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Developments In Sustainable Shrimp Farming In Southeast Asia

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Abstract

In Southeast Asia, shrimp aquaculture has been practiced for many years and is a traditional coastal farming activity in several countries. The recent trend has been towards more intensive forms of culture resulting in a number of problems. However, experiences in the region suggest that shrimp farming can be socially, environmentally and economically sustainable and contribute to the production of food and alleviation of poverty in coastal areas, provided that appropriate management practices are adopted. Technical, economic, social and environmental issues have to be considered in the development and implementation of such management practices.

In the light of serious shrimp disease problems which have affected shrimp farming worldwide, and various environmental and social interactions, some have concluded that shrimp farming development in the region has not been completely sustainable. This paper provides background on the major sustainability issues and management strategies which need to be considered in the development of sustainable shrimp aquaculture. Good farm management practices such as farm siting, construction and design, seed quality, feed and fertilizer, water management, sediment management, shrimp health management practices, and efficient use of inputs and resources should be voluntarily followed and monitored. In order to maintain social harmony and minimize environmental impacts, integration of aquaculture into coastal area management as well as appropriate zoning, policies, regulations and legislation should be allowed for a balanced coastal development. Furthermore, active cooperation among farmers and their involvement in policy setting and planning for coastal development can contribute to better understanding of key issues and promotion of better management practices.

Fortunately, awareness and experience in sustainable management of coastal shrimp aquaculture in Southeast Asia is growing, and a number of local, national and regional initiatives are being taken to develop and implement improved management practices. At international levels, the FAO Code of Conduct for Responsible Fisheries Responsible Fisheries (CCRF), adopted in 1995 as a global inter-governmental consensus on the promotion of sustainable fisheries and aquaculture developments, provides a framework of basic principles and norms which all stakeholders concerned with shrimp culture can use as a common platform for better understanding, consultation and collaboration. Examples of recent efforts by NACA, in cooperation with FAO and other interested partners, in the implementation of the CCRF are given, and suggestions are provided to further promote the sustainable development of shrimp culture. A number of researchable issues on sustainable shrimp aquaculture are also reiterated for discussion in this seminar-workshop.

Introduction

FAO production statistics show that shrimp aquaculture expanded very rapidly in 1985-1995, averaging a 24.8% annual growth rate. Growth declined to only 8% per year in 1990-1995. But, since 1995, growth has been stunted due mainly to viral diseases, market issues, and environmental-related problems. In 1997, around 941,000 tons of shrimps and prawns valued at US$6.1 billion were cultured. Since 1991, cultured shrimps accounted for 27-29% of total shrimp production.

Global production of cultured shrimp and prawn continues to be dominated by Southeast Asia, which produced 504,769 tons accounting for 54% of global production in 1997 (Table 1). Thailand, the world's largest producer, saw its production decrease from a peak of 265,524 tons in 1994 to around 215,000 tons in 1997 because small shrimps were harvested in low or zero-water exchange culture system to minimize disease problems. The Philippines also reported similar decreases due to disease and reduction of stocking density. The growth of shrimp culture in Indonesia was interrupted by the local political situation and economic crisis. New countries such as Vietnam and Malaysia showed gradual increase in shrimp aquaculture outputs. Overall, shrimp production in Southeast Asia decreased by an average of 4.5% per year since 1995.

Thailand, Indonesia, Vietnam, Philippines and Malaysia dominate giant tiger shrimp (*Penaeus monodon*) aquaculture production, which is the major farmed shrimp species in these countries, making up around 52% or 83% of total global shrimp production and Southeast Asia production, respectively.

Table 1. **Shrimp production in Southeast Asia (in mt)**

	1992	1993	1994	1995	1996	1997
Brunei	2	4	5	10	27	57
Banana	-	-	-	-	-	-
Giant tiger	2	4	5	10	27	57
Other	-	-	-	-	-	-
Indonesia	141,586	138,578	132,406	145,216	151,086	158,480
Banana	21,779	29,167	23,860	31,676	28,822	31,800
Giant tiger	98,358	87,285	83,193	89,344	96,237	99,680
Other	21,449	22,126	25,353	24,196	26,027	27,000
Malaysia	2,963	3,994	5,858	6,779	7,501	9,519
Banana	142	57	69	66	89	139
Giant tiger	2,821	3,937	5,789	6,713	7,412	9,380
Other	-	-	-	-	-	-
Myanmar	1	3	3	5	7	8
Banana	-	-	-	-	-	-
Giant tiger	1	3	3	5	7	8
Other	-	-	-	-	-	-

