Tobago, 7 – 18 April 1997.
Representatives from the Brazil-Guianas coastal states: Brazil, French Guiana, Guyana, Suriname, Trinidad and Tobago, Venezuela, as well as from Cuba, Jamaica, CFRAMP and FAO, participated in the Workshop. The objectives of this Workshop were as follows:

- To undertake full assessments of the status of the stock or stocks, the current levels of exploitation and the potential yields of the Brazil-Guianas shrimp and groundfish resources.
- To examine the biological, economic and social implications of different harvesting and management strategies for the resources, to provide decision makers with information on which to identify an appropriate management strategy for each stock.

One of the more important results of the Workshop was the rigorous evaluation of the input data within the context of stock assessments, which demonstrated to the participants the exact types of data needed for such assessments. Also, detailed procedures appropriate to the data available were developed and used to analyse the data from both shrimp and groundfish fisheries in order to assess the status of the stocks and the impact of fishing on them. These procedures were based on surplus production modelling for shrimp, (the method also has potential for the regional groundfish stocks), length-based catch curve analysis (shrimp) and length-based growth, catch curve and yield-per-recruit analyses (groundfish).

Taking into consideration the difficulties in data availability and accessibility, substantial progress was made at the Workshop in assessing the most important shrimp and groundfish resources of the Brazil-Guianas Shelf. It was recognised that an on-going process of data collection and analysis, with further capacity building, was still required. As a part of this process, a follow-up Workshop in 1998 was seen as essential. Therefore the Second CFRAMP/FAO/DANIDA Stock Assessment Workshop on the Shrimp and Groundfish Fishery on the Brazil-Guianas Shelf, was held in Georgetown, Guyana, 18 – 29 May 1998. The objectives of this Workshop were as follows.

- To use new data that had become available since the 1997 Trinidad and Tobago Workshop to update the assessments of the shrimp and groundfish stocks selected for assessment in 1997, so as to evaluate the current status of the resources and identify any major changes that may have occurred over the last 12 months;
- To begin integrating the national assessments of shrimp and groundfish into sub-regional assessments of shared stocks;
- Where feasible, to improve upon, or extend, the assessments undertaken in 1997 by further analysis and/or application of alternative assessment methods;
- To provide managers with the biological information to enable them to make informal management decisions on the shrimp and groundfish fisheries, including:
  - consideration of multi-fishery impacts on groundfish stocks, including impacts of bycatch in the shrimp fisheries, to begin evaluation of overall management strategies.
  - using the results of the assessments to investigate alternative options for managing the shrimp and groundfish stocks and the probable average annual yields of both shrimp and groundfish under these alternative options.

Based on the assessments undertaken at that Workshop, there was no evidence of biological overfishing of most shrimp stocks that were examined. Exceptions were the estimated high fishing mortality on *P. brasiliensis* in Guyana and a declining trend in CPUE of *P. subtilis* in the Trinidad and Tobago fishery. However, there is evidence that the latter case could have been caused by environmental factors rather than overfishing. In contrast to the shrimp stocks, there were indications that most of the groundfish stocks examined were experiencing fishing mortality in excess of desirable target levels and therefore that the long-term productivity of these stocks was under threat.
Other recommendations and conclusions were as follows:

- The Working Group should continue with the assessments of *P. subtilis* and *P. brasiliensis* and start assessments for *P. notialis*;

- The Working Group should begin to compare and to interpret the national assessments for *P. subtilis* and *P. brasiliensis* in a regional context;

- The Working Group should further examine the linkages between parent stock, recruitment and the environment in shrimp and the implication of these linkages for assessment and management;

- Each country should ensure that adequate, accurate data on catch, effort and the size and sex composition of catches (including discards) are being collected for all the important fisheries and for each of the priority finfish stocks identified at the Workshop;

- The importance of estimating bycatch and simultaneously, considering means of reducing bycatch was emphasised;

- For the planned 1999 Workshop, the countries should undertake growth, catch curve and yield and biomass per recruit analyses to estimate the current states of exploitation of each stock and the desirable biological reference points.

The four Fisheries Directors from Guyana, Suriname, Trinidad and Tobago and Venezuela, who were present for the last two days of the Workshop, issued a statement expressing their satisfaction with the activities of the *Ad hoc* Shrimp and Groundfish Working Group and requested CFRAMP and FAO to continue with their collaborative effort in this regard.

During 1998, it was agreed by FAO that the on-going activities of the *Ad hoc* Shrimp and Groundfish Working Group would form a part of the FISHCODE project funded by the Government of Norway and intended to facilitate implementation of the Code of Conduct for Responsible Fisheries (Project GCP/INT/648/NOR). With this funding and on-going cooperation with CFRAMP, it was possible to schedule two more stock assessment Workshops in 1999 and 2000. Therefore, FAO and CFRAMP, in collaboration with IBAMA, organised the third Workshop on the assessment of shrimp and groundfish fisheries on the Brazil-Guianas shelf in Belém, Brazil, from 24 May to 10 June 1999.

With good progress having been made on the biological assessments, it was determined that the group would begin studying bio-economic assessments and assist the national decision makers in working towards optimal management of their resources. Hence biological and bio-economic evaluation of management strategies, including multispecies and multi-fleet strategies and the reporting of these results to senior fisheries officials was the primary goal of the workshop.

A list of participants in the Workshop is given at the end of this report.
2 BACKGROUND TO THE SHRIMP AND GROUND FISH FISHERIES OF THE REGION

The Brazil-Guianas shelf has one of the most important penaeid shrimp fisheries in the world. The fishing grounds stretch between the Amazon and Orinoco rivers. These rivers are not absolute barriers, however and stock biomass moves across them. In Brazil for example, juveniles of brown shrimp appear to migrate from the coast of the State Pará (East of the Amazon) towards fishing grounds situated in front and to the west of the estuary. At the other end of the area, there is no clear-cut discontinuity across the Orinoco River. However, consideration of the regional topography suggests that the shrimp populations in the Gulf of Paria may not mix to a great extent with those located southeast of Trinidad.

2.1 Brazil

The shrimp fishery in northern Brazil is one of the most important fisheries in the country. The main fishing area is located between the mouth of the Parnaiba River and the border of French Guiana, along the coast of the States of Maranhão, Pará and Amapá. Fishers use artisanal, small-scale and industrial vessels, outfitted with trawls (puca-de-arrastro or guizo), cast nets (tarrafa) and fixed traps (zangaria). The main species caught are *Penaeus subtilis*, *P. schmitti* and *Xiphopenaeus kroyeri*.

The small-scale fishery is concentrated in the Maranhão area, where small, motorised trawlers (7 to 11 m) are commonly used to catch *X. kroyeri* and *P. schmitti*. The artisanal fishery is conducted in estuaries and shallow waters, using fixed gear or hand-operated trawl nets. The shrimp produced by the small-scale and artisanal fisheries are sold fresh or, sometimes, frozen in domestic freezers. A significant amount is also cooked in saltwater and sun-dried. The products from these fisheries are sold locally or exported to other States in Brazil.

In the past, many foreign trawlers have operated in Brazilian waters under international fishing agreements, but this ended in 1978. Since then, only national vessels or Brazilian flag vessels under leasing agreements have operated in the area. From 1985, the Brazilian government has been doing away with the leasing agreements, which led to some vessels being incorporated into the national fleet. The leasing agreement arrangements ceased before the end of the 1980s.

Most of the industrial vessels operating in the shrimp fisheries in the north coast of Brazil are based in Belem/Macapa (159), in the States of Pará/Amapá. Some vessels are based in Fortaleza and Camocim, in the State of Ceará and others in Parnaiba, State of Piauí. In general, the trawlers are the Tampa/Florida type, made of steel and ranging from 19 to 25 m. They are powered by 235 to 540HP engines and operate double rigged trawls. The vessels are equipped with instruments for satellite navigation, radio communication, echosounding and freezing. Some of the vessels from Piauí are smaller in size and a few of them operate with single trawls. In 1994, using data from the States of Pará and Ceará, an average of six trips per vessel per year was determined, with each trip lasting about 36 days. The crew is generally made up of 5 fishers, but a few larger vessels may have a crew of 6.

The best shrimp yields used to be obtained from February to November, but over the last two years the trawlers have been getting good catches all year round.

The shrimp caught by the industrial fishery are frozen mainly with head-off, with some processed as whole shrimp on-board vessel. Most of the processed shrimp tails are exported to the USA and Japan, with the whole shrimp being exported mainly to Japan.

A study in 1998 (Damasceno, 1988), showed that for the shrimp fishery in northern Brazil the bycatch was about 7.2kg per kg of shrimp, of which 4.4 kg was useful for human consumption. It is believed that the above rates have not changed significantly since then.

Until 1997, the management measures for this fishery used to be:
• Limitation of the number of licensed vessels to 250;
• A closed season from December to January;
• Prohibition of trawling in waters within 10 miles of the coast in Amapá and Pará and up to 3 miles of the coast in Maranhão.

Based on recent assessments of the stock and after negotiations with the shrimp fishery industry, these measures were modified and the following established:
• Limitation of the number of licensed vessels to 185;
• Close the fishery in the area between latitudes of 00°20’ N and 01°10’ N and longitudes of 47°00’ W and 47°55’ W;
• A total annual total allowable catch (TAC) of 4600 t;
• Prohibition of trawl fisheries within 10 miles of the coast in Amapá, Pará and Maranhão.

2.2 French Guiana

The entire shelf of French Guiana is exploited for shrimp, using various fishing strategies. The area most exploited is between the 20m and 90m isobaths. A regulation forbids trawling within 30m. Inside 20m the catches are mainly of small individuals, which is in keeping with the migratory behaviour of the juvenile shrimp, from mangroves, marshes and estuaries. Seasonally, the best catches occur from December to May during the wet season.

The main shrimp species exploited on the continental shelf is *P. subtilis*, with its landings representing nearly 95% of the total shrimp landings of the area. The other species landed is *P. brasiliensis*, which is not separated in landings, but its proportion is estimated from market samples.

From 1979 to 1990, the fishery was exploited by French, US and Japanese companies. The landings of the various species of shrimps were exported head-less to USA and Japan. Following the naturalisation of the fishery under the French flag due to the extension of the EEC area, the new market was mainly for small shrimp as well as the larger sizes, but always whole. All the shrimps are processed at sea and packaged frozen.

The market demand has induced a change in the habits of shrimp-trawler operators, who during the second half of the year exploit juveniles in the shallow waters. Due to the recent fluctuations on the international market, a decrease in the demand was observed, resulting in a reduction in effort of the French fleets from 22500 days at sea in 1989 to 15700 in 1994. This was confirmed in 1997 and in 1998.

There is no fishery for *X. kroyeri* although the resource seems to be significant. Some fixed gear operations in the estuaries catch these shrimp and sell the landings on the local market.

The trawl fishery has been controlled by a total allowable catch (TAC) system implemented by the European Union (EU) and since 1992, by a local licence system fixing the maximum number of trawlers allowed to exploit the stock.

2.3 Suriname

Shrimp is exploited over the entire EEZ in the depth range from 20 to 90m. There are three main fishing areas, namely, the “Western Grounds” between 40 to 90m in the western part of the EEZ; the “Middle Grounds” between 25 and 40m off the central EEZ; and the “Puw Patch” between 30 and 80m in the eastern part of the EEZ. Depth is very important for the distribution of shrimp and a distinction is usually made between “deep fishing grounds” of more than 50m depth and “shallow fishing grounds” less than 50m depth.
In 1995, the shrimp trawling fleet was owned by 22 fishing companies. The fleet can be divided into a Japanese fleet (2 companies operating under the Japanese flag), Korean fleet (hoisting a variety of flags) and the Surinamese fleet, of which the Sugam Company is the main component. All shrimp trawling companies use the same kind of vessel, the traditional double-rigged “Florida” or “Gulf of Mexico” type trawler.

The strategies of the two main components of the fleet (Japanese and Korean) are fundamentally different. The Japanese companies specialise in the exploitation of the deeper grounds, targeting the species $P. brasiliensis$. Fishing is almost exclusively done at night. The Korean fleet, as well as the trawlers operating under the Suriname flag, tend to exploit the shallower fishing grounds. Trawlers of both fleets carry out long trips of 50 to 100 days. The Japanese vessels make two hauls of 5 ½ hours in a night, while Korean vessels make hauls of 4 hours during the day.

Almost all shrimp landings take place at the two shrimp processing plants SAIL (Suriname American Industries Limited) and SUJAFI (Suriname Japan Fisheries). The bulk of the production is exported to Japan, with limited exports to Europe, USA and the Caribbean.

Besides the shrimp fleet, there is a growing number of trawlers targeting finfish. Except for part of the SUGAM fleet, which delivers at SAIL, most of the finfish trawlers use other landing places. Part of this fleet consists of former shrimp trawlers using a gear adapted to increase the finfish catch. The fleets also include larger vessels, generally with higher engine power. The vessels operated by Guiana Seafoods target $X. kroyeri$.

Small-scale fishers use funnel nets or “fyke nets” in the tidal zones and in estuaries to catch $X. kroyeri$ and $Nematopalaemon schmitti$. In certain seasons, their catch includes small amounts of juvenile $P. subtilis$.

Fishing for groundfish is carried out in marine waters, brackish waters, rivers and other inland water bodies by artisanal fishers. The fishing vessels can be classified into snapper boats, decked Guyana boats, open Guyana boats and korjaal (canoes of different types). A number of small fishing devices are operated without a boat. The main fishing gears are vertical hook and lines, drifting gillnets, kieuwnet and spannet (fixed gillnets), njawarie (pin seine), fuiknet (Chinese seine) of different sizes, haritete (river seine) and dragnets.

Fisheries in Suriname are currently regulated by the Decree on Marine Fishery (Decree C-14), operational since 1 January 1981. The legislation is being revised and a new fisheries law is expected to be promulgated soon. For the time being, the shrimp trawl fishery is being regulated by the following:

- **Registration:** Compulsory registration of the boats, which are classified into three categories, according to their nationality.
- **Annual Fees:** Annual licence fees based on nationality of owner or company and whether the operation is established in Suriname or not.
- **Closed Seasons:** Shrimp trawling is forbidden in areas shallower than:
  - 12 fathoms (22m) from January to June;
  - 15 fathoms (27m) from July to December.
- **Destination of catch:** The entire catch has to be landed in Suriname. Transshipment at sea is prohibited.
- **Reporting:** Each vessel has to report its position daily to its base. In addition, a logbook has to be filled out and submitted to the Fisheries Department within three days after completion of each trip and a landing report has to be delivered to the Fisheries Department within three days after delivery of the catch.

In 1989 and 1992, the State Commission for the Fishery recommended that the limit on the number of trawlers should be set at 100.
2.4 Guyana

Guyana has a coastline of 432 km and a continental shelf area of 48,665 km². The average width of the continental shelf is 112.6 km, while the area of the EEZ is 138,240 km². The living marine resources being exploited within the EEZ are mainly the demersal resources (shrimp and finfish) and to a limited extent, the pelagic resources over the continental shelf and towards the continental slope.

The offshore industrial shrimp trawl fleet exploits mainly penaeids (*Penaeus subtilis*, *P. brasiliensis*, *P. notialis*, *P. schmitti*) in the case of the penaeid trawl fleet and *Xiphopenaeus kroyeri* in the case of the seabob/finfish trawl fleet. *Nematopalaemon schmitti* is also caught seasonally to a lesser extent as incidental catch in the seabob/finfish fishery.

The Chinese seine vessels of the inshore artisanal fleet exploit both *X. kroyeri* and *N. schmitti*. Some of the larger penaeid shrimp are occasionally caught in the Chinese seine fishery, with various finfish species, including juveniles. DOF estimates put the number of these vessels at 354 for the year 1996.

The Offshore Industrial Fishery consists of 127 trawlers, 5 fish/shrimp processing plants and numerous wharves and dry docking facilities. The trawlers are 48% foreign owned. Foreign trawlers mainly exploit penaeid shrimp (*P. brasiliensis*, *P. notialis*, *P. schmitti* and *P. subtilis*) with finfish and small amounts of squid (*Loligo* spp.) and lobster (*Panulirus* spp.) as bycatch. The locally owned trawlers mainly exploit seabob (*Xiphopenaeus kroyeri*) and various finfish species (*Macrodon ancylodon*, *Micropogonias furnieri*, *Nebris microps*, *Arius* spp., *Cynoscion* spp.), with small quantities of penaeid shrimp as bycatch.

The penaeid and seabob/finfish trawlers are the standard Gulf of Mexico type trawlers. Chinese seine vessels are small flat-bottomed dory type vessels 6.4 to 12.2m (21 - 40ft.) in length and are powered by sails or outboard engines (frame survey, 1994). Penaeid shrimp trawl vessels normally have a crew of 5, while seabob vessels and finfish vessels carry 5 - 6 and 4 - 5 crewmembers respectively. Chinese seine vessels carry 2 - 4 crew.

Upwards of 95% of the penaeid shrimp are exported, primarily to the U.S.A. and smaller amounts to Japan, Canada and CARICOM countries. Approximately 90% of the seabob is exported, primarily to the U.S.A. and smaller amounts to CARICOM countries. The whitebelly shrimp is landed whole. It is then dried and the shell is removed. The shell or shrimp meal is used as livestock feed. The dried shrimp is sold either locally or exported. Finfish is landed whole and sold fresh.

The overall goal for the management and development of the Fisheries Sub-Sector is to achieve sustainable levels of production, productivity and real incomes of fishery producers and other groups involved in the delivery of products to domestic and export markets, thereby contributing to national production, income and welfare. The current limit on the penaeid shrimp trawl fleet is 100 vessels and the limit on the seabob fleet is 30 vessels.

Artisanal fishers operate on the continental shelf at distances up to 56 km (30 miles) from the shore, all along the coast. The most productive period generally runs from March to October, which is the period when the common species (*X. kroyeri*, *N. schmitti*, *Macrodon ancylodon*, *Cynoscion virescens*, *Micropogonias furnieri*, etc.) are caught. Most scombrid species (*Scomberomorus brasiliensis*, *S. cavalla*, etc) are abundant from May to September. During the months of November to February, most finfish species are relatively scarce and the fishing effort is increased to obtain a reasonable catch. This coincides with the period when the winds are high and the sea rough.

The Inshore Artisanal Fishery is made up of an estimated 1331 boats ranging in size from 6-18 m and powered by sails, outboard, or inboard engines. All the boats are made from wood and are manufactured locally. The fishing gear in use includes pin seines, Chinese seines/fyke nets, cadell lines/demersal longlines", drift nets/gillnets, circle seine and handlines/snapper lines.
A flat-bottom dory powered by sail, paddle, or small outboard engine is used for Chinese seine, cadell lines and a few pin seines to give more manoeuvrability over shallow, muddy and sandy bottom areas. The boats that operate close to shore are not equipped with iceboxes. A V-bottom boat, 7.6-9.2m (25–30ft) with an ice-box, an outboard engine, but no cabin, is used by smaller gillnet fishermen. A larger V-bottom vessel, 12.2 - 15.3m (40 - 50ft) with an inboard engine and cabin, is used for larger gillnet and handline operations.

There are about 4 500 artisanal fishermen and of these about 1 000 are boat owners. Sixty to seventy percent of the boat owners are members of Fishermen's Cooperatives, which acquire and sell fishing requisites to their members (unpublished Fisheries Background Report, 1994).

The management objective for the Inshore Artisanal Fishery is to increase the landings to a sustainable level which would enable the Fishery to contribute to improved nutrition for the population, export earnings, increase employment and aggregate output thereby stimulating growth of the national economy (Shepherd et al., 1997).

2.5 Venezuela

The area where the shrimp fleet operates is located in the Atlantic zone of Venezuela, between Bocas del Dragón in the Northern Gulf of Paria, to the Boca Grande, Southern Orinoco River Delta, covering an area of 71 000 km². Although, there has been a reduction in effort over the last ten years, its distribution in the zone has shifted towards the south of the Orinoco river delta, where 33% of the total effort made in the zone is being applied. The industrial fleet operates in the area throughout the year.

Most of the vessels use the Florida type trawls, however the fishing gear has been changed in ten vessels (7% of the fleet) to fish trawl nets. Four of these vessels use a single net from the stern, while the other six use two nets from the sides of the boat.

Over the last eight years, although still high, the number of fishing enterprises decreased by 39, from 97 in 1991 to 58 in 1998. Likewise, the number of industrial trawlers decreased by 37%, from 140 in 1990 to 88 in 1998. All vessels are based in the ports of Güiria, Cumaná and Punta Meta.

Seabob, X. kroyeri, which used to be discarded before 1991, is now landed. It is peeled in factories located in Güiria and sold in national markets.

During 1998, the bycatch accounted for 93% of the total catch in the nets. Of this, 33% was sold in the local market and the other 60% was returned, mostly dead, to the sea. The main fish species are: croaker (Micropogonias furnieri), curbina (Cynoscion spp.), dog trout (Macrodon ancyldon), lane snapper (Lutjanus synagris), catfishes (Bagre bagre; Arius spp.; Cathorops sp.), Atlantic moonfish (Vomer setapinis), Atlantic cutlassfish (Trichiurus lepturus), sharks (Rizhoprionodon sp.; Mustelus sp.). These species represent 80% of the total bycatch landings.

Approximately, 40% of the shrimp are exported. Headless shrimp are exported to the North-American market, while whole shrimp are exported to Europe. The small shrimp (penaeid and seabob) are peeled and sold in national markets. There are 10 processing plants for shrimp and fish in the Atlantic zone of Venezuela.

The artisanal shrimp fishery takes place in the northern Gulf of Pari, by fishermen with beach seines, without boats and in front of Pedernales, in the Northern Orinoco river delta near Pedernales, where the fishermen use small trawl nets, similar to the ones used by the fishermen from Trinidad and Tobago. The latter fishery originated in 1992 and operates during the entire year. There are around 28 wooden vessels operating in the area, with outboard engines, with a length of 7 to 9 m. The catch is sold to processing plants located in Güiria and Soro.

The construction of new conventional trawling units has been forbidden since 1989, in order to stabilise the size of the fleet. Until 1993, the Government had promoted the move of
industrial units to Guiria, in order to increase the fishing effort in the Atlantic zone and decrease it in other more traditional fishing areas. Since then, the situation has been reversed and the number of trawl units in the Atlantic zone has progressively decreased.

2.6 Trinidad and Tobago

The areas fished are the North Coast, Gulf of Paria, Columbus Channel and Orinoco Delta. Overall, the total areas fished within each coast are: the North Coast - 234.98 km², the Gulf of Paria – 1,957.32 km², the Columbus Channel - 826.23 km² and the Orinoco Delta - 393.7 km². The total area fished is 3,412.23 km². The principal exploited species are the penaeids: *Penaeus brasiliensis* (hoppers), *P. notialis* (pink shrimp), *P. schmitti* (white/cork shrimp), *P. subtilis* (brown shrimp) and *Xiphopenaeus kroyeri* (honey/jinga shrimp). The latter species is also targeted by bait trawlers. A significant quantity of finfish, crabs and squid are landed as bycatch. Several species of groundfish exploited incidentally in the demersal trawl fishery are also targeted by an inshore gillnet fishery. The most commercially important and abundant groundfish species are *Micropogonias furnieri* and *Cynoscion jamaicensis*.

There are four trawler fleets: two inshore, artisanal fleets, an offshore, semi-industrial fleet and an offshore industrial fleet. Major trawling activities are centred on the Gulf of Paria in the west, the Columbus Channel in the south and seasonally in areas off the north coast. A census of fishing vessels conducted in November 1991 identified some 209 active, locally registered trawlers. These vessels are categorised into four types (Types I - IV) according to their lengths, engine horsepower and degree of mechanisation (Maharaj *et al.*, 1993). Nine trawlers currently comprise the semi-industrial fleet (Type III) and 21 the industrial (Type IV) fleet. The exact numbers of artisanal vessels (Type I and II) currently operating have been estimated as 113 and 66 respectively.

There are around 570 fishermen actively involved in the local trawl fishery, of which 231 are fishing full-time and 339 part-time (Fisheries Division Vessel Census, 1991).

Shrimp processing in Trinidad and Tobago is handled by a variety of privately owned companies, which have replaced the National Fisheries Company (NFC) monopoly. This activity cannot be clearly differentiated into industrial shrimp processing and artisanal shrimp processing, since catches from all classes of trawlers are used at the processing plants. Only about 16 processors/exporters operate full-time. The traditional export markets for shrimp are the U.S.A., U.K. and Canada.

The sites of major groundfish fishing activity are the west (Gulf of Paria) and south (Columbus Channel) coasts of Trinidad, with minor activity occurring on the east and north coasts. While trawling accounts for major landings of groundfish, the main fishing gear used to target groundfish is the monofilament demersal set gillnet, known locally as; "transpearing", "monoflemming", or "white net". Other gears, which also capture groundfish, include demersal longlines or "palangue", banking, beach seine, fishpots and multifilament gillnets or "fillet", which though set on the surface may also catch groundfish due to deployment in shallow waters. This is an inshore fishery and most fishing is done in depths between 9-14m. The vessels targeting groundfish are pirogues between 6-10m long. They are constructed of wood, fibreglass or fibreglass coated wood. These vessels may use one or two outboard engines with average horsepower of 45-75 HP.

The effort limit for the vessels in the industrial shrimp fleet was set at the fleet level existing in 1988 (Fisheries Division, T and T, 1997).

2.7 Jamaica

Most shrimp fishing occurs along the south coast of Jamaica. This may be attributed to the fluvial discharge along the south coast, which provides a favourable mud bottom substrate. The major fishing areas in which shrimp fishing occurs are Kingston Harbour (St. Catherine) and Savanna-la-mar (Westmoreland). To a lesser extent, shrimp is caught in areas such as
Alligator Pond (Manchester) and Farquhars Beach (Clarendon), mainly as incidental catch. In areas such as Leith Hall, Bowden Bay and Port Morant, the shrimp is targeted primarily as bait.

The Jamaican shrimp fishery is primarily artisanal in nature. The fishery supports approximately 2,000 persons, including vendors and fishers. The species being caught are *P. schmitti*, *P. notialis* and *P. brasiliensis*.

The fishery uses mainly non-motorised wooden dugout canoes approximately 5m in length (oar propelled) and 8.5m fibreglass canoes powered by 40HP outboard engines. The wooden vessels use monofilament gillnets to catch shrimp and the fibreglass vessels use trawls. Some fishers also use shove nets to catch shrimp.

For the trawl nets, shrimping is done primarily at night and lasts 10 to 12 hours. Each haul lasts for about 45 minutes, with the net being towed behind the boat in a circular manner. About 6 hauls are made per night. Monofilament gillnets are thrown overboard and allowed to settle for five to ten minutes. The vessel is then rowed in a circular motion, after which, the net is pulled in and the shrimp picked off the net. This is repeated several times. The length of time spent catching shrimp is about four to five hours.

In addition to the above, shove nets are used by fishers who catch shrimp for bait. Fishing may last from half an hour to four hours. This is done in shallow mangrove areas and sea grass beds.

Shrimp are processed on shore and sold whole. The product is stored on ice and sold locally to hotels, restaurants and households.

The fishery is an open access one. The regulations for the fishing industry fall under the Fisheries Act (1975) and the regulations of 1976. All fishers are given concessions on the importation of fishing gear and equipment and also the purchase of fuel. By law, all fishers should be registered and licensed. The licences are renewable annually.
3 EXISTING APPROACHES TO FISHERIES MANAGEMENT IN THE BRAZIL-GUIANAS SHELF

B. Chakalall, K. Cochrane and T. Phillips

3.1 Legal framework

Developments over the last few years regarding several international initiatives in the fields of fisheries conservation and management have had an impact on the work carried out by national fisheries administrations and on sub-regional, regional and global fisheries bodies and organisations. Such developments include the Agreement to Promote Compliance of International Conservation and Management Measures by Fishery Vessels on the High Seas (Compliance Agreement), The Code of Conduct for Responsible Fisheries, Agenda 21 of the United Nations Conference on Environment and Development (UNCED) and the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN Fish Stocks Agreement).

3.1.1 The Law of the Sea Convention and living marine resources

The United Nations Convention on the Law of the Sea of 1982 resulted in the global acceptance of a coastal state’s authority to manage fisheries within its jurisdiction. This authority created new opportunities and responsibilities for coastal states as well as problems of adjustments to countries operating distant water fleets.

The core of the Law of the Sea Convention on fisheries consists of Articles 61 and 62, which deal with the conservation, management and utilisation of the living resources within the EEZ. Article 61 specifies that the living resources in all economic zones must be managed and conserved to prevent over-exploitation. It requires the coastal state to take measures to maintain or restore populations of harvested species at levels, which can produce a maximum sustainable yield and to determine the “allowable catch of the living resource”. The coastal state is required “to take into account the best scientific evidence available” to determine management and conservation measures.

Since coastal states retain the primary responsibility to explore, exploit, conserve and manage the living resources within the EEZ, they have the obligation to ensure that conservation measures and regulations are complied with. Article 73 allows the coastal state to board, inspect, arrest and take judicial action against foreign fishers, within important limitations, in order to ensure compliance with its laws and regulations.

3.1.2 Compliance Agreement

From the point of view of national legislation, perhaps the core provisions of the Agreement to Promote Compliance of International Conservation and Management Measures by Vessels on the High Seas (Compliance Agreement) are those relating to the responsibility of the Flag State and to the gathering and exchange of information.

Article III of the Compliance Agreement is dedicated to the concept of flag state responsibility in respect of fishing vessels operating on the high seas. This Article places a general obligation on flag states to take such measures as may be necessary to ensure that vessels flying their flags do not engage in any activity that undermines the effectiveness of international conservation and management measures. They are required not to allow any of their flag vessels to be used for fishing on the high seas unless they have been authorised by the appropriate national authorities and are in accordance with conditions of the authorisation.
The provisions designed to ensure adequate flow of information on high seas fisheries activities form the second main pillar of the Compliance Agreement. Flag States will thus be required to maintain detailed records on all vessels authorised to fish on the high seas and to make all such information available to FAO on a “real-time” basis. FAO in its turn will then make the information available to all contracting parties and to global, regional and sub-regional fisheries management organisations.

3.1.3 Code of Conduct for Responsible Fisheries

The Code of Conduct for Responsible Fisheries was adopted by the FAO Conference at its Twenty-eighth Session in October 1995. The Code’s primary purpose is to facilitate the creation of an enabling environment at national, subregional, regional and global levels for enhanced fisheries (including aquaculture) management, to elicit and facilitate the structural changes required in the fisheries sector to ensure that sustainable development practices are pursued and to improve the contribution made by the fisheries sector to food security.

As a voluntary instrument, the Code sets out the principles and international standards of behaviour for responsible practices with a view to ensure the effective conservation, management and utilisation of living aquatic resources, with due respect for the ecosystem and biodiversity. The Code recognises the nutritional, economic, social, environmental and cultural importance of fisheries and the interests of all those concerned with the fishery sector.

Article 7 of the Code deals with various aspects of fisheries management such as management objectives, management framework and procedures, data gathering and management advice, implementation of the precautionary approach, considerations in selecting management measures and effective implementation of responsible management. States should apply, as appropriate, these guiding principles in the management of their fishery resources. According to Article 7.1.1 of the Code “all those engaged in fisheries management should, through an appropriate policy, legal and institutional framework, adopt measures for the long-term conservation and sustainable use of fisheries resources”.

With respect to fisheries management the Code calls on States and sub-regional and regional fisheries management organisations and arrangements to adopt appropriate measures, "based on the best scientific evidence available which are designed to maintain or restore stocks at levels capable of producing maximum sustainable yields, as qualified by relevant environment and economic factors". Article 7.2.2 of the Code provides examples of the appropriate measures, which include, inter alia, that:

- Excess fishing capacity is avoided and the exploitation of stocks remain economically viable;
- The economic conditions under which fishing industries operate promote responsible fisheries;
- The interests of fishers, including those in subsistence, small-scale and artisanal fisheries are taken into account;
- Biodiversity of aquatic habitats and ecosystems is conserved and endangered species protected;
- Depleted stocks are allowed to recover, or where appropriate, are actively restored;
- Adverse environmental impacts on the resource from human activities are assessed and, where appropriate, corrected.

3.1.4 UN Fish Stocks Agreement

Agreement) was adopted in August 1995. The objective of the Agreement is to ensure the long-term conservation and sustainable use of straddling stocks and highly migratory fish stocks through effective implementation of the relevant provisions of the 1982 Law of the Sea Convention. The main thrust is towards the duties of the Flag State in controlling the activities of its vessels and also the measures it should take to ensure compliance and enforcement of the relevant conservation and management measures. The Agreement deals with the role of sub-regional and regional management bodies and arrangements and cooperation in scientific research. The need for international cooperation in enforcement of conservation and management measures set by sub-regional and regional bodies is stressed. Finally, the Agreement stresses, in Annex I, the Standard Requirements for the Collection and Sharing of Data.

3.2 Regional Cooperation

All the international fisheries agreements mentioned above raise the importance of regional cooperation in fisheries. Perhaps the Code of Conduct for Responsible Fisheries emphasises this need more eloquently for the Guianas-Brazil region and more importantly, provides guidelines on how it could be achieved. Article 7.1.3 of the Code states:

>For transboundary fish stocks, straddling fish stocks, highly migratory fish stocks and high seas fish stocks, where these are exploited by two or more States, the States concerned, including the relevant coastal States in the case of straddling and highly migratory stocks, should co-operate to ensure effective conservation and management of the resources. This should be achieved, where appropriate, through the establishment of a bilateral, sub-regional or regional fisheries organization or arrangement.

3.3 Precautionary approach to fisheries

Acceptance of the Precautionary Approach to Fisheries (FAO 1995) is implicit in the Code of Conduct and the steps necessary for responsible fishing when confronted by complexity and uncertainty are well described in the Guidelines to the Precautionary Approach to Fisheries. These Guidelines emphasise that sustainable utilisation requires the application of prudent foresight and suggest that this includes, amongst other attributes, the following:

(i) The avoidance of changes that are not potentially reversible;

(ii) The prior identification of undesirable outcomes and of measures that will avoid them;

(iii) That any necessary corrective measures are implemented without delay and are rapid and effective;

(iv) That where there is uncertainty, primary attention should be given to conserving the productive capacity of the resource;

(v) That the fishing and processing capacity should be in harmony with the production potential of the resource, to avoid continual social and economic pressure to over-exploit the resources in order to utilise this capacity; and

(vi) That all fisheries should be conducted according to an explicit and appropriate management plan and that the administrative and legal framework exists to ensure implementation of the plan.

These themes and others, are also picked-up in the Code of Conduct for Responsible Fisheries which urges States to apply the precautionary approach using the best scientific evidence available, including stock specific target and limit reference points and what actions should be taken if the points are exceeded. Of these, (i), (ii) and (iv) refer more specifically to the resource and require good insight into the status and dynamics of the resource. The series of Brazil-Guianas workshops, under the auspices of the WECAFC Ad hoc Working...
Group on the Brazil-Guianas Continental Shelf, have been designed to provide such insights, including, where appropriate, identification of reference points and evaluation of the consequence or outcomes of different management strategies. The avoidance of irreversible changes and prior identification of undesirable outcomes and identification of uncertainty, presuppose a certain level of knowledge of the resource. In addition, point (iv) stresses that where there is uncertainty, the doubt should be used in favour of the resources.

3.4 National fisheries legislation

The coming into force of the 1982 Law of the Sea Convention and the recent international initiatives in fisheries mentioned earlier have made it necessary for countries of the Brazil-Guianas region to revise their fisheries legislation.

3.4.1 Brazil

Article 187 of the Federal Constitution of Brazil provides for the definition of an agriculture policy and explicitly includes agro-industrial activities, agriculture and livestock, fisheries and forestry. Article 225 of the Constitution identifies a number of principles that concerns the environment. Included among these principles, are the protection of fauna and the ecological management of species and ecosystems. Both these principles implicitly include fisheries. The responsibility for the application of these principles lies with the “Poder Publico” (the Government).

Legislation 9.649 of 27 May 1998, which deals with the organisation of the Presidential Office (Presidencia de la Republica) and Ministries, established a significant change in the prevailing trend with respect to areas of competence of Ministries. The Ministry of Agriculture and Supply was given the responsibility for promoting agriculture and animal production, including fisheries and rubber. The Ministry of the Environment, Water Resources and Amazonia was given the responsibility for the preservation, conservation and rational use of renewable natural resources. Article 14 of Legislation 9.649 establishes that the “Executive Power” should revise the structure, functions and attributes of IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources) in order to separate the functions of development and promotion of fisheries resources and rubber, with the objective of transferring them to the Ministry of Agriculture and Supply.

As can be observed, Brazil is in a process of change. Through this change the responsibility for the conservation and management of the fisheries resources will lie with IBAMA while the Ministry of Agriculture and Supply will be responsible for fisheries development. The process of decentralisation and federalisation that the Brazilian Constitution requires the design and implementation of innovative and adequate fisheries management plans with an appropriate legal framework. There is a need to clarify and harmonise the existing legal framework with respect to a unified fisheries policy for management and development.

3.4.2 French Guiana

The common fisheries policy of the European Union, which came into effect in January 1983, covers French Guiana as an overseas department of France. The policy calls for common rules for fishing in the maritime waters and co-ordination of structural policies of Member States to promote harmonious and balanced development of the fishing industry (Council Regulation (EEC) No. 101/76). Member States could have exclusive fishing access to waters up to six miles or in some cases twelve miles from the shore. Provision is made for the European Council to adopt the necessary conservation measures for fish stocks in the Maritime waters of one or other Member State. These measures could include restrictions to the catching of certain species, to areas, to fishing seasons, to methods of fishing and fishing gear.

Even though EU regulations may apply, the Member State could pass legislation concerning the conservation and management of its fishery. These include, inter alia, temporary bans for
regulating the fishing of certain species to limit catch by vessel and by species or species
groups, determining minimum size, regulating mesh size and technical characteristics of
vessels. Member States of the Commission will have to be notified of these laws, regulations
and administrative rules.

3.4.3 Guyana
Fisheries in Guyana are regulated by the Fisheries Act of 1957, the Fisheries Regulations of
1959, the Fisheries (Pin Seine) Regulations of 1962, the Fisheries (Aquatic Wildlife Control)
Regulations of 1966 and by the Maritime Boundaries Act of 1977. In 1986, the Government
of Guyana, through the Fisheries Division, obtained technical assistance from FAO in
drafting a new fisheries act and regulations but they were never debated. A new fisheries act,
which takes into consideration recent international instruments such as the 1982 Law of the
Sea Convention, was drafted in 1998 with technical assistance from FAO. The new act,
which has been circulated for comments, should be brought before the Guyana Parliament
before the end of 1999 for debate and adoption. The new act would impact on the entire
fisheries sector (marine, inland and aquaculture) and deal with areas such as the
management of local and foreign fishing activity within the EEZ, control of fishing effort in the
industrial shrimp fishery, closed areas and seasons, regional cooperation, access
agreements, fisheries research and monitoring and surveillance.

3.4.4 Suriname
Fisheries in Suriname are regulated by the Decree on Marine Fishery, Decree C-14, in force
since 1st January 1981. This legislation has been revised and a new fisheries law was drafted
in 1992 with technical assistance from FAO. Unfortunately, it has not yet been promulgated.
The new draft law stipulates the elaboration of annual management plans for the fishery
types, in which all regulatory measures will be established. This approach should allow
fisheries managers to adapt to the changing conditions of exploitation.

Regulations currently in force pertain to registration, annual fees, reporting, closed areas and
destination of catch (see Section 3.8).

3.4.5 Trinidad and Tobago
The existing legislation, the Fisheries Act of 1916, was found inadequate as a legal basis
upon which a modern fisheries management system can be structured.

In June 1995, a draft Fisheries Management Act and Policy Directions for Marine Fisheries in
Trinidad and Tobago in the 1990s, were prepared with the technical assistance of FAO. The
Act provides the framework for the management of both local and foreign fishing activity in the
waters under the jurisdiction of Trinidad and Tobago. One of the major objectives as
outlined in the draft National Marine Fisheries Policy was to provide for a move from a
system of uncontrolled, free access to the fisheries resources towards a system of controlled
access. Policy would be dependent upon the preparation of Fishery Management Plans
based on the best available scientific and socio-economic information. The revised legislation
was also intended to take into consideration the Government’s participation in international
agreements and national responsibilities for management of the resources of the Exclusive
Economic Zone.

This draft Act, which should facilitate fisheries management, data collection, licensing,
registration and enforcement, was circulated in 1997 to fishers and stakeholders in the
fisheries sector for comments. The draft Fisheries Management Act has not yet been
promulgated.

3.4.6 Venezuela
Trawl fisheries in Venezuela have been regulated by the joint resolutions of the Ministry of
Agriculture (MAC/DGSPA/No. 46) and Ministry of the Environment (MARNR/DAA/No. 103)
from 30th January 1980. The fishing areas for the trawling fleet and the ones reserved to the artisanal fishers are specified, both in the coastal zone and in the island territories. A second resolution (MAC/DGSPA/No. 391) from 13th December 1990 (Annex III) regulates the activity of the trawling fleet in the Gulf of Venezuela, establishing a closed season from 15th December to 8th January and from 15th August to 10th September. Now all these resolutions are under study, in order to establish up-to-date norms for this fishery.

3.5 Institutional structure

Figure 3.1 provides the basic institutional structure for fisheries management and development in the countries of the sub-region. Fisheries administration is under the Ministry of Agriculture in all the countries except Brazil, where the responsibility is shared between the Ministry of Agriculture, responsible for development, issuing of licences and for the economic aspects and IBAMA (Instituto Brasiliero do Meio Ambiente e dos Recursos Naturais Renovaveis), responsible for conservation and management and for enforcement. Brazil is currently in the process of restructuring its fisheries administration and the organogram presented in Figure 3.1, which is under discussion by the Brazilian Government, was agreed in April 1999. It is anticipated that the final structure and functions and the inter-relationships between the three principal agencies should be ready by the end of 1999.

In most countries fisheries research is conducted by the national fisheries administration, which is under the Ministry of Agriculture. Only Brazil and Venezuela have delegated fisheries research to specialised agencies. In Brazil CEPNOR (Centro de Pesquisa e Extensão Pesqueira do Norte do Brasil) is responsible for research in the North of Brazil (Atlantic Ocean and Amazon Basin). In Venezuela FONAIAP (Fondo Nacional de Investigaciones Agropecuarias), a specialised research agency under the Ministry of Agriculture has the responsibility for fisheries research.

In French Guiana, IFREMER (Institute français pour l’exploitation de la mer) is responsible for research and it provides scientific advice on all aspects of fisheries to the French Ministry of Agriculture which is responsible for conservation and management, including monitoring control and surveillance.

In most countries either the navy, air force, army or coast guard have been delegated the responsibility for monitoring, control and surveillance. This is done in collaboration with the national fisheries administrations, through agreements with the appropriate line agencies, which is the Ministry of Agriculture in most countries and IBAMA in Brazil.
Figure 3.1 Organisation of government for fisheries management for the Brazil-Guianas region, Brazil and French Guiana
Figure 3.1 (continued) Organisation of government for fisheries management for the Brazil-Guianas region, Guyana
Figure 3.1 (continued) Organisation of government for fisheries management for the Brazil-Guianas region, Suriname and Trinidad and Tobago
Figure 3.1 (continued) Organisation of government for fisheries management for the Brazil-Guianas region, Venezuela
3.6 Current management goals

The countries of the Brazil-Guianas region have set the primary goal of fisheries management as the long-term conservation of the resource (Table 3.1), i.e. maintaining the capacity of the resource at or about the level at which they are providing maximum sustainable yields (MSY). For the majority of fish stocks in the region it is not known whether MSY has been reached or not.

The other major goal is to maximise economic benefits derived from the fishery through revenue (licence fees), foreign exchange earnings and employment creation. The countries of the Brazil-Guianas region also place emphasis on food production and on the contribution of fisheries to national food security.

Table 3.1 Management goals

<table>
<thead>
<tr>
<th>Country</th>
<th>Management Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>Prevention of overfishing</td>
</tr>
<tr>
<td></td>
<td>Increasing production</td>
</tr>
<tr>
<td></td>
<td>Contribution to employment</td>
</tr>
<tr>
<td></td>
<td>Long-term conservation of the resource</td>
</tr>
<tr>
<td></td>
<td>Better utilisation of bycatch</td>
</tr>
<tr>
<td>French Guiana</td>
<td>Long-term conservation of the resource</td>
</tr>
<tr>
<td></td>
<td>Optimising yield per recruit</td>
</tr>
<tr>
<td>Guyana</td>
<td>Long-term conservation of the resource</td>
</tr>
<tr>
<td></td>
<td>Increasing benefits for the country (foreign exchange earnings)</td>
</tr>
<tr>
<td></td>
<td>Generating employment</td>
</tr>
<tr>
<td></td>
<td>Contributing to national food security</td>
</tr>
<tr>
<td></td>
<td>Optimising profitability of the industry</td>
</tr>
<tr>
<td>Suriname</td>
<td>Long-term conservation of the resource</td>
</tr>
<tr>
<td></td>
<td>Maximising foreign exchange earnings</td>
</tr>
<tr>
<td></td>
<td>Generating employment</td>
</tr>
<tr>
<td></td>
<td>Producing food protein</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>Long-term conservation of the resource</td>
</tr>
<tr>
<td></td>
<td>Controlling access (proposed in new draft legislation, 1995)</td>
</tr>
<tr>
<td>Venezuela</td>
<td>Long-term conservation of the resource</td>
</tr>
<tr>
<td></td>
<td>Improving profitability of the industry</td>
</tr>
<tr>
<td></td>
<td>Developing the Guyana area</td>
</tr>
</tbody>
</table>

3.7 Fishery management issues

Table 3.2 provides a summary of current fishery management issues identified by the countries of the region. It should be pointed that initially (in 1984) the countries of the Brazil-Guianas region placed emphasis on the shrimp fishery primarily because of the economic
value of this fishery. However, with time this emphasis has gradually shifted to the main commercial finfish species that are currently being harvested and in 1998 ten species were identified for assessment. A number of countries have identified the growing lucrative snapper fishery as one that needs to be addressed collectively, given the current exploitation patterns by boats from within the sub-region.

