MAINTAINING A BALANCE:

# The Economic, Environmental and Social Impacts of Shrimp Farming in Latin America

Coastal Resources Center

*University of Rhode Island*

M A I N T A I N I N G A B A L A N C E :

# The Economic, Environmental and Social Impacts of Shrimp Farming in Latin America

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# ACRONYMS

| | |
|---|---|
| ANDAH | National Association of Honduran Aquaculturists |
| BMP | best management practice |
| CAAM | President's Environmental Advisory Commission of Ecuador |
| CENAIM | National Center for Aquaculture and Marine Research, Ecuador |
| CRSP | Honduras Pond Dynamics/Aquaculture Collaborative Research Support Program |
| EAP | Pan-American Agricultural School at Zamorano, Honduras |
| EIA | environmental impact assessment |
| FAO | The United Nations Food and Agriculture Organization |
| GDP | gross domestic product |
| HFTE | Hemispheric Free Trade Expansion project, USAID |
| ICM | integrated coastal management |
| INRENARE | Panama National Institute of Renewable Natural Resources |
| MARENA | Ministry of Environment and Natural Resources, Nicaragua |
| MEDE-PESCA | Fisheries and Aquaculture Department of the Ministry of Economy and Development, Nicaragua |
| NGO | nongovernmental organization |
| PD/A CRSP | Pond Dynamics/Aquaculture Collaborative Research Support Program |
| PL | postlarvae |
| USAID | United States Agency for International Development |
| ZEM | Ecuador's coastal management special area |

# F o r e

# w o r d

*Maintaining a Balance* surveys social and environmental issues concerning shrimp aquaculture in Latin America and highlights opportunities to improve management. The study is based on the best available secondary sources and several years of field work in Ecuador. By comparing Latin America's experience with that of other regions it may be possible to avert severe impacts such as those recently suffered in Asia.

The report was supported with funding from the Hemispheric Free Trade Expansion (HFTE) Project of the U.S. Agency for International Development (USAID), Office of Regional Sustainable Development, Bureau for Latin America and the Caribbean. The objective of the HFTE project is to help to resolve key market issues impeding environmentally sound and equitable free trade in the hemisphere. HFTE supports the commitments of the leaders of the countries in the hemisphere at the 1994 Summit to the Americas for achieving economic integration and free trade through the creation of a Free Trade Area of the Americas while ensuring environmental protection and the sustainable use of natural resources.

*Maintaining a Balance* reflects USAID's commitment to sharing coastal management concepts and tools across countries and regions. We believe that this will encourage dialogue among local communities investors, policymakers and managers setting the stage for more sustainable development in coastal nations worldwide.

David Hales
Deputy Assistant Administrator
USAID Center for Environment

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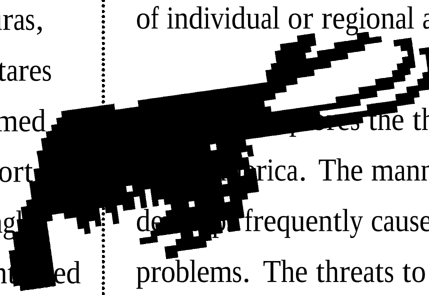
Shrimp farming is a significant export industry in Latin America which has important impacts on the environment and coastal communities. There are over a dozen countries in Latin America with a diversity of experience in shrimp aquaculture. The major shrimp aquaculture nations are Ecuador, Mexico and Honduras, with about 180,000, 20,000 and 14,000 hectares of shrimp ponds, respectively. Nearly all farmed shrimp in Latin America is produced for export, primarily to American markets, but increasingly to European and Japanese markets. With continued strong demand for shrimp, growth of the shrimp aquaculture industry in terms of per hectare production and total pond area will continue and may expand to other countries.

Sustainable shrimp aquaculture is defined in this paper as developmental and operational practices that ensure the industry is economically viable, ecologically sound and socially responsible. Sustainability in shrimp aquaculture can only be reached if short-term and long-term effects on the environment and community are appropriately recognized and mitigated; long-term economic and biological viability of farm operations are maintained; and, the coastal resources upon which shrimp farming depends are protected. Economic viability is directly influenced by sustainability. Practices which are not ecologically sound will, in the long term, fail economically or will lead to the failure of individual or regional aquaculture operations.



[illegible] the threats to sustainability in [illegible]rica. The manner in which the industry de[illegible] frequently causes social and environmental problems. The threats to sustainability lie principally in the absence of adequate governance mechanisms to prevent the unplanned and unregulated over-development of the shrimp industry and other human activities in specific estuaries and stretches of coasts, thus leading to declines in water quality, shrimp diseases, user conflicts and ultimately reductions in pond productivity or pond abandonment.

The underlying causes of environmental and social problems in Latin America are complex and include poorly defined and insecure land tenure; open access property rights for water and seed shrimp; inadequate institutional capacity and environmental regulations; unworkable legal frameworks; inadequate shrimp farm technical expertise; and inadequate understanding of coastal ecosystem conditions and trends. Integrated coastal management is

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suggested as a governance framework for advancing sustainable shrimp aquaculture. The multi-dimensional nature of the problem calls for an integrated approach to coastal economic development and environmental management.

Important advances have been achieved recently in various international forums on the principles of environmental and social sustainability, and on codes of best practice. Urgently needed is a better understanding of how to more effectively address the underlying causes of the problems and to translate principles of sustainable shrimp aquaculture to tangible practice. Specific actions explored in this paper include:

- Formulation of best management practices that lower impacts and sustain production
- Improvement of the use of impact assessment techniques for watershed management and shrimp pond siting, design, construction and operation
- Formulation of trade-related incentives such as product certification schemes
- Monitoring of estuary conditions and trends
- Development of community management plans and user group agreements
- Providing extension and technical assistance that addresses the environmental, social and economic impacts of shrimp farming
- Improvement of land use zoning, use of buffer zones and permitting procedures
- Providing incentive-based measures such as subsidized credit, donor conditionality, and water a land pricing

A second phase of the United States Agency for International Development Hemispheric Free Trade Expansion Project will implement and assess several of these management approaches. The desired outcomes are increased sharing of country experience to promote sustainable shri aquaculture; recommendations for improved shrimp aquaculture management and practice in different country contexts; improved dialogu between the shrimp industry, government and nongovernment organizations; and, testing of approaches to mitigate the social and environmental impacts of shrimp aquaculture.

S E C T I O N   O N E

# Overview of Latin American Shrimp Aquaculture – Production, Consumption and Trade

### 1.1 Patterns of Production, Consumption and Trade

Scientific data on marine fisheries suggest that nearly half the established world fisheries are already fished at or beyond their limit of sustainable yield (National Research Council 1992). With the decline in the world's capture fisheries, aquaculture will continue to expand if the increasing demand for fish and shellfish products is to be met (National Research Council 1992). Aquaculture, in various forms, comprises about a quarter of the global food fish supply (New 1997).

During the past decade, shrimp farming in the tropical/temperate regions has undergone explosive development; this growth continues. Aquaculture has played a significant role in meeting the rising global demand for shrimp. Overfishing of wild shrimp, limits on the growing supplies of seafood and high prices have all helped to increase the attractiveness of shrimp aquaculture. Cultured harvests accounted for only 9.2 percent of total shrimp production in 1984, but by 1994 that figure had increased to 29.9 percent. Table 1.1 shows total world shrimp production and compares aquaculture and capture harvests.

**Table 1.1**

**World Shrimp Production by Source, 1984-1994**

*(Volume in 1,000 tons)*

| Year | Capture | Culture | Total Harvest | Proportion Cultured (%) |
|---|---|---|---|---|
| 1984 | 1,744 | 172 | 1,916 | 9.0 |
| 1985 | 1,935 | 213 | 2,148 | 9.9 |
| 1986 | 1,958 | 305 | 2,263 | 13.5 |
| 1987 | 1,896 | 492 | 2,388 | 20.6 |
| 1988 | 1,981 | 569 | 2,550 | 22.3 |
| 1989 | 1,947 | 613 | 2,560 | 23.9 |
| 1990 | 1,963 | 662 | 2,635 | 25.2 |
| 1991 | 2,006 | 823 | 2,829 | 29.1 |
| 1992 | 2,055 | 881 | 2,936 | 30.0 |
| 1993 | 2,067 | 835 | 2,902 | 28.8 |
| 1994 | 2,155 | 921 | 3,076 | 29.9 |

*Source: FAO 1996*

Ecuador emerged as the early shrimp aquaculture industry leader. The first commercial shrimp pond was constructed in 1969 (the pond is still in operation) and by 1982 Ecuador had the world's largest area under production. Today, cultured

shrimp is the second leading export commodity in Ecuador, representing 15.6 percent of all exports and 3.12 percent of the Gross Domestic Product (GDP) (Stein et al. 1995). The Ecuadorian shrimp industry has grown exponentially in the past 20 years, mainly as a result of increased production areas (Hirono and van Ejs 1990). In 1975, ocean capture provided 85 percent of the 5,800 metric tons of shrimp exports. By 1991, 132,000 hectares (ha) of coastal land had been converted to shrimp ponds, and only 7 percent of shrimp exports were from capture fisheries (Parks and Bonifaz 1994). The industrial support infrastructure includes shrimp hatcheries, feedmills, export companies and processing plants. Olsen and Arriaga (1989) estimated that the industry employs more than 170,000 part-time and full-time people.

**In Ecuador shrimp ponds are a major feature of the coastal landscape.**

Honduras, Mexico and Nicaragua have also experienced rapid growth of the shrimp aquaculture industry. Mexico could be the Latin American country with the greatest potential for additional growth. Shrimp aquaculture was promoted in both Mexico and Honduras as a means for non-traditional economic development in coastal areas. Mexico's first shrimp farm was built in Sinaloa in 1977. As the volume of wild-caught shrimp from the gulf began to drop off in the mid-1980s the Mexican government saw aquaculture as a way to maintain the high level of export earnings from shrimp. The proportion of total Mexican shrimp harvest from culture was about 11 percent by 1991, an order-of-magnitude increase from 1985 (Wells and Weidner 1992).

Despite growing production in Ecuador, China overtook Ecuador by 1984 as the leading producer of cultured shrimp, and by 1989 the center of shrimp farming in the world had shifted to Asia (Lambregts and Griffin 1992). Today, significant volumes of shrimp are farmed in only two regions of the world: Asia, which produces approximately 80 percent of the world's cultured shrimp; and Latin America, which accounts for the remaining 20 percent.

**Table 1.2**
**Cultured Shrimp Harvests by Country, 1994**
*(Production volume in tons)*

| Country | Harvest |
|---|---|
| Thailand | 267,764 |
| Indonesia | 167,410 |
| Ecuador | 98,731 |
| Philippines | 92,647 |
| India | 91,974 |
| China | 63,872 |
| Vietnam | 36,000 |
| Bangladesh | 28,763 |
| Mexico | 13,454 |
| Others | 60,002 |
| **TOTAL** | **920,617** |

*Source: FAO 1996*

In 1994, the top shrimp aquaculture producers were Thailand, Indonesia, Ecuador, Philippines, India, China, Vietnam, Bangladesh and Mexico. These countries supply approximately 93 percent of the cultured shrimp imported by the two largest markets: Japan and the United States (FAO 1996). Table 1.2 shows shrimp aquaculture production by country and source.

The extraordinary growth of the shrimp aquaculture industry worldwide can be attributed to rapidly growing demand for shrimp products, more producers entering the industry because of high profit margins and improved technologies in aquaculture production.

Shrimp is the single most valuable marine species that can be cultured with existing technology (Weidner et al. 1992). Shrimp farming profits are generally high relative to other income generating economic activities (Gujja and Finger-Stich 1995). In Honduras, the profitability of semi-extensive and extensive operations has been assessed using a shrimp farm simulation model (Vergne et al. 1988). The results show an internal rate of return of greater than 14.4 percent for all but the largest extensive farms. It is not unusual for investors to recover their entire investment in pond construction, pumps and even packing houses in a single year (Burroughs and Olsen 1995; Csavas 1994). The total value of world production in 1993 is estimated at US$ 3.4 billion (Produits de la Mer 1994).

Aquaculture has also been promoted by loans and support (through technical assistance and extension services) by international lending and aid institutions. The United Nations Food and Agriculture Organization (FAO), the World Bank, the Asian Development Bank (ADB), the United States Agency for International Development (USAID), and many other lending and donor institutions have provided millions of dollars in support of aquaculture projects. From 1983 to 1993, it is reported that aid to all aquaculture represented a third of all the total moneys committed to fisheries (FAO 1994). In 1997, a World Bank loan to Mexico, primarily for shrimp aquaculture, was approved. In Honduras, shrimp aquaculture has received support from USAID, beginning with a 1986 program to promote the development of non-traditional products.

***Major Consuming Markets***. The preconditions for the success of any industry are market demand and adequate prices. On both counts, the prediction for the farmed shrimp industry is good. Shrimp is a luxury food in high-income nations, and there is as yet no evidence that the demand for shrimp is saturated. The three major consuming markets for shrimp are the United States, Japan and Western Europe. Led by these regions, global shrimp consumption increased by nearly 4 percent annually from 1970-1988 (Rosenberry 1993). In some regions, growth in consumption has increased much more dramatically. In the United States, consumption increased by 50 percent from 1980 to 1988. The combined imports of Japan and the United States represent about three-quarters of world shrimp consumption. Table 1.3 shows shrimp consumption in 1993 by major markets.

**Table 1.3**
**Shrimp Consumption in Major Markets, 1993**

| Country / Region | Consumption (million kg) | Percent of World Consumption |
|---|---|---|
| U.S. | 364 | 40 |
| Japan | 318 | 35 |
| Europe | 182 | 20 |
| Other | 45 | 5 |

*Source: Filose 1995.*

Frozen shrimp exports are dominated by cultured-shrimp producing countries. As shown in Table 1.4, Japan, the United States and the European Union account for some 90 percent of world frozen shrimp imports in value.