Table 1. **(Continued)**

Philippines	78,396	95,816	92,647	90,491	78,067	41,610
Banana	760	230	378	346	709	687
Giant tiger	75,996	86,096	90,426	88,850	76,220	40,102
Other	1,640	9,490	1,843	1,295	1,138	821
Singapore	57	77	14	17	98	95
Banana	57	77	14	12	78	11
Giant tiger	-	-	-	5	20	20
Other	-	-	-	-	-	64
Thailand	184,884	225,515	265,524	260,713	224,836	215,000
Banana	4,752	3,285	3,000	1,814	1,827	1,700
Giant tiger	179,358	219,900	259,724	257,062	220,372	211,100
Other	774	2,330	2,800	1,837	2,637	2,200
Vietnam	37,800	42,000	45,000	52,000	65,000	80,000
Banana	7,560	8,400	9,000	10,400	13,000	16,000
Giant tiger	28,350	31,500	33,750	39,000	48,750	60,000
Other	1,890	2,100	2,250	2,600	3,250	4,000
Total	445,689	505,987	541,457	555,231	526,622	504,769
Banana	35,050	41,216	36,321	44,314	44,525	50,337
Giant tiger	384,886	428,725	472,890	480,989	449,045	420,347
Other	25,753	36,046	32,246	29,928	33,054	34,085

FAO Aquaculture Production Statistics, 1999

Definitions of Sustainable Development

There are a number of definitions of sustainability, although there are many different views on this topic. The commonly quoted FAO definition of "sustainable development" is:

"the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (Barg, 1992).

In practice, sustainable development involves a consideration of technical, social, inter- and intra-generational equity, environmental, economic and institutional issues (Muir, 1996). With reference to aquaculture, management of sustainable development therefore requires attention of:

- Farming system and technology,
- Economic/financial sustainability,
- Social sustainability - social benefits, equity and interactions,
- Environmental sustainability - mainly interactions and use of major resources such as land, water, seed and feed, and
- Institutional and legal context.

Problems and Issues of Shrimp Farming

Diversity in the shrimp culture sector

Shrimp farms are commonly classified into extensive (low input systems characterised by low stocking densities, tidal water exchange and shrimp yields of less than 500 kg/ha/yr); semi-intensive (supplemental feeding, intermediate stocking, occasional pumping of water and yields of 1-2 tons/ ha/yr); and intensive high stocking density formulated feeds, aeration and water pumping with yields of more than 2 tons/ha/yr). Farms may also be monoculture or polyculture (usually more common with low input systems); they may be operated as alternate cropping, involving one crop of shrimp followed by a harvest of another species (sea bass, milkfish) or crop (rice-shrimp alternate cropping systems in Vietnam). The farm size is also very variable, but shrimp farms in Southeast Asia are mainly small-scale.

Thus, an important consideration when discussing shrimp farming and its management is the diversity of farming systems in operation as well as their location, size, management and the people involved. Inevitably, with such diversity, most management decisions should be made based on a clear understanding of the diversity and practical circumstances at the local level.

Shrimp farming also supports a large number of associated “industries”, including input suppliers (such as nauplii production, hatchery operators, manufacturers and suppliers of feeds, equipment, chemicals, pond construction, sediment removal, etc.) and people and businesses dealing with post-harvest handling and processing, distribution, marketing and trade. This diverse and sometimes fragmented structure of these sub-sectors has also to be considered in assessments of the nature of shrimp farming and its management (Fegan, 1996).

Economic significance

Shrimp farms generate considerable economic returns. Globally, it earns around US$6 billion yearly at farmgate prices, with the value increasing substantially as shrimp moves up the market chain to the consumer. In 1995, shrimp aquaculture production was estimated to be worth US$20 billion in Asia, with infrastructure investment in ponds alone around US$11.5 billion (ADB/NACA, 1998).

Poverty alleviation through income generation among coastal peoples is a critically important development objective (Islam and Jolley, 1996) to which shrimp and other forms of coastal aquaculture can contribute.

Social interactions: people involved, employment, and social impacts

A diversity of people from various backgrounds, social groups and traditions is involved in shrimp farming. Investment and economic output from shrimp generates considerable employment in developing (but also developed) countries from input suppliers (e.g. hatchery operations, feed sales), producers (farmers and farm workers) and in post-harvest and processing, including employment for women. Employment in distribution, marketing and trade is also significant. Exact numbers employed in shrimp farming are unknown. Some estimates suggest that globally around 1 million people may be involved, although this figure is probably an underestimate.

In Thailand, more than 150,000 people are directly employed in shrimp farming (Kongkeo, 1995), in addition to a large number involved in input supplies, support services, handling and processing of shrimp products.

Employment generated by shrimp farming can compare very favourably with some other agricultural and traditional activities in coastal areas. A survey (ADB/NACA, 1998) of around 5,000 diverse shrimp farms in Asia showed that intensive shrimp farming provided an average of 558 person-days/ha/yr. Semi-intensive shrimp farms provided a similar figure, but traditional/extensive farming systems had a much lower estimate of 192 person-days/yr. Even if multiple-use traditional activities are accounted, the employment potential of semi-intensive and intensive shrimp farming clearly compares well with traditional coastal activities such as rice, mangrove crab, and timber collection. Rice farming employment figures are commonly reported at around 200-250 person-days/ha/yr.

In Southeast Asia, small-scale farmers make up a major proportion of the shrimp farming/hatchery population, although there is a considerable variation among countries. A 1996 survey of 400 intensive shrimp farmers in Thailand showed that a majority of shrimp farmers were previously rice farmers or fishermen in rural areas. However, most investors from towns left their shrimp farming business since the golden age of shrimp farming has passed. Shrimp aquaculture can therefore contribute to diversification of employment opportunities in coastal areas. Such positive contributions to development among local people obviously need to be strengthened.