The majority of countries identified the protection of known nursery areas and recruitment overfishing as areas of concern, primarily because current regulations were not enforced. Conflicts between different user groups, especially between artisanal and industrial fishery sectors, were also identified as an area of concern. In several countries of the region the artisanal fishery is very important from the social and economic perspective. The artisanal fishery of the region produces approximately 70% of the finfish landed, the major portion of which is for national consumption.

Conflicts also arise between fishers exploiting different resources on the same fishing grounds. Some countries cited fishing gear interaction (e.g. between gillnets and trawls) as an area of conflict.

### 3.8 Current management regulations

Table 3.3 contains a summary of the current management regulations with respect to shrimp and ground fish fisheries in the countries of the Brazil-Guianas region. These include closed areas and seasons, effort limitation and gear specifications.

The shrimp fishery in the Brazil-Guianas region is the most important and lucrative fishery and probably for this reason more serious attempts have been made at managing this fishery. For example, all the countries have placed a cap on the number of industrial shrimp trawlers to limit effort. Two countries, Brazil and French Guiana, have determined TACs for the shrimp fishery, while Venezuela has restricted shrimp fishing to 16 000 fishing days per year. Most countries have established closed areas and/or closed seasons for industrial trawling.

With respect to selectivity no minimum length or weight has been determined for the penaeid shrimps and for the commercial finfish species currently being harvested. Selectivity is only related to gear specifications.

With the exception on the limit to the number of snapper boats operating in French Guiana and Guyana, no serious attempts have been made to restrict effort in the finfish fishery, especially in the dominant small-scale sector. As a matter of fact, enforcement of the regulations is one of the main deficiencies of the current management system.

Up until 1996 and subsequent WECAFC workshops, no studies had been done to demonstrate the impacts of current management regulations on the status of the fishery resources in the area.
### Table 3.2 Fishery Management: Issues

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>CONSERVATION</th>
<th>EFFORT</th>
<th>ECONOMICS</th>
<th>POTENTIAL CONFLICTS</th>
<th>UNDER-UTILISED RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>- Impact of artisanal fishing</td>
<td>- Re-evaluate optimal level of effort</td>
<td>- Efficiency of national fleet (poor transfer of technology from rented</td>
<td>- Artisanal (finfish) fishermen:</td>
<td>- Bycatch</td>
</tr>
<tr>
<td></td>
<td>- Protection of nursery areas</td>
<td></td>
<td>boats)</td>
<td>gear destruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Enforcement</td>
<td></td>
<td>- Impact of artisanal fishing</td>
<td>Aquaculture: use of coastal areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Artisanal (shrimp) fishermen: sequential fishing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>French Guyana</td>
<td>- Overfishing</td>
<td></td>
<td>- Year to year yield fluctuations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Recruitment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suriname</td>
<td>- Recruitment</td>
<td>- Definition optimal level of effort</td>
<td>- Heavy operating costs, in foreign currency</td>
<td>- Artisanal fishermen:</td>
<td>- Bycatch</td>
</tr>
<tr>
<td></td>
<td>- Overfishing</td>
<td></td>
<td></td>
<td>(gilnetters): loss of gear</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Protection of nursery areas</td>
<td>- Control of illegal fishing and transshipment</td>
<td></td>
<td></td>
<td>- Large sizes</td>
</tr>
<tr>
<td></td>
<td>- Enforcement</td>
<td></td>
<td></td>
<td></td>
<td>- <em>P. brasiliensis</em></td>
</tr>
<tr>
<td>Guyana</td>
<td>- Overfishing</td>
<td>- Definition optimal level of effort</td>
<td>- Heavy operating costs, in foreign currency</td>
<td>- Artisanal fishermen:</td>
<td>- Bycatch</td>
</tr>
<tr>
<td></td>
<td>- Enforcement</td>
<td></td>
<td></td>
<td>(gilnetters): loss of gear</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Control of illegal fishing and transshipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Interference with finfish and seabob trawling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>- Enforcement</td>
<td>- Optimal level of effort unknown</td>
<td>- Heavy operating costs, in foreign currency</td>
<td>- Artisanal fishermen:</td>
<td>- Bycatch</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(gilnetters): loss of gear</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trinidad and</td>
<td>- Recruitment</td>
<td>- Optimal level of effort unknown</td>
<td>- Economic over-exploitation</td>
<td></td>
<td>- Parts of area (Orinoco</td>
</tr>
<tr>
<td>Tobago</td>
<td>- Overfishing</td>
<td></td>
<td></td>
<td></td>
<td>estuary and South coast)</td>
</tr>
</tbody>
</table>

Adapted from Charlier, 1992.
Table 3.3 Summary of current management regulations by fishery or species

<table>
<thead>
<tr>
<th>Species</th>
<th>Minimum length (mm)</th>
<th>Minimum weight (g)</th>
<th>Closed Areas</th>
<th>Seasons</th>
<th>TAC</th>
<th>Effort Limitation (Vessels)</th>
<th>Gear</th>
<th>Licence Fee (p.a.)</th>
<th>Other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penaeid Shrimp</td>
<td></td>
<td></td>
<td>No shrimp trawling in coastal zone up to 10 miles in Amapá, Pará and Maranhão.</td>
<td>Dec - Jan</td>
<td>4 600 t</td>
<td>Licensed vessels limited to 250, 105 fished in 1998</td>
<td>Trawl net 45 mm cod-end TEDs</td>
<td>Depends on LOA of vessel; R$640 for vessels 20-24 m.</td>
<td>The closed area is considered a nursery. Concrete blocks are placed in area to prevent trawling. Licence renewable annually; submission of catch and effort data on prescribed logbooks a prerequisite. Majority of shrimp vessels 20-24 m LOA</td>
</tr>
<tr>
<td>Snapper (L. purpureus)</td>
<td></td>
<td></td>
<td>Traps, 8 cm square mesh; hand lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Traps introduced in 1997. Two stocks identified genetically, NE Brazil and Northern Brazil; separated by Amazon River</td>
</tr>
</tbody>
</table>

US$1 = R$1.60

BRAZIL
<table>
<thead>
<tr>
<th>Species</th>
<th>Min. length (mm)</th>
<th>Min. weight (g)</th>
<th>Closed Areas</th>
<th>Seasons</th>
<th>TACs (Vessels)</th>
<th>Effort Limitation</th>
<th>Gear</th>
<th>Licence Fee (p.a.)</th>
<th>Other</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snapper ((L. synagris Rhomboplites aurorubens L. purpureus))</td>
<td></td>
<td></td>
<td></td>
<td>46</td>
<td>Hand-lines Traps</td>
<td>75% of catch must be landed in Cayenne</td>
<td></td>
<td></td>
<td></td>
<td>41 Venezuelan. The 5 Barbadian boats are not currently fishing</td>
</tr>
<tr>
<td>Species</td>
<td>Min. length (mm)</td>
<td>Min. weight (g)</td>
<td>Closed Areas</td>
<td>Closed Seasons</td>
<td>TAC</td>
<td>Effort Limitation</td>
<td>Gear</td>
<td>Licence Fee (p.a.)</td>
<td>Other</td>
<td>Comments</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>--------------</td>
<td>----------------</td>
<td>-----</td>
<td>-------------------</td>
<td>---------------</td>
<td>-------------------</td>
<td>----------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Penaeid Shrimp</td>
<td>L tot.</td>
<td>L tail</td>
<td>W tot.</td>
<td>W tail</td>
<td></td>
<td>(Vessels)</td>
<td></td>
<td></td>
<td></td>
<td>The trawl fleet is demarcated in terms of their operations and the vessel licences indicate the operation- shrimp, seabob/finfish, finfish.</td>
</tr>
<tr>
<td></td>
<td>Trawling prohibited 18m isobath shoreward</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>Trawl 45mm cod end TEDs</td>
<td>G$ 157 000 for foreign boats and G$ 37 000 for locally owned boats Note: 1 US$ = G$ 170 approx.</td>
<td>Each penaeid shrimp vessel is required to land a minimum of 16t of finfish bycatch per annum. Transshipment of catch at sea prohibited</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seabob/ Finfish (mixed)</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Trawl 45mm cod end TEDs</td>
<td>G$37 000</td>
<td></td>
<td>Limited to local ownership</td>
<td></td>
</tr>
<tr>
<td>Industrial finfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stern Trawl</td>
<td></td>
<td></td>
<td></td>
<td>All 6 vessels not currently operating</td>
</tr>
<tr>
<td>Snapper (L. purpureus)</td>
<td>35 proposed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>hand line, traps</td>
<td></td>
<td></td>
<td>28 vessels currently operating of which 10 leased from Venezuela by local company. Current request from Trinidad for 16 vessels to fish, using traps with 2.5 inch square mesh</td>
<td></td>
</tr>
<tr>
<td>Artisanal Finfish (mixed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fyke net, gillnet, hook and line, pin seine, traps, cadell</td>
<td>G$100 per ft LOA. G$100 per fish pen for fyke net. For snapper vessels, G$7 500 for Territorial sea licence, G$30 000 for Fishery Zone Licence.</td>
<td>Mainly small-scale</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## SURINAME

<table>
<thead>
<tr>
<th>Species</th>
<th>Min. length (mm)</th>
<th>Min. weight (g)</th>
<th>Closed Areas</th>
<th>Closed Seasons</th>
<th>TAC Effort Limitation (Vessels)</th>
<th>Gear</th>
<th>Licence Fee (p.a.)</th>
<th>Other</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penaeid Shrimp</td>
<td>L tot. L tail W tot. W tail</td>
<td>&gt; 12 fathom</td>
<td>&gt;15 fathom</td>
<td>no shrimp trawling</td>
<td>Jan-Jun</td>
<td>No limitation (recommended: 120 in 1986, 100 in 1989 and 90 in 1999)</td>
<td>Trawl net 45 mm cod-end TEDs</td>
<td>US$7 500 for national and foreign boats</td>
<td>no catfish in bycatch 2% export tax in US$</td>
</tr>
<tr>
<td>Seabob</td>
<td></td>
<td></td>
<td></td>
<td>No limitation</td>
<td>Maximum 20 boats</td>
<td>45 mm cod-end TEDs</td>
<td>US$1 000</td>
<td>Repatriate US$1 kg(^{-1}) at Central Bank</td>
<td></td>
</tr>
<tr>
<td>Industrial Finfish (mixed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artisanal Finfish (mixed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mainly small-scale</td>
</tr>
<tr>
<td>Snapper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Foreign owned and operated through bilateral agreement</td>
</tr>
<tr>
<td>Species</td>
<td>Minimum length (mm)</td>
<td>Closed Areas</td>
<td>TAC Effort Limitation (Vessels)</td>
<td>Gear</td>
<td>Licence Fee (p.a.)</td>
<td>Other Comments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
<td>------</td>
<td>-------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$L_{\text{tot}}$, $L_{\text{tail}}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$W_{\text{tot}}$, $W_{\text{tail}}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. schmittii</strong></td>
<td></td>
<td>Trawl types I and II 1.8-18.0m isobath; Type III 9.0-41.4m isobath; Type IV 9.0-48.6m isobath, in the Gulf of Paria and in Columbus Channel 8.0-41.4m isobath. No demersal trawling on East coast and from 15 Nov-15 Jan on North coast (nights only) and Sánt Déau.</td>
<td>Trawl boats are being maintained at present number: Type I – 113 Type II – 66 Type III – 9 Type IV – 21</td>
<td>All vessels use four-seamed, flat nets. Types I and II (artisanal) use one stern trawl. Type III (semi-industrial) one stern trawl. Type IV, twin otter trawls and TEDs. Cod-ends: fish trawl 7.5cm; shrimp trawl 3.5cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. notialis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. subtilis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. braziliensis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>X. kroyeri</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M. furnieri</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. jamaicensis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. acoupa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M. ancylodon</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>All finfish species caught by trawl nets, gillnets, longlines, handlines, fishpots</strong></td>
<td>All vessels use four-seamed, flat nets. Types I and II (artisanal) use one stern trawl. Type III (semi-industrial) one stern trawl. Type IV, twin otter trawls and TEDs. Cod-ends: fish trawl 7.5cm; shrimp trawl 3.5cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Co-management for demersal trawl fishery; self-imposed penalties by industry for violations.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Minimum length (mm)</td>
<td>Minimum weight (g)</td>
<td>Closed Areas</td>
<td>Closed Seasons</td>
<td>TAC Effort Limitation</td>
<td>Gear</td>
<td>Licence Fee</td>
<td>Other</td>
<td>Comments</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------</td>
<td>--------------------</td>
<td>-----------------------</td>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-----------------------------</td>
<td>-------------</td>
<td>-------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Vessels)</td>
<td>(p.a.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial fleet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 miles from the coast</td>
<td>Trawl nets with TEDs</td>
<td>Bol$2 640</td>
<td></td>
<td>Maximum 16 000 fishing days per year. Maximum 235 days at sea per boat</td>
</tr>
<tr>
<td>Artisanal trawling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15 Jan – 15 Dec and 15 May – 15 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All species</td>
<td>&gt; 10 m, 3.5cm total mesh opening</td>
<td></td>
<td></td>
<td></td>
<td>15 Jan – 15 Dec and 15 May – 15 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artisanal beach seines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 miles from the coast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15 Jan – 15 Dec and 15 May – 15 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 1 US$ = Bol$ 600 approx
3.9 Regional approach to management

Given the nature of the fishery resources in the Brazil-Guianas region and the shared nature of the majority of the fish species of high economic values that are currently being harvested, a regional approach (See Section 2.0) to management is essential for sustained fisheries production and to achieve the management goals set by the countries. Initially, the following two common goals identified by the countries could serve as the basis for the regional approach:

- The long-term conservation of the resource; and
- The optimisation of economic benefits (revenue, foreign exchange, employment).

The regional approach to management should be based on the precautionary approach to fisheries (Section 3.0) and the Code of Conduct for Responsible Fisheries (Section 1.3), which presupposes a certain level of knowledge of the resource. Since the establishment of the WECAFC Ad hoc Working Group on the Brazil-Guianas Continental Shelf in 1984, a number of workshops (1986, 1988, 1992, 1996, 1997, 1998, 1999) on the assessment of the shrimp and ground fish resources and on bio-economic modelling have generated a significant body of knowledge on the resources and their exploitation. The information generated by these workshops should provide a sound scientific base on which to build the regional approach to management.

The 1992 Workshop held in Suriname recognised the need to formalise meetings within a certain framework or mechanism to ensure continuity and to co-ordinate any cooperative investigation programme and agreed that it would be desirable to establish a Scientific Advisory Committee (SAC) for the management of the shrimp and groundfish fisheries in the Brazil-Guianas region. This suggestion should be revisited in the light of the achievements since 1992 by the WECAFC Ad hoc Working Group of the Brazil-Guianas continental shelf and the recent international initiatives in the field of fisheries in pursuing a regional approach to fisheries conservation and management in the sub-region. It is recommended that a regional fisheries management organisation or arrangement be formed to facilitate the management of the shrimp and ground fish fisheries of the Brazil-Guianas continental shelf.

3.9.1 Challenges

The major challenges facing fisheries management, as identified by FAO in 1998 through a High Level Panel of External Experts, include:

- Maintaining the contribution made by fisheries to food security, employment, national economic development and recreation;
- Strengthening the base for fisheries management and aquaculture development through improved data collection and scientific assessment so that decisions concerning management and development options could be more rationally based and informed;
- Improving governance and more effective conflict resolution;
- Promoting national capacity building and the strengthening of regional institutions;
- Facilitating greater transparency in fisheries sector decision making at all levels through greater stakeholder participation in national and regional processes;
- Improving access to and the dissemination of, good quality and timely information in the most appropriate formats, in support of responsible fisheries and aquaculture;
- Reducing bycatch and discards through the use of more selective gear and fishing operations and innovative and value-added processing and market development for species currently discarded and expanding and promoting of uniform quality criteria for internationally traded fish and fish products; and
• Integrating coastal area planning and management more effectively.

In the medium to long term the major challenge facing marine fisheries in the Brazil-Guianas continental shelf is improved and responsible management of fish stocks. This will require the regulation of production in a precautionary manner so that excessive effort, leading to overfishing, is not applied to target stocks.

Within the context of marine fisheries management, the following challenges that were highlighted by the international community are relevant to the Brazil-Guianas region:

• The more effective translation of social, economic and biological information into concrete fishery management policy, in which objective policy frameworks and performance criteria are given priority;

• The more explicit recognition and implementation of access rights in both artisanal/small-scale and industrial fisheries so as to reinforce management input and output controls;

• Reducing bycatch and discards through the use of more selective gear and fishing operations

• The management of fleet capacity and the clarification of the role of subsidies to industry which may distort production arrangements; and

• The strengthening of monitoring, control and surveillance (MCS) as a means of ensuring that agreed fishery conservation and management measures are implemented effectively, speedily and as intended;

These challenges can be most effectively addressed through a regional approach to management.
Biomass dynamic models share most data requirements and assumptions with production models. Unlike production models, however, they do not assume stocks are in equilibrium. They are an attempt to acknowledge the time lags occurring between removals of biomass by fishing and growth in biomass due to the intrinsic productivity of fish stocks. They try to explain changes in an abundance index (normally CPUE) as a function of the removal of biomass by fishing, the biomass in the previous time period and the growth in biomass. The growth in biomass is commonly made a function of the biomass in the previous time period and of a few parameters describing the productivity of the stock. Although originally developed to model annual changes in biomass they can be used to model seasonal patterns too (Die et al. in prep). Annual and monthly biomass dynamic models were used during the last two workshops to conduct assessments of shrimp fisheries.

Biomass dynamic models are very simple representations of the dynamics of fish stocks. As a result they make very strong assumptions about the nature of the system being modelled and of the data used to fit them. It is important to remember such assumptions and when possible test them. For a review of such assumptions see Punt and Hilborn (1997).

There are a few simple rules that should be remembered when these models are used. In general, the longer the time series the better the results from fitting biomass dynamic models. The abundance index must also have some sort of trend, or at least time periods with significantly different values of abundance. These changes in the index must also be related to changes in catch (e.g. increasing or stable catches should lead to decreases in the abundance index), otherwise the model will not be able to fit the data. The likelihood of being able to estimate all parameters of the model depends entirely on the information content of the data. The modeller must also be wary when the information content is poor. In such case fitting the model may give an optimum solution that is unfeasible biologically. This is specially the case for the parameter $r$, the biomass growth rate. When fitting these models to short time series with little information content, the best solutions are often those with very high values of $r$ (larger than 1.0). Such solutions should be disregarded unless we know the species is short-lived and highly productive, in which case large $r$ values are possible.

The exact range of feasible values of $r$ for marine stocks has not been studied. Haddon (1997) reports for an Australian shrimp fishery a value of $r$ of 0.5 with 95% confidence limits between 0.2 and 0.95. For the South African hake, a fish that lives 10-12 years, Punt and Hilborn (1997) report a value of $r$ of 0.39, with 95% confidence intervals between 0.33 and 0.45. On the basis of theoretical considerations based on life history characteristics Adams (1980) suggested $r$ values of 0.9, 0.6 and 0.3 for stocks with maximum age of 13, 20 and 35 years respectively. Values of $r$ larger than 1.0, however, must be considered with caution even for very short-lived stocks like shrimp.

Model parameters tend to be strongly correlated, especially $r$ and $K$. Stocks with large $r$ tend to have $K$ values that are small in comparison to the catch extracted. Stocks with low $r$ values tend to have a biomass that is large in comparison to the catch extracted. As a result it is possible to obtain parameter sets that fit the data similarly, but with large differences in terms of stock productivity as measure by $r$. In such cases we do not advise to choose the best parameter on the basis of a fitting criterion alone (SSQ, Log Likelihood). Both sets of parameters should be used to reach alternative explanations of the status of stocks. Alternatively, on the basis of knowledge on the life history of the fish one may chose to fix the $r$ or the $K$ parameter and let the data determine the value of the other parameter. These models are simple to implement and spreadsheet programs like EXCEL can be easily adapted to fit any type of variation of the original model. During the workshop, we have implemented biomass dynamic models directly in EXCEL, but we also used the BIODYN software developed by Punt and Hilborn (1997).
5 DEVELOPMENT OF A MULTISPECIES-MULTIGEAR PER-RECRUIT MODEL THAT INCORPORATES PARAMETER VARIABILITY

A. J. Booth

5.1 Introduction

The purpose of fisheries management is to ensure the sustainable utilisation of fish stocks over time in an effort to promote the economic and social well-being of the harvesting fishers (Hilborn and Walters 1992). Essentially, sustainable management is dependent on the ability of fisheries managers to determine at what levels of fishing effort (or fishing mortality) and at which gear selectivity scenarios the catch of a species is sustainable and that the spawning stock remains adequate.

In many fishery scenarios abundance indices such as catch-per-unit-effort or biomass survey and/or length- or age-based catch data are not available. When abundance indices are available, these are often temporally disjunct and of little quantitative value. As a result the use of data intensive stock assessment methods such as Ad hoc tuned-Virtual Population Analysis (Pope and Shepherd 1985; Butterworth et al. 1990), integrated analysis (Deriso et al. 1985) and age-structured production models (Punt 1994; Booth and Punt 1998) cannot be applied. For these reasons per-recruit models (Beverton and Holt 1956, 1957) are favoured.

A per-recruit modelling approach, which allows for the easy evaluation of per-recruit to changes in fishing mortality and age-at-selectivity, has been widely applied in both marine and freshwater environments (Pulfrich and Griffiths 1988; Blay and Asabere-Ameyaw 1993; Booth and Buxton 1997; Thompson and Allison 1997). These models, however, assume that the parameters considered are constant and that the system is in a steady state (Punt 1993). In addition, these models have traditionally treated the target species in isolation from its environment, as well as from other species and from other gears. Since most fisheries present a scenario where many species are caught by each gear in a multigear fishery and in which interactions exist between species and their environment, the use of single species models in managing these fisheries is inadequate. These ‘traditional’ per-recruit models allow for the evaluation of the response of the per-recruit of a single species to changes in fishing mortality and age-at-50%-selectivity in a single fishery. Management advice based on the assessment of a fishery in isolation is inadequate when there are a number of fisheries harvesting the stock at differing ages-at-selectivity (Djama and Pitcher 1997). It has also long been recognised that when a common gear harvests a number of species, it is impossible to manage each species at its optimum level (Beverton and Holt 1957; Anderson 1975, Mitchell 1982; Pikitch 1987). For these reasons, Murawski (1984), Pikitch (1987) and Weyl et al. (in prep) have developed yield- and spawner biomass per-recruit models that account for the interaction of different species captured by the same gear or for different gears harvesting the same species at different selectivities.

5.2 The development of a multispecies-multifishery per-recruit model

Multispecies-multi-fishery per-recruit models are based on an extension of the traditional per-recruit models. A concise review of these “traditional” models is provided before showing the specific points of departure from the “traditional” approach.

The fundamental assumption of all per-recruit analyses is that the parameters for recruitment, growth, mortality and selectivity are temporally invariant, with the stock in a steady state situation. Under these assumptions, the composition of the stock is then
calculated by considering a cohort during its lifespan (Beverton and Holt 1957). The relative proportion of fish at age \( a \) \((N_a)\), is defined recursively as:

\[
\begin{align*}
\tilde{N}_a &= \begin{cases} 
1 & \text{if } a = 0 \\
\tilde{N}_{a-1}e^{-(M+S_{a-1}F)} & \text{if } 1 \leq a < \max \\
\tilde{N}_{\max-1}e^{-(M+S_{\max-1}F)}/(1-e^{-(M+S_{\max-1}F)}) & \text{if } a = \max 
\end{cases} \tag{1}
\end{align*}
\]

where \( S_a \) is selectivity at age \( a \), \( F \) is the instantaneous rate of fishing mortality on fully recruited cohorts, \( M \) is the instantaneous rate of natural mortality and \( \max \) is the maximum recorded age, essentially a lumped plus-group.

Weight-at-age is described as:

\[
W_a = \alpha(l_a)^\beta \tag{2}
\]

where \( l_a \) is the length-at-age determined using any suitable growth model and \( \alpha \) and \( \beta \) are the parameters describing the length-weight relationship.

Yield-per-recruit (YPR) and spawner biomass-per-recruit (SBR) as a function of fishing mortality (\( F \)) were determined by:

\[
YPR_F = \sum_{a=0}^{\max} w_a S_a F \tilde{N}_a [1 - e^{-(M+S_a F)}] / (M + S_a F) \tag{3}
\]

\[
SBR_F = \sum_{a=0}^{\max} \psi_a w_a \tilde{N}_a \tag{4}
\]

and biomass-per-recruit (BR) as function of age are determined as:

\[
BR_a = w_a \tilde{N}_a \tag{5}
\]

where \( \psi_a \) is the proportion of mature fish at age \( a \).

In a multigear fishery, the number of fish at age \( a \) is determined by the relative fishing mortality rate of each gear and its inherent selectivity. The total mortality rate (\( Z \)) is increased with each gear due to the additive effect that each gear has on the total fishing mortality rate (\( F \)) such that for \( j \) fisheries:

\[
Z_a = M_a + \sum_j S_a F_j \tag{6}
\]

For example, when three fisheries, 1, 2 and 3, are active the relative number-at-age of species \( i \) \((\tilde{N}_{ia})\), is described as:

\[
\tilde{N}_{ia} = \left\{ \begin{array}{ll}
1 & \text{if } a = 0 \\
\tilde{N}_{i,a-1} \exp(-(M_a + (S_{a1}F_{a1} + S_{a2}F_{a2} + S_{a3}F_{a3}))) & \text{otherwise}
\end{array} \right. \tag{7}
\]

where \( M \) is the rate of natural mortality, \( S_{a1}, S_{a2} \) and \( S_{a3} \) are the selectivities for age class \( a \) of the three fisheries under consideration and \( F_{a1}, F_{a2} \) and \( F_{a3} \) are the proportional fishing mortality rates (yr\(^{-1}\)) for each of the three fisheries.

Since the fishery targets each species, the coefficients of proportionality between fishing effort and fishing mortality (i.e. the catchability coefficients) will vary between species due to differences in their availability and vulnerability to the various gear (Murawski 1984).
At any given level of effort, the $F$ for each species in a multispecies fishery will be different. Catchability coefficients were estimated using the linear relationship:

$$F_{ij} = q_i \times f_j$$

(8)

where $q_i$ is the vector of catchability coefficients of species $i$ and $f_j$ is the vector of standardised effort in fishery $j$. Although alternative forms of Equation 8 have been suggested for various species (Peterman and Steer 1981), in this study the relationship between $f$ and $F$ is assumed to be linear for all species. The fishing mortality of species $i$ in each fishery $j$ ($F_{ij}$) could be determined by the proportional contribution of the catch (kg) of species $i$ by each gear to the total catch of that species in all gears.

The spawner-biomass-per-recruit for each species $i$ ($SBR_i$) in a multigear fishery is then determined by:

$$SBR_i = \max_{a=0} \sum \psi_{ia} w_{ia} \tilde{N}_{ia}$$

(9)

and yield-per-recruit for species $i$ ($YPR_i$) in a multispecies fishery was determined by:

$$YPR_i = \max_{a=0} \left[ \left( w_{ia} \tilde{N}_{ia} (1 - \exp(- (M_i + \sum_f S_{iaj} F_{ij}))) \right) \frac{\sum_f S_{iaj} F_{ij}}{M_i + \sum_f S_{iaj} F_{ij}} \right]$$

(10)

where $w_{ia}$ is the mass of species $i$ at age $a$, $S_{iaj}$ is the selectivity for age class $a$ of species $i$ by fishery $j$, $F_{ij}$ is the instantaneous rate of fishing mortality rate (yr$^{-1}$) for species $i$ for all fisheries $j$ under consideration, $M_i$ is the rate of natural mortality of species $i$ and $\max$ is the maximum recorded age for species $i$.

The annual yield of each species $i$ in all fisheries ($Y_i$) can be estimated by the equation:

$$Y_i = YPR_i \times R_i$$

(11)

where $YPR_i$ is the yield-per-recruit of species $i$ and $R_i$ is the number of recruits of species $i$ at equilibrium level. The level of pristine recruitment $R_i$ is a complicated parameter to estimate. Values can be obtained by cohort analysis, stratified sampling of juveniles or reparameterising 11. Assuming that given an annual total catch $Y_j$ from $j$ fisheries harvesting species $i$, then the number of recruits $R_i$ is calculated as:

$$R_i = \frac{Y_j}{YPR_i}$$

(12)

The yield of all species in the fishery $j$ ($Y_j$) was calculated by:

$$Y_j = \sum_i Y_i$$

(13)

and to obtain the total yield from all fisheries, all individual fishery yields were summed as:

$$Y_{total} = \sum_j Y_j$$

(14)

Gross annual revenue $GR_i$ for a species $i$ from all fisheries can simply be estimated as:

$$GR_i = Y_i \times P_i$$

(15)

where $P_i$ is the price be unit weight of species $i$.

The total gross revenue from all species and all fisheries is simply:
\[ GR_{total} = \sum_j GR_j \]  

(16)

5.3 Calculation of biological reference points

Various biological and target reference points (BRPs and TRPs) can be estimated within a per-recruit framework (see Caddy and Mahon, 1995 for a thorough discussion on the topic).

The most commonly used BRPs and TRPs calculated from the yield-per-recruit curve are:\n\[ F_{MAX} (= F_{MSY}) \] – the value of fishing mortality corresponding to the maximum of the yield-per-recruit curve and \( F_{o.x} \) – the value of fishing mortality corresponding to where the slope of the yield-per-recruit curve is \( x\% \) of the slope at the origin. Similarly, the most commonly used BRP/TRPs calculated from the spawner biomass-per-recruit curve is \( F_{SB(x\%)} \) – the value of fishing mortality corresponding to where spawner biomass-per-recruit curve is \( x\% \) of the pristine, unfished estimate.

5.4 Incorporating variability into the assessment framework

Due to the inherent difficulty in the estimation of various life history and fishery parameters, such as \( L_\infty, K, t_0, M, q \) and \( a_{50} \), the sensitivity of the per-recruit models to variability in these parameters needs to be assessed. A bootstrap estimation procedure is the most suitable routine used to estimate the standard error and confidence intervals of the BRP/TRPs generated by the model.

In the bootstrap procedure a large number (at least 500) \( (U_{500}) \) of random parameter samples \( (M_U; U=1,2,\ldots,U_{500}) \) were generated, each with its inherent error structure (inter alia normal, uniform or log-normal) and a corresponding set of \( (\hat{F}^1, \hat{F}^2, \ldots, \hat{F}^{U_{500}}) \) TRPs computed for each set of resampled input parameter sets.

The variance of \( \hat{F} \) is estimated as:

\[
Var(\hat{F}) = \frac{1}{U_{500} - 1} \sum_{U=1}^{U_{500}} \left[ \hat{F}^U - \bar{F} \right]^2
\]

(17)

where \( \bar{F} \) is the mean of the \( \hat{F} \) vector.

The standard error for the TRP \( \hat{F} \) is estimated as:

\[
SE_{\hat{F}} = \sqrt{\frac{Var(\hat{F})}{U_{500}}}
\]

(18)

The percentile method is used to estimate 95% confidence intervals, where the 2.5% and 97.5% quartiles from the sorted \( \hat{F} \) vector are chosen to represent the upper and lower 95% confidence intervals, respectively (Buckland 1984).
6 NORTHERN BRAZIL SHRIMP FISHERIES
J.A. Negreiros Aragão and K.C. de Araújo Silva

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)

<table>
<thead>
<tr>
<th>Year</th>
<th>Landings (kg)</th>
<th>Number of Days at Sea (DS)</th>
<th>CPUE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tails Whole</td>
<td>Boat Tricks Sea DS</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>169 789 264 871</td>
<td>6 42 987</td>
<td>28298.2 4042.6 172.0</td>
</tr>
<tr>
<td>1971</td>
<td>646 485 1 008 517</td>
<td>27 169 3 518</td>
<td>23943.9 3825.4 183.8</td>
</tr>
<tr>
<td>1972</td>
<td>264 864 413 188</td>
<td>16 88 1 896</td>
<td>16554.0 3009.8 139.7</td>
</tr>
<tr>
<td>1973</td>
<td>1 084 594 1 691 967</td>
<td>28 182 4 550</td>
<td>38735.5 5959.3 238.4</td>
</tr>
<tr>
<td>1974</td>
<td>716 625 1 117 935</td>
<td>34 221 5 967</td>
<td>21077.2 3242.6 120.1</td>
</tr>
<tr>
<td>1975</td>
<td>495 418 772 852</td>
<td>26 153 4 394</td>
<td>19054.5 3238.0 112.7</td>
</tr>
<tr>
<td>1976</td>
<td>871 955 1 360 250</td>
<td>29 248 7 018</td>
<td>30067.4 3515.9 124.2</td>
</tr>
<tr>
<td>1977</td>
<td>1 162 124 1 812 913</td>
<td>48 330 9 133</td>
<td>24210.9 3951.6 149.3</td>
</tr>
<tr>
<td>1978</td>
<td>1 718 407 2 680 715</td>
<td>50 299 8 502</td>
<td>34368.1 5747.2 202.1</td>
</tr>
<tr>
<td>1979</td>
<td>2 063 529 3 219 105</td>
<td>86 493 11 256</td>
<td>23994.5 4185.7 183.3</td>
</tr>
<tr>
<td>1980</td>
<td>3 571 165 5 571 017</td>
<td>158 912 23 913</td>
<td>22602.3 3915.8 127.2</td>
</tr>
<tr>
<td>1981</td>
<td>4 476 648 6 983 571</td>
<td>150 913 24 684</td>
<td>29844.3 4903.2 181.4</td>
</tr>
<tr>
<td>1982</td>
<td>3 770 477 5 881 944</td>
<td>155 807 25 702</td>
<td>24325.7 4672.2 146.7</td>
</tr>
<tr>
<td>1983</td>
<td>3 899 217 6 082 779</td>
<td>179 892 27 273</td>
<td>21783.3 4371.3 143.0</td>
</tr>
<tr>
<td>1984</td>
<td>5 493 466 8 569 807</td>
<td>254 1 339 40 355</td>
<td>21627.8 4102.7 136.1</td>
</tr>
<tr>
<td>1985</td>
<td>5 131 828 8 005 652</td>
<td>287 1 450 49 677</td>
<td>17880.9 3539.2 103.3</td>
</tr>
<tr>
<td>1986</td>
<td>4 574 966 7 136 947</td>
<td>256 1 341 46 510</td>
<td>17871.0 3411.6 98.4</td>
</tr>
<tr>
<td>1987</td>
<td>6 435 427 10 039 266</td>
<td>246 1 362 46 852</td>
<td>26160.3 4725.0 137.4</td>
</tr>
<tr>
<td>1988</td>
<td>6 356 622 9 916 330</td>
<td>228 1 247 39 593</td>
<td>27879.9 5097.5 160.5</td>
</tr>
<tr>
<td>1989</td>
<td>4 489 849 7 004 164</td>
<td>242 1 227 39 650</td>
<td>18553.1 3659.2 113.2</td>
</tr>
<tr>
<td>1990</td>
<td>3 918 749 6 113 248</td>
<td>256 1 136 36 226</td>
<td>15307.6 3449.6 108.2</td>
</tr>
<tr>
<td>1991</td>
<td>4 328 753 6 752 855</td>
<td>243 1 117 36 379</td>
<td>17813.8 3875.3 119.0</td>
</tr>
<tr>
<td>1992 (*)</td>
<td>3 888 590 6 066 200</td>
<td>188 30 838</td>
<td>126.1</td>
</tr>
<tr>
<td>1993 (*)</td>
<td>5 256 606 8 200 305</td>
<td>218 35 679</td>
<td>147.3</td>
</tr>
<tr>
<td>1994 (*)</td>
<td>4 071 472 6 351 497</td>
<td>209 34 261</td>
<td>118.8</td>
</tr>
<tr>
<td>1995 (*)</td>
<td>3 922 517 6 119 126</td>
<td>180 29 479</td>
<td>133.1</td>
</tr>
<tr>
<td>1996 (*)</td>
<td>3 739 746 5 834 004</td>
<td>163 26 794</td>
<td>139.6</td>
</tr>
<tr>
<td>1997 (*)</td>
<td>2 833 543 4 420 327</td>
<td>137 22 444</td>
<td>126.2</td>
</tr>
<tr>
<td>1998 (*)</td>
<td>3 473 956 5 419 372</td>
<td>131 21 462</td>
<td>161.9</td>
</tr>
</tbody>
</table>

(*) 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).

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)**

<table>
<thead>
<tr>
<th></th>
<th>$M$ (year$^{-1}$)</th>
<th>$L_{\infty}$ (total mm)</th>
<th>$K$ (year$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>1.920</td>
<td>177</td>
<td>1.17</td>
</tr>
<tr>
<td>Females</td>
<td>1.752</td>
<td>217</td>
<td>1.06</td>
</tr>
</tbody>
</table>

**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**

<table>
<thead>
<tr>
<th>Model</th>
<th>MSY Applied</th>
<th>$f_{MSY}$</th>
<th>CPUE at MSY</th>
<th>CPUE reference fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudepe 1985</td>
<td>Fox</td>
<td>8 400</td>
<td>51 000</td>
<td>165</td>
</tr>
<tr>
<td>Sudepe 1985</td>
<td>Fox</td>
<td>7 300</td>
<td>32 000</td>
<td>228</td>
</tr>
<tr>
<td>Sudepe 1986</td>
<td>Fox</td>
<td>7 900</td>
<td>44 886</td>
<td>176</td>
</tr>
<tr>
<td>Isaac et al.</td>
<td>Fox</td>
<td>8 499</td>
<td>52 436</td>
<td>162</td>
</tr>
<tr>
<td></td>
<td>Schaefer</td>
<td>9 016</td>
<td>72 298</td>
<td>125</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Limits</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>1.10</td>
<td>MSY 4906 903</td>
</tr>
<tr>
<td>$K$</td>
<td>17 843 284</td>
<td>$f_{MSY}$ 46 737</td>
</tr>
<tr>
<td>$B_{1991}$</td>
<td>12 104 549</td>
<td>SSQ 0.41</td>
</tr>
</tbody>
</table>

$q$ 0.000012

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Limit</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>0.80</td>
<td>MSY 4712 891</td>
</tr>
<tr>
<td>K</td>
<td>23 694 951</td>
<td>fMSY 45 850</td>
</tr>
<tr>
<td>B1991</td>
<td>17 904 004</td>
<td></td>
</tr>
<tr>
<td>q</td>
<td>0.00000868</td>
<td>SSQ 0.35</td>
</tr>
</tbody>
</table>

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.
7 ASPECTS OF FISHING FOR SNAPPER (*Lutjanus purpureus*) ON THE NORTH COAST OF BRAZIL

M. Asano Filho, R.F. Curtrim Souza and D. Dinnis Bezerra

7.1 Background

Snapper fishing started as a subsistence fishery in the Northeast Region of Brazil, around 1961 with small boats and primitive gears. From 1961 onwards, Portuguese fishermen started to use manual longlines (*linhas “pargueiras”*). In the 1970s, a gear called *bicicleta* (literally “bicycle”) began to be used as ancillary equipment for line recovery. Between 1974 and 1978, *linha pargueira* use expanded, but at that time it was used on board boats launched from a mother vessel.

Between 1980 and 1992, boat fishing was at its peak, but landed fish of poor quality due to poor handling of the catch. Subsequently, *linha pargueira*, operating with the *bicicleta*, expanded again and now combines productivity with good quality through improved handling of the catch. In 1997, snapper trap fishing started in the North Region with a small fleet, aiming at increasing productivity and quality.

The snapper fishing area in Brazil can be divided into three zones: the Oceanic Banks, the Northeast Continental Shelf and the North Continental Shelf. The North Continental Shelf, where the landings of the fleet are made in the State of Pará, is located between 46°20'W and 51°30'W. This area became important during the 1980s, having as its base the port of Bragança.

Presently, fisheries in the Northern Region use two different gears: “espinhel vertical” or “pargueira” (longline) and “covo” (trap). Longline “pargueira” is made with PA monofilament lines, 2mm diameter and 2330 DB (flatted shank) hooks, size 613 to 618 and it has 15 to 20 hooks per mother line (Fig. 7.1), with a lead weight of approximately 1.5kg. The gear to collect the main line is the bicycle (“bicicleta”). The “covo” or “manzuá” is a type of trap in the shape of a basket, with an iron structure surrounded by a PE screen (Fig. 7.2). The “sanga” (mouth) is funnel shaped and the lid, where the caught fish is kept, has a hinge, which facilitates removing the fish. The “covo” also has a bag where the bait is stored.

Comparing the two fishing systems above, traps appear to have some advantages. They appear to have a higher catch efficiency, although this should be verified through further analysis and they are more selective, allowing smaller individuals to escape, depending on the size of the funnel. Also, trap fishers land fish that is still alive, while with the “pargueira” fish die due to injuries caused by the hooks and/or to stress.

Among the species caught using “pargueira” longline and/or “manzuá” trap, there are: pargo piranga (*Rhomboplitis auroubens*), arabaina (*Elgatis bipinnulatus*), serigado (*Mycteroperca bonaci*), cioba (*Lutjanus analis*), ariacó (*Lutjanus synagris*), cavala (*Scomberomorus cavalla*), garajuba (*Caranx barholomaei*), piraúna (*Cephalopholis fulva*), mariquita (*Holocentrus ascensionis*), garoupa (*Epinephelus morio*), sapuruna (*Haemulon aurolinatum*) and urbana verdadeira (*Elops saurus*).

There are three different types of vessels fishing snapper:

- **Small Size Vessels (“Barco de Pequeno Porte – BPP”)** – engine powered boats (average of 24 HP), made of wood, with a total length ranging from 8 to 12 m and total hold capacity of 6 t. The boats are equipped with compass and echosounder, generally use longline and have trips up to 15 days at sea, fishing an average of 8 days and landing fish on ice. Usually the number of crew is 6.

- **Medium Size Vessels (“Barco de Médio Porte – BMP”)** – engine powered boats (average 50HP), made of wood, with a total length above 12 m and a total hold
capacity of 8 t using ice. The boats are equipped with compass, GPS, VHF radio and echosounder and use longline or traps (“manzuá/covo”), with trips up to 25 days at sea, fishing an average of 11 days. When traps are used, the number of traps is usually 6. The usual number of crew is 8.

- Industrial Vessels (“Barco Industrial – BIN”) – engine powered boats (average of 150HP), with a steel hull, total length above 15m and a total hold capacity of 45t, using ice. The boats are equipped with compass, GPS-plotter, VHF radio, SSB radio and echosounder, using longline or traps (“manzuá/covo”). When traps are used, the number of traps is usually 10. The boat can make trips up to 60 days at sea, but currently, the trips for fresh fish last 10 to 20 days (average 15 days) and the usual number of crew is 19 (linha pargueira) or 12 if using traps.

![Figure 7.1 Linha pargueira used in the North Brazil Red Snapper fisheries](image1)

**Figure 7.1 Linha pargueira used in the North Brazil Red Snapper fisheries**

![Figure 7.2 - Traps (covo) used to catch red snapper in North Brazil](image2)

**Figure 7.2 - Traps (covo) used to catch red snapper in North Brazil**
7.1.1 Landing ports

In the North Region, all snapper is landed in the State of Pará at 11 different landing points. The main ports are Belém, Vigia, São João de Pirabas and Bragança (Fig. 7.3), which account for an average of 98% of the total landings.

![Figure 7.3 Landing production in 4 different landing sites in 1997-98](image)

**Belém**

Presently, there are 4 fishing companies in Belém, with 5 steel boats, all of them using traps targeting fresh fish. Three of these companies catch, process and market the product and one of them is limited to catching fish only.

In 1998, the city of Belém accounted for a total landing production of 295.72 t of fresh snapper, with an average price of R$ 2.2 kg\(^{-1}\) (approximately US$ 1.35 kg\(^{-1}\), using the present exchange rate). All the production is sold in the Brazilian Northeast region, mainly in the States of Ceará and Pernambuco.

**Vigia**

There is only one company fishing for snapper in Vigia. It has two steel boats, both operating with traps and also processes and markets the product. In 1998, Vigia accounted for the landing of 214.50 t of fresh snapper, which was mainly exported.