These global averages are not representative of the Latin American market. In 1997, some 61 percent of Ecuador's cultured shrimp exports were destined for the United States, 26 percent to Europe, and 13 percent to Japan (Laniado

**Table 1.4**
**World Imports of Frozen Shrimp, 1993**

| Country / Region | Value (million US$) | Percent of Market Share |
|---|---|---|
| Japan | 2,946 | 40 |
| U.S. | 2,080 | 28 |
| EU | 1,605 | 22 |
| Other | 762 | 10 |

*Source: Yearbook of Fisheries Statistics, Commodities, 1984–1993, Fisheries Department, FAO.*

1997). A greater percentage of Mexican cultured shrimp exports are destined for the United States.

### 1.2 The Production Process

Shrimp aquaculture culture techniques and inputs to the production process have relevance for the type and magnitude of environmental and social off-pond impacts. This section and the following provide a layman's overview of the production process and culture techniques in Latin America.

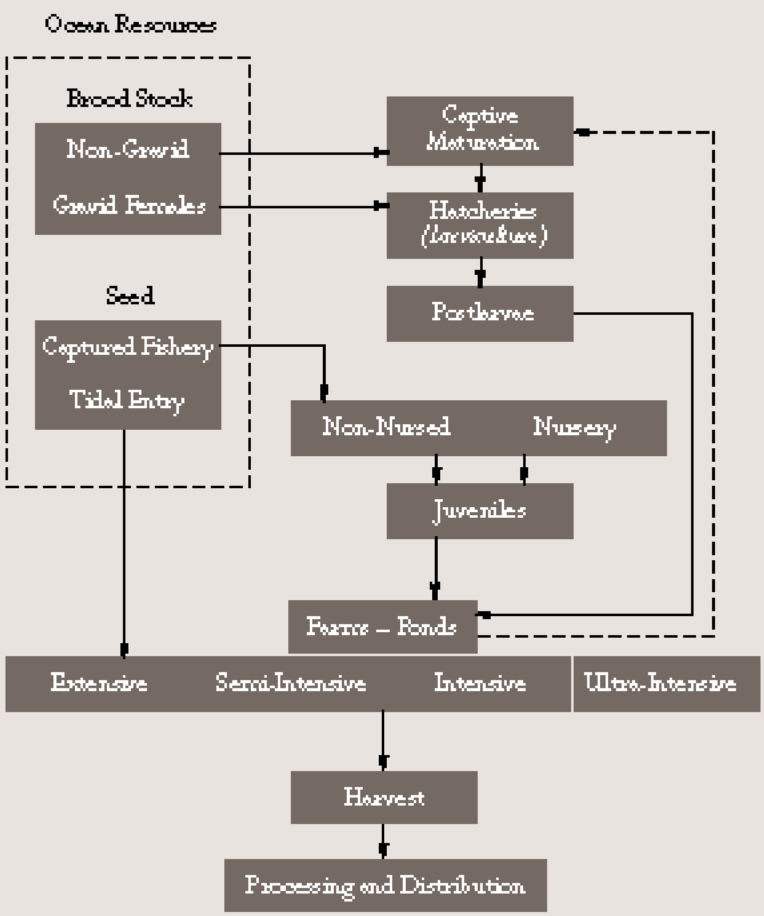
Shrimp farming requires dependable sources of seed shrimp, sites for growout ponds where there is readily accessible water of adequate quality and quantity, inexpensive feed and labor, and near-by processing and shipping plants. Figure 1.1 shows the production cycle of the shrimp aquaculture industry.

***Land.*** Land is of critical importance to shrimp farming, and countries with large aquaculture sectors tend to have large endowments of suitable land. In Latin America, the cost of land or wetland for a farm is frequently inconsequential. In many nations, intertidal lands, including mangroves, are public property that can either be occupied at no cost or leased for a nominal fee.

As aquaculture expands, land suitable for shrimp aquaculture becomes more scarce and costly. In Ecuador, for example, observers of the industry believe that there are limited additional opportunities for further growth of the industry's output due to the inability to expand total pond area.

**Figure 1.1**

**Shrimp AquacultureProduction Cycle**




*Source: Fast 1992*

*Seed Stock/Hatcheries.* Juveniles which have passed through three larval stages are called post-larvae (PL). These originate from three sources: captive brood stock reared for mating; captured wild, gravid (fertilized) females which then spawn; and captured wild PL ready for stocking. These are stocked in growout ponds. Penaeus vannamei, or "whiteleg" shrimp, is the predominate species produced in Latin America, accounting for 90 percent of production. Hatcheries produce a steady supply of PL, which is important for farmers involved in year-round production, as wild PL are only available for half the year. In addition, hatcheries are able to supply farmers in times of PL shortages, which can occur periodically due to weather variability, overfishing and environmental problems.

To obtain hatchery fry requires raising newly hatched shrimp through several larval and postlarval stages. The entire process from hatched egg to PL lasts approximately 18 to 20 days. Hatcheries sell two products: nauplii (tiny, newly hatched larvae) and PL. Nauplii are sold to specialists who grow them to the postlarval stage. PL are stocked in nursery ponds or directly into growout ponds.

The hatchery industry has been slow to develop in many countries due to its overall risks and the abundance of wild PL. For example, Rosenberry (1996) reports that in Honduras in 1996 there were only 10 hatcheries. Lara (1997) reported the total has increased to 15 hatcheries. DeWalt et al. (1996) reported that wild shrimp stocks account for 67 percent of production in Honduras. In the absence of hatcheries, shrimp farms are dependent on the vagaries of wild PL stocks and imported PL.

Larvae collectors gather shrimp larvae from the estuaries and mangroves for shrimp farms. There are two different levels of larvae collection practiced in the Gulf of Fonseca: independent artisanal collectors with hand-held nets; and employees of shrimp farms who collect from boats, on a much larger scale. In 1993, one farm maintained 31 boats in operation (DeWalt et al. 1996).

When wild PL become scarce, the industry responds. In Ecuador, for example, the lack of wild PL stimulated investment in the hatchery industry, and by 1987 there were over 100 hatcheries to overcome the seed shortage; today there are some 343 hatcheries. Increasingly, shrimp pond owners purchase PL from pathogen-free or resistant hatcheries. This limits the introduction

**Depending on the culture technique, shrimp ponds produce one to three crops per year.**

and proliferation of diseases especially in areas where non-endemic species will be cultured.

When wild PL are abundant, they are preferred because they are thought to be more hardy and possess hybrid vigor resulting in better economic returns (Villalon 1993). The yield rate of wild PL is estimated at 50 to 60 percent, while only 20 to 25 percent of hatchery seed survive. Wild PL also survive better under stress or adverse ecological conditions (Chauvin 1995). Only the strongest larvae in the wild live to the PL stage. New technologies are developing and production methods are improving the quality of hatchery-reared PL, making them hardier and thus more able to survive the stress of a culture environment.

Another advantage of wild stock is cost. Where labor is cheap, wild PL are often collected inexpensively in comparison to hatchery PL, that require constant attention in feeding and maintenance of water parameters.

PL may be placed in nursery ponds where they are cultured for 30-45 days before being placed in growout ponds. Nursery ponds allow the farmer to produce more crops per year from the growout ponds. Since the PL get a head start in the nursery ponds, the culture period in the larger growout ponds is shortened. Also, when a large pond is stocked with PL shrimp, most of the biological carrying capacity of the pond is unused. Since the growout ponds are the only ponds that can produce harvest-sized shrimp, these ponds should be cycled as frequently as possible during a growing season. This is facilitated by use of nursery ponds. The process is called "staging."

Since juvenile shrimp have a higher survival rate and are inherently easier to count than PL, the farmer has a vastly improved calculation of the shrimp biomass in the ponds throughout the culture cycle. The pond manager can feed accordingly and avoid feeding shrimp that have perished. Species classification is also much easier at the juvenile than PL stage. If unusable species of wild PL have been mistakenly purchased (a common error), the transfer operation provides a second chance to verify stock quality.

***Feed.*** Fish meal pellets are used to feed cultured shrimp. The cost of feed is a significant expense to shrimp farmers. This is particularly true as production becomes more intensive. Shrimp raised in intensive aquaculture ponds are fed about three times their harvested weight. Aquaculture utilizes about 15 percent of the world fish meal production, and it has been projected that by the year 2000 overall consumption of fish meal will rise to one quarter of world production (Beveridge et al. 1991). Research is now being conducted on reducing the protein content of feed to increase the viability of feed in water (Chamberlain, in press). This could considerably reduce the cost to farmers and reduce the impact of feed on pond effluents.

*Processing*. Typical operations harvest two, and sometimes three, crops per year. The harvest is processed, packaged and mostly shipped overseas by container, sometimes even by air. Processing can involve heading, peeling, cleaning/deveining, sorting, weighing, packing and quick freezing. Increasingly it also involves such value-added activities as butterflying, breading, or turning shrimp into finished products such as egg roles.

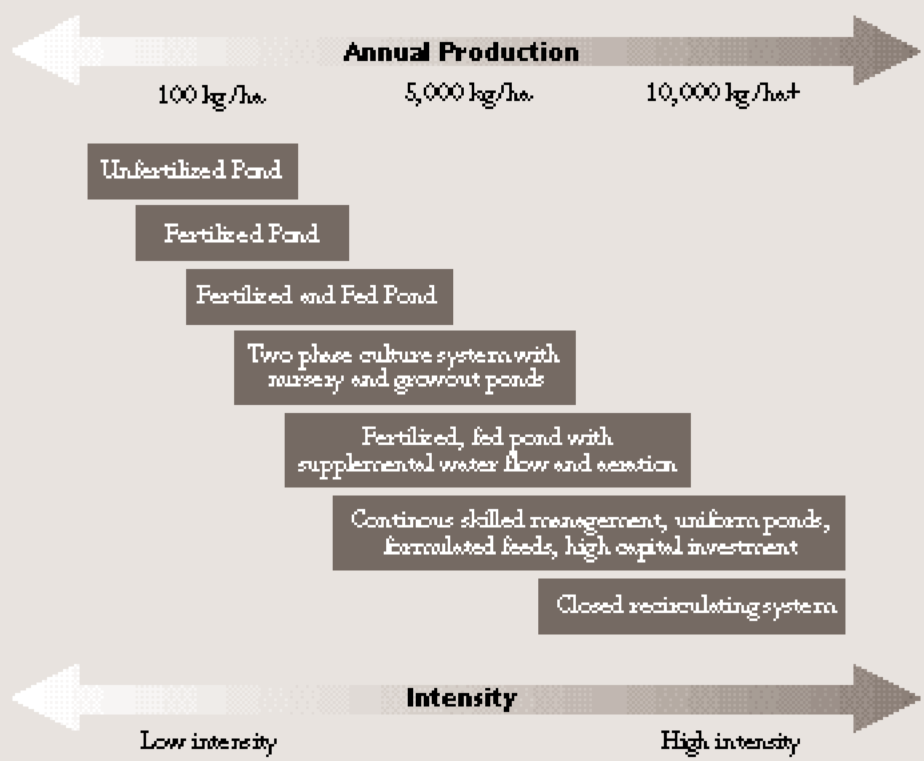
### 1.3 Culture Techniques

There are basically two types of shrimp farmers on the extremes of a continuum (Figure 1.2). The first is the farmer who depends on natural advantages to compete in the market place. These farmers use extensive methods, relying on cheap land and labor, abundant water and naturally occurring seedstock and feed. Few costly inputs are required, so the entry costs and risks to the farmer are low. Producers are dependent on the vagaries of the natural environment, such as weather fluctuations, availability of naturally occurring PL and tidal flows. Moving to the right on the continuum, capital inputs, control of growout parameters and technical skills become increasingly important. As the shrimp farmer increases control over the environment, the level of intensity associated with the culture system increases (Stickney 1994). At the extreme right of the continuum are ultra-intensive producers. They rely on advanced technology for higher survival rates and stocking densities to increase their yield per ha. Their capital investment is substantially greater, but they exercise more control over the growout environment, reducing many of the risks associated with climatic fluctuations.

In the most intensive ponds, the systems are nearly closed and water is recycled.

**Figure 1.2**

**The Intensity and Production Level Continuum of Shrimp Aquaculture**




*Source: Mauze 1995*

**Table 1.5**

**Comparison of Inputs for Three Shrimp Production Types**

| Characteristics | Extensive | Semi-extensive | Intensive |
|---|---|---|---|
| Pond size | 1-100 ha | 5-25 ha | 0.01-5 ha |
| Management | minimal attention | continuous, skilled | continuous, skilled |
| Pond shape | irregular | more regular | uniform square or rectangle |
| Stocking density (per ha) | 5,000-30,000 | 25,000-200,000 | 200,000+ |
| Water exchange rate (per day) | 5-10% (tides) | 10-20% (pump) | 30%+ (pump) |
| Water depth (m) | 0.4-1.0 | 0.7-1.5 | 1.5-2.0 |
| Shrimp feed | naturally occurring organisms (sometimes supplemented w/ organic fertilizer) | shrimp feed augments naturally occurring organisms | primarily formulated feed (less than 5% naturally occurring foods) |
| Survival rates | <60% | 60-80% | 80-90% |
| Crops/yr | 1-2 | 2-3 | 2.5-3 |
| Potential energy requirement (horsepower/ha) | 0-2 | 2-5 | 15-20 |
| Labor needs (persons/ha) | <0.15 | 0.10-0.25 | 0.5-1 |
| Disease problems | minimal | usually not a problem | can be serious |
| Production costs (US$) (per kg) | $1-$3 | $3-$5 | $5-$7 |
| Construction costs (US$) (per ha) | low | $15,000-$25,000 | $25,000-$100,000 |
| Yields (kg/ha./yr) | 50-500 | 500-5,000 | 5,000-10,000 |

*Sources: Fast 1992; Muir and Roberts 1982; Lambergts and Griffin 1992*

There are five different methods of aquaculture mentioned in the literature, ranging from extensive to ultra-intensive techniques, but the most common techniques are extensive, semi-extensive and intensive (Table 1.5). Typical extensive ponds may yield 50 to 500 kilograms of live shrimp per ha, semi-extensive from 500 to 5,000 kilograms, and intensive from 5,000 to 10,000 kilograms. Although most of the shrimp farms built in the early 1990s were semi-extensive and intensive, much of the world's production still comes from extensive systems.

