Japan International Cooperation Agency (JICA)
Museu Paraense Emilio Goeldi (MPEG)
Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis (IBAMA)

# THE FISHERY RESOURCES STUDY OF THE AMAZON AND TOCANTINS RIVER MOUTH AREAS IN THE FEDERATIVE REPUBLIC OF BRAZIL

## FINAL REPORT SUMMARY

JUNE 1998

SANYO TECHNO MARINE, INC.

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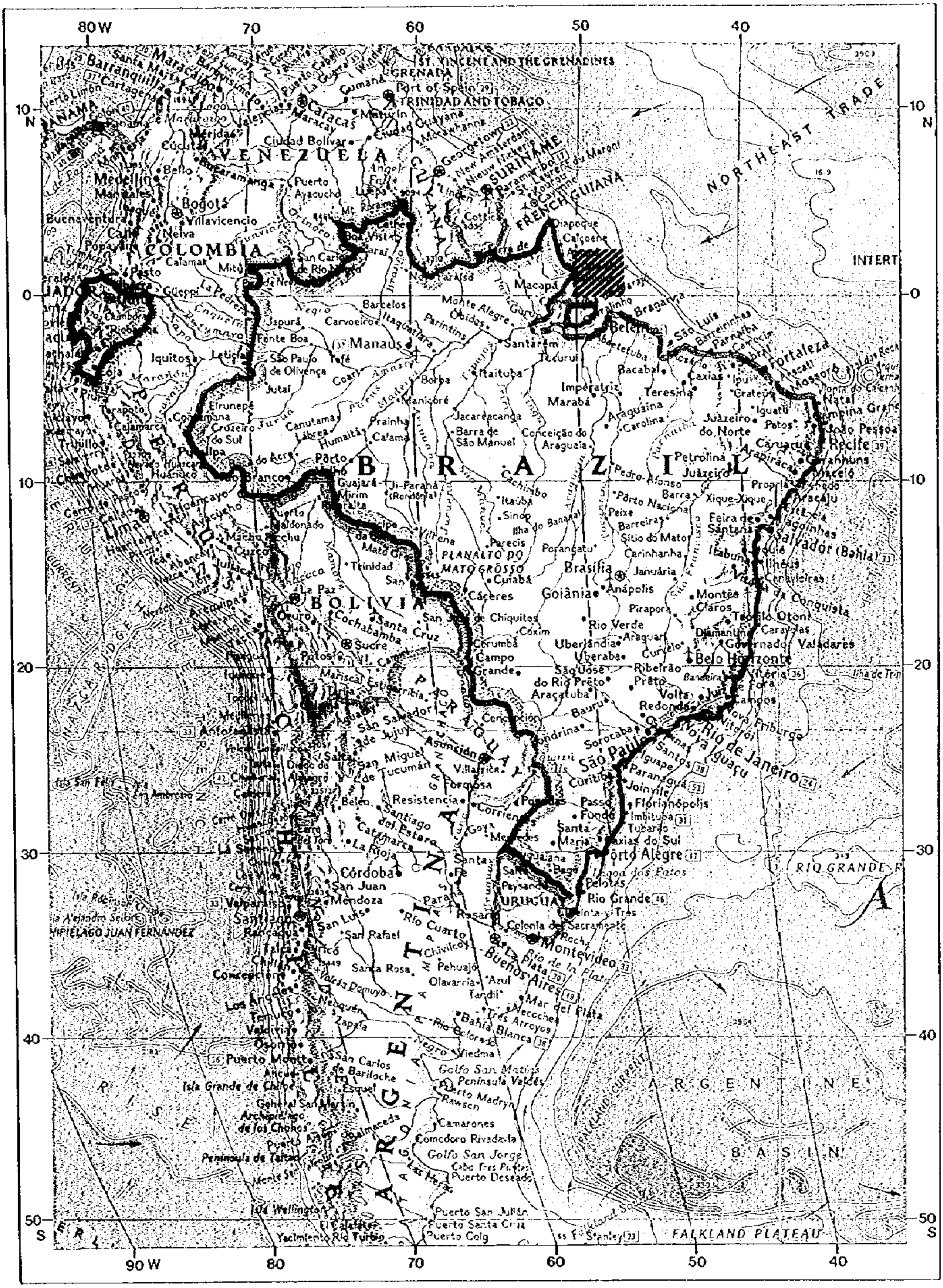
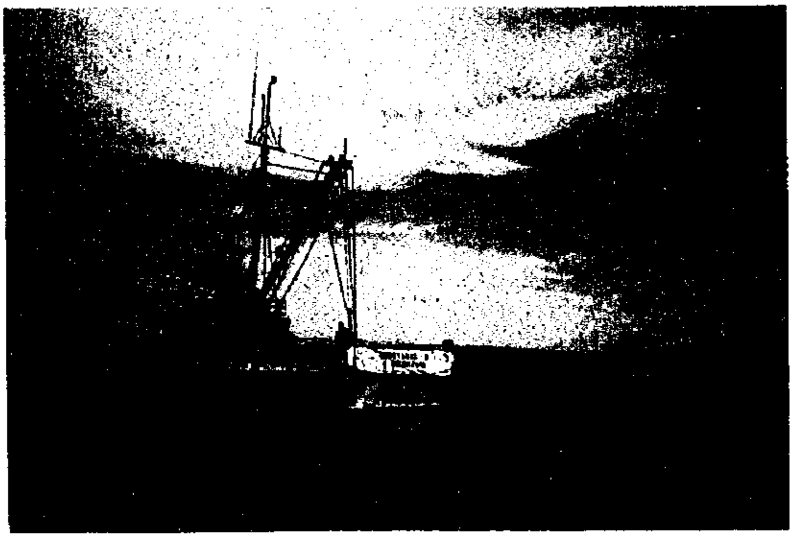
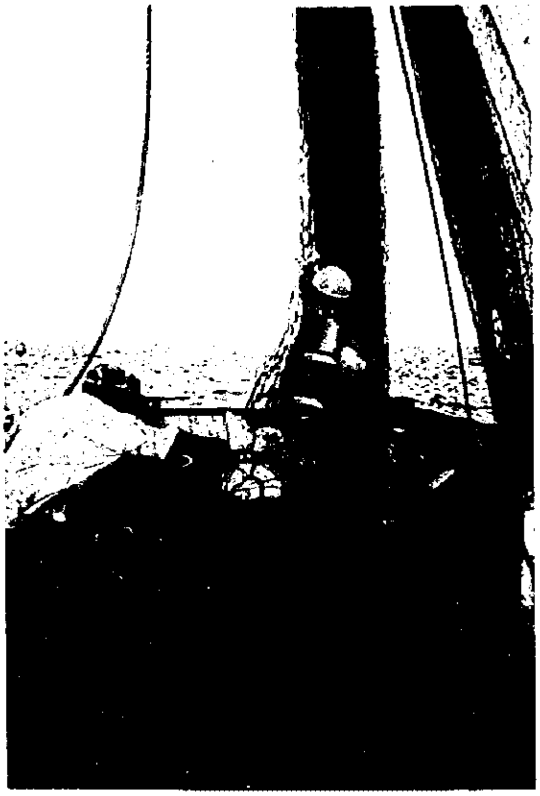



The map of the Federative Republic of Brazil and Sea-Borne Survey Area



Crustamar V hauling up the trawl net



Trawl net attached the transmitter of a net recorder

Catch in cod-end (mainly piramutaba)

The receiver of a net recorder

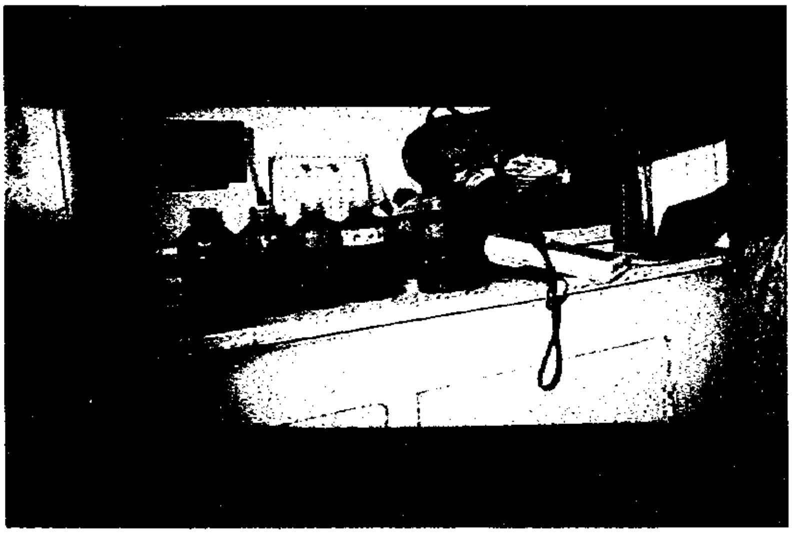
Sorting fish

Multi-item biological measurement

Vertical measurement of water temperature and salinity with a STD

Body length composition measured by measuring-card punching method

Preliminary tagging experiment



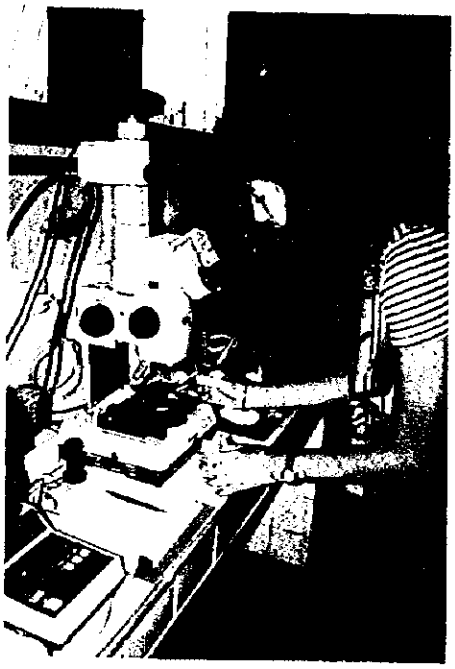
Measuring of surface water pH with a pH-meter

Sea-Borne Survey

Extraction of otoliths from pescadinha gó

Embedding otoliths into plastic resin

Preparation for 1mm-thick slices of otoliths



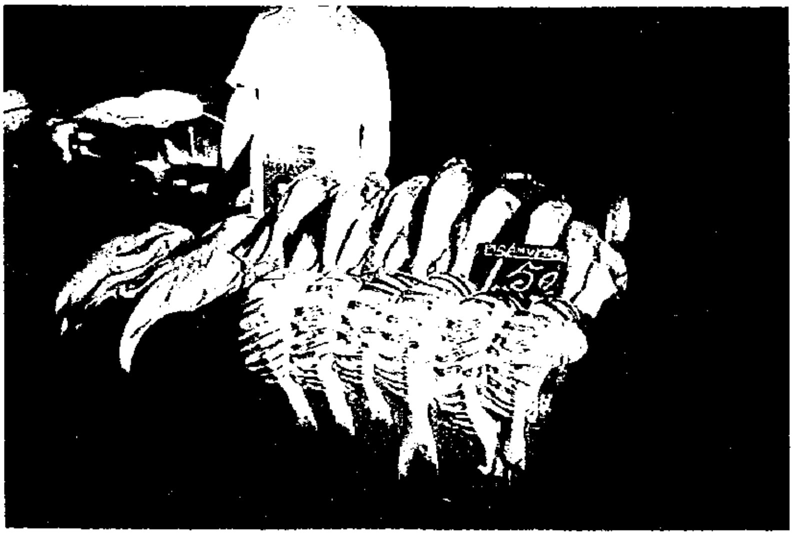
Measurement of rings

Vertebra (centrum) of piramutaba (FL: 575mm)

Otolith of pescada branca (TL: 503mm)

Piramutaba processed in the industrial fishery company

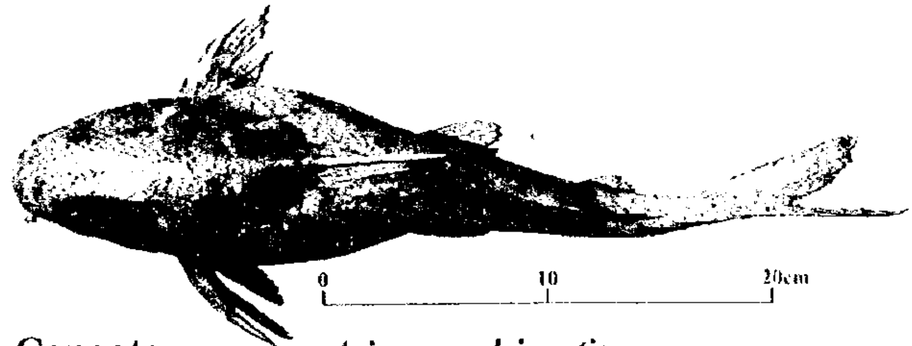
Body length composition survey at the landing site



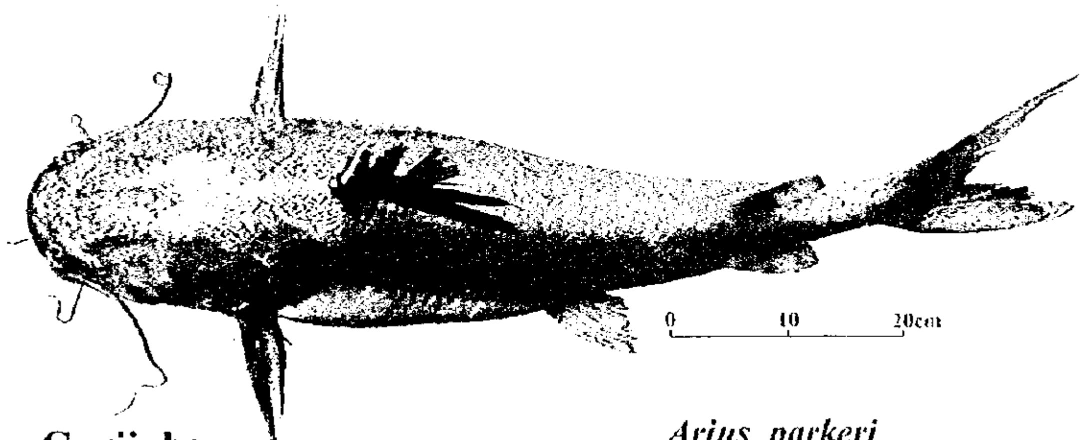
Piramutaba sold at a Ver o Peso

Interview survey

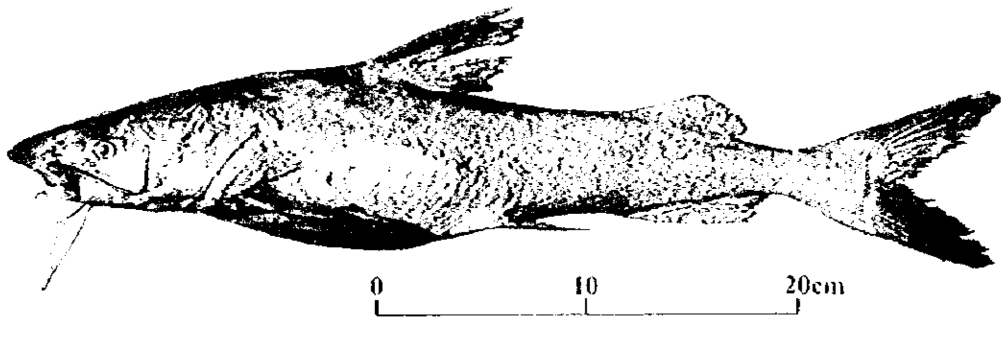
Artisanal fishermen colony in Mosqueiro Island



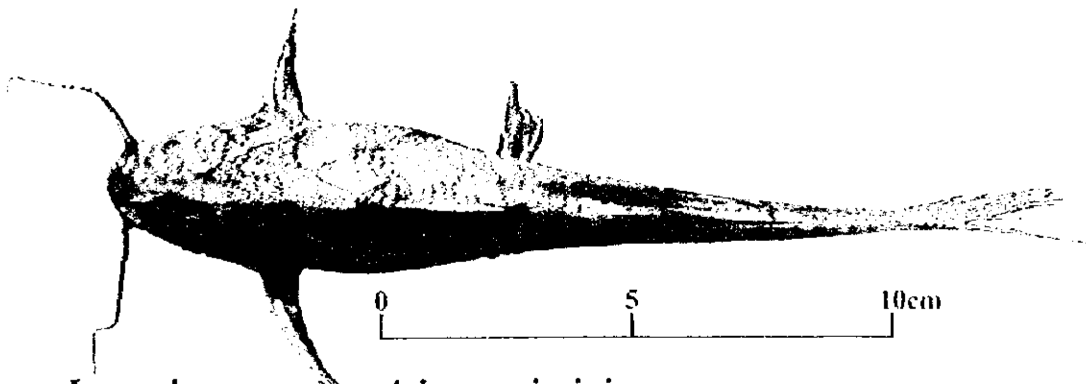

**Cangata** *Arius quadriscutis*




**Gurijuba** *Arius parkeri*

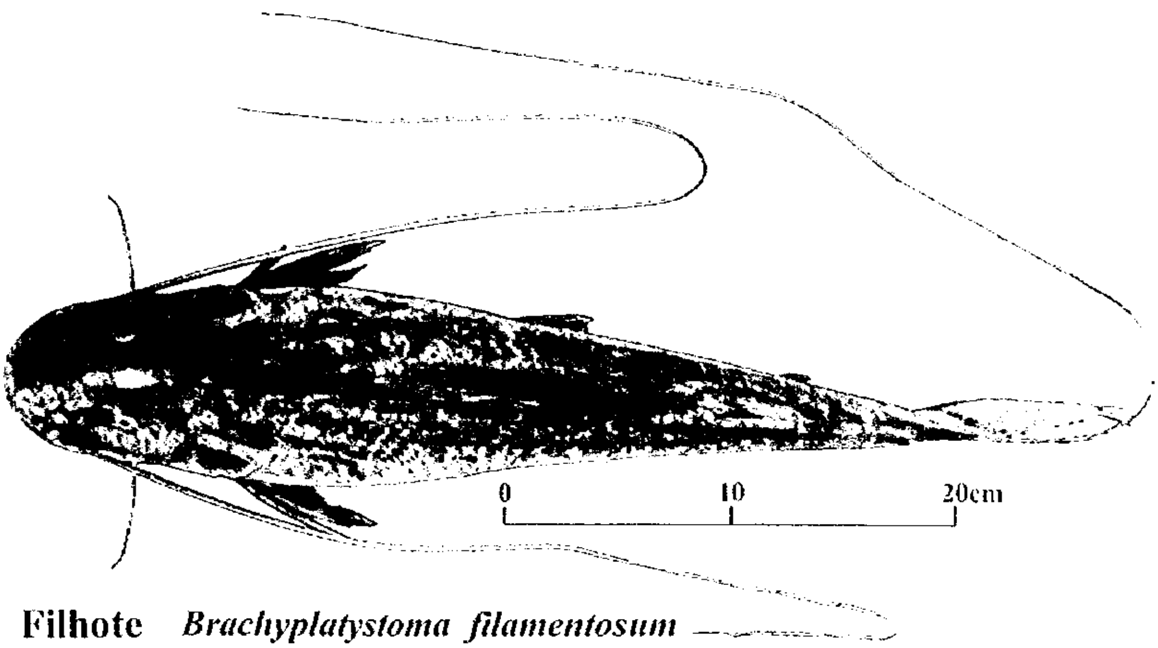



**Cambeua** *Arius grandicassis*

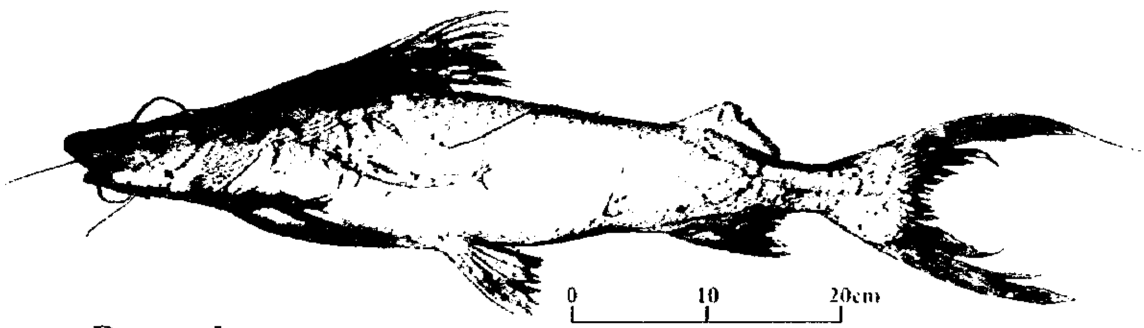



**Jurupiranga** *Arius rugispinis*

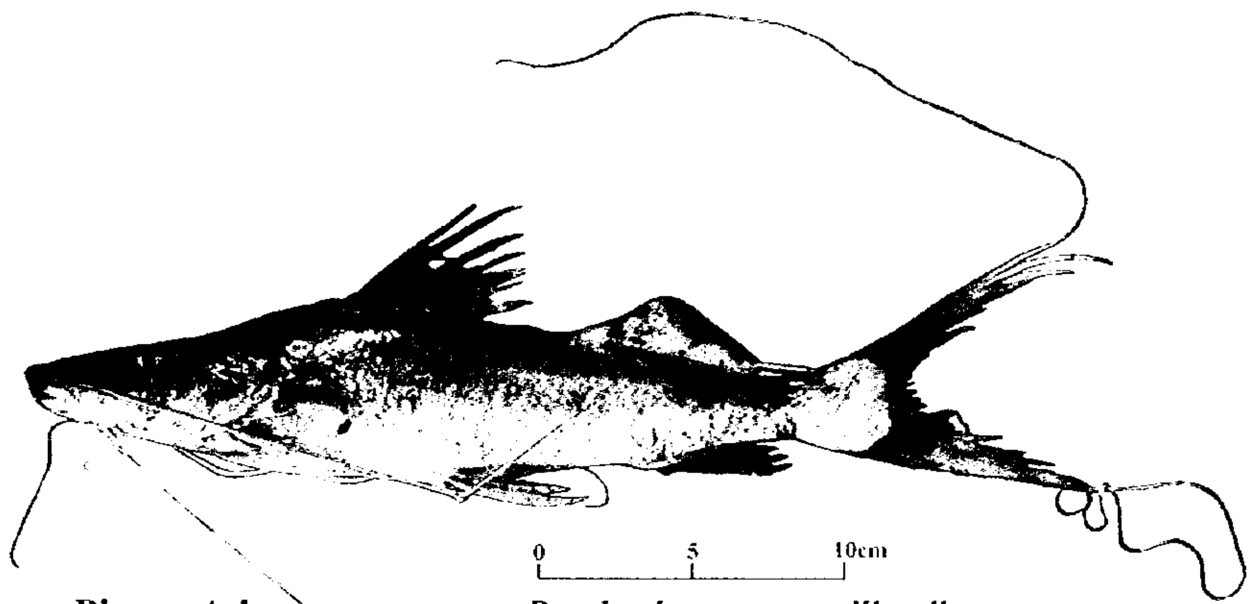
Key fish species and dominant species with respect to estimated stock size



