2-1-4 Mariculture

(1) Shrimp Culture

① Overview of Shrimp Culture

In the early 1970s, Costa Rica was a pioneer in the Latin American countries in shrimp culture, but until recently this industry was stagnating.

There are various reasons why shrimp breeding in Costa Rica is now less developed than in its neighbors. To some extent, this derives from the technical and financial failure of some of the early shrimp breeding operations.

Costa Rica is in the tropical savannah climate region, and this is the ideal environment for breeding tropical shrimps year round. However, the coastline along the Pacific coast of Costa Rica is very hilly, which makes it very expensive to build aquacultural ponds. Over on the Atlantic coast, there is a serious lack of basic facilities and this combined with poor climate means that there is even less potential for organizing aquacultural ponds. It is estimated that the total area in Costa Rica that could handle breeding is between 5000 and 7000 ha.

One appropriate species for breeding in Costa Rica is the whiteleg shrimp (*Penaeus vannamei*). It does exist on the Pacific coast of Costa Rica, but the post-larvae of this species are not available in sufficient abundance to make

them usable as seedlings for large scale industrial shrimp culture.

Whiteleg shrimp natural post-larvae are easily obtained in neighboring countries (Honduras, Nicaragua, El Salvador, Guatemala), but if the shrimp breeding industry develops any further, it will surely become necessary for the industrial breeders to create new incubation grounds to ensure secure and stable supplies of post-larvae.

Despite the fact that Costa Rica suffers from the above limitations, the Cosechas Marinas project has achieved successes as a commercial hatcheries, and the policy of the Costa Rican government in this area should be able to increase the speed of development of the shrimp culture industry.

② Analysis of Shrimp Culture

A. Culture Locations

Only the Pacific coastline of Costa Rica has locations suitable for shrimp breeding. This coastline is approximately 1100 km long, and is divided into four sectors according to climate, soil, and topography.

i Northern Pacific Coast Region

The northern Pacific coast region stretches from Golfo de Nicoya to the Nicaraguan border and has a lot of estuaries bordered with mangrove with good brackish water. However, there is insufficient fresh water on the north side of Cabo Velas. Apart from during the rainy season, the salt content of the waters in this region seems to be too high for shrimp breeding.

The mangrove soil of the estuaries has a lot of organic matters and oxygen, which means that it is not well suited to shrimp culture. This also makes construction of ponds very expensive. The Costa Rican government is protecting the mangrove forests because they are natural breeding grounds for fish and shrimp seedlings.

Considering all of these limitations and factors, it is estimated that the total area in the north Pacific coast region suitable for aquaculture development is less than 1000 ha.

ii Nicoya Bay Region

While it is said that there is as much as 2000 ha. of land in the Nicoya Bay region suitable for shrimp breeding, there are many limitations and restrictions on shrimp breeding development in this region. It seems that the potential for shrimp breeding in this region has been exaggerated. One major problem here is that a large proportion of this land is in the mangrove forest belt.

The second reason is that the coastal region topography is very hilly and the alluvial plain is very narrow and small in area. These impose severe limitations on the size of the breeding ponds that could be built there.

iii Central Pacific Coastal Region

The central Pacific coastal region has approximately 4000 ha. of land appropriate for shrimp culture, and the best area is in the vicinity of Quepos. Isla Damas near Quepos has excellent clean sea water on the land side, and the salt content varying between 10 and 20% remains ideal year round for breeding whiteleg shrimp. On the ocean side undiluted sea water can be obtained which is necessary for incubation.

iv Southern Pacific Coast Region

The southern Pacific coast region extending from Uvita to the Panama border is estimated to have 3000 ha. that could be used in various ways for shrimp breeding. However, this region suffers from insufficient infrastructure,

insufficient communications and connections with important harbors and consumption centers, and bad climate.

B. Species of Shrimp

The post-larvae of prawns (Penaeidae) living in the Pacific Ocean off the coast of Costa Rica are principally of the species *Penaeus vannamei*,*P. stylirostris*, and *P.occidentalis*.

The *Penaeus vannamei* species is best suited to propagation. It can be bred at high breeding density, and to some extent the technology required for breeding the species is already in place.

P. stylirostris is not very resistant to low value of oxygen dissolved in the water and very sensitive to water quality, is very easily damaged by handling stress, and nutritional conditions are severe. There are other problems such as low immunity to certain types of virus pathogens. On the other hand, its growth rate is very fast, and because of this it is being bred at low density (one per square meter), and combined with *P. vannamei* (5 to 10 per square meter). When *P. occidentalis* is bred in a lake, its growth is slow and it does not have a good survival rate.

C. Aquacultural Technology Foundations

The Cosechas Marinas project included Costa Rican technologists with a lot of experience and Costa Rican incubation ground managers, while the Chomes project is

being supported by technical assistance from a French consulting firm. However, apart from the people employed in these projects, it can be said that the Costa Rican shrimp breeding industry has a firm technical foundation.

D. Feeding and Raising

At the moment in Costa Rica, there is no production and sale of mixed feed for shrimps.

(2) Freshwater Aquaculture

① Positioning of Freshwater Aquaculture in Costa Rica

The foundations for freshwater aquaculture are already in place in Costa Rica, and the technology is also well established, but the government has not yet established a national plan for aquaculture development. However, freshwater aquaculture does have the following advantages and it seems likely that in the near future it will become as important as seawater aquaculture.

A. This can be done in agricultural areas suffering from a general lack of animal proteins.

B. It mainly involves consumption of land, and consequently there are not many distribution problems.

C. It can be done on agricultural land not well suited to industrialization, thereby improving land utilization.

D. It also enables multipurpose use of water resources (reservoirs, dams, etc.).

E. Agricultural waste matter can be used.

② Low Ground Breeding

The first species bred in Costa Rica were tilapia (*Tilapia mossambica* and *T. melanopleura*), and the first of these were brought in from El Salvador by the Ministry of

Agriculture in 1963. In 1974 the Fish and Wild Animal Resources Bureau of the Ministry of Agriculture instituted a new Aquaculture Department, and this marks the beginning of promotion of aquaculture development centering on lake breeding throughout the country started. Chinese freshwater carp, carp (hakuren), and other fish were introduced. Breeding of trout in high altitude cold regions was also begun.

Freshwater breeding development has been promoted by MAG. Apart from trout, breeding is done using Chinese-type organic fertilizer and plankton as food, and unfortunately operations are rather careless. Table 10 lists the main freshwater breeding grounds in Costa Rica.

③ High-Altitude Breeding

The Aquaculture Office has been encouraging breeding of trout in high-altitude locations as small-scale side business for farms, and for production of animal protein sources and export products. The majority of the breeding grounds are located in the Valle de Copey de Dota in San Jose Province at an altitude of 1500 meters.

④ Other Types of Breeding

Onitenaga shrimp (Macrobrachium rosenbergii) and freshwater clams and other species are also being bred.

TABLE 10 MAIN FRESHWATER BREEDING GROUNDS IN COSTA RICA

Name	Year Built	Location	Tank Area	Owner
FABIO BAUDRIT MORENO	1974	ALAJUELA	1.3ha	Costa Rica University
ENRIQUE JIMENEZ NUNEZ	1977	GUANACASTE	5ha	Ministry of Agriculture
LOS DIAMANTES	1981	LIMON	2.7ha	Ministry of Agriculture
28 MILLAS	1977	LIMON	5ha	National Banana Association
LA RITA	1977	LIMON	*	ASBANA, S.A.
RIO BLANCO	1979	*	40ha	JAPDEVA +
CENTRO DE DIVERSIFICATION ACUICOLA DE TURRIALBA	1968	CARTAGO	1.9ha	Center for Aquaculture Diversification
SAN CARLOS	*	ALAJUELA	1ha	
FRAIJANES DE ALAJUELA	*	ALAJUELA	*	

Notes *: Unknown
+: JAPDEVA: Atlantic Coast Port Authority Economic Development Commission

Source: Estudio Acerca del Potencial de Aquacultur en Enstanques en Costa Rica

2-2 Fisheries Administration

(1) National Development Plan

MIDEPLAN announced a five-year plan in December 1982 (1982 to 1986) divided into two parts. The first part contained the overall plan, and the second the individual sections of the plan.

The following is a summary of the proposals contained in the undeveloped planning statement for the fisheries industries.

① Overview

A. To promote development of the fisheries industry, investment funds for establishing facilities for fishing boats, fishing gear, and materials and for freezing, processing, and packaging (canning) of fish products should be increased. Sea bed breeding of shellfish and mollusks and also freshwater breeding of fish should be encouraged, along with deep sea fishing to exploit resources not currently being used. Production also of by-products and fish meal produced form the remnants generated when by-products and fish and shellfish are processed is also to be promoted.

B. As the catch increases and fisheries production increases, it is necessary to develop extended advertising and promotional activities to increase consumption of fresh fish, and the cost price of

fishing gear should be reduced in order to be able to sell fresh fish at lower sales prices.

② Individual Plans

A. Evaluation from the Standpoint of Resources

i While increasing the technical level of the fishermen, their income should be improved and this would be a way to help artisanal fishing. It is also necessary to improve the nutritional intake of the people of Costa Rica.

ii The catch of shrimp and sardines should be increased.

iii The catch of tuna by shipping boats registered in Costa Rica should be increased.

iv Regional breeding development work should be assisted and national projects in this area promoted.

v To orient the fishing industry towards united organization of fishermen and to improve the effect of support from national and governmental institutions, research is required to harmonize relations between all these organizations in the fishing industry sector.

vi Costa Rica possesses an excellent ecological environment for developing fish and seafood propagation, and the government should support development of projects in this area and also establish a well-

organized research system. Technology transfers should be sought to develop activities under current technical assistance contracts to the maximum in linking up with other countries.

B. Implementation Planning for Measures to Promote Production

i A fisheries industries development should be proposed.

ii A development work plan should be developed to promote sea bed breeding of shellfish and mollusks and freshwater breeding of fish.

iii Funds required by artisanal fishermen for fishing boats, fishing gear, materials, facilities for freezing and packaging the products and so on should be increased.

iv Aggressive development of advertising and promotional activities should be undertaken to increase domestic consumption of white fish.

v To improve and develop distribution of the catch from artisanal fishermen and small-scale fishing companies, as well as generally promoting the development of the fisheries industry, a fishing terminal should be built at Bario El Carmen in the city of Puntarenas, and a study should be undertaken to investigate the need for constructing fisheries industries bases in Quepos.

Along with these works it is also necessary to develop demersal shrimp resources.

C. Production Targets

The national development five-year plan contains production targets by industry for primary industries in Table 11, and targets for the fisheries industries are included in this.

TABLE 11 1983 TO 1986 PRIMARY INDUSTRY NATIONAL DEVELOPMENT PRODUCTION TARGETS
(Units: 1000 ton, Sums: Million colon)

	1983		1986		Annual Increase in Value 1983 to 1986 (%)
	Production	Value	Production	Value	
1. Traditional Products		5,686.0		6,473.2	4.4
1) Coffee	124.6	2,424.1	148.7	2,902.2	6.2
2) Bananas	1,112.6	1,614.4	1,180.7	1,713.2	2.0
3) Cattle (No. of head)	69.4	1,190.7	76.8	1,316.7	3.4
4) Sugar Cane	2,624.6	351.7	3,099.5	415.3	5.7
5) Cocoa	5.0	105.1	6.0	126.2	6.3
2. Non-traditional Products		70.0		87.0	7.5
1) Melons	4.0	34.4	4.8	41.3	6.3
2) Coconut Oil	10.5	30.3	11.9	34.6	4.5
3) Peanuts	1.3	5.3	2.7	11.1	29.0
Total		5,756.0		6,560.2	4.5
1. Grains		866.7		934.6	2.5
1) Rice	230.4	573.4	235.6	586.4	0.6
2) White Corn	86.3	124.2	92.9	133.8	2.5
3) Yellow Corn	18.3	26.3	22.8	32.8	7.6
4) Kidney Beans	20.0	90.6	24.0	108.6	6.2
5) Minor Grains	47.2	52.2	65.4	72.4	
2. Oil Plants		237.2		331.2	11.7
1) Raw Cotton	2.2	29.6	5.5	73.8	35.0
2) Soy Beans	3.0	10.5	14.4	50.3	70.0
3) Coconuts	200.0	160.0	194.0	155.2	-1.0
3. Tabacco	2.5	37.1	3.5	51.9	11.9
4. Vegetables		133.0		160.8	6.5
1) Potatoes	25.6	107.7	31.4	132.0	7.0
2) Onions	3.7	12.8	4.2	14.6	4.4
3) Tapioca	27.7	12.5	31.5	14.2	4.3
5. Daily Products		1,341.5		1,559.0	5.1
1) Milk (Million Litres)	317.6	889.0	378.3	1,058.8	6.0
2) Pigs (No. of Head)	10.7	166.1	12.0	186.8	4.0
3) Chickens (No. of Head)	13.2	155.1	14.4	169.9	3.1
4) Eggs (Million)	237.0	131.3	259.0	143.5	3.0
6. Marine Products	16.0	106.4	18.0	119.7	4.0
7. Wood (Thousand cubic meters)	585.0	337.4	609.5	351.1	1.5
Total		3,022.2		3,455.8	4.6
Overall Total		8,788.2		10,016.0	4.5
Note: Proportions of Marine Products (%)					
Proportion of Domestic Consumption		3.5		3.5	
Proportion of Overall Total		1.2		1.2	

(2) Fisheries Promotion Plan

In 1984 the fisheries and fish propagation industry accounted for 0.41% of Costa Rica's GDP. Employing approximately 30,000 people, its products were important protein sources for the people of Costa Rica.

