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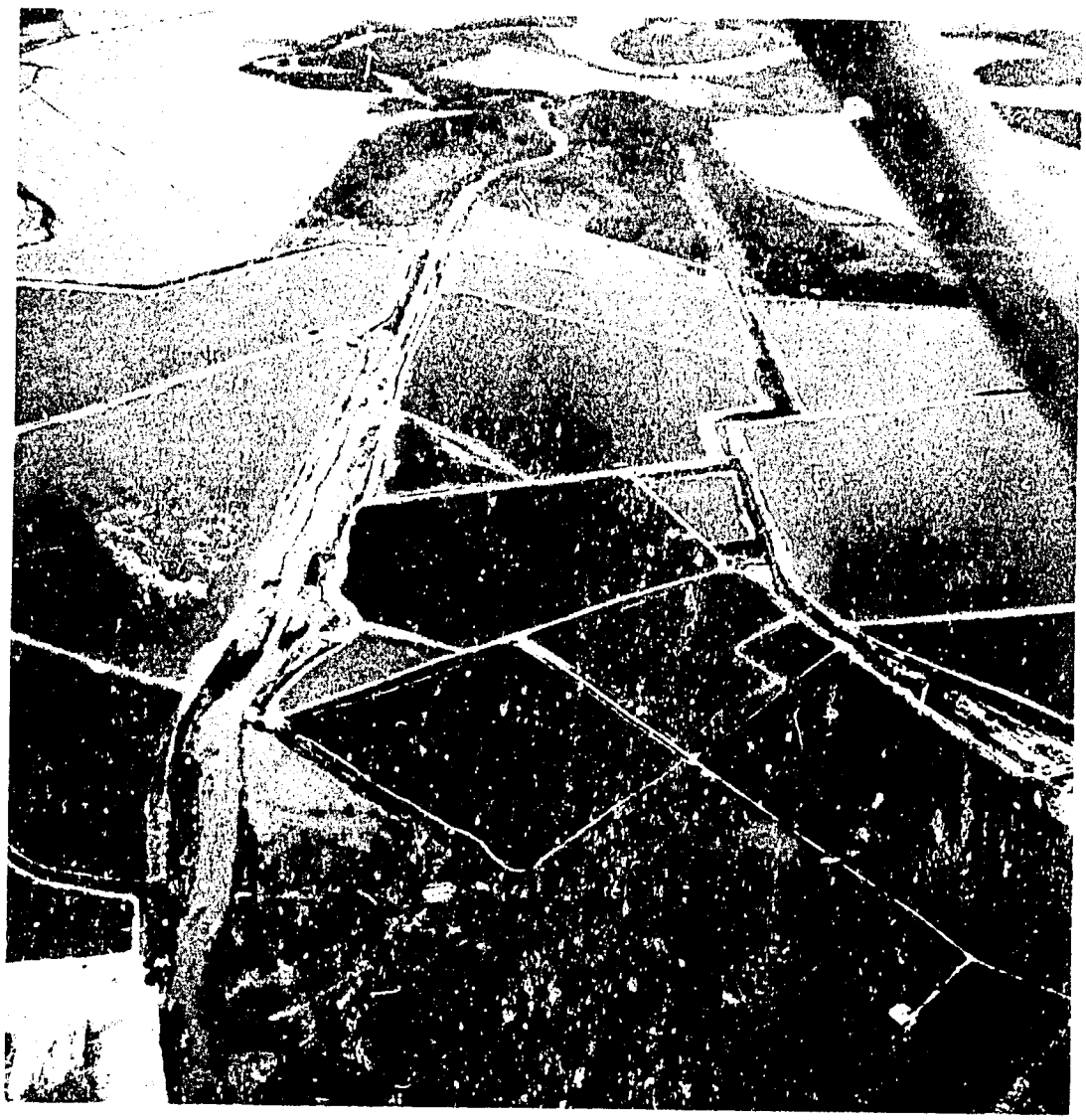
PN-ABA-524

SHRIMP POND SITING AND MANAGEMENT ALTERNATIVES

FINAL IN 3.F-17

MANGROVE ECOSYSTEMS IN ECUADOR

Prepared for the
U.S. Agency for International Development



by

Samuel C. Snedaker, Joshua C. Dickinson, III,

Melvin S. Brown and Enrique J. Lahmann

Miami, Florida
1986

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SHRIMP POND SITING AND MANAGEMENT ALTERNATIVES IN MANGROVE ECOSYSTEMS IN ECUADOR

Final Report
USAID Grant No. DPE-5542-G-SS-4022-00

Prepared for the
U.S. Agency for International Development
Office of the Science Advisor

by

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PREFACE

One of the most rapidly-expanding and profitable economic development activities in South America has been the Penaeid shrimp-growout pond (mariculture) industry in Ecuador which had its beginnings in the late 1960s. It now ranks number two, after petroleum, as a major export commodity and foreign currency earner for Ecuador. In addition, shrimp mariculture has completely transformed much of the coast of southern Ecuador into a mosaic of interlocking and contiguous growout ponds. In addition, it has also stimulated the development of a variety of local support industries.

Prior to the "El Niño" event of 1982/83, the shrimp mariculture industry began to experience increasingly severe and unpredictable shortages in the wild post-larval shrimp (PL) that are harvested in shallow coastal waters to stock commercial growout ponds. For several years, the demand for PL had exceeded their natural availability and led the shrimp producers, represented by such organizations as ACEBA (Asociacion de Cultivadores de Especies Bioacuaticas), to begin to seek a solution to the continuing shortage. Although the El Niño event destroyed a significant part of the physical infrastructure upon which the industry relied, the chaotic period was also characterized by a relatively large population of PL suitable for capture and pond stocking. Nevertheless, the experienced producers recognized that the long-term trend portended continued annual shortages in PL availability.

With respect to the decreasingly availability of PL stocks, it was known from a variety of published sources that coastal mangrove forests are the primary nursery habitats for many species of marine shrimp as well as a large number of other species of shellfish and finfish. These intertidal forests provide a refuge from competitors and predators, and are a source of nutrient-enriched organic matter which serves as a food substrate. It was therefore locally concluded that the extensive conversion of the coastal mangrove forests to shrimp growout ponds, particularly in the southern provinces (e.g., Guayas and El Oro, and also in Manabi), was somehow implicated in the reduction of the availability of larval and juvenile shrimp. The local producers, mainly ACEBA, made known their desire for a solution to the U. S. Agency for International Development (USAID) relative to destruction of mangrove forests and the problematic availability of PL. Among other points, the producers argued that continued conversion of mangrove forest areas to maricultural ponds could lead to the collapse of the mariculture industry. After a series of discussions with the producers and USAID, the authors, working through the University of Miami, obtained a research grant from the USAID Office of the Science Advisor's Program in Science and Technology Cooperation (PSTC). The stated purpose of the grant was to research the relationship among shrimp pond siting and management practices, and, the acknowledged reductions in both mangrove forest area and PL stocks. The corollary grant objective was to develop guidelines or recommendations on

siting and management which could lead to higher and stabilized levels of pond production yields.

The research was formally initiated in mid-1984 and concluded in mid-1985. The major part of the field work took place during February and March 1985 during which time experimental aerial photographs were taken and field investigations made of representative ponds and surrounding mangrove forests in Guayas, El Oro and Manabi provinces. In addition, information was acquired on pond siting and management practices from a variety of Ecuadorean sources for comparison with information obtained elsewhere by the authors (see, for example, Dickinson 1983) as well as data and information reported in the literature. This report summarizes and discusses the findings. It is hoped that this report represents a significant contribution to our increasing knowledge of the practical benefits, problems and alternatives, associated with the extensive globally-expanding shrimp mariculture industry.

TABLE OF CONTENTS

Preface.....ii
List of Figures.....vi
List of Tables.....vii
Acknowledgements.....viii

1.0.0. INTRODUCTION.....1
1.1.0. Scope of Project.....3
1.2.0. Major Project Activities.....4

2.0.0. BACKGROUND.....7
2.1.0. Types and Levels of Mariculture Management.....7
2.1.1. Type I: Subsistence and Artisanal Open-System mariculture.....7
2.1.2. Type II: Extensive Closed-System Mariculture.....10
2.1.3. Type III: Semi-Intensive Closed-System Mariculture.....12
2.1.4. Type IV: Intensive Artificial-System Mariculture.....12

3.0.0. FIELD EVALUATIONS.....14
3.1.0. Introduction.....14
3.1.1. Shrimp Pond and Mangrove Field Studies.....14
3.1.2. Interviews.....18
3.1.3. Water Quality Methodology.....18
3.1.4. Mangrove Forest Assessment.....20
3.2.0. Shrimp Farm Evaluations.....24
3.2.1. Production Levels.....24
3.2.2. Major Problems.....24
3.2.3. Ideal Conditions.....25
3.2.4. The Future Outlook.....26
3.3.0. Water Quality.....28
3.4.0. Aerial Imagery Evaluation.....32

4.0.0. SHRIMP MARICULTURE IN ECUADOR.....36
4.1.0. Mariculture Types and Management Levels.....36
4.1.1. Type II: Extensive Closed-System, Management Level 5.....36
4.1.2. Type II: Extensive Closed-System, Management Level 6.....36
4.1.3. Type III: Semi-Intensive Closed-System, Management Level 7.....37
4.1.4. Type III: Semi-Intensive Closed-System, Management Level 8.....37
4.2.0. Construction Costs.....38
4.3.0. Operational Costs.....38
4.4.0. Shrimp Pond Siting.....39
4.4.1. Pond Size.....39
4.4.2. Pond Location.....39
4.5.0. Water Quality Management.....41

5.0.0. ENVIRONMENTAL CONSIDERATIONS....42
5.1.0. Upstream Use and Misuse of Resources....42
5.2.0. Agriculture....42
5.3.0. Mangrove-Based Fisheries....43
5.4.0. Effects On Mangrove Forests....43

6.0.0. SOCIOECONOMIC CONSIDERATIONS....47
6.1.0. Marginal Habitats Converted to Economic Use....48
6.2.0. Mariculture Provides Employment Opportunities....48
6.3.0. Dietary Protein Levels are Increased....50
6.4.0. Local Economic Benefits and Hard Currency Earnings Stimulate Economic Development Within the Region....51
6.5.0. Government Revenue Base is Strengthened....51
6.6.0. Construction of Hatcheries Will Solve the Major Problem....52

7.0.0. CONCLUSIONS....53
7.1.0. Pond Siting and Management Intensification....53
7.2.0. Development of Maturation and Hatchery Facilities....54
7.3.0. The Recurrent Post Larvae Crisis....55
7.4.0. Alternate and/or Exotic Culture Species....55
7.5.0. Fishery Sector Development....56
7.6.0. Intertidal Zone Management....59
7.7.0. Activities of Interest to Development Assistance Agencies....59
7.8.0. Research Needs....60

8.0.0. LITERATURE CITED AND BIBLIOGRAPHIC REFERENCES....62

Appendix A. SOME TRADITIONAL USES OF SOUTH AMERICAN MANGROVE FORESTS..A-1
Introduction....A-1
The Mangrove Forests of South America....A-2
Geographic Distribution....A-2
Forested Area....A-2
Species Composition....A-3
Historical and Traditional Uses....A-3
Utilization and Economic Value....A-4
Literature Cited....A-6

Appendix B. MANGROVE FOREST AREA IN ECUADOR....B-1
Literature Cited....B-3

LIST OF FIGURES

Figure 1.1. Map of Ecuador and northern Peru. Shrimp mariculture started in the southern Provinces of Ecuador (Guayas and El Oro), and to a lesser extent in the Tumbes area of Peru, but is now most heavily concentrated in the Guayas drainage basin to the south of Guayaquil.

Figure 1.2. Aerial view of shrimp growout ponds in southern Ecuador showing the encroachment on mangrove wetlands (at top of photo) and agricultural land (at bottom of photo).

Figure 2.1. Some generalized trends associated with the increasing intensification of mariculture. Whereas yields per unit area can be significantly increased, such factors as investment cost and risk, and destruction of the natural resource base, also increase. (Adapted from: Figure 24 *in* Snedaker, Samuel C. and Charles D. Getter. 1985. *Coastal Resources Management Guidelines*. Renewable Resources Information Series, Coastal Management Publication No. 2. Research Planning Institute, Columbia, South Carolina. 205 p.)

Figure 3.3. Aerial view of shrimp growout ponds in southern Ecuador showing color differences that are related to differences in water quality and in phytoplankton species and abundance.

Figure 5.1a. Influence of the cumulated area of reclaimed land on annual shrimp (*Penaeus japonicus*) catches in the Seto inland Sea (from Doi *et al.* 1973).

Figure 5.1b. Relationship between mangrove area (10^4 ha) and shrimp production (10^3 ton) (from Martosubroto and Naamin 1977).

Figure 6.1. Comparison of selected shrimp growout-pond construction and operating characteristics in intertidal mangroves, supra-tidal coastal habitats, and non-tidal coastal areas, cross-referenced to different climatic conditions.

LIST OF TABLES

Table 1.1. Foreign exchange earnings in Ecuador for the years 1978-84, given in million U.S. dollars, FOB. (Source: Central Bank of Ecuador)

Table 1.2. Sea and farm production of shrimp in Ecuador for the years 1979-84 given in metric tons. (Source: Direccion General de Pesca)

Table 3.1. Geographical location and summary characteristics of ten selected Type II shrimp (*Penaeus vannamei*) farms in Ecuador.

Table 3.2. Structural comparisons of mangrove forests near shrimp ponds in southern Ecuador. Complexity components are expressed on a 0.1 ha basis.

Table 3.3. Ecuadorean shrimp pond characteristics obtained from aerial imagery and on-site ground truthing.

Table 3.4. Ecuadorean shrimp pond characteristics obtained from aerial imagery and on-site ground truthing.

Table 4.1. Number of concessions and/or authorizations listed by province according to area as of December 1984. (Source: Unidad de Estudios Pesqueros y Estadisticas)

Table 4.2. Areas of shrimp culture are listed with the number of hectares per province up to 1983. (Source: Depto. de Estudios Pesqueros y Estadisticas)

Table 4.3. Relationship between coastal elevation relative to tidal amplitude and the suitability of sites at these elevations for the construction of shrimp growout ponds. Mangrove forests tend to be the most productive at the same tidal elevations that are believed to be the most suitable for growout ponds. (Adapted from from Watson 1928 and Rabanal 1976)

Table 5.2. Areas in Ecuador authorized for shrimp farming in 1976-1984. (Source: Departamento de Estudios Pesqueros y Estadisticas.)

Table 6.1. Comparison of selected shrimp growout-pond construction and operating characteristics in intertidal mangroves, supra-tidal coastal habitats, and non-tidal coastal areas, cross-referenced to different climatic conditions.

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1.0.0. INTRODUCTION

The extensive and diverse coastal zone of Ecuador (Figure 1.1) is a major focus of actual and potential economic development. Convergent in the coastal plain are the presence of rich alluvial soils, abundant water from rainfall and river drainages, and a productive estuarine zone. The human response to this wealth of resources has been the establishment of commercial agriculture based on bananas, cacao, cotton, rice and other grains, fisheries and mariculture, urban-industrial centers, tourism, and an extensive supporting infrastructure. Coastal Guayaquil, for example, is the business center of Ecuador. Further sustained development of these economic activities, and the resources upon which they are dependent, is necessarily based on the integrated management of human activities both in the coastal zone and in upstream watershed areas.

Among the various economic activities in the coastal zone is the 160 million dollar (US$) per year shrimp industry which now surpasses bananas as the leading non-petrocarbon export (Table 1.1). The capability of Ecuador to produce shrimp (Table 1.2) is related directly to the characteristics of the country's coastal environment with its extensive estuaries, year round growing season, suitable soil conditions, and a balance of fresh water and ocean current inputs, except during El Niño events.

Table 1.1. Foreign exchange earnings in Ecuador for the years 1978-84, given in million U.S. dollars, FOB. (Source: Central Bank of Ecuador)

Year	Crude Oil	Bananas	Coffee	Shrimp
1978	558.0	171.8	281.2	42.3
1979	1,032.0	200.1	263.1	63.1
1980	1,390.0	237.1	130.4	65.9
1981	1,560.1	207.9	105.9	77.5
1982	1,388.3	213.3	138.8	122.3
1983	1,636.8	152.9	148.6	175.1
1984	1,622.7	132.6	174.2	159.9

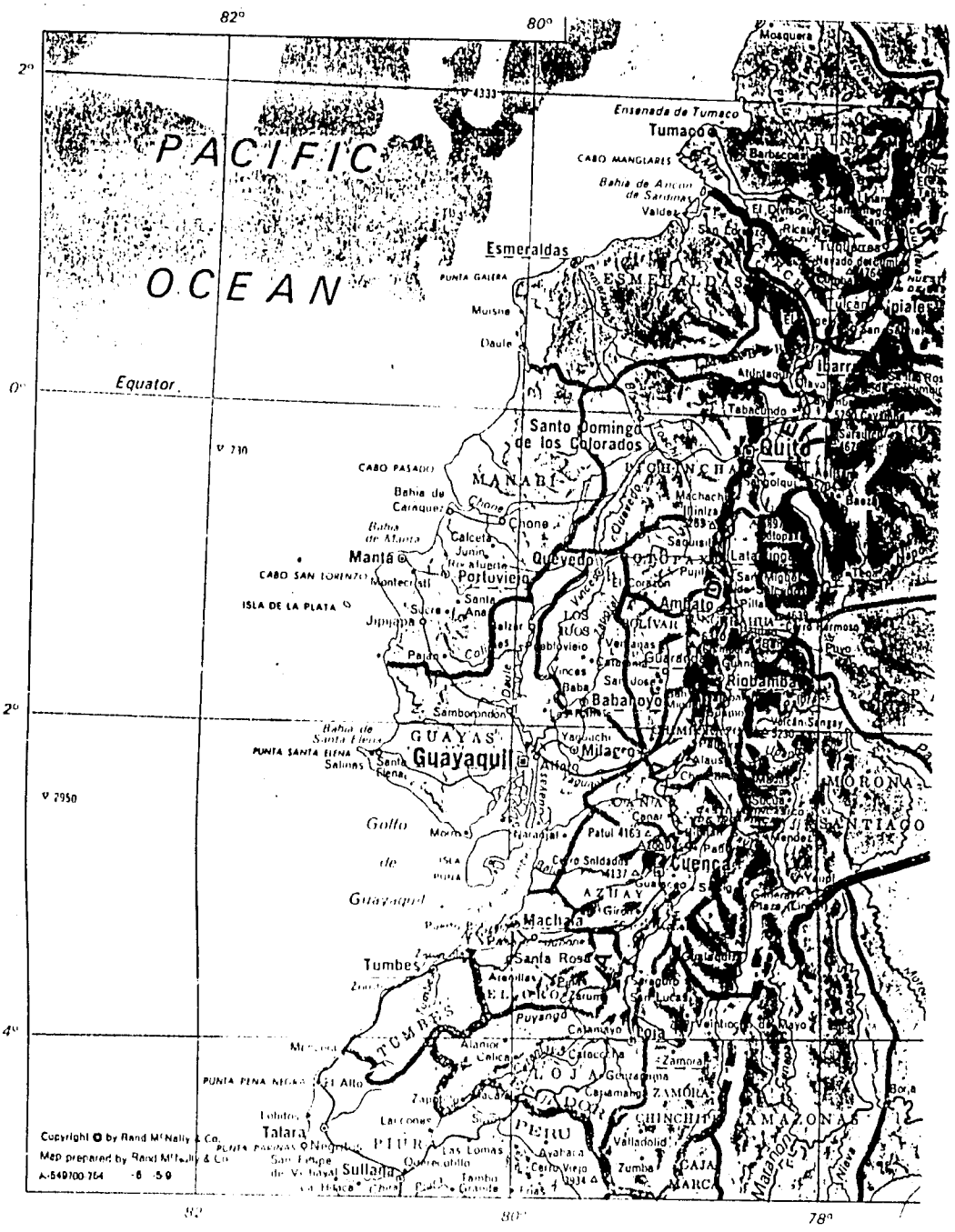

Figure 1.1. Map of Ecuador and northern Peru. Shrimp mariculture started in the southern Provinces of Ecuador (Guayas and El Oro) and to a lesser extent in the Tumbes area of Peru, and is now most heavily concentrated in the Guayas drainage basin to the south of Guayaquil.

