Choosing the Road to Sustainability:
the Impacts of Shrimp Aquaculture and the Models for Change

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Introduction

Aquaculture has a long history, tracing its roots back thousands of years. Local farmers and fishers have cultured fish, mollusks, and crustaceans for generations, using traditional methods and local ingenuity to improve their living conditions through low-intensity aquaculture. Though these systems produced low yields, production was sufficient to meet the needs of local residents. Such early systems are still practiced by many indigenous coastal peoples. But newer, more intensive systems of aquaculture have recently overshadowed the traditional forms, and actually threaten these earlier systems. This paper provides a general overview of the negative consequences of the shrimp aquaculture industry's rapid growth in the past few decades, which has had serious repercussions for both coastal environments and coastal peoples. It relates the criteria for sustainable aquaculture recently created by a working group of non-governmental organizations (NGOs), and finally, explores practical, existing models for sustainable shrimp aquaculture. These models require adequate research and development by those industries and institutions who are truly interested in ensuring the long-term sustainability of their enterprises. For the purposes of this paper, we define sustainable production as that which 1) maintains the integrity of affected ecosystems, 2) is equitably balanced with the natural resources and resource-users of the affected coastal zone, 3) is structured so as to promote social and economic equity within and between nations, and 4) is economically viable.

The Blue Revolution

Beginning in the 1960s and 1970s, industrial processes were widely introduced into aquaculture to encourage commercial production. Then in the early 1980s, major improvements in hatchery production and feed processing allowed rapid advances in shrimp farming techniques, making it possible to produce dramatically increased yields. This "Blue Revolution" has in many ways retraced the same path as the "Green Revolution" in agriculture, which contributed to the growth of large-scale export-oriented agribusiness enterprises in developing nations, but also generated widespread criticism for its environmental and social impacts. Lower prices of seed stock and improvements in feed technologies were major factors contributing to the rapid growth spurt in the shrimp aquaculture industry. Another important contributing factor was improved marketing of the shrimp product. In a short span of time, lowered retail prices meant higher consumer demand for the product. The new aquaculture techniques resulted in an explosive expansion of coastal shrimp aquaculture throughout developing nations in Asia and Latin America.

Today, this industry is overwhelmingly export-oriented, mainly serving consumers in Japan and the USA, although sizable markets now exist in Europe, Canada, Hong Kong and Singapore. Over 85% of worldwide farmed shrimp production takes place in Asia. Approximately twothirds of these shrimp products are exported to Japan and the United States for consumption, with the remainder divided among other foreign markets and luxury domestic markets. Though trawler-caught shrimp still dominate 2/3 of the world shrimp market, the rate of growth in farmed shrimp production will allow that sector to overtake, and even surpass, the wild-caught production by the year 2000. (1) Farmed shrimp production has truly skyrocketed, rising from just 26 thousand metric tons of production in the 1970s to 100,000 metric tons in the early 1980s to over 700,000 metric tons in 1995. (2)

Bankrolling a Bankrupt System

Shrimp aquaculture has become a global industry that has an annual farm-gate value of over $4 billion dollars, and an annual retail value of over $20 billion dollars. (3) It has great profit potential for the astute investor and entrepreneur. Spurred on by governments eager for increased export dollars, shrimp aquaculture development has been aided by generous support and incentives from international lending institutes, including the World Bank, Asian Development Bank, Inter-American Development Bank, and others. "The World Bank participated actively in the launching of the shrimp industry in Asia. Out of an investment of US $ 1.685 billion in 1992 for Indian agriculture and fisheries, the World Bank allocated US $425 million for aquaculture development. A substantial part of this sum seems to be destined for intensification and expansion of shrimp ponds..." (4).

However, the global economic figures and the allure of quick investment returns belies the fact that the shrimp aquaculture industry is a young giant with dramatic problems. It has a well-earned reputation as a "boom and bust" industry. The spread of deadly infectious viruses has ruined once thriving shrimp aquaculture industries in Taiwan (1988), China (1993), and Vietnam (1995), causing hundreds of millions of dollars worth of losses. Taiwan, once the world leader in farmed shrimp production, has never recovered from its crash in 1988. Thailand, Ecuador, and India, who have all vied for first or second place in farmed shrimp production, have also all suffered disease problems which have caused 50% or more of their pond operations to be shut down. In this way, the shrimp aquaculture industry is extremely vulnerable, and investments in shrimp aquaculture are continually at risk. While some ponds have been recuperated and put back into use, many have become wastelands, unfit for any resource-extractive purposes. Yet, while the World Bank funded a study in Thailand in 1994-95 to diagnose the widespread disease problems in the Thai shrimp ponds, it was simultaneously developing a loan proposal for Mexico, to develop semi-intensive and intensive shrimp aquaculture ventures based on the same management models as those in Thailand. The World Bank's Mexico Aquaculture loan has been indefinitely postponed due to many issues; principal among them was the opposition by local environmental organizations and fishermen associations.

