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International Coastal Resources Management Project

The University of Rhode Island

AND

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Funding provided by the Office of Forestry, Environment and Natural Resources, Bureau of Science and Technology, U.S. Agency for International Development

The four major goals of the AID/URI Coastal Resources Management Project (CRMP) are: 1) to apply, as appropriate, existing experience in coastal resources management to developing countries; 2) to assist three developing nations in the design and implementation of integrated coastal resources management programs; 3) to advance the state-of-the-art of coastal resources management in developing countries; and 4) to build URI's capability to assist developing nations with coastal resources management.

The CRMP will work with the cooperating pilot countries to:

- develop procedures for the assessment of the impacts of coastal development proposals
- develop institutional and technical solutions for resource use conflicts
- support research to better understand the issues that affect the condition and use of coastal ecosystems
- improve the capabilities of in-country professional staff to plan for and manage coastal development

The countries selected for pilot projects are Ecuador, Sri Lanka and, tentatively, Thailand.

The AID/URI Coastal Resources Management Project is funded by the Office of Forestry, Environment and Natural Resources, Bureau of Science and Technology, U.S. Agency for International Development through a Cooperative Agreement with the International Center for Marine Resource Development, at The University of Rhode Island.

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Cooperative Agreement LAC-5518-A-00-5054-00

DEVELOPMENT OF A STRATEGY FOR A SUSTAINABLE SHRIMP MARICULTURE INDUSTRY IN ECUADOR

August 4-8, 1986

BANCO CENTRAL DE ECUADOR

GUAYAQUIL, ECUADOR

WORKSHOP FORMAT

In order to maximize the efficiency of discussions, we have decided to employ "facilitated workshop" techniques that have proved to be effective in similar situations. This calls for the following:

1. Adherence to an agenda for the discussions agreed to by the participants that set time allocations for each topic.

2. A neutral facilitator who will manage the discussions and keep the meeting on schedule.

3. A recorder who summarizes the substance of each participant's contribution on sheets of newsprint as the discussion proceeds. These sheets will be posted on the wall of the meeting room as they are prepared and will serve as a "group memory". These sheets become the basis for the workshop proceedings that will be reviewed by all participants on the final day of the workshop. Since the workshop will be conducted in both Spanish and English, we will need two recorders.

Each session will begin with one or more brief presentations that will summarize and evaluate the information gathered on that topic. Presentations on any one topic will last for no more than an hour. The discussion will then focus on the following topics:

1. Comments on the information and assessments presented. We are very interested to know the participants' views of the accuracy and completeness of the information presented and reactions to the speaker's interpretation and assessment of this information.

2. The problems posed; we are particularly concerned with identifying problems that an integrated management program should address. Problems may be defined as "adverse outcomes that we wish to avoid" such as loss of shrimp post-larvae habitat, or reduced quality of the water pumped into shrimp ponds.

3. Priorities for action by government agencies and the industry.

4. Priorities for research and planning that will directly assist in management.

Participants are encouraged to think ahead of time about what they may wish to say on these topics.

We have scheduled the workshop sessions for the afternoons and evenings in the hope that this will encourage the full participation of industry representatives and others who must attend to other responsibilities during the week of the workshop. The free mornings will also allow time for discussions among the participants and time to prepare the synthesis of the previous day's sessions for inclusion in the proceedings.

Since there is great interest in the topics of the workshop, we will present the highlights of our findings on each topic and the outcomes of the discussions during an all-day session open to the public on Friday, August 9th. This will provide for further discussion and a preliminary reaction to the workshop recommendations.

3'

TENTATIVE AGENDA FOR THE DIGEMA - URI WORKSHOP
ON THE
DEVELOPMENT OF A STRATEGY FOR A SUSTAINABLE SHRIMP MARICULTURE
INDUSTRY IN ECUADOR

August 4 - 8, 1986

Banco Central de Ecuador
Guayaquil, Ecuador

<u>August 2, Saturday</u>

Arrive in Guayaquil

<u>August 3, Sunday</u>

8:00 a.m. Air travel to Puerto Salinas

- Airborne view of mangroves, Camaroneras and Salinas
- Tour of Hatchery Row Facilities in Salinas, San Perdo and San Pablo

1:30 p.m. Ceveche Bash at the Hatchery Row Club in Balinita

- Informal Discussions
- Return to Guayaquil

August 4, Monday

10:00 a.m.	Opening Ceremony at Central Bank • Appropriate Dignitaries
12:00 p.m.	Buffet Luncheon at the Uni Hotel
1:30 p.m.	Workshop Opening; Procedural Guidelines
2:00 p.m.	ENVIRONMENTAL ASPECTS • Shrimp Mariculture in the Context of Ecuador's Coastal Ecosystems R. Twilley • Summary Presentation of Relevant Research at the Fisheries Institute R. Jimenez or L. Solorzano • Summary Presentation of the CLIRSEN Database A. Alverez or J. Valdiviezo
3:00 - 5:00 p.m.	Facilitated Discussion
5:00 - 7:00 p.m.	Dinner Break
7:00 p.m.	ECONOMIC ASPECTS • An Economic Analysis of Trends in the Shrimp Mariculture Industry in Ecuador J. Sutinen, W. Spurrier and J. Broadus • Shrimp Mariculture Development and Coastal Resource Management: Lessons from Asia and Latin America C. Bailey
8:00 - 10:00 p.m.	Facilitated Discussion

6

August 5, Tuesday

1:00 p.m.	POST LARVAL SUPPLY
	Natural System
	• Factors Affecting the Relative Abundance of Shrimp in Ecuador G. Turner
	• Composition, Distribution and Abundance of Post Larvae and Juvenile Shrimp in the Gulf of Guayaquil R. Zimmerman
	Hatcheries
	• Near and Long Term Role of Hatcheries in the Industry E. Arellano, M. Lestlie, C. Mock, P. Boeing and P. Maugle
2:15 - 5:00 p.m.	Facilitated Discussion
5:00 - 7:00 p.m.	Dinner Break
7:00 p.m.	Operation of Ponds
	• Status and Options for Improving the Efficiency of Pond Mariculture J. Villalon, R. Laniado, and P. Maugle
7:30 - 10:00 p.m.	Facilitated Discussion

August 6, Wednesday

1:00 p.m.	MANAGEMENT OF FISHERIES
	Adult Fisheries
	• Management of the Shrimp Capture Fishery E. Klima and R. Jimenez
	• Population Dynamics of Adult Shrimp Captured by the Trawler Industry C. McPadden
	Post Larvae
	• Preliminary Evaluation of Shrimp Fishery Closures in 1986 R. Naboa and R. Horna
1:45 - 5:00 p.m.	Facilitated Discussion
5:00 - 7:00 p.m.	Dinner Break
7:00 p.m.	Legal and Institutional Issues
	• The Legal and Institutional Framework for Farmed Shrimp Management in Ecuador E. Perez, D. Robadue and S. Olsen
	• Some Specific Legal Issues Posed by Shrimp Mariculture in Ecuador E. Perez
7:45 - 10:00 p.m.	Facilitated Discussion

August 7, Thursday

1:00 p.m.	Towards a Sustainable Industry • Shrimp Mariculture in Ecuador: Issues and Management Alternatives • Synthesis of Workshop Findings
1:30 -5:00 p.m.	Facilitated Discussion
5:00 p.m.	Dinner Break
7:00 - 10:00 p.m.	Discussions Continued
10:00 p.m.	Meeting Closure

8

August 8, Friday

9:00 a.m.	Public Presentation of Week's Activities
9:15 a.m.	Introduction and Welcome
9:30 a.m.	Towards a Strategy for a Sustainable Industry Presentations by: S. Olsen & E. Figueroa
10:30 a.m.	Environmental Aspects Presentations by: R. Twilley & L. Solarsano
12:00 p.m.	Lunch Break
1:00 p.m.	Economic Aspects Presentations by: J. Sutinen & W. Spurrier
2:00 p.m.	Post Larval Supply Presentations by: R. Zimmerman & E. Arellano
3:00 p.m.	Operation of Ponds Presentation by: J. Villalon & P. Maugle
4:00 p.m.	Management of Fishery Stocks Presentations by E. Klima, R. Jimenez & R. Horna
5:00 p.m.	Legal and Institutional Issues Presentations by: S. Olsen and E. Perez

-9'

WORKSHOP REGISTRATION FORM*

NAME: _____

TITLE: _____

MAILING ADDRESS: _____

_____

_____

TELEX NUMBER: _____

CABLE ADDRESS: _____

YOUR INTEREST IN SHRIMP MARICULTURE IS:

_____

_____

_____

_____

*Please complete and return this form to Paul Maugle and/or Kris Merschrod so that wse can assure that you receive the Workshop Proceedings.

IMPACTS OF SHRIMP MARICULTURE PRACTICES ON THE ECOLOGY OF COASTAL ECOSYSTEMS IN ECUADOR

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Report to the University of Rhode Island

Coastal Resources Management Project

Ecuador Pilot

May 1986

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INTRODUCTION

In response to a rapid change in human activities in the past 5 years, there has been a concern for the development of a management plan to protect both the economic and natural resources of the coastal zone of Ecuador. The change has been largely due to the expansion of three industries including agriculture, oil exploration, and shrimp farming. The former economic activity has stimulated an increase in the population of certain coastal areas in association with an increase in other manufacturing activities. These changes in the coastal watershed have prompted concern over increased levels of petrochemicals, particularly hydrocarbons, and domestic sewage that may negatively impact the quality of estuarine and coastal waters. Another major change in the land use of coastal Ecuador has been an increase in the construction of shrimp ponds in the intertidal zone of the southern and northern provinces. Initially the expansion of the shrimp farming industry occurred at the expense of more inland intertidal areas or salinas that are basically void of any vegetation. Yet, as these areas became scarce, construction involved the destruction of zones inhabited by mangroves. The loss of this natural resource and the practices associated with shrimp farming in general (e.g. pumping of estuarine water through the ponds) may be associated with recent observations in changes in the environmental quality of esteros in Ecuador. There are other less obvious impacts that have not been considered which are also associated with the shrimp industry.

There are other changes in land use in coastal Ecuador that may impact the coastal zone. Agriculture, particularly the production of rice in southern provinces, has increased over the past several years. The application of

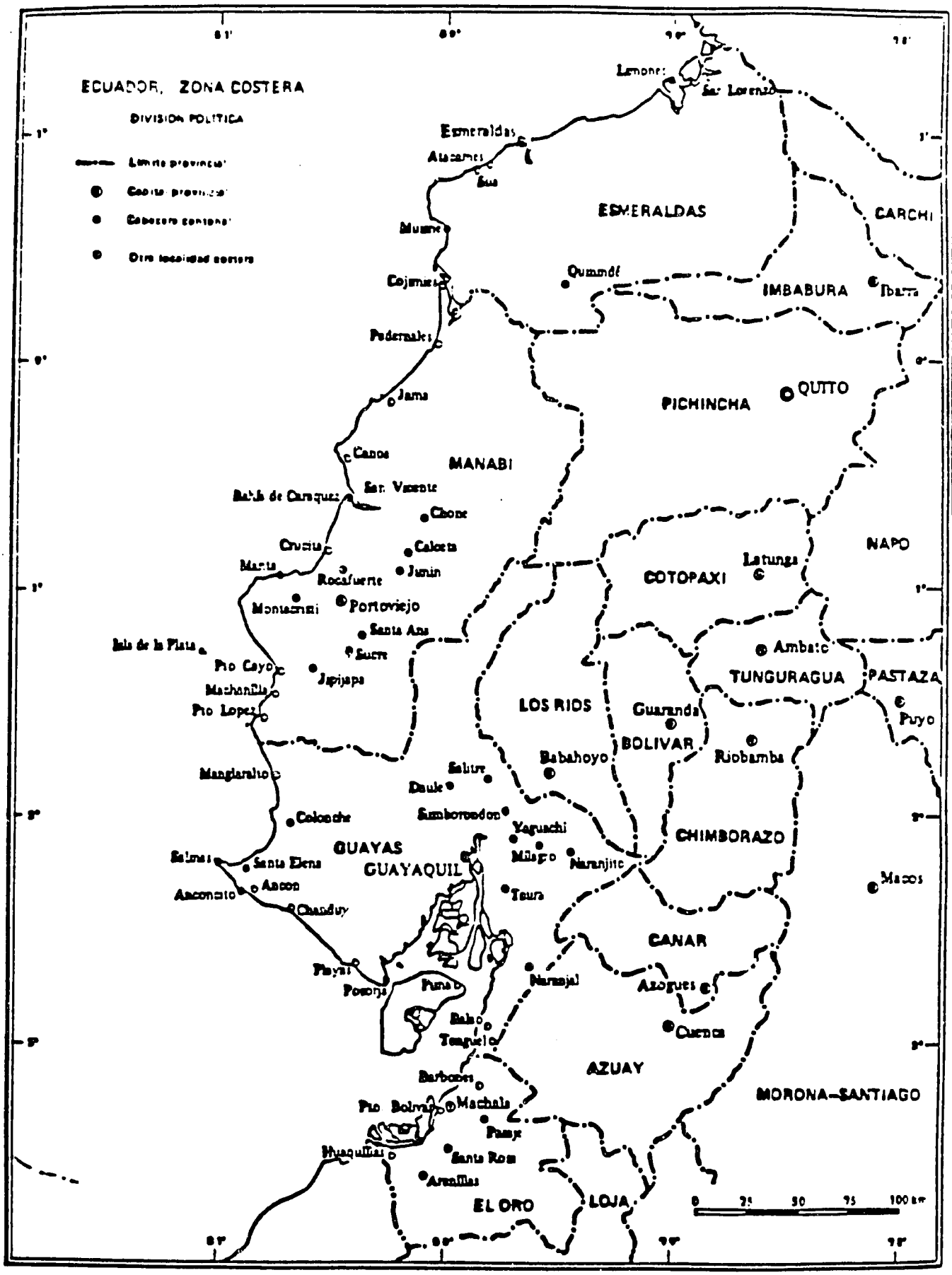


Figure 1. The coastal provinces of Ecuador.

agrochemicals including pesticides and fertilizers may influence the ecology of aquatic ecosystems downstream from these watersheds. The magnitude of this impact depends on the area of land use relative to the volume and turnover of the adjacent body of water. Also, there are plans for the development of hydrologic projects that will divert the natural flow of freshwater from the estuaries for urban and agricultural use. In order for these modifications of the landscape to be a positive influence on socio-economic qualities of the people of Ecuador, there must also be some consideration of the importance of natural resources to this quality of life. This initial report is an analysis of the impacts of present human activity in the coastal zone using a systems approach to include the diversity in landscapes and human activities. The goal of this analysis is an itemization of the potential factors associated with the activities of industry, agriculture and aquaculture, with some priorities as to what may be critical to maintaining a proper interface of these industries with the natural resources of the coastal zone.

GENERAL DESCRIPTION OF THE COASTAL ZONE OF ECUADOR

Regional Setting

The landscape of Ecuador has been divided into three major regions by the Andean highlands bordered on the east by the Amazon region and to the west by the coastal lowlands (from Filho 1983). This report will deal with the provinces that make up the coastal lowlands that extend from 1 ^{o} N to 3° 20' S for a distance of approximately 900 km (Fig 1; FAO 1978 from Filho 1983;

Table 1. Location, drainage basin, discharge and population of the major rivers along the coastal zone of Ecuador.

RIVER	PROVINCE	DRAINAGE (km^2)	DISCHARGE (m^3/s)	POPULATION
Esmeraldas	Esmeraldas	21186	1026.70	1,049,500
Cayapas	Esmeraldas	6190	341.10	20,160
Muisne	Esmeraldas		25.01	
Jama	Esmeraldas	1607	22.41	
Mataje	Esmeraldas		11.23	
Atacames	Esmeraldas		1.57	
S U A	Esmeraldas		.59	
Chone	Manabi	2597	31.00	131,040
Portoviejo	Manabi	2230	6.93	204,120
Jipijapa	Manabi		.82	
Jaramijo	Manabi		.15	
Manta	Manabi		.04	
Guayas	Guayas	35243	1143.70	2,189,880
Canar	Guayas		60.50	
Taura	Guayas		60.11	
Balao	Guayas		23.15	28,980
Jagua	Guayas		13.71	
Naranjal	Guayas	3060	12.07	
San Pablo	Guayas		8.20	
Churute	Guayas		2.04	
Tenguel	Guayas		2.05	
Zapotal	Guayas		.48	
Valdivia	Guayas		.37	
Manglaralto	Guayas		.12	
Barbasco	Guayas		.08	
Grande	Guayas		.08	
Jubones	El Oro	4280	95.58	131,040
Arenillas	El Oro	550	19.92	15,120
Santa Rosa	El Oro	926	8.23	39,060
Zarumilla	El Oro	480	7.90	

McPadden 1985). The areal extent of this region is 284,000 km^2 and consist of three major river and estuarine ecosystems: the Rio Esmaraldas in the north, Rio Chone which flows into the Bahia de Caraquez, and the Gulf of Guayaquil in the south (Table 1). The four coastal provinces of Ecuador, from north to south, include Esmeraldas, Manabi, Guayas, and El Oro (Fig 1). The province of Los Rios

is part of the watershed that feeds the rivers flowing through the Guayas province to the sea. Nearly half of the countrys population is located in the coastal region (8,500,000 inhabitants) for a population density of about 29 per km^2.

The coast of Ecuador has a tropical climate with marked wet and dry seasons. More than 95% of the annual precipitation falls during the wet season from January to May while 2% or less occurs during the dry season (Stevenson 1981). Annual precipitation varies from less than 500 mm in the central provinces and the coast of the southern provinces, to over 3000 mm at Santo Domingo de las Colorados in the north (Fig. 2; Enginer Journal 1972; Schaeffer-Novelli 1983). Annual mean temperatures vary little along the coast from 24.2 to 27 C, thus potential evapotranspiration is about 1300 mm per year. Most of the coastal area is part of Holdridge's (1967) classification of an arid life zone, particularly in the central province of Manabi, since precipitation is less than evapotranspiration potential (Schaeffer-Novelli 1983). There seems to a moderately wet climate in the south with abundant freshwater from runoff around Guayaquil, while in the central province the arid climate results in very sparse vegetation and much of the coastline is very dry. Then in the north near Esmeraldas, the climate is again more humid tropical with abundant rainfall and the vegetation is more lush.

There are also seasonal changes in the water masses off the coast of Ecuador, influenced mainly by the strength of the northward flowing Humboldt current that prevents the insurgence of warmer equatorial waters flowing south. There are three major types of water masses that interact off the coast of Ecuador: equatorial subsurface water (ESSW), tropical surface water (TSW), and subtropical surface water (STSW) (Cucalon 1984). High salinities are associated with the

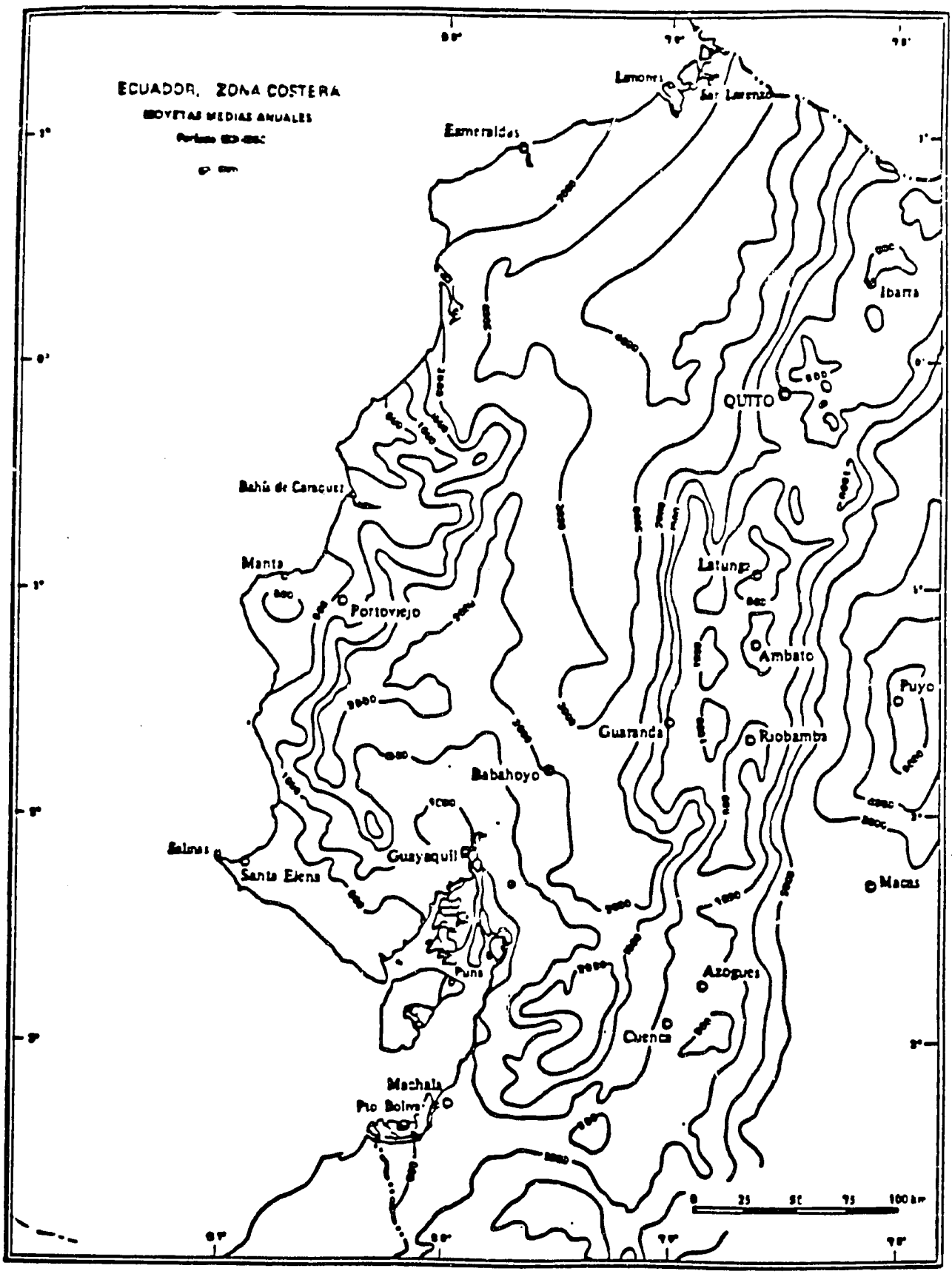


Figure 2. Contours of annual precipitation in the coastal provinces of Ecuador.

equatorial subsurface and subtropical surface waters, yet the temperature of the latter are much higher (15-28 C compared to 13-15 C). Tropical surface waters also have temperatures greater than 25 C, however high precipitation in the eastern tropical Pacific Ocean result in salinities less than 34 parts per thousand (Dietrich 1957). Changes in water characteristics resulting from the mixing of these water masses include different temperatures and salinities depending on the dominant flow. Extreme southerly flows of equatorial waters resulting in higher temperatures of Ecuadorean coastal waters have been associated with El Nino events, which have been documented in 1954-1957 and recently in 1981-1984.

Gulf of Guayaquil

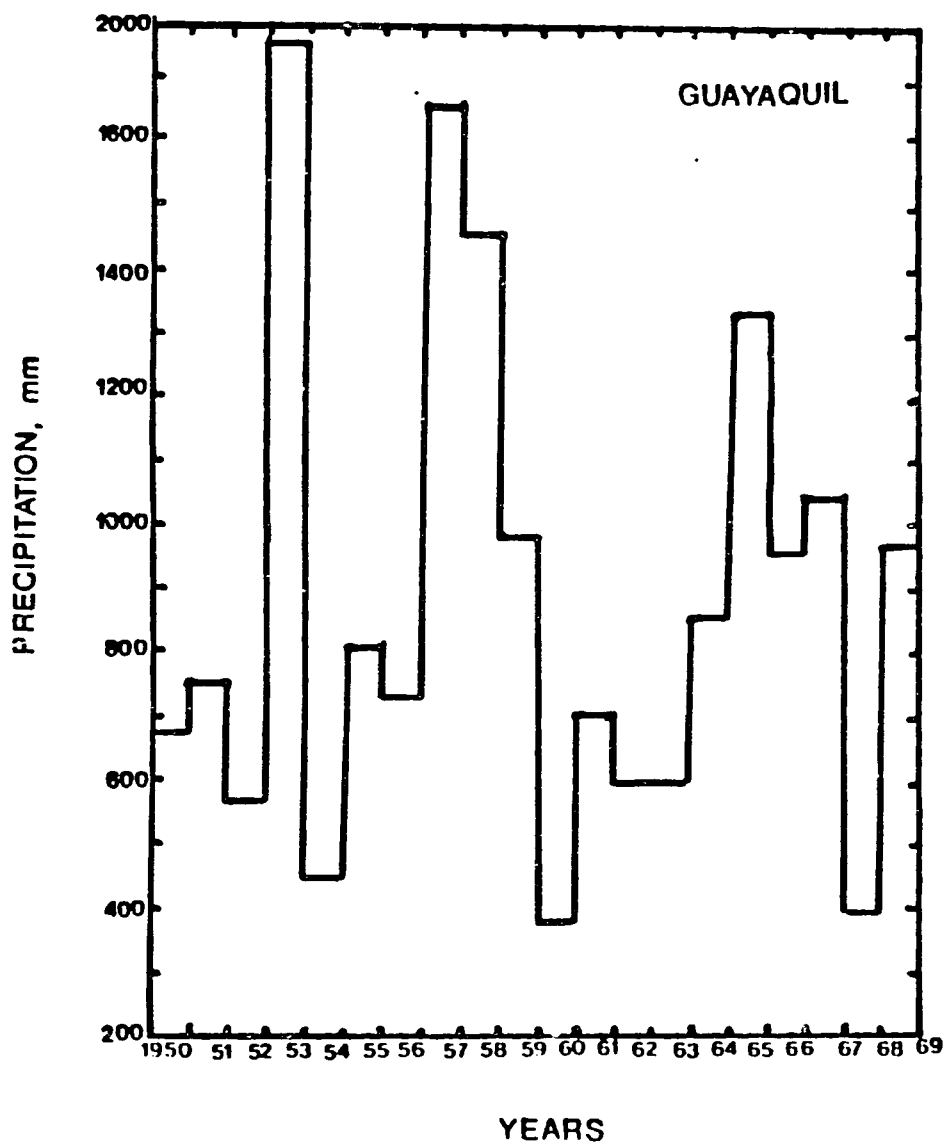
The Gulf of Guayaquil receives runoff from some 20 rivers and is the largest estuary on the western Pacific coast of South America (Table 1; Cucalon 1984 from McPadden 1985). The economic activity of the Gulf of Guayaquil consists mainly of its port facilities, potential for exploration of gas and oil, and fisheries. The port handles 95% of the country's imports and 50% of its exports (Enginer Journal 1972). This southern coastline also includes the largest city in Ecuador, Guayaquil (1.7 million people), which is increasing at an annual rate of 3.8% (Enginer Journal 1972). This city represents nearly 53 % of the population of the Guayas river basin which has 3.14 million people.

The Gulf of Guayaquil is 204 km wide with a longitudinal axis of 130 km and a surface area of approximately 12,000 km^2. The Gulf's watershed is 51,230 km^2 for a watershed:water surface area ratio of 4.3. Water depth at the center of the Gulf is 60 m (Pesantes 1975 from Filho 1983); the 0-18 m depth contour is 39% of

the surface area whereas the remainder is 18-92 m deep. At the mouth is an island surrounded by a shallow channel (12 m), the Canal de Jambeli, and a deeper channel (average depth of 20 m), the Canal del Morro. These two channels empty into a continental shelf whose outer limit borders the Peru-Chile trench 75 km eastward from the island. The shelf slope averages 1.4 m/km and has a maximum depth of 4,000 m 140 km offshore (Cruz-Orozco 1974 from Filho 1983).

Landward from the Gulf is a large saltwater estuary, the Estero Salado, which extends some 40 miles upriver as far as Guayaquil. Based on statistics in Table 1, 86.2 % of the freshwater that enters this estuary is from the Guayas River. This river system forms 5 km upstream from the city of Guayaquil at the confluence of Rio Daule and Rio Babahoyo and flows 60 km to the Gulf. The drainage system north of Guayaquil that forms the River Guayas has a mean precipitation of 885 mm/yr which has ranged annually from less than 400 to more than 1800 mm (Fig. 3). With a drainage area of 35,000 km^2, runoff is approximately 35,000 million m^3/yr or 1078 m^3/s (Table 1) (CEDEGE 1984). Based on a discharge of 21 $(10)^9$ m^3 from 684 mm rainfall per year in 1961 (Stevenson 1981), runoff was 410 mm/yr which is equivalent to a runoff coefficient of 59.9%. Discharge varies from 200 m^3/s during the dry season to more than 1600 m^3/s during the rainy season (Fig. 3). There is a 21 day lag in precipitation and river height.

Tides are semi-diurnal (M_2 = 12.42 h) and are of general equal amplitude. Tidal progression is approximately from north to south and is amplified by oceanic currents, winds, and waves that flow in the same general direction (Cruz-Orozco 1974 and Murray et al. 1975 from Filho 1983). Tides average 1.8 m at entrance of channels near the island, but are amplified to heights from 3 to 5 m near the city of Guayaquil. Recorded mean current speeds for Canal de Jambeli are 50 cm/s and



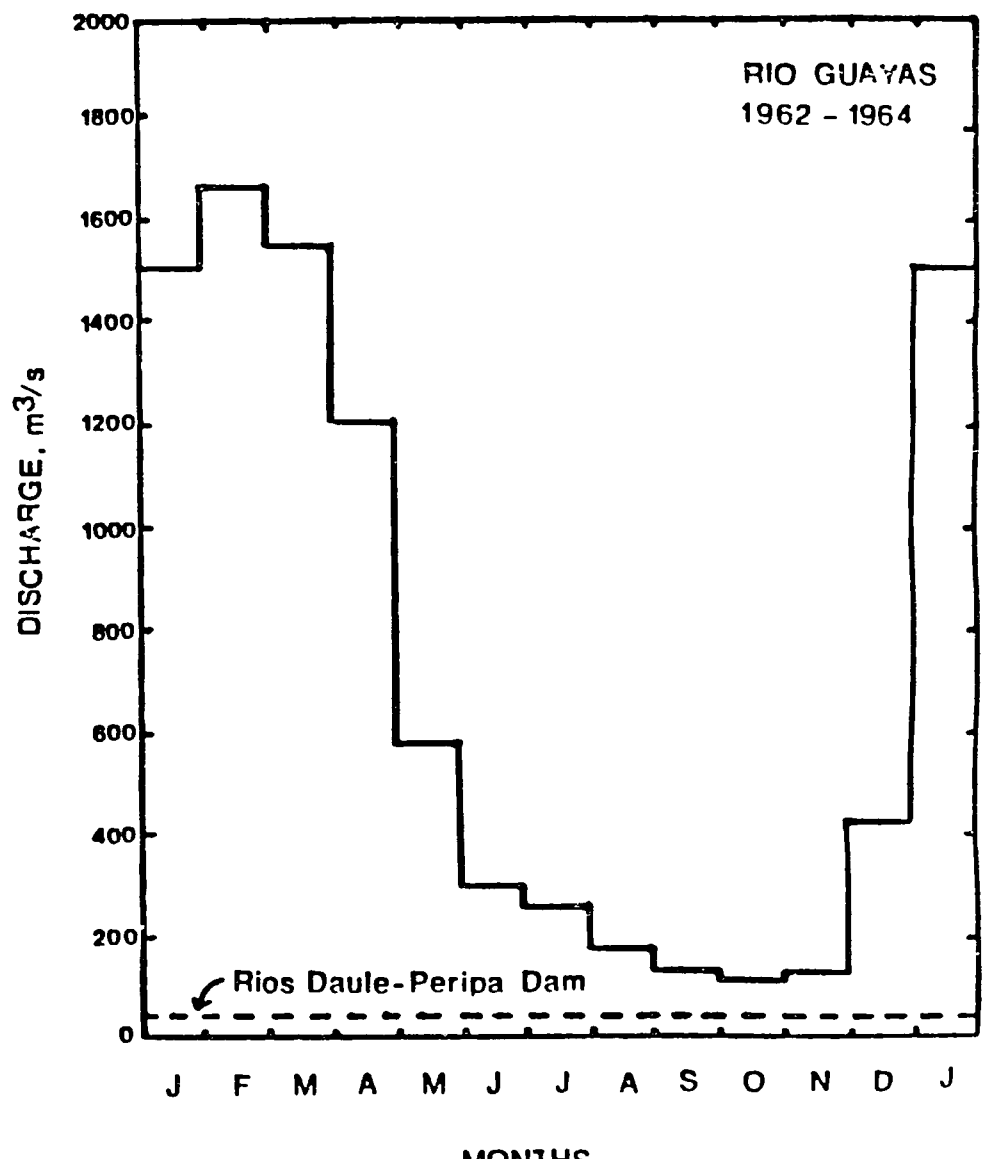


Figure 3. A) Forty year record of annual precipitaion in Guayaquil. B) Average monthly discharge of the River Guayas from 1962 to 1964. (Both figures from Stevenson 1981).

25 cm/s for flood and ebb tides, respectively, at its narrowest point; and decrease to nearly equivalent flows of 35 cm/s during flood and ebb tide at the mouth. Flushing time of the Gulf of Guayaquil is about 21 days (Murray et al. 1975 from Filho 1983). Winds occur from the southwest at 1.8 m/s during the wet season and from the northwest at 3.5 m/s in the dry season (Stevenson 1981). There is evidence of seiches in the inner estuary with a period of 3.2-3.5 hours (Stevenson 1981).

Description of Maricultural Practices

Aquaculture represents human efforts to manipulate natural cycles of aquatic organisms to enhance production of aquatic resources for his benfit and today this industry produces nearly 15 % of the 60 million metric tons of fisheries harvested worldwide (Siddall et al. 1985). Mariculture is a form of aquaculture that pertains to the manipulation of marine organisms for human enterprise. In Ecuador, the Incas practiced mariculture 400 years ago by closing off lagoons which were temporarily flooded with seawater and penaeid shrimp larvae. Yet the first commercial shrimp operations did not begin until 1969 (Siddall et al. 1985). In the last five years there has been a tremendous increase in shrimp pond construction, leveling off in the past couple of years. The preferred location for these ponds is near the coast, which provides sources of clean water and abundant stocks of juvenile shrimp. Only Penaeus vannamei and P. stylirostris survive and grow well in the shrimp ponds.

The methods of shrimp mariculture in the intertidal zone are grouped into three classifications based on the densities of juvenile shrimp stocked in the

ponds. Extensive mariculture, using a stocking density of 10,000-20,000 juveniles per ha, relies little on further supplements from seawater exchange via pumping or from artificial fertilization. Predators are present and annual yields are relatively low at 100-400 kg/ha. An increase in stocking rates to 50,000-60,000 juveniles per ha in semi-extensive systems require some supplemental feeding program for an enriched supply of food, and exchange of seawater to control for water quality problems such as decreased levels of dissolved oxygen. Production rates more than double with this program. Semi-intensive operations stock ponds at 100,000 juveniles per ha and feed is supplied or ponds are fertilized to increase sources of food. Water exchange with the estuary is higher and annual production rates increase to 1,000-1,800 kg/ha. These supplemental feeding and fertilization methods are required to meet the demand for food created by higher stocking densities. The main source of nutrition in these ponds is the bloom of phytoplankton that results from the addition of urea and superphosphates added prior to stocking. Supplimentary feeding is carried out towards the end of the growth cycle, usually the last four weeks. The semi-intensive system has a grow out time of 120 to 140 days per harvest. Logical future trends would be for intensive mariculture with higher stocking rates and more intensive management to the system. More intense systems have been recommended for more efficient utilization of existing ponds, without having to expand into other intertidal habitats (Siddall et al. 1985). Presently the farmed shrimp industry has been limited by the lack of juvenile shrimp for these types of stocking rates (McPadden 1985). There are only about 30,000 ha of ponds seeded which has required 4 billion post larvae; to stock available ponds (75,000 ha) would require 10 billion post larvae.

IMPACTS ASSOCIATED WITH REGIONAL HYDROLOGY

Daule-Peripa River Dam Project

A dam is proposed at the confluence of the Daule and Peripa rivers for the provision of water, control of river flow, and hydroelectric power. Water will be diverted with an aquaduct from the Rio Daule to the Sante Elena peninsula for potable water, irrigation for agricultural purposes, and industrial use. The Rio Daule drains one-third of the Guayas river basin and has a mean capacity flow of 11,500 million m^3/yr or 365 m^3/s. The total river basin of both the Daule and Peripa rivers is 420,000 ha and receives a mean precipitation of 1800 mm per yr (Table 2). A thorough description of the soil characteristics and land use of this watershed are provided in CEDEGE (1970).

Table 2. Area of the Guayas watershed above the Daule-Peripa dam associated with each of the rivers that make up the impoundment.

RIVER	AREA (ha)	DISCHARGE (m^3/s)
Rio De Oro	180,000	
Rio Daule	113,900	365
Rio Peripa	126,100	
TOTAL	420,000	

The dam will provide an impoundment with a capacity for storing 6.0 km^3 of water with a surface area of 270 km^2, mean depth of 21 m and volume of 5.4 km^3. The projected uses of the water are summarized in Table 3 and include industrial

domestic and agricultural purposes. Potable use includes a population of 300,000 inhabitants at 400 L/person per day, irrigation is based on 42,000 ha of agriculture at 13,000 m^3 ha^{-1} yr^{-1}, and industry is projected to use 20 $(10)^6$ m^3/yr. Projected industrial use includes petroleum refinery, nitrogen fertilizer complex, petrochemical complex, and a petrochemical port facility at Monteverde. Total use is approximately 756 $(10)^6$ m^3/yr or about 25 m^3/s, which will be uniform use during the year. There will be a strict design flow of 24 m^3/s and will be partitioned for uses as described in Table 3. Total demand for the aquaduct is 760 $(10)^6$ m^3/yr maximum and 705 $(10)^6$ m^3/yr mean flow. The impact of this diversion on discharge of the Rio Guayas to the Estero Salado is minor during the rainy season, but is more than 10% of the flow from August to November (Fig. 3).

Table 3. Summary of projected use of water (m^3/s) to be diverted by an aqua duct from the Daule and Peripa rivers to the Sante Elena peninsula.

USE	MAXIMUM	MEAN
Industrial	4.0	4.0
Domestic	2.7	2.7
Agriculture	17.4	15.7
Total	24.1	22.4

The Daule-Peripa dam will also influence the flow of water from the watershed upstream from the confluence of the Daule and Peripa rivers that normally discharges into the Guayas river. Presently the proposed operation of the dam calls for an average annual flow of about 174.7 m3/s (Jenkins 1979). As demonstrated in Fig. 4, this flow will vary from a high of 321 m3/s during the wet season in April, to a low of 124 m3/s in August. Compared to the normal discharge

at this confluence (Fig. 4), this modified flow during the wet season represents a huge deficit of freshwater that usually flows up to 1000 m3/s. During the dry season, the dam will provide water above the average discharge of about 50 m3/s from the water stored in the impoundment. Based on average monthly flows, the normal discharge of 343 m3/s from these two rivers will be restricted to 175 m3/s, a reduction of about 49 % of the normal flow (Fig 4). Based on the discharge data in Table 1, this reduction represents a loss of 15% of the freshwater to the Guayas river and 13% from the Estero Salado. Since the function of estuaries as productive nurseries is based on the presence of freshwater, this project must be thoroughly evaluated relative to economically important fisheries in the coastal zone. The possible impacts of the loss of freshwater from the Guayas river and Estero Salado will be discussed below.

Pumping Associated with Shrimp Farming

More intense shrimp farming techniques involve stocking ponds at higher densities of juveniles, which require additional fertilization and supplemental feeding to make sure there is adequate food supply for secondary productivity. These practices also require strict management for proper water quality to make sure that the phytoplankton blooms resulting from nutrient enrichment do not caus severe oxygen loss. Such water quality conditions will increase the mortality of the shrimp. One of the solutions to this potential water quality problem is to increase the exchange of seawater through the ponds by pumping water from the estuary. This exchange rate varies from 3 to 8 % the volume of the shrimp pond under semi-extensive mariculture and increases with more intense farming practices. Present practice is for pumping to occur without regard to tidal flow

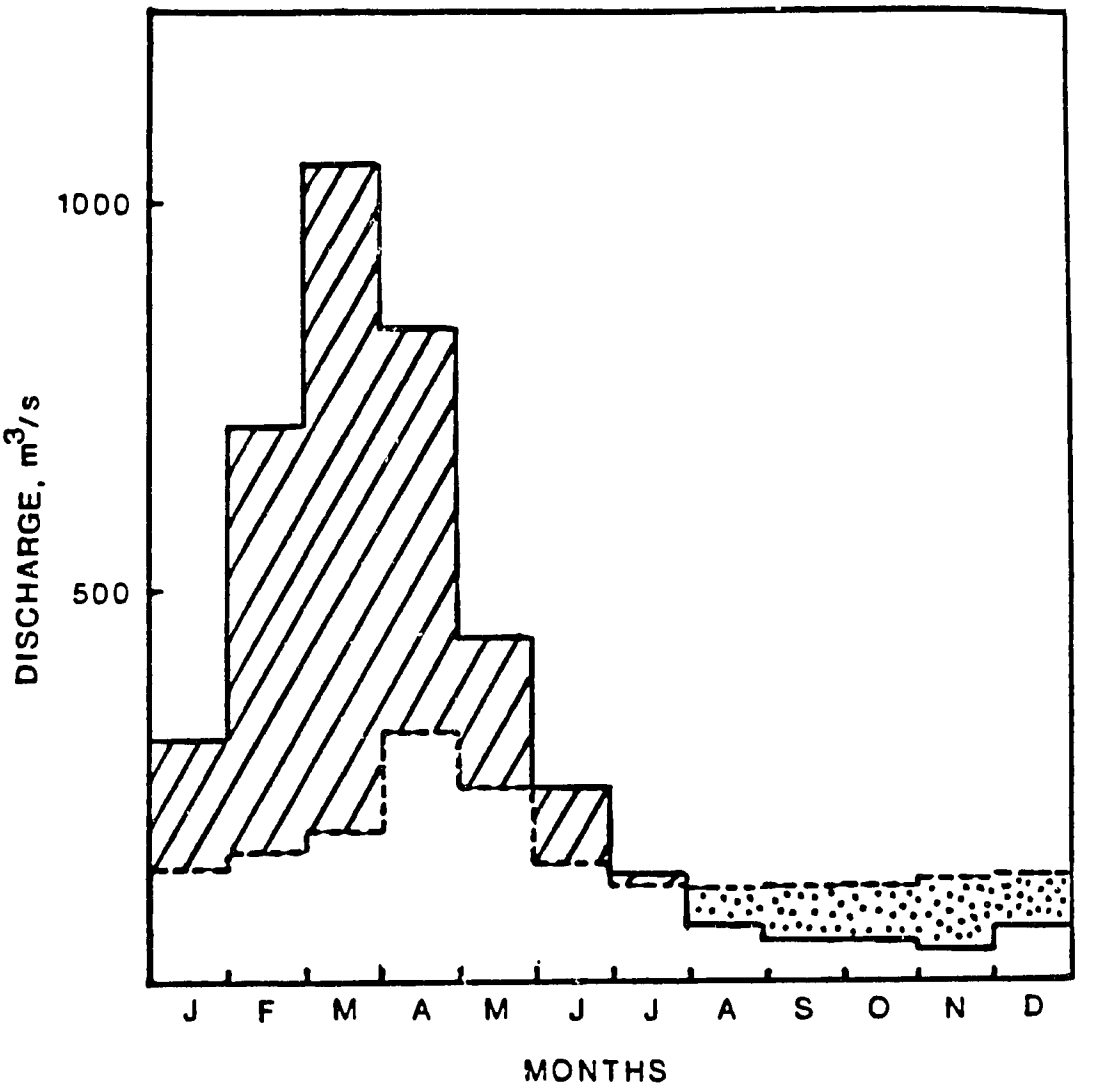


Figure 4. Normal discharge at the confluence of the Daule and Peripa rivers (solid line) compared to the restricted flow controlled by the proposed dam (dotted line). Slanted lines represent discharge lost from the estuary during the wet season, and the stipuled area is discharge provided by the impoundment during the dry season (From Jenkins 1979).

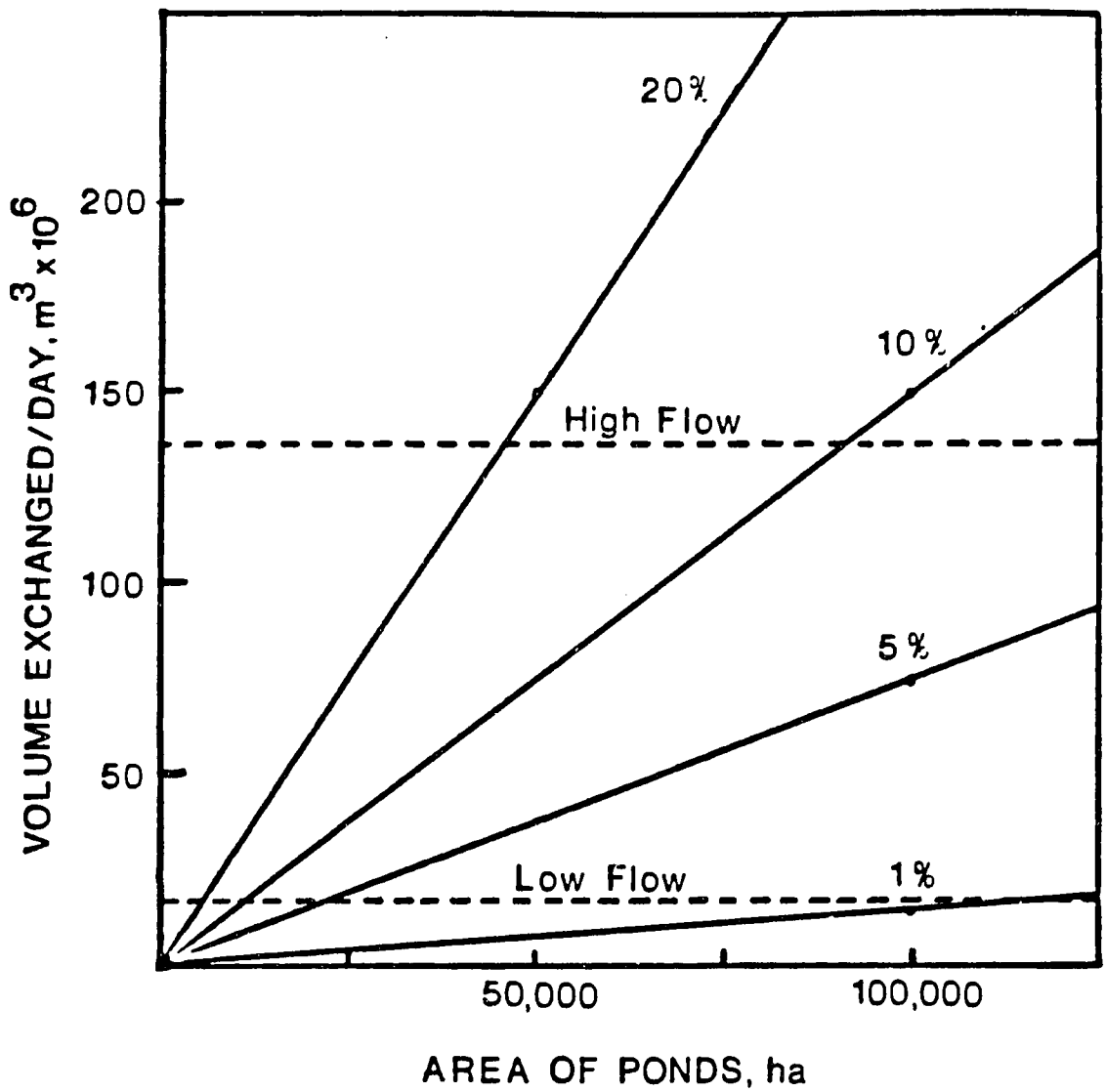


Figure 5. Volumes of water exchanged with shrimp ponds per day at differenct pumping rates (percentage of the volume of a shrimp pond per day) based on the area of ponds (ha) with a mean depth of 1.5 m.

and schedules are based on convenience. The total volume of water pumped from the Estero Salado depends on this pumping rate and the total area of ponds under operation. Figure 5 shows the volume of estuarine water exchanged with ponds (using a mean depth of 1.5 m) based on variations in these two factors, and how these volumes compare to the discharge of the Rio Guayas during the dry and wet season. At a present operation of 30,000 ha of ponds under semi-extensive practices (5 % pumping rate), the volume of water exchanged daily with the estuary is approximately 20 $(10)^6$ m^3 (Fig. 5). This volume is greater than discharge from the Rio Guayas during the low flow period. At intensive operations of ponds (10 % pumping rate), the same area of ponds would exchange nearly 36 % of the riverine discharge during high flow periods. These types of reasonable scenarios underscore the importance of this activity to the pattern of water flow in this estuary.

Consequences of Impacts to Natural Resources

Water Quality

The flow of water in an estuary is controlled by tides, coriolis forces, salinity and temperature gradients, and river flow. Collectively these factors control the residence time of water within the system and influence the concentration of materials within the estuary. Factors that decrease the residence time may cause an increase in the concentration of materials in the system. The loss of freshwater from the Guayas river represents such an impact on the hydrology of the Estero Salado. Such a change in an estuary amplifies the importance of water quality since materials dissolved in the water will remain within the estuary for a longer period of time. The inputs of nutrients, toxic

substances such as pesticides and heavy metals, and hydrocarbons, should be of increased concern if the residence time of water within the estuary will increase. This is because the flushing of the estuary from the river provides a mechanism that minimizes the negative impacts of these types of dissolved substances on biota in the estuary. Those activities in the estuary that rely on clean water such as mariculture and other fisheries, will be influenced by the loss of freshwater to the estuary because of its control on water quality.

Salinization

These two hydrologic alterations, the Daule-Peripa dam and the pumping of water into shrimp ponds, may influence the distribution and concentration of salinity in the Gulf of Guayaquil. It is estimated that the loss of freshwater at the confluence of the Daule and Peripa rivers will be 49% of the normal discharge. In an arid coast such as in Ecuador, this loss of freshwater could be significanct to the water budget of the Estero Salado. A better synthesis of existing information on water flow in the watershed and estuarine ecosystem, such as in the context of a water budget, must be made before the impact of this project can be evaluated.

The exchange of waters from the estuary with shrimp ponds is a modification in the normal flow of water in the intertidal area. A majority of the water that is pumped into the ponds is to replace losses associated with seepage and evaporation. Although there are no data on water budgets for extensive mariculture, observations suggest that less than half of the water removed from the estuary is returned in a flow through design (P. Maugle, personal communication). The amount of water loss due to evaporation is important and is

probably higher than occurs in the estuary, since shallow depth of the ponds decreases the heat absorption capacity of the water column. This increase in water loss could result in hypersaline effluents to the estuary. Wetlands generally lose less water per area due to evapotranspiration than open water, and mangroves in south Florida are known to have lower rates of evapotranspiration than potential evaporation (Lugo et al. 1980). Therefore the conversion of intertidal areas vegetated by mangroves to open pond systems could contribute to increased salinity of estuarine waters by enhancing loss of freshwater via evaporation in the coastal zone. In a coastal zone such as in Ecuador where mean annual temperatures are so high, this loss of freshwater could have negative consequences to the natural resources of the area.