Table 1.2. Sea and farm production of shrimp in Ecuador for the years 1979-84 given in metric tons. (Source: Direccion General de Pesca)

Year	Total	Sea	Farm
1979	12,485	7,787	4,698
1980	16,980	7,800	9,180
1981	20,100	8,000	12,100
1982	29,500	8,000	21,500
1983	36,600	7,500	29,100
1984	26,079	------	------

Shrimp ponds have been located in the intertidal and neighboring upland environment where soil conditions permit construction of dikes and where brackish estuarine water is readily accessible. Initially, ponds were located primarily in salinas which are saltflats or areas of sparse halophytic vegetation, where construction costs are minimum. As the pressure on land has increased, more ponds have been built in intertidal mangrove forest areas and on supra-tidal land that was previously dedicated to agriculture. Inevitably, intersectoral conflicts have arisen among the various development sectors in the coastal zone and in the watershed upstream of it. Coupled with the variability and overall reduction in the availability of seed shrimp, or semilla (hereafter refered to as "PL" for postlarva), for stocking ponds, the industry is facing major conflicts and challenges that must be overcome to ensure its economic survival and benefit to the country. This project identifies some of the conflicts and challenges that are of direct importance to the shrimp industry and the coastal economy of Ecuador. Some of these conflicts and challenges are analyzed in depth to form the bases for a set of recommendations of mitigating measures.

1.1.0. Scope of Project

This study of the Ecuadorean shrimp pond industry had two primary objectives and several ancillary and supportive tasks. Due to the extensive concern of the local shrimp producers in Ecuador, the first major objective was to determine the extent to which the conversion of the coastal mangrove forests might be responsible (or not) for the decrease in the availability of PL required for pond stocking. In this same regard, has the conversion resulted in any confirmed, or confirmable, decrease in the other species of mangrove-estuarine dependent shellfish and finfish. The second of the primary objectives was to develop recommendations for improved pond siting and management which would lead to increased economic stability and a lessened environmental impact. The primary objectives were consistent with the interests of most of the interested parties in Ecuador.

The ancillary objectives focussed around a socioeconomic overview of the shrimp pond industry within Ecuador. The secondary tasks associated with this subject included a rough economic assessment and an analysis of where the industry might go in the future and what might be its options for continued survival. In this regard, a goal of this project has been to identify productive management strategies for shrimp mariculture within the larger context of optimum coastal resource management. The mangrove ecosystem, in this context, is seen as the major productive component which is now under the particularly severe threat from what is recognized as an indiscriminate expansion of the network of shrimp ponds (Figure 1.2), a phenomenon that is not wholly restricted to Ecuador.

All of the objectives and tasks were completed and the results are described in detail in this report. In addition, a set of recommendations of mitigating measures have been put forth for consideration by the shrimp producers in Ecuador, the various international assistance agencies and the Government of Ecuador. The study conclusions and recommendations draw significant benefit from the experiences of the authors in other regions of the world where coastal shrimp mariculture represents a developing industry facing similar opportunities and constraints.

In this latter regard, the USAID mission in Peru, which seeks to take advantage of the results of this project, invited one of the authors (JCD) to assess the developing intersectoral conflicts that are associated with the expanding shrimp farm area in the Department of Tumbes. The coastal geomorphology and ecosystems in Tumbes represent an extension of the conditions found in the contiguous province of El Oro in Ecuador. The present report therefore includes discussions and conclusions which in part are based on information obtained from the field work conducted in Peru.

1.2.0. Major Project Activities

1.2.1. Management studies and biophysical characterization of ten shrimp farms in the Provinces of Guayas and El Oro in Ecuador were conducted. This included structural comparisons of the mangrove forests that are located in close proximity to shrimp farming operations and which could be affected by large pond impoundments.

1.2.2. Overflights were taken to obtain color and color infrared photographs of shrimp ponds and contiguous mangroves so as to evaluate potential correlations between water quality characteristics and pond management practices, and location within the coastal zone.

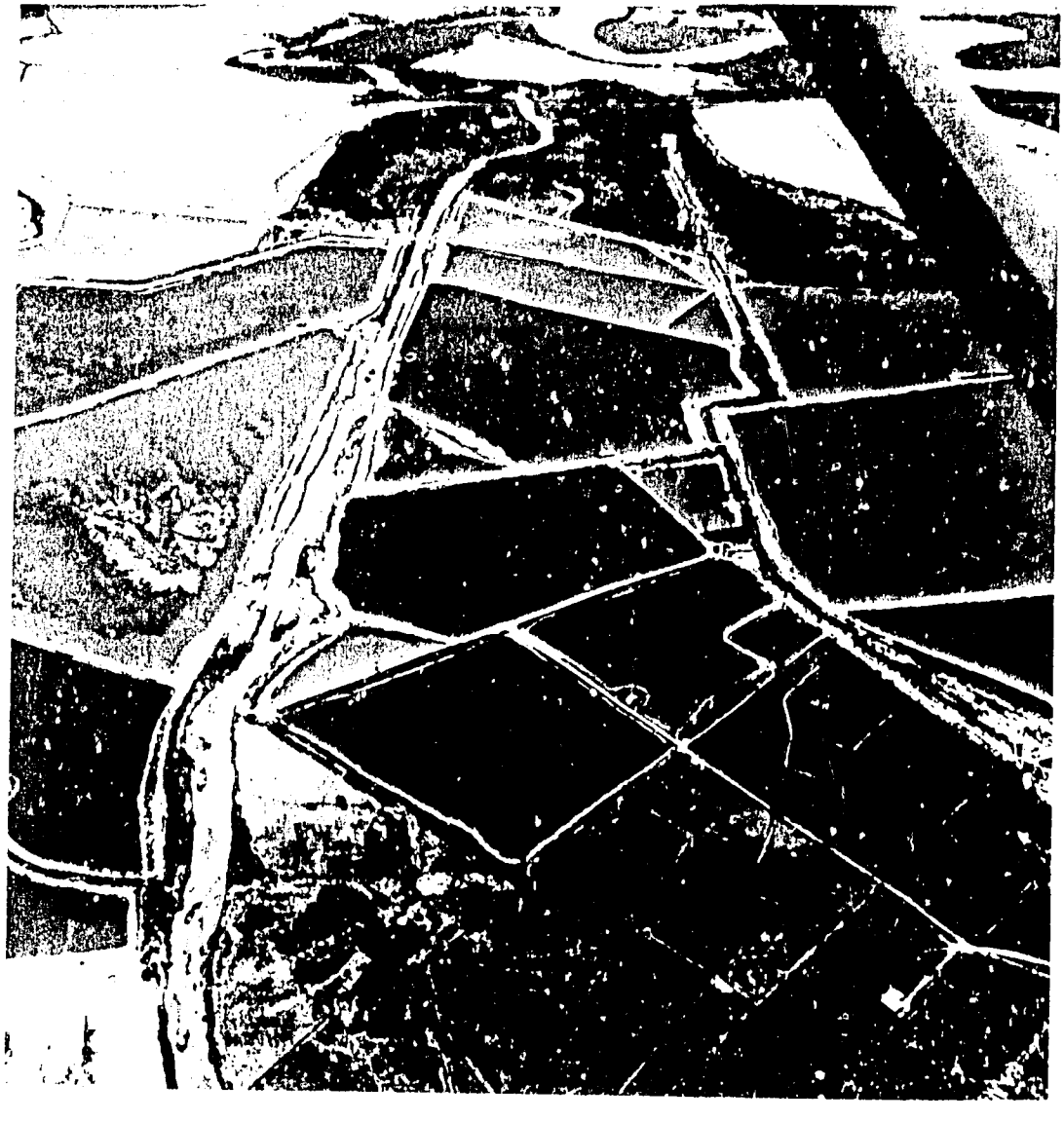

Figure 1.2. Aerial view of shrimp growout ponds in southern Ecuador showing the encroachment on mangrove wetlands (at top of photo) and agricultural land (at bottom of photo). The color values and contrast are not true due to the method of reproducing copies for this report. (Photo credit: Joshua C. Dickinson, III)

1.2.3. Actual and potential strategies by shrimp producers, regulatory agencies, regional planners, researchers, AID and other donors were synthesized and evaluated to assess the significance of mariculture as a component in potential plans for promoting sustainable coastal development.

1.2.4. The shrimp mariculture industry in Ecuador was evaluated *sensu lato* within the context of the global phenomenon of the promotion of shrimp farming as an economic panacea for developing countries.

The first two of these activities had a particularly important secondary benefit in that they involved the participation and training of four students from the Escuela Politecnica del Litoral in Guayaquil. In addition, the evolving results from the project were shared with colleagues in other countries to foster international cooperation and to share pertinent aspects of the locally-developed knowledge.

2.0.0. BACKGROUND

2.1.0. Types and Levels of Mariculture Management

The term "mariculture" describes the purposeful management and/or the culturing of marine plants or animals under open, semi-controlled or controlled conditions. As a specialized form of aquatic agriculture, or aquaculture, the practice has been known for several thousand years (Ling 1980). Although there are numerous types of marine-animal mariculture, which range from the deceivingly simple to extraordinarily complex factory-type operations, the range of types can be roughly defined as functions of the total investment and management intensity (Snedaker and Getter 1985) as illustrated in Figure 2.1. In this regard, investment includes all of the economic inputs such as labor, knowledge and money, whereas management intensity is defined as the sum of all subsidies and inputs apportioned over the actual production area to which they are applied. In general, production or yield tends to be proportional to the sum of the inputs as are certain kinds of potential problems which increase the risk. These financial or economic aspects of shrimp mariculture in Ecuador are discussed elsewhere in this report.

Whereas the information presented in Figure (2.1) is based on the three commonly-used mariculture categories (see, for example, Hirono 1983) it was recognized early in this project that a greater resolution of specific operating characteristics would be required for analytical purposes. Thus, as part of this project four types of mariculture (non-country specific) were defined each of which can be further characterized by increasing intensities of management. The definition of four Types and ten Management Levels are based on the global variations in mariculture as well as the somewhat narrower range of conditions that are typically found in Ecuador.

2.1.1. Type I: Subsistence and Artisanal Open-System Mariculture

In its simplest form, this type of mariculture is characterized by low investment and low intensity management, and although it appears to be a relatively simple operation, it is sometimes dependent upon a high level of sophistication developed through trial and error. The term "open" refers to the fact that the ambient marine and/or estuarine waters are allowed to circulate freely among the animals being cultured. This circulation of water is the mechanism for the continual input of nutrients, food materials and oxygen, and the continual removal of metabolic wastes including carbon dioxide; free circulation is in effect a natural water-quality maintenance mechanism. Figure 2.1 illustrates that this type of mariculture is also characterized by proportionately low yields per unit area (and implicitly, per

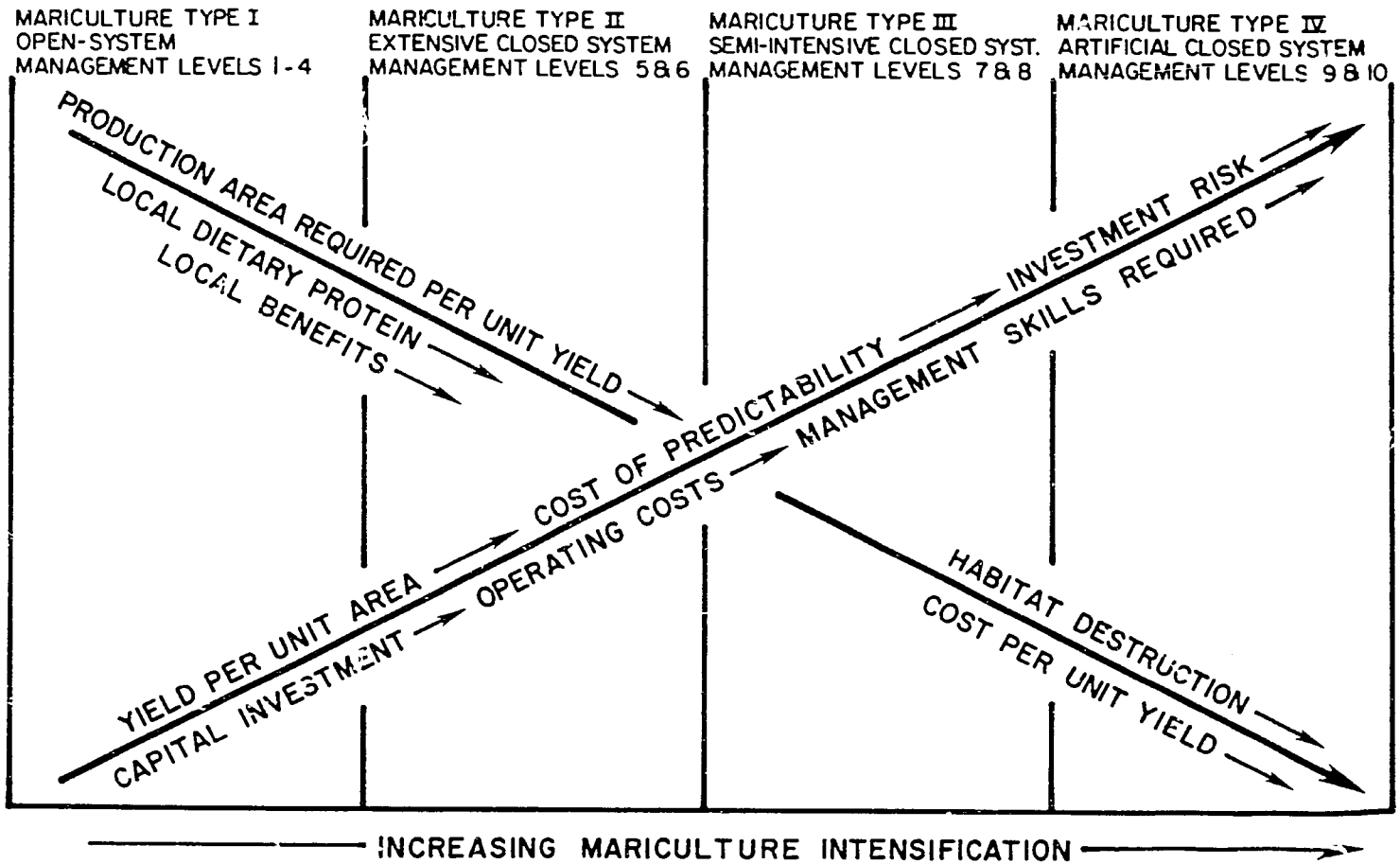

Figure 2.1. Some generalized trends associated with increasing intensification of mariculture operations. Whereas yields per unit area can be significantly increased, such factors as investment cost and risk, and destruction of the natural resource base, also increase. (Adapted from: Figure 24 *in* Snedaker, Samuel C. and Charles D. Getter. 1985. *Coastal Resources Management Guidelines*. Renewable Resources Information Series, Coastal Management Publication No. 2. Research Planning Institute, Columbia, South Carolina. 205 p.)

unit time). However, it is sustainable with minimal effort, planning or management, due in large part to the fact that a relatively undisturbed natural ecosystem is self-maintaining. Four Management Levels are recognized in this type of mariculture and are described as follows:

ML-1: Use of aggregating devices and methods to concentrate mobile animals in natural environments.

ML-2: Use of artificial or natural substrates to concentrate sessile or burrowing animals in natural environments.

ML-3: Use of confining devices such as cages or retaining pens to maintain concentrations of mobile animals in natural environments.

ML-4: Use of barriers or enclosing devices to retain populations of mobile animals in relative large areas of natural environments.

The open-system type of mariculture is widespread throughout the world and provides a convenient source of protein for local populations. In Benin, there are good examples of two of the simpler forms (Blasco 1985). In an example of ML-1, one or several *Rhizophora* trees are grown in shallow water for the purpose of aggregating local species of fish and crustaceans among the protective prop root system. Harvesting is accomplished by luring the organisms into open water with bait and then capturing them with a cast net. In a contrasting example of ML-3 in the same region of Benin, circular enclosures of some 20-25 m are created in shallow water by forming a wall of branches stuck into the sediment. Within the enclosures, "thickets" are created with mangrove brush to create a submerged habitat that produces higher yields than the surrounding waters. In each of these examples, there are relatively low management inputs and relatively low yields, which albeit low in comparison to other mariculture types, are higher than that required by capture fisheries in the same area. In addition, both forms are open to the ambient water in which they are found.

Other examples of open-system mariculture defined as ML-2 include various forms of the cage culture of finfish, oyster and mussel culture on artificial substrates, and cockle culture on mud flats (see Macintosh 1982). In general, open-system mariculture is notable because it does not require the destruction of coastal or nearshore resources, requires minimal management inputs and relies almost wholly on the undisturbed ecosystem. As a result, it is the one type of mariculture that is implicitly sustainable.

One of the better documented examples of ML-4 is the so-called tapos fishery of western Mexico (Pedini 1981) which is in essence a "trapping" system that is also utilized in other regions of the world. With respect to penaeid shrimp, the tapos system centers on the trapping of sub-adult shrimp in natural areas and forcing them to migrate through relatively small weirs where they are caught. Alternatively, the migrating shrimp concentrate at

barriers where they are fished with castnets and handnets. Although the trapping of migrating shrimp is not mariculture per se, it is included here because it can involve considerable investment and management ability. It should be also noted, however, that Pedini (1981), among others, consider the tapos fishery to have a high potential to be exploitive and detrimental to the basic resource.

2.1.2. Type II: Extensive Closed-System Mariculture

A somewhat more investment-intensive form of the open-system type of mariculture can be viewed as a transition between the examples described above and the more advanced forms of extensive mariculture described below. The transition mode is based on the construction of relatively small earthen ponds which are flushed by normal tidal action. This characteristic also permits the stocking of the ponds by simply allowing the larval and juvenile organisms to enter on incoming tides at the specific times of the year when they are most abundant. The entrapped animals are then retained in the pond by grates or screens across the tidal inlet/outlet.

In the more advanced extensive forms, the stocking utilizes larvae or juvenile animals that have been caught elsewhere and introduced into the pond. In addition, supplemental feeding may be used along with controlled water exchange through the use of pumps. In practice, management of the pond environment can be made very complex although most penaeid producers are reluctant to assume greater risks. In this type of mariculture, two Management Levels can be identified as follows.