"Food for the Hungry?"

One high profile rationale used by international lending agencies to justify the investments in aquaculture has been its importance as a tool to help meet food needs in developing countries, i.e. to "feed the poor". Ironically, the shrimp produced from these investments have been channeled exclusively to luxury consumers in domestic and international markets, and have never become a food source for those who are truly hungry. Each year Japan imports more than 4 million tons of fish products from over 120 nations, accounting for nearly one third of all international trade in seafood. Japan's import of shrimp products increased from "29% of the total imports of seafood in 1986 to 46% in 1991. In the United States, which contains the second largest shrimp market, shrimp consumption reached 2.5 pounds per capita .." (5).

When the "food for the hungry" rationale has failed, the industry's employment potential is raised as a way for those who are hungry to obtain sustainable incomes. This would certainly be an important benefit, as over 50% of the earth's population is now residing in coastal zones, which must at the same time play many vital "life support" functions for both the marine and terrestrial ecosystems. Even while coastal peoples rely heavily upon local fisheries for staple food and livelihood, these same coastal areas must often serve as the nurseries and breeding grounds for both near-shore and offshore marine species. In fact, scientists have estimated that 3/4 of the tropical world's marine catch is dependent upon mangrove forests for food or habitat, for some part of their life cycle. Thus, with rising numbers of fisherfolk depending upon the coastal resource base, alternative employment, such as in shrimp farms, would aid in preventing over-harvesting of regional fish stocks. But, this is only true if the shrimp farms themselves are not negatively impacting the coastal environment, and if the shrimp farms are actually hiring the local people.

In fact, there are grave concerns about the impacts of shrimp aquaculture on the environment, and in local communities. Quantitative, comprehensive studies are urgently needed to accurately document exactly who is being employed by the shrimp aquaculture industry in developing nations, and for how long. Initial studies conducted in the Philippines and in India (6) show that much of the local employment generated by shrimp farms is temporary, requiring high labor inputs only to construct the ponds. After initial facility development is completed, the shrimp aquaculture industry is a capital-intensive, rather than labor-intensive industry. For example, an intensive shrimp aquaculture business in India employs just 5 workers, while a rice paddy business of equal size requires 50 workers (Ibid.). Yet, in spite of its low local employment needs, shrimp aquaculture is being promoted in developing nations which have an abundance of labor, and shortage of capital.

Because of these reason, the World Bank and the Asian Development Bank have become increasingly reluctant to consider loans exclusively for shrimp aquaculture development over the past two years. Yet, the United Nations Food and Agriculture Organization (FAO) has recommended a doubling of aquaculture production in general by the year 2010 "in order to maintain present levels in per capita fish consumption for the world's increased population." (7) In its report on aquaculture, the FAO foresees substantial coastal aquaculture development in the Africa region. It also is currently providing strong technical support for coastal semi-intensive shrimp aquaculture development in many nations, such as Mexico, where there are three FAO aquaculture offices in the state of Sinaloa alone. The main purpose of these offices are to provide support for shrimp aquaculture ventures.

Identifying Unsustainable Aquaculture

The section below describes the three most common types of commercial shrimp aquaculture, and those characteristics which are contributing to the degradation of coastal ecosystems.

1) Industrial Extensive System

Initially, industrial extensive aquaculture meant simply the enlargement of traditional extensive ponds, combining shrimp production with rearing of herbivorous fish, such as carp or milkfish. "Stocking densities are around 10,000- 30,000 shrimp per hectare (1-3 per cubic m.)" (8). "The tides provide a water exchange rate of 5 to 10% per day. Shrimp feed on naturally occurring organisms which may be encouraged with organic or commercial fertilizer. Construction and operating costs are low and so are yields. Cast nets and bamboo traps produce harvests of 50 to 500 kilograms per hectare per year. Production costs range from $1.00 to $3.00 per kilogram of live shrimp..." (9)

Extensive shrimp ponds range in size from 5 - 50 hectares or larger. But whereas traditional extensive systems depend entirely on incoming tides to stock the ponds, industrial extensive ponds are partially, or mostly stocked with juvenile shrimp. Most of the industrial extensive pond stocking worldwide is dependent on wild caught shrimp fry, although there has been some growth in the use of hatchery larvae over the past several years. Industrial extensive shrimp mariculture is often dependent on generator-powered pumps to help increase the tidal water exchange, which is approximately 5-10% daily in extensive ponds. The pumps are needed because industrial extensive systems are increasingly taking on several characteristics of more intensive systems, which require higher inputs of "clean" water. These include: increasing the stocking density, using feed and fertilizer additives, and treating the ponds with pesticides and antibiotics to combat disease/predator problems. The pond waste waters are discharged, via drainage canals, back into the surrounding coastal estuaries, lagoons, and sea channels. In fact, the distinguishing factor between extensive and semi-intensive commercial shrimp culture is becoming more a matter of the size of the pond than a difference of management practices. Extensive shrimp aquaculture ventures are mainly concentrated in Ecuador, Honduras, Colombia, India, Bangladesh, Indonesia, and Vietnam.