Mangroves and Climate

Mangroves do not fall into the classification of world life zones or plant formations by L.R. Holdridge (1967). These life zones are based on available precipitation, evapotranspiration, and mean temperature (biotemperature). Thus, the structure of plant communities can generally be described in relation to the net availablity of water (precipitation minus evapotranspiration). Yet intertidal plant communities have the advantage of obtaining water from several sources other than just precipitation; these include groundwater flow, river flooding, and/or tidal inundation. In arid regions, where water loss by evapotranspiration is high relative to precipitation, the high tidal amplitude and riverine discharge of estuaries such as the Estero Salado subsidize the demand for water from high annual mean temperature (Cintron et al. 1981). Thus mangroves are able to generate structure uncharacteristic of the very dry life zone in which they exist.

In a survey by Pool et al. (1977), mangrove forests with the second and fourth highest complexity index occurred in tropical dry forest life zones; these forest had more structure than those mangrove forests occurring in moist tropical life zones.

Yet mangroves that exist in arid environments are very susceptible to slight changes in hydrology. For mangrove forests in arid life zones, small shifts in precipitation patterns become very noticeable in mangrove forest structure (Cintron et al. 1978). Cyclic patterns in mangrove forest succession and structure have been documented for arid environments of Puerto Rico in relation to cyclic patterns in rainfall (Cintron et al. 1978). Similar observations have been made for mangroves in south Florida (Davis and Hilsenbeck 1974). In all of these cases, a reduction in rainfall resulted in increased soil salinity which resulted in an increase in tree mortality. This increased mortality resulted in vegetation shifts from forests to tannes or salinas (areas within the intertidal zone void of vegetation) that expanded at the expense of the area previously colonized by mangroves. Cintron et al. (1978) suggested that management of mangroves in dry forest life zones should account for this cyclic phenomenon by maintaining buffer zones for the expansion of mangroves during wet years. Also, tree mortality should be accepted as a natural process in these forests, and thus short-term observations should be placed in the perspective of the cyclic nature of these systems.

In Ecuador the diversion of freshwater from Guayaquil Bay must be managed with concern towards a possible negative impact on mangroves. Mangroves found along the waterways of the southern provinces of Ecuador exist in a relative arid environment and are thus very susceptible to slight changes in hydrology,

particularly freshwater supply since potential evapotranspiration rates are similar to precipitation (Fig 6). Thus any loss of freshwater will result in stress to these wetland forests. The extreme variation in precipitation from less than 400 mm/yr to more than 1800 mm/yr amplify the importance of freshwater to the maintenance of these intertidal systems (see Fig. 3). Margalef and Crespo (1979) suggested that the loss of freshwater from the dam will not likely affect the mangroves, yet they did not take into account the climatic nature of the existence of mangroves in the southern provinces. A program to investigate the susceptibility of a loss of freshwater to the distribution of mangroves in the Bay of Guayaquil and its effect on fisheries (such as shrimp larvae) should be considered for monitoring the impact of hydrological changes to this natural resource.

Shrimp Recruitment and Development

The concern discussed above relative to the potential impact of changes in freshwater discharge to Estero Salado on mangroves can also be applied to potential impacts on the seasonal distribution of economically important fisheries that exist in this estuarine ecosystem. The Estero Salado, which harbors most of the fishery resources of the inner Gulf of Guayaquil, does not receive freshwater discharge directly from the Guayas river. Therefore the flushing rate of this section of the inner gulf is less than the more southern sections that are linked directly to discharge from the river. As a consequence of less discharge, the Estero Salado may be more susceptible to increases in the concentration of materials dissolved in the water column. Salinity is a conservative element in the water column and indicates the concentrating nature of this body of water.

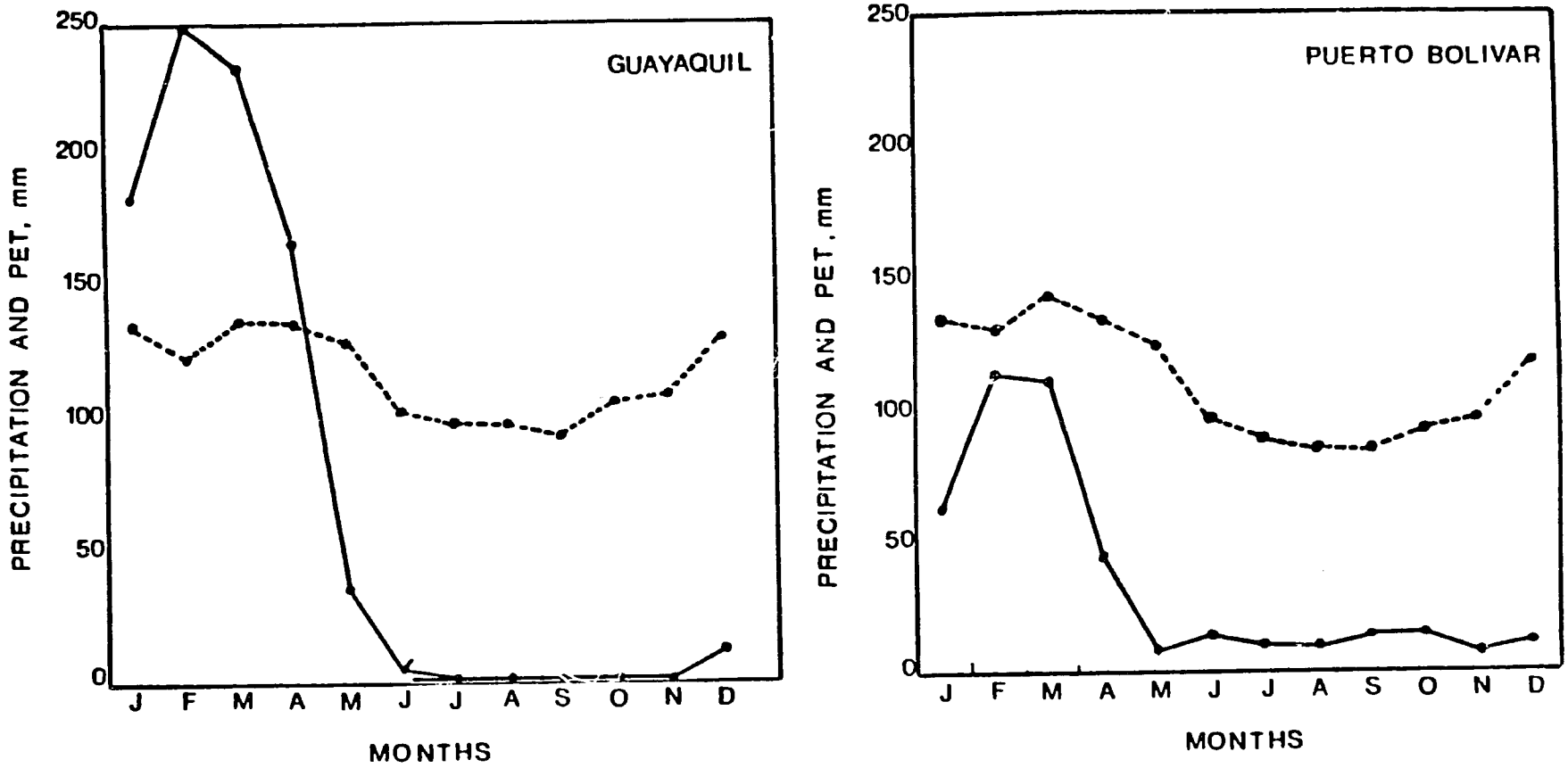


Figure 6. Relative magnitude of precipitation (solid line) and potential evapotranspiration (PET, dashed line) for two locations along the coast of Estero Salado (data from Schaeffer-Novelli 1983).

Precipitation during 1985 was relatively low, and salinities in the Estero Salado were hypersaline with values up to 39 parts per thousand (R. Zimmerman, personal communication). This increase in salinity suggests that other materials, such as toxic chemicals and nutrients may also be concentrated (assuming that their behavior is conservative). Organisms that harbor the Estero Salado such as shrimp are very susceptible to changes in water quality such as salinity and toxic substances which may decrease their survival level in the estuary. Once these concentrations reach the threshold at which they can tolerate these chemicals and ions, the productivity of these fisheries will decline. These occurences of higher salinities need to be related to potential impacts on the recruitment, maturation, and spawning of estuarine species. At what levels of salinity due normally productive nursery areas of the Estero Salado become unproductive? What specific fisheries are most susceptible to increases in salinty?

These issues of impacts related to changes in the hydrology of the estuary relative to fisheries also needs to address the importance of seasonal programming to the movement of organisms into estuarine nurseries. Seasonal programming refers to the occurrence of fisheries such as shrimp larvae in the Estero Salado during only specific months of the year. This pattern is important to the life cycle of these organisms by providing conditions important to the spawning and maturation stages of the organisms. This seasonal movement of organisms is thought to be dependant on the seasonal nature of salinity. The function of the estuary as a nursery may depend on the seasonal nature of salinity. Since the Daule-Peripa dam is designed for a near constant flow of water to the Estero Salado, the potential impact of this project should be evaluated relative to the natural function of this estuarine ecosystem. Therefore it is not only a matter

of quantity or absolute changes in salinity within the Estero Salado, but also the seasonal nature of these attributes of the ecosystem that must be considered. Since the mariculture industry relies on shrimp postlarvae that seasonally utilized the estuary, management plans should strongly consider those factors that influence recruitment of fisheries in the Estero Salado.

IMPACTS ASSOCIATED WITH EUTROPHICATION

Land Use

Patterns in land use have a strong influence on the nature of aquatic ecosystems downstream from the watershed. The linkage of a watershed to an aquatic ecosystem is water, and many human activities such as agriculture and urban development are designed for efficient means of flood control that increase runoff. This increased flow of water may transport other by-products of human activity such as chemicals dissolved or suspended in the discharge. These chemicals include plant nutrients applied to agricultural fields to enhance production of crops, and nutrients associated with domestic waste. These macro-nutrients also have a stimulatory effect on plants living in aquatic ecosystems, and can enhance their productivity as well. Other chemicals that are a by-product of human activity in watersheds are those that are used to control pests, and those which are exported from industrial activities. Many of these materials are toxic to living resources of an aquatic ecosystem. This section will describe the quality of the Gulf of Guayaquil in relation to changes in the

flux of nutrients and toxic substances that may be associated with changes in land use and economic activity of this coastal zone of Ecuador.

Nutrients

Inputs

Diffuse inputs. Sources of nutrients in the watershed that contribute to the loading of aquatic ecosystems may be described as either diffuse or from some specific point of effluent. Diffuse loadings include runoff from natural vegetation in the watershed or from agricultural or forestry that manipulate the landscape for a specific type of crop. Much research has gone into developing nutrient loading rates for differenct types of native vegetation and for specific types of crops in watersheds from a variety of geographic areas. Most of these loading rates have been developed for watersheds located in temperate climates, and little is known on the loss of nutrients from tropical watersheds. However, there are some differences in humid tropical ecosystems, such as those found in the Guayas river basin, that render them susceptible to significant nutrient losses from disturbance due to various agricultural or forestry practices. These factors include the high slope of the landscape, high precipitation inputs, leaching rate of the soils, and low organic matter content of the surface horizons of the soil. The loss of nutrients from the watershed will depend on these factors and the application rate of fertilizers for each specific crop.

There are five crops raised along the coast of Ecuador including bananas, rice, sugar cane, cacao and coffee (Filho 1983). These agricultural products come primarily from the Guayas lowlands, situated north and east of the city of

Guayaquil, and along the eastern shore of the Gulf of Guayaquil (Table 4). Statistics for the Guayas and Los Rios provinces have been combined to represent agricultural activity in the Guayas river basin. Over 50% of total aqricultural activity described in Table 4 for the coastal zone of Ecuador occurs in the Guayas river basin. The major agricultural product of this river basin is cacao which represents 41% of the crops listed. The Guayas river is a major producer of rice, with nearly 95% of the total rice production along the coast occurring in these two provinces. Agriculture traditionally supported the national economy until the early 1970's, but has decreased in importance as an export product over the last couple of years. Recently there has been a renewed interest in increasing agricultural production, particularly of rice in the Guayas river basin.

The production of rice in the Guayas river basin is of particular significance to the nutrient economy of the river and esteros because of the large area of production (Table 5), the potential exparsion of this crop in the watershed, and its proximity to waterways. The production of this crop involves the manipulation of a wetland by exchanging large volumes of water with the rivers. Rice, as a wetland, as a great potential for the loss of certain nutrients such as nitrogen via denitrification (the conversion of nitrate to nitrogen gas which returns to the atmosphere), and may thus serve as a sink of the nitrogen applied. However, the fate of this nutrient and others in rice fields depends on the practices used in raising the crop, particularly the flooding regime used. The impact if any of this type of land use needs further investigation, but is potentially significant to any nutrient budget of this watershed.

Table 4. Cultivation areas in hectares for different crops in the coastal provinces of Ecuador (data taken from Solorzano 1981).

CROP	GUAYAS	LOS RIOS	GUAYAS RIVER BASIN	MANABI	ESMERALDAS	EL ORO	TOTAL
Rice	35280	37058	72338	1304	1918	128	75688
Cotton		540	540	5656			6196
Soy Beans	10038	24470	34508	165	37	90	34800
Cacao	12134	116115	128249	40077	12367	16117	196810
Coffee	31681	42020	73701	138431	11000	15176	238308
SUM	89133	220203	309336	185633	25322	31511	551802

Table 5. Areal cultivation of rice associated with the rivers in the coastal region of Ecuador (from Solorzano 1981).

RIVERS		AREA
	GUAYAS	35280
Guayaquil		1600
Daule		7745
Samborandon		4198
Balzar		3038
Yaguachi		8003
Milagro		1106
El Triunfo		5164
Naranjal		4426
	RIOS	37058
Babahoyo		19409
Baba		3033
Vinces		3000
Urdaneta		1214
Pueblovieio		2160
Ventanas		860
Quevedo		7382
	MANABI	1304
Santa Ana		565
Portoviejo		442
Rocafuerte		297
	ESMERALDAS	1918
Esmeraldas		293
Quininde		1625
	EL ORO	128
Santa Rosa		128

The loading of nutrients to the Guayas river and Gulf of Guayaquil cannot be evaluated based on present information available. This type of analysis could be based using information in Tables 4 and 5 along with application rates for each

crop and a runoff factor for those fertilizers applied to the fields. Also, information is needed on the historical changes in land use in the Guayas river basin to determine the role of agriculture relative to other land use practices of this watershed. Table 6 gives some idea of what fertilizers are used in Ecuador, the relative importance of each based on import statistics, and an indication of an increase in the import of fertilizers to the country. Import statistics do not include all of the fertilizer use in the country since nitrogen producing plants have recently gone into production near Guayaquil. Changes in the application of nutrient additions to the watershed can only be reconciled based on changes in land use and application rates.

Table 6. Quantity of fertilizer (mt/yr) imported into Ecuador (interpreted from values given from Solorzano 1981). Annual values for 1980 are based on first six months of the year.

FERTILIZER	1978	1979	1980
10-30-10	12393.8	17749.7	15463.5
12-24-12	342.4	677.8	1886.5
8-20-20	2725.2	3337.9	3113.9
8-24-8	5458.5	6505.0	7671.5
12-12-18	1003.5	1269.8	468.7
16-16-16	2781.5	595.8	99.7
Simple Superphosphate	2798.1	2325.9	3346.2
Urea	6052.4	1277.3	11470.2
Potassium sulfate	33.8	112.0	--
Ammonia sulfate	2003.3	3377.7	892.0
Potassium	7342.3	8334.3	7654.2
Triple superphosphate	1311.9	--	--
Diammonium phosphate	1924.1	3890.9	3406.9
Ammonia nitrate	--	131.5	
Pure	28	110	
Sum	46198.75	49695.6	55473.3

Point source inputs. Point source effluents are associated with urban areas and manufacturing activities. Loading rates of nutrients from cities are dependent on the population and the treatment of waste before they are released to the river or estuary. Another important factor is the combination of storm sewers with sewage treatment facilities that result in the discharge of untreated waste during high rainfall events. Nutrient loading from these sources are considered point sources since they are usually associated with a pipe that discharges waste directly to an adjacent aquatic system. However, nutrient waste from population centers can also be diffuse loadings via groundwater transport from septic systems. In the watershed of the Gulf of Guayaquil, there is very little treatment of domestic waste and most of it is either released directly to the rivers or esteros via ditches, or is diverted to some septic pond. Thus nutrient loading factors for point source inputs in this watershed are basically related to population numbers and higher rates for per capita nutrient input.

The population in the coastal provinces of Ecuador has increased over the past 35 years, but the most dramatic increase has occurred in the Guayas province (Fig. 7). From 1962 to 1982 the population of this province more than doubled to a level over 2,000,000 persons. And in the last several years the rate of growth has been even greater with a present population of over 2,568,452 (Fig. 7). Together with the population of Los Rios, there are nearly 3.14 million people in the Guayas river basin based on the statistics in Fig. 7. Nearly 64% of the population of the river basin is located in major cities in Table 7, with 53% of the basin population located in the vicinity of Guayaquil. Of the major cities listed in Table 7, 84% of the population is considered urban and the remainder is rural. These demographic statistics indicate that the majority of domestic waste

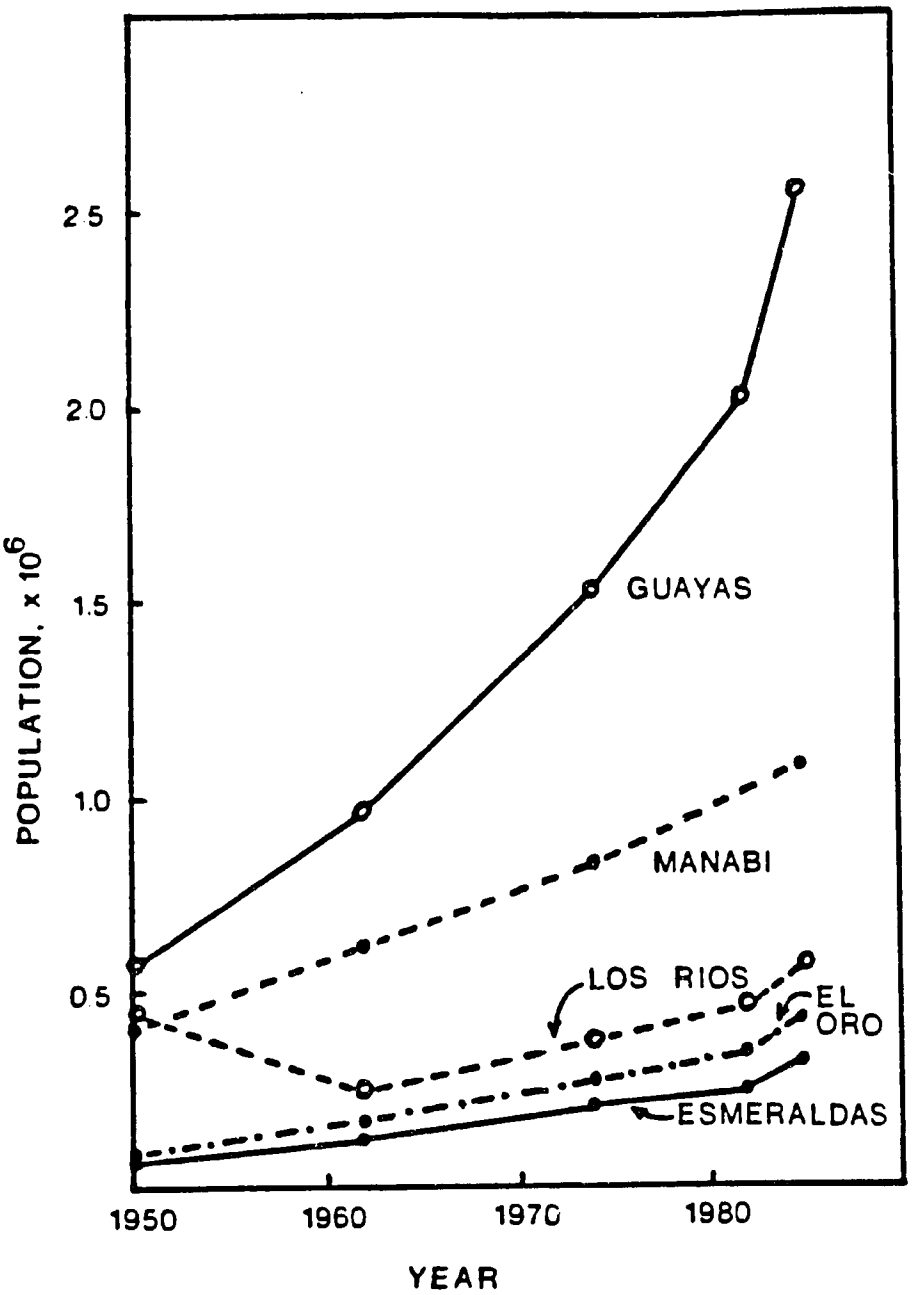


Figure 7. Population during the past 35 years in the coastal provinces of Ecuador (data from Gomez 1986).

generated in this river basin is located in close proximity to the major water bodies. Over half of this potential nutrient waste is along the shores of the Estero Salado.

Table 7. Estimated populations in the major cities in the provinces of Guayas and Los Rios provinces in 1985.

CITY	PROVINCE	POPULATION		
		Urban	Rural	Total
Guayaquil	Guayas	1511249	159517	1670766
Salinas	Guayas	22367	63240	85607
La Libertad	Guayas	53560	13923	67483
Naranjal	Guayas	12073	32761	44834
Manglaralto	Guayas	12300	21450	33750
Playas	Guayas	22660	5891	28551
Santa Elena	Guayas	12829	3335	16164
Santa Rosa	Los Rios	33572	19978	53250
TOTAL		1680610	320095	2000405

Initial estimates of the impact of urban waste on the quality of water in the rivers and estuaries of the southern coastal zone of Ecuador are listed in Table 8. These estimates are for the major population centers along the waterways of the Guayas river basin (including the Guayas and Los Rios provinces) and include a total population of 1.7 million people, which is 54% of the total population of the watershed. The population has been distinquished among those with some treatment of sewage inputs compared to the population with raw domestic waste discharge. This distinction more adequately describes that sewage which is

transported to the rivers (treated sewage), versus sewage that is transported to septic ponds (untreated sewage). From the statistics presented, 62% of the population has waste that is not treated, however 86 % of the 54.83 $(10)^6$ m^3 of waste discharged to rivers and esteros annually is from treated sewage. Based on these population statistics and per capita rates for each treatment, the loading rates for oxygen demand (biological and chemical), solids (total and dissolved), and nutrients (total nitrogen and phosphorus) have been calculated. This preliminary analysis indicates that the city of Guayaquil discharges nearly 92% of the domestic waste (BOD plus COD) and even a greater percentage of the nutrients into Estero Salado. Better estimates of the physical features of the Estero Salado are needed to determine what this effluent means to the water quality of the estuary. But it is highly likely that this major urban center located on the shore of this estero is a major factor in the quality of water in this aquatic ecosystem.

Table 8. Estimates of the discharge of domestic waste from the Guayas Watershed based on the population of the major cites of the Guayas and Los Rios provinces.

CITY	TREATMENT	POPULA-TION	VOLUME	BOD	COD	TSS	TDS	TN	TP
				GUAYAS					
Guayaquil	SEWER	634720	46.335	12504	27927	12694	23167	2094.5	253.8
	UNTREATED	876520	6.399	6048	14024	14024			
	TOTAL	1511240	52.734	18552	41951	26718	23167	2094.5	253.8
Salinas	SEWER								
	UNTREATED	22360	.163	154	357	358			
	TOTAL	22360	.163	154	357	358	0	0.0	0.0
La Libertad	SEWER								
	UNTREATED	65450	.478	452	1047	1047			
	TOTAL	65450	.478	452	1047	1047	0	0.0	0.0
Naranjal	SEWER	4580	.335	90	202	92	167	15.0	2.0
	UNTREATED	7480	.055	52	329	329			
	TOTAL	12060	.390	142	531	421	167	15.0	2.0
Manglaralto	SEWER								
	UNTREATED	12300	.090	85	197	197			
	TOTAL	12300	.090	85	197	197	0	0.0	0.0
Playas	SEWER								
	UNTREATED	28550	.208	197	457	457			
	TOTAL	28550	.208	197	457	457	0	0.0	0.0
Santa Elena	SEWER								
	UNTREATED	15670	.114	108	251	251			
	TOTAL	15670	.114	108	251	251	0	0.0	0.0
				LOS RIOS					
Santa Rosa	SEWER	6040	.441	119	266	121	220	20.0	2.0
	UNTREATED	27530	.201	190	440	440			
	TOTAL	33570	.642	309	706	561	220	20.0	2.0
TOTAL	SEWER	645340	47.111	12713	28395	12907	23554	2129.5	257.8
	UNTREATED	1055860	7.708	7286	17102	17103	0	0	0
	TOTAL	1701200	54.819	19999	45497	30010	23554	2129.5	257.8

An indication of nutrient loading to Estero Salado is provided from information on the seasonal concentrations of different nutrient species relative to periods of high and low flow of the rivers that feed into this estuary (Fig. 8). Ammonium concentrations above 15 ug-at/L occur in three of the four rivers surveyed and concentrations as high as 40 ug-at/L occurred in the Rio Milagro. These are very high concentrations for aquatic ecosystems, yet they all occur during the low flow season, and thus do not necessarily indicate high input to the Estero Salado. However, peak nitrite and nitrate concentrations with values greater than 2.0 and 50.0 ug-at/L, respectively, occurred in all the rivers from February to June during periods of high river flow (see Fig. 3 for seasonally of river flow in the Guayas river basin). In the case of nitrate, this represents a potentially high loading of nitrogen to the estuary. And the pattern for nitrate was common among the river systems investigated, indicating that this may be representative for the whole river basin (Fig. 8). Concentrations of nitrite above 2.0 ug-at/L are indicative of nitrification which usually is accompanied by decreases in dissolved oxygen concentrations (dissolved oxygen is required for the oxidation of ammonium to nitrate; nitrite is an intermediary ion of this process). Low dissolved oxygen concentrations were observed in the Rio Colorado during the wet season, but the other rivers were nearly saturated with dissolved oxygen throughout the year. High concentrations of silicate and phosphate were also associated with the wet season, indicating that the delivery of these nutrients may also be substantial to the downstream estuaries. This type of information, along with discharge data for each river system, is important for the development of nutrient loading rates to Estero Salado. This type of analysis is a first step in the development of an understanding of nutrient distribution in the watershed and aquatic ecosystem of the Gulf of Guayaquil

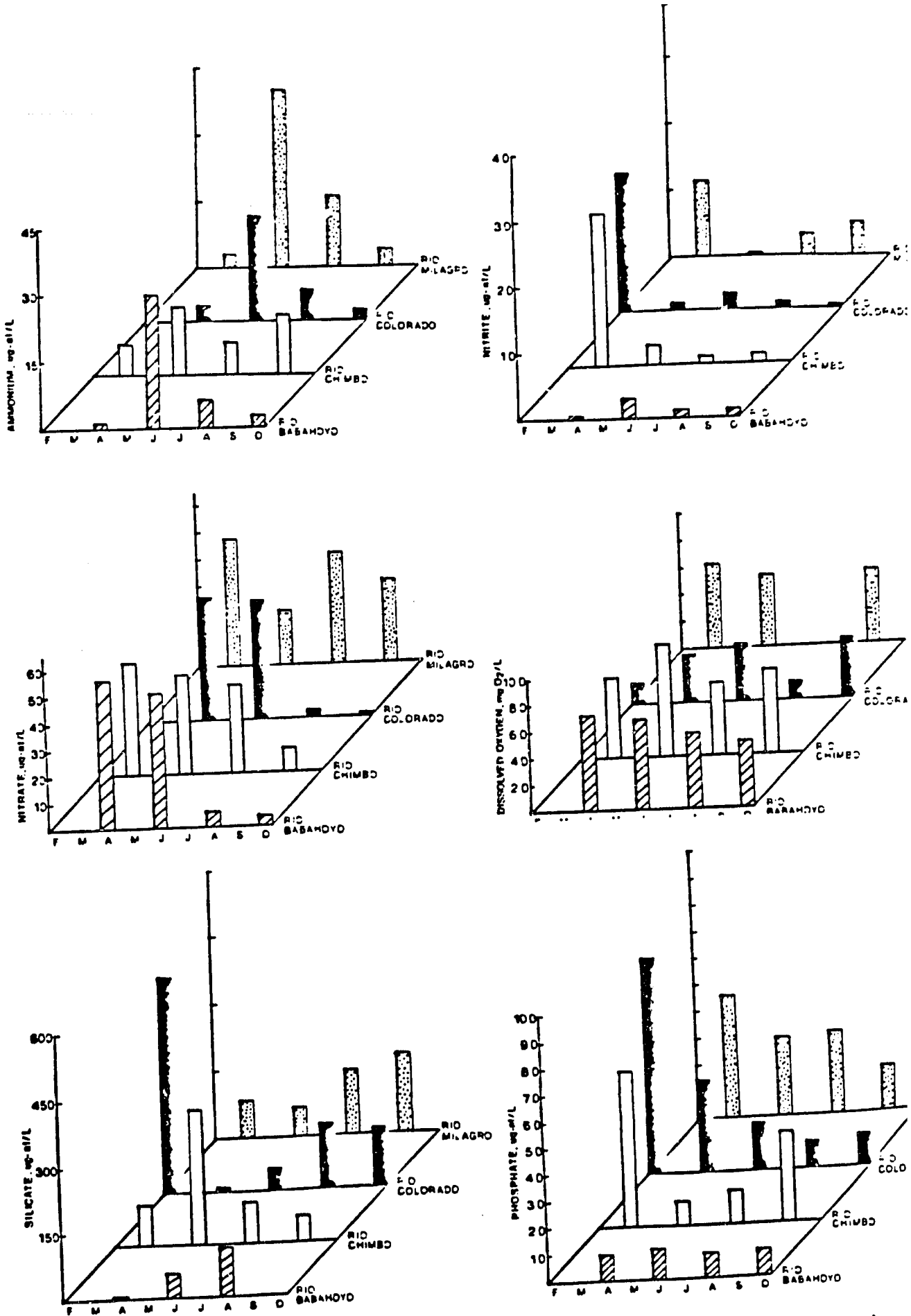


Figure 8. Concentrations of nutrients for different rivers in the Guayas river basin (data from Rendon et al. 1983).

Impacts of Nutrient Enrichment

Nutrients that increase the productivity of agricultural crops and are the by-products of human nutrition also stimulate the primary productivity of aquatic ecosystems. Changes in aquatic ecosystems in response to nutrient enrichment can be defined as eutrophication, which mainly concerns changes in water quality. One popular index of water quality that relates to the health of aquatic organisms is dissolved oxygen. Conditions below 4 mg/L are considered stressful to many fisheries, and therefore are relative to a level of some economic importance. The negative effects of anoxia can be direct to some economically important fisheries and indirect by disturbing basic food chains such as the benthos. There are several sources of oxygen demand, some of which have been documented for the Estero Salado from inputs of domestic sewage. The discharge of organic materials that consume oxygen during decomposition (biological oxygen demand) and of some inorganic nutrients (chemical oxygen demand), can cause a decrease in the dissolved oxygen needed by organisms to exist in aquatic environments. A balance of processes that contribute (photosynthesis and diffusion) and remove (BOD and COD) dissolve oxygen is necessary for a healthy environment for economically important fisheries.

Anoxia or low dissolve oxygen conditions have been historically observed in some stratified esturies, such as in the Chesapeake Bay where anoxia of bottom waters was observed in the 1930's (Newcombe and Horne 1938). What is of concern in the Chesapeake Bay, and may be relavent to many estuarine ecosystems, is the recent increase in anoxia both in the increased volume that is impacted and the longer duration of this condition in the water column. One of the many possible

contributing factors to increased anoxia in the Chesapeake Bay is thought to be the linkage between increased nutrient loading, enhanced production of phytoplankton biomass, and the consumption of oxygen in the decompostion of this organic material in the system (either in the water column or in the surface sediments; Officer et al. 1984). Thus nutrient abatement and control becomes a central issue in dealing with this phenomenon of water quality and health of a productive estuarine ecosystem. Such may also be of some significance to the coastal zone of the Guayas province of Ecuador.

Dr. Jimenez has commented on the constant presence of red tides in areas of the estuary. Red tides are also common in the Gulf of Guayaquil caused by the ciliate Mesodinium rubrum and the dinoflagellate Prorocentrum sp. (De Arcos 1982). Further offshore red tides may be associated with upwelling, more inshore phenomenons may be linked to water quality conditions of the estuary. Although anoxia has not been well documented in this system, that may be more a matter of a lack of information rather than absence of the problem (based on personal communication). Together with the input of organic material from the watershed, particularly from domestic waste, the red tide phenomenon may contribute to a critical oxygen demand in this system. More information is needed in order to adequately evaluate whether this water quality exist, and what factors could be contributing to the nature of this problem.

This linkage between nutrient loading, phytoplankton blooms (red tides) and anoxia is of critical concern to those economic interests in the coastal zone of Ecuador. Anoxia represents a water quality parameter that may decrease the productivity and survival of certain economically important fisheries in the Estero Salado. The presence of wild postlarvae and the development of larvae in

hatcheries rely on a certain level of dissolved oxygen in the estuary. Once these levels decline below some threshold at which shrimp larvae will not survive, then mortality will increase resulting in the loss of a financial investment. The mortality of larvae in shrimp ponds is also dependent of the water quality of the estuary. Low dissolved oxygen levels in waters pumped from the Ester Salado may cause lower harvests of shrimp from the ponds. The mariculture industry is very susceptible to low dissolved oxygen levels in the estuary, and as described above this water quality parameter is linked to the loading of nutrients in the Estero Salado.

Toxic Substances

Pesticides

Agriculture also contributes to the potential problem of toxic substances in the rivers of the Guayas basin from the application of pesticides to the watershed. The magnitude and type of pesticides used in Ecuador are shown in Table 9, based on the import of these chemicals into the country.

Table 9. Amount of pesticides (kilos) imported into Ecuador (Solorzano 1981).

NAME	1979 (kilos)	1980 (kilos)
Insecticides	1392458	1080912
Herbicides	2805342	1852957
Fungicides	707032	979946
Nematicides	1049647	941388
Moluskicides	10000	5000
Growth Stimulants	60300	--
Emulsifiers	49784	25402
Miticide	1170	--
Raticide	5619	4177
Seed Disinfectant	25130	6950
Tanning Presevatives	--	152728
Wood Preservatives	50286	29850

Some idea concering the magnitude of pesticides utilized in the Guayas river basin is demonstrated in Table 10. This table is based on the area of rice and soy beans under cultivation in the Guayas and Los Rios provinces, and the specific application rate for each crop. This analysis is only an approximation of the use of these chemicals in the watershed. It is not known which, if any, of these chemicals are transported to the rivers and estuaries. Dr. Solorzano has expressed concern about the concentrations of pesticides in the estuary, but no information on concentrations of these chemicals is available. CEDEGE river basin study found that DDT levels in the rivers flowing into the estuary were low, but no documentation was available.

Table 10 . Application rate and input of pesticides used in the cultivation of rice and soy beans based on the area of each crop in the provinces Guayas and Los Rios, the watershed of the Gulf of Guayaquil

RICE			Soy Beans		
PESTICIDE	TREATMENT	INPUT	PESTICIDE	TREATMENT	INPUT
Ronstar 25	2 L/ha	144676	Bravo	3 L/ha	103524
Ronstar 12	4	289352	Daconil	2.5 Kg/ha	86270
Machete	4	289352	Afalon	3	103524
Saturno	3	217014	Preforan	15 L/ha	517620
Propanil	8	578704			
Hormonales	2	144676			
Furadan	15 Kg/ha	1085070			
Curater 5-10%		0			
Diazinon	1	72338			
Ozadin	.5	36169			
Lorshan	.5	36169			
Endrin	2	144676			
Lannate	2	144676			
Dipterex 95%	1	72338			
Bin 75	300 g/ha	21701400			
Benlate	250 g/ha	18084500			
Kasumin	.75 L/ha	54253.5			
Inosin	.75	54253.5			

The sensitivity of aquatic organisms to low levels of pesticides in the environment is shown in Table 11. For example Endrin, which is applied at an approximate rate of 144,676 kg per year in the Guayas river basin for the production of rice, may be lethal to fish at a concentration of only 0.3 parts per billion. Daugherty (1975) noted that decreased shrimp yields in El Salvador probably resulted from the heavy use of pesticides in cotton farming during the 1960's and early 1970's. Since crustaceans are so closely related to insects that they are very sensitive to insecticides, more so than the target species on crops (Dickinson et al. 1985). Pesticides also have a tendency to become more concentrated along the food chain and thus may stress predators and higher trophic

levels such as fish. More information is needed on the ambient concentration of these chemicals that are toxic to certain fisheries, and on their fate in the aquatic environment before this potential problem can be evaluated.

Table 11. Lethal limits for organochlorine insecticides to fish (concentrations are ul/L). From Edwards (1973). Fish tested include bluegill, fathead minnow, goldfish, guppy rainbow trout, and salmon.

INSECTICIDE	CONCENTRATION	EXPOSURE
Aldrin	0.013-0.280	96 h
BHC	0.22-2.30	96 h
Chlordane	0.077-0.50	96 h
Camphechlor	0.0035-0.1	96 h
DDD	0.042	96 h
DDT	0.002-0.27	96 h
Dieldrin	0.0079-0.037	96 h
Endrin	0.0003-0.001	96 h
Heptachlor	0.019-0.23	96 h
Lindane	0.062-0.152	96 h
Methoxychlor	0.056-0.12	96 h

The use of pesticides such as DDT and DDD and others are of particular concern in regard to potential impacts to waterfowl. Indirect relationships have been developed for the concentration of DDT and the thickness of egg shell for waterfowl (from Edwards 1973). The thining of egg shell from increased concentrations of pesticides has been the most important contributing factor to the decline of certain waterfowl in the United States and Canada. Information is not avaliable to determine if such a concern is warranted for the coastal zone of Ecuador.

Petroleum Hydrocarbons

Petroleum is the number one source of foreign income for the country of Ecuador and many of the petroleum wells are located in the Guayas province. A document has been prepared concerning the impact of oil on coastal provinces (Cintron et al.), and one publication is specifically for the coastal zone of Ecuador (Filho 1983). Hydrocarbons can be lethal to fisheries at relatively low concentrations as indicated in Table 12. However, present information suggests that the concentrations of hydrocarbons in Estero Salado are not high enough to be of concern to the natural resources of this ecosystem.

Table 12. Comparative toxicity of the water soluble fraction of No. 2 fuel oil to differenct life stages of four marine crustaceans. Concen trations are ppm of total hydrocarbon. (Neff et al. 1976 cited from Neff and Anderson 1981).

SPECIES	DESCRIPTION	LC-50	CI (95%)
Penaeus aztecus	Postlarvae	6.6	6.1-6.9
(brown shrimp)	Early juveniles	3.7	3.0-5.1
	Late juveniles	2.9	2.2-3.8
Penaeus setiferus	Postlarvae	1.4	0.9-2.1
(white shrimp)	Juveniles	1.0	0.8-1.2
Palaemonetes pugio	Larvae	1.2	1.0-1.5
(grass shrimp)	Postlarvae	2.4	2.1-2.8
	Adults	3.5	2.4-4.9
Mysidopsis almyra	Postlarvae (1 day old)	1.8	-
(opossum shrimp)	Postlarvae (7 day old)	1.8	
	Adults	.7	

Heavy Metals

There is some mining activity in the Guayas river basin, but preliminary sampling of the estuary indicates that the concentrations of metals present are not high enough for any concern.

IMPACTS ASSOCIATED WITH THE LOSS OF NATURAL RESOURCES

Mangroves

Background

The optimum conditions for growth of mangroves in Ecuador are found in the north along the Esmeraldas river and estuary where wide bands of these forests occur in the intertidal area. However, 69% of the total mangrove area of coastal Ecuador (CLIRSEN 1984) is found in the Guayas province (Table 13). Here narrow bands of mangroves occur along the shoreline due to the relative rates of precipitation compared to evapotranspiration. The existence of 121,464 ha of mangroves in this province has been contributed, and is strongly dependent on, river flow from the Guayas river basin (Schaeffer-Novelli 1983). The second highest mangrove coverage is along the southern border of the Gulf of Guayaquil in the province of El Oro (24,489 ha). Together this gulf and the estuaries in Esmeraldas represent over 95% of the 175,219 ha of mangroves in Ecuador (Fig. 9 and Table 13). There have been several excellent reviews on the ecology of mangroves in Ecuador from which this review is based (Cintron 1981, Schaeffer-Novelli 1983, Cintron and Schaeffer-Novelli)

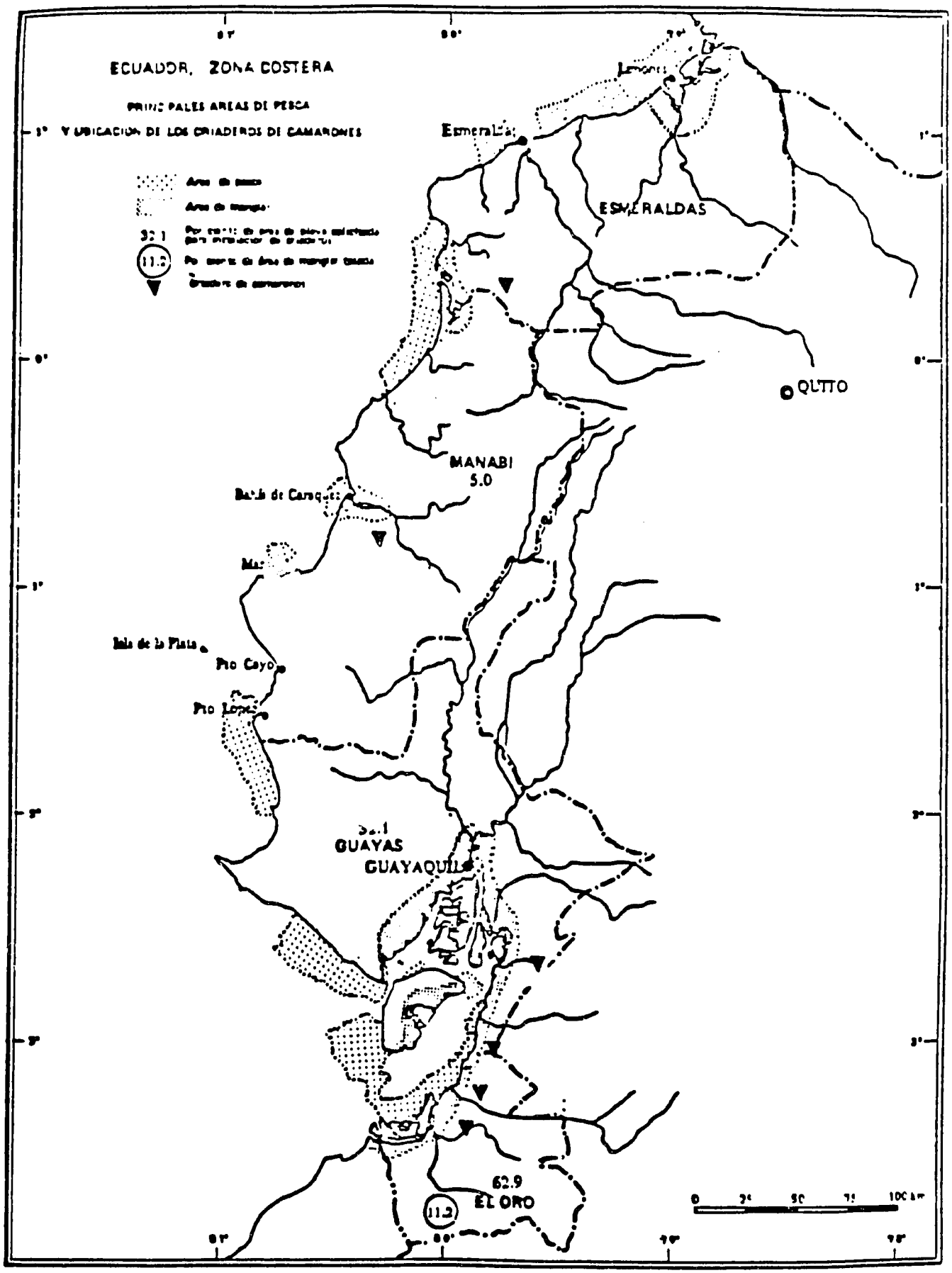


Figure 9. Principle area of coastal natural resources such as mangroves and fisheries along the coast of Ecuador.

Table 13. Land use patterns along the coast of Ecuador (areas in ha).

Land Use	Guayas	El Oro	Manabi	Esmeraldas	Total
Mangroves	121463.5 69.4	24489.3 14.0	7973.4 4.4	21293.2 12.2	175219.4 100.0
Shrimp Ponds	52911.8 59.2	26483.9 29.6	8376.6 9.4	1595.5 1.8	89367.8 100.0
Salinas	17340.1 86.6	2520.0 12.6	163.8 .8	4.4 .0	20028.2 100.0
Total	191715.4 67.4	53493.2 18.8	16513.8 5.8	22893.1 8.0	284615.4 100.0

There are eight species of mangroves found along the coast of Eduador distributed among four families (Table 14). This is nearly twice the diversity of mangrove species found along the Atlantic coast of Central and South America, which are usually restricted to Rhizophora mangle, Avicennia germinans, Laguncularia reacemosa, and Conocarpus erectus. These species are distributed along relatively narrow vegetated band of the intertidal zone of the Ecuadorean coast with a nonvegetated area called salinas in more inland intertidal area. The seaward intertidal zone is colonized by species of mangroves in the Rhizophoraceae family with Rhizophora harisonii on the perimeter of the shoreline and mixtures of the other speicies inland of this zone (Fig. 10, from Cintron et al. 1981). More inland of this fringe of Rhizophora sp. is a mixed zone of Rhizophora and Avicennia germinans. As one moves inland, this zone becomes a monospecific stand of Avicennia and then eventually change to shrub plants or salinas with extreme

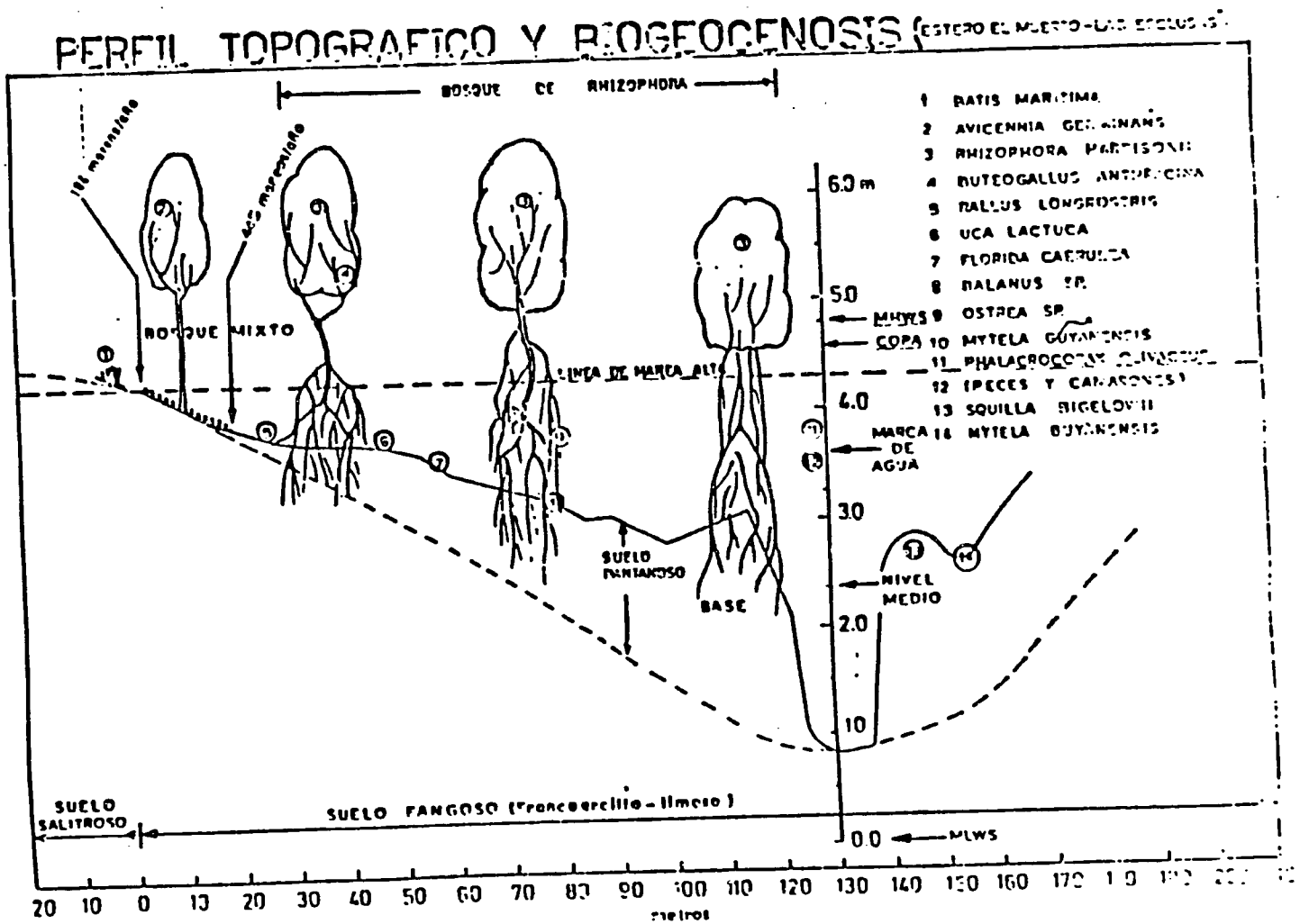


Figure 10. Zonation of mangroves in the intertidal zone along Estero Salado (

considered important factors in the patterns of zonationn observed for mangrove species along the coastline.

Table 14. Mangrove species found along the coast of Ecuador.

Rhizophoraceae
- *Rhizophora harrisonii* (Leachm)
- *Rhizophora racemosa* (GFM Mayer)
- *Rhizophora mangle* (L.)
- *Rhizophora samoensis*

Pellicieraceae
- *Pelliciera rhizophorae* (Planchon and Triana)

Avicenniaceae
- *Avicennia germinans* (L.)

Combretaceae
- *Laguncularia racemosa* (L.) Gaertn f.
- *Conocarpus erectus* (L.)

