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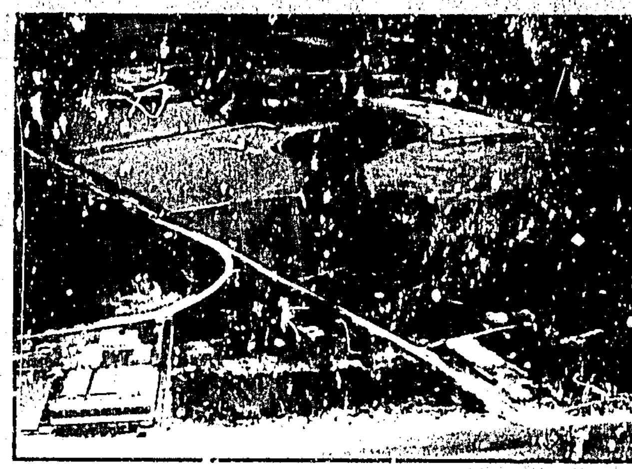

The four major goals of the International Coastal Resources Management Project (CRMP) are to: 1) apply, as appropriate, existing experience in coastal resources management to developing countries; 2) assist three developing nations in the design and implementation of integrated coastal resources management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

The CRMP works with the cooperating pilot countries to:

- formulate and implement integrated coastal resources management strategies
- 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 Thailand.

The International 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 University of Rhode Island. Supplemental funds were provided by USAID/Ecuador.

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Establishing a Sustainable Shrimp Mariculture Industry in Ecuador

Edited by Stephen Olsen and Luis Arriaga

1989

The University of Rhode Island
Coastal Resources Center

Ministerio de Energia y Minas
Direccion General del Medio A[redacted]
Gobierno de Ecuador

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Office of Forestry, Environment and Natural Resources
Bureau of Science and Technology

U.S. Agency for International Development: Ecuador

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Introduction

In March 1986 an Agreement was signed between the Government of Ecuador and the United States Agency for International Development (USAID) to implement a coastal resources management project. The agencies responsible for carrying out the project are the Direccion General del Medio Ambiente in the Ministry of Mines and Energy and the Natural Resources in Washington, D.C. and the USAID Mission in Quito, Ecuador. The Agreement calls for developing a nationwide integrated coastal management program targeted upon priority issues. At the request of the Ecuadorian government, an assessment of the reasons for declines in the productivity of the shrimp mariculture industry in 1984-1986 and development of recommendations to promote a stable, sustainable shrimp mariculture industry was made the first priority for the project.

Our approach to this task was to assemble an interdisciplinary team of people recognized for their expertise in the environmental, economic, technical and socio-political aspects of shrimp mariculture. This team of national and international experts was asked to integrate relevant worldwide experience with the available information applicable to the cultured shrimp industry in Ecuador. They prepared a series of papers that attempt to synthesize existing information and experience that must be considered when attempting to synthesize existing information and experience that must be considered when attempting to formulate an integrated management strategy. These papers were the basis of a workshop held in Guayaquil from August 4 through 8, 1986. The workshop participants included the authors of the synthesis papers and representatives of the shrimp industry, governmental agencies and research institutions. The workshop provided for thorough discussion of the information presented and of the merits of various recommendations for action, planning and research.

Ecuador has been the world's leading producer of cultured shrimp since 1983. Virtually all the product is exported to the United States and is an important source of much-needed foreign exchange for Ecuador. Production peaked initially in 1983 when 35,600 metric tons of shrimp were produced, but by 1985 production had declined to 30,205 metric tons. Two years later, production of both farmed and trawler-caught shrimp had rebounded to a total of 47,778 metric tons worth U.S. $380 million, an all-time high. By the end of 1987, 112,790 hectares of land had been authorized for shrimp pond construction and, according to official sources, approximately 85,000 hectares were in production. This is a dramatic increase since 1985 when approximately 35,000 hectares were believed to be producing shrimp. Major reasons for the high production in 1987 were the success of the hatcheries that now produce a significant proportion of the shrimp postlarvae (PL) used to seed the growout ponds, and a return of abundant supplies of wild-caught PL. By the end of 1987, 99 hatcheries had been authorized and approximately 60 were in operation compared to only 12 in 1986.

The recent increases in farmed shrimp production should not, however, inspire complacency. The wild shrimp stocks that probably will always be the cheapest source of PL and egg-bearing females for hatcheries are under enormous, and increasing pressure from three distinct fisheries. The shrimp ponds have replaced large expanses of mangrove, an estuarine habitat known to be essential to the life cycle of these stocks. At the same time, declining water quality in estuaries and coastal waters all along the coast is degrading the remaining habitat and adversely affecting production in both growout ponds and hatcheries. A combination of factors, including rapid urban growth and increased agricultural production brought by an ambitious dam-building program will inevitably combine to further reduce water quality in years to come.

The stakes for the continued success of the industry are high since shrimp mariculture is now the largest earning private sector activity in Ecuador and the artisanal PL fishery has brought an economic renaissance along much of the coast. As many as 90,000 people are involved in this seasonal fishery in which they may earn as much in a few days as they can in a month as agricultural laborers. Should the fishery collapse or the mariculture industry decline, the social, economic and political consequences for Ecuador could be severe.

External pressures in the form of shifts in the worldwide supply and demand for shrimp may also impact a now-booming industry. Nations around the world are working hard to follow Ecuador's success in a highly lucrative business, and shrimp supplies to markets worldwide may therefore increase dramatically in the not too distant future. The challenge for Ecuador is to attempt to build an industry that is both socially and environmentally sustainable at home, and that can compete successfully in a rapidly changing world marketplace.

This book is broken down into five major headings: Socioeconomic Aspects of Shrimp Mariculture; Legal and Institutional Issues; Environmental Issues; The Shrimp Fishery; and Characteristics of the Mariculture Industry.

Readers will find short Spanish abstracts of each article immediately before the full length English versions. Tables and charts referred to in the text follow each chapter. An appendix has information on exchange rates, acronyms, and authors' addresses.

Many people contributed to producing this volume. Paul Maugle, who set up the workshop in Guayaquil in 1985, assisted with initial editing. Judith Lawson worked with the authors on their original drafts. Gordon Foer oversaw final production. Puffin Enterprises was responsible for graphics and layout. Vicki Desjardins did the final copy editing. Drafts were typed and retyped with great fortitude by Annette Burgess and Jean Krul. To all of these who contributed to this effort we are very grateful.

Antecedentes

En marzo de 1986 fue suscrito el Convenio de Asistencia Técnica entre el Gobierno del Ecuador y la Agencia para el Desarrollo Internacional de los Estados Unidos de América (AID) para implementar un proyecto de Manejo de Recursos Costeros. Las instituciones responsables de la ejecución del Proyecto son la Dirección General de Medio Ambiente del Ministerio de Energía y Minas (DIGEMA) y la Universidad de Rhode Island (URI). El Convenio se enfoca hacia el desarrollo de un programa integrado de manejo de recursos costeros basados en aspectos prioritarios. A pedido del Gobierno Ecuatoriano se dio primera prioridad a la evaluación de las razones de la baja de productividad en la industria camaronera en 1984-1985 y al desarrollo de recomendaciones que permitan una industria de maricultura de camarón estable y constante.

Nuestra táctica para lograr estos objetivos fue conformar un grupo interdisciplinario de expertos en aspectos ambientales, económicos, técnicos y sociopolíticos de la maricultura de camarón. A este grupo de expertos nacionales e internacionales se solicitó integrar la experiencia relevante a nivel mundial con la información disponible relacionada a la industria de camarón en el Ecuador. Los expertos prepararon una serie de artículos técnicos que sintetizan la experiencia e información existentes y que debe ser considerada al tratar de formular una estrategia integrada de manejo. Estos artículos fueron la base de un taller realizado del 4 al 8 de Agosto de 1986 en la ciudad de Guayaquil. Participaron en el mismo los autores de los documentos técnicos, representantes de la industria camaronera, del sector público y de instituciones de investigación. El seminario permitió una amplia discusión de la información presentada y del mérito de las varias recomendaciones de las actividades de planificación e investigación.

El Ecuador se ha constituído en el principal productor de camarón cultivado a nivel mundial desde 1983. La industria creció dramáticamente durante la década precedente con un máximo en el año de 1983, donde se produjeron 35.600 toneladas métricas de camarón. Virtualmente, todo el producto se exporta a los Estados Unidos y constituye una importante fuente de ingreso de divisas para el Ecuador. En 1985 la producción declinó a 30.205 toneladas métricas, valoradas en US$156.000. Esta información, sin embargo, es incompleta debido a que en los últimos años el diferencial cambiario existente entre el mercado oficial y el mercado libre de cambios incentivó el contrabando y la subfacturación de los envíos, situación que ha cambiado a partir de Agosto de 1986. La baja de producción sin embargo es real y se ilustra con la realidad de que aproximadamente la mitad de las 100.000 hectáreas de piscinas camaroneras estuvieron sin operar en el año de 1986.

La razón más evidente de la baja producción en 1984-1985 fue la escasez de postlarvas para la siembra en las camaroneras. Una fuente alterna para suplir la menor captura de postlarvas silvestres ha sido la construcción de 29 laboratorios para la producción de larvas para Agosto de 1986. Se ha planificado la instalación de un total de 68 laboratorios. Por otra parte, está claro que la escasez de larvas en 1984-1985 es solamente uno de los varios problemas que enfrenta la industria, puesto que un amplio rango de aspectos ambientales, técnicos y económicos están colaborando en forma conjunta para limitar la industria camaronera. Los párrafos siguientes constituyen un esfuerzo inicial para analizar estos factores y comprender la interrelación existente entre ellos.

Este libro ha sido dividido en 5 grandes secciones: Aspectos Socioeconomico de la Maricultura de Camaron; Asuntos Legales y Institucionales; Asuntos Ambientales; Pesqueria del Camaron; y Caracteristicas de la Industria Maricultura. Los lectores encontraran cortos resumenes de los ensayos in espanol en cada uno de los capitulos antes de la version completa en ingles. Tablos y graficos referidos en el texto seguiran a cada capitulo. Un apendice contendra informacion sobre tasas de cambio, acronimos y direcciones de los autores.

Update

S. Olsen, L. Arriaga and G. Foer

In the period that has elapsed since the workshop in August 1986, Ecuador's shrimp mariculture industry has recovered from the slump that shook the confidence of many growers in 1985. As shown by Figure 1, exports reached an all-time high of 48,912 metric tons in 1987. The previous year Ecuador surpassed Mexico as the largest exporter of shrimp to the United States. The importance of shrimp as a major source of foreign exchange has grown steadily placing it second only to oil since 1986 (Figure 2).

PL Supply

The recovery of the industry may be attributed primarily to a renewed abundance of wild postlarvae (PL) and the application of free market exchange rates to shrimp exports from August of 1986 to March 1988. Wild PL continue to support a very large artisanal fishery that benefits large numbers of people and continues to support an economic resurgence along many stretches of the coast. Unfortunately, data on the number of participants in this fishery, the composition of their catches, the survival of *P. vannamei* PL between capture and their release in ponds are still to be collected. McPadden's (this volume) estimate of 90,000 PL fishermen is still widely quoted but is probably a high end estimate. The importance of the PL fishery to coastal people has, if anything, become more important.

At the 1986 workshop many participants expressed strong doubts that hatcheries would be able to significantly contribute to the PL supply for many years to come. By the end of 1988, although 99 hatcheries had been authorized, approximately 55 had been constructed and only about 10 were operating. In 1987 the hatcheries produced 1.5 billion PL compared to an estimated 7 billion PL provided to the growout ponds by the artisanal PL fishery. Despite the heavy investment in hatcheries the most efficient way to increase the supply of PL probably remains an extension service program designed to improve PL handling by fishermen, transporters and dealers and concerted efforts to protect wild stocks from overfishing and destruction of habitat. Here again reliable data are lacking. Hatcheries are most needed during years between El Niño events when wild stocks are low. It is interesting to note that, as recommended by some workshop participants, there has been growth in cottage scale hatcheries, particularly in Manabi province.

Conversion of Mangroves to Shrimp Ponds

There is unfortunately no evidence that effective steps have been taken since 1986 to slow or stop the conversion of mangroves into shrimp ponds (Figures 3a, b, c and 4). In 1988 CLIRSEN, using 1987 data again documented the conversion of mangroves. The average annual loss between 1969-1984 and the period of the second survey, 1984-1987, were 1,434 and 2,618 ha/year, respectively. By late 1988 the destruction of mangrove habitat in some estuaries was virtually complete. A stark example is Bahia de Caraquez, a large estuary in the province of Manabi. This had a wide belt of mangroves as recently as 1980. These mangroves have now been virtually all replaced by ponds.

Taxation Policies

At the time of the workshop major concerns were voiced over the government policy requiring growers to export shrimp at a dollar exchange rate some 30 percent below the free market rate. This produced a significant tax on exporters, encouraged a large traffic of smuggled shrimp and under-reporting of sales. This practice was discontinued in August 1986. In March 1988, however, the dual exchange rate was re-imposed and additional forms of taxation were subsequently added.

Ecuador in the International Market

Over the past decade, the international consumption of shrimp grew rapidly, the price of shrimp increased considerably and a number of countries invested heavily in shrimp mariculture. In 1988 Ecuador was replaced by China as the largest producer and exporter of cultivated shrimp in the world, followed closely by Taiwan, Indonesia, and Thailand, each of which may surpass Ecuador in the near future. As a consequence, prices in the world market have either remained stable or begun to decline. Economic problems within Ecuador are leading to increases in production costs and jeopardizing Ecuador's ability to compete in the world market.

Progress Towards Implementing a Management Strategy

Since 1986 the Coastal Resources Management Project has sponsored some initial work on PL handling techniques and a baseline water quality sampling program. As yet no major water quality problems of significant magnitude to threaten mariculture operations have been documented. Low levels of pesticide residues, however, have been found in some shrimp feeds. Nonetheless, burgeoning urban populations and planned major expansions in agricultural production brought by the construction of dams continue to pose real concerns. A water quality monitoring program will be designed in 1989 and should be maintained.

It may be concluded that only modest steps have been taken in response to the recommendations formulated through the 1986 workshop. This could prove to be short-sighted, particularly as the industry plays an increasingly pivotal role in the nation's economy.

ACTUALIZACION

S. Olsen, L. Arriaga M. and G. Foer

En el período transcurrido desde el taller, en agosto de 1986, la industria de la maricultura del camarón del Ecuador se ha recuperado del bajón que sacudió la confianza de algunos cultivadores en 1985. Como se muestra en la Figura 1, la producción de 1987 alcanzó a 48.912 toneladas métricas de producto exportado, que constituye la cifra histórica más alta. En este ano, el Ecuador sobrepasó a México como el mayor exportador de camarones a los Estados Unidos de América. La pérdida de los ingresos provenientes del petróleo, causada por el terremoto que destruyó en un amplio tramo el oleoducto entre la Región Amazónica y el Puerto de Esmeraldas, determinó que el camarón sea aún de mayor importancia para la economía del Ecuador en1987. Las exportaciones de camarón constituyen el segundo rubro de divisas del País, siendo superado sólo por el petróleo (Figura 2).

Suministro de postlarvas

La recuperación de la industria puede atribuirse principalmente a una renovación en la abundancia de postlarvas (pls.) "silvestres". Esto puede ser relacionado con la presencia de las condiciones de El Niño de 1982-1983. Las pls. silvestres continúan sosteniendo una gran pesca artesanal. Desafortunadamente, los datos sobre el número de los que participan en esta pesquería, la composición de sus capturas, la sobrevivencia de pls. de p.vannamei entre la captura y la siembra en los estanques aún no han sido obtenidos.

Mc Padden (en esta publicación) estimó 90.000 el número de pescadores de pls., cifra que es citada ampliamente pero que probablemente puede ser una estimación alta. Esta pesquería continúa sosteniendo un resurgimiento económico a lo largo de muchas áreas de la costa. La importancia de la pesquería de pls. para la población costera será aún más importante puesto que muchos "stocks" de peces y mariscos, utilizados tradicionalmente por los artesanos, han sido agotados en algunas áreas estuarinas. La importancia relativa de la sobrepesca y de la destrucción del habitat todavía no es conocida y, asímismo, no es aún investigada. El colapso de los "stocks" de camarones en el ambiente natural podría ser económicamente devastador para muchas comunidades de pescadores así como para la industria de la maricultura.

En el taller de 1986 muchos participantes expresaron serias dudas de que los laboratorios puedan contribuir significativamente al suministro de pls. durante muchos años. Al finalizar 1988, aun cuando se habian autorizado 99 laboratorios, 55 habian concluido su construccion y solo alrededor de 10 estaban en funcionamiento. La produccion en 1987 fue estimada en 1,5 miles de millones de postlarvas. Esta cifra debe compararse con la estimación de 7.000 millones que proporciona la pesquería artesanal de pls. para las piscinas de crecimiento. A pesar de las altas inversiones en los laboratorios, la forma más eficiente de aumentar el suministro de pls. probablemente constituya un programa de extensión diseñado para mejorar el manipuleo de las pls. por pescadores, transportadores y comerciantes de pls., y esfuerzos concertados para proteger stock naturales de una sobre explotacion y destruccion de habitat natural. Aquí, nuevamente, faltan datos confiables. Lo anterior no significa que los laboratorios no jueguen un papel importante, por el contrario, ellos serán más necesarios, especialmente durante los años entre eventos de El Niño en los que la abundancia de pls. del ambiente natural presenta declinaciones. Es interesante anotar que, conforme recomendaron algunos participantes en el taller, ha existido un fuerte crecimiento en laboratorios en escala de "galpón", especialmente en la provincia de Manabí.

Conversión de manglares a piscinas camaroneras

Infortunadamente no hay evidencias de que se hayan dado pasos efectivos para detener o disminuir la conversión de manglares en piscinas camaroneras (Figuras 3a, b, c and 4). En 1988 CLIRSEN, utilizando datos de 1987, nuevamente documentó la construcción de estanques en áreas manglares y salinas (Figura 2). El promedio anual de pérdida entre 1969 y 1984 fue de 1.431 has. de manglar y, en el segundo período de estudio, 1984-1987, el promedio aumentó a 4.034 has/año. A fines de 1988 la destrucción del habitat de manglares en algunas áreas estuarinas fue prácticamente completo. Un claro ejemplo de esto se encuentra en Bahía de Caráquez, en el estuario del Río Chone, Provincia de Manabí. Tan sólo en 1980 este estuario tenía una ancha faja de manglares, gran parte de la cual ha sido reemplazada por piscinas.

Políticas Tributarias

Durante el taller los principales asuntos mencionados correspondían a la práctica que permitía a los productores exportar el camarón a una tasa de cambio del dólar alrededor de un 30% por debajo de la tasa del mercado libre. En la práctica esto constituía un impuesto significativo para los exportadores y estimulaba un importante tráfico de contrabando de camarones. Esta práctica fue descontinuada en Agosto de 1986 (Regulación 366-86, Junta Monetaria); sin embargo, la tasa doble de cambio fue reimplantada.

Ecuador en el Mercado Internacional

Durante la decada anterior, el consumo internacional de camarones crecio rapidamente, el precio del camaron aumento considerablemente y se realizaron grandes inversiones en la maricultura de varios paises. En 1988, el Ecuador fue reemplazado por China como el mayor productor y exportador de camaron cultivado en el mundo, seguidos muy cerca por Taiwan, Indonesia y Tailandia, que amenazan sobrepasar la produccion ecuatoriana. Como consecuencia los precios en el mercado mundial se mantienen estables o comienzan a declinar. Las consecuencias economicas en el Ecuador estan conduciendo a un incremento en los costos de produccion y comprometiendo la capacidad del Ecuador para competir en el mercado internacional del camaron.

Avance hacia la implementación de una estrategia de manejo.

Desde 1986 el Proyecto de Manejo de Recursos Costeros ha patrocinado algún trabajo inicial sobre técnicas de manipuleo de pls. y un programa de muestreo para estudio de la calidad de agua costera. Hasta la fecha no ha sido documentado algún problema importante en la calidad del agua con la magnitud significativa para que amenace las operaciones de la maricultura. Sin embargo, niveles bajos de reciduos de pesticidas han sido determinados en algunos alimentos para camarones. No obstante, la presión de la población humana y los planes de expansión de la producción agrícola originados en la construcción de presas continúan siendo de interés real. Un programa de vigilancia de la calidad del agua será diseñado durante 1989, el cual deberá ser sostenido en el tiempo.

Se puede concluir en que poco ha sido hecho hacia la adopción de pasos que podrían contribuir a la sustentabilidad de la industria de la maricultura del camarón en respuesta de las recomendaciones formuladas mediante el Taller de 1986. Esto podría demostrar una miopía, especialmente conforme la industria juegue un creciente papel central en la economía de la nación.

SHRIMP, MT AND EXPORTS

Prepared by Gordon Foer

Figure 1

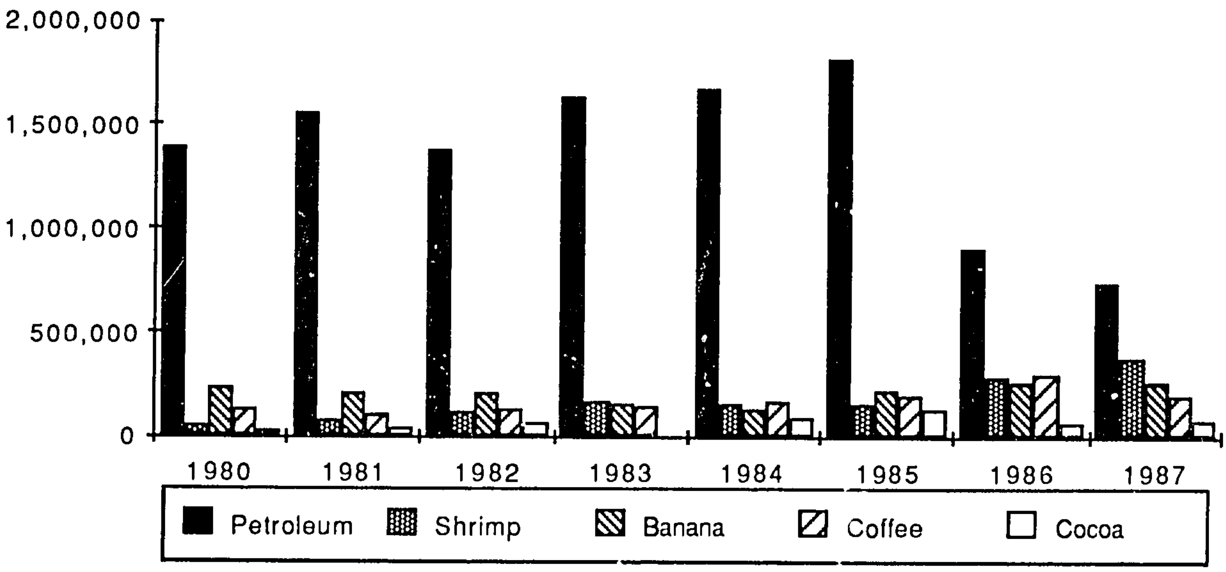
Shrimp Produced in Ponds, and Total Value of Shrimp Exported

YR	METRIC TONS (1)	METRIC TONS (2)	EXPORTS, IN THOUSANDS OF DOLLARS US
1976	1,170		
1977	1,350	3,900	
1978	4,215	5,000	
1979	4,698	6,200	
1980	9,180	9,200	56,884
1981	12,100	11,200	77,525
1982	21,500	16,400	122,348
1983	35,600	23,300	175,073
1984	33,600	21,700	159,840
1985	30,205	18,700	156,486
1986		28,300	287,882
1987		48,912 (3)	383,136
1988			387,000

(1) Subsecretaria de Pesca, quoted in Acuacultura del Ecuador magazine
(2) Subsecretaria de Pesca, from Maugle, Paul 1987.
"Post Larvae Shrimp Mortality Reduction study"
(3) Total m.t. exported, Banco Central

Figure 2

ECUADORS MAJOR NON-MANUFACTURED EXPORTS
in thousands of dollars, FOB



Banco Central del Ecuador, 1988

Figure 3 **MANGROVE LOSS IN ECUADOR: 1969-1987**

Source: CLIRSEN, 1988. Valdiviezo.

Prepared by Gordon Foer

a) Mangrove remaining and rates of loss by province.

Mangrove Area in Ecuador, 1969-1987

PROVINCE	REMAINING (HA) 1969	1984	1987	% LOSS 1969-1984	% LOSS 1969-1987	ANNUAL LOSS 1969-1984 (HA/YR)	ANNUAL LOSS 1984-1987 (HA/YR)
GUAYAS	125,523	119,526	115,000	4.8%	8.4%	0.3% (400)	1.3% (1508)
ESMERALDAS	32,032	30,152	29,257	5.9%	8.7%	0.4% (125)	1.0% (298)
MANABI	12,415	7,973	6,593	35.8%	46.9%	2.4% (296)	5.8% (460)
ELORO	33,654	24,455	23,402	27.3%	30.5%	1 8% (613)	1.4 % (351)
TOTAL	203,624	182,106	174,252	10.6%	14.4%	0.7% (1434)	1.4% (2618)

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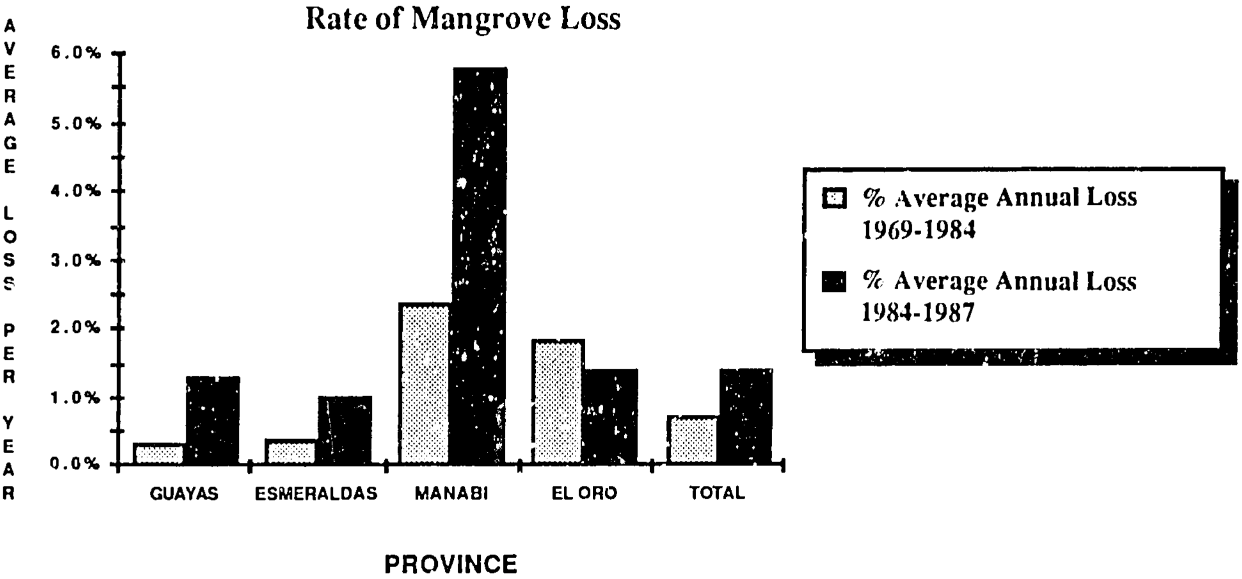
b) Average annual rates of mangrove destruction, in two periods, for each coastal province.



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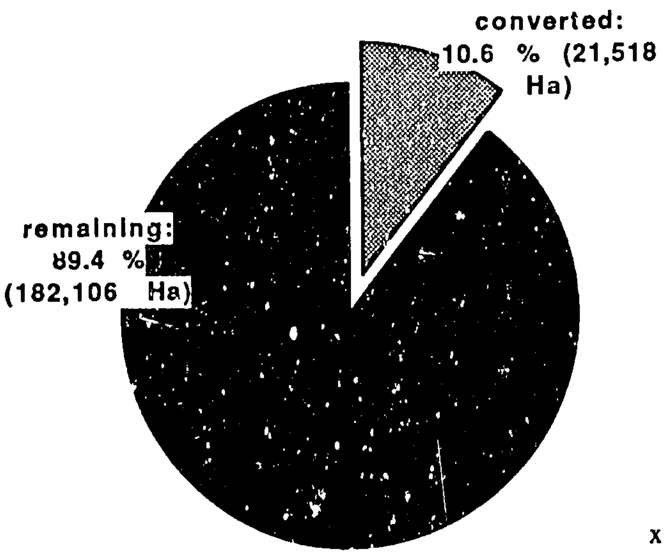
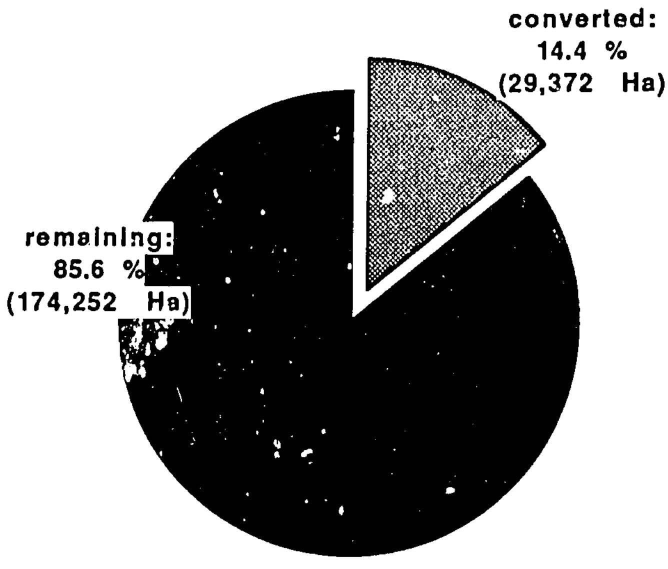
c) Portion of mangrove cover destroyed by 1984 and by 1987, using 1969 as the base year.



1984/1969



1987/1969

Figure 4 **Shrimp Ponds Authorized, Built and In Production In Hectares**

YR	AUTHORIZED (1) (CUMULATIVE)	BUILT (2)	IN PRODUCTION (3)
1975	63		
1976	363		
1977	1,655		
1978	3,177		3,000
1979	5,416		5,800
1980	12,351		6,400
1981	34,458		12,600
1982	46,879		16,600
1983	59,013		29,573
1984	80,895		49,000
1985	93,042	89,366	46,200
1986	108,870		41,547
1987	114,205		
1988	118,304	115,406	90,000 (4)

SOURCES (1) Subsecretaria de Recursos Pesqueros
(2) CLIRSEN
(3) Subsecretaria de Recursos Pesqueros estimate assuming 800 lbs/ha and 2 crops per year
(4) It is estimated that up to 60% of installed capacity is not currently in use (Walter Spurrier, personal communication)

NOTE: Historical data for ponds authorized and in production have been revised by the Subsecretaria and do not agree with data this same source reported elsewhere in this document. Also, other sources have differing estimates for hectares in production.

Summary: An Integrated Strategy to Promote a Sustainable Shrimp Mariculture Industry in Ecuador: Findings and Recommendations

Summary: An Integrated Strategy to Promote a Sustainable Shrimp Mariculture Industry in Ecuador: Findings and Recommendations

Stephen Olsen and Eduardo Figueroa

Introduction

The following findings and recommendations are an attempt to extract an integr. ed management strategy from the papers presented in the volume, the discussions at the Guayaquil workshop in August 1986, and subsequent discussions with governmental agencies and industry representatives in Ecuador. Only if progress is made simultaneously on a number of disparate fronts can the base for a sustainable shrimp mariculture industry in Ecuador be formulated. The priorities we recommend comprise seven elements:

1. Maintain water quality in estuaries and near hatcheries; low growth rates and occasional mass mortalities due to poor water quality are already problems for some hatcheries and growout operations. Development trends in coastal watersheds suggest further reductions in water quality are to be expected unless mitigating actions are quickly taken.

2. Protect and manage the wild shrimp stocks that provide the most abundant and cheapest sources of seed shrimp to the industry. This requires the protection of critical habitats, including mangroves, and safeguards against over-exploitation by both the adult shrimp and postlarvae fisheries.

3. Implement strategic planning to maximize the long-term economic vitality of the industry. Tracking trends in the world shrimp markets, product quality control and forecasting the impacts of declining water quality on the industry are all urgent priorities.

4. Overhaul and simplify the permit system governing the siting and operation of ponds and hatcheries.

5. Critically evaluate the impacts of national policy on the shrimp industry as it is applied through the Fisheries Law.

6. Initiate targeted assistance program to promote information exchange within the industry.

7. Initiate a public education program to help build support for the measures needed to protect the environmental quality that the shrimp industry requires.

Findings and Recommendations

A. Declining Water Quality

Findings

Good water quality is critically important to the success of the cultivated shrimp industry as well as the protection of suitable habitats for juvenile shrimp. A number of development trends are working in combination to reduce water quality in Ecuador's estuaries and coastal waters. Increasing urban development, further industrial growth and the losses of fresh water discharge by river and greater agricultural production brought by dams are all expected to result in further declines in water quality in the years to come. Poor water quality is already having a negative impact on both the productivity of growout ponds and hatcheries. The available, albeit incomplete, data on water quality documents the presence of high concentrations of heavy metals and pesticides, the frequent occurrence of toxic red tides and high concentrations of organics that cause low oxygen levels. Hatchery operators and growers report occasional mass mortalities that they attribute to contaminants in their water supply. Some growers are experiencing blooms of microscopic algae in their ponds and reduced growth rates may also be attributable to the poor quality of the water they pump from estuaries into their pods.

Recommendations

1. A top priority should be to evaluate the many ongoing monitoring and baseline data collection programs and organize them into a sustainable integrated scheme for monitoring water quality in rivers, estuaries and nearshore waters. This would be the first step in prioritizing problems and then tracing them to their source. The integrated monitoring and research program that should emerge from this process must build upon existing institutions and not duplicate capabilities already in place.

2. The shrimp industry badly needs access to an in-country diagnostic laboratory capable of analyzing water samples for both hatchery operators and growers. Such a laboratory could be developed by building upon one of the existing capably run and well-equipped laboratories already operating in Ecuador.

3. Once the levels of pollution are known, steps must be taken to reduce contaminants known to have adverse impacts on the cultural shrimp industry and wild shrimp stocks. At present the high priorities for immediate attention are pesticides residues, mercury, and the organic loadings from domestic sewage.

B. The Shortage of Postlarvae

Findings

Warm water temperatures in nearshore shrimp spawning grounds and the abundant material-rich runoff from the land that accompany periodic El Niño years bring enormous increases in PL abundance. Thus, the abundance of PLs brought by the intense El Niño of 1982-83 raised unrealistic expectations and spurred the over-construction of ponds. The dry periods between El Niño years dominate and the industry, if it is to be sustainable, must be capable of adjusting to cyclic patterns of high abundance interspersed by consecutive years of relative scarcity. During dry periods a number of man-induced changes to the coastal ecosystem may reduce the abundance of PL. Since wild caught PL will always be the cheapest source of seed for growers and hatcheries are unlikely to offer an alternative source in sufficient volumes for many years to come, it is crucially important to minimize actions that will reduce PL abundance. These actions fall under two major headings: loss of habitats and overfishing.

Loss of Habitat. Research conducted worldwide shows a strong correlation between the area of coastal wetlands and the size of the associate penaeid shrimp stocks. There is already widespread concern that the destruction of mangroves in Ecuador's estuaries must be halted because this is known to be an important habitat for shrimp. Data compiled by CLIRSEN document that 11 percent of the mangroves present in Ecuador in 1969 had been destroyed by 1984. Estimates that consider mangrove habitat, and not stands of mangrove trees alone, suggest that 25 percent of this habitat type has been destroyed. Data do not exist to evaluate whether low water quality in the upper reaches of Ecuador's major estuaries is making large areas of formerly important PL habitat unsuitable, but there is some evidence that suggests that some esteros are much more productive of shrimp PL than others.

Overfishing. The PL fishery has within a single decade expanded explosively to a massive effort involving as many as 90,000 artisanal fishermen who work all areas of known abundance. Unfortunately, there are no systematic data on this fishery. We do not know the species composition of catches from different areas or during different seasons or what proportion of the catches are of species not utilized by the growers. The fishery, however, is so large that is is capable of having an effect on the species structure and abundance of Ecuador's shrimp stocks.

It is known that mortalities between capture and acclimation to pond condition are high. Fifty percent mortality is a likely overall average. This suggests that measures taken to reduce the mortality of the PLs already being harvested could result in greater benefits in terms of increased productivity from the industry over all than any other single action.

Recommendations

1. The immediate priority is to reduce the mortality of the captured PL. A well-designed extension program could produce an immediate and significant increase in the numbers of PL available to stock ponds. The Coastal Resources Management Project, utilizing funds provided by the AID Ecuador Mission, is moving immediately to work with the industry and the Instituto Nacional de Pesca to quantify the mortality associated with various handling methods and to implement an extension program for PL fishermen.

2. It should be assumed that the abundance of wild penaeid shrimp stocks during dry years is directly related to area of wetland habitat. Every effort should therefore be made to encourage the effective enforcement of existing bans on the further destruction of mangroves and to safeguard conditions, such as adequate water quality, that make estuaries valuable habitat for juvenile shrimp. Protecting mangrove habitat, rather than mangrove trees alone, should be given careful consideration.

3. Ongoing studies at the Instituto Nacional de Pesca that can lead to the identification of the most productive PL habitats should be expanded and accelerated. If particularly important habitat can be identified they should be protected from both overfishing and biophysical forms of degradation.

4. Related studies should be conducted to produce data on the PL fisheries. The absence of such data makes it impossible to assess the impact of the PL fishery closures implemented in 1985 and 1986. It is also not possible, in the absence of data, to evaluate the optimal timing and location of closures or the likely benefits of other controls over the PL fishery. Given the magnitude of the fishery, however, any measures that reduce fishing effort can only have a beneficial effect on the stocks.

5. An urgent planning priority is to develop demonstration plans for the management of mangroves. It is not feasible to expect that there will be no further destruction of mangroves. Realistic and implementable management strategies that can accommodate the continuing utilization of coastal resources must therefore be developed. In addition, an assessment should be made of techniques to integrate mangroves into shrimp pond operations as a means of stabilizing dikes and alleviating water quality problems. Such techniques could benefit shrimp pond operators while simultaneously replacing lost mangrove habitat.

C. Management of Wild Shrimp Stocks

Findings

Careful attention should be given to managing Ecuador's wild shrimp stocks since these will continue to be the cheapest source of seed to the cultivated shrimp industry while simultaneously supporting an important trawler fishery. Catches of adult shrimp by the trawler fleet have been remarkably consistent for nearly a decade. However, the gradual increase in the number of vessels participating in the fishery have resulted in a very low catch per unit of effort. There have recently been significant changes in the species composition of catches that may possibly be related to large numbers of juveniles removed by the PL fishery. Data being compiled currently of the adult shrimp fishery are inadequate for evaluating the likely impacts of fishery management techniques.

Recommendations

1. The programs already underway at the Instituto Nacional de Pesca with the support of the Mission Brittanica should be built upon to provide the information needed to develop an integrated management plan for the shrimp fishery. The system for collecting catch data

should be expanded. Studies should also be undertaken to determine whether there are distinct shrimp populations and to trace migration patterns. Fisheries data should be correlated with trends on such environmental variables as rainfall and temperature. The management plan should be developed in close collaboration with the fishing industry. It should set clear objectives for management and consider the full range of management techniques including closed seasons and grounds, and a limited entry program. This plan must be integrated with steps taken to protect prime PL habitats in estuaries.

2. The by-catch incidental to the shrimp trawler fishery produces volumes and sizes of fish that should be evaluated for better utilization including export markets and a source of raw material for shrimp feed mills.

D. Measures to Safeguard the Economic Vitality of the Industry

Findings

Ecuador's success with shrimp mariculture is the envy of other countries hungry for foreign exchange and with land suitable for shrimp production. Ecuador can expect increasing competition in the future. Several nations in South Asia and Southeast Asia have long traditions in mariculture and are moving rapidly to expand their production of shrimp for export markets. It is also conceivable that technological breakthroughs could make shrimp production in controlled environments economically feasible in non-tropical countries. Although new producers must overcome numerous hurdles to develop the necessary infrastructure and establish markets, it is not unlikely that competition from growers in other countries could place Ecuadorian producers in a future cost price squeeze.

More than 90 percent of the shrimp currently produced by growers in Ecuador is exported to the United States. The industry now enjoys a reputation for consistent high quality. One port quality shipment of the discovery of contaminants in shrimp grown in Ecuador could jeopardize this market. The growing water quality problems in Ecuador, and the treatments administered to shrimp to counteract disease must be carefully monitored as possible sources of contamination.

It is currently impossible to monitor the economic health of the industry because the data base is inadequate. It is not possible to trace trends, identify bottlenecks and prioritize needs for extension services and research.

Recommendations

1. The shrimp growers, through one or more of their trade organizations, should monitor trends in world markets and be in a position to advise their members on developments in world production and markets.

2. The shrimp growers, working in association with government, should strengthen a program to monitor and certify the quality of all shipments of shrimp to foreign markets.

3. A program to gather and analyze basic economic data on the industry should be designed and implemented.

4. A study should be made of the economic impacts of present and potential future water pollution conditions on the cultured shrimp industry.

E. Governmental Involvement in the Industry

Findings

The existing permit system for granting concessions in government controlled "tierra baja" and authorizing the construction and operation of shrimp ponds is highly complex and is a major expense for applicants in both time and money. One grower at the workshop commented, "It is far easier to successfully raise any variety of shrimp than to obtain the necessary permits." It is also not at all clear what benefits, in terms of protection of critical habitats, appropriate siting and constructive practices of safeguarding the public trust, accrue from the existing system. The complexity and expense of the existing system does explain whay it has been ignored by many participants in the industry.

Shrimp mariculture is governed by a number of laws and governmental policies, the most important of which is the Fisheries Law. The laws were designed to govern activities that differ in many important aspects from the shrimp culture industry. The Fisheries Law favors large scale vertically integrated companies. It is questionable whether the application of this policy to the shrimp mariculture industry is in the best interest of either the industry or the nation. Current incentives to promote hatchery development may be ill-founded.

Recommendations

1. The permit system should be overhauled and greatly simplified. The first step should be to define the objectives for the system and then to design a process that assures the participation of the necessary governmental agencies in a coordinated and timely manner. A one-stop permit process would be preferable to the existing sequential approval process. The evaluation and disposition of permit applications should be based on criteria designed to minimize impacts on important habitats and foster good construction practices.

2. Governmental policies that shape the shrimp industry should be critically studied. It may be appropriate to consider legislation designed specifically to govern shrimp mariculture. In particular, policies designed to encourage large-scale vertically integrated operations, and restraints placed by various regulations, should be re-examined. A diversified industry that includes a large number of small-scale businesses may bring greater benefit to Ecuador and be better able to respond to changes in world markets than an industry dominated by a few heavily capitalized large operations.

F. Technical Assistance

Findings

The shrimp growers and hatchery operators working today in Ecuador are among the best in the world. The industry, however, has grown in a gold rush atmosphere and a number of adjustments must be made if it is to successfully stabilize. Generally speaking, there is good communication among hatchery operators and the best worldwide expertise is available to them. However, there is a real need for a carefully targeted extension and research program for the growers. Here information exchange has been stifled by an atmosphere of intense competition and secrecy among growers. Priorities for extension include assistance in monitoring water quality and setting pumping rates, in feeding and in the design of ponds.

Recommendations

1. An extension program targeted on specific aspects of shrimp culture should be designed and implemented in close coordination, and with the active support of the industry. Such a program could be supported by a levy imposed on all exports.

2. Greater support should be given to the hatchery technician training program offered by the Polytechnic Institute of the Coast (ESPOL). The absence of trained personnel to operate hatcheries is an urgent problem that must be addressed.

G. Public Education

Findings

There is little appreciation among governmental officials and the public at large for the interrelationships among human activities that alter the environment and the quality of services that the environment can sustain. In the absence of an appreciation for these relationships it will be difficult to obtain the public support necessary to make environmental management programs a success. A recurring theme at the workshop was the need for broad dissemination of information on the conditions and problems affecting the quality of the ecosystems that support shrimp mariculture. It was also frequently repeated that governmental policies and programs need to be prepared with great participation from those who will be affected by governmental programs particularly when their cooperation is a prerequisite to the successful implementation of such policies and programs.

Recommendations

1. A commitment should be made to public education on environmental matters. It should be targeted on priority issues and seek to inform society at large to the need for controls over activities that degrade the resource base upon which all depend.

Next Steps

The effective implementation of an integrated strategy for sustainable shrimp mariculture will require both commitment and a concentrated effort on the part of the industry, government, and the research community. The planning, research and policy development outlined here will also require a significant commitment of funds. However, much is already being done and a major challenge lies in the coordination of existing programs and institutions. The Coastal Resources Management Project could, if judged appropriate by all concerned, assume primary responsibility for coordinating the implementation of the initiatives proposed. This would include periodic evaluations of progress and re-examination of priorities with all the participants. Although shrimp mariculture is only one of the topics that the coastal management project must address, it is sufficiently important to justify a major commitment of funds and energy.

Sumario: Una Estrategia Integrada para el Desarrollo de Maricultura de Camarón en el Ecuador

Stephen Olsen y Eduardo Figueroa

Introducción

Este documento presenta un resumen de las principales conclusiones y recomendaciones desarrolladas por el Proyecto de Manejo de Recursos Costeros, encaminadas al desarrollo sostenido de la industria de maricultura de camarón en el Ecuador. Es el resultado de un proceso de investigación y evaluación en el que actuaron un grupo de expertos internacionales, un seminario-taller realizado en Guayaquil en Agosto de 1986 y discusiones subsiguientes con agencias gubernamentales y representantes de la industria en el país. Otros documentos que son producto de este proceso serán preparados y distribuídos en forma separada. Los artículos propuestos por el grupo de expertos internacionales están siendo revisados para ser posteriormente publicados en inglés y español. Igualmente un resumen de las discusiones del taller con las recomendaciones propuestas está siendo preparado como documento aparte.

Las prioridades que recomendamos como parte de una estrategia integrada de manejo comprenden siete elementos fundamentales:

1. Mantener la calidad de agua en estuarios y en las cercanías de las camaroneras y laboratorios de larvas; en la actualidad han empezado a presentarse con relativa frecuencia tasas de crecimiento bajas y ocasionalmente mortalidades altas que se estima son debido a la mala calidad de agua utilizada en las operaciones. Las perspectivas de desarrollo de la zona costera sugieren un deterioro creciente de la calidad del agua a menos que se tomen inmediatamente medidas para su mitigación.

2. Manejar y proteger los stocks de camarón silvestre que proveen la semilla de camarón más abundante y más barata para la industria. Esto requiere la protección de los habitat críticos, incluyendo los manglares, y la toma de medidas para evitar la sobreexplotación tanto por la pesquería de camarón adulto como por la de postlarvas.

3. Planificación estratégica para maximizar la vitalidad económica a largo plazo de la industria: se determina como urgente prioridad el conocer las tendencias del mercado mundial de camarón, establecer un alto control de calidad del producto y predecir los impactos del deterioro de la calidad del agua.

4. Revisar y simplificar el sistema de permisos que establece la localización y operación de camaroneras y laboratorios de larvas.

5. Realizar una evaluación crítica de los impactos que ocasiona la política nacional sobre la industria camaronera conforme a la aplicación de la Ley de Pesca.

6. Iniciar un programa de asistencia técnica dirigido a promover el intercambio de información dentro de la industria.

7. Iniciar un programa de educación pública que ayude a construir el soporte y la conciencia necesarios para proteger la calidad ambiental que el desarrollo de la industria requiere.

Conclusiones y Recomendaciones

A. Deterioro de la Calidad del Agua

Conclusiones

La buena calidad del agua es críticamente importante para el éxito de la industria del cultivo de camarón así como para la protección del habitat del camarón juvenil. Una serie de acciones combinadas se está desarrollando, resultando en el deterioro de la calidad del agua en los estuarios y aguas costeras del país. El incremento del desarrollo urbano, crecimiento industrial y disminución de la descarga de agua dulce por los ríos, debido a un incremento de la producción agrícola y a la construcción de presas deteriorarán aún más la calidad del agua en los próximos años. La mala calidad del agua es una gran preocupación por sus efectos negativos tanto en las camaroneras como en los laboratorios. La disponibilidad de datos, aunque sea incompleta, sobre la calidad del agua, indica la presencia de altas concentraciones de metales pesados y pesticidas, casos frecuentes de mareas rojas tóxicas y altas concentraciones de materia orgánica que disminuyen los niveles de oxígeno disuelto. En los laboratorios y en las camaroneras los técnicos informan ocasionalmente de mortalidades en masa que ellos atribuyen a contaminantes en sus fuentes de agua. Algunos han observado un crecimiento dramático de algas microscópicas en sus estanques y bajas tasas de crecimiento. Esto se atribuye a la mala calidad del agua bombeada de los esteros a las camaroneras.

Recomendaciones

1. Una de las principales prioridades debe ser la ejecución de programas de control y la creación de una base de datos que permita incluírlos en un esquema integrado de monitoreo de la calidad del agua en los ríos, estuarios y aguas costeras. Los programas de control e investigación que se obtengan de este proceso pueden ser implementados por las instituciones existentes a fin de evitar duplicación de gastos y esfuerzos.

2. La industria camaronera necesita con urgencia tener acceso a un laboratorio de diagnóstico capaz de analizar muestras de agua tanto de las camaroneras como de los laboratorios de larvas. Este laboratorio podría desarrollarse teniendo como base a cualquier laboratorio bien equipado ya existente en el Ecuador.

3. Una vez que los niveles de contaminación sean conocidos se deberán tomar acciones a fin de reducir los contaminantes existentes y evitar impactos adversos sobre la industria de cultivo de camarón y la producción de camarón silvestre. Al momento, las prioridades de atención inmediata son los resíduos de pesticidas, mercurio y las descargas orgánicas del alcantarillado doméstico.

B. Escasez de Postlarvas

La razón más evidente de la baja producción en 1984-1985 fue la escasez de postlarvas para la siembra en las camaroneras.

Conclusiones

El avance de aguas más cálidas hacia el lugar de desove del camarón y el mayor flujo de agua rica en nutrientes, originada en la alta pluviosidad asociada a la presencia del fenómeno de "El Niño", propician el incremento en la abundancia de larvas de camarón. Esta situación creó falsas expectativas que condujeron a la construcción excesiva de camaroneras en los años 1982-1983.

Si la industria camaronera desea optar por una actividad sostenida, debe ser capaz de ajustar su accionar a los patrones cíclicos de gran abundancia y épocas de escasez relativa, en forma alterna. Durante la estación seca, cambios en el ecosistema costero inducidos por el hombre pueden reducir la abundancia de postlarvas. Ya que la captura de poslarva en el medio natural siempre será una fuente barata de semilla para las camaroneras es importante que se minimicen las actividades que tiendan a reducir la producción natural de semilla. Estas actividades se dividen en dos grupos: pérdida del habitat y sobrepesca.

Pérdida del habitat. Investigaciones realizadas a nivel mundial nos demuestran la fuerte correlación existente entre las marismas de la zona costera y el volumen del recurso de camarón penacido. Es ampliamente aceptado que la destrucción de los manglares en los estuarios del Ecuador debe ser suspendida, ya que constituyen el habitat ideal del camarón.

Datos recopilados por el CLIRSEN indican que en un período de 15 años, entre 1969 y 1984, la superficie cubierta por manglares en la costa ecuatoriana fue reducida en un 11%. Por otra parte, estudios que consideran al manglar como ecosistema y no sólo como conjunto de árboles, sugieren que ha sido destruído en un 25% de este tipo de habitat.

Hay evidencias de que las zonas interiores de los esteros son las más productivas en cuanto a postlarvas; sin embargo, no existen datos que indiquen que la disminución en la calidad del agua en estas zonas de los estuarios del Ecuador haya sufrido cambios de manera que áreas anteriormente importantes como habitat de postlarvas, actualmente sean inapropiadas para su desarrollo.

Sobrepesca. La pesquería de la postlarva, ha presentado un crecimiento explosivo en la última década, lo que involucra a casi 90.000 pescadores artesanos que laboran en todas las áreas conocidas por su abundancia en postlarvas. Desafortunadamente, no existe una información sistemática sobre esta pesquería. No conocemos la composición de las capturas en cuanto a especies en las diferentes áreas y diferentes estaciones, así como tampoco la proporción en que están las especies no utilizadas por las camaroneras. De todos modos, esta pesquería es tan grande que es capaz de ocasionar cambios en la estructura de las especies y en la abundancia del "sotck" de camarones en el Ecuador.

Se conoce que las tasas de mortalidad en la captura de la postlarva y su aclimatación en las camaroneras de cría son altas, teniendo como promedio un 50% de mortalidad. Esto nos hace pensar que las medidas a tomarse tendientes a reducir dicha mortalidad se convertirían en beneficio más grande, en cuanto al incremento de la productividad de las camaroneras.

Recomendaciones

1. Es de alta prioridad la reducción de las tasas de mortalidad de las postlarvas capturadas mediante un programa de extensión bien diseñado, que propiciaría la disponibilidad de un mayor número de postlarvas en las camaroneras. En consecuencia, como parte del Proyecto de Manejo de Recursos Costeros y con el financiamiento de la Misión de AID del Ecuador, se ha establecido contactos inmediatos con la industria e Instituto Nacional de Pesca para conformar un grupo de trabajo y cuantificar la mortalidad de las postlarvas en relación a los varios métodos de manipuleo a los que están sujetas y para implementar programas de extensión a los pescadores dedicados a la captura de postlarvas.

2. Debería asumirse que la disponibilidad del camarón silvestre (penacido) durante los años secos, está directamente relacionada con el habitat de marismas. Por lo tanto, el esfuerzo debería estar orientado a fortalecer las restricciones existentes que eviten la destrucción del manglar y salvaguardar condiciones tales como buena calidad del agua, que hacen de los estuarios el habitat óptimo para el camarón juvenil. Se debe considerar seriamente el proteger al habitat de los manglares y no sólo a los árboles de mangle.

3. Los estudios que realiza el Instituto Nacional de Pesca, que puedan conducir a la identificación de los habitat más productivos para las postlarvas deben ser ampliados y acelerados. Si un habitat particularmente importante es identificado debería protegérselo de la sobrepesca y de las formas biofísicas de degradación.

4. Deberían realizarse estudios relacionados con la producción de datos de esta pesquería; la ausencia de tales datos hace imposible determinar el impacto ocasionado por las vedas a la captura de larvas implementadas durante los años 1985 y 1986. Es también difícil, sin información alguna, hacer evaluaciones sobre la época o área óptima para la implantación de una veda o probables beneficios si es que se implementan otros tipos de control sobre esta pesquería. Dado el tamaño de las pesquerías de camarón, cualquier medida que se tome que reduzca el esfuerzo pesquero sólo puede beneficiar al "stock".

5. Una de las prioridades de planificación es el desarrollo de planes demostrativos para el manejo de manglares.

   No es factible esperar que no haya más destrucción de los manglares. Se deben desarrollar e implementar estrategias de manejo reales que permitan adecuar el uso contínuo de los recursos costeros. Además, se debe estudiar las técnicas para integrar los manglares a las operaciones de las camaroneras, como por ejemplo estabilizar los muros de los estanques y mitigar los problemas de calidad del agua. Dichas técnicas beneficiarían la operación de las camaroneras y simultáneamente reemplazarían el habitat del manglar perdido.

C. Manejo de los "Stocks" de Camarón Silvestre

Conclusiones

Se debe prestar una atención cuidadosa al manejo de los "stocks" de camarón silvestre del Ecuador ya que estos continuarán siendo la fuente más barata de semilla para la industria de cultivo de camarón, al mismo tiempo, son la base de una pesquería de arrastre muy importante. Las capturas de camarón adulto realizadas por la flota camaronera han sido notablemente consistentes durante casi una década. Sin embargo, el incremento gradual de barcos camaroneros que participan en la pesquería ha dado como resultado una captura muy baja por unidad de esfuerzo. Recientemente ha habido cambios significativos en la composición de las especies de las capturas lo que probablemente esté relacionado con capturas de grandes números de juveniles por la pesquería de postlarvas. Los datos acumulados actualmente acerca de la pesquería de camarón adulto presentan una base inadecuada para evaluar los efectos probables de las técnicas de manejo de esta pesquería.

Recomendaciones

1. Los programas actualmente llevados a cabo por el Instituto Nacional de Pesca bajo el auspicio de la Misión Británica deben ser implementados para proporcionar la información necesaria que desarrolle un plan de manejo integrado aplicable a la pesquería de camarón. El sistema para acumular datos de captura debe ser ampliado así como se deben llevar a cabo estudios que determinen si es que existen poblaciones distintas de camarón y que establezcan los patrones de migración. Los datos de las pesquerías deben ser correlacionados con las tendencias de los factores ambientales tales como lluvia y temperatura. El plan de manejo de la pesquería debe ser desarrollado en íntima colaboración con la industria pesquera y debe fijar objetivos de manejo precisos considerando todas las técnicas de manejo, incluyendo las vedas estacionales y zonales así como un programa de participación en las pesquerías de menor producción. Este plan debe ser complementado con los pasos necesarios para la protección de los habitat más importantes de las postlarvas en los estuarios.

2. La fauna de acompañamiento de las pesquería de arrastre del camarón produce volúmenes y tallas de peces que deberían ser evaluados para su óptima utilización, ya sea en mercado de exportación o como fuente de materia prima para la elaboración de alimento para el camarón.

D. Medidas para Proteger la Vitalidad Económica de la Industria Camaronera

Conclusiones

El éxito de la maricultura del camarón en el Ecuador ha ocasionado la emulación de otros países deseosos de incrementar su intercambio de divisas y que cuentan con tierra disponible para la producción de camarón, por lo que el Ecuador deberá esperar un incremento en la competencia en el futuro próximo. Varias naciones del sur y sureste asiático tienen gran tradición en la maricultura y están aumentando rápidamente la producción de camarón para el mercado de exportación. Es concebible, también, que el avance tecnológico haga factible la producción de camarón en ambientes controlados en países no tropicales. Aunque los nuevos productores deban vencer numerosos obstáculos para desarrollar la infraestructura necesaria para el cultivo de camarón y también establecer mercados, es posible que el Ecuador se vea envuelto en una competencia económica fuerte.

Más del 90% del camarón cultivado en el Ecuador se exporta actualmente a los Estados Unidos gozando la industria de muy buena reputación por la alta calidad del producto. Un embarque de mala calidad o el encontrar contaminantes en el camarón proveniente del Ecuador podría arruinar este mercado. Por lo tanto, el creciente problema con respecto a la calidad del agua, así como el tratamiento que se da al camarón para contrarrestar enfermedades, deben ser manejados con mucho cuidado ya que pueden ser fuentes de contaminación. Actualmente no es posible controlar la salud económica de la industria ya que se cuenta con muy pocos datos, siendo imposible establecer tendencias, identificar problemas que congestionen el flujo de la industria y fijar prioridades que requieran un mayor servicio e investigación.

Recomendaciones

1. La industria camaronera, a través de uno o más de sus organismos de comercio, debería controlar tendencias en el mercado mundial y estar en capacidad de poner al tanto a sus miembros en cuanto al desarrollo de la producción y el mercado mundial.

2. La industria camaronera, en asociación con el Gobierno del Ecuador, debería fortalecer el programa para controlar y certificar la calidad de los embarques a mercados extranjeros.

3. Se debería desarrollar e implementar un programa para la recolección y el análisis de información económica básica.

4. Se debería llevar a cabo un estudio acerca del impacto económico que se presentaría en el futuro, originado por la actual contaminación de agua en la industria camaronera.

E. Participación del Gobierno en la Industria Camaronera

Conclusiones

El sistema vigente de autorizaciones para la concesión del uso de "tierra baja" y la autorización para la construcción y operación de camaroneras es muy complejo, significando un gasto mayor de tiempo y dinero para los interesados. Un cultivador de camarón comentó lo siguiente en el taller, "Es más fácil tener éxito en la crianza de cualquier variedad de camarón que obtener los permisos necesarios". Tampoco está claro qué beneficios se obtienen del sistema actual en cuanto a la protección de habitat críticos, la determinación de sitios y construcciones apropiadas y la conservación del patrimonio público. Lo complejo del sistema actual explica el por qué ha sido ignorado por muchos participantes en la industria.

La maricultura de camarón está regulada por un número de leyes y políticas gubernamentales, siendo la más importante la Ley de Pesca. Estas leyes fueron designadas para regir actividades que difieren en muchos aspectos importantes de la industria camaronera. La Ley de Pesca favorece a las compañías de gran escala integradas verticalmente y es cuestionable si la aplicación de esta política a la industria del cultivo de camarón beneficia a la industria o a la nación. Los incentivos actuales para promover la creación de laboratorios no siempre tienen bases sólidas.

Recomendaciones

1. El sistema de permisos debería ser revisado y ampliamente simplificado. Como primer paso se debería definir los objetivos y luego diseñar un sistema que asegure la participación de las agencias gubernamentales necesarias de una manera coordinada y oportuna. Un sistema por el cual un permiso sea aprobado o no mediante una sola gestión es preferible al actual sistema secuencial de aprobación. La evaluación y trámite de permisos debería basarse en la existencia o no de criterios que minimicen impactos en habitat importantes y en el fomento de prácticas de construcción adecuadas.

2. La política gubernamental que delinea la industria del camarón debería ser críticamente estudiada. Quizás sea apropiado considerar una legislación diseñada específicamente para la maricultura de camarón. En particular, las políticas que propician operaciones a gran escala integradas verticalmente y las limitaciones impuestas por varias regulaciones deben ser reconsideradas. Una industria diversificada que incluya a un gran número de negocios a menor escala quizás traiga mayores beneficios para el Ecuador y sea capaz de adaptarse a cambios en el mercado mundial mejor que una industria dominada por unas pocas grandes operaciones fuertemente capitalizadas.

F. Asistencia Técnica

Conclusiones

Los camaroneros y los encargados de los laboratorios que actualmente operan en el Ecuador están entre los mejores del mundo; sin embargo, la industria ha crecido en una atmósfera de enriquecimiento precipitado y un número de ajustes debe ser llevado a cabo para estabilizarla exitosamente. En general, hay una buena comunicación entre los operadores de laboratorio quienes también tienen a su alcance la opinión de expertos mundiales. Sin embargo, existe una necesidad real de establecer programas de ampliación e investigación determinados. Aquí el intercambio de información se ve obstaculizado por una atmósfera de competencia intensa y de secretismo entre los camaroneros. Las prioridades que se deben aplicar incluyen la asistencia en el manejo de la calidad de agua, en la determinación de tasas de bombeo, la alimentación y el diseño de los estanques.

Recomendaciones

1. Un programa de extensión enfocado a aspectos específicos del cultivo de camarón debe ser diseñado e implementado con la ayuda e íntima colaboración de la industria. Dicho programa podría ser financiado por una tasa impuesta a todas las exportaciones de camarón.

2. Se debería prestar más ayuda al programa de entrenamiento para técnicos de laboratorio que se ofrece en la Escuela Superior Politécnica del Litoral (ESPOL). La falta de personal entrenado para la operación de los laboratorios es un problema urgente que debe ser enfrentado.

G. Educación Pública

Conclusiones

Existe poca apreciación entre los funcionarios del gobierno y el público en general en lo que se refiere a la interrelación de las actividades humanas que alteran el medio ambiente y a la clase de usos que puede soportar. La ausencia de un marco conceptual que permita entender esta interrelación hará difícil obtener el apoyo público necesario para hacer de los programas de manejo del medio un éxito. Un tema en el cual se insistió en el taller fue la necesidad de una amplia divulgación de la información sobre las condiciones y problemas que afectan la calidad de los ecosistemas que sustentan la maricultura de camarón. También, se repitió frecuentemente que las políticas y programas gubernamentales necesitan ser preparados con una mayor participación de quienes se verían afectados por tales programas, particularmente, cuando su cooperación sea un requisito necesario para la implementación exitosa de las políticas pertinentes.

Recomendaciones

1. Se debería adoptar un compromiso serio para apoyar los programas de Educación Pública sobre asuntos ambientales. Se debería enfocar en los asuntos de mayor prioridad y buscar la forma de informar a la sociedad sobre la necesidad de un control sobre las actividades que degradan la base de recursos, de los que todos dependen.

Acciones Futuras

La implementación efectiva de una estrategia integrada para el desarrollo de una maricultura sostenible de camarón requerirá tanto un compromiso como un esfuerzo concentrado por parte de la industria, el gobierno y las instituciones de investigación. La planificación, investigación y política de desarrollo descrita aquí requerirá también de un compromiso de financiamiento significativo. Sin embargo, ya se está logrando algo, y uno de los mayores desafíos consiste en la coordinación de programas e instituciones existentes. El Proyecto de Manejo de Recursos Costeros podría, si es que así se juzga apropiado, asumir la responsabilidad de coordinar las iniciativas propuestas. Esto incluiría evaluaciones periódicas de progreso y de las prioridades. A pesar de que la maricultura de camarón es sólo uno de los tópicos dentro del Proyecto de Manejo de Recursos Costreros, es lo suficientemente importante para justificar un compromiso mayor de fondos y energía.

Más allá del papel de coordinador, el Proyecto de Manejo de Recursos Costeros está en posición de desarrollar varios elementos de la estrategia. El Proyecto ya ha comprometido fondos para diseñar e implementar un proyecto de investigación y extensión que tiene como objetivo la reducción de las tasas de mortalidad de postlarvas de camarón. El Proyecto también ha facilitado fondos de USAID/Quito para lograr una ampliación modesta de una investigación que se está llevando a cabo en el Instituto Nacional de Pesca acerca de la distribución y abundancia relativa de postlarvas en la costa y en los estuarios. El Proyecto de Manejo de Recursos Costeros también está diseñando un programa integrado de evaluación y monitoreo de la calidad de agua para el segundo año de trabajo. Otras iniciativas financiadas por este Proyecto y que están relacionadas directamente a las recomendaciones presentadas aquí incluyen el desarrollo de planes para el manejo de manglares, un programa de educación pública y el análisis de leyes e instituciones que afectan el manejo de recursos costeros del Ecuador.

Socioeconomic Aspects of Shrimp Mariculture

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

Un Análisis Económico de las Tendencias en la Industria de la Maricultura del Camarón en el Ecuador

Jon G. Sutinen, James Broadus, and Walter Spurrier B.

Resumen

El documento analiza el estado de la economía de la Industria de la Maricultura del Camarón a mediados de los años 80.

La producción de camarones en escala significativa comenzó en Ecuador en 1952 con buques de arrastre. Hasta 1955 la producción fue menor que 1.000 toneladas métricas (t.m.), se duplicó en 1956 y superó las 3.000 t.m. en 1958. En la década de los 60 aumentó unas 3,5 veces hasta un máximo cercano a 9.000 t.m. en 1969.

Los cambios en la pesca costera están relacionados significativamente con los eventos de "El Niño", en cuyos años el promedio es de 7.900 t.m., mientras en los años de ausencia de este fenómeno el promedio baja a 6.300 t.m. Las variaciones en la productividad no se explican totalmente con los eventos de El Niño, por ello deben tenerse en cuenta razones económicas, variaciones en la flota y otras condiciones.

La industria del cultivo del camarón se desarrolló en la década 1976-1985. En 1976 la producción fue de 9.000 t.m. y alcanzó un máximo de 44.600 t.m. en 1983 (35.700 t.m., de cultivos). En 1984 y 1985 la producción en estanques cayó a 33.600 y 30.205 t.m., respectivamente, lo que fue atribuído a falta de postlarvas para la "siembra".

En 1985 habían tres tipos de cultivo: (1) extensivo (rendimientos: 600 lbs/camarón entero/ha/año); (2) semi-extensivo (rendimientos: 2.150-2.400 lbs); y, (3) semi-intensivo (rendimientos: 3.000-5.000 lbs). No hay registros adecuados para estudios de costos-beneficios.

El factor decisivo en el cultivo es el aporte de postlarvas (pls), que proviene de tres fuentes: pesca, laboratorios e importación. Se estimó que unos 90.000 pescadores, a tiempo parcial, se dedicaron a la captura de pls en 1983; que desde 1979 se han usado entre 4×10^9 y 11×10^9 pls/año; que la producción de laboratorios en 1984 fue de unos 300 millones de pls.

A fines de 1985 la superficie autorizada para construcción de piscinas alcanzó las 94.000 has y el máximo probable en cultivo fue de 48.000 has en 1984, disminuyendo en 1985 a unas 30.000 has. Más del 75% de la superficie autorizada correspondió a la provincia del Guayas, el 15% a El Oro y el resto a Manabí y Esmeraldas (1985). Los suelos usados para piscinas corresponden a: manglares (70%), salitrales (15%) y tierras agrícolas (15%). Se estima que el total de suelos disponibles para cultivo está entre 70.000 y 260.000 has.

Antes de 1980 el número de empacadoras de camarón eran menos de 20, pero para 1985 el número es superior a 70. El 10% de las empresas exportaba el 45% del camarón, entre 1982 y 1984. El valor de las exportaciones creció desde menos de 25 millones de dólares (E.U.A.) en 1976 hasta cerca de 185 millones en 1983, constituyendo el segundo rubro en el ingreso de divisas y el 7% del valor de todas las exportaciones del país. El principal destino de las exportaciones son los E.U.A. y sólo un 4% se envió a Japón y Europa. Hay informaciones de envíos informales de camarón al Perú, desde donde se exporta.

Los créditos concedidos a la industria del camarón hasta mediados de 1980 fueron por el Banco Central del Ecuador en 300 millones de dólares, principalmente a través de bancos comerciales. También, han jugado un papel importante las inversiones extranjeras.

El documento presenta informaciones sobre las políticas de Gobierno y los incentivos establecidos para el desarrollo de esta actividad y plantea recomendaciones que, fundamentalmente, son de dos tipos: (a) cambios en las políticas tendientes a reducir el contrabando y extender los plazos de las concesiones de suelos para piscinas o hacer renovaciones automáticas; y, (b) investigaciones y organización de las informaciones, debiendo atenderse aspectos como determinación de costos, evaluación de la demanda de pls, calidad del producto, condiciones del mercado internacional, etc.

Introduction

This paper is an attempt to document and analyze the economic status of the Ecuadorian shrimp mariculture industry in the mid-1980s. Where possible, the likely economic impacts of prevailing policies on the industry and the Ecuadorian economy are explained. Full economic analysis would be possible only with much more extensive research.

Early History (1952-1975)

Production of shrimp on a significant scale began in Ecuador in 1952 with the introduction of offshore trawlers. Offshore production was under 1,000 metric tons (m.t.) through 1955, more than doubled in 1956, and exceeded 3,000 m.t. for the first time in 1958. Production by shrimp trawlers paralleled growth in the fleet and increased by nearly 3 1/2 times in the 1960s, peaking at nearly 9,000 m.t. in 1969. 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 (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 6,000 m.t. each year. In 1972, production rebounded and reached nearly 8,000 m.t. in 1973. Production again dropped to a modest 6,500 m.t. in 1974, but reached 7,500 m.t. 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 that 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.

Changes in offshore production also correlate significantly with El Nino events. These climatic events typically begin during December or January, last from two months to two years, and enhance shrimp production with much higher than normal air and water temperatures, precipitation and sea level.

El Nino events occur regularly, usually every five to seven years, affecting abundance and, hence, production for one to two years. Full offshore production in non-El Nino years averages 6,300 m.t., while in El Nino years production averages 7,900 m.t., a 27 percent difference (using the mean production level of 7,000 m.t. as a base). In short, the offshore shrimp fishery is subject to wide variation in production and economic fortune due to natural environmental changes alone. 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. 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.

Still, 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 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.

The shrimp industry in Ecuador has been export-oriented almost from its beginning. The first exports of shrimp occurred in 1954, two years after offshore trawling began. Two packing firms were established in these early years. No data are available on processing and marketing activities prior to 1970. The volume of reported exports peaked at 5,000 m.t. (product weight) in 1972, and the value peaked at U.S. $14.6 million in 1975 (Table 3).

Freight on board prices in current U.S. dollars rose fivefold during the period and, even after adjusting for inflation, prices exhibited a healthy threefold increase overall from 1970 to 1975. Slightly more than 80 percent of Ecuador's shrimp production was exported during 1970-75, 97 percent of that to the United States. Still, only 3 percent of all shrimp exports to the United States during the first half of the 1970s came from Ecuador, though the situation began to change by the end of the decade. Imports of Ecuadorian shrimp by the United States began in 1954 (Table 4). The quantities of imports between 1954 and 1975 equal the quantities of production. Slight discrepancies between the U.S. import and Ecuadorian export data may be due to different recording procedures.

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 fivefold (in weight) due to the growth of shrimp farming in the country so that Ecuador is now the second largest supplier of shrimp imports to the United States. The success of shrimp mariculture in Ecuador has prompted large-scale investments in similar shrimp cultivation operations in Panama, Brazil and other tropical countries.

Total Shrimp Production

In 1976, total shrimp production was 9,000 m.t., while in 1983 production peaked at 44,600 m.t.. Cultivated shrimp comprised a small fraction of total production in 1976, but by 1983 cultivated shrimp may have comprised 75 percent of the total (Table 5).

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 was insignificant compared 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), though production probably remained relatively small through 1978. The first year of significant cultivated production in 1979, at nearly 4,700 m.t., was still less than offshore production. Then, in 1980, cultivated production nearly doubled to almost 9,200 m.t., and exceeded offshore production for the first time. Cultivated production continued to expand into 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 m.t., an increase of 66 percent over 1982. If these estimates are reasonably precise, they show that cultivated production increased 7 1/2 times from 1979 to 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 U.S. dollar). However, according to official estimates, cultivated production dropped to 33,600 m.t. in 1984 and 30,200 m.t. in 1985, due presumably to the lack of postlarvae for stock ponds.

Accurate data on the current number and size of shrimp farms in Ecuador are not available. Only the number of hectares authorized for cultivation by the government is known. It is likely that for much of the period through 1980, authorized hectares were considerably less than the actual area used in the shrimp farming. Since 1981, however, it appears that the actual area in farms was less than the authorized hectares (Table 6). 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

While shrimp cultivation originated in El Oro province, the greatest 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 over the last decade. These data should be treated as indicative only, since, as stated above, government authorizations are not an accurate record of the actual amount of land cultivation.

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 while, at the other extreme, there are a few large farms of several hundred hectares with 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. A description of the area of lands awarded in 1984 is given in Table 8, excluding a few large farms of 1000-2,000 hectares.

As of early 1985, there were three 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 growout 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 2,150-2,400 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 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 3,000-5,000 pounds of whole shrimp per hectare, per year (McPadden, 1985).

There is no record of the percentage of Ecuador's cultivated production committed to each method. Li Puma and Meltzoff (1985) claim that the exensive 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. 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 cultivated 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 enhance 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 restocking.

Harvested 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 cultivated shrimp industry is needed before the following important issues and questions can be addressed:

- How have the costs and earnings shaped past developments in the industry, in terms of farm size and number, location, methods used, stocking densities, feed use, etc.?
- What are the major determinants of profit and loss?
- What is (are) the most profitable type(s) of farm(s) in terms of size, and stocking, feeding and harvest methods?
- Can the costs of entering the industry be recovered over a reasonable period?
- Given the current costs and earnings picture and general trends, what developments in the industry can be expected in the near future?