While increased yields from the larger ponds have initially offered investors much higher profits, the industrial extensive system has created a host of environmental problems, stemming from the massive conversion of mangrove forests and other valuable coastal lands to shrimp ponds. Some shrimp aquaculture proponents have used figures indicating that shrimp aquaculture is only responsible for less than 7-8% of global mangrove forest destruction. (10) However, even if this figure is accurate, it refers to all deforestation since pre-agricultural times. Other data indicates that between 20%-60% of all recent mangrove deforestation in farmed shrimp producing nations is due to shrimp farms. (11) Coastal development plans and regulations which would assess the ecological carrying capacity of a given coastal zone for the maximum acreage of extensive ponds, have been virtually nonexistent in any meaningful form. The result has been that too many ponds were built in close proximity to one another, causing the loss of large tracts of mangrove forests, agricultural lands, salt flats and marshes. The overabundance of shrimp pond developments has led to problems of coastal soil and ground water salinization, erosion, siltation, and land subsidence. In Bangladesh, there have been numerous instances where the bunds of the extensive shrimp ponds were breached, in some cases intentionally by the shrimp pond owners so that they could discharge polluted water. This caused saline flooding of nearby crops, orchards, and drinking water sources of coastal villagers.

To compound the problems generated by the large-scale land conversion, the industrial extensive system is guilty of further abuses of coastal water resources. Industrial extensive systems in general have no mechanism to treat water from the shrimp ponds before it returns to the coastal ecosystem. Chemical pollution has become a serious problem, where farmers have adopted the use of pesticides. Chemicals that kill non-target species can result in near total depletion of certain species of fish, such as the use of a pesticide in Ecuador that was designed to kill a predator fish, the "millonario", which was invading the shrimp ponds in the province of Esmeraldas.

Another factor that has contributed to local fisheries declines is the selective harvesting process to catch the wild shrimp larvae for stocking the ponds. In fact, while the world is grappling with global fisheries declines due to the rate of by-catch and the number of vessels on the sea, it is useful to know that the shrimp fry fishery for aquaculture has the highest by-catch rate in the world, up to 20 lbs. of fish lost for every one lb. of shrimp larvae caught. Worse, the shrimp larvae by-catch consists mainly of other fish larvae which then never reach the reproductive stage. This certainly contributes to declining wild fisheries, including decreases in wild stock of the very shrimp larvae required by the industry, which once thrived in the now vanished mangrove forests. Vital habitats have been permanently lost for fish, mollusks, and crustaceans, as well as numerous birds, migratory species and endangered species.

Other associated social problems involve the loss of the traditional land base to the invasive extensive shrimp ponds, and with it, the means of sustenance for the coastal communities. For example, in just one province India alone, Andra Pradesh, 48,000 people were displaced in a period of less than three years by extensive and semi-intensive shrimp farm developments. In one district of Thailand, 4,000 rice paddy farmers were displaced by a shrimp aquaculture company.

2) Semi-Intensive Systems

Semi-intensive shrimp aquaculture is the main system practiced today worldwide. Semi-intensive systems are found in South and Southeast Asia., the USA, and Latin America. Semi-intensive ponds are built above the high tide line, and range in size from 5-25 acres. Pumps are used, instead of natural tidal flows, to exchange between 10 to 20% of the nearby estuarine or sea water a day. Semi-intensive systems increase the production rate still further than commercial extensive ponds. "With stocking rates ranging from 25,000 to 200,000 juveniles per hectare (3-20 per sq. m.), there's more competition for the natural food in the pond, so farmers augment production with shrimp feeds. Construction costs range from $10,000 to $25,000 per hectare. Yields range from 500 to 5,000 kilograms per hectare per year. Production costs range from $2.00 to $6.00 per kilogram of live shrimp. (12)

Though this form of aquaculture produces greater short-term profits than the extensive systems, the environmental and social costs, also referred to as the external costs, may be greater. In addition to repeating the same problems discussed above, the higher stocking densities and additional feed inputs of semi-intensive systems create new sets of water quality problems involving organic and chemical pollution. Massive amounts of organic wastes produced in these ponds builds up to dangerous and unwieldy levels. In fact, waste disposal problems have plagued the more intensive aquaculture systems since their inception. The increase in stocking densities and water exchange has meant that not only do the pond bottoms retain the organic bacteria, chemical additives and antibiotics, but also, these substances are released into the surrounding waterways. Nutrient-loading has resulted in eutrophication and algal blooms, killing many native flora and fauna. Decreased water quality is one factor that is believed to be contributing significantly to local wild fisheries declines--but once again, there have been very few studies conducted to provide an accurate picture of what is happening in the environment. Eventually, pollution buildup reaches a critical stage whereby even the shrimp ponds themselves become too contaminated, leading to the loss of entire harvests as the shrimp succumb to diseases and poisoning.