The frequency of tidal amplitudes in Fig. 11 shows two periods of the year in March and April, and in October and November when peak number of tides greater than 5 m occur. The former period of peak tidal amplitude corresponds to the wet season and peak discharge from the Guayas river basin. Low tidal amplitude and the dry season occur from June to September (Fig. 11). The high tidal frequency and discharge for the river basin create conditions suitable for a high degree of mangrove forest structure such as those in the San Lorenzo Bay area. Density of trees with diameter at breast height (dbh) greater than 10 cm is 185 ($\pm$ 50) trees per ha, and a basal area of 62.4 ($\pm$13) m^2 per ha (from Cintron 1981). This volume of mangroves is greater than for forests in Venezuela, Columbia, Malaysia and Puerto Rico (Cintron 1981). Structure of mangrove forests from Hacienda Tenguel is less and those studied by Cintron (1981) had a basal area of 13.5 m^2 per ha and a tree density of 365 trees per ha. Morgan (1980) found that basal area for

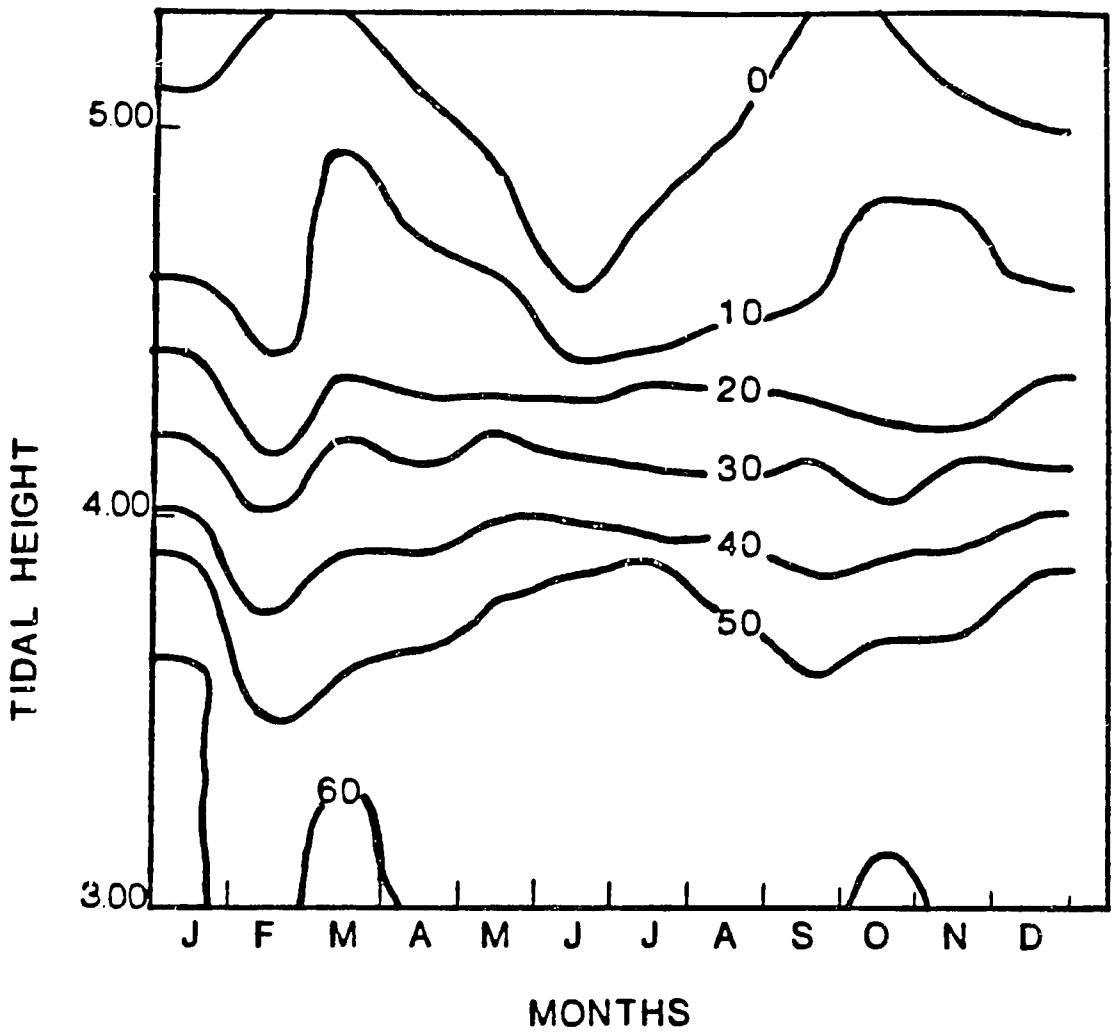


Figure 11. Contours of the frequency of tides with different amplitude in the upper Estero Salado near Quayaquil (data from Cintron 1981).

mangroves in Ecuador varied between 15.6 and 43.5 m^2 per ha with a high density of small diameter trees (0-830 trees with > 10 cm dbh per ha). Based on this information and relationships between forest structure and productivity, the litter productivity of these forest would be comparable for riverine mangroves. As indicated in Fig. 12, this would be equivalent to values between 10 and 12 t ha^{-1} yr^{-1}. Fig 12 also demonstrates a concept presently held for mangroves that litter productivity increases as the hydrologic energy (defined as the combination of river and tidal flooding) also increases (Pool et al. 1975; Twilley et al. 1986).

Hydrologic energy may also contribute to how much of this litter material is transported to the estuary (Fig. 12; Twilley 1985). Based on only three studies, it seems that as tidal frequency and amplitude increased within a forest, a larger percentage of litter falling from the canopy is exported from a forest. Together with higher litter fall with greater hydrologic energy, riverine forests may contribute considerably more material per ha than more inland basin mangrove forests. Yet, as demonstrated by Twilley (1982) for the Rookery Bay ecosystem, the areal coverage of the more inland forests was much greater, and therefore they contributed an equal amount of organic matter as did the fringe mangroves to the estuary. Mangrove litter supports a diverse food chain including many economically important species (Odum and Heald 1972). Studies of carbon and nitrogen isotopes that can determine the source of food of marine organisms (within some limits of interpretation) have indicated that commercially important shrimp derive a large portion of their diet from inshore waters in Malaysia (Rodelli et al. 1984) and in Rookery Bay (Macko and Ziemann 1983). As well as being a source of food, mangroves may also serve as an important habitat for a

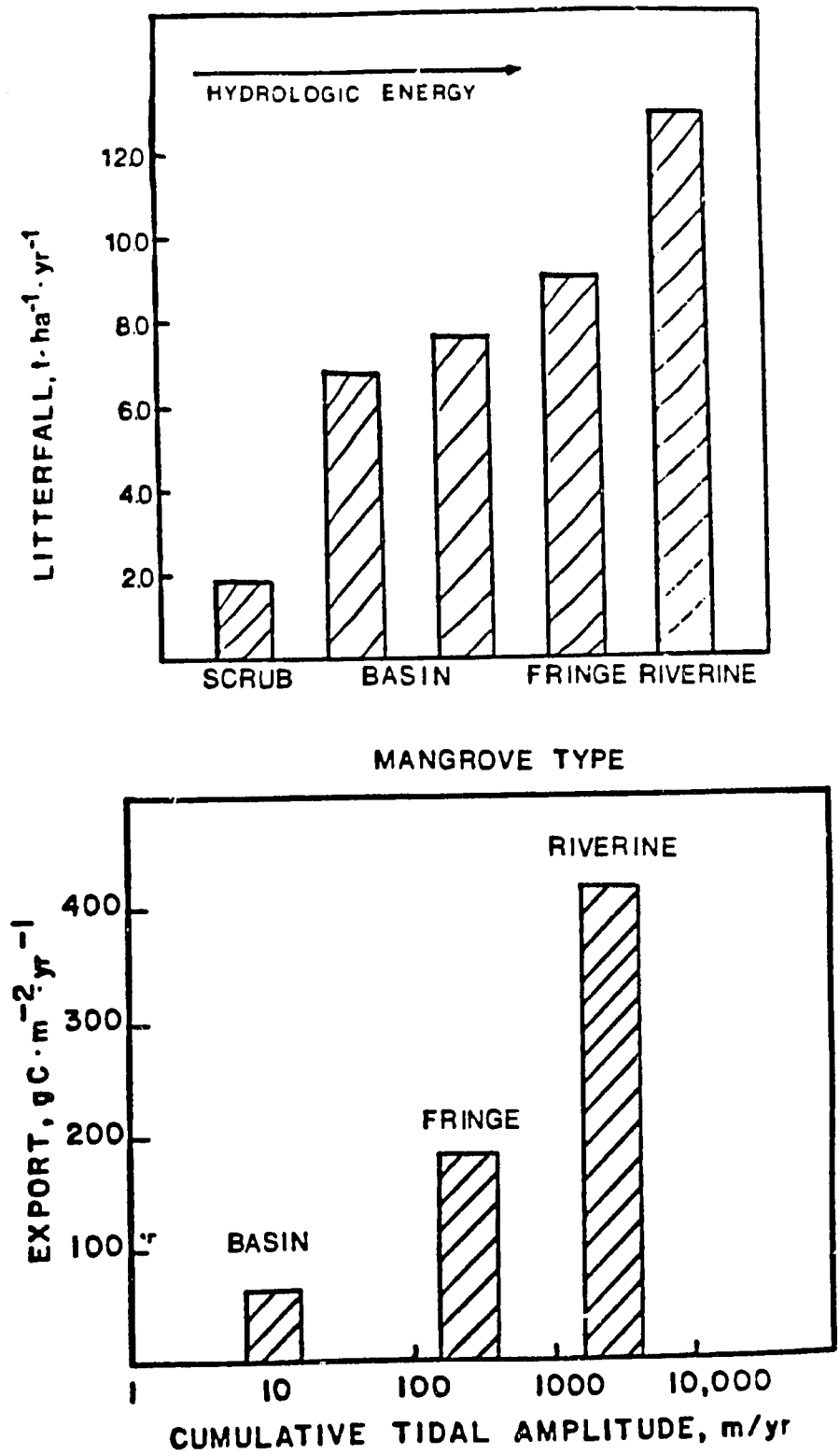


Figure 12. Litter fall (A) and export of organic carbon (B) relative to the hydrologic energy (combination of tidal and river flooding) in different types of mangrove forests (from Twilley et al. 1986 and Twilley 1985).

wide variety of marine fauna. These references have supported the present belief that mangroves are an important resource for the maintenance of commercially important fisheries in the coastal zone of the tropics.

Exploitation

Silviculture. Although the structure of mangrove forests in Ecuador is high compared to other sites in the Caribbean and South America, these areas are not very extensive owing to the narrow intertidal zone that can support mangrove vegetation. The forests of the northern and southern regions of the coastal zone are too limited for the development of a silviculture industry in this country (Morgan 1980). However, there is some evidence that mangroves along the Esmeraldas and San Lorenzo rivers in the northern province of Esmeraldas are exploited for bark extraction, charcoal production and wood export to the country of Columbia.

Most of the utilization of mangroves in the northern and southern provinces is for consumption by local fishermen that inhabit the mangrove areas. Schaeffer-Novelli (1983) states that selective tree cutting practices have occurred in the last 30-40 years resulting in the elimination of the larger trees in most of the mangrove forests. These trees have been used for the extraction of bark and the production of charcoal which are sold locally. Wood from the mangroves is also used for building materials and heat for cooking.

Shrimp farming. The most observable exploitation of mangroves along the coastal zone of Ecuador is the construction of ponds for the production of mainly shrimp and also fish. Ponds are constructed by first diking to dry the planned area and then heavy equipment removes the existing forests and excavates about 1 m

of the topsoil. This pattern of land use in the intertidal zone first involved the wholesale destruction of mangroves such as occurred in Machala, in the southern province of El Oro. The close proximity of ponds to the shore lowers costs associated with supplying water and larvae to the ponds. Following this period of total mangrove destruction, pond construction was authorized mainly in the salinas and inland mangrove zones which lessened the impact to the mangrove habitat. However, as the area of ponds authorized for construction increased dramatically in the early 1980's (Fig. 13), less of this unvegetated intertidal area was available and mangroves were again heavily impacted by the mariculture industry. Recently there has been a decree that prohibits the authorization of ponds in mangroves, but there are several thousand hectares of ponds that have already been authorized but not built that could be located in areas of mangroves.

The exact loss of mangroves along the coastal province of Ecuador from the construction of ponds is uncertain. Initial estimates were based on the area of ponds authorized for construction together with estimates of unauthorized construction. From this total, mangrove loss was assumed equivalent to lands remaining once the salina areas had been utilized. The crux of the problem with these estimates is knowing the exact area of ponds that have been constructed in Ecuador. A recent survey from CLIRSEN (1984) cites that there presently exist 89,368 ha of shrimp ponds with 59% located in the Guayas province (Table 13). The two southern provinces of Guayas and El Oro have 79,396 ha or 88.8% of the total area of shrimp ponds along the coast of Ecuador (Table 13). There remains 19,860 ha of salinas in these two provinces compared to only 168 ha for the remainder of the coastline.

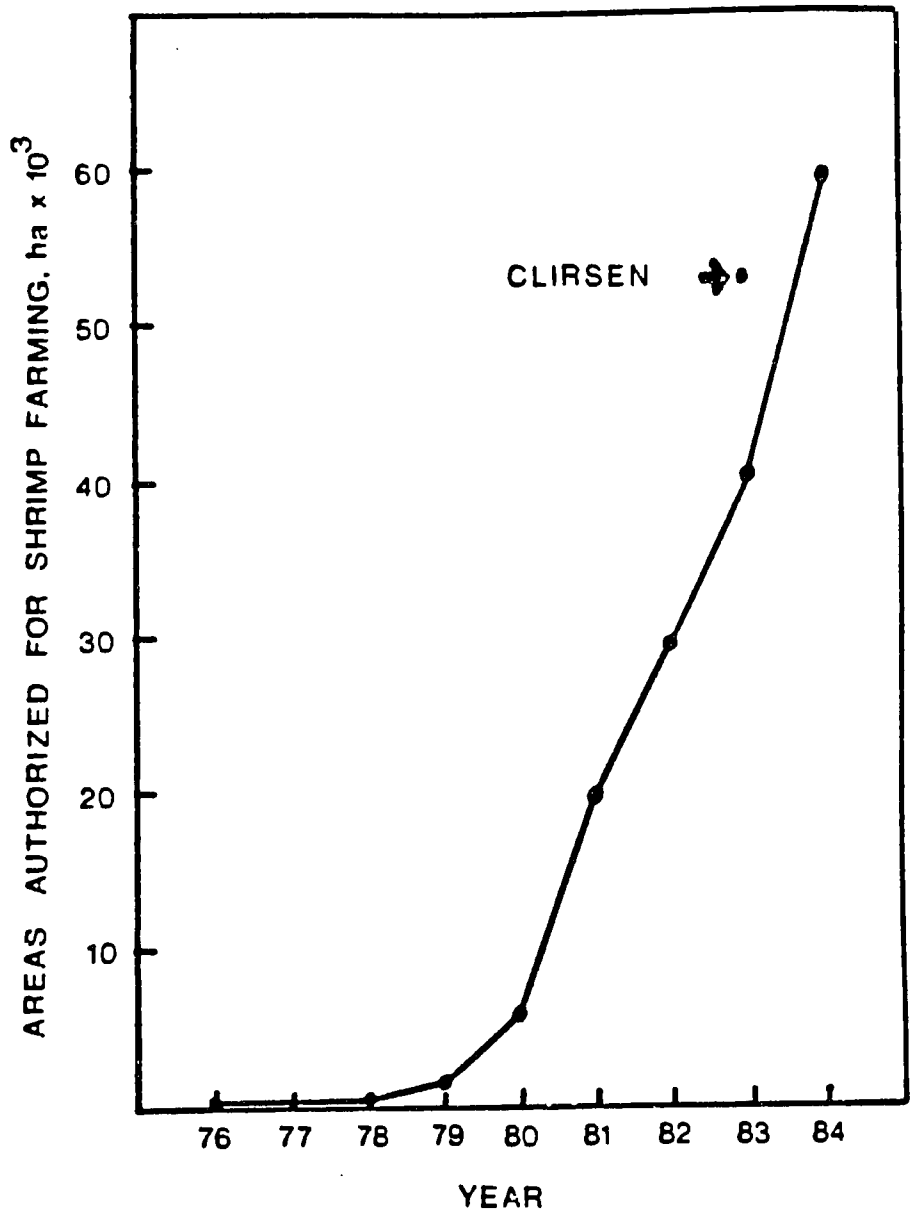


Figure 13. Areas of ponds authorized by the Ecuadorean government for the construction of shrimp ponds.

These statistics can be used to estimate the loss of mangroves in the Guayas province knowing the relative type of landscape used for the construction of these ponds. A scale representing the use of mangroves for the production of ponds is shown in Fig. 14, which demonstrates that if all of the shrimp ponds in the Guayas province were built in mangrove areas, this would represent a loss of 30.3 % of the mangrove resource. At a utilization rate of 10% (10% of ponds built in mangroves), the loss of mangrove habitat would be 4.2%. Historical records for the southern coast of the Gulf of Guayaquil in the province of El Oro at Piloto Machala, give some indication as to the relative use of land for the construction of ponds (Table 15). From 1966 to 1977 there were 834.2 ha of ponds constructed, and based on the loss of mangroves during this period, 55% of these ponds were built in mangrove habitats. This is a slight overestimate since urban areas also increased at the apparent expense of mangroves, since the total loss of mangroves plus salinas is more than what can be accounted for by pond construction. If urban expansion was equally divided between salinas and mangroves, then mangrove loss would represent 45% of the ponds constructed. From 1977 to 1982, there was an increase of 1496.5 ha of ponds and the combined loss of salinas and mangroves does not account for this increase. Decreases in land use of agriculture and other vegetation (highland) also occurred in this period and could account for the additional pond construction and urban expansion. However, assuming that all of the mangrove loss was from pond construction, then 63% of the expanded pond area resulted in the loss of this habitat. Based on these estimates, then from 45 to 63% of the land utilized for ponds was from mangrove habitats, and therefore from 16 to 21 % of the mangrove in the Guayas province were lost due to shrimp farming. Pond construction in the Pto. Bolivar region of El Oro resulted in the loss of 29.7% of the mangroves that were present in 1966 (Table 15; CLIRSEN 1983).

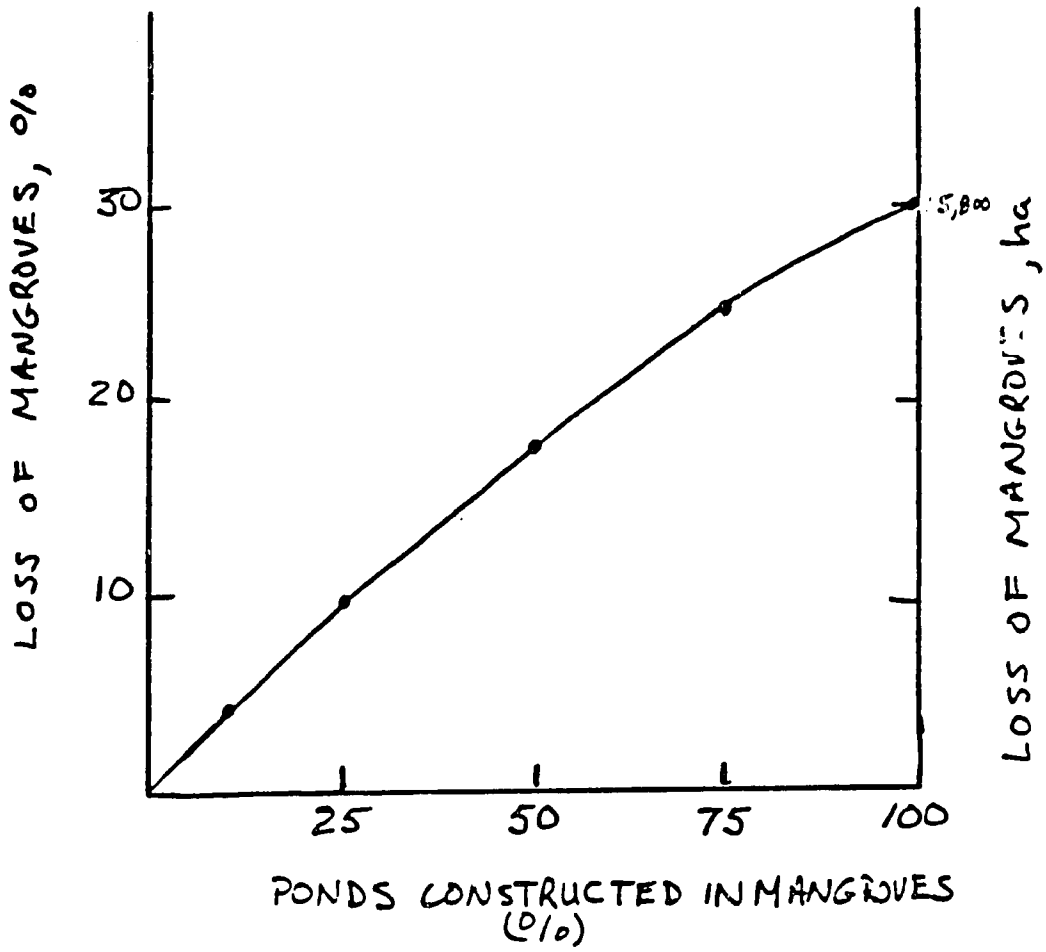


Figure 14. The percentage loss of mangroves in the Guayas province based on the percentage of ponds constructed that were sited in mangrove areas.

Table 15. Historical records of land use patterns (areas in hectares) showing the decline in mangroves near Guayaquil (CLIRSEN 1983). (Area located in Province El Oro, Piloto Machala)

LAND USE	1966	1977	1982
Mangrove	4692.9	4231.7	3294.7
Camaroneas	0.0	834.2	2330.7
Salinas	1087.7	478.5	162.6
Agriculture	615.2	730.2	634.7
Vegetation	466.3	332.2	139.4
Urban	256.7	434.7	588.5
Rivers	1437.5	1514.5	1465.7
TOTAL	8556.3	8556.0	8616.3

Consequences of the Loss of Mangroves

The loss of mangroves from tropical estuaries may have direct consequence to economically important fisheries by representing a loss of habitat and of food. Mangrove destruction may also have an indirect effect on fisheries by changing water quality. Estimates above suggest that between 16-21% of the mangrove area in the Guayas province has been destroyed by the production of shrimp ponds. This represents a loss of approximately 10,500 ha of habitat and respective leaf litter that would be utilized as a food source by various marine fauna. Dr. Roger Zimmerman (per. communication) has found that P. vannamei and P. stylirostris inhabit areas up in the mangroves, but it is not known whether these habitats enhance the survival or growth of these and other marine organisms in the Estero Salado. Associations exist between the production rate of shrimp and the extent of mangrove area (Macnae 1974,Turner 1977, Jothy 1984). Turner (1977) calculated

that one hectare of mangroves can yield without management more than 600 kg/yr of shrimp and 100 kg/yr of fish. Although these statistics do not bear causal relationships, they do point out that wherever a productive post larvae fishery exist, there is the presence of the mangrove habitat (Turner, personal communication). This is particularly evident along the coastline of Ecuador (Fig. 9). Without further information on possible dependance of shrimp larvae and other marine fauna on mangroves for part of their life cycles, the effect of mangrove clearing on natural populations in the Gulf of Guayaquil is unknown. The evidence above suggest that this information is critical to sustaining a productive fishery in the Estero Salado.

The loss of mangroves may be related to the problem of obtaining post larve for the shrimp ponds that have been constructed in the coastal zone. The loss in habitat and food may have contributed to the decline in production of natural populations of postlarvae in the Estero Salado. However the destruction of mangroves also represents a loss of other natural resources to the people of Ecuador. There is a diverse natural resource of fisheries that are utilized by Ecuadoreans for their own use or for local distribution. A rich diverse fauna also exist that relies on the mangrove habitat for survival. Therefore, the loss of mangroves represents an impact to other diverse natural resources other than just single species of P. vannamei.

Since waters of the Gulf of Guayaquil are tightly coupled to the intertidal zone via 3-5 m tides, mangroves may influence the nature of these waters in several ways. Sediments suspended in the water column are deposited in mangroves during flooding and this material enriches the sediment of these forests. The extensive root system of mangroves enhances this trapping process and retards the

forces of erosion along the shoreline. Although this function has been overstated to the extent of calling mangroves "land builders", they do contribute to the sedimentary processes that exist in estuarine ecosystems. There are examples where the loss of mangroves from the shoreline accelerated land loss due to erosion. Nixon et al. (1985) showed that total suspended sediment load of an estuary in Malaysia, in which mangroves had been reclamed for agriculture, was an order of magnitude higher than in an adjacent mangrove dominated system. The Gulf of Guayaquil is also a very turbid tropical estuary, and this sediment load contributes to the low productivity of this system. Further reductions in vegetation along the shoreline may exacerbate this condition.

Some preliminary evidence indicates that mangroves may be a sink of nutrients in the coastal zone. This may seem to contradict the outwelling concept of mangroves discussed above. One explanation is that net uptake may occur with inorganic nutrients, while nutrients bound up in the detritus may be exported out of these systems. Walsh (1967) noticed that nutrient concentrations in waters moving through a mangrove in Hawaii decreased on concentration. Nedwell (1975) using enclosures to measure nutrient uptake in mangrove sediments noticed they had a great capacity to dissimilate nitrate, particularly in areas of nutrient enrichment from sewage discharge. The use of mangroves for treatment of nutrient enriched effluent has received some preliminary investigation (Sell 1977), but this function is still poorly understood. The loss of mangroves may be a contributing factor to changes in water quality, particularly nutrient levels, in the Estero Salado.

Fisheries

General Description

Ecuador's most important fishery resources, including 10 species of Penaeid shrimp Table 16, are concentrated in the Gulf of Guayaquil (Jimenez 1983 and Ramiriz 1982 from Filho 1983). Ecuadorean shrimp production rose dramatically from 1979 to 1984 and in 1983, the year of highest production on record, shrimp production was estimated at 36.6 thousand metric tonnes, with an export value of $183 million US dollars. This volume of shrimp was nearly triple the amount produced in 1979 and was due to the expansion of the farmed shrimp industry, making Ecuador the worlds leading farmed shrimp producer (McPadden 1985).

Table 16. List of shrimp of commercial importance (McPadden 1985).

COMMON NAME	FAMILY	SPECIES
BLANCO	Penaidae	*Penaeus vannamei* *Penaeus stylirostris* *Penaeus occidentalis*
CAFE	Penaidae	*Penaeus californiensis*
ROJO	Penaidae	*Penaeus brevirostris*
ZEBRA	Penaidae	*Trachypenaeus byrdi* *Trachypenaeus pacificus* *Trachypenaeus faoe*
POMADA/Titi	Penaidae	*Xiphopenaeus riveti* *Protrachypenaeus precipua*
CARAPACHUDA	Solonoceridae	*Solonocera* spp
CAMARONES DE PROFUNDIDAD	Pandalidae	*Hetercarpus* spp.

This dramatic expansion of the farmed shrimp industry has stimulated the development of a new fishery for postlarvae and seed shrimp in the coastal zone of Ecuador. Industry sources estimated that up to 90,000 artisanal fisherman were involved in the 1983 harvest and in 1984 numbers of fisherman working along the coast were even higher (McPadden 1985). Seed fishing is concentrated in areas of significant freshwater discharge along the coastline such as El Oro and Esmeraldas, but the highest effort occurs in the Guayas province. The esteros or creeks are fished most intensively at low spring tides using fine mesh hand nets when the postlarvae are concentrated in the lower reaches of the creeks. The catches are non-selective, including small fish, penaeid postlarvae and juvenile shrimp. Some selection for postlarvae is made by sieving the catch through perforated plastic containers. Seed fishing along the coastline is different with the use of fine butterfly push nets to collect postlarvae in the surf zone.

The stock of seed contains a mixture of P. vannamei, P. stylirostris, P. occidentalis and P. californiensis and freshwater Carid species. Since only the former two species survive best in the mariculture ponds, owners pay according to the proportion of the stock that is P. vannamei and P. stylirostris (McPadden 1985). Yet this does not control for the nondiscriminant harvesting of shrimp from the estuaries since selection is a post harvest process that results in the loss of these lesser valued species from the estuary. The peak of the seed fishing season is from December to March when fisherman may take up to 40,000 postlarvae a day at a size ranging from 7-10 mm.

Both the sea and farmed shrimp industries rely on the maturation, spawning, postlarval recruitment and offshore movements of the various species of shrimp listed in Table 16. McPadden (1985) describes the recruitment of shrimp larvae as

a year round phenomenon, yet the highest densities of P. vannamei occur from November to July and larvae become scarce from April onwards. A major factor associated with the movements of immature shrimp is the temperature of offshore waters that are controlled by the mixture of warm water flowing southwards from the Panama Bight with cold waters flowing northward from the Peru current. This mixing occurs between Manta and Punta Santo Elena along the coast of Ecuador and gradually moves southwards into the Gulf of Guayaquil. This southerly flowing water causes an increase in sea water temperature and initiates the onset of the rainy season (Cucalon 1984 from McPadden 1985). Thus the magnitude of offshore water temperatures and inland precipitation (and freshwater discharge) may be strongly correlated and is variable in occurence but usually occurs from November to March. Years of abnormally warm water temperatures and high rainfall are associated with El Nino climate patterns and have resulted in the explosive populations of white shrimp off the coast of Ecuador from enhanced spawning, maturation and recruitment in this coastal zone.

It appears that the distribution of shrimp are also defined by certain types of habitat. P. occidentalis distribution is mainly confined to waters just off the major estuaries, whereas P. vannamei is distributed along the coast north of the Gulf of Guayaquil (McPadden 1985). The presence of postlarvae and juveniles of P. vannamei in the Estero Salado and immature shrimp in shallow offshore waters, suggest that there are major nursery areas for this species in the Gulf of Guayaquil, and there are probably other large nursery areas on the coast of Bahia de Caraquez and Esmeraldas (McPadden 1985). Roger Zimmerman (personal communication) has sampled larval and juvenile shrimp in five esteros and noticed

that P. vannamei is consistently most abundant at the innermost stations within the esteros.

Loss of Fishery Resources

One of the major limiting factors in the expansion and potential increase in farmed shrimp production to levels observed in 1983 is apparently the availablilty of postlarvae. Total production in shrimp was down in 1984 compared to the previous year not only due to low catch rates in the trawl fishery, but also largely due to the lack of larvae for shrimp ponds during the second half of the year. It is estimated that during 1985, that only half of the shrimp ponds constructed in the Guayas province were in operation because of the lack of postlarvae. It is estimated that only 30,000 - 40,000 ha of shrimp ponds are operational in Ecuador in 1985 and that the postlarvae harvest during that year was 4 billion provided largely by the "laveros". This is equivalent to an annual stocking rate of about 133,000 postlarvae per ha of pond or about 65,000 postlarvae per ha per season based on two harvest per year. This is fairly intensive mariculture and production rates per ha of pond seem to be decreasing, although such calculations are tenuous since the information on the quantity shrimp sold and the area of ponds actually in operation are somewhat confusing.

Several factors are associated with the decline in postlarvae in the esteros along the coast of Ecuador including lower water temperatures (back to normal temperatures following an El Nino event), loss of mangrove habitat, decline in water quality, which may contribute to the loss of other food sources, or to increased stress to the shrimp fishery. Poorer water quality could contribute to increase occurence of disease and poor maturation of postlarvae and thus impact

the health of the available fishery. These factors include impacts on both the recruitment or availability of postlarvae and also the maintenance of those larvae that occur within the estuary.

The lost of postlarvae may be considered as species specific, however the indiscriminant utilization of this fishery causes impacts to other natural resources in the esteros. In 1985, 90,000 "laveros" harvested some 4 billion postlarvae using nonselective techniques that could potentially impact non-target species that are either discarded or cannot survive the conditions of the ponds. Data are wanting on the impact of large scale harvests of juveniles on the secondary productivity of these coastal waters. This is particlarly true relative to the concomittant decrease in habitat and food source due to the destruction of mangroves. It is not known if this harvesting pressure may have an influence on the decline of shrimp species that are economically important to offshore trawlers, but are of little value to the farmed shrimp industry.

CONCLUSIONS IN RELATION TO COASTAL ZONE MANAGEMENT

Natural Stocks and Shrimp Mariculture

The uniqueness of the Ecuadorean fishery is the utilization of the shrimp stock by both an offshore fishing effort and the artinsanal seed fishery. These two fishing efforts create a substantial demand for this natural resource. It is poorly understood how the relative pressures of harvesting compared to recruitment influence the population dynamics of shrimp. Also, how important are other natural resources such as mangroves to the maintenance of these species, or is this habitat factor completely masked by the influence of climatic changes in

offshore water temperature on population dynamics? The shrimp ponds have a more specific demand for certain species that can survive pond conditions, yet present harvesting techniques are fairly nonselective and may be detrimental to a wide variety of marine organisms.

Management plans for this fishery may have to optimize for a more selective nature of harvesting seed shrimp for the ponds. If the harvesting pressure from the seed and sea industry continue to negatively impact the recruitment of wild larvae into the estuaries, then some regulatory action may be required to lessen the demand on this natural resource. This is particularly true during shifts in climate when water temperatures are limiting the source of larvae into the estuaries. Particular attention needs to be addressed relative to the impact of the seed fishery up in the concentrated areas (low salinity and high density of postlarvae) of the esteros.

Mangroves and Shrimp Mariculture

The explosive nature of the shrimp farming industry along the coast of Ecuador, particularly in the southern provinces of Guayas and El Oro, have had a destructive impact on the mangrove forests. There is now a general feeling that mangroves must be protected in order to halt the further decline of postlarvae production in the esteros resulting from the loss of this habitat. In fact there are now laws that require future authorizations for the construction of ponds not be permitted in mangrove forests. In order to accomodate these laws and maintain or increase the level of shrimp production in the existing ponds, the operation of mariculture in these systems must be intensified. This was in fact a

recommendation of a team of experts reviewing the shrimp farming industry in Ecuador (Siddall et al.1985). Yet while this approach may seem to address the issues of mangroves and shrimp mariculture, it fails to recognize an important consequence to the estuarine ecosystem. The intensive utilization of existing ponds would create increased pumping of estuarine water through a system that would be heavily fertilized and would therefore lead to increased loading of nutrients to the estuary. This management alternative would increase the pollution of the estuary in the name of preventing the destruction of mangroves. Increase nutrient loading would probably result in lower rates of shrimp production in the ponds (see discussion below for water quality).

The shift from extensive to intensive mariculture would not necessarily have to negatively impact the estuarine ecosystem if the mangroves could be utilized in the operation of the ponds. Mangroves may represent sinks of the primary nutrients used in the fertilization of ponds, that being phosphates and nitrogen. The effluent from the ponds could be distributed in nearby mangrove forests for nutrient removal prior to the return of the water back to the estuary. This use of mangroves as a nutrient buffer, which would most likely enhance the productivity of the mangroves, would serve as means of minimizing the negative impact of intensive aquaculture on the estuarine ecosystem. Mangrove sediments may also have the capacity to absorb some of the BOD associated with pond effluent high in chlorophyll biomass that may impact the oxygen balance in the estuary.

Such utilization of mangroves in the vicinity of shrimp ponds should be promoted not only in relation to the nutrient buffer capacity of these wetlands; but also based on their capability to prevent or retard erosional processes along the shorelines of ponds. Sediment stablilzation is an important natural function

of mangroves along the coastline; they particularly minimize the impact of storm surges. These uses of mangrove as a natural resource is an acknowlegement of the free services these subsystems provide to control water quality and enhance the productivity of the estuarine ecosystem.

Recognizing the importance of mangroves to the shrimp mariculture industry, and thus to the economic future of this enterprise, is important in preventing additional losses of this natural resource. But other aspects of the operation of this industry must be considered relative to mangroves, such as the utilization of these forests as intensive mariculture becomes possible. Eventhough there is a law that denies the construction of newly authorized ponds in mangrove areas, there are thousands of ha of ponds that have been authorized but not constructed that are exempt from this decree. Presently it is the lack of postlarvae (and capital) that has controlled the construction of those ponds in mangrove habitats. Thus those factors that would increase the supply of postlarvae, such as another El Nino and associated warmer temperatures of offshore waters, represent a threat to this natural resource. Another threat is the production of postlarvae by hatcheries. Hatcheries may be viewed as an operation that would save these forests from further destruction. However, if hatcheries and laveros could maintain enough postlarvae for 45,000-50,000 ha of ponds as predicted, then the presure for the utilization of premiere mangrove sites would increase above existing levels (present postlarvae levels can keep less than 30,000 - 45,000 ha of ponds supplied). Thus the growth of the hatchery industry to supply postlarvae must be viewed in the context of impacts on natural resources. And as stated above, if this means more intensive farming techniques, then mangroves should be part of the operational scheme to enhance the production of this industry.

Water Quality and Shrimp Mariculture

This ecosystem analysis of the shrimp farming industry has pointed out that the pumping of estuarine water into ponds that are presently operational is equivalent or slightly greater than the volume of water dicharged from the Guayas river basin into the estuary during low flow period (dry season). The fate of this water and its change in quality has significant implications to the Estero Salado since this effluent could represent a loading rate equivalent to the Guayas river during the dry season. It is not certain how much of this water is returned to the estuary in a flow through design. Some of the water is loss to evaporation, to seepage (and thus represents groundwater flux to the estuary) and is stored in the ponds. Better information is needed in the form of some preliminary water budget on this pumping process to evlauate its impact.

As the intensity of shrimp farming increases, the demand for supplemental food for the postlarvae is provided by in situ production stimulated by applying nitrogen and phosphate fertilizers to the ponds. The loading of these chemicals and its impact on the water quality of the Estero Salado depends on the discharge of effluent (again emphasizing the importance of the water budget discussed above and the fate of these chemicals within the ponds. Much of the nitrogen and phosphate are absorbed by phytoplankton in the ponds and are thus returned to the esturary in organic form. These organic nutrients represent biological oxygen demand as the plankton biomass decomposes. Nutrients released during decomposition may then be available for biological uptake and may contribute to the red tide phenomenon recently observed in the estuary. Therefore nutrient effluent from the ponds may contribute either directly or indirectly to the

balance of dissolved oxygen in the estuary, which is so important to the health of this system.

Because of the high sediment loading to the ponds via pumping estuarine water with high total suspended matter concentrations, much of the added nutrients, particularly phosphate, may be adsorbed to the suspended material and deposited to the pond sediments. Thus simple estimates of nutrient and BOD loadings based on the volume of water pumped and application rates of fertilizers for each type of farming practice are inadequate. More information is needed on the quality of water within the ponds during different phases of operation.

The loss of water from the ponds may also contribute to the increase in salinity of the system. All of these factors are compounded when considering the loss of freshwater to the Estero Salado from the dam and other changes in land use in the watershed. These changes will increase the residence time of water within the estuary and result in the concentration of water quality problems. This demonstrates the importance of a comprehensive water budget for those human activities in the direct vicinity of the estuary such as the shrimp industry, as well as for those changes in land use in the watershed such as agriculture, urban expansion, and industry. As discussed in this document the life zones of coastal Ecuador make it imperative that freshwater be a strong consideration in evlauating the impact of changes in land use on natural resources along the coast.

Existing information suggest that the production of shrimp ponds has decreased from 1600 to 250 kg of shrimp ha^{-1} yr^{-1} over the past couple of years. Along with a decrease in revenue from this industry has been an increase in the operational cost of shrimp farming. These two factors are somewhat related and

among other factors could indicate the negative impact of poor water quality on this industry. The deterioration of pond sites is dependant on the fertility of the ponds which is either provided by the existing sediment of the pond or by artificial fertilization. The productivity of a newly constructed pond on fertile sediment in a mangrove area (fertile sediments are obvious since the structure of the mangroves in this area is so great) is supported for the first couple of years by the nutrients bound up in the existing soil (assumin acid sulphate soils are not present; Simpson et al. 1983). After several harvest from the pond, this nutrient reserve (nutrients are supplied to the water column by exchange across the sediment water interface) is depleted, and artificial enrichment is required to maintain the same level of productivity. Thus, part of the operation of these shrimp ponds, even those under extensive mariculture, may require some fertilization or production levels will decrease.

The production level and operation costs of shrimp farming is also dependent on the quality of water that is pumped from the estury into the ponds. Concentrations of low dissolved oxygen in the estuary will cause stress to organisms that are trying to develop in the ponds and will increase their rates of mortality. The presence of toxic chemicals such as pesticides or petroleum hydrocarbons in the water supply may be stressful at extremely low concentrations to the postlarvae shrimp. Also, the feeding habits of planktivorous marine organisms is affected by the concentration of suspended sediment load. The net growth of organisms decrease as these sediment concentrations increase because the efficiency of acquiring food decreases. Salinity is another important water quality factor in optimizing the production of shrimp ponds; and several factors have been indentified in the estuary and the watershed that could influence this

variable. As discussed under the fisheries section in the chapter on natural resources, the present stocking rate is high at about 65,000 postlarvae per ha per harvest. One of the reason demand is so high even though the acreage of ponds in operation has decreased, is that the mortality rates in the ponds is estimated as greater than 50% (P. Maugle, personal communication). These mortality rates could be associated with some of the water quality factors discussed above, and represent a threat to the ability of shrimp ponds to generate a net profit. Thus production levels and revenues may be decreasing while operation costs associated with buying more post larvae for the ponds is increasing.

The successful operation of hatcheries is similarly linked to the quality of water in the Estero Salado. At present there are some 68 hatcheries in construction; 20 hatcheries in some initial phases of operation; and production in 1985 was about 500 million post larvae. Water quality of hatcheries is a key issue in their productivity because of the susceptibility of larvae to disease. Those potential stressors in water such as low dissolved oxygen, toxic chemicals and sediments could have a significant impact on the ability of hatcheries to supply postlarvae to the farmed shrimp industry. Presently, in the view of the low supply of wild larvae in the estuary, hatcheries are considered a key to providing postlarvae to pond operators.

The Ecosystem and Shrimp Mariculture

This analysis of the coastal zone of Ecuador has emphasized the awareness of all the ecological linkages associated with the management of natural and economic resources of this country. This is in contrast to some types of coastal zone management that emphasize the development of institutions for regulation. These

linkages are shown in Fig. 15 which identifies four major subsystems of the coastal ecosystem. In each of these subsystems there are changes associated with the use of the landscape by humans for economic profit. This profit is dependent on the function of the natural resources of that subsystem since it provides a free service to the economic activity which keeps operation costs down. For instance, the production of wild postlarvae in the esteros may be linked to the habitat and food provided by the mangroves, therefore these forests provide a free service equivalent to the cost of operating a hatchery. Clean water used for farming shrimp in ponds has a much lower operational cost than water contaminated with toxic chemicals or has low dissolved oxygen. But each of these subsystems is not an isolated entity and is coupled to other subsystems mainly by the flow of water. Water flows downhill and thus the land use activities upstream in the Guayas river basin will have an impact on the Estero Salado. These factors have been described in this report and include the quantity of water flowing from the river basin and the chemicals dissolved in this water originating from agriculture, industry, and urban land use. Since water flows one-way in rivers, there is very little feed back of the quality of the estuarine environment on the watershed. This is a problem with treating the cost of these land use activities as externalities since it is unlikely that the activity in the watershed will ever bear the economic cost of its waste products.

In the estuary, tides generate a two-way flux of waters that couple the estuarine subsystem with the intertidal zone and with offshore waters. Thus high sediment and nutrients can be exchanged with estuarine waters to mangroves, and the litter and habitat provided by the mangroves can be linked to the estuary. As the landscape of the intertidal zone is replaced from mangroves to shrimp ponds and artificial means of water exchange replace tides, then the function of the

ecosystem changes. These changes in function translate into the inability of the subsystem to provide some of the free services, such as the enhancement of clean water and producing wild stock of natural resources, that occur in an unaltered system. The great challenge facing humans today is to interface industrial enterprises with the functions of natural resources in such a way as to optimize for the maintenance of both. The shrimp industry, along with other land use practices in the coastal zone of Ecuador (including the watershed), present such a challenge; and the key to the succes of these programs depends on acknowledging th. importance of the linkages between the natural and economic resources of this country.

RECOMMENDATIONS

1. Documentation of the loss of mangroves from the coastal zone of Ecuador; since mangroves are the center of the controversy on impacts in the coastal zone, then all premises related to this impact will require information on the extent of this loss.

2. Documentation of the present structure of mangrove forests to identify present and future impacts on this natural resource;

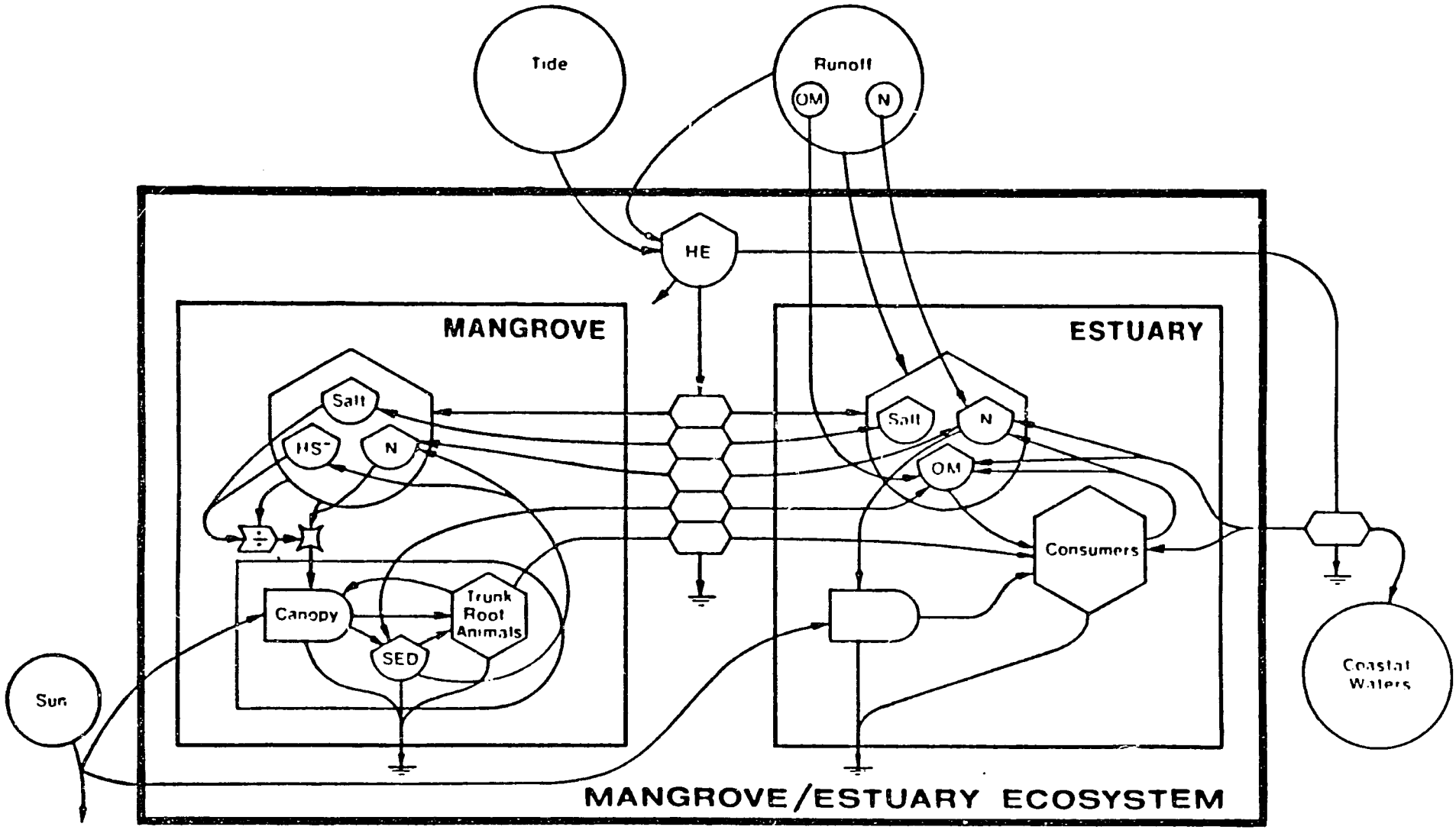
3. Restoration and integration of existing mangrove forests as part of the operation of shrimp ponds; utilize mangroves for treatment of effluents from ponds in operation and for the erosion control and sediment stablization in areas of pond construction;

4. Develop a water budget for the Estero Salado and the Guayas river basin including a synthesis of existing information and the calibration of present data gathering to increase the utility of this data base;

5. Integrate with this water budget a systems analysis of nutrients and other chemicals (toxic substances) in order to develop a water quality model for this ecosystem; include in this model the fate of chemicals in the estuary, and the mode of impact of these chemicals on economically important fisheries such as shrimp;

6. Institute a water quality monitoring program design to determine the present levels of nutrients, dissolved oxygen (including BOD and COD), pesticides, heavy metals, petrochemical hydrocarbons and physical characteristics (temperature, light, and salinity) in the fresh and estuarine waters of the Estero Salado; this program could also be extended to aid in the operation of shrimp ponds and hatcheries to help in decisions concerning water quality management;

7. Evaluate the relative contribution of cold/warm water intrusions in the Gulf of Guayaquil, loss of mangrove habitat, nutrient loading and water quality on the mariculture industry of Ecuador.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22.

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DRAFT

An Economic Analysis of Trends in the Shrimp Cultivation Industry of Ecuador

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I. Introduction

Shrimp cultivation in Ecuador expanded rapidly in the late 1970s and early 1980s, and the industry rose to become a significant source of foreign exchange earnings for the country and employment in the coastal provinces. The industry's fortunes dimmed in 1985, resulting from a drop in the availability of wild postlarvae shrimp to stock the ponds. The industry was in crisis as ponds went unstocked and debts unpaid.

The crisis evoked several questions: Had the industry's widespread destruction of mangroves, a critical habitat for juvenile shrimp, caused the shortfall of postlarvae? Were natural fluctuations in water temperature and salinity the primary reason for the change in the availability of postlarvae? Or, were stocks of postlarvae damaged by pollutants in the Guayas estuary?

Almost any explanation of the changes in postlarvae abundance raises additional concerns of what policies the government of Ecuador and the shrimp industry should pursue. The industry is an important sector of Ecuador's economy, and the industry's health is largely dependent on the natural resources of the coastal zone. How, if at all, should the government intervene to ensure these coastal resources are used in the best interests of the country? Are present governmental policies encouraging or discouraging the best use of these resources?

Responses to such questions should include an assessment of the full economic impact of various policies. Such an assessment attempts to determine and compare the economic status before and after, or with and without, a policy change.

We do not attempt in this paper a comprehensive assessment of the economic impact of policies. Instead, we attempt to document and analyze the economic status of the industry in the mid-1980s. Where possible, we explain the likely

economic impacts prevailing policies have had on the industry and the Ecuadorian economy. A full economic analysis would be possible only with much more extensive research.

The results of our analysis is presented in three parts. In the next section we discuss the early years of shrimp production in Ecuador, before shrimp cultivation became significant. In section III we discuss in detail the emergence and growth of shrimp cultivation, the industry's economic impacts and trends, and its links to the larger world market. In section IV we briefly examine the current situation and outlook for the industry, and in section V we conclude with a few recommendations for policy and research.

II. EARLY HISTORY, 1952-1975

A. SHRIMP PRODUCTION

Production of shrimp on a significant scale began in Ecuador in 1952 with the introduction of offshore trawlers. Offshore production and the trawler fleet grew rapidly and steadily through the 1960s. Offshore production was under 1000 mt through 1955, more than doubled in 1956, and exceeded 3000 mt for the first time in 1958. Production by shrimp trawlers increased by nearly 3 1/2 times in the 1960s, peaking at nearly 9000 mt in 1969 (see Table 1).