**São João de Pirabas**

There is only one fishing company located in São João de Pirabas fishing for snapper. It has a fleet of 20 wooden boats, although only 4 boats catch snapper and they use traps. This company does not process fish, but exports all landings to the Northeast Region. In 1998, São João de Pirabas accounted for landings of 232.62 t of fresh snapper.
Bragança

The city of Bragança is the largest landing area of the North Region, accounting for 62% of the total annual production. There is one ice plant, but no record of fishing companies operating in the city. Vessels come from other cities in the State, but land at Bragança.

All landings are exported to the Northeast Region, where intermediate companies acquire it. In 1998, Bragança accounted for the landing of 2 166.9 t of snapper. The records show a fleet of 58 boats, 93% of which operate with longlines and the remainder use traps.

7.1.2 Data collected in the north of Brazil

Landings and effort data in the North Region, from 1996 on, were obtained through the Estatpesca Project, carried out by the Centro de Pesquisa e Extensão Pesqueira do Norte do Brasil (CEPNOR/IBAMA), supported by the Superintendence for the Development of the Amazon (SUDAM) and the REVIZEE Program (Program for Assessment of Potentially Sustainable Resources in the Exclusive Economic Zone). Up to 1995, the Ministry of Agriculture collected the data on the snapper landings in Brazil only through inspections of the landed catch.

At present, data collection consists of forms filled out by data collectors on landings in each of the locations with fishing activities. The completed forms contain information on the species caught, prices, catch and fleet.

Biological data collection by SUDEPE began in the North Region of Brazil in early 1978 and continued until 1988. In August 1997, CEPNOR/IBAMA undertook this task, concentrating on samples taken at 4 landing points (Belém, Vigia, São João de Pirabas and Bragança). A sub-sample of 150 individuals to study reproduction and feeding cycles has been taken from the length samples. This project is also part of the REVIZEE Program.

7.1.3 Production

From 1995 to 1998, snapper fishing in the North Region had a total production ranging from 493 to 2 900 t year⁻¹. It has been suggested that in 1995 the production was underestimated due to the absence of a consistent sampling programme. In 1996, the sampling programme was adjusted to reflect more closely the characteristics of the region, but total production for this year was probably still underestimated (Fig. 5.1.7). Therefore for statistical purposes, only the years 1997 and 1998 may be used, as during these years collection was reliable.

For these last two years, snapper production has been stable, with landing peaks in October (Fig. 7.4). In Belém, snapper landings have remained stable over the last two years, despite a reduction in the number of boats. In Vigia, production decreased by 16.62 t, probably due to a relocation of BMP boats. In S.João de Pirabas, there was a reduction of 291 t in production also due to the decrease in the fleet size (BMP boats). In Bragança 1998, production increased to 337 t compared with previous years; this may be due to an increase in the fleet size (BPP boats) and the switch to traps by the end of 1997.

There are currently two fishing methods for snapper: “pargueira” (longline) is responsible for 50% of catchings in the area and is used by the larger number of vessels. Traps started to be used in August 1997 by a steel boat based in the city of Vigia (Fig. 7.5). During the last two years (1997-98), wooden vessels with longlines accounted for 60% of the total catch, steel vessels with longlines for 22%, wooden vessels with traps for 13% and steel vessels with traps for 5%.
Figure 7.4 Annual production of snapper in northern Brazil. The increase in estimates from 1995 to 1997 is probably due to improvements in the sampling programme rather than any real increase in production.

Figure 7.5 Production in North Region for different gears 1997-98

7.1.4 CPUE

CPUE for this analysis was calculated as metric tonnes per day (t day$^{-1}$). Calculations were performed to verify the CPUE behaviour during the years of 1997 and 1998, for the different fishing systems and fishing boats in the 4 ports reporting snapper landings. CPUE was calculated as follows:

\[
CPUE = \frac{\text{Landing (t)}}{\text{Days at sea}}
\]

\[
CPUE \text{ (average)} = \frac{\text{Total Landed (t)}}{\text{Total days at sea}}
\]
The highest CPUE was found in the steel vessels fishing with traps (Fig. 7.6). The longline fishing showed an average CPUE of 0.569 (steel boat) and 0.389 t day\(^{-1}\) (wood boat) in the year of 1998. The traps showed an average of 0.688 (steel boat) and 0.371 (wooden boat) t day\(^{-1}\) in spite of having a smaller number of vessels.

![Figure 7.6 Average catch rates for each vessel / gear type 1997-1998](image)

During the last two years, a transition in the fishing system was observed, with a switch from longline to trap. Two of the four landing points, Belém and Vigia, with the exception of only one wood boat in Belém, do not use the longline any more. Snapper fishing in these two cities is carried out only by steel boats with traps and has shown a growth in CPUE during the last two years, which may continue to increase even further into 1999.

### 7.1.5 Biological parameters

Biological studies for snapper started in 1967, when the first growth curve was determined (Menezes and Gesteira, 1974), but at this time snapper fishing was of a low intensity (Ivo and Hanson, 1982). The von Bertalanffy growth parameters determined at that time were:

\[
L_\infty = 98.9\text{cm}, \quad K = 0.090 \quad \text{and} \quad t_0 = -2.7 \text{years}.
\]

From 1970 to 1975, data on catch and effort were collected and biological samples were taken at landing sites. During this period, reproduction studies were done and the spawning was found to be discontinuous and periodic (biannual) and the size at first sexual maturity for females was estimated as 42 cm in total length (Gesteira and Ivo, 1973).

In 1979-82, scale readings were carried out on 430 individuals of both sexes and the following growth parameters were estimated: \(L_\infty = 92.9\text{cm}, \quad K = 0.103 \quad \text{and} \quad t_0 = 2.8 \text{years}.
\)

With the data from 1967-81, total mortality was estimated from a catch curve as \(Z = 0.835 \text{year}^{-1}\) (Fonteles-Filho and Oliveira, 1983).

Ivo and Hanson (1982) presented two hypotheses for the snapper stock. The first one suggested the existence of only one stock, with two classes of individuals, originating from two different periods of spawning, one in March-April and the other one in October. The second hypothesis suggested the existence of two stocks because of the difference in the period of spawning, with two groups of females spawning once each year. Sales (1998)
conducted a genetic analysis and observed the existence of two red snapper stocks one from the Northeastern (43°-46°) and the other from the Northern Region (47°-49°). Therefore, the second hypothesis proposed by Ivo and Hanson (1982) seems to be the correct one.

7.1.6 Preliminary analysis of the biological data

**Growth**

Data on the total length from landings samples taken in 1998 were used. They were grouped in 2cm frequencies every three months. Frequencies ranged from 19 to 84cm throughout the year. The Bhattacharya method was used to determine cohort growth and ELEFAN to estimate growth parameters. Nevertheless, the analysis was not considered satisfactory and therefore published estimates were used for the calculations: \( L_\infty = 92.9\text{cm}, K = 0.103 \) and \( t_0 = 2.8 \) years (Ximenes and Fonteles-Filho 1988).

**Natural mortality**

An estimate of natural mortality was obtained with FISAT, through the equation of Pauly, where the value of \( M = 0.29 \) was obtained. Analyses were also repeated using an estimate from the literature for \( M = 0.20 \) (Gesteira and Ivo, 1973).

**Fishing mortality**

Fishing mortalities were determined by a length-converted catch curve (Table 7.1). An increase in fishing mortality in the third quarter was observed due to the increase in the fishing effort.

Yield-per-recruit (YPR) simulations were carried out using two values for natural mortality \( M=0.2 \) and \( M = 0.29 \) (Table 7.2). The analysis result shows that using \( M = 0.2 \) seems to give the most reliable results, since the values obtained represent the actual red snapper fishery stage.

Management measures may be needed to protected the spawning stock as SBR\(_{40}\%) reference point (\( F=0.33 \)), since the average fishing mortality (\( F=0.75 \)) is much higher than the \( F_{0.1} \) (\( F=0.46 \)) related to conservation reference point (Fig. 7.7). Hence, the stock is probably overexploited. Additional analyses will be necessary to verify the effect of fishing on the spawning stock and recruitment.

**Table 7.1 Fishing mortality estimates for Lutjanus purpureus in 1997**

<table>
<thead>
<tr>
<th></th>
<th>( R^2 )</th>
<th>( F ) (M=0.29)</th>
<th>( F ) (M=0.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 quarter</td>
<td>0.79</td>
<td>0.539</td>
<td>0.629</td>
</tr>
<tr>
<td>2 quarter</td>
<td>0.94</td>
<td>0.577</td>
<td>0.667</td>
</tr>
<tr>
<td>3 quarter</td>
<td>0.94</td>
<td>0.905</td>
<td>0.995</td>
</tr>
<tr>
<td>4 quarter</td>
<td>0.89</td>
<td>0.644</td>
<td>0.734</td>
</tr>
<tr>
<td>Mean</td>
<td>0.666</td>
<td>0.756</td>
<td></td>
</tr>
</tbody>
</table>
Table 7.2 Simulations of yield per recruit (YPR) and various biological reference points, using two values of natural mortality (M)

<table>
<thead>
<tr>
<th>M=0.2</th>
<th>F</th>
<th>F+0.01</th>
<th>SBR</th>
<th>YPR (F)</th>
<th>YPR (F+0.01)</th>
<th>Slope</th>
<th>SBR 50%</th>
<th>SBR 40%</th>
<th>SBR 30%</th>
<th>0.1 Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>F=0</td>
<td>0</td>
<td>0.01</td>
<td>519.57</td>
<td>0.00</td>
<td>8.28</td>
<td>8.28</td>
<td>259.79</td>
<td>207.83</td>
<td>155.87</td>
<td>0.83</td>
</tr>
<tr>
<td>0.1 Slope = 0.8277</td>
<td>0.46</td>
<td>0.46</td>
<td>143.82</td>
<td>162.06</td>
<td>162.89</td>
<td>0.83</td>
<td>71.91</td>
<td>57.53</td>
<td>43.15</td>
<td>0.08</td>
</tr>
<tr>
<td>SB 50% = 259.787</td>
<td>0.25</td>
<td>0.26</td>
<td>259.79</td>
<td>126.30</td>
<td>128.99</td>
<td>2.68</td>
<td>129.89</td>
<td>103.91</td>
<td>77.94</td>
<td>0.27</td>
</tr>
<tr>
<td>SB 40% = 207.8296</td>
<td>0.33</td>
<td>0.34</td>
<td>207.83</td>
<td>144.59</td>
<td>146.37</td>
<td>1.79</td>
<td>103.91</td>
<td>83.13</td>
<td>62.35</td>
<td>0.18</td>
</tr>
<tr>
<td>SB 30% = 155.8722</td>
<td>0.43</td>
<td>0.44</td>
<td>155.87</td>
<td>159.28</td>
<td>160.27</td>
<td>0.99</td>
<td>77.94</td>
<td>62.35</td>
<td>46.76</td>
<td>0.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M=0.29</th>
<th>F</th>
<th>F+0.01</th>
<th>SBR</th>
<th>YPR (F)</th>
<th>YPR (F+0.01)</th>
<th>Slope</th>
<th>SBR 50%</th>
<th>SBR 40%</th>
<th>SBR 30%</th>
<th>0.1 Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>F=0</td>
<td>0</td>
<td>0.01</td>
<td>302.68</td>
<td>0.00</td>
<td>5.15</td>
<td>5.15</td>
<td>151.34</td>
<td>121.07</td>
<td>90.80</td>
<td>0.51</td>
</tr>
<tr>
<td>0.1 Slope = 0.5151</td>
<td>0.50</td>
<td>0.51</td>
<td>75.80</td>
<td>108.18</td>
<td>108.69</td>
<td>0.51</td>
<td>37.90</td>
<td>30.32</td>
<td>22.74</td>
<td>0.051</td>
</tr>
<tr>
<td>SB 50% = 151.34</td>
<td>0.25</td>
<td>0.26</td>
<td>151.34</td>
<td>81.03</td>
<td>82.81</td>
<td>1.78</td>
<td>75.67</td>
<td>60.53</td>
<td>45.40</td>
<td>0.18</td>
</tr>
<tr>
<td>SB 40% = 121.071</td>
<td>0.33</td>
<td>0.34</td>
<td>121.07</td>
<td>93.43</td>
<td>94.66</td>
<td>1.22</td>
<td>60.53</td>
<td>48.43</td>
<td>36.32</td>
<td>0.12</td>
</tr>
<tr>
<td>SB 30% = 90.803</td>
<td>0.44</td>
<td>0.45</td>
<td>90.80</td>
<td>103.90</td>
<td>104.63</td>
<td>0.73</td>
<td>45.40</td>
<td>36.32</td>
<td>27.24</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Figure 7.7 Yield-per-recruit (--) and spawning stock biomass per recruit (---) (M=0.2)
7.1.7 Conclusions

- Total production remained stable over the last two years.
- Traps have a higher catch rate than longlines.
- There is a production peak in the third quarter of the year.
- Licences for boats operating with traps and for boats operating with longlines must be assessed separately.
- The yield-per-recruit analysis suggests that the stock may be overexploited.
- Data collected in 1997 do not permit calculation of growth parameters ($L_\infty$, $K$ and $t_0$), possibly because biological samplings come from two different stocks.

7.1.8 Recommendations

- For a better analysis of catch and effort, data collection on landings in the region must be maintained.
- For at least four more years, additional vessels should not be allowed to fish until a better bio-economic analysis can be done.
- From the total licences granted for snapper fishing, a ratio for trap fishing should be established.
- Separate analyses should be carried out for each sample representing the different stocks.
- We suggest that the $F_{0.1}$ be considered as the target reference point.
8 THE FISHERY FOR BROWN SHRIMP (*Penaeus subtilis*) IN FRENCH GUIANA

A. Charuau and D. Die

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 km², 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](image)

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Penaeus subtilis</em></td>
<td>3512</td>
<td>3618</td>
<td>3117</td>
<td>3660</td>
<td>2833</td>
<td>3854</td>
<td>3684</td>
<td>3755</td>
<td>3667</td>
<td>3785</td>
</tr>
<tr>
<td><em>Penaeus brasiliensis</em></td>
<td>192</td>
<td>308</td>
<td>209</td>
<td>290</td>
<td>225</td>
<td>299</td>
<td>316</td>
<td>562</td>
<td>310</td>
<td>151</td>
</tr>
<tr>
<td><em>Solenocera acuminata</em></td>
<td>143</td>
<td>167</td>
<td>84</td>
<td>74</td>
<td>17</td>
<td>107</td>
<td>180</td>
<td>16</td>
<td>73</td>
<td>92</td>
</tr>
<tr>
<td><em>Parapenaeus edwardsianus</em></td>
<td>41</td>
<td>55</td>
<td>259</td>
<td>150</td>
<td>140</td>
<td>55</td>
<td>33</td>
<td>326</td>
<td>89</td>
<td>167</td>
</tr>
</tbody>
</table>

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.
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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Landings in tonnes</td>
<td>3512</td>
<td>3618</td>
<td>3117</td>
<td>3660</td>
<td>2833</td>
<td>3854</td>
<td>3684</td>
<td>3755</td>
<td>3667</td>
<td>3785</td>
</tr>
<tr>
<td>Numbers of samples</td>
<td>48</td>
<td>57</td>
<td>115</td>
<td>110</td>
<td>80</td>
<td>81</td>
<td>80</td>
<td>95</td>
<td>81</td>
<td>114</td>
</tr>
<tr>
<td>Mean sample numbers of <em>P.subtilis</em></td>
<td>442</td>
<td>375</td>
<td>426</td>
<td>533</td>
<td>339</td>
<td>508</td>
<td>539</td>
<td>432</td>
<td>482</td>
<td>506</td>
</tr>
<tr>
<td>Effort in fishing days</td>
<td>22494</td>
<td>18854</td>
<td>1452</td>
<td>1583</td>
<td>1547</td>
<td>1557</td>
<td>1604</td>
<td>1684</td>
<td>1691</td>
<td>1619</td>
</tr>
</tbody>
</table>

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

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](image)

### 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*](image)

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](image)

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.)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Limit</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation Error Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>1.11</td>
<td>MSY</td>
</tr>
<tr>
<td>K</td>
<td>15858</td>
<td>(U_{MSY})</td>
</tr>
<tr>
<td>Q</td>
<td>0.000024</td>
<td>(f_{MSY})</td>
</tr>
<tr>
<td>Process Error Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>1.21</td>
<td>MSY</td>
</tr>
<tr>
<td>K</td>
<td>14662</td>
<td>(U_{MSY})</td>
</tr>
<tr>
<td>Q</td>
<td>0.000025</td>
<td>(f_{MSY})</td>
</tr>
</tbody>
</table>

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 \( f_{\text{MSY}} \) 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fishing Power Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>( r )</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>24.3%</td>
</tr>
<tr>
<td>( K )</td>
<td>-21.8%</td>
</tr>
<tr>
<td></td>
<td>-9.2%</td>
</tr>
<tr>
<td>MSY</td>
<td>-4.7%</td>
</tr>
<tr>
<td></td>
<td>-3.7%</td>
</tr>
<tr>
<td>( f_{\text{MSY}} )</td>
<td>-3.3%</td>
</tr>
<tr>
<td></td>
<td>4.5%</td>
</tr>
</tbody>
</table>

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), \( f_{\text{MSY}} \) (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).
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).

**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
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
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, $F_{\text{max}}$ 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.

<table>
<thead>
<tr>
<th></th>
<th>K (month⁻¹)</th>
<th>L_∞ (cephalothorax mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. subtilis</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isaac, Dias Neto and Damsceno (1992)</td>
<td>females</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>0.0974</td>
</tr>
<tr>
<td>Dintheer and Le Gall (1988)*</td>
<td>females</td>
<td>0.190</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>0.155</td>
</tr>
</tbody>
</table>

* 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.
9 RED SNAPPER (*Lutjanus purpureus*) FISHERY IN FRENCH GUIANA

A. Charauau and D. Die

### 9.1 Introduction

The Management Area is comprised between Maroni river, in the western part and Oyapock river, in the eastern part of the fishery (see Fig. 9.1). The potential surface of the fishery for red snappers is approximately of 26000 km², from the isobaths of 50-120m. It is harvested on the rocky grounds by a Venezuelan fleet of 41 licensed hand liners, from Pampatar and Carupaño (Table 9.1). The licences are nominative and free and assigned by the EU. Under the licence agreement, the skippers have to land and sell 75% of their catches to two processors in French Guiana with whom they have a production contract.

![Figure 9.1 Map of the fishing zones for red snapper (*L. purpureus*) in French Guiana](image)

A new fishery exploited by fishermen from La Martinique and La Guadeloupe was initiated in 1996. They operate with pots mainly on muddy grounds. That fishery is also targeting vermilion snapper (*Rhomboplites aurorubens*) and lane snapper (*Lutjanus synagris*). For this assessment, this new activity was considered too recent and too small to introduce significant trends in the fishery in 1997 and 1998. However, it is likely that in the next assessments this new factor must be introduced in the assessment of the red snapper.
Table 9.1 Summary of landings, effort and CPUE of *L. purpureus* on the fishery of French Guiana, from 1986 to 1997.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of licensed boats</th>
<th>Mean no. of boats at sea</th>
<th>Effort (Days fishing)</th>
<th>Effort hours fishing</th>
<th>Landings (t)</th>
<th>CPUE (kg per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Venezuela</td>
<td>Barbados*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>20</td>
<td>5</td>
<td>9</td>
<td>1409</td>
<td>15635</td>
<td>677</td>
</tr>
<tr>
<td>1987</td>
<td>25</td>
<td>5</td>
<td>10</td>
<td>2875</td>
<td>33846</td>
<td>716</td>
</tr>
<tr>
<td>1988</td>
<td>25</td>
<td>5</td>
<td>13</td>
<td>2973</td>
<td>30951</td>
<td>1116</td>
</tr>
<tr>
<td>1989</td>
<td>35</td>
<td>5</td>
<td>20</td>
<td>5200</td>
<td>53234</td>
<td>1366</td>
</tr>
<tr>
<td>1990</td>
<td>35</td>
<td>5</td>
<td>18</td>
<td>4559</td>
<td>48898</td>
<td>1278</td>
</tr>
<tr>
<td>1991</td>
<td>35</td>
<td>5</td>
<td>20</td>
<td>4638</td>
<td>45879</td>
<td>1115</td>
</tr>
<tr>
<td>1992</td>
<td>41</td>
<td>5</td>
<td>18</td>
<td>5360</td>
<td>44700</td>
<td>1197</td>
</tr>
<tr>
<td>1993</td>
<td>41</td>
<td>5</td>
<td>19</td>
<td>4516</td>
<td>43844</td>
<td>1383</td>
</tr>
<tr>
<td>1994</td>
<td>41</td>
<td>5</td>
<td>20</td>
<td>4953</td>
<td>44580</td>
<td>1468</td>
</tr>
<tr>
<td>1995</td>
<td>41</td>
<td>5</td>
<td>17</td>
<td>5284</td>
<td>48996</td>
<td>1462</td>
</tr>
<tr>
<td>1996</td>
<td>41</td>
<td>5</td>
<td>27</td>
<td>9001</td>
<td>71645</td>
<td>2110</td>
</tr>
<tr>
<td>1997</td>
<td>41</td>
<td>5</td>
<td>23</td>
<td>7478</td>
<td>64729</td>
<td>1578</td>
</tr>
<tr>
<td>1998</td>
<td>41</td>
<td>5</td>
<td>28</td>
<td>7891</td>
<td>71244</td>
<td>1840</td>
</tr>
</tbody>
</table>

* These licences to Barbados were given by the EU under a scheme for ACP countries, but never used.

When Venezuelan boats return to Margarita approximately every quarter, they leave French Guiana with the equivalent of 25% of their total annual catch. In previous analysis that amount was not taken into account but it is used in the present assessment. An approximation is made for the estimation of the corresponding effort.

The timing of the fishing by Venezuelan fishermen is marked by two events:

- From April to June there is a decrease in monthly effort (Fig. 9.3) during the wet season in French Guiana.
- At the end of November and at the beginning of December, they return to Margarita, coming back to the fishery the following February.

The activity of shrimp trawlers is an important source of mortality for young red snappers. Preliminary evaluations of the number of juveniles caught during surveys by typical shrimp-trawlers give estimates as high as 1.5 to 2 million individuals caught by the French Guiana fleet.
Figure 9.2 Catches per unit effort (---) and total landings (-----) of *L. purpureus*. There has been a slight decline in CPUE as catches have decreased (see also Table 9.1).

![Graph showing catches per unit effort and total landings for *L. purpureus*.](image)

Figure 9.3 Effort, landings and CPUE of *L. purpureus* on the fishery of French Guiana on the series (1985-1998)

![Graph showing effort, landings, and CPUE for *L. purpureus* in French Guiana.](image)
9.2 Data and biological inputs

Length compositions of the Venezuelan production of red snapper from French Guiana have been sampled since 1985 (Table 9.2).

Discard data are not available and, in fact, the very small fishes, probably unmarketable, are used as bait for the hooks. The amount of bait (the sardine caught in the Gulf of Paria) is often insufficient for covering their needs during all the voyage on the Guiano-Brazilian shelf.

The biological parameters are given in Table 9.7. The growth parameters and the value for natural mortality are from Perodou (unpublished thesis, 1994). Preliminary works using the programme ELEFAN has been done in 1998. They give information consistent with the values calculated by Perodou. In the paper, the lengths of fishes are given exclusively as fork-length.

Table 9.2 Data and input parameters for *L. purpureus* caught by Venezuelan - Handlines - # 5/0 and # 6/0, in French Guiana

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers of samples</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Mean number of snappers by sample</td>
<td>324</td>
<td>602</td>
<td>288</td>
<td>282</td>
<td>575</td>
<td>426</td>
<td>374</td>
<td>291</td>
<td>270</td>
<td>175</td>
<td>388</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Values</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>von Bertalanffy Growth: ( K ) year(^{-1} )</td>
<td>0.12</td>
<td>Pérodou 1994</td>
</tr>
<tr>
<td>( L_\infty ) (fork length in cm)</td>
<td>95.0</td>
<td></td>
</tr>
<tr>
<td>Natural Mortality year(^{-1} )</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Age at 100% maturity (years)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Length/weight relationship: ( a )</td>
<td>0.01489</td>
<td></td>
</tr>
<tr>
<td>Length/weight relationship: ( b )</td>
<td>3.01767</td>
<td></td>
</tr>
<tr>
<td>Conversion factors: Nominal weight from gutted weight</td>
<td>1.105</td>
<td></td>
</tr>
<tr>
<td>Total length from fork length</td>
<td>1.087</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prevost 1989</td>
<td></td>
</tr>
</tbody>
</table>

9.2.1 Comments on the general quality of the inputs

Length frequency data, from 1986 onwards, are available on a monthly basis from samples of the landings only in Cayenne. The fish landed in Venezuela are not sampled.

Information on the landings composition and the numbers of hours fished per voyage are obtained from logbooks. The exact situation of the daily fishing is given by the skipper for a zone and a depth (see map). No discard sampling programmes have been undertaken.

For the present assessment, the series 1988 to 1998 was retained for running length cohort analysis (LCA) and the complete series (1986-1998) for the VPA.

9.2.2 Landings and effort

As for penaeid shrimps, the capture of the snappers is not sorted on board and the production of the three species, *Lutjanus purpureus*, *Lutjanus synagris* and *Rhomboplites aurorubens* are estimated through the scientific sampling (Table 9.3).
Table 9.3 Estimated catches in tonnes of snappers by the Venezuelan fleet in the French Guiana EEZ

<table>
<thead>
<tr>
<th>Year</th>
<th><em>Lutjanus purpureus</em></th>
<th><em>Rhomboplites aurorubens</em></th>
<th><em>Lutjanus synagris</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>677</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>1987</td>
<td>716</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>1988</td>
<td>1116</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td>1989</td>
<td>1366</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>1990</td>
<td>1278</td>
<td>51</td>
<td>3</td>
</tr>
<tr>
<td>1991</td>
<td>1115</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>1992</td>
<td>1197</td>
<td>94</td>
<td>3</td>
</tr>
<tr>
<td>1993</td>
<td>1383</td>
<td>135</td>
<td>1</td>
</tr>
<tr>
<td>1994</td>
<td>1468</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>1995</td>
<td>1462</td>
<td>119</td>
<td>4</td>
</tr>
<tr>
<td>1996</td>
<td>2110</td>
<td>137</td>
<td>10</td>
</tr>
<tr>
<td>1997</td>
<td>1578</td>
<td>117</td>
<td>10</td>
</tr>
<tr>
<td>1998</td>
<td>1840</td>
<td>179</td>
<td>2</td>
</tr>
</tbody>
</table>

The landings are strongly correlated with fishing effort ($R^2=0.82$, df=11). A correlation between landings per unit effort and effort can be detected ($R^2=0.40$, df=11), but is heavily dependent on the 1986 data point. The relationship essentially disappears with the removal of that point ($R^2=0.08$, df=12), suggesting it is unreliable.

In spite of a control of the use of licences in Cayenne, it is likely that a part of the catches can be sold in Paramaribo, Suriname and that the share of the catch that returns to Venezuela is therefore not known. When a boat sells its catch in Paramaribo, there are no data (effort and landing) on the corresponding trip. Illegal landings should be included, but data are not available. Snapper landings in Cayenne are probably under estimated.

The main bycatch of the hook and line fishery comprises ten species of groupers, which are not landed in Cayenne, various Carangidae, pelagic sharks, which are processed on board (salted and dried) and, seasonally, *Scomberomorus* spp. (king mackerels).

The estimated total directed effort follows exactly the number of boats in the time series. Two years’ effort data may be inaccurate. In 1986 and 1987, the regulation had just started and the licence system did not work correctly.

In 1996, there was an observed increase in effort. The list of licensed boats was revised, day after day, which permitted the replacement of boats leaving periodically the fishery, so this increase could be an artefact of the licensing process rather than any real increase in effort.

The average CPUE of the red snapper fleet has remained around 28 kg hour$^{-1}$ fishing for the last 10 years (Fig. 9.2). CPUE is usually highest from June to November (Fig. 9.3).

### 9.2.3 Mean size

Mean sizes (fork-length) in the landings (Fig. 9.4) are available since 1986. There has been a marked decrease in mean size of red snapper in the landings since 1991. That decrease corresponds to an important increase in the number of small specimens in the landings. There has been a trend of increasing numbers of fish landed as the mean fish size has decreased (Fig. 9.4). The size of the traditional hooks (# 5/0 and #6/0) has remained unchanged, suggesting selectivity has not changed through changes in gear used.
Figure 9.4 Total number of *L. purpureus* (○) and mean fork-length in the range 20-32cm (—) in landings of the Venezuelan fleet in French Guiana from 1986 to 1998. The average size declines as the estimated numbers of fish in the landings is rapidly increasing.

![Graph showing total numbers and mean fork-length](image)

Figure 9.5 Fishing mortality by fork length from LCA for *L. purpureus*

### 9.3 Assessments

#### 9.3.1 Length cohort analysis

The Length Cohort Analysis used the average annual length compositions, from 1988 to 1998. LCA assumes the fishery was at equilibrium during this period. The terminal F chosen is $F = 0.25$, which gave for the lengths 55 to 67cm better smoothed values of F.

Input data and results are given on Table 9.4. The results suggest a peak selectivity around 38cm FL (Fig. 9.5). The yield-per-recruit curve suggests that the $F_{MSY}$ is exceeded by at least 25% (Fig. 9.6), while the spawning stock biomass per recruit (SSB/R) has reached very low levels.
Figure 9.6 Y/R and SSB/R (in kg) from LCA for *L. purpureus* in French Guiana

Table 9.4 Input values and results of Length Cohort Analysis (LCA) *L. purpureus* in French Guiana. The von Bertalanffy growth model used parameters: $L_\infty = 95\text{cm}$. $K = 0.12\text{ year}^{-1}$

<table>
<thead>
<tr>
<th>Length (cm)</th>
<th>Catches (year$^{-1}$)</th>
<th>M</th>
<th>$dt$</th>
<th>Fdt (year$^{-1}$)</th>
<th>F</th>
<th>Z (year$^{-1}$)</th>
<th>Zdt</th>
<th>Average number attaining size</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>182</td>
<td>0.2</td>
<td>0.1119</td>
<td>0.0001</td>
<td>0.0008</td>
<td>0.2008</td>
<td>0.0225</td>
<td>2090638</td>
</tr>
<tr>
<td>21</td>
<td>308</td>
<td>0.2</td>
<td>0.1134</td>
<td>0.0002</td>
<td>0.0013</td>
<td>0.2013</td>
<td>0.0228</td>
<td>2044206</td>
</tr>
<tr>
<td>22</td>
<td>1191</td>
<td>0.2</td>
<td>0.1149</td>
<td>0.0006</td>
<td>0.0052</td>
<td>0.2052</td>
<td>0.0236</td>
<td>1998069</td>
</tr>
<tr>
<td>23</td>
<td>2873</td>
<td>0.2</td>
<td>0.1166</td>
<td>0.0015</td>
<td>0.0128</td>
<td>0.2128</td>
<td>0.0248</td>
<td>1951482</td>
</tr>
<tr>
<td>24</td>
<td>6506</td>
<td>0.2</td>
<td>0.1182</td>
<td>0.0035</td>
<td>0.0293</td>
<td>0.2293</td>
<td>0.0271</td>
<td>1903679</td>
</tr>
<tr>
<td>25</td>
<td>12356</td>
<td>0.2</td>
<td>0.1199</td>
<td>0.0068</td>
<td>0.0565</td>
<td>0.2565</td>
<td>0.0308</td>
<td>1852772</td>
</tr>
<tr>
<td>26</td>
<td>19988</td>
<td>0.2</td>
<td>0.1217</td>
<td>0.0113</td>
<td>0.0931</td>
<td>0.2931</td>
<td>0.0357</td>
<td>1796661</td>
</tr>
<tr>
<td>27</td>
<td>31650</td>
<td>0.2</td>
<td>0.1235</td>
<td>0.0187</td>
<td>0.1511</td>
<td>0.3511</td>
<td>0.0433</td>
<td>1733728</td>
</tr>
<tr>
<td>28</td>
<td>39684</td>
<td>0.2</td>
<td>0.1253</td>
<td>0.0245</td>
<td>0.1955</td>
<td>0.3955</td>
<td>0.0496</td>
<td>1660183</td>
</tr>
<tr>
<td>29</td>
<td>49577</td>
<td>0.2</td>
<td>0.1272</td>
<td>0.0323</td>
<td>0.2538</td>
<td>0.4538</td>
<td>0.0577</td>
<td>1579904</td>
</tr>
<tr>
<td>30</td>
<td>55492</td>
<td>0.2</td>
<td>0.1292</td>
<td>0.0384</td>
<td>0.2974</td>
<td>0.4974</td>
<td>0.0643</td>
<td>1491263</td>
</tr>
<tr>
<td>31</td>
<td>59018</td>
<td>0.2</td>
<td>0.1312</td>
<td>0.0437</td>
<td>0.333</td>
<td>0.5330</td>
<td>0.0699</td>
<td>1398447</td>
</tr>
<tr>
<td>32</td>
<td>67795</td>
<td>0.2</td>
<td>0.1333</td>
<td>0.0541</td>
<td>0.4059</td>
<td>0.6059</td>
<td>0.0808</td>
<td>1303976</td>
</tr>
<tr>
<td>33</td>
<td>63030</td>
<td>0.2</td>
<td>0.1355</td>
<td>0.0546</td>
<td>0.4028</td>
<td>0.6028</td>
<td>0.0817</td>
<td>1202772</td>
</tr>
<tr>
<td>34</td>
<td>65930</td>
<td>0.2</td>
<td>0.1377</td>
<td>0.0622</td>
<td>0.4515</td>
<td>0.6515</td>
<td>0.0897</td>
<td>1108438</td>
</tr>
<tr>
<td>35</td>
<td>64699</td>
<td>0.2</td>
<td>0.1401</td>
<td>0.0669</td>
<td>0.4779</td>
<td>0.6779</td>
<td>0.0949</td>
<td>1013298</td>
</tr>
<tr>
<td>36</td>
<td>63602</td>
<td>0.2</td>
<td>0.1425</td>
<td>0.0726</td>
<td>0.5094</td>
<td>0.7094</td>
<td>0.1011</td>
<td>921515</td>
</tr>
<tr>
<td>37</td>
<td>63415</td>
<td>0.2</td>
<td>0.1449</td>
<td>0.0804</td>
<td>0.5546</td>
<td>0.7546</td>
<td>0.1094</td>
<td>832935</td>
</tr>
<tr>
<td>38</td>
<td>57540</td>
<td>0.2</td>
<td>0.1475</td>
<td>0.0814</td>
<td>0.5521</td>
<td>0.7521</td>
<td>0.1109</td>
<td>746641</td>
</tr>
<tr>
<td>39</td>
<td>54116</td>
<td>0.2</td>
<td>0.1502</td>
<td>0.0858</td>
<td>0.5713</td>
<td>0.7713</td>
<td>0.1158</td>
<td>668245</td>
</tr>
</tbody>
</table>
### 9.3.2 Age-based assessment

A trial analysis was carried out converting length to age based on a growth model. Length compositions were divided into age compositions according to the growth parameters of the species. This species is thought to spawn during the whole dry season offshore and during the wet season, the larvae and juveniles are progressively recruited to the fishery on muddy grounds in coastal waters.

<table>
<thead>
<tr>
<th>Length (cm)</th>
<th>Catches (year(^{-1}))</th>
<th>M</th>
<th>dt</th>
<th>Fdt</th>
<th>F (year(^{-1}))</th>
<th>Z (year(^{-1}))</th>
<th>Zdt</th>
<th>Average number attaining size</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>49677</td>
<td>0.2</td>
<td>0.1529</td>
<td>0.0886</td>
<td>0.5791</td>
<td>0.7791</td>
<td>0.1191</td>
<td>595171</td>
</tr>
<tr>
<td>41</td>
<td>39931</td>
<td>0.2</td>
<td>0.1558</td>
<td>0.0799</td>
<td>0.5127</td>
<td>0.7127</td>
<td>0.1110</td>
<td>528326</td>
</tr>
<tr>
<td>42</td>
<td>38431</td>
<td>0.2</td>
<td>0.1587</td>
<td>0.0862</td>
<td>0.5429</td>
<td>0.7429</td>
<td>0.1179</td>
<td>472811</td>
</tr>
<tr>
<td>43</td>
<td>34603</td>
<td>0.2</td>
<td>0.1618</td>
<td>0.0874</td>
<td>0.5401</td>
<td>0.7401</td>
<td>0.1198</td>
<td>420214</td>
</tr>
<tr>
<td>44</td>
<td>28469</td>
<td>0.2</td>
<td>0.1650</td>
<td>0.0808</td>
<td>0.4897</td>
<td>0.6897</td>
<td>0.1138</td>
<td>372788</td>
</tr>
<tr>
<td>45</td>
<td>25575</td>
<td>0.2</td>
<td>0.1684</td>
<td>0.0814</td>
<td>0.4835</td>
<td>0.6835</td>
<td>0.1151</td>
<td>332686</td>
</tr>
<tr>
<td>46</td>
<td>19264</td>
<td>0.2</td>
<td>0.1718</td>
<td>0.0684</td>
<td>0.3979</td>
<td>0.5979</td>
<td>0.1027</td>
<td>296525</td>
</tr>
<tr>
<td>47</td>
<td>17260</td>
<td>0.2</td>
<td>0.1754</td>
<td>0.0679</td>
<td>0.38</td>
<td>0.5870</td>
<td>0.1030</td>
<td>267575</td>
</tr>
<tr>
<td>48</td>
<td>14671</td>
<td>0.2</td>
<td>0.1792</td>
<td>0.0639</td>
<td>0.3563</td>
<td>0.5563</td>
<td>0.0997</td>
<td>241392</td>
</tr>
<tr>
<td>49</td>
<td>13322</td>
<td>0.2</td>
<td>0.1832</td>
<td>0.0641</td>
<td>0.35</td>
<td>0.5500</td>
<td>0.1007</td>
<td>218485</td>
</tr>
<tr>
<td>50</td>
<td>12726</td>
<td>0.2</td>
<td>0.1873</td>
<td>0.0679</td>
<td>0.3625</td>
<td>0.5625</td>
<td>0.1053</td>
<td>197548</td>
</tr>
<tr>
<td>51</td>
<td>11389</td>
<td>0.2</td>
<td>0.1916</td>
<td>0.0675</td>
<td>0.3524</td>
<td>0.5524</td>
<td>0.1058</td>
<td>177798</td>
</tr>
<tr>
<td>52</td>
<td>9670</td>
<td>0.2</td>
<td>0.1961</td>
<td>0.0636</td>
<td>0.3245</td>
<td>0.5245</td>
<td>0.1028</td>
<td>159943</td>
</tr>
<tr>
<td>53</td>
<td>7631</td>
<td>0.2</td>
<td>0.2008</td>
<td>0.0555</td>
<td>0.2761</td>
<td>0.4761</td>
<td>0.0956</td>
<td>144311</td>
</tr>
<tr>
<td>54</td>
<td>6497</td>
<td>0.2</td>
<td>0.2058</td>
<td>0.0519</td>
<td>0.2521</td>
<td>0.4521</td>
<td>0.0930</td>
<td>131152</td>
</tr>
<tr>
<td>55</td>
<td>6944</td>
<td>0.2</td>
<td>0.2110</td>
<td>0.0612</td>
<td>0.2899</td>
<td>0.4899</td>
<td>0.1034</td>
<td>119501</td>
</tr>
<tr>
<td>56</td>
<td>5471</td>
<td>0.2</td>
<td>0.2165</td>
<td>0.0533</td>
<td>0.2461</td>
<td>0.4461</td>
<td>0.0966</td>
<td>107766</td>
</tr>
<tr>
<td>57</td>
<td>5475</td>
<td>0.2</td>
<td>0.2222</td>
<td>0.0589</td>
<td>0.265</td>
<td>0.4650</td>
<td>0.1033</td>
<td>97847</td>
</tr>
<tr>
<td>58</td>
<td>4957</td>
<td>0.2</td>
<td>0.2283</td>
<td>0.0592</td>
<td>0.2592</td>
<td>0.4592</td>
<td>0.1048</td>
<td>88240</td>
</tr>
<tr>
<td>59</td>
<td>3584</td>
<td>0.2</td>
<td>0.2348</td>
<td>0.0473</td>
<td>0.2013</td>
<td>0.4013</td>
<td>0.0942</td>
<td>79457</td>
</tr>
<tr>
<td>60</td>
<td>4041</td>
<td>0.2</td>
<td>0.2416</td>
<td>0.0589</td>
<td>0.244</td>
<td>0.4440</td>
<td>0.1073</td>
<td>72312</td>
</tr>
<tr>
<td>61</td>
<td>2958</td>
<td>0.2</td>
<td>0.2488</td>
<td>0.0478</td>
<td>0.1921</td>
<td>0.3921</td>
<td>0.0976</td>
<td>64958</td>
</tr>
<tr>
<td>62</td>
<td>3254</td>
<td>0.2</td>
<td>0.2564</td>
<td>0.0583</td>
<td>0.2274</td>
<td>0.4274</td>
<td>0.1096</td>
<td>58921</td>
</tr>
<tr>
<td>63</td>
<td>2940</td>
<td>0.2</td>
<td>0.2646</td>
<td>0.0589</td>
<td>0.2224</td>
<td>0.4224</td>
<td>0.1118</td>
<td>52804</td>
</tr>
<tr>
<td>64</td>
<td>2645</td>
<td>0.2</td>
<td>0.2732</td>
<td>0.0593</td>
<td>0.2169</td>
<td>0.4169</td>
<td>0.1139</td>
<td>47220</td>
</tr>
<tr>
<td>65</td>
<td>3003</td>
<td>0.2</td>
<td>0.2825</td>
<td>0.0761</td>
<td>0.2694</td>
<td>0.4694</td>
<td>0.1326</td>
<td>42136</td>
</tr>
<tr>
<td>66</td>
<td>2136</td>
<td>0.2</td>
<td>0.2924</td>
<td>0.0614</td>
<td>0.2101</td>
<td>0.4101</td>
<td>0.1199</td>
<td>36903</td>
</tr>
<tr>
<td>67</td>
<td>2487</td>
<td>0.2</td>
<td>0.3031</td>
<td>0.0815</td>
<td>0.269</td>
<td>0.4690</td>
<td>0.1421</td>
<td>32733</td>
</tr>
<tr>
<td>68</td>
<td>2337</td>
<td>0.2</td>
<td>0.3145</td>
<td>0.0887</td>
<td>0.2821</td>
<td>0.4821</td>
<td>0.1516</td>
<td>28396</td>
</tr>
<tr>
<td>69</td>
<td>2367</td>
<td>0.2</td>
<td>0.3268</td>
<td>0.1056</td>
<td>0.323</td>
<td>0.5230</td>
<td>0.1709</td>
<td>24401</td>
</tr>
<tr>
<td>70</td>
<td>1470</td>
<td>0.2</td>
<td>0.3402</td>
<td>0.0768</td>
<td>0.2257</td>
<td>0.4257</td>
<td>0.1448</td>
<td>20566</td>
</tr>
<tr>
<td>71</td>
<td>1454</td>
<td>0.2</td>
<td>0.3547</td>
<td>0.0884</td>
<td>0.2493</td>
<td>0.4493</td>
<td>0.1594</td>
<td>17793</td>
</tr>
<tr>
<td><strong>plus group</strong></td>
<td><strong>8429</strong></td>
<td>0.2</td>
<td>0.25</td>
<td>0.4500</td>
<td></td>
<td></td>
<td></td>
<td>15172</td>
</tr>
</tbody>
</table>
The length distributions for years 1986 to 1998 were split into 9 nominal age groups (plus-group at 10), using a size distribution slicing method. The age compositions were analysed using a tuned VPA (extended survivors analysis; CEFAS, Lowestoft, UK package containing slicing, tuning and VPA software). As it is a new assessment method for this stock, the tuning was performed with the default options: catchability for all ages was assumed to be independent of stock size, on the reduced CPUE series for years 1993-1998.

![Graph showing effort and F for L. purpureus](image)

**Figure 9.7 Effort and F for L. purpureus.** There has been a large increase in F in recent years

The results indicated large increase in effort and F (Fig. 9.7). There was a strong log-linear relationship between fishing mortality and fishing effort ($R^2=0.90, 11df$).

VPAs can provide biased estimates of population parameters for the most recent years in the series, especially when there is a recent trend in fishing mortality. This is the case for these data where fishing mortality and fishing effort have increased over the last 4 years (Fig. 9.7). Retrospective analysis was used to explore the impacts of such trends and estimate a correction factor on recruitment. Retrospective analysis consists of running multiple VPAs, with a minimum number of years for the first series and increasing the length of the series by adding an additional year on each subsequent run. Hence, the first series was 1986-1991, the second 1986-1992 and so on, creating 8 separate VPAs. These analyses provide an indication of how recent estimates of population parameters change as new data are added.

We conducted retrospective analysis of the data for *L. purpureus* and analysed the trends in recent estimates of recruitment and fishing mortality of the age 3 group (Fig. 9.8 and 9.9). In all cases recruitment estimates are overestimated for recent years, but this overestimation decreases as the number of years of data used for such estimation of recruitment increases. Overestimation is large for estimates made with only one year of data (70%) but decreases quickly and is only 10% after 5 years. We fitted an exponential function to such overestimation and used it to correct the estimates of recent recruitment made with the most recent data (Fig. 9.10).