3) Intensive Systems

Intensive shrimp culture "introduces small enclosures (0.1 to 5 hectares) , high stocking densities (more than 200,000 juveniles per hectare (10-30 per sq. m.), around the clock management, heavy feeding, waste removal and aeration. Machine powered aeration--the addition of air, or oxygen, to the water--permits much higher stocking and feeding levels. The water exchange rate is 30% per day and up. Construction costs range from $25,000 to $250,000 per hectare. Sophisticated harvesting techniques and easy pond cleanup after harvest permit year-round production in tropical climates. Yields of 5,000 to 20,000 kilograms per hectare per year are common. Production costs range from $4.00 to $8.00 per kilogram of live shrimp..." (13)

The same pollution problems which have arisen in both extensive and semi-intensive shrimp culture can be greatly magnified by intensive shrimp aquaculture operations. In Asia, the average intensive farm has been found to survive only 2 to 5 years before serious pollution and disease problems cause shutdowns. Taiwan's experience with its own once thriving intensive aquaculture industry exemplifies a common scenario: ponds were overstocked and poorly cleaned, resulting in a toxic "sludge" formation on the bottoms of the ponds. This led to a virtual collapse of Taiwan's shrimp aquaculture industry. Unfortunately, important lessons which should have been learned from Taiwan's unsustainable shrimp cultivation practices were not learned. Overstocking and indiscriminate use of feeds and water additives still are being widely practiced today. In Thailand, where nearly 85% of the shrimp ponds are intensive systems, over half of the shrimp ponds have closed down in the first decade of Thailand's entry into the great race for world dominance in the shrimp export market. The Thai corporations such as Charoen Pokphand (CP) have survived by vertically integrating their industries, such that the bulk of their profits now come from providing feed, hardware, and consultant services (technical support) to the actual producers.

In addition to the many local economic crises engendered by unsustainable shrimp aquaculture, the consequent global environmental and social problems are alarming. Displacement of once self-reliant local communities has resulted from the encroachment of shrimp aquaculture along many tropical coastlines. While again, no global analysis has been funded or conducted, given the case studies that the Mangrove Action Project has collected, it is likely that hundreds of thousands of coastal farmers and fishers have been displaced by shrimp aquaculture developments from their once self-sufficient communities. Many of these people are forced to leave their families behind as they search regionally for seasonal labor jobs; or, they and their families migrate to urban areas where life is more precarious and their futures more uncertain. Loss of the invaluable coastal resources has led to destabilization of once sustainable, traditional livelihoods, as those who stay in the coastal zones resort to more and more destructive practices in order to extract enough food/income to survive from the diminished coastal resource base.

Unsustainable shrimp aquaculture is endangering the biodiversity and very existence of critical coastal ecosystems on the three continents where it has rapidly spread. (Initial developments have already begun on both the East and West coasts of Africa.) Shrimp farms replace a diverse, multiple resource environment with large-scale monoculture operations. One source estimates that nearly 800,000 hectares of mangrove forests worldwide have been destroyed by shrimp farming alone (14). With regard to the actual shrimp production, there are now only two species which occupy nearly 80% of all shrimp in trade. The species are commonly known as the "Black Tiger Prawn" and the "Western White Shrimp". While the global shrimp population has a diversity of over 120 species, there are just six species which now predominate in all shrimp culture operations. The shrimp aquaculture industry has in many cases indiscriminately released exotic or genetically altered species into the marine environment, and the long-term effects of these actions are still unknown. The pollution and loss of habitat has also endangered many other coastal flora and fauna, both in the sea and on the land. Just a few of the many endangered species which depend upon the same coastal habitats used for shrimp aquaculture include: the salt water crocodile, dugong, Olive Ridley sea turtle, crab-eating monkey, and the dark throated cuckoo.

Even the shrimp product itself, which is widely marketed and in popular demand in consumer nations, is questionable in regards to health risks associated with human consumption. The often indiscriminate use, or misuse, of antibiotics, pesticides, and other water and shrimp feed additives has raised some serious questions for consumers. Some antibiotics used in shrimp production are similar to antibiotics used to treat human diseases. Studies are currently being conducted by a team of scientists in the United States and the Philippines, to determine whether antibiotics used for shrimp production can create a resistance to these antibiotics in the humans who consume farmed shrimp. Due to escalating public concerns over health risks, Japan has identified over 20 antibiotics used in the farmed shrimp industry and has banned shrimp farmed with these antibiotics. Meanwhile, the United States Food and Drug Administration (FDA) only looks for residues of between just two to six antibiotics, and as yet, bans no shrimp cultivated with their use.