These positive aspects need to be set against the risk associated with calamities such as for example floods or shrimp disease, which, when they occur, can make such employment gains and other benefits short-lived. In some countries, concern has been raised about the distribution of benefits from shrimp farming (Olsen and Coello, 1995) and social conflicts have also sometimes arisen with other coastal resource users and communities as a result of rapid expansion of ponds (Bailey, 1988; Clay, 1996). Such issues have to be properly understood and ‘managed’ within the context of a management framework for sustainable shrimp aquaculture.

Environmental interactions

Environmental interactions of aquaculture in general arise from a wide range of interrelated factors including availability, amount and quality of resources utilized, type of species cultured, size of farm, farming systems management, and environmental characteristics of the farm site. These interactions arise because aquaculture relies heavily on environmental “goods” (e.g., water, feed ingredients, seed, etc) and “services” (e.g., coastal ecosystems for pond water discharge). Three issues arise from these interactions:

- aquaculture in general, and shrimp farming in particular, is highly sensitive to adverse environmental changes (e.g., water quality, seed quality), and can be seriously affected by aquatic pollution;

- aquaculture inevitably interacts with non-aquaculturists that rely on “commonly-shared” resources such as water and public land and may arise when formal and informal institutional, legal, and social structures are inadequate for conflict resolution and for allocation of resources among competing groups; and

- it is in the long-term interests of aquaculturists to work towards protection and enhancement of environmental quality. This raises interesting possibilities for aqua-farmers to work in partnership with communities and other groups with a mutual interest in protection of aquatic environments (Barg *et al.,* 1997), given that aquaculture needs good quality water and other natural resources.

They key environmental interactions of coastal shrimp culture are well known and are related mainly to the habitat and aquatic resources in shrimp aquaculture areas. Environmental impacts may arise through impacts on aquaculture, of aquaculture on the environment, and impacts of aquaculture on aquaculture. Perhaps less well known and documented is that coastal aquaculture, including shrimp culture, can contribute to environmental improvement, such as:

- Removal of nutrients and organic materials from coastal waters through seaweed and mollusc culture;
- An alternative source of employment for local peoples utilizing coastal habitats. For example, mixed aquaculture-mangrove systems can restore mangrove habitats in some countries (e.g., Indonesia's tambaks, Vietnam's mixed-farming systems);
- Mariculture providing an alternative to destructive fishing in coral reefs;
- Rehabilitation of fish stocks through stocking; and,
- Monitoring of environmental conditions

Management Strategies for Sustainability

Background

Management strategies for sustainability require consideration of a complex range of factors but generally require the consideration of strategies at different levels: (a) the farming activity (e.g., in terms of the location, design, farming system and operational management); and (b) the 'integration' of aquaculture into the developmental and environmental context characteristic of the specific coastal area in question.

Implementation of such management activities also implies human interventions at various levels, from the level of the farmer or investor to government policy. Because of the complex interactions of environmental, social and economic levels, an integrated view of coastal resource use, where shrimp aquaculture is but one activity among different economic and social uses, is essential.

Guidelines are already emerging for the improvement of management practices for shrimp aquaculture. In addition to efforts in the past (ADB/NACA, 1991; FAO/NACA, 1995), these include recent studies in Asia which produced the Regional Aquaculture Sustainability Action Plan (ASAP), prepared during the Regional Workshop on Aquaculture Sustainability and the Environment in Beijing, China in October 1995 (ADB/NACA, 1998), and the more global FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO, 1995) and its associated Technical Guidelines FAO, 1997. In very broad terms, these initiatives identify management strategies at the level of:

- Technology and farming systems: The importance of appropriate farming technology/system and management of major inputs and outputs, with special attention to the major resources of feed, water, sediments and seed. Management actions taken at this level mainly involve the farmer and input suppliers.
- Adoption of integrated coastal area management approaches: The importance of integrating aquaculture projects within existing environmental (and social) systems in coastal areas is being increasingly recognised. This approach requires consideration of proper site selection and planning and management strategies, which allow allocation of resources among different coastal resource users. Management actions at this level are more complex and involve more 'players', including the farmer, other users of coastal resources, and government.

  Policy and institutional support: The importance of an unambiguous and supportive policy framework is strongly emphasised. Specific issues to be addressed may include aquaculture legislation, economic incentives and dis-incentives, public image, private sector and community participation in policy formulation, increasing the effectiveness of research, extension and information exchange. Management actions taken at this level are primarily the responsibility of government, although formulation of policy should also involve input from other 'stakeholders'. Policy decisions and their implementation play a strong role in influencing the management possibilities at the previous two levels.