The Ministry of Agriculture formulated policies for the fisheries industry in 1988 as follows.

"Overfishing and indiscriminate fishing will be suppressed and accurate information on resources of ocean fish will be developed. While promoting effective utilization of unused resources, efforts will be undertaken to improve the diet of the people of Costa Rica. Export of fisheries products will be promoted to increase income of foreign exchange. These proposals were studied by the Costa Rican Legislature, which then passed special legislation to implement the policies agreed upon. The following two plans were formulated, and the first was implemented, while the second of them has been partially implemented.

① Fisheries industry development project supported by advice from FAO

This covers education and support for fishermen's cooperatives, construction of infrastructure in Puntarenas and Cuajiniquil, distribution and sales of catches by the CNP, and support for introduction of shrimp trawlers and processing equipment for fostering creation of fisheries industries companies.

This was implemented between 1976 and 1983 with advice from FAO and mediation on finances to BID.

② Puntarenas Bay multipurpose harbor construction

This project covers construction of a fishing boat wharf in Puntarenas and construction of infrastructure on reclaimed land in an estuary. Unfortunately, however, funds were insufficient, and at the moment financial support has been applied for to (BCIE) and to the governmental financial institutions of the advanced countries. While a section of the fishing boat wharf and one building have been constructed, and are being used, construction on the remainder of the project is at the moment at a standstill.

(3) Related plans

The following is a summary of the assistance and results achieved in promoting fisheries industry development currently being implemented by international agencies and by various foreign countries in Costa Rica, plans currently progressing, and various proposals currently in the planning stages.

① Spanish specialists Chorotega region fisheries industries economic survey (individual surveys)

These were undertaken between 1985 and 1987 over a three-year period, and one specialist each on marine biology of the ICI family and on distribution of fisheries products were dispatched by the Spanish government. They produced a survey report and an advice report. The Costa Rican counterparts were MAG and MIDEPLAN. The reports included the following items.

A. Reports on the special characteristics of the Chorotega region Pacific coast fishing industry

B. A plan for education of fishermen and organization of fishermen's cooperatives and proposals for improving distribution and sales

C. Proposals on comprehensive fishing industries development planning for the Chorotega region. At the moment, nothing has been done on implementing any of these proposals.

(2) Canadian international development cooperation work group project

The work group receives cooperation and financial support from the International Development Cooperation Council, established in 1970 by the state government of Quebec in Canada, and this project has been underway since 1987 with the following activities.

The Costa Rican counterparts are INFOCOOP and two coops in the fishermen's cooperatives association.

A. A project for introducing and supporting personal computer use in the Marine Products Bureau and instruction and support on operation

B. Project to support fishermen's cooperatives and the fishermen's cooperatives association

i Economic advice and financial support for fishermen's cooperatives associations in two regions, that is the FEDEPESCA in the City of Puntarenas and ORCOOPES in the Chorotega region

ii With a plan for integrated loading of catches from all the fishermen's cooperatives under the two associations, and financing for the funds required for constructing facilities, the work group is providing support some in the form of grant aid, and some of which has to be paid for under the name of FEDECREDITO (finance for associations).

The grant aid that has already been allocated amounts to CA$400,000 for FEDEPESCA and CA$300,000 for ORCOOPES. Funds required above and beyond this for facilities construction and operation after completion of construction will be covered by a plan for long-term low-interest financing.

iii Support for distribution and sales of catches

iv Plans for improving the technical capacities and for training and education of the members of all the fishermen's cooperatives in the two associations

v Assistance and cooperation for diversification of products by processing catches

③ Projects of FAO and Norway government institute

A. This covers support and assistance in proposals of a development plan based on improving the technical level of the fisheries industry, and promoting effective utilization and management of resources, and it is planned to extend from July 1988 until December 1989.

B. A continental shelf demersal fish resources study extending from the south coast of Mexico to Costa Rica (details unknown)

④ West German technical cooperation work group fisheries increase and breeding expansion project

This aims at introduction and expansion of techniques and technology for increasing breeding of fish and shellfish including shrimp and freshwater fish and started out in April 1987 and is still underway. The West German investment budget for this is $1,750,000US.

⑤ EEC fisheries industries development support project

This aims to work towards supplying the shortfall in animal protein in the diet of the people of Latin America, and in concrete terms it includes ocean resources studies, increased breeding of fish and shellfish, education and training for artisanal fishermen, and support in all of these areas. The EEC contribution of financial assistance amounts to SDR466,000 (equivalent to approximately $605,000US), while EEC member countries are contributing SDR305,000 (equivalent to approximately $400,000US), the total comes to SDR771,000 (equivalent to approximately $1,005,000US), and the implementation period has not been decided yet.

⑥ Italian government institute Nicoya Bay artisanal fishing syndicate support project

This aims to support and provide assistance for the Nicoya Bay artisanal fishermen's syndicate union (SUPAP), and the Costa Rican Workers Central Council, the support group forthis union, negotiated with the Italian government through Mr. L. Villalobos, the Minister of Labor, to work out this project, and obtained $US1,000,000 in grant aid for construction of infrastructure to support distribution of catches obtained from Italian national workers groups, and in addition to that, they are also receiving long-term low-interest loans amounting to $US450,000 for expansion of the catches and productivity, as reported in a local newspaper dated 3 August 1988.

Part of this grant finance appears to be being applied to a section of the plans for construction of the multipurpose facilities in the Puntarenas Harbor. MAG is not in any way involved in this project whatsoever.

⑦ Dutch government Nicoya Peninsula region development assistance project

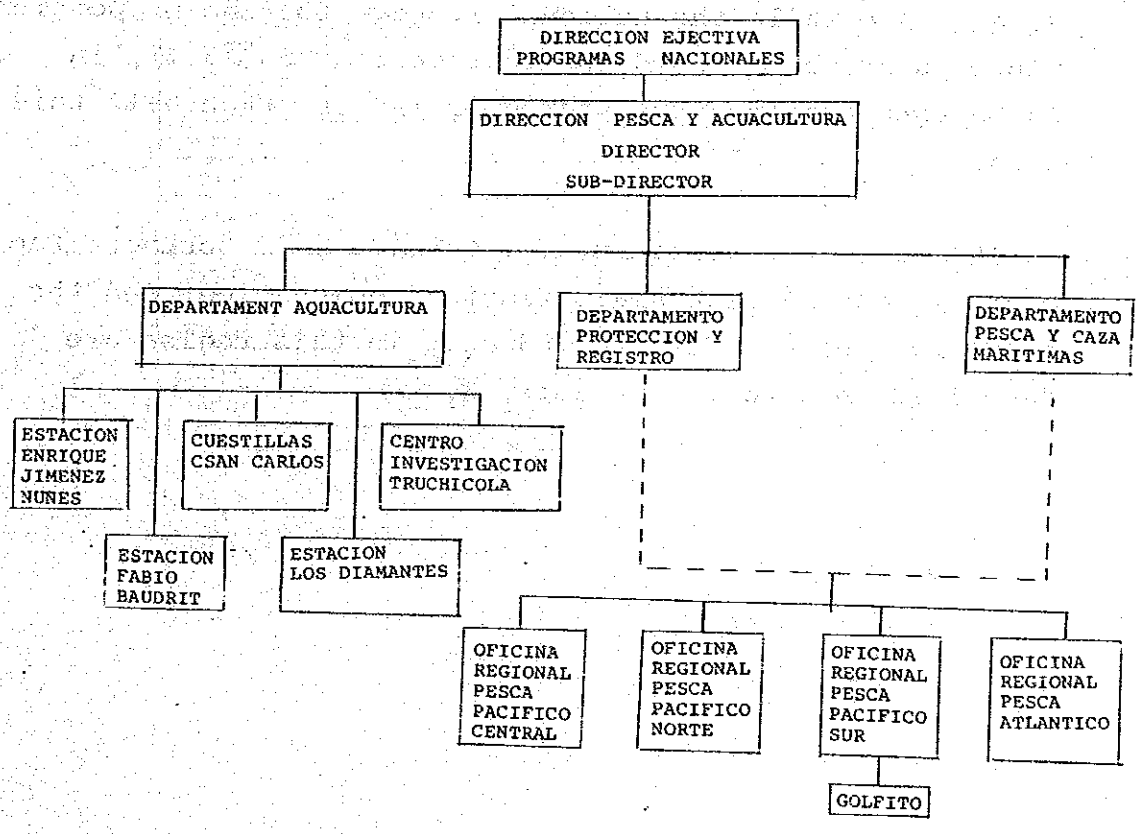
This project covers effective utilization of resources in the three areas of agriculture, forestries, and fisheries, and assistance in firmly establishing technology for expanded breeding and for establishing sales routes as well as financial assistance for all of these, and the explanatory document on this project was produced by the International Agriculture Center, an institute of the Dutch government, and the International Agriculture Center's economic research institute, which was submitted to MIDEPLAN in February 1988.

The Dutch requested MIDEPLAN and MAG as the counterparts in Costa Rica, but the implementation period for this project has not been decided yet.

(4) Fisheries administration structure

The main agency for overseeing the fisheries industry is the Ministry of Agriculture, which regulates agriculture and stock raising. Under the Minister of Agriculture stands the Vice-Minister, and under him comes the Marine Products Bureau.

The Marine Products Bureau is divided into three sections, the Fishing Industries Resources Division, Resources Protection and Licensing Division, and the Propagation Division, it has four regional offices besides.



SOURCE: MAG

2-3 Northwest Pacific Coast in Costa Rica

Costa Rica is located between latitude 8 and 11 degrees North and longitudes 83 and 86 degrees East. It has a total area of 51,100 square kilometers, and a population of 2,460,000 (1984). The country is divided into seven provinces, and provinces are subdivided into cantons.

Guanacaste Province is located in the northwest of Costa Rica, and is on the Pacific coast. Guanacaste Province accounts for 19.8% of the total land area of the country, has 7.8% of its population, and a population density of 19.0 persons per square kilometer, and thus it has the smallest population density in the country.

Fifty-one per cent of the working population of Guanacaste Province are engaged in agriculture, forestries, and fisheries, much higher than the national average of 31.4%. And while the national average for the proportion of the population involved in manufacturing is 13.4%, in Guanacaste Province the statistic is less than half this at 5.5%.

The subject of this survey, Guanacaste's northern Pacific coast is dotted with small fishing communities, and the conditions of the fishing industry in this region are described in detail in Chapter 3.

TABLE 12 REPUBLIC OF COSTA RICA DATA BY PROVINCE (1984)

No.	Province	Number of Cantons	Area (Km^2)	Population			Number of Persons Per Household	Population Density (Km^2)
				Total	Males	Females		
1	San Jose	20	4,960	893,254	433,876	459,378	4.2	180.1
2	Alajuela	15	9,753	430,634	218,275	212,359	4.5	44.2
3	Cartago	8	3,125	269,860	136,271	133,589	4.8	86.4
4	El Dia	10	2,656	195,389	97,057	98,333	4.5	73.5
5	Guanacaste	11	10,141	193,024	97,987	95,037	4.4	19.0
6	Puntarenas	11	11,277	291,008	149,845	141,163	4.1	25.8
7	Limon	6	9,188	187,057	97,714	89,343	4.2	20.4
	Total	81	51,100	2,460,266	1,231,024	1,229,202	4.4	48.1

Source: Nacional Census (1984)

TABLE 13 GUANACASTE PROVINCE NUMBER OF EMPLOYEES IN MAIN INDUSTRY

Main Industries	National Figures		Guanacaste Province	
	Employees	Distribution Percentage	Employees	Distribution Percentage
Agriculture, Forestries and Fisheries	249,400	31.4	28,833	51.0
Industrial Development and Quarrying	1,549	0.2	296	0.5
Manufacturing	106,046	13.4	3,129	5.5
Electricity, Gas, and Waterworks	9,035	1.1	462	0.8
Construction	41,760	5.2	3,060	5.4
Trade	87,555	11.0	4,296	7.6
Transportation, Warehousing, Communications	19,875	2.5	227	0.4
Finance, Insurance, Real Estate	20,267	2.6	599	1.1
Public Officials	176,093	22.2	9,784	17.3
Other	82,246	10.4	5,894	10.4
Totals	793,826	100.0	56,580	100.0

Source: Nacional Census (1984)

Chapter 3 Survey Particulars

Chapter 3 Survey Particulars

3-1 Fisheries Resources Survey (Work I)

3-1-1 Survey Purpose and Method

(1) Objective of survey

To estimate the distribution and biomass of the main demersal species along the northern Pacific coast of the Republic of Costa Rica (the Region ranging in depth from 50 to 500 m from Cabo Blanco to Bahia Santa Elena Bay, thereby contributing to the advancement of the fishing industry in the same Region.