The costs of farmed shrimp production can be high--more than half the costs of intensive systems are related to the purchase of shrimp feed. Costs of seed stock, labor, pond equipment, water treatments and medicines for the shrimp contribute to total production costs. But these are the internal costs only, not including the greater external costs of the industry. External costs include recuperating endangered species, recovering lost water quality, replanting mangrove forests, rehabilitating displaced communities and fishworkers, and numerous others. Not only are these costs seldom adequately considered by industry economic analyses, but the shrimp aquaculture industry to date has invested extremely few resources into paying these external costs. The question must arise--are the temporary profits earned by a few ambitious investors worth the immense costs which both society and environment must bear?

In Search Of Solutions

Current methods of modern industrial shrimp aquaculture are in serious need of reform. One of the first steps toward sustainable solutions that the Mangrove Action Project and many of its member NGOs propose, is a worldwide one year moratorium on further shrimp aquaculture expansion, with the exception of small scale pilot projects for sustainable systems. During this time the international community, including industry, NGOs, and development institutions, must jointly support studies to map coastal resources in areas of significant present or proposed aquaculture activity, and to assess the impacts of different users so that the record of the shrimp aquaculture industry can be fairly judged. The moratorium is needed until proposed shrimp aquaculture developments can be adequately proved to be sustainable. Methods of economic valuation of coastal ecosystems, in particular mangroves, are essential if ecologically sound and socially equitable shrimp aquaculture is to take place. In this context it must be recognized that the economic value of the shrimp exports cannot take precedence over the broader social, economic, and environmental value of the coastal zone.

The aforementioned impacts of shrimp farming pose a direct and obvious threat to the future of agriculture and wild fisheries, and hence to global food production, if we are indeed discussing the production of staple foods for the populations who need food, rather than discussing the production of a luxury food item. The FAO Code of Conduct for Responsible Fisheries, in Article 9, states that aquaculture development should not negatively impact artisanal fisheries. Improved national and regional implementation of the FAO Code of Conduct, the Convention on Biological Diversity, and other existing laws and international agreements, will help to prohibit unsustainable aquaculture, before there is more irreversible damage, loss of biodiversity, or harm to coastal communities. In addition to improving compliance with existing controls, there is an urgent need in some nations for the creation of better regulations that can guide the development of more sustainable methods of aquaculture. Such laws should ensure the preservation of coastal ecosystems and cultures, the future of wild fish stocks, and hence, the future of the shrimp industry itself.

A number of possible solutions exist, but the viability of any new proposed method must be proven through extensive testing before applied large-scale in the field. In this way the massive failures that have resulted from undertaking untested operations in the past can be prevented. Reliable and consistent standards for stricter monitoring of the aquaculture industry must be developed and enforced, while cooperative industry participation in this regulatory process must occur. There is a strong need for an international "watch dog" body which can help establish guidelines for sustainability, ensure compliance, and participate in brokering international agreements that can create win-win situations for all who are involved. This body should be partially filled by representative non-governmental organizations working with local community representatives in a monitoring and consultative role.

Towards these ends, we suggest that a sustainable system be guided by the following principles:

The "Precautionary Principle"... The Precautionary Principle requires governments and industries involved in activities with potentially grave environmental impacts to take all necessary measures to assess environmental impacts before proceeding with any particular method or site-specific development. Where negative impacts are possible or likely, such projects should be stopped or modified.

Diversification... Individual aquaculture facilities should culture a diversity of species so as to avoid imbalances in wild fisheries, the rampant spread of disease, and selective killing of non-target species.

Integration... Aquaculture can be integrated with other human activities such as agriculture so that multiple resources may support a broader range of livelihood opportunities. Likewise, shrimp farms must be limited in the percentage of land they occupy in a given area.

Localization... Aquaculture must be developed around the needs of local communities. Assuming a facility has met all the requirements for sustainability, it should incorporate these in operations and long-term planning.

The following (edited) list of guidelines for sustainability were presented as an NGO Declaration to the United Nations Commission on Sustainable Development, in New York, in April, 1996.

* Ensure that aquaculture development does not limit access to coastal resources by coastal communities and artisanal fisheries.

* Ensure the use of environmental and social impact statements to prevent or modify potentially damaging projects; ensure regulation and continuous monitoring of operations.

* Ensure the protection of mangrove forests, wetlands, and other ecologically sensitive areas.

* Discontinue the wholesale conversion of agricultural/cultivable land to aquaculture use.

* Stop the use of toxic pesticides and antibiotics, in addition to shrimp feeds consisting of fish that is or could be consumed by people.