The resulting recruitment trend (dotted line) is considerably different from the one shown by the uncorrected recruitment estimates provided by the VPA (drawn line). The corrected estimates suggest that there may not have been any increases in recruitment since 1991, quite unlike the suggestion from the VPA that recruitment had continued to increase since 1991 (Fig. 9.11).
Figure 9.8 Retrospective VPA results of recruit numbers by year for *Lutjanus purpureus* in French Guiana, from 1986 to 1998

Figure 9.9 Retrospective VPA results of F for age 3 for *Lutjanus purpureus* from 1986 to 1998
The retrospective VPA also suggested that fishing mortality estimates were underestimated by the VPA. We looked at biases for age group 3, the main target of the present fishery. Biases were not as large as those observed for recruitment. The estimate of $F$ for age 3 and for the most recent year is underestimated by 20%, but by year 5 this has fallen to 5%. The trend of $F$ does not change substantially and continues to suggest that there have been very large increases in $F$ over the last 10 years (Fig. 9.12).

To moderate that trend in biomass, a recalculation of stock numbers at age was carried out according to the following method. The numbers at age 1 in 1996, 1997 and 1998 were corrected by replacing the numbers at age 1 to 4 of the 1999 age compositions (at 1\textsuperscript{st} January) with the numbers of the same ages from the arithmetic mean on the series 1990-1995, using the formula: $N_t = N_0 e^{-zt}$. That range of years was chosen outside the present trend.
The corrected data produces similar patterns to the uncorrected VPA, but the trends have been reduced. Mean Fs on ages 3 to 7 have increased from 1986 to 1997 with the increasing effort and there has still been an increase in recruitment between 1988 and 1990 (Fig. 9.11).

Figure 9.12 Overestimation of F by VPA and corrected values from retrospective VPA for *Lutjanus purpureus* in French Guiana, from 1986 to 1998

Figure 9.13 Biomass and SSB based on the corrected VPA. There has been a decline in biomass in recent years

One of the main requirements for a VPA is that the catch at age data represent all the catches from the stock. This is not strictly the case for the data from French Guiana. We do not know the real limits of the stock and whether it is shared with those of neighbouring countries. In addition, we know that part of the catch of red snappers caught in French Guyana is landed elsewhere by Venezuelan vessels. It seems that this catch landed outside
French Guyana may be mainly composed of large fish. Recently, there is also a new group of vessels from the French Antilles that harvest *Lutjanus* within French Guyana and those do not land their catch in Cayenne. Finally, it is also known that discards of juvenile red snappers occur in the shrimp fishery.

To get an idea of the possible effects of having incomplete catch data we conducted an analysis that tested the effects of underestimation of the number of large fish caught. We assumed that there was no bias at the beginning of the time series, but that the under-reporting of large fish increased linearly with size and time and that 30% of large fish went unreported.

The impact of such level of under-reporting can be seen in the estimates of recruitment, fishing mortality and spawning stock biomass (Fig. 9.14). The effect is relatively constant with time for recruitment and for the average fishing mortality. It therefore would not change stock trends, but rather the absolute estimates of those two parameters. Recruitment would be underestimated by 10% and fishing mortality would be overestimated by 10% (Fig. 9.14).

![Figure 9.14 Potential bias in spawning biomass, F and recruitment for from unreported catches of *Lutjanus purpureus*](image)

For the spawning stock biomass there is a trend in the bias with time. This is a direct result of the fact that we assumed that the rate of under-reporting has increased with time and specially for large fish (that make up the bulk of the spawning stock). The bias is large for recent years reaching 30%.

### 9.4 Stock - recruitment and yield per recruit

Yearly recruitments were plotted against SSB of the preceding year (Figure 9.15). The fitted model suggests a strong inverse correlation between SSB and recruitment, reflecting the opposite trends between F and recruitment in the analysis. It is difficult to say whether the estimated recruitment is a true recruitment or a mixed recruitment comprising juveniles and young individuals migrating from the muddy grounds.

A yield per recruit and a spawning stock biomass per recruit (SSB/R) analyses were carried out using the Thompson and Bell method, available in the Lowestoft Virtual Population Analysis Package. The yield per recruit analysis (Fig. 9.16) suggests that $F_{MSY}$ is 50% of the
current mean F (ages 3-9). These results are more pessimistic than those obtained with the yield per recruit analysis calculated with LCA. The SSB/R results show the usual sharp decrease in SSB/R at higher fishing mortality levels. This contrasts with the abnormal stock recruitment relationship in Fig. 9.15.

![Graph showing relationship between Spawning Biomass (t) and Recruits (thousands).](image1)

**Figure 9.15** Relationship between SSB and level of recruits in the following year of *Lutjanus purpureus*, based on the corrected VPA. The results suggest a strong density dependence between spawning stock and recruitment.

![Graph showing yield per recruit (Y/R) and SSB per recruit (SSB/R) for different fishing mortalities, as a proportion of current mean F for ages 3-9.](image2)

**Figure 9.16** Yield per recruit and spawning stock biomass per recruit for different fishing mortalities, as a proportion of current mean F for ages 3-9. Results are taken from the corrected VPA.
9.5 Discussion and management considerations

The growth parameters remain one of the main sources of uncertainty in these assessments. Other sources of uncertainty are related to the estimation of fishing effort and the annual length compositions of the catches by shrimp trawlers. Fishing effort should also be investigated, mainly for 1987 and 1988. Finally, the analysis would be enhanced with information of all catches (including discards), which are most likely taken from this stock.

The main problem with the assessment, is the interpretation of the positive relationship between F and recruitment (Fig. 9.17) estimated from the VPA. The retrospective VPA suggests that this relationship could be the result of bias and correlated estimates of F and recruitment. However, the red snapper does cannibalise its young and is territorial, which means that when a large red snapper is caught, a source of natural mortality for juveniles is directly eliminated and the reef where the population lives can shelter more young fishes migrating from the muddy grounds. It is therefore possible there is a density-dependent feedback, but the VPA may tend to grossly overestimate that effect.

In general, the numbers of young fish has been increasing in the landings. The VPA has interpreted this as increased recruitment, but may also be due to increased availability of young fish in the fishing grounds. If this is the case, then F is increasing for juveniles, which is offset by a possible lower natural mortality by predation.

Given the uncertainty of the results, it is important to avoid any further increases in effort without improvements in the assessment.

Figure 9.17 Fishing mortality and recruitment estimates for *Lutjanus purpureus*, from the uncorrected VPA. There was a strong log-linear relationship between recruitment and F estimates ($R^2=0.71$, df=11)
10.1 General background

The stock assessment work programme of the Fisheries Department of Suriname has been established in accordance with recognised fisheries management priorities. Current management issues have been discussed by representatives of all stakeholder groups (fishermen, fish processors, fish merchants, exporters, the public sector, etc) during a two-day national workshop on fisheries management in January 1998. The following major issues were identified:

- There is a lack of control and surveillance at sea, which results in very poor enforcement of any management measures. This increases the risk of overfishing of some of the resources. This situation also has a bearing on the quality of the data that are collected for stock assessment purposes, since no reliable information can be obtained on illegal fishing activities.

- The shrimp fishery exhibits strong yield fluctuations from year to year. The total annual landings have varied in recent years from 2 000t to more than 3 000t tail weight. In addition, fishing companies are affected by a sustained decline of the yields since 1995. Average catch per fishing day, which used to fluctuate around 100kg tail weight, has decreased to less than 50kg since September 1996. Investigation is required to find out to what extent natural causes like recruitment fluctuations, environmental causes, etc. explain this change, as opposed to the impact of fishery related causes (too much effort, competition of other fleets) and/or other human causes.

- The major recent development in the finfish fisheries is the entry of new fleets, generally larger vessels equipped with trawls of various types. These vessels compete with pre-existing (mostly small-scale) fishermen for some fish species and they also target other species that were only lightly exploited before. A multi-fleet and multi-species approach is appropriate to investigate these issues.

- A seabob fleet has also developed recently. Since it operates in the shallow coastal zone, it competes with other fleets exploiting resources in that area. The new seabob fleet faces complaints from the shrimp fishery, as well as from various parts of the small-scale fisheries that exploit seabob and finfish. Investigations on the mutual impacts of all these activities are important to management.

10.2 Collection of data for stock assessment

There are four main programmes through which the Fisheries Department is collecting the information required for the assessment of the resources.

- Through a Fisheries Information System, data on landings and effort are regularly collected. For the small-scale fisheries, where many different small fishing units land at numerous places, the system is based on a network of field enumerators. The companies operating larger vessels (this includes all types of trawlers and the vessels using vertical lines) are requested to submit their data after each trip.

- There is an observer programme that aims at the collection of information on bycatch and fishing grounds on board of fishing vessels. It also collects biological samples (finfish and seabob).

- There is a sampling programme on shore, recording biological data on selected species (finfish, seabob and shrimp).
• **Economic information** has only been recorded on an irregular basis for specific studies.

Priorities have also been set in the species to be assessed. Although the situation of all major commercial species ultimately has to be elucidated and then monitored, analyses focused in 1998 on the following:

• **Shrimp**: specific assessments are under way for the two major species sustaining the fishery, brown shrimp (*Penaeus subtilis*) and hopper shrimp (*Penaeus brasiliensis*).

• **Seabob**: *Xyphopenaeus kroyeri*.

• **Finfish**: most attention is given to the species that are significant in the trawl catches. Of particular interest are the species caught by several types of gear, like sea trout (*Cynoscion virescens*), other species of the family Sciaenidae and lane snapper (*Lutjanus synagris*).

### 10.3 Shrimp fishery

#### 10.3.1 Port samplings

Port sampling at the processing plants was resumed in March 1996. It produces data on the species/gender and size composition of the monthly shrimp landings. This information will complement similar data covering the years 1985 to 1991. Based on the observations of these two periods and the landings by commercial size categories, similar compositions will be calculated for the periods in which there was no sampling (before 1985 and from January 1992 to February 1996). A continuous database will then become available.

#### 10.3.2 Length–based cohort analysis by month

A length–based cohort analysis has been applied to monthly data on the second period of data (1996-1998), updating the 1998 workshop results (which covered the first period). The parameters used were the same as previously used (Table 10.1).

<table>
<thead>
<tr>
<th>Species</th>
<th></th>
<th>Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L∞ (mm tail)</td>
<td>K (month⁻¹)</td>
<td>M (month⁻¹)</td>
</tr>
<tr>
<td><em>P. subtilis</em> F</td>
<td>136</td>
<td>0.0885</td>
<td>0.146</td>
</tr>
<tr>
<td><em>P. subtilis</em> M</td>
<td>110</td>
<td>0.0924</td>
<td>0.146</td>
</tr>
<tr>
<td><em>P. brasiliensis</em> F</td>
<td>144</td>
<td>0.1000</td>
<td>0.146</td>
</tr>
<tr>
<td><em>P. brasiliensis</em> M</td>
<td>133</td>
<td>0.1000</td>
<td>0.146</td>
</tr>
</tbody>
</table>

It should be noted that the most recent results are provisional, as the figures on landings provided by some of the fishing companies still need to be completed and verified.

The brown shrimp fishing mortalities exhibit a similar seasonal pattern in both periods, being about twice as high in the second part of each year as in the first part (Fig. 10.1). The fishing mortality level also seems to be similar between the periods 1985-91 and 1996-98. Hopper shrimp (*P. brasiliensis*) mortalities in the 1996-98 period are also comparable with the values found in the earlier period (Fig. 10.2).
Figure 10.1 Monthly fishing mortalities, *P. subtilis*, Suriname, 1985-1998

Figure 10.2 Monthly fishing mortalities, *P. brasiliensis*. Suriname, 1985-1998

The biomass estimates, however, appear much lower for the 1996-98 period than in 1985-91. This is most visible in the case of the brown shrimp (Fig. 10.3). These brown shrimp biomass estimates also show relatively high variability from month to month. For *P. brasiliensis*, a decrease in the biomass estimates is observed only in the second part of the second period (1997, Fig. 10.4).

10.3.3 Multi-fleet analysis

Two components can be distinguished in the shrimp trawling fleet, the Korean and Japanese fleets. Korean and Japanese companies have differing strategies and fishing grounds and they exert different mortalities on the shrimp species. In addition to these two fleets, the seabob vessels are also catching some brown shrimp. A multi-fleet analysis including these three components could help estimate the extent to which the seabob fleet may affect the shrimp fishery and provide insights on the interactions between the two shrimp trawler fleets.

A length-based cohort analysis has been carried out since the last workshop on the total female brown shrimp landings of the three fleets. The size composition of the Korean and the Japanese components was taken from the average numbers landed, by month, over the years 1985-1991. The composition of the seabob fleet landings was the results of samples
carried out on board of the vessels in 1997 and 1998. The three length compositions differ (Fig. 10.5).

The fishing mortalities from LCA were used in a Thompson-Bell model to run simulations to see how catches would change with changing fishing mortality. The fishing mortalities were multiplied by a range of constants, first all together and then to one fleet at a time while the mortalities of the two other fleets were kept constant. These simulations suggested that:

![Figure 10.3 Monthly average biomass, *P. subtilis*, Suriname, 1985-1998](image1)

![Figure 10.4 Monthly average biomass, *P. brasiliensis*, Suriname, 1985-1998](image2)
Figure 10.5 Length frequency distribution of *P. subtilis* female catch by fleet.

Table 10.2 Fishing mortality estimates from LCA for the three fleets fishing *P. subtilis*. The total calculated fishing mortalities were divided into components allocated to the three fleets, proportionally to their contribution to the landings in each size.

<table>
<thead>
<tr>
<th>Size range</th>
<th>Total F</th>
<th>Korean</th>
<th>Japanese</th>
<th>Seabob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>Max</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>45</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>45</td>
<td>50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>50</td>
<td>55</td>
<td>0.03</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>55</td>
<td>60</td>
<td>0.14</td>
<td>0.12</td>
<td>0.01</td>
</tr>
<tr>
<td>60</td>
<td>65</td>
<td>0.57</td>
<td>0.52</td>
<td>0.04</td>
</tr>
<tr>
<td>65</td>
<td>70</td>
<td>1.25</td>
<td>1.14</td>
<td>0.10</td>
</tr>
<tr>
<td>70</td>
<td>75</td>
<td>1.72</td>
<td>1.50</td>
<td>0.19</td>
</tr>
<tr>
<td>75</td>
<td>80</td>
<td>2.18</td>
<td>1.86</td>
<td>0.29</td>
</tr>
<tr>
<td>80</td>
<td>85</td>
<td>3.09</td>
<td>2.58</td>
<td>0.40</td>
</tr>
<tr>
<td>85</td>
<td>90</td>
<td>4.04</td>
<td>3.17</td>
<td>0.66</td>
</tr>
<tr>
<td>90</td>
<td>95</td>
<td>4.05</td>
<td>3.04</td>
<td>0.79</td>
</tr>
<tr>
<td>95</td>
<td>100</td>
<td>4.68</td>
<td>3.38</td>
<td>1.10</td>
</tr>
<tr>
<td>100</td>
<td>105</td>
<td>4.90</td>
<td>3.54</td>
<td>1.24</td>
</tr>
<tr>
<td>105</td>
<td>110</td>
<td>4.86</td>
<td>3.42</td>
<td>1.34</td>
</tr>
<tr>
<td>110</td>
<td>115</td>
<td>4.87</td>
<td>3.50</td>
<td>1.37</td>
</tr>
<tr>
<td>115</td>
<td>120</td>
<td>4.90</td>
<td>3.52</td>
<td>1.37</td>
</tr>
<tr>
<td>120</td>
<td>125</td>
<td>4.10</td>
<td>2.95</td>
<td>1.15</td>
</tr>
</tbody>
</table>
- Further increases in the total effort (fishing mortality) would not lead to an increased value of the landings (Fig. 10.6).

- The seabob fleet does not seem to affect the shrimp fishery much. This is mainly due to the fact that volumes of small sizes caught by this fleet appear relatively insignificant (Fig. 10.7).

- An increase in fishing mortality by the Korean fleet would decrease the brown shrimp yields of the other fleets, as well as the total landed value (Fig. 10.8).

- Increasing the fishing mortality by the Japanese fleet would also decrease the yields of the other two fleets, but it would not cause a notable decrease in the total value. The gain of larger shrimp caught by the Japanese fleet would offset the loss of the less valuable, smaller shrimp caught by the Korean fleet (Fig. 10.9).

![Figure 10.6 Yield value (P. subtilis female) by fleet vs fishing mortality multiplier](image1)

![Figure 10.7 Yield value (P. subtilis female) by fleet vs seabob fleet F multiplier](image2)
These are preliminary observations and it should be pointed out that the size distribution of the landings by the seabob fleet, which is a key to this analysis, is based on samples. It therefore only covers a limited portion of the operations (however, covering an entire year). In addition, inter-annual variations are of course not accounted for and it would be advisable to repeat the analysis based on separated annual data.

The proportion of brown shrimps in the seabob trawlers catch probably varies from trip to trip, even from haul to haul, showing peaks in delimited seasons and areas, depending on recruitment. It is also possible that trawlers licensed for seabob could target brown shrimp at times when seabob yields are low. These cases may be easily missed by a sampling programme covering more or less one out of twenty landings, yet they might have an impact on the overall size distribution of brown shrimp caught by seabob vessels. We also expect a large year-to-year variability because there are years with and without strong brown shrimp recruitment peaks, so analyses based on a particular year's data may give substantially different results.
10.4 Seabob Fishery

10.4.1 General description of operations
The first fishing company started operating in 1996 and a second one joined the fishery in 1997. Today, they have fleets of 15 and 8 vessels respectively, which are former shrimp trawlers with freezers replaced by ice holds. The gear is an adapted shrimp trawl, with a higher vertical opening and a lighter headrope. Detailed information on the operations, fishing grounds, are being recorded by observers.

10.4.2 Data collection on efforts and landings
Landing reports are requested from the companies, on a trip-by-trip basis, including dates leaving and arriving from port, seabob landed by commercial grades and other components of the landings (finfish and ungraded shrimp).

Factory samples
Seabob has been sampled during the unloading at the first processing plant (one boat per month). The purpose was to assess the presence of brown shrimp in the seabob landings. The components of the samples (seabob, other shrimp and fish by species) were weighed and all *Penaeus* shrimp was measured (as far as possible). The seabob itself, however, proved to be too damaged at the time of landing to be measured.

Sampling on board
Observers on board seabob trawlers collected a seabob sample from every haul during on average one trip per month. The treatment of these samples at the laboratory included measuring all seabob and brown shrimp and recording the weights of all components, by shrimp and finfish species. An analysis based on these length frequency distributions could not been completed in time for the workshop.

10.4.3 Impact on Penaeus shrimp species
Amounts and size composition of shrimp catch by seabob trawlers were estimated from observers samples and landing reports. *P. subtilis* and *P. schmitti* were reported in small quantities. According to these provisional results, the impact of the seabob fleet on shrimp populations appears quite small (see 10.3).

10.5 Finfish fisheries

Catch and effort data are recorded at landing by enumerators for the small-scale fisheries, whereas trawl fishing companies are requested to report the same data after every trip. Biological information (length frequency compositions for the main species) has been recorded on board trawlers, but the collection of biological data on shore (for finfish landed by small-scale fishermen) has not succeeded due to a lack of staff. Assessments have been undertaken on lane snapper (*Lutjanus synagris*) and sea trout (*Cynoscion virescens*).

10.5.1 Assessment of lane snapper (*Lutjanus synagris*)
Lane snapper (*Lutjanus synagris*) has only recently gained importance in the landings in Suriname. It is one of the target species of the recently developed fleet of finfish trawlers (called “kotters”, 5 vessels under Dutch flag). It also forms part of the bycatch of the shrimp trawlers and in 1998, a third fleet (2 larger mid-water trawlers under Korean flag, called “Osito”) has taken part in the harvest. There is therefore a good case for multi-fleet analysis with 3 fleets.
Growth and mortality parameters have not been estimated in this sub-region (Brazil-Guyanas shelf). Estimates from other areas of the Atlantic Ocean (Brazil, Cuba, Mexico) were found in FishBase. In order to allow for a first analysis, the following values for the length-weight relationship and growth parameters were selected among those proposed by this database:

\[ a = 0.0427 ; \ b = 2.72 \]
\[ L_\infty = 55 \text{ cm} \]
\[ K = 0.28 \text{ yr}^{-1} \]

The equation of Pauly provided an estimate for the natural mortality \( M \) (setting the sea temperature at 27º gave \( M = 0.65 \text{ yr}^{-1} \)).

The size composition and the landings by the two finfish trawler fleets were calculated from the samples measured on board both types of vessels in the course of 1998 and from accurate reports on the 1998 landings. Similar data are not available over the same period for lane snapper taken as a bycatch by the shrimp fishery. For the purpose of this analysis, a length frequency distribution and an estimate of the landings by this fleet dating from 1991 was used. The landings in numbers by size for each fleet are shown in Fig. 10.10.

![Figure 10.10 Estimated numbers of L. synagris caught by length class in 1998 for Kotters and Osito fleets and in 1991 for shrimp bycatch](image)

A catch curve analysis was carried out on these catch data and a fishing mortality \( F = 0.494 \text{ year}^{-1} \) was estimated. A Beverton and Holt per recruit analysis was used to estimate yield per recruit (Fig. 10.11) and biomass per recruit (Fig. 10.12). YPR appears to be currently below its maximum level, unless the selectivity (which has not been estimated) is assumed to be such that length at first capture is under 15 cm, which is not supported by the estimates of fishing mortalities by size (Table 10.2). BPR is estimated to be, in the current situation, around a third of the pristine level.
Figure 10.11. Yield per recruit under different lengths at first capture (cm) of *L. synagris*, based on 1998 data

Figure 10.12 Stock biomass per recruit of *L. synagris*, based on 1998 data
A Thompson-Bell model used fishing mortalities for each length class (Table 10.2) to simulate the effect of varying fishing mortality. The mortalities were multiplied by a range of constants, first all together, then separately to one fleet at a time while the mortalities of the other two fleets were kept constant. The results, expressed in total weight caught, suggest that:

- Increasing the total effort could lead to substantial increases in total landings (Fig. 10.13). The “Osito” fleet, however, would experience a reduction in its harvests, unlike the two other fleets. This would coincide with a gradual elimination of the larger sizes that make up most of the “Osito” catch.

- The “kotters” fleet dominates the fishery so much that it is unaffected by the other fleets (Fig. 10.15, 10.16). On the contrary, an increase of the effort of the “kotters” fleet would be detrimental for the “Osito” fleet (Fig. 10.14).

- Shrimp bycatch, even though removing mainly juveniles from the fishing grounds, does not seem substantially to affect the fishery (Fig. 10.15). This observation relies on our assumption that this species does not make up a large portion of the bycatch and that the information on size composition and volumes collected almost 10 years ago is still valid.

Table 10.2 Results from a length-based cohort analysis estimating fishing mortality by length class. The distribution of the F by size into fleet components was estimated based on contribution of each fleet to the landings to each size.

<table>
<thead>
<tr>
<th>Size range</th>
<th>Fishing mortality</th>
<th>Size range</th>
<th>Fishing mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Kotters</td>
<td>Osito</td>
</tr>
<tr>
<td>Min Max</td>
<td>Min Max</td>
<td>Min Max</td>
<td>Min Max</td>
</tr>
<tr>
<td>11 20</td>
<td>0.00 0.00 0.00 0.00</td>
<td>37 38 0.33 0.31 0.02 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>20 21</td>
<td>0.01 0.00 0.00 0.00</td>
<td>38 39 0.44 0.41 0.03 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>21 22</td>
<td>0.02 0.01 0.00 0.00</td>
<td>39 40 0.42 0.39 0.03 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>22 23</td>
<td>0.03 0.02 0.00 0.00</td>
<td>40 41 0.47 0.42 0.06 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>23 24</td>
<td>0.04 0.03 0.00 0.00</td>
<td>41 42 0.57 0.48 0.08 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>24 25</td>
<td>0.06 0.04 0.00 0.00</td>
<td>42 43 0.54 0.43 0.10 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>25 26</td>
<td>0.08 0.06 0.00 0.00</td>
<td>43 44 0.58 0.43 0.15 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>26 27</td>
<td>0.08 0.07 0.00 0.00</td>
<td>44 45 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>27 28</td>
<td>0.10 0.08 0.00 0.00</td>
<td>45 46 0.63 0.45 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>28 29</td>
<td>0.12 0.10 0.01 0.01</td>
<td>46 47 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>29 30</td>
<td>0.16 0.14 0.01 0.01</td>
<td>47 48 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>30 31</td>
<td>0.19 0.18 0.01 0.01</td>
<td>48 49 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>31 32</td>
<td>0.21 0.20 0.01 0.01</td>
<td>49 50 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>32 33</td>
<td>0.24 0.23 0.01 0.00</td>
<td>50 51 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>33 34</td>
<td>0.26 0.25 0.01 0.00</td>
<td>51 52 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>34 35</td>
<td>0.28 0.26 0.01 0.00</td>
<td>52 53 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>35 36</td>
<td>0.30 0.28 0.02 0.00</td>
<td>53 54 0.60 0.42 0.18 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>36 37</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 10.13 Yield in weight of *L. synagris* vs F multiplier for all fleets

Figure 10.14 Yield in weight of *L. synagris* vs F multiplier for Kotters fleet only
10.5.2 Assessment of sea trout (Cynoscion virescens)

*Cynoscion virescens* is a major commercial species in Suriname. It is a demersal fish, distributed in coastal waters to depths of around thirty meters. It is caught by a number of gears, the most important being trawls, drifting gillnets and Chinese seines. Among the trawlers, the same fleets as for lane snapper can be distinguished viz. the Korean (or “Osito”) and the Dutch (or “kotters”) fleets.

The Kotter fleet uses bottom trawls, while the Korean fleet uses mid-water trawls. In recent years, the catches have decreased, leading to concern about the status of the resource. This assessment focused on the trawl fleet, on which most data were available.
Table 10.3 Fleet characteristics of the Dutch “kotters” and Korean “Osito” vessels catching *Cynoscion virescens*

<table>
<thead>
<tr>
<th></th>
<th>Dutch fleet</th>
<th>Korean fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual landings (all species, kg)</td>
<td>2 330 827</td>
<td>819 502</td>
</tr>
<tr>
<td>Number of days at sea (1998)</td>
<td>1 120</td>
<td>180</td>
</tr>
<tr>
<td>Number of hauls (1998)</td>
<td>4 144</td>
<td>1 526</td>
</tr>
<tr>
<td>Number of boats (1998)</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Average trawling time (hours)</td>
<td>3.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Average daily catch (kg)</td>
<td>2 081</td>
<td>4 553</td>
</tr>
<tr>
<td>Average catch per haul (kg)</td>
<td>562</td>
<td>537</td>
</tr>
<tr>
<td>Average catch per hour (kg)</td>
<td>148</td>
<td>199</td>
</tr>
</tbody>
</table>

The Dutch fleet accounted for approximately 75% of the landings in 1998, but the Korean vessels have a higher fishing power, apparently resulting from undertaking more trawls per day than the Dutch vessels (Table 10.3).

The weight-length conversion parameters were obtained from samples of whole fish taken in 1998 by the quality control laboratory in Paramaribo. The log-linear model parameter $b$ was fixed to a value of 3 and parameter $a$ was estimated, so:

$$W = 0.0069 L^3$$

The von Bertalanffy growth parameter $L_\infty$ was first estimated using the FISAT package using the length frequencies of the two trawler fleets, which were available for all months of 1998. This provided an estimate of $L_\infty = 94.6$ cm. An estimate of parameter $K$ was calculated using the modal progression analysis routine included in FISAT, but the poor quality of data made the results unreliable. A number of alternative modal pathways were identified from the data but, taking into account the previously estimated $L_\infty$ of 94.6 cm, the only fits that appeared feasible were identified:

<table>
<thead>
<tr>
<th>$L_\infty$</th>
<th>96.6</th>
<th>98.77</th>
<th>91.99</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K$</td>
<td>0.32</td>
<td>0.23</td>
<td>0.83</td>
</tr>
<tr>
<td>$t_0$</td>
<td>-0.14</td>
<td>-0.13</td>
<td>-0.18</td>
</tr>
</tbody>
</table>

The arithmetic average of these estimates of $L_\infty$ is 95.6 cm and of $K$ is 0.46 year$^{-1}$.

The M value was estimated to be 0.74 year$^{-1}$ by Pauly’s empirical equation, using the above von Bertalanffy parameters and assuming a mean water temperature of 25°C.

$$\log M = -0.0152 -0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log t.$$  

A length-converted catch curve analysis (using a spreadsheet designed by Ehrhardt and Legault, 1996) was used to estimate F for the stock. This was done by fitting a length converted catch curve to the length frequencies of the separate months (Table 10.4) based on the growth and mortality parameter estimates given above.
Table 10.4 Fishing mortality by month obtained from a length-converted catch curve

<table>
<thead>
<tr>
<th>Month</th>
<th>Feb</th>
<th>Mar</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>1.78</td>
<td>2.69</td>
<td>2.09</td>
<td>1.17</td>
<td>0.94</td>
<td>2.52</td>
<td>1.85</td>
<td>2.84</td>
<td>0.90</td>
<td>1.86</td>
</tr>
<tr>
<td>R²</td>
<td>0.95</td>
<td>0.92</td>
<td>0.94</td>
<td>0.86</td>
<td>0.97</td>
<td>0.98</td>
<td>0.99</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

The average of the fishing mortality estimates obtained (F=1.86 year⁻¹) was used in the further analysis.

Figure 10.17 Length frequency distribution for C. virescens by fleet from samples taken during 1998

Examination of the length frequencies of the Dutch and Korean fleets indicated differences in their selectivity, with the former catching a higher proportion of smaller fish (Fig. 10.17). Average length was 44 cm for the Korean fleet and 35 cm for the Dutch fleet. Fishing mortalities were therefore calculated separately for the data sets of each fleet. The values obtained were considerably higher than the mean annual F resulting from the combined monthly length frequencies.

Table 10.5 Fishing mortality estimates for each fleet from catch curves fitted separately to each fleet’s length frequency samples

<table>
<thead>
<tr>
<th></th>
<th>Dutch Kotter fleet</th>
<th>Korean Osiri fleet</th>
<th>F mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2.48</td>
<td>2.09</td>
<td>2.28</td>
</tr>
<tr>
<td>R²</td>
<td>1.00</td>
<td>0.98</td>
<td></td>
</tr>
</tbody>
</table>
In addition, a weighted length frequency of the annual catches from the two fleets was calculated, weighted according to the annual catch of each fleet (all species). The total catch for 1998 of the 5 Dutch vessels was 2 330 827 kg and that of the Korean fleet was 819 502 kg. Catch curve analysis on this weighted distribution produced an $F$ estimate of 2.34.

A length of maturity of 33 to 34 cm was chosen, which is equivalent to an age of 0.88 years old. From the landings length frequencies, the size and age of first capture of the Dutch fleet was determined to be 35 cm (0.95 years old) and that of the Korean fleet to be 44 cm (1.29 years old).

These values were used as inputs in a multi-fleet per recruit model (Booth 1999). Biological reference points were generated, which, when compared to the estimated current $F$, give indications on the status of the stock (Tables 10.6 – 10.8). The weighted $F$ was considered to be the best estimate of the current $F$. In addition to the per recruit analyses for the combined fleet, separate analyses were undertaken for the Dutch and Korean fleets (as if they operated alone).

### Table 10.6 Yield per recruit analyses for the combined fleet

<table>
<thead>
<tr>
<th>Current status (combined fleets)</th>
<th>Biological Reference Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unexploited</td>
</tr>
<tr>
<td>$F$</td>
<td>2.34</td>
</tr>
<tr>
<td>Spawning Biomass per Recruit (g)</td>
<td>117</td>
</tr>
<tr>
<td>Yield per recruit (g)</td>
<td>213</td>
</tr>
<tr>
<td>Slope YPR</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

### Table 10.7 Yield per recruit analyses for the Korean fleet. The same parameters as for the combined fleet were used

<table>
<thead>
<tr>
<th>Current status (Korean fleet)</th>
<th>Biological Reference Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unexploited</td>
</tr>
<tr>
<td>$F$</td>
<td>2.09</td>
</tr>
<tr>
<td>SBR (gr)</td>
<td>196</td>
</tr>
<tr>
<td>YPR (gr)</td>
<td>253</td>
</tr>
<tr>
<td>Slope YPR</td>
<td>-0.07</td>
</tr>
</tbody>
</table>
Table 10.8 Yield per recruit analyses for the Dutch fleet. The same parameters as for the combined fleet were used

<table>
<thead>
<tr>
<th>Current status (Dutch fleet)</th>
<th>Biological Reference Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unexploited</td>
</tr>
<tr>
<td>F</td>
<td>2.48</td>
</tr>
<tr>
<td>SBR (g)</td>
<td>96</td>
</tr>
<tr>
<td>YPR (g)</td>
<td>201</td>
</tr>
<tr>
<td>Slope YPR</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

Examination of the behaviour of the catch curve analysis suggested that it was particularly sensitive to the values of \( K \), which is known only approximately for \( C. \) virescens in Suriname. Therefore, as a sensitivity test, the lowest reasonable \( K \) estimate consistent with the length frequency data was used (\( K=0.23 \) \( L_\infty=95.6 \) cm). These new values were used to estimate, with Pauly's empirical equation, a natural mortality \( M=0.47 \).

With these parameters, a catch curve analysis produced an \( F \) 1.07. The selectivity of the two fleets also needed to be recalculated with the modified growth parameters. The results were 1.89 years for the Dutch fleet (35 cm) and 2.57 years for the Korean fleet (44 cm), while a length at maturity of 34 cm would correspond to an age of 1.82 years. These new parameters were used in a new per recruit analysis (Table 10.9).

Table 10.9 Yield per recruit analyses for the Dutch and Korean fleets combined, using the lower bound \( K \) parameter, with other parameters modified accordingly

<table>
<thead>
<tr>
<th>Current status (2 fleets)</th>
<th>Biological Reference Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unexploited</td>
</tr>
<tr>
<td>F</td>
<td>1.07</td>
</tr>
<tr>
<td>SBR (g)</td>
<td>181</td>
</tr>
<tr>
<td>YPR (g)</td>
<td>158</td>
</tr>
<tr>
<td>Slope YPR</td>
<td>-0.12</td>
</tr>
</tbody>
</table>

The different analyses undertaken all indicate a high fishing mortality for \( Cynoscion \) virescens. According to the calculations, maintaining the current \( F \) level will lead to the spawning biomass per recruit (SBR) being reduced to 11.3% of the initial level. With the new set of parameters (lower \( K \) value), the sustained application of the estimated \( F \) would lead to a reduction of the SBR to 21.3% of its original level, which is still very low. The fishing pressure therefore appears to be excessive.

A number of measures could be considered in order to improve the situation of the stock:

- Increase the mesh size of the Dutch fleet to at least that of the Korean fleet.
• Reduce the effort exerted by one or both fleets by reducing the number of boats.
• As an alternative to excluding some vessels, closed seasons for fishing could be considered as a means of reducing total effort to the desired level.
• A further means of reducing the catch and providing a refuge for the spawning stock, would be to introduce restricted areas for fishing with trawlers. Further studies are required to investigate the necessary size of the closed area or areas.

Without adequate action to reduce fishing mortality to sustainable limits, it is very unlikely that the catch rates will improve over time and they may deteriorate. A possible scenario would be to decrease the fishing effort of the Dutch fleet by 40% and that of the Korean fleet by 50%. At the same time, the mesh selectivity of both fleets could be brought to 130% of the present value of the Korean fleet. These measures would lead to a reduction of the spawners biomass to 39% of its original level, which is better than the current calculated situation (20%). Fishing mortality would however still be at an excessive level of 1.4.
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 ancyloclon, 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 \textit{P. brasiliensis} preferentially, ceased operations in November 1996.

### 11.2 Distribution of the species

Cervigon \textit{et al} (1993) provides a description of the biology of the main shrimp species. The pink-spotted shrimp, \textit{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, \textit{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. \textit{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, \textit{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. \textit{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 \textit{P. brasiliensis}, \textit{P. notialis} and \textit{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

<table>
<thead>
<tr>
<th>Growth Parameters</th>
<th>\textit{P. brasiliensis}</th>
<th>\textit{P. notialis}</th>
<th>\textit{P. subtilis}</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_\infty ) (mm tail)</td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td>153</td>
<td>137</td>
<td>149</td>
</tr>
<tr>
<td>( K ) (month(^{-1}))</td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>0.15</td>
<td>0.2268</td>
</tr>
<tr>
<td>( M ) (month(^{-1}))</td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Growth parameters (Table 11.1) were obtained from a review of the existing literature on the species and region. However, information on \textit{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 $L_\infty$ 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 $L_\infty$, $K$ 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 $L_\infty$, $K$ 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.
12 ASSESSMENTS OF FISHERIES IN GUYANA FOR BANGAMARY (*Macrodon ancylodon*) AND BUTTERFISH (*Nebris microps*)

A. Hackett, K. Cochrane and A. Booth

12.1 Introduction

The pattern of growth of these fish species was modelled using the von Bertalanffy growth equation (VBGF). Length-at-age data generally provide the best estimates of the three VBGF parameters. Such data are commonly obtained from annual marks in the otoliths and these marks are taken as related to periods of rapid and slow growth over an annual cycle, in relation to seasonal fluctuation of the environment, providing estimates of the age of fish. However, in this case, length-at-age data were not available and length frequency data had to be used for estimation of growth parameters. Length frequency data, in addition to being easier to obtain than length-at-age data, have the advantage of being inexpensive since measured fish need not be purchased.

Length-based methods were used to study the growth and mortality rates of bangamary (*Macrodon ancylodon*) and butterfish (*Nebris microps*) in Guyana. Length frequency data was collected from the Chinese seine, nylon gillnet and trawl fisheries during January 1996 – March 1999 in order to estimate the length structure of the population. Length frequency distributions were analysed. Von Bertalanffy growth parameters were derived from the mean length of the normal distributions. The growth parameters obtained for *N. microps* were unrealistic, therefore values of $K=1.18$ yr$^{-1}$ and $L_\infty=49.57$ cm for *N. microps* were taken from Suriname.

Growth parameters of *M. ancylodon* estimated from previous assessments were $K=0.66$ yr$^{-1}$ and $L_\infty=43.57$ cm. Natural mortality rates of 1.20 yr$^{-1}$ and 1.70 yr$^{-1}$ and an average value of total annual mortality of 2.7 yr$^{-1}$ and 9.3 yr$^{-1}$ for *M. ancylodon* and *N. microps* respectively were estimated. These were used in the multispecies multigear yield per recruit analysis to evaluate the status of the fishery and forecast the effects of changes in the fishing pattern. Results indicate that *M. ancylodon* may be over-exploited.

*Macrodon ancylodon* (bangamary) is exploited by several fisheries and gear types in Guyana, including the Chinese seine, nylon gillnet, pin seine and shrimp trawl. Each of these gear types will have different size selectivities, where the selectivity is also a function of the species. It is essential to know the selectivity characteristics of a gear type before using catch and length frequencies of catches from that gear type for estimating abundance, size structure of the population, growth and length parameters.

The Chinese seine fishery accounts for 27% (354 vessels) of the artisanal fleet of Guyana based on the 1994 Artisanal Frame Survey. The Chinese seine is a funnel-shaped net, 16m long and 4-6m wide at the mouth. The mesh size at the mouth of the net is 8cm and gradually decreases as it proceeds to the bag of the net where the mesh size is 1cm. A flat-bottom dory vessel powered by sail, paddle, or small outboard engine is used in the fishing operations.

The vessels work according to the tide and spend between 6-12 hours per day fishing. The net is attached to poles (pens) and set on mud banks, mainly in river mouths, where tidal currents sweep the fish and shrimp into the seine. This operation is heavily dependent upon the influence of the river currents. These poles (pens) are set at depths between 2-4 fathoms (3.6-7.2m), at a distance of about one mile from the shore. Each vessel operates between two to ten seines. The crew size of these vessels ranges between 2-4. The Chinese seine fishermen used between 3-12 Chinese seines per fishing trip depending on the season for whitebelly (March-April).
The catch consists primarily of *N. schmitti*, *Xiphopenaeus kroyeri*, *Macrodon ancylodon*, and *Nebris microps*. In 1997, preliminary estimates of Chinese seine catch consist of 36.8% *M. ancylodon*, 12.5% *Nebris microps*, 13.4% *X. kroyeri*, 29.8% *N. schmitti* and 7.5% others. A large amount of juvenile fish is caught in the Chinese seine fishery and is discarded with 100% mortality or used to produce fishmeal (Chakalall and Dragovich, 1980).

The nylon gillnet vessels, which account for 18.6% or 244 vessels of the artisanal fleet of Guyana, are equipped with outboard motors up to 48HP, which fish and land their catch along the entire coast of Guyana. Some of the vessels, equipped with ice-boxes, remain at sea for 2-3 days, whilst those with old freezers with ice with go on one-day trips. A nylon gillnet vessel will have a crew of 4 consisting of a captain and three fishermen. Species caught by this gear includes *Macrodon ancylodon*, *Nebris microps*, *Cynoscion virescens*, *Cynoscion acoupa*, etc.

The Offshore Industrial Fishery consists of 125 shrimp trawlers. The trawlers are 48% foreign owned. Foreign trawlers mainly exploit penaeid shrimp (*P. brasiliensis*, *P. notialis*, *P. subtilis* and *P. schmitti*) with finfish and small amounts of squid (*Loligo spp.*) and lobster (*Panulirus spp.*) as bycatch. The locally-owned trawlers mainly exploit seabob (*Xiphopenaeus kroyeri*) and various finfish species (*Macrodon ancylodon*, *Micropogonias furnieri*, *Nebris microps*, *Arius spp.*, *Cynoscions spp.*), with small quantities of penaeid shrimp as bycatch.

Nylon or polyethylene jib trawl nets are used in both the penaeid and seabob/finfish fleet (Guyana Department of Fisheries, 1994). Turtle Excluder Devices (TEDs) are mandatory for the entire shrimp trawl fleet. Penaeid shrimp trawl vessels normally have a crew of 5 while seabob vessels and finfish vessels carry 5-6 and 4-5 crew respectively.

### 12.2 Biology

*Macrodon ancylodon* was reported as one of the most abundant fishes off Guyana representing 18% of the catch (Lowe-McConnel 1966). *Macrodon ancylodon* is one of the major species caught by the Chinese seine fishery. It is also common in the pin seine, nylon gillnet and trawl fisheries.

Mature fishes were only seen from very inshore catches in 8 fathoms (15m) from the southeast in August, October and February. The estuarine and inshore zones appear to be principal nursery and rearing grounds for this species, demonstrated by the large numbers of immature *M. ancylodon* caught by Chinese seine in the inshore and estuarine areas. The young of *M. ancylodon* are said to be particularly abundant in the Chinese seine during the rainy season, but this may reflect greater attraction to estuaries when more fresh water is pouring out to sea. *Macrodon ancylodon* is said to move inshore during the rains and offshore during the windy weather (Lowe-McConnell, 1966). This species tend to move into offshore marine water when they reach the adult stage.

*M. ancylodon* are chiefly demersal feeding mainly on bottom dwelling organisms such as shrimp and small fish. The *Xiphopenaeus kroyeri* (seabob) is the main prey of this species (Bianchi 1992) and is closely associated with its distribution. The small specimens from the Chinese seine all had shrimp in their stomach contents; the larger ones from the trawl contained penaeid and mantis shrimp, small anchovies and *Stellifer spp.* *M. ancylodon* is in turn preyed on by *Cynoscion virescens* and has also been found in the stomachs of the barracuda, *Sphyraena guachancho* and the shark, *Carcharinus maculipinnis* (Lowe-McConnell 1966).