Table 1. Total Shrimp Production, 1954-1975

Year	Production (mt)	Number of Vessels
1954	660	n.a.
1955	850	30
1956	2090	57
1957	2790	72
1958	3340	108
1959	3120	100
1960	2560	91
1961	4600	97
1962	4700	106
1963	5200	125
1964	5000	119
1965	5700	n.a.
1966	5300	162
1967	6000	176
1968	6600	192
1969	8700	248
1970	6200	n.a.
1971	5900	276
1972	6800	246
1973	7800	255
1974	6500	266
1975	7500	247

Source: McPadden (1985)

The growth of the trawler fleet parallels the growth of production in these early years of the fishery's development. The trawler fleet nearly

doubled in the late 1950s, reaching 100 vessels in 1959. Double-rigged trawlers were first introduced in 1960, and the number of trawlers increased by 2 3/4 times in the decade, totalling nearly 250 vessels in 1969 (see Table 1).

By 1970, the offshore fishery for shrimp had fully developed.

In the 1970s the offshore trawl fishery experienced cyclical variations in production and fleet size. During 1970-71, offshore production fell to about 6000 mt each year. In 1972, production rebounded and, in 1973, nearly reached 8000 mt. Production again dropped to a modest 6500 mt in 1974, and was reported to be 7500 mt in 1975. The number of trawlers peaked at 276 in 1972, and then declined to just under 250 by 1975. Hence, by the middle of this decade, the production sector of the offshore shrimp fishery had reached maturity. The resource was fully exploited and the fleet size appeared to be oscillating about its long-run maximum.

One significant feature of changes in offshore production is their correlation with El Nino events. Among other characteristics, El Nino events result in much higher than normal air and water temperatures, precipitation, and sea level. El Nino events typically begin during December or January of a year, and may last from two months to two years.

Table 2 shows the incidence of El Nino events and their severity. The El Nino of 1958 may have begun the year before, and may have been severe--we do not know from the information available. The principal point, however, is that substantial increases in offshore shrimp production occurred at this time. Peaks in offshore shrimp production also coincided with the El Nino events in 1965, 1969 and 1973.

The correspondence between El Nino events and shrimp production is, of course, easy to explain. The greater precipitation and water temperatures that

constitute an El Nino event enhance the natural growth of the shrimp resource, making it more abundant.

Table 2

El Nino Events

Years	Severity
1958	not known
1965	not known
1969	mild
1972-73	severe
1976	moderate
1982-83	severe

El Nino events occur regularly. The chances are high for one to occur every 5-7 years, affecting abundance and, hence, production for 1-2 years. Our calculations indicate full offshore production in non-El Nino years averages 6300 mt, and in El Nino years production averages 7900 mt, a 27 percent difference (using the mean production level of 7000 mt as a base). In other words, the offshore shrimp fishery is subject to wide variation in production and economic fortune due to natural environmental changes alone.

The changes in the size of the shrimp fleet appear to be closely related to levels of productivity (defined here as production per vessel) in the fishery. During 1956-57, productivity exceeded 35 mt (per year per vessel) and the fleet size nearly doubled in 1958. Productivity was in the 42-47 mt range in the first half of the 1960s, coinciding with introduction of the Florida trawler; and in the 34-38 mt range in the second half of the decade. During the decade the fleet expanded from 91 to 248 vessels. It is not clear whether the higher productivity was a result of improved environmental conditions or improved technology. In the first part of the 1970s, when productivity fell to less than 30 mt, the fleet contracted in size.

Changes in productivity do not explain all changes in the fleet size, and El Nino events do not explain all changes in production. Clearly, economic and other conditions undoubtedly would also explain a good part of the trends in the offshore shrimp fishery during 1952-1975. Unfortunately, the data needed for a complete analysis are not available.

B. PROCESSING, MARKETING AND TRADE

The shrimp industry in Ecuador has been export oriented nearly since its beginning. The first exports of shrimp occurred in 1954, two years after offshore trawling for shrimp commenced. There were two packing firms established in these early years.

No data are available on processing and marketing activities through 1969. The available data on Ecuador's exports of shrimp begin with 1970. For the period 1970-75, the volume of reported exports peaked at 5000 mt (product weight) in 1972, and the value peaked at US $14.6 million in 1975 (see Table 3).

Table 3. Ecuador's Exports of Shrimp, 1970-75

Year	Volume (mt)	Value (million US $)	FOB Prices (US $)	
			per lb.	per kg
1970	2266	1.7	0.35	0.77
1971	2941	4.3	0.67	1.47
1972	5036	12.9	1.17	2.57
1973	2839	9.2	1.47	3.23
1974	3593	11.4	1.44	3.17
1975	3754	14.6	1.77	3.89

Source: Banco Central del Ecuador (1982)

FOB prices in current US dollars rose five-fold during the period. However, when these prices are adjusted for inflation, the trend in prices presents a different picture. In constant 1967 US dollars, the FOB price rose

three-fold from 1970 to 1973, fell by nearly 15 percent in 1974, and then nearly recovered to the 1973 peak in 1975. Even after adjusting for inflation, prices exhibited a healthy three-fold increase overall during the period.

We estimate slightly more than 80 percent of shrimp production was exported during 1970-75. Official Ecuadorian statistics indicate nearly all (97%) shrimp exports were to the United States. However, Ecuador's shrimp exports to the U.S. constituted only 3 percent of all shrimp exports to the U.S. during the first half of the 1970s. This situation, as we show below, began to change by the end of the decade.

Imports of Ecuadorian shrimp by the U.S. began in 1954 (Table 4). The quantities of imports nearly parallel the quantities of production during the period. The discrepancies between the U.S. import and Ecuadorian export data may be due to different recording procedures.

Table 4. U.S. Imports of Ecuadorian Shrimp, 1954-1975

Year	Quantity (mt)	Value (US $1000)
1954	249	310
1955	729	1074
1956	1341	2085
1957	1758	2873
1958	2017	3122
1959	2142	2943
1960	1905	2793
1961	2929	2986
1962	2328	4082
1963	2559	4120
1964	2618	4261
1965	2576	4427
1966	2381	4507
1967	2721	5358
1968	2859	5915
1969	4046	9164
1970	2724	5735
1971	3424	6054
1972	3152	10354
1973	3409	11174
1974	2823	11480
1975	3663	17382

Source: National Marine Fisheries Service.

III. THE PAST DECADE, 1976-1985

Just as the decade of the 1960s saw development of the offshore shrimp fishery, the past decade witnessed development of the shrimp cultivation industry in Ecuador. Total production and exports of shrimp rose five-fold (in weight terms), all essentially due to the growth of shrimp farming in the country. Ecuador now is the second largest supplier of shrimp imports to the United States. And the success in Ecuador has prompted large-scale investments in similar shrimp cultivation operations in Panama, Brazil and other tropical countries.

The purposes of this section of the paper are two: (1) to describe the shrimp industry in Ecuador and its relationship to international markets, and (2) to analyze the economic trends and patterns which characterized the industry during the period.

A. SHRIMP PRODUCTION

In 1976 total shrimp production was 9000 mt and in 1983 production peaked at 44,600 mt. In 1976 cultivated shrimp comprised a small fraction of total production, but by 1983 cultivated shrimp may have comprised 75 percent of the total (Table 5). We now examine cultivated production which became the dominant production sector of the shrimp industry during the period.

Table 5. Total, Trawler and Farm Shrimp Production, 1976-1985

Year	Total Production (mt)	Trawler Production (mt)	Farm Production (mt)
1976	9000	n.a.	n.a.
1977	8600	n.a.	n.a.
1978	9200	n.a.	n.a.
1979	12485	7787	4698
1980	16980	7800	9180
1981	20100	8000	12100
1982	29500	8000	21500
1983	44600	8900	35600
1984	37900	6300	33600
1985	36228	6023	30205

Sources: McPadden (1985), Direccion General de Pesca.

A.1. CULTIVATED PRODUCTION

Modern shrimp farming on a commercial scale began in 1968 or 1969. The first ponds were built in El Oro province by individuals involved in the banana industry. Yields were initially low and total production nearly insignificant in comparison to offshore trawl production. By 1974 about 600 hectares were in production (McPadden, 1985).

By 1977 entry into shrimp cultivation was like a "gold rush" (Hirono, 1983). Accurate statistics on cultivated production are not available, but production probably remained relatively small through 1978.

The first year of significant cultivated production was 1979, at nearly 4700 mt, though still less than offshore production. Cultivated production nearly doubled in 1980, at nearly 9200 mt, and exceeded offshore production for the first time.

Cultivated production continued to expand in the early 1980s. Official estimates show production growing by 32 percent and 78 percent in 1981 and 1982, respectively. In 1983, estimated cultivated production peaked at 35,600

mt, an increase of 66 percent over 1982. If these estimates are reasonably precise, they mean that cultivated production increased 7 1/2 times during the five years 1979 through 1983, a remarkable achievement in any industry.

The production increases of 1982 and 1983 may be largely attributed to favorable environmental and economic conditions (abundant postlarval shrimp and a strengthening US dollar). However, the unfavorable environmental and economic conditions that prevailed earlier during 1980 and 1981 (a drought and a weaker U.S. dollar) did not deter expansion.

Sector production took a downturn in 1984 and 1985, from all reports due solely to the lack of postlarvae with which to stock ponds. Cultivated production dropped to 33,600 mt in 1984 and 30,200 mt in 1985, according to official estimates.

Data on the number and size of shrimp farms in Ecuador are not available. The only data available are the number of hectares authorized for cultivation by the government. For much of the period through at least 1980 authorized hectares likely were considerably less than the actual area in shrimp farming, since not all land in cultivation was officially authorized by the government. Since 1981 there is reason to believe that the actual area in farms was less than the totals authorized.

There are a few estimates of land actually in cultivation for a few years (Table 6). According to these estimates, the number of hectares in cultivation increased from 24,000 hectares in 1980 to 48,000 hectares in 1984, a 100 percent increase in just five years.

Table 6. Total Areas of Shrimp Farms, 1976-1986

Year	Authorized Area[a] (cumulative; in hectares)	Area in Cultivation (estimated; in hectares)
1976	439	
1977	2,345	
1978	4,178	
1979	6,945	24,000[b]
1980	14,707	30,000[c]
1981	35,382	32,000[d]
1982	49,069	32,500[e]
1983	62,938	
1984	87,576	48,000[f]
1985	94,352	
1986	n.a.	30,000[g]

Sources: a) Direccion General de Pesca
b) Calvas (1980)
c) NMFS (1981)
d) Barniol (1980)
e) Central Bank (1982)
f) Parodi (1985)
g) Maugle (1986)

These data do not distinguish between land area of farms and land area in ponds. Also, we do not know how much of the stated area was idle in a given year.

Farm Operations. Shrimp cultivation originated in El Oro province, but the great expansion occurred in Guayas province in the islands of the Estero Salado and on the northwestern banks of the Estero. According to McPadden (1985), the expansion was facilitated by abundant quantities of intertidal mangrove areas and salt flats which could be developed at low cost, and an

abundance of postlarval shrimp. Relatively modest development of shrimp farming also occurred in the provinces of Manabi and Esmeraldas. Table 7 shows the numbers and areas of government concessions for shrimp farming by province for the last decade. These data should be treated as indicative only, since, as stated above, government authorizatiors are not an accurate record of the actual amount of land in cultivation.

Table 7. Areas Authorized for Shrimp Farming by Province, 1976-1985

Year	Total		Province							
			Guayas		El Oro		Manabi		Esmeraldas	
	#	ha.	#	ha.	#	ha.	#	ha.	#	ha.
1976	6	439	2	300	3	119	1	20	--	
1977	21	1,906	5	615	11	559	5	732	--	
1978	25	1,833	22	1,766	1	15	2	52	--	
1979	31	2,767	15	1,706	4	318	12	743	--	
1980	73	7,762	54	6,613	10	874	8	225	1	50
1981	189	20,675	104	15,210	71	4,379	11	630	3	456
1982	116	13,687	40	10,620	30	2,156	14	739	2	172
1983	122	13,869	86	11,312	14	1,326	17	859	5	372
1984	229	24,638	157	20,562	37	2,551	27	1,124	8	401
1985	130	6,776	58	3,504	26	2,199	15	283	13	790
Cumulative Total	942	94,352	573	72,208	225	14,496	112	5,407	32	2,241

Source: Direccion General de Pesca

The size of shrimp farm operations appears to vary greatly. Many farms are small, producing small amounts of shrimp on a few hectares of land. At the other extreme are a few large farms on several hundred hectares with, we assume, large production levels. At least one large farm is part of an integrated firm which owns a fleet of trawlers and is a major exporter of shrimp. There are no data showing production by farm. Therefore, we do not

know if the bulk of cultivated shrimp is produced by a few large farms or by several small farms.

An indication of the distribution of farms by land area is given in Table 8. Of over 700 concessions awarded by the government at the end of 1984, over half were for farms of less than 50 hectares, and a third were for farms between 50-200 hectares. A few large farms of 1000-2000 hectares do not appear in these statistics, however (McPadden, 1985).

Table 8. Number of Authorized Farms by Size, 1984

Area (hectares)	Total	Provinces			
		El Oro	Guayas	Manabi	Esmeraldas
TOTAL	773	167	494	92	20
0- 50	408	107	221	67	13
50- 100	107	32	57	15	3
100- 200	141	15	116	7	3
200- 300	92	11	77	3	1
300- 500	13	1	12	-	-
500- 700	7	1	6	-	-
700-1000	4	-	-	-	-
1000-more	1	-	1	-	-

Source: McPadden (1985)

There is no evidence in the literature available of what size of farm is most profitable. Land area, or area in ponds, may or may not be a principal determinant of profit levels. This, along with other features of farm operations, requires further study.

As of early 1985, there were basically three different types of farm operations in Ecuador: (1) extensive, (2) semi-extensive, and (3) semi-intensive. The extensive method is the simplest. Ponds are stocked at low densities, no supplemental feed or fertilizer is used, water exchange is

minimal, and yields are low (about 600 pounds of whole shrimp per hectare per year). The extensive method is common on small farms and on the older farms of El Oro province where shrimp cultivation originated (McPadden, 1985).

The semi-extensive method is distinguished from the extensive method by the use of nursery ponds (to grow the postlarvae to the juvenile stage before transfer to grow-out ponds), higher stocking densities, fertilization of ponds, supplemental feeding near the end of the growth cycle, and regular monitoring of the pond environment and shrimp biomass. Yields are from 1500-2400 pounds of whole shrimp per hectare per year. The semi-extensive method is common in Guayas province on farms of 100 hectares or larger (McPadden, 1985).

The semi-intensive method is distinguished from the semi-extensive by still higher stocking densities, the use of fertilization and supplementary feeding throughout the growth cycle, and high exchange of water. Yields are the highest of the three methods, from 3000-5000 pounds of whole shrimp per hectare per year (McPadden, 1985).

There is no record of the quantity of cultivated production accounted for by each production method. LiPuma and Meltzoff (1985) claim the extensive method is used for 35 percent of the shrimp ponds, the semi-extensive method for 55 percent, and the semi-intensive method for 10 percent. If this distribution and the above yields are reasonably accurate then farms using extensive methods account for only 9 percent of total cultivated shrimp production, semi-extensive for 58 percent, and semi-intensive for 33 percent. That is, semi-extensive farming operations account for the largest share of production.[1]

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[1]These shares were calculated using the upper end of the range for yields per hectare given above. These higher yield values are consistent with estimated cultimated production and estimated area actually in cultivation in 1984.

Production practices. No detailed account is available of the production practices followed for each method of farming. McPadden (1985) describes the practices of the semi-extensive method as follows: upon purchase, postlarvae are first stocked in nursery ponds, which have been fertilized. The stocking density in the nursery ponds is 1 million postlarvae or more per hectare. After about 45 days growing in the nursery ponds, the juvenile shrimp are transferred to growout ponds at lower densities. The growout ponds are stocked at 30,000-35,000 juveniles per hectare, and fertilized to control phytoplankton, a primary source of nutrition for the shrimp. The ponds are regularly monitored for primary productivity, oxygen levels, biomass and growth. Near the end of the growth cycle, when the shrimp attain an average weight of 12 grams, special feeds are added to the ponds. We do not know the usual length of the growth cycle for this method. (McPadden reports the growout period for the semi-intensive method is 120-140 days.) Harvests occur about twice a year, synchronized to the availability of wild postlarvae for stocking.

According to Barniol (1980) the decision to harvest is determined by the weight of the shrimp and their growth rate, the market price, and the extent of predation (by crabs, ducks, and human thieves). Harvest is accomplished by partially draining the pond and using throw nets to capture the shrimp, or by completely draining the pond and capturing the shrimp as they leave the pond with the water. After harvest, ponds are completely drained and dried, the bottom is cleaned and leveled, and repairs are made to canals, walls, etc. After refilling the pond with water, fertilizers are applied before re-stocking.

After harvest the shrimp presumably are taken to a processing and packing plant; however no description of handling, transport and other methods is available.

Costs and earnings. A complete and accurate record of the costs and earnings of production in the industry would enable analysis of several important issues and questions. For example: (1) How has the costs and earnings situation shaped past developments in the industry, in terms of farm size and number, location, methods used, stocking densities, feed use, etc.? (2) What are the major determinants of profit and loss? (3) What is (are) the most profitable type(s) of farm(s), in terms of size, and stocking, feeding and harvest methods? (4) Can the costs of entering the industry be recovered over a reasonable period? (5) Given the current costs and earnings picture and general trends, what developments in the industry can we expect to see in the near future?

Unfortunately, a complete and accurate record is not available and the questions above cannot be answered with any certitude. The most complete costs and earnings data available are from a survey conducted for a study of the industry by the Central Bank of Ecuador (1982). The survey sample consisted of 112 shrimp farms with a geographic distribution closely approximating that of all shrimp farms at the time. Half or more of the farms surveyed in El Oro, Manabi and Esmeraldas were small (i.e., 1-50 hectares), while just one-third of the farms surveyed in Guayas were small. We do not know how close this size distribution approximated the actual size distribution at the time of the survey. The Bank's study gives the average production costs and prices per pound by province for the years 1979, 1980 and 1981. Table 9 summarizes some of the results of the Central Bank's study. Unfortunately, we do not know what items are included in the study's cost figures, which makes interpreting gross margins quite difficult.

Table 9. Costs and Earnings, 1979-1981 (sucres per pound)

Average Costs of Production

Province	1979	1980	1981
Guayas	46.25	48.33	35.62
El Oro	36.23	36.00	34.19
Manabi	30.00	30.17	30.78
Esmeraldas	---	---	---
TOTAL	37.49	38.16	33.53
	Average Price		
Guayas	96.50	64.83	59.15
El Oro	63.00	64.04	61.25
Manabi	71.00	63.78	58.89
Esmeraldas	76.80	64.20	59.80
TOTAL	76.80	64.20	59.80
	Gross Margins		
Guayas	50.25	16.50	23.53
El Oro	26.77	28.04	27.07
Manabi	41.00	33.61	28.11
AVERAGE	39.30	26.10	26.20

The study by Liao and Chao (1983) probably uses data from 1982. They report average production costs of 15-27.5 sucres per pound for the extensive cultivation method. We have few characteristics of the firms on which this estimate is based, and we do not know what items are included in their cost figures. No information is provided on earnings.

McPadden (1985) reports farms using semi-intensive methods with average production costs in the range of 220-270 sucres per pound. LiPuma and Meltzoff (1985) cite costs for farms using semi-intensive methods that translate to operating costs of about 120 sucres per pound. They also provide data which

translates to 113 and 161 sucres per pound for extensive and semi-extensive farming methods.

There is too much disparity among these data for them to be of much use. The more recent data given by McPadden, and LiPuma and Meltzoff appear not based on an adequate sample of firms in the industry, and cannot be used to draw any firm conclusions. The systematic survey conducted for the Central Bank's study make these data most credible. However, the results are not presented in a form useful for present purposes.

Production Inputs. The principal inputs to the cultivated production process include postlarval shrimp, land, water, human capital, and physical capital. Other inputs include feed and fertilizer. Clearly, the availability and quality of these inputs affect farms' performance and determine the shape of the industry. We now describe the status of each of these inputs over the last few years.

POSTLARVAE. Perhaps the single most critical input in shrimp cultivation is the postlarval, or seed, shrimp. Two species, *Penaeus vannamei* and *Penaeus stylirostris*, have been successfully cultivated on a commercial scale in Ecuador. Of the two, *P. vannamei* appears to provide the greater economic return.

The total quantities of postlarvae used by all farms for shrimp cultivation is not known. Table 10 presents the few estimates available of postlarval use. If the basis for these estimates is sound, then it appears postlarval use has ranged from 4 to 11 billion a year since 1979.

Table 10. Estimated Postlarvae Use

Year	Estimated Hectares in Cultivation	Estimated Number of Postlarvae Required for Stocking (in billions)	
		NMFS Method**	Other sources
1979	24,000[b]	5.3	
1980	30,000[c]	6.6	4-6[e]
1981	32,000[d]	7.0	3.6-4.8[d]
1982	32,500[e]	7.2	
1983			9.0[f]
1984	48,000[g]	10.6	
1985			
1986	30,000[h]	6.6	

Sources: a) NMFS, 1985b; b) Calvas, 1980; c) NMFS, 1981; d) Barniol, 1980; e) Central Banks, 1982; f) McPadden, 1985; g) Parodi, 1985; h) Maugle, 1986.

*The NMFS (1985b) method assumes (i) an average stocking density of 50,000 postlarvae/hectare/crop, (ii) a postlarvae survival rate of 50 percent, and (iii) an annual average of 2.2 crops.

The actual quantities of postlarvae used are determined, in large part, by the interaction of demand and supply conditions. These conditions for postlarvae are not well understood, i.e. they have not been studied and documented. However, we conjecture the following: the quantity demanded at a point in time depends on the area of ponds available for stocking and desired stocking densities which, in turn, depend on the production methods used, the expected selling price for grown shrimp, and the purchase price of postlarval shrimp. The quantity supplied depends on the natural abundance of postlarvae at a point in time, the methods and their costs of harvesting, handling and delivering postlarvae to the farms, and the selling price of postlarvae. If

the market for postlarvae is working well, the price of postlarvae rises or falls until the quantity demanded equals the quantity supplied, and no one is willing to buy or sell more at this market equilibrium price. We do not doubt that the actual determinants of demand and supply and their interaction are more complex than described here.

As shown above, the information on the economics of the farm is incomplete, thus we are unable to provide a useful analysis of postlarvae demand. In order to explain and predict some important events in the industry a good understanding of postlarvae demand conditions is essential. A comprehensive demand analysis should show (i) the quantitative relationship between the price and quantity demanded of postlarvae by firms, including the price at which postlarvae demand would be completely choked off, (ii) which farms (by type, size, etc.) would and would not stock at various prices, (iii) how stocking rates are affected by changes in postlarvae price, and (iv) how postlarvae demand is affected by shrimp export prices and other factors.

Next we present a descriptive analysis of supply conditions for postlarval shrimp. There are three distinct sources of postlarvae supply in Ecuador: those caught in the wild, those produced in hatcheries, and those imported from outside the country. Each of these supply sources is discussed in turn.

WILD POSTLARVAE. During the period 1976-1985, wild postlarvae accounted for nearly all of the postlarvae used in cultivated production. Until hatcheries become a significant source of supply, the availability of wild caught postlarvae will continue to be a major determinant of the status of shrimp production in the country.

Wild postlarvae are caught primarily in the Estero Salado, and along the coasts of El Oro and Guayas provinces. Additional postlarvae are caught in lesser quantities, but year round, along the coasts of Manabi and Esmeraldas

provinces. The peak season for postlarvae fishing normally is from December through March; and May through October normally is the period of postlarvae scarcity. Postlarvae abundance also varies annually, depending on hydrographic and climatic conditions. During the El Nino event of late 1982 and 1983 postlarvae were abundant, and during 1984 and 1985 postlarvae were relatively scarce.

Of course no records exist on the numbers of fishermen in the postlarvae fishery over the years. A report by NMFS (1981) estimated 2000-3000 artisanal fishermen collected postlarvae in 1980. Assuming, conservatively, that 5 billion postlarvae were caught and sold by fishermen at 25 sucres per thousand, gross earnings to postlarvae fishermen amounted to 125 million sucres. Various sources estimate 90,000 or more fishermen participated in the postlarvae fishery in 1983. McPadden (1985) estimates their gross earnings at 900 million sucres in that year. These estimates imply average earnings per postlarvae fisherman fell from 42,500 sucres (US $1700 at the time) or more in 1980 to 10,000 sucres (less than US $120) in 1983. Given that inflation, as measured by the consumer price index, more than doubled during this period, the fall in real average earnings was even more dramatic.

Once again, we emphasize that these estimates should be treated as indicative only. For example, many of the 90,000 postlarvae fishermen in 1983 worked part-time in the fishery. Also, it is common in most production activities for a small proportion of producers to supply a large share of the product (here, postlarvae). If this was the case, the more productive postlarvae fishermen were earning much more than these estimates indicate. Supporting this conjecture is a report by NMFS (1985b) that fishermen who shifted to the postlarvae fishery have been able to buy motors and replace their dugout canoes with fiberglass boats. Many postlarvae fishermen have seen their incomes increase by two-fold or more.

The predominant gear for harvesting postlarvae is a fine mesh net. In the Estero Salado, fishing with hand nets occurs most intensively during the bimonthly low tides when the postlarvae are concentrated at the lower reaches of creeks. Along the coast, butterfly push nets are used to collect postlarvae in the surf (McPadden, 1985).

After capture, the postlarvae are separated from small fish, juvenile shrimp and debris with a simple sieve. Brokers, or intermediaries, commonly purchase the postlarvae from fishermen and transport them in tanks and barrels and sell the postlarvae to farms. About half of the postlarvae are lost in transit (Horna, et al, 1985). According to LiPuma and Meltzoff (1985), the brokers' markup is from 100 to 150 percent. Other reports indicate much larger markups. The price of a tank or barrel is established by estimating the number of P. vannamei and P. stylirostris postlarvae it contains (McPadden, 1985).

Table 11 presents what data are available on postlarvae prices. We note there are two prices. The price at the beach is that paid fishermen by brokers; the price at the farm is that paid brokers by shrimp farmers. Unless noted otherwise in the source document, the reported price is assumed to be the price paid at the farm.

Table 11. Postlarvae Prices (sucres/1000)

Date	Beach Price	Farm Price	Estimated Real Farm Price (1979 sucres)
1980		75-100[a]	60-80
2/84		450-540[b]	160-190
2/85	100[c]	400-600[c]	110-165
5-7/85		1300[d]	330
8-9/85		1800[d]	440
10-11/85		1500[d]	365
12/85-1/86		1200[d]	285
2-3/86		500[d]	120
3/86		700-800[e]	

Sources: a) Calvas, 1980; NMFS, 1981; b) NMFS, 1984; c) McPadden, 1985; d) Leslie, 1986; e) Maugle, 1986

The incomplete nature of the price data results in a less than satisfactory interpretation. First, we know that January, February and March are usually times of relative abundance, and therefore should have the lowest prices in a given year. Similarly, the last half of a year usually corresponds with relative scarcity, and prices should be highest. The data are consistent with these expectations. Comparing prices across years is more tenuous. The nominal prices for February in 1984, 1985 and 1986 are about the same. However, after adjusting for inflation (by the imperfect method of dividing by the consumer price index), real postlarvae prices for February have declined. This price decline may have been caused by an improvement in supply conditions, or a weakening of demand conditions, or both over these two years. Supply conditions could have improved, for example, due to an increase in postlarvae abundance and/or increased efficiency in capturing, handling and transporting methods (all of which have been reported; see McPadden, 1985, and NMFS, 1985b). Demand conditions could have weakened, for example, if the costs of farm operations rose and/or if the selling price of shrimp fell. Demand for wild postlarvae would also weaken if postlarvae from alternative sources (i.e., hatcheries, imports) became available at competitive prices. But, there is no evidence this occurred. Another possible reason for weakened postlarvae demand, if it weakened at all, may have been the fall in the area of ponds cultivated from 1984 to 1985. If ponds can be readily brought back into cultivation with low set-up costs, then the reduction in pond area would not have weakened demand. On the other hand, if ponds are slow and costly to be brought back into production, then the reduction would have weakened the demand for postlarvae.

While not shown in Table 11, postlarvae prices also vary geographically. They are highest in Guayas province, where most ponds are located, and lowest in Manabi (LiPuma and Meltzoff, 1985).

HATCHERY PRODUCTION. The future of shrimp cultivation in Ecuador depends in large part on hatcheries. To date, the production of postlarvae in hatcheries has been of minor proportions, having a negligible effect on total supplies of postlarvae. If hatchery development proves both technically and commercially feasible, sustained expansion of shrimp cultivation will be realized.

The first hatchery was established in Guayas province in 1980. By the end of 1984, four hatcheries were in production and 14 others in various stages of development. McPadden (1985) estimated these hatcheries to have a maximum production potential of 2.4 billion postlarvae per year. Hatchery production in 1984 was less than 300 million postlarvae (NMFS, 1985b). Various sources indicate by the end of 1985 from five to 30 hatcheries were in production, with about another 30 hatcheries being planned. Hatchery production in 1985 exceeded 500 million postlarvae (Leslie, 1986). The rapid increase in hatchery development in 1984 and 1985 was clearly induced by the dramatic drop in world postlarvae supplies in 1984.

Most hatcheries are intended to produce postlarvae to stock the ponds of the company which built the hatchery (NMFS, 1985a). That is, the hatchery and farm are operated as an integrated unit. Some private processors also have built their own hatcheries (whether these are fully integrated hatchery-farm-processing operations is not clear).

Most hatcheries have located in Guayas province in an area, known as "hatchery row," between the Santa Elena Peninsula and Valdivia. This location, some distance from most ponds, is preferred because of year round access to ocean water with its higher salinity.

The hatchery production methods used in the country are not well documented. The little evidence available suggests most, if not all, production through 1985 resulted from the spawning of wild caught gravid

females. Most hatcheries, however, have or plan to have pilot maturation facilities which would reduce or eliminate dependence on wild caught broodstock.

Solving the maturation puzzle is critical. The motivation for hatchery production is to provide postlarvae when wild postlarvae are relatively scarce, otherwise postlarvae prices are too low to cover the cost of hatchery-produced postlarvae. As long as hatcheries rely on wild caught broodstock, their production will roughly parallel wild postlarvae production. Another means of eliminating dependence on wild broodstock is to import nauplii, and postlarvae, which some firms have done.

Even if maturation is achieved, hatchery production may not be immune from fluctuations in environmental conditions. Cold seawater can reduce hatchery production and means of heating water supplies must be used occasionally. Also, disease and natural changes in the composition of algae and bacteria in the water can affect production.

In addition to broodstock and water, another important input to the hatchery production process is Artemia, which is a primary feed for shrimp larvae. Artemia can be produced locally, but most supplies are imported from the U.S.

If hatcheries are to make a significant contribution to the development of shrimp cultivation they will have to be commercially viable. The few reports available suggest that hatchery production costs were about 500-600 sucres per 1000 postlarvae in 1985 (NMFS, 1985a; Maugle, 1986).

To determine what minimum average price is required to make hatchery operations commercially viable, we turn to data provided by Leslie (1986), presented in Table 12. These data assume the hatcheries produce free of serious problems. Our calculated prices suggest the small "bamboo" type hatchery may be able to compete with supplies of wild postlarvae even during

periods of relative abundance of postlarvae. The high tech hatcheries, requiring higher prices, would be viable only during periods of relative scarcity.

Table 12. Hatchery Costs

Investment Hatchery	Investment Cost	Expected Production (10^6 PL/yr)	Production Costs (per 1000 PL)	Minimum Average Price Required*
	(US dollars)		(sucres)	(sucres)
I. High Tech, Large	2-2.5 million	300	500-800	1090
II. High Tech, Small to med.	250-800 thousand	60-120	400-600	835
III. Japanese Tech, Large	1 million	200	300-500	675
IV. Japanese, "Bamboo"	30-100 thousand	12-40	250-400	490

Source: Leslie, 1986
*Calculated using the formula $K x i \leq (P-C) \times Q$, where K is capital investment cost, i is the rate of interest (assumed .25), P is the average price, C is production cost per 1000 postlarvae, and Q is expected production rate. For this calculation, we used the upper values of the ranges given for K, Q and C. The exchange rate used is S/140 = $1.00.

A number of qualifications should be made regarding the calculation and meaning of the minimum average prices shown in Table 12. First, the prices are sensitive to the interest rate. For example, using the lower rate of 20 percent reduces the price by 65 sucres for the large, high tech hatchery. Second, using the lower end of the range of production costs results in a lower price (e.g., the "Bamboo" hatchery price would be 340 sucres).

A third qualification is that hatchery produced postlarvae may have a greater or lesser value to growers than wild postlarvae. For example, if

survival rates of wild postlarvae are higher than hatchery postlarvae, then the price farms are willing to pay for hatchery postlarvae will be less than the wild postlarvae price. The difference in the two prices will be proportional to the difference in their survival rates, assuming no other differences. To illustrate, assume the survival rates of wild postlarvae are 70 percent each in nursery and growout ponds, and 60 percent each for hatchery postlarvae. With these rates 49 percent of the wild postlarvae survive to harvest, and 36 percent of the hatchery postlarvae survive to harvest. That is, the overall survival rate of hatchery postlarvae is about three-fourths of the overall survival rate of wild postlarvae. Growers, therefore, will purchase hatchery postlarvae instead of wild postlarvae only if the price of hatchery postlarvae is no more than three-fourths the price of wild postlarvae. If the wild postlarvae price is S/1000, then hatchery postlarvae will sell for S/750. Therefore, for the large, high tech hatchery to be commercially viable, wild postlarvae prices would have to exceed S/1450.

IMPORTS OF POSTLARVAE. Another source of supply of postlarvae is the importation from other countries. Postlarvae have been imported from several Latin American countries, the U.S. and the Philippines. During the height of postlarvae scarcity in 1985, prices of imported postlarvae were reported to be about 2500 sucres per 1000 postlarvae. The many problems in shipment reportedly eliminate imports from countries other than Peru as a significant source of supply.

LAND. As indicated above, the data on land use in shrimp cultivation are not complete. There are data on the amount of land authorized for shrimp cultivation, there are estimates of the quantity of land in cultivation in a given year, and there are a few estimates of land converted to or developed for shrimp cultivation. These data basically reveal the following: the amount of authorized land increased monotonically during the period 1976-1985, reaching

94,000 hectares at the end of 1985. The amount of land actually in cultivation rose continuously through 1983 or 1984, probably peaking at about 48,000 hectares, and then dropped off in 1985 to about 30,000 hectares. The amount of land converted to shrimp cultivation is always greater than the amount actually in cultivation. In the years through 1983 or 1984, the difference was probably small. For example, Parodi (1985) reports that 48,000 hectares were in production in 1984, and another 7,000 hectares were under development. But in 1985, with the shortage of postlarvae, land was taken out of production, resulting in a large difference. LiPuma and Meltzoff (1985) report 75,000 hectares had been converted to shrimp farms as of 1985. If accurate, this means 60 percent of the converted land was not in production in 1985.

As of 1985, over 75 percent of the land authorized for shrimp cultivation was located in Guayas province, 15 percent in El Oro province, and the remainder in Manabi and Esmeraldas provinces. It is not clear to what extent land actually in cultivation follows this pattern. There are three types of land converted to use for shrimp cultivation: mangroves, salt flats and agricultural land. According to LiPuma and Meltzoff (1985) about 70 percent of the land used for cultivation was converted mangroves, 15 percent converted salt flats, and 15 percent converted agricultural land, at the end of 1984.

Mangroves and salt flats lie in the intertidal zone and agricultural land lies above water at high tide. Table 13 shows the distribution by land types authorized for 1983 and 1985. These data suggest a trend toward using more agricultural land.

Table 13. Areas of Authorized Shrimp Farms by Land Type, 1983 & 1985

	Intertidal Land	High Land	Total
1983	27,400	33,000	60,400
1985	36,500	57,900	94,400

Sources: 1983 from McPadden (1985); 1985 from Direccion General de Pesca.

The shift to agricultural land appears to be due to three factors (LiPuma and Meltzoff, 1985): (i) Prime land in the intertidal zone is becoming harder to obtain. McPadden (1985) reports almost all coastal land in El Oro has been used for shrimp cultivation, and most industry people believe nearly all the prime land in the country already has been developed. (ii) There is a shift towards more intensive cultivation methods for which agricultural land is more suited. (iii) Farms located in the intertidal zone cannot be used as collateral for loans since the government retains title to the land.
Estimates of the amount of land available for shrimp farming operations range from 70,000 to 260,000 hectares (McPadden, 1985). These estimates are not very useful for defining the potential of shrimp cultivation in Ecuador, however. As the industry expands new farms are faced with using land which requires higher investment costs, or higher operating costs, or both. The quantity of land suitable for commercially viable shrimp cultivation will ultimately be determined by the costs and earnings of farms on marginal land. McPadden (1985) suggests these economic forces are already being felt in El Oro, Manabi and Esmeraldas provinces where higher development and water pumping costs are limiting the expansion of shrimp farming.

Data on land prices have the potential for explaining changes in the industry and signaling future trends. As the industry expands one would expect the price for prime land to rise, and the price of increasingly marginal land to fall. The few price data available do not distinguish the quality of the land involved and, therefore, interpretation of land price behavior is not possible.

An important feature of land use for shrimp cultivation is that the intertidal zone land (converted mangroves and salt flats) is owned by the government. Individuals, or groups of individuals, are granted 10 year concessions to develop and operate shrimp farms on these lands. An issue of

interest is whether the 10 year period of a concession is sufficient to bring about the best development and use of the land. Ten years may not be long enough to provide an adequate return on certain investments in a farm. Short tenure induces practices that result in near term benefits and, possibly, in costs delayed to after the life of the concession. Short concession periods are not in the interest of its owner, and not in the interest of the larger society. Unfortunately, without more information and more study, we cannot determine what the appropriate period of a concession should be. One solution would be to make concessions continuously renewable provided certain specified terms are always satisfied by the concession owners.

LABOR. Shrimp cultivation and ancillary activities have come to employ significant numbers of people. For the 1980-81 period local sources estimated employment at about 40,000, most as farm laborers, and 2,000-3,000 fishermen collecting postlarvae (NMFS, 1981). For the 1983-84 period, Parodi (1985) cites estimates of 25,000-45,000 people employed on farms and boats, in packing plants, hatcheries, feed mills, ice plants, and other service industries (note that these estimates are for the entire shrimp industry, not just cultivation). In addition there were 90,000-120,000 people working to collect postlarvae.

The total employment on shrimp farms is not known. LiPuma and Meltzoff (1985) report the largest operations employ about 70 men, while farms less than 50 hectares tend to employ less than a dozen full-time people, hiring temporary labor for construction and harvest assistance.

It is not evident how dependent shrimp cultivation is on skilled labor. Hatcheries, as noted above, are highly dependent on skilled technicians. The salaries skilled labor commands and what farms are willing to pay are topics for further investigation.

As the industry evolves, employment may decline. The successful development of hatcheries may (not necessarily) eventually displace those employed collecting wild postlarvae. If farms move towards more intensive cultivation methods fewer, more skilled laborers may be required.

EQUIPMENT. Most of the equipment used in the industry is imported. This class of production inputs includes diesel engines, pumps, graders, refrigeration, earth moving and hatchery equipment. Most is imported from the U.S. NMFS (1981) estimates imports of U.S. equipment for the shrimp industry to have been as much as US $10 million per year in the early 1980s.

A.2 TRAWLER PRODUCTION

Official statistics do not separate offshore trawler and farm raised shrimp production after 1975. Some estimates (cited in McPadden, 1985) indicate offshore trawl production was fairly stable and healthy, at between 7000-8000 mt, during the latter part of the 1970s. Other sources (see NMFS, 1981) claim a drought, which began in 1977 and lasted to 1981, reduced the abundance of shrimp and resulted in trawler catches substantially below previous levels. Most reports indicate the fleet size remained fairly stable around 250 vessels during the late 1970s.

The years 1981 and 1982 were difficult for the offshore trawl fleet. The government increased fuel prices substantially and owners of fishing vessels went on strike for 40 days. Some sources report trawl production below 5000 mt for 1981 and as many as 50 vessels abandoning shrimping in 1982 (Department of State, 1981, 1982). Shrimp trawlers were being sold at low prices and converted to other fisheries.

The El Nino event of late 1982 and 1983 dramatically improved the fortunes of the shrimp trawl fishery. Offshore production in 1983 was well above average. Sources report trawl catches of 9,000-15,000 mt during the year

(Department of State, 1984; McPadden, 1985). In 1983 no shrimp trawlers were available for sale, and several vessels from other fisheries were converted to shrimp trawling.

Offshore production dropped sharply in 1984 with the passing of the El Nino event. Parodi (1985) indicates production per vessel may have been as low as 20 mt in 1984.

B. PROCESSING AND MARKETING

All shrimp production is processed and packed by several firms and nearly all of the product is exported. Details on the processing and packing practices are not available. The number of firms has grown substantially. Prior to 1980, the number of packing firms totalled less than 20, and by 1985 their number exceeded 70.

The available evidence suggests no serious problems with the structure and performance of the processing and exporting sector. Additional firms have been able to enter, and the product is reasonably well distributed among the many firms. Ten percent of the firms exported about 45 percent of the product (by weight and value) during 1982-1984. The largest firm in recent years, Enaca, has had its share of product exported fall from 20 percent in 1980 to 10 percent in 1984.

The quantity and value of shrimp processed and exported paralleled the growth of production during 1976-1985. Table 14 shows that the value of shrimp exports rose from less than US $25 million in 1976 to nearly US $185 million in 1983. These export values represent foreign exchange earnings for the national treasury.

Table 14. Exports of Shrimp

Year	Quantity (mt)	Value (million US$)
1976	4,768	24.6
1977	4,364	25.6
1978	4,288	24.0
1979	4,043	31.0
1980	9,674	66.4
1981	12,133	83.9
1982	16,966	130.0
1983	23,534	184.7
1984	20,339	154.2
1985	19,799	155.7

Sources: 1976-1979, Banco Central (1982)
1980-1985, Direccion de Pesca

During the decade, shrimp rose to take a prominent place among major export commodities for Ecuador. The country's primary export has been petroleum, accounting for a half to two-thirds of Ecuador's exports by value. Other important export commodities are bananas, coffee, and cacao.

In 1980, shrimp constituted the fourth most valuable export commodity (preceded by petroleum, bananas and coffee). In 1983 and 1984 shrimp was the second most valuable export commodity. But in 1985, shrimp returned to fourth place. At its peak in 1983, shrimp accounted for seven percent of exports (by value), and in 1985 for less than six percent.[2]

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[2]These rankings are based on the data permisos de exportacion, from the Banco Central del Ecuador, 1986.

The export values do not represent the value of gross sales by exporting firms. Foreign exchange must be converted to sucres through the central bank at rates below free market rates. Table 15 displays our estimates of exporters' sales. The U.S. dollar amount of shrimp exports has been converted to sucres at the official exchange rate for 1981 and 1982, and at the intervention rate for 1983-1985. The rate at which exporters were allowed to convert U.S. dollars increased from 24.80 sucres to 70 sucres in March, 1983 (see Table A.1 in the appendix for exchange rates since 1981). This increase in the exchange rate plus the increase in production resulted in a nearly four-fold increase in exporters' sales in 1983 over 1982. Even when adjusted for the increase in the general price level, the increase in real sales was nearly 150 percent.

Table 15. Estimated Exporter Sales

Year	Sales[a] (billions of current sucres)	Adjusted Sales[b] (billions of 1978/79 sucres)
1981	2.08	1.52
1982	4.29	2.79
1983	15.85	6.80
1984	13.64	4.49
1985	14.79	3.73

a) U.S. dollar value of exports multiplied by the official exchange rate for 1981 and 1982, and by the intervention exchange rate for 1983-1985.

b) Sales divided by the consumer price index, May 1978/April 1979 = 100.

The amount of product available for export decreased in 1984 and 1985. Estimated sales decreased in 1984 and increased in 1985 due to increases in the intervention exchange rate. However, real sales fell due to overall inflation.

Our estimates of sales do not include the export tax credit provided the industry. In recent years the tax credit has equalled 15 percent of FOB value converted at the lower official exchange rate. Since the credit is payable in 15 months and at zero interest, most exporters sell their tax credit certificates at a 50 percent discount (Parodi, 1985). The net result of the tax credit is five additional sucres for each U.S. dollar of exports, or about 1.0 billion sucres added to our estimate of a year's sales.

Table 16 presents average export prices (FOB) over the decade. We have converted the U.S. dollar prices to sucres at the official and intervention exchange rates to provide estimates of prices received by exporting firms. Once again, the switch to the higher intervention rate in 1983 greatly benefitted exporters. Their price nearly tripled. In real terms, however, the price rose by about 75 percent from 1982 to 1983, and declined significantly through 1984 and 1985.

Table 16. Export Prices, FOB, 1976-1985

Year	FOB Price per pound[a] (US$)	Estimated Exporters' Price[b] (sucres per lb.)	Adjusted Exporters' Price[c] (1978/79 sucres)
1976	2.34		
1977	2.66		
1978	2.55		
1979	3.48		
1980	3.11		
1981	3.14	78[d]	57
1982	3.47	115	75
1983	3.58	307	132
1984	3.44	304	100
1985	3.58	340	86

a) Sources: 1976-1979, Banco Central (1982)
1980-1985, Direccion de Pesca
b) U.S. dollar value of exports multiplied by the official exchange rate for 1981 and 1982, and by the intervention exchange rate for 1983-1985.
c) Sales divided by the consumer price index, May 1978/April 1979 = 100.
d) Average farm price was about 60 sucres/lb (Central Bank, 1982).

Few data are available on the prices paid by packers to farms, so an analysis of price margins cannot be conducted. The Central Bank (1982) study found the average farm price in 1981 to be 60 sucres per pound. If our estimate of 1981 exporters selling price is nearly correct, that leaves a margin of only 18 sucres (30 percent) per pound to cover packing, storage and other costs. If further study shows such thin margins, just covering packers costs, there would be no reason to be concerned about the pricing policy pursued by packers in the industry.

As indicated above, most shrimp have always been exported. Through about 1981, 80 percent or less was exported; but in 1984 about 99 percent was reportedly shipped out of the country.

The principal destination of shrimp exports has been the United States. Only a small fraction of the exports, about 4 percent, are shipped to Japan and Europe. The domestic market for shrimp is small. For a number of years the government required 20 percent to be sold domestically, and in 1983 this requirement was reduced to 4 percent. While the requirement has not been wholly successful, the extent to which it has disrupted marketing activities is not known. Harmful inefficiencies may have been introduced in the system by attempts to enforce this requirement.

Reports of smuggling shrimp to Peru for export are common. The more favorable exchange and tax credit rates in Peru are the apparent cause. The extent of this smuggling is not documented, but some reports indicate it is substantial. Recorded United States imports of shrimp from Peru increased from less than 1000 mt in 1980 and 1981 to over 4,000 mt in 1983. Recorded imports for 1984 and 1985 were 3,000 mt and 2,000 mt, respectively (NMFS, 1986). Some informed observers argue that Peru's small shrimp industry is capable of producing for export no more than 1000 mt on average, and possibly 2000 mt in

good years (such as 1984). The difference of 1000-2000 mt likely is comprised of Ecuadorian shrimp routed through Peru. Therefore, an additional five to 10 percent is likely smuggled out to Peru. This amounts to annual losses to the government of Ecuador of 8 to 15 million dollars in foreign exchange earnings, plus 2.5 to 5 million dollars in tax revenues (resulting from the difference between the intervention and free market exchange rates). An increase in the intervention exchange rate, to significantly reduce the difference with the free market rate, would help greatly to reduce the extent of smuggling.

The development of shrimp cultivation has had a beneficial impact on the processing and export sector. Initially, packers opposed the development of shrimp ponds, fearing pond construction and collection of postlarvae would cause trawler catches to decline. Since then some of the larger packers have become some of the major owners of shrimp ponds. Enaca, the largest shrimp exporter, is a vertically integrated firm with a large trawler fleet and a hatchery. El Rosario, another large exporter, also owns its own hatchery.
The structure of the industry appears to have improved. In 1979, only two firms exported nearly 50 percent of the product. By 1985, the number of firms has grown four-fold and the product is somewhat more evenly distributed among firms.

C. INTERNATIONAL MARKETS

As indicated above, nearly all (96 percent) of shrimp exports are to the United States. Small quantities are shipped to Japan, and occasionally a few to Europe. We next examine the U.S. market.

C.1 U.S. IMPORTS OF ECUADORIAN SHRIMP

In 1976 Ecuador already was the fourth largest supplier of shrimp imports to the U.S., accounting for 4 percent of all U.S. shrimp imports. Mexico was

the largest supplier, with 35 percent, followed by India, with 18 percent, and Panama, with 5 percent.

By 1980, Ecuador had taken over as the second largest supplier of U.S. shrimp imports. Mexico still held a 35 percent share of imports, but Ecuador's share rose to over 9 percent. Panama and India were third and fourth with 6 percent shares.

In 1983, the year of peak production and exports, Ecuador's share climbed to 15 percent. Mexico's share declined to 25 percent, and India was a strong third at 9 percent.

Table 17 lists the quantities and values of U.S. imports of Ecuadorian shrimp. Imports by weight doubled from 1976 to 1980, and increased 2 1/2 times from 1980 to 1983. The quantities imported declined in 1984 and 1985 due to the postlarvae shortage.

Table 17. U.S. Imports of Ecuadorian Shrimp, 1976-1985

Year	Quantity	Value
	(mt)	(US $1000)
1976	4,252	25,627
1977	3,915	23,996
1978	4,975	30,033
1979	6,229	54,483
1980	9,180	68,081
1981	11,243	80,303
1982	16,417	136,509
1983	23,349	218,729
1984	21,183	185,548
1985	19,964	166,087

The value of imports increased by 2 1/2 times from 1976 to 1980, and increased over three-fold from 1980 to 1983.

Average price (the unit value) rose steadily from about $2.75 per pound of tails in 1976 to about $3.35 in 1980, and to about $4.25 in 1983. Price fell to just under $4.00 in 1984, and further to about $3.75 in 1985.

With both quantity and price decreases in 1984 and 1985, overall value fell by nearly 25 percent from 1983 to 1985. Despite the setbacks, Ecuador remained second only to Mexico as the largest supplier of shrimp imports to the U.S.

To better assess these recent trends and prospects for the future, we must examine the U.S. shrimp market in some detail.

C.2 THE U.S. MARKET FOR SHRIMP IMPORTS[3]

The U.S. is the world's leading consumer of shrimp. As one of the most popular seafood commodities throughout the U.S., shrimp is sold in various product forms, including (i) raw tails with the shell on, (ii) raw peeled tails, (iii) breaded, and (iv) canned. Most of product forms (i)-(iii) are marketed frozen.

Imported shrimp tend to flow through the same channels of distribution as domestically produced shrimp. Importers sell to processors, who in turn market their products through brokers and wholesalers. NMFS (1981) reported that three U.S. based importers purchase more than 50 percent of all Ecuadorian shrimp shipped to the U.S. (Two of these firms were known to have sizeable investments in shrimp companies in Ecuador.)