* Stop the use of exotic/alien species and the use/development of genetically modified organisms.

* Stop the pollution of fresh water/ground water supplies necessary for drinking water or agriculture.

* Ensure that abandoned or degraded aquaculture sites are ecologically rehabilitated and that the companies or industry responsible bear the costs of rehabilitation.

* Ensure that aquaculture is integrated in a compatible manner with the social, cultural, and economic interests of coastal communities; this includes the meaningful participation of local user groups in coastal management planning.

* Discontinue the funding and promotion of aquaculture by multilateral banks, bilateral aid agencies, and the UN food and agriculture organization which are inconsistent with the above criteria.

Until now, there has been extremely little research and development devoted toward implementing alternative methods which are significantly different from those of the current dominant models (extensive, semi-intensive, intensive), that could satisfy the above criteria for sustainability. Given the track record of these models, the time has come for dedicated scientific research and development of more sustainable alternatives.

Working Models for Sustainability

The Mangrove Action Project has investigated potential models for sustainable shrimp aquaculture production over the past two years. MAP's approach to its research as well as its networking involves a process of "Co-learning". Co-learning aims to make use of both traditional and modern methods, from both developed and developing nations. In effect, co-learning is a process of building bridges between the old and the new, and between the different actors and methods which are involved in any initiative. Thus, below we offer sketches of three different models for sustainable production: two from traditional aquaculture, and one that is a brand new experiment involving heavy technological and capital inputs. These forms of shrimp aquaculture are all currently being practiced in areas of the world today, and they all appear to meet most if not all of the above criteria for sustainable shrimp culture.

Traditional Extensive Systems:

There are some traditional methods of shrimp aquaculture which have been practiced sustainably on a small scale for thousands of years. These systems are low-intensity, usually sustainable systems which depend on diurnal tidal inundations to supply the larval shrimp and all of their food nutrients to the ponds. Usually the ponds are relatively small, and often placed within the mangrove forests. Since mangroves also serve as natural shrimp nurseries, there are sufficient supplies of shrimp larvae to naturally stock the ponds. Excavation of shallow ponds among the mangroves allows a containment area for juvenile shrimp to mature without much maintenance required. Stocking rates in these traditional ponds are less than 10,000 fry per ha (<1 per sq. m.). Usually, these are polyculture ponds, also containing finfish, such as milkfish in combination with the shrimp. Yields are low, perhaps less than 500 kg per ha per annual harvest, but this provides additional supplemental income and protein source to make such production worthwhile. Traditional pond production mainly satisfies local consumer needs, as very little product is exported. (15)

Model 1) Indonesia's traditional "Tambak" System

In Indonesia the tambak system combines rice paddy production with finfish and shrimp aquaculture, whereby the fish and shrimp are reared in the rice paddies after the rice has been harvested. The man-made dikes, which usually separate and protect the paddy from the incoming tides, are intentionally breached so that sea water can enter at high tide. In this way larval fish and shrimp are captured and reared to maturity. After the fish or shrimp are harvested, the paddies are reconverted in preparation for the next rice crop. This system of production traces its roots back many hundreds of years, and may be one of the earliest forms of aquaculture practiced in Asia.

Model 2) The Gei Wai System

In Hong Kong, another traditional aquaculture system evolved, perhaps centuries ago. Gei Wais basically utilize the positive attributes of natural mangrove forests as nursery and breeding grounds for fish, crabs, mollusks, and shrimps. Wide channels around one to three meters in depth are excavated around what becomes a small island of healthy mangrove forest.

The channels allow the several acres or more of each Gei Wai pond to hold sufficient waters at low tides to sustain the captured shrimp and fish. At high tides renewed sources of nutrients enter the ponds through constructed sluice gates to sustain pond life anew. In this fashion, up to 1900 kg of shrimp can be raised and harvested annually from one Gei Wai. Today, there is only one remaining area of Hong Kong, called Mai Po, which borders Deep Bay, where gei wais are still found. These few remaining gei wais are protected as a nature reserve by the Hong Kong Government. Mai Po continues to serve as an important site for long-distance migratory birds and wildlife. The World Wide Fund for Nature Hong Kong has managed this site since 1984, utilizing the sale of its harvested shrimp to help subsidize the expenses involved in site management. One of the greatest recent threats to the Mai Po reserve and its gei wais is the intrusion of mounting water pollution from mainland China. Fish and shrimp varieties and populations have already declined.