Table 1.6 shows the major shrimp aquaculture producing nations, area under production and methods used. The methods used vary within a country as well as between them.

Seed and feed are the most important cost items for shrimp farming. Their combined cost ranges from 41 to 83 percent of total annual operating costs. Labor, depreciation and energy costs are also important (Shang 1992). The importance of specific inputs varies depending on the intensity of production. For example, fuel/energy costs for intensive ponds are four times greater than semi-extensive ponds, which in turn are far greater than extensive ponds which have few energy needs. Likewise, the cost of feed increases dramatically with intensity of production, accounting for as much as 40 percent of the value of the shrimp sold from intensive systems while not being a cost item in extensive systems. Table 1.7 shows the major costs for the shrimp aquaculture industry in eight sites.

***Extensive Culture***. Extensive shrimp aquaculture is primarily used by growers when there is limited infrastructure, few trained aquaculture specialists, inexpensive land and high interest rates

**Table 1.6**

**Shrimp Production and Methods Used**

| Country | Hectares in Production | Extensive | Semi-extensive | Intensive | Number of Farms | Number of Hatcheries |
|---|---|---|---|---|---|---|
| ***Asia*** | | | | | | |
| Bangladesh | 140,000 | 90% | 10% | 0% | 13,000 | 10 |
| China | 120,000 | 10% | 85% | 5% | 6,000 | 1,200 |
| India | 200,000 | 60% | 35% | 5% | 10,000 | 180 |
| Indonesia | 350,000 | 70% | 15% | 15% | 60,000 | 400 |
| Philippines | 60,000 | 40% | 40% | 20% | 1,000 | 300 |
| Taiwan | 7,000 | 0% | 50% | 50% | - | - |
| Thailand | 70,000 | 5% | 15% | 80% | 16,000 | 1,800 |
| Vietnam | 200,000 | 80% | 15% | 5% | 2,000 | 600 |
| ***Latin America*** | | | | | | |
| Belize | 600 | 0% | 90% | 10% | 6 | 1 |
| Brazil | 2,000 | 50% | 50% | 0% | - | - |
| Colombia | 2,600 | - | - | - | - | - |
| Costa Rica | 800 | 0% | 100% | 0% | 4 | 1 |
| Ecuador | 130,000 | 60% | 40% | 0% | 1,200 | 320 |
| Honduras | 12,000 | 5% | 95% | 0% | 55 | 10 |
| Mexico | 14,000 | 25% | 65% | 10% | 240 | 20 |
| Nicaragua | 4,000 | 0% | 100% | 0% | 20 | 3 |
| Peru | 3,000 | 5% | 90% | 5% | 40 | 3 |
| Venezuela | 800 | 0% | 100% | 0% | 7 | 4 |

*Source: Rosenberry 1994, 1996. The above figures are approximate only, and do not include all shrimp farming nations.*

**Table 1.7**

**Major Cost Items (Percent) of Shrimp Culture in Semi-extensive or Intensive Operations**

| Item | Ecuador | China | Japan | Indonesia | Philippines | Taiwan | Texas | Thailand |
|---|---|---|---|---|---|---|---|---|
| Postlarvae | 27 | 6 | 5 | 30 | 9 | 15 | 27 | 20 |
| Feed & fertilizer | 25 | 77 | 43 | 45 | 32 | 43 | 30 | 29 |
| Electricity & fuel | 4 | - | 12 | - | - | 5 | 3 | 7 |
| Labor | 3 | 12 | 9 | 13 | 11 | 7 | 10 | 9 |
| Maintenance | 4 | - | 11 | - | - | 2 | 2 | 3 |
| Interest | 24 | - | - | - | - | 7 | 6 | 8 |
| Depreciation | 9 | - | 3 | - | - | 3 | 9 | 18 |
| Other | 4 | 5 | 17 | 12 | 48 | 18 | 13 | 6 |

*Source: Shang 1992*

(Weidner et al. 1992). Individual and family group producers, who generally lack access to credit, are able to set up their operation with few inputs and little technical know-how. Ponds are large (20 to 100 ha), and land and construction in coastal areas are inexpensive. The most primitive form of containment for extensive aquaculture consists of a man-made "plug" or dam in a natural watercourse or channel which creates a pool or pond.

Extensive pond enclosures have an irregular shoreline, the depth is variable but shallow (0.4-1.0 meter) and there may be a considerable amount of vegetation left in the pond. Mangrove swamps or salt flats are often used for extensive pond construction. These are areas where general conditions are less than optimal for more intensive culture. Producers rely on the tides to provide food for the shrimp and a means of water exchange. Feed for the shrimp is naturally occurring; in some cases, fertilizer or manure is added to promote algal growth. Sources vary on the actual stocking densities used to classify culture as extensive — estimates range from 5,000 to 30,000 shrimp per ha. Extensive ponds are stocked with PL collected in nearby estuaries. Survival and yield are low, as are cost and risk, making this strategy attractive under certain conditions. Disease outbreak is rare due to the low stocking densities.

***Semi-Extensive Culture***. This is the preferred method in most of Latin America and the Caribbean. Semi-extensive cultivation involves stocking densities greater than the natural environment can sustain without additional inputs. Ponds are smaller (5-15 ha) than the enclosures used in extensive culture and more regular in shape, thus allowing more control over the growout environment. The depth is more uniform and the shoreline more regular. Ponds are constructed with levees or dikes and are much easier to harvest.

Costs associated with production are much higher relative to extensive production. Semi-extensive culture involves a more complex system of ponds, introduction of a nursery phase, installation of a pump system to regulate water exchange, skilled management, labor, purchased feed and seedstock, and increased use of diesel or electrical energy. Pumps exchange 10 to 30 percent of the water daily. Aerators may be used to help improve water quality and boost yields. With stocking rates of 25,000 to 200,000 juveniles per ha, farmers augment natural food in the pond with shrimp feed. Juveniles (both wild and hatchery produced) are raised in nursery ponds until they are large enough to be stocked at lower densities in growout ponds. In the areas where non-endemic species are used, such as in the Caribbean and on the east coast of South America, the dependence on hatchery raised stock is more acute, in some areas approaching 100 percent. The chances of crop failure increase with increasing intensity because of higher stocking densities, more dependence on technology, and the pressure on water quality exerted by the culture species (Stickney 1994).

***Intensive Culture***. Intensive shrimp culture aims for extremely high production rates (5,000 to 10,000 kg per ha per year), through greater inputs of operating capital, equipment, skilled labor, feed, nutrients, chemicals, drugs and antibiotics. Pond size is relatively small (0.01 to 5 ha) and stocking densities are high (more than 200,000 juveniles per ha). Other characteristics are higher number of crops per year (2-3 crops per year) and water exchange rates of 50 to 300 percent daily. In addition to high water exchange rates, mechanical aeration systems are employed for circulation and aeration of culture waters. Often, electronic water quality monitoring and other monitoring are employed to give the manager as much timely data as possible on system performance.

Intensive systems are usually coupled with their own hatcheries (or a binding contract with a hatchery) to assure a regular and reliable supply of PL shrimp for pond stocking. In addition, nursery ponds are included in the design to optimize the biomass transferred into the final growout ponds, and to consequently increase the number of crops produced per growing season.

Intensive culture requires personnel who are experts in managing shrimp production systems, since intensive ponds must be watched continually to detect potential problems. Problems can develop quickly, and if not detected and resolved rapidly, can cause catastrophic losses of the crop in a matter of hours.

# Shrimp Aquaculture and the Environment in Latin America

## 2.1 Overview

The shrimp aquaculture production process suggests a number of potential environmental impacts that can occur in a two-stage sequence. The first set of impacts occur in pond siting, design and construction; the second set of impacts occur in pond operation. The most important environmental concern of shrimp farming is the impact of pond siting on fragile ecosystems. A particular concern is the conversion of mangrove ecosystems. More extensive farms require larger areas and are therefore a greater threat to the transformation of habitat. Extensive farms are also more likely to be located on former mangrove habitat.

Environmental impacts of shrimp pond operations can include:

- Salinization of soils and saltwater intrusion into freshwater aquifers
- Land subsidence from withdrawal of groundwater
- Rerouting of water flows through pond enclosures
- Effluent discharges of shrimp feed and waste, and chemicals used for pesticide control, disinfection and growth promotion
- Mortality of by-catch from the capture of wild PL
- Introduction of new species and diseases into the ecosystem

Extensive ponds rely on wild PL and are more likely to have an impact on other aquatic animals through by-catch from the capture of wild PL. But more intensive culture is more input-intensive (e.g., energy, feed, chemicals and water) and produces greater volumes of waste. Where pond management practices are inappropriate, and environmental controls on effluent discharge and other aspects of pond operation are inadequately enforced, downstream environmental impacts will occur.

Table 2.1 provides an overview of the main environmental impacts of shrimp aquaculture development and practice.

## 2.2 Loss and Degradation of Mangrove Ecosystems

In the past 10 to 20 years, shrimp farming has significantly contributed to mangrove destruction. Globally, shrimp farming may be responsible for between 10 and 25 percent of the mangrove clearing that has taken place since 1960 (Clay 1996).

By one estimate, 765,500 ha of mangroves have been cleared for aquaculture (mostly shrimp) with 639,000 ha in Asia alone (Phillips et al. 1993). In regions where shrimp aquaculture has become important, it is estimated that 20 to 50 percent of recent mangrove destruction is due to shrimp aquaculture (NACA 1994). Between 1969-1995, mangrove land in Ecuador declined from 203,625 ha to 149, 570 ha, a loss of 27 percent (Icaza 1997). The major cause of damage to mangrove ecosystems is shrimp farming (Bodero and Robadue 1995).

One study estimated that in the Gulf of Fonseca region, between 1973 and 1992, mangrove land declined from 30,697 ha to 23,937 ha, a decline of 22 percent (DeWalt et al. 1996). During that time approximately 4,307 ha of shrimp farms were developed in areas once covered by mangroves, representing 64 percent of total mangrove loss (DeWalt et al. 1996). Another study found only a 6.5 percent reduction in Gulf of Fonseca mangrove forests over the period of 1987-1994 (Oyuela 1995). This reduction is attributable to several activities in addition to shrimp farming;

**The human pressures on mangrove ecosystems are significant worldwide.**

**Table 2.1**

**Overview of Potential Environmental Impacts of Shrimp Pond Construction and Operation**

| Activity | Potential Impact | Potential Results |
|---|---|---|
| • Construction of shrimp ponds, canals and access roads<br>• Dredging and deposition of dredge materials | • Destruction or degradation of coastal aquatic ecosystems (wetlands, saltwater marshes, mangroves and mud flats)<br>• Alteration of estuarine flow and local hydrology | • Loss of habitat and reduced ecosystem productivity and resilience<br>• Loss of wild stocks of shrimp, waterfowl and other estuarine-dependent organisms<br>• Desertification of local area<br>• Loss of nutrient recycling<br>• Alteration of microclimate<br>• Increased soil erosion and sedimentation<br>• Increased beach erosion<br>• Increased natural hazards (storm flooding, erosion)<br>• Salinization of underground water table by intrusion and percolation |
| • Withdrawal of groundwater | • Saltwater intrusion and salinization of freshwater aquifers | • Degradation of potable and agricultural water supply<br>• Land subsidence |
| • Estuarine water intakes | • Removal of juveniles and larvae of fish and shellfish | • Lower catches for subsistence fishers and coastal user groups<br>• Loss of seedstock for shrimp farmers<br>• Reduced fisheries stock |
| • Effluent discharges from ponds | • Eutrophication of adjacent waters from organic matter and inorganic fertilizers in shrimp ponds<br>• Chemical contamination of coastal waters through use of drugs/antibiotics, chemicals for pest control, growth promotion, and disinfection | • Wildlife disease and mortality in adjacent aquatic systems<br>• Shift in benthic biota and species diversity<br>• Reduced productivity of nearby shrimp ponds from contaminated water<br>• Human health effects<br>• Proliferation of antibiotic-resistant pathogens |
| • Overfishing of postlarvae and egg-laden female shrimp | • Declining wild shrimp population along coastline<br>• Bycatch | • Lower catches for subsistence fishers and coastal user groups<br>• Loss of seed stock for shrimp farmers<br>• Reduced fisheries stock |
| • Introduction of exotic species | • Proliferation of pathogens, predators and parasites along with non-endemic species in the coastal environment | • Loss in shrimp aquaculture productivity<br>• Loss of aquatic life or shift in species composition and diversity |
| • Spreading of viral and bacterial diseases through movement of postlarvae | • Introduction of disease to existing farms and to local ecosystems<br>• Loss in shrimp aquaculture productivity | • Loss of aquatic life or shift in species composition and diversity |

*Source: Clay 1996*

including cutting for firewood, salt production, building materials and tanning.

Mangrove forests are extremely productive, yet are fragile ecosystems that perform many important ecological functions in coastal areas. To understand the ecological role that mangroves play with respect to shrimp, it is important to understand the shrimp life cycle. Mating occurs in the open seas, and 15 to 20 days later the females spawn approximately 500,000 to one million eggs directly into the sea. Each larva fends for itself as it develops through some 12 stages of nauplius, protozoa and mysis before metamorphosing into a postlarva (Bailey-Brock and Moss 1992). In these stages of rapid growth, the shrimp migrate from the open sea to the estuaries. Once shrimp reach the postlarval state, they enter the estuaries seeking shallower, often fresher waters where they find abundant food. In the nursery grounds, protected and nourished by nutrient-rich mangrove forests, the shrimp develop into juveniles. With approaching maturity, they return once again to the open sea for mating. The role played by the mangrove ecosystem in the life cycle of shrimp is believed to be the most valuable service provided by Ecuador's mangroves (Twilley et al. 1993). The destruction of mangroves for shrimp farming affects the availability of shrimp larvae, which ironically is vital to the Latin American shrimp aquaculture industry that relies significantly on wild PL for seed.