(2) Survey policy

In order to achieve the aforementioned objective, the following survey tasks were set.

① Determination of seabed topography and depth soundings
② Determination of oceanographic conditions
③ Confirmation of species distributed in Region
④ Selection of principal species and determination of their distribution
⑤ Estimations of main species biomasses
⑥ Confirming the existence of Guardian banks and distributions of species living there
⑦ Others
   A. Distributions of marine resources principally around rocky reefs
   B. Determining diurnal periodic activities of fish for

the purpose of estimating catch efficiency of fishing equipment

C. Taxonomic identification of the main groups of marine fish

For the effective conduct of the survey, it was implemented as a preliminary survey and a main survey. In performing the analyses the survey Region was divided into 3 Regions using the 10° 30' N. latitude line and the Cape Guiones southwesterly line; these were numbered as Regions 1, 2, and 3 from north to south (see Fig. 2).

(3) Survey method

1) Vessel used: *Nisshin Maru #201* (98.71 tons); (see Appendix Table 1)

2) Survey particulars

A. Preliminary Survey (from 4/1/87 to 6/1/87)
This was determined to be a basic survey for the purpose of planning the main survey.

i Survey of seabed topography and depth sounding

Term: Entire survey period

Region: Coastal Regions, Guardian banks (4/11 to 4/14, 1987) (Figs. 3a and 3b)

Method: Depth measurements using fish detector, and determination of seabed type by trawling.

ii Oceanographic survey

Term: 5/20 to 5/23, 1987

Observation stations: 28 stations (Fig. 4)

Method: Measurements of water temperature in all water layers (0 to 400 m) using XBT and a digital thermometer. Due to trouble with equipment, measurements of salinity and dissolved oxygen were cancelled. In addition, observations were made of general sea and meteorological phenomena.

iii Fishing survey

Term: 4/26 to 5/29, 1987

Equipment used: Single-rigged trawl net (Figs. 5a, 5b)

Double-rigged trawl net (Fig. 6)

Number of survey stations: 28 stations for single-rigged trawl net (50 to 300 m depth), 69 stations for double-rigged trawl net (50 to 100 m depth)

Towing time: 30 minutes in general

Towing speed: 3 to 4 knots in general

Processing of Catch: After weighing the total weight of the catch for each haul, as well as the weight of major species, the size compositions of the principal species were taken. Major species were photographed.

iv Biological survey

Identification of species: Samples of some of the catch underwent species identification (work performed mainly by CIMAR).

Biological measurements: For major species, measurements were made of body length, weight, sex, and gonad weight (work performed mainly by CIMAR).

v Larvae collection survey

Term: 4/26 to 5/29, 1987

Net used: Larvae net

Collection stations:

Method: Collection by larvae net at night (work performed mainly by CIMAR).

B. Main survey

10/27/1987 to 3/10/1988

6/8/1988 to 10/30/1988

Plan formulated on the basis of preliminary survey results.

i Survey of seabed topography and depth sounding

Term: Entire survey period

Region: Coastal Regions, Guardian banks (11/29 to 12/2, 1987) (Figs. 3a and 3b)

Method: Same as preliminary survey.

ii Oceanographic survey

Term: first 10/27 to 11/2, 1987
second 12/27 to 12/30, 1987
third 6/10 to 6/13, 1988
fourth 9/1 to 9/3, 1988
fifth 10/25 to 10/30, 1988

Observation stations: 23 stations (Fig. 4) On the first time 13 stations were added during the Guardian bank survey.

Method: Based upon the method used for the preliminary survey. However, on the fifth time a DO meter (Submersible Data Logger, Model 606) was used for measurements of dissolved oxygen and salinity.

iii Fishing survey

O Bottom trawling

Term: first 11/7/1987 to 1/14/1988
second 1/11 to 3/8, 1988
third 6/10 to 8/7, 1988
fourth 9/3 to 10/3, 1988

Equipment used: Same as preliminary survey

Number of survey stations: Survey stations were allocated in proportion to the area of strata (depth zone and Region).

First; single-rigged trawl net (50 to 500 m depth) 127 stations (Fig. 7a)
double-rigged trawl net (50 to 150 m depth) 51 stations (Fig. 7b)

Second; single-rigged trawl net (50 to 500 m depth) 121 stations (Fig. 7b)
double-rigged trawl net (50 to 150 m depth) 52 stations (Fig. 8b)

Third; single-rigged trawl net (50 to 500 m depth) 121 stations (Fig. 7c)
double-rigged trawl net (50 to 200 m depth) 55 stations (Fig. 8c)

Fourth; single-rigged trawl net (50 to 500 m depth) stations (Fig. 7d)

Towing time: Same as preliminary survey.

Method: The single-rigged trawl net survey was conducted as the principal fishing survey during daylight hours over the entire survey Region. The double-rigged trawl net survey was conducted at night in shallow Regions of 50 to 150 m (200 m in the third round) depth.

Catch processing: Based upon processing used in preliminary survey.

O Test fishing by bottom long lining (two types) and shrimp pots

Term: first, 8/13 to 8/26, 1988; second, 10/8 to 10/21, 1988

Gear used: First;

bottom long line (type 1)	(see Appendix Fig. 1)
bottom long line (type 2)	(see Appendix Fig. 2)
shrimp pots	(see Appendix Fig. 3)

Second;

bottom long line (type 1)
bottom long line (type 2)
shrimp pots

Number of survey stations:

bottom long line (type 1)	25 (Fig. 9)
bottom long line (type 2)	26 (Fig. 9)
shrimp pots	23 (Fig. 9)

Method: Setting and hauling of bottom long lines and pots were performed at times appropriate to sea conditions.

Processing of catch: Same as the procedures for trawling.

O Continuous day-night survey catch at the same station by single-rigged trawl net

Term: First; 7/21 to 7/22, 1988
Second; 9/22 to 9/23, 1988
Third; 10/1 to 10/2, 1988

Gear used: Single-rigged trawl net
Method: Continuous operation involving seven 30-minute trawls at 4-hour intervals at the same station.
Processing of catch: Processed by the method for trawling.

iv Biological survey
Species identification: Same as preliminary survey.
Biological measurements of living organisms: Same as preliminary survey.

v Larvae collection survey
Term: 12/15/1987 to 2/9/1988
6/10/1988 to 10/12/1988
Net used: Same as preliminary survey.
Collection stations: 131 points
Method: Same as preliminary survey.

(4) Counterpart

The counterpart for the Fisheries Resources Survey is the Centro de Investigación en Ciencias del Mar y Limnología (CIMAR). CIMAR is a research center dedicated to the scientific study of marine and fresh water problems.

In Costa Rica, CIMAR undertakes fisheries industry resources surveys. CIMAR is one of the 18 research centers at the Costa Rica University, and they have 16 people working on marine biology and limnology.

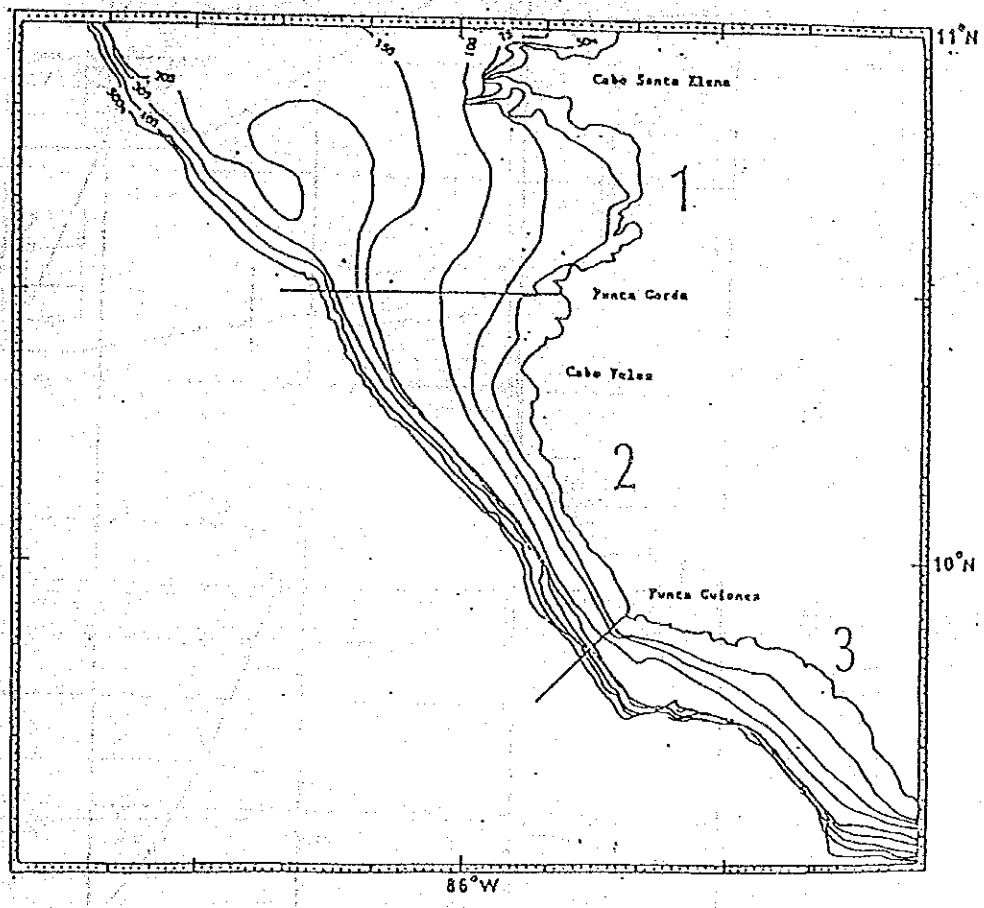


Fig. 2 Area Surveyed

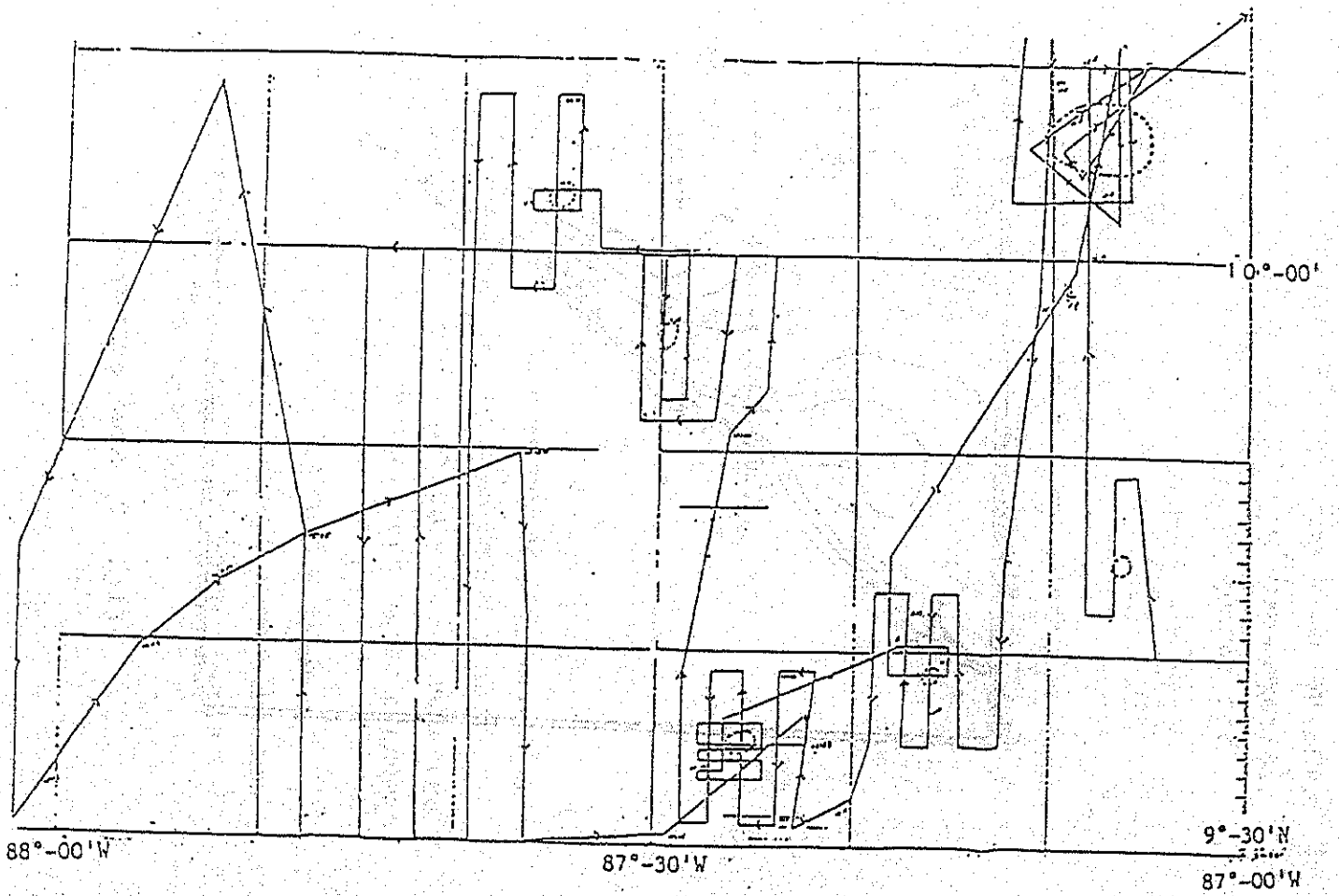


Fig. 3a Chart of Routes Followed in the Search for Guardian Banks (First Time)