Unfortunately, adequate records are not available at this time. The most complete costs and earnings data available are a survey of the industry conducted by the Central Bank of Ecuador (1982). This study gives the average production costs and prices per pound on 112 farms in four provinces 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 farm size distributions in the study's cost figures, which makes interpreting gross margins difficult. A study by Liao and Chao (1983) reports average production costs of 15-27.5 sucres per pound for the extensive cultivation method. However, neither characteristics of the farms on which this estimate is based, nor a description of the items included in their cost figures are given, and no information is provided on earnings. McPadden (1985) reports average production costs in the range of 220-270 sucres per pound for farms using semi-intensive methods. LiPuma and Meltzoff (1985) cite costs of abut 120 sucres per pound for farms using semi-intensive methods. They also report costs of 113 and 161 sucres per pound for extensive and semi-extensive farming methods.

Disparity among these data make them difficult to use. Furthermore, recent data given by McPadden, and LiPuma and Meltzoff are based on an inadequate sample of farms 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 condition of the industry.

Postlarvae

Perhaps the single most critical input in shrimp cultivation is the postlarvae, 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. There are three distinct source of postlarvae supply in Ecuador: fisheries, hatcheries, and imports from outside the country.

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

The actual quantities of postlarvae used are largely determined by the interaction of demand and supply conditions. Although these have not been studied and documented, the following are reasonable suppositions: The quantity demanded at a given time depends on the area of ponds available for stocking and desired stocking densities. These, 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, the methods and their costs of harvesting, handling and delivering them to the farms, and their selling price. 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.

Because the information on the economics of the farms is incomplete, an analysis of postlarvae demand is impossible. To explain and predict some important events in the industry, a comprehensive analysis of postlarvae demand conditions should include:

- 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
- which farms (by type, size, etc.) would and would not stock at various prices
- how stocking rates are affected by changes in postlarvae price
- how postlarvae demand is affected by shrimp export prices and other factors

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.

No records exist on the number of fishermen in the postlarvae fishery over the years. A report by the National Marine Fisheries Service (NMFS) (1981) estimated 2,000-3,000 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 per postlarvae fisherman fell from 42,500 sucres (U.S. $1,700) or more in 1980 to 10,000 sucres (less than U.S. $120) in 1983. Since inflation, as measured by the consumer price index, more than doubled during this period, the fall in real average earnings was even more dramatic.

These estimates should be treated as indicative only because 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. 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 supports this conjecture. In fact, many postlarvae fishermen have seen their income increase by two to tenfold or more (Maugle, 1986).

Brokers, or intermediaries, commonly purchase the postlarvae from fishermen and transport them in tanks and barrels to sell to farms. 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 is established by estimating the number of living P. vannamei and P. stylirostris postlarvae it contains (McPadden, 1985). Table 11 presents available data on postlarvae prices. Two prices are given: the price paid to fishermen by brokers and the price paid to brokers by shrimp farmers. Unless noted otherwise in the source document, the report price is assumed to be the price paid by the farmers.

Unfortunately, the price data are incomplete and difficult to intepret. 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, but 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 postlarval 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. There is no evidence that postlarvae became available from alternative sources (i.e., hatcheries, imports at competitive prices), but 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 could have been 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 restarting ponds was a slow and costly proposition, 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 limited, with negligible effects on total supplies of postlarvae.

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 that by the end of 1985, from five to 30 hatcheries were in production, with 30 more planned, and production that year exceeded 500 million postlarvae (Leslie, 1986). The rapid increase in hatchery development in 1984 and 1985 was clearly induced by the dramatic drop in wild postlarvae supplies in 1984.

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 1,000 postlarvae in 1985 (NMFS, 1985a; Maugle, 1986). Data from Leslie (1986) indicate minimum average prices required to make hatchery operations commercially viable (Table 12). The calculated prices suggest that small "bamboo" type hatcheries may be able to compete with supplies of wild postlarvae even during periods of relative abundance, while "high-tech" hatcheries, requiring higher prices, would be viable only during periods of relative scarcity.

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 for wild postlarvae are higher than for hatchery postlarvae, then the price that farms are willing to pay for hatchery postlarvae will be less. The difference in the two prices will be proportional to the difference in their survival rates, assuming no other differences.

Imports of Postlarvae

Another source of postlarvae is importation. Postlarvae have been imported from several Latin American countries, the United States and the Philippines. During the height of scarcity in 1985, prices of imported postlarvae were reported to be about 2,500 sucres per 1,000. Shipping problems reportedly eliminate imports from countries other than Peru as a significant source of supply.

Land

Data on land use in shrimp cultivation 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. For example, 60 percent of the converted land was not in production in 1985 (LiPuma and Meltzoff, 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, though it is not clear to what extent land actually in cultivation follows this pattern.

There are three types of land converted to shrimp cultivation: mangroves, salt flats and agricultural land. According to LiPuma and Meltzoff (1985), at the end of 1984 about 70 percent of the land used for cultivation was converted mangroves, 15 percent was converted salt flats, and 15 percent was converted agricultural land. Other estimates, based on aerial photography are given by Alvarez (this volume). 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.

The shift to agricultural land appears to be due to three factors (LiPuma and Meltzoff, 1985):

- Prime land in the intertidal zone is becoming harder to obtain.
- There is a shift towards more intensive cultivation methods for which agricultural land is more suited.
- 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 that 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. A concern is whether the concession is sufficient to bring about the best development and use of the land, and also whether it provides 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 may not be in the interest of the larger society. Unfortunately, without more information and more study, it is impossible to determine the optimal period of a concession. One solution would be to make concessions continuously renewable, provided certain specified terms are always satisfied by concession owners.

Labor

Shrimp cultivation and ancillary activities 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 (these estimates are for the entire shrimp industry, not just cultivation). In addition, there were 90,000-120,000 people just collecting postlarvae. The total employment on shrimp farms is not known. LiPuma and Meltzoff (1985) report the largest operations employ about 70 men, while farms of 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 eventually displace people employed in collecting wild postlarvae. If farms move toward more intensive cultivation methods, fewer but more skilled laborers may be required.

Equipment

Most of the equipment used in the industry, including diesel engines, pumps, graders, refrigeration, earth moving and hatchery equipment, is imported from the United States. NMFS (1981) estimates that imports of U.S. equipment for the shrimp industry was as much as U.S. $10 million per year in the early 1980s.

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 7,000-8,000 m.t. during the latter part of the 1970s. Other sources (NMFS, 1981) claim that a drought, which began in 1977 and lasted until 1981, reduced the abundance of shrimp and resulted in trawler catches substantially below previous levels. Most reports indicate that the fleet size remained fairly stable around 250 vessels during the late 1970s.

Both 1981 and 1982 were difficult years 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 5,000 m.t. for 1981 and that as many as 50 vessels abandoned 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. Sources report trawl catches of 9,000-15,000 m.t. during 1983 (Department of State, 1984; McPadden, 1985). Also 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, with production per vessel perhaps as low as 20 m.t. (Parodi, 1985).

Processing and Marketing

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 that 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.

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

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 1982-84. 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 U.S. $25 million in 1976 to nearly U.S. $185 million in 1983. These export values represent foreign exchange earnings for the national treasury.

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 7 percent of exports (by value), and in 1985 for less than 6 percent.

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. In Table 15, 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. This increase in the exchange rate plus the increase in production resulted in a nearly fourfold 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.

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.

These sales estimates do not include the export tax credit provided to the industry. In recent years the tax credit has equalled 15 percent of export prices (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 billion sucres added to the estimate of a year's sales.

Table 16 presents average export prices (FOB) over the decade, with the U.S. dollar prices converted 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 benefited 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.

Few data are available on the prices paid by packers to farms, so an analysis of price margins cannot be conducted. The Banco Central (1982) study found the average farm price in 1981 to be 60 sucres per pound. If the estimate of 1981 exporters' selling price is correct, a margin of only 18 sucres (30 percent) per pound remained to cover packing, storage and other costs. If further study shows such thin margins, just covering packers' costs, there would 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, 99 percent was reportedly shipped out of the country. The principal destination of shrimp exports has been the United States, with only about 4 percent 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, but 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 and harmful inefficiencies may have been introduced in the system by attempts to enforce this requirement.

Reports of informal transfer of shrimp to Peru for export because of more favorable exchange and tax credit rates are common. Although the extent of this smuggling is not documented, some reports indicate it is substantial. Recorded United States imports of shrimp from Peru increased from less than 1,000 m.t. in 1980 and 1981 to over 4,000 m.t. in 1983. Recorded imports for 1984 and 1985 were 3,000 m.t. and 2,000 m.t., respectively (NMFS, 1986). Some informed observers argue that Peru's small shrimp industry is capable of producing for export no more than 1,000 m.t. on average, and possibly 2,000 m.t. in good years (such as 1984). The difference of 1,000-2,000 m.t. (5 to 10 percent) is likely comprised of Ecuadorian shrimp smuggled out through Peru. This amounts to annual losses to the government of Ecuador of $30 million to $40 million in foreign exchange earnings, plus $10 million to $15 million in tax revenues resulting from the differences between the intervention and free market exchange rate. To significantly reduce the difference with the free market rate would help greatly to reduce the extent of smuggling.

International Markets

As indicated above, nearly all (96 percent) of Ecuador's shrimp exports are to the United States. Small quantities are shipped to Japan and occasionally to Europe.

U.S. Imports of Ecuadorian Shrimp

In 1976 Ecuador was already the fourth largest supplier of shrimp imports to the United States, 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 took 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. 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. Prices fell to just under $4 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 United States.

U.S. Market for Shrimp Imports

The United States is the world's leading consumer of shrimp. As one of the most popular seafood commodities, shrimp is sold in various product forms, including (1) raw tails with the shell on, (2) raw peeled tails, (3) breaded, and (4) canned. Most of these product forms (1-3) 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 United States. 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 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 the 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 18 presents the available data on these imports.

In the raw, shell-on product form, size is an important market feature. According to a NMFS survey (Newman et al., 1985), the predominant sizes imported were 31-40 shrimp per pound 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 the prices of 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 percent to 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 percent to 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.

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).

According to Vodruska, the primary reason for the merked increase 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 shimp. 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 is also 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 United States (Newman, et al., 1985).

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 constitutes 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).

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 U.S. $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 U.S. $20 million to $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).

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.

Government Programs and Policies

The government of Ecuador (GOE) has implemented numerous programs and policies which directly affect the shrimp industry. Some of the programs and policies as they affect export activities, shrimp cultivation, and postlarvae production are discussed below.

Export Activities

The system prevailing in March 1983 through August 1986 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 one 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 that installed a packing plant. Firms are now allowed to substitute installing hatcheries instead of packing facilities in order to qualify for incentives. Also, an additional 5 percent export tax credit is being granted to exporters using shrimp that 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.

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.

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 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 consequence 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 ban 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 in some cases, for example, to prevent the transmission of disease by imported postlarvae.

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.

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 in the long term (except during El Nino events when they are in great abundance). Hatchery production of postlarvae must and will supply the balance. Whether hatcheries will someday produce significant quantities of postlarvae depends both on technical and economic considerations. The principal technical consideration is when and how the local industry will solve the maturation cycle. The economic 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 latter sector.

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 vertical integration in the future is unclear without further study. Some government policies (e.g., the incentives law) may inadvertently 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 of the U.S. shrimp market. Most signs indicate a growing U.S. market over the next few years. Newman (1985) projects 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 percent to 17 percent. If these projections are realized, Ecuador could increase its exports to the United States to about 57 million pounds (26,000 m.t.) and retain its 14 percent share of U.S. imports. It appears that the U.S. market can comfortably absorb any reasonable increases in Ecuadorian shrimp production and exports.

Newman also attempted to project prices of imported shrimp, but could not do so reliably. However, he notes historical patterns that suggest real shrimp prices will likely rise over the period 1985 to 1990. In this analysis, he assumes 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 yen and other currencies may induce more shrimp exports to Japan and Europe. The future prospects for Ecuadorian shrimp in these markets are unknown.

Recommendations

We end with recommendations for policy changes and future research.

Policy

1. Reduce incentives to smuggle.

Official export policies during 1983-1986 made smuggling shrimp to Peru for export very attractive and resulted 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, for 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.

Research

1. Establish an information system and ongoing database.

Too little data currently 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 if 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. Determine the 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. Evaluate postlarvae demand.

Postlarval 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. Evaluate international market conditions.

Since the shrimp industry is export oriented, its future fate depends on conditions in the shrimp markets of the United States, 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 Ecuadorian shrimp industry abreast of long-term trends. Such information should be invaluable for guiding future investments and marketing strategies of the local industry.

5. Evaluate product quality.

Ecuadorian shrimp have commanded lower prices 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. Describe and evaluate structure and organization of the industry.

The shrimp industry currently exhibits extensive vertical integration, while the degree of concentration does not appear 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 and consequences of excess capacity and the susceptibility of the industry to boom-bust cycles.

Table 1
Total Shrimp Production
1954-1975

Year	Production (m.t.)	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)

Table 2
El Niño Events

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

Source: Thompson (1981)

Table 3
Ecuador's Exports of Shrimp
1970-1975

Year	Volume (m.t.)	Value (million U.S.$)	FOB Prices (U.S. $) 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)

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

Year	Quantity (m.t.)	Value (U.S. $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

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

Year	Total Production (m.t).	Trawler Production (m.t.)	Farm Production (m.t.)
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	39900	6300	33600
1985	36228	6023	30205

Sources: McPadden (1985), Direccion General de Pesca

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	2345	
1978	4178	
1979	6945	24000[b]
1980	14707	30000[c]
1981	35382	32000[d]
1982	49069	32500[e]
1983	62938	
1984	87576	48000[f]
1985	94352	
1986	n.a.	30000[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)

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

Year	Total #	Total ha	Guayas #	Guayas ha	El Oro #	El Oro ha	Manabi #	Manabi ha	Esmeraldas #	Esmeraldas ha
1976	6	439	2	300	3	119	1	20	–	–
1977	21	1906	5	615	11	559	5	732	–	–
1978	25	1833	22	1766	1	15	2	52	–	–
1979	31	2767	15	1706	4	318	12	743	–	–
1980	73	7762	54	5613	10	874	8	225	1	50
1981	189	20675	104	15210	71	4379	11	630	3	456
1982	116	13687	40	10620	30	2156	14	739	2	172
1983	122	13869	86	11312	14	1326	17	859	5	372
1984	229	24638	157	20562	37	2551	27	1124	8	401
1985	130	6776	58	3504	26	2199	15	283	13	790
Cumulative Total	942	94352	573	72208	225	14496	112	5407	32	2241

Source: Direccion General de Pesca

Table 8
Number of Authorized Farms by Size
1984

Area (hectares)	Total	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	–	6	–	--
1000-more	1	-	1	–	--

Source: McPadden (1985)

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

PROVINCE	1979	1980	1981
		Average Costs of Production	
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

Source: Banco Central del Ecuador

Table 10
Estimated Postlarval Use

Year	Estimated Hectares in Cultivation	Estimated Number of Postlarval Required for Stocking (in billions) NMFS Method*[a]	Other Sources
1979	24,000[b]	5.3	
1980	30,000[c]	6.6	4-6[c]
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, 1984: 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.

Table 11
Postlarvae Prices (Sucres/1,000)

Date	Beach Price	Farm Price	Estimated Real Farm Price (1979 sucres)
1980		75-100[a]	60-180
2/84		450-540[b]	160-190
2/85	100[e]	400-600[c]	110-165
5/7/85		1300[c]	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	

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

Table 12
Hatchery Costs

Investment Hatchery	Investment Cost (U.S. dollars)	Expected Production (10 PL/hr)	Production Costs (per 1000 PL) (sucres)	Minimum Average Price Required* (sucres)
High tech, Large	2-2.5 million	300	500-800	1,090
High tech, Small to med.	250-800 thousand	60-120	400-600	835
Japanese tech, Large	1 million	200	300-500	675
Japanese "Bamboo"	30-100	12-40	250-400	490

Source: Leslie, 1986.

* Calculated using the formula Kxi < (P-C) x Q, where K is capital investment costs, i is the rate of interest (assumed .25), P is the average price, C is production cost per 1,000 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.

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; from Direccion General de Pesca).

Table 14
Exports of Shrimp

Year	Quantity (m.t.)	Value (million U.S.$)
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).

Table 15
Estimated Exporters[1] 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.

Table 16
Export Prices, FOB, 1976-1985

Year	FOB Price per pound[a] (U.S.$)	Estimated Exporters' Price[b] (sucres per lb)	Adjusted Exporters Price (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).

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

Year	Quantity (m.t.)	Value (U.S. $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

Source: NMFS

Table 18
U.S. Consumption of Shrimp, 1976-1985
(1,000 lbs, heads-off equivalent, and lbs per capital)

Year	Consumption Total	Per Capita
1976	447630	2.073
1977	480082	2.201
1978	460082	2.087
1979	399810	1.793
1980	435788	1.932
1981	447236	1.964
1982	464476	2.020
1983	526527	2.274
1984	593852	2.533
1985	625000E	2.690

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

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 Salinas, KS
Molinos Champion	Farm production Feed mill	Continental Milling Corporation New York, NY

Source: Parodi (1985)

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Shrimp Mariculture Development and Coastal Resources Management: Lessons from Asia and Latin America

Desarrollo de la Maricultura del Camarón y Manejo de Recursos Costeros: La Lección Aprendida de Asia y Latinoamérica.

Conner Bailey

Resumen

En Asia Oriental, la maricultura de camarones peneidos de Japón y Taiwan está basada en sistemas altamente intensivos. Los costos de producción en Japón son altos, alrededor de US$25,50 por Kg, en Taiwan los costos son menores, unos US$5,00 por Kg, que sin embargo son unas cinco veces mayores que los de Ecuador.

En Asia Sudeste hay una larga tradición en acuicultura y se están desarrollando varios proyectos de cultivo de camarones (Indonesia, Tailandia, Filipinas, Sri-Lanka, Malasia). En Tailandia un laboratorio privado produce 45 millones de postlarvas (pls) por año de Penaeus monodon. En el período de 1978-1981 el valor promedio de las exportaciones de camarón de Indonesia, Malasia, Singapur, Tailandia y Filipinas fue de US$400 millones (50% corresponde a Indonesia). La producción esta ligada principalmente al mercado japonés pero hay gran interés de extenderse al mercado de Estados Unidos.

En el Sur de Asia hay sistemas extensivos de cultivo de camarón. India exportó 55.000 t.m. de camarón congelado a los Estados Unidos, con un valor de US$275 millones. Los cultivos de camarón son alternados con los de arroz tolerante de altas salinidades. Bangladesh tiene en el camarón el segundo rubro de exportación.

El Banco Mundial y el Banco de Desarrollo Asiático han planificado programas de apoyo financiero para el cultivo del camarón en los países citados.

La maricultura del camarón en Latinoamérica difiere marcadamente de la asiática. Así, en Latinoamérica no hay una larga tradición en maricultura, constituyendo una nueva adaptación atractiva para la exportación. En Asia la mayor población reside en las partes costeras, con una alta explotación de los recursos, mientras que en Latinoamérica la población está concentrada en el interior, por ello el gran tamaño de las "granjas" camaroneras de Latinoamérica, en comparación con las asiáticas. Después de Ecuador, Brasil y México tienen el mayor potencial para desarrollar esta industria.

En Africa se conoce que hay planes preliminares para la construcción de estanques en Madagascar y Kenya y que hay extensas áreas físicamente apropiadas para cultivos en Madagascar, Costa de Marfil, Benin, Gana, Nigeria y Kenya.

El documento presenta varias consideraciones respecto de la relación entre el buen estado del manglar y el desarrollo de la maricultura, basándose especialmente en trabajos realizados en el Sudeste de Asia y Panamá.

Analizando los aspectos sociales y económicos de la maricultura del camarón en el Ecuador, el autor señala la necesidad de considerar los efectos de este desarrollo en las comunidades que dependen tradicionalmente de los recursos costeros para su sustento, las cuales son generalmente política y económicamente marginales dentro de las sociedades nacionales. Quienes adoptan las políticas necesitan ser sensibles al impacto del desarrollo de la maricultura del camarón en el empleo, distribución de ingresos y en la nutrición, tanto para las comunidades locales como para la sociedad en general.

Las recomendaciones del autor se refieren a la necesidad de que las autoridades ecuatorianas reconozcan la existencia de problemas serios en el manejo de recursos costeros, originados en la conversión del manglar a estanques camaroneros, a la necesidad de una revisión de la distribución de beneficios, al desarrollo de estrategias de producción de bajo costo, incluyendo a productores de pequeña escala que tienen limitados recursos financieros y técnicos.

Introduction

In less than two decades, shrimp mariculture has become a significant source of foreign exchange earnings for a small number of tropical developing countries. The rapid expansion of shrimp mariculture has also had a significant impact on coastal resource use in many countries. The purpose of this report is to review coastal resource management problems stemming from shrimp mariculture development in Asia and Latin America, and to assess the effectiveness of steps taken to mitigate these problems. The study is based on an extensive literature review and nine years of field experience in Southeast Asia. Approximately half of this time was spent studying coastal resource use and management in Malaysia, the Philippines and Indonesia.

This report was prepared with the assistance of Mr. Munirrudin Mullah, a fisheries biologist from India working on his doctorate in the Auburn University Department of Fisheries and Allied Aquacultures, and Mr. James Seger, a doctoral student in agricultural economics. The report itself is divided into four sections, beginning with an overview of tropical shrimp mariculture development. Following this is a discussion of coastal resource management problems associated with shrimp mariculture and the experience of several countries in dealing with these. Next comes a discussion of social issues surrounding shrimp mariculture development. Finally, a concluding section reviews key findings and presents a set of recommendations designed to help policymakers formulate sustainable development strategies.

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 systems are summarized in Table 1.

East Asia

Mariculture of penaeid shrimp in both Japan and Taiwan is based on highly intensive culture systems. In Japan the industry is geared to a small luxury market for live shrimp, and production costs are as high as U.S. $25.50 per kilogram (kg) (Mock, 1983). Shrimp mariculture in Taiwan is less intensive and less costly, though at U.S. $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, but high production costs are likely to limit Taiwan's role as a supplier in the international market for shrimp.

Although the Chinese aquaculture tradition is not limited to Taiwan, the focus of aquacultural development within the People's Republic of China has been on freshwater fish for domestic consumption, and not on shrimp mariculture. Considering mariculture generally, a United Nations Development Programme (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 is currently undergoing a major reorientation of its economic structure to encourage greater private initiative to increase foreign exchange earnings and speed modernization of its economy. The implications for shrimp mariculture are still unclear. It is known, however, that China has entered into a joint venture enterprise with a Japanese company (National Marine Fisheries Service, 1985a), and that a private company in China is soliciting a U.S. partner for a shrimp mariculture joint venture (NMFS, 1985c).

Southeast Asia

Like East Asia, Southeast Asia has a long-established aquaculture tradition. Coastal mariculture throughout the region can be described as an extensive polyculture of milkfish (*Chanos chanos*) and penaeid shrimp (primarily *Penaeus monodon* and *Penaeus merquiensis*). Until recently, ponds were stocked primarily through tidal action; and milkfish fry, shrimp postlarvae 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 as well as low production costs.

By the early 1970s, international stocking of both milkfish and penaeid shrimp had been introduced but was not yet common (Ling, 1973). Production was still oriented primarily towards milkfish production for domestic markets, though during the 1970s marine shrimp landings throughout the region tapered 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.

Current estimates indicate that Southeast Asia has over 400,000 hectares (ha) of brackish water ponds in production using extensive polyculture systems. This total could double or even triple (Table 1), though such development 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 are currently 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 U.S. $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 (see Villalon, this volume), it is likely that most Southeast Asian producers will continue to use 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 inhouse hatcheries producing shrimp on a semi-intensive basis (American Embassy, Bangkok, 1986; Pedini, 1981). One large private hatchery producing 45 million *P. monodon* postlarvae 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 by granting "pioneer status," a 5-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 now 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 U.S. $400 million (Floyd, 1984). Indonesia alone accounted for roughly half of this figure. More recent data from the Food and Agriculture Organization (FAO) suggest that exports from this region increased during 1982 and 1983 (FAO, 1983).

Japan is the principal 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 also has a long history of involvement in the fisheries of Asia that continues today in the form of joint venture enterprises which capture, process and export shrimp to Japan. Many independent shrimp exporters from Southeast Asia are also linked to Japanese buyers through credit obligations (Angell et al., 1985).

Although most shrimp producers in Asia are linked to Japan for the time being, there is considerable interest among producer nations in diversifying market outlets, including expanding sales to the United States. However, before producers are able to do this, they must overcome quality control problems. For example, Asian countries have had difficulty marketing in the United States because the Food and Drug Administration (FDA) has detected persistent problems with bacterial and other 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., 1985). Once these problems are overcome, there is no reason to expect that *P. monodon* and *P. merquiensis* will not achieve consumer acceptance in U.S. markets. *P. merquiensis* 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 is already accepted by U.S. consumers in California (personal observation and interviews with retail outlets).

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 low-cost improvements.

India holds a long-established position as the world's leading exporter of high quality shrimp. In 1985, India exported over 55,000 metric tons (m.t.) of frozen shrimp valued at U.S. $275 million (Marine Products Export Development Authority, 1986; see also the Newsletter of the The World Aquaculture Society, Vol. 17, No. 1, 1986, p. 6). This figure represents 86 percent of the total value of India's fisheries exports. Exports of diced and canned shrimp were insignificant, accounting for less than 0.1 percent of export value. Marine capture fisheries account for almost all export-quality shrimp.

Along both the east and west coasts of India, extensive shrimp mariculture is frequently rotated 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 during harvest, when the fields are drained. 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*). The goal of this research has been to develop simple technologies that require low input levels while improving yields and profits. The government is focusing most of its attention on developing small-scale shrimp mariculture operations. Farmers owning 5 hectares (ha) or less are eligible for low-interest loans to finance land acquisition or pond construction. Some programs include a subsidy of 25 percent to 33 percent for construction costs. A separate program is designed to provide working capital to small-scale producers.

Shrimp is Bangladesh's second most important export commodity (Kibria, 1985). 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 percent of the exported value (American Embassy, Dhaka, 1986). The production system resembles that of India. Both the World Bank and the Asian Development Bank are reported planning to provide financial assistance for shrimp mariculture development (Scura, 1985). Like India, Bangladesh will continue to base its shrimp mariculture on low-cost extensive production practices.

Sri Lanka is also 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 5-year tax holiday on profits 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 are already 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.

Latin America

Shrimp mariculture in Latin America differs markedly from that in Asia. In 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. Also, in most parts of Asia, a high proportion of the population lives in coastal areas, and coastal resources tend to be highly exploited. In contrast, in most of Latin America, the population is concentrated in the interior, and coastal resources are generally less heavily exploited. 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 (estate) tradition of large holdings in much of the region's agricultural sector.

Table 2 shows an estimate of projected shrimp mariculture production in Latin America by 1990. Ecuador is expected to remain the dominant producer in the region, but other nations will begin to compete for market shares.

After Ecuador, Brazil and Mexico are the countries with the greatest long-term potential for shrimp mariculture. 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 that Brazil has number of well-established hatcheries and is likely to be self-sufficient in hatchery-produced postlarvae. 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 suggests, though national economic problems 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.

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). Many species are grown, mostly finfish for domestic consumers, and production is largely based on extensive methods.

Ardill (1982) notes that preliminary plans are 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, however, it is difficult to imagine African shrimp producers having a significant impact on world markets in the foreseeable future.

Summary

In 1983, the United States passed Japan as the world's leading importer of shrimp, though Japan still remains the leader in terms of total import value and per capita consumption (Rackowe, 1984). The United States and Japan together consume approximately two-thirds of the 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, it is clear that this impact is already being felt in the United States 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, suggesting that by the turn of this century harvests of cultivated shrimp will more than double.

Management of Physical and Biological Resources

Throughout the tropics, industrialization, urbanization, increased use of agricultural chemicals, and other consequences of economic development have resulted in widespread environmental stress and degradation. Coastal areas in particular have been greatly affected because (1) they are the downstream recipient of organic and inorganic pollutants and (2) development is often most pronounced in the coastal zone. Many coastal resource management problems are attributable to a narrow sectorial approach to development planning and the consequent failure to recognize environmental linkages and potential adverse effects. For example, soil erosion caused by opening new land for agricultural production may result in excessive sedimentation in coastal wetlands. Runoff from agricultural chemicals may affect water quality and negatively affect shrimp mariculture. Conversion of coastal wetlands to other uses (e.g. mariculture or agricultural production) also affects habitats of other 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. To the extent that natural resources are destroyed or degraded, future development opportunities are limited or foreclosed.

Mangrove Habitat

Mangroves provide structure and stability in an otherwise featureless and fluid zone. Mangroves are highly complex and productive ecosystems that serve a wide variety of useful functions incl··ding prevention of coastal erosion and encouraging soil deposition, provision of food, shelter, and sanctuary for birds and mammals, as well as spawning, nursery and forage areas for numerous finfish, crustacean, and mollusc species. Mangroves also provide 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 have historically utilized the resources found therein for a variety of purposes (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, national and international development policymakers traditionally regarded mangroves as wastelands that 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, scientific evidence makes it clear 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 in most major shrimp-producing nations to establish hatcheries, postlarvae captured in the wild are likely to remain the most important stocking source for the foreseeable future. Convincing evidence exists that mangroves are critically important habitat for shrimp in the postlarval and juvenile stages of their life cycle (Prahl, 1978; Martosubroto and Naamin, 1977; Turner, 1977, 1985, 1986). Continued destruction of mangrove habitat is likely to exacerbate existing postlarvae shortages, the primary constraint to increased shrimp mariculture production in many countries, which until recently included Ecuador.

Southeast Asian Mangroves

Throughout Southeast Asia, coastal resources are under heavy pressure. As a region with a strong maritime tradition, the coastal zone has always 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, "open access" characterizes 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 well-established resource management programs in place. However, such is not the case, though over the past decade most countries have attempted to establish such programs. These efforts are reviewed below to identify common achievements and constraints.

The Philippines

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

During the early 1970s, preliminary scientific evidence (e.g., Odum, 1972) indicated 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 10 years, the conversion of mangrove in the Philippines slowed dramatically; between 1972 and 1982, only 2,130 ha 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 must first 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. Lessees are given 5 years to develop their holdings or forfeit their leases. Regulations also stipulate that no ponds may be within 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 postlarvae and juveniles seek shelter and food along the fringe of mangrove forests and are less dependent on the condition of mangroves further inland. This action was meant to strike a balance between mariculture development and habitat preservation, which also appears to be the case with a regulation that requires lessees to plant trees within at least 20 meters of the edge of tidal streams.

Siddall (1985) reports 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 effect on what happens at the provincial or sub-provincial levels. From personal experience in the Philippines, the author suggests 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.

Indonesia

Like the Philippines, brackish water aquaculture in Indonesia is well established and based on extensive polyculture of milkfish and shrimp. Much of the existing area devoted to aquaculture was originally in mangrove, and most opportunities for future expansion of pond area are found in mangrove areas. The best estimate is that Indonesia has approximately 3.8 million ha 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. However, the potential for aquaculture development in the huge mangrove forests of Indonesia is limited. A large portion of this area is found in very remote locations where human populations are sparse and the necessary supportive infrastructure (roads, electricity, ports, etc.) does not exist.

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

In Indonesia, as in the Philippines and many other countries, the key constraint to establishing integrated and sustainable development strategies is the sectorial approach of government 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 prejudices that limit their purview to those issues directly related to agency jurisdiction and goals.

For example, 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) agree that there should be a greenbelt of mangrove, but disagree on the dimensions of the protected area. 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.

In a review of Indonesian coastal resource management, Burbridge (1983) examined the uniform greenbelt concept and found it seriously flawed as a management tool because it ignored qualitative differences between mangroves and so failed to safeguard the multiple-use qualities of this resource. He called for a more flexible approach to defining mangrove management units that would protect estuarine and deltaic mangrove areas crucial to fisheries production, and still 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 brackish water ponds would be detrimental to sustainable coastal and estuarine fisheries production.

Development takes priority over resource conservation and management in policies affecting mangrove and other tidally influenced swamp lands, which support not only shrimp mariculture development, but also programs of land reclamation for agricultural purposes. Vast areas have been drained 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 are frequently 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." Balanced against these pro-development influences are a number of senior Indonesian government officials who are aware of the need to see beyond sectorial and agency boundaries and promote environmentally sustainable forms of development. The Ministry of Population and the Environment (MPE), for example, is unlike other ministries in that it represents no sectorial interests. Rather, it acts as a cross-sectorial 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 the capital. To be effective, it must rely on its powers of persuasion and to be persuasive, the MPE needs access to independent sources of information. Therefore, the MPE sponsored and supported the establishment of Environmental Study Units at major regional universities throughout Indonesia. The Units are commissioned to conduct studies that inventory local resources and assess management needs.

The key element in the MPE's achieving a degree of success has been the personal influence of the agency's leader on the President and on 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 the part of some Indonesian leaders that development of natural resources is too important to be left to narrow sectorial interests.

Mangrove Management in Panama

Siddall (1985) notes that shrimp mariculture in Panama has had relatively little negative impact on mangrove, compared with the Philippines and Ecuador, because Panama has clear administrative jurisdictions, adequate information for management purposes, and semi-intensive rather than extensive shrimp mariculture production systems.

Unlike in either the Philippines or Ecuador, a single agency (the Direccion General de Recursos Renovables, or RENARE) has responsibility for protection of mangrove forests in Panama. 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 has also shown a willingness to enforce their regulations, fining shrimp farmers whose ponds encroached on mangrove. Monitoring the impact of pond construction is done by comparing aerial photos taken prior to and after pond construction. The Direccion Nacional de Acuacultura has cooperated with RENARE, encouraging 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. Because adequate salt flats were available to meet the need of new investors, pressure on mangrove resources was much reduced.

Finally, 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 attempted to replicate successful techniques developed by Ralston-Purina rather than the extensive methods employed in Ecuador and the Philippines.

Management of Wild Shrimp Populations

With few exceptions, shrimp mariculture development is occurring where wild populations of penaeid shrimp exist and are exploited for export markets. In most cases, 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.

Although Ecuador has a large shrimp mariculture industry, its wild stocks are also under heavy fishing pressure, both from the trawl fishery and from the artisanal fishery for postlarvae. 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 about resource depletion has led to a seasonal closure both for shrimp trawling and the harvesting of postlarvae.

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 shrimp postlarvae was concern about adequate supplies for stocking ponds.

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

Managing Marine Shrimp Fisheries

Between 1980 and 1983, the government of Indonesia imposed a ban on virtually all trawling (Bailey, 1987). 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 (1987). 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 achieve maximum sustainable yields.

Besides official concern about resource depletion, the government was forced to take action because of the negative impact of trawlers on the incomes of small-scale fishermen. There are nearly 1 million small-scale fishermen in Indonesia, approximately 40 percent 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.

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 and sought to keep trawlers from operating in coastal waters.

In practice, however, these regulations proved difficult to enforce and were, therefore, ignored. The primary constraints to adequate enforcement include lack of clear enforcement responsibilities among government agencies, and inadequate personnel and patrol craft. Furthermore, enforcement problems were increased by political influence of trawler owners and by corruption (Bailey, 1987).

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, where an industrial-scale fishery operates in joint-venture enterprises with Japanese partners. For a short while, the initial ban on trawlers led to declining harvests. But by 1982, landings of demersal species along the north coast of Java surpassed those preceding the trawler ban (Bailey, 1987). During this period, the number of fishermen in this area increased by 10 percent and average household incomes among small-scale fishermen increased by 30 percent (ibid.).

The impact of the trawler ban 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 percent, due in part 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 and from brackish water pond operators, who had previously been ignored by most exporters content to have shrimp virtually delivered to their door by trawler fisherman.

One advantage of 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 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, though 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.

Managing Fisheries for Postlarvae 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 postlarvae 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 surprising that little attention has been devoted to management of directed fisheries for postlarvae and gravid females. The exceptions to this pattern appear to be Ecuador and Panama. In Ecuador, a seasonal closure on postlarvae has been imposed for the months of June and July (the season of peak postlarvae 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 then captured and sold to private hatcheries (P. Maugle, personal communication). Concern that such exploitation may have a serious impact on marine shrimp populations led to an area-specific ban on fishing for gravid females in Panama in 1976.

However, there may be good reasons why other nations appear not to share these concerns over directed fisheries for postlarvae and gravid females. In countries with long coastlines, 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, postlarvae 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, the fishing effort for postlarvae 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 postlarval stage is not only dispersed, but is also less intense.

This is not to say that postlarval fisheries are totally unregulated. In the Philippines, local municipal governments leased out postlarval fisheries and milkfish fry fisheries to the highest bidder, though 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 postlarvae 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 postlarvae. Similarly complex and efficient networks exist in Indonesia (personal observations).

No information is available regarding limits placed on fisheries for gravid females except in Panama. Gravid females appear to be incidental to the overall shrimp catch of trawlers and other demersal fishing gear, though it is entirely possible that some trawler operators target gravid females. 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 created concern.

Social Issues in Shrimp Mariculture Development

Shrimp mariculture has transformed the coastal ecology of Ecuador and brought about significant economic 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 are often associated with access to institutional resources (e.g., banks, government agencies) within a society, the kinds of contacts that often are crucial to economic success.

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 that combine the concepts of resource management and resource allocation:

- Natural resources are limited.
- Biologically renewable resources are finite but can sustain harvest over an infinite period of time if carefully managed.
- 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 good water quality. In Ecuador, these limits are being approached (McPadden, 1984; Parodi, 1985).

In 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 have traditionally been heavily exploited on a sustainable basis by local residents for a wide variety of purposes.

This leads 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 is itself a matter of fundamental importance in conceptualizing the policy implications of shrimp mariculture development. In most countries, including Ecuador, the state has established claim to coastal resources, which 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 have traditionally used available resources to meet needs for cash and household sustenance. Communities of people who depend on such coastal resources tend to be politically and economically marginal within the national society so it is not surprising that what they regard as their traditional rights to local resources is 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 uses.

The primary motivations for expropriating resources over which locals have traditional use rights are foreign exchange earnings and profits; the primary measures used to assess the feasibility of development are technical and financial. Smith and Pestanno-Smith (1985, see also Smith, 1984) argue that a wider range of variables should be addressed 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, these 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, since 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 and whose immediate needs are income and employment. Shrimp farming does generate some employment, but the industry cannot be viewed as 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, and wage rates for unskilled workers in coastal communities tend to be low, reflecting the opportunity cost of labor. The irony is that the very process of shrimp mariculture development contributes directly 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 Pestanno-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. 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 to those who have the financial means to develop significant aquaculture and other enterprises.

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. Unfortunately, few serious management initiatives have been taken in these countries. The Philippines appear 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 policy makers alike that issues of resource management have been given little attention in the headlong rush to develop local shrimp mariculture industries.

Thus, the major findings of this study--which was 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, therefore, seem destined to experience many of Ecuador's coastal resource management problems. There are, nonetheless, important messages herein for Ecuadorian policy makers 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 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 United States). 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 on 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 wholly different sets of economic criteria which emphasize risk minimization 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. By contrast, 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). 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. For example, 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, and 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 postlarvae (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 those of 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 postlarvae supply. It is unlikely that hatchery development will reduce the need for postlarvae caught in the wild.

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 postlarvae are further indications of official concern. Below are recommendations addressing a unique set of issues.

Resource Use Conflicts: A Research Agenda

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

Policy Review: Distribution of Benefits

If Ecuadorian policy makers 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.

Develop Low-Cost Production Strategies

Efforts should be made to focus biological and technical research on cost-minimization rather than on production-maximization so Ecuador's shrimp mariculture industry can 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 low-cost technologies, which may be particularly well suited to small-scale producers with limited technical or financial resources.

Table 1
Tropical Shrimp Mariculture: Regional and National Comparisons

REGION/COUNTRY	HA. IN PRODUCTION Current	Potential	YIELD kg/ha/yr	CULTURE SYSTEM
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	1986a			2000		
	Hectares (ha)	kg/ha/yr	Harvest (m.t.)	Hectares (ha)	kg/ha/yr	Harvest (m.t.)
ASIA						
INDIA	30,000	150	4,500	73,000b	750b	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.

b Estimates for Indian production in year 2000 based on data in Table 2.
Estimates for all other countries at year 2000 based on educated guesswork.

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Legal and Institutional Issues

Institutional Issues of Shrimp Mariculture in Ecuador

Aspectos Institucionales de la Maricultura del Camarón en Ecuador

Efraín Pérez y Donald D. Robadue, Jr.

Resumen

Este estudio examina tres elementos principales de la política ecuatoriana en la maricultura del camarón y su base ecológica: control de la construcción y operación de piscinas camaroneras; manejo de la pesquería; y, conservación de los ecosistemas de manglar. En las regulaciones sobre estos tres aspectos es común la falta de claridad en la correlación entre problemas, políticos e implementación, especialmente en relación a la protección ambiental.

El rápido crecimiento de la maricultura del camarón entre 1977 y 1984 planteó el mayor desafío a las instituciones reguladoras de esta actividad. Los requisitos para las concesiones de tierra y permisos de operación inicialmente estuvieron basados en leyes y regulaciones que datan de las décadas de 1960 y 1970. Entre 1984 y 1985, la Dirección General de la Marina Mercante (DIGMER) y la Dirección General de Pesca (DGP) adoptaron nuevas políticas que contienen criterios específicos para la maricultura del camarón, pero para entonces la mayoría de los permisos ya habían sido otorgados.

El proceso para establecimiento de una "camaronera" comprende tres pasos: obtención de la tierra; obtención del permiso de operación; y, evaluación de la maricultura por el Gobierno. El primer paso es el más complejo y puede comprender trámites hasta en siete dependencias diferentes.

La otención del terreno para una camaronera en zonas de playa y bahías es solicitado a la DIGMER, que sigue un trámite para delimitación e inspección del sitio. La concesión es de un máximo de 50 ha para individuos y hasta 250 ha para corporaciones. Cuando una camaronera incluye tierras altas, la extensión puede ser mayor. Los extranjeros pueden obtener concesiones de tierra dentro de la jafa de 50 Km, medidos desde la orilla, con autorización del Presidente de la República. Cumplido estos requisitos, la solicitud se somete a la DGP del Ministerio de Industria, Comercio, Integración y Pesca y al Ministerio de Defensa, para la emisión de Acuerdo Conjunto. La concesión otorgada es válida por 10 años. Si el sitio corresponde a tierras baldías, que son de propiedad del Estado, se necesita la autorización del Instituto Ecuatoriano de Reforma Agraria y Colonización (IERAC). En caso de tierras altas, el Ministerio de Agricultura y Ganadería debe certificar que no son de uso agrícola, aún en el caso de tierras de propiedad privada.

El permiso de operación para la "camaronera" se obtiene en la DGP, presentando una solicitud con el diseño del proyecto. Esta autorización es firmada por el Subsecretario de Recursos Pesqueros. La evaluación de maricultura del camarón por parte del Gobierno incluye la "clasificación" de la empresa, lo cual permite obtener los beneficios que otorga la Ley de Pesca para esta industria. Se debe anotar que muchas construcciones de piscinas son efectuadas sin haber obtenido la autorización legal. Otro problema es la construcción de piscinas en áreas de manglares, habiéndose observado esto inclusive en la Reserva Ecológica de Churute.

En el trabajo se efectúa un análisis amplio sobre las instituciones y regulaciones que controlan a la industria del camarón, incluyendo a la pesquería tradicional que efectúa la flota, los laboratorios productores de larvas, la implantación de vedas de captruas de larvas y adultos del camarón. También, se analiza el marco legal y administrativo para la protección del manglar, anotando que el crecimiento de la maricultura del camarón ha contribuído significativamente a la destrucción del manglar. Según CLIRSEN, se estima que un 11% del manglar fue destruído entre 1969 y 1984.

Entre las conclusiones se mencionan que el Ecuador no carece de los mecanismos básicos para controlar los efectos negativos de la maricultura del camarón en el medio ambiente y que, no obstante las mejoras logradas en la vigilancia durante los últimos dos años, la experiencia es adversa en cuanto a la utilización de los instrumentos legales e institucionales para mantener la base de recursos naturales que sustenta a la industria del camarón.

Introduction

Since 1975, shrimp mariculture has emerged as a major economic activity in the coastal zone of Ecuador, providing a new source of export earning during a period when income from traditional agricultural products and petroleum has faltered. Between 1980 and 1986, the value of production from shrimp farms increased 500 percent, from U.S. $56.9 to $287.9 million. The growth of the industry was accomplished by the rapid conversion of salt flats, coastal lagoons and mangrove habitat into growout ponds for postlarval forms of wild and hatchery-raised shrimp. About 11 percent of Ecuador's mangroves and 39 percent of its salt flats were converted to shrimp farms between 1969 and 1984. As the industry matures in the 1980s, numerous concerns exist about the stability of its future, in part related to the loss of adult and larval shrimp habitat, overharvesting of larvae, deteriorating environmental quality caused by the shrimp industry itself, as well as urbanization and increased agricultural activity.

An Ecuadorian legal and institutional framework was in place to govern the development of the shrimp mariculture industry during its explosive growth. This study examines three central elements of Ecuadorian policy toward shrimp mariculture and its ecological basis in the coastal zone: the siting and construction of shrimp farms, fisheries management and the conservation of mangrove ecosystems.

A persistent theme in all three aspects of shrimp mariculture regulation in Ecuador is the unclear correlations of problems, policies and implementation, especially with regard to protecting the environmental basis for a healthy industry. Ecological concern is a recent one in Ecuador, probably prompted by the dramatic decline in postlarvae stocks in the mid-1980s. Specifically, the variability of wild postlarvae abundance provided evidence that a decline in the productivity of the ecosystem can hurt shrimp mariculture. Most current laws and regulations, however, were not designed with ecosystem management in mind. Attention has been concentrated instead upon allocating shore area uses and collecting lease or title fees. Current policies also provide incentives for development that are irrelevant to mangrove felling, without capability or commitment to either enforce the policy or develop a new one that would provide actual protection to mangrove ecosystems. Also, some external factors, such as the increased abundance of postlarval shrimp during the El Nino years of 1982-83 and 1986-87 temporarily removed natural limitation on shrimp farm productivity. Finally, other factors, including a stagnant economy and the earthquake which cut oil exports in 1987, tend to outweigh consideration of the effects of environmental changes on shrimp production.

Controls on the Development and Operation of Shrimp Farms

The rapid growth of shrimp mariculture in the coastal zone of Ecuador between 1977 and 1984 presented a major challenge for regulatory agencies. During this period, the Merchant Marine and Coastal Directorate for Fisheries (DIGMER) enforced lease and operating permit requirements based on laws and regulations from the 1960s and 1970s. Although in 1984 and 1985 these agencies adopted new policies which contain decision-making criteria specific to shrimp mariculture, the majority of leases and operating permits in effect were issued before these new criteria were put into place.

The laws and regulations that govern the establishment of shrimp farms create a three-step governance process for shrimp farm owners and operators. As Figure 1 illustrates, the first task is to acquire a site for the farm. The site may include areas in the beach and bay zone that must be leased from the Merchant Marine and Coastal Directorate. Vacant upland can be purchased from the National Institute for Agrarian Reform. The use of private upland for shrimp farming requires clearance from the Ministry of Agriculture.

Once the site is acquired, permission to operate the farm must be obtained from the Undersecretary of Fisheries through the General Directorate of Fisheries. Specific criteria for approving shrimp farm applications were adopted only as recently as 1985. When approved, a farm is subject to periodic reviews of its lease and operating permits. From an administrative perspective, the site acquisition process is the most complex of the regulatory procedures and can involve as many as seven different agency departments.

Acquisition of Shrimp Farm Sites

Leases in the Beach and Bay Zone. Portions of many shrimp farms are in the beach and bay zone, which is defined as the zone between the lowest and highest tide marks. Land beyond the highest tide mark is considered upland. The Merchant Marine and General Coastal Directorate (DIGMER) is charged with issuing leases to individuals and corporations seeking to carry out activities in this zone. Leasing is administered through the Beach and Bay Department of the National Maritime Directorate of DIGMER (Regulation D 981, 1963). The Military Oceanographic Institute (INOCAR) was assigned the task of mapping this coastal strip, but so far the boundaries have not been allocated (Padilla, 1986). Currently, the inspectors are charged with marking boundaries on an ad hoc basis. They rely on vegetation to estimate locations of tide lines, and they consult with local residents.

The Roman law and Napoleonic code, upon which the Ecuadorian civil code is based, considered the beach as common property. As a result, permanent use of the beach and bay zone in Ecuador is allowed only under conditions established by the code of maritime police. Figure 2 illustrates the procedure which must be followed to obtain a lease in the beach and bay zone. First, the prospective lessee uses these boundaries to prepare a contour map showing the location of the project. The Beach and Bay Department prepares a report that must include a certificate stating that the petitioner does not hold other leases and that possession of the lease is not subject to dispute.

An individual is allowed to lease a maximum of 50 hectares of the beach zone, while corporations are permitted to lease up to 250 hectares. Since a shrimp farm could include both beach and bay zone and uplands, its total size can be greater than the limits set in the lease. Alien citizens and corporations must also obtain authorization from the joint chiefs of staff and the president of the republic. This applies to all foreign-owned land within the 50 kilometer belt inland from the shoreland.

After these requirements are met, the application for a lease is submitted to the General Directorate for Fisheries, as well as the Ministry of Industry, Commerce and Fisheries (MICIP), and the Ministry of Defense. Once the General Directorate for Fisheries issues a favorable report, the two ministries issue a joint agreement (acuerdo) which is published in the official register. The lessee can then make arrangements to begin paying the annual lease fee. The lease is valid for ten years and is renewable.

According to the code of maritime police, an annuity must be paid for every kind of permanent use of a beach and bay zone. Since beach and bay use was mainly for piers and docks, the usage areas were reckoned in square meters, as were its annual rates. The annuity per square meter was quoted at one-half sucre, about three cents. With the advent of the shrimp pond industry, the reckoning had to be done in hectares. The price of the annual fee at the current rates would have been (5.00 x 10,000 meters) 50,000 sucres or U.S. $300 per hectare.

The first official acknowledgment of the increasing rate of shrimp pond construction in Ecuador came with a reform to the code of maritime police (P.S. 482, 1975), reducing the amount which had to be paid for shrimp pond construction in the beach and bay zone.

Obtaining Title to a Vacant Upland Site. By law all vacant land in Ecuador is the property of the state and is under the control of the Ecuadorian Institute for Agrarian Reform (IERAC). This agency is able to dispose of upland that, according to legal standards, is not performing its "social function." The IERAC executive director is empowered to award property rights in upland areas when the grantee pays its estimated commercial value. Also, under certain conditions it is possible for peasants' cooperatives and for private persons, in that order, to also claim vacant land and receive an IERAC grant. IERAC also has the power to expropriate land and grant it to third parties. Prior to issuing a grant for the upland area, a certificate must be acquired from the provincial agriculture and livestock directorate in the Ministry of Agriculture stating that the land is not fit for agricultural purposes.

For general agricultural land, rights can be obtained at a cost of 3,000 to 5,000 sucres per hectare. This is a one-time payment because it is made to buy the land. A special procedure was enacted in 1984 for land grants for shrimp farming with new minimum prices established (A. IERAC, 23 October 1984, Creacion de la Unidad Ejectora de Tierras para Acuacultura). Its main objective was to charge higher prices, more in keeping with shrimp farming incomes. If for general agricultural land, rights were in the range of 3,000-5,000 sucres per hectare, land for shrimp farming cannot be granted for less than 50,000 sucres ($100 U.S.) per hectare (Art. 5, A. 23 October 1984). IERAC's 1986 grant program estimated that almost 436 million sucres would be collected through shrimp farm land grants during the year (IERAC, Plan Anual Operativo, 1986, 48).

Private Land. Sites for privately owned shrimp farms must also be certified by the Ministry of Agriculture as unfit for agriculture before a shrimp farm operating permit can be granted from the General Directorate for Fisheries. However, when the lot for the shrimp farm is to be purchased or incorporated from a larger holding, effectively causing a property subdivision, a permit from the IERAC is required in addition to the certificate from the Ministry of Agriculture.

Shrimp Farm Operating Permits

Every shrimp farm must obtain an operating permit from the General Directorate for Fisheries. The petitioner must first demonstrate the possession of a lease (the joint acuerdo), an IERAC grant, or a certificate from the Ministry of Agriculture (for private lands). Under new rules published in 1985, the petitioner has to provide a very detailed map of the farm project, showing the design of wall sections, pump stations, water channels and rights-of-way. The minimum distance between the shrimp farm and an agricultural area is 500 meters. Nursery ponds must be at lea... 4 meters away from an agricultural area.

The director general of fisheries has 15 days to issue a report on the project. In the case of a favorable report, the documents are sent to the undersecretary for fisheries resources. In this office, the acuerdo of authorization for fisheries activities is drawn up and signed by the undersecretary. The last step in this procedure is the publication of the acuerdo in the official register (Figure 3).

Under the new 1985 regulations, mariculture permit holders are obliged to allow for official inspections whenever the authorities see fit, to protect the ponds' adjacent mangroves and agricultural areas, to prevent pollution of the site, to keep records on farming and sales records, and to provide for natural or artificial nursery ponds, and to comply with the forestry law, maritime police code, their regulations and related laws. In September 1985, issuance of permits for new ponds was suspended.

Assessment of the Governance of Shrimp Mariculture

Shrimp exports have become a vital part of the Ecuadorian economy. Agricultural exports from Ecuador peaked in 1978, and have declined steadily since then (Figure 4). Events such as the 1982-83 El Nino adversely affected banana crops, and the prices of sugar, coffee and cacao fell. Shrimp farm exports began to increase, due both to massive investments and the unusual abundance of shrimp postlarvae. This growth in shrimp exports took place during a time of economic crisis in Ecuador, which in 1983 saw the gross domestic product decline in real terms by 3.0 percent over the previous year. In addition, disbursed external public debt grew from $.4 billion in 1975 to $6.3 billion in 1983. Debt service on those loans jumped from $50 million to $870 million in the same time period. It is within this context of economic crisis that the regulation of shrimp farms has taken place.

The volume of applications for approvals of every type increased dramatically after 1978. In addition, many shrimp farms were constructed before required permissions were obtained as farm owners rushed to take advantage of the abundant supply of postlarvae and the promise of huge profits. During the mid-1980s, revisions were made to some of the laws and regulations pertaining to shrimp mariculture. For example, a new set of rules was published in 1985 covering the procedures and review criteria to be used by the General Directorate for Fisheries in evaluating requests for "classification" of enterprises to take better advantage of the benefits of the fisheries law. A basic problem for regulatory agencies has been bringing all of the shrimp farms under their respective jurisdictions into conformance with the leasing and operating permit procedures.

From a public policy perspective, however, an equally important concern is to identify the objectives of the regulatory effort. The historic reason for the leasing procedure was to assure that the use of the communal beach and bay zone was in the public interest. The IERAC role in the granting procedure is to make sure that public land is sold to private individuals in accord with the priorities set by the law of agrarian reform. In both cases, the objective of raising revenues through lease fees and titles is central to the regulatory activity.

Leased and Nonleased Development in the Beach and Bay Zone. The amount of area leased for shrimp mariculture increased dramatically, beginning in 1979 (Figure 5). Because the industry grew so rapidly, many farms did not obtain leases prior to their construction, circumventing review by the Merchant Marine and Coastal Directorate and the need to pay the annual lease fees. The Center for the Integrated Survey of Natural Resources (through remote sensing), CLIRSEN, and DIGMER have been working jointly to identify unauthorized farms in beach and bay zones. Studies to date using aerial photographs show that there may be 60 farms in the Guayas Gulf illegally occupying beach and bay zone areas. Of these, ten have a surface area of up to 200 hectares each. Without site inspections, it is not yet possible to say that every identified farm is actually within DIGMER jurisdiction, i.e., in the beach and bay zone (Cevallos, 1986).

The limited number of DIGMER personnel available makes it difficult to handle new applications for leases as well as keep track of development activity. The mariculture development of the late 1970s and early 1980s was unprecedented in volume and geographic scope. It became common to make the inspections in airplanes provided by anxious prospective lessees because many of the proposed pond sites were located in remote areas which can be reached only by air or water. The flood of applications has subsided, and most of the available sites in central and southern Ecuador are now occupied. However, construction of approved and as yet unauthorized farms continues throughout the coast.

The Granting of Titles in Vacant Upland Areas. The definition of vacant upland, which falls under the jurisdiction of the Ecuadorian Institute for Agrian Reform (IERAC), is essentially negative. That is, IERAC governs land not in the beach and bay zone, though definitions of this zone are sometimes inconsistent. For example, salt flats next to mangroves are generally regarded as in the beach and bay zone even though they may not be covered by the highest tides; diked ponds which no longer experience tidal influence are also considered part of the beach and bay zone. Fortunately, IERAC usually does not claim these areas.

However, a 1985 report by the National Forestry Directorate (DINAFOR), contends that it has been a practice for IERAC to grant areas for shrimp farm construction in national forestry domains, specifically the Reserva Ecologica Manglares de Churute. Although construction of shrimp farms located directly in mangrove areas has been expressly forbidden since 1978, allegedly, less strict inspection procedures in the IERAC provide the opportunity for individuals wishing to avoid obtaining a lease from DIGMER to obtain a title to the area by claiming that it is upland (Alarcon, 1986).

Authorization of the Operation of Shrimp Farms. Like DIGMER and its leasing procedures, the General Directorate of Fisheries has seen a tremendous increase in applications for operating permits, and a dramatic rise in the area which it must now supervise. Figure 6 shows the surge in authorizations that started in 1977. By 1980 the workload was four times greater, and in 1981 ten times greater than in 1977. As of 1985, 942 shrimp farms covering 94,352 hectares had been authorized.

According to some sources, most shrimp farms are operating without one or more of the required permits. In a recent publication, Horna is quoted as stating that in 1985 just 10 percent of the shrimp farms were operating legally, 20 percent had initiated permit procedures, and a full 70 percent in every size class were operating illegally. Even if all 60,000 hectares of ponds completed in the first half of 1986 were illegal, it would amount to only 38 percent of the total of authorized and constructed ponds in Ecuador (Maugle, 1986). However, the percentage of farms that started operations prior to receiving their operating permit is not known.

Recognizing the problem of failing to account for all farms in the regulatory process, the General Directorate of Fisheries has pressed unauthorized farm operators to apply for operating permits. In 1984, it issued an order requiring shrimp processing and packing plants to demand that their suppliers provide invoices which are imprinted with the number and date of the acuerdo of authorization. In the same regulation, a deadline was established for compliance by March 31, 1985, but was extended to June 30, and then to August 15. In September 1985, the issuance of permits for new shrimp ponds was suspended, but it was left to the discretion of the General Directorate of Fisheries to grant permits for ponds already constructed illegally, with a deadline of September 30. In March 1986, a new term for authorizing the illegal farms was set for April 30, 1986. This deadline also passed. In April 1987, the enforcement of the prohibition was postponed indefinitely following a year of declining oil revenues in 1986 and an earthquake that destroyed the oil pipeline that brought crude oil from eastern Ecuador to the coast for shipment.

In view of the fact that the specific regulations for shrimp mariculture were only published in 1985 and that, technically speaking, new farms cannot be constructed, it is difficult to determine what decision criteria were employed during the previous period when most shrimp farms were authorized and constructed. LiPuma and Meltzoff (1986) contended that, "Besides diligence and persistence, the key to quick approval can be a series of unofficial payments given to members of the various government agencies."

In many cases, the prohibition on cutting mangroves has proved to be ineffective. Since economic and social circumstances strongly favored expansion of the shrimp mariculture industry, the prohibition on new pond construction proved to be a crude and inappropriate tool for assuring the long-term stability of the shrimp farm industry.

Fisheries Administration and Institutions

The National Council for Fisheries Development was established by the fisheries law. The Council, based in the port city of Guayaquil (Ley de Pesca y Desarrollo Pesquero, as amended by D.S. 2963), is charged with the establishment of the fisheries policy in the entire country. It has seven members: the minister of industries, commerce, and fisheries, or the undersecretary for fisheries resources, the minister of foreign affairs, the minister of finances and public credit, the minister of agriculture and livestock, the general secretary for planning of the Council for National Development (CONADE), the general director of the Merchant Marine and Coastal General Directorate (DIGMER) and a representative for the private fisheries activities. Official advisers to the Council are the directors of the Industrial Development Center (CENDES), the general director for fisheries (INP) and the director for integration of the Ministry of Industry, Commerce, Integration and Fisheries (MICIP), or his permanent deputies. All binding decisions of the Council are issued as "Resoluciones CNDP."

The Undersecretary of Fisheries Resources (Subsecretaria de Recursos Pesqueros) and the National Council for Fisheries Development have been in Guayaquil since 1978 (Decreto Supremo, 2963). The undersecretary heads the National Council, is in charge of the execution and enforcement of the fisheries laws and bylaws, and works out the programs and plans of projects to be approved by the Council. Since 1985 (amendment of the fisheries law, D.L. 03), the Council authorizes starting operations of fishery firms (permit) and grants "classifications" for the "A" and "B" tax and tariff exception categories.

The General Directorate of Fisheries (Direccion General de Pesca) administers, directs and controls the fisheries activities in the country. Among its duties are to inspect the fisheries firms to make sure that they carry out the law and, in case of infringement, to act as judge; also, to grant fisheries registration for national foreign vessels and yearly fisheries permits. Statistical data is collected in the Direccion General de Pesca.

Fisheries Law and Regulation

Code of Maritime Police. The code of maritime policy regulates the uses of the coastal zone and empowers the Merchant Marine and Coastal Directorate to apply sanctions to individuals acting in contravention to its mandates. This code regulates the use of beach and bay zone through a leasing system along with Reglamento de Tramites de la Marina Merchante y del Litoral and the regulation of aquaculture.

Ecuador's fisheries law dates from 1974. Its main features are the degree of control it keeps on the fisheries industry and the incentives it provides. With such incentives the law meant to encourage large vertically integrated enterprises such as canning and fisheries corporations. Such enterprises were thought to be the most likely to succeed in Ecuador and, therefore, better for the country. Consequently, the larger and more vertically integrated a corporation is, the more incentives it receives in the law.

Those firms that qualify are granted the status of "classified" enterprises and receive benefits according to the degree of their vertical integration. There are three categories: Special, A and B. The "Special" category applies to enterprises that harvest and process their own products at sea, incorporating high technology and investments. Firms that are not vertically integrated, such as those that work only in processing, fit into the "B" category. Finally, category "A" are those enterprises that are judged by the undersecretary of fisheries resources to be making an important contribution to the development of the industry, even if they are not highly vertically integrated or working at sea. The incentives to these enterprises comprise a whole range of tax and tariff exceptions and tax deductions on investments.

For those not able to sustain the necessary investments, the fisheries law (Art. 24) and its regulations (D.S.759, 1974, Chapter VI) offer the alternative of association with other enterprises in joint ventures whose terms were carefully spelled out (D.S. 759, Art 39). The resulting joint venture must include vessels, technical equipment, cold storage and land-based processing plants as with every other classified fisheries enterprise (Art. 26).

The law divides fisheries activities into the following steps: (1) extractive phase (catch), that can be (a) industrial, (b) artisanal, (c) scientific research, and (d) sport fisheries; (2) processing; and (3) commercial. For every one of these phases it establishes rules and authorizations, and gives ample power to administrative institutions on matters such as harvest closures, inspection, gathering of information, zoning, and prohibitions on constructing dams or palisades in rivers, estuaries and creeks, that could adversely affect aquatic species.

Shrimp Farming. During the first years of the shrimp mariculture industry, the fisheries law was enforced without consideration for the needs of this activity. Aquaculture regulation (Reglamento para la cria y cultivo de especies bioacuaticas) was enacted in 1985, but it concerned itself basically with lease procedures for the beach and bay zone.

Only in the last few years have specific regulations for shrimp mariculture been issued. One such regulation (R. 131-84-CNDP, 1984) from the National Council for Fisheries Development, set policies for enterprise classification and shrimp exportation. Another (D.E 1142, 1985) sets new regulations for granting classifications and reclassifications of fisheries enterprises in categories A and B. A third (Regulation R. 131-84-CNDP) awards benefits through classification and allows shrimp pond owners to form joint ventures with packing plants. Such category A enterprises must have a cold storage plant with a capacity for at least 30 metric tons of raw products. Since the shrimp are caught alive from the mariculture pond and may arrive alive at the packing plant, it is clear that cold storage is not an important element for the shrimp farm business as it is for the sea fisheries, where several days pass between catching and landing, and arrival at the packing plant.

Recent reforms in the fisheries law (D.L. 03, 1985), and its regulation (D.E. 1312, 1982), a new regulation for aquaculture (D.E. 1062, 1985), and several others have greatly simplified procedures for the shrimp farm business. However, shrimp mariculture has grown dramatically without the need for such development incentives.

Hatcheries and Larvae. Semacua, a business subsidiary of Empacador Shayne in Guayaquil, started construction of the first Ecuadorian shrimp larval hatchery as far back as 1979, in Anconcito. It received authorization from the Ministry of Natural Resources (today Ministry of Energy and Mines), that was in charge of fisheries affairs before these were transferred to MICIP. The hatchery's permit was granted according to the fisheries law because, although neither the law nor its regulation mentioned artificial reproduction, the hatchery business was considered an exploitation of aquatic resources and a fisheries activity.

A current law (Regulation A. 123, 1985) controls hatchery activities as the production of aquatic species in laboratories involving the processes of maturation, breeding, spawning, birth, larval stage, growth and feeding. This regulation also applies to catching fecund and adult aquatic species in their natural environments (Art. 1, A. 123, 1985), even in closed seasons (A. 957, 1985) when a pass is required from the undersecretary of fisheries resources.

Today a permit for installing a hatchery must be sought from the undersecretary of fisheries resources. The application must be accompanied by a technical and economic feasibility study. The general director of fisheries may either approve the application or reject it; the permit is granted through an acuerdo (Ch. II, A. 123, 1985).

A resolution (131-84-CNDP) of the National Council for Fisheries Development allows hatcheries to obtain a classification so they can import equipment with a tariff exemption, as well as granting a 50 percent tax credit on certain investments. It also awards classification to shrimp farmers who install a hatchery, giving them permission to export their products. Shrimp farmers who have acquired classification because of projected construction of a shrimp packing plant can later swap this project for a hatchery and still keep the classification.

Lastly, a MICIP regulation (A. 22, 1986), lists the Ecuadorian products that may not be exported, including all species of shrimp seed, larvae and gravid shrimp females. It is possible that this prohibition could be interpreted as amending Article 9 for hatcheries laboratories (A. 1234, 1985), which gives jurisdiction to the undersecretary of fisheries resources "to resolve special cases in this matter."

Hatcheries activities need legal authorization, but that is not the case for catching larvae in its natural environment, which are freely exploited except under circumstances where the exportation is forbidden (A. 071 and 135, 1985 and A. 22, 1986). Larvae import is tariff-free (D.E. 964, 1985).

Closures. More attention is currently paid to better-known phenomena of shrimp population dynamics. There is, for example, a regulation (D.E. 1336, 1985) for closures of shrimp fishing for postlarvae, mature females and adults. Different time of year are specified for closures according to the estimated cycles of shrimp development and the regulation forbids all shrimp fishing in the entrances of the estuaries. The regulation by law (A. 957, 1985) gives hatcheries the right to catch fecund females and mature males during closed season for reproduction purposes. Finally, the regulation addresses the need for studies of the possibility of establishing shrimp hatcheries to repopulate the seas.

A framework for enforcing the closure of fisheries for postlarvae, juveniles, mature and fecund shrimp catch was enacted by regulation E.D. 1336, 1985. It provisionally established June 1 to July 31, 1986, as a closed season for postlarvae and adult shrimp. Additionally, regulation A. 262, 1986 prohibits catching shrimp postlarvae in certain zoned beach areas; there are other beach areas where shrimp postlarvae fishing is forbidden during the weekend.

To summarize, closures can be classified as follows: permanent closures as exist in the entrance of estuaries, for postlarvae at certain beaches, and for postlarvae at other designated beaches during the weekend. Periodic closures affect the shrimp trawling fisheries, with the exception of deep sea trawling, and catching postlarvae and adult shrimp, with the exception of authorized hatcheries.

Assessment of the Legal and Administrative Framework of Fisheries Management Pertaining to Shrimp Mariculture in Ecuador

The rationale behind the fisheries law scheme was that the most viable fisheries businesses in Ecuador were exporters and their natural market was the United States. Exporting to the United States required high volume and quality. High volume was reached with big investments, and high quality was only guaranteed for business that complied with strict government-enforced controls of the entire industrial process.

The ambitious goals of the law were never reached. Unfortunately for the canning industry, the big enterprises never materialized. Some enterprises went out of business leaving only two major firms, with the rest being medium-sized firms. Moreover, at no time did a substantial bulk of canned products go to the American markets. Instead, they went mostly to partner countries in the Andean Pack (Andean common market), principally Venezuela, despite the resistance of competing Venezuelan national industries, official harassment and red tape. Additionally, a strong cooperative movement never took hold in the Ecuadorian fisheries. Nor has the artisanal port facilities system materialized.

The shrimp fleet has historically been, and still is, the biggest in Ecuador. In 1975 it accounted for 59.8 percent of the fisheries fleet, though this percentage has been decreasing. In 1982 it represented 50 percent of the total fisheries fleet of 460 vessels in Ecuador (CENDES, 1983, 151). Unlike the fish canning industry, offshore trawl shrimp fishery exports to the United States commenced in 1954 (McPadden, 1985) and continues to keep that country as its natural market. Perhaps this is because the Ecuadorian national laws are more favorable to the shrimp trawl fishery than to the shrimp pond industry.

The optimal structure, size and degree of integration of the shrimp farm industry are different from the optimal structure, size and degree of integration of the exporting canning fisheries and, as such, require a different legal framework. For example, a grant of a "special" category requires a person to own at least one seaworthy vessel, or to have at least two vessels in a joint venture, and to own a land-based cold storage plant with a minimum capacity of at least fifty tons of raw product (A. 13319, 1976). Clearly, these restrictions are inappropriate for mariculture enterprises.

Although the administrative situation has changed somewhat in the last three years, the improvements in shrimp mariculture administration are still governed by the fisheries law enacted more than two decades ago for the sea fisheries industry--an activity quite different from shrimp farming.

Furthermore, the basic tenets of that law--the bigger the enterprise and the more vertically integrated, the better for the country--have never been questioned. In consequence, larger enterprises have been the more favored. How good has this approach been for the shrimp fisheries industries development? No one knows. It may be better to offer more benefits to smaller enterprises, or a combination of benefits for all the firms because nobody is able to show objectively that the underlying rationale of the existing fisheries law has been or will be better for the fisheries industry development than any other.

Finally, a key fact is that, to date, most shrimp farming businesses in Ecuador do not enjoy any kind of classification or tax benefits.

Mangrove Conservation

Introduction

The growth of shrimp mariculture in Ecuador has contributed significantly to the destruction of mangrove forests and ecosystems. Between 1969 and 1984, C'.IRSEN estimates that 11 percent of the country's mangrove forest has been destroyed, with considerable variation among regions. Snedaker (1986) estimates that as much as 30 percent of the Ecuadorian mangrove ecosystem was lost during this same period. This loss continues as new ponds, both authorized and illegal, continue to be constructed.

Shrimp pond operations started in El Oro province in the late 1960s, followed by sudden growth in the 1970s in both `` Oro and Guayas provinces. In El Oro province, mangrove and brackish lagoons are far more limited than in Guayas, according to a study conducted in Machala-Puerto Bolivar, the most heavily populated area in El Oro province This area contains between one-sixth and one-eighth of the total mangrove surfaces of the province. The sample shows that between 1966 and 1982 in the pilot area, the mangrove forest decreased by 29.7 percent (CLIRSEN, 1985) with destruction of the mangrove ecosystems (lagoons and wt areas) even greater. Construction of shrimp ponds can be directly blamed for this decline.

Along the rest of the Ecuadorian coastal zone, the ecological consequences of shrimp pond construction in mangroves is not well understood because of the lack of historical data or comparative studies. It is possible, however, that the pressures on mangrove ecosystems in Guayas have not been as strong as they were in El Oro province, perhaps because the salt flats suitable for shrimp pond construction are much larger in Guayas. Guayas province possesses 69 percent of the total salt flat areas in the Ecuadorian coastal zone compared to 14 percent of El Oro. Thus, it is inappropriate to directly extrapolate findings from El Oro to Guayas. Even so, if all the Guayas shrimp ponds were constructed in mangroves, that could account for as much as a 30 percent decline in the total mangrove resource of the Guayas province (Twilley, this volume).

Protective measures have not been successfully implemented. The case of the shrimp pond construction in the area Reserva Ecologica Manglares de Churute is well documented. According to the Direccion Nacional Forestal (DINAFOR), a significant number of shrimp ponds have been legally constructed there, although those lands were declared a "state forestry domain" in order to conserve the mangrove ecosystem there. There is a consensus today among the shrimp farm operators regarding the importance of mangrove conservation. They are aware that widespread mangrove destruction may have negative repercussions on their industry. The essential question is whether prohibitions on mangrove destruction is an effective means of protecting the mangrove ecosystem of Ecuador for the long-term benefit of the coastal economy.

Legal and Administrative Elements of Mangrove Conservation

The Direccion Nacional Forestal (DINAFOR) is a de[illegible]ent of the Ministry of Agriculture a[illegible] Livestock charged with the development of forestry resources in the country, preservation of natural areas and outstanding wild life, flora, landscapes, historical and archeological relics, and aquatic systems (Reglamento Organico Funcional de la Direccion Nacional Forestal, D.E. 1529, 1983).

Part of the forestry law deals with forest exploitation and industry. Title II, "Natural areas and flora and wildlife," refers to conservation of the national forestry domain and its administration through a set of management categories (parks, reserves, etc.; Table 3). Unit chiefs, forestry district directors and the national forestry director are entitled to pass judgment on misdemeanors against the law (Ley Forestal y de Conservacion de Areas Naturales y Vida Silvestre, Ley C.L. 74, 1981).

Concern for mangrove protection has grown steadily in Ecuador. Decreto Supremo 2939-B, 2978 and bylaw A. 0036, 1979, ruled that DINAFOR should zone the mangrove areas in the country. A 1978 law forbade shrimp pond construction in mangrove areas, but allowed for mangrove exploitation in other selected areas. It has been determined that the main mangrove forest concentration of Ecuador is found in the Gulf of Guayaquil, in the Guayas River, and in the estuaries of the Mataje, Najurungo and Santiago (Informe Sobre la Delimitacion del Bosque Protector de los Manglares en Ecuador, no date). The report recommended a halt in permits for shrimp pond construction. Similarly, in 1985, mangrove conservation, protection and restoration was declared to be in the public interest, and mangrove exploitation and clearing forbidden (D.E. 824-A, 1985).