The brokers and wholesalers distribute the shrimp products to institutional and retail outlets. The majority of shrimp reaches U.S. consumers through institutional outlets, i.e. restaurants, hotels, cafeterias, schools, hospitals, and the military. As much as 80 percent of the shrimp

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[3]Unless otherwise cited, the following information is from Newman, et al. (1985). Another useful description is contained in Rackowe (1983).

supply is believed marketed through the institutional trade. The remainder is sold to the final consumer through retail stores, such as fish markets, supermarkets and grocery stores. Most canned shrimp are marketed by the retail sector, and most breaded and raw tails, shell-on shrimp are sold by institutional outlets.

The majority of shrimp imports enter the U.S. as raw tails with shell-on. In 1984, for example, two-thirds of U.S. shrimp imports were of this form. Raw peeled shrimp accounts for most of the rest of U.S. shrimp imports.

Mexico and Ecuador are the two principal suppliers of raw, shell-on imports, with about 30 percent and 20 percent shares by value, respectively. Ecuador's share of this market has grown from 12 percent by value in 1980. Table A.3 presents the available data on these imports.

In the raw, shell-on product form, size is an important market feature. According to a National Marine Fisheries Service survey, the predominant sizes imported were 31-40 during 1980-84. Imports from Ecuador are mainly in this size range.

The U.S. market also appears to distinguish country of origin as an important characteristic of shrimp. Vondruska (1986) found statistically significant differences between Ecuadorian and Gulf of Mexico white shrimp. The prices of Ecuadorian white shrimp in the 26/30, 31/35, and 36/40 sizes average 1.0-1.3 percent lower than the same sizes of Gulf of Mexico white shrimp for the period 1974-1986. West coast Mexican white shrimp, on the other hand, averaged 2-9 percent higher in price than their Gulf of Mexico counterparts. These patterns do not always hold, however. During the second half of 1985 and early 1986, Ecuadorian prices were generally above the prices for Gulf whites. Vondruska does not attempt to explain these price differentials. Perhaps the handling and packing methods used in Ecuador, or the species composition, can account for the differences.

C.3 TRENDS IN THE U.S. SHRIMP MARKET

U.S. consumption of shrimp has grown substantially since the mid-1970s. Total consumption increased from about 450 million pounds of tails in 1976 to an estimated 635 million pounds in 1985 (see Table 18). The growth in both total and per capita consumption since 1980 is attributed to (1) recovery of the U.S. economy, (2) a strong U.S. dollar which has stimulated imports, (3) reduced availability of king and snow crab, and (4) a lack of growth in the Japanese market until 1984 (Vondruska, 1985).

Table 18. U.S. Supply and Use of Shrimp, 1976-1985
(1,000 pounds, heads-off equivalent, and pounds per capita)

Year	Beginning Stocks	Landings	Imports	Total Supply	Ending Stocks	Exports	Consumption Total	Consumption Per Capita
1976	54336	245597	271896	571829	76697	52502	447630	2.073
1977	71697	288443	271811	631951	93950	57919	480082	2.201
1978	93950	256882	240413	591244	64555	66607	460082	2.087
1979	64555	205588	269241	539384	88496	51079	399810	1.793
1980	88496	207868	258069	554433	77587	41059	435788	1.932
1981	77587	218900	259111	555598	64638	43723	447236	1.964
1982	64638	175614	319597	559849	58176	37198	464476	2.020
1983	58176	155592	421179	634946	71482	35936	527527	2.274
1984	71482	188132	422340	681954	61512	26590	593852	2.533
1985	61512	210000E	452232	724000E	61684	26940	635000E	2.690

Data for 1978-85 subject to revision.
E: Landings, total supply, and consumption estimated for 1985.
Prepared by John Vondruska, February 7, 1986.

According to Vondruska, the primary reason for the marked increased in U.S. shrimp imports in 1982-1983 was weakened Japanese demand. In the 1980s, the combination of lower real income growth, a weaker yen, and higher shrimp prices in Japan dampened consumer demand for shrimp.

However, the stronger U.S. dollar may explain much of the growth in imports and consumption in the early 1980s. Exchange rates are known to have played a significant role in international movements of shrimp. The relative exchange rates between, say, Ecuador's sucre and the U.S. dollar and the Japanese yen can determine the destination of export shipments. While domestic supply and demand, along with preferences for certain species and sizes, play a major role in marketing decisions, the exchange rate also is a principal factor. For example, in 1980-1983, when the U.S. dollar began to appreciate faster than the Japanese yen against the Mexican peso, Mexican shrimp exports that historically were sent to Japan were instead shipped to the U.S. (Newman, et al., 1985).

C.4 JAPANESE AND EUROPEAN MARKETS

Ecuadorian exporters have not had much success entering the Japanese market. The Japanese appear to turn to Ecuador only when shrimp from their principal sources are not available. Some sources report that Japanese consumers do not like the species of white shrimp (P. vannamei and P. stylirostris) which constitute most of Ecuador's exports (NMFS, 1981). The small amounts of shrimp regularly shipped to Japan are of deepwater red shrimp (McPadden, 1985).

Very little shrimp is shipped to Europe. A study of European markets has been commissioned, and exporters are trying to gain access to these markets. Much will depend on relative exchange rates (Spurrier, 1985).

D. CREDIT AND FINANCE CONDITIONS

Access to credit to finance investment and production activities is essential for any industry. The available evidence suggests that the shrimp

industry, until recently had little difficulty obtaining loans or attracting investment from abroad.

The Central Bank of Ecuador estimated loans to the shrimp industry in mid-1980 totalled US $300 million. Most loans were through commercial banks. Foreign investors also have played a significant role in Ecuador's shrimp industry. U.S. investment in all segments of the industry is estimated to be US $20-30 million (U.S. Consulate, 1984). Table 19 lists companies with significant U.S. investment. Empacadora Shayne, one of the largest shrimp companies in Ecuador, was reported as being 50 percent owned by U.S. agribusiness entrepreneurs. Empacadora Nacional, one of the largest packers, as of 1981 was a wholly-owned subsidiary of the International Proteins Corporation of Fairfield, New Jersey. U.S. banks and importers of Ecuadorian shrimp have made loans and advance payments to shrimp farmers and packers (NMFS, 1981).

Table 19. U.S. Investment in the Shrimp Industry

Ecuadorian Company	Areas of Activity	U.S. Investor
Empacadora Nacional	Shrimp boats Packing plant Hatchery Farm production	International Protein Corp. Fairfield, NJ
Acuespecies S.A.	Farm production	Amorient Aquaculture Int'l, Laguna Niguel, CA
Langostinos S.A.	Farm production	Castel and Cooke, San Francisco, CA
Frescamar S.A.	Packing plant Hatchery Farm production Feed mill	Morrison Grain Company Salina, KS
Molinos Champion	Farm production Feed mill	Continental Milling Corporation New York, NY

Source: Parodi (1985)

Through November, 1984, low-interest government financing was available. Government interest rates were 2-3 percentage points below commercial rates. In early 1985, however, the lack of short-term credit was perceived as a serious constraint on shrimp farming operations (McPadden, 1985). During 1985, the industry had to borrow at interest rates of 25 percent or higher. By early 1986, the government had made available approximately 100 million sucres for loans to farmers to buy postlarvae (Maugle, 1986). Some sources indicate the assistance was too little and too late, and the funds were not properly applied. Hence, the credit problem was not resolved.

E. GOVERNMENT PROGRAMS AND POLICIES

The Government of Ecuador (GOE) has implemented numerous programs and policies which directly affect the shrimp industry. We now discuss some of the programs and policies as they affect (i) export activities, (ii) shrimp cultivation, and (iii) postlarvae production.

E.1 EXPORT ACTIVITIES

The prevailing system of three exchange rates (official, intervention, and free) effectively works to impose an ad valorem tax of 25 percent or more on shrimp exports. The export tax credit (known as "CAT) has done little to reduce the tax. One result of this policy is to induce under-invoicing of export shipments and the smuggling of shrimp to Peru (with its more favorable exchange rates and CAT). There are at least two ways to reduce or eliminate the under-invoicing and smuggling: one is to increase border monitoring and controls, and another is to reduce the effective tax on exports. The tax may be reduced by either raising the intervention exchange rate closer to the free rate or by increasing the export tax credit and making it payable immediately or with a reasonable rate of interest. The GOE in 1985 increased its

monitoring of export shipments to check that invoices properly show quantity and value. Exporters are being assessed 1 percent of FOB to pay for this added supervision. This fee in effect adds one point to the existing export tax. The details are not clear, but there is a law which until recently provided incentives to shrimp companies which installed a packing plant. Firms are now allowed to substitute installing hatcheries instead of packing facilities in order to quality for incentives. Also, an additional 5 percent export tax credit is being granted to exporters using shrimp which originated in hatcheries. Such incentive policies tend to create distortions and waste in the economy as evidenced by the excess packing capacity that reportedly exists.

E.2 SHRIMP CULTIVATION

Perhaps the most important policy affecting shrimp cultivation is the granting of concessions for the use of land in the intertidal zone on which to build and operate shrimp farms. Above we discussed the need to extend the life of these concessions.

LiPuma and Meltzoff (1985) observe that the current policy of granting royalty-free concessions induces extensive farming methods and the destruction of an excessive amount of mangroves. A land tax or royalty would encourage more intensive farming practices, reduce the excessive destruction of mangroves, and be a relatively easy tax to administer.

E.3 POSTLARVAE PRODUCTION

The postlarvae shortages in 1984 and 1985 stimulated pressure on the GOE to take a variety of actions, including protecting wild stocks and assisting the development of hatcheries. We leave for others to analyze the measures taken to protect the wild stocks.

The policy to provide certain incentives for shrimp companies to construct hatcheries may, as stated above, introduce distortions and waste in the economy. Without more details on how the incentive policy works we cannot analyze its likely consequences in detail.

There is a legitimate role (from an economics perspective) for government to engage in research and training regarding hatchery methods. However, there is not a legitimate governmental role in the production of postlarvae for commercial use. This is best left to the private sector. The available evidence does not indicate to what extent the GOE is involved in hatchery research, training, and production. Therefore, we cannot evaluate these programs and policies.

There are reports that the GOE has lifted its earlier bans on the importation of postlarvae and Artemia. Usually, artificial barriers to trade are not useful and can only mitigate economic progress in the long run. Lifting such import (as well as export) barriers is good for the industry and good for Ecuador. Barriers or controls are warranted, for example, to prevent the transmission of disease by imported postlarvae.

IV. THE CURRENT SITUATION AND OUTLOOK

In this short section we summarize the present conditions in the industry and attempt to identify a few trends likely to appear in the near future. Our discussion covers production and trade.

A. PRODUCTION

The cultivation sector is now the dominant source of shrimp production. Pond capacity currently exceeds the amount that can be stocked with the quantities of postlarvae available. The supply of wild postlarvae varies with environmental conditions and cannot be expected to fully supply shrimp farms' needs (except during El Nio events when they are in great abundance) in the long term. Hatchery production of postlarvae must and will supply the balance. Whether hatcheries will someday produce significant quantities postlarvae depends both on technical and economics considerations. The principal technical consideration is when and how the local industry will solve the maturation cycle. The economics considerations are whether the cost of hatchery production will be low enough (relative to price) to support large levels of postlarvae production.

When the problem of postlarvae supply is resolved, the most scarce production input may become land. What land is suitable for cultivation depends on infrastructure (e.g., access to roads) and economics (e.g., costs of pumping water), among other things. If land does become a limiting factor we can expect to observe more intensive cultivation methods adopted, to the extent that the market can support the higher costs of such methods.

Offshore production of white shrimp is expected to remain at modest levels, varying as hydrographic conditions change. Little change is expected in this sector.

B. TRADE

As production expands, trade will expand. Our first concern is how the structure of the trading (export) sector can be expected to change. At present there is some degree of vertical integration, extending from production through U.S. based import businesses. Whether we will see more or less such vertical integration in the future is unclear without further study. Some government policies (e.g., the incentives law) may inadvertantly encourage uneconomical vertical integration. How much concentration (the share of product marketed by a few firms) we will likely see in the future is also unknown without further investigation.

Our second concern is the future condition of the U.S. shrimp market. Most signs indicate a growing U.S. market over the next few years. Newman, et al. (1985) project U.S. import demand for shrimp out to 1990. Using an econometric model, they project imports of shrimp to increase from the 1983-84 average of 342 million pounds to a range of 390-413 million pounds by 1990. This represents an expansion in import demand of from 12 to 17 percent. If these projections are realized, Ecuador could increase its exports to the U.S. to about 57 million pounds (26,000 mt) and retain its 14 percent share of U.S. imports. It appears the U.S. market can comfortably absorb any reasonable increases in Ecuadorian shrimp production and exports.

Newman, et al., also attempted to project prices of imported shrimp, but could not do so reliably. However, they note historical patterns suggest real shrimp prices will likely rise over the period 1985 to 1990. In their analysis, they assume real prices increase at an average annual rate of 3.5 percent, somewhat lower than the long-run trend in shrimp price increases.

Currency exchange rates are an important determinant of trade flows and of earnings by exporters and producers. Changes in exchange rates are impossible to forecast. The recent softening of the U.S. dollar against the year and other currencies may induce more shrimp exports to Japan and Europe. The future prospects for Ecuadorian shrimp in these markets are unknown.

V. RECOMMENDATIONS

We end with recommendations for policy changes and future research.

A. POLICY

1. Reduce incentives to smuggle.

Current official export policies make smuggling shrimp to Peru for export very attractive, and result in significant losses to the Government of Ecuador. We recommend increasing the intervention exchange rate and/or increasing the export tax credit rate. Terms of payment of export credit should be either immediate or with an appropriate rate of interest.

2. Extend the term, or make renewal automatic, of land concessions.

The current 10-year term of land concessions is likely too short, promoting inefficient use and waste. An extended term, e.g. 30 years, would provide more secure land tenure and induce more efficient use of land resources. Making renewal automatic, subject to certain reasonable conditions being fulfilled, would accomplish the same end.

B. RESEARCH

1. Establish an information system and on-going data base.

Too little data presently exists on shrimp cultivation activities. The following data will be needed to properly monitor and study the industry:

(i) The number of operating firms and hectares of nursery and growout ponds of each farm.

(ii) The number of hectares of ponds actually stocked throughout the year.

(iii) Annual production rates of each farm.

(iv) Postlarvae prices, at the beach and farm.

A system to collect, process and store these data should be established by government or industry.

2. Costs and earnings of farms.

An in-depth survey of a representative cross-section of farms is needed. The survey should collect basic data on fixed and variable costs, sales, input quantities (postlarvae, fuel, feed, fertilizer) for a year. Information on production practices, farm size and land type also should be collected. The data and information should be analyzed to assess the profitability (or lack of) of different farm sizes, production methods, locations, etc. The results of a comprehensive, systematic costs and earnings study will indicate which types of farms are more successful, and would help guide the industry in its future growth. It will also allow industry and government to better assess future prospects for the industry.

3. Postlarvae demand.

Postlarvae shrimp constitute the single most important input for shrimp cultivation. The future success of the industry depends on commercially viable hatcheries. The degree to which hatcheries will be commercially viable depends on how much postlarvae farms are likely to demand and how much farms are willing and able to pay for postlarvae. Therefore, in conjunction with the costs and earnings study, we recommend an analysis of demand for postlarvae.

4. International market conditions.

Since the shrimp industry is export oriented its future fate depends on conditions in the shrimp markets of the U.S., Japan and Europe. Detailed studies of each of these markets and of shrimp cultivation developments in other tropical countries (e.g., Brazil, Philippines, India) will help to keep the Ecuador shrimp industry abreast of long-term trends. Such information should be invaluable for guiding future investments and marketing strategies of the local industry.

5. Product quality.

Ecuadorian shrimp often command a lower price than their U.S. and Mexican counterparts. Is this due to quality? Can changes be made to improve quality and prices of Ecuadorian shrimp in the U.S. market? Studies to answer these questions would bring obvious benefits to Ecuador.

6. Structure and organization of the industry.

The shrimp industry currently exhibits extensive vertical integration, while the degree of concentration appears not great at present. We propose studies to investigate the following questions: What are the consequences for Ecuador of the current vertical integration, and can we expect more or less of it to occur in the future? Similarly, can we expect more or less industry concentration of production in the future and what will be the consequences? Other issues concern the extent ~~of~~ and consequences of excess capacity and the susceptability of the industry to boom-bust cycles.

Table A.1. Exchange Rates, 1981-1985 (in sucres per dollar)

	1981	1982	1983	1984	1985
OFFICIAL					
January	24,80	24,80	33,00	54,90	66,50
February	24,80	24,80	33,00	56,40	66,50
March	24,80	24,80	42,20	57,90	66,50
April	24,80	24,80	43,00	59,43	66,50
May	24,80	29,56	43,84	60,95	66,50
June	24,80	33,00	44,90	62,48	66,50
July	24,80	33,00	46,45	64,00	66,50
August	24,80	33,00	48,00	65,55	66,50
September	24,80	33,00	49,50	66,49	66,50
October	24,80	33,00	51,05	66,50	66,50
November	24,80	33,00	52,55	66,50	84,55
December	24,80	33,00	54,10	66,50	95,00
INTERVENTION					
January				88,97	95,00
February				88,92	95,00
March			70,00	88,92	95,00
April			77,00	88,35	95,00
May			79,20	89,31	95,00
June			85,80	88,46	95,00
July			90,40	89,75	95,00
August			89,40	95,37	95,00
September			86,40	95,60	95,00
October			82,80	95,00	95,00
November			84,20	95,00	95,00
December			87,00	95,00	95,00
~~FULL~~ FREE					
January	28,71	34,45	65,95	89,26	119,21
February	29,47	35,33	70,72	89,10	120,13
March	30,18	40,14	78,39	89,08	118,80
April	30,16	42,72	81,92	88,75	114,81
May	30,57	44,75	82,89	89,49	113,83
June	30,28	53,28	92,21	88,85	111,08
July	28,63	61,69	95,96	90,37	108,63
August	30,57	54,71	93,65	96,01	104,62
September	32,10	57,62	86,86	100,48	109,37
October	32,88	59,33	83,47	108,34	114,66
November	34,01	58,30	83,68	117,58	121,73
December	33,23	62,90	86,50	117,70	124,39

Source: Banco Central del Ecuador.

Table A.2. Consumer Price Indices (May 1978/April 1979 = 100)

	1981	1982	1983	1984	1985
January	124,4	145,1	186,1	278,6	362,0
February	128,0	146,3	190,6	283,6	366,2
March	131,7	148,1	196,4	290,6	372,9
April	133,5	150,2	205,9	298,0	383,9
May	136,2	151,7	220,3	301,7	388,5
June	136,8	153,9	233,0	303,7	396,1
July	137,1	156,9	245,5	307,3	402,3
August	137,8	159,8	255,2	313,0	403,1
September	139,0	162,2	265,1	317,9	406,6
October	140,4	169,3	272,7	324,9	408,9
November	142,9	174,9	272,1	334,5	414,1
December	143,4	178,4	270,0	340,2	423,1

Source: Instituto Nacional de Estadisticas y Censos (INEC)

Table A.3. U.S. Imports of Shrimp, Shell-on, by Principal Sources, 1980-84

Source	1980	1981	1982	1983	1984
	Quantity (1,000 pounds)				
Mexico	57,669	49,506	61,836	65,316	63,925
Ecuador	18,126	23,627	34,402	49,526	45,634
Panama	13,107	14,746	17,454	15,349	15,657
Brazil	3,321	4,519	5,954	6,454	12,319
Salvador	4,571	6,073	7,210	4,707	8,504
Taiwan	615	758	1,794	5,319	5,754
Peru	1,475	1,910	2,949	9,130	5,482
Venezuela	3,872	1,592	2,027	2,059	4,908
Colombia	2,241	2,452	2,527	2,426	3,258
Guyana	4,177	1,684	2,016	4,127	3,471
All other	29,576	34,085	43,158	52,537	56,783
Total	138,750	140,953	181,329	216,950	225,696
	Value (1,000 dollars)				
Mexico	244,219	213,311	296,505	294,046	285,054
Ecuador	62,374	78,204	131,606	212,157	183,028
Panama	44,961	52,809	60,838	57,362	60,472
Brazil	10,054	12,189	23,450	26,689	47,136
Salvador	15,282	19,860	25,878	16,896	23,503
Taiwan	1,878	1,967	4,992	16,585	22,120
Peru	3,999	5,698	9,568	35,370	20,990
Venezuela	15,986	6,530	9,126	8,666	19,676
Colombia	10,272	11,213	13,562	14,478	17,793
Guyana	12,583	6,143	10,936	23,054	17,649
All other	97,609	112,329	146,868	191,002	216,573
Total	519,217	520,253	733,328	896,306	913,993
	Unit value (per pound)				
Mexico	$4.23	$4.31	$4.80	$4.50	$4.46
Ecuador	3.44	3.31	3.83	4.28	4.01
Panama	3.43	3.58	3.49	3.74	3.86
Brazil	3.03	2.70	3.94	4.14	3.83
Salvador	3.34	3.27	3.59	3.59	2.76
Taiwan	3.05	2.60	2.78	3.12	3.84
Peru	2.71	2.98	3.24	3.87	3.83
Venezuela	4.13	4.10	4.50	4.21	4.01
Colombia	4.58	4.57	5.37	5.97	5.46
Guyana	3.01	3.65	5.43	5.59	5.08
All other	3.30	3.30	3.40	3.64	3.81
Average	3.74	3.69	4.04	4.13	4.05

Source: National Marine Fisheries Service, Newman, et al. (1985).

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SHRIMP MARICULTURE DEVELOPMENT AND COASTAL RESOURCE MANAGEMENT: LESSONS FROM ASIA AND LATIN AMERICA

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Contribution to
"Development of an Integrated Management Strategy for
Shrimp Mariculture in Ecuador"

Coastal Resources Management Project
University of Rhode Island
United States Agency for International Development

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SHRIMP MARICULTURE DEVELOPMENT AND COASTAL RESOURCE MANAGEMENT: LESSONS FROM ASIA AND LATIN AMERICA

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I. INTRODUCTION

In the span of less than two decades, shrimp mariculture has become established as a significant source of foreign exchange earnings for a small number of tropical developing countries. The rapid expansion of shrimp mariculture also has had a significant impact on coastal resource use patterns in many countries. The broad purpose of this report is to review and discuss coastal resource management problems stemming from shrimp mariculture development in Asia and Latin America, and assess the effectiveness of steps which have been taken to mitigate these problems.

The study is based on an extensive literature review and nine years field experience in Southeast Asia. Approximately half of this time has been spent studying coastal resource use and management in Malaysia, the Philippines, and Indonesia. During 1983 I visited Ecuador as a member of a team from Woods Hole Oceanographic Institution that was invited by a Presidential High Level Commission to examine coastal resource management issues in the Galapagos Islands. During that visit, I met with several staff members of the Instituto Nacional de Pesca and the Escuela Superior Polytechnica del Litoral to discuss development and management of the shrimp mariculture industry.

Preparation of this report has benefitted from the assistance of two Auburn University graduate students with knowledge of shrimp mariculture and coastal resource management. Mr. Munirrudin Mullah is a fisheries

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biologist from India working on his doctorate in the Department of Fisheries and Allied Aquacultures; he is preparing to conduct dissertation research on penaeid shrimp mariculture in India later this year. Mr. James Seger received his Masters degree in marine affairs from the University of Washington, where he focused on aquaculture planning in the Third World. Mr. Seger currently is working towards his doctorate in Agricultural Economics.

II. OVERVIEW OF TROPICAL SHRIMP MARICULTURE DEVELOPMENT

This section provides a descriptive summary of tropical shrimp mariculture developments in Asia, Latin America, and Africa, and discusses future industry trends based on investor activity and government policy among countries in those regions. Regional and national comparisons on pond area, productivity, and type of production system are summarized in Table 1.

A. East Asia

Mariculture of penaeid shrimp in both Japan and Taiwan is based on highly intensive culture systems. In Japan, production costs are as high as US$25.50 per kg (Mock, 1983). The industry is geared to a small luxury market for live shrimp. Shrimp mariculture in Taiwan is less intensive and less costly, though at US$ 5.00 per kg production costs are roughly five times that of Ecuador (Mock, 1983). Like Japan, Taiwan produces high quality shrimp for domestic markets. High production costs are likely to limit Taiwan's role as a supplier in the international market for shrimp.

Clearly the Chinese aquaculture tradition is not limited to Taiwan. However, the focus of aquacultural development within the People's Republic of China has been on freshwater fish for domestic consumption,

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and not on shrimp mariculture. Considering mariculture generally, a UNDP report concluded that "This is an area of aquaculture in which China is not very advanced..." (UNDP, 1979:39).

The People's Republic of China currently is undergoing a major reorientation of its economic structure to encourage greater private initiative. China desires to increase foreign exchange earnings in order to proceed with modernization of its economy. The implications for this in regards to shrimp mariculture at this time are still unclear. It is known, however, that China has entered into a joint venture enterprise with a Japanese company (NMFS, 1985a), and that a private company in China is soliciting a U.S. partner for a shrimp mariculture joint venture (NMFS, 1985c).

B. Southeast Asia

Like East Asia, Southeast Asia also has a long-established aquaculture tradition. Coastal mariculture throughout the region can be described as extensive polyculture of milkfish (*Chanos chanos*) and penaeid shrimp (primarily *P. monodon* and *P. merguiensis*). Until comparatively recently, ponds were stocked primarily through tidal action. Milkfish fry, shrimp PLs, and other marine organisms were trapped and held until harvest. Low population densities, little if any pond fertilization, and the absence of supplemental feeding resulted in low yields. However, production costs also were low.

By the early 1970s, intentional stocking of both milkfish and penaeid shrimp had been introduced but was not yet common (Ling, 1973). Production at this point still was oriented primarily towards milkfish production for domestic markets. During the 1970s, however, marine shrimp landings throughout the region tappered off amid mounting evidence of over-exploitation of demersal resources (Pauly, 1979). By the early

1980s, Southeast Asian governments and international donors had identified shrimp mariculture as a major growth industry and source of foreign exchange earnings.

Southeast Asia's coming thrust into shrimp mariculture should be taken seriously. Current estimates indicate that over 400,000 hectares of brackishwater ponds are in production using extensive polyculture systems. As indicated by the figures presented in Table 1, this total could double or even triple. Development along this line, however, is not likely to be as significant as efforts to achieve incremental improvements in the productivity of existing ponds.

The Asian Development Bank and the World Bank currently are supporting shrimp mariculture projects in Indonesia, Thailand, the Philippines, Sri Lanka, Malaysia, and Bangladesh. Scura (1985) notes that these two multilateral donors are planning to commit more than US$200 million to development of Asian aquaculture. This level of investment in an already well-established industry could have a major impact on world markets. Although some of these projects will encourage adoption of semi-intensive production systems, it is likely that most Southeast Asian producers will continue using an extensive culture system modified somewhat by low levels of artificial stocking and supplemental fertilization and/or feeding.

There are exceptions to this pattern. Thailand's shrimp mariculture industry includes a few large firms with in-house hatcheries that are producing shrimp on a semi-intensive basis (American Embassy, Bangkok, 1986; Pedini, 1981). One large private hatchery producing 45 million *P. monodon* PLs per year is the recipient of a loan from the International Finance Corporation, a subsidiary of the World Bank. In Malaysia, the government is encouraging private sector investment in shrimp mariculture

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by granting "pioneer status," a five year tax holiday or investment credit of up to 100 percent, a subsidized loan program for producers, and an abatement of income subject to tax for exporters (American Embassy, Kuala Lumpur, 1986).

Southeast Asian nations are major suppliers of shrimp to the international markets. During the period 1978-1981, the combined average annual value of shrimp exports from Indonesia, Malaysia, Singapore, Thailand and the Philippines was approximately US$400 million (Floyd, 1984). Indonesia alone accounted for roughly half this figure. More recent FAO data suggest that exports from this region increased during 1982 and 1983 (FAO, 1983).

Japan is by far the major importer of Southeast Asian shrimp. The reasons for this have less to do with consumer preference for Asian species of penaeid shrimp than with linkages established through more generalized patterns of international trade. Japan is Asia's 'economic colossus of the north,' a fact reflected in volume of trade and frequency of sailings between Japan and tropical developing countries of Asia. Japan has a long history of involvement in the fisheries of Asia and this continues today in the form of joint venture enterprises which capture, process, and export shrimp to Japan. Many independent shrimp exporters from Southeast Asia also are linked to Japanese buyers through credit obligations (Angell et al., 1985).

Most shrimp producers in Asia are linked to Japan for the time being. This may not always be the case, and there is considerable interest among producer nations in diversifying market outlets, including expanding sales to the U.S. However, before they are able to do so they must overcome quality control problems. Countries in this region have had difficulty marketing in the U.S. because the Food and Drug Adminstration (FDA) has detected persistent problems with bacterial and other forms of

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contamination. As a result, shrimp from the region often are very carefully tested before being released, resulting in expensive delays and frequent rejections (Bailey, et. al., 1984). Once these problems are overcome, there is no reason to expect that *P. monodon* and *P. merguiensis* will have any difficulty in achieving consumer acceptance in U.S. markets. *P. merguiensis* is a medium-sized white shrimp that U.S. consumers will find indistinguishable from *P. vannamei* and *P. stylirostris*. The larger tiger prawn (*P. monodon*) is more distinctive, but already has established acceptance among U.S. consumers.

C. South Asia

India and Bangladesh have established shrimp mariculture industries based on extensive cultivation methods involving natural stocking through tidal action. Both countries appear poised to expand the area devoted to shrimp mariculture and to increase productivity through selective improvements which will retain the essentially low-cost nature of the industry.

India has a long established position as the worlds leading exporter of high quality shrimp. In 1985, India exported over 55,000 mt of frozen shrimp valued at US$ 275 million (Marine Products Export Development Authority, 1986; see also the Newsletter of The World Aquaculture Society, Vol. 17, No. 1 [1986], p. 6). This figure represents 86% of the total value of fisheries exports. Exports of dried and canned shrimp were insignificant, accounting for less than 0.1% of export value. Marine capture fisheries account for almost all of the supply serving this trade.

Along both the east and west coasts of India, extensive shrimp mariculture frequently is conducted in rotation with salt-tolerant rice varieties grown in reclaimed coastal land. After the rice harvest, the sluice gates are opened to allow for natural stocking of fish and shrimp through

tidal action. Large areas (in some cases several hundred hectares) are inundated at the same time. No supplemental feeding is used and management inputs are minimal. Minimal labor costs are incurred, and these come mainly during harvest, which is accomplished by draining the fields. Productivity per hectare is low and could be improved, but costs of production are extremely low.

India is in a position to maintain its leadership in shrimp export markets through mariculture development. Since the 1960s, when shrimp exports became a major growth industry, considerable research effort has been devoted to understanding the biology of major indigenous species (especially *P. monodon* and *P. indicus*). As a result, a solid foundation has been established for research focused on mariculture of these species. The goal of this research has been to develop simple technologies that require low input levels but which will improve yields and profits. The government is focusing most of its attention on developing small-scale shrimp mariculture operations. Farmers owning 5 hectares or less are eligible for low interest loans to finance land aquisition or pond construction. Some programs include a subsidy of between 25% and 33% for construction costs. A separate program is designed to provide working capital to small-scale producers.

The government of Bangladesh has identified shrimp mariculture as an important source of foreign exchange earnings and offers exporters a transferable permit to import goods up to 80% of the exported value (American Embassy, Dhaka, 1986). Shrimp is Bangladesh's second most important export commodity (Kibria, 1985). The production system resembles that of India described above. Both the World Bank and the Asian Development Bank are reported to be planning to provide financial assistance for shrimp mariculture development (Scura, 1985). Like India,

shrimp mariculture in Bangladesh will continue to be based on low-cost extensive production practices.

Sri Lanka also is developing a shrimp mariculture sector with the assistance of foreign investors (American and Taiwanese) and international development assistance (Asian Development Bank). Government incentives to the shrimp mariculture industry include a five year tax holiday on profits arising from exports, and income tax exemption for dividends paid to shareholders of qualified companies during this period (American Embassy, Colombo, 1986). Chamberlain (1985c) reports that there already are two operational hatcheries. The American Embassy in Colombo (1986) reports that one of these hatcheries was established as an experimental facility to develop hatchery feeds.

D. Latin America

Shrimp mariculture in Latin America differs markedly from that of Asia. In most parts of Latin America coastal mariculture is a new adaptation made attractive by export markets. Export opportunities clearly are an important spur to continued development in Asia, but this expansion will build on a long tradition of mariculture experience. In most parts of Asia, a high proportion of the population lives in coastal areas, and coastal resources tend to be exploited with a high degree of intensely. In contrast, in most parts of Latin America, the population is concentrated in the interior and coastal resources generally are less heavily exploited than in Asia. These differences contribute to the relatively large size of individual Latin American mariculture farms compared to those in Asia. The scale of mariculture operations in Latin America is consistent with the *latifundia* tradition of large holdings in much of the region's the agricultural sector.

Table 2 provides one estimate of projected shrimp mariculture

production in Latin America by 1990. Ecuador is expected to remain the dominant force within the region, but other nations will begin to compete for market share.

After Ecuador, the Latin American countries with the greatest long term potential for shrimp mariculture are Brazil and Mexico. Mock (1982) reports that a solid research infrastructure has been established to support development in Brazil. Scott (1985) notes that the Brazilian government is willing to provide a variety of incentives to attract investors. Scott also reports Brazil has a number of well established hatcheries and is likely to be self sufficient in hatchery produced PLs. He notes that the high cost of feed is the single most important factor constraining growth.

Mexico may have greater potential for development of shrimp mariculture than Table 2 would suggest. Difficulties being experienced within that nation's economy may slow growth in the short term. Under current law, all development of shrimp fisheries, including shrimp mariculture, are activities reserved for cooperatives and not private farms. Under these conditions, it is likely that the current extensive system of shrimp mariculture (practiced by closing off lagoons) will continue as the dominant production system .

E. Africa

Shrimp mariculture has yet to become an established industry in any African nation. Coastal aquaculture is a traditional enterprise in many countries and includes the use of earthen ponds and brush parks in lagoons (Coche, 1982). A wide range of species are grown, most of which are finfish for domestic consumers. For the most part, production is based on extensive methods.

Ardill (1982) notes that preliminary plans were being made to construct shrimp ponds in Madagascar (200 ha) and Kenya (50 ha). Extensive

areas in several nations (Madagascar, Ivory Coast, Benin, Ghana, Nigeria, and Kenya) are physically suited to shrimp mariculture, and competing land uses may not be as great as elsewhere in tropical developing countries. Despite this potential, it is difficult to imagine African shrimp producers having a significant impact on world markets in the foreseeable future.

F. Summary

In 1983, the U.S. passed Japan as the world's leading importer of shrimp, though in terms of total import value and per capita consumption Japan remains the leader (Rackowe, 1984). The U.S. and Japan together absorb approximately two-thirds of total world shrimp exports. Rackowe (1983) estimated that by 1990 additional supplies produced by shrimp mariculture would begin having a significant impact on world markets. Indeed, at present it is clear that this impact already is being felt in the U.S. and is having the effect of holding down prices (Prochaska and Keithly, 1984). This is, then, a very good time for Ecuador to take stock of her shrimp mariculture industry and determine future development directions.

The above review of shrimp mariculture development indicates significant investment in this industry in Asia and Latin America. Table 3 contains data comparing estimated 1986 shrimp mariculture production with projected production in the year 2000. These figures suggest that by the turn of this century harvests of cultivated shrimp will more than double.

III. MANAGEMENT OF PHYSICAL AND BIOLOGICAL RESOURCES

In this section consideration is given to problems of managing physical and biological resources in coastal areas where shrimp mariculture development has or is occuring. The purpose is to synthesize this international experience for the benefit of public and private decision makers within Ecuador.

A. Dimensions of the Problem

Throughout the tropics, industrialization, urbanization, increased use of agricultural chemicals, and other consequences of economic development have resulted in widespread environmental stress and degredation. Coastal areas in particular have been heavily affected because (1) they are the downstream recipient of organic and inorganic pollutants and (2) these very processes are most pronounced in the coastal zone. To the extent that these resources are destroyed or degraded, future development opportunities are limited or foreclosed.

Many coastal resource management problems are attributable to a narrow sectoral approach to development planning and the consequent failure to recognize environmental linkages and potential adverse effects. For example, soil erosion caused by opening of new land for agricultural production may result in excessive sedimentation in coastal wetlands. Run-off from agricultural chemicals may affect water quality and negatively affect shrimp mariculture. Conversion of coastal wetlands to other uses (e.g., maricultural or agricultural production) also affects habitat of critical importance to valuable marine species. Urban and industrial pollution of coastal waters (e.g., chlorinated hydrocarbons, petroleum products, heavy metal and other industrial pollutants, and untreated domestic sewage) all reduce environmental carrying capacity and preclude certain development options, including mariculture.

B. Mangrove Habitat

Mangroves provide structure and stability in an otherwise featureless and fluid zone. Mangroves are highly complex and productive ecosystems which serve a wide variety of useful functions. These include (1) preventing coastal erosion and encouraging soil deposition (2) providing food, shelter, and sanctuary for birds and mammals, (3) providing spawning, nursery and forage areas for numerous finfish, crustacean, and mollusc species; and (4) providing a source of building materials, food, firewood, charcoal, and other products for local human populations.

In most humid tropical regions where mangroves exist, local populations utilize the resources found therein for a variety of purposes and have done so over long periods of time (Bailey, 1983; Hamilton and Snedaker, 1984; Peterson and Schmittou, 1985; Snedaker et al., 1986). Despite the intensity with which local populations have exploited mangrove resources, until recently national and international development policymakers regarded mangroves as wastelands which contributed little to national development. Inadequate knowledge and appreciation of the value of mangrove resources may explain past actions which resulted in massive destruction of mangrove for timber, land reclamation (for agricultural or other purposes), or conversion to shrimp ponds. Today, however, the excuse of ignorance is wearing thin given overwhelming scientific evidence that healthy mangroves and other coastal ecosystems are vital to sustainable coastal development.

Those concerned with sustainable development of shrimp mariculture have particular cause for concern regarding destruction of mangrove habitat. Despite efforts to establish hatcheries in most major shrimp producing nations, in the foreseeable future PLs captured in the wild are likely to remain the most important source of stocking materials. Convincing

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evidence exists that mangroves serve as critically important habitat for shrimp in the post-larval and juvenile stages of their life cycle (von Prahl, 1978; Martosubroto and Naamin, 1977; Turner, 1977; Turner, 1985; Turner, 1986). Destruction of mangrove habitat is likely to exacerbate existing PL shortages, which are the primary constraint to increased shrimp mariculture production in many countries, including Ecuador.

C. Southeast Asian Mangroves

Throughout Southeast Asia, coastal resources are under heavy pressure. As a region with a strong maritime tradition, the coastal zone always has supported relatively large populations. Over the past several decades, the relative proportion of the population living within a short distance of the sea has increased. Many landless agricultural workers and others seeking to improve their fortunes have moved to the coast, where access to important natural resources is not restricted by private ownership. In general, these conditions of "open access" characterize both mangroves and inshore fishing grounds.

Given long-standing familiarity with coastal resources, and the growing importance of these resources, we might expect Southeast Asian nations to have in place well-established resource management programs. However, such is not the case, though over the past decade most countries have attempted to establish such programs. These efforts are reviewed with the object of identifying common achievements and constraints.

1. The Philippines

Brackishwater ponds in the Philippines were established primarily to grow milkfish (*Chanos chanos*), with harvests of penaeid shrimp an incidental bonus. Existing ponds were developed almost exclusively from mangrove areas, and any further expansion will be at the expense of mangrove forests (Peterson and Schmittou, 1985). Siddall et al. (1985) note

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that prior to the 1970s, mangroves were considered to have little value in the Philippines. Permits to convert mangrove into brackishwater ponds typically received *pro forma* approval. During the period 1952-1972 brackishwater ponds more than doubled in area from 88,681 hectares to 174,101 hectares (Peterson and Schmittou, 1985).

During the early 1970s, preliminary scientific evidence (e.g., Odum, 1972) became available indicating that mangrove ecosystems were highly productive and supported a wide range of economically important activities, including commercial fisheries for shrimp and other valuable marine organisms. A series of restrictions were imposed during the 1970s and in the next ten years the conversion of mangrove slowed dramatically; between 1972 and 1982, only 2,130 hectares of new ponds were created (Peterson and Schmittou, 1985). During this time mangroves became a public trust to be administered jointly by the Bureau of Forest Development (BFD) and the Bureau of Fisheries and Aquatic Resources (BFAR). Both BFD and BFAR are agencies of the Ministry of Natural Resources (MNR).

Current regulations stipulate that approval to convert mangrove into fishponds first has to be obtained from the BFD, which then turns administrative control over to the BFAR. Final approval for development is granted by the MNR. Leases are granted for 25 year terms and may be renewed for an additional 25 year period. Leasees are given 5 years to develop their holdings or forfeit their lease. Regulations also stipulate that no ponds may be established within a "greenbelt" which includes 40 meter strips along rivers and other inland waters, and 100 meter strips facing bays and the sea. The purpose of this greenbelt is to preserve important features of the mangrove habitat which are of particular value to wild populations of shrimp and other marine organisms. The assumption is that shrimp PLs and juveniles seek shelter and food along the fringe of mangrove

forests and are less dependent on the condition of mangroves further inland. The intent of this action was to strike a balance between mariculture development and habitat preservation. This also appears to be the case with a regulation which required leasees to plant trees extending at least 20 meters from the edge of tidal streams.

Siddall et al. (1985) report that the effectiveness of these measures has suffered due to administrative weaknesses within the BFD and the BFAR. When examining resource management issues in the Philippines, it is necessary to realize that well-meaning policies established at the national level often have little to do with what happens at the provincial or sub-provincial levels. From personal experience in the Philippines, I would suggest that a primary cause of "administrative weakness" is corruption. It remains to be seen when or if the administration of President Aquino will be able to overcome this problem.

2. Indonesia

Like the Philippines, brackishwater aquaculture in Indonesia is well established and based on extensive polyculture of milkfish and shrimp. Much of the existing area devoted to brackishwater aquaculture originally was in mangrove, and most opportunities for future expansion of pond area are to be found in mangrove areas. Estimates of mangrove abundance range from 1.6 million hectares to 6 million hectares. However, the best estimate is that Indonesia has approximately 3.8 million hectares of mangrove, more than any other nation (Burbridge and Koesobiono, 1982). Over half of this total (2.9 million hectares) is located on the Indonesian portion of New Guinea (Irian Jaya). Sumatra and Kalimantan also have extensive mangrove forests. The enormous area of mangrove forests in Indonesia is, however, misleading when considering potentials for aquaculture development. A large portion of this area is found in very remote locations where human

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populations are sparse and necessary supportive infrastructure (roads, electricity, ports, etc.) does not exist.

The Indonesian government is pursuing a policy of expanding brackishwater pond construction, primarily within those areas where this industry already is well established. During the current Fourth Five Year Plan (1983/84 to 1988/89), government plans include opening up of 100,000 hectares of new brackishwater ponds for shrimp mariculture and intensifying production on 120,000 hectares of the existing 194,000 hectares (Republic of Indonesia, 1983). Some areas where new ponds are to be established appear to be unsuitable (Burbridge and Maragos, 1985), but there is little doubt that Indonesia is commited to expand shrimp mariculture.

As is the case in the Philippines, jurisdiction over mangrove forests is divided between government agencies separately responsible for fisheries and forestry. The Ministry of Forestry and the Directorate General of Fisheries (DGF) both agree that there should be a "greenbelt" of mangrove, but these agencies disagree on the dimensions of this protected area. This debate, which began during the 1970s when Forestry and Fisheries both were under the same Ministry (Agriculture), has moved no closer to resolution since Forestry was established as a separate Ministry. The Ministry of Forestry argues that a 50 meter "greenbelt" is sufficient to protect fisheries interests, and claims exclusive jurisdiction over all else. The DGF argues that a 400 meter "greenbelt" is necessary.

The DGF's view of mangrove forests reflects that agency's sectoral interests. In principle, the DGF position is that mangroves contribute to sustainable marine fisheries yields and should therefore be protected. However, the DGF should not be mistaken as a conservationist agency; indeed, a major program thrust is to extend brackishwater aquaculture, and

in particular shrimp mariculture, into new areas. Turner (1985) documents an example from Java where the DGF is planning to establish shrimp mariculture in the only area along the entire south coast where extensive mangrove forests exist. This particular mangrove supports a major shrimp fishery and a thousands of small-scale fishermen.

Development takes priority over resource conservation and management in policies affecting mangrove and other tidally influenced swamp lands not only in support of shrimp mariculture development, but also for programs of land reclamation for agricultural purposes. Vast areas have been drained to provide land for rice cultivation under government sponsored transmigration schemes. In many cases, these lands are agriculturally marginal and it is not certain that their use for agriculture can be sustained (Burbridge and Maragos, 1985). Acid sulphate soil conditions frequently are encountered. No adequate studies have been made regarding the impact of this development on related ecosystems, including estuarine and coastal fisheries. Burbridge and Maragos (1985:78) conclude: "As a result of the failure to coordinate and integrate development policies and to regulate the exploitation of coastal resources, the ability of coastal resource systems to sustain development is being eroded."

In his review of Indonesian coastal resource management, Burbridge (1983) examined the "greenbelt" concept and found it seriously flawed as a management tool. His basic concern was that proposals to create a uniform "greenbelt" ignored the qualitative differences between mangrove and so failed to safeguard the multiple use qualities of this resource. He called for a more flexible approach in defining mangrove management units which would protect estuarine and deltaic mangrove areas of great value to fisheries production, and yet permit firewood collection or the harvest of other valuable forest resources by local residents. His preliminary analysis

of the value of mangrove for sustained development suggested that the fishery value may be greater than the forestry value, and that conversion of mangrove to brackishwater ponds would be detrimental to sustainable coastal and estuarine fisheries production.

In Indonesia, as in the Philippines and many other countries, the key constraint to establishing integrated and sustainable development strategies is the sectoral approach of line agencies (e.g., forestry, agriculture, fisheries) which appear unable or unwilling to consider the multi-use/multi-user nature of most coastal resources. Individual agencies approach coastal resource management and development with a set of blinders which limits their purview to those issues directly related to agency jurisdiction and goals.

Balanced against these pro-development influences are a number of senior Indonesian government officials who are aware of the need to see beyond sectoral and agency boundaries and promote environmentally sustainable forms of development. A Ministry of Population and the Environment (MPE) has been established under the leadership of Dr. Emil Salim, a well-respected and influential spokesperson for the environment. The MPE is quite unlike other ministries in that it represents no sectoral interests; rather, it acts as a cross-sectoral coordinating ministry, and has the authority to bring together different ministries to promote coordination of their activities.

The MPE has a small staff, limited budgetary resources, and no significant presence outside of the capital. To be effective, it must rely on its powers of persuasion. To be persuasive, it is necessary to have control over independent sources of information. To accomplish this end, the MPE has sponsored and supported the establishment of Environmental Study Units and major regional universities throughout Indonesia. These Units are

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commissioned to conduct studies which inventory local resources and assess management needs.

The key element in the MPE's achieving a degree of success has been Dr. Salim's personal influence with the President and his fellow ministers (Burbridge and Maragos, 1985). This means that the environmental conscience of the Indonesian government remains personalized rather than institutionalized. Nonetheless, creation of the MPE represents a recognition on the part of some leaders within the Indonesian government that development of natural resources is too important to be left to narrow sectoral interests.

D. Mangrove Management in Panama

Siddall et al. (1985) note that shrimp mariculture in Panama has had relatively little negative impact on mangrove compared with the Philippines and Ecuador, the other two nations in their comparative study. They explained this important difference with reference to: (1) clear administrative jurisdictions; (2) adequate information for management purposes; and (3) the adoption of semi-intensive rather than extensive shrimp mariculture production systems in Panama.

Unlike either the Philippines or Ecuador, in Panama a single agency (the Direccion General de Recursos Renovables, or RENARE) has responsibility for protection of mangrove forests. RENARE appears to have adopted a clear conservationist posture (e.g., prohibiting the exploitation of red mangrove for its bark until a careful assessment could be made of the impact of this practice). RENARE also has shown a willingness to enforce their regulations, fining shrimp farmers whose ponds encroached on mangrove. Monitoring of the impact of pond construction is possible by means of comparison with aerial photos taken prior to pond construction. The Direccion Nacional de Acuicultura has cooperated with RENARE, encouraging

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potential investors to establish ponds in salt flats by publicizing the risks of acid sulfate soils and high construction costs associated with establishing shrimp ponds in mangrove areas.

The adoption of semi-intensive production methods drastically reduced the amount of land necessary for shrimp mariculture. The primary influence behind adoption of this system appears to be the presence of Ralston-Purina, which introduced shrimp farming to Panama. Subsequent investors have attempted to replicate successful techniques developed by Ralston-Purina rather than the more extensive methods employed in Ecuador and the Philippines. Because adequate salt flats were available to meet the need of new investors, pressure on mangrove resources was much reduced.

E. Management of Wild Shrimp Populations

With few exceptions, shrimp mariculture development is occuring where wild populations of penaeid shrimp exist and are exploited for export markets. In most cases (Ecuador being a notable exception), shrimp exports derived from capture fisheries far outweigh those generated by culture systems. Because most marine shrimp populations are under heavy pressure, management of fishing effort is a matter of concern to most governments.

Ecuador is no exception to this rule. There stocks are under heavy fishing pressure both from the trawl fishery and from the artisanal fishery for PLs. Unusual climatic conditions associated with El Niño in 1983 and low sea temperatures in the Gulf of Guayaquil during 1984 also appear to have affected wild shrimp populations. Concern regarding resource depletion has led to a seasonal closure both on shrimp trawling and the harvesting of PLs.

McPadden (1984:44) notes that although Ecuador's capture fishery for

shrimp is overcapitalized and appears to have experienced declining catch per unit effort ratios over the past twenty years, there is little evidence of decreased landings due to overfishing. In Ecuador, the primary factor which led to the seasonal closure on offshore trawling and harvest of PLs is closely related to concern regarding supply of PLs for stocking purposes.

Within the foreseeable future, shrimp mariculture development in Ecuador and in most other tropical developing countries will be dependent upon wild marine shrimp populations to provide stocking materials, either as PLs or as gravid females to produce PLs in hatcheries (Mark D. Leslie, Hatchery Manager, AQUA CAB, S.A., Guayaquil, *personal communication*). Thus, management of marine shrimp stocks increasingly will be guided by the twin aims of ensuring sustainable harvests from the sea, and ensuring an adequate supply of PLs for stocking, either directly or indirectly through hatcheries.

The following section provides details on initiatives taken in Indonesia and the Philippines to manage marine shrimp populations. Following this, the discussion turns to management of fisheries for PLs and gravid females.

1. Managing Marine Shrimp Fisheries

It was noted above that between 1980 and 1983, the government of Indonesia imposed a ban on virtually all trawling (Bailey, *in press*). Indonesian trawlers were small by Ecuadorian standards, displacing on average 20-30 gross tons. The boats were wooden hulled and powered by diesel engines generating 135-200 h.p.

Trawlers were first introduced to Indonesia in 1966. Within 11 years their numbers had grown to over 3,000, mostly concentrated along the Malacca Straits and off the north and south coasts of Java. Data on Indonesia's demersal fisheries resources have been reviewed by Dwiponggo

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(*in press*). His analysis clearly indicates that during the period 1975-1979, each of these three centers of trawler activity experienced levels of demersal fishing effort beyond that necessary to acheive maximum sustainable yields.

