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XIV. ENVIRONMENTAL IMPACTS OF COASTAL AQUACULTURE DEVELOPMENT

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Management measures to mitigate deteriorating water quality and the adverse environmental impacts of aquaculture development are to be dealt with as a priority area and a holistic approach is needed. Environmental baseline studies are necessary to establish and assess environmental quality and to be able to quantify this quality in economic terms.

INTRODUCTION

The traditional farming system based on the emperical knowledge of the behaviour of animals and their tending in impounded water bodies has, over the years, transformed to semi-intensive and intensive systems involving culture of selected, fast growing species in high stocking density, water exchange, supplementary or total feeding and other management practices. While each of these systems interact with the environment, the degree or the scale of this interaction varies depending on the location, system practice, quality of water supply, its exchange and management, feed and feeding strategies employed, use of fertilizers, chemicals and drugs, accumulation of wastes in the pond and their removal and treatment of effluent discharge from the ponds. Though the technological advancements and appreciable investments have resulted in the increase of production in the semi-intensive and intensive culture systems in the past two decades, the effect of concentrated development of coastal aquaculture on the ecology and environment has, in recent years, attracted considerable attention and discussions, particularly in the context of failure of rapidly developed shrimp culture in Taiwan, Thailand and China, and the disasters encountered due to environmentally related diseases and other problems in our country. The experiences gained in these issues have emphasised the urgent need of development of sustainable aquaculture with due ecological considerations.

ENVIRONMENTAL IMPACTS ARISING FROM COASTAL AQUACULTURE

Ill planned and concentrated development of coastal aquaculture is known to bring about the following impacts on the ecology and environment of an area; (1) reduction of productive and eco-essential mangroves in the coastal areas due to their conversion to fish ponds; (2) self-pollution of ponds due to excessive sediment deposition, poor quality water supply, accumulation of wastes due to excess feeding and other metabolities, unregulated use of fertilizers, chemicals and drugs; (3) improper designing and lay out of ponds in the area with inadequate facilities for water supply and drainage; (4) salinisation of areable lands and underground freshwater resource; (5) eutrophication and use of the coastal environment beyond its carrying capacity; (6) effect of effluent discharges from the ponds as well as from other pollution generating agro-industries in the area and (7) the conflict in the use of coastal area by different production systems and the consequent ecological imbalances.

1) Interference with the mangrove ecosystem

The experience from Philippines about conversion of mangrove swamps to aquaculture and its effect is a classic example of the impact of indiscriminate human interference on the coastal environment. According to Saclauso (1989), recent statistics show that about 50% of Philippines mangrove forests have been developed into brackish water fish ponds.

The mangrove ecosystem plays a significant role in the food web of the complex group of marine organisms as well as valuable estuarine and near shore fisheries and in the maintenance of biodiversity of the area. It also serves as a sanctuary, nursery and breeding grounds for a number of terrestrial and aquatic fauna. The large scale conversion of mangroves to ponds would not only destroy the unique ecosystem but also adversely affect the natural biodiversity of the coastal zone and mangrove dependent fisheries. However, the realisation of the fact that mangroves often contain the underneath acid sulphate soils and pose difficulties in the construction of ponds with proper tidal water exchange has arrested their conversion to fish farms in recent years in several regions.

2) Pond water deterioration and self pollution of ponds

The semi-intensive and intensive farming involves higher stocking densities and consequently requires higher rate of feeding of the stocked population with compounded diets and better water quality management. As prawns are known to be rather not efficient converters of feed, excessive feeding would naturally gets wasted and accumulated in the sediment of the pond bottom. This together with the other metabolites results in the self pollution of the pond ecosystem. This situation, along with the supply of water of poor quality and often development of undesirable blooms leads to the depletion of dissolved oxygen of the pond water and results in the large scale mortality of the stocked population or leads to frequent disease outbreaks. The collapse of shrimp culture in Taiwan in 1988 and later in Philippines has been assigned to these reasons of self-pollution of shrimp ponds.

Self-pollution of salt water ponds also occurs due to improper use of fertilizers, haphazard application of bio-active compounds used in the control of diseases and number of hormones and growth promoters used to alter the sex and to enhance the growth and production of the cultured organisms. Although, comprehensive information on the physiological effect of these chemicals, drugs and hormones in the target species or the longevity of the inhibitory compounds in the tissues or the fate of these bio-active compounds discharged from ponds to environment or the development and transfer of resistance in microbial community are not available at present, it is essential that the effect of these are fully elucidated and criteria defined for sustainability of the aquaculture.

3) Site selection and pond design

In site selection for aquaculture, it is essential to consider the bio-physical requirements of the cultured organism, the characteristics of the site, essential physical, chemical and biological variables. These include morphology of the coastline and bathymetry, water source and its quality, current speed and direction, sediment particle size, inorganic nutrients, organic contents of sediment, natural resources available, planktonic biomass and other species composition, and bacterial population.