ML-5: Use of artificially-constructed and naturally-flushed earthen ponds for the growout of naturally-occurring larval, juvenile and/or sub-adult mobile animals.

Although this transitional form of extensive mariculture can result in relatively high yields per unit effort when proper management is employed, it is more common to find that it is uneconomical, highly destructive of coastal resources, and non-sustainable. A classic example is found in the Chokaria Sundarbans near Chittigong, Bangladesh, where most of the entire mangrove-dominated intertidal zone has been converted to this type of mariculture over a relatively few years (Gil Smith, *pers. comm.*). Although the yields are extremely low, the relatively high export market value of the shrimp makes the enterprise a highly profitable venture in the context of the Bangladesh economy. As a result, the present "owners" (owners by right of long term occupancy) of parcels of land in the Chokaria Sundarbans have been displaced by new owners who have the political insight and financial means to search titles and prove earlier legal ownership sometimes dating back to the Nineteenth Century.

In the Chokaria mariculture example, yields range from 50 to 400 kg/ha, with most ponds falling at the lower part of the range. This is due primarily to the fact that when the PL are allowed to enter the ponds on an incoming tide, the water also contains the eggs and larva of competitors and predators. A single predator such as the sea bass *Lates* can reduce the final yield of a pond to almost zero (in Latin America, the robalo, or snook, *Centropomus* hac the same role). Even when the PL are purchased from local suppliers, eggs of predators can still enter the ponds on subsequent tidal cycles causing similar production decreases. In addition to the destruction of the coastal forest, which is estimated at 40,000 to 50,000 ha, the harvesting of wild PL is destructive to the local fisheries. The practice is to use the equivalent of beach seines in shallow waters to harvest PL, but also captured are larva and juveniles of many other marine life species. The seine catch is dumped on dry land for sorting and the living PL are quickly separated from all other organisms which are left to die. The intensity of the PL harvesting effort in the Chokaria Sundarbans area suggests that a significant fraction of the fishery resources could be compromised through the relatively large losses of other young-of-the-year marine and estuarine species.

A variation of this form of management may involve the use of stocking organisms obtained elsewhere, e.g., government hatcheries as in Thailand, and brought to the ponds for growout. In this regard, however, unless the pond owners-managers take more adequate care in managing pond water quality, and in controlling competitors and predators, the yields are unlikely to be significantly increased.

ML-6: Use of any of the above management approaches together with minimal but assured inputs of such subsidies as pumps for water renewal, fertilizers to stimulate organic production, or supplemental use of available feeds to promote accelerated weight gain.

In general, this is a very common management approach which is based on the preexistence of relatively low-producing ponds *and* proprietary initiative or ability to increase production through simple or low cost subsidies. Its apparent popularity is due to the fact that in the majority of instances production in low-yield ponds can be significantly increased through rather simple means. For example, trash-fish from commercial trawlers can be introduced into ponds as an inexpensive source of protein to increase growths rates of omnivorous shrimp. Likewise, small pumps can be installed to exchange pond water, not on a regular basis, but when water quality is perceived to be deteriorating.

Activities at this management level, ML-6 are considered to represent the first major step toward intensification and increased pond production. However, the step only appears to be taken when there is no reluctance to invest in pumps, fertilizer, feed, etc., because of concern over an assured and continuing supply of stocking animals. As a further distinction with the

more intensive types of mariculture systems, the activities at the management level are for the most part totally discretionary.

2.1.3. Type III: Semi-Intensive Closed-System Mariculture

ML-7: Use of artificially-constructed earthen ponds equipped with high volume pumps for continual water renewal and accompanied by artificial stocking, fertilization and/or supplemental feeding.

At this level of management, all of the management practices and subsidies are generally considered to be operating requirements, under all but the poorest economic conditions. Typically, this approach requires a relatively large capital investment and is therefore economically practical only when implemented on a very large scale. Shrimp farms that operate both at the ML-7 and ML-8 may cover areas as large as 1000 ha or more. Also, the owners and/or producers frequently have, or desire to have, their own hatcheries as an assured source of stocking animals. (Note that in Ecuador, a 300 ha pond is considered the minimum size relative to the required capital investment, although smaller farms are present.)

ML-8: Same as ML-7 with intensified management, increased subsidies and continual monitoring of water-quality, stocking-density, and/or animal growth-rate, etc.

This is a variation of ML-7 and is distinguished mainly by the increased levels of monitoring of all operating parameters. For example, supplemental feeding rates are based on estimated populations sizes, and biomass, of the growing animals. This tends to reduce feeding costs and water quality problems by the use of more feed than is required, while at the same time ensuring that optimal feed is provided for maximum growth gain. This level of management ML-8 is considered to represent the most sophisticated approach short of going with intensive artificial-system mariculture.

2.1.4. Type IV: Intensive Artificial-System Mariculture

In general, this type of mariculture system approaches being a factory operation that is mostly self-contained and which does not necessarily require a coastal zone location. However the type is included here for two reasons. First, it may represent the ultimate technological type of mariculture system and second, many of the hatchery operations being initiated in Ecuador are highly intensive. However, because an evaluation of hatchery operations and technology opportunities are not relevant to this study, the two Management Levels are defined (below) but not further elaborated.

ML-9: Use of manufactured breeding, rearing and growout ponds, tanks and raceways, for high density stocking coupled with precision control of all

environmental parameters including water quality, controlled "forced" feeding, regular waste disposal, and aeration or oxygenation of the water.

ML-10: Use of totally artificial and controlled systems that approach the limits of technology for the production of marine organisms. Based on recent theoretical advances, shrimp yields are reported to be able to approach approximately 9 kg/yr per liter of production water (Donald Macintosh, *pers. comm.*). Whereas actual commercial production systems have not yet been developed, the potential exists for breakthroughs in the state of the art concerning this approach to shrimp production.

3.0.0. FIELD EVALUATIONS

3.1.0. Introduction

A field evaluation of selected shrimp farms was conducted for the purpose of ground-truthing experimental aerial imagery for potential use in evaluating management alternatives, and secondly, to use the field work as a teaching forum to instruct Ecuadorean students in basic project design, water quality analyses, mangrove forest evaluation, and to expose them to different aspects of one of their country's major industries. Other goals included the identification of the major shrimp pond management practices, the present problems of the industry, and the structural properties of mangrove forests.

The field evaluation included: (1) interviews with the owners and/or managers to discuss pond operating practices, farm history, problems and future directions; (2) the evaluation of water quality, past history and present operating conditions of selected ponds; (3) aerial color imagery of the farm, study ponds and surrounding areas; and (4) the evaluation of any mangrove forest area located near shrimp ponds. This information was used to determine if some correlation existed between the color aerial imagery of the ponds, their water quality and operating conditions. It was believed that if correlations were found, then aerial photography could become a more useful tool for the regulation and management of the shrimp farm industry in Ecuador.

3.1.1. Shrimp Pond and Mangrove Field Studies

A total of ten shrimp farms, consisting of 41 ponds, and six mangrove forests were evaluated during the field session. Table 3.1 summarizes the location, descriptive characteristics, and management practices, of each of the shrimp farms. The ten farms represent a cross-section with regard to location, length of time in operation, and the level of management. All of the study farms were stocked exclusively with *Penaeus vannamei*. The mangrove forests, representing five forest types, were evaluated for structural properties and human impact.

Balao Grande: This shrimp farm in Guayas province had initially been constructed in the uplands, but because of expansion, new ponds were being located in forested mangrove areas. Due to the incorporation of fertilization and supplemental pumping of water, the farm was given a rating of ML-6. The farm appeared to be well managed, although problems resulting in large die-offs of shrimp were being experienced during the evaluation. The cause was unknown, but it was thought to be the result of a toxic dinoflagellate bloom. The pond manager had received his technical training in the United States through a private consulting group. The mangrove basin forest, located adjacent to the farm, was considered to be in good condition as no stress symptoms were evident and human intervention seemed to be minimal; only a few trees had been felled. Surface salinities in the area were 11 ppt.

Table 3.1. Geographical location and summary characteristics of ten selected Type II shrimp (*Penaeus vannamei*) farms in Ecuador.

Location	Original Habitat	Yrs. Ops. ([a])	Mgt. Level ([b])	Pond Size (ha)	Stocking Rates/ha (10^3)	Feed, Fert. ([c])	Water Control ([d])
Balao Grande	uplands & mangrove	8.0	6	10-68	15-20	fert.	T-P
Chongon	uplands & mangrove	0.3	8	20	65-75	both	PC
Machala (a)	salina	12.0	6	12-38	18-25	none	PC
Machala (b)	mangrove	?	5	?	?	none	T-P
Machala (c)	uplands	15.0	6	≤120	?	feed	T-P
Machala (d)	salina & mangrove	14.0	7	10-27	30	feed	PC
Islas de las Conchitas (a)	salina	2.5	7	9-20	45	feed	PC
Islas de las Conchitas (b)	salina	?	5	?	?	none	T-P
Puerto Roma (Rio Guayas)	salina	4.0	7	12-18	100	both	PC
Naranjal	mangrove	6.0	6	8-13	80-90	both	T-C

[a]Yrs. Ops.: Number of years in operation.
[b]Management Level: This is a qualitative determination of the level of actual management at each of the evaluated shrimp farms.
[c]Feed/fertilizer: Identifies the use of supplemental feed and/or fertilizer.
[d]Water control: This identifies the primary methods of filling and exchanging water within the pond(s): "T-P" (tidal with auxiliary pumping), and "PC" (continuous exchange of pond water via pumps).

Chongon: This farm, also in Guayas province, was the most technically advanced of the ten farms evaluated. Pond design, particularly the shaping and contouring of the pond bottom to facilitate drainage and harvesting, was unique. The source water was supplied by a pumping station consisting ofeight to ten large diesel pumps. Pond water was aerated and pumped to an elevated storage basin to create a hydraulic head to allow for the rapid filling of all of the ponds. This system, although expensive to construct and operate, gave the farm manager total control of water movement throughout the farm system. The farm also used both feed and fertilizer and the management level was rated at ML-8. The major part of the farm had been constructed in the uplands, but some of the out-lying ponds were built within mangrove areas. No direct utilization of the mangrove forest was observed and the only disturbance was the clearing of forested areas for pond construction. The mangrove area was classified as a fringe forest and was judged to be well flushed due to the absence of litter accumulation on the ground. Surface water salinities in the area were 29 ppt.

The following four shrimp farms are indicated as Machala (a to d) and are located near the city of Machala in the southern coastal province of El Oro.

Machala (a): This shrimp farm had been constructed in a salina. Water was constantly available to the farm via an extensive canal system. The ponds seemed to be well managed, but no supplemental feeding or fertilization was used and stocking densities were moderate to low. The farm was rated at ML-6 because of the somewhat sophisticated water supply system. The construction of a system that can provide an uninterrupted input of water is considered to be a priority factor in good pond management. There were no contiguous or adjacent mangrove forests in the area. Surface water salinities were 21 ppt.

Machala (b): This site consisted of many small artisanal shrimp farms averaging four to eight ponds each. In most cases, the ponds had been dug by hand labor. The mangroves which form the perimeter of the area were in the process of being cleared and burned to create sites for additional ponds. This was also being done by hand-labor, employing only saws, axes and shovels; no heavy earth moving equipment was observed in the area. The shrimp farm selected for study was typical of others in this area; it consisted of four to six ponds. No feeding of fertilization was employed and little information was available with regard to specific management practices. Stocking rates were unknown and did not seem to be of much importance. There was a portable pump on site which was used to supply the water to the ponds during high tide. The farm was accordingly rated at ML-5. The only water available for salinity testing was the pond water; it ranged from 28 to 30 ppt.

Machala (c): This was the largest shrimp farm in areal extent of those that were visited. The farm, consisting of ponds in excess of 120 ha in size, was constructed in the uplands. Supplemental feeding was used and the overall management level was judged to be ML-6. This farm had packaging and long-term cold-storage facilities available on site, a capability unique among the farms

that were studied. Due to the upland location, there were no adjacent mangrove forests. The source water for the ponds had a salinity of 37 ppt.

Machala (d): This area had previously been a vast mangrove basin forest which was cleared and replaced by ML-5, 6, and 7 shrimp farm operations. There were also indications that mangroves were being harvested for use as construction materials. Some rudimentary charcoal production was also observed, with all parts of the tree being utilized, as opposed to the practices in other areas where only the trunks are utilized (Ong 1982). The study farm was originally constructed in a salina but, like others, had expanded into mangrove forest areas. The farm utilized a constant source of pumped water and employed supplemental feeding; it was rated at ML-7. The salinity of the intake water during the site visit was 2 ppt. This low salinity resulted in the ponds being populated with the freshwater prawn, *Macrobrachium* spp. The pond manager considered the presence of *Macrobrachium* spp. to be a major problem because he felt that it lowered the production of *P. vannamei*.

The Isla de las Conchitas farms (a and b) are located in the province of Guayas along the Estro Salado River.

Isla de las Conchitas (a): The farm selected for study had been constructed in a salina environment and pond water was obtained from the adjacent river by pumping. The intake orifice of the pump was positioned below the mean low water level of the source water to ensure continuous access to water. The technical pond-management skills were relatively advanced and supplemental feeding was used. The management level applicable to this farm was assessed at ML-7. The mangrove forest type at this site was classified as an overwash forest. As is typical of this forest type, there was a high density of large, elevated proproots and a well-flushed substrate. No utilization of the mangroves for wood or building materials was observed in the area. Surface salinities in the area were 33 ppt.

Isla de las Conchitas (b): The ponds at this site had been constructed in a salina and water was only available at high tide via a single pump. The management of the farm was considered to be artisanal. Due to the lack of an on-site manager or supervisor, an in-depth interview was not possible. Pond management was rated at ML-5. The adjacent, mixed-species mangrove forest consisted mostly of relatively small scrubby trees. No utilization of the trees was apparent. Surface water salinity was 23 ppt.

Puerto Roma (Rio Guayas): This farm was located in the province of Guayas on the bank of the Rio Guayas and had been constructed in a salina. Water was supplied continuously by pumping from the river. Some aspects of the level of technical management expertise employed at this farm was relatively advanced and included the use of PL grow-out ponds (the PL were allowed to grow to a predetermined size in small ponds prior to the transfer to larger ponds for final grow-out). The farm also used both supplemental feed and fertilizer, and was in the process of developing a hatchery. Overall pond management,

however. was rated at ML-7. A riverine-type mangrove forest, consisting of very tall trees, surrounds the farm. Some sparse fellings were observed, especially among the larger diameter trees. These trees were reported to be used for the construction of structures at the shrimp farm and for a pier on the river bank. Salinity of the surface river water was 10 ppt.

Naranjal: This Guayas shrimp farm, prior to construction, had previously been a mangrove forest dominated by large trees. The farm consisted of many small ponds (8-13 ha), and water was provided by a canal system during high tide. This farm was rated at ML-6 due to the lack of a continuous supply of water for optimum pond turnover. The stocking rates were the highest recorded during the study and supplemental feed and fertilizers were both used. Due to inaccessability, the mangrove forest was not evaluated. The salinity of the source water was 7 ppt.

3.1.2. Interviews

Interviews were conducted with the person having the highest authority at each farm. In almost all cases this was the owner, manager or both. Because of the high degree of secretiveness among shrimp producers concerning proprietary information such as feeding rates and production, interviews focussed on general, rather than farm-specific questions. Each of the interviews covered five major areas: (1) history of the shrimp farm and the land upon which it was constructed (upland, transitional, salina and mangrove), (2) physical description of the shrimp ponds (e.g., size, depth, etc.), (3) operation and management practices, (4) problems encountered or perceived, and (5) perceptions of ideal conditions. Items 1, 2, and 3 have been summarized in Table 3.1. Items 4 and 5 of the interview schedule were subsequently divided into four subject areas: production levels, major problems, ideal conditions and future projections.

3.1.3. Water Quality Methodology

To evaluate pond conditions within and among different shrimp farms, several water quality parameters were measured. The parameters used can be divided into two major groups. The first group (Secchi disk, turbidity and visual color data) characterizes the water clarity and color was used to ground-truth the aerial color imagery. The second group of parameters established the basic water quality conditions. This suite of analyses included pH, salinity, temperature, chlorophyll content, biomass and species composition. The methodology that was used was consistent with standard methods (USEPA 1979; Greenberg, Connors and Jenkins 1981).

All water quality measurements and water samples were taken at the discharge point of the shrimp ponds and from the source waters. These sampling points were chosen to determine the effect of management practices on water quality (e.g., production stage, flushing rates, and the use of supplemental

feed and/or fertilizer). This also afforded a common sampling point for standardization. Source waters were collected for use as unaltered reference samples. The water samples were collected with a clean, 2 *l* flask at a depth of 0.5 m. Two of the on-site measurements were dependent upon ambient light conditions (Secchi Disk and color). Every effort was made to standardize these readings by taking them between 1000 and 1500 hrs during cloudless periods.

The Secchi Disk, a white circular plate which is used to determine the degree of visibility (transparency) in water, is lowered into the water; the depth at which the disk disappears from sight is the Secchi disk transparency value. This value approximates one percent of the light level at the water surface. It should be noted that with minor modification, this technique is the most common tool used to quantify shrimp pond water quality conditions in Ecuador. Managers use this method to determine pond flushing rates and the need for feed and/or fertilizer. Values are reported in centimeters.

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight path through the sample. Turbidity readings are similar to the Secchi disk measurements in that both are a measure of water clarity (transparency). Turbidity was measured with a Hach Model 2100A, direct reading, lab nephelometer. Values are reported in NTUs (nephelometric turbidity units). NTUs are comparable to Jackson Turbidity Units (JTU) and Formazin Turbidity Units (FTU) (USEPA 1979).

Visual color was determined by the platinum-cobalt method. This method is useful for measuring the water color caused by naturally occurring materials. The color is determined by visual comparison of the pond water with known concentrations of standarized colored solutions. The color determinations are reported as a numerical unit from 1 to 21. In several cases where the color fell between two colors, a mid-point estimate was made.

Salinity and temperature were determined with a Goldberg temperature compensated refractometer and a mercury-filled thermometer, respectively. Salinity values are reported in ppt, parts per thousand. Temperature is reported in degrees Celsius.

The pH of the water was determined with a specific-ion meter and combination jell-filled electrode. The specific ion meter used in this project was an Orion Model 407A. The pH values are reported in standard pH units.

The chlorophyll, biomass and species composition determinations were to be done by the Instituto Nacional de Pesca, but because of a severe illness (hepatitis) contracted by the individual doing the analyses, and inadequate funding, only the chlorophyll values are available at the present time.

Chlorophyll pigments *a*, *b*, *c*, and pheophytin *a*, were determined using the method described by Strickland and Parsons (1968). A known volume of well-mixed sample was filtered through a magnesium carbonate saturated glass

fiber filter. The filter paper was then folded upon itself, wrapped in aluminum foil and placed on ice. Immediately upon return to the base station, the samples were frozen and held at -10° until analysis could take place. The samples were analyzed using a spectrophotometer for chlorophyll pigments a, b, c and pheophytin a. Chlorophyll values are expressed in mg/m^3 ($\mu g/l$).

Pheophytin is a natural degradation product of chlorophyll which has an absorption peak in the same spectral region as chlorophyll a. Because it can be a source of error, pheophytin was determined in the samples and appropriate corrections were made to compensate for its presence.