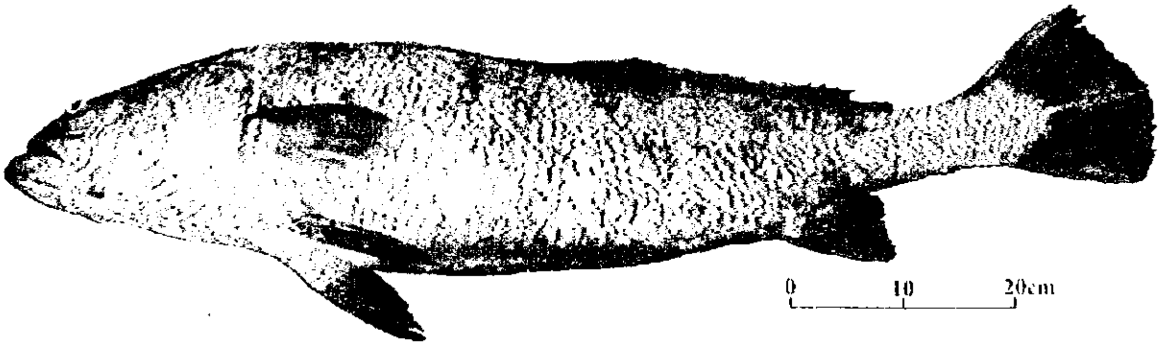

**Filhote** ***Brachyplatystoma filamentosum***



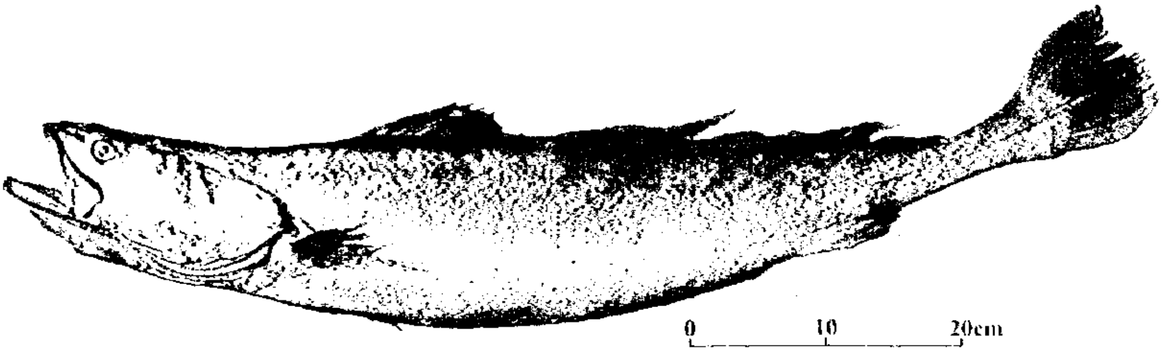

**Dourada** ***Brachyplatystoma flavicans***



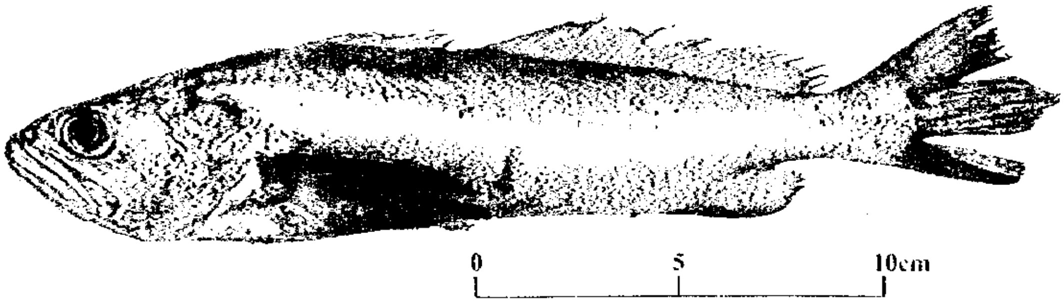

**Piramutaba** ***Brachyplatystoma vaillantii***



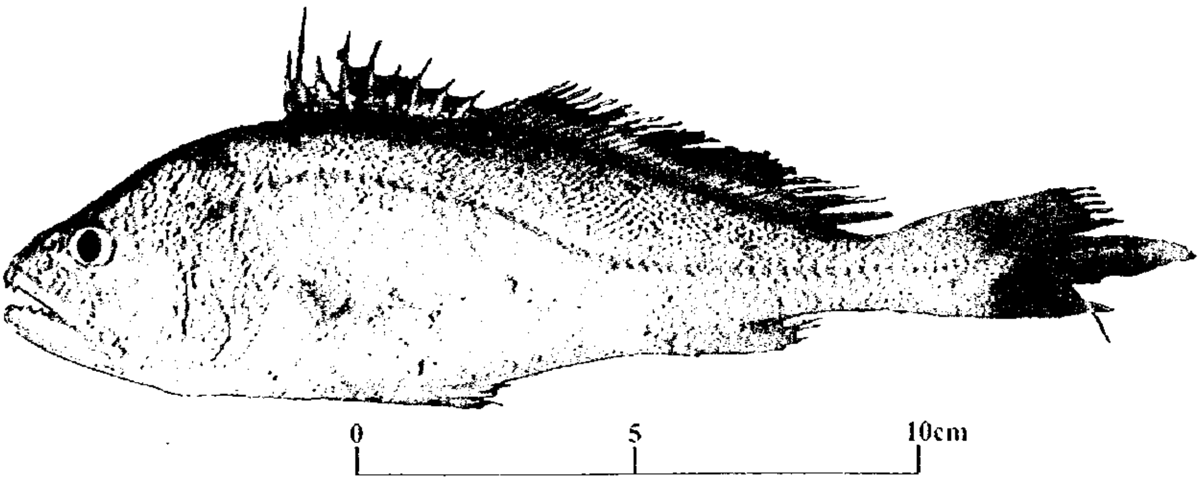

**Pescada amarela** *Cynoscion acoupa*




**Corvina** *Cynoscion virescens*




**Pescadinha go** *Macrodon ancylodon*




**Pescada branca** *Plagioscion squamosissimus*

Key fish species and dominant species with respect to estimated stock size

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# 1. INTRODUCTION

The Amazon is the world's largest river in volume of freshwater outflow, and accounts for about 15% of the total freshwater discharged from rivers into the ocean in the whole planet (Baumgartner & Reichel, 1975). The Amazon River discharge typically ranges from 80,000 $m^3/s$ in November to 250,000 $m^3/s$ in May, and the Amazon River discharges a mean value of $1.8 \times 10^5$ m/s of fresh water onto the North Brazilian Shelf at the equator (Oltman, 1968; Figueiredo et al., 1991). The discharge is large enough to prevent the intrusion of sea water into the river mouth throughout the year. The riverine water meets the sea water for the first time in a front zone formed hundreds of kilometers along the shallow continental shelf, located between the isobaths of 10 and 20 m, some 100–200 km seaward of the mouth (Gibbs, 1970; Nittrouer et al., 1986; Geyer et al., 1991). Because the Amazonian Estuary has been pushed out onto the continental shelf and the complex and very active oceanic environment has been formed, this area is expected to have a very good potential of productivity for fishery resources.

Supported by incentives from the Brazilian government, fishery industries were established in the 1960s around the city of Belém, State of Pará, focusing on piramutaba — a fish that forms large schools in freshwater in the Amazonian Estuary. But piramutaba catches reached a maximum in 1977 and have been declining ever since, indicating overexploitation. However, no resources survey or study has been conducted so far on piramutaba or other commercially important species in the Amazonian Estuary and nearby coastal waters.

For this reason, in 1994 Brazil requested Japan the implementation of a study with the goal of assessing the present status of fishery resources in the Amazonian Estuary and establishing the guidelines for their management towards a sustainable development. As a result, a three-way joint effort including the Japan International Cooperation Agency (JICA), the Emilio Goeldi Museum in the State of Pará / National Council of Research and Technological Development (MPEG / CNPq), the Center for Fishery Studies in the Northern Region / Brazilian Institute for the Environment and Renewable Natural Resources / (CEPNOR / IBAMA), conducted this resources study of the Amazonian Estuary in the rainy and dry seasons of 1996 (Phase 1) and 1997 (Phase 2).

The study itself comprised (1) a Sea-Borne Survey; (2) a Laboratory Survey; and (3) a Landing Site Survey. Phase 1 Sea-Borne Survey was to have been carried out in the 1996 Rainy Season but was instead cancelled due to a number of aspects concerning Brazil's domestic affairs. As the ultimate objective was to establish guidelines for the management of fishery resources, data obtained from these three surveys was analyzed to the extent of their possibilities (Fig. 1).

This summary is an abridgment of each chapter of the Final Report of the Fisheries Resources Study of the Amazon and Tocantins River Mouth Areas. Contents are perhaps simplified, but include the necessary minimum for the comprehension of the study.

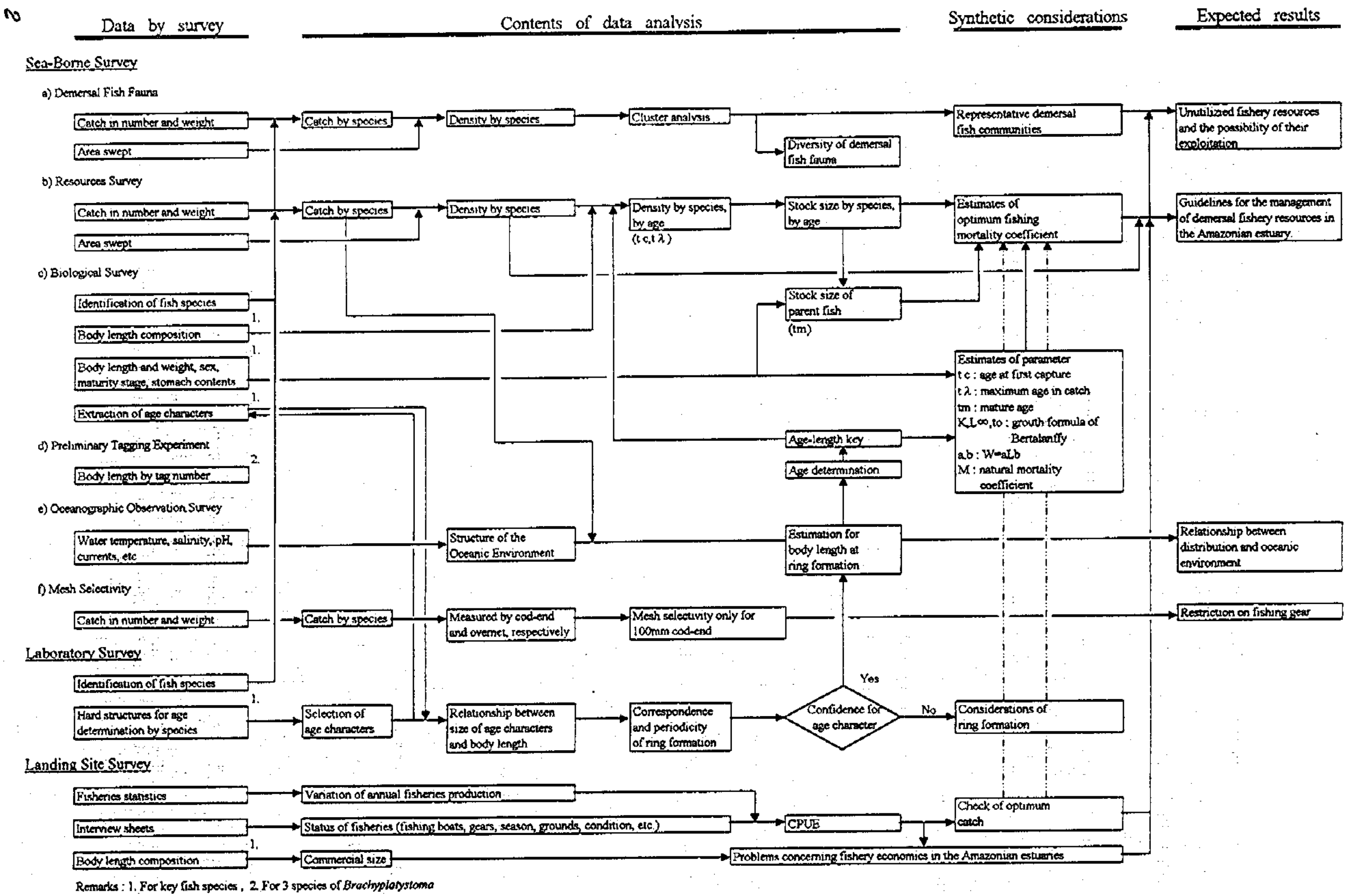



Figure 1. Analytical flow of data obtained from each survey

# 2. OUTLINE OF THE STUDY

## 2.1. Objectives of the Study

The objectives of the study were the following:

a) To evaluate the stock size of piramutaba (laolao catfish) *Brachyplatystoma vaillantii*, dourada *B. flavicans*, filhote (kumakuma catfish) *B. filamentosum*, pescada-branca *Plagioscion squamosissimus*, pescada-amarela (acoupa weakfish) *Cynoscion acoupa*, pescadinha-gó (king weakfish) *Macrodon ancylodon* and gurijuba (gillbacker sea catfish) *Arius parkeri*;

b) To gather data on geographical distribution, size composition and other biological characteristics for the above seven species;

c) To establish techniques for age determination for the above seven species;

d) To gather information on the oceanic environment such as water temperature and salinity;

e) To understand the current situation and problems of fisheries;

f) To evaluate the present status of exploited fishery resources, study the possibilities of utilization and exploitation of unutilized and unexploited fishery resources, and lay out guidelines for the management of demersal fishery resources.

## 2.2. Study Area

The Sea-Borne Survey was confined to the area comprised within latitudes 0°05'N and 2°30'N and longitudes 47° 50' W and 50° 30' W, offshore from a line connecting Cabo Norte and Cabo Maguari, between the depth lines of 5 m and 50 m (Fig. 2).

The Landing Site Survey collected data at fishing villages, fish landing ports and fishery markets in the Amazon River and Estuary areas.

## 2.3. Survey Dates and Periods

Survey dates and periods were as per Table 1.

Table 1. Survey dates and periods.

| Year (Phase) | Season | Sea-Borne Survey | Laboratory Survey | Landing Site Survey |
|---|---|---|---|---|
| 1996 (1) | Rainy | (discontinuance) | 18 Feb. – 19 Apr. | 27 Feb. – 2 Apr. |
| | Dry | 1st leg : 8 Aug. – 22 Aug. | 9 Sept. – 1 Nov. | 5 Aug. – 7 Sept. |
| | | 2nd leg : 28 Aug. – 10 Sept. | | |
| | | 3rd leg : 17 Sept. – 30 Sept. | | |
| 1997 (2) | Rainy | 1st leg : 7 Mar. – 20 Mar. | 2 Apr. – 21 May | 3 Mar. – 24 Mar. |
| | | 2nd leg : 27 Mar. – 10 Apr. | | |
| | | 3rd leg : 16 Apr. – 28 Apr. | | |
| | Dry | 1st leg : 8 Aug. – 22 Aug. | 5 Sept. – 6 Nov. | 4 Aug. – 12 Aug. |
| | | 2nd leg : 28 Aug. – 8 Sept. | | |
| | | 3rd leg : 17 Sept. – 26 Sept. | | |

## 2.4. Survey Vessels

Two piramutaba fishing vessels, 'Marilu' (75 GRT, 350 HP, 22 m in length) and 'Crustamar' (99 GRT, 375 HP, 22 m in length), were renovated for use as research vessels for JICA.

## 2.5. Fishing Gear Employed

A bottom trawl net with a 58.2 m-long ground rope and a 50.2 m-long head rope was employed, similar to those currently operated by the fishery industries for piramutaba. In addition, a covernet was attached around the cod-end in order to study the escapement rate of young and small fish through the latter.

## 2.6. Participating Agencies

The following agencies took part in the study:

a) Sea-Borne Survey: Sanyo Techno-Marine, Inc. (STM)/JICA, MPEG/CNPq, CEPNOR/IBAMA, The Brazilian Ministry of the Navy, Central Pesca Ltd.

b) Laboratory Survey: STM/JICA, MPEG/CNPq, CEPNOR/IBAMA.

c) Landing Site Survey: STM/JICA, MPEG/CNPq.

# 3. METHODOLOGY

## 3.1. Sea-Borne Survey

**a) Resources Survey**

The survey area was stratified into three strata ( the isobath ranges of 5-10 m, 10-20 m and 20-50 m ), and divided into 1,330 square blocks of 3 minutes in latitude and longitude. Number of planned trawl stations was 120 in each seasonal survey, and these trawl stations were allocated in proportion to the area of these three strata. Trawl stations (blocks) were selected through the random sampling method as sampling units and trawling was conducted for 30 minutes in blocks (Table 2). The positions of the planned trawl stations for the 1996 Phase I Dry Season are shown in Figure 2 as an example of the randomly selected stations.

**Table 2. Area, number of blocks and number of trawl stations per stratum.**

| Stratum (isobath range) | Area in $km^2$ | Number of 3'-square blocks | Planned number of trawl stations |
|---|---|---|---|
| 5 - 10m | 17,200 | 539 | 55 |
| 10 - 20m | 15,700 | 504 | 50 |
| 20 - 50m | 9,300 | 287 | 15[a] |
| Total | 42,200 | 1,330 | 120 |

[a] In the case of allocation of stations in stratum 20 - 50m, the area of this stratum was weighted by a factor of 0.5.