Lay out, design and construction of the ponds are the most important aspects not only for the success of aquaculture operation but also from the environmental impacts of culture. Since 'ideal' sites may not always be available, it is the ability for adaptive design and application of appropriate engineering principles which would significantly determine the productivity and environmental compatibility of an aqua farm (FAO, 1992). The construction of ponds either on individual units or as cluster of ponds with pumping units, supply canals and drainage net works are important factors of ecological relevance. Equally important are the set up of systems for water renewal and waste water discharge in land based farms. For proper water exchange in the culture of organisms in net enclosures as in cages in inshore waters, anchorage, size of the nets and mesh used, distance between stakes etc. have to be taken into consideration in relation to depth of water, slope of the bottom and the speed of the currents in the area. The total biomass expected will determine the quantum of waste produced and water exchange requirements. However, unfortunately, the varying degrees of exposure of the environment to deterioration are very often not taken into consideration while planning and designing an aqua farm.

4) Salinization of fresh water resource

In certain areas in India as well as other south east countries conflicts are already reported caused by affected villagers due to salinization of fresh water resource mainly caused by seepage of saline water used in the aqua farms. Salinization of acrable lands and under ground freshwater aquifers is also reported in the shrimp culture ponds constructed in higher grounds and supplied with pumped salt water. Adequate care has to be taken to avoid such ecological implications during the design and construction of farms.

5) Eutrophication and carrying capacity

The release of soluble inorganic nutrients (nitrogen and phosphorus) from intensive fish and shrimp farming has the potential to cause nutrient enrichment and eutrophication of a water body. It has also been pointed out that organic compounds together with components such as vitamins could influence the growth or toxicity of particular species of phytoplankton. It is stated that at the present level of coastal fish farming, nutrient enrichment and eutrophication of open coastal waters is unlikely, but could occur in semi enclosed coastal embayments which have restricted exchange of water with more open coastal waters. Similarly, the carrying capacity of the coastal waters varies from location to location and depends on the climate, hydrobiology and several other factors. Imre Csavas (1994) has showed the variations in the magnitude of cultured shrimp out put per kilometre of the coastline in different countries and opined that although the decline in the production of shrimps in countries such as Vietnam, China, Indonesia and Philippines may not be due to the environmental issues or ceiling, the water quality in these regions have already become a major concern.

6) Effluent discharge from farms

The adverse effects of the discharge of effluents rich in nutrients and organic material from prawn ponds include increased sedimentation and siltation, hypoxia, hyper nutrification and alternations of productivity and community structures of benthic organisms (FAO, 1992).

At present most of the shrimp farms do not have proper water treatment systems and drain water directly to rivers or the sea. Waste water from shrimp farms is high in nitrogen, phosphorus, carbon compounds, organic matter, shrimp excretary products, plankton and some chemical and antibiotic medicine. The effluent waters from the shrimp ponds includes the water released during rearing in the ponds as well as the water discharged during harvesting (OEPP, 1994).

Table 1
Typical effluent characteristic of a shrimp farm in Thailand

Pond size (ha)	0.78	-	0.56
Pond depth (m)	1.50	-	1.80
Salinity (ppt)	10.00	-	35.00
Temp. (^{0} C)	22.00	-	31.00

pH	7.50	-	8.90
Total phosphorus (mg/l)	0.05	-	3.40
Total nitrogen (")	0.50	-	3.40
Total ammonia (")	0.05	-	0.65
Dissolved oxygen (")	4.00	-	7.50
Chlorophyll *a* (μg/l)	20.00	-	250.00
Total suspended solids (mg/l)	30.00	-	190
Water exchange frequency (% day)	5.00	-	40.00

Source : FAO Technical Paper No. 328 (1992).

Although the magnitude of the parameters are much less than other effluent streams, the significance of shrimp farm effluents covers from the high volumes of low concentration effluent and concentrated release during harvest and the cleaning of shrimp ponds (Banchong Tiensongrusmee, 1995).

Table 2
Effluent water quality from nine intensive shrimp ponds in Thailand. Samples collected throughout one growout cycle from January to may 1993.

Parameters	Inflow water	Discharge water	Discharge during harvest
Total nitrogen mg/l	0.28 - 0.77	1.46 - 3.11	1.57 - 5.06
Total Phosphorus mg/l	0.05	0.25 - 0.70	0.21 - 1.30
Ortho-phosphate mg/l	0.05 - 0.12	0.05 - 0.14	0.05 - 0.24
Nitrite-N mg/l	0.001 - 0.012	0.003 - 0.043	0.004 - 0.033
Nitrate-N mg/l	0.02 - 0.41	0.01 - 0.43	0.01 - 0.09
Total ammonia-N mg/l	0.05 - 0.63	0.05 - 1.70	0.51 - 1.51
Unionised ammonia mg/l	0.001 - 0.009	0.001 - 0.006	0.003 - 0.0198
pH	7.2 - 8.1	7.4 - 8.3	7.0 - 8.3

Parameters	Inflow water	Discharge water	Discharge during harvest
Temperature °C	27.8 - 30.8	28.8 - 30.2	29.0 - 32.0
Total organic carbon mg/l	0.1 - 19.02	18.86 - 37.25	17.24 - 39.44
Salinity ppt	31.7 - 34.3	35.0 - 37.0	36.0 - 39.0

Source : Banchong Tiensongrusmee 1995.

