SHRIMP MARICULTURE DEVELOPMENT IN ECUADOR: SOME RESOURCE POLICY ISSUES

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ABSTRACT

During the past 15 years, Ecuador has become the Western Hemisphere's leading producer and exporter of shrimp. Growth has come about largely through mariculture development. About 8,000 metric tons (MT) of shrimp have been captured off the Ecuadorian coast each year since the late 1970s. Meanwhile, pond output has increased several-fold, from less than 5,000 MT in 1979 to over 100,000 MT 12 years later (Table 1).

Mariculture has expanded largely at the expense of renewable natural resources. Mangrove swamps, characterized by extremely high biological productivity and, therefore, a critical element of coastal ecosystems, have been displaced. In addition, shrimp postlarvae (PL) collection has at times been excessive and wastewater emissions from some enterprises harm the environment. Mariculture also suffers from water pollution from agricultural, urban, and industrial sources.

This paper first describes the extent and consequences of coastal ecosystem disturbance; then presents a causal analysis of environmental problems. Policies contributing to depletive management of wetlands and related resources are similar to policies stimulating tropical deforestation. The tenurial regime rewards those who convert coastal ecosystems into shrimp ponds, just as frontier property arrangements encourage agricultural colonists to convert natural ecosystems into farmland (Southgate 1990). In addition, mariculture's geographic expansion, like agriculture's, has been accelerated by inadequate spending on education, research, and extension (Southgate 1991).

If this policy regime remains unchanged, continued deterioration of Ecuador's coastal ecosystems is inevitable.

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ALTERATION OF COASTAL ECOSYSTEMS

Damage to coastal resources is the subject of widespread concern in Ecuador. Although many shrimp ponds have been constructed in salt flats ("i.e.", the dry land that builds up through evolution of the mangrove system), maricultural expansion has been considerable in intertidal areas alongside the shore. Particularly troubling has been the displacement of mangrove swamps. Renewable resources are also under threat because of excessive postlarvae (PL) capture and water pollution.

Mangrove Deforestation

Remote sensing studies suggest that 118,000 hectares (ha.) of shrimp ponds had been established along the Ecuadorian coast by 1987 (CLIRSEN 1988). Of that total, 38,500 ha. had been constructed in salt flats and 28,500 ha. directly displaced mangrove swamps. Urban expansion accounted for an additional 1,400 ha. of mangrove deforestation. In all, 15% of the mangrove swamps and three quarters of the salt flats existing in Ecuador in 1969 had disappeared by 1987, the last year for which comprehensive data are available (table 2).

Coastal ecosystem destruction accelerated through the middle 1980s. Swamp displacement amounted to 21,600 ha. from 1969 to 1984. This is equivalent to annual losses of 0.7%. Between 1984 and 1987, though, the mangrove deforestation rate nearly doubled, to 1.3% "per annum," 6,900 ha. having been lost (table 2).

Almost certainly, mangrove deforestation has slackened during the last few years. Shrimp prices are falling (see below), and capital needed to establish a competitive maricultural enterprise has gotten scarce. In addition, many of the enterprises brought on line since 1987 have chosen to locate outside of wetlands because soils in mangrove swamps tend to be highly acidic, which creates problems for shrimp production. To summarize, environmental as well as economic factors are contributing to reduced mangrove deforestation.

Although conversion of wetlands into shrimp ponds is declining because of environmental and economic factors, mangrove forests continue to be lost or degraded because of urban expansion. The slums of Guayaquil, Machala, and other coastal cities tend to establish themselves in wetlands because, as is noted later in this paper, those areas are essentially an open access resource. Even when wetlands are not directly displaced, ecosystem degradation occurs because mangrove swamps are a source of charcoal and building materials.

Over-Fishing

Since mangrove deforestation appears to be decelerating (outside of a few locations), shortages of shrimp PL are becoming a relatively more important source of concern.

When the ocean off the Ecuadorian coast is warm, PL are abundant and no operation has problems stocking its ponds. There are a few thousand full-time PL fishers, complemented by perhaps 10,000 working a few days a month (Scott and Gaibor 1992). As long as prices do not fall too low, a skilled gatherer can earn $25 to $30/day (Thia-Eng and Kungvankij 1989, 7).