3.1.4. Mangrove Forest Assessment

Six different mangrove forest locations adjacent to shrimp ponds, and representing a range of environmental conditions, were selected for study to obtain an overview of the present status of Ecuadorean mangrove forests. The site descriptions employed the mangrove-forest type names developed by Lugo and Snedaker (1974).

The point-center quarter method (Cottam and Curtis 1956) was used to measure the structural properties of the mangrove forests contiguous to shrimp mariculture ponds. Two linear transects were established at each of the study sites outlined above. The distance between the trees and randomly selected points along each transect was measured. At each site, a total of 80 trees having a diameter at breast height (DBH) greater than 2.5 cm were identified to genus, and, their height and DBH were measured. With this information, the complexity index (CI) developed by Holdridge (1967) was calculated for the forest. The complexity index integrates the stand basal area, stand height, stand density and number of species into a single number. It is calculated on a 0.1 ha basis and is used as an index to compare structural patterns and relative vigor of different mangrove forests.

In addition to the complexity index, the importance value of Curtis (1959) was estimated for each genus within each forest. The importance value is the sum of relative density, relative dominance and relative frequency of individuals represented by that genus compared to all other genera. The importance value of a species (a genus in this case) reaches a maximum of 300 in monospecific (monogeneric) stands.

Prior to the initiation of the study, it was decided to make the identification of the mangrove trees at the generic level. At present, there is no agreement with respect to the number and identity of the mangrove species present in Ecuador, particularly among the *Rhizophora*. Horna, Medina and Macias (1980) report the presence of four species of *Rhizophora*: *R. harrisonii*, *R. mangle*, *R. racemosa*, and *R. samoensis*. Horna *et al.* (*op. cit.*) cites Cintron *et al.* (1979) and Horna (1980) as first reporting the presence of the two latter species in Ecuador. However, in another paper, Cintron

(1981a) reports only the presence of *R. mangle* and *R. brevistyla*. Tomlinson (1978) considers *R. harrisonii* to be a taxonomic synonym for *R. brevistyla*. In summary, the present situation with respect to the taxonomic classification of the Ecuadorean mangroves does not provide enough certainty to allow us to report them at the species level, especially in a pilot project of the nature reported here.

Table 3.2 summarizes the most important structural attributes of the mangrove forests that were studied. Their complexity indices, with the exception of Balao Grande, are low compared to mangrove forest in other countries (see Pool, Snedaker and Lugo 1977, Jimenez 1981); the low values are comparable only to the stressed scrub-mangrove environments of south Florida. Two main factors seem to be responsible for these low values: (1) human intervention in the form of mangrove habitat destruction, selective clearing, and (2) the alteration of surface water flushing patterns. Of the two, human intervention seems to play a greater role in explaining the low complexity index observed. The practice of constructing shrimp ponds on salinas (salt flats) that extend into adjacent mangrove areas, as was observed at several sites, has detrimentally affected the species composition of the mangrove forests. Since *Avicennia* and *Laguncularia* tend to be found closer to the salinas than *Rhizophora*, which is found closer to the untouched mangrove fringes near the canals, the former two species seem to be affected to a greater degree. This situation is reflected by an extremely high importance value for *Rhizophora* when compared to these other genera.

It should be noted that the high importance value for *Rhizophora* reflects its relative density, relative dominance, and relative frequency, in comparison to the other mangrove genera. The high ranking does not imply that the *Rhizophora* are ecologically more valuable than the *Avicennia* and *Laguncularia*. Those other genera are equally valuable although they have not received the same level of scientific attention as has *Rhizophora* (Snedaker and Brown 1981, see also, Twilley *et al.*, 1986).

The low basal area (BA) of the mangrove forests is also striking, especially when compared to the values reported for Ecuador by Acosta-Solis (1957) (BA = 62.4 +/- 13 m^2/ha), and Canadas and Torres (n.d.) (BA = 17.6 +/- 1.99 m^2/ha), both of which are cited in Cintron (1981a). This low basal area seems to be another consequence from human intervention in the mangrove forests. A selective clearing of the forest was observed in several areas where the largest mangrove trees (greatest height and DBH) were being harvested to be used as construction material for piers, bridges, electric poles and housing.

All of the forests, with the exception of Isla de las Conchitas and Puerto Roma, show good seedling regeneration. Isla de las Conchitas, because it is an overwashed island, it is flushed by the daily tides which presumably carry away most of the seedlings or otherwise prevent establishment. However, some of the structural characteristics for this particular stand indicate that it

is in relatively good condition. In contrast, the status of the mangroves at Puerto Roma is not clear and is thus worthy of further research attention to determine, particularly with respect to seedling recruitment.

Table 3.2. Structural comparisons of mangrove forests near shrimp ponds in southern Ecuador. Complexity components are expressed on a 0.1 ha basis.

Site	Genus Present	Genus Density (Trees/0.1 ha)	Relative Density (%)	Genus Basal Area (m^2)	Rank
Machala (d)	*Rhizophora*	58.8	100.00	0.718	1
Puerto Roma (Rio Guayas)	*Rhizophora*	21.4	97.37	0.867	1
	Laguncularia	0.6	2.63	0.001	2
	Totals	22.0		0.868	
Chongon	*Rhizophora*	132.9	93.75	0.378	1
	Avicennia	7.1	5.00	0.011	3
	Laguncularia	1.8	1.25	0.048	2
	Totals	141.8		0.437	
Isla de las Conchitas (a)	*Rhizophora*	221.2	100.00	1.056	1
Isla de las Conchitas (b)	*Rhizophora*	279.0	93.75	0.740	1
	Avicennia	7.4	2.50	0.002	3
	Laguncularia	11.2	3.75	0.017	2
	Totals	297.6		0.759	
Balao Grande	*Rhizophora*	111.6	55.00	0.892	1
	Avicennia	86.2	42.50	0.249	2
	Laguncularia	5.1	2.50	0.026	3
	Totals	202.9		1.167	

[a]Relative dominance; [b]Relative frequency; [c]Importance value; [d]Complexity index

Table 3.2. (Con't.) Structural comparisons of mangrove forests near shrimp ponds in southern Ecuador. Complexity components are expressed on a 0.1 ha basis.

Site	Genus Present	Stand Height (m)	Rel. Dom.[a] (%)	Rel. Freq.[b] (%)	I.V.[c] (%)	CI[d]
Machala (d)	*Rhizophora*	26.16	100.00	100.00	300.00	1.10
Puerto Roma (Rio Guayas)	*Rhizophora*		99.92	95.24	292.52	
	Laguncularia		0.08	4.76	7.48	
	Totals	35.00				1.34
Chongon	*Rhizophora*		86.65	80.00	260.40	
	Avicennia		2.24	16.00	23.42	
	Laguncularia		10.93	4.00	16.18	
	Totals	9.43				1.75
Isla de las Conchitas (a)	*Rhizophora*	11.43	100.00	100.00	300.00	2.54
Isla de las Conchitas (b)	*Rhizophora*		97.48	86.36	277.59	
	Avicennia		0.24	9.09	11.83	
	Laguncularia		2.28	4.55	10.58	
	Totals	8.37				5.63
Balao Grande	*Rhizophora*		76.44	54.55	185.98	
	Avicennia		21.30	39.39	103.17	
	Laguncularia		2.26	6.06	10.83	
	Totals	19.17				19.48

[a]Relative dominance; [b]Relative frequency; [c]Importance value; [d]Complexity index

Although it is premature to draw a conclusive judgement as to the conditions of the mangrove forests in southern Ecuador, some trends are apparent. The low complexity index, low density and low basal area of the forests studied indicate the presence of some sort of stress, probably anthropogenic. These low structural values, coupled with the decrease in mangrove areas reported in the studies done by the Ecuadorean Center for Remote Sensing of Natural Resources (CLIRSEN), should be of concern to everybody related in one way or another to coastal marine activities.

3.2.0. Shrimp Farm Evaluations

The following discussion is based on the results of the on-site interviews with shrimp farm personnel. The interviews were conducted in Spanish and the answers to each of the questions were considered to be factual and trutnfully stated. Additional information on these topics was also obtained from other sources in Ecuador and is discussed later in this report.

3.2.1. Production Levels

To evaluate the operating conditions of the shrimp farms owner/operators were asked if the present level of production was satisfactory. In spite of the great differences in stocking rates (Table 3.1), all the interviewed individuals, except one, felt that the present level of shrimp production was satisfactory. Several individuals felt that production could be increased, although only conservative steps were being taken to achieve this goal.

3.2.2. Major Problems

The major problems perceived by the pond operators were the uncertainty and scarcity of the PL supply, the difficulty of maintaining water quality, the lack of technical management skills and the increase in operation costs. These problems are often interrelated. The major increase in operation costs was said to be caused by the increased cost of PL due to their scarcity. Accompanying scarcity was the increasing percentage of undesirable (non-*P. vannamei*) PL and a lower survival due to poor handling of PL brought from distant sources. (Note: some PL have been brought from as far as Esmeraldas in northern Ecuador, and Peru and Guatemala. The development of hatcheries is seen as the only solution to this problem.) Water quality problems have been largely the result of negligence in monitoring dissolved oxygen which can be badly aggrevated by overstocking, over-fertilization and/or excess feeding. Technical personnel often have little relevant training in mariculture and many "biologists" have academic training in such fields as forestry, agronomy or basic biology. Shrimp pond management technology tends to be developed by trial and error, and unfortunately, when an error does occur, the field biologist is often fired and little is learned from the experience. Lack of supervision relates closely to absentee ownership which is a major contributor to poor management. Not mentioned by those interviewed, but referenced elsewhere, is the increasing cost of credit which affects both construction and operating costs (Parodi 1985).

3.2.3. Ideal Conditions

A portion of the interview dealt with that which the farm owner/manager considered to be ideal conditions. This question was valuable in the sense that it gave the owner/manager the opportunity to express his experience and "hind-sight". The questions, although somewhat limited in scope, dealt with the siting of ponds, pond size and depth, preferred shrimp species, stocking density, and the availability of PL for stocking.

In almost all discussions, it was felt that the pond size should be smaller than what was presently being managed. The existing pond sizes ranged from 8-120 ha, with the ideal size ranging from 5-50 ha. The size most often chosen was 10 ha with the reason given that smaller ponds, even through they are more expensive to construct (per unit area), are cheaper to stock and operate. Other benefits mentioned were: water quality is easier to control; harvesting is more efficient with fewer shrimp lost which results in a higher realized productivity; the chances of losing the harvest due to deteriorating pond conditions during grow-out are less; and the venture capital loss from a smaller pond is minimized. Many felt that if they had the opportunity to improve their operation, their first step would be to reduce the pond size.

The unanimous choice of species for stocking shrimp ponds was *P. vannamei;* this is also the species currently in use. Several owners and operators said they had tried other species but none of the other species was perceived to have the hardiness of *P. vannamei.* When asked if they would be willing to try another species heralded to be better than *P. vannamei*, the answer was no. They felt that this species was by far the best. No one is willing to gamble with another species when the conditions (production, marketability and survivorship) are considered good.

The choice of pond location was split between mangrove, salina, uplands, and transitional areas. The obvious reason for choosing any of these areas is their proximity to sea water. The individuals who chose the salinas and mangrove areas felt that the transitional and uplands zones were the worst areas for the construction of ponds due primarily to their distance from a water source, although these areas were given as the ideal more frequently than the other two zones. The uplands and transitional zones were favored because of lower construction costs and better water management ability. Construction costs are lower because the need to clear land is less, and it is more accessible. Managing the water is easier because of the increase in elevation which makes it possible to establish a hydraulic head. The substrate at all of the investigated locations which included the four areas chosen, were almost identical. There was some discussion regarding the shrimp productivity of the different areas. Everyone felt that their area was the most productive. No quantitative information is available to substantiate this, and is probably the result of management and water control practices rather than pond location.

The perceived optimum pond depth ranged from 0.6 to 1.5 m. These depths are those which were in use at the time, and are relatively standard. The depths were chosen for construction economics, ease of harvest and water control.

The perceived optimum stocking density of semilla ranged from 20,000 to 100,000 individuals per hectare. This wide range of stocking densities is based on conservative management practices presently being employed. The owner or operator felt that these densities were profitable and were within the biological limitations of the pond (water quality). It should be noted that the shrimp farms which are managed with the greatest amount of technical and professional expertise, were those which chose the higher stocking densities as the ideal.

The optimum conditions voiced for semilla were, expectedly, to have a constant supply throughout the year. One owner stressed that not only did he think a constant supply was necessary, but it also had to be of a high quality, i.e., a high percentage of *P. vannamei*. He explained that if he could not acquire wildstock consisting of 80% or higher of *P. vannamei*, he would not stock his ponds. Another variation of the constant year round supply theme was that PL come from hatchery stock. It was felt that the hatchery stock would represent a much higher quality than the wildstock because of the absence of other species (e.g., predators, competitors) and that genetic similarity would necessarily occur in hatchery stock. No one appeared to understand or appreciate the risks that might be associated with raising a large number of genetically similar organisms.

3.2.4. The Future Outlook

The pond owner/managers indicated that they felt a dramatic change was presently taking place in the Ecuadorean shrimp farm industry. This change is the result of the rapidly increasing costs for operating the ponds. The cost increase is primarily the result of the limited supply of semilla for stocking, but also included is feed, fertilizer, land (purchase, use permits, construction and clearing), and personnel. Another critical part of the increased cost is the cost (i.e., interest) of borrowing money. The loss of a pond's production in the past was of little consequence. The semilla used for stocking were abundant and cheap, operating costs were almost nonexistent, and feed and fertilizer were rarely used. At present, due to the dramatic increase in costs, the loss of a pond's production is a substantial financial setback, even for the large operators. Few owners can or are willing to absorb these losses. As a result, the shrimp pond industry is becoming more cautious in their operating practices. This is resulting in lower stocking densities, the construction of smaller ponds, efforts to maintain a higher water quality in the ponds, and to hire better trained managers.

Another aspect of the industry that is changing is its shroud of secrecy. In the past, owners and managers were not willing to discuss their operating techniques (e.g., stocking rates, types and amount of feed and fertilizer used, and grow-out periods) with other individuals involved in the industry. This resulted in an industry which was closed within itself. Technology and information, new or old, had to come from the outside even though it had originated from within. Due to increased costs and the discovery that there are no secrets or "magic" to raising shrimp, many owners and managers are beginning to work together. The result has been the recent birth of industry-wide organizations for the purpose of information exchange, problem solving and representation. These organizations and of course, the rapidly increasing operating costs, have resulted in the formation of several shrimp pond cooperatives. It is believed by the Ecuadoreans that this type of venture will reduce operating costs and will be particularly helpful to the owners of the smaller shrimp farms.

The impact of high technology and intensive management on the industry was felt to be of minimal importance at this time. Only in the area of commercial rearing of PL, was high technology seen to have any present application. It was felt that the shift to higher stocking rates, intensive feeding and water quality control was not viable at the present time because of economic factors. No one can afford the initial capital outlay or the losses incurred from failure. Although, when and if the supply of semilla again becomes abundant, resulting in what is perceived as a decrease in costs, these avenues of intensive management will be explored. The opposite may also be the case: as larval abundance increases with the next "El Niño"-related warming of the waters in the Gulf of Guayaquil, the incentive to build expensive hatcheries may decrease. This is particularly true for smaller national producers unable to make major capital investments. In Honduras, a firm with capital resources to build a hatchery has not done so because the cost of wild PL is about 20% of the cost of producing them in a hatchery (W. S. MacGrath, Jr., Shrimp Culture, Inc., pers. comm.)

In summary, the owners and operators, perceive the shrimp farm industry as a whole to be rapidly shifting into a very cautious mode of operation. This conservative attitude covers almost every aspect from overall industry-wide expansion to the management practices of the individual farms, including stocking rates and pond size. The only avenue which is not operating in a conservative mode is the development of technology and its application to commercially raise large quantities of semilla. If commercial rearing of semilla is not a generally accessible technology for the industry as a whole, a major readjustment can be expected. Vertically integrated, well capitalized enterprises with reliable hatchery facilities will remain, and firms dependent on the erratic supply of wild PL will largely disappear.

3.3.0. Water Quality

The results of the water quality analysis (Table 3.3, see also 3.4) provided some interesting information regarding the variation in water quality among ponds. Secchi disk values, turbidity, salinity, temperature, pH and chlorophyll were quite varied among farms and several of the parameters (Secchi disk, salinity, temperature and chlorophyll) varied greatly even within farms. The most striking variations were salinity, temperature and pH. These parameters are all critical to the metabolic functioning of aquatic organisms (e.g., osmoregulation, rate of metabolism and chemical reactions), and in this case, *P. vannamei*. Salinity ranged from 3 to 39 ppt, temperature ranged from 28 to 36°C and pH ranged from 6.5 to 8.6. For *P. vannamei* to not only to survive, but to also grow under this wide range of conditions gives emphasis to the fact that it is a very hardy and resilient organism. This obviously is the main reason why *P. vannamei* is the organism of choice for stocking and it explains why so many owners and managers refuse to even consider trying another species.

The chlorophyll *a* concentration, an indicator of phytoplankton biomass, was elevated above that of the source waters (Table 3.4) at all but one of the shrimp farms. This increase in phytoplankton biomass, which is used as a food source by the shrimp, is an important aspect of pond management. The reverse situation at Machala (a) could have been the result of a phytoplankton bloom occurring in the source water canal which resulted in elevated concentrations during the actual sampling (or there could have been an error in the laboratory analysis for this sample).

The three common chlorophyll pigments, *a*, *b* and *c*, can provide an indication of gross phytoplankton composition (Weber 1973). The presence of chlorophyll *c* in most of the source and pond water samples probably indicates an abundant population of diatoms and dinoflagellates. Both of these organisms contain only chlorophyll *a* and *c* (Prescott 1968 and Boney 1969). The reason for the absence of chlorophyll *c* in the pond and source water at Balao Grande and Chongon is unknown. The source water in these areas was typical in regard to the other water quality parameters.

Surface water salinities in the ponds showed a general increase over that of the incoming source water. This is presumed due to the relatively high rates of evaporation which occur in the ponds. The increased salinities are probably benefical to the shrimp in the ponds which receive very low salinity source water. The increased salinity (over that of very low salinity water) would approach the optimal conditions for *P. vannamei*.

Table 3.3. Ecuadorean shrimp pond characteristics obtained from aerial imagery and on-site ground truthing.