Stock size was estimated through the areal expansion method. For this, total catch of both cod-end and covernet was considered. Stock size, standard error and coefficient of variation were calculated according to the following formulae:

$$dij = Xij / aij$$

$$Bi = Ai \cdot \overline{di}$$

$$SBi = Ai \frac{Sdi}{\sqrt{ni}}$$

$$B = \sum Bi$$

$$SB = \sqrt{\sum SBi^2}$$

$$CV = SB / B \times 100$$

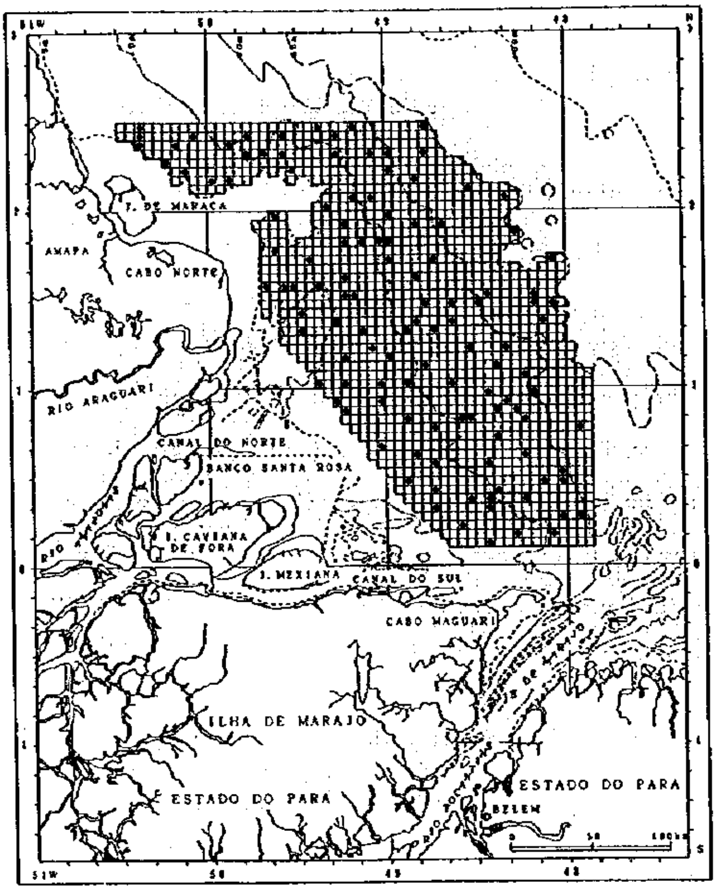



**Figure 2. Sea-Borne Survey area, sampling units (blocks of 3-minute intervals in latitude and longitude) and positions of trawl stations determined by random sampling (Phase 1 Dry Season shown as example).**

where

- $d_{ij}$ : density at $j$-th station in $i$-th stratum (kg/km$^2$)
- $X_{ij}$ : catch at $j$-th station in $i$-th stratum (kg)
- $a_{ij}$ : area swept at $j$-th station in $i$-th stratum (km$^2$)
- $B_i$ : stock size in $i$-th stratum (kg)
- $A_i$ : area in $i$-th stratum (km$^2$)
- $\overline{d_i}$ : mean density for $i$-th stratum (kg/km$^2$)
- $SB_i$ : standard error of stock size in $i$-th stratum
- $Sd_i$ : standard deviation of density in $i$-th stratum
- $n_i$ : number of hauls in $i$-th stratum
- $B$ : overall stock size (kg)
- $SB$ : standard error of overall stock size
- $CV$ : coefficient of variation (%)

Area swept per haul was calculated as the product of the distance towed on the sea floor by the width between wing-nets. In this analysis, it was assumed that all the fish in the path of the trawl net were caught and that the herding effect of the pendant-warp was negligible. It was not possible to obtain information on the possible occurrence of fish above the level of the head rope (that is, 4–5 m above the sea floor), and the exclusion of such fish could lead to an underestimation of stock size.

**b) Biological Survey**

For each of the seven key fish species and in each trawl station, (1) a size distribution determination was planned for 100 specimens caught by cod-end and covernet and (2) a multi-item biological measurement was scheduled on 20 specimens, comprising the measurement of body length and body weight, sexing, determination of maturity stage in females, examination of stomach contents and extraction of structures for age determination.

**c) Preliminary Tagging Experiment**

A tagging experiment involving the three species of *Brachyplatystoma* was planned.

#### d) Oceanographic Observations

Vertical water temperature and salinity (via an STD), pH in the surface (via a pH meter) and current conditions in the some layers (via an acoustic Doppler current profiler) were measured at each trawl station. Weather conditions over the ocean were also recorded.

### 3.2. Laboratory Survey

#### a) Selection of Structures for Age Determination

The following hard structures were examined and compared for each of the key fish species to be selected for age determination: fin spines, vertebral centra, scales, otoliths and opercles.

#### b) Selection of Portions of the Fish Body to Be Sampled

For vertebral centra and scales among age characters (hard structures), the proper portion of the fish body to be sampled was examined.

#### c) Treatment and Processing of Age Characters

For each of the seven key fish species, age character samples were subjected to a number of treatment steps and properly processed.

#### d) Measurement of Rings

Among the sampled age characters, vertebral centra and otoliths showed comparatively clear rings, which were counted and had their radia measured.

### 3.3. Landing Site Survey

#### a) Collection of Fishery Statistics

From various fishery statistics collected, the fisheries situation was examined for Brazil as a whole, for the Northern Region of Brazil and for the State of Pará.

#### b) Interview Survey

An interview survey was conducted to examine the actual conditions of fisheries centered in the Amazonian Estuary, on aspects such as a profile of fisheries and their trends, the pricing of fishery products, the role of fishery brokers, etc.

#### c) Size Composition Survey

Commercial size distribution for the seven key fish species was surveyed.

# 4. DATA ACQUISITION

## 4.1. Sea-Borne Survey

**a) Resources Survey**

The number of trawl stations actually trawled was as follows: (1) Phase 1 (1996) — zero for the Rainy Season Survey, 111 for the Dry Season Survey (52 in the 5–10 m stratum, 47 in the 10–20 m stratum and 12 in the 20–50 m stratum); (2) Phase 2 (1997) — 120 for the Rainy Season Survey (respectively, 55, 52 and 13 in each of the strata) and 120 for the Dry Season Survey (respectively, 55, 50 and 15 in each of the strata). The actual positions of trawl stations agreed with the planned locations with a few exceptions.

Hauled distances and the width between wing-nets were recorded in all stations. These allowed for the calculation of mean values of area swept per haul, shown in Table 3.

**Table 3. Area swept per haul ($km^2$).**

| Area swept | Phase | | | |
|---|---|---|---|---|
| | 1 | | 2 | |
| | Rainy Season | Dry Season | Rainy Season | Dry Season |
| Mean | - | 0.08855 | 0.08837 | 0.07473 |
| Standard deviation | - | 0.02300 | 0.02797 | 0.02457 |
| Range | - | 0.03704 – 0.14468 | 0.04013 – 0.16438 | 0.02741 – 0.13538 |

The mean value of area swept per haul in the Phase 2 Dry Season Survey was some 0.014 $km^2$ smaller than in the two previous surveys. Also, mean net mouth height was 3.9 m in the Phase 2 Dry Season Survey — about 1 m lower than in the other surveys at 4.8 m and 4.7 m, respectively. This discrepancy may account for a slight difference in the estimation of stock size between the latest and the previous surveys.

**b) Biological Survey**

Table 4 shows the number of specimens of each key fish species whose size distribution was determined (body length composition data) and of those subjected to a multi-item biological measurement.

**Table 4. Number of specimens used in biological survey.**

| Key fish species | Phase 1 | | | | Phase 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Rainy Season | | Dry Season | | Rainy Season | | Dry Season | |
| | BLC | MIBMs | BLC | MIBMs | BLC | MIBMs | BLC | MIBMs |
| *Brachyplatystoma vaillantii* | - | - | 1,079 | 286 | 3,165 | 995 | 1,130 | 460 |
| *Brachyplatystoma flavicans* | - | - | 0 | 194 | 37 | 440 | 0 | 310 |
| *Brachyplatystoma filamentosum* | - | - | 0 | 3 | 0 | 12 | 0 | 3 |
| *Plagioscion squamosissimus* | - | - | 0 | 21 | 0 | 58 | 0 | 32 |
| *Cynoscion acoupa* | - | - | 0 | 12 | 0 | 17 | 0 | 30 |
| *Macrodon ancylodon* | - | - | 4,025 | 1,265 | 6,912 | 1,762 | 4,393 | 1,755 |
| *Arius parkeri* | - | - | 13 | 214 | 0 | 358 | 47 | 457 |

BLC : Body length composition ; MIBMs : Multi-item biological measurements

**c) Preliminary Tagging Experiments**

In Phase 2, experimental tagging was carried out in 9 stations in the Rainy Season Survey and in 7 in the Dry Season Survey. Release stations of tagged fish were located in the 5–10 m stratum in the offshore the Southern and Northern Channels (some points actually in the 10–20 m stratum in the Northern Channel front). The number of tagged and released specimens per species was as follows: piramutaba *Brachyplatystoma vaillantii*, 830 specimens (430 in the Rainy Season, 400 in the Dry Season); dourada *B. flavicans*, 172 specimens (169 in the Rainy Season, 3 in the Dry Season); and filhote *B. filamentosum*, 3 specimens (all in the Rainy Season). The total number of tagged and released specimens was 1,005 (602 in the Rainy Season, 403 in the Dry Season).

To the present, no tagged and released specimen has been recovered.

**d) Oceanographic Observations**

Data on vertical water temperature and salinity, pH in the surface and weather conditions were obtained for all trawl stations. However, water current direction and velocity was recorded only in 72 stations in the Phase 1 Dry Season Survey, and in 107 and 97 stations respectively in the Phase 2 Rainy Season and Dry Season Surveys.

## 4.2. Laboratory Survey

Table 5 shows the number of age character samples taken from individuals of the seven key fish species, and that of specimens used for measurements of rings.

**Table 5. Number of samples for age determination, with the number of specimens used for measurements of rings indicated in parentheses.**

| Key fish species | Age characters | Phase 1 | | Phase 2 | |
|---|---|---|---|---|---|
| | | Rainy Season | Dry Season | Rainy Season | Dry Season |
| *Brachyplatystoma vaillantii* | Vertebra | 5 | 207 | 497 (100) | 243 (132) |
| *Brachyplatystoma flavicans* | Vertebra | 2 | 169 | 362 ( 98) | 271 (100) |
| *Brachyplatystoma filamentosum* | Vertebra | 2 | 3 | 10 ( 10) | 3 ( 3) |
| *Plagioscion squamosissimus* | Otolith | 3 | 11 | 38 ( 38) | 33 ( 32) |
| *Cynoscion acoupa* | Otolith | 2 | 9 | 15 ( 15) | 30 ( 30) |
| *Macrodon ancylodon* | Otolith | 4 | - | - | 103 ( 51) |
| *Arius parkeri* | Vertebra | 1 | 187 | 334 (118) | 452 (118) |

## 4.3. Landing Site Survey

**a) Collection of Fishery Statistics**

Main fishery statistics collected through the survey comprised the 1980–1990 fishery statistics reports published by the Brazilian Institute of Geography and Statistics (IBGE) and the 1994 Camarão Norte e Piramutaba report issued by IBAMA.

**b) Interview Survey and/or Size Composition Survey**

Localities where either survey took place add up to 28 points centered around the Amazonian Estuary, including Manaus, Iranduba, Óbidos, Santarém in the upper course of the Estuary. Interviews were conducted with a total of 218 individuals. The Size Composition Survey was performed on 4,601 specimens of piramutaba *Brachyplatystoma vaillantii*, 2,198 of dourada *B. flavicans*, 167 of filhote *B. filamentosum*, 2,652 of pescada-branca *Plagioscion squamosissimus*, 370 of pescada-amarela *Cynoscion acoupa*, 900 of pescadinha-gó *Macrodon ancylodon* and 213 of gurijuba *Arius parkeri*.

# 5. RESULTS

## 5.1. Sea-Borne Survey

**a) Distribution and Standing Stock Size of Key Fish Species**

The distribution figures reflecting catch weight in each trawl station are shown as revised at each square kilometer. Stock size in weight was calculated according to the methodology explained in 3.1.a.

a-1) Distribution

The distribution pattern of the seven key fish species was divided into the following groups according to water depth:

(1) Species distributed mainly in waters shallower than 10 m, here called freshwater fishes: piramutaba *Brachyplatystoma vaillantii*, dourada *B. flavicans*, filhote *B. filamentosum* and pescada-branca *Plagioscion squamosissimus*.

(2) Species distributed mainly in waters deeper than 10 m, here called marine (seawater) fishes: pescada-amarela *Cynoscion acoupa*, pescadinha-gô *Macrodon ancylodon* and gurijuba *Arius parkeri*.

As it will be shown, there is a bottom salinity front around the 10 m isobath, so this frontal zone could be a mixed distribution region for these two groups, or perhaps the boundary for their respective distributions.

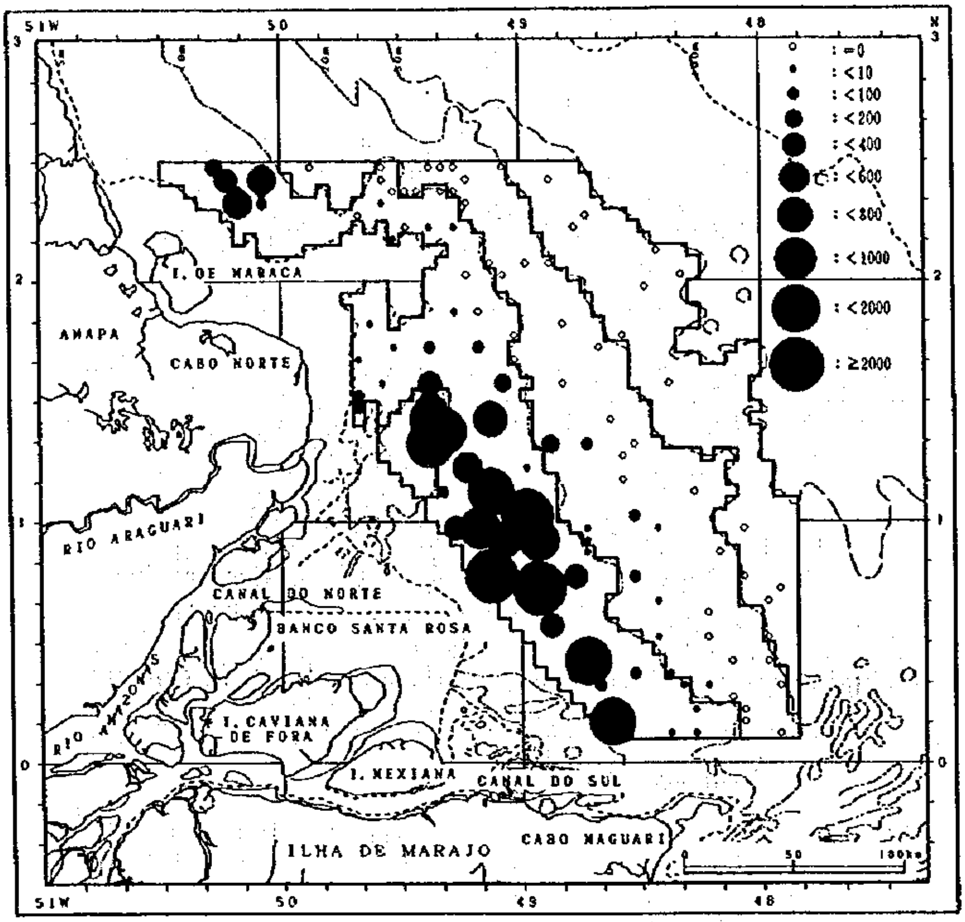
Among the four freshwater species, piramutaba showed wider distribution — particularly in the Rainy Season — and higher density in kg/km$^2$ near the banks of the Amazonian Estuary (Table 6, Fig. 3).

**Table 6. Mean density by stratum for freshwater fish species (kg/km$^2$).**

| Key fish species | Stratum (isobath range) | Phase 1 | Phase 2 | |
|---|---|---|---|---|
| | | Dry Season | Rainy Season | Dry Season |
| Piramutaba | 5−10m | 88 | 684 | 212 |
| *Brachyplatystoma vaillantii* | 10−20m | 53 | 95 | 5 |
| Dourada | 5−10m | 68 | 150 | 136 |
| *Brachyplatystoma flavicans* | 10−20m | 7 | 45 | 16 |
| Filhote | 5−10m | 2 | 3 | (0.4) |
| *Brachyplatystoma filamentosum* | 10−20m | (0.1) | 0 | 0 |
| Pescada branca | 5−10m | 1 | 9 | 3 |
| *Plagioscion squamosissimus* | 10−20m | 0 | 0 | 0 |

None of those 4 species occurred in the 20−50m stratum.

(A)




(B)

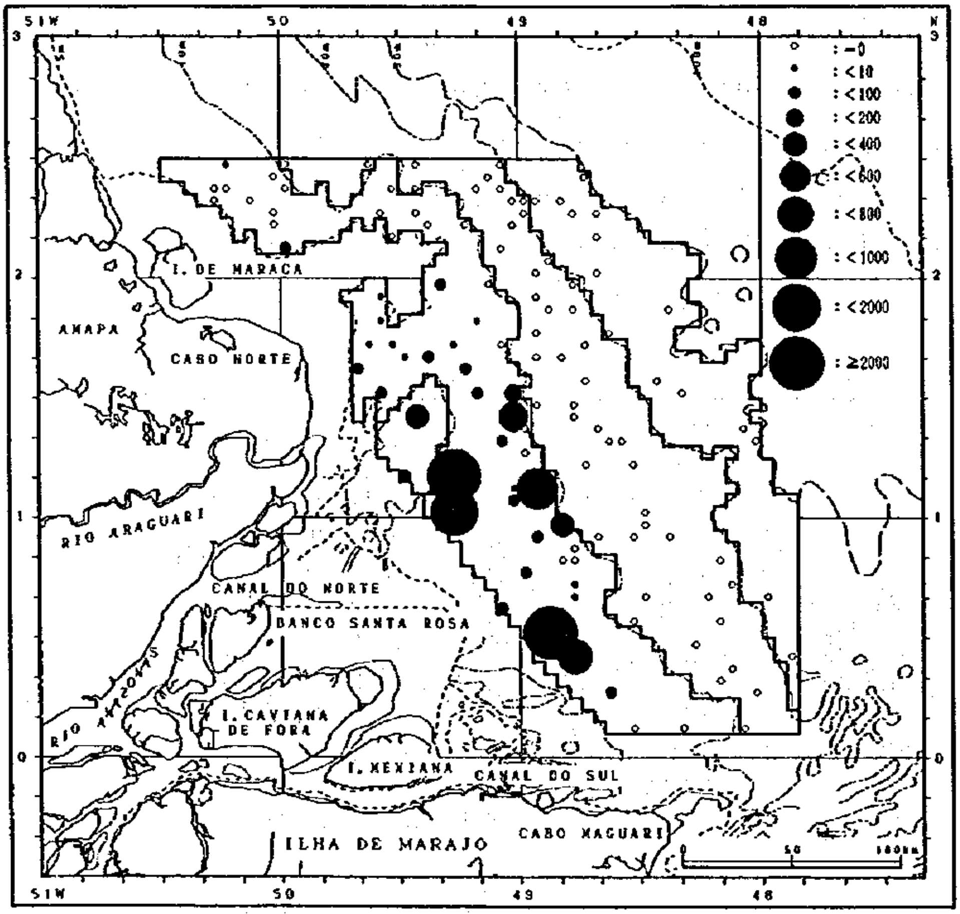



**Figure 3. The density (kg/km$^2$) of a freshwater species Piramutaba *Brachyplatystoma vaillantii* at each station.**

**(A) Phase 2 Rainy Season Survey; (B) Phase 2 Dry Season Survey.**

Conversely, among the three marine species, pescadinha-gó presented wider distribution and higher density in kg/km$^2$. This species occurred in practically all marine areas except for those near the estuary banks, where piramutaba predominated. High densities of pescadinha-gó were found in the 10–20 m stratum in the southern portion of the study area, during the Phase 2 Dry Season — in contrast to their scattered distribution in waters deeper than 10 m in the Rainy Season of the same Phase (Table 7, Fig. 4).