The capture of wild fry involves considerable losses. Of the 9 to 12 billion PL collected annually during the early and middle 1980s, only half were of the desired species, "Penaeus vannamei." Other kinds of shrimp were discarded, usually on dry sand where they died. Other organisms caught in the nets met the same fate. Mortality of "P. vannamei" was also high, exceeding 80% between the beaches and the ponds (LiPuma and Meltzoff 1985, 20).

In a good or ordinary year, these losses have no great effect on Ecuadorian mariculture. But when coastal waters are cool, populations of juvenile shrimp in the wild fall dramatically, which can cause some pond capacity to lie idle. To guard against this risk, the industry began constructing hatcheries in the middle 1980's. Existing hatcheries, which number 120 or so, can satisfy as much as 65% of industry demand (Barniol 1992).

A few operations, at which mature shrimp are mated repeatedly to produce PL (Barniol 1992), are largely insulated from the impacts of over-fishing and habitat destruction. But most hatcheries are not self contained. Instead, gravid females captured by ocean-going trawlers and artisanal fishers are the primary source of seed. Needless to say, these latter facilities can suffer when gravid females become scarce, which occurs from time to time.

Water Pollution

The environmental impacts of mariculture development are not limited to uprooting of mangroves and collecting too many PL and gravid females in the wild. Wastewater discharged from shrimp ponds impairs water quality in the Gulf of Guayaquil and other coastal waters, which are already threatened by pollution from urban, industrial, and agricultural sources.

Many maricultural operations around the Gulf of Guayaquil are semi-extensive, with pond stocking rates ranging from 10,000 to 50,000 PL/ha. (Villalon et al. 1989, 251). At those rates, supplementary fertilization, with urea and superphosphates, is needed to induce the phytoplankton blooms on which juveniles feed. Fertilization, along with supplemental feeding for larger stock, depletes oxygen. If dissolved oxygen levels fall too low, shrimp die.

To avoid this outcome, seawater is exchanged, through pumping, for pond water. Water flushed from ponds contains nutrients, which increases biological oxygen demand in surrounding waters. Nutrients are also available for biological uptake, which Twilley (198 9, 98) suggests might contribute to the red tides (blooms of red-colored toxic algae) observed occasionally in the Gulf of Guayaquil. The same author also speculates that daily discharges of semi-extensive operations' wastewater, which can be highly saline (Snedaker et al. 1986), into the Gulf of Guayaquil might exceed fresh water yield from the Rio Guayas Basin during the dry season (Twilley 198 9, 98).

Aside from what takes place in habitats adjacent to maricultural enterprises, the environmental impacts associated with discharging wastewater from ponds probably pale in comparison with water pollution from other sources. Solorzano (1989) finds that emissions of untreated domestic and industrial waste from the City of Guayaquil is a principal cause of high bacterial contamination, low dissolved oxygen content, and high nutrient concentrations in the Daule and Guayas Rivers, which are the principal freshwater tributaries of the Gulf of Guayaquil. Water pollution around other coastal cities is, likewise, severe. Solorzano (1989) also reports high nitrate and pesticide pollution from agricultural sources. Finally, freshwater flow into the Gulf during the peak of the wet season has been reduced significantly since completion of the Daule-Peripa dam (Arriaga 1989, 151). However, the same project has probably caused freshwater flow to increase during the dry season when salinity is potentially a more serious problem.

CONSEQUENCES OF COASTAL ECOSYSTEM DISTURBANCE

Determining the consequences of mangrove deforestation, water pollution, and over-fishing is difficult. The life cycle of "P. vannamei" in the wild has been characterized. Specifically, it is known that females shed their eggs in the open sea, where they hatch. After a larval phase, PL move into estuaries seeking out nutrient-rich niches ("e.g.", those around mangrove roots). As they mature, they become bottom-dwelling and, after a few months, they return to the sea (McPadden 1985). In addition, the environmental factors ("e.g.", temperature, salinity, and so forth) influencing this cycle is generally understood.

However, much more biological research must be done before the economic costs associated with coastal ecosystem disturbance can be estimated. Among the empirical questions that need to be answered are those that follow.