Official concern regarding resource depletion provides only half the reason the Indonesian government imposed the trawler ban. The other side of the equation, and the factor that forced the government to take action, was the negative impact of trawlers on the catches and incomes of small-scale fishermen. There are nearly 1 million small-scale fishermen in Indonesia, approximately 40% of whom operate in the three areas identified above as the centers of trawling activity. The far greater fishing power of trawlers placed small-scale fishermen at a serious disadvantage in competing for a limited and often dwindling resource. During the 1970s, as ever greater numbers of trawlers began encroaching on what they regarded as their traditional fishing grounds, small-scale fishermen responded with violence to protect their livelihoods. Trawlers were attacked with, among other things, molotov cocktails -- a particularly effective weapon when used at night against wooden boats at sea.

Competition and conflict between trawlers and small-scale fishermen, combined with mounting evidence of resource depletion, spurred fisheries policymakers to impose restrictions on trawler operations. For the most part, these regulations specified use of larger mesh sizes, limited the numbers of trawlers permitted licenses to operate, and sought to restrict trawlers from operating in coastal waters.

In practice, however, these regulations proved difficult to enforce and therefore were ignored. The primary constraints to adequate enforcement include lack of clear enforcement responsibilities among government agencies, and inadequate personnel and patrol craft. The difficulties

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involved in overcoming these problems were increased by political influence exerted by trawler owners and by corruption (Bailey, *in press*). Evidence of continued illegal operations, and increasingly violent conflict between fishermen, led to the proclamation of Presidential Decree No. 39 in 1980 banning all trawlers from waters off Java, Sumatra, and Bali. In 1983, this ban was extended nationwide with the exception of the Arafura Sea. (Conflict between trawlers and small-scale fishermen does not occur in this remote part of the archipelago, where there exists an industrial scale fisheries featuring joint-venture enterprises with Japanese partners.)

The ban on trawlers led initially to declining harvests, but this was a short-term phenomenon. By 1982, landings of demersal species along the north coast of Java surpassed those preceding the trawler ban (Bailey, *in press*). During this period, the number of fishermen in this area increased by 10% and average household incomes among small-scale fishermen increased by 30% (*ibid.*). The trawler ban's impact on shrimp exports was less serious than initially expected. Prior to 1980, trawlers had accounted for the bulk of all shrimp exports. The quantity of shrimp exports did decline between 1980 and 1983, but foreign exchange earnings increased by 15% in part due to improved product quality. Unlike the shrimp landed by trawlers, most of which had been on ice for several days, small-scale fishermen land their catch every day (Dudley and Tampubolon, 1985). Once logistical problems were overcome, shrimp processors successfully adapted to obtaining supplies from small-scale fishermen <u>and</u> from brackishwater pond operators, who previously had been ignored by most exporters content to have shrimp virtually delivered to their door by trawler fishermen.

One advantage of a total ban on all trawling is that it is relatively easy to enforce compared with regulations which restrict trawlers from operating within a certain distance from shore or from using nets below a

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certain mesh size. Regulations of this sort have been attempted in numerous countries with little success due to ineffective enforcement (Garcia, 1986). Like total bans, seasonal closures are relatively easy to enforce. Identifying the optimal period for closure in the context of a multispecies fishery requires detailed information on population dynamics, including the spawning habits and life cycles of the most important species.

2. Managing Fisheries for PLs and Gravid Female Shrimp

Despite concentrated efforts to develop hatcheries, shrimp farmers in Ecuador and most other major producing nations continue to depend on the harvest of PLs from the wild to provide stocking materials for their ponds. Moreover, those hatcheries which have not yet established closed-cycle systems continue to depend on the capture of gravid females for spawning. Within the foreseeable future, shrimp mariculture development will continue to depend on the harnessing of the reproductive energies of wild shrimp populations.

It is, then, surprising that little attention has been devoted to management of directed fisheries for PLs and gravid females. The exceptions to this pattern appear to be Ecuador and Panama. In Ecuador, a seasonal closure on PLs has been imposed for the months of June and July (the season of peak PL abundance is November-March). The offshore fishery for adult shrimp is closed during this period and also during January. There is no closed season for gravid females per se. In Panama, it is reported that some fishermen have discovered a means of locating gravid females which are captured and sold to private hatcheries (P. Maugle, *personal communication*). Concern that such exploitation would have a serious impact on marine shrimp populations led to a area specific ban on fishing for gravid females.

There may be good reasons why other nations appear not to share these

concerns over directed fisheries for PLs and gravid females. In large countries such as India, Indonesia, and the Philippines, wild shrimp populations are widely distributed rather than relatively concentrated, as they are in Ecuador and Panama. In Indonesia and the Philippines, PLs are harvested in areas at great distance from mariculture sites and shipped overland or sometimes by air in oxygenated plastic bags packed in cardboard boxes. Thus, fishing effort for PLs is not concentrated in any one location or even one region. Also, the use of artificial stocking is not yet widespread, and where employed generally does not involve the same level of stocking density. Thus, pressure on shrimp populations at the PL stage not only is dispersed, it also may be less intense in absolute terms.

This is not to say that PL fisheries are totally unregulated. In the Philippines, local municipal governments lease out PL fisheries and milkfish fry fisheries to the highest bidder. However, this system is designed to generate local revenues, not control levels of fishing effort (Smith and Panayotou, 1984). The fishery is open and numerous individuals (and often whole families) take part in this seasonal activity. What the concessionaires obtain is the right to act as sole buyer for PLs and fry caught within their area. A complex market for milkfish fry is well established in the Philippines and in 1974 efficiently moved 1.35 billion fry from coastal waters through a variety of middlemen and on to growout ponds and pens (Smith, 1981). These well-established networks also serve to move shrimp PLs. Similarly complex and efficient networks exist in Indonesia (*personal observations*).

I have uncovered no information regarding limits placed on fisheries for gravid females other than in Panama. Gravid females appear to be 'incidental' to the overall shrimp catch of trawlers and other demersal fishing gear. It is entirely possible that some trawler operators target on

gravid females. Their value is recognized throughout Southeast Asia. Mock (1983) reports that gravid *P. monodon* are shipped from Malaysia to hatcheries in Taiwan. Virtually all hatcheries in the region depend on gravid females caught in the wild. However, the number of hatcheries remains quite small and the level of fishing effort which they support appears not to have attracted concern.

IV. SOCIAL ISSUES IN SHRIMP MARICULTURE DEVELOPMENT

Shrimp mariculture has transformed the coastal ecology of Ecuador and brought about significant economic development. This section is addressed to the social consequences of shrimp mariculture development.

Whenever a significant form of socio-economic change occurs, some individuals are more likely to benefit than others. In the case of a new economic opportunity brought about by technological innovation, age, education, and economic class often influence adoption behavior. Further, these variables often are associated with relative access to institutional resources (e.g., banks, government agencies) within society, the kinds of "contacts" that often are crucial to economic success in any society

Having the right "contacts" may be particularly important in the context of natural resource development. As a starting point, let us consider a few propositions which combine the concepts of resource management and resource allocation:

1. Natural resources are by definition limited.

2. Biologically renewable resources are finite and yet if carefully managed can sustain harvests over an infinite period of time.

3. Management of limited resources is an inherently political process which entails conscious allocational decisions.

The first proposition is self-evident, though it does not address the crucial issue of dimensions: how limited? In the context of shrimp mariculture, the necessary resources include coastal land with appropriate physical characteristics and water of good quality. In Ecuador, these limits are being approached (McPadden, 1984; Parodi, 1985).

In and of itself, the second proposition should excite little controversy. Let us, then, consider mangrove forests as a biologically renewable resource, capable of sustaining harvests of products useful to a society over an infinite period of time. In most tropical developing countries, mangrove forests traditionally have been heavily exploited on a sustainable basis for a wide variety of purposes by local residents.

This leads us to the third proposition, which links resource management and the political process of resource allocation. The process of shrimp mariculture development transforms a multi-use/multi-user coastal resource into a privately owned single purpose resource.

The existence or absence of property rights over coastal resources itself is a matter of fundamental importance in conceptualizing the policy implications of shrimp mariculture development. In most tropical developing nations, private property systems coexist with common property systems and with systems which allow open access to coastal resources. A purely open access system is one where no property rights exist, no limits are placed to the entry of individuals who wish to share in exploitation of the resource, and no restrictions are placed on how the resource is to be exploited. In common property resource systems, boundaries and limits to entry do exist and are imposed by the local community, which controls or "owns" the resource in question. The resource in question may be exploited equally by all or allocated to certain individuals.

The definition of common property implies some institutionalized

means of resource allocation, the existence of some clearly marked boundary, and the ability to exclude outsiders. There is a rapidly growing literature describing the workings of common property institutions in a variety of coastal resource settings around the world (e.g., Ruddle and Johannes, 1985). During the 20th century, these systems tended to disappear under pressure of population growth and cash-based profit-oriented capitalist economies (Peterson, 1982). Moreover, local communities were unable to obtain recognition of, much less legal standing for, their rights to manage natural resources which they regarded as common property (i.e., <u>their</u> property).

In most countries, including Ecuador, the State has established claim to coastal resources. This, in turn, provides legal justification for allocating access to these resources. The alienation of publicly owned mangrove forests for shrimp pond construction is a good example of this allocation process. In many tropical developing countries, mangrove forests are heavily utilized by local residents who exploit available resources to meet needs for cash and household sustenance. In most cases, this exploitation has continued on a sustainable basis over a considerable period of time. Communities of people who depend on such coastal resources tend to be politically and economically marginal within the national society. It is not surprising that what they regard as their traditional rights to local resources are unknown or ignored by the larger society (Collier, 1978). This only becomes a problem when the resource in question becomes valuable as, for example, is the case with coastal mangroves deemed suitable for shrimp pond construction, logging, or other use.

In many tropical developing countries policies which encourage development of privately owned shrimp ponds involves expropriation of resources over which local residents have traditional use rights. The

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primary motivations are foreign exchange earnings and profits; the primary measures used to assess the feasibility of development are technical and financial. Smith and Pestaño-Smith (1985; see also Smith, 1984) argue that a wider range of variables need to be addressed in order to assess the "social feasibility" of development. As used by these authors, social feasibility is a broad concept which refers to all aspects of development except those which are technical and financial. This concept brings to the forefront of consideration socio-economic, socio-cultural, legal, political, and institutional dimensions of development.

If development is a process through which improvements are made to the quality of life for society as a whole, rather than for certain classes or groups, this set of issues must be addressed. In particular, policymakers need to be sensitive to the impact of shrimp mariculture development on employment, income distribution, and nutrition--both within local communities and within society as a whole. For example, many species of finfish, crustaceans, and molluscs are dependent upon mangrove and other coastal wetlands for critical periods in their life cycles. Massive mangrove conversion threatens the sustainability of marine harvests, the livelihoods of many local fishermen (and others who depend directly or indirectly on mangrove resources), and the primary source of protein for large numbers of people who cannot afford meat or other more expensive protein sources.

Shrimp mariculture is profitable, but the profits usually are not earned by those whose interests are threatened, those whose immediate needs are income and employment. Shrimp farming does generate some employment, but the industry cannot be viewed as a labor-intensive considering the small number of people employed per areal unit of production or the limited employment generated per unit of capital investment. Most of those who find jobs are hired as unskilled laborers and guards. Wage rates for

unskilled workers in coastal communities tends to be low, reflecting the opportunity cost of labor. The irony is that the very process of shrimp mariculture development directly contributes to low wages by reducing local opportunities through conversion of open access multiple use resources into privately owned property.

These negative consequences of development are not the blind chances of a cruel economic fate, but rather are the direct result of structural inequalities of wealth and power within certain developing nations. The issues are clearly put by Smith and Pestaño-Smith (1985:7):

> The vast majority of residents in coastal communities are desperately poor. They are poor because of their lack of access to alternative employment opportunities and because existing community and national structures and institutions often allow local elites to capture the bulk of any benefits that come from more productive technologies introduced to or adopted by such communities. Large-scale aquaculture enterprises frequently displace small-scale fishermen and aquaculturists through subsidized financing and institutional arrangements that favor the large-scale or corporate investor.

An important example of "institutional arrangements" favoring well-connected investors is the question of property rights. As discussed above, coastal residents often regard mangrove and other coastal resources as common property of the community, legitimated by historic use and traditional rights. However, governments generally do not recognize these rights and claim the authority to grant long-term leases.

V. CONCLUSIONS

The purpose of the foregoing review was to identify coastal resource management issues posed by shrimp mariculture development, and to assess the experience of tropical developing countries in mitigating adverse social and environmental consequences of this development.

A. Findings

As I reviewed available literature, discussed matters with colleagues, and considered my own experience, it became clear that few serious management initiatives have been taken. The Philippines appears to be a partial exception to this finding, but in most countries the profitability and foreign exchange earnings potential of shrimp mariculture are so strongly attractive to private investors and government policymakers alike that issues of resource management have been given little attention in the headlong rush to develop local shrimp mariculture industries.

Thus, the major finding of this study--which started out to review resource management initiatives that might be adapted to Ecuadorian conditions--is that many nations are striving to repeat Ecuador's development successes and are therefore seem destined to experience many of Ecuador's coastal resource management problems. There are, nonetheless, important messages herein for Ecuadorian policymakers concerned with sustainable development.

The first message is that the era of rapid growth is over. This is so not only because Ecuador is approaching limits to the area that can be brought into shrimp production, but also because major increases in production elsewhere are likely to hold down world market prices, especially for the medium sized shrimp such as are most commonly produced in ponds.

Further, Ecuadorian producers are going to experience an erosion in profitability as low-cost Asian producers become more prominent in world markets. Ecuador's shrimp mariculture industry has prospered because production costs have been far below that of the alternate source (i.e., Gulf of Mexico shrimp trawlers) in their primary market (the U.S.). Asian producers are likely to prosper at the expense of Ecuadorians for the same reason

Most producers in South and Southeast Asia are small-scale operators using minimal inputs in an extensive culture system. Although their productivity will remain low, in most cases costs of production will be negligible. Net income per hectare under these conditions also may be low, but given limited alternatives for investment and employment, this is not likely to discourage producers from continued involvement in the industry. Low rates of return to investment, labor, and management simply reflects the common level of opportunity costs for these items among small-scale producers in most tropical Asian countries.

Compared with small-scale Asian producers using minimal inputs, many Ecuadorian shrimp farmers could be regarded as high-cost producers. Moreover, these small-scale Asian producers are more likely than their Ecuadorian counterparts to continue producing shrimp even if the bottom drops out of the world market. Ecuadorian shrimp farmers generally are commercially-oriented entrepreneurs sensitive to opportunity costs, especially those for capital and management. Asian producers are no less rational, but operate on the basis of wholely different sets of economic criteria which emphasize risk minimalization and diversification of production activities. Meltzoff and LiPuma (1985) suggest that Ecuadorian entrepreneurs have relatively short planning horizons and are likely to move into an enterprise which offers potential for quick profits, and then

pull out once these opportunities are reduced. Asian mariculturists have been in 'business' for thousands of years. In Ecuador, shrimp are but the most recent commodity of a string which began with cacao and until recently was represented by the 'yellow gold' of bananas (Delavaud, 1980). Does anyone seriously think that this history of boom-and-bust has ended? Given this perspective of history, what is the likely staying power of Ecuador's shrimp mariculture industry in the face of low-cost Asian producers?

History is not destiny, but in this competitive context, Ecuador's industry leaders and government officials clearly should consider with caution the economic feasibility of anticipated technological innovations which will alter the structure of production costs within the industry. In particular, let me draw attention to the likely consequences of intensified production practices on Ecuador's competitive position. There is no question that more shrimp per hectare can be grown over the course of a year by improvements in pond design (e.g., establishing separate nursery ponds), increasing stocking density, and increasing supplemental feeding. It must be recognized that these measures not only increase input costs, they create dependencies on inputs. Input prices are beyond the control of individual producers or even the shrimp industry as a whole.

Input suppliers (e.g., feed mills) may be in a position to increase prices to the point where they capture most of the industry's profits. Consider the interest of feed suppliers in developing shrimp mariculture. Ralston-Purina established the industry in Panama as a means of developing demand for its primary product line, and subsequently sold its successful hatchery and grow-out operations. In Sri Lanka, the first business to invest in shrimp mariculture was a company primarily concerned with formulating feeds for hatcheries, not the production of PLs

(American Embassy, Colombo, 1986). In the Philippines, San Miguel Corporation, the nation's largest corporation, is involved in shrimp mariculture development primarily to promote its line of feeds.

These companies realize that the greatest long-term profit potential in any industry dependent on supplemental feeding is in the supply of these feeds. As the world market for shrimp matures, the squeeze of rising costs and falling prices will affect the profits of individual producers far more than feed mills and other input suppliers.

If farm-gate shrimp prices fail to keep abreast of input costs, a natural tendency of individual producers will be to increase production to maintain income. This strategy leads to increased supply and continued downward pressure on prices. Intensifying production may be a rational action by individual producers, but for the shrimp mariculture industry as a whole it may lead to serious economic difficulties. Development in this direction is likely to promote the kinds of structural changes that will make the shrimp mariculture industry of Ecuador vulnerable to low-cost international competitors.

There are serious implications in this for coastal resource management: if intensification is not an alternative, the only means of increasing production is through extensification, that is the opening of new areas for shrimp farming. This tendency should be resisted. The construction of new ponds, were this permitted, is possible only through conversion of mangrove. In an Ecuadorian version of Hardin's (1962) "Tragedy of the Commons," the conversion of mangrove may be rational for individual producers, but the negative impact on the industry could be serious if not catastrophic for the simple reason that less mangrove probably translates into reduced PL supply. It is unlikely that hatchery development will reduce the need for PLs caught in the wild.

3. Develop Low-Cost Production Strategies

Efforts should be made to focus biological and technical research on cost-minimization rather than on production-maximization. This is necessary in order for Ecuador's shrimp mariculture industry to remain competitive with Asian producers. These low-cost production technologies may emphasize greater reliance on locally abundant inputs, including labor. Extension personnel should be trained in these low-cost technologies, which may be particularly well-suited to small-scale producers with limited technical or financial resources.

B. Recommendations.

Ecuadorian policymakers are to be commended for recognizing the existence of a serious coastal resource management problem posed by uncontrolled conversion of mangrove to shrimp ponds, and for acting to halt the conversion process. Seasonal closures affecting offshore shrimp trawling and inshore harvest of PLs are further indications of official concern. Other members of this team have specific responsibilities for addressing these issues and the training to do so. I wish to address my recommendations to a different set of issues.

1. Resource Use Conflicts: A Research Agenda

Shrimp mariculture frequently involves the conversion of a multiple use resource. Insufficient information exists to establish the tradeoffs involved either qualitatively (who is being effected) or quantitatively (how much is being gained or lost). In most parts of Asia, the multiple use quality of coastal resources is the factor chiefly responsible for the concentration of population in the coastal zone, and it is this feature that provides the greatest hope for sustainable development. Are future development options within Ecuador being foreclosed by current patterns of resource exploitation?

2. Policy Review: Distribution of Benefits

If Ecuadorian policymakers are to play a role in shaping the future course of their nation's shrimp mariculture industry, they need to know the impact of past development on employment generation, income distribution, and nutritional status of the population. They need to establish goals for the future which specifically address these and other issues, including optimal scale of shrimp farming enterprises. This policy review should build on information collected when examining resource use conflicts.

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Table 1

Tropical Shrimp Mariculture: Regional and National Comparisons

REGION/COUNTRY	HA. IN PRODUCTION		YIELD	CULTURE SYSTEM
	Current	Potential	kg/ha/yr	
ASIA				
INDIA	30,000[a]	2,000,000[b]	50 - 1,200[b,c]	Extensive, rice fields[d]
BANGLADESH	28,000[e]	n a	30 - 50[e]	Extensive, rice fields[e]
INDONESIA	193,700[f]	1,000,000[g]	100 - 300[c]	Extensive, polyculture[b,c]
THAILAND	36,400[h]	100,000[h]	100 - 300[c]	Extensive, polyculture[b,c]
PHILIPPINES	176,000[i]	400,000[i]	100 - 300[b,c]	Extensive, polyculture[b,c]
MALAYSIA	675[j]	50,000[j]	1,000[j]	Semi-intensive[j]
TAIWAN	3,200[b]	3,200[k]	15,000[b]	Intensive[b]
CHINA	8,200[k]	n.a.	90[k]	Extensive[l]
LATIN AMERICA				
ECUADOR	60,000[m]	70,000[m,n]	240 - 1,200[o]	Semi-intensive[o]
PANAMA	2,500[p]	6,000[p]	300 - 2,000[p]	Semi-intensive[c]
PERU	3,200[p]	6,000[p]	500[p]	Semi-intensive[p]
BRAZIL	3,000[q]	8,100[k]	n.a.	Extensive[r]

SOURCES:

[a] National Marine Fisheries Service (1985a)
[b] Shang (n.d.)
[c] Pedini (1981)
[d] Kurian and Sebastian (1982)
[e] Kibria (1985)
[f] Directorate General of Fisheries (1985)
[g] Ling (1973)
[h] American Embassy, Bangkok (1986)
[i] Peterson and Schmittou (1985)
[j] American Embassy, Kuala Lumpur (1986)
[k] National Marine Fisheries Service (1984)
[l] UNDP (1979)
[m] McPadden (1984)
[n] Parodi (1985)
[o] Mock (1983)
[p] Weidner (1985b)
[q] National Marine Fisheries Service (1985b)
[r] Scott (1985)

Table 2

Shrimp Farming in the Caribbean and Latin America*
(metric tons)

COUNTRY	1982	1990
Ecuador	21,500	40,000
Panama	2,500	4,500
Brazil	400	4,000
Peru	600	3,500
Honduras	250	2,500
Mexico	--	2,000
Colombia	--	2,000
Venezuela	--	1,500
Belize	--	1,500
Bahamas	--	1,300
Guatemala	100	1,000
Martinique	150	750
Others	25	5,250
TOTALS	25,325	69,800

* Includes fresh water shrimp.

Source: Chamberlain (1985a).

Table 3

Tropical Shrimp Mariculture: Projected Development to Year 2000

REGION/COUNTRY	1986[a]			2000		
	Hectares	kg/ha/yr	Harvest (mt)	Hectares	kg/ha/yr	Harvest (mt)
ASIA						
INDIA	30,000	150	4,500	73,000	750	54,750
BANGLADESH	28,000	50	1,400	40,000	350	14,000
INDONESIA	193,700	200	38,740	250,000	500	125,000
THAILAND	36,400	200	7,280	70,000	500	35,000
PHILIPPINES	176,000	200	35,200	200,000	500	100,000
MALAYSIA	675	1,000	6,750	5,000	500	25,000
TAIWAN	3,200	15,000	48,000	3,200	15,000	48,000
CHINA	8,200	90	738	?	?	?
Sub-Totals	476,175		142,608	641,200		401,750
LATIN AMERICA						
ECUADOR	60,000	800	48,000	70,000	1,000	70,000
PANAMA	2,500	1,500	3,750	5,000	1,500	7,500
PERU	3,200	500	1,600	5,000	800	4,000
BRAZIL	3,000	500	1,500	15,000	800	12,000
Sub-Totals	68,700		54,850	95,000		93,500
TOTALS	544,875		197,458	736,200		495,250

NOTES.

[a] Estimates for year 1986 based on data in Table 1, as modified by personal experience and judgement.

DRAFT

FACTORS AFFECTING THE RELATIVE ABUNDANCE OF SHRIMP IN ECUADOR

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July 2, 1986

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1. INTRODUCTION

The purpose of this report is to examine what is known about the factors influencing the relative abundance of penaeid shrimp stocks in Ecuador and to make recommendations for managing the stocks as well as coastal management in general.

Penaeids are fished extensively throughout the Ecuadorian coastal zone from boats and in ponds built within the mangrove lined estuaries. Fisheries catch increased from 222,000 mt in 1975 to 725,000 metric tons (mt) in 1982, and seafood now ranks 2nd or 3rd (behind oil and bananas) in exports. Fisheries exports are dominated by shrimp (40% in 1980) and represented $160 million in 1984, or 7.2% of Ecuador's export earnings. Between 6.8 and 9.4% of the total population depend on the shrimp industry for their livelihood (Paroldi 1975). Most shrimp are exported to the United States (51 mt in 1983). The increased shrimp catches are primarily due to increased harvest of cultured shrimp (Figure 1). In 1983 pond production was 60% of the total shrimp harvest.

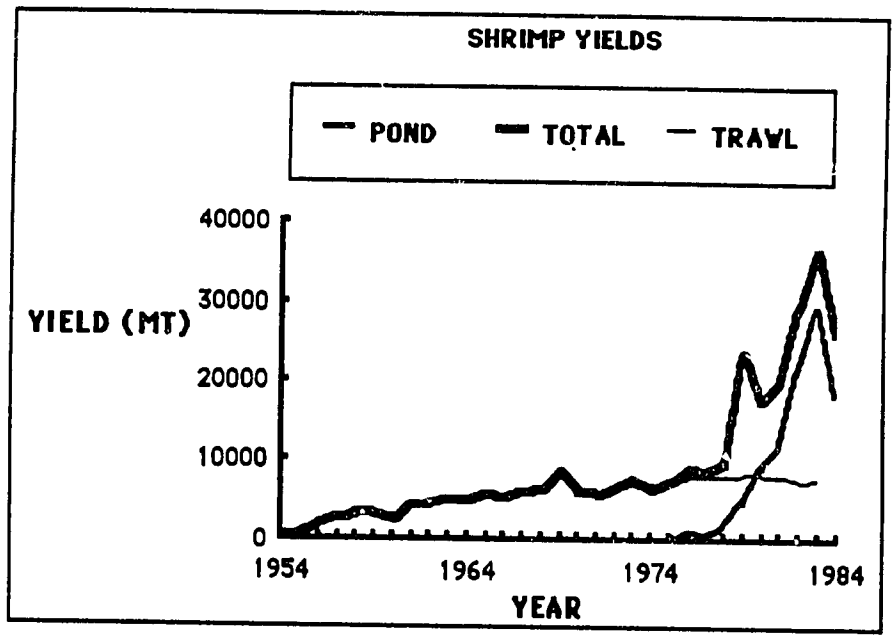

Figure 1. Total shrimp harvest, pond harvest and fleet harvest for Ecuador from 1954-1984.

Several nationally important management issues have arisen as the economic value of the shrimp harvest has grown, the pond area increased, the mangrove area declined, and the workforce changed. The social and

economic issues have been recently reviewed by LiPuma and Meltzoff (1985). The biological aspects of shrimp recruitment and supply are the subject of this report.

Ecuador has one of the world's largest concentration of shrimp culture ponds, most of which are concentrated along the Gulf of Guayaquil. In 1986 there were 94,352 ha of authorized ponds (Olsen and Maugle 1986) and an unknown area of illegal ponds. Trawl fishermen have accused the pond operators of depleting the stock of shrimp larvae and juveniles to supply the ponds. Also, there is concern about the impacts of clearing mangroves for ponds, pollution, and annual stock variability. The ponds are generally stocked from the wild supply of post larvae and recently there has been a shortage which led to serious economic difficulties for the pond operators. In 1985 50% of the ponds were idle due to a shortage of wild-caught postlarvae which represent one-half to one-third the pond operation expenses (Lipuma and Meltzoff 1985). As many as 90,000 - 120,000 people may be involved in the postlarval collection effort; the effects on the shrimp population of collecting so many postlarvae is unknown. Many of the ponds are in mangrove zones which are very productive components of the estuarine ecosystem (Cintron 1979) for both fauna and flora.

1.1 Questions To Be Addressed

Questions which need to be addressed include:

What are the impacts of clearing mangroves?
What is the natural variation in recruitment?
Can the natural post larvae supply be increased?
How much does the harvest of post larvae and juveniles influence the offshore stock size?

1.2 Penaeid Shrimp Life Cycles

Penaeid shrimp life cycles generally begin in the open sea as eggs which mature through nauplius, protozoeal and zoeal stages. After drifting of the pelagic larval phases, the post larvae enter estuarine areas on flood tides, and seek substrates, such as mangrove roots, to which they cling until the next tide stage and successively penetrate deeper into the estuary. Eventually they live a benthic existence while they grow larger in the food-rich and predator-reduced environment. After several weeks or months, they move back into the ocean, but generally remain in the

shallow zones (Figure 2). Fishermen harvest them in the estuaries as postlarvae for stocking ponds or as subadults and adults in the nearshore and deep oceanic waters. For reasons discussed below, most commercially-important penaeid shrimp are considered to be estuarine dependent.

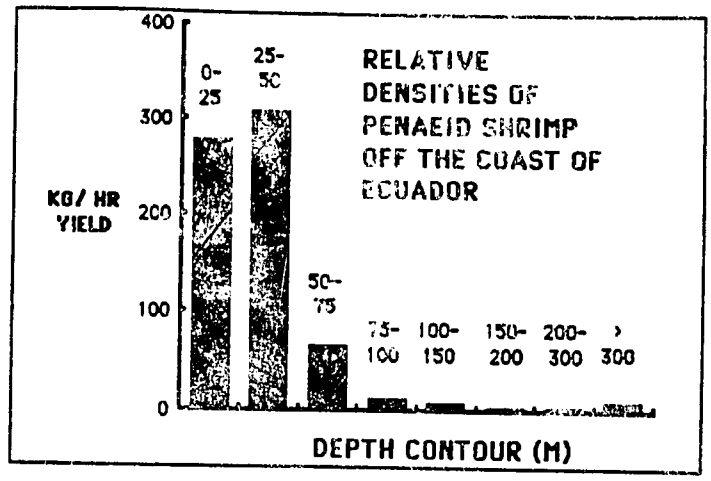

Figure 2. The relative density of penaeid shrimp stocks off the coast of Ecuador by depth contour (adapted from data in Loesch and Cobo 1972).

The capability of estuarine mangrove areas to support major fisheries is widely acknowledged by scientists but not well-understood. Numerous species benefit from the high productivity and nutrient cycling of mangrove dominated-estuaries. The juveniles of many commercially-important fisheries congregate in shallow zones and use them for feeding and refuge from predators. Shrimp, in particular, take advantage of favorable shallow water habitats during critical life cycle stages.

Various studies have revealed that prawn postlarvae occur virtually year-round in mangrove waters, although numbers fluctuate seasonally in relation to the lunar, diurnal, and tidal cycles. In the estuaries and backwaters of wet India, post larvae are most numerous during the intermonsoon period (October to May) while on the east coast there tends to be a premonsoon (August to November) and post monsoon (January to April) peak in abundance (ICAR 1978, in Macintosh 1982). The timing of the highest recruitment varies with each species and reflects the spawning seasonality of the adult prawns. In the Cochin backwaters, peak numbers of *M. dobsoni* postlarvae occur from August to January. December to May is the peak for *P. indicus*; for *P. semisulcatus* it is January to March, for *P. monodon* April to May, and for *M. affinis* and *M. monoceros* March to August (Suseeland and Kathirvel 1980.).

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1.3 The Shrimp Industry in Ecuador

The commercial species of importance in Ecuador are listed in Table 1. *Penaeus vannamei, P. stylirostris* and *P. occidentalis* are the most important (Table 2).

Table 1. List of shrimp of commercial importance (McPadden 1985).

Common name	Family	Species
Blanco	Penaidae	*Penaeus vannamei* *P. stylirostris* *P. occidentalis*
Cafe	Penaidae	*P. californiensis*
Rojo	Penaidae	*P. brevirostris*
Zebra	Penaidae	*Trachypenaeus byrdi* *T. pacificus* *T. faoe*
Pomada/Tltf	Penaidae	*Xiphopenaeus riveti* *Protrachypenaeus precipua*
Carapachudo	Solonoceridae	*Solonocera spp.*
Camrones de Profundidad	Pandalidae	*Heterocarpus spp.*

Table 2. Distribution of shrimp species in marine and pond harvests (from M. Cobo, mimeo report).

Species	% Commercial Catch	% Pond Harvest
P. occidentalis	70	
P. styliorstris	15 to 20	5
P. vannamei	2 to 3	95
P. californiensis	3	0
Trachypeneus byrdi	minor	0
T. faoea	"	0
T. similis pacificus	"	0
X.iphopeneus riveti	"	0
Protrachypene precipua	"	0
Solenocera florea	"	0

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The catch in the ponds has increased dramatically in recent years, but the areal rate of production (kg/ha) for all ponds has declined significantly (Figure 3). There are several reasons why this decline may be occurring: 1) the best sites may have already been chosen leaving only the poorest sites for later development; 2) ponds may be abandoned or never used for economic reasons; 3) the statistics are not accurate; and/or, 4) pond operators are now relying more on natural stocking of ponds through tidal action rather than stocking with larvae collected locally.

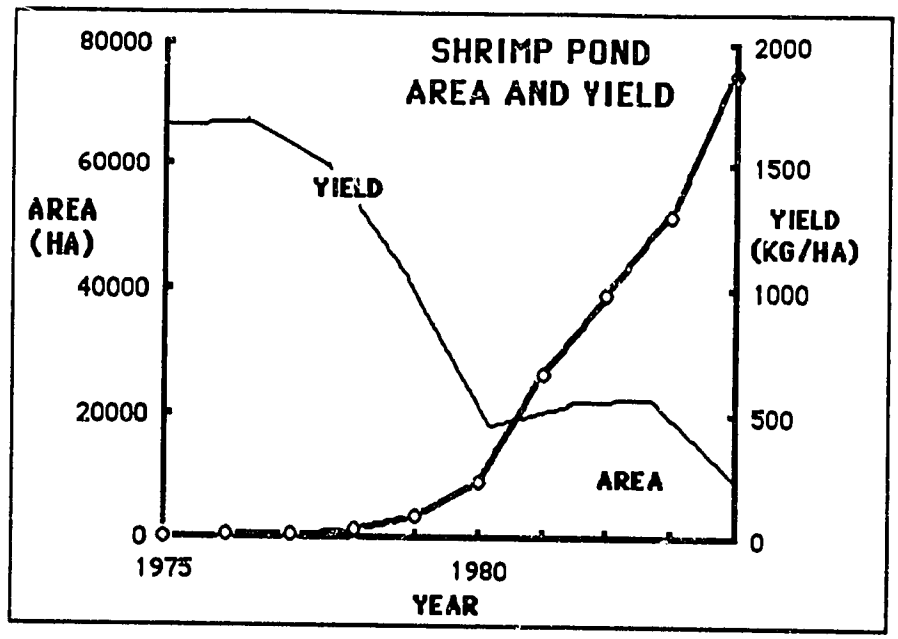

Figure 3. The area of shrimp ponds (authorized) and the apparent yield per ha from 1975-1984. There are differences between pond area as reported by McPadden's (1985) and Olsen and Maugle (1986) for1983-84. McPadden's data is used here since he also reported shrimp yields from the ponds he knew of; although the pond area may be higher, the yield might also be higher by the same percent.

1.4 Shrimp Recruitment Relationships

Mortality from larvae to adult stages in penaeid shrimp stocks is generally considered to be most severe while the organism is smallest. In many fisheries the variations in recruitment of an age group into the exploited stock is often driven by adult spawning biomass size; but stock recruitment relationships for penaeid shrimp are not clearly demonstrable (Garcia 1983). That is, the adult stock size is determined by the changes in juvenile, even post larvae abundance, not adult spawning success. In other

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words, variations in stock recruitment are not primarily the net result of changes in adult spawning biomass.

However, there are causal relationships, with reasonable assumptions about them, between larval and juvenile abundances and the subsequent adult densities (Garcia and LeReste 1981). Recruitment success is clearly dependent on climatic factors, predation levels, food supply, and habitat quality. Of these, the details of what constitutes quality habitat are not very precisely defined for penaeid shrimp but is considered to be the one long-term factor influencing sustained shrimp harvests. The relative significance of climate and habitat is discussed in the next section.

2. EFFECTS OF COASTAL WETLAND AREA ON RECRUITMENT OF PENAEID SHRIMP STOCKS

2.1 Wetland Area: Stock-Size Relationships

Reviewers of shrimp life cycles generally conclude that larval movement and recruitment from the spawning sites offshore into estuaries is *very* high; It is so high that postlarval growth and survival in the estuary are probably the most important factors affecting the harvestable adult population size (Garcia and LeReste 1981; Garcia 1983; Turner and Brody 1983). Although estuarine salinity and temperature changes affect the annual potential for postlarval survival (discussed below), the *long-term* yields are linearly related to both the quantity and quality of intertidal habitat. Despite the difficulty in obtaining good measures of fishing effort and reliable landings statistics, we have several examples of this relationship throughout the world. Included here are site-specific examples from Malaysia, the Philippines, the northern Gulf of Mexico (Louisiana), and a general summary for the developed shrimp fisheries of the world.

Jothy (1984) provides data from Malaysia for mangrove area and shrimp yields. Although the author does not describe the time period of the shrimp landings data nor the amount of fishing effort, there is a clear relationship between shrimp landings and mangrove area in each of the states along Malaysia's coastline (Figure 4).

Pauly and Ingles (1986) compiled similar statistics for the Philippines and the same relationship holds between shrimp landings and mangrove zone (Figure 5). Pauly and Ingles (1986) live in the Philippines and had access to long-term data on both the artisanal and commercial trawl catches (these were combined in their data tables). They were also in a good position to eliminate the under- and over-reporting of catch data and the abuse of mangrove areal estimates for economic interests concerned with the mangrove lumber concession.

There is a more complete data from the entire northern Gulf of Mexico. The landings data from these estuaries is long-term data and the monitoring is relatively good. The area intertidal vegetation is also well known through several surveys since 1960. The area of vegetation is directly and linearly related to the total landings in any one year. That is, where the landings in an estuary are high or low, the landings offshore are high or low, respectively. There is an excellent linear relationship between

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average landings in any one estuary and the area of intertidal vegetation (Figure 6). The vegetation in these estuaries is not dominated by mangroves (except in isolated cases). There is no significant relationship between water surface area and landings, except for a possible inverse relationship. In addition, the species of shrimp caught are directly related to the kinds of intertidal coastal vegetation within that hydrologic unit.

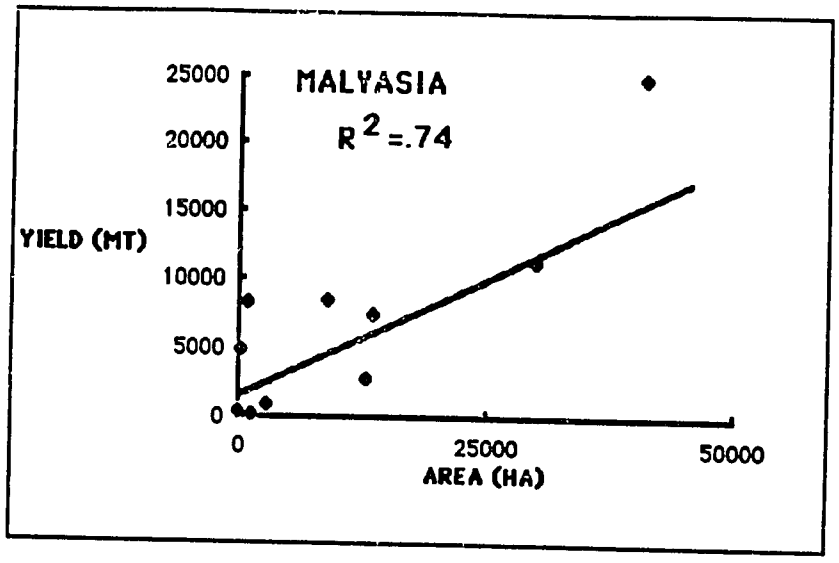

Figure 4. The relationship between intertidal vegetation and penaeid shrimp yields in Malaysia (adapted from data in Jothy 1984).

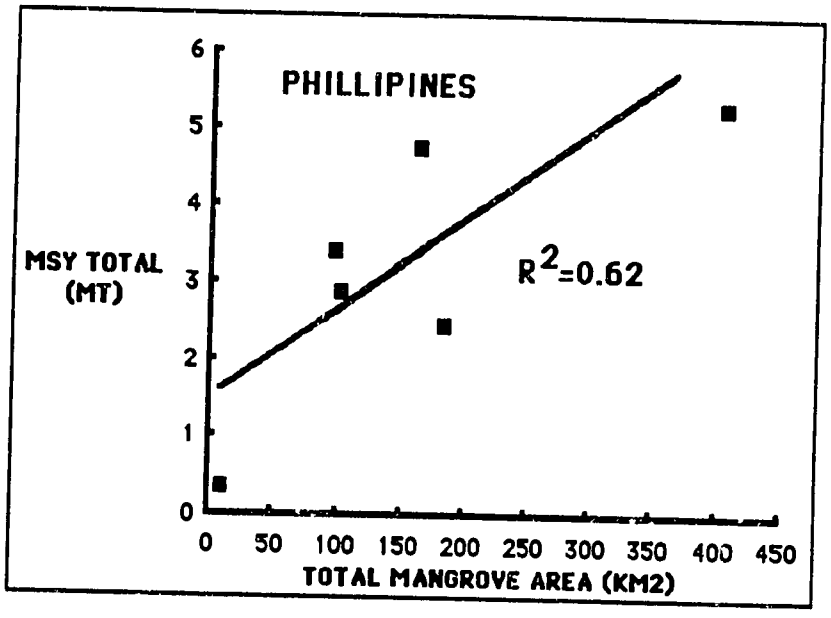

Figure 5. The relationship between mangrove areas in the Philippines and the annual yields of penaeid shrimp (adapted from data in Pauly and Ingles in press).

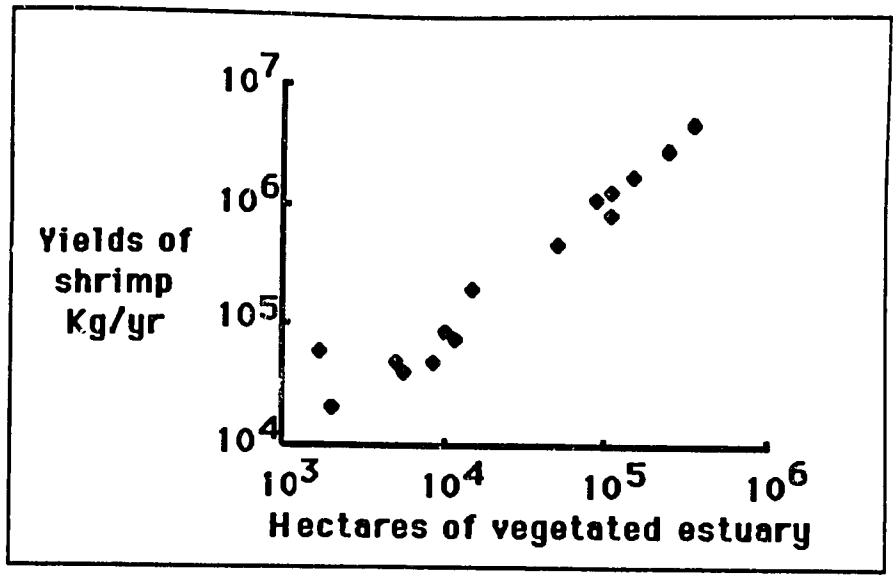

Figure 6. The relationship between intertidal vegetation and penaeid shrimp yields from the estuaries of the northern Gulf of Mexico (from Boesch and Turner 1985).

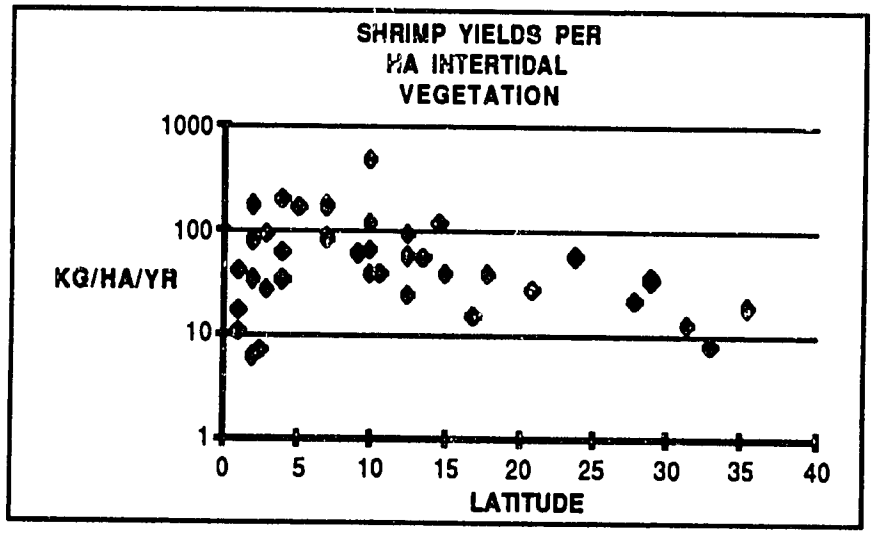

Figure 7. The relationship between intertidal vegetation and penaeid shrimp yields from developed fisheries (modified and updated from Turner 1977).

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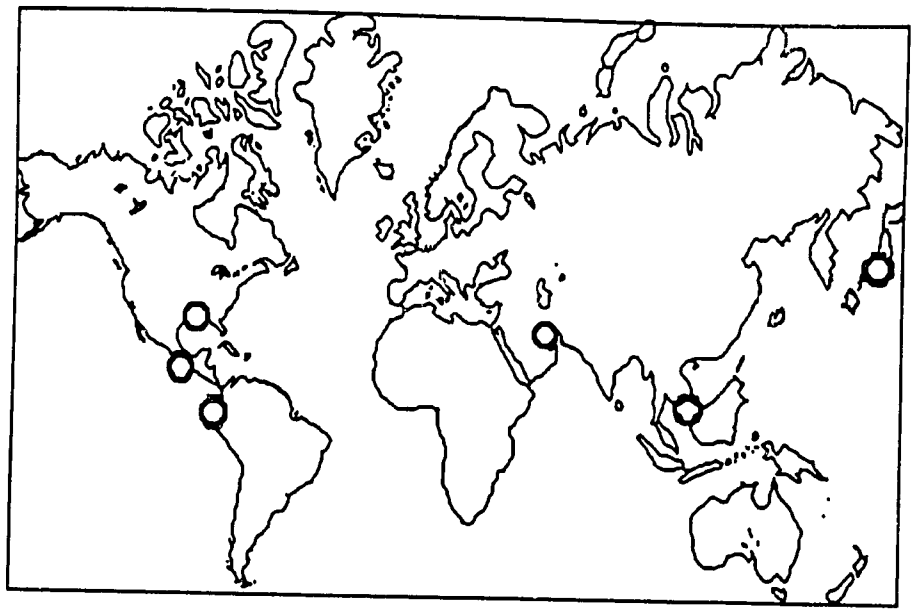

Figure 8. Locations where decreases in intertidal vegetation have been followed by decreases in penaeid shrimp landings (see text for discussion).

Table 3. Summary of examples of penaeid shrimp stock changes following intertidal wetland changes.

Area	Vegetation Changes	Stock Changes	Source
Louisiana	quantity, quality	quantity, quality	Turner unpubl.
Kuwait and Saudi Arabia	quantity	quantity	Morgan and Garcia 1982
Japan	none; mudflat reclamation	quantity	Doi et al. 1973
El Salvador	quantity	quantity	Daugherty 1975
Vietnam	quantity	quantity	Norman 1983

The same direct relationship between between commercial harvests of penaeid shrimp and intertidal vegetation is found worldwide though it changes with latitude, rising with decreasing latitude until around 5° N/S where it declines (Figure 7).

The above conclusions regarding wetland area and penaeid shrimp yields have been indirectly tested through large-scale changes in wetland area. Several examples have been documented with various degrees of success (Figure 8; Table 3). Examples like those of the Netherlands, where the entire estuary were blocked off and the fisheries collapsed (e.g. Boddeke 1978) are not discussed since more than wetlands were altered.

In Louisiana, USA, the coastal wetland loss rate is 0.8%/yr (Craig et al. 1979; Turner 1979, 1982; Turner et al. 1982). The changes in vegetation there are accompanied by a re-proportionment of the catch among the estuaries in direct relation to the loss or gain of wetlands in that estuary. There are also changes in the quality of estuarine wetlands and shrimp. The wetland plants have become more salt-tolerant (as reflected in the species distribution) in the past 30 years with the decline in wetland area. With this vegetation change there are changes in the types of shrimp which are representative of brackish species (Figure 9).

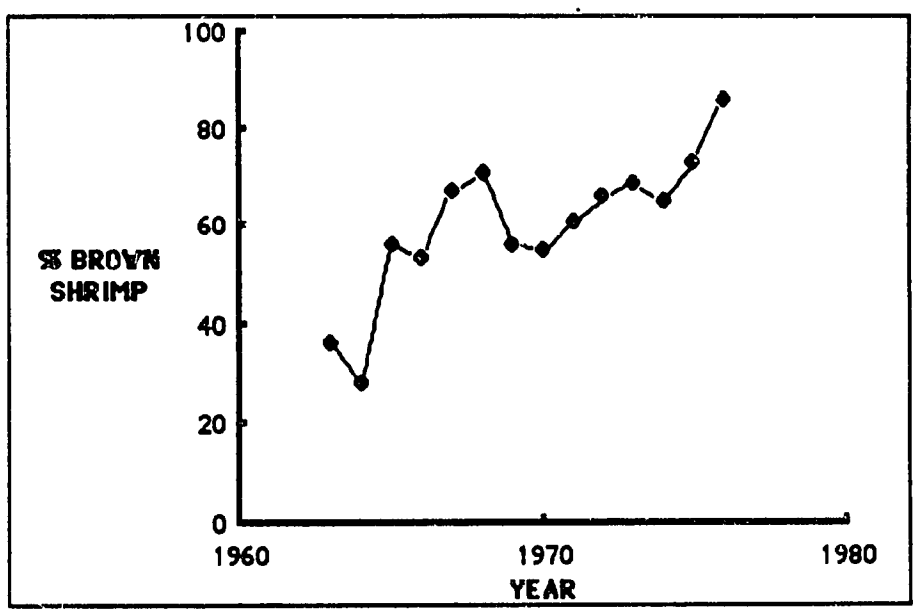

Figure 9. The percent of brown shrimp (*P. aztecus*) caught in the inshore waters of Louisiana from 1963-1976 (NMFS statistics).

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In Japan, Doi et al. (1973) showed that the decline in yields of *P. japonicus* declined in proportion to land reclamation in the estuary (Figure 10). However, the intertidal land was not vegetated, but mostly shallow mudflats. Morgan and Garcia (1982) noted a long-term decrease in the recruitment of *P. semisuculatus* in Kuwait and Saudi Arabia which was not related to changes in effort, but probably to estuarine land reclamation. In El Salvador mangroves were cleared for agriculture and the shrimp fisheries declined, though the fisheries analysis is far from complete due to the present difficulty in obtaining good landings and effort estimates (Daugherty 1975).

The last example is from the People's Republic of Vietnam. One result of the chemical defoliation of the southern coastal zone during the lastest war was the widespread loss of mangroves. Though the analysis is not generally available to the scientific community for review, there apparently was a severe decline in coastal fisheries stocks, including shrimp (Norman 1983).