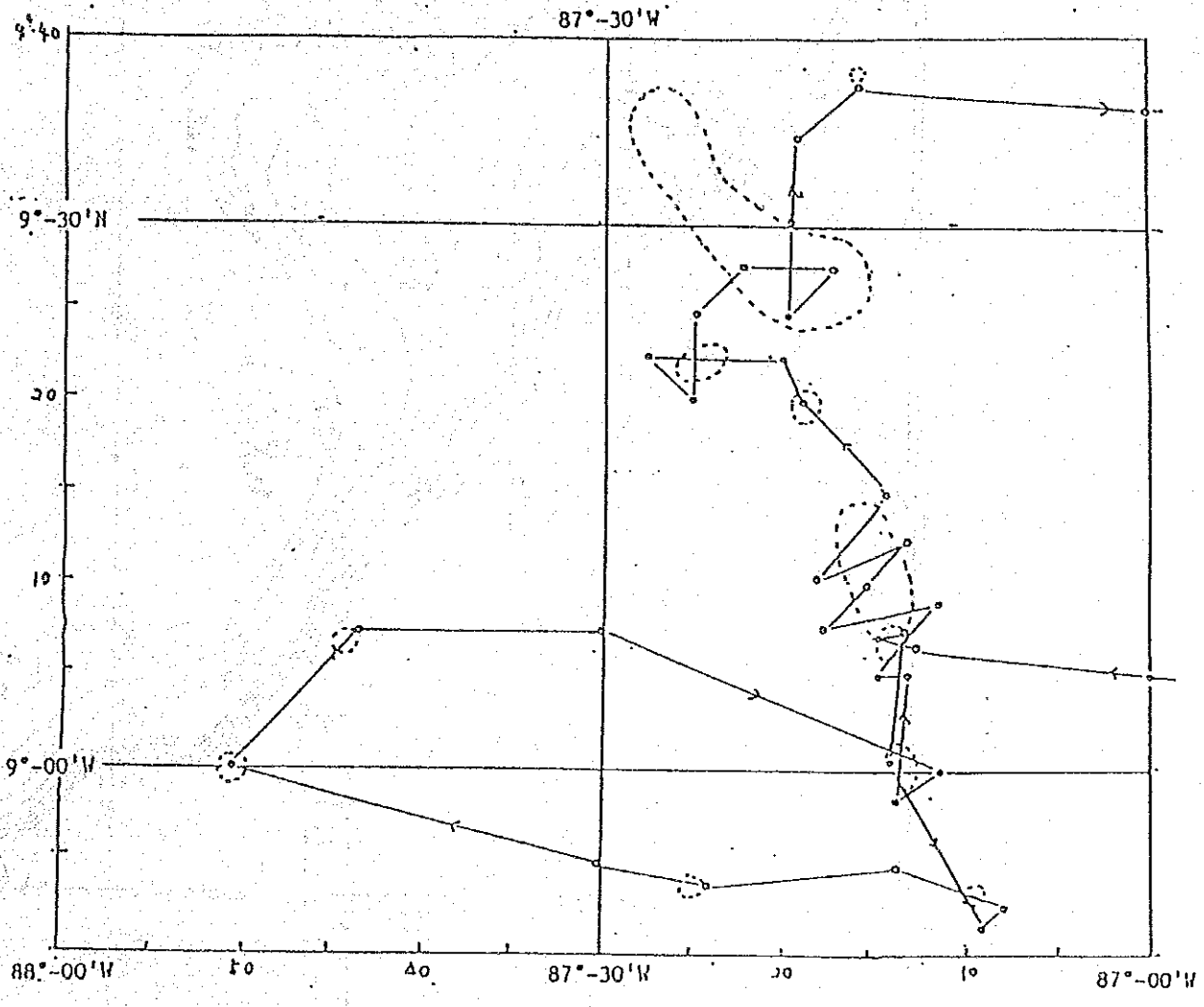


Fig. 3b Chart of Routes Followed in the Search for Guardian Banks (Second Round)