Farm management practices

There are already a number of significant changes taking place in management practices at the farm level in several countries. The following are major management considerations for shrimp farming based on the ASAP and FAO's CCRF:

Farm siting: Many problems that have emerged with shrimp culture could be conveniently avoided by appropriately siting farms, which consider existing environmental suitability and social values and options for alternate uses. For example, problems associated with semi-intensive and intensive shrimp ponds in mangrove areas can be avoided by locating farms behind coastal mangrove belts (see Menasveta, 1997). Some of the constraints causing poor siting such as unclear land-use rights and others (see Fegan, 1996) should also be addressed. Mangrove land, for example, whilst widely recognised as a poor site for intensive shrimp pond development, may (in the past at least) have been more easily accessible because of lack of clear property rights and government incentives, which previously recognised mangroves as land of marginal value. Fortunately, there is increasing recognition that mangroves are not suitable sites for intensive farms, because of various risk factors (e.g., acidic soils, peaty and soft soils, etc). The cost of land in supra-tidal areas such as rice fields is higher, but the cost of construction for intensive ponds is much lower because heavy machines can be used efficiently. When shrimps are cultured in mangrove areas where water and soil contain high organic loads, disease problems always occur. In contrast, pond bottom in supra-tidal areas can be completely dried-out for efficient removal of the fouled bottom layer by heavy machines. Where farms are located behind mangrove areas, care is required to minimise potential salinisation impacts on surrounding lands through buffer zones, good farm construction and design (see below).

Farm systems development: Development of sound shrimp farming systems may enhance sustainability. Effluent from intensive ponds may be a useful source of nutrients and organic matter for mangroves, for instance. Integrated systems of farming freshwater fish, where aquaculture is integrated with agriculture, are recognized as environmentally sound systems given their efficient rates of conversion and recycling of nutrients and organic materials. There are many examples involving freshwater aquaculture, where pond water and sediments have been used to fertilize agricultural crops, thus eliminating the potential environmental impacts of effluent (see Edwards, 1993 for review). Such systems tend to be inherently more environmentally sustainable because they rely on more inputs from within the farming system, and therefore tend to have less demand for environmental 'goods' and 'services'. There are a number of advantages to diversification of systems, such as spreading the risk associated with monoculture among different crops and recycling of nutrients and organic matter.

Rice-shrimp farming is widely practiced in some parts of the Mekong delta in Vietnam, and in other delta areas in Asia. Such systems, which alternate rice farming in the rainy season with shrimp in the dry season (when there is salt intrusion), have been shown to be sustainable over long periods (Mekong Secretariat, 1992) and suffered less shrimp disease problems during recent white spot outbreaks (ADB, 1996). Alternate cropping between shrimp and fish has also been recommended on intensive farms. Mixed fanning systems have also been promoted in some areas. Integrated aquaculture-mangrove forestry (silvo-fisheries) offers one approach to conservation and utilization of the mangrove resource which allows for maintaining a relatively high level of integrity with the mangrove area while capitalizing on the economic benefits and poverty alleviation potential of brackishwater aquaculture (Fitzgerald, 1997). Indeed, silvo-fisheries have been used in mangrove replanting projects now being undertaken in Vietnam, Indonesia, and Philippines. These models should be further researched and mangrove-compatible systems promoted.

Intensive farming can be sustainable if well located and practiced with good management (e.g., incorporating some of the practices identified in this paper) since some intensive and semi-intensive shrimp farms have been operating in Asia for at least ten years. The opening up of ecologically-sensitive areas for extensive monoculture farming seems hard to justify given the large areas required for profitable farming and the low economic returns per unit area. Future development of shrimp farming systems is therefore likely to be towards more intensified systems, although perhaps not as intensive as in the recent past, and will necessarily have to give much greater attention towards 'management for sustainability'.

Farm construction and design features: Farm construction practices and design are important in the management of environmental interactions, and much can be done to mitigate environmental problems by adoption of appropriate practices in the construction and design of farms. To prevent conflicts with nearby rice farms, the ponds must be designed to have proper drainage system without interfering with freshwater canals. Pond embankments should be well compacted to prevent seepage of saline water into rice paddies. Saltwater intrusion can be avoided by siting farms on clay soil areas. The incorporation of water treatment ponds (as in the case of Thailand, where larger farms are now required by law to incorporate a settlement pond in farm designs) can help to reduce effluent load. Buffer zones between farms and surrounding land can also be used to minimise impacts on surrounding ecosystems, protect nursery grounds for aquatic life, and protect traditional activities. Mangrove buffer zones provide protection from storms, maintain traditional fisheries, and may even improve water quality (Macintosh, 1996). The water supply and drainage canals should be designed to reduce mixing of inflow and outflow waters and to adequately disperse effluents. To facilitate optimal water circulation in ponds, the pond shape for intensive culture systems should be square or round with an optimal size of 0.5-1.0 ha.

Selection of suitable species and seed: Shrimp culture in some countries also relies on wild shrimp post-larvae (Banerjee, 1993), leading to concerns about social and environmental impacts of shrimp seed collection. The increasing trend towards use of hatchery-reared shrimp helps reduce the reliance (and potential impact) on wild stock. The use of indigenous shrimp species would be preferable to introduced species, and genetic improvements may provide better stocks. Care needs to be taken not to impact on wild stocks with such practices, but protocols now being developed may help in this regard (e.g., FAO, 1997). Reduction in shrimp stocking densities has also been practiced, since farmers have now become aware that lowering of stocking densities can lead to more sustainable harvests. For example, farmers in Thailand are now reducing stocking densities in intensive farms and finding that profitability is maintained and the risk of disease reduced.