**Table 7. Mean density by stratum for marine fish species (kg/km$^2$).**

| Key fish species | Stratum ( isobath range ) | Phase 1 Dry Season | Phase 2 Rainy Season | Phase 2 Dry Season |
|---|---|---|---|---|
| Pescada amarela | 5−10m | 4 | 4 | 20 |
| *Cynoscion acoupa* | 10−20m | 18 | 22 | 50 |
| | 20−50m | 15 | 8 | 15 |
| Pescadinha go | 5−10m | 11 | 86 | 11 |
| *Macrodon ancylodon* | 10−20m | 77 | 199 | 228 |
| | 20−50m | 20 | 301 | 107 |
| Gurijuba | 5−10m | 39 | 69 | 137 |
| *Arius parkeri* | 10−20m | 120 | 137 | 179 |
| | 20−50m | 17 | 33 | 70 |

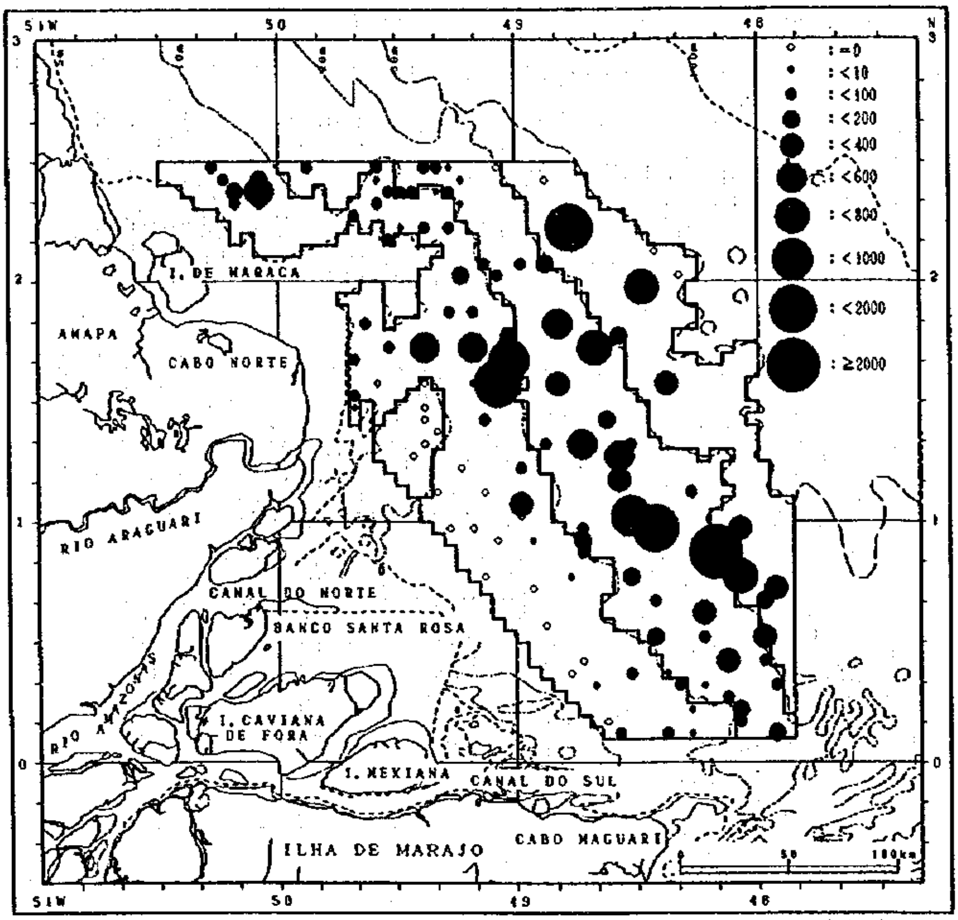
a-2) Stock size

Estimates of the stock size of the key fish species are shown in Table 8. The stock size of the four freshwater species piramutaba, dourada, filhote and pescada-branca was large in the Rainy Season, when the Amazon River discharge is voluminous, and small in the Dry Season. Most of the stock size of those species was found in the 5–10 m stratum, regardless of the season. Of the four freshwater species, piramutaba had the largest stock size. The total stock size of piramutaba had a wide seasonal variation: 13,260 tonnes in the Rainy Season, and 2,341 and 3,723 tonnes respectively in each Dry Season. The stock size of filhote and pescada-branca was very small, ranging from 7 to 157 tonnes in the course of the survey.

Of the three marine species, pescada-amarela and gurijuba had their total stock size increased in chronological order — values for the Phase 2 Dry Season, respectively 1,279 and 5,824 tonnes, were 2.6 and 2.1 times larger than those for the Phase 1 Dry Season. The total stock size of pescadinha-gó was 7,406 tonnes in the Phase 2 Rainy Season, a value about 6,000 tonnes larger than that of the previous Dry Season and 3,000 tonnes larger than that of the following Dry Season. Those three species had 50–80% of their respective total stock size (40% for pescadinha-gó in the Rainy Season) found in the 10–20 m stratum.

Fishes other than the key fish species who showed large stock size included the sea catfishes cambéua (Thomas sea catfish) *Arius grandicassis*, cangatá (Bressou sea catfish) *A. quadriscutis* and jurupiranga (softhead sea catfish) *A. rugispinis*, as well as the sciaenid pescada-cambuçu (green weakfish) *Cynoscion virescens* (see color plates).

(A)




(B)

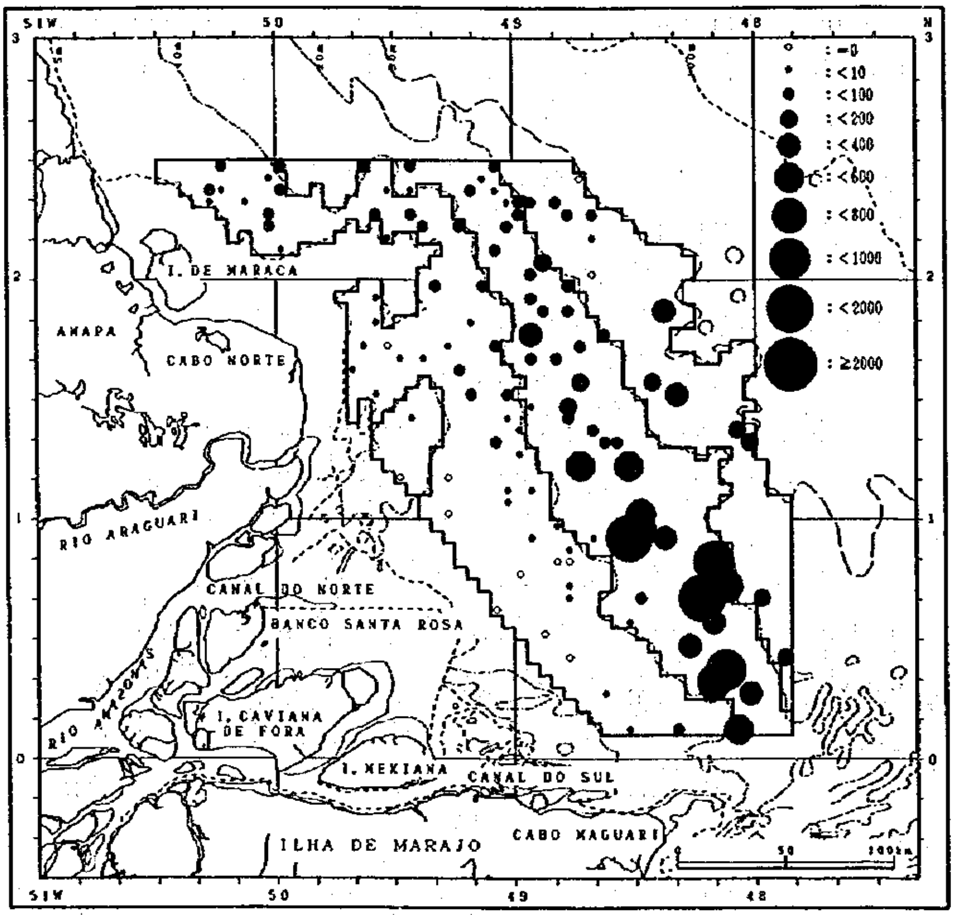



Figure 4. The density (kg/km$^2$) of a marine species Pescadinha-gó *Macrodon ancylodon* at each station. (A) Phase 2 Rainy Season Survey; (B) Phase 2 Dry Season Survey.

**Table 8. Stock size estimates of key fish species.**

| Key fish species | Stratum ( isobath range in m ) | Stock size in tonnes | | |
|---|---|---|---|---|
| | | Phase | | |
| | | 1 | 2 | |
| | | Dry Season | Rainy Season | Dry Season |
| **Piramutaba** | 5−10 | 1,510 | 11,770 | 3,648 |
| *Brachyplatystoma vaillantii* | 10−20 | 831 | 1,490 | 75 |
| | Total | 2,341 | 13,260 | 3,723 |
| | 95% confidence interval | ±1, 962 | ±9, 980 | ±3, 764 |
| | Coefficient of variation | 37% | 33% | 45% |
| **Dourada** | 5−10 | 1,164 | 2,577 | 2,336 |
| *Brachyplatystoma flavicans* | 10−20 | 107 | 703 | 246 |
| | Total | 1,271 | 3,280 | 2,582 |
| | 95% confidence interval | ±730 | ±1, 684 | ±1, 587 |
| | Coefficient of variation | 24% | 22% | 27% |
| **Filhote** | 5−10 | 29 | 53 | 7 |
| *Brachyplatystoma filamentosum* | 10−20 | 2 | 0 | 0 |
| | Total | 31 | 53 | 7 |
| | 95% confidence interval | ±38 | ±55 | ±13 |
| | Coefficient of variation | 53% | 44% | 87% |
| **Pescada branca** | 5−10 | 21 | 157 | 43 |
| *Plagioscion squamosissimus* | 95% confidence interval | ±30 | ±135 | ±42 |
| | Coefficient of variation | 65% | 38% | 43% |
| **Pescada amarela** | 5−10 | 64 | 67 | 349 |
| *Cynoscion acoupa* | 10−20 | 289 | 339 | 790 |
| | 20−50 | 143 | 71 | 140 |
| | Total | 496 | 477 | 1,279 |
| | 95% confidence interval | ±304 | ±333 | ±684 |
| | Coefficient of variation | 38% | 33% | 26% |
| **Pescadinha go** | 5−10 | 184 | 1,481 | 182 |
| *Macrodon ancylodon* | 10−20 | 1,214 | 3,127 | 3,586 |
| | 20−50 | 182 | 2,798 | 991 |
| | Total | 1,580 | 7,406 | 4,759 |
| | 95% confidence interval | ±578 | ±2, 511 | ±1, 899 |
| | Coefficient of variation | 17% | 18% | 18% |
| **Gurijuba** | 5−10 | 678 | 1,178 | 2,363 |
| *Arius parkeri* | 10−20 | 1,889 | 2,157 | 2,813 |
| | 20−50 | 155 | 310 | 648 |
| | Total | 2,722 | 3,645 | 5,824 |
| | 95% confidence interval | ±1, 093 | ±1, 372 | ±1, 578 |
| | Coefficient of variation | 17% | 17% | 14% |

Area by stratum: 17,200km$^2$ (5-10m), 15,700km$^2$ (10-20m), 9,300km$^2$ (20-50m), and 42,200km$^2$(total).

### b) Biology of Key Fish Species

#### b-1) Size composition

Distinctive features of size composition of the key fish species were summarized from the Final Report in Table 9, with each 1 cm size class for pescadinha-gó and each 2 cm size class for the other species.

The four freshwater species were found to have the following size ranges throughout the surveys: piramutaba, 2–70 cm; dourada, 4–84 cm; filhote, 14–68 cm; and pescada-branca, 6–68 cm. Mean sizes in each seasonal survey were: piramutaba, 25–29 cm; dourada, 47–49 cm; filhote, 34–43 cm; and pescada-branca, 21–35 cm. Except for piramutaba, all species reached larger sizes in the Rainy Season. The mean size of piramutaba decreased in survey order. Piramutaba and dourada had their respective mean size larger in the 5–10 m stratum. Except for the poorly sampled filhote, the remaining three species had a poly-modal size distribution pattern, and their dominant modes in overall size composition in each survey occurred in the following size class ranges: piramutaba, 14–24 cm; dourada, 58–66 cm; and pescada-branca, 10–14 cm. The dominant modal classes were larger in the Rainy Season.

The three marine species were found to have the following size ranges throughout the surveys: pescada-amarela, 64–120 cm; pescadinha-gó, 2–40 cm; and gurijuba, 12–134 cm. Mean sizes in each seasonal survey were: pescada-amarela, 95–96 cm; pescadinha-gó, 17–18 cm; and gurijuba, 50–53 cm, their respective seasonal amplitudes not being wide. The mean sizes by stratum for those three species became larger from shallow to deep strata. Size distribution pattern was poly-modal for pescada-amarela and gurijuba, and mono-modal for pescadinha-gó. The dominant modes in overall size composition in each survey occurred in the following size class ranges: pescada-amarela, 98–120 cm; pescadinha-gó, 15–18 cm; and gurijuba, 28–30 cm (Rainy Season) and 40–46 cm (Dry Seasons). Their dominant mode classes in each season and stratum are clearly depth-dependent, their becoming larger from shallow to deep strata.

Except for pescada-amarela, the stock of the other six key species included the recruitment of their small fish outside the catchable size.

#### b-2) Relationship between body length and weight

The relationship between body length and weight for the key fish species — given by the equation $W = aL^b \times 10^{-6}$ (W, body weight in grams; L, body length in centimeters; a, b, coefficients) — was presented in figure with the correlation coefficient r and the number of specimens n (see Final Report). In this report, values of a, b, r and n are shown in Table 10.

Because there was no significant difference between sexes in the relationship, the result was established through the combined data for both sexes. The correlation coefficients in each survey (in all surveys for filhote and pescada-amarela) are very high for all key fish species and their respective relationships were very similar to each other.

## Table 9. Summarized size composition of key fish species.

**(1) Piramutaba *Brachyplatystoma vaillantii***

| Survey season | Stratum (isobath range) | Total number of specimens | Fork length in cm Range | Mean | Distribution pattern | Dominant modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 9,153 | 4 – 68 | 29 | poly-modal | 14 – 16 |
| | 10 - 20 m | 5,808 | 6 – 52 | 29 | poly-modal | 20 – 22 |
| | 5 - 20 m | 14,961 | 4 – 68 | 29 | poly-modal | 14 – 16 |
| Phase 2 Rainy | 5 - 10 m | 86,009 | 4 – 70 | 28 | poly-modal | 22 – 24 |
| | 10 - 20 m | 12,644 | 4 – 68 | 24 | poly-modal | 10 – 12 |
| | 5 - 20 m | 98,653 | 4 – 70 | 28 | poly-modal | 22 – 24 |
| Phase 2 Dry | 5 - 10 m | 37,134 | 2 – 68 | 25 | poly-modal | 14 – 16 |
| | 10 - 20 m | 793 | 6 – 60 | 23 | poly-modal | 16 – 18 |
| | 5 - 20 m | 37,927 | 2 – 68 | 25 | poly-modal | 14 – 16 |

**(2) Dourada *Brachyplatystoma flavicans***

| Survey season | Stratum (isobath range) | Total number of specimens | Fork length in cm Range | Mean | Distribution pattern | Dominant modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 1,973 | 6 – 82 | 47 | poly-modal | 58 – 60 |
| | 10 - 20 m | 315 | 10 – 66 | 42 | poly-modal | 60 – 62 |
| | 5 - 20 m | 2,288 | 6 – 82 | 47 | poly-modal | 58 – 60 |
| Phase 2 Rainy | 5 - 10 m | 4,722 | 6 – 80 | 49 | poly-modal | 64 – 66 |
| | 10 - 20 m | 1,184 | 6 – 84 | 49 | poly-modal | 58 – 60 |
| | 5 - 20 m | 5,906 | 6 – 84 | 49 | poly-modal | 64 – 66 |
| Phase 2 Dry | 5 - 10 m | 4,657 | 4 – 82 | 49 | poly-modal | 62 – 64 |
| | 10 - 20 m | 656 | 6 – 70 | 40 | poly-modal | 6 – 8 |
| | 5 - 20 m | 5,313 | 4 – 82 | 48 | poly-modal | 62 – 64 |

**(3) Filhote *Brachyplatystoma filamentosum***

| Survey season | Stratum (isobath range) | Total number of specimens | Fork length in cm Range | Mean | Distribution pattern | Dominant modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 10 | 60 – 62 | 61 | – | – |
| | 10 - 20 m | 20 | 14 – 28 | 21 | – | – |
| | 5 - 20 m | 30 | 14 – 62 | 34 | – | – |
| Phase 2 Rainy | 5 - 10 m | 129 | 14 – 68 | 43 | – | 62 – 64 |
| Phase 2 Dry | 5 - 10 m | 30 | 28 – 48 | 37 | – | – |

**(4) Pescada branca *Plagioscion squamosissimus***

| Survey season | Stratum (isobath range) | Total number of specimens | Total length in cm Range | Mean | Distribution pattern | Dominant modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 207 | 8 – 58 | 21 | poly-modal | 10 – 12 |
| Phase 2 Rainy | 5 - 10 m | 568 | 8 – 68 | 35 | poly-modal | 12 – 14 |
| Phase 2 Dry | 5 - 10 m | 385 | 6 – 66 | 21 | poly-modal | 10 – 12 |

**Table 9. Continued**

**(5) Pescada amarela** ***Cynoscion acoupa***

| Survey season | Stratum (isobath range) | Total number of specimens | Total length in cm Range | Mean | Distribution pattern | Dominant modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 35 | 68 – 94 | 82 | – | 92 – 94 |
| | 10 - 20 m | 91 | 88 – 104 | 98 | – | 102 – 104 |
| | 20 - 50 m | 24 | 88 – 114 | 101 | – | – |
| | 5 - 50 m | 150 | 68 – 114 | 95 | poly-modal | 102 – 104 |
| Phase 2 Rainy | 5 - 10 m | 30 | 70 – 102 | 82 | – | 92 – 94 |
| | 10 - 20 m | 139 | 64 – 120 | 97 | poly-modal ? | 118 – 120 |
| | 20 - 50 m | 16 | 94 – 96 | 95 | – | 94 – 96 |
| | 5 - 50 m | 185 | 64 – 120 | 96 | poly-modal | 118 – 120 |
| Phase 2 Dry | 5 - 10 m | 164 | 66 – 112 | 88 | poly-modal | 88 – 90 |
| | 10 - 20 m | 273 | 70 – 120 | 99 | poly-modal | 104 – 106 |
| | 20 - 50 m | 25 | 98 – 100 | 99 | – | 98 – 100 |
| | 5 - 50 m | 462 | 66 – 120 | 95 | poly-modal | 98 – 100 |

**(6) Pescadinha go** ***Macrodon ancylodon***

| Survey season | Stratum (isobath range) | Total number of specimens | Total length in cm Range | Mean | Distribution pattern* | Modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 23,019 | 2 – 37 | 14 | mono-modal | 13 – 15 |
| | 10 - 20 m | 81,235 | 5 – 37 | 18 | mono-modal | 17 – 18 |
| | 20 - 50 m | 4,376 | 6 – 33 | 18 | mono-modal | 18 – 19 |
| | 5 - 50 m | 108,630 | 2 – 37 | 17 | mono-modal | 17 – 18 |
| Phase 2 Rainy | 5 - 10 m | 175,921 | 6 – 32 | 16 | mono-modal | 13 – 14 |
| | 10 - 20 m | 251,102 | 5 – 40 | 17 | mono-modal | 15 – 16 |
| | 20 - 50 m | 76,887 | 7 – 36 | 19 | mono-modal | 17 – 18 |
| | 5 - 50 m | 503,910 | 5 – 40 | 17 | mono-modal | 15 – 16 |
| Phase 2 Dry | 5 - 10 m | 28,679 | 4 – 35 | 14 | mono-modal | 12 – 13 |
| | 10 - 20 m | 263,668 | 5 – 40 | 18 | mono-modal | 16 – 17 |
| | 20 - 50 m | 30,813 | 10 – 32 | 19 | mono-modal | 20 – 21 |
| | 5 - 50 m | 323,160 | 4 – 40 | 18 | mono-modal | 16 – 17 |

* Some low-peak, poorly defined modes were disregarded.