Assessment of Mangrove Conservation in Ecuador

A 1958 DINAFOR report contends that it has been common for the Ecuadorian Institute for Agrarian Reform (IERAC) to grant areas for shrimp pond construction in national forestry domains, namely, Reserva Ecologica Manglares de Churute (DINAFOR, 1985, 16). Apparently, lack of coordination and clear definition of agency responsibilities regarding mangroves has created much confusion so that agencies are often working at cross purposes. There are adequate legal measures for mangrove conservation. However, due to chronically inadequate budgets and a limited number of public servants in charge of controlling and prosecuting misdemeanors in protected areas, enforcement is inadequate.

A first step would be for the lead agencies to coordinate among themselves so no more permits are granted for farms in the state's forestry domain. This would also be a good occasion to inquire into the failure of the so-called "tripatite commission" to carry out joint inspections on shrimp pond sites. The cooperation of those operators already established in the Reserva Ecologica Manglares de Churute operation must be sought to create a management plan, so that they help DINAFOR conserve the remaining area of the reserve.

As the time approaches for the periodic lease renewals of the first shrimp ponds (lease terms are ten years) there will be a good opportunity to initiate long-term mangrove conservation control. The use of coarse tools, such as prohibitions on all mangrove disturbance, that are difficult and costly to enforce, must be replaced by area-specific mangrove management programs that can enlist the support and involvement of all those who depend directly and indirectly upon the productivity of mangroves for their livelihood. Public education and support must also be an ingredient in the strategy, since the funding and enforcement problem will not be resolved in the short term. Lease regulation considers clearing of mangroves as an infraction for which renewal of the leases can be denied. After the CLIRSEN studies, it is possible to make historical comparisons to determine where mangrove destruction has occurred so that DINAFOR will be able to punish violators.

Conclusions

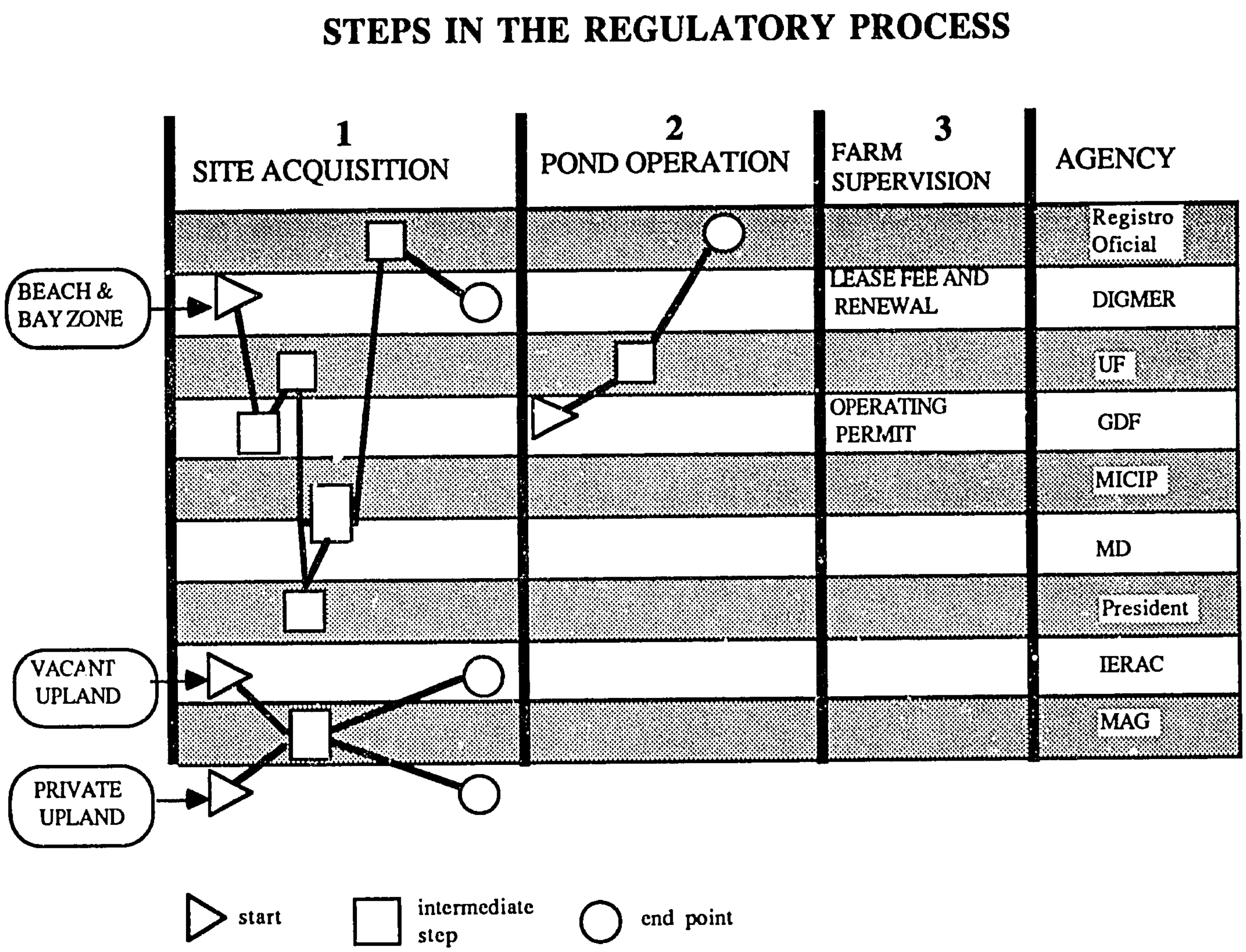
Ecuador does not lack basic mechanisms for regulating the environmentally disruptive aspects of shrimp mariculture and significant improvements to the policies have been made in the last two years. However, it has been largely unsuccessful in utilizing available legal and institutional tools to create an effective program for maintaining a sustained natural resource base for shrimp mariculture. One major deficiency is traceable to Ecuador's failure to adopt policies specific to shrimp mariculture, or to establish relevant decision making rules and criteria early in the expansion phase of the industry. Both the lack of clear purpose and complex administration have worked against successful coastal management in the case of shrimp mariculture, which is particularly significant in light of the fact that expansion of shrimp exports has been desperately needed.

Given its experience, Ecuador could simply rewrite its laws and regulations on shrimp mariculture to address these problems. However, a more useful approach would be for Ecuadorians to learn from their experience with shrimp mariculture and become the first developing nation to design and implement wise controls on mariculture. Gaining support and cooperation for any development restrictions is difficult under the best circumstances because each rule must be able to stand up to careful, often skeptical, scrutiny. First, restrictions aimed at protecting the "environment" must be interpreted in terms of keeping resource-based industries sustainable or preventing one economic or public use from causing damage to another.

Second, the mechanism for making decisions must be simple, both to encourage compliance and to allow flexibility within government agencies which are chronically understaffed, underfunded, or not necessarily organized to effectively regulate every activity under their jurisdiction.

Finally, the continuing attempts in Ecuador to establish mechanisms for governing the use of coastal resources should be viewed as a key ingredient of the overall national effort to develop the country's economy and its political institutions. In this respect, the problems of establishing and implementing effective management of shrimp mariculture provide Ecuador with a valuable experience to draw on as it considers how best to develop its vast coastal zone in the remainder of the 1980s and beyond.

Figure 1. An outline of the regulation of shrimp farming.



DIGMER: Merchant Marine and Coastal Directorate
UF: Undersecretary for Fisheries
GDF: General Directorate of Fisheries
MICIP: Ministry of Industry,Integration and Fisheries
MD: Ministry of Defense
IERAC: Ecuadorian Institution for Agrarian Reform and Colonization
MAG: Ministry of Agriculture and Livestock

Figure 2. Acquisition of leases in the beach and bay zone.

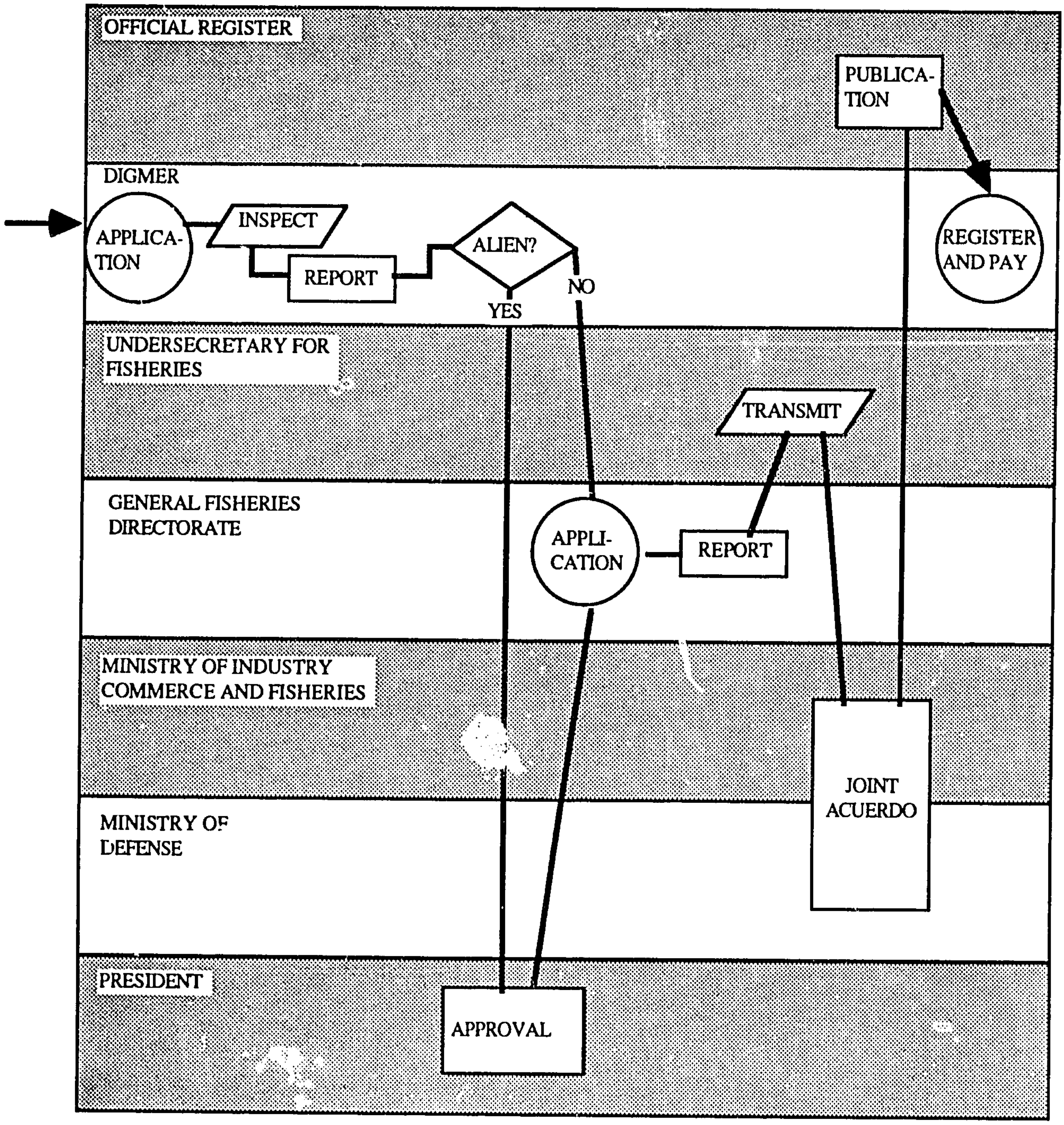


Figure 3. Procedures for acquiring a shrimp pond operating permit in Ecuador.

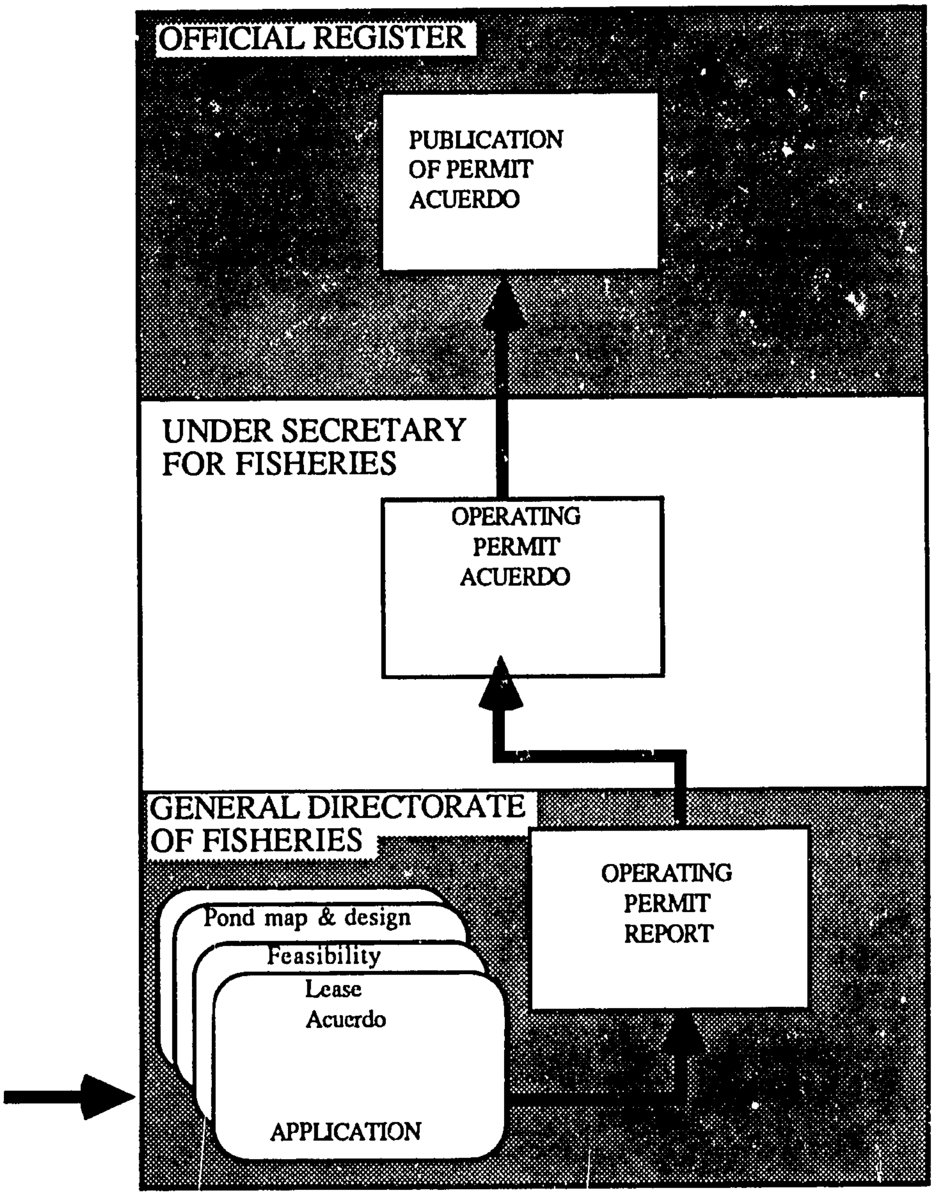
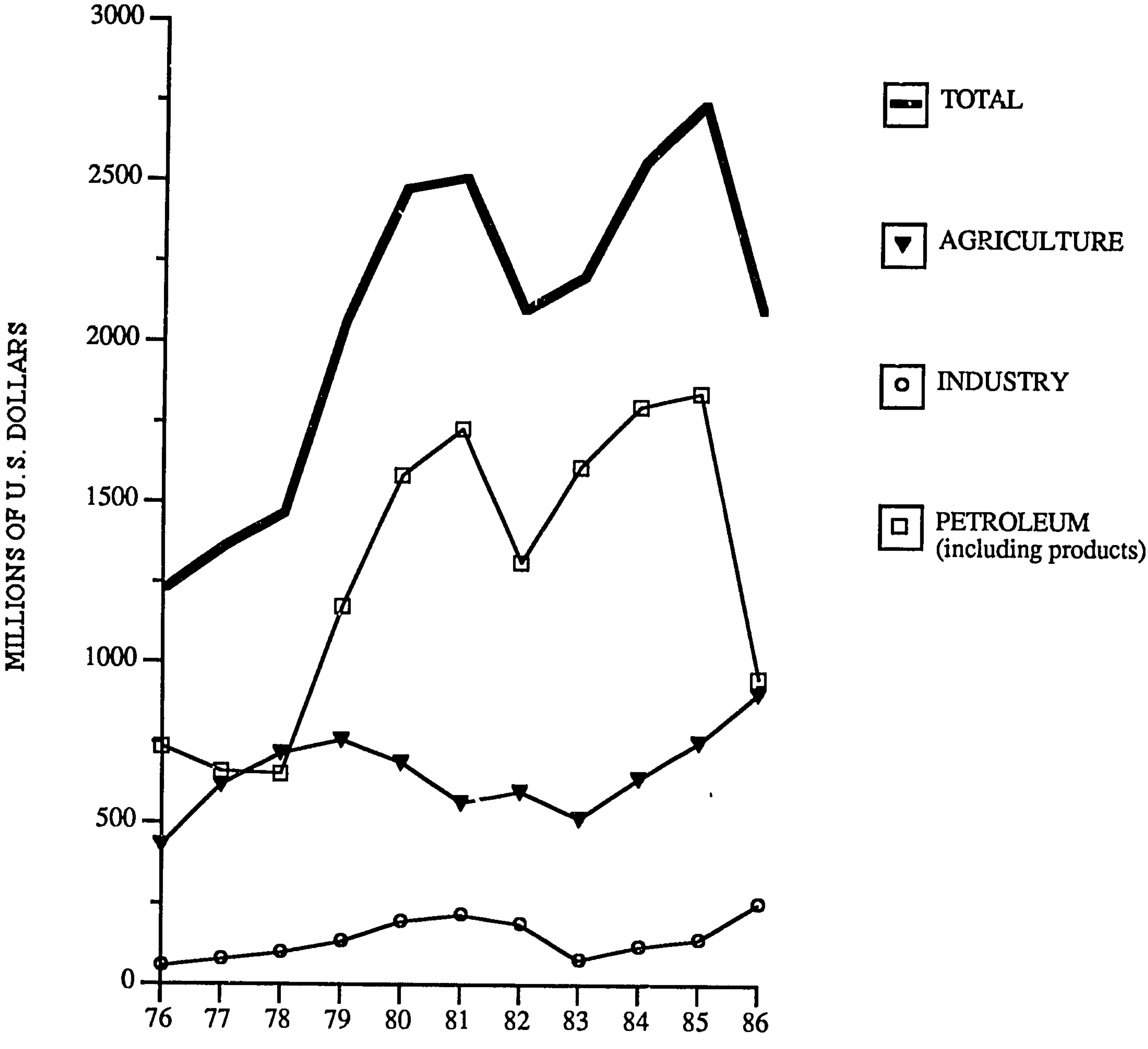
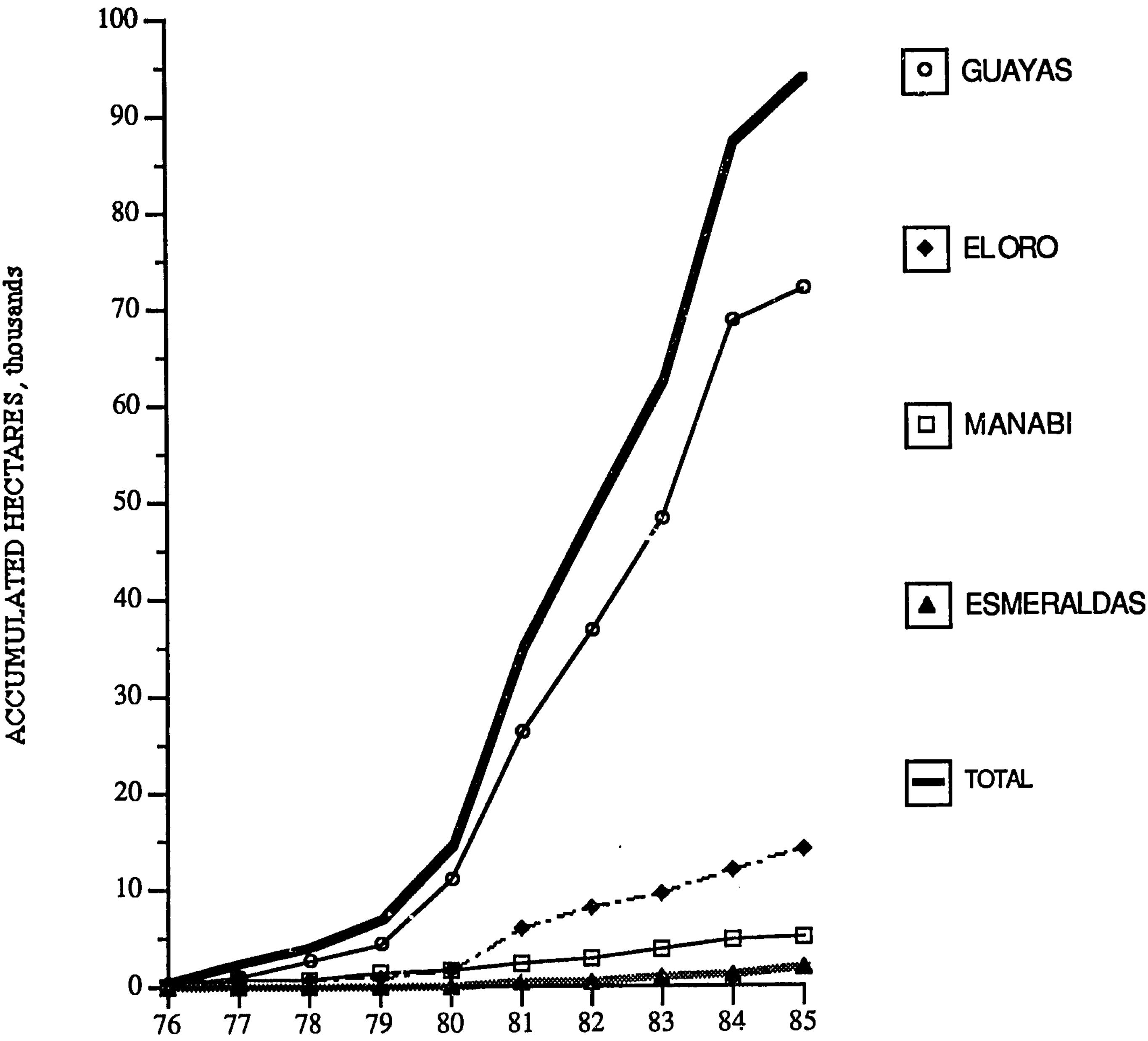


Figure 4. Ecuadorian exports by sector, 1976-1986.



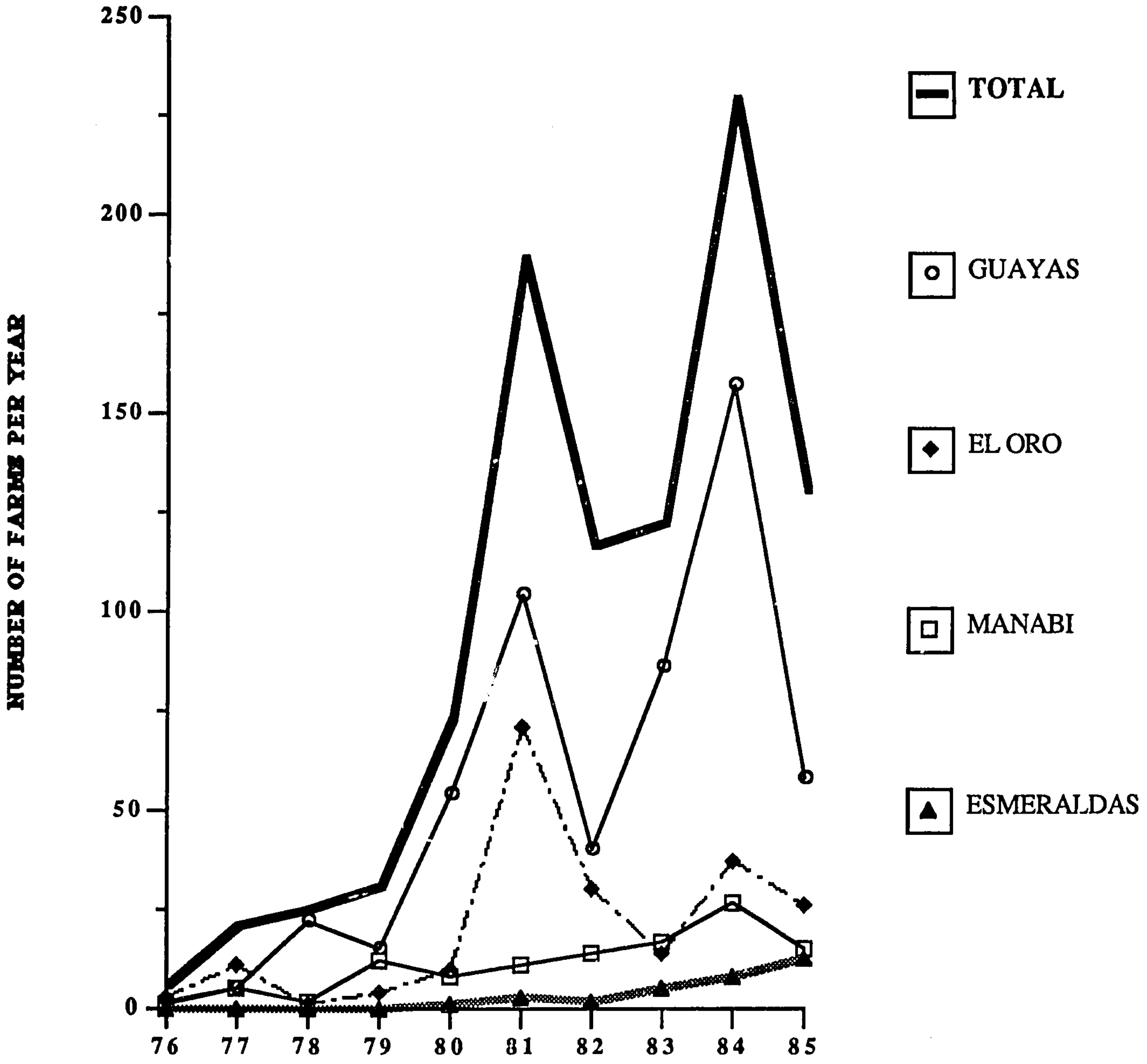
SOURCE: Ecuador:An Agenda for Recovery and Sustained Growth, World Bank, 1984. (1976-1979) Banco Central del Ecuador Boletin 1.587, Febrero ,1986. (1980-1985)

Figure 5. Cumulative area authorized for shrimp farming in Ecuador, 1976-1985.



Source: General Directorate of Fisheries

Figure 6. Number of authorized shrimp farms per year in Ecuador, 1976-1985.



Source: General Directorate of Fisheries

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Environmental Issues

Impacts of Shrimp Mariculture Practices on the Ecology of Coastal Ecosystems in Ecuador

Análisis del Ecosistema del Estuario del Río Guayas en el Ecuador: Implicaciones para el Manejo de Manglares y la Maricultura del Camarón.

Robert R. Twilley

Resumen

La expansión de la construcción de piscinas para el cultivo del camarón en la zona intermareal ha causado el mayor cambio en el uso del suelo en el área costera. Este crecimiento, en su mayor parte, está ubicado en las provincias de Guayas y El Oro. El mayor río y más importante sistema estuarino de la costa fluye a través de estas provincias hacia el Golfo de Guayaquil. El Golfo y los estuarios adyacentes constituyen el ecosistema estuarino mayor de la costa occidental de Sudamérica. La descarga media del río Guayas es de 1.143,7 m^3/s, con amplias variaciones estacionales que van desde un promedio de 200 m^3/s en la época seca hasta unos1.600 m/s, en la estación lluviosa.

El cultivo del camarón en esta área, se halla influenciado por algunas actividades también en expansión, como la agricultura, exploración de petróleo, desarrollo urbano y pesquerías.

Basándose en la densidad de siembra de postlarvas (pls) por hectárea (ha), los métodos de cultivo son clasificados en: (a) extensivo (siembra de 10.000 - 20.000 pls/ha; rendimientos de 100-400 Kg/ha/año); (b) semi-extensivo (50.000 - 60.000 pls/ha con suplemento alimenticio; obtiene doble producción a la del método extensivo); y, (c) semi-intensivo (100.000 pls/ha; con suplemento alimenticio o fertilización; rendimientos 1.000 - 1.800 Kg/ha).

La existencia de la amplia zona de manglares en la provincia del Guayas (121.464 ha) ha sido atribuída a un gran aporte de la Cuenca del Guayas y a las altas tasas de evapo-transpiración. Esto, asociado a la frecuencia de mareas, ha creado las condiciones fovarables para desarrollo del manglar con densidades de 185 árboles/ha y una área basal de 62,4 m^2, lo que indica mejores condiciones que en Venezuela, Colombia, Malasia y Puerto Rico.

En el estuario del Guayas, la calidad del agua está influenciada por las aportaciones provenientes de la Cuenca del Río Guayas, el intercambio con la zona intermareal y los procesos oceanográficos físicos del Golfo.

El trabajo revisa la influencia de la industria de la maricultura del camarón en la calidad del agua, estimando que la cantidad de agua de recambio entre los esteros y las piscinas, mediante bombeo, es de $20 \times 10^6 m^3$ por día, (30.000 has de piscina, tasa de recambio 5%/día), volumen que es tan grande como la descarga del río Guayas durante el período de estiaje. Esto, asociado a la evaporación en las piscinas, indica una gran descarga de aguas hipersalinas en el estuario.

Se discute el efecto de la calidad del agua en el cultivo del camarón y los factores que influyen en la producción como son: pérdidas de manglar; salinización del agua en los esteros; futura operación de la presa Daule-Peripa; enriquesimiento excesivo de nutrientes y posterior anoxia; presencia de sustancias tóxicas como hidrocarburos, pesticidas y metales pesados. También, se realiza un análisis global, desde el punto de vista ecológico, de las interacciones entre la industria del cultivo del camarón y el estuario del río Guayas, especialmente referidas a factores asociados a la calidad del agua, incluyendo las descargas de aguas residuales domésticas e industriales, el incremento de bombeo de agua, la fertilización en las piscinas y perturbaciones climáticos como las originadas en el evento de El Niño.

Las recomendaciones del autor comprenden: efectuar el inventario de la pérdida de manglares; distribución actual del bosque de manglar para identificar impactos actuales y futuros; restauración e integración del manglar en las operaciones de las camaroneras, para control de la erosión, estabilización de sedimentos y tratamiento de efluentes en las camaroneras; estudios sobre balance hídrico en el estuario del Guayas; desarrollar un modelo sobre la calidad del agua para el ecosistema del estuario; establecer un programa para vigilancia de la calidad del agua.

Introduction

The Incas practiced mariculture in Ecuador 400 years ago by closing off lagoons which were temporarily flooded with seawater and penaeid shrimp larvae. While the Indian shrimp farmers used their harvests themselves, the rapid growth of mariculture as an industry over the last decade in Ecuador has made it the leading farm shrimp producer in the world (McPadden, 1985). The first commercial shrimp operations did not begin there until 1969 (Siddall et al., 1985), and by 1979 farming produced only 4,698 metric tons (m.t.) of shrimp compared to 7,787 m.t. caught at sea. Ecuadorian farmed shrimp production rose dramatically from 1979 to 1984; in 1983, the year of the highest production on record, shrimp ponds produced 29,100 m.t. while production from the sea remained at 7,500 m.t. The export value of the total tonnage in 1983, nearly triple the amount produced in 1979, was U.S. $183 million, ranking shrimp second only to petroleum as an export commodity for Ecuador.

The expansion of the farmed shrimp industry resulting in the construction of ponds within the intertidal zone has caused a major change in coastal land use. Initially shrimp ponds were constructed in more inland, barren intertidal areas (salinas). Locating the ponds closer to the shore lowers costs associated with supplying water and larvae to the ponds. From 1980 to 1984 nearly 10,000 hectares (ha) of ponds were authorized for construction annually, increasing the total to 60,000 ha by 1983 (Figure 1). A recent survey by CLIRSEN (1984) shows that there are currently 89,368 ha of shrimp ponds along the coast of Ecuador (Table 1), many occupying former mangrove habitats.

This expansion of the farmed shrimp industry has been largely confined to the two southern coastal provinces, Guayas and El Oro (Table 1). The largest river and estuarine ecosystem of the coastal lowlands, the Guayas River basin and estuary, flows through these provinces and into the Gulf of Guayaquil. The Gulf of Guayaquil and adjacent estuaries are the largest estuarine ecosystem on the western Pacific coast of South America (Cucalon, 1984). This ecosystem handles 95 percent of the country's imports and 50 percent of its exports, and its coastline includes the most populated city in Ecuador, Guayaquil (Engineering Journal, 1972). The shrimp farming industry developed in an area of the coastal zone that is influenced by several other expanding industries including agriculture, oil exploration, urban development, and coastal fisheries. In addition, this region maintains an extensive area of intertidal communities including nearly 83 percent of all mangroves in Ecuador (Table 1).

One of the major reasons that farmed shrimp production has not returned to high levels observed in 1983 is reduced availability of postlarvae (PL) for stocking ponds. Total production in shrimp was down in 1984 compared to the previous year, not only because of low catch rates in the trawl fishery, but also because of the lack of larvae for shrimp ponds during the second half of the year. It is estimated that during 1985, only half (30,000-40,000 ha) of the shrimp ponds constructed in the Guayas province were in operation because of the lack of postlarvae. The 4 billion postlarvae provided largely by the "laveros" (primarily push net fishermen) represented 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 harvests per year. This is fairly intensive mariculture and production rates per ha of pond seem to be decreasing. However, such calculations are tenuous since information on the quality of shrimp sold and the area of ponds actually in operation is somewhat confusing.

Several factors have been associated with the decline of postlarvae in the estuaries along the coast of Ecuador, including lower water temperatures following an El Niño event in 1982-83, loss of mangrove habitat, decline in water quality and overfishing. Poorer water quality has contributed to increase in disease and poor maturation of postlarvae, and lower growth rates and higher mortality of wild shrimp, which affect the availability of wild postlarvae as well as the survival of larvae transported to growout ponds.

Coastal resource management to sustain optimum levels of productivity is complicated by conflicting goals of diverse user groups. Changes in watershed land use and utilization of estuarine waters have prompted concern over possible negative impacts to the quality of coastal resources and resultant damage to the shrimp industry. Also, construction and operation of the shrimp industry itself have raised concerns about its negative impact on the coastal zone.

This paper will show the interactions of various economic enterprises and environmental resources, and will recommend elements for an integrative management scheme for the coastal zone of Ecuador.

Geography

The coastal zone of Ecuador (1°N to 3°20'S) consists of four coastal provinces (Esmeraldas, Manabi, Guayas, and El Oro) situated in 284,000 km^2 of lowlands between the Pacific Ocean and the Andean highland (Figure 2). There are three climatic zones along the coast: a moderately wet climate in the south with abundant fresh water from runoff around Guayaquil; an arid central province with very sparse vegetation; and, in the north near Esmeraldas, a more humid, tropical zone with abundant rainfall and runoff. More than 95 percent of the annual precipitation falls during the wet season from January to May (Stevenson, 1981), and 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 (Engineer Journal, 1972; Schaeffer-Novelli, 1983). Annual mean temperatures (from 24.2° to 27° C) vary little along the coast, thus potential evapotranspiration is about 1300 mm per year.

The two major river and estuarine ecosystems of the coast are Rio Esmeraldas in the north and the Rio Guayas which flows into the Gulf of Guayaquil in the south (Figure 2). The Gulf of Guayaquil receives runoff from some 20 rivers with a watershed of 51,230 km^2, equivalent to a watershed: water surface area ratio of 4.3. The Guayas River is the major source of fresh water to the Gulf, which forms 60 km inland at the confluence of Rio Daule and Rio Babahoyo. This fresh water enters the Rio Guayas estuary, and to a lesser extent the Estero Salado, around the city of Guayaquil and then flows 55 km to the Gulf of Guayaquil. The mean discharge of 1143.7 m^3/s for the Guayas river is the highest among the 30 rivers in the coastal zone of Ecuador, representing 39 percent of the total discharge from this lowland region. Mean precipitation in the Guayas River drainage system north of Guayaquil is 885 mm/yr, which may range from less than 400 mm to more than 1800 mm during any one year (Figure 3). Discharge is strongly seasonal ranging from 200 m^3/s during the dry season to 1600 m^3/s in an average wet season (Figure 3). Tides are semi-diurnal and are of equal amplitude (1.8 m) in the Gulf of Guayaquil, but are amplified to 3-5 m in the Rio Guayas estuary near the city of Guayaquil. Flushing time of the Gulf of Guayaquil is about 21 days.

Shrimp Mariculture Management

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 hectare (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 is a semi-extensive system that requires some supplemental feeding and exchange of seawater to control water quality problems such as decreased levels of dissolved oxygen. Production rates more than double with this program. The most highly managed system is semi-intensive operations that stock ponds at 100,000* juveniles per ha and supply food supplements or fertilize the ponds to increase sources of food. Water exchange with the estuary is higher and annual production rates increase to 1,000-1,800 kg/ha.

The dramatic expansion of the farmed shrimp industry and increased levels of pond management stimulated the development of a new fishery to provide postlarvae and seed shrimp for stocking mariculture ponds. Industry sources estimated that up to 90,000 artisanal fisherman were involved in the 1983 harvest and in 1984 numbers of fishermen working along the coast were even higher (McPadden, 1985). Seed fishing is concentrated in areas of significant fresh water discharge along the coastline, such as El Oro and Esmeraldas, with the highest effort occurring in the Guayas province.

The catches are non-selective, with small fish, penaeid postlarvae and juvenile shrimp including a mixture of *P. vannamei*, *P. stylirostris*, *P. occidentalis* and *P. californiensis*, as well as some fresh water *Carid* species. Since only the former two species survive best in mariculture ponds, owners pay according to the proportion of the stock that is *P. vannamei* and *P. stylirostris* (McPadden, 1985). Selection is a post-harvest process and therefore less-valued species are lost 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.

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* Villalon et al. (this volume) report slightly higher stocking densities.

A major factor associated with the availability of immature shrimp is temperature of offshore water. Temperatures are controlled by the mixture of warm water flowing southward from the Panama Bight with cold waters flowing northward from the Peruvian Humboldt Current. This mixing occurs between Manta and Punta Santo Elena along the coast of Ecuador and gradually moves southward into the Gulf of Guayaquil. The southerly flowing water causes increase in seawater temperature and initiates the onset of the rainy season (Cucalon, this volume; Cucalon, 1984; McPadden, 1985).

Years of abnormally warm water temperatures and high rainfall are associated with El Niño events and have resulted in the explosive populations of white shrimp off the coast of Ecuador. The high availability of postlarvae that supported the expansion of the shrimp industry in 1983 and 1984 has been associated with these offshore processes (Cucalon, this volume).

Reclamation of Mangroves

Eight species of mangroves are distributed along a narrow band of the outer intertidal zone of Ecuador with a non-vegetated area called "salinas" (salt flats) in more inland intertidal areas (Table 2). The existence of 121,464 ha of mangrove in the Guayas province has been attributed to extensive river flow from the Guayas River basin and high rates of evapotranspiration (Schaeffer-Novelli, 1983).

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 species inland of this zone (Cintron et al., 1981). More inland of this fringe is a mixed zone of *Rhizophora* and *Avicennia germinans*. Still farther inland lies a monospecific stand of *Avicennia*, which yields eventually to shrub plants or Salinas with extreme hypersaline soil conditions. High tidal frequency and river discharge create conditions suitable for mangrove forest structures in the northern provinces with tree density of 185/ha and a basal area of 62.4 m^2/ha. This density is greater than for mangroves in Venezuela, Columbia, Malaysia and Puerto Rico (Cintron, 1981). Mangrove forests are less dense in the southern provinces (Cintron, 1981), particularly surrounding shrimp ponds (Snedaker et al., 1986).

The most obvious exploitation of mangroves along the coastal zone of Ecuador is the construction of ponds for the production of shrimp and fish. This land use pattern in the intertidal zone first involved wholesale destruction of mangroves in Machala and in the southern province of El Oro. Following this period of total mangrove destruction, pond construction was authorized mainly in the Salinas and inland mangrove zones. However, as the area of pond construction increased dramatically in the early 1980s, 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 new authorization of ponds in mangroves. Several thousand hectares of ponds have already been authorized in the intertidal zone, though construction in many instances has not yet begun.

The exact number of mangroves lost to the construction of ponds along the coastal province of Ecuador is uncertain. A recent survey from CLIRSEN (1984) shows that 79,396 ha or 88.8 percent of the total area of shrimp ponds along the coast of Ecuador is located in the two southern provinces of Guayas and El Oro (Table 1). A diagram representing the potential loss of mangroves based on proportion of ponds constructed in mangrove areas is shown in Figure 4. This diagram demonstrates that if all 52,912 ha of shrimp ponds in Guayas province (Table 1) were built in mangrove areas, the original mangrove area would have been 174,375 ha, and mangrove loss would be 30.3 percent of the resource. At a utilization rate of 10 percent of ponds built in mangroves, the loss of mangrove habitat would be 4.2 percent.

Historical records of the southern coast of the Gulf of Guayaquil in the province of El Oro at Machala give some indication as to the proportion of mangroves used for the construction of ponds (Table 3). From 1966 to 1977 there were 834.2 ha of ponds constructed and, based on the loss of mangroves during this period, 55 percent of these ponds were built in mangrove habitats. This estimate is probably exaggerated since urban areas also apparently increased at the expense of mangroves. If urban expansion was equally divided between salinas and mangroves, then 45 percent of the ponds constructed in this period would have been in mangroves.

From 1977 to 1982, an additional 1496.5 ha of ponds were built, however, there was no corresponding loss of salinas and mangroves. Rather, decreased land use for agriculture was observed, which could account for the additional pond construction and urban expansion. However, assuming that all of the mangrove loss was from pond construction, then 63 percent of the ponds were constructed in mangrove habitats. Based on this range of 45-63 percent of pond construction in mangrove habitat in El

Oro, an estimated 16-21 percent+ of the mangrove in the Guayas province may have been lost to shrimp farming. Recent estimates by CLIRSEN indicate that mangrove loss in the Guayas Province is much less, at about 4 percent+ of the original mangrove cover. This would mean that about 10 percent of the shrimp ponds constructed in this province were built in mangrove (Figure 4).

Factors Influencing Water Quality

Water quality of the Guayas River estuary is influenced by inputs from the watershed, exchanges with the intertidal zone, and physical oceanographic processes in the Gulf of Guayaquil. Activities in the watershed include a dam project that will influence fresh water input, expanding agriculture with associated discharge of chemicals including nutrients and pesticides, sewage from increased urbanization, and toxic substances from industrial activities (Arriaga, this volume). Exchange of estuarine water with the intertidal zone via tides has been replaced with diesel pumps that pump water to improve the productivity of grow-out ponds. Natural resources within the intertidal zone, including mangrove, may also influence water quality, though the function of these communities is still uncertain. Offshore waters influence the temperature and salinity of the Guayas River estuary, most notably during El Niño events and during presence of red tides in coastal waters. These diverse natural and anthropogenic influences on water quality in the estuary complicate water quality management in this coastal ecosystem.

Daule-Peripa River Dam Project

A dam is proposed at the confluence of the Daule and Peripa rivers for water supplies, control of river flow, and hydroelectric power. Water will be diverted with an aqueduct from the Rio Daule to the Santa Elena peninsula for potable water, irrigation for agriculture and industrial use. The dam will also increase the flow of fresh water to the Guayas River estuary during the dry season to prevent salt water intrusion in the lower Daule River and enhance agriculture in this area. The Rio Daule drains one-third of the Guayas River basin and has a mean capacity flow of 11.5 km^3/yr or 365 m^3/s. The total river basin of both the Daule and Peripa Rivers is 420,000 ha and it receives a mean precipitation of 1800 mm per year. A thorough description of the soil characteristics and land use of this watershed are provided in a report by the Guayas River Basin Commission (CEDEGE, 1970).

The dam will create an impoundment with a storage capacity of 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 impoundment will supply potable water for 300,000 people at 400 liters per person per day, irrigation water for 42,000 ha of land and 20 million cubic meters per year for industry. Projected industrial use includes a petroleum refinery, nitrogen fertilizer complex, petrochemical complex, and a petrochemical port facility at Monteverde.

The dam will influence the amount of water from the Daule and Peripa Rivers that normally discharge into the Guayas River. Presently the proposed operation of the dam calls for an average annual flow of from 100 to 175 m^3/s (Jenkins, 1979; Arriaga, this volume). This flow will vary from a high of 321 m^3/s during the wet season in April, to a low of 124 m^3/s in August. Compared to the normal flow of the Daule and Peripa Rivers (Figure 5), this modified flow is much lower than the fresh water discharge of up to 1000 m^3/s that usually occurs during the wet season. During the dry season, to control salt water intrusion, the dam will provide water above the average discharge of about 50 m^3/s from supplies stored in the impoundment. Based on average monthly flows, the normal discharge of 343 m^3/s for these two rivers will be restricted to 175 m^3/s, a reduction of about 49 percent (Figure 5). This reduction represents a loss of 15 percent of the fresh water to the Guayas River and 13 percent from the Guayas River estuary. The loss of fresh water from an estuary in a semiarid zone such as the Guayas province may influence the patterns of salinity in the ecosystem.

+ Alvarez et al. (this volume) report slightly different percentages of mangrove loss for 1986-1984.

Nutrient Loading

Sources of nutrients from watersheds to aquatic ecosystems may be described as either diffuse or from some specific point of effluent. Diffuse nutrient inputs include runoff from natural vegetation or from managed landscapes such as agriculture or forestry areas. Much research has gone into developing nutrient loading rates for different types of native vegetation and for specific types of crops in watersheds in various geographic areas. Most of these loading rates have been developed for watersheds located in temperate climates. Less is known about the loss of nutrients from tropical watersheds.

The five principle crops raised along the coast of Ecuador are 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 percent of the agricultural activity described in Table 4 for the coastal zone of Ecuador occurs in the Guayas River basin.

The Guayas River basin is a major producer of rice, with nearly 95 percent of the total rice production along the coast occurring in the Guayas and Los Rios provinces. Rice in the Guayas River basin is of particular significance to the nutrient economy of the Guayas River estuary because of the large area of production (Table 5), the potential expansion of this crop in the watershed once the Daule-Peripa dam is completed (projected at 17,000 ha during the initial phase of the project), and its proximity to waterways.

Point Source Inputs

Point source effluents are associated with urban areas and industry. However, nutrient waste from urban centers can also be diffuse loadings via groundwater transport from septic systems. Loading rates of nutrients from cities are dependent on population density and degree of waste treatment prior to discharge into aquatic systems. In the Guayas River basin, there is very little treatment of domestic waste. Sewage is either released directly to the rivers or estuaries via ditches (referred to as "treated"), or is diverted to septic ponds. Thus nutrient loading from point sources in this watershed is largely related to population density and per capita rates of nutrient input from untreated sewage.

The population in the coastal provinces of Ecuador has increased over the past 35 years, most dramatically in the Guayas province (Figure 6). From 1962 to 1982 the population of this province more than doubled to over 2,000,000 persons. In the last several years, the growth rate has been even greater with a present population of over 2,568,452 (Figure 6). Together with the population of Los Rios, there are 3.14 million people in the Guayas River basin (Figure 6), of which 84 percent is considered urban, with 53 percent of the basin population located in the vicinity of Guayaquil. Currently, only 18 percent of the 34,700 ha city is serviced by sewers. The city's contaminated waters are emptied, untreated, into the Guayas River (El Guasmo pumping station), Daule River (El Progreso pumping station), and Estero Salado.

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 6. 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, or 54 percent of the watershed population.

Treated sewage here refers to sewage which is transported directly to the rivers and estuaries, whereas untreated sewage is transported to septic ponds. From the available statistics, waste from 62 percent of the population is pumped to septic ponds (untreated), however, 86 percent of the 54.83 (10)6m^3 of waste generated annually is discharged directly to aquatic ecosystems. 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 over 90 percent of all domestic wastes that enter the river, and an even greater percentage of the nutrients that enter the Guayas River estuary. Solorzano (this volume) claims that domestic and industrial waste has lowered water quality in the Daule and Guayas Rivers by contributing to a high level of bacterial contamination, decreasing dissolved oxygen content and increasing concentration of nutrients.

River Discharge

Rates of nutrient input from rivers discharging into the Guayas River estuary and Estero Salado may be estimated from information on seasonal concentrations relative to periods of high and low river flow (Figure 7). Ammonium concentrations above 15 ug-at/L occur in three of the four rivers surveyed and concentrations as high as 40 ug-at/ occurred in the Rio Milagro. These high concentrations occurred during the low flow season, and thus do not necessarily indicate high input to the Guayas River estuary. However, peak nitrite and nitrate concentrations with values greater than 2.0 and 50.0 ug-at/, respectively, occurred in all the rivers from February to June during periods of high river flow (see Figure 3 for seasonal river flow in the Guayas River basin). The pattern for nitrate was common among the river systems investigated, indicating that this may represent a high input of nitrogen to the estuary (Figure 7). Concentrations of nitrite above 2.0 ug-at/ are indicative of nitrification, which is usually 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, 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 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 the Guayas River estuary.

Toxic Substances

Pesticides

Agriculture may also contribute toxic substances such as pesticides to rivers and estuaries of the Guayas basin (Table 7). Table 7 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 and does not indicate their actual transport to aquatic systems. Dr. Solorzano (personal communication) has expressed concern about the concentrations of pesticides in the estuary, but only traces of pesticides have been detected at the beginning of the rainy season in the Daule River (Solorzano, this volume). A CEDEGE river basin study showed that DDT levels in the rivers flowing into the estuary were low, but little documentation was available.

Petroleum Hydrocarbons

Petroleum is the primary source of foreign income for Ecuador. The impact of oil on coastal provinces was documented (Cintron et al., 1981), and one publication refers specifically to the coastal zone of Ecuador (Filho, 1983). Concentrations of oil hydrocarbons in the Guayas River estuary and Ester Salado range from 0.10 to 2.80 ug/L (Solorzano, this volume). Concentrations are generally less than 2 ug/L except near oil spills or centers of commercial oil vessel activity.

Heavy Metals

There is some mining activity in the Guayas River basin, and several metals have been found concentrated in riverine and estuarine sediments. Solorzano (this volume) gives recent measurements of copper, iron, cadmium in the water columns of the Babahoyo, Daule and Guayas Rivers, and mercury in the sediment of the Guayas. The reader is referred to that report.

Shrimp Farming

Pumping of Estuarine Water

More intense shrimp farming techniques involve stocking ponds at higher densities of juveniles, which necessitates additional fertilization and supplemental feeding to assure an adequate food supply for secondary productivity. This level of pond management requires strict control of water quality since phytoplankton blooms resulting from nutrient additions may deplete dissolved oxygen concentrations to levels that will cause shrimp mortality.

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 percent to 8 percent of the volume of the shrimp pond per day under semi-extensive mariculture, and may increase with more intense farming practices. The total volume of water pumped from the Guayas River estuary to shrimp ponds depends on pond management practices and the total area of ponds under operation. Figure 8 shows the volume of estuarine water exchanged with ponds (using a mean pond depth of 1.5 m) based on various exchange rates (percent of pond volume per day), and areas of ponds in operation. These exchange volumes are compared to the low and high flow discharge of the Guayas River. At a present operation of 30,000 ha of ponds under semi-extensive management (5 percent pumping rate), the volume of water exchanged daily with the estuary is approximately 20 $(10)^6$ m^3 (Figure 8). This volume is greater than fresh water discharge from the Guayas River during low flow periods. With intensive pond management (10 percent pumping rate), the same area of ponds would exchange nearly 36 percent of the riverine discharge during high flow periods. These types of reasonable scenarios underscore the importance of the impact of shrimp ponds on the water flow pattern in this estuary.

Most of the water that is pumped into the ponds replaces losses associated with seepage and evaporation. Although there are no data on water budgets for semi-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 in the ponds is probably higher than in the estuary, since shallowness decreases the heat absorption capacity of the water column. Open water generally loses more water per area to evapotranspiration than wetlands. For example, mangroves in south Florida are known to have lower actual rates of evapotranspiration than potential rates (Twilley, 1982). Therefore, the conversion of intertidal areas originally vegetated by mangroves to shrimp ponds could increase the loss of fresh water from the Guayas River Estuary. This increase in water loss could result in the discharge of hypersaline waters to the estuary. Snedaker, et al (1986) found that water in 22 of 30 ponds surveyed had higher salinities than the source water.

Fertilization

Supplemental feeding and fertilization are required to meet the demand for food at higher stocking densities of postlarvae in ponds. A main source of nutrition for shrimp in growout ponds is phytoplankton blooms that result from urea and superphosphates added prior to stocking. Supplemental feeding is carried out toward the end of the growth cycle, usually in the last four weeks. The impact of these chemicals on the water quality of the Guayas River estuary depends on their fate within the pond and on effluent discharge rates. Much of the nitrogen and phosphate applied to ponds are absorbed by phytoplankton and are thus returned to the estuary in organic form. These organic nutrients represent biological oxygen demand with the decomposition of this plankton biomass. Nutrients released during decomposition may then be available for biological uptake and contribute to the red tides recently observed in the estuary. Therefore, nutrient effluent from ponds may contribute either directly or indirectly to the balance of dissolved oxygen in the estuary.

Mangroves

Since the Guayas estuary is tightly coupled to the intertidal zone via 3-5 meter tides, mangroves may influence these waters in several ways. Sediments suspended in the water column are deposited in mangroves during flooding, enriching these forests. The extensive root system of mangroves enhances the sedimentation process and retards the forces of erosion along the shoreline (Scoffin, 1970). Nixon (1984) observed that total suspended sediment load of an estuary in Malaysia, in which mangroves had been reclaimed for agriculture, was an order of magnitude higher than in an adjacent mangrove-dominated system.

Some preliminary evidence indicates that mangroves may also be a sink for nutrients in coastal waters. This may seem to contradict the theory that mangroves act as a source of detritus to estuarine ecosystems (Odum and Heald, 1972; Twilley, 1985; Twilley et al., 1986). One explanation is that net nutrient uptake may be a balance between inorganic nutrient input and organic nutrient export. Walsh (1967) noticed a decrease in inorganic nutrient concentrations in waters moving through a mangrove in Hawaii. Nedwell (1975) used enclosures to measure nutrient uptake by mangrove sediments and noticed they had a great capacity to remove nitrates, 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 Guayas River estuary.

Impact of Water Quality on Shrimp Mariculture

Existing information suggests that the production in shrimp ponds has decreased from 1600 to 250 kg of shrimp/ha/yr over the last several years, though stocking rates have been maintained at about 65,000 PL/ha per harvest. Mortality rates in shrimp ponds are estimated at greater than 50 percent (P. Maugle, personal communication), and evidence suggests that maturation rates are also lower. In addition, there has been a decline in the availability of wild PL to the shrimp farming industry, restricting the acreage of ponds in operation. Decrease of wild PL has increased demand for PL from hatcheries. Currently, there are some 68 hatcheries under construction. Twenty hatcheries still in initial phases of operation produced about 500 million postlarvae in 1985.

Good water quality is critical to the productivity of hatcheries because larvae are susceptible to disease. Both PL supply and shrimp growth and mortality in ponds determine the productivity of this industry; and both depend on the quality of water in the estuary.

Mangroves and Fisheries

The loss of mangroves from tropical estuaries may have direct consequence to economically important fisheries through loss of habitat and food. Zimmerman and Minello (this volume) have found that *P. vannamei* and *P. stylirostris* inhabit areas 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 do exist between the production rate of shrimp and the extent of mangrove area (Macnae, 1974; Turner, 1977; Jothy, 1984) because one hectare of mangroves can yield more than 600 kg/yr of shrimp and 100 kg/yr of fish without management (Turner, 1977). Based on an approximate loss of 10,500 ha of mangrove (Figure 4), the reduction in shrimp production from the estuary would be equivalent to 6,300 m.t./yr. Although these statistics do not show causal relationships, they do point out that whenever a productive postlarvae fishery exist, there is the presence of the mangrove habitat as observed in Ecuador (Turner, this volume). 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 Guayas River estuary will remain unknown. Mangrove destruction may also have an indirect effect on fisheries by changing water quality.

Salinization

The Daule-Peripa dam and the pumping of water into shrimp ponds, may influence the distribution and increase the concentration of salinity in the Guayas River estuary. Mangroves that exist in arid environments such as the coast of Ecuador where evapotranspiration is greater than precipitation are very susceptible to slight changes in hydrology. For mangrove forests in arid life zones, small shifts in precipitation result in increased soil salinity followed by an increase in tree mortality and a shift in vegetation from forests to tannes or Salinas (Davis and Hilsenbeck, 1974; Cintron et al., 1978). In Ecuador the diversion of fresh water from the Guayas River estuary must be managed with awareness of possible negative effects on mangroves since they exist in a relatively arid environment. Margalef and Crespo (1979) suggested that the loss of fresh water from the dam will probably not affect mangroves, though the researchers did not take into account the climatic influence of mangrove distribution in the southern provinces.

Increases in salinity due to changes in fresh water supply to the Guayas River estuary may also impact economically important fisheries in this estuarine ecosystem. The Estero Salado, which harbors most of the fishery resources of the inner Gulf of Guayaquil, does not receive fresh water discharges 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. Precipitation during 1985 was relatively low, and the Estero Salado was hypersaline with values up to 30 parts per thousand (Zimmerman and Minello, this volume). 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, such as shrimp, that inhabit the Estero Salado are very susceptible to changes in water quality, especially salinity and toxicity which may increase mortality and retard growth rates.

Changes in fresh water supply may also influence seasonal movement or recruitment of organisms into the Guayas River estuary. The recruitment of shrimp into an estuary is important to their life cycle because the estuary provides optimal conditions, such a low predation, during critical stages of maturation. Seasonal timing of recruitment is thought to be dependent on fluctuations in salinity along with influx of offshore water masses. 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 disturbing seasonal fluctuations of salinity in the estuary. Since the mariculture industry relies on shrimp postlarvae that seasonally utilize the estuary, management plans should strongly consider those factors that influence recruitment of fisheries in the estuarine ecosystem.

Nutrient Enrichment and Anoxia

Nutrients that increase the productivity of agriculture and are the by-products of human nutrition also stimulate the primary productivity of aquatic ecosystems. Changes in water quality in response to nutrient enrichment is called eutrophication. Dissolved oxygen is a popular index of water quality; oxygen concentrations below 4 mg/ are considered stressful to many fisheries. The negative effects of low dissolved oxygen to fisheries can also be indirect by disturbing basic food chains. The discharge of organic materials that consume oxygen during decomposition (biological oxygen demand, BOD) and of some inorganic nutrients (chemical oxygen demand, COD), can cause a decrease in concentrations of dissolved oxygen in the estuary. A balance of processes that contribute (photosynthesis and diffusion) and remove BOD and COD dissolved oxygen is necessary for a healthy environment for economically important fisheries.

Anoxia or low dissolved oxygen conditions have been observed historically in some stratified estuaries, such as in the Chesapeake Bay where anoxia of bottom waters was observed in the 1930s (Newcombe and Horne, 1938). A concern regarding the Chesapeake Bay that may be relevant to many estuarine ecosystems is the recent increase in anoxia in greater volumes of water and the persistence of this condition in the water column. The linkage between increased nutrient loading, enhanced production of phytoplankton biomass, and the consumption of oxygen during decomposition of this organic material in the system either in the water column or in the surface sediments may contribute to anoxia in the Chesapeake Bay (Officer et al., 1984). Therefore, nutrient abatement and control becomes a central issue in dealing with similar water quality problems in estuarine ecosystems such as the Guayas River estuary.

Red tides, phytoplankton blooms that discolor the water, are a common occurrence in the Gulf of Guayaquil and in the inland waters of the Guayas River estuary (De Arcos, 1982; Jimenez, 1980; Jimenez, this volume). These blooms vary in species composition, density of cells, and duration. The most direct influence on the estuary is fish kills caused by the presence of toxic organisms such as *Gonyaulax catenella and Gymnodium breve*. *Gonyaulex monilata* occurred in the upper portion of the Gulf of Guayaquil in April 1980, and in March 1986 along the coast of Manglaralto. The 1980 bloom resulted in high fish mortality (Jimenez, 1980), while the 1986 bloom caused significant mortality of shrimp postlarvae in eight hatcheries, interrupting operations for 30-45 days (Jimenez, 1986).

Other red tides in the Guayas River estuary include *Gyrodinium stratum* in September 1982, *Mesodinium rubrum* in August 1984, *Prorocentrum maximum* from February 1985 to February 1986, and a recent bloom of *Nitzschia sp.* (Jimenez, this volume). These blooms caused high mortality in shrimp ponds when phytoplankton contaminated waters were pumped from the estuary.

Anoxic waters are apparently uncommon in the Guayas River estuary, occurring only in areas near sewage outfalls (Arriaga, this volume). A survey of five stations in Estero Salado found that dissolved oxygen concentrations at 1 m depth ranged from 3.5 to 5.3 ml/ (Solorzano, this volume). Concentrations are normally lower near the bottom; for instance, Solorzano and Viteri (1981) measured concentrations of 3.5 ml/ at 1 m depth compared to 2.0-2.5 ml/ near the bottom at two stations adjacent to the city of Guayaquil. The strong tides with amplitudes from 3 to 5 m in the Guayas River estuary are responsible for the well-mixed aerated water column. Even during presence of red tides in the estuary, anoxic problems in ponds are not caused by pumping anoxic water from the estuary; rather, anoxia in pond water develops when water that contains materials that may promote low oxygen conditions is pumped into the less well-mixed shrimp ponds.

Toxic Substances

Hydrocarbons

Hydrocarbons can be lethal to fish at relatively low concentrations (Table 8). However, current information suggests that the concentrations of hydrocarbons in Estero Salado are less than 2 ug/, an order of magnitude less than concentrations that may affect the natural resources of this ecosystem.

Pesticides

Crustaceans, especially larvae, are usually more sensitive to low concentrations of pesticides than are other marine organisms (Costlow, 1982). The extensive use of these chemicals in the estuarine watershed creates a potential hazard to the shrimp mariculture industry in Ecuador. Table 9 shows the amount of pesticides imported into Ecuador in 1979 and 1980. For example, Endrin, which is applied at an approximate rate of 145 m.t. per year in the rice paddies of the Guayas River basin significantly reduced growth rates of rapidly growing juvenile *Mysidopsis bahia* (McKenney, 1986), at concentrations of 60 mg/L. In addition, physiological measurements of metabolic dysfunction in *mysids* exposed sublethally to pesticides in laboratory and field conditions showed lower growth and reproductive capacity in these organisms during later stages of their life cycle (McKenney, 1986). Daugherty (1975) noted that decreased shrimp yields in El Salvador probably resulted from the heavy use of pesticides in cotton farming during the 1960s and early 1970s. Pesticides have a tendency to become more concentrated along the food chain and thus may stress predators and higher trophic levels such as fish. Before this problem can be solved, 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.

Metals

High concentrations of heavy metals in certain areas of the estuarine ecosystem demonstrate the affects of urban development and industry. Solorzano (1986) expressed particular concern for the concentration of copper, cadmium and mercury in the water column and sediments of the Guayas River estuary. Copper concentrations are higher than 10 ug/ which is considered innocuous to aquatic species (Ketchum, 1975), although these concentrations could be due to natural processes. Cadmium is also present in concentrations that could impact aquatic organisms (Ketchum, 1975), and sediments showed significant mercury contamination (Solorzano, 1986).

The Ecosystem and Shrimp Mariculture

The interactions of the shrimp farming industry with the Guayas River estuarine ecosystem are summarized in Figure 9. Water quality influences the supply of wild PL as well as the successful production of PL by hatcheries. Water quality also determines the survival and growth rates of PL once they are stocked in growout ponds. Although water quality of ponds depends principally on the type of management used, characteristics of the water pumped from the estuary can also determine the number of shrimp produced in the ponds. Activities in the Guayas River basin affect the quality of water in the estuary and, therefore, the shrimp industry through chemicals such as nutrients and pesticides from agriculture, sewage from the large population centers around the estuary, and heavy metals from industry. The distribution and turnover rate of these pollutants and salinity in the estuarine water column of the estuary are influenced by the discharge of fresh water from the watershed. Thus a dam on the Daule-Peripa Rivers must be evaluated in terms of its potential impact to water quality in this estuary, given the strong seasonal nature of its fresh water inputs.

There are also many natural occurrences that influence water quality and the shrimp industry in this ecosystem (Figure 9). For example, elevated water temperatures in the Gulf of Guayaquil may be a dominating factor in the tremendous recruitment of shrimp into the inner estuaries during climatic disturbances known as El Niño. Red tides are also recruited from the Gulf of Guayaquil to the estuaries, in addition to the blooms that occur in situ. The extensive areas of mangroves are considered nurseries for economically important shrimp larvae as well as possibly influencing nutrient and sediment dynamics in this turbid estuary. Tides affect water quality in the estuary by mixing the water column and preventing stratification that could lead to problems with low levels of dissolved oxygen. Considering the huge amounts of untreated sewage that is discharged into this system, there are few accounts of anoxia with in the estuary, a pattern that has been attributed to the presence of strong tidal currents within the system.

The many interactions of the human and natural resources of this estuarine ecosystem underscore the complexity inherent in questions regarding the fluctuations of PL supply and the apparent decrease in pond production of shrimp in the past several years. The shrimp industry is not only affected by changes in the quality of water pumped from the estuary, but it also contributes to the problem by loading nutrients (fertilization), increasing fresh water loss (pumping), and destroying mangrove forests (construction) (Figure 9). The benefits of pond management involving these practices must also be evaluated in the context of their possible negative effects on water quality and the shrimp industry itself.

There is now a general feeling in Ecuador that the loss of mangrove habitat has contributed to the decline of wild postlarvae, particularly during periods of normal recruitment. In fact, new authorizations forbid construction of ponds in mangroves. In order to accommodate these laws and maintain or increase the level of shrimp production in the existing ponds, mariculture operations must be intensified (Siddall et al., 1985). Thus the supply of postlarvae in the estuary has a strong influence on both the rate of pond construction and the type of pond management (Figure 9). The intense utilization of existing ponds would create increased pumping and fertilization of estuarine water which would, in turn, lead to increased loading of nutrients to the estuary. This management alternative may adversely affect water quality of the estuary even though the objective is to lessen negative impacts by preventing the loss of mangroves from the ecosystem. The negative impacts of pond construction on the ecosystem are replaced by increased pumping and fertilization associated with more intensive shrimp pond management (Figure 9). These issues demonstrate the importance of considering shrimp pond management in the context of the ecosystem and, particularly, paying close attention to those factors associated with water quality control (Figure 9).

The shift from extensive to intensive mariculture may not necessarily impact the estuarine ecosystem if mangroves could be utilized in the operation of ponds. Mangroves may act as sinks of several primary nutrients used in the fertilization of ponds, particularly phosphates and nitrogen. Mangrove sediments may also have the the capacity to absorb some of the BOD associated with pond biomass that is high in chlorophyll and as an effluent, may impact the balance of dissolved oxygen in the estuary. Effluents from shrimp ponds could be distributed in nearby mangrove forests for nutrient removal prior to the return of pond water back to the estuary. This use of mangroves as a nutrient buffer, which would most likely enhance mangrove productivity, would serve as a means of minimizing the negative impact of intensive aquaculture on the estuarine ecosystem. Mangroves could also be utilized in pond management to prevent or retard erosion along the shorelines of ponds. Sediment stabilization is an important natural function of mangroves along the coastline, particularly because they minimize the impact of storm surges.

Even though there is a law that denies the construction of newly authorized ponds in mangrove areas, there are thousands of hectares of ponds that were previously authorized but not constructed, and are exempt from this decree. It is only the lack of postlarvae and capital that has controlled the construction of ponds in mangrove habitats. Thus, an increase in the supply of postlarvae by warmer temperatures of offshore waters or increased production from hatcheries, represent a danger to mangroves.

Hatcheries have been viewed as an operation that would save mangrove forests from further destruction. However, if hatcheries and larveros become able to produce enough postlarvae for 45,000-50,000 ha of ponds as predicted, then pressure to utilize mangrove sites for pond construction is likely to develop (present postlarvae levels keep less than 30,000 - 45,000 ha of ponds supplied). Thus, the growth of the hatchery industry to supply postlarvae will have some influence on management decisions to either intensify existing ponds or to construct new ones. If this means more intensive farming techniques, then mangroves should be part of the operational scheme to enhance the production of this industry.

Profit in shrimp farming is income generated from pond production less the costs associated with pond operation The level of shrimp production and operation costs including dredging, construction, pumping, fertilization, and land (authorizations) depend largely on the quality of water that is pumped from the estuary into the ponds. Several factors have been identified in the estuary and the watershed that could influence water quality and, thereby, determine the economy of the shrimp industry. Many of the natural resources such as mangroves and tides provide the shrimp industry with clean water and important habitats that enhance wild PL supply and shrimp production in ponds (Figure 9). The loss of these free services increases the cost of shrimp production, such as the cost of providing PL by operating hatcheries. Negative effects from other industries and shrimp mariculture itself on water quality and natural resources should have some influence on the costs and profits of shrimp farming, since it is so vitally linked with the estuarine ecosystem.

The management practices that are best for the shrimp farming industry in Ecuador point up the need for integrative approaches to coastal zone management. The interactions of the shrimp farming industry with the Guayas River estuary, along with the watershed and offshore waters, indicate the complexity and diversity of management options. For instance, management plans to deal with the fluctuation of PL in the estuary must address the influence of fresh water discharge, offshore water temperatures, loss of mangrove habitat, pesticides from agriculture, and untreated sewage from major population centers. Also the industry itself has a potentially major impact on the ecosystem, so decisions concerning shrimp pond management must consider the possible negative effects on shrimp production and PL supply. The shrimp farming industry must consider the processes and functions of existing natural resources of the estuary in developing plans that will sustain the long term production of mariculture in this coastal zone.

Recommendations

- Document 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 loss.
- Document the present distribution of mangrove forests to identify present and future impacts on this natural resource.
- Restore and integrate existing mangrove forests into the operation of shrimp ponds. Utilize mangroves for treatment of effluents from ponds in operation, and for erosion control and sediment stabilization in areas of pond construction.
- Develop a water budget for the Guayas River estuary, including a synthesis of existing information and the calibration of current data gathering, to increase the utility of this data base.
- Integrate an analysis of nutrients and toxic substances into the water budget 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 economically important fisheries.

- Institute a water quality monitoring program design to determine the current 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 Guayas River estuary. This program could also be expanded to aid shrimp pond and hatchery operators with decisions concerning water quality management.
- 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.

Table 1.
Land use patterns along the coast of Ecuador (areas in ha)

Land Use	Guayas	El Oro	Manabi	Esmeraldas	TOTAL
Mangroves	121463.5	24489.3	7973.4	21293.2	175219.4
	59.4	24.0	4.4	12.2	100.0
Shrimp ponds	52911.8	26483.9	8376.6	2595.5	89367.8
	59.2	29.6	9.4	1.8	100.0
Salinas	17340.1	2520.0	163.8	4.4	20028.2
	86.6	12.6	.8	.0	100.0
TOTAL	191715.4	53493.2	16513.8	22893.1	284615.4
	67.4	28.8	5.8	8.0	100.0

Source: CLIRSEN, 1984

Table 2.
Mangrove species found along the coast of Ecuador

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

Pelliceraceae
- *Pelliciera rhizophorae* (Planchon and Triana)

Avicenniaseae
- *Avicennia germinans* (L.)

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

Table 3.
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	4962.9	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

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	35,280	37,058	72,338	1,304	1,918	128	75,688
Cotton		540	540	5,656			6,196
Soya	10,038	24,470	34,508	165	37	90	34,800
Cacao	12,134	116,115	128,249	40,077	12,367	16,117	196,810
Coffee	31,681	42,020	73,701	138,431	11,000	15,176	238,308
TOTAL	89,133	220,203	309,336	185,633	25,322	31,511	551,802

Source; Solorzano, 1981.

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

Rivers	Area
GUAYAS	35,280
Guayaquil	1,600
Daule	7,745
Samborandon	4,198
Balzar	3,038
Yaguachi	8,003
Milagro	1,106
El Triumfo	5,164
Naranjal	4,426
RIOS	37,058
Babahoyo	19,409
Baba	3,033
Vinces	3,000
Urdaneta	1,214
Puebloviejo	2,160
Ventanas	860
Quevedo	7,382
MANABI	1,304
Santa Ana	565
Portoviejo	442
Rocafuerte	297
ESMERALDAS	1,918
Esmeraldas	293
Quininde	1,625
EL ORO	128
Santa Rosa	128

Table 6.
Estimates of the discharge of domestic waste from the Guayas watershed based on the population of the major cities of the Guayas and Los Rios provinces

City	Treatment	Population	Volume	BOD	COD	TSS	TDS	TN	TP
GUAYAS									
Guayaquil	sewer	634,720	46.335	12,504	27,927	12,694	23,167	2094.5	253.8
	untreated	876,520	6.399	6,048	14,024	14,024			
	TOTAL	1,511,240	52.734	18,552	41,951	26,718	23,167	2094.5	253.8
Salinas	sewer								
	untreated	22,360	.163	154	357	358			
	TOTAL	22,360	.163	154	357	358	0	0.0	0.0
La Libertad	sewer								
	untreated	65,450	.478	452	1,047	1,047			
	TOTAL	65,450	.478	452	1,047	1,047	0	0.0	0.0
Naranjal	sewer	4,580	.335	90	202	92	167	15.0	2.0
	untreated	7,480	.055	52	329	329			
	TOTAL	12,060	.390	142	531	421	167	15.0	2.0
Manglaralto	sewer								
	untreated	12,300	.090	85	197	197			
	TOTAL	12,300	.090	85	197	197	0	0.0	0.0
Playas	sewer								
	untreated	18,550	.208	197	457	457			
	TOTAL	28,550	.208	197	457	457	0	0.0	0.0
Santa Elena	sewer								
	untreated	15,670	.114	108	251	251			
	TOTAL	15,670	.114	108	251	251	0	0.0	0.0
LOS RIOS									
Santa Rosa	sewer	6,040	.441	119	266	121	220	20.0	2.0
	untreated	27,530	.201	190	440	440			
	TOTAL	33,570	.642	309	706	561	220	20.0	2.0
TOTAL	sewer	645,340	47.111	12,713	28,395	12,907	23,554	2129.5	257.8
	untreated	1,055,860	7.708	7,286	17,102	17,103	0	0	0
	TOTAL	1,701,200	54.819	19,999	45,497	30,010	23,554	2129.5	257.8

Engineering Journal, 1972.