Appropriate feeds and fertilisers: Feed is required in intensive farming systems, where the amount used (and efficiency of use) and the type of feed becomes important. The amount of excess nutrient and organic matter can be significantly reduced by improved feeding practices, such as carefully controlled feeding and use of feeding trays (AAHRI, 1996). Surveys have also shown that food conversion ratio is less on small family-operated farms than on large-scale farms (CP News, 1994). Small farms are more efficient than large-scale farms run by workers due to the sense of belonging. There is increasing attention being paid to reduction in the use of fish meal in diets for aquaculture. The use of moist and fresh diets are known to be more polluting and wasteful of resources and tend to be less used on intensive farms in Asia, because of concerns over water pollution and introduction of shrimp pathogens. It can be expected that improved feeds (such as with more appropriate protein content) and feeding systems will be adopted over the next five years (Chamberlain, 1996), a move that could further reduce loadings of pond effluent.

Re-design of systems to provide for recycling of excess nutrients and organic matter in effluent into secondary aquaculture products (e.g., fish, mollusc) or even agricultural crops (Tookwinas, 1996) could also help increase the efficiency of resource use and make additional contributions to local food supplies (as well as reducing effluent loads to local coastal waters).

Fertiliser is generally required for plankton blooming during the initial stage while the stocked post-larvae mainly rely on natural feed. In low water exchange systems, the accumulated nutrient in pond will later serve as fertiliser.

Water and sediment management including effluent control: Various options for control of effluent loads in shrimp ponds which can be applied to reduce any impacts of effluents on surrounding waters, and keep any discharge within assimilative capacities of recipient water bodies. In Thailand, the generally practiced low water exchange system which was mainly developed for reducing the risk of introduction of shrimp pathogens, virus carriers and toxic particles released by nearby farms into the ponds, can dramatically reduce effluent loads. To maintain good water quality, circular water movement in Thai shrimp ponds is facilitated by heavy aeration to concentrate all the waste at the center of the pond rather than remaining spread throughout the pond bottom. This will cause the remaining bottom area clean which is necessary for low water exchange system. Although the quality of the existing pond water is poor when there is less water exchange, shrimp can gradually adapt to this condition. If there is heavy introduction of new water into the pond, it will cause high mortality to shrimp due to the sudden change in water quality (chemical, biological and physical). This low water exchange system has been used to expand shrimp farms into areas with little access to seawater.

If ponds are located in unavoidably polluted or disease-prone areas, particularly along rivers and canals, a closed (zero water exchange) system should be developed. This system has reservoirs, which later serve as water treatment ponds. After settlement in the reservoir, the incoming water is chlorinated to eliminate some pathogens and virus carriers. Waste water from grow-out pond is pumped into this treatment pond where organic loads and silt will settle in and phytoplankton and zooplankton are consumed by introduced fish and bivalves, e.g. tilapia, mullets, milkfish, green mussels or oysters, acting as bio-filter. The clear surface water is allowed to overflow into the supply canal where heavy aeration is applied so as to eliminate toxic gases before pumping back into the grow-out pond. This system is not suitable in open-sea areas where salinity is usually high due to increased evaporation.

The closed system is also used for *Penaeus monodon* culture in freshwater, particularly in areas accessible to estuarine waters. If the soil is still salty, the salinity of stocked freshwater at the depth of 30 cm in grow-out ponds will rise to about 5 ppt within 1-2 weeks. Otherwise, pathogen-free hypersaline water (150-200 ppt) from salt farms should be transported by truck and subsequently diluted to 5 ppt in the grow-out pond. After seed stocking, freshwater is gradually added to fill the pond to the desired level. Because of a nearly five-fold dilution and the absorption of sodium chloride by the bottom soil, the final salinity will become nearly 0 ppt, which is not harmful to the surrounding environment. The stocking density is reduced to $20/m^2$ so that shrimp can grow to the size of 20-25 g within 3 months. Freshwater will stunt the shrimp only after 100 days of culture period. This 3-month culture will force the farmers not to pollute their ponds as the amount of feed is much less than 4-5 months. Another advantage of this technique is that yellow head and white spot viruses hardly occur in freshwater. However, the long-term impact on the environment needs more careful study.

Culture in full-strength seawater with high water exchange system is the most suitable technique for shrimp farms along the coast where farm effluent can be completely drained out to the open sea. In the past, these farms faced a major problem of stunted shrimp caused by high salinity and clear water. In fact, high salinity (over 40 ppt) will affect shrimp only during the juvenile stage when they mainly consume zooplankton, which are not available in normal high salinity and clear water. Heavy fertilization with minimal water exchange during early stage is required so as to increase natural food for shrimp juvenile. Bacterial infection and pond bottom deterioration caused by overblooming of phytoplankton also hardly occur under such high salinity conditions.