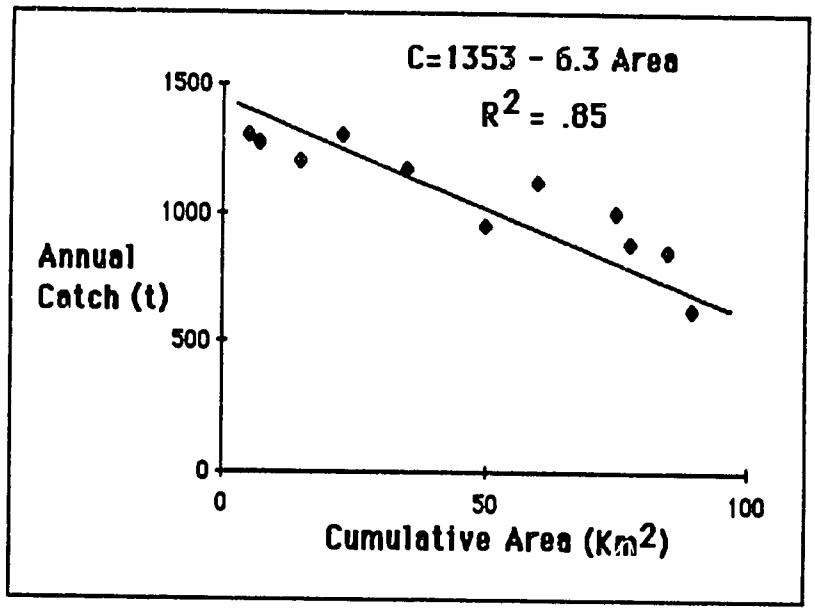

Figure 10. The decline of shrimp yields in Japan as related to reclamation of intertidal lands (from Doi et al. 1973).

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2.2 Causal Relationships Leading to the Wetland:Stock Relationships

Experiments in predator-prey interactions give similar patterns of interpretation. For example, wetlands blocked off from the estuary with levees or bulkheads result in decreased amounts of adult shrimp at the altered sites (Mock 1967; Trent et al. 1976). The wetland edge is particularly high in organics. The more important component, however, may be the protection the plant structure offers prey from predators. Field and laboratory predator-prey experiments with *P. aztecus* in vegetated and non-vegetated salt marsh habitats indicate that small juveniles use the food-rich habitat among the stems to escape predators (Minello and Zimmerman 1983a,b; Zimmerman and Minello 1984; Zimmerman et al. 1984; Minello and Zimmerman 1985). The number of predator attacks on prey and the percent success of attacks declines with increasing vegetation complexity. Thus the shallow wetland habitats appear to be favored sites for juvenile shrimp; this is consistent with observations on organism adaptation to resource depression in the presence of predators (Charnov et al. 1976). These responses are also observed for freshwater lakes with wetlands fringing their borders, coral reefs, sea grasses and rivers (Groen and Schmulbach 1978; Johannes 1978; Savino and Stein 1982; Strange et al. 1982; Duroucher 1984; Heck and Thomas 1984; Holland and Huston 1984; Robblee and Zieman 1984; Hoyer et al. 1985; Risotto and Turner 1985). Boesch and Turner (1984) attempted to review the general dependent relationship between fishery species and salt marshes and concluded that "disproportionately little effort in fisheries research and management is devoted to coastal habitat evaluation, protection and enhancement."

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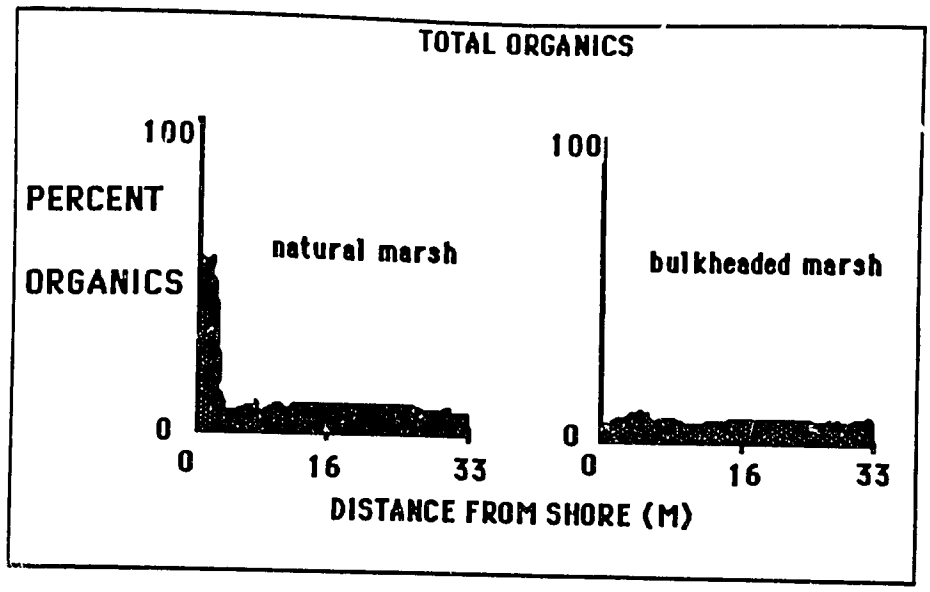

Figure 11. The organic content of the marsh soils as a function of distance from the marsh edge into the open water. The figure on the left is for a natural marsh; the other figure is for a nearby marsh that has been impounded by a bulkhead (adapted from Mock 1967).

2.3 Postlarvae and Adult Supply

The question arises whether or not there is some decline in shrimp landings or post-larval supply that might follow the loss of mangroves due to aquaculture pond growth. To address this question it is worthwhile to determine the changes in the area of mangroves since significant pond construction began in or about 1976.

Mangrove area in Ecuador has declined as a direct result of the construction of aquaculture ponds in the mangrove zone. Valdivies (no date) estimated that there are a total of 175,219 ha of mangroves and 89,368 ha of brackish water aquaculture ponds (Table 4) in Ecuador as of 1982. There is no information, as yet, on the change in mangrove zone into the ponds, some of which come from high (non-mangrove zones) and salt pans. But one study of the Guayas River estuary (CLIRSEN 1983) indicates that 16% of the pond growth from 1966 to 1982-3 occurred in mangroves (Table 5; the study area included about 2% of the total mangrove area in Ecuador). If we assume that about half the present aquaculture ponds are in former mangrove zones, then about 45,000 ha of mangroves are no longer functioning as a forested wetland ecosystem. This is equivalent to a decline of 20% in the last 10 years.

Is this estimated 20% decline in mangrove matched by an equivalent decline in shrimp landings or post-larval supplies? This is a difficult question to address with present landings statistics for Ecuador. There are several reasons for this. Although the trawl effort has remained somewhat constant for the last 15 years (Figure 12), the catch per effort (CPUE) has fluctuated for reasons discussed in the next section of this report. Briefly put, natural variations in a variety of fisheries stocks, especially shrimp, fluctuate *at least 20%* in any one year. It is very difficult to tease out any statistically-significant long-term changes in shrimp recruitment with even the best of data sets in light of average climatic influences under these circumstances.

Further, the 20% declines in mangrove are cumulative declines; in 1980 they were only around 10%, so the impact of this areal decline in mangrove is small relative to fluctuations in the environment which change stocks annually (discussed below). Even so, the CPUE in the last several years is lower than average, given the level of effort.

Another issue is whether or not the effort in the last few years has even remained constant. Without compensating for a changing effort, as

well as vessel number, it is even more difficult to separate out the relative influences of climate, effort and mangrove zone decline. Certainly the effort has not been completely constant since the size of the boats (measured in horsepower) has changed since only 1980 (Figure 13).

Table 4. Area of mangrove, camaroneras and salinas in Ecuador, circa 1982-84 (Valdivieso, no date).

	Has		
Province	Camaroneras	Manglares	Salinas
Guayas	52,912	121,464	17,340
El Oro	26,484	24,489	2,520
Manabi	8,377	7,973	164
Esmeraldas	1,595	21,293	4
Total	89,368	175,219	20,028

Table 5. Changes (in hectares) from 1966 to 1982 in mangrove, salinas and other estuarine zones in a pilot study area in El Oro Province (from CLIRSEN 1983).

Zone	1966	1977	1982
urban	256.7	434.7	588.5
mangrove	4,692.9	4231.7	3,294.1
camaroneas	0.0	834	2,330.6
rivers	1,437.5	1,514.5	1,465.7
salinas	466.3	333.8	139.4
high land vegetation	466.3	333.8	162.6
agriculture	615.2	730.2	634.7
Total	8,556.3	8,548.6	8,555.1

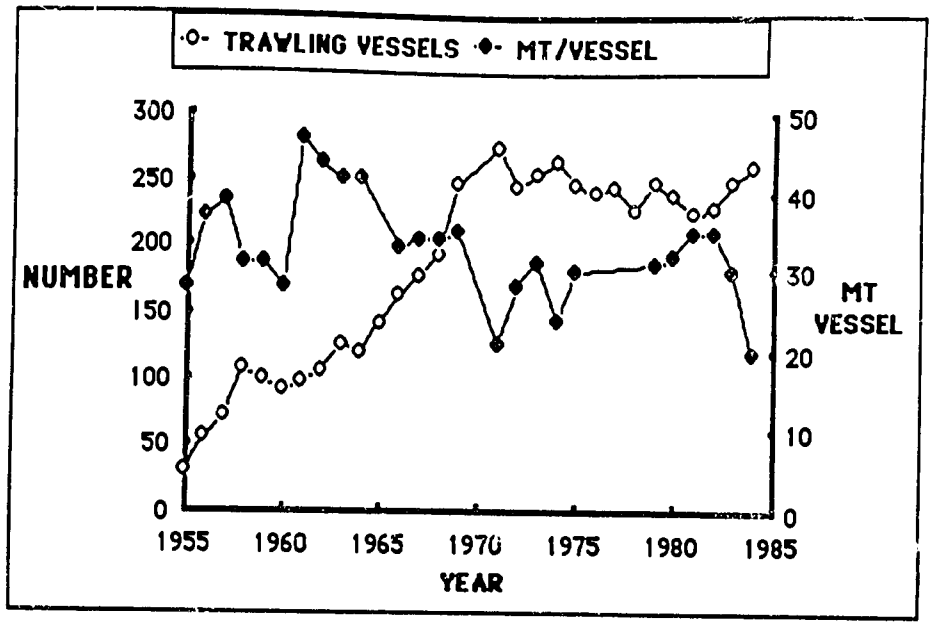

Figure 12. The number of trawling vessels in the industrial shrimp fleet and the catch per vessel from 1954 to 1984.

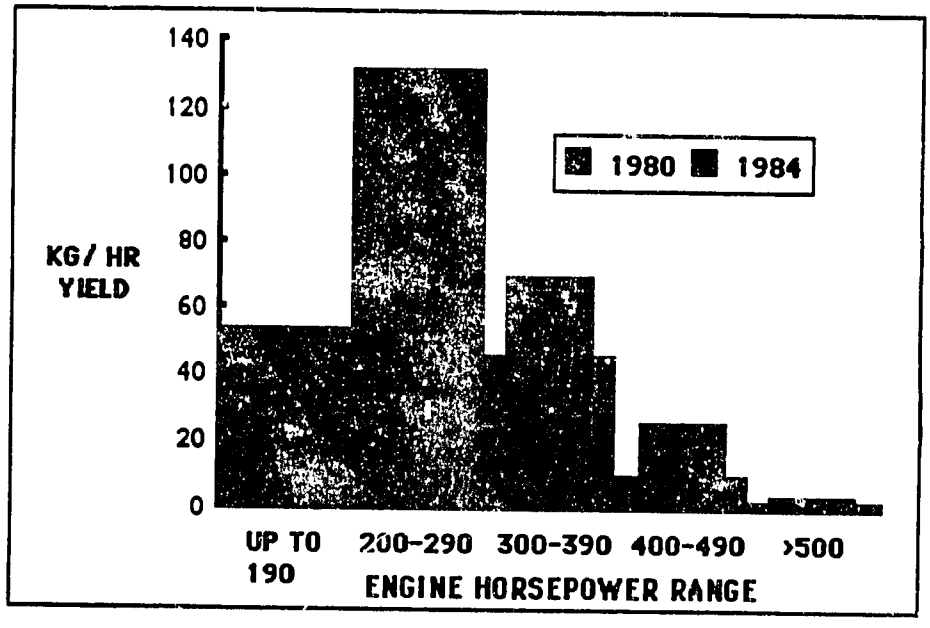

Figure 13. The distribution of horsepower in the offshore trawling fleet (from McPadden 1985).

3. EFFECTS OF CLIMATE ON ANNUAL FLUCTUATIONS OF PENAEID SHRIMP STOCKS

3.1 Natural Variations in Stock Size

Adult stock harvests may vary as much as 100% from year to year. Table 6 shows the coefficient of variation for the harvest in the Ecuadorian trawling fleet and several other world shrimp fisheries. The Ecuador fleet has a very low variation in CPUE (catch-per-effort) of 20%, compared to up to 90% elsewhere. Clearly there has been high stability in recruitment over the last 25 years in Ecuador. However, there is still much variation from year to year. Understanding the factors leading to this variation is important to the fisheries management.

Table 6. Variation in the catch per effort of various developed shrimp fisheries. The data are from Gulland and Rothschild (1984; page numbers) and this report.

Country	years (n)	Coefficient of Variation (%)	Species	Source Page
Australia	10	52	single	42
Australia	11	19.5	single	43
Brazil-Guiana	19	23.8	all	61
Kuwait	16	43.5	all	74
Saudi Arabia Bahrain	11	39.7	all	74
Iran	12	50.4	all	75
Indonesia	9	93.2	all	107
Senegal	14	31.6	all	133
Senegal	12	33.1	all	133
USA-Gulf of Mexico	12	29.8	single	164
USA-Gulf of Mexico	12	24.5	single	164
Ecuador	25	20.0	all	---

It is now well-documented that these large annual variations are associated with changes in estuarine conditions when the juveniles are in the estuary. Variation in estuarine salinity and temperature are the best-documented climatic influences (Table 7), but the frequency and intensity

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of frontal passages, river discharges or substrate conditions may also be important. Numerous data sets on catch-per-effort are available (e.g. Gulland and Rothschild 1984; Kapetsky 1981; Kapetsky and Lasserre 1984a,b), but there is no systematic and comparative analysis of climatic influences. Copeland and Bechtel (1974) analyzed the salinity and temperature preferences of several penaeid species in estuaries of the northern Gulf of Mexico. They clearly demonstrated the interactive *optimal* preferences by shrimp for temperature and salinity, rather than linear relationships dominated by one factor.

Table 7. Examples of the effects of climate on coastal penaeid shrimp stocks.

Location	Species	Effect on yields	Source
North Carolina (USA)	*P. duorarum*	temperature (-)	Hettler and Chester (1982)
Louisiana (USA)	*P. setiferus*	salinity (-)	Barrett and Gillespie (1973)
	P. aztecus	riverflow(-)	"
Louisiana (USA)	*P. setiferus*	salinity (-) temperature (+)	Turner (1979)
	P. aztecus	salinity(+) temperature (+)	
Northern Gulf of Mexico (USA)	*P. setiferus*	salinity (-) temperature (+)	Copeland and Bechtel (1974)
	P. aztecus	salinity (+) temperature (+)	
Florida (USA	*P. duorarum*	water level (+)	Browder (1986)
Laguna Madre, Texas (USA; hypersaline)	*P. fluviatilis* *P. aztecus*	rainfall (+)	Gunter and Edward (1969)
Australia	*P. merguiensis*	rainfall (+)	Staples et al. (1984) Ruello (1973)
Indonesia	*P. merrguiensis* *P. monodon*	riverflow (+)	Turner (1975)
Senegal	*P. duorarum*	salinity (+)	Le Reste (1980)

Cun and Marin (1962) examined fisheries landings data to determine the annual changes in the percent catch which is *P. vannamei* and *P. Stylirostris* within the Gulf of Guayaquil at the northern part of the Gulf (zona de Golfo) and the central and southern part (zona de Playas). Some of their data are graphed in Figure 14. Variations are high and range from 0 to 22 % of the catch from 1965-1979. There is not very good coincidence between sites among years. Whereas catches of *P. vanvamei* were gradually climbing in the Zona de Golfo, they were falling in the zona de Playas.

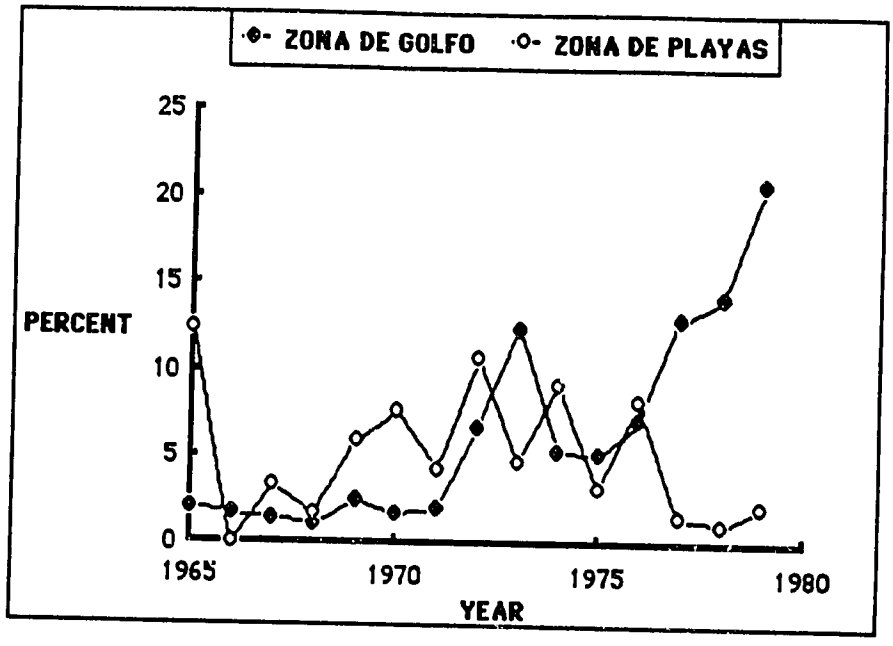

Figure 14. Annual changes in the percent catch which is *P. vannamei* within the Gulf of Guayaquil at the northern part of the Gulf (zona de Golfo) and the central and southern part (zona de Playas). Adapted from Cun and Marin (1982).

The most dramatic changes in climate in coastal Ecuador are related to weather events regulating the appearance of El Nino along the coast. The oceanic currents influencing the area include the nearshore Humbolt current and the Equatorial and Tropical surface currents. Strong upwelling and temperature gradients develop. Equatorial waters move further southward when the north-flowing and cold Humboldt current weakens. It is dry when the Humbolt current predominates; water and air temperatures are around 21-22 °C. Winds are generally strongest from August to November (Pesantes 1975). As waters warm through February-March air temperatures increase to an average of 25 °C. and can exceed 27

°C during an El Nino year, which is relatively wet. Winds average 4 knots during the rainy season from January to April.

The flow of the Jubones River was used as a surrogate for regional variations in rainfall and temperature. The Jubones enters the Guayas estuary, and its watershed is about 8.3% of the total drainage basin (Table 8). One gaging station was selected and the variations in river discharge (1965-1979) compared to annual variations in adult shrimp stock CPUE. Both lagged seasonal averages were examined. One result of this analysis is in Figure 15. There is an inverse relationship with riverflow and CPUE. Since El Nino usually brings wet and warm weather, the indication is that El Nino events are not favorable for shrimp recruitment. However, the most recent El Nino events of the 80's resulted in very high values of CPUE, but are not included here because of the lack of riverflow data. Better relationships could be accomplished with access to more comprehensive climatic data. The major point of this figure is to encourage analysis of the climatic influences on Ecuadorian shrimp CPUE (as well as other species). It has proven feasible elsewheres (e.g. Table 7) and can be done with these data if some imaginative and comprehensive analyses are attempted.

Table 8. Drainage area and percent of the total for the major rivers in the vicinity of the Guayas estuary (from Stevenson 1981).

River	Drainage Area (km2)	Percentage Total Area
Guayas	32,800	64.00
Jubones	4,280	8.34
Naranjal	3,060	6.00
Boliche	1,300	2.50
Arenillas	550	1.07
		Total % = 81.91

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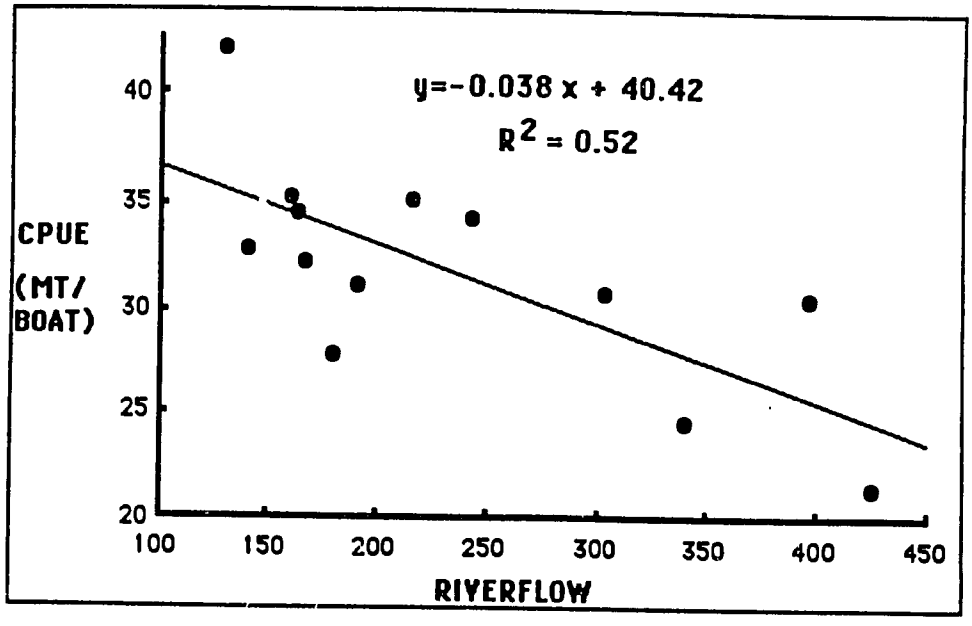

Figure 15. An example of climatic relationships with shrimp landings. Shown here is the relationship between winter riverflow (January through March) and trawl fisheries catch per vessel for Ecuador from 1965 to 1979. As discussed in the text, the catch in the latest El Nino year resulted in a very high value for CPUE, suggesting that the curve rises steeply to the right of beyond the. riverflow shown in this graph.

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4. IMPLICATIONS FOR MANAGEMENT OF PENAEID SHRIMP STOCKS

The management options available to penaeid shrimp managers might be described as being of three types: *economic*, or fleet and processing management, *personnel*, or socio-cultural elements, and *habitat* management. Habitat management is emphasized here. It seems to this author that without more attention to the latter the first two become less important and more difficult to implement. Up to 20% of the mangrove zone in Ecuador has been converted to fish ponds. The primary causal agent of changes in these wetlands are man-made activities and are therefore manageable. As the potential crop of both post- larvae and adults decreases with these wetland losses, options to manage whatever remains becomes much more difficult. Penaeid shrimp managers must include habitat management as their primary responsibility. Otherwise, we will have the recurring inconvenience of trying to understand why our models don't work as well any more, how to divide fewer and fewer stocks among more and more people, especially fishermen, and to watch our well-designed and static management plans falter with changing environmental conditions.

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5. CONCLUSIONS

Penaeid shrimp recruitment from larvae to adult is influenced strongly by climatic events and habitat quality and quantity. The hypothesis that habitat quantity sets adult stock sizes is supported by limited field observations of predator-prey interactions, the direct relationships between yields and intertidal area, relative densities in disturbed and natural habitats, and by observations following wetland removal from the ecosystem. Conservation of habitat quantity is of high significance to sustained stock recruitment success since it seems to be the final determinate of natural potential stock densities which climatic influences annually modify.

The shrimp industry in Ecuador is expansive and intensive and shows signs of increasing user-use conflict.

The variations are high enough now to mask the relatively smaller changes in stock size due to present reductions in mangrove.

6. RECOMMENDATIONS

Develop an integrated study plan; the issues are complicated, involve multiple resource use and have long-lasting implications for a variety of social, political and natural resources.

Complete an analysis of the effects of climate on the annual variations in stocks. It would be especially useful to examine the effects of oceanic temperature anomalies on shrimp and on other stocks.

Conserve mangrove zones if the government wants to avoid major changes in stocks of postlarvae, juveniles and adults. Stock harvest is probably at its natural limit, and conservation, rather than further exploitation of the few remaining stocks, is in order.

Restore mangroves (where possible) through reestablishment of the natural hydrology.

Support maintenance of mangrove buffer zones around whatever zones are cleared. These should be at least natural twice the levee width and include the levee.

Determine if the decline in kg/ha of ponds is real. If not real, where are the data incorrect and can this situation be rectified? If real, what are the reasons behind it? Are they ecological, economic or political?

Examine the existing data to see if there are any other data which could be summarized for long-term analysis.

Develop a complete fisheries statistical analysis and continue data collection.

Support the newly-established effort to formalize a Captain's log book to summarize fishing effort: trips, hours, etc.

Establish a workshop to increase the supply of postlarvae by decreasing the mortality of those caught.

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"Recruitment and Distribution of Postlarval and Early Juvenile Penaeid Shrimp in a Large Mangrove Estuary in the Gulf of Guayaquil during 1985"

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INTRODUCTION

Objective and Design

The objective during 1985 was to initiate a program to assess recruitment and distribution of postlarval and juvenile penaeid shrimp throughout a large mangrove estuary in the Gulf of Guayaquil. The survey included five different branches (esteros) of a major estuary beginning at the city of Guayaquil and extending 50 km to the Gulf of Guayaquil. Sampling sites (Fig. 1) were stratified within each estero to represent 1) the mangrove interior, 2) the estero mouth, and 3) the area just outside of the mouth. All the esteros were dominated by mangrove habitat and a salinity gradient was evident which extended from the Guayas River to marine waters of the Gulf of Guayaquil. The esteros sampled were situated along this gradient and were locally identified as 1) Estero Data, 2) Estero Morro, 3) Estero Corvinero, 4) Estero Grande, and 5) Estero Salado (Fig. 1).

Sampling During 1985

Sampling was begun in February of 1985, and was continued monthly through January of 1986. During highest tides of each month, three replicate trawls were taken at each of the three sites within each estero using a one-meter wide beam trawl. The trawl was hand pulled over a distance of 32 meters for each replicate. (For a complete description of the design and procedures, see Report to the Secretary General of the Organization of American States, Division of Applied Sciences, Washington, DC, Performance Contract #WSC0007, Vol. 2, (1985), Roger J. Zimmerman, National Marine Fisheries Service, Galveston, TX 77550).

Personnel

Personnel from the Institute of National Marine Fisheries in Ecuador collected all the samples, processed the material, and entered the data into

a computer file. Dr. Roberto Jimenez supervised the project in Ecuador with technical assistance from Rosa Garcia, Douglas Burgos, Javier Landiver, Monica Dik, Cesar Aguirre, and Ingrid von Buchwald. Mr. Santiago French supervised computer operations and Dr. Thomas Minello, (National Marine Fisheries Service, Galveston) analyzed the 1985 data. Dr. Roger Zimmerman served as the principal advisor for the project and was responsible for the design and data interpretation.

PRELIMINARY RESULTS FOR 1985

Shrimp Abundances

Overall Abundances Among Species - Rank order of abundance among species during 1985 was 1) *Penaeus californiensis*, 2) *P. vannamei*, 3) *P. stylirostris*, and 4) *P. occidentalis*. *Penaeus californiensis* (overall mean = 9.07 per sample) were roughly 9 times more abundant than postlarvae and juveniles of all other species (Table 1).

Seasonal Abundance Patterns - *P. californiensis* were numerous throughout the year, with peaks in June, January and February (Fig. 2). *P. vannamei* were also present throughout the year, with minor peaks during July, September, and January (Fig. 3). *P. stylirostris* were present in samples taken in May, September, and December with highest abundances in March and November samples (Fig. 3).

Abundance Patterns Among Esteros - The largest numbers of shrimp, including all species, occurred in Estero Morro (Table 1). The four remaining esteros were roughly similar in overall abundances that were each significantly lower than Estero Morro. As might be expected, Estero Morro had the highest numbers of the two most abundant shrimps, *Penaeus californiensis* (18.48 per sample) and *P. vannamei* (1.37 per sample). Estero Data had numbers of *Penaeus vannamei* (1.16 per sample) similar to those in

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Estero Morro, but numbers of P. californiensis (5.98 per sample) were not. Esteros Corvinero, Salado, and Grande were substantially lower in abundances of P. vannamei than those in Esteros Data and Morro. This result suggests that esteros closest to the recruitment source receive and provide nursery habitat for more shrimp per unit area than those further away. P. stylirostris followed the same abundance pattern among esteros as that of P. vannamei. Numbers of P. occidentalis during 1985 were too low to establish a pattern.

Abundance Patterns Among Sites - P. californiensis were the most numerous at interior and playa (beach) sites across all esteros (10.24 and 10.91 per sample, respectively; Table 2) and less numerous at boca (mouth) sites (5.48 per sample; Table 2). P. vannamei were most abundant at interior sites (1.42 per sample; Table 2) and least abundant at boca and playa sites (0.40 and 0.31 per sample, respectively; Table 2). P. stylirostris were also more abundant at interior sites compared to boca and playa sites (Table 2). Importantly, the pattern across all shrimp species was that of highest abundances at interior sites and lowest abundances at boca sites.

Shrimp Sizes

Predominant sizes of shrimp in the esteros were among those of postlarvae and juveniles between 5 mm and 70 mm total length (measured from the tip of the rostrum to the end of the telson). Mostly, they were small with monthly mean sizes ranging between 12 mm and 20 mm total length for P. califoriensis and between 12 mm and 37 mm total length for P. vannamei. Overall mean sizes of P. vannamei were larger than P. califoriensis (Figure 4).

Physical Conditions

A. Temperature - Temperatures in the esteros ranged from a high of 31°C

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in February and March to a low of 24°C in July and August (Figures 5). A seasonal trend of high temperatures during the wet season and low temperatures during the dry season was evident.

B. Salinity - Salinity ranged between 22 o/oo during April and 39 o/oo during August (Figure 5). The magnitude of seasonal changes in salinity reflected the duration and intensity of the wet and dry seasons. The relatively high salinities throughout much of 1985 indicated a relatively dry year.

C. Environmental Gradients - A salinity gradient was reflected in the main estuary by low salinities in Estero Salado and high salinities in Estero Morro. Lowest salinities were at interior sites of Estero Salado and Estero Corvinero, and highest salinities were at the interior site of Estero Morro. Temperatures did not differ greatly between esteros or among sites, although the interior sites within all esteros were more variable than playa and boca sites. Mangrove habitat at the interor sites was more extensive than at boca and playa sites. Playa sites usually consisted of open water near a barren shoreline or mud flat just outside of the mouth of each estero. Boca sites were just inside the mouth of each estero and were dominated by a wide entrance channel with mangroves along the shoreline.

DATA TRENDS

Interspecies Relationships

Penaeus vannamei and *P. stylirostris* were similar in patterns of abundance among esteros and between sites. Although both of these species were present throughout the year, densities were comparatively low. *P. californiensis*, on the other hand, was present in high numbers throughout the year. All three species demonstrated abundance peaks that were associated with the wet season and all were more abundant in esteros nearest the Gulf of Guayaquil (Estero Morro and Estero Data) and

significantly less abundant in the middle and upper parts of the main estuary (Esteros Corvinero, Grande, and Salado).

Abundance Relationships to Temperature and Salinity

Seasonal temperatures and salinities followed an inverse relationship, with low salinities and highest temperatures occurring in the wet season during February, March and April. In opposite fashion, low temperatures corresponded to highest salinities in July, August and September. As stated previously, the duration of relatively high salinities across all estuaries indicated that 1985 was a dry year. Importantly, abundances of P. californiensis were also comparatively high throughout the year and all other species were comparatively low except during January and February of 1986. In the early part of the 1986 wet season, densities of P. vannamei increased to highest levels, especially in the esteros near the coast. The low numbers of P. vannamei and P. stylirostris during 1985 suggest a close relationship to high rainfall and warm water conditions that may be less important to P. califoriensis.

Abundance Relationships to Environmental Gradients

The three most abundant shrimp species appeared to be attracted to the interi areas of all the esteros that were dominated by mangroves. These areas bly serve as the primary nursery habitats for P. californiensis, P. vannamei and P. stylirostris. The relatively high shrimp abundances observed at the playa sites (outside estero mouths) suggest accumulations of shrimp going to and coming from the esteros. Once inside the esteros, the small postlarvae move rapidly through the mouth to the interior mangrove nursery. A shrimp density gradient among esteros was evident with esteros at the head of the main estuary (Corvinero, Salado, and Grande) containing fewer shrimp per unit area than esteros at the mouth of the main

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estuary (Data and Morro). These density relationships are most certainly influenced by the size of shrimp recruitment events (overall recruitment was low during 1985), distances of esteros from the recruitment source (the Gulf of Guayaquil), and differences in area among esteros.

RESEARCH RECOMMENDATIONS

Influence of Postlarval Fishery

A postlarval fishery for pond stocking has developed so that every estero in Ecuador is exploited by large numbers of individual fishermen during monthly high tides (90,000 persons are estimated to be involved in the fishery) . The variety of methods used by these fishermen have not been documented and their effects on reduction and selective structuring of recruits in the nursery is not known. Our information suggests that *P. vannamei* and *P. stylirostris* are selectively taken by the fishermen and *P. californiensis* is selectively excluded. The impact of such differential exploitation may have a long-term restructuring effects on the overall shrimp population.

A program is recommended that will evaluate the postlarval fishery. The program should include projects that 1) thoroughly describe and compare various methods used by fishermen, 2) monitor the species distribution among postlarvae taken by fishermen compared to natural abundances among species and 3) evaluate the effect of structuring among species by selective fishing.

Habitat Selection Within the Nursery

Three shrimp species appear to utilize the interiormost areas within esteros as primary nurseries. Relatively fine scale habitat selection and resource partitioning among these species can be expected within such areas. Selection and partitioning implies different resource needs, some of which may be critical to survival and production.

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A program addressing specific habitat utilization among species within the nursery is needed. The initial project should address differences in abundances within and between species comparing the following habitats, 1) mangrove, 2) open-water channels, 3) intertidal mud flats, and 4) nonvegetated shoreline (flooded salitral). The data can be used to develop investigations that focus on habitat specific resource requirements.

Influence of Physical Conditions

The data from 1985 indicate a cool dry year that may have affected recruitment and the subsequent distribution of abundances among shrimp species (*P. califoriensis* were high; *P. vannamei* and *P. stylirostris* were low). Since annual variability can be expected (including warm and wet El Nino events) related changes in shrimp recruitment and distribution among species are likely.

A long-term program is needed to address the relationship between nursery recruitment (abundances of postlarvae and early juveniles) and annual changes in temperature and rainfall. A standardized monitoring program within selected nurseries is recommended which can provide data on numbers of shrimp per unit area along with measurements of environmental conditions.

Table 1. Shrimp abundances among esteros in a large estuary near Guayaquil, Ecuador during 1985.

Estuarine Branch	*Penaeus californiensis*	*Penaeus vannamei*	*Penaeus stylirostis*	*Penaeus occidentalis*	All Shrimp
	Mean number per 1X32 m beam trawl drag				
Estero Data	5.98	1.16	0.29	0.22	7.39
Estero Morro	18.48	1.37	0.21	0.08	20.14
Estero Corvinero	5.70	0.27	0.18	0.02	6.17
Estero Grande	7.33	0.19	0.03	0.03	7.58
Estero Salado	6.70	0.37	0.08	0.12	7.27

Note: The above esteros are listed in order beginning at the mouth and extending to the head of the main estuary (see Fig. 1).

Table 2. Shrimp abundances of among sites in esteros of a large estuary near Guayaquil, Ecuador during 1985.

Site	Mean number per 1X32 m beam trawl drag				
	Penaeus californiensis	*Penaeus vannamei*	*Penaeus stylirostis*	*Penaeus occidentalis*	All Shrimp
Interior	10.24	1.42	0.28	0.11	12.05
Mouth (Boca)	5.48	0.40	0.08	0.18	6.14
Beach (Playa)	10.91	0.31	0.14	0.01	11.37

Note: The means given are across esteros Data, Morro, Corvinera, Grande and Salado.

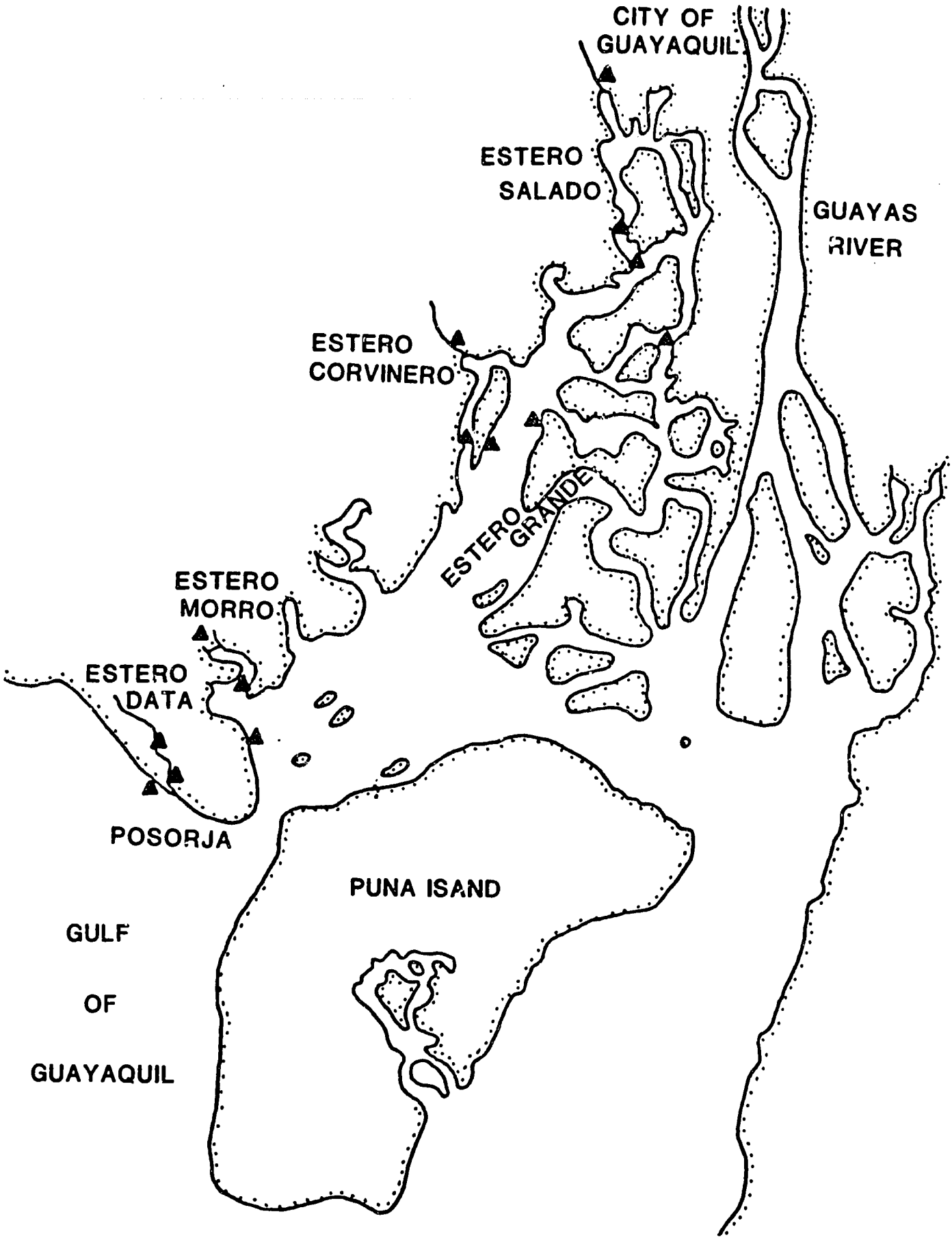

Figure 1. Sampling sites in branches (esteros) of a large estuary near Guayaquil, Ecuador during 1985.

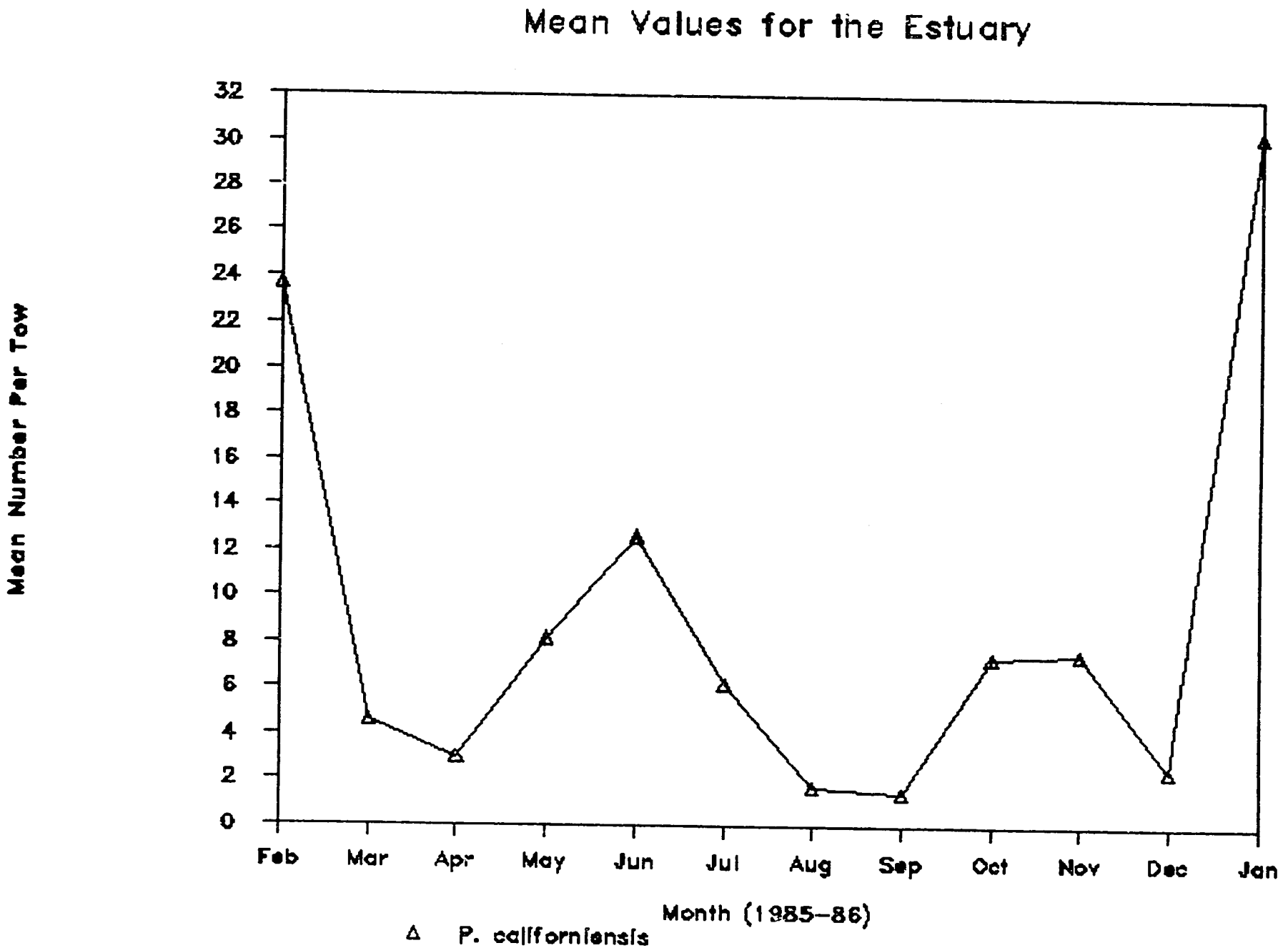

Figure 2. Monthly abundances of P. califoriensis averaged from sites in five esteros of a large estuary near Guayaquil, Ecuador during 1985.

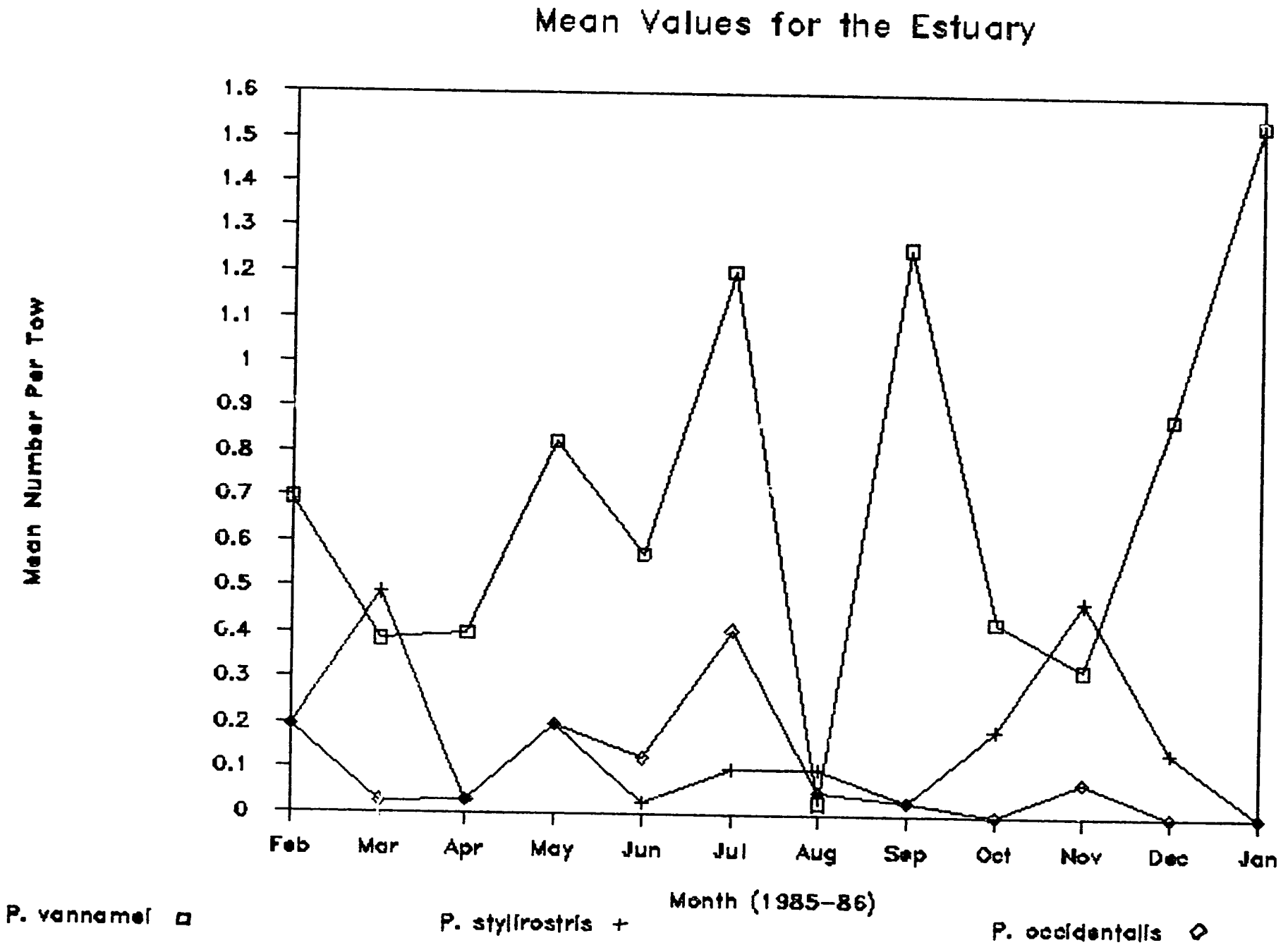

Figure 3. Monthly abundances of P. vannamei, P. stylirostris and P. occidentalis averaged from sites in five esteros of a large estuary near Guayaquil, Ecuador during 1985.

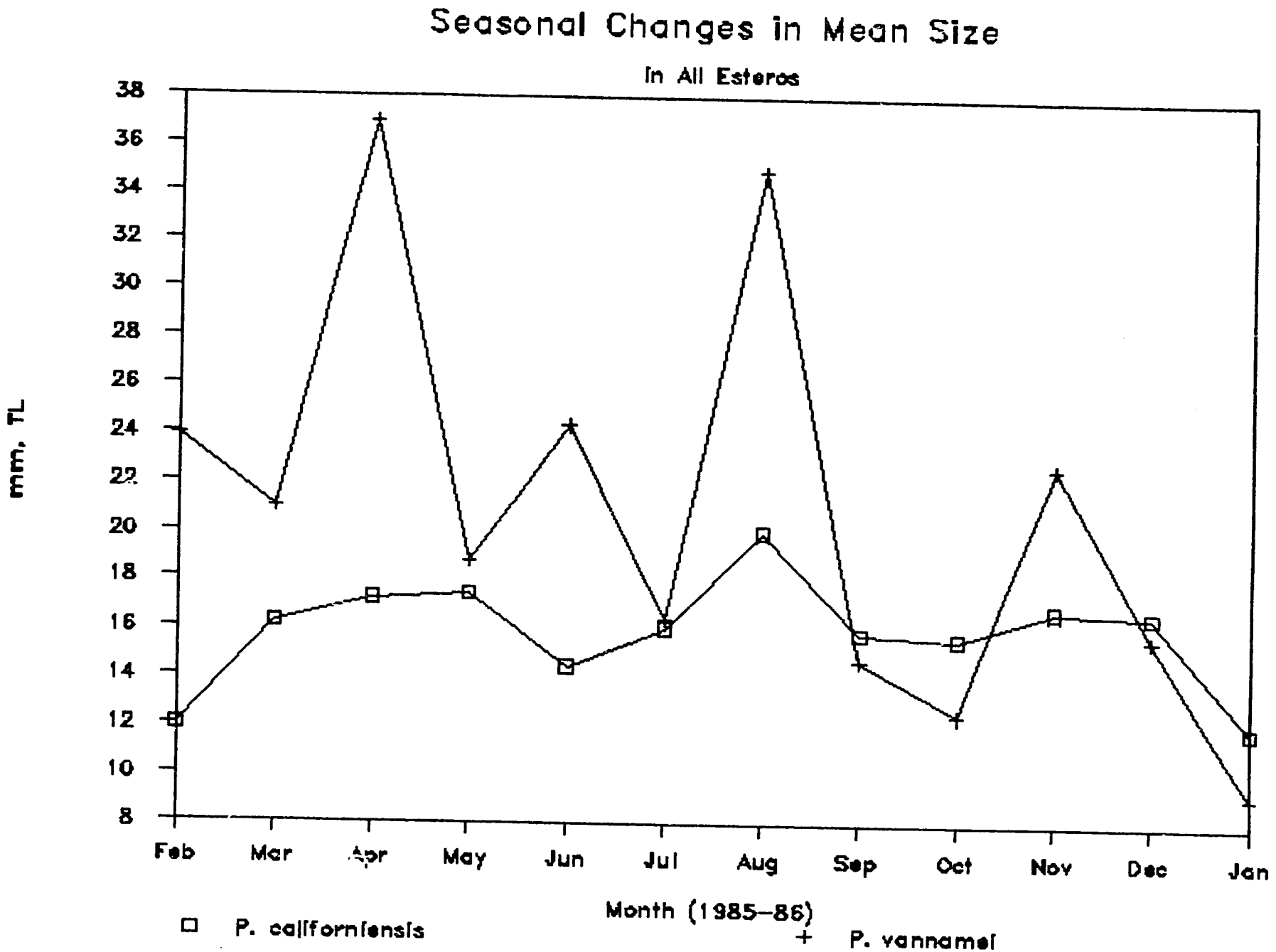

Figure 4. Mean sizes of P. califoriensis and P. vannamei averaged across five esteros of a large estuary near Guayaquil, Ecuador during 1985.