*Nebris microps*, much prized as food, is a distinctive orange-coloured sciaenid with a huge mouth and very small eyes. It is occasionally taken in large numbers in the trawl. They are most apparent when onshore winds are stirring the inshore waters, but they have been found down to 22 fathoms (40m) in the northwest in March. They are also caught in large numbers, together with their young stages, in Chinese seines in the river estuaries. Samples of trawl caught and market *N. microps* ranged in size from 15/16 cm to 28/31 cm. No ripe or ripening
Table 12.1 Length frequency data for *M. ancylodon* for the period January-March 1996

<table>
<thead>
<tr>
<th>Size Class</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Jan-Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>502</td>
<td>502</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>14</td>
<td>657</td>
<td>671</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>0</td>
<td>663</td>
<td>663</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>0</td>
<td>792</td>
<td>792</td>
</tr>
<tr>
<td>13</td>
<td>20</td>
<td>22</td>
<td>317</td>
<td>359</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
<td>215</td>
<td>174</td>
<td>393</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
<td>160</td>
<td>194</td>
<td>394</td>
</tr>
<tr>
<td>16</td>
<td>48</td>
<td>127</td>
<td>52</td>
<td>227</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
<td>362</td>
<td>31</td>
<td>413</td>
</tr>
<tr>
<td>18</td>
<td>66</td>
<td>234</td>
<td>29</td>
<td>329</td>
</tr>
<tr>
<td>19</td>
<td>28</td>
<td>121</td>
<td>56</td>
<td>205</td>
</tr>
<tr>
<td>20</td>
<td>36</td>
<td>154</td>
<td>94</td>
<td>284</td>
</tr>
<tr>
<td>21</td>
<td>52</td>
<td>73</td>
<td>46</td>
<td>171</td>
</tr>
<tr>
<td>22</td>
<td>12</td>
<td>81</td>
<td>12</td>
<td>105</td>
</tr>
<tr>
<td>23</td>
<td>10</td>
<td>13</td>
<td>21</td>
<td>44</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>63</td>
<td>15</td>
<td>90</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
<td>130</td>
<td>5</td>
<td>145</td>
</tr>
<tr>
<td>26</td>
<td>6</td>
<td>0</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>27</td>
<td>0</td>
<td>40</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>28</td>
<td>2</td>
<td>19</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>29</td>
<td>2</td>
<td>26</td>
<td>10</td>
<td>38</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>33</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>31</td>
<td>0</td>
<td>28</td>
<td>10</td>
<td>38</td>
</tr>
<tr>
<td>32</td>
<td>0</td>
<td>47</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>33</td>
<td>0</td>
<td>33</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>34</td>
<td>0</td>
<td>26</td>
<td>20</td>
<td>46</td>
</tr>
<tr>
<td>35</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

*N. microps* has been observed in trawls. Small fish (11mm) from Chinese seines have a huge mouth in relation to the body size (Lowe-McConnell 1966).

### 12.3 Data used for the assessment

The data used for the assessment of *N. microps* were monthly length frequencies from Chinese seine and trawl data (January 1996-October 1997, March 1998-March 1999 respectively). The data used for the assessment of *M. ancylodon* (bangamary) were monthly length frequency from the Chinese seine and trawl samples from January-December 1998.
The samples were taken from unsorted landings and each fish was measured, to the nearest centimetre below, from the tip of the snout to the longest caudal fin. During the data collection exercise landing sites/wharves were visited three times per week. These sites were selected randomly. A minimum target of 150 fish lengths per gear type were required per month.

12.3.1 Approaches used for the integration of the data

For the given vessels, if the total landings (M. ancylodon) were not measured, the sample length frequency was extrapolated to account for the total frequency. Each size class was taken at 1cm intervals. The length frequencies were grouped into three monthly samples (Table 12.1) gives grouped length frequency of M.ancylodon and N. microps for the period April-June 1998 from the Chinese seine and trawl samples.

<table>
<thead>
<tr>
<th>Quarters</th>
<th>Obs</th>
<th>Date</th>
<th>Mean (cm)</th>
<th>Std.Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Mar</td>
<td>1</td>
<td>15/01/96</td>
<td>12.00</td>
<td>0.849</td>
</tr>
<tr>
<td>Jan-Mar</td>
<td>2</td>
<td>15/01/96</td>
<td>15.02</td>
<td>0.726</td>
</tr>
<tr>
<td>Jan-Mar</td>
<td>3</td>
<td>15/01/96</td>
<td>18.38</td>
<td>1.149</td>
</tr>
<tr>
<td>Apr-Jun</td>
<td>1</td>
<td>15/04/96</td>
<td>24.08</td>
<td>1.628</td>
</tr>
<tr>
<td>Apr-Jun</td>
<td>2</td>
<td>15/04/96</td>
<td>26.77</td>
<td>0.524</td>
</tr>
<tr>
<td>Apr-Jun</td>
<td>3</td>
<td>15/04/96</td>
<td>29.66</td>
<td>0.738</td>
</tr>
<tr>
<td>Apr-Jun</td>
<td>4</td>
<td>15/04/96</td>
<td>34.23</td>
<td>0.852</td>
</tr>
<tr>
<td>Jul-Sep</td>
<td>1</td>
<td>15/07/96</td>
<td>29.50</td>
<td>0.256</td>
</tr>
<tr>
<td>Oct/Nov</td>
<td>1</td>
<td>15/10/96</td>
<td>27.80</td>
<td>0.801</td>
</tr>
<tr>
<td>Jan-Mar</td>
<td>1</td>
<td>15/01/97</td>
<td>17.91</td>
<td>1.402</td>
</tr>
<tr>
<td>Jul-Sep</td>
<td>1</td>
<td>15/07/97</td>
<td>23.48</td>
<td>0.972</td>
</tr>
<tr>
<td>Jul-Sep</td>
<td>2</td>
<td>15/07/97</td>
<td>27.15</td>
<td>1.910</td>
</tr>
<tr>
<td>Jul-Sep</td>
<td>3</td>
<td>15/07/97</td>
<td>31.80</td>
<td>0.636</td>
</tr>
</tbody>
</table>

12.4 Estimation of L∞ and K parameters

Due to the small sample size in each month, the length frequencies for each year were grouped into three months intervals.

Preliminary identification of modal lengths and standard deviations were done using the Bhattacharya method, using the FISAT software (Gayanilo et al. 1995). The results were used as starting values in the NORMSEP routine, which was also run using FISAT.
The mean lengths and standard deviations obtained from the Bhattacharya method were used as starting values in the NORMSEP routine. However, it was found that NORMSEP sometimes generated unrealistic modes in this way. In these cases, the starting values were adjusted until the modes identified by NORMSEP were considered to be biologically realistic.

The modes identified were then used in the Linking of Means routine of FISAT in order to generate a Gulland and Holt plot of growth increments against initial length (Sparre and Venema, 1992). This generated estimates of $K$ and $L_\infty$.

Reasonable estimates of $K$ and $L_\infty$ were obtained for *M. ancylodon* using this method (Table 12.2), but the values for $L_\infty$ and $K$ estimated for *N. microps* were very unrealistic (results are not shown). Therefore, estimates for $L_\infty$ and $K$ for *N. microps* were taken from Suriname.

### 12.5 Gear selectivity

The catchability of a gear usually varies with the size (therefore age) of the animal caught. Selection of a gear may be explained by a number of factors, of which the ability of the meshes (hooks) to retain the fish is only one. Another important factor is the availability of fish on the fishing grounds. Certain size groups may not be caught, simply because they are not present on the fishing ground. Often small (juvenile) fish are in near-shore nursery grounds, where they cannot be exploited with large industrial vessels. Large fish, on the other hand, may prefer deeper waters outside the reach of the artisanal fishery.

The best estimates of the selectivity characteristics of a gear type for a given species or community can be obtained if the catch composition can be compared with good estimates of the actual population or community composition. However, such comparative estimates are very rare and it is more normal to obtain estimates of size selectivity for a given species by comparing the size compositions from different gears fished in the same localities (see e.g. Sparre and Venema, 1992). However, examination of the length frequencies of landings for *M. ancylodon* and *N. microps* from the three major gear types, Chinese seine, gillnet and trawl, indicated that all of these gear had different selectivity characteristics and it was not possible to set one as a standard. (Fig. 12.1) Therefore, for the Chinese seine and trawl, the length at 50% selection was assured to occur where the frequency was 50% of the frequency of the first major mode (Fig. 12.1). No reduction in selectivity of older fish was assumed. This was done for the samples for *M. ancylodon* and *N. microps*. For nylon gillnet, it was assumed that the selectivity curve would be approximately a normal distribution.

The measured length frequencies of the nylon gillnet samples for *M. ancylodon* were grouped annually, to provide large enough sample sizes. Hence, the samples consisted of aggregated length frequencies obtained from landings by gillnet for the years 1997 and 1998. The frequencies for each length and year were not normalised.

Selectivity function was calculated for the nylon gillnet fishery. Three estimated selectivities (one for each year and 1997/1998 combined) were estimated (see Fig. 12.2 for the 1997/1998 combined). This was not done for *N. microps* since the data was not available at the workshop.

\[
S^*_f = \exp\left(\frac{(l - l_m)^2}{2\sigma^2}\right)
\]

The selectivity function for gillnets can be described by a normal distribution:

where $S^*_f$ = the estimated selectivity of the gear for a fish of length, $l_m$ = the length of fish for which the gear has the highest selectivity and $\sigma$ = the selectivity standard deviation.
Figure 12.1 Length frequency of *M. ancylodon* for 1998 for Chinese seine (C/S) nylon gillnet (GNN) and trawl gears

Figure 12.2 Observed (•) and predicted (—) *M. ancylodon* length frequency for nylon gillnet

12.5.1 Results Macrodon ancylodon

Using a non-linear minimisation routine, the parameters of the normal distribution and the scaling factors were estimated for the gillnet fishery (Table 12.3). Since the $L_{50\%}$ estimated were similar, but the combined sample had the largest number of points, it was suggested that the values for the 1997/1998 combination be used.
Table 12.3 Selectivity parameters of the normal distribution and scaling factor for the nylon gillnet fishery catching *M. ancylodon*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>L&lt;sub&gt;50%&lt;/sub&gt;</td>
<td>30.1</td>
<td>30.5</td>
<td>30.3</td>
</tr>
<tr>
<td>SD</td>
<td>2.98</td>
<td>4.22</td>
<td>3.78</td>
</tr>
<tr>
<td>Scale</td>
<td>16106.6</td>
<td>26045.8</td>
<td>41491.9</td>
</tr>
</tbody>
</table>

Table 12.4 Selectivity parameters of the mean/age for trawl and nylon gillnet catching *M. ancylodon*. These values were taken from the Report of the Second CFRAMP / FAO / DANIDA Stock Assessment on the Shrimp and Groundfish Fishery on the Brazil-Guianas shelf where a start was made in applying the multi-species multi-fleet yield per recruit to the inshore fisheries of Guyana

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Length at 50% selectivity (cm)</th>
<th>Age yr&lt;sup&gt;-1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore Trawl</td>
<td>10.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Nylon gillnet</td>
<td>26.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Chinese seine</td>
<td>4.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>

L<sub>50%</sub> for Chinese seine was estimated at 16.2 cm at an age of 0.8 yr<sup>-1</sup>. For the trawl fishery, a L<sub>50%</sub> was estimated at 26.2 cm at an age of 1.6 yr<sup>-1</sup>. However, these values were not used in the per-recruit model as input parameters. It is believed that there are discards of small fish in the trawl fishery. Most of the time the trawl vessels would land fish of marketable size. Hence in addition to selectivity by the gear, there is also selectivity by the crew. This was supported by the results obtain from a trawl survey conducted in French Guiana by IFREMER, where there were smaller length classes in the catch as compared to those sampled by observers. With these biases in mind, alternative parameters were used as input parameters for the per-recruit modelling (Table 12.4).

12.5.2 Results *Nebris microps*

L<sub>50%</sub> for Chinese seine was assumed to be 16.1 cm and for the trawl to be 26.0 cm. These values were similar for *M. ancylodon*. However, with the problem mentioned above, input parameters for the per-recruit models would be based on those collected from the French Guiana trawl survey. These estimates will be refined when data is gathered from the Trawl Observer programme, which will start during the later part of 1999 in Guyana.

12.6 Catch Curve Analysis (Ehrhardt and Legault 1996)

Estimates of Z were obtained from the catch curve analysis using the software described by Ehrhardt and Legault (1996). This was done for each quarterly length frequency sample of the Chinese seine and Trawl catches. Hence, an assumption of equilibrium was made in determining Z. The inputs for this routine were the pooled quarterly length frequencies for the study period, along with the L<sub>∞</sub> and K values estimated for *M. ancylodon* (43.57 cm and 0.66 yr<sup>-1</sup>) and *Nebris microps* (49.57 cm, 1.18 yr<sup>-1</sup>).

116
Growth parameters \( (L_{\infty} \text{ and } K) \) for \( M. \ ancylodon \) were estimated from the previous assessment on this species at the previous workshop in May 1998. The maximum age of the fish was estimated at 7 yr\(^{-1}\), the length of maturity used was 21 cm with a corresponding age of 1 year (McConnell 1966).

Sensitivity analyses of estimates of \( F \) and of yield-per-recruit (YPR) and biomass-per-recruit (BPR) results were undertaken on 0.5 and 2.0 of the estimated \( M \). The values of \( M \) and \( Z \) were used to estimate \( F \) at the time of sampling from the equation: \( Z = F + M \).

Natural mortality, \( M \), was obtained using Pauly's empirical equation as contained in FISAT, using the \( K \) and \( L_{\infty} \) values estimated and a value of mean temperature 27\(^\circ\)C. FISAT does not include estimates of the confidence intervals of the estimated \( M \).

12.6.1 Results Macrodon ancylodon

By looking at the length frequency samples for the two fisheries, it seems as if the Chinese seine were not selecting the larger fish in the population, which are found to some extent in the trawl fishery and to a larger extent in the gillnet fishery. The larger fish may not be fully represented in the Chinese seine, either because they are not commonly found in the shallow waters or because they avoid or escape from the gear.

A length-converted catch curve was fitted to the quarterly samples for the trawl and Chinese seine catches with an \( L_{\infty} \) of 43.57 cm and \( K \) of 0.66 yr\(^{-1}\) (Fig. 12.3). An average fishing mortality \( F \) of 1.5 yr\(^{-1}\) was estimated using the Chinese seine samples whilst an average fishing mortality \( F \) of 2.9 yr\(^{-1}\) was estimated for the trawl fishery (Table 12.5).

The fishing mortality was estimated to be higher in the trawl than in the Chinese seine. The Chinese seine seems to be selecting the medium size fish but at a relatively low level of \( F \), while the trawl seems to be selecting the medium fish at a high level of \( F \). The high fishing mortality in the trawl fishery also may be due to the larger fish escaping the gear.

From the length frequency samples for 1996-1997 from the Chinese seine catch, there are high numbers of large fishes (20-39 cm) during the month of June. For the trawl, the larger fishes were occurring in the months of October and November. The Chinese seine samples
showed the smaller fishes occurring in larger numbers during the month of February. This is consistent with the observation that *M. ancylodon* tends to move inshore during the rainy season (June-July) into the estuaries. Here they are caught by the Chinese seine in the estuaries during the rains, the time of the year at which they are thought to spawn. The young in particular are abundant in the Chinese seine catches during the rainy season. They tend to move off-shore during the northeast trade winds in January-March.

Using the results obtained in Table 12.5, the following mortality estimates were derived by taking the arithmetic averaging over the three/four samples:

- Average F (Chinese seine) = $1.5 \pm 0.9 \text{ yr}^{-1}$
- Average F (Trawl) = $2.9 \pm 1.34 \text{ yr}^{-1}$
- Average Z (Chinese seine) = $2.7 \pm 0.9 \text{ yr}^{-1}$
- Average Z (Trawl) = $4.1 \pm 1.34 \text{ yr}^{-1}$

<table>
<thead>
<tr>
<th>Sample Period</th>
<th>Chinese Seine Fishery</th>
<th>Trawl Fishery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>F</strong> (yr⁻¹)</td>
<td><strong>Z</strong> (yr⁻¹)</td>
</tr>
<tr>
<td>Jan-Mar 1998</td>
<td>2.4</td>
<td>3.60</td>
</tr>
<tr>
<td>Apr-Jun 1998</td>
<td>1.4</td>
<td>2.62</td>
</tr>
<tr>
<td>Jul-Sep 1998</td>
<td>3.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Oct- Dec 1998</td>
<td>0.57</td>
<td>1.78</td>
</tr>
</tbody>
</table>

### 12.6.2 Results *Nebris microps*

Results from the catch curve analysis (Table 12.6), show high fishing mortality values for both fleets. By looking at the catch curve, it appears that the gear is only capturing the fish at a selected length range, after which the fish is disappearing more or less at age one year. The only explanation for this is that with a high K value of 1.18 the fish seems to be reaching its maximum length very quickly. By substituting lower values for K in the model, the F values are reduced.
Table 12.6 Estimates of fishing mortalities (F) and total mortality (Z yr\(^{-1}\)) of *N. microps* landed by the Chinese seine and trawl vessel operating in Guyana during January-December 1998. The coefficient of determination (R\(^2\)) and the number of points (n) used from the length-converted catch curves are also shown. Natural mortality (M) was assumed as 1.7 yr\(^{-1}\). Values of L\(^\infty\) and K were 49.57 and 1.18 yr\(^{-1}\) respectively.

<table>
<thead>
<tr>
<th>Sample Period</th>
<th>F (yr(^{-1}))</th>
<th>Z (yr(^{-1}))</th>
<th>R(^2)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Mar 98</td>
<td>1.7</td>
<td>3.4</td>
<td>0.09</td>
<td>30-35</td>
</tr>
<tr>
<td>Apr-Jun 98</td>
<td>13.6</td>
<td>15.3</td>
<td>0.90</td>
<td>31-38</td>
</tr>
<tr>
<td>Jul-Sep 98</td>
<td>7.5</td>
<td>9.2</td>
<td>0.89</td>
<td>29-36</td>
</tr>
<tr>
<td>Oct-Dec 98</td>
<td>2.5</td>
<td>4.2</td>
<td>0.47</td>
<td>28-33</td>
</tr>
<tr>
<td>Jan-Mar 99</td>
<td>7.6</td>
<td>9.3</td>
<td>0.75</td>
<td>30-35</td>
</tr>
</tbody>
</table>

Using the results in Table 12.6, the following mortality estimates were derived by averaging over the samples' estimates:

- Average F (Chinese seine) = 7.6 ± 10.6 yr\(^{-1}\)
- Average F (Trawl) = 6.6 ± 4.8 yr\(^{-1}\)
- Average Z (Chinese seine) = 9.3 ± 10.6 yr\(^{-1}\)
- Average Z (Trawl) = 8.3 ± 4.8 yr\(^{-1}\)

### 12.7 Catch per unit of effort (CPUE) trends

Trends in CPUE were examined for *M. ancylodon* for the period 1996-1998. This was also in keeping with the recommendation made at the last workshop to monitored the stock using CPUE data.

The landings of *M. ancylodon* of all Chinese seine vessels sampled for the month was summed and divided by the total effort (# of seine) for that month to obtain the monthly CPUE. This was done with the data collected from 1996-1998. Annual CPUE was also calculated using the formula:

\[
\text{Annual CPUE} = \frac{\text{Total landings of } M. \text{ancylodon per year}}{\text{Total effort (# of seine) per year}}
\]

From the plot of the CPUE for *M. ancylodon* from the Chinese seine fishery for the period 1996-1998, there seems to be similar trend in CPUE for 1997 and 1998 except for the last three months of the year. There were similar peaks in March and may for 1997 and 1998 with similar downward trends in April, June and August although the latter was not so pronounced. The annual CPUE for the same period (i.e.1996-1998) showed a reduction in CPUE in the year 1998 (Fig. 12.4). It is not known whether this reduction in the CPUE is due to the El Niño effect. Further investigation should be carried out by use of rainfall data.
12.7.1 Estimation of the catchability coefficient by fleet for M. ancylodon

The fishing mortalities estimated for the Chinese seine and the trawl fishery from the catch curve analysis were used in turn to estimate the catchability parameter. The total fishing mortality was distributed over the three fleets (Chinese seine, trawl and nylon gillnet) as follows:

\[ F_f = F \times \left( \frac{L_f}{TL} \right) \]

where \( F_f \) = fishing mortality of fleet \( f \), \( F \) = total mortality (\( F=1.5 \)), \( L_f \) = total fleet landing of species and \( TL \) = total landings of species for all fleet. Catchability coefficient (\( q \)) of each fleet was calculated as follows:

\[ q = \left( \frac{F_f}{E} \right) \]

where \( q \) = catchability coefficient and \( E \) = effort (number of vessels).

Table 12.7 Results of the catchability coefficient of various fisheries on M. ancylodon.

<table>
<thead>
<tr>
<th>Fleet Type</th>
<th>Catchability coefficient (( q ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese seine</td>
<td>0.001</td>
</tr>
<tr>
<td>Nylon gillnet</td>
<td>0.003</td>
</tr>
<tr>
<td>Trawl</td>
<td>0.004</td>
</tr>
</tbody>
</table>

12.8 Multifishery-multispecies per-recruit modelling (Booth 1999)

The fisheries of the sub-region are complex with a variety of the gear, all of which catch a number of different species. Hence single species assessment can provide only partial answers in terms of optimal management and additional studies need to be made to investigate the interactions between different types of fisheries and the impacts of them on the communities of resources. This requires multi-species and multi-fleet assessments. With
data available, a multi-fleet per recruit approach was adopted for the multi-species and multi-fleet assessments.

The multispecies-multifishery per-recruit method is an extension of the traditional per-recruit models and is described in Section 5 of this report.

### 12.8.1 Results

The nylon gillnet fishery on it owns has a maximum yield per recruit of approximately 62g which occurs at a value of $F$ greater than 3 yr$^{-1}$ (Table 12.8). The nylon gillnet gear is selecting the fish after maturity at a specified range and over. In contrast, because it catches a large number before they have completed the period of relative rapid growth, the inshore Chinese seine fishery has a maximum yield per recruit at only 32g which occurs at an $F$ above 0.75 yr$^{-1}$. For the offshore trawl fishery, the maximum yield per recruit was only 37g, which occurs at $F$ of 0.93 yr$^{-1}$. Although the yield in this fishery is higher than that of the inshore Chinese seine, it is evident that the capture of many juvenile fish by the Chinese seine fishery has an impact on the yield of the trawl fishery. This will also affect the yield of the nylon gillnet fishery since with the high mortality of juvenile fish, less recruits would be made available to the other fisheries, resulting in growth overfishing. Although the Chinese seine is capturing a large amount of juvenile fish, the yield is not high since the fishes are not given the opportunity to grow and mature in size and weight to substantially contribute to the biomass.

Similarly the spawner biomass per recruit using the nylon gillnet fishery is reduced to 40% of its unexploited level with an $F$ of 1.89. For the offshore trawl fishery, the spawner biomass per recruit is reduced to 40% of its unexploited level with an $F$ of 0.54. The inshore Chinese seine fishery would deplete the stock to 40% of its unexploited level with an $F$ of 0.48.

The interaction of the offshore trawl and inshore Chinese seine fisheries was examined. The presence of the Chinese seine fishery reduces the potential yield of the combined fishery (Table 12.8). Since the Chinese seine is capturing the fish in its juvenile state, then less fish would be available to the trawl fishery. In combining the trawl and nylon gillnet fisheries and running the model, the potential yield of the combined fishery is reduced with the presence of the trawl fishery. In combining all three fisheries, a potential maximum yield was recorded at 39.9g at $F$ of about 1.2 yr$^{-1}$. The presence of both the Chinese seine and the trawl fisheries has a somewhat double effect on the reduction of the potential yield of the combined fishery.

<table>
<thead>
<tr>
<th>Values</th>
<th>Chinese seine Fishery</th>
<th>Trawl</th>
<th>Nylon Gillnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{\text{max, YPR}}$</td>
<td>0.75, (32.4g)</td>
<td>0.93, (37.1g)</td>
<td>&gt;3, (62g)</td>
</tr>
<tr>
<td>$F_{50%}$</td>
<td>0.35</td>
<td>0.39</td>
<td>1.14</td>
</tr>
<tr>
<td>$F_{40%}$</td>
<td>0.48</td>
<td>0.54</td>
<td>1.89</td>
</tr>
<tr>
<td>$F_{30%}$</td>
<td>0.65</td>
<td>0.74</td>
<td>3.7</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>0.5</td>
<td>0.6</td>
<td>1.33</td>
</tr>
</tbody>
</table>
Table 12.9 Results of the multifishery-multispecies analysis illustrating the interaction of various fisheries on *M. ancylodon* (Yield per recruit values in parenthesis)

<table>
<thead>
<tr>
<th>Values</th>
<th>Chinese seine / Trawl fishery</th>
<th>Trawl / Nylon gillnet Fishery</th>
<th>Combined Fisheries</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F_{\max}, \text{YPR})</td>
<td>0.88, (35.7g)</td>
<td>1.4, (42.1g)</td>
<td>1.2 , (39.9g)</td>
</tr>
<tr>
<td>(F_{50%})</td>
<td>0.39</td>
<td>0.57</td>
<td>0.53</td>
</tr>
<tr>
<td>(F_{40%})</td>
<td>0.52</td>
<td>0.81</td>
<td>0.73</td>
</tr>
<tr>
<td>(F_{30%})</td>
<td>0.72</td>
<td>1.1</td>
<td>1.03</td>
</tr>
<tr>
<td>(F_{0.1})</td>
<td>0.6</td>
<td>0.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

### 12.9 Discussion

The main analytical steps covered in this investigation were:

(i) To estimate growth and mortality rates of *N. microps* and *M. ancylodon*;
(ii) To estimate the selectivity of the gear for both species;
(iii) To examine the impact of more than one fishery on *M. ancylodon* and on the yield by undertaking multi-species and multi-fleet assessments for *M. ancylodon*;
(iv) To estimate other biological parameters for input into a bio-economic model.

Due to the high uncertainty in the value of \(K\) for *N. microps*, the per-recruit model was not applied to this species, however with improved estimates the model could be applied. High values of fishing mortality in the trawl fishery were observed. This was similar for other species of sciaenids investigated during the workshop.

The selectivity results indicate that a narrow size range of *M. ancylodon* is retained by the nylon gillnet gear. Fish of 30.3 cm were optimally selected yet selectivity is reduced substantially in fish larger or smaller than the mean. A fish of 25 cm, for example, is only as vulnerable to the gear as a 30 cm fish, etc. As a result, length frequency data obtained from nylon gillnet catches will reflect the selection properties of the gear more than the length composition of the population. This characteristic excludes the possibility of using the samples for estimating growth or mortalities rates. The gear unfortunately only gives an indication, itself affected by selectivity, of the abundance of fish between approximately 25 and 38 cm.

The Chinese seine and trawl fisheries seem to be capturing the juvenile *M. ancylodon* hence reducing the number of recruits to other fisheries. The trawl fishery also seems to be catching the medium size to large fishes which results in a reduction of the spawner biomass. The two fisheries are competing for the stock.

There seems to growth overfishing taking place in the Chinese seine and trawl fisheries. Also in the trawl and gillnet fisheries there seems to be recruitment overfishing taking place. These phenomena can have serious effect on the stock in the future and cannot be overlooked.

Catchability coefficient (q) values obtained are preliminary values since there is some uncertainties in the nylon gillnet landings of *M. ancylodon* for 1997.
12.10 Conclusion

The collection of length frequency data from nylon gillnet fisheries should be reduced to a lower level priority as compared to the priorities given to Chinese seine and the trawl gears. Greater effort should, however, be placed into sampling the other two gears for length frequency samples.

Due to the high values of $F$ estimated for $N. \text{microps}$ based on the high $K$ value used in the analysis, no management measures would be suggested for this species. Refined estimates of $L_\infty$ and $K$ should be obtained from the literature or by combining the data from Guyana and Suriname and applying it to the model in some future workshop.

The following conclusions are drawn from the results of the multispecies multifleet per recruit model:

(i) For the seabob fleet, restrict the trawling for seabob to the area of high adult abundance with the view of reducing the conflict with the artisanal fishermen and damage to nursery areas and juveniles.

(ii) For the finfish fleet, mesh size regulation and appropriate finfishing trawl

(iii) For the Chinese seine fleet, determine at what level this fishery is becoming mainly a finfish targeting fleet instead of a whitebelly shrimp fleet and institute a mesh size regulation.

Since the Chinese seine and trawl fisheries are contributing to growth overfishing and the trawl and gillnet fisheries to recruitment overfishing, then studies should be conducted to ascertain at what time of the year the species spawn and also the age of spawners. It would be very important to gather some knowledge on which gears are capturing the spawners at what age. This would require the collection of gonads and otoliths for this species.
13 STOCK ASSESSMENT OF TWO SCIAENID FISHERIES IN THE WEST COAST OF TRINIDAD AND TOBAGO

S. Soomai, N.M. Ehrhardt, K. Cochrane and T. Phillips

13.1 Introduction

The sciaenid fisheries is a part of the groundfish fisheries in Trinidad and Tobago and dominated by two species, *Micropogonias furnieri*, the whitemouth croaker and *Cynoscion jamaicensis*, the Jamaica weakfish. The fisheries are based mainly in the Gulf of Paria on the west coast of Trinidad. These two species are considered the most commercially important and are the most abundant of the sciaenids landed on the west coast. Most artisanal fishing is done in depths between 9–14m, although these species are also caught by the offshore shrimp trawlers. The artisanal vessels used in the catching of groundfish are pirogues 6-10m long and are constructed of wood and fiberglass or fiberglass coated wood. These vessels may use one or two 45 to 75HP outboard engines (Henry and Martin 1992). There is no mechanisation of operations, but most vessels carry ice chests for catch storage. Vessels are owned by private individuals with some persons owning more than one. The Fisheries Division vessel census conducted in January 1998, identified 728 vessels on the west coast of Trinidad which operate gears that capture groundfish. In 1994, croaker accounted for 65% (627 t) of the total landings and 63% (TT$2.6M) of the total value of the groundfish landed by the artisanal fishery, apart from trawling. Jamaica weakfish accounted for 9% by weight (87 t) and 15% by value (TT$0.6M).

Stock assessments of these sciaenid fisheries are difficult due to the combination of biological and fishery features such as lack of appropriate biological understanding of the dynamics of the species and the usually high exploitation exerted on the species. Besides fishing by artisanal and semi-industrial trawlers which accounts for major landings of groundfish in the form of bycatch or as a targeted species according to the season, five other gear types are used to catch these species. The main fishing gears used to target sciaenids are the monofilament demersal set gillnet, known locally as “transpearing”, multifilament gillnets or “fillet, which, though set at the surface, also catch groundfish due to deployment at shallow depths, demersal longlines or “palangue”, banking and a-la-vive (two other line methods). The mesh sizes for the gillnets range from 95-114 mm (Henry and Martin 1992) and 24.5-38 mm stretched mesh for the trawl nets (Trinidad Fisheries Division Trawler Gear Survey 1991). The species are often landed in small amounts in many places along the shoreline from artisanal, semi-industrial and industrial fishing vessels.

Many fish stock assessment techniques applicable to sciaenids require numbers of animals caught, not yield and thus the total landings in weight for each landed place must be converted to numbers of animals. Once the number of animals within given age or size intervals are known, cohort analysis can be used to estimate the fishing mortality rate and population size. However, biological samples of these species have not been sufficient to generate the minimum data required to express total landings in numbers by size categories. This report presents the combined assessments carried out at the 2nd CFRAMP/FAO Stock Assessment Workshop in Liliendaal, Guyana, 1998 (FAO 1999a and 1999b) and the 3rd CFRAMP/FAO Stock Assessment Workshop in Belém, Brazil, 1999 (this workshop). This is a first attempt to assess the *Micropogonias furnieri* and *Cynoscion jamaicensis* stocks in Trinidad and Tobago making use of monthly catch and effort data available for the period 1989-1997.
13.2 Data

The landings and fishing effort of sciaenid fisheries on the west coast of Trinidad are collected by enumerators based at the major landing sites. The data over the periods 1989-1994 and 1995-1997 are stored in a DBASE and an ORACLE database respectively and raised to the entire fleet to account for non-enumerated fishing days and vessels. This data gathering, however, does not represent a complete fishery statistical system since it lacks components for the collection of biological data from the artisanal and industrial fleets. In addition, there is no collection of landings and effort data from the industrial fleet. During this workshop analyses were made of monthly CPUE corresponding to *M. furnieri* and *C. jamaicensis* landed by six gear types. This information corresponds to 9 years of monthly data, which could be used to assess monthly stock biomass and fishing mortality if a catchability coefficient could be estimated.

13.3 Stock assessment methods

The following stock assessment algorithm was used in the analysis:

1. Fishing effort was standardised for the different gear types used in the sciaenid fisheries and for months following the analysis of variance technique of Robson (1966). This technique consists in defining CPUE for a given gear type $i$ and month $j$ as a function of a standard gear type $s$ and month $m$. Thus CPUE can be expressed as:

   \[
   CPUE_{i,j} = CPUE_{s,m} \cdot \rho_i \cdot D_j \cdot \text{error}_{i,j}
   \]

   where $\rho_i$ is the fishing power of gear $i$ relative to gear $s$, $D_j$ is the relative abundance in month $j$ relative to month $m$ and error is a measurement error associated with the CPUE estimation procedure. This multiplicative model is logarithmically transformed and the resulting log-linear model identified with a singular (no interaction terms) “analysis of variance” of the form:

   \[
   Y_{i,j} = \mu + \alpha_i + \beta_j + \epsilon_{i,j}
   \]

   where $\mu$ is the log of $CPUE_{s,m}$, $\alpha_i$ is the log of $\rho_i$, $\beta_j$ is the log of $D_j$ and $\epsilon_{i,j}$ is the log of error. Therefore, the analysis of variance will provide estimates of each factor $i$ and $j$ if log of CPUE are available for each $i$ and $j$. This procedure is contained in a FPOW-FORTAN routine.

2. Based on observed CPUE trends, locales of seasonal CPUE depletions were identified and the time scale was split to include only the depletion months observed in the locales. Then, a DeLury-type estimator (Chien and Condrey 1985) was used to obtain seasonal estimates of the catchability coefficient for each species separately. Catchability estimates derived from the Chien and Condrey method use catch in numbers per unit effort (CPUE), cumulative catch in numbers and average effort data over a number of time periods to estimate catchability in the following process. For a number of successive time periods, CPUE is regressed against cumulative catch (accumulated to half way through the time period) to yield an estimate of the slope $q'$ using the following linear regression model:

   \[
   CPUE_t = qN_0 - q'K_t
   \]

   where $q' = \frac{1}{f_t}(1 - e^{-(qf_t + M)})$

   where $q$ is the catchability coefficient, $N_0$ is the population size at the beginning of the depletion period, $f_t$ is the average fishing effort corresponding to the depletion period selected, $M$ is the natural mortality rate and $K_t$ is the cumulative catch during the depletion period. In this study, catch was not available in numbers but in weight, thus a
growth effect on catchability should be expected. However, the species are rather long-lived and growth during a depletion period of a few months was assumed negligible when compared to the mortality processes.

The catchability parameter is then estimated as:

\[
q = \frac{L}{\int \ln(1-q'y) + M}
\]

The depletion equation assumes recruitment does not occur during the regressed range, an assumption that can be broken by many tropical species. Recruitment will cause the (K, CPUE) points to be moved up and to the right due to the catch of animals not in the cohort, thereby decreasing the slope of the regression line, which should be considered when assessing the results.

3. A seasonal (monthly) average abundance by species was estimated as the simple ratio of standardized CPUE and seasonal catchability.

4. The seasonal (monthly) fishing mortality rate was estimated as the ratio of catch to average abundance.

5. Then, yield-per-recruit using the population parameters defined for the two species in last year’s workshop was obtained. These yield per recruit computations were done using the Thompson and Bell discrete model. Similarly, estimates of egg-per-recruit were calculated using a maturity and fecundity schedule. These estimates were used to define reference fishing mortality rates (those F-values maximizing yield-per-recruit and spawning-per-recruit at a prescribed level of pristine spawning). These mortality reference points were then compared with already estimated seasonal F-values. This comparison provides a general sense of the status of exploitation of the two stocks.

13.4 Results and discussion

During the period 1989-1994 all trips made for a particular gear type were recorded as the effort directed towards the species. For the period 1995-1997, however, only those trips, which caught the species by a particular gear type, were recorded as effort. Recognising this difference, total trips during the period 1995-1997 were obtained from the field data in order to make the data sets compatible.

The FPOW-FORTRAN routine has memory allocation restrictions, which did not allow the performance of an ANOVA for the entire time period in the standardisation of fishing effort. As such, a double standardisation of fishing effort was performed, standardising by sectors of time relative to a common year base 1989 with the banking gear as standard. Five data sets were constructed for *M. furnieri* as follows: I – 1989, 1990, 1991; II – 1989, 1992, 1993; III – 1989, 1994; IV – 1989, 1995, 1996 and V – 1989, 1997 (Fig. 13.1).


In this process, the \( \alpha \) and \( \beta \) estimates changed with the data set for each year. Thus, standardisation was subsequently done across \( \alpha \) and \( \beta \) using the link to 1989. To achieve this, the ratio of CPUE was calculated from I/II, I/III, I/IV and I/V. Then, for *M. furnieri* the standardised CPUE for 1992 and 1993 were multiplied by I/II, CPUE for 1994 by I/III, CPUE for 1995,1996 by I/IV and CPUE for 1997 by I/V (Fig. 13.3).

For *C. jamaicensis*, the standardised CPUE for 1992 and 1993 were multiplied by I/II, CPUE for 1994, 1995 by I/III and CPUE for 1996 and 1997 by I/IV (Fig. 13.4).

Using these results, standardised CPUE was then plotted against monthly cumulative catch for each year, where monthly cumulative catch was determined from the total landings by month for the six gear types. Plots of the monthly CPUE on cumulative monthly catch are given in Figures 13.5 and 13.6 by biological year.

Based on the observed CPUE trends, locales of seasonal CPUE depletions were identified for both species using the plots in Figures 13.5 and Figure 13.6. It must be noted that the selection of these depletion months/points were based on the changes in the CPUE values and not the cumulative catch. The seasonal CPUE depletion locales identified for *C. jamaicensis* and *M. furnieri* are set out in Table 13.1.
Table 13.1 Depletion months defined for *M. furnieri* and *C. jamaicensis*

<table>
<thead>
<tr>
<th><em>M. furnieri</em></th>
<th><em>C. jamaicensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Month-Year</td>
<td>Month-Year</td>
</tr>
<tr>
<td>Nov 89 - Feb 90</td>
<td>Nov 89-Aug 90</td>
</tr>
<tr>
<td>Dec 90 - May 91</td>
<td>Oct 90-July 91</td>
</tr>
<tr>
<td>Dec 91 - May 92</td>
<td>Nov 91-July 92</td>
</tr>
<tr>
<td>Nov 92 - Feb 93</td>
<td>Oct 92-July 93</td>
</tr>
<tr>
<td>Dec 93 - May 94</td>
<td>Oct 93-Aug 94</td>
</tr>
<tr>
<td>Dec 94 - May 95</td>
<td>Oct 94-July 95</td>
</tr>
<tr>
<td>Sept 95 - Apr 96</td>
<td>Dec 95-June 96</td>
</tr>
<tr>
<td>Jan 97 - Apr 97</td>
<td>Sept 96-Mar 97</td>
</tr>
</tbody>
</table>

Identification of depletion locales in the plots were more conspicuous for *C. jamaicensis* than in *M. furnieri* which could be due to *C. jamaicensis* displaying a higher seasonal recruitment pattern. This may be explained by the spawning behaviour of *C. jamaicensis* in the Gulf of Paria, which shows a peak spawning in February that coincides with the periods of highest salinity and temperature (Shim 1981). It is also reported that spawning is continuous with a peak observed during the dry season (January to June) based on the presence of juveniles year round in the Gulf of Paria (Manickchand–Heilman and Julien–Flus 1990).

According to Shim (1981), recruitment of juveniles of *C. jamaicensis* begins early in May and continues until November in the Gulf of Paria (Shim 1981). Juveniles 5 – 10 cm in length are recruited into the fishery within a few months of hatching. In *M. furnieri* spawning frequency, determined by the frequency of females with hydrated eggs, were estimated at 12 times per year (Manickchand–Heilman and Ehrhardt 1996). In Northwestern Trinidad spawning was observed year round with peaks in the dry season (Manickchand-Heileman and Julien-Flus 1990).

Following on this, the De Lury-type estimator (Chien and Condrey 1985) was used to obtain seasonal estimates for each species separately. Plots for the Chien and Condrey method to estimate the catchability coefficient for the 89/90, 90/91, 91/92, 92/93, 93/94, 94/95 and 96/97 biological period for *C. jamaicensis* and *M. furnieri* are given in Figures 13.7 and 13.8. The catchability coefficient q for the seasonal CPUE locales set out in Table 13.1 as well as instantaneous fishing mortality rate F for the biological years constructed for each species are shown in Table 13.2.
Figure 13.5 CPUE, measured in units of banking, against cumulative catch for *Micropogonias furnieri* for the period 1989-1997 on the west coast of Trinidad.
Figure 13.6 CPUE, measured in units of banking, against cumulative catch for *Cynoscion jamaicensis* for the period 1989-1997 on the west coast of Trinidad

132
Table 13.2 Catchability coefficient, q and fishing mortality, F, for biological years constructed for *M. furnieri* and *C. jamaicensis*

<table>
<thead>
<tr>
<th>Biological Year</th>
<th>q</th>
<th>F</th>
<th>Biological Year</th>
<th>q</th>
<th>F</th>
</tr>
</thead>
</table>

Based on the locales of seasonal monthly depletion, biological years were constructed for both species by extrapolating the months from which the catchability coefficient, q, was calculated. This gave a complete biological year and assumes that the catchability coefficient calculated from the depletion months was valid for this period. Natural mortality was taken from the literature as 0.36 yr$^{-1}$ (Ehrhardt and Arena 1977).

Seasonal (monthly) average abundance which is the average biomass after the catch was removed, was calculated from the ratio of standardised CPUE and seasonal catchability, where the catchability coefficient q was taken as the average q from the locales of seasonal depletions. The instantaneous fishing mortality rate F was estimated as the ratio of catch to average abundance. An initial, or start of the season, biomass

\[ \text{Biomass} = Z \times \text{average abundance} / (1 - \exp(-Z)) \]

was then estimated for these biological years.

Some of the monthly F values obtained within the biological year were relatively high for both species. In some instances, these F values were unusually high which can be due to the selection of months comprising the biological year. Months at the beginning of the biological year with a high F value may be better fitted in the previous or subsequent biological year.

The high fishing mortality may be due to the following:

(i) Depletion is occurring in a very small localised area, the Gulf of Paria;
(ii) These species may later be quickly replenished from continued influx of fish from another source outside the Gulf of Paria;
(iii) Both species are subjected to exploitation by 6 gear types. Some of these gears, due to small mesh sizes being used in a mainly inshore fisheries, as in the shrimp trawl fishery, catch fish of all sizes thus creating the potential for very high exploitation
(iv) In the methods used, the seasonal trends of recruitment may affect the ability to generate appropriate decreasing trends in CPUE on cumulative monthly catches.
(v) Migration out of the area which is interpreted as mortality due to a decrease in biomass of both species.
Table 13.3 Parameters used in the yield per recruit analysis for *Cynoscion jamaicensis* and *Micropogonias furnieri*

<table>
<thead>
<tr>
<th>M. furnieri</th>
<th>C. jamaicensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_\infty$ = 74.1</td>
<td>$L_\infty$ = 36.25</td>
</tr>
<tr>
<td>$K$ = 0.145</td>
<td>$K$ = 0.396</td>
</tr>
<tr>
<td>$t_0$ = -0.145</td>
<td>$t_0$ = -0.24</td>
</tr>
<tr>
<td>$a$ = 4.78E-05</td>
<td>$a$ = 0.00449</td>
</tr>
<tr>
<td>$b$ = 3.0375</td>
<td>$b$ = 3.297</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Length (cm)</th>
<th>Sel.*</th>
<th>Mat.*</th>
<th>Fecundity</th>
<th>Weight (kg)</th>
<th>Length (cm)</th>
<th>Sel.*</th>
<th>Mat.*</th>
<th>Fecundity</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.3</td>
<td>0.3</td>
<td>0.1</td>
<td>146</td>
<td>0.076</td>
<td>14.1</td>
<td>0.6</td>
<td>0.1</td>
<td>484</td>
<td>0.027</td>
</tr>
<tr>
<td>2</td>
<td>19.8</td>
<td>0.7</td>
<td>0.3</td>
<td>3246</td>
<td>0.415</td>
<td>21.3</td>
<td>1</td>
<td>0.8</td>
<td>4887</td>
<td>0.108</td>
</tr>
<tr>
<td>3</td>
<td>27.1</td>
<td>1</td>
<td>0.8</td>
<td>18686</td>
<td>1.081</td>
<td>26.2</td>
<td>1</td>
<td>1</td>
<td>15380</td>
<td>0.213</td>
</tr>
<tr>
<td>4</td>
<td>33.5</td>
<td>1</td>
<td>1</td>
<td>60042</td>
<td>2.045</td>
<td>29.5</td>
<td>1</td>
<td>1</td>
<td>29663</td>
<td>0.315</td>
</tr>
<tr>
<td>5</td>
<td>39.0</td>
<td>1</td>
<td>1</td>
<td>139560</td>
<td>3.242</td>
<td>31.7</td>
<td>1</td>
<td>1</td>
<td>44343</td>
<td>0.399</td>
</tr>
<tr>
<td>6</td>
<td>43.7</td>
<td>1</td>
<td>1</td>
<td>264359</td>
<td>4.597</td>
<td>33.2</td>
<td>1</td>
<td>1</td>
<td>57228</td>
<td>0.464</td>
</tr>
<tr>
<td>7</td>
<td>47.8</td>
<td>1</td>
<td>1</td>
<td>435398</td>
<td>6.037</td>
<td>34.2</td>
<td>1</td>
<td>1</td>
<td>67516</td>
<td>0.512</td>
</tr>
<tr>
<td>8</td>
<td>51.4</td>
<td>1</td>
<td>1</td>
<td>648368</td>
<td>7.504</td>
<td>34.9</td>
<td>1</td>
<td>1</td>
<td>75258</td>
<td>0.546</td>
</tr>
<tr>
<td>9</td>
<td>54.4</td>
<td>1</td>
<td>1</td>
<td>895433</td>
<td>8.951</td>
<td>35.3</td>
<td>1</td>
<td>1</td>
<td>80867</td>
<td>0.570</td>
</tr>
<tr>
<td>10</td>
<td>57.1</td>
<td>1</td>
<td>1</td>
<td>1167024</td>
<td>10.345</td>
<td>35.6</td>
<td>1</td>
<td>1</td>
<td>84832</td>
<td>0.586</td>
</tr>
<tr>
<td>11</td>
<td>59.4</td>
<td>1</td>
<td>1</td>
<td>1453315</td>
<td>11.663</td>
<td>35.8</td>
<td>1</td>
<td>1</td>
<td>87588</td>
<td>0.598</td>
</tr>
<tr>
<td>12</td>
<td>61.4</td>
<td>1</td>
<td>1</td>
<td>1745223</td>
<td>12.889</td>
<td>36.0</td>
<td>1</td>
<td>1</td>
<td>89485</td>
<td>0.605</td>
</tr>
<tr>
<td>13</td>
<td>63.1</td>
<td>1</td>
<td>1</td>
<td>2034995</td>
<td>14.018</td>
<td>36.1</td>
<td>1</td>
<td>1</td>
<td>90780</td>
<td>0.611</td>
</tr>
<tr>
<td>14</td>
<td>64.6</td>
<td>1</td>
<td>1</td>
<td>2316437</td>
<td>15.046</td>
<td>36.1</td>
<td>1</td>
<td>1</td>
<td>91660</td>
<td>0.614</td>
</tr>
<tr>
<td>15</td>
<td>65.9</td>
<td>1</td>
<td>1</td>
<td>2584931</td>
<td>15.974</td>
<td>36.2</td>
<td>1</td>
<td>1</td>
<td>92256</td>
<td>0.616</td>
</tr>
</tbody>
</table>

*Selectivity and Maturity as a proportion of the stock.