Management strategies for effluent need also to be carefully balanced against discharge targets, to avoid unnecessary costs. Nutrient and organic matter concentrations in effluent are highest during shrimp harvesting and subsequent cleaning of ponds, when effluent quality can be very poor due to disturbance and release of material previously bound to the sediment. Effluent targets could be met in many circumstances by concentrating management efforts in the treatment of harvest water and sediment. A significant proportion of nutrients and organic material is tied up in bottom sediments, and consequently some countries have placed restrictions on indiscriminate discharge of shrimp farm sediments (FAO/NACA, 1995). Sediments also have potential as a useful fertiliser. There is increasing interest in the use of bio-filtration, including wetland-mangrove habitats in appropriately located sites on the farms (Robertson and Phillips, 1995).

Physical removal of pond sludge is a major operation in Thai shrimp farming to eliminate silt, organic matter, pathogens and virus carriers, toxic gases such as ammonia, hydrogen sulfide and methane accumulated in the pond bottoms from previous crops. During the dry season, the fouled layer of the pond bottom is scraped off by bulldozer and dried on the pond dikes or removed by excavator to dry in a reserved area nearby. During the rainy season when heavy machine is not practical, sludge can be removed in suspension by high-pressure hoses and then pumped to a settlement pond to avoid contaminating the water supply.

There are numerous other options for bio-filtration, including the use of molluscs, seaweeds, finfish ponds. Recent studies have also been made with the use of halophytes for treatment of saline aquaculture effluent, such as *Suaeda* sp. and *Salicorna* sp., succulent marsh plants which can be used as fodder for some livestock.

Whilst various research have focused on various aspects of intensive pond effluent treatment, it is also becoming clear that controlling effluent loads released to the coastal environment requires a 'holistic' type of approach. This should be based on the understanding of the local farming systems, properly defining problems (if any), and development of locally appropriate solutions (Smith and Masters, 1996; Boyd, 1997) depending on individual farming systems or location of specific environmental concerns.

Shrimp health management practices: Shrimp diseases are a major manifestation of the lack of sustainability in all types of shrimp culture (Chamberlain, 1996). Farm and shrimp health management practices favoring hygienic measures, and the safe and effective use of therapeutants and other chemicals need to be developed. The adoption of the systems approach which gives emphasis on management of conditions which lead to disease and reduced chemical use is also being promoted - a potentially "win-win" situation which may be both profitable and can minimize environmental costs. The development of captive broodstock for major farmed shrimp species and programs for their genetic improvement should result in farmers having better quality shrimp post-larvae free of and/or resistant to specific pathogens. Specific pathogen-free seed or high health shrimp post-larvae or low pathogen seed is also showing promise. Pruder et al (1995) emphasized that sustainability and farm profitability can be achieved by integrating high health shrimp seed with disease control and appropriate farm management practices.

Key Issues to Minimize Environmental and Social Impacts

Pond rehabilitation

The area of "abandoned" or unproductive shrimp farms is controversial and poorly defined, but there is increasing interest in rehabilitation of some farming sites, and recognition that such efforts may contribute to sustainability (e.g. mangrove replanting, meeting social objectives, contributing to re-employment). In the Philippines, mangrove areas released by the government for large areas of extensive ponds, are being reverted to public land and reforestation, as well as various forms of aquaculture. In some localities, intensification of shrimp farming in the best ponds of a farm might allow some of the ponds sited in former mangrove areas to be returned to mangrove. There may also be opportunities for extensive farms on mangrove land to replant part of the farm, and intensify the remaining pond area. This is an area of increasing interest (Stevenson and Burbridge, 1997).

Coastal area management

The concept of 'integration' can be extended to the integration of aquaculture farms into the coastal area, a concept that is given increasing attention as a result of pressures on common resources in coastal areas arising from increasing populations combined with urbanization, pollution, tourism and other changes (Sorensen, 1997). Integrated coastal management (ICM) is a process that addresses the use, sustainable development and protection of coastal areas, and according to GESAMP (1996) "comprehensive area-specific marine management and planning is essential for maintaining the long-term ecological integrity and productivity and economic benefit of coastal regions". There have already been considerable efforts within countries as well as internationally to address economic, social and environmental problems being experienced in a wide range of coastal areas. Few of these efforts address aquaculture specifically, but nevertheless aquaculture (and shrimp farming in particular which requires coastal land) has some considerable benefit to participating in such activities.

ICM involves a participatory and strategic planning process that spans issue identification and assessment, public education and stakeholder consultation, selection of issues to be addressed, geographic focus and activities to address issues, formulation and adoption of a management plan, and capacity building within the public sector for implementation. Roles and responsibilities for planning and implementation of ICM need to be clearly delineated. An institutional structure for ICM typically contains distinct but clearly linked mechanisms for: (i) achieving interagency coordination at the national or regional level (e.g., through an inter-ministerial commission, authority of executive council); and (ii) providing for conflict resolution, planning and decision-making at the local level (Tobey and Clay, 1997). Tobey (1997) indicates ICM can be made operational through:

- land use zoning and buffer zones;
- regulations, including permitting to undertake different activities;
- non-regulatory mechanisms, such as incentive-based measures, technical assistance and extension, voluntary agreements and adoption of Best Management Practices;
- construction of infrastructure;
- conflict resolution procedures;
- voluntary monitoring; and
- impact assessment techniques.