Can these traditional systems be viable at the scale of commercial shrimp aquaculture enterprises? Perhaps not; however, it must be noted that shrimp aquaculture operations themselves are often out of scale with the multiple needs and users of natural resource base they depend upon. Some research indicates that the eco-cultural principles traditional methods are based on can be successfully adapted to larger-scale operations. For example, MAP is aware of efforts in Thailand, the US, and Ecuador to diversify aquaculture production whereby two or more mutually compatible species are cultivated in a particular pond. Some shrimp ponds are trying to improve their water quality by introducing seaweed and mollusk culture within the drainage canals of the pond complex to remove nutrients and pollutants before the water is discharged. In Vietnam, prawn farming which partly serves an export market also integrates rice production and garden cultivation for local markets. Also, in areas where shrimp production has suffered from widespread disease, the industry has sought to diversify their crops. These are all good first steps, but increased efforts are needed. MAP believes that given adequate research and testing, the traditional models can offer important principles, like those outlined above, for sustainable farmed shrimp production at the commercial level.

Model 3) Modern Closed System Shrimp Aquaculture

In the US, Thailand, and other countries where industrial shrimp aquaculture is being competitively pursued, a new alternative method is being lauded as more sustainable. This is the so-called "closed production system" approach. The aquaculture industry has itself been wrestling with those many insurmountable problems inherent in the so-called "open production systems." This stems from the fact that these present-day methods of shrimp aquaculture still pollute and degrade their surrounding environments, while at the same time depending on a healthy state of natural resources to maintain their own production. This reliance on the health of the external environment, such as the sea and fresh water sources, while at the same time degrading these very vital supporting systems with massive amounts of toxic effluents, classifies these self-degenerative open-cycle production schemes as "throughput systems."

The "closed-system" potentially eliminates many of the obvious failures of the modern "open-production system", by operating in a more environmentally "friendly" fashion. Recirculating production pond waters, while removing toxins from these fouled waters is one step in the right direction. Recycling of the effluent waters emanating from the production ponds can be done in various ways, ranging from complex and costly water filtration systems to establishment of settlement ponds, or integrated secondary containment ponds.

High technology closed systems are being tested now with some hopes for success. Taking the closed system to its ultimate levels has led some ambitious aquaculturists to set up facilities within a fully contained facility, where all levels of the shrimp production operation take place indoors. Such a large enclosed facility was in operation in Texas, until recently. However, it appears now that internal managerial problems have curtailed these operations.

Nevertheless, there is still hope that innovative closed-system aquaculture might one day succeed, where the open-cycle systems have so miserably failed. Water quality is obviously a major concern of any aquaculture facility, and elimination of antibiotics, pesticides, and fertilizers will help alleviate one of the major contributing factors leading to water quality loss during production. Also, improved feeds and feeding regimes are important considerations in water quality control, as is regular careful monitoring and assessment of the internal pond environment.

Integrated aquaculture techniques are also proving promising for semi-closed production methods. In some ponds, oysters and other shell fish, fin fish, and seaweeds are being cultivated either together with the shrimp, or in separate but interconnected ponds. The recycling shrimp pond water provides many nutrients for the other cultured species, which in turn can filter out a lot of the particulate matter and pollutants, thus helping to purify the fouled waters. For example, oysters can filter up to 50 gallons of water per day. Thus, they can potentially aid considerably in absorbing the excess organic substances in the ponds.

In addition to the ecological advantages of an organic, closed-system approach, the pond operator can actually stagger harvests and sizes to produce whatever the current market demands on a year round basis. While the initial financial risk is steep, the closed-system eliminates many of the production risks that are beyond the control of most shrimp farm operators, such as pollution and disease from coastal water exchange, natural predators, weather peculiarities, and the side effects or long-term effects of medicinal additives such as synthetic antibiotics. These drawbacks are increasingly unappealing to consumers who want to know how their food is produced.

One great disadvantage at present is the very high startup costs for a fully integrated and enclosed facility. These high technology and capital intensive systems cannot replace in importance for developing nation coastal communities the more labor intensive and sustainable traditional systems, which have served for generations local consumption needs. However, such closed-systems hold great potential to one day fill the current outside market demands of those numerous shrimp importing nations, especially when today's consumption demands far outweigh the current ability of the industrial aquaculturists to produce enough shrimp in environmentally and socially friendly ways.

Sustainable Shrimp Aquaculture in the Context of Community Based Coastal Zone Management

An overnight global conversion from open coastal ponds to indoor shrimp pools is hardly likely. As long as shrimp aquaculture continues to take place in heavily populated, and heavily used coastal environments, all shrimp mariculture enterprises should be considered in the balance of other coastal needs. Thus, in addition to environmental diagnosis and corrective scientific measures, social analysis is mandatory to determine who are the beneficiaries of shrimp aquaculture developments, particularly in developing countries. Sustainable solutions for specific shrimp aquaculture operations can be meaningless if there is not a wider approach to sustainability in the entire coastal zone in which the company practices. Community-based coastal zone management (CBCZM) is an approach that works to ensure stability and balance between the multiple resources, and multiple users of the coastal zone. CBCZM recognizes the rights of local community groups to meaningfully participate in regional coastal management plans. Local people who have a stake in the economic, ecological, and cultural future of their environs will be much more likely to cooperate in protecting and managing coastal resources sustainably.