Location	Pond Stage[a]	Secchi Disk cm	Turbid. NTU	Color[b] units	Munsell Color H V/C
Balao Grande	recent	12.7	8.1	17.0	5Y 4/2
	3 mos.	20.3	7.4	17.0	5Y 3/2
	2 mos.	12.7	24.0	17.0	2.5 GY 8/2
	1 mo.	12.7	12.9	17.0	5Y 6/2
	source	20.3	13.7	16.5	nd[c]
Chongon	1 mo.	48.0	3.1	16.5	5Y 5/3
	2 mos.	73.0	3.6	17.0	7.5 GY 5/2
	3 mos.	65.0	3.5	19.0	7.5 GY 4/2
	1 mo.	70.0	2.0	17.0	7.5 GY 4/2
	source	55.0	5.3	16.5	nd
Machala (a)	near harvest	30.0	29.0	17.0	5Y 5/2
	recent	30.0	23.0	21.0	5Y 5/2
	4 mos.	25.0	15.0	17.0	5Y BG 3/2
	source	24.0	25.0	21.0	nd
Machala (b)	unknown	40.0	10.6	19.0	nd
	unknown	40.0	31.0	21.0	nd
Machala (c)	near harvest	50.0	24.0	16.5	2.5 B 5/2
	recent	60.0	32.0	nd	7.5 GY 5/2
	source	28.0	28.0	17.0	nd
Machala (d)	2 mos.	48.0	17.0	19.0	7.5 GY 5/2
	recent	25.0	23.0	19.0	7.5 GY 5/4
	near harvest	40.0	23.0	16.0	nd
	source	20.0	53.0	21.0	nd
Isla de las Conchitas (a)	2 mos.	30.0	23.0	19.0	5 G 5/2
	1 mo.	20.0	24.0	18.0	7.5 GY 8/4
	2.5 mos.	40.0	12.0	19.0	5 GY 5/4
	source	80.0	6.0	16.0	7.5 GY 5/4

[a]Pond Stage: The period of time since the pond was stocked; "recent" means recently stocked; "source" is the source of pond water.
[b]Color: Platinum-cobalt units.
[c]nd: Indicates that no data values are available or that the sample area was not included in the aerial photo coverage (or cannot be interpreted).

Table 3.3. (Con't.) Ecuadorean shrimp farm characteristics obtained from aerial imagery and on-site ground truthing.

Location	Pond Stage[a]	Secchi Disk cm	Turbid. NTU	Color[b] units	Munsell Color H V/C
Isla de las	unknown	35.0	14.0	21.0	5 Y 4/3
Conchitas (b)	source	35.0	20.0	16.0	7.5 GY 8/4
Puerto Roma	nursery pond	30.0	33.0	17.0	5 Y 5/4
(Rio Guayas)	5 mos.	25.0	35.0	15.0	5 GY 7/4
	In harvest	15.0	88.0	14.0	5 GY 7/4
	source	nd	40.0	nd	10 YR 6/1
Naranjal	1 mo.	8.0	58.0	21.0	7.5 YR 6/6
	7 mos.	35.0	14.0	19.0	5 GY 6/4
	4 mos.	35.0	16.0	19.0	5 GY 6/4
	4 mos.	40.0	27.0	17.0	5 GY 5/4
	0.5 mo.	38.0	20.0	16.0	5 GY 5/4
	2.5 mos.	40.0	23.0	18.0	5 GY 5/4
	2.5 mos.	45.0	11.0	19.0	5 GY 6/4
	source	35.0	19.0	16.0	5 GY 7/4

[a]Pond Stage: The period of time since the pond was stocked; "recent" means recently stocked; "source" is the source of pond water.
[b]Color: Platinum-cobalt units.
[c]nd: Indicates that no data values are available or that the sample area was not included in the aerial photo coverage (or cannot be interpreted).

Table 3.4. Ecuadorean shrimp pond characteristics obtained from aerial imagery and ground truthing.

Location	Pond Stage[a]	Chlorophyll *a*	*b*	*c*	pheo *a*[b]	Sal. ppt	Temp. °C	pH units
		mg/m³						
Balao Grande	recent	22.5	nd[c]	nd	4.0	20	36	8.3
	3 mos.	90.0	8.6	nd	31.3	30	33	8.6
	2 mos.	194.3	nd	nd	nd	29	29	8.4
	1 mo.	53.3	nd	nd	10.0	29	29	8.2
	source	3.5	nd	nd	4.4	11	27	7.3
Chongon	1 mo.	14.7	0.1	nd	6.2	29	29	7.6
	2 mos.	16.2	nd	nd	2.9	29	28	7.5
	3 mos.	14.2	nd	nd	4.7	29	29	7.0
	1 mo.	6.9	nd	nd	6.7	29	29	7.5
	source	5.9	nd	nd	4.1	29	28	7.2
Machala (a)	near harvest	76.8	nd	nd	1.7	36	30	8.1
	recent	45.4	2.2	2.2	18.9	32	34	8.3
	4 mos.	47.3	nd	1.5	8.1	30	30	8.3
	source	101.1	nd	25.9	48.3	21	32	7.5
Machala (b)	unknown	30.7	1.3	6.5	0.7	30	35	7.9
	unknown	26.6	0.1	3.3	5.6	28	36	7.9
Machala (c)	near harvest	24.8	nd	13.0	5.0	28	30	8.2
	recent	30.8	nd	4.0	3.9	39	31	8.1
	source	9.6	nd	2.1	3.4	37	30	8.1
Machala (d)	2 mos.	79.4	3.5	15.7	28.4	14	32	8.2
	recent	99.6	nd	15.4	22.5	14	29	8.2
	near harvest	126.2	0.9	51.6	21.22	16	31	8.5
	source	7.3	0	5.0	4.7	2	30	7.5
Isla de las Conchitas (a)	2 mos.	46.5	6.3	19.6	nd	29	30	8.1
	1 mo.	31.0	nd	0.5	1.0	26	35	8.2
	2.5 mos.	30.8	nd	nd	2.0	27	33	7.8
	source	14.3	nd	1.5	1.2	26	33	7.5

[a]Pond Stage: The period of time since the pond was stocked is given; "recent" means recently stocked; "source" is the source of pond water.
[b]Pheophytin *a*
[c]ND: Indicates that values were below detection limits.

Table 3.4. (Con't.) Ecuadorean shrimp pond characteristics obtained from aerial imagery and ground truthing.

Location	Pond Stage[a]	Chlorophyll *a*	*b*	*c*	pheo *a*[b]	Sal. ppt	Temp. °C	pH units
		mg/m³						
Isla de las	unknown	41.8	0.2	nd[c]	9.6	29	32	8.2
Conchitas (b)	source	20.9	0.11	nd	2.5	23	31	8.3
Puerto Roma	nursery pond	91.2	nd	20.5	nd	11	31	8.1
(Rio Guayas)	5 mos.	176.4	0.5	31.9	5.2	3	32	8.4
	In harvest	55.0	nd	7.3	nd	4	32	8.1
	source	74.3	nd	1.3	1.7	10	31	8.4
Naranjal	1 mo.	125.8	nd	17.3	nd	15	30	6.5
	7 mos.	58.3	6.1	18.3	1.3	9	30	8.1
	4 mos.	66.5	20.3	29.7	nd	10	31	8.1
	4 mos.	31.7	1.9	5.6	nd	9	32	8.0
	0.5 mo.	8.5	0.5	3.0	2.4	14	33	8.1
	2.5 mos.	26.6	nd	7.4	2.6	11	35	8.0
	2.5 mos.	35.7	5.1	6.3	3.0	10	33	7.7
	source	34.3	nd	0.6	nd	7	30	7.4

[a]Pond Stage: The period of time since the pond was stocked is given; "recent" means recently stocked; "source" is the source of pond water.
[b]Pheophytin *a*
[c]nd: Indicates that values were below detection limits.

3.4.0. Aerial Imagery Evaluation

One of the purposes of this study was to determine if color aerial imagery would be useful in evaluation of pond management practices, e.g., assessing overall water quality, stocking densities, flushing rates and pond health, and other production-related parameters. Two methods were used to perform the aerial reconnaissance. One employed the use of standard emulsion photography based on a large format (2.25 in) single-lens reflex plane-mounted camera. The other system that was used was a plane mounted, VHS format video system. Both units proved to be of value. The emulsion imagery provided excellent color resolution and also permitted the use of infrared film. The video system provided real-time imagery which would be very beneficial in conjunction with a long-term synoptic evaluation of pond water quality and productivity. In this latter mode, ponds of interest could be flown and photographed with the video system and then evaluated after touch down using a small portable monitor or any available televison. Coupled with synoptic data and information

on pond conditions, an empirical base could eventually be developed for assessing pond conditions without field visits, or water sampling and analyses.

To identify the color of the shrimp pond water from the aerial imagery, the Munsell system of color description was used. This is a common method for describing and analyzing color gradations in terms of hue, value and chroma. The color value from the Munsell chart is recorded as hue, value/chroma, or symbolically, H V/C. The aerial color transparencies were placed on a light table with balanced and constant illumination and then the colors were visually evaluated using the Munsell Color system.

To determine if there were any relationships among pond color (both Platinum-cobalt and Munsell), water quality, pond stage (see Table 3.3 and 3.4), PL stocking densities, and the use of feed or fertilizer, correlation coefficients were determined. The results indicated that there were no correlations between pond color and any of the other parameters, at least based on this one-time sampling. Marginal correlations were detected between stocking rate and turbidity, and between Secchi-disk values and chlorophyll concentrations. Two of the parameters, turbidity and Secchi disk, are commonly used by pond managers to monitor pond conditions.

The aerial imagery did indicate somewhat extraordinary color differences among ponds (e.g., Figure 3.3, Table 3.4); the lack of any strong correlation between the colors and the measured parameters is believed to be result of the the statistically-small sample resulting from the experimental overflights and sampling. Also, the Platinum-cobalt method for the field evaluation of water color may be too gross of a method to provide the sensitivity needed to detect subtle spatial differences or temporal changes in pond water color. It is restricted to a narrow range of colors which are encountered in "natural" aquatic systems. In addition sun angle and/or cloudiness can have dramatic effects upon interpretation. The other method employed used the Munsell chart to quantify the colors from the aerial transparencies. This system did not have the problems encountered using the Platinum-cobalt method and provided a much wider choice of colors. It is limited by the sensitivity of the human eye and even though the colors available are numerous an exact match is sometimes difficult.

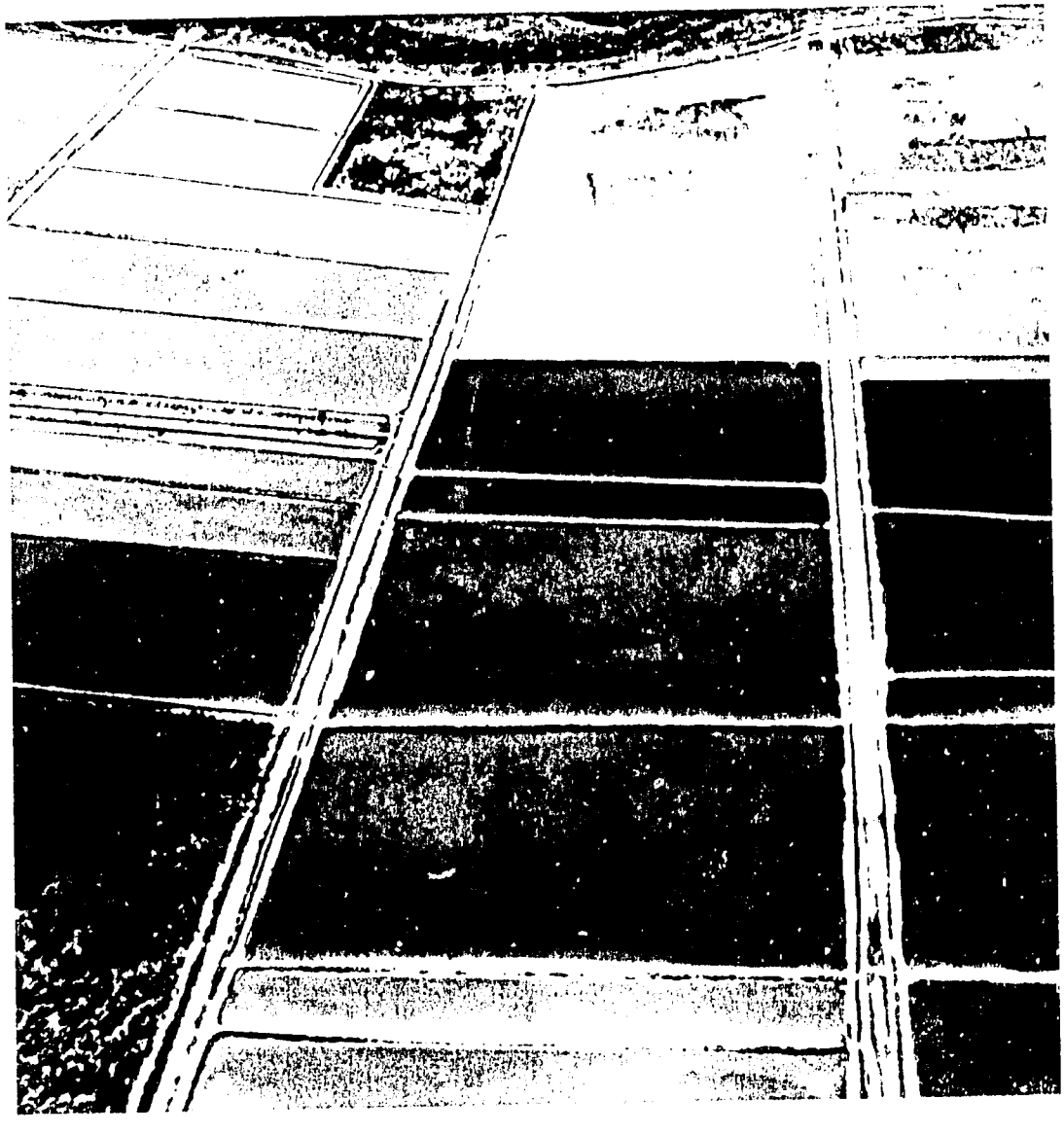

Figure 3.3. Aerial view of shrimp growout ponds in southern Ecuador showing color differences that are related to differences in water quality and in phytoplankton species and abundance. The color values and contrast are not true due to the method of reproducing copies for this report. (Photo credit: Joshua C. Dickinson, III)

The aerial reconnaissance work in Ecuador proved to the satisfaction of the principals that regular aerial video surveillance could be used as a very inexpensive and efficient management tool for farm pond operators/managers, cooperatives, or government agencies. In this regard, the use of a color video camera would be preferred to an emulsion film-loaded camera. Color video can provide close-to real time results of relatively large areas (i.e., large ground areas of farms and ponds) and is less costly than a film camera. For example, video tapes can be reused and tape playbacks can be viewed on a TV fitted with a tape reader. In actual practice, a number of correlation flights would have to be made to establish a reliable record of pond appearance and water quality as it relates to shrimp growth. Based on an empirical record, information from subsequent surveillance flights could be directly translated into management actions.

4.0.0. SHRIMP MARICULTURE IN ECUADOR

The shrimp mariculture industry in Ecuador is the largest and most advanced in Latin Americaand as well as being a major source of foreign currency earnings for Ecuador. In addition to other distinctions, the industry is also faced with many different types of problems. In order to deal with the issues of siting and management in this study, we first present our findings that characterize the industry and some of it problems.

4.1.0. Mariculture Types and Management Levels

The mariculture industry in Ecuador is dominated by two types of mariculture systems (Types II and III) and four levels of management (Levels 5, 6, 7 and 8). The two types are the extensive closed-system and the semi-intensive closed system; the dominant forms of management encompass management practices that range from minimal to relatively advanced. In the following characterization and discussion, other identifying terms are also used primarily because writers have previously only recognized three types of shrimp pond management.

4.1.1. Type II: Extensive Closed-System, Management Level 5

This type of locally-named "artisanal" system is represented by the simplest operations that tend to have a disproportionately-heavy reliance on tidal flushing and only rudimentary management inputs. Also, pond sizes tend to be relatively small as compared to the average size of commercial ponds. The small scale and relatively low level of management distinguishes it from ML-6 systems which tend to have a more programmed, or planned, approach to grow-out pond operations.

4.1.2. Type II: Extensive Closed-System, Management Level 6

This type of mariculture system, also termed "artisanal" in Ecuador, utilizes relatively small ponds and relatively low PL stocking densities (10,000-15,000 PL per ha) according to McPadden (1985). Water exchange in the ponds is accomplished mainly by tidal filling and gravity drainage, although in some instances there is auxiliary pumping. Pumps are usually on hand for emergency situations (e.g., low dissolved oxygen) as opposed to being relied upon for routine operations. The nutrition of the growing shrimp depends entirely on ambient phytoplankton primary production and estuarine detritus. These are generally small sized operation with yields on the order of 275 kg of whole shrimp per year with minimal investment and risk. These operations would correspond approximately to the 408 concessions in the 0-50 ha range in Table 4.1., although there are some very large farms that have Type II operations.

Table 4.1. Number of concessions and/or authorizations listed by province according to area as of December 1984. (Source: Unidad de Estudios Pesqueros y Estadisticas)

Area (ha)	Total	Provinces			
		El Oro	Guayas	Manabi	Esmeraldas
Total	773	167	494	92	20
0- 50	408	107	221	67	13
50- 100	107	32	57	5	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	-	4	-	-
1000-more	1	-	1	-	-

4.1.3. Type III: Semi-Intensive Closed-System, Management Level 7

This type of mariculture system, also called "technical management" involves a higher level of empirical technology but is also characterized by a general tendency to maintain investment and operating costs at the lowest possible level, for example, in the cost of water pumping, pond fertilization and supplemental feeding. In this type of operation, nursery ponds are generally used, and juvenile stocking densities range up to 35,000 per ha. The relatively high density is usually limited to ponds where fertilization is also employed to promote phytoplankton productivity. Stocking is more a factor of wild PL availability rather than a matter of choice. The operational production strategy appears to be based on the spreading of PL over many ponds as possible so as to take advantage of phytoplankton productivity rather than to concentrate all management investment in fewer ponds at a higher stocking density. Yields are in the range of 680-910 kg/ha/yr based on 2.2 harvests per year. These operations correspond to the 100-500 ha range in Table 4.1.

4.1.4. Type III: Semi-Intensive Closed-System, Management Level 8

The "professional" or semi-intensive management system involves farms that are generally part of vertically-integrated operations that are owned by packing/shipping firms. Relatively sophisticated biophysical data are taken regularly by biologists and recorded for use in making management decisions. Water turnover rates are generally high, but are also controlled by a quantitative determination of need which results from the monitoring and analyses. The stocking density of ponds in these large farm systems is around

80,000 PL per ha, which are dominantly hatchery reared. The growout ponds receive high but measured levels of fertilizer and supplemental feeds. Yields are on the order of 1360-2270 kg/yr of whole shrimp. These 700-1000 ha operations have the greatest potential to intensify rapidly as new techniques in managing high levels of inputs are developed and accepted by the industry (McPadden 1985).

4.2.0. Construction Costs

According to farm owners, the preferred site for the construction of growout ponds has traditionally been the salinas where construction costs are relatively low compared to mangrove areas. Also, tidal streams are readily accessible for water supply at a relatively low pumping head. It is because of the prevalence of salinas in the arid and semi-arid southern provinces (e.g., El Oro, Machala) that the shrimp industry started in Ecuador, and now dominates, in this part of the country. However, the areas of salinas are limited in extent and shrimp pond expansion has been increasingly forced into lower-elevation mangrove forest areas and into the uplands. Upland locations for pond sites generally involve the lowest construction cost particularly when the area has already been cleared for agriculture or pasture. The cost differential is approximately US$1000/ha compared to US$6000/ha in areas dominated by mangrove forests; pond construction costs in the salinas fall between these two extremes (Rafael Horna, *pers. comm.*). Current costs to develop a new shrimp farm that is complete with all the infrastructure, costs approximately US$5400/ha. The price of land ranges from US $830-1250 per ha (McPadden 1985). In the Chongon area near Guayaquil, farmland that is suitable for conversion to shrimp ponds could sell for as much as US$2000 per ha (Jose Villalon, *pers. comm.*).