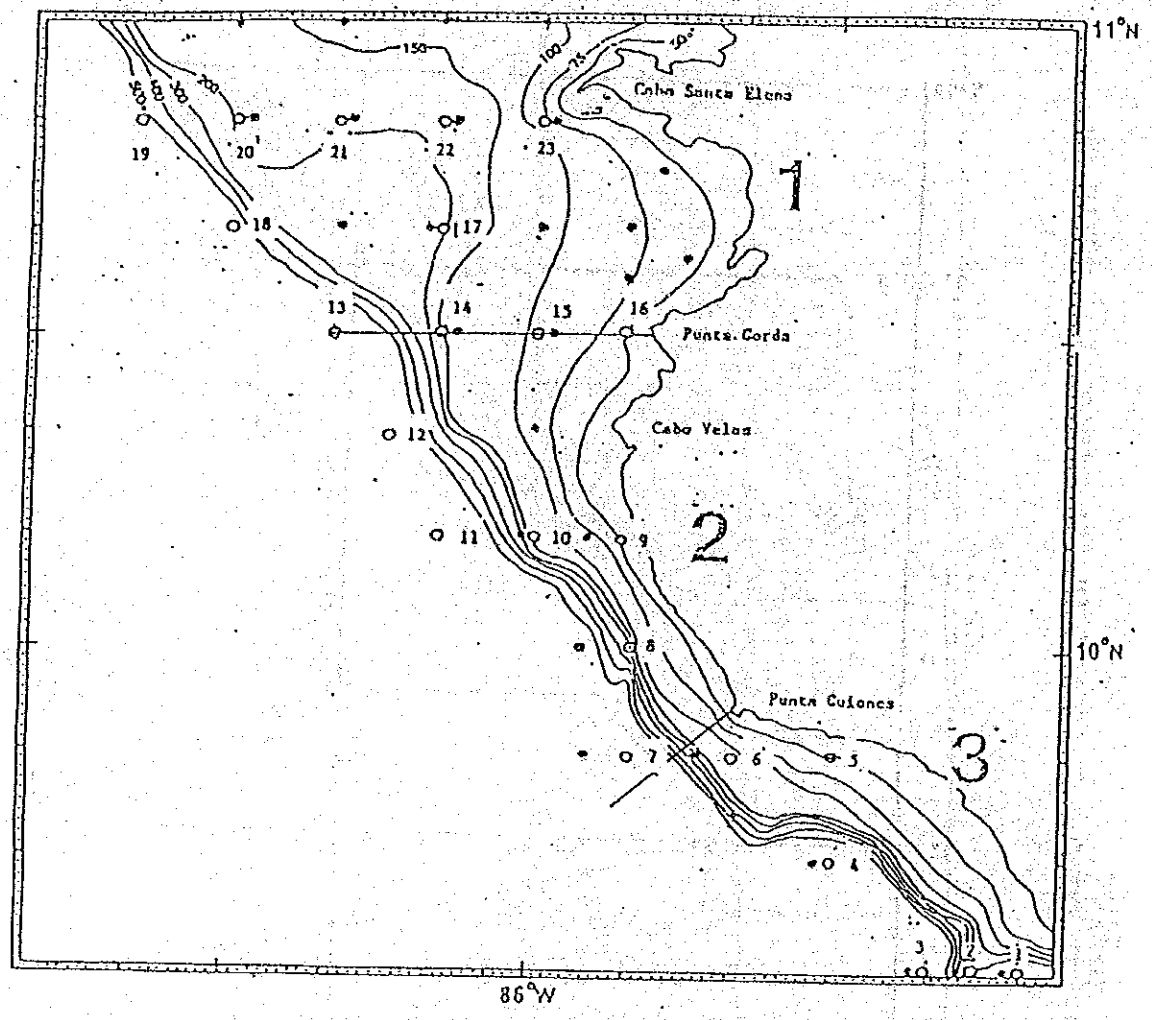


Fig. 4 Chart of Oceanografic Observation Stations

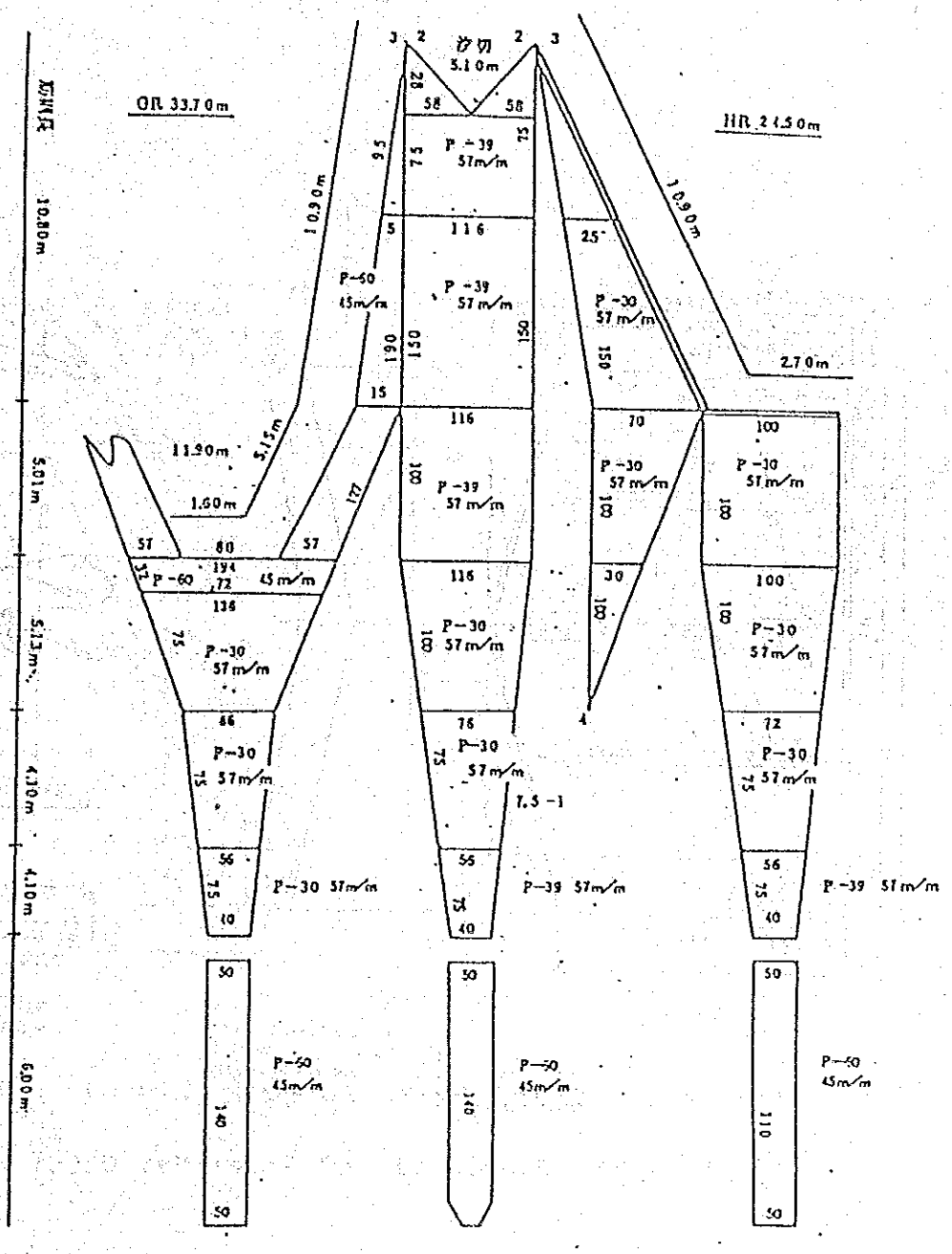


Fig. 5a Single-rigged Trawl Net Expansion Plan

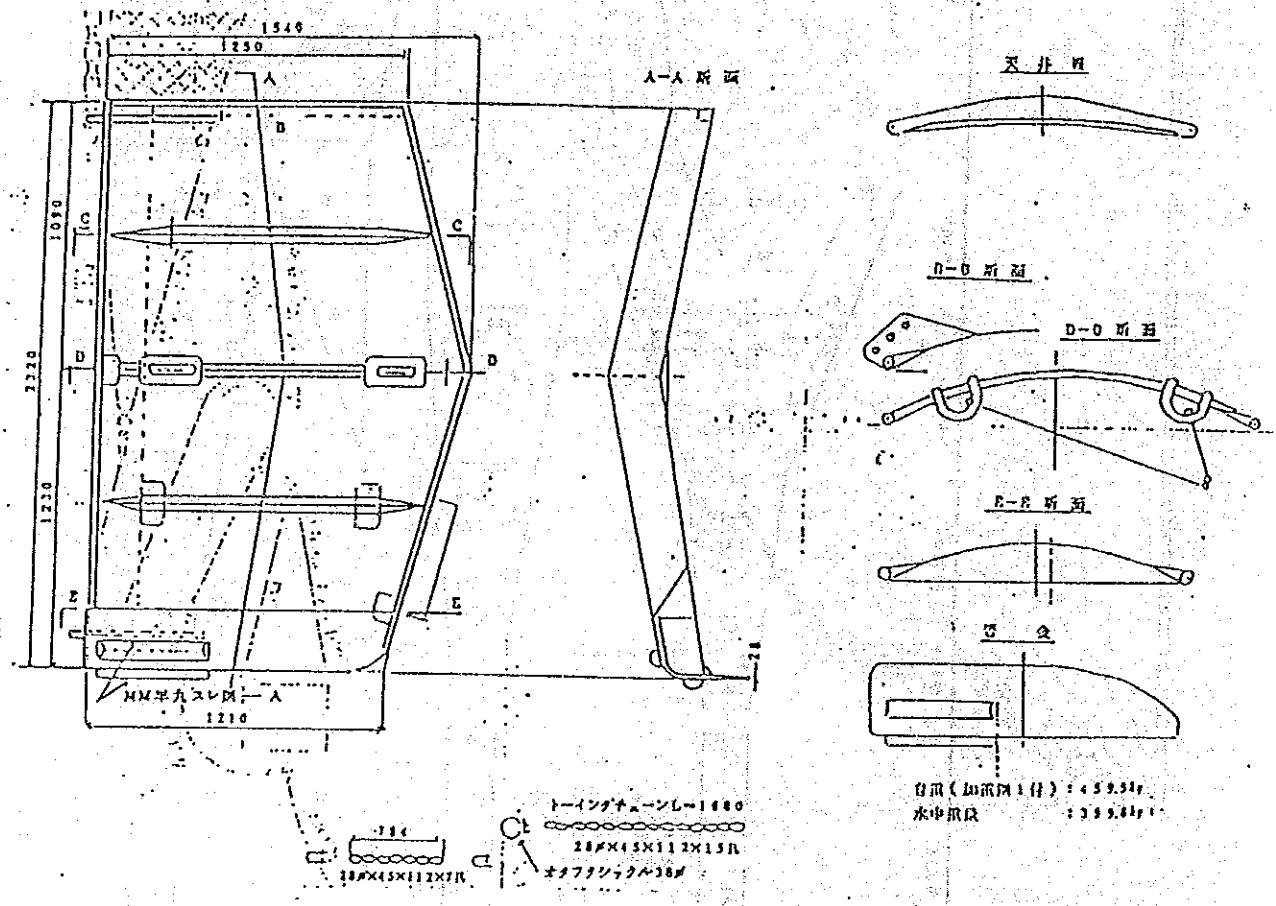


Fig. 5b Single-rigged Trawl Net Otter Board

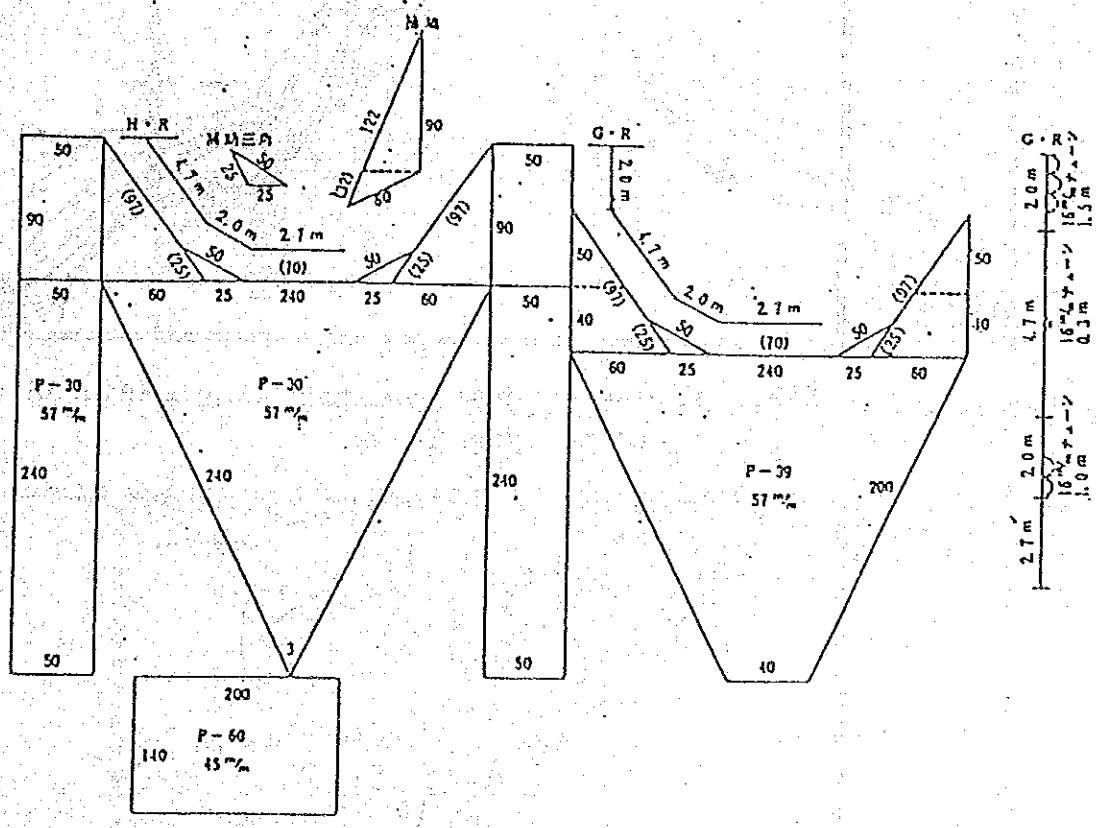


Fig. 6 Double- rigged Trawl Net Expansion Plan

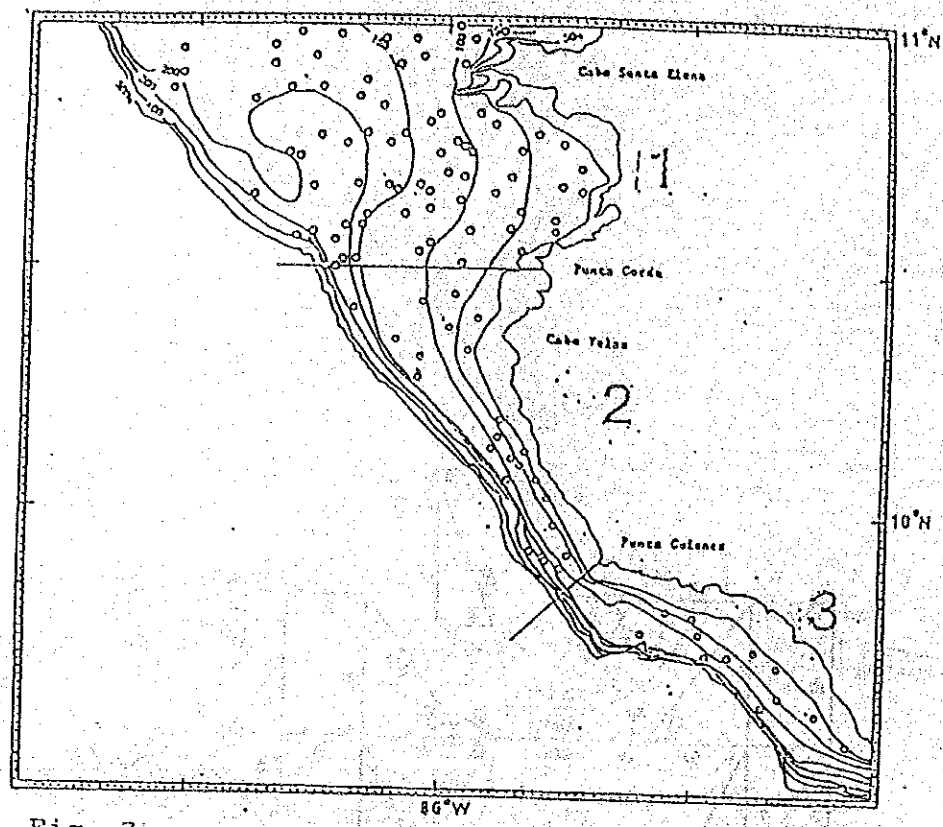


Fig. 7a Survey Stations for Single-Rigged Trawling (First Round)

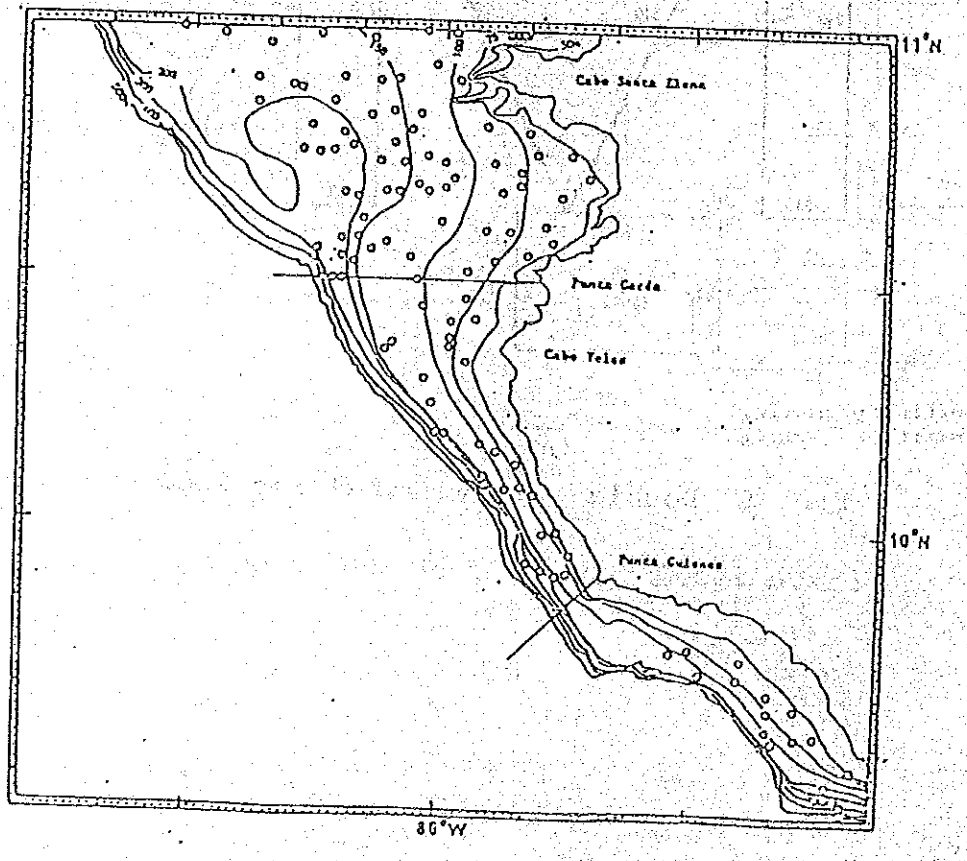


Fig. 7b Survey Stations for Single-Rigged Trawling (Second Round)

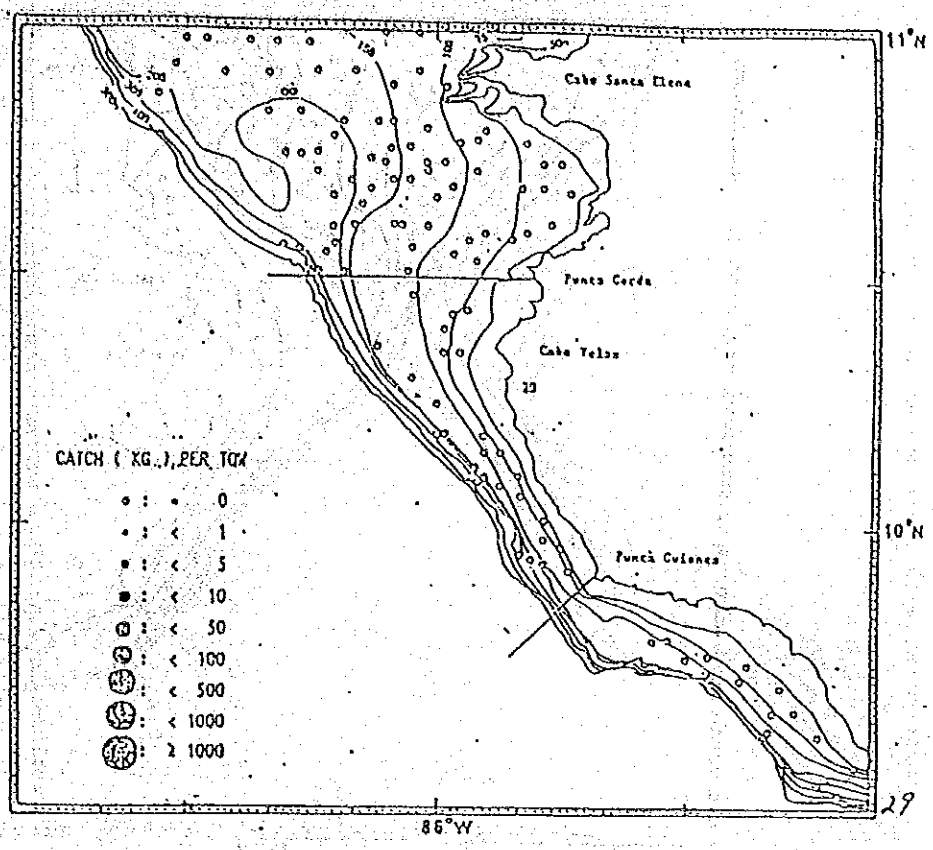


Fig. 7c Survey Stations for Single-Rigged Trawling (Third Round)