Unfortunately, traditional knowledge or expertise is often undervalued, or misunderstood, by governmental or non-governmental organizations attempting to implement sustainable resource management programs involving local communities. Yet, coastal zone management programs could provide an invaluable opportunity to document and maintain the traditional wisdom that is so often weakened by modern developments. A more integrated approach would blend the "traditional" and the "modern", highlighting the merits of both. A recommended approach to local resource management is for governments to provide the legal and the administrative framework to support traditional coastal management systems. Such efforts must engender community support, trust, and involvement from the beginning.

There must be a recognition of inherent differences in philosophy which often separate so-called "modern" and "traditional" approaches. Modern systems are technically based and designed to serve consumers who are disconnected from production processes. Traditional systems, on the other hand, have both a social, cultural and spiritual base. By definition they serve the local populations which manage them. Thus, when attempting to apply a particular traditional method to modern aquaculture to create long-term sustainability, it is important to holistically identify the elements of that system which are responsible for its success, rather than simply adopting its practices. Otherwise, the advantages of using that system as a model will be lost, and there will be no guarantee of sustainability. Adapting the production methods of a traditional system to suit the needs of a global economy may be of questionable merit, if local communities are excluded from owning, managing, or working within the enterprises. Also, there is questionable merit to site-specific ecologically sustainable enterprises if local communities do not consume any portion of the farmed shrimp yields, and must increasingly produce adequate protein for themselves from the diminished coastal resource base that they now share with the shrimp industry.

SUMMARY

As we have seen, the coastal zone, where more than half the world's population is concentrated, must serve numerous functions in maintaining human populations, biodiversity, fisheries, and climate patterns. The widespread, unchecked development of commercial shrimp aquaculture lacking in proper testing or research has led to extensive damage to coastal ecosystems. Among these impacts, numerous countries throughout Asia and Latin America have lost significant portions of critically important mangrove forests. In 1996, specific standards for sustainable production were advanced by non-governmental organizations (NGOs). These NGOs propose a moratorium on shrimp aquaculture developments until alternative systems, based on the standards for sustainability, can be implemented. Some hope for sustainable models that could change aquaculture practices for the better include traditional aquaculture methods, such as the gei wei and the tambak, and new technological innovations, such as the"hyper-intensive" closed-system shrimp produced in indoor facilities. These models reflect the basic principles of precaution, integration, diversification, and localization. Finally, all models for site-specific sustainable production must be placed with the context of community based coastal zone management, in order to fairly balance the many needs and users of coastal zones. Sustainable shrimp aquaculture production that responds to these concerns will have the best chances for the long term ecological, economic, and social stability that is needed for successful operations.

Notes:

Commercial Shrimp Varieties:

A wide variety of shrimp are raised aquaculturally. However the Black Tiger (Penaeus monodon), named for its large size (up to 336 mm.) and striped tail, dominates world production with a 57% share of the market in 1995 (mainly produced in Asia). The Western White Shrimp (Penaeus vannamei) has a 20% world market share, being produced largely in Latin America, especially in Ecuador, which is the largest shrimp exporter in the Western Hemisphere. Other cultured species include, "Penaeus stylirosis (the Pacific Coast of Latin America), P. chinensis (northern China), P. japanicus (Australia, Japan, China, and Taiwan), P. Penicillatus (Taiwan and China), and P. merguiensis and P. indicus (extensive farms throughout South East Asia). Merguiensis and indicus, both considered 'white' shrimp, have attracted attention recently because they tolerate low water quality better than monodon, they can be grown at high densities, and they are readily available in the wild." (12)

The Natural Cycle of Shrimp Development

Though shrimp aquaculture methods greatly vary, there is an underlying natural theme which each mode of production seeks to emulate in one way or another. In the wild, shrimp breed close to shore, the bountiful shrimp larvae then utilize the protective roots of the lush mangrove forests for their nursery grounds. Within the mangrove swamp the larval shrimp feed on the rich forest detritus while passing through their early developmental stages, from postlarvae to juvenile.

Juvenile shrimp eventually leave the protective mangrove forest areas to dwell further out at sea, where they develop into adults, returning to the inshore areas later to breed. This cycle of Nature has been so successful that there had never before been a shortage of shrimp, and local fishers could depend on a good harvest each year.

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The Mangrove Action Project, MAP - MAP is an NGO network and information clearinghouse that formed to support local organizations worldwide in their efforts to reverse mangrove forest destruction. MAP has collected information on sustainable and unsustainable shrimp aquaculture since its inception in 1992. The organization's activities include networking, education, advocacy, and financial support to locally based pilot projects and conservation campaigns.

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