It is also reported that the loading at the time of cleaning operations are substantially more than loading during the culture period, because of discharge of material previously bound to sediment particulate matter. Impacts on receiving waters are likely to be most significant at this time. If the waste water is discharged without proper dilution or sufficient treatment it would cause pollution on the receiving water body. In recent years several types of treatment ponds have been suggested. The treatment may be physical, chemical and biological. Generally, filtration is the common treatment measure employed to remove suspended solids. It is reported that the application of 200 - 900 kg/ha of gypsum at every 7 to 10 days would reduce turbidity. In recent years synergistic culture of sea weeds and molluscs which feed low in the food chains and deliberate planting of mangroves are also suggested in the treatment of effluent.

Table 3

Shrimp pond effluent during normal operation compared to other types of wastewater

Parameter (mg/l)	Shrimp pond effluent	Domestic untreated	Primary treatment	Biological treatment	Fish processing plant effluent
BOD	4.0 - 10.2	300	200	30	10.000 - 18.000
Total N	0.03 - 12.4	75	60	40	700 - 4.530

Parameter (mg/l)	Shrimp pond effluent	Domestic untreated	Primary treatment	Biological treatment	Fish processing plant effluent
Total P	0.01 - 2.02	20	15	12	120 - 298
Solids	119 - 225	500	-	15	1,880 - 7.475

Source : Bonchong Tiensongrusmee, 1995.

7) Social considerations/conflicts

The picture may not be complete without mentioning the social consideration and conflicts arising out of the rapid development in aquacultural sectors. The investment for aqua farms has, by and large came from entrepreneurs and not from farmers or fishermen. Hence, there is an apprehension that in the long run the fishermen are at a receiving end, although some initial benefits like employment opportunities are provided. Satellite farming strategies introduced by certain agencies to overcome this problem, is considered as an appropriate step, and perhaps, the only practical way to involve the small-scale fish farms in shrimp culture development. The development of coastal aquaculture has also lead to conflicts in land use and in certain region on rice production. It is also competing with the capture fisheries in the estuarine and brackish water areas. These issues require careful consideration and pragmatic approach for the balanced growth and utilization of the resources in the coastal zone.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Realising the importance of maintenance of a balanced environment for the sustainable growth of coastal aquaculture, role of the environment and aquaculture has been discussed and being discussed in several forums and committees.

According to the guidelines given by FAO (1991) EIA is a process whereby the potential impacts of a proposal on the social, biological, chemical and physical environment are assessed and justified, and the means sought to minimize or eliminate negative effects.

In India, it has already been suggested to have an environmental Action Plan (EAP) divided into two parts, viz. (i) an Environmental Monitoring Plan that will provide the base line information both on the fisheries project impacts on the environment, and the environment impact on the fisheries project and (ii) an Environment Management Plan which would describe the management interventions that are necessary to directly investigate possible negative environmental impacts from project activities (Alagarswamy, 1994). Regulating the activities in the coastal regulation zone (CRZ) as notified under Environmental Protection Act 1986, the States and the Union Territories have been directed to prepare the coastal zone management plans including coastal aquaculture. Further, the guidelines are also being formulated by the Ministry of Agriculture for the development and management of coastal aquaculture with appropriate consideration for the protection of environment and other land use.

FUTURE PROSPECTS AND PROBLEMS

Management measures to mitigate deteriorating water quality and the adverse environmental impacts of aquaculture development are to be dealt with as a priority area and a holistic approach is needed. Environmental base line studies are necessary to establish and assess environmental quality and to be able to quantify this quality in economic terms.

Adverse environmental impacts of shrimp culture could not be avoided without designing shrimp ponds as modules of a comprehensive irrigation drainage system. This would adjust permissible product output of the whole system to the availability of water and the disposability of the wastes. Designing a suitable pond system accommodating ponds to grow secondary culture like seaweed, mollusc, milkfish, mullet or tilapia is to be incorporated. This would serve waste utilization rather than simple disposal.

Unfortunately, not much data are available on the environmental impacts of shrimp farming, and little effort has been made to define criteria for sustainability. Hence, R &D effort should be targetted to evolve suitable methods for sustainable and eco-friendly coastal aquaculture programmes.