Mangroves are also the nursery grounds for many other species of commercially valuable fish and are home to many other species (e.g., plants, birds, mammals and amphibians). Chua (1993a, p. 202) reports that "large-scale mangrove clearing endangers the survival of some endemic species; it destroys nursery grounds and other critical habitats for waterfowl and many aquatic animals including shrimp and fish; and affects the food chain of the estuarine ecosystems and the habitats of mangrove terrestrial wildlife."
The result may be the destruction of an entire ecosystem (Pullin 1993).

Other ecological functions of mangroves include nutrient recycling and maintenance of water quality. Mangroves also function as a natural barrier against storms and heavy winds. The forests trap sediment and the roots secure the land, preventing it from being washed away during storm surges. Removal causes coastal erosion, saline intrusion and associated agricultural damage, and changes in patterns of sedimentation and shoreline configuration (Phillips et al. 1993).

The construction of shrimp ponds, canals, embankments, access roads, and water pump systems in or near former mangrove areas changes or restricts natural movements of water, and can affect uncut mangroves near shrimp ponds because they are extremely sensitive to changes in water quality and circulation. The mangrove ecosystem is an open one, interacting with other ecosystems and extending in influence far beyond the intertidal zone.

It is increasingly recognized that mangroves do not make good sites for semi-extensive and intensive shrimp farming because of acid sulfate soils, physical isolation (e.g., lack of communications and infrastructure), the expense of clearing mangroves and seasonally unsuitable salinity conditions (Stevenson and Burbridge 1997). Clark (1991) finds that there is a high rate of failure for pond systems located in converted mangrove areas. However, the lure of short-run profits continues to be a powerful incentive to the marginal shrimp farmer to convert mangrove forests to shrimp ponds.

While mangroves have been cut to make way for ponds, and this is the most serious impact, there may be other ways that shrimp farming impacts mangroves. These interactions are not well studied. One class of potential impacts is associated with hydrological changes. These are:

- Salinity changes caused by isolation of the mangrove from brackish water, freshwater flooding or discharge of saline pond water into low salinity mangrove areas.
- Changes to estuarine flow and local hydrology caused by isolation from brackish water and normal tidal inundation by construction of ponds, canals and access roads.

Another class of potential impacts of existing shrimp farms on mangrove ecosystems involves effluent discharge. These are:

- Excessive sedimentation of mangroves
- Eutrophication
- Release of potentially harmful chemical contaminants from farms affecting mangrove fauna
- Disease spread from shrimp ponds to mangrove fauna.

**Table 2.2**

**Matrix of Mangrove Goods and Services**

| | Location of Goods and Services: On-Site | Location of Goods and Services: Off-Site |
|---|---|---|
| Marketed | Usually included in economic analysis, e.g., poles, charcoal, woodchips, crabs | May be included in economic analysis, e.g., fish or shellfish caught in adjacent waters |
| Nonmarketed | Seldom included in economic analysis, e.g., medicinal uses, domestic fuel wood, nurseries for juvenile fish, feeding ground for estuarine fish, biodiversity attributes, education, research | Usually ignored, e.g., nutrient flows to estuaries, buffer to storm damage |

*Source: Dixon 1991*

## 2.3 Mangrove Values and Alternative Uses

The economic impacts of shrimp aquaculture on mangroves have been thoroughly studied. Table 2.2 summarizes the various economic values of mangroves. The table illustrates that many of the economic values associated with mangroves are nonmarket and off-site, and are not easily quantified. The result is the undervaluing of mangrove resources, leading to their more rapid conversion and loss.

Interest in mangrove conservation has resulted in an increase in scientific literature concerning the value of mangrove forests. The value of a mangrove forest is site specific and highly variable. Dixon (1989), for example, estimates that the value of mangroves ranges from US$ 25 per ha per year to over US$ 1,000 per ha per year, depending upon the site and the extent of goods and services included in the analysis. In general terms, economic studies show that:

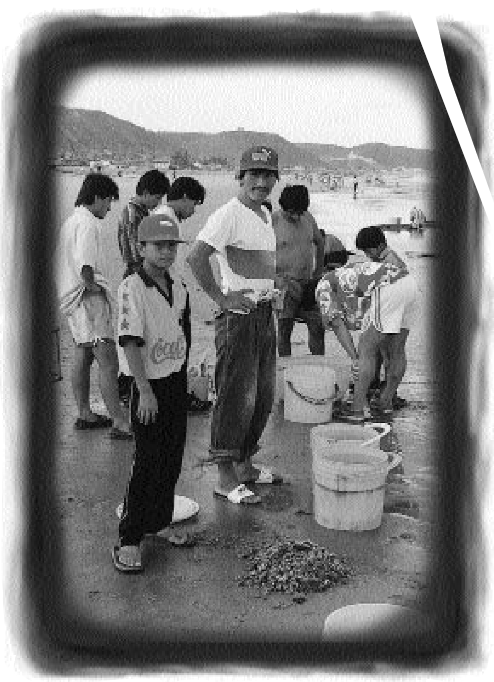
- The on-site values of directly harvested products, such as fish and wood for charcoal, construction and tannin, often tend to be quite low relative to the total mangrove value.
- The off-site values for fisheries can be high, although such estimates involve significant uncertainty. The role of mangrove in water quality control is also poorly understood, but replacing mangroves with other forms of water treatment can be extremely expensive. The off-site value of coastal protection can also be very high. The highest value areas are those closest to the coastline, near coastal populations and urban development.
- On-site, nonmarketed values are not well documented. However, some studies have found that the nonmarket value of mangroves as a working ecosystem is significant relative to alternative uses of the land (Kapetsky 1986; Aguero 1994).

Other studies have compared the costs and benefits of different uses of mangrove forests (for Latin America, see Gammage 1997; Gonzalez 1993). Results are variable, yet it is possible to make some general statements concerning mangrove use based on economic analysis:

- In general, extensive farming practices make poor use of land and mangrove resources compared to other uses.
- Shrimp culture in mangrove forests tends to make economic sense from the perspective of society only in marginal, low value areas that are shown to be suitable for shrimp culture (e.g., good water supply, soils), provided that the risk of failure can be reduced by provision of good quality inputs and suitable management.
- Sustainable management of activities affecting the quality of mangrove areas significantly improves the long-term benefits to society of mangrove uses.
- "High value" mangrove areas with high on-site and off-site nonmarket value should not be converted.

### 2.4 Declining Wild Shrimp Population and By-Catch in the Harvest of Wild PL

Since most shrimp farmers prefer wild PL because they perform better in ponds than hatchery-produced PL, the pressure on wild supplies is intense. By 1989, the annual demand for PL in Ecuador was about 16 billion; about 4 billion was supplied by hatcheries (Hirono and van Ejs 1990). Wild PLs are collected by a few thousand full-time harvesters and up to 100,000 part-time harvesters (Chauvin 1995; Olsen and Coello 1995). Hand-thrown nets are used to collect the PL; when full, the nets are dragged onto shore and the unwanted species are discarded (Parks and Bonifaz 1994). Southgate and Whitaker (1992) speculated that the excessive collection of PL for shrimp farms and egg-laden female shrimp for hatcheries is a cause of declining shrimp populations along the coastline. The same problem is thought to exist in the Gulf of Fonseca.



**Wild capture of PL for shrimp farms is an important source of income and employment in many coastal regions.**

Artisanal capture of shrimp also results in the loss of many other species through by-catch. One study in Honduras cites a ratio of 1:5 in target-to-ancillary catch (Vergne et al. 1993). Another study cites a ratio of shrimp to by-catch of 4:1 (Curry 1995). The by-catch is destroyed because larvae fishers dispose of all undesired species on dry land. The full ecological effects of artisanal capture of shrimp and by-catch are thought to be important but have yet to be fully assessed.

Larval fishers in Ecuador, Honduras and other Latin American countries have received training in techniques to reduce by-catch and to separate and return by-catch alive to the estuary.

### 2.5 Water Use Impacts

The demands of shrimp aquaculture for large volumes of unpolluted water are central to the sustained profitability of shrimp farm operations. Extensive shrimp pond systems rely on the ebb and flow of tides to change the water. Semi-extensive and intensive ponds control water exchange with pumping. Twilley (1989) estimates that the exchange of water for 50,000 ha of shrimp ponds in the Guayas Province, Ecuador, is equivalent to half the peak freshwater discharge of the Guayas River during the wet season. More intensive production systems require a greater flow of water. Each metric ton of shrimp produced in intensive aquaculture farms requires about 50 to 60 million liters of water (Gujja and Finger-Stich 1995). Water can be obtained by pumping it in from the ocean at great cost, pumping it from nearby rivers or estuaries, or pumping it from underground. Many farms use a combination of these sources to obtain water.

The environmental impacts of water use to fill shrimp ponds can include saltwater intrusion into freshwater aquifers, salinization of soils and land subsidence caused by pumping water from shallow underground deposits (Phillips et al. 1993). Snedaker (1986) observed that drawing water to shrimp ponds can cause leaching and drainage of pesticides and herbicides from active farmlands into nearshore waters. These problems have been experienced in Asia, but there is little evidence of them in Latin America. Twilley (1989), however, suggests that pumping of water into shrimp ponds may have increased the salinity of the Guayas River estuary potentially impacting fisheries and living organisms.

### 2.6 Water Contamination

Pond effluent discharged by shrimp farmers can contain three main types of contaminants: nutrients, drugs and antibiotics, and chemicals. The total amount of contaminants from pond and hatchery water discharges increase with the intensity of operations.

As farms are increasingly concentrated, one farm's contaminated effluent becomes the source of water uptake for the neighboring farm. The result can be rapidly declining water quality and the spread of disease. There is a growing body of evidence that environmental impacts related to shrimp aquaculture (e.g., water contamination from neighboring farms) play a significant role in outbreaks of disease now affecting shrimp ponds in Asia and Latin America (Phillips et al. 1993). Stress resulting from exposure to poor environmental conditions weakens shrimp and makes them more susceptible to disease (Boyd and Musig 1992). Shell (1993) found that poor water quality, resulting primarily from high levels of feeding, has emerged as the most important enemy of shrimp farming worldwide. In an analysis of Nicaragua's aquaculture sector, Jensen et al. (1995) found that pollution from shrimp farming is an important risk to the industry. The authors concluded that if the Estero Real is overdeveloped with shrimp farms, shrimp pond effluents could pollute the estuary and literally "kill the golden goose" (Jensen et al. 1995, p. 57).

***Nutrients in Pond Effluents***. Nutrients, including wastes and fecal matter, uneaten food and chemical fertilizers, are a major effluent and can result in local hypernutrification and regional eutrophication. Locally (in waters adjacent to a shrimp pond), nutrient contaminants released accumulate in nearby sediments. This benthic deposition can lead to a build-up of anoxic sediments, increased levels of hydrogen sulfide, depletion of oxygen at the bottom and increased bacterial populations (Chua et al. 1989). The result is a change in the nutrient cycle as the soluble waste in the water column alters the natural composition of macro- and micro-nutrients (Chua et al. 1989).

Regionally, the nutrient effluent from shrimp farms can stimulate algal blooms which can cause fish kills through toxin production or by causing anoxic conditions (Maclean 1993). Weston (1991) reports that certain species of phytoplankton can kill fish and shellfish by physical damage to sensitive tissues, clogging of gills or production of toxins. Massive algae blooms remove oxygen from the water and literally suffocate other species as these blooms dominate coastal waters.

Stanley (forthcoming) states that effluents from shrimp pond drainage canals are causing eutrophication and reducing water quality along the San Bernardo, Pedregal, and Jagua estuaries of southern Honduras. Stanley further notes that a report (COHECO 1994) concluded that the high levels of phosphorous contaminants and organic matter in estuarine water indicated that all new shrimp farms face "high economic risk."

In contrast, the Honduras Pond Dynamics/ Aquaculture Collaborative Research Support Program (CRSP), that has generated the only known long-term database on the impact of shrimp farming on estuarine water quality, finds no long-term trend in eutrophication in either riverine or embayment estuaries in southern Honduras between 1993-1997. CRSP is a collaborative effort of universities, the private sector and the public sector. The goal of the effort is to provide a scientific basis for estuarine management and sustainable shrimp culture in Honduras.
An extensive bibliography documents CRSP water quality studies in the Gulf of Fonseca, Honduras (Green et al. 1997; Green et al. 1997a; Teichert-Coddington (in press); Teichert-Coddington 1995; Teichert-Coddington and Rodriguez 1995; Teichert-Coddington and Rodriguez 1995a; Teichert-Coddington et al. 1997; Teichert-Coddington et al. 1997a; Teichert-Coddington et al. 1996).

***Drugs and Antibiotics in Pond Effluents*.** Antibiotics and other drugs used to control diseases are used in aquaculture, especially in hatcheries and in semi-extensive and intensive aquaculture operations (Chua 1993b). Due to the abuse of these drugs in many countries, there is now cause for concern that some new and very aggressive fish pathogens are emerging (Pullin 1993). Chua et al. (1989) list three primary environmental concerns associated with the overuse of antibiotics:

1. The continued use of antibiotics and/or their persistence in sediments could lead to the proliferation of antibiotic-resistant pathogens and this may complicate disease treatments.
2. Antibiotics are transferred to wild fish in the vicinity of farms using medicated feeds, and shellfish accumulate antibiotics in their tissues.
3. The presence of antibiotics in bottom sediments may affect natural bacterial decomposition, and hence, influence the ecological structure of the benthic microbial communities.

Drugs and antibiotics are not as widely used in Latin America as they are in Asia, where pond operations are more intensive. The severity of environmental impacts associated with their use in Latin America is not documented, but is not generally considered a significant concern.

***Chemicals in Pond Effluents***. Chemicals are the third contaminant contained in the effluent discharged from shrimp ponds. Chemicals are used in aquaculture for disease prevention, pest control, disinfection, anesthesia and growth promotion. Products used include disinfectants, soil and water conditioners, pesticides and feed additives. These chemicals, when discharged into nearby waters, may have lethal or sublethal effects on non-target organisms in the environment (Pillay 1992). For example, pesticides used to eradicate predators can also kill crustaceans living in the general vicinity of the farm (Chua et al. 1989).