4.3.0. Operational Costs

The overall cost of shrimp production in Ecuador is estimated to be between US$1.80-2.25 per lb of tails (industry estimates), and the average price FOB for 26-30 count shrimp tails has been around US$5.00 (McPadden 1985). These figures indicate that shrimp production can be quite profitable as long as North Americans are willing to pay two to five times as much for shrimp as they pay for alternative sources of high-quality protein such as steak and chicken. It is also obvious that the great majority of the Ecuadoreans, as well as the neighboring Peruvians, cannot afford to purchase this form of protein as long as it is produced through a type of mariculture which is more advanced than Type I. The cost of production is extremely sensitive to the price of post larvae. For example, in 1984/85, the cost of PL had become greater than feed/fertilizer, labor or fuel. At times when PL have been unavailable at any price, the producers are unable to operate their pond systems and suffer severe financial losses. Fuel is subsidized by the Ecuadorean government at below the world price. Should the price of diesel

fuel rise and/or be indexed to the world price, then the costs of shrimp production could increase substantially due to both the increase in pumping cost and the high fuel-cost component in feed and fertilizer production. The present depressed world market for oil, however, favors continued heavy use of fuel.

4.4.0. Shrimp Pond Siting

There are two major considerations in the siting of shrimp ponds: (1) the initial investment and subsequent operation costs, and the long term fertility of the ponds as it relates to the production of shrimp; and (2) the size and location of ponds, particularly as they relate to the maintenance of water quality.

4.4.1. Pond Size

Production or growout-pond sizes range from 8-120 ha with a large number in the 15-20 ha range. Although most operators agree that 8-10 ha would be the optimum size pond, the actual ponds are larger than the stated optimum because no experience was available when most of the farms were constructed. When the industry was first getting started, large ponds were less costly to construct (particularly in the salinas) and there was no inherent problem in stocking a large pond when PL were both abundant and cheap. Under the Type II management scheme that is based on natural phytoplankton production with limited pumped water exchange (ML-6), there was no particular advantage in having a smaller pond (Felipe Orellana, *pers. comm.*). However, under the more intensive forms of management that are being progressively introduced, large ponds may become a definite problem. At high stocking densities with fertilization and feeding, water exchange becomes critical. If oxygen levels drop, rapid water turnover is essential; this is a difficult proposition in a 30 ha pond, even with very large pumps. If a pond is lost due to whatever the cause, the investment loss is directly proportional to the size of the pond. Below a certain size, wind driven turnover is likely to be less, however, but this was not quantified.

4.4.2. Pond Location

A listing of the location of ponds according to whether they are in the uplands or in the intertidal zone is given in Table 4.2 (for comparative purposes, see also Table 4.3). These official figures are interesting even if they are not necessarily accurate. Farms illegally located in mangrove areas are not listed in the government statistics. A farm above the high tide line can be owned outright rather than being developed as a ten-year concession which is an incentive to have a farm recorded as located in the uplands. Also, shrimp farm land located in mangrove areas cannot be used as collateral for loans.

The sample area chosen for the study of mangrove conversion (Terchunian and Klemas 1982) indicates that a much higher proportion of intertidal land, particularly salinas, are being converted to shrimp ponds. The important "Multi-temporal Study of Shrimp Ponds, Mangroves and Salinas" (CLIRSEN 1985) will, for the first time, provide an accurate picture of where ponds are, and the areas of mangroves, salinas and uplands that are affected. Unfortunately, however, the final (citable) report of study was still unable to us at the time this report was prepared.

Table 4.2. Areas of shrimp culture are listed with the number of hectares per province up to 1983. (Source: Depto. de Estudios Pesqueros y Estadisticas)

Provinces	Total ha in shrimp	Intertidal zones shrimp ha	Zones above high tide mark shrimp ha
Esmeraldas	1,050,17		1,050,17
Manabi	3,712,89	1,856,38	1,856,51
Guayas	46,112,34	20,658,91	25,453,43
El Oro	9,566,46	4,878,63	4,687,83
Total	60,441,86	27,393,92	33,047,94

Table 4.3. Relationship between coastal elevation relative to tidal amplitude and the suitability of sites at these elevations for the construction of shrimp growout ponds. Mangrove forests tend to be the most productive at the same tidal elevations that are believed to be the most suitable for growout ponds. (Adapted from from Watson 1928 and Rabanal 1976)

RELATIVE COASTAL ELEVATION	SUITABILITY FOR GROWOUT PONDS
Coastal uplands (dry)	Unsuitable without massive excavation and/or extensive use of pumps
Above upper reach of high tides	Also unsuitable for reasons above
Flooded by extreme high tides	Suitable only if excavated
Within range of normal tides	Ideal for growout ponds
Not drained by normal low tides	Unsuitable without the use of pumps to periodically drain ponds
Infrequently drained or submerged	Unsuitable without empoldering and and pumped discharge of water

4.5.0. Water Quality Management

The major concern of pond operators is to maximize shrimp growth and at the same time avoid an oxygen crisis. High density stocking, heavy fertilization and massive plankton blooms, and excess supplemental feeding all lead to reduced dissolved oxygen levels, which if too low and persistent lead to the death of the shrimp. In practice, water clarity is monitored (with a Secchi disc) and the management rule of thumb is to maintain phytoplankton blooms at a Secchi depth of 30-35 cm. A larger bloom presents a potential oxygen problem and greater water clarity is an indicator of inadequate food supply. Bright green water color is also considered to be an indicator of potential oxygen problems. Dr. Jimenez, Director of INP, states that "Red Tide" blooms have caused oxygen depletion problems when affected waters have been pumped into ponds along the Estero Salado south of Guayaquil. Peruvian farms north of the Tumbes River have been faced with salinities as high as 55 ppt and a pH above 8, because of the lack of freshwater runoff, especially during dry years. In general, the water quality values given by Yoong-Basurto and Reinoso-Naranjo (1982) might be considered to be optimum under most, if not all, circumstances.

5.0.0. ENVIRONMENTAL CONSIDERATIONS

5.1.0. Upstream Use and Misuse of Resources

Deforestation and erosion result in increased sediment load and changes in the hydroperiod of runoff. Sediment decreases the habitat diversity of coastal streams, raises river beds with a resultant increase in the frequency and severity of flooding, causes mortality of mangroves, and hampers navigation. Rapid runoff followed by low flow conditions results in alternate flooding and fresh water scarcity for agriculture, fisheries and aquaculture, and for urban-industrial uses, as well as for preventing salt water intrusion.

In addition to the downstream effects of watershed mismanagement, dam construction and water diversion, as in the case of the Daule-Peripa on the upper Guayas River, and proposed structures on the Jubones and other rivers, will result in sediment (and associated mineral nutrients) starvation, reduced water availability and hydroperiod changes. Potential results are increased coastal erosion, water shortages and salt water intrusion, all of which can have deleterious effects on the downstream shrimp farms. The shrimp farm industry in Ecuador is affected in one way or another by all of the upstream events whether natural or man induced.

5.2.0. Agriculture

There are two types of problems associated with agriculture: the direct, and probably irreversible loss of agricultural land that has been converted to shrimp ponds, and the salinization of contiguous crop land due to salt water intrusion. In the case of crop land conversion, the landowner may receive payment for his land. When lands which have been used for communal grazing are claimed for ponds, there is no compensation to those who lose access. Salinization and impeded drainage caused by shrimp ponds result in damage to agricultural land that is costly to reverse and those land users who are affected receive no compensation for lost production. The value of the impacted land is depreciated for owners who lack the resources to convert their land into shrimp ponds. The social consequences of this can be significant when the affected population includes small farmers with little political power or economic alternatives. Shrimp is a luxury export while rice and cassava are primarily a source of food within the regional economy. In Peru, a law passed in April 1985 actually facilitates the conversion of agricultural land into land for aquaculture.

5.3.0. Mangrove-Based Fisheries

A large proportion of fish and crustaceans caught by commercial and artisanal fishermen depends in part on the mangrove ecosystem for food and/or shelter (Odum and Heald 1975). To the extent that mangroves are being destroyed directly by pond construction or indirectly by blockage or diversion of tidal flow, there is a loss of marine seafood production. Extensive mangrove mortality evidently linked to shrimp pond construction was noted during photo reconnaissance along the El Oro coast, north of Machala in 1982. In the Tumbes River estuary of Peru, mangrove mortality was noted along tidal streams during aerial reconnaissance in May 1985. Without a detailed field study, it is not possible to determine whether the mortality is due to heavy sedimentation and changes in tidal and fresh water circulation caused by the El Niño event, or to mortality caused by pond construction. The affected people are the fishermen and the consumers of seafood. Those who augment their incomes by harvesting "conchas negras," mangrove crabs and oysters are immediately affected when mangroves are lost. The impact on the catch of other fishermen is more difficult to document. If an effect on fish catch could be documented, it would be in the isolated Chone estuary in Manabi Province where the highest percentage of total mangrove cover has been destroyed.

Also directly related to mangrove destruction, is the loss of animal species that are associated with the mangrove habitat. Prominent among these, is the crocodile which is no longer seen in southern Ecuador and is in danger of extinction in Peru. The relation of such species loss to economic growth is, at best, tenuous. Rather, the concern is ethical and intimately related to national values and development in the minds of many citizens and scientists.

5.4.0. Effects On Mangrove Forests

Mangrove forests play a significant role in the life cycles of a number of economically and ecologically important fish and invertebrate species. This fauna is highly dependent on the habitat provided by the mangrove root system and on the mangrove leaf detritus that forms the basis for nearshore and estuarine food webs (Odum and Heald 1975). In particular, shrimp fisheries around the world have been closely associated with mangrove forests (Idyll, Tabb and Yokel 1968, Sastrakusumah 1971, Macnae 1974, Turner 1977, Martosubroto and Naamin 1977). Intertidal lands in general, whether marsh, mangrove or salina, have an important relation to estuarine production. Modification of these areas directly affects fishery production in many areas (Figure 5.1a,b). In Ecuador, the shallow waters near mangrove-dominated shorelines are extensively used for capturing shrimp post larvae, semilla, to stock shrimp growout ponds.

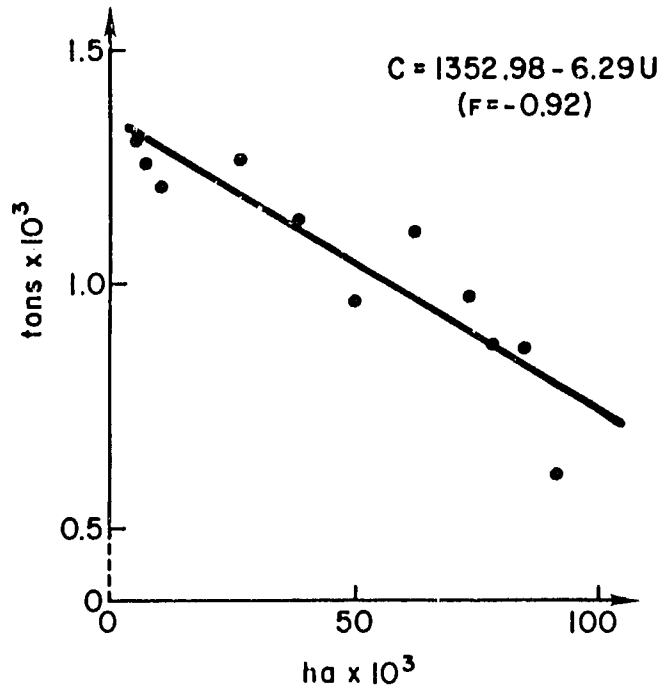

Figure 5.1a. Influence of the cumulated area of reclaimed land on annual shrimp (*Penaeus japonicus*) catches in the Seto inland Sea (from Doi *et al.* 1973).

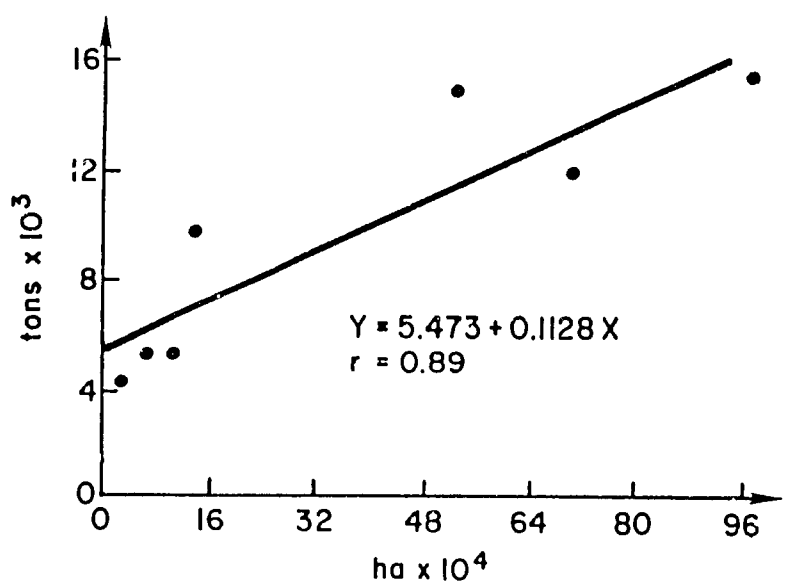

Figure 5.1b. Relationship between mangrove area (10^4 ha) and shrimp production (10^3 ton) (from Martosubroto and Naamin 1977).

In spite of a growing awareness of the importance that mangrove forests have on the structure and function of marine coastal ecosystems (*vide* Saenger, Hegerl and Davie 1983, Hamilton and Snedaker 1984), these highly productive forests have undergone deleterious modifications in many places for a variety of purposes. At the present time, the conversion of mangrove areas for the construction of shrimp ponds may be the most ubiquitous worldwide problem. This practice involves the complete destruction of the mangrove ecosystem and its replacement by activities that do not perpetuate the natural values. For Ecuador, Terchunian *et al.* (1986) have estimated a 16% reduction in the area of mangrove forest between 1966 and 1982 in southern Gulf of Guayaquil. Data for all the coastal provinces of Ecuador (Table 5.2) illustrate the rapid rate at which coastal habitats have been destroyed for the construction of ponds.

Table 5.2. Areas in Ecuador authorized for shrimp farming in 1976-1984. (Source: Departamento de Estudios Pesqueros y Estadisticas.)

Year	Total		Guayas		El Oro	
	No.	Hectares	No.	Hectares	No.	Hectares
1976	2	63,25	1	50,00	1	13,25
1977	3	297,45	-	-	2	263,75
1978	6	651,43	4	600,00	2	51,43
1979	17	2,138,70	8	1,340,00	2	244,28
1980	46	5,724,80	33	4,948,10	9	624,70
1981	136	17,487,22	77	12,991,74	48	3,578,39
1982	99	12,760,11	57	9,846,37	28	2,055,42
1983	100	12,544,24	69	10,437,93	9	875,62
1984	209	23,162,25	144	19,447,91	33	2,308,34
Total	618	74,829,35	393	59,661,95	134	10,015,18

Table 5.2. (Con't.) Areas in Ecuador authorized for shrimp farming in 1976-1984. (Source: Departamento de Estudios Pesqueros y Estadisticas.)

Year	Manabi		Esmeraldas	
	No.	Hectares	No.	Hectares
1976	-	-	-	-
1977	1	-	-	-
1978	-	-	-	-
1979	7	554,42	-	-
1980	3	102,00	1	50,00
1981	8	460,90	3	456,19
1982	12	686,04	2	172,28
1983	17	858,99	5	371,70
1984	24	1,004,24	8	401,76
Total	72	3,700,29	19	1,451,93

6.0.0. SOCIOECONOMIC CONSIDERATIONS

Many international-agency and/or national-government assisted development programs provide funds, loans, guarantees and/or direct subsidies to encourage the shrimp mariculture industry in the mangrove coastal zone because it is believed among other things that: (1) productive use is made of a marginal habitat which is otherwise unsuited for agriculture or most other direct uses, (2) the activity provides abundant employment opportunities for local people and may also increase the population's dietary intake of protein, (3) the economic benefits have a multiplier and spill-over effect that stimulates other forms of economic development in the coastal regions, (4) the sale of shrimp on the international market generates a significant source of hard currency income, and (5) the government revenue base is strengthened by fees, taxes and duties imposed on the industry. The arguments are persuasive largely because of the relatively-high world-market price of shrimp and the fact that once a pond has been constructed and placed into production, net profits are almost guaranteed at minimal cost at management levels 5 and 6. The latter argument is based on the fact that ponds can and do produce, at insignificant operating costs, small quantities of shrimp which yield relatively large profits when sold. As one strategy for the regional development of coastal lowlands, shrimp mariculture is currently viewed as the best possible alternative by some assistance and lending agencies, as well as private lenders and investors.

At the present time in Ecuador, the decline and variability in the availability of PL has forced producers to begin the construction of hatcheries to ensure future supplies for stocking growout ponds. Whereas this initiative has a number of positive benefits, a hatchery-based industry is less likely to remain concerned about the conservation of intertidal mangrove habitats that are the spawning and nursery grounds for wild stocks of fish and shellfish, including shrimp. Assured supplies of PL could lead to further destruction of the coastal zone for pond construction and therefore result in an aggravation of extisting natural resource problems. Also, hatcheries are not a panacea in the sense that there are a variety of potential problems that also require serious attention. For example, how will the coastal provinces deal with the unemployment of people who presently harvest PL for stocking growout ponds?

In spite of the rigor of the pro-mariculture arguments and the persuasive nature of the stated facts, most of the economic and social promises attributable to shrimp mariculture have turned out to be either unproven or false whereas many of the other widely-believed benefits remain highly questionable. The presumed benefits listed above are discussed in detail, as follows.

6.1.0. Marginal Habitats Converted to Economic Use

Throughout the world, the mangrove forest-dominated coastlines of the tropics have traditionally been considered to be of marginal value to man unless converted to some other use, such as rice agriculture (*vide* Ponnampurnam 1984). This view is still held by many people although there is an abundance of evidence documenting the value and worth of mangrove habitats for fisheries and coastal protection (Saenger, Davie and Hegerl 1983), and for direct economic utilization (Hamilton and Snedaker 1984). More importantly, the mangrove-estuarine complex is a nursery ground for shrimp (Doi *et al.* 1973, Turner 1977, Martosubroto and Naamin 1977) and is thus the source of the PL for stocking ponds. The conversion of the mangrove habitat into shrimp ponds, by definition, can be a self-defeating action with respect to the perpetuation of other living resources.

Also in this regard, Snedaker (*in press*) has argued that the luxuriant mangrove-dominated intertidal zone in high rainfall/runoff areas may be one of the least desirable sites for constructing mariculture ponds (Table 6.1). In Ecuador, the argument is, at least, partially sustained by the fact that the best sites were once considered to be the more-inland salinas (see also, Tauber 1982).

6.2.0. Mariculture Provides Employment Opportunities

Employment is generated during the construction and operation phases of shrimp farm development. Involved in the construction phase are mariculture consultants, engineers, heavy equipment operators, various tradesmen and laborers. Importers of heavy equipment and pumps represent, at least, one of the major beneficiaries. In Ecuador, construction is highly mechanized and therefore results in the labor expenditures being a relatively small part of the construction budget. People living in the neighboring uplands or in fishing communities in the estuarine zone benefit only marginally from construction. They cannot sell land to prospective shrimp farmers because the intertidal land is public property and is obtained by the entrepreneurs as a concession from the government.