- How are natural stocks affected both by PL harvesting and by collection of gravid females?

- What is the relationship between PL numbers and mangroves and other coastal habitats?

- What impacts does water pollution have on plant and animal populations in the wild?

Research conducted in other parts of the world suggest that linkages addressed by the preceding questions are not trivial. In particular, positive relationships between coastal wetland area and shrimp catch have been documented in Malaysia, the Philippines, and the Gulf of Mexico (Turner 1989, 123-124).

In addition, there is economic evidence to support the claim that habitat destruction and over-fishing have had adverse impacts on shrimp mariculture in Ecuador. By the middle of 1988, prices paid by hatcheries for gravid females had risen to $10, according to industry sources. By late 1991, prices were ranging from $30 to $55 when fishing for gravid females was legal and up to $120 when temporary bans on such fishing were in effect. The price increase undoubtedly reflects a decline in natural supplies.

In real terms, the price paid by maricultural enterprises for PL has risen from $2/thousand in the late 1970s to over $4/thousand throughout the.1980s. Those prices vary considerably, however. During years, like 1983, when there is a strong El Nino climatic event, PL are abundant because shrimp stocks rise rapidly along with ocean temperatures. At other times, prices may rise above $10/thousand (Sutinen "et al." 1989, 40). In 1985, when real prices peaked at $15/thousand, payments for PL amounted to 44% of the costs of a semi-extensive enterprise. The same year, PL shortages resulted in under-utilization of pond capacity (LiPuma and Meltzoff 1985, 17-18). Many ponds also sat idle in 1990 for the same reason.

CAUSES OF ENVIRONMENTAL DEGRADATION

Like other parts of Ecuador's rural economy (Scobie "et al." 1990), the shrimp industry feels the impacts of governmental interference with market forces. Exports are subject to a 1% tax. Also, imports of high-quality feed have been restricted at times (Rosenberry 1990).

Over-valuation of the Ecuadorian sucre can discourage production and impinge on industry earnings. However, the main effect is to encourage smuggling. In 1984, when the official exchange rate was only 80% of the market rate, a fifth of the national shrimp harvest was shipped illicitly to Peru, where it was in turn sent to the United States and other countries (LiPuma and Meltzoff 1985, 20).

Since smuggling is relatively easy, the impacts of currency distortions on shrimp industry performance are not all that great. Two other elements of the policy environment have a much stronger influence on maricultural enterprises' use and management of coastal resources. The first is property arrangements. The second element is inadequate investment in the shrimp industry's scientific base.

Inappropriate Property Arrangements

Depletive management of Ecuador's coastal ecosystems has much to do with the legal standing of resources. By law, coastal beaches, salt-water marshes, and everything else below the high tide line is a national patrimony. But for all intents and purposes, access to most of that land is completely free. For example, no public agency attempts to keep an accurate count of PL collectors in different parts of the country. Never, it seems, have there been any serious proposals to subject that group's activities to legal control.

Permanent settlement in coastal wetlands is also unregulated. For example, a community of crab fishers has established itself, without any sort of governmental approval or interference, in the Churute Ecological Reserve, a mangrove swamp 40 KM south of Guayaquil. Similarly, expansion of the port city's slums into adjacent wetlands is totally uncontrolled.

There is some regulation of shrimp pond construction along the shore. Specifically, a 10-year use permit must be obtained from the General Merchant Marine Directorate. Depending on the pond's location, approvals might be needed from the Ministry of Agriculture and Livestock, the Ecuadorian Institute of Agrarian Reform, and other public agencies. Annual fees charged permit holders amount to 11% of the minimum monthly wage for each hectare. Generally, this works out to less than $10/ha./year.

Some individuals have been able to construct ponds without permits and, once operations have begun, to claim that the site was above the high tide line (and therefore not subject to public control). Others have found it useful to take on a government official as a partner. The advantage of this is that the many-months normally spent waiting for a permit to be approved can be avoided. Another option is to offer bribes, which are reported to have reached $100/ha. (LiPuma and Meltzoff 1985, 9).