The use of chemicals can also pose a health hazard to workers, nearby residents and consumers. Concerns have been expressed about shrimp being contaminated with mercury, cadmium, organochloride and organo-phosphate pesticides, dioxins and antibiotics (Barg 1992).

### 2.7 Introduction of Non-Endemic Species

Whether exotic or native, the introduction of species into an area can have a detrimental impact on biodiversity. Despite farmers' best efforts, escapes from fish farms usually occur, especially from semi-extensive and extensive aquaculture operations (Pullin 1993). The transfer of species for aquaculture can lead to the introduction of pathogens, parasites and predators where they had not previously existed (Pullin 1993).

It is well known that in both Latin America and Asia there has been widespread transfer of shrimp within and between countries. Shrimp have been introduced (transported and released outside of the present species range) and transferred (transported and released within the present species range) for shrimp farming purposes. Introductions are generally irreversible, the result is unpredictable. The end result is the potential loss of genetic diversity which can negatively affect a species' present condition and, more importantly, potentially affect the species' ability to adapt to a changing environment (National Research Council 1992). Introduced species often compete with native species, eliminating, or interbreeding with them. A serious concern is the potential for overwhelming the wild gene pool with a more restricted gene pool of hatchery stock through repeated releases (National Research Council 1992). Many scientists believe that this would lead to a weakening of the wild genetic stock.

# Economic Development, Environmental Degradation and the Sustainability of Shrimp Aquaculture

The long-run viability of the shrimp aquaculture industry requires both prudent management of the environmental impacts of shrimp aquaculture and ecosystem management. The cumulative impacts of multiple human activities in a watershed can lead to the long-run degradation of the natural resource base upon which shrimp farming depends.

With rapid population and economic growth in coastal areas of Latin America, it becomes increasingly difficult to maintain readily accessible water of adequate quality and quantity, and dependable sources of wild capture seed shrimp. In Latin America, nearly 70 percent of the population now lives in cities, and 60 out of 77 of the region's largest cities are coastal (Hinrichsen 1997). Water and soil quality problems can be associated with industrial, residential, agricultural and infrastructure development. Water contaminants may include pesticides, silt, fecal coliform, petroleum hydrocarbons, organic chemicals and heavy metals. Water contamination, mangrove conversion and overfishing affect PL abundance.

In general, the impacts of human activities on shrimp aquaculture are not well documented. Linking human activities and impacts is difficult because ecosystems are complex, and there are usually multiple sources of diffuse impacts occurring over a long time frame and extended geographic area. Environmental change is brought by the cumulative effects of the overall development process in a given locale. Lack of monitoring data and natural random shocks to ecosystems add uncertainty.

The Guayas estuary is an example of the balance between economic growth and shrimp farming. The estuary is the site of approximately 110,000 ha of shrimp ponds and the source of about 65 percent of farmed shrimp in Ecuador; these shrimp ponds are dependent on the quality and steady flow of water in the estuary system. At the same time the region is home to 45 percent of the population. Rapid urban growth in a concentrated area with inadequate sanitation, industrial growth and effluents, gas and petroleum exploration and drilling, and nearby banana, coffee and cacao cultivation, all draw upon the environmental services of the Guayas estuary. To date little has been done to characterize and measure change in the waters and coastal environments which are so critical to the Ecuadorian economy. Little is known about

progressive changes in water quality and sources and concentrations of contaminants. The Environmental Advisory Commission (CAAM), with funding from the World Bank, is launching a comprehensive study of the environmental situation in the gulf area as part of a larger national project on environmental protection (CAAM 1996).

Shrimp aquaculture in the Gulf of Fonseca region, that encompasses shrimp farming in Honduras, Nicaragua and El Salvador, faces similar challenges. In the El Salvador part of the Gulf of Fonseca, Gammage (1997) observed that chemical runoff and siltation threaten estuaries and mangroves, and the fish and shrimp production that they yield. In contrast, the CRSP water quality monitoring project in estuaries of the shrimp producing regions of Honduras has not found that water quality conditions are a threat to shrimp aquaculture or are diminishing.

Jensen et al. (1997) reported that potential pesticide contamination is a constraint to development of Nicaraguan shrimp farming. There are plans to

**Manufacture of charcoal from mangrove and other forests is an important source of income and energy in developing nations.**

develop 14,000 ha for cotton in the Estero Real area. Cotton is a chemical-intensive agricultural crop. Concerns about increased pesticide use in the same watershed where shrimp farming is practiced have been raised (Jensen et al. 1997). Peanut production now covers 24,000 ha and also involves heavy use of pesticides that are toxic to shrimp (Jensen et al. 1997).

Conversion of mangroves destroys shrimp nursery grounds, and can affect water quality, water flow and entire estuarine ecosystems. While knowledge of mangrove area in any country is important for policymaking and resource management, data on mangrove area and losses are extremely poor, a fact recognized in the recently compiled World Mangrove Atlas (Spalding et al. 1997). Shrimp aquaculture is an important cause of mangrove conversion in Latin America, particularly in specific locations. Overall, however, other human activities are a more serious source of mangrove loss. In Latin America, mangroves have been cut for fuel wood, commercial lumber, charcoal and for extraction of tannin from bark; cleared for conversion to agriculture, salt production, coastal industrialization, urbanization and residential development; and degraded or destroyed as a result of changes to water flow and quality (e.g., from water diversion and damns, and siltation from highland agriculture) (Suman 1994; Gujja and Finger-Stich 1995).

The declining environmental condition manifests itself in declining shrimp pond productivity, increased incidence of shrimp disease and pond failure. The incidence of disease is a result of both reductions in water quality, and poor pond siting and shrimp farm practice. The majority of shrimp aquaculture producing countries report increasing problems with disease and water quality. In 1988 the Taiwan shrimp industry collapsed due to disease and it has never fully recovered (Wildman et al. 1992).

Disease has been a serious threat to shrimp farming in Ecuador. In 1989 Ecuadorian shrimp farmers experienced what was named the "Seagull Syndrome." Yields fell suddenly and seagulls were seen preying on the weakened shrimp in the ponds. The collaboration of an international group of researchers and scientists isolated the problem as a bacteria of the genus Vibrio. Antibiotics introduced with feed rations proved effective in eliminating the bacteria.

In 1992 pond survival in Ecuador again dropped off dramatically and these massive mortalities were described as the "Taura Syndrome," due to its prevalence in the areas surrounding the Taura River basin. Research showed that the occurrence of these shrimp mortalities coincided with a marked increase in the use of fungicides to combat sigatoka negra, black leaf spot disease of bananas; but conclusive experimental proof demonstrating the fungicide caused the Taura Syndrome does not exist. Scientists have not been able to reproduce the syndrome. At its peak, some 15,000 ha of shrimp ponds were idled to allow soils and water quality conditions to return to normal between crops because of the Taura Syndrome (Jensen et al. 1995); annual losses have been estimated to exceed US$ 100 million (Stein et al. 1995). One strategy to avoid disease problems is to overstock with wild seed and harvest ponds early, which yields smaller shrimp.

The Taura Syndrome disease is readily spread by many vectors, including birds and the common flying insect known as water boatman (corrixidae), and has now been documented throughout Latin America as well as in the United States. In June 1996 South Carolina Natural Resources Department officials estimated that as much as half of the commercial Pacific white shrimp crop reared in four South Carolina shrimp farms could be lost to an outbreak of the Taura Syndrome virus.

Disease control is critical to the sustainable development of the aquaculture industry. In July 1997 public hearings were held in the United States following completion of the National Marine Fisheries Service / Joint Subcommittee on Aquaculture report on "An Evaluation of Shrimp Virus Impacts on Cultured Shrimp and on Wild Shrimp Populations in the Gulf of Mexico and Southeastern U.S. Atlantic Coastal Waters." Ecological risk assessment of shrimp viruses is seen as an important area for further work on disease control.

In summary, because of the many economic activities in coastal areas and watersheds with cumulative impacts on environmental quality and shrimp aquaculture, the development of aquaculture needs to be seen within an integrated coastal management (ICM) context. ICM is cross-sectoral and involves consideration of interacting activities and the closely coupled socio / ecological processes. ICM strives to adopt an ecosystem-based approach to planning and decisionmaking in broadly defined coastal watersheds and the adjoining coastal ocean. ICM came into common use worldwide in the last 25 years with the recognition that the misuse and overuse of coastlines and estuaries requires a fresh approach to planning and management.

Integrated management considers not only shrimp aquaculture, but other relevant sectors in a given locale — typically including fisheries, agriculture, forestry and tourism — and the needs and aspirations of the communities that will be most directly affected. Site-specific plans can be prepared for any coastal area and shrimp farming operations, and can be integrated within a larger development and resource management scheme. Elements of an integrated approach include environmental management and planning on an estuary or watershed basis with appropriate environmental regulations and incentives, such as zoning to control coastal development, clean technologies in industrial sectors, public sanitation services and sustainable agricultural practices.

# Socioeconomic Impacts of Shrimp Aquaculture

Shrimp aquaculture impacts do not stop at the biophysical environment, but extend throughout society. Experience shows that social impacts vary considerably depending on the form of aquaculture and the policies, if any, that guide its development (Pollnac 1991; Bailey 1988; Meltzoff and LiPuma 1986). In most instances, however, shrimp aquaculture has important direct and indirect social and economic impacts on the lives of people who live in areas where it is undertaken.

Shrimp aquaculture brings much-needed foreign earnings from exported shrimp. But this positive impact must be weighed against other social and economic impacts. Shrimp aquaculture can lead to losses in traditional livelihoods, marginalization of local residents and the erosion of their resource rights. Large-scale aquaculture enterprises frequently displace small-scale fishers and locals, putting additional environmental strain on nearby natural resources, and causing conflicts between displaced and other marginal people in the area. Furthermore, the conversion of mangroves and transformation of estuaries that has occurred in Ecuador and Honduras, for example, is thought to be associated with the decline or collapse of some estuarine fisheries. When this happens conflicts between shrimp farmers and other user groups can be intense.

Chua et al. (1989) observed that tropical shrimp culture has been found to have largely negative social consequences because its benefits in terms of profits or protein supply simply do not favor the coastal residents. Few of the benefits of large-scale shrimp culture are returned to the people living in coastal areas. Once the pond is constructed, labor needs are limited. Farm employment ranges from 0.1 to 1.0 persons per ha. While many jobs have been created through the growth of the shrimp industry, the majority are low paying and seasonal. Due to the nature of shrimp aquaculture, resource-poor individuals are often excluded because of lack of capital, lack of skills, and the inability to acquire and process information related to project siting and obtaining concessions. By transforming estuaries and reducing access, shrimp farming can reduce the availability of high-protein food, fuel and building materials to the poorer segment of society.

There are exceptions. In areas where lands are already held in large estates, and where relatively little labor is used or where previous economic production systems collapsed, the conversion of large areas to shrimp farms actually creates a new source of much-needed employment for rural, unemployed workers. Likewise, small farmers

who have title to their land and who choose to produce shrimp can often make good money doing so. In Ecuador, the fishery for wild PL shrimp has provided thousands of people with a new source of income.

However, where publicly-owned open waters and mangroves change from commonly used areas to restricted-access areas for aquaculture, or where highly populated farming areas are converted from agricultural production systems to less labor intensive shrimp production, the social and economic consequences of shrimp farming can be considerable (Gujja and Finger-Stich 1995). The major adverse social and economic impacts of shrimp aquaculture are identified in Table 4.1. The social and economic impacts and conflicts of shrimp aquaculture are illustrated in the Gulf of Fonseca, which is shared by Honduras, Nicaragua and El Salvador. The Gulf of Fonseca is a unique natural resource, rich in biodiversity with large stands of mangroves, lagoons and areas of dry tropical forest. Warm temperatures, extensive tidal flats and salt flats (playones) make this area

**Artisanal fisheries are a traditional use of estuaries and mangrove wetlands.**

**Table 4.1**

**Overview of Potential Social and Economic Impacts of Shrimp Pond Construction and Production**

| Action | Impact | Result |
|---|---|---|
| • Shrimp products are exported | • Most benefits do not occur locally | • No protein benefit from shrimp or improvement in local diet<br>• "Flight" of aquaculture earnings to foreign banks<br>• Local communities do not receive employment or improved infrastructure |
| • Government failure to adequately manage publicly-owned coastal wetlands | • Claims outstrip government's capacity to manage resources or even ensure claims are honored | • Widespread encroachment on public-sector property leads to displacement of artisanal fishers and others dependent on fisheries resources, and land use conflicts |
| • Excessive collection of PL and egg-laden female shrimp | • Declining shrimp population along coastline<br>• By-catch | • Loss of income for fishers<br>• Reduction of natural shrimp and fish stocks, loss of recruitment stocks |
| • Clearing mangroves | • Loss of natural mangrove products (i.e., fuel wood, poles, fish and game, etc.)<br>• Destruction of shrimp and fish nursery grounds | • Loss of income and subsistence products for local population<br>• Lower productivity, lack of seedstock |
| • Construction of shrimp ponds in former mangrove areas | • Displacement of rural coastal communities | • Loss of income by those who traditionally depend on mangrove resources |

*Source: Clay 1996*

conducive to extensive and semi-extensive shrimp aquaculture production (DeWalt et al. 1996). Plains around the gulf extend 25 miles inland, where they meet the volcanic highlands. The plains are primarily used for the production of melons and other crops, and the dry forest areas support cattle production. Table 4.2 shows the changes in land use and vegetation cover in the Gulf of Fonseca from 1973 (considered to be the year prior to the development of the first shrimp farm) to 1992.