Table 7.
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

Pesticide	Treatment		Input
Ronstar 25	2.00	L/ha	144,676
Ronstar 12	4.00		289,352
Machete	4.00		289,352
Saturno	3.00		217,014
Propanil	8.00		578,704
Hormonales	2.00		144,676
Furadan	15.00	Kg/ha	1,085,070
Curater 5-10%			0
Diazinon	1.00		72,338
Ozadin	0.50		36,169
Lorshan	0.50		36,169
Endrin	2.00		144,676
Lannate	2.00		144,676
Dipterex 95 %	1.00		72,338
Bin 75	300.00	g/ha	21,701,400
Benlate	250.00	g/ha	18,084,500
Kasumin	0.75	L/ha	54,253.5
Inosin	0.75		54,253.5

Soy Beans

Pesticide	Treatment		Input
Bravo	3.00	L/ha	103,524
Daconil	2.50	Kg/ha	86,270
Afalon	3.00		103,524
Preforan	15.00	L/ha	517,620

Solorzano, 1981

Table 8.
Comparative toxicity of the water soluble fraction of No. 2 fuel oil to different life stages of four marine crustaceans
Concentrations 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 days old)	1.8	
	adults	.7	

Figure 1 Areas of ponds authorized by the Ecuadorian government for the construction of shrimp ponds.

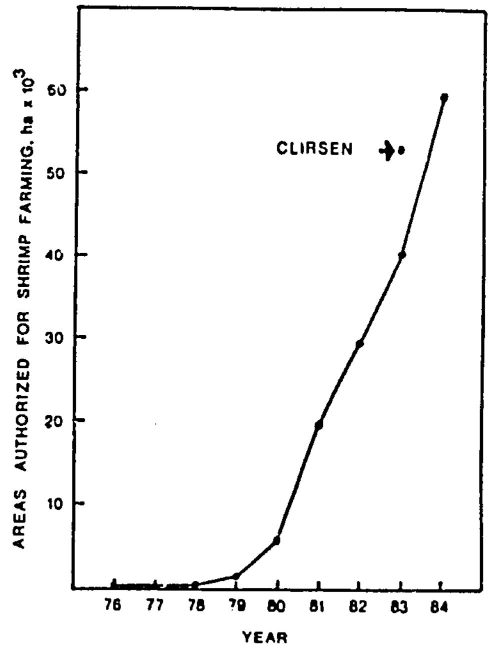


Figure 2 The coastal provinces of Ecuador

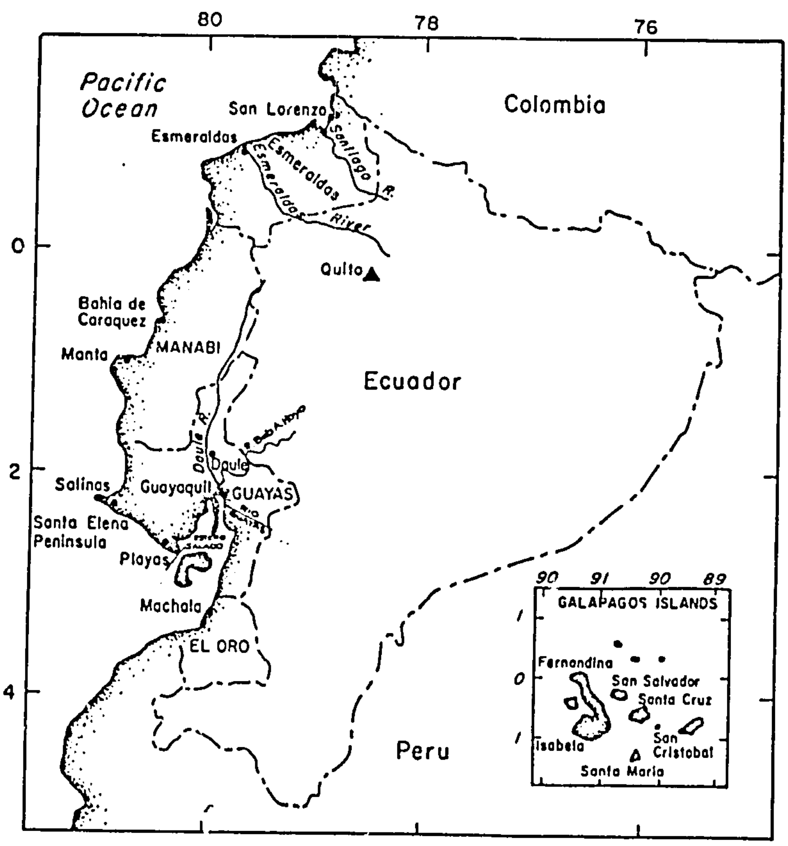


Figure 3 A) Forty year record of annual precipitation in Guayaquil. B) Average monthly discharge of the River Guayas from 1962 to 1964. (Both figures from Stevenson 1981).

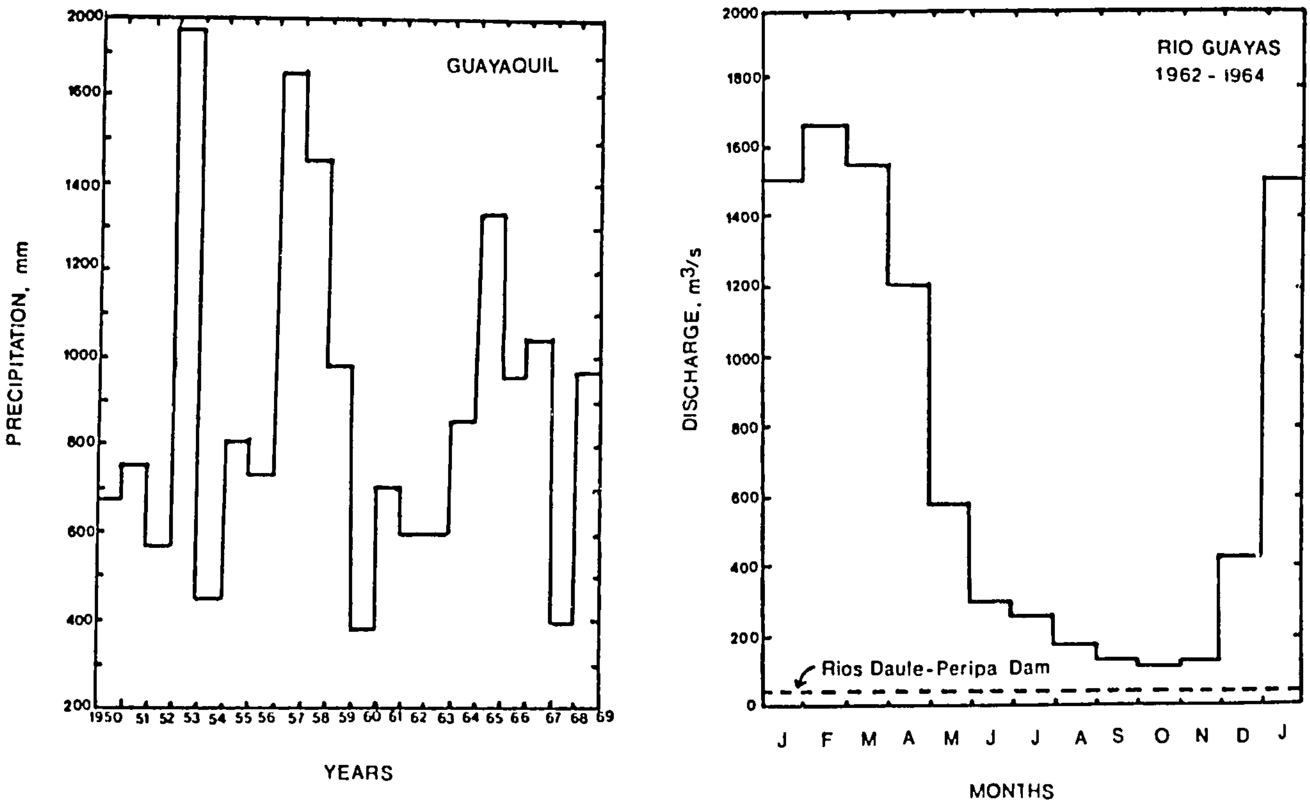


Figure 4 **Hypothetical loss of mangroves in the Guayas province, given that a percentage of ponds are constructed in mangrove forest. For example, if all ponds as of 1984 (53,000 ha) had been constructed in mangroves, then 30% of Guayas mangroves would have been cut. (See table 1).**

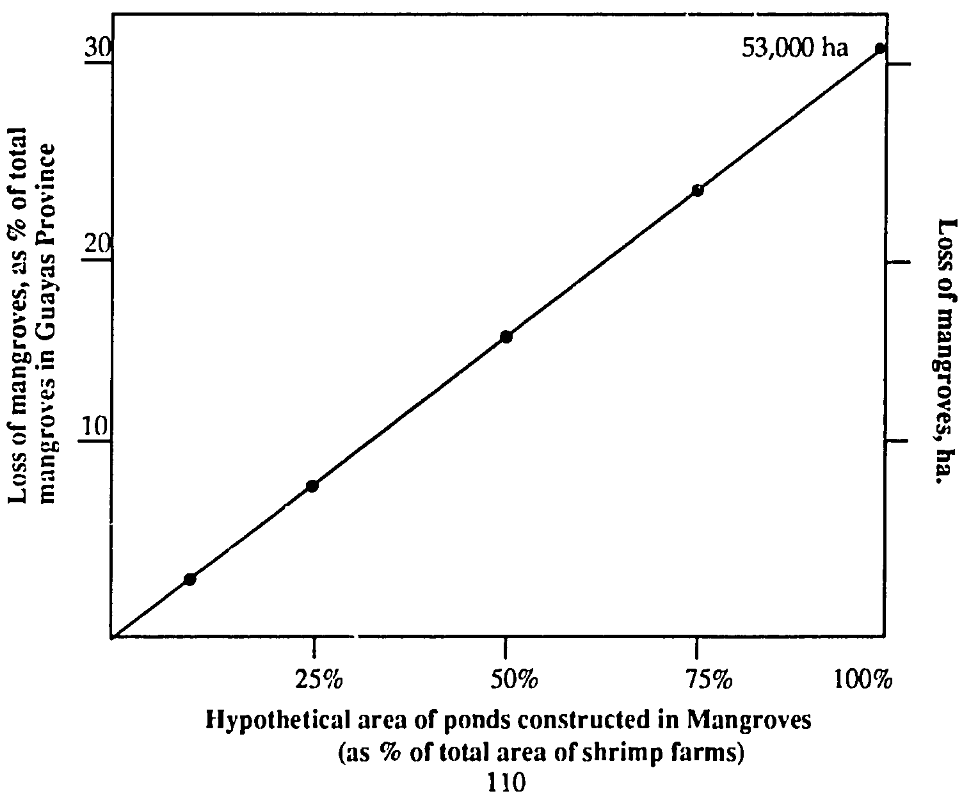


Figure 5 Normal discharge at the confluence of the Daule and Peripa Rivers (solid line) compared to the restricted flow controlled by the proposed dam (dotted line). Slanted lines represent discharge lost from the estuary during the wet season, and the stipuled area is discharge provided by the impoundment during the dry season (From Jenkins 1979).

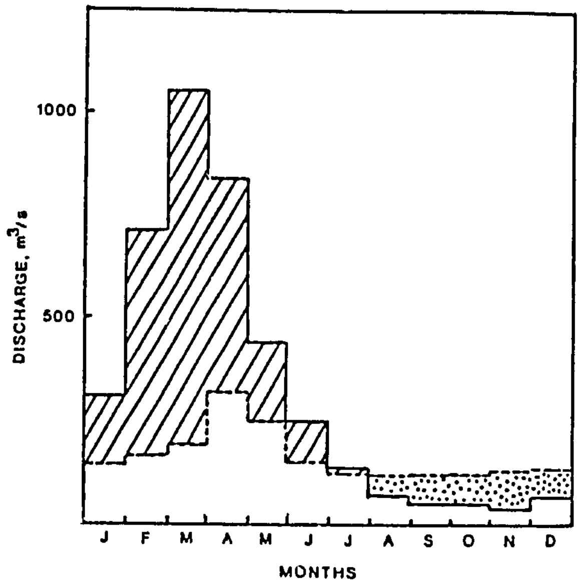


Figure 6 Population during the past 35 years in the coastal provinces of Ecuador (data from Gomez 1986).

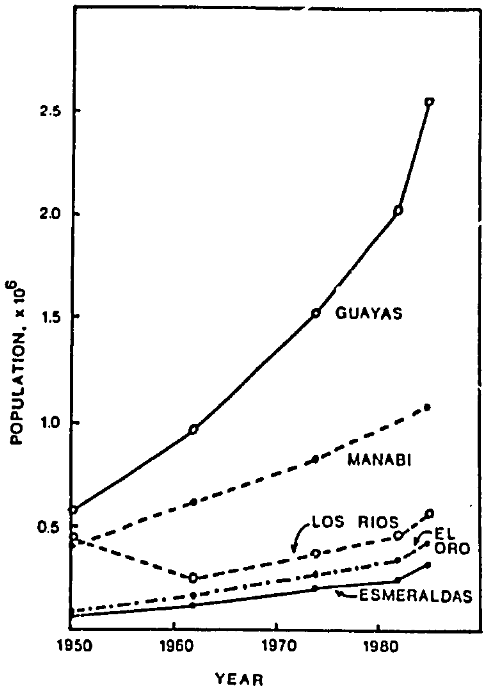


Figure 7 Concentrations of nutrients for different rivers in the Guayas River basin (data from Rendon et al., 1983).

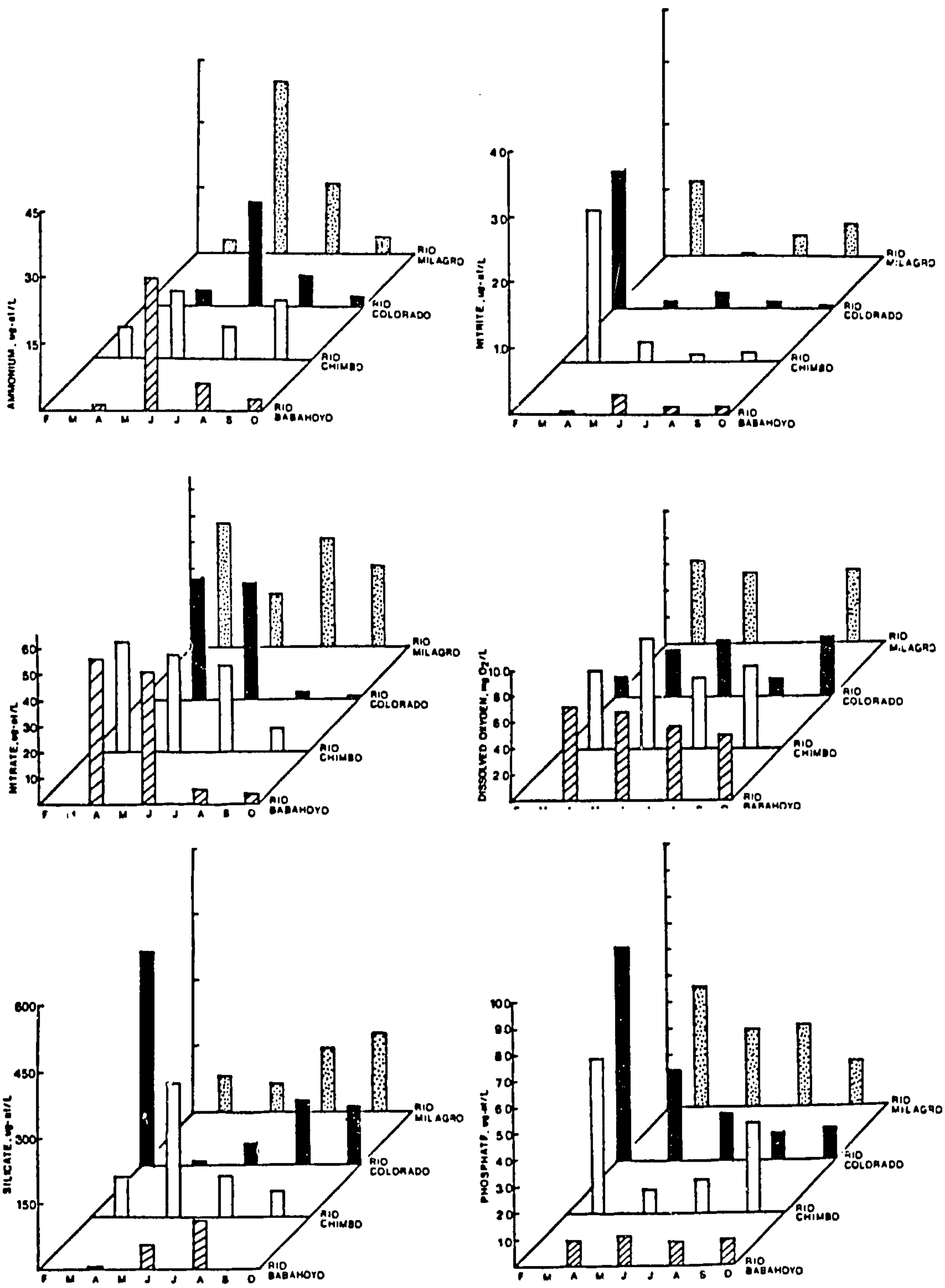


Figure 8 Volumes of water exchanged with shrimp ponds per day at different pumping rates (percentage of the volume of a shrimp pond per day) based on the area of ponds (ha) with a mean depth of 1.5 m (see text).

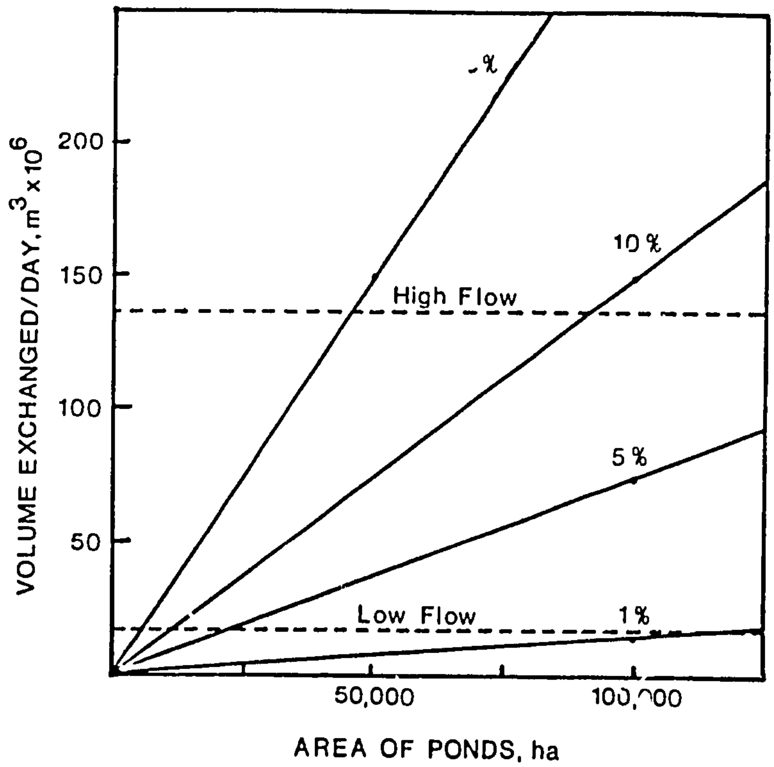
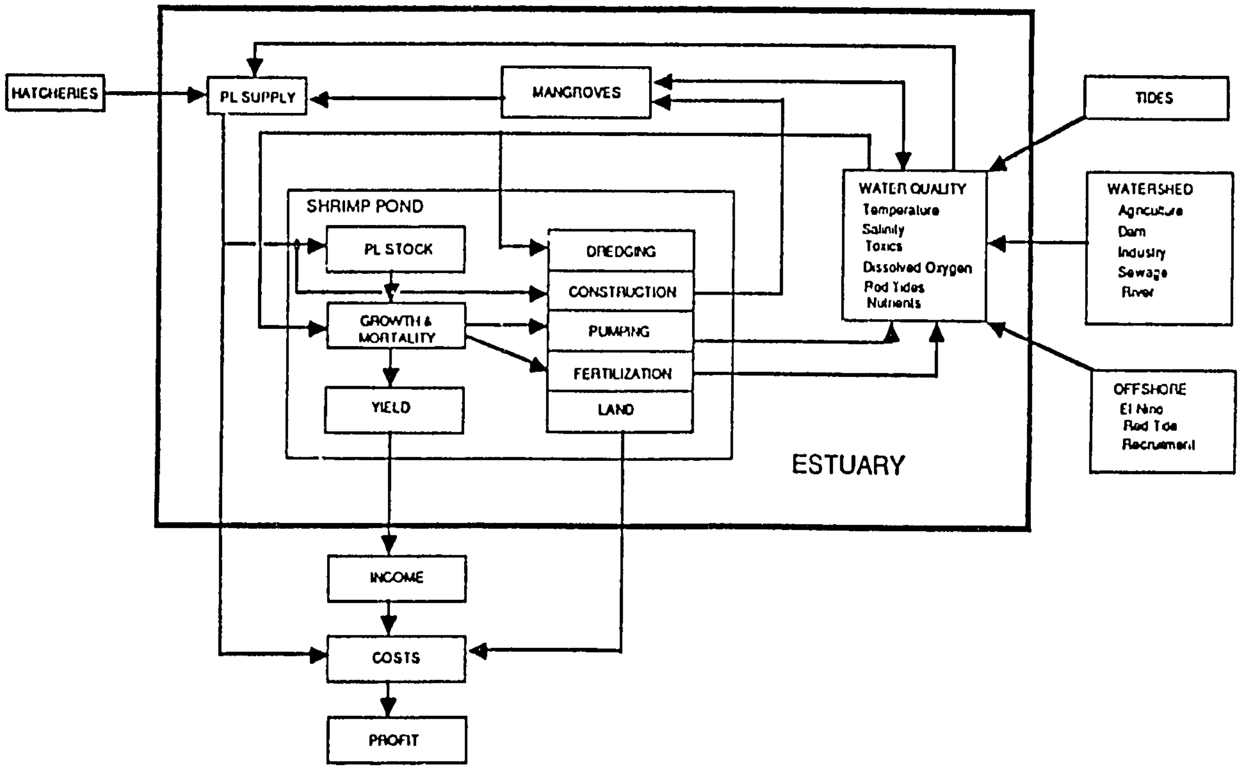


Figure 9 Interactions between shrimp farming and Guayas River estuarine ecosystem.



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Factors Affecting the Relative Abundance of Shrimp in Ecuador

Factores que Afectan la Abundancia Relativa del Camarón en el Ecuador

R. Eugene Turner

Resumen

La producción de camarones peneidos en Ecuador tiene significación nacional, en términos de volumen, valor y ocupación de mano de obra. Aunque la producción en piscinas aumento grandemente en los últimos años, los datos disponibles sugieren que la producción por superficie (Kg/ha) ha declinado significativamente. Desde la perspectiva del manejo del recurso, las preguntas claves comprenden: ¿Cuáles son los impactos de la tala del manglar?; ¿Cuál es la variación natural en el reclutamiento?; ¿Se puede aumentar el suministro de postlarvas naturales?; ¿Cómo influye la captura de postlarvas y juveniles en el tamaño del "stock"?.

Después de presentar informaciones sobre el ciclo biológico del camarón y las relaciones del reclutamiento en abiente natural, el autor trata sobre los efectos de áreas pantonosas costeras en el reclutamiento del camarón, sosteniendo que el crecimiento y la supervivencia de las postlarvas en los esteros constituyen, probablemente, los factores más importantes que afectan a la magnitud de la población adulta. Se incluyen ejemplos de Malasia, Filipinas y Golfo de México (Luisiana), en los cuales se demuestra que los rendimientos a largo plazo están relacionados linealmente tanto a la calidad como a la cantidad del habitat intermareal.

Asunto relevante, además de la riqueza orgánica del ecosistema de manglar, es la protección que porporcionan las estructuras de la planta a los camaroneros juveniles, conforme ha sido demostrado en experimentos sobre la relación predador-presa, que son citados en el trabajo.

Se analiza la influencia del clima sobre las fluctuaciones anuales del "stock" de camarones, estableciéndose que en el Ecuador hay una baja variación anual (20%) de la "captura por unidad de esfuerzo" (CPU), en comparación con la de otros países (hasta un 90%). La presencia o ausencia del fenómeno de El Niño, es determinante en las variaciones anuales.

En las conclusiones, el autor expresa que la conservación de la "cantidad de habitat" es altamente significativo para mantener el éxito sostenido en el reclutamiento de los "stocks", puesto que parece que la extensión del habitat es el factor determinante de las densidades potenciales del "stock" natural, que son modificadas anualmente por influencias climáticas.

En consecuencia, la recomendación del autor es la conservación de las zonas de manglares, si el Gobierno desea prevenir grandes cambios en los "stocks" de postlarvas, juveniles y adultos. Donde sea posible, el manglar debe ser restribuído mediante el restablecimiento de la hidrología natural. La zona de amortiguación del manglar alrededor de las áreas taladas debería ser al menos el doble del área talada.

También, concluye en que la industria del camarón presenta signos del aumento de conflictos entre usuarios de los recursos, necesitándose datos precisos para lograr el éxito en la interacción entre todas las partes interesadas.

Finalmente, recomienda divulgar técnicas para aumentar el suministro de postlarvas mediante la disminución de la mortalidad durante su manipuleo.

Introduction

Penaeids are harvested extensively throughout the Ecuadorian coastal zone from boats and in ponds built within the mangrove-lined estuaries. The harvest is of national significance in terms of volume, value and employment (Sutinen et al., this volume). Resource management questions have arisen as the mariculture system developed. For example, trawl fishermen have accused the pond operators of depleting stocks of wild shrimp postlarvae (PL) and juveniles to supply the ponds. As many as 90,000 to 120,000 people may be involved in postlarvae collection each year, and the effects on the shrimp population is unknown. Recent PL shortages have led to serious economic difficulties, particularly for the pond operators; in 1985, 50 percent of the ponds were idle due to a shortage of wild-caught postlarvae, which represent up to one-half of pond operation expenses (LiPuma and Meltzoff, 1985). Many of the ponds are in mangrove zones which are very productive components of the estuarine ecosystem (Cintron, 1981) and contribute to both flora and fauna, including shrimp. Although catches in the ponds increased dramatically in recent years, the available data suggests that the areal rate of production (kg/ha) for all ponds has declined significantly. There are several reasons for this decline:

- The best sites may have already been chosen leaving only the poorest sites for later development.
- For economic reasons ponds may be abandoned or never used.
- The statistics are not accurate.
- Pond operators are now relying more on natural stocking of ponds through tidal action than on stocking with caught larvae.
- Pond fertility is depleted after three harvests, and management steps were not taken before seeding the fourth production period.
- Most ponds were unauthorized and, therefore, were not counted in earlier estimates of productivity.
- Informal exports of shrimp through Peru, among other countries, have also contributed to this skewed appearance.

From a resource management perspective, the key questions to be addressed concerning the relative abundance of natural shrimp stocks are:

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

Life Cycles of Wild Penaeid Shrimp

Shrimp begin life in the open sea as eggs which mature through naplius, protozoeal and zoeal stages. After drifting during the pelagic larval phases, the postlarvae enter lower-salinity estuarine waters on flood tides and seek nutrient-rich substrates, such as mangrove roots, to which they cling until the next tide takes them deeper into the estuary. Eventually the shrimp become benthic (bottom-dwelling), growing larger in the food-rich and predator-reduced environment. After several weeks or months, they return to the ocean, remaining in the shallow zones (Figure 1). Fishermen harvest shrimp from estuaries as postlarvae for stocking ponds, or as subadults and adults in the nearshore and open oceanic waters. For reasons discussed below, most commercially-important penaeid shrimp are assumed to be estuarine dependent.

The capability of estuarine mangrove areas to support major fisheries is widely acknowledged by scientists, but not well understood. The juveniles of many commercially important fisheries congregate in shallow zones for feeding and refuge from predators. Such behavior makes these species more adaptable for mariculture operations. Shrimp, in particular, take advantage of favorable shallow water habitats during critical life cycle stages. Various studies have revealed that shrimp postlarvae are present virtually all year in mangrove waters, although numbers fluctuate seasonally in relation to the lunar, diurnal and tidal cycles.

Shrimp Recruitment Relationships

Penaeid shrimp stocks suffer the greatest mortality when the organism is smallest. In many fisheries, variations in recruitment of an age group into the exploited stock is driven by adult spawning biomass size. But stock recruitment relationships for penaeid shrimp are not clearly demonstrable (Garcia, 1983) because the adult stock size is determined by the changes in juvenile, even postlarvae abundance, and is not primarily related to changes in adult spawning biomass.

However, there are reasonable causal relationships between larval and juvenile abundances and the subsequent densities (Garcia and LeReste, 1981). In turn, the stock recruitment success is clearly dependent on climatic factors, predation levels, food supply and habitat quality. Of these, though not precisely defined for penaeid shrimp, habitat is considered the principal long-term factor influencing sustained shrimp harvests. Shrimp mariculture in Ecuador may have contributed to the change in the dominant species, from Penaeus occidentalis to P. vannamei. P. vannamei is more adaptable to coastal ponds environments, and inefficient techniques may release to the estuary 1,000 pounds of 16-20 gram preadult shrimp during the harvest of a single 10 hectare pond.

Effects of Coastal Wetland Area on Recruitment of Penaeid Shrimp Stocks

Coastal Wetland Area and Shrimp Stock Size

Researchers agree that larval shrimp movement and recruitment from the spawning sites offshore into estuaries 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 postlarvae survival, the long-term yields are linearly related to both the quantity and quality of intertidal habitat. Despite the difficulty in obtaining reliable measures of fishing effort and landings, there are several examples of the habitat-yield relationship throughout the world.

Jothy (1984) provides data from Malaysia relating mangrove area and shrimp yields (Figure 2). 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.

Pauly and Ingles (1986) compiled similar statistics for the Philippines and the same relationship holds between shrimp landings and mangrove zone (Figure 3). The researchers live in the Philippines and had access to long-term data on both the artisanal and commercial trawl catches. They eliminated under- and over-reporting of catch data and the abuse of mangrove areal estimates for economic interests concerned with the mangrove lumber concession.

Long-term data and monitoring from the entire northern Gulf of Mexico are also available. The area of intertidal vegetation is also well known through several surveys since 1960, with the area of vegetation directly and linearly related to the tidal landings in any one year (Figure 4). The vegetation in these estuaries is not dominated by mangroves (except in isolated cases). There is also 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 in each area.

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

The important commercial species in Ecuador are listed in Table 1 and distribution of harvest by species is shown in Table 2.

The relationships of wetland area to penaeid shrimp yields have been indirectly tested through large-scale changes in wetland areas. Several examples have been documented with various degrees of success (Figure 6, Table 3).

In Louisiana, the coastal wetland loss rate is 0.8 percent per year (Craig et al., 1979; Turner, 1979, 1982; Turner et al., 1982). Changes in vegetation are accompanied by changes in the shrimp catch in direct relation to the loss or gain of wetlands in each estuary. There are also demonstrated relationships between the quality of estuarine wetlands and shrimp catch. Due to the loss of wetland areas over the past 30 years, more salt-tolerant vegetation has dominated, with accompanying increase in brackish shrimp species (Figure 7).

In Japan, Doi (1983) showed that the decline in yields of P. japonicus was proportional to land reclamation in the estuary (Figure 8). However, the intertidal land was mostly unvegetated, shallow mudflats. Morgan and Garcia (1982) noted a long-term decrease in the recruitment of P. semisuculatus in Kuwait and Saudi Arabia related 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 difficulty in obtaining good estimates of landings and effort (Daugherty, 1975).

Finally, in the People's Republic of Vietnam, the chemical defoliation of the southern coastal zone during the latest war caused 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).

Causal Relationships Leading to the Wetland-Stock Relationships

Experiments in predator-prey interactions in wetlands show similar patterns in shrimp yields. For example, wetlands blocked off from the estuary with levees or bulkheads result in decreased numbers of adult shrimp at the altered sites (Mock, 1967; Trent et al., 1976). Although the wetland edge is particularly high in organics, a more important factor may be the protection from predators that plant structures offer the shrimp. Field and laboratory predator-prey experiments with P. aztecus in vegetated and non-vegetated salt marsh habitats indicate that small juveniles hide among plant stems to escape predators (Minello and Zimmerman, 1983a,b; Zimmerman and Minello, 1984; Zimmerman et al., 1984; Minello and Zimmerman, 1985). The number of successful predator attacks on prey declines with increasing vegetation complexity. Thus wetland habitats appear to be favored sites for juvenile shrimp, which is consistent with observations of 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, seagrasses and rivers (Groen and Schmulbach, 1978; Johannes, 1978; Savino and Stein, 1982; Strange et al., 1982; Durouchcr, 1984; Heck and Thomas, 1984; Holland and Huston, 1984; Robblee and Zieman, 1984; Hoyer et al., 1985; Risotto and Turner, 1985).

Mangrove Loss and Postlarvae and Adult Supply

Does decline in shrimp landings or postlarval supply follow the loss of mangroves due to mariculture pond construction? To address this question, it is worthwhile to determine the changes in mangrove areas since significant pond construction began in or about 1976.

The decline in mangrove area in Ecuador as a direct result of the construction of mariculture ponds in the mangrove zone is estimated at 10.6 percent by Alvarez (this volume). Valdiviezo (no date) estimated that there were a total of 175,219 hectares (ha) of mangroves and 89,368 ha of brackish water mariculture ponds (Table 4) in Ecuador as of 1982. One study of the Guayas River estuary (CLIRSEN, 1983) indicates that 16 percent of the pond growth from 1966 to 1982-83 occurred in mangroves (Table 5). Assuming that about 10 percent of the present mariculture ponds are in former mangrove zones, then about 9,000 ha of mangroves are no longer functioning as a forested wetland ecosystem.

Is this estimated 10.6 percent decline in mangrove matched by an equivalent decline in shrimp landings or postlarval supplies? This is a difficult question to address with present landings statistics for Ecuador. Although the trawl effort has remained somewhat constant for the last 15 years (Figure 9), the catch per unit effort (CPUE) has fluctuated; but natural variations in a variety of fisheries stocks, especially shrimp, fluctuate at least 20 percent in any one year.

Further, the 10.6 percent declines in mangrove are cumulative. In 1980 declines were only around 1.0 percent, so the impact of mangrove loss is relative to annual environmental fluctuations that affect stocks. Even so, the CPUE in the last several years is lower than average.

Another question is whether or not fishing effort in the last few years has remained constant. Without compensating for a changing effort, as well as vessel numbers, it is difficult to separate out the relative influences of climate, effort and mangrove decline. Certainly the effort has not been completely constant because the size of the boats (measured in horsepower) has changed since 1980 (Figure 10).

Effects of Climate on Annual Fluctuations of Penaeid Shrimp Stocks

Natural Variations in Stock Size

Adult stock harvests may vary as much as 100 percent from year to year. Table 6 shows the coefficient of variation for the Ecuadorian trawling fleet and several other world shrimp fisheries. The Ecuador fleet has a very low variation in CPUE of 20 percent compared to up to 90 percent 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 management of this fishery.

It is now well documented that these large annual variations are associated with changes in estuarine conditions. Variation in estuarine salinity and temperature are the best-documented climatic influences (Table 7), but the frequency and intensity of frontal passages, river discharges or substrate conditions may also be important. Numerous data on CPUE are available (e.g., Gulland and Rothschild, 1984; Kapetsky, 1981; Kapetsky and Lasserre, 1984 a,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.

Cun and Marin (1982) examined fisheries landings data to determine the annual changes in the catch of P. stylirostris in the northern (zona de Golfo), central and southern parts (zona de Playas) of the Gulf of Guayaquil between 1965 and 1979 (Figure 11). The interannual variations were high and there were differences in species dominance between areas, though the reasons are not yet understood.

Data on the flow of the Jubones River, which enters the Guayas estuary (Table 8) was used as a surrogate for regional variations in rainfall and temperature, demonstrating an inverse relationship with riverflow and CPUE (see also Figure 12). Since El Nino usually brings wet and warm weather, these events seem to indicate that such events are unfavorable for shrimp recruitment. However, the most recent El Nino events of the 80s resulted in very high values of CPUE, but are not included here because of the lack of riverflow data. The major point of this figure is to encourage analysis of effects of climate on Ecuadorian shrimp CPUE (as well as other species). This approach has proven feasible elsewhere (e.g., Table 7).

Implications for Management of Penaeid Shrimp Stocks

The options available to penaeid shrimp managers might be described as being of three types: economic, or fleet and processing management; personnel, or socio-cultural management; and habitat management. Habitat management is emphasized here. The primary cause of changes in these wetlands are manmade activities and may, therefore, be manageable. Without more attention to habitat, the first two concerns will become less important and more difficult to implement. As the potential crop of both postlarvae and adults decreases with wetland losses, options to manage whatever remains become much more limited.

Penaeid shrimp managers should regard habitat management as their primary responsibility. Otherwise, they will be faced with trying to divide fewer and fewer stocks among more and more people, especially fishermen, while watching their well-designed but static management plans falter with changing environmental conditions.

Conclusions and Recommendations

Below are some conclusions and recommendations based on the review of penaeid shrimp biology and the present situation in the Ecuadorian fishery. These will necessarily be broadly stated since implementation must be flexible to reflect local variations in economics, personnel, politics and environment.

1. Conclusion: Penaeid shrimp recruitment from larvae to adult is strongly influenced by habitat quality and quantity. The hypothesis that habitat quantity determines adult stock sizes is supported by limited field 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 determinant of natural potential stock densities which climatic influences modify annually.

Recommendations: Mangrove zones must be conserved 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.

- Where possible, mangroves should be restored through reestablishment of the natural hydrology.
- Mangrove buffer zones around cleared zones should be at least twice the levee width and include the levee.

2. Conclusion: The shrimp industry in Ecuador is expansive and intensive, and shows signs of increasing user-use conflict. Minimization of conflict is possible but all parties must be involved to optimize interactions. Accurate data is required for this interaction to succeed.

Recommendations: An integrated study plan which includes all users and all aspects of the environment should be developed. One agency must represent the ecosystem since resource conflicts are partially based on individual exploitation of the common resource, e.g., mangroves and water quality; the issues are complicated, involve multiple resource use and have long-lasting implications for a variety of social, political and natural resources.

- Determine if the decline in kg/ha of ponds is real. If not, determine where the data are incorrect. Can this situation be rectified? If the decline is 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.

3. Conclusion: The variations are high enough now to mask the relatively smaller changes in stock size due to present reductions in mangrove.
Recommendation: An analysis of the effects of climate on the annual variations in stocks should be completed. It would be especially useful to examine the effects of oceanic temperature anomalies on shrimp and on other stocks.

4. Conclusion: Postlarvae supplies can be increased without exploiting additional mangrove zones by reducing the loss of postlarvae after capture and before introduction into ponds.
Recommendation: Promulgate techniques to increase the supply of postlarvae by decreasing the mortality of those caught.

Table 1
List of Shrimp of Commercial Importance (McPadden, 1985)

Common Name	Family	Species
Blanco	*Penaidae*	*Penaeus vannamiei* *P. stylirostris* *P. occidentalis*
Cafe	*Penaidae*	*P. californiensis*
Rojo	*Penaidae*	*P. brevirostris*
Zebra	*Penaidae*	*Trachypenaeus byrdi* *T. pacificus* *T. face*
Pomada/Titi	*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	5
P. styliorstris	15 to 20	95
P. vannamei	2 to 3	0
P. californiensis	3	0
Trachypeneus byrdi	minor	0
T. faoea	"	0
T. similis pacificus	"	0
Xiphopeneus riveti	"	0
Protrachypene precipua	"	0
Solenocera florea	"	0

Table 3
Summary of Examples of Penacid Shrimp Stock Changes Following
Intertidal Wetland Changes

Area	Vegetation Changes	Stock Changes	Source
Louisiana	Quantity, quality	Quantity, quality	Turner unpub.
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

Table 4
Area of Mangrove, Camaroneras and Salinas
in Ecuador, circa 1982-1984 (Valdivieso, no date)

Province	Camaroneras	Manglares	Salinas
Guayas	52,912	119,526	17,340
El Oro	26,484	24,456	2,520
Manabi	8,377	12,416	164
Esmeraldas	1,595	30,153	-
TOTAL	89,368	186,551	20,024

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	4,231.7	3,294.1
Camaroneas	0.0	834.0	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

Table 6
Variation in the Catch per Effort of Several Developed Shrimp Fisheries
(from Gulland and Rothschild, 1984)

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
U.S.A. Gulf of Mexico	12	29.8	Single	164
U.S.A. Gulf of Mexico	12	24.5	Single	164
Ecuador	25	20.0	All	—

Table 7
Examples of the Effect of Climate on
Coastal Penaeid Shrimp Stocks

Location	Species	Effect on Yield	Source
North Carolina (U.S.A.)	*P. duorarum*	Temperature (-)	Hettler and Chester (1982)
Louisiana (U.S.A.)	*P. setiferus*	Salinity (-)	Barrett and Gillespie (1973)
	P. aztecus	Riverflow (-)	
Louisiana	*P. setiferus*	Salinity (-) Temperature (+)	Turner (1979)
	P. aztecus	Salinity (+) Temperature (+)	
Northern Gulf of Mexico (U.S.A.)	*P. setiferus*	Salinity (-) Temperature (+)	Copeland and Bechtel (1974)
	P. aztecus	Salinity (+) Temperature (+)	
Florida (U.S.A.)	*P. durarum*	Water Level (+)	Browder (1986)
Laguna Madre, Texas (U.S.A.; hypersaline)	*P. fluviatilis* *P. aztecus*	Rainfall (+)	Gunter and Edwards (1969)
Australia	*P. merguiensis*	Rainfall (+)	Staples et al. (1984) Ruello (1973)
Indonesia	*P. merguiensis* *P. monodon*	Riverflow (+)	Turner (1975)
Senegal	*P. duorarum*	Salinity (+)	Le Reste (1980)

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)	Percent 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

Figure 1. The relative density of penaeid shrimp stocks off the coast of Ecuador by depth contour (adapted from data in Loesch and Cobo, 1972).

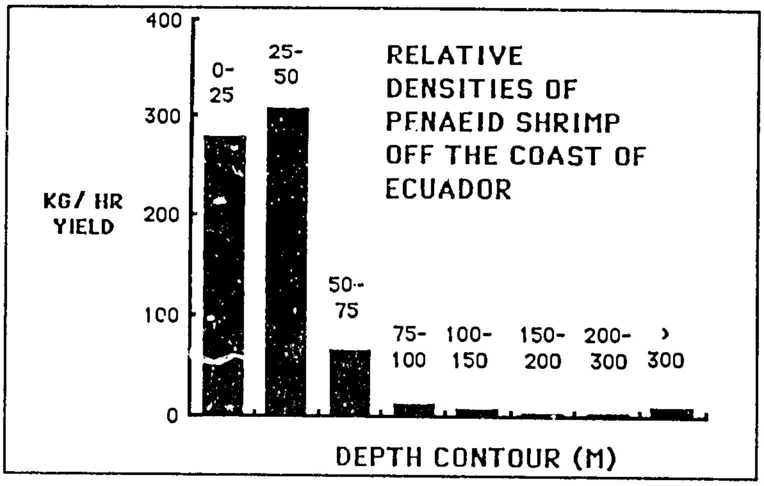


Figure 2. The relationship between intertidal vegetation and penaeid shrimp yields in Malaysia (adapted from data in Jothy, 1984).

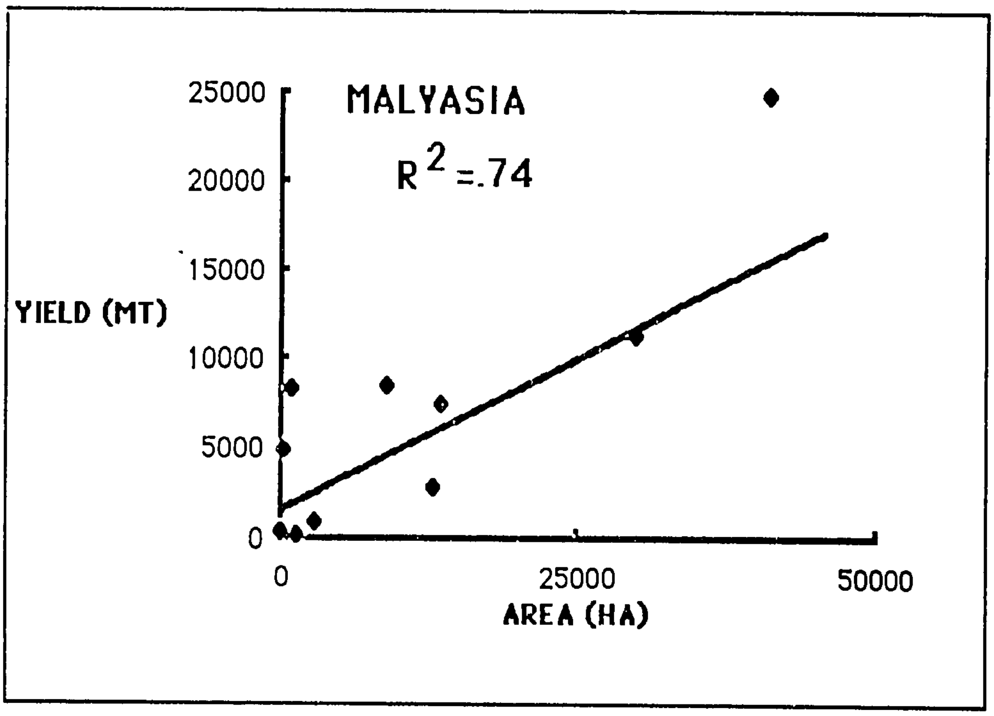


Figure 3. The relationship between mangrove areas in the Philippines and the annual yields of penaeid shrimp (adapted from Pauly and Ingles, in press).

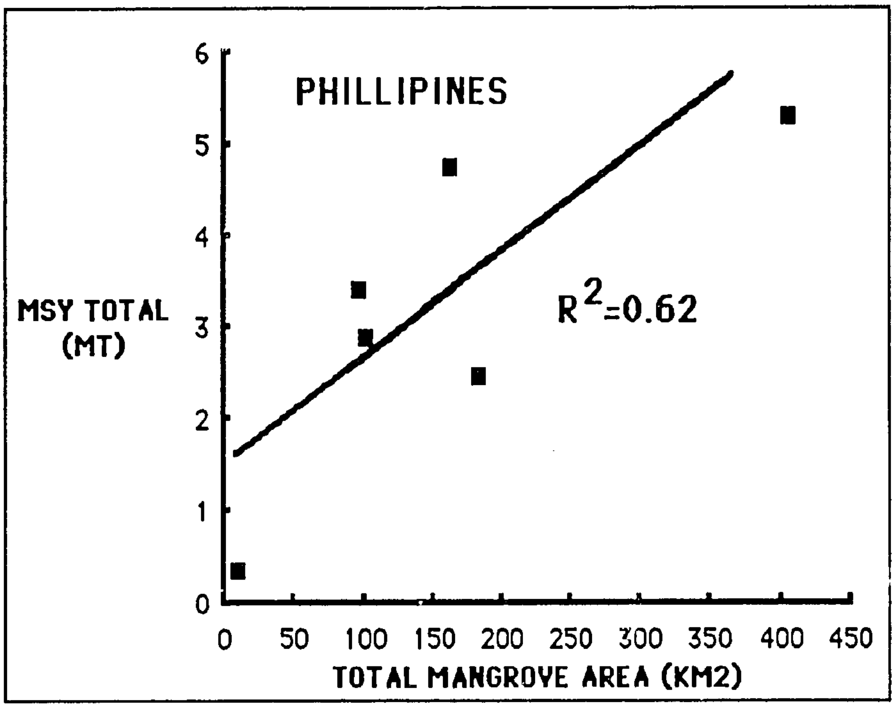


Figure 4. The relationship between intertidal vegetation and penaeid shrimp yields from the estuaries of the northern Gulf of Mexico (from Boe::ch and Turner, 1985).

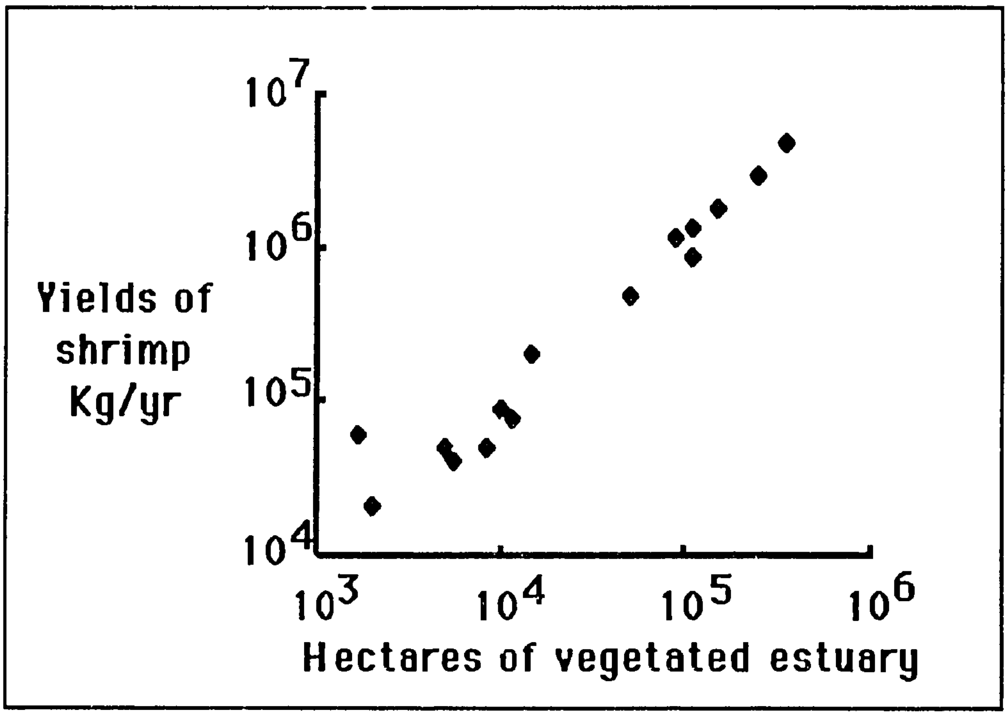


Figure 5. The relationship between intertidal vegetation and penaeid shrimp yields from developed fisheries (modified and updated from Turner, 1977).

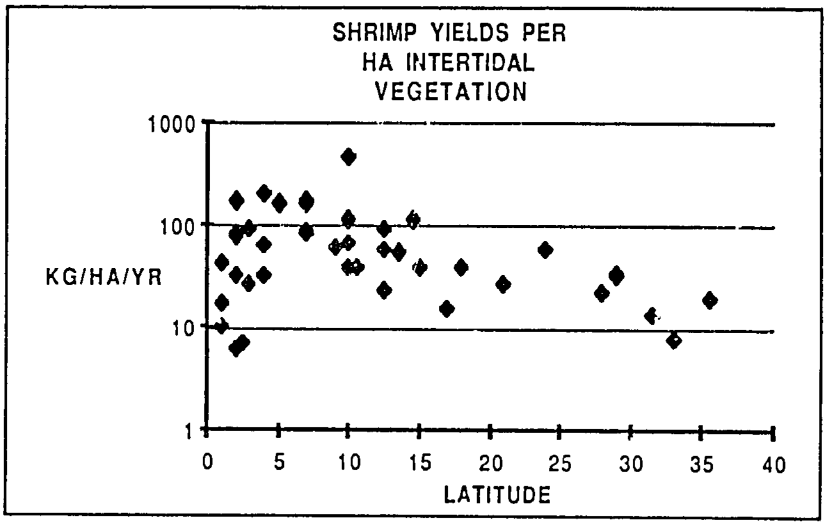


Figure 6. Locations where decreases in intertidal vegetation have been followed by decresaed in penaeid shrimp landings.

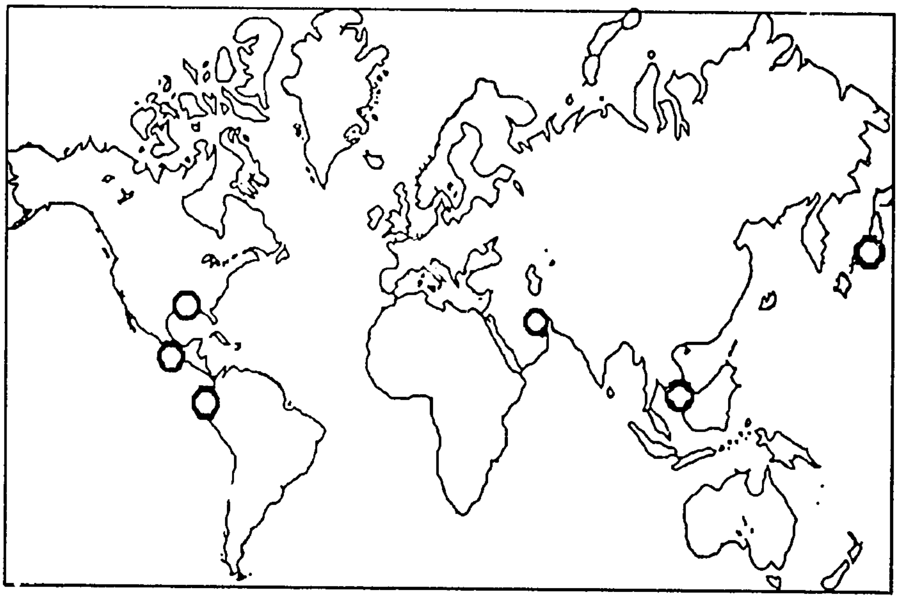


Figure 7. The percent of brown shrimp (P. aztecus) caught in the inshore waters of Louisiana from 1963-1976 (NMFS statistics).

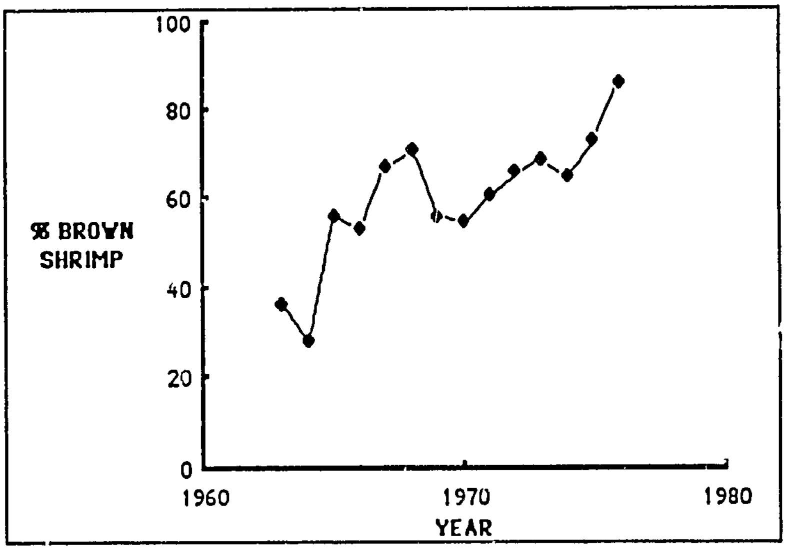


Figure 8. The decline of shrimp yields in Japan as related to reclamation of intertidal lands in Japan (from Doi, 1983).

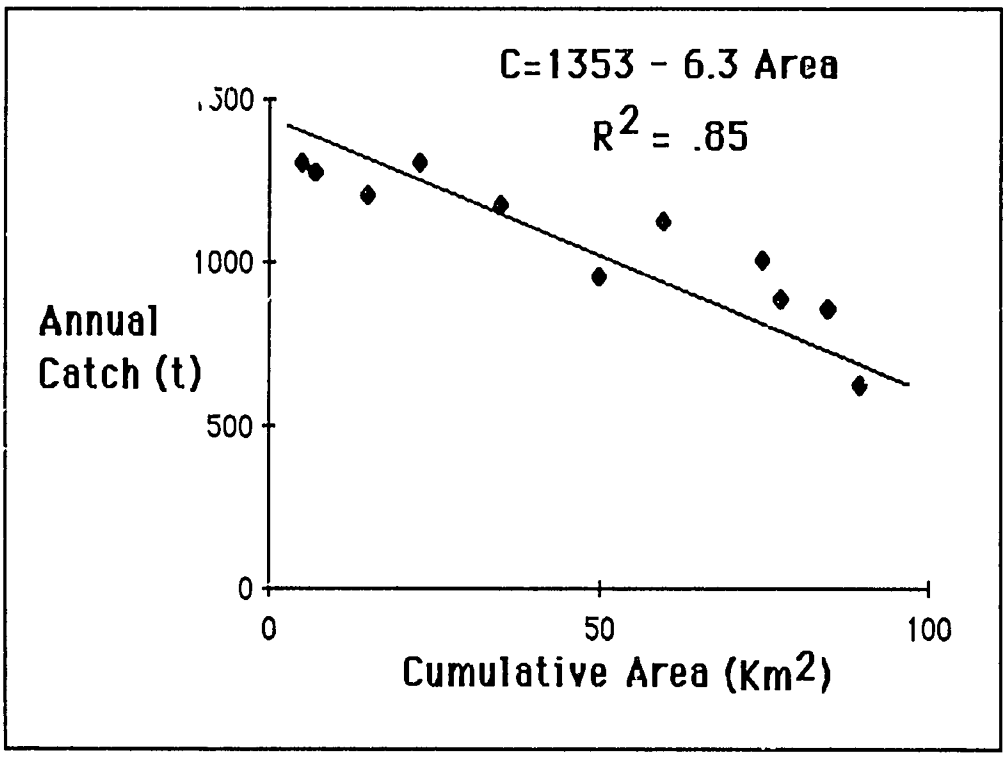


Figure 9. The number of trawling vessels in the industrial shrimp fleet and the catch per vessel from 1954 to 1984.

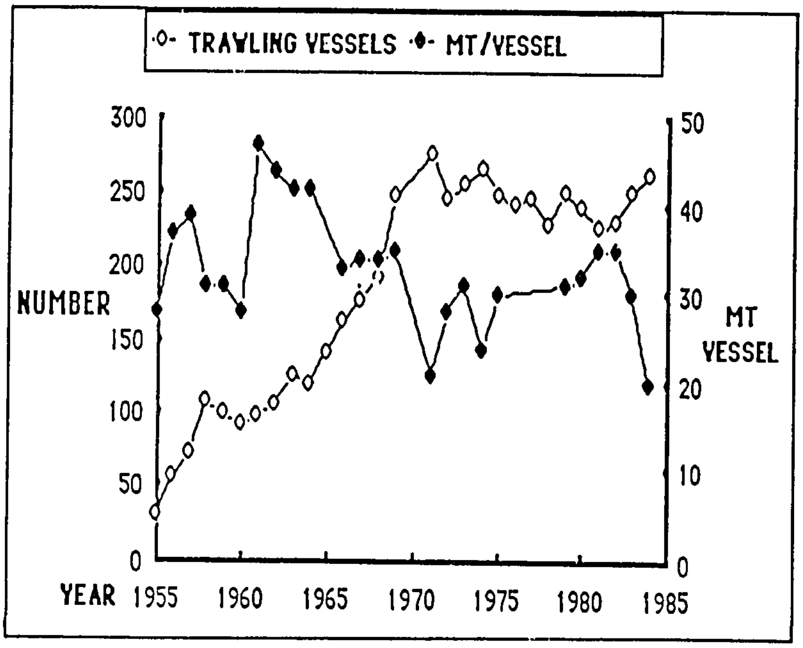


Figure 10. The distribution of horsepower in the offshore trawling fleet.

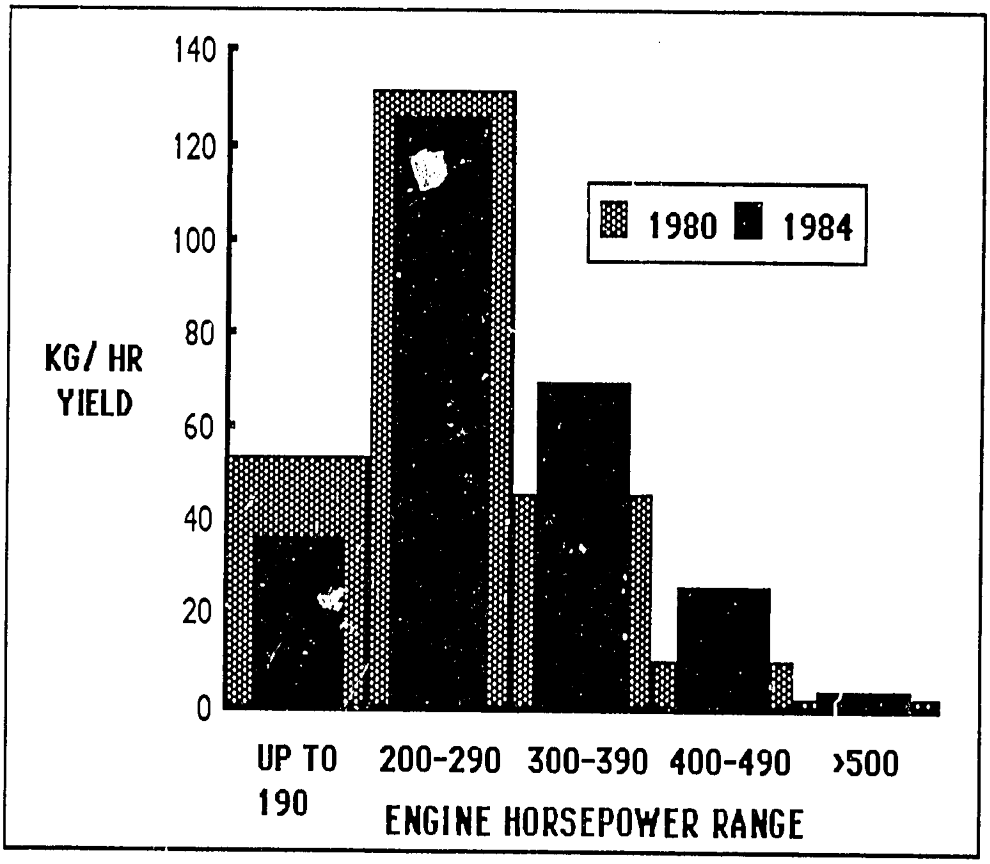


Figure 11. Annual changes in the percent catch which is P. vannamei within the Gulf of Guayaquil at the northern part of the Gulf (zona de Golfo) and the central and southern part (zona de Playas) (from Cun and Marin, 1982).

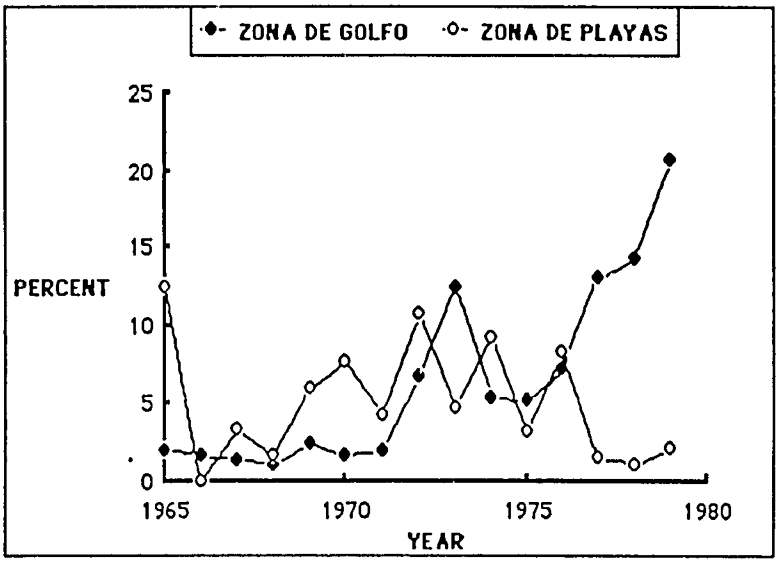
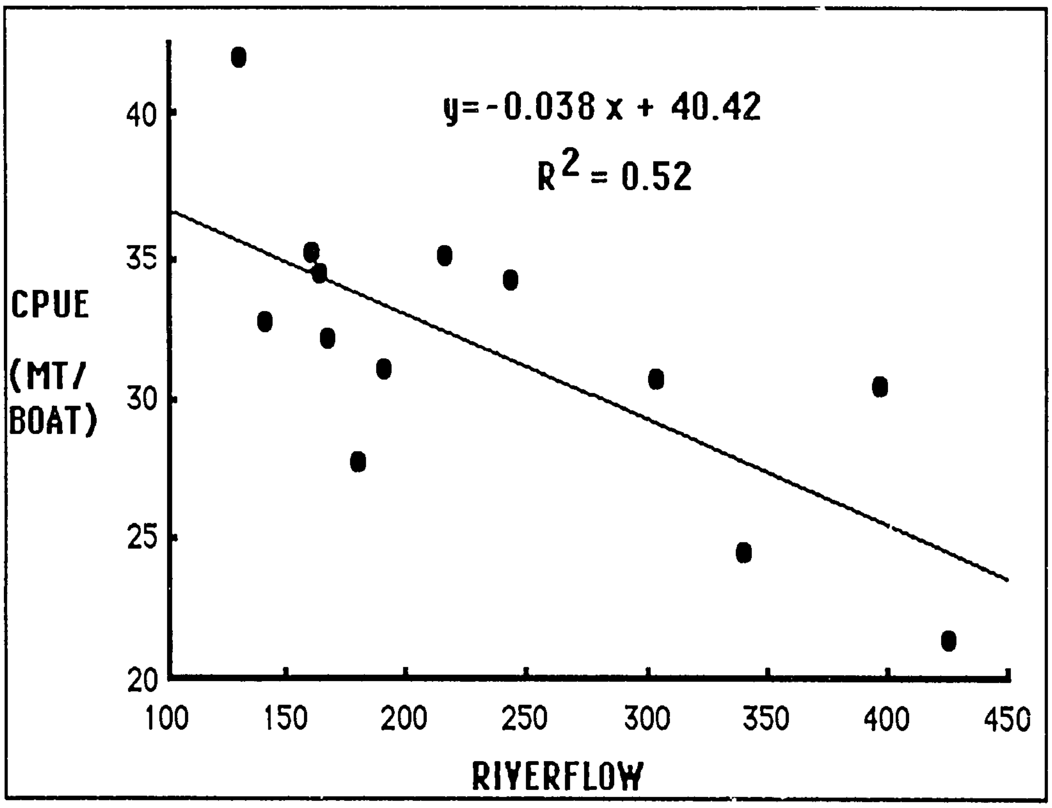


Figure 12. An example of climatic relationships with shrimp landings. Shown here is the relationship between winter riverflow (January through March) and trawl fisheries' catch per vessel for Ecuador from 1965 to 1979. The unofficial record of catch in the latest El Nino year resulted in a very high value for CPUE (not shown), suggesting that the curve rises steeply to the right, beyond the riverflow shown in this graph.



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Multi-temporal Study of Mangrove, Shrimp Farm and Salt Flat Areas in the Coastal Zone of Ecuador, Through Information Provided by Remote Sensors

Estudio Multi-temporal de las Areas de Manglar, Piscinas Camaroneras y Salitrales en la Zona Costera del Ecuador, Mediante Información Proporcionada por Sensores Remotos.

Agustín Alvarez, Byron Vásconez y Luis Guerrero

Resumen

La comparación de datos estadísticos de dos series de mapas de la costa ecuatoriana, muestran que en 1969 había unas 203.695 ha de manglares, las cuales fueron reducidas a 182.107 ha, en 1984, lo que significa una disminución del 10,6%.

La causa principal del cambio en los manglares y salitrales es la actividad humana, incluyendo: (a) construcción de piscinas camaroneras, las que existían en pequeña escala en 1969, pero que en 1984 cubrían una superficie de 89.367 ha; y (b) expansión urbana hacia las áreas de manglares (Limones, Esmeraldas, Muisne, Guayaquil, Machala y Puerto Bolívar) que suman una pérdida de 1.200 ha.

Por otra parte, se observan cambios en la línea de costa, alrededor de las islas, especialmente en el Golfo de Guayaquil, debido a la acumulación de sedimentos transportados por los ríos Guayas, Jubones y otros ríos menores, y a la propagación natural del manglar en las áreas de sedimentación. Esta colonización expontánea de manglares suma unas 1.600 ha y está localizada principalmente al sur de la Isla Escalante, entre las Islas Malabrigo y Los Ingleses, y a lo largo de la línea de costa entre el rio San Pablo y Puerto Bolívar.

Los salitrales, antes de la construción de piscinas cubrían aproximadamente 51.495 ha (1969), mientras que en 1984 la existencia era de 20.024 ha, lo que indica que habrían sido utilizadas unas 31.471 ha entre tales años.

Introduction

Utilizing information collected from remote sensors, radar images, infrared, black and white, and panchromatic aerial photographs, a series of thematic charts of the mangrove areas, shrimp farms and salt flats of the Ecuadorian coast were developed. The first series consists of 100 charts, which contain information (updated to November 1984) on mangrove areas, shrimp farms and salt flats. The second series consists of 98 charts containing historical information on mangrove areas and salt flats before the beginning of construction of shrimp farms, taking 1969 as the reference year. These charts also cover other land use categories such as brush, agricultural areas, forests and urban settlements.

Comparing the statistical data of the two series of charts showed that in 1969, coastal Ecuador contained approximately 203,695 hectares (ha) of mangrove area, which by 1984 was reduced to 182,107 hectares, or a reduction of 10.6 percent. The principal cause of this change in the mangrove and salt flat areas is human activity including:

- construction of ponds for shrimp mariculture, which in 1969 existed on a small scale, but by 1984 covered an area of approximately 89,367 ha.
- urban expansion: all human settlements located close to the mangrove areas have grown extensively, including Limones, Esmeraldas, Muisne, Guayaquil, Machala and Puerto Bolivar.
- Total urban expansion accounts for loss of approximately 1,200 ha of mangrove and salt flats.

There is also a definite change in the coastlines on the continental shores, around the islands and especially in the Gulf of Guayaquil because of:

- accumulation of sediments transported by the Guayas and Jubones Rivers, and other minor tributaries.
- natural propagation of mangrove, which spontaneously colonize areas covered by sedimentation. This spontaneous growth of mangroves accounts for an area of approximately 1,600 ha, and is located principally to the south of Escalante Island, between the islands of Malabrigo and Ingleses, and along the coast between the mouth of the San Pablo River and Puerto Bolivar.

Background

Coastal resources are becoming increasingly important. Rational, efficient and scientific management are fundamental for their conservation and optimal utilization. In Ecuador, an important coastal resource is the mangroves, which are a very complex structure due to the interaction of ocean, land and atmosphere, and the animal life which inhabits them.

Mangroves have been exploited to satisfy various human needs such as:

- pilings for construction
- charcoal
- tannic acid
- fish, crustaceans and mollusks used as food and in commerce

The raising of *Penaeus* shrimp began in Ecuador in 1966 in small natural lagoons left after spring tides. Due to the high profitability of this activity, artificial ponds for shrimp farming were built, originally in salt flat areas. But by 1978-79, shrimp farms started to expand to include mangrove areas, creating the need for basic cartographic documentation upon which to base coastal resource management decisions.

The Military Geographic Institute (CLIRSEN) decided to test the applicability of remote sensing technology to the preparation of thematic charts of the mangrove ecosystem, using a zone between Machala and Puerto Bolivar as a pilot site.

The objectives of the pilot study were to:

- determine whether tele-detection techniques used for qualitative and quantitative studies of the test site mangrove areas could be applied to the whole Ecuadorian coast.
- evaluate changes in coverage and land use caused by human activities.
- present multi-temporal cartographic documentation, which will serve as support for the investigation and management of this ecosystem.

The results obtained by this pilot study were completely satisfactory. The results also suggested that the study should be continued for the remaining coastline, with preferential use of infrared color photography. Therefore, the Subsecretaria de Recursos Pesqueros, Direccion de la Marina Mercante and CLIRSEN formed an agreement for technical cooperation to continue a full-scale remote sensing study of mangrove, shrimp farm and salt flat areas in the coastal zone of Ecuador. The following is a summary of that project.

Methodology

The methodology applied in the present study was an elaboration of that used in the pilot study of Machala--Puerto Bolivar. Information was collected on the mangrove areas in Ecuador from remote sensing data, radar images, infrared, black and white (b/w) and panchromatic aerial photographs. The Military Geographical Institute supplied base maps which were used as a basis for the transcription of the information obtained. Radar images were utilized in the form of 20 mosaics and 6 strips at a scale of 1:100,000. The photographs collected were 120 infrared b/w photographs of the Gulf of Guayaquil, 30 infrared photographs of the areas of San Lorenzo and Esmeraldas, and 910 aerial photographs (panchromatic), varying in scale between 1:10,000 and 1:60,000.

Procedure

The study procedure consisted of several substages. The first involved the preparation of thematic charts of mangrove areas, shrimp farms and salt flats with information updated to November 1984. The scale used was 1:25,000. For this part of the project, radar images and infrared photographs were utilized and interpretation was checked in the field. The next step was preparation of thematic charts of mangrove and salt flat areas before construction of shrimp farms, using 1969 as the reference year. Finally, the cartography was elaborated on a scale of 1:25,000, complimentary to the material acquired from the Military Geographical Institute. This process included:

- determination of thematic legend
- interpretation of radar images and aerial photographs
- preparation of preliminary maps
- field tests and readjustment of visual interpretation
- taking agricultural soil samples for analysis of salinity and quantifying mapped areas of mangrove, shrimp farms and salt flats

The following thematic legend was used:

- M1 mangrove, height exceeding 15m
- M2 mangrove, height between 5 and 15m
- M3 mangrove, height less than 5m
- C shrimp ponds, built or in construction
- S salt flats
- Ag agricultural areas
- M brush
- B natural forest, no mangrove

- V mixed forest with mangrove occupying approximately 60 percent of area (typical of San Loren. o, Esmeraldas).
- U urban areas

Conventional procedures were used in the interpretation of the aerial photographs. For interpretation of the radar images, the fact that the images were taken on the X-band, 3.2 cm wavelength were taken into account. With the visual interpretation, prints were made which were used in the preparation of the preliminary maps. During the ground truthing, the preliminary maps were utilized and necessary readjustments of photo interpretation were made. These tests were made from the ground, water and from the air, and the results used to refine the maps updated to 1984. Results of areas quantified with the final maps are shown in Table 1.

Results

Cartographic Results

A series of 100 thematic maps (1:25,000) of mangrove areas, shrimp farms and salt flats were prepared, with data updated to November 1984. Another series of 98 maps of mangrove and salt flat areas were prepared using 1969 as reference, (see "Estudio Multi-temporal de Manglares, Camaroneras y Areas Salinas de la Costa Ecuatoriana, Mediante Informacion de Sensores Remotos," CLIRSEN, 1986, pg. 40-42).

Results of Soil Analysis

Results obtained show no incidence of salinity originating from shrimp ponds in agricultural lands. The results can only be accepted as reference and it is recommended that additional tests be made at different times of the year to obtain more reliable information.

Discussion

Analysis of the statistical data indicates that the areas covered by mangrove in Ecuador suffered a reduction of approximately 21,587 (ha), or 10.6 percent, between 1969 and 1984. In general, the reduction of mangrove covered areas is caused principally by construction of shrimp ponds, and to only a minor degree by urban expansion (Table 2). The province most affected is Manabi, with a loss of 38 percent, caused exclusively by the construction of shrimp farms.

Urban expansions during the 15 year study period cover approximately 1,152 ha, distributed as follows:

- Limones 24 ha
- Atacames 51 ha
- Muisne 7 ha
- Guayaquil 1,010 ha
- Machala--Puerto Bolivar 60 ha

Urban expansion also extends into salt flat areas, particularly in Guayaquil and Machala.