The tenurial roots of coastal ecosystem degradation can be described as a mixture of a tragedy of the commons (Hardin 1968) and rent capture. Excessive collection along beaches, in mangrove swamps, and in other habitats, like over-fishing in the ocean, is a clear example of over-exploitation of an open access resource. Fishers know that they can capture the benefits of extra fishing effort (in the form of payments for their catch). By contrast, the costs associated with decreased breeding populations and other forms of fishery depletion are shared by all who make their living, directly or indirectly, from coastal ecosystems.

Water pollution from shrimp ponds and other sources is, likewise, a tragedy of the commons. The benefits of releasing saline water rich in nutrients into public waterways are internalized by the individual operator (in the form of avoided treatment costs) while the costs of emissions (associated with damage to ecosystems) are an externality.

Habitat destruction involves negative externalities as well. However, the conversion of wetlands and other coastal ecosystems is also an example of rent capture. A rudimentary analysis shows that the net revenues generated by a shrimp pond far exceed the costs associated with obtaining use permits. For a semi-intensive operation yielding only 1.80 MT/ha./year, average costs are a little less than $4,000/ha./year (LiPuma and Meltzoff 1985, 17). With shrimp prices currently exceeding $4,000/MT, annual net returns are more than $3,000/ha. Clearly, a significant portion of coastal ecosystem destruction is motivated by individuals' desire to capture that income stream in exchange for an initial payment of $100/ha. followed by annual fees of less than $10/ha.

Inadequate Investment in Human Capital and Scientific Base

The property arrangements contributing to the conversion of coastal ecosystems into shrimp ponds are similar to those that accelerate agricultural colonization of natural ecosystems elsewhere. There is another parallel between mariculture's geographic expansion and agriculture's, which is that both are a consequence of inadequate investment in human capital, research, and extension.

The history of the Ecuadorian shrimp industry is a classic illustration of Hayami and Ruttan's (1985) thesis that geographic expansion usually precedes productivity-enhancing investment in agriculture and other parts of the rural economy. The first shrimp ponds, in which extensive technology was employed, were built close to shore. Dikes by the sea could be opened to let in clean seawater and the PL and nutrients it contains. Yields were minimal. But costs were also low, neither supplementary stocking nor fertilization nor feeding being required.

As the sites best suited to extensive mariculture have been occupied, production technology has changed. Ponds located farther from and a little above the ocean have to be stocked and fertilized artificially. As noted earlier in this paper, this makes mechanized exchange of pond water for sea water necessary. The transition to semi-extensive technology has also been accelerated by subsidization of the diesel fuel used to operate pumps. If Ecuadorian energy prices were to rise to international levels, expenditures on diesel fuel would no longer account for 12% of the operating costs of a semi-extensive maricultural enterprise (LiPuma and Meltzoff 1985, 17). Instead, diesel prices would be at least three times higher and fuel expenditures would amount to more than a quarter of those costs.

Although spending on pumps and other machinery can be considerable, management of many semi-extensive operations is still rudimentary. Stocking, fertilization, and application of antibiotics (to combat disease) are usually haphazard. In addition, many enterprises do not employ competent biologists or maintain records that would, over time, allow them to achieve efficient mixes of inputs and outputs.

In recent years, semi-intensive technology has begun to be adopted. Ponds are being designed and operated so as to achieve efficient water exchange and aeration. The number of biologists employed to manage PL stocking and application of feed and nutrients is also increasing. In addition, stocking densities in semi-intensive ponds are higher, as are yields.

Further improvement in shrimp production technology can be expected in Ecuador, with more enterprises undertaking the careful management that characterizes a semi-intensive operation. Aside from firms located close to Guayaquil, the industry's access to laboratories where water quality can be tested and where shrimp diseases can be assessed remains minimal. Accordingly, there are opportunities to achieve more precision in the application of fertilizers, feed, and antibiotics and also in water exchange.

Additional spending on research would also ease Ecuadorian mariculture's dependence on PL captured in the wild. In particular, more widespread understanding of the factors influencing shrimp reproduction ("i.e.", temperature, water chemistry, and above all, nutrition) would allow more hatcheries to become self-contained. That is, those facilities would be able to breed PL from mature adults instead of merely extracting eggs from gravid females. Once this is done, the problem of excessive PL collection will be solved.