**(7) Gurijuba** ***Arius parkeri***

| Survey season | Stratum (isobath range) | Total number of specimens | Fork length in cm Range | Mean | Distribution pattern | Dominant modal class (cm) |
|---|---|---|---|---|---|---|
| Phase 1 Dry | 5 - 10 m | 1,080 | 18 – 78 | 46 | poly-modal | 42 – 44 |
| | 10 - 20 m | 1,528 | 20 – 134 | 57 | poly-modal | 62 – 64 |
| | 20 - 50 m | 40 | 60 – 78 | 69 | – | 76 – 78 |
| | 5 - 50 m | 2,648 | 18 – 134 | 53 | poly-modal | 40 – 42 |
| Phase 2 Rainy | 5 - 10 m | 1,415 | 12 – 116 | 51 | poly-modal | 28 – 30 |
| | 10 - 20 m | 2,763 | 12 – 108 | 50 | poly-modal | 28 – 30 |
| | 20 - 50 m | 207 | 12 – 74 | 46 | – | 40 – 42 |
| | 5 - 50 m | 4,385 | 12 – 116 | 50 | poly-modal | 28 – 30 |
| Phase 2 Dry | 5 - 10 m | 3,369 | 16 – 92 | 50 | poly-modal | 42 – 44 |
| | 10 - 20 m | 3,324 | 16 – 96 | 53 | poly-modal | 44 – 46 |
| | 20 - 50 m | 236 | 38 – 86 | 64 | – | – |
| | 5 - 50 m | 6,929 | 16 – 96 | 52 | poly-modal | 44 – 46 |

**Table 10. Relationship between body length and weight for key fish species.**

| Key fish species | Survey season | $W = aL^b \times 10^{-6}$ | | | |
|---|---|---|---|---|---|
| | | a | b | r | n |
| Piramutaba *Brachyplatystoma vaillantii* | Phase 1 Dry | 5 | 3.1512 | 0.997 | 286 |
| | Phase 2 Rainy | 6 | 3.1276 | 0.997 | 995 |
| | Phase 2 Dry | 5 | 3.1498 | 0.998 | 460 |
| Dourada *Brachyplatystoma flavicans* | Phase 1 Dry | 5 | 3.1892 | 0.991 | 194 |
| | Phase 2 Rainy | 8 | 3.0608 | 0.996 | 440 |
| | Phase 2 Dry | 5 | 3.1161 | 0.998 | 310 |
| Filhote *Brachyplatystoma filamentosum* | All seasons | 9 | 3.0467 | 0.995 | 18 |
| Pescada branca *Plagioscion squamosissimus* | Phase 1 Dry | 9 | 2.9914 | 0.996 | 21 |
| | Phase 2 Rainy | 8 | 3.0545 | 0.994 | 58 |
| | Phase 2 Dry | 7 | 3.0455 | 0.994 | 32 |
| Pescada amarela *Cynoscion acoupa* | All seasons | 0.6 | 2.7380 | 0.957 | 59 |
| Pescadinha go *Macrodon ancylodon* | Phase 1 Dry | 80 | 3.4155 | 0.991 | 1,266 |
| | Phase 2 Rainy | 70 | 3.4472 | 0.993 | 1,762 |
| | Phase 2 Dry | 1 | 3.3493 | 0.989 | 1,755 |
| Gurijuba *Arius parkeri* | Phase 1 Dry | 2 | 3.3153 | 0.987 | 214 |
| | Phase 2 Rainy | 4 | 3.1882 | 0.990 | 358 |
| | Phase 2 Dry | 2 | 3.2693 | 0.994 | 457 |

b-3) Sex ratio

Sex ratio for the key fish species (number of female specimens / number of male specimens) is given in Table 11.

Among the seven key fish species, filhote, pescada-branca and pescada-amarela had few specimens and thus their sex ratio as determined was regarded as unreliable. Overall sex ratio for the other four species was, in survey order: piramutaba, 2.06, 0.86 and 1.04; dourada, 1.18, 1.17 and 1.71; pescadinha-gó, 1.08, 1.45 and 1.04; gurijuba, 1.65, 0.86 and 1.24. Except for dourada, of which few specimens were caught in different strata, the other three species of this latter group indicated a depth-dependent change in their sex ratio. In all seasons, piramutaba had a higher sex ratio in deeper stratum. Pescadinha-gó had a higher sex ratio in deeper stratum in Phase 1, but in shallower stratum in Phase 2. However, the sex ratio of gurijuba was the reverse of that of pescadinha-gó.

**Table 11. Sex ratio for key fish species.**

| Key fish species | Stratum (isobath range) | Phase 1 Dry Season | Phase 2 Rainy Season | Phase 2 Dry Season |
|---|---|---|---|---|
| Piramutaba *Brachyplatystoma vaillantii* | 5–10m | 1.55 | 0.80 | 1.04 |
| | 10–20m | - (Only female) | 1.90 | 1.67 |
| | 5–20m | 2.06 | 0.86 | 1.04 |
| Dourada *Brachyplatystoma flavicans* | 5–10m | 1.08 | 1.34 | 1.75 |
| | 10–20m | 3.33 | 0.72 | 1.39 |
| | 5–20m | 1.18 | 1.17 | 1.71 |
| Filhote *Brachyplatystoma filamentosum* | 5–10m | - (Only female) | 0.70 | 2.00 |
| Pescada branca *Plagioscion squamosissimus* | 5–10m | 1.50 | 1.21 | 5.00 |
| Pescada amarela *Cynoscion acoupa* | 5–10m | 0.33 | 4.00 | 1.88 |
| | 10–20m | 0.60 | 1.13 | 0.35 |
| | 20–50m | 0 (Only male) | - (Only female) | 0 (Only male) |
| | 5–50m | 0.36 | 1.50 | 0.64 |
| Pescadinha go *Macrodon ancylodon* | 5–10m | 0.84 | 1.70 | 2.62 |
| | 10–20m | 1.10 | 1.33 | 1.04 |
| | 20–50m | 2.21 | 1.36 | 0.63 |
| | 5–50m | 1.08 | 1.45 | 1.04 |
| Gurijuba *Arius parkeri* | 5–10m | 1.88 | 0.78 | 1.03 |
| | 10–20m | 1.70 | 0.82 | 1.52 |
| | 20–50m | 0 (Only male) | 1.95 | 2.79 |
| | 5–50m | 1.65 | 0.86 | 1.24 |

b-4) Female maturity stage

Frequency of female individuals ((females / females + males + individuals with indeterminate sex) × 100) and composition of female maturity stages by size group (small, intermediate and large) are presented in Table 12.

Among the four freshwater species, all females of piramutaba, dourada and filhote were immature without relation to their sizes. Small and intermediate-size females of pescada-branca were all immature, but the large-size females were immature, semi-mature, mature and spent (post-spawning).

Of the marine species, all small females and most of the medium-size females of pescadinha-gó and gurijuba were immature. Many of the large-size females of pescadinha-gó were immature (Phase 1 Dry Season and Phase 2 Rainy Season) or semi-mature (Phase 2 Dry Season). Many of the large-size females of gurijuba were semi-mature (Phase 1 Dry Season), spent (Phase 2 Rainy Season) or mature (Phase 2 Dry Season). Females of pescada-amarela in the 60–120 cm size range were mostly semi-mature (Phase 2).

Except for filhote and pescada-amarela, the frequency of the other five species indicated a size-dependent, being higher the larger the fish.

**Table 12. Female frequency and maturity stage composition by size group for key fish species. The latter indicated in parenthesis.**

| Key fish species | Size groups (body length range) | Frequency and maturity stage* composition (%) | | |
|---|---|---|---|---|
| | | Phase | | |
| | | 1 | 2 | |
| | | Dry Season | Rainy Season | Dry Season |
| Piramutaba *Brachyplatystoma vaillantii* | Small size (under 20cm) | 6 (I: 100) | 14 (I: 100) | 11 (I: 100) |
| | Intermediate size (20-40cm) | 27 (I: 100) | 36 (I: 100) | 52 (I: 100) |
| | Large size (over 40cm) | 76 (I: 100) | 55 (I: 100) | 42 (I: 100) |
| Dourada *Brachyplatystoma flavicans* | Small size (under 20cm) | 0 | 5 (I: 100) | 1 (I: 100) |
| | Intermediate size (20-50cm) | 43 (I: 100) | 50 (I: 100) | 59 (I: 100) |
| | Large size (over 50cm) | 55 (I: 100) | 55 (I: 100) | 62 (I: 100) |
| Filhote *Brachyplatystoma filamentosum* | - | | 44 (I: 100) | : from all data |
| Pescada branca *Plagioscion squamosissimus* | Small size (under 20cm) | 0 | 15 (I: 100) | 0 |
| | Intermediate size (20-40cm) | 0 | 27 (I: 100) | 0 |
| | Large size (over 40cm) | 76 (II: 32, III: 32, IV: 36) | 69 (I: 36, II: 19, III: 45) | 83 (I: 19, II: 81) |
| Pescada amarela *Cynoscion acoupa* | 60-120cm size | 27 (I: 50, II: 25, III: 25) | 60 (II: 67, III: 33) | 39 (II: 78, III: 22) |
| Pescadinha go *Macrodon ancylodon* | Small size (under 10cm) | 5 (I: 100) | 0 | 0 |
| | Intermediate size (10-20cm) | 37 (I: 93, II: 6, III: 1) | 40 (I: 100) | 34 (I: 78, II: 22) |
| | Large size (over 20cm) | 82 (I: 59, II: 29, III: 10, IV: 2) | 78 (I: 83, II: 13, III: 5) | 56 (I: 26, II: 56, III: 18) |
| Gurijuba *Arius parkeri* | Small size (under 40cm) | 21 (I: 100) | 41 (I: 100) | 36 (I: 100) |
| | Intermediate size (40-80cm) | 53 (I: 82, II: 12, III: 5) | 39 (I: 87, II: 10, IV: 3) | 53 (I: 85, II: 10, III: 3, IV: 2) |
| | Large size (over 80cm) | 79 (I: 13, II: 51, III: 36) | 69 (I: 37, II: 7, IV: 56) | 79 (I: 3, II: 22, III: 62, IV: 13) |

* I: immature, II: semi-mature, III: mature, IV: spent.

b-5) Feeding habits

Stomach contents of the key fish species were analyzed via the occurrence method.

The three species of *Brachyplatystoma*, pescada-branca and gurijuba were found to be piscivorous, although their diet sometimes also included shrimp. Pescada-branca was found to feed on fish and shrimp, and pescadinha-gó mainly on shrimp.

### c) The Oceanic Environment

#### c-1) Water temperature and salinity

Water temperature and salinity observed during the survey was respectively within 25.9–30.7°C and 0.05–36.70 psu ranges. Four clusters were determined from T-S diagrams, defined as the following water masses:

(1) River waters: water temperature, 28–29°C (Dry Seasons) and 27–28.5°C (Rainy Season); salinity < 1 psu; in areas between the isobaths of 5 m and 20 m, and between 0–15 m deep (the occurrence in deeper than 10 m deep is limited to off the Northern Channel of the Amazon);

(2) Offshore ocean waters: 26–28.5°C and ≧35 psu; mainly in areas between the isobaths of 10 m and 50 m, and throughout the water column in the Dry Seasons, and only below 5 m deep in the Rainy Season;

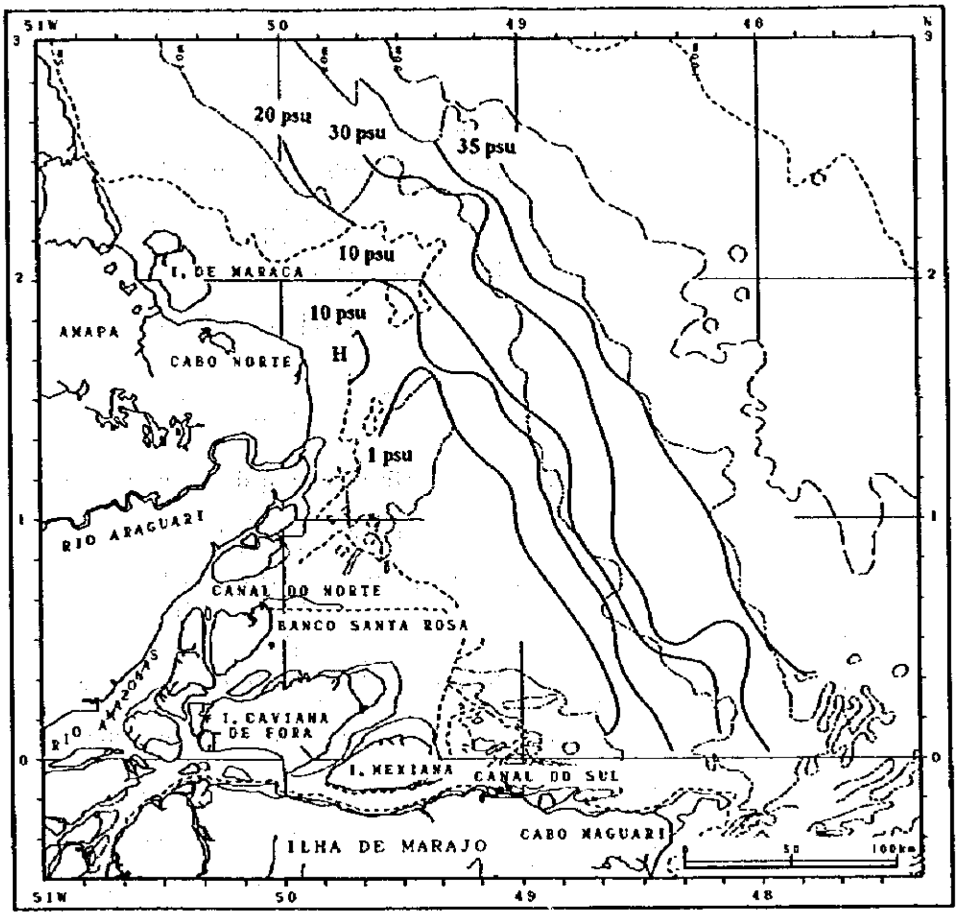
(3) High-temperature surface waters: 29–30.5°C and 0.05–34 psu; in areas between the isobaths of 5 m and 20 m, and between 0–12 m deep in the Dry Seasons (mostly between 0–5 m deep), and between 0–2 m deep in the Rainy Season;

(4) Mixed river and ocean waters: 27–29°C and 1–35 psu; over the entire marine area except for locations where there were the ocean water or river water columns from the surface to the bottom, such as offshore and near shore areas in the survey area, and between 0–20m deep. The vertical distribution of salinity formed two types of water columns, one of vertically well-mixed fresh and marine waters, the other a stratified water column forming a halocline. The former case occurred in areas between the isobaths of 5 m and 20 m and had salinity values as high as those offshore, while the latter was found almost over the entire area, and from a few meters below the surface down to 10 m deep although in the Rainy Season it could occur below 10 m deep.

The salinity distribution in the bottom layer (1 m above the sea floor) exerts great influence on the distribution of demersal fishes. The salinity distribution pattern in the Phase 2 Rainy and Dry Seasons are illustrated in Figure 5. Since the observations were taken over two months, the lack of simultaneity must be taken into account.

River waters occurred near the river mouth at the Amazonian Estuary, and ocean waters were distributed from near the isobath of 20 m to the offshore continental shelf. In the Rainy Season, river waters somewhat influenced offshore, while in the Dry Season ocean waters did so inshore. Those two water mass formed mixed waters over a 50–100 km-wide area through their interactions. Because of the great changes in salinity across the continental shelf, it appears that a bottom front has been formed near the isobath of 10 m in the Amazonian Estuary, south of latitude 2° N. Particularly, the existence of a conspicuous salinity front near 1° N revealed the bottom is strongly influenced by the flow of river waters from the Amazon.

(A)




(B)

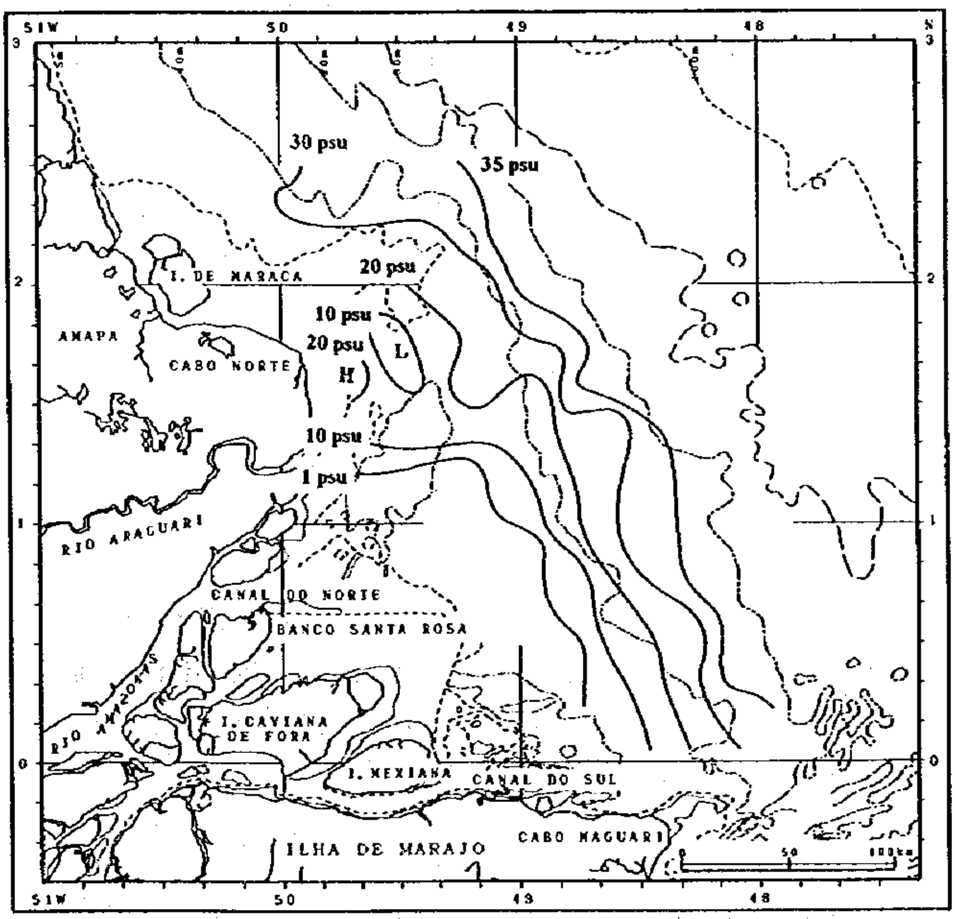



**Figure 5. Horizontal distribution of salinity in the bottom (1 m above the sea bed). (A) Phase 2 Rainy Season Survey ; (B) Phase 2 Dry Season Survey.**

c-2) Distribution of pH in the surface

Values of pH observed over the entire survey were in the 7.05–8.64 range. A pH value of 8.0 was found in the area between the isobaths of 10 m and 20 m, and pH was lower than that value in the shoreward area from that area and higher in the offshore.

On the other hand, pH values in the area between the isobath of 5–10 m north of latitude 2° N and west of longitude 50° W were relatively higher than those in other areas of the same isobath range.

c-3) Current conditions

Due to problems concerning the performance of the equipment and its measurement of layer thickness, data on current conditions were limited. Also, data on the speed in the shoreward area from around the isobath of 10 m were obtained by problematic means and are therefore omitted.

Currents in the surface layer were predominantly directed across the continental shelf (either towards the shore or off), suggesting they are regulated by tides. Currents in the bottom layer seem stronger in areas toward the offshore. Also, there seems to be a relatively strong northward and northwestward currents in the northern offshore portion of the survey area. The highest current speed recorded was about 150 cm/s. Currents were stronger in the surface layer than in the bottom layer and it appears that a vertical shear has been formed.

The current direction in the area between the isobath of 5 m and 10 m suggested the outflow of the Amazon River would be the most important cause for determining that.

c-4) Meteorology

Fair weather was overwhelmingly more frequent in the Dry Seasons, while there were about equal frequencies of fair and cloudy weather in the Rainy Season. Prevailing winds were gentle breezes from the east. Predominant wave heights were 0.1–1.25 m in the Dry Seasons and 0.1–0.5 m in the Rainy Season.

## 5.2. Laboratory Survey

**a) Selection of Age Characters**

Vertebral centra were selected as age characters for piramutaba *Brachyplatystoma vaillantii*, dourada *B. flavicans*, filhote *B. filamentosum* and gurijuba *Arius parkeri*, while otoliths were chosen for pescada-branca *Plagioscion squamosissimus*, pescada-amarela *Cynoscion acoupa* and pescadinha-gó *Macrodon ancylodon*.

**b) Selection of Fish Body Parts to Be Sampled**

As a general standard, vertebrae from the 10th to the 20th were chosen as samples for age determination.

### c) Relationship Between Size of Age Characters and Body Length

The relationship between vertebral centrum radius and fork length, and between otolith radius and total length, was calculated by means of a linear or an exponential regression equation, of which the one with the highest correlation coefficient was chosen. The selected expressions were:

| | | | |
|---|---|---|---|
| piramutaba | $FL = 143.41\ CR^{0.784}$ | $r = 0.993$ | (Fig. 6) |
| dourada | $FL = 147.49\ CR^{0.809}$ | $r = 0.990$ | |
| filhote | $FL = 129.14\ CR^{0.853}$ | $r = 0.987$ | |
| pescada-branca | $TL = 74.51\ OR^{1.064}$ | $r = 0.979$ | |
| pescada-amarela | $TL = 469.72\ OR^{0.435}$ | $r = 0.694$ | |
| pescadinha-gó | $TL = 118.97\ OR^{0.743}$ | $r = 0.694$ | (Fig. 7) |
| gurijuba | $FL = 145.62\ CR^{0.769}$ | $r = 0.986$ | |

where

- FL : fork length (mm)
- TL : total length (mm)
- CR : radius of vertebral centrum
- OR : radius of otolith
- r : correlation coefficient

Correlation between size of age character and body length was very high for all species except pescada-amarela and pescadinha-gó. Samples of pescada-amarela were biased toward large fish (larger than 60 cm in total length), and otoliths of pescadinha-gó were too small and led to errors in measurement, so the correlation between otolith radius and total length was low for those species.