In general, mangrove covered areas are continuing to diminish. But it must also be noted that new areas are being colonized, especially around islands and along the coastline of the Gulf of Guayaquil (Table 3). This process of mangrove colonization will increase with sedimentation in the areas along the Guayas, Jubones and Canar Rivers and other minor tributaries.

Table 1
Changes Produced in the Coverage and Soil Use of the Mangrove Ecosystem

	MANGROVE			SALT FLATS		
	1969	1984	Dif.	1969	1984	Dif.
GUAYAS	125,613.33	119,526.162 95.15%	6,087.168 4.85%	40,898.8	17,340.091 42.4%	23,558.709 57.6%
EL ORO	33,633.5	24,455.8 72.715	9,177.7 27.29%	9,781.5	2,520.006 25.77%	7,621.494 74.23%
ESMERALDAS	32,032.55	30,152.58 94.13%	1,879.97 5.87%	-	-	-
MANABI	12,415.75	7,973.414 64.22%	4,442.336 35.78%	815	163.75 20.1%	651.25 79.9%
TOTALS	203,695.13	182,107.956 89.4%	21,587.174 10.6%	51,495.3	20,023.847 38.9%	31,471.453 61.1%

Table 2
Utilization of Mangrove Areas for Urban Expansion

Approximate Figures

Guayaquil	1.010 ha
Machala Pto. Bolivar	60 ha
Atacames	51 ha
Limones	24 ha
Muisne	7 ha
TOTAL	1.152 ha

Table 3
Colonization of Mangrove (New Growth)
Aproximate Figures

Isla Puna	56 ha
Isla Malabrigo e isla de los Ingleses	510 ha
Sur Islas Escalante	289 ha
Linea de Costa entre San Pablo y Pto. Bolivar	745 ha
TOTAL	1,600 ha

Before the beginning of shrimp pond construction and urban expansion (circa 1970), salt flats covered approximately 51,495 ha. In 1984, some 20,023 ha were still available, which indicates that 31,471 ha have been utilized in the intervening years.

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The Daule-Peripa Dam Project, Urban Development of Guayaquil and Their Impact on Shrimp Mariculture

El Proyecto de la Presa Daule-Peripa, el Desarrollo Urbano de Guayaquil y sus Efectos en la Maricultura del Camarón.

Luis Arriaga

Resumen

El documento está centrado en dos factores considerados importantes para la maricultura del camarón: las operaciones de la presa Daule-Peripa y el desarrollo urbano de Guayaquil, los cuales están ligados al problema del mantenimiento de la calidad del agua en el estuario del río Guayas.

Inicialmente se ofrecen informaciones sobre el sistema fluvial de la cuenca del Guayas y las características del proyecto de propósito múltiple Jaime Roldós Aguilera (Proyecto Daule-Peripa).

El plan para desarrollo agrícola en la Cuenca Inferior del río Daule, comprende 50.000 ha (área entre Palestina y Petrillo), con una primera fase de 17.000 ha orientadas al cultivo de arroz, maíz, soya, frejol, tomate, cebolla e higuerilla, con cultivos alternados de melón, pimentón y sandía. Sobre esta base se estima que habrá un aumento significativo en el uso de insecticidas y herbicidas, en su mayoría compuestos órgano-colorados, órgano-fosforados y carbamatos. A este respecto no existen datos confiables de referencia sobre las concentraciones de pesticidas existentes en organismos, sedimentos y agua en el estuario del Guayas.

De acuerdo a las condiciones de la cuenca aportante a la presa Daule-Peripa, no se espera problemas en la calidad del agua a este nivel; por ello la vigilancia debería centrarse básicamente en la parte baja de la cuenca.

En relación a los efectos del desarrollo urbano de Guayaquil y Eloy Alfaro (Durán), y las descargas de los desechos domésticos e industriales, se presentan informaciones disponibles sobre las condiciones físico, químicas y bacteriológicas proporcionadas por varios autores y por los trabajos sobre modelos de calidad del agua desarrollados en la Empresa Municipal de Alcantarillado de Guayaquil (EMAG), señalando que la presencia de bacterias coliformes fecales, en el curso del río Daule, desde la altura de la Toma, y frente a la parte norte de Guayaquil, sobrepasan los niveles aceptables, según los índices de referencia usados por la EMAG.

Puesto que la construcción de piscinas camaroneras llegan hasta la periferia de la ciudad de Guayaquil, el tratamiento de las aguas residuales se hace cada vez más urgente. Por otra parte, debería establecerse un programa de vigilancia de los pesticidas en el curso inferior del río Daule, puesto que podrían constituir el mayor riesgo para las camaroneras del estuario del Guayas.

Introduction

Shrimp production in ponds has shown accelerated growth in Ecuador during the last decade. It constitutes a very important economic activity, showing its benefits in generation of jobs, foreign currency, and use of areas formerly considered unproductive. At the same time, the industry presents a variety of problems, the consequences of which cannot as yet be estimated: destruction of mangroves, conflicts concerning the use of coastal land, modifications of the coastal ecosystem, obstacles in natural drainage systems, etc.

Numerous studies have analyzed the characteristics of the Ecuadorean shrimp industry, its traditional fishing methods and farming of shrimp in ponds. Besides the industry's problems with collection and production of postlarvae, the availability of areas suitable for the construction of additional ponds and processing and commercializing the final product, additional factors must be considered because of their critical effects on the long-term health of the shrimp industry, especially shrimp farming.

These factors are related to environmental conditions and the quality of water in shrimp breeding and nursery areas. Natural processes such as floods, sedimentation, erosion and predation affect water quality, as do the results of human activity, including domestic, industrial and agricultural sewage, and changes in the natural flow of water due to the construction of dams, reservoirs, flood control projects, or extraction of water for human use and irrigation. Naturally, some of these factors, if adequately managed, can have a positive effect on shrimp farming, such as construction of dams and reservoirs, which permit control of water volumes and protection from floods.

While many of the ideas in this paper may generate additional research, the scope of this presentation is limited to those basic considerations that the author believes are most important:

- the effects of the Daule-Peripa dam (currently under construction) and associated projects on the shrimp industry.
- the impact of urban development on shrimp aquaculture, particularly in Guayaquil, as shrimp farms are already located very close to the suburban limits of the city.

The geographical area referred to in this paper is limited to the areas of shrimp farms located around the Guayas river estuary and the Estero Salado.

The Guayas River Basin

The fluvial system of the Guayas River consists basically of the Daule and Babahoyo Rivers and their tributaries. It drains an area of approximately 33,700 square kilometers (km) and is distributed as follows:

Daule River basin	13,800	km
Babahoyo - Vinces River basin	17,900	km
Taura River and others (10)	2,000	km
	33,700	km

The Guayas River, from the junction of the Daule and Babahoyo Rivers at Guayaquil to its mouth opposite Isla Verde Island, is approximately 56 km long. Parallel to its course lies an extensive body of salt water called Estero Salado, with many inlets and an ample mangrove ecosystem. Tidal influence is present as far as 100 km upriver.

The Guayas River and the Estero Salado are connected at one point by the Estero Cobina, a man-made canal with locks, which permits the transit of small vessels. More open communication exists in the area called the Interior Guayas River Estuary, between the islands of Escalante and Puna. The amount of fresh water entering the Estero Salado is difficult to determine, but constitutes a factor of major importance in the ecological characteristics and processes of the entire area (Twilley, this volume).

The Daule - Peripa Dam Project

The Jaime Roldos Aguilera multiple purpose project (Daule-Peripa Project) has the following objectives:

- to furnish water for irrigation and human consumption in the lower part of the Daule basin, for the Santa Elena peninsula and the province of Manabi.
- to generate hydroelectric power.
- to provide protection against flooding in the lower sections of the Daule basin during rainy seasons.
- to improve the supply of drinking water for the settlements and towns along the shores of the Daule River and the city of Guayaquil.
- to provide an increased flow of water to avoid salt water intrusion in the lower part of the Daule River during dry season.

To meet these objectives, several important projects have been developed, such as canal systems for irrigation of the Santa Elena peninsula and Manabi, hydro-electric plants, etc.

Table 1 indicates the principal technical specifications of the Daule-Peripa Project and reservoir, as provided by CEDEGE (Comision de Estudios para el Desarrolo de la Cuenca del Rio Guayas). The area which drains water into the reservoir comprises 4,025 km (Mendoza, 1983). The reservoir will flood 77 km along the shores of the Daule River and 98 km along the Peripa, plus the lower parts of their tributaries.

The area of deforestation and removal of vegetation matter will comprise 33,750 hectares (ha), and the area to be flooded will cover 27,000 ha. The annual draw-down will be approximately 10 meters, and the flooded area will remain at 18,000 ha.

Agricultural Development Project

The proposed irrigated area comprises 125,000 ha and is located in the lower Daule River basin, the Santa Elena peninsula and the province of Manabi. In the lower Daule section, the irrigated area of 50,000 ha is located on both shores of the Daule River between Palestina and Petrillo.

The first phase of this project (Mendoza et al., 1983) covers 17,000 ha, divided into four sub-projects (San Jacinto, Higueron, El Mate and America). The area will be used for plantations of rice, corn, soybeans, beans, onions, tomatos and castorbeans, besides alternate produce such as cantaloups, peppers and watermelons (Herman, 1986). The number of hectares assigned to each product is shown in Table 2. It must be noted that there will be a progressive incorporation of areas to be irrigated during a period of seven years (1983-1989), according to the rate of development as indicated on Table 3. This is also important from the point of view of a necessary increase of irrigation water flow rate, and the use of pesticides and fertilizers.

Use of Pesticides and Fertilizers

Rice is the main crop in the lower Daule basin. Mendoza established these figures for land use for the year 1981 for the following products:

Rice	6,446	ha (rainy season)
	6,025	ha (dry season)
Coffee	226	ha
Cocoa	254	ha
Others	134	ha (rainy season)
	92	ha (dry season)

Information on the use of pesticides on rice in the area of the agricultural project can be found in Table 4. There is no adequate information available on the use of pesticides on other products. The same table (4) gives an estimate on the use of pesticides on completion of phase one of this project. The estimate is calculated on the basis of normal dosage per hectare in these plantations, and according to the intensity of soil use (Campana, 1986).

The major part of the pesticides indicated on Table 4 are organochlorine and organophosphorus compounds, plus carbamate compounds and other urea-based herbicides. Regarding the possible effects of these pesticides the following must be taken into account:

- Organochlorine pesticides are relatively insoluble in water, but are absorbed readily by particulated matter and easily transported to rivers. The toxic is accumulated in fatty tissue, crustaceans being particularly sensitive to these compounds. Some chlorine insecticides, such as Dieldrin, remain active in soil for an average of eight years (range 5-25 years) and usually are applied in doses of 1 to 3 kilos per ha per year.
- Organophosphorus pesticides are relatively water soluble, less stable than organochlorine types and, therefore, do not persist in the environment. For this reason, the degree of bioaccumulation is not important in these compounds. These compounds, however, are highly toxic to aquatic organisms.
- Carbamates and other urea-based herbicides are moderately water soluble compared to the above groups. These compounds are absorbed by particulated matter and remain in sediments for prolonged periods. They are of minor toxicity to fishes and molluscs, but highly toxic to crustaceans. For this reason, some carbamates have been used for control of crustaceans, which in some cases are considered pests.

One of the problems associated with the use of pesticides is the method of application. For instance, in dispersion from aircraft, only 25 percent of the pesticide may reach its target, while the rest drifts into adjacent areas.

It has not been possible to obtain concrete data on the concentrations of pesticides in the water and in aquatic organisms in Ecuador, or data on tests dealing with rates of tolerance. Experiences in other countries could possibly be used as references. For example, the following average limits of tolerance for white shrimp (*Penaeus schmitti*) were established in bioassays in Venezuela:

Temperature	37.4°C
Ammonia as N	5.3 mg/l
Dissolved Oxygen	1.6 mg/l

The execution of the first phase of the agricultural development project in the lower Daule basin will undoubtedly produce large increases in the volume of pesticides used. It will be of paramount importance to establish a monitoring program, particularly on the presence of organochlorine pesticides and the degree of sensitivity of shrimp to these compounds.

The use of fertilizers, on the other hand, is not considered harmful to aquatic organisms, as long as the fertilizers do not accumulate in waters that flush slowly. In such cases, excessive amounts of nutrients such as nitrogen and phosphorus can induce phytoplankton blooms, followed by deoxigenation and anaerobic collapse (eutrophication). Sediments are also affected by deposits of nutrients, which can be liberated through agitation or turbulence.

Water Quality in the Daule River Basin

Based on the physical, chemical and bacteriological values of the water of the Daule River basin, Mendoza concluded that the water in the upper part of the river is suitable for drinking, irrigation and other uses. This region is part of the supporting sector which drains into the Daule-Peripa reservoir. In the lower section of the Daule River, the water is not suitable for direct human consumption during the dry season, but can be used for irrigation, except for the area below the La Toma, due to salt water intrusion during the dry season.

Water quality values found in the lower part of the Daule River (water treatment plant, La Toma) are shown in Table 5. The high concentration of coliform bacteria calls for attention.

From this data, no problems of water quality in the Daule-Peripa basin are expected. But much attention must be paid to control of contamination from sewage (both domestic and agricultural) in the middle and lower part of the Daule basin.

An additional problem is the potential risk of eutrophication in the Daule-Peripa reservoir (due to excessive accumulation of nutrients) and subsequent phytoplankton blooms. An environmental conservation plan designed by CEDEGE includes the necessity of cleaning and eliminating of excessive plant growth in the reservoir and in the supporting hydrographic system.

Although this paper concentrates on the identification of water quality problems of the Daule River, it is also important to consider information on conditions of the Babahoyo River. A water quality model by EMAG (Empresa Municipal de Alcantorillado de Guayaquil) for the mouth of the Babahoyo River and its confluence with the Daule showed very high values of fecal coliform bacteria during 1979-1980:

fecal coliforms	8.08 x 10>	MPN/100 M1
dissolved oxygen (DO)	6.5	mg/l
free oxygen	6.5	mg/1
chloride	6.949	mg/l

Water Flow in the Daule and Guayas Rivers

The rate of flow of the Guayas River determines processes such as dilution of salt water intrusion, dilution of contaminants, interchange with the Estero Salado system and self-purification before its discharge into the ocean. For this report, no data on direct measurements of flow rates of the Guayas and Babahoyo Rivers were available, but both show wide seasonal variations, especially between the dry and rainy period, as does the Daule River.

The most precise data available correspond to the flow of the lower part of the Daule River. The historic average for this river may be derived from a time series of 32 years (1950-1981). Table 6 shows figures for the average monthly flow rates at La Toma, as published by CEDEGE. Based on this information the average monthly flow rate is 333.4 cubic meters per second (m^3/sec). A high flow rate of 1.043.6 m^3/sec, is registered in March (rainy season) and a low of 39.9 m^3/sec during November (dry season).

To establish flow rates of the Guayas and Babahoyo Rivers, also indicating their monthly variations, the consistent relationship between the Daule and the Babahoyo has been utilized. The EMAG water quality model indicates that the flow rate of the Babahoyo River is 50 percent higher than the Daule during the dry season, and 100 percent higher during the rainy season.

Table 6 summarizes the average flow rates of the Babahoyo at its mouth, and flow rates for the Guayas at its point of origin opposite the city of Guayaquil. An average flow rate of 30.276 x 10 m^3 per year was established, which is the contribution of the Guayas River to its interior estuary. The discharge of the Taura River and other small tributaries have not been taken into consideration.

The projected Daule River flow rate needed to satisfy the demand for water in the future (year 2006) is the following:

• deviation to the Santa Elena peninsula for irrigation, domestic and industrial use	24.1 m^3/sec
• irrigation for 17 ha in lower Daule basin (1st phase of agricultural development	7.0 m^3/sec
• potable water (Guayaquil)	12.0 m^3/sec
• flow rate necessary to avoid salt water intrusion to La Toma	28.0 m^3/sec

These figures establish the need for a constant flow rate which is higher than the average figures registered during the dry season (September-December). This problem will be solved with the operation of the Daule-Peripa Project, which will control the flow of water and will provide a constant flow rate of 100 m^3/sec (V. Mendoza, CEDEGE, personal communication).

Urban Development of Guayaquil-Durán and Its Effects on Water Quality

It is frequently stated that the problems which affect the quality of bodies of water in the proximity of Guayaquil (Guayas River and Estero Salado) are caused principally by discharges of untreated domestic and industrial sewage. Only sewage originating from the Alborada residential development, located to the north of the city, receives partial treatment. This critical environmental problem increases continually due to the excessive growth rate of Guayaquil, at present 4.5 percent annually (CLIRSEN, 1985).

Nevertheless, the results of studies by EMAG and the situation presented by the water quality models show a somewhat optimistic picture of the bodies of water which surround Guayaquil.

Actual Conditions of the Estero Salado

N. Campana, (1986) presents an analysis of the average physical and chemical characteristics of the Estero Salado for both the dry and rainy seasons. Table 7 contains data for five different test sites on the estuary. The sites had been selected to show the most relevant variations in the complex system of creeks and canals typical of the Salado. Results indicate that the conditions of contamination in the proximity of Guayaquil show positive signs of improvement as distance from the city limits increases. For instance, at the mouth of the Chongón River close to the quarantine station of the port of Guayaquil, the water is relatively clean.

Also, in the area of the Estero Salado, where most of the shrimp ponds are located, water quality is satisfactory, according to data supplied by EMAG.

Water Quality Models

EMAG has developed water quality models for the Daule and Guayas Rivers and for the Estero Salado to establish the following: concentrations of residual discharges from Guayaquil and Duran into the surrounding bodies of water; water quality produced by the increase of population in this area; and to determine how the above will affect water quality in the future (1996-2006). At the same time, the results of the above studies determine the number of sanitary installations needed to preserve the quality of the environment. The models cover the following parameters (Castagnino, 1983, 1985):

Guayas River	Daule River	Estero Salado
salinity	salinity	salinity
coliform bacteria	coliform bacteria	coliform bacteria
oxygen	oxygen	oxygen
BOD (Biological Oxygen Demand)	BOD	BOD
–	nutrients	phytoplankton
–	toxic elements	–

The principal references utilized in the EMAG models for different uses of water are given in Table 8. The ultimate type of uses for the different areas of the Salado have also been determined:

- areas of esthetic protection
- areas reserved for shrimp mariculture
- recreational areas
- areas of ecological protection
- extraction of potable water

Finally, criteria for the evaluation of the environmental impact of both the positive and negative aspects of the sewer system of Guayaquil have been observed. Local effects (sewage discharge, pumping sites, water treatment plants, odors, etc.), sanitation and other regional effects are all considered by the model.

Impacts at the Site of La Toma

Assuming that the rate of flow of 40 m^3/sec is maintained in the areas above La Toma, the model predicts coliform bacteria concentrations (the critical factor in the water quality of this zone) of 3,886 MPN/100 ml, originating from the discharges from the northern area of Guayaquil. These values are higher than the permissible maximum.

Impact on the Shrimp Mariculture

In this case, the model references correspond to the areas dedicated to shrimp farms in the proximity of the Guayas River (Santay Island and Guayaquil Peninsula). Projecting the volume of discharges to the year 2006, there will be a loading of fecal coliform bacteria equivalent to 3,056.2 and 4.082.1 MPN/100 ml in this zone. Beginning in 1996, then, primary treatment (reduction of 95 percent of coliforms) will be necessary.

Based on an annual population growth rate of 4.5 percent, with 80 percent serviced with potable water and sewage systems, an estimate of 200 liters per day of waste water has been estimated. This waste water will have to be treated in ponds which will be located along the Salado Estuary. These ponds will have the following dimensions and treatment capacities:

	Year 1996	Year 2006
Pond T-1	(13 ha) 12.960 m^3/sec	(15 ha) 21.300 m^3/sec
Pond T-2	(13 ha) 12.960 m^3/sec	(75 ha) 74.868 m^3/sec

Treatment in ponds, or any other system that may be used, must comply with the following standards:

Reduction	Percent
• coliform bacteria	95
• phosphorus	40
• orthosphosphates	40
• carbonaceous BOD	85
• nitrogenated BOD	30

Conclusions

The major risk for shrimp farms, originating from the future operation of the Daule-Peripa dam and associated projects, lies in the use of pesticides from agricultural development. The first phase comprises the incorporation of 17,000 ha of farmland located in the lower part of the Daule basin. Special attention must be paid to control of concentrations of organochlorinated pesticides. So far, it has not been possible to obtain information regarding concentrations of pesticides in waters and in aquatic organisms.

Controls over potential processes of eutrophication in the Daule-Peripa reservoir must also be constructed, even though no significant impact on shrimp aquaculture is to be expected from this source. It is considered more convenient to exercise control of eutrophication in the areas where shrimp farms are located and in the areas of mangrove in the vicinity of Guayaquil.

There is no information available on the interchange between the freshwater system of the Guayas River and the salt water system of the Estero Salado. However, the main interchange takes place in the interior estuary of the Guayas River.

The major risks of contamination originating from the discharges of the city of Guayaquil consist of the high concentration of fecal coliform bacteria, which in some areas of the Daule and Guayas Rivers and the Salado estuary, exceed acceptable levels. These factors indicate the need for treatment of all sewage being discharged into the Guasmo and Durán.

Table 1.
Specifications of the Daule-Peripa dam and reservoir

RESERVIOR SPECIFICATIONS	
Volume of the reservoir	
At normal level (elevation 85 m)	5,500 x 10^6 m^3
Flooded area	27,000 ha
Volumes used	
For flood control	700 x 10^6 m^3
For power generation	3,500 x 10^6 m^3
For irrigation	500 x 10^6 m^3
For sediment control	300 x 10^6 m^3
Dam specifications	
Earth fill	90 m
Height above river bed	78 m
Length of crest	250 m
Spillway	
Maximum natural flow	14,350 m^3/sec
Maximum regulated flow	3,480 m^3/sec
Diversion works	
Number of diversion tunnels	2
Diameter of diversion tunnels	9 m
Length of tunnels	550 m
Discharge capacity of each tunnel	890 m^3/sec
Electric Power works	
Installed capacity	130 MW
Guaranteed capacity	81 MW
Firm annual energy	510 GWH/year
Designed discharge per unit	133.2 m^3/sec
Lateral Dams	
Approximate length	10 km
Approximate volume of dams	5.9 x 10^6 m^3

Source: CEDEGE, Guayaquil

Table 2
Areas of plantations in phase 1 of agricultural project (in ha)

Ciclo Cultivo	Rice	Corn	Soybeans	Beans	Tomatoes	Peppers	Castorbeans	Others (*)	Total Ha
Winter	12,260	1,377	686	-----	-----	-----	619	778	15,720
Summer:									
1st crop	11,011	1,489	928	599	317	289	619	778	16,040
2nd crop	-----	1,499	928	599	317	122	-----	-----	3,465
Intensity of annual soil use									35,225

(*) 70 ha Cotton and 78 ha Sorghum
Source: Adapted from CEDEGE: 1981, Table page 34(3)

Table 3
Progressive incorporation of ageas to be irrigated.
Phase 1 of project (ha)

Years	1 (1983)	2 (1984)	3 (1985)	4 1986)	5 (1987)	6 (1988)	7 (1989)
Hectares 16,040	1,881	1,956	2,032	11,581	13,007	14,437	

Source: CEDEGE

Table 4

Use of pesticides in the area of agricultural development (Daule-Peripa Project) (From, Mendoza, eta al, 1983)

Pesticides		Annual consumption (*)	Consumption of agricultural project (**)
Herbicides			
Propanil:	Winter	39,480	68,656
	Summer	36,708	61,662
Agroxone:	Winter	4,935	8,582
	Summer	4,589	7,708
Gesoprin:	Winter	-----	4,131 kg
	Summer	-----	8,994 kg
Lazo:	Winter	-----	2,058 kg
	Summer	-----	8,563 kg
Gesagard:	Winter	-----	686 kg
	Summer	-----	1,856 kg
Afalón:	Winter	-----	-----
	Summer	-----	1,198 kg
Ronstar:	Winter	-----	-----
	Summer	-----	2,219 l
Amiben:	Winter	-----	-----
	Summer	-----	1,440 kg
Treflan:	Winter	-----	-----
	Summer	-----	465 kg
Insecticides			
Endrín:	Winter	19,740	17,164
	Summer	18,354	15,415
Folimat:	Winter	3,948	-----
	Summer	3,671	-----
Furadán:	Winter	92,120 kg	19,278 kg
	Summer	85,652 kg	41,972 kg
Azodrín:	Winter	-----	8,582
	Summer	-----	7,708
Sevín:	Winter	-----	2,063 kg
	Summer	-----	6,051 kg
	Summer	-----	951
Nuracrón:	Winter	-----	686
	Summer	-----	2,745
Aldrín:	Winter	-----	1,029 kg
	Summer	-----	4,686 kg
Dorrhan:	Winter	-----	-----
	Summer	-----	899
Dipterex:	Winter	-----	-----
	Summer	-----	951
Lannate:	Winter	-----	-----
	Summer	-----	206
	Summer	-----	310 kg
Orthene:	Winter	-----	-----
	Summer	-----	206
	Summer	-----	310 kg

(*) only for rice planatations, which comprise 96 percent of total area cultivated.

(**) with annual intensive soil use of 33,050 ha, including plantings of rice, corn, soybeans, beans, tomatoes, peppers, castorbeans (see Table 2).

Mendoza, et al. 1983

Table 5
Average physical, chemical and bacteriological parameters at LA TOMA site (Daule River), (1980-1982).

Parameter	1980 R.S.	1980 D.S.	1981 R.S.	1981 D.S.	1982 R.S.	1982 D.S.
Temperature (°C)	28.9	27.5	28.0	27.1	28.5	—
Suspended solids (mg/l)	284.0	646.0	153.0	452.0	34.4	—
Settling solids (mg/l)	0.4	1.8	---	0.9	0.2	—
Dissolved solids (mg/l)	194.0	670.0	129.0	1,026.0	---	—
Total solids (mg/l)	478.0	1,316.0	282.0	1,478.0	697.0	—
pH	7.4	7.4	7.2	7.3	7.0	—
Salinity (mg/l)	151.1	501.3	80.3	815.0	90.0	—
Clorides (mg/l)	67.0	282.0	28.0	436.0	37.0	—
Sulfates	82.0	61.0	---	78.0	11.5	—
N-organic (mg/l)	0.415	0.146	0.22	0.208	0.04	—
$N\text{-}NH_3$ (mg/l)	0.04	0.01	---	0.55	---	—
$N\text{-}NO_2$ (mg/l)	0.07	0.03	0.0	0.02	0.07	—
$N\text{-}NO_3$ (mg/l)	4.84	4.76	0.27	2.27	0.78	—
Oxygen (mg/l)	5.85	5.92	6.12	6.22	6.36	—
BOD (mg/l)	2.34	1.44	1.41	1.0	1.30	—
Fecal coliforms (MPN/100 ml)	4,193	25,949	2,614	2,264	3,268	—
Total coliforms (MPN/100 ml)	8,757	62,536	8,440	9,383	7,422	

Source: Data from EMAG, in Mendoza et al
R.S. = Rainy season
D.S. = Dry season
--- = No data

Table 6
Average monthly flow rate of the Daule River (1980-1981) and estimated flow rates of the Guayas and Babahoyo Rivers (m^3/sec)

River	Rainy Season Jan.	Feb.	Mar.	Apr.	May	June	Dry Season July	Aug	Sept	Oct	Nov	Dec	Yr. Aver.
Daule (1) (La Toma)	297.7	689.2	1,043.6	847.9	482.7	231.0	131.1	68.3	54.7	49.4	39.9	65.5	333.4
Babahoyo (2)	595.4	1,378.4	2,087.2	1,695.8	695.4	346.5	196.7	102.5	82.1	74.1	59.9	98.3	640.2
Guayas (3)	893.1	2,067.6	3,130.8	2,543.7	1,448.1	577.5	327.8	170.8	136.8	123.5	99.8	163.8	973.6

(1) Volumes observed by CEDEGE
(2) Estimated volumes (Factors: rainy season - 2.0; dry season - 1.5)
(3) Estimate at junction of Daule and Babahoyo Rivers

Table 7
Values registered in the Salado inlet for
dry season (June-December) and rainy season (January-May), 1985 averages

	T°C	Salinity (mg/l)	D.O. (mg/l)	BOD5 (mg/l)	P-Total (mg/l)	Fecal Colif. (NMP/100ml)	Total Colif. (NMP/100ml)	pH	NH_3 (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)
<u>Dry Season</u>											
Site (*)											
S4-A (Pte 5 de Junio)	25.7	15,195	3.08	11.50	0.66	94,666	174,166	7.6	0.30	0.01	1.26
S6-A (Pte Calle Portete)	25.5	21,705	3.53	2.54	0.27	2,933	8,916	7.5	0.15	0.08	1.32
S12-B (La Chala)(**)	30.0	13,130	0.0	20.56	1.35	16.6×10^6	123×10^6	7.3	0.85	0.03	2.92
S13-A(Estero Cabina)	25.6	20,916	4.24	1.15	0.18	564	976	7.6	0.01	0.03	1.04
S15-A(Des. Río Chongón)	25.6	21,642	4.97	2.17	0.21	430	447	7.8	0.06	0.001	1.15
<u>Rainy Season</u>											
Site (*)											
S4-A	27.5	18,638	3.07	5.86	0.33	179,833	337,667	7.3	0.37	0.70	1.40
S6-A	27.7	24,431	3.56	0.96	0.14	17,867	54,520	7.4	0.19	0.84	1.47
S12-B	28.4	17,430	0.05	10.22	0.68	$11{,}337 \times 10^5$	$21{,}175 \times 10^5$	7.1	1.06	0.42	2.24
S13-A	28.2	24,458	4.70	0.93	0.09	1,682	2,300	7.4	0.02	0.13	1.15
S15-A	28.2	25,390	6.08	1.33	0.10	4	5	7.7	0.07	0.04	1.26

Data taken from N. Campaña, 1986 (partially)
* see Figure 2
** pumping station (discharge site))

Table 8
Index of references used in water quality models, EMAG

Water use	Fecal coliforms (NMP/100ml) less than...	Dissolved Oxygen (mg/l) more than	Chlorophyll "a" (mg/m^3) less than...
esthetic protection (except coliforms)	–	1.5	50
protection of water sources for shrimp mariculture	3,000	3.5	–
recreation (human contact with water)	1,000	4.0	20
ecologic protection for fish	–	4.0	–
pumping sites for water treatment plants	4,000	1.0	–

Source: Castagniño

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Status of Coastal Water Quality in Ecuador

Estado de la Calidad del Agua Costera en el Ecuador.

Lucía Solórzano

Resumen

El desarrollo industrial y técnico en el Ecuador ha causado la contaminación de algunos sectores de la costa ecuatoriana. Según algunos estudios, las áreas más afectadas son el Río Guayas, el Estero Salado, el Río Esmeraldas y los lugares próximos a las industrias pesqueras.

En el río Guayas, los niveles en la superficie de oxígeno disuelto y DBO fluctúan entre 2,7 a 4,5 mg O_2/l y entre 0,65 a 2,88 mg O_2/l, respectivamente. Los valores de fosfato, nitrato y nitrógeno orgánico disuelto en superficie (1 m profundidad) tienen los siguientes rangos: 2,0 a 6,0 ug-at PO_4P/l; 10 a 50 ug-at NO_3N/l; y, 40,0 a 60,0 ug-at NO_3N/l, respectivamente. El cobre está entre 38,92 y 94,52 ug/l; el hierro entre 131,85 y 414,80 ug/l; y, el cadmio entre 1,0 y 14,5 ug/kg. Las investigaciones de mercurio en los sedimentos indica valores entre 1.532 y 3.250 ug/kg, peso seco. Los niveles de hidrocarburos de petróleo son menores que 2 ug/l.

En el Estero Salado, los niveles de oxígeno superficial fluctúan entre 3,0 y 4,7 mg O^2/l. Los valores superficiales (1 m) de fosfato, nitrato y amonio están entre 2,8 y 33,4 ug-at PO_4-P/l; 3,8 y 18,5 ug-at NO_3N/l; y, 5,2 y 114,2 ug-at NH_4-N/l, respectivamente. Los valores de cobre, cadmio, hierro y mercurio en los sedimentos varían entre 65,0 y 799,5 mg/kg (peso seco), o,5 y 3,2 ug/kg (peso seco), 0,56 y 2,93 g/kg (peso seco), y 190 y 4.900 ug/kg (peso seco), respectivamente. Los niveles hidrocarburos de petróleo en la superficie (1 m) son similares a los del río Guayas, excepto en los lugares donde se los suministra a los buques comerciales. En un proyecto futuro se efectuarán determinaciones de niveles de cobre, cadmio y mercurio, de las fuentes para las masas de agua y de la vías de reducción.

Las masas de agua mencionadas anteriormente son eutróficas. Las concentraciones de cobre y cadmio están sobre los límites considerados inócuos para los organismos acuáticos. No hay contaminación significativa por hidrocarburos de petróleo.

Summary

The industrial and technical development of Ecuador has caused the contamination of some sections of the Ecuadorian coastal sea. According to some studies, the more affected areas are the Guayas River, the Estero Salado, Esmeraldas River and the sections near the fishing industries.

In the Guayas River, the surface levels of dissolved oxygen and biochemical oxygen demand (BOD) fluctuate between 2.7 to 4.7 mg O_2/l and 0.65 to 2.88 mg O_2/l, respectively. The surface (1m depth) phosphate, nitrate and dissolved organic nitrogen values range between 2.0 to 4.0 µg-at PO_4 P/1, 10 to 50 µg-at NO_3 N/l and 40.0 to 60.0 µg-at DON N/l, respectively. Surface water concentrations of copper range between 36.92 and 94.52 µg/l, iron between 131.85 and 515.80 µg/l and cadmium between 0.1 and 14.5 µg/l. The research on mercury in the sediment has yielded values between 1.53 and 3.25 µg/kg of dry weight. Petroleum hydrocarbon levels are lower than 2 µg/l.

In the Estero Salado, the surface levels of oxygen fluctuate between 3.0 and 4.7mg O_2/1. The surface (1m) values of phosphate, nitrate and dissolved organic nitrogen are between 2.8 to 33.4 µg-at. PO_4-P/l, 5 to 10 µg-at, NO_3-N/1, and 6.7 to 72.7 µg-at. DON-N/1, respectively. The copper, cadmium, iron and mercury values in the sediment vary between 65.0 and 799.5 mg/kg (dry weight), 0.5 and 3.2 µg/kg (dry weight), 0.56-2.93 g/kg (dry weight) and 190 and 4,900 µg/kg (dry weight), respectively. The levels of petroleum hydrocarbon in the surface (lm) are similar to those in the Guayas River, except in the places where the commercial ships are supplied. Determining copper, cadmium and mercury levels and sources in the water masses, and means of reduction will be undertaken in a future research project.

The water masses mentioned above are eutrophic. The concentrations of copper and cadmium are over the limit considered as innocuous for aquatic organisms. There is no significant contamination by petroleum hydrocarbons.

Introduction

The economic growth of Ecuador between 1970 and 1980, together with industrial and technological development and rapid population increase produced serious ecological effects, particularly in some sections of the costal sea. The application of detergents for domestic use, heavy metals in industry, insecticides in agriculture and petroleum hydrocarbons for transportation and other uses, greatly increased. The effects of these substances on the environment prompted the scientific community to investigate the levels of these materials in the water bodies that receive domestic and industrial waste from the largest population centers of the country. The Ecuadorian government, responding to requests from the institutions conducting the marine contamination studies, partially financed some of the research projects. The scientific findings clearly justify the need to maintain permanent environmental monitoring programs in at least some of the areas where there are conflicting uses of resources.

Background

Geography

Ecuador straddles the equator and has an area of 283,562 km^2. It has a population of roughly 8 million people (1982 census).

The Ecuadorian coastal region is located between the shoreline and the external slopes of the occidental mountains that extend to a height of 1800 meters. This coastal area is generally 100 to 200 km wide, except in the adjacent part of the Guayaquil Gulf, where it is only from 20 to 30 km (Vinueza, 1984). The coastline is 1,300 km long, including all its irregularities, and 560 km in a straight line. In this region there are river basins that are the main recipients of the domestic and industrial discharges from the towns located there.

The areas below are the most affected by contaminating agents from various sources. These areas are classified (Solorzano, 1981) according to degree of contamination:

Area	Classification	Comments
Guayas River	severe	domestic and industrial debris, discharges from Guayaquil and towns nearby located in the basin; agrochemical residues from Guayas River effluents
Estero Salado	serious	domestic and industrial debris; discharges from the city of Guayaquil and oil terminal
Esmeraldas River	moderate	effluents mainly from refinery and carried by Tiaone River
Sectors adjacent to fisheries, beaches, etc.	moderate	industrial discharge on beaches, etc.

Other areas that require special attention, like the mangrove zone, particularly on the Gulf of Guayaquil, Manta (port, fishing industries, etc.) port areas including oil terminals like La Libertad and Puerto Bolívar, etc., are not listed because there is not enough information about the contamination levels.

In this work we will only refer to water bodies that surround the city of Guayaquil.

The Guayas River

The Guayas River travels a distance of 50 km before reaching the Gulf of Guayaquil. It is formed by the Daule and Babahoyo Rivers. Like its tributaries, the Guayas River is affected by the tide. The Babahoyo has four main tributaries: Vinces, Catarama-Zapotal, San Raulo and Yaguachi. These rivers are located in the northeast and southeast sectors of the lower basin. The Yaguachi River is the most meridional of the Babahoyo River tributaries. It is formed by the Chanchan and Chimbo Rivers, and also receives the water of the Milagro River. It is the Yaguachi River that shows the most significant changes in water quality of all the rivers that form the Guayas Basin. The Vinces River, that changes its name to Baba in its upper course, has its origins near the city of Santo Domingo. This river has numerous tributaries. The Daule River is the second most important tributary of the Guayas River and drains the western part of the basin (Vinueza, 1981). Its main tributaries in that margin are the Pedro Carbo, Colimes, Puca and Congo Rivers (Figure 1).

Sanitary Sewage System of Guayaquil

The city of Guayaquil is located along the Guayas River. It has approximately 1.2 million inhabitants (Dicc, Larousse, 1986) with a projected growth of 4.5 percent for the period of 1981 to 1990. In the year of 1990 Guayaquil's population will be approximately 1.75 million, and 2.72 million by the year 2000.

The total area of the city is 34,700 hectares (ha), of which only 6,100 ha have an adequate sewage system. The existing service reaches only 58 percent of the population. In 1979, 450,000 people in Guayaquil did not have sewers and every year 21,000 more people are added to this number. A large percentage of the non-serviced area is occupied by marginal urban developments and by industries (Empresa Municipal de Alcantarillado de Guayaquil, EMAG, 1980). The city's contaminated waters are emptied, without treatment, into the Guayas River, Daule River and Estero Salado.

Guayaquil has two separate classes of sewers: sanitary and pluvial. The sanitary sewage has a northern and southern division, both of which discharge the waste waters into the El Progreso and Guasmo plants. The main collector of the northern systems is 10.5 km long and serves 2,500 ha with an approximate population of 250,000 inhabitants. This collector starts in the Prosperina Section of Guayaquil and continues to the preliminary treatment at the Progreso plant, then empties into the Daule

River near the juncture of the Babahoyo River. The main collector of the southern systems is 7.5 km long and serves 1,300 ha, with an approximate population of 250,000 inhabitants. The southern collector ends in the treatment station of El Guasmo and the sewer water is discharged later through sub-aquatic piping in the Guayas River (Figure 2).

Water Quality in the Guayas River

The population explosion, as well as the rapid industrial growth of Guayaquil have increased the volume of residual waters far beyond the capacity of existing infrastructure services, thereby altering the chemical-physical conditions of the water bodies that receive them. These alterations are shown in some of the parameters detailed below.

Salinity

The salinity at the surface (1m) of the Guayas River varies continuously, but higher salinity values are always in the river outlet due to the exchange with the waters of the Gulf of Guayaquil. The salinity range is within 1 percent in the Daule River to 30 percent near the Gulf. During the rainy season, the surface salinity (1m) decreases along the river.

Dissolved Oxygen

According to Valencia (1980), the dissolved oxygen values are between 2.7 and 4.7 mg 0_2/l oxygen, with the higher values found in the area adjacent to the Babahoyo River, far from the influence of populated areas. On the other hand, in the Daule River where the debris of Guayaquil is discharged, the oxygen levels decrease to less than 2.7 mg O_2/1.

Biochemical Demand of Oxygen

The analyses performed by EMAG (1979) shows values of biochemical oxygen demand (BOD) from 0.65 and 2.88 mg/l, reaching higher levels in places where domestic waste discharges occur.

Bacteria

The domestic and industrial waste waters of Guayaquil discharged into the Daule and Guayas Rivers produce high levels of bacterial contamination, resulting in a decrease in the rivers' oxygen content, high BOD and increased concentrations of inorganic and organic nutrients that have direct effects on the ecosystems of both rivers.

Fortunately, after treatment at La Toma treatment facilities, the drinking water supplied to the Guayaquil population is of excellent quality, according to the Sanitary Microbiology Department of the National Institute of Hygiene and Tropical Medicine "Leopoldo Izquieta Perez" of Guayaquil (Table 1).

Nutrients

The distribution of surface (1 m) nutrients in the Guayas River is irregular, depending upon tides and the volume of debris discharged into the river. Valencia (1980) found that surface phosphate values fluctuated between 2.0 to 4.0 ug-at PO_4-P/1, except that in the area adjacent to the Progreso station, the concentration of phosphate increased by up to 50 percent. The author also reported similar distributions of nitrate. The levels of this nutrient were quite high, fluctuating between 10.0 and 50.0 µg-at. NO_3-N/1, with the lowest levels detected in the southern part of Guayaquil and off Santay Island, and the highest values measured near the Progreso Station, where the sewage water is discharged (Figure 2). Dissolved organic nitrogen levels (DON) were measured at 40.0 and 60.0 µg-at. NO_3-N/1, and were similarly distributed.

Metals

According to Perez (work in preparation) the quantities of copper, iron and cadmium on the surface (1m) of the Babahoyo, Daule and Guayas Rivers are variable, fluctuating between 36.92-94.52 µg/1, 131.85-515.80µg/l, and 0.05-14.5 µg/l, respectively. In the Guayas River, copper as well as iron tend to decrease inversely to salinity. In Babahoyo River, the levels of both metals are slightly higher than those of the Guayas River. Cadmium is found in almost all sampling sites of the Guayas River, with concentrations between a minimum value of 1.9 µg/l and a maximum of 10.4 µg/l. In the Daule River, cadmium levels are under 1 µg/l, except in those samples taken in the vicinity of the domestic sewage effluent, (Progreso Station), where values of 11.4 and 14.5 µg/l have been recorded.

Mercury

Mercury levels in the sediment of the Guayas River vary from 1.53 to 3.257 µg/kg of dry weight, (Chalen de Padilla, 1986). Similar results were obtained by the same author in the Jambeli Channel located in the inner estuary of the Gulf of Guayaquil.

Petroleum Hydrocarbons

The amount of dissolved hydrocarbons and/or coloids found by the author (1986) in the lower courses of the Babahoyo, Daule and Guayas Rivers varied between 0.10 µg/l and 2.80 µg/l. The highest value was recorded in a sample taken in the Guayas River after an oil spill from a commercial vessel.

Pesticides

Pesticide research has recently been conducted in some of the rivers that form the basin of the Guayas River. The pesticides investigated were DDT, Aldrin, Chlordane, Mirex, Lindane, Opade OP, Dieldrin and Heptachlore. Traces of the pesticides were detected only at the beginning of the rainy season (information provided by Agricultural Health Laboratories, Ministry of Agriculture, Ecuador).

Estero Salado

Estero Salado is a sea inlet that reaches from Canal del Morro on the south, to Guayaquil on the north. Its depth varies from 5 to 10 meters. The daily tides are approximately 3m high in Canal del Morro, 3.5m in Puerto Nuevo in Guayaquil, and 4m in the vicinity of the State University of Guayaquil. The current of the tides reach a speed higher than 100m/sec (Murray, Siripong and Santoro, 1973), and the accumulation of sediments is scarce, except in small sections of Estero Salado that are protected by mangroves. The tide currents also cause strong vertical and horizontal mixing that tends to homogenize the physical and chemical properties of the waters.

Water Quality in the Estero Salado

According to Arriaga (1976), the sewage effluents enter Estero Salado at a rate of approximately 100 l/sec, which is equivalent to 81,640 m^3 in 24 hours. If we take into account the bacteria, inorganic nutrients and soluble organic nutrients, metals, petroleum hydrocarbons, and other organic components that are present in waste water, we will better understand the alteration that occurs to the physical/chemical properties of the Estero.

Salinity

The salinity of the Estero varies between 22 and 31 percent (Pesantes, 1975). During almost all the year, the Estero has greater than 25 percent salinity, with only slight changes observed between Canal del Morro and near to Guayaquil. In areas adjacent to this city, the salinity is influenced by the domestic effluents, and especially by precipitation. These changes can be significant from one year to the other, depending on the intensity of the rains during the rainy season.

Dissolved Oxygen

The domestic discharge of 400,000 inhabitants of Guayaquil deposited into the Estero Salado is equivalent to a biochemical oxygen demand of 10,000 m.t./year, which greatly affects the concentration of dissolved oxygen. From Canal del Morro to nearby places of Guayaquil, the surface levels of oxygen fluctuate between 3.0 and 4.7 mg 0_2/l.

The concentration at the surface tends to be slightly higher than at 1 meter above the bottom. The author and Viteri (in press) found surface levels (1m) of 3.13 ml 0_2/l and bottom values of 1.79 to 2.33 mg 0_2/l, in two stations adjacent to the city of Guayaquil.

Bacteria

Research by Reyes (personal communication, 1976) indicates that, water contamination of the Estero was quite low. In contrast, microbiological analysis by Guzman (personal communication) showed the increase of contamination that occurred during the following decade.

Nutrients

In the section of Estero Salado that surrounds the city of Guayaquil, Ayarza (in press) found surface phosphate values that varied between 4.9 and 33.4 µg-at P-PO/1 and ammonia levels of 5.2 to 114.2 µg-at NH_4-N/1 (Table 2). The section that showed the highest levels corresponded to the area adjacent to two residential areas of the city of Guayaquil (Urdesa and Miraflores).

Valencia (1980) found phosphate levels higher than 4.0 µg-at PO_4-P/1 in waters near the gate at the Guayas River-Estero Salado (Figure 3), and in waters near the main avenues of Guayaquil. Ormaza in 1986 (work in preparation) found phosphate levels that fluctuated between 1.6 and 2.85 µg-at. PO_4-P/1 along the Estero Salado from Guayaquil to Canal del Morro.

Valencia (1980) reports surface values of nitrate from 5.0 to 10.0 µg-at. NO_3-N/1 in waters adjacent to the gate at the Guayas River-Estero Salado (see Figure 3). Levels lower than 5.0 µg-at. NO_3-

N/1 in other stations located between 5 de Junio Bridge and Portete Bridge were found by the author and Viteri (in press). Ormaza (work in preparation) recorded nitrate values between 8.4 and 18.5 µg/l in the area between Canal del Morro and Guayaquil. The highest value was found at buoy 50, near some shrimp farms. The values of soluble organic phosphate and soluble organic nitrogen found by the author were between 0.05 and 1.09 µg-at. PO_4-P/1 and 6.7 and 72.7 µg-at. NO_3-N/1, respectively.

Metals

The sediment of one section of Estero Salado, located between Portete and 5 de Junio Bridge, was analyzed for copper, cadmium and iron content. The results obtained show a copper range between 65.0 and 799.5 mg/kg (dry weight), cadmium between 0.5 and 3.2 u/kg (dry weight), and iron between 0.56 and 2.93 g/kg (dry weight). The higher levels of copper and iron were found in the vicinity of industries, while the maximum cadmium value was found near the center of the city.

Mercury

According to Chalen de Padilla (1986) the sediment of Estero Salado showed mercury values between 190 and 4,900 µg/kg of dry weight, but Ayarza (1987) reports that in some sections of the Estero near the city their samples gave negative results for this metal (Table 3). The author (1986) also found that some samples of bivalves from the same section showed lower levels of mercury than the permissible limit accepted by the FDA of the United States (Table 4).

Petroleum Hydrocarbons

Levels of petroleum hydrocarbons soluble and/or coloids were relatively low in samples taken in the Estero Salado near Guayaquil. In fact, samples taken throughout the Estero Salado showed values lower than 2 µg/l, except in those taken near oil spillages from commercial vessels (Solorzano, 1986). However, there are found extremely high values in Estero del Muerto, a section of the Estero Salado where commercial vessels take on oil (Valencia, 1986).

Conclusions

The ecology of the aquatic systems that surround the city of Guayaquil has been affected by domestic as well as industrial discharges. Current research indicates that contamination is caused predominantly by domestic waste. The eutrophication observed in the Guayas River, as well as in the Estero Salado, indicates that the growing city has a great impact on the marine environment. The circulatory processes in both the Guayas River and the Estero Salado mix the waters vertically and horizontally so that the chemical and physical parameters of the surface and the bottom are similar and there is less change to anoxic conditions in deep waters. The nutrient levels in the section adjacent to Guayaquil, are higher than in the rest of the Estero Salado, while in the Guayas River, the highe levels of nutrients are observed near the sewage outfalls.

Heavy metals are also of concern, particularly copper, cadmium and mercury. The copper concentration in the aquatic systems studied has a relative importance and is over the limit of 10 µg/l considered innocuous for aquatic species (Ketchum, 1975), though part of this copper may be merged to organic material present in the water, inhibiting its toxicity to marine organisms. Research with this contaminant is part of a project to be developed in the near future in the Contamination Laboratories of Institute Nacional de Pesca. Presently, the origin of such high levels of copper is unknown, but the possibility that such levels could be the results of continental erosion processes has not been rejected.

Cadmium levels throughout almost all places sampled, in Estero Salado as well as Guayas River, are variable, but higher levels are associated with the city of Guayaquil. The level considered innocuous to aquatic species is 10 µg/l (Ketchum, 1975), and some values recorded in the water masses that surround

Guayaquil justify a more detailed study of cadmium distribution and concentration to determine its source and develop ways of controlling its discharge.

The sediment of the inner estuary of the Gulf of Guayaquil, including the sediment of the Guayas River, lower courses of the Babahoyo and Daule Rivers and of all the Estero Salado, showed significant mercury contamination, the exact source of which is unknown. However, gold extraction industries in the coastal section near the Jambeli Channel use approximately two tons of mercury per year, and could be contaminating the small rivers that empty into the channel. This would explain the absence of mercury in sediment samples and organisms taken in other sections near Guayaquil (Solorzano, 1986). Non-published data produced by Chalen de Padilla from migratory fish, including tuna and shark specimens captured in Ecuadorian coastal waters also show low levels of mercury.

Both dissolved petroleum hydrocarbons and/or coloids of the Guayas River, as well as those of the Estero Salado, were found at levels lower than 2 µg/l, which suggests the absence of contamination due to petroleum hydrocarbons.

Table 1
Treated and non-treated waters from La Toma treatment station in 1984

Month	Untreated water: Plate Count	Untreated water: Coliforms NMP per 100 ML Total	Untreated water: Coliforms NMP per 100 ML Fecal	Treated water: Plate Count	Treated water: Membrane filtered bacterial coliform colonies per 100 ML Total	Treated water: Membrane filtered bacterial coliform colonies per 100 ML Fecal
January	13,000	1,300	790	10	0	0
February	150,000	3,400	2,700	0	0	0
March	190,000	3,500	700	0	0	0
April	40,000	200	90	5	0	0
May	80,000	330	170	10	0	0
June	20,000	1,100	700	30	0	0
July	30,000	2,100	950	5	0	0
August	20,000	2,400	790	20	0	0
September	20,000	140	80	0	0	0
October	25,000	490	230	10	0	0
November	30,000	1,100	790	0	0	0
December	20,000	330	130	10	0	0

Source: Teresa de Guzman, Departamento de Microbiologia , National Institute of Hygiene and Tropical Medicine.Unpublished data.

Table 2
Nutrients in Estero Salado, section adjacent to Guayaquil between
5 de Junio and Portete Bridges.

Sampling site		NH_4-N ug-at/l	PO_4-P ug-at/l
5 de Junio	1m	26.7	14.46
	10m	24.2	8.80
Empacadora	1m	21.4	24.80
	8m	16.8	7.01
San Eduardo	1m	9.6	9.41
	6m	16.6	6.06
Pte. Portete	1m	1.8	7.28
	10m	5.2	4.48
Salitral	1m	4.0	6.18
	10m	6.2	4.57
Fertisa	1m	10.2	4.92
	10m	7.2	5.11
C.C.Q.Q.	1m	26.8	15.10
Pte. Urdesa	1m	26.3	15.02
	4m	39.8	9.94
Pte. Alban Borja	Surface	30.2	25.96
Policentro	Surface	16.4	24.76
Parque Urde sa Norte.	Surface	81.2	20.46
Pte. Miraflo res	Surface	114.2	33.40
Frente Si Cafe	Surface	32.8	24.62

Source: Ayarza, in press.

Table 3
Mercury in the sediment of the stations sampled in the secion of Estero Salado
adjacent to Guayaquil between 5 de Junio and Portete Bridges

Site	mg/kg dry weight
Ptc. 5 de Junio	313
San Eduardo	481
Empacadora	Negative
Puente Portete	685
Salitral	Negative
Fertisa	1,680
Facul.CC.QQ.	Negative
Puente Urdesa	2,980
Puente Alban Borja	376
Puente Miraflores	128
Frenta a "Si Cafe"	1,290

Source: Ayarza, in press.

Table 4

Mercury content in aquatic organisms of Estero Salado, near the city of Guayaquil

Organisms	Weight (grams) with shell	Weight (grams) without shell	Length (mm)	% Moisture
Mytella strigata	0.13	0.46	11.42	76.3
Tagelus (Tagelus) affinis	1.74	1.00	30.70	86.0
	4.24	2.27	33.70	78.9
	2.16	1.33	33.90	78.1
	2.36	1.38	37.60	71.8
	3.09	1.86	39.70	75.4
	3.52	2.14	43.80	74.3
	11.16	6.19	48.20	24.9
	13.80	6.68	50.00	80.9
	8.22	5.02	55.75	82.1
	14.44	8.60	61.40	76.3
	12.91	7.87	67.80	81.4
Mytella guayanensis	0.20	0.10	11.85	61.0
	2.64	0.84	35.3	82.1
	6.25	0.84	48.6	76.8
	8.28	2.43	50.0	79.7
	8.08	2.25	55.1	83.8
	10.43	2.94	61.3	75.8
	12.78	3.35	67.1	84.0
Ostrea calumbiensis	9.53	1.6370	41.5	
	13.98	2.237	47.2	87.2
	15.70	3.478	49.2	88.4
	24.53	2.96	53.7	83.9
	14.39	1.99	55.2	84.8
	16.40	1.36	56.7	96.9
	13.90	2.87	57.2	80.4

Source: Solorzano, 1986.

Figure 1.   Scheme of the River Guayas basin.

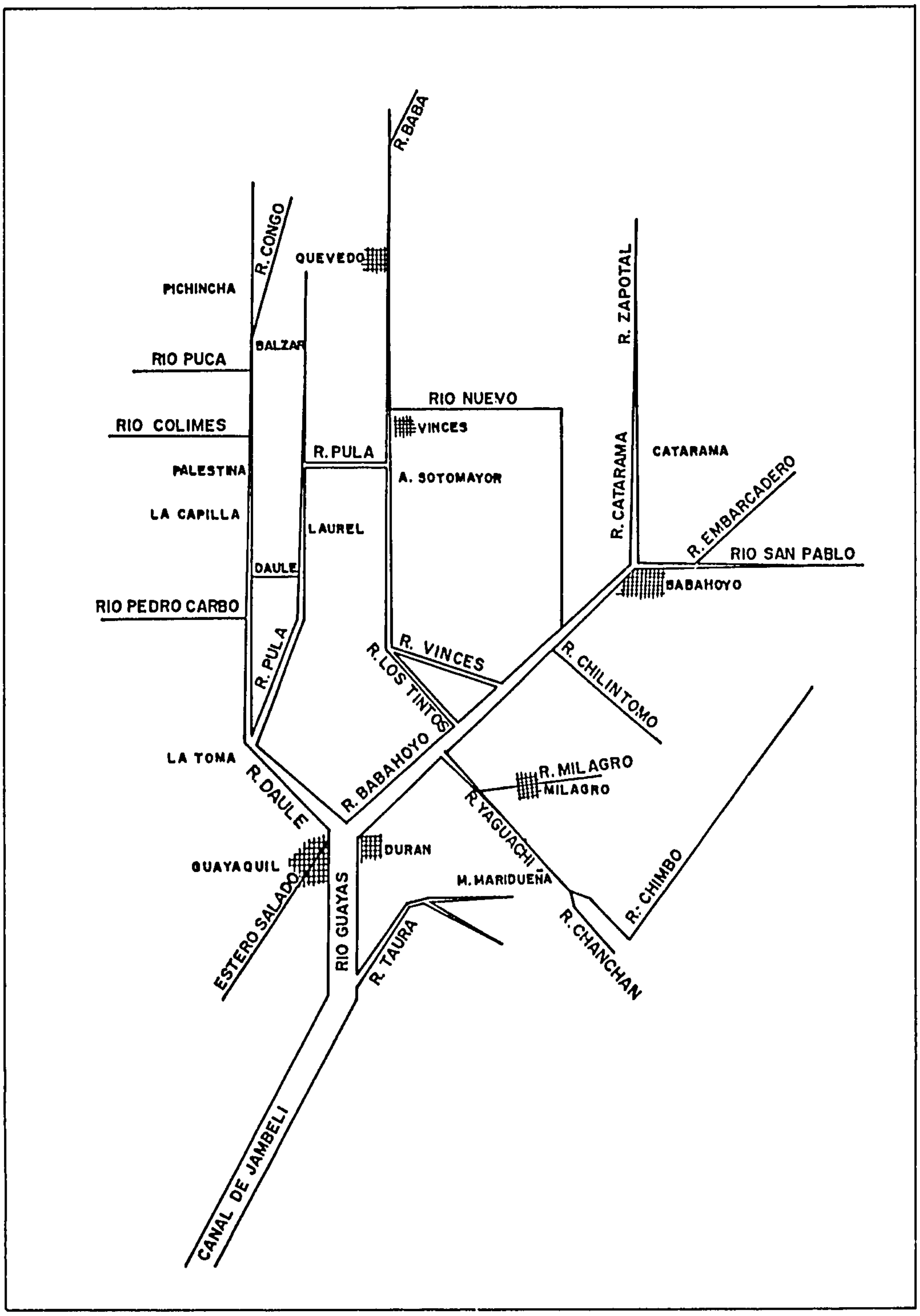


Figure 2. Infrastructure of the basic sewage system of Guayaquil, according to EMAG, 1980.

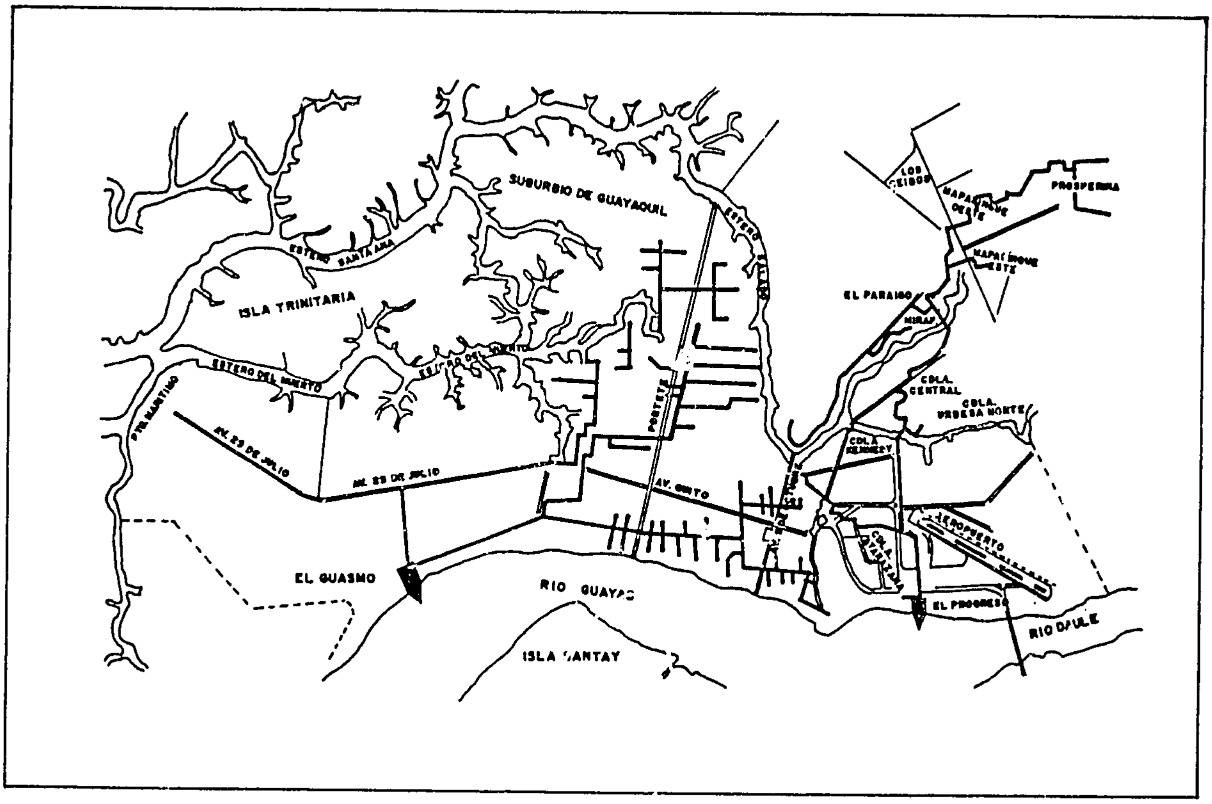
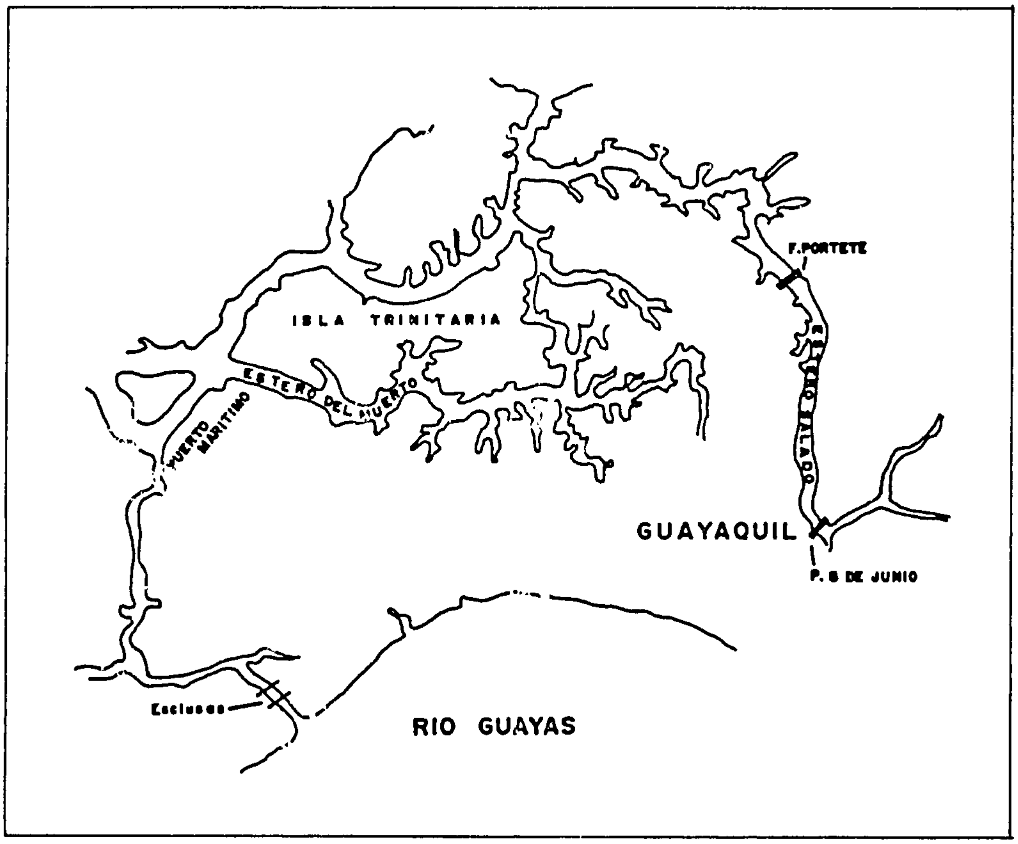


Figure 3. Urban section of the Estero Salado.



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Red Tide and Shrimp Activity in Ecuador

Marea Roja y la Actividad Camaronera en Ecuador

Roberto Jiménez

Resumen

El fenómeno llamado "**marea roja**" usualmente es causado por una explosión monoespecífica en la producción del fitoplancton, pudiendo ocurrir también con actividad del zooplancton y origina una coloración del agua que puede ser verde o rojo-amarillento. Mareas rojas causadas por dinoflagelados como Gymnodium breve y Gonyaulax catenella son tóxicas para peces e invertebrados. Otros organismos como el ciliado Mesodinium rubrum, no son tóxicos para la fauna marina.

Desde el comienzo de las investigaciones en 1969, han ocurrido 28 incidentes de mareas rojas. Una marea roja descrita por el autor, causada por M. rubrum (Cyclotricnium memieri), en el Golfo de Guayaquil, en mayo de 1973, produjo alta fertilidad en el área con concentraciones de clorofila de 93,7 mg/m^3, similar a los casos asociados al fenómeno de El Niño de 1976.

En abril de 1980, una extensa área de marea roja ocurrió en el Golfo de Guayaquil (Canal de Jambelí), causando mortalidad en los peces. El organismo responsable fue Gonyaulax monilata. Entre 1980 y 1981 fueron registrados siete casos de mareas rojas causadas por Mesodinium rubrum, a lo largo de la costa del Ecuador. En noviembre de 1981 un caso de discoloración de las aguas, típico de la marea roja, fue determinado en el Estero Salado, debido a la diatomea Skeletonema costatum que alcanzó concentraciones de 100'000.000 células/l y altas concentraciones de clorofila (más de 100 mg/m^3).

El autor presenta un resumen de las características de diversos casos de marea roja observados en el período 1980-86 en aguas ecuatorianas.

El bombeo de agua con marea roja a las piscinas ha causado altas tasas de mortalidad en el camarón. También, el uso de altas concentraciones de fertilizantes ha originado un florecimiento excesivo de algas, habiéndose informado concentraciones de Nitzschia mayores que 1'200.000 células/litro, lo cual causa mortalidad en el camarón por anoxia. También se ha observado frecuentemente la proliferación de filamentos de algas azules, resgistuándose en algunas piscinas camaroneras cifras mayores que 75'000.000 de filamentos por gramo de sedimento. Mediante estudios de contenido estomacal se ha verificado que el sabor del camarón cambia y que tiene olor rancio, cuando se alimenta con esta alga.

El documento concluye en la importancia del control de las poblaciones de plancton en las piscinas camaroneras y de la vigilancia de las poblaciones de camarón, especialmente después del florecimiento de las algas, lo cual puede indicar una anoxia potencial y problemas de mortalidad.

Introduction

The so-called "red tides" are spectacular phenomcnoma in the oceans of the world. Red tide is usually caused by a monospecific (single species) explosion in phytoplankton production, though water coloration can also occur with activity of zooplankton and may actually be green or yellowish-red. Also, referred to as sea decoloration or hemotalasia in scientific literature, these brightly colored areas in the sea can appear in clusters or singly and last for days, weeks or months.

Red tide phenomena, caused by dinoflagellates like *Gymnodium breve* and *Gonyaulax catenella*, are toxic to fish and invertebrates. Other red tide organisms, such as the cilliary photosynthetizer *Mesodinium rubrum*, are not toxic to sea fauna.

Red Tide Awareness

Towns located near the South American coast have frequently used local names for these phenomena, "sea purge" in Galicia; "tidal wave" in Peru: "el turcio" in Venezuela.

In Ecuador the media has begun to refer to these disturbances as "red tide," which is a readily identifiable way to offer information to fishing communities when such phenomena occur along the Ecuadorian coast. Previously, most of the data pertaining to the organisms that cause the red tides came from Chile, and was based on information obtained from fishermen.

Incidents and Effects of Red Tide - 1969-1979

Twenty-eight red tide incidents have occurred in Ecuador (Figure 1) since marine phytoplankton research began (Table 1) in 1969. For example, two red tides associated with *Mesodinium rubrum* occurred in the Gulf of Guayaquil in February 1968. This paper's author described a red tide also caused by *Mesodinium rubrum (Cyclotricnium mernieri)* in the Gulf of Guayaquil in May 1973. This particular incident produced high fertility in the area with chlorophyll concentrations of 93.7 mg/m^3 similar to those associated with El Niño phenomena of 1976. In November 1978 a red tide was observed in the open sea near the Port of Manta, associated with accumulation of *radiolarian* colonies (genus *Collozoum*).

Another red tide caused by *Cochlodinium catenatum* occurred in July 1979, south of the Gulf of Guayaquil. *C. catenatum* is a "naked" dinoflagellate with complex morphological characteristics. It is frequently present in chains of eight cells; 4 and 16 cell chains are not uncommon. The concentration of *C. catenatum* in the red tide area reached 1,900,000 cells on the sea surface, with its concentration significantly reduced with depth. This phototropic characteristic of the organism was reflected in the high daily primary production rate (about 5,000 mg c/m^3) near the surface in the red tide area.

Despite efforts to culture the specie using various mediums, the organism did not survive for more than a few days.

Incidents and Effects of Red Tide - 1980-1986

There were several major red tides in 1980. In April of that year, an extensive area of red tide occurred in the Gulf of Guayaquil (Canal de Jambeli), turning the sea oxide red in color and causing high fish mortality. Microscopic analysis confirmed that the organism responsible was the dinoflagellate *Gonyaulax monilata* that is frequently associated with high fish mortality. The highest concentrations (988,000 cells/l) were found at 5 meter depths, while the surface showed 600,000 cells/l, and concentrations greatly decreased at 10 meters. The greater concentrations at the surface were favored by a stable water column with surface temperature between 26.8^o and 27.2^o, contrasted to 21.0^o recorded at 10 meters.

In general, these red tide phenomenoma are associated with strong sunlight exposure, a significant contribution of riverine an drainfall water and stability of the water column. All these elements were present when the red tide occurred in Canal de Jambeli in 1980. This red tide persisted for a short time.

Also, in April 1980, a large expanse of red tide occurred in the Galapagos caused by *Mesodinium rubrum* and *Prorocentrum gracile* with concentrations of 21,300,000 cells/1 and 2,340,000 cells/1, respectively. There was a high fish mortality rate, mainly south of Isabela and Canal Bolivar, with hundreds of dead fish reaching the beach near Puerto Villamil. This was the first reported red tide in the Galapagos Islands. Finally, in August 1980 in Valdivia, there was a red tide caused by *Noctiluca scintilans* and *M. rubrum* (Jimenez, in print).

Between 1980 and 1981 seven red tides caused by *Mesodinium rubrum* were recorded along the coasts of Ecuador, during cruises on board the B/1 **Tohalli** of the Instituto Nacional de Pesca. In all events recorded, high cell concentrations caused discolorations of the sea, and the high chlorophyll values detected in the red tide areas caused increased fertility. The effects of this high fertility can be significant for trophic pellagic chains.

Red tides were present in the Gulf of Guayaquil and in the northern part of Puna in November 1981. The patches were narrow and quite long and were caused by high concentrations of *Prorocentrum* sp.). Accumulations of the organisms were more significant in areas where there were greater concentrations of detritus and organic materials, with high photosynthesis fixation of 7.918 mg c/m^3. The cells and detritus particles resembled macroscopic organic conglomerates.

In November 1981, in the Estero Salado, the Instituto Nacional de Pesca recorded a significant change of water color to brownish-red, typical of red tides. The organism causing this discoloration was the diatom *Skeletonema costatum*, that attained extraordinary cell concentrations of 100,000,000 cells/1, with high concentrations of chlorophyll a (more than 100 mg/m^3). Another organism observed during this phenomenon was *Gymnodinium*. The phytoplankton causing the discoloration was formed by sea cells due to high tide influence that increased the Estero Salado's salinity to 28.1 ppt.

A high intensity red tide was observed in the Guayas River in September 1982. The color was a strong dark brown caused by *Gyrodinium stratum* that reached concentrations of 93,000,000 cells/1. The affected area was about 50 km long from the northern part of Guayaquil to off Puna Island in the Gulf of Guayaquil. The red tide persisted for over one month. At this time, the negative effects of pumping discolored water into shrimp ponds was first noted. Although *Gyrodinium stratum* is not toxic, such high concentrations within the ponds caused anoxia and subsequent shrimp mortality. Thousands of shrimp died, according to shrimp farmers, though exact figures could not be obtained since the shrimp biomass within the ponds is not usually estimated until harvest time. Also, shrimp mortality is difficult to determine since dead shrimp are generally eaten by other shrimp.

In August 1984, in Estero Bajen in the estero Salado, a red tide caused by *Mesodinium rubrum* reached concentrations of 70,000,000 cells/1 with 4,000 mg/m^3 of chlorophyll a. This incident was reported by shrimp farm owners. On this occasion, high shrimp mortality occurred due to low oxygen levels in the water, mainly at night. As in other instances, the recommendation was for frequent water changes to prevent proliferation of the organism in the closed pond systems.

A red tide occurred in Estero Salado in September 1984. This incident was not as intense as that in the Guayas River in 1982, and disappeared in a few days.

In February 1984, along the coast of Ecuador, a red tide caused by *Mesodinium rubrum* covered a 1000 mile long area between Funtilla de Sta. Elena and Cato pasado. The organism was dispersed over an area greater than 200 square miles. The denser patches showed concentrations of up to 7,600,000 cells/1 and 140 mg/m^3 of chlorophyll a. These high cell concentrations were also associated with a near coastal bloom which created increased productivity of Ecuadorian coastal waters. In February and March 1985, there were red tide reports in the Gulf of Guayaquil and Galapagos, caused by *M. rubrum*.

Between February 1985 and February 1986, there was a high density, nontoxic red tide in the internal estuary of the Gulf of Guayaquil, associated with *Prorocentrum maximum*. It persisted for 12 months in Estero Salado, causing no problems to shrimp farms since the higher cell concentrations were located in the center of the Esteros and not in nearshore water used for water changes by the shrimp farms. Due to strong currents predominant in the area, most of the organisms causing the red tide swept to the external part of the Gulf where they did not thrive, probably because this specie prefers estuarine waters. Though it was suspected that the large amounts of organic [illegible]al from this organism can cause a reduction of the oxygen content at sub-surface levels in the wa[illegible]r column, it was observed that the oxygen concentrations near the bottom were similar to those found on the surface, as indicated below:

Location	Date	Depth in Meters	Oxygen/ml/L	T°C
Estero Corvinera	23-07-85	2	3.88	24.7
	(09h30)	6	3.60	24.4
Estero Calaco	17-02-86	2	4.53	29.1
	(16h18)	18	4.66	29.0
Estero Corvinera	19-02-36	2	5.05	28.6
	(11h00)	9	4.99	28.4

Some other species caused red tides in the inner part of the Gulf of Guayaquil in 1985, but their intensity was lower , i.e. *Scrippsiella trochoidea* with concentrations of 3,150,000 cells/1; *Gymnodinium sp.* with maximum levels between 3,250,000 cells/1 and 9,750,000 cells/1; with concentrations of 1,300,000 cells/1.