The asymptotic ($L_\infty$) length for *M. furnieri* is 82.9cm for females and 65.3cm for males as calculated from ageing using otoliths (Manichchand-Heileman and Kenny 1990). Asymptotic ($W_\infty$) weight was 3641.6g for *M. furnieri*. Actual observed sizes caught are within the range 10-40cm in length. These differences between observed and expected maximum lengths imply a very intense exploitation on the resources that has considerably reduced the larger (thus older) animals in the stock. This condition may justify the estimated F-values.

A yield per recruit analysis was performed using the von Bertalanffy parameters for the respective species ($L_\infty$, $K$, $t_0$). Table 13.3 gives the values and parameters used in yield and egg per recruit calculations and Figures 13.9-13.10 show the plots.

In the case of *M. furnieri* the $F_{0.1}$ is 0.192 with a corresponding YPR of 28 grams per recruit and the eggs per recruit as a proportion of the unexploited state is 0.284. For *C. jamaicensis* the $F_{0.1}$ is 0.255 at which level the YPR is 39.8 grams per recruit and egg per recruit as fraction of pristine egg per recruit is 0.313.

The estimated F values in each season from the depletion analyses obtained for the years 1995, 1996 and 1997 for *C. jamaicensis* and *M. furnieri* were considerably lower than those obtained using CPUE for the period 1989-1994. The F-values obtained for the nine year
period, 1989-1997, are however still well above the optimum biological condition of the species and therefore indicate that the resources are not generating optimum yield and most likely experiencing severe spawning potential decreases.

Figure 13.9 Yield per recruit plot for *Micropogonias furnieri*

Figure 13.10 Yield per recruit plot for *Cynoscion jamaicensis*
13.5 Conclusion

The results of this assessment clearly indicate a very intensive exploitation of these resources. This may be attributed to the combined effort of six gear types operating in the Gulf of Paria. The analysis, however, used CPUE for the Trinidad and Tobago artisanal fleet. Information from the Trinidad and Tobago industrial trawl fleet or other fleets operating in the Gulf of Paria was not available and hence the biomass and F-values generated from this analysis may not adequately represent the status of the fisheries. Changes in biomass and F values may also be influenced by migration of the species and not mortality. In addition to this, the parameters used in the yield per recruit analyses were from the literature due to the unavailability of this information based on the Trinidad stock. It is therefore recommended that a biological sampling programme be implemented for the groundfish species so that data on the size structure of both species are collected from both the artisanal and industrial fleets.

At this workshop, a joint analysis was also performed with Venezuela for M. furnieri, which used artisanal and industrial data from both countries (Alio et al. 1999). The results showed a high level of exploitation of the resources and follow on the general conclusions of this assessment.
14 ANALYSIS OF INDUSTRIAL TRAWL AND ARTISANAL FISHERIES OF WHITEMOUTH CROAKER (*Micropogonias furnieri*) OF VENEZUELA AND TRINIDAD AND TOBAGO IN THE GULF OF PARIA AND ORINOCO RIVER DELTA


14.1 Background

The whitemouth croaker, *Micropogonias furnieri*, is one of the important fish species exploited in the Gulf of Paria and the Orinoco River delta by the fleets of Trinidad and Tobago and Venezuela. The Venezuelan fleets landing the species are comprised of 324 artisanal vessels and 88 industrial trawlers. The wooden artisanal vessels are 5-14 m long and propelled by outboard engines. They use multiple gear, 67% operate with gillnets, 64% with longline, 9% with hook and line and 4% with traps. Most vessels (78) in the industrial fleet target shrimp and fish, while 10 vessels use stern gear and only target demersal fish. In Trinidad and Tobago the species is landed by an industrial trawl fleet and an artisanal fleet (comprised of smaller vessels outfitted with trawl or other gear types) which both operate in the Columbus Channel and Gulf of Paria.

The percentage composition of *M. furnieri* in the landings from the industrial and artisanal fleets is similar for both Venezuela and Trinidad and Tobago. In Venezuela, the industrial trawl fleet accounts for 61% of the country’s landings of this species while the artisanal fleets land 39%. In Trinidad and Tobago, the industrial fleet (type IV trawlers) accounts for an average of 69% of the country’s landings of the species. This is based on a percentage composition by weight for *M. furnieri* derived from logbook records for 1991-1992 (Maharaj et al. 1993). The Trinidad and Tobago artisanal and semi industrial vessels (Types I and II trawlers as well as small vessels outfitted with gillnets, handlines and baited hooks and Type III trawlers respectively) account for the remaining 31% of the landings.

Important changes in the combined fleets’ landings of this species have been observed, falling from a yearly average of 2344t in 1988–1993 to less than a 1000t in 1996 (Figs 14.1 and 14.2). The fishing effort of industrial and artisanal fleets in both countries (bi-national fleet) has also shown significant changes in time. With the decrease in effort reported in recent years the stocks seem to be recuperating.

Earlier yield per recruit analyses of the state of the fishery in the region (Manickchand-Heileman and Kenny 1990; Alvarez et al. 1998) concluded that *M. furnieri* was fully exploited. During the period 1993-1995, Alvarez et al. (1998) estimated the \( f_{\text{MYR}} \) for the Venezuelan fleet to be in the interval 0.4–0.45 (assuming natural mortality rates between 0.79 and 0.39, respectively). They also estimated that the average fishing mortality was 0.5, showing that the current effort level is slightly above this limit.

In this study we re-evaluate the dynamics of the *M. furnieri* fishery in the Gulf of Paria, by means of biomass dynamic models (Punt and Hillborn 1996), using catch data from the entire bi-national fishery and two indices of abundance (CPUE for Venezuelan industrial trawl fleet and CPUE for the Trinidad and Tobago artisanal fleet). Furthermore, a yield per recruit analysis was made, using estimations on fishing mortality from data collected on board of the Venezuela industrial fleet.
The whitemouth croaker is distributed from the southern Greater Antilles (Caribbean) and along the continental shelf from Costa Rica to Argentina. This demersal species is abundant on the continental shelf of the Guianas and northeastern Venezuela (Cervigón 1993). It inhabits areas of the shelf and estuaries, over muddy and sandy bottoms, down to 60 m depth. It spawns in shallow coastal waters and nursery areas are located in the shallow coastal zones and near the river mouths (Lowe-McConnell 1966; Novoa et al. 1998).
14.2 Data sets

Data for the Trinidad and Tobago industrial trawl fleet were available for the period 1992-1995 and were estimated from the catch and effort of a single trawler and extrapolated to the remaining 20 trawlers in the fleet (Table 14.1). Catch data of this fleet for the period 1987-1991 and 1996-1998 were estimated by assuming that the performance of the fleet was similar to the Venezuelan industrial fleet for the respective period (Table 14.2). Information on catch and effort for the artisanal fleet of Trinidad – Tobago was obtained from six different gear types for the period 1989-1997 (Table 14.1). The catches for the period 1987-1988 and 1998 were estimated by the average catch of this fleet for the period 1989-1997 (Table 14.2).

Data on catch and effort from the Venezuelan industrial trawl fleets were available for the period 1987-1998; those on catch from the Venezuelan artisanal fleet were only available for the period 1987-1996. The data on catch for the latter fleet for the period 1997-1998 were approximated by the average catch of that fleet during the period 1987-1996 (Table 14.2).

Since the bi-national artisanal fleet operating with six different fishing gears (trawl nets, gillnets, hook and line, etc.) and two industrial trawl fleets are targeting *Micropogonias furnieri* in the study area, the general effort applied by all fleets was estimated in industrial trawl units (days at sea or d-a-s). It was calculated by dividing the yearly total catch by the cpue of the Venezuelan industrial trawlers (Table 14.2).

Monthly information on size structure of *Micropogonias furnieri* (both sexes combined) was recorded in Venezuela by observers on board and from samples measured in the FONAIAP laboratory in Cumaná, during the period Jun – Nov. 1993 and Feb., Mar., May, Aug. and Nov. 1994.

Table 14.1 *Micropogonias furnieri* catch and effort information from the Trinidad – Tobago artisanal and industrial fleets operating in the Gulf of Paria

<table>
<thead>
<tr>
<th>Year</th>
<th>Artisanal (type I, II and III trawlers + 5 other gears)</th>
<th>Industrial (Type IV vessels)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Catch (t)</td>
<td>Effort (trips*)</td>
</tr>
<tr>
<td>89</td>
<td>671</td>
<td>219391</td>
</tr>
<tr>
<td>90</td>
<td>173</td>
<td>88937</td>
</tr>
<tr>
<td>91</td>
<td>312</td>
<td>216937</td>
</tr>
<tr>
<td>92</td>
<td>454</td>
<td>282826</td>
</tr>
<tr>
<td>93</td>
<td>614</td>
<td>377610</td>
</tr>
<tr>
<td>94</td>
<td>882</td>
<td>322044</td>
</tr>
<tr>
<td>95</td>
<td>358</td>
<td>135324</td>
</tr>
<tr>
<td>96</td>
<td>388</td>
<td>155803</td>
</tr>
<tr>
<td>97</td>
<td>608</td>
<td>211893</td>
</tr>
</tbody>
</table>

* - Trips are equivalent to days
** - d-a-s represents days at sea
Table 14.2. *Micropogonias furnieri* catch and effort information from the Venezuelan artisanal (VA) and industrial fleet (VI) and from the Trinidad and Tobago artisanal (TA) and industrial fleet (TI), operating in the Gulf of Paria during the period 1987-98. The Venezuelan industrial fleet also operates in the Orinoco river delta. Effort information corresponds to the Venezuelan industrial fleet. Total effort (all fleets) was estimated as total catch/Venezuelan industrial CPUE.

<table>
<thead>
<tr>
<th>Year</th>
<th>Catch VI (t)</th>
<th>Catch VA (t)</th>
<th>Catch TA (t)</th>
<th>Catch TI (t)</th>
<th>Total catch (t)</th>
<th>Effort VI (d-a-s)</th>
<th>VI CPUE (kg/d-a-s)</th>
<th>Total effort all fleets (d-a-s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>87</td>
<td>620</td>
<td>305</td>
<td>496**</td>
<td>620***</td>
<td>2041</td>
<td>6719</td>
<td>92.3</td>
<td>22121</td>
</tr>
<tr>
<td>88</td>
<td>922</td>
<td>382</td>
<td>496**</td>
<td>922***</td>
<td>2722</td>
<td>7175</td>
<td>128.5</td>
<td>21185</td>
</tr>
<tr>
<td>89</td>
<td>870</td>
<td>240</td>
<td>671</td>
<td>870***</td>
<td>2651</td>
<td>8710</td>
<td>99.9</td>
<td>26540</td>
</tr>
<tr>
<td>90</td>
<td>818</td>
<td>203</td>
<td>173</td>
<td>818***</td>
<td>2012</td>
<td>13252</td>
<td>61.7</td>
<td>32601</td>
</tr>
<tr>
<td>91</td>
<td>745</td>
<td>282</td>
<td>312</td>
<td>745***</td>
<td>2084</td>
<td>13011</td>
<td>57.3</td>
<td>36389</td>
</tr>
<tr>
<td>92</td>
<td>611</td>
<td>363</td>
<td>454</td>
<td>680</td>
<td>2109</td>
<td>9952</td>
<td>61.4</td>
<td>34353</td>
</tr>
<tr>
<td>93</td>
<td>840</td>
<td>437</td>
<td>614</td>
<td>893</td>
<td>2784</td>
<td>12762</td>
<td>65.8</td>
<td>42296</td>
</tr>
<tr>
<td>94</td>
<td>488</td>
<td>210</td>
<td>882</td>
<td>465</td>
<td>2045</td>
<td>8851</td>
<td>55.1</td>
<td>37097</td>
</tr>
<tr>
<td>95</td>
<td>324</td>
<td>95</td>
<td>358</td>
<td>724</td>
<td>1502</td>
<td>9348</td>
<td>34.7</td>
<td>43329</td>
</tr>
<tr>
<td>96</td>
<td>166</td>
<td>195</td>
<td>388</td>
<td>166***</td>
<td>916</td>
<td>6727</td>
<td>24.7</td>
<td>37102</td>
</tr>
<tr>
<td>97</td>
<td>261</td>
<td>270*</td>
<td>608</td>
<td>261***</td>
<td>1400</td>
<td>6952</td>
<td>37.5</td>
<td>37300</td>
</tr>
<tr>
<td>98</td>
<td>516</td>
<td>270*</td>
<td>496**</td>
<td>516***</td>
<td>1798</td>
<td>8669</td>
<td>59.5</td>
<td>30207</td>
</tr>
</tbody>
</table>

*, Approximated by the average catch during the period 1987-96
**, Approximated by the average of the T-T artisanal fleet for the period 1989-97.
***, Approximated by the value of the catch from the Venezuelan industrial fleet for the same year

14.3 Biomass dynamics stock assessment

14.3.1 Method

Due to the lack of information on size structure from most of the fleets in the study area, the population dynamics of the resource was modeled using biomass dynamics model, assuming observation error was dominant (Punt and Hillborn 1996). The population model used was:

\[ B_{y+1} = B_y + rB_y \left( 1 - \frac{B_y}{B_\infty} \right) - C_y \]

\[ I_y = qB_y e^{\theta y} \]

where \( B_y \) = the biomass in year \( y \), \( r \) = the intrinsic growth rate parameter, \( B_\infty \) = the average unexploited equilibrium biomass, \( C_y \) = the catch in year \( y \), \( I_y \) = the biomass index
(CPUE in this case), $q$ = the catchability coefficient and $\eta_y$ = the log normally distributed observation error.

As two biomass indices were used in this case, two separate $q$'s were estimated. The model used information on total catch for the entire fishery and two indices of abundance, the monthly CPUE values of the Venezuelan industrial trawl fishery during the period 1987-1998 and the CPUE for the artisanal fleet of Trinidad and Tobago during the period 1989-1997.

Because of the uncertainty on the actual value of the instantaneous rate of increase ($r$) of the species, the parameter was constrained to vary in the range 0.2 to 0.5. The Excel 97 Solver Add-in was used to fit the unexploited stock size ($B_\infty$), initial biomass at the beginning of the exploitation ($B_0$) and catchability for both fleets ($q$ Venezuela and $q$ Trinidad and Tobago), that minimized the sum of squares between the log-expected and log-observed values of both yearly indices of abundance. The results of the model provided estimates for the Maximum Sustainable Yield (MSY) and the effort at which the MSY can be obtained ($f_{MSY}$).

### 14.3.2 Results

The biomass dynamics model was initially run without constraints, allowing Solver to estimate the instantaneous growth rate parameter "$r$". As the estimated value of $r$ was considered too high for this species, the model was re-run with fixed values of $r$. The estimate for the MSY varied from 1036 t to 1639 t when the instantaneous rate of increase of the population was allowed to vary from 0.2 to 0.5, respectively (Table 14.3, Fig. 14.3). The estimated effort level that would allow the MSY for the corresponding values of $r$ varied between 19500 and 23700 d.a.s. The catchability coefficients estimated for the Venezuelan fleets (0.005 to 0.011) were much larger than those estimated for the fleets from Trinidad and Tobago (9.15 $10^{-5}$; Table 14.3) and vary appreciably with the $r$ value. In contrast, the catchability coefficient of the Trinidad and Tobago fleets was very stable for the different values of $r$.

![Figure 14.3 Estimated MSY and fMSY for the fishery of M. furnieri in the Gulf of Paria and the Orinoco river delta, as a function of the instantaneous growth rate value](image-url)
Figure 14.4 Predicted (—) and observed (•) CPUE for the Venezuelan fleet of *M. furnieri* in the Gulf of Paria and the Orinoco river delta

Figure 14.5 Predicted (—) and observed (•) for the Trinidad and Tobago fleet of *M. furnieri* in the Gulf of Paria

The carrying capacity \( B_\infty \) for the estuarine ecosystem of the Gulf of Paria was estimated at 13000t to 21000t, depending on the \( r \) value. The value for the biomass at the starting moment of the simulation maintained values below \( B_\infty \) for \( r \) values between 0.3 and 0.5. For smaller values of \( r \), the optimization routine could only find a solution with \( B_i \) being equal to \( B_\infty \), which is unrealistic as the fishery had been in existence for many years prior to 1987. In all simulations the observed catch would be an average of 21% of the available biomass per year.

The observed and predicted CPUE values follow a similar pattern with a steady declining trend and recuperation at the end of the time series. The fit appears to be better for the Venezuelan fleet (Fig. 14.4 and 14.5). The approximation of predicted to the observed cpue values could be improved with higher \( r \) values, but \( r \) beyond 0.5 were considered unrealistic.
Table 14.3. Sensitivity of results of biomass dynamics model simulation with error associated in the data, for the Trinidad and Tobago – Venezuela fisheries of *M. furnieri*, when changing the instantaneous growth rate (r) parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Instantaneous growth rate (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>( B_\infty (t) )</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>20728</td>
</tr>
<tr>
<td>0.25</td>
<td>20728</td>
</tr>
<tr>
<td>0.3</td>
<td>20728</td>
</tr>
<tr>
<td>0.35</td>
<td>20728</td>
</tr>
<tr>
<td>0.4</td>
<td>20728</td>
</tr>
<tr>
<td>0.45</td>
<td>20728</td>
</tr>
<tr>
<td>0.5</td>
<td>20728</td>
</tr>
</tbody>
</table>

| \( q (\text{Venezuela}) \) |      |      |      |      |      |      |      |
| 0.2                        | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|
| 0.25                       | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|
| 0.3                        | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|
| 0.35                       | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|
| 0.4                        | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|
| 0.45                       | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|
| 0.5                        | 0.00512| 0.00580| 0.00679| 0.00774| 0.00874| 0.00969| 0.01056|

| \( q (\text{Trinidad - Tobago}) \) |      |      |      |      |      |
| 0.2                        | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |
| 0.25                       | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |
| 0.3                        | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |
| 0.35                       | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |
| 0.4                        | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |
| 0.45                       | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |
| 0.5                        | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} | 9.51 \times 10^{-05} |

| MSY (t)                    |      |      |      |      |      |      |      |
| 0.2                        | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |
| 0.25                       | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |
| 0.3                        | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |
| 0.35                       | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |
| 0.4                        | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |
| 0.45                       | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |
| 0.5                        | 1036 | 1171 | 1303 | 1409 | 1505 | 1581 | 1639 |

| \( f_{\text{MSY}} (d-a-s) \) |      |      |      |      |      |      |      |
| 0.2                        | 19514| 21539| 22079| 22622| 22892| 23219| 23681|
| 0.25                       | 19514| 21539| 22079| 22622| 22892| 23219| 23681|

14.4 Yield per recruit stock assessment

14.4.1 Method

With the available information on monthly size structure of the species from the Venezuelan trawl fleet, the Bhattacharya method was employed to estimate modes and their movement over time to estimate growth. Furthermore, the variation in monthly fishing mortality (F) was estimated by means of linearized catch curve analyses (using the algorithm of Ehrhardt and Legault 1996). Average F values were weighted by the size of the monthly samples. The paucity of data and the short series of months for which the data on size structure was available prevented the use of virtual population analyses.

Figure 14.6 Estimated age for *M. furnieri*. K value would depend on the assumed trajectory of growth (0.13 with option A and 0.6 with option B)
14.4.2 Results

The number of modes observed for any month in the Bhattacharya analyses varied between 4 and 6. The progression of modes was unclear. Approximating the position of modes with ages (Fig. 14.6), it was estimated that the parameters of the von Bertalanffy growth equation could have the following values: $L_\infty = 70$ cm; $K = 0.6$ and $t_0 = -0.13$. However, depending on the position of the growth curve, the value of K probably lies between 0.13 and 0.6.

Since observed sizes were already larger than 70 cm, it was decided that the following analyses about fishing mortality were to be performed using estimates of $K$ and $L_\infty$ from the literature ($L_\infty = 83$ cm and $K = 0.13$ year$^{-1}$; Manickchand-Heileman and Kenny 1990). The monthly linearized catch curve analyses resulted in values for the fishing mortality ($F$) between 0.4 and 3.2, depending on the value of $K$ used in the analyses (Table 14.4). With the preferred value from the literature of $K = 0.13$, the estimated average annual value of $F$ was 0.47.

Table 14.4. *Micropogonias furnieri*. Estimates of F using linearized catch curve analyses on samples from the Venezuelan industrial trawl fleet operating in the Gulf of Paria and Orinoco River delta. Maximum total length ($L_\infty$) was assumed 83cm and natural mortality (M) 0.4 (after Manickchand-Heileman and Kenny 1990)

<table>
<thead>
<tr>
<th>Year</th>
<th>Period</th>
<th>F</th>
<th>Sample Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>K = 0.13</td>
<td>K = 0.2</td>
</tr>
<tr>
<td>93</td>
<td>Jun</td>
<td>0.27</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Jul</td>
<td>0.23</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Aug</td>
<td>0.04</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Sep</td>
<td>0.92</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td>Oct</td>
<td>0.52</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>Nov</td>
<td>0.63</td>
<td>1.19</td>
</tr>
<tr>
<td>94</td>
<td>Feb</td>
<td>0.56</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>Mar</td>
<td>0.56</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>0.01</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Aug</td>
<td>0.55</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Nov</td>
<td>0.07</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weighted average*</td>
<td>0.42</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>0.004</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>95% Conf. Interv.</td>
<td>0.41 - 0.43</td>
<td>0.63 - 0.66</td>
</tr>
</tbody>
</table>

* F values were LOG$_{10}$ transformed before average calculations
The yield per recruit analysis of the *M. furinieri* fishery (Fig. 14.7) was carried out using the parameters indicated in Table 14.5. This analysis suggests a current effort leading to a fishing mortality (F) value of 0.47 assuming a K value of 0.13 and an F value of 3.54 with a K value of 0.6 (Table 14.6). At an F value of 0.4 (with a K value of 0.13), a recommended minimum of 40% spawners biomass will be removed and this is very close to the current F value. The F_{40%SBR} value would increase to 0.51 (with a K value of 0.6), when the current F value increases to 3.54.

Table 14.5 Parameters used in the yield per recruit analysis of the fishery of *M. furnieri* in the Gulf of Paria and Orinoco river delta. The parameters “a” and “b” correspond to the length–weight relationship; M is the natural mortality (after Manickhand - Heileman and Kenny 1990)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Used in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_\infty</td>
<td>83 cm</td>
</tr>
<tr>
<td>K</td>
<td>0.13 mo^{-1}</td>
</tr>
<tr>
<td>to</td>
<td>-0.13 mo</td>
</tr>
<tr>
<td>a</td>
<td>0.03</td>
</tr>
<tr>
<td>b</td>
<td>2.64</td>
</tr>
<tr>
<td>M</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Figure 14.7 Curves of per recruit analysis for the fishery of *M. furnieri* in the Gulf of Paria and Orinoco river delta with a K value of 0.13 year^{-1} and L_\infty = 83 cm
Table 14.6. *Micropogonias furnieri*. Yield and biomass per recruit analyses (Y/R and B/R) on samples from the Venezuelan industrial trawl fleet operating in the Gulf of Paria and Orinoco River delta. Symbols: K = exponential parameter of the von Bertalanffy growth equation; F = fishing mortality; SBR = biomass of spawners

<table>
<thead>
<tr>
<th></th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.13</td>
</tr>
<tr>
<td>Current F</td>
<td>0.47</td>
</tr>
<tr>
<td>F 40% SBR</td>
<td>0.4</td>
</tr>
<tr>
<td>SBR virgin (g)</td>
<td>273</td>
</tr>
<tr>
<td>SBR 40% (g)</td>
<td>109</td>
</tr>
<tr>
<td>% SBR at current F</td>
<td>35</td>
</tr>
<tr>
<td>Y/R 40% SBR (g)</td>
<td>47</td>
</tr>
<tr>
<td>Y/R F current (g)</td>
<td>49</td>
</tr>
</tbody>
</table>

14.5 Discussion

Results agree with previous estimates on the level of exploitation of the *M. furnieri* fishery in the region. The use of the surplus production biodynamic model suggested that the Maximum Sustainable Yield of the species in the region is about 1500 t (1300 to 1600 t). This level of exploitation was surpassed several times between 1987 to 1993 and a subsequent decline was recorded in the landings of all fleets of the region. The reduction of the effort after 1993, followed by landings below the MSY level observed in the fishery until 1996, may explain the recuperation in stock number as observed in the landings after this year. The MSY was surpassed again in 1998, when approximately 1800t were landed. If the increasing trend in effort continues, another decline in the landings can be expected in the near future.

Comparison of the results of the biomass dynamic model with the estimated values of F from the linearized catch curve analysis suggests that a lower value of the growth coefficient, K, is closer to the true value. When a value for the growth coefficient (K) of 0.13 was used in the linearized catch curve analysis, the estimated mean value of F was 0.42 year^{-1} (Table 14.4), which is close to the F value (0.47 year^{-1}; Table 14.6) estimated by per recruit analysis to result in a surviving spawners biomass of 40%.

It is difficult to obtain from the simulation models a clear idea about the value of the effort that should be maintained in the fishery. The values obtained from the simulations reflect the estimations made for an array of fisheries with very different characteristics. Probably a good approach towards establishing a proper level of effort would be to determine the effort each of the fisheries was making in a critical year (1997 in this case, when stocks recuperated; see Fig 14.1) and to maintain such level in the near future.

It is suggested that effort should not be allowed to increase beyond current levels of exploitation and further it is recommended that the level of effort should be maintained below that observed in 1997. The open access management strategy that has been typically applied to artisanal fisheries in the past, should therefore be replaced by a limited effort regime if future declines in the fisheries are to be avoided.
In the evaluation of *M. furnieri*, migration of the species presents a problem since individuals at different size ranges may be targeted by various fleets in a region. Unless data is available from all active fisheries, it would be difficult to obtain an accurate value for the fishing mortality since reductions in biomass from an area due to migration may be interpreted as being a consequence of a mortality process. In the Gulf of Paria a series of fleets belonging to the bordering countries in the region have been fishing for several decades. However, only since the late 1980s have data on catch and effort and, more recently, on size been gathered, mainly in the Venezuelan side of the Gulf. The availability of data on landings size structure in the Trinidad side of the Gulf is therefore necessary to provide an improved assessment of the current state of the fishery. Alternatively, a series of surveys testing density and size structure on the areas where the different stages of *M. furnieri* distribute in the Gulf may be a faster and less expensive way to estimate the status of the stocks. Such surveys would also provide information on other important fish species in the region.
15 PRELIMINARY ASSESSMENT OF THE JAMAICAN PENAEID SHRIMP FISHERIES OF KINGSTON HARBOUR

A. Galbraith and N.M. Ehrhardt

15.1 Introduction

The penaeid shrimp fisheries of Jamaica occur mainly in the Kingston Harbour. The Harbour may be divided into three distinct areas, Hunts Bay, the Main Basin and the Outer Harbour. The sediments of Hunts Bay and the Main Basin are predominantly mud with an average depth of 3 m for Hunts Bay and between 10–14m for the Main Basin. The Outer Harbour is comprised of more firm and sandy sediments. Depth in this area varies between 10–15 m. The Kingston Harbour is influenced by two rivers and several gullies. The major ones being the Rio Cobre River, the Duhaney River and the Sandy Gully.

Two fleets exploit the white shrimp (Penaeus schmitti) stock. These fleets are of two types. Type 1 are wooden canoes using mono-filament nylon gillnets of 1.4–1.9cm mesh size and Type 2, fibreglass (FRP) boats that use hand operated trawls of 1.9cm mesh size. The monofilament nylon gillnets function as encircling nets and are operated for four to six hours per outing. The nets are set for approximately two to three minutes before being hauled into the canoe. Trawl nets are operated for approximately twelve hours with a drag time of approximately forty-five minutes. The FRP boats are powered by 40 HP engines.

The fleets fish predominantly in two distinct areas with some degree of overlap. The Type 1 fleets fish in Hunts Bay and tend to follow the stock in its migration to the deeper waters of the Outer Harbour. The Type 2 fleets fish in the Main Basin and Outer Harbour and marine areas adjacent to these sites. However fishing is concentrated in the Main Basin and Outer Harbour.

Stock assessment of the penaeid shrimp fisheries of the Kingston Harbour is important in order to provide sound advice for the management of the fishery. Presently the fishery is open access. Persons that operate in this fishery have few skills and rely on this fishery for a substantial portion of their livelihood. It is important that sound data collection, management and analytical systems are implemented to provide guidance to policy and decision makers in order to facilitate the introduction of management measures.

15.2 Data

Sampling for landings and effort and biological data was conducted randomly, at least twice per month, over a period of 31 months. Data are available from the Kingston Harbour fishery from September 1996 – March 1999.

The number of vessels sampled over the period reflected approximately 72% of landings of the Type 1 fleet and 80% of landings of the Type 2 fleet. The data were recorded from the landing site using trip interview sheets. These recorded: area fished, depth fished, time spent fishing, number of fishing days, gear type, mesh size and landings by species. The sampled landings and effort data were raised to estimate total landings for the Penaeus schmitti fishery. Total landings in a month were estimated as follows:

\[
\text{Total landings} = \left[ \frac{\text{(Number of boats landed)}}{\text{(number of boats sampled)}} \right] \times \text{(sampled catch)} \times \text{(number of fishing days for the month)}.
\]

The biological data recorded total length, carapace length, tail length with and without telson and weight for the whole animal. A portion of the landings was sampled. The total landings and effort were recorded in addition to the sample weight. Shrimps are landed whole and unsorted.
15.3 Methods

The sampled catch per unit effort (CPUE) of both gear types was calculated on a monthly basis. The CPUE of both fleets was standardised using the Robson (1966) analysis of variance procedure. China nets were selected as the standard gear for the estimation of relative fishing power. This was due to the data set being more complete for this gear. The CPUE in September 1996 was used as the standard date in the relative abundance estimation.

The standardised CPUE of the trawl fleet was obtained by dividing the CPUE of the trawl fleet by the estimated relative fishing power. Then the average of the standardised CPUE of both the fleets was determined.

The monthly average standardised CPUE were plotted against cumulative catch in order to determine depletion trends. These depletion points were used in a DeLury-Type Depletion Model after Chien and Condrey (1985), to determine the catchability coefficient, q. Based on the results obtained for q, the monthly biomass and fishing mortality were determined as

\[
\text{Biomass} = \text{std. CPUE}/q \\
\text{Fishing mortality} = \text{fishing effort} \times q
\]

These methods are described in more detail in Section 13 describing the assessment of Trinidad groundfish.

15.4 Results

The relative fishing power of Type 2 vessels is 2.498 times that of Type 1 vessels. The fishing power of the Type 2 boat is higher than that of the Type 1 boat primarily due to the nature of operation of both fishing gears. The Type 1 boats use monofilament gillnets, which function as encircling nets. This method is not efficient for targeting benthic organisms such as shrimps. Catch per unit of effort is most strongly influenced by the skill of the fisherman in locating the shrimp and handling the gear. The Type 2 vessels are powered by 40 HP engines and use bottom trawls. These boats are able to sweep a wider area in less time than the monofilament gillnets and therefore exert a higher fishing power per unit time fished.

![Figure 15.1 Monthly standardised CPUE for the *P. schmitti* fishery in Kingston Harbour](image)
A plot of seasonal standard CPUE showed a decreasing trend from month 11–21 (August 1997–August 1998) that approximated a depletion trend (Fig. 15.1). Based on the appearance of this graph, a DeLury-Type linear regression was fitted to the CPUE on cumulative catch including a correction for M (Fig. 15.2). Following the Chien and Condrey (1985) method, the catchability coefficient, q, was estimated as a function of average effort, the slope of the DeLury type regression fitted above and M, the natural mortality rate. Natural mortality was estimated at 0.16 month⁻¹. This gave an estimate of the catchability coefficient to be $1.146 \times 10^{-5}$ per unit of standardised effort (Fig. 15.2). This indicates that 0.1146 of the biomass of the exploitable portion of the stock will be caught per 10 000 hours fished.

**Figure 15.2 Determination of the catchability coefficient after Chien and Condrey (1985)**

**Figure 15.3 Total landings plotted against estimated population biomass**
There has a general increasing trend with population biomass (Fig. 15.3). This indicates that the fishery is capturing a level of biomass according to what is made physically available to it at a given time during the fishing season. There is no clear correlation between fishing mortality and population biomass, although some general and fuzzy increasing trend in fishing mortality rate with population biomass is apparent (Fig. 15.4). There is a clearer relationship between fishing mortality rate and landings (Fig. 15.5). It is noted that at high levels of landings, the fishing mortality rate may reach above 0.14 month$^{-1}$, which is close to the natural mortality rate.

15.5 Discussion

Figure 15.2 assumes that the decline in CPUE is caused by a stock depletion. The data show a rather high variability in spite of the trend. The catchability coefficient $q$, is a function of the efficiency of the gear or fleet in operation and is a factor of several variables. These include seasonality, time of day fished, areas being targeted, abundance of stock, efficiency
of fishing gear etc. The q estimate may be an average of a highly dynamic seasonal parameter. This condition will have significant impacts on the results provided in Figures 15.3 – 15.5, which are based on the average value.

15.6 Conclusions and recommendations

It may be concluded that the restricted fishery for *Penaeus schmitti* in the Kingston Harbour is being exploited at levels commensurate with the available abundance. It appears that the fishery is exerting levels of fishing mortality which are still below those that may result in maximum production from the stock. However, it is noted that in a few instances the fishing mortality rate approached the rate of monthly natural mortality thought appropriate for this species (i.e. M = 0.16 month\(^{-1}\)). Therefore, it is concluded that any further expansion of fishing effort should be cautiously implemented as the new effort may quickly drive the stock to full utilisation.

It is recommended that more rigorous data collection system be implemented. This will facilitate the use of more accurate stock assessment methods. Data on the size structure of the landings by gear, sex and month should continue to be collected. In addition, appropriate information on the level of effort exerted temporally and spatially over the stock will provide for better future estimates of fishing power, hence a better base to standardise fishing effort.
16 APPLICATION OF A MULTISPECIES-MULTIGEAR PER-RECRUIT MODEL THAT INCORPORATES PARAMETER VARIABILITY TO THE SHRIMP AND GROUNDFISH FISHERIES OF GUYANA

A. Booth, K. Cochrane, A. Hackett and D. Shepherd

16.1 Summary

Tropical fisheries typically harvest many species by a variety of fishing gears. As a result, their stock assessment and management is complicated. Limited biological information on the harvested stocks and/or technical information available on the harvesting fishers often exacerbates this situation. Under these circumstances, the most suitable stock assessment framework is often aged-structured per-recruit modelling.

A multispecies-multigear per-recruit modelling approach was applied to the brown shrimp (*Penaeus subtilis*) and the bangamary (*Macrodon ancylodon*) in Guyana. Results from the deterministic and stochastic analyses revealed that the bangamary stock was overfished from growth and recruitment perspectives. This was in contrast to the brown shrimp that was fully fished with its spawner biomass-per-recruit at $F_{0.1}$ (marginal yield) and $F_{SB40}$ levels. The status of the bangamary resource is of concern and immediate cognisance needs to be taken by management agencies. Management initiatives need to be adopted to reduce fishing effort on this resource so as to increase the level of spawner biomass-per-recruit that is currently estimated to be below 20% of pristine, pre-harvesting levels. This would reduce the risk associated with its recruitment-overfished status.

16.2 Introduction

The industrial fishery of Guyana is a large-scale "limited entry" fishery consisting of 127 trawlers (61 foreign-owned) of which 73 were licensed to catch penaeid shrimp, 48 to catch seabob/finfish and 6 to catch finfish. The penaeid and seabob/finfish trawlers are the standard Mexico-type trawlers ranging in length from 19-23m, with the American vessels being on average 20.4m long. The local vessels are powered by inboard Caterpillar diesel engines, while vessels of the American fleet are powered by Cummings engines. The finfish vessels are Japanese-built stern trawlers that are approximately 13.7m long and are powered by Yanmar diesel engines.

The artisanal fishery consists of approximately 1331 vessels, of which approximately 60% use gillnets, 27% use Chinese seine, 8% use cadells and 5% pin seines. These vessels range in size from 6 to 18m and are powered by sails, outboard or inboard engines. They operate from approximately 85 landing sites along the coast. A flat-bottom dory powered by sail, paddle or small outboard engine is used for Chinese seine, cadell lines and a few pin seines to give more manoeuvrability over shallow, muddy water and sandy bottom areas. These boats which operate close to shore are not equipped with ice boxes. A V-bottom boat ranging in size from 7.6-9.2m and with no cabin but with an ice box and powered by an outboard engine is used by smaller gillnet (gillnet nylon) fishermen. A larger V-bottom vessel size either 8-11m or 12.-15m, with either outboard or inboard engine and cabin are used for larger gillnet and handline operations. There is also a semi-industrial fleet of red snapper vessels, which are shared by foreign and local fishers. There are 39 vessels in this fishery which uses either traps or handline to exploit the red snapper resources (see Section 12).

There is a need to move towards objective management of these fisheries based on the best scientific information available. This is best achieved via the use of reference points (see Caddy and Mahon, 1995). These are technical values derived from analyses that estimate
the state of the fishery or population and whose characteristics are therefore useful for
the management of the unit stock. These management quantities allow the management agency
to adjust fishing effort to ensure the stock remains at or above the reference points selected
in each case.

Bangamary is one of the most important groundfish species in the Guyana fishery and is
taken by several different fleets. It is particularly important in the artisanal fisheries and
dominates the catches in the socially important Chinese seine fishery. *P. subtilis* is one of the
most important of the penaeid shrimp species which support important commercial fisheries
in Guyana. It is most commonly caught by commercial trawl vessels, which also take *M.
ancylodon* as bycatch, hence providing a technological interaction between the two species.
Management of either species, therefore requires consideration of the impacts of
management measures on the other, so as to optimise the overall result. These two species
have been the subjects of a dedicated study over the last three years (Hackett *et al.*, this
volume; Shepherd *et al.*, this volume) and were therefore selected for this multispecies
analysis.

The study on *M. ancylodon* has included the collection of catch and effort data from the
Chinese seine fishery (Hackett *et al.*, this volume). This time series is, however, still too short
for use in the estimation of population parameters and similar data are not available for the
other fisheries harvesting this species. This points towards the use of a multispecies-
multigear per-recruit modelling (Booth, this volume) for its assessment. Per-recruit models
allow for the evaluation of the response of the yield- and spawner biomass-per-recruit of one
(or more) species to changes in fishing mortality and age-at-50%-selectivity from one or
more gears. Data on the size composition of *P. subtilis* landings and the total landings have
been used for extensive age structured assessments of this stock and are reported
elsewhere.

This paper presents a multispecies-multigear per-recruit model that incorporates biological
information for two species that are harvested by a total of four gear-types.

### 16.3 Methods

#### 16.3.1 Assessment framework

Unfortunately, complete directed catch and effort data are unavailable for *M. ancylodon*,
principally due to it being landed in a variety of fisheries. In contrast, *P. subtilis* is only landed
in the trawl fishery where it is one of the main species landed. The lack of data for *M.
ancylodon* led to the decision to use a multigear-multispecies assessment model
(incorporating four gears and two species) for its assessment. The methods used are
outlined in Booth (this volume).

The model was found to be sensitive to the choice of the time step used in the numerical
integration (≈ dt), affecting the functional form and magnitude of the yield-per-recruit curve.
Discrete approaches typically use an annual time step (to mimic the Beverton and Holt,
1956, 1957) yield-per-recruit integral). The base case scenario of 50 000 steps yr⁻¹ was used
in the sensitivity analysis and compared with alternative simulations using time steps ranging
between 1 step yr⁻¹ and 10 000 steps yr⁻¹. An annual time step was only found to be 80%
similar to the base case scenario. In contrast, the simulation results revealed convergence in
the yield-per-recruit curve after 100 steps yr⁻¹ with the yield-per-recruit curve being 98%
similar to the base case scenario. A monthly time step (of 12 steps yr⁻¹) was considered
appropriate for the study as it explained ca. 95% of the base case scenario, was biologically
relevant for the assessment of short-lived shrimp species, was easily incorporated into
existing spreadsheet models and significantly reduces computation time.

Input parameter variability was noted and included within the assessment framework. At this
stage, in order to avoid the difficult problem of correlation in the population dynamics
parameters, only uncertainty in natural mortality, *M*, was included as this was considered to
be the most important source of uncertainty in the assessments. A uniform distribution was assumed for the natural mortality estimate, ranging between 75% and 125% of the “base case” estimate for both species. A total of 200 bootstrap iterations were conducted to construct 95% confidence parameters for the selected target reference points (TRPs). Clearly, as only a subset of the uncertainty in the input parameters was included in these analyses, these estimates of uncertainty are likely to be underestimated.

16.3.2 Reference points

Five possible target reference points (TRPs) and two limit reference points (LRPs) were estimated for the yield-per-recruit and spawner biomass-per-recruit curves. The TRPs were, $F_{\text{max}}$, the fishing mortality which corresponds to the maximum of the yield-per-recruit curve, $F_{0.1}$ or marginal yield value (Gulland and Boerema 1973) where the slope of the yield-per-recruit curve is 10% of that at the origin and $F_{SB50}$ and $F_{SB40}$ which are the fishing mortalities that correspond to a reduction in the spawner biomass-per-recruit curve to 50% and 40% of its unexploited equilibrium levels, respectively. The last two of these reference points could also be considered as LRPs for some stocks (see Mace and Sissenwine, 1993). The two LRPs were $F_{SB30}$ and $F_{SB20}$.

16.3.3 Input parameters

Biological and technical parameters for both $M. \text{ancylodon}$ and $P. \text{subtilis}$ were obtained from Hackett et al. (this volume) and Shepherd et al. (this volume). All input parameters used within the analyses are summarised in Table 16.1.