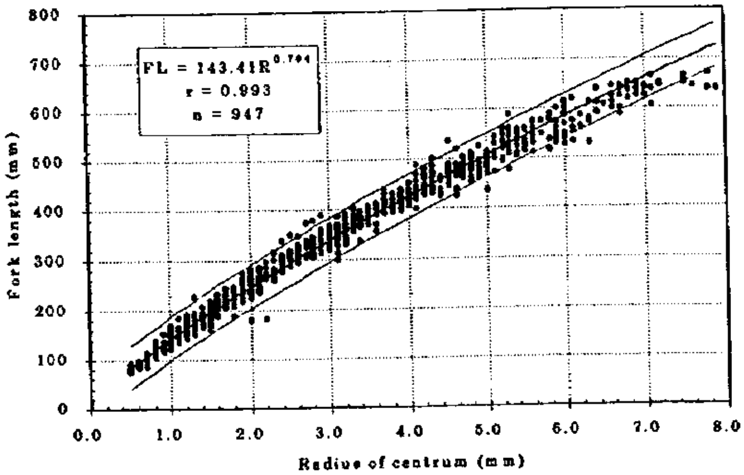



**Figure 6. Relationship between vertebral centrum radius and fork length in Piramutaba *Brachyplatystoma vaillantii*.**

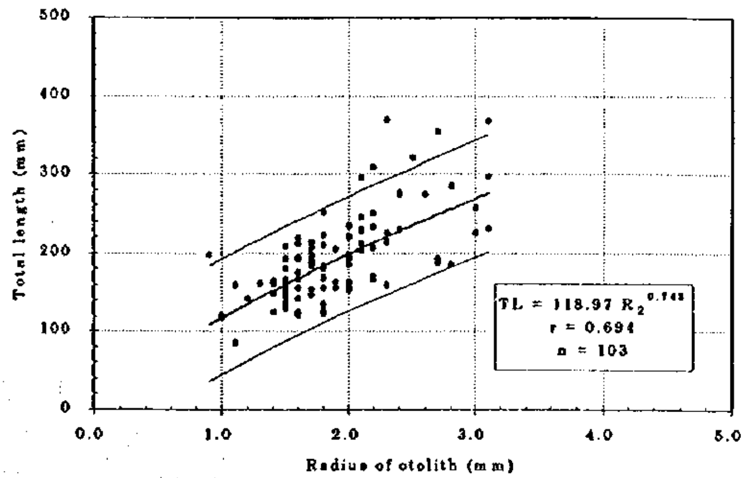



**Figure 7. Relationship between otolith radius and total length in Pescadinha-gó *Macrodon ancylodon*.**

#### d) Correspondence in Ring Formation

For all key fish species, the radius of each ring ($r_1$, $r_2$,..., $r_n$) was plotted against the radius R of the character (vertebral centrum or otolith) for each ring group. Then a regression line for the distribution of those values was calculated as passing through the origin of the coordinates (for example, see Fig. 8 for piramutaba or Fig. 9 for pescadinha-gó), and the value points would be scattered along that line. This scattered distribution of ring radius values showed that there was no correspondence between individuals in ring formation.

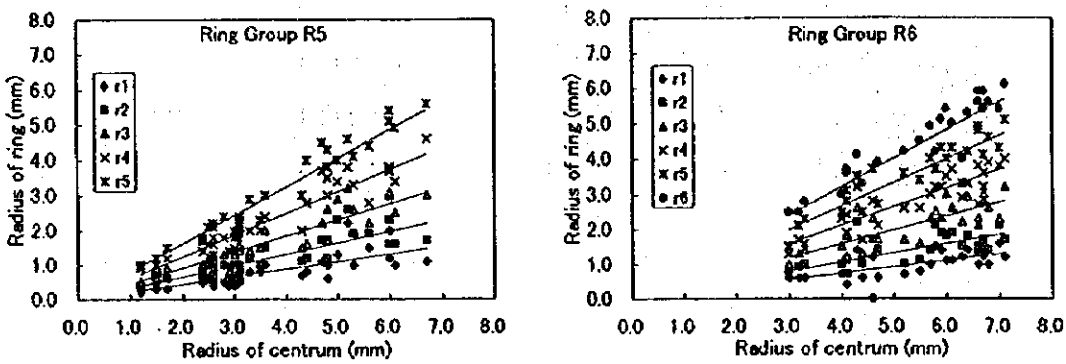



**Figure 8. Relationship between vertebral centrum and ring radii by ring group in Piramutaba *Brachyplatystoma vaillantii*.**

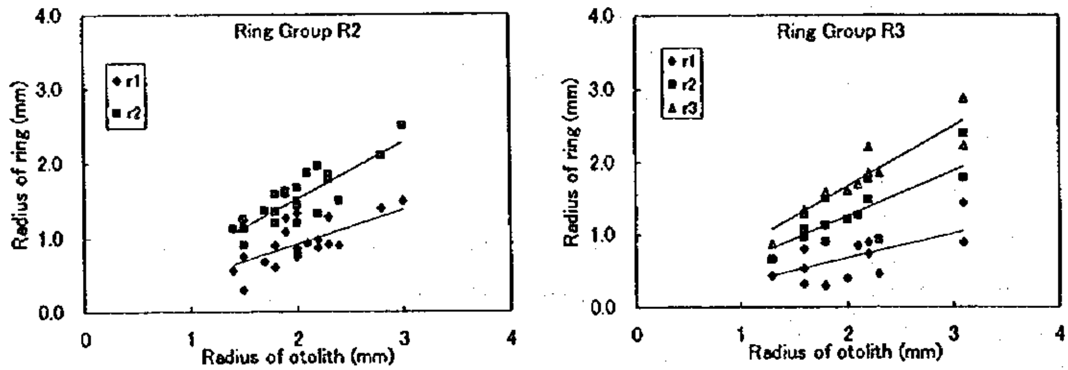



**Figure 9. Relationship between otolith and ring radii by ring group in Pescadinha-gó *Macrodon ancylodon*.**

#### e) Periodicity of Ring Formation

For all key fish species, in order to identify the period of ring formation in their respective age characters, the marginal increment of vertebra centrum or otolith, expressed by ( $\alpha$ ), was defined as:

$$\alpha = \frac{R - r_n}{r_n - r_{n-1}}$$

where R : radius of centrum or otolith (mm)

$r_n$ : radius of the outermost ring (mm),

$r_{n-1}$ : radius of the ring just behind the outermost one (mm).

In case there is periodicity in ring formation, the value of $\alpha$ should be below 1.0.

The value of $\alpha$ did not remain below 1.0, but rather surpassed that value very often. This $\alpha$ value allowed to deduce there is no periodicity in ring formation.

**f) Cohort Analysis of Size Composition**

Among the key fish species, distribution of length frequencies of piramutaba, dourada, pescadinha-gó and gurijuba as obtained during the Sea-Borne Survey was submitted to one to four iterations of moving average leading to a cohort analysis. The results identified 4–9 cohorts, and examples are found in Fig. 10 for gurijuba and Fig. 11 for pescadinha-gó.

Each cohort was adjusted to a normal distribution curve (Figs. 10 and 11), to whose modal length (mean length) a Ford-Walford plot (Walford, 1946) was applied to estimate maximum length. However, this estimated value proved not to be reasonable (for instance, see Fig. 12 for a Ford-Walford plot for piramutaba). This may be interpreted as an indication that population growth is not periodical, or that a cohort is not expressing an annual class.

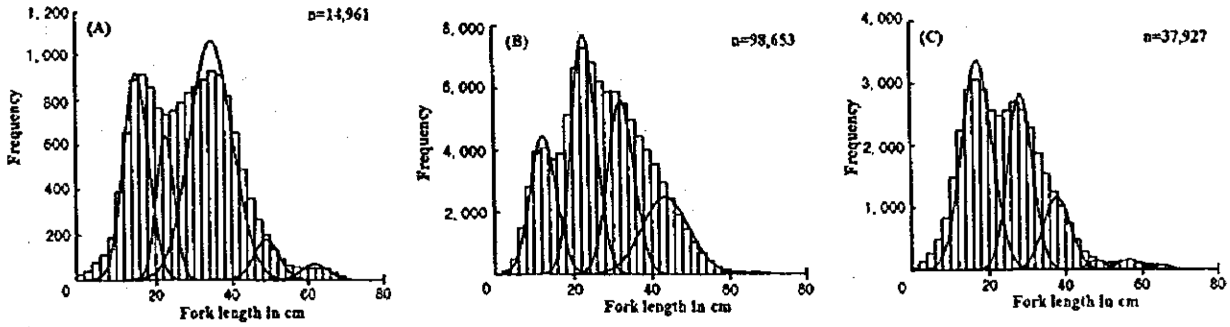



**Figure 10. Cohort analysis of size composition for Piramutaba *Brachyplatystoma vaillantii* (After 2nd iterations of moving average). (A) Phase 1 Dry Season Survey; (B) Phase 2 Rainy Season Survey: (C) Phase 2 Dry Season Survey.**

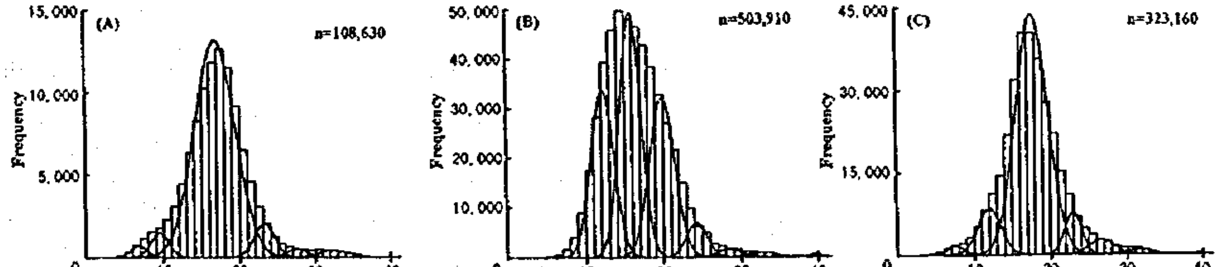



**Figure 11. Cohort analysis of size composition for Pescadinha-gó *Macrodon ancylodon* (After 1st iteration of moving average). (A) Phase 1 Dry Season Survey; (B) Phase 2 Rainy Season Survey: (C) Phase 2 Dry Season Survey.**

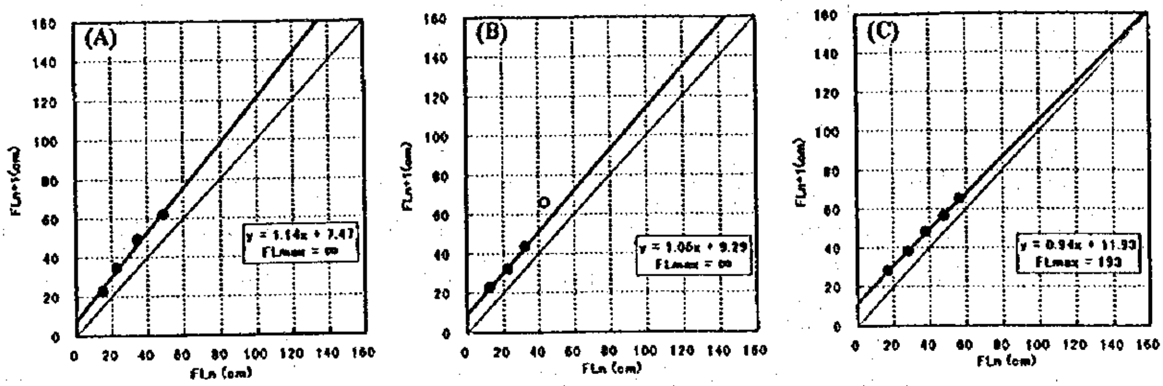



**Figure 12. Ford-Walford plot for Piramutaba *Brachyplatystoma vaillantii* mean length values by cohort. (A) Phase 1 Dry Season Survey; (B) Phase 2 Rainy Season Survey; (C) Phase 2 Dry Season Survey. (Black dots: points employed in the plotting of the regression line; white dots: points not employed in the plotting of the regression line).**

## g) Conclusions

Age determination was tried through the study of rings found in age characters (vertebral centra and otoliths) of key fish species and by means of cohort analysis of size composition, but by the end of this survey both of those methods proved either unfeasible or inconclusive. But the rings formed in each age character (scales, vertebral centra, otoliths) are not poorer than those found in species of temperate and cold regions. Those rings are thought to reflect fluctuations in the metabolism related to various aspects of the fishes life history: growth, development, spawning, etc., and as such they are the subject for future research and a continuation of this study is expected. Concretely, it is quite possible that individuals with marginal increments over 1 could have, externally to the outermost ring, one or two rings that are fully formed but overlooked. Furthermore, a two type of sample in a ring diameter size in the center position were recognized. These are classified into the following ring types:

type-1 a relatively large diameter ring

type-2 a fairly small diameter ring

The difference in diameter sizes of type-1 and type-2 are presumably originated in the difference of spawning seasons of samples. Type-1 was mostly spawned after the ring formation period. On the contrary, type-2 was mostly spawned before the ring formation period.

At present, individual differences in perception among those who read rings are undeniable, so in the future it will be necessary that samples collected so far are reexamined as it becomes possible to discern those elements important for age determination and the problem of ring reading is solved. At that stage, continuous collection of samples will be needed over the years.

## 5.3. Landing Site Survey

### a) An Outline of Fisheries in Northern Brazil Based on Fishery Statistics

a-1) Fisheries production in Northern Brazil

From 1978 to 1989, total fisheries production in Brazil varied with a minimum amount of 800 thousand tonnes in each of the bookend years 1978 and 1989, and peaking in 1985 with 960 thousand tonnes — the 19th largest catch in the world. Fisheries production in Northern Brazil formed by seven States — yielded 90–180 thousand tonnes (10–20 % of that of the entire country), with a slight tendency toward increase. On the other hand, fisheries production in the State of Pará has been of about 100 tonnes (50–80% of that of Northern Brazil), tending to decrease. The percentage of inland waters fishery production in the total fisheries production has been around 60 % for the State of Pará, 80% for Northern Brazil and 20% for all Brazil. The importance of inland waters fisheries is a particular feature of Northern Brazil, which includes the State of Pará. Piramutaba comprised about 30% of the inland fisheries production in the State of Pará in the 1980–1989 period. This species is of most importance for the State of Pará (Sources: IBGE, 1981–1990, except 1985; IBAMA, 1994).

a-2) Production of piramutaba in Northern Brazil and catch effort for piramutaba by industrial fishery

Production of piramutaba — the most important commercial fish in the Amazonian Estuary — varied from 10 to 30 thousand tonnes in Northern Brazil between 1980 and 1989. Over 60% of that total was caught by industrial fishery trawlers in the State of Pará, and that percentage rose to about 90% after 1981. Maximum catch effort by industrial fishery trawlers was obtained in 1980, with 69 fishing vessels, about 700 fishing trips and a total of some 9,000 days at sea. Catch per unit effort (CPUE) reached its peak in 1977, with about 650 tonnes per vessel, 45 tonnes per trip and 4.8 tonnes per day at sea.

a-3) Commercial route of piramutaba

Some 80–90% of piramutaba caught in the 1987–1988 period were utilized as raw material (mainly as chilled round fish) for products. About 80–85% of that raw material were processed into fish products. Frozen fish head, frozen headless fish and frozen fish meat cuts with bone made up for over 80% of the total of those fish products. Some 60–80% of those products are sold to the domestic market as frozen fish fillet, frozen fish meat cuts with bone and frozen headless fish. In the 1984–1990 period, some 4,000 tonnes of piramutaba were exported at a value of US$ 5 million. The mean export price for piramutaba — US$ 1–2/kg — was lower than that of fish in general, US$ 2–3/kg (Source: IBAMA, 1994).

### b) Status of Fisheries in the Amazonian Estuary Based on the Interview Survey

The number of fishermen and fishing vessels in artisanal fishery communities depended on the size of markets for consumption, and their geographical distribution was not determined by proximity to fishing grounds — a major feature of this river basin. In most cases, the basic fisheries infrastructure in the community was underdeveloped. The standard fishing vessel would have the following features: tonnage, <1–30 tonnes, power, 0–100 HP, length, <5–25 m, made of wood. In general, vessel size and equipment tended to depend upon the size of the community to which they belonged. The equipment, however, was poor in any case. Over 90% of the fishing gear utilized were gill nets, and longlines made up for the rest. Most fishermen — including all with special skills — belonged to fisherman colonies organized in their respective communities. Recently, however, the activity of these colonies have been laid stagnant.

Industrial fishery companies use much larger and more powerful bottom trawlers than vessels employed in artisanal fishery — tonnage, 85–100 tonnes; power, 300–350 HP; length, 22–23 m; steel made. Their infrastructure was complete with landing jetties, processing plants, etc.

Annual landed quantity of fish per vessel tended to depend upon the latter's size and equipment. For both artisanal and industrial fisheries, the annual number of fishing days was between 100 and 300 days (220 on the average); however, the number of fishing days per trip was higher in industrial fishery than in artisanal fishery. In the latter, duration of fishing time per haul was generally 10–12 hours with gill nets. The number of crew members on board in artisanal fishery was about 5; in industrial fishery, the crew numbered 5–9.

Industrial bottom trawl fishing exhibited by far the highest value of catch per day at 2,000–4,000 kg/day. With a few exceptions, there were no significant differences in catch per day per tonne between industrial and artisanal fisheries or their respective fishing methods, being under 50 kg/day/ton. Catch per day per horsepower was 8–35 kg/day/hp for industrial bottom trawl fishing and 16–42 kg/day/hp for part of artisanal gill net fishing (less than 10 kg/day/hp in other cases).

Fishing grounds exploited by artisanal fishery comprised the coastal area of Marajó Bay and the Amazon River, but switched to the Northern Channel of the Amazon River in the Rainy Season. Landed fish species were independent of fisheries type or gear, and comprise freshwater and marine fishes.

For most species retail prices were the same regardless of community size, with a tendency to be higher in the Rainy Season. On the other hand, the export price for piramutaba fillets sold to the United States by industrial fishery companies was 2 to 3 times higher than the retail price for piramutaba sold in Belém. Purchase prices paid by fishery brokers varied according to fish species and community size, being about 1/2–1/3 of retail prices. Most brokers would purchase highly rated fish species from specific fishing vessels regardless of size or degree of freshness, to wholesale them at the market.

### c) Commercial Sizes of Key Fish Species

The mean process size of piramutaba *Brachyplatystoma vaillantii* landed by industrial bottom trawlers was 36–37 cm fork length, while the mean market size of the same species landed by artisanal gill nets was 35–57cm. The mean size of piramutaba as sold in markets was larger at Ver-o-Peso. The mean process size of dourada *Brachyplatystoma flavicans* landed by industrial bottom trawlers was 51 cm fork length, and the mean market size of the same species landed by artisanal gill nets was 34–69cm.

The mean market size of dourada was again larger at Ver-o-Peso. The other five key fish species were not landed by the industrial fishery and their mean market size were as follows: filhote *Brachyplatystoma filamentosum*, 77cm fork length (Ver-o-Peso size); pescada-branca *Plagioscion squamosissimus*, 31–47cm total length (with one exception, no difference in market size); pescada-amarela *Cynoscion acoupa*, 55–109cm total length (larger size at Ver-o-Peso); pescadinha-gó *Macrodon ancylodon*, 23–31cm total length (larger size at Ver-o-Peso); gurijuba *Arius parkeri*, 61–78 cm fork length (smaller size at Ver-o-Peso).

### d) Some Problems Concerning Fishery Economics in the Amazonian Estuary

Based on the Interview Survey conducted, some problems concerning fishery economics in the Amazonian Estuary are summarized in Table 13.