In the early 1990s, Honduras emerged as the leading shrimp culture industry in Central America (Weidner 1992). In 1993 shrimp aquaculture exports generated about US$ 60 million in foreign exchange, making cultured shrimp the third largest export after bananas and coffee. The area occupied by shrimp increased from 1,064 ha to 11,515 ha between 1982 and 1992. During the same period, mangrove land decreased from 28,776 to 23,937 ha, a decline of 17 percent, most of which is attributed to shrimp aquaculture (DeWalt et al. 1996). In 1996 the government, together with the Honduran National Association of Shrimp Farmers (ANDAH), introduced a moratorium on expansion of shrimp farms in the country (Varela 1996).

depending on the source. They employ a broad range of strategies to make a living: from cast-net harvesting of shrimp and finfish in lagoons and tidal pools, to gathering shellfish and crabs in the mangroves. Conflicts over use of the gulf's resources have often resulted in violence. Three fishers have been killed and many have been harassed and threatened by shrimp farm security guards (DeWalt et al. 1996). Fishers have blocked roads and burned boats, motors and buildings connected to shrimp farm operations (DeWalt et al. 1996).

**Table 4.2**

**Land Use and Vegetation Cover for the Gulf of Fonseca**

| Category | 1973 | 1982 | 1992 |
|---|---|---|---|
| Agriculture/grazing | 84,570 | 85,787 | 83,782 |
| Salt flats | 46,569 | 44,585 | 40,956 |
| Mangrove | 30,697 | 28,776 | 23,937 |
| Shrimp farms | - | 1,064 | 11,515 |
| Salt producers | 957 | 1,122 | 1,325 |
| Population centers | 848 | 1,542 | 1,914 |
| Total | 163,641 | 162,876 | 163,429 |

*Source: DeWalt et al. 1996*

Many different interest groups vie for control of the resources in the region and lay the blame for the environmental and economic problems they experience on each other. The rapid and chaotic growth in shrimp farming means that land once open to public use for fishing and cutting of firewood and bark for tannin production is being lost to private use (Vergne et al. 1993). Estuary fishers and the communities in which they live have been the most vocal and demonstrative opponents of the shrimp farms. Their primary complaint is that they are denied access to areas which they have used for their livelihoods for generations. Estimates of the number of full- and part-time estuary fishers range from 2,000 to 5,000,

There is also a conflict between larvae collectors and estuary fishers and communities. The latter two groups accuse larvae collectors of overexploitation, reducing the amount of shrimp and fish available in the estuaries. Some communities have gone as far as posting signs prohibiting larvae collectors from entering their communities.

# Underlying Sources of Environmental and Social Problems in Latin American Shrimp Aquaculture

Improved management of the environmental and social impacts of shrimp aquaculture must address the underlying causes of environmental and social problems if it is to succeed in the long run. The causes — or the symptoms — of the problems include:

- Laws without workable implementation guidance and mechanisms
- Non-transparent decisionmaking processes and management policies
- Sectoral government management, rather than integrated, ecosystem management
- Improper siting and land/water use planning
- Inappropriate technology
- Inadequate assessment, monitoring and corrective measures

Most of these symptoms can be traced to the fundamental or underlying causes that include:

- Lack of public sector institutional capacity
- Public ownership of coastal resources
- Environmental externalities
- Inadequate information

### 5.1 Lack of Institutional Capacity

World experience in developed and developing nations alike, demonstrates that the greatest constraint to sustainable shrimp aquaculture is limited institutional capacity and ability to effectively practice ICM. The failure of institutions to adequately regulate the rapid growth of the shrimp aquaculture industry has had significant consequences on communities, the environment, and on the ecosystem qualities essential to sustainable aquaculture. Typical institutional obstacles to ICM throughout the region include:

- Planning and management of human activities is organized and justified sector by sector, and cannot respond to the complex interrelationships within coastal regions
- Weak leadership and policy direction at many levels
- Lack of trained staff with the skills needed to effectively manage institutions
- Overlapping jurisdictions and interagency conflicts
- Centralized decisionmaking, often without consultation with stakeholders at the local level where the impact of the decisions have their greatest effect
- Inadequate funds and/or capabilities to implement existing procedures and regulations

• Lack of public support for management initiatives
• Lack of procedures and laws for public information disclosure on governmental decisions

In most Latin American shrimp farming nations, a blurred mix of government agency jurisdictions with respect to shrimp aquaculture and use of coastal lands is a key issue (Robadue et al. 1994; Perez and Robadue 1989). Most countries take a piecemeal approach to regulating aquaculture. Individual laws attempt to address specific problems in isolation, but there is rarely any attempt to develop a comprehensive regulatory structure to address the problems posed by the industry. In Ecuador, for example, the subsecretary of fisheries has jurisdiction over the harvesting of bioaquatic species and the operation of shrimp farms. The Navy controls construction in the narrow (8 meter) beach and bay zone above mean high water. The National Water Resources Institute manages the use of water where the fisheries exist, the National Public Works Agency addresses contamination problems in fresh and

**Conservation of sustainable use of mangrove ecosystems is an important management challenge.**

coastal waters, and the National Forestry Institute is responsible for tree harvest and management.

Regulations frequently fall between ministries (e.g., agriculture, forestry, fisheries, commerce, etc.). This often leads to contradictory messages or duplicated efforts. In most countries there are conflicts concerning not only which agencies are responsible for enforcing which regulations, but also whether local, state or national governments have ultimate authority over the issues involved. Often a single agency must play the conflicting dual role of regulator and industry promoter, potentially compromising the ability of the agency to be effective in one or both roles. For example, the Fisheries Division of the Ministry of Economics and Development in Nicaragua supports aquaculture development, but is also responsible for granting concessions and regulating the industry. A similar situation exists in Mexico. Mechanisms to resolve these institutional issues must be part of efforts targeted at sustainable shrimp aquaculture development. An analysis of the institutional issues facing Ecuador in 1988 portrayed the challenge in a manner that can be applied to many nations in the region (Box 1).

The concession process for shrimp ponds illustrates the limitations in the capacity of key institutions. In most areas there is a lack of transparency in the process, and responsibility for granting concessions is often not clear. Overlapping jurisdictions may occur, and little cooperation exists between agencies.

Latin American countries often lack the trained personnel and equipment to streamline and rationalize the process of granting concessions. In Honduras, for example, the authority for granting concessions has been passed from one agency to another, finally ending up under the jurisdiction of the Ministry of Agriculture and Livestock. The confusion over the boundaries and ownership status of concessions has resulted in overlapping concessions, the same area being granted to one or more shrimp farmers. It also results in poor enforcement of the permit system. A widespread problem throughout Latin America is that smaller operators often have neither the technical capacity or money required to follow through the often complex concession process. In certain areas, such as in Mexico, nongovernmental organizations (NGOs) and special interest groups have been working with indigenous groups in assisting them in obtaining concessions.

There are examples of more effective permitting procedures. In Venezuela it is reported that relatively stringent government regulation and permitting requirements have encouraged controlled growth and long-term stability for the industry (Clifford 1997). The same may be true for Belize. Both Venezuela and Belize are unique, however, in that the industry is small and easier to manage.

Some countries have experimented with institutional restructuring to overcome institutional problems, such as concentration of authority in

## Box 1.

## Coastal Management Lessons from Ecuador: Institutional Issues

In 1988, a proposal for the structure and objectives of a coastal management program for Ecuador (Matuszeski et al. 1988) was widely circulated after a two-year process of public workshops and consultations within government. The proposal identified a number of principles that were used to set priorities and guide institutional design:

- There are already in place sufficient laws and authorities to properly manage coastal resources. New laws are not necessary. What is required is better coordination and enforcement of existing legislation.
- There is a general lack of knowledge on the part of public officials of the precise nature and extent of the laws they seek to carry out. Generally this manifests itself in self-imposed limits on the enforcement authority. Occasionally it results in unnecessary duplication of government activity.
- There is a serious shortage of adequately trained enforcement personnel in nearly all agencies; salaries and logistic support are also inadequate. The result is a high level of frustration on the part of those seeking to have the laws enforced, and a general attitude on the part of the public that the government does not really expect the laws will be obeyed.
- There are many overlapping areas of jurisdiction in government entities. In the case of coastal resources management, it would be more productive to improve coordination among government entities rather than trying to reorganize the existing distribution of responsibilities.
- The private sector does not have a high level of confidence in the ability of the government to simplify procedures, expedite decisions or enforce regulations on coastal resources. This attitude cannot be expected to change until real improvements can be shown.
- An important element of coastal resources management must be an extensive education program at all levels to create a civic consciousness about coastal resources and the critical role they will play in the future of Ecuador.
- Apart from the need of specific mechanisms to improve coordination among government entities in aspects related to coastal resources, the adequate management of the different areas will require several administrative levels in order to be effective.
- Recognition and support of the management programs must come from presidential and ministerial levels. This support will allow the different government entities to improve their cooperation and the enforcement of policies; the regional and local entities become more concerned about solving conflicts affecting their areas; and the public sector and general public opinions to be considered in areas that are important to their interests.

a new centralized ministry. But without improvements in the government's capacity for coastal management and institutional cooperation, such restructuring has little value and can end in failure. The greatest challenge is not to create new institutions, but to ensure that there is adequate capacity to make existing institutions and laws more effective. It doesn't matter how good shrimp aquaculture regulations are on paper, it matters if and how they are enforced (Suman 1994). For example, the laws in Ecuador concerning cutting of mangroves and concessions of land for shrimp aquaculture are considered by specialists to be fully adequate. What is missing is an ability and willingness to administer and enforce the laws.

A number of Latin American countries have created interagency commissions to coordinate action on coastal concerns (e.g., Belize, Brazil, Colombia and Ecuador). In other countries, existing agencies have been given the task of coordination. In Panama the National Institute of Renewable Natural Resources (INRENARE) is addressing the difficult task of coordinating all agency activities in mangrove areas (the National Aquaculture Directorate of the Ministry of Agrarian Development is responsible for shrimp farming, the General Directorate of Marine Resources of the Ministry of Commerce and Industry regulates artisanal fisheries in estuaries and mangroves, and the National Land Registry of the Treasury Ministry grants concessions of public lands in mangroves and salinas).

Coordinating bodies provide a structure for developing mutually beneficial working relations and exchanging views on pressing coastal issues. Sorensen and McCreary (1990) cautioned, however, that some agencies may only participate passively in interagency commissions and the accomplishments of such commissions too easily are reduced to collecting information, preparing inventories and writing guidelines that do not produce effective action. While mechanisms for interinstitutional collaboration and problem solving are essential, they will only produce significant benefits if supported by a larger effort.

### 5.2 Public Ownership of Natural Resources (Land, Water and PL)

Coastal areas and their management are unique due to the pervasive feature of publicly owned resources (the intertidal area, open sea and coastal waterways). Rights to the use of these resources are often not well defined. Who owns or has the right to use the water that flows through an area, the wild PL that are captured for growout ponds, and land in the intertidal zone? In the absence of clear title and regulations, resources are simply appropriated. As long as no other use for the resources arises, there is usually no problem except for competition for resource use among increasing populations. Conflicts arise when traditional resource ownership and management systems are altered by new opportunities for other competing uses. The outcome of the inability on the part of government to recognize and enforce traditional tenure arrangements is widespread encroachment of publicly owned lands. In Ecuador, Southgate and Whitaker (1992) observed that the "claims [on coastal areas] far outstrip the government's capacity to manage resources or even to ensure that its claims are honored by other parties."

Poor management of coastal publicly owned resources is a key cause of environmental degradation and user conflicts related to shrimp aquaculture. Insecurity of tenure and the motivation of short-term profits leads to a lack of concern for the long-term sustainability of their production and the conservation of natural resources. The clear recognition and protection of existing property rights is vital to progress towards more sustainable uses of coastal resources. Gonzalez (1993) has shown empirically that there are significant net social benefits of controlling open access to mangrove wetlands in Ecuador.

The concession fee for use of public land for shrimp aquaculture is typically negligible despite the high ecosystem value of the land. In Ecuador the lease fees for farms in the "bay and beach zone" are US$ 3 per ha per year (Burroughs and Olsen 1995). Water, both salt and fresh, costs only what it takes to pump. In Honduras, those with concessions of one to two years pay nothing. Those with leases of three to five years pay US$ 0.36/ha/yr, while those with more than 16-year leases pay US$ 1.35/ha/yr (Clay 1996). The Estero Real, in Nicaragua, is divided into two zones: north and south. The initial concession fee ranged from US$ 20-30/ha of approved land area, followed by payment of US$ 50-70/ha of pond area when in production, depending on the zone. Collection of these fees has been inconsistent (Jensen et al. 1995). The revenues collected from concession leases and fines are directed to the Fund for Sustainable Development of Fisheries and Aquaculture that was created in 1993 (Jensen et al. 1995).

Costa Rica passed a law in 1996 that redefines allowable uses of public lands (Rosenberry 1996). The government has placed a moratorium on new leases, and under a new forestry law, over a five-year period, existing shrimp ponds on government land would lose their lease, and the ponds would be turned back to mangroves. Furthermore, private land would not be allowed to run intake and discharge canals through the mangroves, nor would they be able to pump water from the mangroves. Both Honduras and Nicaragua have also adopted national moratoriums on new land concessions for shrimp farming.

### 5.3 Environmental Externalities

Most Latin American developing countries do not have environmental regulations or an overall management plan for the development and use of coastal areas, and have failed to invest in the scientific base to support the sustainable development of the aquaculture industry. When regulations do exist, they are generally not enforced.

Inadequate, or nonexistent environmental controls are an implicit subsidy to shrimp farming, since the owners of shrimp farms do not pay for the full environmental costs of their activities.

There are some exceptions. Water emissions standards on shrimp aquaculture ponds are enforced in Venezuela. In Nicaragua, shrimp farms are required to monitor and report on water quality to the Ministry of Environment and Natural Resources (MARENA). In Honduras, a new environmental law includes permitted effluent concentration levels in waterways (Stanley, forthcoming). Both Nicaragua and Honduras have introduced restrictions on intensive shrimp culture to avoid potential harmful environmental impacts. The ANDAH participated in the preparation of a 1996 Honduran moratorium on new shrimp farm development (presently in effect), until the carrying capacity of specific regions can be determined based on water quality and hydrographic studies.