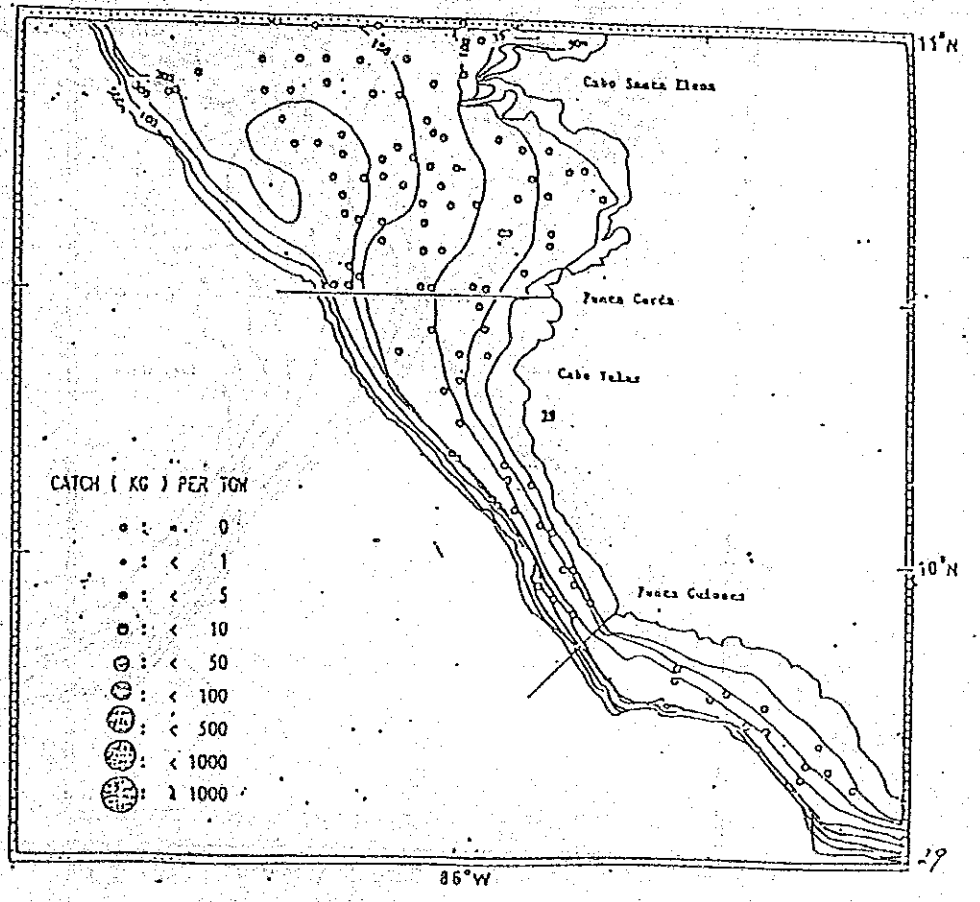


Fig. 7d Survey Stations for Single-Rigged Trawling (Fourth Round)

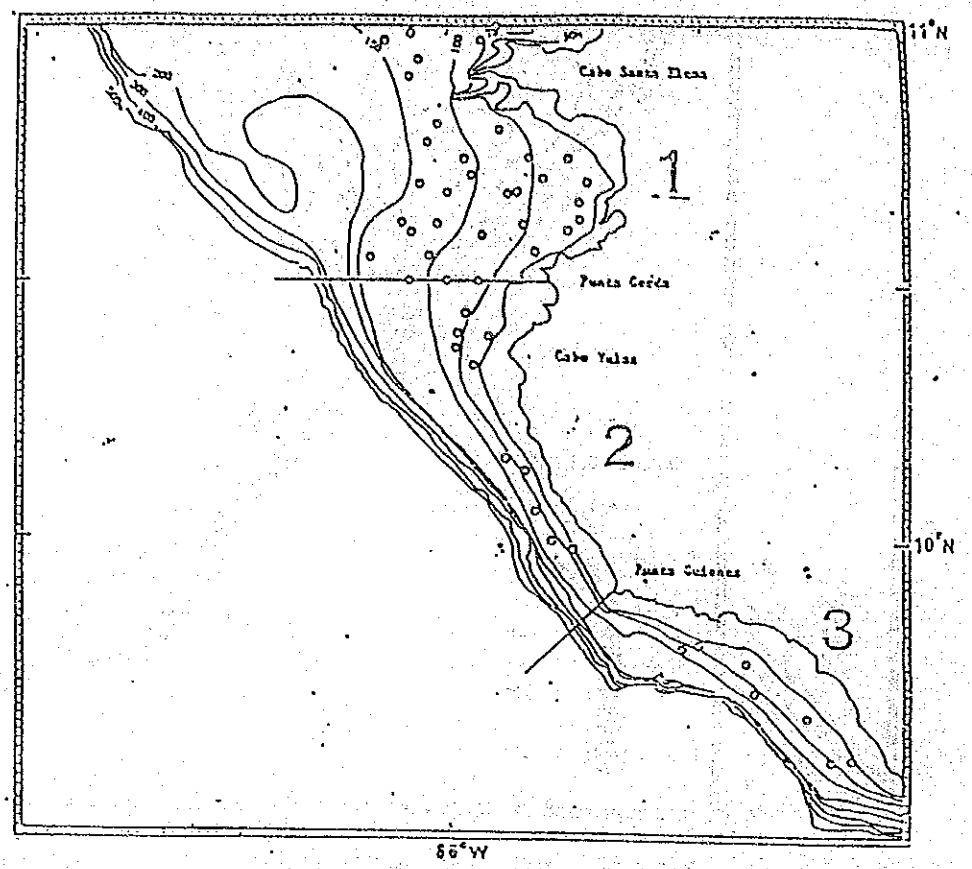


Fig. 8a Survey Stations for Double-Rigged Trawling (First Round)

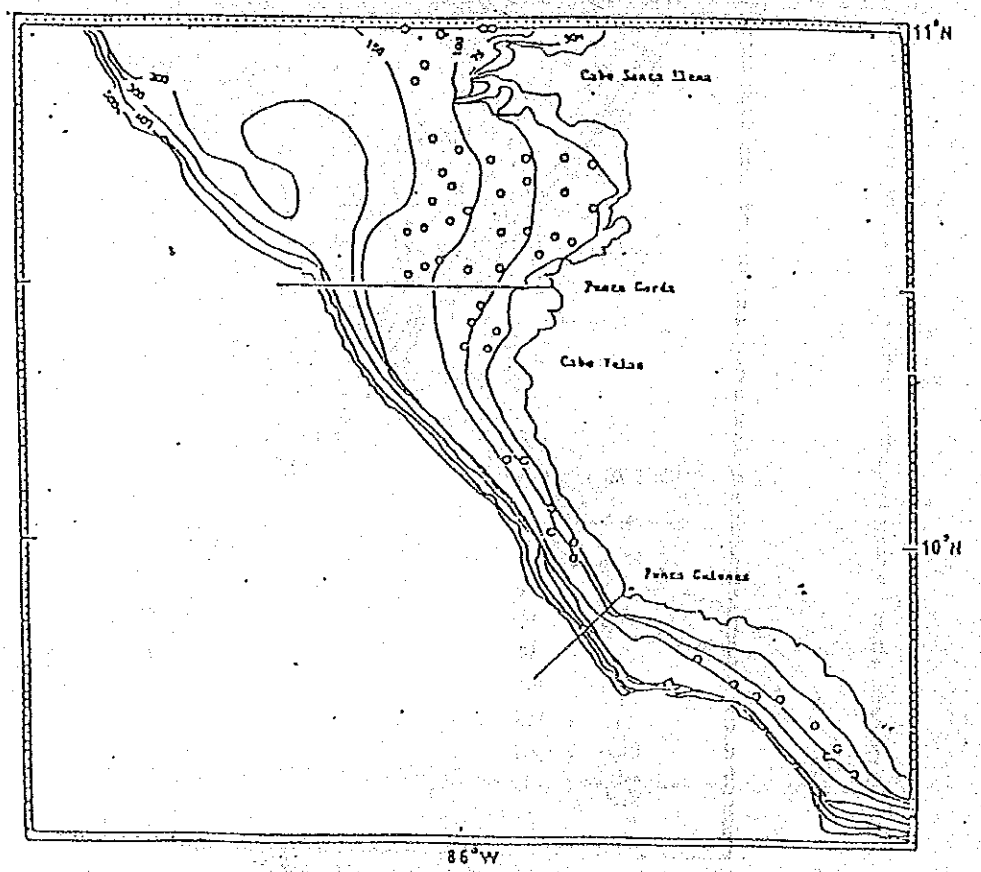


Fig. 8b Survey Stations for Double-Rigged Trawling (Second Round)

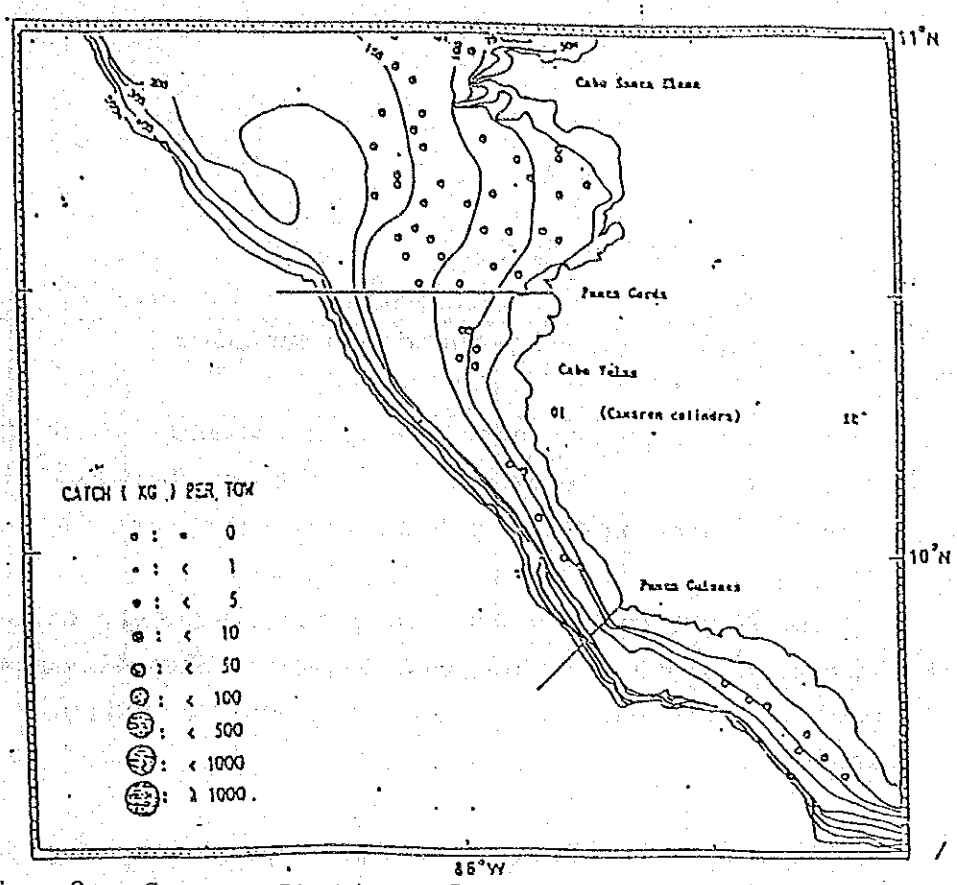


Fig. 8c Survey Stations for Double-Rigged Trawling (Third Round)