Farm operations involve hatchery (if present) personnel, a biologist (average, one per 300 ha of ponds), pump operation and maintenance personnel, and laborers who handle feed and/or fertilizer and general maintenance tasks, such as the cleaning of screens, and/or those who serve as guards against poachers and natural predators. The total labor cost, including administrative duties is about 20% of the overall production cost (Parodi 1985) in spite of the fact that laborers receive minimum wages. Efforts by labor to organize unions have been broken. There are essentially no small, labor intensive mariculture operations and the industry is dominated by the middle and upper income economic classes; absentee ownership is the rule. The major beneficiaries of the shrimp mariculture industry are the estimated 120,000, or

Table 6.1. Comparison of selected shrimp growout-pond construction and operating characteristics in intertidal mangroves, supra-tidal coastal habitats, and non-tidal coastal areas, cross-referenced to different climatic conditions.

SHRIMP POND CHARACTERISTIC	INTER-TIDAL MANGROVES (HUMID CLIMATES)	SUPRA-TIDAL SALTFLATS (ARID/SEMI-ARID CLIMATES)	INLAND HIGH GROUND (MOST CLIMATIC CONDITIONS)
1. Turnover of pond water	Possible to use tides for renewal of pond water	May require intensive pumping	Requires intensive pumping
2. Pond drainage for shrimp harvesting and sediment oxidation	Pumping required due to infrequency of very low tides permitting gravity drainage	Gravity drainage possible each month	Gravity drainage assured
3. Acid-sulfate soils	High probability in non-carbonate environments	Relatively low probability in most non-carbonate coastal environments	Not a problem in well-drained oxidized soils
4. Control of salinity	Sometimes difficult to maintain relatively high pond water salinity	Generally easy to maintain relatively high salinity; potential hypersalinity	Depends on access to both seawater and freshwater
5. Cost of construction	High due to cost of cutting and removing mangrove trees growing on soft sediments	Low cost due to absence of large mangrove trees	Depends on prior land use and presence of vegetation
6. Subsurface leakage	Not a problem	Generally not a problem	Always a problem on soils with low clay concentrations
7. Access to ponds	Generally by boat	By boat or land vehicle	Land access is most common
8. Major cost	Construction and maintenance of ponds	Pond operation and management	Water pumping

more, people who are engaged in capturing and handling PL. Many of these people are underemployed farmers and laborers who have immigrated from the Andean region.

Foreign ownership is of growing importance in Ecuadorean shrimp farming. Foreign firms have a distinct advantage because of more flexible and inexpensive capital resources as compared to Ecuador. These externally-backed firms are more capable of capital intensive investments such as hatcheries, high capacity pumps, supplemental feed and highly trained technicians than are their local counterparts cum competitors.

6.3.0. Dietary Protein Levels are Increased

The primary reason that shrimp mariculture is a preferred commercial opportunity is the high price that shrimp (most any quality and size) command on the world market. Almost anywhere in the world, quantities of shrimp can be sold for any of the hard currencies and at a net profit. Because of the high price, shrimp that are consumed locally, are sold through higher class restaurants and food markets; poor people cannot afford to pay the established brokerage price of shrimp. The cost of production of shrimp under capital intensive management is between $2.00 (McPaddon 1985) and $3.32 (Parodi 1985) per kilogram, but results in an ultimate retail cost several times the cost of beef. When shrimp appear in local markets, it is obvious to the observer that they are shrimp that have been rejected by international buyers; sometimes incipient rancidity is evident, as well as discoloration and loss of firmness, all of which are indicators of reduced quality.

In some areas, theft of shrimp from pond systems is relatively common due to the very large sizes of the farms and the related difficulty of providing meaningful security. From a well-stocked pond of mature adult shrimp, an individual working along the banks of pond with a cast net can obtain in excess of 50 kilos of shrimp within a few hours. It could be easily argued that this is really a *sub rosa* means of increasing the level of dietary protein in the diets of the rural poor. However, hearsay evidence and anecdotes strongly suggest that the majority of the stolen shrimp is sold for profit rather than consumed by the poacher's family and/or friends.

In general, the existence of production shrimp growout ponds in a coastal region does not imply that the local population is benefitting from increased protein in their diet. Any benefits that do accrue to local people assume some other form which may be generated either through the local black market or the barter economy.

6.4.0. Local Economic Benefits and Hard Currency Earnings Stimulate Economic Development Within the Region

As a result of the large profit margin that is usually associated with the production and marketing of shrimp, equally large sums of money accrue to the owners and operators of ponds through the sale of shrimp. As suggested above, local sales are frequently insignificant and the local earnings therefore only have a small impact on economic development; the majority of the shrimp are sold on the international market where the profits tend to be much higher. Thus, it is the hard currency earnings that offer the major potential economic benefits for the country.

This argument, however, assumes that hard currency earnings remain in the country of origin and are invested in new opportunities that create jobs and other economic opportunities. Conventional street-wisdom, however, indicates that the majority of the earnings do not contribute to national economic objectives because they remain in foreign depositories. It is believed that in some instances foreign buyers deposit sale receipts in foreign bank havens such as Panama, Hong Kong, the Cayman Islands and the Netherland Antilles. This certainly does not mean that all owners/operators operate in the grey and black market areas, but the large number who do, cause a significant reduction in the hard currency yield to the national government.

6.5.0. Government Revenue Base is Strengthened

As an extension of the argument above, when "convenient", the marketable shrimp may be smuggled to, and sold through, third-party countries which offer exemptions from duties and taxes as well as promises of the expedient forwarding of perishable commodities. Whether or not proceeds from sales are paid to foreign accounts or the shrimp are sold through foreign ports, the results are the same: the country of origin is deprived of the revenues.

Mariculture also affects the tourist industry which in many countries is considered to be a valuable source of hard currency earnings. For example the development of mariculture is affecting the developing potential for tourism based on sport fishing in resort areas such as Bahia de Caraquez. In Peru, concessions for shrimp farms are being granted and ponds are being constructed behind the first dune within 50 m of the sea (Dickinson 1985). Such activities close future options for tourism development and limit access to the sea for fishing; recreation is also restricted for rich and poor alike. Shrimp ponds that are located in such close proximity to the sea are also vulnerable to changes in the coastline during storm events. By weakening the dune barrier, incursion by the sea is invited with the potential for damage to inland property.

6.6.0. Construction of Hatcheries Will Solve the Major Problem

The most widely acknowledged problem surrounding the shrimp farm industry is the decline and large variability in the availability of PL. Whereas a number of reasons for the problem have been put forth (e.g., destruction of mangrove forest nursery grounds, pollution, excessive harvesting of PL, etc.), the search for the actual cause is considered to be less important than the search for, economic solution. The acknowledged solution is the construction of hatcheries to either provide a guaranteed source of PL or, less importantly, to supplement wildform harvests. In addition to providing an assured source of PL, the use of hatchery stock also minimizes the introduction of predators and competitors including non-preferred species of shrimp. Hatcheries also offer a higher degree of control over production operations and could ly lead to the desired intensification of existing farm pond systems.

Whereas hatcheries do offer a number of economically-important advantages, a widespread reliance on hatcheries in Ecuador for PL could also generate some very significant socioeconomic problems. Foremost among these is the potential loss of income earning opportunities for the estimated 120,000 persons engaged in harvesting wild PL stocks. For individuals and families with no other viable source of income or subsistence (particularly those who have migrated in from the Andean region), the coastal provinces could become burdened with a large population of unemployed poor people.

It also appears that most of the planning effort by the industry is being focused on hatcheries (and sources of less-expensive locally-produced feed materials) as opposed to other important issues, such as potential changes in the U.S. market. For example, in May of 1986, 400,000 lbs of frozen shrimp from Venezuela were denied entry in the U.S. because of an import rule change. Also, although it may be an ongoing proprietary effort by the industry, no evidence was found concerning plans for the potential impact of any advances in the state-of-the-art of shrimp production or by increased availability of shrimp from whatever source. If, for example, a major breakthrough allowed the establishment of factory-type production operations on a major scale in Florida, the import of higher-priced Ecuadorean shrimp could either become non-competitive or simply stopped to protect a local U.S. industry. In the opinion of the authors, the question is not if this will happen, but rather when. The same economic impact on the Ecuadrean shrimp industry could also arise from increased lower-priced imports from countries other than Ecuador.

7.0.0. CONCLUSIONS

Although the Ecuadorean shrimp-farm industry stands as one of the world's more successful mariculture endeavors, the industry has developed by undergoing a lengthy process of trial and error, and is still faced with a number of current and potential problems. These problems break down into: (1) the immediate problems that can be solved through overt actions by the producers, the Government of Ecuador, and interested international-assistance agencies, and (2) the potential problems of external origin and over which little control can be exerted. Solutions to several of the current problems are addressed in this section.

7.1.0. Pond Siting and Management Intensification

Yields of shrimp in kg/ha/yr in Ecuador vary widely from farm to farm and from year to year. A general conclusion can be made by looking at the global mariculture industry in that yields in Ecuador and much of the world, in general, are substantially lower than the potential. Among the reasons are (a) absentee ownership with attendant disinterested management, (b) lack of a mariculture tradition in many societies; it is much easier to find a good cowboy or cotton picker than a worker who can detect oxygen stress in a shrimp pond, (c) a general lack of state-of-the-art technology, most of which has been developed in Southeast Asia, Taiwan and Japan, and (d) the reality that shrimp production has been, until recently, tremendously profitable despite relatively low yields. National production of shrimp for export could be increased substantially without converting any more intertidal land into shrimp ponds. This is desirable because the more appropriate land has already been converted, virtually all costs of production have increased, and, due to values intrinsic to the mangrove ecosystem, the opportunity cost of further conversion is unattractive.

Recommendations: The private sector, the shrimp producer, is the primary beneficiary and the most apt to achieve higher productivity levels through individual and collective effort. Government has a potential role through incentives, regulation and taxing. Possible actions in these regards include the following:

1. Provide training for fisheries biologists from private industry, government and universities. This strategy will achieve the greatest dispersal of experience. The most relevant technology and professional experience are found in Asia and the Pacific, and to a lesser extent in the U.S. (e.g., Hawaii and Texas). A combination of three approaches is needed. One of the prerequisites is that the biologists involved have adequate basic scientific education. Trained biologists have two options: intensive courses, internships and study tours in other parts of the world or practical courses in-country with experts from other countries with sophisticated technology. The ideal would be for the biologists to both observe other functioning production

systems at small and large scales and to have training within their own physical and sociocultural environment.

2. Institutions, such as the Subsecretary of Fishery Resources, Sub-direction of the Environment, ESPOL, INP, IMARPE (Peru), and the universities, have the human resources to serve the aquaculture industry. Needed is the specialized training mentioned above, commitment of funds by government and the industry, and cooperative agreements for the use of existing production facilities for experimental projects. Such public entities should take greater responsibility for ensuring that new technology is adapted to the needs of small scale, poor farmers and fishermen, as well as wealthy entrepreneurs.

3. Owners and managers of shrimp farms would benefit from visiting aquaculture operations in other countries. Self-financed study tours could be arranged by AID in the most appropriate countries.

4. The imposition of a tax on land in shrimp farms based on the potential production per hectare would encourage intensification by penalizing inefficient operations and raise public funds. The funds should be used exclusively for projects, training and research in coastal ecosystem restoration, estuarine resource management and in mariculture production and diversification. Any tax or royalty should also be structured to both encourage intensification while at the same time penalizing the misuse or waste of coastal resources.

5. Mariculture represents a direct extension of the land holding patterns found in agriculture into the intertidal zone. Only government has the capability to set aside or acquire lands appropriate for small scale mariculture and to provide support for individuals or cooperatives which includes training, technical assistance, credit and marketing assistance.

6. The success of the Ecuadorean shrimp industry has been based on two major factors: an equitable environment and a favorable U.S. market. Of the two, less attention is given to the near-term and long-term economic environment than is justified by an industry of such magnitude. It is strongly recommended that producers (private interests) and government (public interests) create an economic study office to track present trends and develop future economic forecasts. Both stand to benefit in the event that significant changes affect the U.S. and world market for shrimp.

7.2.0. Development of Maturation and Hatchery Facilities

The capacity to produce abundant PL seed stock will likely give the competitive edge to these growout producers who are efficient in controlling costs (and production risks) and who manage their pond systems at the top edge of technology. The same argument also applies to the increased use of feed,

particularly if it can be produced from local waste products and thus made available at reduced costs. The developing situation could lead to a production industry dominated by a relatively few large enterprises with strong financial links hatchery-PL suppliers and feed manufacturers. It is therefore recommended that it is in the best interest of Ecuador to ensure that PL (and feed) are also made easily available to the backyard and small producer to encourage small-scale economic development and better access to dietary protein.

7.3.0. The Recurrent Post Larvae Crisis

The dominant factor in wild PL abundance appears to be water temperature; female *P. vannamei* produce tremendous quantities of eggs when waters are warm and likewise, produce relatively few eggs when the water is cold. Even under intense fishing pressure, PL are likely to be abundant under favorable water conditions and scarce under less favorable conditions, irrespective of fishing pressure. El Niño events of varying intensity occur on the average of every 4.7 yrs, the 1982/83 event being unique in its magnitude. The abundance of PL and the catch of shrimp by trawlers were both unusually large. In contrast, during the 1984/85 period of persistent cold water, PL abundance was disastrously low. Another El Niño event appears to be developing at the present time. The destruction of mangroves presently appears to have little effect on PL abundance, but conversely, significant effects on juvenile and adult forms can be expected to occur when habitat and organic matter production is no longer available in the required quantity. Obviously, a stable, highly capitalized, shrimp industry cannot function in an environment in which PL abundance varies according to sporadic climate-driven oceanographic processes.

If major investments are to be made by the private sector or government in the shrimp mariculture industry, closed cycle PL hatchery systems are a necessity, but not necessarily the final solution (for reasons stated elsewhere). Wild PL are adequate for lower intensity management on farms where capital investments have already been made and the owner can afford to survive an idle operation during years of PL scarcity. It does not appear that imposing a closed season on PL fishing will have any significant positive effect on PL abundance in subsequent years.

7.4.0. Alternate and/or Exotic Culture Species

Recent introductions of the Asian Tiger shrimp, *P. monodon*, for example into the Miami market, indicate that a very large market potential may eventually exist for non-traditional species of shrimp. However, at the offering price of US$14 for five 6-count shrimp there was little initial demand at the local retail level. Because the North American appetite for all shapes and sizes of shellfish remains stronger than previously thought, the

market potential for high quality shrimp at reasonable prices will persist. Accordingly, an entrepreneurial production system that could take advantage of this potential would profit immensely.

The installation of highly efficient maturation and closed cycle hatchery facilities lies at the core of any near-term modernization effort. If this is carried out solely as a private sector activity, the elimination of firms without the capital and technology to install such facilities is virtually assured. If the government were able to establish strategically located hatcheries, a number of economically and socially valuable objectives could be achieved. These include: (a) the opportunity to bring small/cooperative producers into shrimp farming at scales that would not be possible if an integrated hatchery facility were a prerequisite for entry into shrimp farming, (b) similarly, otherwise efficient intermediate scale operations would have the option of buying government produced PL rather than making obligatory investments in a hatchery, (c) an efficient, not-for-profit hatchery system could serve as a regulator of the price that corporate farms might otherwise charge associate producers and independents for excess PL production, and (d) a hatchery that could afford to adjust its output could reduce production during periods when wild PL were abundant and cheap. Such a facility could also carry out non-proprietary research on the reproduction of exotic and other local species of potential commercial importance.

It is therefore recommended that the Government of Ecuador establish a hatchery network. Government involvement in a hatchery should be limited to overall policy determination by a commission representing large corporate, medium scale private and small cooperative shrimp producers, Subsecretary of Fisheries, ACEBA, the university research community, and international donors supporting the industry. Such a hatchery system should be financed in part by the sale of PL with the remainder being derived from taxes on the productive potential of shrimp farms. Other funding mechanisms include an excise tax, a penalty tax on inefficiency, a royalty tax on concession land, and documentary stamps. Priority should be given to supply small and intermediate sized producers.

7.5.0. Fishery Sector Development

Some of the problems that affect the productivity of the fishery sector are undoubtedly self-inflicted due to overfishing and habitat destruction. Masking the effects are annual and sporadic oceanographic processes over which man exerts no control. The most dramatic is El Niño, an event that occurred in 1982/83 in the most severe form ever recorded. Annually, between November and March, the interface between warm equatorial waters and the colder Humboldt Current, shifts southward into the Gulf of Guayaquil which brings with it, the onset of the rainy season. This phenomenon is correlated with the main maturation, spawning and post larval recruiting season for penaeid shrimp (Cucalon 1984). Trawler fishing success is closely correlated with the timing

of the temperature interface shift and the last El Niño event resulted in a dramatic, but temporary increase in catch. The post larva catch closely parallels the trawler success patterns.

The post Niño period has been atypical. The 1984/85 rainy season was below normal; in Tumbes, only 35 mm fell during the whole wet season. Sea water temperatures remain some 5°C below normal. The fisheries station at Puerto Pizzaro, Peru reported water temperatures 10°C below normal in May 1985. Trawlers were catching small quantities of shrimp and populations of conchas negras and other shellfish are down. Probably related to the same phenomena is the disastrous scarcity of PL. Unemployment was widespread among the estimated 120,000 Ecuadorean and 5,000 Peruvian PL fishermen who had been dedicated to catching PL for the shrimp ponds (Parodi 1985). As much as half of the production capacity of the Peruvian farms was idle, either because the ponds are understocked, or are not in production at all. Some of the Tumbes shrimp farmers became so desperate for larvae that some owners flew to Guatemala to get their PL. The first importation was a failure because 90% of the PL were species inappropriate for pond cultivation (Dickinson 1985a). They planed to send a biologist on the next trip. There is a bright side to this dilemma. First, the forced slowdown of the expansion of shrimp operations has allowed a chance for reflection and perhaps the mitigation of some of the conflicts with other sectors. Second, the industry is on the verge of significant change. Wild PL are unlikely to provide a reliable or adequate supply for pond operations in the future. In this regard, however, a warming trend toward the end of 1985 led to an increase in the abundance of PL, after which prices were down to US$5.00/1000 PL by early 1986 (W. S. MacGrath, Shrimp Culture, Inc., pers. comm.). A return to levels of production of recent years and growth will probably be based on hatchery raised PL. The scarcity in Peruvian waters of gravid *P. vannamei* females for use in hatcheries makes it particularly important for the industry to establish closed cycle hatcheries in which *P. vannamei* or other species, are reproduced in captivity. The possibility of accomplishing this in the immediate future is remote.

The probability exists that large companies, perhaps transnationals, will be the first to acquire the appropriate technology for closed cycle shrimp production; at least one company (and probably others) reports to have done so in Ecuador. These companies are likely to become dominant and buy out, or substantially control, much of the industry. A large number of entrepreneurs will be excluded from the business.