Stakeholder "bargaining" to reduce environmental externalities is scarce because of high transactions costs, poor information and the prevailing structure of interests and power. Thus, estuary fishers cannot easily bargain with shrimp farmers to reduce the impacts of the shrimp industry on the fishery. However, where the stakes are high and user groups are well organized, opportunities for dialogue may appear. For example, legally formed user groups in Ecuador's special area management zones (ZEMs) are successfully negotiating with shrimp farmers to find common solutions to externality problems (Box 2).

### 5.4 Inadequate Understanding of Ecosystem Interactions and Functioning

Ignorance and poor information of how coastal ecosystems respond to human actions, and the ecosystem and social values which are consequently lost are another major underlying cause of unsustainable shrimp aquaculture. There is enormous uncertainty surrounding human-made disruptions to coastal ecosystems. For example, the overall effects of habitat alteration on the ecological integrity of a coastal estuary are often not fully recognized. What happens to coastal ecosystem stability and resilience (its capacity to recover from external stress and shocks, both man-made or natural) when the system is disrupted is poorly understood, as are the interconnections and interdependencies between the coastal sea, estuaries and their watersheds. It is known that ecosystems undergo an irreversible collapse when certain thresholds of damage are reached; but one cannot predict where such thresholds lie.

Earlier it was noted that the problem of insufficient information provokes debates among Honduran fishers and the shrimp industry. The dispersed, mobile nature of the fishery has made it difficult to pinpoint which actors — fishers, larvae collectors or natural events — are most at fault for declining fish stocks. In the Gulf of Fonseca, the shrimp farmers argue fish catches are falling due to changing water temperatures, and increases in the number of fishers, illegal explosives and motorized boats. Artisanal fishers continue to blame the arrival of the larvae gatherers using hoop nets. Unified efforts at environmental management have been hampered since the relationship between each user's action and fish stock levels is uncertain.

It is of the utmost importance to assess the implications of the scientific uncertainty that swirls around important issues in ecosystem management, and then formulate responsible courses of action. Without good estimates of the rate of degradation and the costs of damages, it is difficult to say what an optimal conservation strategy should look like. The many uncertainties mean that policy formulation should be based on a precautionary approach. This implies providing for a responsible margin of error in decisions with uncertain ecological consequences. It also suggests that where there are threats of serious or irreversible ecological loss, lack of full scientific certainty should not be used as a reason for postponing management actions to prevent that loss.

**Box 2.**

**The Users' Agreement of Jambeli, Ecuador**

Since 1990, the Program for Coastal Resource Management (PMRC) has been establishing a pilot program for integrated coastal management in five distinct areas within Ecuador's coastal provinces. Principles that frame the PRMC's work include:

1) community and government participation in each phase of the coastal management development process,
2) coordination and association between user groups, and
3) local capacity building.

Each of the five "Special Management Zones" has an executive committee, a body of the local government that brings together local user groups: shellfish and crab collectors, fishers, shrimp farmers, tourism business and private institutions. The committee works by consensus to plan adequate management of the resources in the zone.

The PMRC's work has produced fruit in Puerto Bolivar Jambeli, a small island in the Machala Special Management Zone. It is located in El Oro, the second most deforested province of Ecuador. On the island of Jambeli, 60 percent of the mangroves have been cut. Principal among user conflicts is the diminished habitat for crab and shellfish collectors. The signing of a "Users' Agreement for the Preservation of the Ecosystem of Jambeli," has stopped the deterioration of the island and the anarchic installation of shrimp ponds. Conflict problems between different coastal resource users were presented at a series of 10 local meetings during 1994, attempting to harmonize social, environmental and economic needs.

Among the achievements since the signing of the agreement:

- Ten ha of mangrove have been reforested
- Fifteen people, including loggers and larvae fishers, have been trained in reforestation skills
- PMRC obtained basic biological information on mangrove growth
- At least 50 percent of the conflicts between shrimp farmers and fishers/collectors have been peacefully resolved.

*Source: Bravo 1996*

# Conservation, Management and Mitigation of Adverse Impacts

Significant advances have been achieved in the last few years in a diversity of regional and international forums on the principles of sustainable shrimp aquaculture and codes of practice. In response to increased awareness and understanding of the environmental and social problems of shrimp farming, there is a growing international consensus that environmental mitigation and restoration should be an integral part of shrimp farm management. The urgent challenge is to advance understanding of how principles of sustainable shrimp aquaculture translate to tangible practice in Latin America.

A mix of management actions is needed to translate principles of sustainable shrimp aquaculture to practice. The actions developed and eventually implemented must be based upon an appreciation for the implementing capacity of the institutions involved, knowledge of the ecosystems affected, assimilative capacity, motivations and incentives of the stakeholders, the economic setting, and acceptable cultural ways to better bring private behavior in line with social goals (Olsen 1993). Below, eight groups of management actions for sustainable shrimp aquaculture are suggested.

***1. Best Management Practices That Lower Impacts and Sustain Production.*** Long-term sustainability of the shrimp aquaculture industry can only be achieved by following proper development guidelines aimed at developing a viable industry, while maintaining a sound and healthy ecosystem which will insure a sustainable seed source and adequate water quality. Without proper site selection, proper design and adequate management, shrimp farm operations will more than likely fail. This impacts long-term sustainability in that coastal lands will have more than likely been degraded, financing will have been secured and lost, concessions will have been granted, and impacts to the environment and communities will have occurred without economic benefits.

Codes of practice for shrimp aquaculture that provide guidance on better environmental and social practice are being formulated in a number of international forums, such as the Global Aquaculture Association. The formulation of codes of practice can assist in the development of best management practices (BMPs) which regional, national or international industry associations might agree to adopt on a voluntary basis. Codes can also be useful in identifying criteria for donor funding, in guiding programs of technical assistance and extension, and could potentially be the basis for certification schemes.

The list of practices below is not comprehensive, but illustrates the types of practices that would lead to more environmentally, socially and economically sustainable shrimp aquaculture. BMPs will need to be refined and developed to meet the conditions and needs of specific countries and regions.

## *Siting, Design and Construction of Ponds:*

- Restrict or prohibit location of ponds in mangrove areas, wetlands and other biodiverse areas, or in diked-off areas of open water.
- Maintain the natural environment surrounding the site as much as possible. If mangrove trees surround the site or the inlet canals of the estuary, leave as much of this ecosystem undisturbed as possible.
- Maintain adequate buffer zones. Among other benefits, appropriate buffer distances between the farm and other water bodies (e.g., shorelines or the banks of tidal channels and rivers), reduce the danger of off-site contamination.
- Design roads to minimize impact on the hydrology of the area. Appropriately placed culverts will

**Larveros in Ecuador were taught to use new nets to reduce bycatch waste.**

allow for normal water flow and will limit impact to fresh and saltwater wetlands and
to mangrove stands.

- To minimize disturbance during construction, discard mangrove soil and residues removed from the project site far outside the mangrove areas or coastal waterways.

### *Pond Management:*

- Train larveros (larvae fishers) and introduce larvae collection and handling methodologies to increase PL survival and reduce the by-catch and mortality levels of associated species. The establishment of collection seasons and areas closed to collection of PL can be used to regulate the industry, and promote overall aquatic health of the coastal ecosystem.
- Curtail PL imports or transfers from active disease areas or producers until either the animals are certified disease free or the diseases have been diagnosed in the area of importation.
- Promote breaching of impoundment dikes when ponds are abandoned so that the pond area is able to revert (eventually) to its former status.
- Make use of settlement ponds so that waste levels in the discharged water achieve adequate water quality levels.
- Improve food delivery and use efficiency.
- Reduce water exchange through recycling and use of low water exchange systems.
- Discharge water into areas with adequate tidal flow for dispersal of pond effluent (not in stagnant areas of mangrove).
- Encourage appropriate use of drugs and chemicals.

***2. Impact Assessments.*** Improved and more widespread utilization of practical and meaningful environmental impact assessment (EIA) procedures can be recommended as a critical strategy for identifying adverse environmental and social impacts of aquaculture, and for developing management plans to mitigate impacts. Impact assessments should be undertaken at two levels: individual operations and ecosystems; the latter to understand the collective impact of all ponds in an area versus their carrying capacity.

Some Latin American shrimp aquaculture-producer nations have legislation and experience with EIAs, including Belize, Venezuela, Mexico, Nicaragua and Honduras. Creation of the Environmental Ministry in Honduras resulted in the General Environmental Law of 1993, requiring an environmental license for all new development activities based on an EIA by a qualified provider of this service. Based on EIAs, the Environmental Ministry has negotiated mitigation activities in an approval process for pond expansion at specific sites. In Nicaragua, parties interested in aquaculture must present an environmental impact study to MARENA before the Fisheries and Aqua-culture Division of the Ministry of Economic Devel-opment (MEDE-PESCA) approves a concession.

Bilateral and multilateral agencies can assist in environmental planning by providing technical assistance in the early phases of site selection and feasibility studies. One option is to make a site and technical review of any shrimp aquaculture proposal by knowledgeable personnel an integral part of loan approval. Fees for review could be in the form of points once the loan is approved. EIAs were part of the World Bank/Mexico aquaculture development project formally approved in 1997.

In order to assess the impacts and develop the appropriate mitigation measures, EIA documents should include but not be limited to the following items (Vergne 1996):

- A hydrodynamic study of the area, including impacts due to the project
- Proposed plans and technical description of the project
- Baseline ecological studies of the area
- Biological inventories of the site
- Identification of impacts and mitigation measures
- A detailed plan of action for construction, operation and mitigation of environmental and social impacts

Table 6.1 provides additional detail on items that might be considered in an EIA for shrimp aquaculture operations.

For EIAs to be effective, it is imperative that the process not be overly complex and cumbersome. Requirements and procedures must be clear and straightforward. It should not be seen as a bureaucratic requirement under the jurisdiction of one agency, unconnected to integrated coastal management. Finally, EIA processes have little value if institutional capacity does not exist to see that pond operation conforms with the management plan for construction, operation and mitigation of environmental and social impacts.

***3. Trade-Related Incentives.*** The power of consumer demand is in itself a considerable trade-related incentive to mitigate the environmental and social impacts of shrimp aquaculture. A reduction in consumer demand in the United States caused by a negative image of the production process and product could have a significant impact on the industry. The potential for shifts in market demand are real. Experience shows that consumers and political supporters can be mobilized around environmental issues associated with methods of production or capture of internationally traded commodities. For example, in May 1996, the United States imposed an import embargo on shrimp imports which are trawl caught without the use of turtle excluder devices illustrating that consumer education helps to create markets for specific types of shrimp produced in specific locations in verifiable ways.

Increasingly, at least in developed countries, there is likely to be consumer demand for sustainable shrimp and more and better labeling information. Consumers will want to know what country the shrimp comes from and how it was produced. Shrimp producers could receive better prices for shrimp produced with more environmentally and socially sustainable practices if it were possible to differentiate their product in the market (e.g., cer-

**Table 6.1**

**Considerations for Environmental Impact Assessment of Aquaculture**

| Physical Parameters | Biological Parameters | Social and Cultural Parameters |
|---|---|---|
| *Dredging Works:*<br>● Bathymetric studies<br>● Coastal topography<br>● Currents<br>● Water quality<br>● Salinity patterns<br>● Surface hydrology<br>● Basic coastal morphology<br><br>*Grow-out facility:*<br>● Description of water intake<br>● Description of pumping station and delivery canal<br>● Description of effluent canal<br>● Soil topography and morphology<br>● Water quality<br>● Subsurface water quality<br>● Description of flora and fauna communities | ● Identification of sensitive communities and species<br>● Identification of species of commercial importance<br>● Identification of endemic or threatened species<br>● Introduction of non-endemic species<br>● Identification of protected areas | ● Identification of current land users<br>● Identification of population centers and makeup<br>● Income and employment figures<br>● Transportation<br>● Public services<br>● Areas of concern |

*Source: Vergne 1996*

tified use of BMPs, shrimp not produced in former mangrove areas). In the absence of market differentiation of cultivated shrimp according to production practices, some environmental NGOs have announced their support of a moratorium on the consumption of all farm-raised shrimp.

A certification scheme would require producers to follow generally recognized and verifiable guidelines. Agreement on what those guidelines should be, and how to verify them, is a major challenge. The development of an internationally recognized set of guidelines used to certify shrimp will require the input of many stakeholders worldwide (government authorities, producers, retailers, buyers, consumers, NGOs, community groups, etc.). Certification that is meaningful and credible to consumers would need to be undertaken by third parties.

Currently, international shrimp trade is already highly differentiated into dozens of categories (by size, species, country of origin, degree of processing, method of production, etc.). Shrimp trade would not be unduly complicated by more categories. However, as shrimp enters the retail market, most of the differentiation is lost. Consumers do not currently receive the detailed information to which buyers have access when buying shrimp. Shrimp sold directly to consumers on the retail market are mainly differentiated by size and whether or not the product has been frozen. Usually, they are not differentiated by whether they are wild caught or pond raised, by species, or by the country of origin or export. In order to have shrimp certified in the marketplace, they will have to be differentiated by how they were raised. There will have to be a certifiable "chain of custody" from the producer to the consumer.

There are other trade and environment issues related to shrimp aquaculture that have been discussed in various forums, such as the possibility of creating an environmental value-added tax. The objective of such a tax would be to generate revenue that would be dedicated to supporting the sustainable production of specific commodities, as well as to mitigate environmental impacts associated with current production systems (e.g., mangrove replanting). Alternatively, a small, incremental charge on shrimp products imposed on the final consumer by the private sector itself, as part of a public awareness campaign, could generate significant funds and improve the image of the industry. The revenue could be dedicated to a trust fund to address environmental and social problems associated with shrimp aquaculture.

***4. Monitoring of Ecosystem Conditions and Trends.*** The main environmental problem with aquaculture is that it expanded too quickly into regions where the consequences were not immediately known. It expanded without overall baseline data, environmental and social impact assessments, and management plans for the use of the productive yet fragile resources upon which it depends. Every effort should be made to predict the impacts of shrimp aquaculture in a region before it is begun and as the industry is established and expanded.