In March 1986, in the coast of Manglaralto there were red tides of *M. rubrum* associated with *Gonyalaux monilata* in significant concentrations. A number of hatcheries are located in this area and significant mortality of hatchery-reared postlarvae occurred, paralyzing operations of eight facilities for 30 to 45 days.

In April and May of 1986, this *M. rubrum* red tide moved to the Gulf of Guayaquil, but the toxic organism *G. monilata* was not present. Later on, in June 1986 extensive red tides were reported in the Gulf of Guayaquil in Engunga, caused by *M. rubrum* and *Ceratium dens*, which reached concentrations of 2,200,000 cells/1 and 840,000 cells/1, respectively.

Impact of Red Tides on Shrimp Mariculture Operations

Many shrimp farms of the affected zone pumped red tide contaminated water to their ponds, with resultant high shrimp mortality rates. The highest concentration found in the ponds were:

Species	Concentration
Mesodinium rubrum	3,900,000 cells/1
Ceratium dens	675,000 cells/1
Prorocentrum gracile	450,000 cells/1
Scrippsieila trochoidea	90,000 cells/1
Microflagellates	225,000 cells/1

It is important to state that many shrimp ponds use high concentrations of fertilizers that cause excessive algal blooms. Concentrations of *Nitzschia* have been reported at more than 1,200,000 cells/1, which causes mortality of shrimp due to anoxia. Also, ammonia levels of 50 ug/l have been recorded.

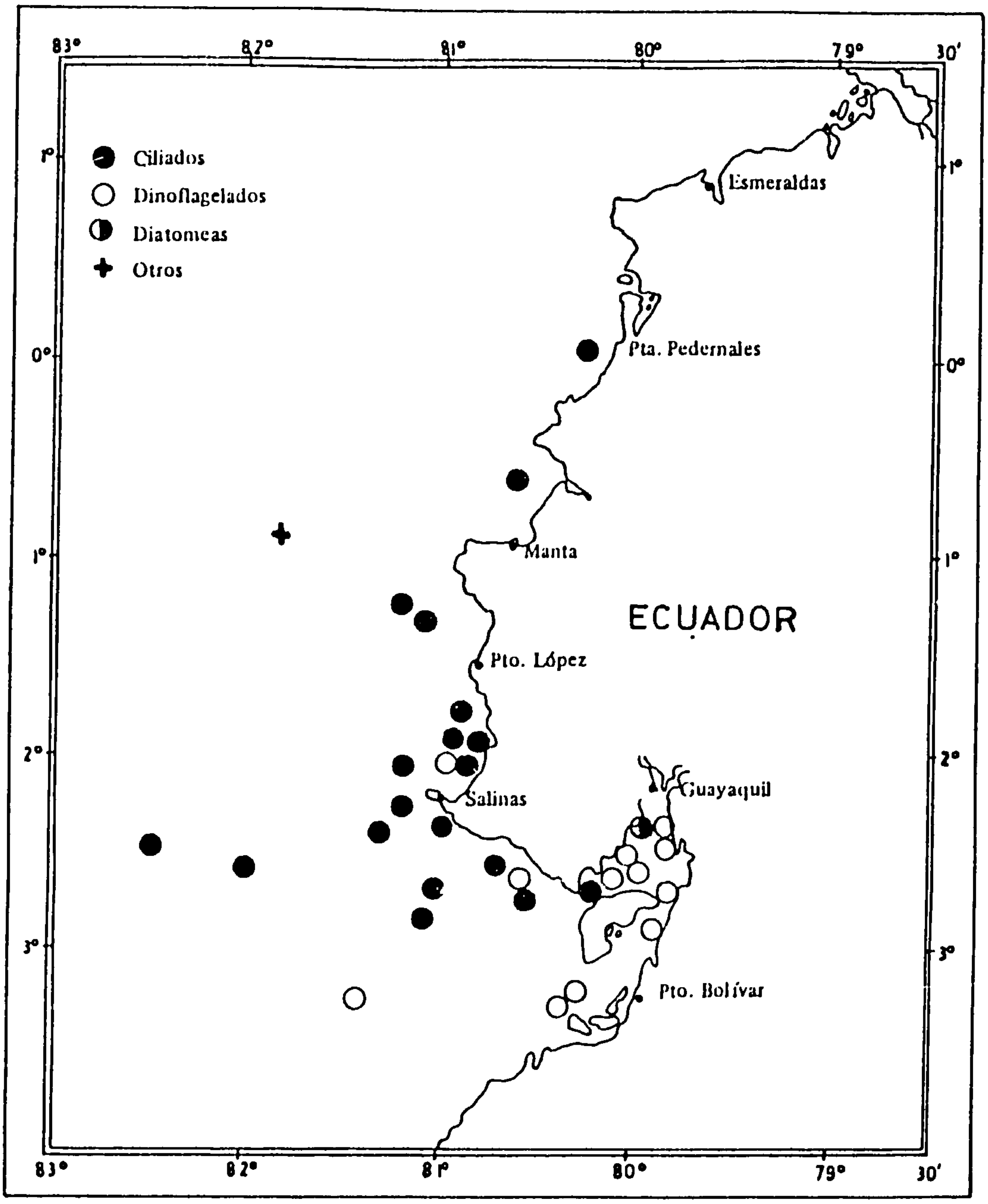
Problems arising from proliferation of filaments of blue-green algae have occurred frequently. In some ponds, up to 75,000,000 filaments/gm of sediment have been recorded. Through studies of stomach contents of shrimp, it has been verified that when shrimp feed on these algae, the flavor of the shrimp is changed and they have a musty odor. Although significant proliferation of blue-green algae has been observed among the plankton of open Ecuadorian waters, this type of algae also reproduces quite easily in closed systems such as shrimp ponds.

Finally, sampling in shrimp ponds shows that, depending upon the environment, phytoplanktonic forms frequently cause red tide phenomena within the ponds. Those blooms affect the growth and mortality of shrimp due to excessive numbers of planktonic organisms or toxics released by the cells. In conclusion, it is important to the shrimp industry to improve their control over plankton populations in shrimp ponds and to monitor shrimp populations from pond seeding to harvest, especially after algal blooms which indicate potential anoxia and mortality problems.

Table 1
Recorded red tides in Ecuadorian waters

Year	Depth in meters	Location	Organism	Cells/Litre
1931	2	Sta. Elena-Esmeraldas	ciliado?	—
1968	2	Golfo de Guayaquil	*Mesodinium rubrum*	—
1973	5	Golfo de Guayaquil	*Mesodinium rubrum*	—
1976	3	Golfo de Guayaquil	*Gymnodinium splendens*	—
1976	4	Pta. Sta. Elena	*Ceratium deflexum*	—
1978	9	Manta	*Collozoum sp.*	—
1979	7	Punta Payana	*Cochlodinium catenatum*	1,900,000
1980	4	Canal de Jambeli	*Gonyaulax monilata*	988,000
1980	8	Valdivia	*Mesodinium rubrum*	14,755,000
1980	8	Valdivia	*Noctiluca scintilans*	—
1980	4	Islas Galapagos	*Mesodinium rubrum*	21,300,000
1980	4	Islas Galapagos	*Prorocentrum gracile*	2,340,000
1981	3	Isla de la Plata	*Mesodinium rubrum*	4,367,000
1981	8	Golfo de Guayaquil	*Mesodinium rubrum*	3,000,000
1981	9	Isla Puna	*Prorocentrum sp.*	49,330,000
1981	9	Estero Salado	*Skeletonema costatum*	100,000,000
1982	9	Rio Guayas	*Gyrodinium striatum*	93,000,000
1984	9	Estero Salado	*Gyrodinium striatum*	440,000
1984	8	Estero Salado	*Mesodinium rubrum*	70,000,000
1984	2	Pto. Lopez	*Mesodinium rubrum*	7,600,000
1985	3	Isla Galapagos	*Mesodinium rubrum*	—
1985	2	Golfo de Guayaquil	*Mesodinium rubrum*	—
1985	2 - 12	Estero Salado	*Prorocentrum maximum*	283,000,000
1985	6	Estero Salado	*Scrippsiella trochoidea*	3,150,000
1985	2	Estero Salado	*Mesodinium rubrum*	1,500,000
1985	8 y 11	Estero Salado	*Gymnodinium sp.*	9,750,000
1986	3	Manglaralto	*Mesodinium rubrum*	3,000,000
1986	3	Manglaralto	*Gonyaulax monilata*	90,000
1986	4 - 5	Golfo de Guayaquil	*Mesodinium rubrum*	23,100,000
1986	6	Golfo de Guayaquil	*Ceratium dens + M. rubrum*	840,000

Figure 1. Locations of red tide outbreaks in Ecuadorian waters during 1982.



Oceanographic Characteristics Off the Coast of Ecuador

Características Oceanográficas frente a la Costa del Ecuador

Emilio Cucalón

Resumen

En el presente trabajo se resaltan las principales características oceanográficas prevalecientes frente a la costa de Ecuador, su variabilidad estacional e interanual. Se presentan algunas evidencias de como variaciones incranuealcs de baja frecuncia en las concdiones ocieanográficas de la región, El fenómeno de el Niño, inducen cambios significativos en la compsocipo y distribución de aguans de lasmás importantes pesquerías, provocando el descalabro de unas y foreciendo el desarrollo de otras. Asío por ejemplo, durante el desarrollo del último fenómeno de El Niño en 1982-83, la pesquría de peces pelpagicos de gran importancia comercial como macarela (Scomber japonicus), sardinas (Sardinops sagax, Estremeres teres) y pincahagua (Opisthonema spp.) fue drásticamente reducida, mientras que la pesquería del camarón alcanzó nivles nunca antes registrados.

Se destacan, además, otros tipos de variabilidad interanual de característica y frecuencias diferentes a las de El NIño, las cuales podrían también estar relacinadas ocn fluctuaciones en algunas pesquierías. Tal es el caso del "Frente Ecuatorial" que durante el invierno de 1985 estuvo más al norte de su límite usual, originando que las aguas costeras sean 2^{o}C más frías que lo esperado. En este año las capturas totales de los pequeños peces pelágicos (macarela, sardinas) superó el millón de toneladas, constituyen así un record en estas pesquerías.

Summary

The main seasonal and interannual variations in oceanographic characteristics off the Ecuadorian coast are presented in this paper. In addition, some evidence is presented as to how low frequency interannual variations in the oceanographic conditions of the region (El Niño) induce significant changes in the composition and distribution of important fisheries, causing the collapse of some, and favoring the development of others. For example, during the development of the last El Niño phenomenon in 1982-83, the pelagic fisheries of great commercial importance, such as mackerel (*Scomber japonicus*), sardines (*Sardinops sagax, Etrumeus teres*) and pinchagua (*Opisthonema spp.*), were drastically reduced, while the shrimp fishery reached record levels. Other kinds of interannual variability besides those of El Niño, which could likewise be related to fluctuations in some fisheries, are also presented.

Introduction

All the seacoast countries around the world recognize the vital necessity of increasing their knowledge about how the variation of oceanographic conditions influence the composition, distribution and abundance of the living resources of the sea, so they can be administered reasonably as a sustainable food resource. The oceanic region along the coast of Ecuador presents great variability, both in physical environment and living resources, a factor that has an important impact on the economy of the country.

Since any phenomenon that affects water temperature, currents and other ocean characteristics, will likewise affect annual abundance or distribution of many species of fish and crustaceans, it is crucial that resource managers have as complete an understanding as possible of the relationships between living resources and environmental conditions.

Study Area

The study zone is an area of the eastern equatorial Pacific Ocean situated immediately off the coast of Ecuador. This area, which extends latitudinally from 1°N to 3°20'S, is a transition zone between the tropical and subtropical regimes. To the north, the Panama Bight is defined as the area of the eastern tropical Pacific Ocean that lies between the Isthmus of Panama (about 9°N) and Punta Santa Elena (about 2°S), and extends from the coasts of Panama, Colombia and Ecuador to about 81°W longitude (Figure 1). This area is characterized by warm (>25°C), low salinity (<34.0 ppt) tropical water. To the south, off Peru, the subtropical water is cold (<22°C) with high salinity (>35.0 ppt) because of the Humboldt Current (or Peru Current), which is strongly influenced by coastal upwelling. Between these two water masses lies a transition zone called the equatorial front, which displays marked seasonal variations and is identified by intense surface thermo-haline gradients.

Seasonal Variability: Circulation and Associated Hydrography

The area is characterized by two clearly differentiated seasonal periods: summer (January-April) and winter (July-October). The remaining months are considered transition periods between these two seasons. More than 95 percent of the annual precipitation falls during summer (Stevenson, 1981).

In summer, a narrow, southward coastal flow of warm (25°-27°C), low salinity (33.0-33.8 ppt) water from the Panama Bight is evident along the coast of Ecuador to approximately 2°-3°S (Figures 2 and 3). This tropical surface water is also characterized by low-nutrient concentrations, and its flow may be defined as a response of the local circulation to seasonal variations of the wind field in the region. The summer meridional winds that blow parallel to the coast weaken, whereas the northeast trade winds blowing across Central America strengthen, increasing the meridional transport of water across the equator.

This flow is indicated on several maps as the El Niño Current (the Holy Child Current), not to be confused with the El Niño phenomenon. This current develops each year during the summer months, and is responsible for the presence of warm waters along the coast of Ecuador during this period. On the other hand, the El Niño phenomenon describes a large scale ocean atmospheric anomaly (Pacific Ocean), characterized by the aperiodic influx of unusually warm surface water (29°-30°C) in the southeast Pacific Ocean, particularly off Ecuador and Peru.

Ordinarily, during the summer, the position of the equatorial front is quite unpredictable, since it may be formed weakly and moved to the south off Peru, or may be completely absent. To the south, in the Gulf of Guayaquil, the surface temperature varies between 26° and 28°C. The isohalines tend to be orientated longitudinally, varying from 26.0 ppt in the inner part of the Gulf to 34.0 ppt in the outer, due to the river discharges into the estuary during this season.

The vertical distribution of temperature presents a sharp, shallow thermocline (maximum vertical temperature gradient) between approximately 10m and 20m depth, associated with the seasonal increase of solar heating and the weakening of the meridional winds during this time. The thermal gradient reaches values of up to 10°C/5m depth in some areas. In general, the water column is well stratified.

In winter, the presence of the intense equatorial front is the most important oceanographic feature. The front is identified by surface thermo-haline gradients between approximately 1°S (25°C-33.6 ppt) and 2°S (19°C-35.0 ppt) (Figures 4 and 5) and extends down to 30-40m depth. The seasonal position of the front is determined by a balance between the force of the Humboldt Current (induced by the meridional winds) and the horizontal hydrostatic pressure gradient generated across the front. Thus, any change in the strength of the wind in the region will produce a latitudinal displacement of the front.

During winter the subtropical surface water is displaced to the north relative to its summer position, in response to strengthening meridional winds and the Humboldt Current. To the south, in the Gulf of Guayaquil, the presence of relatively cold (21°-23°C) and saline (34.0-34.8 ppt) surface water indicates that river discharges into the estuary are lowest because it is the dry season.

Also at this time, the distribution of temperature and salinity throughout the water column presents strong thermo-haline gradients from 30m to 50m depth below a surface mixed layer. This mixed layer displays seasonal variations associated with the force of the meridional winds, being normally evident during winter.

The cold and saline water on the southern side of the equatorial front is also characterized by high nutrient concentrations. This water corresponds to the mixture between the subtropical surface water from the Humboldt Current and the underlying equatorial subsurface water which upwells to the surface south of 2°S. This upwelling process brings cold and nutrient-rich subsurface water up to the surface, giving rise to a higher productivity of the phytoplankton, which through successive links in the ocean food chain ultimately reaches the major fish populations.

Interannual Variability: The El Niño Phenomenon

Occasionally and quite unpredictably, extensive areas of the southeast Pacific Ocean, particularly off Ecuador and Peru, are subjected to an aperiodic influx of unusually warm surface water, commonly referred to as the El Niño phenomenon. These invasions of anomalously warm water, coming mainly from the north and/or from the west, produce dramatic changes in the local meteorological, oceanic and biological regimes. In this century, major El Niño events were recorded in 1925, 1929, 1939, 1941, 1953, 1957-58, 1965, 1972-73, 1976, and 1982-83.

During El Niño, warm water accumulates along the coasts of Ecuador and Peru and the upwelling of colder water seems to weaken. Fish stocks practically disappear, drastically reducing the catches of the fishing fleet and causing many marine birds, dependent on fish for food, to die of starvation. For example, during the 1972-73 El Niño event, the Peruvian anchovy (*Engraulis ringens*) catch dropped from over 10 million metric tons (m.t.) in 1970 and 1971, to approximately 4.5 million m.t. in 1973 (Caviedes, 1975). Also, the population of guano birds fell from 6.5 million in 1971, to 1.8 million in 1972 (Vildoso, 1976).

Moreover, the coastal areas suffer torrential rainfalls due mainly to an abnormal southward displacement of the intertropical convergence zone of the winds (ITCZ) during El Niño years. Disastrous floods cause severe damage to the crops of the region. The financial consequences of these events are catastrophic for the local fisheries, and the economic repercussions are adversely felt throughout the affected countries.

During the development of the last El Niño phenomenon (October 1982-July 1983), the entire coast off Ecuador was covered by very warm waters, up to 28°-30°C (Figure 6), and there was a remarkable increase in the stability of the water column that isolated the surface layer from the nutrient-rich water below the thermocline. In fact, the thermocline was depressed to depths four times greater than normal, 80-100m. Since the major supply of inorganic nutrients to the euphotic zone is in water below the thermocline, it is clear that any process depressing the thermocline away from the surface layer, where there is enough light for photosynthesis, will necessarily reduce productivity (Barber and Chavez, 1983).

Another important feature observed during the development of the 1982-83 event, was the existence of a surface mixed layer. In normal conditions, there is no surface mixed layer in summer, however, during 1983, this layer was evident up to 30m depth. Because light decreases exponentially as a function of depth, the depth of the surface mixed layer determines the quantity of light that can be captured by the phytoplankton for the synthesis of organic material; less amount of light will be available to the phytoplankton as the surface mixed layer deepens. In this way, the supply of both nutrients and light was significantly reduced as El Niño progressed.

The subsequent decrease in phytoplankton productivity caused considerable disturbance to organisms of higher trophic levels, such as zooplankton, ichthyoplankton and fish. Small pelagic fish including mackerel, sardines and pinchagua did not spawn at normal rates, greatly reducing usual abundance (Garcia, 1983). The total catch for these fisheries dropped from over 180,000 m.t. during the first quarter of 1982 (prior to El Niño), to approximately 43,000 m.t. during the same period in 1983, and consisted almost exclusively of mackerel (Jimenez and Herdson, 1984).

The 1982-83 El Niño phenomenon had a great socio-economical impact on the coastal region of Ecuador, caused by a tremendous increase in rainfall, flooding and landslides, damage to transportation facilities, huge agricultural losses, in addition to disturbance of many coastal fisheries. The only commercially important sea resource that benefitted from the anomalous oceanographic conditions prevailing during this event was the shrimp fishery. The total catch reported by the shrimp fleet in 1983 increased by more than 200 percent relative to the previous years (Figure 7, McPadden, 1985).

Other Interannual Variations

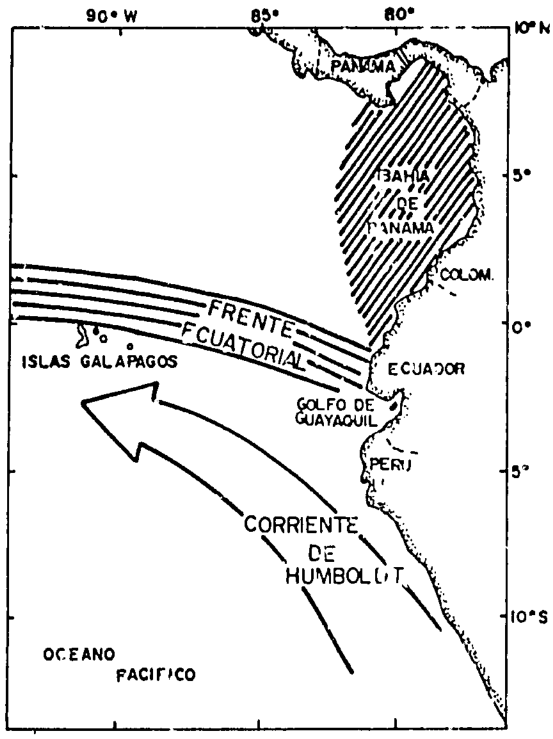
Other kinds of interannual variability in ocean characteristics can also be related to fluctuations in some fisheries. For example, during winter 1985, the equatorial front was located further north than its normal limits, to about latitude 0° (Figure 8). This shift in the front was associated with a strengthening of the Humboldt Current, which pushed its cold and saline waters further north than its usual limits, causing Ecuadorian coastal waters to be 2°C colder than expected for this time of the year. The total catch of small pelagic fish (mackerel, sardines) was over 1 million m.t. in 1985, the highest annual catch ever registered (Figure 9). Sardines (*Sardinops sagax*) constituted 70 percent of the catches, surpassing mackerel for the first time (Mariduena, 1986).

In another instance, the advance of cold and saline subtropical water of the Humboldt Current towards the coast of Ecuador was observed in March 1986 and not at its usual time in May or June. This created important changes in the oceanographic conditions of the region, giving rise to the presence of waters 2°C colder than expected for the season (Figure 10). This anomaly in the physical environment coincided with the presence of quantities of valuable Peruvian anchovies in Ecuadorian waters for the first time (Mariduena, personal communication). Considering the close relation between the distribution of these small pelagic fish and the circulation of the water masses in the region, long-term monitoring of such oceanographic changes could be invaluable.

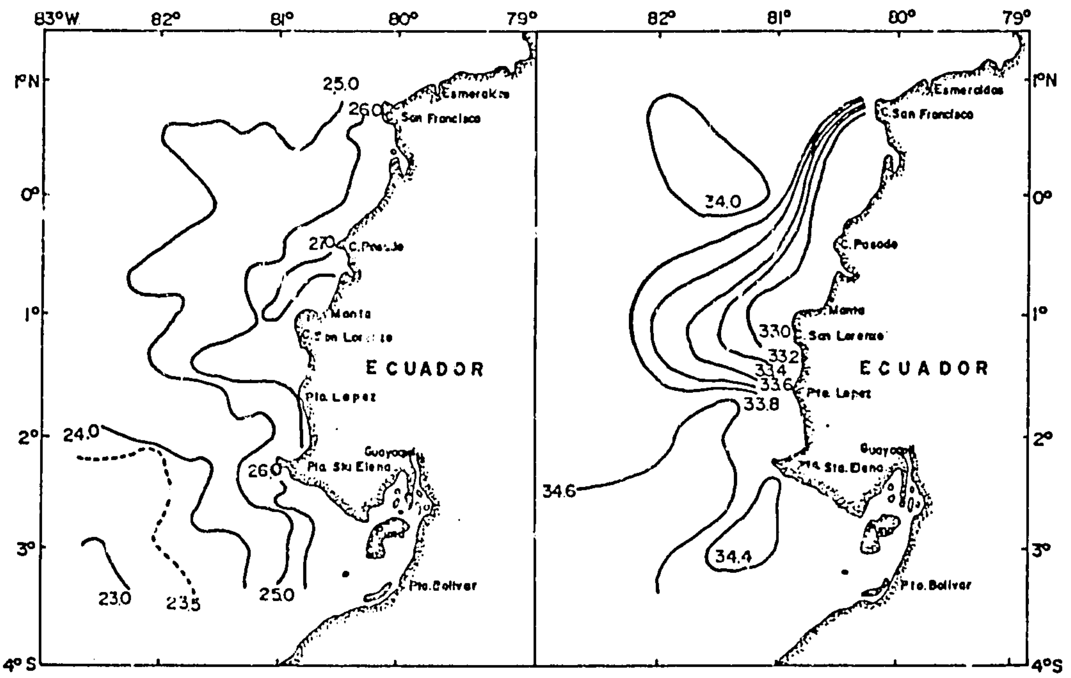
Conclusion

The economy of Ecuador is strongly influenced by its fisheries, so that a better understanding of the climatic, ecological and economic implications of the variability in the oceanographic conditions of the region would provide a very important guide for long-range economic planning. Undoubtedly, the living resources of the sea respond directly and indirectly to these variations in their physical environment, as evidenced by past fluctuations in the composition and distribution of some of the most important fisheries. How and to what extent do these changes in the oceanographic conditions determine fluctuations that can cause the collapse of some fisheries and/or favor the development of others? Are these interannual variations of local or regional character? Do they occur more or less often than the El Niño phenomenon? These are some of the questions that have to be answered in the future to make management of Ecuador's living marine resources more successful and economically dependable.

Figure 1.- Area of the eastern tropical Pacific Ocean showing the different water masses involved in the study zone.



Figures 2 and 3.- Surface distribution of temperature (°C) and salinity (ppt) in February-March 1981, respectively.



Figures 4 and 5.- Surface distribution of temperature (°C) and salinity (ppt) in August 1981, respectively

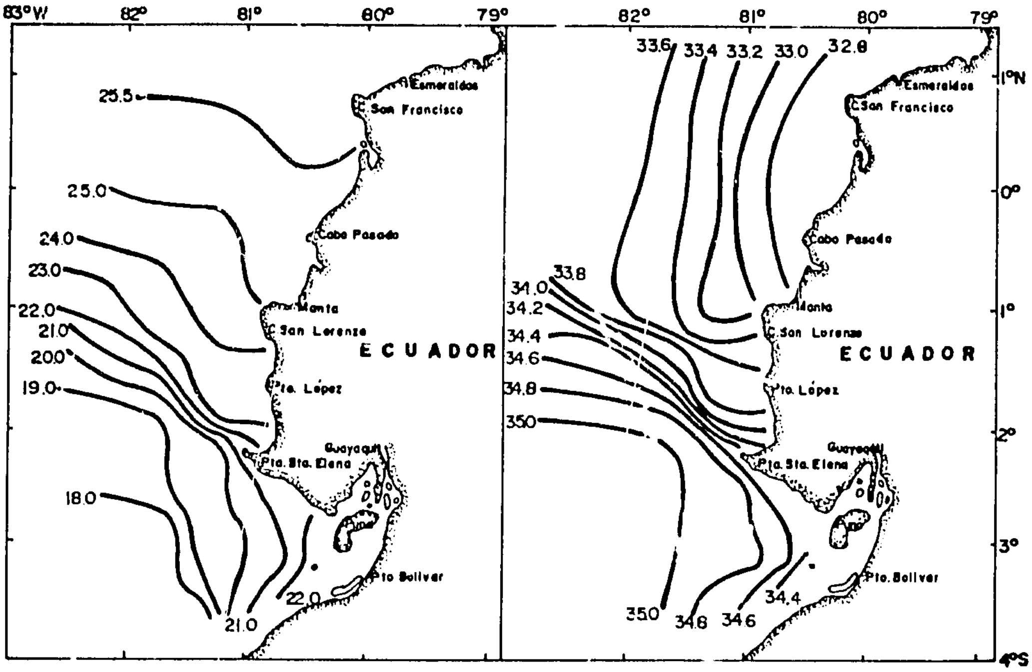


Figure 6.- Surface distribution of temperature (°C) in February 1983, during the development of the El Niño phenomenon.

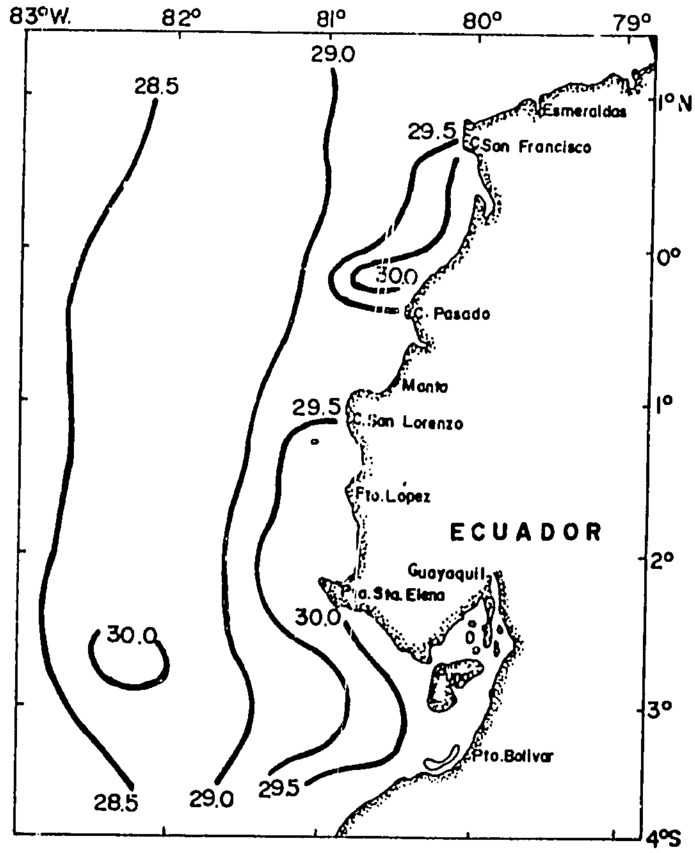


Figure 7.- Estimated total annual shrimp catch for the 1974-1985 period

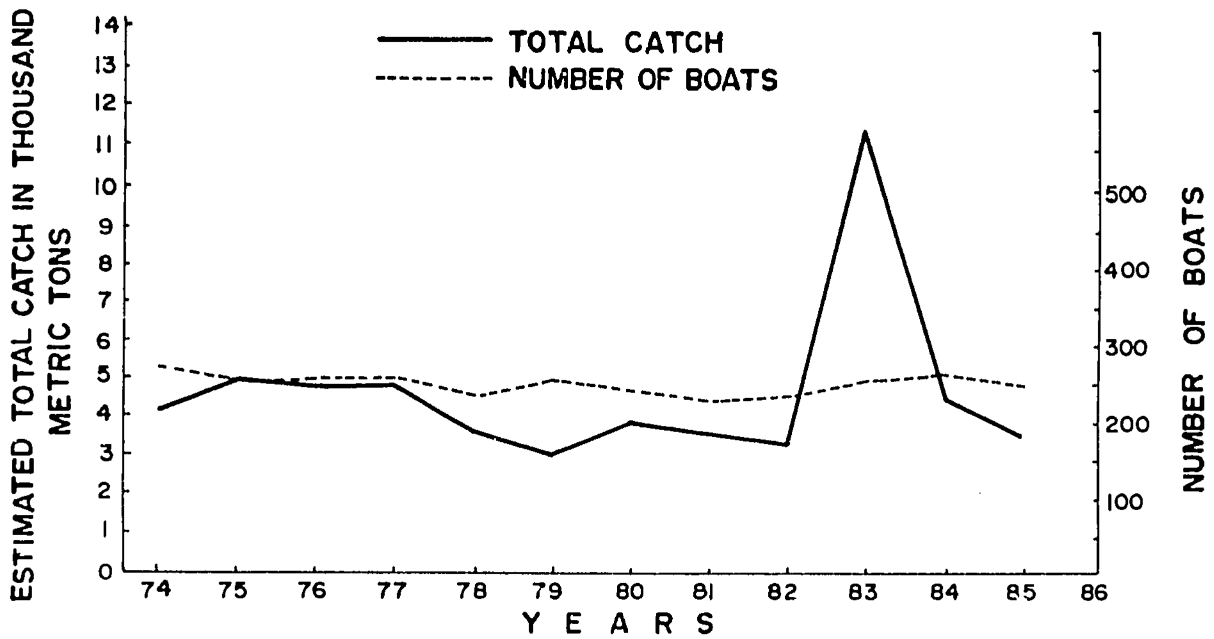


Figure 8.- Surface distribution of temperature (°C) in July 1985.

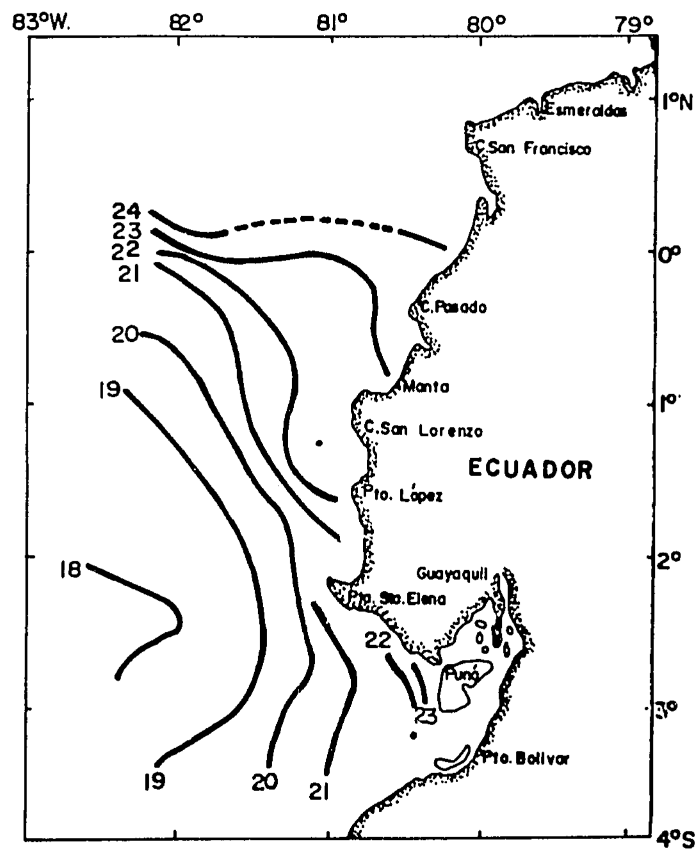


Figure 9.- Total annual catch of the small pelagic fish (mackerel, sardines, pinchagua) during the 1964-1985 period (source: Maridueña, 1986).

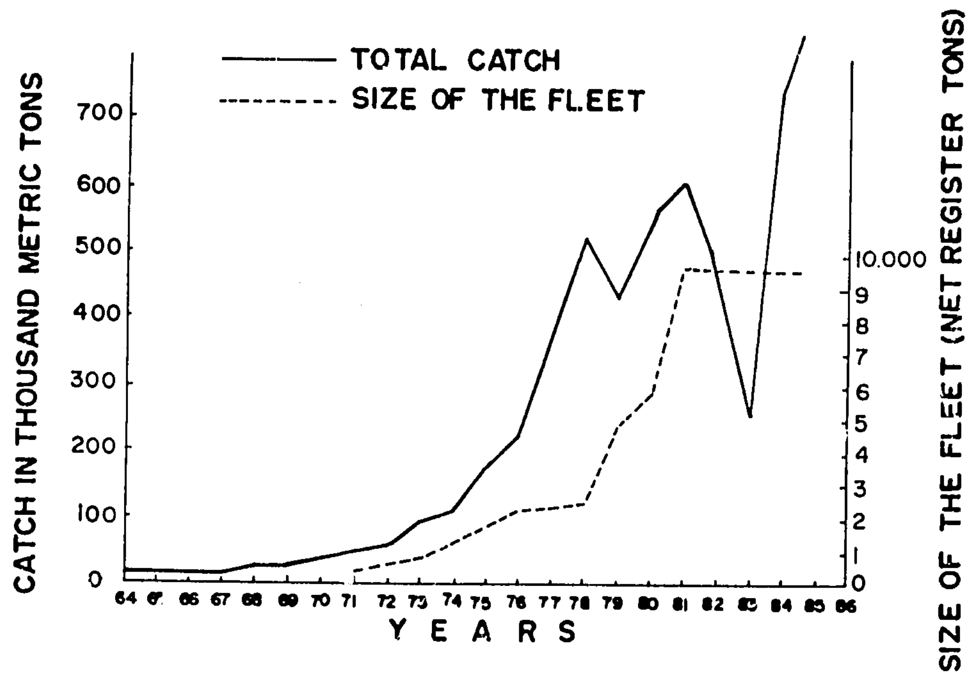
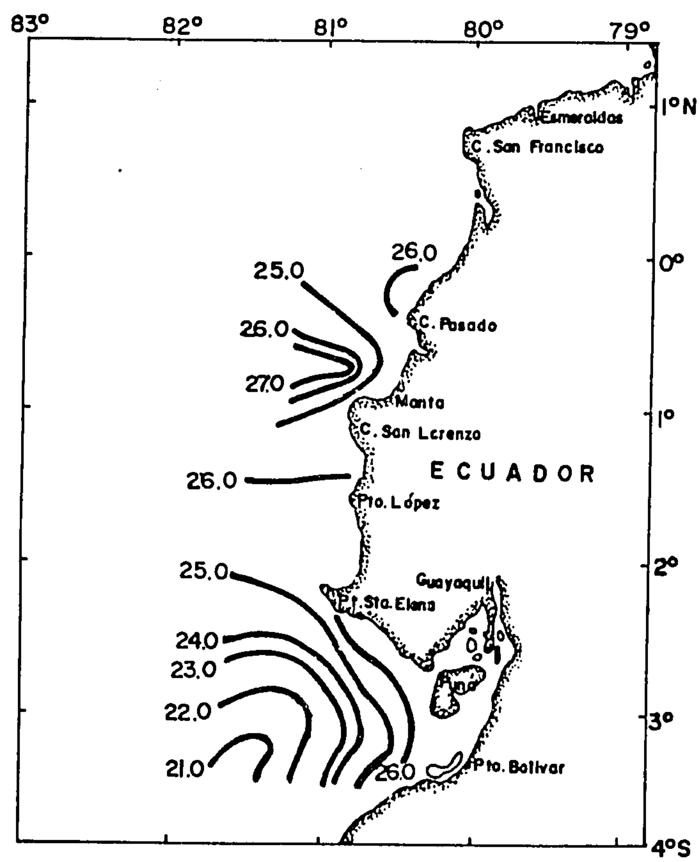


Figure 10.- Surface distribution of temperature (°C) in March 1986.



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The Shrimp Fishery

The Ecuadorian Shrimp Trawl Fishery, 1974-1985

La Pesquería del Camarón con Buques de Arrastre, 1974-1985

Charles McPadden

Resumen

Hasta comienzos de los años 70, la producción de camarones en Ecuador consistió en capturas en el mar. El promedio fue de 6.000 a 8.000 t.m., peso entero. Luego ocurrió la expansión de la industria del cultivo de la especie Penaeus vannamei y, en menor extensión, de P. stylirostris. El año de mayor producción fue 1983, con unas 44.000 t.m. de camarón entero. El aumento de este año se debió principalmente a la presencia del evento de El Niño. En los demás años la captura se mantuvo entre 33.000 y 35.000 t.m. de camarón entero, por año.

El número de buques no ha cambiado sustancialmente en este período, pero se incrementó la presión de pesca sobre los "stocks" de postlarvas (pls), debido al aumento de las hectáreas de piscinas en producción (94.000 ha autorizadas, a fines de 1985). La demanda anual de pls se estimó en unos $6,6 \times 10^9$ pls, con un mínimo de siembra en 1985 de 2,5 - 2,6 pls x 10^9 Durante 1984 y 1985 se ha observado muy bajas capturas de pls.

La flota camaronera se expandió de 30 buques en 1954 a unos 249 en 1985, la mayoría entre 50 y 70 pies de eslora.

En la pesca del camarón blanco (P. occidentalis, P. stylirostris y P. vannamei) en el Golfo de Guayaquil, durante los primeros años dominó P. occidentalis, declina gradualmente hasta 1983 cuando sólo significó el 20% de las capturas. En 1985 aumentó al 37%. En cambio P. vannamei aumentó del 8% hasta un 40%, en el mismo período. En el primer semestre de 1986 la composición por especies de las capturas fue de 54%, 29% y 17% para P. occidentalis, P. stylirostris y P. vannamei, respectivamente. Hacia el Norte del Golfo, desde la Punta de Santa Elena hasta el cabo de San Francisco, las capturas de P. stylirostris forman entre el 20 y 40% de las capturas. Las otras dos especies van del 6 al 25%.

Los datos sobre frecuencias de longitud del camarón blanco, muestran una disminución del promedio (longitud de cola) entre abril y junio, que corresponde al período del reclutamiento a la pesquería. Por otra parte, no se ha establecido correlaciones entre los parámetros ambientales y la abundancia de pls y adultos de camarón. A este respecto, en los laboratorios, el desove exitoso de P. vannamei y P. stylirostris requiere temperaturas entre 25^o y 30^oC, anotando que las temperaturas en el Golfo de Guayaquil de abril a noviembre usualmente están bajo este rango. El inicio de la época principal de desove está asociada al aumento de la temperatura en el Golfo, debido al ingreso de aguas cálidas del norte. Así, la estación de desove está entre noviembre-abril, que coincide con el período de mayor abundancia de pls en la línea de costa. De abril en adelante, la temperatura en el Golfo baja de 25^oC, por influencia de la Correinte de Humboldt. Al Norte, en Esmeraldas por ejemplo, las temperaturas son altas todo el año y el "stock" tiene un período más extendido que en el Golfo.

En el trabajo, el autor analiza otros aspectos de la pesquería, tales como los datos sobre frecuencia de longitudes, las capturas por unidad de esfuerzo y asuntos económicos. Anota que parece prudente reducir el esfuerzo de pesca mediante la implantación de vedas durante el principal período de reclutamiento, no obstante que puede presentar conflictos de intereses entre dueños de buques y cultivadores. Anota varias medidas reguladoras de la pesquería establecidas desde 1977, pero que no han sido totalmente aplicadas.

Introduction

Until the early 1970s Ecuadorian shrimp production consisted mainly of sea harvest shrimp. Annual production during this period averaged between 6,000 and 8,000 metric tons of whole shrimp. Since then production has steadily increased due to the expansion of the shrimp aquaculture industry which produces white shrimp of the species *Penaeus vannamei* and to a lesser extent *Penaeus stylirostris.*

In 1983 production peaked at an estimated 44,000 m.t. of whole shrimp. This dramatic increase was primarily influenced by the increase in sea catches due to the effect of the El Niño event throughout the year. Since then production has decreased and remained at between 33,000 and 35,000 m.t. of whole shrimp per annum.

Although the number of vessels fishing shrimp has not changed substantially during this period, there as been an increase in fishing pressure on postlarval shrimp stocks due to the increase in hectares (ha) under production. Direccion General de Pesca figures estimate a total of 94,000 hectares of authorizations up to December 1985.

Shrimp growers have relied almost entirely on wild-caught postlarvae (PL) to seed their growout pond, which has resulted in the development of an extensive postlarval fishery in the saltwater creeks (esteros) and along the Ecuadorian coastline. The current annual demand for postlarvae is estimated to be in the region of 6.6 billion[1] and it is estimated that a minimum of 2.5-5.6 billion[2] postlarvae were harvested to produce the 1985 pond-raised shirmp crop.

Poor catch rates in the offshore fishery and a postlarval scarcity on the Guayas coastline after the main breeding period during 1984 and 1985 caused concern in the industry as to whether the decline was due to the heavy fishing pressure on stocks which eventually might lead to the collapse of the trawl and postlarval fisheries. As a result, the trawl fishery was closed from December 15, 1985 to January 31, 1986 during the breeding season for white shrimp. It was also prohibited to fish for postlarvae from June 1 to July 31, 1986.

The lack of information on the fishery became apparent during this crisis period. As a result, a joint Overseas Development Administration/Instituto Nacional de Pesca technical cooperation program was established in 1985 to set up a data base on the trawl fishery and carry out research into the distribution, abundance and spawning of the commercially important shrimp species. This program, combined with research being carried out on postlarval stocks and oceanographic research, would provide the Instituto Nacional de Pesca with a base on which to manage the shrimp fisheries.

The purpose of this paper is to review the trawl fishery using data available at the Instituto National de Pesca up to 1985 with emphasis on the most important group of the white species *Penaeus occidentalis, Penaeus stylirostris, Penaeus vannamei*, and to outline further research and management lines.

Data Sources

Information on total production, fleet size and shrimp exports has been made available through the Dirección General de Pesca, the government agency responsible for compiling statistics on the shrimp industry.

Data on catch rates has been obtained by monthly interviews with shrimp vessel skippers. Monthly data on species composition, length frequency (tail length, measured to the end of the telson), and catch composition by species weight have also been obtained by Instituto Nacional de Pesca from factory samples of the landed catch in Guayaquil.

The catch per unit of effort (CPUE) has been calculated as the average catch per fishing day of the total reported catch per fishing trip. It has not been possible to separate the different commercial shrimp types in the reported catch data. Interview data has been used as a general index of the distribution of fishing effort.

Data on production of the different commercial trip types has been obtained from an analysis of quality control certificates (Certificados de Control de Calidad) held by the Instituto Nacional de Pesca.

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[1] 30,000 ha/2.2 crops per annum, 50,000 PL/ha 50% mortality

[2] 18,222 m.t. of pond shrimp/35 tails/1b, 50 percent to 70 percent mortality

The data analysed are from the fishery in the Gulf of Guayaquil. Although the fishery exists all along the Ecuadorian coastline, insufficient data were available to carry out an analysis of the whole fishery.

General Description of the Fishery

According to Cobo and Loesch (1966), the offshore trawl fishery commenced in 1952, and the catch during that period was consumed locally. It was not until 1954 that the first shrimp were exported to the United States. McPadden (1985) gives information on the fleet size and total landings from 1954 to 1984. The fleet expanded from 30 vessels in 1954 to some 249 registered vessels operating in 1985.

The bulk of the vessels operate out of Guayaquil into fishing grounds in the Gulf of Guayaquil. A small fleet of some 52 vessels based at Posorja at the mouth of the Gulf of Guayaquil operate a day fishery into grounds between Puna and Playas, concentrating on Pomada/Titi shrimp. Other important centers for the trawl fishery are in Esmeraldas in the north, where some 26 vessles are permanently based and which is also fished by vessels from Guayaquil. The Manta/Palmare stretch of the coast is fished by vessels from Guayaquil, and Manta is used as a landing and refueling port. Although no up-to-date data are available on landings by areas, Arana, Freire and Marín (1978) estimated that 66 percent of the 1976 catch was landed in Guayaquil, 24 percent in Esmeraldas, and the rest in Manta and Bahia de Caráquez.

The majority of the vessels are 50-70 feet in length with engines ranging from 220 hp to 440 hp. Most of the vessels are fitted with refrigerated seawater tanks and spend 15 to 22 days at sea per trip. Some of the smaller vessels, mainly those that fish Pomada/Titi, carry ice and can spend up to four days at sea. All vessels use double-rigged otter trawls with mesh sizes of 2 ins. in the main body of the net and 1.4 ins. in the cod end.

The bulk of the production (see Tables 1a,b,c) is white shrimp, which formed approximately 90.3 percent of the production in 1985. White shrimp are generally fished in shallow waters at 5 to 15 fathoms.

Red and brown shrimp formed 1.84 percent of the production in 1985 with red shrimp being the most important of the two. This species, *Penaeus brevirostris* is, fished in depths of 20 fathoms and greater, forms an important fall back for the fleet in times when white shrimp are scarce. In recent years there has been an increase in landings of this species.

Pomada/Titi formed 4.34 percent of the production in 1985 and, as previously mentioned, is an important fishery for the Posorja based fleet. Its production has remained relatively stable over the years. Cobo and Loesch (1966) noted that production of Pomada/Titi was 1352 m.t. in 1964.

Tiger shrimp are caught in the shallow waters in the mouth of the Gulf of Guayaquil and also form an important part of the Posorja fleet landings. Most of the production goes for internal consumption.

Carapachudo shrimp, a species of red shrimp found in relatively deep water, forms an important fishery for the fleet operating in the Esmeraldas area; production from this fishery has been increasing in recent years.

The deepwater shrimp fishery has developed over the past five years. This fishery has not been studied in any detail and little is known of its future potential for expansion.

Total Catch and Catch Per Unit Effort (CPUE)

Very little information exists on fleet operations, distribution of fishing effort, total fishing effort and catch statistics. In the absence of better data, estimates of production have been made for the fishery as a whole using CPUE data for the Gulf of Guayaquil.

Tables 1a,b,c show the total production figures for the different types of shrimp. The methods of estimating the figures and data sources are listed at the end of the table. No data from quality control certificates was available for the period of 1974 to 1978; figures obtained from the Dirección General de Pesca were used for these years. The estimates for sea-produced shrimp have been calculated from CPUE data from the Gulf of Guayaquil allowing a standard 22 fishing days per month and the number of vessels registered per annum. These estimates are problably higher than the real numbers, however, they are useful in demonstrating trends in the fishery in a general manner, as only limited effort data and no relative CPUE data by shrimp type and area are available.

Of greatest interest is the white shrimp production which appears to have remained relatively stable between 1974 and 1977. After 1977 the production decreased by approximately 1000 m.t. and again remained relatively stable until 1983 when it rose dramatically during the El Niño period. The estimated white shrimp catch during 1984 was extremely low based on the high exports of red and brown shrimp during that year. It is likely that some of the red and brown shrimp exported in 1984 were shrimp held back during 1983 when production was high. The figures have been recalculated allowing for the same production in 1984 and 1985 and is less than 50 percent of the 1974-1977 annual production.

The composition of the white shrimp production for each species has been estimated in Table 1c using weight data from factory samples of the landed catch. Between 1974 and 1977 the overall quantity of *P. occidentalis* and *P. stylirostris* remained relatively stable. There was a gradual increase in the amount of *P. vannamei* until 1977 when the weight in factory samples increased by 40 percent over the 1974 figure.

Between 1978 and 1983 there was a gradual decrease in the amounts of *P. occidentalis* and *P. stylirostris* landed and a corresponding increase in the quantity of *P. vannamei*. By 1982 the amount of *P. vannamei* landed was almost treble the amount in 1974, and landings of *P. occidentalis* had decreased by more than half the original 1974 value. *P. stylirostris* began to decline in 1977 and continued to decline to reach a similar level as the 1974 landings.

1983 was an exceptional year due to the effects of the El Niño phenomenon, and landings of all three species increased dramatically. *P. vannamei* and *P. stylirostris* landings were both some 1000 m.t.. higher than *P. occidentaliss*,which in earlier years dominated the catch.

The low catch rates and consequent low production in 1984 and 1985 mean a further decrease in landings of white shrimp.

During 1985 the amount of *P. vannamei* decreased by 24 percent and *P. stylirostris* by 32 percent of pre El Niño figures. *P. occidentalis* figures decreased by 45 percent during the same period. The overall production of *P. vannamei* during 1984 and 1985 appears to have remained stable, whereas the other two species declined in the landed catch.

Figure 1 shows the average daily catch rate per month from 1980 to June 1986. It has not been possible to allow for differences in fishing power in the various types of fishing vessel nor has it been possible to separate out the different commercial types from the reported catch.

Prior to 1983, catches peaked between the May to July-August period, corresponding to the main recruitment season into the fishery. The 1982, 1984 and 1985 recruitment peaks are not well defined and there appears to have been a general decline in CPUE over that period, except for 1983. Data for 1986 indicate that the CPUE increased after the December-February closure and, although initially higher than that for the past two years, it is declining to a level similar to that of those years.

Species Composition of White Shrimp Catches

The annual species composition of white shrimp catches is shown in Figures 2a and b. From Figure 2a, it can be seen that *P. occidentalis* dominated the catches during the early years in the Gulf of Guayaquil and has gradually declined between then and 1983, when it formed only 20 percent of the numbers sampled. *P. vannamei* , on the other hand, increased from 8 percent to approximately 40 percent during the same period. The percentage of *P. stylirostris* has remained relatively stable between 25 percent to 40 percent of the shrimp sampled. Data for 1985 indicate that the percentage of *P. occidentalis* has increased to 37 percent of the shrimp sampled. In the first six months of 1986, overall species composition was 54 percent, 29 percent and 17 percent for *P occidentalis*, *P. stylirostris* and *P. vannamei* , respectively.

Figure 2b shows the annual species compositions for areas between Punta Santa Elena and Cabo San Francisco. *P. vannamei* forms the bulk of shrimp catches in this area with *P. occidentalis* forming only 6 percent to 25 percent and *P. stylirostris* forming 20 percent to 40 percent of the annual species composition.

Figures 3a-3h compare the monthly species composition for 1974, 1976, 1979 and 1981-1985. It can be seen in Figures 3a-c for the Gulf of Guayaquil in 1974, 1976 and 1979 that the bulk of the shrimp sampled were *P. occidentalis* (40 percent to 90 percent). *P. vannamei* fluctuated between 10 percent and 20 percent of the monthly samples. *P. stylirostris* compositions remained relatively stable, except during 1976 when it dominated in the catches. A mild El Niño phenomenon was experienced during this year.

In 1981 and 1982, *P. occidentalis* still dominated in the catches but the composition of the samples showed wider fluctuations than in the previous years. In 1983 *P. vannamei* formed the highest percentage, peaking from April to August. A major El Niño event occured during this year. Figure 3g for 1984 shows *P. occidentalis* again as the predominant species in the Gulf of Guayaquil, with *P. vannamei* forming between 18 percent and 36 percent of the monthly composition, a level higher than between 1974-1979. The species composition during 1985 showed wide fluctuations and is markedly differnt from the smooth patterns of the species compositions prior to 1979, with both *P. vannamei* and *P. occidentalis* peaking in the samples. Throughout the 1981-1985 period the percentage of *P. stylirostris* has been relatively stable, fluctuating between approximately 20 percent and 45 percent of the monthly samples.

Data for the species composition of white shrimp catches taken in the areas between Punta Santa Elena and Cabo San Francisco in the north are also shown in Figures 3a-3h. Figure 3a for 1974 shows *P. occidentalis* as the predominant species. From 1976 onwards, *P. vannamei* is the dominant species in the area, with *P. occidentalis* forming the lowest percentage except for the occasional monthly sample. These fluctuations are likely to be the result of misreporting of fishing areas during interviews and small numbers of vessles sampled rather than major changes in species composition.

Length Frequency Data

Length frequency data for factory samples taken in 1985 are presented in Figures 4, 5 and 6.

Data for *P. occidentalis* shows the smallest size ranges entering the fishery from May to July at 70-85 mm tail length. In male samples the mode varied between 105 mm and 125 mm and, in females, from 110 mm to 130 mm. From August onwards the smaller size classes were not encountered in the samples.

Length frequency data for *P. stylirostris* shows the lower size ranges entering the fishery in March-April. A modal progression from May (90-95 mm) to September (105-115 mm) with male samples and from May (90-95 mm) to September 115-120 mm) with females is evident.

In the case of all three species of white shrimp, the smallest size classes entering the fishery during 1985 were in the range of 70-80 mm which corresponds to the commerical grades 41/50-61/70 tails per pound.

For comparative purposes with other authors who have worked on the fishery, the data has been presented in the form of average monthly tail length in Figure 7. All three species show a decrease in the average tail length between April and June, corresponding to the main recruitment period in the fishery. On the average, specimens of *P. stylirostris* and *P. occidentalis* were 14-15 mm larger than *P. vannamei* in the samples taken.

Figure 8 shows white shrimp exports by commercial grade in 1985. The 26/30, 31/35 grades formed the highest portion of the exports and are the most common size ranges harvested by the Ecuadorian pond-raised shrimp industry, which forms the bulk of current exports.

White shrimp with a tail count greater than 60 to the pound formed only 3.12 percent of the exports, while shrimp tail counts greater than 90 to the pound formed 0.47 percent of the 38.7 million pounds of white shrimp tail exported in 1985.

Environmental Aspects

Shrimp stocks have been shown to vary considerably in year to year recruitment, which can be attributed not only to fishing effort but also to environmental conditions.

Rothschild and Brunenmeister (1984) reviewed work on the effects of temperature and salinity on shrimp abundance and growth in the northern Gulf of Mexico. Staples, Dall and Vance (1984) used these parameters to develop a predictive model for the *Penaeus merguiensis* fishery in the southeastern Gulf of Carpentaria.

Although the Instituto Nacional de Pesca carries out oceanographic research, no attempt has been made to date to correlate basic environmental parameters with adult and postlarval shrimp abundance. The Gulf of Guayaquil is strongly influenced by the annual shifts in the warm water front and the cold waters of the Humboldt Current to the south of the Gulf. The interface between these two bodies of water lies approximately between Punta Santa Elena and Manta (Cucalón, 1983). The warm body of water moves south into the Gulf of Guayaquil, causing a rise in temperature and the onset of the rainy season in November-December each year. The extent of the water movement is variable and, in years when it moves further south than normal, gives rise to what is known as an El Niño event. The effects of this can be clearly seen on shrimp production during 1983.

Successful spawning of *P. vannamei* and *P. stylirostris* under hatchery conditions requires temperatures of 25-30^{o} (degrees Celsius), and temperatures in the Gulf of Guayaquil from April to November are normally below this level. It is not known whether *P. occidentalis* has the same temperature requirements. The commencement of the main spawning season appears to be associated with the termperature rise in the Gulf of Guayaquil due to the ingression of warm water from the north when waters reach 28^{o}C and higher. The spawning season lasts from November to April and coincides with the main period of postlarval abundance on the Guayas coastline. From April onwards, temperatures in the Gulf of Guayaquil drop to below 25^{o}C due to the influence of the cold waters of the Humboldt Current, and spawning drops off in the Gulf of Guayaquil. Areas to the north of the Gulf of Guayaquil, such as Esmeraldas where temperatures are high all the year round, have breeding stocks of white shrimp for a much more extended period than the Gulf of Guayaquil and the Guayas coastline.

It has been suggested that the poor catch rates in the trawl fishery during 1984 and 1985 were partially caused by adverse environmental conditions. Figure 9 shows the CPUE for the trawl fishery and the average monthly rainfall from 1974 to 1985. The rainfall data is from the I.N.O.C.A.R. (Military Oceanographic Institute) meteorological station in Guayaquil. Insufficient time was available to establish the relationship between rainfall and CPUE.

Rainfall in 1984 was high while estimated production was low. It is apparent that rainfall in 1982 and 1985 was lower than normal, and it is possible that environmental factors affected shrimp abundance in these years.

Economic Aspects

Table 2 gives a breakdown of the operational costs, catch and landings of a sample of five vessels. The data were obtained from a fishing company's monthly statements for each of the vessels over a twelve month period in 1985. It can be seen that there is a wide degree of variation between the total landings, operational costs and earnings of the vessels, which are largely attributable to the skill of the skipper and the amount of time spent fishing. Of the five vessels, only two managed to make an overall profit. Operational costs were in the region of 550,000 sucres per month and a minimum catch of 1,424 pounds of shrimp per trip was required to break even. The major operational costs were repair, maintenance and fuel. Given the poor catch rates in 1985, it is likely that only the best vessels managed to cover their operational costs each trip and the fishery was approaching its limits of economic viability.

Another important aspect of the shrimp trawl fishery which helps maintain its economic viability is the shrimp by catch. An extremely well-organized collection and transport system exists between the trawlers and shore-based merchants for the shrimp by catch. Martínez (personal communication) estimates that catch rates of up to 17.7 kg/h of marketable fish can be taken by shrimp vessels. He estimates the relationship between shrimp and saleability by catch to be in the region of 1:4.45, representing earnings of 7,000 to 15,000 sucres per fishing day.

Discussion

Cobo and Loesch (1966), working on the fishery in the early 1960s estimated the maximum theoretical production of wild-caught shrimp to be in the region of 1,500 m.t. to 1,800 m.t. per annum. Since then the fishery has expanded considerably and in the 1970s reached almost twice this figure. From 1977 onwards, production has declined, and during 1984 and 1985, production was the lowest on record. The CPUE for 1986 increased in the months just after the closed season and has gradually decreased to 1984-85 levels. The main decline appears to have been in the levels of the two species *P. occidentalis* and *P. stylirostris*.

The size ranges encountered in the trawl fishery indicate that there is little or no growth in overfishing. Although the data available on catch rates are not enitrely reliable, they do indicate a trend towards a long-term decline in production since 1977, which could be attributed to overfishing rather than short-term environmental effects.

The fleet size has remained relatively constant over this period and it is likely that fishing effort has not increased dramatically. During this period, a major increase in fishing pressure has occurred with the development of the postlarval shrimp fishery which captures postlarvae of *P. vannamei*, *P. stylirostris*, *P. occidentalis* and *P. californiensis*. In the absence of any quantifiable data on the postlarval fishery, and since the overall stock recruitment relationship is not known, it is not possible to say conclusively that the postlarval fishery is affecting stock levels.

The gradual increase in the amount of *P. vannamei* in the catches has been noted by other workers (Cobo and Loesch, 1966; Barniol, 1980). This trend became most marked from 1977 onwards which roughly coincides with the period of increased production due to shrimp farming activities. It should be noted that there was a minor El Niño in 1976. The amount of *P. vannamei* in the catches that peaked during the 1983 El Niño has decreased slightly since then. Indications are that the amount of *P. vannamei* has remained relatively stable during 1984 and 1985. It is worth noting that the fishing effort on postlarvae expanded from 1983 onwards to include fishing for postlarvae on the beaches from Posorja northward.

This author (1985) noted that the species composition of catches from areas to the north of the Gulf of Guayaquil contained a much higher proportion of *P. vannamei* than catches from the Gulf of Guayaquil. Preliminary unpublished data from the current O.D.A./I.N.P. research programme indicate that during 1985-86 virtually no spawning of *P. vannamei* took place in the Gulf of Guayaquil. The author postulated a northerly movement of *P. vannamei* stocks from the Gulf of Guayaquil with the main spawning areas for this species lying from Punta Santa Elena northwards to Sua-Atacames in Esmeraldas. If this proves correct, *P. vannamei* might become susceptible to increases in fishing effort caused by the expansion of the coastal postlarval fishery.

The other possibility is that the El Niño years of 1976 and 1983 have influenced the overall abundances of the dominant species and that the increased abundance of *P. vannamei* can be accounted for by a species interaction between it and *P. occidentalis*. Current research by the Instituto Nacional de Pesca on postlarval distribution and abundance in the Estero Salado should help clarify this.

Management Aspects

It currently appears that the shrimp fishery has declined since 1983. In spite of very low catch rates in the second half of 1985, there was good postlarval availability on the coast during the spawning season. The fishery increased after the closed season and appears to be maintaining itself at a level lower than pre-1983 levels. Although the data available are not entirely reliable, they indicate that the decrease in production has resulted primarily from decreased levels of *P. occidentalis* and *P. stylirostris*.

The management problems are complex. Almost all stages of the penaeid life cycle are targets of fishing activities. Apart from the trawl fishery, there is an artisanal coastal fishery which is evolving into a target fishery for adult broodstock shrimp. Mature males and females are fished along the coast with trammel nets to supply broodstock for shrimp hatcheries. Postlarvae are heavily fished in the esteros and along the coast. Each year this fishery becomes more sophisticated and has expanded to the use of canoes with double butterfly nets fishing postlarvae just offshore during 1986. An extensive fixed or stake net fishery for juvenile shrimp exists in the esteros, though very little is known about it. A recent survey in one of the esteros indicated that up to 25 percent of the smaller branches are being actively fished and almost all the larger creeks have set stakes, indicating that they are periodically fished.

In the long term, a reduction in fishing effort by reduction of the fleet size through wastage would be recommendable. Also, although there is no direct evidence that the fishing fleet's activities alone are causing a decline in population levels, it would be prudent to reduce the fishing effort in the short term by the imposition of a closed season during the main recruitment period. This, however, presents conflicts of interest between the main user groups, the trawl fishery and the shrimp growers. On one hand, a closure of the fishery to protect breeding stocks during the main spawning season from November to March might ensure optimal postlarval harvest, but that would not protect the stocks from possible overfishing by the postlarvae fishery. To ensure any definite benefit, a closure on the postlarval fishery at some stage during spawning would be needed to allow recruitment of postlarvae into the nursery grounds.

A closure of the estero fisheries during the main recruitment period from April to June is also recommended to allow optimal recruitment into the trawl fishery. This again will present user conflicts as the artisanal estero fishermen harvest most shrimp during this period.

Not much is known of the distribution of fishing effort by the fleet or the effects of closure on fleet activities in areas to the north of the Gulf of Guayaquil where *P. vannamei* is the predominant species. A closure of areas to the north of the Gulf, particularly during the breeding season, would protect spawning stocks of *P. vannamei* and, at the same time, allow the trawl fishery to operate in the Gulf of Guayaquil. Consideration would have to be given to allow the sourcing of mature shrimp to meet the developing hatchery needs.

The Ecuadorian shrimp industry has developed with minimal government control, although recommendations such as stabilizing the fleet size at 160-170 vessels were made by the Food and Agriculture Organization in the early 1970s. In addition, legislation existed in 1977 for a closed season from the mouth of the Rio Balao to the Jambeli point between December and April; it was also prohibited to fish for juveniles in the river mouths in the demarked area. The Acuerdo Ministerial 2305 of August 1984 declared an eight mile zone along the Ecuadorian coast exclusively for the use of the artisanal fisheries.

However, much of this legislation has not been fully enforced. Any attempts at recommended management strategies will undoubtably suffer implementation and surveillance problems, and will not be effective unless measures are made to rectify this situation. In the final analysis, decisions on closures are a combination of political and economic factors. It is unlikely that the industry as a whole will readily accept recommendations as long as the various fisheries remain economically viable and there is no threat to postlarval supplies.

Acknowledgements

I would like to express my gratitude to the Director of the Instituto Nacional de Pesca, Dr. Roberto Jiménez, and the staff of the Institute for their assistance while working in Ecuador; a special word of thanks is due to Mr. José Ortíz, for his patience and efforts while working in the field, and to Biol. L. Arriaga, for translating this paper.

Table 1a.

Estimated Shrimp Production 1974-1985

		White Shrimp *Penaeus vannamei* *P. stylirostris* *P. occidentalis*	**Brown Shrimp** *P. californiensis*	**Red Shrimp** *P. brevirostris*	**Pomada/Titi** *Protrachypenaeus precipua* *Xipopenaeus riveti*	**Tiger shrimp** *Trachypenaeus byrdi* *Trachypenaeus pacificus* *Trachypenaeus faoea*		**Carapachudo** *Solonocera spp.*	**Deep water** *Heterocarpus*	
Year	1 No. of Vessels	2 Total* production (m.t.) (Pond/Sea)	3 Total* production (m.t.) (Sea)	4 Total* production (m.t.) (Sea)	5 Total* production (m.t.) (Sea)	6 Total* production (m.t.) (Sea)	7 Total* production (m.t.) (Sea)	8 Total* production (m.t.) (Sea)	9 Estimated Sea catch (m.t.)* (Gulf)	10 Est. total sea catch (m.t.)*
1974	266								3503	4207
1975	247								4213	4917
1976	241								4119	4823
1977	245								4094	4798
1978	229								3001	3705
1979	250	5072	118	110	644				2476	3120
1980	240	9401	244	213	530	30		8	3323	3891
1981	227	12701	156	23	535			320	2762	3617
1982	230	18958	122	70	616			84	2693	3393
1983	249	25804	540	226	526	9		609	10413	11557
1984	262	19412	724	1254	1127	3	70	869	2553	4622
1985	249	19804	135	273	954	19	391	354	1992	3710
Estimates allowing the same production of Red and Brown in 84 and 85										
1983	249	25804	1013	1207	679	9		609	10413	11710
1984	262	19412	135	273	954	3	70	689	2553	4449
1985	249	19804	135	273	954	19	391	354	1992	3710

DATA SOURCES *(HEAD OFF) # (HEAD ON)

Column No.

1 # Dirección General de Pesca; 2-8 # Certificados de Control de Calidad I.N.P; 9 # C.P.U.E. Data raised to the number of vessels x 22 days fishing/month; 10 # Column 9 + cols. 3-8

Table 1b

Year	No. of vessels	9 Estimated sea catch (m.t.)* (Gulf)	10 Estimated total sea catch (m.t.)*	11 Estimated white sea catch (m.t.)*	12 Estimated total production figures (m.t.) (Pond/Sea)#	Estimated av. monthly catch per vessel (lbs.)* (Gulf)
1974	266	3503	4207	3048	6500	2414
1975	247	4213	4917	3665	7500	3127
1976	241	4119	4823	3584	9000	3133
1977	245	4094	4798	3562	8600	3064
1978	229	3001	3705	2611	9727	2403
1979	250	2476	3120	2248	9006	1816
1980	240	3323	3891	2866	15793	2538
1981	227	2762	3617	2583	20646	2231
1982	230	2693	3393	2501	30032	2147
1983	249	10413	11557	9647	41677	7667
1984	262	2553	4622	575	35096	1786
1985	249	1992	3710	1584	33045	1467
Estimates allowing the same production of Red and Brown in 84 and 85						
1983	249	10413	11710	8193	44112	7667
1984	262	2553	4449	2145	32842	1786
1985	249	1992	3710	1584	33045	1467
	*	(Head Off)	#	(Head on)		

DATA SOURCES
Column No.

9 C.P.U.E. Data raised to the number of vessels x 22 days fishing/month

10 Column 9 + cols. 3-8

11 rows 1-5 allowing white shrimp as 87o/o of the sea catch col. 9 - red and brown exports

12 rows 1-5 estimates from the Dirección General de Pesca; rows 6-15 estimated by summing cols. 2-7 and converting to whole shrimp + col. 8

Table 1c
Estimated white shrimp production by species (1974-1985)

Year	No. of vessels	Estimated white sea catch (m.t.)*	*P. vannamei*	Estimated white species shrimp production by species (m.t.)* *P. stylirostris*	*P. occidentalis*
1974	266	3048	229	828	1991
1975	247	3665	289	1201	2176
1976	241	3584	313	1557	1716
1977	245	3562	362	1424	1911
1978	229	2611	393	633	1585
1979	250	2248	539	588	1125
1980	240	2866			
1981	227	2583	743	667	1152
1982	230	2501	691	887	944
1983	249	9647	3662	3500	2485
1984	262	575	147	161	267
1985	249	1584	525	473	586
Estimated as in Table 1a.					
1983	249	8193	3130	2972	2111
1984	262	2145	549	601	995
1985	249	1584	525	473	586

* (Head off)

Table 2
Shrimp Landings and Operational Costs During 1985

	Total shrimp Landings	Average catch per month	Total value of catch	Average monthly value of catch	Total operational costs per annum	Average monthly Operational costs	Profit Loss after costs
Vessel No. 1	15,254 lbs.	1,553 lbs.	S/7,137,788	S/648,890	S/7,028,898	S/638,991	S/+133,516
Vessel No. 2	28,758 lbs.	2,397 lbs.	8,707,417	725,618	6,225,009	518,751	+2,527,716
Vessel No. 3	16,118 lbs.	1,394 lbs.	7,795,793	649,649	8,072,021	672,668	-2,958,658
Vessel No. 4	6,904 lbs.	991 lbs.	2,684,797	383,542	4,209,342	601,335	-2,530,084
Vessel No. 5	5,102 lbs.	510 lbs.	2,046,367	204,538	3,035,318	303,523	-1,870,463
Average	14,793 lbs.	1,360 lbs.	5,674,432	522,467	5,714,118	547,055	

Average price/lb. (head off) S/384.
Minimum breakeven quantity/trip 1,424 lbs. of shrimp (head off)

Breakdown of Operation Costs	Percentage of Overall Costs
Repairs and Maintenance	43 percent
Fuel and Oil	38 percent
Insurance	9 percent
Victuals, Crew payments Licences, etc.	10 percent

Figure 1. Average Daily Catch/Month

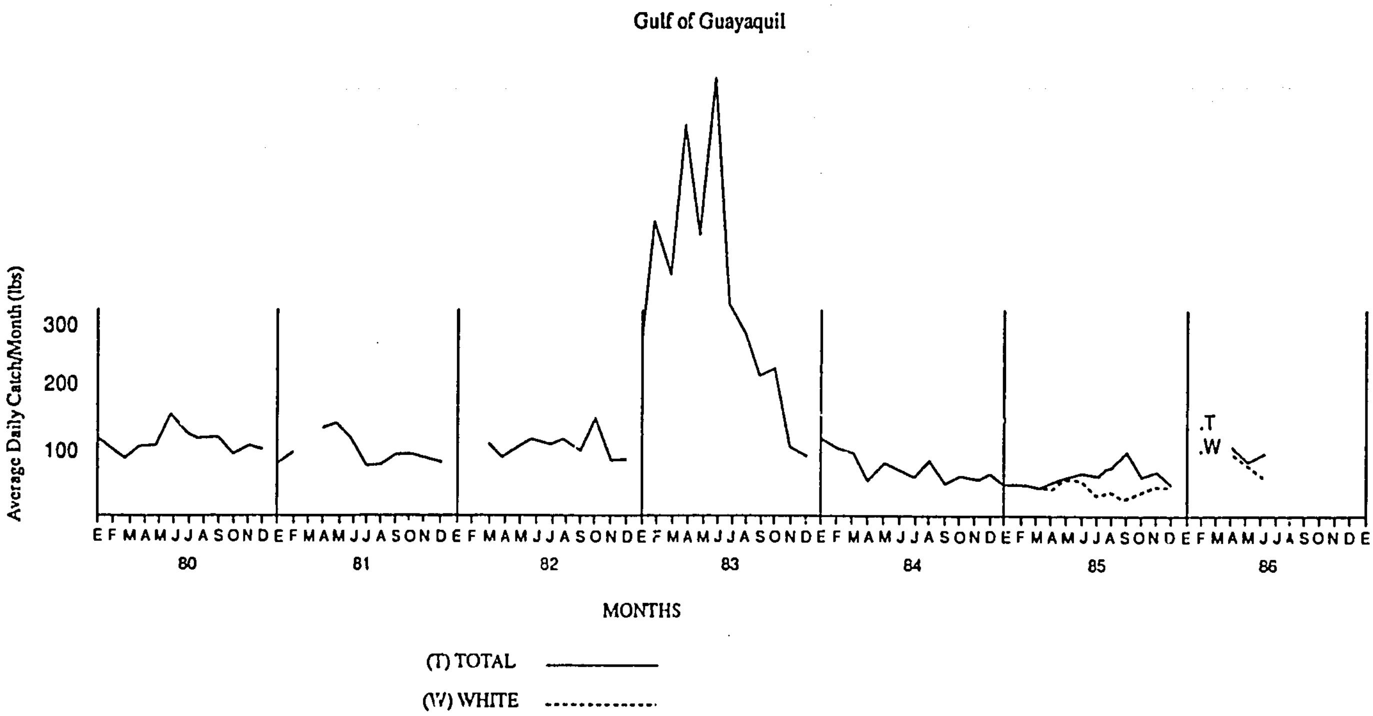


Figure 2a. Mean Annual Species Composition

Gulf of Guayaquil

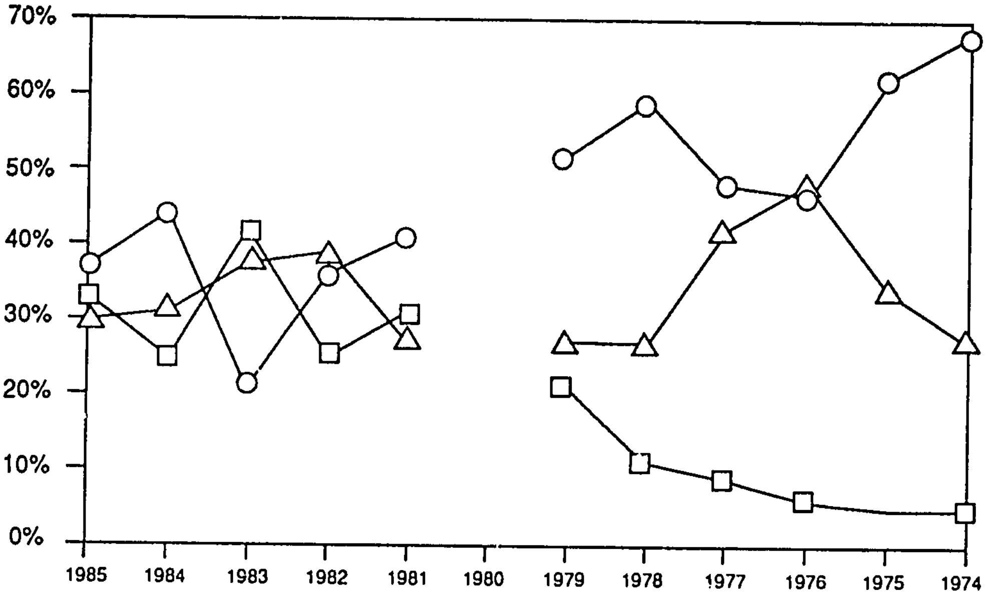


Figure 2b. Punta Santa Elena - Cabo San Francisco

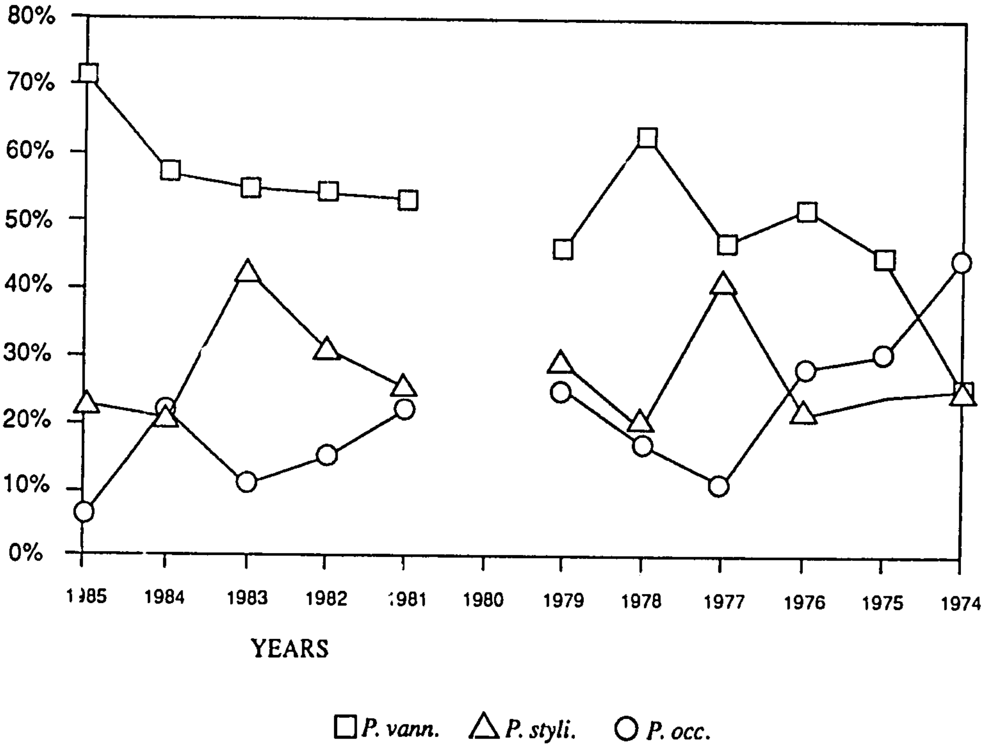


Figure 3a. Monthly Species Composition
White Shrimp

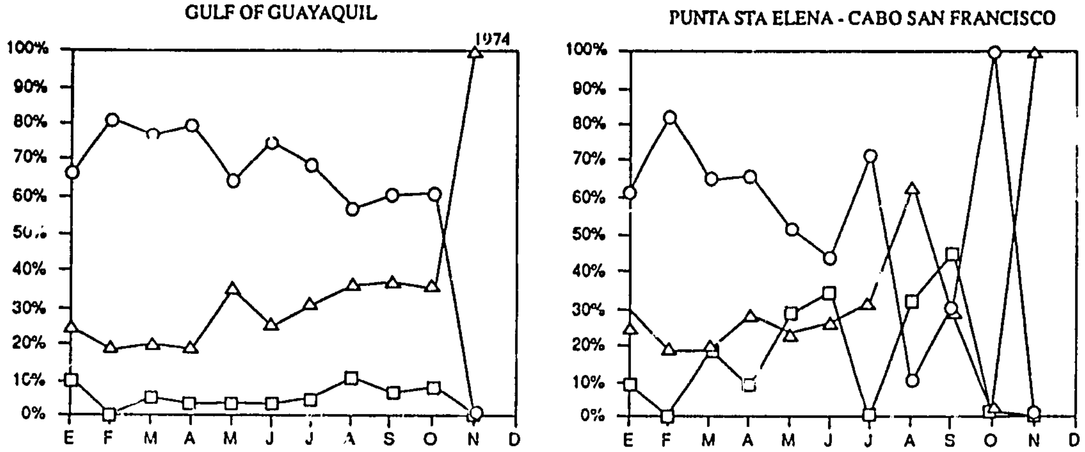


Figure 3b.