Estimation of selectivity by the various gears was problematic. The trawl and seine net gears were the simplest as both the $M. \text{ancylodon}$ and $P. \text{subtilis}$ were assumed to reach a size when they were susceptible to the gear, after which all available animals were retained by the gear. A temporally invariant logistic ogive, modified to reflect knife-edged selection, was therefore determined from the length-converted age frequency data. Despite the selection pattern in the gill-net fishery that appeared to be normally distributed, a logistic curve was used in these analyses, as the current version of the software did not allow for a selectivity with a normal distribution. This will be included in the future. The logistic ogive used to estimate selectivity for all gears was of the form:

$$S_a = \frac{1}{1 + e^{-(a-a_{50})/\delta}}$$

where $S_a$ is the selectivity of the gear on a fish of age $a$, $a_{50}$ is the age-at-50%-selectivity and $\delta$ is the parameter that determines the width of the age-specific selectivity function. Knife-edged selectivity was mimicked by fixing $\delta$ at 0.01. The implications of this assumption on the results, necessitated by the structure of the software used for the stochastic analyses, will be examined in subsequent studies.
Table 16.1 Parameter estimates used in the per-recruit analyses for *Macrodon ancylodon* and *Penaeus subtilis* off Guyana

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>M. ancylodon</th>
<th>P. subtilis</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_\infty$</td>
<td>Predicted asymptotic length</td>
<td>435.7 mm (TL)</td>
<td>122.7 mm (CL)</td>
</tr>
<tr>
<td>$K$</td>
<td>Brody growth coefficient</td>
<td>0.66</td>
<td>1.11</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Parameter for length/weight equation</td>
<td>0.00000272</td>
<td>0.0000319</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Parameter for length/weight equation</td>
<td>3.35</td>
<td>2.918</td>
</tr>
<tr>
<td>$M$</td>
<td>Natural mortality rate</td>
<td>1.20 yr$^{-1}$</td>
<td>1.85 yr$^{-1}$</td>
</tr>
<tr>
<td>$F$</td>
<td>Fishing mortality rate</td>
<td>1.51 yr$^{-1}$</td>
<td>1.026 yr$^{-1}$</td>
</tr>
<tr>
<td>Max</td>
<td>Maximum age</td>
<td>7.00 years</td>
<td>1.33 years</td>
</tr>
<tr>
<td>$a_m$</td>
<td>Age-at-50%-maturity</td>
<td>1.00 year</td>
<td>0.5 years</td>
</tr>
<tr>
<td>$\delta_m$</td>
<td>Width of maturity logistic ogive</td>
<td>0.10 years</td>
<td>0.1 years</td>
</tr>
<tr>
<td>$a_{50}: Trawl$ net</td>
<td>Age-at-50%-selectivity</td>
<td>0.40 years</td>
<td>0.2 years</td>
</tr>
<tr>
<td>$\delta_{50}: Trawl$ net</td>
<td>Width of the selectivity logistic ogive</td>
<td>0.01 years</td>
<td>0.1 years</td>
</tr>
<tr>
<td>$a_{50}: Gillnet$</td>
<td>Age-at-50%-selectivity</td>
<td>1.80 years</td>
<td>-</td>
</tr>
<tr>
<td>$\delta_{50}: Gillnet$</td>
<td>Width of the selectivity logistic ogive</td>
<td>0.01 years</td>
<td>-</td>
</tr>
<tr>
<td>$a_{50}: Chinese seine$</td>
<td>Age-at-50%-selectivity</td>
<td>0.18 years</td>
<td>-</td>
</tr>
<tr>
<td>$\delta_{50}: Chinese seine$</td>
<td>Width of the selectivity logistic ogive</td>
<td>0.10 years</td>
<td>-</td>
</tr>
<tr>
<td>$a_{50}: Pin seine$</td>
<td>Age-at-50%-selectivity</td>
<td>0.18 years</td>
<td>-</td>
</tr>
<tr>
<td>$\delta_{50}: Pin seine$</td>
<td>Width of the selectivity logistic ogive</td>
<td>0.10 years</td>
<td>-</td>
</tr>
<tr>
<td>$F_{Trawl net}$</td>
<td>Gear-specific fishing mortality rate</td>
<td>0.62 yr$^{-1}$</td>
<td>1.026 yr$^{-1}$</td>
</tr>
<tr>
<td>$f_{Trawl net}$</td>
<td>Fishing effort</td>
<td>215 vessels</td>
<td>215 vessels</td>
</tr>
<tr>
<td>$q_{Trawl net}$</td>
<td>Catchability coefficient</td>
<td>0.002883</td>
<td>0.004771</td>
</tr>
<tr>
<td>$F_{Gillnet}$</td>
<td></td>
<td>0.53 yr$^{-1}$</td>
<td>-</td>
</tr>
<tr>
<td>$f_{Gillnet}$</td>
<td></td>
<td>433 vessels</td>
<td>-</td>
</tr>
<tr>
<td>$q_{Gillnet}$</td>
<td></td>
<td>0.001216</td>
<td>-</td>
</tr>
<tr>
<td>$F_{Chinese eine}$</td>
<td></td>
<td>0.35 yr$^{-1}$</td>
<td>-</td>
</tr>
</tbody>
</table>
The proportional contribution of the trawl net ($F_{\text{trawl net}}$), gillnet ($F_{\text{gillnet}}$), Chinese seine net ($F_{\text{Chinese seine net}}$) and pin seine net ($F_{\text{pin seine net}}$) fisheries to the estimated instantaneous rate of fishing mortality ($F$) for *M. ancylodon* was estimated by multiplying the total fishing mortality, $F$, by the annual catch in mass for each gear as a proportion of the total annual catch. The total fishing mortality estimate for *P. subtilis* was attributed to the trawlfishery.

The coefficients of proportionality between fishing effort and fishing mortality (i.e. the catchability coefficients) will vary between species due to differences in their availability and vulnerability to the various gear (Murawski 1984).

At any given level of effort, the $F$ for each species in a multispecies fishery will be different. Catchability coefficients were estimated using the linear relationship:

$$F_{ij} = q_{ij} f_j$$

where $q_{ij}$ is catchability coefficient of species $i$ in fishery $j$ and $f_j$ is the standardised effort for species $i$ in fishery $j$. Although alternative forms of the relationship have been suggested for various species (Peterman and Steer 1981), in this study the relationship between $f$ and $F$ was assumed to be linear for both species.

### 16.4 Results

Isopleth diagrams, generated using single species-single gear per-recruit models, describing the response of yield-per-recruit to different values of fishing mortality ($F$) and age-at-50%-selectivity for *M. ancylodon* and *P. subtilis* are illustrated in Figures 16.1-16.4. The yield-per-recruit response isopleths showed that, in both species, yield-per-recruit increased rapidly at low values of $F$ over most of the age range of $a_{50}$ (equivalent, in these analyses, to the age at knife-edge recruitment). Maximum yield-per-recruit was attainable at values of $a_{50}$ between 0.8 and 1.5 years in *M. ancylodon* and at values of $a_{50}$ older than 1 year in *P. subtilis*. Asymptotic yield-per-recruit was attained at high values of $F$ when the age-at-50%-selectivity was between than 0.8 and 1.5 years in *M. ancylodon* and greater than 1 year in *P. subtilis*. The spawner biomass-per-recruit response isopleths were similar for both species. Spawner biomass-per-recruit decreased rapidly with increasing values of $F$, particularly at low ages-at-50%-selectivity. In *M. ancylodon*, spawner biomass-per-recruit did not drop below 50% of pristine, unharvested levels after 2 years of age, irrespective of the increase in fishing mortality exerted on the stock.
Figure 16.1 Isopleth diagrams describing the response of *M. ancyledon* yield-per-recruit to different combinations of fishing mortality and age-at-50%-selectivity. Analysis was conducted using a single-gear model with the ‘base case’ scenario where $M = 1.2$ year$^{-1}$. 

159
Figure 16.2 Isopleth diagrams describing the response of *P. subtilis* yield-per-recruit to different combinations of fishing mortality and age-at-50%-selectivity. Analysis was conducted using a single-gear model with the ‘base case’ scenario where $M = 1.85$ year$^{-1}$. 
Figure 16.3 Isopleth diagrams describing the response of *M. ancylodon* spawner biomass-per-recruit to different combinations of fishing mortality and age-at-50%-selectivity (in years). Analysis was conducted using a single-gear model with the ‘base case’ scenario where $M = 1.2 \text{ year}^{-1}$. 
Figure 16.4 Isopleth diagrams describing the response of *P. subtilis* spawner biomass-per-recruit to different combinations of fishing mortality and age-at-50%-selectivity (in years). Analysis was conducted using a single-gear model with the ‘base case’ scenario where $M = 1.85$ year$^{-1}$

Yield- and spawner biomass-per-recruit as a function of fishing mortality ($F$) are illustrated in Figures 16.5 and 16.6. Since the age-at-50%-selectivity in the Chinese seine and pin seine net fisheries were identical, only the trawl, gill and Chinese seine net fishery exploitation scenarios are shown. For *M. ancylodon*, higher yield-per-recruit was obtained at higher rates of $F$ in the gill-net fishery than in the other fisheries, reflecting its higher $a_{50}$ (Figure 16.5). Similarly, spawner biomass was not depleted below 50% at higher fishing mortality levels (> 3 yr$^{-1}$) in the gill-net fishery than in the other fisheries.
Figure 16.5 Yield-per-recruit and spawner-biomass-per-recruit of *M. ancylodon* in Guyana with ‘base case’ trawl net, gillnet and Chinese/pin seine net fishing. Analyses were conducted using the ‘traditional’ single-species models with the ‘base case’ scenario where $M = 1.2$ year$^{-1}$.

The fishing mortality and fishing effort TRPs and their associated 95% bootstrap confidence intervals are summarised in Table 16.2 for the trawl net, gillnet, Chinese seine net and pin seine net fishing scenarios. Comparing the four major fisheries harvesting *M. ancylodon*, a marginal-yield fishing strategy ($F_{0.1}$) was obtained at higher fishing mortalities in the gill-net fishery where $a_{50}$ occurred after the age-at-50% maturity. In all scenarios, higher fishing pressure was necessary to obtain the marginal yield ($F_{0.1}$) than the $F_{SB40}$ TRP. From a single-
Table 16.2 Target reference points as a function of fishing mortality and fishing effort and their 95% confidence intervals (in parenthesis) for *M. ancylodon* and *P. subtilis* using four gears from Guyana. Current *M. ancylodon* $F = 1.51$ year$^{-1}$ and *P. subtilis* $F = 1.03$ year$^{-1}$. Current fishing effort 215 trawlers, 433 gillnetters, 655 Chinese seiners and 73 Pin seiners.

<table>
<thead>
<tr>
<th></th>
<th><em>M. ancylodon</em></th>
<th><em>P. subtilis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fishing mortality</td>
<td>Fishing effort</td>
</tr>
<tr>
<td><strong>Trawl net</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{\text{max}}$</td>
<td>0.93  \ (0.72, 1.16)</td>
<td>322 \ (249, 402)</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>0.59  \ (0.46, 0.73)</td>
<td>205 \ (160, 253)</td>
</tr>
<tr>
<td>$F_{SB50}$</td>
<td>0.39  \ (0.32, 0.45)</td>
<td>135 \ (111, 156)</td>
</tr>
<tr>
<td>$F_{SB40}$</td>
<td>0.54  \ (0.44, 0.62)</td>
<td>187 \ (153, 215)</td>
</tr>
<tr>
<td>$F_{SB30}$</td>
<td>0.73  \ (0.61, 0.84)</td>
<td>253 \ (211, 291)</td>
</tr>
<tr>
<td>$F_{SB20}$</td>
<td>1.04  \ (0.87, 1.19)</td>
<td>361 \ (302, 412)</td>
</tr>
<tr>
<td><strong>Gillnet</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{\text{max}}$</td>
<td>&gt;3 \ &gt;2459</td>
<td>&gt;2459 \ &gt;2459</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>1.61  \ (1.15, 2.08)</td>
<td>1324 \ (946, 1710)</td>
</tr>
<tr>
<td>$F_{SB40}$</td>
<td>&gt;3 \ &gt;2459</td>
<td>&gt;2459 \ &gt;2459</td>
</tr>
<tr>
<td><strong>Chinese seine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{\text{max}}$</td>
<td>0.74  \ (0.60, 0.87)</td>
<td>1368 \ (1109, 1608)</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>0.50  \ (0.4, 0.59)</td>
<td>924 \ (739, 1091)</td>
</tr>
<tr>
<td>$F_{SB50}$</td>
<td>0.35  \ (0.29, 0.39)</td>
<td>647 \ (536, 720)</td>
</tr>
<tr>
<td>$F_{SB40}$</td>
<td>0.47  \ (0.4, 0.53)</td>
<td>869 \ (739, 980)</td>
</tr>
<tr>
<td>$F_{SB30}$</td>
<td>0.64  \ (0.55, 0.73)</td>
<td>1183 \ (1017, 1331)</td>
</tr>
<tr>
<td>$F_{SB20}$</td>
<td>0.90  \ (0.78, 1.01)</td>
<td>1664 \ (1423, 1867)</td>
</tr>
</tbody>
</table>
gear per-recruit perspective and considering uncertainty in the assessments, the results suggest that the *M. ancylodon* stock is severely overfished. In all fisheries, except the gillnet fishery, current levels of fishing mortality exceeded the biologically least conservative TRP, $F_{SB20}$. The TRPs calculated for *P. subtilis* generated a less worrying result. The current fishing mortality exerted on the stock was estimated to be below the $F_{max}$ and $F_{SB40}$. The stock was estimated as currently being fished at marginal yield ($F_{0.1}$) levels.

Since “traditional” single-gear/single-species yield-per-recruit and spawner biomass-per-recruit models treat each fishery in isolation, the combined effect of all fisheries on the *M. ancylodon* stock cannot be determined. The various TRPs considered here, therefore, only provide information that can be used in the application of effective management action if, for example, three of the four fisheries are closed in the case of *M. ancylodon*. As the closure of any fishery is probably not a viable management option, *M. ancylodon* was assessed using multispecies-multigear yield- and spawner biomass-per-recruit models, which enables the examination of the performance of the fisheries as a whole and the impact on all of them, of changes in any one.

As a part of this assessment, a preliminary sensitivity analysis was conducted on both species by changing the assumed natural mortality “base case” estimate (Table 16.3). The results revealed that the TRPs that assessed the status of the stock from a reproductive perspective ($F_{SBx\%}$) were most robust to changes in the estimate of natural mortality. These results suggest that assessing the stocks from a spawner biomass-per-recruit perspective was more robust than setting reference points based on yield-per-recruit. As a consequence of this feature and the need to set fishing mortalities at levels which do not result in reductions in recruitment, spawner biomass-based reference points are considered the most important index for assessing the status of the *M. ancylodon* and *P. subtilis* stocks and for guiding management.

Yield- and spawner biomass-per-recruit response isopleths for the gillnet and Chinese seine net fisheries are illustrated in Figures 16.7 and 16.8. These fisheries were chosen as they represented the least (gill-net) and most (Chinese seine) destructive fisheries in terms of recruitment overfishing (by the rapid reduction of spawner biomass) and growth overfishing (harvesting of fish that are too small, before they can realise their growth potential). Figure 16.7 translates directly with Figure 16.5 in that, in the absence of one of the fisheries where $F = 0$, the response in both yield- and spawner biomass-per-recruit is the equivalent of the other fishery. The response surface between the two represents the trade-offs (interactions)
between the two fishing mortalities. When assessing the stock from either a spawner biomass-per-recruit perspective, the optimal combination of fishing mortalities for both fisheries was attained from the relevant TRP on the isopleth contour plot.

Figure 16.6 Yield-per-recruit and spawner-biomass-per-recruit of *P. subtilis* in Guyana with ‘base case’ trawl net fishing. Analyses were conducted using the ‘traditional’ single-species models with the ‘base case’ scenario where $M = 1.85 \text{ yr}^{-1}$.
Figure 16.7 Isopleth diagrams showing the response of *M. ancylodon* yield-per-recruit (YPR) to changes in fishing mortality ($F$) in the gill-net and Chinese seine fisheries. Analyses were conducted using the multispecies-multi-fishery models and assumed that all fishing mortality was partitioned between these two gears in proportion to current landings.
Figure 16.8 Isopleth diagrams showing the response of *M. ancylodon* spawner biomass-per-recruit (SBR) to changes in fishing mortality (*F*) in the gill-net and Chinese seine fisheries. Analyses were conducted using the multispecies-multifishery models and assumed that all fishing mortality was partitioned between these two gears in proportion to current catches.

Results from the multispecies-multigear analysis are summarised in Table 16.3. They summarise TRPs obtained from simultaneously increasing the fishing mortalities from all four fisheries on both species, maintaining as constant the percentage contribution that each fishery makes to the total catch. Overall, the TRPs obtained for the *M. ancylodon* stock are
Table 16.3 Sensitivity of various fishing mortality-based Target Reference Points (TRPs) to variations in the “base case” estimate of natural mortality used in the per-recruit analysis for the trawlfishery

<table>
<thead>
<tr>
<th>TRP</th>
<th>Percentage change in the “base case” natural mortality estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-20%</td>
</tr>
<tr>
<td></td>
<td>M. ancylodon ($M = 1.2 \text{ year}^{-1}$)</td>
</tr>
<tr>
<td>$F_{\text{MSY}}$</td>
<td>0.76 (82%)</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>0.49 (83%)</td>
</tr>
<tr>
<td>$F_{SB50}$</td>
<td>0.34 (87%)</td>
</tr>
<tr>
<td>$F_{SB40}$</td>
<td>0.46 (85%)</td>
</tr>
<tr>
<td>$F_{SB30}$</td>
<td>0.64 (88%)</td>
</tr>
<tr>
<td></td>
<td>P. subtilis ($M = 1.85 \text{ year}^{-1}$)</td>
</tr>
<tr>
<td>$F_{\text{MSY}}$</td>
<td>1.39 (85%)</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>0.93 (88%)</td>
</tr>
<tr>
<td>$F_{SB50}$</td>
<td>0.71 (92%)</td>
</tr>
<tr>
<td>$F_{SB40}$</td>
<td>0.97 (92%)</td>
</tr>
<tr>
<td>$F_{SB30}$</td>
<td>1.32 (92%)</td>
</tr>
</tbody>
</table>

Table 16.4 Multigear-multispecies target reference points (TRP), estimated annual yield in metric tons (Y) and gross revenue (GR) for *M. ancylodon* and *P. subtilis* using four gears from Guyana. Current GR = US$ 51 090 and current *M. ancylodon* $F = 1.51 \text{ yr}^{-1}$ and for *P. subtilis* $F = 1.03 \text{ yr}^{-1}$

<table>
<thead>
<tr>
<th></th>
<th><em>M. ancylodon</em></th>
<th><em>P. subtilis</em></th>
<th>GR (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMSY</td>
<td>1.13</td>
<td>1.63</td>
<td>52 575</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>0.71</td>
<td>1.06</td>
<td>48115</td>
</tr>
<tr>
<td>$F_{SB50}$</td>
<td>0.51</td>
<td>0.77</td>
<td>42430</td>
</tr>
<tr>
<td>$F_{SB40}$</td>
<td>0.71</td>
<td>1.05</td>
<td>47914</td>
</tr>
<tr>
<td>$F_{SB30}$</td>
<td>0.99</td>
<td>1.44</td>
<td>51720</td>
</tr>
<tr>
<td>$F_{SB20}$</td>
<td>1.42</td>
<td>2.03</td>
<td>52 566</td>
</tr>
</tbody>
</table>
Results from the bio-economic analysis (Table 16.4; Figure 16.9) suggested that *M. ancyloodon* was a more valuable catch, both in terms of mass landed and in gross revenue generated. The maximum gross revenues are currently generated for both species are achieved at similar levels of effort, ca. 300 vessels.

**Figure 16.9** Estimated gross revenue for *M. ancyloodon* and *P. subtilis* as a function of trawl fishing effort (in number of vessels). Two sets of target reference points are provided: $F_{\text{max}}$ and $F_{\text{SB40}}$. Each TRP block summarises the 95% confidence intervals based on uniformly distributed variability in the estimates of natural mortality.

### 16.5 Discussion

Results from all the analyses revealed that *M. ancyloodon* is severely overfished, both from growth and recruitment perspectives. The status of the *P. subtilis* stock, in contrast, revealed that it was fully fished with the current fishing mortality similar to the $F_{0.1}$ and $F_{\text{SB40}}$ TRPs.

Due to the dependence of recruitment on spawner stock, many scientists concerned with the management of marine species have tended to base their target reference point (TRP) recommendations on the results of spawner biomass-per-recruit models (Butterworth *et al.* 1989; Booth and Buxton 1997; Griffiths 1997a,b). The definition of a spawner-biomass TRP ($F_{\text{SB}(\%)}$) involves setting the fishing mortality to a level at which spawner biomass-per-recruit is reduced to a percentage of its pristine level. Although there is no single widely accepted...
FSB(x) TRP, spawner biomass-per-recruit recommendations generally lie between 25% and 50% of unexploited levels (Deriso 1987; Sissenwine and Shepherd 1987; Butterworth et al. 1989; Quinn et al. 1990; Clark 1991; Punt 1993; Mace 1994; Booth and Buxton 1997). In the absence of information on the surplus production function or the spawner biomass-recruitment relationship, the FSB(x) TRPs are currently considered the most robust, allowing for the determination of a fishing mortality rate that may provide relatively high yields at lower risks (Clarke 1991; Punt 1993).

Peak yield-per-recruit is attained if an infinite fishing mortality is applied when the biomass of a cohort is at its maximum (Pereiro 1992). If this maximum is applied, only after the age-at-50%-maturity, the risk of spawning failure is reduced. However, if the age-at-50%-maturity is less than or equal to the age-at-50% selectivity there could be an overfishing situation where the spawner biomass-per-recruit would rapidly reach levels where recruitment would fail. Thus, the maintenance of the spawner stock at levels where it can replace itself is vital.

Management of the Brazil-Guianas species, where knowledge of stock dynamics is still relatively weak, should therefore focus on the maintenance of spawner biomass at a precautionary 40% of unexploited levels (FSB40). Although the FSB40 strategy is a less conservative strategy than F0.1 or FSB50, the relationship between spawner stock size and recruitment is at present unknown and any increase in effort must be viewed with caution.

‘Traditional’ per-recruit analysis showed that both the trawl and seine-net fisheries harvested M. ancylodon at an age well below the age-at-50% maturity and this would lead to a rapid decrease in spawner biomass-per-recruit (and possibly spawner biomass) with small increases in fishing effort. Conversely, the gill-net fishery harvests fish above the age-at-50%-maturity. Gillnet fishing is therefore more sustainable and more robust to errors in setting limits on fishing effort, as large increases in fishing mortality would only result in a marginal drop in spawner biomass-per-recruit. Serious consideration needs to be given to reducing both fishing effort (and hence fishing mortality) and to increase the age-at-selectivity if the sustainability of the resource is to be maintained. The per-recruit indications that P. subtilis is fully-exploited suggests that no additional management measures are required in terms of this species, for the trawl fishery as long as fishing effort is maintained at present levels. Considering that P. subtilis is economically important within this fishery, if economic goals are considered the most important for the shrimp and groundfish fisheries, management measures for M. ancylodon should, therefore, be initiated in the Chinese and pin seine fisheries. However, if social goals are considered more important, such as maintaining the livelihoods of artisanal fishermen, this solution may not be the best option. Using techniques such as those employed here, decision makers could be advised on the implications of a range of options for reducing fishing mortality in the different fisheries, assisting them in making decisions best suited to the selected objectives. What is clear, is that there is a need for a reduction in fishing mortality, especially on the immature age classes and if this is not achieved, then both economic and social benefits will suffer in the future.

It must be noted that the per-recruit analysis of the P. subtilis stock should be viewed in conjunction with other non-equilibrium stock assessments. This is principally due to the inappropriateness of per-recruit modelling approach for short-lived and fast-growing species that are strongly influenced by environmental variables as the models equilibrium assumptions are violated.

The current gross revenue generated for both species was similar to the maximum gross revenue predicted by the model. While this could be interpreted as indicating that fishing effort in the trawl fishery is currently at an appropriate level from an economic perspective and that the current harvesting rate merely needs to be maintained, the detrimental impact on M. ancylodon spawner biomass-per-recruit at this level of effort (Table 16.2) needs to be seriously considered. Current levels of fishing mortality on the M. ancylodon stock are higher than those required to reduce spawner biomass-per-recruit to below 20% of pristine levels. This is clearly unacceptable as it has been shown that at these levels there is a high risk of future stock collapse (Mace and Sissenwine 1993, Caddy and Mahon 1995) and the current
position is therefore clearly not sustainable. Management from a multispecies-multigear perspective therefore requires that a compromise is reached between gross revenues generated in the short-term and the maintenance of spawner biomass-per-recruit above acceptable levels (e.g. LRPs) for all species. The sensitivity of the spawner biomass of *P. subtilis* to fishing effort with the current selectivity of the trawl gear on the species also needs to be considered. With the current age-at-50%-selectivity of *P. subtilis* of 0.2 years, compared to an age-at-50%-maturity of 0.5 years, any increase in fishing effort could have a serious impact on spawner biomass (Figure 16.6). This needs to be explored by further analyses. For example, a bio-economic analysis could provide valuable information on the implications of increasing trawl mesh size to catch larger shrimp and fish. From a simple per-recruit perspective both yield- and spawner biomass-per-recruit would increase, with a likelihood of both increased net revenues and decreased risk to the stock. But this needs more investigation before any specific management action to achieve this objective could be recommended.

The multispecies and multi-fishery characteristics of Guyana are shared by many marine fisheries (Japp *et al.* 1994; Beckley and Fennessy 1996) The “traditional” single-species-per-recruit models, which ignore important species and gear interactions, provide only very incomplete information for such fisheries. However, the common lack of historical data negates the use of more comprehensive methods such as multispecies VPA (Sparre 1991; Magnusson 1995) in most fisheries. Therefore, the multispecies-multi-fishery per-recruit approach is frequently a very useful management tool for these fisheries, at least until such time as reliable long-term directed catch-at-age or catch-at-length data are available. It is recognised that the per-recruit approach has limitations, such as its assumption of constant recruitment (Pereiro 1992) and, therefore, it has to be used with caution. This problem could be addressed later within a Monte-Carlo simulation framework by incorporating long-term probabilistic forecasts using stochastic recruitment. It is crucial that relevant long-term catch-at-age or catch-at-length data are collected in all fisheries. These data, together with estimates of total catch and total effort for each fishery, will facilitate integrating the results of the per-recruit analysis with the output of other age-structured models in order to provide more accurate, comprehensive and sustainable strategies for long-term management.

Various aspects of the biology of *M. ancylodon* and *P. subtilis* need further investigation. There is an urgent need to obtain accurate age and growth estimates, by sex, as scanaids, such as *M. ancylodon*, are typically long-lived and slow growing, even in tropical environments (Beckman *et al.*, 1989, 1990; Barbieri *et al.* 1994; Griffiths and Hecht, 1995, 1996; Murphy and Taylor, 1989; Ross *et al.*, 1995). These growth parameters form the basis of all age-based models and, where poorly known, further reduce the inaccuracy from length-based modelling approaches. In addition, under such circumstances, length-frequency analysis induces additional bias when estimating natural and fishing mortality due the correlation between lumped parameters. With regard to the stock assessment framework used, there needs to be a move away from equilibrium based models for groundfish in Guyana. This has been achieved for the shrimp resources studied in these workshops that have been assessed, for example, using cohort analysis. This has been possible, primarily due to the availability of accurate annual estimates of age and growth and comprehensive age-structured catch statistics. Assessment of groundfish needs to take cognisance of this progress made in the shrimp assessments. The monetary value of the industrial and artisanal catches together with their importance to subsistence fishers should be sufficient motivation to collect such data for the main groundfish species as well. It is recommended that total catches and effort per fishery and suitable biological data should be collected for all the more important groundfish species, not just *M. ancylodon* and also that the economic and social value of groundfish should be studied. These data and information would contribute significantly towards their sustainable utilisation and management.
17.1 Introduction

The use and management of shrimp and groundfish resources of the Brazil–Guyana shelf require a systematic integration of the resource biology and ecology with the economic and social factors that determine resource and fishers’ behaviour over time. The approach suggested for the development of management strategies for shrimp and groundfish fisheries of this region, involves the following steps:

(i) Identify the set of management questions needed to be addressed by the working group,

(ii) Undertake biological, economic and social assessment of the fishery, i.e. estimate size and dynamics of the population structure, age structure of the catch, costs and revenues of alternative fishing methods, direct employment and export earnings,

(iii) Select the performance variables for the shrimp fishery,

(iv) Establish limit and target reference points for the selected performance variables,

(v) Identify alternative management strategies for the fishery with the specific policy instruments,

(vi) Identify different states of nature for those fishery variables and parameters (i.e. recruitment seasonality, natural mortality, unit costs of effort, catchability, etc.) that involve high levels of uncertainty,

(vii) Determine if mathematical probabilities can be assigned for the occurrence of the identified states of nature,

(viii) Build decision tables with and/or without mathematical probabilities,

(ix) Apply different decision criteria reflecting different degrees of caution or risk aversion to select the optimum management strategy,

(x) Estimate the probabilities of exceeding the limit reference points of performance variables for the alternative management strategies under consideration,

(xi) Re-evaluate the fishery periodically to establish new reference points and management strategies.

The use of reference points (Caddy and Mahon 1995, Die and Caddy 1997) as guides for resource administration represents an important step in the management process. Also, the recognition of the uncertainty present in various parts of the fishery system is fundamental for a precautionary approach to the decision making process. To aid this process, the use of fisheries specific mathematical models allow researchers, managers and resource users to experiment with different management options in order to observe the possible dynamic consequences on different parts of the system and corresponding performance variables.
17.2 The precautionary approach to shrimp fisheries management: dealing with risk and uncertainty

Butterworth et al. (1993) and Hilborn and Peterman (1996) among others have identified a set of sources of uncertainty associated to stock assessment and management procedures. These include uncertainty in resource abundance, in model structure, in model parameters, on behaviour of resource users, in future environmental conditions and in future economic, political and social conditions. To deal with these variety of uncertainties using a precautionary approach, it was suggested, in the Lysekil meeting (FAO 1995), the use of Bayesian and non-Bayesian decision theory (Perez and Defeo 1996, Defeo and Seijo 1999) and the incorporation of limit and target reference points to manage fisheries (Caddy and Mahon 1995). Under this approach, decision makers in fisheries are expected to select one management strategy, \( d \), out of a set of \( D \) alternative strategies. When selecting a strategy, the fishery manager should be aware of the corresponding consequences. These consequences are likely to be a function of the cause-effect relationships specified in the fishery model, the estimated bio-economic parameters and the possible states of nature (Seijo et al. 1998). There is a probability that a target reference point (i.e. resource biomass, yield, rent, direct employment, export earnings, contribution to food security in coastal areas, etc.) may not be achieved because of inherent randomness of natural systems, incomplete knowledge of the fishery system and changes in economic and biological/ecological exogenous variables (Garcia, 1996a).

Monte Carlo analysis allows introducing the uncertainty associated with natural variations and imperfect knowledge about the system being assessed through dynamic bio-economic analysis. The process consists of an iterative calculation of the performance variables, where in each trial a new value for the unknown parameter is generated with the specified probability density function.

17.3 Decision tables with and without mathematical probabilities

In decision theory, it is important to be able to estimate a loss of opportunities function, \( L(d, \theta) \), which reflects the resulting losses of having selected strategy \( d \) when the state of nature occurring is \( \theta \).

If prior or posterior probabilities are available to build decision tables, the expected values (EV) and their corresponding variance (VAR) should be estimated for the selected fishery performance variable (e.g. net present value of the fishery, biomass, yield, direct employment, export earning, among others) as follows:

\[
EV_d = \sum P(\theta)PV_{\theta d}
\]

\[
VAR_d = \sum P(\theta)(PV_{\theta d} - EV_d)^2
\]

where \( P(\theta) \) are the probabilities associated to the different states of nature, \( PV_{\theta d} \) are the values of the performance variable resulting from management decision \( d \) when state of nature \( \theta \) occurs. A risk neutral fisheries manager will select the management strategy that generates the maximum expected value with no consideration of the corresponding variance. A risk averse decision maker will tend to select the fisheries management strategy that generates the minimum variance. There are however different degrees of risk aversion and therefore the decision theory provides alternative criteria for increasing degrees of caution in decision making (Shotton 1995, Shotton and Francis 1997). To apply these concepts to the precautionary approach to fisheries we will describe in the following section decision criteria with and without mathematical probabilities.

17.4 Bayesian criterion

The Bayesian criterion is a procedure that uses prior or posterior probabilities to aid the selection of a management strategy. It indicates the shrimp fishery manager should select
the decision that minimises the expected loss of opportunities. Decisions without experimentation use prior distributions estimated out of experiences that are translated subjectively into numerical probabilities. Shrimp fishery decisions that are based on experimentation can use posterior probabilities. Posterior probabilities are the conditional probability of state of nature \( \theta \), given the experimental data.

### 17.5 Decision criteria without mathematical probabilities

In the absence of sufficient observations to assign probabilities to possible states of nature, there are three decision criteria reflecting different degrees of precaution concerning selection of management strategies (Seijo et al. 1998, Defeo and Seijo 1999).

#### 17.5.1 Minimax criterion

The Minimax criterion estimates the maximum loss of opportunities of each management strategy and selects the one that provides the minimum of the maximum losses. This criterion proceeds as if nature would select the probability distribution, defined for all possible states of nature, that is least favourable for the decision-maker.

#### 17.5.2 Maximin criterion

This criterion uses the performance variable decision table that estimates the resulting values for a set of combinations of alternative decisions and states of nature. The criterion calculates a vector of the minimum values for the performance variable resulting from each alternative management decision. Then, the shrimp fishery manager proceeds to select the maximum of the minimum of those values. This is the most cautious of the decision theory approaches.

#### 17.5.3 Maximax criterion

A risk prone fishery manager would tend to apply the Maximax decision criterion when selecting the management strategy. The criterion calculates a vector of the maximum values for the performance variable resulting from each alternative management decision. Then, the shrimp fishery manager proceeds to select the maximum of the maximum of those values and the corresponding decision that generates it.

### 17.6 Bio-economic model for a multi-species multi-fleet shrimp fishery

A short and long run dynamics model for the fishery was developed considering seasonality of recruitment and effort and integrating the dynamics of crustacean species harvested by heterogeneous fleets.

#### 17.6.1 Biological sub-model

An estimation of stock size is needed as an input in order to initialise the model. Survivors through fishing seasons are calculated following equation (1):

\[
N_{i,j,t+1} = N_{i,j,t} + \int_{j}^{t+DT} (N_{i,j-1,t-1} \cdot S_{i,j-1,t-1} - N_{i,j,t}) dt
\]

where \( N_{i,j,t} \) is the number of individuals of species \( i \) aged \( j \) in time \( t \), \( S_{i,j-1,t-1} \) is the survival rate of individuals of age \( j-1 \) in time \( t-1 \) and \( DT \) is the time increment, assumed in the spreadsheet as \( DT=1 \).

The survival rate of individuals at different ages over time is estimated as \( S_{i,j}=1-(1-\exp(-\Sigma F_{i,j,m,t} + M_j)) \) represents the selectivity pattern (both generated from the technological sub-model)
and $M_t$ is the natural mortality during the fishing season. Biomass by sex and age is determined by:

$$B_{i,j,t} = N_{i,j,t} \cdot (a_i \cdot L_{i,j}^{b_i})$$  \hspace{1cm} (2)

where, $L_{i,j}$ is the length of shrimp species $i$ at age $j$ and $a_i$ and $b_i$ are constants from species length-weight relationship. Length at age for the different species is calculated using the von Bertalanffy growth model:

$$L_{i,j} = L_{i,0} \cdot (1 - e^{-k_i(\frac{t-i}{t_0})})$$  \hspace{1cm} (3)

Total biomass of each shrimp species at the end of the month is determined by:

$$TB_{s,t} = \sum_{i=2}^{i=15} B_{i,t}$$  \hspace{1cm} (4)

Recruitment to the stock (age 1) for the following year could be considered constant or dynamic using alternative recruitment functions (e.g. Beverton-Holt), either deterministic or stochastic:

$$R_t = f[SSB_i, ENV_t, u_t]$$  \hspace{1cm} (5)

where $SSB_i$ = the spawning stock biomass of species $i$ at time $t$, $ENV_t$ = the critical environmental factor affecting fluctuations in recruitment levels (e.g. precipitation in relevant watershed) and $u_t$ = a random variable generated with the appropriate probability density function and variance to account for random and uncertain factors. For a sex specific population structure, the numbers of males and females entering the fishery could be calculated by multiplying $R_t$ by the sex proportion.

**Recruitment seasonality**

Recruitment seasonality was modelled using a distributed delay model (Seijo et al. 1998). The model can be described as follows:

$$dR_1 = \frac{g}{DEL} (pl_{i,t} - R_{1,i})$$  \hspace{1cm} (6)

$$dR_2 = \frac{g}{DEL} (R_{1,i} - R_{2,i})$$  \hspace{1cm} (7)

$$\ldots$$

$$\ldots$$

$$dR_g = \frac{g}{DEL} (R_{g-1,i} - R_{g,i})$$  \hspace{1cm} (8)

where $pl_i$ = shrimp postlarvae recruiting to the area, $R_{g,i}$ = shrimp recruits to age 1, $R_{1,i}$, $R_{2,i}$, ..., $R_{g,i}$ are the intermediate rates of the delay process used to represent the distribution of seasonal recruitment, $DEL$ = average maturation time and $g$ = order of the distributed delay.

**17.6.2 Technological / Economic sub-model**

To initiate this sub-model, current effort (total fishing days) for each fishing season is needed. Furthermore, the length of the closed season is required. The first step is to calculate the seasonal fishing mortality per fishing gear. Fishing mortality is calculated by age according to the following equation:

$$F_{i,s,j,g} = f_{i,g} \cdot SEL_{i,j} \cdot q_{s,g}$$  \hspace{1cm} (9)
where \( f_{i,g} \) = the fishing days per gear in each fishing season, \( SEL_{a,i} \) represents the selectivity pattern by age, while \( s \) represents the sex. Current number of fishing days is required to initialise the model. The amount of fishing days by gear in subsequent years is calculated endogenously by the model, as will be explained below. The catchability coefficient is denoted by \( q \) and is estimated in the model by the Baranov (1918) area swept method.

To estimate the catch by gear, age and sex in the fishing season \( t \), the following catch equation is used:

\[
C_{t,i,j,m} = \left[ \frac{F_{t,i,j,m}}{F_{t,i,j,m} + M_t} \right] \left[ 1 - e^{-(F_{t,i,j,m} + M_t)} \right] N_{i,j,d}
\]  

Catch throughout the year is estimated by:

\[
TC_{m,j} = \sum_{j=1}^{24} C_{t,i,j,m}
\]  

Numbers of vessels \( (NV_{t,m}) \) involved in a year is calculated by relating total fishing effort applied in a year to total fishing days per vessel:

\[
NV_{t,m} = \left( \frac{f_{t,m}}{TFDV} \right)
\]  

where \( TFDV \) is the total fishing days per vessel in a year.

### 17.6.3 Economics sub-model

To predict the new effort per gear (total fishing days) in the next season, the dynamic of the effort is modelled using Smith’s approach (Smith 1969):

\[
f_{t+DT,m} = f_{t,m} + \int_t^{t+DT} (\phi \cdot \pi_{m,t}) dt
\]  

where \( \phi \) is a positive constant (Smith 1969) and \( PP \) is the private profit generated over time from the economics sub-model. If \( \phi \) is equal to zero, then effort is constant throughout time. Furthermore, the technological sub-model allows evaluating changes in the duration of the closed season.

The revenue per fleet is calculated using:

\[
TR_{m,j} = \sum_{i,j} C_{i,j,m} \cdot p_{i,j}
\]  

where \( p_{i,j} \) is a vector of ex-vessel prices per age (size). Profits generated by each fleet per fishing season is calculated as:

\[
\Pi_{m,t} = TR_{m,j} - TC_{m,t}
\]  

where \( TC_{m,t} \) are total costs of fleet type \( m \) in season \( t \). The total profit per year is determined by adding the monthly profits over the year. The total costs per gear are separated in variable and fixed cost.

**Net present value for the fishery**

Net present value (NPV) was calculated according to equation

\[
NPV_m = \sum_{t=0}^{T} \frac{\Pi_{m,t}}{(1-\delta)^t}
\]
where $\delta$ is the discount rate. The time period simulated was 4 years. Different rates of discount were used in the analysis to reflect different prices of time.

The above described model was applied to the Trinidad – Venezuela shared shrimp fishery of the Gulf of Paria.
18 CASE STUDY FOR A MULTI-SPECIES MULTI-FLEET SHARED STOCK FISHERY: PRELIMINARY BIO-ECONOMIC ANALYSIS OF THE TRINIDAD AND TOBAGO / VENEZUELA TRAWL FISHERY

18.1 Description of the Trinidad and Tobago fishery

Based on a trawl vessel census conducted in 1997 by the Fisheries Division of Trinidad, the trawl fleet comprises a total of 126 vessels: 30 artisanal Type I (7 to 10 m with outboard engines) and 66 artisanal Type II vessels (8 to 12 m with inboard diesel engines); 11 semi-industrial Type III vessels (10 to 12 m with inboard diesel engines); and 19 industrial Type IV vessels (17 to 22 m Gulf of Mexico double-rigged vessels) (Fabres et al. 1995). All trawlers operate in the Gulf of Paria. In addition, the industrial fleet operates in the Columbus Channel, as well as on the north coast of Trinidad. Up until 1995, 70 artisanal vessels were also permitted to trawl in the Orinoco Delta of Venezuela under an agreement between the two countries.

Five species of shrimp are exploited by the trawlers: *Penaeus subtilis; P. schmitti; P. notialis; P. brasiliensis;* and *Xiphopenaeus kroyeri*. Several species of demersal finfish from families such as Sciaenidae, Serranidae, Haemulidae and Lutjanidae are caught incidentally or may be targeted. Estimated landings of shrimp in 1995 are 994t from the industrial fleet, 134t from the semi-industrial fleet and 688t from the artisanal fleet. Bycatch landings for 1995 are estimated to be 1134t from the industrial fleet, 213t from the semi-industrial and 78t from the artisanal fleet.

18.2 Description of the Venezuela fishery

This fishery comprises two fleets: an industrial fleet and an artisanal fleet. The industrial trawl fleet comprises 88 vessels (mostly metal vessels 24 to 30 m in length) that target shrimp (*P. subtilis* and *P. schmitti*) and finfish of the families Sciaenidae, Carangidae, Haemulidae, Trichiuridae, Lutjanidae, Arridae and Mustelidae. This fleet operates in the southern Gulf of Paria and in front of the Orinoco river delta. Landings of this fleet during 1998 reached 6178t of finfish and 636t of shrimp (436t of *P. subtilis* and 200t of *P. schmitti*). The artisanal fleet of trawlers comprised 28 wooden vessels (8 m in length with outboard engines) and operates in the northern area of the Orinoco river delta. This fleet targets only juvenile *P. schmitti* and during 1998 landed 131t.

18.3 Methods

The bio-economic model incorporates data for all the Trinidad fleets but only the industrial Venezuelan fleet (not the Venezuelan artisanal fleet). The model covers a four-year period. Data were included for 1995 to 1998 for Venezuela and 1995 to July 1996 for Trinidad. The model incorporates four of the shrimp species exploited in the Gulf of Paria-Columbus Channel region: *P. subtilis; P. schmitti; P. notialis;* and *X. kroyeri*. Data from Venezuela are included for only the first two species since the landings of the latter two are negligible. *P. brasiliensis* was excluded from the model since, although the species is important for the Trinidad industrial fleet, the data are not available. In the case of Venezuela, the landings of *P. brasiliensis* are negligible. Bycatch landed by the Trinidad trawl fleet was taken to be 1.1 times that of the shrimp landed by the fleet, while the bycatch landed by the industrial Venezuelan fleet was taken to be 10.1 times the shrimp landed by that fleet. Two recruitment peaks (February/March and July/August) were assumed for all shrimp species except *X. kroyeri* based on an assessment of *P. schmitti* conducted by Altuve et al. (1998), as well as a post larval abundance study conducted by Alio et al. (1990). Figure 18.1 illustrates the seasonal recruitment pattern generated by the model. Figure 18.2 illustrates the yield of the
four shrimp species estimated by the model over the four-year period and Figure 18.3 the observed and estimated catch of *P. subtilis* over the period.