THE FUTURE OF SHRIMP MARICULTURE AND COASTAL ECOSYSTEMS IN ECUADOR

To be sure, many maricultural enterprises in Ecuador have adopted production technology that is more capital intensive, involves more sophisticated biological management, or both. Nevertheless, extensive operations, featuring low costs and low yields, continue to be the norm. As of 1987, 60% of Ecuador's shrimp ponds were extensive, 25% were semi-extensive, and only 15% were semi-intensive (CPC 1989, 27) .

Because extensive production technology is still dominant, shrimp yields in Ecuador, which average 0.59 MT/ha./year, are below world norms. They are only 71% of what is achieved in Honduras, which is the second largest producer in the Western Hemisphere. In Mexico, which recently reformed the investment and land acquisition policies that prevented it from growing shrimp for the lucrative North American market (where most of Ecuador's output is shipped), annual yields are 1.00 MT/ha. (Rosenberry 1990). Even more ominous in terms of Ecuador's international competitiveness is the performance of major Asian producers. As is reported in table 3, Chinese and Thai yields are two-thirds higher.

Needless to say, the entry of more efficient producers into the world shrimp market has caused prices to fall. In real terms, Ecuador has seen prices decline by more than 40% since 1986 (Table 4). Market values will continue to go down as existing producers expand their output and as new countries get into the market (Rosenberry 1990).

One consequence of growing international competition could be to put Ecuador's less efficient producers out of business. Some extensive operations ought to survive because of their low costs. Also, semi-intensive enterprises, which have relatively high yields, can probably withstand further price declines. The threat to semi-extensive operations, though, is serious. Their costs are higher than those of extensive producers while their yields are not all that great. Additional reductions in the value of output will be difficult for them to bear.

Tough times for some parts of the Ecuadorian shrimp industry could result in environmental damage. Producers with poor long term prospects will not hesitate to damage coastal ecosystems if profits can be gained by doing so. In particular, they are not likely to adopt pollution controls. Similarly, they will resist any initiative to reduce over-fishing that results in increased PL prices in the near term.

Finally, maricultural development as a whole will continue to result in ecosystem destruction if property arrangements are not reformed. As long as some segments of the industry remain profitable, it will be possible for individuals to capture rents by converting mangrove swamps and other public lands into shrimp ponds. Unless the government stops treating those lands as a free good, they will be destroyed.

APPENDIX

Table 1. The Ecuadorian Shrimp Harvest, 1979 to 1989*

Year	Ocean Harvest	Pond Production
1979	7,787 MT	4,698 MT
1980	7,800	9,180
1981	8,000	12,100
1982	8,000	21,500
1983	8,900	35,700
1984	6,300	33,600
1985	6,023	30,205
1986	9,166	43,628
1987	9,580	69,153
1988	10,800	77,759
1989	6,150	64,231
1990	6,885	69,620
1991	7,574	101,174

* Source: Periodic reports of the General Fishing Directorate.

Table 2. Area of Mangrove Swamps, Salt Flats, and Shrimp Ponds, 1969, 1984, and 1987*

Year	Mangrove Swamps	Salt Flats	Shrimp Ponds
1969	203,700 ha	51,500 ha	0 ha
1984	182,100	20,000	89,400
1987	175,100	12,400	117,700

* Source: CLIRSEN 1988.

Table 3. Shrimp Mariculture Productivity: World's Top Five Exporters

Country	Production	Productivity
China*	165,000 MT	1.06 MT/ha
Indonesia*	90,000	0.36
Thailand*	90,000	1.12
Ecuador**	70,000	0.59
Philippines*	50,000	0.62

* Source: Production and productivity in 1989 from Rosenberry (1990).
** Source: Production and productivity in 1987 from Tables 1 and 2.

Table 4. Shrimp Price Trends

Year	Value*
1980	$10,737.81/MT
1981	9,558.02
1982	9,709.85
1983	10,220.88
1984	9,125.33
1985	9,222.01
1986	10,670.87
1987	8,777.79
1988	7,438.31
1989	7,355.91
1990	6,445.99
1991	6,438.99

* 1990 U.S. dollars, free-on-board, monthly reports of the Central Bank of Ecuador.

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