The integration of shrimp farming into coastal area planning and management has been the subject of considerable interest and it is recognized that this is an important step which will contribute to sustainability. However, practical experience in implementation for aquaculture is limited, which is in large measure because of the absence of adequate policies and legislation and institutional problems, such as the lack of unitary authorities with sufficiently broad powers and responsibilities. Integration of aquaculture into integrated coastal management is a subject area which will receive more attention in the future as practical experience of ICM in general improves (for a critical review of experiences in ICM, see Sorensen, 1997). A recent GESAMP working group has also looked into this aspect and developed some strategies for integration of aquaculture into integrated coastal management planning (U. Barg, FAO, Rome, personal communication).

An important principle of ICM is adoption of participatory approaches. In inland areas, aquaculture is commonly practiced on privately owned land, often in well-established agricultural farmland. Coastal aquaculture in contrast is often developed close to (or sometimes) on public land or water, leading to increased risk of conflicts with other coastal resource users (Bailey, 1988). The problems are likely to be most serious where there are traditional community-based uses of common property resources, large coastal populations and/or aquaculture operations, and other development interests (e.g., tourism), as large "consumers" of environmental "goods" and "services" in relation to existing resource availability. In such situations, effective formal or non-formal conflict resolution and the participation of concerned 'stakeholders' in planning of balanced resource use for aquaculture and other uses is necessary to avoid or resolve conflicts between shrimp farmers and other users of common property. Rubino and Wilson (1993) emphasize that procedures for resolving conflicts between aquaculturists and other marine or public water resource users may also promote public acceptance of coastal aquaculture in general.

Experience with coastal fisheries management in general shows that failure to include coastal residents in natural resource management can lead to lack of community compliance resulting in resource depletion and conflicts, particularly when government capacity to enforce laws and regulations is limited. A promising approach to this problem may be "co-management", which involves the cooperation of the local community in establishing and enforcing local management rules with the support from government (Pomeroy, 1994). The co-management approach has proved useful for community-based management of some coastal capture fishery resources, but the devolution of ownership and management of resources to local people and communities should be explored for coastal aquaculture.

Davy (1991) emphasized the importance of local ownership and management of coastal resources considering that "trends in the development of fisheries (including aquaculture) in Japan indicate that only through ownership or a system of fishery rights is there a satisfactory foundation for future development". More attention should be given to explore and develop such local community-based development strategies. As pressures on coastal resources inevitably increase with expanding populations, or accelerating resource extraction rates, the further development of mechanisms for effective conflict resolution and apportioning of resources between all types of coastal aquaculture and other sectors will become increasingly more important components of sustainable aquaculture management.

There are already examples where cooperation among individual shrimp farmers can also help improve management of common resources for sustainability. For example, the farmers' association in Surat Thani and in Chantaburi in Thailand coordinate the timing of pond intake and discharge, thus avoiding some of the problems associated with self-pollution of water supplies (Phillips and Macintosh, 1997). The association is also now active in replanting of mangroves in coastal areas. Farmer associations can also provide more effective means of voicing individual farmer concerns and aspirations and are being promoted in several countries. NACA is also in the early stages of establishing a regional farmers association in Asia, to promote such coordinated activities.

Aquaculture zoning

Zoning of land (and water) areas for certain types of aquaculture development may also be another strategy for 'integrating' aquaculture into coastal areas. It may help in controlling environmental deterioration at the farm level, and in avoiding adverse social and environmental interactions. In Malaysia, government policy is to identify specific coastal aquaculture zones, compatible with existing land use patterns. In Korea, Japan, Hong Kong and Singapore (FAO/NACA, 1995), there are well developed zoning regulations for water -based coastal aquaculture operations (marine cages, molluscs seaweeds). Zoning can also be designed in ways to encourage multiple use if appropriate, following agreed allowable and non-allowable uses, promoting optimal and balanced coastal resource use. Zoning for aquaculture may be particularly beneficial for small-scale shrimp farmers, who can be provided with proper water supply/drainage infrastructure, avoiding the ad hoc water supply and drainage systems resulting from uncoordinated development of individual farms (ADB/NACA, 1996).

Aquaculture legislation

Government regulations are an important component of management in supporting aquaculture developments, maintaining environmental quality, reducing negative environmental impacts, allocating natural resources between competing users and integration of aquaculture into coastal area management. Regulation of aquaculture, often (but often also one of the traditional users) recognised as a 'newcomer' among many traditional uses of natural resources, has commonly been conducted with an amalgam of fisheries, water resources, agricultural and industrial regulations (Rubino and Wilson, 1993). It is becoming increasingly clear that specific regulations governing aquaculture may be necessary (Howarth, 1995; Howarth, 1996), not least to protect aquaculture development itself. "Constructive aquaculture policies and regulations can accentuate the benefits of cooperation and head off potential problems" (Rubino and Wilson, 1993). This also strongly emphasised in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995; FAO, 1997).