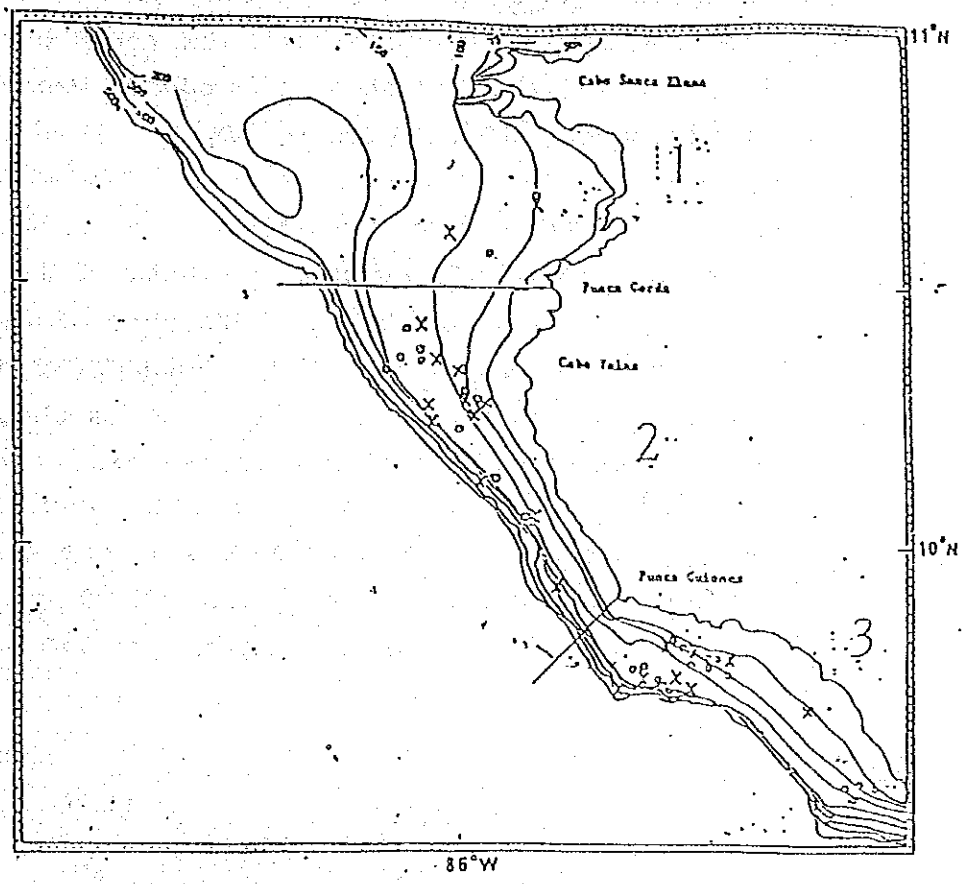


Fig. 9 Survey Stations for Bottom Long Lines and Shrimp Pots

o: Survey Stations for Bottom Long Lines

x: Survey Stations for Shrimp Pots

3-1-2 Survey Results

(1) Seabed topography and depth sounding

While the shorelines in Regions 2 and 3 lack great variation, that in Region 1 is rather complex, with many indentations creating peninsulas, bays, and inlets.

The 200 m isobath runs in a northwesterly direction 10 nautical miles west of Cabo Blanco. Thus the continental shelf, while narrow in Regions 2 and 3, suddenly widens in Region 1.

The depth of water at the place encountering the continental slope is about 200 m in Region 1, but is a very shallow 120 to 140 m in Regions 2 and 3; the slope is characterized by its steepness and its rough bottom (Figs. 10a, 10b, 10c). Table 14 shows the square measure of the stratification for each Region by depth.

In many places the continental shelf seabed is muddy, but there is a reef zone along the coast. This is especially pronounced in the southern part of Region 1, as well as in Regions 2 and 3. Also, depths of from 80 to 120 m in Region 1 are deep ooze. This suggests that the ocean current flowing through this Region is weak.

TABLE 14 AREA ($N.M^2$) OF SURVEY REGION BY DEPTH ZONE

Depth / Ocean area	50 to 75 m	75 to 100 m	100 to 150 m	150 to 200 m	200 to 300 m	300 to 400 m	400 to 500 m	Total
Region 1	149	185	296	501	232	51	43	1,457
Region 2	69	104	145	27	44	41	41	471
Region 3	70	56	86	16	23	22	28	301
Total	288	345	527	544	299	114	112	2,229

(2) Guardian banks

It is said that the Guardian banks are found sporadically at 9 and 10° N. latitude and 87 and 88° W. longitude. In order to investigate the actual existence of the banks, as well as their positions and morphology, searches were conducted with a fish detector on two occasions, from April 11 through 14, 1987 and from November 29 through December 2, 1987, in the Regions shown in Figs. 3a and 3b using the *North Pacific Ocean, Central America - West Coast, Punta Remedios to Cabo Matapalo* (No. 21500) chart published by the Defense Mapping Agency Hydrographic/Topographic Center.

The survey was unable to confirm the existence of the banks. It is thought that one reason is that the search was inadequate due to a short survey term. The *Bathymetric Atlas* 1973 (No. 0902N) published by the U. S. Naval Oceanographic Office, Washington merely shows a Guardian

sea mountain in this Region at 880 fathoms.

(3) Oceanographical conditions

① An overview of oceanographical conditions

Ocean currents in the Region of the equator in the Pacific can be divided into four main currents. The first is the North Equatorial Current flowing west through 8° to 20° N. latitude, the second is the South Equatorial Current flowing west through 3° N. latitude to 10° S. latitude, and the third is the North Equatorial Countercurrent flowing east between the first two. These are all principally surface currents. The fourth is the Equatorial Undercurrent flowing east through 2° N. latitude to 2° S. latitude (Fig. 11).

It is the North Equatorial Countercurrent which strongly affects the surface water of Costa Rica's Pacific coast. The velocity of this current is less than 20 cm/s during March and April, but 35 to 60 cm/s during other months. After this current flows north in the vicinity of Costa Rica it turns west and merges with the North Equatorial Current. It is also called the Costa Rica Current. The water of this current is 27°C or warmer, and has a low salinity of less than 33 $^{o}/_{oo}$.

On the other hand, below the surface there is a broad, oxygen-poor intermediate layer of low temperature, an upwelling that revolves counter-clockwise called the Costa

Rica Dome, which has been found to be approximately 200 km in diameter, and is present the entire year at 9° N. latitude and 89° W. longitude. The water mass of this upwelling is characterized by low temperature (below 17°C), high salinity (at least 33.8 °/$_{\infty}$), low oxygen content (2.0 to 0.25 ml/l), and high orthophosphates (1.0 to 1.2 ug-atom/l) (Figs. 12, 13, 14).

It is safe to say that the waters along Costa Rica's coast is affected on the surface by the North Equatorial Countercurrent, and in the intermediate water by the upwelling of the Costa Rica Dome.

② Vertical profile of water temperature

Based upon the data obtained from six rounds (including the preliminary survey) of observations in the coastal Region, Appendix Fig. 2 was created to show the average temperature vertical distributions for the entire survey Region for each of the observations. As is clear from the figure, in every month there was found a distinct thermocline from a depth of 10 to 20 m at the top and ranging down to 50 to 75 m at the bottom. The vertical temperature gradient in the thermocline was as much as 1°C for every 10 m. This fact suggests that the surface-water-layer was very thin, and that the water at the bottom of the thermocline is originated from the Costa Rica Dome upwell.

A look at the vertical temperature distribution for each month shows that in the layers of a depth less than approximately 100 m the temperature in May of 1987 was very high, and then falls with months, but the values for September and October of 1988 were similar. As observed data from January through May is lacking, it is unclear whether or not this interesting phenomenon changes seasonally.

It should be noted that the term of this survey falls within the period of time in which was manifested the El Niño phenomenon that continued for the long period of 18 months from the autumn of 1986, ending in the spring of 1988. Accordingly, it is probably appropriate to regard the high temperatures of the water above the thermocline described above as due to the El Niño phenomenon, which affected even the Region surveyed. In passing, the El Niño phenomenon, which lasted from the autumn of 1986 to the spring of 1988, showed a maximum deviation of about 2°C, and was therefore small in scale (in 1982/1983 there was a deviation of over 5°C, said to be the largest in this century), though it may be characterized in the following manner.

i Although in the past the phenomenon usually arose in the spring or summer and was at its greatest extent in the autumn or winter, it began this time in the autumn.

ii The phenomenon lasted a year and a half, thereby continuing over a long period of time.

iii The focus of deviation in sea surface temperatures occurred in the central Pacific, not along the coast of South America (Fig. 16).

In addition, the connection between this phenomenon and worldwide abnormal weather has been pointed out.

③ Water temperature by Region

A comparison of water temperatures by Region shows that during December of 1987 the temperatures from 0 to 50 m in Region 1 were markedly lower than those in Regions 2 and 3. In addition, no specific trends were discerned by Region. It is difficult to determine whether the low temperatures during December of 1987 were due to the effects of the constant seasonal northeasterly winds during this period, or to the southerly descent of the California Current.

The reason why no certain trend was discerned in the monthly changes of water temperature is thought to be that the Region where the Costa Rica Dome upwell makes contact with coastal waters changes from month to month. This can also be inferred from the temperature distribution maps of each layer. It is also conjectured that there is a strong relationship between the Region in which the upwell penetrates the coastal waters and the distribution of demersal fish.

It is a noteworthy fact that subsequent to continued seasonal winds during the winter when the northeasterly seasonal winds are strong, a precipitous drop in surface temperature is sometimes observed along the coast in Golfo de Papagayo. It is conjectured that such a drop in temperature affects the movements and behavior of the pelagic fish which dwell in the surface layer.

④ Water temperature and dissolved oxygen content

Data has been obtained only for October of 1988, but this report would like to touch upon the relationship between temperature and dissolved oxygen content. It would seem, however, that the values contain some error because at the time of dissolved oxygen measurements sufficient correction was not made for the differences among instruments. Fig. 16 shows the relationship between water temperature (°C) and dissolved oxygen content (ml) at the time of the October observations. Although there are some irregularities between temperature and oxygen content, they do show a positive correlation. The figure shows the relationship between the average temperatures and oxygen contents for each layer throughout the entire survey area, and illustrates the relationship between the two with a curve.

The figure shows O_2 at about 6 ml/l in the surface layer at 26°C or above, 6 to 2.5 ml/l in the thermocline, which ranges between 25 and 19°C, and less than 2.5 ml/l in the intermediate layer below 19°C. Using the relationship

between these temperatures and oxygen contents it is possible to generally determine the characteristics for temperature and oxygen content of the surface layer, thermocline, and intermediate layer (Costa Rica Dome), respectively, at least 26°C (6 ml/l), 25 to 20°C (6 to 2.5 ml/l), and less than 18°C (2 ml/l). WYRTKI (1964) demonstrated almost the same relationship in a figure illustrating temperature and oxygen content in the area affected by the Costa Rica Dome.

A look, with respect to this relationship, at the water mass with a temperature of 18°C and a dissolved oxygen content of 2 ml/l, that is, the top edge of the dome, shows that although there are differences depending upon the month of the survey, the upper edge of the dome is generally found at between 40 and 90 m. During the survey performed by the NORAD/UNDP/FAO Program in February, May, and August of 1987 within the Golfo de Nicoya and the offshore waters, the depth of water of 2 ml/l was from 50 to 100 m. Thus a characteristic of this area is that an oxygen-poor water mass of 2 ml/l pushes its way up into the shallow surface layer.

⑤ Living organisms and dissolved oxygen content

In general, when the layer inhabited by a marine organism becomes extremely poor in oxygen, the organism will avoid that Region and move to one which is oxygen-rich. A Region in which oxygen has decreased markedly makes it impossible for organisms to survive, and becomes a

dead zone. However, the relationship between organisms and oxygen differs by species, body size, temperature, and other factors, but knowledge concerning these is extremely limited. As environmental quality standards in Japan, suitable oxygen content is at least 4 ml/l for fish and large shrimps, and at least 3.5 ml/l for crabs and octopus. It has been reported (Tamura, 1949) that the lethal oxygen content for *Chrysophrys major* (red seabream) is about 0.2 ml/l, and 3 ml/l or more for salmon and trout. Also, data on trawling operations in the Bay of Aden do not particularly show a relationship between demersal fish catches and bottom layer temperature, but they do show a relationship between catch and dissolved oxygen content, with an apparent marked drop in the catch when oxygen is less than 2 ml/l (Banse, 1967). In areas of the Central and South American Pacific coasts where oxygen-poor water pushes its way up as far as the surface layer, no *Thunnus abesus* (bigeye tuna) are found in places where oxygen content is less than 1 ml/l even though the temperature may be suitable (10° to 15°C) (Hanamoto, 1987). Thus, in the Region where the indicators of about 18°C and 2 ml/l oxygen for the Dome in coastal Costa Rica are found, it is conjectured that the distribution of demersal fish is more or less affected. Determination of this relationship is a task for the future.

⑥ Conclusion

The oceanographic observations in the survey Region were insufficient because they were confined to a small area

with surveys being conducted on only a few occasions, and because most measurements were of temperature, with measurements of salinity and oxygen content being carried out only once. However, some precious knowledge was obtained, and is shown below.

i The surface layer is extremely thin.

ii There is a strong thermocline beginning at 0 to 10 m and extending down to 50 to 75 m in depth.

iii The water mass below the thermocline is thought to be the upwell of the Costa Rica Dome.

iv The water masses of the surface layer, thermocline, and intermediate layer (Costa Rica Dome upwell) can generally be fixed at an approximate oxygen content of 6 ml/l at 26°C or above, 6 to 2.5 ml/l at 25 to 20°C, and about 2 ml/l at 18°C, respectively.

v It appears that the area where the upwell approaches the coast changes month by month.

vi Subsequent to continued seasonal winds during the winter along the coast of Region 1, a drop in surface temperature is sometimes observed.

vii It is thought that the El Niño phenomenon, which lasted from the autumn of 1986 to the spring of 1988, affected even the temperature of the surface layer and the thermocline in the survey Region.