While the future cannot be predicted with precision, closed-cycle hatchery based shrimp production is most likely to become far more intensive than it is today. Densities per hectare, water pumping and levels of feeding will all increase. Likely to decrease also, is the size of ponds and the overall area of individual farms. If this prediction is correct, then the overall pressure on the land will decrease because less land would be needed and the capital cost threshold, to enter the business, would increase. Pressure would increase on the limited areas where ideal conditions of water quantity and quality

prevail. Under this scenario, land use conflicts would be quite different, if not less severe, and the destruction of coastal resources might lessen.

The social and economic inequity that is associated with the co-opting of public, intertidal lands for the benefit of a few, has parallels in the history of occupation of the best land, ever since the the arrival of Columbus. It would not be in the best economic or social interests of the shrimp producing countries for coastal mariculture to become dominated by a few large corporations, either national or transnational. Actually, productive and profitable mariculture operations may be both small or large in scale, capital or labor intensive, and involve various potential species other than *P. vannamei*. A carefully managed estuarine environment which includes mangroves, can provide the basis for a profitable sustained yield fishery that is independent of aquaculture. Donor agencies should be aware of a number of options available for helping the poorest of the poor.

Several of the non-exclusive options that are open include:

1. State-operated, closed-cycle, shrimp hatcheries which provide PL to all interested shrimp farmers, regardless of size or level of intensity of management; this has proven to be a successful practice in Thailand.

2. The importation of large quantities of early stage larval shrimp by more sophisticated operations for growout to older PL in hatcheries.

3. Broad diffusion of hatchery technology which permits large companies, consortia of smaller companies, cooperatives and government entities to all get into the production of PL of various salt and fresh water species.

4. Access to capital and energy-intensive production subsidies which involve water oxygenation by frequent turnover of water or other means of aeration, and the use of supplemental high quality feed and highly trained operators.

5. Labor intensive production which involves relatively low rates of water turnover, enrichment of ponds with crop residues, use of small mangrove lined ponds (source of shade and organic matter), use of other species such as *P. monodon*, and dependence on family management. This is essentially the Asian model.

6. Restructuring the government role in shrimp mariculture to emphasize financial rewards to productive users of land and water resources with financial penalties imposed for inefficiency, abandonment of facilities, and/or failure to maintain minimal levels of production.

7.6.0. Intertidal Zone Management

Despite actions to the contrary, the intertidal zone remains the patrimony of all the people and should be managed in the public interest. Mariculture, fisheries, forests and a diverse fauna depend collectively on the maintenance of the quality, quantity and timing of fresh and estuarine water flow, and upon the protection of the mangrove vegetation cover (Dickinson 1985b). Specific goals in coastal management include:

1. Optimization of the productivity of the intertidal zone with respect to all possible activities: shrimp mariculture, rack and cage culture, fishing and shellfish gathering, *Artemia* and salt production, forest products and nature oriented tourism which has a potential value to the economy and society. A high net contribution of these activities to the economy and the maintenance of future options require intelligent management of the location, extent and operation of each activity.

2. Throughout Ecuador's history, the rural population has been systematically deprived of access to land and the means of production. The same process has begun in the intertidal lands. Management of the area should include effective and equal access to intertidal land, technical assistance and credit loans in order to assure full access and benefit from mariculture, fisheries and other activities for the poor, national entrepreneurs and international corporations.

It is therefore recommended that the government of Ecuador, drawing upon data published by CLIRSEN in its *Multitemporal Study of Mangroves, Camaroneras and Salinas*, and other studies such as this, should establish a zonation of optimal use of intertidal lands. The prime function of such a map is to establish a firm basis for granting and renewing mariculture concessions. This zonation should be legally codified. Because of the volatile nature of the shrimp industry and its negligible contribution to the national food supply, every effort should be made to diversify the economic and food production base of the intertidal zone. Included should be programs specifically designed to serve the economic and social needs of the local population.

7.7.0. Activities of Interest to Development Assistance Agencies

The production of pond-raised shrimp potentially can potentially yield four to five times the economic value of product per hectare than irrigated agriculture. The major limiting factor at the moment, is the supply of larvae which is an essential element in any intensification of production. Given the economic potential of aquaculture in its several forms, ranging from capital-intensive large enterprises to labor-intensive backyard family operations, intensification support merits attention by USAID. Capital is not the primary limitation; rather, it is the absence of practical advice and information. For example, with respect to capital, Ralston-Purina of Panama (and others) has

reputedly succeeded in closing the reproductive cycle of *P. vannamei*. They are prepared to establish a hatchery in Peru and supply larva. The cost is approximately two million dollars. Those few large enterprises capable of guaranteeing capital expenditures of this magnitude will tend to dominate the industry. Donors should carefully examine the social context of support of this sort.

The problem of inadequate technical information could be partially solved by exchanges of experienced practitioners and scientists in various parts of the world for the purpose of learning from one another. Unfortunately, however, many international assistance agencies, such as USAID, prefer to fund and support qualified but inexperienced U.S. nationals rather than involving highly-experienced foreign passport holders from other countries. For example, Ecuador could benefit from the Asian experience, whereas other countries with developing shrimp farm industries, could benefit from the Ecuadorean experience. Mechanisms do exist for cross cultural collaboration through such non-governmental organizations as the United Nations and various private voluntary organizations.

7.8.0. Research Needs

1. It should be recognized that the major market for Ecuadorean shrimp is the U.S. and that most socioeconomic-type studies in Ecuador fail to take advantage of predictions of changes in U.S. market conditions, potentials and limitations. Studies of the U.S. market should be made to establish the character of the import market for, at least, five-year planning horizons.

2. It should also be recognized that as long as shrimp continue to command a relatively high market price, individuals and organizations will continue to research better and more efficient methods for producing shrimp (and other seafood). In the event that major breakthroughs are made in such areas as pond management intensification and factory production, owners/operators of large ponds, land extensive systems could face financial ruin. "Think-tank" type research should be undertaken to forecast potential changes in technology and outline alternate solutions to a range of future market conditions.

3. There is grossly insufficient public (i.e., non-proprietary) knowledge concerning the biology, ecology, physiology and reproduction of the penaeid shrimp to permit effective management. An interdisciplinary approach to problems of migration, reproduction, habitat and culture could have considerable economic benefit.

4. Shrimp ponds represent highly subsidized subsystems that replace huge areas of naturally-sustaining systems and components such as mangroves and salinas. Organized research should be undertaken to evaluate alternative sites for potential use as shrimp ponds, for example, degraded and agriculturally-unproductive coastal uplands. Similarly organized research should also focus

on intensifying the management of existing ponds as an alternative to the construction of additional ponds.

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APPENDIX A

SOME TRADITIONAL USES OF SOUTH AMERICAN MANGROVE FORESTS[1]

INTRODUCTION

Up until the late 1960s, coastal mangrove forest ecosystems were considered to be a form of wasteland in most parts of the world (cf. Lugo and Snedaker 1974) and were either ignored or abused. However, in a few countries in Asia (e.g., Bangladesh, Pakistan, Malaysia, Thailand, etc.) mangrove forests were viewed as natural forest resources that could be managed for economic gain. In contrast, the mangrove forests on the Atlantic, Pacific and Caribbean coasts of South America were, with certain exceptions, never managed or utilized beyond that of providing subsistence needs for local populations. Part of the reason for the benign neglect of the South American mangrove forests was the fact that the majority of the major population centers were located in high altitude mountain environments (e.g., Bogota, Colombia and Quito, Ecuador) or in areas distant from any mangrove forest (e.g., Caracas, Venezuela and Lima, Peru). To a large extent, this preference for high inland elevations was due to the cooler, more favorable climate (cf. Holdridge 1967) and a relatively lower incidence of diseases such as yellow fever and malaria.

Beginning in the 60s and extending through the early 70s, the ecological and economic values of mangroves began to be documented (see Golley, Odum and Wilson 1962, Odum 1969, Odum 1971, Heald 1971, Snedaker and Lugo 1973). Among the cited values are the roles of mangrove forests in coastal protection (e.g., against storms and erosion), the perpetuation of coastal water quality, and, in the maintenance and the production of coastal and marine finfish and shellfish populations. Based on this new perspective, various international organizations such as Unesco, FAO, UNEP, USAID, and IUCN, initiated a variety of programs with scientific, conservation and management objectives that resulted in widely communicated results (vide Rollet 1981, FAO 1982, Saenger, Hegerl and Davie 1983, Snedaker and Snedaker 1984, Hamilton and Snedaker 1984, Snedaker and Getter 1985). In part because of a decade of international publicity, and for a variety of other reasons, most of the countries of South America now have an expanding interest in the mangrove forest-dominated coastal zone as a multiple resource for national economic development. In many aspects, the situation in Ecuador represents a microcosm of the changes that are rapidly taking place in the traditional uses of mangroves and the socioeconomic consequences of current coastal development.

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[1]Excerpted and developed from a discussion paper presented by S. C. Snedaker at the United Nations University Workshop on the Socio-economic Situation of Pioneer Settlements in Mangrove Forests, Nong Nooch Village, Thailand, 27-31 May 1985.

THE MANGROVE FORESTS OF SOUTH AMERICA

Geographic Distribution

The mangrove forests of South America extend north from northern Peru on the Pacific Coast and from Brazil's southern state of Rio Grande do Sul on the Atlantic coast. Aridity and the cold Humboldt current limit the southern extension on the Pacific coast to about 6°S latitude, whereas higher rainfall and warm currents along the southern coast of Brazil permit limited mangrove growth to about 28°S latitude. Throughout the continent, the structural development of mangrove forests is best in areas that receive relatively high rainfall and/or abundant freshwater runoff; a similar pattern has been documented for Central America and the Caribbean (Pool, Snedaker and Lugo 1977). The only major exception is the delta region of the Amazon River where there is no significant influence of salinity in the coastal zone. In the absence of salinity, mangroves cannot compete with freshwater species which form the dominant vegetation (West 1956). In contrast, the delta of the Orinoco has extensive mangrove forests due to the seasonal periodicity in freshwater discharge and the dry-season rise in the ambient salinity.

Forested Area

The total area of mangrove forest land in South America, including Panama, has been estimated at some 4.6 million ha which represents about 22 percent of the world's 21 million ha (Snedaker and Brown *in prep.*) The national areas range from 2.5 million ha in Brazil to 2500 ha in northern Peru (Table 1). Most of the largest single areas of undisturbed forest are found in remote areas that are largely inaccessible, for example, the Orinoco delta in eastern Venezuela (495,200 ha) and the Pacific Coast of Colombia (451,300 ha). Similar expanses also occur in northern Brazil.

Table 1.- Mangrove Forest Area in South America

	Hectares
Brazil	2,500,000
Colombia	501,300
Ecuador	177,555
French Guiana	55,000
Guyana	80,000
Panama	486,000
Peru	2,449
Venezuela	673,569
Surinam	115,000
TOTAL	4,590,873 hectares

Species Composition

South American mangrove forests are limited to 10 to 15 species (the actual number of species varies among taxonomic authorities) distributed among the genera *Rhizophora*, *Avicennia*, *Laguncularia*, *Conocarpus*, and *Pelliciera*. This contrasts with the larger number and higher diversity of species (and genera) that are found within Old World mangrove forests. The diversity of associated animals is also significantly higher in the Old World which argues that the center of origin of the mangroves *sensu lato* lies in the Old World.

Historical and Traditional Uses

The historical uses that have been made of mangroves and mangrove products are very poorly documented and much of the extant information is based on conventional wisdom and anecdote. However, the earliest recorded utilization of mangroves is inferred from a law promulgated by King Jose of Portugal in 1760. The law, imposed on Brazil, made it illegal to fell mangrove trees without simultaneously utilizing the bark. It was feared that the extensive felling of trees for firewood would limit the availability of bark for the tanneries. In addition to a financial penalty the law also imposed a three month jail term (Hamilton and Snedaker 1984).

There is a paucity of evidence in the ethnographic and archaeological literature concerning direct uses of mangroves by pre-Colombian Indians although they are known to have inhabited coastal areas characterized by extensive mangrove forests (cf. Meggers, Evans and Estrada 1965). In general, pre-Colombian and historical uses are presumed to be the same as the traditional uses that are observed today. In this regard, the dominant traditional uses include the cutting of trees for firewood, charcoal, small diameter poles for light construction and domestic use. In each case, these represent small-scale operations undertaken by single families or several adults from one village. This is unlike similar activities in parts of Asia where the harvesting and sale of poles and the production of charcoal are small to medium size industries. In South America, and Latin America in general, the small-scale production of charcoal is inefficient and produces a product of variable quality. However, there is a relatively high demand for charcoal by the Panamanian middle class, and it commands a fairly high price. In Panama, the production technique is based on constructing a densely-packed cone (4 m diameter x 2-3 m high) of small logs and branch wood (0.25-0.5 m long) covered with earth and fired from the center. In the Panama City charcoal market, the buyers demand smokeless charcoal which the small producers can supply only by allowing the wood to burn for an excessive period of time; the technique does not permit the control of the kiln temperature and the resulting smokeless charcoal has a very low caloric value (Snedaker 1981).

Another small-scale use of mangroves has been the stripping of bark from felled *Rhizophora* trees for the production of tannin. However, the collapse of the world market for tannin has almost eliminated tannin production activities

on all but a very small scale in South America. One of the larger producers is located in southwest Costa Rica and utilizes bark stripped from *Rhizophora* trees in Panama and illegally exported to Costa Rica. Other than this one activity, tannin production elsewhere is presumed to be minimal and performed at the family level.

Summaries of the traditional uses of mangroves have been reported by Saenger, Hegerl and Davie (1983) by region and country, and by Hamilton and Snedaker (1984) by species. A more detailed review of the uses of mangroves was prepared by Walsh (1977). In general, these publications confirm that much more has been reported about the traditional uses and socioeconomic values of the Asian mangroves than that of the South American mangroves. In part, this is believed to be due to the differences in the regional distribution of human populations in both regions.

Utilization and Economic Value

The utilization of mangrove forests for economic purposes has had a long and mostly successful history in Asia. In fact, the only complete forest management plans that exist as models for sustained forest yield are from the Asian region (e.g., Curtis 1933, Dixon 1959, Khan 1966, Choudhury 1968). In South America, no such plans exist although some international organizations such as FAO have made efforts to develop plans for selected mangrove forest areas. Irrespective of the absence of forest management plans, there are schemes for large scale forest utilization albeit not on a sustainable basis.

Mangrove forest utilization on large commercial scales has only recently been instituted in South America although most of the government inspired efforts remain in the planning stage. At the present time, the Governments of Brazil, Panama and Venezuela are working toward the development of forest management plans. However, their implementation and the subsequent development of mangrove forest-based industries is extremely slow due to the widespread opinion that mangrove wood and wood products have minimal value when compared to other tropical forest species. One notable exception is the commercial harvesting of large *Rhizophora* trees in the Orinoco delta (Hamilton and Snedaker 1984) for transport and use elsewhere in Venezuela as power utility poles. In addition to the environmental impact (Pannier 1979), other knowledgeable observers claim that the Orinoco harvesting is exploitive and not likely to lead to an industrial base that offers permanent job opportunities in a region that is only minimally developed. With respect to the other countries in South America, plans to utilize mangrove forest resources as timber, all tend to be highly exploitive as opposed to being based on a sustained and perpetual yield. In part, this is due to the short term economics which favor the clear felling of all commercial timber at one time for sale to international wood chip buyers. In addition to the economic situation that does not favor sustained yield management, there is also the perception problem that mangrove wood and wood products are inferior to available substitutes.

Other forms of utilization of the mangrove ecosystem involve the clearing of the forest (with or without utilization of the wood) and the conversion of the land to salt-evaporation ponds or to maricultural ponds. Conversion to rice agriculture is not seen as an option in South America as it is in parts of Asia and Africa. Salt evaporation ponds are limited to arid and semi-arid climates and may only infrequently require the conversion of mangrove forests. Investors and developers of maricultural ponds for shrimp (mostly penaeids) production also prefer semi-arid climates and seek out salt flats, barren coastal areas, and former mangrove areas for the construction of ponds. This preference is due to the fact that the land is devoid of trees, essentially flat and close to salt water, which translates into a low land-preparation and pond construction cost. However, the extremely rapid development of the mariculture industry in South America is forcing the developers of new pond systems to convert productive mangrove forest areas as well as productive farm land. Prior to 1980, only Ecuador had made a significant investment in shrimp mariculture, but the perceived financial success has inspired other countries to follow suit, sometimes with the assistance of international development organizations. As a result, most Central and South American countries have either begun encouraging mariculture or have announced plans to stimulate investment in this industry.

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APPENDIX B

MANGROVE FOREST AREA IN ECUADOR[1]

	Area in Mangrove Forest hectares (acres)	Notes
ECUADOR	177,555 (438,560)	(1)
Provincia Esmeraldas	40,300 (99,500)	(2)
Provincia Manabi	6,000 (14,800)	(3)
Provincia Guayas	90,190 (222,800)	(4)
El Oro	40,265 (99,500)	"
Galapagos	800 (2,000)	(5)

(1) Total area estimate obtained by summarizing (in hectares) the individual areas. FAO/PNUMA (1981) estimates the total area at 235,000 ha. The true estimate is expected to lie somewhere between these two values.

(2) There are various estimates for Esmeraldas including 8,000 ha (Berthon 1959), 29,600 ha (Acosta-Solis 1957), 40,300 ha (Dixon *et al.* nd) and 180,800 ha (Rafael R. Horna Zapata, Francisco Yoong Basurto and Blanca Reinoso de Ayeiga, *pers. comm.*). Dixon *et al.'s* estimate is used in the summary and is considered to be a reasonable provisional value.

(3) Data (in hectares) provided by Rafael R. Horna Zapata, Francisco Yoong Basurto and Blanca Reinoso de Ayeiga (*pers. comm.*). The Ministerio de Agricultura y Ganaderia (1980) gives an estimate of 14,700 ha but this is believed to be too high (Gilberto Cintron, *pers. comm.*).

(4) Data (in hectares) obtained from Cintron (1981a,b). In addition to the mangrove areas, there are salt flats comprising some 42,712 ha in Guayas and 13,024 ha in El Oro. These areas are not included in the forest area estimate used here.

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[a]Appendix B has been modified from a draft report prepared by Samuel C. Snedaker and Melvin S. Brown, entitled, "Biosphere Inventory of Mangrove Forest Lands: Total Area, Current Status, Managing Institutions, and Research Initiatives," a project of the Unesco/SCOR Working Group 60 on Mangrove Ecology supported by the USDA Forest Service as part of the U.S. Man and Biosphere Program.

There is a relatively large variation in estimates for the mangrove area in Ecuador, and the more conservative alternatives are used in the report. For example, Dixon *et al.* (nd) state that there are 403 square kilometers of mangrove forest in the San Lorenzo-Limones area, of which 290 square kilometers are in regenerating forest and an additional 113 square kilometers in 'degraded' forest (Gilberto Cintron, *pers. comm*). Below are other estimates for Ecuador provided by Rafael R. Horna Zapata, Francisco Yoong Basurto and Blanca Reinoso de Ayeiga (*pers. comm.*). These may be unrealistically high, particularly for Esmeraldas.

	Hectares	(acres)
ECUADOR	316,800	(782,500)
Provincia Esmeraldas	180,800	(446,600)
Provincia Manabi	6,000	(14,800)
Provincia Guayas	80,000	(197,600)
El Oro	50,000	(123,500)
Galapagos	800	(2,000)

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