**Table 13. Some problems concerning fishery economics (fishing and distribution) in the Amazonian Estuary.**

| Heading | Problem |
|---|---|
| Fisheries production | • Low equipment assets and fisheries productivity in artisanal fishery |
| | • Decline in stocks of piramutaba, an important fish caught in large quantities |
| | • Catch concentrated on stocks of relatively large demersal fish |
| | • Said fish highly ranked in food chain and less abundant than other lower-ranking animals in the chain |
| | • Said fish allowed by their life histories to adapt to live within the confines of the Amazon River Mouth, which become their fishing grounds |
| | • Fish distribution over fishing grounds varying with seasonal environmental changes, particularly river water dynamics which is linked to rainy and dry seasons |
| | • Incompleteness of information on migration, fish run and life history of key fish species for fisheries |
| | • Lack of statistics on catch, landing and effort of artisanal fishery (a thorough data system still to be implemented) |
| | • Intensification of competition within industrial fishery companies for stock procurement and conflict between industrial and artisanal fisheries |
| | • Low diversity of fisheries, mainly concentrated on two kinds — gill net and bottom trawl net fishing |
| Work in fisheries | • Majority of fishery workers are full-time professionals |
| | • Many fishery workers are laborers hired by the capitalistic fisheries |
| | • Relatively few household-managing fishermen |
| | • Many underemployed laborers among fishery workers, particularly the formers from rural areas to urban centers |
| | • Migration of young workers out of fishing villages due to increase of labor demand in cities |
| | • Low value of labor (worker surplus) |
| | • Fishery worker movements are difficult to understand |
| | • Instability of employment relations (fishing season-term jobs, contracts in uncertain terms, etc.) |
| | • Peculiarities of work conditions (on board work, seasonal work, irregular working hours, etc.) |
| | • Controlling employment relations |
| | • Reduction of hired labor following financial difficulties in industrial fishery |

**Table 13. Continued**

| Heading | Problem |
|---|---|
| Fisheries management | • Instability of fisheries management leading to low confidence in financing<br>• Shortage of government loans and the like<br>• Stocking and loan system of brokers and vessel owners (advance payment of funds)<br>• Failure of fishery household management system<br>• High capital-intensive debt rate — poor capital turnover rate — high fixed rates (general characteristics of the physical constitution of capitalistic management)<br>• Increase in fishery cost due to sudden price hikes of fisheries supplies such as nets and fuel<br>• Increase in fisheries as a speculative venture (entry of funds outside from fisheries)<br>• Qualitative crudity of fisheries processing |
| Distribution and price | • Monopoly of commerce of fishery products by brokers<br>• Lack of improvement in distribution mechanisms, particularly in the wholesale system<br>• Precariousness of quality control<br>• Distribution is overwhelmingly of fresh fishery products, leaving little room for durable items such as frozen or processed products<br>• Distribution is overwhelmingly of food products, with few avenues for products not destined for human consumption, such as animal feed, fodder or fertilizers<br>• Export prices of piramutaba products are fixed<br>• Low diversity of export items<br>• Relatively high prices of fishery products |
| Cooperatives - Finance | • Lack of cooperatives related to fisheries (fisheries cooperative associations, fishermen's production associations, fish processors' cooperative associations, and the like); legislation still to be established<br>• Government and its agency financing institutions still to be established<br>• Lack of low-interest financing organizations and of a guarantee system for making up for loss of confidence in fisheries<br>• Stagnancy in the movement of existing fishermen colonies |
| Fishing villages | • Relatively backward living environment, with a shortage of medical and public welfare facilities, community centers and libraries<br>• Insufficient countermeasures against contamination of fishing grounds, particularly lack of treatment facilities for industrial and urban sewage, waste, trash and refuse in fishing villages within city limits<br>• Lack of consolidation of an infrastructure for fisheries production, especially of items related to the villager's daily life, such as fishing ports, sites of public use and roads around them<br>• Lack of cold storage facilities and distribution systems such as shipping facilities<br>• Migration of young workers from fishing villages to urban centers without leaving successors<br>• Absorption of a surplus urban population, especially noticeable in fishing villages within city perimeters<br>• Few self-supporting fishermen, a majority of hired laborers in the industry |

# 6. EVALUATION OF EXPLOITED FISHERY RESOURCES

## 6.1. Present Status of Exploited Fishery Resources

In order to evaluate the present status of fishery resources in the Amazonian Estuary, it is necessary to have a clear picture of the actual situation of fisheries in that region. What follows is a summary of the results from the Landing Site Survey from the standpoint of fisheries production.

There, fishery resources have been caught and utilized by small-scale artisanal fishery and by industrial fishery. Artisanal fishery makes use of small fishing boats, targeting mainly coastal fish species with their gill nets. Their productivity is relatively low and their catch is sold to fishery brokers. The basic fisheries infrastructure in the artisanal fishermen villages is insufficiently consolidated and there is not enough information that could concretely show the entire picture of artisanal fishery.

On the other hand, most industrial fishery companies have a fishing division and a processing division. Their fishing divisions are using hired professional fishermen aboard 100 ton-class powered steel vessels, catching mainly piramutaba *Brachyplatystoma vaillantii* with bottom trawl nets both offshore and in the same waters exploited by the artisanal fishery. In their processing divisions, hired laborers mainly produce fishery products centered on frozen products by using the landed fish as their raw materials. These industries have official approval and their fishery activities are well documented.

Catch statistics for artisanal fishery in the Amazonian Estuary are not known at present. Fortunately, the results of the current Landing Site Survey allowed to estimate the total catch of the 56 fishermen colonies in the State of Pará for the year 1996 as approximately 39,210 tonnes. IBAMA reported the total catch of industrial fishery for 1996 as 13,204 tonnes. Comparing catches of both fisheries for that year, it can be seen that the artisanal fishery catch was at least three times the industrial fishery catch. That alone would show the importance of artisanal fishery from the standpoint of catch. Since, however, catch statistics of artisanal fishery are unavailable, the present status of exploited fishery resources should be made clearer through the analysis of the relatively complete annual data on catch and fishery statistics of industrial fishery.

**a) Catch Statistics of Industrial Fishery**

IBAMA has published bottom trawl catch statistics by industrial fishery over a period of 25 years, from 1972 to 1996. According to these, the total catch by the bottom trawl increased from 7,771 tonnes (7,771 tonnes for piramutaba) in 1972 to a maximum of 33,482 tonnes (32,123 tonnes for piramutaba) in 1977; afterwards, it declined over the years and in 1992 it reached 9,492 tonnes (7,342 tonnes for piramutaba), a reduction to 28% of the maximum catch value ever obtained. However, since the industry introduced in 1993 the practice of multiple-trawler fishing, catch has risen again, with a total of 13,204 tonnes (11,641 tonnes for piramutaba) in 1996. Statistics for 1997 have not been published yet as of June 1998. In the above-mentioned period, the percentage of piramutaba comprised from 77% (in 1992) to 100% (in 1972, 1973 and 1974) of those statistics. The item "Others" includes dourada *Brachyplatystoma flavicans*, mero *Epinephelus itajara*, gurijuba *Arius parkeri*, filhote *Brachyplatystoma filamentosum* and other species.

As explained before, since industrial fishery statistics indicate piramutaba is the most important target fish for the industry, the evaluation of the present status of fishery resources exploitation can be focused on this species. For that, it would be necessary to deduce piramutaba catch by industrial fishery in 1997. An estimate catch of 7,370 tonnes was calculated for that year's catch from the annual statistics of piramutaba catch in 1977–1996.

**b) Resources Survey**

The resources survey was conducted with the same vessels and methodology in the 1996 Dry Season (August to September) and 1997 Rainy and Dry Seasons (respectively, March to April and August to September).

The stock size calculated from the catch by cod-end (mesh size 100 mm) is called the catchable stock size — the basis for resources management.

Catchable stock size of the seven key fishes is shown in Table 14. A number of points can be observed:

(1) Estimated total stock size was as follows: 33,660 tonnes for the 1996 Dry Season, 45,610 tonnes for the 1997 Rainy Season and 67,270 tonnes for the 1997 Dry Season. Seven key fishes represented the following percentages of the total stock size: 20%, 44%, 20% in the respective seasonal surveys.

(2) In each season, stocks of piramutaba, dourada, filhote, as well as of pescada-branca *Plagioscion squamosissimus*, were mainly distributed in the 5–10 m stratum. In contrast, stocks of pescada-amarela *Cynoscion acoupa*, pescadinha-gó *Macrodon ancylodon* and gurijuba were found in depths from 5 to 50 m, being mainly distributed in the 10–20 m stratum.

(3) Mean stock size for the three surveys was, in decreasing order, 5,820 tonnes for piramutaba, 4,050 tonnes for gurijuba, 2,340 tonnes for dourada and 740 tonnes for pescada-amarela. The other key fish species had a low stock size: 400 tonnes for pescadinha-gó, 70 tonnes for pescada-branca and 30 tonnes for filhote.

(4) Estimated seasonal stock sizes of piramutaba were 1,990 and 3,330 tonnes for the respective Dry Seasons and 12,150 tonnes for the Rainy Season. Seasonal stock sizes of dourada were 1,200 and 2,560 tonnes for the respective Dry Seasons and 3,250 tonnes for the Rainy Season. In both cases, those stock sizes were higher in the Rainy

Season, as piramutaba and dourada live in riverine waters. In other words, in the Rainy Season the freshwater portion in the survey area expands toward the offshore due to precipitation, widening the distribution area and increasing the density for both species. The increase in stock sizes of piramutaba and dourada in the 1997 Dry Reason was due to the fact that density (kg/km$^2$) of both species in the 5–10 m stratum was higher than in the 1996 Dry Season. Estimated seasonal stock sizes of gurijuba were 2,710 and 5,820 tonnes for the respective Dry Seasons and 3,630 tonnes for the Rainy Season. The increase in gurijuba stock size in the 1997 Dry Season can be explained by the fact that density in the 5–20 m depth range was higher than in the 1996 Dry Season.

## 6.2. Evaluation of Exploited Fishery Resources

A comprehensive evaluation of resources requires a thorough view of both the qualitative and quantitative aspects of catchable stock. The former includes biological parameters such as growth, maturation, spawning and natural mortality, the latter refers to the stock size. However, as explained later, the available data on those biological parameters are quite incomplete at present. In the following sections the catchable stock size of piramutaba is evaluated, mostly focusing on the quantitative aspects.

### a) Catch and Catchable Stock Size

The current status of piramutaba stocks was evaluated based on catch and catchable stock size. As mentioned before, catch by industrial fishery in 1996 amounted to 11,641 tonnes according to fishery statistics, and the estimate for 1997 based on the catch variation in 1977–1996 is of 7,370 tonnes. The corresponding catchable stock sizes were 1,990 tonnes for 1996, from the Dry Season, and 7,740 tonnes for 1997, calculated from a mean value between Rainy and Dry Seasons.

Comparing catch and catchable stock size, it can be observed that the difference between both values is a theoretically impossible contradiction — namely, in 1996 and 1997 the industry would have caught respectively 5.8 times and 1.0 time the catchable stock size of piramutaba.

With respect to this, the catchable stock size in 1996 is only based on the Dry Season data, and the catch in 1977 is an estimated value calculated from catch variation of the past 20 years. On the other hand, for the estimation of stock size, the distribution area of piramutaba — particularly in the offshore area of the Southern Channel and area shallower than 5m water depth — was not thoroughly covered by the survey, and fishing gear efficiency was assumed as 1.0. Thus, certain prerequisite conditions for stock estimation were not met, leading to an underestimated value of stock size.

In contrast, a primary factor of overestimation, the herding effect of the fishing gear, has been ignored. The estimated stock size of piramutaba shows a large variation between the Rainy and Dry

**Table 14.** **Catchable stock size of key fish species. Upper , Phase 1 Dry Season Survey ( 7 Aug.-30 Sept., 1996; 110 stations);** ***Middle , Phase 2 Rainy Season Survey ( 7 March - 28 Apr., 1997; 120 stations);*** **Lower , Phase 2 Dry Season Survey ( 2 Aug. - 26 Sept., 1997; 120 stations).**

| Stratum (m) | Area (km²) | Stock size in tonnes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Piramutaba | Dourada | Filhote | Pescada branca | Pescada amarela | Pescadinha go | Gurijuba | Others | Total |
| 5 - 10 | 17,200 | 1,340 | 1,100 | 20 | 20 | 60 | 30 | 670 | 8,160 | 11,400 |
| | | *10,730* | *2,550* | *50* | *150* | *70* | *110* | *1,180* | *8,790* | *23,630* |
| | | 3,250 | 2,310 | 10 | 40 | 350 | 30 | 2,360 | 13,970 | 22,320 |
| 10 - 20 | 15,700 | 650 | 100 | 0 | 0 | 270 | 220 | 1,880 | 16,060 | 19,180 |
| | | *1,420* | *700* | *0* | *0* | *340* | *150* | *2,140* | *9,520* | *14,270* |
| | | 70 | 250 | 0 | 0 | 790 | 260 | 2,810 | 33,870 | 38,050 |
| 20 - 50 | 9,300 | 0 | 0 | 0 | 0 | 140 | 30 | 160 | 2,750 | 3,080 |
| | | *0* | *0* | *0* | *0* | *70* | *240* | *310* | *7,080* | *7,700* |
| | | 0 | 0 | 0 | 0 | 140 | 140 | 650 | 5,970 | 6,900 |
| Total | 42,200 | 1,990 | 1,200 | 20 | 20 | 470 | 280 | 2,710 | 26,970 | 33,660 |
| | | *12,150* | *3,250* | *50* | *150* | *480* | *500* | *3,630* | *25,390* | *45,600* |
| | | 3,330 | 2,560 | 10 | 40 | 1,280 | 430 | 5,820 | 53,810 | 67,270 |
| Coefficient of variation (%) | | 37 | 24 | 70 | 66 | 38 | 24 | 18 | | |
| | | *8* | *23* | *44* | *40* | *33* | *21* | *17* | | |
| | | 46 | 27 | 87 | 46 | 26 | 21 | 14 | | |

Seasons, as the water discharge of the Amazon River rises or falls.

One of the indicators of accuracy in stock size estimates is the coefficient of variation, which should be around 10% to be of any practical value for stock management. For all six key fish species except gurijuba, the coefficient of variation ranged from 20% to 90%. Another such indicator, the confidence interval of 95% for stock size estimates of key fish species, had a wide amplitude. Therefore, stock size estimates in this survey for key fish species other than gurijuba (coefficient of variation 14–18%) cannot be said to be very accurate.

Despite the existence of uncertain issues as described above on the actual relationship between catch and stock, it is clear that in recent years industrial fishery has caught many times the stock of piramutaba and, it is possible to have exerted an damaging fishing pressure over their stocks.

**b) Catch per Unit Effort (CPUE)**

Catch per unit effort (CPUE) is one of the numerical means for expressing stock condition. IBAMA statistics offer, besides catch, data on fishing effort such as number of operational vessels, number of fishing trips and number of days at sea. Based on those statistics of number of days at sea, the CPUE of piramutaba was calculated for the period from 1975 to 1996, its variation being illustrated in Figure 13. CPUE has declined for 3.2 tonnes/day in 1975 to 2.6 tonnes/day in 1996.

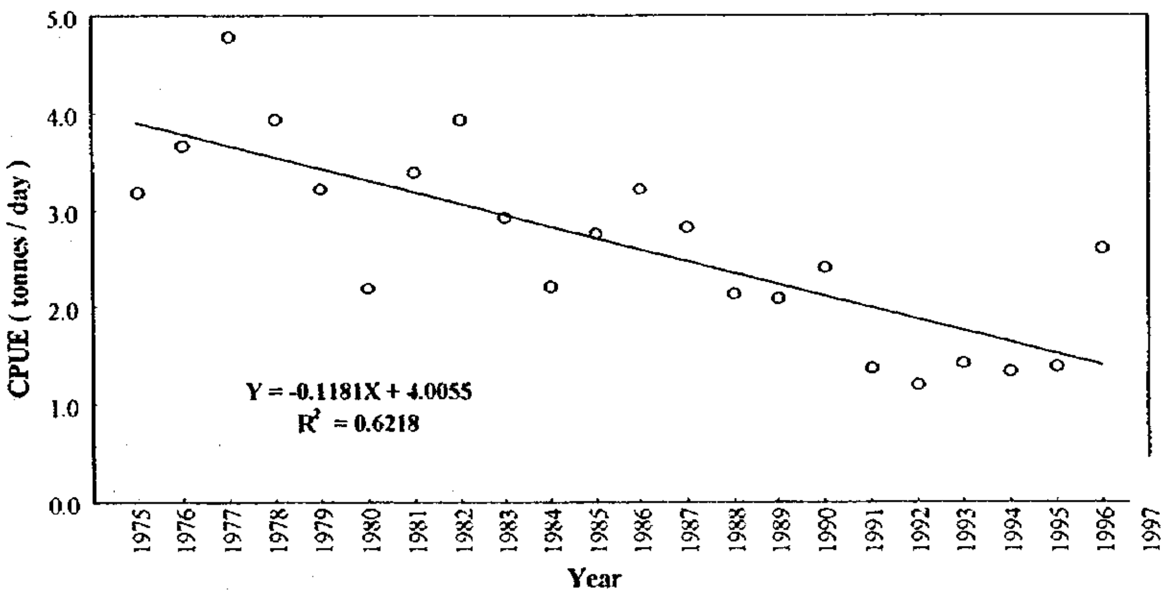



**Figure 13. Annual variation of CPUE for Piramutaba by industrial fishery. (Note: 1970s to 1992, two-trawler fishing; from 1993 on, three- or four-trawler fishing). (Source: IBAMA, 1997).**

Examining this yearly reduction in more detail, some aspects can be observed:

(1) Based on a 25 year history and experience of exploitation, industrial fisheries have concentrated on the selective fishing of piramutaba;

(2) As they are caught, piramutaba are selected on board to meet commercial size requirements;

(3) More than the officially licensed number of 48 vessels are operating in piramutaba fisheries;

(4) Piramutaba fishing vessel setups from the early 70s until 1992 had been a pair of trawlers dragging one net. However, for reasons of cost reduction and compensation for a decline in catch, the setup was changed in 1993 to three trawlers and two nets or four trawlers and three nets;

(5) Navigation instruments, school-detecting sonar and other equipment have been installed aboard fishing vessels, recently resulting in relative improvements in catch efficiency.

As the above items (1), (4) and (5) represent an improvement in the quality of fishing effort, one can think that the reequipment and rescaling of the fishing fleet by the industry in the period from 1975 to 1980 resulted in a decline of CPUE in recent years. Standardized studies of effort affecting catch efficiency are necessary for the correct assessment of the annual variation of CPUE.

Although not covered by this study, a revised value of CPUE considering recent improvements in fishing effort by the industry should indicate a relative decline in piramutaba stock.

**c) Summary**

To allow a comparison of these estimated stock size results with those in other areas, Table 15 lists the results of demersal fish resources surveys conducted in various parts of the world, with different survey vessels, key survey regions, survey period, survey area, number of trawl stations. There, the mean density of potentially occurring demersal fishes, a standard adopted for all surveys, was relatively low for the Amazonian Estuary: 0.8 and 1.6 tonnes/km$^2$ in the Dry Season and 1.1 tonnes/km$^2$ in the Rainy Season.

Surveys have shown that in subarctic and temperate zones there are few species, each of them abundant, while in the tropicsthere are many species but little abundance — a fact described as "the phenomenon of rich north vs. poor south" in the Northern hemisphere. Demersal fish stocks in the neotropical Amazon River Mouth Area reflect this rule in that there are many species indeed, while it cannot be said they are potentially abundant.

On the problem of species abundance with respect to the food chain, the number of individuals of fishes ranking high in the chain should be less than of lower-ranking ones. The key fish species studied in the present survey were all piscivorous, and their low number of individuals could be also due to their high position in the food chain.