Regulation of aquaculture is a particularly intricate exercise due to the interdependency of the activity upon the state of aquatic environment in which it is conducted and the use of a wide range of environmental "goods" and "services". Land and water, in particular, may already be governed by various "non-aquaculture" laws and regulations developed for other purposes (Howarth, 1996). Rubino and Wilson (1993) and Howarth (1995) provide more information on some of the key issues to be considered in legislation.

Environmental impact assessment

Environmental impact assessment (EIA) can be an important legal tool and the timely application of EIA (covering social, economic and ecological issues) to larger scale coastal aquaculture projects can be one way to properly identify environmental problems at an early phase of projects, enabling proper environmental management measures (which will ultimately make the project more sustainable) to be incorporated into project design and implementation. Sri Lanka, Indonesia and Malaysia already have some EIA regulations covering development of large-scale shrimp culture, but more widespread and effective use of EIA may be worthwhile.

A major problem with EIAs is that they are difficult (and generally impractical) to apply to smaller-scale shrimp farm developments and cannot take account of the potential cumulative effects of many small-scale farms. Such problems, which can seriously influence sustainability because of the effect of self-pollution and inter-farm spread of shrimp pathogens, can only be solved through an integrated coastal management approach and more regional level environmental assessments.

Environmental quality standards

A number of countries have adopted various environmental quality standards to control environmental effects of shrimp aquaculture, including the effects of pond effluent on receiving waters. Such standards are notoriously difficult to monitor and enforce (one of the reasons being the large number of farms, often spread over large geographical areas, and limited capacity and time for monitoring). In any event, to be ecologically effective, water quality standards for effluent should be set based on the farm type and environmental quality objectives for receiving waters. In view of such difficulties a more practical approach may be the design and implementation of "best management practices" which for the purposes of maintaining desired environmental quality may include such issues as management techniques such as more efficient feed and feeding methods and reduced stocking densities, reduced water use, effluent treatment and reuse through settlement ponds, and responsible disposal or re-use of pond sediments.

Shrimp culture often suffers from water pollution caused by other industries (FAO/NACA, 1995). Thus, attention should be given to water pollution controls in other sectors, rather than concentrating on shrimp culture alone. Water quality management should be part of a comprehensive integrated approach to environmental management in coastal areas. Whilst adoption of more integrated approaches would greatly benefit the protection of environmental quality and coastal aquaculture also, unfortunately, such approaches are relatively rare in many areas.

Some On-going Asia Regional Initiatives

There are a number of ongoing regional initiatives which are providing support and development cooperation in dealing with some of the above management issues.

Asia regional quarantine and health certification

On the request of NACA member countries, NACA and FAO are cooperating on the drafting and adoption of regional guidelines for health certification and quarantine of aquatic animals in the Asia-Pacific region, based on regional circumstances but also consistent with international legislation and agreements. Thus, they should be applicable not only to both participating and non-participating countries in Asia, but also to many countries in other parts of the world.

Capacity building and technical guidelines to support the application of the CCRF to shrimp aquaculture

NACA and FAO are working on a project entitled Technical Guidelines and Capacity Building for the Application of the Code of Conduct for Responsible Fisheries to Shrimp Aquaculture (Phase I) designed to assist countries in Asia in the development of capacity and guidelines to support implementation of the Code of Conduct with respect to shrimp aquaculture. The emphasis of the project is on working at a practical level to translate the global Code of Conduct for Responsible Fisheries to national and local levels.

SEAFDEC has also recently approached NACA for cooperation in providing assistance to SEAFDEC Member Countries in the implementation of a global code of conduct in aquaculture.

Development of "best practices" in shrimp aquaculture

In addition, NACA is participating in a number of regional and international research initiatives aimed at identifying "Best Management Practices for Sustainable Shrimp Culture" which is partly supported by the World Bank. As part of this global collaborative effort, FAO is also planning to organize a global expert meeting on best management practices in shrimp culture in late 2000 or early 2001, to provide the opportunity for the various international and national initiatives to present and discuss their findings in an open forum of experts and stakeholders interested in sustainable shrimp culture development.

Research to support sustainable shrimp aquaculture

ACIAR and NACA also collaborated in an analysis of researchable issues for shrimp aquaculture in the Asian region. The key areas identified in this review (which is in press) are as follows:

- to develop high health, low risk pond management methods;
- to develop practical methods of immuno-prophylaxis for shrimp;
- to investigate interactions between nutrition and shrimp health;
- to assess causes of water quality deterioration and the effects on shrimp health;
- to develop effluent management and waste treatment technologies;
- to investigate endocrinology of broodstock maturation;
- to develop domesticated stocks;
- to develop high health health hatchery production methods;
- to better understand pond dynamics and ecology;
- to understand the role of biological agents and microbial ecology in improving the pond environment; and
- to develop more effective strategies for collaboration with farmers and transfer of research results to the farm.

These and other research and development initiatives should provide a significant support to countries of the region in the development and implementation of improved management practices for shrimp aquaculture.

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