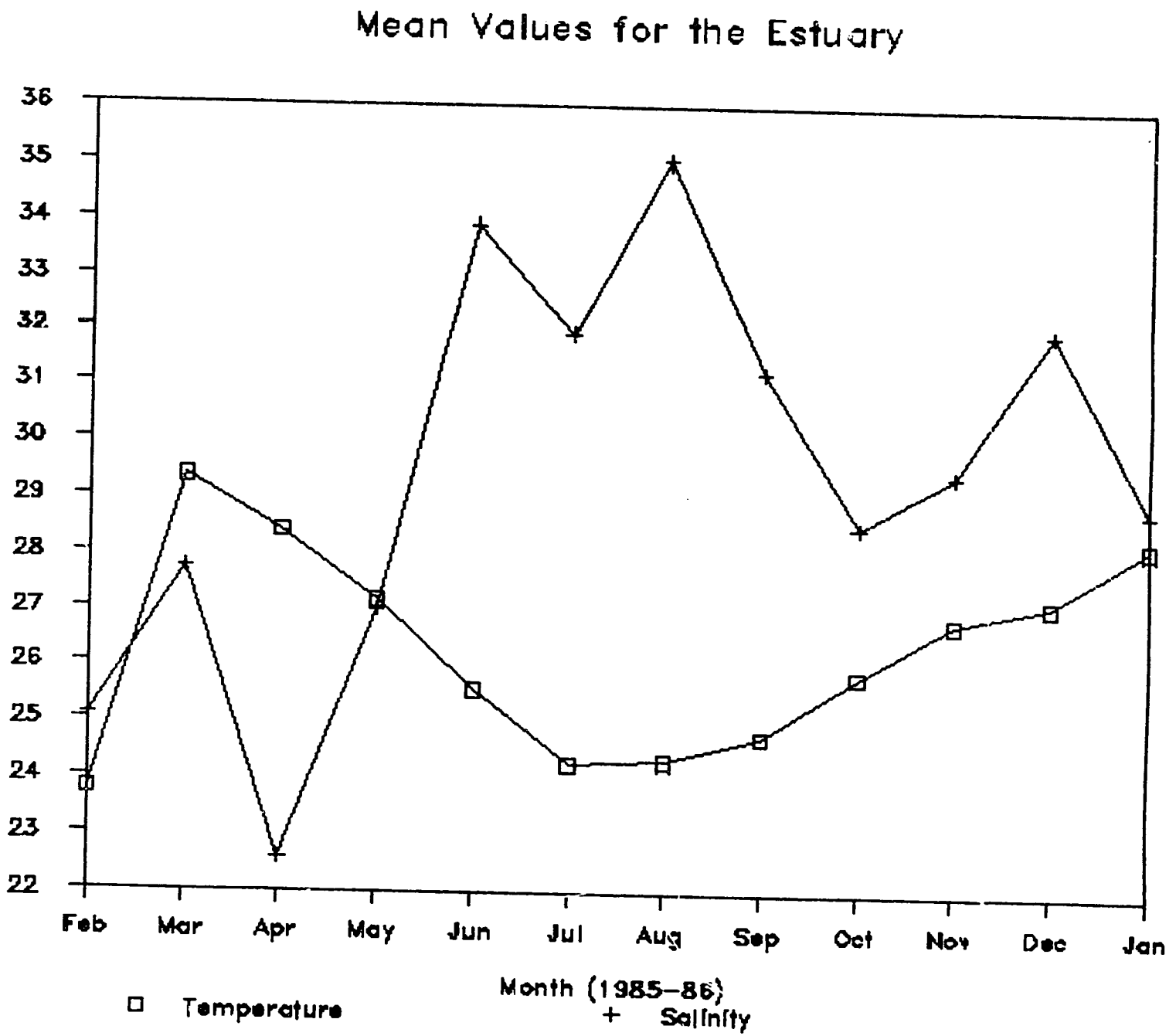

Figure 5. Mean temperatures and salinities averaged across five esteros of a large estuary near Guayaquil, Ecuador.

SHORT AND LONG TERM ROLE OF HATCHERIES IN THE SHRIMP POND CULTURE INDUSTRY

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PREFACE

This manuscript contributes to the important work of designing an adequate means to acheive continunity of shrimp production and assuring both the rational exploitation of this natural resource and the continued flow of income that it generates. In the authors view, the criteria that are presented here are not only of interest to the producer but also to those at the level of political decision making.

The authors have synthesized views on the larvae supply and have tried to identify the most important short and long term problems involved in the supply of hatchery larvae destined for pond culture, as well as suggesting measures for the countries benefit.

INTRODUCTION

The Ecuadorian shrimp industry has experienced a substantial increase in activity since the 1970's. Exports totalled 2,700 Metric Tons (MT) in 1970, 10,200 MT in 1980, 23,400 MT in 1984 and 19,900 MT in 1985.

Since 1982 the average price for exported shrimp has been US $3.60 per pound, which have produced an estimated annual income of more than 200 million dollars given the sale of shrimp at and below billed prices. It is estimated that 75% of these exports, since 1980, came from ponds and 25% from the shrimp fishing fleet.

Presently more than 90% of the larval supply comes from the natural environment, caught by artisanal fishermen called "laveros". Estimates vary but apparently more than 90,000 people are involved in this fishery. When fishing is good a lavero may earn as much as 2,500 sucres or approximately $17 USD per day.

The shrimp industry, with an initial investment of approximately 2 Billion dollars cannot continue to depend solely on a natural supply of larvae, which is only seasonally available. The development of hatcheries permitting current levels of exportation to be maintained is required, if the industry is to stabilize. The conventional conservation methods for shrimp resources, which can help maintain the levels of the resource as well as improving its management, are still in the planning stages and will require many years of research.

The still unknown annual fluctuations in larval distribution on the coast, both seasonal and spatial, make it impossible to adequately predict Ecuador's annual shrimp production. For this reason the shrimp sector has started to plan and develop shrimp culture laboratories (hatcheries), in order to guarantee a steady supply of post larvae when the natural populations become less available.

During the period begining with the construction of a hatchery until it comes on-line (in operation), which is called the "Technical-Economical-Financial Transition Period", many problems arise that will have to be solved both in the short and long term.

SUGGESTIONS FOR SOLVING SOME PROBLEMS

POND PRODUCTION

Those farmers having ponds can optimize their production immediately by focusing their attention on the transition point. This improvement in transportation methods for wild larvae as well as methods for their acclimation, stocking and maintenance in nursery ponds, will have direct immediate and visable postive affect on the industry.

POSTLARVAE HANDLING

The hatcheries that are already in operation should cooperate to assure more confidence in the use of their larvae, coordinate the preparation of their respective ponds, eliminate possible stress factors, control environmental parameters, and prepare cost effective feeds of adequate nutritional value.

CONSTRUCTION AND DEVELOPMENT OF HATCHERIES

The expansion of hatcheries will demand managers and technicians at all levels, and it will also require an adequate supply of brood stock and/or nauplii, sound culture techniques, and adequate transportation to nursery ponds.

SIZE AND CAPACITY OF THE HATCHERY

The average size of hatcheries under construction today, has decreased, apparently due to a desire on the part of managers to supply 100% of the larvae for ponds controlled by the enterprise. There are at present, 68 hatcheries in various stages of planning or construction, of these 51 have received approval to begin operation, see table 1.

Table 1. NUMBER AND CAPACITY OF AUTHORIZED HATCHERIES*

PROVIENCE	NUMBER	PROJECTED CAPACITY (IN MILLIONS)
GUAYAS		
-SANTA ELENA	23	2,404
-OTHER AREAS	10	861
EL ORO	3	126
MANABI	11	1,056
ESMERALDAS	4	208
TOTAL	51	4,655

* Direccion General de Pesca

Farms larger than 800 hectares of cultivatable area, generally plan for a minimum of two harvests per year with an average stocking density of 50,000 post larvae per hectare, with an average harvest of 2,500 pounds/harvest/year at sizes from U21/25 to U36/40. In this case the size of the hatchery selected for is one which can produce at least ten (10) million post larvae per month. There is also a high percentage of shrimp farms in the 80 to 400 hectare size range. In these cases the hatchery is designed to produce five (5) million post larvae per month.

From an economic point of view, higher levels of production lower the relative production cost. Moreover, for small hatcheries, production costs will depend on the initial investment, the system applied, and the number of personnel involved.

At the present time, it appears that larger companies will function better for the short term since the personnel have more job stability than those in smaller companies but in the long term the small and medium sized hatcheries will be better able to survive a crisis. Such crises might be economical, technical or administrative.

On the other hand, by installing more small hatcheries, more technical personnel will be needed. These persons are in great shortage at present in Ecuador, as well as all over the world. A short term solution could be to use technicians that move from one hatchery to another. This is also a way to transfer "Know-how", as long as the technicians who do this have sufficient experience.

The question is, how many hatcheries, of what size are required by Ecuador to guarantee a steady level of production? This is a very difficult question to answer exactly because the country is still not prepared technically to support a "boom" of hatcheries. On the other hand, if this development so necessary for the country, is not undertaken now, the increases in costs, the rise in the dollar and the difficulties with importation of equiptment, will make future costs and investments much greater, and may even make further development - stability prohibitory. Correcting errors made now, will benefit the Ecuadors shrimp industry, not only in the short term but may also have a long term stabilizing effect.

PROBLEMS IN THE APPLICATION OF TECHNOLOGY AND THE DEVELOPMENT OF THE ECUADOREAN HATCHERY SYSTEM

SHRIMP CULTURE METHODS

Although many commercial hatcheries claim to have the best technology, it is beyond the scope of this paper to point out unnecessary technological complications which do not benefit the hatchery industry in the long term. It is necessary to establish simple methods that will not cause major stress or problems in the system.

In principle Ecuador could produce many postlarvae from hatcheries presently planned for and in construction but this does not imply that a large percentage of these postlarvae survive to be harvested from ponds. For this reaseon wee need to study and know post larval and juvenile nutritional requirements. There is also a need to supply a larger sized post larvae (>PL10) to the farms, thereby enhancing

survivability as well as confidence of the shrimp farmers in the hatchery produced seed stock.

Penaeus vannamei is the species of shrimp that farmers use in most quantity. Ecuador also has stocks of P. stylirostris which grows rapidly in the pond environment with little handling (ie. low density culture). Wild stock post larval, P. stylirostris are available in quantites at a different time of the year than P. vannamei, allowing farmers to extend the stocking period, thus permitting a more even flow of marketable shrimp. Farmers could utilize hatchery produced P. stylirostris, a further advantage, when P. vannamei nauplii are not available.

SHORTAGES OF BROODSTOCK AND NAUPLII

Hatcheries raise larvae from eggs through a metamorphic stage to post larvae. Shrimp hatcheries obtain fertile eggs in two ways. The first is to gather the spontaneous spawn of gravid females caught by shrimp fishermen (sourcing). To produce two billion post larvae Ecuador's hatcheries will require five billion nauplii or approximately 14 million nauplii each night. Gravid female shrimp are available year-round from coastal waters in Esmeraldas. Empacadora Nacional operates the largest sourcing fleet in Ecuador, and produces 2-5 million nauplii each night. Gravid females are also captured off of San Pablo from October through February. During that period between 4-20 million nauplii each night are collected. These data suggest that the wild stock gravid population(s) can almost supply the projected demand from October through February, but the supply of nauplii from Esmeraldas cannot supply the hatcheries with nauplii for the rest of the year.

The second is from gravid female shrimp maintained in maturation facilities within the hatchery. This method employs the ablation of one eyestalk to accelerate the development of the ovaries (maturation), and where natural mating has not occured the attachment of sperm to the female shrimp prior to spawning. Maturation production varies depending on techniques used, experience of the manager and availability of brood stock. Year-round production ranges from 20,000 to 150,000 nauplii per tank per night. This suggests a need for some 250 tanks. Most hatcheries presently under construction incorporate maturation systems. As many as 400 tanks may come on line when these facilities begin operating. The production of nauplii will then depend upon how rapidly commercial maturation techniques can be mastered and the availability of brood stock.

The zones and times of spawning of P. vannamei are not exactly known although some areas are known for this species by the laveros. Broodstock P. vannamei are captured in large quantities principally between December and March due to higher ocean temperatures. The egg-bearing breeders supply a certain quantity of nauplii to different laboratories so they can operate at their full capacity. If that hatchery does not have an operational maturation system, larvae cannot be produced throughout the year. Due to insufficient supply of nauplii during certain times of the year, there is a tendency to use high density larval culture techniques. If there are not adequate controls, disease problems can become critical, leading to a potential decrease in productive capacity. This situation can be rectified when functional systems of maturation or a "Nauplius Distribution

Center" become operational. If, for example there were sufficient supply of nauplii, and a tank in a hatchery showed signs of disease or low survival rate, with such a center it would be possible to throw out the tank and replace it with nauplii at appropiate densities.

The short supply a high quality broodstock for use in maturation systems could be solved by maintence of special tanks or ponds at the hatchery or pond site, or by selective fishing (sourcing) by the offshore fleet. The utilization of broodstock from ponds would require special consideration be placed on pond size and maintenance as well as supplimentary feeding, and disinfection before transport to the hatchery.

THE NEED FOR ECUADOREAN TECHNICIANS AND ADEQUATE FINANCING OF HATCHERIES

The industry has grown so fast that the efforts now being made at Universities and Polytechnic schools to prepare technicians will only have limited effect. This is due to economic factors and a lack of experimental and educational laboratories (with the exception of the ESPOL Hatchery). In the future it will be necessary to train three levels of technicians:

-Technician 1, who would become, with more experience, a hatchery manager.

-Technician 2, who would function as a medium level technician and could become a hatchery manager with time.

-Technician 3, who could be the actual operator of the hatchery.

The level one technicians are those who have either local or international academic training in diverse programs of Mariculture, Marine Biology,Veterinary Medicine, etc. They will be the ones that plan and operate the system.

The level two technicians are those who, on the short term and without necessarly having an academic degree, are being trained at actual commercial hatcheries, as well as training centers (such as ESPOL). They will be the ones that carry out the technical effort.

The level three technicians are the local operators that carry out the routine work, gain experience in their own hatcheries, and with common sense help solve problems in the system. They too could be prepared by programmed special courses and training.

Of special importance is a knowledge of the administrative aspects of the hatchery, such as financial accounting, purchasing and supplies and particularly personnel management.

The management of the hatchery is critical because adequate communication and comprehension amoung field personnel (Hatchery) and the central administration would permit more stable personnel in their laboratory.

The principal "bottlenecks" that presently inhibit complete development and operation of shrimp hatcheries in Ecuador are the lack of adequately trained technicians and inadequate financial support.

CONCLUSIONS AND RECOMENDATIONS

Many actions at all levels should be taken to help the shrimp industry reach a stable level of developemtn. Here we mention a few of these related to hatcheries and comment about shrimp pond improvements.

SHORT TERM ACTIONS

Shrimp production could be increased by optimizing actual installed capacity. Improving actual pond management includes addressing problems of transportation and acclimation of wild post larvae, appropiate feeding, harvesting and adequate marketing.

The future of shrimp hatcheries and the industry will depend on the substancial and stable quality and quantity of larvae that are available. It is not the same if 1 Billion PL 5 postlarvae of low quality are produced each year, rather than 500 million PL 15. The hatcheries should produce larvae of excellent quality (both in nutrition and size) even at lower production levels, since these larvae would have higher market acceptability and preferential price.

Wildstock postlarvae may always exist as strong competition for hatchery produced seed. Hatchery produced seed, once there efficient use in ponds becomes standard may be a long term solution towards a stable mariculture industry in Ecuador.

MEDIUM AND LONG TERM ACTIONS

Various commercial scale laboratories should be placed in operation. Applied research with direct and rapid impact on production should be strongly stimulated, and research on diseases should be initated not only in governmental laboratories but also in private laboratories.

In the medium and long term, basic research should be carried out. This might best be done in Centers for Technical Assistance and Extension, which should be consolidated at all levels and emphasize training of Ecuadorean personnel.

The necessary support for soft loans for hatcheries should also be included amoung these basic needs.

The study of broodstock maturation processes is urgently needed so that an adequate supply of eggs and nauplii can be obtained on a continuing basis. Once these maturation processes are understood in an adequate manner, a Nauplius Distribution Center should be installed that would permit the operation of small and medium sized hatcheries.

Finally, the Ecuadorean Government should permit ESPOL, by means of its Shrimp Larval Culture Project, to serve the needs of the entire shrimp sector. One way to assure this is to allocate funds so that the operation of the hatchery and training laboratory is not stopped. Another might be to permit ESPOL to operate ponds, as other government agencies (Navy) do, export the product, and use the funds to support hactchery training operations. Measurable results of the ESPOL Shrimp Project "open door" policy of technical transfer can only properly be assessed in the long term.

REVIEW OF ECUADOREAN SHRIMP FISHERIES AND SUGGESTIONS FOR MANAGEMENT AND RESEARCH

by

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INTRODUCTION

I have been asked by the University of Rhode Island under contract with United States Agency for International Development to review and evaluate the offshore shrimp fisheries of Ecuador and to make recommendations concerning their management and research. In this paper I review, in a general sense, the information available for the offshore shrimp fishery of Ecuador, synthesize some of the major findings and make recommendations concerning their management and research.

BACKGROUND

The Ecuadorean offshore trawl fishery commenced in 1952 according to Cobo and Loesch (1966). Total shrimp production and number of boats operating were recorded since 1954 through 1975. Since 1976, with the inception of the culture industry, accurate information on total production is not available for the offshore Ecuadorean trawl fisheries. During the period of adequate record tabulation, the fishery fluctuated from a high of 8,700 metric tons in 1969 to a low of around 5,000 metric tons in 1964. Production appears to be fairly stable at around the 6,000 metric ton level. The number of vessels has gradually increased to approximately 250-300 vessels in 1985. Cun and Marin (1982) estimated that *Penaeus occidentalis* comprised between 50 and 60 percent of the white shrimp catch between 1965 to 1979 and is the most important species to the trawl fishery. The second important species is *Penaeus stylirostris* and may constitute between 25 and 40 percent of the catch during the 1965 through 1979 period, whereas *Penaeus vannamei* is of only minor importance in the Gulf of Guayaquil and other areas, contributing on the average approximately 6 percent of the catch. It should be noted, however, that there appears to be considerable annual variation in the species caught by the offshore fishery. In some years, such as 1973 and 1977, *P. vannamei* comprised 12 percent of the total catch, and in 1979, 21 percent of the commercial catch

was made up of this species. McPadden[1] shows that in 1985 P. vannamei made up at least 30 percent of the white shrimp catch in the Gulf of Guayaquil (Table 1).

Two other species, Penaeus californiensis and P. brevirostris, do not appear to be major to the offshore catch; however, this may be due to the fact that they are found farther offshore, and the fishery may not operate in offshore waters as readily as in the nearshore waters. This appears to be two fisheries: one north of Manta with both white and brown shrimp as main components and the other south of the Manta, mostly composed of white shrimp. The interchange of shrimp and stock delineation between the two areas is unknown.

Detailed information on monthly catch-per-unit effort is available from 1973 to the present, but only limited annual CPUE estimates from 1956 to 1972 are available. The data from June 1973 to the present are based on interviews with vessel captains in the Gulf of Guayaquil. McPadden (1985) has used these data to clearly demonstrate the measures of relative abundance from the 1973 to the 1986 time frame. In addition, monthly mean size and length frequency distribution by species is available in a raw form, but has not been analyzed in any depth. The monthly length frequency distributions by species are supposedly available but not in a computer format, so they cannot be easily analyzed to determine periods of peak recruitment.

Dr. Somers, FAO consultant from Australia, evaluated the impact of the postlarval and offshore shrimp fisheries on the long-term recruitment of major commercial species of shrimp with particular reference to P. vannamei. Findings of both Dr. Somers and myself indicated that total annual production statistics are based on export records and definitely do not distinguish between farm and sea production. A series of estimates by

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[1]Charles McPadden, personal communication, Instituto Nacional de Pesca Letamendi 102 Yla Ria, Casilla 5918 Guayaquil Ecuador.

Somers[2] have been made to calculate total production; however, none of these appear to be reliable, but may be adequate to depict an overall trend in production and may be used to indicate an overall trend in number of vessels in the offshore fishery. Production has gradually increased from 1954 to the present. Somers identifies the production estimates by various researchers throughout this time frame (Figure 1).

The annual CPUE in the early years of the fishery was relatively high but varied greatly, ranging from a high of 352 pounds per day in 1956-57 to approximately 143 pounds per day in 1958-1959 (Table 2). Generally, the annual CPUE was about 200 pounds per day in the Esmeraldas region and 177 to 120 pounds per day in the Gulf area during the 1961 to 1964 time frame. In recent years, total annual CPUE has more or less been stable from 1973 through 1982, fluctuating around 120 pounds per day (Figure 2). The only exception, of course, was the el nino year where the CPUE jumped to 345 pounds per day and thereafter dropped to low levels of 78 and 68 pounds per day in 1984 and 1985. Dr. Somers has been able to separate the annual CPUE into all species and P. vannamei. The average annual catch rate for 1984--85 was 73 pounds per day and is below the average 113 pounds per day for the 1973-79 time frame. The specific catch rate for P. vannamei was 23 pounds per day in 1984-85, but is greater than the average 13 pounds per day for the 1973 through 1979 time period. The initial catch rate for all species combined for the first few months in 1986 was 126 pounds per day and is similar to the earlier catch rates for 1973 through 1979, but somewhat lower than the early years in the fishery, 1961-64.

Presently, the British Mission under Charles McPadden has instituted two major programs for data collection: 1) an observer at sea program was initiated in November 1985, in which observers participate in fishing trips each month from the ports of Posorja, Guayaquil, Manta, and once every two months from Esmeraldas. Information is collected on the catch-per-tow,

[2]Ian Somers, personal communication, CSIRO Div. of Fisheries, P. O. Box 120, Cleveland Qld, 4163, Australia.

hours fished, areas fished, and species composition. In February, a log-book system was initiated throughout the country. Information will be obtained on catch-per-tow by area and time fished. The best data base presently available for analysis of the shrimp fishery is the information obtained from interviews; however, as I said before, there is no reliable information on total catch or fishing effort. McPadden[1] has thoroughly reviewed the present available data and as a result has initiated the above mentioned programs. The el nino year, 1982-83, was phenomenal in that the offshore fishery catch-per-unit effort increased dramatically during this time period, probably a result of increased spawning activity, better survival of juveniles, and good recruitment to the offshore fishery. Immediately after the el nino year in January 1984, monthly CPUE dropped to pre-el nino year levels. Since that time the CPUE appears to have decreased each month and has continued to decrease through 1985. Since March 1985, McPadden has obtained information on CPUE by white and brown shrimp. These data reveal that the monthly CPUE for white shrimp has decreased to a level below 40 pounds per day, whereas brown shrimp monthly CPUE has peaked in September 1985 at over 110 lbs/dav. The brown shrimp fishery apparently has increased, as much of the effort was probably altered to the offshore fishery since CPUE was so low in the white shrimp fishery.

The Ecuadorian government initiated a closed season from December 1985 to January 1986. After the season opened, the CPUEs were at least two times higher than before the closed season. This is as would be expected, since fishing effort was decreased to zero during the closure period. However, it is extremely disturbing to view the CPUE before the closure period, as it continually declined to extremely low levels. If these data represent what is actually happening in the fishery and reflect the availability and abundance of white shrimp, one should consider implementing regulations to reduce fishing mortality. Monthly catch rates of less than 40 pounds per day are extremely low as compared to any of the other world penaeid fisheries for the type of vessels that are presently being utilized off Ecuador.

Somers indicated that there was insufficient evidence to demonstrate any significant declines in recruitment to the offshore fishery; however, I feel it only fair to point out that the CPUE level is extremely low and has declined precipitously from the initial CPUEs after the fishery had stabilized in the 1961-64 time frame and that caution should be realized with this low CPUE level. If the percent species composition is correct as identified by McPadden, there has been a significant increase in the portion of P. vannamei captured and this is apparently reflected in the increased CPUE for P. vannamei in the last few years; however, the decline in the other species is of some concern and should be viewed very cautiously. Possible causes for the decline in CPUE other than overfishing may be the reduction in the mangrove area which are utilized as nursery areas by larval and juvenile shrimp (Zimmerman and Minello [MS]). Turner (MS) indicates that over 20% of the mangrove area has been lost in the last 10 years in Ecuador.

McPadden has also been able to crudely estimate the number of postlarvae delivered to the ponds by the artisinal fishery for aquaculture, but there is considerable uncertainty concerning these values. Maugle[3] indicates that up to 50% of the larvae caught die before they reach the pond, therefore the estimates are probably underestimated by at least a factor of 2. There appears to be a peak of production of postlarvae around 4 billion individuals (i.e. perhaps 8 billions) in 1984, declining somewhat after that. McPadden indicates that the catch estimates of postlarvae in 1985 were slightly lower than the corresponding estimates for 1984. He also has pointed out that the postlarval fishery is pursued by at least 90,000 participants, and he has clearly identified a need for accurate monitoring of this fishery to determine recruitment levels both in the postlarval and offshore fisheries.

BIOLOGICAL HYPOTHESIS

Charles McPadden has indicated that juvenile white shrimp are predominantly found in the Gulf of Guayaquil and that mature animals have not been

generally observed in this area. As a result, it is hypothesized that the Gulf of Guayaquil is a prime nursery area for P. vannamei and perhaps other white shrimp species. The size of the nursery area and timing may very well be dictated by the influence of the southerly cool currents and the availability of warm currents from the north. The movement of warm water (26°C) from the north into the Gulf of Guayaquil during the September, November, October period may enhance spawning for white shrimp and transport larvae into the Gulf. If the warm water area is sufficiently large and the time frame great, spawning and recruitment will probably be very good. However, if the southern cooler currents with temperatures of 22° and 23°C restrict the warm water during this period, it obviously may have a detrimental effect on the spawning and survival of larvae and juveniles during this time frame. Further, if the cold southern water penetrates, it may move or cause the juveniles to migrate out of the Gulf north toward the Esmeraldas area during the April-May period. Therefore, it appears that the success of spawning and survival and recruitment into the fishery may well be dictated by the degree of movement of the northern warm waters into the Gulf of Guayaquil and restriction of movement of cold southern waters into the Gulf of Guayaquil.

Somers[2] has demonstrated a remarkably good relationship between rainfall and CPUE (Fig. 3). Low rainfall results in low CPUEs; as rainfall increases, so does CPUE. However, this relationship is dominated by the el nino phenomenon of 1983 and its corresponding high rainfall and high CPUE. The relationship is extremely good at the lower and mid level of the scale and implies a good linear relationship with relatively low levels of rainfall up to 2000 mm per year. This relationship indicates that recruitment from the 1973-84 time frame has been influenced by environmental conditions rather than any other factors. Overfishing does not appear to be a major factor in the success of year-class strength based on this relationship.

FISHERY MANAGEMENT AND SCIENTIFIC INFORMATION

Governments have the general responsibility for conserving marine resources and have a major aim to ensure that the stocks of marine resources are available to future generations in the same quantities they are available to the present generation. The resources of Ecuador are not just for use by the present generation, but future generations as well, and we should look to these resources as providing a safeguard for the future. President Theodore Roosevelt of the United States at the turn of the century said, "The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value." Resource managers have the responsibility of conserving the stocks for future generations. They must, of course, prevent recruitment overfishing and certainly minimize growth overfishing. The difficulty arises in allocation of the resources between competing user groups. The manager does well by utilizing the best scientific information available and input from the industry and consumer groups. Obviously, there is a need for information between the scientists, the managers, the harvesters, and enforcement. I have depicted the flow of such information in Figure 4.

The acceptability of management decisions are based on the flow of information. It is equally important that significant input be provided by the users of the resources so that their views be known. This, then, has to be tempered with the best scientific information available so that allocation can be made in an equitable and fair manner to all the users. Various methods have been used to provide industry input. One method has been to set up special panels as advisory groups to government officials making management decisions. Further, in the United States a special group of individuals associated with utilization of the resources are legally mandated to develop management plans for federal waters (Leary, 1985). These plans are then submitted to the Government for either approval, modification, or disapproval. Another system is a single czar who controls all management decisions with little or no user input. Regardless

of which management system is eventually used, it is important that good scientific information be available for the decision makers. I therefore recommend that Ecuador consider expanding its present program of collecting shrimp statistical information. This program initiated by McPadden for maintaining logbooks and interviewing vessel captains which provides data on catch, effort, CPUE, and species composition should be expanded, and a comprehensive program to collect other fishery dependent data as well as fishery independent data should be implemented.

Fishery-Dependent Data

It is important to have a permanent program to collect fishery-dependent data (Klima, 1980). The following fishery-dependent data is critically needed for management decisions:

1. total catch,
2. fishing effort, and
3. size composition and species composition of the commercial catch.

I recognize that it might not be possible to regularly census the offshore fishery and that some type of sampling program probably would be required to obtain accurate total catch and fishery effort information. Therefore, I recommend that a special study be conducted to determine the experimental design, methodology, and approach for a national country-wide sampling program to collect fishery statistics.

The key to implementing a sampling program to estimate total catch and effort would be to obtain mandatory records of the number of trips each vessel makes accurately, and, of course, cooperation of the industry. To implement such a system, it would appear necessary to establish key field stations at major unloading ports throughout the country, such as Esmaraldas, Manta, Bolivar, and Guayaquil. These field stations could be manned by a small team of data collectors and research scientists. Not only could they collect and obtain fishery-dependent data on fishery catch statistics, but they could also monitor and conduct research on other projects.

Equally important will be the collection of accurate information on the artisanal postlarval fishery. Specific information is needed on the quantity of postlarvae by species caught by month and area, as well as number of individuals participating in this fishery. Sampling the artisinal postlarval fishery on a regular basis could be conducted from the field stations. A special study should determine the best experimental design, approach, and methodology to monitor the artisinal postlarval fishery.

Fishery-Independent Surveys

A major question concerning the stocks of shrimp off Ecuador is the interchange between the Esmeraldas and the Gulf of Guayaquil. A well planned tagging study could be conducted by tagging shrimp in either or both areas and obtain recoveries from the fleet. However, this information would need to be supplemented with the amount of fishing effort deployed in both areas, as well as the effort expended in areas between the Gulf of Guayaquil and Esmaraldas. The collection of tag recoveries would certainly be enhanced by the establishment of field stations, as mentioned previously. Should such a study be required, it would be essential to develop a good experimental design and plans so that meaningful information could be obtained. Prior training in proper tagging methodology and data analysis would also be beneficial (Klima, 1981).

Fishery-independent surveys to monitor the shrimp populations on the fishery grounds are expensive but do provide long-term information on trends and status of abundance of the major species. Fishery-independent surveys conducted once or twice a year would be useful in evaluating shrimp closures (Matthews, 1982). I recommend development of the experimental design before implementation of any at sea fishery-independent surveys. The present on-going program to monitor the distribution and abundance of postlarval and juvenile shrimp in the Guayaquil estuary should be continued, but expanded to other areas of the coast.

MANAGEMENT OF ECUADOREAN FISHERIES

Presently the two shrimp closures implemented off Ecuador appear to have been successful. To truly evaluate this, a statistics system needs to be implemented so that a true evaluation of the closed areas can be made (Nichols, 1982; Klima et al. 1982; Poffenberger, 1982; and Matthews, 1982). Without such evidence, it will be unlikely that continued industry support will be available. It has been my experience in the United States that even with good information, the political whims of various user groups may be swayed because of selfish interests. Therefore, I strongly recommend that a system of catch statistics be implemented for the country so that accurate information can be obtained on total catch, fishing effort, and CPUE as well as size composition and species composition of the commercial catch. Without that basic information, little or no progress will be made in terms of evaluating the closures off Ecuador.

The establishment of a permanent long-term program to collect fisheries statistics from both the offshore fishery and the postlarval fishery will form a data base that will be extremely useful in evaluating both fisheries. Further, without that type of data base, it is unlikely it will be possible to determine if recruitment overfishing has occurred. The fishery-dependent data bases can be used to analyze trends of both the postlarval and offshore fisheries and determine the impact on the major shrimp stocks of Ecuador.

Although recruitment overfishing does not appear to be evident, the low CPUEs in 1984 and 1985 experienced in the fishery and the switch in species composition from *Penaeus occidentalis* and *P. stylirostris* to *P. vannamei* is of some concern. Therefore, I recommend that the government seriously look at a method of imposing a limited entry system since there seems to be adequate numbers of vessels to capture the amount of shrimp presently being harvested. Any increase in fishing effort or number of vessels will only decrease CPUE and the per boat share of the resource. I further recommend that the government consider continuing the experimental closures. The rationale behind this is that a reduction in fishing mor-

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tality will not hurt the fishery and, in fact, may be a long-term benefit. The exact timing of the closure should be altered to coincide with peak recruitment of juvenile shrimp in the fishery.

Long-term planning is essential to the well-being of the shrimp industry of Ecuador. I feel that a management and research plan jointly developed by the government and shrimp industry would be beneficial. The plan should identify goals and objectives and describe possible management actions and select the action that will ensure a viable fishery. Implementation of the plan will require adequate financial resource for management, research, and enforcement.

SUMMARY

1. In this paper I summarize the information available on the Ecuadorean shrimp fisheries and identify some of the data gaps that I feel are necessary ingredients for management decisions. However, I also feel it is the responsibility of the government to develop a long-term plan for the management of their shrimp fisheries. Included in this plan should be goals and objectives for not only management and enforcement, but research as well. Further, once this plan is developed, adequate resources must be made available to commit to the management and research necessary to implement this plan.

2. The closed season and area concept appears to have been successful because of the increased CPUE immediately following the closure. However, this increased CPUE may be due to the reduction of fishing effort which allowed an increase in biomass through growth to the population or it could conceivably have been an increase in recruitment which allowed a delay in harvest to be a larger and more profitable size. Unfortunately, there is not adequate data to determine the reason for the increased CPUE. Nevertheless, the closed season and area concept should probably continue if only because it reduces fishing effort.

3. A sound statistical data collection system should be developed not only to evaluate closures, but also evaluate conditions of the stocks and to provide advice for future management actions.

4. Consideration should be given to limiting future expansion of the offshore shrimp fleet by developing some form of limited entry system.

5. Fishery-independent surveys may also be needed to evaluate management actions and determine recruitment and distribution of postlarval and early juvenile shrimp, as well as conducting mark-recapture studies to determine stock boundaries.

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Table 1. Percent of *Penaeus vannamei*, *P. stylirostris*, and *P. occidentalis*, in the Gulf of Guayaquil in 1985. (Source : McPadden, personal communication.)

	P. stylirostris	*P. vannamei*	*P. occidentalis*
March	30	35	35
April	25	30	44
May	28	34	38
June	27	52	21
July	34	40	26
August	25	33	42
September	60	25	15
October	37	38	35
November	33	44	23
December	39	24	37

Table 2. Total catch in million of pounds, fishing effort in days fished, and CPUE for white shrimp for the Gulf of Guayaquil and Esmeraldas (from Cobo and Loesch, 1966).

Area	Year	Total Weight	Fishing Effort	CPUE
	1956-57	2.94	8.4	352
	1957-58	3.60	12.6	286
Gulf and	1958-59	2.78	19.4	143
Esmeraldas	1959-60	3.19	16.1	198
	1960-61	2.60	12.3	212
	1961-62	2.39	12.4	191
	1962-63	2.33	14.1	165
	1963-64	2.08	15.4	185
Esmeraldas	1961-62	0.88	3.4	248
	1962-63	0.88	4.3	206
	1963-64	0.84	5.1	164
Gulf	1961-62	1.59	9.1	177
	1962-63	1.45	9.9	147
	1963-64	1.24	10.3	120

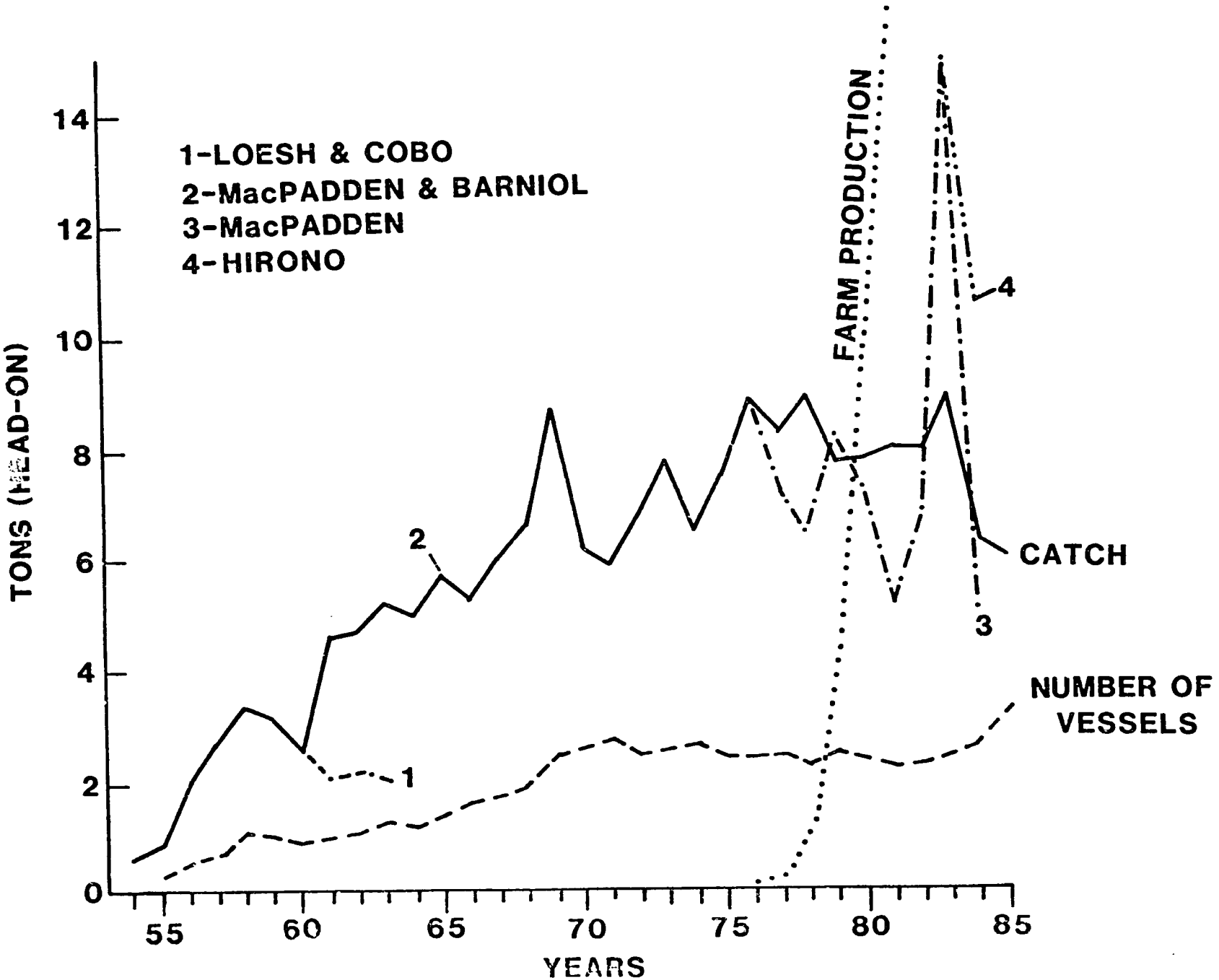

Figure 1. Total estimated shrimp production and number of shrimp vessels for Ecuador.

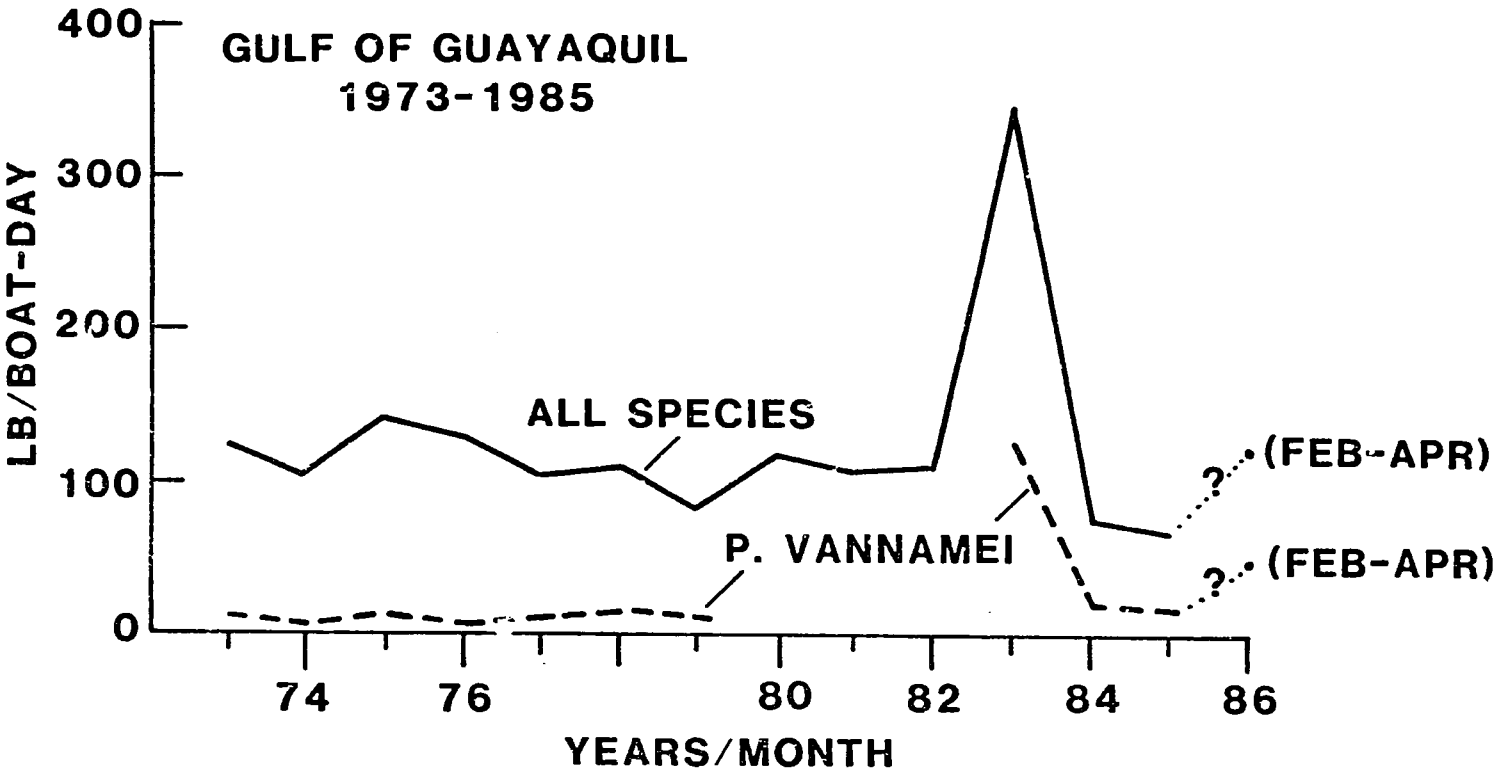

Figure 2. Monthly catch per unit effort (lbs head-off) for all shrimp species and P. vannamei in the Gulf of Guayaquil from 1973 to 1985.

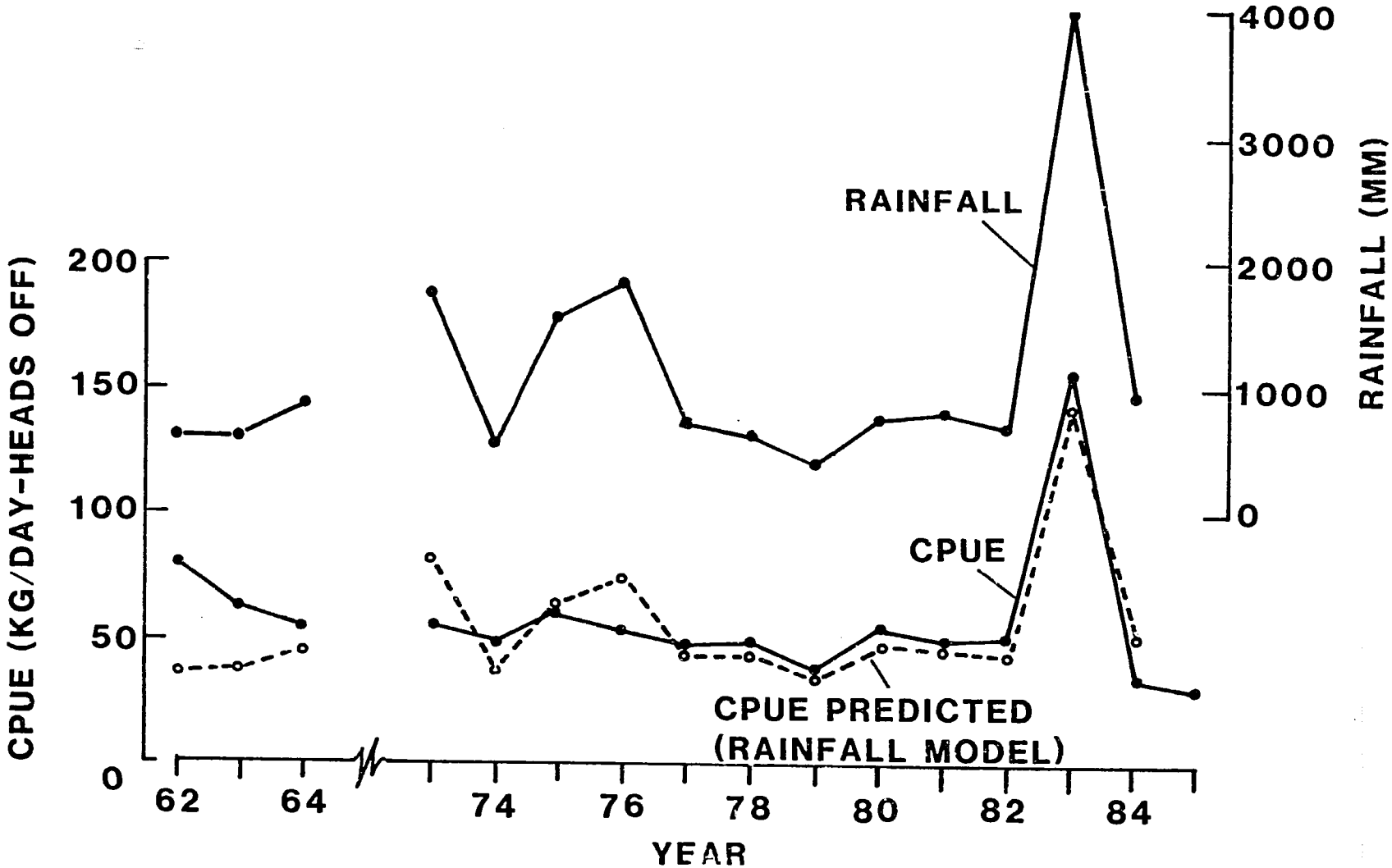

Figure 3. Relationship between rainfall (mm) and CPUE (kg/day, heads off) in the Gulf of Guayaquil (CPUE = 22.2 + 0.034 rainfall; r^2 = .88).

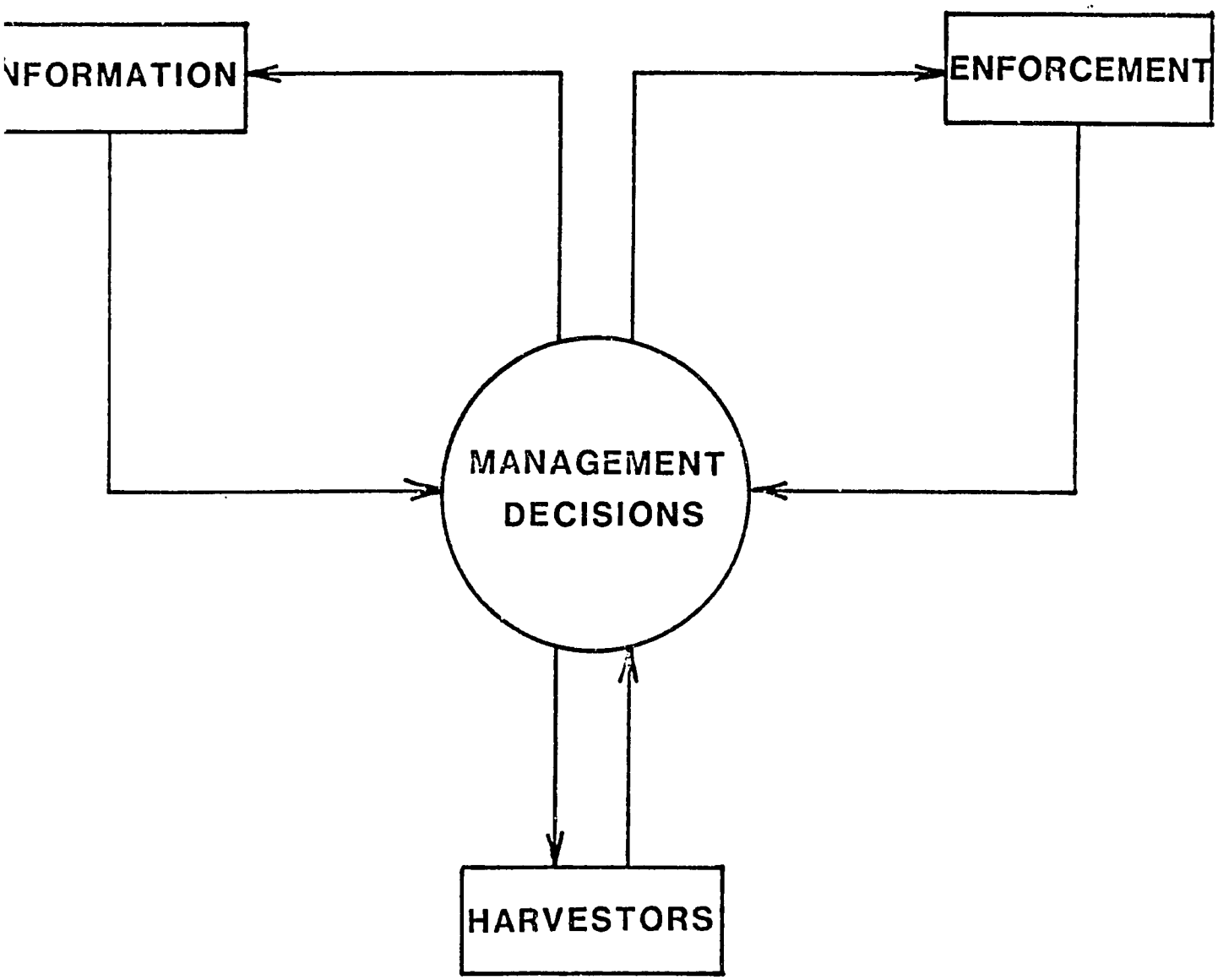

Figure 4. Information flow used to make fishery management decisions.