Most governments have failed to invest in the scientific information systems that they need to determine the sustainable development of the shrimp aquaculture industry. This failure has resulted in a lack of knowledge about which issues pose the most serious threats to the industry and which technologies and management techniques might be the most effective to address them. The problems must be identified, prioritized and addressed if the industry is to become more sustainable. Both baseline data and ongoing monitoring of estuarine water quality, and wide publication of results would improve awareness and decisionmaking and the industry's overall environmental performance.

Currently there are endless debates about the conversion of mangroves: how much has occurred, who caused it or what has been its impact. The collection of adequate baseline data will result in informed discussions on environmental impacts that have occurred due to shrimp aquaculture. The data is important because it will help producers, through appropriate feedback loops, reduce their impact as well as allow them to counter the negative claims that are being made against the industry.

Recognizing the value of scientific information, some Latin American countries have launched ecosystem monitoring initiatives. In Ecuador, with a grant from the European Community, a system of monitoring some 35 shrimp farms in the Gulf of Guayaquil has been launched that will attempt to identify the sources of water pollution in the gulf.

In Honduras, the USAID-supported Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP), ANDAH, the Pan-American Agricultural School at Zamorano (EAP) and the General Directorate of Fisheries and Aquaculture in the Ministry of Natural Resources are working together to develop more nutrient-efficient shrimp production technologies, and to study the impact of shrimp farming on the Gulf of Fonseca and its estuaries as well as the impact of the environment, particularly water quality, on the shrimp industry. The impetus for this effort which began in 1992 came from the members of ANDAH because they recognized that the sustainability of their industry was dependent on the long-term environmental condition of the gulf. The project has made recommendations to shrimp producers on means to reduce nutrient inputs to shrimp ponds while maintaining shrimp yields, and many of the farms have adopted these technologies. By reducing nutrient inputs to ponds, the nutrient levels in pond effluents are reduced thus reducing the flow of nutrients to the surrounding estuaries and the gulf. In an effort to establish baseline data and to measure the impact of improved nutrient management technologies, the project has established a system to measure and monitor nutrient and sediment levels in the gulf.

In Nicaragua, MEDE-PESCA is monitoring water flow in the Estero Real estuary in a project with Auburn University (USA).

***5. Community-Based Coastal Management and User Group Agreements.*** The approach of many countries to destruction of critical coastal habitat is to adopt ever more stringent and more unenforceable regulations designed to prohibit or severely limit human activities of all kinds in mangrove wetlands and other protected areas. Most Latin American countries have adopted legislation or presidential decrees banning further mangrove clearance and forest conversion, but there are few examples where such bans have proved effective. An alternative strategy that is now gaining considerable support among both government agencies and the public is the development of area-specific community management techniques that promote a diversity of sustainable use activities and enlist the support and involvement of all those who depend directly and indirectly on the local ecosystem.

The formulation of community-based coastal management plans is the culmination of a governance process that involves assessment of conditions and trends, issue identification, stakeholder consultation and strengthening of human and institutional capacity. Successful management plans strike a balance with respect to conservation and development, recognition and addressing conflicts among user groups, involvement of major stakeholder groups in the preparation of the plan, and clearly specifying institutional responsibility and jurisdiction for implementation. Official approval of a management plan following public review and negotiation is the final step before implementation.

User groups will often demonstrate a great interest and commitment to a process that promises to resolve pressing resource management issues. Beginning in 1990, a major element of the aquaculture management strategy of the Ecuador PMRC was to focus practical exercises in five ZEMs. An important result of the practical exercises is the development of domestic capacity to work on the priority issues posed by aquaculture, working with different user groups such as shellfishers, shrimp farmers, larvae fishers and artisanal finfishers. Agreements negotiated between traditional fishers, woodcutters and shrimp farm owners have proved a powerful tool in resolving conflicts between these groups. The specific recommendations of a shrimp aquaculture working group organized by the PMRC and examples of management actions in the ZEMs are shown in Table 6.2.

There are other examples in other Latin American countries. The objective of a project in the Estero Real estuary, Nicaragua, funded by the Danish International Development Agency is to refine a management plan that defines allowable activities, delineates zones where individuals may carry out these activities, and establishes optimal levels of resource exploitation (Garcia 1994).

### *6. Extension and Technical Assistance That Address the Environmental, Social and Economic Impacts of Shrimp Farming.*

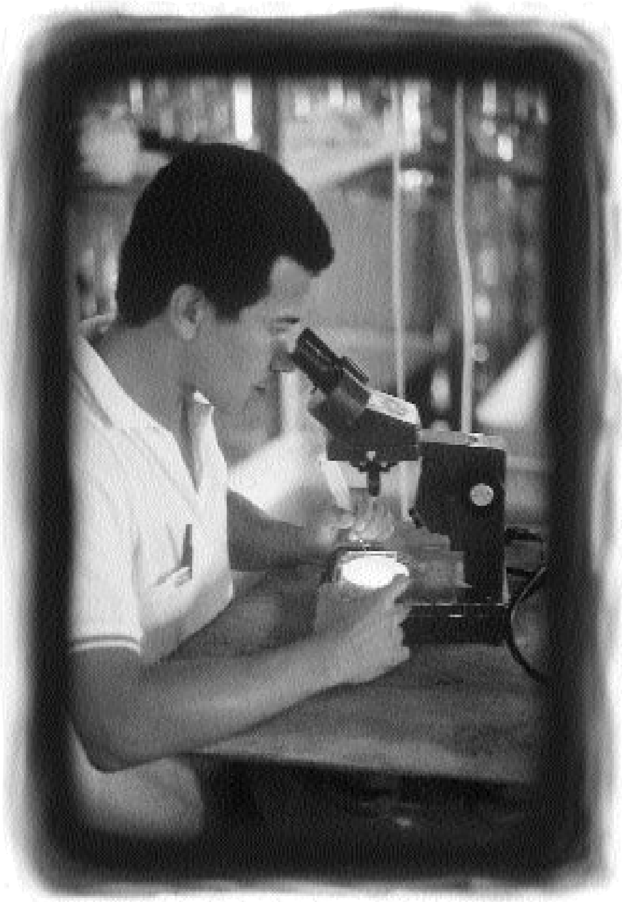
The proper planning and design of a project, and daily management of a commercial aquaculture farm, requires expertise, training and experience. The development of domestic professional support services is critical to industry development in Latin America. In Nicaragua, Jensen et al. (1997) found that:

- The need to develop disease prevention, diagnosis and treatment capabilities in a timely manner is critical.
- There is a lack of knowledge and field experience on the proper design and sizing specifications for water pumping stations.
- There is a need for improved capacity for conducting site selection assessments and project feasibility studies.

Research and technical assistance to the shrimp farmer will lead to more rapid introduction of new and promising technologies and management practices that improve the long-run sustainability of the industry. Improved farming techniques and technologies offer opportunities to:

- Reduce water use and extend the life of ponds
- Identify and diagnose diseases

**Research can aid technological improvements for the industry.**



- Improve feed delivery and use efficiency
- Decrease the need for antibiotics
- Help maintain water quality and reduce the effluent flow of production systems
- Reduce the reliance on wild-captured PL and improve hatchery performance.

The small shrimp farmer with limited technical expertise would benefit most from technical assistance. There is, however, limited experience in Latin America with technical assistance programs for the small shrimp farmer. In Honduras, the Federatión de Asociaciones de Productores y Exportadores Agropecuarios y Agroindustriales de Honduras and the Fundación para la Investigación y Desarollo Empresarial provide technical assistance to shrimp aquaculture in general. With technical guidance from the La Lujosa Water Quality Laboratory, ANDAH has sponsored technical workshops for producers to promote efficient feeding, fertilization and water exchange practices to improve water quality in estuaries surrounding shrimp farms.

A Rural Technology Development Program, under the auspices of USAID, works with the Salvadorian Foundation for Economic and Social Development in El Salvador, and the Private Agribusiness and Agroindustrial Council in Costa Rica, to assist small operators in aquaculture and fisheries development projects. Investors are assisted directly or through seminars in aquaculture.

In Ecuador, the government has greatly expanded the Coastal Polytechnical University's coastal laboratory into a center for aquaculture research and development (the National Center for Aquaculture and Marine Research (CENAIM)) in 1990, through a major donation by the Japanese foreign assistance agency. CENAIM has focused on providing technical information for large-scale producers; it has not

**Table 6.2**

**Shrimp Aquaculture Management Recommendations, Ecuador**

| Aquaculture Management Recommendation | Management Actions in ZEMs |
|---|---|
| Create public education and awarness program | • Presentations, site visits, school programs, community discussions, simple educational materials |
| Monitor water quality | • Focus on needs of Rio Atacames shrimp farmers<br>• Monitoring program and work with local volunteers in Rio Chone |
| Reduce mortality of shrimp PL capture | • Training and extension program for PL fishers in San Pedro, Playas<br>• Shrimp larvae collecting training workshops in all ZEMs<br>• Development, testing and dissemination of new nets for larveros |
| Establish larvae collection centers | • Project in Bunche to create collection center<br>• Assessment of nurseries in Canoa and Machala<br>• Assistance to Valdivia nurseries |
| Reforest shrimp canals | • Test projects in Rio Atacames and initiatives in Rio Chone |
| Diversify aquaculture | • Identification of issues in Bunche<br>• Development of fattening techniques for cockle |
| Develop criteria to control impact of shrimp ponds on surrounding areas | • User group agreement among traditional users, authorities and shrimp farmers; resolution of conflict over shrimp farm water intake canal in Rio Atacames |
| Create buffer zones around shrimp ponds | • User group agreement in Rio Muisne |
| Study freshwater aquaculture | • Study of freshwater wetlands in La Segua, Rio Chone, funded by United Nations Environment Programme |

*Source: Olsen and Coello 1995*

yet been able to play a major role in promoting broad-based extension services to those shrimp farmers unable to finance their own teams of shrimp pond biologists and technicians.

In Nicaragua, MEDE-PESCA administers the Regional Program for Fisheries Development in Central America funded Regional Shrimp Training Center, which began activities in 1994 (Jensen et al. 1995). This regional training center provides practical training to shrimp producers in Central America. It works in cooperation with the Shrimp Farming Demonstration Farm (Centro Demonstrativo Experimental) in Puerto Morazán. The 70-ha facility has been used as a demonstration farm by MEDE-PESCA since 1993. Research activities include appropriate feeding of shrimp ponds and disease control. MEDE-PESCA, through its aquaculture department, also provides extension functions and technical assistance to shrimp farming cooperatives and collectors of wild PL (Jensen et al. 1995).

Throughout Latin America, additional resources are needed for technical assistance to the small farmer, for extension projects and demonstration farms to promote technologies, for increasing the productivity of individual ponds, for the promotion of small-scale hatcheries, and to improve harvest techniques of wild PL fishers.

***7. Zoning.*** A fundamental tool of land use management is the identification and protection of key ecosystems which need to be conserved to ensure resource sustainability. The aim of zoning is to establish clearly demarcated geographic zones with specific permissible and nonpermissible uses, which could include identification of zones for aquaculture and for mangrove conservation. Zoning schemes can be adopted by a municipality, or regulatory or planning agency, that have the authority to make and enforce decisions. While the process of zoning may not be easy, in the long run it can make enforcement easier and can help reduce conflicts between aquaculture operations and other coastal resource users (Bodero and Robadue 1997). Elements of zoning include:

- A specific list of allowable and non-allowable uses
- Precise designations of the water, shore and land areas covered by the zone
- A regulatory procedure for issuing and enforcing permits
- Sanctions for violating the terms of the permit, as well as of the zone
- Policies and procedures for giving variances for activities in the zone or to nonconforming uses.

In a zoning scheme for mangrove ecosystems, the social and ecological value of the ecosystem and appropriate uses should be determined. Areas of high conservation value that are critical for storm protection, nursery habitat or water quality should be identified for use as protected areas and maintained in a natural state. Other areas might be identified for conservation and nondestructive uses. Bodero and Robadue (1997) suggested three types of nondestructive uses of mangrove ecosystems: 1) uses which are always allowed and encouraged, such as honey production, passive recreation, flood hazard protection (buffer zones), subsistence fisheries and nondestructive types of aquaculture such as shellfish repopulation; 2) uses which could be accepted only when permitted and carefully monitored, such as ecotourism and education activities, and selective harvest using acceptable cutting and rotation techniques; and, 3) uses which are permissible only if an overriding public benefit has been demonstrated, such as in the case of a proposal to create a canal for water circulation to an aquaculture project, piers, buildings or a nonrenewable form of wood harvest.

***8. Incentive-Based Measures.*** Incentives can be defined broadly to include those management measures that make use of the price system and market forces to achieve their objectives. They include both positive and negative incentives (the "carrot" and the "stick"). A few examples of economic incentive measures that are grounded in experience in other natural resource-based activities such as agriculture and forestry in the United States and elsewhere include:

*Subsidized Credit*. The capacity of the shrimp aquaculture industry to adopt more sustainable practice is hampered by lack of access to credit. Although credit constraints affect the entire industry, they usually impact the mid-size and smaller operators to a greater level because they usually do not have the financial capacity to qualify for standard loans. A positive incentive, and potential solution, is the creation of programs that provide low interest operational and construction loans to small family-sized operations. Qualification could be based on income needs, project site design acceptability and willingness to participate in technical assistance programs.

*Pricing of Land and Water*. As discussed earlier, a major subsidy to shrimp aquaculture and incentive to rapid growth is the existence of free, or nearly free, land and water inputs. A management option is to introduce (or increase) water pricing and public land pricing so that the shrimp farming industry faces, to a greater extent, the full social costs of their activities.

*Donor Conditionality*. Donor institutions that want to encourage/support the expansion of shrimp aquaculture could insist that financing be dependent on environmental and social conditionalities. Environmental conditionalities could include such things as the percent of a holding that can be converted to shrimp ponds, the acquisition and disposal of water, and the sources of PL.

*Environmental Performance Bonds*. In some countries, timber and mining companies are required to post a bond with the regulating authority sufficient to cover costs of rehabilitation in the event of non-compliance with environmental standards by the responsible company. In principle, the same system could be applied to the construction and operation of shrimp aquaculture ponds.

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