It is assumed that these factors are strongly related to the distribution and ecology of marine resources. In particular, it is thought that the intermediate layer (2 ml/l at 18°C) pushing up near the surface layer has an impact on the distribution and ecology of bottom-dwelling species.

(4) Species observed (CIMAR)

Table 15 lists the species collected in this survey by the single- and double-rigged trawling nets, bottom long lines, and shrimp pots.

TABLE 15 SPECIES SIGHTED

Species	Family	Species	Family
Crutacea			
Heterocarpus sp.	Pandlidae	Arius platypogon	Ariidae
Nephropsis sp.	Nephropidae	Azeria panamensis	Bothidae
Penaeus brevirostris	Penaeidae	Bollmannia clamydes	Gobiidae
Penaeus californiensis	Penaeidae	Bollmannia stigmatura	Gobiidae
		Bothidae sp.	Bothidae
Pleuronectodes sp.	Calatheidae	Brotura clarkae	Ophidiidae
Solenocera agassissi	Solenoceridae	Bregmaceros bathmaster	Bregmacerotidae
Syclonia sp.	Sicyonidae	Calamus branchysomus	Sparidae
Squilla sp.	Squillidae	Caranx victus	Carangidae
		Carcharhinus sp.	Carcharhinidae
Calappidae sp.		Carcharhinus altimus	Carcharhinidae
Ethusa sp.	Dorippidae	Carcharhinus porosus	Carcharhinidae
Euphylax sp.		Carangoides otrynter	Carangidae
Illiacantha sp.	Leucosiidae	Caulolatilus affinis	Branchiostegidae
Majidae sp.		Cherublemma emmelas	Ophiidae
Malopsis panamensis	Calappidae	Chlorophthamus mento	Chlorophthalmidae
Portunidae sp.		Citharichys platophrys	Bothidae
Parthenopidae sp.		Coryphaena hippurus	Coryphaenidae
Stenorhynchus sp.	Majidae	Coelorhynchus scaphopsis	Macrouidae
		Cyclopsetta panamensis	Bothidae
Mollusca		Cyclopsetta querna	Bothidae
Conidae sp.		Cynoponticus coniceps	Muraenesocidae
Fasciolariidae sp.		Cynoscion nannus	Sciaenidae
Muricidae sp.		Cynoscion reticulatus	Sciaenidae
Pectinidae sp.		Decapterus sp.	Carangidae
Loligopsis diomedeae	Loliginidae	Decodon melasma	Labridae
Octpus sp.	Octopodidae	Diplectrum eumelum	Serranidae
		Diplectrum euryplectrum	Serranidae
Pisces		Diplectrum labarum	Serranidae
Albula Vulpes	Albulidae	Diplectrum macropoma	Serranidae
Alectis ciliaris	Crangidae	Diplectrum rostrum	Serranidae
Antennarius avalonis	Antennariidae	Diplectrum sp.	Serranidae
Antennarius sp.	Antennariidae	Diplobatis ommata	Torpedinidae
Apogon dovii	Apogonidae	Echiophis sp.	
Argentina aliceae	Argentinidae	Engyophrys sanctilaurentii	Bithidae

Engyophrys sp.	Bothidae
Epinephelus acanthistius	Serranidae
Epinephelus analogus	Serranidae
Epinephelus nigritus	Serranidae
Epinephelus niveatus	Serranidae
Etrumeus acuminatus	Clupeidae
Eucinostomus gracilis	Gerreidae
Eucinostomus argenteus	Exocoetidae
Exocoetidae sp.	Exocoetidae
Fodiator acutus	
Gerranidae sp.	
Gymnothorax equatorialis	Muraenidae
Haemuron maculicanda	Haemulidae
Haemuron steindachneri	Haemuridae
Hemiramphidae sp.	
Hemanthias peruanus	Serranidae
Hemanthias signifer	Serranidae
Hildebrandia nitens	Congridae
Hippoglossina bollmanni	Bothidae
Hippoglossina tetrophthalmus	Bothidae
Hoplunnis pacifica	Nettastomatidae
Kathetostoma averruncus	Uranoscopidae
Labridae sp.	Labridae
Lophiodes caulinaris	Lophiidae
Lophiodes spiluris	Lophiidae
Lophiodes sp.	Lophiidae
Lepophidium pardale	Ophidiidae
Lepophidium prorates	Ophidiidae
Lepophidium stigmatistium	Ophidiidae
Lutjanus argentiventris	Lutjanidae
Lutjanus colorado	Lutjanidae
Lutjanus guttatus	Lutjanidae
Lutjanus peru	Lutjanidae
Monolene asaedai	Bothidae
Monolene maculipinna	Bothidae
Monolene dubiosa	Bothidae
Merluccius gayi	Merluccidae
Mulanidae sp.	
Mustelus lunulatus	Triakidae
Naricine brasiliensis	Torpedinidae
Naricine entemedor	Torpedinidae
Neobythites stelliferoides	Ophidae
Nezumia sp.	Macrouidae
Ophichthus pacificus	Ophichthidae
Ophidion sp.	Ophichthidae
Orthopristys chalceus	Haemulidae
Paralabrax loro	Serranidae
Paralichthys woolmani	Bothidae
Peprilus medius	Stromateidae
Peprilus snyderi	Stromateidae
Peristedion barbiger	Peristediidae
Peristedion crustosum	Peristediidae
Physiculus nematopus	Moridae
Physiculus rastrelliger	Moridae
Pomadasys branikii	Pomadasydae
Pomadasys macracanthus	Pomadasydae
Pomadasys panamensis	Pomadasydae
Pontinus furcirhinus	Scorpaenidae
Pontinus sierra	Scorpaenidae
Porichthys nautopaedium	Batrachoididae
Prionotus albirostris	Triglidae
Prionotus birostratus	Triglidae
Prionotus horrens	Triglidae
Prionotus gymnosthetus	Triglidae
Prionotus loxias	Triglidae
Prionotus ruscarius	Triglidae
Prionotus stephanophrys	Triglidae
Prionotus teaguei	Triglidae
Prionotus xenisma	Triglidae
Pronotogrammus eos	Serranidae
Pronotogrammus sp.	Serranidae
Pseudupeneus grandisquamis	Mullidae
Pseudopriacanthus serrula	Priacanthidae
Raja equatonalis	Rajidae
Raja velezi	rajidae
Rechias sp.	
Sarda orientalis	Scombridae
Sciaenidae sp.	
Scomber japonicus	Scombridae
Scorpaena histrio	Scorpaenidae
Scorpaena plumieri	Scorpaenidae
Scorpaena russula	Scorpaenidae
Selene peruviana	Carangidae
Selene oerstedii	Carangidae
Serranus aequidens	Serranidae
Sphoeroides annulatus	Tetraodontidae
Sphoeroides lobatus	Tetraodontidae
Sphoeroides sechurae	Tetraodontidae
Sphyraena ensis	Sphyraenidae
Sphyrna levini	Sphyrnidae
Squatina armata	Squatinidae
Syacium ovale	Bothidae
Syacium talitrons	Bothidae
Symphurus atramentatus	Cynoglossidae
Symphurus leei	Cynoglossidae
Synchiropus atrilabiatus	Callionymidae
Synodus evermanni	Synodontidae
Synodus scituliceps	Synodontidae
Synodus sechurae	Synodontidae
Torpedo tremens	Torpedinidae
Trichiurus nitens	Trichiuridae
Thunnus albacares	Scombridae
Zalieutes elater	Ogeocephalidae
Zapterix ezasperatta	Rhinobatidae

(5) Distribution of principal species

Appendix Figs. 4a, 4b, 4c, and 4d show the catch distributions by survey station and species for the 28 principal ones taken in the four rounds of single-rigged trawling surveys. The amounts of the catches were standardized by calculating them on the basis of a 30-minute towing time. As is clear from the figures, although there were few survey stations trawled on the continental slope due to bad seabed conditions, this Region is characterized by the smaller catch taken for each species. It is also obvious that certain species are distributed at certain depths (Fig.18). The reason for this is thought to be that bottom-dwelling species have habitat segregation.

Appendix Figs. 5a, 5b, and 5c show the catch distributions by survey station and species for the 29 principal ones taken in the three double-rigged trawl net surveys. One can conjecture from the figures that, just as noted above, each species lives by habitat segregation. It would also appear as though one could discern a deep relationship between the distributions of the various species in deep Regions and sea conditions, in particular the upwelling and coastal contact of the Costa Rica Dome, but it was not possible to perform an adequate analysis. These are some very interesting tasks yet to be dealt with.

(6) Size composition of principal species

A total of over 600 measurements of size composition were performed on the 55 principal species of fish captured with trawling during the survey. This data is presented in the Appendix Table 3. Judging by the number of appearances of modes in length composition, and with some additional inference, the species can be generally classified in the manner shown below, as uni-mode, bi-mode, and poly-mode.

Uni-mode

Penaeus brevirostris (Camarón rosado)
Solenocera agassizii (Camarón fidel)
Heterocarpus sp. (Camarón camello)
Pleuronectodes sp. (Langostino)
(Camarón colindra)
Loligolopsis diomedeae (Calamar)
Illex sp. (Calamar)
Argentina aliceae (Quiebra palito)
Citharichtys platophrys (Lenguado)
Synodus evermanni (Garrobos)
Eucinostomus gracilis (Palmito)

Some of the *Penaeus brevirostris* and *Solenocera agassizii* were bi-mode, but since the mode was small they were classified as uni-mode. There are also some species for which placement in this category is doubtful, such as *Lepophidium stigmatistium, Physiculus rastrelliger, Orthopristys chalceus, Porichthys nautopaedium, Haemulon*

maculicanda, *Bollmannia clamydes*, and *Neobythites stelliferoides*.

Bi-mode

Pepnaeus californiensis (Camarón café)
Perilus medius (Salema)
P. Snyderi (Salema)
Pronotogrammus eos
Serranus aequidens (Menta)
Diplectrum euryplectrum (Menta)
D. eumelum (Menta)
D. labarum (Menta)

Poly-mode

Merluccius gayi (Merluza)
Prionotus stephanophrys (Cabro)
P. ruscarius (Cabro)
Hippoglossina tetrophthalmus (Lenguado)
Pontinus sierra
Synodus scituliceps (Garrobos)
S. sechurae (Garrobos)
Mustelus lunulatus (Tiburón)
Lutjanus peru (Pargo seda)
L. argentiventris (Pargo)
L. guttatus (Pargo)
Paralabrax loro (Cabrilla)
Hemanthias signifer
Trichiurus nitens (Pez cinta)

Cyclopsetta panamensis (Roncadores)
P. branikii (Roncadores)
Calamus brachysomus (Paz cadáver)
Selene peruviana (Palometa)
S. oerstedii (Palometa)
Carangoides otrynter (Jurel)
Cynosion nannus (Corvina)
Sphyraena ensis (Barracuda)
Etrumeus acuminatus (Sandina)
Brotula chrakae (Congrio)
Cherublemma enmalas

However, one cannot simply derive age from the number of the mode. This area is in the tropics, and thereby has a high water temperature all year with little seasonal variation. This would lead one to believe that the spawning season for many species of fish lasts all year, or over long periods of time, thereby making for a complex mode manifestation when capturing schools that arose at different times. Possibly as an indication of these circumstances, little data has been obtained which allows one to track the growth of fish. It is necessary to gather more data by another means in order to elucidate age, growth, and other such characteristics.

Next, a look at the body length frequency of the approximately 50 species captured in this survey reveals the fact that, as with the smallest *Pleuronectodes sp.*, about 30 of these species are less than 20 cm in length. In addition, only the six large species listed below exceed

30 cm in length, and it is an interesting fact that no large fish were caught on the continental slope.

Mustelus lunulatus (Tiburón)
Paralabrax loro (Cabrilla)
Cyclopsetta panamensis (Lenguado)
Epinephelus nigritus (Cabrilla negra)
Brotula clarkae (Congrio)
Selene perunivna (Palometa)

(7) Biomass estimations for principal species

① Biomass estimations for principal species

Trawling surveys with the single-rigged trawl net were conducted four times during the period from November, 1987 to October, 1988. The survey Region was from 50 to 500 m in depth and designated by S/W. In consideration of such circumstances as the length of the survey, 140 survey stations were used.

The survey stations were placed by depth (7 layers) and Region (3 Regions) in proportion to the square measure of each Region, thus being based on stratified random sampling. However, the actual survey stations numbered only 115 to 121, and this is mainly because at depths of over 300 m the seabed was inferior, thus making it impossible to select survey stations. The surveys were conducted during daylight hours; towing time was generally 30 minutes, and speed was 3 to 4 knots.