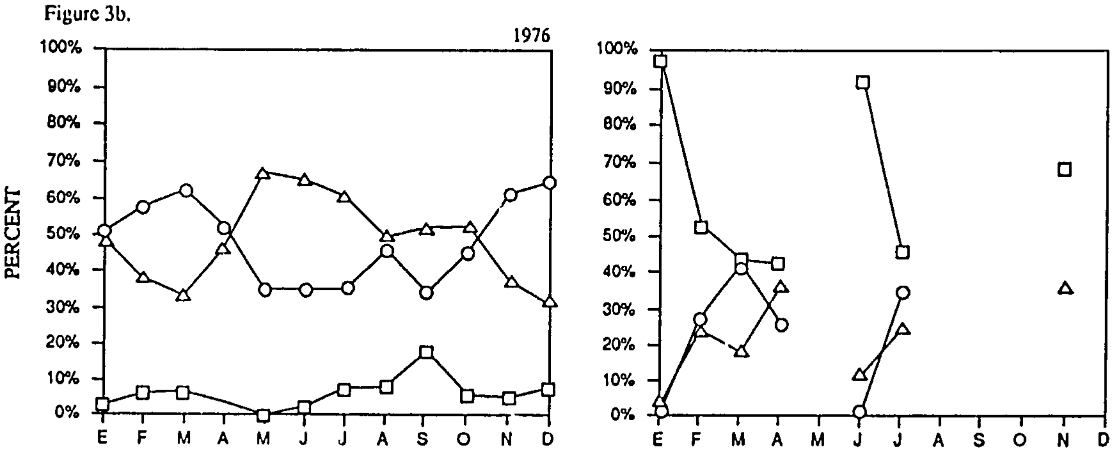
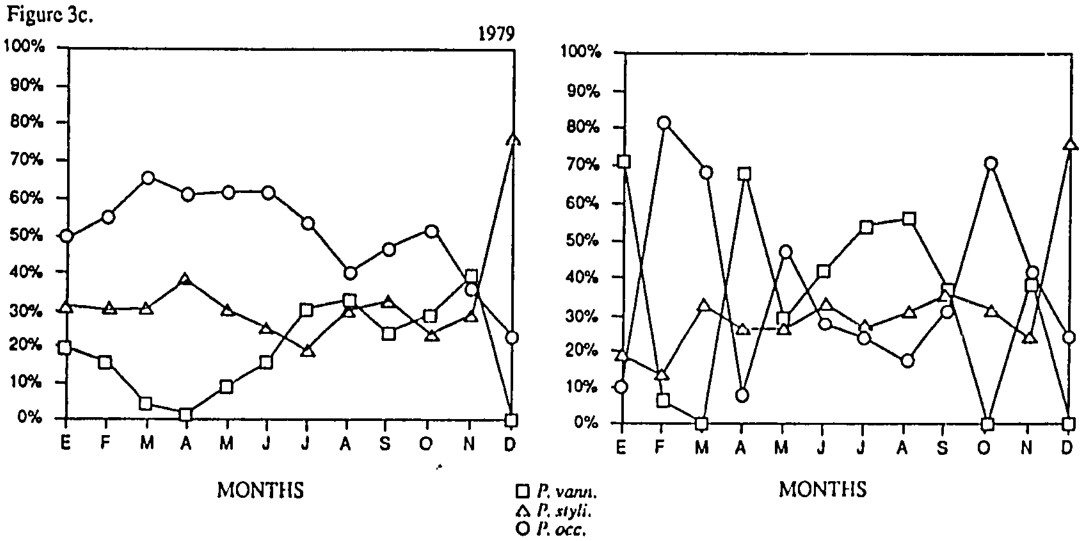
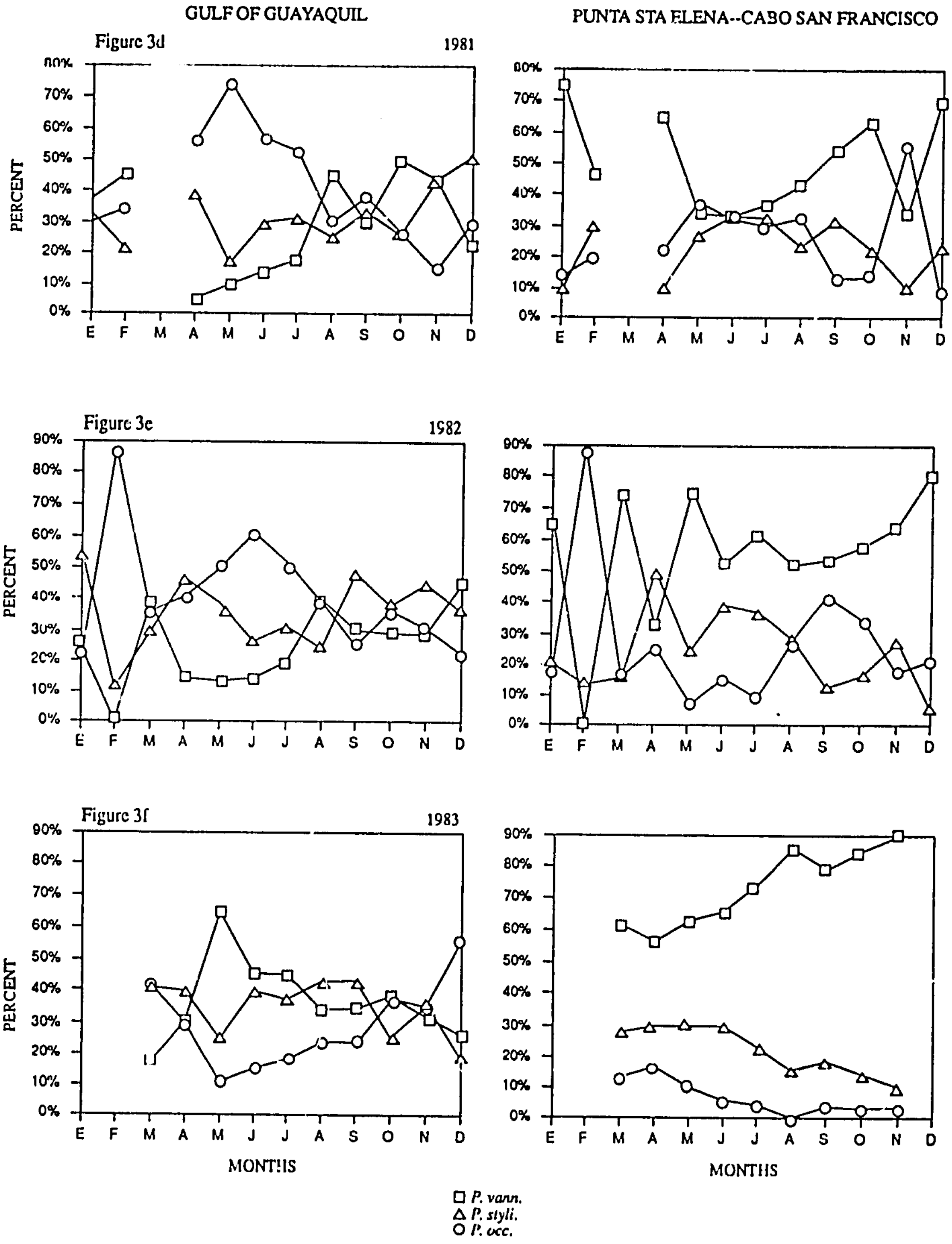


Figure 3c.



Monthly Species Composition White Shrimp



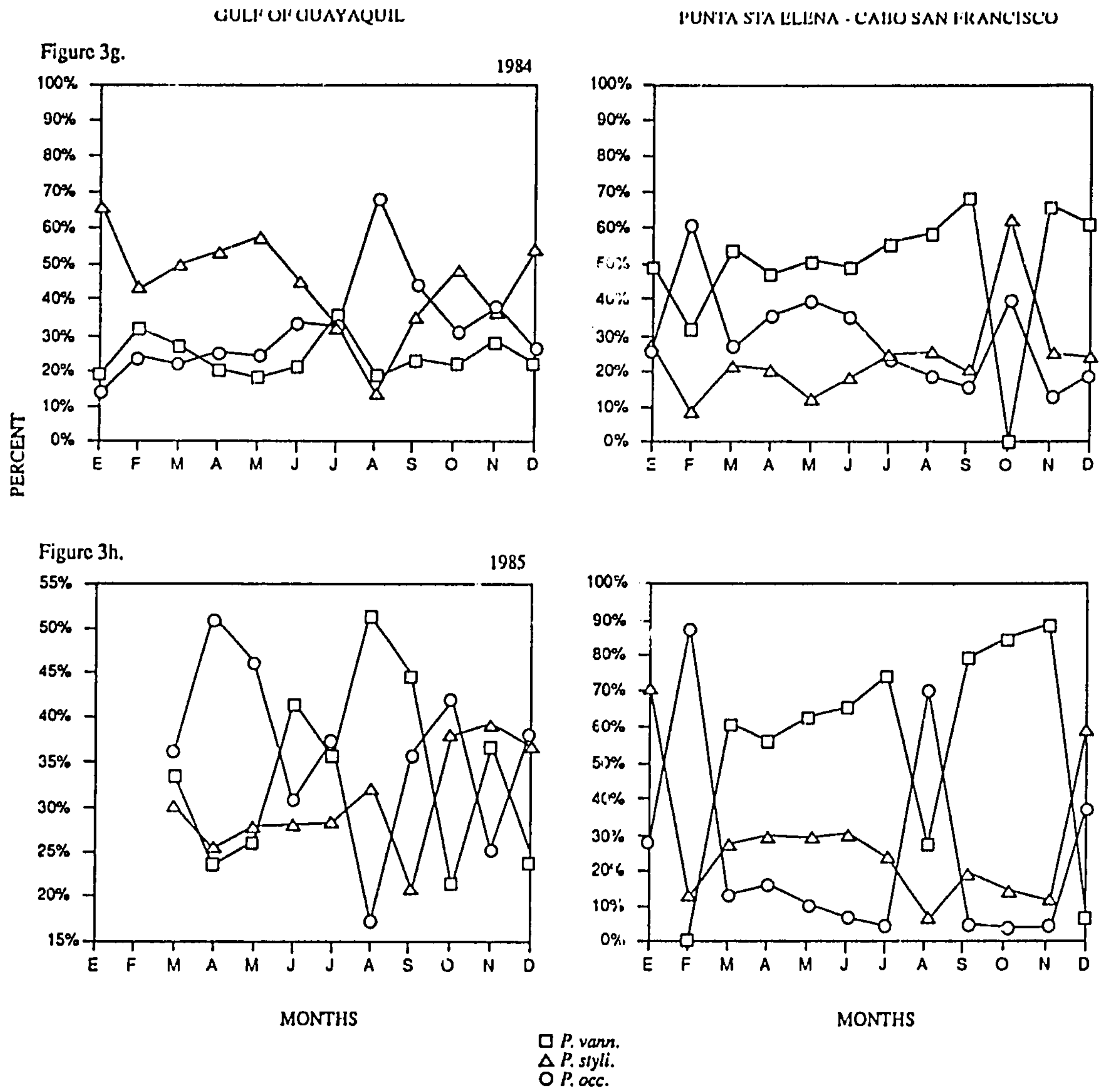

GULF OF GUAYAQUIL
PUNTA STA ELENA - CABO SAN FRANCISCO
Figure 3g.
1984
Figure 3h.
1985
PERCENT
E F M A M J J A S O N D
MONTHS
MONTHS
P. vann.
P. styli.
P. occ.

Figure 4

Gulf of Guayaquil

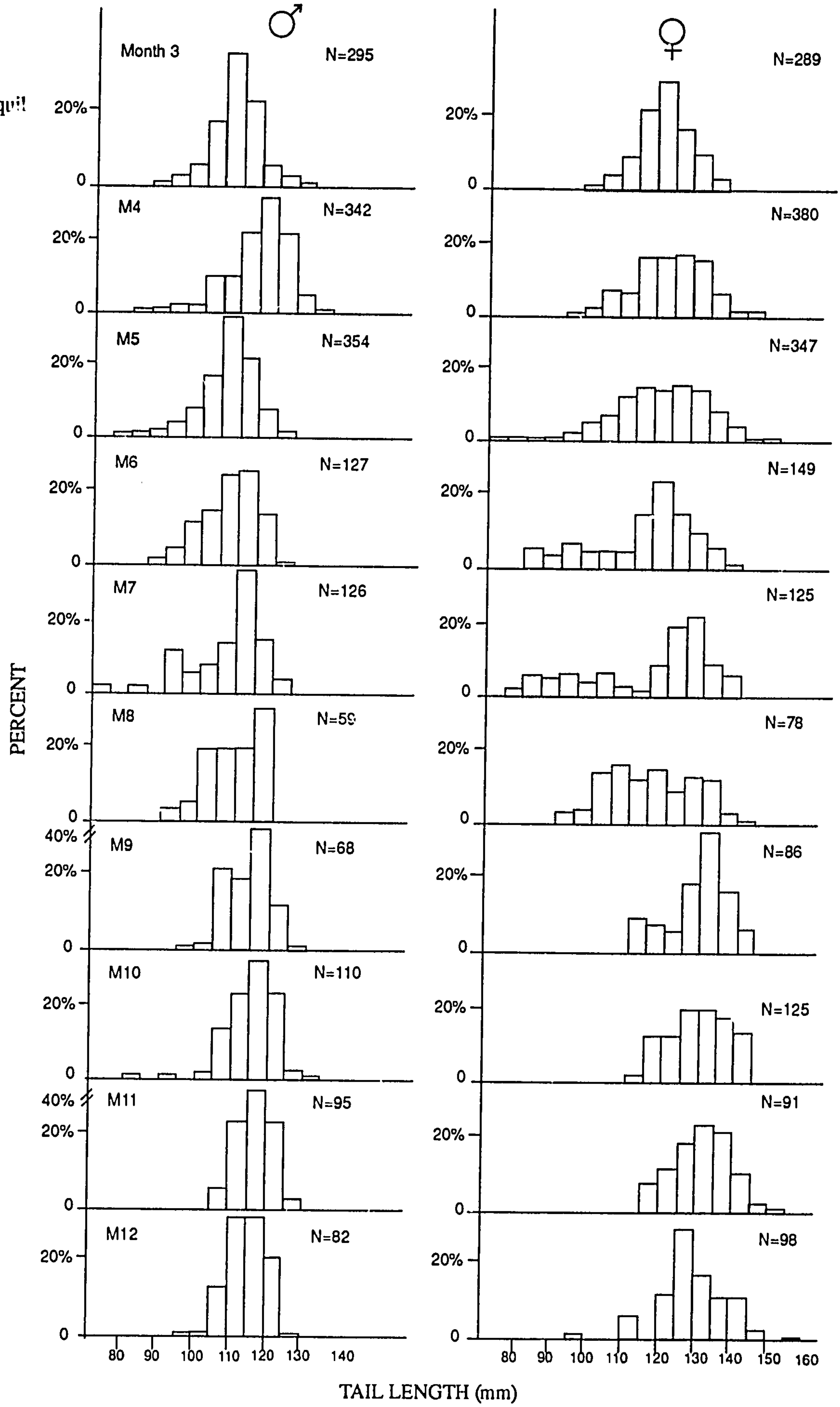


Figure 5.
Tail Length Frequency
P. Stylirostris 1985

Gulf of Guayaquil

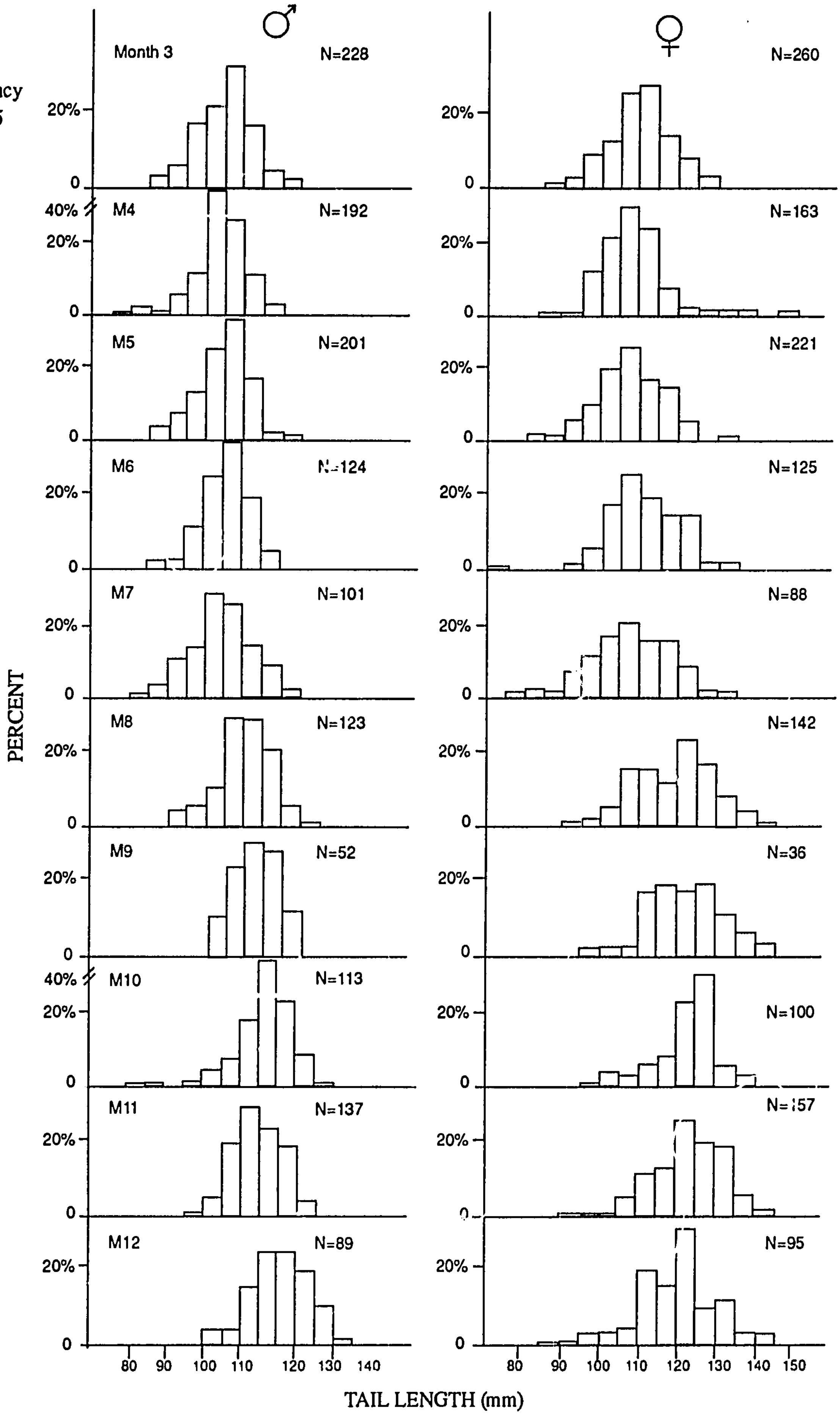


Figure 6.

TAIL LENGTH FREQUENCY
P. Vannamel, 1985

Gulf of Guayaquil

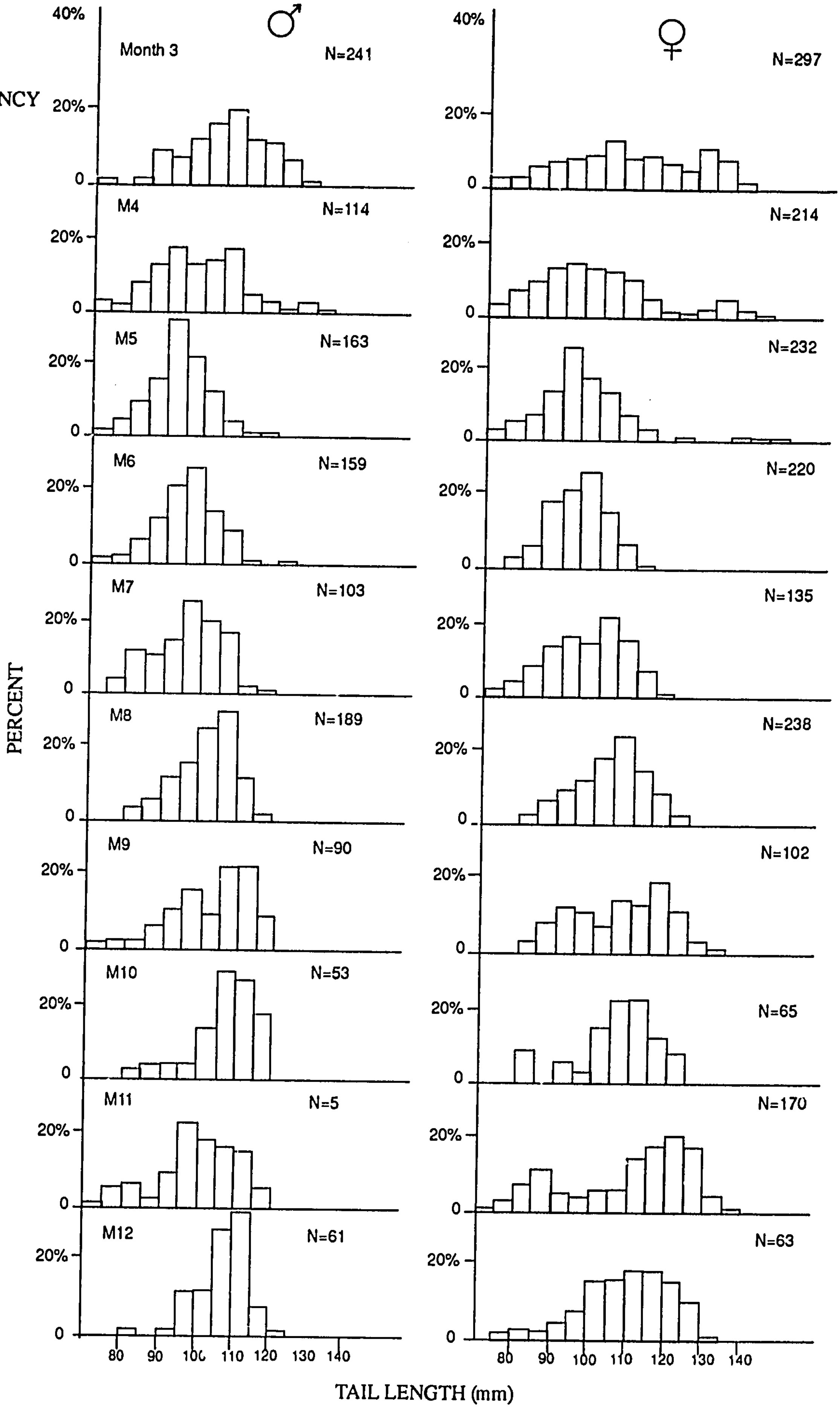


Figure 7. Average Monthly Tail Length - Gulf of Guayaquil 1985

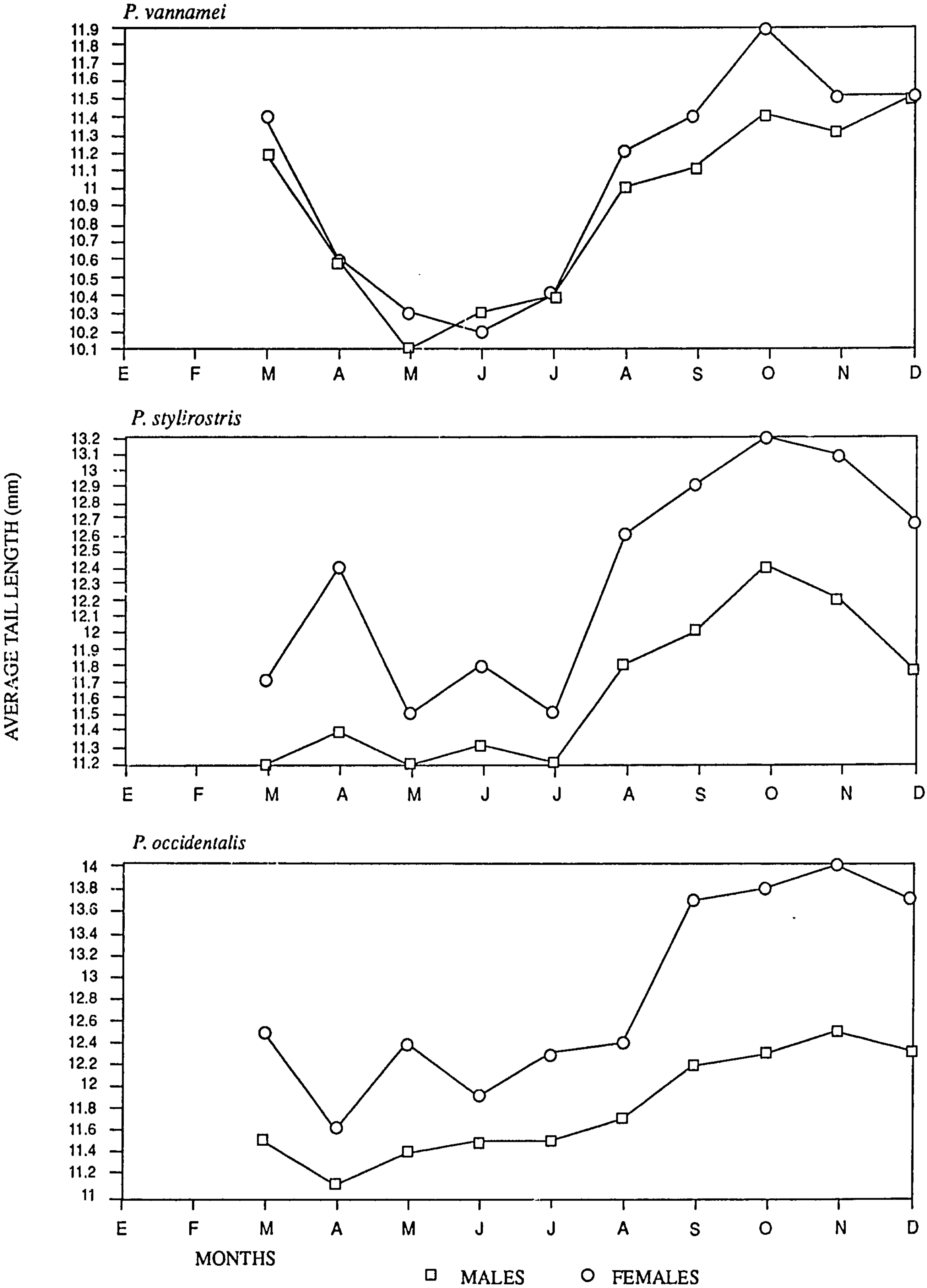


Figure 8. White Shrimp Exports 1985

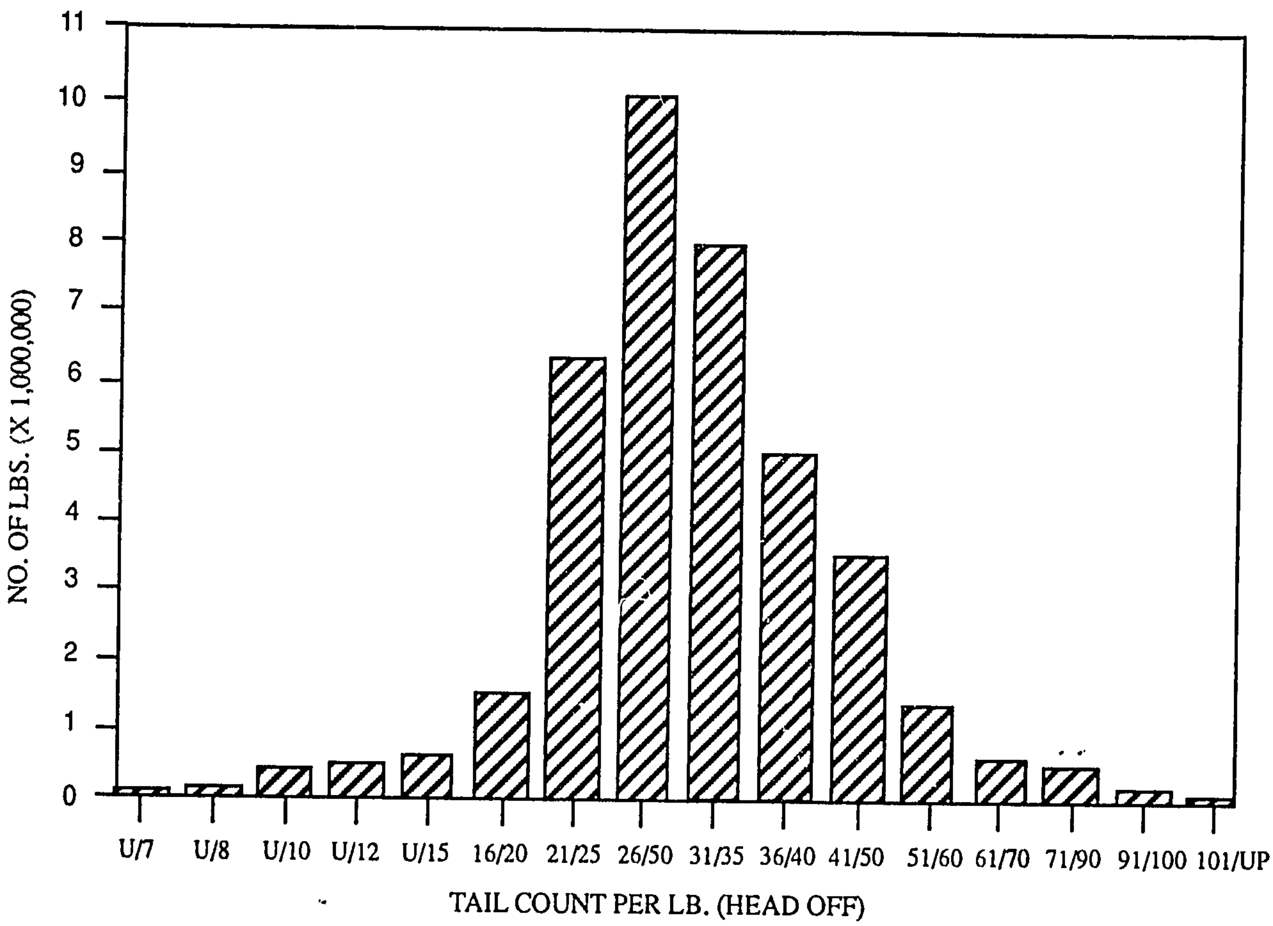
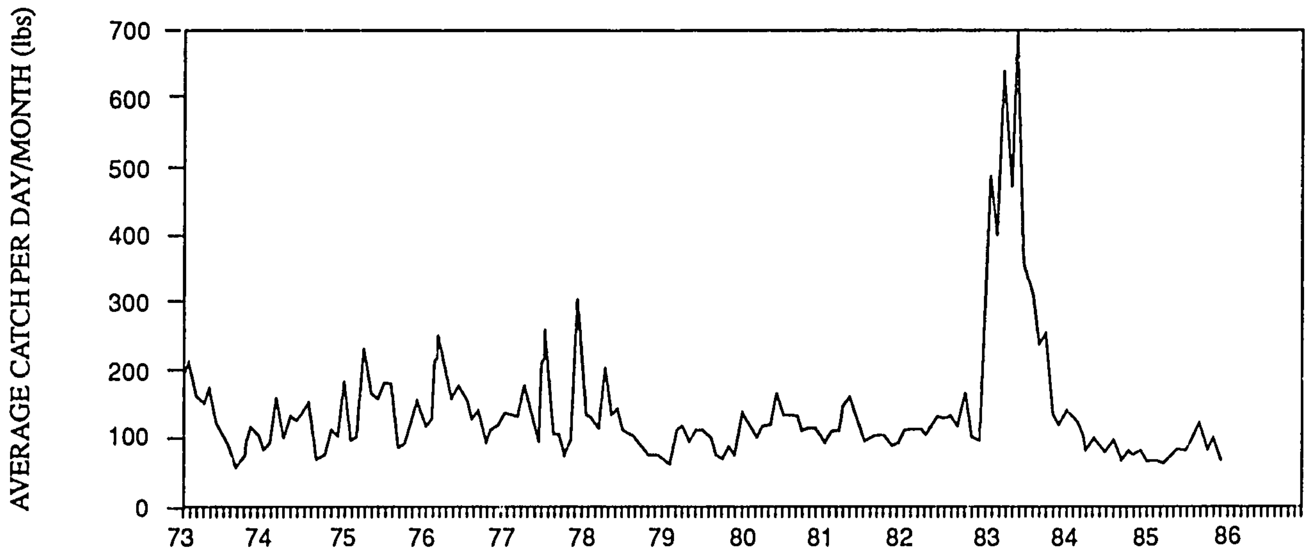
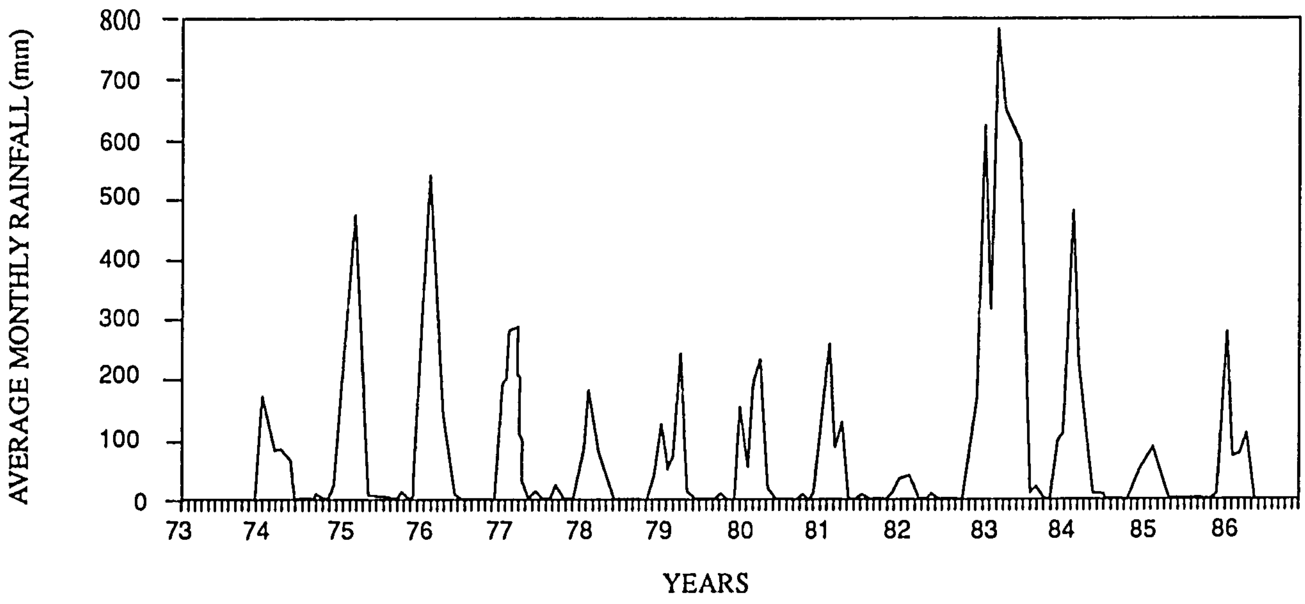


Figure 9. Monthly C.P.U.E. - Gulf of Guayaquil 1973-1985



Average Monthly Rainfall Guayaquil 1974-1986



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Review of Ecuadorian Offshore Shrimp Fisheries and Suggestions for Management and Research

Revisión de la Pesquerí: Ecuatoriana del Camarón Costero y Sugerencias para su Manejo e Investigación.

Edward F. Klima

Resumen

En la pesca de arrastre del camarón blanco entre 1965 y 1979, las capturas de Penaeus occidentalis comprendieron entre el 50 y el 60% de los desembarques totales de camarón blanco, siendo la especie más importante en la pesca con buques de arrastre. En segundo lugar se ubicó la especie P. stylirostris (25 - 45%) y finalmente P. vannamei (6%). A este respecto debe anotarse que se observó amplias variaciones anuales en la composición por especies de las capturas.

La Captura por Unidad de Esfuerzo (CPUE) (captura anual promedio por buques) en los primeros años varió grandemente, desde 352 lb/día (1956-1957) hasta 143 lb/día (1958-1959). En general, la CPUE fue de alrededor de 200 lb/día en la zona de Esmeraldas y 177 - 120 lb/día en el Golfo de Guayaquil, entre 1961 y 1964. Desde 1973 hasta 1982, la CPUE ha sido más o menos estable, fluctuando alrededor de 120 lb/día. Un aumento significativo fue observado en el año de El Niño de 1983, cuando la CPUE saltó a 345 lb/día, pero luego cayó a niveles bajos de 78 y 68 lb/día.

Se ha supuesto que el Golfo de Guayaquil es el principal lugar de cría para P. vannamei y tal vez para otras especies de camarón blanco. Igualmente, se piensa que el tamaño y la persistencia del área de cría puede estar determinada por la influencia de las corrientes de aguas frías y cálidas. Somers demostró una relación estrecha entre la cantidad de lluvias y la CPUE: conforme aumentan las lluvias también lo hacen las CPUE. Sin embargo, esta relación encontrada está dominada por la presencia de El Niño de 1983, que mostró gran cantidad de lluvias y muy alta CPUE.

El autor analiza a continuación aspectos referidos a la información científica para manejo, las necesidades de datos estadísticos y el manejo actual de las pesquerías, incluyendo la implantación de vedas. Finalmente presenta varias recomendaciones, tales como: Ampliar el programa de recolección de datos estadísticos (capturas, esfuerzo de pesca, composición por especies y por tallas de las capturas comerciales, catura artesanal de postlarvas), efectuar estudios independientes para evaluar las acciones de manejo y determinar el reclutamiento y distribución de postlarvas y juveniles de! camarón, así como estudios de marcación-recaptura para determinar los límites de los "stocks".

Introduction

The Ecuadorian offshore trawl fishery commenced in 1952, according to Cobo and Loesch (1966). Between 1954 and 1975 the fishery fluctuated from a high of 8,700 m.t. in 1969 to a low of around 5,000 m.t. in 1964, with production fairly stable at around 6,000 metric tons. Since 1976, with the inception of the culture industry, accurate information on total production is not available for the offshore trawl fisheries. However the number of vessels has gradually increased to approximately 250-300 in 1985.

Predominant Species

Cun and Marin (1982) estimated that *Penaeus occidentalis* comprised between 50 percent and 60 percent of the white shrimp catch from 1965 to 1979, and is the most important species to the trawl fishery. The second important species is *Penaeus stylirostris* which constituted between 25 percent and 45 percent of the catch during the 1965 through 1979 period; *P. vannamei* was 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 of this species. McPadden (personal communication) 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, *P. californiensis* and *P. brevirostris*, do not appear to be a major part of the offshore catch, possibly because these species are found farther offshore, and the fishery may not operate in offshore waters as readily as in the nearshore waters. There appear to be two principal fisheries: one north of the port of Manta with both white and brown shrimp as main components, and the other south of Manta, composed mostly of white shrimp. The interchange of shrimp and stock delineation between the two areas is unknown.

CPUE

Detailed information on monthly catch-per-unit effort (CPUE) by commercial double-rigged trawlers is available from 1973 to the present, but annual CPUE estimates from 1956 to 1972 are limited. The data from June 1973 to the present are based on interviews with vessel captains in the Gulf of Guayaquil. Charles McPadden (personal communication) has used this data to clearly demonstrate the measures of relative abundance from 1973 to 1986. In addition, monthly mean size and length frequency distribution by species is available in 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.

In 1986 Ian Somers (personal communication), U.N. Food and Agriculture Organization (FAO) consultant from Australia, evaluated the impact of the postlarval and offshore shrimp fisheries on the long-term recruitment (adding to harvestable population) of major commercial species of shrimp, with particular reference to *P. vannamei*. Findings of both Somers and this author (1986) show that total annual production statistics are based on export records and do not distinguish between farm and sea production. A series of production estimates were made by Somers and, although none of these appears to be reliable, they may be adequate to depict an overall upward trend in production and the number of vessels in the offshore fishery. Somers identifies the production estimates by various researchers throughout this time frame (Figure 1).

The annual CPUE per boat in the early years of the fishery was relatively high but varied greatly, ranging from a high of 352 lbs/day in 1956-57 to approximately 143 lbs/day in 1958-59 (Table 2). Generally, the annual CPUE was about 200 lbs/day in the Esmeraldas region and 177 to 120 lbs/day in the Gulf area between 1961 and 1964. Total annual CPUE has been more or less stable from 1973 through 1982, fluctuating around 120 lbs/day (Figure 2). A significant increase in catch was noted in the El Niño year (1983) where the CPUE jumped to 345 lbs/day and thereafter dropped to low levels of 78 and 68 lbs/day.

Recently the British Mission under Charles McPadden instituted two major programs for data collection. First, in November 1985 an observer-at-sea program was initiated in which observers participate in fishing trips each month from the ports of Posorja, Guayaquil and Manta, and every other month from Esmeraldas. Information is collected on the catch-per-tow, hours fished, areas fished and species composition. Second, in February 1986, a logbook system was initiated throughout the country. Information will be obtained on catch-per-tow by area and time fished. The best data base on the shrimp fishery available for analysis is the information obtained from interviews on catch and fishing effort. Reliable information is not available on total catch or total fishing effort.

CPUE and El Niño

The El Niño year (1983), was phenomenal in that the offshore fishery CPUE increased dramatically, probably as a result of increased spawning activity, better survival of juveniles and good recruitment to the offshore fishery. Immediately after the El Niño, in January 1984, monthly CPUE dropped to pre-El Niño year levels. Since that time, the CPUE appears to have decreased each month and has continued to decrease through 1985.

Somers (1986) has separated the annual CPUE for the 1984-1986 period into all species and *P. vannamei*. The total average annual catch rate for 1984-1985 was 73 lbs/day, well below the average 113 lbs/day for the 1973-1979 time frame. The specific catch rate for *P. vannamei* was 23 lbs/day in 1984-1985, considerably greater than the average 13 pounds per day for 1973-1979. The initial catch rate for all species for the first few months in 1986 was 126 lbs/day, which is similar to the earlier catch rates for 1973-1979, but somewhat lower than earlier years (1961-1964) in the fishery.

Since March 1985, McPadden has obtained information on CPUE for white and brown shrimp. This data reveals that the monthly CPUE for white shrimp decreased to a level below 40 lbs/day, whereas brown shrimp monthly CPUE peaked in September 1985 at over 110 lbs/day.

Managing Recruitment

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. However, it is disturbing that the CPUE before the closure period 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, regulations to reduce fishing mortality should be considered.

Somers (1986) indicated that there was insufficient evidence to demonstrate any significant declines in recruitment to the offshore fishery. However, the current CPUE levels (less than 40 lbs/day) are extremely low compared to any other world penaeid fisheries for the type of vessels that are presently being utilized off Ecuador, and has declined precipitously from the initial CPUEs after the fishery had stabilized between 1961 and 1964.

If the percentages of species composition are correct, as identified by McPadden, there has been a significant increase in *P. vannamei* captured as reflected in the increased CPUE for this species in the last few years; however, the decline in the other species should cause concern. A significant cause for the decline in CPUE other than overfishing may be reduction in the mangrove areas that are used as nursery areas by larval and juvenile shrimp (Zimmerman and Minello, this volume). Alvarez (this volume) indicates that 10.6 percent of the mangrove area has been lost in the last ten years in Ecuador.

McPadden has also been able to estimate the number of postlarvae delivered to mariculture ponds by the artisanal fishery, but there is considerable uncertainty concerning these values. Maugle (personal communication) indicates that up to 50 percent of the caught larvae die before they reach the pond, therefore the estimates are probably low by at least half. There appears to be a peak of postlarvae production at around 4 billion individuals (i.e. perhaps 8 billion) in 1984, declining somewhat after that. McPadden (1985) indicates that the catch estimates of postlarvae in 1985 were slightly lower than the corresponding estimates for 1984. He has also pointed out that the postlarval fishery involves 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 stocks.

Biological Influences on Fisheries

Water Temperature

It is hypothesized that the Gulf of Guayaquil is a prime nursery area for *P. vannamei* and perhaps other white shrimp species. McPadden (1985) indicated that juvenile white shrimp are found predominantly in the Gulf of Guayaquil, whereas mature animals have not generally been observed in this area. The size and persistence of the nursery area may be dictated by the influence of the warm or cool currents. The movement of warm water (26°C) from the north into the Gulf of Guayaquil during September, October and November probably enhances spawning for white shrimp as well as transporting larvae into the Gulf. If the warm water area is large enough and lasts long enough, spawning and recruitment will probably be very good. However, if the cooler southern currents with temperatures of 22°C to 23°C confine the warm water areas during this period, spawning and survival of larvae and juveniles are negatively affected. Further, if the cold southern water penetrates the Gulf, the juveniles may migrate north toward the Esmeraldas area during the April-May period.

Rainfall

Somers has demonstrated a close relationship between rainfall and CPUE (Figure 3). Low rainfall results in low CPUEs; as rainfall increases, so does CPUE. However, this relationship is dominated by the El Niño phenomenon of 1983 and its corresponding high rainfall and high CPUE. The correlation is extremely good at the lower and mid-level of the scale and implies a linear relationship with relatively low levels of rainfall (up to 2,000 mm per year). This relationship indicates that recruitment from 1973 to 1984 was influenced more by environmental conditions than by other factors. Overfishing does not appear to be a major factor in the success of year-class strength.

Fishery Management and Scientific Information

Governments have prime responsibility for conserving marine resources and ensuring that marine stocks are available to future generations in the same quantities as to the present generation. U.S. President Theodore Roosevelt 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 share this responsibility. They must, of course, prevent recruitment overfishing and certainly minimize growth overfishing (i.e., harvesting animals before the maximum population of that year-class is achieved). Difficulty arises most often in allocation of the resources between competing user groups. Managers must utilize the best scientific information available, as well as input from the industry and consumer groups. Obviously, there is a need for information exchange among scientists, managers, the harvesters and enforcement (Figure 4).

The acceptability of management decisions depends on the flow of information, therefore it is important that significant input be provided by the users of the resources. Various methods may be used to provide industry input. For example, special panels may be established as advisory groups to government officials making management decisions. In the United States, having citizen advisory groups is a legal requirement during development of management plans for federal waters (Leary, 1985).

At the opposite end of the continuum is a system headed by an industry 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. Therefore, it is recommended that Ecuador consider expanding the program initiated by McPadden to collect statistical information on the shrimp industry from logbooks and interviews of vessel captains regarding catch, effort, CPUE and species composition. Also, a comprehensive program to collect other fishery-dependent data as well as fishery-independent data should be implemented.

Fishery-Dependent Data

The following fishery-dependent data is critically needed for management decisions:

- total catch
- fishing effort
- size composition and species composition of the commercial catch

While it might be impossible to take a regular census of the offshore fishery, some type of sampling program is required to provide accurate total catch and fishery effort information. A special study should be conducted to determine the appropriate experimental design, methodology and approach for a country-wide sampling program to collect the necessary fishery statistics.

The key to implementing a sampling program to estimate total catch and effort is to make recording the number of vessel trips mandatory. Of course, cooperation of the industry is critical; without assurance from the government that the confidentiality of the data will be maintained, it will be impossible to obtain this cooperation. It is also necessary to establish field stations at major unloading ports, such as Esmeraldas, Manta, Bolivar and Guayaquil. These field stations could be manned by a small team of data collectors and research scientists who would obtain fishery catch statistics.

Equally important is the collection of accurate information on the artisanal postlarvae fishery, including the quantity of each species of postlarvae caught monthly, areas fished and the number of individuals involved. Sampling the artisanal postlarvae fishery on a regular basis could also be conducted from the field stations.

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 study could be conducted by tagging shrimp in either or both areas and obtaining recoveries from the fleet. 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 Esmeraldas. Finally, the collection of tag recoveries would be enhanced by the establishment of field stations.

Fishery-independent surveys to monitor the shrimp populations in the fishery grounds are expensive but do provide long-term information on status and trends of the major species. For example, such surveys conducted once or twice a year would be useful for evaluating effects of shrimp closures (Matthews, 1982). The current program to monitor the distribution and abundance of postlarvae and juvenile shrimp in the Guayaquil estuary should be continued, and expanded to other areas of the coast.

Management of Ecuadorian Fisheries

The two shrimp closures recently imposed by Ecuador appear to have been successful, but without a system of statistics on total catch, fishing effort, CPUE, as well as size composition and species composition of the commercial catch, it is impossible to accurately assess the effects of closures (Nichols, 1982; Klima et al, 1982; Poffenberger, 1982; and Mathews, 1982). Without such evidence, it will also be unlikely that continued industry support for periodic closures will be available, though sometimes, even with good information, the political whims of various user groups may be swayed because of selfish interests.

Establishing a permanent, long-term program to collect fisheries statistics from the offshore fishery and the postlarval fishery will form a data base for evaluating both. Without that type of data base, it will be difficult to determine if recruitment overfishing is occurring. The fishery-dependent data bases can also 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 a serious problem, the fishery's low CPUEs in 1984 and 1985, and the switch in species composition from *P. occidentalis* and *P. stylirostris* to

P. vannamei are of some concern. The Ecuadorian government should consider a method of imposing a limited entry system since there seem to be enough vessels to capture the amount of shrimp currently being harvested. Any increase in fishing effort or number of vessels will only decrease CPUE and the per boat share of the resource. The government should also consider continuing the experimental closures. The rationale behind this is that a reduction in fishing mortality will not hurt the fishery and, in fact, may be a long-term benefit. The 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. The author recommends that a management and research plan be jointly developed by the government and shrimp industry to identify goals and objectives and to describe possible management actions that will ensure a viable fishery. Implementation of the plan will require adequate financial resources for management, research and enforcement.

Summary

It is the responsibility of the Ecuadorian government to develop a long-term plan for the management of their shrimp fisheries. Included in this plan should be implementable goals, objectives and financial support not only for management and enforcement, but for research as well. To these ends, the British Mission is working to develop such a plan.

The closed season and area restrictions imposed in 1985 to 1986 by the government appear to have been successful because of the increased CPUE immediately following the closure. Unfortunately, there is inadequate data to determine whether the increased CPUE was due to the reduction of fishing effort which allowed an increase in biomass through population growth, or, conceivably, because of an increase in recruitment which allowed the delayed harvest to be larger and more profitable. Nevertheless, the closed season and area concept should probably continue, if only because it reduces fishing effort.

A sound statistical data collection system should be developed not only to evaluate closures, but also to evaluate conditions of the stocks and to provide advice for future management actions. The collection of fishery statistics should and must be considered confidential data and should only be released in summary form to protect individuals. 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. Joint planning and development of such programs between industry and the Istituto Nacionale de Pesca (INP) will accelerate supported implementation of these programs.

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

Table 1

Penaeus vannamei, *P. stylirostris*, and *P. occidentalis*, expressed as percentage of these species total catch in the Gulf of Guayaquil in 1985.

	P. stylirostris	*P. vannamei*	*P. occidentalis*
March	33	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

(Source: McPadden, personal communication)

Table 2

Total catch in millions of pounds, fishing effort in thousands of days fished, and CPUE for white shrimp for the Gulf of Guayaquil and Esmeraldas.

Area	Year	Total Weight, millions of pounds	Fishing Effort, thousands of days fished	CPUE lbs/day
	1956-57	2.94	8.4	352
	1957-58	3.60	12.6	286
Gulf and Esmeraldas	1958-59	2.78	19.4	143
	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

(Cobo and Loesch, 1966)

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

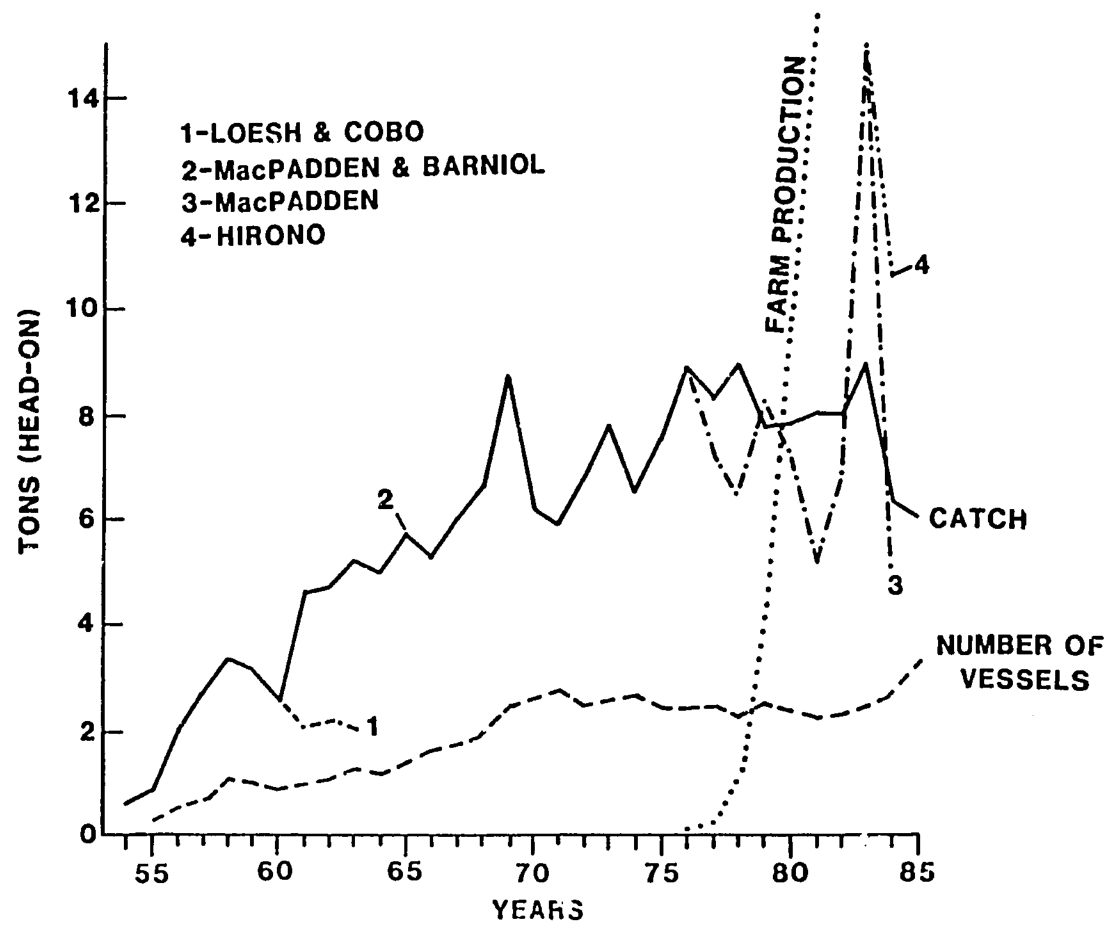


Figure 2. Monthly catch per unit effort (lbs head-off) for all shrimp species and *P. Vannamei* in the Gulf of Guayaquil from 1973 to 1985.

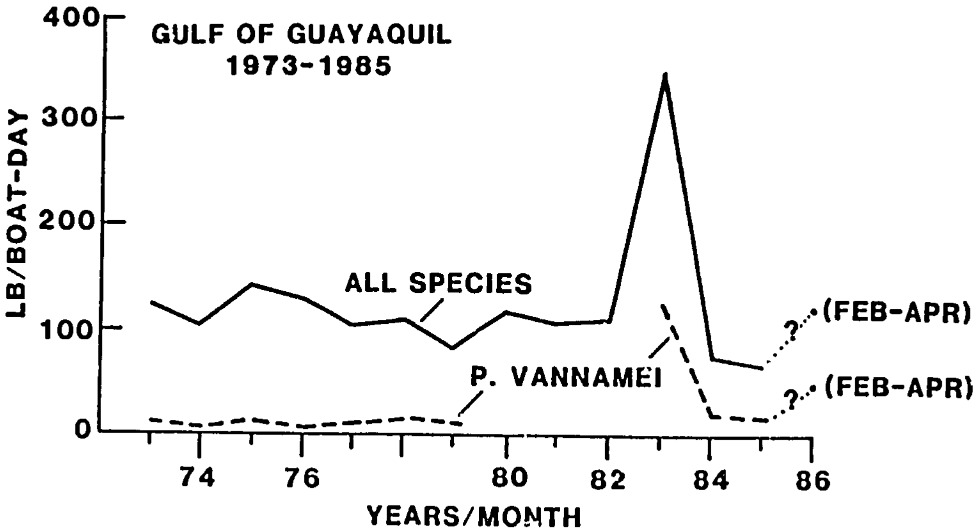


Figure 3. Relationship between rainfall (mm) and CPUE (kg/day, heads-off) in the Gulf of Guayaquil (CPUE = 22.2 + 0.034 rainfall; r^2 = .88).

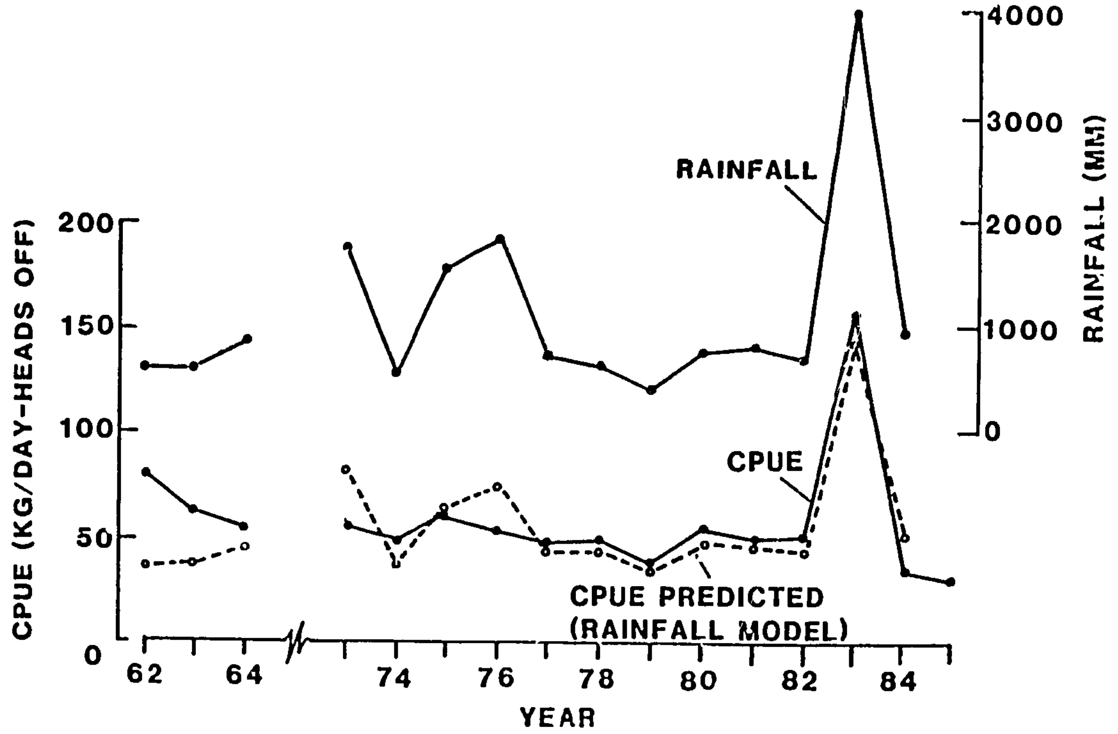
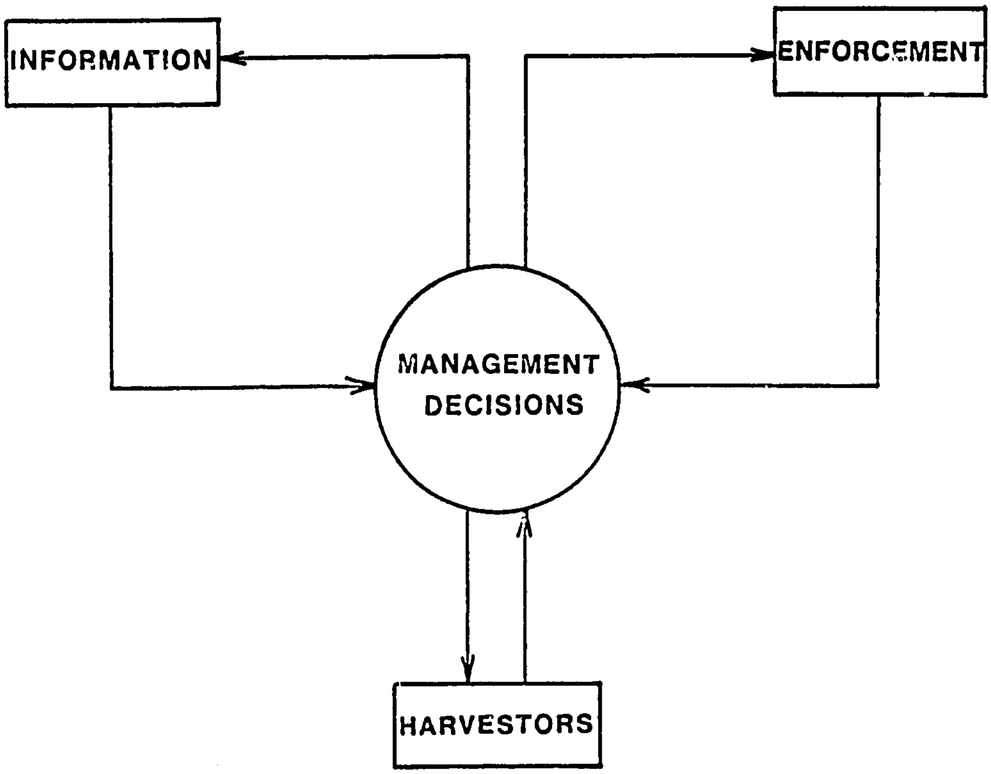


Figure 4. Information flow used to make fishery management decisions.



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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

Reclutamiento y Distribución de Postlarvas y Juveniles de Camarones Peneidos en un Estuario Grande de Manglares en el Golfo de Guayaquil durante 1985.

Roger J. Zimmerman y Thomas J. Minello

Resumen

El estudio se refiere a los patrones de distribución y abundancia de camarones Penaeus en cinco esteros (Data, Morro, Corvinero, Grande y Salado) en el Estuario del Río Guayas, todos ellos dominados por habitat de manglar y donde es evidente el gradiente salino. El período del estudio comprende desde febrero de 1985 hasta enero de 1986.

Los extremos de la temperatura del agua fueron: 31°C en febrero y marzo (estación lluviosa) y 24°C en julio y agosto (estación seca). La salinidad, en contraste, varió más que la temperatura y una relativa alta salinidad durante 1985 fue indicación de un año seco. El gradiente ambiental en el estuario fue evidente: bajas salinidades en el Estero Salado, en la cabeza del estuario, y altas salinidades en el Estero del Morro y Golfo de Gauyaquil. Dentro de los esteros, las menores salinidades correspondieron a los lugares interiores con ingreso de aguas dulces (Esteros Salado y Corvinero) y las salinidades más altas debidas a la evaporación tambien estuvieron en lugares interiores de los esteros más próximos a la costa (Esteros Morro y Data).

Las tallas de las postlarvas (pls) y juveniles obtenidas en los esteros estuvieron entre 5 mm y 70 mm de longitud total (rostro-telson) y el orden de abundancia fue: (1) Penaeus californiensis, (2) P. vannamei, (3) P. stylirostris y (4) P. occidentalis. El primero fue nueve veces más abundante que los demás.

El patrón de abundancia estacional indicó que P. californiensis fue numeroso todo el año, con máximos en febrero (1985) y enero (1986). P. vannamei tambien estuvo presente todo el año en los muestreos, pero fue menos abundante y sus picos correspondieron a julio, septiembre y enero. P. stylirostris, también escaso, presento su mayor abundancia en las muestras de marzo y noviembre. Por otra parte, los patrones de abundancia indicaron que los esteros más cercanos a la fuente de reclutamiento (Golfo de Guayaquil) ofrecen un habitat para un mayor número de camarones por unidad de área, que aquellos esteros más alejados. Así, el mayor número para todas las especies estuvo en la boca del Estero del Morro. Los esteros Corvinero, Salado y Grande, en la parte interior, tuvieron sustancialmente menor abundancia. También, la mayor abundancia de camarones se escontró en los lugares con manglar, al interior, mientras que en los lugares de aguas abiertas, en la mitad de los esteros, la abundancia fue menor.

La distribución estacional de los parámetros ambientales sugieren que una mayor abundancia de P. californiensis se relaciona con altas salinidades, mientras que la menor abundancia de las otras especies implican lo contrario.

Los datos de 1985 indican que un año seco y frío parece afectar negativamente el reclutamiento y la distribución de P. vannamei y de P. stylirostris. Sin embargo, todas las especies respondieron con incrementos durante la estación lluviosa, demostrando que las condiciones meteorológicas ayudan a regular la época y el tamaño de los eventos de reclutamiento.

Es importante reconocer que las tres especies utilizaron las áreas interiores de los esteros como criaderos primarios. Las muestras indican que todas las especies fueron atraídas al interior de las áreas dominadas por manglares y, en consecuencia, sirvieron como habitat de cría primario para las tres especies en referencia.

Las informaciones sobre capturas de pls indican que P. vannamei y P. stylirostris son obtenidos selectivamente y, de la misma manera, se excluye a P. californiensis. El impacto de esta explotación diferencial podría tener, en el largo plazo, un efecto de reestructuración en la población total de camarones.

Introduction

The general relationship between area of intertidal vegetation and commercial yield of shrimp has been reported by Turner (1977). Since this relationship extends to the tropics (Martosubroto and Naamin, 1977; Jothy, 1984), understanding the nursery role of intertidal mangrove habitat for shrimp may be important in management of tropical estuaries (Garcia and le Reste, 1981; Turner, this publication).

The life cycle of most penaeid shrimp begins with offshore spawning and continues through a series of planktonic larval stages that terminate with postlarvae carried into estuaries by tidal currents (Staples and Vance, 1985). Once in the estuarine environment, juvenile shrimp find ideal nursery conditions for growth and survival. Vegetation in estuaries offers young shrimp a protective structure that is effective against predatory fishes (Minello and Zimmerman, 1984) and substrate that encourages development of epibenthic plant and animal foods (Gleason and Zimmerman, 1984; Leber, 1985). Estuarine bottom without vegetation is also valuable and deters predation with sediments favorable for shrimp burrowing and turbid water that obstructs predator vision (Minello et al., 1987). Nonvegetated muddy bottom may also provide large numbers of infaunal worms on which shrimp feed (Flint, 1985).

The variety of useful estuarine habitats allow various shrimp species to select different microhabitats (Zimmerman and Minello, 1984). Accordingly, one species may select mangrove habitat while another thrives in intertidal mud flats. The suitability of different habitats for meeting preferences of young shrimp will vary along environmental gradients and through interannual variability. For example, annual changes can shift habitat-related abundances of shrimp foods, such as phytoplankton, epiphytic algae, epifauna, infauna, and detritus, thus favoring one or another shrimp species according to dietary preferences. Likewise, mangrove habitat in brackish water at the head of an estuary is likely to provide different resources than mangrove habitat in marine water at the mouth of an estuary. Congeneric species of shrimp may exploit these separately because they use the estuary differently.

In the Ecuadorian estuary formed between the Guayas River and the Gulf of Guayaquil, environmental variability is an important feature (Stevenson, 1981). This large estuary is located in northwestern tropical South America in a transitional position between humid Colombia and arid Peru (Cruz-Orozco, 1984). Rainfall is highly seasonal and varies annually dependent upon the position of cold water currents offshore (Cucalon, 1983). Normally, the cold water offshore has a drying influence, but when currents are deflected, such as during El Nino events, high rainfall occurs. Rainfall and commercial yield of shrimps in Ecuador appear to be positively correlated (McPadden, 1985; Klima, this publication); yet the relationship between rainfall and utilization of nursery habitats by shrimp in the Guayas Estuary is not clearly understood.

The aim of current research is to characterize habitat utilization and resource partitioning among shrimp species in the Guayas Estuary. In the long-term, the program is designed to compare effects of wet and dry years between habitats with and without vegetation. An initial study is presented here, addressing shrimp distributions in the estuary during 1985, a dry year.

Methods

Objectives

The first objective was to relate distribution and abundance patterns among Penaeus species in the Guayas Estuary to seasonal rainfall and salinity characteristics. The second objective was to demonstrate that juveniles of some shrimp species are attracted to mangrove habitats.

Study Sites and Design

The study was designed to survey five large branches (esteros) of the estuary along an environmental gradient beginning at the outskirts of the city of Guayaquil and extending 50 kilometers to Morro Point at the Gulf of Guayaquil. Within each estero, sampling sites were stratified to represent (1) the mangrove interior, (2) the area in the middle of the estero, and (3) the area just outside the entrance to the estero. All of the esteros were dominated by mangrove habitat that became more extensive toward the interior. Within the main estuary, a salinity gradient was evident from where the Guayas River entered at the head of the estuary, extending to the mouth and marine conditions at the Gulf of Guayaquil. The esteros studied along this gradient were Estero Data, Estero Morro, Estero Corvinero, Estero Grande, and Estero Salado (Figure 1).

Within esteros, the selection of sampling sites was designed to assess shrimp distributions and abundances related to nearness of mangroves. Accordingly, the interior sites were located in extensive mangrove areas at the head of each estero. By comparison, the other sites were removed from mangrove dominance. Outer sites were at the entrances to esteros where shorelines consisted mostly of sandy beaches. Middle sites were just inside the esteros where wide channels formed large bodies of open water. The middle sites were located inside along the wide channels comprising the main body of open water in the esteros.