**Figure 18.1** Seasonal recruitment pattern for *P. schmitti*  

**Figure 18.2** Yield of shrimp species estimated by the model over the four year period  

**Figure 18.3** Observed and estimated catch of *P. subtilis*
Table 18.1 Input parameters for the bio-economic model of the Trinidad and Tobago (fleet 1) / Venezuela (fleet 2) trawl fisheries

<table>
<thead>
<tr>
<th></th>
<th>P. schmitti</th>
<th>P. notialis</th>
<th>P. subtilis</th>
<th>X. kroyeri</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruitment, R (individuals)</td>
<td>12 000 000</td>
<td>20 000 000</td>
<td>180 000 000</td>
<td>5 000 000</td>
</tr>
<tr>
<td>Growth parameter, k (month⁻¹)</td>
<td>0.35</td>
<td>0.25</td>
<td>0.0927</td>
<td>0.09</td>
</tr>
<tr>
<td>Natural mortality coefficient, M (month⁻¹)</td>
<td>0.2</td>
<td>0.2</td>
<td>0.146</td>
<td>0.2</td>
</tr>
<tr>
<td>Maximum weight, W_max (g)</td>
<td>162.296</td>
<td>145.589</td>
<td>64.932</td>
<td>27.789</td>
</tr>
<tr>
<td>Maximum Total length L_max (mm)</td>
<td>250</td>
<td>220</td>
<td>176</td>
<td>155</td>
</tr>
<tr>
<td>Parameter t₀ of growth equation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Discount rate</td>
<td>0.0045</td>
<td>0.0045</td>
<td>0.0045</td>
<td>0.0045</td>
</tr>
<tr>
<td>Effort dynamics parameter (fleet 1)</td>
<td>0.000003</td>
<td>0.000003</td>
<td>0.000003</td>
<td>0.000003</td>
</tr>
<tr>
<td>Effort dynamics parameter (fleet 2)</td>
<td>0.000003</td>
<td>0.000003</td>
<td>0.000003</td>
<td>0.000003</td>
</tr>
<tr>
<td>Average price of species 1 ($ tonne⁻¹)</td>
<td>7 400</td>
<td>7 400</td>
<td>3 700</td>
<td>1 380</td>
</tr>
<tr>
<td>Unit cost of effort fleet 1 ($ vessel⁻¹ day⁻¹)</td>
<td>407</td>
<td>407</td>
<td>407</td>
<td>407</td>
</tr>
<tr>
<td>Unit cost of effort fleet 2 ($ vessel⁻¹ day⁻¹)</td>
<td>618</td>
<td>618</td>
<td>618</td>
<td>618</td>
</tr>
<tr>
<td>Catchability coefficient fleet 1</td>
<td>0.002</td>
<td>0.000694</td>
<td>0.000694</td>
<td>0.000694</td>
</tr>
<tr>
<td>Catchability coefficient fleet 2</td>
<td>0.002</td>
<td>0.000694</td>
<td>0.000694</td>
<td>0.000694</td>
</tr>
<tr>
<td>Length 50% retention fleet 1 (mm)</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
</tr>
<tr>
<td>Length 75% retention fleet 1 (mm)</td>
<td>121</td>
<td>121</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>Selectivity parameter S1 fleet 1</td>
<td>3.647</td>
<td>3.647</td>
<td>3.647</td>
<td>3.647</td>
</tr>
<tr>
<td>Selectivity parameter S2 fleet 1</td>
<td>0.0341</td>
<td>0.0341</td>
<td>0.0341</td>
<td>0.0341</td>
</tr>
<tr>
<td>Area swept fleet 1 (km² day⁻¹)</td>
<td>1.08</td>
<td>1.08</td>
<td>1.08</td>
<td>1.08</td>
</tr>
<tr>
<td>Total area of resource distribution (km²)</td>
<td>5000</td>
<td>3000</td>
<td>6000</td>
<td>1500</td>
</tr>
<tr>
<td>Length 50% retention fleet 2 (mm)</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
</tr>
<tr>
<td>Length 75% retention fleet 2 (mm):</td>
<td>121</td>
<td>121</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>Selectivity parameter S1 fleet 2</td>
<td>3.647</td>
<td>3.647</td>
<td>3.647</td>
<td>3.647</td>
</tr>
<tr>
<td>Selectivity parameter S2 fleet 2</td>
<td>0.0341</td>
<td>0.0341</td>
<td>0.0341</td>
<td>0.0341</td>
</tr>
<tr>
<td>Area swept fleet 2 (km² month⁻¹)</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Parameter “a” of the total length (mm) to total weight (g) relationship</td>
<td>0.00000111</td>
<td>0.00000876</td>
<td>0.0000290</td>
<td>0.00000346</td>
</tr>
<tr>
<td>Parameter “b” of the total length (mm) to total weight (g) relationship</td>
<td>3.405</td>
<td>3.0637</td>
<td>2.82789</td>
<td>3.1524</td>
</tr>
</tbody>
</table>
Table 18.2 Final biomass of *P. subtilis* and present value of rent for the Trinidad and Venezuelan fleets

<table>
<thead>
<tr>
<th>Total Effort</th>
<th>Effort Trinidad</th>
<th>Effort Venezuela</th>
<th>NPV of TT fleet</th>
<th>NPV of VEN fleet</th>
<th>Joint NPV</th>
<th>Final biomass of <em>P. subtilis</em> (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d.a.s)</td>
<td>(d.a.s)</td>
<td>(d.a.s)</td>
<td>(US$)</td>
<td>(US$)</td>
<td>(US$)</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>1000</td>
<td>1000</td>
<td>10.1</td>
<td>11.8</td>
<td>21.9</td>
<td>861.8</td>
</tr>
<tr>
<td>4000</td>
<td>2000</td>
<td>2000</td>
<td>13.8</td>
<td>17.6</td>
<td>31.4</td>
<td>799.9</td>
</tr>
<tr>
<td>6000</td>
<td>3000</td>
<td>3000</td>
<td>16.3</td>
<td>21.5</td>
<td>37.8</td>
<td>744.5</td>
</tr>
<tr>
<td>8000</td>
<td>4000</td>
<td>4000</td>
<td>18.1</td>
<td>24.0</td>
<td>42.1</td>
<td>694.9</td>
</tr>
<tr>
<td>10000</td>
<td>5000</td>
<td>5000</td>
<td>19.1</td>
<td>25.3</td>
<td>44.4</td>
<td>650.3</td>
</tr>
<tr>
<td>12000</td>
<td>6000</td>
<td>6000</td>
<td>19.6</td>
<td>25.8</td>
<td>45.4</td>
<td>610.0</td>
</tr>
<tr>
<td>14000</td>
<td>7000</td>
<td>7000</td>
<td>19.7</td>
<td>25.6</td>
<td>45.3</td>
<td>573.6</td>
</tr>
<tr>
<td>16000</td>
<td>8000</td>
<td>8000</td>
<td>19.4</td>
<td>24.9</td>
<td>44.3</td>
<td>540.6</td>
</tr>
<tr>
<td>18000</td>
<td>9000</td>
<td>9000</td>
<td>18.8</td>
<td>23.8</td>
<td>42.6</td>
<td>510.5</td>
</tr>
<tr>
<td>20000</td>
<td>10000</td>
<td>10000</td>
<td>17.9</td>
<td>22.3</td>
<td>40.2</td>
<td>483.1</td>
</tr>
<tr>
<td>22000</td>
<td>11000</td>
<td>11000</td>
<td>16.9</td>
<td>20.5</td>
<td>37.4</td>
<td>458.1</td>
</tr>
<tr>
<td>24000</td>
<td>12000</td>
<td>12000</td>
<td>15.7</td>
<td>18.6</td>
<td>34.3</td>
<td>435.1</td>
</tr>
<tr>
<td>26000</td>
<td>13000</td>
<td>13000</td>
<td>14.4</td>
<td>16.4</td>
<td>30.8</td>
<td>414.1</td>
</tr>
<tr>
<td>28000</td>
<td>14000</td>
<td>14000</td>
<td>12.9</td>
<td>14.2</td>
<td>27.1</td>
<td>394.7</td>
</tr>
<tr>
<td>30000</td>
<td>15000</td>
<td>15000</td>
<td>11.4</td>
<td>11.8</td>
<td>23.2</td>
<td>376.8</td>
</tr>
<tr>
<td>32000</td>
<td>16000</td>
<td>16000</td>
<td>9.8</td>
<td>9.3</td>
<td>19.1</td>
<td>360.2</td>
</tr>
<tr>
<td>34000</td>
<td>17000</td>
<td>17000</td>
<td>8.1</td>
<td>6.8</td>
<td>14.9</td>
<td>344.9</td>
</tr>
<tr>
<td>36000</td>
<td>18000</td>
<td>18000</td>
<td>6.4</td>
<td>4.2</td>
<td>10.6</td>
<td>330.7</td>
</tr>
<tr>
<td>38000</td>
<td>19000</td>
<td>19000</td>
<td>4.7</td>
<td>1.6</td>
<td>6.3</td>
<td>317.5</td>
</tr>
<tr>
<td>40000</td>
<td>20000</td>
<td>20000</td>
<td>2.9</td>
<td>-1</td>
<td>1.9</td>
<td>305.2</td>
</tr>
</tbody>
</table>

Limit reference points (LRPs) were established for two performance variables, namely the standing biomass of *P. subtilis* (the dominant species taken by both fleets) at the end of the four-year period and the present value of rent of the Trinidadian and Venezuelan fleets. The limit reference points specified were 0.25 of the virgin biomass (B_max) of *P. subtilis* (i.e. 481t) and 0.5 of the Maximum Economic Yield (MEY) for the two fleets (i.e. US$8.8 million for Trinidad and US$14.3 million for Venezuela). The former LRP, 0.25 B_max, was calculated using the formula B_max = CPUE_max/q. CPUE_max was taken as that of *P. subtilis* (0.226 t/fishing day) in 1977 from the Venezuelan industrial fleet (Marcano et al. 1997) and q as the catchability coefficient (generated by the bio-economic model for the Venezuelan fleet) of *P. subtilis* at age 18 months (0.00012) when the individuals are fully recruited. The LRP 0.25 B_max (481t) obtained using data from Venezuela, as detailed above, was more conservative and thus used over 0.25 B_max (340 tonnes) obtained from Trinidad data. The limit reference point, 0.5 MEY, was determined for the entire Trinidad fleet and the Venezuelan industrial fleet separately where the MEY was derived from the bio-economic model.

Natural mortality (M) was identified as a parameter representing a major source of uncertainty and hence the M for each of the four species was allowed to vary randomly while running Monte Carlo with varying levels of fishing effort for each fleet. The levels of effort used for the analysis were 5 000 to 20 000 days per fleet at 2 500-day intervals, or 10 000 to
The objective here was to observe the performance variables (final biomass of *P. subtilis* and the present value of rent of the Trinidadian and Venezuelan fleets) and the probabilities of exceeding the LRPs at various levels of fishing effort. The optimum effort at which the present value of rent of the fishery (Trinidad and Venezuelan fleets combined) is maximized was then determined for the two fleets. One constraint here was that the fishing effort of each fleet be at least 5 000 days.

The bio-economic parameter sets used to model the dynamics of the Trinidad – Venezuela shrimp fishery are presented in Table 18.1.

### 18.4 Results

Table 18.2 provides the net present value of the rent for the Trinidad and Venezuela fleets as well as the final biomass of *P. subtilis* at the end of the four-year period for a range of fishing efforts: 1 000 to 20 000 days at sea (d.a.s.) per fleet at 1 000-day intervals. The probability of the performance variables exceeding the limit reference points (0.25 $B_{\text{max}}$ and 0.5 MEY) is given in Table 18.3 for a range of fishing efforts: 5 000 to 20 000 d.a.s. per fleet at 2 500-day intervals.

**Table 18.3 Probability of exceeding LRPs, 0.25 $B_{\text{max}}$ *P. subtilis* and 0.5 MEY of the Trinidad and Venezuelan fleets**

<table>
<thead>
<tr>
<th>Total Effort (d.a.s)</th>
<th>Effort TT (d.a.s)</th>
<th>Effort Venezuela (d.a.s)</th>
<th>0.25 $B_{\text{max}}$ <em>P. subtilis</em></th>
<th>Profits at 0.5 MEY TT</th>
<th>Profits at 0.5 MEY VE</th>
<th>Profits at 0.5 Joint MEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 000</td>
<td>5000</td>
<td>5000</td>
<td>2.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>15 000</td>
<td>7500</td>
<td>7500</td>
<td>15.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>20 000</td>
<td>10 000</td>
<td>10 000</td>
<td>49.0</td>
<td>0.0</td>
<td>8.0</td>
<td>0.0</td>
</tr>
<tr>
<td>25 000</td>
<td>12 500</td>
<td>12 500</td>
<td>88.0</td>
<td>4.0</td>
<td>35.0</td>
<td>14.0</td>
</tr>
<tr>
<td>30 000</td>
<td>15 000</td>
<td>15 000</td>
<td>96.0</td>
<td>27.0</td>
<td>60.0</td>
<td>46.0</td>
</tr>
<tr>
<td>35 000</td>
<td>17 500</td>
<td>17 500</td>
<td>100.0</td>
<td>56.0</td>
<td>85.0</td>
<td>82.0</td>
</tr>
<tr>
<td>40 000</td>
<td>20 000</td>
<td>20 000</td>
<td>100.0</td>
<td>92.0</td>
<td>100.0</td>
<td>98.0</td>
</tr>
</tbody>
</table>

Figure 18.4 illustrates that as the fishing effort increases the final biomass of *P. subtilis* decreases such that the LRP of 481t is achieved at approximately 10 000 d.a.s. per fleet which is not much greater than the current effort of 17 523 d.a.s. for both fleets (taken as that from 1995 being 8 175 days (in Type IV units) for the Trinidad fleet and 9 348 days for the Venezuelan fleet – see arrows on figures). Figure 18.5 shows that as the total effort of the two fleets increases, the probability of exceeding 0.25 $B_{\text{max}}$ increases, with the probability being 39% at the current level of effort. At the current effort, the final biomass was estimated at approximately 512t.

Figure 18.6 indicates that the joint net present value reaches a maximum of approximately US$45.4 million (US$25.8 million for Venezuela and US$19.6 million for Trinidad) at approximately 6 000 d.a.s. per fleet. The rent for the Venezuelan fleet is eliminated by a fishing effort of that fleet of 20 000 days. Figure 18.7 shows that the risk of exceeding the limit reference point of 0.5 MEY increases fairly rapidly with increasing effort from about 10 000 days for the Venezuelan fleet and beyond 12 500 days for the Trinidad fleet. At the current level of effort, the net present value of rent was estimated at approximately US$24.7 million for Venezuela and US$18.5 million for Trinidad, with a 5% probability that profits will...
be less than 0.5 MEY for the Venezuelan fleet and no risk of exceeding this LRP in the case of the Trinidad fleet as well as for both fleets combined.

Figure 18.4 Final biomass of \( P. \textit{subtilis} \) at the end of the four year period. The arrow marks the current effort.

Figure 18.5 Risk of exceeding LRP: 0.25 \( B_{\text{max}} \) of \( P. \textit{subtilis} \).

Figure 18.6 Present value of rent of the Trinidad and Tobago / Venezuela trawl fishery.
The optimum effort at which the MEY of US$46.1 million (US$28.5 million for Venezuela and US$17.6 million for Trinidad) for the shared fishery is attained is estimated to be 5 000 days for the Trinidad fleet and 7 697 days for the Venezuelan fleet. At this level of effort, the final biomass of *P. subtilis* is estimated to be approximately 584t, with a 1% risk of exceeding 0.25 $B_{\text{max}}$.

### 18.5 Conclusions

The preliminary bio-economic analysis conducted reveals that the fishing effort of both the Trinidad and Venezuelan fleets should not be increased beyond the current level. In addition, the optimum allocation of fishing effort between the two fleets which would yield maximum profits to this shared fishery is 61% of the current effort of the Trinidad fleet and 82% of the current effort of the Venezuelan fleet.

### 18.6 Recommendations for future research

This analysis must be considered to be preliminary. The input parameters to the model need to be refined. With regard to the Trinidad industrial fleet in particular, in the absence of a formal system of data collection for these trawlers, landings and effort data used are very rough estimates. It should be noted that while an estimate of 994t shrimp was used in this analysis for 1995, an estimate of 1000t was obtained from logbook records for this fleet for 1991, compared to an estimate of 423t for 1995 based on personal communication with the President of the Trinidad and Tobago Trawler Owners Association. A logbook programme will be implemented for this fleet in the near future. In addition, the costs should be determined as a function of yield, effort and number of boats in accordance with Sparre and Willmann (1993). Recruitment should also be represented as a stochastic function, with a probability distribution that approximates that of environmental factors that could affect this process, such as mean Orinoco river discharge or maximum yearly wind speed in the Gulf of Paria (Alió *et al.* 1999b).
19 REPORT ON MEETING OF THE TASK GROUP ON SNAPPER FISHERIES OF THE BRAZIL-GUIANAS SHELF

Participants: J. Ailio (Venezuela), M. Asano Filho (Brazil), B. Chakalall (FAO), A. Charau (French Guiana), P. Chalier (Suriname), K. Cochrane (FAO), R. da Silva Furtado Cutrim (Brazil), A. Hackett (Guyana), L. Marcano (Venezuela), T. Phillips (CFRAMP), S. Soomai (Trinidad), Mario IJspol (Suriname). Observers (FAO): A. Booth, D. Die and J. Prado

Brief reports were presented by a participant from each coastal state on the status of fisheries for snapper in their country and the primary management issues.

Table 19.1 The incidence of legal cross-border fishing for snapper in the EEZs of the Brazil-Guianas shelf. X = fishing currently taking place; Q = requests for the right to fish in that country have been made by the Fishing Nation

<table>
<thead>
<tr>
<th>Nation where fishing occurs</th>
<th>Brazil</th>
<th>French Guiana</th>
<th>Suriname</th>
<th>Guyana</th>
<th>Venezuela</th>
<th>Trinidad and Tobago</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>X</td>
<td>Q</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>French Guiana</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suriname</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guyana</td>
<td></td>
<td></td>
<td>X</td>
<td>X*</td>
<td>Q</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trinidad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Venezuela-owned vessels being used by local companies.

French Guiana

At present, there are 41 vessels from Venezuela which have licences to fish for snapper in French Guiana and normally 25-26 of these are fishing at any one time. In addition, 5 licences are reserved for vessels from Barbados, but these 5 licences have never been used. A condition of the licences is that 75% of production must be landed in Cayenne. *Lutjanus purpureus* is the target species for the snapper fishery. In 1998, total landings in French Guiana were approximately 1 800 t (nominal weight). In addition, there is a trap fishery with important bycatch of *Rhomboplites aurorubens* undertaken by vessels from some French Lesser Antilles islands.

The greatest problem confronting management of the fishery is a lack of knowledge on the landings made outside French Guiana, which occur mainly in Lesser Antilles, Suriname and Venezuela. The other discrepancy is the bycatch in the shrimp fisheries, which is largely unknown. Surveys with typical shrimp trawlers gave yearly figures as high as 1.0 to 1.5 million individuals, of which 75% were discarded.

Brazil

The fishery for snapper in northern Brazil started about 10 years ago. In 1995, production was approximately 500 t but it had risen to 3 000 t by 1998. Fishing was initially only by handline, but in 1997 new vessels entered the fishery making use of traps with 8 cm square mesh panels. Genetic studies have suggested that there could be two stocks, one centred on NE Brazil and the other on northern Brazil, separated by the Amazon River. Landings from
both stocks take place in the same four cities and up until now, the stocks have not been analysed separately. It should be possible to separate them, by identifying the fishing area from which data originate. The fishery consists of Brazilian vessels, but there has been a request from Guyana-based interests to fish for snapper in Brazil.

**Guyana**

There were 6 vessels in the Guyana snapper fishery in the 1980s, but the number has now risen to 28. Of these, 10 vessels are Venezuelan owned, but are fishing on behalf of a local company and 18 vessels represent the Guyana fleet which has now expanded from 6. Both traps and hook and lines are used in the fishery. An upper limit of 33 vessels has been set by the government. The Trinidad and Tobago government is currently negotiating a fisheries agreement with Guyana to obtain licences for their snapper fleet of 16 vessels to fish in Guyana's EEZ. These vessels would be using traps with 2.5-inch square mesh. If an agreement can be reached, the vessels would be required to operate from a base in Guyana. A local company, Noble House Seafoods, proposed to enter into arrangement with 25 Venezuelan boat owners for these vessels to deliver fish to its new processing plant.

**Suriname**

The fishery for *L. purpureus* in Suriname has been in existence for many years and is undertaken by Venezuelan vessels. Initially all landings were taken back to Venezuela, but there have been on-going attempts to get more of the catch landed in Suriname. There are good data on the amount landed in Suriname, which used to be around a few hundred tonnes, reaching 500 t in the 1970s and 1500 t in 1997. An agreement between the two governments establishes the fee for licences, the local prices and puts a limit on the number of vessels allowed to fish. However, there is no control on what happens at sea, the actual fishing effort is not known and there is no data on what is sold outside Suriname. *R. aurorubens* and other non-snapper species are taken as a bycatch in this fishery.

Landings of *L. synagris* have become more important since a midwater trawl fleet began to target the species in 1993 and the yields have risen to approximately 1 000 t per year. The fleet has two components, a Dutch fleet that targets *L. synagris* and a Korean fleet that targets *Cynoscion virescens*. There is also pressure from other fishing groups who wish to enter the fishery, but existing participants have complained of declining catches.

**Trinidad**

Since there is no formal sampling or data collection programme in place, there is little information on catches of snapper in Trinidad and landings are not separated by species but grouped as “snapper”. Three snapper species are important in the landings: *L. purpureus*, *L. synagris* and *R. aurorubens*. They are caught by the artisanal fishery, which uses a range of gear types involving trawling, nets, handlines and pots. In addition, a multigear fleet, estimated at seven vessels, use pots to catch snappers in the shelf area off the east coast. These are industrial vessels, which have a capacity for an average of 50 traps per vessel. Research on the biology of the lane snapper was conducted by the Institute of Marine Affairs in 1987.

**Venezuela**

Six species of snapper are caught in Venezuela, from the Gulf of Venezuela in the west to the Atlantic Zone. There is a fleet of approximately 300 vessels of which about 150 operate in the EEZ of most countries of the region, with licences granted by the corresponding governments. Over the last 10 years, considerable order has been brought into this fishery, including the licensing of all vessels. Landings of *L. purpureus* from Venezuelan waters have ranged from 500 to 2 000 t per annum in the last decade, while landings from foreign waters are usually in the vicinity of 3 000 t. A major problem in attempts to assess the fishery and resources is that there is very little information on catches in foreign waters as only a small
fraction of these are landed in Venezuela. The biology of some species is being studied at present.

Discussion

The Task Group agreed that the fisheries for snapper in the Brazil-Guianas region were in particular need of a regional approach to management for the following reasons:

1. The extent of foreign interests in the region, with landings occurring both within the nation being fished and the port state and sometimes in third countries as well, mean that close cooperation and sharing of information on landings, catches, effort and distribution of effort are essential, if the resources and fisheries are to be assessed and monitored accurately.

2. The artisanal nature of the fisheries makes monitoring and control particularly difficult, again requiring close cooperation to ensure accuracy and completeness.

3. While the stock structure of the snapper species in the region is unknown, it is likely that stocks are separated by the major rivers, which could lead to shared stocks north of the Orinoco delta and between the Orinoco and Amazon deltas.

Such cooperation should include open and transparent sharing of all data and information on snapper fishery operations between coastal states and interested parties, as well as cooperation in scientific research, assessments, monitoring, control and surveillance of the fishery. To facilitate cooperation in monitoring, research and assessment, it was agreed that an informal Task Group should be formed. This informal Task Group could normally communicate by means of email or fax, but it should be coordinated by an appointed co-ordinator and enjoy the support of all coastal states.

It was agreed that, as a first step in regional cooperation and possibly in the formation of the Task Group, an inventory on fishing activities, available information and data currently available and being collected would be compiled by a regional Ad hoc Snapper Group. The inventory would consist of the following sections:

- Brief but comprehensive description of existing fisheries for snapper in each country, including discussion of current management approaches and management issues (approximately 2 pages per country).
- Outline, with references, of assessments already undertaken on snapper fisheries in the region.
- Inventory on data available in and currently being collected by each country and research on snapper currently being undertaken in each country.
- Inventory on current knowledge of the incidence of snapper in bycatch and discards of other fisheries in the region.
- Full bibliography on snapper species in the region and snapper fisheries.
- Conclusions and recommendations for future work.

Subject to approval from their relevant authorities, the following agreed to contribute to the Inventory:

<table>
<thead>
<tr>
<th>Country</th>
<th>Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>M. Asano Filho and R. da Silva Furtado Cutrim</td>
</tr>
<tr>
<td>French Guiana</td>
<td>A. Charuau</td>
</tr>
<tr>
<td>Guyana</td>
<td>A. Hackett</td>
</tr>
<tr>
<td>Suriname</td>
<td>M. IJspol and P. Charlier</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>S. Soomai</td>
</tr>
<tr>
<td>Venezuela</td>
<td>Asdrubal Larez (Co-ordinator), J. Alio and L. Marcano</td>
</tr>
</tbody>
</table>
DIRECTORS present: Italo Jose Vieira (Brazil), Anatole Charuau (French Guiana), Ruben Charles (Guyana), Rene Lieveld (Suriname), Ann Marie Jobity (Trinidad and Tobago), Gustavo Lagarde (Venezuela).

Ms. Jobity of Trinidad was selected as Chairperson.

The Agenda was adopted unchanged.

REGIONAL APPROACHES TO MANAGEMENT OF SHARED STOCKS

Ad hoc Working Group funding

It was pointed out that the funding from CFRAMP for the activities of the Ad hoc Working Group would end after 2000 and funding from FAO would end after 2001. The necessity for continuing the cooperation that had existed over the last three years, at both the technical and management levels, had been clearly demonstrated and it was agreed that the member countries were committed to continuing the activities. The Directors agreed to explore the possibilities of financing their participation in workshops from 2002. At the same time they requested FAO to continue providing the secretariat, through WECAFC and technical assistance that will be required for the group.

For the next two meetings, the Directors agreed to review the logistics and format of the meetings with the objective of increasing efficiency and reducing costs.

Using current information in management

A question was raised as to how the information being generated by the Ad hoc Working Group was to be applied in management at both the national and regional levels. In response, it was pointed out that already the TAC for shrimp in northern Brazil had been set on the basis of assessments undertaken at Ad hoc Working Group workshops.

It was suggested that the first step in application of the results of the technical assessments must be to disseminate the knowledge to the stakeholders and to make them aware of the status and possible management strategies for their fisheries. This would have the effect of generating awareness and support for the necessary management actions and requires that reports from the technical workshops are also prepared in a manner suitable for distribution to a non-technical audience.

It was suggested that the technical reports from workshops should be provided to the managers in advance of the managers’ meeting, to allow time for a thorough study before discussions. This approach would require that the technical meetings were separated from the managers’ meeting.

GROUND FISHERY

Snapper Task Group report

The report of the Snapper Task Group was accepted and the recommendation was supported that the proposed Snapper Task Group should prepare a review and
synthesis on snapper fisheries and on the available knowledge and data on snapper and snapper fisheries in the region.

**Management of fleet capacity**

This agenda item was intended to generate discussion on possible approaches to managing fleet capacity in the light of assessment results from the *Ad hoc* Working Group indicating over-exploitation in many groundfish stocks.

The problem of shrimp vessels switching to groundfish fishing, but still using shrimp gear was highlighted as a problem in Guyana. Amongst signs of difficulties, reports were frequently received in several countries from fishermen on declining catches and catch rates, supporting the assessment results. However, particularly in the artisanal fisheries, new entrants were continuing to join, mainly because of social and economic reasons.

It was stated that the results from the Working Group assessments were extremely useful evidence, which could be used to assist in motivating changes.

A suggestion was made that while it would be politically very difficult to reduce effort in the artisanal fisheries, it may be more acceptable in some instances to freeze effort at current levels, at least preventing further growth in effort. This approach was being pursued or considered in some countries for both industrial and shrimp fisheries.

**Review of priority species**

At the 1998 Director’s Meeting, a list of 10 high priority groundfish species was drawn up for the region and it was agreed that emphasis should be given to undertaking up-to-date assessments of these species in the region. However, little progress had been made on this in the inter-sessional period. Countries were urged to give greater attention to this in the following inter-sessional period, to broaden the existing knowledge on the status and management of groundfish stocks.

**Cooperative studies**

Results from this Workshop had highlighted the generally poor estimates of some parameters for fish species, especially growth parameters, which had large impacts on estimates of natural and fishing mortality. It was agreed that the countries should work cooperatively in improving these estimates by dividing tasks amongst themselves. For example, different countries could undertake growth studies on different species and then exchange results. The CFRAMP project with the Institute of Marine Affairs (IMA) for otolith reading was brought to the meeting’s attention and CFRAMP member countries were urged to make use of it by sending otoliths to IMA.

Assessments on groundfish were identifying gear types that have undesirable selection characteristics for fish and some research would be required to consider alternative designs or mesh sizes. Again, regional cooperation would be beneficial in addressing this.

**SHRIMP**

**Bycatch and discards**

It was pointed out that 50% of the value of catch in Venezuela shrimp fisheries was bycatch, as shrimp catches had fallen considerably. It was suggested that this was happening in many countries and that the fishing industry was adjusting itself to falling shrimp catches and rising prices for groundfish. However, in Suriname the bycatch tended to belong to the crew. Suriname proposed that experiments should be conducted using different types of net to determine the economic feasibility of targeting fish and catching shrimp as a bycatch. A study undertaken in Brazil, showed that 72 species occurred in the bycatch, but 70% of the bycatch was made up of *M. ancylodon*. 
For every kilogram of shrimp taken, 7.7 kg was bycatch of which 4.4 kg was useful for human consumption. Suggestions for using this bycatch included having a boat collecting bycatch at sea but this was rejected as being too expensive. A second proposal was that boats should be equipped with a second hold in which to keep the fish, but this would have involved a 2 m increase in width of the boats. At present equipping boats with BRDs (bycatch reduction devices) based on an Australian design was being considered.

Venezuela reported that experiments undertaken by them showed consistent increases in catches of fish in nets with BRDs, as a result of under-sized fish not blocking the bag and causing the doors to close. Thus, while the shrimp catch decreased by only 6%, fish catch increased by 30%.

With reference to the GEF project, the intention was to undertake widespread consultations to arrive at regional or country-group agreements on particular problems and priorities. With this in mind, an open consultation was planned for January 2000 to attempt to develop project proposals. All relevant countries would be invited to participate in this meeting and to bring ideas and proposals, preferably generated during national consultations including stakeholders.

REGIONAL COOPERATION FOR IMPROVED MANAGEMENT

Trinidad and Tobago – Venezuela cooperation.

The cooperation between these two countries during the workshops had been very positive and beneficial to both countries. It was suggested that this success could provide a stimulus to activate the Protocol on Joint Research established under the 1985 Agreement that may still be valid and could be started under the current 1997 Cooperation Agreement between Venezuela and Trinidad. Participants from both countries agreed on the need for a forum on research issues of common concern, including sharing of data.

Venezuela suggested that a representative from Trinidad could attend the national workshop for the dissemination of the results of the working group.

Other bilateral or multilateral initiatives

Interest in fostering cooperation between Venezuela and Suriname was also expressed.

It was reported that Suriname and Guyana were preparing a concept agreement on fishing, to cover Guyana’s artisanal fishing activities in Suriname.

Guyana and Trinidad are currently discussing a possible agreement to enable vessels from Trinidad and Tobago to fish for snapper resources and associated species in Guyana.

It was strongly recommended that some protocol on collection of detailed data on landings and effort, including size structure of catches, should be an integral part of such agreements to enable the host country to undertake assessments of the status of the stock.

It was reported that during the CFRAMP extension, the programme would be working with the CARICOM countries to establish a regional fisheries mechanism to provide the services determined by these countries.
INTER-SESSIONAL ACTIVITIES

Priorities for intersessional work

There was considerable discussion on allocating responsibilities for undertaking growth studies on the key fish species. It was agreed that CFRAMP would initiate contact between CEPNOR (Brazil) and IMA (Trinidad) on cooperation in age and growth studies on selected groundfish species.

Most of the 10 priority species had been, were being, or would be, studied by at least one of the countries, as indicated on the list below, where the letters indicate the first letter of each country that has, is or will be working on the species.

- Whitemouth croaker: Micropogonias furnieri (T; V)
- King weakfish: Macrodon ancyodon (B; V; G)
- Acoupa weakfish: Cynoscion acoupa (B)
- Jamaica weakfish: Cynoscion jamaicensis (T)
- Green weakfish: Cynoscion virescens (V; S)
- Smalleye croaker: Nebris microps (V; S)
- Gillbacker sea catfish: Arius parkeri
- Crucifix sea catfish: Arius proops
- Lane snapper: Lutjanus synagris (T; V)
- Southern red snapper: Lutjanus purpureus (B; V)

The Directors agreed to use the above list to identify others working on species of common interest, so as to exchange data and expertise and to avoid duplication as far as possible. In this way it is hoped that as many species as possible will be covered during this inter-sessional period.

Another inter-sessional activity already referred to was the Snapper Task Group.

Dissemination of results to stakeholders

It was suggested that dissemination of results to stakeholders could be done through national workshops and that FAO, through the FISHCODE Project and possibly CFRAMP could send one or more representatives to participate in this and discuss the aims of the project and aspects of fisheries management. This would require that the workshops were held in sequence to minimise travel costs for those from outside the region.

The difficulties of translating technical information into terms that could be understood by the fishers were emphasised, as well as the difficulties associated with reaching the widely dispersed artisanal fishers. Producing a video of appropriate talks and presentations and the use of posters and pamphlets were suggested as possible means of reaching wider audiences.

It was agreed that FAO would liaise with the countries and attempt to organise a regional series of national meetings/workshops involving all the countries who wished to participate. It would be left up to each country to decide on the format of the meetings and the participants. It was agreed that this would be arranged for March 2000.
ANY OTHER BUSINESS

- Review of current data collection programmes The series of workshops, along with CFRAMP’s activities in some of the countries had led to substantial increases in data collection. This had been invaluable in making progress in the assessment of the stocks and fisheries. However, it was important periodically to review the data collection systems and to ensure that they were cost-effective and appropriate for the assessment and management needs. It was important that data collection systems were self-sustainable and not dependent on external funding.

- It was suggested that one or more presentations on the bio-economic analyses undertaken at this workshop should be given at the GEF Meeting in Costa Rica in January 2000. Joel Prado, FAO, would co-ordinate this.

- It was pointed out that many participants at this workshop had been unable to complete the preparations requested of them and had reported that lack of time in the lead up to the workshop had prevented them from achieving this. The Directors undertook to examine the workload of the participants and ensure that they had adequate time for intersessional activities.

- Venezuela made a preliminary offer to host the 2000 Workshop, subject to approval from the appropriate authorities. They indicated that they would be able to provide a definite answer within two months. The CFRAMP and FAO organisers expressed their thanks to Venezuela for this expression of interest.

- The Directors thanked FAO and CFRAMP for the work done at the workshop and for the good progress made assessing the resources and fisheries of the Brazil-Guianas shelf, as well as for providing this opportunity for them to meet and discuss issues of common concern.
21 REFERENCES


Booth, J A., 1999. An introduction to multifishery-multispecies per-recruit modelling that incorporates parameter variability into the assessment framework. Department of Ichthyology and Fisheries Science, Rhodes University, South Africa. 9p


Chakalall, B and Dragovich, 1980. The artisanal fishery of Guyana. Southeast Fisheries Center, Miami, USA. (Ms.),27p


Fischer, W., 1978. FAO Species Identification Sheets for Fishery Purposes. Western Central Atlantic Fishing Area 31. Volume VI.


Shim, D.J., 1981. A contribution of the biology of Cynoscion jamaicensis (Pisces: Sciaenidae) in the coastal waters of Trinidad. Thesis: University of the West Indies, St. Augustine, (Trinidad and Tobago). M. Phil. University of the West Indies; St Augustine (Trinidad and Tobago). 148 p.

Shotton, R., 1995. Attitudes to risk relative to decisions on levels of fish harvest. ICES CM T: 54. ICES, Copenhagen.


SUDEPE, 1986. Relatório da II Reunião do Grupo Permanente de Estudos (GPE) de camarão da costa Norte do Brasil – Subgrupo de biologia pesqueira e tecnologia de pesca – realizada no período de 12 a 15/05, em Belém/Pa. SUDEPE/PDP (mimeo)


LIST OF PARTICIPANTS

SCIENTISTS

BRAZIL

Mr José Augusto Negreiros Aragão
Brasilia
e-mail: aragao@mcanet.com.br

Mr Dennys Diniz Bezerra
Fishing Engineer
Instituto Brasileiro do Meio Ambiente
e dos Recursos Naturais Renovaveis
CEPNOR, Campus FCAP, Av. Perimetral
s/n, CEP 55.077.530, Belém - Pará
Tel: (0055-91) 274 1237
Fax: (0055-91) 274 1429
e-mail : dennysdiniz@hotmail.com

Mr Mutsuo Asano Filho
Fishing Engineer
Instituto Brasileiro do Meio Ambiente
e dos Recursos Naturais Renovaveis
CEPNOR, Campus FCAP, Av. Perimetral
s/n, CEP 55.077.530, Belém - Pará
Tel: (0055-91) 274 1237
Fax: (0055-91) 274 1429
e-mail: mutsuo7@hotmail.com

Ms Katia Cristina de Araujo Silva
Scientist
Instituto Brasileiro do Meio Ambiente
e dos Recursos Naturais Renovaveis
CEPNOR, Campus FCAP, Av. Perimetral
s/n, CEP 55.077.530, Belem - Para
Tel: (0055-91) 274 1237
Fax: (0055-91) 274 1429
e-mail: ksilva@ibama.gov.br

Ms Rosália Furtado Cutrim Souza
Fishing Engineer
Instituto Brasileiro do Meio Ambiente
e dos Recursos Naturais Renovaveis
CEPNOR, Campus FCAP, Av. Perimetral
s/n, CEP 55.077.530, Belém - Pará
Tel: (0055-91) 274 1237
Fax: (0055-91) 274 1429
e-mail : rcutrim@ibama.gov.br

FRENCH GUIANA

Mr Anatole Charuau
Délégué Régional
IFREMER, Délégation de Guyane
Domaine de Suzini
B.P. No. 477
97331 Cayenne Cedex
Tel: (00594) 30 22 00
Fax: (00594) 30 80 31
e-mail: acharuau@ifremer.fr

GUYANA

Ms Angela Hackett
Fisheries Officer
Fisheries Department
Ministry of Fisheries, Crops & Livestock
18 Brickdam Werk-en-Rust
Georgetown
Tel: (592) 2 64398
Fax: (592) 2 59552
e-mail: guyfish@solutions2000.net

Ms Dawn Shepherd
Fisheries Officer
Department of Fisheries
Ministry of Fisheries, Crops & Livestock
18 Brickdam, Stabroek
Georgetown
Tel: (00592) 2 64398
Fax: (00592) 2 59552
e-mail: guyfish@solutions2000.net

JAMAICA

Ms Avery Galbraith
Fisheries Officer, Fisheries Division
Ministry of Agriculture
Marcus Garvey Drive, Kingston
Tel: (00876) 923 8811
Fax: (00876) 923 8811
e-mail: fish..div@cwjamaica.com
SURINAME

Mr Pierre Charlier
Rue des Chirennes No. 31
5560 Houyet,
Belgium
Tel: (32) 82 666667
e-mail: pierrecharlier@win.be

Mr Mario IJspol
Fisheries Division, Ministry of Agriculture, Animal Husbandry & Fisheries
P.O. Box 2957, Cornelis Jongbawstraat 50
Paramaribo. Tel: (597) 4 76741/72233/434560
Fax: (597) 4 24441

TRINIDAD & TOBAGO

Ms Lara Ferreira
Fisheries Officer
Fisheries Division
Ministry of Agriculture, Land & Marine Resources
Ground Floor, NHA Building
South Quay, Port of Spain
Tel: (868) 634 4504/5
Fax: (868) 634 4488
e-mail: mfau2fd@tstt.net.tt

Ms Suzuette Soomai
Fisheries Officer, Fisheries Division
Ministry of Agriculture, Land & Marine Resources
Ground Floor, NHA Building
South Quay, Port of Spain
Tel: (868) 634 4504/5
Fax: (868) 634 4488
e-mail: mfaudfd@tstt.net.tt

VENEZUELA

Mr José Javier Alió Mingo
Researcher
Fondo Nacional de Investigaciones Agropecuarias (FONAIAP)
Ciape Sucre, Avenida Carupano Caiguire,
Apdo. No. 236, Cumaná 6101
Tel: +58-93-317557
Fax: +58-93-317557
e-mail: jalio@sucre.edu.udo.ve

VENEZUELA

Mr Luis Marcano
Researcher
Fondo Nacional de Investigaciones Agropecuarias (FONAIAP)
Ciape Sucre, Avenida Carupano Caiguire,
Apdo. No. 236, Cumaná 6101
Tel: +58-93-317557
Fax: +58-93-317557
e-mail: ciapes@sucre.edu.udo.ve

DIRECTORS
(Participating in Directors meeting 8 and 9 June 1999)

BRAZIL

Mr José Maria Gadelha
Superintendent of IBAMA
Regional Office of Pará, IBAMA/SEDE
Av. Conselheiro Furtado, nº 1306
CEP. 66035-350 – Belém/Pa
Tel: (55-91) 241 2621
Tel: (55-91) 223 1299

Ms Marilia Marreco
President of IBAMA
IBAMA
Av. SAIN L-4
Bloco - "B" - Ed. Sede
CEP. 70.800-200
Brasilia - DF
Fax: (55-61) 322.10.58/316.10.25

Mr Italo José Vieira
IBAMA/CEPNOR, Campus FCAP
Av. Perimetral s/n, CEP 55.077.530,
Belém - Pará
Tel: (55-91) 274 1237
Fax: (55-91) 274 1429
e-mails: ijvieira@hotmail.com

ijvieira@interconect.com.br
GUYANA
Mr Reuben Charles
Chief Fisheries Officer,
Fisheries Department,
Ministry of Fisheries, Crops and Livestock,
18 Brickdam
Werk-en-Rust, Georgetown
Tel: (592) 2 64398/59559
Fax: (592) 2 59552/59551
e-mail: guyfish@solutions2000.net

SURINAME
Mr Rene Lieveld
Director of Fisheries, Fisheries Division
Ministry of Agriculture, Animal Husbandry & Fisheries
P.O. Box 2957, Cornelis
Jongbawstraat 50, Paramaribo
Tel: (597) 476741/472233
Fax: (597) 424441

TRINIDAD AND TOBAGO
Ms Ann Marie Jobity
Acting Director of Fisheries, Fisheries Division
Ministry of Agriculture, Land and Marine Resources
Ground Floor, NHA Building
South Quay, Port of Spain
Tel: (868) 623 5989
Fax: (868) 623 8542
e-mail: mfaud2fd@tstt.net.tt

VENEZUELA
Mr Gustavo Lagarde
Director de Administracion y Control Pesquero
Servicio Autónomo de los Recursos Pesqueros y Acuícolas (SARPA)
Ministerio de Agricultura y Cría
Torre Este, Piso 10
Caracas 1010
Tel: (0058-2) 5781855 or 5090383-4
Fax: (0058-2) 5781855 or 5743587
e-mail: sarpaplatino.gov.ve

CFRAMP
Mr Terrence Phillips
RAU Leader/Biologist
Shrimp & Groundfish Resource Assessment Unit
P.O. Box 3150
Carenage Post Office, Carenage
Trinidad & Tobago
Tel: (809) 634 4528/4530
Fax: (809) 634 4549
e-mail: tphillips@wow.net

FAO CONSULTANTS
Mr Anthony Booth
Lecturer
Dept. Ichthyology and Fisheries Science
Rhodes University
P.O.Box 94
Grahamstown 6140
South Africa
Tel.: +27-46-6227420
Fax: +27-46-6224827
e-mail: t.booth@ru.ac.za

Mr David Die
RSMAS
University of Miami
4600 Rickenbacker Causeway
Miami FLA 33149
USA
Tel: (1 305) 361 4607
Fax: (1 305) 361 4457
e-mail: DDie@rsmas.miami.edu

Mr Nelson M. Ehrhardt
Professor
Rosenstiel School of Marine & Atmospheric Science (RSMAS)
Division of Marine Biology & Fisheries
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149-1098, U.S.A.
Tel: (001-305) 361 4741
Fax: (001-305) 361 4902
e-mail: nehrhardt@rsmas.miami.edu
FAO CONSULTANTS
Mr Juan-Carlos Seijo
Rector
Centro Marista de Estudios Superiores, A.C.
Km 7 Antigua Carretera Mérida-Progreso x Av. Marcelino Champagnat
Mérida, 97110 Yucatán, México
Tels: (52-99) 81-52-25
Fax: (52-99) 81-52-43
e-mail: jseijo@cemaes.marista.edu.mx

SECRETARIAT
Mr. Arnaldo P. S. Costa, Coordinator
Mr. Otoniel Nylander, Driver
Ms Ellen C. B. Tavares, Secretary

C/o CEPNOR
Av. Tancredo Neves s/n
Terra Firme, Campus da FCAP
6607-530 Belém/Pará/Brazil
Tel: (55) 91 274 1237
Fax: (55) 91 274 1429
e-mail: ijvieira@hotmail.com
ijvieira@interconect.com.br

Mr Bisessar Chakalall
Regional Fisheries Officer
FAO Sub-Regional Office for the Caribbean (SLAC)
P.O. Box 631-C, Bridgetown
Barbados
Tel: (246) 426 7110
Fax: (246) 427 6075
e-mail: bisessar.chakalall@field.fao.org

Ms Luzia Jucá, Bi-lingual secretary and Interpreter

Mr Kevern Cochrane
Technical Secretary: WECAFC
Fishery Resources Officer
Fishery Resources Division, FAO
Viale delle Terme di Caracalla
00100 Rome, Italy
Tel: (003906) 5705 6109
Fax: (003906) 57056500
e-mail: kevern.cochrane@fao.org.

Mr Joel Prado
Fisheries Industry Officer
Fisheries Industry Division
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy
Tel: +39-06-57054931
Fax: +39-06-57055188
e-mail: joel.prado@fao.org
This document assembles the reports on the marine shrimp and groundfish fisheries of northern Brazil, French Guiana, Guyana, Suriname, Trinidad and Tobago and eastern Venezuela prepared for and during the third Workshop on the assessment of shrimp and groundfish fisheries on the Brazil-Guianas Shelf, held Belém, Brazil, 24 May to 10 June 1999.

Section 2 includes papers dealing with overviews of important shrimp and groundfish resources and their fisheries. Section 3 deals with fisheries management practices in the context of the Code of Conduct for Responsible Fisheries. Sections 4 and 5 contain papers on stock assessment methodology applicable in the region.

Sections 6 to 18 deal with national or sub-regional assessments of selected shrimp and groundfish fisheries. Section 17 also deals with the bio-economics of shrimp fisheries in general and in particular with seasonality, risk and uncertainty.

Section 19 is a report of a task group on snapper fisheries of the Brazil-Guianas Shelf, it includes a discussion on future management measures.

Section 20 contains a report on a meeting where the results of assessments were presented to the fisheries managers and recommendations were drafted for follow-up activities.

The names and addresses of the various authors can be obtained from the section headings and the list of participants in Section 22.

There is an extensive list of references in Section 21.