As described above, fishery resources in the Amazon River Mouth Area cannot be said to be abundant in comparison to other regions in the world. Piramutaba stocks are targeted by the industry and if one sees the question from several different angles, the conclusion is that they have

**Table 15. Results of resources surveys aimed at demersal fish species.**

| Area | Period | Survey area ($km^2$) | Number of stations | Stock size (tonnes) | Mean density ($tonnes/km^2$) | Depth zone (m) | Main species |
|---|---|---|---|---|---|---|---|
| Bering Sea | May - Sept., 1979 | 658,740 | 950 | 9,003,400 | 13.7 | 14 — 1,080 | Pollock, Yellowfin sole, Pacific cod, Flounders |
| Aleutian Islands | June - Nov., 1980 | 119,426 | 319 | 1,799,200 | 15.1 | 1 — 900 | Cods, Rattails, Flatfishes |
| Agulhas Bank of | Nov. - Dec., 1980 | 66,813 | 146 | 276,186 | 4.1 | < 183 | Cape bake, Panga, Cape horse mackerel |
| South Africa | Nov. - Dec., 1981 | 70,241 | 186 | 347,149 | 4.9 | < 183 | Cape hake, Panga, Cape horse mackerel |
| | June, 1982 | 70,241 | 136 | 316,668 | 4.5 | | Cape hake, Panga, Cape horse mackerel |
| New Zealand E,F | March - May, 1982 | 343,532 | 220 | 279,200 | 8.1 | 201 — 800 | Hoki, Barracudas, Blue whiting |
| | March - April, 1983 | 61,071 | 114 | 636,500 | 10.4 | 201 — 600 | Hoki, Barracudas |
| Greenland East, West | June - Nov., 1988 | 277,860 | 180 | 920,500 | 3.3 | 201 — 1,400 | Greenland halibut, Atlantic cod, Res fishes |
| | April - Nov., 1989 | 277,860 | 142 | 298,000 | 1.1 | 201 — 1,500 | Greenland halibut, Res fishes, Grenadiers |
| Sea of Marmara, | June - Aug., 1991 | 51,835 | 172 | 49,669 * | 1.0 | 20 — 500 | Hake, Red mullet, Atlantic horse-mackerel |
| Aegean Sea and | Dec., 1991 - Jun., 1992 | 51,835 | 86 | 26,674 * | 0.5 | 20 — 500 | Hake, Red mullet, Atlantic horse-mackerel |
| Mediterranean Sea | April - June., 1992 | 51,835 | 140 | 28,406 * | 0.5 | 20 — 500 | Hake, Red mullet, Atlantic horse-mackerel |
| | Sept. - Nov., 1992 | 51,835 | 155 | 21,229 * | 0.4 | 20 — 500 | Hake, Red mullet, Atlantic horse-mackerel |
| South China Sea | — | — | — | 3,771,000 | 4.0 | — 50 | |
| | — | — | — | — | 2.0 | 51 — 500 | |
| Amazonn and Tocantis | Aug. - Sept. 1996 | 42,200 | 111 | 33,660 | 0.8 | 5 — 50 | Sea catfish, Piramutaba |
| River Mouth | March - April, 1997 | 42,200 | 120 | 45,600 | 1.1 | 5 — 50 | Sea catfish, Piramutaba |
| | Aug. - Sept., 1997 | 42,200 | 120 | 67,270 | 1.6 | 5 — 50 | Sea catfish, Piramutaba |

* : Recruitment stock size

been situated in need of closely monitoring.

As the Landing Site Survey revealed, fishermen said in interviews on the recent changes in fisheries in the Amazonian Estuary that there has been "increase in fishing effort (that is, in the number of vessels), decrease in catch, and no variation — or even a decrease — in size of the fish caught".

Reflecting upon these informations together, for instance, a reduction of fishing effort is necessary in piramutaba fishery in the Amazonian Estuary.

### 6.3. Procedures for Further Surveys and Research

An evaluation of resources requires at demersal first some biological information on target resources — data such as age composition, sex ratio and stock size. The next step is to advance toward a diagnosis of the resources by establishing their growth curve, maturation age, reproduction, natural mortality rate, mortality rate due to catch and so on. The combined analysis and evaluation of all these data would make possible a solid policy for the management of those resources.

This was the first systematic resources survey aimed at demersal fishes of the Amazon River Mouth Area and, as such, it did not bring out much information that could be directly utilized for stock evaluation. However, precious data were obtained on biological aspects and on the stock size for the seven key fish species. In order to evaluate the present survey, the questions were organized below around some useful points.

The trawl survey method has the advantage of allowing to estimate stock size simultaneously to collecting biological data on the target resources. The resources survey should be designed in a way of getting a good coefficient of variation, which is directly related to the accuracy of the estimate and depends on the distribution density of the target species and the number of trawl stations. Through analyzing the coefficients of variation and confidence intervals of the estimated stock sizes for each species by season or by stratum obtained from the present survey, an efficient plan of survey period, area and depth zone by target species can be established and it allows for a quite accurate estimate of stock size.

Body length data of target species were extremely important in order to clarify growth and age composition. Size composition of catch in covernet and cod-end reflected well the natural conditions of the target stock. However, the catch landed at fishing ports, fish markets and companies by artisanal or industrial fisheries may not reflect a natural size composition because that had been previously selected fishing ground, fishing method and mesh size, and marketable size. Therefore, any study of size (age) composition based on landed catch demands much caution.

Age determination of seven key fish species was tried focusing on the rings formed on hard structures — vertebral centra and otoliths. However, as those rings turned out not to be formed periodically, age could not be determined through them. A cohort analysis based on size frequency distribution — as determined by the Sea-Borne Survey — was performed, but this method did not yield positive results either. For an evaluation of the current status of resources and the implementation of a management policy, knowledge on growth and age of target species is essential. Now it is necessary to drive a continuous effort toward age determination by some methods such as feeding experiment, tagging experiment, sample collection of long continuance.

It is also essential to clearly know the age at maturation and the reproduction of fish species. This knowledge can be a trend indicator for the stock, as in many fishes a lowering of standards in the stock is accompanied by a change toward an earlier age at maturation.

Information on feeding habits is extremely important for elucidating the flow of energy in a community. Therefore, it should be hereafter necessary to identify food organisms and evaluate their weight to allow for a quantitative analysis.

The biological parameters described above are closely associated with environmental changes in the Amazon Estuary through the rainy and dry seasons. It is important to consider the present survey as a blueprint for the steady continuation of data gathering.

# 7. UNUTILIZED AND UNEXPLOITED FISHERY RESOURCES

## 7.1. Unutilized Fishery Resources and Their Utilization

The existence of unutilized fishery resources is mostly known through bycatches obtained from existing fishery or resources surveys. However, the commercial worth of the exploitation of those resources should be appraised — whether their value is high enough or they can be caught in sizable numbers. From this viewpoint, unutilized fishery resources are defined as comprising those among the 104 fish species captured during the resources survey that are not being commercially utilized — that is, species outside the Brazilian domestic market — and whose stock size is large to a certain extent.

To evaluate which species are being commercially utilized, fish names taken from the fishery statistics published by the Brazilian Institute for Geography and Statistics (IBGE) (1990 edition, as they have not been issued after 1991) and from the results of the fish price fluctuation survey regularly carried out at the Ver-o-Peso Market in Belém by the MPEG (in all 45 records from July 1994 to June 1995) were examined.

Two species — buchudinho *Stellifer rastrifer* and canguito *Arius phrygiatus* — can be picked among the unutilized resources. The former is a small-size drum of about 15 cm, very common as a bycatch in industrial shrimp trawl nets in the coast of the Guianas and the Gulf of Paria. It does not have much value as a food fish but, depending on the circumstances, it could be useful in the manufacture of fisheries byproducts. By means of a trawl net with a 100 mm mesh cod-end, it would be possible to catch about 10% of the stock. The latter species is a small-size sea catfish of about 20 cm without much importance for the industry, but one that could have some value for household consumption in artisanal fishermen. Also, like in the previous case, in the right circumstances it could serve for making fisheries byproducts.

## 7.2. Unexploited Resources and the Possibility of Their Exploitation

Unexploited resources in the Amazon River Mouth Area are defined as those distributed offshore in depths below 20 m — currently almost unexplored by either artisanal or industrial fisheries — and whose stock size is large to a certain extent, over 200 tonnes.

The unexploited resources comprise the following eleven species: the elasmobranchs cação *Carcharhinus porosus*, martelo *Sphyrna lewini* and cação-rodela *Sphyrna tudes;* the ariids cambéua *Arius grandicassis*, gurijuba *A. parkeri* and cangatá *A. quadriscutis;* the sciaenids pescada-cambuçu *Cynoscion virescens*, pescadinha-gó *Macrodon ancylodon*, pescada-curuca-grande *Micropogonias* *furnieri*, and pescada-sete-buchos *Nebris microps;* and the trichiurid espada *Trichiurus lepturus*. Of those, gurijuba and pescadinha-gó are important species in the Amazon River Mouth Area. Pescada-cambuçu and pescada-curuca-grande are one of the most important commercial species on the continental shelf of the Venezuela and the Guianas and are marketed fresh. Sharks are ordinarily salted and the other species are marketed fresh and have a certain commercial value.

One hopes the exploitation of those resources could be an alternative for the bottom-trawling by industrial fishery that today concentrate on piramutaba. Effective alternative methods of exploitation could be employed, such as longline fishing for sharks, pescada-cambuçu or gurijuba, nocturnal herding-light fishing for espada and, according to the occasion, trawl nets and gill nets for other species. In that instance, a marketing research is needed to study the profitability of these fisheries and, upon their fruition, it will be necessary to regulate the intensity of their exploitation by checking the annual fluctuation in CPUE and body length composition under continuous fishing effort.

# 8. GUIDELINES FOR THE MANAGEMENT OF DEMERSAL FISHERY RESOURCES IN THE AMAZONIAN ESTUARY

## 8.1. Characteristics of Fishery Resources

Fishery resources comprise living organisms that are utilized by human beings through fishery activities, and as such they have their own characteristic features. One is the fact they are renewable natural resources, and therefore different from mineral resources such as petroleum, coal and the like. Also, they are free from ownership. Furthermore, they undergo enough changes to render uncertain any predictions of their future.

Freedom for ownership may lead to overexploitation and stock erosion, but the ability of self-renewal can make fishery resources, with proper management, a shared property of humankind for a long time to come.

## 8.2. The Concept of Fishery Resources Management

Fishery resources being self-renewable, if adequate measures are taken, it would be possible to continuously explore them and later hand them over to future generations. The increment of biomass of a given species in a closed area is usually expressed by a logistic (sigmoid) curve with small differential values at the origin and at the carrying capacity level, and large differential values at the middle biomass level. In fishery resources, total biomass increase (increase in growth and recruitment) minus total biomass reduction (catch and natural mortality) equals surplus yield, which corresponds to the sustainable yield and is represented by a parabola-shaped curve against a progress of exploitation of stock biomass. If fisheries utilized only the surplus yield, there would not be a consequent decrease in biomass.

## 8.3. Trends in Fishery Resources Management

Current trends in fishery resources management had to change drastically with regards to past inclinations due to the United Nations Convention on the Law of the Sea. By this convention, it is recognized that the sovereign rights of exploitation of living resources in the Exclusive Economic Zone (EEZ) belong to the adjacent coastal nations, who would determine their capacity to harvest them and take proper action toward their conservation and management. Those nations would determine their respective allowable catch and the surplus, if any, should be offered to other nations.

Future fishery resources management should be in accordance with this convention. Therefore, it is urgent that the Government of Brazil evaluate the present status of various fishery resources in the EEZ and then organize its own management policy.

## 8.4. A Summary of Fisheries and Resources

The fisheries and their resources in the Amazonian Estuary so far elucidated from the present study can be summarized as follows:

**a) In General**

a-1) The basic fisheries infrastructure or socioeconomic infrastructure of the fishing communities in the Amazonian Estuary is underdeveloped, and fisheries education is not widespread. This results in people related to fisheries lacking the mentality of properly utilizing fishery resources for the long run, so as to keep them on for the common good of humankind.

a-2) As it is characteristic of tropical areas, fish species are numerous there. However, the population density of each species is low, and thus fishery resources are not abundant.

a-3) Piramutaba, the industrial fishery prime target stock in the Estuary, is in a condition of overexploitation.

**b) Regarding Artisanal Fishery**

b-1) Within employing their current fishing gears and applying their current rate of effort, the impact on fishery resources by artisanal fishery cannot be strong. It will be impossible this fleet would overfish the piramutaba stock.

b-2) The artisanal fleet explores a larger area, catches more different species, makes a better selection of profitable fish sizes as compared to the industrial fleet.

b-3) The infrastructure utilized by the artisanal fleet is underdeveloped, and so ports and places utilized for fish landing and processing facilities are hygienically precarious.

b-4) Fishermen of the artisanal fleet are not effectively organized into unions or societies. Their professional minds prohibit government officers from guiding and inquiring on their fisheries organizations.

**c) Regarding Industrial Fishery**

c-1) Fishery resources in the region have been heavily exploited both selectively and arbitrarily by the industrial fishery.

c-2) Correspondingly, non-target species and small individuals have been wastefully discarded, indicating that industrial fishery is not properly utilizing fishery resources and is unable to avoid squandering them.

Some recommendations are proposed next, based on the findings above.

## 8.5. Recommendations for the Management of Fishery Resources

**a) From the Standpoint of Fisheries Biology**

a-1) Acquisition of biological information

Sound management of fishery resources requires the continuous maintenance of a program of collecting basic biological data such as size and age composition of catch, CPUE values for both artisanal and industrial fisheries in each kind of fishing ground (river/estuary), and season and place of spawning. In addition, it is necessary to publish periodic reports containing analyses of those data and current estimates of some important biological parameters such as growth rate, mortality due to natural causes and to fishing, minimum size for maturation, etc. In this study, limited information was obtained on key fish species other than piramutaba. It is necessary to make an effort to obtain information also on those other species.

a-2) Follow-up to the fishery resources study

Elucidation of the variation in fishery resources requires a precise picture of the changes undergone by those resources under current fishery activities and environmental conditions. It is necessary to carry out many similar surveys in the future, using the same methodology on a comparable scale. The study area should be only shallow waters (5 to 20 m), for instance 5–10m stratum for three species of *Brachyplatystoma* and pescada-branca and 10–20m stratum for pescada-amarela, pescadinha-gó and gurijuba, in order to decrease the variance in their stock size estimates.

a-3) Collection, organization and management of fishery statistics

For the efficient and sustainable exploitation of fishery resources, it is essential that the collection, organization and management of all fishery statistics is carried out by the appropriate fisheries administration agency.

(1) Artisanal fishery

It is necessary to make an effort so as to obtain, at the very least, statistics for monthly catch and fishing effort by fish species.

(2) Industrial fishery

i) It is necessary to improve the present fishery statistics , especially position information on the fishing operations. There is also the need to increase the ability of quickly processing data on catch by month, by fishing ground, by fish species and size. Once those fishery statistics are fully provided, their analysis will enable the formulation of a strategy for fishery resources management.

ii) Changes in fishing effort promoted by the introduction of three- and multiple-trawler fishing instead of the customary two-trawler technique have to be evaluated with regards to the power and efficiency of those recent fishing method.

iii) It is necessary to conduct tagging experiments with the commercially important large catfishes of the genus *Brachyplatystoma* to study their migratory patterns.

a-4) Research on the amount of fishery resources discarded by industrial fishery fleet

For an efficient utilization of fishery resources and an accurate estimation of current catch statistics, it is also necessary to elucidate the amount of fishery resources thrown away by the industrial fleet.

a-5) Repopulation

Studies on the artificial reproduction and others of piramutaba should be conducted in order to establish a general program of its stock repopulation.

**b) Socioeconomic Considerations**

b-1) Promotion of fisheries education

It is necessary to bring up qualified professionals through fisheries education at all levels — specialized schools, high schools and colleges — both in Brazil as a whole and in the States of Pará and Amapá in particular.

b-2) Education and organization of the fishing communities

For fisheries management to become a reality, the most important point is the understanding and cooperation in the fishing communities regarding the management of fishery resources. Continuous dissemination of fisheries education and knowledge to these people is essential. Existing cooperatives and associations involving artisanal fishermen should be stimulated back into action at the very least.

People involved in industrial fishery are already organized in labor unions, but need to be better educated on fishery resources and on the conservation of water area environments.

b-3) Organization and arrangement of fisheries administration

The management, research and study of fishery resources in the northern region of Brazil, conducted at present mainly by CEPNOR/IBAMA, require a proper enhancement of that organization to duly cope with the diversification of emerging administrative and research issues.

b-4) Organization of the socioeconomic infrastructure

The socioeconomic infrastructure concerning production, processing, storage, distribution, sales, etc. with respect to fisheries around the Amazonian Estuary should be established properly. Also, an educational program aimed at teaching local consumers how to process and cook fish species that are usually discarded or not utilized by either the artisanal or the industrial fleet is deemed necessary.

### c) Fishery Regulations

There are two kinds of fishery regulations. Qualitative restrictions can be applied to fishing gear, fishing methods, fishing grounds and fishing seasons — such as length and mesh-size limits. Quantitative restrictions refer to fishing effort — e.g., a limit on the number of vessels or fishing gear utilized. Generally speaking, fisheries regulations are used in fact as a combination of several regulations according to the present status of fisheries.

For the enforcement of any kind of regulation, however, it goes without saying that proper understanding and cooperation of fishery-related personnel should be obtained beforehand.

c-1) Restrictions on fishing gear and fishing methods

There are basically two kinds of fishing gear in fishery in the Amazonian Estuary: the bottom trawl net and the gill net. Longlines and all different kinds of traps are restricted to some areas close to the coastline and are not of much importance in total landed quantity of fish in the Estuary.

Previous studies have shown the current gill net mesh sizes cannot overexploit the target fishery resources. On the other hand, the bottom trawl net can cause the overexploitation of these resources with little effort. The restrictions here proposed should apply to bottom trawl nets of the industrial fleet.

As for the application of restrictions on cod-end mesh size, there is no basic information in the present study that could suggest either way. It is necessary that the 100 mm minimum size for stretched cod-end established by law on 9 March 1983 be observed.

c-2) Restrictions on fishing grounds and fishing seasons

The objective of restricting fishing grounds and seasons is the conservation of the larval or young fish of the target fishery resources and that of their respective spawning grounds and seasons for spawning fish school. Piramutaba does not spawn in the Estuary, so these restrictions will be not effective there. However, the small fishes are carried down to the Estuary, which becomes their nursing ground, and the current legislation indeed forbids the industrial fleet to operate in this area (south of 0° 05' N and west of 48° 00' W).

Furthermore, the dry season is the period when piramutaba schools migrate up the Amazon River. The total stock size of piramutaba in the survey area in the Dry Season is less than in the Rainy Season. Since the fish are confined into a restricted freshwater area in the Estuary, industrial fishing vessels often operate inside the forbidden area during this period. Restrictions on the fishing season can reduce the impact of industrial fleet activities on the piramutaba stock in the Estuary.

c-3) Restrictions on fishing effort

Limitation on the number of vessels may be the most effective of all restrictions proposed because it is comparatively more manageable. As a first step, in restrictions on fishing effort for piramutaba trawl fishing the number of licensed vessels should be reduced. If further restrictions are needed, it would be appropriate to relate the number of licensed vessels to the estimated stock size of piramutaba in the Dry and Rainy Seasons respectively. An even stronger measure would be controlling the number of licensed vessels in accordance with closely monitored actual piramutaba resources conditions.

Should a reduction of licensed vessels be adopted, there may be the problematic possibility that the industrial fleet request monetary compensation for their estimated losses.

c-4) Limitations on catch

This limitation should be put forth in accordance with the United Nations Convention of the Law of the Sea in addition to other restrictions. In this case, the establishment of a catch quota by species and a system of monitoring and enforcement by both the appropriate government administrative body and a research institution is essential. The above-mentioned Brazilian Government Directive establishes the maximum catch allowed for piramutaba as 21,500 tonnes. As the total landing quantity of piramutaba in recent years have fluctuated around 10,000 tonnes, that maximum limit seems to overestimate the potential of the present stock. It is suggested that maximum catch value be reduced.

## 8.6. The Rational Utilization of Fishery Resources and a Strategy for Fisheries Management

Based on the results of this project, and with the goal of providing grounds for the fisheries management policy aimed at the sustainable development of fishery resources in the area, the following suggestions are proposed.

### a) Special Suggestions on Piramutaba Fishing Grounds

a-1) Improvement of utilization of catch by industrial fishery

Investment in fishfood processing technology, marketing and nutritional education in order to make different fishes more attractive for consumers should involve both government agencies and the private sector. Better utilization of caught fishes — piramutaba and bycatch ones — will reduce waste of fishery resources in the piramutaba fishing grounds.

a-2) Encouragement of the usage of selective fishing gear

Bottom trawling is an expensive fishing method that is also little selective, and so its usage should be more and more restricted in piramutaba fishing grounds. On the other hand, fishing gear such as gill nets and longlines are very selective and would hardly lead to the overfishing of local stocks. The usage of resources-friendly gear would require many workers and help employ a good number of the personnel eventually laid off by the industry.

**b) General Suggestions on the Fisheries in the Amazon River Mouth Area**

b-1) Encouragement of the utilization of other fishery resources, demersal and pelagic

The vessels in the industrial fishing fleet operating in Northern Brazil are actually capable of exploring areas farther and deeper into the ocean than they have done hitherto. Those farther, deeper environments have not yet been commercially exploited and are currently being studied by Project REVIZEE (an acronym in Portuguese for Program for the Evaluation of the Sustainable Potential of Living Resources in the Exclusive Economical Zone), a marine resources survey project by the Brazilian Government. The results of that study will be extremely important for the future organization of fisheries in northern Brazil, and could well contribute for the further expansion of the fishing activities of the fleet now concentrated mainly on piramutaba.

b-2) Preparation of the fisheries industry in order to work with a wider range of products

Tropical fishing grounds typically harbor a great number of species, each represented a few more stocks with little biomass. Therefore, tropical fisheries should avoid specialization – that is, local fleets should not concentrate on a single fishing stock. Processing of a large number of species is not easy as the market tends to be very conservative. Thus, research on fishfood processing technology and investment in the marketing of a variety of fish species is recommended to overcome this situation.