Sampling

Sampling during the first year began in February 1985 and continued through January 1986. Samples were taken using a one-meter wide beam trawl with a 500 micron mesh (Renfro, 1963) during the highest tides of each month. Three replicate tows were obtained from each of the three sites within each estero. The beam trawl was pulled by hand over a distance of 33 meters on the bottom for each of the three replicates. Thus, the total distance at each site was about 100 meters, and since the trawl was one meter wide, the area covered was also equivalent to the distance towed. The trawl was deployed from the stern of a small boat while the boat moved slowly forward into the current and a line attached to the trawl was paid out. At the end of the line the boat was held in position while the trawl was slowly pulled in by hand into the current. On deck the sample was washed free of mud then removed and placed in a container with 10 percent formaldehyde in seawater for preservation. Shrimp and other organisms were removed and measured during laboratory processing of the samples. Penaeid shrimp were identified according to Loesch and Avila (1965) and Yoong and Reinoso (1983) and measured in millimeters from the tip of rostrum to the tip of telson (total length). Other organisms were identified using local taxonomic keys. Data were entered onto an IBM System 36 computer file for analyses.

Results

Physical Conditions

Temperature: Water temperature extremes ranged from a high of 31oC in February and March (wet season) to a low of 24oC in July and August (dry season). Mean temperatures throughout the estuary were moderate during every month (Figure 2) suggesting only minor influences on shrimp activity.

Salinity: By contrast, salinity was more variable than temperature. Conditions during 1985 were dominated by low rainfall (Figure 3), and the relatively high salinities throughout 1985 were indicative of the dry year. The monthly changes in salinity (Figure 2) reflected the duration and intensity of the wet and dry seasons.

The Environmental Gradient: An environmental gradient in the estuary was evident as reflected by low salinities in Estero Salado, at the head of the estuary, and high salinities in Estero Morro, at the Gulf of Guayaquil. Within the esteros, the lowest salinities were at the interior sites of upper esteros, where freshwater entered (Estero Salado and Estero Corvinero), and the highest salinities due to evaporation, were also at interior sites, in these instances at esteros nearest the coast (Estero Morro and Estero Data). Temperatures, as previously noted, did not differ between esteros or among sites, although interior sites were the most variable. Along the estuarine gradient, the ratio of mangrove to open-water area was greatest in the upper estuary and diminished toward the coast where intertidal mudflats, sandy beaches and subtidal habitats prevailed.

Shrimp Sizes

Sizes of postlarvae and juvenile shrimp taken in the esteros were 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. californiensis, and between 12 mm and 37 mm total length for P. vannamei, the two most abundant species. Overall, mean sizes of P. vannamei were greater than P. californiensis.

Shrimp Abundance Patterns

Overall abundances among species: Rank order of abundance in the estuary among Penaeus during 1985 was: (1) Penaeus californiensis, (2) P. vannamei, (3) P. stylirostris, and (4) P. occidentalis. The dominant species, Penaeus californiensis (overall mean = 9.07 per sample), was roughly nine times more abundant than all other shrimp species (Figure 4).

Seasonal abundance patterns: P. californiensis were numerous throughout the year, with peaks in February 1985 and January 1986 (Figure 5). P. vannamei were also present throughout the year, but much less abundant with minor peaks during July, September and January (Figure 5). P. stylirostris were also few in number and had highest abundances in March and November samples (Figure 5).

Abundance patterns among esteros: Our results show that esteros closest to the recruitment source (the Gulf of Guayaquil) provide nursery habitat for more shrimp per unit area than those farther away. Accordingly, the largest numbers for all shrimp species were located at the mouth of the estuary in Estero Morro (Figure 4). The remaining esteros in the estuary were roughly similar in overall abundances. 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 was outside of the main estuary with its mouth opening directly into the Gulf of Guayaquil. This estero had abundances of Penaeus vannamei (1.16 per sample) similar to those in Estero Morro, but abundances of P. californiensis (5.98 per sample) were lower. Esteros Corvinero, Salado and Grande, inside the main estuary, had substantially lower abundances of P. vannamei and P. stylirostris. The number of P. occidentalis were too low during 1985 to establish a pattern. P. brevirostris did not occur in the samples.

Abundance patterns among sites: Shrimp abundance was highest at interior mangrove sites, with lowest abundances at the open-water sites in the middle of esteros. P. californiensis were the most numerous at interior sites and at the entrances to esteros (10.24 and 10.91 per sample, respectively; Figure 6) and fewest in the middle estero sites (5.48 per sample; Figure 6). By comparison, P. vannamei and P. stylirostris were most abundant at interior sites (1.42 per sample; Figure 6) and least abundant at middle and entrance sites (0.40 and 0.31 per sample, respectively; Figure 6).

Interspecies Relationships

Penaeus californiensis was the most abundant shrimp followed distantly by P. vannamei and P. stylirostris (Figures 4 and 5). Penaeus vannamei and P. stylrostris were similar in number and abundance pattern. Both species were present throughout the year, but at low densities. In each, increases in numbers occurred in short-term pulses. P. californiensis on the other hand, was more uniformly present in high numbers throughout the year.

The two most abundant species, P. californiensis and P. vannamei, responded during the wet season with peaks in abundance (Figure 5). All species were more abundant in the esteros nearest the Gulf of Guayaquil (Estero Morro and Estero Data) and less abundant within the upper main estuary (Esteros Corvinero, Grande and Salado). Penaeus occidentalis was notably rare in most of our samples and, like P. brevirostris, apparently did not use the nursery habitats sampled the same as the other species.

Abundances Relative to Temperature and Salinity

Seasonal temperatures and salinities followed an inverse relationship (Figure 2), with lowest salinities and highest temperatures occurring in wet season months of February, March and April. Lowest temperatures corresponded to highest salinities in dry season months of July, August and September. As stated before, the predominance of relatively high salinities in the estuary reflected the fact that 1985 was a dry year. The high abundances of P. californeinsis suggest a relationship to the relatively high salinities, while low abundances of the other species imply the opposite. This observation is supported by a change during high rainfall periods in January and February of 1986, when P. vannamei became the most abundant species in the esteros near the coast. This change and the overall low numbers of P. vannamei and P. stylirostris during 1985, suggests a strong dependence on rainfall and warm season conditions by these two species. By contrast, high rainfall may be relatively less important and very low salinities may even be detrimental to abundances of P. californiensis.

Discussion

Influence of the Physical Environment

Our data from 1985 indicate a cool dry year that appears to have adversely affected recruitment and distribution of two shrimp species in the estuary. This was reflected by the low abundances of P. vannamei and P. stylirostris throughout the 1985 wet and dry seasons. However, all species responded to some extent with increases during the wet season and this relationship demonstrates that meteorological conditions help to regulate the timing and size of recruitment events. The size of recruitment, in turn, appears to affect extensiveness of distribution. Since annual variability can be expected (including dry years as well as wet El Nino years), corresponding changes in numbers and distributions among these shrimp species are likely.

The effect of meteorological patterns is less evident in P. californiensis although dry conditions during 1985 appeared to favor this species. The dominance of P. californiensis may have to do with lack of congeneric species competition, increased food, favorable transport and dispersion of postlarvae or any number of causes not currently understood. The relationship to marine conditions is also supported by data from Loesch and Avila (1966) who reported dominance of P. californiensis in the estuary during drought years of 1962 and 1963.

A long-term program is needed to address relationships between nursery recruitment (abundances of postlarvae and early juveniles) and annual changes in temperature and rainfall. A program is especially needed to determine causal mechanisms within selected nurseries that control specific habitat characteristics for shrimp as they relate to physical conditions.

Habitat Selection Within the Nursery

Among the most numerous shrimp species from our samples, all were attracted to the interior areas dominated by mangroves (Figure 6). Accordingly, these mangrove rich areas served as primary nursery habitat for P. californiensis, P. vannamei and P. stylirostris. Inside the esteros, all postlarvae apparently moved rapidly to the interior mangrove nursery. One difference was the relatively high numbers of P. californiensis at the entrances to the esteros which suggests ecological separation between this species and the others. Differences in shrimp abundances were also evident between esteros at the head of the main estuary containing fewer shrimp per unit area (Corvinero, Salado and Grande) and esteros at the mouth of the main estuary with more shrimp per unit area (Data and Morro). This density gradient may have been due to the relatively small shrimp recruitment during 1985. Regardless of the cause, distance from the recruitment source (the Gulf of Guayaquil) appeared to be a significant factor in determining the number of young, especially for P. vannamei and P. stylirostis, in an estero.

It is important to recognize that three shrimp species utilized the interior areas within esteros as primary nurseries. This raises the possibility of relatively fine-scale habitat resource and selection by these species. Moreover, selection for the mangrove nursery implies habitat requirements that may differ from the other shrimp species, P. brevirostris and P. occidentalis, in Ecuadorian fisheries. Our data indicate that mangroves in the Guayas Estuary do not serve as a nursery for these two species.

Investigations addressing habitat-specific utilization differences among species within the Guayas Estuary are needed. Abundance differences between shrimp species occupying habitats, including intertidal mangrove, intertidal mud flats, and various subtidal bottoms without vegetation, could reveal further important habitat selection. Our data indicates habitat selection and such nursery habitats may be irreplaceable. In other regions, differences in selection of nursery habitat by shrimp have been demonstrated, such as between seagrasses and mangroves in Australia (Staples et al., 1985) and marsh and mud bottom in Texas (Zimmerman and Minello, 1984). These studies show that a variety of habitats in an estuary may have nursery value, depending on the shrimp. Differences between species in feeding habits, interactions with predators and with the physical environment easily account for habitat selection differences. Importantly, the Guayas estuary has ten commercially important penaeids (McPadden, 1985) and, for most of these, nursery habitats have yet to be identified.

Consequences of the Postlarval Fishery

A postlarval fishery for pond stocking exploits every estero in Ecuador. An estimated 90,000 fishermen are involved in this fishery during monthly high tides (MacPadden, 1985). The variety of methods used by these fishermen has not been documented, and the effects of their fishing on reduction and structuring of recruitment in the nursery are not known. Our information suggests that P. vannamei and P. stylirostris are selectively taken by fishermen and P. californiensis is selectively excluded. The impact of such differential exploitation could have a long-term restructuring effect on the overall shrimp population.

Further studies to evaluate the effect of the postlarval fishery are recommended. The program should compare various methods used by fishermen and test the potential of each for changing species distribution and population structure.

Summary

Mangrove areas in the Guayas estuary are extensively used as nurseries by at least three commercially important Penaeus species. Of these, P. vannaemi and P. stylirostris were closely associated with mangroves and P. californiensis was more generally distributed. The esteros nearest the coast had highest shrimp densities and numbers diminished toward the head of the estuary.

Conditions during 1985 were dominated by below average rainfall and higher salinities that apparently favored increased abundances of P. californiensis. By contrast, P. vannaemi and P. stylirostris were adversely affected by low rainfall as reflected by low abundances. During early 1986, P. vannaemi responded to increased rainfall with markedly greater abundances. Since the target species for pond stocking is P. vannaemi, and P. californiensis is considered an inferior mariculture shrimp, these relationships have a dramatic effect on Ecuador's shrimp industry. During wet years, P. vannaemi postlarvae are abundant and the industry thrives; during dry years, such as in 1985, desirable postlarvae are scarce and the industry suffers.

Surprisingly, the offshore shrimp fishery does not correspond to relative abundances of juveniles in the Guayas mangrove nursery. The most abundant shrimp in offshore catches is P. occidentalis which is among the least abundant in association with mangroves. The nursery is either in another region or in another habitat within one estuary. In any case, the nursery for P. occidentalis has not been identified. In opposite manner, P. californiensis is among the most numerous of shrimp using the Guayas estuary and its abundance is not reflected in offshore catches. We concur with Klima (this publication) that this species is under-exploited due to poor definition of adult fishing grounds. Both of these subjects, characterization of the P. occidentalis nursery and identification of the P. californiensis adult grounds, are useful areas for future research.

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

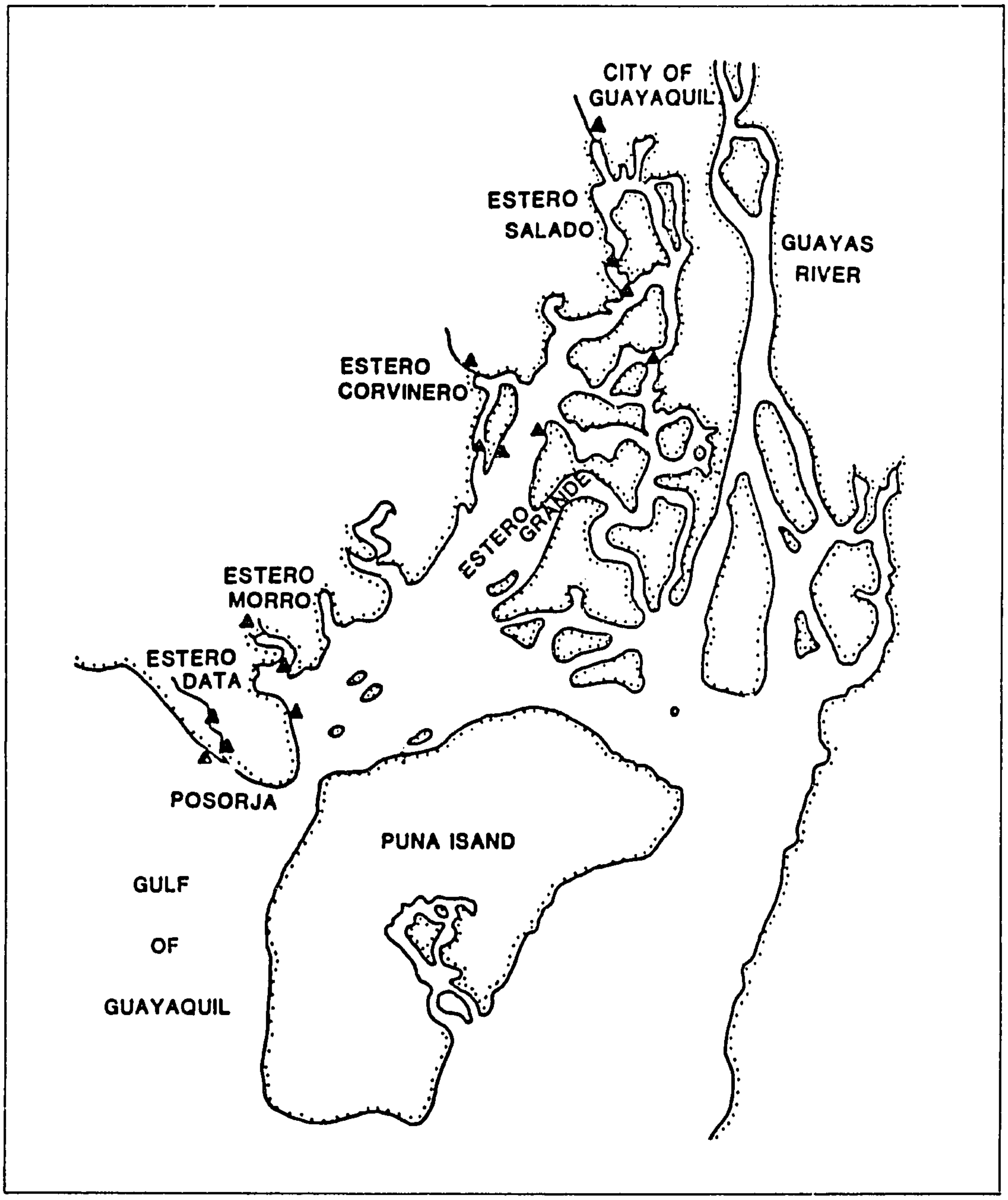


Figure 2. Mean temperatures and salinities, 1985-86.

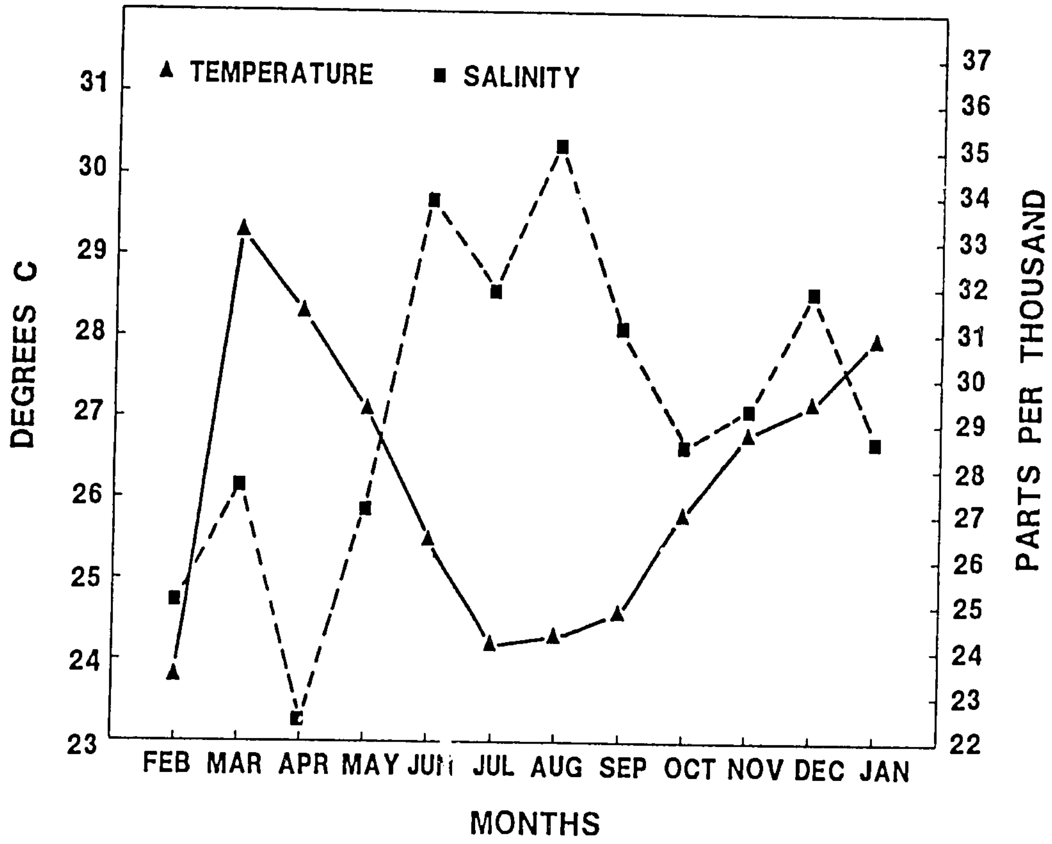


Figure 3. Mean rainfall.

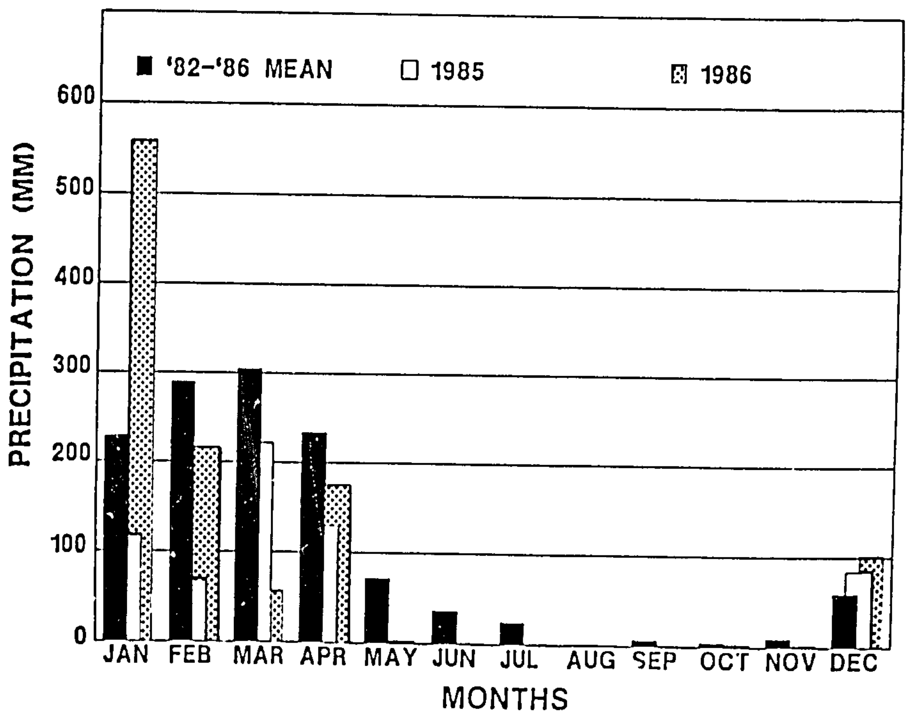


Figure 4. Shrimp abundance between osteros.

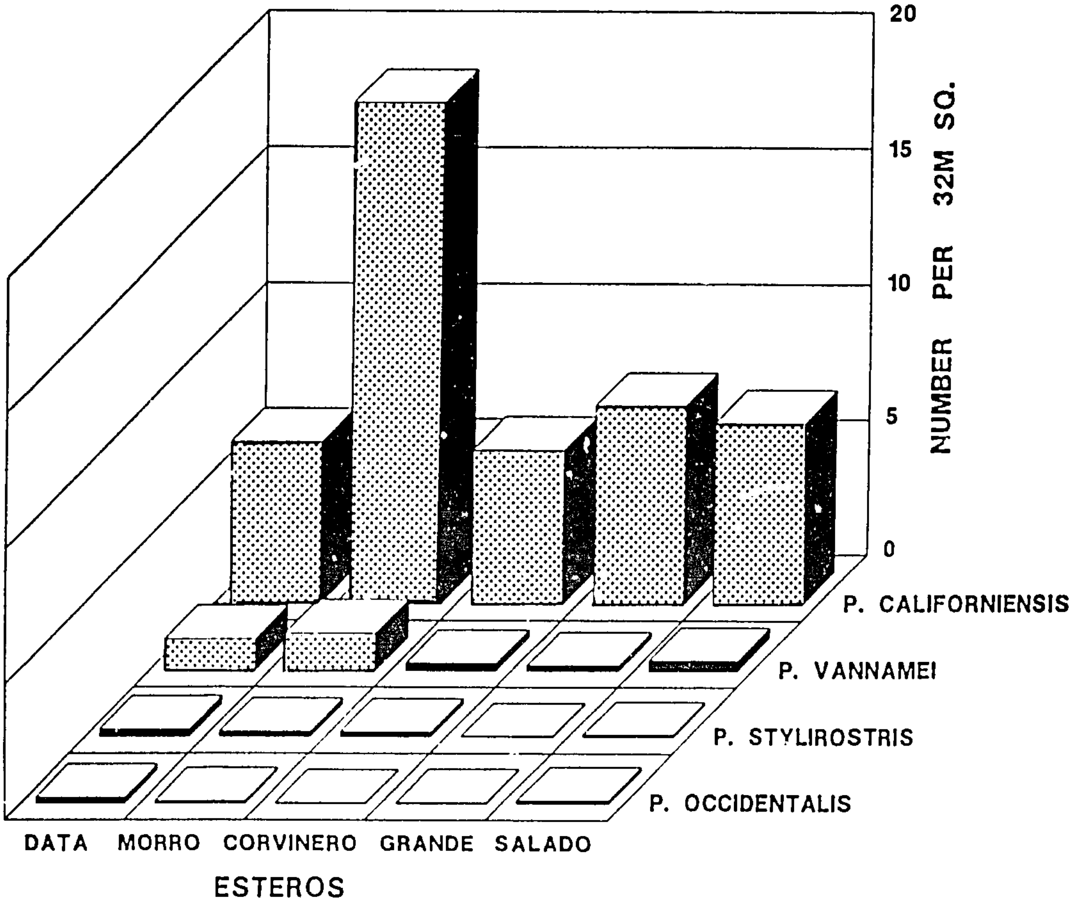


Figure 5. Temporal abundance patterns.

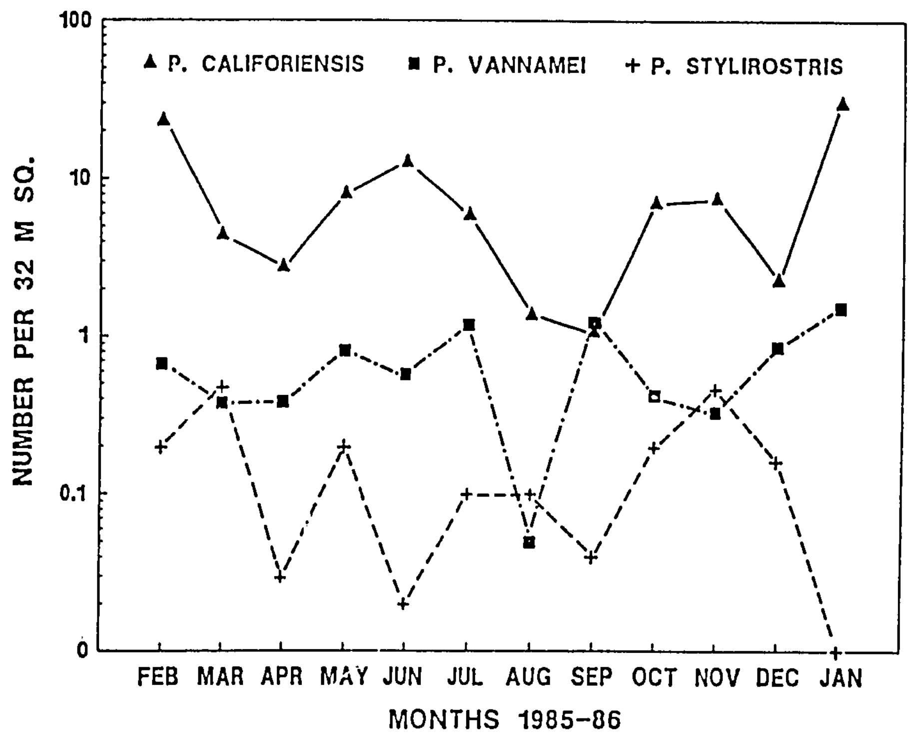
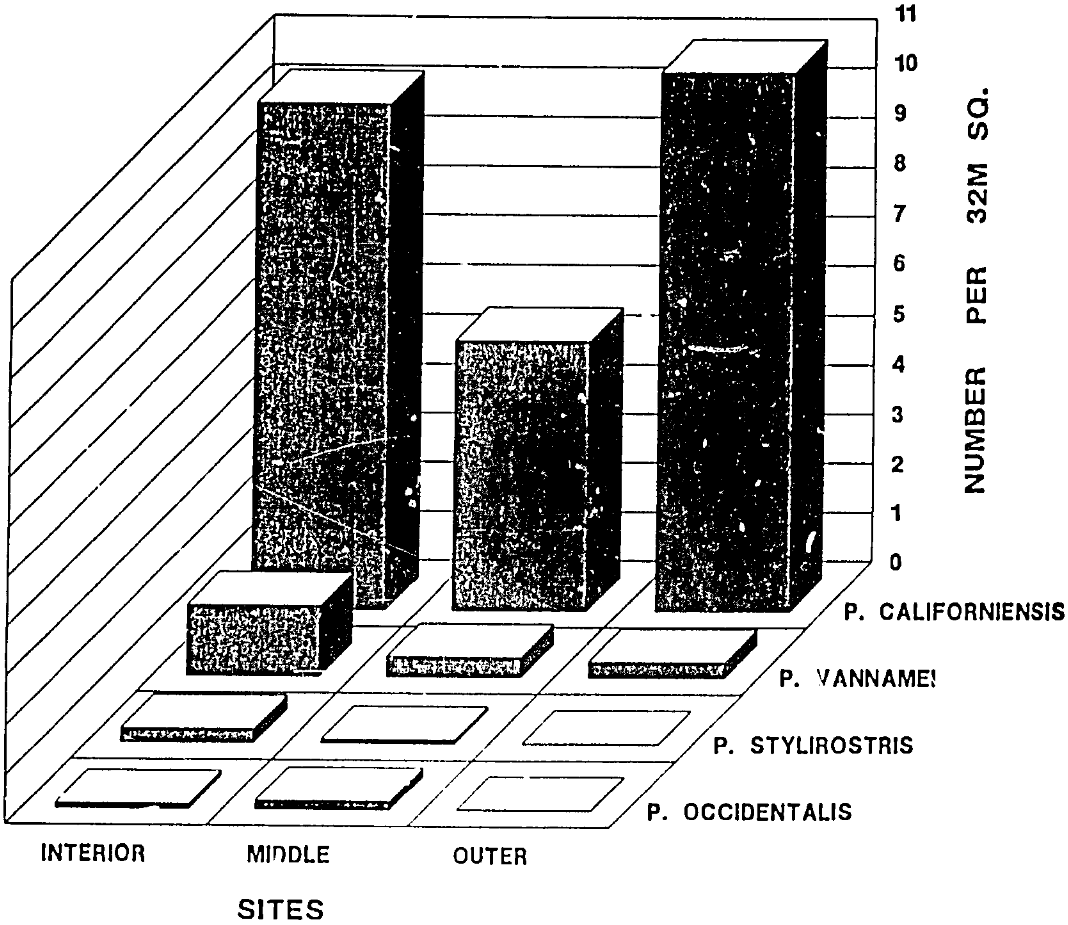


Figure 6. Shrimp Abundances Within Esteros



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Characteristics of the Mariculture Industry

Present Status and Future Options for Improving the Efficiency of Shrimp Mariculture

Estado Actual y Opciones Futuras para Mejorar la Eficiencia de la Maricultura del Camarón

José R. Villalón, Paul D. Maugle y Rodrigo Laniado

Resumen

En 1986 había más de 94.000 ha autorizadas para construcción de piscinas camaroneras, estaban terminadas unas 60.000 ha y de éstas sólo un 50% estaban en producción de postlarvas (pls).

La mayoría de los cultivadores siguen un método de manejo semi-extensivo, con densidades de siembra de 10.000 a 50.000 pls/ha. Se usa el flujo de mareas o el bombeo diario para el intercambio de agua en las piscinas. Los nutrientes son proporcionados por la producción natural del fitoplancton en los estanques. Las empresas con más alto grado de infraestructura y recursos económicos usan el método semi-intensivo con densidades de siembra de 100.000 a 180.000 pls/ha. En general, densidades de siembra mayores que 50.000 juveniles requieren de fertilización o la dispersión de las pls en muchas piscinas para aprovechar la ventaja de la productividad el fitoplancton. Los estanques para "semillero" usados en las operaciones simi-intensivas son sembrados con más de 2 millones de pls por hectárea. De aquí son trasladados a las piscinas de crecimiento después que alcancen pesos de 0,5 a 1,0 gr.

Aproximadamente del 50 al 60% de pls "sembradas" en las piscinas del Ecuador son obtenidas en el ambiente natural. El 50% de pls corresponden a P. vannamei, selección que está basada en su capacidad para resistir y crecer en el ambiente riguroso de las piscinas, antes que en la disponibilidad de pls. Cuando las pls están mezcladas con detritus y el tiempo de transporte es largo, la mortalidad de pls puede llegar a un 50%. En general las pls capturadas se venden aun intemediario que las transfiere a centros de acopio para la limpieza, luego son empacadas y transportadas hasta los criaderos, usando para esto aire y oxígeno comprimidos. La temperatura no se controla en el tanque de transporte. La aclimatación de las pls se realiza en piscinas de crecimiento, siendo esta operación materia de controversias considerables.

Los autores analizan en detalle varios aspectos de los sistemas de manejo en los estanques "semilleros" y de las piscinas de producción, incluyendo el uso de alimentos concentrados granulados (pellets).

La vigilancia de los parámetros ambientales (oxígeno disuelto, pH, temperatura, salinidad, turbiedad), es efectuada en las piscinas con cultivos semi-intensivos con fines de manejo. Así, valores de oxígeno menores que 3 ppn origina la suspensión de alimentos y aumento del ingreso de agua por bombeo; temperaturas menores que 24°C es la referencia para aumentar la profundidad del agua en las piscinas; si la turbiedad es menor que 32 cm o hay pH alto, se suspende la fetilización.

Se acepta ampliamente en Ecuador que la conversión de áreas de manglar a pisicinas camaroneras es una de las razones principales de la declinación de la abundancia de pls. También, los autores mencionan que lugares para piscinas en algunas áreas de El Oro compiten con tierras agrícolas y de patoreo.

Entre las recomendaciones planteadas por los autores se encuentran: (a) capacitar técnicos, habiéndose estimado que el Ecuador necesitará entre 700 y 800 técnicos para laboratorios y para las piscinas ya autorizadas; (b) un programa de capacitación para personal de los centros de colección y para los que transportan las pls; (c) proporcionar facilidades de mantenimiento para desarrollo de pls; (d) establecer un laboratorio de diagnóstico para aplicación de niveles adecuados de alimentación; (e) mejorar los conocimientos de los productores; (f) difusión de métodos apropiados para aclimatación de pls y estanques "semilleros"; (g) desarrollo de raciones ecuatorianas para maduración en los laboratorios.

Historical Development of Shrimp Mariculture in Ecuador

The Incas may have been the first to farm shrimp in Ecuador some 400 years ago by impounding waters containing penaeid shrimp larvae. Modern shrimp mariculture began in the late 1960s in El Oro province in southern Ecuador when an owner of a banana plantation noticed that flood waters impounded behind a dike yielded a bountiful harvest of shrimp. By 1977 there were some 360 hectares (ha) of shrimp ponds in production (R. Naboa, personal communication). In the early days of the industry, investors were able to pay off the costs of pond construction within two or three years. This, combined with seemingly abundant postlarvae and the relatively high price for shrimp in the U.S. market, led to the rapid development of the shrimp mariculture industry. By 1983 the shrimp industry had expanded to an estimated 89,367 ha of (Alvarez, this volume) and production peaked in 1982-83 at 23,300 metric tons (m.t.) of shrimp reportedly worth U.S.$218.7 million (National Marine Fisheries Service, 1986).

There is a feeling among producers interviewed by the authors that the shrimp industry is currently undergoing a consolidation. The rapid expansion experienced in the early 1980s is over. Future development, the producers say, will not be in the area of new pond construction but in the acquisition of concessions not presently in use and the development of hatcheries.

The so-called integrated enterprise has recently become the predominant "survival unit" in the Ecuadorian shrimp industry. It incorporates shrimp ponds with packing and export operations, and may have a hatchery in operation or under construction. Such an integrated enterprise may include several of the following segments:

- import house(s) in the United States and other markets
- packing plant
- growout ponds (this may include several companies)
- feed and/or fertilizer plant
- fishing fleet (sourcing)
- larval collection and air and/or ground transport group(s)
- hatchery

Area in Production

In 1986 there were more than 94,000 ha of shrimp ponds authorized for construction and approximately 60,000 ha had been completed (Table 1). Based on a preliminary aerial survey and interviews with shrimp producers in the Guayas-El Oro production areas, the authors estimate that only half of the completed ponds were in production in June-July 1986, presumably because of postlarvae shortages.

Pond Management Techniques

The national crisis brought about by the depletion of wild stock postlarvae (PL), during 1984-85, has divided Ecuadorian farm management strategies into two distinct camps with contrasting culture and management strategies.

Semi-Extensive

Most farmers pursue a semi extensive management strategy which calls for stocking densities of 10,000 to 50,000 PL per hectare. These farmers accept lower production returns along with substantial reductions in their production costs. Producers using semi-extensive systems may use the tides and/or daily pumping to provide water exchange in gravity drained flow-through ponds. Nutrients are provided by natural phytoplankton production in the ponds.

Semi-Intensive

Companies with a higher degree of infrastructure and economic resources maximize their production by utilizing a semi-intensive method. Here, higher stocking densities of 100,000 to 180,000 PL per hectare are maintained, with correspondingly higher fixed costs. The majority of these companies aggressively pursue wild stock postlarvae by paying more for catches, or are meeting their stocking demands with their own hatchery production. Nursery ponds utilized in semi-intensive operations are stocked with up to 2 million PL per hectare. The juveniles are moved from nursery ponds to growout ponds after reaching weights of 0.5 to 1.0 grams. Stocking densities at levels higher than 50,000 juvenile shrimp require fertilized growout ponds, or postlarvae spread over many ponds to take advantage of phytoplankton productivity and reduce risks of loss from overstocking. Stocking density is often a function of wild stock postlarvae availability.

Generally, the small farmers or farmers who do not have a highly developed infrastructure do not share the technological advancement employed by the larger companies. This lack of technology among the smaller producers using semi-extensive methods has resulted in high mortality at high stocking densities. On the other hand, farmers who have higher fixed costs and infrastructure development, have also aggressively pursued the advancement of their technology which is reflected in an increase in overall production levels.

Demand for Postlarvae

Pond operators obtain postlarvae by one or more of several methods, including:

- purchase from middle men
- collecting PL with personnel from the shrimp farm in estuaries close to the farm
- collecting from artificial estuaries (semilleros) constructed in mangrove areas bordering the shrimp farm
- collecting in the intake canals
- collecting from nursery ponds, when they are tidally filled during the monthly flood tide aguaje)
- purchases from a hatchery
- imports from other countries

Approximately 50 percent to 60 percent of the postlarvae stocked in Ecuadorian ponds are wild-caught and purchased from middle men. Postlarvae prices are based on availability, principally of Penaeus vannamei. These animals typically change hands two to three times between the fishermen and the growers' ponds. A fisherman receives approximately 100 sucres per 1,000 postlarvae from middlemen. The postlarvae are then sold to the pond owners or to other middlemen for approximately 450 to 1,000 sucres per 1,000.

Wild-caught Penaeus vannamei are generally more abundant during the months of December through March. During these months well above 50 percent of the catch is P. vannamei with a notable decrease in the presence of P. occidentalis. The selection of P. vannamei as the species of choice was not based on its availability (Klima, 1986 and Zimmerman et al., 1986) but on its ability to resist and grow in a very rigorous pond environment (Snedaker et al., 1986).

During the 1985-86 stocking season the supply of postlarvae remained high through the middle of March 1986 (Table 2). Producers who had ample funds were able to rapidly stock their ponds. Many of the larger pond owners have resorted to hiring groups of fishermen and a middleman to transport the postlarvae and pay them a salary nearly double what they would otherwise earn. A fisherman can thus earn between 2,000 and 5,000 sucres in a day, which may account for a significant percentage of overall annual earnings for these artisanal fishermen. Since the capture of postlarvae is determined by moon phase, tide, water temperature, location and the fisherman's skill, he may be limited to five to eight days of good fishing per month. A middleman can sell between 500,000 to 1 million PL per day, but this activity is limited by the length of time that PL are available and his capital expenditures, which include equipment and short-term operating loans at interest rates of 25 percent to 50 percent per two month period.

Postlarvae can represent 40 percent to 60 percent of the overall operating costs in a farm operation. Several producers have resorted to importing postlarvae from the United States and other countries, though there have been problems with poor quality and size consistency. A comparison of the effect of wild and imported seed stock on production cost estimates is given in Table 3.

There are no data on the numbers or species composition of the postlarvae caught by the artisanal fishery, but the Camara de Productores de Camarones del Guayas estimates that the fishery had provided 3 to 4 billion P. vannamei PL each year until the 1983-84 El Nino. There is an unmistakable trend following the El Nino toward short spawning seasons and subsequent lack of wild seed stock. Table 4 provides estimates for the number of PL utilized by the industry in recent years and the potential PL demand.

Postlarval Transport and Survival

When wild-caught postlarvae are mixed with detritus, and the length of time from capture point to transport tank is prolonged, PL mortalities can be as high as 50 percent. The catch is then sold to middlemen who transfer the postlarvae to collection centers for further cleaning. When sufficient numbers have been accumulated, the postlarvae are repacked and transported to nursery ponds. Compressed air and oxygen are used to maintain postlarvae during transport, with battery (12v) operated air compressors and air stoves. The water temperature in the transport tanks is not controlled, nor are chemicals added which would inhibit the effect of disease or chelate toxicants. In the past, the number of larvae being purchased was estimated by eye. Although this technique seemed adequate during times when wild-stock postlarvae were abundant and prices were relatively low, economic competition eventually forced farmers to mathematically quantify their postlarvae. Volumetric counting techniques rapidly became standard operating procedure, although they had inherent counting errors of up to approximately 30 percent depending on container design, water volume, larvae density, and mixing techniques. As a result, some of the more technically advanced producers now use a reduction counting technique with standardized water temperatures and mechanical mixing apparatuses. This technique has successfully lowered the margin of error to acceptable levels of approximately 10 percent. The improvement of the level of confidence in the quantification of postlarvae stocked into ponds has resulted in the development of a valuable tool for water management decisions, feed conversions, harvest projections and fertilization programs.

Acclimation of Postlarvae

Postlarval acclimation to growing ponds is a subject of considerable controversy. Many producers favor limited acclimation procedures. A technically advanced farm, Empacadora Nacional, uses a slow acclimation program combined with controlled ecological conditions in the acclimation station. This program uses a continuous flow-through system while feeding Artemia salina, nauplii and steamed egg yolk. Acclimation densities of up to 500 five-day-old postlarvae per liter, a rate of two parts per thousand salinity change per hour, and a 1 degree Celsius change in temperature have yielded a 1 percent mortality over a 12-hour acclimation period, a significant improvement over the previous rudimentary techniques. The lengthier process also allows farm biologists to evaluate the condition and behavior of the postlarvae.

Nursery Pond Management Systems

Stocking a nursery pond is not generally a problem, providing the postlarvae do not come long distances or from environmental conditions which vary greatly from pond conditions. Survival estimates are made from samples of 100 animals, which in some cases are held in fine-meshed nets in the nursery ponds for 48 to 96 hours.

Among the more technically advanced companies, which generally employ semi-intensive management techniques, much attention is paid to the preparation of nursery pond bottoms to produce nutrient-rich water, since it is believed that feeding reduces mortality during the critical first three weeks. Producers prepare both growout pond and nursery pond bottoms by allowing them to completely sun dry and oxidize. Humid areas are hand-tilled and oxidized with a saturated solution of hypochloride. Water is allowed to half fill the nursery after passing through a 1 mm filter screen. Inflows and effluent weirs are then sealed for five days. Fertilizer at a concentration of 1.3 parts per million (ppm) of nitrogen and 0.3 ppm of phosphorus is applied in a single dose. Algae are allowed to grow for two to five days before the nursery ponds are completely filled. Water is commonly transparent to a depth of 30 centimeters at this point. Feed for juvenile shrimp with 35 percent protein is added 24 hours prior to stocking at a rate of 100 pounds (45 kg) per hectare. The nursery ponds are then stocked at densities of up to 2 million postlarvae per hectare. The shrimp are harvested by draining the pond 50 days after stocking when their average weight is 1.5 grams. Survival rates as high as 65 percent are commonly recorded using these techniques.

Production Pond Management

Stocking

Growout ponds can be stocked in two ways. First, postlarvae can be placed directly in 5 to 15 hectare units for a 180 to 210 day growout period, bypassing the need for nursery ponds. With the second method, larger juvenile shrimp harvested from nursery ponds, as described above, are placed in the growout ponds.

Stocking densities in growout ponds farmed by semi-intensive methods range from 50,000 to 180,000 hatchery-reared postlarvae per hectare. Feed and fertilization are carefully controlled and ponds are treated as production units. Yields range from 1,400 to 1,300 kg per hectare per year of whole shrimp.

Semi-intensive management systems utilized by integrated enterprises, generally employ trained biologists who rely upon a wide range of physical and chemical information when making management decisions. Ecological parameters are monitored in all ponds.

According to Empacadora Nacional C.A. (a major feed producer), stocking PL directly in growout ponds at densities of 160,000 PL per hectare may yield 45 percent survival after a 180-day growout period. Stocking with juveniles at densities of 80,000 per hectare yields 75 percent survival at the 22 gram size, the target harvest weight, obtained in approximately 140 days.

Shrimp harvests as high as 3,500 pounds per hectare per turnover with two turnovers per year are common in semi-intensive operations. However, semi-extensive producers often realize a greater margin of profit with lower stocking densities, lower levels of technology and a reduced management effort.

Feeding

In semi-intensive operations, the use of compounded dry pelleted feeds is widely accepted. Daily applications are made from canoes in a zig-zag fashion over the entire pond surface. There are two basic feed formulations currently in use. One consists of 35 percent protein and 8 percent fat, and is used to feed juveniles until they obtain an average size of 6 grams. Once the juveniles reach 6 grams, the feed ration changes to a growout production formula containing 25 percent protein and 5 percent fat. Feed ration levels are adjusted weekly according to the shrimp weight. Stringent quality control guidelines are followed in the feed manufacturing process. Local producers strive to maintain the stability of the pellet in the water for more than four hours and maintain digestibility greater than 70 percent. The use of shrimp heads and other by-products in shrimp feeds are being considered.

Several producers utilizing semi-intensive management strategies have recently recognized disease-related production problems. Use of medicated feeds (Table 5) could have a significant impact on production capacities, provided the following factors are taken into consideration:

- identification of benefits from point specific versus broad spectrum prophylactic antibiotic applications
- economic feasibility at the commercial level
- the evaluation of potential environmental and health impacts

Costs and Profits

Many producers using semi-extensive management strategies fertilize only during the dry season when the water pumped from the estuary is less productive. While these producers have used locally produced shrimp feeds, they often view the use of feed with great distrust. The feed, in their opinion, breaks down in the water, making it little more than an expensive fertilizer that does not produce sufficient improvement either in quantity or size of shrimp to offset the additional capital outlay.

Excluding the cost of financing the shrimp farm operation during the growth period, it costs from U.S. $.70 to as much as $1.20 to produce a pound of shrimp using the semi-extensive approach (harvest rate of 15,000/ha/2.2 harvests/yr), and approximately U.S. $.40 more per pound to use feeds. Producers receive between U.S. $2.20 to $3.50 per pound of shrimp depending on the size of the shrimp and time of year.

Although there would appear to be a greater net profit to the semi-extensive producer if higher stocking densities were used, neither the quality of the feed nor the technology currently available seem adequate to prompt changing their methods. However, some producers are open to alternative farming strategies providing sufficient quantities of PL are available for higher density stocking, high quality feed is available and adequately trained biologists are available to operate the shrimp farms.

Ecological Monitoring

Monitoring of dissolved oxygen, pH, water temperature, salinity and water turbidity is carried out twice daily in many semi-intensive operations; commonly at 6 a.m. and again at 2 p.m. Although a routine fertilization program is utilized, results from water quality analysis override the routine schedule of fertilization.

Dissolved oxygen and water temperatures are priority parameters and used as warnings in basic biological management decisions. A low dissolved oxygen reading of less than 3 ppm dictates the suspension of feeding and an increase in the flow of incoming water. A low water temperature of less than 24oC is the basis to increase water depth in a pond, in an attempt to cushion or reduce the rate of change in water temperature in the deeper areas by decreasing pond surface area in relation to total volume. In the afternoon, high dissolved oxygen and/or high water temperatures dictate similar reactions. Afternoon monitoring is also used as a guideline for fertilization. Water turbidity readings of less than 32 cm and/or high pHs also call for the suspension of routine fertilization. Hydrogen sulfides, ammonia and phosphate concentrations are analyzed weekly in all ponds.

Water Quality Management

Each pond in the semi-intensive management system, whether a nursery or production pond, is managed for its percentage of water volume exchange. Water level readings over the effluent weir boards are measured every 2 hours for 12 hours. The diurnal tide reflects two shifts in pumping capacity so that water level values can be extrapolated over a 24-hour period to calculate inflow volume. Once the pond system is calibrated, adjustments are made daily, based on ecological parameters, stocking densities and shrimp weight. Generally, production ponds are initiated with a 6 percent daily exchange rate, while final water exchange rates may gradually increase over time to 17 percent per day. Some of the more advanced producers, using extensive management practices also pump daily at rates ranging from 5 percent to 10 percent of the pond volume.

Production Capabilities

With stocking densities of 15,000 to 30,000 PL per hectare and 1.5 to 2.2 harvests per year, many farmers estimate harvest levels at 800 to 2,100 pounds/hectare/year.

Should producers change their production strategy to one which incorporates low stocking densities with fewer turnovers (harvests) per year, then they would be able to produce larger-sized animals and potentially more valuable crops. For example, one company (Langacua, S.A.) using an extensive management strategy stocks 18,000 to 25,000 juveniles per hectare. These animals grow to 24 gm size (26-30 count) in 100-120 days in the rainy season and 120-140 days in the dry season, with an overall survival rate of 90 percent, yielding approximately 600 pounds of shrimp 2.5 times per year. This extensive strategy produces on the average 2,100 pounds per hectare per year. Such an approach seems to offset potential losses due to inadequate supply of postlarvae and may have the potential of stabilizing overall production, making levels of production achieved in previous years obtainable at lower costs, with fewer postlarvae and/or producers.

Pond Siting, Construction and Utilization

It is widely believed in Ecuador that the conversion of mangrove areas to shrimp ponds is a major reason for the decline of PL abundance. Alvarez (this volume) provides estimates for the changes in area of mangroves, salinas and shrimp ponds between 1969 and 1984. Based on remote sensing data, he estimated that the total mangrove area in Ecuador has decreased by 10.6 percent during this period.

CLIRSEN, as reported by Valdiviezo (1985) utilizing information obtained from the 1982-83 remote sensing studies, tabulated mangroves, shrimp ponds and salt flats in El Oro and Guayas Provinces (Table 6). The location and distribution of mangrove in El Oro, is distinct from other provinces, and may be described as a narrow belt less than 100 meters wide running along the periphery of the estuary. Shrimp ponds, agriculture and pasture lands lie inland from this narrow mangrove belt. In many areas shrimp ponds were built leaving no mangrove buffer. Sites for shrimp ponds in several areas in El Oro also compete directly with agricultural and pasture lands.

Mangroves in the Guayas Province are concentrated on islands and as belts of varying widths along the continent. Shrimp ponds in the area appear to have first been built in salina (salt flat) areas and later expanded into surrounding mangroves.

If one were to prioritize the damage to the mangrove resources along the Ecuadorian coast, the most impacted area would be El Oro, followed perhaps by Manabi. In the Guayas, although impacted by the shrimp farm development, a considerable mangrove area still exists. The potential threats to mangroves in the Guayas and to the shrimp industry may lie in a combination of increased siltation, reduced water circulation, and upstream changes in water quality due to a reduction of fresh water inputs and increase in chemical intensive agricultural practices. For a more detailed discussion see Twilley (this volume).

Coastal areas in Esmeraldas, containing less than 2,000 ha of shrimp ponds, have been little affected by the industry. Considering the copious amount of rainfall in this province (Twilley, this volume), the impact on mangrove areas from shrimp farm development may be limited to a maximum of 5,000 hectares, which is a maximum of one quarter of the apparent mangrove area in 1983.

Investment Requirements

During 1984 investments to develop a shrimp farm ranged from 40,000 to 600,000 sucres per hectare (Table 7). If the only access to the farm was by boat, an additional investment would be required.

Beyond the initial acquisition and construction costs associated with the development of a shrimp farm, large pumps and piping as well as water quality equipment are basic requirements. Much of this equipment must be imported. For discussions of the problems associated with imports see Perez and Robadue (this volume).

Recommendations

Many actions should be taken at all levels to help the shrimp industry reach a stable level of development. Here a few measures related to shrimp pond improvements are discussed:

1. The single most effective way to stabilize this industry is to close the gap between the legal and apparent (s/165:1 U.S.D.) exchange rates. In the early months of 1985, exporters received 108.50 sucres per dollar exported, in addition to a 15 percent Abono Tributario for the total dollar value exported, which is calculated at s/95:1 U.S.D. The abono is like a bond with a one year maturity, so exporters discount it 31 percent of its value. The real benefit is calculated as follows: (95 x 0.15) - 0.31 (95 x 0.15) = s/9.83. Thus, the legal exporter of shrimp receives s/108.50 + 9.83 = s/118.33 for each dollar of export product. This step was taken in late 1986.

2. The rapid growth of the industry has made it impossible for the universities and polytechnic schools to provide enough suitably trained technicians. It is estimated that Ecuador will require an additional 700 to 800 trained hatchery technicians to fully utilize hatcheries presently under construction. With over 900 authorized shrimp farms in Ecuador, it is estimated that between 18,000 and 22,000 technicians are employed. Improvements in hatcheries and the daily operating procedures on shrimp farms through an extension program could have a direct and visible benefit for the industry and Ecuador. Such a program could be supported through a group of banks and the DIGEMA-URI Coastal Resources Management Program. It would focus on ponds which are not currently in production as well as on operators which require loans to operate or expand operations. All new loans to producers could be used to procure technical assistance from one of the approved technical assistance groups in operation today. It would be the responsibility of the extension service to examine the technical capability of consultants and technical assistant groups, and issue them a permit to work within the system. Additionally, a diagnostic laboratory with support activities in the field could be funded, bringing to Ecuador experts in areas of specific need.

Services provided by a comprehensive extension program would include:

- periodic training courses
- hatchery techniques
- water quality management
- pond production techniques
- feed development
- diagnosis of diseases
- information and data base development
- dissemination of reliable information
- postlarvae handling, transport and acclimation
- mangrove restoration
- development of an international shrimp marketing lobby

3. An immediate improvement in pond production can be achieved if producers would focus their attention on wild stock and hatchery- produced postlarval handling and acclimation methods. The efficient use of postlarvae has the greatest immediate potential gain for the producer as well as conserving this limited natural resource. Improvements in capture, transport, handling and acclimation methods for postlarvae can have an immediate and visible positive effect.

4. A training program for postlarvae collection center and transport personnel along with a certificate for course completion should be developed. Such a program would focus on improving survivability of harvested postlarvae, and conduct routine spot checks to

confirm adherence to correct procedures to help guarantee delivery of high quality wild stock postlarvae.

5. Postlarval holding facilities at farm sites to further develop postlarvae, from PL 5 to PL 21-30 should be developed. These facilities would enhance survival of hatchery-produced stock in the pond environment.

6. Steps should be taken to establish an in-country diagnostic laboratory which could monitor populations of shrimp and be responsible for the application of appropriate levels and types of medicated feeds.

7. Steps should be taken to enhance the knowledge of producers, and keep them appraised of recent advances in hands-on technology. This might be done through routine news releases.

8. Other areas that could have direct, immediate and visible positive effects on the industry include:
   - development and dissemination of improved methods for postlarval acclimation
   - stocking of nursery ponds
   - the development of acclimation, nursery and growout pond maintenance programs.

9. Pond producers should coordinate their efforts with hatchery producers to assure that their respective ponds are adequately prepared to receive postlarvae.

10. More effort should also be given within the pond producers' enterprises to control environmental parameters to prevent causes of undue stress.

11. Many improvements to feeds currently used in Ecuador can be made using locally available feed stuffs. Cost effective feeds of adequate nutritional value should be further developed using in-country feed stuffs and processing by-products for all segments of the industry (i.e. larval, maturation, nursery and growout pond diets).

12. An Ecuadorian maturation diet for use in hatcheries needs to be developed because present stocks of oysters and other shellfish in Ecuador will be gravely impacted when all the hatcheries presently under construction come on-line.

Table 1
Estimated Shrimp Pond Surface Area (in hectares)
Authorized, Completed and in Use

Province	Authorized in 1986[1]	Construction in 1984[2]	Completed and Under Construction in 1986	In Use in 1986
Guayas	72,208	52,912	-----	-----
El Oro	14,496	26,484	-----	-----
Manabi	5,407	8,377	-----	-----
Esmeraldas	2,241	1,595	-----	-----
TOTAL	94,352	89,368	60,000[3]	30-40,000[4]

[1] R. Horna et al., 1986.
[2] CLIRSEN, 1986.
[3] R. Horna, O. Crespo, W. Bustamente, A. Lopez, 1986.
[4] Aerial observation, P. Maugle, March 1986: corroborated by the Camera de Productores de Camarones del Guayas, 1986.

Table 2
1985-86 Postlarval Costs to Pond Operators*

	Sucres per thousand
May - July 1985	1,300
August - September 1985	1,800
October - November 1985	1,800
December - January 1986	1,200
February - March 1986	500

* From M. Leslie, personal communication.

Table 3
Comparison of Production Cost Estimates to a Producer Using
Wild Stock and Imported Seed Stock in an Extensive Management Method*

	Wild stock	Imported seed stock
Unit sold at U 26-30	20.00**	20.00
(PL Cost)	3.00	7.00
Gross margin	17.00	13.00

* Expenses vary significantly from one farm to another, and economies of scale are achieved above 120 to 150 hectares.

** Sales are based on an average price for U 26-30. Costs in sucres at 118 sucres per U.S. dollar.

Table 4
Two Means for Estimating Demand by Ecuador's Shrimp Mariculture Industry for Postlarvae

Estimated farm production[1] year	(m.t.)	Postlarvae required[2] (millions)	Area in cultivation[3] (ha)	Demand for postlarvae[4] (millions)
1977	3.9	420.4	360	55.4
1978	5.0	539.0	1,010	155.5
1979	6.2	668.4	3,150	485.1
1980	9.2	991.8	8,875	1,366.8
1981	11.2	1,207.4	26,360	4,059.4
1982	16.4	1,767.9	39,120	6,024.5
1983	23.3	2,511.7	51,700	7,961.8
1984	21.7	2,339.3	59,350	9,139.9
1985	18.7	2,015.9	43,150	6,645.1

[1] Source NMFS (1986) Ecuador/U.S. Shrimp Imports

[2] Based on the following calculation and assumptions (for 1977):
3.9 metric tons x 2.2 lbs/kg x 1,000,000 = lbs.
x 0.70 (tail weight) x 35 shrimp/lb)/year
x 1/0.5 (50% survival) = 4.20 x 10 8 larvae.

[3] Source: Dept. Estudios Pesqueros y Estadisticas, Sub Sec. de Pesca

[4] Estimates based on the area in cultivation used the following calculation (for 1983):
(e.g.) 51,700 ha x 35,000 pl/ha x 2.2 harvests/year
x 1/0.5 (50% survival) = 7.96 x 10 9 larvae.

Table 5
Cost Evaluation of Several Wide Spectrum Antibiotics as a Feed Additive

Antibiotic	Dosage Recommendations* (mg. per kg)	Cost** (per 50 kg bag of feed)
Nitrofurazone	100	$0.35
(9.3%)	500	1.75
Oxytetracycline	500	3.75
	1,000	7.50
Terramycin Fremix	500	2.30
(TM-50D 50 g/lb)	1,000	4.59

* Source: Lightner (see references)

** Argent Chemicals, 1985. This company has also obtained average growth rates of 0.95 grams per week for juveniles up to 6 gram size, and 1.25 grams per week for shrimp greater than 6 grams in size, at densities of up to 70,000 juveniles per hectare. Final feed conversions range from 2.2 to 3.0:1.0. Although these conversions may not prove optimal they are well within economic feasibility.

Table 6
Coastal Land Use in Ecuador (in hectares) in 1983
(Valdiviezo, 1985)

Province	Shrimp Ponds	Mangroves	Salinas
Guayas	52,911	121,463	17,340
El Oro	26,483	24,488	2,520
Manabi	8,376	7,873	163
Esmeraldas	1,595	21,293	4
TOTAL	89,367	175,119	20,028

Table 7
Pond Construction in Sucres Circa February 1984

Land concessions on the mainland	Previously in use	Land clearing 200,000/ha Construction 400,000-600,000/ha
	Undeveloped	120,000/ha
Land concessions on islands	Previously in use	400,000/ha
	Undeveloped	80,000-120,000/ha
Private undeveloped agricultural lands on the mainland	Low land*	60,000-80,000/ha
	High land**	40,000-60,000/ha
Private undeveloped land on islands		120,000/ha

* Below the high tide level.
** Above the high tide level.

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Role of Hatcheries in the Shrimp Pond Culture Industry

El Papel de los Laboratorios en la Industria del Cultivo del Camarón en Piscinas

E. Arellano, M. Leslie, C. Mock, P. Boeing y P. Maugle.

Resumen

Desde 1982 el precio promedio del camarón para exportación ha sido de un US$3,60/lb, produciendo un ingreso anual estimado en unos 200 millones de dólares. Desde 1980, el 75% de estas exportaciones provienen de las piscinas y el 25% de la pesca camaronera de la flota de arrastre.

Para 1986-1987, del 60 al 70% del suministro de larvas proviene del ambiente natural, obtenidas por los "larveros".

La industria del camarón, con una inversión inicial de 2 x 109 dólares, no puede continuar dependiendo sólo del suministro de larvas obtenidas en el medio natural, donde están disponibles sólo estacionalmente. El desarrollo de los laboratorios es requerido para mantener los niveles actuales de exportación.

Los 68 laboratorios autorizados hasta la fecha, podrían producir 6,7 x 109 postlarvas por año.

Para producir pls los laboratorios ecuatorianos usan dos sistemas: (a) desove expontáneo de hembras grávidas capturadas por pescadores; y, (b) suministro de huevos de hembras grávidas mantenidas en condiciones de maduración en el laboratorio (ablación).

Los autores concluyen en que la producción de camarones puede aumentar inmediatamente mejorando el manejo de las piscinas existentes, incluyendo la solución de problemas en el transporte y aclimatación de las pls capturadas del ambiente natural o de laboratorio, así como en la alimentación, captura y mercadeo. Recomiendan que se estimulen las investigaciones aplicadas para estabilización de la producción y de los procesos de maduración.

Introduction

The Ecuadorian shrimp industry has experienced a substantial increase in activity since the 1970s. Exports totalled 2,700 metric tons (m.t.) in 1970, 10,200 m.t. in 1980, 23,400 m.t. in 1984 and approximately 30,000 m.t. in 1986.

Since 1982 the average price for exported shrimp has been U.S. $3.60 per pound, producing an estimated annual income of more than $200 million. Since 1980, 75 percent of these exports came from ponds and 25 percent from the shrimp trawler fleet.

By 1986-1987, 60 to 70 percent of the larval supply came from the natural environment, caught by artisanal fishermen called "larveros." Estimates vary, but apparently more than 90,000 people are involved in this fishery. When fishing is good, a larvero may earn as much as 2,500 sucres or approximately U.S. $17 per day.

The shrimp industry, with an initial investment of approximately $2 billion, cannot continue to depend solely on a natural supply of larvae, which are only seasonally available. If the industry is to stabilize, the development of hatcheries is required to maintain current levels of exportation. 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 unexplained annual fluctuations in larvae distribution on the coast, both seasonal and spatial, make it impossible to adequately predict Ecuador's annual wild stock shrimp production. For this reason, the shrimp industry has started to plan and develop shrimp hatcheries to guarantee a steady supply of postlarvae as the natural populations become less available. The table below summarizes the status of shrimp hatcheries in Ecuador in August 1986:

Shrimp Hatcheries in Ecuador: August 1986

Status	Location				
	Esmeraldas	Manabi	Guayas	El Oro	Total
Hatcheries					
in operation	3	7	16	3	29
in construction	6	6	6	2	20
authorized	--	4	12	3	19
land allocated	--	--	26	--	--
Sub Stations*	10	--	--	--	10
Ecuadorian Hatchery Technicians	5	13	44	1	63
Expatriate Technicians	9	15	42	3	69
Investment**	46	623	2374	207	3250
Operational Costs**	6	104	378	74	562

* Sub stations used to spawn mature female shrimp to obtain nauplii.
** Costs given in millions of sucres, 150 sucres to U.S. $1.

Hatcheries

Technical and economic information from the 68 laboratories cited in Table 1 indicate that they would be able to produce 6.7 billion postlarvae per year. It should be noted that hatcheries do not function on a continuous basis, and including "down-times" this estimate of productive capability could be approximately half. The average size of hatcheries under construction today has decreased, apparently because managers want to supply 100 percent of the larvae for ponds controlled by the enterprise and many have realized that large hatcheries by themselves are not cost effective. By February 1987 there were 105 hatcheries in various stages of planning or construction, 51 of which have received approval to begin operation (see Table 1).

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 postlarvae per hectare and an average harvest of 2,500 pounds/harvest/year at sizes from U21/25 to U36/40. Hatcheries associated with farms of this size can produce at least 10 million postlarvae 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 up to 5 million postlarvae per month and a correspondingly smaller harvest.

From an economic point of view, higher levels of production would seem to lower the relative production cost. In small hatcheries, production costs depend on the initial investment, the growing system applied and the number of personnel involved. Present experience indicates that smaller hatcheries tend to be more economical and operate at better profit margins.

Currently, it appears that integrated companies will function better for the short term since the personnel have more job stability than those in non-integrated companies; but in the long term the small and medium-sized hatcheries will be better able to survive economical, technical or administrative crises because their complexity and expenses are less.

On the other hand, with more small hatcheries, more technical personnel are needed which temporarily created a shortage of these people in Ecuador, as well as all over the world. In Ecuador, the solution to this problem has been to use technicians who move from one hatchery to another. In this way, the transfer of "know-how" is being facilitated, assuming the technicians have sufficient experience.

The question is how many hatcheries and of what size does Ecuador require to guarantee a steady level of production? This is a very difficult question to answer exactly because only now is the country prepared technically to support a "boom" of hatcheries. However, if this necessary development is not undertaken now, the increases in costs, the rise in the dollar and the difficulties with importing of equipment will make future costs and investments much greater and possibly prohibitory. The shrimp mariculture industry is affected by a number of factors: supply of postlarvae, demand, price and levels of production. The table below gives a summary of these factors:

Summary of How Larvae Control the Shrimp Mariculture Industry

Wild caught	Affected by climatological factors
Postlarvae Supply	Hatchery produced (affected by technical ability and cost effective measures). Pollution effects
Demand	Growth in cultivable area (ha of ponds) Number of harvests per year (2-4) Stocking density (pls/ha) (30,000-60,000-120,000; Extensive--Semi-intensive--Intensive system)
Price	Availability of wild caught seed stock Area caught (beach vs. estero) Distance transported Percent *Penaeus vannamei*

Production	Acclimation ability and transportation lbs/ha/year vs. dollars/ha/year Optimization of profits in ponds and hatcheries
Market	Price fluctuations of shrimp. Quality of the product. World production.

Although many commercial hatcheries claim to have the best technology, complicated technologies will not necessarily benefit the hatchery industry in the long term. Instead, relatively simple production methods that will not cause major stress or problems in the system are needed.

Shortages of Broodstock and Nauplii

Hatcheries raise larvae from eggs through a metamorphic stage to postlarvae. 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 2 billion postlarvae, Ecuador's hatcheries will require 4 billion nauplii or approximately 14 million nauplii each night. Gravid female shrimp are available all year from coastal waters in Esmeraldas. Empacadora Nacional operates the largest sourcing fleet in Ecuador, and they, among others, produce 2-5 million nauplii each night. Gravid females are also captured off San Pablo from October through March, where 4-20 million nauplii are collected each night. These data suggest that the wild stock gravid population(s) can almost supply the projected demand from October through March, but the supply of nauplii from Esmeraldas cannot supply the hatcheries with nauplii for the rest of the year.

The second source of eggs 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 occurred, the attachment of sperm to the female shrimp prior to spawning. Maturation production varies depending on techniques used, the experience of the manager and availability of brood stock. Year-round production ranges from 20,000 to 150,000 nauplii per tank per night, which suggests a need for some 250 tanks. All hatcheries presently under construction incorporate maturation systems and as many as 400 tanks may be available 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. Currently, almost 50 percent of nauplii used in hatcheries came from maturation facilities.

The zones and times of spawning of *P. vannamei* are not exactly known, although some areas where this species is common are known, and large quantities of brood stock *P. vannamei* are captured between December and March when ocean temperatures are higher. If a hatchery does not have an operational maturation system, it is difficult to produce postlarvae throughout the year. Because there are large quantities of nauplii at certain times of the year, there is a tendency to use more cost effective, high density larval culture techniques, but disease problems have on occasion become critical, leading to short-term decreases in productive capacity.

The short supply of high quality broodstock for use in maturation systems could be solved by maintenance of special tanks of ponds at the hatchery or pond site, or by selective fishing (sourcing) by the offshore fleet. To date attempts to use pond-raised broodstock has been unsuccessful in Ecuador. Special consideration needs to be placed on pond environment and nutritional quality of diets for these animals.

Conclusions and Recommendations

Shrimp production could be increased immediately by making optimal use of facilities already installed. Improving management of existing ponds includes addressing problems of transportation and acclimation of wild-caught and hatchery-produced postlarvae, appropriate feeding, harvesting and adequate marketing.

The future of shrimp hatcheries and the industry is dependent upon a stable quality and supply of a large quantity of larvae. Producing 1 billion PL 5/6 postlarvae of low quality each year is not as profitable as producing 500 million PL 15s. The hatcheries must consistently produce larvae of superior nutrition and larger size, even at lower production levels, since these larvae have higher market acceptability and stable price.

Wildstock postlarvae may always exist as strong competition for hatchery-produced seed, but if the use of hatchery products in ponds becomes standard, the hatcheries may be a long-term solution for a stable mariculture industry in Ecuador.

Applied research with direct, rapid impact on the stabilization of production, should be stimulated, and research on diseases should be initiated in government and private laboratories. 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 adequately understood, a nauplius distribution center should be installed to facilitate the operation of small and medium-sized hatcheries.

Long-term, applied research with direct and rapid impact on production should be strongly stimulated. The Ecuadorian government should encourage ESPOL, by means of its Shrimp Larval Culture Project, to serve the needs of the entire shrimp industry. One way to assure this is through grants. Another might be to permit ESPOL to operate ponds, as other government agencies do, to export the product, and to use the funds to support hatchery training operations.

Appendices

ECUADOR
RATE OF EXCHANGE TO THE U.S. DOLLAR
(ANNUAL AVERAGE IN SUCRES)

	Free Market Intervention Buy	Private Free Market Buy
1970		23.14
1971		25.02
1972		26.06
1973		24.79
1974		24.91
1975		25.24
1976	27.01(1)	27.29
1977	26.83	27.09
1978	25.99	26.26
1979	26.53	27.36
1980	26.75	27.41
1981	27.58(2)	30.56
1982	30.00(3)	50.31
1983	82.37(4)	83.20
1984	91.55	96.75
1985	95.00(5)	115.11
1986	122.05	151.35(6)
1987	169.97	193.23
1988 (Jan/June)	243.76	400 Sept.

(1) Executive Decree No. 529 of July 14, 1976 authorized the Central Bank to intervene in the Free Market Exchange.
(2) Average applicable from January-August 13.
(3) Average applicable from March 3-December.
(4) Average applicable from March 21-December.
(5) Average applicable from January-November 11.
(6) Average January-November 1986.
Source: Banco Central del Ecuador y Superintendencia de Bancos.

ACRONYMS
(LISTA DE ACRONIMOS)

AITEC	Acción International Técnica International Technical Action
BEDE	Banco Ecuatoriano de Desarrollo Ecuadorian Development Bank
BID	Banco Interamericano de Desarrollo Inter-American Development Bank
BNF	Banco Nacional de Fomento National Development Bank
CAF	Corporación Andina de Fomento Andean Development Corporation
CEDEGE	Comisión de Estudios para el Desarrollo de la Cuenca del Río Guayas Study Commission for the Development of the Guayas River Basin
CEDIG	Centro Ecuatoriano de Investigación Geográfica Ecuadorian Center for Geographic Studies
CELADE	Centro Latinoamericano de Demografía Latin American Demography Center
CEPAR	Centro de Estudios de Población y Paternidad Responsable Center for the Study of Population and Paternal Responsibility
CEPE	Corporación Estatal Petrolera Ecuatoriana Ecuadorian Petroleum Corporation
CESA	Control Ecuatoriano de Servicios Agrícolas Ecuadorian Control for Agricultural Services
CLIRSEN	Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos Center for Remote Sensing of Natural Resources (Military Geographic Institute)
CNDP	Consejo Nacional de Desarrollo Pesquero National Council for the Development of Fishing
CONADE	Consejo Nacional de Desarrollo National Planning Council
CPPS	Comisión Permanente del Pacífico Sur Permanent Commission for the South Pacific
CRM	Centro de Rehabilitación de Manabí Center for Rehabilitation of Manabi
DGP	Dirección General de Pesca National Fishing Directorate
DIGEIM	Dirección General de Intereses Marítimos de la Armada Office of Maritime Affiars of the Navy
DIGEMA	Dirección General del Medio Ambiente Department of the Environment
DIGMER	Dirección General de la Marina Mercante y del Litoral National Merchant Marine and Directorate for the Coast
DINAF	Dirección Nacional Forestal National Forestry Department

DINEFONASA	Dirección Nacional Ejecutiva del FONASA National Board of Directors of FONASA
DITURIS	Dirección Nacional de Turismo National Tourism Department
EMAG	Empresa Municipal de Alcantarillado de Guayaquil Municipal Sewage Company of Guayaquil
EPNA	Empresa Pesquera Nacional National Fishing Company
ESPOL	Escuela Superior Politécnica del Litoral Polytechnic University of the Coast
FAO	Organización de las Naciones Unidas para la Alimentación y Agricultura Food and Agriculture Organization of the United Nations
FONAPAR	Fondo Nacional de Participación National Fund for Participation
FONAPRE	Fondo Nacional de Preinversión National Pre-investment Studies Fund
FONASA	Fondo Nacional de Saneamiento Ambiental National Fund for Environmental Sanitation
IEOS	Instituto Ecuatoriano de Obras Sanitarias Ecuadorian Institute for Sanitary Works
IERAC	Instituto Ecuatoriano de Reforma Agraria y Colonización Ecuadorian Agrarian Reform and Colonization Institute
IESS	Instituto Ecuatoriano de Seguridad Social Ecuadorian Social Security Institute
IGM	Instituto Geográfico Militar Military Geographic Institute
ILDIS	Instituto Latinoamericano de Investigación Social Latin American Institute for Social Studies
INEC	Instituto Nacional de Estadísticas y Censos National Statistic and Census Institute
INEMIN	Instituto Ecuatoriano de Minería Ecuadorian Mining Institute
INERHI	Instituto Ecuatoriano de Recursos Hidráulicos Ecuadorian Institute for Hydraulic Dynamics
INIAP	Instituto Nacional de Investigaciones Agropecuarias National Farming Research Institute
INOCAR	Instituto Oceanográfico de la Armada Oceanographic Institute of the Navy
INP	Instituto Nacional de Pesca National Institute of Fishing
JUNAPLA	Junta Nacional de Planificación National Planning Board

MAG	Ministerio de Agricultura y Ganaderia Ministry of Agriculture and Ranching
MICIP	Ministerio de Industrias, Comercio, Integración y Pesca Ministry of Industry, Commerce, Trade and Fishing
PREDESUR	Programa de Desarrollo del Sur Southern Development Program
OIPE	Oficina Integrada de Planificación de Esmeraldas Esmeraldas Planning Office
SRP	Subsecretaria de Recursos Pesqueros Sub-secretary of Fishing Resources
SUINBA	Superintendencia del Terminal Petrolero de Balao Superintendent of the Balao Petroleum Terminal
SUINLI	Superintendencia del Terminal Petrolero de La Libertad Superintendent of the Libertad Petroleum Terminal
SUINSA	Superintendencia del Terminal del Salitral Superintendent of the Salitral Petroleum Terminal
TEPRE	Terminal de Productos Limpios de la Refineria Estatal State Clean Products Refinery Terminal
TRANSNAVE	Transportes Navieros Ecuatorianos Ecuadorian Sea Transport
UNCLOS	Convención de la Ley del Mar de las Naciones Unidas Law of the Sea Convention of the United Nations
USAID	United States Agency for International Development

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